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Ministry of Education, Youth and Physical Culture
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Union of Czech Mathematicians and Physicists
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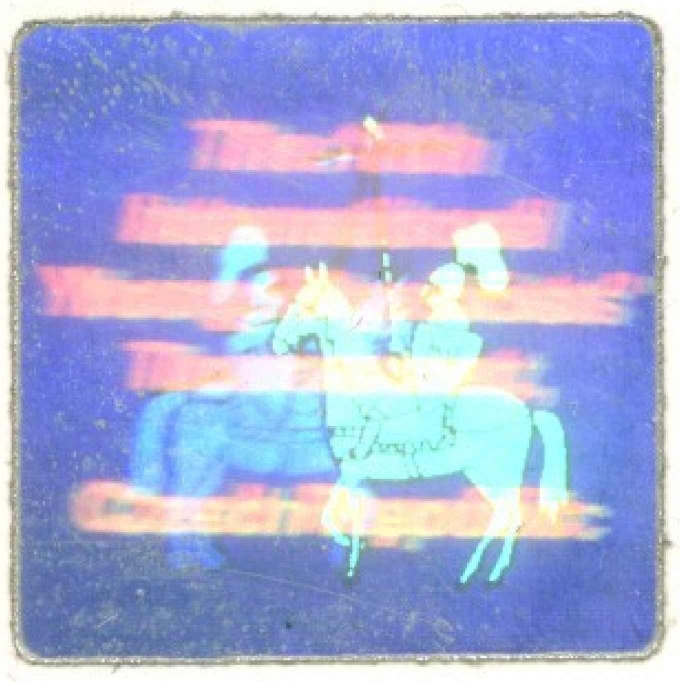
10th International Young Physicists' Tournament

Prague - Cheb - 1997

Zdeněk Kluiber et alt.



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HRADEC KRÁLOVÉ
1998

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from left

Dr. Z. Kluiber - chairman of 10th IYPT

Dr. E. Yunosov - vicepresident of the Intcommittee of IYPT

Prof. Dr. G. Tibell - representant of EPS

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Young Physicists Tournament

1 Tournament for groups of talented students

Zdenek Kluiber

Among the students of the secondary schools it is possible to find a great number of students who, due to their great interest for physics (and mathematics) have very good study and working results, which are also proved by their success in the international tournaments. These students frequently decided to become in their future carrier either the research workers in physics or to become either university or secondary schools teachers. An important assumption to fulfil this resolution is that these students during their secondary school studies have the possibility not only to learn new scientific ideas from the field of physics (certainly on the level corresponding to the secondary school) but also have a possibility to prove their creativity which simulates work of the research worker or teacher.

One of the most important tournaments of the talented students devoted to physics is the International Young Physicists Tournament (IYPT).

1.1 Introduction

The Tournament of Young Physicists (YPT) has a long tradition. It was founded at the Faculty of Physics of the Moscow University in 1979. The important role at its foundation was played by Academician E.P Velichov, Academician G.T. Zacepin (actual President of the International Committee YPT), professor S.M. Cudinov and Dr. Yunosov-Fais. All important aspect of this Tournament, involving for example organization of the tournament, preparation of problems, have a close connection with the name of Dr. Yunosov, vice-president of the International Committee of the YPT [1-4].

During the first tent years YPT was organized as a tournament of Moscow secondary school students. Since 1985 till 1988 could apply for the participation in the YPT any secondary school from the former Soviet Union. The tenth annual tournament was then organized as a Soviet tournament and simultaneously as aT International Young Physicists Tournament (IYPT).

In the beginning of the history of the IYPT in the year 1987 were physicists from the Moscow University, foreign physicists and finally also physicists who were interested in the didactics of physics.

YPT corresponds to the development of the new talented students of physics through the form of the solution of the interesting problems which were presented to the students by R. Feynman and P.L. Kapica, Nobel Prize winners for physics [5-6].

The first till the sixth tournaments IYPT took place in Russia Moscow, Protvino-Serpuchov), the seventh tournament took place in Netherlands (Groningen] [3], 8th tournament took place in Poland [Spaala], 9th tournament took place in Gruzia Kutaisi), and the 10th tournament took place in the Czech Republic (Cheb)7-10]. The IYPT is understood as an analogy of the international physical conference, but it also involves certain elements of sport. Due to these facts is the IYPT for the student of the age between 15-20 years very attracting.

In many countries have been organized Republic Committees of the YPT, which successfully fulfill their duties. They are usually composed from research workers in physics and from university and secondary school teacher of physics. The representatives of these committees are considered as members of the International Organizing Committee.

YPT therefore represents tournament of teams composed from five members from students from secondary schools. Usually are solved original, difficult problems - more generally formulated physical problems similar to those which are solved by scientists in the process of study of the real physical phenomena. The formulation of the problems has the greatest simplicity.

The participants of the tournament themselves have to suggest and to find data necessary for the solution, they have to find an optimum model for the description of the studied phenomenon, they have to choose the best method of the solution and finally they have to discuss obtained results.

The most important role of the YPT is a discussion of the obtained results, which requires a profound understanding of the given problem and simultaneously also a quick capability of reactions. The words "competition in physics" fully describes a competition among students. That is why in the logo of the YPT there are two knights with coats-of-arms with the equations

$$E = m.c^2 \text{ and } E = h.f$$

The chivalry of the competition is certainly a rule. The presentation of the solution of the problems together with the defending of the solution and its discussion are among most important positives point of the YPT. The whole tournament is governed by the rules, which are in details described in chapter 4.

1.2 Preparation and characteristic features of the young physicists' tournament

The problems to be solved in the YPT are prepared by the group of authors. Since 7th IYPT before each tournament is organized a seminar, during which are formulated the problems for the annual competition. The group of authors has usually 10 members. The problems can be suggested by all the countries, which take part in the competition [11].

In the years 1980 - 1986 the problems for YPT were published in the journal Quant. In this journal were also published all information and results of the tournament. The problems for the solution is send from the country which organize the tournament to all participating countries.

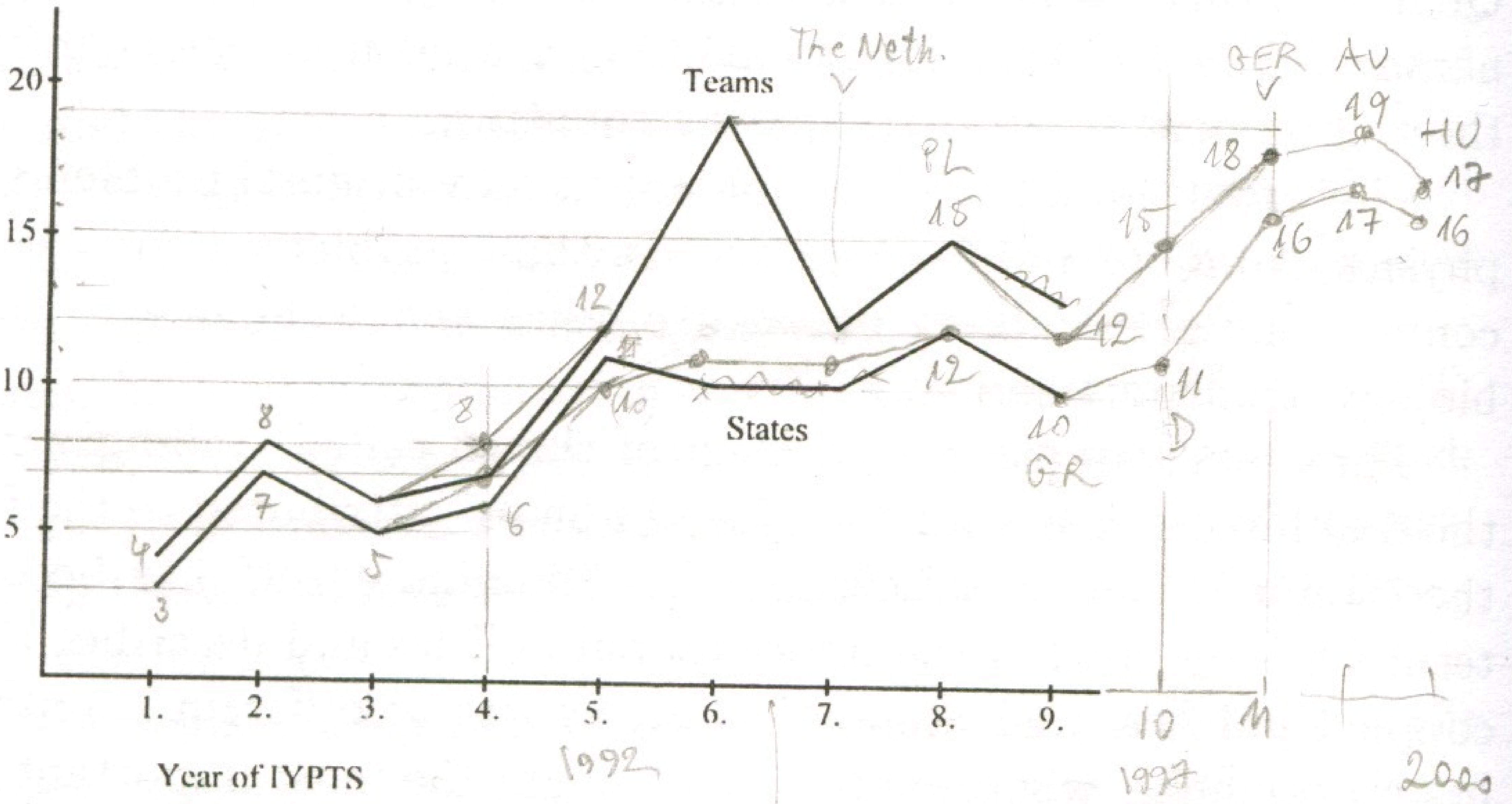
The problems for the solution are usually original problems from all fields of physics, from life and from nature. In these problems there are also involved the connections are coupling between physics and technique, economics, medicine, biology, transport and sport.

Thus for example the problem of the so called "falling wave" in the row of the domino cubes is with "a sense of humor" attributed to the former minister of the foreign affairs H. Kissinger. The "domino effect" has become an important term from the field of the international politics and describes the situation when coupled political and economical structures of different countries are destroyed in an avalanche, when the first from them, the most important one, is destroyed. In the YPT it was necessary to calculate and to measure the velocity of the falls of the cubes as a function of their parameters and their distribution. The set of the YPT problems involves also problems, which require also experimental processing, approval of the theoretical calculations and certainly a discussion.

One of the problems deals with the capability of the team to have a non-traditional idea, for example: Try to shock your rival with an extraordinary physical paradox. Students are in this way directed to the creation of their own devices and apparatuses, which require also a certain technician skills. One of the problems, usually the seventeenth and the final one, connects physics with a humor. It is of course only an external effect "because by tradition these problems belong to the most complicated problems speaking about its physical background both theoretical as well as experimental. The typical example is a following one: "If I knew in advance where I fall, I place there a straw." The solution of the problem of the safety free fall is obviously based on the practical viewing of this phenomenon. All teams naturally collected different types of straws, but they also collected information from different branches of sports, from accident departments of hospitals, from the preparatory courses of the security teams, from "the physics of the agricultural plants" etc.

There are a great number of problems in which physics is connected with a biology: the problem of a mosquito flight, the tremble of an aspen tree, the growth of grass through asphalt etc. The very complex solution is usually required by the problems from different sports. The most frequently are solved problems concerning outstanding sportive achievements in different branches of sport which are highly estimated by public, e.g. a record time of the 100 meters runner, high jump of men and pole jump. Almost in each annual tournament is also involved a problem from astronomy, astrophysics or meteorology. These problems have a connection with results of selected astronomic or metereologic observations, or on the contrary they belong to the domain of the theory. Thus for example are suggested problems concerning behavior and motion of the cosmic bodies,

Figure 1: Number of teams and states participating in IYPTs



e.g. how it is possible to observe with modern astronomic means an impact of the meteorite of the mass 1000 tons on the surface of the Sun. Naturally some problems are easier and some are more difficult. However all of them bring to the students the pleasure of discovering the solution.

The most important features of YPT problems are:

1. The problems solved are very close to the real research in physics.
2. The unique solution of the problems is not known, it is not known even to the authors and to the members of the evaluating commissions.
3. The nature itself is more complex then it can be involved into calculations or into experiments - it is a never ending challenge to the mankind.
4. The problems have not uniquely stated conditions under which they must be solved.
5. All problems have their own short, typical name, which in a certain aspect expresses their most important features - it gives keywords of the problem.

1.3 Countries participating in IYPT

Presented tables give basic information about participation and results of teams during last ten IYPT (see table 1 and table 2). The graph expresses number of teams and countries, which took part in different annual international finals of the IYPT [12-14].

Notes: + present
- absent
O observer

Table 1: Participation of teams in IYPTs

State	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Armenia	-	-	-	-	+	-	-	-	+	-
Belarussia	-	-	-	-	+	+	+	+	+	+
Bulgaria	+	+	-	-	-	-	-	-	-	-
Burjatia	-	-	-	-	+	+	-	-	-	-
Czech Rep.I	-	-	-	-	-	+	+	+	+	+
Czech Rep.II	-	-	-	-	-	-	-	-	-	+
Czechoslov.	+	+	+	+	+	-	-	-	-	-
Finland	-	-	-	-	-	-	-	+	-	O
France	-	-	-	+	-	-	-	-	-	-
Georgia I	-	-	-	-	+	+	+	+	+	+
Georgia II	-	-	-	-	-	-	-	-	+	-
Netherlands	-	+	+	+	+	+	+	+	-	-
Italy	-	-	-	O	-	-	-	-	-	-
Israel	-	-	-	-	-	-	-	O	-	-
Kazachstan	-	-	-	-	+	-	-	-	-	-
Latvia	-	-	-	-	-	-	-	O	-	-
Lithuania	-	-	-	-	-	-	-	O	-	-
Hungary	-	+	+	+	+	+	+	+	+	+
Moldavia	-	-	-	-	-	+	-	-	-	-
Germany I	O	+	-	-	-	-	-	+	+	+
Germany II	-	-	-	-	-	-	-	+	-	-
Poland I	-	+	+	+	+	+	+	+	+	+
Poland II	-	-	-	-	-	+	-	+	-	-
Russia Novg.	-	-	-	-	+	+	-	+	-	-
Russia Mosc.	-	-	-	+	+	+	+	+	+	+
Russia Frj.	-	-	-	-	-	+	+	-	-	-
Russia Jek.	-	-	-	-	-	+	-	-	-	+
Russia Lug.	-	-	-	-	-	+	-	-	-	-
Russia Prot.	-	-	-	-	-	+	-	-	-	-
Russia Ural	-	-	-	-	-	-	-	-	-	+
Singapore	-	-	-	-	-	-	-	-	-	O
Slovakia	-	-	-	-	-	+	+	+	-	+
Slovenia	-	-	-	-	-	-	-	O	-	-
USSR	+	+	+	+	-	-	-	-	-	-
USSR Latvia	+	-	+	-	-	-	-	-	-	-
USSR Ukraine	-	+	-	-	-	-	-	-	-	-
Sweden	-	-	-	-	-	-	+	O	-	+
Switzerland	-	-	-	-	-	-	-	-	-	O
Ukraine	-	-	-	-	-	+	+	+	+	+
Ukraine Lvov	-	-	-	-	-	-	-	-	-	+
Ukraine Od.	-	-	-	-	+	+	-	-	+	+
Uzbekistan	-	-	-	-	-	+	+	+	+	+
Great Brit.	-	-	-	+	-	-	-	-	-	-
No of countries	3/4	7/8	5/6	7	10	11	11	12	10	11
teams	4	8	6	8	12	19	12	15	12	15

Table 2: Results of teams in IYPTs

State	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Belarussia	-	-	-	-	1	-	3	3	-	2
Bulgaria	3	1	-	-	-	-	-	-	-	-
Czech Rep.I	-	-	-	-	-	3	1	2	1	1
Czechoslov.	3	3	3	-	1	-	-	-	-	-
Georgia I	-	-	-	-	3	1	2	3	-	3
Georgia II	-	-	-	-	-	-	-	-	2	-
Netherlands	-	3	2	3	2	-	3	3	-	-
Hungary	- (2)	-	3	1	3	2	-	2	3	1
Germany I	-	1	-	-	-	-	-	1	2	-
Poland I	-	3	3	3	-	3	-	3	-	3
Poland II	-	-	-	-	-	-	-	3	-	-
Russia Jek.	-	-	-	-	-	-	-	-	-	3
Russia Novg.	-	-	-	-	-	3	-	-	3	-
Russia Mosc.	-	-	-	3	2	-	1	-	3	3
Russia Frj.	-	-	-	-	-	-	3	-	-	-
Slovakia	-	-	-	-	-	-	-	3	-	-
USSR	1	2	1	2	-	-	-	-	-	-
USSR Latvia	~~2~~	-	2	-	-	-	-	-	-	-
USSR Ukraine	-	-	-	-	-	-	-	-	-	-
Ukraine Lvov	-	-	-	-	-	2	-	-	-	3
Ukraine Od.	-	-	-	-	-		-	-	-	3

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The YPT is highly supported by the European Physical Society. Since the 5th IYPT the representatives of EPS Prof. Dr. J. Depireux, Prof. Dr. G. Tibell and Prof. Dr. H. Schopper took part in these tournaments.

1.4 Conclusion

IYPT is a physical tournament of a very high standard with a direct contact with students. It has a social character, it stimulates the development of the English language, working language of physics, and communicative skills among students. Among its important goals it is also finding and succeeding development of the talented students of physics.

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2 10th IYPT in the Czech Republic

Zdenek Kluiber

The organization of the jubilee 10th IYPT has been offered to the Czech Republic also because of its previous success, gained by the teams of its representatives during 5th till 9th annual competitions. In all of these cases the teams were formed by the students of the Gymnasium Zborovska, Prague. The main merit for the organization of the 10th IYPT in the Czech Republic has Director of the project ASTRA 2000 of the Foundation CHARTA 77, Doc. Ing. J. Rosenkranz, CSc., who carried through that the offer concerning organization of the international tournament of secondary schools students of physics have been accepted. Following leading Czech physicists have taken the patronage on the 10th IYPT:

RNDr. Vladimir Dvorak, DrSc., Director of the Institute of Physics,

Academy of Sciences Czech Republic, Doc. Ing. Josef Rosenkranz, CSc., Director of the project ASTRA 2000,

Doc. Ing. Stefan Zajac, CSc., 1st vice-chairman of the Union of Czech mathematicians and physicists,

Prof. Ing. Ladislav Musilek, CSc., dean of the Faculty of Nuclear and Physical Engineering, CTU,

Prof. RNDr. Bedrich Sedlak, DrSc., dean of the Faculty of Mathemathics and Physics, Charles University.

Organization Committee of the 10th IYPT:

Chairman of the 10th IYPT: RNDr. Zdenek Kluiber, CSc.
Gymnazium Zborovska 45, 150 00 Prague 5

Vice-chairman: Doc. Ing. J. Rosenkranz, CSc.
Foundation Charta 77, Washington street 17, Prague 1

Secretary: Michael Prouza
Faculty of Mathematics and Physics, Charles
University,
Ke Karlovu 2, Prgue 2

Members:RNDr. Jaroslav Kocvara,
Gymnazium , Nerudova 7, Cheb
Dr. Petr Kuzel, PhD.

Institute of Physics AS CR,
Na Slovance 2, Prague 8
Prof. Hana Oblukova
Gymnazium, Zborovska 45, Prague 5
Mgr. Miroslav Stulak,
Gymnazium Nerudova 7, Cheb
Doc. Ing. I. Stoll, CSc.
Faculty of Nuclear Physics and Engineering, CTU
Brehova 7, Prague 1
Doc. Ing. Stefan Zajac, CSc.
Union of Czech Mathematicians and Physicists,
Zitna 25, Prague 1

10th IYPT was organized between June 1st - 7th, 1997 at the Gymnasium in Cheb, Nerudova street 7. There were several reasons for organizing this tournament in Cheb. One of the most important of them is that Gymnasium in Cheb belongs among the best secondary schools in the Czech Republic. The team of teachers has an outstanding level, the team is headed by an excellent director RNDr. J. Kocvara. The school has a wide range of experiences for example with organization of the republican Physical Olympiad Tournament and other actions of the state importance. The IYPT has been also supported by the town Cheb and the whole region. The building of the school is new, there are also wide range of possibilities for food and accommodation.

The part in the organization of the 10th IYPT has been taken also by the Project ASTRA 2000 Foundation Charta 77, Ministry of the Youth, Education and Sports of the Czech Republic, Institute of Physics, of the Academy of Sciences of the CR, Faculty of the Physical and Nuclear Engineering of the CTU, Union of the Mathematicians and Physicists, Journal Prospects of Mathematics and Physics, Mathematical and Physical Gymnasium, Zborovska 45, Prague, Faculty of Economics, West Bohemian University in Cheb, town Cheb, and Czech Power Engineering Company (CEZ).

The patronage and support of the 10th IYPT has been also offered by:

Association of the Secondary Schools Clubs in the CR,
Faculty of the Mathematics and Physics f Charles University,
District Authorities,
Expert and Partner Engineering,
The Office of the President of the Republic,
Academy of Sciences of the Czech Republic,
Mr. L. Dobrovsky,
Talent-centre of the Institute of the children and youth of the Ministry of the Edı

The 10th IYPT has been financially supported by following organizations:

Ministry of Education, Youth and Sports of the CR,
Commission for the cooperation with foreign countries (Germany),
Main sponsor of the tournament - Czech Power Engineering
Company - CEZ,
The Townhall of Cheb,
European Physical Society,
Association of the secondary schools clubs of the CR,
China-ware factory Leander,
The company 1946,
Expert and Partner Engineering,
Ariane Schola,
District Office in Cheb,
Coca-Cola Company.

For participation in the 10th IYPT have been invited 36 countries. The invitation has been accepted by 11 countries from which arrived 15 teams: Belorussia, Czech Republic - 2 teams, Gruzia, Hungary, Germany, Poland, Russia - 3 teams, Slovak Republic, Sweden, Ukraine - 2 teams and Uzbekistan. As for the number of teams this year's tournament was the third biggest tournament in the history of IYPT.

The delegations of each country were formed by:
- head of the delegation,
- team leader and
- five students.

Among the participants of the 10th IYPT were as guests or observers also representatives from following countries: CR, Finland, Germany, Poland, Singapore, Slovakia, Sweden and Switzerland.

The most important guests of the 10th IYPT were:
Prof. Dr. Klaus von Klitzing, Germany, Nobel Prize winner for Physics 1958, Prof. Dr. Herwig Schopper, for a long period director of CERN, DESSA and president of the European Physical Society, Prof. Dr. Gunar Tibell, Sweden, representative of the European Physical society, president of the Forum for Education and Dr. Jevgenij J. Junosov, vice-president of the International Committee TMF, Russia.

The outstanding organization of the 10th IYPT has been assured by the team of 70 persons from Gymnasium Cheb. The team was lead by RNDr. J. Kocvara. The activities of the team also covered the transport, accommodation, food, and cultural and social events. Important role for the whole tournament played also a publication of 5 numbers of the journal" Daily Physics" with a large number of information, discussions a tournaments results.

The program of the 10th IYPT was following:

June 1st: Arrival of delegations and guests.
June 2nd: Morning (M): Beginning of the tournament, Lecture of RNDr, J.Grygar,
 Afternoon (A): Eliminative competition in Physics,
 Evening (E): Lecture of Prof. Dr. von Klitzing, Welcoming party
June 3rd: M: Eliminative competition in Physics,
 A: Eliminative competition in Physics,
 E: Lecture of Prof. Dr. H. Schopper.
June 4th: M:a. Students and team leaders: excursions to
 - Power plant Tisova (CEZ),
 - China-ware-factory Leander Loucky, Karlovy Vary
 b. Heads of delegations, guests, Members of the International Committee YPT- Conference "10 years of YPT".
 A: Semifinal in competition in Physics.
 E: Cultural program.
June 5th: M: Final in competition in Physics.
 A a. Seminar - lecture :RNDr. J. Kocvara, Mgr. M.Slavik.
 b. Lecture Doc. RNDr. J. Kleczek, DrSc.
 c. Proclaiming of winners, handing the prizes, closing ceremony.
 E: Sport activities, ethnic cultural program, closing of the tournament.
June 6th: All day excursion - Prague.
June 7th: Departure of delegations and guests.

All participants of the IYPT took part in the excursion around town Cheb, guests and members of the evaluation committee visited West Bohemian Radiocommunication transmitter Zelena Hora and Frantiskovy lazne.

During the tournament the Czech Power Engineering Company (CEZ) organized exhibition " Energy for everybody", the company Ariane Schola organized one-days exhibition of teaching aids and demonstrations, the company Lighgate organized one-days exhibition of holograms of art objects and company Geonika organized two-days exhibition of optical systems for teaching of physics. The important role on the tournament organization was played by computer technique of the Hewlett-Packard, which was for the purposes of the tournament lended and installed by the company Expert and Partner Engineering. This company which took care of this computing technique during the whole tournament, gives an important support to the Czech Committee of the YPT. The culmination point of the social program of the 10th IYPT certainly was for most of its participants the visit of Prague. After seeing the Prague Castle, Little Quarter and Charles

Bridge, participants could see other important parts of Prague and to learn about its cultural and social centers. The main parts of the accompanying scientific program of the 10th IYPT were lectures of Prof. Dr. von Klitzing " Metrologie", the lecture of Prof. Dr.H. Schopper (see chapter 6) and the lecture of RNDr. J. Grygar (see chapter 7). Organization of these lectures was performed by RNDr. V. Dvorak, DrSc.

Lectures of Doc. RNDr. J. Klezcek DrSc., RNDr. Kocvara and the lecture of Mgr. M. Slavik were outstanding example for dissemination of astronomy and experimental physics.

The interest of the participants of experts was also devoted to the international conference "10 years of the Tournament of Young Physicists" (see chapter 9). This conference, which was prepared by Doc. Ing. S. Zajac, CSc.; helped to make a bilan of the history, to describe the presence and to propose the directions of the future development of the YPT.

An important event within a framework of the 10th IYPT has been a research organized by the Talent-centre of the Institute of Children and Youth of the Ministry of Education, Youth and Sports of the CR. The research was headed by Mgr. L. Starosta. Obtained results will be used to increase the quality of the content and forms of the YPT, and for the work with gifted students for their study of physics. The conclusions taken from the research, together with data concerning Talent-centre, project ASTRA 2000, as well as data concerning the work with talented students will be in the form of Proceedings offered to the international institutions and working teams interested in these problems in

cooperation with UNESCO.

All winners (list of winners see chapter 5) participants of the tournament, heads of the delegations and team leaders, and guests obtained prizes, presents and souvenirs. Most of the presents were offered by CEZ, by Association of the secondary schools clubs of the CR, by Gymnasium Cheb, by town Cheb, by factories from the Cheb region and by Gymnasium Zborovska 45, Prague.

Participants of the IYPT were during opening and closing ceremony welcomed by: RNDr.V. Dvorak, DrSc., Doc. Ing. S. Zajac, CSC., Dr. J. N. Junosov, Doc. Ing. J. Rosenkranz, CSc., Prof. Dr. Tibell, RNDr. P. Hejda, CSc., Prof. M. Valikova, Dr. R. Lehn., and by RNDr. Z. Kluiber, CSc.

In the opening ceremony chairman of the 10th IYPT read from the letter of the Director of the Office of the President of the Republic, who expressed his full support to the tournament. The actions of 10th IYPT are also accessible on the videocassette, prepared by Mgr. M. Slavik, the copy of which was given to representatives each of the participating countries. This interesting document can help to the further development of the YPT. The other documentation in the form of photographs was prepared by Mgr. M. Stulak. These pictures will be used for other publications.

Very good work in the organization of the 10th IYPT was done by the group of former students from gymnasium Zborovska 45, Prague 5, Mr. M. Prouza, Mr. K. Vyborny, Mr. P. Holzhauser and Mr. P. Janecek, former winners of the 9th IYPT. The students prepared a new program to see immediately actual state of the competition in the disciplines of physics. In this way the time required to evaluate different rounds of competition was substantially decreased. This group of students together with students from Gymnasium Cheb formed efficient working team, capable to present the results of competition almost just after the last round of the competition. This efficiency has been highly estimated by all participants of the tournament.

The 10th IYPT has been estimated by all participants as a most successful tournament in its 10th years history. The all organization team should be acknowledged for a great work which has been done during this important international event.

2.1 List of participanting teams

01 Sweden/Swd
Per Norlin
Ali Mohammad
Karin Tilgus
Magnus Safstrom
Poya Tababat-Khani

02 Germany/Ger
Hendrik Hoeth
Thomas Preusser
Adrian Zimme
Thomas Schmidt
Markus Kapp

03 Russia-Ural/R-U
Leonid Volkov
Andrei Kazantsev
Evgeny Gornov
Alexei Boiartchenkov
Vadim Sedelnikov

04 Belarus/Bel
Sergei Zukovskiy
Alexei Starovoitov
Alexander Gedranovich
Alexander Licholap
Pavel Shlapak

05 Hungary/Hun
Janos Asboth
Imre Balcut
Adam Zawadowski
Csala Toth
Kristian Kereplesy

06 Ukraine-Lvov/UkrL
Maxym Morus
Andriy Haidys
Oleh Fareniuk
Yaroslav Lutsyshyn
Orest Nera

07 Uzbekistan/Uzb
Alysher Rakhmanov
Evgenia Remeeva
Skukhrat Saidov
Evgeniy Kim
Igor Ivanov

08 Poland/Pol
Adam Glogowski
Pawel Nowak
Maciej Borowka
Marcin Robakowski
Marek Mossakowski

09 Czech-Opava/CzhO
Vladimir Peringer
Michal Nop
Dusan Halama
Jirka Plsek
Antonin Prochazka

10 Ukraine-Odessa/UkrO
Kirill Belokurov
Igor Vorokhaev
Grigoriy Zavorothny
Denis Murakhovskiy
Elisaveta Ovdeenko

11 Georgia/Geo
Nikolai Sambelashvili
Alexander Aivazov
Sergo Sindariani
Igor Vasilkovski
Iuri Oskuzian

12 Russia-Moscow/MSU
Dmitry Melnikov
Semjon Kusin
Anatoly Dymarsky
Petr Mikheev
Michail Zagoruyko

13 Czech-Prague/CzP
Hynek Nemec
Petr Chaloupka
Libor Inovecky
Filip Matejka
Petr Luner

14 Russia-Ekat/Ekt
Alexander Korinokov
Sergei Fotine
Pavel Merkoul
Victor Issaev
Maximilian Prokhorov

15 Slovakia/Slo
Peter Svrcek
Pavol Novotny
Pavol Habuda
Michal Majerik
Jan Trojak

2.2 Observers

GERMANY	Felix Juraschek
FINLAND	Juhani Smolander
SINGAPORE	Willie Yong
GERMANY	Salvatore Manmana
GERMANY	Wolfgang Burger
GERMANY	Brunhilde Jurashek
SINGAPORE	Joe Martinez

2.3 Members of the Interantional Committee of the Young Physicists Tournament

RUSSIA	Valentin Lobyshev
SWEDEN	Gunnar Tibell
RUSSIA	Vladimir Afanassieev
RUSSIA	Zoya Savilova
RUSSIA	Evgeny Yunosov
RUSSIA	Tatjana Korneeva

2.4 Members of Organizational Committee of the 10th IYPT

CZECH REPUBLIC	Ivan Stoll
CZECH REPUBLIC	Josef Rosenkranz
CZECH REPUBLIC	Vladimir Dvorak
CZECH REPUBLIC	Stefan Zajac
CZECH REPUBLIC	Petr Kuzel

2.5 Guests

GERMANY	Klaus von Klitzing
GERMANY	Herwig Shopper
GERMANY	Walter Kinkelin
CZECH REPUBLIC	Jiri Grygar
POLAND	Anna Czakanska
SWEDEN	Maj-Lis Persson
SLOVAKIA	Stanislav Vrbnak

3 List of problems of the 10th IYPT.

The group of the following authors formulated the problems of the 10th IYPT: Yunosov E., Kluiber Z., Laskhishvili G., Lehn R., Lobyshev V., Nadolny A., Prouza M., Urban A. and Urickij Z.

1. . Invent it yourself. Construct and demonstrate a device, which moves in a definite direction under chaotic influence.
2. Coin. From what height must a coin with heads up is dropped, so that the probability of landing heads or tails up is equal?
3. Paper How does the tensile stress of paper depend on its humidity?
4. Electron beam. An electron beam is cast upon a planparallel plate of known homogenous material. Some of the electrons get through it, some do not. Try to simulate processes taking place, e.g. using Monte Carlo methods and compare your results with those described in the literature.
5. Blue blood Human blood is known to be red, but the veins seem to be blue. Explain this phenomenon and illustrate it by a model.
6. Magic tube A compressor blows air into Ranque-Hilsch T-shaped tube a pressure 0,5 MPa or higher so that the air begins to circulate. In such a case hot air is coming out from one end of the tube and cold air from the opposite one. Find out which end of the tube is the "hot" one and explain the difference of the temperature obtained. Investigate the parameters this difference depends on.
7. Water Jet A water jet streaming vertically downward from a tube is divided into drops at some distance from the tube. Choose the conditions under which the length of the unseparated jet is largest. What maximum length did you obtain?
8. Floatation. A piece of a chocolate, which is dropped into a glass of soda water, periodically sinks and goes back to the surface. Investigate the dependence of the period of these oscillations and how it depends on various parameters.
9. Jet-Spread A water jet falling onto a horizontal plane spreads out radially. At some distance from the center the thickness of the layer increases dramatically. Explain the phenomenon.
10. Cooling the Earth How would the temperature of the Earth change with time, if the Sun suddenly stopped radiating?

11. Candle Generator Construct a device for charging an electric capacitor (1000 F/100V) using the energy of a candle burning for a period of one minute.

12. Static Friction A force of motion friction is known to be independent on the rubbing surface area of a body. How does the static friction depend on the rubbing surface area?

13. Tea Cup If one fills a cup with a hot tea (60 - 800C), a thin layer of steam emerges above the surface. One can see that some parts of the steam layer disappear suddenly and reappear after a few seconds. Investigate and explain this phenomenon.

14. Rain On a long time exposure photograph of night rain taken in the light of a projector, the tracks of drops appear interrupted. Explain this phenomenon.

15. Cell and Accumulator How does the voltage current characteristics of a cell and of an accumulator change during discharging?

16. Roghe Spiral The Roghe spiral is a device where a source of current is connected to a vertically suspended spring, the lower end of which dipped mercury. Mercury is a highly dangerous chemical substance and thus experiments with it are not permitted. Substitute the nercury with a less dangerous substance and investigate the functioning of the device.

17. Leap To make a leap it is necessary to squat. How does the height of a leap depend on the depth of the squat?

For further information see for example problem No.4.76 in the book "The Flying circus of physics" written by Jearl Walker (published by John Willey and Sons, Inc. 1975, 1977 or in Russian translation by Mir 1979). You can find other references and a small part of solution of the whole problem in this book too.

4 The regulations of the International Young Physicists Tournament

4.1 The Young Physicists' Tournament (YPT)

is a competition among teams of high school students in their ability to solve complicated scientific problems, to present solutions to these problems in a convincing form and to defend them in scientific discussions – "Physics Fights".

4.2 The problems of the YPT

The problems are formulated by the Organizing Committee (OC) and sent to the national committees of the YPT not later then in November. These problems may be used for the regional and national Tournaments. To compose the problems a meeting of the OC may be held in the host country.

4.3 The participants of the International YPT

1. The national teams
Any invited country is represented by one team. The host country may be represented by two teams.

2. The teams of regions, towns, clubs, colleges
The decision about participation of such a team may be taken by the Organizing Committee of the host country.

3. The membership of the teams
The YPT team is composed of five high school students. The high school graduates participate in the YPT in the year of their graduation. The participation of university students is not allowed. The Organizing Committee may allow participation of teams of four or three students. The composition of the team is not changed during the Tournament. The team is headed by the captain who is an official representative of the team during the Physics Fight (PF).

4. The team is accompanied by two team leaders.

4.4 The membership of the Jury

The Jury is formed by the local OC. It consists of independent members and representatives of the participating countries. Prominent scientists and professors are drawn in the Jury. Team leaders (one from each team) are included in the Jury. Independent members of the Jury are distributed among the groups of teams by the local OC.
The team leaders cannot be the members of the Jury in the groups where their teams participate.

4.5 The agenda of the International YPT

The International YPT is carried out in a period determined by the local OC (in May – July) during at least eight days.
The teams participate in scientific discussions – Physics Fights:
a) 3 Selective PFs; b) Semifinal PF; c) Final PF.
The host country provides a cultural program for the participants.

4.6 VI. The Physics Fight regulations

Three or four teams participate in a PF (depending on the total number of teams). In the course of a Fight the members of a team communicate only with each other.
Before the beginning of a PF, the introduction of the Jury and the teams takes place.

The Fight is carried out in three (or four) Stages. In each Stage, a team plays one of the three (four) roles: the Reporter, the Opponent, the Reviewer (the Observer). In the following Stages of the PF, the teams change their roles according to the role scheme:

Three teams PF			
Team \ Stage	1	2	3
1	Rep	Rev	Opp
2	Opp	Rep	Rev
3	Rev	Opp	Rep

Four teams PF				
Stage / Team	1	2	3	4
1	Rep	Obs	Rev	Opp
2	Opp	Rep	Obs	Rev
3	Rev	Opp	Rep	Obs
4	Obs	Rev	Opp	Rep

4.7 The Stage regulations

The performance order in the Stage of a Selective or Semifinal PF:

The Opponent challenges the Reporter for the problem .... 1 min
The Reporter accepts or rejects the challenge .... 1 min
Preparation of the Reporter .... 5 min
Presentation of the report .... 10 min
Questions of the Opponent to the Reporter and answers
of the Reporter .... 2 min
Preparation of the Opponent .... 3 min
The Opponent takes the floor .... 5 min
Discussion between the Reporter and the Opponent .... 5 min
Questions of the Reviewer to the Reporter
and the Opponent and answers to the questions .... 2 min
Preparation of the Reviewer .... 2 min
The Reviewer takes the floor .... 3 min
Concluding remarks of the Reporter .... 2 min
Questions of the Jury and Grading .... 2 min

In the Final the procedure of challenge is omitted.

The official languages of the International YPT are English and Russian. The Reporter makes the presentation in English.

The presentation of the Opponent and the Reviewer and the discussion may be carried either in English or in Russian. In the latter case translation into English is necessary and the time of presentation is increased by a factor of 1.5.

4.8 The teams performance in the Stage

The Reporter
presents the essence of the solution to the problem, attracting the attention of the audience to the main physical ideas and conclusions. It is desirable to show the pictures, diagrams, slides, photos prepared in advance, and to demonstrate some experiments if the problem is an experimental one.

The Opponent
puts questions to the Reporter and criticizes the report, pointing to the inaccuracy and errors in the understanding of the problem and in the solution. The Opponent analyzes the advantages and drawbacks of both the solution and the presentation of the Reporter. The discussion of the Opponent should not become the presentation of his own solution. In the polemics, the solution presented by the Reporter is discussed.

The Reviewer
presents a short estimation of the presentations of the Reporter and the Opponent.

Limitation of the number of presentations:
during one PF no member of the team may take the floor more than twice (other members of the team are allowed to make brief remarks).

4.9 The rules of challenge to the problem and of the rejection

1. All problems presented in the same PF should be different.

2. Selective PF
The Opponent may challenge the Reporter on any problem with the exception for the problem that:
   a) was presented in this PF;
   b) was presented by the Reporter earlier;
   c) was opposed by the Opponent earlier;
   d) was presented by the Opponent earlier.

If such a challenge cannot be made, the bans d), c), b) are successively removed in the given order.
During all Selective PFs the Reporter may reject the challenge three times in total without penalty. For every subsequent rejection the coefficient of the Reporter (see item X) is diminished by 0.2.
All the problems rejected by the Reporter are included in the Rejection List of

the team. The rejection of these problems in the successive PFs does not involve penalty.

3. Semifinal PF
In every Semifinal group 10 problems are used, which are determined by the OC according to the Rating List prepared by the participants (each team ascribes integer numbers to problems, the sum of these numbers should be equal 100). The Opponent may challenge the Reporter for any of the 10 problems. During the Semifinal PF the Reporter may reject the challenge twice without penalty. For any subsequent rejection the coefficient of the Reporter diminishes by 0.2.

4. Final PF
The teams choose any problem from the whole List of the problems for presentation.

4.10 The grading

After each Stage the Jury rates the teams, taking into account all presentations of the members of the team, questions and answers to the questions, and participation in the discussion. The marks are transformed into grades and then into points with various coefficients for the Reporter, Opponent and Reviewer according to the scheme:

Mark	5+	5	5−	4+	4	4−	3+	3	3−
Grade	53	50	47	43	40	37	33	30	27

	Reporter	Opponent	Reviewer
Coefficient	3.0 or less	2.0 or 2.5	1.0

The coefficient of the Opponent challenging for problem "Think up a problem yourself" is 2.5, since he takes the risk to face the unknown problem. The coefficient of the Opponent chalenging for other problems is 2.0.

If the Jury consists of 5 or 6 persons, then in the evaluation of the mean grade the lowest grade is withdrawn. If the Jury consists of more than 6 persons, then the highest and the lowest grades are withdrawn.

4.11 The resulting parameters

1. For a team in the PF

SP (the sum of points) is the sum of mean grades multiplied by the corresponding coefficients and rounded to 1. SP_j is the sum of points of the team taking place j in a given PF.

R (the rating), characterizes the success of team in the PF. R_j is the parameter of the team taking place j. R_j depends upon j, SP_j and the value of $SP_i - SP_j$ ($i \leq j$). The rating of the team taking place j is determinated according to the following table:

	Team's place in the Fight				
	1	2, 3 or 4 $SP_j \geq SP_1 - 6$	2 $SP_2 < SP_1 - 6$	3 or 4 $SP_j \geq SP_2 - 6$	3 or 4 $SP_j < SP_2$
$SP_j \geq 290$	5	5	4	4	3
$290 > SP_j \geq 240$	4	4	3	3	2
$240 > SP_j \geq 190$	3	3	2	2	1
$190 > SP_j$	2	2	1	1	0

This rule of evaluation of *R* holds for all PFs.

2. For a team in the Tournament

TSP (the total sum of points) equals the sum of *SP* of the team in all PFs,
TR (the total rating) is the sum of ratings of the team in all PFs.

3. For members of a team

The speech of the member of a team as a Reporter, an Opponent or a Reviewer is considered successful if all the grades for it taken into account are higher than 3+. In the successful speeches the member of a team gathers points:

Grade	5+	5	5–
Points	3	2	1

IR (the individual rating) equals the sum of points gathered by the member of the team in all successful speeches, divided by the number of the grades taken into account.

4.12 Selective PFs

In the course of the Selective Fights any one team meets with another team only once, according to the following scheme (numbers ascribed to teams in the scheme are determinated by lot):

1st Selective Fight											
	18 - 20 team Fight						15 - 17 team Fight				
Group	I	II	III	IV	V	VI	I	II	III	IV	V
Reporter	1	2	3	4	5	6	1	2	3	4	5
Opponent	7	8	9	10	11	12	6	7	8	9	10
Reviewer	13	14	15	16	17	18	11	12	13	14	15
Observer	19	20						16	17		

2nd Selective Fight											
	18 - 20 team Fight						15 - 17 team Fight				
Group	I	II	III	IV	V	VI	I	II	III	IV	V
Reporter	11	12	7	8	19	20	17	10	6	7	16
Opponent	16	17	18	13	9	10	9	14	15	11	8
Reviewer	6	1	2	3	14	15	13	1	2	3	12
Observer					4	5	5				4

3rd Selective Fight											
	18 - 20 team Fight						15 - 17 team Fight				
Group	I	II	III	IV	V	VI	I	II	III	IV	V
Reporter	18	13	14	15	16	17	15	11	12	13	14
Opponent	5	6	1	19	20	4	4	5	1	16	17
Reviewer	9	10	11	2	3	8	7	8	9	2	3
Observer				12	7					10	6

The distribution of the team leaders among the groups, which is determinated below, assures that they do not judge their own team. The scheme for the Selective PFs with more than 20 or less than 15 teams, should be composed by using the same principles.

The team leaders distribution among the groups											
	18 - 20 team Fight						15 - 17 team Fight				
Group	I	II	III	IV	V	VI	I	II	III	IV	V
	2	3	4	5	6	1	2	3	4	5	1
Team	8	9	10	11	12	7	8	9	10	6	7
leaders	14	15	16	17	18	13	12	13	14	15	11
	20					19			16	17	

4.13 The Semifinal

Nine teams having the highest *TR* in the Selective Fights participate in the Semifinal. The team taking place 10 to 12 may participate in the Semifinal if its *TR* equals that of the team taking place 9 and its *TSP* differs no more then 6 from that of the team taking place 9.
Teams and team leaders are distributed among three groups according to the tables below. They are enumerated according to their *TR* (if equal than to their *TSP*): the higher *TR* (*TSP*), the lower the number.

Distribution of teams among the groups			
Group	I	II	III
Reporter	1	2	3
Opponent	6	5	4
Reviewer	7	8	9
Observer	(12)	(11)	(10)

Distribution of team leaders among the groups			
Group	I	II	III
	2	3	1
Team	5	4	6
leader	8	9	7
	(11)	(10)	(12)

There can be only one winner of the Semifinal in each group. The winner is determinated by the highest *R*; in case of equality by the highest *TR*; in case of equality by the highest *TSP*; in case of equality by lot.

4.14 The Final

The winners of the Semifinal participate in the Final. If the team which got the highest *TR* is not among these teams, it participates in the Final as a fourth team. If there is more then one of such a team, the decision is taken according to the highest *TSP*; in case of equality by lot.

The order of presentation in the Final is determined by the *TR*, in case of equality by the *TSP*, in case of equality by lot: the higher *TR* (*TSP*), the lower the number in the schemes of item VI.

4.15 The winners of the Tournament

1. Team competition
The participants of the Final assure for themselves place II and compete for place I.
The participants of the Semifinal assure for themselves place III. The following places in the Tournament are determined by the value of *TR*.

2. Individual competition
The individual winner of the Tournament is determined by the value of the individual rating *IR*. The highest *IR*, denoted as *HIR*, serves as a reference. All participants (team members) that have *IR* score higher than 0.8 *HIR* are "winners" and those having *IR* higher than 0.5 *HIR* become a honourable mention (for successful participation).

4.16 The Regulations of the International YPT

are established by the OC and may be changed only by the OC.

Moscow — Groningen — Warsaw — Tbilisi — Prague, 1988 — 1996

5 Final results

5.1 Final results of team competition

Place I Czech Republic - Prague
Hungary
Place II Belarus
Place III Ukraine - Odessa
Georgia
Poland
Ukraine - Lvov
Russia - Ekaterinburg
Russia - Moscow
Place IV Germany
Slovakia
Russia - Ural
Uzbekistan
Sweden
Czech - Opava

5.1.1 The official results of the Finals

Team	SP	R	Prize
Czech Republic	289	4	I
Belarussia	265	2	II
Hungary	289	4	I

5.1.2 10th International Young Physicists Tournament Statistics

How many times have the particular problems been presented or refused, respectively.

Problem No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Reported	2	1	3	4	3	3	2	**6**	3	**6**	3	3	4	1	5	4	4
Refused	1	1	1	2	1	0	**3**	0	2	**3**	**3**	1	1	1	0	1	2

5.2 Final results of individual competition

	Name	Team	Points	
1	Janos Asboth	Hungary	10.20	Absolute Winner
2	Libor Inovecky	Czech-Prague	9.80	Honourable Mentio
3	Adam Glogowski	Poland	8.60	Winner
4	Imre Balint	Hungary	6.90	
5	Petr Chaloupka	Czech-Prague	5.40	
	Denis Murakhovskiy	Ukraine-Odessa	5.40	Honourable Mentio
7	Yaroslav Lutsyshyn	Ukraine-Lvov	5.20	Honourable Mentio
8	Pavel Merkoul	Russia-Ekat	4.40	
9	Igor Vorokhaev	Ukraine-Odessa	4.20	
10	Victor Issaev	Russia-Ekat	4.00	
11	Sergei Zukovskiy	Belarus	3.45	
12	Peter Svrcek	Slovakia	3.40	
13	Anatoly Dymarsky	Russia-Moscow	3.20	
14	Alexei Starovoitov	Belarus	3.00	
	Maciej Borowka	Poland	3.00	
	Alexander Aivazov	Georgia	3.00	
17	Igor Vasilkovski	Georgia	2.80	
18	Nikolai Sambelashvili	Georgia	2.60	
	Poya Tababat-Khani	Sweden	2.60	
	Elisaveta Ovdeenko	Ukraine-Odessa	2.60	
21	Sergo Sindarini	Georgia	2.40	
	Markaus Kapp	Germany	2.40	
23	Alexander Licholap	Belarus	2.20	
24	Hynek Nemec	Czech-Prague	2.00	
25	Hendrik Hoeth	Germany	1.80	
	Iuri Oskuzian	Georgia	1.80	
27	Maxym Morus	Ukraine-Lvov	1.20	
	Andriy Haidys	Ukraine-Lvov	1.20	
	Dmitry Melnikov	Russia-Moscow	1.20	
	Thomas Schmidt	Germany	1.20	
	Petr Luner	Czech-Prague	1.20	
32	Adam Zawadowski	Hungary	1.00	
	Alexander Gerdanovic	Belarus	1.00	
	Per Norlin	Sweden	1.00	
35	Leonid Volkov	Russia-Ural	0.80	
	Grigoriy Zavorothny	Ukraine-Odessa	0.80	
	Olek Fareniuk	Ukraine-Lvov	0.80	
38	Thomas Preusser	Germany	0.60	
	Evgeniy Kim	Uzbekistan	0.60	
	Pavel Schlapak	Belarus	0.60	
	Vadim Sedilnikov	Russia-Ural	0.60	
	Petr Mikheev	Russia-Moscow	0.60	
43	Igor Ivanov	Uzbekistan	0.50	
44	Ali Mohammad	Sweden	0.40	
	Kirill Belukurov	Ukraine-Odessa	0.40	
	Sergei Fotine	Russia-Ekat	0.40	
47	Jirka Plsek	Czech-Opava	0.20	

6 Why To Become A Physicist ?

Herwig Schopper

When I was a young student an old professor asked me whether I had really thought it over carefully if I wanted to become a physicist. He explained to me: "Physics is much too hard work for rich people, on the other hand, it does not bring enough money for poor people and hence there are just a few fanatics who do it." The main advantage of being a physicist is that your profession becomes your hobby. But there are also disadvantages - do not tell your girl friend you are going to be a physicist; she will have to suffer because of your frequent absence. Nevertheless I am happy to be a physicist and I can give you at least three main arguments of why physics is important and why it is gratifying to be a physicist.

6.1 Physics is part of human culture.

The first reason, which to mind is not appropriately appreciated by the public, is the fact that physics is fascinating part of human culture. Usually it is only literature, music, philosophy and other activities in 'humanities' which are considered as culture. But I am deeply convinced that science in general and physics in particular is also a very important part of human culture.

It is a fundamental question why order exists in Nature, why Nature is not in a state of chaos. Usually we consider this fact as normal, but it is not as evident as it might seem to us, the progeny of the teaching of the old Greeks, of Galileo and Newton. When Portuguese monks came for the first time to China and told the Chinese, that there are Laws of Nature, these were laughing at them: "If there are laws, there must also be an authority, imposing the laws and punishing people who are not obeying the laws. Where are these authorities in Nature?" This indicates that our concepts of Laws in Nature are not trivial and in many other cultures do not exist.

One of the important questions physics tries to answer is: What is the position of mankind in Cosmos. Physics, as it developed during the last centuries, helped us to get rid of superstition - we do not consider lightnings to be produced by angry Gods or we do not believe that rain can be solicited by prayers. Our picture of Nature is based on the rational thinking of mathematics and physics. From the important steps initiated by Copernicus we learned that our Earth is not in the centre of Cosmos, but that it is just one of many planets and that our Solar system is not the only one. Indeed the question of whether other planets with life exist is one of the most exciting ones which is investigated by modern astrophysics. Indeed our present concept of the material world (our 'Weltbild') is largely based on physics and the only other major contribution came from Darwin's theory of evolution and recently from the discovery of DNA.

Three important 'philosophical' questions are bothering mankind since hundreds of years: What is matter, what is life and what is conscience.

Physics can contribute to answering all three of these questions. Certainly the question concerning matter belongs to the realm of physics. But also to study what life is , how it originated and developed needs physics since biology now is relying more and more on physics and physical methods. This is equally true for investigation of the nature of conscience since also neuroscience is increasingly applying physics methods.

6.2 Basic physics - is everything known ?

Because of the breath taking progress made during this century some people believe that all mysteries of nature have been unveiled and nothing remains to be discovered. This is completely wrong and I should like to distinguish three most fascinating frontiers of physics (Fig. 1):

- the penetration into microcosm (atomic, nuclear and particle physics)
- investigation of the macrocosm (astronomy, astrophysics and cosmology)
- understanding complexity and self-ordering systems (condensed matter physics, fluids, deterministic chaos, etc.)

Indeed complexity is becoming more and more a common element of the main frontiers in physics. Multibody systems have to be dealt with in nuclear, elementary particle as well as condensed matter physics and the treatment of the deterministic chaos implies the investigation of non-linear systems appearing in many domains of physics.

The idea that physics is practically finished is not new. Already in 1884 Michelson said that physics is at the end, all what people still could do in the future, is to measure constants of nature with an accuracy of 7 decimals. Strangely enough it was Michelson himself who did an experiment which proved the theory of relativity and thus a completely a new world opened up. Jolly, the teacher of Max Planck, advised him not to go into physics, he told him: "Leave physics, we know Max-well's equations, we know thermodynamics, and hence everything is known. Nothing more can be found." The story repeats. Nowadays some people make similar predictions. The well known physicist Stephen Hawking believes that physics is finished and that his theory explains everything. Theorists are sometimes too proud, and think too high of their own work. Many things remain to be discovered and I shall give a few examples of open questions in the following.

6.3 Exploring the microcosm

Giving you a few examples of open questions I have, because of lack time, to limit myself and I hope you will forgive me that I have chosen the field of elementary particle physics, for no other reason than that I have been involved in this field for more than 25 years.

What is matter? Are there ultimate, indestructible constituents of matter? Newton was thinking that matter consists of little balls, infinitely hard spheres which exist eternally. What is the nature of space and time, why does space have three dimensions, why is it that time is the same for everybody, flowing in the same direction? How does the Universe evolve, is there a beginning and an end of Cosmos? Presently a most remarkable development is taking place. It turns out that the penetration into the microcosm and the penetration into the macrocosm get more and more linked and a grand unification in the understanding of nature is at the horizon.

The most important progress in the understanding of the microcosm during the last two hundred year consisted in finding out that if we try to divide matter into smaller and smaller parts one found new "ultimate" constituents (2). Biologists and chemists are talking about large molecules and crystals, but the chemists also indirectly discovered the atom, which they considered as indivisible. Then physicists found that atom is not, as it name implies, indivisible, it can be split - there is a nucleus and the electrons circulating round. Earlier during this century it was discovered that the nucleus itself is very complicated and that it consists of protons and neutrons which together with other particles, e.g. mesons, are called hadrons. Now we found that even these particles, the hadrons, consist of even smaller elements, quarks. In addition the electron has got brothers , the muon and the tau particle which behave exactly like electrons but they are heavier. The electron and its associates are called leptons.

Now you might ask, how will the exploration of the microcosm go on? Shall we be able to break up the quarks into smaller constituents, will the splitting into smaller parts never end? Or is there a principle barrier? I shall come back to that question in a moment.

6.4 LEP - the largest research instrument.

Amazingly the exploration of the infinitely small needs very large devices. Penetrating into the microcosm is very much linked to the development of new instruments, which extend our senses since we cannot 'see' quarks or leptons directly. These instruments, above all huge accelerators, storage rings and detectors, require the development of new technologies. Thus there exists a very close connection between answering deep, fundament a questions and the progress of high technology.

For some decades bigger and bigger accelerators were built, called 'atom smashers', because they where used to break up particles. Now we are doing different things, using a new idea. It is our everyday experience that a head on collision between two cars is much more 'efficient' than hitting a fixed wall. In the so called colliding machines, or storage rings, packets of particles and their antiparticles (opposite electric charge) circulate in magnetic ring in opposite directions, e.g. electrons and positrons. The packets are arranged along the circumference in such a way that they collide at certain points where detecting devices register the collisions.

The trick is that apart from head on collisions matter collides with antimatter. Antiparticles are in a certain way mirror images of particles. If matter and antimatter meets they 'annihilate' each other , they disappear, and their mass m is converted into energy E according to the famous formula of Einstein $E = mc^2$. If an electron and positron collides , they disappear and for a moment very high concentration of energy is created - a kind of fireball - and out of these fireballs new particles are created and can be observed (Fig. 3). This gives us the possibility to create new kinds of matter, which we do not find normally around us on Earth, but which may have existed a very short time after the Big Bang at the origin of our Cosmos. Hence a very close connection between elementary particle physics and cosmology is established. These fireballs which we produce by collisions in the laboratory are a kind of mini-big-bangs which mimic the real cosmic Big-Bang.

This is a very remarkable procedure and to appreciate it I have invented the following analogue picture (Fig. 4). If two strawberries collide, one would expect to get strawberry jam. But that is not the case. In fact, what we get out of the energy concentration of the mini-big-bang, are new particles, whole fruits, not jam, and even heavier fruits than those which collided. Sometimes even a little fish may come out - a Nobel Prize! Some time ago, the present pope, John Paul II, visited CERN and I explain to him: "Look, we are not smashing atoms any more, we are creating matter, new kinds of matter". "No ,no", he said, "you do not create matter, creation is my business, you are producing matter."

Fig.4 Popular version of Fig.3. Two colliding strawberries produce 'fireball' which is converted into whole fruits.

To make a step closer to the Big Bang, we built at CERN, during the time when I was Director- General (1981-1988), the largest research instrument which exists in the world and it will remain biggest device for quite some time. LEP, as it is called (Large Electron-Positron Collider), is housed in a circular tunnel 27 km around and between 50 to 150 metres under ground (Fig. 5). In a highly evacuated tube, electrons, guided by a magnetic field, run around in one direction, positrons in the opposite direction. At four points these particles collide and produce the mentioned fireballs which are observed by four sophisticated detectors. However, it is not so much the size which is impressive, but rather the accuracy which goes with it. If the circumference of 27 km would have been wrong by about 2.5 cm, the machine would not have worked. A so far unprecedented precision was necessary for placing the magnets and new technologies for the surveying had to be developed. Many other interesting technological development were necessary which are also important for practical applications. But to cover them would require another talk.

Looking at Fig.5 reveals another interesting fact. One notices that LEP is crossing the boundary between Switzerland and France several times. This is probably the only example where a laboratory exists on both sides of a frontier - a remarkable example of successful international collaboration, based on the will to find always pragmatic solutions. From the point of view of CERN, we can largely ignore the frontier - anyway even the very efficient Swiss custom officers are not able to count the particles which cross the frontier every second.

When the LEP tunnel was designed it was made sufficiently wide in order to house a second magnetic ring. Indeed a new project, the LHC project (Large Hadron Collider), has recently be approved. A new double-ring of superconducting magnets will be put in the tunnel and will store and collide protons. Construction of the project will start in about two years and will be finished in about 2005. It will be a unique facility in the world and hence the USA and Japan are participating in the construction and exploitation.

Fig.5 shoes the LEP tunnel crossing the border between Switzerland and France. The four detectors are ALEPH, OPAL, DELPHI and L3.

The big LEP detectors, very complicated and technologically demanding, were not built at CERN, but by outside universities in many countries. CERN had the task to co-ordinate these world-wide efforts, and it seemed like a miracle that when all parts were brought to CERN and put together things worked.

6.5 A new concept to understand Nature

Now what is the result of all this work done at CERN but also in many other laboratories? We think today that the old periodic system of 92 Elements of the chemists, which one learns at school, has to be replaced by a new periodic system of elementary particles, which is much simpler (Fig.6). It consists only of 12 particles, which can be grouped into two families: leptons, of which the best known is the electron and the so called quarks. The difference between these two families is that the quarks feel the strong nuclear force, the electrons not. The results obtained at LEP indicate that this table is complete. Of course, the question now arises: are these the ultimate elementary particles, or can we split them and find even smaller ones?

There are experimental and also theoretical indications that we might have come to an end. Quarks exist only inside so-called hadrons, e.g. protons and neutrons (three inside a proton, three inside a neutron). If one tries to liberate a quark, it does not come out, but rather 'fragments' and forms a jet of known particles. Nobody has even seen a free quark. Why? - is a fundamental question and we think we know it. Our concept of fundamental particles has to be modified.

Fig.6: Quarks feeling the strong nuclear force and Leptons not feeling it

We run here into a paradox, known already to the German philosopher Kant: either the ultimate particles (e.g. quarks and leptons) are mathematical points - pointlike particles. Then it is hard to understand, how a mathematical point can have a mass, electric charge, etc. Or the particle is not a mathematical point, but has a finite extension, in which case there is no logical reason, why one cannot split in further. Every time when we find in physics such a paradoxa, it is a sign we are hitting a fundamental problem. Usually the solution is that neither of the two possibilities is right, but one finds that a wrong question has been asked. This implies an enormous cultural element of physics, since we learn that our way of thinking sometimes has to be corrected, that basic principles to explain nature have to be changed.

During the last three hundred years we tried to explain nature by assuming the existence of certain fundamental particles (the 'ultimate, eternal' constituents of matter) and forces acting between them. I believe the really exciting development of particle physics, is that we may have to give up this picture. To understand nature we must not ask any more what the ultimate constituents of matter, what the forces are - we have to ask different questions. An enormous amount of experimental and theoretical work seems to indicate, that the new 'first principles' to understand nature are symmetries. Symmetry for a law of nature means that this does not change under certain operations (also in art symmetries play a major role; the Dutch painter Escher systematically investigated symmetries in paintings; architecture knows, of course, symmetries very well). We think that laws of nature should be independent of the choice of the co-ordinate system and therefore should not change under a translation or a rotation. It can be shown that the invariance of a law of nature implies a conservation law for certain quantities. Thus invariance under translations implies conservation of momentum, under rotation conservation of angular momentum. The outcome of an experiment should not depend on the moment when the clock is started (the choice of time zero) and from the invariance against time translations one can easily deduce the conservation of energy.

Apart from these transformations there exist also other symmetry operations - mirror reflections, or mathematically more complicated gauge transformations of fields (e.g. in electrodynamics). A short summary of a rather long story is that the invariance of fields against certain gauge transformations determines the forces, e.g. the gauge invariance of the electromagnetic field determines fully Maxwell's equations.

Further it has become obvious that forces are more fundamental than particles. If we know the forces, they explain automatically also the particles. The forces themselves are determined by symmetries via gauge invariance and hence symmetries have to be considered as the 'first principles' in explaining nature. Some symmetries are broken, they do not hold under certain conditions, and this determines how different forces are connected.

Let me make a philosophical remark. For a long time we tried to describe nature by ultimate constituents, starting with the atoms of Demokritos. Now we think that symmetries are more fundamental and thus we are much closer to Plato, who claimed that ideas are the ultimate realities. We may interpret this as a shift form the philosophy of Demokritos to the philosophy of Plato - again a sign of how important the influence of physics is on our culture, on our thinking, even on philosophy.

Let me come back to the forces. Until last century only two forces were known, gravitation and electromagnetism. Only in this century the strong nuclear force and the weak nuclear force were discovered. One question is how forces are transmitted throw empty space. How does the light from the sun come to the earth? The light ether which last century was considered to be the carrier of electromagnetic waves was abolished by the theory of relativity. Modern quantized field theory claims that apart from fermions (particles with spins 1-2) which are the constituents of matter (e.g. quarks and leptons), there are other particles - the carriers of the forces. They are called 'bosons' (particles with integer spin). An exchange of these bosons between the fermions produces the forces (Fig.7). It is like two people in two boats exchanging a ball which produce a little recoil every time it is caught or thrown. Looking from distance, one does not see ball, one only sees the result - a repelling force. Each force is characterised by its special carrier (Fig.7) - for the electromagnetic force it is the photon, for the nuclear force we call them gluons (discovered in DESY in 1978), for the weak force we call them Z and W particles (discovered at CERN in 1983).

Fig.7. The four known forces transmitted by field quanta

Have we discovered all forces? We do not know. Or one may ask the opposite question - is it not possible to unify the four known forces into one single force, one universal force which would explain everything which happens in cosmos? Indeed we hope to find a "theory of everything (TOE)" and one possible candidate is called "superstring theory". This theory would be characterised by a beautiful, very high symmetry which would determine this super force. This symmetry would hold at extremely high temperatures. Lowering the temperature, this higest symmetry would be broken and as consequence one force would be separated from the universal force - it would be gravitation (Fig.8). This process continues: lowering the temperature further, another symmetry breaking occurs, and the nuclear force is split off. In a last step the weak nuclear force is separated from electromagnetism.

Experimentally the opposite direction is taken. By increasing the collision energy in storage rings fireballs with higher energy densities are produced getting more similar to the Big Bang. Using more powerful accelerators it was possible to unify the electromagnetic and the weak nuclear force. We now are close to include the strong nuclear force in the unification. Whether it will be possible to achieve a full unification of all forces remains to be proven.

6.6 The unifications microcosm and macrocosm.

It is very fascinating that this scheme, invented to explain the microcosm, can be found also in cosmos. The Big Bang was a high concentration of energy, a very high temperature, high enough to guarantee the validity of the highest symmetry - all forces were united in one single force. Then the cosmos expanded, and by expansion it cooled. During the continuous cooling down which still goes on today, the cosmos passed through the different temperatures at which symmetry breaking takes place and consecutively forces were separated off. This lead to different epochs in evolution of the universe which cannot be discussed in detail.

Fig.8. The hierarchy of forces. The energies indicate where a symmetry breaking happens. They were reached in the universe at the times indicated.

A fundamental question which is on everybody's mind is: will the cosmos expend forever? It depends. The Big Bang can be considered as an explosion which gave monumentum to matter to fly apart. But on the other hand matter has mass, and consequently gravitation tries to pull it together. Will eventually gravitation take over and make the universe collapse and lead to the Big Crunch, as it is sometimes called? Or is gravitation too weak and cosmos will expand forever? There is also an intermediate state possible, where the gravitational pull and the monumentum from the Big Bang are just balanced. Which case is realised in nature depends apparently on how much matter there is in the universe. If there is a lot of matter, gravitation will be sufficiently strong to pull matter together, if there is a little matter, gravitation will be too weak and the universe will expand forever. The matter density corresponding to the intermediate state is calling the "critical density". The actual matter density in cosmos can be experimentally determined-. One can count the stars (a very difficult and tedious job!) and also the galaxies and by estimating their average mass, one can determine the matter density of the "luminous mass". One finds that it corresponds to about 7% of the critical density. But you all know the beautiful pictures of spirals galaxies which rotate. One can show that the gravitation of the luminous mass does not suffice to counterbalance the centrifugal force of the rotation. All these galaxies should have flown apart since a long time - unless there is some invisible mass, "dark matter", which keeps them together. The results on how much dark matter exists in the universe are still somewhat controversial, but it seems that its abundance is about ten times larger than that of the luminous mass. Thus taking into account both the luminous and the dark mass the mass density of the universe coincides within a factor of two with the critical mass density. This is a very surprising result! At the beginning of the universe there could have been anything - the mass density could have been one millionth of the critical density or ten thousand times higher. Why is our universe so close to the balanced intermediate state?

The immediate question comes up: What is the dark matter composed of? Combining measurements of elementary particle physics (in particular flom LEP) and from astrophysics one can show that most of this dark matter is not ordinary matter we are made of. This surprising result is something like a second Copernican revolution! Copernicus told us that the Earth is not in the center of cosmos. Now we learn that even the mass, the matter we are made of, is not typical in cosmos, but that we are only a minority species. But what can the prevailing matter in cosmos be? Here again is a close connection between particle physics and cosmology. Unifying the nuclear force with the electroweak force one predicts new kinds of particles, called supersymmetric particle. It is possible that a large fraction of dark matter consists of some of these exotic particles which we normally do not find around us. But it is also possible that some of the neutrinos do have a novanishing mass. Only further experiments will tell us.

I tried to show, that basic physics is an intellectual adventure. In previous centuries Columbus, Magellan and others explored the world. Now the planet is known and exploratory adventures penetrate into the microcosm or macrocosm. They are as exciting, but fortunately less dangerous!

6.7 Physics of today - the technology of tomorrow

The first argument why physics is interesting and fascinating is the fact that physics is part of human culture as I tried to show above. The second argument, which I think as valid implies that physics of today is the technology of tomorrow. And this will remain true for a long time. Some people claim that this century, which is just coming to its end, was the century of physics whereas the next century will be that of biology. It is centrainly true that biology will play a very important role, but physics still has a great future as well. I should like to give you a few arguments of favour of such a statement.

Let me first of all demonstrate the relation between basic physics and applications by looking back at history. For this purpose I want to use the pyramid shown in Fig.9. Classical physics started to investigate phenomena determined by the human size, i.e. of the order of cm and m. Later it penetrated into macrocosmos in one side to smaller dimensions and into microcosmos on the other side to ever larger dimensions. Starting from basic knowledge which is represented near the base of the pyramid, applications and technologies developed and thus the pyramid grew vertically. Many modern technologies, like the steam engine, cameras, television, radio etc are off- springs of classical physics. Then the atom was discovered, quantum mechanics was invented to understand the atom and finally semiconductors, neon lamps, superconductivity,

Fig.9. Physics penetrated from human sizes to smaller and larger dimensions (base of the pyramid). From this basic knowledge applications developed in time (pyramid grows verticaly).

computers etc became inevitable for daily life. The next step into microcosmos was marked by the discovery of the atomic nucleus and what followed was radioactivity, Einstein's famous equation linking energy and mass, nuclear fission, reactors, fusion and also the atomic bomb. But also isotope technology or nuclear magnetic resonance imagning turned out to be valuable tools for industry and for medical diagnosis and therapy. A next step was made by the discovery of protons, neutrons and other particles, some of which found also already applications and the final step at present is represented by the existence of quarks and leptons as described above. In a similar way one can analyse the steps leading into macrocosmos, but this would take too much space here.

If we look back in history we see that it takes some time for applications and technologies to develop on the basis of basic knowledge. the pyramid grows slowly and often one has to wait several decades before a new product gets into the market. How difficult it is to make predictions in this respect is illustrated by a story about Faraday. When he was engaged in investigating electromagnetic induction, the basis of all electric motors and dynamos, he was visited by a representative of the Treasury who at the end of his visit said to Faraday: "Well, I did not understand most of your explenations, and therefore could you tell me at least whether your work will have any benefits for society?", whereupon Faraday ansewered: "This I cannot predict, but I am sure that one day your successors will levy high taxes on it." And that is what happened! I am not more clever then Mr. Faraday and hence cannot predict what applications elementary particle physics or astrophysics will eventually have. But I see not logical reason why the pyramid should not continue to grow also in future.

But it is possible to point a few applications where physics will be necessary also in the next century. New and better technologies for the production, transport and storage of energy will require strong inputs from physics. Information technology (including computers and networks), micro- and nano- technology, new materials, behaviour of surfaces and the whole area of environmental research, many issues of diagnostics and therapy in medicine - all these will depend very much on further contributions from physics.

Let me give you a few examples were basic physics has recently lead to new developments. Antimatter, still being considered to be a rather abstract element of particle physics, is already an important diagnostic tool in medicine. This is the socalled positron-electron tomography PET. For this purpose radioactive substances are injected into the body which accumulate in particular parts of the tissue, e.g. in the brain. The radioactive nuclei emit positrons, the antiparticles of the electron. These annihilate with electrons in the tissue and as a result two gamma-photons are emitted which go exactly into opposite directions. They can be detected and their point of origin can be localised. Most big hospital nowadays have such a device and the PET method can give complementary information with respect to NMR scanning or X-ray tomography which incidentally are also off-springs of nuclear physics. For example PET has opened completely new aspects for the understanding of the functioning of the brain and for the cause of diseases as Alzheimer.

But not only the results of basic physics can be at the origins of new applications but also instruments developed originally for pure basic research turn out to be the basis of completely new domains of applications. Examples are the use of accelerators for synchrotron radiation sources, medical therapy by heavy particles and energy production by inertial fusion or fission initiated by accelerated particles. Many examples could be given also for spin-offs concernig data acquisition and analysis. The most spectacular example is WWW which was invented at CERN.

The development of synchrotron radiation sources has far reaching consequences for research and industry. Electrons running on a circle emit X-rays because of the centripetal acceleration. This so-called synchrotron radiation has the advantage of being emitted in the plane of the electron orbit and hence it is very concentrated. The intensities one can get are about ten thousant times higher than those from the best X-ray tubes, which means much shorter exposure times. This is relevant not only for physical and technical processes, but also for biological and medical applications. It allows for example the investigation of biological objects which are short lived or under motion. Using special magnets (wigglers and undulators) it is possible to adjust the spectral properties of the radiation. The synchrotron radiation is in addition polarised which is important for special applications.

Synchrotron radiation has become already a very important tool for industry. Alone in Japan about a dozen of such synchrotron radiation sources exist and half of them are used by industry. Also in Europe several of such devices are available - e.g. 3 in Germany, 1 in Italy, 1 in France - and some have been built in developing countries like Taiwan and Thailand. These complicated storage rings, originally developed for particle physics, will become a normal tool for all kinds of investigations and maybe even for production. This may become true for nano-electronics and nano-mechanics. Using synchrotron radiation it has become possible to produce tiny generators and motors with dimensions of less than a human hair. There are speculations that apart from all kinds of technical applications, they could even be introduced into our body, to clean arteries and veins and to execute operation.

Another application of synchotron radiation in medicine is for cardiography and angiography. In X - ray pictures the bones give shadows and one cannot really see what is happening around the heart. This can be avoided by a trick. Synchotron radiation permits to take two simultaneous pictures with two different wave - lengths. One wavelength is just above the absorption edgeof iodine (iodine is used as a contrast medium in the arteries), the other below it. By calculating the difference between the two exposures the influence of the bones is largely removed and one can see the heart and the coronary arteries. This method is already tried in some hospitals.

Another field which will become very important is medical therapy by heavy particles Nowadays every hospital has an X-ray source for the treatment of cancer. But X-rays are not very efficient since within the size of a typical biological molecule they will interact only one or two times and damage the rest of the body. Heavy particles, like protons, alpha particles or carbon ions, on the other hand, produced many more interactions inside a molecule and above all most of the interaction happens at the end of the range of these particles. Hence doses can be administered precisely to a tumour with relatively little damage to the rest of the tissue. Therefore it is to be expected that cancer treatment will change from X-rays to treatment with heavy particles. The total number of patients, who are already treated by heavy particles is steeply going up. Japan is again leading - just a year ago a large accelerator facility has been taken into operation which is use excusively for medical treatment and about 1000 patients per year can be taken care of. A large project is also under consideration in Italy.

Physics in medicine will become one of the promissing job opportunities for physics.

6.8 Physics and international co-operation

Another domain, albeit not scientific, where physics has been playing an essential role is international collaboration. Physics is, for various reasons, one of the best tools to practise international collaboration:

- the laws of nature are valid everywhere, they do not respect frontiers or political systems;
- at least in basic physics there is no military or proprietorial secresy;
- for most physicists their profession is also their hobby and hence financial interests are less relevant than in other professions;
- for some parts of physics, like elementaly particle physics, but also astronomy, one needs large facilities which require that scientists from different countries work together. But the realisation and exploitation of large facilities needs also the involvement of administrators and politicians and hence the spirit of peaceful collaboration radiates into these domains.

Allow me to mention CERN which was founded as the first European organisation after the last war, not only to join European forces to become competitive in the field of nuclear and particle physics with the rest of the world, but also to improve and to foster the peaceful collaboration between countries which have been fighting during the war. Later this collaboration was extended beyond the boundaries of Europe. CERN was the first international organisation which signed an agreement of co-operation with the Soviet Union, in CERN for the first time Chinese physicists from mainland China and from Taiwan worked together and there are many more examples of breakthroughs in political matters. I believe that all the money spent on this kind of research is already justified by promoting international collaboration. It is really there where people working together on concrete scientific and technical problems, spending whole nights together to solve problems, that they start to understand each other, to appreciate different mentalities and to build up confidence, which forms the basis living peacefully together.

6.9 Chances Of Employment For Physicist

During the past decades many physicists, both in the West and the East, were employed for defence work. After the end of the cold war many of these activites were reduced. In addition some industries, mainly because of the recession, felt that they need fewer physicists, partly also because some laboratory work can be replaced by the computer simulations.

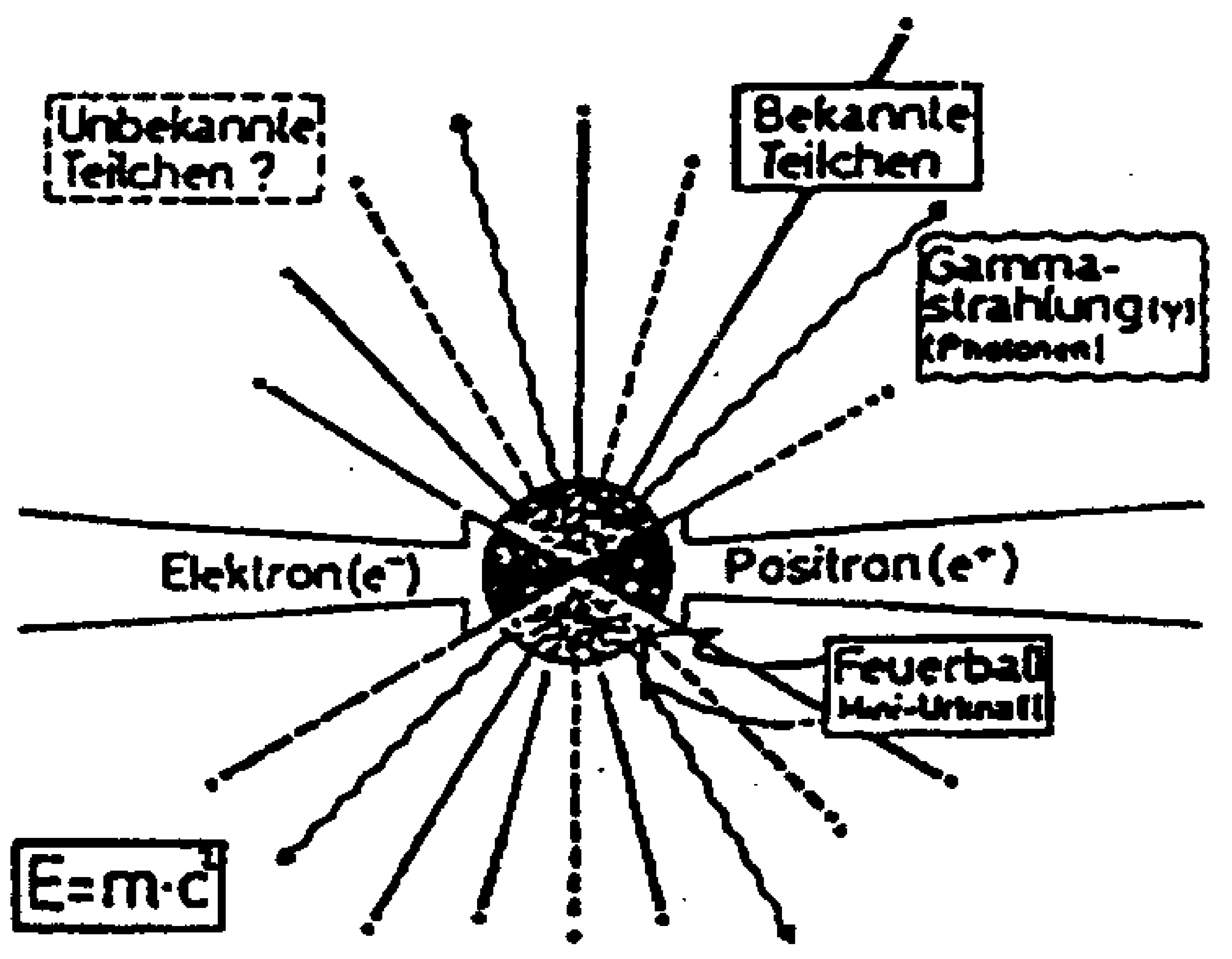
Fig.10. The change of employment in different domains (source: full line Institute für Arbeitsmarkt - und Berufsforschung broken estimates I. A. Nefiodow)

Indeed we are living in world which is rapidly changing. This can be dramatically demonstrated by looking at the development after 1800. At that time 70% of the population were employed in agriculture. This went down very fast and in industrialised countries only 2 or 3% of the population are still working in agriculture. Industrial production increased instead rapidly but it went already through a peak around 1960 with the consequence that the nubmer of people working in industry is going down (Fig.10). Presently the employment in services is increasing and even faster in information technology (including radio, TV, computering etc.)

What are the consequences for the employment of young physicists? To have success as a physicist, it is very important to become a generalist, not a narrow-minded specialist. Engineers are much better in specialisation. The strength of physicists lies in their flexibility, in their ability to approach new problems. Once I had a student, who after his PhD applied to Volkswagen Works. There were 30 candidates, some with a much better knowledge of motocars, but to his surprise he was selected. He asked the personnel manager, why he had been taken, coming from high energy physics, and having nothing to do with motocars. The manager told him: "The topic of your PhD thesis of no interest to us, what is important to us is, that you learned how to work in a team, in an international environment, that you had to follow a given time schedule, that you were accustomed to a given budget and besides you learned useful things like using computers".

Most important may be that physicists learn methods, how to approach compex unfamiliar problems. And last not least it is important to become a leader which implies to be able to communicate and also to defend your case without accepting every compromise, but also without hurting others unnecessarily. Nowadays it is necessary not only to do good work but also to present it - to "market" it. And this will have to be done not only to physicists but to other people. If somebody is looking for a job he will not be interviewed by a physicist but by a personnel manager.

To conclude I would like to say that I was really impressed by what I saw at this tournament. Apart from teaching you physics it provides an opportunity to acquire many of the qualities which I just mentioned. To be successful you had to work in a team, you had to adapt to an international environment and fairness was crucial in spite of the tough competition. This tournament is an excellent undertaking and it should be supported. I hope it will develop further in the future by attracting more teams from different countries. Finally I want to wish all the young students here to become a successful and happy physicist. If you should turn to another field I am sure that this excursion to physics will centrainly be useful.



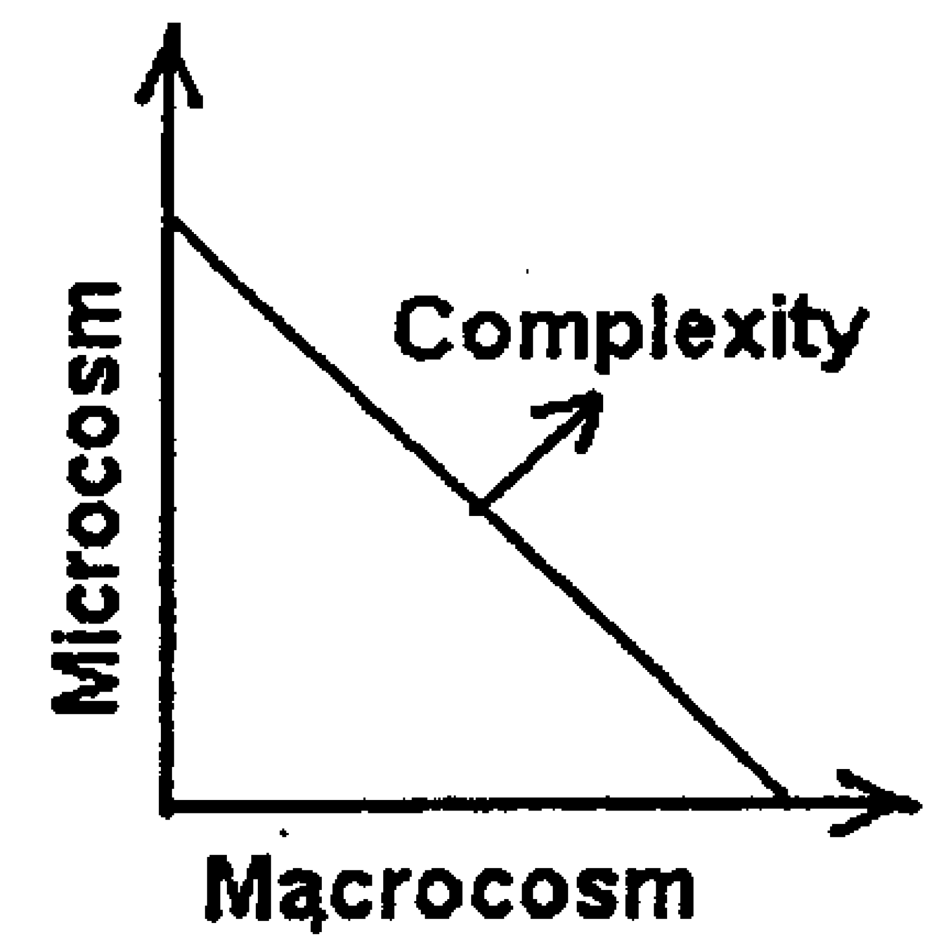


Fig. 1. The frontiers of physics

Fig.3. Mini-Big Bangs produced by the collision of electrons and positrons (matter and antimatter)

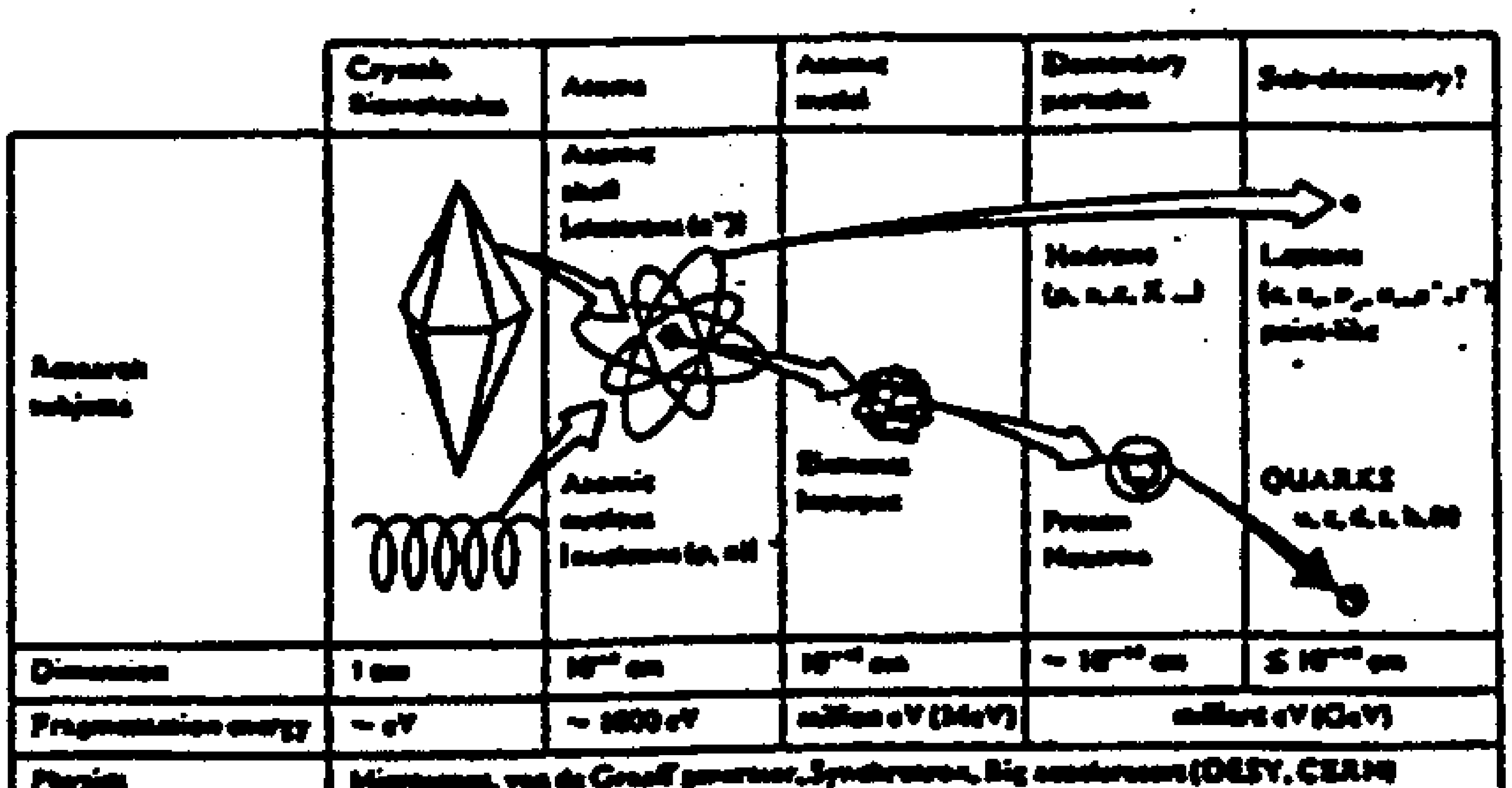


Fig.2. „Ultimate“ constituents of matter

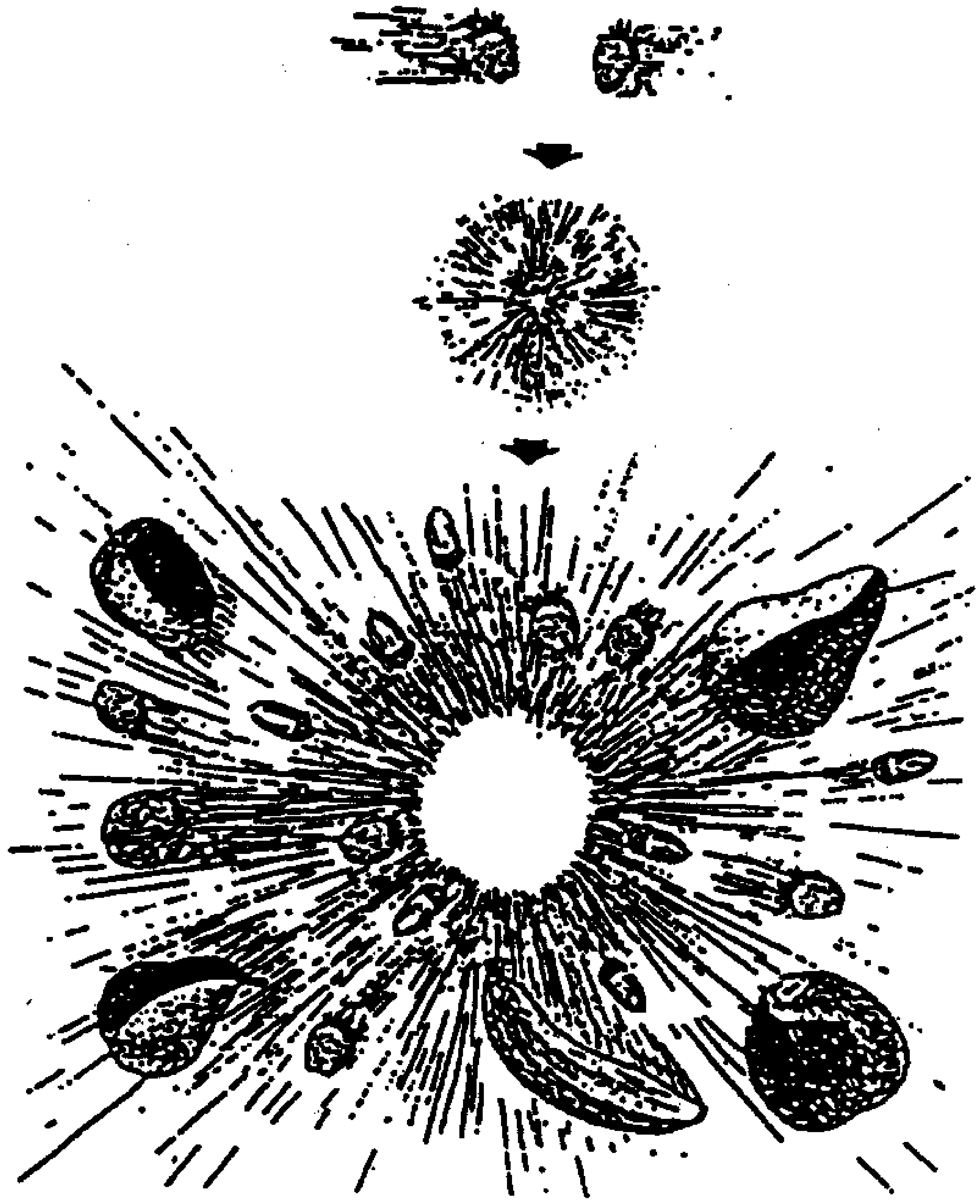


Fig.4. Popular version of Fig.3. Two colliding strawberries produce 'fireball' which is converted into whole fruits

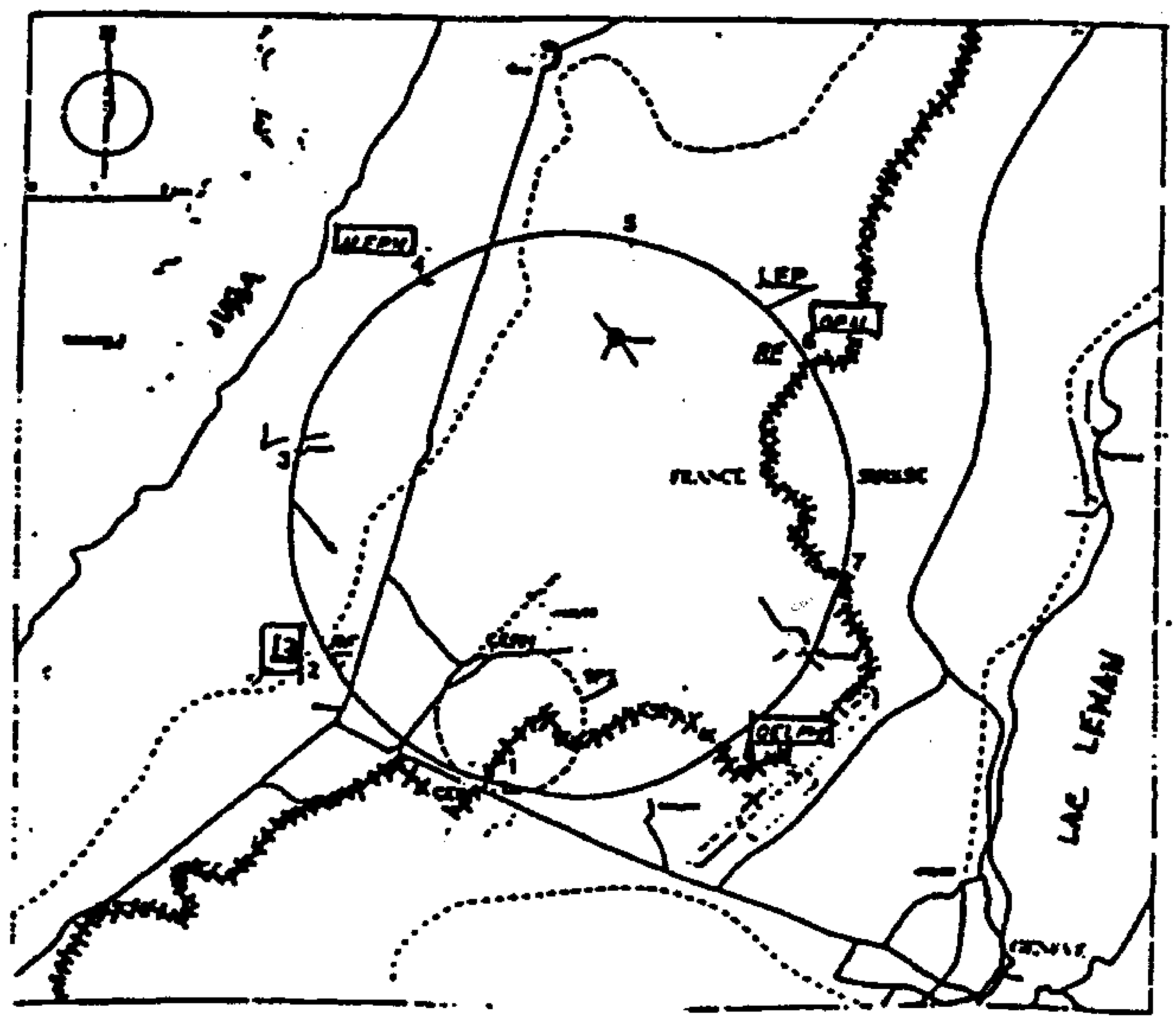


Fig.5.The LEP tunnel crossing the boarder between Switzerland and France.The four detectors are ALEPH, OPAL, DELPHI and L3.

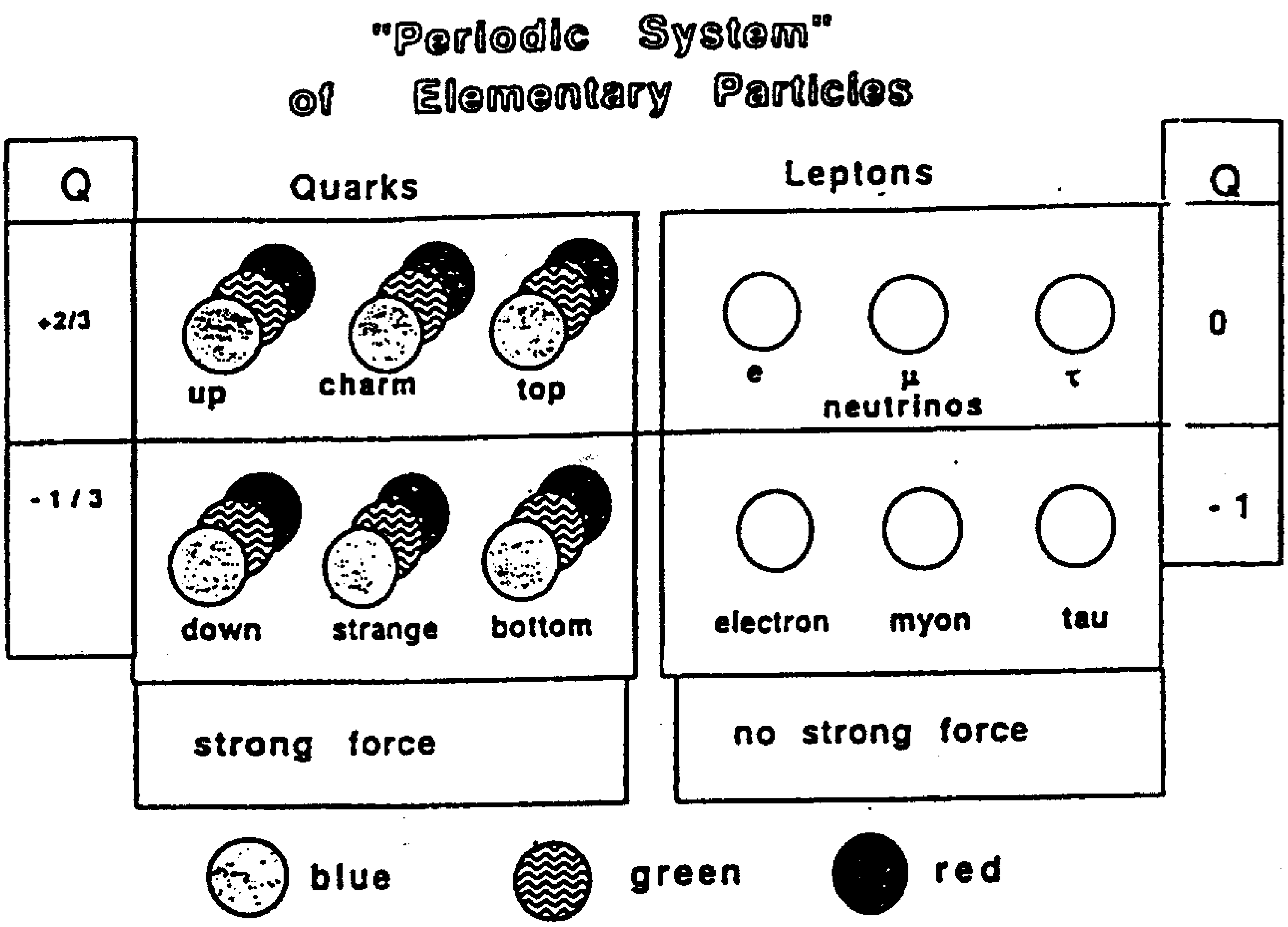
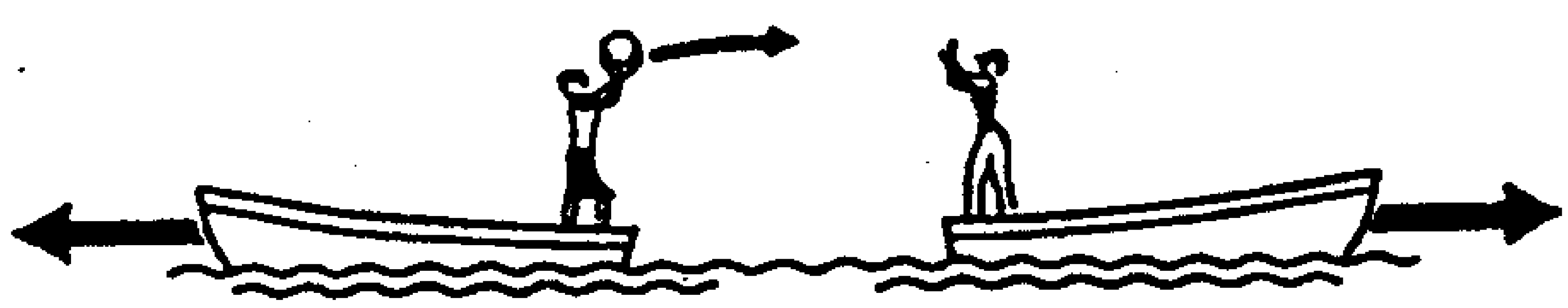


Fig.6. Quarks feeling the strong nuclear force and Leptons not feeling it

FORCES IN NATURE			
Type	Strength at low energies	Binding particle (field quantum)	Occurs in
Nuclear (strong) force	~ 1	Gluon (no mass)	Atomic nucleus
Electromagnetic force	~ 1/1000	Photon (no mass)	Atomic shell Electrical engineering
Weak force	~ 1/100,000	Bosons (heavy) Z^0, W^+, W^-	Radioactive beta decay
Gravitation	~ 10^{-}[illegible]	Graviton?	Heavenly bodies Gravity



The exchange of particles generates FORCE

Fig.7. The four known forces transmitted by field quanta

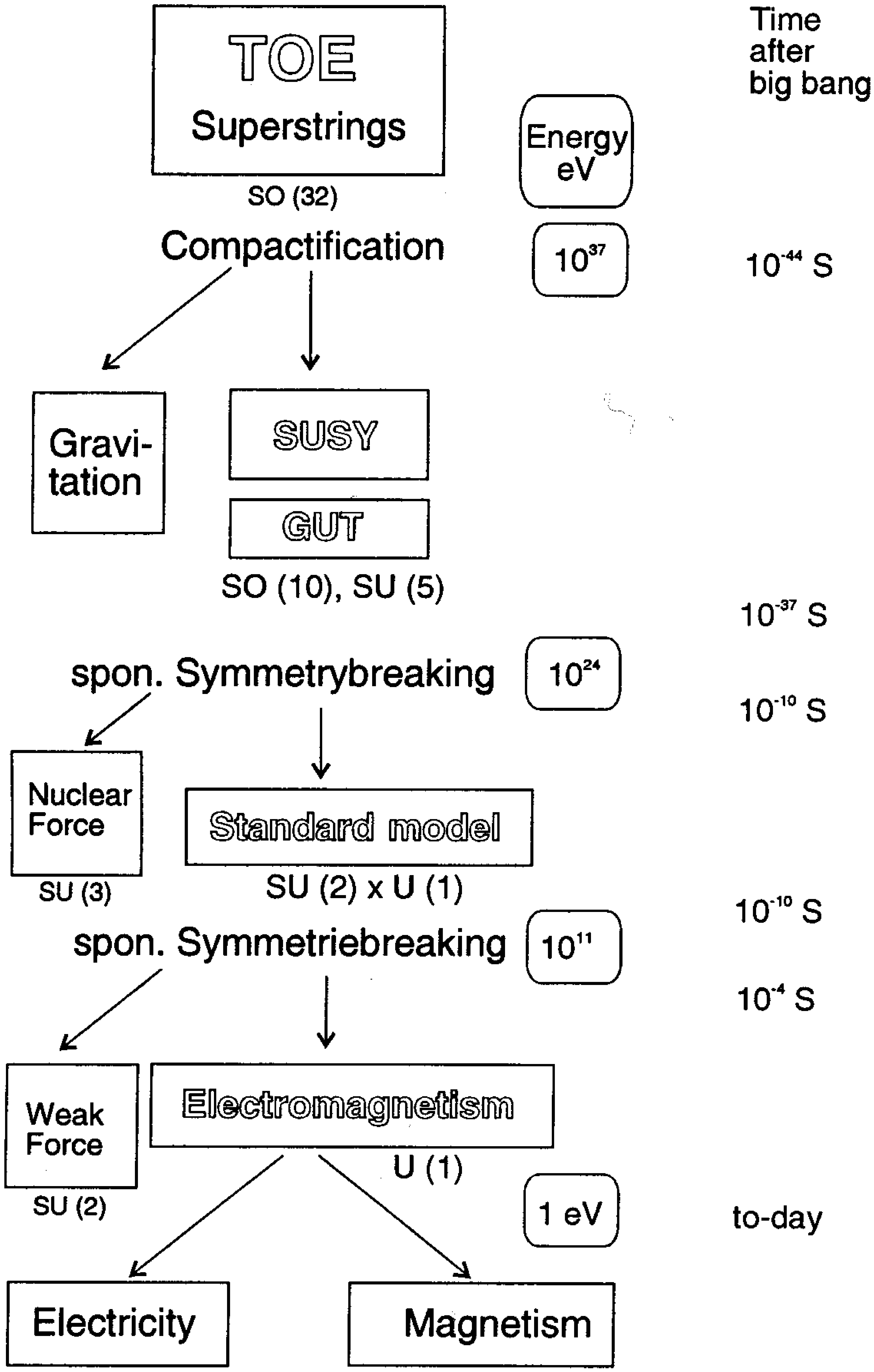


Fig. 8. The hierarchy of forces. The energies indicate where a symmetry breaking happens. They were reached in the universe at the times indicated.

fig. 1

fig. 2


TURNSTILE = PERIODIC OPEN
AND CLOSE OF THE ENTRANCE
AND EXIT OF THE QUANTUMDOT
(SINGLE ELECTRON TRANSISTOR SET)

fig. 3

fig. 4

fig. 5


YPT in Poland
organized since 1989/90
under the auspices of the
Polish Physical Society
Institutions involved:
Institute of Physics PAS
- WARSAW
Youth Palace - KATOWICE
Stages:
(FEB-MARC
1. Correspondence
(1 team - 10 problems)
over 30
teams
Selective
2. Tournaments
(APRIL)
2 physics fights
KATOW.
WARSA
4
4
2
2
3. Final Tournam
(MAY) 2 phys. fights
English language
4
teams
1
IYPT

fig. 6

fig. 7

fig. 8

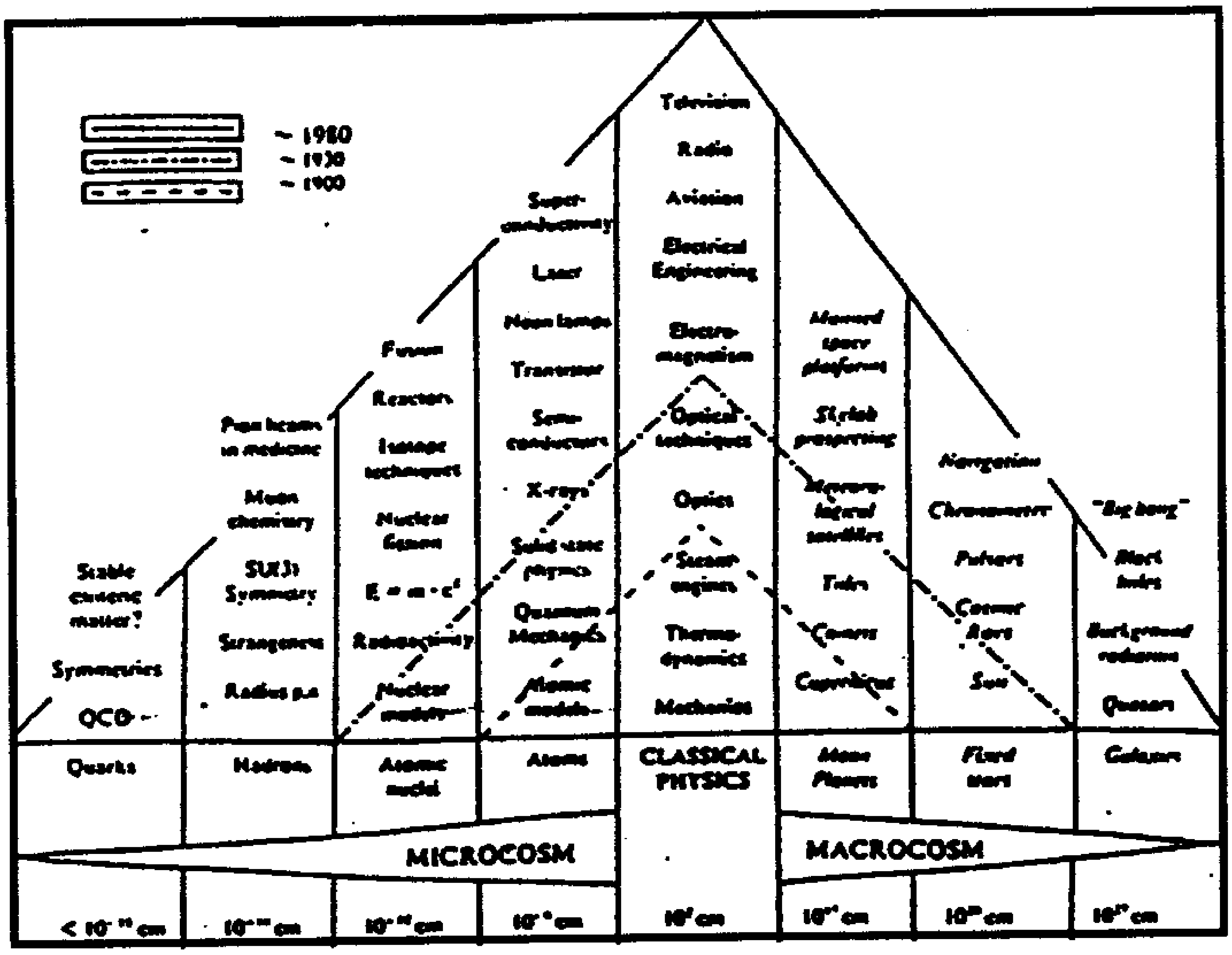


Fig.9.Physics penetrated from human sizes to smaller and lager dimensions (base of the pyramid). From this basic knowledge applications developed in time (pyramid grows vertically)

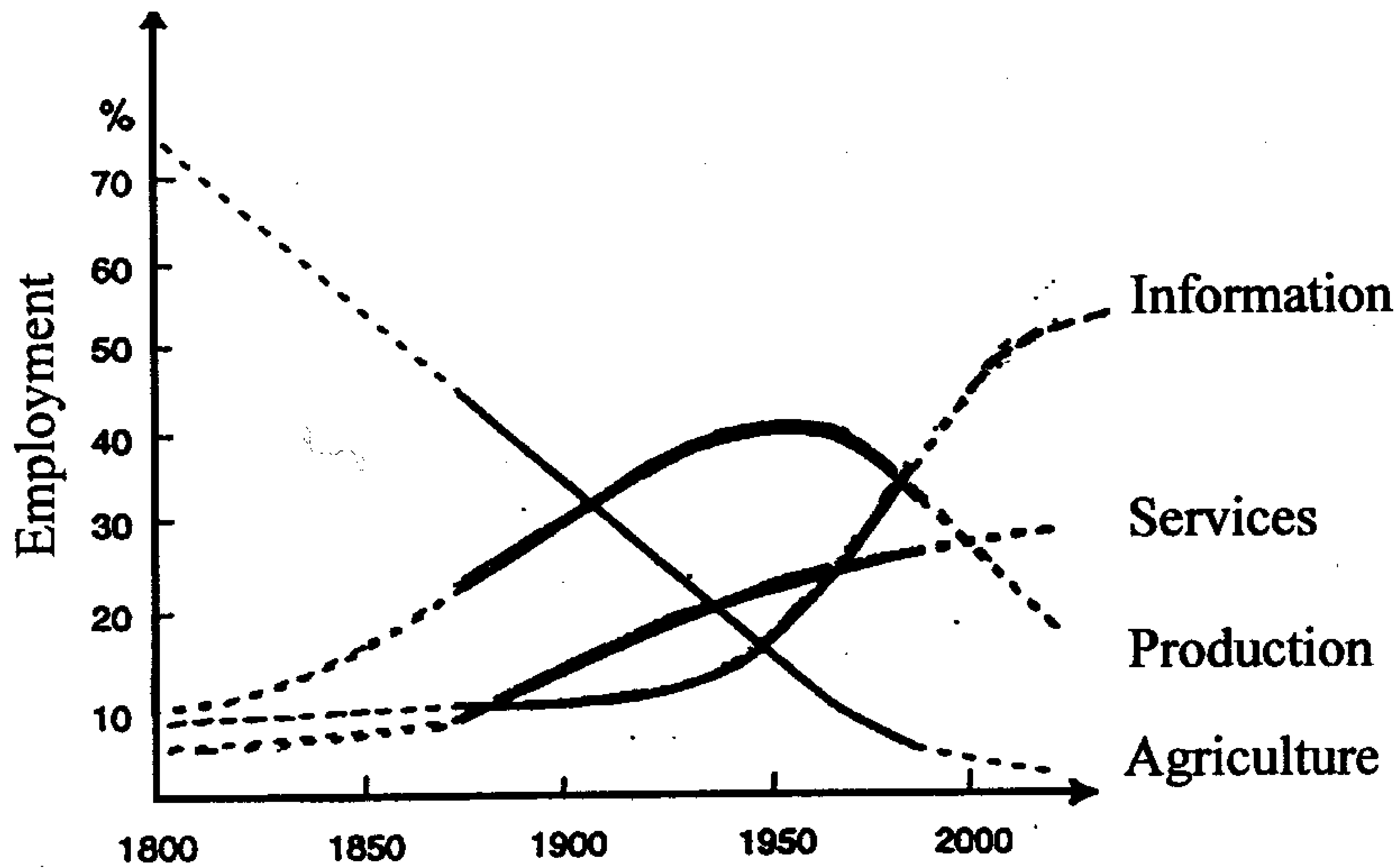


Fig.10. The change of employment in different domains
(source: full line Institute für Arbeitsmarkt- und Berufsforschung
broken estimates I.A.Nefiodow)

7 Precision Making Astronomical Discoveries

Jiri Grygar

7.1 Introduction

Human eye was the only astronomical detector and instrument for millennia. Its angular resolution reaches 1' under optimum conditions while its largest night-vision aperture amounts to 8 mm. However, its quantum efficiency 0.5 is pretty good and its dynamic range is incredibly high ($1{:}10^7$) while the spectral coverage is very narrow. The ratio of the longest and shortest visually detectable wavelengths is barely 1.8:1 (low-sensitivity cones) and almost 1:1 (monochromatic at 510 nm) for the night vision (rods). The human eye has very limited integration capability up to about 1 s. Thus, any instrument and detector that surpasses the abilities of human eye is capable of making new astronomical discoveries as it was shown many times in the distant past. Tycho Brahe (1546-1601) remains the greatest observer hero of the pre-telescopic era who employed the capabilities of the human eye to the utmost. However, Galileo Galilei (1564-1642) who was apparently the first scientist using simple telescopes for watching the skies, was able to make epochal astronomical discoveries in relatively short period between 1609 and 1611 due to rather modest improvement in the precision of his measurements as it is seen in the following table:

Galileo's telescopes

Parameter	Numerical value	Gain over human eye
Aperture	16 ö 38 mm	23 : 1
Resolution	20 ö 10 "	6 : 1
Magnification	3 ö 33 times	33 : 1

These comparably slight improvements of roughly an order of magnitude were sufficient for the great discoveries:

1609, Aug - Dec: Map of the Moon

1610, Jan: Discovery of the four moons orbiting Jupiter

1610, Oct: Discovery of the phases of Venus

1611, Jun: Observation of sunspots; proof of Sun's rotation

1611: The Milky Way consists of myriads of faint stars.

Galileo also spotted the strange appearance of the disk of planet Saturn but his telescopes were not good enough to discover the shape of Saturn's ring. During his systematic observations of Jupiter and its satellites he accidentally marked the position of the planet Neptune but due to its almost starlike appearance he did not recognize its true nature.

7.2 The era of refractors

The followers of Galileo used refractors of the Keplerian type, invented in 1613 by Johannes Kepler (1571-1630). Refractors have attained maximum technically feasible apertures of 1 m at the end of the 19th century. Thus, their gain of sensitivity over the naked human eye has reached more than four orders of magnitude and the gain of angular resolution more than two orders of magnitude. In 1655 Christiaan Huygens (1629-1695) correctly described the shape of Saturn's ring, in 1725 James Bradley (1693-1762) discovered the aberration of light (the aberration constant amounts to 20.5") and in 1838 Friedrich Bessel (1784-1846) measured the first stellar parallax (amounting to slightly less than 1").

7.3 The era of reflectors

Refractors were limited in the aperture and also in spectral response (optical glass is semitransparent in the near ultraviolet region and almost opaque in the near infrared as well as in the far ultraviolet). Thus the invention of reflecting telescope by Isaac Newton in 1671 has marked a new astronomical era. The appropriate technology for casting large reflecting glass mirrors has been, however, available only at the end of 19th century and really big instruments were manufactured only in the course of 20th century as it is seen in the following table.

Record-braking astronomical reflectors

Year	Place	Aperture (m)
1908	Mt. Wilson, CA, U.S.	1.5
1917	Mt. Wilson, CA, U.S.; (Hooker)	2.5
1949	Mt. Palomar, CA, U.S.; (Hale)	5.1
1976	Zelentschukskaya, Russia; (BTA)	6.0
1991	Mauna Kea, HI, U.S.; (Keck I)	10.0
2000?	Mt. Graham, AZ, U.S.; (LBT)	11.8
2004?	Mt. Paranal, Chile; (VLT)	16.0

In general, the angular resolution of the telescope increases directly proportional to its aperture and its sensitivity is proportional to the square of its aperture. The gains are, however, greater than nominal when we take into account the auxilliary systems of active and adaptive optics that are being used with the large reflectors finished or refurbished after 1990.

7.4 Improvements of the detectors

Until about 1885 all observations had to be done with the aid of the human eye. Invention of photography has changed astronomy profoundly. Photographic emulsions have large integration capability and exposures as long as 10 hours considerably improved the sensitivity of the telescopes since 1890. Photographic emulsions with wide and different spectral response were manufactured for various spectral ranges from the far ultraviolet until the near infrared regions. The ability of the photograph to record and preserve faithfully the astronomical pictures for more than a century contributes also to by far the greatest astronomical revolution in detection techniques. Photography was also essential in employing the indispensable spectroscopy in modern astrophysics. There are, however, two drawbacks in using classical photography: the response of the emulsion to the incident light is highly non-linear and the dynamic range of the pictures is small (1:100). Also, the quantum efficiency of the emulsion is low (0.02). Some improvements in linearity and dynamic range were possible in the twenties due to the first use of photocells and then in the forties due to photomultipliers that until now are superior detectors for wide-band and narrow-band photometry in the ultraviolet and optical regions. The latest detector revolution occurred in the eighties when CCD arrays became available. In less than a decade CCD arrays replace photographic cameras except for wide-field imaging and astrometry. CCD boasts with the quantum efficiency of about 0.8, has excellent dynamic range and integration capability and its output is easy to be digitized. Contemporary reflector with the aperture of 0.6 m equipped with modern CCD array can image relatively cheaply the stars, nebulae or galaxies as faint as could the 5 m Hale telescope with photographic camera in the early sixties.

7.5 Non-optical astronomy

In 1932 Karl Jansky (1905-1950) discovered decameter radiowaves emitted by the Milky Way and created radioastronomy as a new tool for studying cosmos. Improved antenna systems and receivers enabled astronomers to open the radio windows of meter wavelengths in the forties, decimeter wavelengths in the fifties, centimeter wavelengths in the sixties, millimetre wavelengths in the seventies and submillimetre wavelengths in the nineties of the century. Thus, all cosmic radio signals accessible due to the radio transparency of the Earth's atmosphere are now available for further analysis (wavelength's ratio $10^4 : 1$). All other "spectral windows" of the electromagnetic spectrum are not accessible from the ground and some effort had to be exerted in order to put the observing platform high enough in the Earth's atmosphere. Sounding rockets and high-altitude balloons enabled ultraviolet imaging of the Sun in 1947 but the real breakthrough into the ultraviolet domain (wavelengths shorter than 330 nm) occurred after the introduction of artificial satellites in 1957. In the same vein X-ray radiation (wavelengths shorter than 10 nm, i.e. photon energies higher than 0.1 keV) became available in 1962 and gamma radiation (wavelengths shorter than 0.01 nm, i.e. photon energies above 100 keV) has been measured since 1975. The remaining spectral window in the medium- and far-infrared (wavelengths 20 to 200 m) was opened in 1983 due to first cryogenic astronomical satellite IRAS.

7.6 Present state of observational astronomy

Thus, only in the last decade all frequencies of the electromagnetic spectrum from the decametric radio to high-energy gamma radiation is open to astronomical studies; the ratio of wavelengths or, reciprocally, of the photon energies is $1O^{2}4$: 1. Spectral resolution reaches record value of 10^{-8} and the ratio of intensities in the optical domain amounts to $10^{2}3$: 1 while time resolution of the intensity variations extends from 3 μ s to $3.10^{1}7$ s (ratio $10^{2}3$: 1). The collecting area of major optical telescopes that determines the amount of photons that can be recorded in the unit of time has increased faster than the overall population of the Earth within the last half of a century as it is seen in the table:

Increase of collecting area of major optical telescopes

Year	Collecting area (m^2)	Earth's population (billion)
1950	50	2.6
1980	150	4.4
1992	270	5.5
2000	1000 ?	6.5 ?

In radioastronomy, since 1963 the largest collecting area belongs to the spherical reflector in Arecibo, Puerto Rico - 70,700 m^2. The giant non-steerable reflector has been upgraded several times in order to improve the signal-to-noise ratio and the receiving wavelength range. The same instrument serves also as the most powerful astronomical radar for studies of objects within the solar system. Moreover, radiotelescopes can be rather easily used as very-long baseline interferometers (VLBI); the baselines being comparable with the diameter of the Earth. This gives astronomy unsurpassable angular resolution, roughly inversely proportional to the wavelength. Present record angular resolution is amazing, indeed:

VLBI interferometry (base 10,000 km) - angular resolution

Wavelength (mm)	Frequency (GHz)	Resolution (milliarcsec)
900	0.33	24
60	5.0	0.4
7	43.0	0.2

7.7 Examples of epoch-making discoveries

The selection of the epoch-making discoveries within the last century is a bit subjective but almost everybody would agree that among them we have to list Hubble's (Edwin Hubble, 1889-1953) linear relation (1929) between distances and redshifts *z* of cosmological objects (galaxies and quasars). The discovery was possible due to the use of the then largest 2.5 m Hooker reflector at Mt. Wilson that remained the most powerful instrument until the erection of 5.1 m Hale reflector at Mt. Palomar in 1948.

7.7.1 Quasars

This new reflector was instrumental in revealing the existence of quasi-stellar objects (quasars) in 1960-63 and their record redshifts (from *z* = 0.16 in 1963 to *z* = 4.9 in 1991). Numerous studies of quasars in all spectral domains is due to many first-class instruments on the ground and in orbit. It is apparent that these objects were born in early phases of the existence of the Universe and represent incredibly efficient machines for converting gravitational energy into electromagnetic radiation.

7.7.2 Pulsars

In the late sixties another type of efficient "energy convertors" were discovered due to the effort of British radioastronomers at Mullard Observatories (Cambridge, England). Under the supervision of Anthony Hewish (1924-) they erected extensive radio array with the total collecting area of 340,000 m^2 operating at 81.5 MHz (3.7 m) with good time resolution of 0.1 s. After 5 months of radio survey of the northern sky Miss Jocelyn Bell (1939-), then the graduate student of Hewish, discovered several radio sources exhibiting regular "oscillations" with periods from 0.25 to 1.34 s. The discovery paper was published in Nature in March 1968 and has lead to the establishment of another new class of objects named pulsating radio sources (pulsars for short). In 1969 Thomas Gold explained pulsars as fastly rotating compact neutron stars with extremely strong magnetospheres. Hewish obtained Nobel prize in physics (1974) for his part in this extraordinary discovery.

7.7.3 Relic radiation

American radioastronomers Arno Penzias (1933-) and Robert Wilson (1936-) built in 1964 horn antenna equipped with extremely sensitive radiometer operating at frequency 4.1 GHz (73 mm) at Holmdel, N.J. (in the same Bell Laboratories where K. Jansky made his pioneer measurements in 1932). In 1965 they announced the discovery of isotropic microwave radiation of the cosmic background, corresponding to the black-body radiation at 3 K. Within a year this surprising discovery was corroborated by the measurements at higher frequency 9.4 GHz by Robert Dicke (1916-1997) and collaborators and in this way it was proved that it is actually a relic of very hot radiation from the radiation era (300,000 years after the Big Bang) of the Universe. The radiation is therefore much older than all stars and galaxies observed by the most powerful optical and radio telescopes. Penzias and Wilson were awarded Nobel prize in physics in 1978.

7.7.4 Extra-solar planets

In 1995 Michael Mayor and Dider Queloz announced that they obtained robust indirect evidence for the existence of Jupiter-like planet orbiting the solar-type star 51 Pegasi located 18 parsecs from our Sun. As evidence they took the measurements of sinusoidal variations of the radial velocity of the star with minuscule amplitude of 59 m/sec. Their echelle spectrograph attached to 1.8 m reflector at Haute Provence Observatory, France is able to detect velocity variations as small as 15 m/sec. Thus, systematic measurements within the span of a year gave the basic parameters of the unseen component - an extrasolar planet (exoplanet for short). The planet revolves around the solar-like star in a circular orbit with the radius of mere 7.5 million km in a period of 4.2 days. Its mass is definitely larger than half of the Jupiter's mass but most probably it is not larger than 2 Jupiters. 51 Pegasi resembles the Sun by its colour and surface temperature. It is a bit lighter than the Sun but it is also a bit larger and 80more luminous than the Sun; thus it is some 2 billion years older than the Sun. The discovery has been a breakthrough: within a year almost a dozen exoplanets were detected in Europe and United States among other solar-type stars by employing the same observational technique . These exoplanets are in general comparable with our Jupiter as concerns their masses. Their orbits vary, however, from very close (like 51 Pegasi) to their central stars until rather loose orbits with periods comparable with that of our Jupiter. Supposing some extraterrestrials observe our Sun from the distance, they could detect our Jupiter through its gravitational influence on the solar radial velocity if their instruments can resolve velocity variations of about 12 m/sec. In the same way Saturn could be detected when the precision increases to 3 m/sec. This is exactly the precision of the best available spectrograph of the giant Keck 10 m telescope operating since 1996 at Mauna Kea, Hawaii.

7.8 Fundamental discoveries after Martin Harwit

Professor Martin Harwit of Cornell University published in 1981 an interesting book where he analyzed in detail the conditions and circumstances leading to important astronomical discoveries in all history of mankind. He isolated 43 "fundamental discoveries" from very ancient past (planets, comets, stars) until present (quasars, pulsars, relic radiation). His analysis clearly shows how technical improvements lead almost inevitably to fundamental discoveries. By technical improvements he means the order of magnitude increases in spectral coverage, angular and time resolutions, better signal-to-noise ratios etc. He further shows that the potential of fundamental discoveries made by a particular novel instrument is limited in time (cf. Galileo has made all epoch-making discoveries within mere three years; next fundamental discoveries were made by the instruments substantially better than his primitive telescopes). It is also apparent that astronomy owes much to the progress in military techniques (radar, missiles, nuclear tests ban surveillance, spy satellites adaptive optics etc.). In recent times principal discoveries are more often made by the engineers and physicists rather than by classically trained astronomers. Harwit concludes his book with the educated guess that only about one third of all fundamental astronomical phenomena are already discovered; thus much work aiming to the improvement of the precision and power of the astronomical techniques lies ahead of us. Moreover, the effort necessary for further improvements increases non-linearly. It is probably fair to predict that almost all work in astronomy has to be done in the years (or better to say, millennia) to come.

References

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8 Thinking physics

Ivan Stoll

The word physics comes from Greek expression for Nature, to understand physics means to learn the secrets of Nature. What can be more important for survival of man on this planet? But understanding must be preceded by interest, curiosity. Curiosity appears at certain stage of our childhood and much of our life depends on that, in what degree our curiosity has been satisfied and our childish questions answered. The childhood of our European civilisation is the period of ancient Greeks and most of the questions about Nature were already formulated by Greek philosophers. Of course there may also be stupid questions, but in principle no question should be considered naive, not worth answering. There exist no small problems, no trifles in Nature, everything has its meaning, its importance. As the saying goes from one claw we can learn the lion.

It is well known that the first step to scientific discovery is noticing something very inconspicuous, something which usually escapes attention of other people. By the way the same is valid for poetry. Ordinary people think that the Moon is not falling to the Earth and only physicists and poets know that it is. Galvani in his time noticed unexpected motions of frog legs, Faraday noticed small current pulses induced by the motion of the core in a magnetic coil, Roentgen observed the fluorescence of a screen far away of his cathode rays tube. We can speak about happy accidents, but many other scientists had also the opportunity to make such observation but they failed to do so. Some declared later that they actually saw the effects of X-rays but did not realized their significance. And that is the point.

The idea never occured to me to drop a piece of chocolate into a glass of soda water. And even if I did it accidentally, I would not probably pay much attention to regular oscillations of chocolate between the bottom and water level. At the 10th International Young Physicists Tournament in Cheb this phenomenon represented very interesting problem with many possible consequencies. In the begining of the 20th century Heike Kamerlingh-Onnes just dropped some mercury into liquid helium and superconductivity was discovered. Perspectives of 2electrotechnics has changed by this accident.

The role of intuition and imagination in physics is often discussed. Examples of great physicists like Archimed, Newton Feynman or Kapitza show clearly that they possesed deep intuitive feeling of Nature. Physicist can usually guess the result of a problem, even divine its approximete numerical value, before he starts with some calculations, not to speak about using computer. Developing such intuition needs experience, but can also be trained by solving problems, discussing them in a similar manner the Young Physicist Tournament is conceived.

Solving the Tournament problems sometimes brings a feelings of unsatisfaction due to the situation that no definite and unambiguous answers are given. Even the members of the jury may have different opinions as for the correct solution. In fact this is quite natural consequence of the complexity of Nature. Physics must work with models, can consider only the substantial, relevant properties of a real system. To express it by Einstein's words - everything should be made as simple as possible, but not simpler. This may be very difficult sometimes and our results can differ according to the model adopted.

Great Russian physicist P.L.Kapitza considered very important to teach young students how to solve such complex problems. In his book "Physics problems" of 1972 he formulated many of them. Determine the maximum distance human voice can be heard or a lighted cigarette can be seen in open landscape in the night. Which way an airplane must move if we want to create the state of weightlessness inside and how long it can last? How fast must we run on the surface of Dead Sea not to sink?. Similar problems often appear at the Young Physicists Tournament [1].

The important thing with physical problems suggestaed to students is that the result must be of interest to them. It may seem obvious but very often we find examples in textbooks not intriguing enough, just for exercising. Real situations taken from Nature and everyday common life can always be fascinating and arouse curiosity.

Of course physics is not just guessing, but also careful calculations and exact experiments. Our conclusions must be verifiesd experimentally, otherwise we have no chance for Nobel Prize. At the same time we do not know experimental quantities with much accuracy, in the best case just to some 5-6 valid decimal digits. But exact measurements of physical constants and other quantities is of extreme importance. Every possible method which can increase the accuracy of our measurements can also lead to new discoveries. Among the workers of physics there are fanatics of accuracy and we owe them very much - they help the building of physics hold more firmly. As an example we can remind the history of the measurement od speed of light and the role of A. Michelson in it. Had Tycho Brahe not reached the observation accuracy of some 2 angular minutes, but say only 10 minutes, Kepler would not have been able to calculate the eliptical trajectory of Mars and modern mechanics would not have started.

This aspect was stresses at the Tournament in Cheb by Nobel Prize Winner for 1985 Klaus von Klitzing. This extremely precise experimentalist was studying the conductivity of two-dimensional electron structures and found a new way how to make much more exact standard of electrical resistance. As he jokingly pointed out physical journal at first refused to publish his article titled "About a new standard for resistance measurement" or so. The subject seemed not too interesting for physics. Nevertheless it resulted not only in new possibilities of measuring fine structure constant and elementary particles properties but also in the discovery of quite new phenomenon, quantum Hall effect, which brought him at last Nobel Prize.

So physics means very exciting activity in deep contact with real world, with Nature, looking for its internal structure, connections and interactions. Reality is very complex, and we can understand only a small part of it. Our only tools is imagination, intuition, mathematics and experiments. But still we can enjoy the tiny parts of knowledge which give us feeling that we understand the Nature corectly and can even use this knowledge for our benefits.

Physics and exact science as a whole is not valued by general public these days too much, partly because of the difficulty to comprehend its very complicated mathematical disguise, partly due to negative sides of rapid technical development. As was pointed out by Herwig Schopper during the discussion at the Tournament, physics of course cannot satisfy all human needs, there are also music, fairy tales, love, hamburgers and other things. But irrational thinking, return to obscure practices and mystics cannot give solution of human problems. Mankind simply will need physics and its applications and the only problem is that it must use them properly. So the prognosis of the role of physics and the satisfaction of the curiosity of young physicists in the beginning of the next millenium is slightly optimistic.

Let us close with a little selection of the thoughts of Albert Einstein, the symbol of scientific thinking of 20th century and a great humanist at the same time.

> *The most beautiful thing we can experience is the mysterious. It is the source of all true art and all science. He to whom this emotion is a stranger, who can no longer pause to wonder and stand rapt in awe, is as good as dead: his eyes are closed.*
>
> *Not everything that counts can be counted and not everything that can be counted counts.*
>
> *Imagination is more important than knowledge.*
>
> *The hardest thing in the world to understand is the income tax.*
>
> *Anyone who has never made a mistake has never tried anything new.*
>
> *Common sense is the collection of prejudices acquired by age eighteen.*
>
> *Science is a wonderful thing if one does not have to earn one's living at it.*
>
> *Thee most incomprehensible thing about the world is that it is comprehensible.*
>
> *Education is what remains after one has forgotten everything he learned in school.*
>
> *The important thing is not to stop questioning. Curiosity has its own reason for existing.*

As far as the laws of mathematics refer to reality, they are not certain, as far as they are certain, they do not refer to reality.

Two things are infinite: the Universe and human stupidity; and I'm not sure about the Universe.

From Kevin Harris 1995

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9 Conclusions of the Conference "10 Years of IYPT"

Zdenek Kluiber

In the work of Conference "10 years of IYPT " took part heads of delegations of all teams participating in the 10th IYPT, prevailing part of the teams leaders, guests of the 10th IYPT and numerous experts from the Czech Republic. The chairmen of the Conference were RNDr. Z. Kluiber, CSc., Dr. E. Junosov and Dr. R. Lehn. Representatives from all participating countries presented contributions on the Conference. The contributions were devoted to the experiences from the organization of the tournaments in certain countries. It was pointed out that such a tournament has an enormous role for finding new talented students for the study of physics (and not only of physics). The role of Dr. E. Yunosov, a founder of the IYPT, was also highly estimated The conclusions of the Conference were formulated as an estimation of the help of the IYPT for talented students.

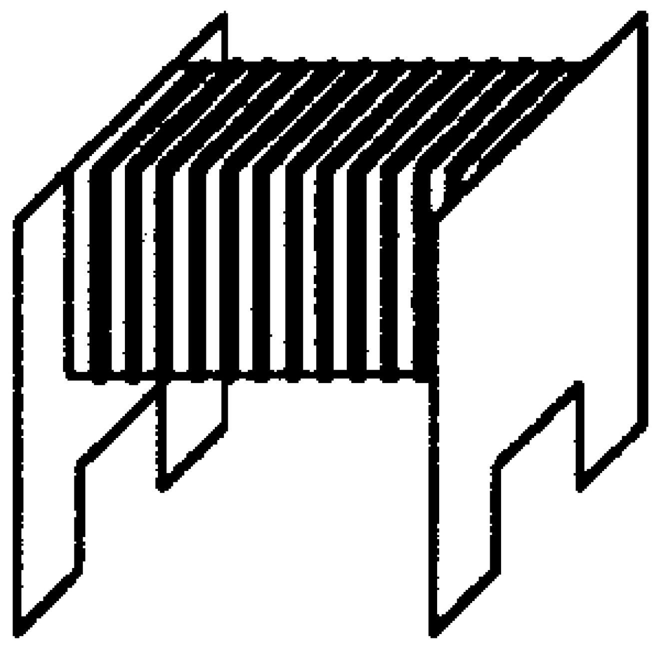
The IYPT helps to these students in the following areas:

1. To work in the community of the similarly enthusiastic people.
2. To solve real problems from physics and from the coupling of physics with respect to other scientific fields and branches.
3. To make a qualitative analysis of the problem a to find physical effects which have a close connection with a given problem.
4. To study a scientific literature, especially in foreign languages.
5. To consult the problems with experts.
6. To create an optimum model of the solved problem.
7. To suggest and to realize corresponding experiments, or apparatuses.
8. To obtain and to work out partial information necessary for the solution of the problem at a specialized working places.
9. To learn how to make a synthesis of the working results.
10. To obtain skills which are necessary for participation at the scientific conference.
11. To obtain skills which are necessary for making the report evaluating somebody else's scientific work.

12. To understand physical competition as a central element of the YPT within a framework of a discussion.
13. To learn how to defend own solution, how to make the reasonable arguments, how to evaluate advantages and disadvantages of rivals - remaining participants of the physical competition.
14. To learn how to prepare for a future study at the university - for the study of physics.
15. To increase the language skills.
16. To make contacts with future potential collaborators.
17. To learn how to publish own results.

The participants of the Conference pointed out further increase of the quality of the competition in the sense of the responsible preparation of the problems, improvement of the work of the evaluation committee and finally increase of the number of the countries participating in the IYPT. It was pointed out, that thanks to its broad background in the development of the knowledge of students there are great chances for the future development of the IYPT.

Figure 2: Scheme of electromagnet



10 Solution of two problems of 10^{th} IYPT

10.1 Coin

Hynek Nemec - Zdenek Kluiber

Problem

From what height must a coin with heads up be dropped, so that the probability of landing with heads or tails up is equal?

10.1.1 Introduction

The dropping or throwing of a coin is one way to decide some disputes. It is known, that if a coin is dropped from a great height, the probability of landing with heads up or tails up is equal. In the following article we will show you the lowest height to obtain such results.

If we drop the coin by hand it is very difficult to measure the height of center of mass. For this reason we used an electromagnet with an adapter from a thin metal sheet (see fig. 2). The coin we used in our experiments was the Czech 5 Kč; we let it fall to a board with syntethic surface. The parameters were the following: thickness of coin - 1.85 mm, radius of coin - 11.5 mm, mass of coin - 4.87 g, coefficient of friction between coin and board – 0.12 and coefficient of restitution between board and coin ≈ 0.88 for heights around 20 mm.

10.1.2 Distribution of initial angular velocities and initial angles

It is impossible to drop the coin in the exact same way - during every experiment the initial angular velocity is different. We determined

Figure 3: Apparatus for the measurement of angular velocities

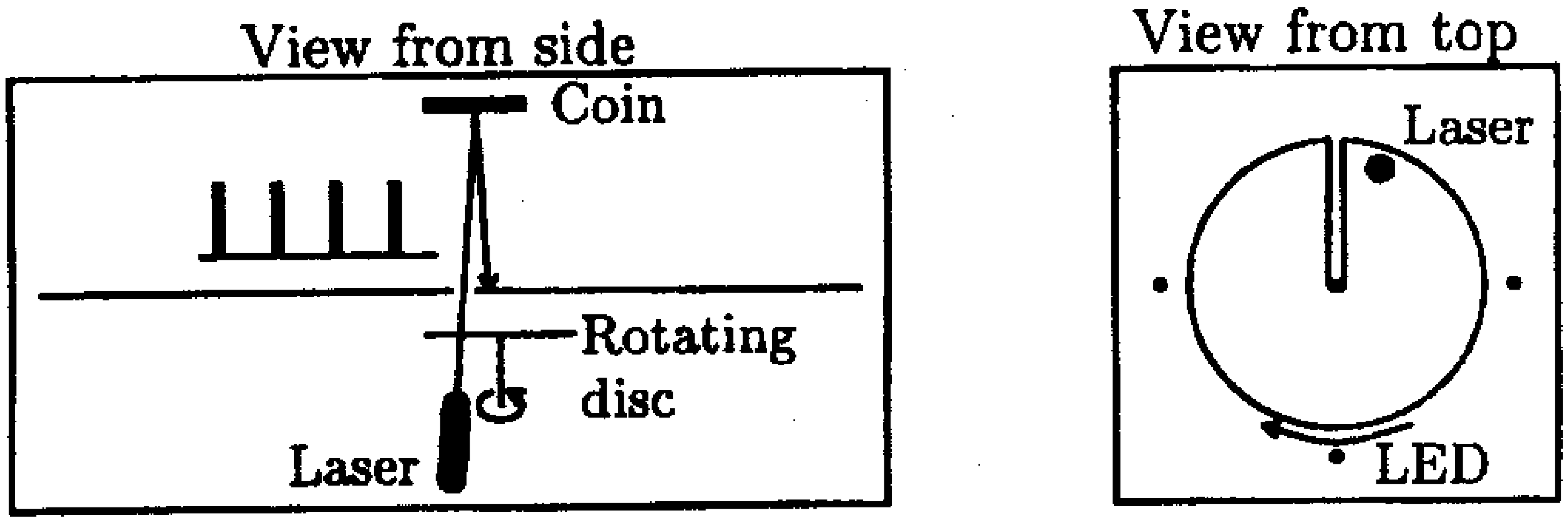


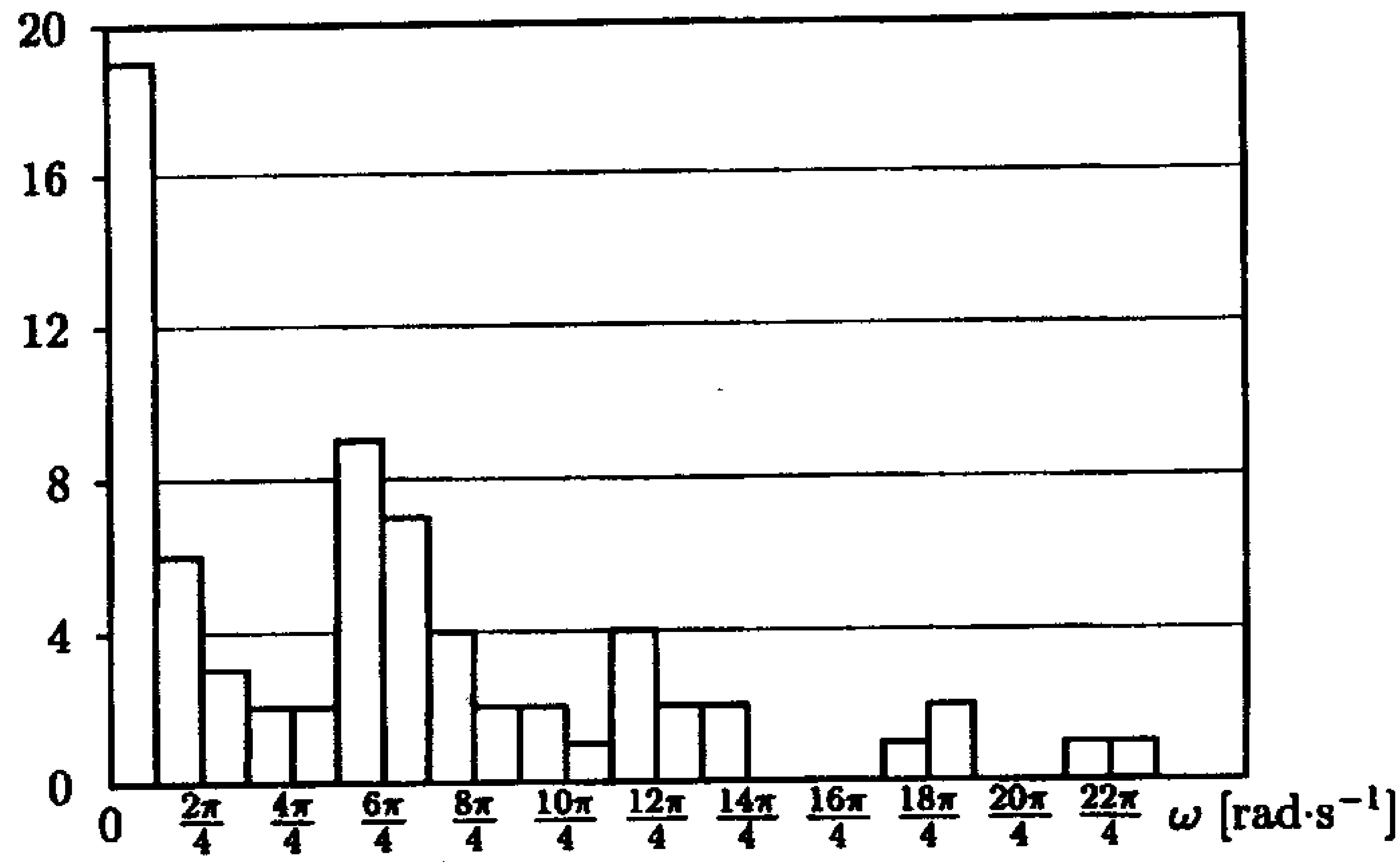
Figure 4: Example of the photo for measurement of distributions

initial angular velocities experimentally. Scheme of apparatus is in fig. 3: the laser ray directed towards the coin was interrupted by rotating a disc (100 rt/s) with a slot – we got short pulses with a frequency of 100 Hz. We took pictures of tracks of rays reflected from the coin (there was a reflective foil on one side of the coin) to a board with a marked dimension (by light emitting diodes). By simple computation we obtained, from displacements of neighbouring tracks, an angular velocity of the coin.

Accuracy of this method depends mostly on the surface quality of the coin and also on the accuracy of light marks on the board and on resolution of photos. An example of a typical photo is in fig. 4. Distribution of initial angular velocities is represented in fig. 5.

It is evident from photos, that some first tracks lie evenly in line (10

Figure 5: Distribution of initial angular velocities



tracks on 100 Hz is equivalent with 5 cm of height, 15 with 11 cm) – it isn't possible to observe the influence of bypassing on photos. It is also evident, that at this time the coin is falling in one plane.

10.1.3 Impact of coin to board

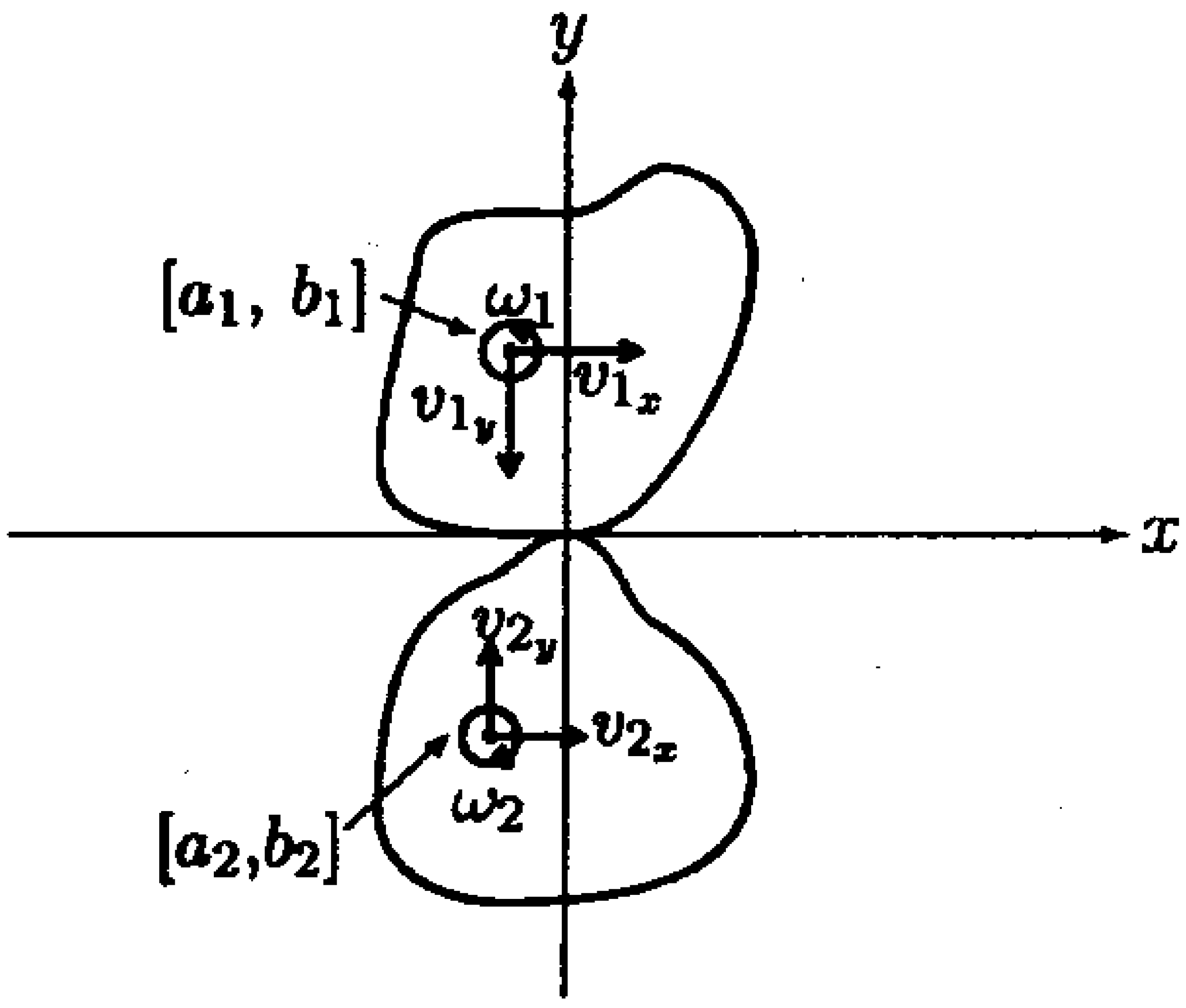
As is evident from the last experiment, we can only consider the impact of a coin in a plane for heights up to 10 cm. makes the solution easier.

In section 10.1.3 we solve a general impact of two bodies in the plane (due to laws of conservation of momentum and angular momentum of bodies) and in section 10.1.3 we adjust some expressions for the case of impact of a coin to board.

General impact of two bodies in the plane Let's have two bodies with masses m_1 and m_2, moments of inertia J_1 and J_2, moving with velocities $\mathbf{v}_1$ and $\mathbf{v}_2$ and angular velocities ω_1 and ω_2. The coordinate system is defined with origin in the point of contact of bodies, where the x-axis is tangential to both bodies. We can resolve the velocities $\mathbf{v}_i$ $(i = 1, 2)$ we can into directions x and y and the corresponding components we denote as v_{i_x} and v_{i_y} (see fig. 6). By index 0 we denote the state before the impact and by f the state after impact.

In every time of collision there are valid laws of conservation of mo-

Figure 6: Description of impact of two bodies



mentum and moment of momentum – we write them in the form

$$m_i\left(v_{i_x} - v_{i_{x0}}\right) = \pm P_t \quad (1)$$

$$m_i\left(v_{i_y} - v_{i_{y0}}\right) = \pm P_n \quad (2)$$

$$J_i\left(\omega_i - \omega_{i_0}\right) = \pm b_i P_t \mp a_i P_n, \quad (3)$$

where a_i and b_i is horizontal and vertical component of radius vector of center of gravity and P_t and P_n is tangential and normal impulse of force (upper sign is for body 1, lower for body 2). Let's define the relative velocity of sliding and compression as

$$S = v_{1_x} + b_1\omega_1 - (v_{2_x} + b_2\omega_2) \quad (4)$$

$$C = v_{1_y} - a_1\omega_1 - (v_{2_y} - a_2\omega_2). \quad (5)$$

We substitute from equations (1–3) and get

$$S = S_0 + B_1 P_t - B_3 P_n \quad (6)$$

$$C = C_0 - B_3 P_t + B_2 P_n, \quad (7)$$

where S_0 and C_0 (initial velocity of sliding and compression) and B_1, B_2 and B_3 are system constants defined as

$$B_1 = \frac{1}{m_1} + \frac{1}{m_2} + \frac{b_1^2}{J_1} + \frac{b_2^2}{J_2} \quad (8)$$

$$B_2 = \frac{1}{m_1} + \frac{1}{m_2} + \frac{a_1^2}{J_1} + \frac{a_2^2}{J_2} \quad (9)$$

$$B_3 = \frac{a_1 b_1}{J_1} + \frac{a_2 b_2}{J_2} \quad (10)$$

$$S_0 = v_{1_{x0}} + b_1\omega_{1_0} - \left(v_{2_{x0}} + b_2\omega_{2_0}\right) \quad (11)$$

$$C_0 = v_{1_{y0}} - a_1\omega_{1_0} - \left(v_{2_{y0}} - a_2\omega_{2_0}\right). \quad (12)$$

Now we solve the collision by graphic method (see [1]). We transform the course of impact into coordinates $[P_t, P_n]$ and we will follow the path of imaginary point $Q = [P_t, P_n]$. At the start, $Q = \mathbf{0}$ is necessary and the normal impulse P_n will increase during the impact.

Let's introduce some useful points: Intersections of line of limiting friction with the lines $C = 0$ of maximal compression (P_{n_c}) and the line ($S = 0$) of no sliding (P_{n_S}) are defined by formulas

$$P_{n_S} = \frac{S_0}{B_3 + B_1 f \operatorname{sgn} S_0} \tag{13}$$

$$P_{n_C} = -\frac{C_0}{B_2 + B_3 f \operatorname{sgn} S_0}. \tag{14}$$

Intersection $P_{n_{SC}}$ of lines $S = 0$ and $C = 0$ we express as

$$P_{n_{SC}} = \frac{S_0 B_3 + C_0 B_1}{B_3^2 - B_1 B_2}. \tag{15}$$

In the first phase of impact, the point Q follows the line of limiting friction $P_t = -f P_n \operatorname{sgn} S_0$ (if possible) until it intersects one of the lines of maximal compression ($C = 0$) or no sliding ($S = 0$).

If the path of point Q intersects the line $C = 0$, then the final impulse P_{n_f} is determined by the formula $P_{n_f} = P_{n_C}(1 + \varepsilon)$, where ε is coefficient of restitution.

Another situation will occur, if the path of point Q intersects line $S = 0$. According to friction and direction of sliding, there are three possibilities: point Q will follow the line of no sliding (enough friction is available to prevent sliding) or it will follow the line of limiting friction (if $\operatorname{sgn} S$ won't change) or travel along the line of reversed limiting friction (defined as $P_n = 2P_{n_S} + f P_t \operatorname{sgn} S_0$), if the direction of sliding will change.

Using an absolute value and function *sgn* we get only a few cases:

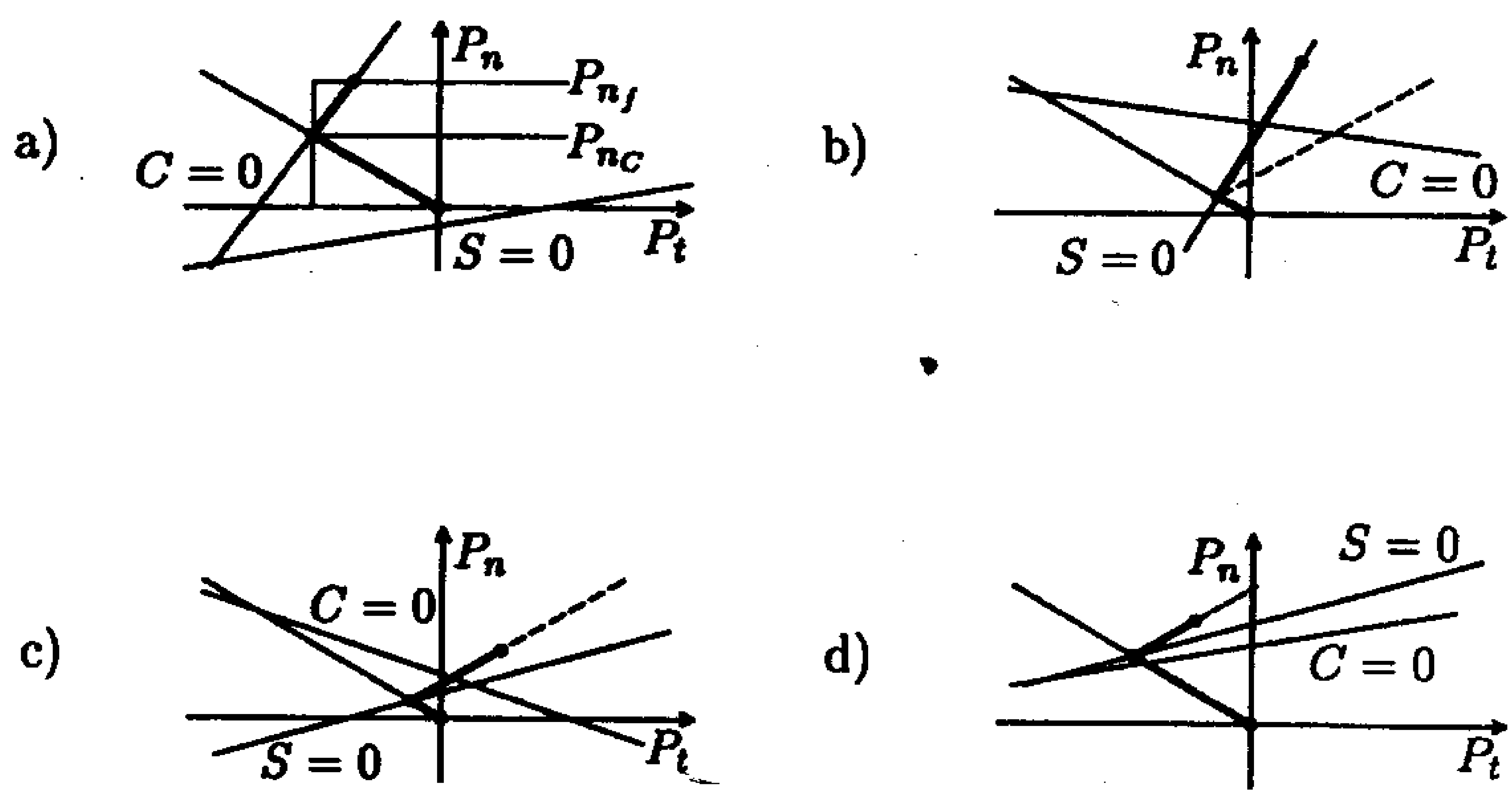
a) $P_{n_S} \leq 0$ or $P_{n_C}(1 + \varepsilon) \leq P_{n_S}$ (see fig. 7a): line $S = 0$ can't be intersected, because its intersection with the initial phase lies under the P_t-axis. P_{n_f} a P_{t_f} are determined by expressions

$$P_{n_f} = (1 + \varepsilon) P_{n_C} \tag{16}$$

$$P_{t_f} = -f P_{n_f} \operatorname{sgn} S_0. \tag{17}$$

b) $P_{n_S} > 0$ and $P_{n_C}(1 + \varepsilon) > P_{n_S}$ and $\left|\frac{B_1}{B_3}\right| \geq \frac{1}{f}$ (fig. 7b): line $S = 0$ is intersected during impact and its slope is greater than slope of line of limiting friction. Point Q travels only along the line

Figure 7: Possible arrangment of lines $S = 0$, $C = 0$ and initial sliding. The thick line marks path of point Q, dashed line reversed limiting friction



$S = 0$ (enough friction is available to prevent sliding) and the impact is terminated at the point with coordinates

$$P_{n_f} = (1+\varepsilon)P_{nsc} \tag{18}$$

$$P_{t_f} = \frac{P_{n_f}B_3 - S_0}{B_1}. \tag{19}$$

c) $P_{ns} > 0$ and $P_{nC}(1+\varepsilon) > P_{ns}$ and $\left|\frac{B_1}{B_3}\right| < \frac{1}{f}$ and $P_{ns} < P_{nC}$ (fig. 7c): the slope of the line $S = 0$ is less than the slope of line of limiting friction; line $S = 0$ is intersected before line $C = 0$. By geometric consideration, we obtain

$$P_{n_f} = (1+\varepsilon)\frac{2P_{ns}fB_3 + C_0 \operatorname{sgn} S_0}{fB_3 - B_2 \operatorname{sgn} S_0} \tag{20}$$

$$P_{t_f} = f(P_{n_f} - 2P_{ns}) \operatorname{sgn} S_0 \tag{21}$$

d) $P_{ns} > 0$ and $P_{nC}(1+\varepsilon) > P_{ns}$ and $\left|\frac{B_1}{B_3}\right| < \frac{1}{f}$ and $P_{ns} < P_{nC}$ (fig. 7d): as the previous case, only the line $C = 0$ is intersected before $S = 0$. Evidently

$$P_{n_f} = (1+\varepsilon)P_{nC} \tag{22}$$

$$P_{t_f} = f(P_{n_f} - 2P_{ns}) \operatorname{sgn} S_0 \tag{23}$$

The values after collision we determine from equations (1–3):

$$v_{1_x} = v_{1_{x0}} + \frac{P_{t_f}}{m_1} \tag{24}$$

$$v_{1_y} = v_{1_{y0}} + \frac{P_{n_f}}{m_2} \tag{25}$$

$$\omega_1 = \omega_{1_0} + \frac{b_1 P_{t_f} - a_1 P_{n_f}}{J_1} \tag{26}$$

Application of general formulas to collision of a coin and board Let's consider a board as body number 2; we assume $m_1 \ll m_2$, $J_1 \ll J_2$, $\mathbf{v}_2 \to 0$ a $\omega_2 \to 0$ and we assume the coin as a cylinder with radius R, height h and density ϱ. Then

$$m_1 = \varrho \pi R^2 h \tag{27}$$

$$J_1 = \frac{m_1 (3R^2 + h^2)}{12} \tag{28}$$

$$B_1 = \frac{1}{m_1} + \frac{b_1^2}{J_1} \tag{29}$$

$$B_2 = \frac{1}{m_1} + \frac{a_1^2}{J_1} \tag{30}$$

$$B_3 = \frac{a_1 b_1}{J_1}, \tag{31}$$

Values of C_0 and S_0 are evident from (12) and (11). We define an angle of rotation φ as a displacement from vertical direction. We obtain coordinates of the center of gravity by geometrical consideration:

$$a_1 = R \cos\varphi \, \mathrm{sgn}(\sin\varphi) - \frac{\sin\varphi \, \mathrm{sgn}(\cos\varphi)}{2} \tag{32}$$

$$b_1 = |R \sin\varphi| + \left|\frac{h\cos\varphi}{2}\right| \tag{33}$$

$$d = y - |R\sin\varphi| + \left|\frac{h\cos\varphi}{2}\right|. \tag{34}$$

10.1.4 Computer simulation, experimental results

Description and simulation of fall of coin Fall of the coin is described by a set of movement differential equations

$$\ddot{x} = 0 \tag{35}$$

$$\ddot{y} = g \doteq -9.81 \tag{36}$$

$$\ddot{\varphi} = 0 \tag{37}$$

until $d > 0$. If $d = 0$, a collision occur[1]. If the total energy (potential+kinetic) is greater than the energy necessary to turn the coin, the computation continues. In the opposite case, we determine from $\mathrm{sgn}(\cos\varphi)$ if the coin is with heads or tails up.

It is evident from experiments and simulations that the coin turns only when it has high energies ($\gg mg\sqrt{R^2 + h^2}$); if it has low energies, the impact will limit to vibrations.

The result of simulation is the diagram[2] of falls of coin (see example on the fig. 8) in dependence on initial height and on initial angular velocities. (Evidently, it is possible to compute dependence on other parameters, as initial angle, initial velocity, coefficients of restitution and friction etc. Simulation of fig.8 took 4 hours.)

By substituting a histogram (fig. 5) into this set of results we obtain a dependence of probability of landing with heads up at the height (fig. 9) from which the coin was dropped. From this graph we can deduct the height where the probability of landing with heads and tails up is the same: for parameters given in the introduction, it is between $1.80R$ and $1.85R$.

Experimental results We measured the relative frequency of landing with heads up depending on the height – it was in the range $1.5R$ and $8R$ (see fig. 9). An error of height measuring should not exceed 0.3 mm.

From experimental results we can speculate that the same probability of landing with heads and tails up lie in the ranges $1.79R$ and $1.91R$. Theoretical results are in agreement with experimental ones, although we neglected vibrational character of collision and bypassing of coin. For a more exact description, it would be necessary to solve vibrations of coin and board [1] and for greater hights describe bypassing of coin [2].

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[1]If modelling this process, it is usually $d \neq 0$. That's why it is good to compute as long as d reaches zero. For to find a zero value (or smallest value) it is good to use the Newton's iteration method.

[2]The unit of hight is in multiple of radius of coin R to get an image of height compared with dimension of coin.

Figure 8: An example of diagramed falls of coin. Parameters: $\varepsilon = 0.88$, $f = 0.12$, initial angle $\varphi = 0$ and initial velocity $v = 0$. On the horizontal axis there are initial angular velocities and on the vertical axis, there is the height, from which the coin falls. Black portions mark places where the coin landed tails up

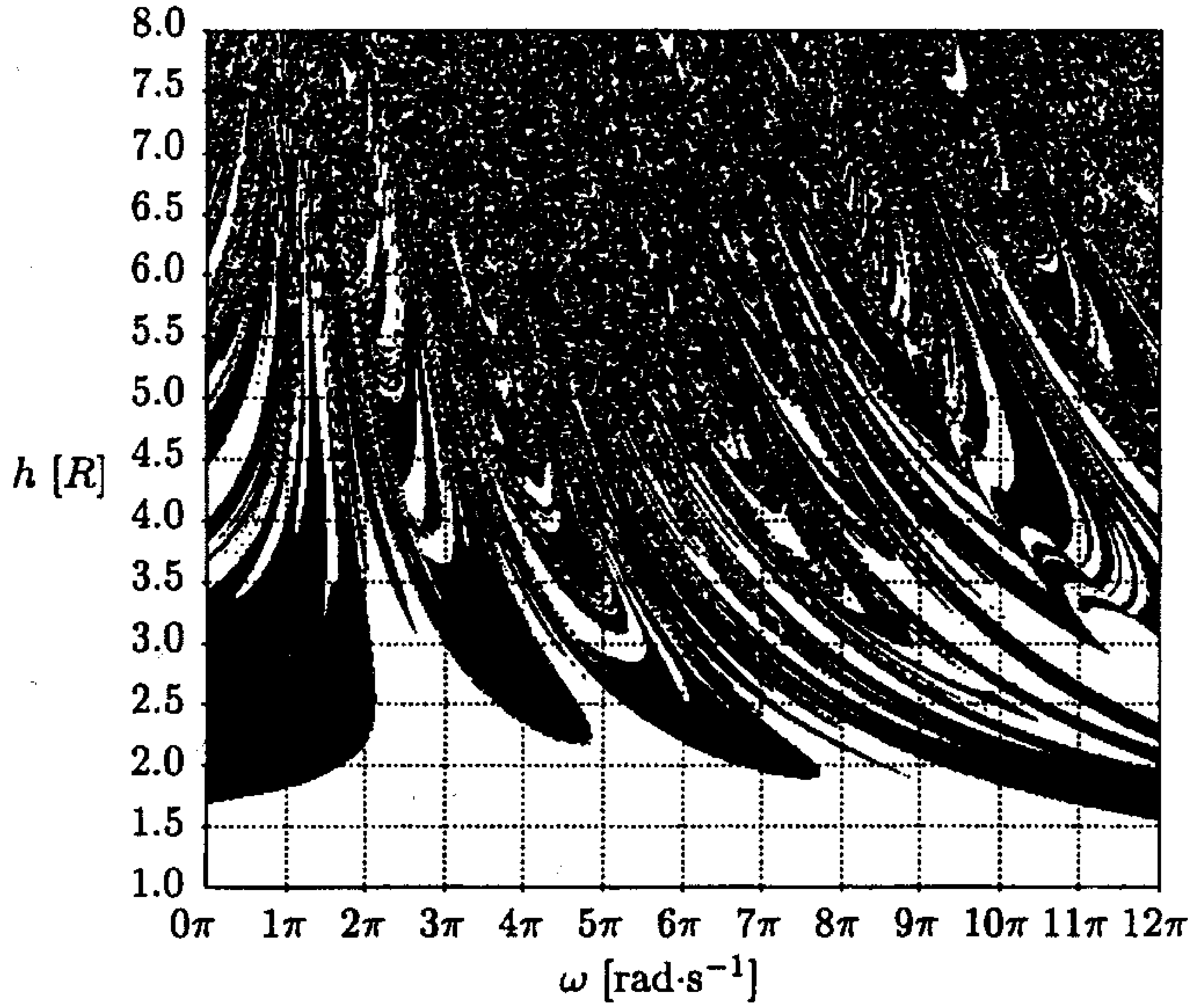
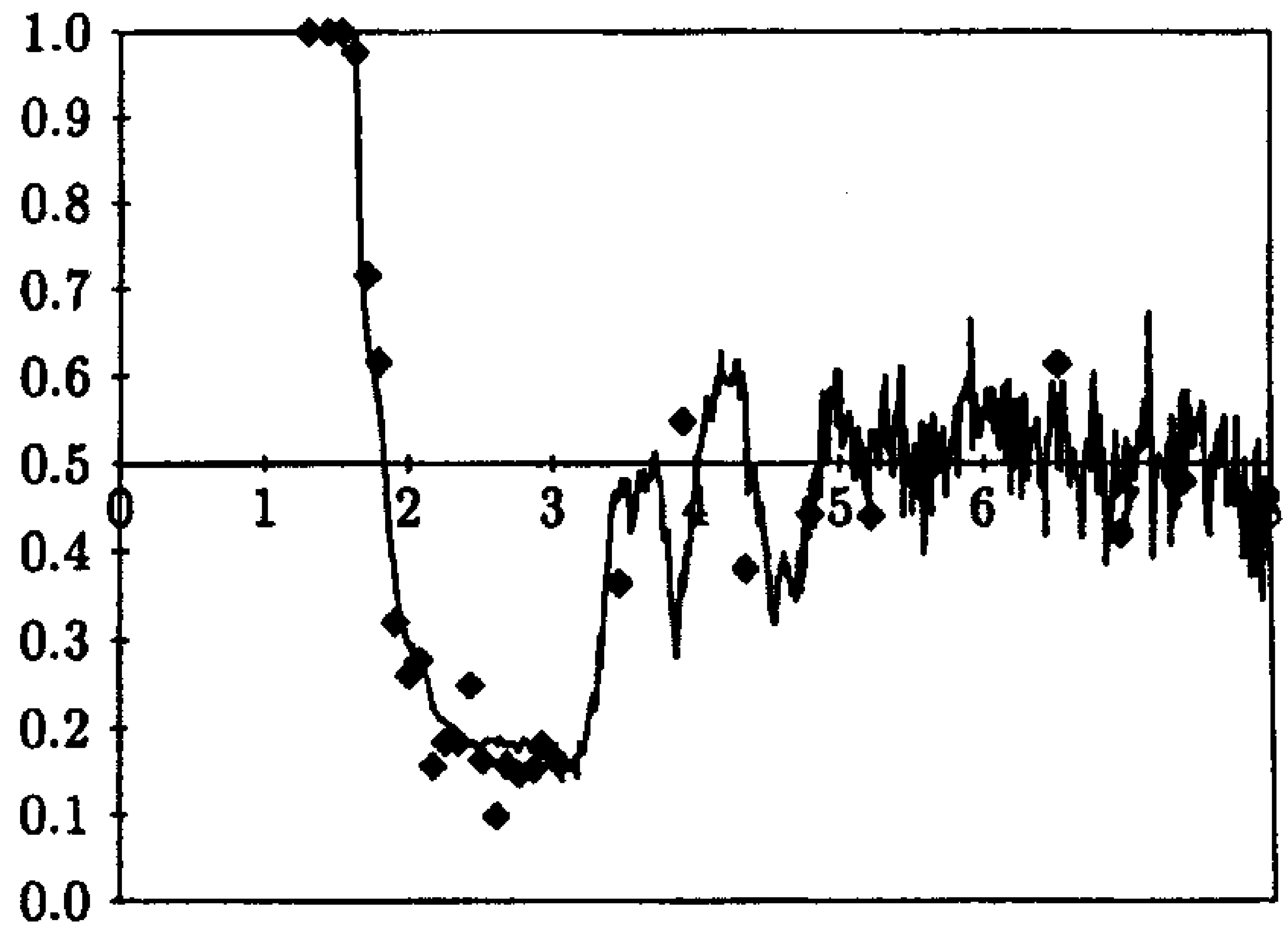


Figure 9: Dependence of probability of landing with heads up on height. The connected curve is a result of theory, the marks ♦ expresses the results of experiments. The coin was dropped 500 times per height



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10.2 Electron beam

Petr Chaloupka - Zdenek Kluiber

This simulation was made as a solution to one of the International Young Physicist Tournament. Here is a sample problem: An electron beam is cast upon a planparallel of known homogeneous material. Some of the electrons penetrate it, some do not. Try to simulate the processes taking place, e.g. using the Monte Carlo method, and compare your results with those published in the literature.

10.2.1 Introduction

Modeling by the Monte Carlo Method is to simulate with the use of the theory of probability and laws of statistics. This method can be used for solving tasks in which a direct algoritm can not be found, or the algoritm is too complicated to be used in practical solutions. The phenomena that occur during the penetration of electrons in solids are known and described. However when we combine these processes there are some influencing parameters which make the direct approach impossible. In the Monte Carlo Method we use models of simple processes in which we include a certain random factor. When we combine these processes we obtain the complex process which includes the influencing factors. If we make a great numer of these *simulations* we will get certain output values or their distribution. The more simulation runs we make the more accurate our result will be.

In our simulation we will always trace one (primary) electron, it is to be the so-called single particle model. When we want to simulate the trajectory of the primary electron we have to follow a couple basic steps. The firt thing is to find out the free path which the electron traveled between two consecutive colisions and the final position of the electron. The next step is to determine what kind of collision is taking place, the angle at which the electron was scattered, and the energy loss of the electron. We repeat this algoritm until the energy of the primary electron is lowered to the level on which the electron can be considered absorbed, or until the electron leaves the target. In order to simulate these processes we need to know the total cross-sections, mean free paths of each single process, and the differential cross-sections of the processes; for which we need to know their dependencies on the scattering angle or on the energy loss of the primary electron.

Because the description of the task is too general we have to simplifiing thing a bit. We have decided to simulate electrons that have energy in the range of hundreds of eV to hundreds of keV. We also suppose that the target is homogeneous and composed of atoms of only one element. We also had to neglect emisions of the secondary electrons,and effects of diffraction. The main objective of our work was to make a simulator that will not be too demanding on the input parameters, but will be able to produce some relatively good results.

10.2.2 Elastic scattering

As we stated earlier an electron is scattered on its way through the target on the atoms of the solid. The collisions that occur can be divided into two groups-elastic and inelastic, by the amount of energy that the electron loses during the collision.

If the electron scatters on the nucleus of the atom we can consider the scattering to be elastic. This also is a certain simplification. We know that in reality there is always some energy loss. However the energy loss is very minimal (about 10^{-2} eV), so we can neglect it and consider the scattering to be elastic.

Because the electron scattering on the nucleus is very localized, this means that the adjacent atoms have no influence on the collision, it's possible to use the model of elastic collision on a single atom as a model of elastic scattering. There are three main models used for simulating the elastic collision on a single atom:

a) Tabulated cross-sections.

b) Rutherford's model.

c) Mott's modiffication of Rutherford's model, which includes the influence of the electron's spin.

The first method gives good results, but it has some disadvantages. There is a need for numerical integration during calculating when we use this method, this would slow down the whole simulation remarkably. Also the data are not available for all elements in all energy ranges. Because of this, we have decided to apply the second method. This method is much easier and it also gives quite good results. The detailed comparison of different ways of modeling elastic scattering can be found in the literature[1].

We will show the formulas for a total cross-section σ and differential cross-section $\frac{d\sigma}{d\Omega}$ for Rutherford's model(Ω is a solid angle). This model includes the influence of the electron cloud on the value of electric potential V. This potential is then by Wentzel[8]:

$$V = -\frac{e^2 Z}{4\pi\epsilon_o r} e^{-\frac{r}{R}},$$

e is an electron charge,ϵ_o dielectric constant ,and r the distance from the center of the atom. And the radius of atom R is:

$$R = a_H Z^{-\frac{1}{3}},$$

a_H is the Bohr's radius of the atom($a_H = 0.0569nm$). Differential cross-section $\frac{d\sigma}{d\Omega}$ is then by [4] expressed as:

$$\frac{d\sigma}{d\Omega} = \frac{4Z^2}{a_H^2} \frac{(1 + E/E_o)^2}{[(\frac{4\pi}{\lambda_e} \sin\frac{\theta}{2})^2 + \frac{1}{R^2}]^2}, \tag{38}$$

where λ_e is the wave-length of the electron, E is the energy of the electron, E_o is a rest energy of the electron: $E_o = m_o c^2 = 511keV$.

The expression (38) is valid for relativistic electrons. In that case we use an expression for electron's wave length

$$\lambda_e = \frac{h}{\sqrt{2m_o E(1 + \frac{E}{2E_o})}}, \tag{39}$$

where m_o is the rest mass of the electron. In the case of non-relativistic electrons we can set $(1 + E/E_o)^2 = 1$ and $\lambda_e = \frac{h}{\sqrt{2m_o E}}$. Because the angle θ is quite small we can use an aproximation to simplify the problem.We set $\sin\frac{\theta}{2} = \frac{\theta}{2}$. Using this we can simplify the expression(38) into

$$\frac{d\sigma}{d\Omega} = \frac{4Z^2 R^4}{a_H^2} \frac{1}{[1 + (\frac{\theta 2\pi R}{\lambda_e})^2]^2}. \tag{40}$$

the solid angle Ω can be expressed as $d\Omega = \sin\theta \; d\theta \; d\phi$ where θ is a polar angle ($0 < \theta < \pi$) and ϕ is an azimuth angle ($0 < \phi < 2\pi$). The value of $\frac{d\sigma}{d\Omega}$ doesn't depend on the value of the azimuth angle ϕ.

We can get the total cross-section σ by integrating the expression(38) over the full solid angle Ω.

$$\sigma = \int_\Omega \frac{d\sigma}{d\Omega} d\Omega = 2\pi \int_0^\pi \frac{d\sigma}{d\Omega} \sin\theta d\theta = \frac{16\pi Z^{\frac{4}{3}}}{(\frac{4\pi}{\lambda_e})^2 + \frac{1}{R^2}} (1+\frac{E}{E_o})^2 = \frac{16\pi Z^{\frac{4}{3}} R^2}{(\frac{4\pi R}{\lambda_e})^2 + 1}. \tag{41}$$

From this we can derive a formula for probability density of electron scattering with its dependence on the scattering angle θ:

$$f(\theta) = \frac{2\pi \frac{d\sigma}{d\Omega} \sin\theta}{2\pi \int_0^\pi \frac{d\sigma}{d\Omega} \sin\theta d\theta}. \tag{42}$$

the probability p of electron being scattered into an angle α is then

$$p = \int_0^\alpha f(\theta) d\theta. \tag{43}$$

After integration

$$p = \frac{(16\pi^2 R^2 + {\lambda_e}^2)(\cos(\alpha) - 1)}{2(8\pi^2 R^2 \cos(\alpha) - 8\pi^2 R^2 - {\lambda_e}^2)}. \tag{44}$$

By manipulating this expression we can easily get a formula for the scattering angle α depending on a random number R_n which ranges from 0 to 1.

$$\alpha = \frac{\pi}{2} - asin[\frac{16\pi^2 R^2 (R_n - 1) + {\lambda_e}^2 (2R_n - 1)}{16\pi^2 R^2 (R_n - 1) - {\lambda_e}^2}]. \tag{45}$$

Formulas (38) and(45) that we derived are dependent only upon the parameters of the target and primary electrons. We can use these formulas to obtain parameters of the electron's trajectories inside the solid. From the total cross-section we are able to get an expression for mean free path (λ) that the electron travels between two elastic collisions.

$$\lambda = \frac{A}{N_a \sigma}, \tag{46}$$

N_a is an Avogadro's number and A is a relative atom number. The mean free path is then measured in terms of mass thickness(kg/m^2). From now on we will measure all distances in terms of mass-thickness, as it is usual in simulations like these.

When the elasting collision occurs we have to find the angle that the electron was scattered into. We get this angle by substituting a random number from the interval $(0, 1)$ for R_n in formula (45).

10.2.3 Inelasting scattering

The inelastic collision is, in comparison to the elastic one, less localized. It means that the adjacent atoms influence the scattering. When the primary electron scatters it looses some energy. In this case the energy loss is not negligible. For simulating the inelastic scattering Bethe's model of continuous slowing down is very often used, as well as a model of a single particle inelastic scattering.

Bethe's model of continuous slowing down When we use the *Bethe's model of continuous slowing down* we consider only elasting collisions. It means that the primary electron can change its direction only because of the elastic collisions, and the change of its energy depends upon the length of its trajectory between collisions. The amount of lost energy is given by a basic formula

$$\Delta W = \int_{x_1}^{x_2} F dx, \tag{47}$$

where F is a force acting on the electron for which there is Bethe's fomula [4]

$$F = \frac{e^4 N_a Z}{4\pi\epsilon_o^2 A E_o \beta^2} \ln\left(\frac{E_o\beta^2}{2J}\right), \tag{48}$$

where $\beta = v/c$. In the case of nonrelativistic electrons we can make a substitution $E_o\beta^2 = 2E$. It is necessary to mention the variable J which is a mean ionisation potential. The mean ionisation potential was derived by Caldwell[5] as a function of proton number Z

$$\frac{J}{Z} = 12(1 + 0.5Z^{-}1) + 0.03Z.$$

Or shortly $J/Z = 13$. As can be seen the expression(48) is not going to work for low energies because of the logarytmic term(the energy loss becomes negative). There must be some adjustments in order to make a succesful simulation. We can either set the energy, at which we consider the electron to be absorbed, to a value for which the fomula (48) works, or we have to make some adjustments to the mean ionisation potential. In the literature [11] we have found that the mean ionisation potential can be adjusted like this:

$$J = \frac{J_c}{1 + \frac{kJ_c}{E}}, \tag{49}$$

J_c is the original Caldwell's mean ionisation potential and k is aproximately 0.85. This way of simulating is quite simple, however it can give some good results.

Model of single inelastic scattering There is a difference between the previous model of inelasting scattering and this one. In this model the primary electron scatters in two types of collisions-elastic and inelastic ones. The electron doesn't loose its energy during travel, but rather during the inelastic collisions that are simulated separately. In these collisions the electron also changes the direction of its trajectory. In order to create such a model of inelastic scattering we need to know the mean free path λ between two collisions.

$$\lambda = \frac{W_{av}}{F} = \frac{1}{F_b} \int_{W_{min}}^{W^{max}} W f(W) dW, \tag{50}$$

where $W_{av}$is a mean value of the lost energy during the inelastic collision. F is a stopping force acting on the primary electron that slows the electron down. $f(W)$ is a probability density of electron loosing the energy W,and W_{min} and W_{max} are boundary limits of the electron's energy loss. In this model we suppose that

$$\frac{d\sigma_{in}}{dW} = \frac{\pi e_{el}{}^4}{E_o W^2}.$$

The value of the energy loss W can then be expressed as:

$$f(W) = \frac{\frac{d\sigma_{in}}{dW}}{\int_{W_{min}}^{W_{max}} \frac{d\sigma_{in}}{dW} dW} = \frac{W_{min} W_{max}}{W_{max} - W_{min}} W^{-2}. \quad (51)$$

Maximal energy loss W_{max} can be maximally equal to the momental energy of the primary electron E. After subtitution:

$$f(W) = (\frac{EW_{min}}{E - W_{min}})W^{-2}. \quad (52)$$

After substituting to the equation (50) and integration we get:

$$\lambda = \frac{1}{F}\frac{EW_{min}}{E - W_{min}} \ln(\frac{E}{W_{min}}). \quad (53)$$

Minimal energy loss W_{min} is a varying parameter that, when we consider the properties of the function, must be greater than 0. In our simulation it was sufficient to set $W_{min} = 10eV$. From this equation we can finally count the electron's mean free path between two inelastic collisions λ depending on the input parameters and the instantaneous energy of the primary electron. Another thing we need to know is the dependence of the value of the lost energy on a random number. The probability p of the electron losing energy ΔW is

$$p(\Delta W) = \int_{W_{min}}^{\Delta W} f(W) dW = \frac{E(\Delta W - W_{min})}{\Delta W(E - W_{min})}. \quad (54)$$

The energy loss ΔW is then dependent upon the random number R_n:

$$\Delta W = \frac{EW_{min}}{R_n W_{min} - E(R_n - 1)}. \quad (55)$$

The energy loss corresponds to a scattering angle θ: $sin^2\theta = \frac{\Delta W}{E}$. During the simualtion the actual energy loss is obtained from equation(53). All shown calcuations for elastic and inelastic scattering are for the scattering angle θ. The azimuth angle ψ is easily obtained from the formula

$$\psi = 2\pi R_n.$$

10.2.4 Program details

Now we know the mean free paths for both types of collisions, from them we can calculate the electron's total mean free path λ_t:

$$\frac{1}{\lambda_t} = \frac{1}{\lambda_{elast}} + \frac{1}{\lambda_{inel}}.$$

Other important formulas are those used for calculating the position and speed of the primary electron. Let x_n, y_n, z_n be the electron's coordinates after the n-th collision and Θ_n, Ψ_n are the directional and azimuth angle. Let Θ, Ψ are the angles we obtained from the previously shown formulas. For calculating the change of primary electron's direction after every collision (Θ_n, Ψ_n) from the previous direction we use formulas:

$$\begin{aligned}
\cos\Theta_n &= \cos\Theta_{n-1}\cos\Theta - \sin\Theta_{n-1}\sin\Theta\sin\Psi, \\
\sin\Theta_n &= \sqrt{1-\cos^2\Theta_n}, \\
\cos\Psi_n &= \frac{\sin\Psi_{n-1}(\cos\Theta_{n-1}\sin\Theta\sin\Psi + \cos\Theta\sin\Theta_{n-1}) + \cos\Psi_{n-1}\sin\Theta\cos}{sin\Theta_n} \\
\sin\Psi_n &= \frac{\cos\Psi_{n-1}(\cos\Theta_{n-1}\sin\Theta\sin\Psi + \cos\Theta\sin\Theta_{n-1}) - \sin\Psi_{n-1}\sin\Theta\cos}{sin\Theta_n}
\end{aligned}$$

From the new angles Θ_n and Ψ_n, old coordinates x_n, y_n, z_n and the free path δS_n we get new coordinates of the primary electron:

$$\begin{aligned}
x_{n+1} &= x_n + \Delta S_n \sin\Theta_n \cos\Psi_n, \\
y_{n+1} &= y_n + \Delta S_n \sin\Theta_n \sin\Psi_n, \\
z_{n+1} &= z_n + \Delta S_n \cos\Theta_n.
\end{aligned}$$

The first step in our simulation is to find the free pathλ_t as shown above. The next step is to get new coordinates of the primary electron. If the electron is still inside the plate we have to find out, in the next step, what kind of collision is taking place. If

$$R_n \leq \frac{\frac{1}{\lambda_{elast}}}{\frac{1}{\lambda_t}},$$

(can be written as:)

$$R_n \leq \frac{\sigma_{elast}}{\sigma_t},$$

it is an elastic collision. In the other case it will be an inelastic collision (in the single inelasting scattering model). In the case of the inelastic scattering model we have to determine the amount of lost energy due to the collision. If the primary electron's energy drops below a certain low level the movement of the electron becomes very localized, we can thus consider the primary electron being absorbed. We set this minimal level $E_{min} = 200eV$. If we a used lower energy level the simulation would slow down remarkably, and lowering the minimal energy wouldn't have much influence on the result. In both types of collisions we have to determine the scattering and azimuth angle.

10.2.5 Results

The first thing we focused our simulation on were coefficients of backscattering for thin films. The results of this simulation are mainly influenced by the model of elastic scattering, so these simulations are good for testing the model of elasting scattering(in our case it's a Rutherford's model). We simulated electrons with energy of $50keV$ going through a plate made of aluminium and carbon(pic. 1). For comparison we have decided to show results from the work of V. Starý[1](obr. 2).

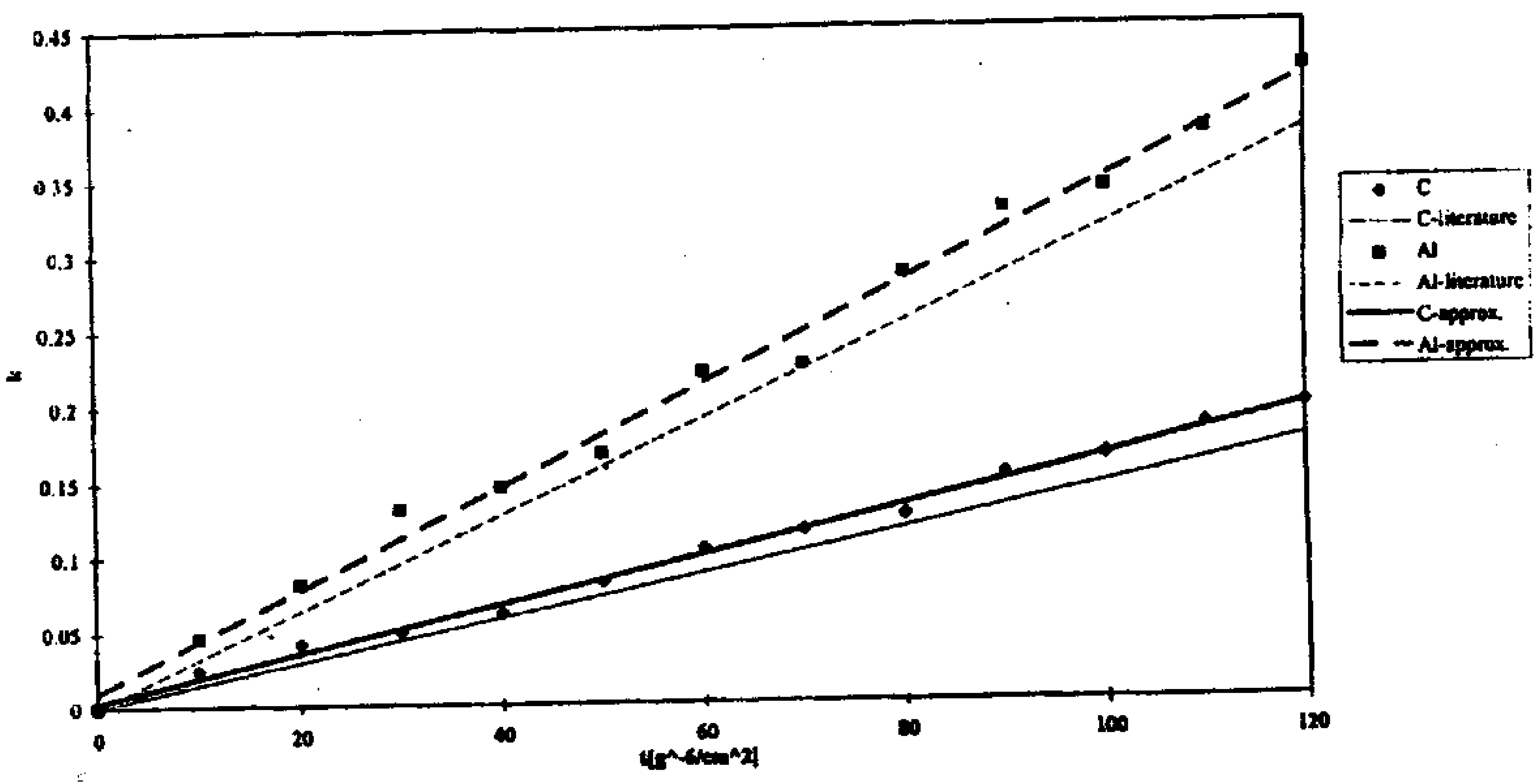
Although the description of the task is said to simulate the electron's penetration through a planparallel plate, we decided to simulate the next penetration through a semi-infinite solid. From these simulations we are able to find the mean depth of penetration x in the material(Al, Be, Cu). We carried out these simulations for both types of models of inelasting scattering (Bethe's model and single inelastic scattering model). The obtained results can be seen in pictures 2a and 2b. For comparison we show the results of experiments(pic. 2c) published in[7]. As you can see from the pictures we obtained quite good results for berilium and aluminium. However the results for copper and especially for gold are not that good.

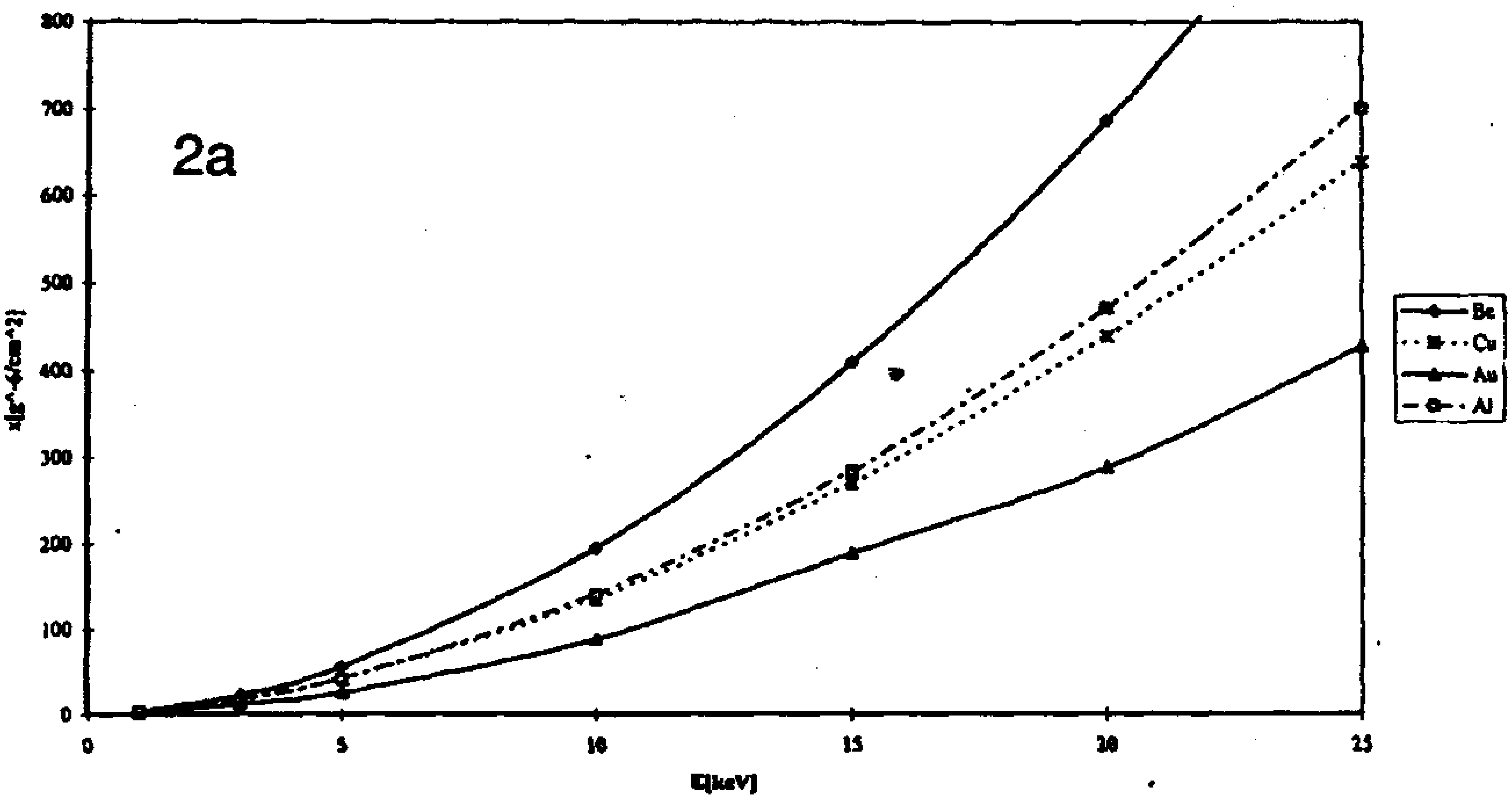
The last thing we simulated were $10keV$ electrons going though a planparallel plate made of copper. In this simulation we were looking for the number of electrons that went through, backscattered or were absorbed(pic. 3a). For comparison we show data from a similar simulation published in[5](pic 3b). Although our simulator doesn't work as well for copper as it does for the other elements we chose this simulation mainly because we had data from literature to compare our results with.

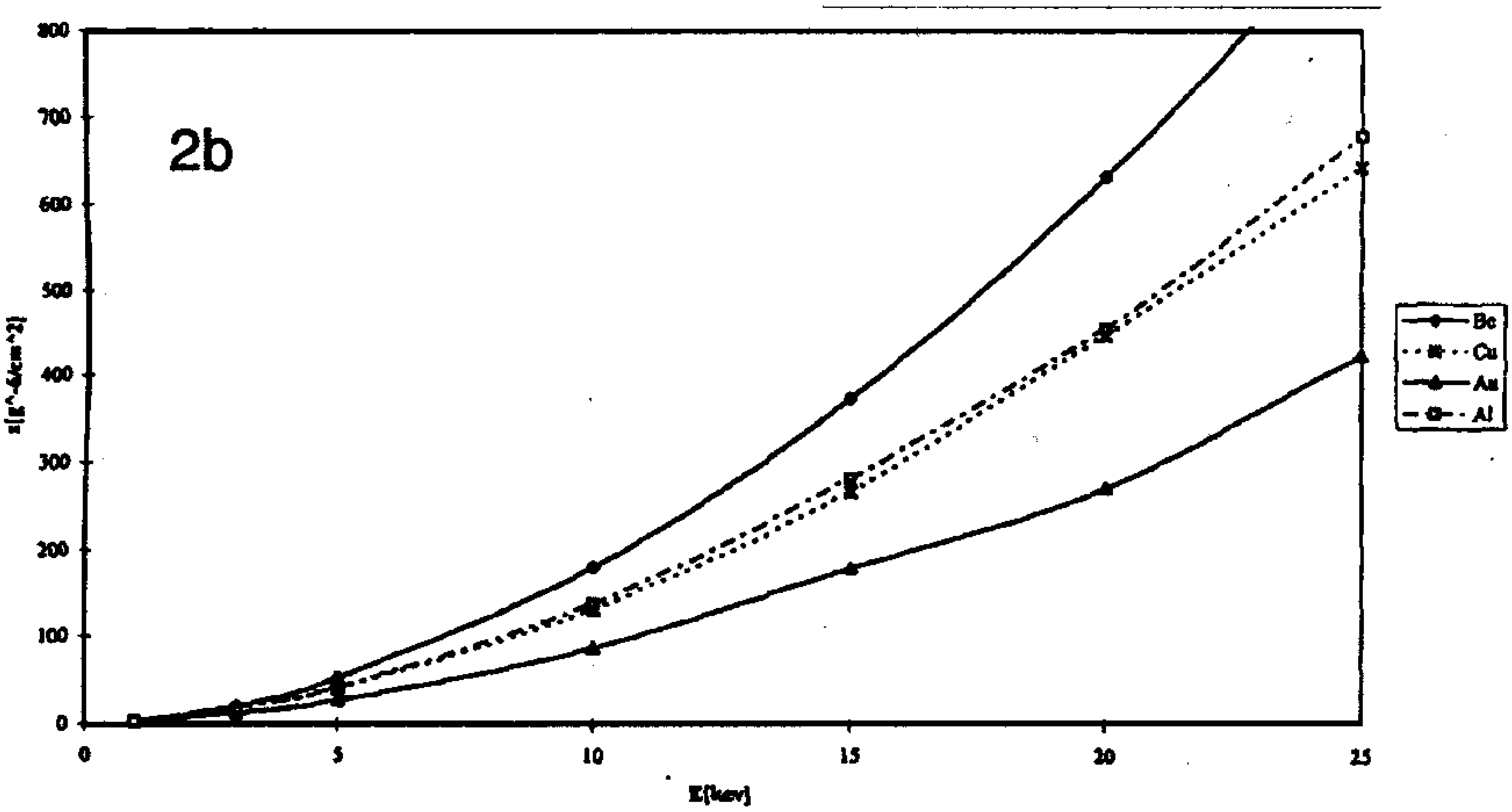
The last picture(num. 4) shows the electron trajectories calculated in a previous simulation. A beam of electrons at energy of 10 keV is cast upon a planparallel copper plate (in the place where the arrow points), which is $250g^{-6}/cm^2$ thick. It can easily be seen from the picture how the electrons scatter in the material and how some of them leave the plate.

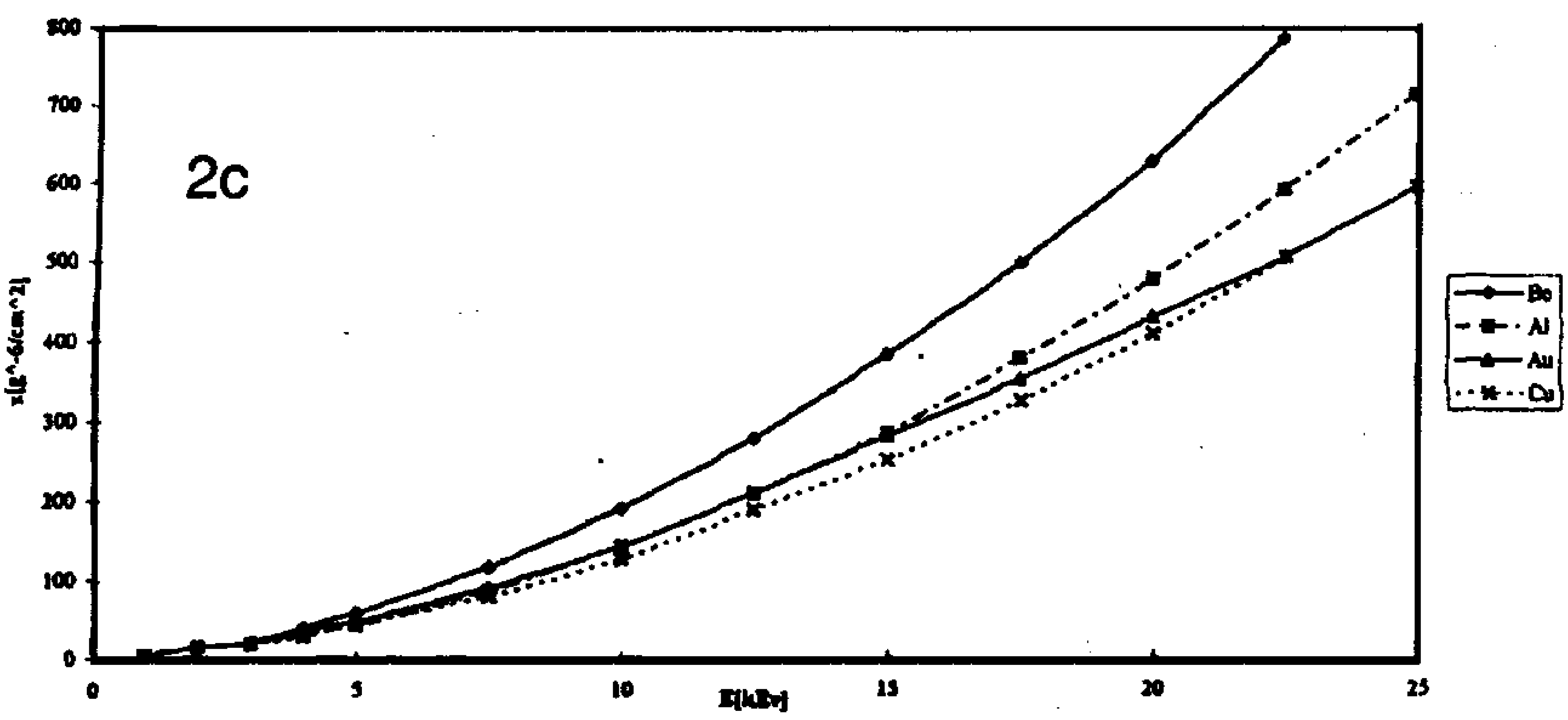
We carried out simulations mainly for aluminium,berilium and copper. We chose these because we were able to compare our result with results published in literature. Although our simulator is very simple and we made lot of simplifications, it gives some results that can be compared with those published in literature.

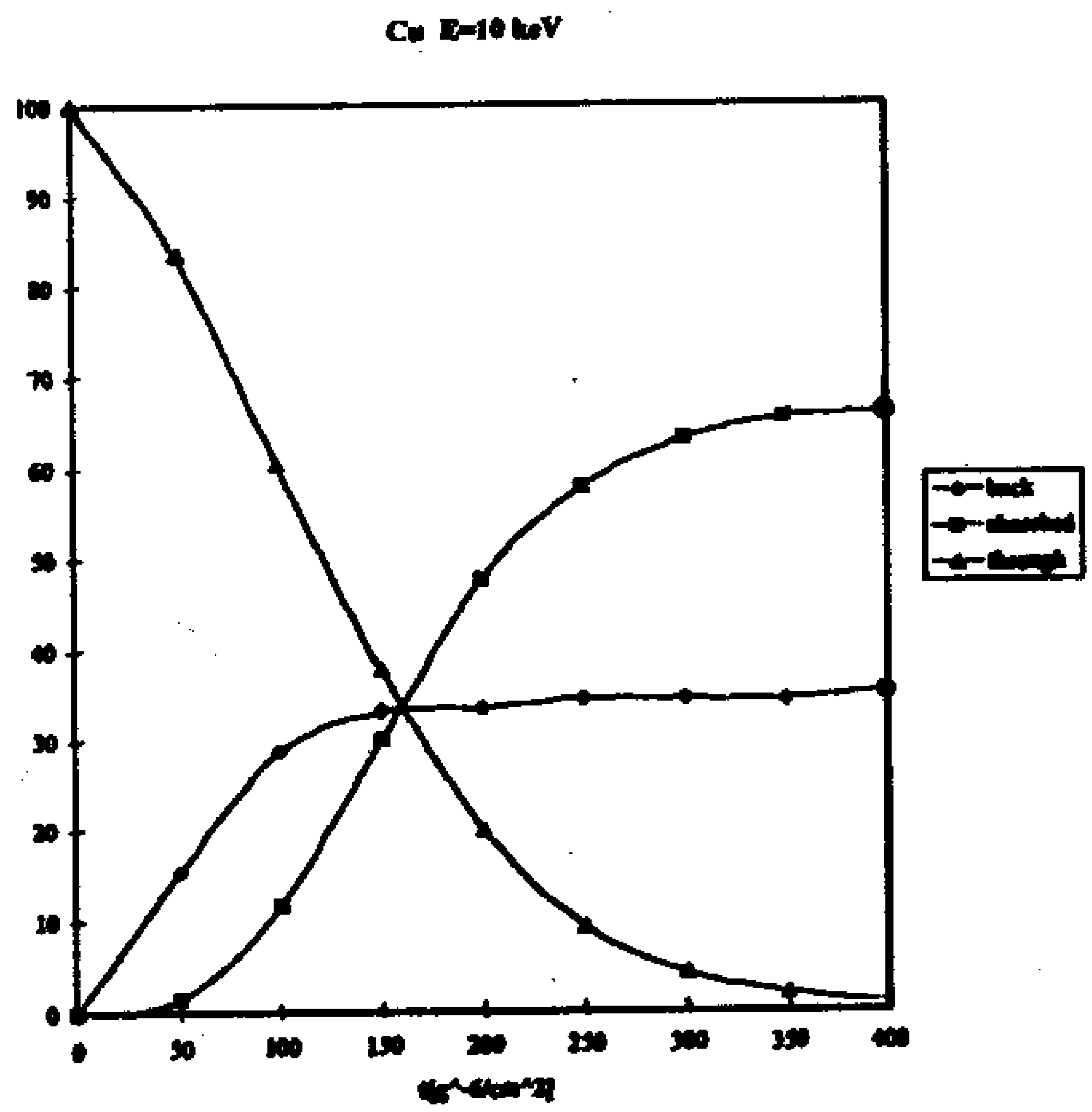
fig. 1



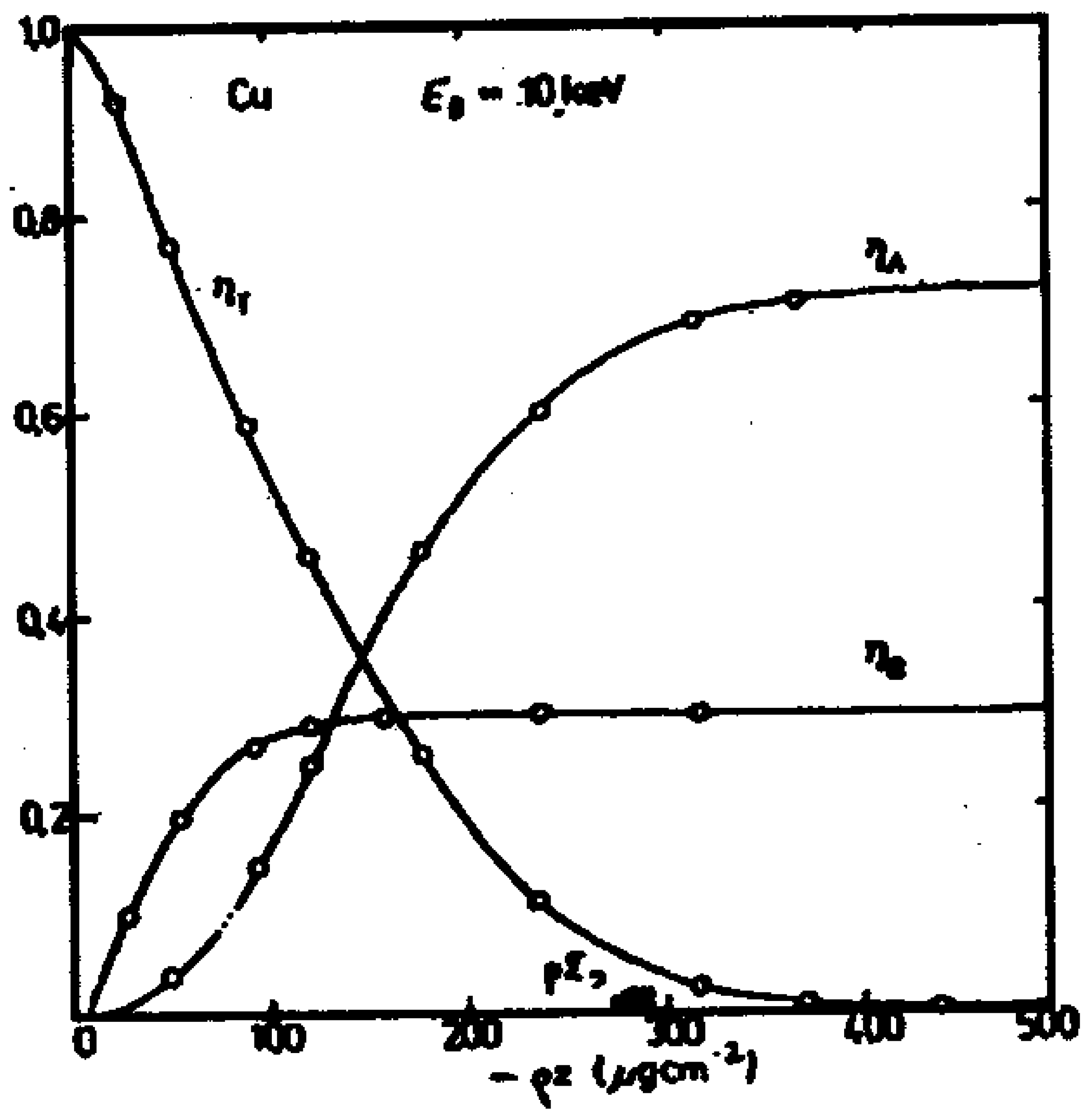

2a
x[g^-6/cm^2]
E[keV]
Be
Cu
Au
Al


2b
x[g^-6/cm^2]
E[kev]
Be
Cu
Au
Al

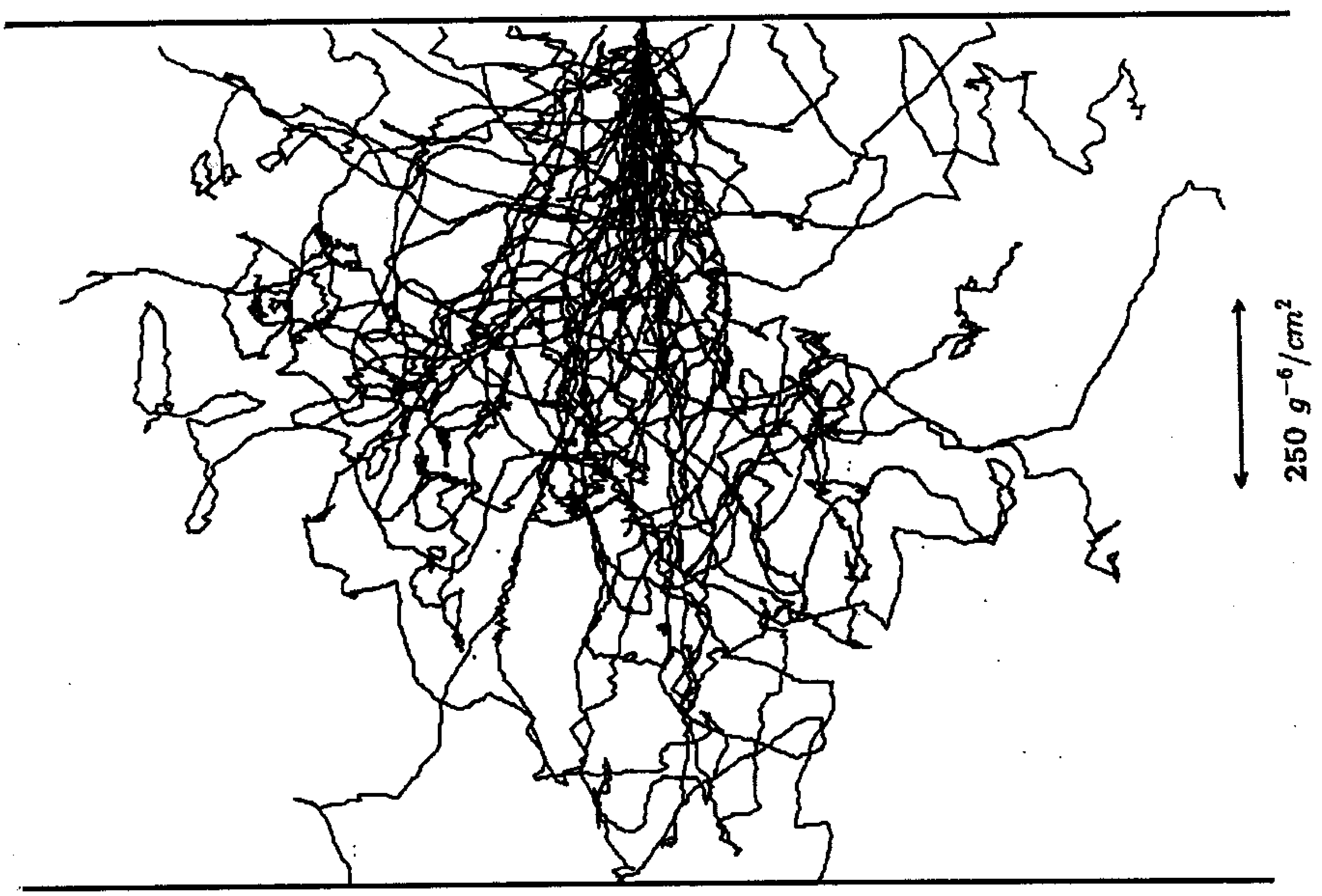

2c
x[g^-6/cm^2]
E[kEv]
Be
Al
Au
Cu



Cu E=10 keV
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
400



1,0
0,8
0,6
0,4
0,2
Cu
E_0 = 10 keV
η_T
η_A
η_B
0
100
200
300
400
500
− ρz (μgcm⁻²)



250 g^{-6}/cm^2

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10.3 Description of pictures

1:
pic.1 Coeficients of backscattering for thin films of C,Al. The results are lineary approximated by thick lines. The thin lines show results taken from literature.

2:
pic.2 Mean depth of penetration of the electron's in Be,Cu,Au,Al and their dependence on electron's energy; a- with a use of model

of continuous slowing down, b- single inelasting scattering model, c- experimental results taken from literature.

3:

pic.3 Number of 10keV electrons that we backscattered, absorbed or went through a planparallel plate made of copper, a- results of our simulation(using the continuous slowing down model) , b- results taken from literature.

4:

pic.4 Trajectories of electron's with the energy of 10keV going through a copper plate of thickness $250g^{-6}/cm^2$

11 Conclusions

Zdenek Kluiber

The interest of the talented students for study of physics is based on the quality of the educational level of the teaching of physics and consecutive activities such as are competitions in physics and other activities. The secondary schools students by its participation in competitions in physics develop their abilities and skills as a basic assumption for their success in physics. Important role in the system of their preparation has corresponding presentation of results of their own professional work, development of the communication skills (also with respect to the international actions) and especially direct contact with physicists. IYPT belongs among the most difficult tournaments of the secondary schools students. This difficulty requires very high knowledge of all its participants. The IYPT develops creative imagination of students, their aptitude to analyze the problems, their logical way of thinking, their possibility of usage of the theoretical knowledge for the study of the natural phenomena, it develops technical capabilities of students. Among the basic positive points is also the development of the discussion in English langu age, capability of reactions and cultivated communication. The 10th IYPT has become an important milestone in the development of tournaments in physics. It created assumptions for broadening of the system of tournaments on the international level, gave the positive marks to the contribution in searching the talented students and pointed out the role of physicists in the improvement of the quality and organization of the competition. The presence of Prof. Dr. K. von Klitzing and Prof. Dr. H. Schopper at the 10th IYPT has become an important estimation of the tournament. It has, however, become also an obligation for its future development. The 10th IYPT, due to its ideas, has become an important contribution to the future development of talented students in physics, it has become a contribution to the representation of the pure physics, it actively helped to the propagation of the Czech Republic and the level of its education in natural sciences. The 10th IYPT has also become a friendly meeting point of physicists.

12 Problems of the 11th IYPT

The group of the following authors formulated the problems for the 11th IYPT: Burger W., Kluiber Z., Kretschmer B., Laskhishvili G.., Lehn R., Ljungfelt S., Lobyshev V., Nadolny A., Rajkovits Z., Tibell G., Urban A. and Yunosov E.

12.1 List of problems

a) Invent yourself - vymyslete sami

Construct an aeroplane from a sheet of paper (A4,80 g/m2). Make it fly as far and/or as long as possible. Explain why it was impossible to reach a greater distance or longer time.

b) Popping body - vyskakující těleso

A body is submerged in water. After release it will pop out of the water. How does the height of the pop above the water surface depend on the initial conditions (depth and other parameters) ?

c) Spinning disc - rotující disk

Investigate and explain the phenomenon of spinning annular disc as it progresses down a straight, cylindrical rod. If the rod is moved upwards at a defined velocity, the disc spins at constant height. Investigate the mechanism.

d) Water streams - vodní proudy

A can with tree holes in the side-wall at the same height slightly above the bottom is filled with water. The water will escape in three separated streams. By gently touching the streams with a finger they may unite. Investigate the conditions for this to happen.

e) Water jet - proud vody

If a vertical water jet falls down onto a horizontal plate, standing waves will develop on the surface of the jet. Investigate the dependence of this phenomenon on different parametres.

f) Mount Everest

Can you see Mount Everest from Darjeeling ?

g) Air bubble - vzduchová bublina

An air bubble rises in a water-filled, vertical tube with inner diameter 3-5 mm. How does the velocity of the rising bubble depend on its shape and size ?

h) Trick - trik

It is known that a glass filled with water and covered with a sheet of paper may be turned upside down without any loss water. Find the minimum amount of water to perform the trick succesfully.

i) Woven textiles - utkané látky

Look at a point-like source through different woven textiles. Describe what you see. What is the explanation of the phenomenon?

j) Repeated freezing - opakované mrznutí

While a vessel filled with an aqueous solution of a volatile fluid (e.g. ammonia, ethanol or acetone) is being cooled, repeated freezing and melting may be observed near the surface. Describe and explain the phenomenon.

k) Current system - proudový systém

In a Petri dish (shallow bowl), small metal balls, e.g., 2mm in diameter, are immersed in a layer of castor oil. The inner rim of the dish contains an earthed metal ring. Above the centre of the dish there is the metal needle which does not touch the oil surface. Investigate what happens when the voltage between needle and earth is about 20 kV. Warning: The high voltage should be obtained by means of a safe generator, e.g., electrostatic generator!

l) Powder conductivity - vodivost prášku

Measure and explain the conductivity of a mixture of metallic and dieletric powders with various proportions of the two components.

m) Rope - provaz

How is it possible that a very long and strong rope can be produced from short fibers? Prepare a rope from fibers and investigate its tensile strength.

n) Water rise - stoupání vody

Immerse the end of a textile strip in water. How fast does the water rise in the strip and what height does it reach? In which way do these results depend on the properties of the textile?

o) Luminiscent sugar - zářící cukr

Investigate and explain the light produced when sugar crystals are pulverized. Are there other substances with the same property?

p) Strange motion - podivný pohyb

Make a mixture of ammonium nitrate and water in the proportion 5 : 1. When the mixture is heated to about $100°C$ it melts. When it cools, it crystallizes and you may observe a strange motion below the surface. Investigate and explain the phenomenon. Safety rules: Do not heat the ammonium nitrate without water, preferably use a water bath! Use protection glasses during the experiment!

q) Icicles - rampouchy

Investigate and explain the formations of icicles.

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Photographs:

Fig. 1 The winning teams of the 10^{th}IYPT left Hungary right the Czech Republic
Fig. 2 The team of Czech Republic, representatives of Czech physics from left - Petr Luner, Libor Inovecky, Petr Chaloupka, Josef Rosenkranz - director of the project ASTRA 2000 the Foundation Charta 77, Hynek Nemec, Vladimir Dvorak - director of the Institute of Academy of Sciences Czech Republic, Filip Matejka, Stefan Zajac - vicechairman of Union of Czech Mathematicians and Physicists
Fig. 3 Prof. Dr. Klaus von Klitzing - lecturing
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Fig. 6 Dr. A. Nadolny - lecturing at the conference "10 Years of IYPT"
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REGION CHEB

- informační středisko - tourist centre
- nemocnice - hospital
- hraniční přechod - border crossing point
- turistický hraniční přechod - tourist border crossing
- městská památková rezervace - town monuments preserve
- zámek - mansion
- hrad - castle
- lázně - spa
- koupaliště - bathing place
- autokempink - auto camp
- benz. čerpadlo - filling station
- restaurace, hotel - restaurant
- lidová architektura - folk architecture
- muzeum - museum

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