Seminar on large European projects

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The seminar, in which 250 scientists took part, was for the purpose of exchange of information between European physicists about the large-scale projects which are being discussed at present or are already being accomplished, and which determine the limits of European potential in the field of fundamental research in the foreseeable future. The Soviet delegation consisted of V. I. Gol'danskiĭ, K. K. Rebane, V. A. Sidorov, G. A. Smolenskiĭ, and the author.

The seminar, organized by the European Physical Society, took place on 25–27 March 1979 in Rome in the old Barberini Palace. We note that Maffeo Barberini, who in the seventeenth century became Pope Urban VII, has entered history as the persecutor of Galileo.

The review papers, which were given by well qualified authors, discussed the following matters: the Joint European Tokamak JET, large optical telescopes, millimeter-range radio-astronomy telescope projects, the UNK accelerator—storage-ring project, the large colliding-beam installation LEP, and the projected European installation for hard synchrotron radiation.

1. The report by G. Palumbo, director of the thermonuclear research program of the European Scientific Commission (Brussels), described the complex five-year program of the western European countries in the field of thermonuclear fusion reactions carried out under the aegis of Euratom. The basic idea of the program is to combine the efforts of scientists of various countries in the solution of the common problem, primarily the construction of the tokamak JET. The principal problems to be solved are the following:

1) Study of the parameters of plasma under conditions close to those which can be expected in a fusion reactor.

2) Study of the interaction of the plasma with the wall.

3) Study of methods of plasma heating.

4) Study of the capture of α particles and the heating of the plasma.

5) General study of plasma, its production and decay. Study of the conditions of scaling for tokamaks.

Progress in the field of thermonuclear research is illustrated in Table I.

A decisive factor for the tokamak program was the success of the Soviet tokamak T-3 in 1968, in which the possibilities of this type of device were demonstrated for the first time.

The characteristics of the European tokamaks are given in Table II.

Significant attention is being devoted to the development of diagnostics, to questions of material study, and to systems for storage and processing of tritium. In the ASPEX installation at Garching, West Germany, the role of impurities in the plasma will be studied, and in the TEXTOR installation—the behavior of the first wall. In addition to tokamaks, some attention is being devoted to other systems—open traps and stellarators. Less attention is being devoted in the European program to fast systems and to laser thermonuclear fusion systems. Palumbo's statements supported the idea of construction of a large international installation of the tokamak type.

Trying to avoid too optimistic predictions, the rapporteur suggested that a demonstration power reactor might be realized at the beginning of the next century.

2. The current state and the developments of new optical telescopes was the subject of a report by L. Woltjer, Director General of the Southern European Observatory (SEO) in Chile, in which scientists of Belgium, Denmark, France, West Germany, Holland, and Spain collaborate. The state of contemporary European optical telescope construction is evident from Table III.

We recall that during these same years in the USA telescopes of diameter 3.8 m were built at Kitt Peak and Sierra Torona. The penetrating power of these instruments rarely exceeds the 25th stellar magnitude, and the resolution 1–2 seconds of arc.

In addition to terrestrial telescopes, in the USA and

TABLE I.

Year	Time τ, sec	Temperature, K	Lawson criterion $n\tau$, sec/cm^3	Containment time, sec
1955	10^{-5}	10^5	10^9	10^{-4}
1960	10^{-4}	10^6	10^{10}	$2\cdot10^{-3}$
1965	$2\cdot10^{-3}$	10^6	10^{11}	$2\cdot10^{-2}$
1970	10^{-2}	$5\cdot10^6$	$6\cdot10^{11}$	10^{-1}
1976	$5\cdot10^{-2}$	$2\cdot10^7$	10^{13}	1
1978	$8\cdot10^{-2}$	$6\cdot10^7$	$2\cdot10^{13}$	1
Reactor	1	10^8	$2\cdot10^{14}$	100

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TABLE II.

Installation	Country	Outer radius, cm	Inner radius, cm	Field, Oe	Current I, kA
T-3	USSR	100	15	3.5	120
T-10	USSR	150	38	4.5	600
Pulser	W. Germany	70	12	2.8	95
TFR	France	100	20	6.0	400
FT	Italy	83	21	10.0	1000
DITE	England	117	27	2.8	250
ASPEX*)	W. Germany	164	40	2.8	500
TEXTOR*)	W. Germany	175	50	2.0	500
JET*)	England	296	125×210	2.8×2.5	3800—4800

*) Under construction.

western Europe a joint project is being developed for an extra-atmospheric instrument (ST) with $D = 2.4$ m which theoretically will be able to provide stellar images up to the 29th magnitude with a resolution of 0".15.

For observation of extended weak objects the possibility is being considered of constructing a very large telescope (VLT)—a terrestrial device for addition of brightnesses with an equivalent diameter 16 m. In the USA a VLT project at 25 m is being considered. The main problems which can be studied with such an instrument are the following:

1) Red shifts of remote galaxies for the study and choice of models of the Universe.

2) Study of absorption lines from quasars for investigations of intergalactic space.

3) Study of the polarization of pulsar radiation.

4) The structure and composition of stars in neighboring galaxies and star clusters.

The rapporteur noted that the cost of an "effective photon" in such a telescope is an order of magnitude less than in the other systems (ST and SEO).

West European scientists are also collaborating in the field of constructing long-base radio interferometers. The plan to work in real time with communication through a special satellite is attractive. This also will lead to the possibility of determining terrestrial coordinates with accuracy 1 cm in a 1000-km base (10^{-8}). Work is being carried out on construction of astronomical satellites with an infrared telescope and an x-ray telescope.

The well known radio engineer, builder of the ISR proton colliding-beam complex at CERN, K. Johnson, reported on the millimeter-region radio-interferometer project headed by him which is being carried out with the combined efforts of French and West German scientists with participation of Spanish astronomers.

TABLE III.

Observatory	Location	Participating countries	D,m	Year of startup
Siding Spring	Australia	England, Australia	3.9	1974
La Silla	Chile	So. Europ. Assn.	3.6	1976
Zelenchuk, large az. tel.	USSR	USSR	6.0	1977
Hawaiian Islands		Hawaii, France, Canada	3.6	1979
		W. Germany		
Calar Alto	Spain	England	3.5	1982
Canary Islands			4.2	In constr.
	Italy		3.5	In constr.
Infrared telescope	Hawaii	England	3.8	1978

The cost of the installation is estimated at sixty million francs. Ten percent of the time will be assigned to Spanish scientists.

The main problem of interest here is study of molecules in the interstellar gas of our Galaxy, the problem of star formation, and also general research in this little-studied region of the radio spectrum.

In the Sierra Nevada mountains in Spain at an elevation of 3000 m there will be brought into operation in 1982 a completely steerable radio telescope of diameter 30 m with a tolerance of 0.07 mm for operation at frequencies from 22 to 230 GHz with an angular resolution of 20" (at frequency 115 GHz). The permissible wind level is 15 m/sec. In France near Grenoble at an elevation of 2500 m it is proposed to construct a radiointerferometer with three completely steerable antennas of diameter of 12–15 m and a base up to 1.5 km in the same frequency region with resolution down to 2" for a 400-m base. The interferometer should be built by 1986.

Great interest was produced by the report on the UNK accelerator—storage-ring complex project presented by the Institute of High Energy Physics at Serpukhov, USSR, and read by V. A. Sidorov. The basis of the project is a 3-TeV proton synchrotron whose parameters are given in Table IV.

It is planned to use the existing U-70 machine as an injector, increasing its intensity to 5×10^{13}. With a two-stage system, placing the rings in a single tunnel of dimensions 5.6 × 3.6 m, it is possible to organize various types of colliding beams. It is planned to use superconducting magnets in the project.

The chairman of the European Committee on Future Accelerators, Marcel Vivargent, reported on the plans for the next large-scale object projected at the present time at CERN—the electron-positron colliding-beam installation LEP at particle energy 100 GeV and luminosity 10^{32}. Interest in a breakthrough into this region is particularly great as a result of the rather clear predictions of the theory of Weinberg and Salam for the masses of charged vector bosons, 78 GeV, and the Z_0 meson with mass 90 GeV. The proposal was advanced to construct a machine in a tunnel of length 30 km at energy 100 GeV in each beam with a microwave system power up to 60 MW. Subsequently the energy in each beam may be raised to 130 GeV. At the present time, designs of accelerating resonators have been developed which also utilize superconductivity and special weak-field magnets with resin impregnation. The time for turn-on of the LEP is estimated as 1988.

TABLE IV.

Parameter	Stage I	Stage II
Orbit length, *m*	19 288	19 288
Injection energy, GeV	70	400
Maximum energy, GeV	400	3000
Injection field, *T*	0.117	0.670
Maximum field, *T*	0.670	5.0
Pulse duration, sec	78	78
Number of particles per pulse	$6 \cdot 10^{14}$	$6 \cdot 10^{14}$

Thus, the coming ten years in the world will be marked by the construction of three large accelerator objects: colliding proton-proton beams of 2×400 GeV at Brookhaven, USA; colliding electron-positron beams of 2×100 GeV at CERN; and the 3-TeV accelerator–storage-ring complex UNK at Serpukhov, USSR.

V. A. Sidorov called the attention of those present to the fact that as the result of loss to synchrotron radiation, beginning at a certain energy, it becomes advantageous to construct electron-positron colliding beams not from cyclic storage rings but from colliding linear accelerators. The principles of such accelerators are presently being developed by physicists at Novosibirsk. An advantage of such a system is that it can be increased in length and energy.

In a brief report A. Salam called attention to the fact that contemporary theory indicates the possibility of decay of the proton with a half-life 10^{29}–10^{33} years. Decay of a significant fraction of the protons and abandonment of the law of conservation of baryon number signifies a fundamental change in the state of the Universe in a time of the order of the proton lifetime. Salam emphasized that different versions of contemporary theory, which consider quarks and leptons as components of a single multiplet, unavoidably lead to a finite proton lifetime with possible decay according to the schemes $p \to 3\nu + \pi^+$ and $p \to e^+ + \pi^0$ with liberation of an energy of about 1 GeV. Observation of such rare decays will require a scintillator mass of 10^4 metric tons. The possibility of such an experiment is being discussed in the USA and at CERN. In discussion of Salam's report it was remarked that if the proton lifetime turns out to be appreciably greater than 10^{33} years, this will mean significant difficulties for the theory. At the present time it can be stated that the proton lifetime is greater than 10^{29} years.

The project of the European Center for Synchrotron Radiation was discussed in the report of Yves Farge, director of the Synchrotron Radiation Laboratory at Orsay and chairman of the Committee on Synchrotron Radiation of the European Science Board. This committee, which was organized in 1977, was asked in November 1979 to provide recommendations on development of research with hard synchrotron radiation. Previously in 1976 the committee, under the chairmanship of H. Maier-Leibnitz of West Germany, reported the following conclusions:

1) A large discrepancy must be expected between the number of scientists desiring to use synchrotron radiation and the possibilities for experiments.

2) Existing installations for high-energy physics are poorly adapted for synchrotron radiation (SR), and the use of existing machines as SR sources is very expensive; the design of the machines excludes the use of wigglers.

3) It is necessary to make use of existing storage rings with operation only to obtain SR.

4) Small storage rings can be built on a national scale.

5) In each machine it is necessary to provide possibilities for international collaboration.

6) Significant efforts must be directed toward construction of a machine for generation of energetic (hard) SR; such a machine should come into operation in 1985 and construction will be begun in 1980.

7) An interdisciplinary committee should begin study of a European machine project for energetic SR.

At the present time a concrete direction of the scientific program of apparatus of this type has been developed, namely, the spectroscopy of deep atomic levels, ESCA at energies up to 50 keV, and Mössbauer studies up to 200 keV. Other subjects are Compton scattering up to 400 keV, rapid measurements of EXAFS in times less than 1 msec, study of surfaces by means of photoemission, and also a number of applied problems. Synchrotron radiation will be used for elastic scattering: First of all, as a result of the significant increase in intensity, there have been new developments in the x-ray study of crystals—topography, structure determination, and small-angle and diffuse scattering in times down to 1 μsec.

The parameters of the storage-ring project are as follows: energy 5 GeV, beam current 565 mA, length (circumference) of orbit 604 m, radius of orbit 22.36 m, critical length λ_c in the magnets–1 Å, and in the wigglers–0.25 Å, photon flux at 1 Å of 4.5×10^{13} cm^{-2} in 1 mrad in a 0.1% band, beam size in magnet 0.18×0.11 mm, in straight sections of length 6.7 m–0.5×0.7 mm, and in straight sections of length 3 m–0.11×0.03 mm; the total power of synchrotron radiation from six wigglers is 1.5 MW; the number of bending magnets is 48 and the number of wigglers 6.

A special committee chaired by Buras of Denmark has considered the questions of the instrumental equipment of this complex.

It is proposed that there arise around the new synchrotron-radiation source in Europe a center similar to that of the Laue and Langevin Institute at Grenoble. This project greatly exceeds in scale that of the largest American installation at Brookhaven for research with synchrotron radiation (energy 2.5 GeV, length 160 m), which should come into operation in 1981.

As a whole the proposals for new European projects show a distinct tendency for organization of large international centers for development of fundamental research, for international planning of such laboratories, and for division of the labor of equipping and using these unique installations.

There was a unanimous opinion of the usefulness of the seminar, which permitted looking from a single point of view at the prospects, and evaluation of the direction, equipment, and problematics of fundamental research in Europe.

It is proposed that the proceedings of the seminar will be published in the near future (see also the EPS News, European Physical Society, April 1979).

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