COMITATO NAZIONALE PER L'ENERGIA NUCLEARE
Laboratori Nazionali di Frascati

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MEETING OF THE EUROPEAN ACCELERATOR STUDY GROUP
SUMMARY OF THE REPORTS

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MEETING OF THE EUROPEAN ACCELERATOR STUDY GROUP

C.N.E.N.
LABORATORI NAZIONALI DI FRASCATI

December 3, 4, and 5, 1962

CALENDAR OF MEETING

Monday, December 3 - 2.30 p.m.

I/1. "GENERAL REPORT ON THE HIGH ENERGY ACCELERATOR STUDY OF THE CERN STUDY GROUP", presented by K. Johnsen (CERN)

I/2. "DESIGN STUDIES IN THE USA FOR A 300 TO 1000 BeV ACCELERATOR", presented by J.P. Blewett (Brookhaven)

I/3. "GROUND INVESTIGATIONS RELATED TO POSSIBLE GEOGRAPHICAL LOCATION OF A FUTURE EUROPEAN MACHINE", presented by C.J. Zilverschoon (CERN)

Tuesday, December 4 - 9.30 a.m.

II/1. "RELATIVE MERITS OF ENERGY AND INTENSITY", presented by K.R. Symon (MURA)

II/2. "INITIAL PERFORMANCE OF THE CAMBRIDGE 6 BeV ELECTRON SYNCHROTRON", presented by M.S. Livingston (MIT)

Wednesday, December 5 - 9.30 a.m.

III/1. "SOLVED AND UNSOLVED PROBLEMS IN SHIELDING CALCULATIONS FOR ACCELERATORS WITH ENERGIES BELOW 150 GeV", presented by C. Passow (Hamburg)

III/2. "SOME TECHNICAL PROBLEMS OF RF ACCELERATION FOR PARTICLE ACCELERATORS ABOVE 10 GeV", presented by G. Shaffer (Hamburg)

III/3. "PAPER ON MANPOWER AND FUNDS FOR HIGH ENERGY RESEARCH IN BRITAIN AND THEIR AVAILABILITY IN THE NEXT FIVE YEARS", presented by T.G. Pickavance (Harwell)

III/4. "PAPER ON AVAILABILITY OF FUNDS AND PEOPLE IN BELGIUM AND THE NETHERLANDS", presented by P.G. Gugelot (Amsterdam)

III/5. "PAPER ON MANPOWER AND FUNDS FOR HIGH ENERGY RESEARCH IN EUROPE", presented by E. Amaldi (Roma)

I/1. - GENERAL REPORT ON THE HIGH ENERGY ACCELERATOR STUDY OF THE CERN STUDY GROUP (Presented by K. Johnsen).

The study is carried out by people attached to the A.R. Division of CERN, some being normal CERN staff and some visitors from other laboratories. However, part of the work is done in close collaboration with other Divisions inside CERN as well as other European laboratories. The way the group has been built up and operates will be described.

Further, basic parameters for a 300-GeV synchrotron will be discussed as well as the phylosophy used in arriving at a set of parameters.

Different possible approaches to the problem of injection will be described and a few parameters given.

A very tentative discussion of the requirements imposed by the efficient utilisation of such a machine will be included.

At last estimates of manpower, time schedule and cost will be given.

I/2. - DESIGN STUDY FOR A 300 TO 1000 GeV ACCELERATOR (Presented by J.P. Blewett).

This design study has not yet been officially approved and so is still proceeding only through the medium of informal discussions and studies on the Brookhaven AGS.

A group of high-energy physicists is preparing a list of desirable specifications for this accelerator and will make recommendations as to its energy and experimental facilities.

Experiments have been performed on the AGS to check the theoretical predictions as to orbit deviations due to magnet misalignments. The information obtained will be useful in choosing aperture dimensions for the larger accelerator. Also, experiments are planned to test the feasibility of injection at magnetic fields lower than 100 gauss.

Proposals for two American design studies are being given serious consideration. One of these, for a machine of the order of 100 GeV, could proceed at the Lawrence Radiation Laboratory. The other, for a national accelerator of 300 to 1000 GeV, might be centered at Brookhaven.

I/3. - GROUND INVESTIGATIONS RELATED TO POSSIBLE GEOGRAPHICAL LOCATION OF A FUTURE EUROPEAN MACHINE (Presented by C.J. Zilverschoon).

In relation to the study of a 300-GeV proton synchrotron, CERN has started on some site investigations:

a) Stability measurements on some different types of ground.

b) An (unofficial) search for possible sites in Europe.

The work under a) has just started and results are not yet available. The work under b) is proceeding gradually.

II/1. - RELATIVE MERITS OF ENERGY AND INTENSITY (Presented by K.R. Symon).

The MURA group in the United States has recently proposed to the U.S. Atomic Energy Commission the construction of a 10-GeV FFAG accelerator capable of accelerating more than 2×10^{14} protons per second. Such an accelerator would be capable of producing intense secondary beams of π-mesons, K-mesons, and anti-protons. There are many kinds of experiments for which such intense beams are needed. The most obvious are the neutrino experiments.

These considerations are related also to the choice of energy and intensity goals for a multi-hundred MeV accelerator. The desirable primary energy and intensity depend to a large extent on a consideration of the secondary beams which can be produced.

Since one is led to the conclusion that one should design a high energy accelerator for the highest beam intensity which is technically and economically reasonable, it is necessary to investigate the theoretical and technical limits on beam intensity and the costs of producing and handling very intense high energy proton beams.

II/2. - INITIAL PERFORMANCE OF THE 6-BeV CAMBRIDGE ELECTRON ACCELERATOR (Presented by M.S. Livingston).

The alternating gradient electron synchrotron was brought into preliminary operation at 2 BeV on March 7, 1962. Operation was limited to about 3 BeV due to overheating and excessive vibration of the choke used for energy storage in the magnet power supply, which operates at 60 cps. During June and July the choke was rebuilt with suitable cooling, allowing operation at full energy. The design energy of 6.0 BeV was attained on August 13. Beam intensities obtained during tune-up operations in the first month were 3 x 10^{10} electrons per pulse or 1.8 x 10^{12} per second. The new accelerator laboratory was formally dedicated to research in high energy physics on September 14, 1962.

Alignment of the 48 magnet secors in a circle of 236-ft diameter, using optical techniques, gave higher precision than expected, with rms errors of 0.010 inch and 0.005 inch in the radial and vertical directions. However, variations in the stray magnetic fields in the sections between magnet sectors, at injection time (30 gauss at the orbit) caused orbit distortions, which were corrected by magnetic shielding and coils. After correction the orbit distortions were reduced below 0.2 inch.

The 20-MeV linac injects pulses of 0.7 microsec duration and 100 milliamp intensity, directed into the orbit by a pulsed magnetic field in one straight section. Linac emittance is well within the acceptance of the synchrotron and the energy spread is ± 1% for 90% of the beam. Variations of both energy and energy distribution within the pulse cause a pulse-to-pulse jitter of about 10%. Electronic improvements to the linac circuits are expected to improve this performance.

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Beam loading of the radiofrequency system used for acceleration determines the present limit on beam intensity. The 32 resonant cavities operating at 476 Mc have high efficiency (Q = 25,000) in order to produce 6 Mv per turn at the peak of the acceleration cycle to compensate for radiation loss. In consequence, the voltages induced by the pulsed, circulating beam exceed the voltage required for acceleration at the start of the cycle, and cause phase shifts which destroy synchronous bunching for high injected intensity. Only about 10% of the beam injected into the first turn is accepted and accelerated. Acceptance is improved by applying a frequency 25 kc higher than the resonance frequency at injection with a frequency-modulation drive of the RF amplifier. Coherent synchronous oscillations have been observed, indicating acceptance of only a limited portion of the phase "bucket". Another phenomenon, as yet unexplained, limits the radial extent of the oscillation envelope to 1.5 inches whenever the radiofrequency power is applied, even, though circulating beams without RF power show an useful magnetic field width of nearly 4 inches.

A programmed cut-off of the radiofrequency power is used to caused the beam to contract inward against a target located about 1.4 inches inside the central orbit. X-ray beams emerge tangentially through vacuum pipes into the experimental hall. X-ray scintillation detectors show an emergent beam pulse of up to 1 millisec duration, which is a 6% duty cycle. The present experimental program uses only X-rays. Apparatus for producing an emergent electron beam of up to 50% intensity is under development.

Support for the construction and operation of the Cambridge accelerator is provided by the U.S. Atomic Energy Commission.

III/1. - SOLVED AND UNSOLVED PROBLEMS IN SHIELDING CALCULATIONS FOR ACCELERATORS WITH ENERGIES BELOW 150 GeV (Presented by C. Passow).

While the data on the multiplicity of high energy particles from accelerators and cosmic rays give sufficient information about the build-up and subsequent attenuation of nuclear materials there is still insufficient information about the lateral distribution of particles. It seems possible to extrapolate the methods used in shielding calculations for accelerators in the 10 GeV range to energies about 150 GeV. For still higher energies the uncertainties seem to be large. Another difficulty is the fact that the biological effectiveness of very high energy particles is not very well known.

III/2. - SOME TECHNICAL PROBLEMS OF RF ACCELERATION FOR PARTICLE ACCELERATORS ABOVE 10 GeV (Presented by G. Schaffer).

This report begins with a survey and comparison of the main parameters of RF systems which have recently been proposed for the construction of circular particle accelerators with energies of one or several orders of magnitude greater than the energy of existing machines: for protons in the energy range of 300-1000 GeV on the one hand, and for electrons in the order of 50 GeV on the other hand. The demand of RF power greatly differs in both cases because of the radiation losses which are dominant for an electron synchrotron. Only in the case of relatively fast acceleration does a 1000 GeV proton synchrotron need the same amount of RF power as a 50 GeV electron synchrotron. Nevertheless, there are many features common to both types of accelerators, such as the acceleration at fixed or nearly fixed frequency, and the choice of frequency range which is mainly defined by the maximum diameter of the accelerated beam. In order to save RF power the use of high Q cavities is suitable in both cases, with a resonant frequency in the range of 300-1000 Mc/s.

The present status of generating extremely high RF power in the uhf range is then discussed. Remarkable progress in this respect has recently been made on velocity-modulated tubes (klystrons) by increasing the perveance of electron guns, and on density-modulated tubes (triodes) by putting the RF circuits into the evacuated system. The development of such super power tubes is essentially simplified if frequency tuning can be avoided.

At high RF fields cavity resonators for optimizing the voltage to power ratio should be evacuated as a complete system, and several of them coupled together as linear accelerator sec

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tions. In principle, accelerating units of this kind have already been built for existing electron synchrotrons. As an example, the problems of design and fabrication of such accelerating structures will be illustrated on the DESY machine.

Finally, a few considerations are made concerning the problem of beam loading which is conspicuous on high impedance accelerating structures if a high intensity circulating beam is desired. This problem is already of great significance on existing electron accelerators. To overcome difficulties with beam loading it is necessary to provide a relatively high average RF power as well as a fast and precise control of the RF power amplifiers. A few ideas on how this could be done are described briefly.

III/3. - PAPER ON MANPOWER AND FUNDS FOR HIGH ENERGY RESEARCH IN BRITAIN AND THEIR AVAILABILITY IN THE NEXT FIVE YEARS (Presented by T.G. Pickavance).

SUNTO DELLA COMUNICAZIONE NON PERVENUTO

III/4. - PAPER ON AVAILABILITY OF FUNDS AND PEOPLE IN BELGIUM AND THE NETHERLANDS (Presented by P.G. Gugelot).

SUNTO DELLA RELAZIONE NON PERVENUTO

III/5. - PAPER ON MANPOWER AND FUNDS FOR HIGH ENERGY RESEARCH IN EUROPE (Presented by E. Amaldi).

SUNTO DELLA RELAZIONE NON PERVENUTO

ACCELERATOR DESIGN STUDIES IN THE U.S.A.

Major accelerator design studies in progress or under consideration in the U.S.A. fall into three classifications, as follows:

1. Meson Factories

a) Yale proposes a 750 MeV proton linear accelerator with a 5% duty cycle and an average output of 1 milliampere.

b) Oak Ridge National Laboratory is designing a 900 MeV isochronous cyclotron. It is expected that a 100 microampere beam at 810 MeV can be extracted from this cyclotron.

c) The University of California at Los Angeles plans for an isochronous cyclotron in which the extraction problem will be solved by acceleration of negative ions. The beam will be extracted by stripping at the outer radius.

d) Los Alamos National Laboratory has not yet decided on the accelerator type to be used.

2. Electron Accelerators

a) At Stanford, Hofstadter proposes the construction of a 4-GeV electron linac to be used exclusively for his studies of particle structure.

b) At Cornell, the 1-GeV electron synchrotron is in the process of conversion to 2.2 GeV and a proposal has been submitted for construction of a 10-GeV electron synchrotron of 100 meters radius.

3. Proton Accelerators

a) MURA's 10-GeV FFAG accelerator is still under consideration.

b) The Lawrence Radiation Laboratory is giving serious thought to a proton synchrotron of about 100 GeV energy.

c) The Brookhaven National Laboratory proposes a design study for a national accelerator of 300 to 1000 Gev.