CERN COURIER

European Organization for Nuclear Research

CERN, the European Organization for Nuclear Research, was established in 1954 to '... provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto'. It acts as a European centre and co-ordinator of research, theoretical and experimental, in the field of sub-nuclear physics. This branch of science is concerned with the fundamental questions of the basic laws governing the structure of matter. The Organization has its seat at Meyrin near Geneva in Switzerland. There are two adjoining Laboratories known as CERN Laboratory I and CERN Laboratory II.

CERN Laboratory I has existed since 1954. Its experimental programme is based on the use of two proton accelerators — a 600 MeV synchro-cyclotron (SC) and a 28 GeV synchrotron (PS). Large intersecting storage rings (ISR), are fed with protons from the PS for experiments with colliding beams. Scientists from many European Universities as well as from CERN itself take part in the experiments and it is estimated that some 1200 physicists draw research material from CERN.

The CERN Laboratory I site covers about 80 hectares almost equally divided on either side of the frontier between France and Switzerland. The staff totals about 3000 people and, in addition, there are about 650 Fellows and Visiting Scientists. Twelve European countries contribute, in proportion to their net national income, to the CERN Laboratory I budget, which totals 353.4 million Swiss francs in 1971.

The CERN Laboratory II was authorized by ten European countries in February 1971; it will house a proton synchrotron capable of a peak energy of hundreds of GeV. CERN Laboratory II also spans the Franco-Swiss frontier with 412 hectares in France and 68 hectares in Switzerland. Its budget for 1971 is 29.3 million Swiss francs.

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Cover photograph : A lorry of the Russian company Sovarto is loaded with equipment at CERN for transport to the Serpukhov laboratory (CERN 40.8.71).

Comment

The bulk of this issue is given to describing the progress of the CERN-Serpukhov collaboration. The time is appropriate, since major items of equipment (around 260 tons in weight) are ready for dispatch to the Soviet Union or are already on their way. In Serpukhov arrangements to receive them are nearing completion. In addition, the large hydrogen bubble chamber, Mirabelle (at Serpukhov in the context of an agreement with France) has taken its first photographs receiving particles from the 76 GeV proton synchrotron and the start of collaborative experiments in bubble chamber physics is not far away. Collaborative experiments using electronic techniques have been most fruitfully under way for several years already.

In recalling briefly the outline of the Agreement between CERN and the State Committee of the USSR for the Utilization of Atomic Energy, concerning scientific and technical co-operation at the Institute of High Energy Physics at Serpukhov, we will prepare the way for the following fuller stories on its component parts. The Agreement was signed in Moscow on 4 July 1967. It covered the provision from CERN of a fast ejection system and radiofrequency separator to be used at the 76 GeV synchrotron and the participation of CERN scientists in the experimental programme at what has been for several years the highest energy accelerator in the world.

The ejection system is an extended version of that used on the CERN proton synchrotron extended to cope with higher beam momentum and to give greater flexibility in operation. It will be integrated with another fast ejection system developed by Serpukhov in collaboration with Leningrad in such a way that, working together or separately, the systems can provide ejected protons down four different beam lines. The beam-line towards the Mirabelle chamber is being provided by CERN using an improved version of the type of transport system of the pulsed bending magnets and quadrupoles used at the CERN PS.

The beam-line to Mirabelle will have a radio frequency separator developed at CERN with more advanced performance coming from a new type of r.f. cavity and new control systems. The 4.7 m hydrogen bubble chamber was built at Saclay and then dismantled after testing and sent to Serpukhov from the spring of 1970. In June of this year, reassembly was complete and the first photographs of beam tracks using 70 GeV/c protons from the accelerator were taken. It is ready for its first experiment with unseparated protons of high energy. Bubble chamber experiments with the r.f. separated beam provided by CERN will begin early in 1972. Three French Laboratories, CERN, and several other laboratories from its Member States are preparing to receive pictures from the chamber and CERN has been involved in an advisory capacity in some of the preparations for handling the data from the chamber.

As mentioned above the electronics experiments have been going very well for several years. The second experiment, working with a boson spectrometer, is in full swing and a third is already planned in considerable detail. It will quickly follow the boson spectrometer experiment on to the experimental floor at Serpukhov.

So well has the collaboration gone, it is no longer restricted to a pure dialogue between CERN and Serpukhov. It has widened to include teams rather than just individuals from the laboratories of the Member States. CERN still remains the channel of communication with IHEP but this third electronics experiment will be performed by a team from Karlsruhe which is currently at CERN performing a similar experiment at lower energies. Other arrangements of the same nature are already under discussion with experiments being proposed by collaborative teams from the CERN Member States.

This introductory paragraph and what follows indicate that the spirit of the Agreement has been fully implemented. Such an extensive and novel collaboration cannot be implemented without problems but these have been surmounted by the vigorous whole-hearted participation of both sides.

The benefits on the physics front needs little emphasis. As a result of the agreement, W. European physicists have had access from the beginning to the highest energies available and Soviet physicists have been able to participate more fully in the CERN programme of research and development while their machine was being completed. But the collaboration has important implications also in terms of relations between nations.

Since the Agreement there have been other examples of getting together in the field of high energy physics notably the protocol signed by the US AEC and the USSR State Committee (described in vol. 10, page 393) and a group from the University of California at Los Angeles working in collaboration with Dubna has just completed data taking on pion electron scattering. It does not seem too presumptuous to suggest that the CERN-Serpukhov collaboration has done a great deal to improve the contacts not only between scientists in Europe but also between peoples in the world.

Fast ejection

From information supplied by B. Kuiper

1. Beam characteristics at ejection are to be processed by a minicomputer. Jacques Nuttall and Fabio Fabiani are checking hardware with software.

2. The ten full aperture kicker magnet modules are contained in a 3 m vacuum tank, shown on its platform. Bernard Féral adjusts the resistor boxes. The high voltage pulses arrive over 120 m of special cables.

3. A pulse generator of one of the two septum magnets shown in front of the power modules of its charging supply. Herman van Breugel inspects storage capacitors.

'Mastodont !' — exclaimed Kyril Petrovic Myznikov on entering the Cesar Hall at CERN in April of this year where the delay-line pulse generators for the Serpukhov kicker magnet were in full assembly. (Myznikov is Head of the Division responsible for beam extraction, targetting and high energy performance at IHEP.) This echoed the reaction of many visitors in particular those who think of ejection as a form of gadgetry. Indeed, the technique has come a long way since the first proton beam was extracted from the PS in 1963 (see vol. 3, pp. 63 and 79) using equipment designed by the same group. The Serpukhov full aperture kicker magnet system, for example, has a stored pulse energy of around 20 kJ, roughly 45 times the energy of the first PS kicker and more than 8 times the energy of the next generation full aperture kicker magnet (FAK) project, presently being discussed for the PS.

This sets the scale of the project; the size is due partly to the higher particle energy and longer pulse length (accelerator circumference), partly to the size of the aperture and partly to the limited length of the straight sections. Moreover the performance required is very complex. The specification calls for the ejection of three proton bursts per acceleration cycle into three different beam channels with, at choice, three different numbers of proton bunches and three different ejection times and energies. This has important consequences in most parts of the ejection system, i. e. in all power supplies, in the two septum magnet systems, in the moving mechanism, in the vacuum system and in the electronics.

Unlike the pulsed proton beam transport system and the radio frequency particle separators which may be treated in a relatively independent manner once the interface conditions are settled, the fast ejection system has to become an integrated part of the accelerator. All the proton distribution equipment is concentrated in a small fraction of its circumference between straight sections 16 and 28 (see vol. 10, p. 31). Three fast ejection channels A, B and C and two slow ejection channels B and D are there interlaced with a number of secondary beam channels using internal targets.

The situation entails a large number of spatial constraints and problems of compatibility of construction and of performance of the various systems with each other and with the accelerator. Part of these constraints became evident only gradually as the design of some of these channels evolved simultaneously with the CERN system. It is also obvious that this concentrated mixture of systems and responsible groups provides a highly fertile ground for endless discussions on who is doing what to the beam, unless there is

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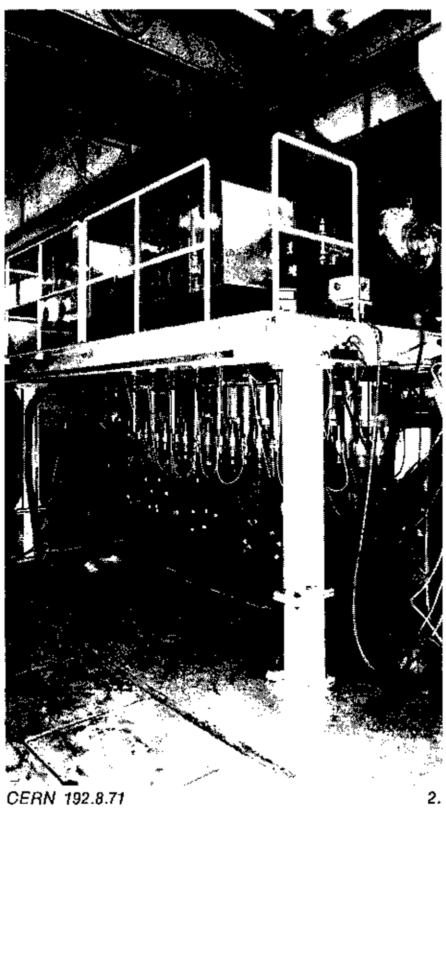

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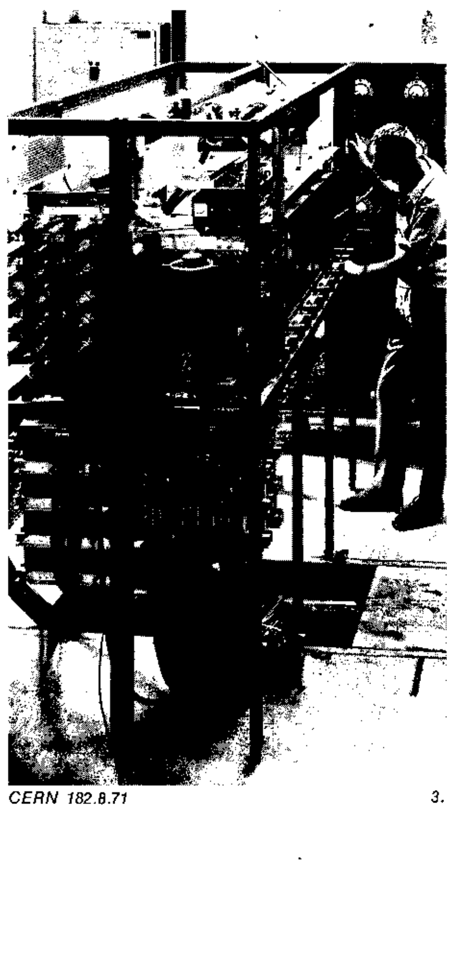

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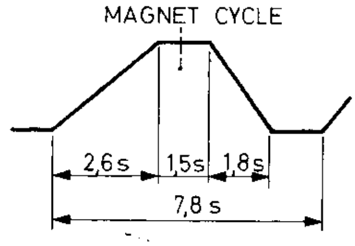
To the right — accelerator parameters. Below — important dates in the fast ejection project and components of the system with a schematic drawing, alongside, of the system as it will be incorporated in the Serpukhov accelerator.

ACCELERATOR :

ENERGY	76	GeV
INTENSITY	10^{12}	ppp
REVOLUTION TIME	5	μs
BUNCH NUMBER	30	
AVERAGE RADIUS	227	m
BEAM DIAMETER	20	mm



DATES

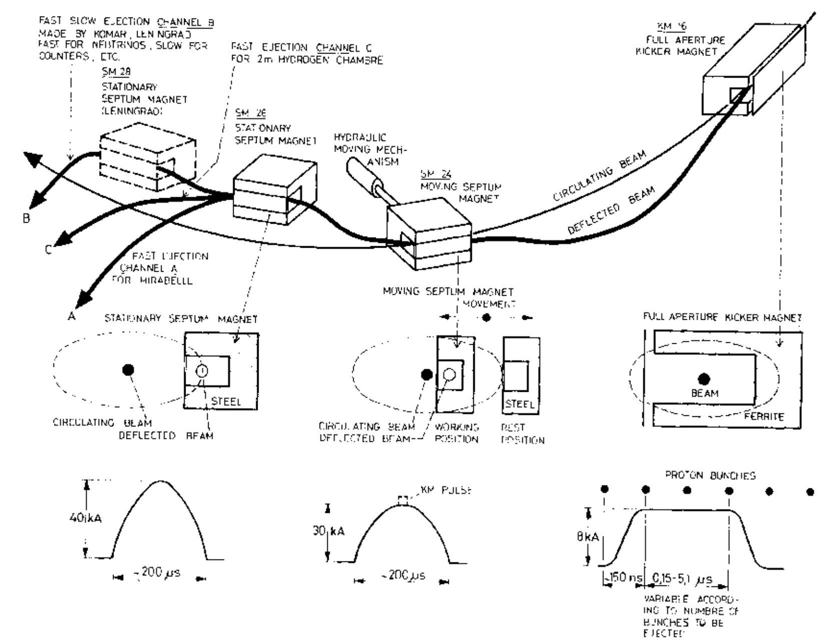
End	1966	First technical discussion on ejection
July	1967	Agreement signed in Moscow
Sept	1967	Draft design study presented
Jan	1969	General start of technical work for Serpukhov
March	1969	Final design study presented and signed by both parties
Year	1969	Prototypes and design
Year	1970	Construction and fabrication
Year	1971	Assembly, tests and transport to Serpukhov
Early	1972	First ejection (hopefully)

EJECTION REQUIREMENTS

Ejection capability from 30 to 76 GeV (different per shot) of 1 to 30 bunches of protons (different per shot) with up to 3 shots per cycle at 250 ms interval into different channels.

COMPONENTS

- Full aperture kicker: KM 16 - 14 × 10 cm² aperture, 3 m long with 0.1 T field giving 1 mrad deflection at 70 GeV; plus pulse generators and power supplies.
- Two septum magnets: SM 24 - 3.5 × 3 cm² aperture, 1.5 m long with 1 T field giving 4 mrad deflection at 70 GeV and SM 26 (mobile) - 6 × 3 cm² aperture, 3 m long with 1.4 T field giving 15 mrad deflection at 70 GeV; plus pulse generators and power supplies.
- Three vacuum tanks for magnets.
- Three vacuum systems and controls.
- One hydraulic moving mechanism plus pump station and controls.
- Programming and timing system.
- Beam diagnostic system (pick-ups, on-line computer and data display,
- General control and interlock system.
- Pulse monitoring system.



adequate beam diagnostic equipment specially tailored to yield the relevant beam information at the crucial points. All these factors helped define the scope of the project.

The system as a whole had to be assembled and tested at CERN before shipment, control flexibility had to be included to ensure compatibility and adequate beam diagnostics had to be provided to avoid ambiguous interpretations. Interfaces between the contracting parties had to be defined such as to minimize discussions.

The project also presented many unexpected aspects which together with the substantial technological extrapolations necessary and the short time available, have caused the group members many headaches. Moreover, activities have been complicated by the language problem, different standards and working habits and slow communications. Nevertheless these were accepted as a challenge both at the technical and personal level.

Indeed such an effort by the relatively large number of persons involved would have been impossible without repeated proof of the goodwill of all parties involved and the exercise of patience and understanding, on both sides, and personal motivation going beyond simply making an ejection system for an accelerator.

The tangible result of the endeavour is now conspicuous in the Cesar Hall in terms of closely packed, bulky (and noisy) steel constructions and a series of well filled electronic racks in a mockup control room in building 15. The equipment has been practically completed and is in the last stages of assembly and testing.

In retrospect, the time of two and a half years for prototyping, design, construction, installation and testing has been very close to the limit. Normally such a project would go in parallel with a larger one and the timescale would be more comfortable. It has only been possible because of: (i) the group's previous project and ejection experience, in particular constructing the Straight Flush facilities (vol. 8, p. 175) the principles of which have been followed for the Serpukhov equipment; (ii) a typical project group structure, with complete priority on the services of a number of designers, draftsmen, mechanics, machine tools and electronicians with their laboratory; (iii) a closely watched, flexible planning which could constantly be adapted to changing conditions of delivery and testing.

In particular, prototype studies have overlapped for a long period with the final design and construction activities and the results have been fed back into the latter. Although this last factor has inevitably entailed some waste, it has proved the more economical way, considering the available time and the general context of the project.

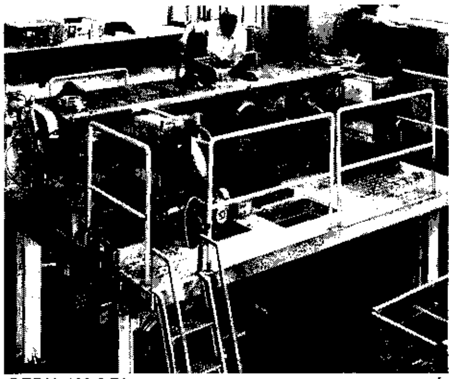
4. *Vacuum tank for the stationary septum magnet being inspected by Albert Bertuol and Mario Minella.*

5. *The end of a septum magnet with connection between inner conductor and septum of single loop excitation winding.*

6. *The fast ejection is linked to the accelerator synchronization pulse trains by a complex programming and timing system that coordinates ejection, beam transport, separators and bubble chamber operations. Tasios Kitsakis is testing its high level output stages.*

7. *The ten kicker magnet modules are powered separately by ten delay line pulse generators which are paired into five structures. René Bonvin closes a cover in front of the high pressure sparkgap switches.*

8. *The mobile septum magnet moves inside a 3 m long vacuum tank, shown together with the electrohydraulic servoactuator and precision magnet guiding system. Alain Bertuol places a TV camera to monitor the motion from the mockup control room.*



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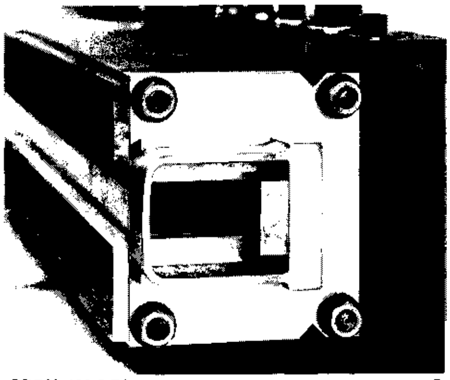

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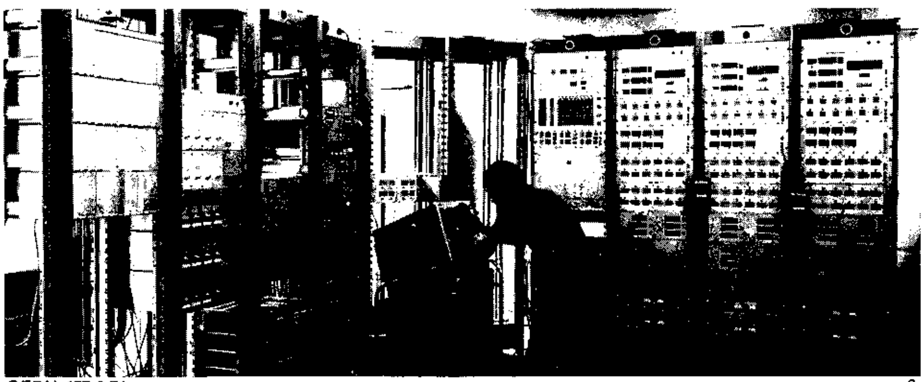

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Active preparations are now being made for shipment of the equipment to Serpukhov. This in itself is a sizable and delicate problem since the 120 tons and 350 m^3 of equipment must be largely disassembled and carefully packed. In order to limit the number of handlings, trucks of a Soviet transport firm will be loaded at CERN then unloaded at IHEP. Transport of the complete ejection system will take six weeks, trucks leaving at a rhythm of two or three per week.

Transport will overlap with the first stages of installation at IHEP. A detailed planning including each operation has been established and foresees a period of three months for disassembly, packing, transport, and reassembly at IHEP. The two last months of these coincide with a long accelerator shutdown. In the fourth month the accelerator will be started up again but there will be access on request to the ring tunnel for the ejection group so as to complete the overall tests of the equipment before first ejection attempts.

In the early stages of the discussions it had been hoped to install the ejection system at the Serpukhov accelerator, using only a fraction of the construction crew for supervision and having by that time sufficient IHEP collaborators trained and familiar with the whole system. For various reasons it has now been decided that practically the whole ejection group will go to Protvino and that the installation of the equipment will be done largely by them. IHEP has had a substantial task in providing the building and services and making all the necessary preparations. A small team of CERN ejection specialists will run the system in for another three months until CERN is satisfied with the performance attained. Active training of Russian specialists will start simultaneously with installation and the moment of handover will be at the end of the running-in period.

Beam transport

From information supplied by
G.C.J. Davies and A. Ball

The ejection system is followed by a beam transport system for the Mirabelle external proton beam which for reasons of economy and compactness is pulsed. The project was started at CERN early in 1968, the main system parameters being fixed at a joint CERN/IHEP meeting in March of that year. The project has been carried out by 5 members of the TC-L beam transport group headed by B. Langeseth, although only F. Völker project co-ordinator, and G.C.J. Davies have been occupied full time on the project; the other members have combined their tasks with similar work on the beam systems for the South-East and West areas at CERN. In 1970 A. Aseev and A. Afonine from IHEP joined the group to participate in the final manufacturing and commissioning stages.

The proton beam is transported from the ejection exit window in SS28 to the external target by way of a system of quadrupole lenses and deflectors, the main parameters of which are given in the table.

A detailed study of beam optics undertaken jointly by specialists at CERN and IHEP included simulation of the beam behaviour under the operation tolerances of the accelerator and transport system. Results of this work did not lead to any major changes to the system as previously described (see vol. 10, p. 33). An alternative focusing configuration requiring only polarity changes in the power supplies to the magnets of the final triplet has been evaluated and the selection of the final focusing system will be made on the basis of measurements of the ejected beam parameters. The expected beam profiles in the horizontal and vertical planes are shown in the figure.

Beam Observation

The beam observation system consists of a remotely operated scintillation screen viewed by a IHEP television system which provides information on beam position and shape. Beam current transformers are used to monitor the beam intensity and evaluate any beam losses. The transformer signal is processed by an analogue digital converter and then numerically displayed. A target charge monitor is provided to determine the interaction efficiency of the proton beam with the target. An ejected bunch counter is used to determine the number of bunches ejected from the accelerator for each shot. The display of all these units is in the local control room.

The various detectors and associated electronics have been developed and manufactured by CERN whilst IHEP have designed and made the TV and associated optical system and have also made tests on various scintillation materials.

With the participation of the visiting IHEP collaborators, testing and calibration of the equipment have been carried out at CERN including beam tests on identical equipment in the SE neutrino area.

MAIN PARAMETERS FOR PULSED BEAM TRANSPORT SYSTEM

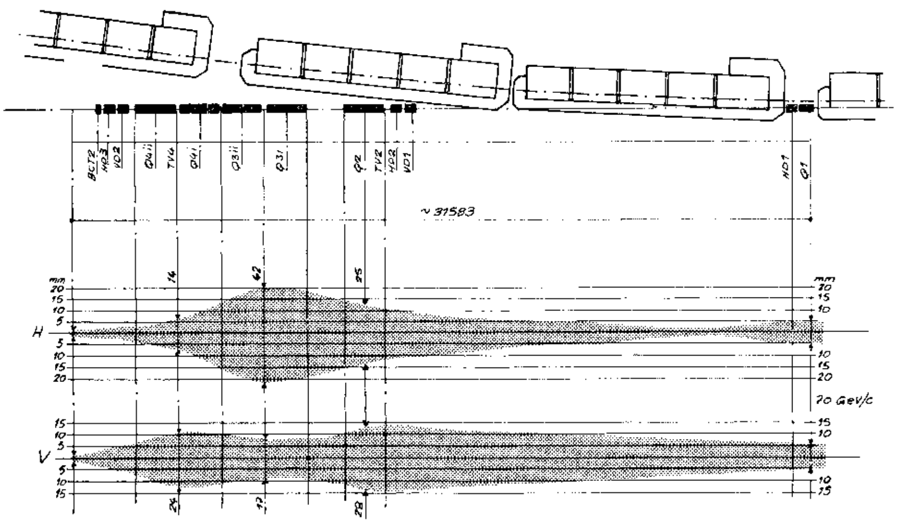
Proton momentum	: 30 - 75 GeV/c
Design value, external beam emittance	: $\pi \times 10^{-6}$ rad. m.
Target cross section	: 10 × 2.00 mm
Repetition period	: 4 pulses at 500 ms separation each cycle of 8 s
Length of beam line	: 35 m (approx.)

	Q1	Q 2	Q 3	Q 4	Deflectors
Magnet aperture dia. (mm)	30	70	70	70	60
Magnetic flux density at 75 GeV/c (T)	1.2	0.8	1.2	1.4	0 - 2.0
Magnetic field gradient (T/m) at 75 GeV/c	78.1	22 0	33.3	39.5	—
Magnetic equivalent length (m)	0.778	1.55	2 × 1.55	2 × 1.55	0.405
Excitation current for 75 GeV/c (kA)	2.5	2.0	2 5	3.0	0 - 2.62
Inductance (mH) per module	0.23	2.1	2.1	2.1	2.4
Resistance (mΩ) per module	57	100	100	100	70
Cooling water pressure (kp/cm²)	25	25	25	25	25
Energy stored in capacitors (kJ) max	10	6	2 × 12	2 × 20	10
D.C. charging voltage (kV) max	5	5	5	5	5
Peak power (kW) D.C.	50	100	2 × 100	2 × 100	50
Average power (kVA) A.C.	6	12	2 × 12	2 × 12	6

Charging voltage stability	: $\pm 5.10^{-4}$
Current stability pulse-pulse	: $\pm 1.10^{-3}$
Magnet duty ratio	: 0.03 % (approx.)

Equipment

The water cooled magnets are of laminated steel construction with multi-turn excitation coils. For the 30 mm quadrupole the field gradient is 93 T/m and for the 70 mm quadrupole the gradient is 45 T/m. The deflectors provide a field of 2 T. Initially a number of problems were encountered in the magnet construction, firstly in achieving the high mechanical tolerances necessary for good field configuration and secondly in obtaining a compact energizing coil capable of withstanding the high voltages and mechanical shock under conditions of prolonged irradiation. These problems have been overcome and all magnets have now been delivered to CERN and power tested. A programme of detailed



The expected profiles of the proton beam in the horizontal and vertical planes in the beam transport system.

magnetic measurements is now under way. One magnet of each type has been dealt with and is now at IHEP ready for installation.

The tests have confirmed the theoretical prediction that it is possible to use a thin walled metallic vacuum vessel in the pulsed magnets without significantly affecting the field configuration which has greatly simplified the construction of the vacuum line.

The discharge switching units for the pulsed current supplies have all been delivered to CERN and are undergoing final tests before installation at IHEP. Thyristors are used as the high voltage switching element to discharge the energy from storage capacitors into the magnet. These circuits have a high Q and are designed such that the oscillation ceases after the first complete cycle. The positive current pulse flows through the magnet and the negative pulse via a low loss reactor with series diodes placed in parallel with the magnet.

The prototype charging unit for the pulsed current supply has been delivered and is undergoing final evaluation testing. This single stage unit has the supply voltage and current regulated by thyristors in the primary circuit of the transformer. Considerable difficulties were encountered in achieving the required voltage stability for high energy beam operation without the addition of a second stage precision regulation unit in the H.T. secondary circuit of the transformer. These difficulties have now been resolved and it is hoped that all supplies will have been delivered to CERN by the end of August.

A control instrumentation system for location in the local control room has been developed and manufactured at CERN. The current in the magnet is determined by monitoring the current in a shunt coupled to an analogue digital converter with numerical display. The timing system for the triggering of the magnet current pulses is provided by a digital timing unit operated by pulse trains obtained from the accelerator. Protective interlocks avoid serious damage in case of malfunction of any particular part of the system.

Commissioning

The installation and commissioning of the pulsed beam transport system will be carried out in several stages. After cable installation at IHEP the first two magnets of the beam transport system were to go in during the August 71 shutdown; the remainder of the beam transport magnets and ancillary equipment being installed during the shutdown in October. Between shutdowns equipment situated in the beam transport supply hall and Local Control Room will be installed and partly tested. The tuning of the beam for operation with the Mirabelle chamber is expected to begin early in 1972.

R. f. separated line

From information supplied by H. Lengeler

Unfortunately no-one has so far found a way of predetermining the types of particle and their momenta which are produced when a primary beam of protons strikes a target. We have to take what comes and then sort out the particular kind of sheep or goat we want. Also from the spray of secondary particles produced in a target we can only handle those travelling in a relatively restricted solid angle and let the rest go to waste. The bubble chamber though is such a sensitive device that virtually all the charged particles entering it will make tracks so that if there are more than a dozen or so at a time the confusion in the picture would make the subsequent analysis far too difficult.

The problem then is to guide into the bubble chamber a small number of the chosen particles, contaminated as little as possible by others of the wrong momentum or mass.

The specification for the separated beam line at Serpukhov requires that the contamination of the emergent beam should not be in excess of a few per cent which means that for every desirable particle lost to the experimenters the system should have rejected up to 200 000 unwanted particles. In practice about 50 % of the wanted particles successfully complete that part of the obstacle course set up for them which is across the separator. Prior to this a factor of 10^6 or so has been lost in the momentum analysis.

The system is designed to select kaons and antiprotons of momentum 16-36 GeV/c, pions up to 60 GeV/c and protons up to 70 GeV/c.

The separator is an r.f. system similar in principle to that described in CERN COURIER, vol. 5, page 35, on the occasion of the putting into operation of the 10 GeV/c negative kaon line at CERN used first in conjunction with the 152 cm British bubble chamber. Since that time the technique has

Mounting of a klystron amplifier. These klystrons produce a pulsed 20 MW r.f. power at 2855 MHz. HT is applied in pulses of 270 kV with 8 μs duration. The r.f. power is fed via a complicated waveguide system on a ceramic r.f. window to the deflectors.

Bird's eye view of the r.f. separator. In the foreground are the three deflectors of 6 m length each with their local control units. Behind are the three pulsed power supplies and the 20 MW klystron amplifiers which are mounted in oil tanks and heavily shielded against X-rays.

been further developed and the present line to the 2 m hydrogen chamber is able to work in the momentum range 10-20 GeV/c (see vol. 7, pp. 125, 252 and vol. 10, p. 31).

To recapitulate briefly the principle: the direct forward going beam of secondary particles is first momentum analysed by passing through a series of focusing quadrupole magnets and collimators to define the acceptance angle and then dipole magnets which bend the trajectory of the incoming particles by an amount dependent on their momentum. This is followed by a second set of bending and focusing magnets to refocus the fraction of the original beam that emerges along a predetermined line. It is then the job of the r. f. separator to sort out the particles according to their fractional difference in speed. This is done by passing the beam through a series of r. f. cavities separated by long flight paths. In the cavities a travelling wave exerts a transverse force on the particles and only those which remain in phase throughout are correctly diverted out of the direct line and avoid running into the beam stopper set up in the straight-on direction.

The increase in energy of the separated beam in relation to the CERN beam requires that the deflecting strength of the cavities rises and the distances are increased. It was not considered practical to go beyond the present 20 MW which is near the maximum capability of the supply klystrons so the length of cavity has been increased from 3.50 m to 6 m and the distance from the first to the third cavity from 50 m to 252 m.

A single cavity has the general appearance of a linear accelerator as it consists of a long cylindrical waveguide inside which are placed transverse discs. There are however important differences. Visually one notices that the iris in the discs is much bigger than in a linac drift tube and the distance between the discs is constant. More important is the mode of operation, as for the separator, the wave that travels down the guide exerts a sideways force on the particles. This dipole-mode is launched by a specially shaped transformer section, coupling the r.f. amplifier waveguide to the separator cavity. The process is one demanding very high precision in the manufacture of the components — a feature of the whole installation.

The r.f. is operating at 2855.2 MHz (wavelength of 10.5 cm). Any beam burst from the accelerator, even when fast ejection is used, is very long compared to the period of the r.f. fields so that particles arrive at any phase with respect to the deflecting field ; the crucial aspect is that the wanted particles stay in the same phase and receive a steady deviation. Because of the circulating time in the

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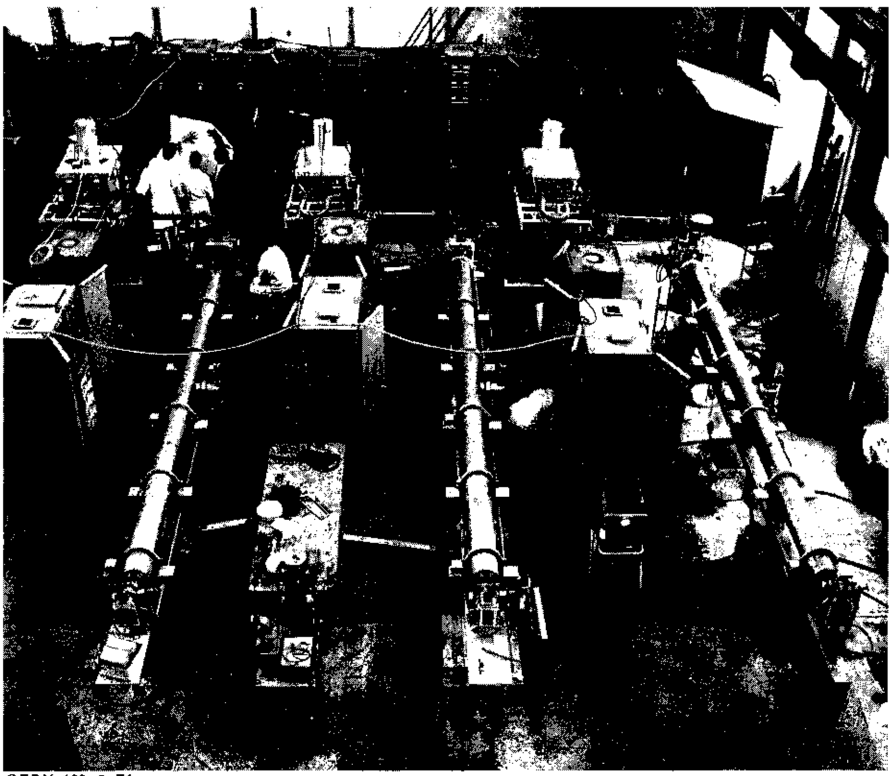

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main ring, the r.f. power must be able to cope with an overall injection time of 5.2 μs.

Before entering the separators the beam diverging from the target has passed through two collimators then four quadrupole magnets which focuses the beam in the horizontal plane and gives a horizontal acceptance of $\pm$ 5 mrad and a vertical acceptance of $\pm$ 3.8 mrad. It then passes through two 6 m bending magnets, two collimators, two more bending magnets and finally two quadrupoles which focuses the beam in two planes into the centre of the first r.f. separator. In between each of the three separators with an intercavity distance of 88 m (1-2) and 164.6 m (2-3) respectively are two pairs of quadrupoles and following the last separator is a transport line containing a further series of collimators, and dipole and quadrupole magnets which makes a second momentum analysis and beam shaping for the bubble chamber.

Work began on the design of the separators soon after the signing of the agreement, by a group under H. Lengeler as project leader and made up of the following : — from CERN — deputy project leader : Ph. Bernard ; mechanical design : M. Candolfi, M. Kubly ; electronics design : Cl. Dalmas, F. Grabowski, A. Imsomby; J.F. Malo ; J.P. Moussard (part-time) ; J.-Cl. Prelaz ; R. Romijn ; electronic-mechanical work: H. Preis; vacuum: P. Cottet; drawing office: Cl. Ruiret; from Serpukhov - electronics: B. Prossin ; deflecting structures and general desing : V. Vaghin ; modulators : V. Zelenin. Much of the precision manufacture has been carried out at CERN. Contributions from industry include three modulators from Ling-Altec of the U.K., the three 6 m disc loaded waveguides which are the heart of the separator cavities from CSF, France and high power klystrons from Thomson-Varian, France.

The tests on the whole system began in March of this year in order to be ready for transport to Serpukhov by road in mid-July, and the beginning of assembly in early August. This work should take about two months. It will be followed by a commissioning and tuning period in time for operation to start, all being well, early in 1972. For some time after that it will be providing separated beams of the highest energies available anywhere.

Mirabelle

After ejection, beam transport, the target, separation of secondary particles and further focusing and transport, the surviving paticles finally arrive at their destination — Mirabelle. This large liquid hydrogen bubble chamber with a total volume of 11 000 l, 7 000 l of which are in the field of view of the cameras, has been described in earlier volumes of the CERN COURIER (see volume 9, page 308 and volume 10, page 117) as well as the first tests which were performed at the laboratory responsible for its construction — Saclay. This series of tests and the improvements based on them enabled a physics test experiment to be carried out in March, 1970, during which, with a beam injected from the Saturne accelerator, 50 000 pictures were taken. These photos have served as the basis for the final evaluation of the film measuring equipment.

Dismantling of Mirabelle at Saclay began in May 1970. The components weighing altogether approximately 3 600 tons were dismantled, packed and listed item by item, acording to a programme carefully worked out to fit in with the schedules for shipment and reassembly at Serpukhov. The crates were dispatched by road to Le Havre, from where they went by sea to Leningrad and then on by rail to Serpukhov. This complicated operation was successfully completed for the equipment to be all on the site by December. Meanwhile, the team responsible for the reassembly and operation of Mirabelle, consisting of about fifty persons with their families had moved to Serpukohv in September. Reassembly began at once and was completed on schedule by the end of the year. The speed with which the operation was performed reflects great credit on all the participants.

The necessary links were established between Mirabelle and the Soviet support systems: supply of electricity, cryogenic and other fluids etc... All of which had been prepared well in advance by both teams.

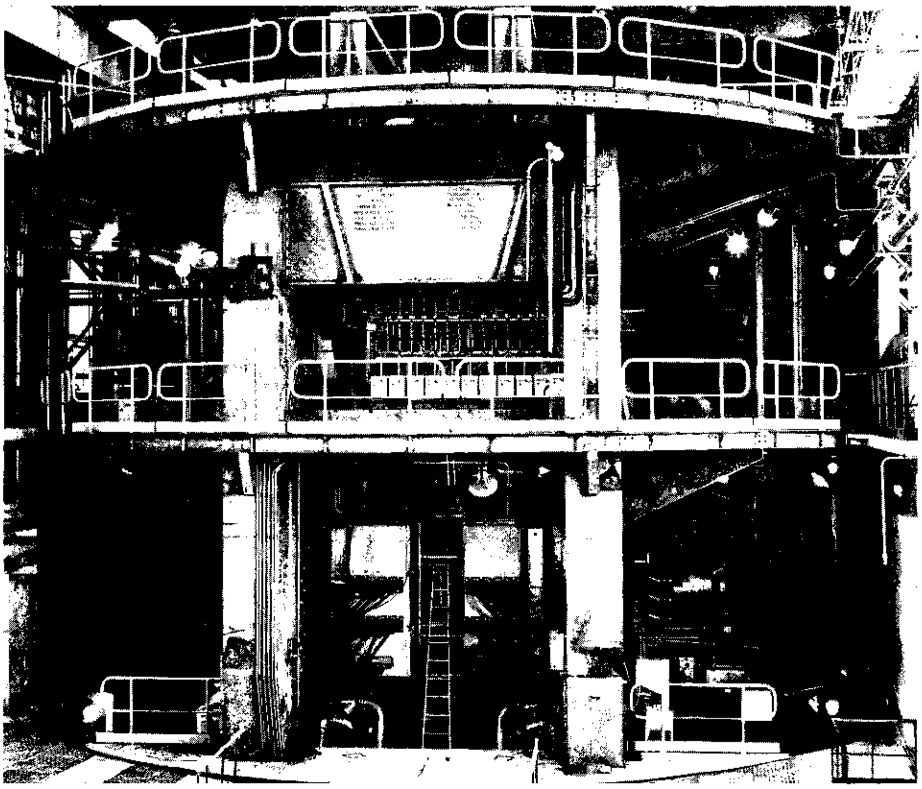
So, on the morning of 10 June of this year, in the hall at one end of the 450 m long experimental area, Mirabelle came back to life. In four days, using a 70 GeV/c proton beam, 20 000 expansions were performed and 4 000 photos taken. These were the first in the world to be taken using a proton beam of this energy and in a liquid hydrogen bubble chamber of this size. They are now being studied. A quick examination has already shown up some interesting points and some of the pictures will probably be selected for measurement.

This first technical experiment at the Serpukhov site, coming after the many complexities of dismantling, shipment and reassembly, has proved very encouraging, especially as regards the sensitivity and reliability of the chamber. Mirabelle has shown that, with its large photographable volume, it is a device eminently suitable for experiments at high energies. What is more, because of the large photographable length (4.70 m), interactions occurring at the beginning of the chamber can be recorded and followed through far enough for the physicists to be able to investigate them very thoroughly as can be judged from the photograph.

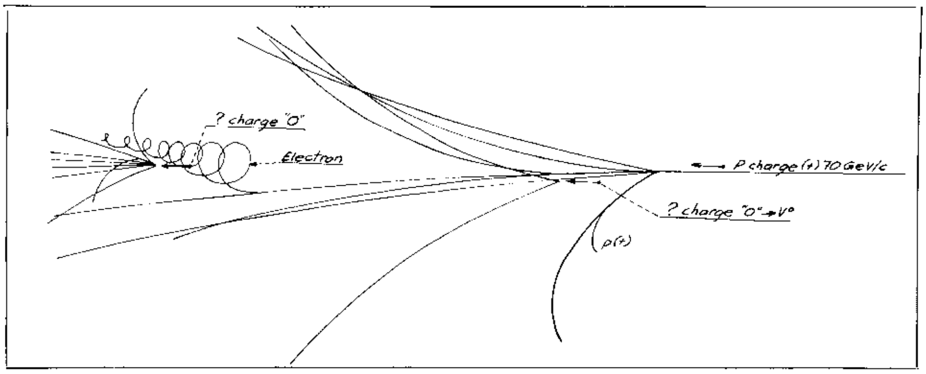
Other experiments will take place between now and the end of the year and then besides the 70 GeV/c proton beam already mentioned the radio frequency separated beams will become available at the end of 1971 or the beginning of 1972. A neutrino beam has also been planned but it is dependent on an increase in intensity of the accelerator and on future decisions regarding the experimental programme.

A general view of Mirabelle re-assembled at Serpukhov. Note the revolving platform which simplified assembly and the alignment of the chamber with respect to the beam.

(Photo CEA)



A photograph taken in the bubble chamber during the first tests at Serpukhov in June of this year. A representation of an interesting sequence of events is shown below. This is one of the first ever bubble chamber photographs with such a high energy incoming beam (70 GeV/c protons) and note how the length of the chamber (4.7 m) enables a series of related events to be recorded.



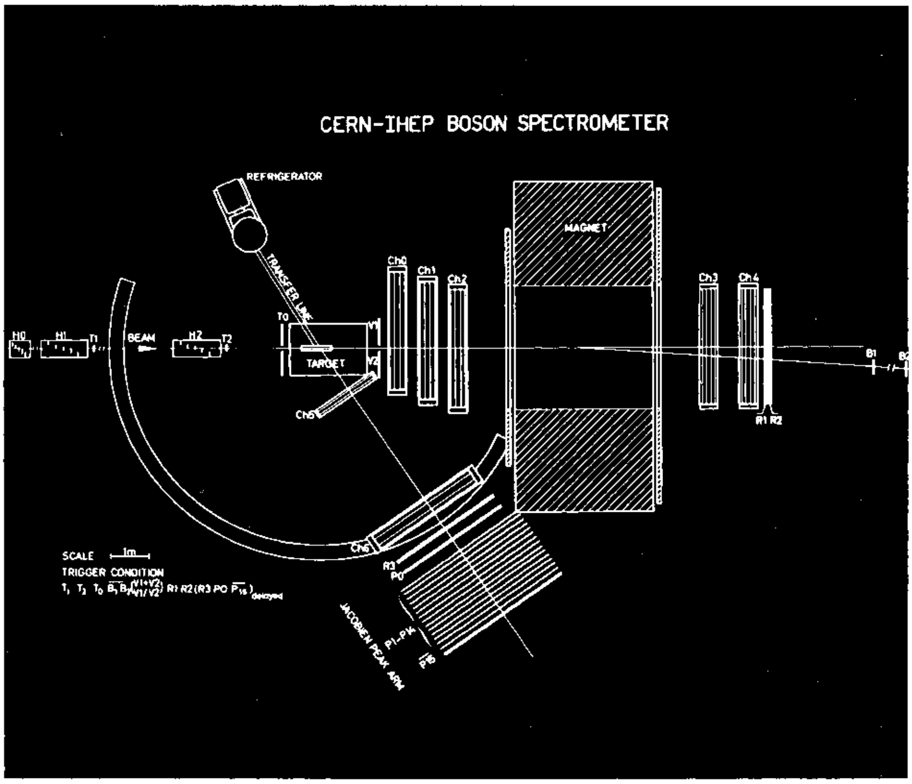
CERN - Serpukhov collaborative experiments

Most of the above information has covered the preparations for experiments using the bubble chamber technique. But we can also now talk of three CERN-Serpukhov collaborative experiments using electronic detectors. The second of them is now in full swing at the 76 GeV proton synchrotron ; the third is taking data at lower energies at the CERN PS.

The first experiments yielded some of the most important results of recent years (reported in vol. 9, page 232). They showed that the total cross-sections for negative particles became virtually constant at much lower energies than expected and that for positive particles, the cross-section instead of approaching the negative value in a regular and steady way, has a dip in the curve at intermediate energies. These results then do not allow one to extrapolate simply from the data obtained over lower energy ranges nor do they conform with the favoured predictions of theory. It looks from some of the very first measurements at the Serpukhov machine as if, as has happened so often in the past, access to higher energies is feeding completely new knowledge, and we hope ultimately understanding, of the behaviour of matter.

The second experiment performed by a joint Serpukhov-CERN team, the CERN component being in turn a collaboration between CERN, Geneva and Munich, has been taking data since about a year ago. It is extending to higher energies the very fruitful application of the missing mass technique developed at CERN in the mid-60 s.

The experiment is to study essentially the characteristics of the x^- particle which is produced together with a proton when a pion strikes a proton : $\pi^- p \rightarrow p + x^-$. The boson spectrometer in its present form (see vol. 10, p. 80) not only allows the x^- mass to be reconstructed but the decay behaviour to be followed in some detail.



Schematic drawing of the layout of detectors in the collaborative experiment which is currently underway at Serpukhov.

The experiment is being performed at two incident pion energies — 25 and 40 GeV/c and for both there are two ranges of data taking — the low missing mass range from zero up to 3 or 3.5 GeV and the high mass range going from 2 - 3.5 GeV in the first case and 3-4.5 GeV in the second.

The beam is of excellent quality and gives per pulse about 500 000 pions per percent momentum bite which stimulates some 30-50 triggers per burst and some 10^5 triggers per day. Data processing takes place in two stages. An IBM 1800 is working on-line with the machine and can handle about 20 % of the data. In parallel all data is stored on magnetic tape which is flown to CERN regularly during running periods for processing on the CDC 6600 and on the CDC 3800 of the University of Geneva. The number of tapes involved is about 7-10 per day and, once set up, the transport operation presented few problems. In the beginning a 24 hours feed back by telex was established so that calibration data was available as early as possible on the experimental floor but progressively the absolute necessity for this has diminished as confidence has been established in both the reproducibility of the equipment and in the significance of that part of the data which the IBM 1800 is handling.

The degree of reliability of the equipment and the experience of the collaborating Serpukhov team have reached the point where the presence of only a technician is indispensable and CERN people (often to their regret) are having to spend less and less time at Serpukhov. A material contribution to the ease of starting up again after a shutdown has been the technique developed by V. Roinishvili of establishing a permanent small flow of argon in all the delicate parts of the spark chambers: e. g. the magnetostrictive readouts. The number of scintillators and electronics circuits was drastically reduced by triggering with a proportional chamber built at IHEP by Y. Antipov and F. Yotch.

The overall surveillance has been also greatly simplified by a data display system developed by A. Lebedev which not only takes into account the essential features of the system but the human engineering aspects, i. e. the requirements of the people who run it. Repair and maintenance of equipment are essentially performed by the technicians of the IHEP team (group leader: L. Landsberg).

So far 4 M triggers have been observed with an average of 0.5 M triggers per run. The experiment may be completed next January after improving the statistics on the interesting channels.

Results so far have been unexpected. Instead of a confused mass of additional effects at higher energies which might have been anticipated the reverse is the case. At both 25 and 40 GeV/c incident energy there is the elastic scattering peak at the beginning. (The experiment almost incidentally is providing information on the slope energy relationship of elastic scattering cross-sections for $\pi^- p$ $K^- p$ and $\bar{p}p$ reactions. After this initial peak which mainly serves to monitor the spectrometer system, the most prominent other effect is a relatively sharp and, even at 40 GeV/c, very clear peak at 1.30 GeV — a mass corresponding to the mass of the A_2 meson. What is so surprising is that well-known particles such as the rho meson pale into insignificance in comparison and it can definitely be said in the 'missing' mass above about 2 GeV there is no structure.

The analysis of several decay channels is now preoccupying the experimenters, such as for example the three-pion decay with spin-parity analysis for which the collaboration has been extended to include R. Sard and G. Ascoli of Illinois.

The third collaborative experiment involves a Karlsruhe team presently working at CERN which will link up with Soviet colleagues from the Institute of Theoretical and Experimental Physics (ITEP) and from Moscow State University. They will study neutron-proton charge exchange scattering covering momenta from 8 to 25 GeV/c at CERN and 20 to 70 GeV/c at Serpukhov.

The equipment destined for Serpukhov is now in action at the CERN proton synchrotron. It will be used to collect the lower energy part of the experiment's data while checking the operation of all the components. This run is likely to be finished around the end of the year and the equipment will move to Serpukhov in the spring of next year.

Heisenberg's Principles

Remote from the noise and bustle of Europe's capital cities, in the charming German lake-side town of Lindau, close to the borders of Austria and Switzerland, Nobel Prize Winners in physics gathered together from June 28-July 2 to talk of their science and its interaction with society.

The first of these annual meetings of Nobel Prize Winners was a medical congress in 1951. The assembly this year was the 21st in the series and the seventh where the main theme was physics.

In a varied programme of talks, followed by discussions with an invited body of students, readers of CERN COURIER would have been particularly interested in the conference given by Professor Heisenberg in which he analyzed his past and present attitudes to the Super Proton Synchrotron project. He was reputed at one time to be strongly opposed to the project and to be the eminence grise in German science policy discouraging participation. Certainly in a number of interviews with the press he made clear that he had reservations about the early proposals but reports on his views were sometimes tendentious and even, one suspects, apocryphal. Here was an opportunity to hear from this great figure of European physics how his thoughts on the project had evolved and what new considerations had led to his approbation. Among the points raised by Heisenberg in his talk were :

When projects of the size and significance of the 300 GeV are in question, it is naïve to believe that politics can be ignored. The scale of expenditure, the choice of location, the relevant urgency are all matters where public discussion is necessary and public policy, i. e. politics, is involved.

First the Physics

From the physics angle, previous experience would suggest that the availability of even larger machines — higher energies — would yield new information and new knowledge. Moreover the field of elementary particle physics concerns the laws of nature to which all physical law can be reduced, it is, in fact, physics at its most fundamental. At the same time the technological stimulus created by this work at the frontiers of knowledge is an element of general importance. Such arguments certainly were in favour of the construction of a machine of 100 GeV or so but for still higher energies the question of cost and relative value had to enter into consideration.

There was a question mark too over the type of discoveries that can be made at higher energies. It could be that there is no longer subdivision of matter, but only the creation of new particles or new particle states, and cosmic ray evidence had not suggested that there was anything more fundamental to be found.

In any case the ISR should reveal any basically new phenomena and if conventional machines of higher energy were then shown to be necessary, one should first consider new techniques so that they could be built more cheaply.

Competing Claims

At the level of expenditure required for a new synchrotron, sums need to be diverted from other activities and if such a synchrotron is being built collectively then this is also a drain on the national pool of assets. The choice to be faced was whether the money be spent on a larger machine or, say, new university buildings, another school or another CERN laboratory, environmental protection or higher energy physics. Choices of this nature were disagreeable to make — particularly when trying to balance the quest for fundamental knowledge against the day-to-day problems of the man in the street. National defence raised even more difficulties and money forthcoming from that direction must first be made available by those who are responsible for this defence.

The U.K. had made a positive contribution towards resolving this argument by agreeing to participate in the new CERN programme at the expense of their national effort in the same field — even if this were to mean closing a national laboratory. It is rare to see demands on the State purse, accompanied by proposals which require sacrifices by those making the demand.

Dispassionate Advice

One acute problem facing governments was their dependence on scientists for scientific advice and it was therefore of prime importance that there should be no confusion between the interested parties and the consultative bodies. In a field as restricted as high energy physics, advisers were inevitably interested and a sacrifice is then necessary as a proof of good faith on the part of the counsellors. It is up to the scientist to convince the politician of the genuineness of his submissions; the U.K. physicists had done so.

Undoubtedly, the formation of an international community was to be encouraged and its institutions and centres supported without too much

View of the experiment in the East Hall which is measuring parameters in neutral kaon decay. The beam is coming from the top right. The three multiwire proportional chambers are arranged two on the downstream and one on the upstream side of the large (2.4×0.6 m) aperture analyzing magnet which is near the top right-hand corner of the picture.

cynicism about the ultimate success. A certain faith was necessary. Happily CERN was one of the best examples of international collaboration but several others, such as Trieste, Ispra, Grenoble and the various space centres were all contributing.

The questions of the location of these centres was, however, also important. There were certain basic requirements which had to be filled in any given circumstance, but the final decision was essentially political and a reasonable distribution across Europe was indispensable. This is far from the case at present and must be corrected in the future.

It had been hoped that the German site of Drensteinfurt would be selected for the 300 GeV but the cost reductions associated with the latest proposition for CERN Lab. II shifted the balance in favour of this second choice. The stability afforded to the present laboratory was also a valuable element and it insured against a future over-provision of facilities in this domain and consequently an excessive production of physicists. Taking into consideration all these aspects then the compromise solution of CERN Lab. II was a good one.

In concluding, Professor Heisenberg recalled the remarks of the U.S. Ambassador in Bonn who (like many others) had compared the construction of giant machines for science nowadays with the erection of the pyramids in ancient Egypt and the cathedrals during the Middle Ages. People in the present era are willing to offer something to the goddess of enlightenment. The power of this enligthenment was, however, limited and we must remain critical of it. A better understanding between peoples had to come from it. The work at CERN was evidently consistent with this ultimate objective.

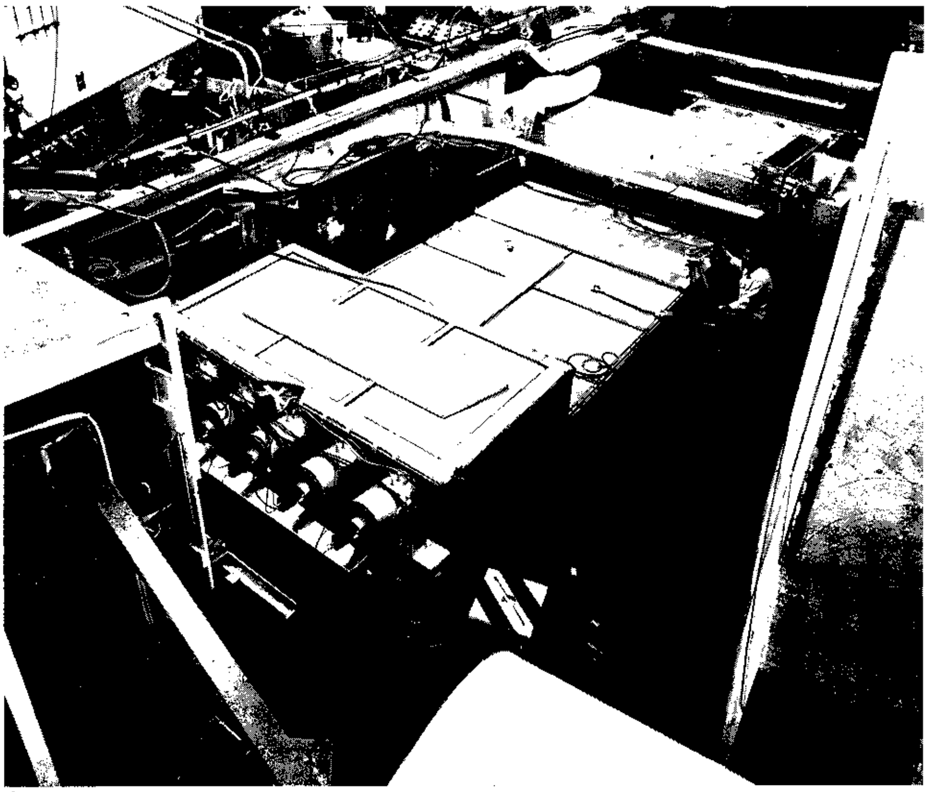
Eta Measurements

In the article in the last issue on the Amsterdam Conference, mention was made of the experiment now being carried out at CERN on various measurements on the $\eta^{\pm}$ parameter, which represents the ratio between the amplitude of the charged two-pion decays of the long-lived neutral kaon (K_L) and that of the short-lived kaon (K_S), i. e. $K_L \rightarrow \pi^+ \pi^-$ and $K_S \rightarrow \pi^+ \pi^-$. Because the K_L decay into two pions violates the charge conjugation x parity symmetry law (CP), it should be possible by these measurements to obtain more accurate information on the validity of a proposed theory to explain the phenomenon of CP violation, the so-called superweak theory.

CP violation

The K° has been at the origin of many puzzling discoveries and new ideas. Already at its first observation it was called strange because it decayed slowly (10^{-10} s), but was produced at an observable rate by cosmic radiation. Therefore this particle did not decay by strong interaction, by which it was produced. The problem was solved by the postulate (made by Prof. Gell-Mann and Prof. Nishijima) that there is a new quantum number S (strangeness) which is conserved ir strong interactions but not in weak interactions. Since such a quantum number is an additive one like the charge number, the antiparticle $\overline{K}^\circ$ of the K° is different from the K°. But, it is still possible by weak interaction to make transitions $K^\circ \longleftrightarrow \pi^+ \pi^- \longleftrightarrow \overline{K}^\circ$. So, K° and $\overline{K}^\circ$ can mix with each other.

In fact, the observed particles which have a definite mass and mean lifetime are not the K° and $\overline{K}^\circ$ but linear combinations thereof, which are called the K_S (short-lived) and K_L (long-lived). Before 1964 it was assumed



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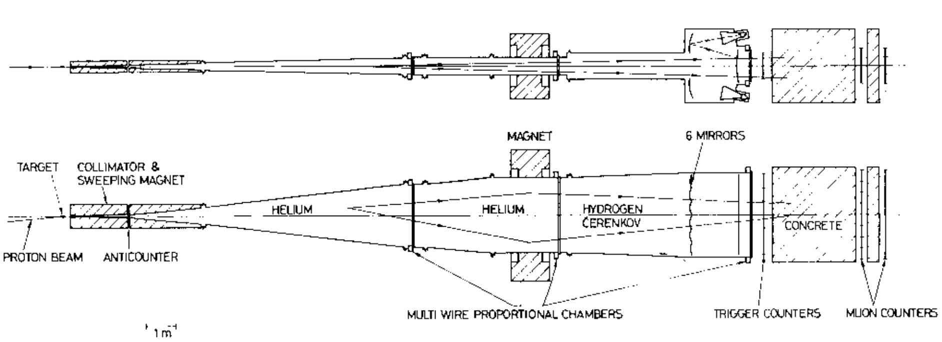


Diagram of the experimental layout: side view on top, plan view below.

(and in agreement with experiment) that the weak interaction is invariant under the combined CP operation where C is the particle-antiparticle conjugation and P the spatial reflection (parity) operator. This would imply that the particles K_S and K_L have a definite CP quantum number. For K_S: CP = +1, for K_L CP = −1.

The discovery that the decay $K_L \to \pi^+ \pi^-$ exists as well as $K_S \to \pi^+ \pi^-$ destroyed the picture of CP invariance of the weak interaction: since the $\pi^+ \pi^-$ state has CP = + 1, there is a change of CP quantum number in the decay $K_L \to \pi^+ \pi^-$.

Since then experimenters have measured with increasing precision the probability of this decay $K_L \to \pi^+ \pi^-$ and the phase angle difference φ^{+-} between the decay amplitudes for $K_L \to \pi^+ \pi^-$ and $K_S \to \pi^+ \pi^-$. (Elementary processes are represented by a complex number having an absolute value and a phase angle, as it is necessary to describe the *wave* character of particles).

The knowledge of this angle φ^{+-} is required to distinguish between different models of CP violation. One of those postulates the existence of a new force in nature, the 'superweak' interaction; it predicts $\varphi^{+-} = 43.2°$. Other models which implement CP violation into the weak interaction, give values of φ^{+-} in the range 35°—50°.

In experiments done up to now, the η^{+-} phase has been measured with an accuracy of only 4°, due partially to the number of observed events being too small.

It has become possible, through the progress made with MPC's (multiwire proportional chambers), to set up an experiment which, by the accumulation of a large number of events within a short time, will allow this phase to be measured to within 1°.

This experiment, carried out by a CERN-Heidelberg group, began at CERN in the East Hall after a great deal of preparation occupying two years. It has run for 6 weeks machine time and several more data taking weeks are still needed. There are also other results to be extracted from the data.

The main features of the MPC's used are their size (5400 wires on six planes, the largest measuring 2.7 × 0.9 m²) and also the fact that this is the first instance of their use in a large scale experiment for both measurement and the selection of interesting events. The resolution time of these chambers is 40 ns, and their efficiency is greater than 99 %. The readout time which is about 400 ns (compared with ~ 5 ms in wire spark chamber experiments) makes it possible to deal with almost 100 000 event candidates per PS burst (5×10^{10} protons in 400 ms). After all undesired candidates have been rejected, 700 two prong events are being recorded at present per PS burst.

The phase φ^{+-} is measured by determining the life time distribution of $K^0 \to \pi^+ \pi^-$ decays and this means measuring the decay points and the momenta of the K°.

As the figure shows, the equipment includes, from left to right, a platinum target which is hit by the protons, a collimator with a slit placed in the field of a magnet and arranged at an angle of 4° with respect to the proton beam axis; a volume of helium reducing multiple scattering; a spectrometer consisting of a wide-aperture analysing magnet (2.4 m × 0.6 m) associated with three multiwire proportional chambers, each with two wire planes; scintillation counters opening the gates of the MPC's whenever there are two particles, one on each side of the counter array, and triggering the readout and decision logic of the MPC's; a large Cherenkov threshold counter (with a novel mirror system) filled with hydrogen at atmospheric pressure to identify electrons, a concrete shield for stopping pions; and 16 scintillation counters to detect muons and locate them.

The flow line of the experiment is as follows:

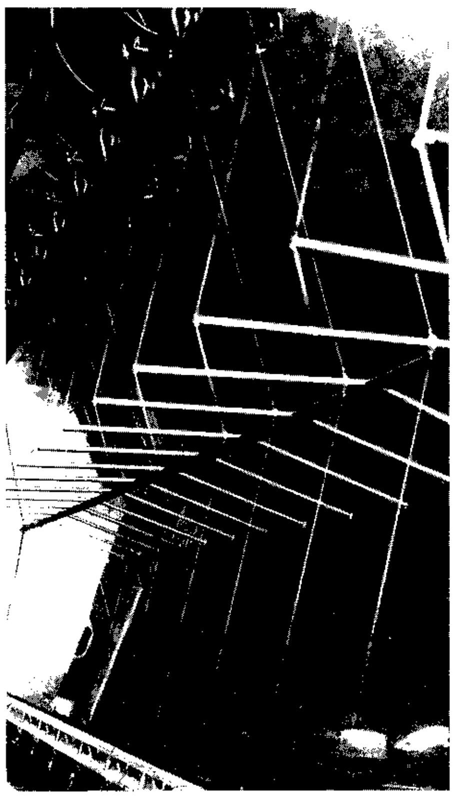
— the production of various particles by the interaction of the protons in the target;

— the elimination of most of the charged particles deflected by the magnetic field, by means of the collimator;

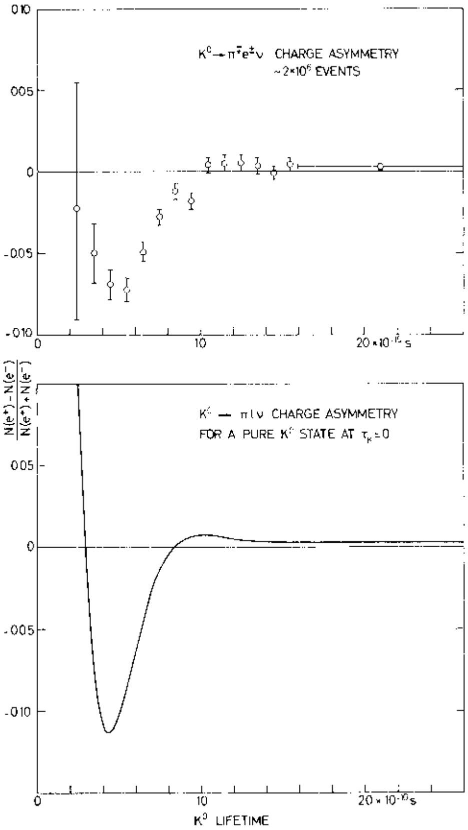
— the reduction of the background by orienting the collimator slit at 4° from the proton beam axis. This angle is the result of a compromise between maximizing the number of high-energy K° produced and minimizing the background caused by the protons;

— the decay of the K° in the volume of helium; the two charged decay products traverse the 6 chamber planes and the trigger counter array;

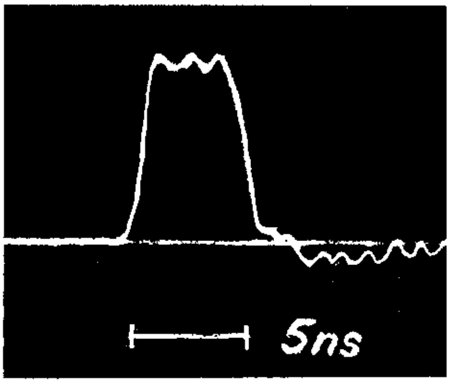
— the start of the recording and deci-



Below : The back of the double-plane mirror of the threshold Cherenkov counter used in the experiment on the measurement of η^{+-} Its design required two apparently contradictory properties: strict planeness and very high transparency with regard to the beam. This did not worry the West workshop, which used a 25 μm gauge aluminised Mylar film, stretched as a reflective surface. The photograph was taken before the aluminium coating was applied on a light frame braced with piano wire.



Charge asymmetry in the decay $K^0 \rightarrow \pi^{\pm} e^{\pm} \nu$ as a function of K^0 lifetime ; 2×10^6 events.



Oscilloscope photograph showing a pulse 100 kV high and 4 ns long produced by the experimental generator developed at CERN.

sion logic by a 2-fold coincidence between 2 trigger counters;

— the selection, by means of the chamber logic circuits, of those events giving twelve tracks one in each of the right and left-hand halves of the six wire planes in the MPC's (one track in the right and one in the left-hand of each plane). It should be noted that, in the case of the horizontal wires, the planes are divided into two distinct halves which are symmetrical on the left and on the right;

— the simultaneous recording of the signals of the electron and muon counters in time with the 2-fold trigger coincidence.

These events are then buffered in an on-line computer and recorded on magnetic tape.

The recording sequence is then finished. The data now have to be processed off-line to allow all the K° decay reactions to be identified, i. e. $K^0 \rightarrow \pi^+ \pi^-$, $K^0 \rightarrow \pi^{\pm} e^{\pm} \nu$, $K^0 \rightarrow \pi^{\pm} \mu^{\pm} \nu$, $K^0 \rightarrow \pi^+ \pi^- \pi^0$.

The identification procedure used is based on the information provided by the muon and electron counters and on spatial and kinematic reconstruction programs using the coordinates of the tracks in the three chambers. The K° decays into muons and electrons are not eliminated but retained to provide information:

1) on the mass difference between K_S and K_L and

2) on the selection rule $\Delta Q = \Delta S$ (charge change equal strangeness change).

Up to now a total of 3×10^8 events, including several million $K^0 \rightarrow \pi^+ \pi^-$, have been recorded.

The analysis of the data collected so far is not finished, but the experiment has demonstrated that it is possible to operate such a large set up of proportional multiwire chambers and to take data at a rate 100 times higher than similar experiments before.

100 kV — 4 ns

High voltage, very short pulse generators with rise and decay times shorter than a nanosecond can find many applications in high energy physics for both experimental and accelerator equipment. E. Gygi and F. Schneider at CERN have just completed an experimental generator capable of providing 100 kV pulses 4 ns long, with rise and decay times of 0.6 ns and a repetition frequency of 1 Hz. It also has a low impedance — 20 ohms — and could thus be used in conjunction with step-up transformers.

The generator is of conventional layout, in that it comprises a charging circuit (a Marx generator plus a charging line) discharging into a line with the same characteristic impedance via a spark-gap. It differs radically from its predecessors in two respects : the very short charging time of the line (40 ns) and the special design of the spark-gap. This makes possible a charging voltage of 200 kV across 8 mm, at a pressure of one atmosphere or less, whereas in an ordinary spark-gap it would not exceed 5 kV in similar conditions.

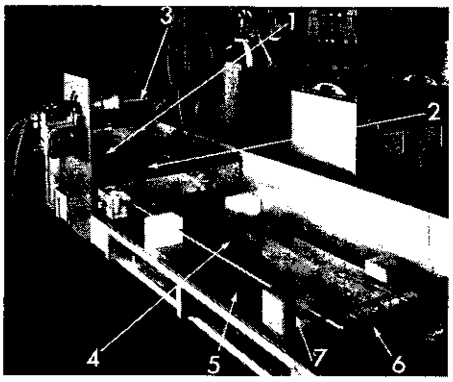
Normally, the maximum voltage which may be applied to the electrodes of a spark-gap depends on the distance, the nature of the gas and its pressure, and the form of the electrodes. Beyond a certain field gradient, discharge is induced by the presence of free electrons in the gap. If the free electrons can be eliminated, the equipment can be operated in the supercritical range, where the charging voltage can be increased by up to forty times, thus providing in the subsequent discharge extremely short pulse rise and duration times. The presence of free electrons results however in an immediate transition from the supercritical to the critical range.

The principal sources of free electrons are those escaping naturally from the surface of a body from thermal and chemical field emission effects and those produced by ionization of the gas in the gap.

Gygi and Schneider's equipment seeks to eliminate these sources in a variety of ways :

1) The electrodes are of platinum or rhodium at the cathode and stainless steel at the anode. The atmosphere is argon at normal pressure and, above all, the charging time is very brief (40 ns). All of these reduce to a negligible value the probability of formation of free electrons by the electrodes ;
2) The distance between the electrodes is very small which reduces the likehood of the passage of cosmic rays ;
3) The electrodes are of a special form and great care has been taken in their manufacture ; the sides, for example, are coated with silicone rubber.

The electrode system is relatively wide which means that the number of discharge points is increased. To take advantage of this the present design of feed line comprises four 80 ohm lines in parallel, reducing the impedance to 20 ohms. Strict simultaneity in the discharge of the electrodes is ensured by a special



View of the pulse generator indicating —
(1) Marks generator; (2) pulse forming network;
(3) UV flash lamp; (4) inner electrode; (5) part of
ground electrode; 6) terminating resistors;
(7) polyurethane support.

The new polarized proton target installed in the East Hall for an experiment to measure the polarization in K-p charge exchange.
The helium 3 cryostat protrudes inside the pole pieces specially added to the ETH magnet used as a spectrometer. The K- beam (coming from the right) passes through the target in the axis of the cryostat.

generator producing short ultraviolet pulses. So far the equipment has been successfully tested to 10^5 pulses with a charging voltage of 200 kV.

From the PS to the West Hall

The next two stages in the PS improvements programme are the booster and the West Hall. Work is proceeding smoothly on the former (see for example the July issue of CERN COURIER) but very little has so far been said about the West Hall and its adjoining buildings, which will house not only BEBC but also the Omega project and a whole set of PS experiments. It has not, however, been forgotten and the major part of transfer line TT2, through which the protons originating from the PS will be directly transferred to the West Hall target areas, has recently been completed.

The design of this 540 metre-long line, which is subject to both horizontal and vertical deflections, and which passes beneath the ISR rings, is very similar to that of tunnels TT1 and TT2 supplying the two rings (see vol. 10, pp. 280 and 316). It is however required to transport in addition to fast ejected protons from the PS, slow ejected protons also.

Proton transfer tests have just taken place along 80 % of its length with excellent results.

In fast ejection, with the magnet currents set to the calculated values, impact points only 5 to 15 mm from the centre of the vacuum chamber were obtained at the end of the line which were reduced to zero after minor adjustment. Moreover, this was achieved with a beam oscillation of 14 mm maximum relative to the chamber axis.

Slow ejection can give rise to problems because of small changes in momentum (about 1 %) over the spill time. The slow ejection system has not yet been installed, so the effect was simulated by making slight variations in the momentum of fast ejected particles. All seems well as the maximum departure from the straight and narrow fell well within the vacuum chamber limits and did not exceed 15 mm.

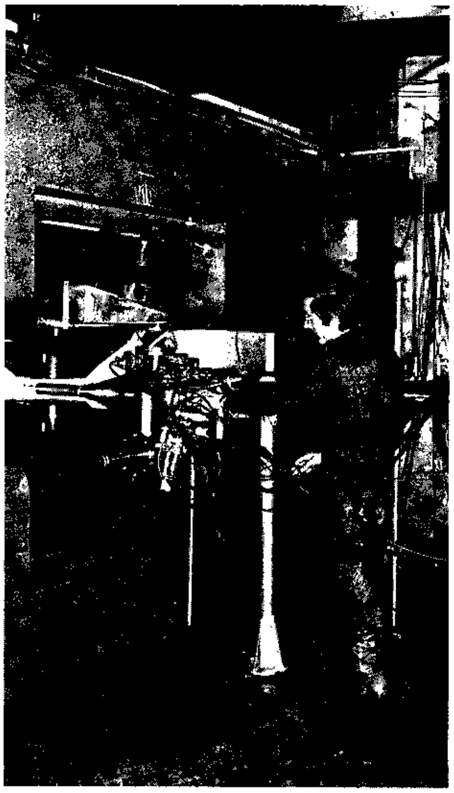
Radiation levels over the entire length of the tunnel also proved to be very low.

The whole of the beam line system passing through the West Hall is scheduled for installation at the beginning of 1972, and should be completed at the end of April, 1972.

45 cm³ polarized target

Continuous progress has been made in the field of polarized proton targets largely because of developments in the techniques associated with target temperatures and high magnetic fields (superconductivity) and by the use of new substances. In many respects, CERN has been a pioneer here, and CERN COURIER has already given accounts (vol. 9, page 300 and vol. 10, page 112) of improvements brought about by the use of alcohols as the material to be polarized, the use of helium 3 instead of helium 4 as a coolant and the polarization of deuterons.

Now at CERN the longest polarized target ever built (15 cm long and 2 cm diameter) has been put into operation. It is cooled by means of a new cryogenic system designed by J. Vermeulen (with advice from P. Roubeau of Saclay), comprising a helium 4 precooler working at 2.5° K associated with a very small pumping system and a horizontal liquid helium 3 cryostat which forms part of a closed-circuit in which the pumping system has an effective pumping speed of 200 l/s. The rate of cooling the system can provide is 100 mW at 0.55° K.



CERN 60.6.71

The target is also designed so that the particle beam striking it, enters the axis of the cryostat. The beam is identified by two scintillation counters connected in coincidence situated, actually inside the cryostat, at a distance of 8 mm from the target. The special feature of the arrangement is that a very wide free angle is left around the target for secondary particle detection. Moreover, the magnetic field of 2.5 Tesla which is obtained from the ETH magnet is made highly uniform by the addition of pole pieces to one side according to an arrangement suggested by Ö. Runolfsson. This magnet normally gives 1.0 Tesla in a volume of $1 \times 1.5 \times 2$ m³.

Polarizations equal to 60 % were obtained during the initial tests, with the cavity filled with butanol spheres. The target is at present being used in an experiment intended to measure the polarization in K^-p charge exchange.

Around the Laboratories

USA Laboratory Budgets

The financial problems facing high energy physics Laboratories in the United States have become still more acute in 'fiscal year 1972' which began on 1 July. With the exception of Cornell (funded by the National Science Foundation), all the major Laboratories draw their money via the US Atomic Energy Commission and the budget request by the AEC for high energy physics in fiscal year 1972 for operating funds has had to be limited to $ 116.4 million compared with $ 118.6 M in the previous fiscal year. Similar cuts in the budgets for equipment and construction amplify the difficulties.

It is the second year that the operating and construction budgets have been cut so that, in total, they are back close to their 1968 level and obviously over the past four years the cost of living has not stood still. In addition, this is occurring in a field where, without any major additions in facilities or in the scale of the experimental programme, a few per cent growth is usually fed in simply to accommodate the growing 'sophistication' of advanced research equipment. Major economies have been needed in all the Laboratories and in all of them the installed research facilities are being underused — often by a large factor. Even the 20 GeV electron linear accelerator at Standford which carries a relatively high priority is now scheduled for operation, on average, only 18 days in each month.

Despite the feeling that things are so bad that they could not possibly get worse (which is suggested in the article on the Brookhaven storage ring plans), there is no doubt that if the present trend continues for much longer, Laboratories are going to sink below the level where they are viable. An added complication is that when the research programme at Batavia gets underway its 'operation' money has to come out of the same pool which will be a heavy additional burden.

Congress reaction

There has been some strong reaction in the US Congress at the rather precipitate way in which, because of the limited funds available to the US AEC Research Division, the research at the 3 GeV fast cycling proton synchrotron at Princeton has had to be run down after only a short machine life and whilst it was still in the midst of improvements.

Nevertheless, the Joint Committee on Atomic Energy has on its own initiative started some knuckle rapping in cutting 'improvement' money for the other Laboratories in the coming year in spite of the fact that they appreciate what this improvement money means to the USA Laboratories and with the high fixed costs of accelerator operation, a few per cent cut becomes a many per cent cut in the actual research programme. To avoid precipitate action in the future, if possible, the Joint Committee has called on the AEC to review the Laboratories, by the end of this year, and make an attempt to establish priorities amongst them. (This recommendation has the positive intent to make longer range planning possible — a very difficult thing to do with the single year budgetary procedures in the USA which can lead to programmes being turned on and off like a tap.) Obviously the outcome could be that further Laboratories go to the wall like PPA or may need to change their character, which is not necessarily all bad.

It seems worthwhile to reprint a good part of the report to the USA Congress by the Joint Committee on Atomic Energy in which they comment on the high energy physics scene:

'The Princeton-Pennsylvania Accelerator is now being shut down. The Joint Committee notes that although a strong effort was made by Princeton University and the University of Pennsylvania to obtain funds to keep this modern accelerator in operation, there seems to have been little effort within the Executive Branch to help provide continuing support. The Committee understands that PPA, a relatively new installation which cost the Federal Government about $ 41 million, was readily convertible to operation as a heavy ion accelerator. Such accelerators are basic tools for cancer research and cancer therapy. The Committee was therefore surprised to learn that the Fannie Ripple Foundation of Newark, New Jersey, which offered $ 230000 to help convert PPA for cancer research, was the only major potential contributor. The Committee is aware of no offer by any Federal agency to convert PPA for use in the field of cancer research despite the recent announcement that developing a cure for cancer is now a major national goal.

The Committee noted with pleasure the progress that Dr. Wilson and his associates have made in the design and construction of the 200 GeV machine at the National Accelerator Laboratory, Batavia, under rather stringent monetary constraints. In particular, the Committee is impressed with the indicated possibility of an 'energy doubler' through the development and application of cryogenic technology. This achievement could potentially increase the energy range of the accelerator to as high as 1000 GeV with attendant economies and efficiencies in the use of electric power. The Committee urges Dr. Wilson and his staff to perform the necessary work in the coming fiscal year to clearly define the scope of this undertaking and to ascertain whether the inclusion of energy doublers can be achieved with-

Recent aerial view of the site of the 33 GeV Alternating Gradient Synchrotron at Brookhaven. Coming in towards the ring from the left on the photograph is the new 200 MeV linac which both feeds the synchrotron and provides protons for medical and biological research and the production of isotopes. Almost diametrically opposite are the two large buildings of the East Experimental Area. Further round is the new neutrino beam-line which will have the refurbished 7 foot bubble chamber and in the woods, top left, is a possible location for 200 GeV storage rings which are now under study.

(Photo BNL)

in the $ 250 million authorized for this project.

At the same time, the Joint Committee is concerned about the future of the five existing high energy accelerators supported by the AEC (i.e. Argonne, Berkeley, Brookhaven, Cambridge and Stanford) once the NAL begins full operation. The high energy physics budget has steadily declined in recent years which has resulted in less than optimum operating schedules at these five laboratories. Because of the high fixed costs, reductions in the operating budget of these accelerators result in a loss of operating hours and a consequent direct reduction of research effort proportionally much larger than might be expected for the respective dollar reductions.

When the NAL becomes fully operational, it will require annual operating funds of $ 60 to $ 70 million including funds for outside user groups. This is more than 50 percent of the 1972 requested funds for all of high energy physics. In addition, NAL plant and capital equipment requirements may be as a high as $ 25 million a year. Obviously, the trend of declining budgets for high energy physics must be sharply reversed if the NAL and the five existing laboratories are to be adequately funded. In this regard, if budget priorities prohibit the necessary increase in funding, the Committee must evaluate very critically the spreading too thinly of whatever Federal support is available for high energy physics. Therefore, the Joint Committee recommends that the AEC carefully examine the minimum level of support necessary to keep each of its high energy accelerator laboratories, including the NAL, viable and productive, and that it develop a priority listing of which accelerators should be kept operating should future funding be less than the minimum necessary to effectively support each of the six laboratories.'

BROOKHAVEN Thinking on 200 GeV storage rings

As practically all elements of the 'conversion project' at the 33 GeV Alternating Gradient Synchrotron near completion, more eyes at Brookhaven are lifting from the problems of seeing through construction programmes to looking at the options open for future high energy research facilities at the Laboratory. With the backing of the experimenters, the machine physicists are beginning to study the possibility of constructing very high energy storage rings, in conjunction with the AGS, using superconducting magnets.

This month (August) the AGS is scheduled to come back into action after a long shutdown. It will be fed by the new 200 MeV linac (initially without its debuncher) and with this higher injection energy it is hoped to accelerate beams of 5×10^{12} protons per pulse by the end of the year and eventually to push to 10^{13} or higher. The linac is performing very reliably and for several weeks has been supplying protons for medical and biological experiments. Preparations are well advanced also for using 200 MeV beams for the production of isotopes. Feeding the synchrotron will be interleaved with these other activities. Multiturn injection will be used with possibilities for stacking both horizontally and vertically. Because of the high intensities (close on 100 mA) available from the linac, the injection procedure has to be virtually lossless ; it has already been demonstrated inadvertently how easily the beam can burn its way into beam-line components. Acceleration of deuterons in the linac was tested in July in preparation for possible acceleration in the synchrotron late next year to provide high energy deuterons for the experimental programme if they are required.

Major modifications in the ring during the shutdown have included the installation of a new vacuum system, new magnet mountings and correction coils. The new magnet power supply has been in operation for some time and has been yielding about one and a half times the average current per second available with the old supply. The new r.f. cavities, which will allow a faster rate of acceleration and which will have a smaller frequency swing because of the higher injection energy, are not ready yet due to late delivery of the ferrite.

Prior to the shutdown the synchrotron was supplying particles for an extensive experimental programme. Bubble chamber beams were available for a small chamber (30/31 inch), the 80 inch hydrogen chamber and (as a neutrino beam) the 7 foot hydrogen chamber. Three beams (further divided) for electronics experiments were drawn from an internal target and good quality beams were available from the slow ejected beam which fed experiments in the East Experimental Area and its new extension (including a hyperon beam, a muon beam and a beam for the study of 'exotic' atoms). The slow ejected beam efficiency is 85 to 90 % and a wire septum will be tried to improve this. It is usually run in parallel with the internal target and this does not drop the efficiency much.

The 7 foot chamber is being moved from its test position to a position further round the ring where it will be possible to feed it with a more flexible arrangement of beams. The move is not losing physics time with the chamber since a variety of modifications have proved necessary. The main ones concern doubling the diameter of the piston (resolving problems resulting from high liquid velocities), installing a new piston sealing system and redesigning the main heat exchanger. It is hoped that the chamber will be ready for cool-down again in the autumn of 1972.

Ironically at a time when the conversion project and improvements to experimental facilities are opening up the possibility of a much broader experimental programme, the Laboratory budgets, comparatively, are at a low ebb. Despite the new capabilities, the available money is not sufficient to sustain a programme as big as that operating before the improvements were implemented. There is however considerable confidence that after the current fiscal year, which began on 1 July, the tide will begin to flow back again and research programmes throughout the USA will be revitalized. It is partly in this context that there is a new gleam in the eyes of the machine builders as they discuss the possibilities of very high energy storage rings.

With the coming into action of the accelerator at Batavia, Brookhaven loses its premier position in high energy physics in the USA. Also, Batavia is the more logical place to push to still higher energies with a superconducting synchrotron if the physics calls for it. Superconducting synchrotrons have been studied in some detail at Brookhaven where some of the leading work on pulsed superconducting magnets is going on (see May issue page 123) but with an injector of several hundred GeV and a large diameter tunnel already available and experimental facilities for very high energy coming together, it would be a much more economical proposition at NAL. Very preliminary thinking on the addition of a superconducting ring (referred to as the 'energy doubler') has started at Batavia. To complement such a facility and to leap-frog it in terms of peak 'useful' energy (though with more limited experimental possibilities) the emphasis at Brookhaven has now swung to superconducting storage rings. This has been urged particularly by J.P. Blewett and has been given added impetus by the very successful operation of the ISR at CERN.

An outline scheme for 200 GeV storage rings (providing useful energy equivalent to a conventional accelerator of 80 TeV) is as follows : Each 'ring' consists of two half circles of magnets (with a few short straight sections) 225 m radius, joined by two very long, 300 m, straight sections. The half circles of the two separate rings may lie very close together in the horizontal plane or sit one on top of the other. The total circumference could be 2 km (two and a half times the circumference of the AGS).

The AGS would feed the rings with protons at an energy of 30 GeV and r.f. cavities in the rings would continue the acceleration up to 200 GeV. This acceleration would be done very slowly (over a time of say 100 s or more) to take the pressure off the superconducting magnet rate of rise of field and off the rate of energy transfer to and from their power supplies. Peak fields in the magnets could be 4 T in the dipoles and 1 T/cm in the quadrupoles with a magnet aperture of 5 cm or more.

A major problem is of course to build up high beam intensities in the storage rings so as to give adequate interaction rates in the colliding beams. A possible scheme would be to concentrate the protons circulating in the AGS into one bunch and to transfer such bunches successively to sit next to one another orbiting the storage rings.

When the conversion project is completed the AGS is expected to accelerate about 10^{13} protons per pulse. At 1.7×10^{13} protons per pulse the circulating current will be 1 A but this is distributed in proton bunches occupying a tenth of the circumference. In the bunches themselves therefore the current could be about 10 A (half the ISR design currents). Unfortunately to transfer individual bunches from the AGS to sit adjacently in the storage rings would put demands on the switching of ejection and injection magnets which could not be met with current technology. It looks however as if some beam gymnastics in the AGS could concentrate the protons into a single bunch. Stacking in the storage rings, as at the ISR, could take the stored current beyond 10 A but to give a manageable r.f. system the energy spread must be much lower than is tolerable in the ISR and the application of such a stacking injection scheme is likely to be limited.

In the long straight sections the beams could be made to cross at a very small angle or to run collinear. Because of the focusing or defocusing action of the quadrupoles preceding the straights the two beams could be made to coincide at the centre of the

Smiles for the success of the 100 MeV test of the Los Alamos Meson Physics Facility. The occasion was suitably toasted with champagne provided by LAMPF Director Louis Rosen and his wife, Mary. Opening the ceremonial bottles in the foreground are: Dr. Donald Hagerman, Dr. Thomas Putnam, Dr. Edward Knapp and Dr. Donald Swenson. The Rosens are visible at the back.

In case anyone was in doubt after the successful tests this sign was erected on the road leading to LAMPF.

(Photos Los Alamos)

straight. With such long straights the experimental arrangements could be very flexible. In addition options are being kept open for running a colliding beam of antiprotons, deuterons or electrons further in the future.

LOS ALAMOS 100 MeV at LAMPF

Ten days ahead of schedule the Los Alamos Meson Physics Facility (LAMPF) 800 MeV linear proton accelerator achieved a 100 MeV beam through the first two stages of the three-stage linac on June 21.

The complete accelerator is scheduled to begin operation by July, 1972, with a full programme of experiments starting in January 1973. The 100 MeV test gives confidence that the major innovations in design which were required to extend the duty factor and average power by a factor of more than 10 over previous drift-tube accelerators are valid.

A peak beam current of 16 mA has been achieved but the average beam current has been held down to 10 μA and the beam has not been run at the full duty factor of 6 % and 1 mA average current because of induced radioactivity problems in the tunnel area.

The June 21 'turn on' and following experiments have tested the 750 keV Cockcroft-Walton injector, beam transport, and the four tanks of the completed Alvarez section. Slightly more than one year ago, on June 10, 1970, the first beam of 5 MeV was sent through the first stage of LAMPF testing the injector, the beam transport system and the first tank of the Alvarez section. The next major test for LAMPF will occur this autumn when a portion of the side-coupled cavity section, developed at Los Alamos by Dr. Knapp and Dr. Nagle, will be operated to accelerate protons for the first time. Beam energy for this test will be 211 MeV.

ARGONNE At the ZGS

The experimental programme at the 12 GeV Zero Gradient Synchrotron is in full flood again after sorting out the magnet coil troubles earlier this year (see June issue page 163). The experiments include:

A study of the eta-pion mass spectrum using optical spark chambers to look at the interaction $\pi^- p \rightarrow \eta \pi^- p$;

A detailed examination of the A2 meson mass region, looking at both charged versions of the A2 via their decays into two kaons, to compile further evidence concerning A2 splitting ;

A study, using wire spark chambers, of the differential cross-section for elastic scattering of positive kaons on protons (from 1 to 1.5 GeV/c in 50 MeV/c steps) checking recent phase shift analyses and the possibility of a Z^*_1 (1900) resonance ;

A measurement of the differential cross-section of the interaction between a neutral kaon and a proton giving a positive kaon and a neutron over the momentum range 0.5 to 1 GeV/c ;

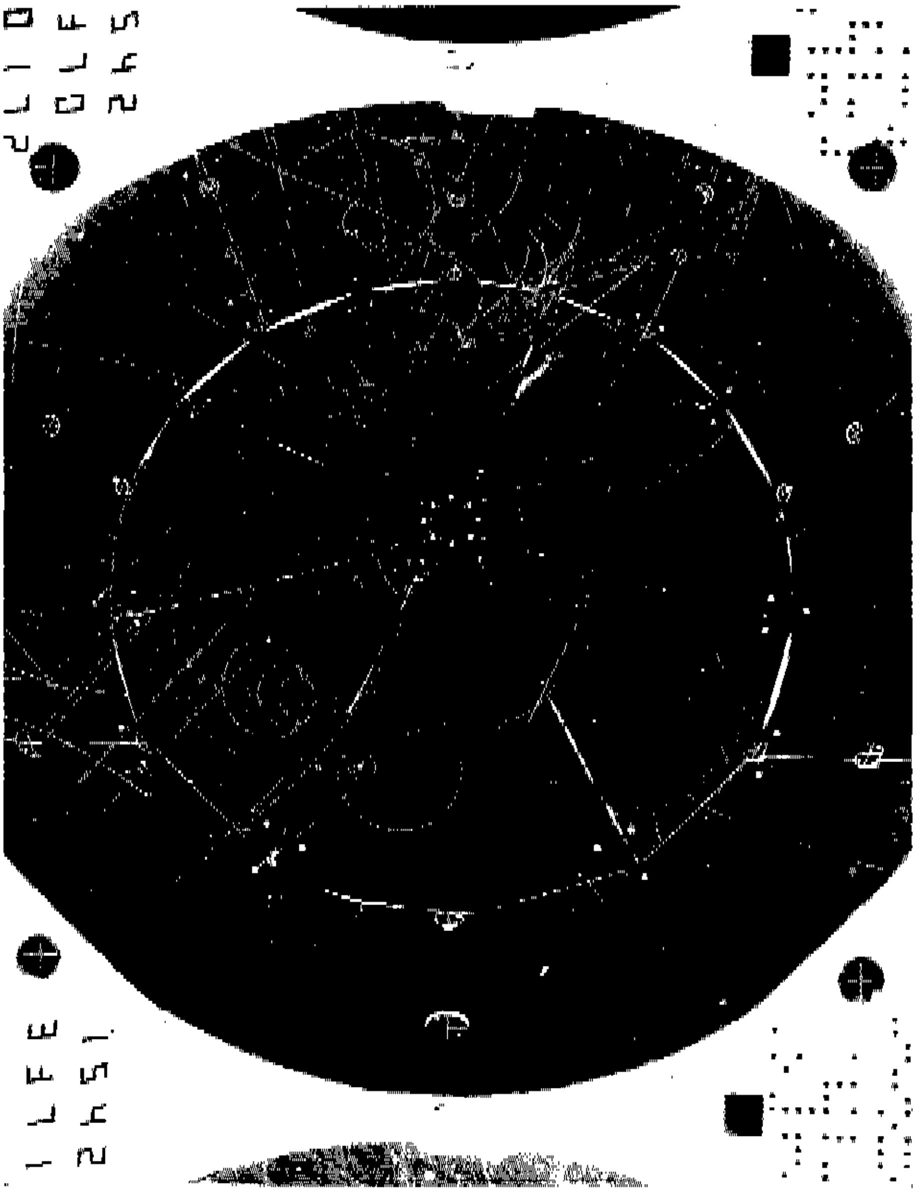
A high precision measurement of the charge asymmetry in the decay of the neutral kaon into three leptons (including an electron) as a very accurate test of the $\Delta S = \Delta Q$ rule ;

Meson production studies from negative pion-proton and negative kaon-proton interactions using a large aperture, high resolution spark chamber spectrometer system ;

Virtually the same spectrometer system will be used to investigate reactions giving neutral kaon - lambda and neutral kaon - sigma over the range 3 to 6 GeV/c.

All the above experiments draw their particles from 'External Proton Beam I' which now extends into a new Annex. Argonne has an unusual targetting system in which the ejected beam is passed through thin targets to produce secondary beams finishing up in a thick target. Passing through the near transparent targets does not damage the emerging proton beam very much as far as the subsequent beam optics are concerned. As many as eight beams have been run simultaneously in this way which is very efficient exploitation under the present operating conditions of the machine which prevent slow ejection into two experimental areas at the same time (of which more later).

The 'External Proton Beam II' is feeding a neutral missing mass survey over the range 1.4 to 2.8 GeV which will also look for doubly charged particles (using an incoming positive pion beam rather than negative pion beam) from 1.1 to 1.8 GeV. EPB II is also the source of neutral kaons for a CP violation experiment which is studying the time dependence of the two pion decays of $\bar{K}^0$ and K^0.



A beautiful photograph of the tracks of 12 GeV/c protons interacting in the 12 foot hydrogen chamber at Argonne showing the excellent quality of the pictures now being obtained. Enthusiasts might like to search for ... a two prong event going to two gammas, a four prong event with a two prong neutron star (a pion, muon, electron decay sequence on one prong), a [illegible] prong event, and a [illegible] prong event with kaon decay. The chamber has built up its neutrino pictures in hydrogen to a quarter of a million and is being filled with deuterium to continue neutrino experiments with a million pictures in deuterium.

A neutral beam is drawn (at 7°) from an internal target for polarization measurements in neutron proton charge exchange scattering from 4 to 12 GeV/c using an improved polarized target and a wire spark chamber spectrometer system.

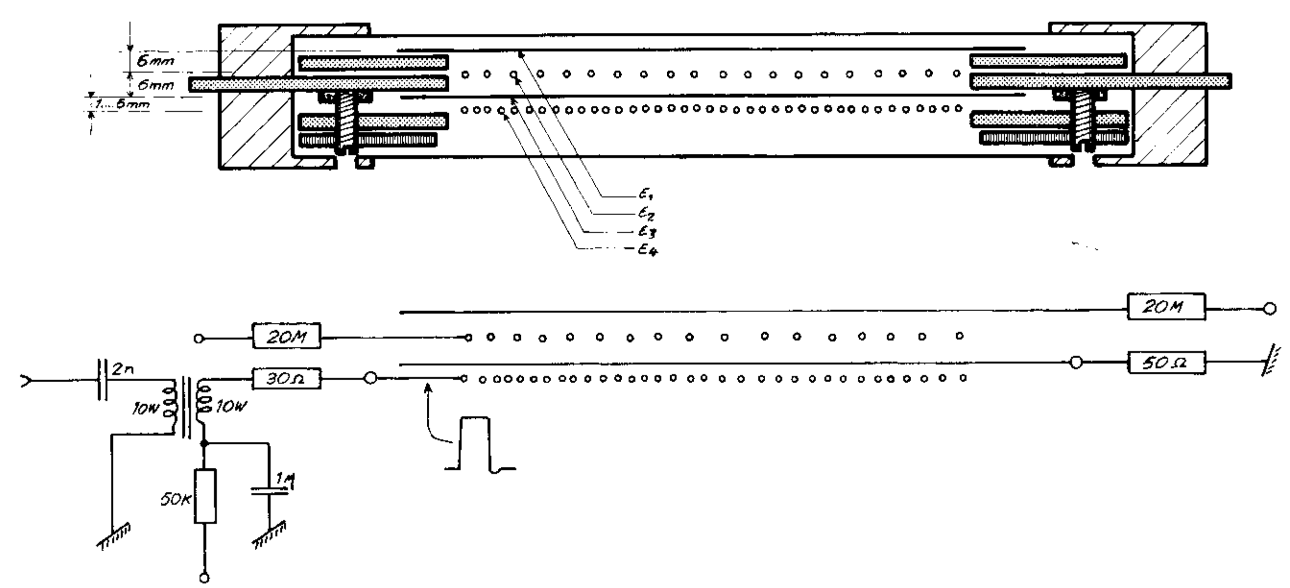
The 12 foot hydrogen chamber is the only bubble chamber now in operation at Argonne (The 30 inch has moved to Batavia and is being rapidly reassembled there to be ready for cooldown on 15 October so that physics could start in November.) The chamber performance is regarded as very satisfactory and the superconducting magnet in particular is working superbly. The chamber expansion system has been improved and vacuum problems due to vibration have been cleared. Interactions in the visible volume due to thermal neutrons creeping in have been cured by applying external cadmium shields. To obtain even intensity across the bubble chamber film, special hand painted filters have been fed into the chamber optics (what W.T. Welford has described as a nice blend of art and science) and have proved very successful. The quality of the pictures now being obtained can be judged from the photograph. The chamber is scheduled to be filled with deuterium in September having by then amassed a quarter of a million hydrogen photographs in a neutrino experiment. When the neutrino experiment is running the bubble chamber devours the full intensity, at full energy, that the ZGS can provide (with the exception of a tiny beam to the $\Delta S = \Delta Q$ experiment).

Modifications to the ZGS

The accelerator has been operating at an average intensity of around 2×10^{12} protons per pulse. This is a little below, for some obscure reason, the intensity that the ZGS can normally average (around 2.4×10^{12}). When the neutrino experiment is under way there is no flat-top on the machine cycle and the pulse repetition rate is about one per three seconds. When the slow ejected beams are in operation there is usually a 700 ms flat top.

Early next year a major shutdown of the ZGS is planned for the installation of new titanium vacuum chambers. These will replace the initial chambers made of corrugated stainless steel where the corrugations were filled with epoxy which for some time has been showing signs of radiation damage — sections peeling away or bubbling up. The new chambers have apertures to accommodate 42 pole face windings. 28 of these will be used for field correction and the remaining 14 will be available to induce a 2/3 resonance for slow ejection. This will enable both slow ejection systems to be operated simultaneously which is not possible with the present integer resonance ejection. It is estimated that four months will be needed for the installation and about a further two months to re-master the machine before opening the physics programme again.

After this, the next ZGS improvement is likely to be the bringing in of the 200 MeV booster (where the first encouraging tests were described in the June issue page 164) to raise the ZGS intensity to 10^{13} protons per pulse or above. The booster vacuum chamber is currently receiving attention and it should be ready for operation again in September hopefully going to 200 MeV. Work is continuing on the various components needed for negative hydrogen ion injection into the booster (including such major technological advances as the removal of a paper cup found strategically placed in a beam transfer pipe). However, whether further tests begin in Septem-



Sectional view of a hybrid chamber in which the upper pair of electrodes forms a proportional chamber and the lower pair a spark chamber. The voltage supply system is indicated in the lower diagram.

ber depends on the success of negative hydrogen ion injection into the ZGS which would enable the booster to run interleaved with the feeding of the ZGS. A Heath Robinson type stripper is ready for installation in the ZGS to enable as many as 100 foils to be changed automatically without halting machine operation. If all goes well it is hoped that 200 MeV injection into the synchrotron will become routine in about a year's time.

KARLSRUHE Hybrid chambers

The composite detector known as a 'hybrid chamber', which tries to fasten onto the advantages of both the proportional chamber and the spark chamber, was described in the report on the Dubna Instrumentation Conference (vol. 10 page 275). This reported the work of the originator of the idea, J. Fischer (Brookhaven) and colleagues. Since then a Karlsruhe group (information from V. Bohmer and H. Schopper) have developed hybrid chambers, four of which are incorporated in a neutron-proton scattering experiment at the CERN proton synchroton and are being used for the first time this month (August).

The proportional chamber, invented at CERN, has the advantage of considerably better time resolution (less than 100 ns) than conventional spark chambers and can be operated at much higher counting rates (about 10^4 per second). In conventional chambers between 0.5 and 1 μs is involved in the memory time — in the transmission of signals, in performing the electronic logic sequences, which in conjunction with counters decide whether the event shall be recorded, and in the application of the high voltage pulse which 'materializes' the track of a charged particle as a spark. This is much longer than the time resolution of the proportional chamber. However, the spark chamber gains in better spatial resolution (positioning a particle to less than 0.3 mm compared with 1 to 2 mm) and particularly in having much less expensive signal read-out systems. Ferrite core or magnetostrictive read-out is much cheaper than the proportional chambers requirement of an amplifier per wire usually costing at least 20 Swiss francs per wire.

The 'hybrid' consists of a proportional chamber and a spark chamber with a drift gap between them. Information from the proportional chamber is transferred across the gap to the spark chamber and read out from there. Four electrodes are enclosed in a gas-filled space. Referring to the diagram — electrodes 1 and 2 form the proportional chamber. The passage of a charged particle liberates electrons which move, under the influence of the static voltage difference applied between the electrodes, to electrode 2, which is a plane of wires, creating an avalanche in the immediate vicinity of a wire. Some of the avalanche electrons do not end on the wire but come under the influence of a field in the drift gap which pulls them to the planes of wires of electrodes 3 and 4. This field and gap width are selected so that during the avalanche drift time the electronic logic has time to decide whether to record the events. If it is to be recorded a high voltage pulse is applied between electrodes 3 and 4 just as the cloud of electrons is present. The amplitude of the pulse is kept sufficiently low so that a spark will not occur at the tracks of individual charged particles but only where the avalanche electrons are present. The track memory time no longer dictates the time resolution which depends only on the length of the avalanche and on the shape of the high voltage pulse.

The Karlsruhe hybrid chamber design has electrodes 1, 3 and 4 made of wires 0.1 mm diameter and 1 mm apart. Electrode 2 is of tungsten wires 35 μm in diameter 2 mm apart. The interelectrode spacing for 1-2 and 2-3 is set at about 6 mm and 3-4 is variable from 1 to 5 mm. The useful area is about 0.3×0.3 m^2.

Tests with the chambers gave the following results. The best time resolution (about 100 ns) was obtained when a gas mixture of neon, helium and argon was used having been blown through methanol or ethanol at room temperature. Unfortunately it was then impossible to determine the discriminating power (how well the chamber was distinguishing the required tracks from others) because the time for the avalanche electrons to reach the spark chamber section was too short. Trying to lengthen this by reducing the strength of the field which pulled them across the drift gap also reduced the detection probability (probably because of higher diffusion and attachment losses in the drift gap). Sacrificing some time resolution (120 ns) by reducing the added alcohol content made it possible to study the discriminating power which was shown to depend critically on the distance between electrodes 3 and 4.

The measurement of detection probability while varying the voltage applied in the proportional chamber (between electrodes 1 and 2) showed a maximum detection plateau extending 60 to 80 V which is rather narrow but adequate for reliable operation. As the voltage is pushed higher the sparks occurring between electrodes 3 and 4 tend to travel back to the proportional chamber region. Spontaneous breakdown occurs at still higher voltages. Detection probability is also affected by the amplitude of the high voltage pulse applied in the spark chamber (between electrodes 3 and 4). For example an increase of 50 V can push the probability from 93 to 95 % but the recording of individual tracks rather than the desired avalanches then increases from about 4 to 8 %.

Further improvements are being attempted by using different gas mixtures, by reducing the distance between electrodes 1 and 2 and by reducing the wire spacing in electrode 2 to 1 mm.

Overall the tests have shown that the hybrid chamber can have a time resolution comparable to that of the proportional chamber while gaining the simplicity and cheapness of spark chamber read-out. Such chambers could have a healthy future in detection systems where the required counting rate goes up to about 10^4 per second.

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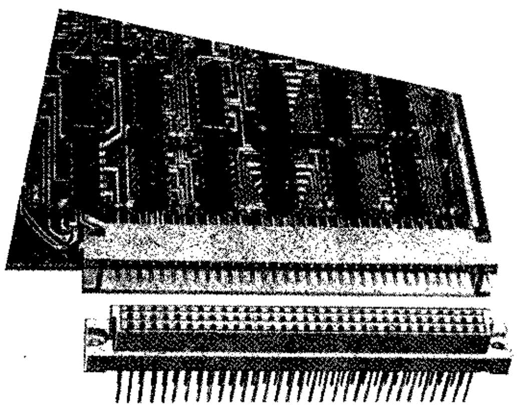

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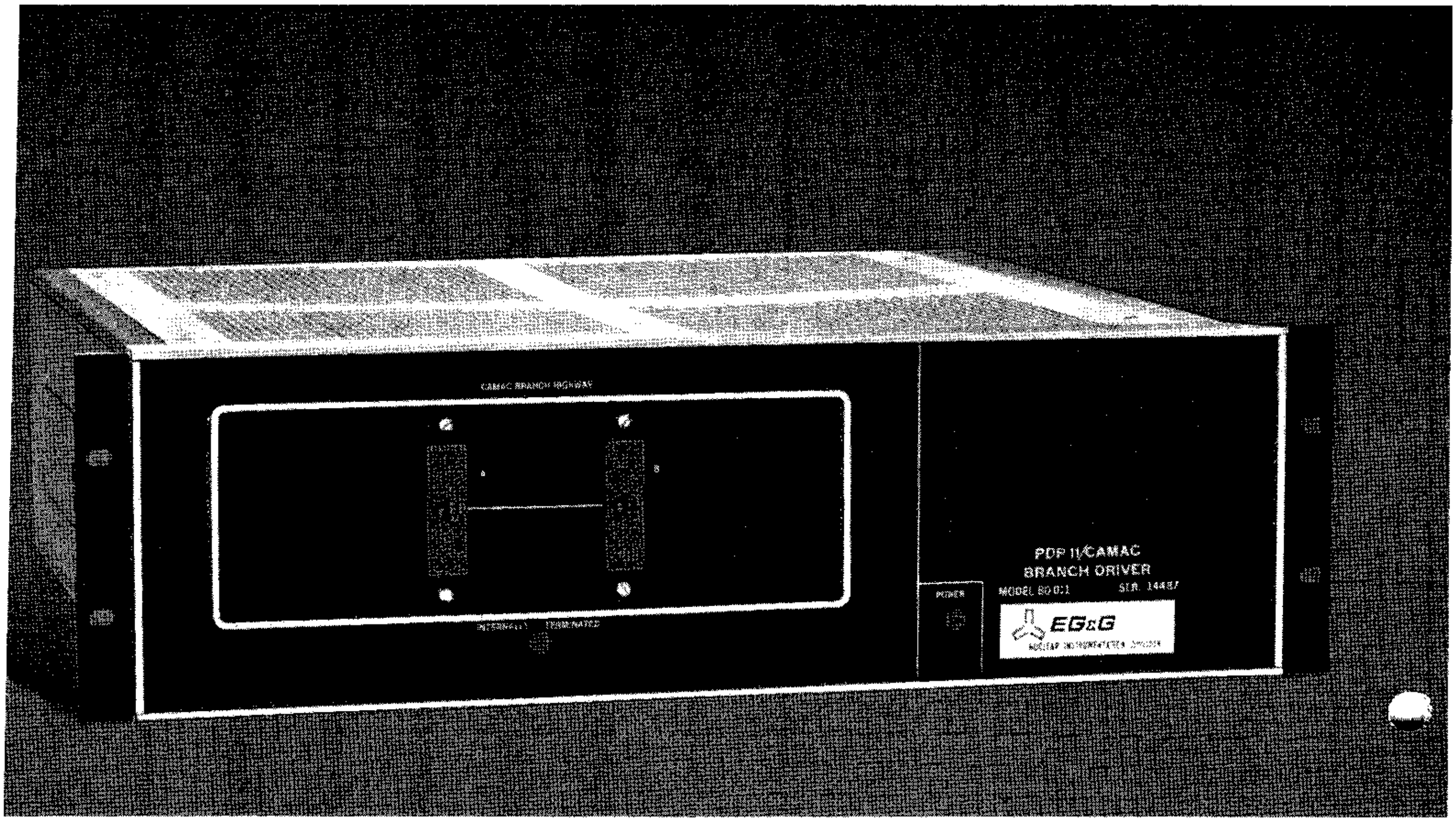

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- As a system element, one BD011 will support up to seven CAMAC crates, and multiple BD011's can be integrated into a single system.
- Designed to take maximum advantage of the addressing structure, software and timing flexibility of the PDP11.
- Transfers single CAMAC data words via Programmed Data Transfer; or if so instructed, becomes BUS Master and transfers blocks of contiguous data via DMA.

Branch Driver Test Module TM024

- Functions as an integral part of the system diagnostic software and allows CAMAC arrays to be debugged to the module level.
- Double-width CAMAC module.
- Diagnostic and data-handler software provided.

Contact EG&G or your nearest EG&G Sales Office for complete details of the BD011, TM024, and our other CAMAC system products.

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