

Comparison of the performance of a LMN and a butanol target for elastic scattering of protons ($pp \rightarrow pp$ at 1.22 GeV/c). The number of events is plotted vertically against the scattering angle. The advantage of the butanol compared to the LMN target is the reduction of the background by a factor of 2.5, if only very loose co-planarity requirements for the interaction are applied.

Butanol targets

Since it became technically feasible from 1962 to build polarized proton targets, they have been used in about fifty experiments at CERN and in a number of other Laboratories. Up to now, these targets have been made of a complex substance (LMN) containing a certain proportion of 'free' protons (nuclei of hydrogen atoms) whose spins become polarized at very low temperature (around 1° K) under the combined influence of a high constant magnetic field of about 20 kG and a weaker magnetic field with a very high frequency, generally around 70 000 MHz. (The ideas and techniques involved were described in CERN COURIER, vol. 7, page 28.)

Thus polarized, these targets may be used in a wide variety of experiments — to determine the spin or parity of strange particles or resonances; to study the role of spin in the dynamics of the interaction by measuring polarization parameters, spin rotation, spin-spin correlation, etc; to check the invariance properties of strong or electromagnetic interactions; to

polarize intense neutron beams by transmission (this was done recently for example, with neutrons emitted by an underground atomic explosion, by a Los Alamos group in Nevada).

Until 1969, LMN (double nitrate of lanthanum and magnesium — $\text{La}_2\text{Mg}_3(\text{NO})_{12} \cdot 24\text{H}_2\text{O}$) had been used exclusively. In spite of the high percentage polarizations obtained, varying from 50 % to 70 % according to Laboratory, this substance has the great drawback, as can be seen in the chemical formula above, that it contains many complex nuclei, which are not polarized. Moreover, the percentage polarization is very sensitive to radiation damage from the beams: for example, polarization is reduced to about half its initial value after the target has been exposed to 2×10^{12} minimum ionizing particles per square cm.

In recent years, several Laboratories have been carrying out research into substances which have a higher density of hydrogen nuclei and less heavy nuclei and which are more resistant to radiation than LMN. At CERN, this research began in 1966, carried out by M. Borghini, S. Man-

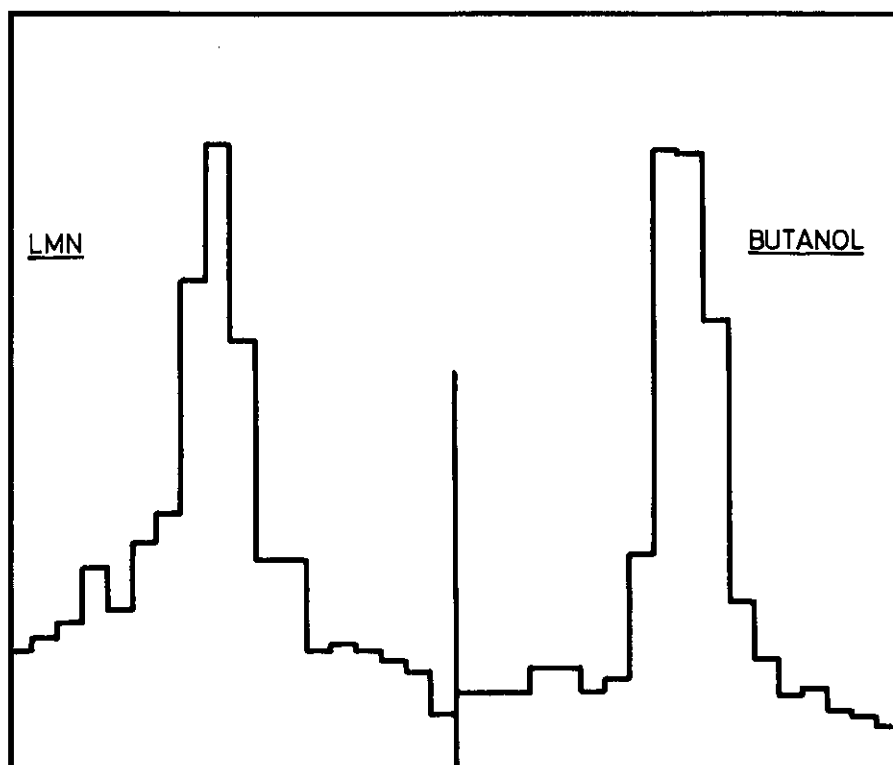
go and O. Runolfsson, and quickly showed good results with ethyl alcohol diluted with a little water. Unfortunately, these results were sometimes difficult to reproduce. (Nevertheless, these targets were used at the Cambridge Electron Accelerator in 1968 to check time reversal invariance of the electromagnetic interaction.)

A systematic study has been made of alcohol mixtures, alcohol and water mixtures and of the role of dissolved molecular oxygen, which led to the choice of a mixture of 95 % normal butanol ($\text{C}_4\text{H}_9\text{OH}$) and 5 % deoxygenated water containing approximately 1 % free radical porphyrine (percentages by weight). Reproducible polarizations of the order of 40 % can be obtained in targets of volume 5 to 10 cm^3 .

The first butanol polarized target was used at CERN in March 1969 for the study of positive kaon - proton and anti-proton - proton scattering at several GeV by the CERN-Holland group, and a second in May for the study of elastic scattering using proton, positive and negative pion, and positive and negative kaon beams at over 5 GeV by the CERN-Orsay-Pisa group. A third target of the same design constructed at Lawrence Radiation Laboratory, Berkeley, has been in use at the Stanford Linear Accelerator since April again checking, with greater precision, time reversal invariance in the electromagnetic interaction, and it is now being used to measure the polarization parameter in positive pion photo-production at high energies. For these latter experiments it has been necessary to have beams of very high intensity, for example 10^{11} electrons per second: alcohol targets are about 200 times more resistant to radiation damage than LMN and can tolerate these conditions.

The following table is a comparison of some of the characteristics of the two substances at a field of 25 kG and a temperature of 1° K.

	LMN	Butanol
Maximum polarization	70 %	40 %
Hydrogen density (g/cm^3)	0.06	0.12
Bound/Free protons	15	3.2
Acceptable number of minimum ionizing particles/ cm^2	2×10^{12}	4×10^{14}



Filling the large container with frozen butanol spheres at 77° K. The cryostat was pre-cooled and covered with plastic to avoid water condensation. The photograph was taken in the polarized target laboratory at CERN where target materials are developed and tested before use in an experiment.

As can be seen, the percentage of polarized hydrogen nuclei is higher in LMN than in butanol, which is an advantage of LMN for certain experiments, for example the polarization of neutron beams by transmission. However, butanol contains twice the amount of polarized hydrogen and 2.5 times less protons or neutrons bound in complex nuclei per unit volume. These two factors are important: they determine the number of useful events produced on polarized hydrogen and the number of background events produced on bound non-polarized protons or neutrons which must be eliminated from the experimental data when it is analysed. The advantage that butanol has over LMN is the ease with which it eliminates background though this depends on the nature of each experiment.

For experiments such as elastic scattering of protons, pions or kaons on polarized protons, which give rise to two charged particles of a relatively low energy, it is possible to distinguish between useful and background events using an LMN target and there is therefore no great call for butanol targets. This is not the case if the cross-sections are low and if the interactions under study are partly masked by other interactions produced simultaneously.

For other experiments, such as the study of charge exchange reactions $\pi^+ p \rightarrow \pi^0 n$ and $\pi^- p \rightarrow \eta^0 n$ which have already been studied with LMN at CERN and $K^+ p \rightarrow K^+ n$ at Argonne, the number of useful events would be increased by a factor of the order of 5 to 10 if it was not necessary to observe the neutron. Polarized butanol targets are then a considerable improvement on LMN. Proposals for experiments of this type have recently been put forward at CERN.

One other advantage of butanol polarized targets which has already been mentioned is their resistance to radiation. This is only a minor advantage for the intensities of ordinary particle beams used for experiments at CERN. However, for the low cross-section interactions, such as high energy wide-angle proton - proton scattering, elastic or inelastic electron scattering and photo-production it would be impossible to use LMN. The develop-



CERN/PI 104.10.69

ment of butanol targets is therefore of crucial importance.

Polarized proton targets have aroused great interest at CERN and other Laboratories, and efforts are being made to improve them. Work is going on in three directions:

- 1) searching for new substances;
- 2) lowering the operating temperature to 0.5° K for instance;
- 3) increasing the magnetic field to 50 kG and the frequency of the alternating field to 140 000 MHz.

The most recent progress made on substances is the production of strong polarizations (50% at 1° K) with ethyl glycol $C_2H_5(OH)_2$ containing a chrome complex by H. Glattli et al. at Saclay. Although the glycol contains less hydrogen and more complex nuclei than butanol, it is interesting because of its higher polarization.

Concerning the influence of temperature on polarization; measurements taken at 0.5° K by A. Masaike et al. at Saclay and R. Hill et al. at Argonne have given polarizations of 82% in ethyl glycol and 67% in butanol respectively using small samples of 10 to 100 mm³.

Finally, superconducting coils, which enable fields of 50 kG to be obtained, have now been constructed or are under construction at Argonne, Saclay and CERN and new results may be expected soon.

PS Shutdown

The annual shutdown of the PS began on 13 October, to last until 26 November. It is being used for the usual overhaul and maintenance work and for a large number of modifications to a variety of components. Most of these modifications are

relatively minor, and it would take up too much space to give a detailed list here. Only the more important ones will therefore be mentioned.

Linac

A lot of work will be done on the Linac in the context of the PS improvement programme. The pulse repetition frequency is to be doubled (from 1 to 2 per second) and the pulse length is to be increased fivefold (from 20 to 100 μs). Points worthy of special mention include:

- a) installation of optical links with the ion source control platform (five infra-red channels such as were described in CERN COURIER vol. 9, page 104);
- b) installation of new digitized servo-controlled tuning systems based on the use of a stepping-motor (200 steps per revolution) which will allow certain changes in the accelerating field in the linac tanks to be computer-programmed;
- c) modification of the power dividers and dephasers of the cavity amplifiers, which will be fitted at the inputs to the CFTH amplifiers;
- d) modification of the two modulators in the r.f. circuit (Siemens and driving modulators) to allow power pulse lengths to be increased from 200 to 300 μs;
- e) an increase in the cooling capacity of the pulsed quadrupoles of cavity No. 1.

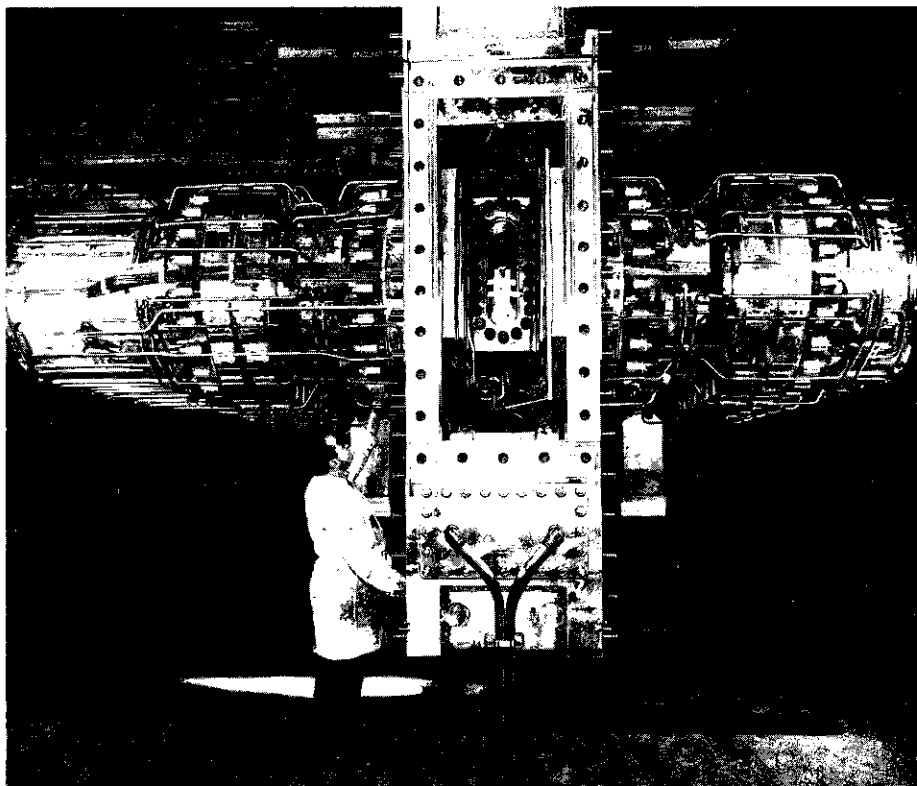
The importance of this work on the Linac is explained by the fact that this PS shutdown is the last before connection is made between the Linac and the Booster at the end of 1970.

Synchrotron ring

The main work to be done on the PS includes the installation of the fast ejec-

The 2 metre hydrogen bubble chamber minus its magnet. The chamber is undergoing a series of modifications during the PS shutdown and for this the two halves of the magnet which normally hide the chamber, safety tanks, cooling pipes etc. are rolled back.

The chamber joined the select band of 10 million picture takers on 6 September. This figure has been reached in five years of operation.



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tion system for the Intersecting Storage Rings in straight section 16 and the setting up of the beam-line to the ISR for the first fifty metres from the PS. This represents a considerable volume of work and will involve almost all the PS groups, the ISR Division and the Technical Services and Buildings Division. The major part of the work will be done during the shutdown, but the rest will continue into February or March 1970. An enlarged vacuum chamber will be installed in four magnets, two downstream and two upstream of straight section 16.

It will also be necessary to turn two magnets around in this region to have the aperture opening towards the outside of the ring so that the ejected beam can emerge. In fact two magnets will be changed with two others in the ring which have the right configuration. Shims have to be fitted to correct stray fields; new vacuum tanks will be installed to take septum magnets; almost all straight sections have to be modified for the installation of dipoles for beam orbit deformation; beam transport magnets,

a beam dump and beam observation systems have to be installed.

Further modification involves the replacement of the vacuum chamber elastomer gaskets by metal ones over one-tenth of the circumference (sector No. II) where turbomolecular vacuum pumps and ion pumps will be installed to give a better vacuum than the oil-diffusion pumps previously in use. The supply lines to these ion pumps will be positioned in an extension to the central ring building.

Preparatory work will also be done for the fitting of a second kicker magnet in straight section 13 in the Spring of 1970. This magnet, which will be identical to the kicker magnet in straight section 97, will reinforce the perturbations induced in the orbit by the ejection magnet to provide greater flexibility in beam sharing.

Some work will be done in preparation for the Booster, especially:

- a) enlarging the aperture through which the Linac-Booster injection line passes;
- b) installing a heat dissipation system in that part of the Booster injection tunnel adjacent to the PS;

- c) piercing an aperture for the connection of the Booster to the PS and building shielding around this aperture;
- d) installing cabinets in the main control room for the Booster controls.

In readiness for the increase in intensity of the proton beam, the shielding of the PS ring will be reinforced. Almost half the ring (between the East and South Halls on the Salève side) will be covered with a further layer of earth a metre thick. This will provide the maximum thickness which the ring structure will safely carry. The other half will be covered when work on the Booster is completed.

External Beams

A large number of alterations are also being made in the experimental halls:

South Hall

- modification of the beam feeding the 81 cm hydrogen bubble chamber (beam k13 will replace k10);
- changing the separators of beam m7 from internal target 1;
- installation of a separator in beam q8 from internal target 8 (q8 becomes m8).

East Hall

- replacement of the pion beam p3 by a proton spectrometer (p3 becomes s5);
- fitting of a helium-cooled hydrogen target in the East target zone to feed s5.

Work on the bubble chambers

The PS shutdown also allows work to be carried out on the three bubble chambers in service at CERN, which have operated very satisfactorily over the past year. The 2 m hydrogen chamber has taken more than 3.8 million photographs during the operating period from November 1968 to October 1969. On 6 September it reached the total of ten million photographs, taken since it came into operation less than five years ago. The 81 cm hydrogen chamber took 1.9 million photographs in the same period (bringing its total close to 13 million since 1961). The 1.2 m propane chamber had taken 1.6 million (bringing its total to 7.5 million since 1960).

No major modifications are to be made to the propane and 81 cm chambers but some improvements will be made to the

2 m chamber. The main one involves the replacement of the glass windows (17 cm thick) which form the two side walls of the chamber, by windows which have fiducial marks better suited for automatic measurement. The new windows are, in fact, the spares already in existence and the two windows which are being removed will, in turn, be re-engraved and put into store as spares.

A very careful check will be made on all the seals to reduce leakage to a minimum. It is intended to use deuterium rather than hydrogen for several months in 1970 and deuterium is about two hundred times more expensive than hydrogen. The storage capacity for deuterium will be increased.

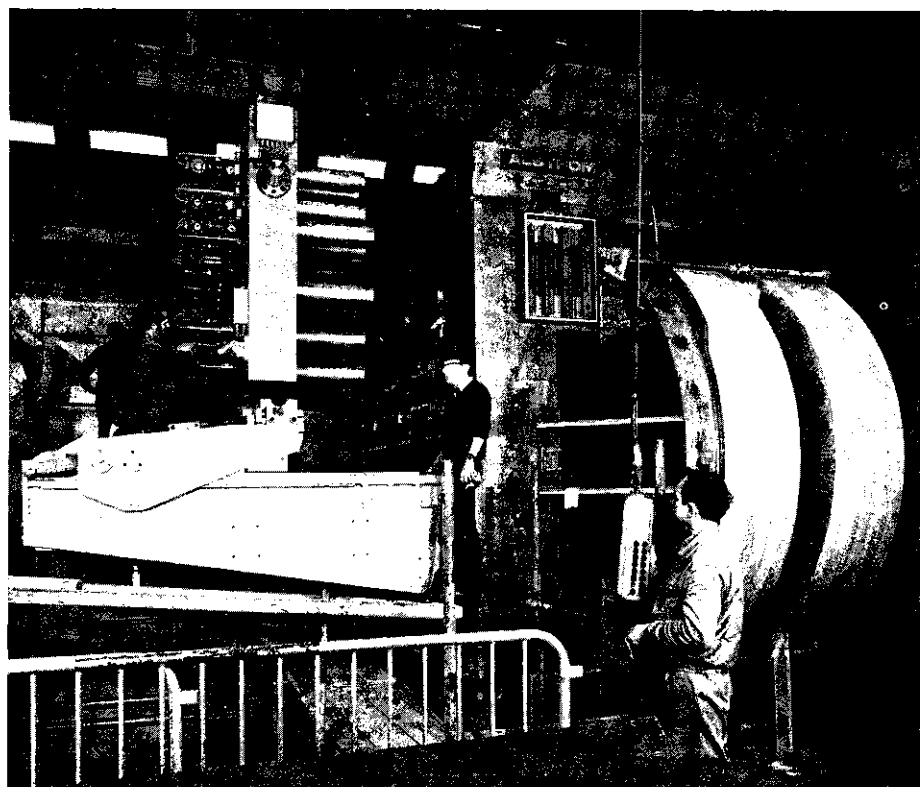
Three of the four large motor generators which supply power to the 2 m chamber are being returned to the manufacturer for general overhaul (which is done every two or three years). The compressor control room will be integrated with the main bubble chamber control room.

Modifications will be made to a section of the outlet line connecting the vacuum tank of the chamber to the safety sphere to allow magnets to be fitted very close to the chamber for low energy beams. Finally, the expansion system, the vacuum and the cooling systems will be completely overhauled.

During the shutdown the magnetic field in the chamber will be mapped for a careful check with the previous map. Measurements will be made at about 1000 points in the chamber (three measurements at each point); the density of the points being greater in the areas where the field is least uniform. The results will be printed on tape. In addition, a computer will be used by way of experiment to make several measurements at each point and to calculate the mean value and the standard deviation.

CAMAC Developments

To meet the ever increasing electronics needs of research centres and industry, 26 nuclear research organizations in Europe, members of the ESONE (European Standard for Nuclear Electronics) Committee began work in 1966 to establish standards for the construction of electro-



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nic plug-in modules and their crates. These modules had to be specially designed in view of the increasing use of computers, the aim being to make it easier to use automatic data acquisition and processing devices.

In May 1968 at the ESONE conference held in Rome, the principle of these standards was approved and was called CAMAC. At the same conference, the first part of the standards, covering the mechanics and logic of the interconnections of modules on the same crate, was adopted (CERN COURIER, vol. 8, page 314).

The second part of the standards, concerning the use and control of CAMAC crates (crate to crate links, crate to control system links, crate to adapters for computers, etc.) and of the nature and level of the various signals used for this purpose, had still to be defined.

This second set of standards, which has been studied by several Working Groups, was adopted at the ESONE Conference held at the end of September this year at Petten (Netherlands). It includes the following points:

A further stage in the assembly of the new heavy liquid bubble chamber, Gargamelle. The pipes which convey pressure changes to the diaphragms of the expansion system are manoeuvred into place at the end of September. The large magnet of the chamber is on the right. The seven nitrogen tanks of the expansion system are also installed in the assembly hall and tests of the system will be carried out using two large tanks to simulate the chamber body itself which will not arrive until early 1970.

1. the method of synchronizing external signals to the crates (this is the call-response-stimulus type);
2. the transfer system for these signals (this is the asymmetrical-twisted-pairs type);
3. the method of processing requests from the modules. The system chosen uses data transmission lines and offers a range of possibilities of directing requests because of the (optional) use of a rear connector which permits a possible link with an additional request processing unit;
4. crate controller: this is a link unit which is placed on each crate (taking the place of two or three modules) and interconnects with the main system. At the command of external signals, it addresses the required module or modules. It also generates the basic CAMAC cycle and varies the signals according to their destination;
5. nature and level of the signals, synchronization of commands and data transmission. These signals are of the 'classic micrology' type. Loads are

An unusual view into the 1.2 m heavy liquid bubble chamber which is also having a wash and brush up while it is out of action during the PS shutdown.



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- designed for a maximum of 8 crates ;
6. the type of main (frontal) connector for the crate controller which is responsible for crate-to-exterior links.

Interest from Industry

Many European manufacturers of electronics equipment are interested in the CAMAC standards and several of them (five in France, two in Italy, four in the Federal Republic of Germany, eight in the United Kingdom, one in Sweden and two in Switzerland) have already put power supplies and CAMAC crates and modules on the market. It is interesting to note that this interest in CAMAC is not limited to the field of nuclear electronics, but extends to other sectors of data handling, such as electronics in medicine, servo-controls in industry, automatic units, etc.

All Laboratories belonging to ESONE are working on the manufacture of CAMAC systems. At CERN, three systems are being built, two of which will be used in nuclear physics experiments. All three conform to CAMAC standards in dimensions and inter-module connections and they are equipped with an external logic

system which, although, it was designed before the second stage of the CAMAC standards was adopted, differs little from the CAMAC standards.

Information on the first part of the standards is already available (Euratom report EUR 4100). The second part will be published as a preprint at the end of the year and will be available from ESONE members.

CODD in action

The CODD (Closed Orbit Digital Display) system, which enables the trajectory of a single proton bunch to be measured as it goes round one turn of the machine, has been linked to the IBM 1800 computer in the control room since the end of August. The PS is the only accelerator with a system of closed orbit measurement of this type. CODD (described in CERN COURIER, vol. 8, page 177) uses 20 beam observation stations of a new design from which numerical signals are transmitted to the computer. It has three functions :

1. to present numerical results on a screen, before processing ;
2. to punch cards recording these signals for later processing;
3. to process signals giving the beam position of a single bunch at the 20 observation stations.

The results may be printed out or presented in analogue form on an oscilloscope screen. Since May 1969, the measurement system has been in operation and a series of tests were carried out in preparation for a direct link with the IBM 1800.

CODD makes it possible to measure the trajectory of a bunch to be ejected by the fast ejection system. A series of tests has therefore just been carried out to compare signals from CODD with the known oscillations produced by the fast kicker magnet. This served to check the functioning of the CODD system.

Until 13 October, the beginning of the annual PS shutdown, CODD was used for the automatic registering on punched cards of the characteristics of a large number of closed orbits at 10 GeV. This has given important statistics on the behaviour of the machine and information functioning of the CODD system.

At the moment only the 20 new observation stations are in use. These have the advantage over the old ones of being able to take measurements over a wide range of beam intensities. Nevertheless, because of the increased possibilities if there were double the number of measurement points, it is planned to link the 20 old stations, which are compatible with the new ones, to the system at the beginning of 1970.

Among the improvements to be carried out on CODD (in addition to bringing in the 20 additional stations) are modifications to the synchronization system and the installation of a semi-automatic calibration system. Artificial calibration signals which simulate a known beam position will be transmitted to a detection station. By observing the results at the end of the measuring sequence any error introduced by the electronics can be determined and the computer can automatically make any necessary corrections when receiving signals from the proton beam.