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MEMORANDUM

To : PH III Committee

From : Torino Group (G.C. Bonazzola, T. Bressani, E. Chiavassa, S. Costa, G. Dellacasa, L. Ferrero, A. Musso, L. Pasqualini and G. Rinaudo)

Concerning : Possible experiments at the SC with a large-acceptance magnetic spectrometer

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We have recently completed an experiment on the production of hypernuclei by the (K^-, π^-) reaction at $p_K = 400$ MeV/c using a set-up which can be modified and improved to perform experiments at the Improved SC.

Basically it consists of a non-focusing large-acceptance double magnetic spectrometer, using a single magnet with the target in the middle (see Fig. 1). The trajectories of the particles are measured by means of six pairs of multiwire proportional chambers (MWPC) placed in front of, inside and behind the magnet. In the first part of the magnet we analysed the momentum of the incoming K^-, in the second one that of the outgoing π^-. We accepted the technical difficulties connected with having the majority of the detectors (MWPC and scintillators) inside the magnetic field and with the long computer time needed to reconstruct the momenta of the particles from the measured co-ordinates, because this solution offered the advantage of a wide solid angle for detecting the outgoing particles ($\sim$ 0.1 sr) and a large momentum acceptance for them ($\sim$ 60 MeV/c). The dimensions of the magnet poles are 200×50 cm^2, with a pole gap of 30 cm (standard MNP 24 magnet). In the first arm the gap was reduced to 15 cm by two shims specially designed to accommodate the three pairs of MWPC labelled C_2, C_3, C_4 in Fig. 1. A field intensity of 15 kGauss is reached in this region. In the second arm (gap of 30 cm) a field intensity of 8.5 kGauss is reached. 1700 wires were used in this experiment, on line to a PDP 11/20 (8 K) computer.

The momentum resolution achieved at 400 MeV/c was $\sim$ 1% FWHM in the first arm and $\sim$ 1.5% FWHM in the second arm. The limitations on the momentum resolution arose mainly from:

1) the spatial accuracy of the MWPC's (a wire spacing of 2 mm was used).

2) the multiple Coulomb scattering in the materials of the central MWPC of each arm (windows of the MWPC, windows of the helium bags, gas filling the chamber, the cathode and anode wires, air between the chamber and the walls of the helium bags).

3) uncertainty in the reconstruction of the momenta by the sampling-parameter method, due to the strong inhomogeneities of the magnetic field.

Substantially better resolution can be obtained by reducing the magnitudes of each of these errors through improvements of minor, and inexpensive, parts of the apparatus. The most important parts of the apparatus for cost and work, viz.

(i) the magnet

(ii) the data-acquisition system

(iii) the reconstruction programs

do not need extensive modifications. Of course, the specific features of the spectrometer (large angular and momentum acceptance) will be maintained or improved.

In the following we give some examples of experiments which could be done at the Improved SC.

I. Double-charge-exchange reactions of pions on nuclei

This would be the most straightforward use of our spectrometer, the only change being the displacement of the MWPC's in the second arm in order to analyse particles of charge opposite to that of the incident ones, emitted at forward angles. To improve the energy resolution in the measurement of the levels of the product nuclei to $\sim$ 1 MeV at $p_\pi \simeq 300$ MeV/c it would be necessary to rebuild all the MWPC's with a wire spacing of 1 mm (possibly 0.5 mm) and use a large drift chamber at the end of the spectrometer (C_6) in order to get a spatial accuracy of $\sim$ 0.3 mm. Fig. 2 gives a sketch of the apparatus.

Assuming a target thickness of 0.5 g/cm^2 (^{12}C), an incident beam of 10^7 π/sec and a differential cross-section of 100 mb/sr we would obtain ∿ 200 events/day.

A preliminary study of the performance (efficiency, dead-time, life, etc.) of the MWPC's irradiated with an intense particle beam (more than $10^6/\text{cm}^2$) must be carried out. The trigger we need to get a clean signature of the events must also be studied.

II. Study of some rare modes of decay of the π

The decay modes:

$$\begin{tikzcd}[row sep=small] & \mu^\pm\nu\gamma & (1.24\times 10^{-4}) \\ \pi^\pm \arrow[ur] \arrow[r] \arrow[dr] & e^\pm\nu\gamma & (3 \quad \times 10^{-8}) \\ & e^\pm e^\mp \nu e^\pm & (< 3.4 \times 10^{-8}) \end{tikzcd}$$

have been studied up to now with stopped π's. For these decays there is only one statistically significant experiment each; for the first mode with emulsions, for the other with counters. The use of stopped pions introduces experimental biases due to absorption and bremsstrahlung in the target, and the sample can be contaminated with spurious events from the μ decay following the normal $\pi \to \mu\nu$ decay. For the counter experiments a relatively wide timing gate was obviously needed in order to collect enough π decays without introducing too large a background from μ decays. The two sources of error can be eliminated if decays in flight are examined. For this we could use the magnet, without shims, to define a decay volume surrounded by MWPC's in which the energy and the direction of the decaying π, the energy and the direction of the produced charged particles and the directions of the γ's could be measured. Fig. 3 gives a sketch of the arrangement.

Assuming an incident beam of 10^7 π/sec (70 MeV) and a decay path in the magnet of 40 cm, we would expect ∿ 5 × 10^6 decays/day in the first mode, and ∿ 500 decays/day in the two others. A very careful study of the trigger and of the geometrical arrangement of the MWPC's in the magnet is needed, but it is conceivable that about 10% of the decays could be accepted; thus ∿ 50 events/day could be collected for the $e\nu\gamma$ and $e^{\pm}e^{\mp}\nu e^{\pm}$ decays. It must be emphasized that the magnetic analysis and the use of a free decay volume offer a unique advantage in determining the kinematical constraints.

III. Radiative capture of $\pi^{\pm}$ in flight by nuclei

The study of the radiative capture of π^{-} at rest has furnished very interesting results. In particular the excitation of the $T^{(3)} = T_0 + 1$ in basic analogues of the giant-resonance dipole states was observed. Apart from the obvious fact that π^{+} cannot be used, the experiments at rest suffer from the two major drawbacks of fixed momentum transfer and the uncertainty in the pionic orbit from which the capture occurs (unless the π-mesic X ray is detected in coincidence). Both the difficulties are eliminated if π's in flight are used to induce the reaction. In addition, both the $T^{(3)} = T_0 \pm 1$ isobaric analogues of the giant resonance could be studied with π^{-} and π^{+} beams.

The magnet and the chambers would be modified to a configuration of a pair spectrometer (Berkeley type), and an additional magnet of smaller dimensions would be used for the momentum analysis of the incident beam (see Fig. 4). Due to the low counting rate expected in the pair spectrometer the large-area chambers would be of the drift type. The overall resolution in the energy of the levels of the product nuclei could be of the order of 1 MeV. The expected counting rate would be of ∿ 100 events/day per level, assuming a target thickness of 0.5 g/cm^{2} (^{12}C), an incident beam of 10^{7} π/sec (70 MeV), 10 μb/sr for the differential cross-section and a detection efficiency of 10^{-3} for the pair spectrometer.

CONCLUSIONS

We think that some experiments are feasible at the Improved SC utilizing the kind of instrumentation with which our Group has accumulated much experience. The considerations on the possible experiments which we have given here must not be taken as a Letter of Intention but, perhaps, as a starting point for discussions with other colleagues or groups interested in this kind of experiment. We should be glad if our ideas would lead to a collaboration on a project to carry out some of the experiments we mentioned, or others for which the apparatus is suitable.

It is clear that such experiments could be carried out in an easier and more precise way if there were a facility consisting of a magnet larger than the one we used, associated with a computer and the read-out logic for a larger number of wires (20,000 or more), as well as drift chambers. This facility could allow a variety of nuclear-physics experiments which need wide angular acceptance and good energy resolution. Examples are:

I. Elastic and inelastic scattering of low-energy pions ($T_\pi < 20$ MeV) on nuclei

The use of a conventional two-arm spectrometer is somewhat difficult due to the short decay path of the pions, whereas a solution involving a nuclear target in the middle of the magnet offers the advantage of very short paths and the possibility of measuring the complete angular distribution at the same time.

II. (π^+,2p) reactions on nuclei and other pion-induced nuclear reactions in which two or more charged particles are detected in coincidence.

III. ($\pi^\pm\pi^0$) reactions on nuclei, with measurement of the spectrum of the neutral pions. One might think of an arrangement in which the nuclear target, placed in the middle of the magnet, is surrounded by a converter for the two γ's from the π^0 decay. The energy and the direction of the incident π, as well as those of the two electrons and the two positrons from the γ conversion, would be measured simultaneously (see Fig. 5).

We believe it to be highly desirable for CERN to provide the SC with a facility of the kind we have described: an Omicron Project. The external groups responsible for the experiments would develop and provide the trigger arrangement and part of the MWPC's or drift chambers. This would be a unique facility, not available at other, comparable, accelerators, making possible investigations which it would be difficult to carry out by other methods.

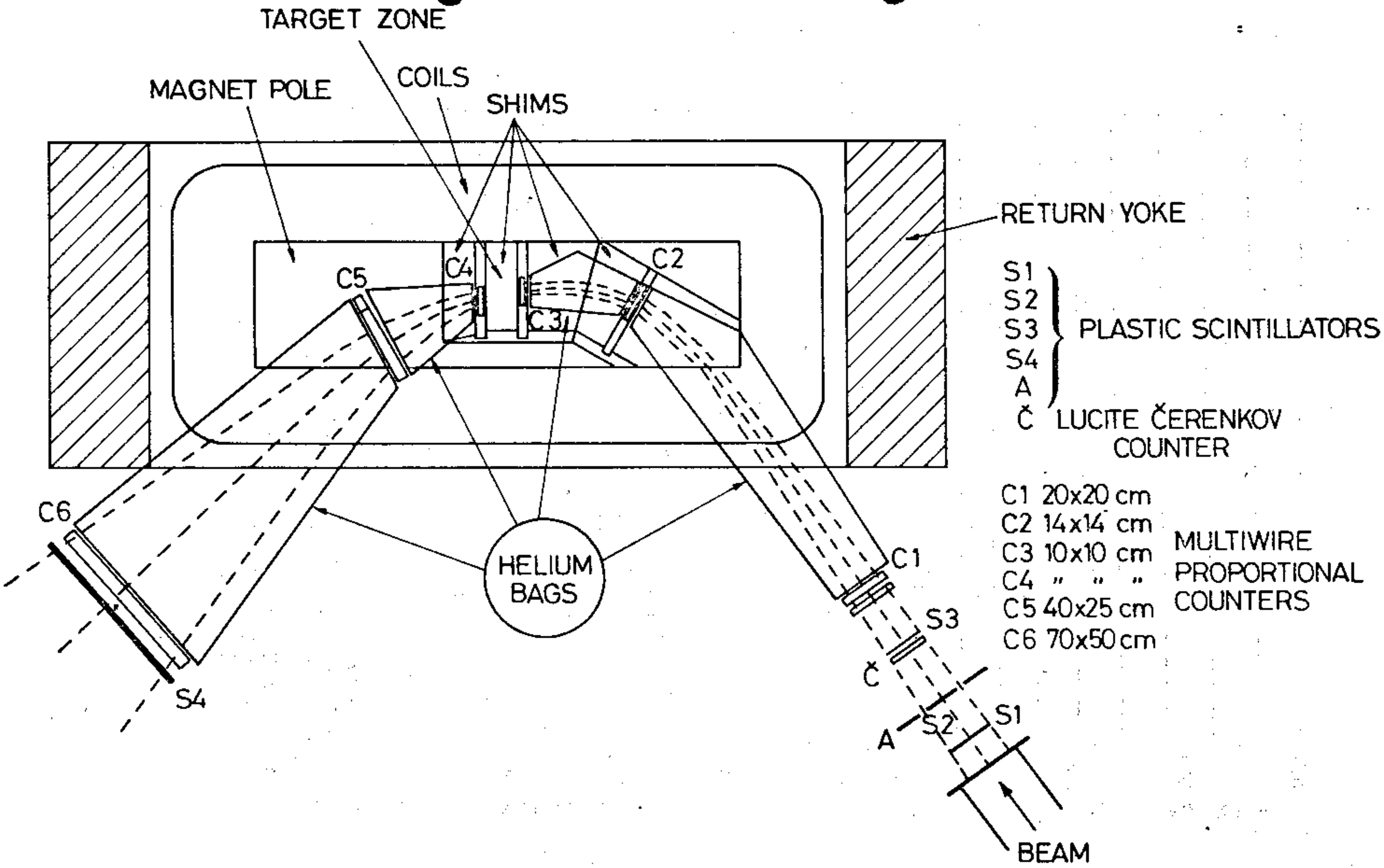
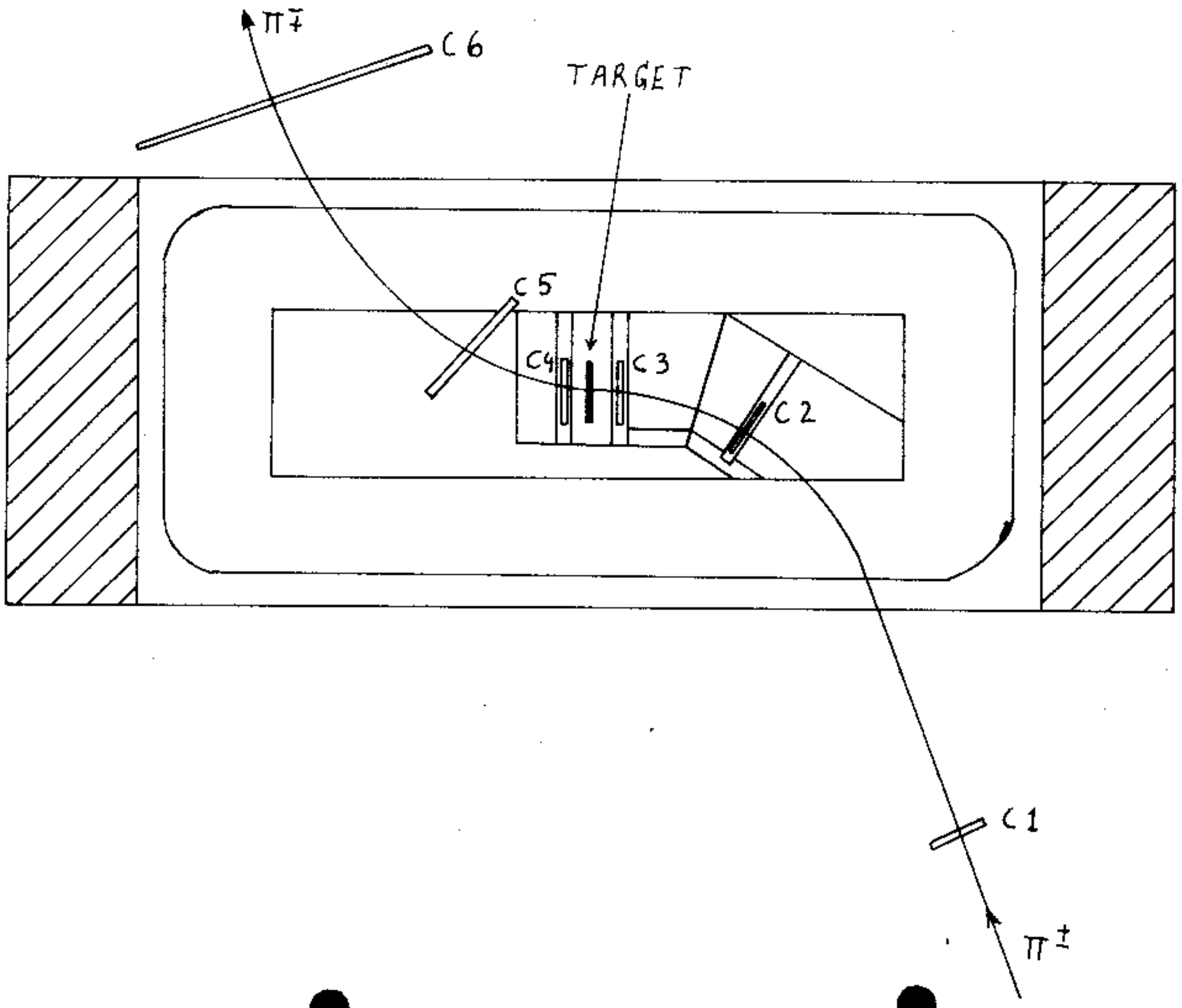
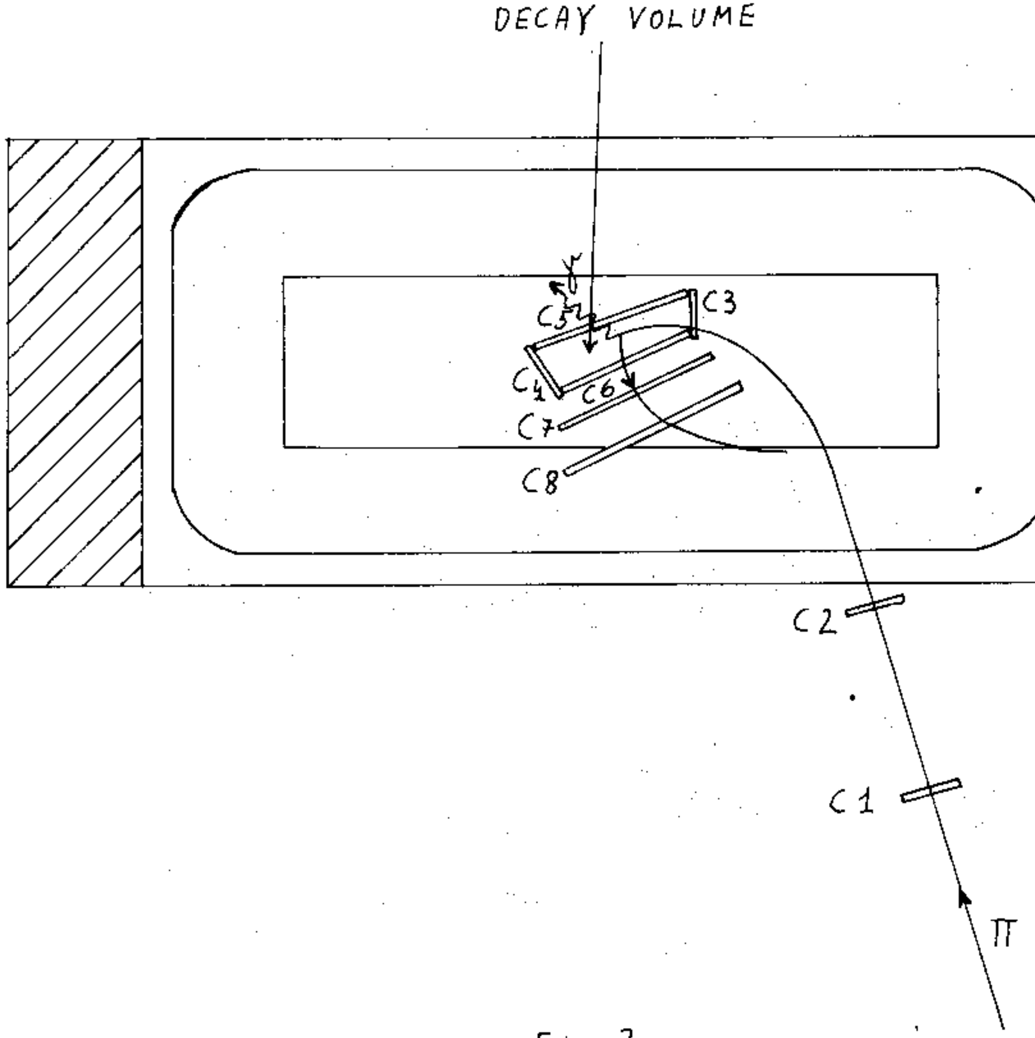

TARGET ZONE
MAGNET POLE
COILS
SHIMS
RETURN YOKE
C5
C4
C3
C2
C1
C6
S4
S3
Č
A
S2
S1
BEAM
HELIUM BAGS
S1
S2
S3
S4
A
PLASTIC SCINTILLATORS
Č LUCITE ČERENKOV COUNTER
C1 20x20 cm
C2 14x14 cm
C3 10x10 cm
C4 " " "
C5 40x25 cm
C6 70x50 cm
MULTIWIRE PROPORTIONAL COUNTERS

Fig. 1


π∓
C6
TARGET
C5
C4
C3
C2
C1
π±



C1 ÷ C8 : MWPC

Fig. 3

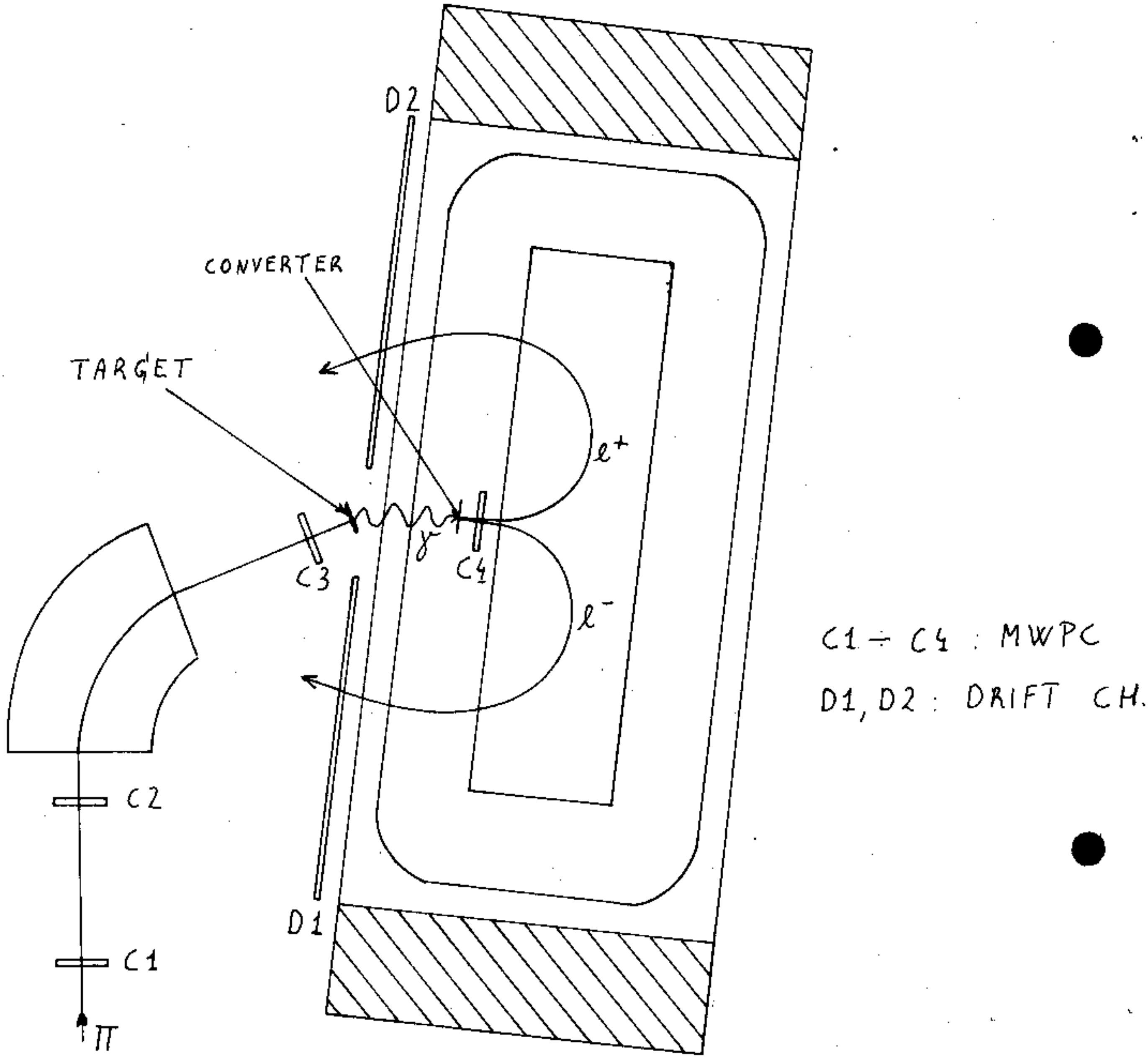

D2
CONVERTER
TARGET
ℓ^+
γ
C3
C4
ℓ^-
C1 ÷ C4 : MWPC
D1, D2 : DRIFT CH.
C2
D1
C1
π

Fig. 4

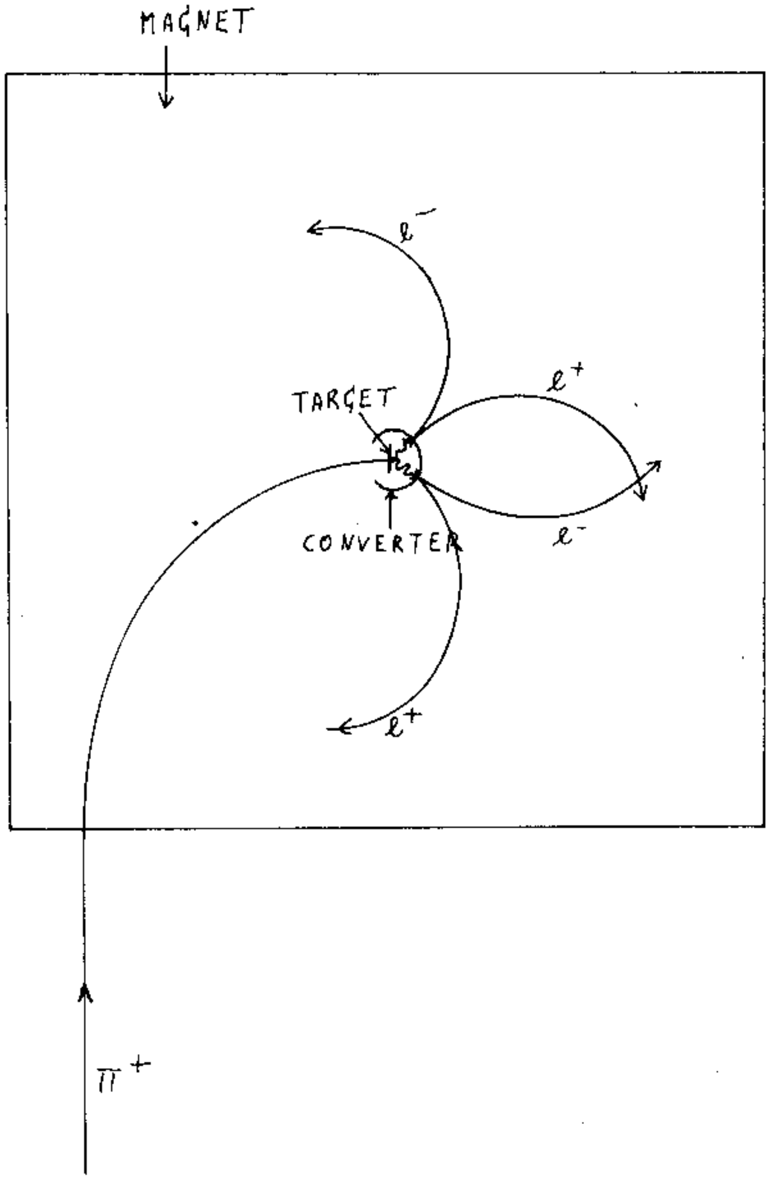


Fig. 5