VIb. 8. A HIGH-INTENSITY μ-MESON BEAM FROM THE 600-Mev CERN SYNCHROCYCLOTRON

A. Citron, C. Delorme, F.J.M. Farley, L. Goldzahl, J. Heintze, E.G. Michaelis, M. Morpurgo, and H. Øverås

CERN
Geneva, Switzerland

Presented by Ansel Citron

At the CERN synchrocyclotron a beam-optical system has been constructed which provides strong fluxes of μ mesons, of both high and low energy, with a low π-meson contamination.

We use two momentum analyzers separated by a decay path (Fig. 1). If monoenergetic π mesons of momentum p decay, the laboratory-system momentum of the μ mesons is distributed almost uniformly over a momentum band extending roughly from 0.6 p up to p (Fig. 2). If we inject π mesons in a certain momentum band I into the decay path and extract particles in a lower momentum band II, then these particles are mostly μ mesons, provided the two momentum bands are well separated (Fig. 2). Although the useful width of band II is usually limited by experimental requirements, the momentum band I should be chosen as wide as possible, if a high intensity is desired, because π mesons out of a wide range of momenta can contribute μ mesons in a given band II.

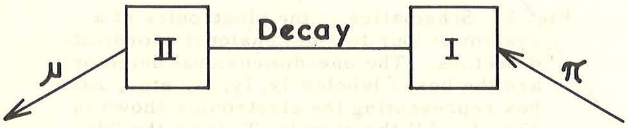

Fig. 1. The double magnetic analysis.

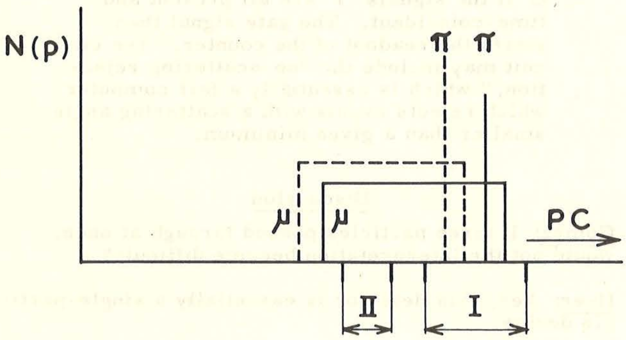

Fig. 2. Momentum spectra of μ mesons from monoenergetic π mesons. The momentum bands selected by the two analyzers are also shown.

Because the laboratory-system decay angles are quite large (up to 100 mrad for 400-Mev/c π mesons), adequate focusing has to be provided all along the decay path.

The π mesons are generated by the internal 600-Mev proton beam of the synchrocyclotron, falling on a Be target. The first momentum analysis (I) is effected by the magnetic field of the synchrocylotron itself (Fig. 3). If a high-energy μ beam is desired, the position and inclination of the decay channel with respect to the target are chosen in such a way that a lower momentum cutoff at 350 Mev/c results, while particles up to 500 Mev/c are admitted with varying efficiencies. The center of gravity of the admitted band lies at 400 Mev/c (Fig. 3 a).

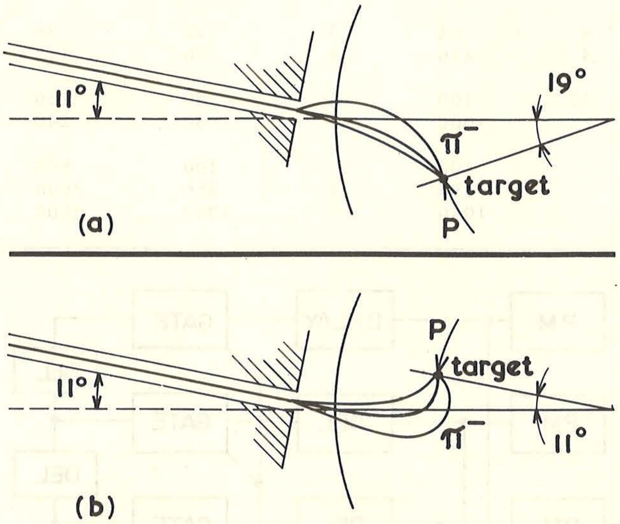

Fig. 3. The synchrocyclotron field as magnetic analyzer.
a. High-energy operation.
b. Low-energy operation.

The decay channel has a total length of 13 m. The decay length for 400-Mev/c π mesons is 22 m. Twenty-four equally spaced quadrupole lenses, of 20 cm aperture and 30 cm magnetic length, with a maximum attainable gradient of 1 kilogauss/cm, provide the focusing. They are usually operated at about half maximum field. It is estimated that 20 to 30% of the μ mesons generated in the channel emerge from it. The first lenses are only about 50 cm from the window of the cyclotron, a number of the subsequent lenses are built into the shielding wall, and the last ones are situated in the experimental hall (Fig. 4).

The emerging μ-meson beam originates from a three-dimensionally distributed source and includes angles of about ±100 mrad with the channel axis. The second momentum analyzer (II) has to transmit such a beam without high losses. A 70-deg alternating-gradient magnet comprising three sections was constructed for this purpose. It is designed to continue the focusing properties of the channel. In order to avoid a drift space between the magnet and the channel and between the magnet and the detector, the coils have been bent up so that they are out of the way. The weight of the magnet is 21 tons, the mean radius of curvature 110 cm; the maximum field at this radius is 10 kilogauss (Fig. 5).

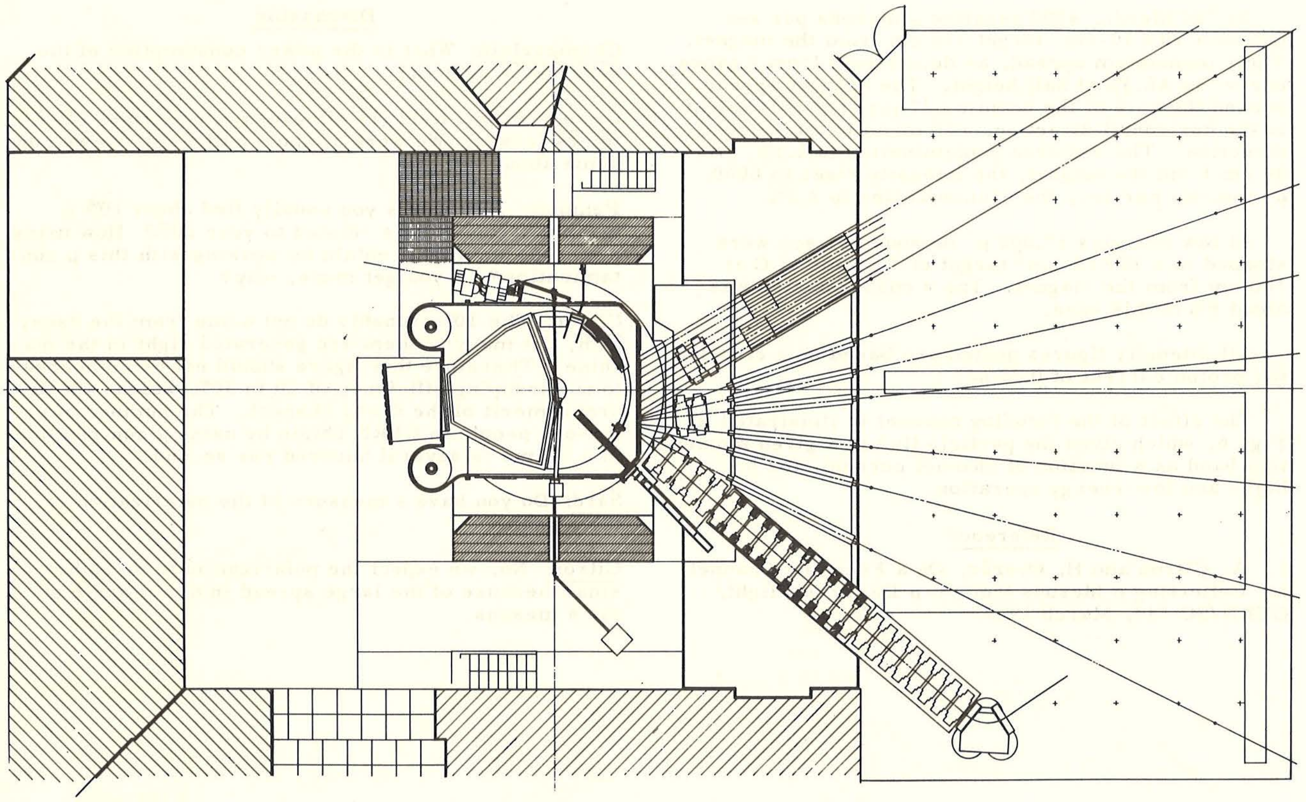

Fig. 4. General layout of the system.

If one wants to obtain low-energy μ mesons, the same system is used, but the cyclotron is operated with the opposite sense of rotation and a different target position (Fig. 3 b). The accepted π band then extends from 230 Mev/c upwards, and the μ mesons have momenta down to 130 Mev/c (60 Mev kinetic energy).

The system, which was planned in 1956-1957, [1] has now been tested. The first results can be summarized as follows.

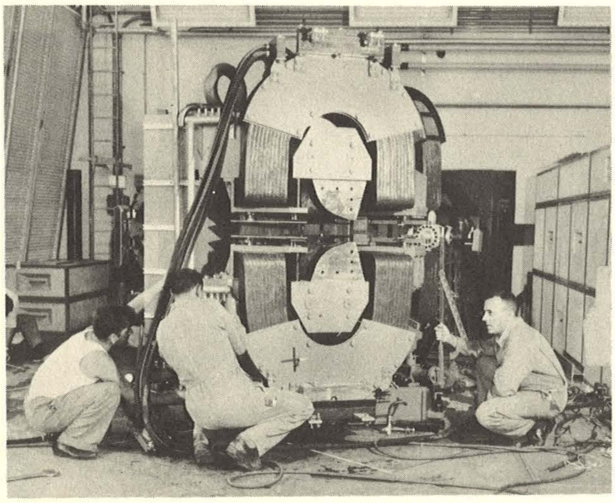

Fig. 5. Photograph of the alternating-gradient bending magnet.

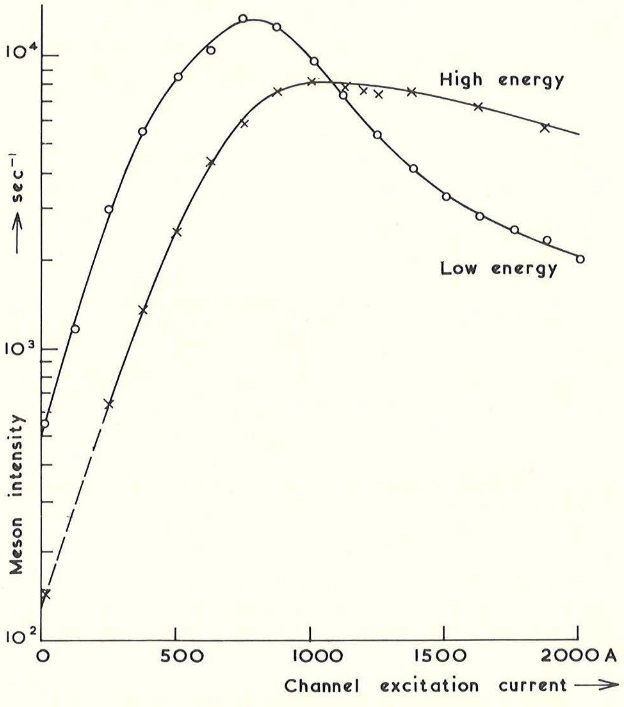

Fig. 6. Particle flux as a function of channel excitation, for high- and low-energy operations. The momentum band selected is centered at 270 Mev/c for high-energy operation, at 160 Mev/c for low-energy operation.

At 280 Mev/c, 4300 negative μ mesons per sec fall on a 10 × 10-cm^2 target 110 cm from the magnet. Their momentum spread, as determined from a range curve, is ±6.3% at half height. The angular spread around the axis of the beam is ±27 mrad at half height in the horizontal direction, ±60 mrad in the vertical direction. The π-meson contamination is 1.5%. At 80 cm from the magnet, the intensity rises to 6000 μ^- mesons per sec, the contamination to 2.2%.

At low energies 10,000 μ^- mesons per sec were stopped in a 10×10-cm^2 target of 7 g/cm^2 of C at 100 cm from the magnet. The π contamination was about 5% in this case.

All intensity figures quoted are based on a circulating proton current of 0.25 μa.

The effect of the focusing channel is illustrated in Fig. 6, which gives the particle flux in a given momentum band as a function of channel current, for both high- and low-energy operation.

Reference

1. A. Citron and H. Øverås, On a Focusing Channel for Collecting μ Mesons from π-μ Decay in Flight, CERN/SC 143, March 1957.

Discussion

Chamberlain: What is the power consumption of the quadrupole system?

Citron: At full field (11 kilogauss at pole tips) 720 kw for 24 lenses. We work at about half field, so we consume about 180 kw.

Penman: In π beams you usually find about 10% μ mesons. How is this related to your 20%? How many μ mesons would you obtain by working with this μ contamination? If you get more, why?

Citron: The 10% probably do not come from the decay path, but many of them are generated right in the machine. Therefore this figure should not be compared to our trapping efficiency of 20 to 30%, which is a figure of merit of the decay channel. The number of μ mesons people in CERN obtain by using μ contribution in π beams is several hundred per second.

Sard: Do you have a measure of the polarization of the μ beam?

Citron: No, we expect the polarization to be rather small because of the large spread in decay angle of the π mesons.