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PROPOSAL FOR AN EXPERIMENT TO DETECT THE POSSIBLE EXISTENCE OF FRACTIONALLY CHARGED PARTICLES

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Recently much interest has been generated around the possible existence of fractionally charged particles *).

In what follows we propose two possible experiments to be performed at the Proton Synchrotron; the first before the shut-down and the second immediately after.

I. USING M_3 BEAM

The principle of the method is simultaneous magnetic and electrostatic analysis with high-velocity threshold rejection to reduce background and dE/dx measurements to provide supporting evidence.

Figure 1 shows the experimental set-up. The following formulae are relevant:

bending magnet $\Theta_M \sim \frac{\mathcal{Q}}{P}$

electrostatic separator $\Theta_s \sim \frac{\mathcal{Q}}{P\beta}$.

If we set the magnetic deflection to accept momentum P_1 for single-charged particles we have $P = qP_1$. Therefore, for charge q we have:

$$\beta = \frac{qP_1}{\sqrt{q^2 P_1^2 + m^2}} .$$

*) Gell-Mann and Zweig.

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Mass resolution

a) Image width

The image as shown in Fig. 2 corresponds to $\Delta\beta \simeq 0.01$.

b) Dispersion in the separator

$$\frac{d\beta}{\beta} = \frac{dP}{P} \times \frac{m^2 q P_1}{(q^2 P_1^2 + m^2)^{3/2}} ,$$

which has maximum value of 0.39 (dP/P) at $m = \sqrt{2}\, qP$.

Hence, the dispersion in the separators for 0.5% momentum acceptance is $d\beta/\beta \leq 0.002\%$.

Limits of cross-section and time needed

We have 1000 $\bar{P}$/burst (with 6×10^{11} circulating protons) with good image conditions.

We have observed that outside the $\bar{P}$ peak in the separator curve the background counting rate is less than 3% of the $\bar{P}$ rate. We have not, in fact, looked further and it can be that the tail decreases more.

We will perform pulse-height analysis on this 3% background and we expect a factor 10 rejection in favour of the fractionally charged particles.

In order to scan mass values from 0.4 GeV up to 1.8 GeV (see Fig. 2) we need 40 points, each one with 10^4 events, i.e. 18 hours of data taking. This allows us to detect an event rate of the order of 10^{-5} the antiproton rate.

Conclusion

We will be able to scan a mass range for the fractionally charged particles, which goes from 0.4 GeV up to 1.8 GeV in one day, with a limit on the cross-section of the order of 10^{-32} cm^2. The method is not limited in the mass value, and, in fact, by reducing the separator voltage we can scan in another 24 hours from 1.8 up to 3.0 GeV masses. Clearly the highest possible mass (~ 5.7 GeV) compatible with the PS energy can be scanned with the same limit for the cross-section.

Time needed

One week of PS as main users.

II. USING THE d_{15} BEAM

We have also studied the possibility of transforming the d_{15} beam into a 40 GeV/c beam. If the fractionally charged particles exist we should be able to observe them by using a beam transport system capable of deflecting these small charges at this high apparent momenta.

The modifications required for the d_{15} beam can be performed during the next shut-down. It is essentially a question of displacing a bending magnet and a few quadrupoles. The characteristics of the d_{15} beam will not be destroyed.

With this 40 GeV/c beam we will perform pulse-height analysis in scintillation counters. The lower limit for the detectable cross-section is going to be given by the muon background. We are studying the problem of reducing this source of background by using a highly directional telescope and large anticoincidence counters. In this way we can increase our previous limit by at least two orders of magnitude.

Conclusion

We propose to make the necessary transformations in the d_{15} beam as soon as possible. If this proposal is accepted, a collaboration with the CERN-ETH Group is envisaged.

Figure captions

Fig. 1 Shows the experimental set-up. The momentum is determined by the beam optics, with momentum acceptance of 0.5%. D is a four-metre long ethylene threshold Čerenkov counter to veto pions, electrons and muons. A and B are two plastic scintillation counters, 5 mm thick and 8 cm in diameter, to record the beam intensity. Counters M_1 and M_2 are 1 cm thick, 28 cm diameter counters, which give two independent dE/dx measurements.

Fig. 2 Shows the spacial resolution which can be obtained with the separator for a momentum spread of 1% at 2.5 GeV/c. To give an idea of the scale, the abscissa is also marked with the values of the mass of a particle 'A' of charge = $1/3$ which would pass through the mass slit at three settings of the separator compensating magnet.

Fig. 3 Shows the variation of the velocity of the 'A' as a function of its mass for fixed values of the nominal beam momentum:

$$\beta = \frac{P}{\sqrt{P^2 + m^2/q^2}} ;$$

where P is the nominal beam momentum, m is the mass, and q is the charge of the 'A'. The dotted lines on the 2.5 GeV/c curve show the resolution in mass, which corresponds to the width of the image at the mass slit.

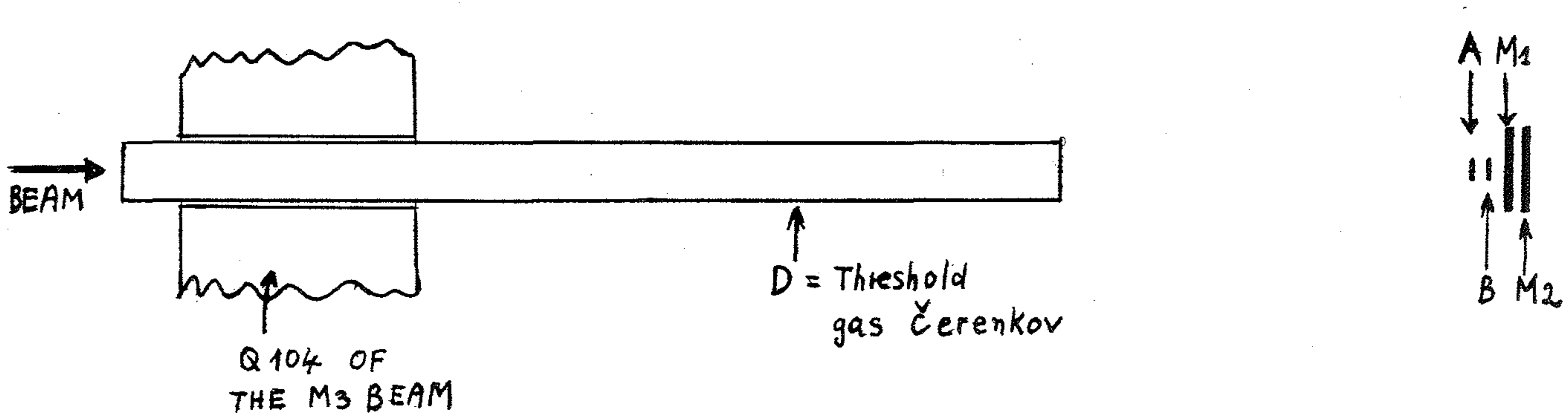


Fig 1

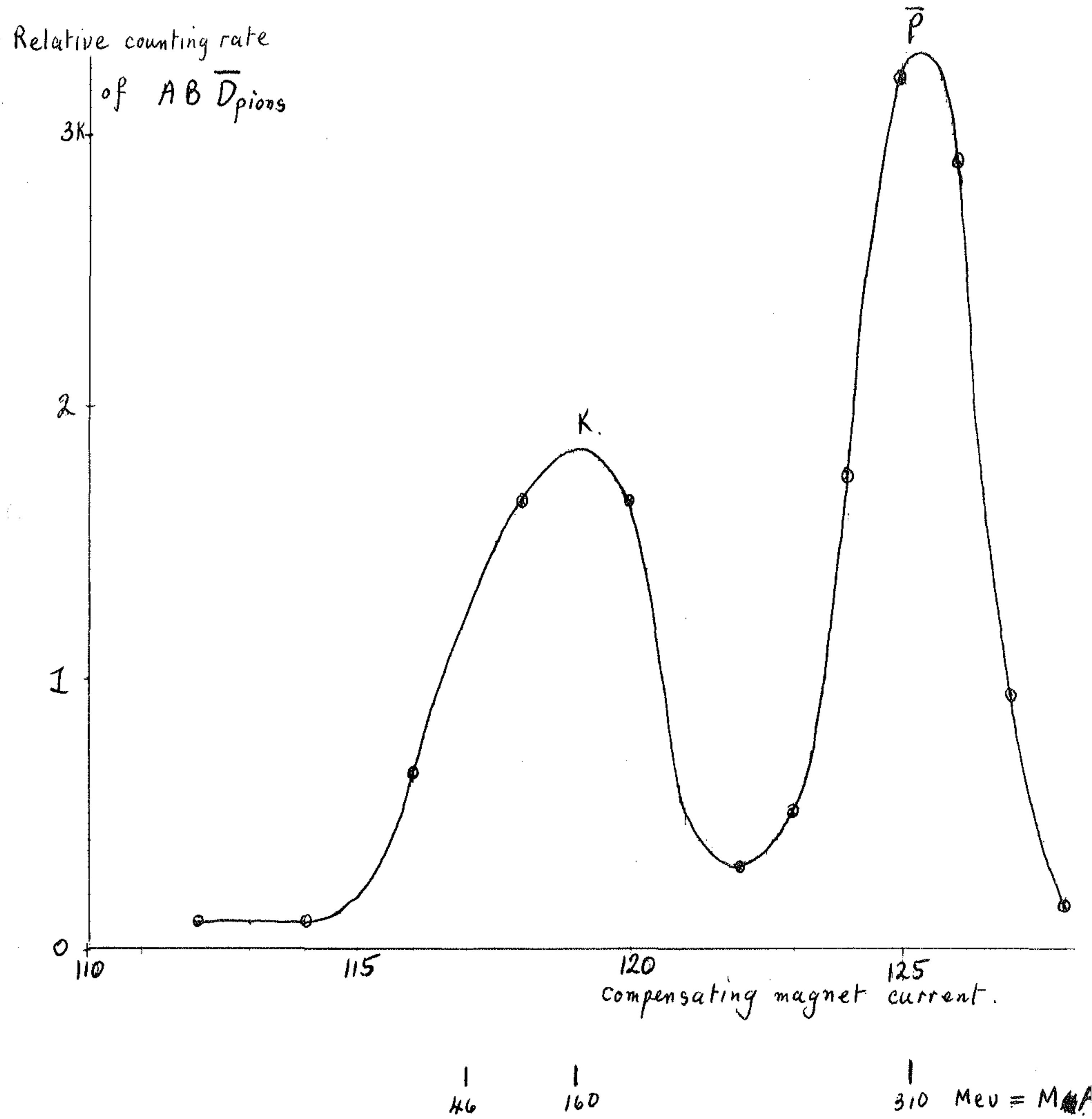
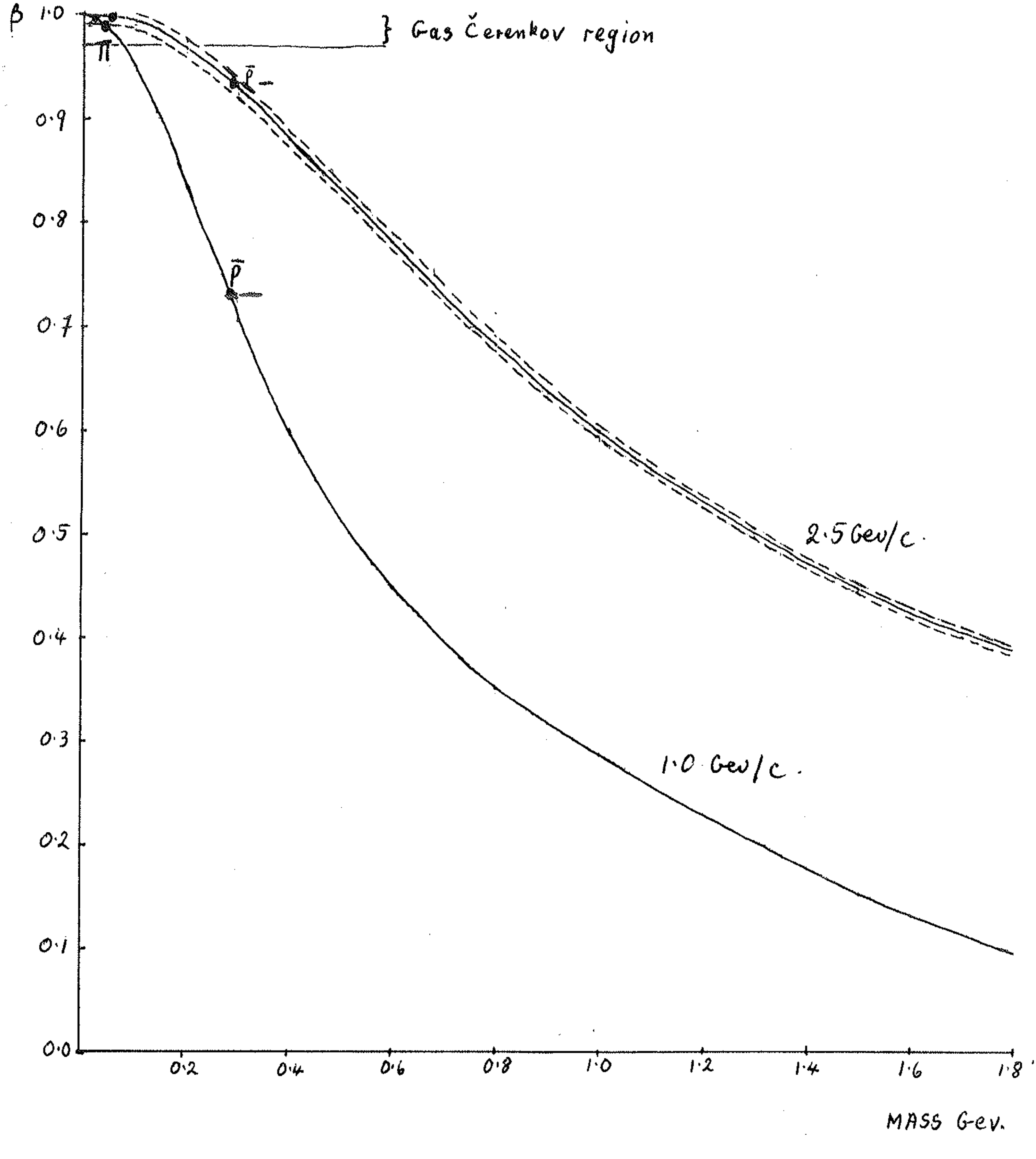

Relative counting rate
of A B $\overline{D}$ pions
3K
2
1
0
110
115
120
125
K.
$\overline{p}$
compensating magnet current.
46
160
310
Mev =

Fig 2



Velocity of "A" as a function of mass for nominal beam momenta of 1·0 and 2·5 Gev/c. The dotted lines on the 2·5 Gev/c curve give an estimate of the mass resolution. The points marked p and π are plotted at the values of β corresponding to these particles and show where they will coincide with the "A".

Fig 3

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