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ELASTIC HADRON SCATTERING AT HIGH ENERGIES

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Elastic scattering at 100 GeV/c has been considered for the purpose of determining the specifications of suitable beams and spectrometer magnets. The full angular distribution would be performed in three separate experiments:

1. small angle scattering using a wire spark chamber spectrometer,
2. intermediate scattering angles using a fixed counter spectrometer and a high intensity beam,
3. large angle scattering using a double arm spectrometer.

Momentum Accuracy

For elastic scattering, Δp = 0.1 GeV/c for both incoming and outgoing particles is adequate. The beam momentum is determined to this accuracy. In the beam designed by Read and Garren, the dimensions of a spectrometer to analyze the scattered particles were considered for an optical spark-chamber array (δx = 0.2 mm), wire chambers (δx = 0.4mm), and counter hodoscopes (δx = 2 mm). Figure 1 shows the relation of the lever arm D (in meters) and the spectrometer field $\int B dl$ in kG-m for p = 100 GeV/c, Δp = 0.1%.

Small-Angle Scattering

For small-angle scattering there is adequate cross section to allow the use of spark chambers to measure the scattering angle, $\theta_{scat.}$ and the momentum loss, $P_{inc.} - P_{scat.}$. The arrangement is shown in Fig. 2. The scattering angle is determined by chambers 1-4 and the momentum of the scattered particles by chambers 3-6. The incoming momentum is determined by the beam. Scattering angles and momentum loss are measured relative to unscattered beam particles. Scattering up to $1/2°$ ($t \sim 1$ GeV) can be measured simultaneously. The spectrometer magnet has been chosen arbitrarily, as $\int Bdl = 100$ kG-m, and the lever arms 30 m each, to illustrate the principle. A magnet aperture of 40 cm $\times$ 10 cm high covers a useful solid angle. The spectrometer would conviently be two 3-m units of 15 kG. These are quite conventional magnets. Triggering is by means of a set of counter hodoscopes, selecting about 1/2% $\Delta p/p$. This trigger is fine in the region of small angle scattering where elastic dominates the near elastic scattering. The range in scattering angle can be increased by increasing the aperture of the magnet or by steering the beam on to the H_2 target. The limitations in beam intensity of a few $\times 10^5$ particles per pulse prevent this setup from being useful for measuring low cross sections.

Manning (CERN/ECFA/Vol. I, p.253) has a detailed design of a small angle scattering experiment using spark chambers for momenta up to 240 GeV/c.

Intermediate Scattering Angles

The principle of the method is to use a set of independent counter telescopes and a magnet to measure simultaneously several scattering angles. The spectrometer magnet is scanned to measure the elastic and near-elastic scattering. The resolution has been chosen to be $\Delta p = 0.1$ and is adequate for elastic scattering (but poor for recoil isobar production). A high-intensity beam, 10^8 say, with a spot of ~1 mrad would be required. Monitoring of the beam is necessary. Counters 4 mm wide ($\delta x = \pm 2$ mm) would need a spectrometer magnet with $\int Bdl = 100$ kG-m, with lever arms of 130 m (for example). The more money spent on the magnet, the shorter the spectrometer and the greater the yield of elastic events. The loss of acceptance due to a low field magnet with small aperture can be compensated for by an increase in beam intensity, if random rates are not too high. The range of scattering angles can be varied by beam steering (see Fig. 3). This can be done by a pair of magnets (M_1, M_2), the second having a wide aperture or by moving the second one on rails as indicated. An experiment similar to this in principle has run at Nimrod using a beam of several 10^9 protons per pulse. Data were taken in the momentum range 2-8 GeV/c and at angles in the range 20-150 mrad. For all the data, the spectrometer and target remained in the same position.

For events in the higher momentum transfer range, the recoil proton will have enough energy to escape from the target. Additional constraints can be obtained by detecting the recoil nucleon. This would be a desirable feature and space should be left for such a possibility.

Large-Angle Scattering

This part of the experiment would be performed using two spectrometers, each magnet not considerably different from the one specified above. Krisch and Serber have discussed such an experiment using incident protons. In order to use the same setup to measure π-p elastic scattering it would be better to use the high resolution diffracted beam at 2.5 mrad suggested for target station 1.

Recoil Isobar Production

To measure mass spectrum in a recoil isobar experiment, it will be necessary to have momentum accuracies in both incoming and outgoing particles of 30 MeV/c to obtain mass resolutions of about 60 MeV/c^2. This momentum resolution is not available in the beams currently being designed at 100 GeV/c. Consequently two spectrometers are required, each three times more effective than those described earlier. This, is of course, possible but not very practical. Further, although the signal-to-noise ratio (i.e. resonance to background) will be better at higher momenta than present momenta, it has to be admitted that the real physics output of such experiments up till now has not been particularly significant. Such experiments at 100 GeV/c are not impossible.

Facilities Required from NAL

1. Spark-chamber experiment

Beam p = 50-150 GeV/c

Δp = 0.1%

Spot required not critical

Intensity - 2×10^5/pulse

Particles: p, π, K, etc. electronically identified by DISCS

Magnet, 100 kG-m, 40 cm wide × 10 cm high gap

H_2 target

Small computer for wire chambers, 16 K store

2. Counter experiment

Beam p = 50-150 GeV/c Δp = 0.1%

Spot--4 mm by 1 mrad

Intensity--10^8-10^9 or more, p, π, K

Monitor--for this intensity

Magnet--as above or better

Computer--data-logger for hodoscope

Real estate for 270 m long spectrometer

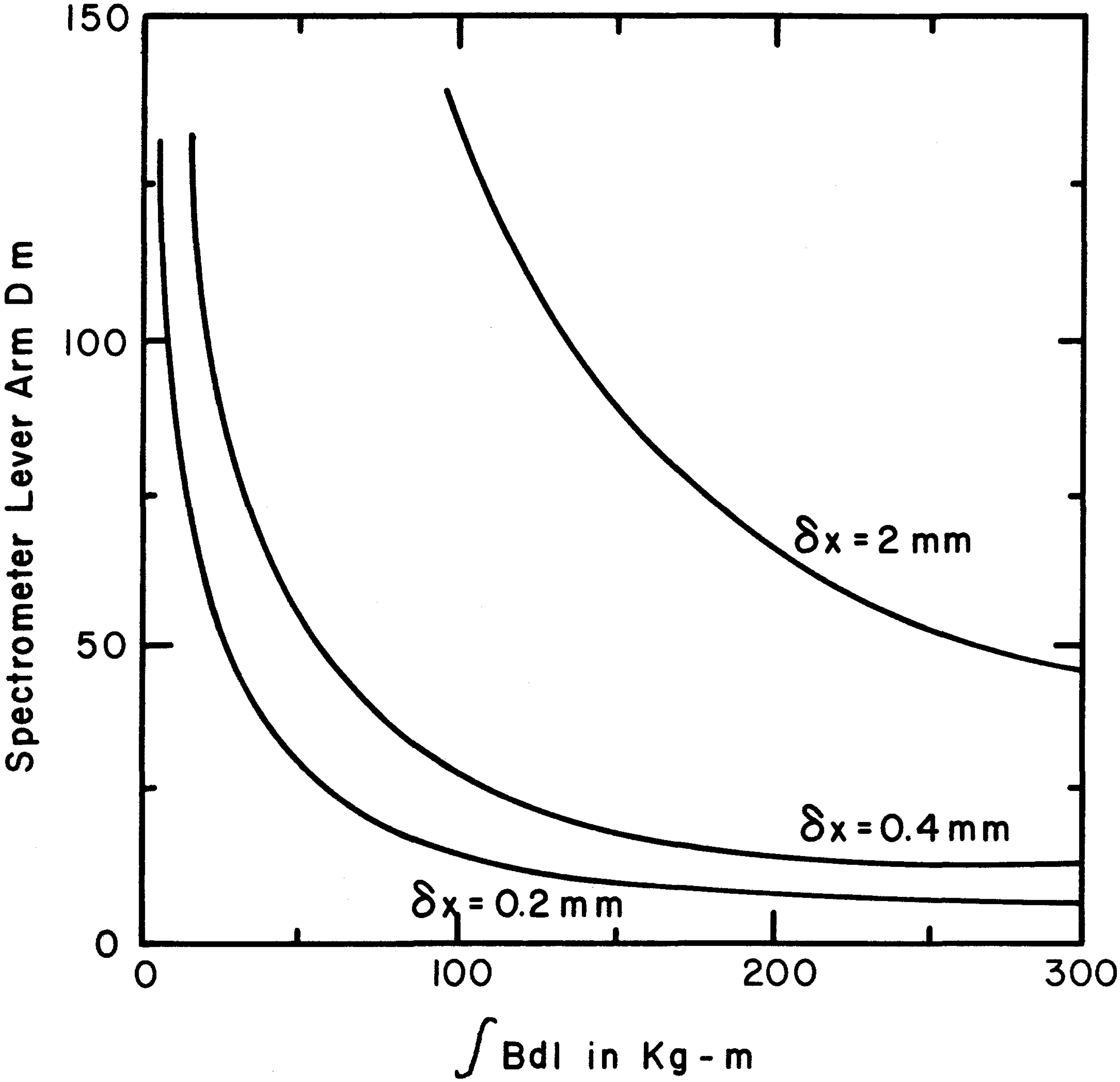

Fig. 1. Parameters of spectrometer.

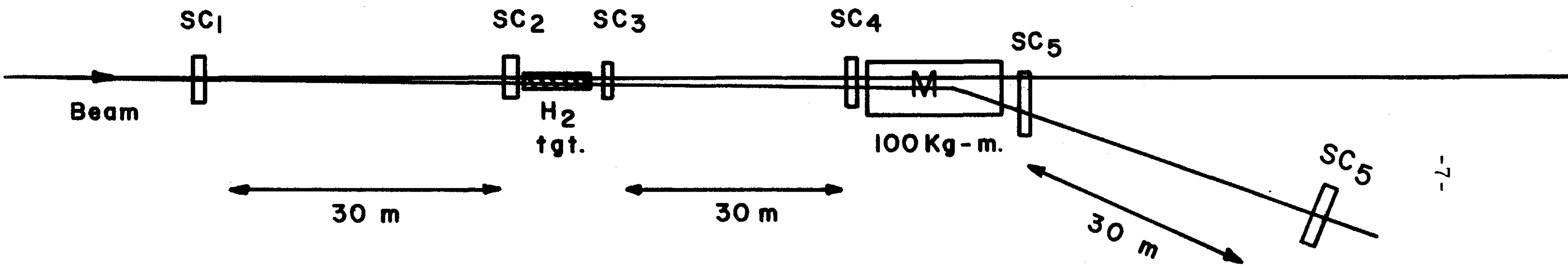

Fig. 2. Arrangement for small-angle scattering.

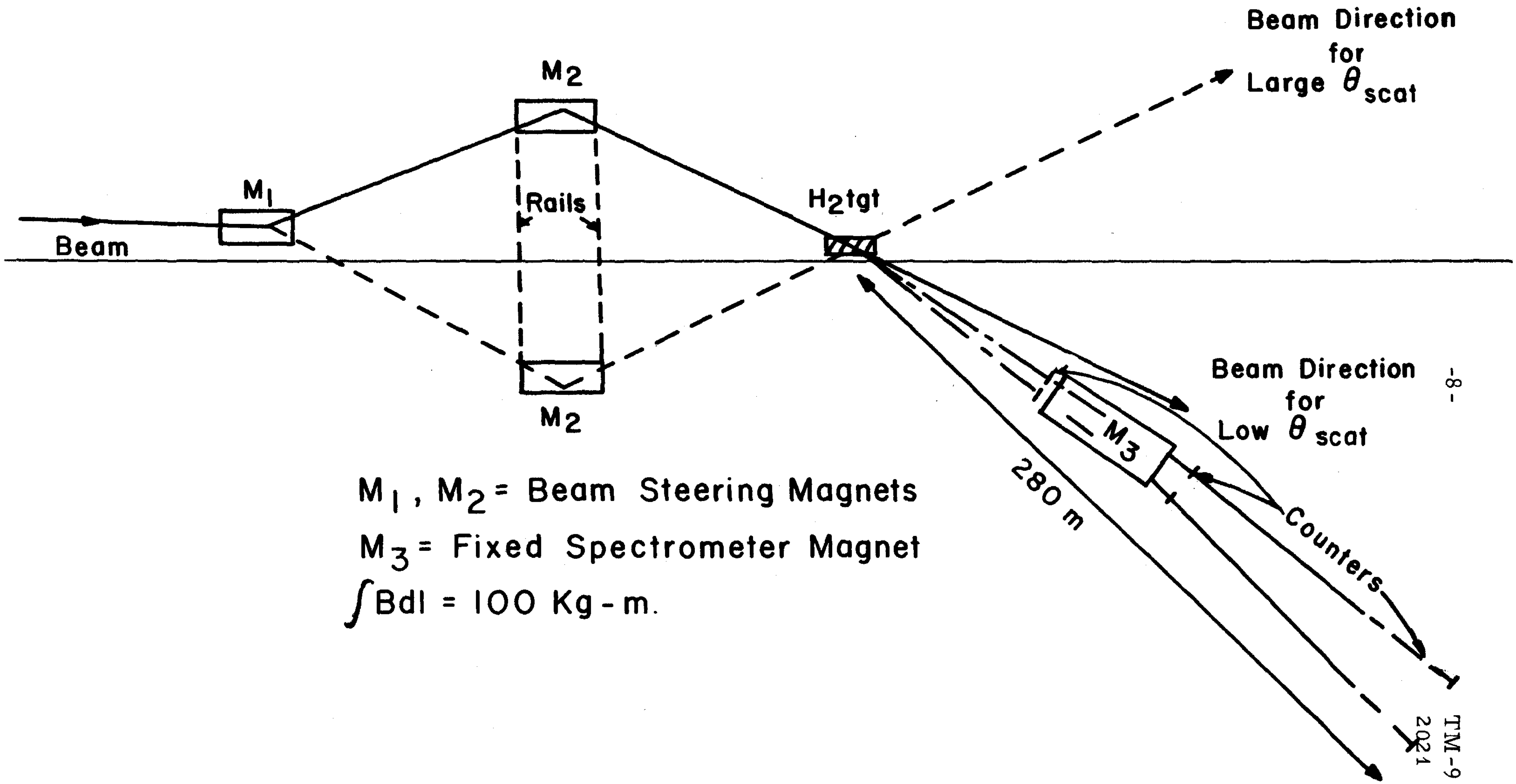

Fig. 3. Schematic arrangement for intermediate angle elastic scattering.

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