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PROPOSAL

Measurement of Inelastic Proton-Proton Scattering at the ISR

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1. INTRODUCTION

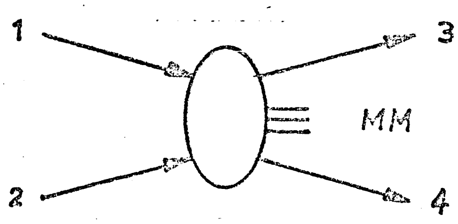
Experiments at the ISR show that the total pp cross section at a CM energy of 50 GeV is around 40 mb, and that the elastic cross section is about 7 mb.[1] The remaining 33 mb are "inelastic". They contain a large number of final states, and the number and complexity of these states will make an analysis of only a few individual reaction channels impossible. It is probable that inelastic reactions will have to be analysed in terms of "inclusive" parameters such as particle spectra and particle correlations.

We therefore propose, at two or three ISR energies,

(i) the measurement of the correlations between two final protons;

(ii) the measurement of the differential cross section as a function of the two protons energies and angles;

(iii) the study of the configuration of the "missing matter" with respect to the two final protons.



We think that the leading protons will constitute one representative description of the dynamics of proton-proton collision at very high energies. It may also prove possible to relate the inelastic pp cross section to the proton structure, as claimed in the case of inelastic ep scattering.

2. EXPERIMENT

The measurements will be done in one experiment with the Split-Field Magnet Facility (SFM). The facility has been described in ref.2, acceptance calculations of the detector are summarized in ref.3.

In a first run we do not attempt any identification of the protons. This limits the selection of the protons to momenta > 10 GeV. Early production experiments in I2[4] will test this procedure and predict the contamination by high momentum K^+ and π^+ and the limitations set by them. In a second run Cerenkov hodoscopes would have to be inserted; the technical solution has been studied by J. Moritz et al. (ISRC/71-30).

The momentum resolution in the SFM is determined by the error in sagitta measurements[3]. We find, as a rule of thumb,

$$\frac{\delta p}{p} \simeq \pm 0.0025p. \qquad [p] \text{ GeV/c}$$

The precision of event reconstruction is further limited by the multiple scattering in the stainless steel vacuum tube. For a corrugated tube of 0.5mm wall thickness we find

$$\delta\theta \simeq \pm \frac{0.003}{p\sqrt{\theta}} \qquad [p] \text{ GeV/c}, \quad [\theta] \text{ rad}$$

neglecting, for the moment, more serious but unavoidable obstructions like supports, detector frames, etc. For missing mass calculations the additional error from the momentum spread of the stored beams enters.

Rates can hardly be estimated. In the first run almost each event is useful. Later selective triggers and limited acceptances of the Cerenkov hodoscopes will reduce the rate.

3. DATA ANALYSIS

The true limitation of the experiment will be the data analysis. The limitation is twofold :

(i) there will be the technical problem of track finding, i.e. the recognition of multiprong events from the digitization of the detector. We expect that the filtering of two "leading" protons is less difficult and can be done as a first step towards a recognition of the complete event. For illustration we show in fig.1 an atlas of events in the SFM, generated at random with a two-fireball model;

(ii) there is the practical problem of limited computer time. We can see for a simple 10x10 grid in (t,E) for each proton: $(10\text{x}10)^2 \cdot (100 \text{ events/bin}) \cdot (10 \text{ sec/event}) = 10^7$sec of CDC 6600 ti

4. PHYSICS

4.1 Proton Identity: In a rigorous sense the transition of the initial to the final proton $1 \to 3$ and $2 \to 4$ cannot be separated from $1 \to 4$ and $2 \to 3$ since the two final state protons cannot be distinguished.

In practice the identification could be based on the criterion

$$\vec{p}_3 \approx \vec{p}_1 \neq \vec{p}_4$$

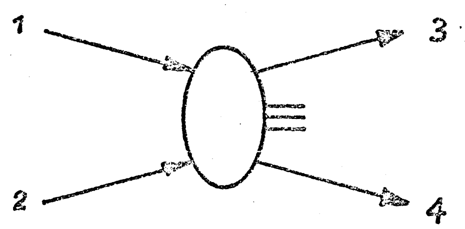
$$\vec{p}_4 \approx \vec{p}_2 \neq \vec{p}_3 \quad .$$

This criterion is empirical, it is taken from the observation of limited transverse momentum or peripheralism. Ambiguities will arise in configurations of comparable transverse and longitudinal momenta:

(i) for large energy losses, with both protons appearing at low momenta $\lesssim$ 500 MeV/c ;

(ii) for large momentum transfers, i.e. the probably rare case of two fast, large angle protons.

4.2 Proton Proton Correlations: Of the 4 four-momenta, p_1 and p_2 are known and p_3 and p_4 are measured. From them 10 invariants can be formed, 6 of which are nontrivial. We then define the 6 variables :



(total energy)^2 $\quad s = (p_1 + p_2)^2$

(4 mom. transf.)^2 $\quad t_{13} = (p_1 - p_3)^2$

$\quad t_{24} = (p_2 - p_4)^2$

$$u_{14} = (p_1 - p_4)^2$$

$$u_{23} = (p_2 - p_3)^2$$

azimuthal correlation $\quad \phi = \arccos \dfrac{(\vec{p}_1 \times \vec{p}_3) \cdot (\vec{p}_2 \times \vec{p}_4)}{|\vec{p}_1 \times \vec{p}_3| \cdot |\vec{p}_2 \times \vec{p}_4|}$

The measurement will yield distribution functions of two or more of these variables, or other variables derived from them. The strongly correlated elastic reaction will serve as a monitor.

The acceptance for single protons is the $(t, E_{in} - E_{out})$ plane is given in fig.2 [3].

4.3 Cross Sections: Inelastic proton-proton scattering can be parametrized in several ways:

(i) by the measurement of the two protons, if present, leading to a fivefold differential cross section

$$\frac{d^5\sigma}{dt_{13}\, dt_{24}\, du_{14}\, du_{23}\, d\phi} \qquad \text{(a)}$$

i.e. measuring angle and energy of two secondary protons. By introduction of the missing mass M_x of the secondaries one can reduce (a) to

$$\frac{d^3\sigma}{dt_{13}\, dt_{24}\, dM^2_x} \qquad \text{(b)}$$

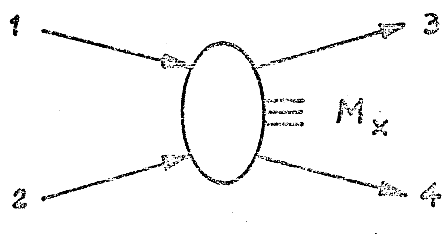
with M_x the missing mass with respect to the two protons.

$$M_x^2 = E_x^2 - \vec{p}_x^{\,2}$$

$$M_x SM_x = E_x \delta E_x - \vec{p}_x \cdot \delta \vec{p}_x$$

assuming $|p_x| \simeq o$ we obtain:

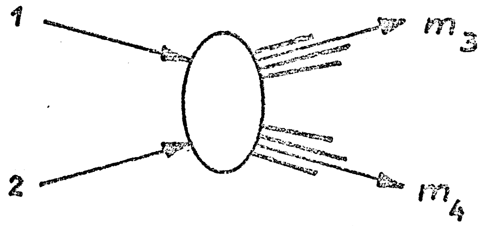
$$\delta M_x \approx \frac{E_1 + E_2 - E_3 - E_4}{M_x} \left(\delta E_{1,2}^{\,2} + \delta E_{3,4}^{\,2}\right)^{\frac{1}{2}}$$



(ii) from the measurement of all - charged - secondaries with each proton, if possible, leading to the cross section

$$\frac{d^3\sigma}{dt\ dm_3^2\ dm_4^2} \qquad \text{(c)}$$

including an appropriate correction for missing neutrals.



4.4 Particle Production: The measurements will provide general information describing inelastic pp collisions. We refrain from a discussion of individual models [5] and list instead some empirical objectives. One will measure:

(i) distributions of charge multiplicity and of momenta $f(p,p_\perp)$, the latter for different final states;

(ii) correlations between proton directions and pion directions, i.e. splitting or not-splitting the event into "fireballs", "jets";

(iii) correlations between the proton inelasticity and the charged pion multiplicity, i.e. the "energy per produced pion";

(iv) study of fully reconstructed events, i.e. 4C fits for four- and six-prongs;

(v) study of charge correlations between the two directions.

REFERENCES :

1. Aachen-CERN-Genova-Havard-Turin Collaboration, Phys. Letters 35B (1971) 361

2. The Split Field Magnet Facility, A. Minten (ed) (1971)

3. SFMD-Note-6, R. Kaufhold (1971)

4. Ratner et al. find a ratio $\pi^+/p \approx 1$ at $x = \frac{p_l}{p_{max}} = 0.25$, $p_\perp = 0.4$ GeV/c and $E_{CM} \simeq 30$ GeV (private communication)

5. For a discussion of the current models we refer to :
D. Horn, TAUP 206-71, Tel Aviv University report (1971).
L. Van Hove, Physics Reports 1C Number 7 (1971).

FIGURE CAPTIONS :

1. a-c Atlas of particle trajectories; the events were generated with a two-fireball model.

2. Accessible region in the $(t, E_{in} - E_{out})$ plane for single protons.

Fig. 1a

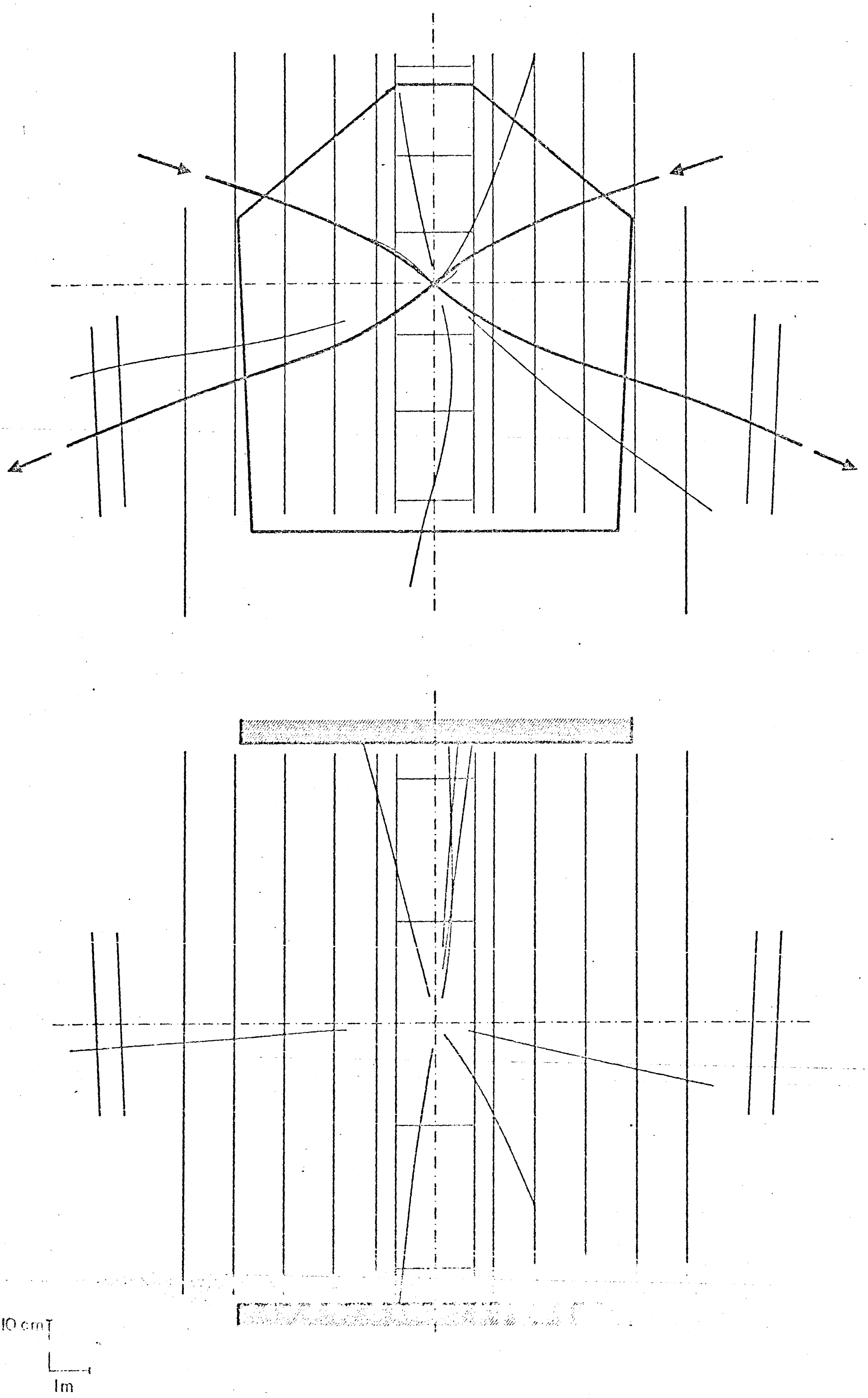


Fig. Ib

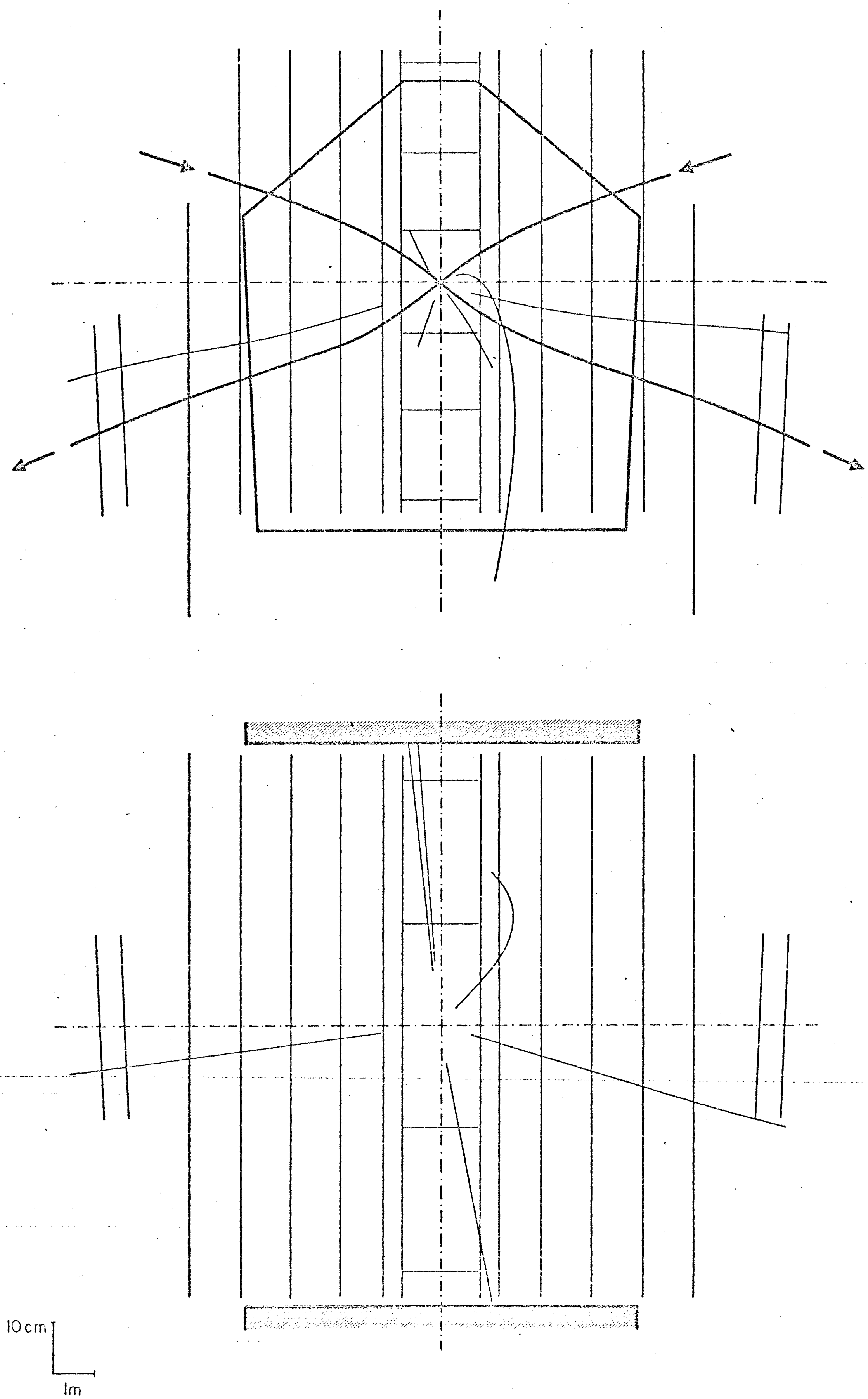


Fig. 1c

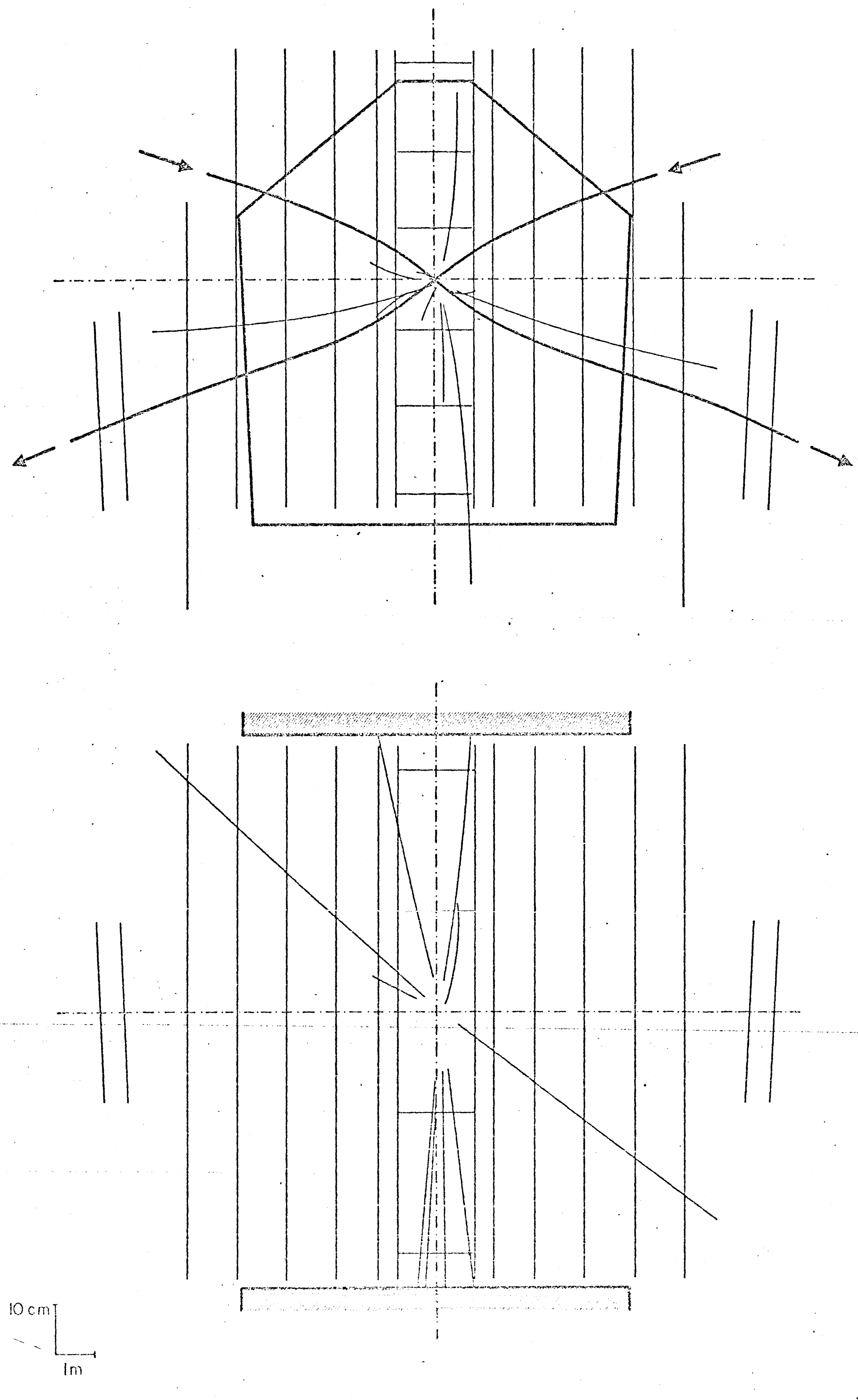
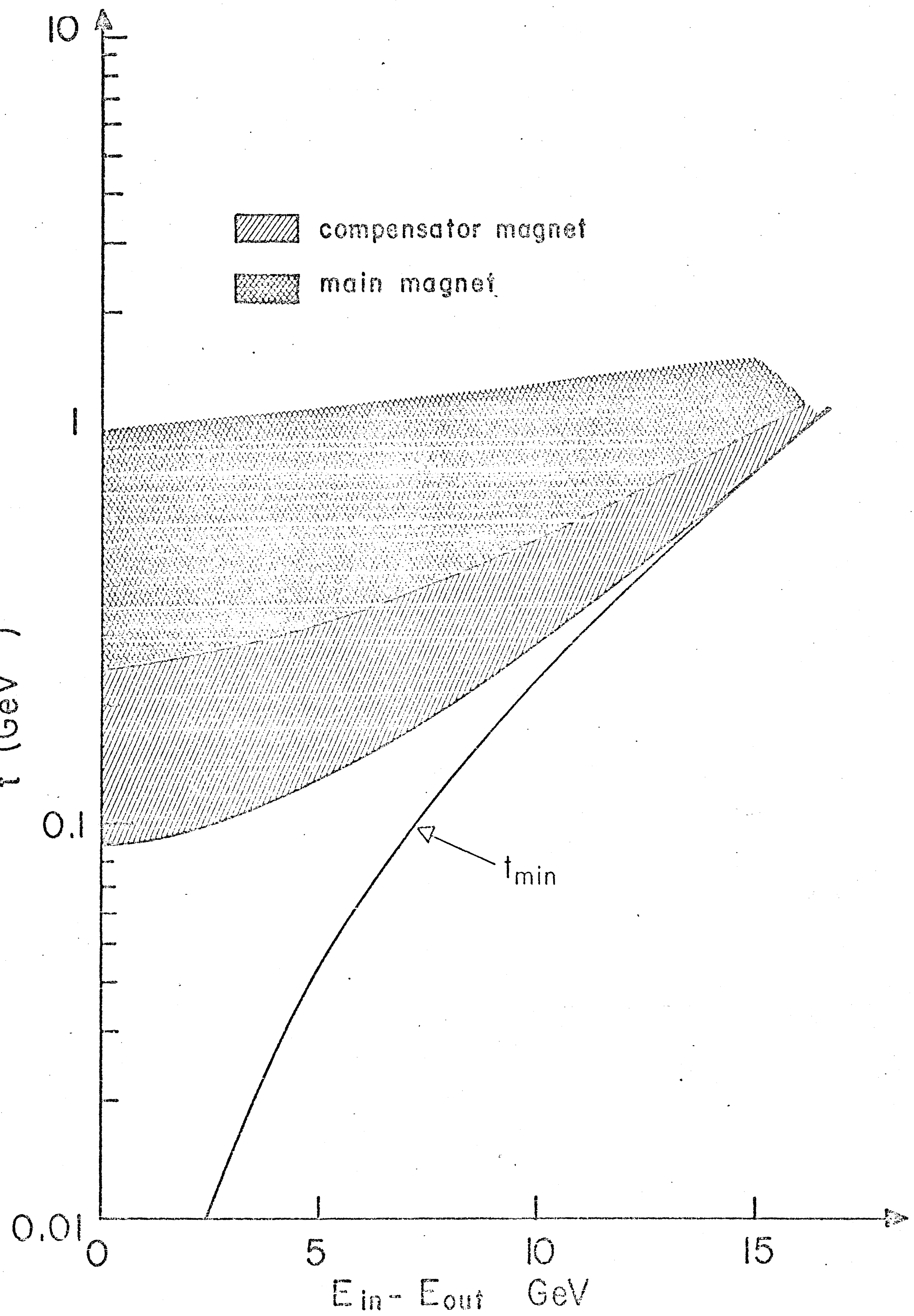


Fig. 2



compensator magnet
main magnet
10
1
0.1
0.01
t (GeV^2)
t_{min}
0
5
10
15
$E_{in} - E_{out}$ GeV

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