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A SUMMARY OF DISCUSSIONS ON A LARGE MAGNETIC ANALYSIS SYSTEM OF ISR REACTIONS

by

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SIS/K 1 003

1. INTRODUCTION

1.1 Purpose of the Project

There is general agreement that a large magnet system should be constructed at the ISR, which should provide the possibility of measuring the momenta of many charged reaction products in a geometry as nearly 4π as practicable. The system should be ready at the same time, or soon after, the ISR is available for experimentation, presumably by about the middle of 1971. It is likely that this will be the only large device capable of observing correlations between interaction products over at least some years; therefore it should be as generally useful as possible.

1.2 Purpose of this Report

This report summarizes information which could be useful in evaluating the merits of three different proposals. A list of references is given at the end. This information has been discussed and completed by a Working Group, which met 5 times. The members of this group were: B. French, B.D. Hyams, K. Johnsen (Chairman), F. Krienen, A. Michelini, A. Minten, B. de Raad, L. Resegotti, J. Steinberger and K. Winter (Secretary); the Director-General and the Chairman of the ISRC were guests.

Figures 1, 2 and 3 show the proposed magnet systems.

Comments and open questions, agreement and disagreement on the main problems, and also opinions are reported here. It is hoped that the report gives a faithful picture of people's views, and that it may help in deciding which magnet system is to be built. This attempt of an evaluation is organized in the following 5 chapters:

2. Acceptance
3. Event reconstruction
4. Detectors
5. Interference with ISR operation
6. Time schedule of construction.

2. ACCEPTANCE

A quantitative evaluation of acceptance, defined as the precision which can be achieved in the momentum measurement of reaction products as a function of their momenta and their (two) emission angles has been made[4]. A comparison of the three proposed magnet systems was made under some assumptions which were applied uniformly to all three projects:

a) A tube 15 cm in diameter centred on the beam.
b) The detector cannot approach obstructions (magnet poles, beam tube) closer than 5 cm, so that particles cannot be detected at a radial distance of less than 12.5 cm from the beam centre.
c) The detector is confined to the region of strong magnetic field $H > H_{max}/2$.

A summary can be found in Tables 1 and 2 for positively and negatively charged particles, respectively. They give the fraction of the solid angle for secondaries with a sagitta > 2 cm for particles with momenta in the range 0.5 to 25 GeV/c and transverse momenta p_T up to 3 GeV/c. The averaged acceptances over these ranges of momenta and transverse momenta are given for all three systems. These global acceptances are of relevance for detection of high multiplicity events over a wide angular range.

The typical event may not be well approximated by an isotropic momentum and angle distribution. A better model may be a statistical distribution, given by the Cocconi-Koester-Perkins formula. For pions one would expect:

$$\text{Pions:} \quad \frac{d^2N}{dpdp_t} = e^{-p^2/p_o^2} \; p_t \; e^{-p_t/p_{t_o}} .$$

Using for the parameters values obtained by Hagedorn

$$p_o = \langle p \rangle = 1.77 \text{ GeV/c}$$

$$p_{t_o} = \tfrac{1}{2} \langle p_t \rangle = 0.17 \text{ GeV/c}$$

the following fractions will be observed with a sagitta > 2 cm

	H - 0	K	S
π^+	0.58	0.92	0.85
π^-	0.62	0.99	0.89
$\pi^+ + \pi^-$	0.60	0.955	0.87

For protons one would guess a flat momentum distribution between 6 and 25 GeV/c and

$$\text{Protons:} \quad \frac{d^2N}{dpdp_t} = p_t \cdot e^{-p_t/p_{t_o}} .$$

Using $p_{t_o} = \frac{1}{2} \langle p_t \rangle = 0.25$ GeV/c one finds the following fractions:

H = 0	K	S
0.47	0.48	0.71

Limitations due to compensation magnets and shims have not been taken into account in these acceptance calculations and may change these results.

Discussion

The assumed size of the beam pipe, 15 cm Ø, and an extra 5 cm distance from it for detectors has been discussed. The standard vacuum pipe has elliptical cross section, 5 cm vertical and 15 cm horizontal diameter and 2.3 mm wall thickness.

Steinberger justified the assumption of 15 cm tube diameter. The beam tube must have thin walls to reduce multiple scattering of particles which traverse it. A rigid, thin-walled tube must have circular cross section. Its diameter is then given by the largest beam dimension for maximum intensity, and equals the horizontal size of the standard elliptical vacuum

chamber. French and Krienen discussed early use of the "Terwilliger scheme" which allows to reduce the horizontal beam size to 5 cm (by superimposing locally all momenta), and the tube to 6 cm diameter. French and Krienen summed up the advantages of this beam:

1) Acceptance of high-energy protons at lower transverse momenta in all three schemes (See Tables 3 and 4). The Krienen system with central field becomes more comparable to Steinberger's split field system.
2) Thinner wall (proportionally to the radius) and so less multiple scattering and nuclear interaction.
3) Better vertex reconstruction for neutral V's decaying inside the tube.

Johnsen, Hyams and Steinberger commented on the disadvantages of a magnet which requires the Terwilliger scheme:

1) Not available over the first 1-2 years.
2) Conflict with other users; in odd number intersection regions the beam blows up twice in the horizontal size.
3) Loss in luminosity by a factor of 4 to 5; this limits study of rare processes.
4) Three times higher pressure and beam-gas interaction rate in the crossing regions due to reduced pumping speed.
5) Interaction of beam tails with the walls and resulting background.
6) This magnet system being planned as the most advanced research possibility on the ISR should be able to run under all beam conditions.

Hyams commented on the particular field configuration chosen by Hyams-O'Neill. It was chosen to minimize the displacement of the circulating proton beam. But he agreed that it is poor in accepting secondaries, particularly because the downstream magnets are badly matched to the central field.

3. EVENT RECONSTRUCTION

Tracks as sampled by various detector arrangements (discussed under 4) have to be reconstructed and tracked through the magnetic field to the production vertex in the beam tube.

Three closely connected problems were discussed:

1) Influence of field inhomogeneities on computing time.
2) Precision of determining the production angles at the vertex from the observed track segments, and the
3) Influence of multiple scattering in crossing the beam tube.

B. French and J. Steinberger have discussed point 1) with Wind from NP division. Wind has devised a method, now currently in use, to determine the momenta of particles in arbitrary magnetic fields. Instead of storing a field map in the computer and integrating track segments through it, he now converts the field map into a tabulated function of five parameters, one being the momentum, the four others track parameters. The momentum of a particle is obtained by comparing its track parameters to the table. The method allows to compress field maps containing some 10^6 points into an array of some 10^3 - 10^4 words. The parameters can be adapted to the particular experiment. Therefore, there is no predictable difference in computer time for event reconstruction in rather homogeneous fields (central and downstream field in H-O system) and less homogeneous fields (magnets with open sides, Krienen and Steinberger system). Hyams expressed doubts as to whether this problem is completely solved.

Winter discussed points 2) and 3) and reported on calculations done by members of his group. They have generated events $p\,p \to p N^*$ and tracked the charged secondaries through one of the systems $\hookrightarrow n + \pi^+$ (split field). New coordinates were chosen at random in three assumed detectors on each track: New tracks were fitted to these new coordinates and X^2 minimized by searching for a new vertex point. The following mass resolutions ΔM_1 were obtained for a detection precision $\sigma = 0.5$ mm.

M_{N^*}	1238	1470	1900	MeV
ΔM_1	$\pm$ 14	$\pm$ 22	$\pm$ 27	MeV
ΔM_2	$\pm$ 18	$\pm$ 26	$\pm$ 31	MeV

Allowing for multiple scattering in traversing a beam tube of 1 mm wall thickness one finds ΔM_2. The small influence of multiple scattering may be particular for the reaction chosen.

Using only the reconstructed particle momenta, but the original and unchanged production angles, one obtains mass resolutions which agree within the Monte-Carlo statistics with ΔM_1 .

4. DETECTORS

Four detector arrangements were presented:

a) Small gap optical chambers in the Krienen system, by B. French.
b) Wire chambers in the S system, by Steinberger.
c) Optical chambers in the S system, by Steinberger.
d) Streamer chambers in the central magnet of the H-O system, by Hyams.

The discussion of the relative merits of different types of detectors will be reported in two parts: (1) possibility to reach the performance given by the acceptance calculations, which used a very abstract detector, (2) resolution in space and scanning possibilities.

4.1 We will proceed with a rapid description of the four detector arrangements and then summarize the discussion and comments.

a) A layout of small gap optical spark chambers in the Krienen system was presented by B. French. The system is shown in Fig. 4; it consists of five 10-gap blocks of chambers in each downstream arm, two inside the central field, one inside the downstream analysing magnet and 2 in the field-free drift space behind; in the central field there is also one block of spark chambers of $\pm$ 1 m radial dimension, $\pm$ 1.5 m

azimuthal and $\pm$ 0.75 m in height. Photography is achieved by four cameras; one camera for each downstream arm and two cameras on top and bottom of the central field.

Discussion and Comments on a)

In the particular example presented by French, the central detector fills only 1/3 of the radial dimension of the magnet, thereby decreasing the maximum sagitta in the central region (which is proportional to BL^2) by a factor 9; also the height is only used to one half. Krienen pointed out that for different experiments the full magnet volume could be used for particle detection by means of optical chambers. Photography is also restrictive to the direction of particles. Winter said that a detector of about the same dimension can be accommodated in the split field magnet (see p. 9, section c and Figure 6). Krienen pointed out that the French layout in the central region is very much different from that proposed by Steinberger (compare Figs. 4 and 6). Winter expressed doubt whether the hole for photography can be further increased without a rapid decrease in field, whereas Krienen was of the opinion that a hole of 2 x 2^2m in a pole of 5 m diameter is acceptable for a reasonably constant field in the medium plane. Steinberger commented on the downstream detector arrangement. Photography into the downstream analysing magnet is achieved through a special slot in the iron. Consequently the system is very rigid and has low information density in a region where the multiplicity of secondaries is expected to be high. The low information density in the downstream magnet will also not allow to measure the maximum sagitta which were calculated. However, a different method of photography, an example of which is shown in Fig. 6 (downstream region) could overcome this rigidity.

b) As a proposal, Steinberger presented groups of 4 gaps of Charpak proportional chambers, with wire orientations 0°, 90°, $+45^\circ$, and -45° in the split field system. This arrangement will give the local direction of tracks similar to optical chambers, and therefore high redundancy. A total of 10^5 wires with a 2 mm spacing will approximate very well the abstract detector used in evaluating the acceptance of the system; a group of

chambers every metre in the downstream region and three groups around the central region. A typical arrangement is shown in Fig. 5. Steinberger commented on his preference for Charpak chambers; they are known to work well in high magnetic fields and have a very short sensitive time τ. Detection of particles by chambers with digital readout has several advantages. The information density can be adjusted according to the requirements and is not limited by optics. Also the orientation of planes and therefore the direction of particles is not restricted.

	sensitive time
Charpak chambers	100 ns
Small gap spark chamber	1 000 ns
Wide gap and streamer chamber	10 000 ns

The short sensitive time of Charpak chambers is perhaps a useful feature in view of the large background from beam-gas interactions.

Discussion and Comments on b)

Minten pointed out that wire chambers by their high price and complexity will always result in a low density of information in the central field. They will also not detect particles emitted into the full solid angle. A better detector, at least for a survey in the central field would be a streamer chamber which is an isotropic detector (later described by Hyams). Krienen commented on the price of Charpak's chambers and said the price of readout electronics is about 40 SFr. per wire and is not expected to decrease much. Steinberger discussed an electronics scheme which uses groups of wires in Charpak chambers as hodoscope elements for event decision. In this way much of the complication of using many scintillators in high magnetic fields (long light guides) can be avoided and the trigger possibilities remain very flexible, as they require no changes in hardware.

c) Steinberger presented a possible layout of optical spark chambers in the split field system to demonstrate the principal feasibility in case their use would be desirable. The layout is shown in Fig. 6; it uses four cameras on the sides, two top mirrors on each downstream group to get 90^{o} stereo views and small mirrors looking into the shadow of the vacuum pipe. About 10% of the vertical space is taken up by mirrors and lost for particle detection.

d) Hyams presented a streamer chamber arrangement in the central field of the Hyams-O'Neill system (see Fig. 7). He referred to the SLAC experience with a 2-gap chamber, 3 m long, 2 m wide and 2 x 30 cm high which is operational. He would put 4 gaps into the central magnet, giving 120 cm height, and rearrange the pillars to give space for the feed electrodes from the outside. The medium plane between the crossing beam tubes is left free over a height corresponding to the tube diameter (15 cm). He would select 4 constraints and 2 constraints events for a survey experiment by triggering on events with $N\gamma \leq 2$; this would give a class of events which is between 10^{-2} and 10^{-3} of the total. The acceptance for events with a charged multiplicity n_{CH} is $(0.50)^{n_{CH}}$ for the H-O system. This detector would also see the vertex of neutral V's. The main advantage of this scheme would however be its high information density. Considering track segments of 1 cm length as independent, one arrives at a factor 10 in density with respect to wire chambers.

Discussion and Comments on d)

Steinberger recalled the problems due to the long sensitive time, perhaps 10 μs, in the presence of heavy background. If the circulating current is not to be limited to a small value, the high information density may even not be sufficient to separate tracks from beam-beam interactions. Gregory commented on the information density in the streamer chamber. High density is required in that part of the solid angle in which the multiplicity is high. From

Summary of the discussion on optical detectors

	H-O	K	S
Possibility of optical chambers in downstream magnets	Good	Good	Good
Fraction of field volume useful for detection	1	0.9	0.9
Possibility of optical chambers near interaction point	Excellent†	Good	Medium
Fraction of field volume used for detection	0.25 of height full width	0.5 of height 0.3 of width (in French lay-out)	0.9 of height full width

the observation of nearly constant average transverse momentum and the observed average longitudinal momenta one could conclude that high multiplicity will occur at angles below 5^{o}. The streamer chamber in the central field and the idea of a central field altogether may not match very well with physics. Hyams pointed out that there may well exist very central collisions producing high multiplicity events at rest in the c.m. system, and cited cosmic ray results supporting this hypothesis.

Steinberger pointed out that there is no need to observe the vertex of neutral V's as the great majority decays inside the vacuum tube at the same average transverse distance from the beam, because of their small transverse momenta. The problem is then rather to sample the decay tracks well enough to see a 'gap' L between the vertex of the V and the beam-beam collision. The error on the gap, ΔL is

$$\Delta L/L \cong \frac{10^{-2}}{\tau} \cdot \frac{m}{p_T} , \quad (\tau \text{ in } 10^{-10} \text{ s})$$

and $\Delta L/L \cong 0.1$ can be reached for lifetimes of 0.3×10^{-10} s. Hyams pointed out that in a system using the standard vacuum pipe a reasonable fraction of the neutral V's would decay outside the tube.

4.2 Space Resolution and Scanning Possibilities

Experimentally observed resolutions, defined as random deviations σ of sparks from particle tracks are given in the table.

Detector	System	σ	References
Small gap opt. chambers	compact	$\pm$ 0.20 mm	Michelini
Wire spark chambers	1.2 mm spacing 2x0.5 m ch.	$\pm$ 0.25	Rubbia
	1.0 mm spacing 1x0.5 m ch.	$\pm$ 0.28 mm	Karlsruhe Gr.
Charpak ch.	2 mm spacing	$\pm$ 0.7 mm	Charpak
	4-gap group	$\pm$ 0.50 mm	
Streamer chamber	$\perp$ to $\vec{E}$	$\pm$ 0.5 mm	DESY, SLAC
	11 to $\vec{E}$	$\pm$ 1.0 mm	

For large optical systems the resolutions are predominantly due to the optics: distortions and index variations. Steinberger pointed out that the depth of focus, D, is limiting the minimum spark size, I, to

$$I = \pm \frac{D}{m \cdot f}$$

where f is the f-number of the lens, typically 10 for multi-spark events, m is the demagnification, typically 30 in the detectors described by French and Steinberger; D = 1.5 m in Steinberger's scheme, D = 1.9 m in French's scheme, giving

$$I = \pm 5 \text{ mm or } \pm 6 \text{ mm.}$$

If the circle of confusion is large, there is also a loss of light intensity. The resolution in wire chambers depends only on the wire spacing and on the mode of operation and no other external parameters and can therefore be estimated with more

reliability. Hyams agreed with this and said that the final resolutions, specially in the downstream regions, could be expected to be equal for optical and wire chambers.

French, Minten and Hyams insisted strongly on the possibility of scanning events, as their topology may be very complicated. Steinberger commented that at present there exist no scanning tables which can accommodate 4 pictures from 4 cameras. Winter pointed out that the topology of events is getting more complicated by the photography because of extra views out of the shadow of the vacuum pipe. Hyams insisted on the advantage of homogeneous magnet fields in the Hyams-O'Neill detector for the purpose of scanning.

Gregory asked if a combination of digital readout of wire chambers and the display of digital data in a topologically obvious way would not ease this problem. Winter answered that this is already a standard procedure at CERN using the display console of the CDC 3100. He reported prices for this installation given to him by Zanella (DD). A high resolution display with the possibility to interact with programmes by a light pen would cost about 100 000 SFr, the controller, which can serve 4-8 display consoles would cost about 200 000 SFr.

Summary of discussion on resolution and scanning

Detector	Resolution	Sensitive time	Scanning possibilities
Large system of small gap optical chambers	$\pm$ 0.3 mm	1 μs	4 pictures, complicated layout
Large streamer chamber	$\pm$0.5 mm $\sigma_\perp$ $\pm$1.0 mm σ_{11}	10 μs	Good
Wire chambers	$\pm$0.3 mm	1 μs	Good on display
Charpak chambers	$\pm$0.50 mm	0.1 μs	Good on display

5. INTERFERENCE WITH ISR OPERATION

Several possibilities of interference with the ISR operation have been discussed.

1. Deformation of circulating proton orbits inside the magnet systems and compensating schemes.
2. Loss in luminosity due to field gradients and multipole fields and due to change in crossing angle.
3. Problems connected with installation and change of experiments (running procedures).
4. Possibility of a 2-stage programme.

5.1 De Raad and collaborators[5] have investigated the orbit deformations in the magnet systems. The circulating beams are matched to the ISR lattice by special compensating magnets or by the magnet system itself. The following table gives the change of crossing angle $\Delta\Theta_{cr}$; the radial shift of the interaction point Δr_c and the largest radial deflection of the beams, Δr_{max}.

Orbit Deformations

	Steinberger	Hyams-O'Neill	Krienen
$\Delta\Theta_{cr}$	$\pm 4.5^{o}$	0^{o}	0^{o}
Δr_c	6 cm	0	0
Δr_{max}	12 cm	4	6 cm

Comments on orbit deformations

The deformation in the Hyams-O'Neill system is small enough to accommodate in it the standard vacuum tube without moving it, if one uses the space normally allocated for injection. Injection and stacking would have to be done while the H-O magnet is off. The circulating beams are then shifted radially and the H-O magnets are switched on in synchronism with the compensators.

Both other systems would require special vacuum pipes which are, or can be deformed to contain the deflected beam orbits. This is technically feasible. But if the magnet is switched off the vacuum pipe and the surrounding detectors have to be moved; this is summarized below.

a) Fixed vacuum tube and detector arrangement

Magnet always on. Field proportional to ISR beam momenta: fixed ratio of momenta in both beams.

b) Flexible tube and detector arrangement

Tube shape proportional to magnet field; magnet can be switched off; upper limit to the ratio magnet field/ISR beam momentum; detectors have to move with the chamber.

If in any of the three systems one wants to operate at lower ISR momentum, but at the maximum field, only solution 2 with flexible tube is possible; in this case a precise disposition of the detectors has to be arranged for each momentum.

The flexibility of the tube (and of the detector) should be such that they allow to change experimental conditions between long blocks of running time. (See for further discussion under 5.3). If the magnet cannot be switched off without moving the vacuum tube and the detectors, it should be maintained in operation even if data collection is stopped due to the failure of any element of the detection system or for any other reason.

Therefore the whole system, including its power supplies, should have the same degree of reliability as the ISR ring magnets. It should also be possible to remove the whole system in periods of the order of days.

5.2 Field gradients and edge focusing effects of the magnet system will modify the focusing properties of the ISR. This can be compensated only partly (order of 50%).

De Raad and collaborators[5] (CERN/68/ISRU/118) have calculated the residual effects and the resulting loss in luminosity $\Delta L/L$. Their results are summarized below (not taking into account effects in the compensating magnets for H-O and K)

	H-O	Steinberger	Krienen
$\frac{\Delta L}{L}$	3%	17%	22%
L_o	1	0.77* due to crossing angle	1

* If the opposite polarity is chosen ($\Delta\Theta_{cr} = 4.5^o$) $L_o = 1.4$.

There was general agreement that these values would not distinguish between different magnet systems as the best luminosity which can be reached is uncertain in an even wider range.

5.3 Starting from a discussion of power cost if the magnet would be powered the whole year and the possible savings (2/3 year ISR operation and during half this time magnet operation, resulting in ~ 1 MSFr/year), some of the practical problems in mounting and modifying experiments were discussed. During periods of mounting and modification the other intersecting

regions should operate, with a minimum of loss in time. Therefore, either the whole magnet or the detector alone has to be removed from the interaction region and transported to the preparation hall. This transport would take at least a few days. During periods of preparation and modification, the interaction region No.4 could be used for other, simple experiments.

5.4 It was emphasized that a two-stage project would leave more flexibility for later improvements. As an example, Johnsen mentioned that after some years of operation one could envisage to redesign the ring magnets adjacent to the interaction region to incorporate them into a larger orbit compensation scheme. The split field magnet could then be transformed into a single polarity of field of increased length in each arm. These considerations should be kept in mind when detailed designs are made. From the point of view of experimental use it would seem acceptable to replace the 2 downstream magnets of the split field system by compensators of reduced length and width.

6. De Raad and Resegotti have looked into a possible time-schedule for the present magnet system and have, in the light of its complexity, arrived at the following result:

During the first half of 1969 the recruitment of a project group and of the necessary supporting staff (drawing office) should be carried out. Meanwhile engineering studies would be undertaken by visitors and, on a part-time basis, by some members of the ISR Department.

The project proper would then start about mid-1969 and take somewhat less than four years, according to the following schedule:

1969 - Second half - General design:

a) mechanical structures, supports, assembling, movements;
b) preferred shapes and sizes of flux return elements;
c) optimum coil size.
- Design and drawings of a 1:5 (or 1:4) scale model.
- Order of the model.

1970 - Manufacturing of the model (January to October).
Preparation for model powering and measurements.
Continuation of detailed design and drawings of main magnets and compensators.
- Measurements on the model (October to December).
Preparation of tendering specifications.

1971 - Tendering and discussion with firms (January to April) and, simultaneously, shimming studies of the model and preparation of final drawings.
- Adjudications and Contracts (May to July).

1972 - Manufacturing and delivery of components.

1973 - Early months - Assembling and erection.

REFERENCES

1. Hyams, O'Neill, "Proposal for an analysing system of ISR reactions", 8 September, 1968.

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5. Couchman, de Raad, Strolin, "Calculation of orbit perturbations", CERN-68/ISRU/118, 4.12.1968.

6. Krienen, "Review of Proposed Magnetic Analysis Systems for ISR Reactions", CERN-68/ISRU/109, 10.6.1968.

Table 1

Fraction of particles with sagitta > 2 cm, accepted by the magnet system (extracted from reference 4). Hatched areas show where this fraction is below 0.6. (Beam tube of 15 cm diameter, clearance from magnet surfaces and beam tube 5 cm).

Particles of positive charge

H - O *

P \ P_T	.1	.2	.3	.5	.7	1	1.5	2	3
25	0	0	0	0	0	1.0	1.0	1.0	.3
20	0	0	0	0	1.0	1.0	1.0	.7	.1
15	0	0	.3	.8	1.0	1.0	.8	.4	0
10	.3	.6	.7	1.0	1.0	.8	.2	0	0
6	1.0	.8	.8	.8	.7	.3	.2	.2	.2
4	1.0	.7	.6	.6	.3	.2	.1	.2	.1
2	.2	.4	.3	.2	.3	.7			
1	.4	.3	.3	.9	1.0	1.0			
.5	.9	1.0	1.0	1.0	.9				
$\bar{\Sigma}$	.42	.42	.44	.59	.69	.75	.55	.42	.12

Average .49

K *

P \ P_T	.1	.2	.3	.5	.7	1	1.5	2	3
25	0	0	0	0	.2	1.0	1.0	.7	.4
20	0	0	0	.2	1.0	1.0	.8	.5	.3
15	0	0	.3	1.0	1.0	1.0	.5	.4	.2
10	0	.5	.1	1.0	1.0	.6	.4	.2	0
6	.7	.8	1.0	1.0	.5	.4	.2	.7	.3
4	.8	1.0	1.0	.5	.8	.8	.9	.9	.6
2	1.0	.9	.8	.9	1.0	1.0			
1	.8	1.0	1.0	1.0	1.0	.8			
.5	1.0	1.0	1.0	1.0	.8				
$\bar{\Sigma}$	.48	.58	.68	.73	.81	.93	.63	.57	.30

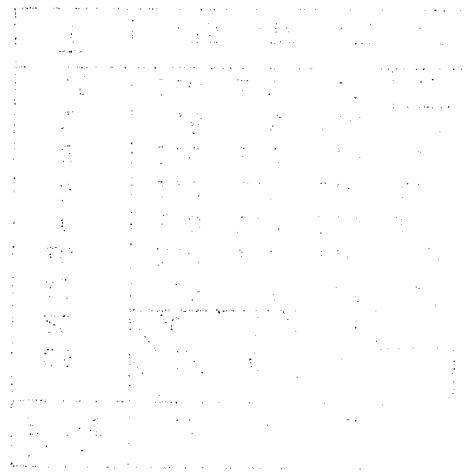
Average .62

S *

P \ P_T	.1	.2	.3	.5	.7	1	1.5	2	3
25	0	0	0	0	1.0	1.0	1.0	1.0	.7
20	0	0	.4	.7	1.0	1.0	1.0	1.0	.6
15	.9	.7	.7	.8	1.0	1.0	1.0	1.0	.5
10	1.0	1.0	1.0	.9	1.0	1.0	1.0	.6	.3
6	1.0	1.0	1.0	1.0	1.0	1.0	.6	.4	.2
4	1.0	1.0	1.0	1.0	1.0	.9	.4	.3	.2
2	1.0	1.0	.9	.8	.7	.5			
1	.8	.8	1.0	.7	.5	.4			
.5	1.0	1.0	.7	.5	.4				
$\bar{\Sigma}$	.75	.72	.75	.71	.84	.85	.83	.72	.42

Average .73

* The letters H-O, K and S stand for the systems proposed by Hvams-O'Neill, Krienen and Steinberger, respectively.



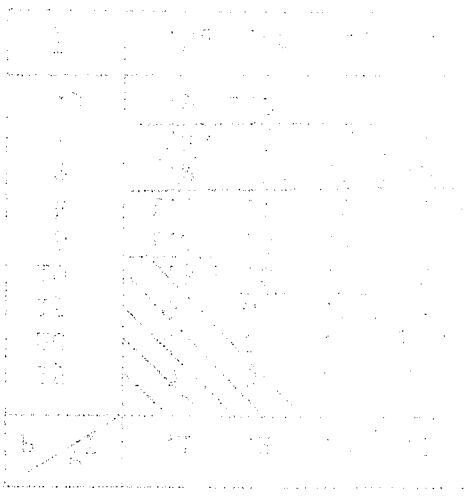


Table 2

Fraction of particles with sagitta > 2 cm, accepted by the magnet system (extracted from reference 4). Hatched areas show where this fraction is below 0.6 (Beam tube of 15 cm diameter, clearance from magnet surfaces and beam tube 5 cm).

Particles of negative charge

H - O

P \ P_T	.1	.2	.3	.5	.7	1	1.5	2	3
25	0	.3	.4	.5	.6	.7	.9	.8	.4
20	.4	.5	.6	.7	.7	.8	.9	.7	.1
15	.7	.6	.7	.7	.8	1.0	.7	.4	0
10	1.0	.8	.8	.8	.7	.7	.3	0	0
6	1.0	1.0	.8	.6	.6	.3	.2	.2	.2
4	.8	.6	.6	.5	.3	.2	.1	.2	.1
2	0	.7	.6	.4	.1	.6			
1	.8	.3	.4	.8	1.0	1.0			
.5	1.0	.9	.9	1.0	.9				
$\bar{\Sigma}$	.53	.63	.64	.67	.63	.66	.52	.38	.13

Average: .53

K

P \ P_T	.1	.2	.3	.5	.7	1	1.5	2	3
25	0	0	0	.5	.6	.8	1.0	.7	.4
20	0	0	.4	.6	.7	1.0	.8	.5	.3
15	.1	.5	.6	.7	1.0	1.0	.6	.4	.2
10	.6	.7	.7	1.0	1.0	.6	.4	.2	0
6	1.0	1.0	1.0	1.0	.5	.5	.6	.7	.4
4	1.0	1.0	1.0	.8	.9	.9	.9	1.0	.6
2	1.0	1.0	1.0	1.0	1.0	1.0			
1	1.0	1.0	1.0	1.0	1.0	.8			
.5	1.0	1.0	1.0	1.0	.8				
$\bar{\Sigma}$	.63	.69	.74	.84	.83	.82	.72	.58	.32

Average: .69

S

P \ P_T	.1	.2	.3	.5	.7	1	1.5	2	3
25	0	.2	.4	.9	1.0	1.0	.9	.9	.7
20	1.0	1.0	1.0	1.0	1.0	1.0	.9	1.0	.6
15	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.5
10	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.7	.4
6	1.0	1.0	1.0	1.0	1.0	1.0	.7	.5	.3
4	1.0	1.0	1.0	1.0	1.0	.9	.5	.4	.2
2	1.0	1.0	1.0	1.0	.8	.4			
1	1.0	1.0	1.0	.6	.5	.4			
.5	1.0	1.0	.7	.4	.4				
$\bar{\Sigma}$	.89	.91	.90	.88	.86	.84	.83	.58	.45

Average: .79

Table 3

Fraction of particles with sagitta > 2 cm accepted by the magnet systems. Hatched areas show where this fraction is below 0.6. (Beam tube of 6 cm diameter, no clearance from the beam tube, but 5 cm clearance from magnet surfaces).

Positive particles

H - O

P \ P_T	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1
25	0	0	0	0	.37	.47	.63	.95	1	1	1
20	0	0	0	.26	.74	1	1	1	1	1	1
15	0	.58	.74	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	.84	.79
6	1	1	1	.95	.89	.79	.79	.84	.68	.53	.33
4	1	1	.79	.74	.84	.89	.53	.42	.37	.37	.37
2	0	.79	.89	.53	.89	.95	.95	1	1	1	1
1	0	.89	1	1	1	1	1	1	1	1	1
Σ	.37	.66	.68	.68	.84	.89	.86	.90	.88	.84	.84

Average: .768

K

P \ P_T	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1
25	0	0	1	1	1	1	1	1	1	1	1
20	0	.37	1	1	1	1	1	1	1	1	1
15	0	.68	1	1	1	1	1	1	1	1	1
10	1	.84	1	1	1	1	1	1	1	.74	.63
6	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	.95	.95	.95
2	1	1	1	.95	.95	1	1	1	1	1	1
1	0	.95	1	1	1	1	1	1	1	1	.84
Σ	.50	.74	1	.99	.99	1	1	1	.99	.97	.93

Average: .920

S

P \ P_T	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1
25	0	0	1	1	1	1	1	1	1	1	1
20	1	.84	.79	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	.75
2	1	1	1	1	1	.95	.95	1	.84	.68	.63
1	1	1	.95	1	1	1	.63	.53	.47	.42	.37
Σ	.87	.85	.97	1	1	.99	.95	.94	.91	.89	.87

Average: .932

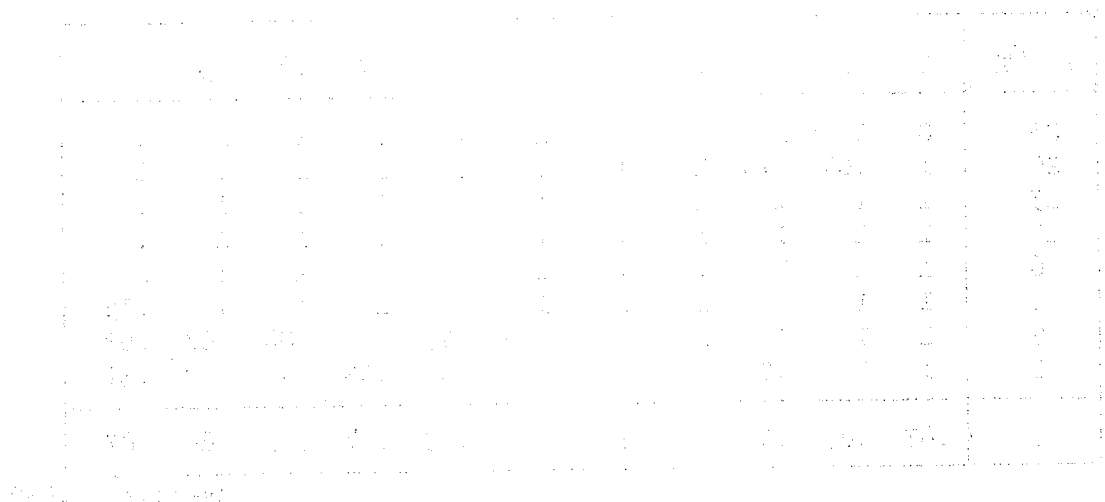


Table 4

Fraction of particles with dagitta > 2 cm accepted by the magnet systems. Hatched areas show where this fraction is below 0.6. (Beam tube of 6 cm diameter, no clearance from the beam tube, but 5 cm clearance from magnet surfaces.

Negative Particles

H - 0

P \ P_T	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1
25	0	0	.32	.37	.68	.74	.79	.84	.84	.84	.89
20	1	.84	.68	.68	.74	.79	.84	.84	.89	.89	.95
15	1	1	1	1	.95	.89	.89	1	1	1	1
10	1	1	1	1	.95	.95	1	.84	.79	.74	.68
6	1	1	1	1	1	1	1	1	.84	.63	.63
4	1	1	1	1	1	1	.63	.53	.47	.37	.32
2	1	.84	1	.84	1	1	.95	.95	1	1	1
1	1	1	.95	.	1	1	1	1	1	1	1
Σ	.87	.84	.87	.86	.92	.92	.94	.87	.85	.81	.81

Average: .870

K

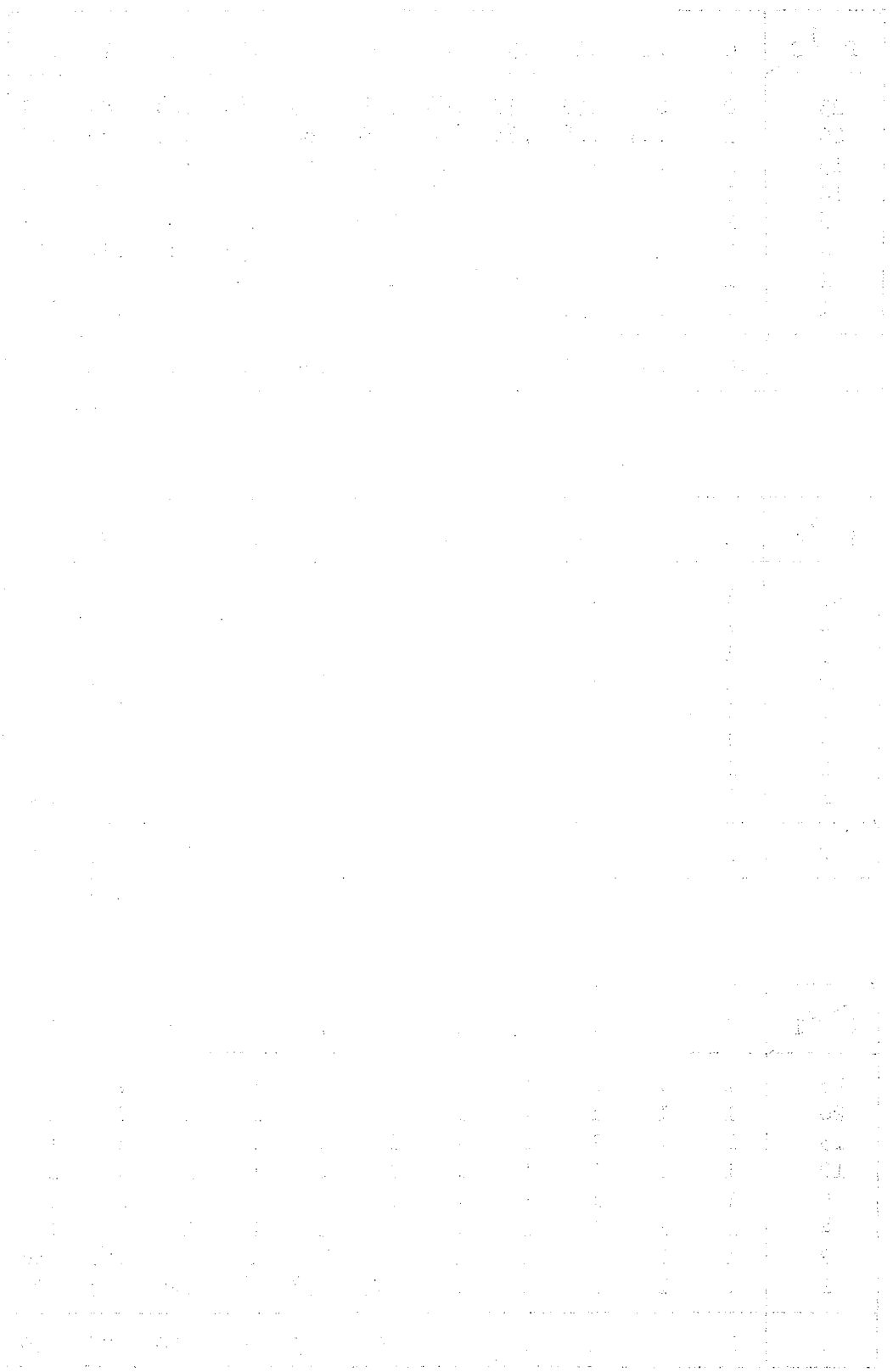
P \ P_T	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1
25	1	1	1	1	.89	.84	.89	1	1	1	1
20	1	1	1	1	.89	.95	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	.95	1	1	1	1	1	.74	.63
6	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	.84
Σ	1	1	1	.99	.97	.97	.99	1	1	.97	.93

Average: .985

S

P \ P_T	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1
25	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	.79	.68	.58
1	1	1	1	1	1	.79	.58	.47	.42	.37	.37
Σ	1	1	1	1	1	.97	.95	.93	.90	.88	.89

Average: .948



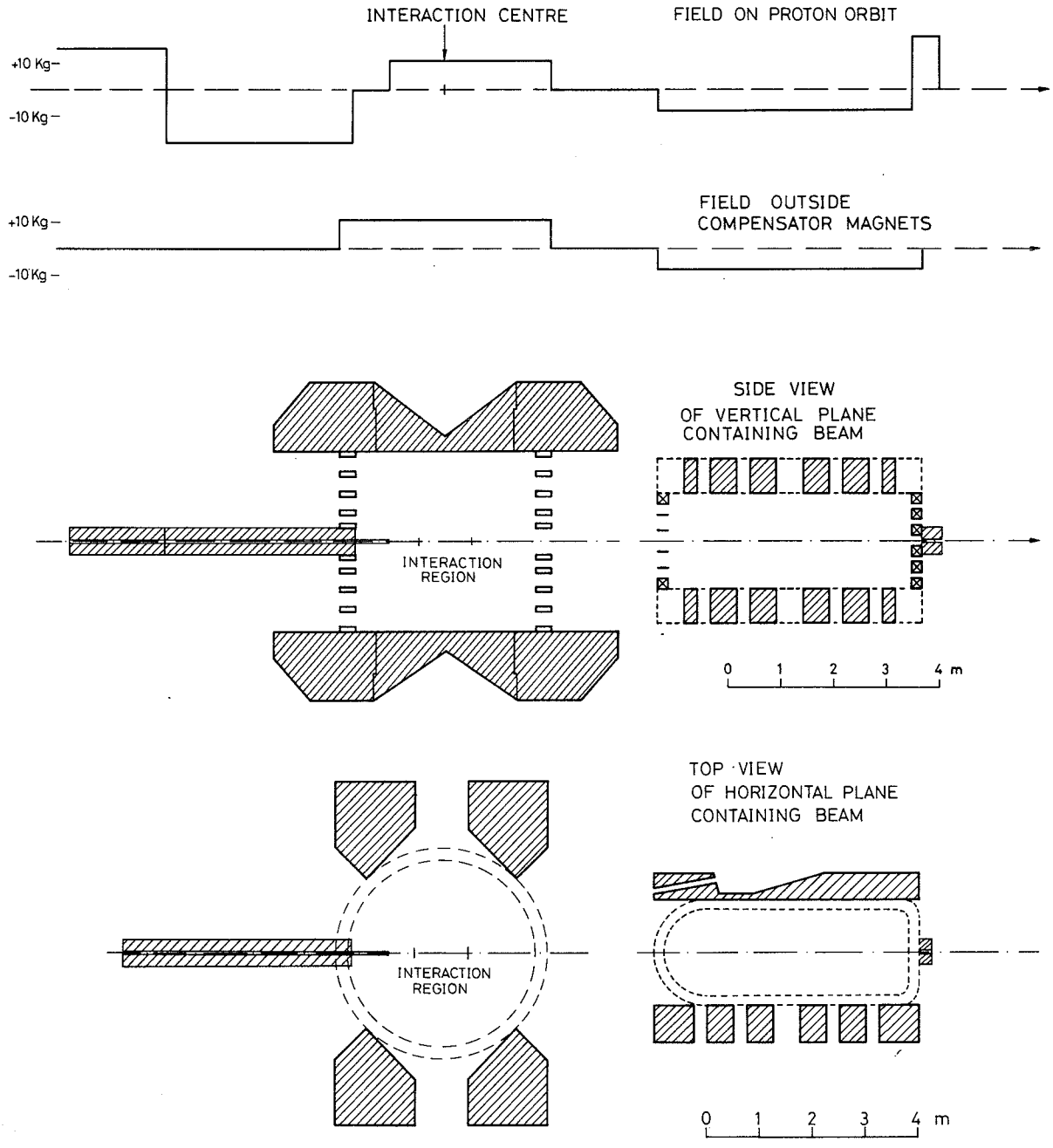
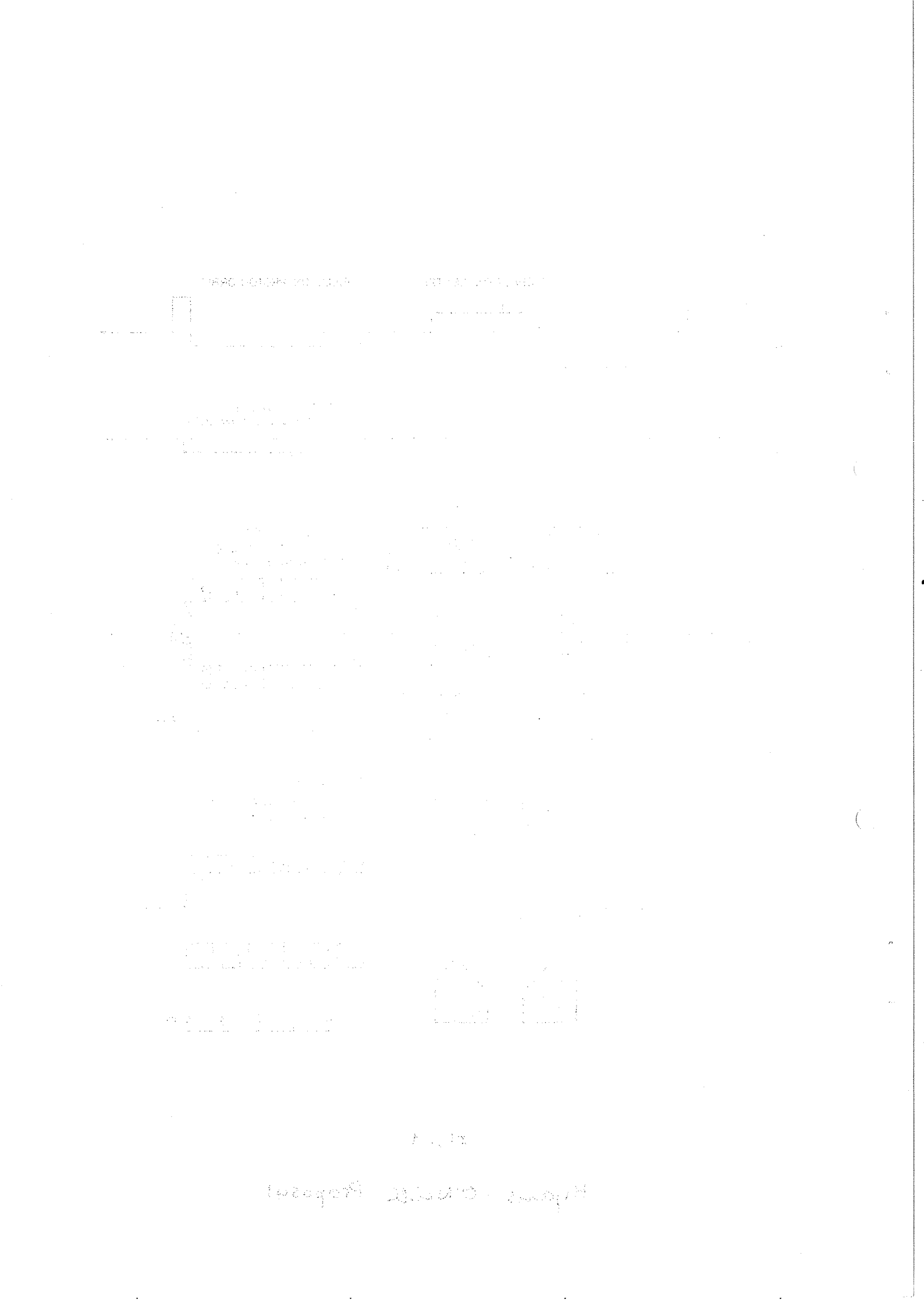


Fig. 1

Hyams - O'Neill Proposal



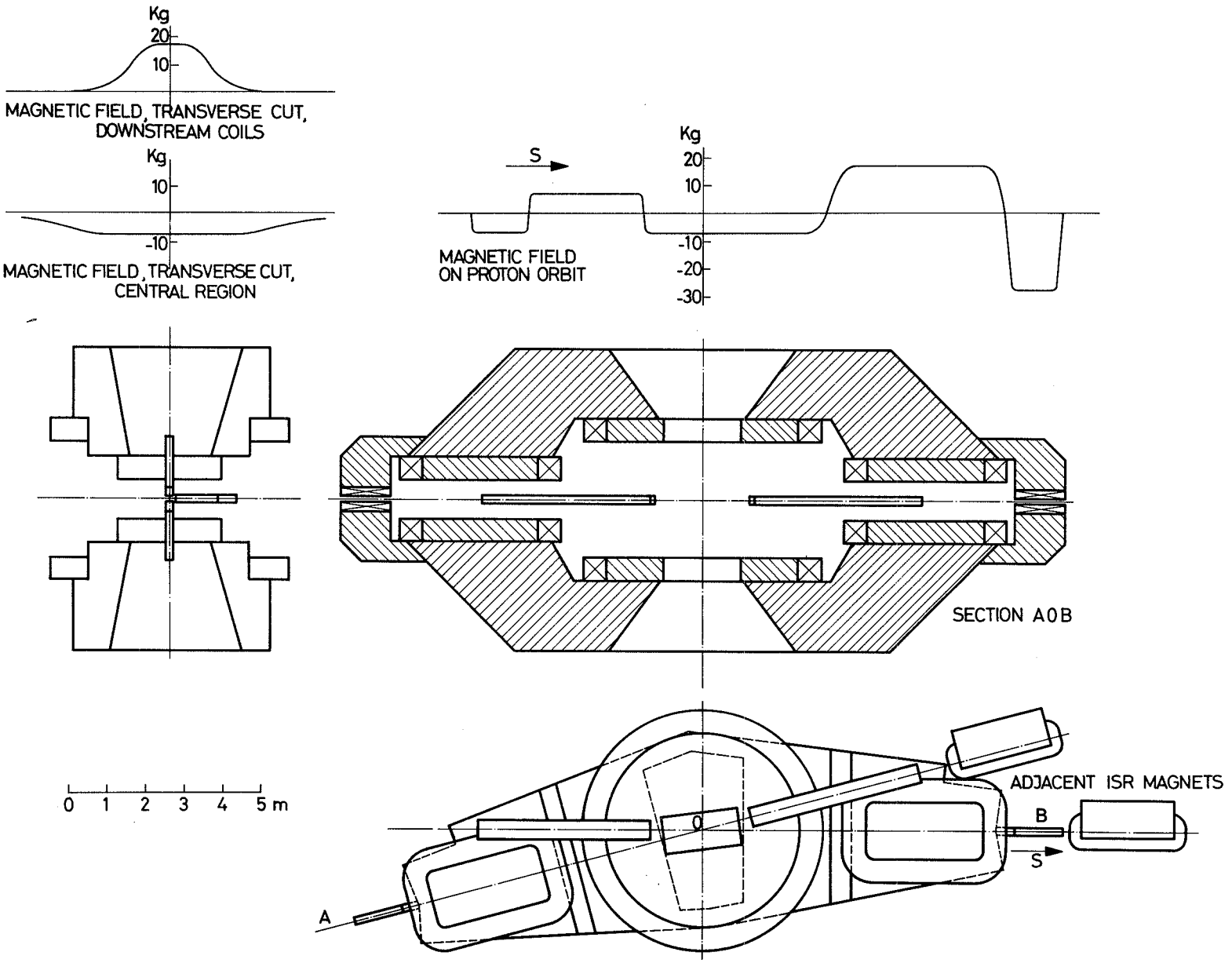
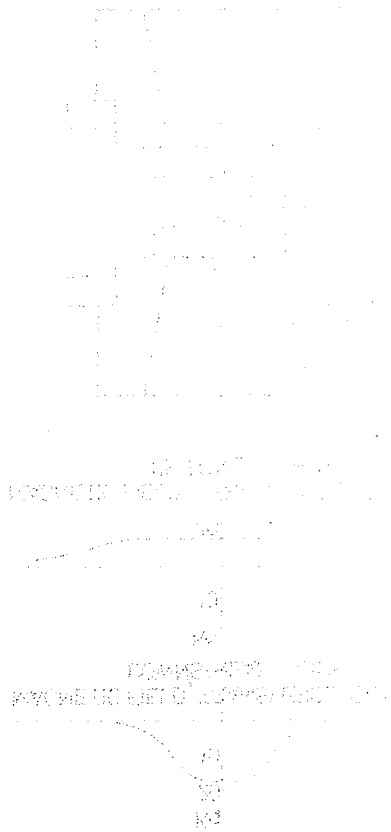


Fig. 2
Kriewen Proposal



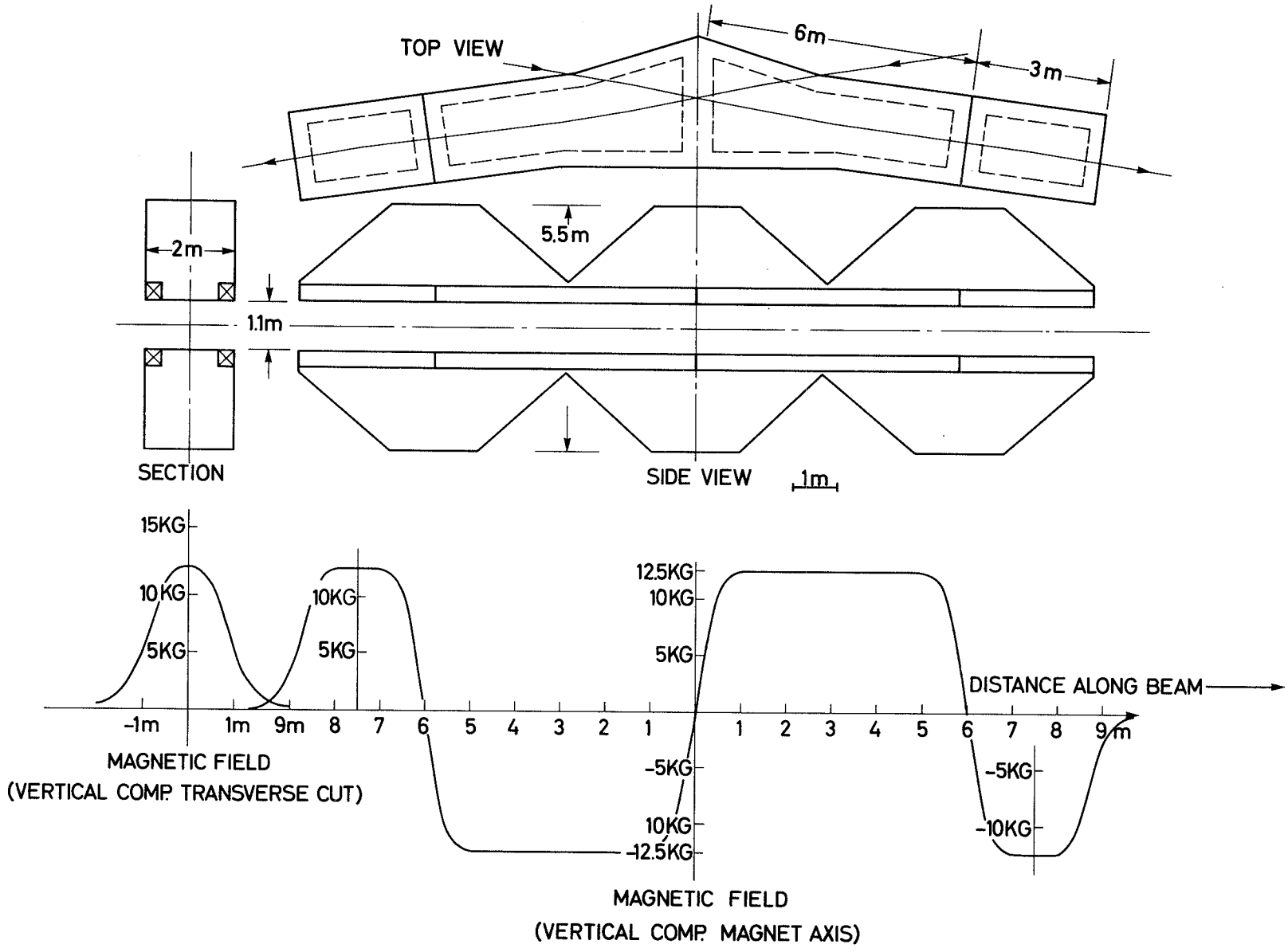


Fig. 3

Steinberger Proposal

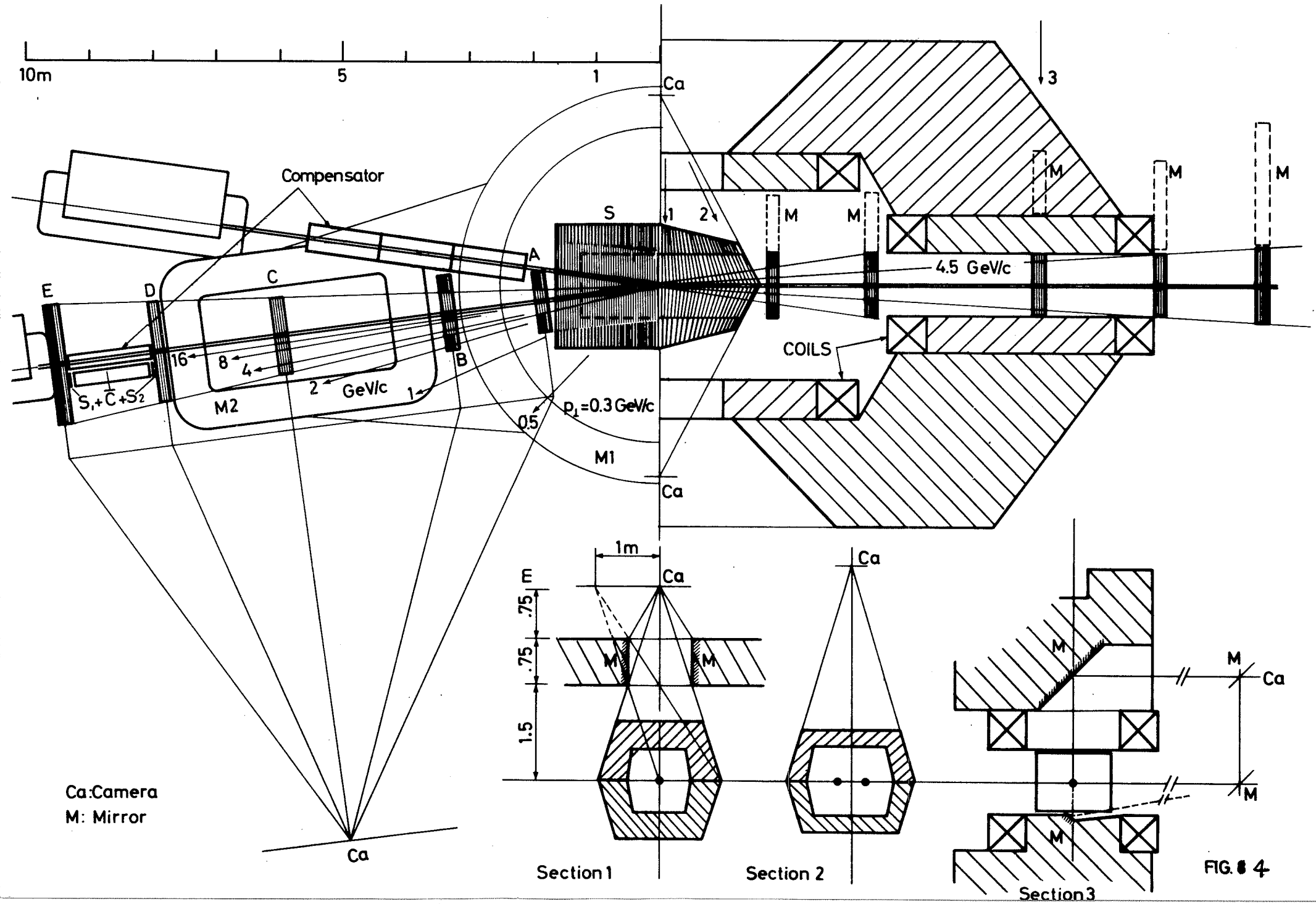

10m
5
1
Ca
3
Compensator
S
1
2
M
M
M
M
M
A
E
D
C
B
16
8
4
2 GeV/c
1
S1+C̄+S2
M2
4.5 GeV/c
COILS
p⊥=0.3 GeV/c
0.5
M1
Ca
1m
.75 m
.75
1.5
Ca
Ca
M
M
M
M
M
M
Ca
Ca:Camera
M: Mirror
Section 1
Section 2
Section 3

FIG. 4

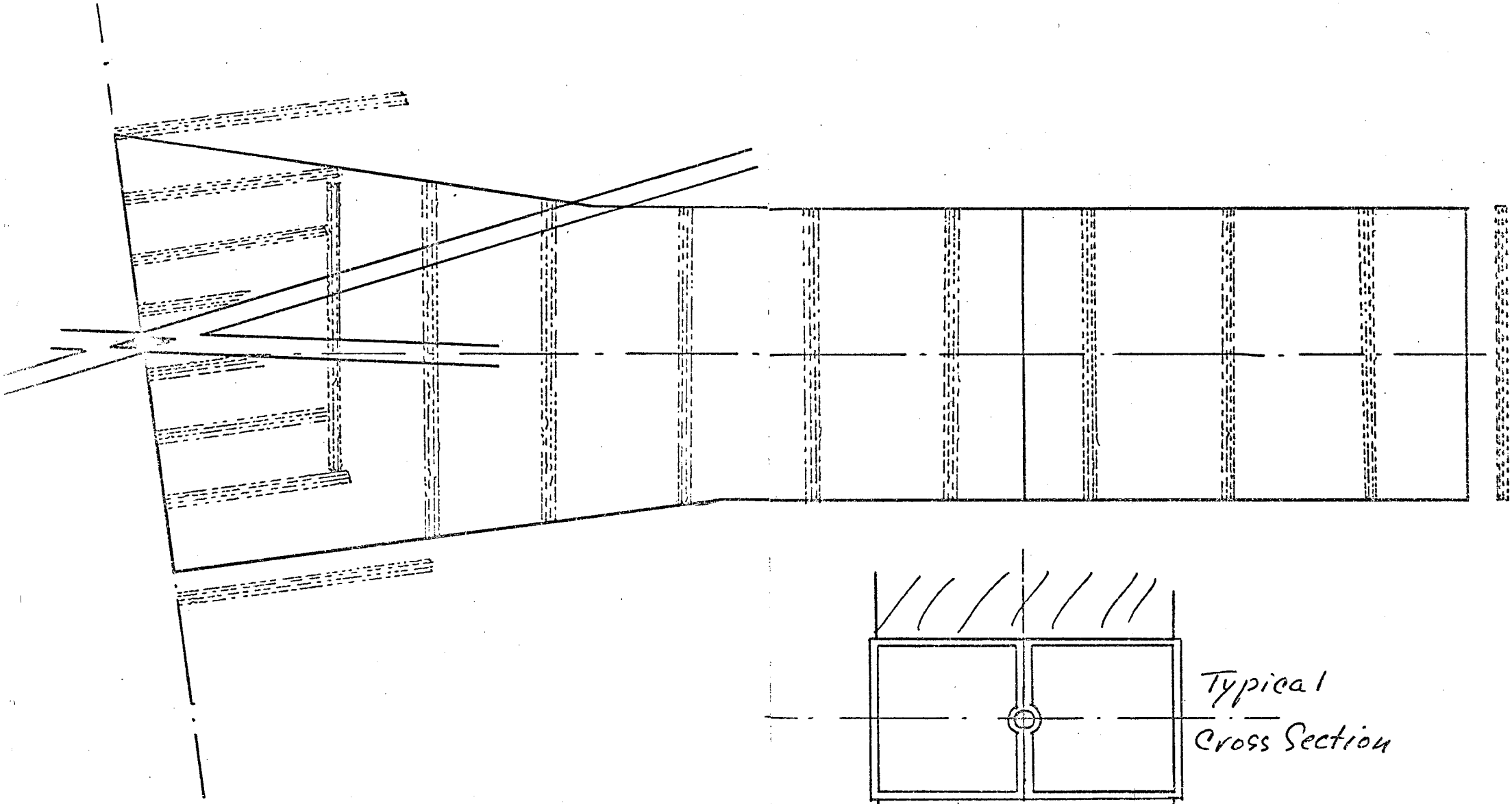
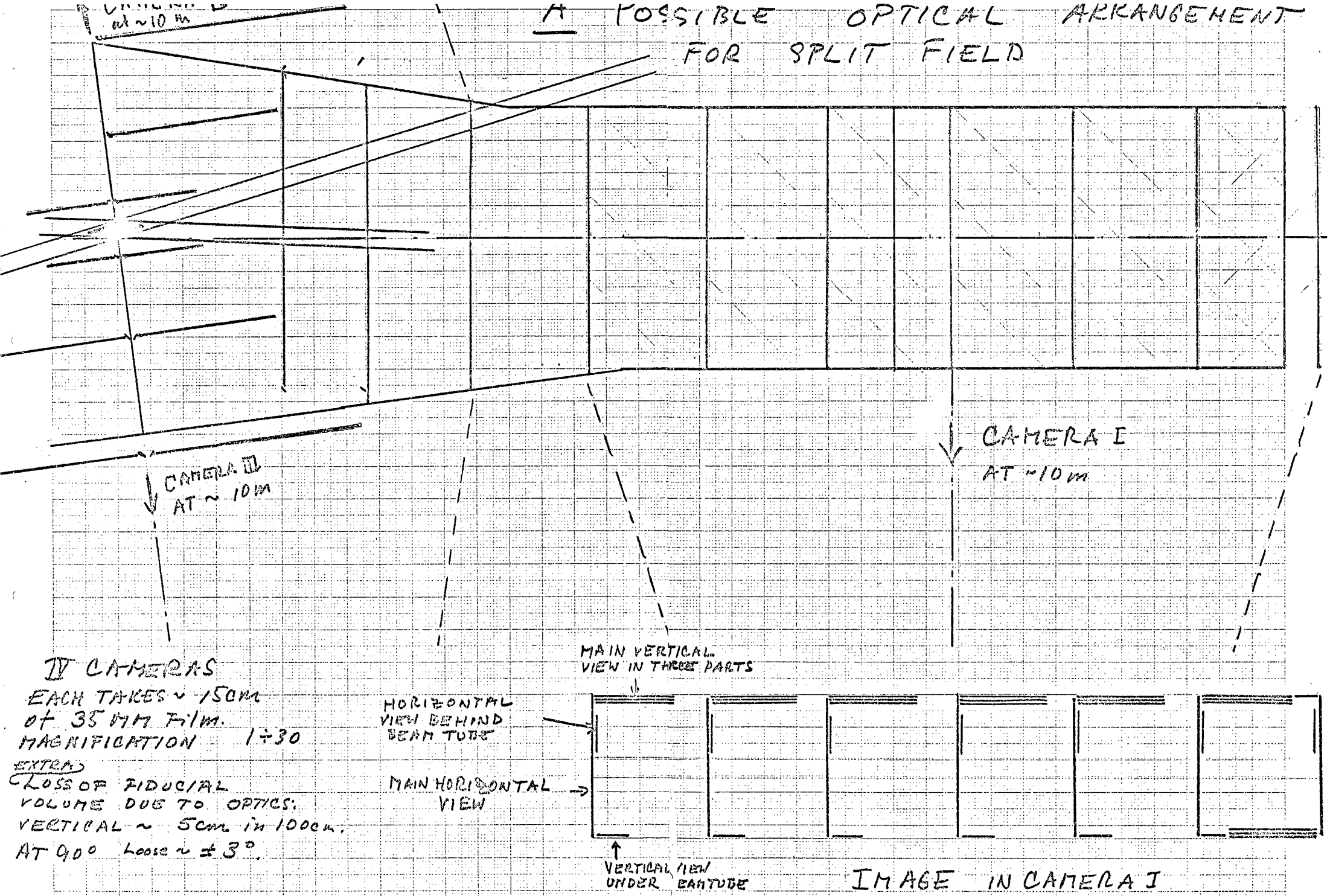


FIG. 5

A POSSIBLE OPTICAL ARRANGEMENT FOR SPLIT FIELD



IV CAMERAS

EACH TAKES ~ 15cm of 35 MM Film.

MAGNIFICATION 1÷30

EXTRA LOSS OF FIDUCIAL VOLUME DUE TO OPTICS:

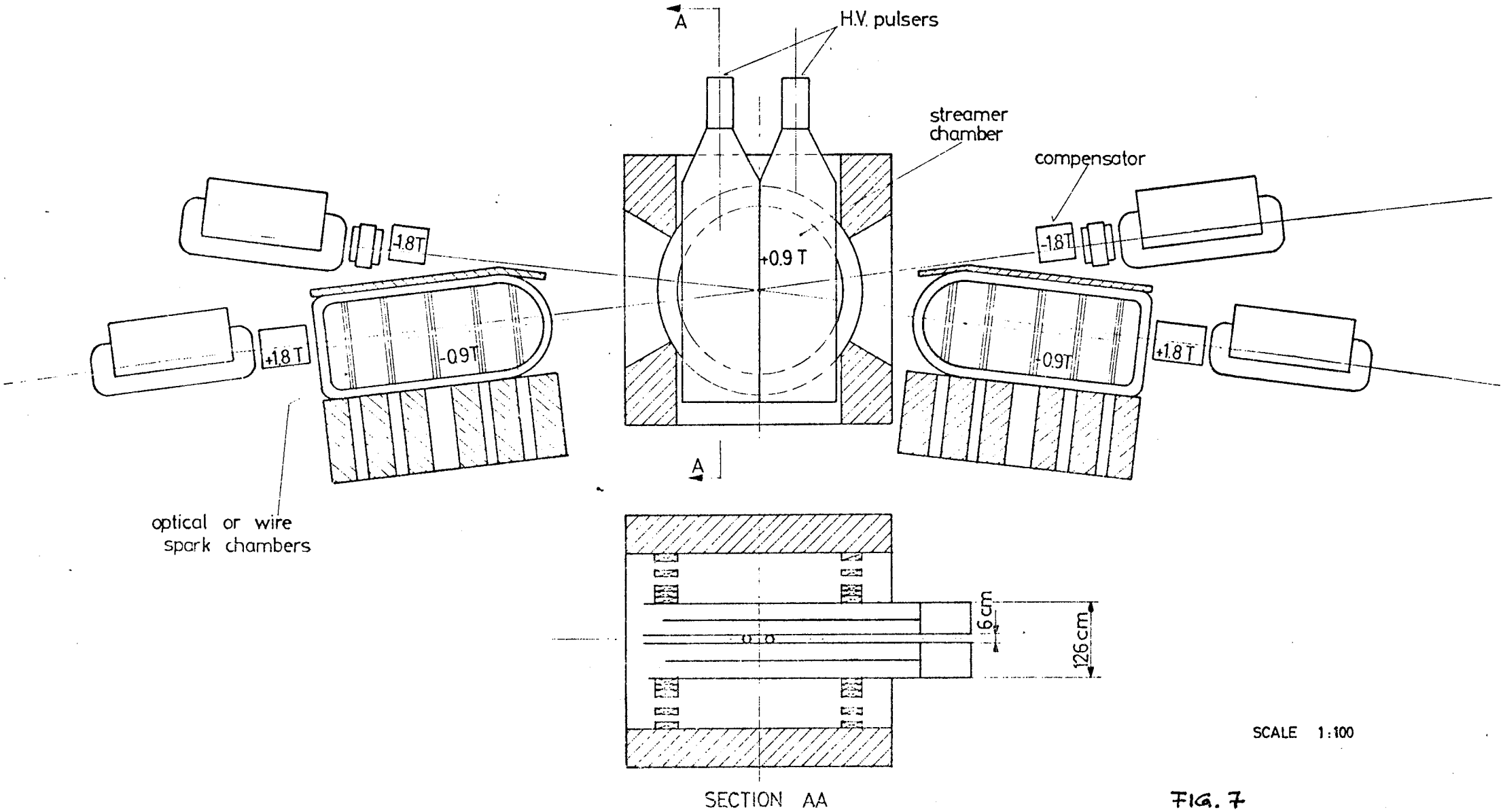
VERTICAL ~ 5cm in 100cm.

AT 90° Loose ~ ±3°.

FIG. 6

HYAMS O'NEILL MAGNET SYSTEM

(Crossing Point has moved right by 50 cm , all compensators shown)



SCALE 1:100

FIG. 7