FNAL PROPOSAL No. 534

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HYBRID NUCLEAR EMULSION - 15' BUBBLE CHAMBER EXPERIMENT TO STUDY NEUTRINO PRODUCED SHORT LIVED PARTICLES

Submitted by

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CONTENTS

INTRODUCTION

The unique ability of nuclear emulsion to serve as a track-sensitive target capable of displaying short-lived decays, such as those associated with the new hadronic and leptonic quantum numbers, has been exploited by "first-generation" experiments such as E247 and E382. These experiments are characterized by a lack of detailed final-state analysis capability, and correctly so, for they were designed as "particle search" experiments. It is clear that as the survey and discovery phase of charm/heavy lepton physics passes, future experiments must have the ability to provide definite identification and momentum analysis of the particles produced. We feel that much can be done with existing Fermi Lab facilities. The short-range sensitivity of emulsion coupled with the particle identification and momentum analysis capabilities of the 15' bubble chamber makes a hybrid emulsion-bubble chamber experiment attractive. We propose an external emulsion target, with drift chambers to provide close-in track detection, and the bubble chamber-EMI system serving as a downstream particle identifier and analyzer. The drift chambers provide improved vertexing accuracy (to minimize emulsion scanning time) and detect conventional short-range decays (K_s^o, Λ) which occur upstream of the bubble chamber. The experiment is designed to use the hadron cameras and run parasitically with the neutrino bubble chamber research program.

EXPERIMENTAL DESIGN

Nuclear emulsion will serve as a track-sensitive target, permitting observation of short-lived particles and correlation of their decay products with tracks observed in the drift chambers and 15' bubble chamber. The total volume of emulsion used represents a compromise between considerations of event rate, geometry, and cost (currently $5000 per liter).

Since emulsion records cosmic ray tracks and other backgrounds continuously, it is necessary to have sufficient target mass to accumulate an adequate number of events in five to ten months of normal running. We propose a volume of 30 ℓ, which provides a reasonable tradeoff between mass (115 kg) and cost ($150,000).

The transverse dimensions of the emulsion modules are limited by the geometry of the bubble chamber nose aperture to approximately 18 x 70 cm. In the beam direction, it is desirable to keep the emulsion thickness down to 8 cm (∿2.7 radiation length, ∿0.25 interaction length) since the vertex location will be least well determined in this dimension.

We therefore propose that the emulsion be in three planes, each 18 x 70 x 8 cm. Each plane will contain five emulsion stacks arranged side-by-side; each stack will consist of 300 pellicles measuring 14 x 8 x 0.06 cm. (see fig. 1) Previous experience has made us wary of large pellicles, which are difficult to clamp and machine properly, and can be awkward to handle during processing and scanning.

Each emulsion plane will be followed by a DC/PC unit containing two 4-plane drift chamber sets (X-Y-X'-Y', where X', Y' are offset to eliminate left-right ambiguities) separated by an MWPC plane for triggering (see Fig. 2). By using an MWPC instead of a counter, we avoid the problems involved in operating PMT's in the bubble chamber magnetic field. The first emulsion plane will be preceded by a pair of beam veto counters.

BUBBLE CHAMBER

The 15' bubble chamber has a large magnetic field of $\sim$30 KG-m (see Fig. 3) across the diameter which is very good for determining momentum of secondaries. The EMI which covers $\sim \pm 120^{o}$ (Fig. 4) will provide good muon identification. We note that since we will know the exact timing of an interaction in the emulsion, the background problem in the EMI will be virtually eliminated and thus the muon identification is considerably improved over that obtained in a standard bubble chamber run. Also, the EMI improvement program will have added an additional plane by the time we take data.

A serious constraint is imposed by the entrance window in the nose cone, which is shown in Fig. 3 . The thin window (1/8" of stainless steel) defines an aperture of 8" vertically by 30" horizontally. Thus, the emulsion target must be located as close as possible to the entrance cone in order to maximize the acceptance. A possibility would be to place the emulsion drift chamber package inside the vacuum tank. We have rejected this because it would allow access to the apparatus only when the chamber is warm.

We propose to modify the existing vacuum tank so that an emulsion-chamber array can be inserted. The existing thin window on the vacuum tank shown in Fig. 5 would be ground out and an insert which would extend into the vacuum tank would be welded to the existing frame. The 1/8" vacuum tank window would then be extended to within 6" of the nose cone window.

Because of the safety requirements, a detailed study would have to be made. We estimate that this would cost approximately $5,000. The fabrication of the insert could be done in our shop in Seattle.† The attachment to the chamber could take place during a scheduled "warm-up". We estimate that the welding should not take more than 3 to 4 days and could be done by the welders on the 15' crew. A possible design is discussed in Appendix I .

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† The welds would have to be certified.

The fringe field from the 15' magnet gives us approximately 4 KG in the region where the emulsion drift chamber package is placed. This allows us to make momentum measurements of the slower particles as discussed below.

We propose to run parasitically with the neutrino bubble chamber research program using the hadron cameras and triggering the flash lamps only when our fast logic tells us that there has been an interaction in the emulsion. Camera 1 looks into the nose cone and thus affords a measurement of the entering hadrons from the emulsion interaction.

The software (TVGP and EMI programs) necessary for analyzing the bubble chamber tracks is operating in Seattle. They are being used in E172.

BUBBLE CHAMBER ACCEPTANCE

Efficiencies for detecting tracks in the 15' bubble chamber were calculated in the following manner. Twenty-six events from the E172 neutrino exposure were reconstructed. To increase the number of available "events" and obtain the proper azimuthal symmetry for production, the momentum vectors were rotated through multiples of 60° about the beam line. Tracks of momentum $\gtrsim 1$ GeV/c were propagated through the magnetic field from the assumed vertex to the bubble chamber window at the nose cone. Any track with vertical (z) displacement of $\leq 4"$ and horizontal displacement (y) of $\leq 15"$ from the center line at the window plane was defined to be good. We found that 73% of the tracks were accepted. Figure 6 gives the acceptance from each of the three planes. We quote the acceptance only from the upper left quadrant; all other results are obtained by symmetry.

DRIFT CHAMBERS

In order to localize the neutrino interaction in the emulsion, we intend to have eight drift chamber planes in the 20 cm gaps between emulsion blocks, four at each end of the gap. Each set of four would consist of two x and two y planes with 1 cm drift regions, staggered by a drift spacing to resolve the left-right ambiguity and allow us to determine if more than one track has traversed a cell.

The drift chambers will also allow momentum analysis superior to that of the emulsion for momenta below 2 GeV and charge determination up to 10 GeV. Assuming that angles can be determined to 0.5 mrad for tracks exiting from the emulsion, and that the drift chambers measure precision to 100 μm, we have

$$\frac{\Delta p}{p^2} = 0.06 \text{ GeV}^{-1}$$

from the 4 Kg fringe field. Therefore, we expect to be able to analyze the lower energy secondaries that are more likely to miss the bubble chamber window.

Finally, we expect to achieve some vertexing capability from the drift chambers for neutral strange particles decaying downstream of the interaction, put before the bubble chamber.

EVENT RATES

Assuming 1 event/20 Tons/10^{13} ppp, the emulsion target should yield 2900 events for a run of 5 x 10^{18} protons, or one event for every 170 in the bubble chamber. If 4-16% of neutrino events produce a charmed particle, we will have a sample of 100-400 events. Of these, 80% will be found in the emulsion, all of which will be useful for lifetime measurements.

We can use the MWPC signals to trigger three of the bubble chamber cameras, leaving the other three cameras free for ordinary running; thus, the proposed experiment can run parasitically with respect to other bubble chamber experiments.

EMULSION TARGET

The target design must permit removal of the emulsion to a safe storage location whenever there is the possibility of charged particles coming down the N5 line, or when a prolonged shutdown is anticipated, and accurately replacing the stacks when neutrino running is resumed. The emulsion stack design and the techniques to be used to relate the emulsion to the drift chamber coordinate system are based on methods used successfully in E382 (particle search/deep inelastic muon scattering in emulsion). In that experiment, the required 26 clamps and associated hardware were built in our machine shop at the University of Washington, while the final machining of the assembled emulsion stacks was done at Fermilab.

Each of the emulsion stacks will be clamped between precisely-machined aluminum bars (with plastic spacers to prevent chemical interaction between aluminum and emulsion) as shown in fig. 7 . The stacks will be assembled in a darkroom (e.g., a windowless room in the hi-rise), with the clamping bars inserted in a machining jig which applies the appropriate pressure (about 200 psi) while leaving the emulsion faces clear for milling. After clamping, the stacks may be handled in ambient light, since only the edges of the pellicles will be exposed. (After development, each pellicle will have a blackened border about 0.5 mm thick, but this region is always severely distorted during processing, and therefore not useful anyway). The stacks will be taken to the hi-rise machine shop, where the front and two side faces of the stacks will be milled flat, thus ensuring that each pellicle's edges are parallel to the corresponding edges of the clamping members. Diagonal scribe marks will be made on the milled faces, leaving notches on each pellicle, readily visible after processing, whose position indicates the vertical location of the pellicle. The machinist will record accurate measurements ($\pm$0.001"=25μ) of the dimensions of each stack, to allow for stack-to-stack variations in milling.

Following machining operations, threaded rods will be inserted and torqued to maintain clamping pressure after removal from the machining jig. At this point the stacks will be wrapped with plastic tape to prevent fluctuations in the water content of the emulsion due to changes in ambient humidity, and taken to the storage area (e.g., the "archives" room under the hi-rise entrance).

From our experience with E382, we estimate a maximum shop time requirement of 4 hr per stack, or 100 hr total. Several of the hi-rise shop craftsmen worked on E382 and E247 stacks, and are familiar with the machining properties of emulsion.

In the exposure area, the stacks mount on stands (fig. 8) equipped with indexing pins which allow stacks to be removed and replaced in a reproducible manner. Tests performed for E382 indicate that replacement can be accomplished to within 25μ of the original position by this method.

COSMIC RAY AND OTHER BACKGROUNDS

The problem of background due to cosmic rays and natural radioactivity must be considered. There is a generally accepted working rule that emulsions should be processed within two to three months from the time of their manufacture. However, when handled properly, emulsions as old as several years can in fact be used for many experiments.

Nuclear interactions (stars) due to cosmic rays are produced in emulsion at the rate of about $1.3/cm^3$/day at sea level, and $300/cm^3$/day at jet airfreight altitude. However, to simulate a neutrino event, a star must be neutral-induced, and have at least one minimum-ionizing particle close to (say, within 20°) the nominal beam direction. Fewer than 1% of the cosmic ray stars satisfy these criteria. Thus, assuming the emulsion is purchased from Ilford, Ltd., flown to Chicago (approximately 12 hr at high altitude), and subsequently left in the beam line and/or storage for 10 months before processing, we would expect fewer than 6 fake events per cm^3. As discussed below, we expect to have the event location defined to within about 0.09 cm^3, so this level of background will be tolerable. The number of cosmic ray stars can be considerably reduced by adding a small amount of shielding above the stacks. Most of the sea-level stars are due to the nucleonic component of the cosmic ray flux, and as fig. 9 shows, a few feet of rock (equivalent to concrete) will reduce the density of stars by an order of magnitude.

The sea-level flux of charged particles (mostly muons) is about $0.0125/cm^2$/sec, sharply peaked in the vertical direction; thus the majority of the 300,000 tracks/cm^2 which will accumulate in the emulsion over 10 months will be perpendicular to the beam direction. In E382, events were located and secondaries followed and measured in the presence of a beam density of 500,000 muons/cm^2 (parallel to the jet direction) without difficulty. The emulsions used in E382 were mostly fresh, but several of the stacks were made up from old Ilford G5 emulsion, which had been stored underground at the

NASA-Houston Lunar Laboratory for two years, and then stored another year at ground level in Seattle. Although the background was higher in the old pellicles, the efficiency for finding deep inelastic muon interactions was, within statistics, identical for old and fresh emulsions.

Natural radioactivity produces a background of grains which can make it difficult to identify and follow tracks. Emulsion itself is very free of radioactivity, while concrete made of granite rock is rather high in radioactive materials. Since the radiation length in emulsion is about 2.9 cm, the emulsion tends to be self-shielding if kept in the form of a stack. We have found that one inch of Pb shielding reduces the background due to nearby concrete by a factor of 2.3.

The background due to the neutrino beam itself should be negligible. From a limited examination of 15' BC photographs, we estimate the muon accompaniment to be about 5×10^{-5} μ/cm^2/pulse of 10^{13} protons on target. Even doubling this estimate leads to a negligible accumulation (order of $100/cm^2$) during a 10 month run. Recently we conducted an experiment (E386) in which emulsion plates were prepared in situ from emulsion gel supplied by the manufacturer, and left in the neutrino beam (in the N5 Tagging Portakamp, just upstream from the 15' BC) for three weeks while an integrated intensity of 0.5×10^{18} protons on target was supplied to the neutrino line. We find no evidence for a density of stars greater than that expected from the cosmic ray flux; thus beam contamination due to neutrons, etc should not be a problem.

TRACK FADING IN NUCLEAR EMULSION

Tracks in nuclear emulsion, like latent images in other photographic media, are subject to fading if the emulsion is left unprocessed for a prolonged period following exposure. Thus, in planning a run of more than six months, some care must be taken to preserve the quality of the first events recorded.

Fading is more rapid in fine-grained emulsions, and for emulsion stored at high temperature and humidity [1].

Ilford G5 emulsion, which is relatively coarse-grained (mean grain diameter $\sim 0.27\mu$ [2]), is quite resistant to fading if kept reasonably cool. Barron and Wolfendale [3] find that the mean time required for a 50% reduction in track grain density is $\sim$500 days at 25°C, but $\sim$1000 days at 5°C. Leide [4] shows that fading is rather strongly humidity dependent if the emulsion is not refrigerated: after 60 days at 25°C, fading is negligible if the relative humidity (RH) is less than about 50%, but severe for RH >70%. Fig.10 shows the temperature/RH region in which fading is minimal.

Leide also performed a thorough study of fading in Ilford K5 emulsion (mean grain diameter $\sim 0.20\mu$). His data [5] indicate that at 25°C, 55% RH, fading of 50% can be expected in about fifty days, while at 4°C, 48% RH, fading after 10 months is only 25%.

From the results quoted, track fading will be less than 10% in 10 months if the emulsion is kept at 20°C, 45% RH -- conditions which can be maintained by an ordinary air conditioning system. Air conditioning would be necessary in any case to protect the emulsion from damage during the summer temperature/humidity extremes common to Fermilab. Although K5 emulsion could be used if the exposure area were refrigerated to 5°C, it is not clear that the slight gain in resolution is worth the difficulties created.

PROCESSING OF EMULSION

Complete facilities for processing the emulsion exist at Seattle. Pellicles are usually labelled, contact printed with a fiducial grid, and mounted on specially-treated glass plates (supplied by Ilford) before development. For plates 600μ thick, the development process takes place at 5°C and requires about 7 days, including fixing and washing. We have two refrigerated tanks in the darkroom, plus two portable refrigerated water-bath tanks which are used for washing the plates; two batches per week can be processed, each batch comprising one stack. Thus processing will require about 13 weeks. It may be desirable to contract out some fraction of the processing to other laboratories, such as LBL and BNL, in order to reduce the time required.

SCANNING OF EMULSION

For drift chamber resolution of 100μ, we estimate that the event vertex will be located to within ± 1.5 mm in the transverse directions, and ± 5 mm in the beam direction. This defines a search volume of $3 \times 3 \times 10$ mm^3 = 0.09 cm^3 which must be scanned for each event, or 30 mm^2 on each of five 600μ plates. From our previous experience, a competent scanner can search 150 mm^2 per hour using relatively low magnification (10X air objective, 15X wide-field oculars). About 25% of the events (those with low multiplicity and/or no heavily-ionizing tracks) will not be found by this procedure, and will require high power (22X oil objective) scanning, which takes about four times as long. Thus the average search time per event will be less than 2 hours. Scanners normally work half-time, 4 hr/day 20 days/month, so the event-finding rate will be 40 events per scanner-month. Seattle has three scanners, Krakow 6; thus the location of 2000 events will require on the order of six months.

IDENTIFICATION OF PARTICLES IN EMULSION

Particles having energies up to several GeV can be identified in nuclear track emulsions by simultaneous measurement of two quantities, dE/dX and $p\beta$.

Within emulsion, for moderate magnetic fields, the momentum of a particle cannot be determined by magnetic deflection, because emulsion is a dense medium, and multiple scattering is significant. For example, the ratio of magnetic to multiple scattering deflection is

$$\frac{\Theta_B}{\Theta_{MS}} = \frac{(0.3\ B\ \ell /\ p\ c)}{\frac{15}{p\beta}\ (\ \ell /\ L_{rad})^{1/2}}$$

$$= \frac{\beta B \sqrt{\ell L_{rad}}}{50} \quad ; \qquad \begin{aligned} & B \text{ in kG} \\ & \ell = \text{path length, cm} \\ & L_{rad} = 2.9 \text{ cm for emulsion} \end{aligned}$$

Thus, for a typical useful track length of 2.5 cm, multiple scattering dominates for B $\lesssim$ 20 kG. However, the multiple scattering itself yields a useful measure of $p\beta$ for particles of energy $\lesssim$ 10 GeV.

Dividing the available track length into segments ("cells") of equal length t, one may measure the coordinates of the track at each cell end (fig.11a below), or the angular displacement between succesive chords (fig. 11b).

If the coordinate method is used, the momentum is given by

$$p\beta = \frac{K\ t^{3/2}}{573\ \bar{D}}$$

where $\bar{D}$ is the average second difference of cell coordinates in microns, and K is a "scattering constant" $\sim$25 MeV.

The primary uncertainty is in the determination of $\bar{D}$; in general, displacements can be measured to an accuracy of $\sim$0.1 micron. The resulant relative error in momentum determination as a function of momentum is given in fig. 11c.

As shown in fig. 11a, momentum determinations from multiple scattering alone can be made with a precision of about 5% at energies under 0.1 GeV, while the accuracy is 10 to 15% for several GeV.

The track grain density can be used to give, through the Sternheimer theory or empirical curves, a measure of dE/dX. For relativistic tracks, the grain density can be measured directly; for slower particles, the grains tend to clump together in "blobs", and it is simpler to measure the blob density. The blob density is a measure of the inter-grain gap distribution, which is in turn a function of the true grain density. [1] For Ilford emulsions, the grain density for relativistic tracks is about $20/100\mu$, so for 1 cm of minimum-ionizing track about 2000 grains can be counted, giving a precision of 2-3% in the determination of dE/dX. Fig. 12 indicates the fluctuations to be expected in such measurements.

When grain density and multiple scattering are simultaneously measured for tracks having lengths of about 1 cm, results similar to those shown in fig. 13 are obtained. As the figure shows, it is possible to separate pions, kaons, and protons for energies as high as several GeV, except for certain overlap regions (e.g., near 1.6 GeV). The scatter of points in the figure gives an indication of the precision with which separations can be carried out.

COSTS

The major costs are the emulsion and drift chambers. The drift chamber estimates are based on $ 50 / channel.

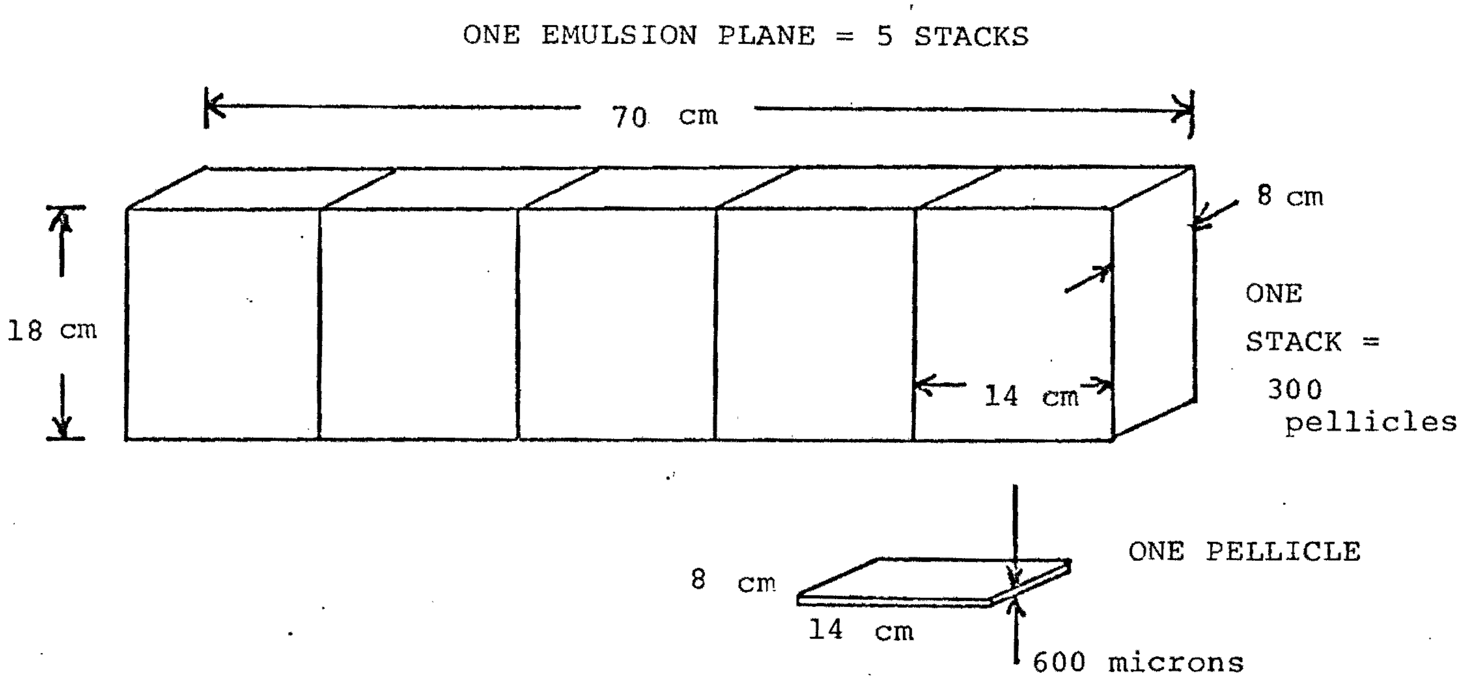
Emulsion		$ 150 K
Drift chamber read out		50 K
Chamber construction		25 K
Trigger MWPC		5 K
Scintillator Vetoes		2 K
	Total	$ 232 K
PREP logic		$ 25 K

We would hope that FNAL would provide in addition to the PREP logic a PDP-11 and magnetic tape drive, and also pay one half of the emulsion cost. The rest of the costs would be borne by the experimenters.

REFERENCES

1. W. Barkas, "Nuclear Research Emulsions" 1, pp 35-37, Academic Press, New York, 1963.
2. Ilford Ltd., Technical Information Sheet Y44.1 (undated).
3. Barron, W. and Wolfendale, A., Br. J. of Applied Phys. 8 297 (1956), quoted in Barkas, op cit, p. 36.
4. Leide, G., Arkiv för Fyzik 11 329 (1956).
5. Leide, G., Arkiv för Fyzik 22 147 (1962).

Fig. 1 : Emulsion Module Structure



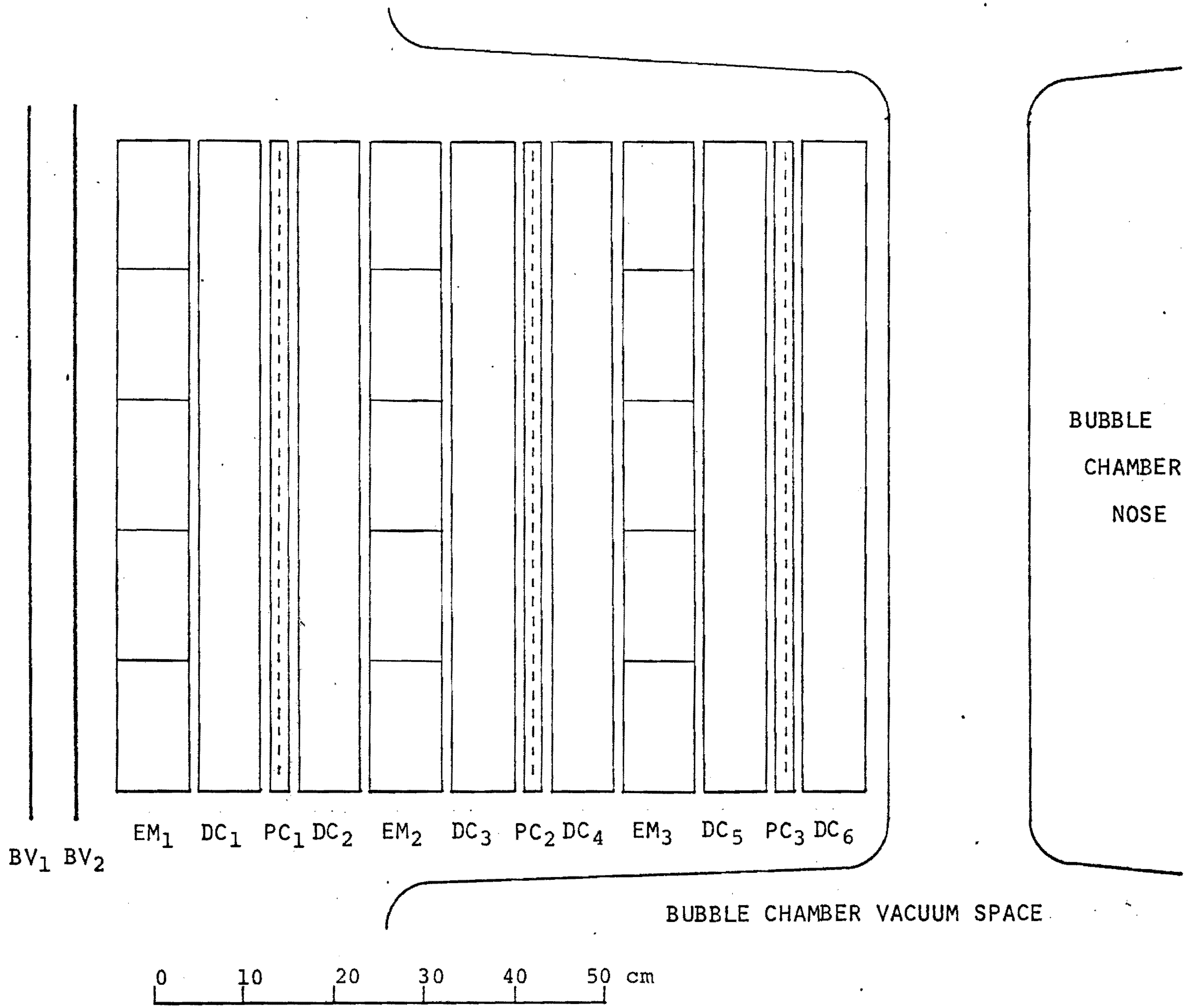
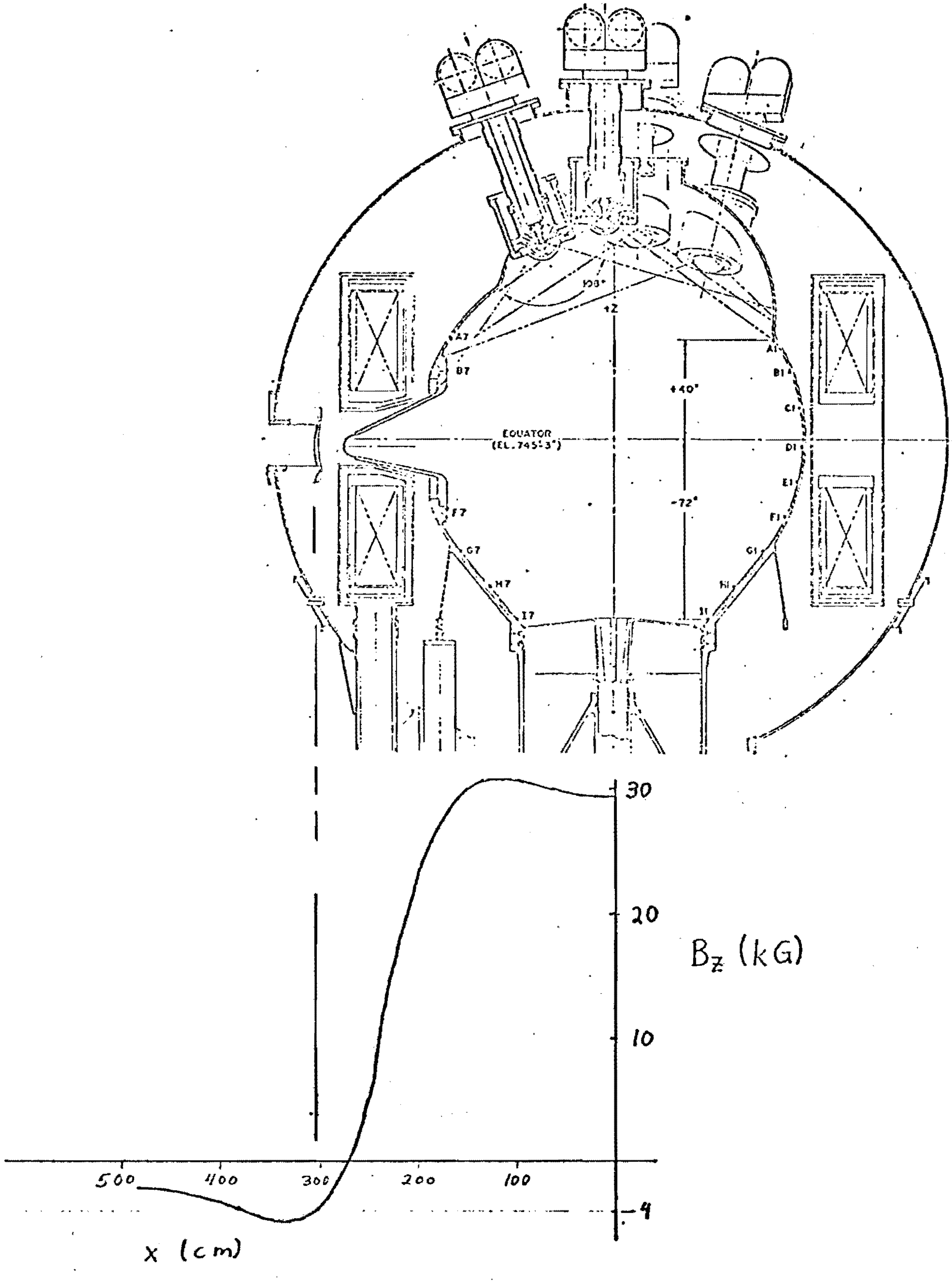
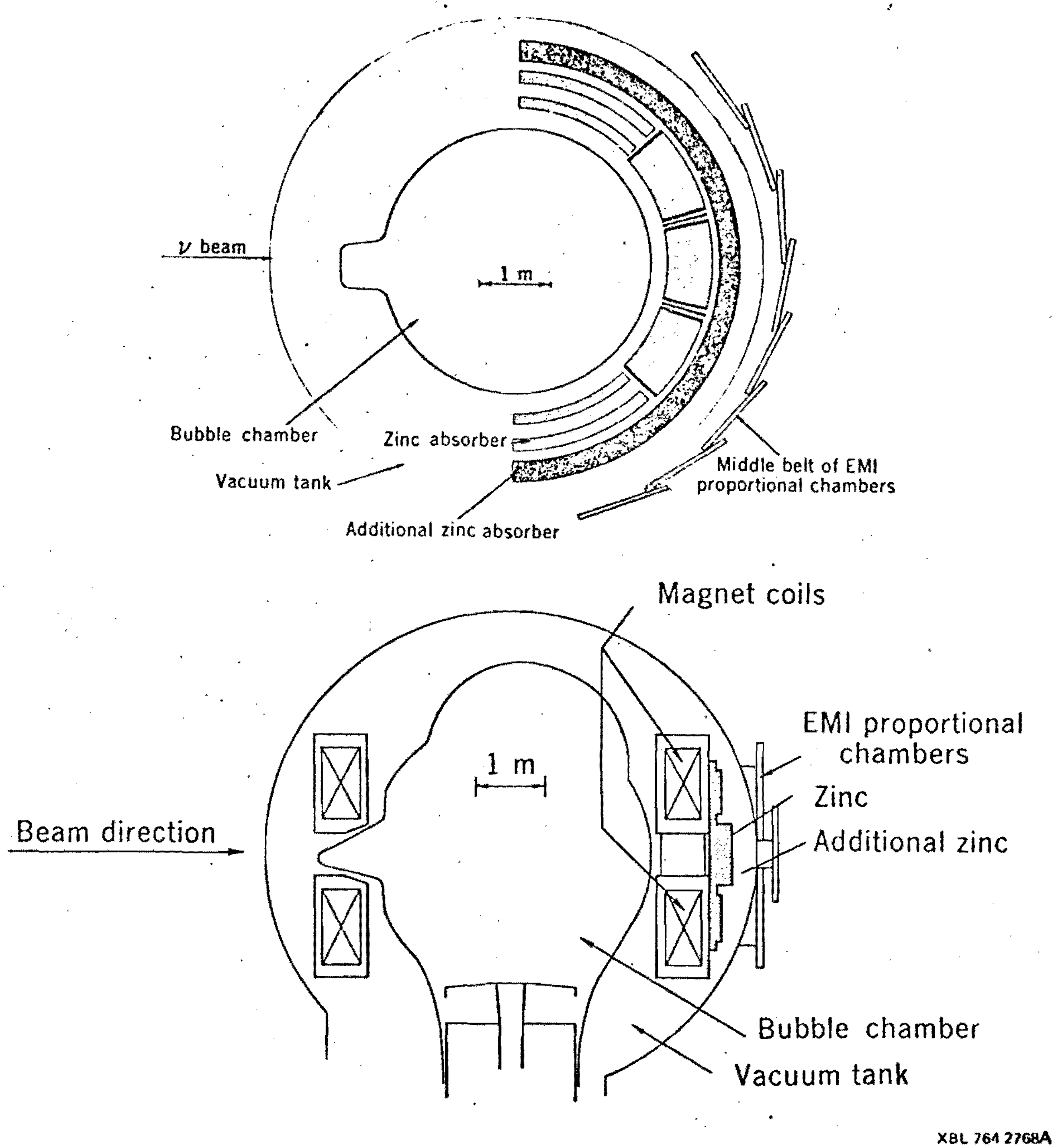


Fig. 2 - Schematic View of Experiment



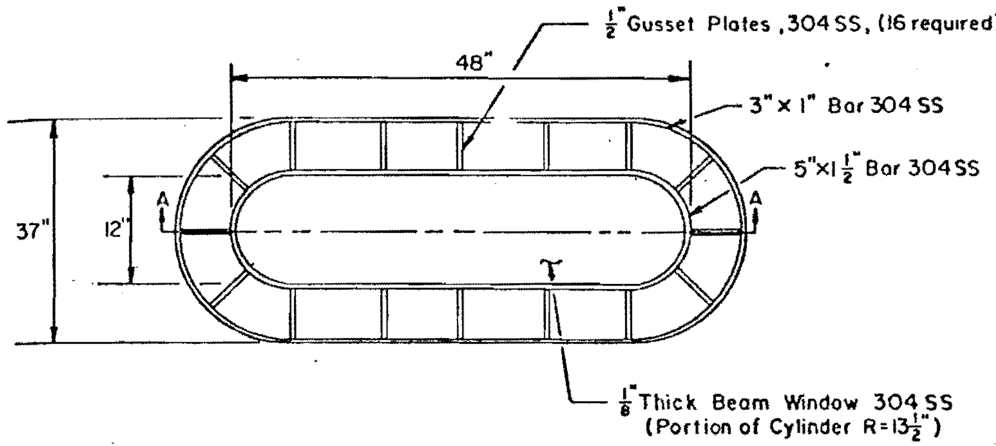
EQUATOR
(EL.745'-3")
+Z
108°
+40°
-72°
A7
B7
F7
G7
H7
I7
A1
B1
C1
D1
E1
F1
G1
H1
I1
30
20
10
-4
500
400
300
200
100
B_z (kG)
x (cm)

Fig. 3



ν beam
1 m
Bubble chamber
Zinc absorber
Vacuum tank
Middle belt of EMI
proportional chambers
Additional zinc absorber
Magnet coils
EMI proportional
chambers
1 m
Zinc
Beam direction
Additional zinc
Bubble chamber
Vacuum tank
XBL 764 2768A

Fig. 4



Vacuum Tank Entrance Window

Fig. 5

FIG. 6

ACCEPTANCE AS A FUNCTION OF INTERACTION POSITION IN EMULSION

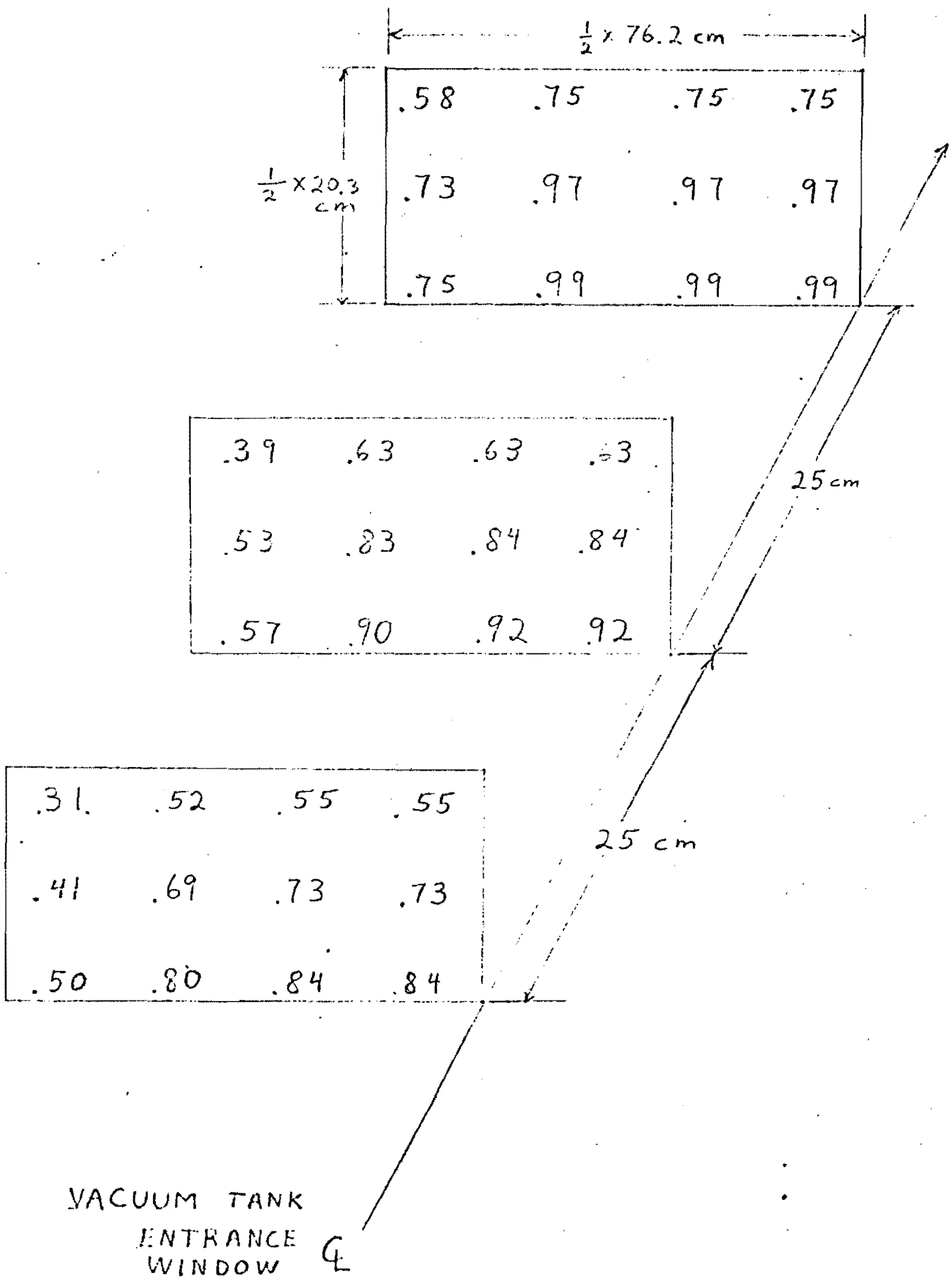


Fig. 7

EMULSION STACK
CLAMPS

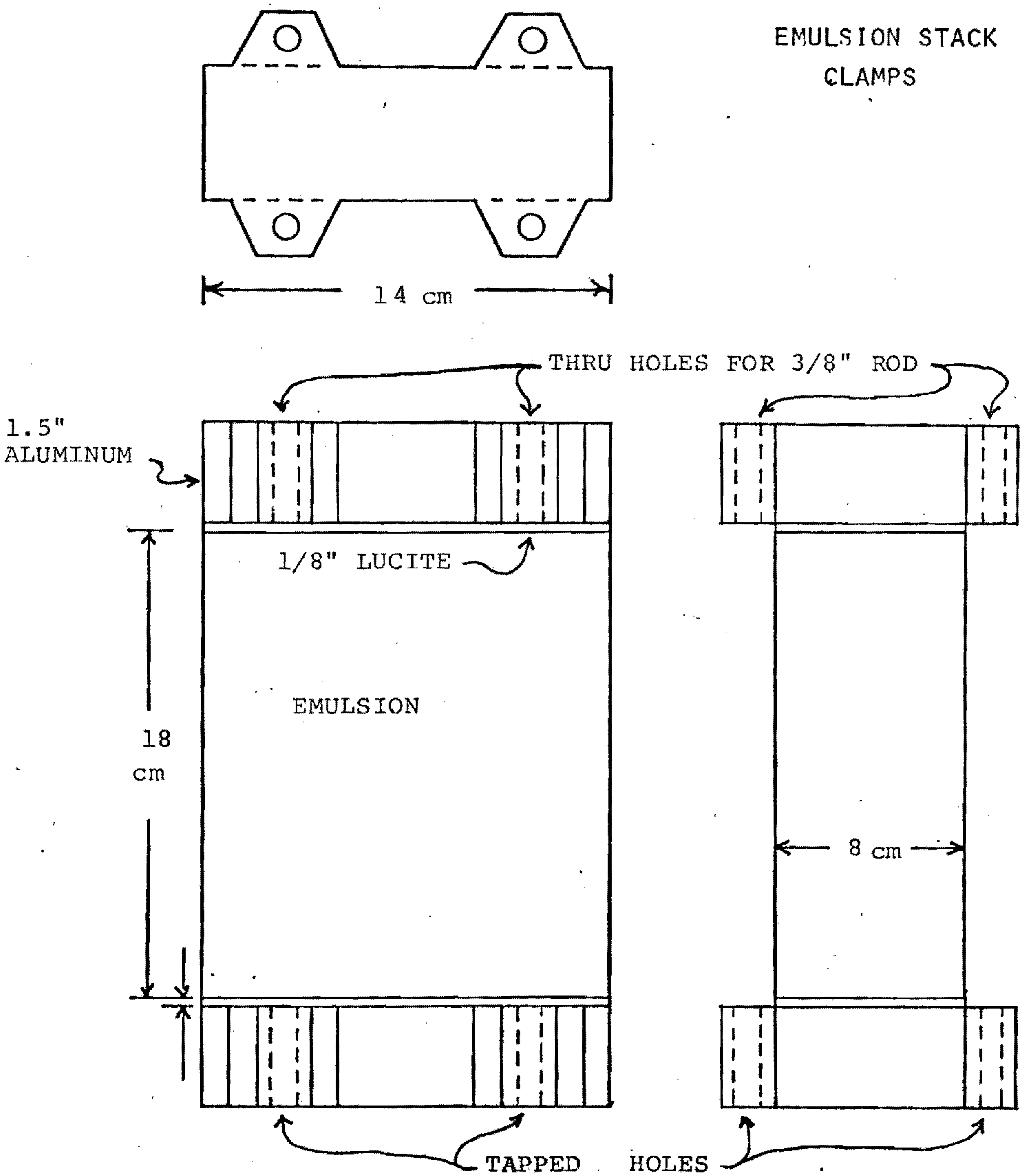
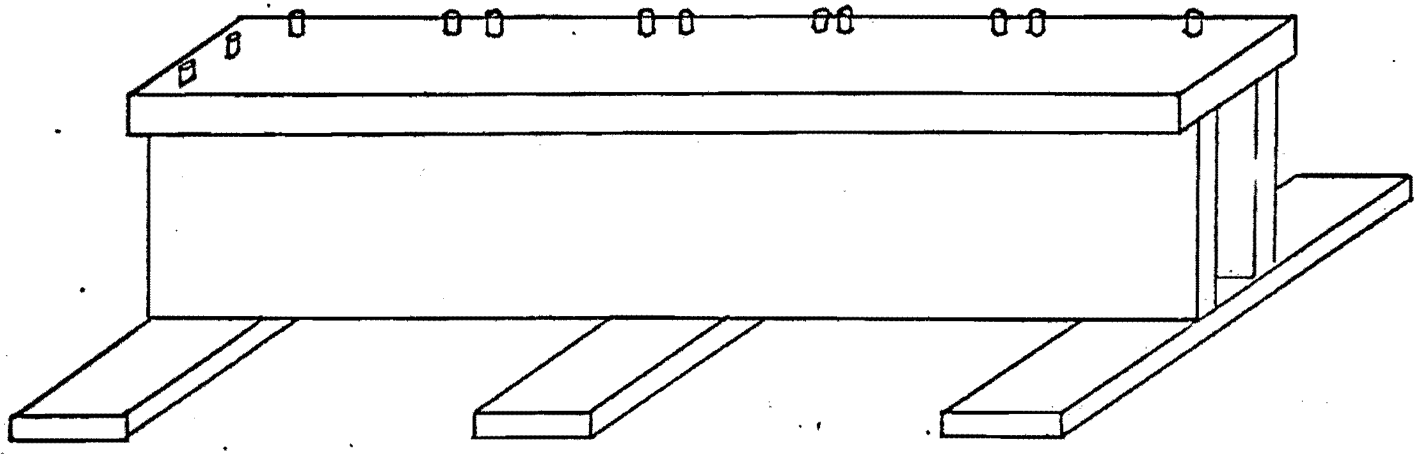


Fig. 8

EXPOSURE STAND FOR EMULSION STACKS



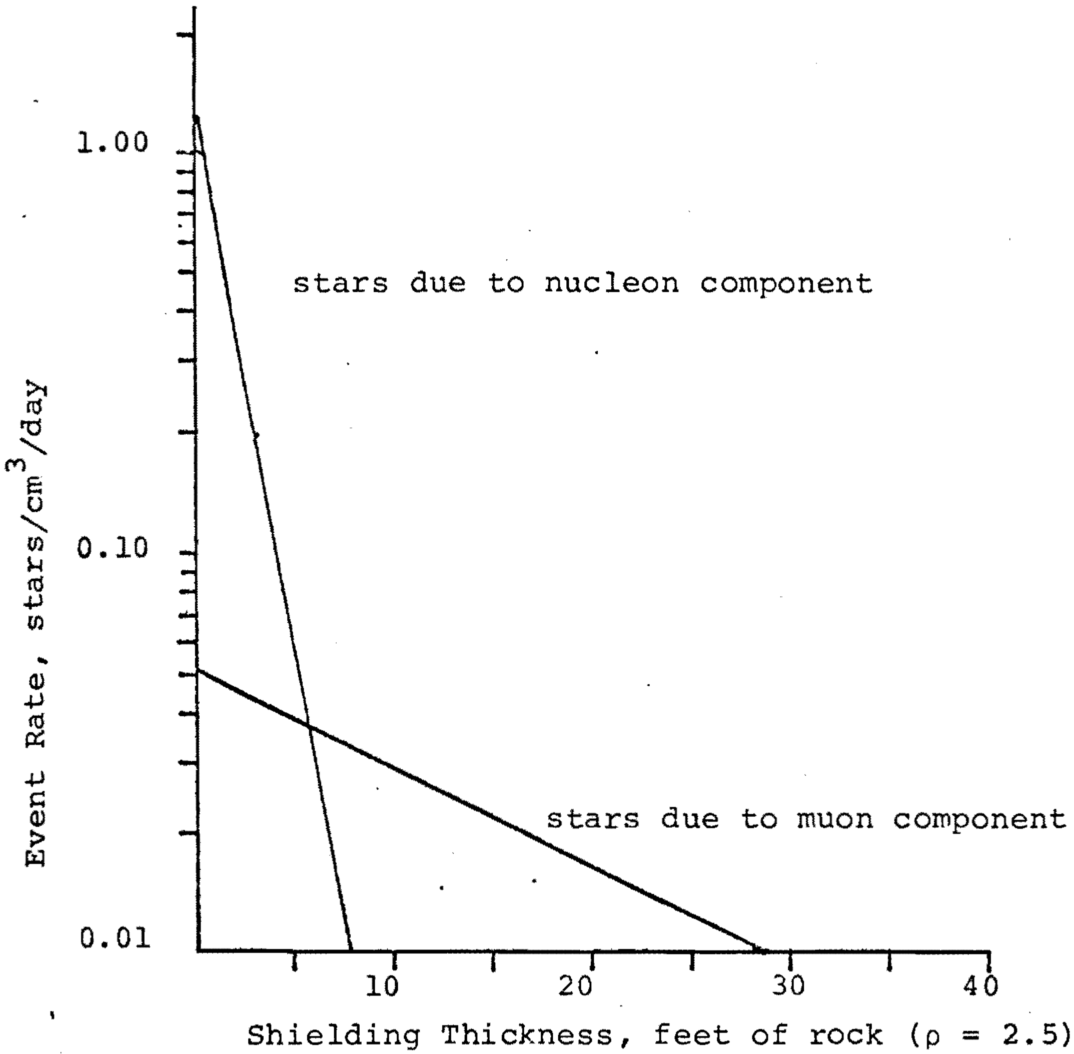


Fig. 9 - Cosmic ray event rate in emulsion vs shielding thickness.

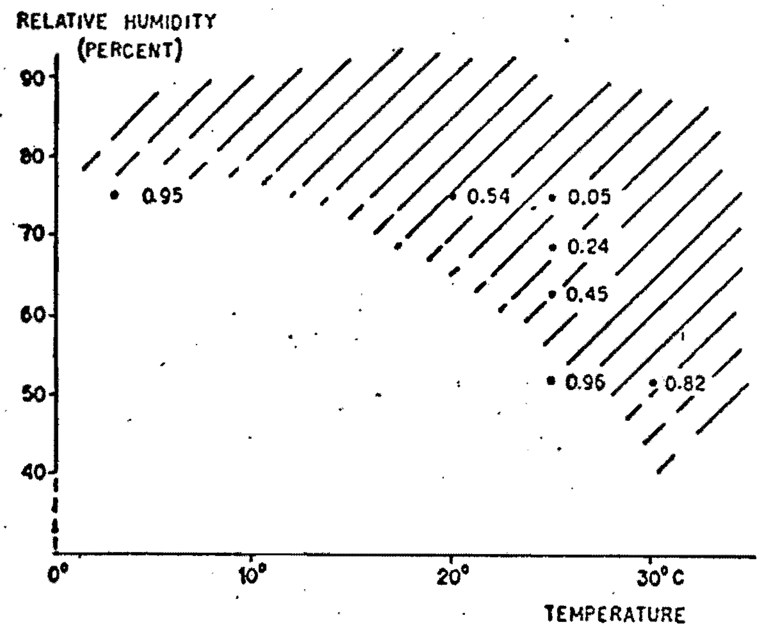


Fig. 10 Track fading in Ilford G5 emulsion (from ref. [4]). Data points are labelled with relative accuracy of mass determination (proportional to relative grain density) after two months storage. Shaded area indicates conditions in which fading is significant.

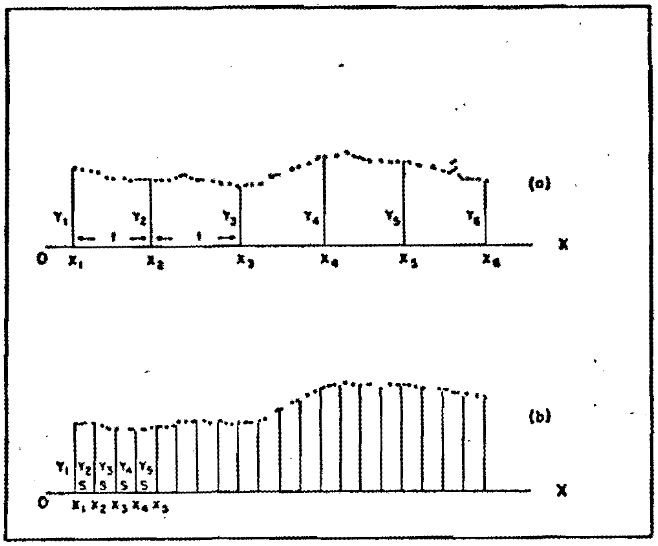


Fig. 11a - Coordinate method
of multiple scattering measurement

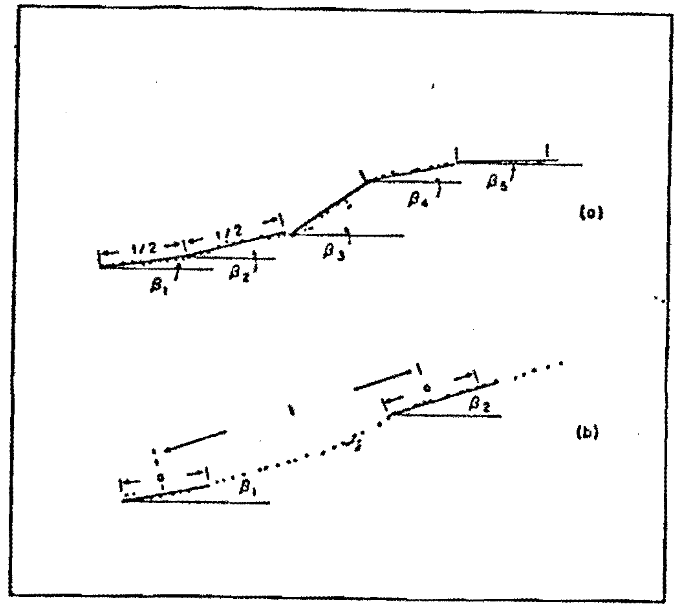


Fig. 11b - Angular method of
multiple scattering measurement

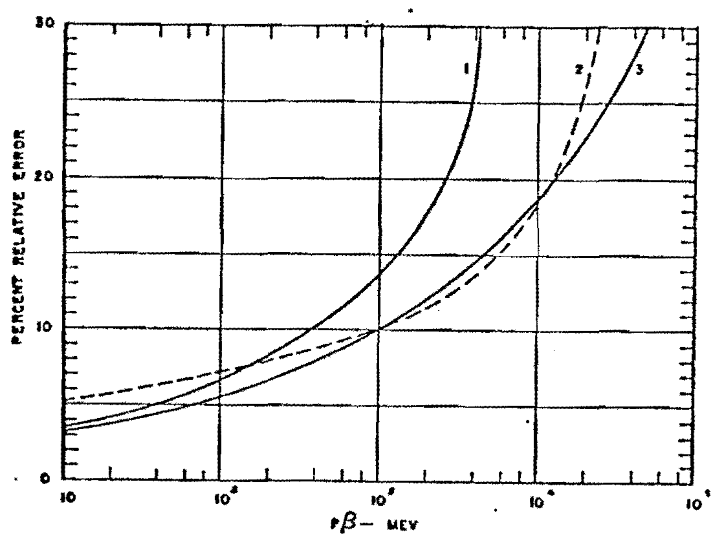


Fig. 11c - Precision of energy determination from scattering measurements, for 1 cm of track and optimum cell length. [1]: coordinate method; [2]: angular method; [3]: "differential sagitta" (variant of coordinate method).

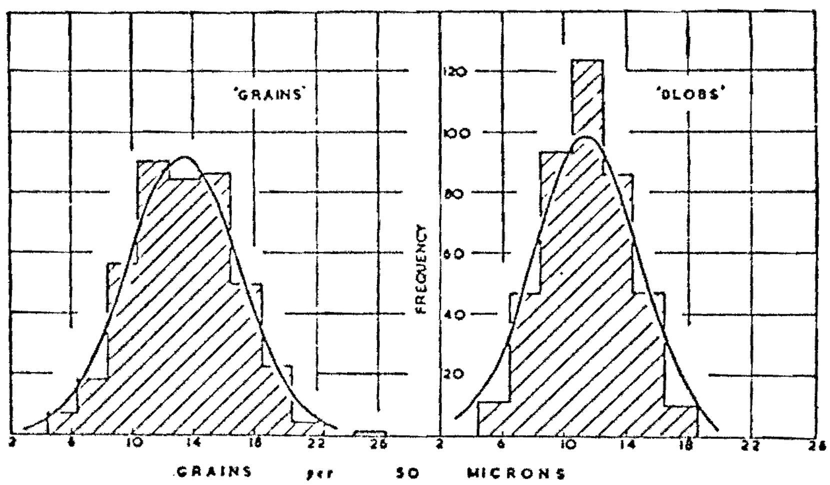


Fig. 12 - Experimental distribution of counts in 50 micron cells from observations on a 21 mm track of $p\beta \sim 15$ GeV.

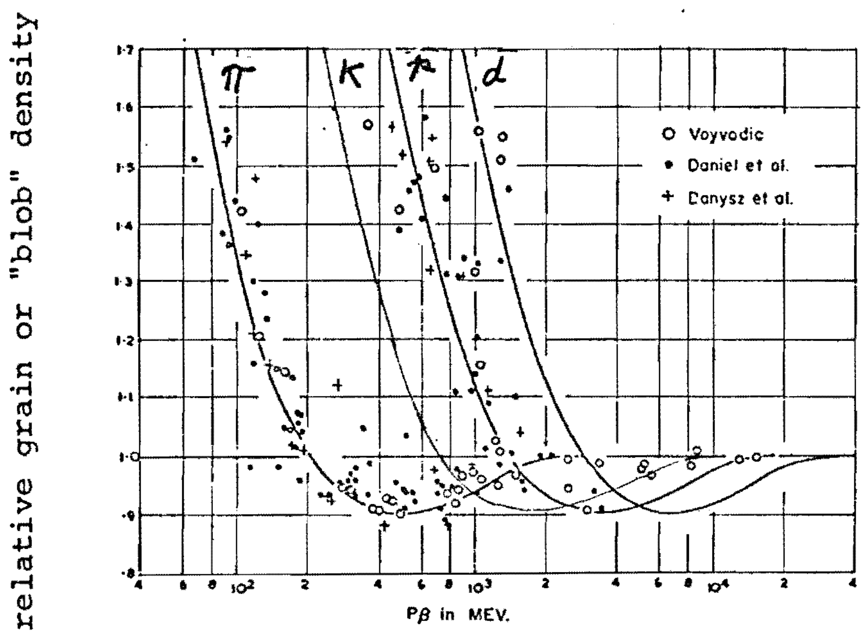


Fig. 13   Experimental data of relative track density (blobs or grains) in the neighborhood of the ionization minimum.

ADDENDUM TO FNAL PROPOSAL No. 534

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MARCH 2, 1977

In responding to the questions raised by the representatives of the PAC as a result of the proposal presentation made on February 11, 1977, we have prepared the following addendum to our Proposal 534:

The current design of the drift chamber/emulsion package is shown in Figs. 1 thru 3. We are planning to support, insert, and lower the apparatus from outside of the proposed well in the 15' vacuum tank. A sketch of this apparatus is shown in Fig. 4. What is not shown are details of the well, extending the vacuum window into the present vacuum area, which we would expect Fermilab to design and construct. What we now can state with some certainty is that we would require a space <u>14" high, extending 2" below the lower edge of the present window and at least 17" deep</u>, but any more would be greatly appreciated.

In preparing this more detailed design, we have stressed the importance of placing the emulsion as close to the nose window as possible, and thus we essentially have been forced to put the entire apparatus inside the present entrance window in order to clear the entrance window support structure. (We would prefer to have a larger, centered window, but assume that a modification of that scale is out of the question.)

From the sketch, we see that this has resulted in the following changes in our proposal:

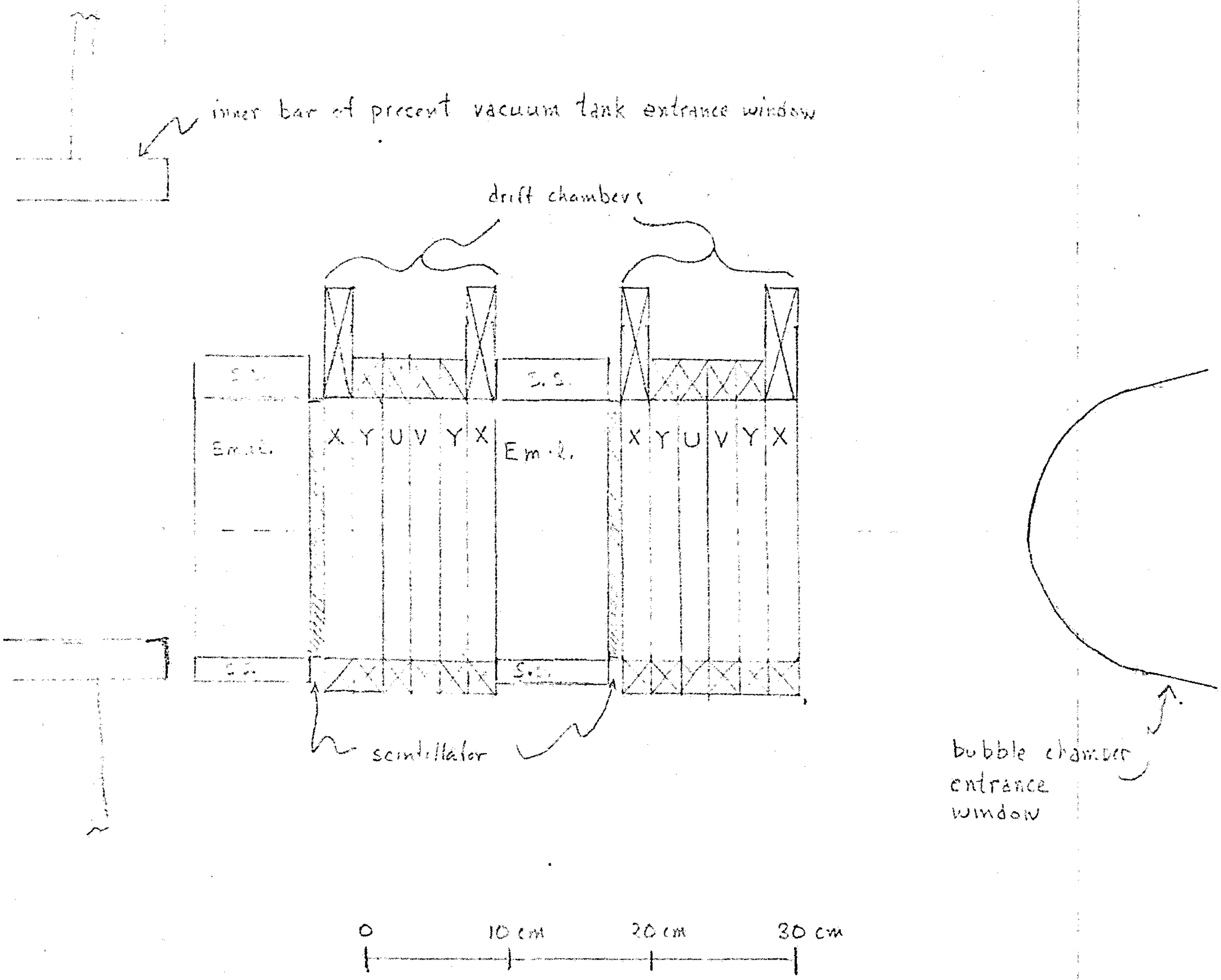
- elimination of an emulsion module, cutting event rates (as well as most equipment costs) by 2/3;
- reduction in the distance between the

emulsion stacks from 20 to 13 cm, which will degrade the momentum measurement by about a factor of 2;

- cutting down the number of drift chambers following each emulsion from 8 to 6, but employing an XYUVYX arrangement with small angle stereo which should still resolve left-right and multiple track ambiguities;
- replacement of the MWPC planes with scintillators to gain space at the expense of light pipes and large phototube shields on the outside.
- changes in the mechanical design of the emulsion stack clamps (Fig. 3).

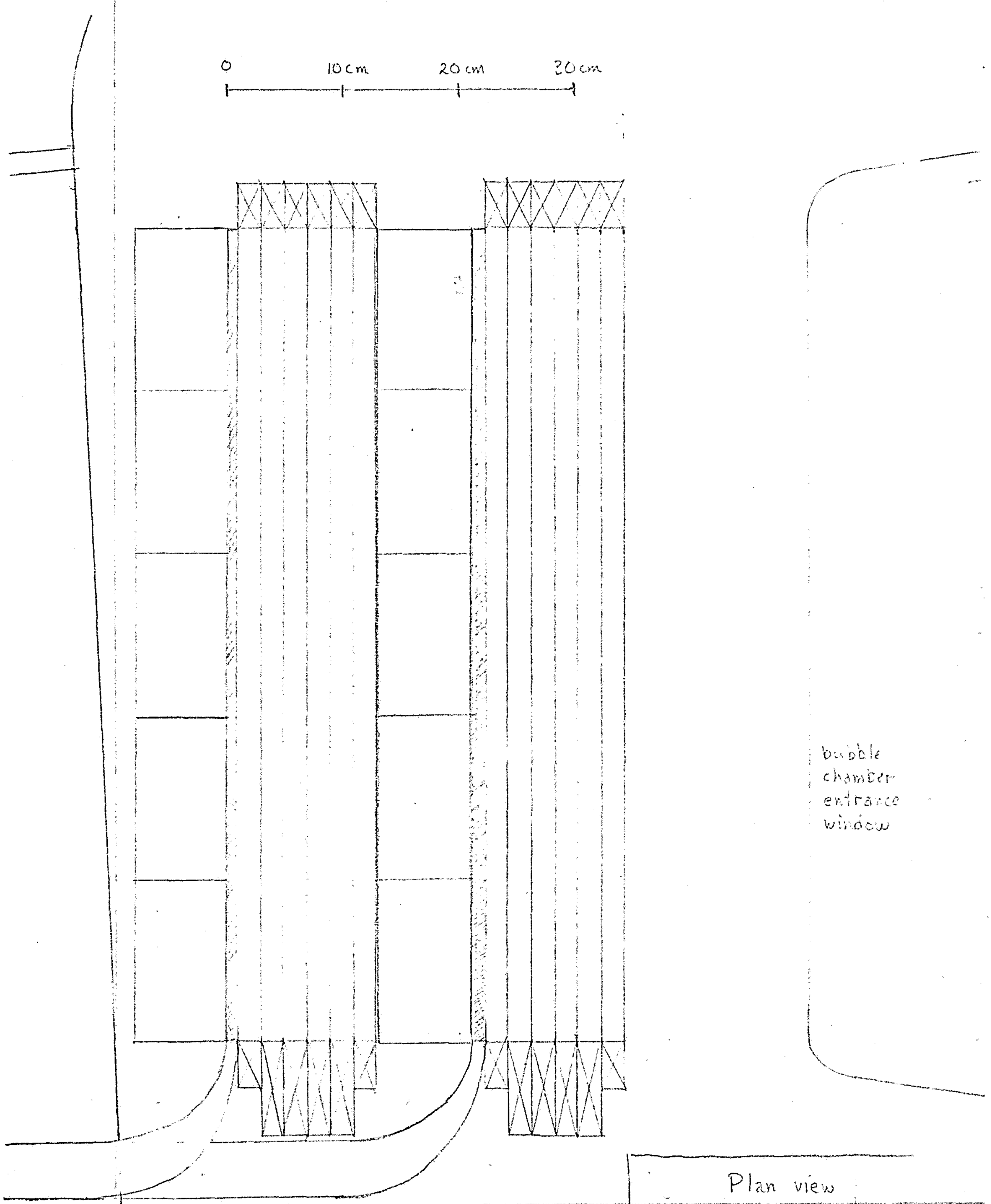
The significant improvement of this design with respect to construction is that we have reduced the number of drift chambers which we will have to build to 12 (originally 24). We have replaced the two MWCP's planes with scintillators which are considerably easier to build in terms of the fabrication time involved.

The hadronic and/or electromagnetic cascade showers which might originate in the emulsion stack upstream of the chamber or in the nose cone material, we believe, based on our experience in E-172, will not present any problem. In E-172 we often observe neutrino interactions in the chamber in which, if one stands back at a distance and looks at the event, one can see nothing but a horrible electromagnetic shower. However, when one sights the event with the eye close to the table (standard scanning technique) one can easily see the hadrons which are going downstream or emanating from the interaction. We have tested this with events in which there are interactions in the wall which give either electromagnetic showers or hadronic showers or interactions upstream and find that there is no difficulty in sighting along a track which enters the bubble chamber and travels some distance using this technique. Of course, this technique is time consuming but, in this experiment we would not expect to do this for more than a few hundred events; and in any case, the time required to do this should only be a small fraction of the time required to scan the emulsions. Having chosen all possible tracks which enter the chamber and could possibly come from the emulsion stack, it would then not be a very difficult task to digitize using a standard Frankenstein machine which we currently employ in E-172, reconstruct these tracks in space, and project them back to see if they coincide with the emulsion event.



Elevation view

FIG. 1



← inner bar of present vacuum tank window

Plan view

FIG. 2

One emulsion stack is shown; five stacks side-by-side form one emulsion module. The clamping members are stainless steel and are held together by 1/4" rods (not shown). The entire module measures 70 cm x 8 cm x 21 cm.

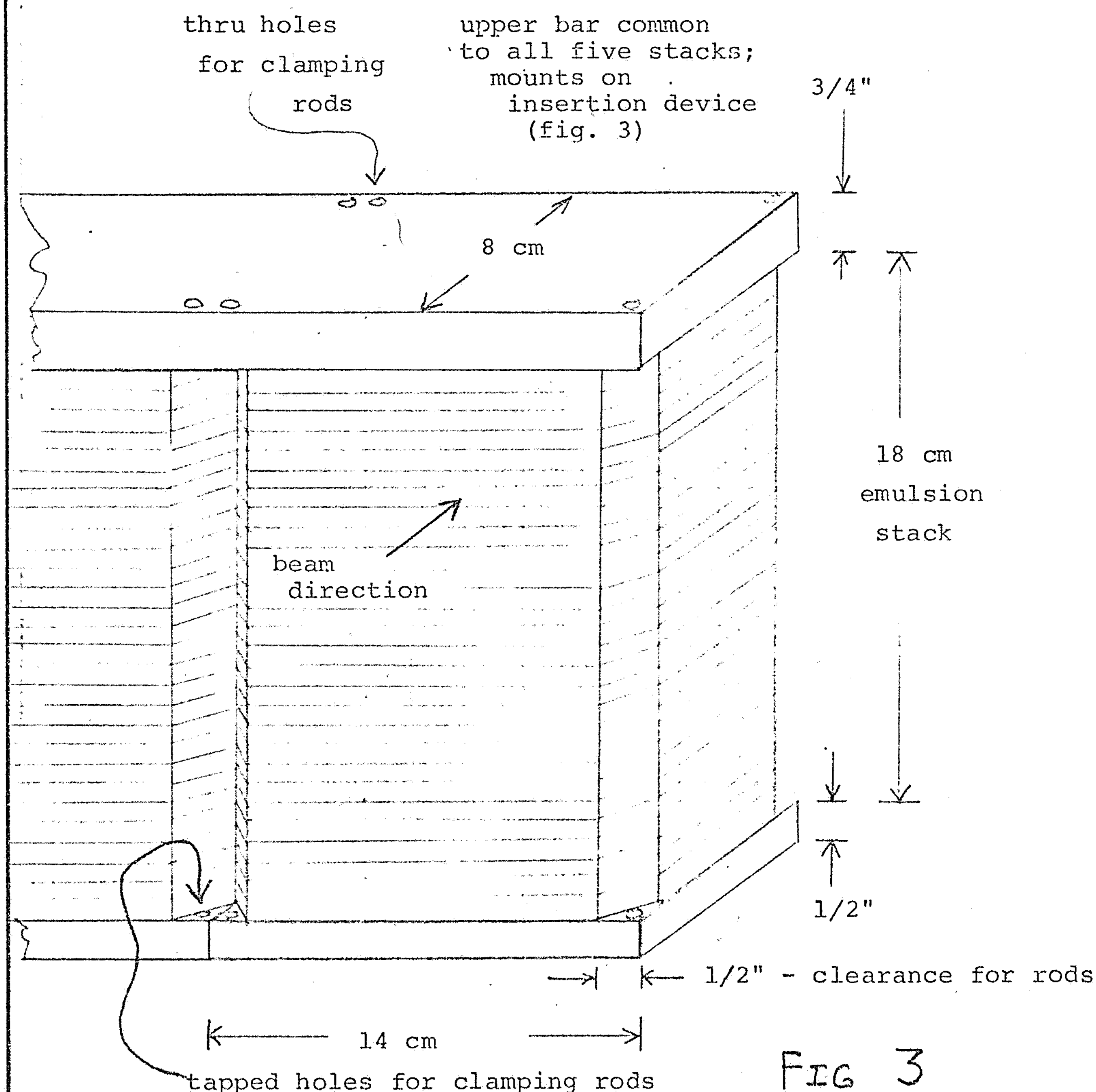


FIG 3

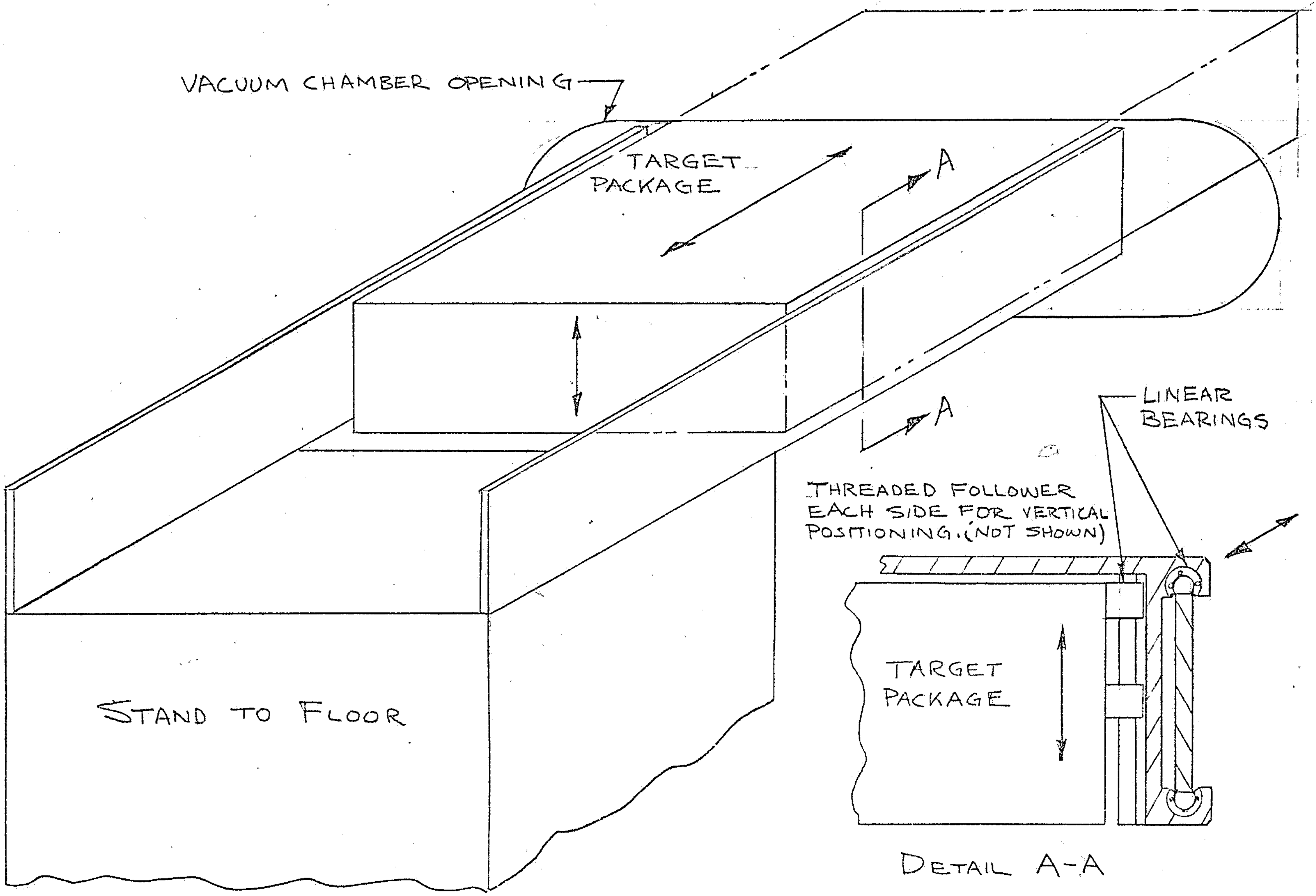


FIG 4 TARGET PACKAGE POSITIONING DEVICE

J.S. 3/2/77