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Proposal to Study Antineutrino Interactions in the Liquid Deuterium 15-ft Bubble Chamber with a Converter Plate System

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28 pgs.

Introduction

We propose to investigate high energy antineutrino interactions in deuterium in the 15-foot bubble chamber using a system of two converter plates in the chamber and the external muon identifier (EMI). This two-plate system is capable of identifying ~ 97% electrons hitting the plates with background from hadrons 10^{-3} and for detecting ~ 90% of gammas considering the gamma production angular distribution.

Motivation to study $\bar{\nu}d$ interactions with the plate system is: (1) There exists only a few high energy $\bar{\nu}$ data because of lower event yield, (2) comparison between $\bar{\nu}p$, $\bar{\nu}n$, νp and νn can be done in the same experiment, and (3) the plate system provides information of electron identification as well as detection of missing π^0's.

The primary physics topics to be studied are as follows:

1. Dilepton production,
2. Charge current reactions, comparison between $\bar{\nu}p$, $\bar{\nu}n$, νp and νn,
3. Neutral current reactions, n-p ratio,
4. Search for new particles,
5. All other interesting physics topics obtained from this experiment.

For this investigation, we request an exposure of 400,000 five-view pictures with a wide-band antineutrino beam using a system of two horns without a plug. The requested proton intensity is 1.3×10^{13} per pulse of energy 400 GeV. We propose to install the two plates in the chamber as will be discussed later. Another alternative scheme like the one described in proposal No. 489[(1)] would also be acceptable, though we prefer the present system.

The event rate is estimated by scaling from the data of Experiment 180.[2] The yield for $\bar{\nu}D$ interactions is 15.0K events (1 event/27pictures) in the deuterium fiducial volume taken in front of the first plate. The yield for νD interactions in the same fiducial volume is 6.1K events, and 11.5K events of $\bar{\nu}/\nu$ interactions are expected in the first plate. In total, 1 event/ 14 pictures. Table I shows the expected event rates for some interesting reactions.

The Converter Plate System

The primary aim for using the converter plates is to detect missing π^0's and to identify electrons with the smallest possible background from hadrons. The simplicity of plate arrangement is one of the most important factors to be considered for gaining clean visible volume for film measurement as well as for technical feasibility of the plate installation.

Considering these points, we proposed a system consisting of two converter plates of 1.5 and 5.5 radiation lengths (x_o) at the downstream end of the chamber as shown in Fig. 1. The plates are separated by 40 cm apart at the beam medium plane. The first plate surface is aligned to cameras 5 and 6 and the second plate to cameras 2 and 3. Since 3-view track reconstruction in front of the plates is desirable, we use five cameras, 4, 5, 6, 2 and 3. The plate material is stainless steel or copper. The total weight is about 5.4 tons for copper and about 5.8 tons for steel. Use of Scotchlite on the plate surfaces is very useful for identifying shower origins.

In order to gain clean visible volume for the track measurement in the liquid, the plates are placed only at the downstream end of the chamber. Deuterium fiducial volume is 15 m^3 in front of the first plate. The solid angle subtended by the last plate observed at the center of the fiducial volume is 0.6 π, corresponding to a cone with opening angle of $\pm 45^{o}$.

The purpose of the first thin plate (1.5x_o) is to identify electrons with high probability and to detect γ's with reasonable efficiency. As discussed in Appendix, it is capable to detect 97% of electrons hitting the plate for $E_e > 630$ MeV. Furthermore, for this single plate, the rate misassigning hadron-induced showers to electron-induced showers is 0.16% by using the p_t^{max} selection shown in Fig. 2. This rate is further reduced by a factor of ~ 2 by detecting the missing γ's from the first plate at the second plate and by identifying whether the γ's come from π^o's or bremsstrahlung. This small background rate from hadrons is one of the most suitable feature of this system for studying the dilepton reaction $\bar{\nu}N \rightarrow \mu^+ e^- X$.

Another feature of this system is that neutral current events with low charge multiplicity can be identified with relatively good detection efficiency by using the thick (5.5x_o) second plate and EMI. Assuming an interaction point at the center of the fiducial volume, the forward going hadron track passes through total material of 1.13 absorption lengths (λa) (D_2 180 cm = 0.45λ_a, Cu 10 cm = 0.68λ_a). This gives that 67% of such hadron tracks would interact inside the chamber.

For the γ's produced from interaction vertices inside the fiducial volume, our experimental examination shows the present two plate system is able to detect ~ 90% of γ's in average considering the γ production angular distribution, shown in Fig. 3. Fig. 4 shows the γ-conversion probability as a function of γ angle for this system. For comparison, the probability for ITC proposed by Berge et al. [1] is also shown. Because of lack of momentum information for most of γ's, the fitting constraint is reduced by 1 for each γ. However, measurement of γ direction would give sufficient information for some reactions. If momentum measurement is necessary, measurement of shower electrons will give γ momentum with error of about 40%.

Physics

1. Dilepton production

One of the most interesting topics in recent ν physics is the observation of the dilepton events. However, there exists only a few high energy $\bar{\nu}$ data because of the low event yield in $\bar{\nu}$ N interactions.

In the proposed experiment, we estimate 75 events for

$$\bar{\nu}\ p/n \to \mu^+ e^- X$$

and 30 events for

$$\nu\ p/n \to \mu^- e^+ X$$

in the deuterium fiducial volume. The plate system provides good electron identification with the low hadron background of $\lesssim 0.001$ and $\sim 90\%$ π^0 detection. Thus, measuring gammas from π^0's either in D_2 or the plates, we could perform 0-constraint fit and examine the invariant masses such as $e^- \bar{\nu}_e K_s^0$.

The background in the sample is hard to estimate. The possible sources of the backgrounds are from asymmetric Dalitz pairs, $\nu_e N \to e^+ X$ etc. But, we believe that the background rate is less than 10%.

2. Inclusive charged current reactions

The recent experimental results at Fermilab have revealed new phenomena in the charged current cross sections above 30 GeV. In particular, the anomalies observed in the total cross section ratio, $\sigma(\bar{\nu})/\sigma(\nu)$ and the y distributions indicate a substantial revision of the conventional (V-A) model.

In this proposal, the estimated yield is about 11.7 K events for the reactions

$$\bar{\nu}\, p/n \rightarrow \mu^{+} X$$

and 4.8 K events for

$$\nu\, p/n \rightarrow \mu^{-} X \ .$$

We study (1) the x, y and other inclusive variable distributions, (2) the total cross sections for proton and neutron target. Comparison between $\sigma(\bar{\nu} p)$, $\sigma(\bar{\nu} n)$, $\sigma(\nu p)$ and $\sigma(\nu n)$ will provide quite useful information to examine the existing theoretical models.

For the muon identification, we rely on the combination of the second plate and EMI, but also apply the transverse momentum balance method(3) which gives about 10% background in the selected μ^{+} sample.

3. Neutral current reactions

Now, we are confronted with a difficult task of determining the detailed properties in neutral current physics. We intend to study both inclusive and exclusive reactions and compare between $\sigma(\overset{\leftrightarrow}{\nu} p)$ and $\sigma(\overset{\leftrightarrow}{\nu} n)$. The estimated yields are each 2.3 K events for the reactions

$$\overset{\leftrightarrow}{\nu}\, p \rightarrow \nu\, X^{+}$$

and

$$\overset{\leftrightarrow}{\nu}\, n \rightarrow \nu\, X^{o}$$

respectively. The detection efficiency of muonless events is fairly high (~ 95%). Neutron background will be estimated by measuring 3-constraint fit $np \rightarrow pp\pi^{-}$ events and K_L^o background by measuring visible K^o events.

The plate system, as stated before, provides the good π^o detection. This allows us to study the exclusive reactions such as

$$\overset{(-)}{\nu} p \rightarrow \overset{(-)}{\nu} p \pi^0 ,$$
$$\overset{(-)}{\nu} n \rightarrow \overset{(-)}{\nu} p \pi^- \pi^0$$

as well as 3-constraint events. Furthermore, the diffractive reactions such as

$$\overset{(-)}{\nu} p \rightarrow \overset{(-)}{\nu} \rho^0 p, \quad \rho^0 \rightarrow \pi^+ \pi^-$$

$$\overset{(-)}{\nu} n \rightarrow \overset{(-)}{\nu} \rho^- p, \quad \rho^- \rightarrow \pi^- \pi^0$$

can be studied compared with the corresponding charged current reactions.

Also, we intend to search

$$\overset{(-)}{\nu} e^- \rightarrow \overset{(-)}{\nu} e^-$$

for which we estimate events $\lesssim 7$ in deuterium.

4. Search for new particles

Search for charmed particles, heavy leptons and intermediate boson is one of major subjects in this proposed experiment. In particular, using the advantage of the plate system, we search for the new particles which decay into electron or gammas. Search for particles with $\tau \sim 10^{-10}$ sec is most suitable in this experiment.

Analysis

Four scanning machines with two magnifications, six film plane digitizers with two magnifications and four image plane digitizers will be in full power operation for the scanning and measuring. All machines have four view projection. We expect to complete all scanning and measuring within about 10 months.

The computer, ACOS 700 with one mega bite memory (IBM 370-158 equivalent) will be full time use for only Tohoku bubble chamber group. TOSBAC 3400 model 51 (PDP 10 equivalent) is also available. TVGP-SQUAW modified at Tohoku has been working for the 15' BC analysis and will be used for the data analysis.

Tohoku group will consider this experiment to be a major commitment and all participants listed in this proposal will give a major effort to handle the data analysis successfully. About 20 scanners will be in the scanning and measuring for this experiment.

Appendix

In order to estimate detection efficiencies for gammas and electrons in the proposed plate system, we have performed the following measurements;

(1) Electron- and hadron-induced showers in the tantalum plate of 1.6 radiation lengths using BNL 80" bubble chamber pictures.

(2) Inclusive gamma production in $\pi^- p$ interactions at 8 GeV using SLAC 82" bubble chamber pictures.

1. Electron- and hadron-induced showers[4]

To study electron shower, we used a sample of pictures taken in the BNL 80" bubble chamber exposed to a 15 GeV/c $\bar{p}$ beam. The chamber has a single Ta plate with 1.6 X_o thickness at the down-stream end of the chamber. First, we scanned for $e^{\pm}$ tracks which were converted from γ's in liquid hydrogen and hitted the Ta plate. The result is shown in Table II. As electron energy E_e increases, the shower production rate increases and the absorption rate decreases. The rate of "no interaction" (electron passes through the plate without any interaction or deflection) does not change considerably.

The multiplicity in showers distributes from 0 to 8. The incident electron energy goes up to $\sim$ 3 GeV, peaking at $E_e \sim 0.5$ GeV in this sample. From the measurement of shower electrons we plot the distributions of p_t^{max}, the highest transverse momentum among the shower electrons with respect to the incident electron. Figs. 2 (a) and (b) show, respectively, the p_t^{max} distributions for $E_e < 0.63$ and $E_e > 0.63$ GeV, indicating that 99% of electron induced showers have $p_t^{max} < 0.04$ GeV/c and the peak position is approximately represented by the multiple scattering effect, $\theta_{proj} \simeq 14\sqrt{L/X_o}/P_e\beta$.

To compare the electron results with those for hadron-induced showers, we collected 6,815 secondary tracks which came from the $\bar{p}p$ interaction vertices and hitted the Ta plate. Of those, 521 tracks interacts at the plate; 392 tracks with at least one dark hadron track from Ta and 129 tracks ambiguous between e and hadron.

Fig. 2 (c) shows the P_t^{max} distribution for those ambiguous showers. Apparently, the distribution is much different from one for the electron caused showers. Applying the cut for $P_t^{max} > 0.04$ GeV/c, the number of ambiguous showers is reduced to 11. This P_t^{max} cut method for selecting electrons on single Ta plate gives the hadron misassign rate of 1.6×10^{-3}.

In the proposed two plate system, the second thick plate detects forward γ's from the first plate. The process, $\pi^o \to \gamma$ (e shower) + γ, ... (a) simulates the process, e $\to$ e shower + γ, ... (b). However, the opening angles between the shower and the γ are

$$\theta\ (\pi^o) > 2m_\pi/E$$

for process (a), and

$$\theta\ (e) \sim m_e/E$$

for process (b), respectively. Thus, we can reduce the hadron background by examining the opening angles. The reduction factor by the second plate is crudely 2 at $E \sim 2$ GeV.

2. Inclusive gamma production

Gammas converted into electron pairs in liquid hydrogen were measured in 8 GeV/c π^-p interactions(5). Correcting for the conversion efficiency using the potential length method, the gamma angular distribution in the laboratory system was obtained, Fig. 5. These gammas almost all originating from π^o's are strongly produced in the forward direction; about 85% in the 45^o

forward cone. We guess that the angular distributions of gammas in hadron- and $\bar{\nu}$-interactions are similar, because the total hadron momentum direction in $\bar{\nu}$ p interactions is almost confined within a forward cone of $\theta_{lab} = 25^o$ at E = 8 GeV. (If E increases, θ_{lab} is proportional to $\sqrt{2M_p/E}$.) The detection efficiency of the plate system for gammas was calculated using the gamma angular distribution in Fig. 5.

References

1. J. P. Berge, F. A. DiBianca, R. Hanft, F. A. Nezrick, W. G. Scott, and W. Smart, Fermilab Proposal No. 489.

2. F. A. Nezrick, private communication.

3. M. Derrick et al., "A Study of High Energy Antineutrino-Proton Interactions", ANL-HEP-PR-76-01 (1976).

4. T. Kitagaki et al., "$e^{\pm}$ tracks in the $\bar{p}p$ Interactions at 15 GeV/c", Tohoku report, TUHEL-76/3 (Oct. 15, 1976).

5. T. Maruyama, "Inclusive Gamma Production in $\pi^{-}p$ Interactions at 8 GeV/c", Thesis (1976).

TABLE I

$\bar{\nu}/\nu$ event yields inside 15 m^3 D_2 fiducial volume, 400 K pictures, 1.3 x 10^{13} ppp, 400 GeV/c, 2 horns without plug.

	$\bar{\nu}$		ν	
CC	p	7.8	p	1.6
	n	3.9	n	3.2
NC	p	1.6	p	0.7
	n	1.6	n	0.7
Dilepton	p/n	0.075	p/n	0.030
Total		15.0^K events		6.1^K events

$\bar{\nu}/\nu$ interactions in the first plate; 11.5 K events.

Table II

Shower production in $1.6X_0$ Ta plate by electrons

	$E_e < 0.63$ GeV		$E_e > 0.63$ GeV		all energy	
	Event No.	rate	Event No.	rate	Event No.	rate
shower	120	0.82	160	0.97	280	0.90
absorption	25	0.17	3	0.02	28	0.09
no interaction	1	0.01	2	0.01	3	0.01
total	146	1.00	165	1.00	311	1.00

Figure Captions

Fig. 1 Two plate system in the 15' bubble chamber.

Fig. 2 P_t^{max} distributions for (a) electron induced showers with $E_e < 0.65$ GeV, (b) electron induced showers with $E_e > 0.65$ GeV and (c) hadron induced showers.

Fig. 3 Laboratory angular distribution of gammas produced in $\pi^- p$ interactions at 8 GeV/c.

Fig. 4 Gamma conversion probability as a function of gamma angle.

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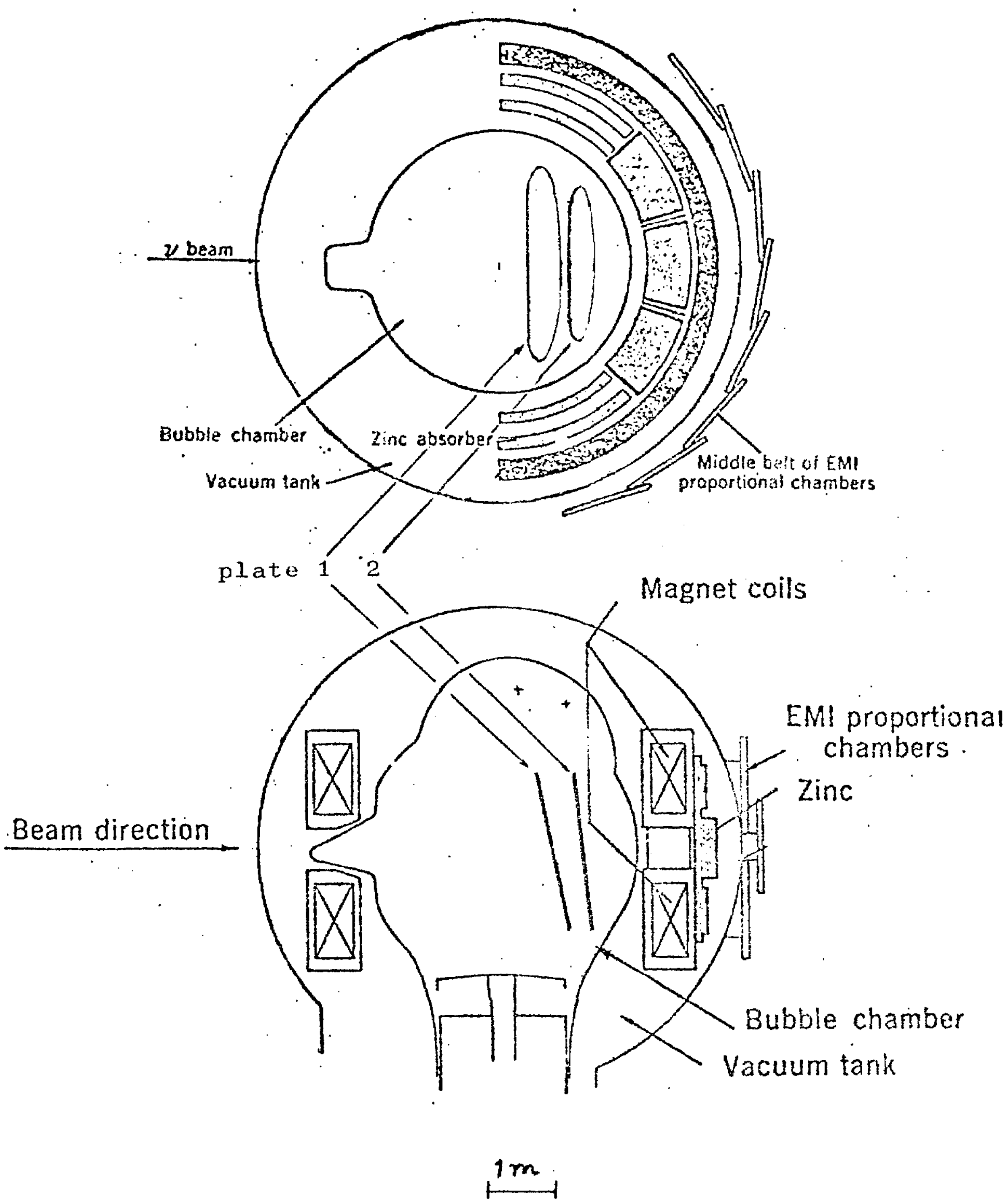

ν beam
Bubble chamber
Zinc absorber
Vacuum tank
Middle belt of EMI proportional chambers
plate 1 2
Magnet coils
EMI proportional chambers
Zinc
Beam direction
Bubble chamber
Vacuum tank
1m

Fig. 1

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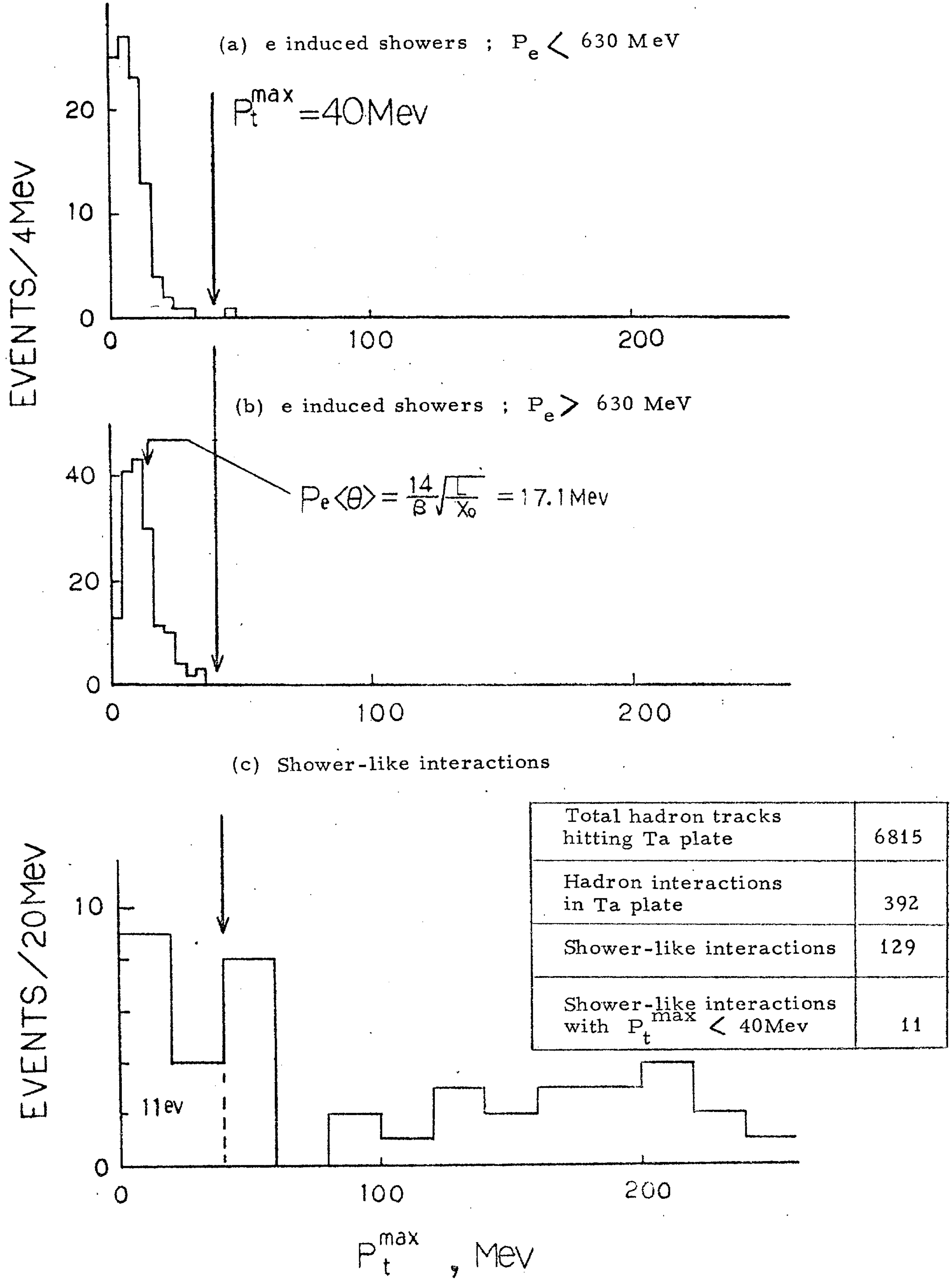

Total hadron tracks hitting Ta plate	6815
Hadron interactions in Ta plate	392
Shower-like interactions	129
Shower-like interactions with $P_t^{max} <$ 40Mev	11

Fig. 2

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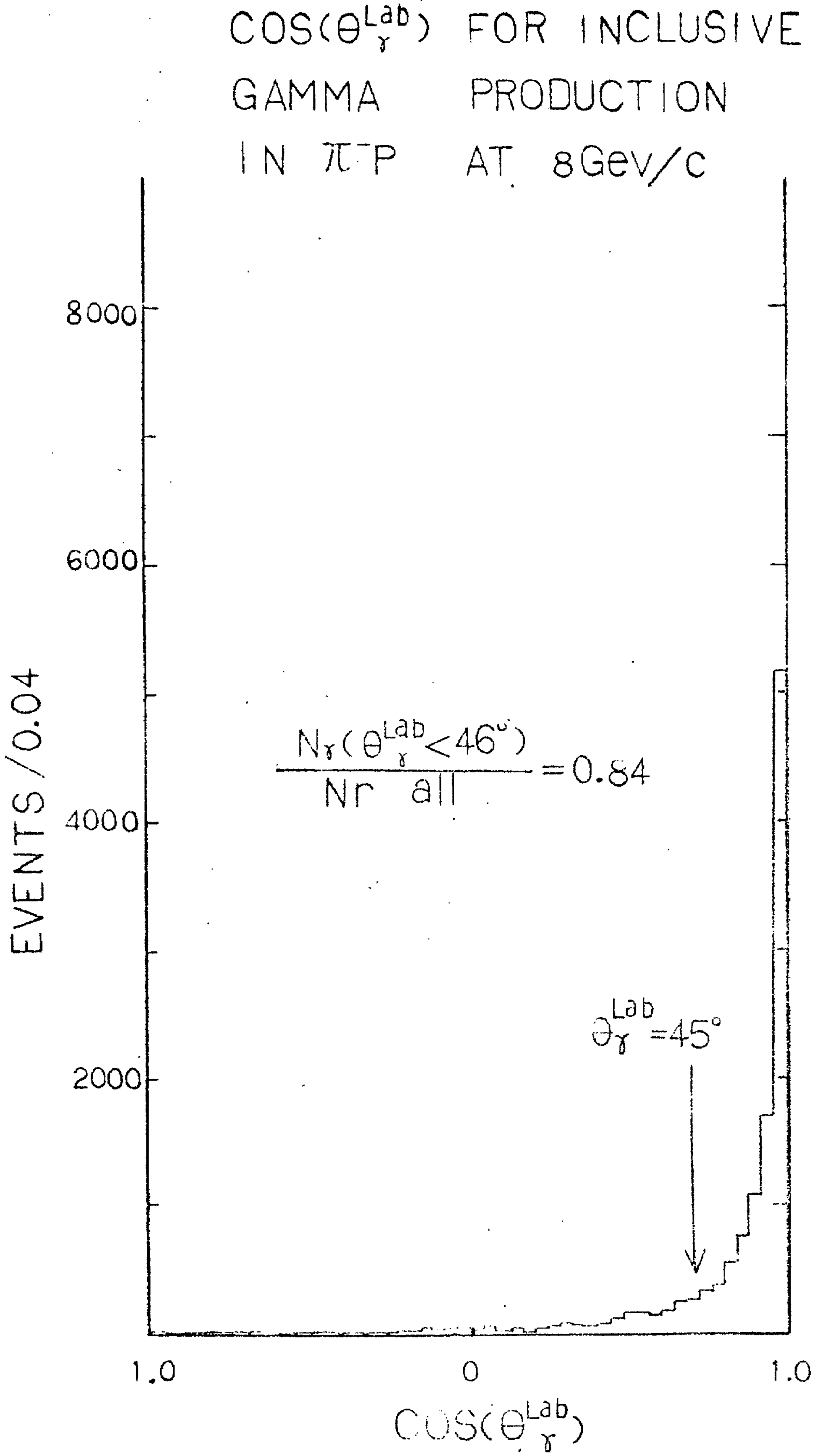
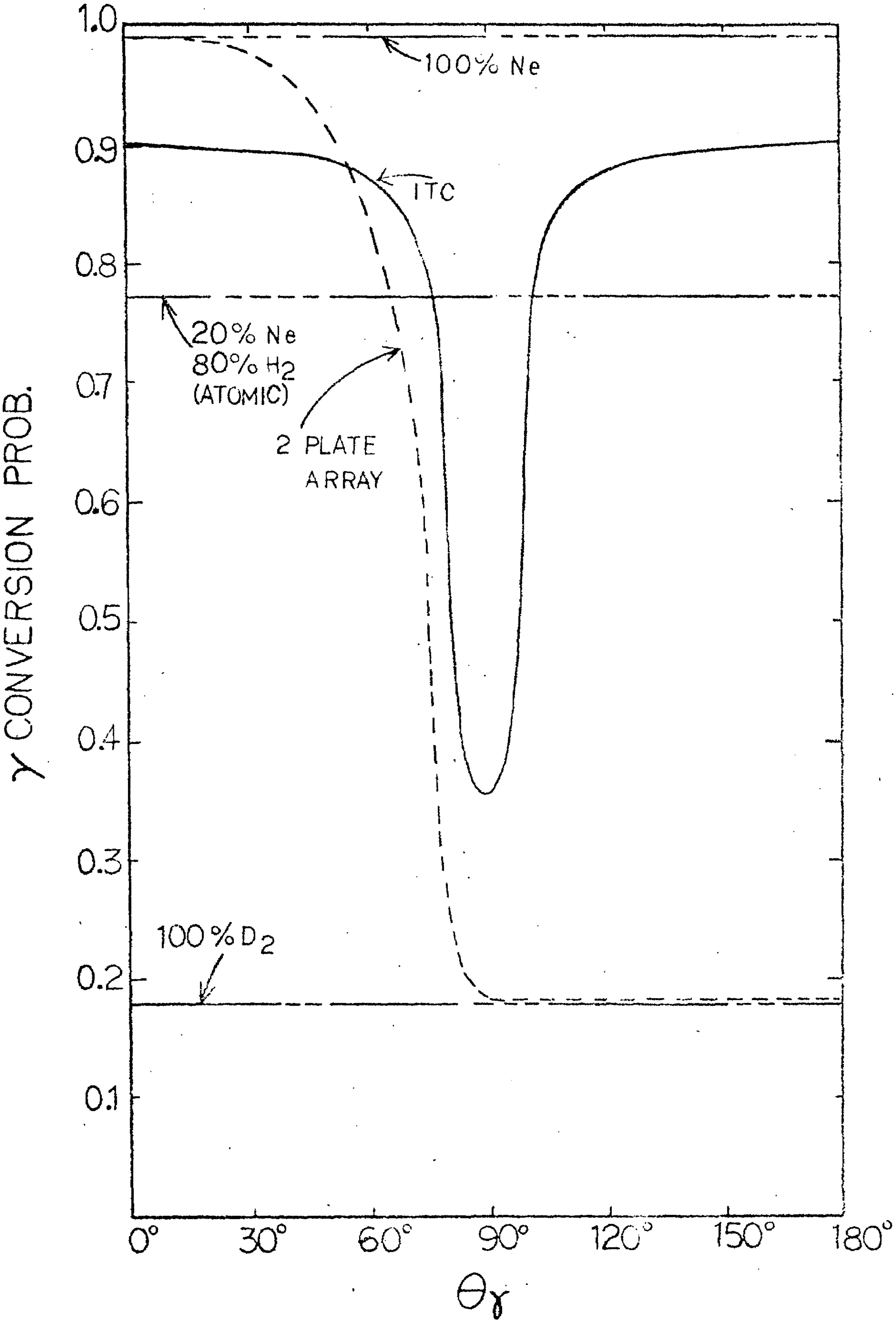

COS(θ_γ^Lab) FOR INCLUSIVE
GAMMA PRODUCTION
IN π⁻P AT 8Gev/c
8000
6000
4000
2000
EVENTS /0.04
Nγ(θ_γ^Lab<46°) / Nr all = 0.84
θ_γ^Lab =45°
1.0
0
1.0
COS(θ_γ^Lab)

Fig. 3

B-543



1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
γ CONVERSION PROB.
100% Ne
ITC
20% Ne
80% H_2
(ATOMIC)
2 PLATE
ARRAY
100% D_2
0°
30°
60°
90°
120°
150°
180°
θ_γ

Fig. 4

Update

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December, 1977

Introduction

We propose to investigate high energy antineutrino interactions in deuterium in the 15-foot bubble chamber using the proposed four converter plates in the chamber and the external muon identifier (EMI). This plate system is capable for identifying about 95% electrons hitting the plates with background from hadrons of less than 10^{-4} and of detecting about 90% of gammas.

Motivation to study $\overset{(-)}{\nu}$ d interactions with the plate system is: (1) comparison between $\bar{\nu}$ p, $\bar{\nu}$ n, ν p and ν n can be done in the same experiment, and (2) the plate system provides information of electron identification as well as detection of missing π^{o}'s.

The primary physics topics to be studied are as follows:

1. Multi-lepton production,
2. Charge current reactions, comparison between $\bar{\nu}$ p, $\bar{\nu}$ n, ν p and ν n,
3. Neutral current reactions, n-p ratio,
4. Search for new particles,
5. All other interesting physics topics obtained from this experiment.

For this investigation, we request an exposure of 400,000 five-view pictures with a wide-band antineutrino beam using a system of two horns without a plug. The requested proton intensity is 1.3×10^{13} per pulse of energy 400 GeV.

Although we intend to analyze the data by ourself, some form of collaboration with other experimental groups will be also considered

The event rate is estimated by scaling from the data of E-180.[1] The total yield for $\bar{\nu}$ D interactions is 15.0K events (1 event/27 pictures) in the deuterium fiducial volume of 15 m^3 taken in front of the first plate. The yield for ν D interactions in the same fiducial volume is 6.1Kevents. About 6K events of $\bar{\nu}/\nu$ interactions are expected in each plate. Table I lists the expected event rates for some interesting reactions.

<u>Characteristics of the Present Plate Geometry</u>

The primary use of the converter plates is to detect missing π^o's and to identify electrons with the smallest possible background from hadrons. Fig. 1 shows the rough sketch of the present plate geometry (four steel plates at down stream end, each 0.72 radiation lengths thick). We wish to use five cameras; 4, 5, 6 for the front part of the chamber to obtain good three view track reconstruction and cameras 2 and 3 for measuring tracks seen between the plates.

This plate system is capable for detecting about 90% of gammas and 55% of the detected gammas convertes more than 70% of the gamma energy to the shower electrons. These values were estimated using a shower simulation (see Appendix). The reconstructed π^o mass distributions with 5% measurement error in momentum indicate that the correct $\gamma\gamma$ pairing reproduce the π^o peak with a FWHM of about 100 MeV and that all $\gamma\gamma$ combinations give about

56% of π^o detection in our plate geometry.

For electron detection, about 95% of electrons produces electro-magnetic showers at the plates. The $\pi^\pm$ rejection rate is well below 10^{-4} as stated in the reply letter from D. Carmony to the PAC. Also, from our experience in the electron shower study with two Ta plates (each 1.6 X_o)[2], we certainly believe the hadron rejection rate of $\sim 10^{-5}$.

Physics

1. Multi-lepton production

One of the most interesting topics in recent ν physics is the observation of the multi-lepton events. The gross features of dilepton events are consistent with charm production in $\nu/\bar{\nu}$ N interactions. However, there still remain several questions to be solved and the observation of trimuon events is suggestive for new phenomena.

In the proposed experiment, we estimate 75 events for

$$\bar{\nu}\ p/n \rightarrow \mu^+ e^- X$$

and 30 events for

$$\nu\ p/n \rightarrow \mu^- e^+ X$$

in the deuterium fiducial volume. The plate system provides good electron identification with the low hadron background of less than 10^{-4} and about 56% π^o detection. Thus, measuring gammas from π^o's either in D_2 or the plates, we are able to perform 0-constraint fit and examine the invariant masses such as $e^- \bar{\nu}_e K^o_s$.

The background in the sample is hard to estimate. The possible sources of the backgrounds are from asymmetric Dalitz pairs, $\nu_e N \to e^+ X$ etc. But, we believe that the background rate is less than 10%.

For the reaction

$$\bar{\nu}\ p/n \to \mu^+ e^+ e^- X,$$

we estimate about 3 events assuming that the rate ($\mu ee/\mu e$) is equal to the rate ($\mu\mu\mu/\mu\mu$) of 0.05. Although, the expected μee event rate is low, the electron and π^o detection would provide more detailed information for production of the individual events.

2. Inclusive charged current reactions

Charged-current neutrino interactions (CC) have been studied extensively and the gross features of the interactions are reasonably understood. The proposed experiment will take advantage of the deutron target which give the direct comparison of $\bar{\nu}$ p/n and ν p/n.

In this proposal, the expected yield is about 11.7 K events for the reactions

$$\bar{\nu}\ p/n \to \mu^+ X$$

and 4.8 K events for

$$\nu\ p/n \to \mu^- X.$$

A comparison between $\sigma(\bar{\nu}\,p)$, $\sigma(\bar{\nu}\,n)$, $\sigma(\nu\,p)$ and $\sigma(\nu\,n)$ will provide quite useful information to examine the existing theoretical models. We will also analyze strange particle production in $\bar{\nu}$ N and ν N interactions and examine the yield in view of charm particle production.

For the muon identification, we rely on improved EMI, but also apply the transverse momentum balance method(3) which gives about 10% background in the selected μ sample.

3. Neutral current reactions

The detailed structure(4) of the neutral current can be determined from measurements of four cross sections, $\sigma(\nu p)$, $\sigma(\nu n)$, $\sigma(\bar{\nu} p)$ and $\sigma(\bar{\nu} n)$. All the four cross sections can be measured in this single experiment. We intend to study both inclusive and exclusive reactions and compare between $\sigma(\overset{(-)}{\nu} p)$ and $\sigma(\overset{(-)}{\nu} n)$. The estimated yields are each 2.3 K events for the reactions

$$\overset{(-)}{\nu}\ p \rightarrow \overset{(-)}{\nu}\ X^+$$

and

$$\overset{(-)}{\nu}\ n \rightarrow \overset{(-)}{\nu}\ X^o,$$

respectively. The detection efficiency of muonless events is fairly high ($\sim$ 95%). Neutron background will be estimated by measuring 3-constraint fit $np \rightarrow pp\pi^-$ events and K_L^o background by measuring visible K^o events.

The plate system, as stated before, provides the good π^o detection. This allows us to study the exclusive reactions such as

$$\overset{(-)}{\nu} p \rightarrow \overset{(-)}{\nu} p\pi^{o},$$
$$\overset{(-)}{\nu} n \rightarrow \overset{(-)}{\nu} p\pi^{-}\pi^{o}$$

as well as 3-constraint events. Furthermore, the diffractive reactions such as

$$\overset{(-)}{\nu} p \rightarrow \overset{(-)}{\nu} \rho^{o} p$$
$$\hookrightarrow \pi^{+}\pi^{-}$$
$$\overset{(-)}{\nu} n \rightarrow \overset{(-)}{\nu} \rho^{-} p$$
$$\hookrightarrow \pi^{-}\pi^{o}$$

can be studied compared with the corresponding charged current reactions.

Also, we intend to search

$$\overset{(-)}{\nu} e^{-} \rightarrow \overset{(-)}{\nu} e^{-}$$

for which we estimate events $\lesssim 7$ in deuterium.

4. Search for new particles

Search for charmed particles, heavy leptons and intermediate boson is one of major subjects in this proposed experiment. In particular, using the advantage of the plate system, we search for the new particles which decay into electron or gammas. Search for particles with $\tau \sim 10^{-10}$ sec is most suitable in this experiment.

Analysis

Four scanning machines with two magnifications, six film plane digitizers with two magnifications and four image plane digitizers will be in full power operation for the scanning and measuring. All machines have four view projection. We expect to complete all scanning and measuring within about 10 months.

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Tohoku group will consider this experiment to be a major commitment and all participants listed in this proposal will give a major effort to handle the data analysis successfully. About 20 scanners will be in the scanning and measuring for this experiment.

Appendix

For the proposed stainless steel plate configuration, we calculate the conversion rate of a single gamma and the detection of π^o. Fig. 1 shows the side view of the plate geometry in the chamber which we have used for this calculation. The plate thickness is ½" equivalent to 0.74 X_o.

For this calculation, a Monte Carlo simulation of electromagnetic shower formation was performed including the effects of ionization loss, multiple scattering and Bremsstrahlung for electron and of compton and pair creation for gammas. The shower simulation was examined compared with the results obtained from the electron-induced shower measurement using the BNL 80" bubble chamber pictures where two Ta plates (1.6 X_o) were at the down-stream end of the chamber. The step in the plate thickness was taken to be 0.02 X_o in this calculation.

Fig. 2 (a), (b) and (c) show the converted electron energy distributions for the incident gamma energies at 0.2, 1.0 and 5 GeV/c, respectively. To calculate the electron energy, we sum up all electron energies from each plate assuming that measurable electron energy is greater than 10 MeV and the measurement error is 5%. If two or more gammas are emitted from any plate, we stop calculating the gamma conversion from the next plate.

For comparison, Fig. 3 shows the electron energy distributions for the 5 plate system with 0.54 X_o thickness each. Apparently, the resolution for the 0.54 X_o plate system is better than that for the 0.72 X_o plate system. For the gammas incident perpendicular to the plates, the gamma detection efficiencies at E_γ = 0.2, 1.0 and 5.0 GeV are

0.83, 0.88, 0.87

for the 0.54 X_o plate system and

0.83, 0.88, 0.89

for the 0.74 X_o plate system, respectively.

Fig. 4 shows the reconstructed (γ,γ) mass distribution for the 0.72 X_o plate system using that the π^o momentum, direction and multiplicity distributions are simulated from the π^+ distributions observed in π^-p interactions at 8 GeV/c.[5] The unshaded area corresponds to the correct $\gamma\gamma$ combinations and the shaded area to the incorrect $\gamma\gamma$ combinations.

The ($\gamma\gamma$) mass distribution from the correct combinations gives FWHM of about 100 MeV and 56% of the π^o detection. The background distribution from the incorrect $\gamma\gamma$ combinations (shaded area under π^o mass region) accounts about 37% of the π^o signal. However, this value depends on the assumption used for the π^o distributions.

TABLE I

$\bar{\nu}/\nu$ event yields inside 15 m^3 D_2 fiducial volume, 400 K pictures, 1.3 x 10^{13} ppp, 400 GeV/c, 2 horns.

	$\bar{\nu}$		ν	
CC	p	7.8	p	1.6
	n	3.9	n	3.2
NC	p	1.6	p	0.7
	n	1.6	n	0.7
Dilepton	p/n	0.075	p/n	0.030
Total		15.0^K events		6.1^K events

$\bar{\nu}/\nu$ interactions in each plate ~ 5.7 K events.

References

1. F. A. Nezrick, private communication.
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3. M. Derrick et al., "A Study of High Energy Antineutrino-Proton Interactions", ANL-HEP-PR-76-01 (1976).
4. Hung and Sakurai, Phys. Letters 63B, 295(1976).
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5. T. Maruyama, "Inclusive Gamma Production in $\pi^- p$ Interactions at 8 GeV/c", Thesis (1976). The average π^+ multiplicity is 1.3 and the momentum distribution peaks at about 0.9 GeV/c. The ($\gamma\gamma$) mass distribution calculated directly from the electron energy gives the reconstructed π^o mass lower than the true π^o mass. Thus, the electron energy was raised up to give the correct π^o mass.

Figure Caption

Fig. 1. The sketch of the plate system in the 15' bubble chamber.

Fig. 2. Electron energy distributions for the incident gamma energies at 0.2, 1.0 and 5.0 GeV. The plate is 0.72 X_o thick.

Fig. 3. Electron energy distributions for the incident gamma energies at 0.2, 1.0 and 5.0 GeV. The plate is 0.54 X_o thick.

Fig. 4. ($\gamma\gamma$) mass distribution. The shaded and the unshaded areas correspond to the incorrect and correct $\gamma\gamma$ pairings, respectively.

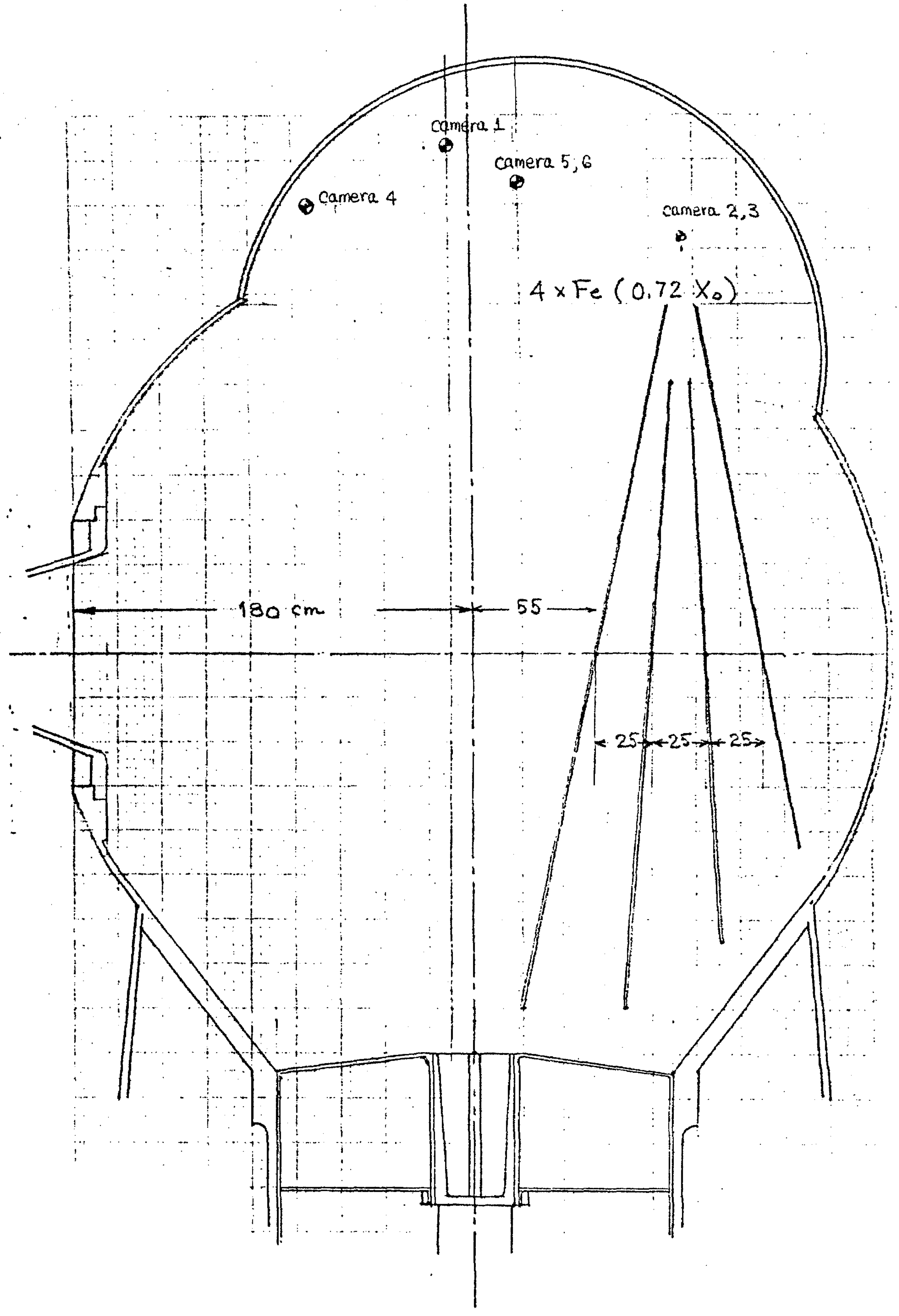
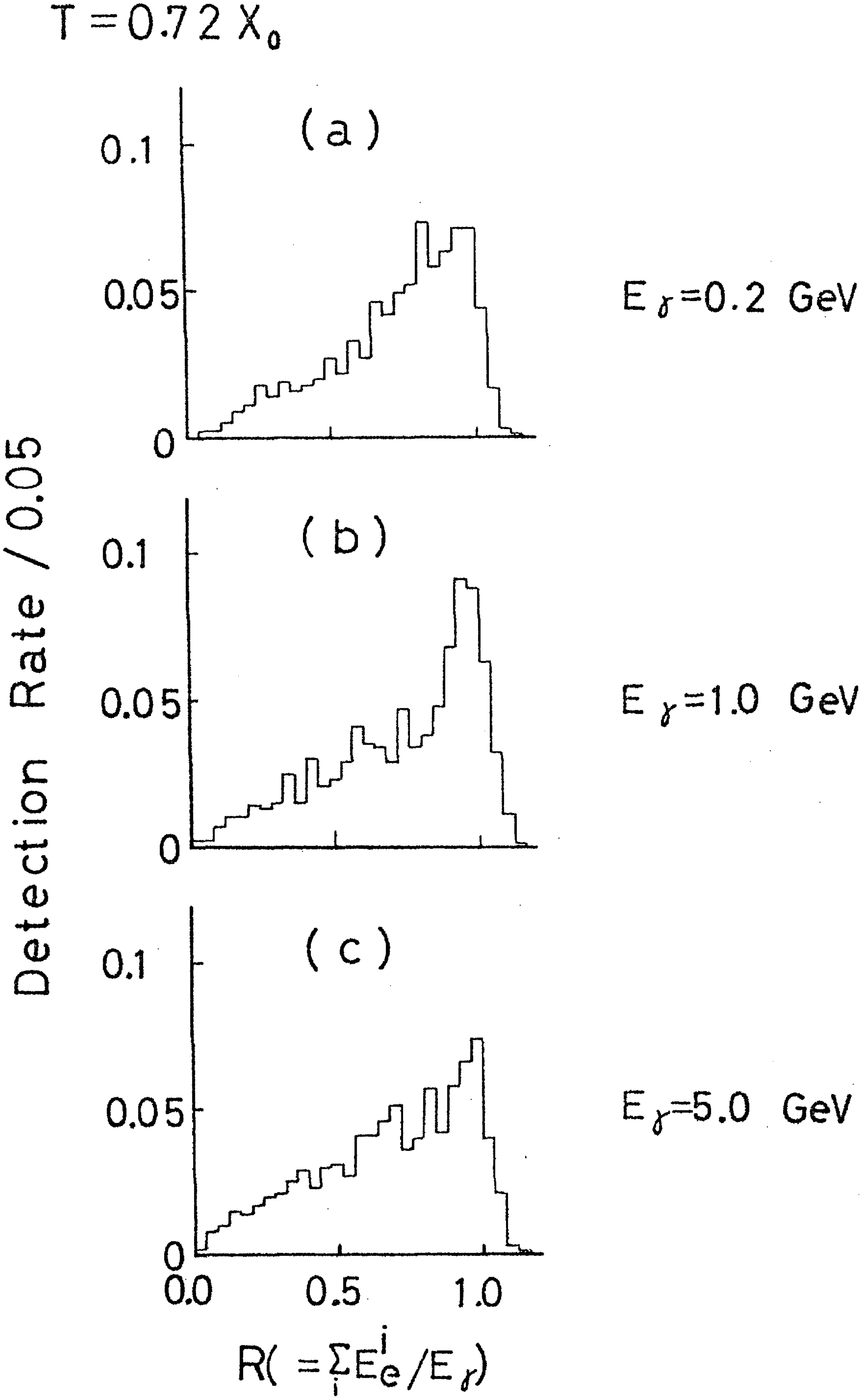

camera 1
camera 5,6
Camera 4
camera 2,3
4 × Fe (0.72 X₀)
180 cm
55
25
25
25

Fig. 1



T = 0.72 X0
(a)
(b)
(c)
0.1
0.05
0
Detection Rate / 0.05
E γ=0.2 GeV
E γ=1.0 GeV
E γ=5.0 GeV
0.0
0.5
1.0
R(= Σi Ee^i / Eγ)

Fig. 2

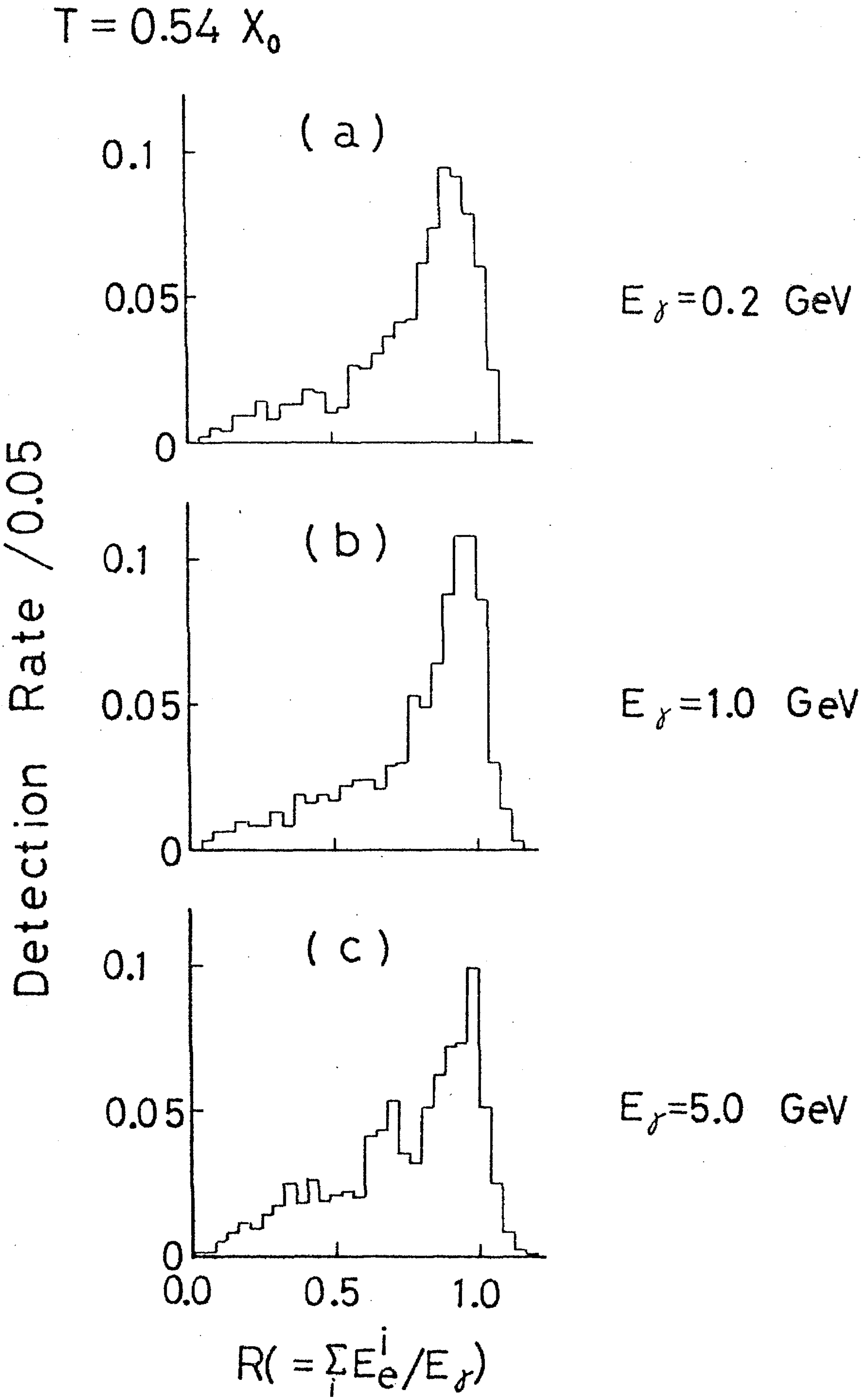

T = 0.54 X0
(a)
(b)
(c)
0.1
0.05
0
Detection Rate /0.05
E γ =0.2 GeV
E γ =1.0 GeV
E γ =5.0 GeV
0.0
0.5
1.0
R(= Σi Eei/Eγ)

Fig. 3

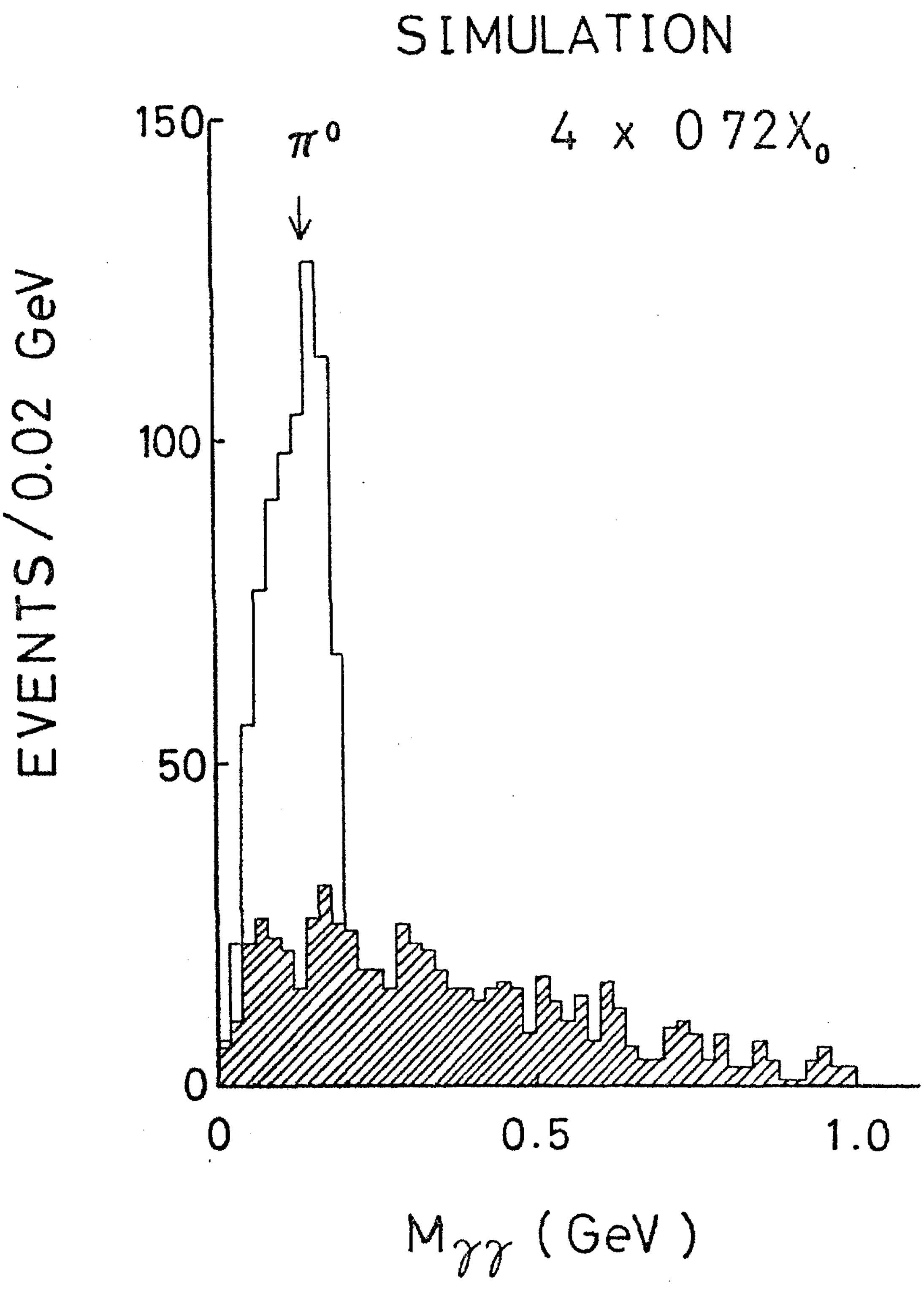

SIMULATION
150
100
50
0
π^0
4 x 0 72X_0
EVENTS/0.02 GeV
0
0.5
1.0
$M_{\gamma\gamma}$ (GeV)

Fig. 4