NAL PROPOSAL NO. 227

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# PROPOSAL TO INVESTIGATE NEUTRINO INTERACTIONS IN DEUTERIUM USING THE NAL 15-FOOT BUBBLE CHAMBER

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# EXPOSURE

We intend to take 300,000 pictures in a horn-focussed neutrino beam from 350 GeV/c protons. In order to estimate the expected number of events we use the calculations done at NAL[1] with the following beam parameters:

1) $10^{13}$ incident protons per pulse.
2) current NAL neutrino beam configuration.
3) real focussing.
4) one interaction length target.
5) Hagedorn-Ranft model and $\pi$ and K fluxes.
6) detector radius of 1.35 m.

The resulting neutrino flux together with event rates is shown in Fig. 1 as a function of neutrino energy. The inelastic event rates for $\nu n$ and $\nu p$ are calculated with a cross section $\sigma(\text{inel}) = (0.75 \times 10^{-38} \text{cm}^2) \cdot E_\nu(\text{GeV})$ as measured at CERN up to about 10 GeV[2] and recently confirmed at NAL with a point at about 30 GeV[3].

For the event rates with constant cross sections we used:

$$\sigma(\nu n \to \mu^- p)^{\,4)} = 0.8 \times 10^{-38} \text{ cm}^2$$

$$\sigma(\nu p \to \mu^- \Delta^{++})^{\,5)} = 1.0 \times 10^{-38} \text{ cm}^2$$

We have used a <u>conservative</u> fiducial volume of 1.5 m in radius which corresponds to a volume of 14 $m^3$. In table I we list the numbers of expected events for a 300,000 picture exposure.

## Table I

| $E_\nu$ (GeV) | $\nu n + \nu p$ inelastic | $\nu n$ elastic |
|---|---|---|
| 5-10 | 1500 | 107 |
| 10-15 | 3750 | 161 |
| 15-20 | 5400 | 168 |
| 20-25 | 5550 | 134 |
| 25-30 | 4950 | 100 |
| 30-35 | 4050 | 67 |
| 35-45 | 3000 | 44 |
| 40-45 | 2250 | 28 |
| 45-50 | 1650 | 19 |
| 50-60 | 2250 | 20 |
| 60-70 | 1290 | 10 |
| 70-80 | 900 | 6 |
| 80-90 | 690 | 4 |
| 90-100 | 570 | 3 |
| 100-120 | 470 | 5 |
| Total | 38,270 | 876 |

In summary, we expect to find

19,000 $\nu n$ inelastic events

19,000 $\nu p$ inelastic events

880 $\nu n$ elastic events

1,040 $\nu p \rightarrow \mu^- \Delta^{++}$

350 $\nu n \rightarrow \mu^- \Delta^{+}$ (using the $|\Delta I| = 1$ rule).

As shown in the following sections our proposed exposure of the bare 15-foot bubble chamber contains a rich variety of measurements. The recent, more realistic, estimates of obtainable neutrino fluxes show that a large number of pictures at the highest proton energies will be required to answer physics questions of interest. Much time and manpower will be needed to extract all the physics information from a neutrino exposure. We feel justified in proposing an initial $\nu$-$D_2$ experiment at 350 GeV/c with 300,000 pictures which is complementary to existing proposals.

Although much can be done without external identification of the $\mu^-$, investigation of inelastic processes would be facilitated by such a device, and we would be interested in collaboration with other groups for its use.

## DETERMINATION OF THE NEUTRINO FLUX

The neutrino flux can be estimated by calculating the $\pi$ and K production spectrum and tracing it through the focussing elements and the beam-detector geometry.[6] We intend to use the elastic events and $\Delta^{++}$ production in order to measure the $\nu$ flux in the energy range from 5 to 45 GeV. This measurement will provide an important check of the flux calculations in the lower energy range.

1) $\nu n \to \mu^- p$:

The elastic cross sections at $q^2 = 0$ is constant for all $\nu$ energies and is given by

$$\frac{d\sigma}{dq^2}(q^2{=}0) = \frac{G^2}{2\pi}(1+\lambda^2) \simeq 2 \times 10^{-38}\ \mathrm{cm}^2/(\mathrm{GeV/c})^2$$
$$\lambda F_A(0)/F_V(0) = 1.23$$

Hence the energy dependence of the event rate at $q^2 = 0$ determines the $\nu$ flux. Using events with $q^2 < 0.1\ (\mathrm{GeV/c})^2$ we expect to find about 170 events. The Pauli exclusion 'damping' at low $q^2$

is illustrated in Fig. 2. The theoretical uncertainty in the $q^2$ dependence at small $q^2$ is estimated to be about 5%.[7] For 4 bins of 10 GeV from 5 to 45 GeV we estimate 15% error in the normalization of the neutrino flux in each bin.

2) $\nu p \to \mu^- \Delta^{++}$:

Data from Argonne and CERN (Fig. 3) indicate that the cross-section for this reaction flattens out at $E_\nu = 1.5$ GeV. If this cross section remains constant in the energy region from 5 to 45 GeV, we expect 1040 events which will enable measurements of the shape of the $\nu$ flux to $\sim$10% using 5 GeV bins.

Together with the low $q^2$ elastic events we estimate the error in neutrino flux to be between 10 and 15%.

## PHYSICS JUSTIFICATION OF THE EXPOSURE

1) The Elastic Reaction $\nu n \to \mu^- p$:

Assuming the conventional V-A interaction with T—invariance, no second class currents, and neglecting terms proportional to the muon mass, the weak hadronic current has the form

$$J^\mu = F_V(q^2)\,\gamma^\mu + \frac{i\mu}{2M_N} F_M(q^2)\,\sigma^{\mu\nu} q_\nu - i\lambda F_A(q^2)\,\gamma^\mu\gamma_5$$

The form factors are normalized to $F(q^2=0) = 1$. The axial scal is given by $\lambda\, F_A(0)/F_V(0) = 1.23$. The scale of the weak magnetism is given by CVC with $\mu = \mu_p - \mu_n$. The $q^2$ dependence of $F_V$ and $F_M$ from CVC is

$$F_{V,M}(q^2) = \left(1 + \frac{q^2}{(.84)^2}\right)^{-2}$$

The differential cross section $d\sigma/dq^2$ is then a function of a single parameter, the axial vector mass $M_A$ in the dipole expression for the axial vector form factor:

$$F_A(q^2) = \left(1 + \frac{q^2}{M_A^2}\right)^{-2}$$

We expect 710 events with $q^2 > 0.1$ $(GeV/c)^2$. With the neutrino flux determined to 10-15% an accurate axial form factor fit is possible. This will be an important extension to higher $q^2$ of the form factor fits obtained at Argonne and Brookhaven. At higher $q^2$ one may detect form factor behavior different from the suggested dipole form. Anomolous behavior at large $E_\nu$ and $q^2$ could signal the presence of second class currents such as an axial magnetic transition $F_E(q^2)$ 8)

$$\left.\frac{d\sigma}{dq^2}\right|_{E_\nu \to \infty} \cong \frac{G^2}{2\pi} \left\{ {F_V}^2 + \lambda^2 {F_A}^2 + \frac{q^2}{4M_N^2} \left[ (\mu F_M)^2 + (C_E F_E)^2 \right] \right\} .$$

2) Other Specific Channels

a) $\Delta$ (1236) Production and Test of the $|\Delta I| = 1$ Selection Rule:

For the quasi-two body $\Delta(1236)$ production the $|\Delta I| = 1$ rule predicts the ratio

$$\frac{\nu p \to \mu^- \Delta^{++}}{\nu n \to \mu^- \Delta^+} = \frac{3}{1}$$

The events $\nu p \to \mu^- \Delta^{++}$ allow 3-constraint fits but with unseen neutron spectator. The events

$$\nu n \to \mu^- \Delta^+ \quad \hookrightarrow \begin{matrix} p\pi^0 \\ n\pi^+ \end{matrix}$$

are zero-constraint events; those with an unseen spectator proton (about 2/3 of the events) allow only "weak 0-C" fits in which starting values of $\sim 0 \pm 50$ MeV/c are assigned for the cartesian momentum components of the spectator. One additional constraint is provided by conversion of a $\gamma$ from a final state $\pi^0$ ( 30% probability for conversion of either $\gamma$ from a $\pi^0$); at least two constraints are provided by interaction of a final-state neutron ($\sim$ 50% detection probability). Assuming validity of the $|\Delta I| = 1$ rule we expect to find 350 $\nu n \to \mu^- \Delta^+$ events of which 150 will have additional constraints from neutrals.

We will be able to look for isotensor currents by studying $\Delta^{++}$ and $\Delta^{+}$ production in the same exposure.

b) Search for $\Delta S = -\Delta Q$ Transitions:

It is important to check the $\Delta S = \Delta Q$ selection rule at high $q^2$. We will scan for the forbidden reactions

$$\nu n \to \mu^- \Sigma^+ \qquad \text{(inverse } \Sigma^+ \text{ leptonic decay)}$$

$$\nu n \to \mu^- \left( \begin{matrix} \Lambda^\circ \\ \Sigma^\circ \end{matrix} \right) \pi^+$$

and also

$$\nu p \to \mu^- \Sigma^+ \pi^+ .$$

c) Multi-pion Production and the Adler Test[9]:

The Adler relation connects neutrino production of a hadronic state F with the $\mu^-$ going forward to the production of F by pions.

$$\frac{d^2\sigma}{dq^2 d\nu} (\nu N \to \mu^- F) \underset{\theta_\mu \approx 0}{\leftrightarrow} \sigma (\pi N \to F) \; , \; \nu = E_\nu - E_\mu .$$

For example, the reaction

$$\nu n \to \mu^- p \pi^+ \pi^-$$

is to be compared with $\pi^+ n \to p \pi^+ \pi^-$ . The neutron target is advantageous here, since it permits reactions in which all final state particles are charged.

d) $\Delta^{++}$ Production and N- $\Delta$ Axial Transition Amplitudes:

The differential cross section for $\nu N \to \mu^- \Delta$ is a complicated function of the vector and axial vector helicity matrix elements[10]. At our neutrino energies ($\langle E_\mu \rangle \sim 20$ GeV for $\Delta$-production) many of the helicity matrix elements are suppressed and measurement of a few terms not separable at lower energies (e.g. at the ZGS) is possible. Here we will be able to contribute 1040 $\Delta^{++}$ events to samples obtained from $\nu$-$H_2$ exposures.

e) Associated Strange Particle Production

We will measure the cross sections for associated production with reactions of the type

$$\nu\ n \rightarrow \mu^-\ K^\circ\ \Sigma^+$$
$$\rightarrow \mu^-\ K^+\ (\Lambda^\circ_{\Sigma^\circ})$$

and

$$\nu\ p \rightarrow \mu^-\ K^+\ \Sigma^+ \quad .$$

3) Inelastic Events

Before discussing the physics in the inelastic reactions we describe procedures to identify $\mu^-$ tracks, and to estimate statistically the hadronic final state energy and hence the incident neutrino energy.

Muon Identification

For neutrino energies up to 9 GeV it is observed [11] that the $\mu^-$ takes on the average one half of the $\nu$ energy. This result is also predicted from Bjorken scaling of the three inelastic structure functions and the ratio $\sigma(\bar{\nu}N) / \sigma(\nu N) = \frac{1}{3}$ [12]. Then one expects that for at least 50% of the inelastics the $\mu^-$ can be selected as the most energetic particle in the final state. For two and three-prong events the $\mu^-$ is uniquely identified. For higher multiplicity events the final state $\pi^-$'s must share the energy not taken by the $\mu^-$. Hence selection of the fastest negative track as the $\mu^-$ should be valid for a majority of the events.

This procedure can be tested in the subsample of events in which $\pi^-$'s are identified by their interactions within the fiducial volume. The average $E_\nu$ for inelastic events in this exposure will be about 25 GeV (see Fig. 1). By extrapolating the CERN measurements for pion multiplicities[13)] we estimate the average charged pion multiplicity to be $\langle n_{\pi^\pm} \rangle \simeq$ 4-5 pions at our average $E_\nu$. It is in the lower multiplicity final states where the assignment of fast negatives as muons is probably more uncertain. Consider reactions containing two negative tracks, such as

$$\nu n \rightarrow \mu^- \; p \; \pi^+$$

The average π-N cross section will be ∼ 40 mb (not including the Δ(1236) region) which implies a 50% probability for the $\pi^-$ to interact inside the chamber. For increasing levels of ambiguity i.e.

$$\nu n \rightarrow \mu^- p \pi^+ \pi^- + n(\pi^+\pi^-) \; ; \; n \quad 1,2,3$$

one has probabilities of 25%, 12%, and 6% respectively for identifying all of the $\pi^-$'s. These events can be used to study the $\mu^-$ kinematics, to determine cuts for $\mu^-$ selection, and to measure the uncertainty in its identification.

## Determination of the Average Final-State Hadron Energy

The neutrino energy can be determined on a statistical basis by estimating the final state hadron energy from the visible energy. A rought estimate for the neutral pion energy is that $E_{\pi^0} \simeq \frac{1}{3} \; E_{hadron}$. If $\langle E_\mu \rangle \simeq \frac{1}{2} \; E_\nu$, then $E_{\pi^0} < \frac{1}{6} E_\nu$. The average $\pi^0$ multiplicity should be about 1/2 the charged pion multiplicity, i.e. about 1-2 $\pi^0$'s. Thus the 30% conversion probability for one or both γ's from a $\pi^0$ should provide an adequate measure of the corrections to $E_{hadron}$ due to $E_{\pi^0}$. Similarly, the invisible energy carried by neutrons can be estimated from secondary neutron interactions ( ∼50% interaction probability). Additional information about the fractional energy going into final state neutrals will be supplied by the neutrino exposures of the 15-foot chamber with neon and neon-hydrogen mixtures.

We expect to find $\sim$ 19,000 $\nu n$ reactions and $\sim$19,000 $\nu p$ reactions in this exposure. Using the above techniques for muon identification and $E_\nu$ estimation we will study the following topics in the inelastic events:

a) Comparison of $\sigma(\nu n)$ and $\sigma(\nu p)$ in One Exposure:

A diffractive model predicts

$$\sigma(\nu n) = \sigma(\nu p)$$

whereas a quark model predicts

$$\sigma(\nu n) = 2\sigma(\nu p) \quad 14)$$

It is advantageous to measure $\sigma(\nu n)$ and $\sigma(\nu p)$ simultaneously in one exposure with the same neutrino flux for both cross sections.

Neutrino-neutron and neutrino-proton interactions are identifiable as even and odd prong events respectively. We expect that about 1/3 of the $\nu n$ interactions will have a visible spectator proton yielding an odd prong count. The spectator momentum, however, is nearly always less than 200 MeV/c, resulting in a characteristic short, stopping track. Data from the $\nu$-$H_2$ exposures will enable one to estimate the overlap of low momentum interaction protons with the Hulthen spectator momentum distribution.

b) Structure Functions

The inelastic cross section

$$\frac{d^2\sigma}{dq^2 d\nu} = f(W_i\ (q^2,\nu)) \quad i = 1,2,3$$

will be measured for proton and neutron targets simultaneously. The measurement of $E_\mu$, $\theta_\mu$ and $E_\nu$ is required and can be done on a statistical basis. It will be interesting to compare the structure functions $W_i$ for n and p reactions with each other. For example, sum rules for $(W_2^{\nu n} - W_2^{\nu p})$ [15] and for $(W_3^{\nu n} + W_3^{\nu p})$ in the scaling region can be tested.

c) Inclusive final state hadron distributions:

As indicated by Feynman [16], inclusive distributions of final state hadrons can be used to look for parton structure of the nucleons. We will examine distributions in transverse momentum $p_\perp$ and rapidity

$$y = \frac{1}{2} \ln\left(\frac{Ec + P_{\parallel}}{Ec - P_{\parallel}}\right)$$

in reactions of the type

$$\nu + N \rightarrow \mu^- + c + \text{anything}$$

d) Linear Rise of the Total Cross Section

Counter experiments will have investigated $\sigma_{tot}$ as a function of $E_\nu$. The bubble chamber study may reveal which final states (topologies at least) are responsible for a turn over of $\sigma_{tot}$ if one is found.

4) Neutral Currents:

Deep inelastic inclusive processes may be the best place to look for neutral weak hadronic currents and test the Weinberg theory.[17] Using Bjorken scaling Pais and Treiman [18] have calculated bounds for the ratio

$$R_{incl} = \frac{\sigma(\nu + N \rightarrow \nu + \text{anything})}{\sigma(\nu + N \rightarrow \mu^- + \text{anything})}$$

Data from inclusive electro-magnetic and weak cross sections imply the following limits:

$$.5 > R_{incl} > .2$$

Using events in which all negative particles interact in the chamber, we will be able to give an answer to the level of the theoretical lower bound.

5) New Particles:

It will be very interesting to scrutinize the photographs and measurements for existence of completely new phenomena such as heavy leptons or W-bosons. If any new phenomenon is revealed by earlier experiments using massive — target detectors, our proposed high energy exposure of the 15 — foot chamber filled with deuterium should be able to clarify the situation.

## MANPOWER AND EQUIPMENT

The SUNY-Tufts Collaboration is prepared to commit the full resources of two active bubble chamber groups to this experiment. These resources are:

Physicists:

SUNY: 5 Ph.D Physicists

Tufts: 4 Ph.D. Physicists

Graduate Students: one from each group.

Present Operations:

| Scanner-Measurer | Measuring Machines FPD's | Measuring Machines IPD's | Scan Machines |
|---|---|---|---|
| SUNY 9-10 | 3 | 4 | |
| Tufts 6-8 | 2 | 2 | 5 |

Two of the experimenters, R.E. and W.A.M. have gained 2 years experience in the ν-hydrogen and deuterium experiments with the Argonne 12-foot bubble chamber.

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## Figure Captions

Fig. 1 Expected neutrino flux and event rates for inelastic events (linearly rising cross section) and the sum of elastic events plus $\Delta^{++}$ production (constant cross section).

Fig. 2 $\frac{d\sigma}{dq^2}$ for elastic events in the Argonne 12-foot chamber filled with deuterium (Ref. 4).

Fig. 3 Cross section for $\nu p \rightarrow u^- \Delta^{++}$ measured at the ZGS and CERN (Ref. 17).

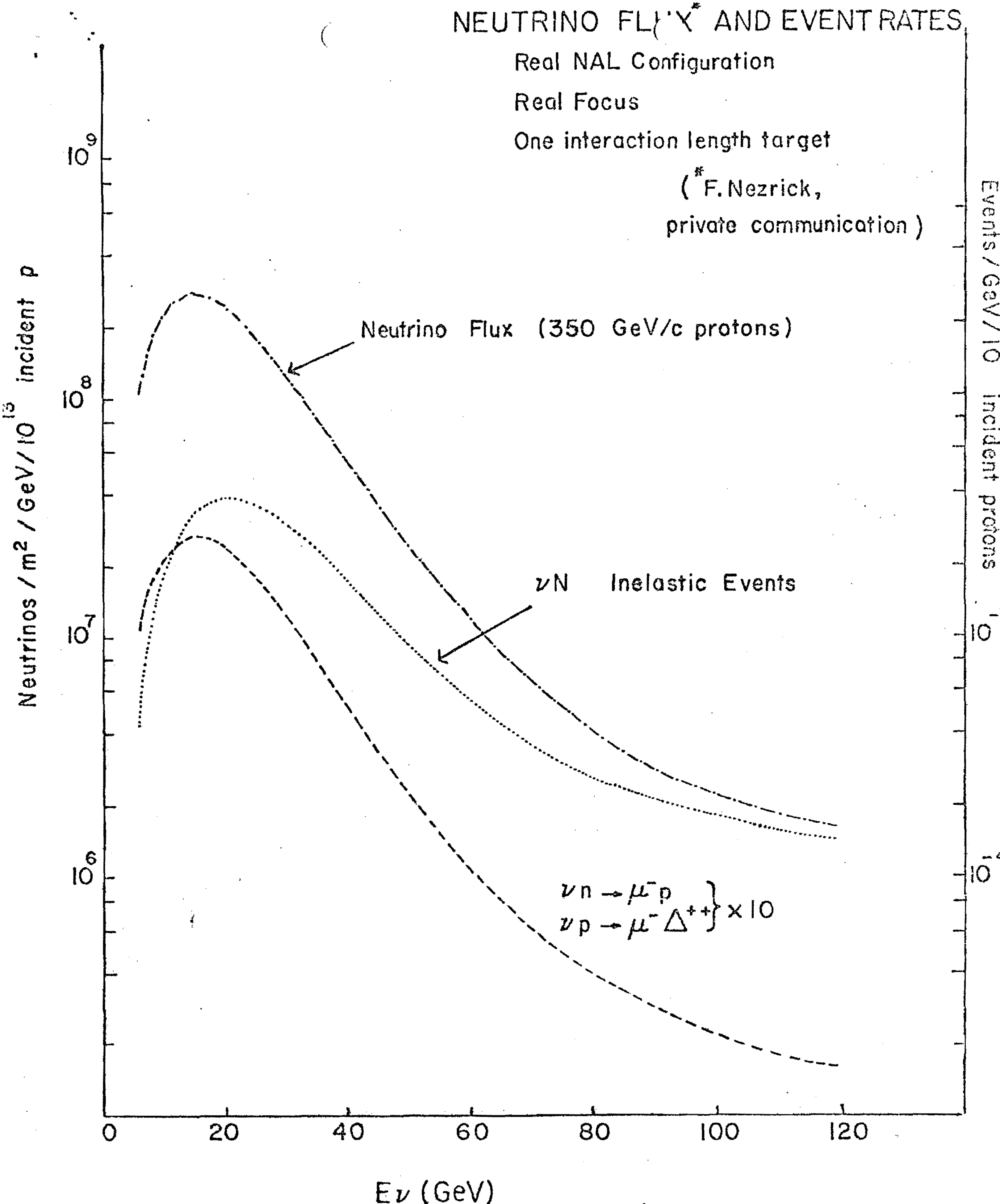
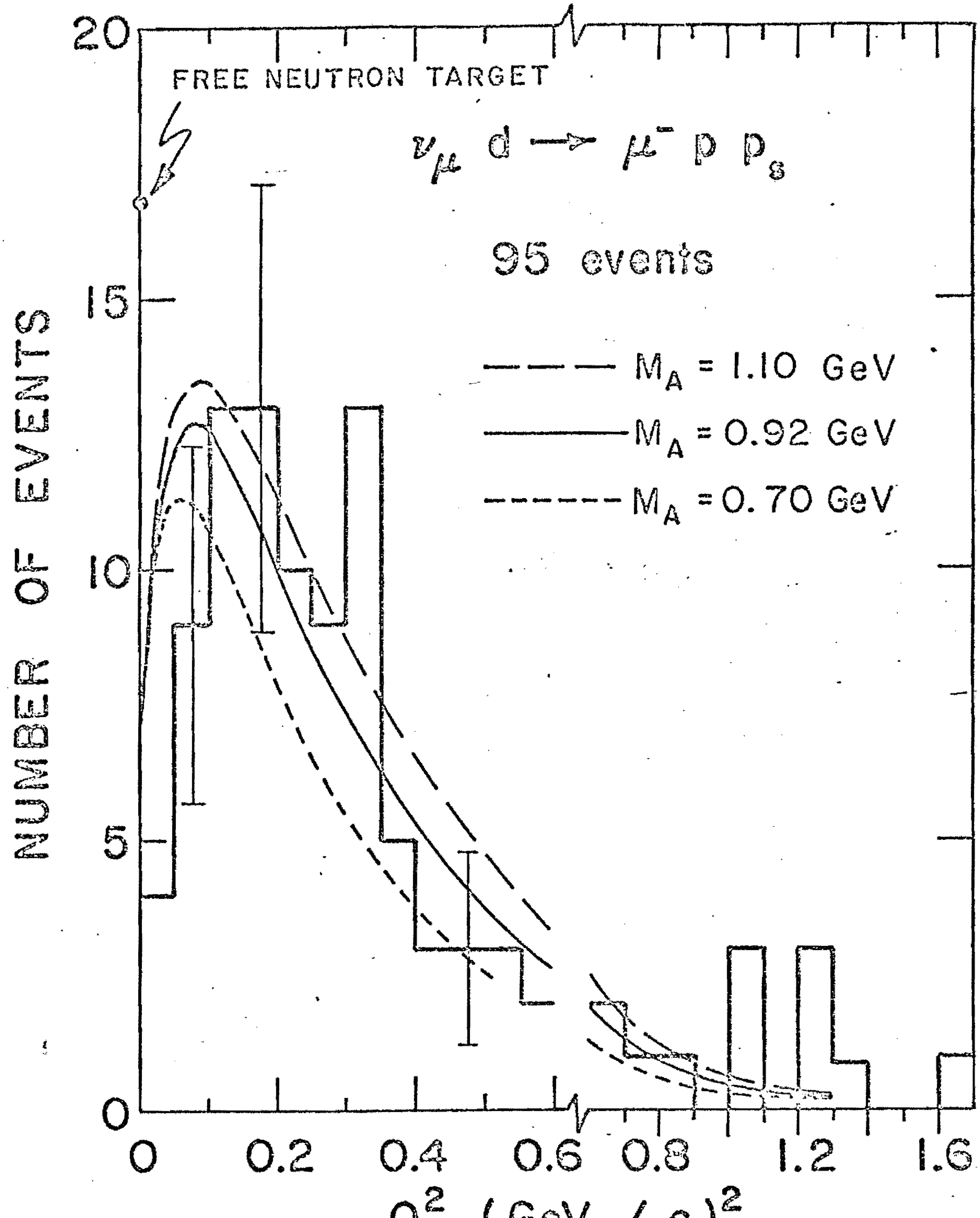

NEUTRINO FLUX* AND EVENT RATES
Real NAL Configuration
Real Focus
One interaction length target
(*F. Nezrick, private communication)
Neutrino Flux (350 GeV/c protons)
$\nu N$ Inelastic Events
$\nu n \to \mu^- p$
$\nu p \to \mu^- \Delta^{++}$
× 10
Neutrinos / m² / GeV / 10¹³ incident p
Events / GeV / 10¹³ incident protons
$E_\nu$ (GeV)
0
20
40
60
80
100
120
$10^9$
$10^8$
$10^7$
$10^6$

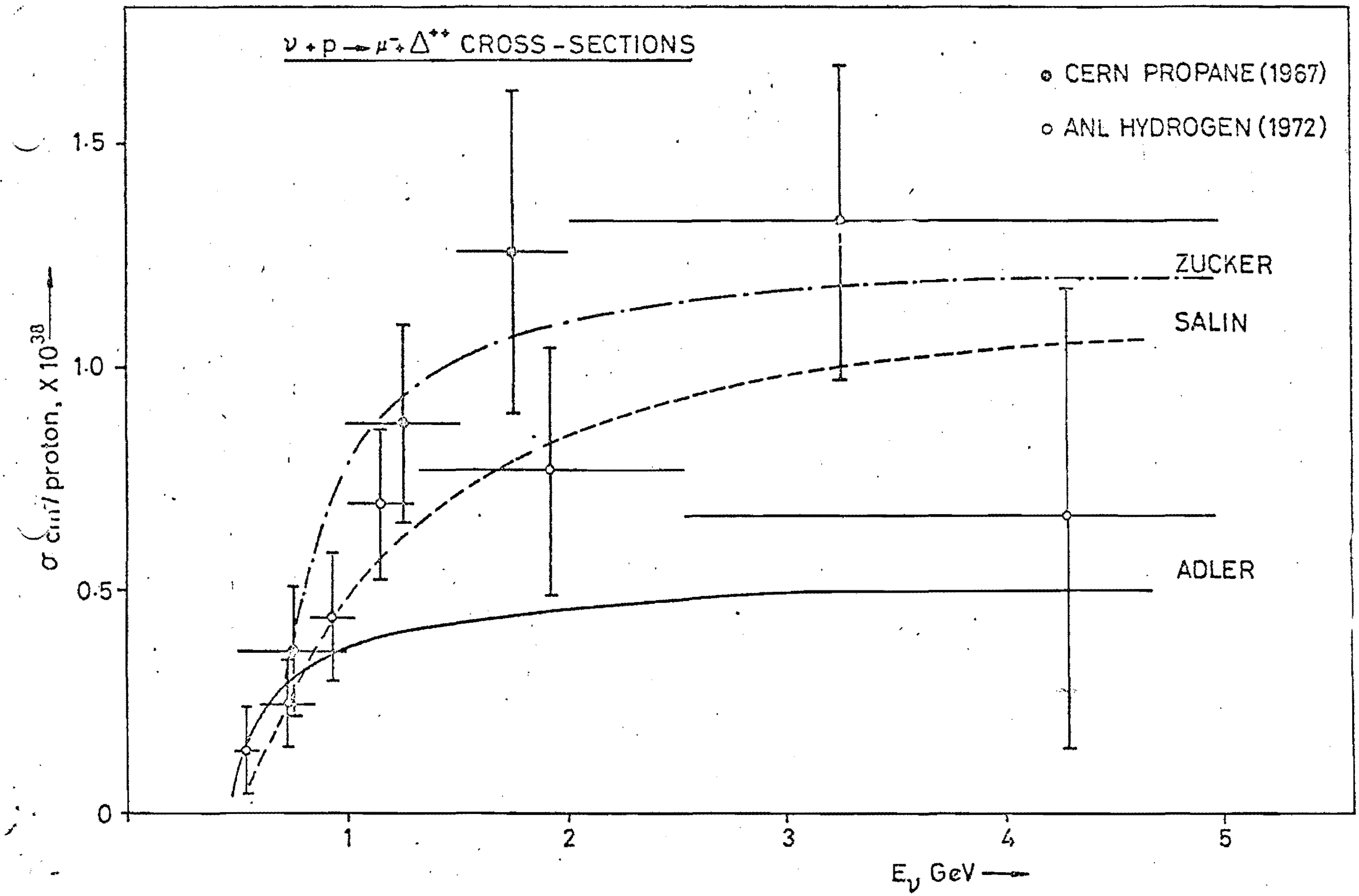
FIG. 1



FREE NEUTRON TARGET
$\nu_\mu$ d → $\mu^-$ p $p_s$
95 events
$M_A$ = 1.10 GeV
$M_A$ = 0.92 GeV
$M_A$ = 0.70 GeV
NUMBER OF EVENTS
$Q^2$ (GeV / c)$^2$
0
5
10
15
20
0
0.2
0.4
0.6
0.8
1.2
1.6


FIG. 2

FIG. 3


ν + p → μ⁻ + Δ⁺⁺ CROSS-SECTIONS
CERN PROPANE (1967)
ANL HYDROGEN (1972)
ZUCKER
SALIN
ADLER
σ cm²/proton, X 10³⁸
1.5
1.0
0.5
0
1
2
3
4
5
Eν GeV

Addendum to FNAL PROPOSAL NO. 227

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# PROPOSAL TO INVESTIGATE NEUTRINO INTERACTIONS IN DEUTRIUM USING THE FNAL 15-FOOT BUBBLE CHAMBER

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This Addendum

1) adds some relevant physics points to our original proposal
2) emphasizes our working experience with the 15-Foot BC (analysis of 300 Gev pp interactions )
3) emphasizes our experience with $\nu$ - physics in the ANL 12-Foot BC and with the handling of the deuterium "target engineering"
4) underlines the commitment of both labs to use all their manpower and equipment solely for the proposed experiment
5) spells out our position with respect to the External Muon Identifier (EMI)

## 1) Some additional physics points:

The eventrates calculated in our original proposal for the FNAL 2-Horn configuration reflect the current status at FNAL and are not expected to vary much in the near future. For example, the FNAL $\nu$ - Summer Study revealed that a new, shorter $\nu$ - beam run at lower energy would not result in a substantially higher $\nu$ - flux[1].

a) Neutral current (NC) reactions:

We will focus our attention on low multiplicity exclusive channels, e.g.

$$\begin{aligned} \nu n \rightarrow\ & \nu(p\pi^-) \\ & \nu(p\pi^-\pi^+\pi^-) \\ & \vdots \end{aligned}$$

with the $\pi^-$ interacting and the help of the EMI (see point 6) ).

The first reaction gives a clean signal and answers for example the question whether an I=3/2 hadronic state is excited by the NC. We expect to find about 100 events of this type.

In the analysis of higher multiplicity events we will exploit known features of charged current events in order to separate off a muonless sample[2] and use the EMI.The combination enables the separation of NC events even at higher multiplicities.[3]

b) Search for charmed particles:

A recently found candidate for a $\Delta S = -\Delta Q$ event at BNL[4]

$$\nu p \to \mu^- \Lambda \pi^+ \pi^+ \pi^+ \pi^-$$

motivates a search for strange excited states ($\Lambda n\pi$).At Stony Brook such a search was made in 200 Gev pp interactions with limited statistics of the strange particle and a negative result.

2) Working experience with the 15-Foot BC:

Both laboratories are currently working together in the analysis of 300 Gev pp interactions in the 15-Foot BC.Modified scanning and measuring equipment allows large magnification inspection of difficult events during scanning and measuring.We use the ANL software for geometrical reconstruction and achieve currently about 500 microns setting error in space,a value similar to the FNAL engineering experiment[5]. We point $V^0$'s and gammas reliably and separate $\Lambda^0$, $K^0$ and gammas kinematically. A systematic study of this separation and the scanning efficiency across the chamber exploiting the symmetry in the pp CM system is under way.Results will be presented at the Seattle Meeting in august 1975.

We are acquiring a good working knowledge of how to handle the 15-Foot BC.

3) Experience with $\nu$ - physics at lower energies:

W.A.Mann from Tufts and R.Engelmann from SUNY have worked together for two years in the ANL $\nu$ - program investigating reactions as

$$\nu n \to \mu^- p$$
$$\nu p \to \mu^- (p\pi^+)$$

in the 12-Foot BC with hydrogen and deuterium filling.They were further participating in the initial phase of the neutral current search.They are well familiar with the deuterium "target engineering" techniques in $\nu$ - physics such as the treatment of exclusion principle effects etc. Furthermore both labs analize currently 100 Gev (SUNY) and 300 Gev (Tufts) pd interactions in the 30-Inch BC and have learned how to handle the deuterium target with many particles in the final state.

4) Manpower and equipment:

The resources of both labs are slightly better than outlined in our original proposal. In particular modified and new equipment for large magnification ( about 60 ) is available.The resources are:

Physicists:

SUNY: 4 Ph. D. Physicists (plus one additional postdoc and one visitor )

Tufts: 4 Ph.D. Physicists

Each lab will have 2 graduate students on this experiment.

Scanner-Measurer:

SUNY: 9 fulltime

Tufts: 7 fulltime

Equipment:

| | Measuring/scanning | | Scanning |
|---|---|---|---|
| SUNY: | 3 FPD | 4 IPD | 3 |
| Tufts: | 3 | 2 | 5 |

Computing:

Stations are on - line controlled. Sufficient large computing facilities for off - line analysis are available in both labs.

5) Commitment of resources to the proposed experiment:

Both laboratories commit their full resources to the proposed experiment. Any other film analysis in conflict with this commitment will be handled by the respective collaborators of both laboratories. (In the case of SUNY a conflict with a possible 500 GeV/c pp analysis of 30-inch BC film would be eliminated by entering a collaboration at the appropriate time. Preliminary contacts have shown that this certainly would not be difficult to do.)

6) Use of the EMI:

We have made the agreement with the EMI group (L. Stevenson, LBL, and V. Peterson, Hawaii) that SUNY Stony Brook will have one PhD physicist work with the EMI group on the on-line data taking and off-line analysis as well. This will ensure that with the technical assistance of the EMI group we will learn how to run the EMI and analyze its data. (For example, in our hadron-deuterium runs in the 30-inch BC we use the downstream PWC system generously made available by the MIT consortium.)

A collaboration - on a limited scale on the part of the EMI group - is left open at the moment.

Summarizing, we want to emphasize that we feel confident that our experience with the 15-foot BC analysis and with neutrino physics in deuterium, as well as our strong scanning capacity enable us to execute the proposed experiment well and speedy.

References and Footnotes

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(3) We base our estimates on: F. Harris, Report on the EMI at the ANL Symposium on Neutral Currents, March 1975.

(4) Reported at the Paris Meeting on Lepton INteractions, March 1975.

(5) W. Smart, Private Communication.