MASTER

THE γ -CONVERTING PLATE SYSTEM FOR
NEUTRINO-DEUTERIUM EXPOSURES IN THE FNAL
15-FOOT BUBBLE CHAMBER

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During May 18-20 of this year the hydrogen-filled 15-foot bubble chamber at Fermilab was operated with an array of four half-inch thick stainless steel plates mounted in downstream portions of the fiducial volume. Notes from the test run, and results from a Monte Carlo study of efficiencies of the plate array for detection of photons and positrons in final states produced in a wide-band neutrino-deutrium exposure, are presented.

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Large exposures of the 15-foot bubble chamber at Fermilab, filled with liquid deuterium and exposed to wide-band ν_μ and $\bar{\nu}_\mu$ beams, are scheduled to get underway this fall. Neutrino reactions in which both neutron and proton targets receive the same incident neutrino flux will be obtained, with final states relatively free of nuclear rescattering. However, the effective photon conversion efficiency with deuterium or hydrogen fills in the 15-foot bubble chamber is about 10%⁽¹⁾, which seriously diminishes interesting measurements in three areas:

- 1) In inclusive neutrino reactions typically 30% of the final state energy will go into neutral hadrons. Since balance of transverse momenta and the alignment of longitudinal momenta between final state lepton and hadron systems are used to distinguish neutral current from charged current event samples, uncertainties from vector momenta of neutral hadrons directly effects this separation.
- 2) Constraining final states will incur feed-in from reactions having identical charge multiplicity but one or two additional π^0 's. In particular, 3-constraint neutron target candidates $\nu_\mu n + \mu^- p(\pi^+ \pi^-)$ will contain contamination from $\nu_\mu n + \mu^- p(\pi^+ \pi^-) + \pi^0$'s.
- 3) Most dilepton reactions $\nu_\mu / \bar{\nu}_\mu + N \rightarrow \mu^\pm + e^\pm + X$ will not be identified.

The 3m³ neutrino Track Sensitive Target developed at CERN for BEBC represents an incisive cure for the otherwise meager radiation length

($\sim 0.2 X_0$) available in a light-liquid exposure. A different technique, which is more modest in its detection capabilities but allows up to 15.5 m^3 fiducial volume for primary interactions, is being explored at Fermilab and is shown in Figure 1. The photograph is a test strip obtained during May 18-20 of this year when the hydrogen-filled 15-foot chamber was pulsed while containing an assembly of four stainless steel plates. As indicated in Figure 2 the plate array occupies the downstream one-third portion of the bubble chamber's fiducial volume. Each plate is 13 mm thick or 0.75 radiation lengths; the horizontal diameters are 292 cm, 272 cm, 244 cm and 198 cm. The plates are tilted from the vertical direction so that camera views two and three, whose stereo axis is parallel to the horizontal axis of the plates, view the array edge-on. The primary interaction fiducial volume can be viewed by one of the upstream cameras such as view 4 (Figure 3).

The May test run revealed a problem with the initial design of the plate array. Tracks and chamber fiducials observed from cameras two and three appeared to be out of focus, while images from upstream camera views were sharp. It is believed that the height of the initial array, extending from 28 cm above the piston cover to 68 cm below the focal plane of cameras 2 and 3, allowed it to funnel heat and turbulence at these cameras. At present, cuts of about 35 cm from the top of each plate and of 0 to 25 cm from the lower edges are being considered so that the plates can be tested again when scheduling permits.

To gauge the utility of the downstream plate array it is necessary to have reliable estimates of its γ and e^+ detection capabilities. We report here a study of the "trimmed" downstream plate array as currently envisaged at Fermilab using the Monte Carlo technique. To simulate all major effects anticipated in a wide-band neutrino-deuteron exposure the following methods have been used:

Photons from $\nu_\mu + D_2$ Reactions, Exclusive Channels:

To simulate neutrino-induced photon production we used four vectors from real charged-current events. For exclusive $\nu_\mu d$ final states containing π^0 's, in particular for $\nu_\mu d \rightarrow \mu^- p(p_s) \pi^0$, we used fitted $\nu_\mu + H_2$ candidates for reactions having identical kinematics. The $\nu_\mu + H_2$ "basis" samples include 108 $\nu_\mu p \rightarrow \mu^- p \pi^+$ events and 72 candidates to reactions $\nu_\mu p \rightarrow \mu^- p + n \cdot \pi$'s, $n = 2$ through 6⁽²⁾. Interaction vertices for events are distributed uniformly throughout a fiducial volume which terminates 30 cm in front of the upstream plate. Orientation of events about the ν_μ -beam direction is averaged. Interactions are taken to occur in the rest frames of nucleons in Hulthen potentials; final state pions are transformed to the LAB and are treated as π^0 's which decay into γ 's, whose trajectory through liquid and/or plates is calculated.

Photons, e^+ 's from $\nu_\mu + D_2$ Reactions, Inclusive Channels:

Simulation of photons produced in inclusive charged-current processes has used 424 γ 's observed in 130 neutrino events in heavy Neon-hydrogen having 40-cm radiation length⁽³⁾. Simulation of dilepton production $\nu_\mu + N \rightarrow \mu^- e^+ + X$ is based upon published distributions.⁽⁴⁾

Showering in Plates; Photon Conversion in Deuterium:

Probabilities for observing γ and e^+ - induced showers in 13 mm steel plates have been estimated from shower tables computed for copper⁽⁵⁾; probabilities for photon conversions in liquid deuterium are determined from tabulations for hydrogen by Knasel⁽⁶⁾.

Results

Photon momentum distributions from our $\mu^- p \pi^0$, $\pi^0 \rightarrow \gamma\gamma$ simulation and from the inclusive $\mu^- V^* X + \gamma$'s data are given in Fig. 5a. It is evident that photons produced in high energy neutrino collisions are usually low energy, typically hundreds of MeV.

The cross section for gamma conversion in hydrogen or deuterium is rising throughout these energies, reaching a constant value at about 1.0 GeV; the probability of occurrence of a detectable plate shower reaches a constant $\sim 42\%$ for $p(\gamma) \gtrsim 500$ MeV/c. In either case, however, the asymptotic energy formula $\epsilon_\gamma = 1 - e^{-x/x_p}$, $x_p = 9/7 \cdot X^{(7)}$, yields an overestimate of γ detection in a bubble chamber plus plate system.

Figures 5a and 5b show that γ 's from our exclusive channel $\mu^- p \pi^0$ generally have lower LAB momenta and wider production angles than are found in inclusive γ spectra. This suggests that γ 's from exclusive reactions may be more likely to escape the bubble chamber without striking downstream plates than are inclusive γ 's. For photons from $\mu^- p \pi^0$ versus inclusive processes, the effect is clearly seen by comparison of potential plate hits along γ trajectories shown in Fig. 5c. For inclusive photons $\sim 37\%$ have paths which traverse all four plates, whereas $\sim 58\%$ of $\mu^- p \pi^0$ photons never encounter a plate. Our simulations predict that the efficiency for photon detection in the plates plus liquid deuterium fill is 72% for γ 's from inclusive processes, but is 36% for γ 's from $\mu^- p \pi^0$. Photon detection efficiencies as a function of incident neutrino energy and as a function of final state photon multiplicity are shown in Fig. 6. A mild trend toward improved detection with increases in either variable is suggested.

The 72% detection efficiency obtainable with plates would enable

reduction of undetected hadronic energy in inclusive neutrino processes to the 10% level. To evaluate the system's utility for separating fittable exclusive channels, one must consider the capability for vetoing contaminants, which is summarized in Figure 7. The plates are predicted to be $\sim 85\%$ effective in "shielding" 3-constraint channels such as $\nu_\mu n \rightarrow \mu^- p(\pi^+\pi^-)$ from 2 or 3 π^0 final states; however, contamination from final states having one extra π^0 such as $\nu_\mu n \rightarrow \mu^- p(\pi^+\pi^-) + \pi^0$ will remain troublesome.

The detection capability of the plate array for positrons from dilepton reactions $\nu_\mu N \rightarrow \mu^- e^+ + X$ in the fiducial volume mentioned above has been studied. The average detection probability for e^+ with plates in deuterium is $\sim 43\%$. For 100K photographs, about 100 $\nu_\mu N \rightarrow \mu^- e^+ + X$ events are expected in the restricted fiducial volume, so that a 300K picture experiment would obtain a detected sample of ~ 100 events.

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FIGURE CAPTIONS

- Fig. 1: Assembly of four steel plates tested in the FNAL 15-foot bubble chamber during May 18-20, 1978.
- Fig. 2: Location of plates in the bubble chamber.
- Fig. 3: Upstream interaction fiducial volume.
- Fig. 4: Momentum-dependent photon detection efficiencies in 13 mm steel and in liquid deuterium.
- Fig. 5: Production and detection characteristics for photons from simulated $\mu^-p\pi^0$ and inclusive neutrino reactions. (a) and (b): Momentum and production angle distributions for produced and detected photons; (c) number of plates along line-of-flight of produced γ 's.
- Fig. 6: Photon detection probability (a) versus visible final state energy, and (b) versus produced photon multiplicity.
- Fig. 7: Probability of detecting ≥ 1 γ from decay of 1, 2, or 3 π^0 's, as a function of total pion multiplicity.

FIGURE 1. _____

FIGURE 2.

BEAM WINDOW ASSY.

12" MODULE EMULSION STACK BOX. (1-UPPER, 1-LOWER).

EQUATOR (BL. 745-3").

3"

NEUTRON, MACRON BEAM LINE.

90" DIA. X 0.157" THK. LEXAN DISC.

16" O.D. X 1.127" WIDE X 0.125" THK. BERYLLIUM COPPER SPRING. (TYP. 8-PLACES).

CHAMBER VESSEL.

CAMERA 1

CAMERA 3

CAMERA 2

CAMERA 4

1/2" DIA. PLATE SPACER/SUPPORT ROD. (2-REQ'D. PER ASSY.)

3" DIA. X 1/2" WALL PLATE SPACER/SUPPORT TUBE. (1-REQ'D. PER ASSY.)

CHAMBER PLATE WELDMENT ASSY. (2-REQ'D.)

3" DIA. X 1/2" WALL PLATE SPACER/SUPPORT TUBE. (2-REQ'D. PER ASSY.)

4" X 4" CHAMBER PLATE SUPPORT BEAM.

4" DIA. BEAM SUPPORT COLUMN (1-FRONT, 1-REAR).

CHAMBER PLATE TO SUPPORT BEAM CLAMP-DOWN PLATES. (PLATES 1 & 3 ONLY). 1" THK.

SPRING SUPPORT PAD (TYP. 6-PLACES).

FIBERGLASS EXPANSION PISTON.

2 SECTION.

PLATE NO.	ANGLE
1	-11°-30'
2	-3°-45'
3	4°-15'
4	12°-0'

APPROX. WEIGHTS:
 PLATE #1 - 1,375 LBS
 " #2 - 1,200 LBS
 " #3 - 1,000 LBS
 " #4 - 700 LBS
 TOTAL - 4,275 LBS

NOTES:

- 1) ALL PLATES $\frac{1}{8}$ THICK STN. STL.
- 2) ALL PLATES TO BE CUT IN HALF THRU VERTICAL C.

FIGURE 3.

5c: NO. PLATES ALONG LINE-OF-FLIGHT

FIGURE 6

FIGURE 7