NEUTRINO-ENERGY ESTIMATES IN A Ne BUBBLE CHAMBER

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ABSTRACT

Using the NAL bubble chamber filled with Ne on restricting events to a small fiducial volume upstream in the bubble chamber, it should be possible to measure the average energy of the incident neutrino to ~ 6% and to identify muons in the final state on a statistical basis. Because of the large mass available and the possibility of making E_ν estimates entirely within the bubble chamber, the Ne bubble chamber should provide a powerful tool in the early exploration of ν_μ interactions at NAL.

A possible configuration for doing neutrino experiments in the NAL large bubble chamber is to fill the chamber with pure neon and to use a small fiducial volume region in the upstream end of the bubble chamber as the target. This possibility is discussed in Proposal 28. Since the bubble chamber contains ~ 30 tons of Ne, it is easy to choose an ~ 5-ton fiducial volume. The remainder of the bubble chamber is used to measure the charged-particle energies by curvature, the π° energy by converting the photons, measuring directly by curvature the e^+e^- energy and for μ identification. A fiducial volume of 1m × 2m × 2m can be used which contains 4.8-metric tons of Ne or approximately 1/6 of the entire Ne in the bubble chamber. This is about 5 times more material than for the entire hydrogen chamber. The remainder of the chamber then provides $\gtrsim$ 8 radiation lengths in the forward direction (X_0 = 24 cm for Ne) and out to 30° and ~ 3 collision lengths (ℓc ~ 60 cm for Ne). The 3 collision lengths provide ~95% probability that a hadron will scatter (including diffraction scattering which should be detectable). Thus, a reasonably good statistical separation of fast π's and fast μ's should be possible.

Since most of the photon energy should be converted within 4 radiation lengths after the target, it should be possible to accept more than one event per picture and perhaps as many as three. In the latter case the experiment would then yield an event in the target fiducial volume every other bubble-chamber picture. Since the rates in the Ne bubble chamber are ~ 30 times greater than hydrogen with the configuration discussed here, a neutrino-beam intensity of ~ 15 times less than that required for the bubble chamber would be adequate. Thus these experiments are almost parasitic at NAL.

To estimate the incident-neutrino energy, the energy of the charged hadrons and π°'s must be obtained. We assume that the dominant uncertainty for the charged particle tracks comes from multiple-coulomb scattering. We also assume that 50 cm will be available for this measurement since the collision length is ~ 60 cm. The $\Delta p/p$ for each track will be, assuming a 30-kG field,

$$\frac{\Delta p}{p} \sim \frac{57}{\beta H} \frac{1}{\sqrt{\ell X_0}} \sim 5.2\%, \; (\ell = 50 \text{ cm}, \; X_0 = 24 \text{ cm})$$

for the high-energy mesons coming from the collision. If ℓ = 150 cm is used, $\Delta p/p$ ~ 3%. The nuclear evaporation energy should be small and can be estimated by measuring the range of the proton recoils in the bubble chamber.

The estimate of π° energies is somewhat more speculative, but based on previous measurements in heavy-liquid chambers it appears that ~ 15% energy resolution is quite reasonable, and ~ 10% may be possible by measuring all the shower products. Note that a negligible fraction of the π° energy escapes the bubble chamber in the forward direction since there are 8 radiation lengths.

If we assume that on average there is 70% of the energy in charged particles and 30% in neutrals, then the average energy resolution would be

$$\frac{\Delta E}{E} \sim \sqrt{[0.7(0.05)]^2 + [0.3(0.15)]^2} \sim 6\%.$$

Thus, the worst energy measurement would be ~ 15% if all the hadrons were neutral and the best ~ 5.0%. It is unlikely that the average energy measurement would be worse than ~ 10% and better than 5%.

It appears that the Ne bubble chamber with a small fiducial-volume target of pure Ne can run on an almost-parasitic neutrino beam (or an unfocused ν beam) and that the incident ν energy can be estimated to (5-10)%.