Proposal ____: Broad Band νd and ν Nuclei in the 15' BC with ITC
Spokesman: Harry H. Bingham
Department of Physics
University of California
Berkeley, CA. 94720
(415)642-1920

PROPOSAL

TO STUDY ANTINEUTRINO INTERACTIONS IN DEUTERIUM AND NUCLEI WITH AN INTERNAL TARGET AND CONVERTER SYSTEM IN THE FERMILAB 15' BUBBLE CHAMBER

H. H. BINGHAM AND W. B. FRETTER
PHYSICS DEPARTMENT, UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720

SUMMARY

We propose a 300,000 photo exposure of the 15' deuterium bubble chamber, with EMI and with the internal target and converter (ITC) system proposed for P489 (νH_2 + plates) and P521 (νD_2 + plates), using a (2-horn or improved) broad band antineutrino beam. Some 13,000 $\bar{\nu}$-deuterium and a comparable number of $\bar{\nu}$-nucleus events will be obtained with π^0 and e^+ detection provided by the plates. New information should be obtained on: dilepton events; possible high y anomalies; on comparison of various reactions from neutron and proton targets (thus separation of valence quark from sea quark processes); on strange particle production; on the target A dependence of various processes. New particles and processes will be reached for.

Introduction. Although an impressive array of important physics results is continuing to come out from ν and $\bar{\nu}$ exposures of the 15' BC filled with H_2 and with various Neon-H_2 mixtures, and further interesting physics is expected from the coming ν-and $\bar{\nu}$-d exposures, there is certain to remain an important domain inaccessible to bare hydrogen and deuterium exposures due to poor neutral particle and $e^{\pm}$ detection and inaccessible to neon exposures because of the complexity of the neon target, secondary interactions within it, and its being limited to a single Z.

Exposures of the 15' BC, filled with deuterium and provided with the internal target and converter (ITC) system will fill in this gap: the pure d_2 target permits far cleaner separation of $\bar{\nu}n$ and $\bar{\nu}p$ processes, far less contamination due to secondary interactions in the nucleus, and far higher precision on individual track momenta than does neon, while the ITC plates (e.g., 9 plates of 0.9 cm steel, 0.5 radiation length and 0.07 nuclear interaction length each, 30 cm apart - see P489 proposal; or, as we propose, 3 plates each, of varying thickness, of 3 materials, e.g., aluminum, stainless, tungsten) permit far greater electron and π^0 identification ($\gtrsim$ 80% vs < 1%) than does pure d_2. The combination, pure d_2 target and good π^0 detection, will permit kinematic fitting of complete charged current events including the π^0's and γ's (and complete reconstruction also even of neutral current events with only a $\bar{\nu}$ missing). It will thus provide detailed information unavailable from either bare d_2 or neon exposures.

The reactions on the plate nuclei will permit study of the A dependence of certain processes.

Event Rates. We expect some 9K $\bar{\nu}$ CC (charged current) events from deuterium (2/3 from protons, 1/3 from neutrons) and 3.6K $\bar{\nu}$ NC (neutral current) events, based

on E172's total number of in-fiducial-volume $\bar{\nu} \to \mu^+$CC events ($\sim$3.8K) and scaling by 0.14/0.75/density), 1.3 x 10^{13}/1.0 x 10^{13}ppp, 1.6 (2-horns vs horn 2 only), 300 Kpix/48 Kpix. Assuming the ratio of plate to deuterium mass (and rate) is 1.3 for an appropriate fiducial volume, we expect an additional 16K $\bar{\nu}$ events from the plates (split among the two or three different plate materials we propose). The current EMI would intercept $\sim$80% of all μ^+ and most of the μ^+ from events above $\sim$50 GeV ($\sim$15% of the events will have E $\gtrsim$ 50 GeV, if no plug is used). There will be in addition a "background" of $\sim$5K ν-d and 6.4K ν-plate events if we run (as we propose to) without the plug for the bulk of the exposure at least, in order not to suppress the high energy $\bar{\nu}$ interactions, and in order to study directly $\bar{\nu}/\nu$ ratios for various interesting processes (e.g., $(\mu^+e^-/\mu^+)/(\mu^-e^+/\mu^-)$).

PHYSICS INTEREST

1) Dilepton events. Because the relative rate $(\bar{\nu} \to \mu^+e^-/\nu^- \to \mu^+)/(\nu \to \mu^-e^+/\bar{\nu} \to \mu^-)$ is only $\approx 0.2\ ^{+0.3}_{-0.2}$ (E172 preliminary result) and because $\bar{\nu}$ fluxes and cross sections are so low, it is highly unlikely that more than a half dozen or so $\bar{\nu} \to \mu^+e^-$ events will have been added by E180 and E460 to E172's small sample over the next year or so. Thus even a few fully reconstructed events using the advantages of nearly free nucleon target kinematics, higher track measurement precision (especially on the e^-), π^0 reconstruction (via the plates) and better sidewise muon identification, will very likely add crucially important clues to the nature of these mysterious events. Assuming the E172 preliminary rate for $(\bar{\nu} \to \mu^+e^-)/(\nu \to \mu^+)$ of 0.1%, we expect only 9 μ^+e^- events but ours may be the key ones. Note that without good π^0 detection, it is impossible to tell whether

or not a $\bar{\nu}$ is missing, as expected (cf P521), and it is clearly impossible to do so with a neon target.

The relative rate of $\bar{\nu} \to \mu^+e^-$ and $\nu \to \mu^-e^+$ is, in the quark model, a measure of the presence of $s\bar{s}$ strange quark-antiquark pairs in the sea. In this picture $\bar{\nu} \to \mu^+e^-$ goes only via $\bar{\nu} + \bar{s} \to \mu^+ + \bar{c}$ ($\bar{c}$ = charmed antiquark) with amplitude proportional to $\cos\theta_{Cabibbo}$ while $\nu \to \mu^-e^+$ can go both via $\nu + s \to \mu^- + c$ (with $\cos\theta_c$ from the sea) and via $\nu + d \to \mu^- + c$ (with $\sin\theta_c$ from valence down quarks). Because $\cot^2\theta_c \approx 20$, the sea and valence contributions to $\nu \to \mu^-e^+$ could be of the same order, and the relative rate ratio $(\bar{\nu} \to \mu^+e^-/\bar{\nu} \to \mu^+)/(\nu \to \mu^-e^+/\nu \to \mu^-) = R$ need not be small. E172's preliminary result, $R \sim 0.2\,^{+.3}_{-.2}$ suggests that the sea contribution is less than the valence, but clearly more data is needed to measure this.

We would hope that the 2nd EMI plane coverage and perhaps timing information will have been much improved over E460 (and E180). We should also, therefore, have fully reconstructed dimuon events to add, unsmeared by secondary interactions in neon, close showers, etc.

2) <u>$\sigma(n)$, $\sigma(p)$.</u> <u>Valence and Sea Quark Contributions</u>

Assuming that the proton is composed primarily of 2 up and one down quark, (p = uud) and n = udd, with identical sea components in p and n; also that the basic CC interactions is $\bar{\nu} + u \to \mu^+ + d$ (i.e., the d valence quarks don't contribute to $\bar{\nu}$ interactions), then $\sigma(p) - \sigma(n)$ should have only a valence (u) quark contribution (and no sea contribution) while $2\sigma(n) - \sigma(p)$ should have only a sea (and no valence) contribution. It will surely be of great interest to separate valence and sea contributions to a wide variety of reactions and processes, beyond those accessible to bare DBC experiments, using the plates for π^0 detection (and

far beyond the possibility of separating $\sigma(n)$ and $\sigma(p)$ clearly in neon). Note $\bar{\nu}p(\text{sea } \bar{s}) \to \mu^+\bar{D}^o n$, $\to \mu^+ D^- p$, $\bar{\nu}n \to \mu^+ D^- n$, ($\bar{D}^o \to \bar{K}^o\pi^o$, $\bar{D}^- \to K^-\pi^o$) for example, $F^- \to \eta^o\pi^-(?)$, $\bar{F}^* \to \bar{F}\gamma(?)$, also $\bar{\nu}n \to \mu^+\omega^o X$, $\mu^+\rho^\pm X$, $\mu^+\eta^o X$, etc., as examples of reactions where the γ and π^o detection is crucial.

3) <u>High y Anomaly</u>. Although E172 (and future E180 and E460 runs) will verly likely shed considerable further light on the existence of a high y anomaly and on its nature, it is very likely that completely reconstructed events, including π^o's, unsmeared by secondary interactions in neon, and with the far better mass and missing mass resolution possible in deuterium than in neon, also the improved sidewise (high y) muon detection afforded by the plates, will be necessary to convincingly exhibit and explain the high y anomaly. Of course if the anomaly is due to a new quark ("beauty", $\bar{\nu} + u \to \mu^+ + b$, etc.), π^o detection and good kinematics is very likely to be necessary to help prove it.

4) <u>Strange particle production</u>. Aside from the interest of strange particles accompanying charmed particle production, the old fashioned strange particle production viewed as $\bar{\nu} + u \to \mu^+ + s$ remains of considerable interest. Here again, good kinematics and γ (cf $\Sigma^o \to \Lambda\gamma$) and π^o (cf $Y^* \to \Lambda\Pi^o$, $\Sigma\Pi^o$, etc.) detection appear essential. Without good Π^o detection and good production kinematics also, it would seem impossible to separate clearly single strange particle production from associated production at the hadron vertex. Any sign of $\Delta s = 2$ transitions (cf $\bar{\nu}p \to \mu^+ \Xi^o$, $\Xi^o \to \Lambda\Pi^o$) would, of course, be very exciting.

5) <u>Events in the plates</u> are not without interest. In spite of secondary interactions in the nucleus and on the way out of the plates, and in spite of γ showers in the plates, the total CC event rates can be determined as a function of target mass number A, of neutrino energy and of lepton to hadron momentum

transfer. That the deuterium and the various plate A's are exposed to precisely the same $\bar{\nu}$ (and ν) spectrum and flux in the same experiment (and analysis) is, of course, essential to an accurate estimate of $\sigma(A)/\sigma(d)$. If $\sigma(A)$ is not precisely proportional to A then a very important line of research opens up (Finite mass of W?, Interference effects as in photoproduction?, Coherent effects?, Effects of nucleus on sea quarks?, etc.)

By putting plates of different thickness (same A) as well as different A's, and by choosing events near the outgoing face of each plate, it should be possible to extrapolate out the effect of secondary interactions on the way out from the effects of secondary interactions in the target nucleus. It will be of considerable interest to compare neutrino and hadron interactions as to the charged (and neutral) multiplicity dependence on A. Any difference between the propagation thru nuclear matter of hadronic vs photo or electroproduced vs neutrino induced showers would, of course, be of great interest. For example, some Charmed and ψ particles and particles carrying new quantum numbers (beauty?) should have lifetimes long enough usually to decay outside the target nucleus and should have lower interaction cross sections than ordinary states.

A considerable fraction (probably over half) of the plate events will be clean enough to measure and analyse as we currently analyse neon events; thus they should contribute to the high y anomaly and other studies done on the deuterium events.

6) New Particle Searches. Aside from the charmed and beautiful particle searches alluded to above, we will keep an eye out, of course, for heavy leptons (those with the same lepton number as μ or e should decay to same via a γ converting in the plates, those with new lepton numbers should deay to μ or e with

a $\bar{\nu}_{\mu \text{ or } e}$ and a ν_{new} - i.e., 2 neutrinos - thus free nucleon kinematics will be important), intermediate bosons, monopoles, etc.

Analysis. We are currently involved with nearly 100% of our effort, in measuring and analysing events from the E172 $\bar{\nu}$-heavy mix experiment (in collaboration with LBL, Hawaii and U. of Washington groups). We have now considerable experience in the analysis of 15' BC events in a variety of liquids, and using the EMI, and we are currently striving to increase our measuring power. We hope to participate in further analysis of E460 events as well and in E388 (dichromatic-$\bar{\nu}$-neon) when it runs. The above experiments would enjoy comparable priority with this proposed experiment, but their measurements, we expect, should be finished well ahead this one's run. We have one approved (E89) and one proposed hadron Fermilab experiment and one approved ANL experiment which we would consider to be of lower priority than this one, if they should conflict. We hope to enjoy enough support that measuring power will not limit the physics output of these experiments.