EFFECTS OF SHIELD LENGTH AND PROTON ENERGY ON BUBBLE-CHAMBER NEUTRINO EXPERIMENTS

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ABSTRACT

The neutrino-BC subgroup have studied the questions of 200-GeV vs 500-GeV operation and the muon-shield length vs event rate. We recommend (1) the bubble chamber to be located at the 500-GeV area, (2) the shield length of ~600 m will enable the bubble chamber to carry out the neutrino experiments with reasonable event rates, and (3) in case the bubble chamber is situated at 1400-1900 configuration, it may be necessary to build a second beam of 100-GeV protons in order to gain high event rates.

The neutrino-BC subgroup have studied the questions of the 200-GeV vs 500-GeV operation, and the muon shield length vs events yield.

To provide input on these questions, we have calculated the event rate for various configurations. We also list some of the strength of bubble chamber as a research tool for studying ν interactions.

In Table I, we summarize the expected yield of neutrino events for various configurations of the muon shield and the decay length and the machine energy. The assumptions used in these calculations[1] were:

1. Hagedorn-Ranft spectrum
2. Focusing efficiency = 50% of perfect focusing
3. One ton of H_2 target
4. 2×10^{13} interacting protons on the target, and
5. Cross section for quasi-two-body reactions such as "elastic", N^* production, etc. = 1×10^{-38} cm^2, and the inelastic cross section = $0.6 \times E_\nu \times 10^{-38}$ cm^2. This is an optimistic assumption as the inelastic cross section could level out above 5-10 GeV ν energy.

For the anti-neutrino experiments, we should include a factor (1/2 to 1/4) in this calculation.

This table does not take into account the accelerator repetition rate. In Fig. 1 we show the event rate for various configurations and operating conditions along with that of existing accelerators. In addition to above-mentioned assumptions, we used rep. rate = 1 pulse/10 sec for 500 GeV, = 1 pulse/4 sec for 200 GeV, = 1 pulse/2 sec for 100 GeV. Number events/hour/GeV of neutrino energy for the constant cross section is shown in Fig. 1(a), and that of inelastic reaction is shown in Fig. 1(b). The neutrino flux distributions for various configurations and that of existing accelerator is shown in Fig. 2 for comparison.

We next summarize briefly some of the advantages and disadvantages of the bubble chamber. It should be noted that this visual technique is one of the most powerful in high-energy research, particularly in an exploratory field where the final state involves many particles. In the past, the bubble chamber has yielded numerous discoveries of unexpected phenomena.

In detail the advantages of HBC(DBC) are:

1. High resolution, isotropic bias-free allows study of final states without complicating nuclear effects.

2. Even without the muon identifiers, HBC(DBC) can do very large amounts of physics outlined in another section of this ν - BC report.[2]

Disadvantages of HBC(DBC) are:

1. Low efficiency of detecting neutral particles,

2. Target mass is smaller compared to NeBC or counter experiments.

Advantages of NeBC are:

1. Detecting π^o's,

2. Larger (compared to HBC) target mass, and

3. If one restrict to a smaller fiducial volume, Ne can be used as a muon identifier.

Disadvantages of NeBC are:

1. Nuclear effects, and

2. Poor resolution of charged particles compared to HBC.

The counter ν-experiments have similar advantages and disadvantages as NeBC.[3]

In order to eliminate some of the disadvantages of HBC ν-experiments, several modifications to the chamber setup are asked in various proposals,[4] namely, the track-sensitive target, hybrid system, and plate.

After considering all neutrino experiment proposals and together with above-mentioned merits, we concluded that there are two types of experiments proposed. One is "search and gross feature study type": For example, W search, $d^2\sigma/dq^2d\nu$ on heavy nuclei, and σ_T vs E_ν belong to this category. The other is "detail-study type", and the HBC does well for physics such as form factors studies, strange particle production, N^*, Y^* production, polarization measurements, deep inelastic scattering on a single nucleon, etc. The counter experiments and some portion of NeBC experiments belong to the first category and HBC experiments with or without auxiliary equipment belong to the second category.

In addition to these specific experiments, one must remember that the bubble chamber is a unique tool for finding the unexpected physics.

Why 500 GeV for BC?

We now turn to the question of 200 GeV vs 500 GeV and consideration of the shield length. Because of large target mass, the counter experiments are particularly suitable to do the "search-type" experiments, and most of counter experiments are designed to look for W bosons with emphasis on muonic decay mode. The NeBC with 25 tons of target can detect both leptonic and hadronic decays of W.

Thus, for the W-search type experiments, we would like to have the neutrino energy as high as possible. Let us assume a counter experiment found W boson during the first months of operation, then BC may be able to measure the branching ratio, production mechanism, etc. shortly thereafter.

Another example may be the deep inelastic scattering. The counter experiments can study $d^2\sigma/dq^2d\nu$ and $\sigma_T(E_\nu)$, and NeBC can do an additional study of hadrons coming out of nuclei, and HBC can do the detail study of scattering on a single nuclcon without folding in the A dependence of reaction.

These are a few examples of the reason why the BC should be located at 500-GeV area.

Consequence of Shield Length

Having concluded that there are advantages for the BC to be located at the 500-GeV area, we consider the effects of shield length.

For the "search-type" experiments with NeBC, the events rates are high even at 1400 m decay length-1400 m shield length; thus the NeBC can run in a parasitic mode or multipulsing mode at any configuration of shield length.

Table I and Fig. 1(a) and (b) show that a larger shield length affects the ν reaction below 30 GeV, and the yields of constant cross section reaction decrease by a large factor. If we take a configuration with the shield length less than 600 m, then the bubble chamber can be run at almost any proton energy above 200 GeV with reasonable event rate.

If we take 1400 m shield-1400 m decay length, we have compounded the difficulties since we have both low-event yield/interacting proton and low-repetition rate. In order to gain high-yield/proton, one wishes to run at the highest energy possible, and then the picture-taking time increases accordingly. One solution to this difficulty may be to build a second neutrino beam with optimized settings for 100-GeV operation. Figure 1 indicates that this setting will have ~ 100 times higher-events rate for neutrino energy less than 20 GeV than the 1400-1400 setting.

Conclusion and Recommendation

1. We would like to see the bubble chamber located at 500-GeV area.

2. Shield length of ~ 600 m will enable the bubble chamber to be operated at any proton energy above 200 GeV and to carry out the neutrino experiments with reasonable event rates.

3. If the bubble chamber is situated at 1400 m decay length, 1400 m soil shield, it will be necessary to build a second beam of 100-GeV proton in order to gain high-event rates.

REFERENCES

[1] F. A. Nezrick (National Accelerator Laboratory), personal communication, 1970.

[2] R. Burnstein et al., Neutrino Bubble-Chamber Physics Group Report, National Accelerator Laboratory 1970 Summer Study Report SS-198, p. 253.

[3] R. A. Burnstein, Information Concerning Neutrino Configurations and Flux: Consequences for Neutrino-Physics Experiments, National Accelerator Laboratory 1970 Summer Study Report SS-180, p. 347.

[4] R. Cence et al., Proposal for a High-Energy Neutrino Experiment in the NAL 30 m^3 H_2, D_2 Bubble Chamber, National Accelerator Laboratory Proposal 9, 1970; V. E. Barnes et al., Neutrino Interactions in the Deuterium-Neon 14-Foot Double Bubble Chamber, National Accelerator Laboratory Proposal 42, 1970; R. Roe et al., Proposal to Study Neutrino Interactions with Protons Using the 14-Foot Bubble Chamber at NAL, National Accelerator Laboratory Proposal 45, 1970; C. Baltay et al., Search for the Intermediate Boson, Lepton Pair Production, and a Study of Deeply Inelastic Reactions Utilizing High Energy Neutrino Interactions in Liquid Neon, National Accelerator Laboratory Proposal 53, 1970.

Table I. Event Yield for Various Configurations.

Assumptions:

1. 2×10^{13} interacting protons
2. Hagedorn-Ranft Spectrum
3. Focusing efficiency = 1/2 of perfect focusing
4. One ton of H_2 target

Ep	Shield-Decay L		EV/pix(σ=1.0 $\times 10^{-38}$ cm^2)	EV/pix(σ=0.6 $\times 10^{-38} \times E_\nu$ cm^2)
500 GeV	300 mS	600 mD	0.16	1.5
	600	600	0.08	0.85
	1400	1400	0.028	0.45
200 GeV	300 m	600	0.08	0.61
	600	600	0.036	0.32
100 GeV	70 m	350 m	0.12	0.60

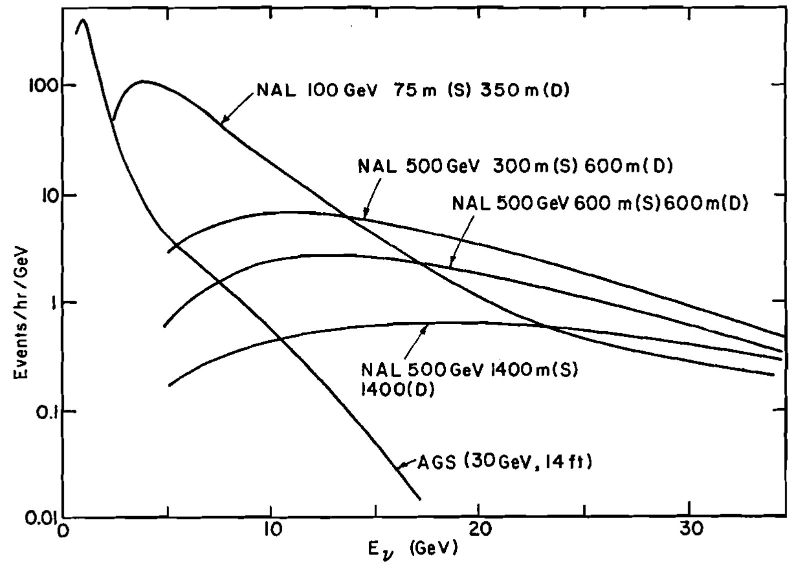

Fig. 1(a). Event rates for constant cross section ν interactions.

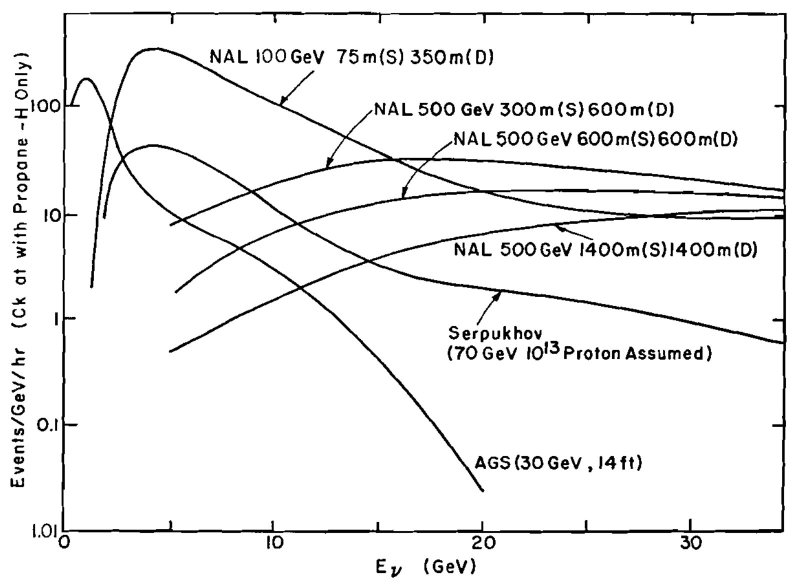

Fig. 1(b). Event rates for cross section = $0.6 \times E_\nu$.

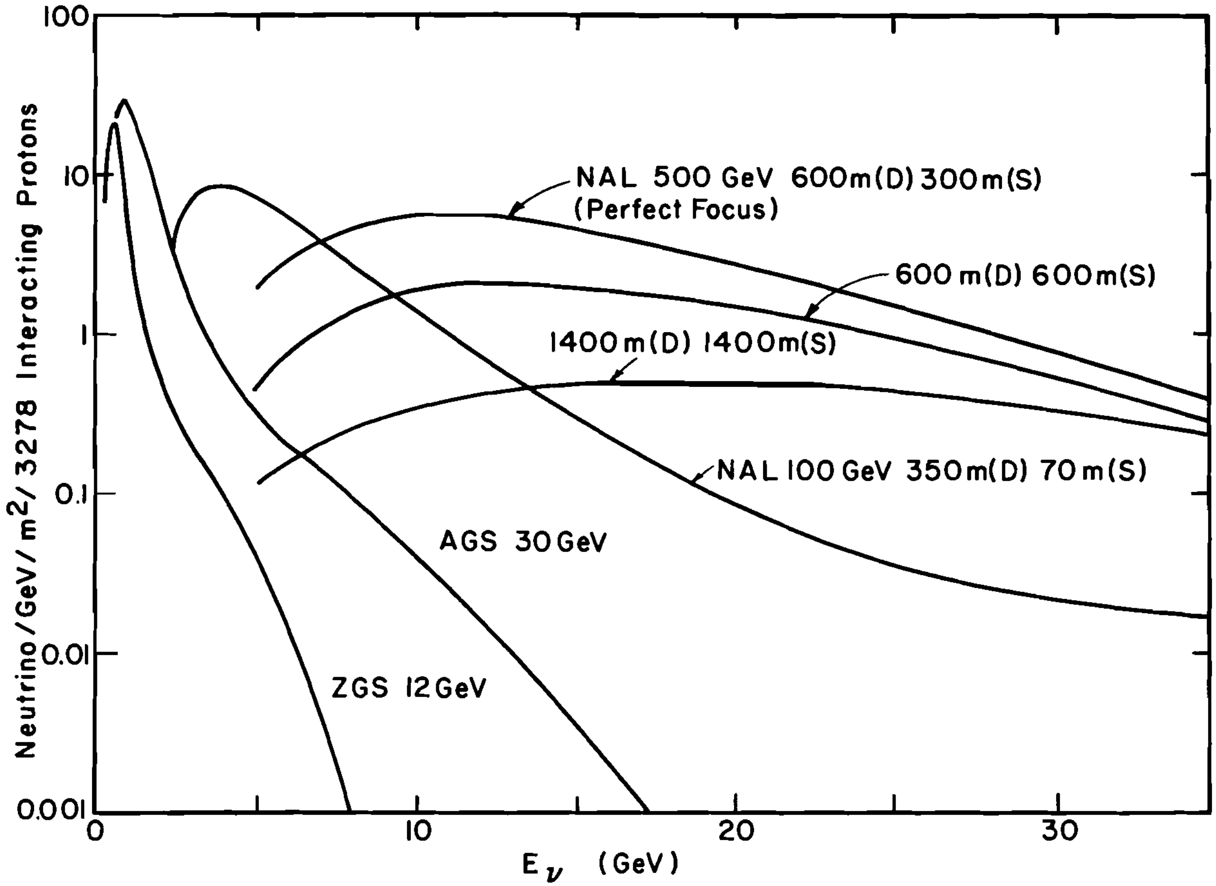

Fig. 2. Neutrino flux for various shield-decay length configurations and machine energy.