NEUTRINO PHYSICS WITH 80" AND 14' BUBBLE CHAMBERS AT BROOKHAVEN NATIONAL LABORATORY*)

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This morning you heard a talk by Robert Palmer in which he described a new focusing device, the "finger". What I woulk like to present this afternoon are some calculations estimating the yield of neutrinos events which I believe one can obtain with this focusing device. First, let me remind you of one of the calculations that was shown this morning.

Slide 1

This slide shows the neutrino flux (number of neutrinos/GeV/m^2/proton) plotted as a function of the laboratory neutrino energy for an ideal focusing system, the finger system and the CERN horn. The former two cases have been calculated using a primary beam of 30 GeV protons and the horn with 24 GeV protons. In all cases absorption in the material of the focusing device, as well as integration over target length were omitted, although an over-all target efficiency of 40% was included. At the low-energy end, where the elastic events take place, the gain of the finger over the horn is roughly a factor of two, while at higher energies where the inelastic events (as well as the associated production) occur, the gain factor is roughly four to five.

Before presenting the anticipated rates, I would first like to briefly state the basis on which these calculations were made. These are enumerated below:

1) The momentum distribution of elastic and inelastic events was taken from the already published CERN heavy liquid bubble-chamber experiment, which employed the horn as a focusing device.

2) The useful volume used for the 80" chamber was three-quarters of the total volume, i.e. 750 litres out of a total visible volume of 1,000 litres. This latter figure is a little more optimistic than Cundy's calculations earlier today in which he took a loss of a factor of two.

3) In the calculations for the 14' chamber being proposed by Brookhaven, which has a total useful volume of 25,000 litres, a gain of a factor of 25 in volume over the 80", the useful volume was assumed to be three-quarters of the total volume.

4) The gain of the finger over the horn was taken from slide 1.

In order to obtain a feeling for the possible gains available, I wish to show the following two slides.

Slide 2

This slide shows the expected gain from the use of a larger chamber. The ordinate is the gain factor of the 14' chamber placed at an optimum position from the target compared to the present placement and use of the 80" chamber, and the abscissa is the neutrino laboratory energy. The low-energy point yields a gain factor of 25 and the plateau corresponds to a

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factor of 12. This is understood in the following manner: at the very low energies the cone of the pions is much larger than the detector, so the scaling goes simply as the volume. At high energies this is not so, and the scaling there goes roughly in proportion to the length of the detector multiplied by the average radius of the detector. In the above case the gain in the high-energy region is larger because the calculation for the 80" chamber was not done for its optimum position, i.e. it is not situated far back enough from the AGS. Thus, if one just scaled in a straightforward manner one would have a calculated factor of eight to ten, instead one gets a factor of 12.

Slide 3

In this slide is displayed the gain factor one achieves if one employs neutrinos instead of antineutrinos as bombarding particles. One notices that at low energies there are twice as many neutrinos as antineutrinos. This is just a reflection of the fact that there are twice as many π^+'s as there are π^-'s in this energy range. It is also known that as one goes higher in energy the neutrino-momentum distribution is dominated not by the π's but by the K's, and also that at higher energies the K^+ to K^- ratio increases so that one gets fewer and fewer antineutrinos, as is shown on the slide.

There is one further important point. Recently at Brookhaven the bubble chamber group was successful in being able to run the 20" hydrogen bubble chamber with various mixtures of hydrogen and neon. This was an idea originally suggested by M. Goldhaber and only recently attempted. The chamber has been filled and made sensitive with mixtures of 10, 20 and 30% of neon by volume and, furthermore, there have been indications that it would be possible to run the chamber completely filled with neon. The temperature and pressure required to do this are not astronomically high, so that it would be possible to achieve sensitivity with the present piston and refrigeration system on the 80" chamber. Therefore, the calculations which follow will include the 80" and 14' chambers filled with hydrogen, deuterium and neon exposed to both neutrinos and antineutrinos as primary beams.

Question: What is the density of neon.

Answer : The density of liquid neon is 1.2 gm/cm^3, but the density used in the calculations is 1.0 gm/cm^3. The radiation length of pure neon is about 30 cm.

Slide 4

In this table are presented the number of neutrino events to be expected (under the assumptions previously enumerated) in an exposure of 1,000,000 pictures with a beam flux of 7×10^{11} proton/pulse. The category marked strange particles refers to associated production of strange particles, while "hyperons" refers to single hyperon production. The latter can only be produced by $\bar{\nu}$ if $\Delta S/\Delta Q = -1$ is forbidden. In estimating the yield of events in this channel a value of 3% of the elastic cross-section was assumed. Several comments are now in order. All experiments in the 14' chamber give a large yield of neutrino events and open for the first time a study of the desirable neutrino proton interaction. Many of the questions that have been put forward concerning form factors, $\Delta S/\Delta Q = -1$ etc. can certainly be readily investigated with such an arrangement. Concerning the near future, an exposure of the 80" chamber filled with deuterium would yield ~ 300 events and this seems to me a worthwhile endeavour. The same chamber filled with neon, although giving 2,800 events in a similar exposure, is not as enticing because of the inherent problem of unravelling the nuclear physics in the interpretation of the data.

The programme is, therefore, to build the finger system, check its performance and then have an extended run in the 80" D_2 bubble chamber with neutrinos. In anticipation of this, the experimental area for the 80" has been designed to accommodate a neutrino beam as well as the presently existing D.C. separated beam and the yet to be installed r.f. beam. This is shown in slide 5. The external proton beam is brought to a focus just outside the shielding allowing free access to the focusing device. The flight path is ≈ 25 m with an equivalent amount of iron shielding placed directly in front of the chamber. In order to accommodate these various beams, the 80" chamber must be translated ~ 8 ft in its building and studies of the feasibility of doing so indicate that it is possible to do so with a down time of the order of a few weeks.

To conclude, it seems clear that with the advent of the finger and large chambers a new area of physics, namely neutrino physics, will become amenable to detailed explorations. In addition limited experiments with the Brookhaven National Laboratory 80" chamber also seem presently feasible, i.e. ν's on deuterium, and will become even more so with the increased intensity of the AGS under the proposed improvement programme.

FIGURE CAPTIONS

Figure 1 : Comparison of neutrino fluxes from an ideal focusing system, the finger system and the CERN horn.

Figure 2 : Expected gain in event rate when 80" chamber replaced by 14' chamber at optimum position.

Figure 3 : Gain in flux when neutrinos used instead of antineutrinos.

Figure 4 : Numbers of events expected per million pictures, using 7×10^{11} protons/pulse.

Figure 5 : Experimental area designed for the 80" chamber.

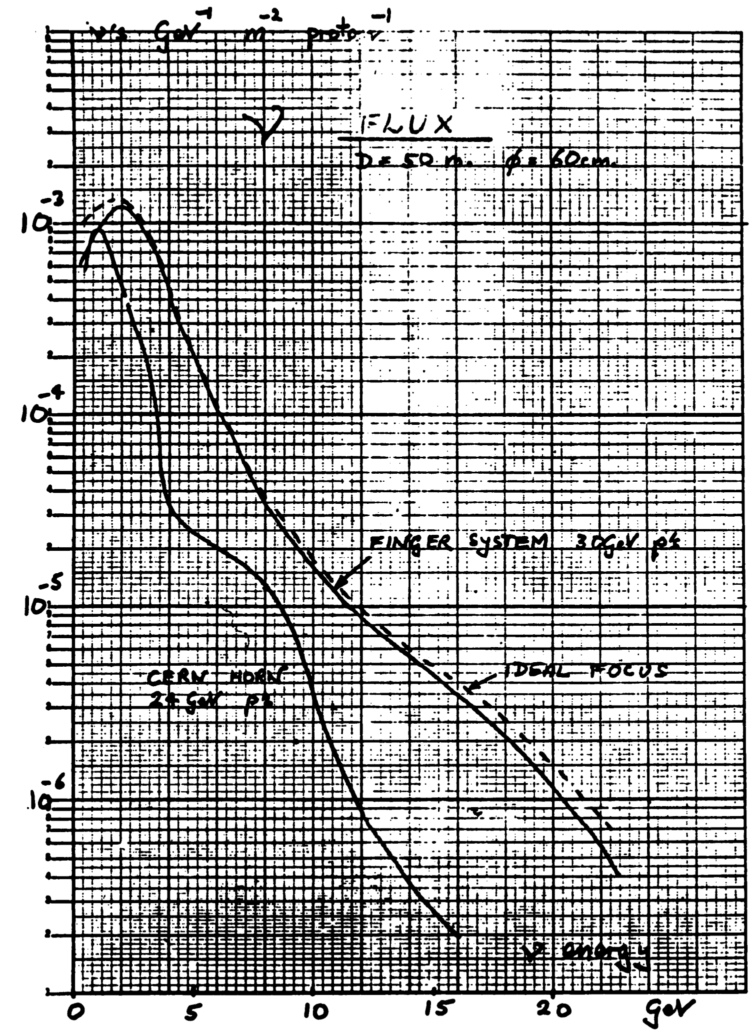
ν's GeV⁻¹ m⁻² proton⁻¹
ν FLUX
D = 50 m. φ = 60cm.
FINGER SYSTEM 30GeV p's
CERN HORN 24 GeV p's
IDEAL FOCUS
ν energy
0
5
10
15
20
GeV

Fig. 1

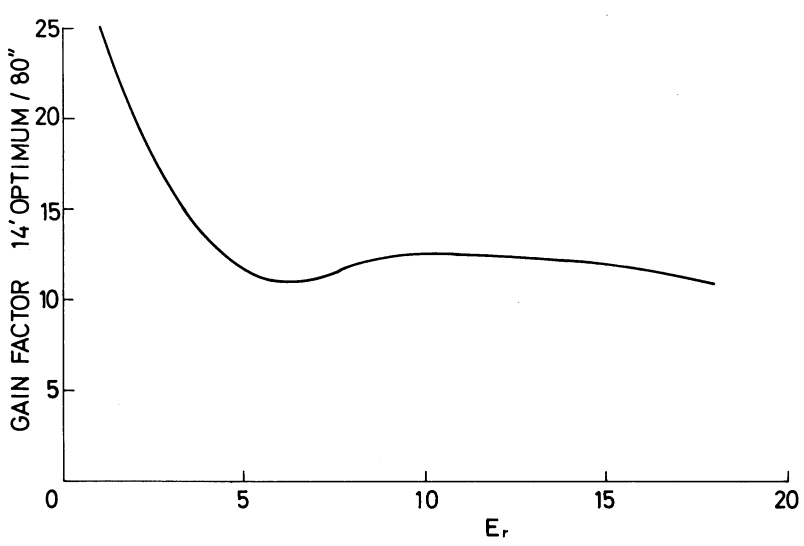
GAIN FACTOR 14' OPTIMUM / 80"
25
20
15
10
5
0
5
10
15
20
Eᵣ

Fig. 2

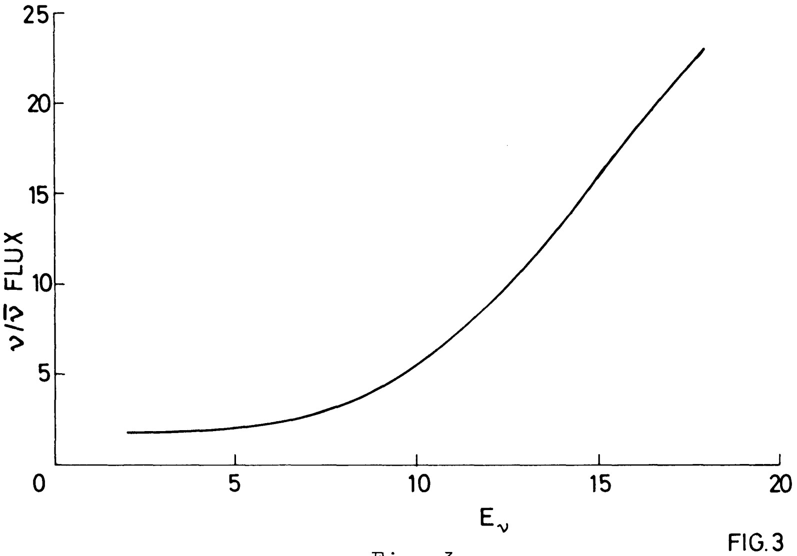

Fig. 3

ν	CERN HLBC	80" H_2 plus finger	80" D_2 plus finger	80" N_e plus finger	14' H_2 plus finger	14' D_2 plus finger	14' N_e plus finger
Elastic	236	0	120	1,000	0	2,250	18,000
Inelastic	209	100	200	1,700	1,600	3,200	27,000
Strange particle	7	4	9	72	50	100	800
$\bar{\nu}$							
Elastic		60	60	500	1,100	1,100	10,000
Inelastic		50	100	850	800	1,600	13,000
Strange particle		1	2	15	12	24	200
Hyperons		2	4	30	24	48	400

Fig. 4

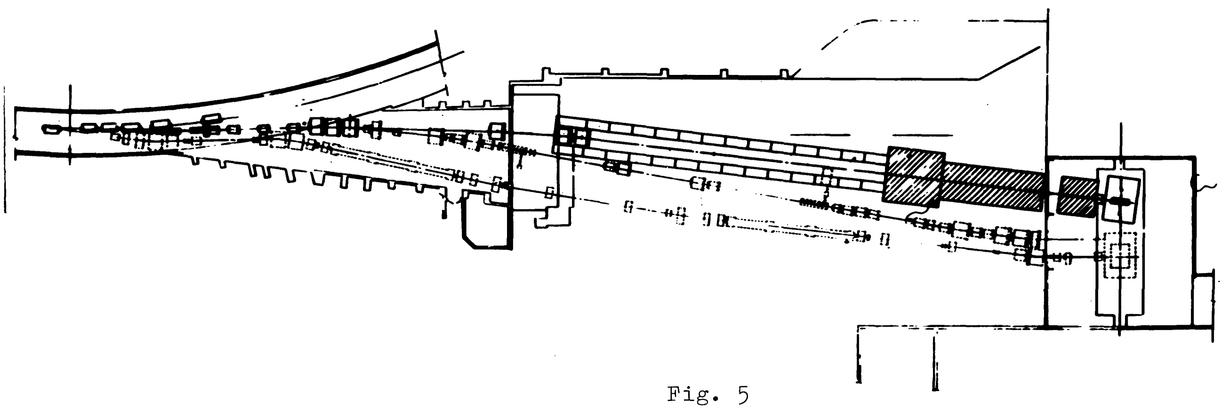

Fig. 5