SS-160
2224

DC HORN FOR VERY HIGH ENERGY SPARK-CHAMBER NEUTRINO EXPERIMENTS

D. H. Frisch
Massachusetts Institute of Technology

and

Y. W. Kang
National Accelerator Laboratory

ABSTRACT

The very high energy neutrino spectrum is calculated using a dc Fresnel horn. This horn gives a large fraction of perfect focusing at very high energy.

I. NEED FOR SPECIAL HIGH ENERGY NEUTRINO BEAM

Spark-chamber experiments using very high energy neutrinos may well require a special lens system for focusing the K mesons which decay into the neutrinos, for two reasons.

1. The several hundred tons of detector to be used will have a high sensitivity (of the order of 100 times that of the 25-ft BC) giving 10 to 100 events per pulse from low-energy neutrinos, far too many for good spark-chamber operation with a very short pulse. With a dc horn, however, the events will be spread out in time, and also the low energy end of the spectrum will be depleted greatly, both effects keeping the pictures quite clear. The number of low-energy neutrinos can be reduced in a short pulse as well as in a long pulse, if the pulsed horn designed for a broad band spectrum can be run efficiently for a high pass-band .

2. Depending on the details of the spark chamber and shielding setup, the trigger backgrounds may be either cosmic rays or beam-associated events. In most setups the scale will be large, with a very energetic and nearly horizontal μ meson as part of the trigger. The cosmic-ray background will be timed out of the trigger, and in any case will be much less per unit area than at low energies; thus usually there will be very little advantage to have a pulsed beam to suppress cosmic rays. On the other hand, large arrays should be triggered as little as possible because servicing them may be quite time-consuming. From this standpoint, as low an instantaneous trigger background rate as possible, and therefore a slow spill, may prove critical to the quality of some experiments.

The purposes of this note are to demonstrate that it is not difficult to design a high-pass dc horn to give a slow spill, and that it gives good collection efficiency for very high energy neutrinos.

II. DESIGN OF A DC HORN

The essential point of the design (and this is nothing new; we could be talking about, e.g., the second element in the Nezrick pulsed horn[1]) is that by making the horn very long, comparatively small currents can be used, yet the transverse dimensions do not increase because the very high energy hadrons which make the very high energy neutrinos are gathered from a very small range of production angles -- that is, the horn can have large f-number. We thus trade magnetic intensity B for length of path in the magnetic field.

There is one trouble with this tradeoff: Since the conducting surfaces of the horn must be very long, the hadrons will pass through the conductors of a conventional tapered structure at nearly grazing angles, giving very large absorption. This defect can be avoided by making the dc horn a Fresnel lens, made of only a few segments, with their long conducting surfaces parallel to the particle trajectories (here the approximation is used that the particles are going parallel to the beam axis) and their short surfaces perpendicular to the trajectories. Then most particles go perpendicularly through only a thin layer of metal, but perhaps 20% of them go tangentially through a very thick layer, keeping the total transmission (scattering is negligible for present purposes) up around 75%.

A simple Fresnel dc horn is shown in Fig. 1, and its parameters and those of a tunnel and shield used in the calculations here are given in Table I. It will be seen that the highest current density, nearest the axis, is still quite modest, allowing quite thin conductors.

The high-energy end of the neutrino at $E_p = 200$ GeV, using this horn with three different currents, is shown in Fig. 2, together with the "perfect focusing" case for the same parameters. Only K's contribute above 60 GeV. Note that the horn should really be relocated to optimize the yield at each current, with the Cocconi angle falling about 1/3 of the way out from the center in order to use the Fresnel lens as nearly as possible (for a given number of steps in it) like a continuous lens. Note also that absorption of hadrons by the material of the lens is not taken into account in the normalization of Fig. 2, but that on the other hand the target is only one interaction length long; these two corrections should just about cancel out.

The neutrino spectrum from both π's and K's with energies 7.5 GeV and up is given for two horn systems--a shortpulsed conventional horn and a dc Fresnel horn--in Fig. 3, illustrating the suppression of low-energy neutrinos. Very low energy neutrinos ($\lesssim$ 5 GeV) are not calculated here, but can be treated as the "no focusing" case in estimates of their contribution to backgrounds; most trigger systems will exclude them in any case.

Table 1. Fresnel Horn and Beam Parameters.

Horn:			
Dimensions of Zones:	Inside diameter		Length
	#1:	16 cm	3 m
	#2:	28 cm	6 m
	#3:	40 cm	12 m
	#4:	54 cm	24 m
Outside diameter:		100 cm	24 m
Current density at i_{total} = 0.20 MA:			4,000 A/cm^2
Total weight with 1-cm thick aluminum ribs:			~1 ton
Average power (1 sec pulse every 5 secs):			1.4 MW
Beam:			
Average number of protons/sec:			10^{13}
Target length $\equiv$ 1 interaction length			3 m
Target radius:			2 mm
Production spectrum:			CKP formula
Distance from target to center of lens:			60 m
Hadron decay distance: (from target)			600 m
Total distance from target to detector:			930 m
Tunnel radius:			0.75 m

Finally, rough estimates of the application of this spectrum to a W-search using a particular spark-chamber setup[2] are given in Table II to give a feeling for the value of designing a high-energy beam for maximum intensity. No attempt has been made here to optimize the decay distance or shield thickness; the values of these parameters have been taken directly from Ref. 1. With this spectrum a factor of 3 increase in intensity allows on the average an increase of about 1 GeV/c^2 in the W mass just observable in the 5 - 12 GeV/c^2 range, at a given detection rate.

Table II. W Production Using Beam of Table I.

SC radius:	1 m
SC weight of iron:	4 modules @50 tons = 200 tons
Detection efficiency:	1/2 for each mode
W Branching ratios:	1/4 to $\mu\nu$; 1/4 to $e\nu$
Yield per mode in 500 hr run:	

M_W(GeV/c^2)	Events/Mode
5	10,000
8	550
10	54
11	19
12	8

REFERENCES

[1] Y. W. Kang and F. A. Nezrick, Neutrino Beam Design, National Accelerator Laboratory 1969 Summer Study Report SS-146, Vol. I.

[2] D. H. Frisch, Beam and Spark-Chamber Detector for Search for W's Produced by Neutrinos, National Accelerator Laboratory 1968 Summer Study Report B.1-68-66, Vol. 1, p. 235.

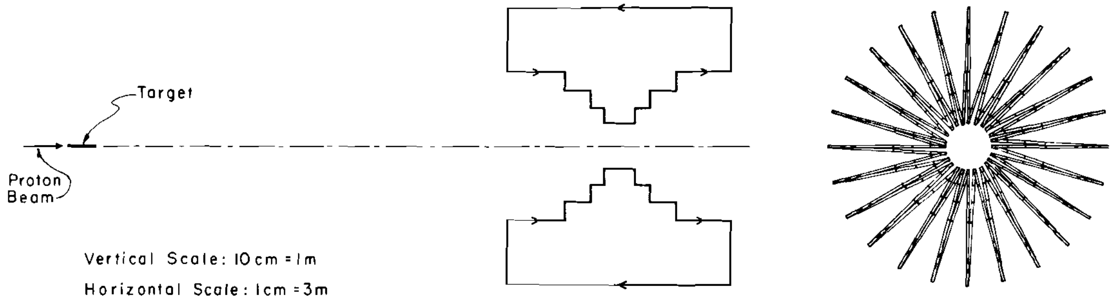

Fig. 1. The profile of the Fresnel focusing system.

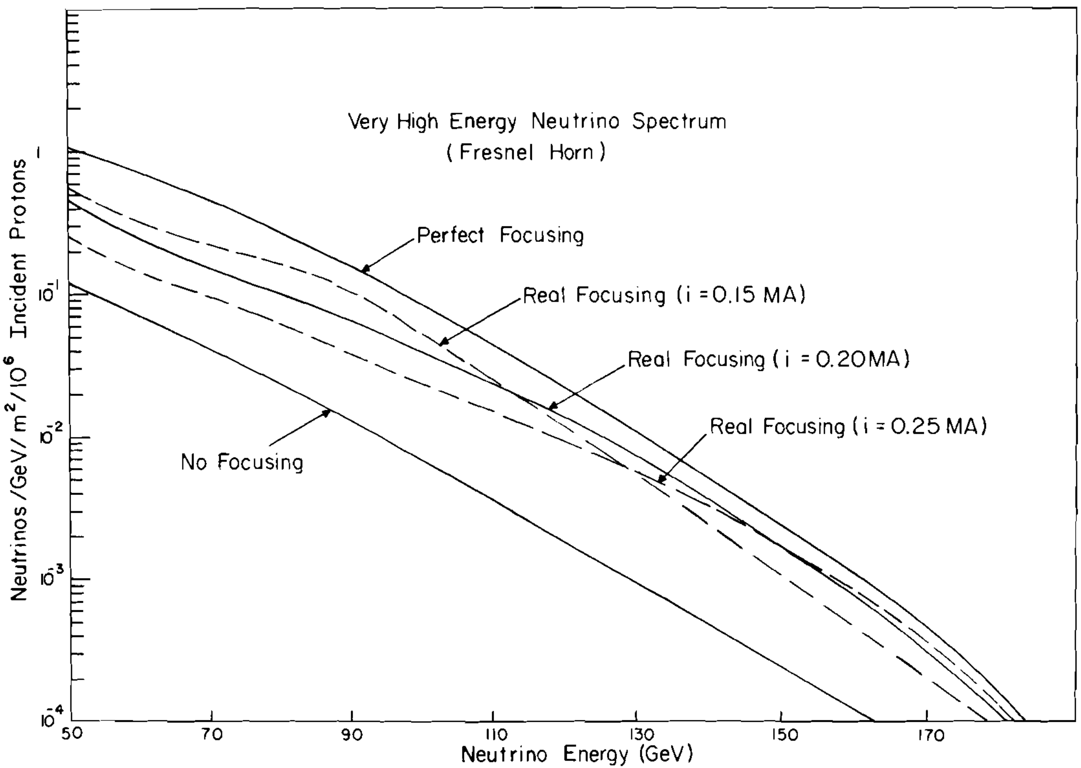

Fig. 2. Very high energy neutrino spectra. Parameters used: decay distance = 600 m, shielding length = 330 m, recess = 10 m, detector radius = 1 m, target length = 3 m = 1 mfp, target radius = 0.002 m, tunnel radius = 0.75 m, target-to-center of horn = 60 m.

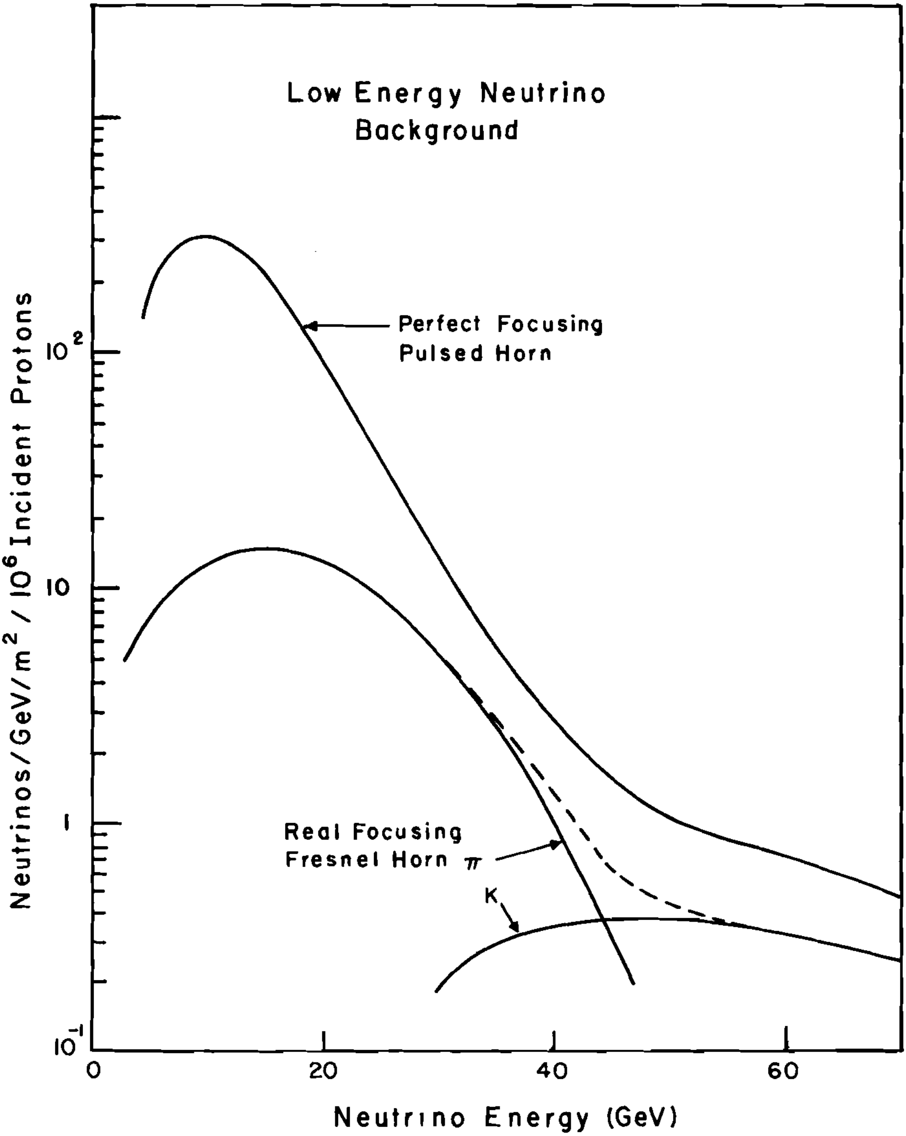

Fig. 3. The neutrino background produced by the Fresnel horn (real focusing) compared with a pulsed horn system.