Present Neutrino Experiments.

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1. – Introduction.

This is a general introduction to neutrino experiments as they are being carried out now at CERN and at BNL. It is meant to serve as an introduction to Prof. Bernardini's lectures on CERN results and to describe the arrangement at Brookhaven which we hope will yield results in a matter of months.

We begin by listing the major elements in present neutrino experiments: 1) High-energy protons, to make pions and kaons, the neutrino parents. Essential element here are the production cross-sections

$$\frac{\mathrm{d}^2 N_\pi}{\mathrm{d}\Omega\,\mathrm{d}p}, \qquad \frac{\mathrm{d}^2 N_\mathrm{K}}{\mathrm{d}\Omega\,\mathrm{d}p}, \tag{1}$$

and their dependence on angle and momentum of the π's and K's. 2) Focussing devices, to increase the density of neutrinos at the detector by decreasing the natural divergence of the secondary beams. 3) Shielding, to stop high-energy *muons* produced along with the neutrinos. This requirement is more than enough to shield the detector from strongly interacting particles generated in the target. 4) Detector of neutrino-induced events. It is the properties of the detector that well determine the sensitivity to such questions as:

a) Is there a W?

b) What are the weak-interaction form factors?

c) What are the details of inelastic neutrino reactions?

d) Are leptons conserved? Are there new leptons?

e) Just how « two » is the two-neutrino result? (CERN says it is very « two » indeed!).

5) Calibration: the efficiency of the detector and the biases introduced, the properties of track photographs of particles, etc. must be understood. In the case of large spark chambers, some of these must be determined by carefully designed calibration studies in beams of known particles. 6) Neutrino flux: —in order to obtain absolute cross-sections, evaluate sensitivity to W mass, examine the energy-dependence of the cross-section — the flux as a function of neutrino momentum, must be studied as an integral part of the experiment.

We now take up these topics in order and describe the CERN and BNL arrangement.

2. – Primary proton beam.

In the 1963-64 experiments, the proton beams are extracted from the machine and strike targets outside the magnet ring. The primary motive for this is the very steep increase of pion yield as one reduces the pion emission angle. The 1961 BNL experiment, with an internal target, accepted pions emitted at 8°. The increase from 8° to 0° is about a factor ~ 10 in π^+ yield.

The extraction from the magnet ring of 25 or 30 GeV protons with an efficiency of $> 95\,\%$ and their delivery onto a target with a spot size of several millimeters represents an extraordinary feat of precision and sophistication in accelerator scholarship. This is accomplished by a series of deflections beginning with a fast «kicker» magnet which rises in ~ 100 ns (between rf bunches) to ~ 500 G, sufficient to deflect the next and subsequent bunches into a stronger septum magnet—one with a very sharp gradient of field. Suffice it to say that both laboratories have accomplished this and have delivered to the experiment a pulse of radiation containing $\sim 7 \cdot 10^{11}$ protons (CERN) or $3 \cdot 10^{11}$ protons (BNL) and having a time structure consisting of 12 (BNL) or 20 (CERN) bunches, lasting a total of ~ 3 μs. This short-time structure is extremely convenient in reducing the «on-time» of the detectors, consequently reducing the cosmic-ray background which would otherwise be quite serious.

One final remark: it is important to have good absolute and relative monitoring of this beam for eventual control of the neutrino flux. At BNL this is accomplished by 1) eletcromagnetic pick-up signals and 2) chemistry after exposure of CH_2 foils.

3. – Focussing.

Conventional magnetic focussing devices (quadrupoles) were not considered for present experiments because of the requirement for collection of a very wide momentum band of pions and kaons, coupled with demand for very large apertures. Recall that the rate of the first neutrino experiment was under 1 event per 10 h. Apart from the desire to increase the neutrino flux,