A DETECTOR FOR CHARGED CURRENT EVENTS IN MUON SCATTERING

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ABSTRACT

In the kinematic region available to a muon beam of 10-15 TeV the cross-section for weak charged current interactions can become similar to that for single photon exchange interactions. The necessary parameters of a detector for such interactions are considered.

1. INTRODUCTION

One of the conclusions of this workshop is that a high energy, high flux muon beam is perfectly feasible[1)]. From 20 TeV primary protons a useable beam is possible with muon energy up to 15 TeV and up to $\sim$10 TeV it is possible to reverse the polarization of the beam. The Q^2 $\sim$20-30,000 GeV^2 kinematically possible with such a beam is well within the regime where the weak and electromagnetic rates are comparable. The muon beam is therefore an alternative to the neutrino beam as a tool to study the weak interaction and has the added attraction that the choice of helicity allows the study of "wrong handed" interactions.

2. KINEMATICS

The kinematics for the reaction

$$\mu + N \rightarrow \nu + X_H$$

are easily shown on the familiar Q^2 - ν plot in Figs 1a) and 1b) on which have been superposed the quantities relevant to detection and measurement in the laboratory, ie

a) The direction of the hadronic three-vector, this direction about which the net p_T of the total hadronic system is zero is also the direction of the exchanged boson.

b) The net p_T of the hadronic system with respect to the incident particle axis. This balances the p_T of the missing neutrino.

c) The direction of the final state neutrino with respect to the incident muon direction.

The most important observation is that the angles are very small.

3. DETECTOR PARAMETERS

a) In order to achieve a high luminosity (the cross-sections even if comparable with the electromagnetic at the high Q^2 are still small) a massive target is necessary. The material however should not have a high atomic number Z because at these ultra-high muon energies the bremsstrahlung losses are severe[2)]. A target/detector with fiducial length 20 metres and density 2gm/cm^3 would give a luminosity of several times 10^{39} cm^{-2} day^{-1} for expected muon fluxes.

b) The "interesting" charged current events must be identified by the absence of a final state muon amongst an abundant yield of single photon exchange events, especially at low Q^2.

c) Since the final state lepton is not detected the two quantities Q^2 and ν which completely specify the event must be deduced from the measurement of the final state hadron system X_H. Its energy must be measured but also its direction and the latter with a resolution significantly better than 1 mrad.

4. THE DETECTOR

The natural choice of apparatus is a combined target/calorimeter detector. It could be massive and a good energy resolution is easily attainable[3]. The lateral dimensions are controlled by the shower length and the net hadron angle, and a detector of 1 m x 1 m area would seem adequate. The need to avoid a high Z material leads naturally in the direction of achieving good angular resolution for the hadron shower by use of a fine-grained calorimeter in the spirit of neutrino neutral current detectors at present energies[4]. With respect to this question of possible angular resolution there are the following considerations:

a) The lateral position of the interaction is known from the accurate knowledge of the incident particle direction.

b) The expected resolution on the position of the shower centroid is expected to be less than 1mm with cell sizes of 5cm[3]. This, in conjunction with the shower length of $\sim$5-10 metres, would seem to make a resolution of <1 mrad possible.

Establishing the absence of a muon implies 100% efficient detection of all scattered muons. This can be achieved by surrounding the main detector volume with layers of iron and, for instance, scintillators. The total area should be $\lesssim$100 m^2.

With the above considerations Fig. 2 is presented as a highly idealized sketch of a possible detector.

5. CONCLUSIONS

No major obstacles have been found to the use of a low density ($\sim$2gm cm^{-3}) fine grained target/calorimeter detector for the charged current interactions of high energy muons.

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REFERENCES

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3) Yu. Prokoshkin - Hodoscope Calorimeters as Basic Coordinate Energy Detectors of Particles in the 10 TeV Range. Paper contributed to Group VIII of this Workshop.

4) CERN-SPSC-75-59 (1975).

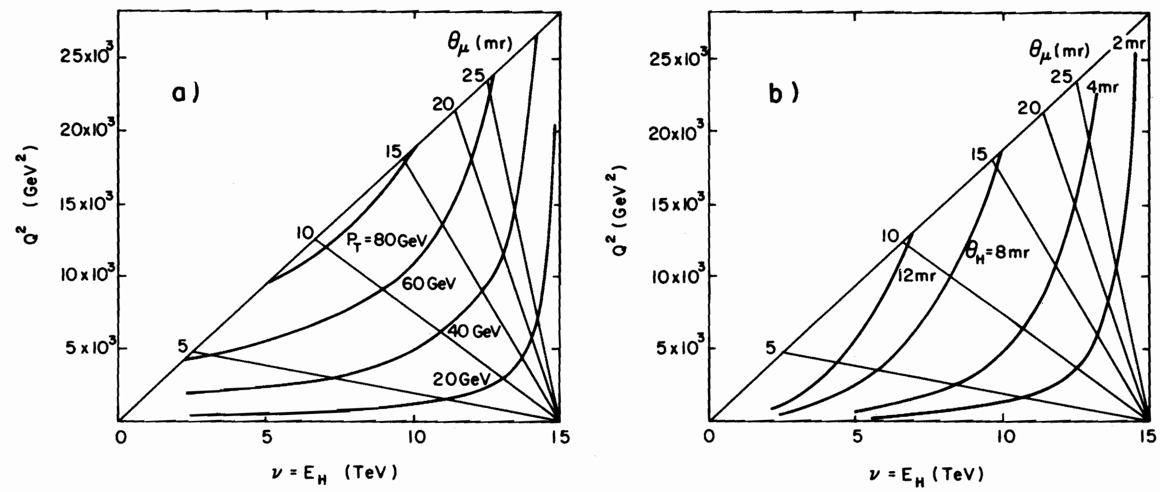

FIG. 1

KINEMATIC PLOTS

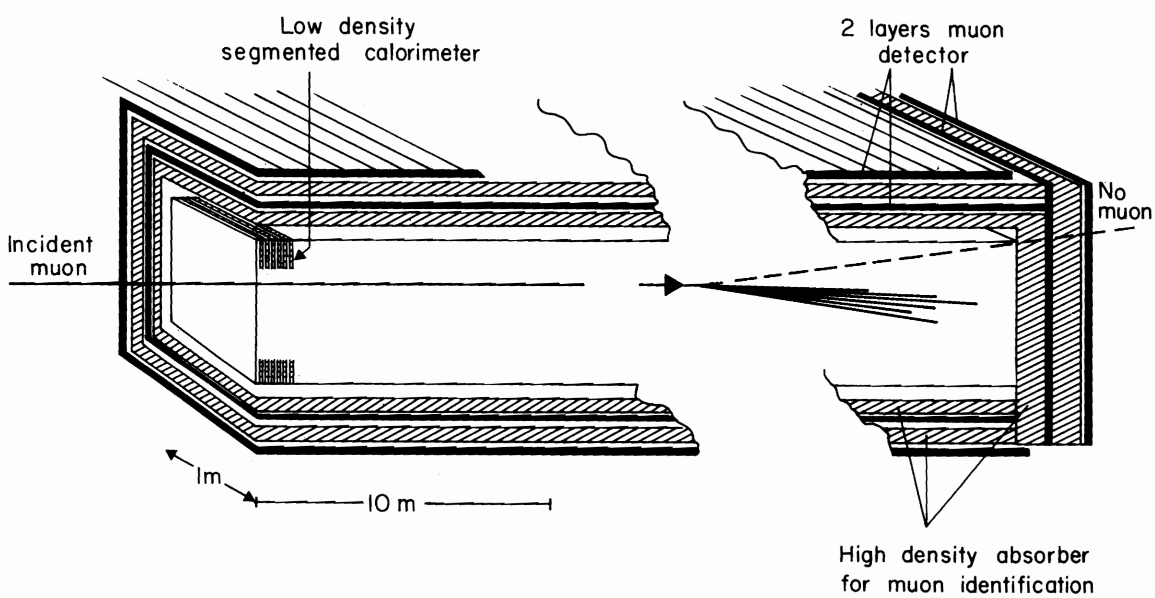

FIG. 2

SKETCH OF IDEALISTIC CHARGED CURRENT DETECTOR