BEAM PIPE SPECTROMETER FOR ep FINAL STATES

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ABSTRACT

A 200 m-long iterated detector system with calorimetry and particle identification can be used to analyze beam pipe hadron jets from ep collisions using TeV range protons. Neutral and charged secondaries with as much as three-fourth the beam momentum are detected and measured with good efficiency.

One important feature of the proton as a high energy particle is its relatively complex structure. In most of the interesting collisions involving incident high energy protons, much or most of the energy is carried away by "spectator" partons whose materialization generally creates hadron jets along the beam axis. Measurement of particles in these jets can provide constraints for the balance of not only energy and momentum but flavor. The technical problems of working close to the beam line are severe but probably no worse than those associated with identifying leading particles in a central detector exposed to jet multiplicities of order 50.

Particularly for a beam pipe spectrometer, the characteristics of the storage rings are crucial. We assume E_p = 20 TeV, E_e = 140 GeV, Radius = 12 km, number of bunches = 1000, protons per bunch > 10^{11}, maximum useful magnetic field = 10T, luminosity $\gtrsim 10^{31}$ cm^2/sec, beam pipe radius = 4 cm, ep crossing angle = 3 mrad. The proposed spectrometer (Fig. 1) consists of a series of similar detector systems, one following each magnetic lens or dipole. Each detector system (Fig. 2) includes a segmented transition radiation detector, as described by Willis[1)], followed by uranium-scintillator sampling calorimeters for both e-γ and hadron energy measurements.

In order to minimize the loss of secondaries within the insertion quadrupoles the aperture is larger (10 cm radius) than that needed for the nominal beam envelope. The somewhat arbitrarily chosen beam pipe aperture is far larger than that required by the emittance of the 0.4-1 TeV proton injector. We assume that aperture stops elsewhere in the storage rings collect beam particles that are lost gently. An excellent vacuum exists everywhere in the beam pipe, so that hard beam-gas scattering rates in the detectors are far below one per bunch passage. The time resolution of the detector elements is sufficient to identify interactions within the bunch structure ($\sim$250 ns interval). This presents no problem for scintillators and solid state detectors, but the MWC's, if used, will have to be designed carefully. The calorimeters help to protect the transition radiation detectors from electron beam background. In addition, the detection systems should be spaced to avoid local coincidences of the proton and electron bunches along the beam axes.

The strong dispersion in the spectrometer will separate well the charged particles in the beam pipe jet. The transition radiation detectors are well suited to the $\pi/K/p$ identification. In the calorimeters e and μ are identified, and γ's are distinguished from neutral hadrons. For muons and for pions above a few TeV [$E_c \geq 1$ keV] it is also possible to measure synchrotron radiation in solid state detectors at the entrance to each detection system (not shown in Fig. 2). These detectors would be in a poor vacuum separated by thin (0.025 mm thick) beryllium windows from the high vacuum of the beam pipe. They would have to be kept back from the line of the unperturbed beam to avoid beam proton radiation associated with the discontinuities in the magnetic field[2)]. The particle identification system in each detector will provide angular resolution better than 10^{-3} radians. Hence trajectories will be correlated with energy, providing redundancy for particle identification and the rejection of background.

Figure 3 shows which detectors, identified in Fig. 1, are struck by neutral particles produced at various angles to the beam axis. Detector A is effectively part of the central detector. Figure 4 shows what happens to charged secondaries produced with various total and transverse momenta. The shaded areas represent flux striking the poletips of the lenses. Some information regarding these particles could be recovered by instrumentation of the magnet apertures outside the beam radius. For simplicity we consider momenta of at least 1 TeV. We have neglected the focusing of the electron beam insertion quadrupoles.

The characteristic transverse momentum for secondaries in the beam pipe jet depends on quark binding and (QCD) radiative effects. It is observed to rise with energy; at multi-TeV energies it may be of order 1 GeV/c. The beam pipe spectrometer therefore, has good efficiency for detecting particles throughout the interesting energy range, and a good measurement of total energy can be made.

The total spectrometer length is only 200 m out of an available straight section length of (1/2)x1500 m. With further iteration using strongly dispersive sections therefore, positive secondaries with more than 3/4 the beam momentum could be detected efficiently.

[1)] W. Willis, Proceedings of the Workshop on Possibilities and Limitations of Accelerators and Detectors (ICFA), FNAL, April 1979, pp. 245-253.

[2)] CERN Courier, September 1978, p. 294.

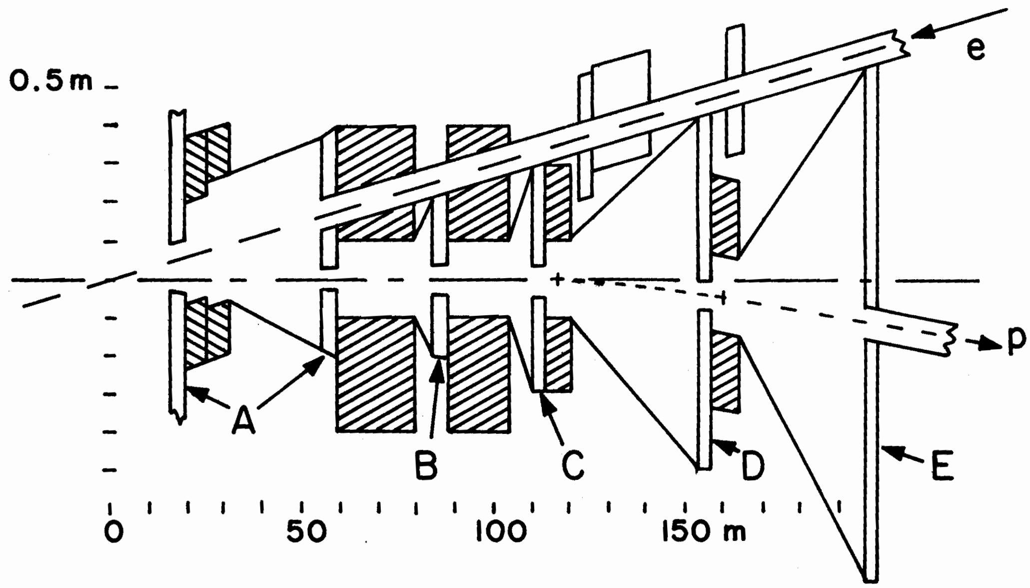

FIGURE 1 - Beam Pipe Spectrometer. A through E are similar detection systems. For the electron insertion lenses the field gradients are ∿8.6T/m. Each superconducting proton lens has ∿100T/m. The superconducting dipoles are of strength 66.7T-m.

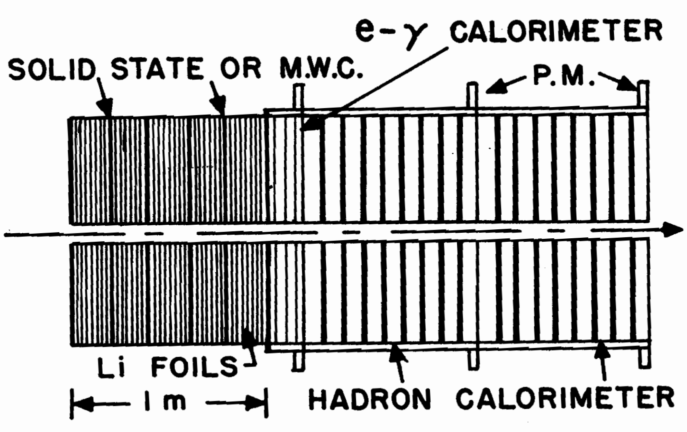

FIGURE 2 - One detection system. The calorimeters are segmented azimuthally. The transition radiation detector gives radial and azimuthal coordinates.

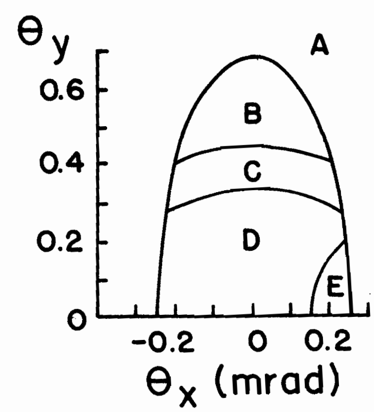

FIGURE 3 - Acceptance for neutrals.

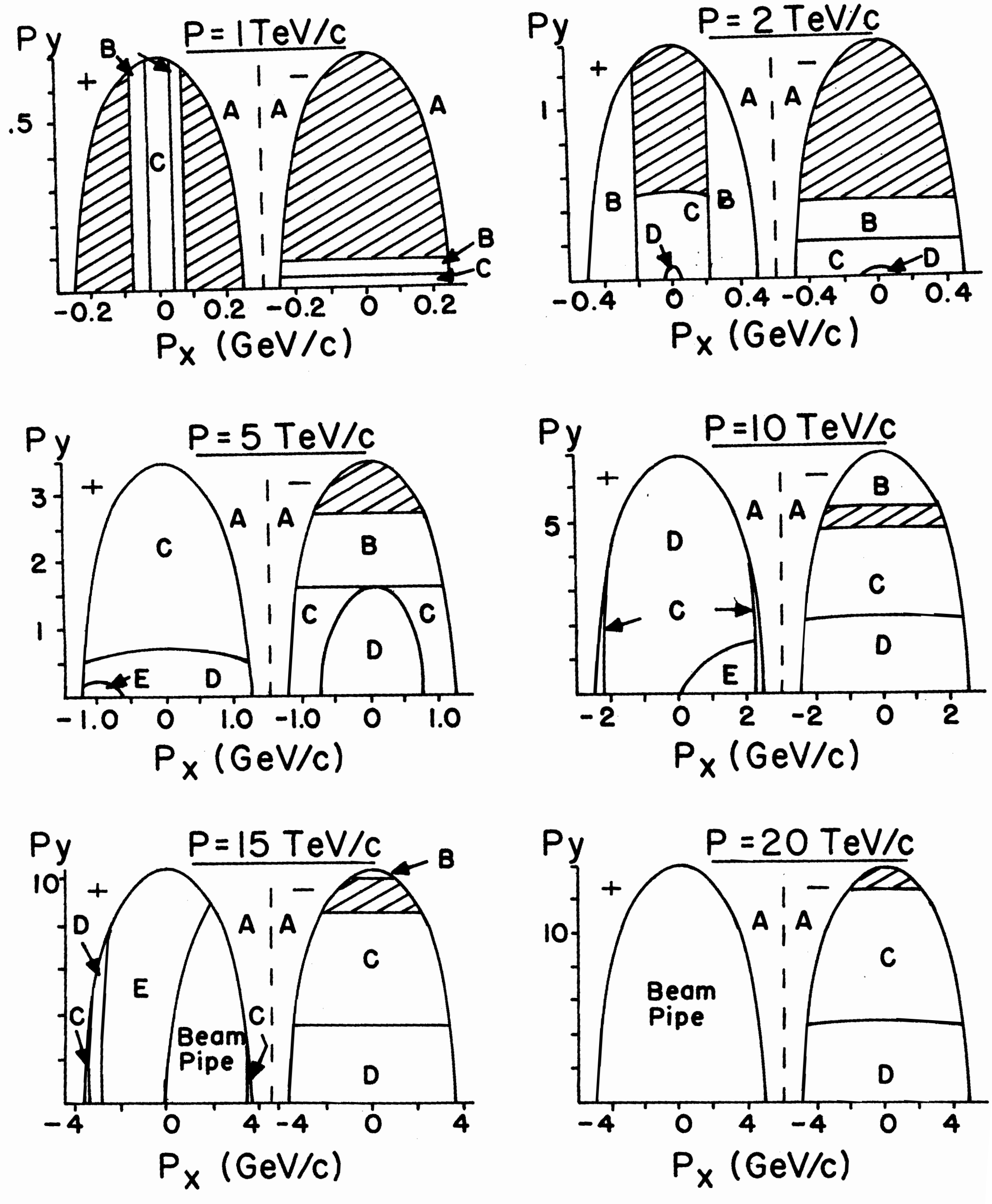

FIGURE 4 - Acceptance for charged particles of various momenta.