Present Concept for a Hall D Detector

Scott Teige
Indiana University, Department of Physics

1 Introduction

A design for a detector optimized for meson spectroscopy has evolved from discussions at several workshops:

- Indiana University Workshop - July 14 to 16, 1997
- North Carolina State University Workshop - November 13 to 15, 1997
- Carnegie-Mellon Workshop - March 13 to 14, 1998

We also benefitted from the experience of LASS, Crystal Barrel and others.

The current detector concept was generated by several design constraints. Since the highest energy beams will not be immediately available the detector must be designed to be useful (or scalable) over a range of energies. A general purpose detector should be able to measure charged particle momenta with very good acceptance and resolution. This implies a magnetic spectrometer, the design of which is non-trivial given the very high desired beam rates and the correspondingly high e^+e^- pair rates. Identification of charged particle species (π/K/p separation) is also desirable. Photon detection, to identify final states with one or more π^0, η or ω mesons, is also clearly essential. Each of these issues is addressed below.

2 Scalability

Beam energies up to 12 GeV have been considered for this design study. It is assumed that the beam energy will be increased incrementally starting at 6 GeV with the possibility of data taking at each of several successive beam energies. This scenario leads naturally to a detector built in stages over a period of several years, the capabilities of the detector increasing with time and adapting to the appropriate beam energy. The general features of such a detector are discussed further below but the following items were identified as issues that are strongly energy dependent.

- Time of flight is a workable solution for particle ID for photon energies from 6 to 8 GeV but becomes impractical for for beam energies from 10-12 GeV.

- Crystal Barrel and LASS experience tells us that a solenoid alone is insufficient to measure the momentum of charged particles at angles less than about 8 degrees to the beam axis. As energies increase, more and more particles enter this forward cone.

- A "stage I" detector is solenoidal using TOF for particle ID. By design, it can be reconfigured into a "stage II" detector by adding a dipole magnet, downstream tracking and, for example, DIRC particle ID capability.

3 Charged particle momenta reconstruction

Momentum analysis for charged particles at various energies was considered. Monte-Carlo studies indicate that a solenoidal momentum analysis magnet is adequate up to an endpoint of about 8 GeV. Beyond 8 GeV the Lorentz boost populates the very forward regions of the detector and the resolution available from the solenoid alone degrades. At higher energies a dipole magnet and forward tracking is added.

The dipole magnet introduces a special design problem, that is, the opening of e^+e^- pairs produced in the target creating a "sheet of flame" that prohibits operation of downstream tracking chambers. This problem can be addressed in one of two ways:

- Deaden this region of the downstream tracking chambers by inserting a thin sheet of dielectric material between the anode and the cathhode

- Contain the e^+e^- pairs in a "flux exclusion" tube for their trip through the dipole. Normal, laminated ferromagnetic materials are probably adequate but the possibility of a super-conducting tube exists.

4 Charged particle identification

Up to 8 GeV, time of flight (TOF) is adequate for $\pi/\mathrm{K}/p$ separation. 100 picosecond resolution and momentum resolution achieved by Crystal Barrel have been simulated with Monte-

Carlo and found to be adequate both inside the solenoid and in the forward region.

From 10 to 12 GeV unrealistic time resolutions must be used to get useful π/K separation in the forward region while in the solenoid region TOF continues to work well for a substantial fraction of events. Forward region particle ID can be achieved with ring-imaging type Cerenkov techniques. Due to the rapid increase in cost, channel count and complexity of the calorimeter as the distance from the target to the calorimeter increases, a thin counter is very desirable. The DIRC ("Detector for Internally Reflected Cerenkov" photons) technique may be workable and satisfies this "real estate" constraint. More conventional ring imaging techniques are also under consideration.

5 Photon reconstruction

Nearly any interesting final state will contain photons from π^0, η or ω decays. Because of this electromagnetic calorimetry is essential. Lead glass calorimetry for the forward region will certainly work and is cost effective. Because it detects Cerenkov light, it is fast and can be used in the trigger. Inside the solenoid, a fast, scintillating type of calorimetry must be used because readout with photomultiplier tubes is not possible. Lead layered with scintillating fibers or pure Cesium Iodide are possibilities that can be read out with photodiodes.