

## CHAPTER 1

# OVERVIEW OF EXPERIMENT T-864

### 1.1 Objectives

Fermilab experiment T-864, referred to as MiniMax, is ultimately a search for disoriented chiral condensates<sup>1</sup> (dcc's) produced in high energy (1.8 *TeV* center of mass energy)  $p\bar{p}$  collisions. MiniMax restricts its search to the far-forward direction (a region midway between central and diffractive rapidities) where, to date, little experimental work has been done at Tevatron energies<sup>2</sup>. In fact, little work at all has been done with events having the distribution of particles in  $\eta$ - $\phi$  (Lego)<sup>3</sup> space expected in dcc production. In addition to the search for dcc's, many other important generic multiparticle measurements can be performed for the first time in the far-forward region by experiment T-864. These include, but are not limited to, the measurement of  $\pi^{\pm,0}$  production as a function of  $\eta$  and the analysis of strange-particle production manifest in  $K_s^0$  and  $\Lambda^0$  creation and decay.

### 1.2 Description of the Apparatus

MiniMax is situated at the Fermi National Accelerator Laboratory (FNAL) in Batavia, Illinois. Opposing beams of approximately 0.9 *GeV*  $p$ 's and  $\bar{p}$ 's collide in a region distributed about a nominal vertex, C0—see Fig. 1-1. The tracking coordinate system, which has been the standard throughout most of the experiment, is left-handed with its origin at C0, positive  $z$ -axis pointing from C0 toward the detector, positive  $x$ -axis pointing into the hallway of the tunnel and positive  $y$ -axis pointing towards the ceiling.

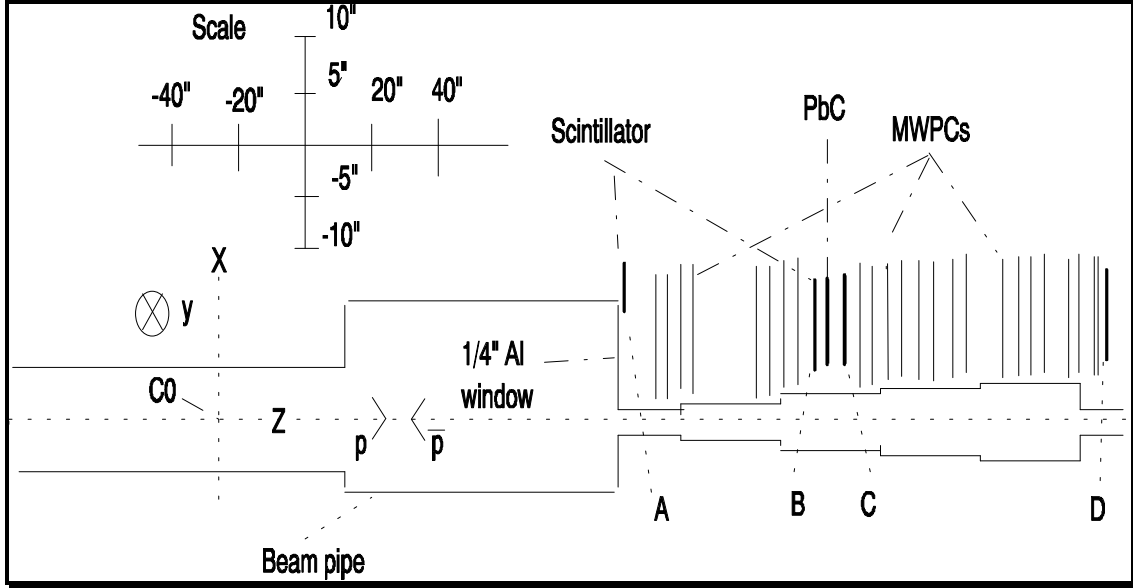
The particle detector consists of twenty-four Multiple Wire Proportional Chambers (MWPC's), several scintillation counters, a flared beam pipe, a set of electromagnetic calorimeters (not shown) and a thin slab of lead. The properties, dimensions and positions

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<sup>1</sup> K. L. Kowalski and C. C. Taylor, CWRUTH-92-6, hep-ph/9211282 (1992) and references cited therein.

<sup>2</sup> J. D. Bjorken, M. J. Longo, et. al., "Maximum Acceptance Detector for the Fermilab Collider (MAX)," Submitted to FNAL April 1, 1993: 4.

<sup>3</sup> See below for a definition of  $\eta$ - $\phi$  or "Lego" space, especially Eq. (1.1).



**Fig. 1-1: Detector Design Schematic**

of these apparatus are detailed in Appendix A. MWPC's serve as the main data collection vehicle, each providing "one coordinate's" worth of information about a charged track. Typically, successive MWPC's are oriented at large angles relative to each other in order to best isolate a particle's path. As depicted in Fig. 1-1, the MWPC's are configured in a telescope-like manner directed towards C0 covering the largest possible acceptance compatible with desired chamber orientations. The acceptance of an MWPC is defined in terms of the amount of azimuthal angle  $\phi$  and the pseudorapidity  $\Delta\eta$ ,

$$\eta = -\ln(\tan(\theta/2)) \quad (1.1)$$

where  $\theta$  is the polar angle with respect to the z-axis, covered. The detector's acceptance is the region of  $\eta - \phi$  space accessible to all MWPC's.

In order to detect photons ( $\gamma$ 's), the main decay product of the  $\pi^0$ , there must be enough dense material, "converter," within the detector to facilitate conversion of  $\gamma$ 's into  $e^+e^-$  pairs. A single sheet of lead converter (PbC) is used in practice to best localize these conversions for easiest analysis. Minimax has the ability to move the PbC in and out of the acceptance at any time via a "lead-mover," allowing measurement of efficiencies and backgrounds created by the PbC. The effects of too much PbC, namely increased probability of interaction with  $\pi^\pm$ 's and conversion products causing excessive chamber occupancy after the PbC, must be weighted against inefficiencies in detecting  $\gamma$ 's caused by too little PbC. Thicknesses ranging from 0.5 to 2.0 radiation lengths of lead have been used, but no optimal thickness has yet been determined; other materials such as copper may also be used in the future. Two thirds (16) of the MWPC's are placed after the PbC to aid in the reconstruction of tracks where chamber occupancies are highest.

The T-864 beam pipe was designed to minimize effective interactions with particles, while subject to the constraints that it hold sufficient vacuum and does not generate excessive power loss or promote dangerous beam resonances. The final configuration, installed in February 1995, is displayed in Fig. 1-1. Its most notable feature is a large central tank with a very thin (1/4" aluminum) window shadowing the acceptance of the detector. This serves to minimize the amount of material through which a typical particle entering the detector will have passed. The flaring of the down-stream pipe has been shown to reduce the likelihood of beam pipe showers<sup>4</sup>.

Also interspersed along the detector are several plastic scintillation counters. In addition to the ones displayed in Fig. 1-1 (counters A, B, C and D), there is one additional counter after the MWPC's and eight others at about -80" along the z-axis. Timing and energy deposition information from these are used in combination to produce event triggers. Various triggers have been shown to effectively bias toward low- or high-multiplicity events as well as to differentiate between collider, beam-halo and beam-gas collisions. For example, an appropriate collider trigger can eliminate all but a few percent of potential beam-gas contamination. At the rear of the detector, a stack of calorimeters reside which measure electromagnetic energy deposition. They can be potentially used in correlation with MWPC tracking to confirm the presence of  $\gamma$ 's and  $e^\pm$ 's .

### 1.3 Preview of Data Analysis

A brief outline of expected data analysis procedures and problems will help motivate the following chapters on tracking and provide a starting point for understanding the difficulties that must be overcome. From the description in Section 1.2, it is clear that the information obtained from a given event consists of a list of MWPC wires activated and a measure of the energy deposited in the scintillators and calorimeters. The purpose of the work leading up to this thesis was to find optimal ways for this information to determine what particles that actually passed through the detector and identify their species and trajectory.

It is fairly easy to reconstruct the paths of charged particles through the detector; however, determination of species is more difficult. Usually, a guess can be made based upon where the track points—towards C0, signaling a potential pion, or towards the beam pipe, signaling an interaction or decay product. Tracking becomes more complicated for neutral particles (such as  $K_S^0$ ,  $\Lambda^0$ ,  $\pi^0$ ,  $\gamma$ ) that are detectable only through decay or interaction products. The first two decay in flight<sup>5</sup> primarily into charged-particle pairs that can be readily detected by the MWPC's; however since  $\pi^0 \rightarrow \gamma\gamma$ , which can be detected as pair conversions in the PbC, the other decay channels of the  $K_S^0$  and  $\Lambda^0$  could

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<sup>4</sup> *HERA-B Proposal, DESY report, DESY-PRC 94/02 (May 1994), W. Hofmann and W. Schmidt-Parzefall spokespersons.*

<sup>5</sup>  $K_S^0$  yields either  $\pi^+\pi^-$  (69%) or  $\pi^0\pi^0$  (31%);  $\Lambda^0$  yields either  $p+\pi^-$  (64%) or  $n+\pi^0$  (36%).

be confused with primary  $\pi^0$ 's or  $\gamma$ 's from beam pipe interactions. Clearly, even with tracking and vertexing algorithms that identify converted  $\gamma$ 's, actually identifying their “ancestry” is nontrivial.

If identifying the species of particles found was the only challenge, tracking would be trivial. However, Monte Carlo simulation has shown that all tracking algorithms, to some degree, signal the presence of tracks that do not correspond to particles actually passing through the detector. These spurious tracks constitute the most significant source of error in data analysis. It has also been seen in experiment and simulation that both the time required to track events and the number of spurious tracks found increases with the actual multiplicity of tracks passing through the detector; unfortunately—or fortunately, MiniMax is interested in counting neutral and charged particles in especially these events. Another major difficulty, in addition to high multiplicity events, with the interpretation of raw MWPC data occurs from activation of MWPC wires not related to tracks of interest. Such “noise” wires usually arise due to particles showering in the pipe, floor, and chambers, cosmic rays, tunnel lights, etc. Other problems stem from large numbers of electromagnetic shower products (usually soft electrons) emanating from the PbC that are by-products of the necessary process of detecting photons. The tracking algorithm developed in this thesis seeks to minimize these effects as well as to understand the efficiencies in estimating the numbers and species of charged and neutral particles actually present.