The Initial Alignment of the Central Preshower Detector

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1. Introduction

This document outlines some preliminary thoughts on the alignment of the central preshower detector (CPS). We will establish a target alignment precision and a strategy for the initial alignment of the detector.

The central preshower detector has three concentric cylindrical layers with a mean radius of 72.15 cm. Each layer is constructed in octants with each octant containing 160 scintillator strips. The strips are triangular in cross section with sides 0.59 cm in length. The length of the strips is 241.2 cm and each end of the strip is read out from an embedded fiber at the triangle's center that extends half the length of the strip. In the innermost layer the strips run axially and in the outer two layers the strips have stereo angles of about $\pm 23°$.

We mainly consider here the alignment of each octant, treating it as a rigid body. The mechanical construction of the CPS octants will tightly constrain the positions of the individual strips, but effects of sag and small variations in the strip packing may be noticable within the desired alignment precision, so a strip by strip alignment may be needed at a later stage.

2. **Coordinate System and Pin Survey**

It is natural to adopt cylindrical coordinates for describing CPS positions. The z-axis in the local coordinate system runs down the axis of the CPS cylinders, with z increasing as one goes from North to South (in the proton direction). The y axis is vertical (increasing as one goes up) and the x axis horizontal. The angle ϕ is measured in the usual counterclockwise sense from the x axis.

The CPS octants were assembled into their concentric cylinders and their positions were surveyed prior to their installation on the solenoid in April 1998.[1] Each module has an alignment pin at the North and South ends of one edge. (The module edge with the pins touches the edge without pins in the next module.) The module positions (at the North end) nominally have module one between zero and 45 degrees in ϕ, module 2 between 45 and 90 degrees, and so on. Pin positions were surveyed to an accuracy of better than 25 μm and the angular displacements from the nominal positions calculated. These angular displacements are given in the table below. There is a gap of 1 mm between the last strip of one octant and the first strip of the next. As we develop the alignment software, the survey numbers will form the basis for the initial alignment data.

Octant number	1	2	3	4	5	6	7	8
$\Delta\phi$ North end (degrees)	.038	.002	-.019	-.006	-.013	.004	.007	.035
$\Delta\phi$ South end (degrees)	.033	-.008	-.019	.016	.024	.001	.013	.003

3. **Goal for Alignment Precision**

We adopt 50 μm as our target alignment precision. As discussed below both the intrinsic detector resolution and physics considerations suggest that if we can achieve this target precision, then misalignment will present negligible systematic problems for data analyses.

3.1 Intrinsic Resolution

The space between neighboring strip centers of triangles of the same orientation (say both point up) is 7.08 mm. In between will be a triangle of the opposite orientation (say point down), so just by knowing the hit strip you know where you are to within 3.54 mm. Most minimum ionizing particles will pass through two strips in a layer (from the geometry you expect 67% to leave light in two strips, but low light yield in the corners and threshold cutoffs will reduce this fraction about 10%). By using the relative signal sizes in the two strips one can achieve a position resolution significantly better than the strip center spacing. In a study of a CPS octant at a cosmic ray test stand, Suen Hou found that the intrinsic spatial resolution of the CPS detector is $510 \pm 10\mu$m.[2] Our 50 μm target was obtained by taking one tenth of this figure.

3.2 Physics Considerations

The CPS clusters will mainly be used to identify and locate electromagnetic objects — electrons, photons, and pi-zeros. Electromagnetic showers leave energy in several adjacent strips. A 50 GeV electron, for example, will typically leave energy in 9 strips in the innermost layer and 12 strips in the outermost.[3] By calculating an energy weighted centroid, the particle position can be precisely located. Residual distributions for Monte Carlo electrons show a resolution of 540 μm (in $r - \phi$, 1.9 mm in z).[4] This figure is comparable to the MIP resolution, so we again conclude that 50 μm is a suitable target figure.

For electrons, the CPS cluster positions need to be precise enough to match tracks from the central tracker with clusters in the calorimeter. The 50 μm target is more precise than needed for this purpose. Where the position resolution may be more important is in locating photon cluster positions. The direction of the photon will be more precisely determined by the CPS than the calorimeter.

4. **Strategy for Initial Alignment of Octants**

For each octant we will need to determine six numbers for displacements and rotations of the local CPS coordinates relative to the DØ coordinate system.* The displacement of the center of the CPS coordinate system relative to the DØ coordinate system will be specified by δx, δy, and δz. Rotation about the z-axis will result in a $\delta\phi$ offset, rotation about the x-axis gives a $\delta\beta$, and rotation about the y-axis a $\delta\gamma$. We have created each of these six displacements in Monte Carlo data, plotting ϕ residuals versus ϕ and η and have observed the characteristic pattern of each of these offsets in each layer. We are working on a scheme to disentangle the six effects.

In addition to alignment effects, the fringe field of the solenoid can produce offsets from the nominal position of objects. In order to distinguish alignment effects from fringe field effects it would be useful to take alignment data with the magnetic field off. The fringe field effects can then be separately mapped in data with the field on.

Cosmic ray muons can be used for alignment, comparing reference tracks obtained from the central tracking with CPS cluster positions. (We assume here that triggers for cosmic ray muons passing through the central tracker are available and that such tracks can be well reconstructed offline.) Given a cosmic ray flux of about $0.02/\mathrm{cm}^2/\mathrm{s}$ and the effective area of a CPS module, we expect a rate of about 170 cosmic rays per second in a given module. Assuming factors of order one in the propagation of errors from the eventual residual formulas, a 50 μm precision based on a 510 μm intrinsic resolution for MIP's can be obtained with about 200 events per octant. Hence a few seconds of cosmic ray data taking should give us an initial octant alignment. To align strip by strip will require 160 times as much data, so perhaps 10 minutes of data taking is needed to get initial strip positions. If individual strips must be mapped along z to describe deformations from the assume rigid body shape, considerably more data would be needed.

* At this point we are assuming that the DØ coordinate system will be defined relative to the central fiber tracker.

5. **Summary**

In summary we propose using cosmic ray muons with the magnetic field off to align the central preshower detector to within a 50 μm precision. Such a precision should render alignment effects negligible in Run II physics analyses.

REFERENCES

1) Ken Del Signore, memo, April 1999.

2) A. Bross *et al.*, “Cosmic Ray tests of the DØ Preshower Detector,” submitted to *Nuclear Instruments and Methods*, June 2000.

3) Patricia Wagner, “Characteristics of the DØ Central Preshower Detector as Defined by a Fast Monte Carlo Algorithm,” Master’s Thesis, University of Kansas, Dec. 1999.

4) Andre Turcot, presentation at EM-ID meeting, February 2000.