Minimum Reflected Spot Size Measurements for Hall B’s Second Ring Imaging Cherenkov Detector

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Measurement results of the minimum reflected spot size, $d_0$, of spherical mirrors for Hall B’s second Ring Imaging Cherenkov (RICH II) are discussed in this note.

The RICH detector’s array of ten spherical mirrors, Fig. 1, focus Cherenkov light generated by charged particles with incident angles between 12° and 35° with respect to the beamline onto the photomultiplier tubes; mirror specifications are listed in Table I.

![Fig. 1. RICH spherical mirror array, consisting of ten mirrors. Tested mirrors 5 and 5C are labeled in red.](image)

Table I. Specifications for RICH II spherical mirrors.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius of curvature</td>
<td>2700</td>
</tr>
<tr>
<td>$d_0$</td>
<td>2.5</td>
</tr>
</tbody>
</table>

To determine whether mirrors made by Composite Mirror Associates, using a new fabrication mold, meet specifications, the minimum reflected spot size $d_0$ of mirrors 5 and 5C was measured [1] in the horizontal and in the vertical positions. Results are shown in Table II.

![Fig. 2. Test station.](image)

Table II. Results for first set of $d_0$ measurements.

<table>
<thead>
<tr>
<th>Mirror</th>
<th>Position</th>
<th>Lowest $d_0$ observed [mm]</th>
<th>Fit $d_0$ [mm]</th>
<th>Fit mirror radius of curvature [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>horizontal</td>
<td>1.950</td>
<td>1.98</td>
<td>2710.21</td>
</tr>
<tr>
<td></td>
<td>vertical</td>
<td>2.291</td>
<td>2.29</td>
<td>2702.53</td>
</tr>
<tr>
<td>5C</td>
<td>horizontal</td>
<td>2.248</td>
<td>2.26</td>
<td>2708.40</td>
</tr>
<tr>
<td></td>
<td>vertical</td>
<td>3.430</td>
<td>3.31</td>
<td>2700.78</td>
</tr>
</tbody>
</table>

![Fig. 3. $d_0$-vs-$z$ data and fit for mirror 5.](image)

![Fig. 4. $d_0$-vs-$z$ data and fit for mirror 5C.](image)

Figure 2 shows the test station setup. After taking into account the distance $D$ between the charge-coupled device (CCD) stand and the mirror stand and the offset values, the radius of curvature $R$ is given by the equation $R$ [mm] = 2803.276 [mm] - $z$ [mm]; where $z$ is the $z$ position of the CCD on the $z$-linear stage.
The $d0$ measurements for RICH II mirrors show that these new mirrors do not have the same quality as the RICH I mirrors. For mirror 5C of RICH I, the image of the reflected source light looks like a circular spot, Fig. 5, whereas for mirror 5C of RICH II, the image is distorted—not a circular spot, Fig. 6.

When the CCD stage is moved ~4 mm closer to the mirror, for mirror 5C of RICH I, the CCD image of the reflected light source has the same general shape as the mirror, Fig. 7, whereas with mirror 5C of RICH II, the image is distorted, Fig. 8.

To test whether these differences are due to the mirrors or due to the test equipment, the following checks were done.

1. The ambient light was reduced in the cleanroom. The results, Table III, were similar to the first set of measurements, Table I; thus, the darkening of the cleanroom had no effect on the $d0$ measurements.

2. The CCD stand and mirror stand of the test station were realigned using a laser-collimator set up to ensure that the CCD $z$-axis is parallel and aligned to the $z$-axis of the mirror stand. The only change after realignment was that the image on the CCD stayed in the same location rather than moving on the CCD as $z$ changed.

3. The intensity of the fiber-optic source used to direct light towards the mirror was increased as much as possible. This change resulted in a lower CCD exposure time being required to get the desired CCD count levels, but the overall results were not affected.

4. The fiber used to direct light toward the mirrors was cut and polished; again there was no effect.

Since none of the changes improved the results, it appears that RICH II mirrors 5 and 5C are of poorer quality than the mirrors 5 and 5C of RICH I.

Table III. Results for $d0$ measurements after darkening cleanroom.

<table>
<thead>
<tr>
<th>Mirror</th>
<th>Position</th>
<th>Lowest $d0$ observed [mm]</th>
<th>Fit $d0$ [mm]</th>
<th>Fit mirror radius of curvature [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>horizontal</td>
<td>2.468</td>
<td>2.81</td>
<td>2709.8</td>
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<tr>
<td></td>
<td>vertical</td>
<td>2.670</td>
<td>2.69</td>
<td>2704.26</td>
</tr>
<tr>
<td>5C</td>
<td>horizontal</td>
<td>2.008</td>
<td>2.16</td>
<td>2708.23</td>
</tr>
<tr>
<td></td>
<td>vertical</td>
<td>2.989</td>
<td>3.01</td>
<td>2702.15</td>
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