RICH Spherical Mirror Optical Tests

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After manufacturing of the Ring Imaging Cherenkov (RICH) Detector's spherical mirrors, their radii of curvature were measured by optically measuring the image size of a reflected source. Results show that only one mirror is 2 mm beyond the specification of 2700 mm ± 27 mm.

RICH uses ten carbon-fiber-reinforced polymer, spherical mirrors (Fig. 1), which focus Cherenkov light generated in the aerogel volume by charged particles, whose incident angle with respect to the beamline between 12° and 35°. To verify compliancy with specification, optical measurements of reflected image size *d0* of a source were taken for each mirror.

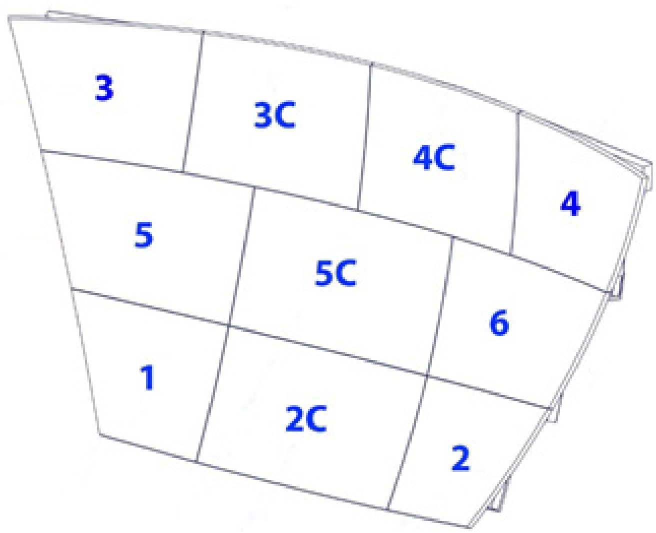

FIG. 1. Drawing of RICH spherical mirror assembly with mirror names labeled.

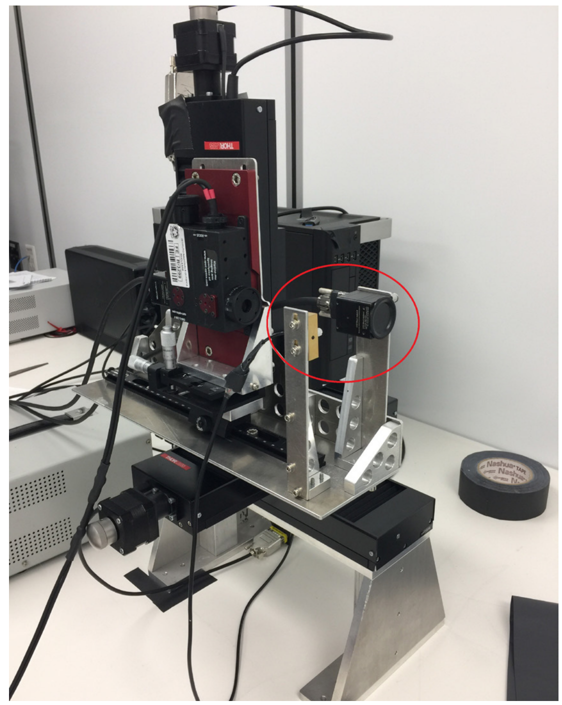

FIG. 2. CCD stand with stepper motors. The CCD and *d0* source are the two objects circled in red.

The *d0* measurements were taken inside a darkened clean room using a 4.2-megapixel Ximea charge-coupled device (CCD) and the *d0* source, both held by a stand with stepper motors on all axes, Fig. 2. The *d0* source comprised a red LED light connected to a jacketed fiber optic thread, which directed the light towards the mirror. A Debian Linux PC controlled and powered the CCD and *d0* source via USB, Fig. 3.

A Windows PC controlled the stepper motors, allowing for precise alignment of the CCD stand with the mirror being tested. The mirror was held in a separate stand placed approximately 2700 mm away from the CCD stand and allowed rotation in the *x-y* plane and in the *x-z* plane. Manual hand screws controlled mirror rotation and allowed for alignment with the *d0* source image and the CCD.

The distance between the mirror and the CCD, where the minimum *d0* is observed, gives the radius of curvature *R* of the mirror. The expected results were that *d0* < 2.5 mm and *R* = 2700 ± 27 mm.

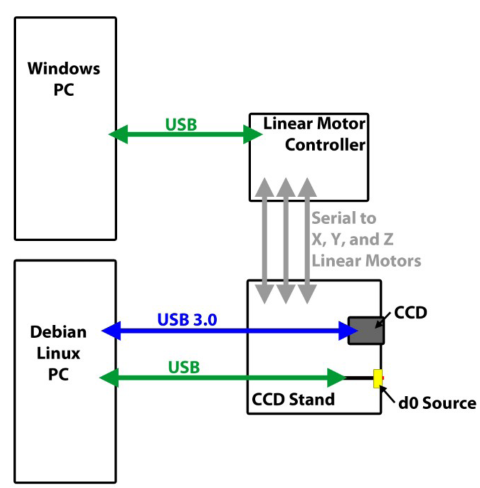

FIG. 3. System diagrams for controls and communication for *d0* measurements.

For each mirror, *d0* was measured by recording an image of the source with the CCD and analyzing the image with a ROOT-based program. Based on the number of photon counts observed in CCD pixels, the program found where the maximum number of counts was observed. The location of the maximum number of counts was assumed to be the center of the *d0* image. Then searching outwards from this center, the program found where the counts in a pixel were 5% of the maximum number of photons measured. These points should form a circle because the spherical mirror focuses light to a single point at its focal point. *d0* is measured from this circle. Figure 4 is an image taken by the CCD.

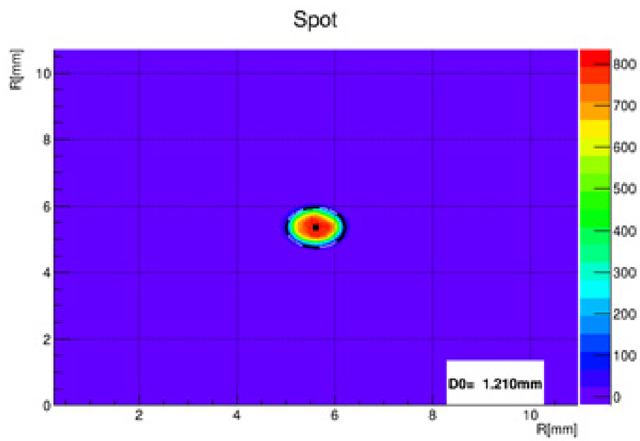

FIG. 4. CCD image of spot measured for mirror 5. The circle fit by the root-based program to measure *d0* is shown around the spot image.

To ensure that the minimum *d0* was found, several *d0* measurements were taken at different distances *z*. For a perfect mirror, the *d0* values and *z* measurements form a “V” shape, with the vertex at *d0*. Since the RICH mirrors did not have the final reflective coating, the measurements at the minimum formed a smooth and continuous curve rather than a “V”. Therefore, the points near the minimum were fit with a parabolic function to find a fit-*d0*, the corresponding *z0*, and the mirror’s radius of curvature. Despite not being a perfect mirror, at z > *z0* and z < *z0*, the data is linear, Fig. 5.

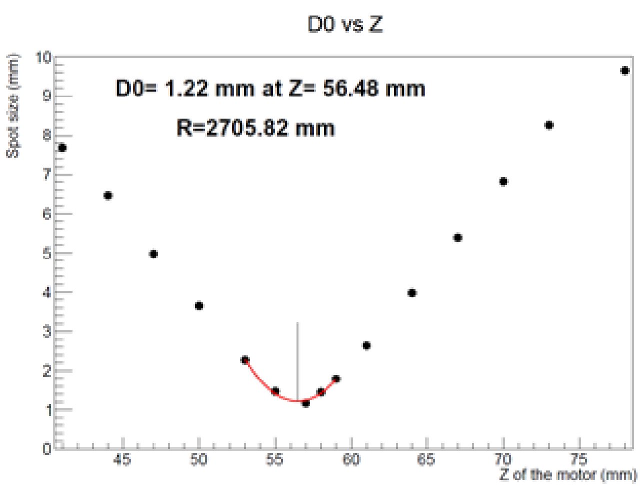

FIG. 5. Plot of *z* position of the motor vs. *d0* spot size. The points near the minimum fit with a parabolic function have the parabola fit plotted in red. The data not near the minimum appear to be linear.

Results of *d0* measurements showed that the mirrors meet specifications. All mirrors had *d0* < 1.8 mm. Measured radii were within the acceptable range, except for mirror 6. All results are in Table I.

		Measured		Parabolic fit		
Mirror	Configuration	*d0* [mm]	*z* [mm]	*d0* [mm]	*z* [mm]	*R* [mm]
3	horizontal	1.17	57.00	1.22	56.48	2705.82
3C	horizontal	1.29	60.50	1.40	60.42	2701.88
4C	horizontal	1.39	61.00	1.46	61.09	2701.21
4	horizontal	1.41	61.00	1.40	61.28	2701.02
5	horizontal	1.41	57.50	1.49	57.90	2704.40
5C	horizontal	1.37	56.00	1.47	55.75	2706.55
	vertical	1.55	60.50	1.49	61.29	2701.01
6	horizontal	1.80	8.00	1.79	7.48	2729.81
1	horizontal	1.51	57.00	1.55	56.82	2705.48
2C	horizontal	1.19	56.50	1.34	56.48	2705.83
	vertical	1.21	61.50	1.36	61.69	2700.62
2	horizontal	1.30	58.50	1.42	58.36	2703.94
	horizontal	1.40	58.50	1.46	59.18	2703.12

TABLE I. Measured *d0* results and fit *d0* results. Mirrors 2C and 5C were measured in both vertical and horizontal positions because of their symmetric shape. Mirror 2 was measured twice, with measurements occurring a few months apart, to verify that the quality of the mirror did not decrease during its storage.