MANUAL FOR CLAS12 RICH SPHERICAL MIRROR CHARACTERIZATION

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1 Contacts

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2 General description of the RICH Spherical Mirror System

The spherical mirror of the RICH detector is made of 10 sub-mirrors of approximate dimensions 600 x 800 mm^2 for a total area of about 3.5 m^2. The mirrors are made of two sheets of carbon fiber reinforced polymer (CFRP) and a honeycomb core of the same material. The area density is around 4.2 kg/m^2. The mirror drawing [1] is visible in Fig. 1.

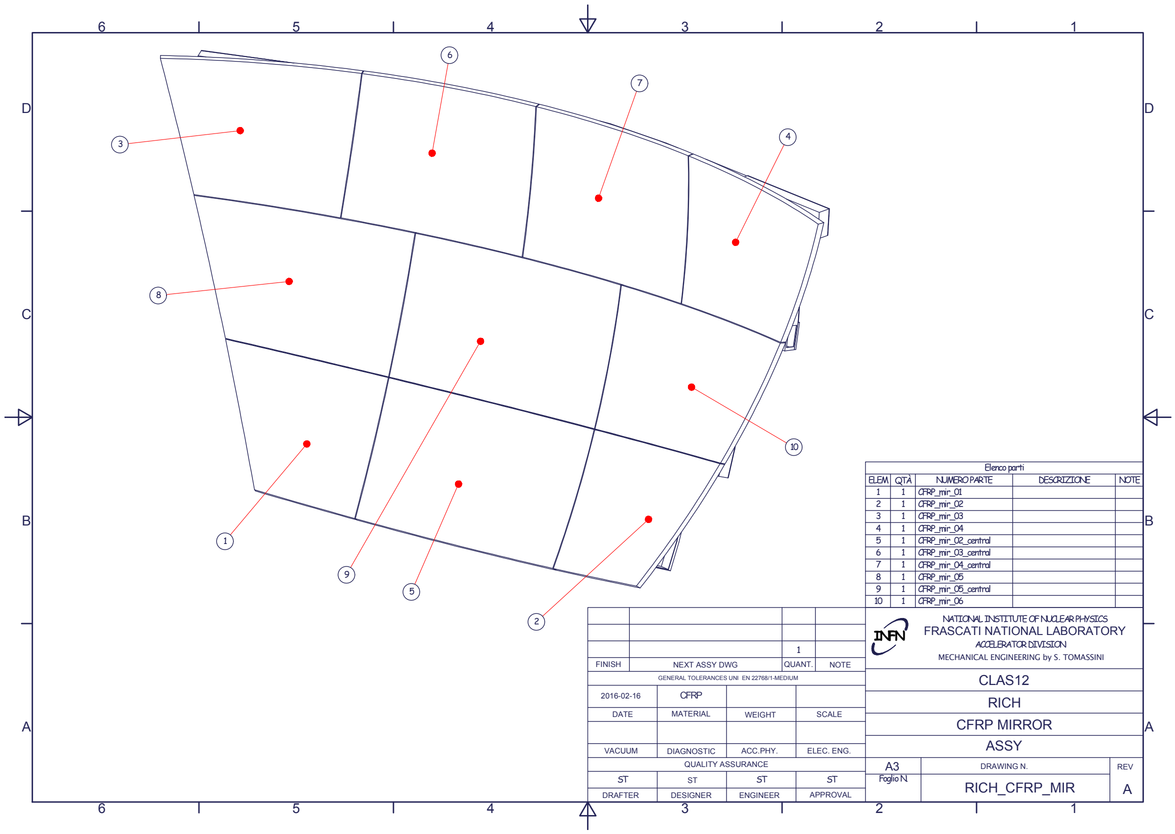

Figure 1: Mirror drawing.

The mirrors are being delivered to JLab for acceptance tests. In the fall, they will be assembled in the supporting structure at CMA, (Tucson), and then sent to the ECI coating company, (Philadelphia). This document describes the handling and testing procedures for the acceptance tests.

The mirror are labeled as:

1. CFRP_mir_01, delivered at JLab in
2. CFRP_mir_02, delivered at JLab in
3. CFRP_mir_03, delivered at JLab in June 2016
4. CFRP_mir_04, delivered at JLab in June 2016
5. CFRP_mir_02_central, delivered at JLab in May 2016
6. CFRP_mir_03_central, delivered at JLab in May 2016

[1]the electronic version is available at https://www.jlab.org/Hall-B/secure/clas12/RICH/Mirrors/SphericalDrawings/2016-02-16-CFRP-Mirrors_Assy-2700.pdf.

7. CFRP_mir_04_central, delivered at JLab in May 2016
8. CFRP_mir_05, delivered at JLab in
9. CFRP_mir_05_central, delivered at JLab in May 2016
10. CFRP_mir_06, delivered at JLab in

Each mirror should fulfill the following specifications to ensure the optical performance required by the RICH detector.

1. Spot-image diameter D0 < 2.5 mm: the reflected spot af a point-like source at the mirror center should be point-like, except for the aberrations occurring at the mirror surface. This is verify by the spot-image measurement described in Sec. 4.
2. Radius $= 2700 \pm 1$ % mm : the radius of curvature can be approximated by the distance of the mirror to the sensor when the spot-image is at the minimum size.
3. Surface rms < 0.5 μm: a Shack-Hartmann wavefront sensor is used to measure the distortion of the reflected wavefront with respect the ideal sphere when the point-like source is on the mirror center. The residuals correspond to the double of the surface imperfections.
4. Geometrical tolerance < 0.5 mm: when mounted on the support the mirrors have a 3 mm gap to allow alignment while minimizing the dead space. The mirror 3D geometry should be precise enough to not interfere with this gap. A measurement with a coordinate measurement machine (CMM) can be done to verify the mirror 3D geometry.

3 Safety considerations

3.1 Personnel

The mirror characterization does not present risks for the personnel except for the automatize movements of the supports (when activated) and the working on a dark and enclose room.

3.2 Cameras

The cameras are sensitive to dust and light over-exposure. Take care to operate with the cover on the camera until everything is mounted and pre-aligned. Turn off the EEL-121 light before turning ON the camera.

3.3 Mirrors

The CFRP mirrors are sensitive to the environmental conditions (i.e. temperature) and subject to moinsture absorption. The EEL-121 cleaning room is conditioned, however special care has to be taken to minimize the exposition of the mirror to the ambient humidity. The mirror surface should be preserved untouched and any stress to the mirror substrate minimized.

- Any mirror operation should be done inside a clean-room (EEL-121 or EEL-124).
- Never allow the mirror to go above 40 Celsius degrees in temperature.
- Keep the mirror inside their envelopes (plastic foam, Al bag and cartoon box).
- After opening, keep the Al bag as much as possible sealed (with tape) to prevent moinsture absorption.
- When working on the mirror, wear plastic gloves and mask.
- Do not touch, scratch, hit the reflecting surface (examples of risks are tool falling, fingerprints, dust, tape glue). In order to prevent the packaging tape touching by chance the surface, take care to fix any tape free end to a fixed element (i.e. the table).
- Hold the mirrors only from the back.
- Move the mirrors in two persons to reduce the risks of stress and fall.
- The CFRP material is rigid thus the mirrors should be self-sustaining. However any stress and torque should be minimized.

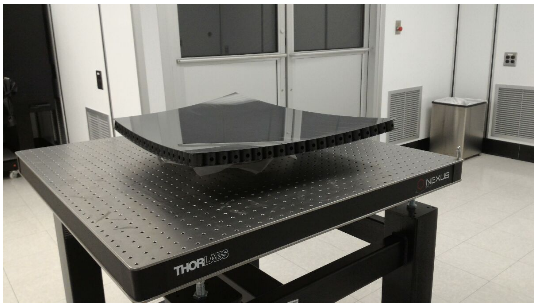

Figure 2: Unpacked mirror lying on table.

4 Spot-Image Measurement

Since the setup for the full optical characterization of the mirrors is not ready yet, in this phase only a spot size measurement will be done (the diameter is called D0 hereafter). The specification for accepting the mirror is D0<2.5 mm. Typical values (from previous measurements) should be D0<1.5 mm.

The optical instrumentation shipped from Italy comprises:

- light source made of a red-light LED (powered via USB port) glued to a short 1 mm diameter optical fiber;
- XIMEA CMOSIS 10-bit photocamera with a 1 cm wide sensor and 2048x2048 pixels acquired via USB3 port;
- mechanical support for photocamera and source (not motorized yet);
- mechanical support for the mirror alignment (not available yet).

The photocamera and the source are managed by a linux PC. The PC must be configured with Debian linux and it should be connected to JLab internet guest network. To access the computer, **User:** lab **Passwd:** ask to Detector Support Group (DSG).

Figure 3: Mirror in vertical position for spot-image measurement.

Procedure:

1. unpack the mirror on a table, hold and place it on the back surface, see Fig. 2.
2. place the mirror in position for the measurement: put the mirror in an almost vertical position, with the "Top" side on top, the bottom leaning on two foam supports near the corners and the back touching the clean-room wall almost in the mirror center, see Fig. 3. The foam supports should be 1-2 cm far from the wall to allow adjustments.
3. place the camera on a table in front of the mirror, at a distance of about 2.7 m. The plastic cap should be mounted on the camera to prevent dust contamination and over-light exposure.
4. the source should be located at about 1 cm from the camera case, with the fiber ending in corrispondence with the camera sensor, see Fig. 4.

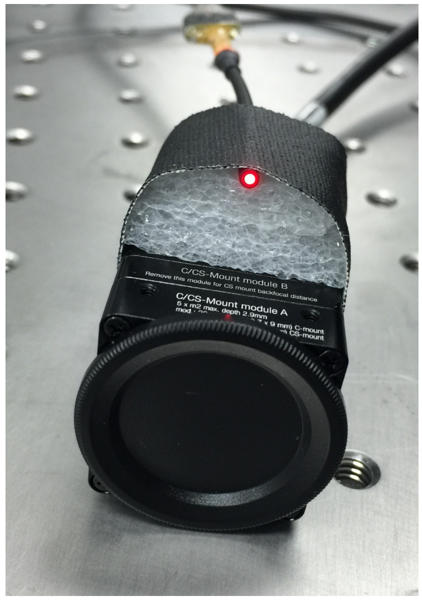

Figure 4: Fiber mounted on top of the camera.

5. look for the reflected spot: use a white sheet of paper and search the spot in the space in front of the mirror at about 2.7 m of distance; at the right distance, the spot should be visible also with the room lights on.

6. align the system: gently push the foam supports just a little (about a mm step) towards or far from the wall to change the vertical orientation and bring the reflected spot at the same height of the camera center.

7. move the camera support left-right to center the spot on the camera center and back-fort toward the mirror to focalize the spot on the sensor, see Fig. 6.

8. turn OFF the EEL-121 room light before turning ON the camera (remove the camera plastic cover).

9. use xiCamTool graphic interface program to look the camera live stream and fine adjust the spot position at the center of the sensor and focalize the spot size at its minimum.

10. create the correct directory for storing the measured data and work from it:
    /data/lab/mirror_name/date_of_measurement/
    An example is /data/lab/CMA_3/2016-08-02/.

11. **take a picture**, use ximea-shot <gain> <expo>

    gain: gain of the sensor, default value = 0 (do not change it)

    expo: exposition time (ms), default value = 1 (do not exceed 20 ms).

    This script returns a txt image grey.txt and a string with the minimum and maximum values recorder, the number of pixels with no or saturated signals. In order to adjust the exposition time, take several measurements until the maximum is around 850-950. When you are satisfied, rename the image as mis[n].txt. As the camera has its own electronic background and there could be some residual light in the environment, a background image should also be recorded. Use the program above with the same settings of the image to be corrected, with a screen in front of the mirror to prevent light reflection. Rename the `grey.txt` output file as `bkg[n].txt` [2].

12. subtract the background, use `txt-image-sub` <`mis[n].txt`> <`bkg[n].txt`>.
    This script returns a txt image `out.txt` that should be renamed as `mis[n]_corr.txt`.

13. perform a D0 analysis, use `d0-valG` <`mis[n]_corr.txt`>.
    This root-based program returns a string with the following values in mm:
    <`D0`> <`D0err`> <`Diameter along X`> <`Diameter along Y`> <`X_center`> <`Y_center`>
    and stores a root file with several graphs, see Fig. 5:

    grSpot: 2D histo with the spot and the D0

    grD0: Normalized Intensity D0

    PrX: Spot Projection on X

    PrY: Spot Projection on Y

    TotInt: Total Intesity

    Int: Running Intensity

    To open the root file use `root -l` <`filename.root`> and list the content with `.ls()`. Plot a graph with <`graph_name`>`.Draw()` or simply navigate on the graphics using `TBrowser b`.

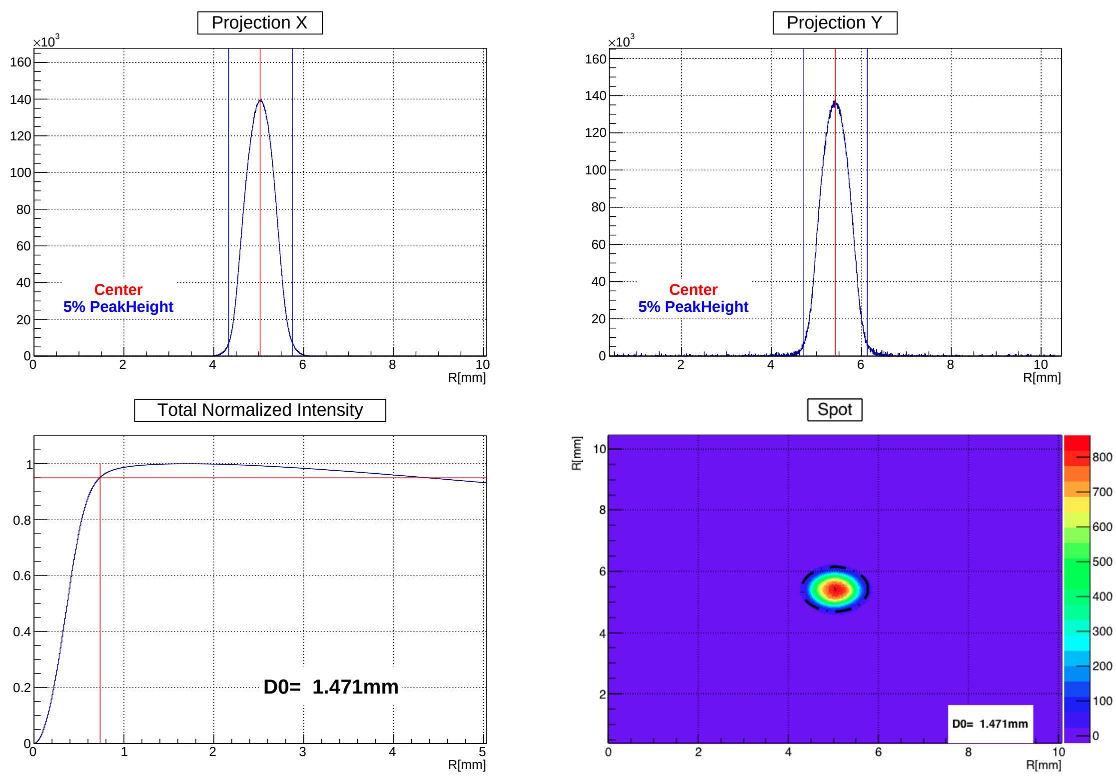

Figure 5: Examples of the D0 analysis graphs: the reflected spot profiles PrX and PrY (top), the normalized intensity radial profile grD0 (bottom-left) should present a flat plateau in case of correct background subtraction, the 2D histo of the reflected spot image grSpot.

[2] do not use blanck space in the file names or tabs in the file text.

14. perform a mirror centering (z scan), take several background-subtracted images at different distances (z camera position) from the mirror. The range of the scan should not exceed ±3 cm. For each image, store the information of the "z camera position" and "D0 value" in a dedicated `scan.txt` file. All the values should be in mm and the z values should be ordered from the smallest to the largest.

15. perform a scan analysis, use `d0-fit-z0` <`scan.txt`> or `d0-fit-z0-pdf` <`scan.txt`>. The program perform a parabolic fit to find the position with the minimum D0, corresponding to the mirror center and return a string with the found values in mm:
    <`D0 at minimum`> <`z at minimum`>.
    The second script returns also a `ScanZ.pdf` file, to be renamed by the user.

16. measure the D0: perform a D0 analysis at the z position corresponding to the minimum spot size. This should correspond to the sensor being at the mirror center. At this position, measure the distance of the camera from the wall holding the mirror as a raw estimate of the mirror radius.

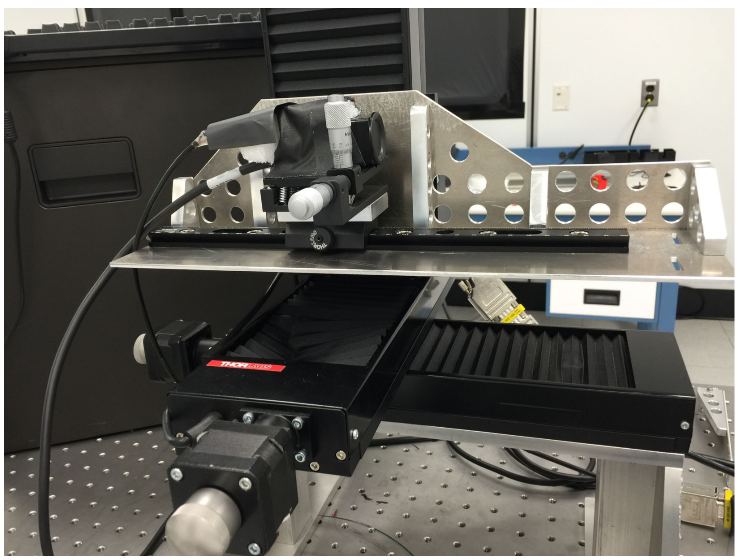

Figure 6: Sensor support and positioning. The light source is visible on top of the camera.

5 Coordinate Measurement Machine

Figure 7: Mirror leaning on the cylindrical support, awaiting to start the CMM operations.

Procedure:

1. The measurements must be performed in the clean room.

2. Unpack the mirror on a table, hold and place it on the back surface, see Fig. 2.

3. Place the mirror in position for the measurement: put the mirror horizontally on the cylindrical support used for the first 4 mirrors. Check that the mirror is safely stable on the support by gently touching the back vertixes. If not, lift the mirror to shift its position on the support until a stable condition is found, see Fig. 7.

4. Ask the operator to be careful to not hang over the mirror with the head of the machine, to avoid the risk that it could fall onto the mirror.

5. All the following measurements must be performed on the two skins of each mirror, see Fig. 8:

   - the 4 edges of the mirror, by touching the mirror from the side in step of 2 or 3 cm, so that at least 20 points are measured on the short sides and 30 on the long sides;
   - the 4 corners, by touching the mirror on the back of the skin at 2-3 mm step on both side of the corner; is not required to extend the measurement along the edge on the back of the two skins.

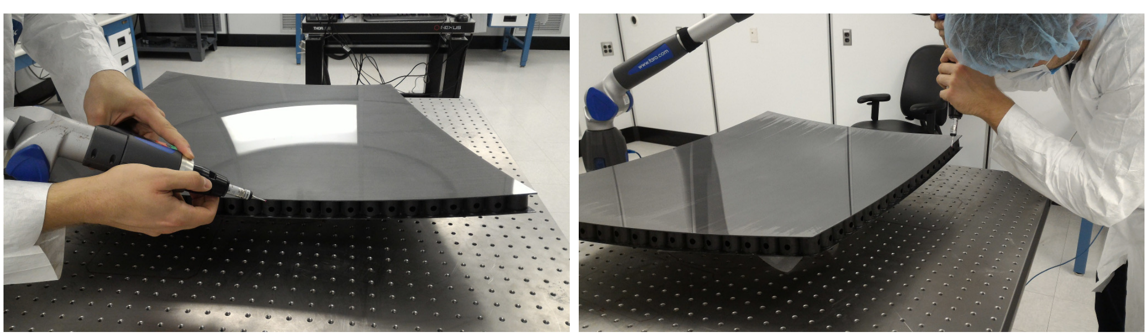

Figure 8: Operation during CMM measurement

6 Experts

If the root macro (directory /lab/d0) has been modified it needs to be compiled with the string
g++ -I ‘root-config --incdir‘ -Wall -O2 ‘root-config --libs‘ -lz <macro.C> -o <macro>.

If the macro has been modified and compiled, the compiled binary needs to be moved to /usr/local/bin as root in order to be able to run the program in every directory.

Compact the acquired text images to save space with gzip -9 <filename>.