Mirror System of the CBM RICH Detector

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CBM

Compressed Baryonic Matter experiment at FAIR

The CBM RICH Detector

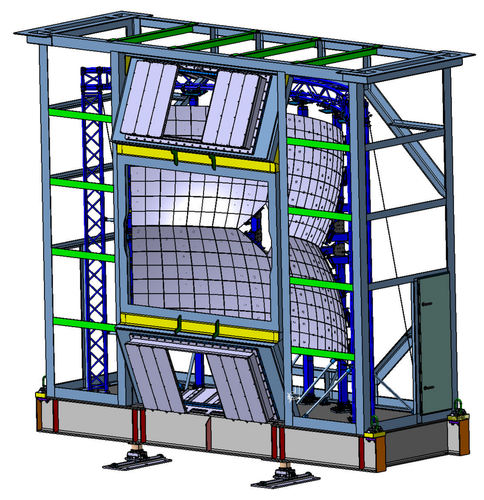

Fig. 1: CBM-RICH.

The CBM RICH is the essential detector for identification of electrons in order to measure di-electron emission from hot and dense matter which is one of the most promising signals to characterize this matter created in A+A collisions in CBM

Mirror Data:

Area	Segments	Material	Coating	Radius	Focal Length
$13\,m^2$	80	Glass	$Al+MgF_2$ or $Al+MgF_2+HfO_2$	3 m	1.5 m

RICH Data:

Gas	n	$l \times w \times h$	Volume	π-threshold	UV-cutoff
CO_2	1.00045	$2.2 \times 6 \times 5.2\,m^3$	$70\,m^3$	$4.65\,GeV/c$	180 nm

Photodetector planes: MAPMTs (H12700, 1000 pcs), 65k channels, DiRICH readout, free streaming DAQ, placed inside large shielding boxes

Mechanical Design of Mirror Wall

Fig. 2: Left: Full-size pillar prototype with 3 mirrors mounted. Top: Mirror backside. Bottom: Pillar adjustment plate.

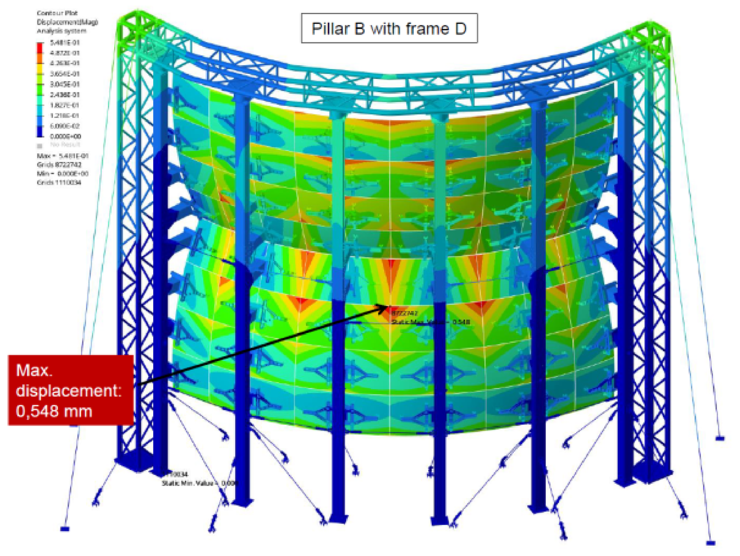

Fig. 3: Simulations have shown that the maximum displacement of the mirror wall due to gravity is 0.55 mm.

- Mirror wall design with focus on low material budget but high stability.
- 6 pillars holding two rows of mirrors each.
- Mirrors glued to holders at three spots to reduce displacement due to gravity
- Cardan shafts allow for distortion-free fine adjustment of mirrors
- FEM calculations show max displacement by 0.55 mm due to gravity (see fig. 3).

Mirror Characteristics

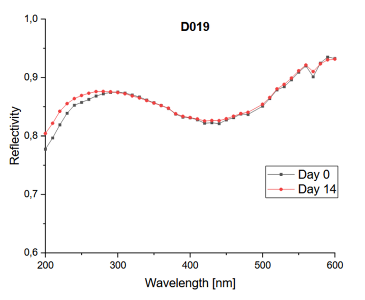

Fig. 4: Reflectivity of mirror D19. 14 days in the climate chamber.

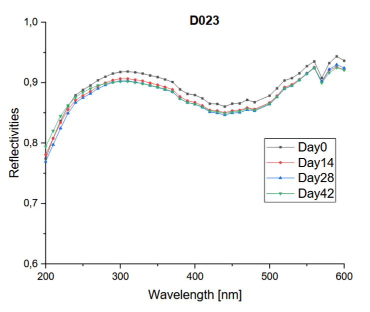

Fig. 5: Reflectivity of mirror D23. 6 weeks in the climate chamber.

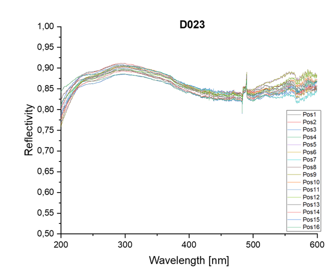

Fig. 6: Reflectivity at 16 locations on a single mirror.

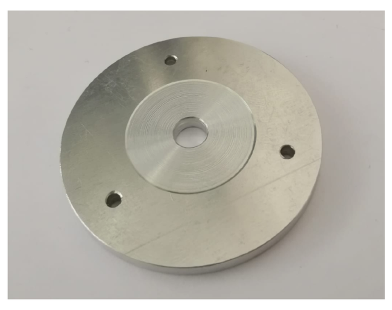

Fig. 7: Holes in the mount allow excess glue to escape, reducing distortions.

- Reflectivities of the HfO_2+MgF_2 coating were compared before and after harsh treatment (40 °C and 70 % humidity) in a climate chamber for 2/6 weeks.
- Reflectivity is stable. Drop of 1 % in fig. 5 is attributed to dust contamination.
- Glue: 0.7 g of Momentive RTV 157

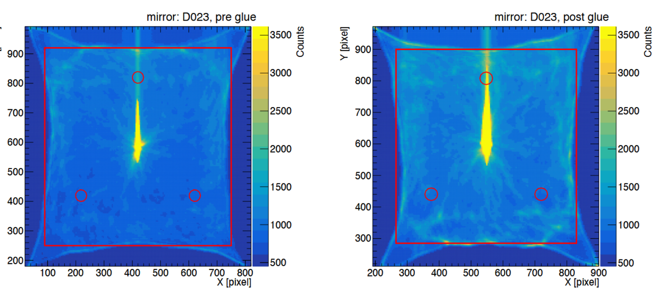

Fig. 8: Qualitative inspection of local surface homogeneity before and after gluing; red circles indicate the position of the glued mounts. There is only little change.

Mirror Alignment Control System

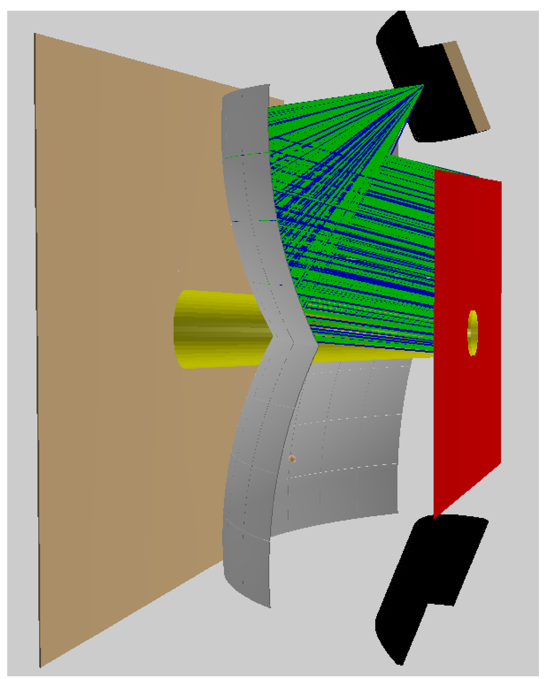

Fig. 9: Simulation Setup.

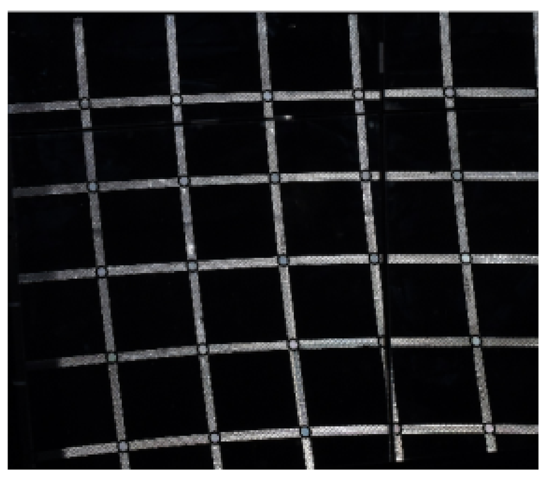

Fig. 10: Perfect alignment in RICH prototype.

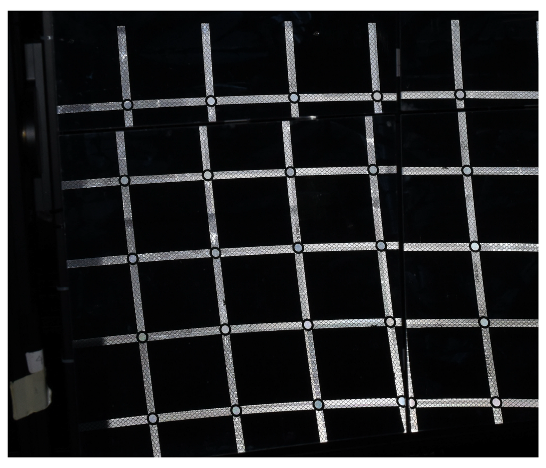

Fig. 11: Misalignment in RICH prototype.

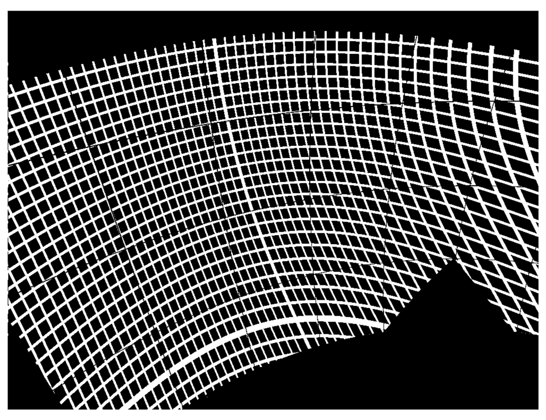

Fig. 12: Image created by raytracing for quantitative measurement.

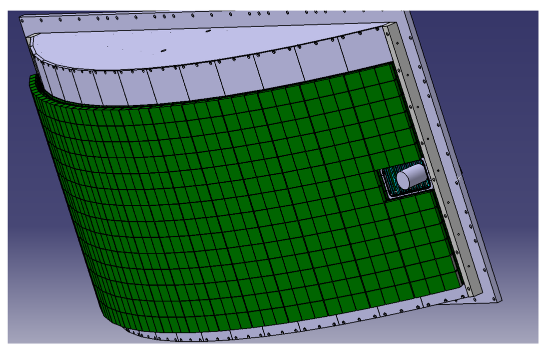

Fig. 13: Planned camera location. The grey cylinder is the lens.

Purpose

- Mirror alignment must be supervised to ensure correct track-ring matching; beyond 1 mrad = 0.05° misalignment, the matching deteriorates.
- Larger misalignment must be detected in order to correct for it in software during data analysis.
- The RICH detector will be exchanged with the CBM-MUCH detector on a 1 to 2-year basis by craning, which poses the risk of misalignment.

Principle: CLAM

(Continuous Line Alignment and Monitoring)

- Originally developed for the COMPASS RICH-1 [1].
- A reflective grid placed near the entrance window is observed by cameras via the mirror.
- Alignment can be assessed qualitatively by eye.
- Misalignment can be determined quantitatively either using calibration measurements or using the procedure below:

Quantitative Measurement: Procedure

- In order to determine the actual orientation of the mirror, a simulation (fig. 9) is fitted to the measured image.
- Simulation uses raytracing to create an image given a set of rotation parameters Θ.
- Those values of Θ that create the largest overlap with the measured image, are an estimate of the true mirror orientation.

System Components

- 4 cameras placed at the sides of the photodetector plane. Mounted to modified backplanes
- Wide angle lenses
- Camera readout via ethernet
- The entry window is expected to bulge. Therefore, the grid will not be attached to the entry window, instead a grid of tensioned strings will be used.

Simulation Studies

- The expected precision of the method is investigated using a simulation.
- The misalignment is determined very precisely (< 0.5 mrad, fig. 14) if focal length and camera orientation are known precisely
- If the focal length used to create I_{true} and I_{sim} differ, the results deteriorate (fig. 15). The tolerance is between 2% and < 1% depending on the mirror tile.

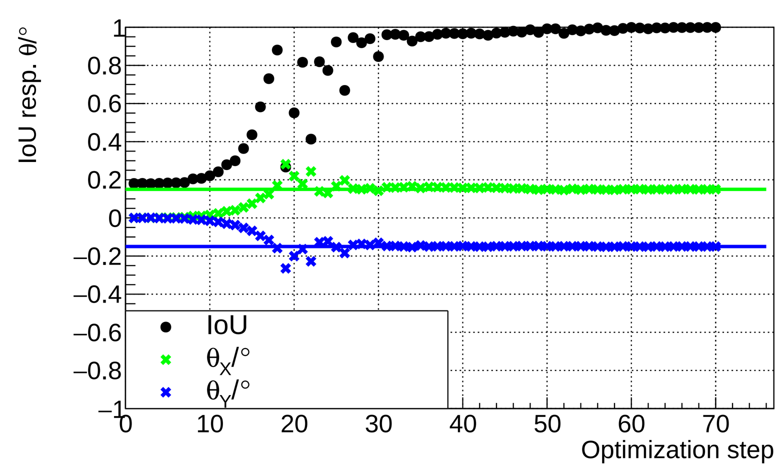

Fig. 14: Optimization. The overlap (black) approaches 1, θ_X and θ_Y estimates (crosses) approach the true value (solid lines).

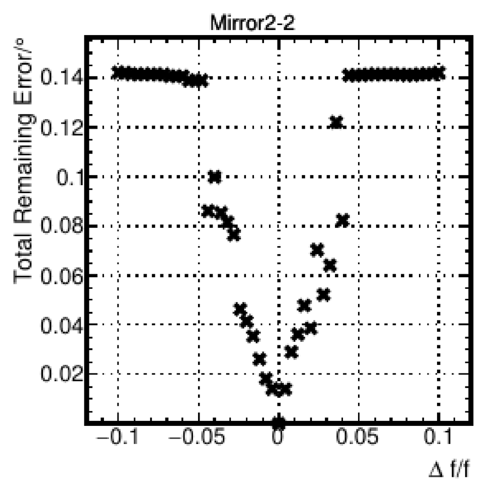

Fig. 15: Remaining uncorrected error after optimization depending on relative error of the camera's focal length ($\Delta f/f$)

Summary

- FEM simulations show the stability of the mirror wall design.
- The mirrors' reflectivity is stable after treatment in the climate chamber. The gluing procedure does not cause problematic distortions.
- A system for mirror alignment and control is under development. It shows promising performance in simulation studies.

[1] S. Costa et al. "CLAM, a continuous line alignment and monitoring method for RICH mirrors". In: Nucl. Instrum. Meth. A 553.1 (2005), pp. 135–139.

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