Measurements of the mirror surface homogeneity for the CBM-RICH detector

Elena Lebedeva
for the CBM collaboration
(University Giessen)

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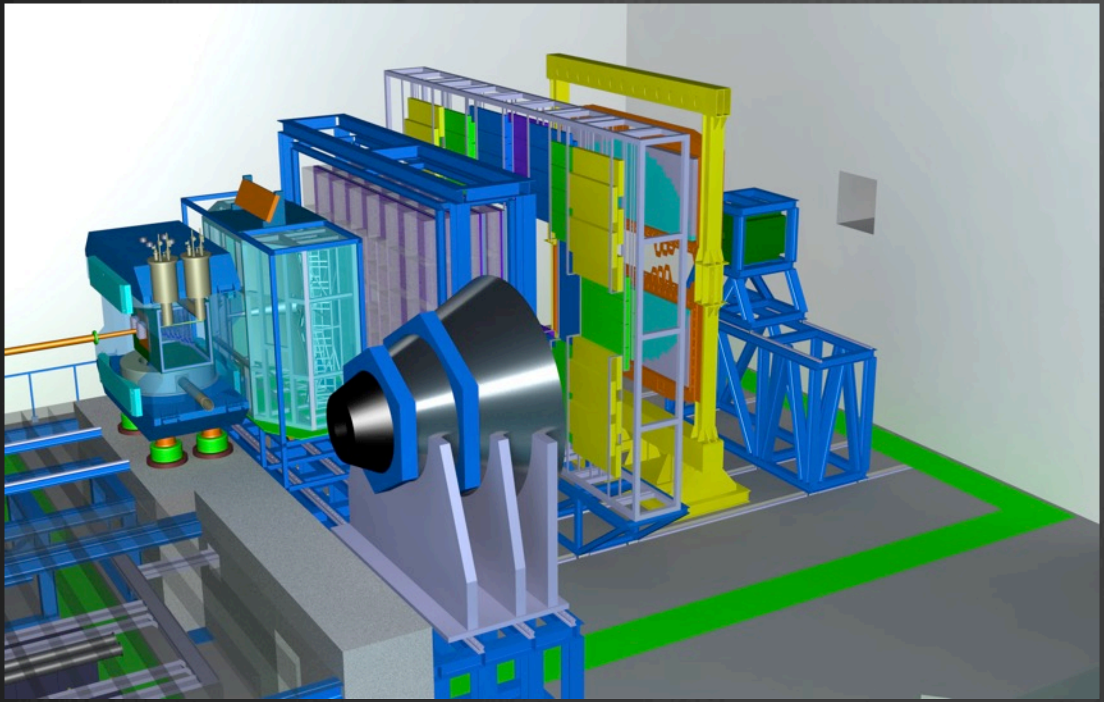
CBM experiment

- Exploring the QCD phase diagram at moderate temperature.



Energy range to be studied:

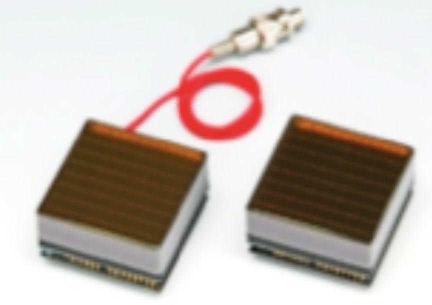
- SIS 100 2-11AGeV
- SIS 300 11-35 AGeV for Au-Au collisions

Sequence of the detectors:

- **MVD** and **STS** within the dipole magnet – tracking, momentum determination, vertex reconstruction
- **RICH**, **TRD**– electron identification
- **MUCH** – muon identification
- **ToF** – hadron identification
- **ECAL** - photons, π^0
- **PSD** – event characterization

RICH detector

- The CBM-RICH detector is designed to provide electron identification in momentum range up to 8 GeV/c.
- It will be operated with:
  - **1.7m long CO_2 radiator gas** (n=1.00045, threshold for pions is 4.65 GeV/c)
  - **Multi-Anode Photo Multipliers** (MAPMTs) as photon detector
  - **Spherical glass mirror** as focusing element (80 mirror tiles: 6mm thickness, trapezoidal form of approx. 40×40 cm^2, Al+MgF_2 reflective and protective coating)

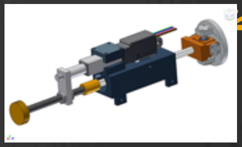


Hamamatsu H8500

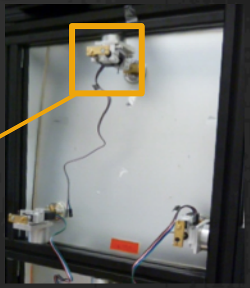
JLO Olomouc

Mirror surface homogeneity

- A good optical quality of the spherical focusing mirror, in particular in terms of reflectivity and surface quality (homogeneity), is essential for the performance of the RICH detector.
- The optical surface homogeneity determines the imaging quality or "sharpness" of the projected Cherenkov rings and has direct influence on the ring finding and fitting performance.
- Surface homogeneity is measured
  - globally with the D_0 measurement
  - locally with the Shack-Hartmann and/or Ronchi test



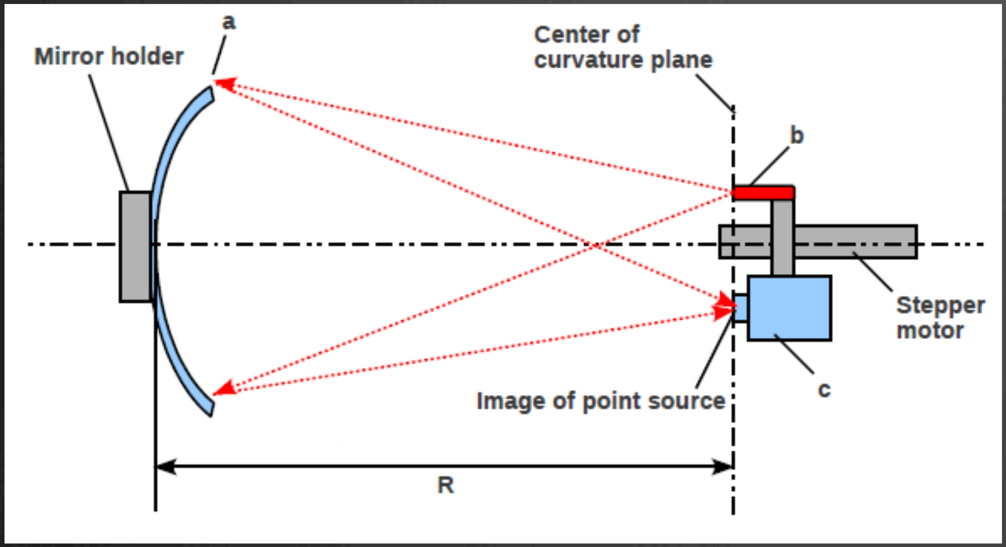
cardanshaft



mount system

D_0 measurements

Experimental setup for D_0 measurements



a – **spherical mirror** (SIMAX glass 40×40 cm^2 from JLO Olomouc with R_{cur} = 3m)

b – **laser point source** with wavelength 650nm

c – Andor iKon **CCD camera** with 1024×1024 pixels (13.3×13.3 mm^2)

R – **radius of mirror curvature**

- D_0 is defined as diameter of the circle, which contains 95% of the total light intensity reflected by the mirror when illuminated with a point source.
- D_0 is expected to be the smallest at a distance of the radius of the mirror curvature.

D_0 measurements

Two different measurements were done for each mirror:

- at the nominal radius of curvature
- for the smallest spot of reflected light

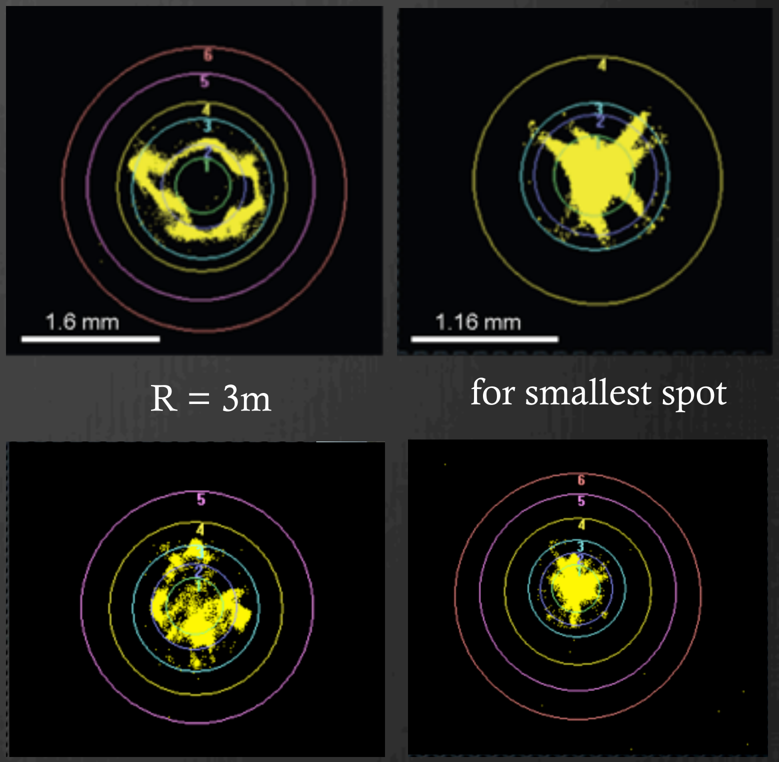
Ideally both measurements give the same results.

Mirror	$D_{0,min}$ [mm]	ΔR [mm]	D_0 (R=3m) [mm]
SP01	1.16	+5	1.60
SP02	1.42	+12	2.58
SP03	0.88	+5	1.81
SP04	1.3	+13	2.89
Mounted mirror	0.98	+3	1.4

Due to cutting process the mirrors lose some of their concavity leading to a larger radius.

D_0 value is well below the anticipated photon detector pixel granularity of 5-6 mm.

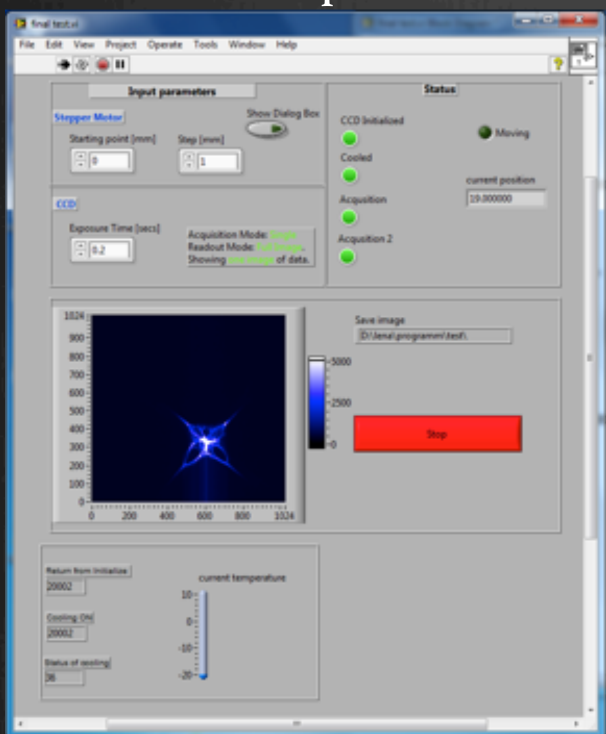
CCD camera view



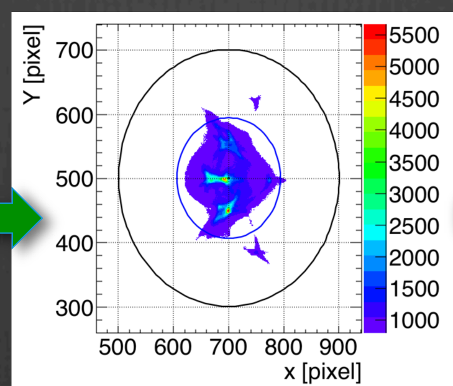
D_0 measurement automatization

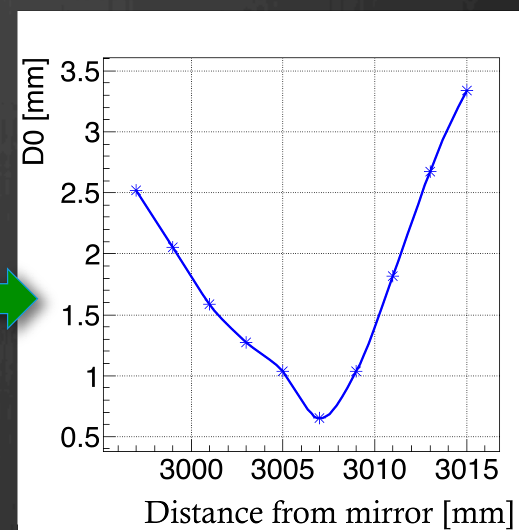
- Automatization of the process allow to make fast measurements and more precise analysis, quality control for 80 mirror tiles.

LabView program to speed up the measurement process



D_0 analysis with C++ program



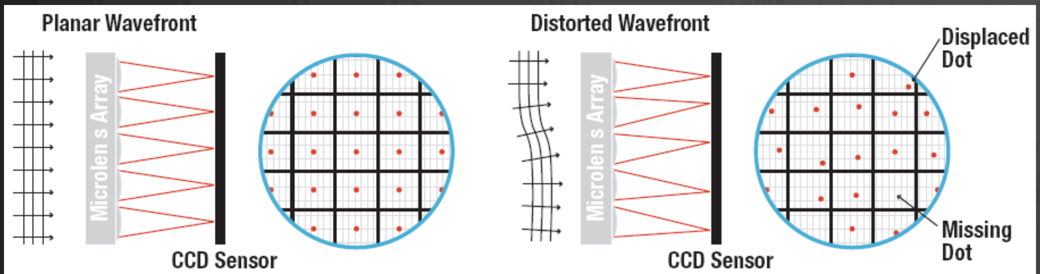


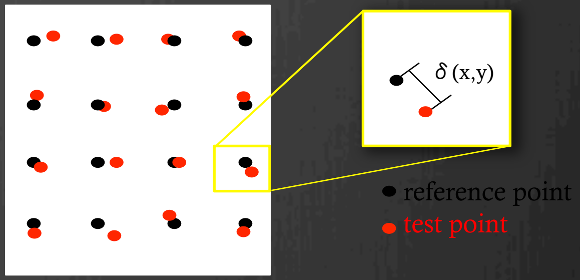
Determination of the radius of curvature R for measured mirror

Shack-Hartmann method

- Shack-Hartmann test enables to reconstruct the topography of the mirror reflective surface. It can give information on the location of mirror deformations and deviations from an ideal spherical surface.

Principle





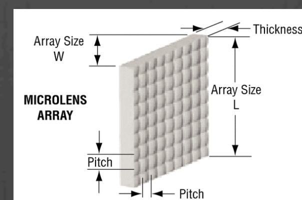
- A Shack-Hartmann wavefront sensor uses a lenslet array to divide an incoming reflected wavefront from the mirror into an array of smaller beams.
- Each beam is focused onto a camera that is placed at the focal plane of the lenslet array.
- In case of ideal mirror the grid of spots on the detector is formed.
- The mirror with surface deformations will distort a wavefront, what will cause some lenslets to focus with spots displaced from the optical axis.

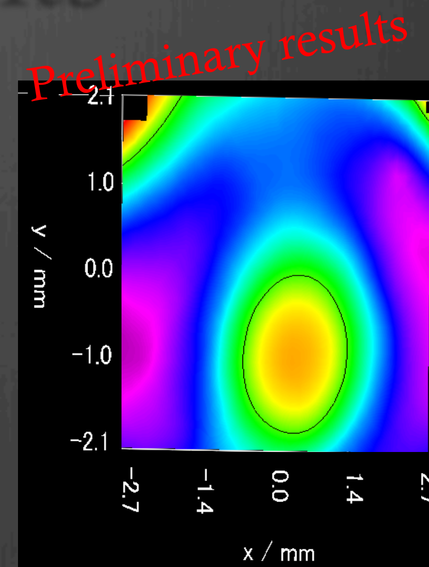
First Shack-Hartmann measurements

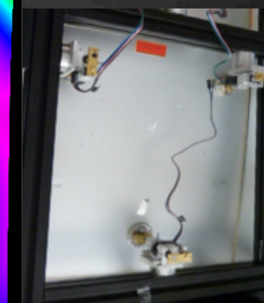
Wavefront sensor based on a CCD camera

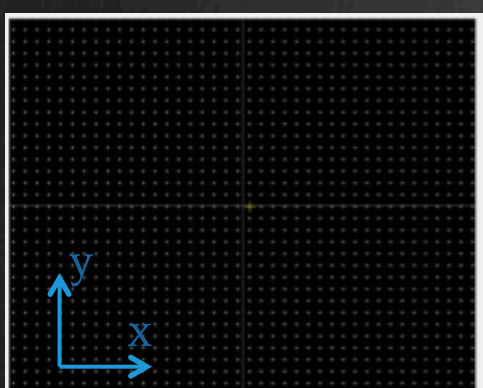
Uses an anti-reflection coated microlens array that reduces the reflection from the array to below 1% within the wavelenth range of 400-900nm.

Microlens arrays with pitch 150 μm and 300 μm

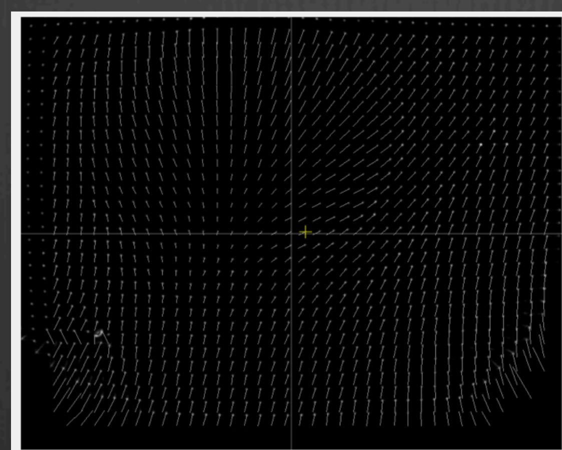








Camera view of reference points



shows the shift between the actual spot position and its corresponding reference position as a line

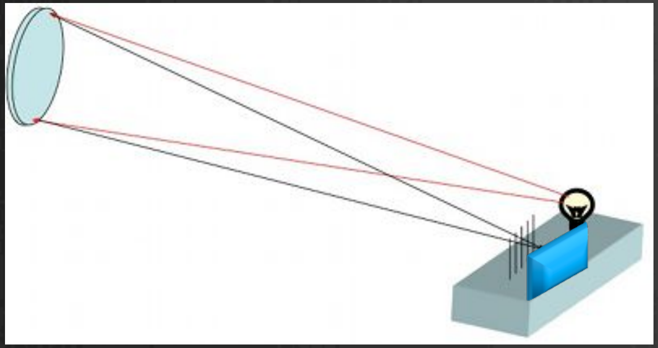
Displays the reflected wavefront as a 2D image. The wavefront data array is retrieved from the spot shifts which are directly proportional to the local derivatives of the wavefront.

The wavefront deformation is displayed in the direction of z-axis.

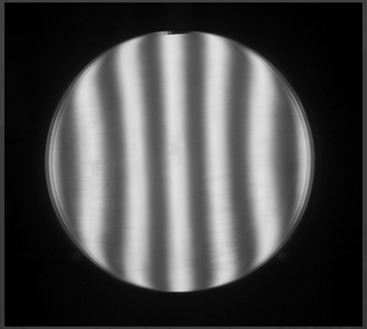
Ronchi Test

Principle

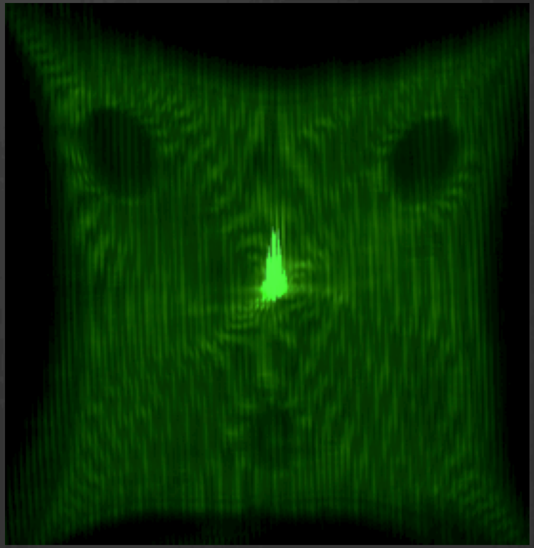
- Linear grating mask placed in front of CCD camera, reflected light from mirror passes though the grating mask.
- On the camera a shadowgraph (Ronchigram) of the linear grating is observed.
- The shadowgraph is deformed by surface irregularities. Fast qualitative check; can also be used for quantitative evaluation of mirror surface deformations.



Example of Ronchigram



CCD camera view



Deformation caused by mounted system nicely can be observed

Summary

- Mirror quality measurements:
  - Radius of curvature: + 5-10 mm from nominal radius due to cutting process
  - Global surface homogeneity measured with D_0 measurement: 1-2 mm
  - Local deformations possibly due to mirror mounts – first measurements