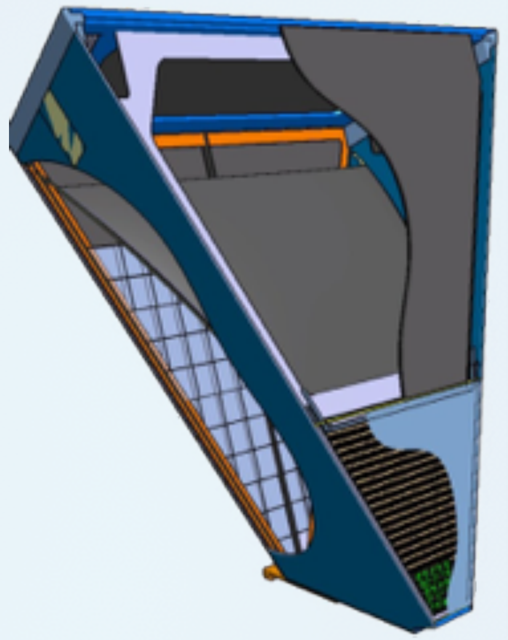
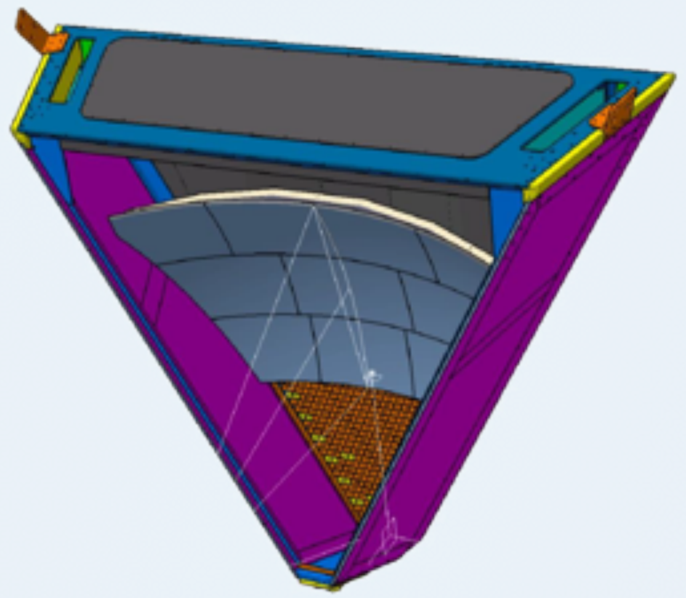
Giovanni Angelini
Hugs 2016

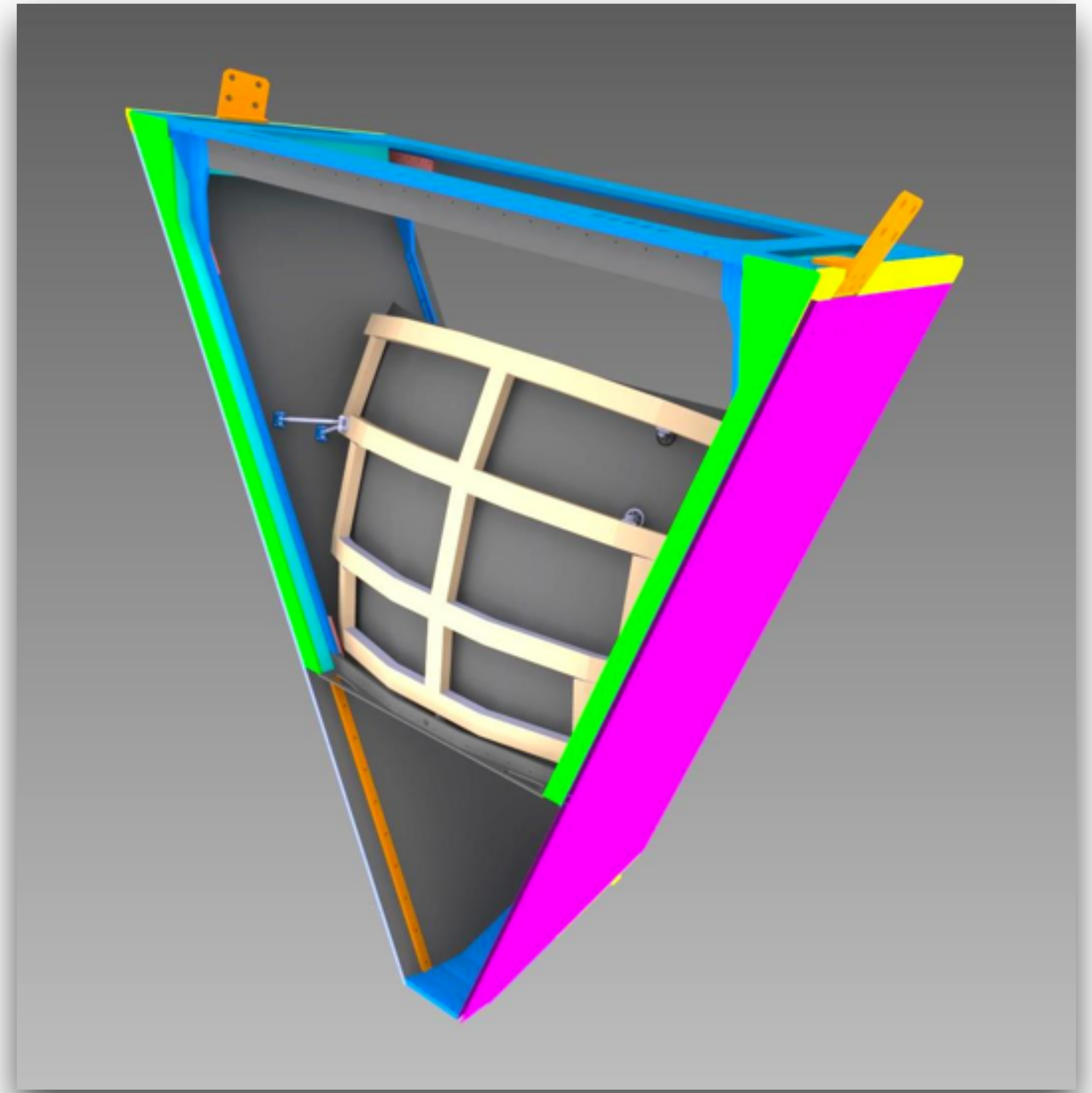




Istituto Nazionale di Fisica Nucleare

The mirror system for CLAS12 RICH

Outline



- CLAS12 RICH: An Hybrid Rich
- Resolution on Cherenkov Photons
- Mirror System Characterization

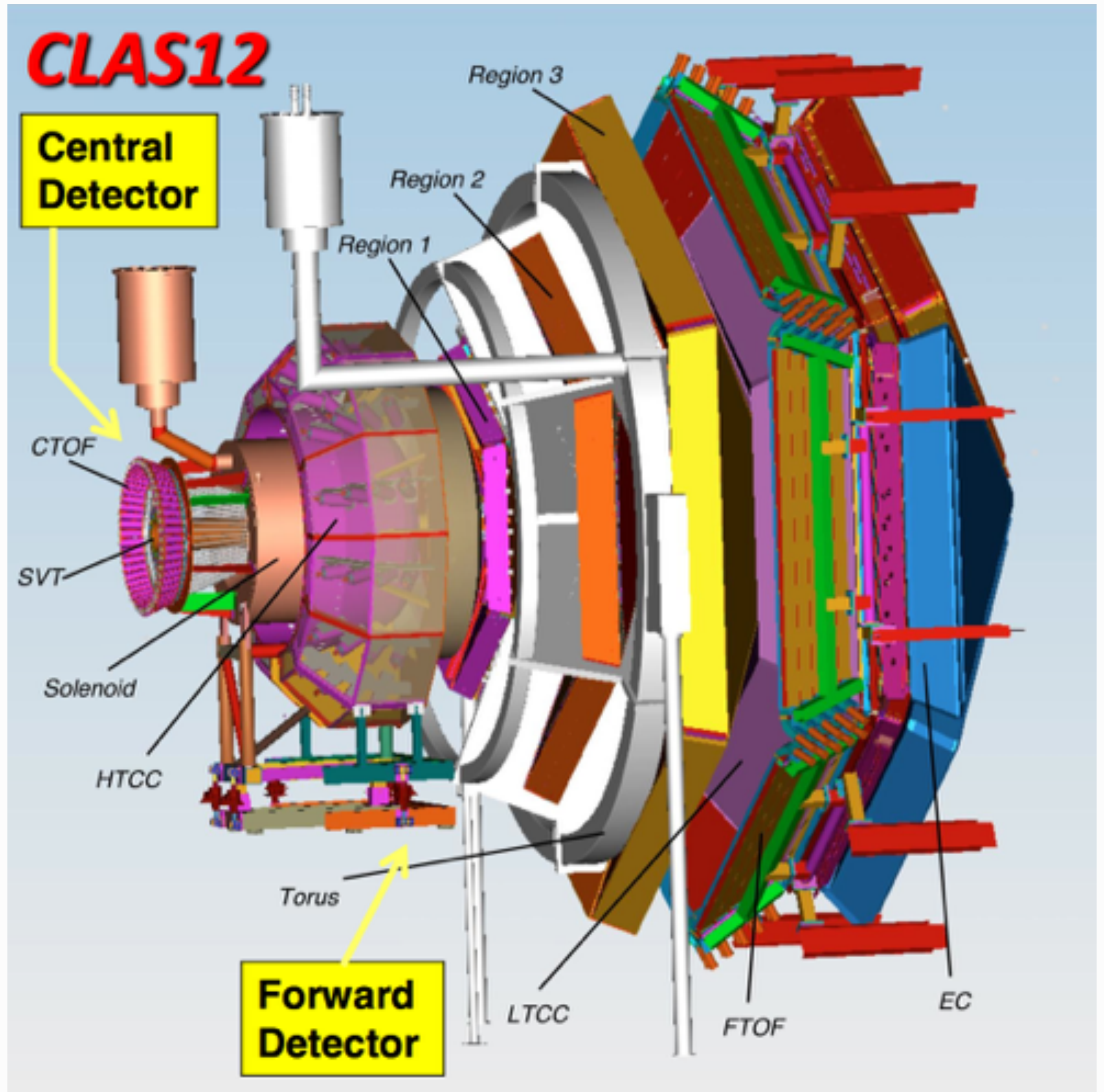
CLAS12 RICH

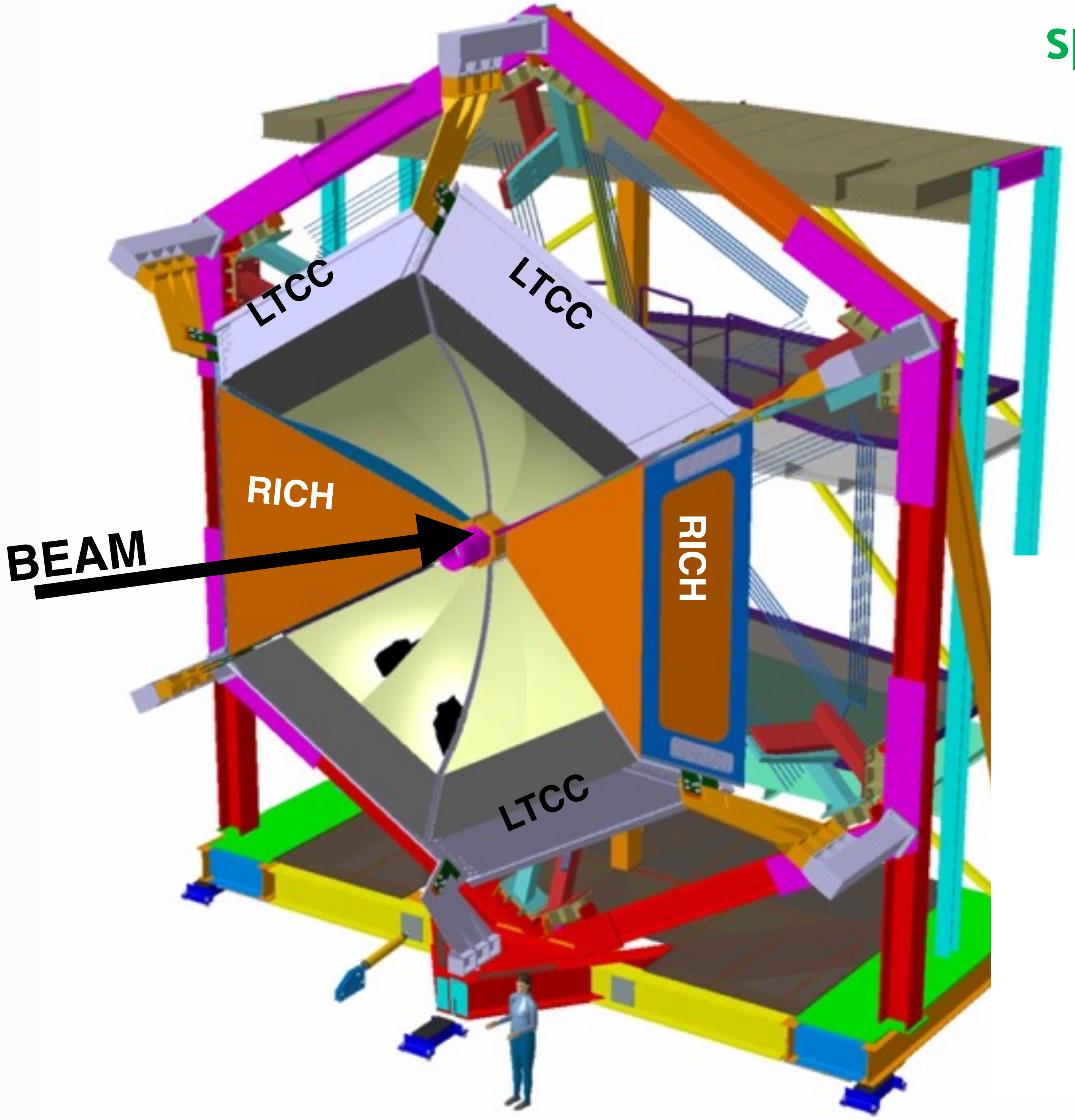
INSTITUTIONS
INFN (Italy) Bari, Ferrara, Genova, L.Frascati, Roma/ISS
Jefferson Lab (Newport News, USA)
Argonne National Lab (Argonne, USA)
Duquesne University (Pittsburgh, USA)
Glasgow University (Glasgow, UK)
J. Gutenberg Universitat Mainz (Mainz, Germany)
Kyungpook National University, (Daegu, Korea)
University of Connecticut (Storrs, USA)
UTFSM (Valparaiso, Chile)

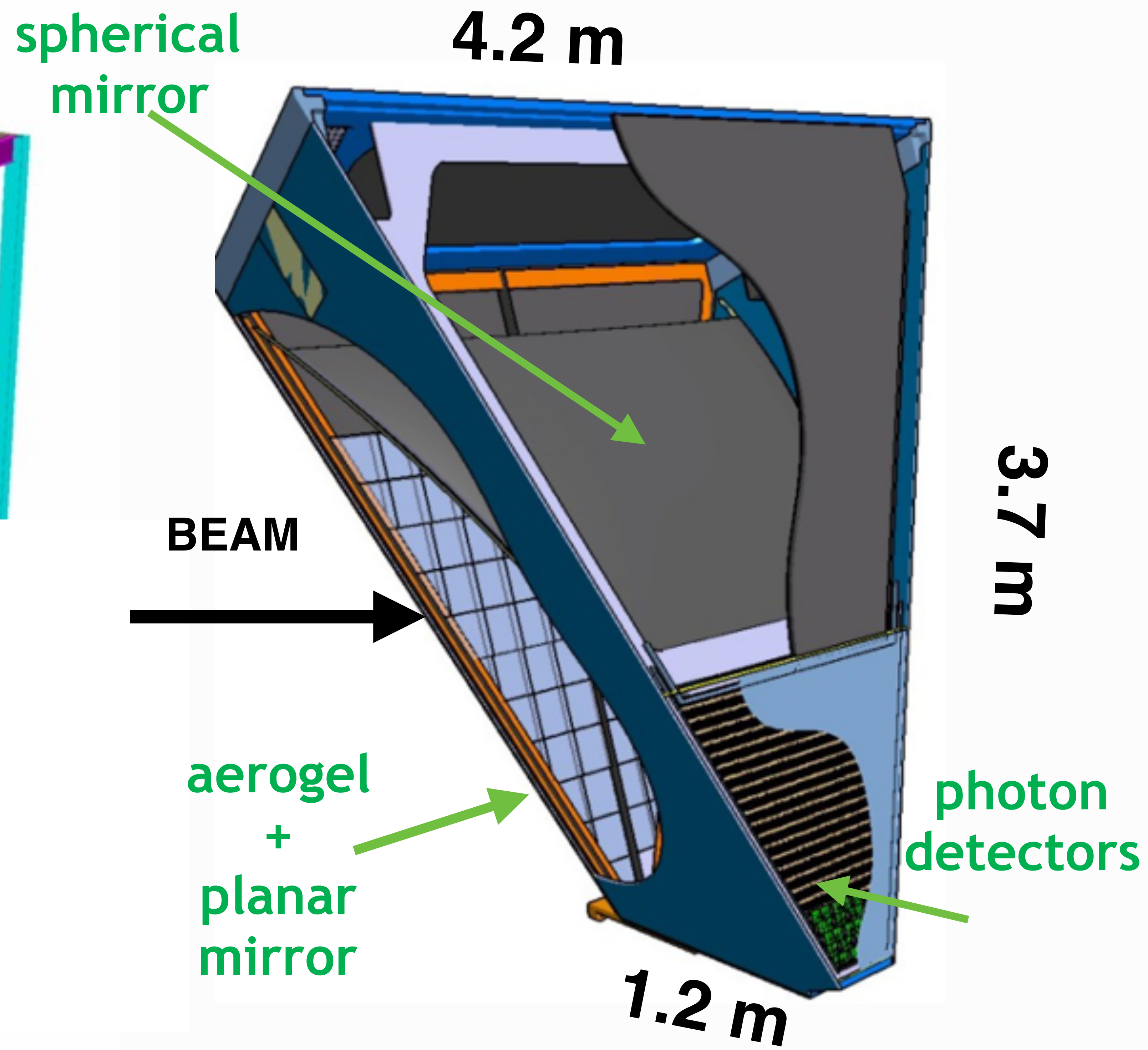
E12-09-07: Patronic Distribution using Semi-Inclusive production of Kaons.

E12-09-08: Boer- Mulders Asymmetry in Kaon Electro-Production

E12-09-09: Spin-Orbit correlation in Kaons Electro-Production

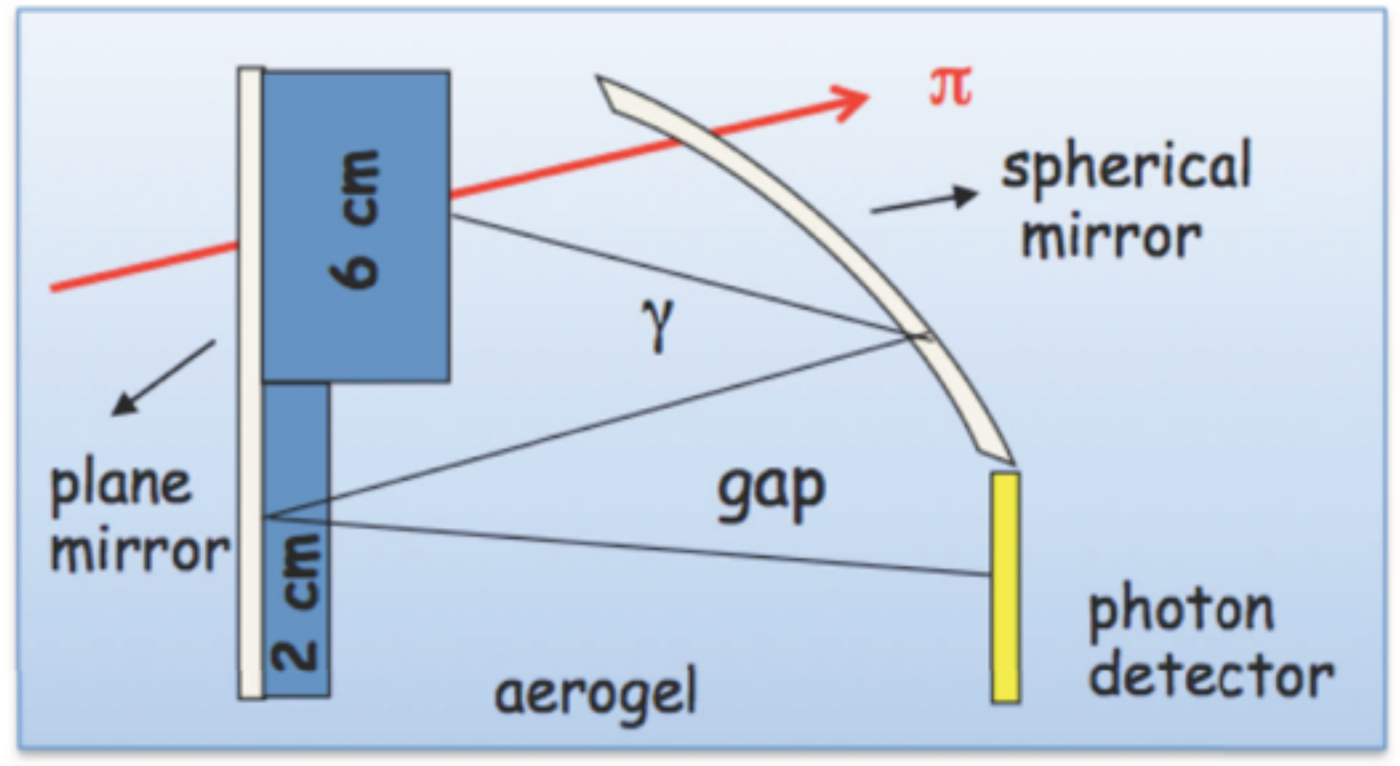






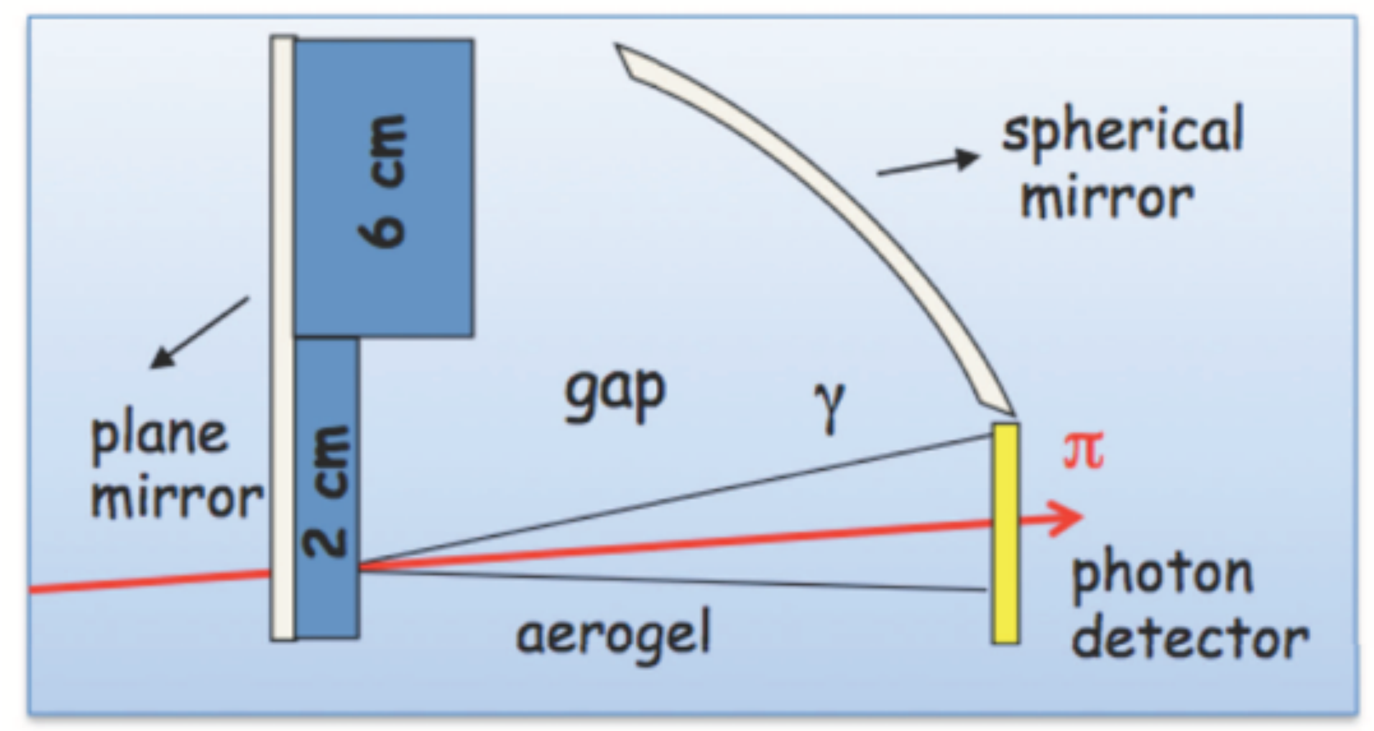
The Hybrid Geometry

FOCUSING REGION
13° -25°

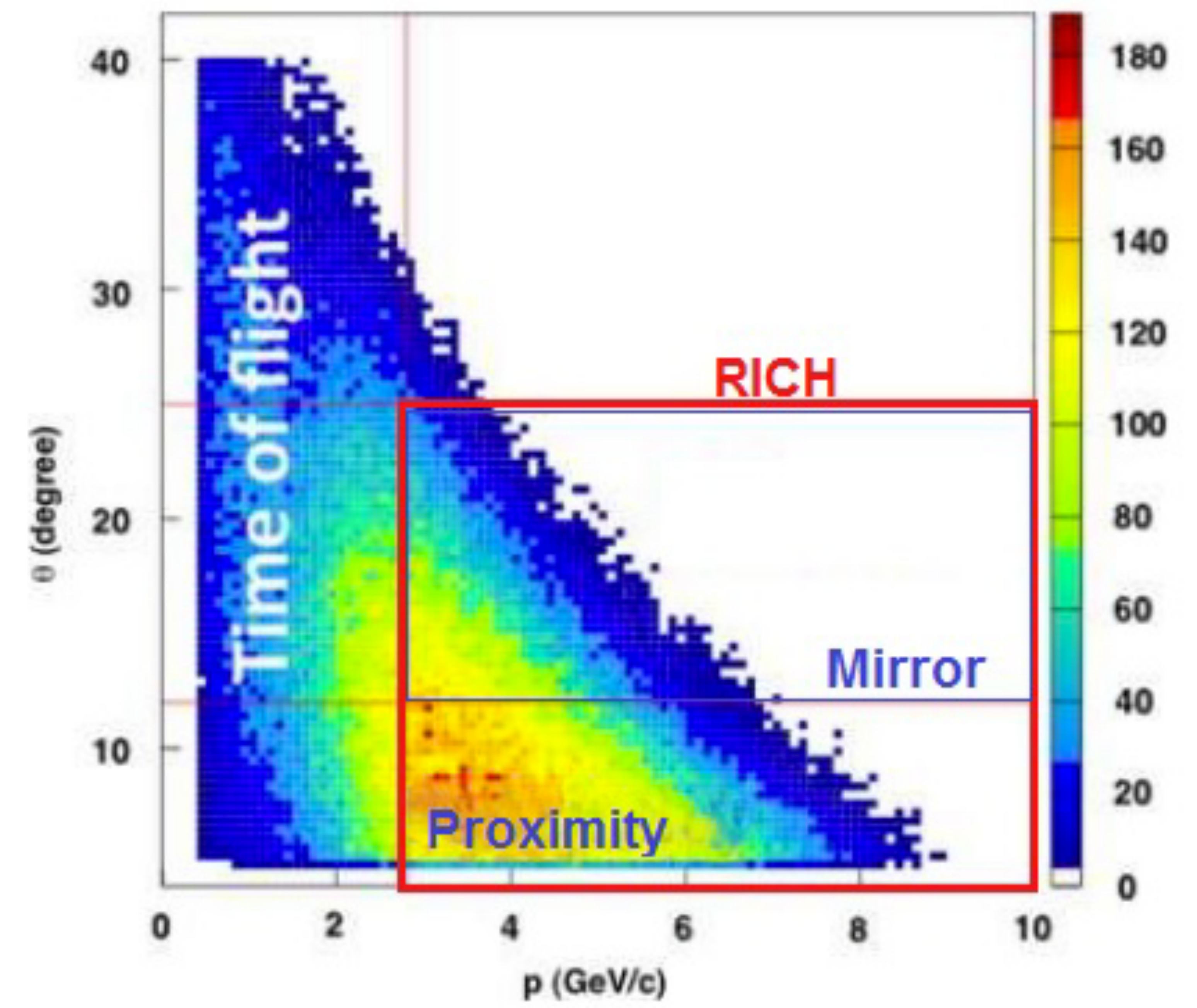


- Multiple passage of Cherenkov photons in aerogel.
- 3 m gap
- Thick aerogel (3cm+3cm) to compensate photon loss
- Focalizing mirror to reduce the emission point uncertainty

PROXIMITY REGION
5° -13°

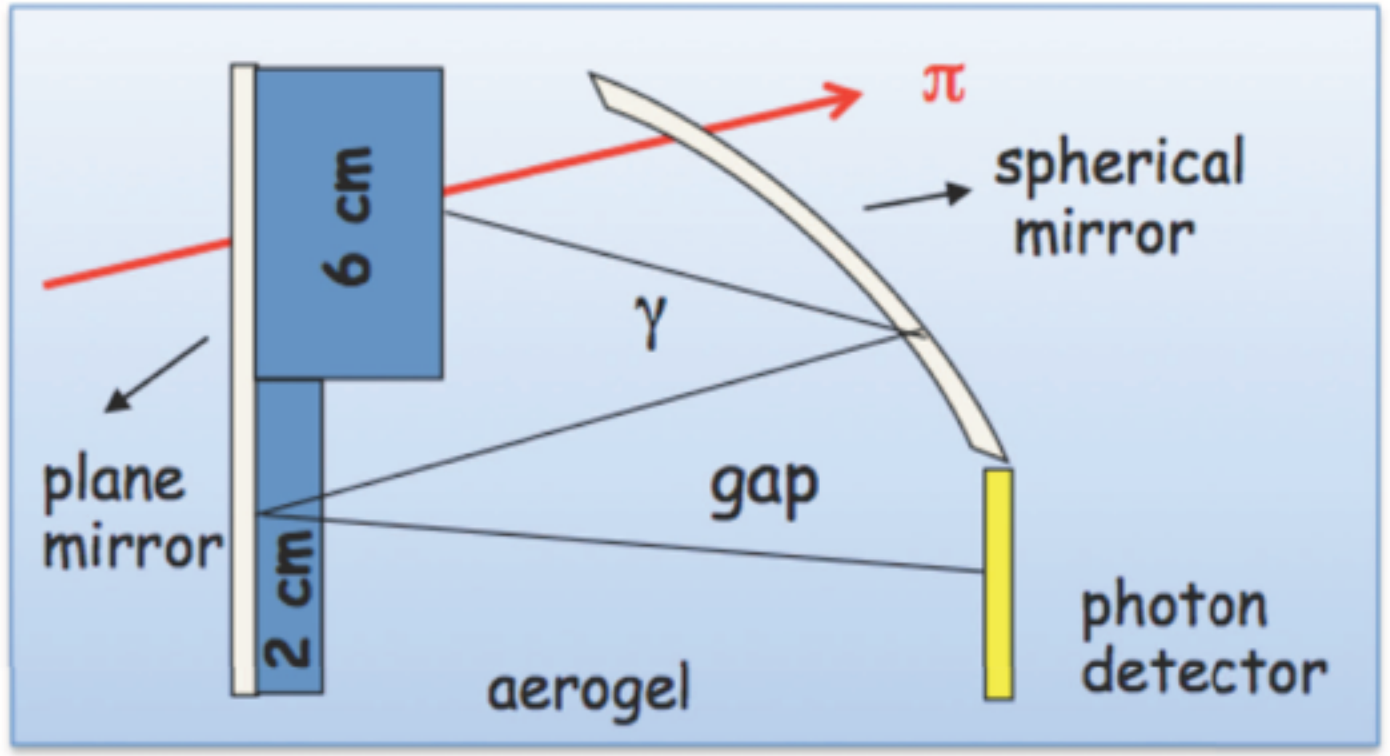


- Direct imaging of the Cherenkov photons
- 1m gap
- Thin aerogel (2cm)

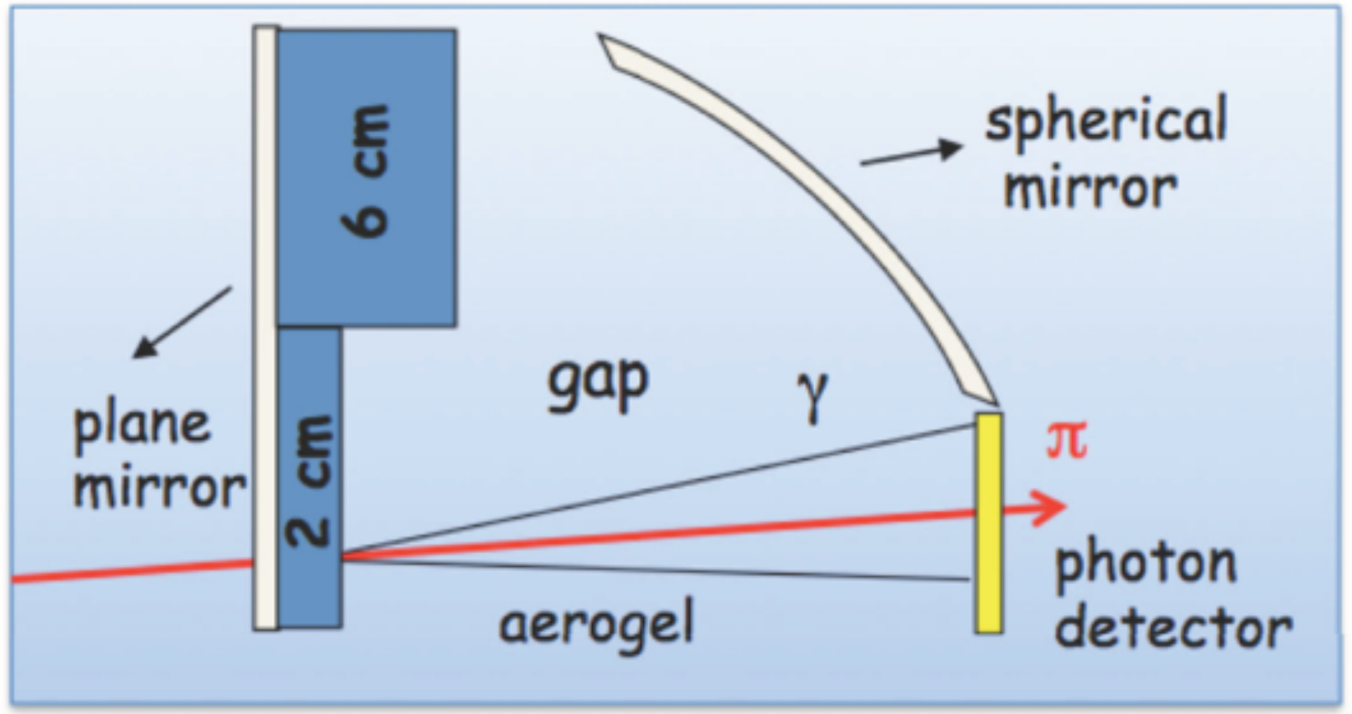


The Hybrid Geometry

FOCUSING REGION
13° -25°



PROXIMITY REGION
5° -13°



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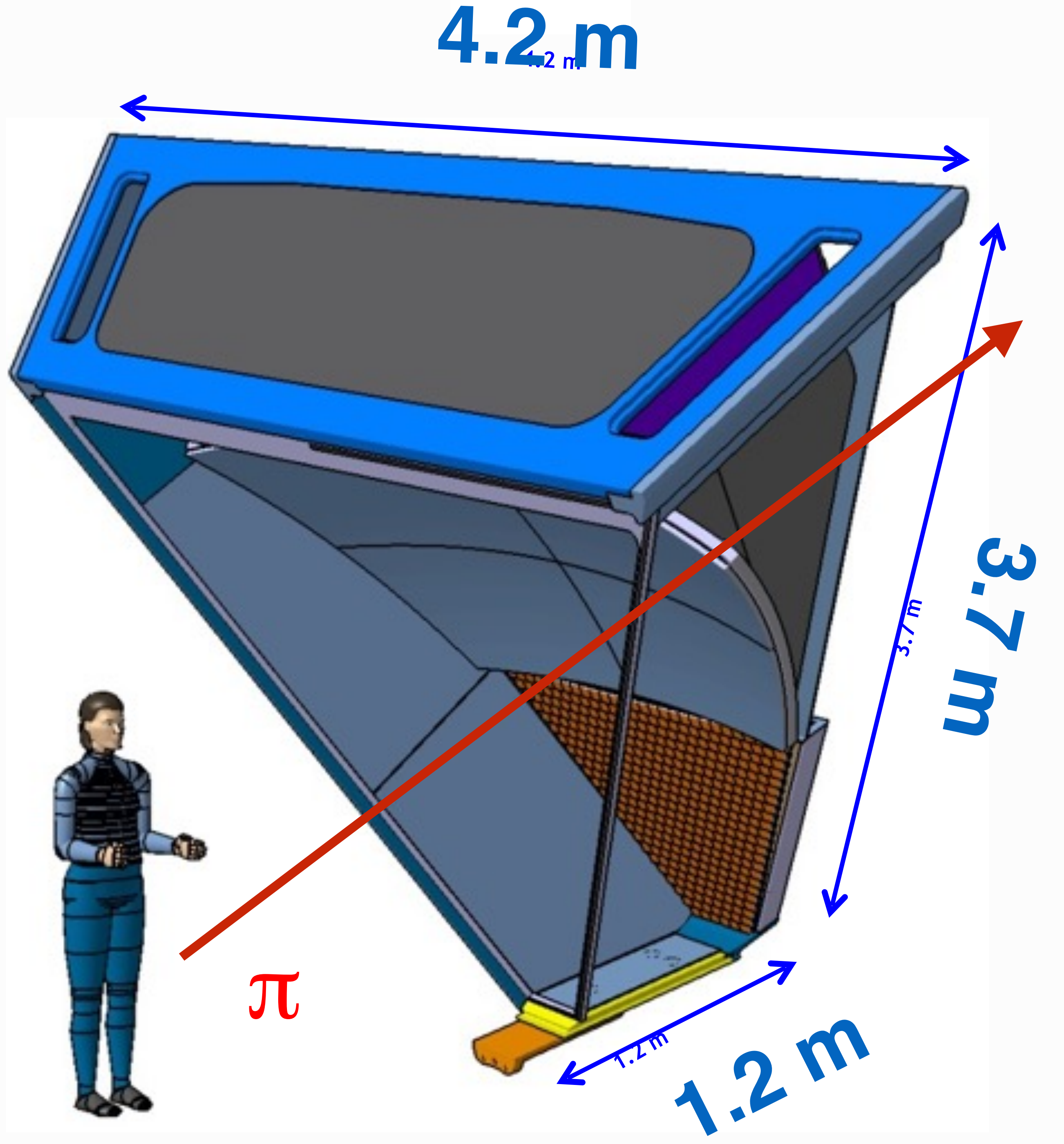

- Direct imaging of the Cherenkov photons
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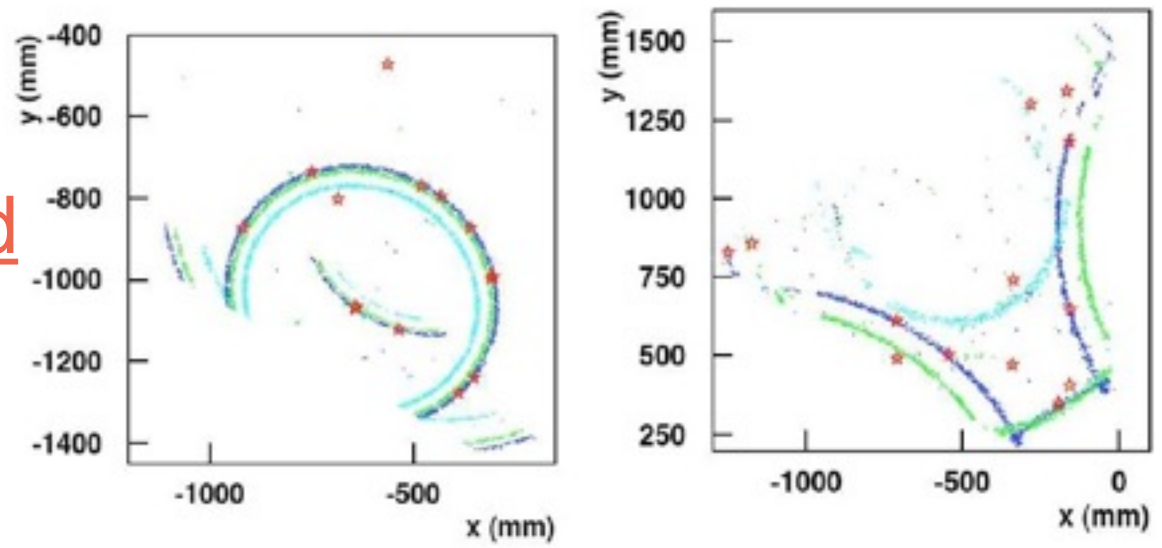
Two simulated events

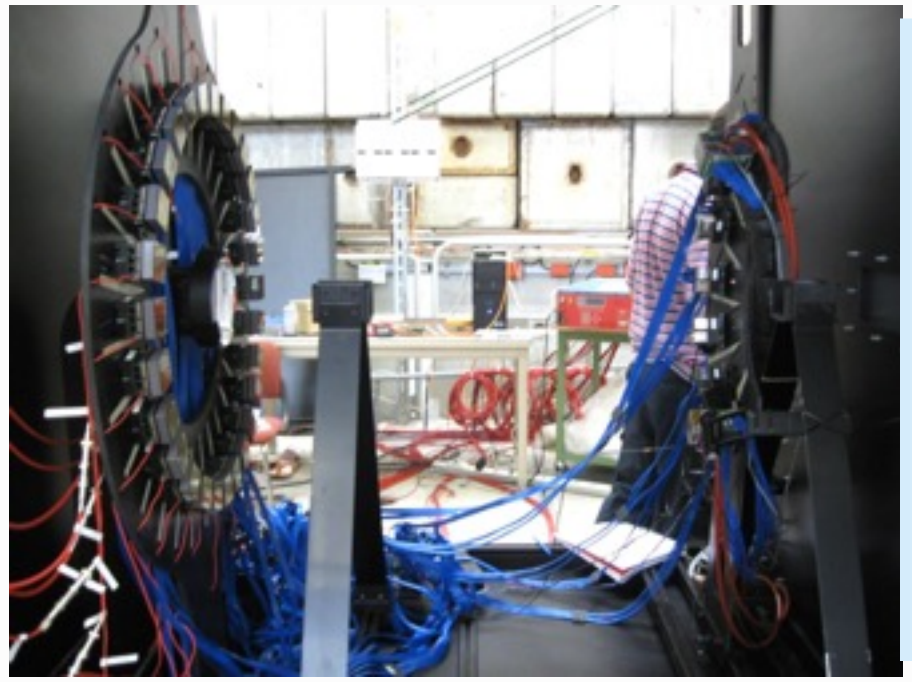
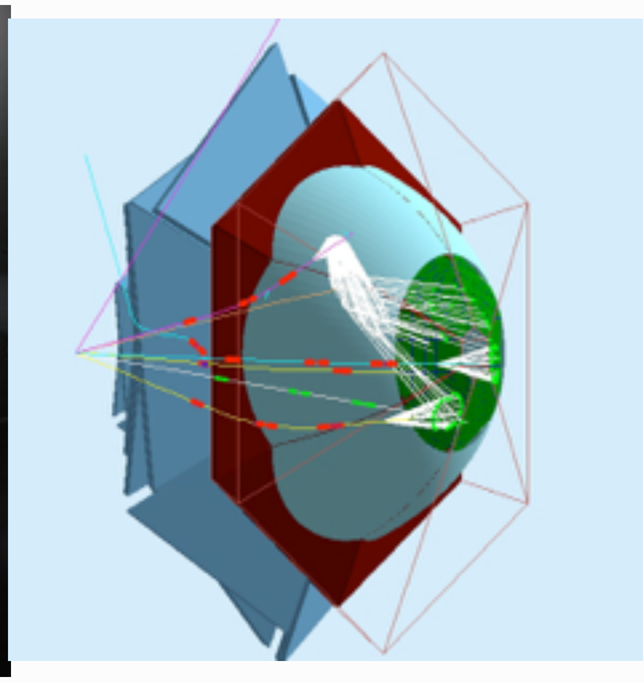
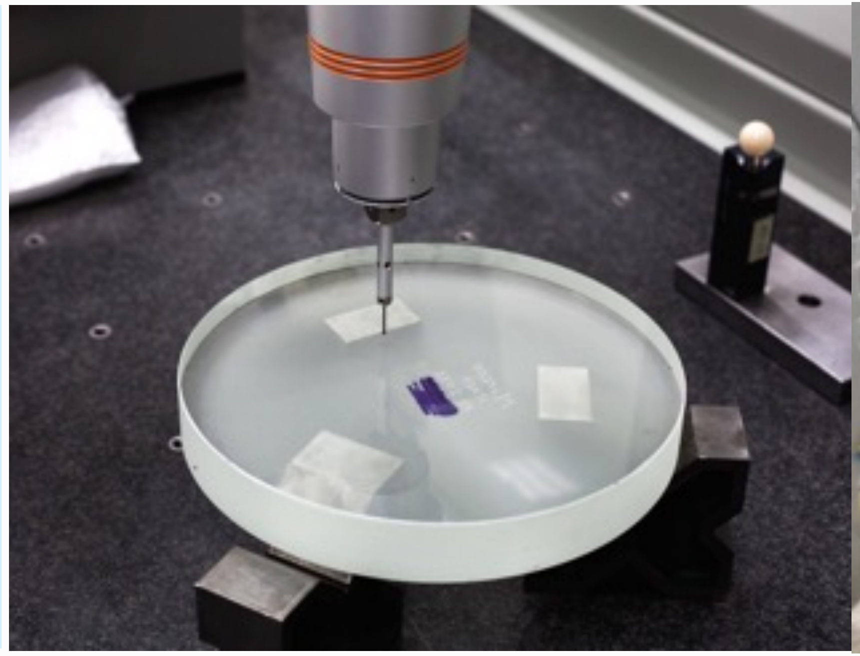
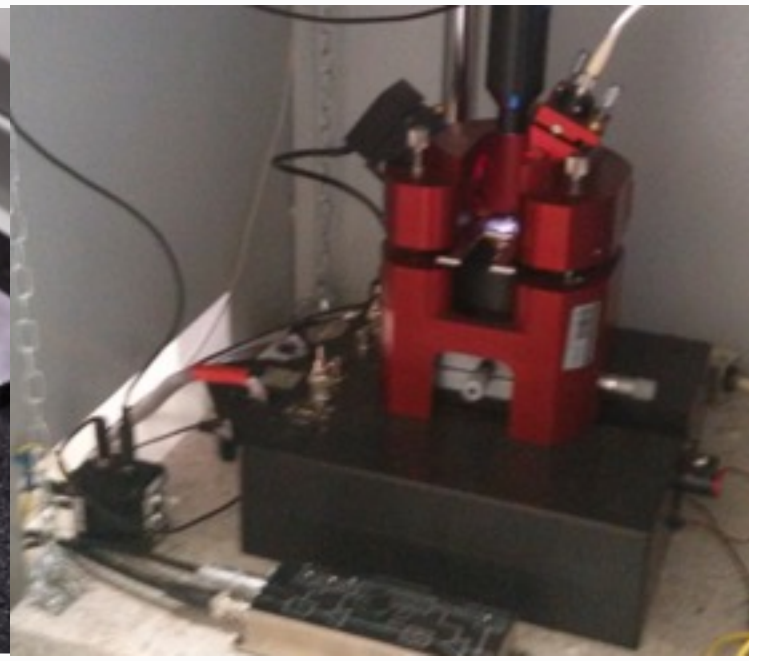
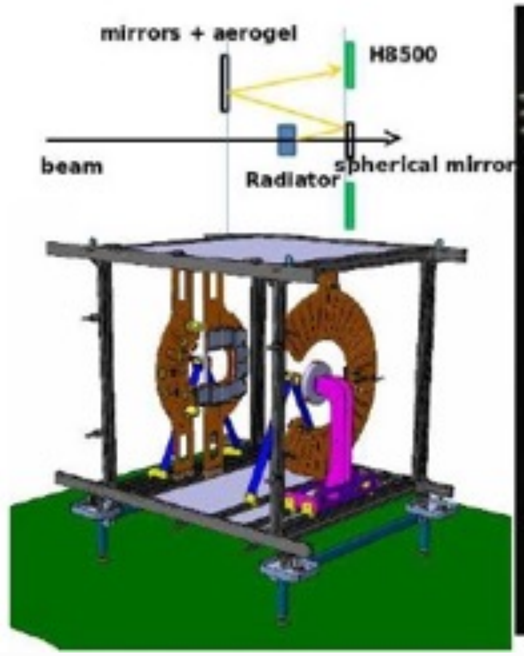


Photon direction resolution

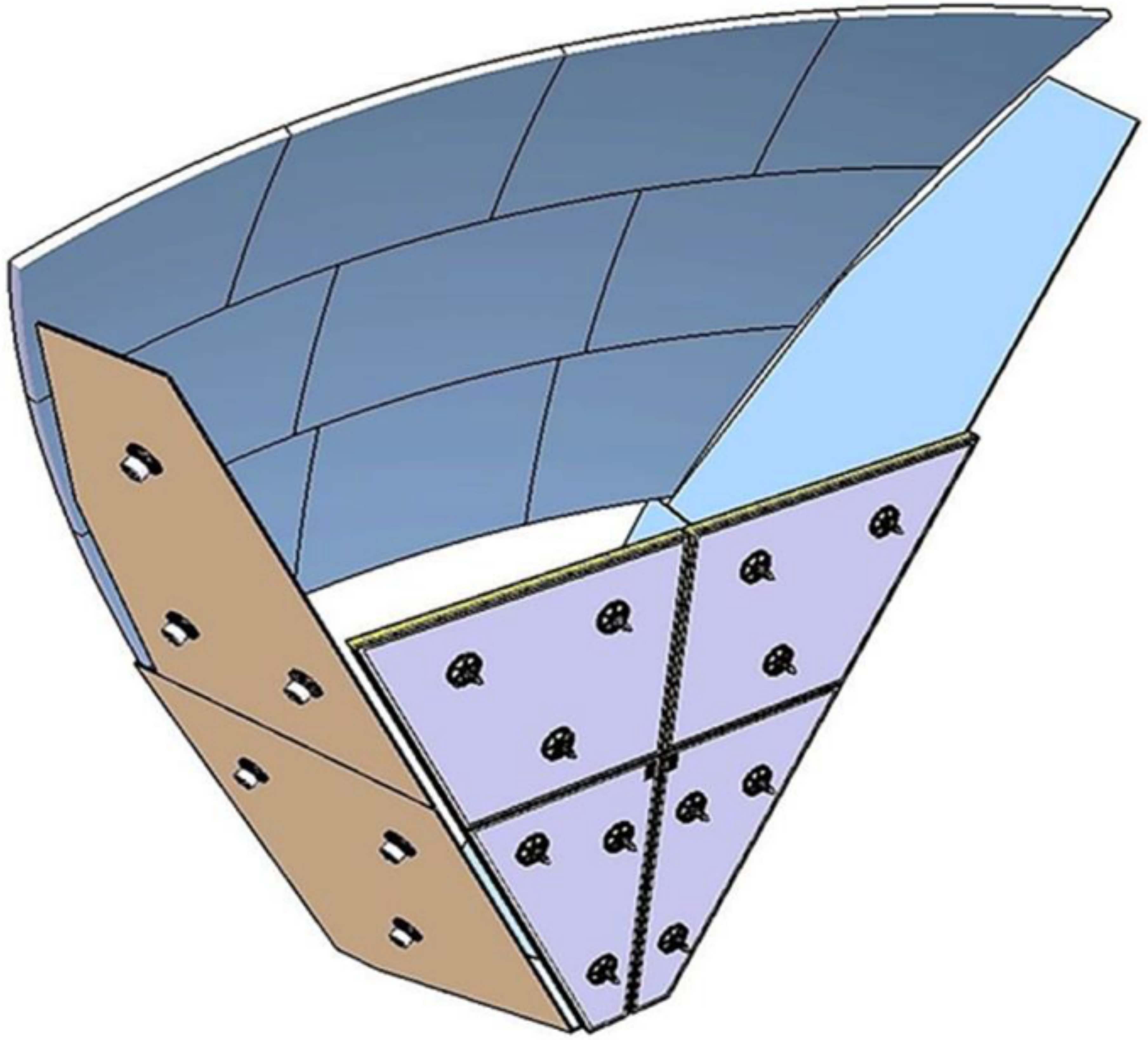
Resolution	Direct (mrad)	Reflected (mrad)
Emission Point	1.7	1.7
Readout Accuracy	2.1	1.0
Chromatic Aberration	3.0	2.5
Aerogel Optical Prop.	≤ 1	≤ 2
★ → Mirror System		≤ 1
σ_θ (1 p.e.)	4.2	3.9

Validated with large scale prototype

Studied in laboratory and Simulated

The Mirror System



10 CFRP Spherical Mirrors (R= 2.7 m)

-two layers of carbon fiber, 1mm each
-honeycomb core
-total thickness is 20mm
Equivalent thickness is 1.7% of X0 About 25% of the total

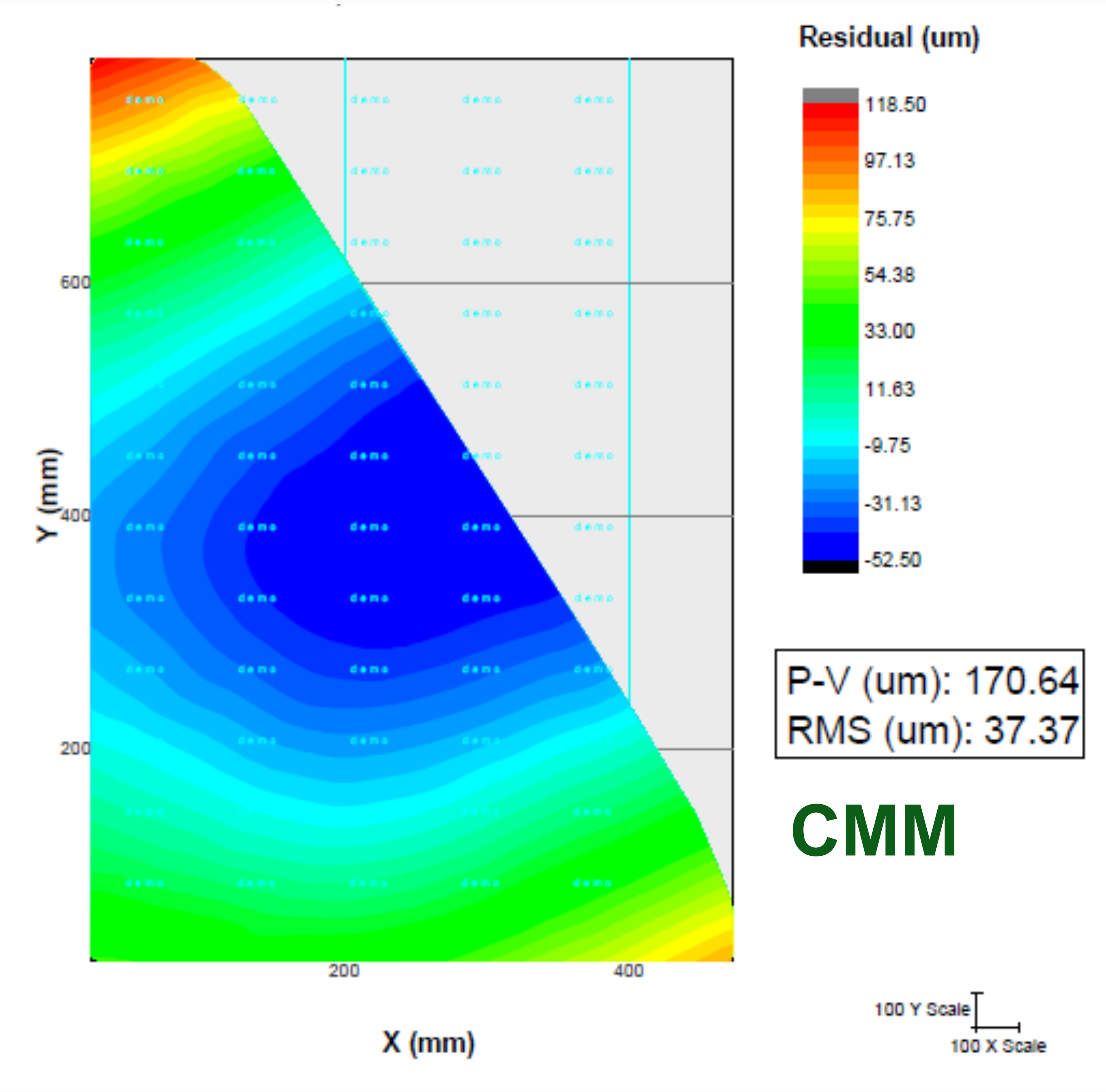
9 Glass Planar Mirrors

-two layers of glass skin, 0.7 mm each
-Al honeycomb core
-total thickness is 10mm E
quivalent thickness is 1.3% of X0 Less than 20% of the total at large angles

Resolutions

SURFACE MEASURAMENTS

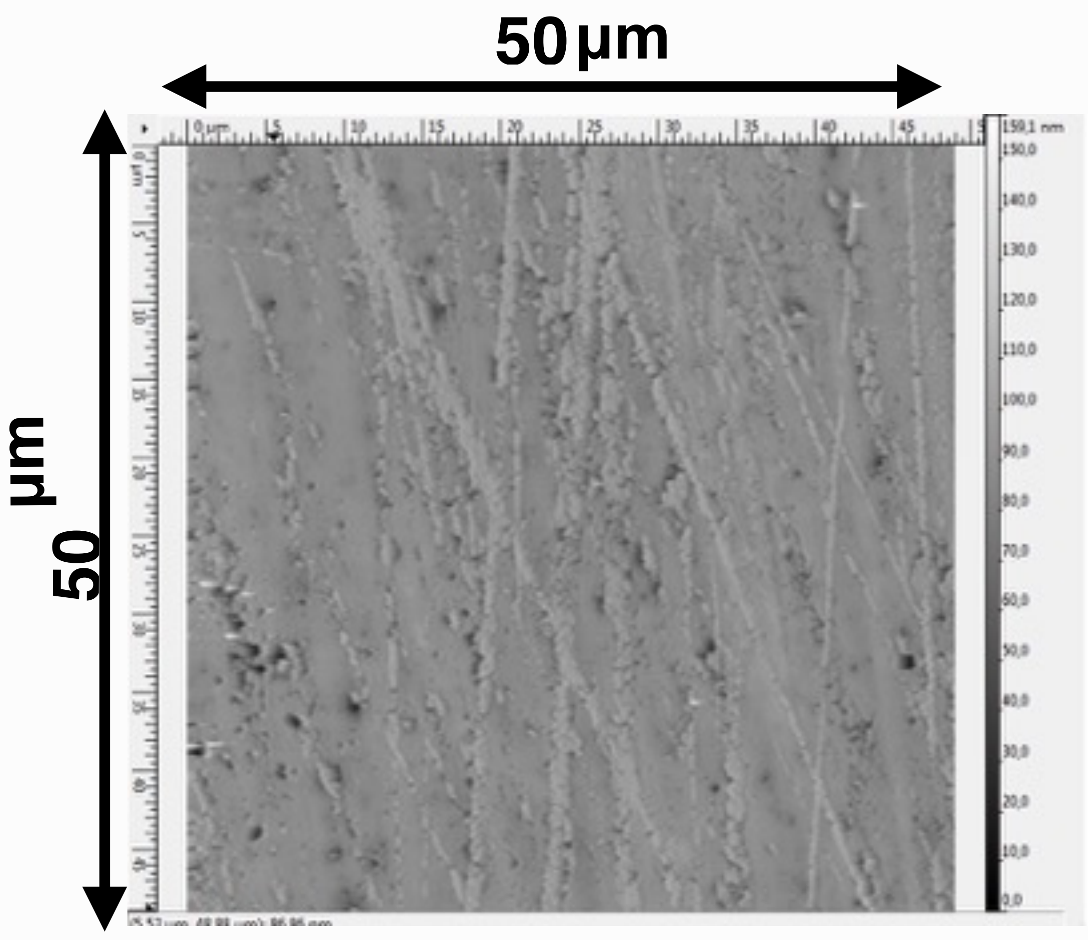
MACROSCOPIC



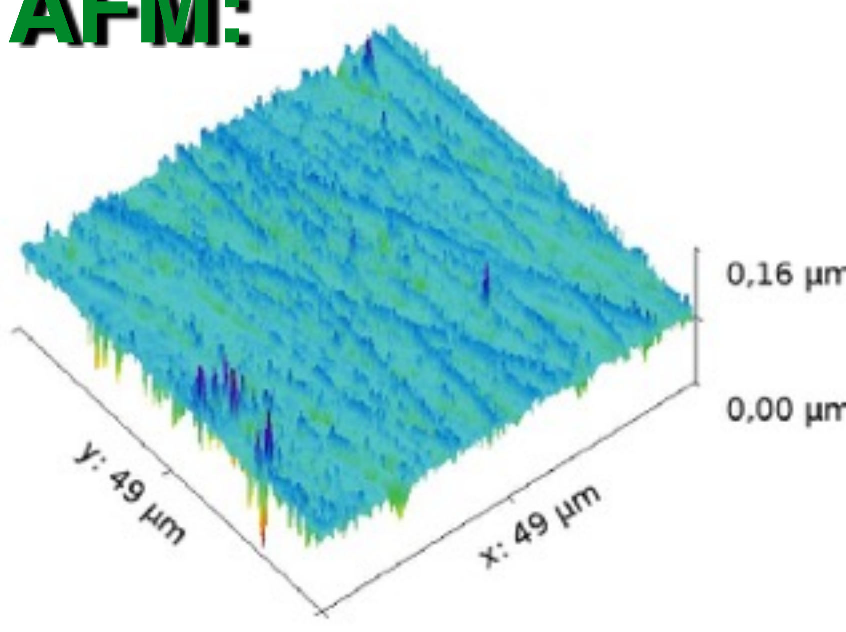
CMM

Geometrical Optics

MICROSCOPIC



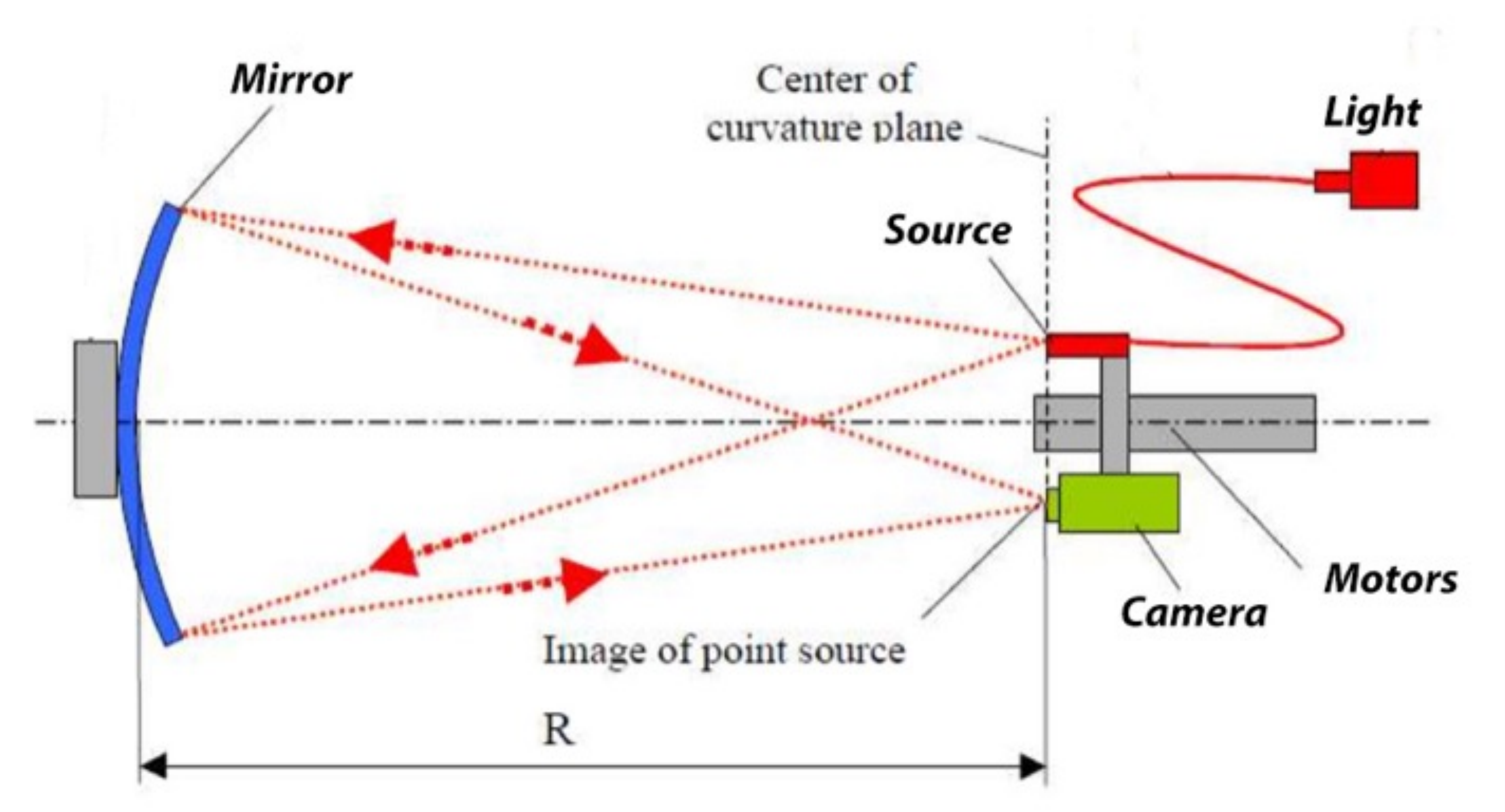
AFM:

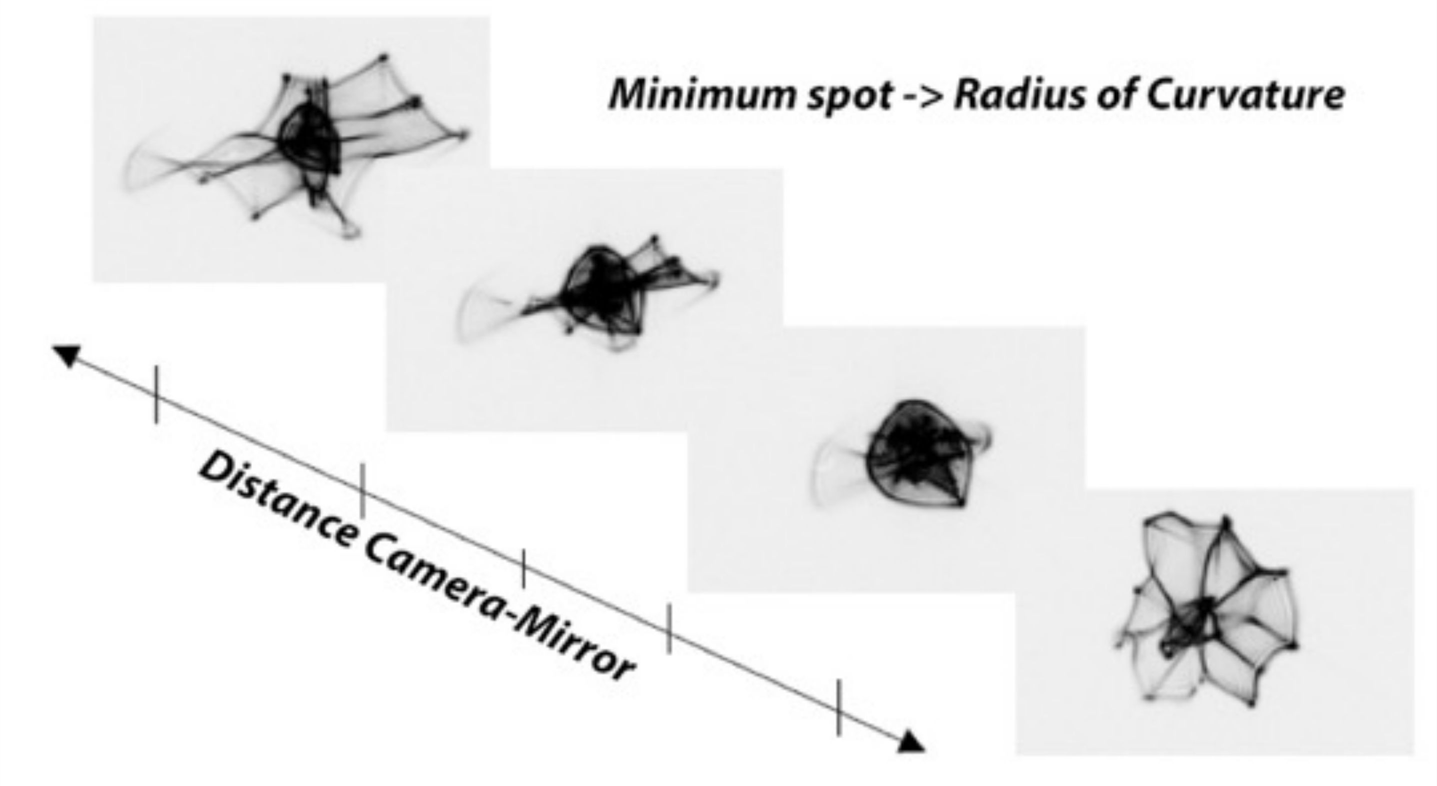


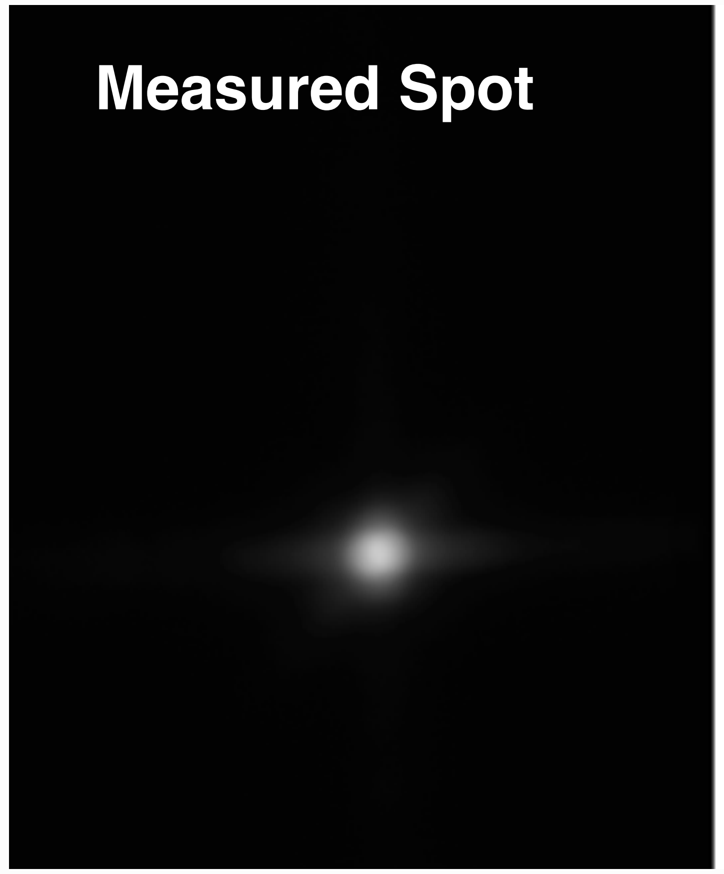
Interference and Diffusion

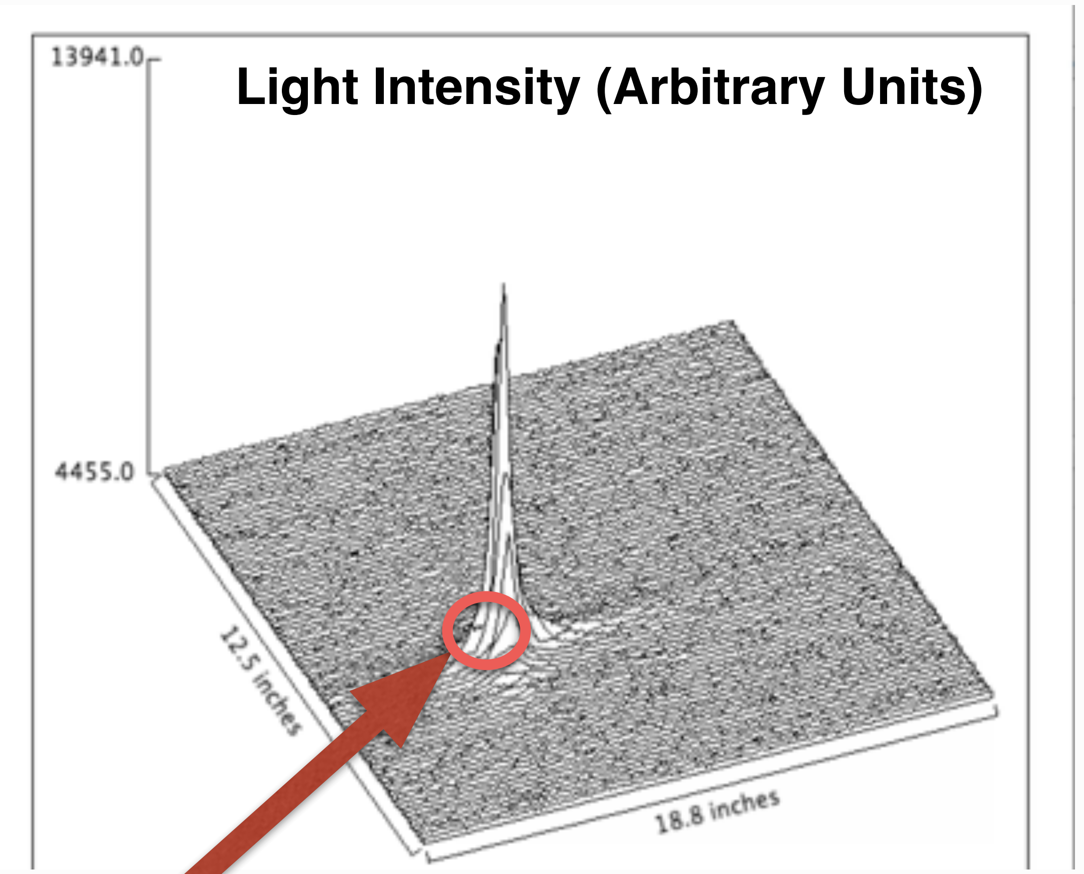
Resolutions

SPOT MEASUREMENT









D_0 95 % of the light intensity

If gaussian = $\pm 2\sigma_s$

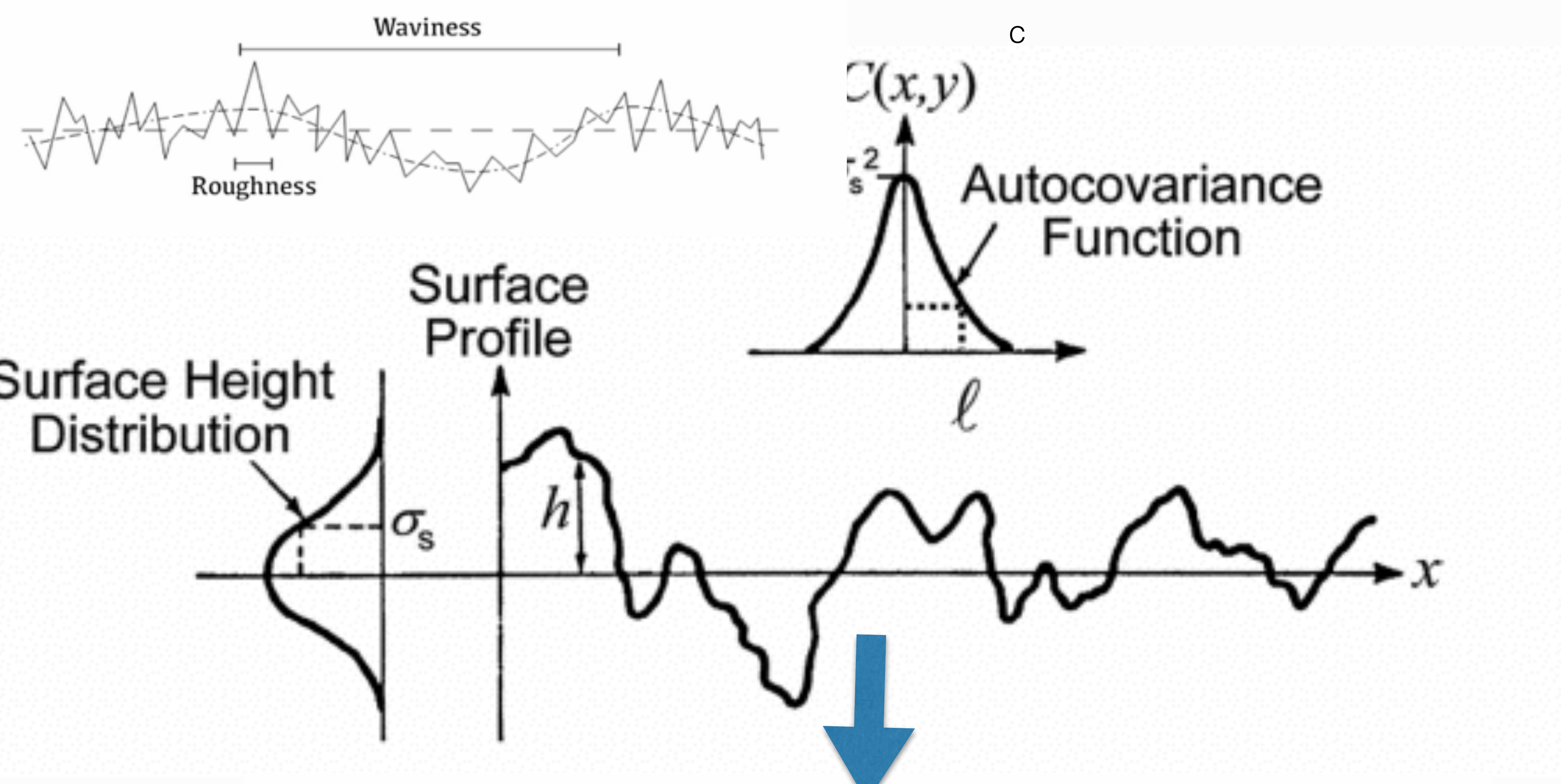
$$\sigma_\theta = \frac{\sqrt{\sigma_s^2 - \sigma_p^2}}{2R} \approx \frac{\sigma_s}{2R} = \frac{D_0}{8R}$$

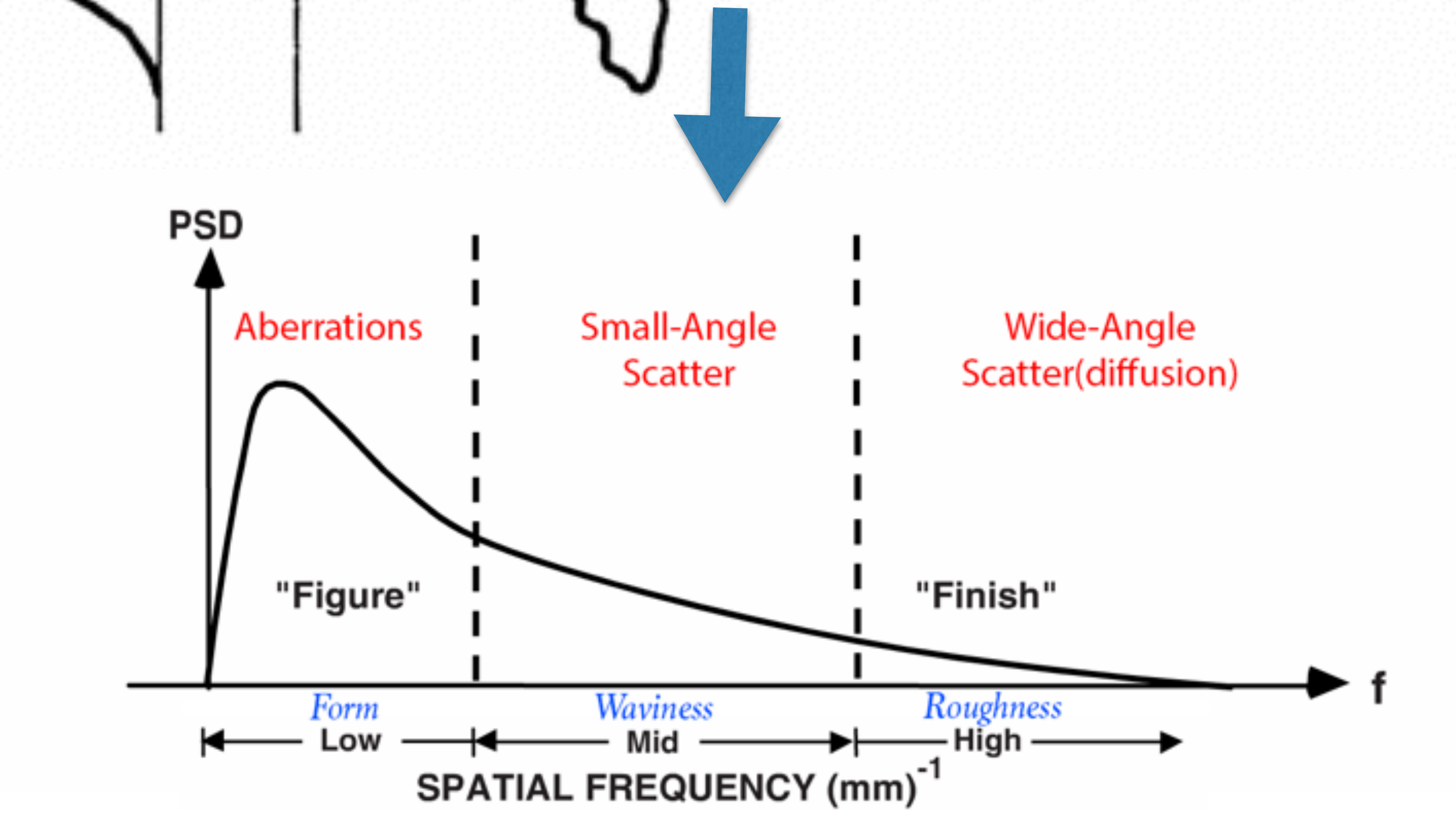
Point source (σ_p)

→ $D_0 < 6$ mm

For each mirror

Surface Characterization





RMS Roughness

Correlation length

$$ACV(x,y) = \iint h(x,y) \cdot h(x',y')dx'dy',$$

Wiener-Khinchin theorem

Fourier Transform

$$PSD(f_x,f_y) = \lim_{L\to\infty} \frac{1}{L^2} \left| \iint_{-L/2}^{L/2} h(x,y)e^{-2i\pi(f_x x + f_y y)}dxdy \right|^2$$

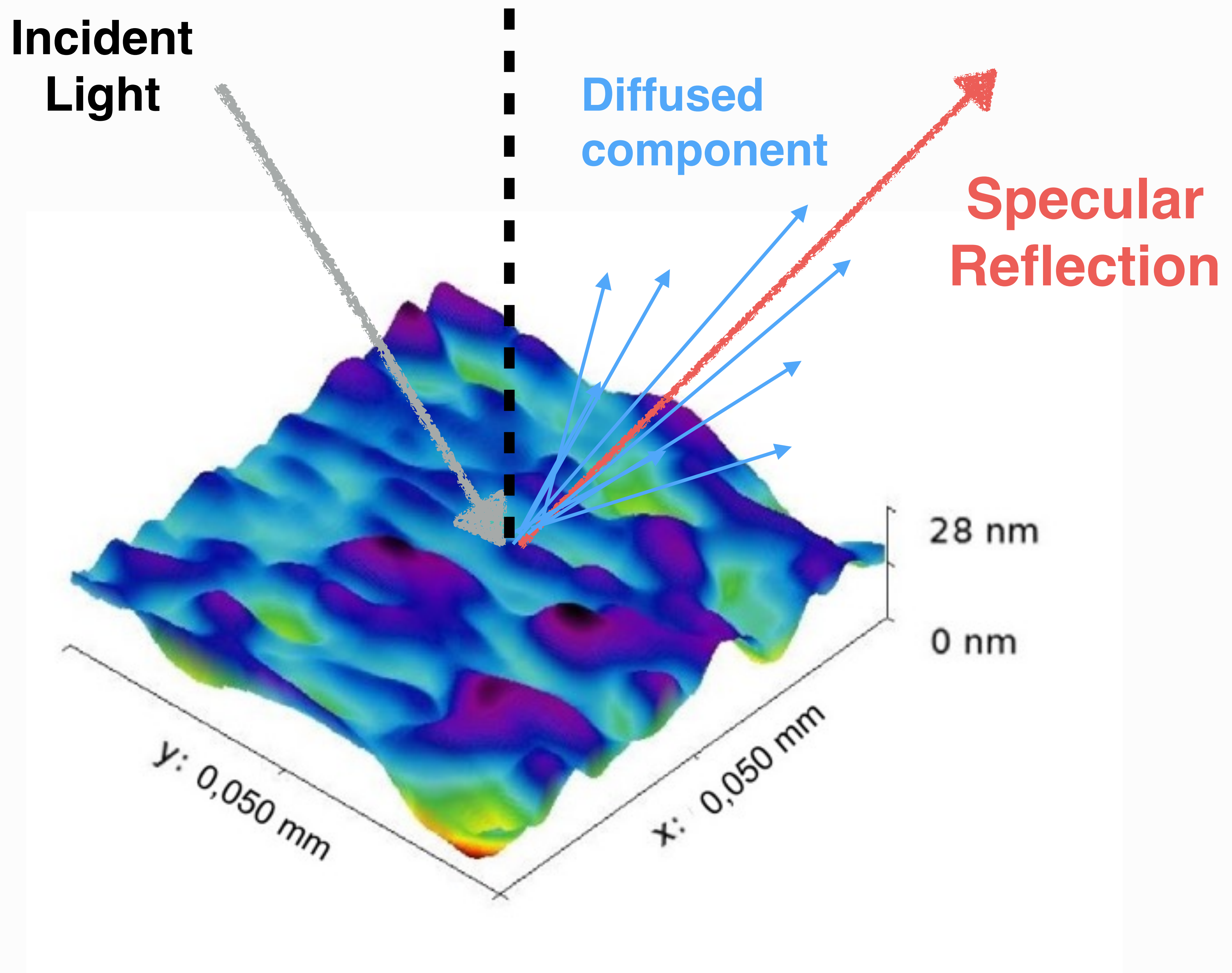
$$\sigma_r = \sqrt{2\pi \int_{1/D}^{1/\lambda} PSD(f) f df};$$

Under the assumption of Gaussian Height Distribution and Isotropy in the material:

$$PSD(f) = \pi l_c^2 \sigma_{tot}^2 exp\left[-(\pi l_c f)^2\right]$$

$$ACV(\tau) = \sigma_{tot}^2 exp\left[-\left(\frac{\tau}{l_c}\right)^2\right]$$

Micro-Scale Imperfections



Rice-Rayleigh model:

$$\left(\frac{4\pi\sigma_r}{\lambda}\right)^2 << 1 \qquad l_c > 40\,\sigma_r$$

Specular:

$$R_s = R_0 \cdot exp\left[-\left(\frac{4\pi\sigma_r cos(\theta_i)}{\lambda}\right)\right]^2$$

Bennet - Porteus

Diffused:

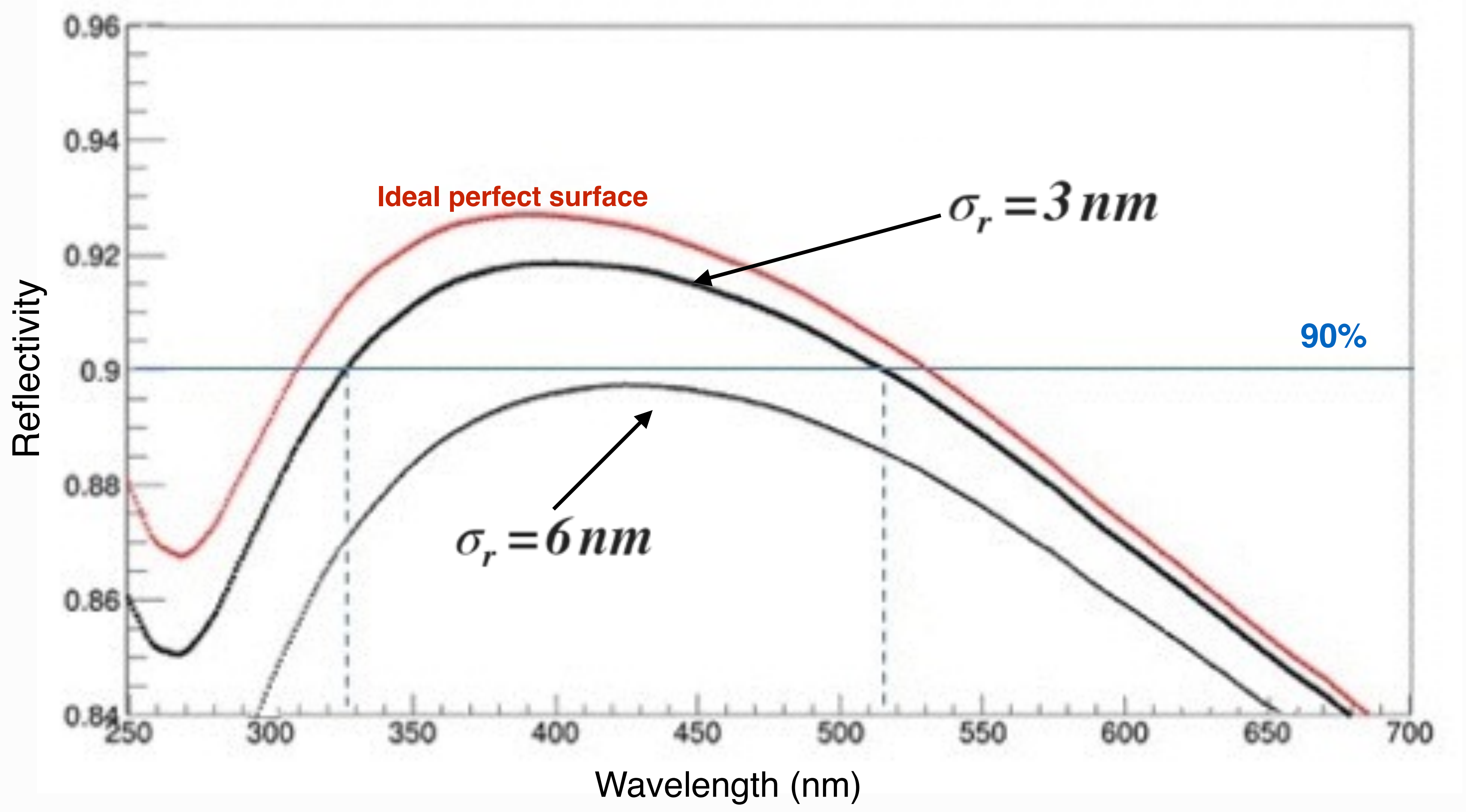
$$\propto \left(\frac{16\pi^2}{\lambda^4}\right) cos(\theta_i) cos^2(\theta_s) \cdot Q \cdot PSD(f_x, f_y).$$

Micro-Scale Imperfections

SPECULAR COMPONENT

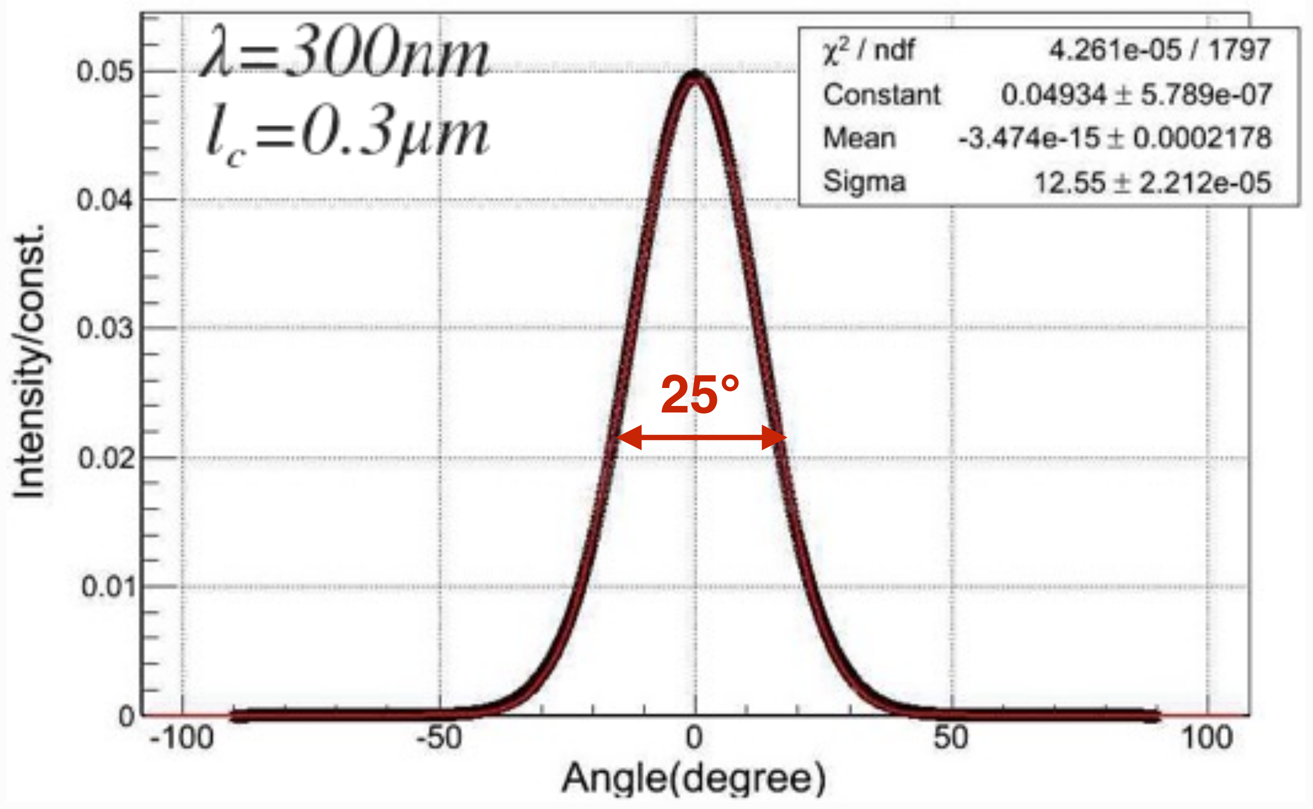
Only depends on the RMS roughness

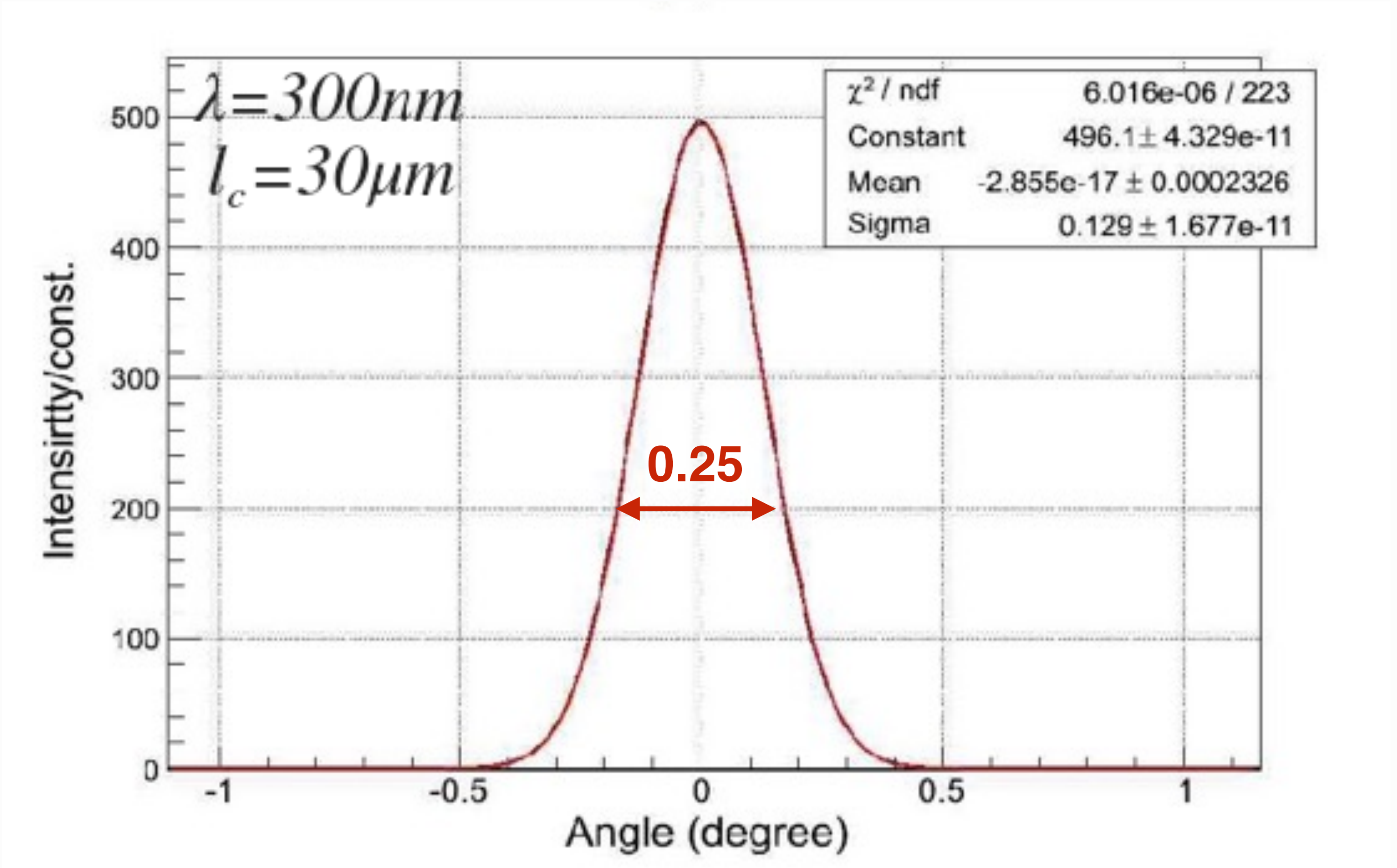
Coating : AL + MgF2 (140 nm)



DIFFUSED COMPONENT

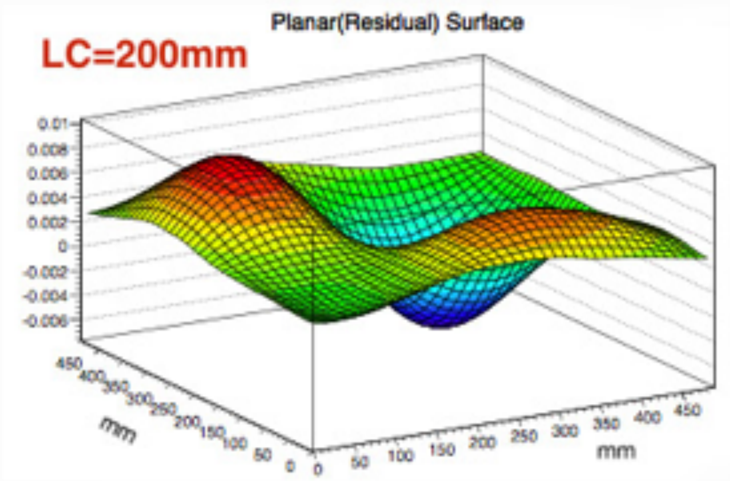
The angular distribution depends on the correlation length



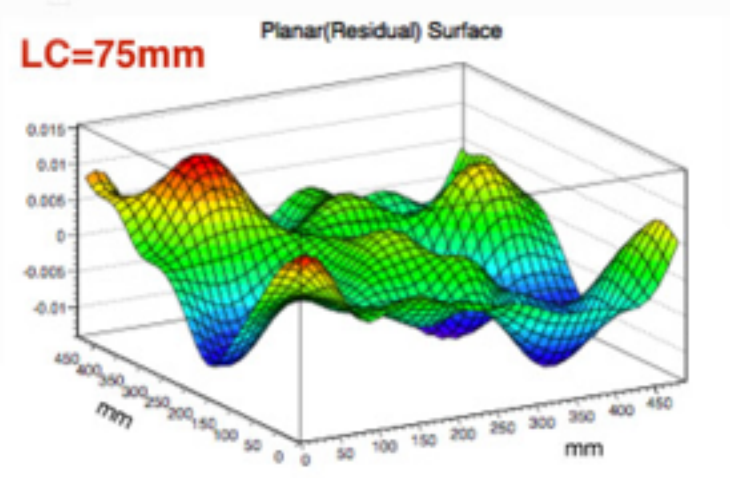


Diffused light within 1 pixel: $l_c > 15\ \mu m$ **(Planar)** $l_c > 60\ \mu m$ **(Spherical)**

Middle/Big-Scale



RMS = 2 μm



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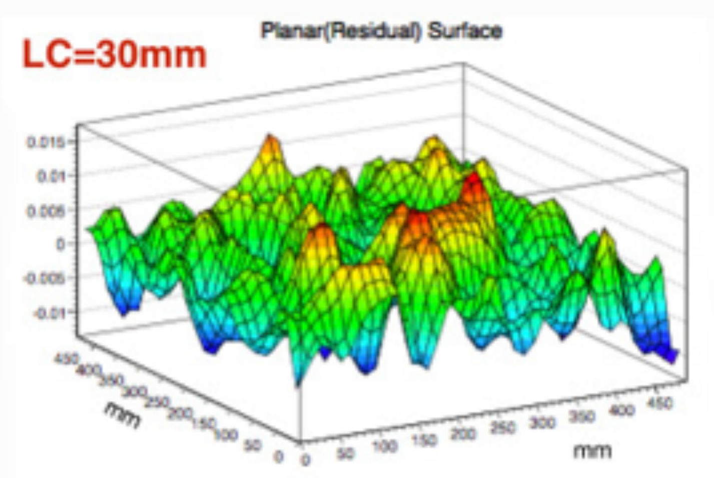
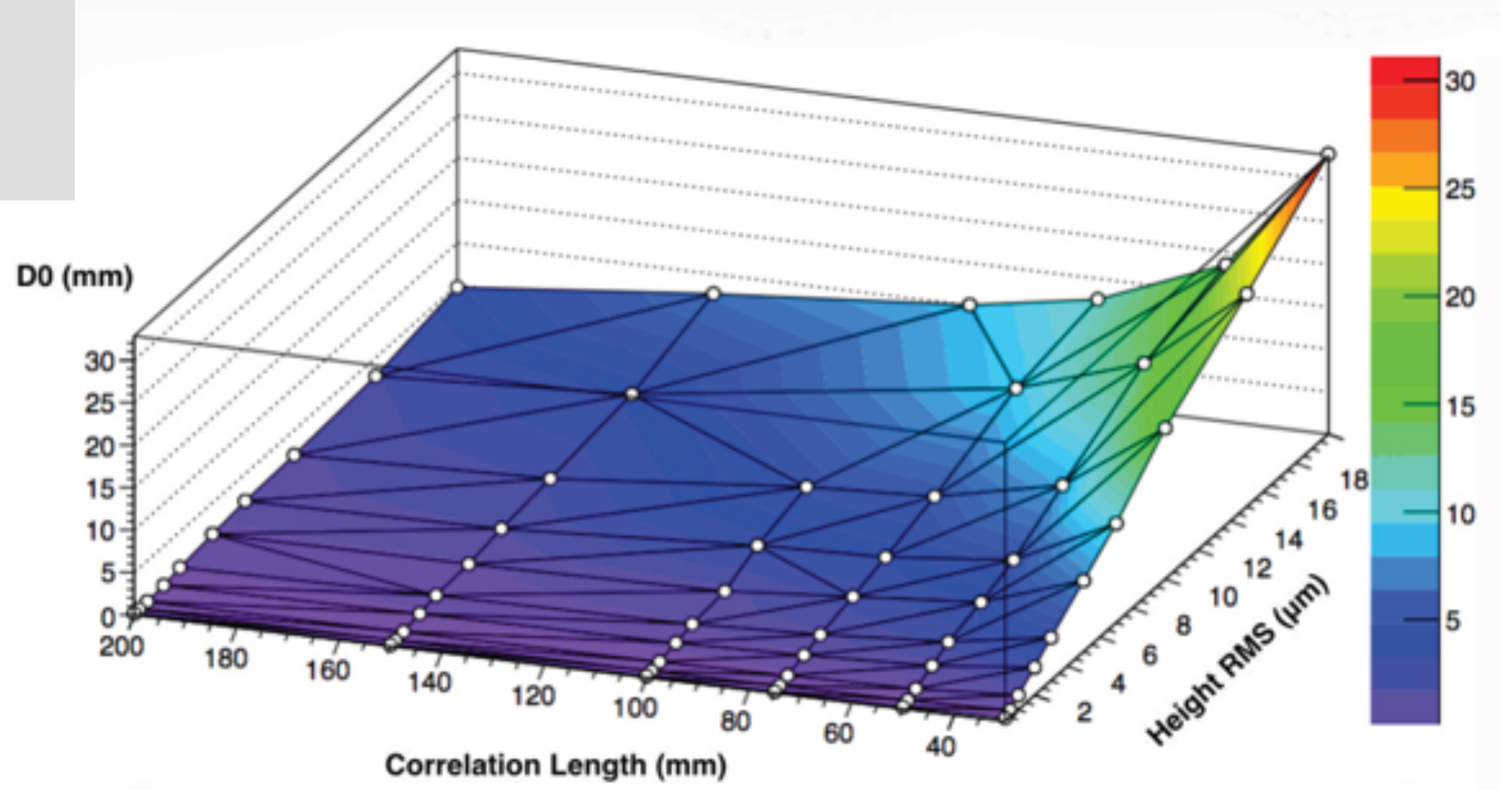
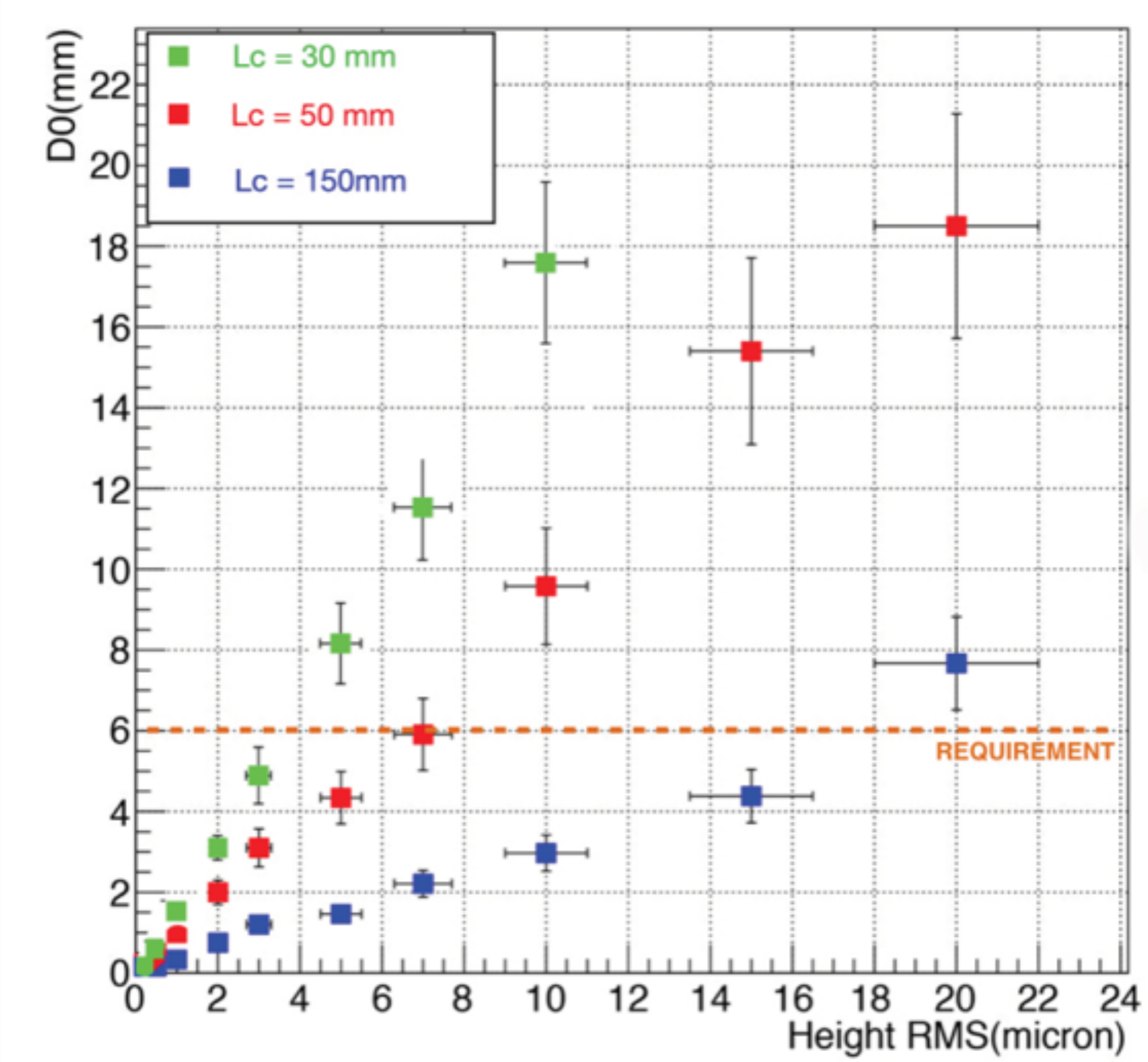
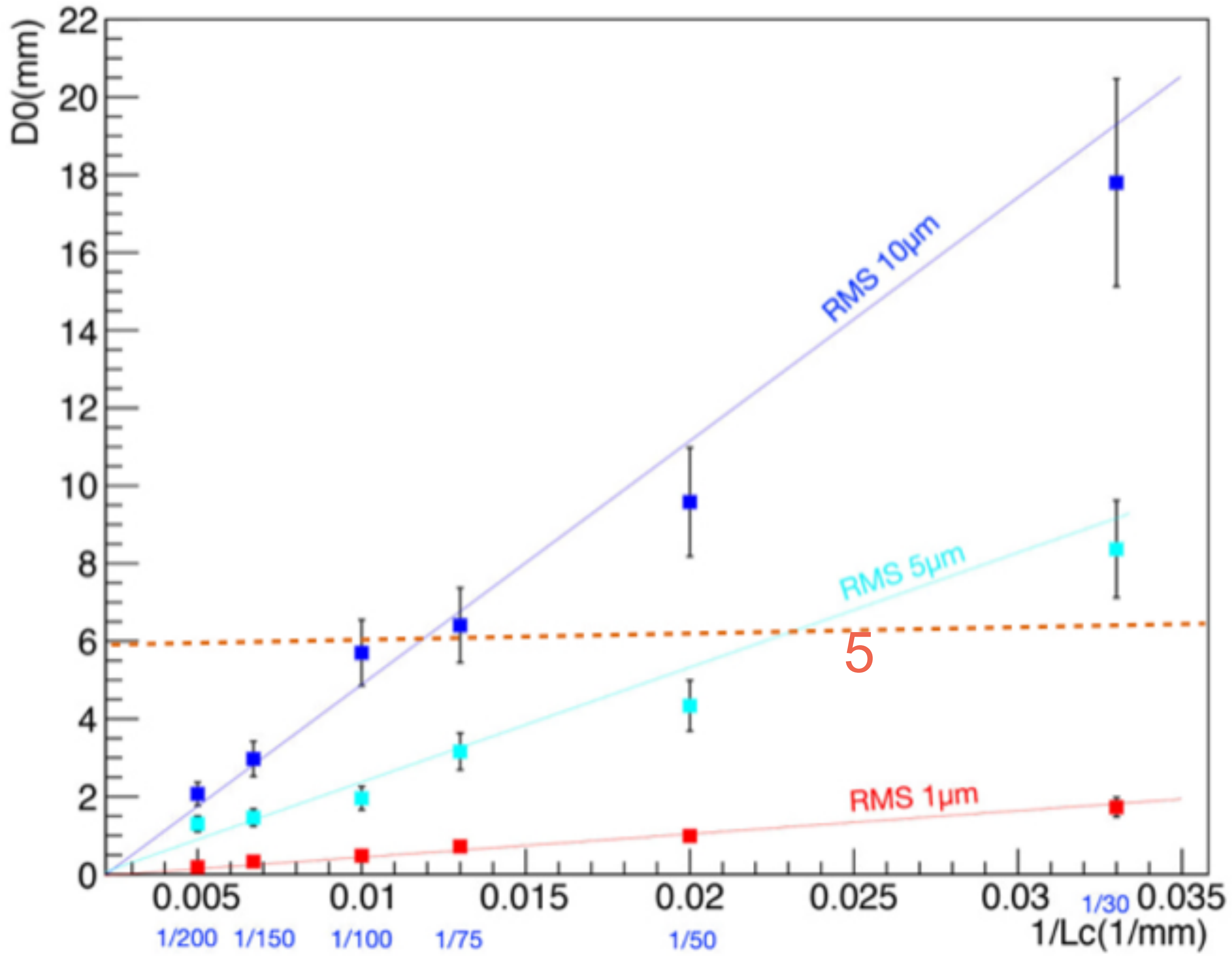


RMS = 2 μm

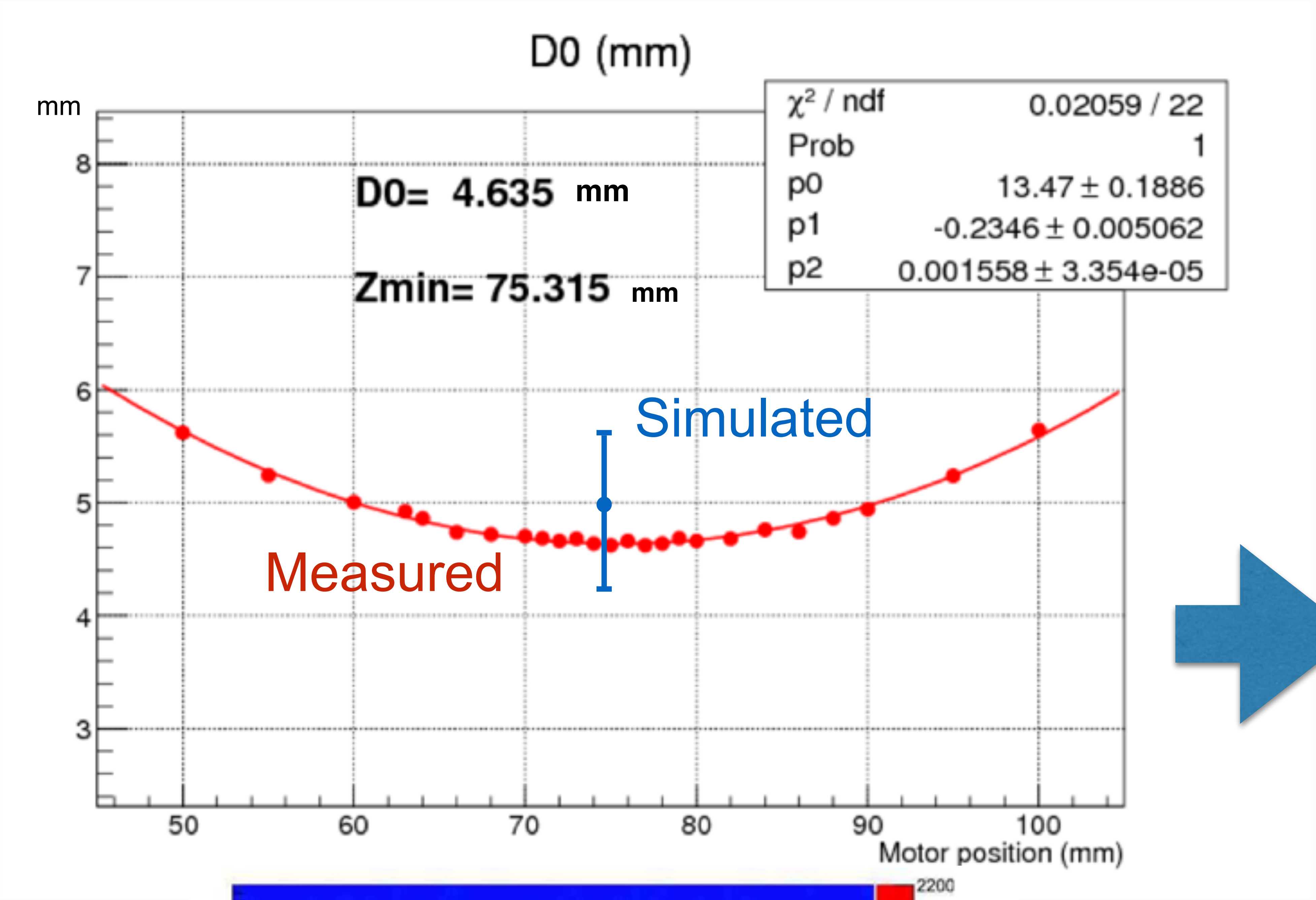


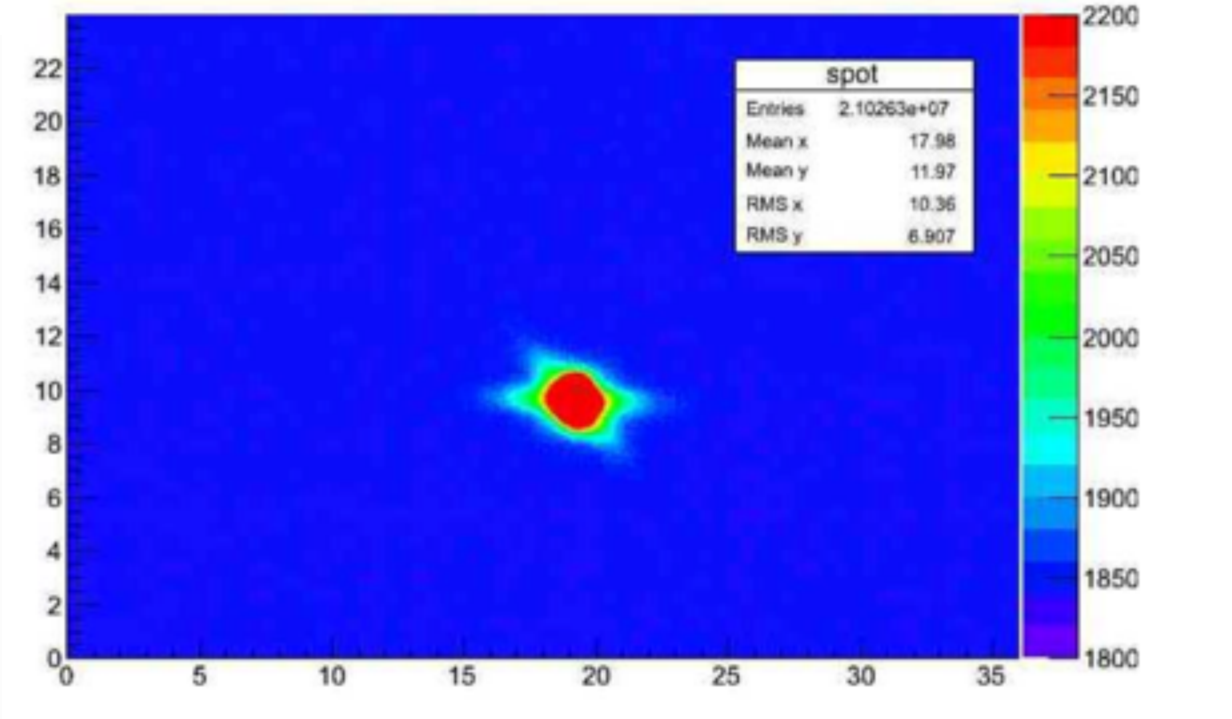




$$D0 \propto \sigma_N \propto \frac{RMS}{Lc}$$

Conclusions





Parts of the Spherical Mirror are arrived this month at JLAB.

Thanks for Watching