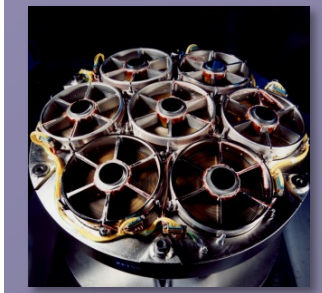
eROSITA

X-Ray Optics

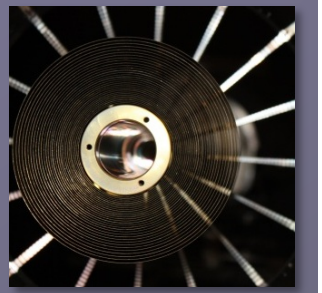
- Design
- Manufacturing
- Recent X-Ray tests
- Status Summary

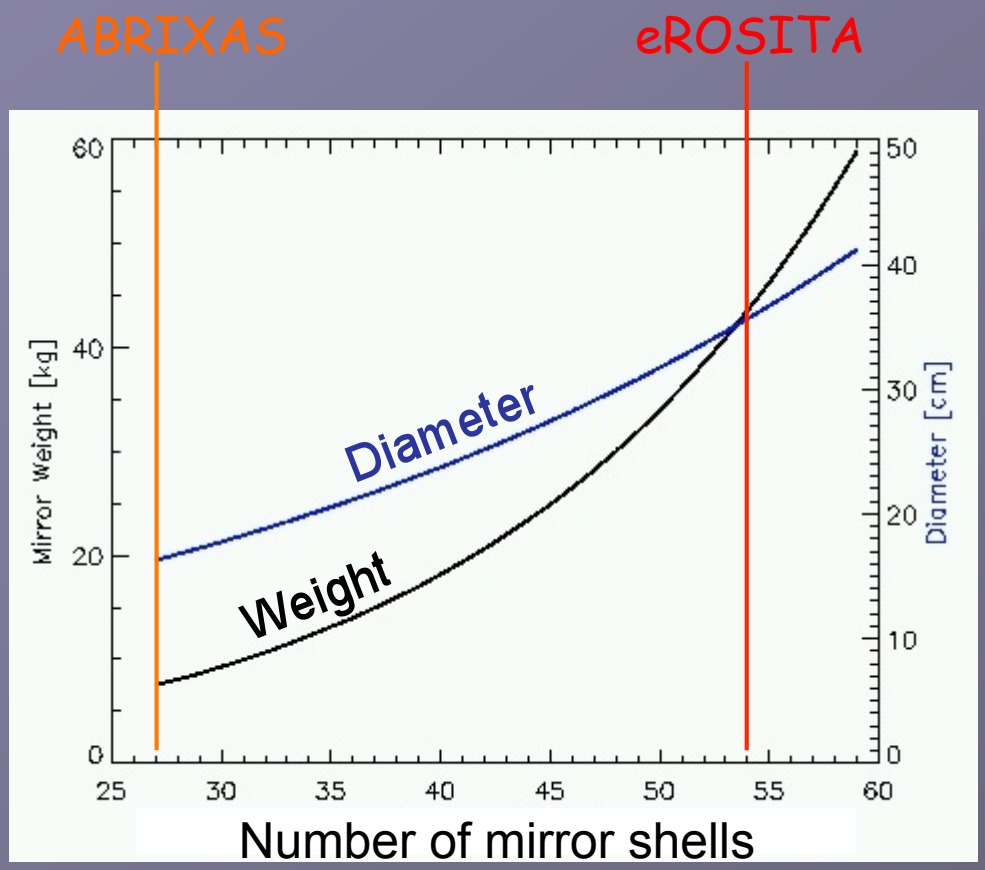
Peter Friedrich, MPE on behalf of the eROSITA team



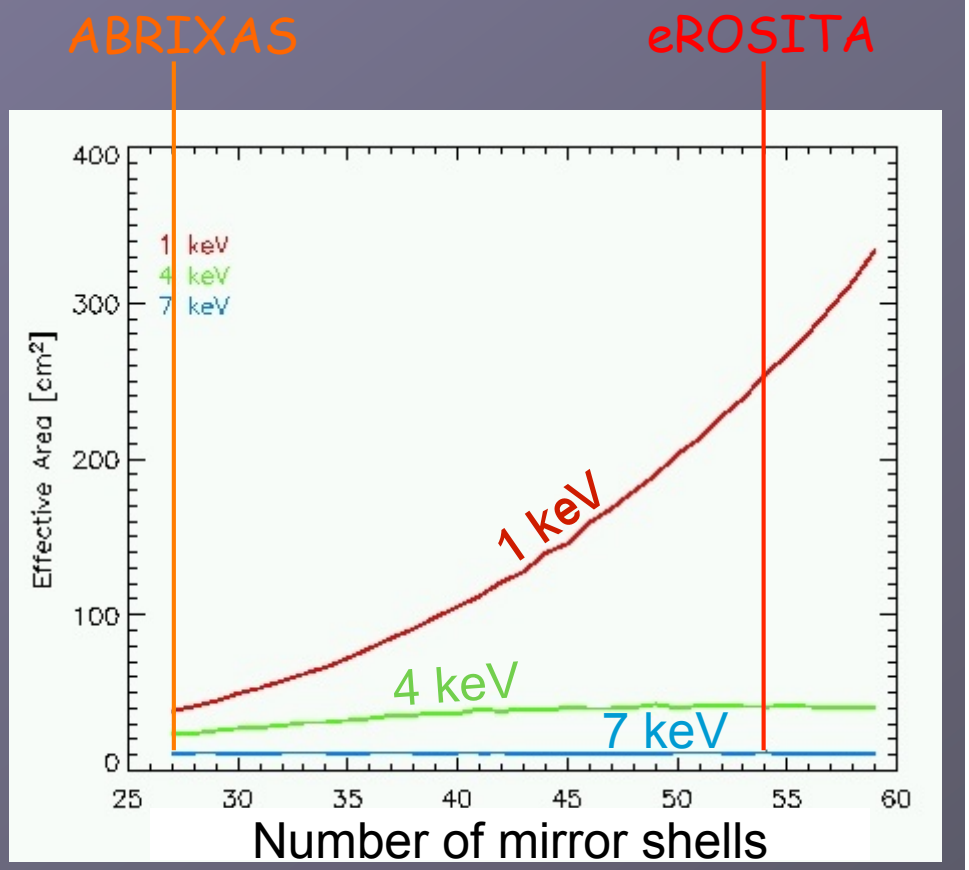
Mirror Design

From ABRIXAS (ROSITA, DUO) to eROSITA

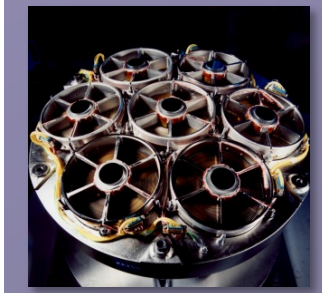




Weight and diameter of the mirror system depending on the number of mirror shells

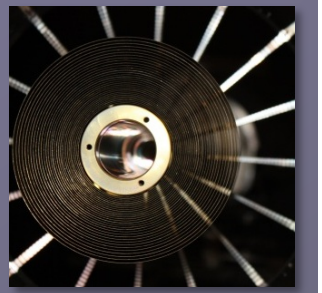


Effective area of the mirror system for different energies depending on the number of mirror shells



Mirror Design

From ABRIXAS (ROSITA, DUO) to eROSITA

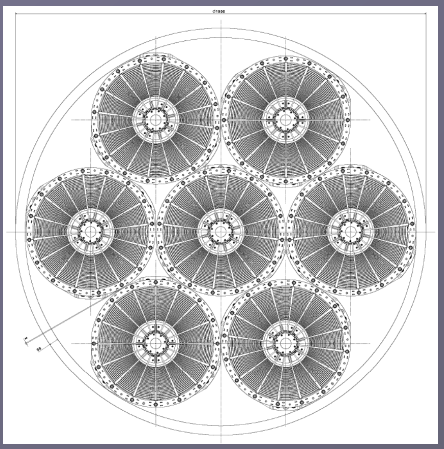


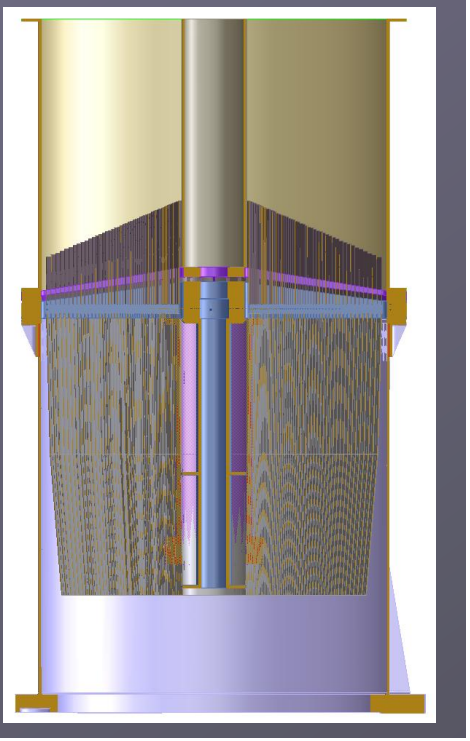
- Much larger collecting area (factor 5 at low energies)
- Better on-axis angular resolution (15″ on-axis)
- Larger field-of-view (61′ Ø)

Mirror Design

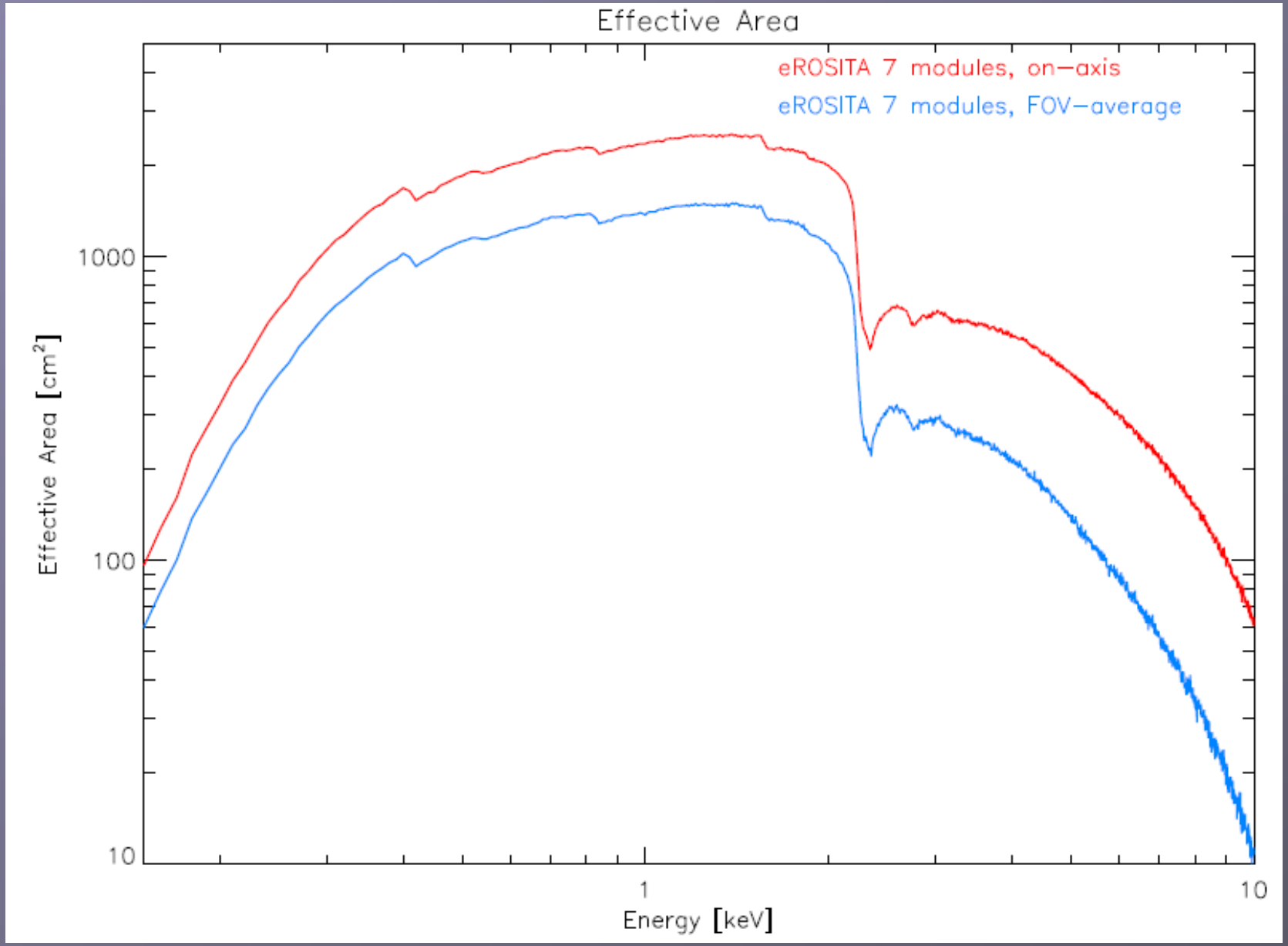
Basic Data of the eROSITA Telescope

Mirror Type	Wolter 1
Number of mirror modules	7
Orientation of mirror modules	parallel
Degree of nesting	54
Focal length	1600 mm
Largest mirror diameter	365 mm
Smallest mirror diameter	76 mm
Micro-roughness	<0.5 nm
Energy range	~0.2 – 10 keV
Coating	Gold (> 50 nm)
Field-of-view	61'



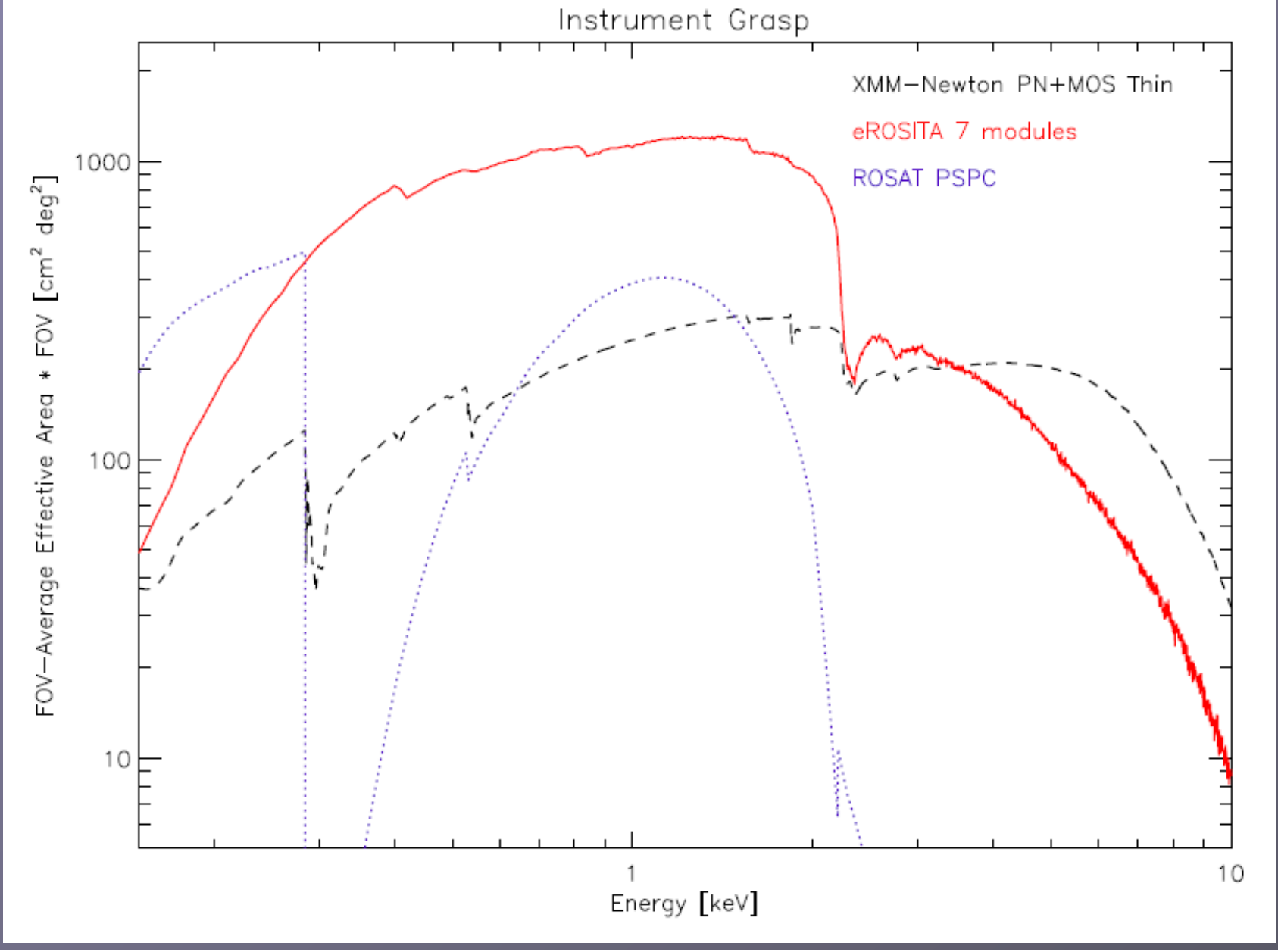


Effective Area



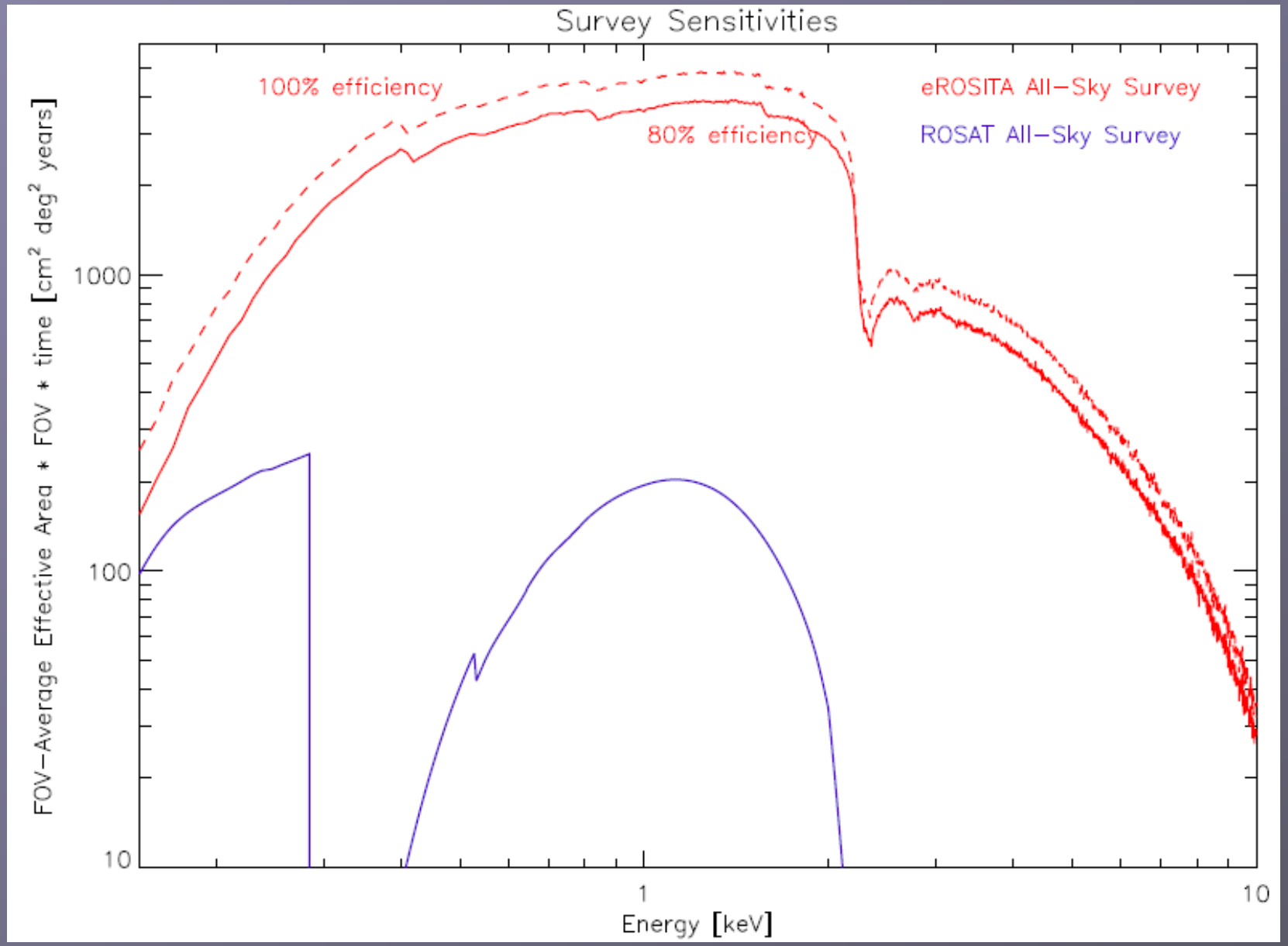
Comparison with XMM and ROSAT

Grasp: effective area × field-of-view

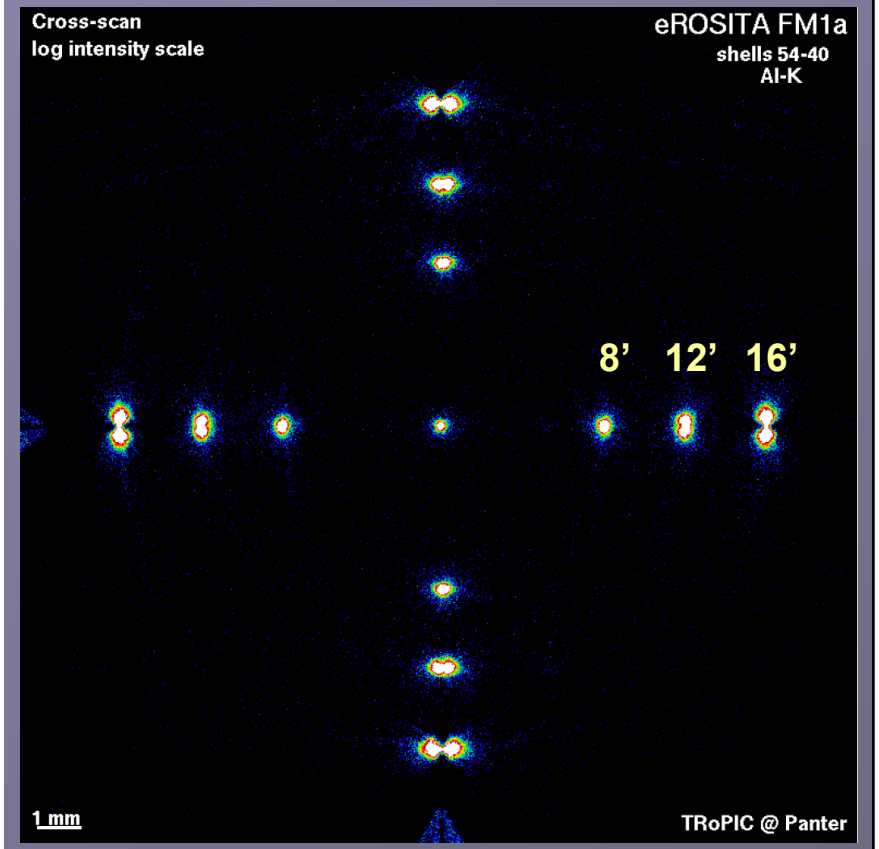


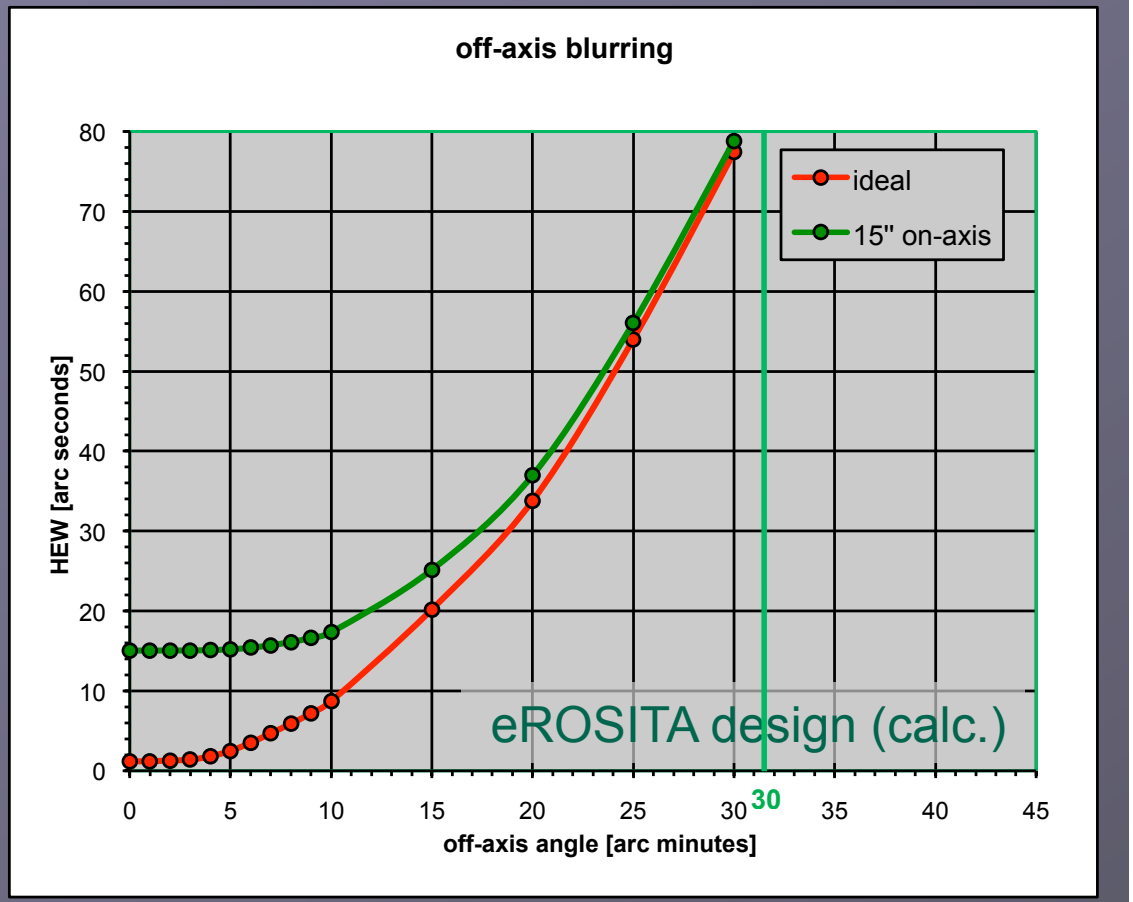
Comparison with ROSAT

Survey efficiency: effective area × field-of-view × survey duration

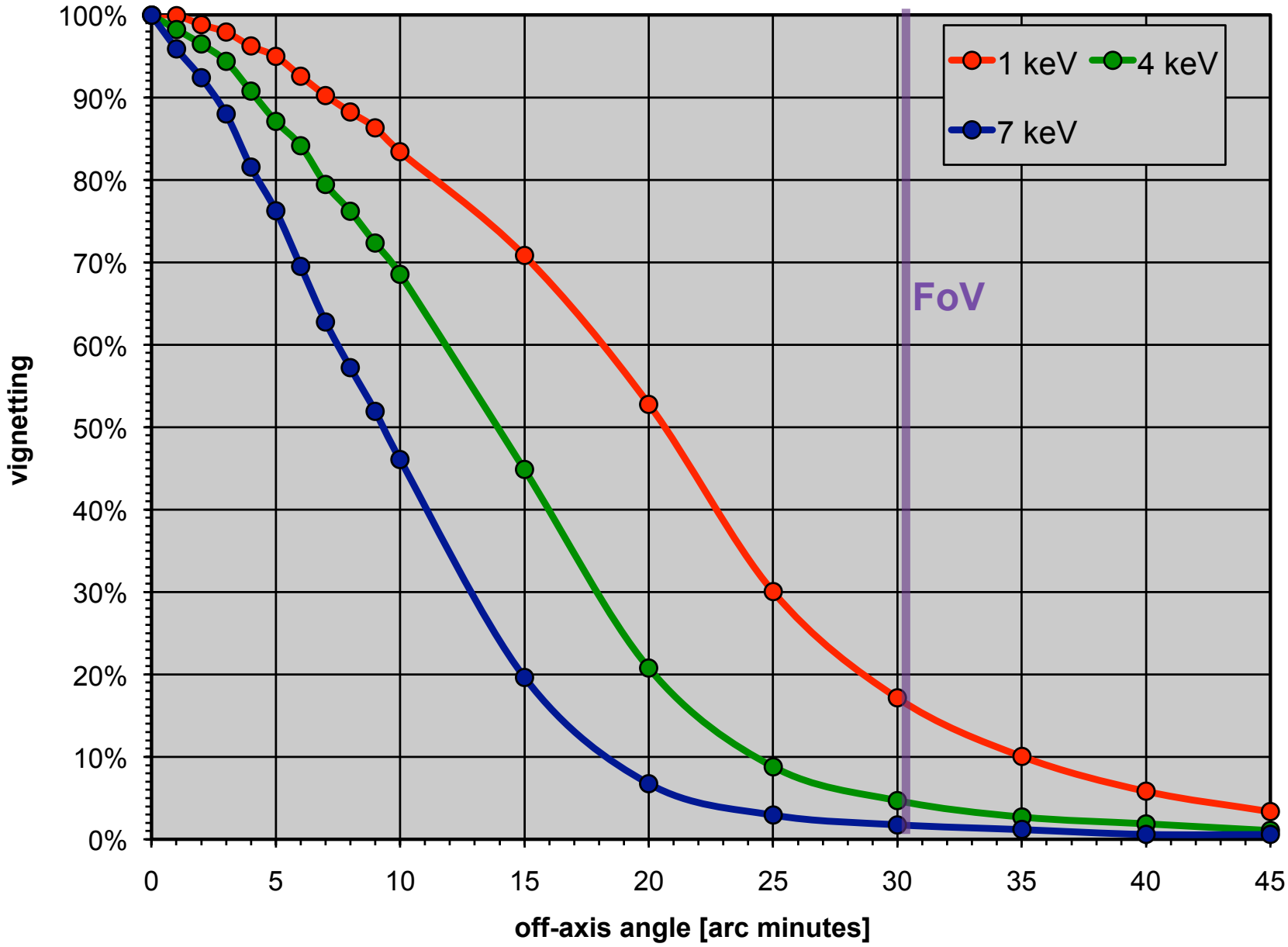


Point Spread Function (PSF)





Vignetting Function



Point Spread Function (PSF)

Angular Resolution Error Budget Summary

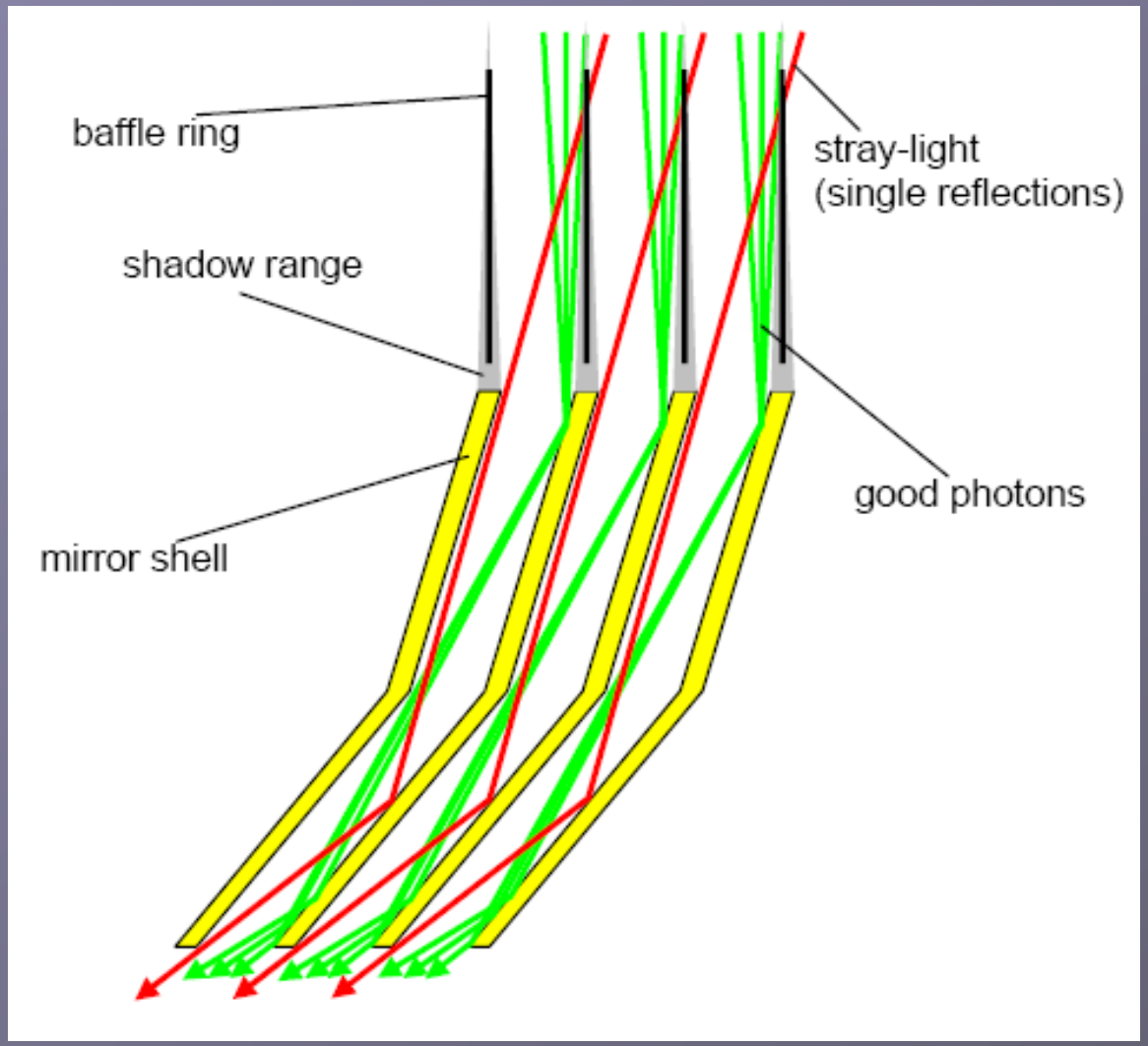
- On-Axis PSF: 15'' HEW
- Average PSF over the 61' FOV: 26'' HEW

} mirror system

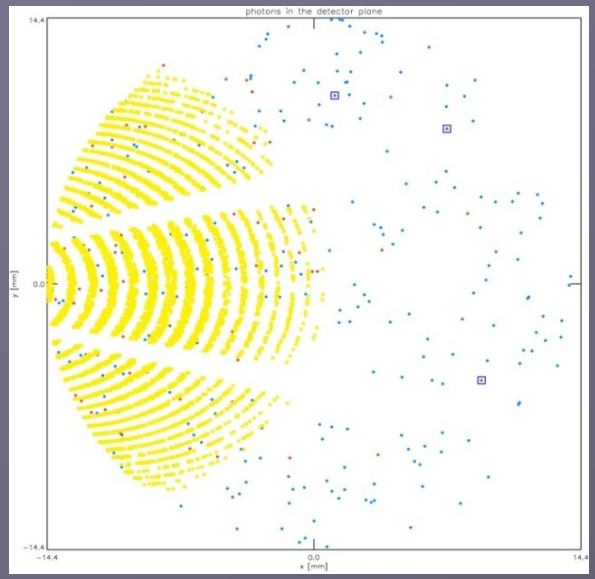
↓ 15'' → detector, structure, attitude

- Angular resolution of the survey: ~30'' HEW

X-Ray Baffle against Straylight

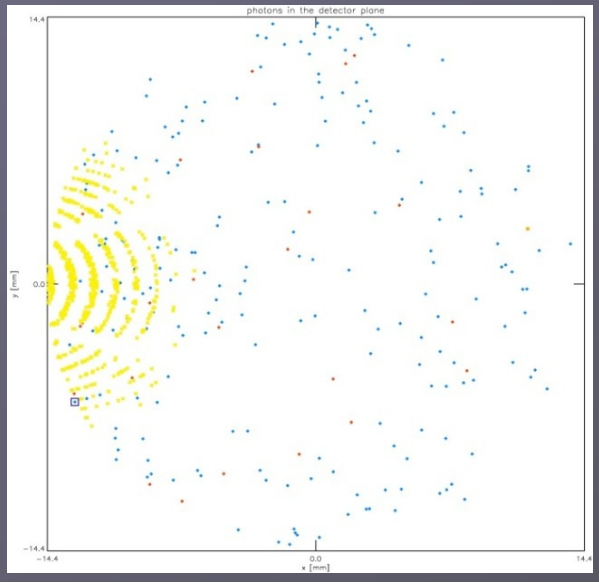


without baffle



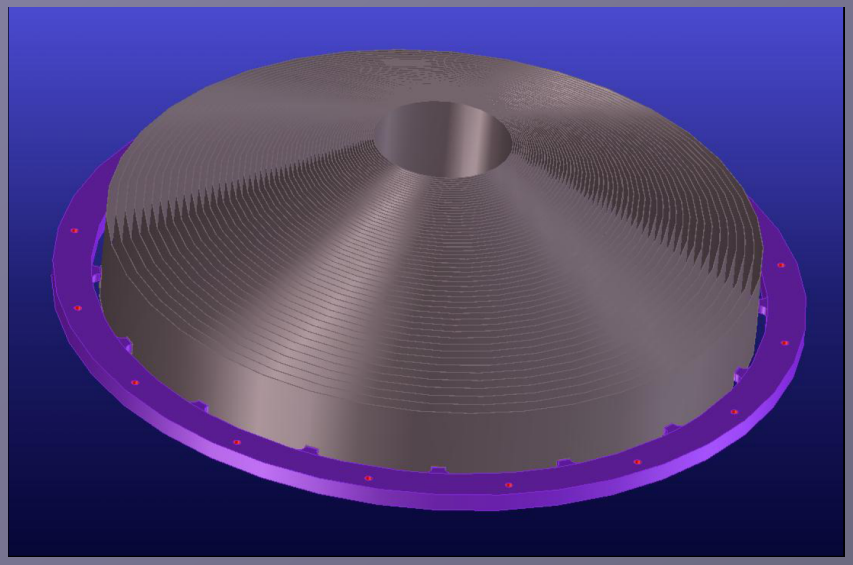
source 1° off-axis

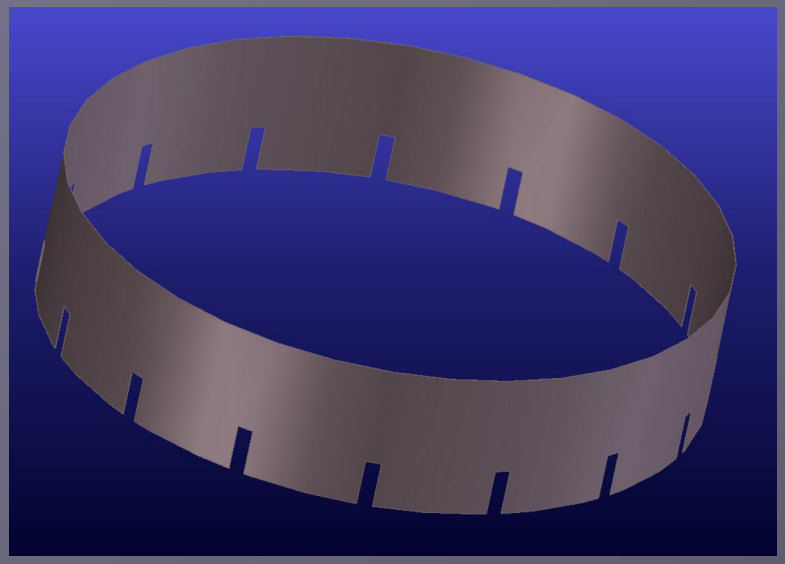
with baffle



X-Ray Baffle against Straylight

- System of 54 cylindrical shells
  - height outer 50 mm, height inner 110 mm, wall thickness 125 µm
- Straylight reduction from ~30% to ~1.5% @1keV (~43% to ~4% @4keV)





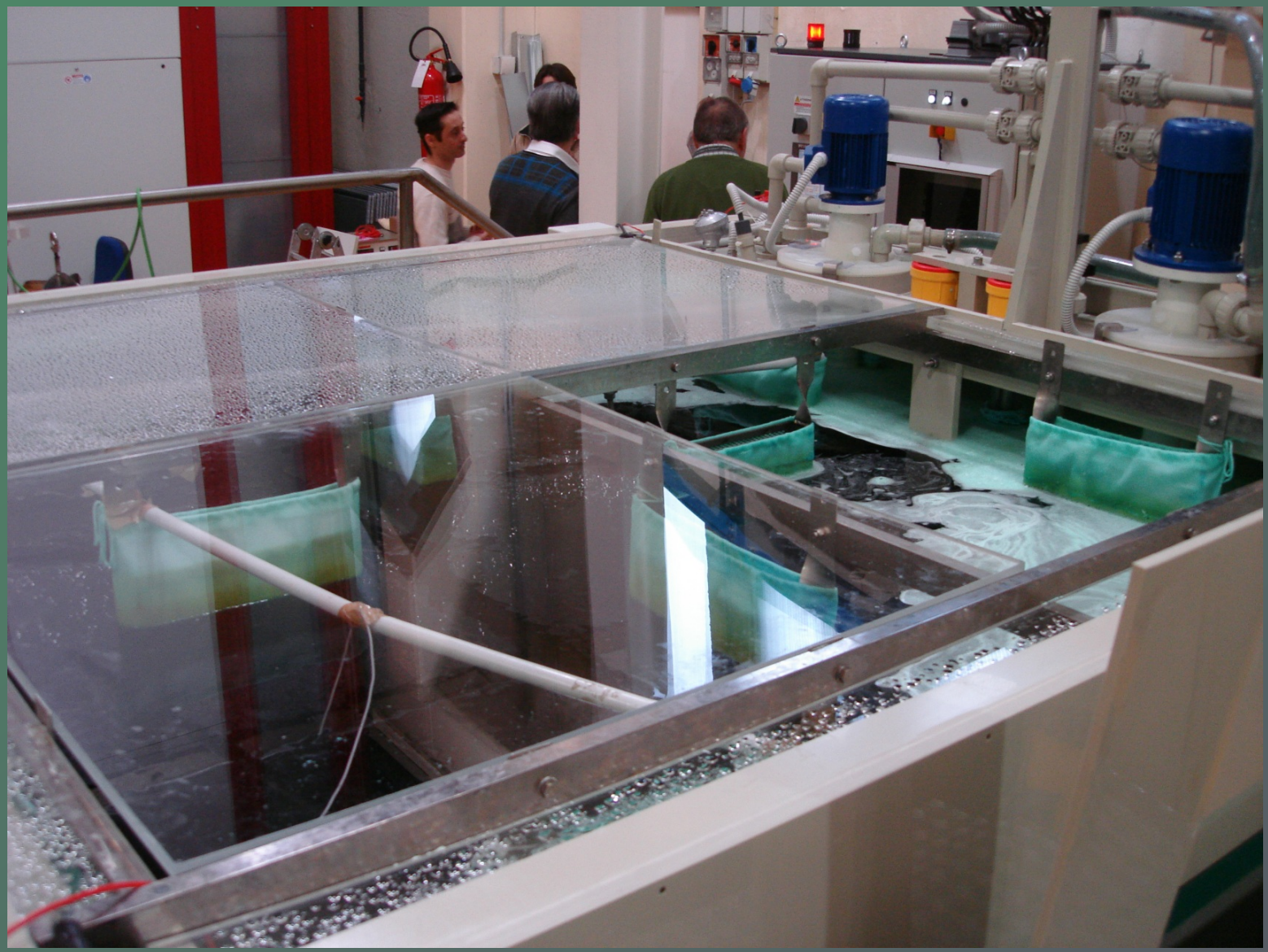
- mounted on spider wheel on top of mirror module
- QM ready and tested

Mandrels

Refurbished ABRIXAS mandrels

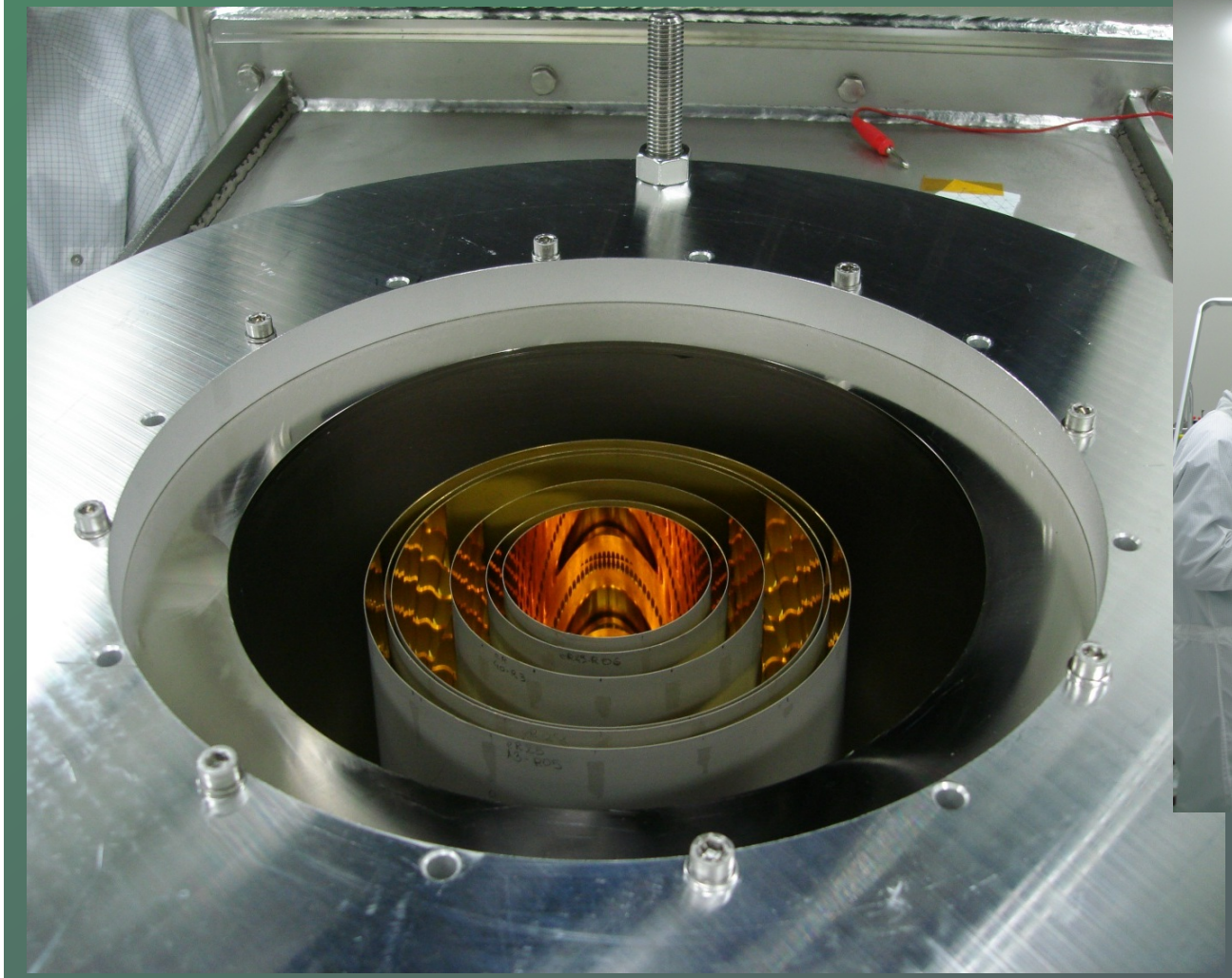
Polishing of new mandrels at Media Lario on on a Zeeko polishing machine

Electroforming Baths



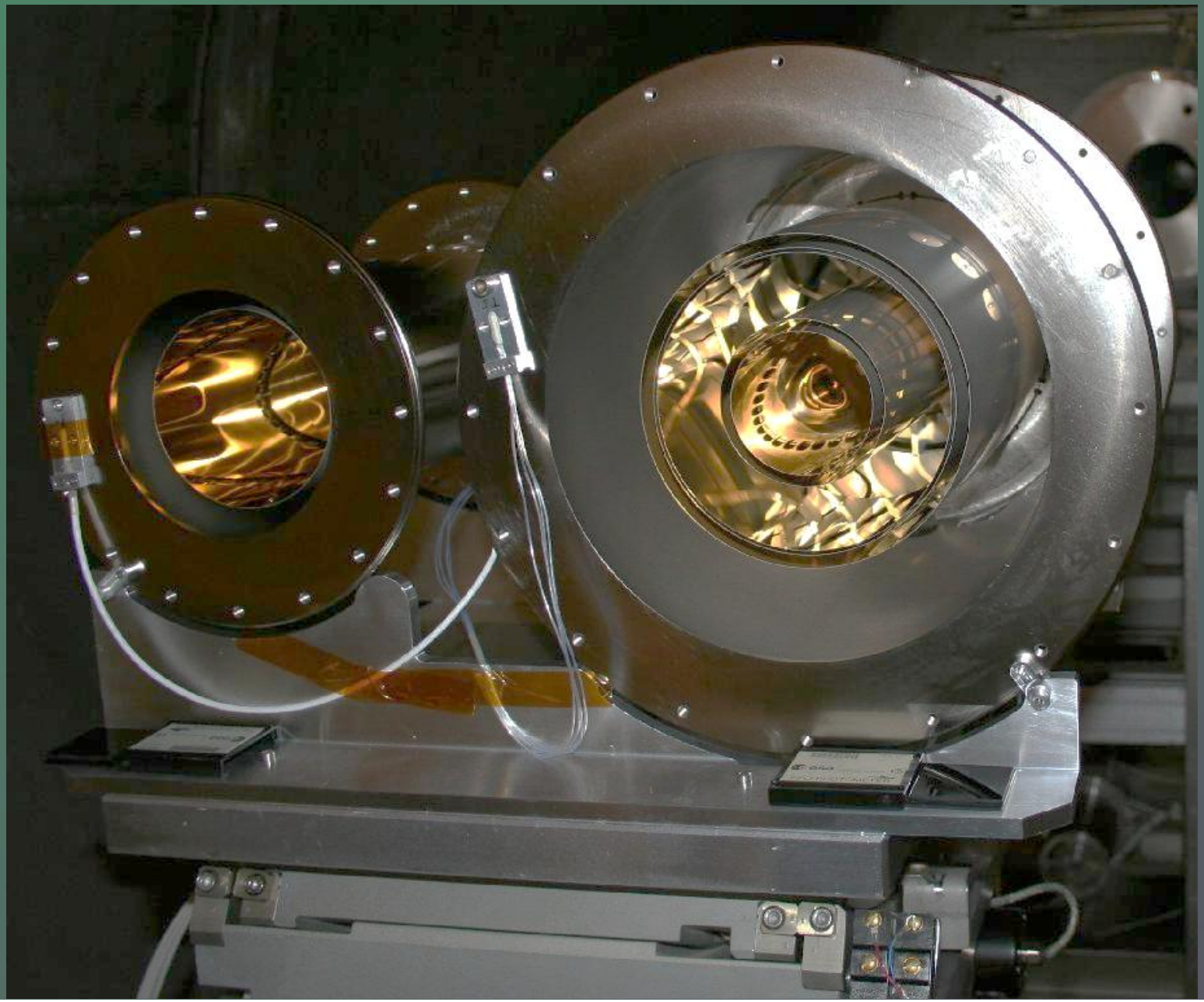
Vertical Optical Bench

(mirror integration facility)

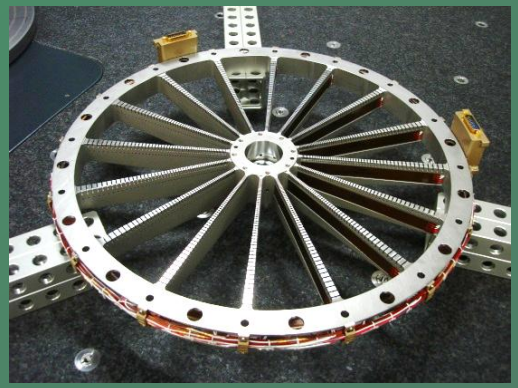


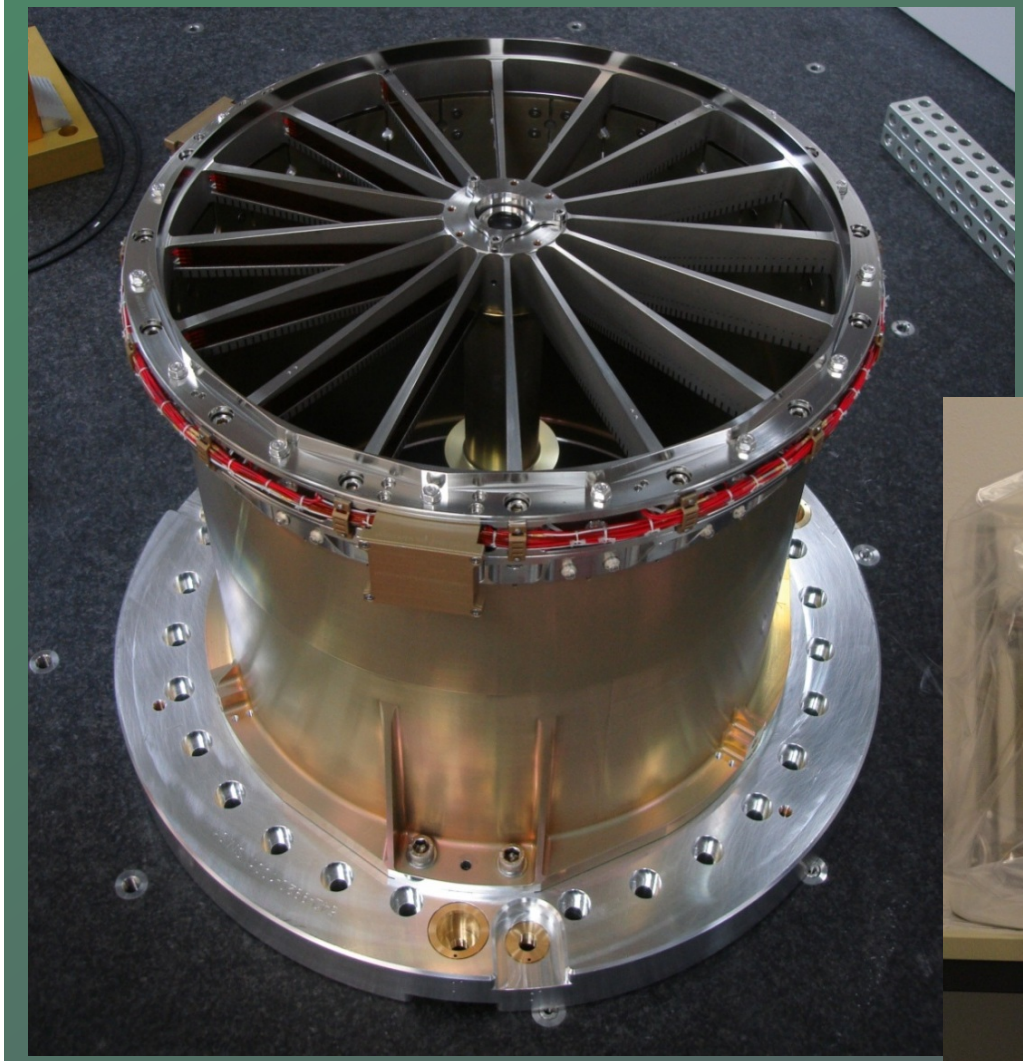
Media Lario Technologies

Test Mirrors



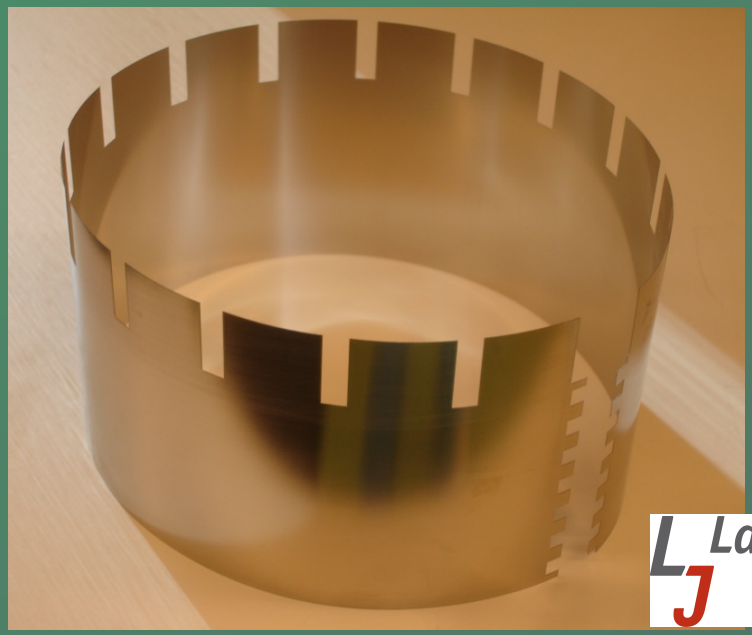
Mirror Module Structure



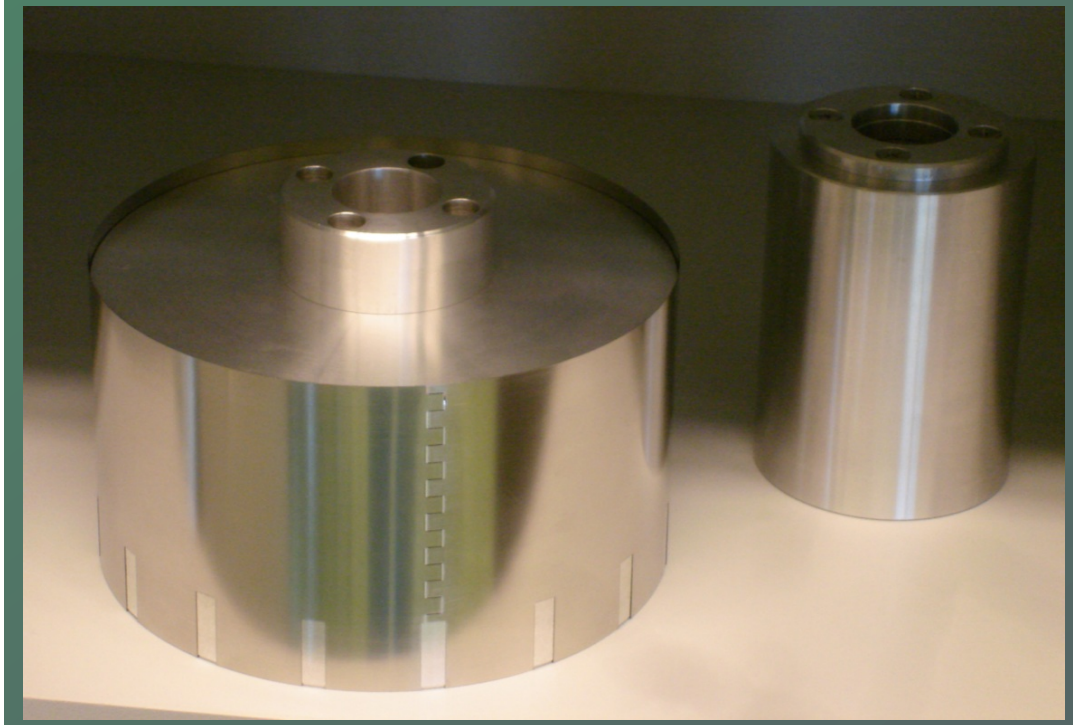


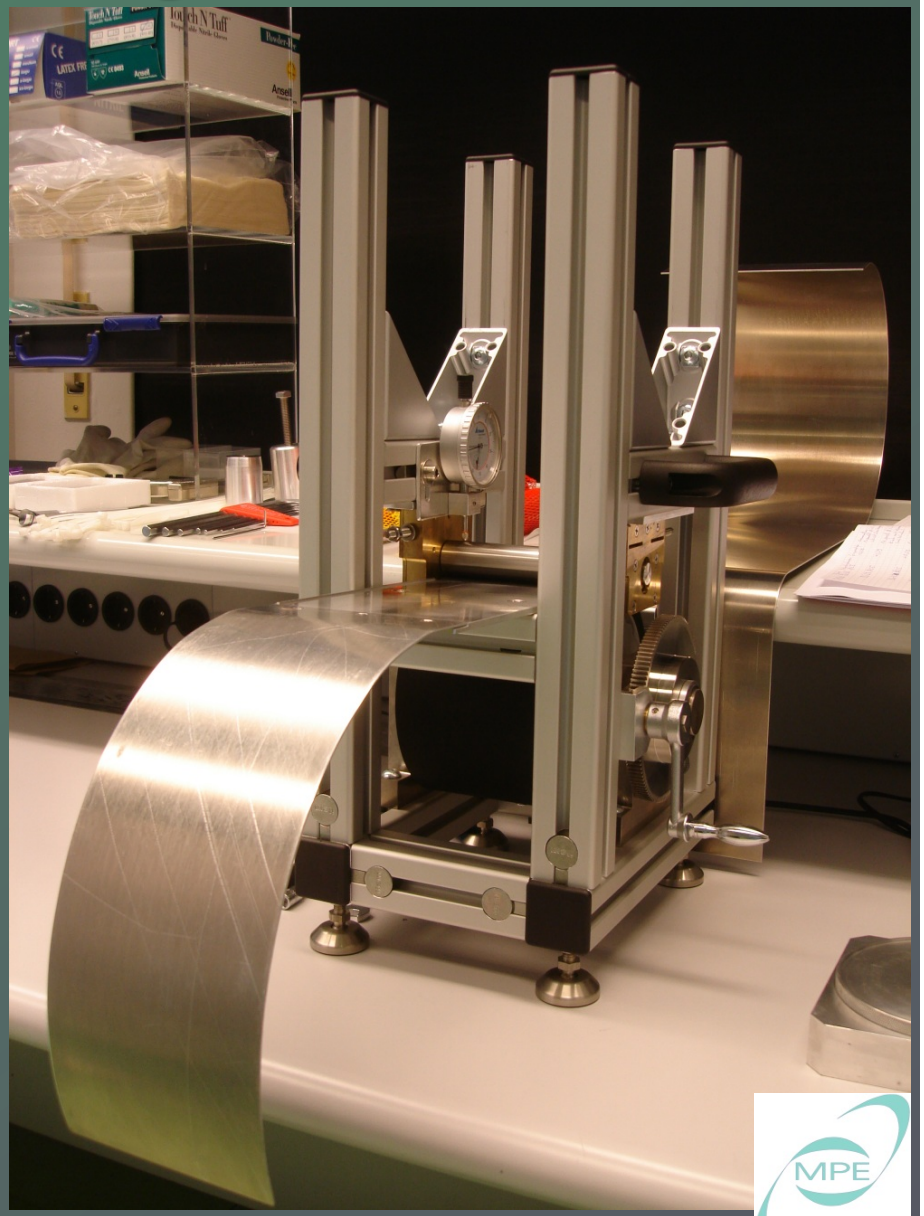
KAYSER-THREDE

X-Ray Baffle



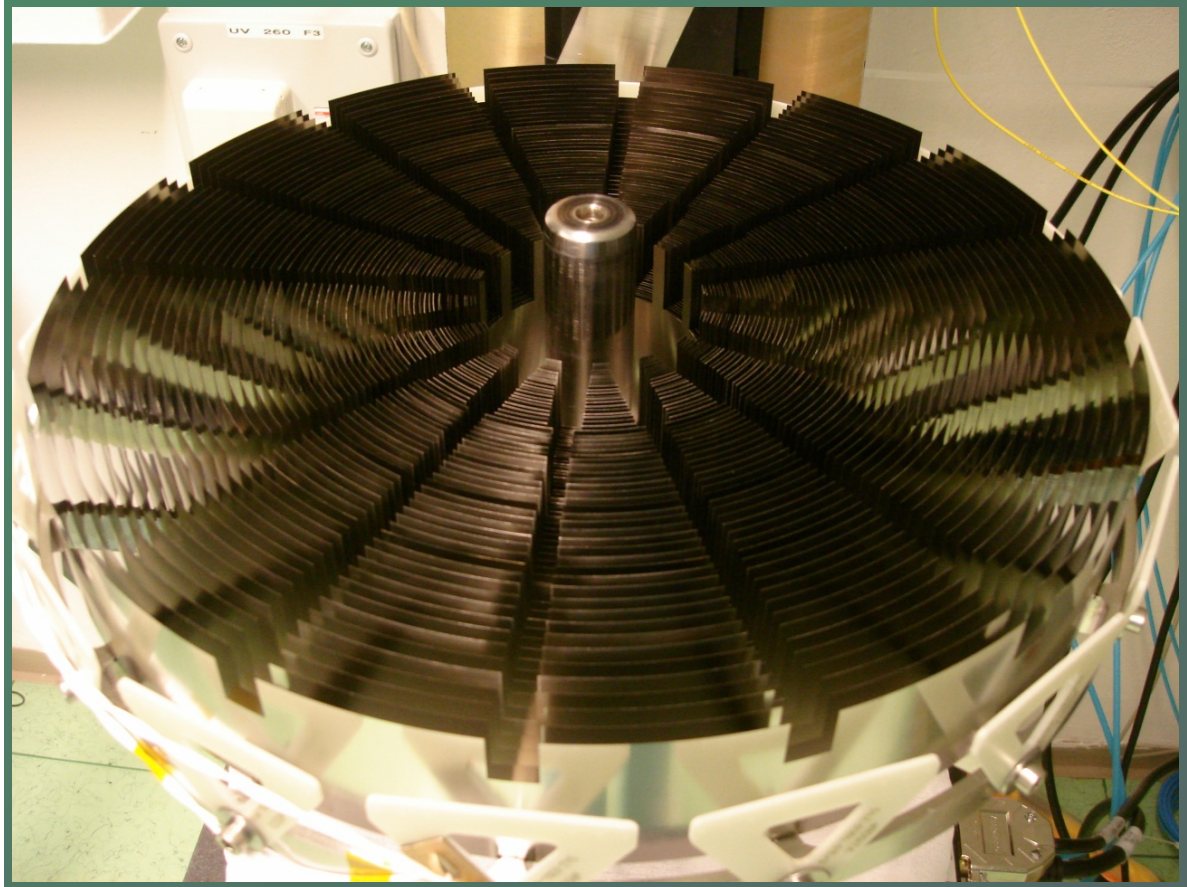
LaserJob



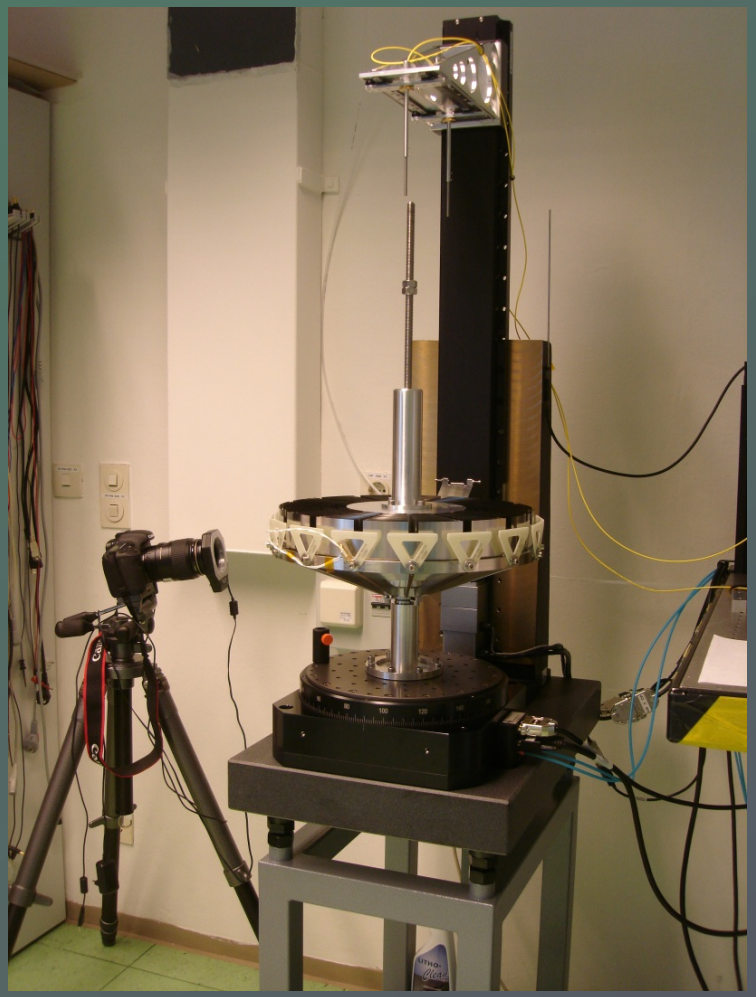


MPE

X-Ray Baffle



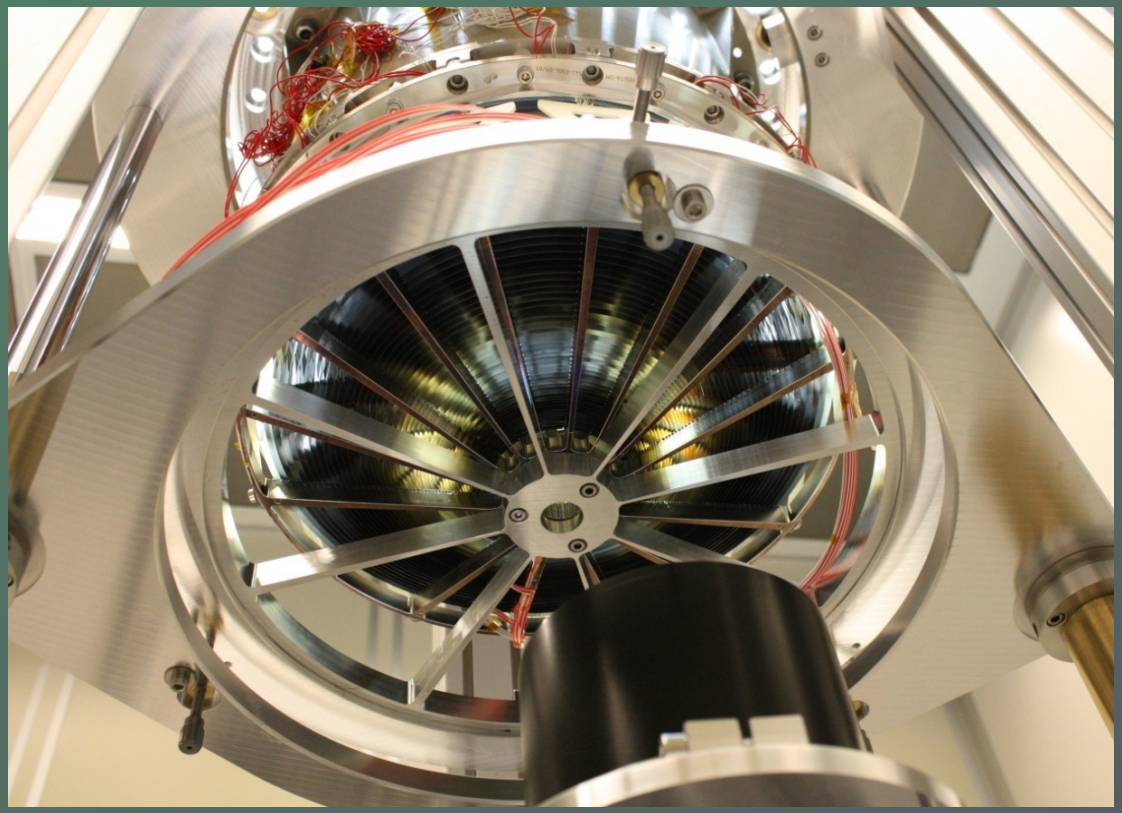
X-ray baffle QM



Rotation table for Integration

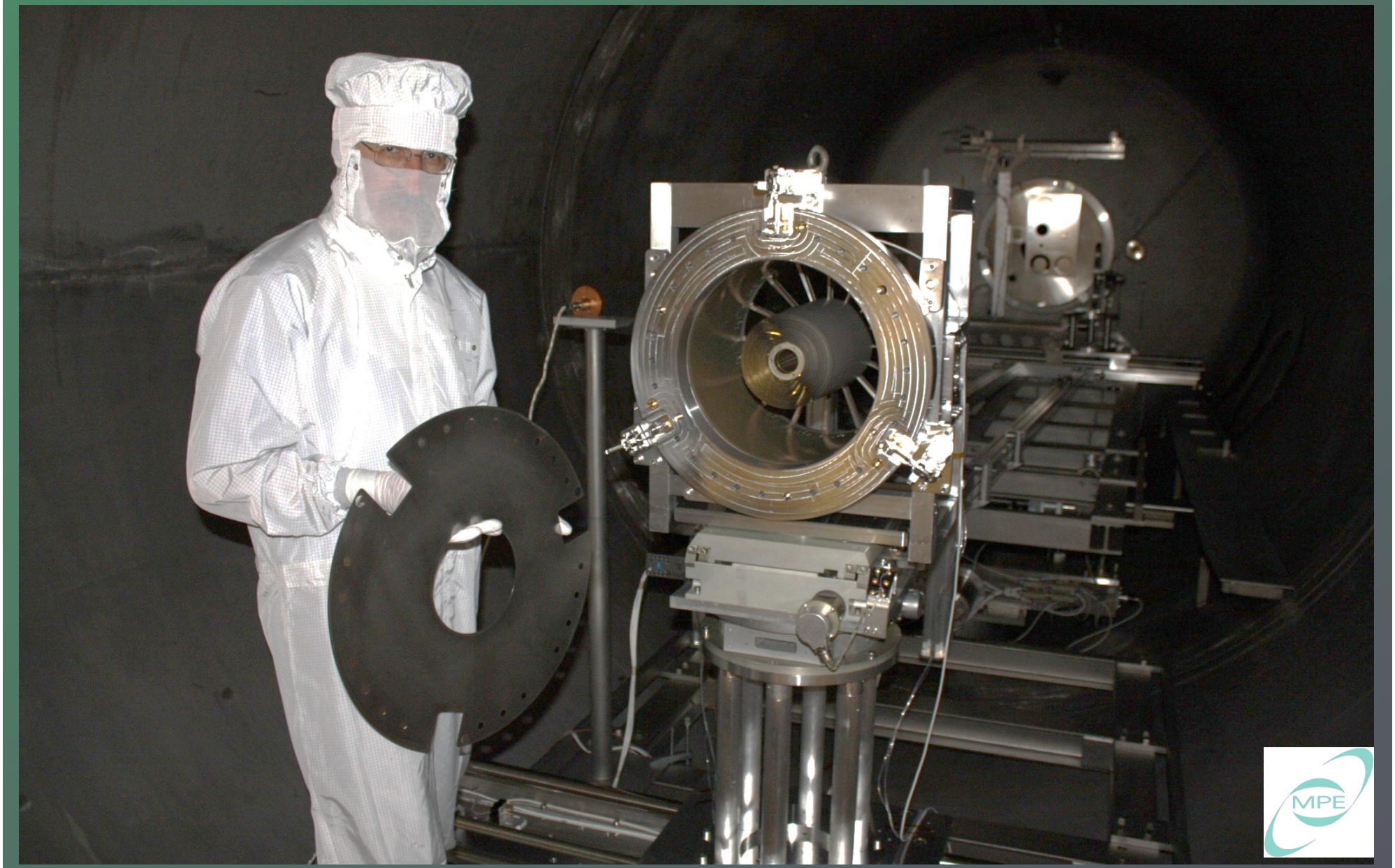
X-Ray Baffle

alignment to MM…

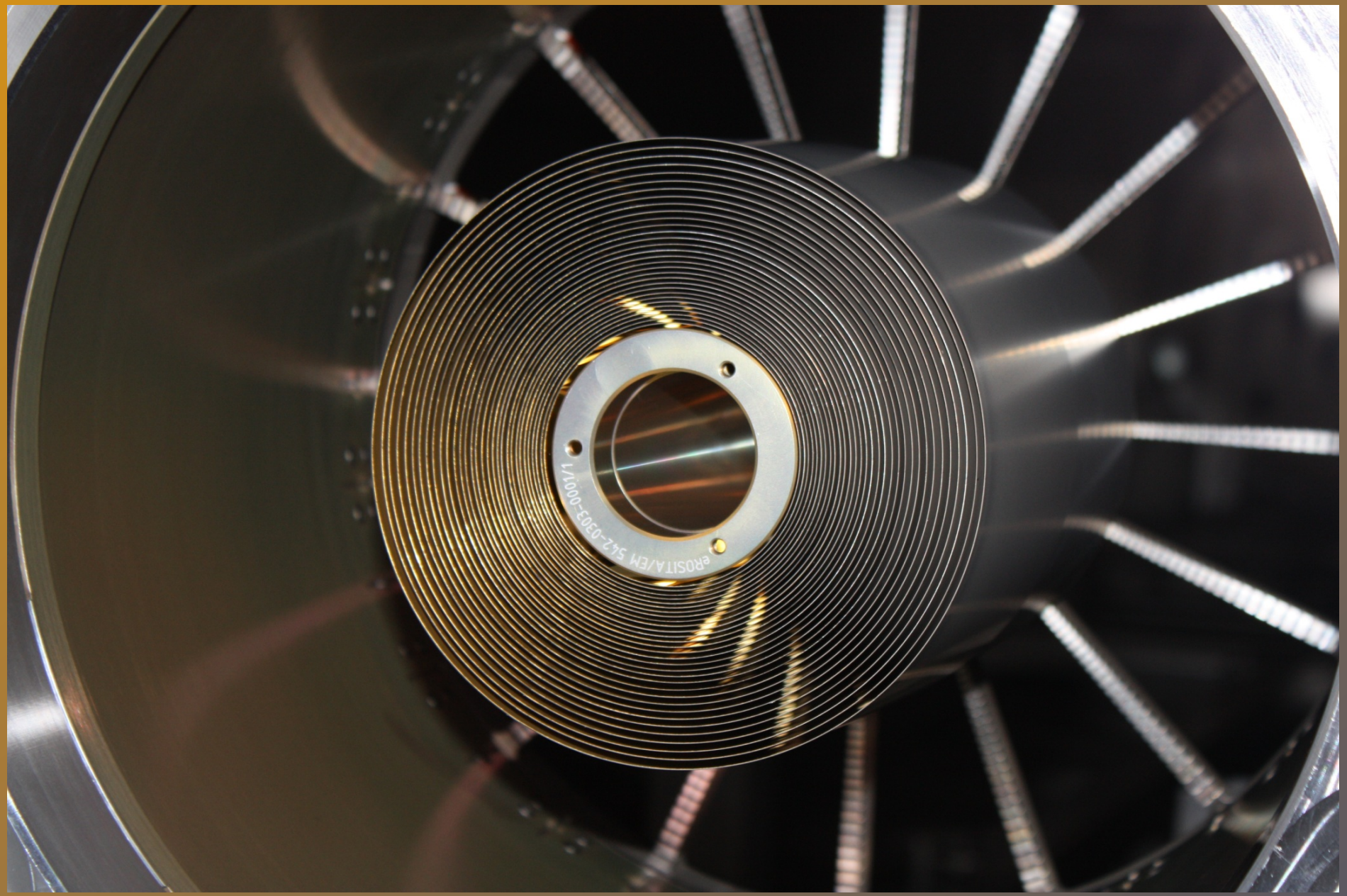


…under optical control

X-Ray Test Facility PANTER



FM1 with 31 shells in X-Ray Test



PSF of FM1/2 with 31/15 shells

MM and Mirror Groups

Shells	Target	Energy	PSF			
			HEW*	HEW**	W90	scattering
FM1 shells 24-54	C-K	0.28 keV	17.1 arcsec	14.1 arcsec	89.4 arcsec	5.2%
FM1 shells 24-54	Al-K	1.49 keV	16.2 arcsec	15.4 arcsec	74.3 arcsec	5.1%
FM1 shells 24-54	Ag-L	2.98 keV	16.4 arcsec	16.6 arcsec	92.8 arcsec	6.9%
FM1 shells 24-54	Cr-K	5.41 keV	17.2 arcsec	17.0 arcsec	130.3 arcsec	9.5%
FM1 shells 24-54	Cu-K	8.04 keV	15.5 arcsec	15.5 arcsec	140.9 arcsec	11.8%

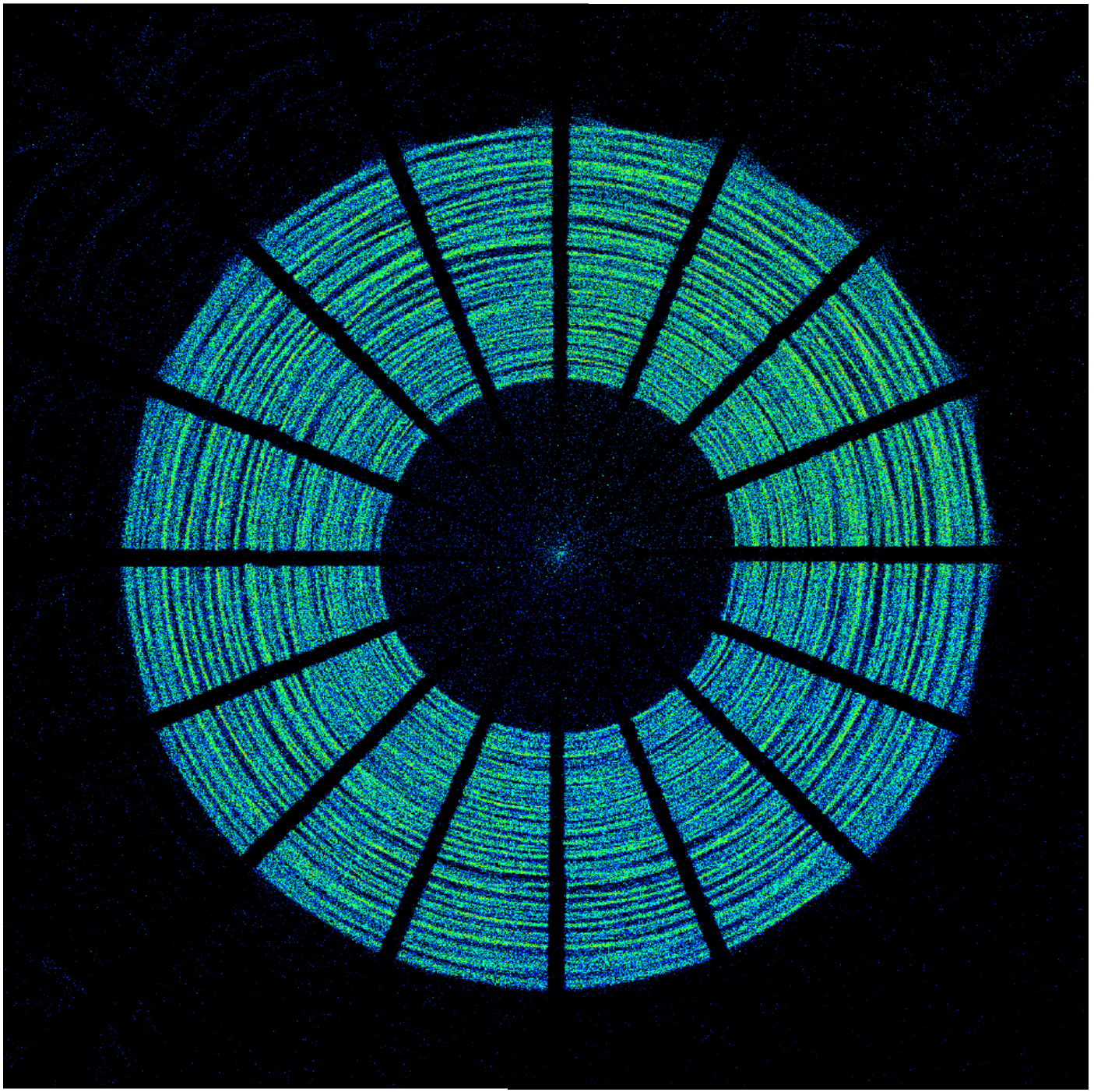
Shells	Target	Energy	PSF			
			HEW*	HEW**	W90	scattering
FM1 shells 40-54	Al-K	1.49 keV	13.6 arcsec	12.9 arcsec	43.5 arcsec	2.5%
FM2 shells 40-54	Al-K	1.49 keV	14.4 arcsec	13.9 arcsec	49.4 arcsec	2.8%
FM1 shells 24-39	Al-K	1.49 keV	17.8 arcsec	17.3 arcsec	94.6 arcsec	5.2%
FM1 shells 34-39	Al-K	1.49 keV	19.4 arcsec	17.6 arcsec	101.6 arcsec	9.0%
FM1 shells 28-33	Al-K	1.49 keV	17.5 arcsec	16.5 arcsec	100.6 arcsec	8.4%
FM1 shells 24-27	Al-K	1.49 keV	16.7 arcsec	16.1 arcsec	84.5 arcsec	3.2%
FM1 shells 24-27	Cr-K	5.41 keV	20.8 arcsec	20.7 arcsec	186.7 arcsec	14.3%

* sub-pixel resolution based on all split events
** HEW sub-pixel resolution based on triple/quadruple split events

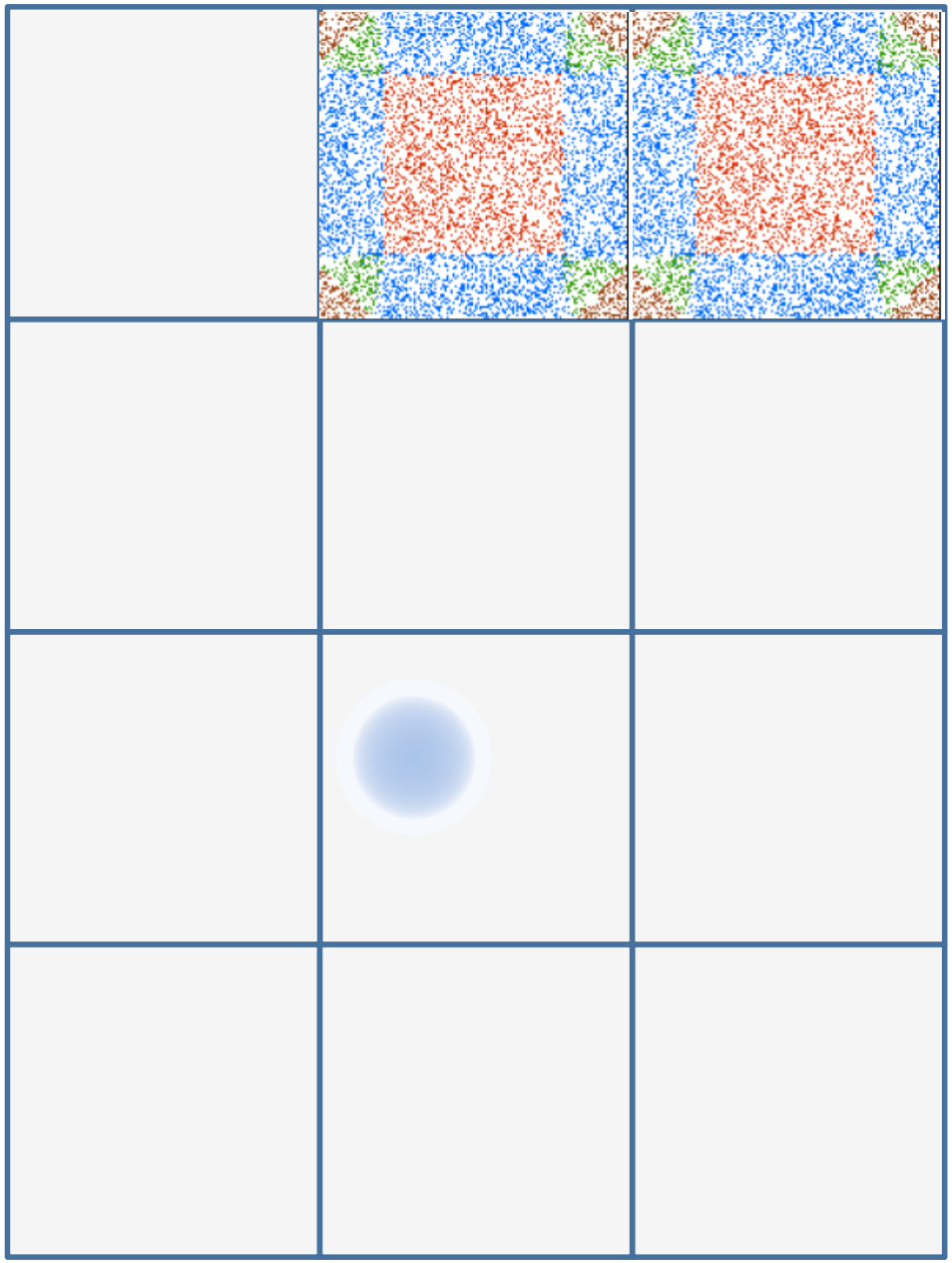
FM1b

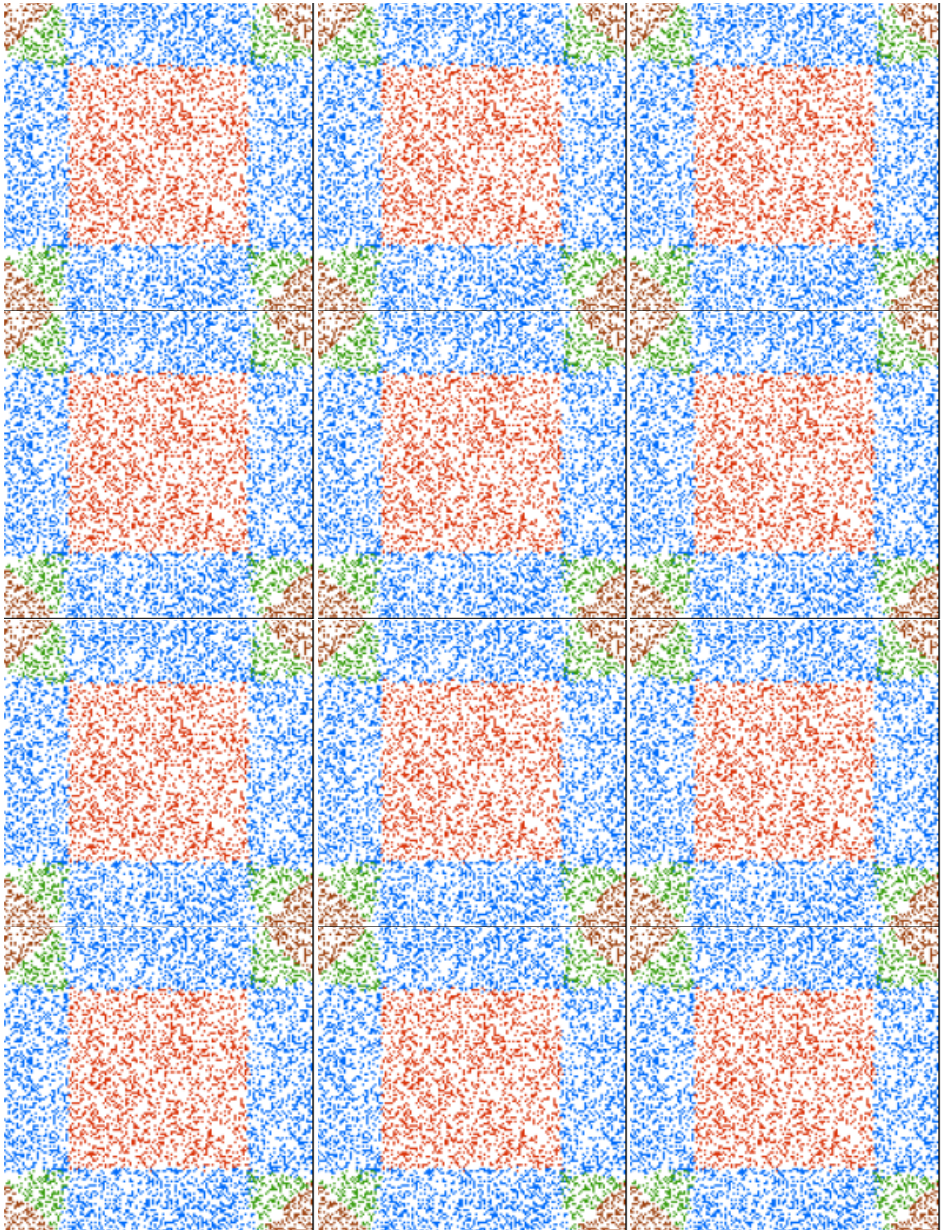
Extrafocal Image

(composit)



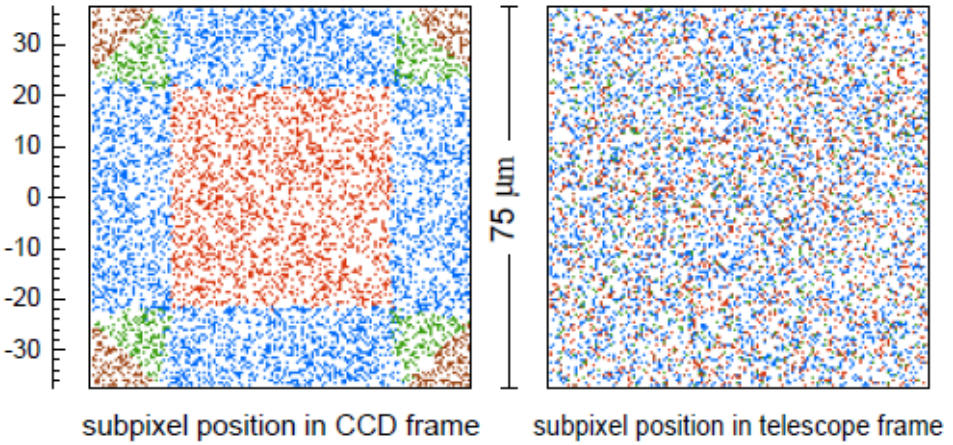
Pixelscan and Sub-Pixel Analysis

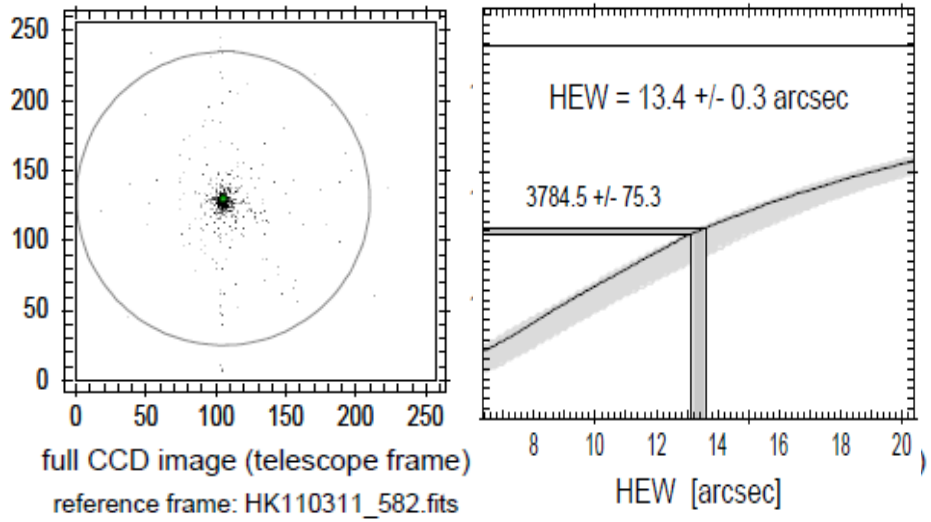




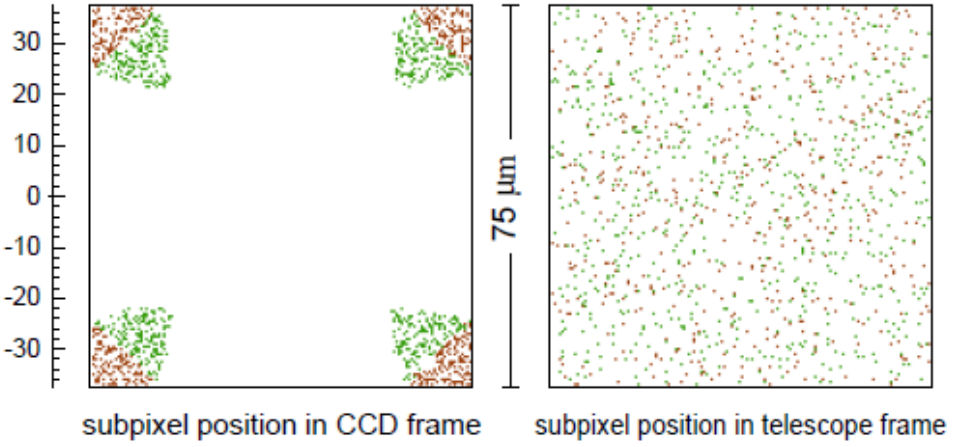
Sub-Pixel Analysis for Al-K (1.49 keV)

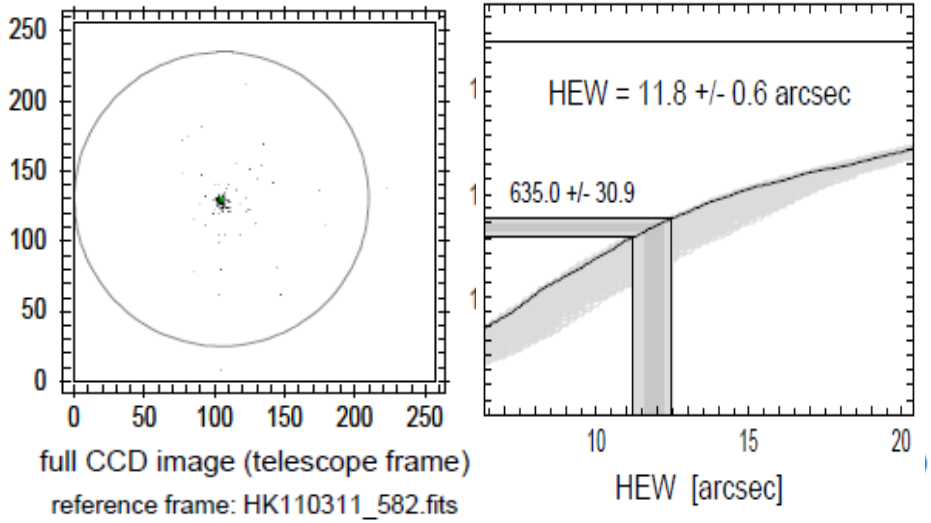
all events





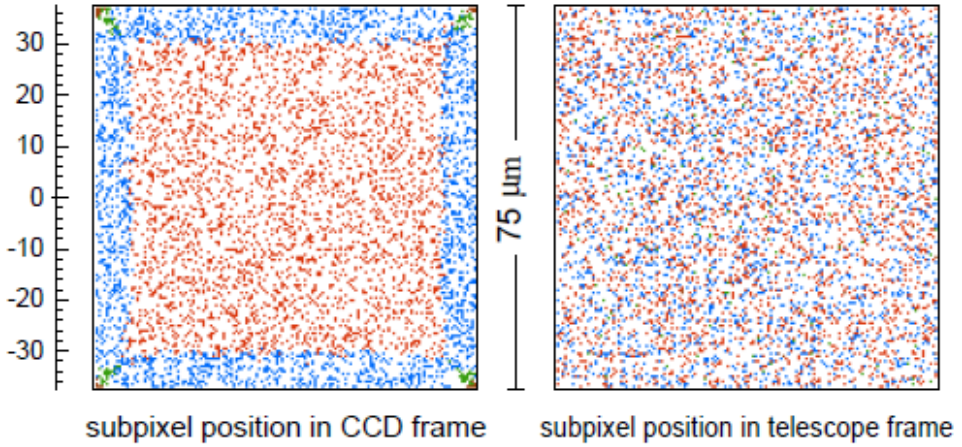
triple / quadruple events

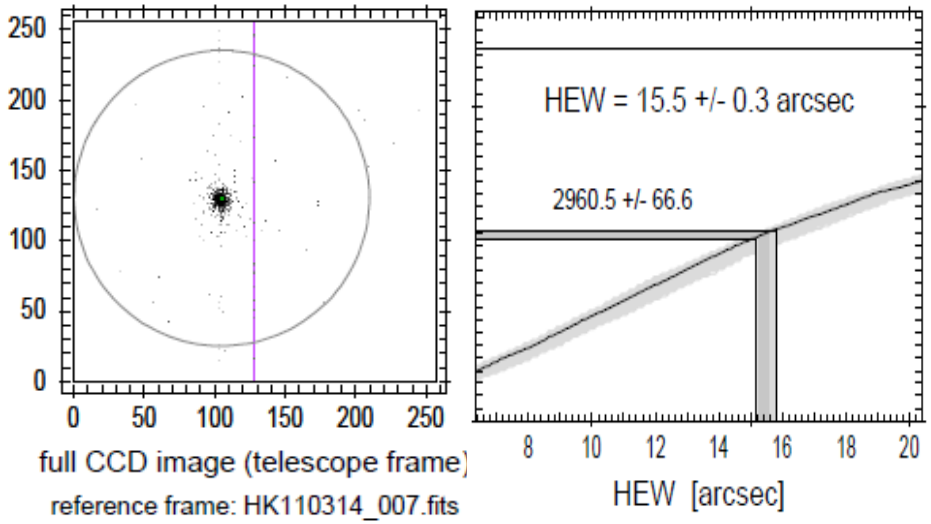




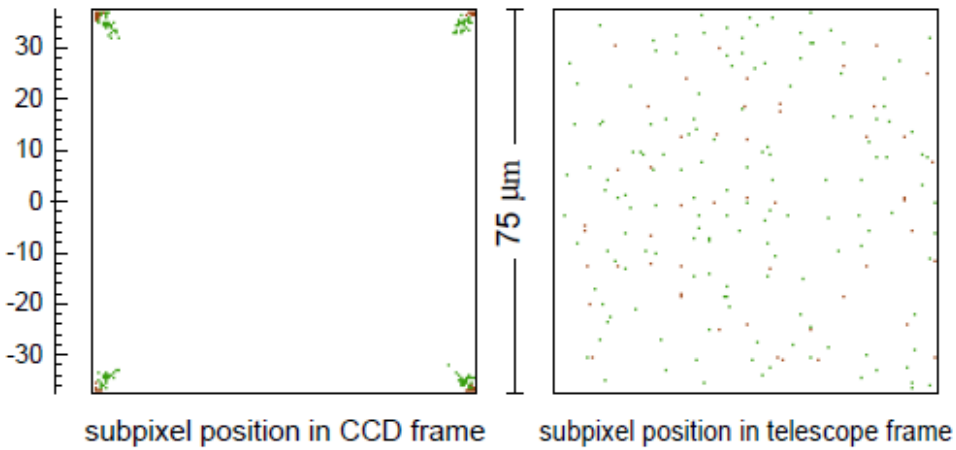
Sub-Pixel Analysis for C-K (0.28 keV)

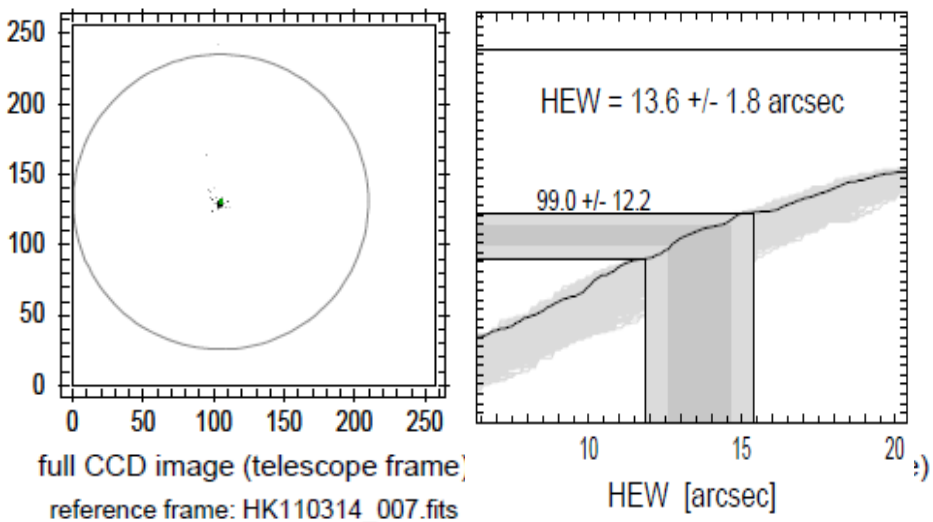
all events





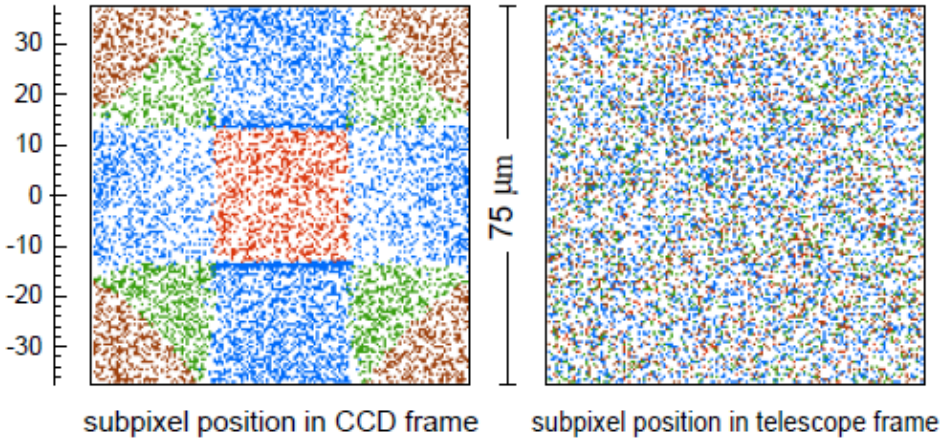
triple / quadruple events

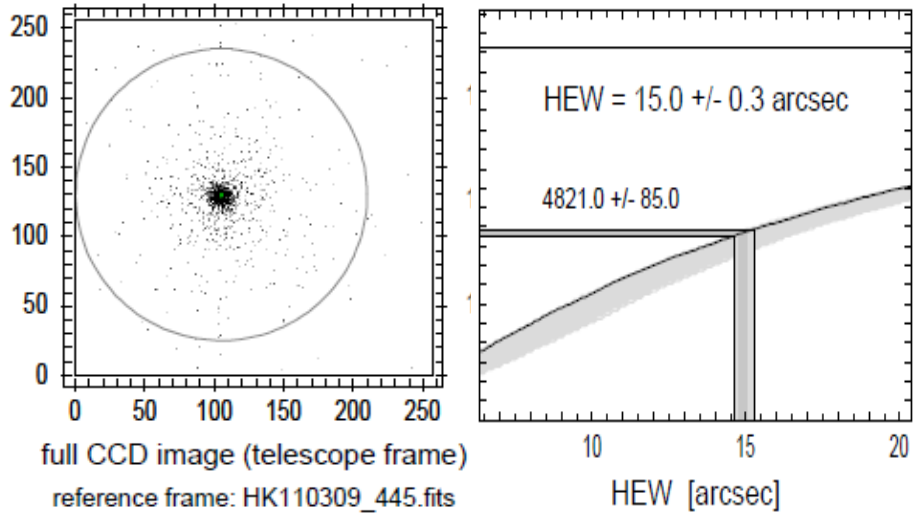




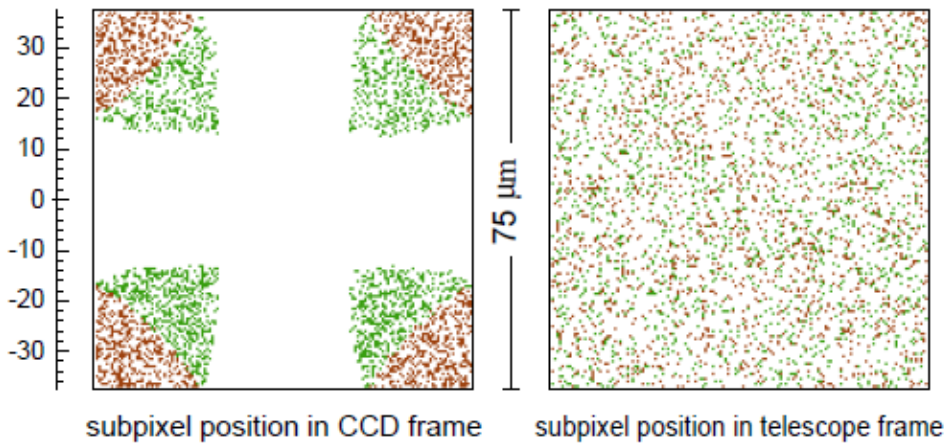
Sub-Pixel Analysis for Cu-K (8.04 keV)

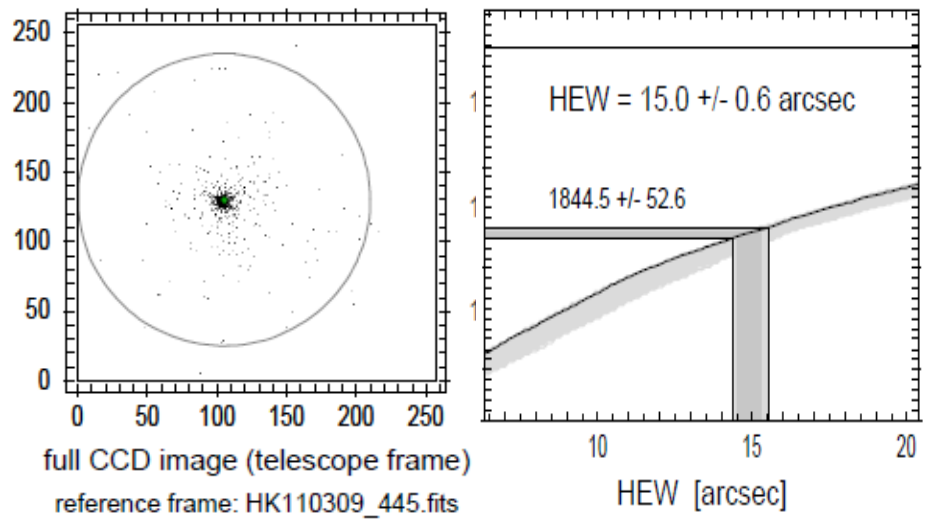
all events





triple / quadruple events





ABRIXAS

for comparison:
(from Friedrich et al. SPIE 1998)

Spatial Resolution (HEW)

	1.5 keV	8.0 keV
FM1	22.8"	28.4"
FM2	25.2"	26.2"
FM3	23.5"	28.3"
FM4	26.4"	33.7"
FM5		
FM6	25.3"	29.4"
FM7	25.2"	30.8"

Goal: **42” HEW** on-axis

Basic goal: **60” HEW** in the survey (integration over all off-axis angles)

Eff. Area of FM1 with 31 shells

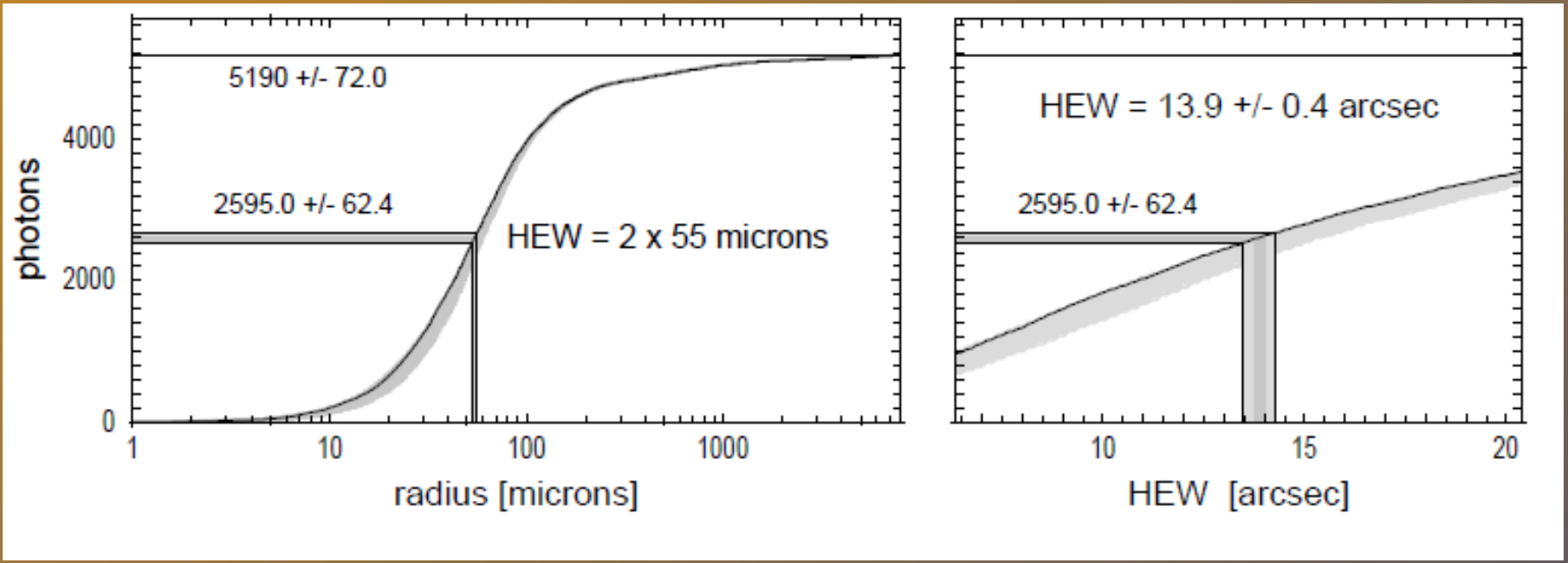
MM and Mirror Groups

Target	Energy	Effective Area			Date
		measured	calculated	loss / win	
C-K	0.28 keV	113.299 cm^2	119.89 cm^2	-5.5%	8th June 2011
Al-K	1.49 keV	106.770 cm^2	118.38 cm^2	-9.8%	6th June 2011
Cr-K	5.41 keV	57.714 cm^2	63.69 cm^2	-9.4%	8th June 2011
Cu-K	8.04 keV	24.350 cm^2	28.84 cm^2	-15.6%	8th June 2011

Group	Energy	Effective Area			Date
		measured	calculated	loss / win	
Group 40-54	1.49 keV	28.322 cm^2	34.29 cm^2	-17.4%	6th June 2011
Group 24-39	1.49 keV	79.655 cm^2	84.09 cm^2	-5.3%	6th June 2011
Group 34-39	1.49 keV	21.876 cm^2	23.83 cm^2	-8.2%	6th June 2011
Group 28-33	1.49 keV	30.594 cm^2	32.45 cm^2	-5.7%	6th June 2011
Group 24-27	1.49 keV	26.004 cm^2	27.81 cm^2	-6.5%	6th June 2011

PSF of single shell #12

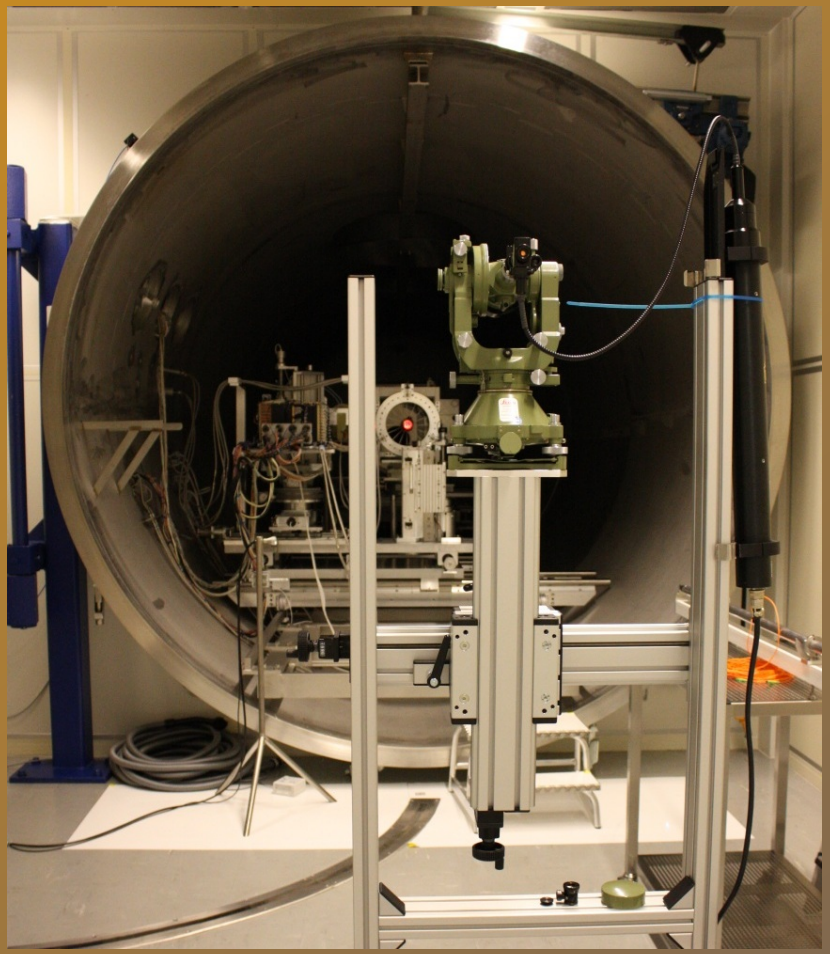
Shells	Target	Energy	PSF			
			HEW*	HEW**	W90	scattering
shell 12/2	C-K	0.28 keV	14.7 arcsec	11.3 arcsec (±2)		
shell 12/2	Cu-L	0.92 keV	14.4 arcsec	13.5 arcsec		
shell 12/2	Al-K	1.49 keV	13.9 arcsec	12.7 arcsec		
shell 12/2	Ag-L	2.98 keV	14.5 arcsec	13.7 arcsec		



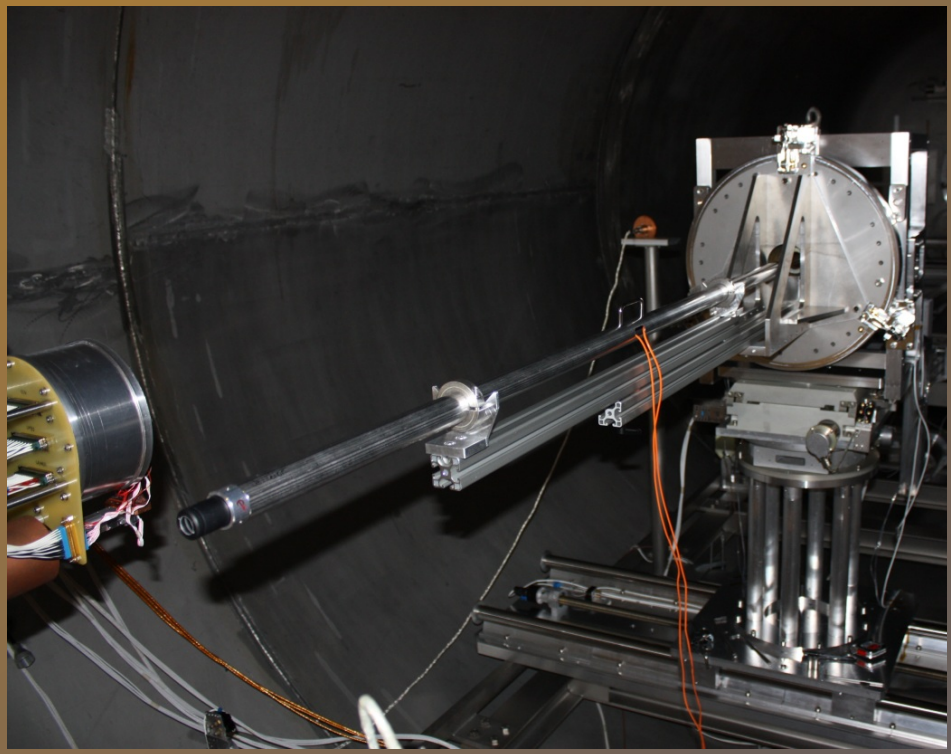
* sub-pixel resolution based on all events
** HEW sub-pixel resolution based on triple/quadruple split events

Optical Axis Alignment and Focus

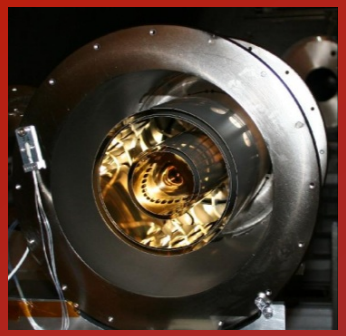
The X-ray optical axis is defined by the HEW minimum of a PSF cross-scan. The alignment of the X-ray optical axis is measured with respect to the reference mirror; accuracy ≈ 10″.

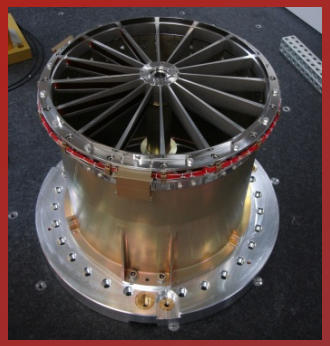


The focal length is measured with a mechanical-optical gauge giving the distance between the in-focus position of the detector and the reference mirror in the MM; accuracy ≤ 0.1 mm.



Status Summary





Mandrels:

- 27 refurbished ABRIXAS mandrels available
- 14 new mandrels completed, other 13 in progress
  (Completed MLT Mandrels 1,12,16-27, Zeiss refurbished 28-54)

Mirror Module DM (QM) and Test Mirrors:

- DM (3 real mirror shells + 24 dummy shells) X-ray tested before and after vibration / thermal cycling
- 4 “multi-shell drums” with 5 or 6 mirror shells tested:
  HEW 14.8”, 20.8”, 22.8”, 16.1”
  alignment contribution: 2.9”, 7.8”, 11.3”, 3.8”

Mirror Module FMs:

- all 8 FM structures (1 spare) ready for mirror integration
- integration of FM 1, FM 2, FM3, and FM4 is going on
- X-rays test of partially integrated FM1 and FM2 (15/31 shells) are successfully done; no significant alignment contribution
- Larger single shell (#12) X-ray tested: HEW ~13”
- Preparation of largest single shell (#1) for X-Ray test

X-ray Baffle:

- QM has been built
- successful integration to mirror module DM
- Qualification (vibration, thermal vacuum) done
- Improvements in manufacturing for FM identified