NuSTAR optic calibration

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DTU Space
National Space Institute

Mission Overview

NuSTAR

Pegasus XL launch

6º inclination
≥600 km circular

Spacecraft

- Three-axis attitude control
- Single string

Instrument

- Two hard x-ray telescopes
- 10 meter focal length
- Two CdZnTe detectors

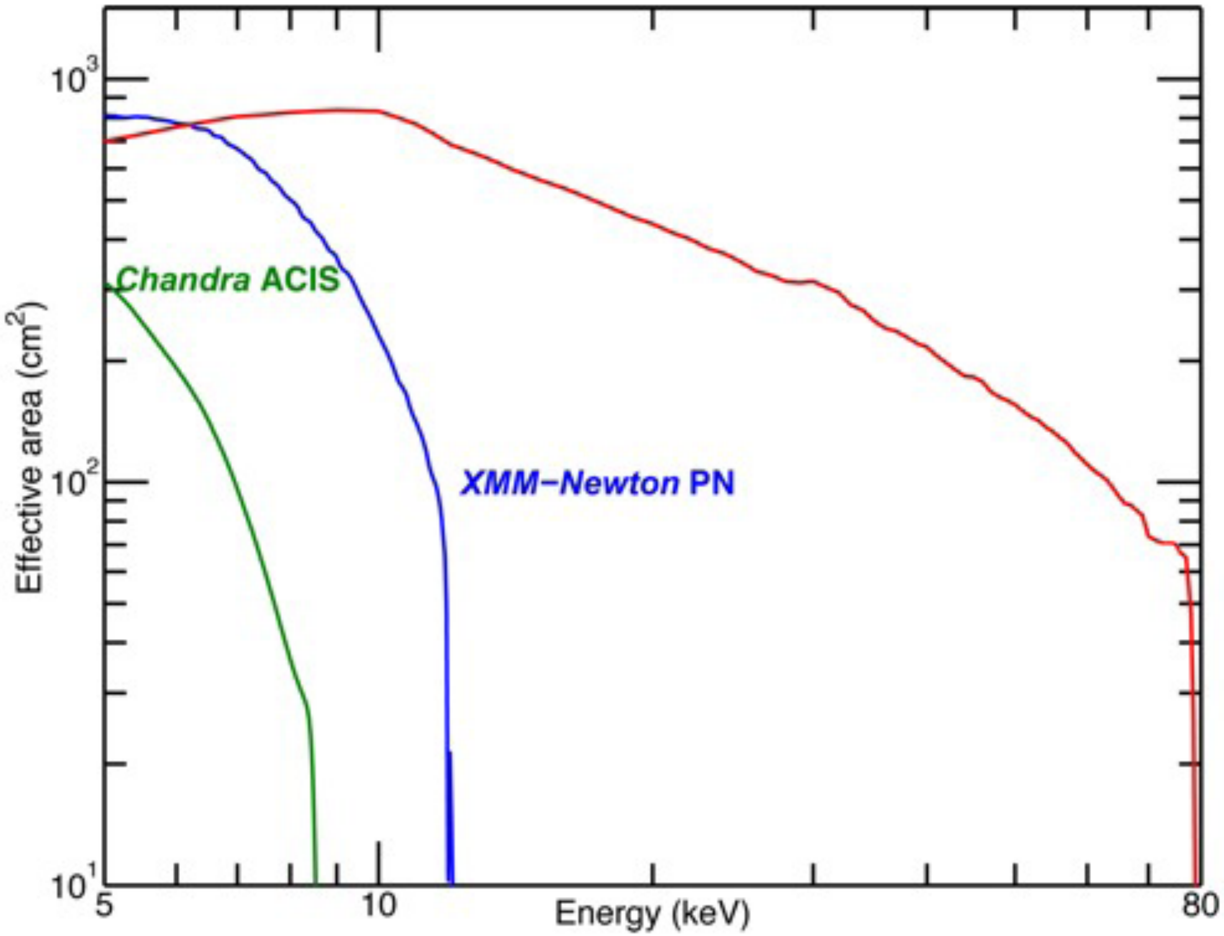
Mission Profile:

Launch Feb 2012

Primary mission lifetime: 2 yrs

Science Targets

- Supernova remnants
- Deep sky survey
- Galactic center survey
- High energy galactic targets
- High energy extra galactic targets
- Solar observations



10^3
10^2
10^1
Effective area (cm^2)
Chandra ACIS
XMM−Newton PN
5
10
80
Energy (keV)

Calibration approach

Perform a series of detailed measurements to probe the angular and spectral response of each multilayer group, sampling as much of the optic as time permits (~10 days per flight unit). **Was done in March 2011.**

Each measurement is performed through an aperture which allows the beam to be measured directly by a non-position sensitive detector.

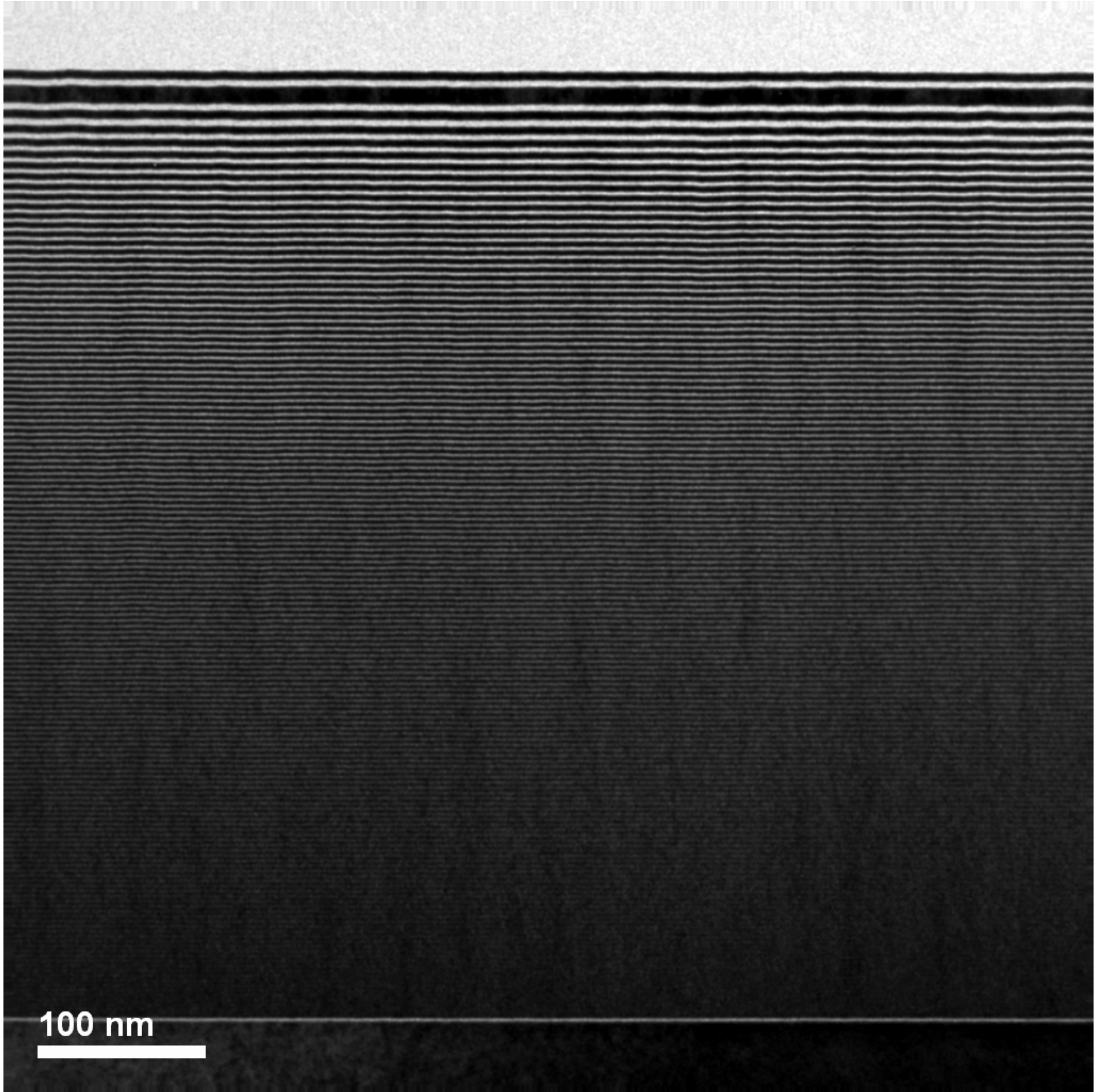
These measurements will be coupled with detailed information on the individual mirror segments since the coating properties depend somewhat on e.g. the placement in the coating chamber.

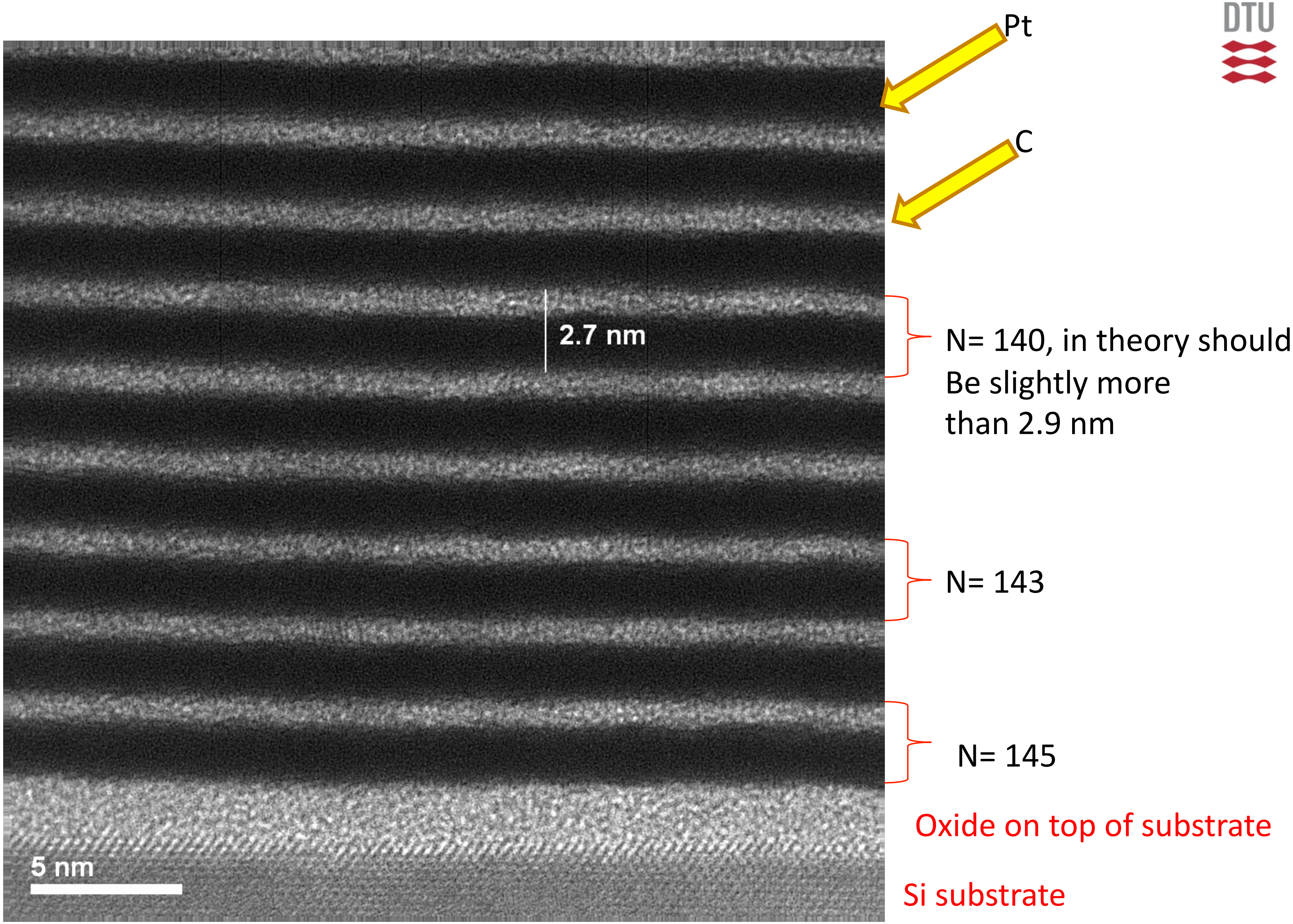
FM0:

Group	Material	Angle [mrad]	Layer range	D_{min} [Å]	D_{max} [Å]	N	c	s [Å]	G_{Top}	G_{high}	D_{stack} [μm]
1	Pt/SiC	1.34 -1.52	1 - 12	31.7	128.125	150	0.245	4.5	0.7	0.45	0.631
2	Pt/SiC	- 1.73	13 – 24	30.5	120.935	150	0.228	4.5	0.7	0.45	0.611
3	Pt/SiC	- 1.96	25 – 36	29.0	119.500	155	0.234	4.5	0.7	0.45	0.592
4	Pt/SiC	- 2.22	37 – 49	29.0	118.188	155	0.214	4.5	0.7	0.45	0.578
5	Pt/SiC	- 2.52	50 – 62	29.0	107.750	155	0.225	4.5	0.7	0.45	0.575
6	Pt/SiC	- 2.85	63 – 76	29.0	103.250	155	0.225	4.5	0.7	0.45	0.586
7	Pt/SiC	- 3.23	77 – 89	29.0	98.750	155	0.212	4.5	0.7	0.45	0.577
8	W/Si	- 3.67	90– 104	25.0	95.228	291	0.238	4.3	0.8	0.38	0.955
9	W/Si	- 4.16	105 – 118	25.0	83.942	291	0.220	4.3	0.8	0.38	0.934
10	W/Si	- 4.72	119 - 133	25.0	74.471	291	0.190	4.3	0.8	0.38	0.902

FM1 and FM2:

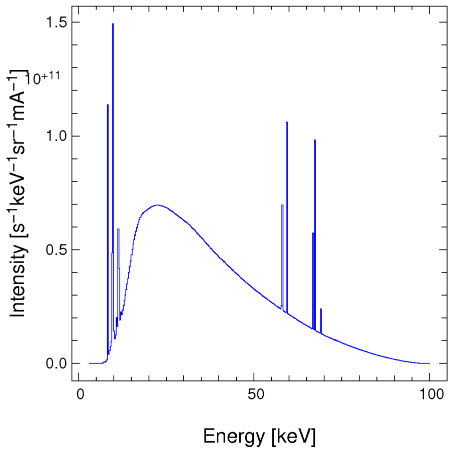
Group	Material	Angle [mrad]	Layer range	D_{min} [Å]	D_{max} [Å]	N	c	s [Å]	G_{Top}	G_{high}	D_{stack} [μm]
1	Pt/C	1.34 -1.52	1 - 12	29	133.66	145	0.245	4.5	0.7	0.45	0.558
2	Pt/C	- 1.73	13 – 24	29	131.58	145	0.228	4.5	0.7	0.45	0.547
3	Pt/C	- 1.96	25 – 36	29	129.56	145	0.234	4.5	0.7	0.45	0.551
4	Pt/C	- 2.22	37 – 49	29	121.84	145	0.214	4.5	0.7	0.45	0.537
5	Pt/C	- 2.52	50 – 62	29	109.50	145	0.225	4.5	0.7	0.45	0.541
6	Pt/C	- 2.85	63 – 76	29	107.50	145	0.225	4.5	0.7	0.45	0.541
7	Pt/C	- 3.23	77 – 89	29	102.75	145	0.212	4.5	0.7	0.45	0.534
8	W/Si	- 3.67	90 – 104	25.0	95.228	291	0.238	4.3	0.8	0.38	0.955
9	W/Si	- 4.16	105 – 118	25.0	83.942	291	0.220	4.3	0.8	0.38	0.934
10	W/Si	- 4.72	119 - 133	25.0	74.471	291	0.190	4.3	0.8	0.38	0.902

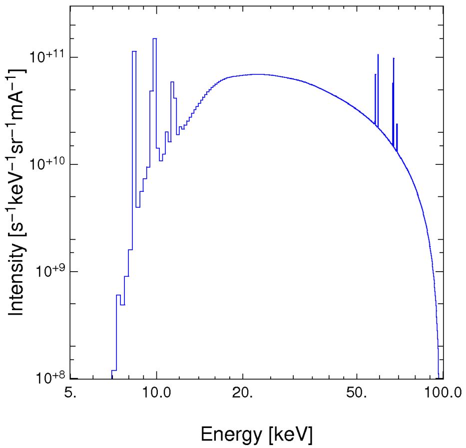

100 nm



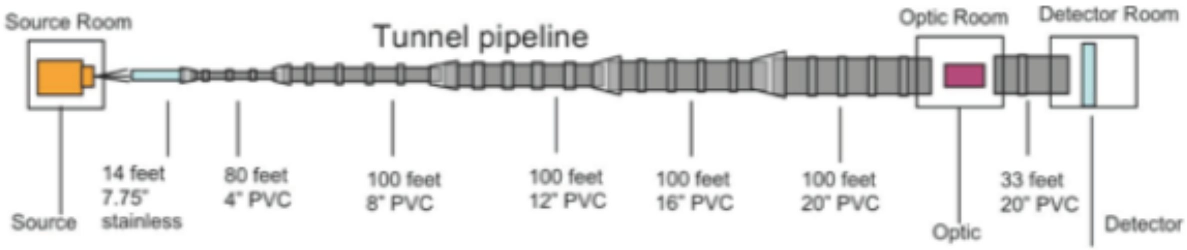
2.7 nm
5 nm
Pt
C
N= 140, in theory should
Be slightly more
than 2.9 nm
N= 143
N= 145
Oxide on top of substrate
Si substrate

The Rainwater Memorial Calibration Facility at Nevis, Columbia University





A model spectrum of the flux falling on the optic including tube emission, scattering, and absorption along the path (work in progress).



Evacuated to 0.2 torr. Windows are mylar supported by a kevlar weave.

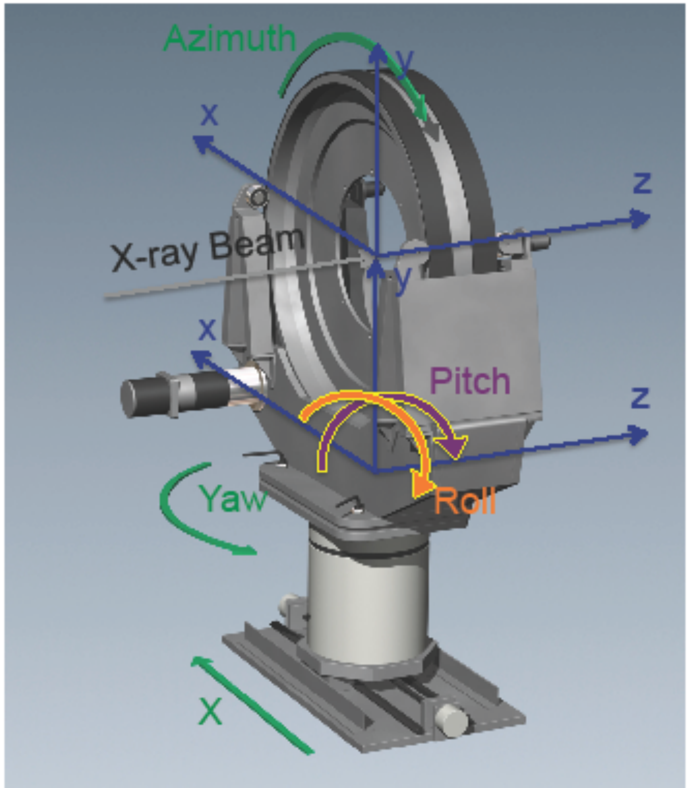
The mounting rig for the optic

in the calibration beam line.

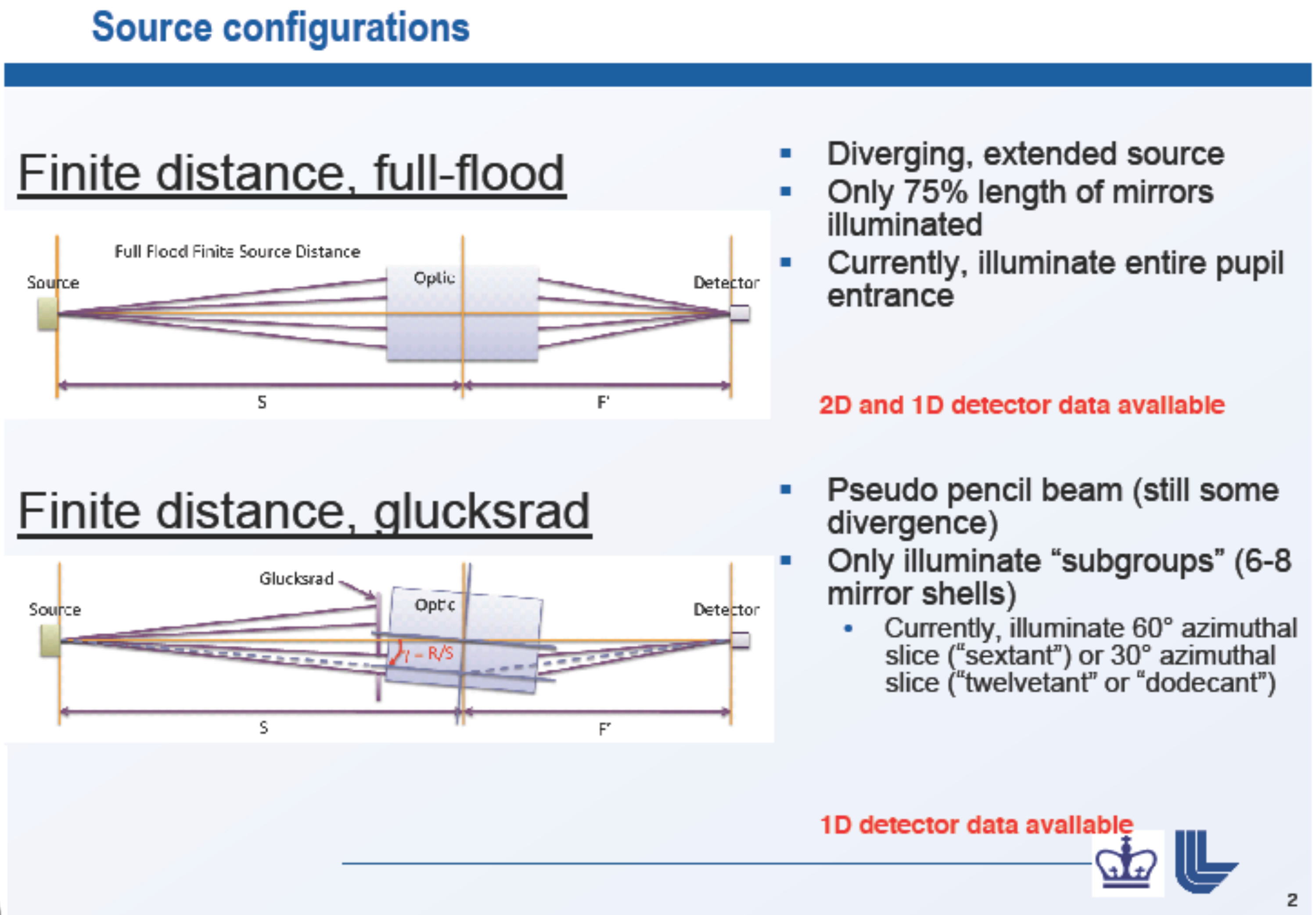
The motor controlled axes provide

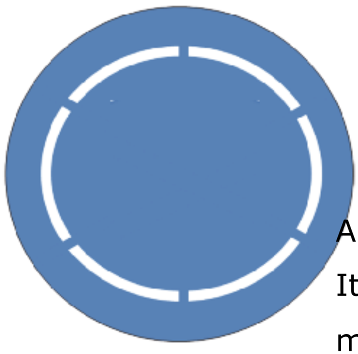
the required adjustments including

the initial alignment.



21

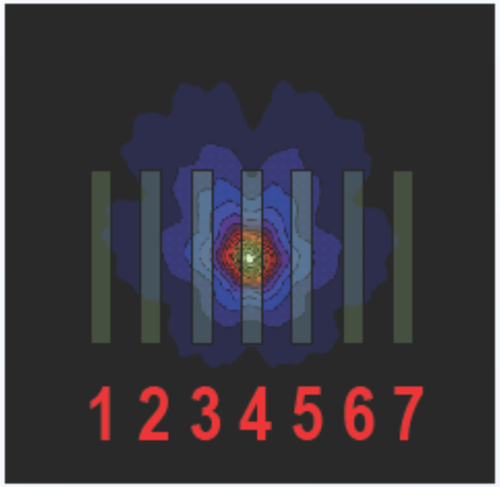




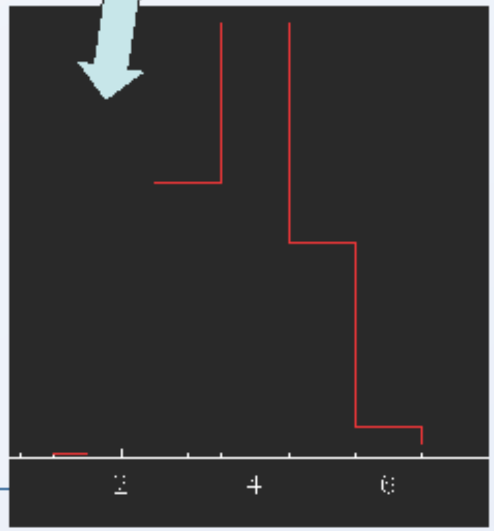
An aperture plate made of 4 mm Pb sandwiched between Al support plates.

It is precisely afixed to the inner mandrel of the optic and it masks off all but one multilayer group in the optics module under test. This aperture plate is supplemented with a selection in the azimuth angle.

1D data scans (continued)

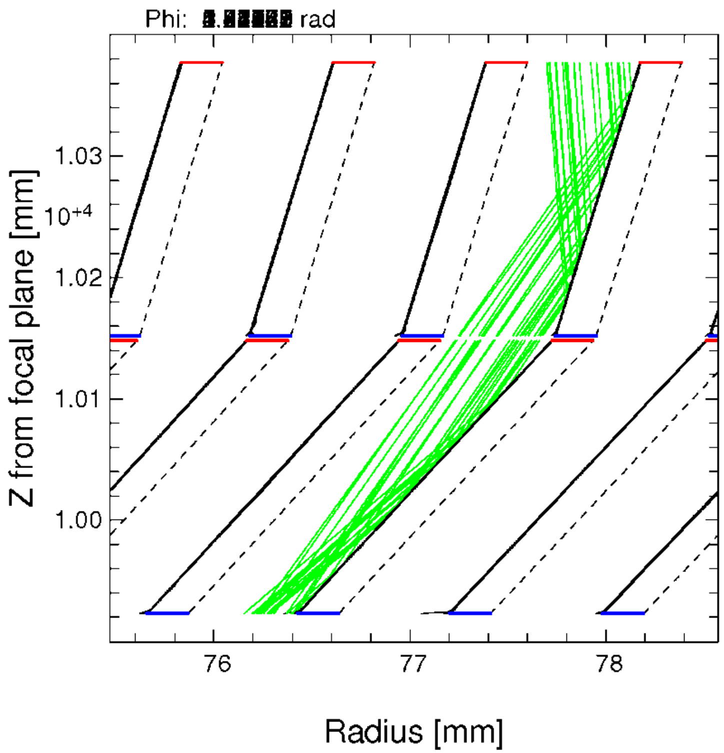


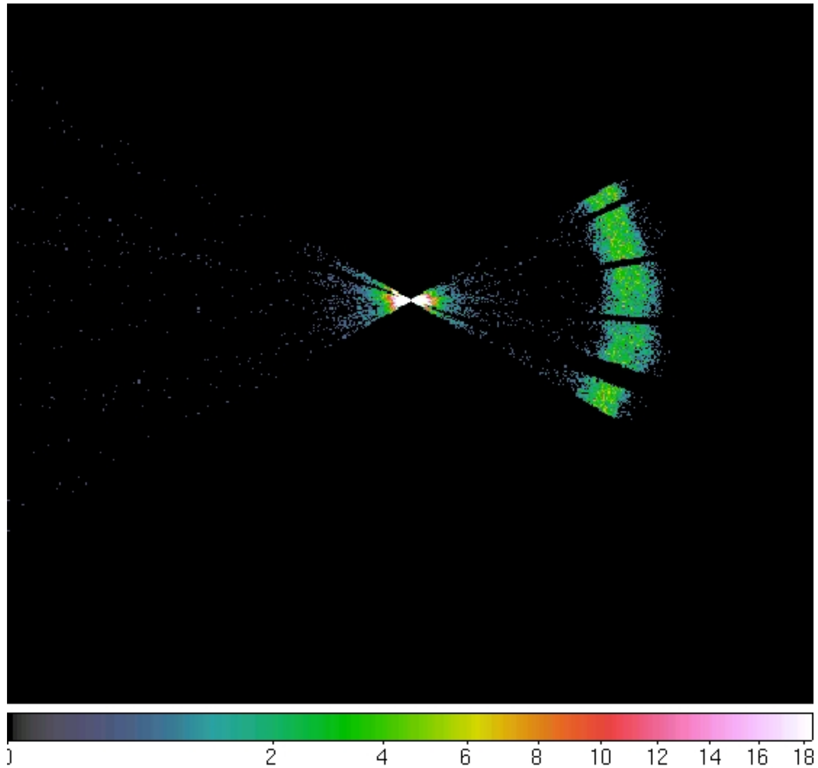
- Notional idea
  - Slit/detector area is long green rectangle
  - Slit/detector moved left-to-right across PSF in seven steps
  - Get a plot like this



- Shape of 1D scan depends intimately on:
  - Underlying PSF
  - Aperture/slit dimensions

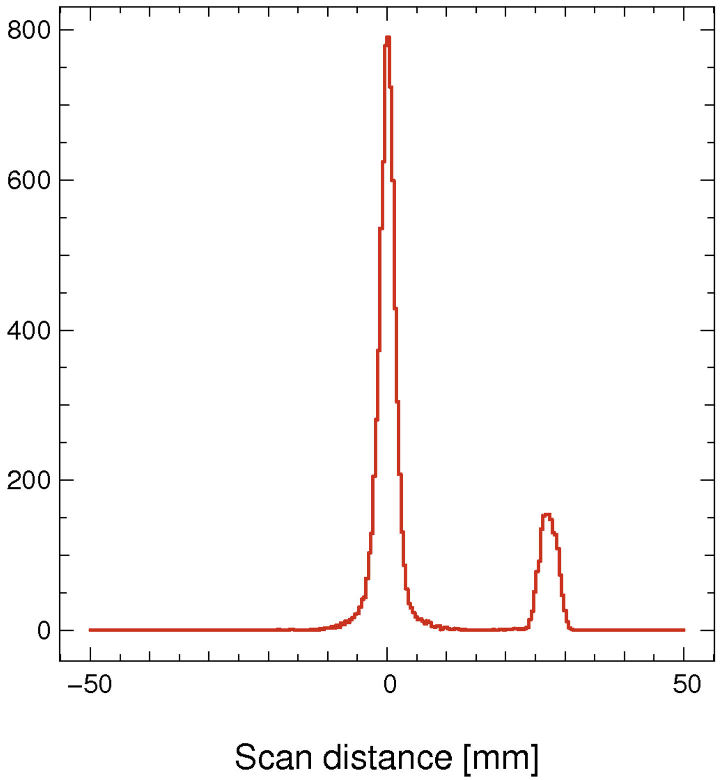
6

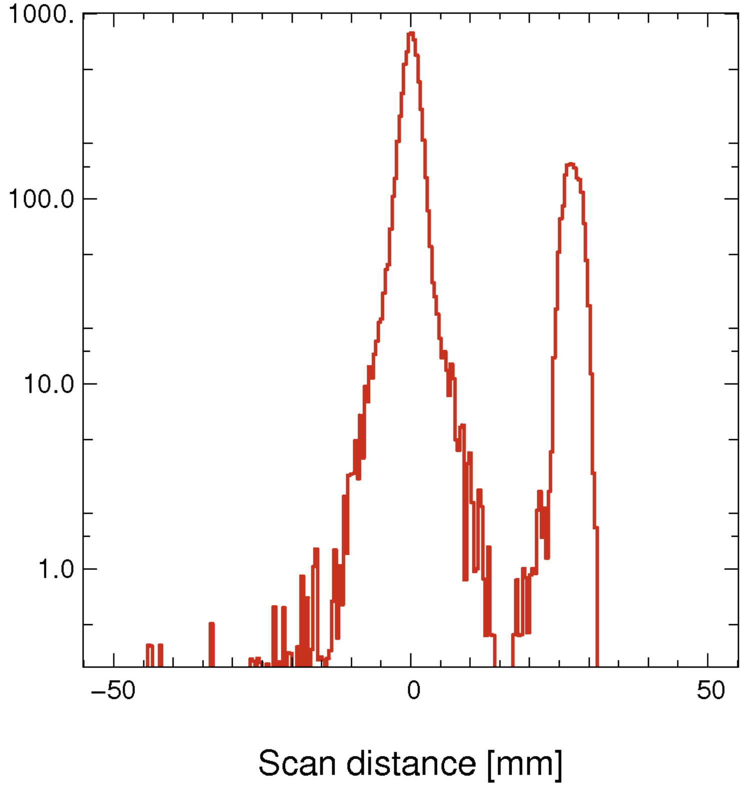

Phi:
rad
1.03
10+4
1.02
1.01
1.00
Z from focal plane [mm]
76
77
78
Radius [mm]


2
4
6
8
10
12
14
16
18

Simulating the detector scans across the ghost peak (one bounce)

Photons and the focal spot (two bounces)

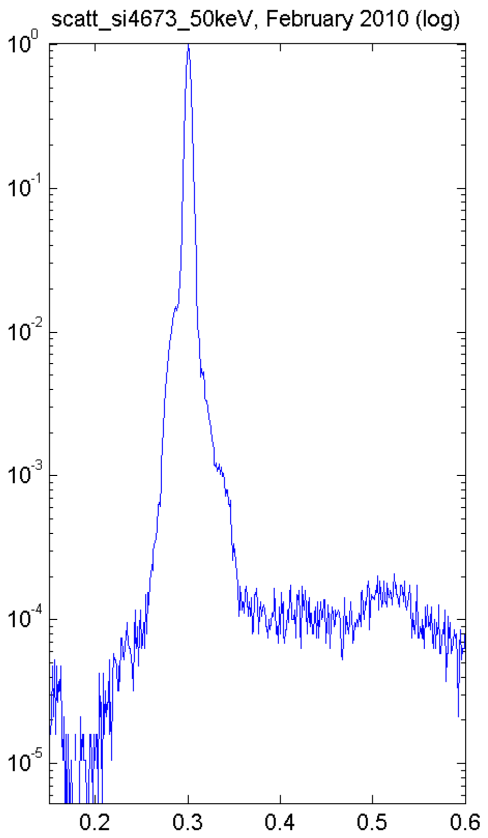




W/Si

0.15 deg

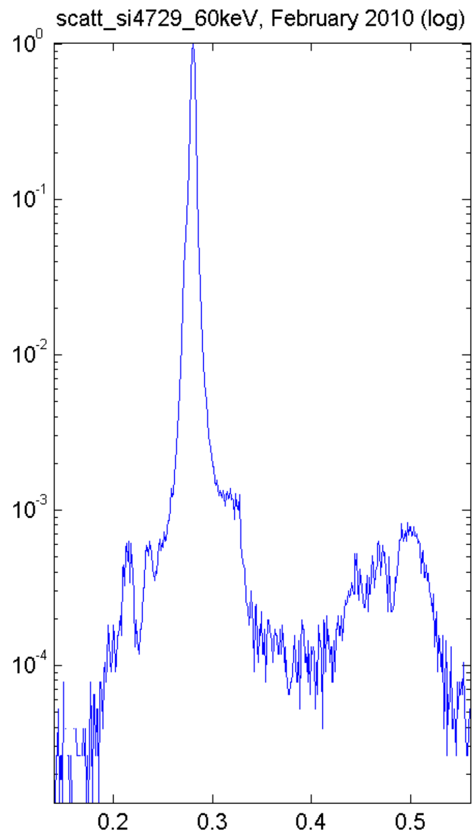
50 keV



Pt/C

0.14 deg

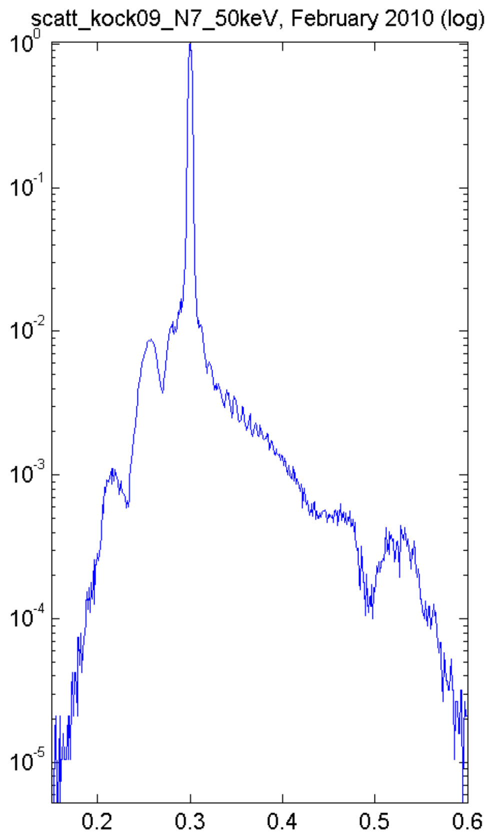
60 keV



Pt/SiC

0.15 deg

50 keV

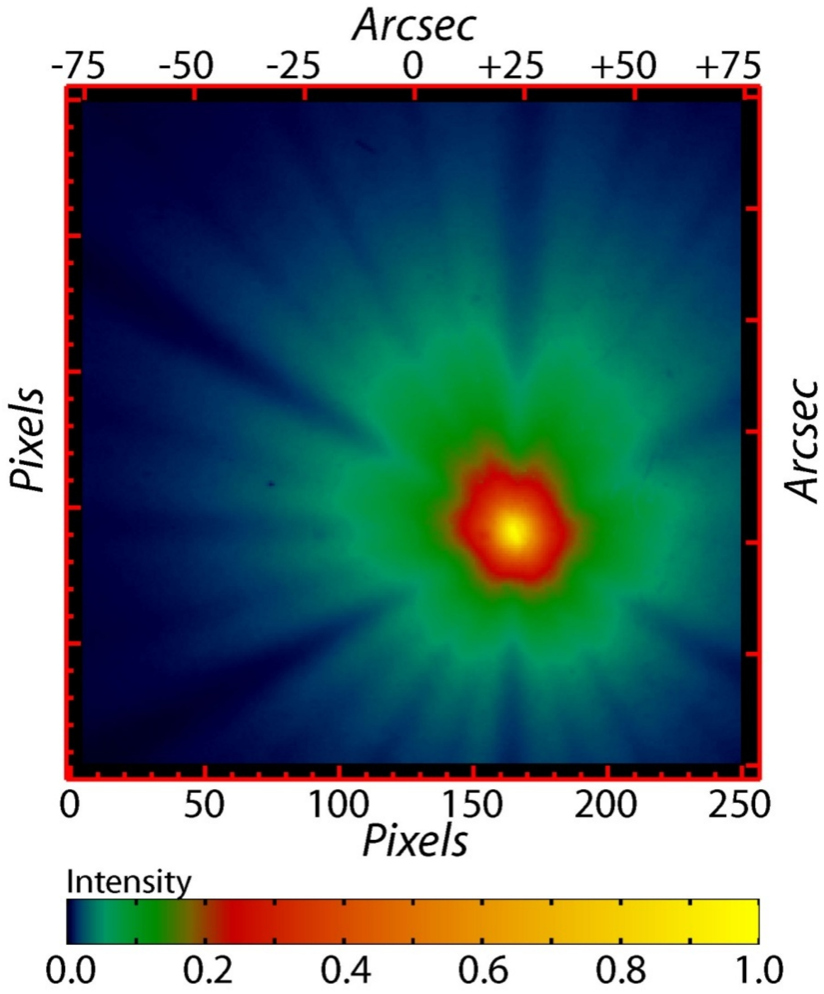


A summary of the witness sample measurements –

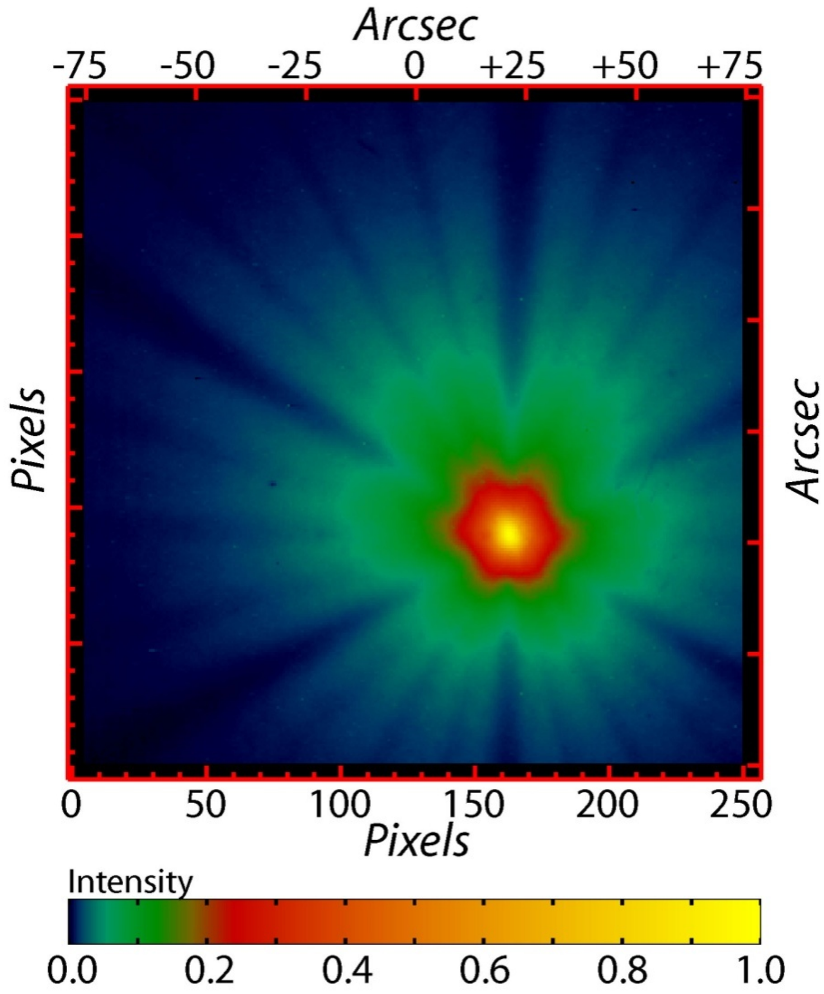
and the reason for rejecting the Pt/SiC coatings

Results @ 50 keV	HPD (50%) arcsec	90% diameter arcsec
W/Si	8	42
Pt/C	7.5	32
Pt/SiC	8	93

Fine resolution 2D detector images from FM0

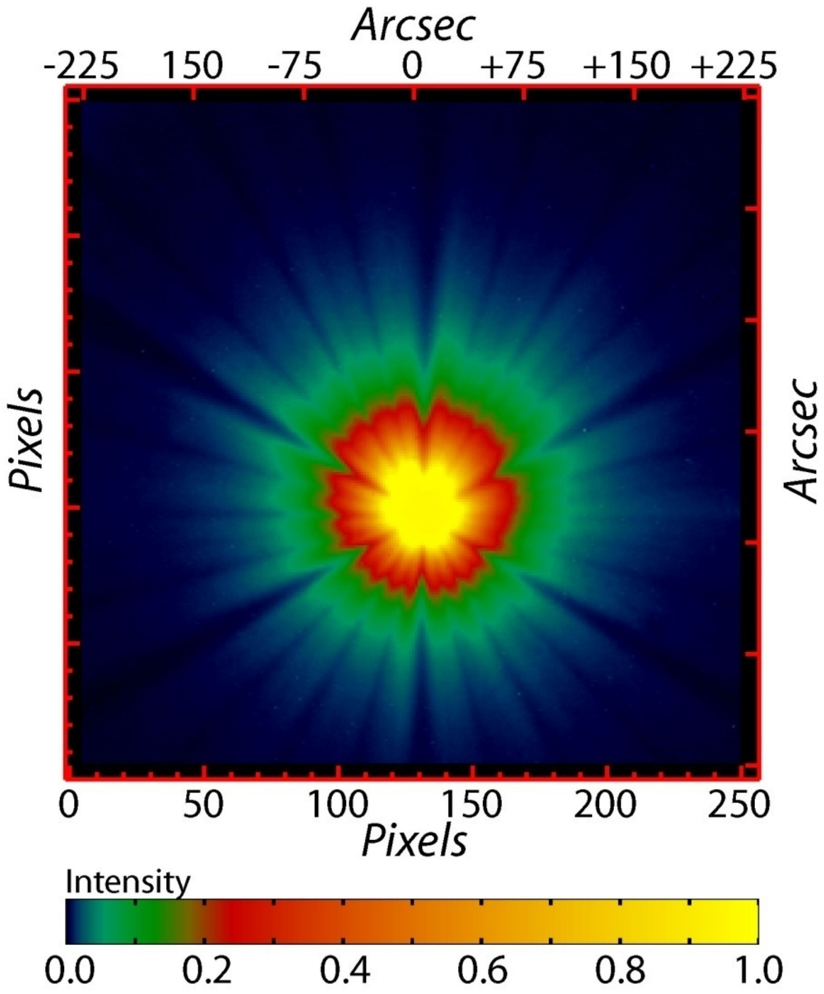


Broad spectrum

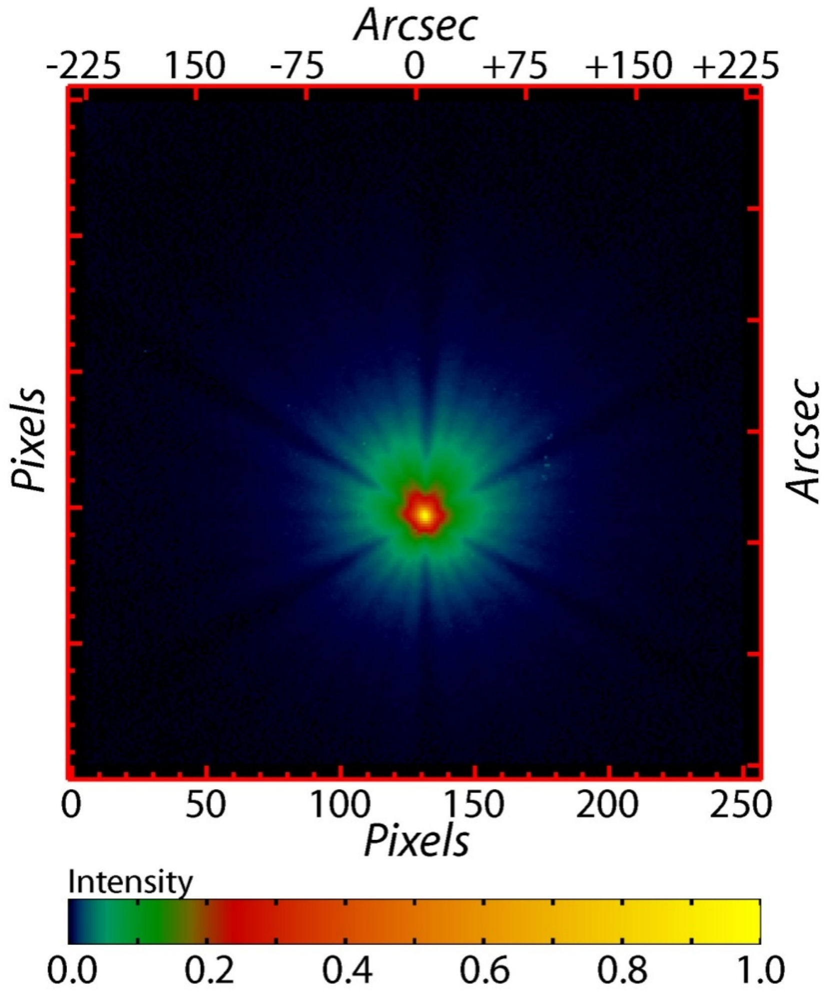


High-band spectrum

Coarse resolution 2D detector images FM0



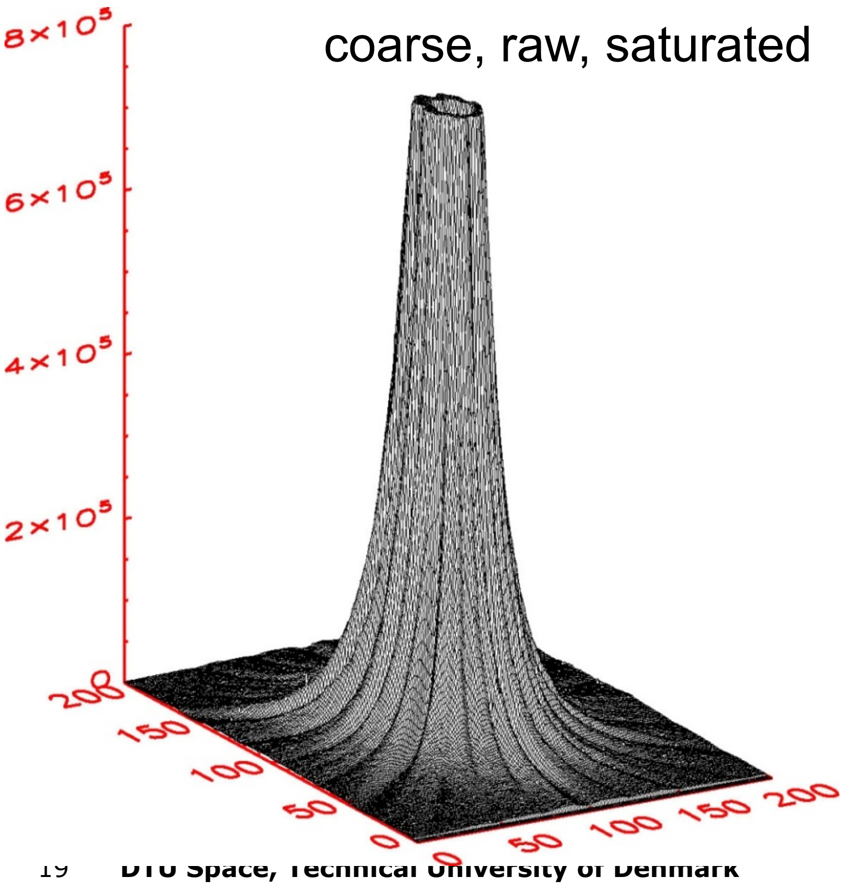
Broad spectrum

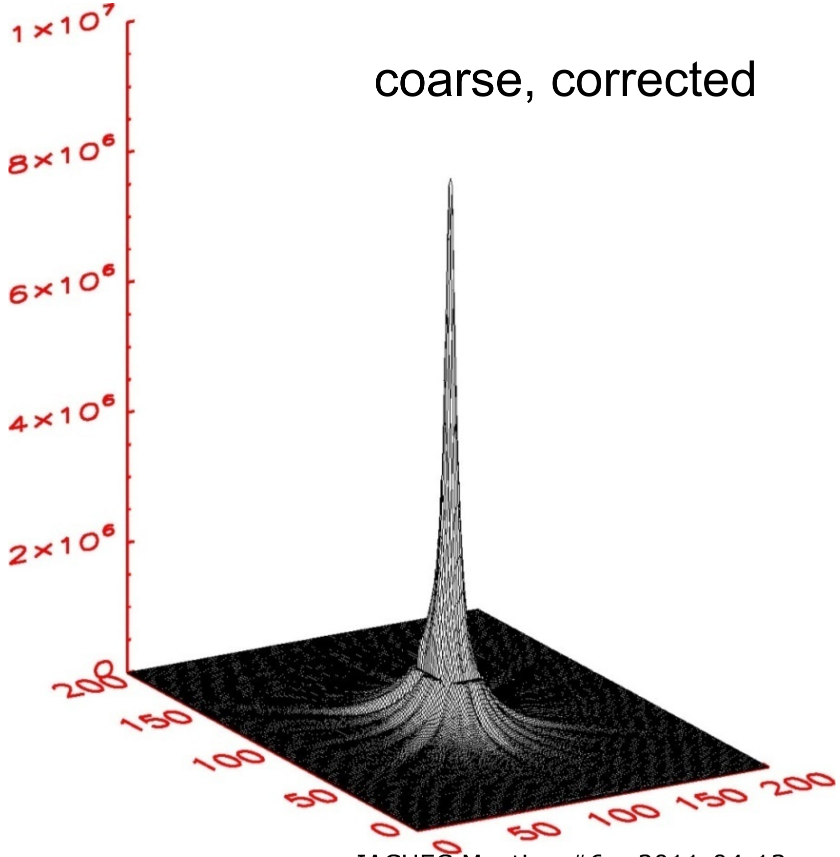


High-band spectrum

Saturated core, coarse data

The saturated core is filled in with the unsaturated core from the fine resolution result. The result is ’needle’ on top of wide wings.





Calibration summary

With the results at hand from the on-ground measuments of FM1 and FM2:

- Detailed understanding of the PSF as a function of energy
- Determination of the telescope effective area

Parallel efforts for the detector calibration

In-flight calibration is a separate chapter

The end