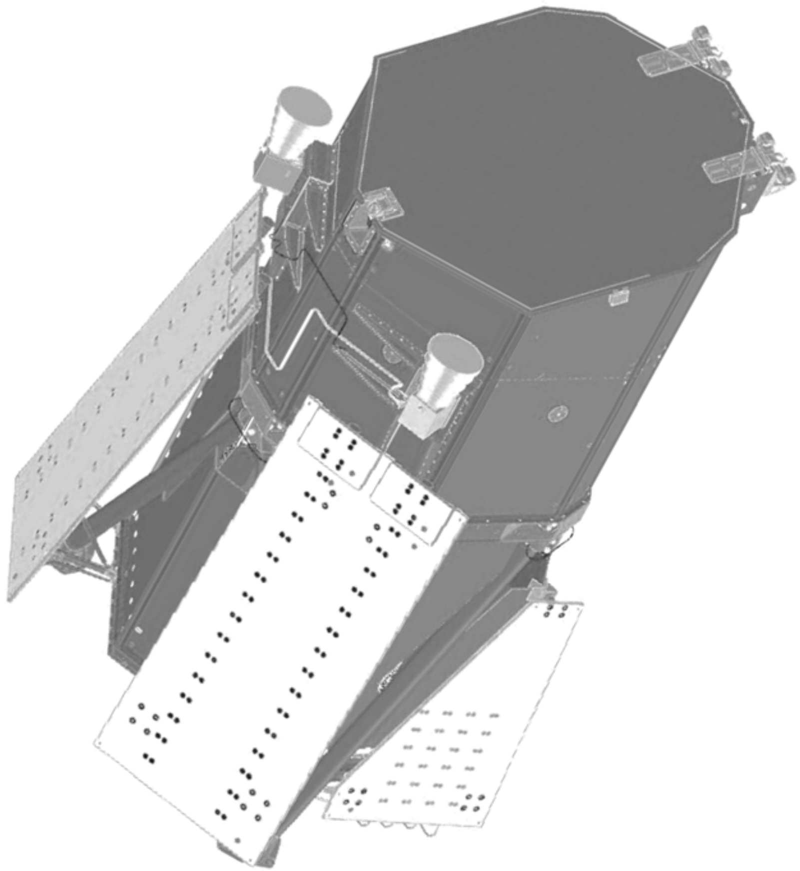
Status / Progress of the eROSITA X-ray Observatory:



Vadim Burwitz, Max-Planck-Institut für extraterrestrische Physik

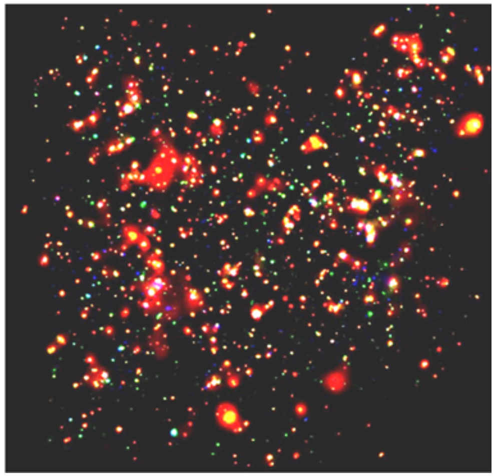
On behalf of the eROSITA Team

IACHEC #9, May 13, 2014, Airlie Center, Warrenton, Virginia, USA

eROSITA

Eine Himmelsdurchmusterung im Röntgenbereich
und die Erforschung der Dunklen Energie

- All-sky Survey ~30 times more sensitive than ROSAT
- Detection of 100.000 Clusters of Galaxies in order to constrain parameters of Dark Energy

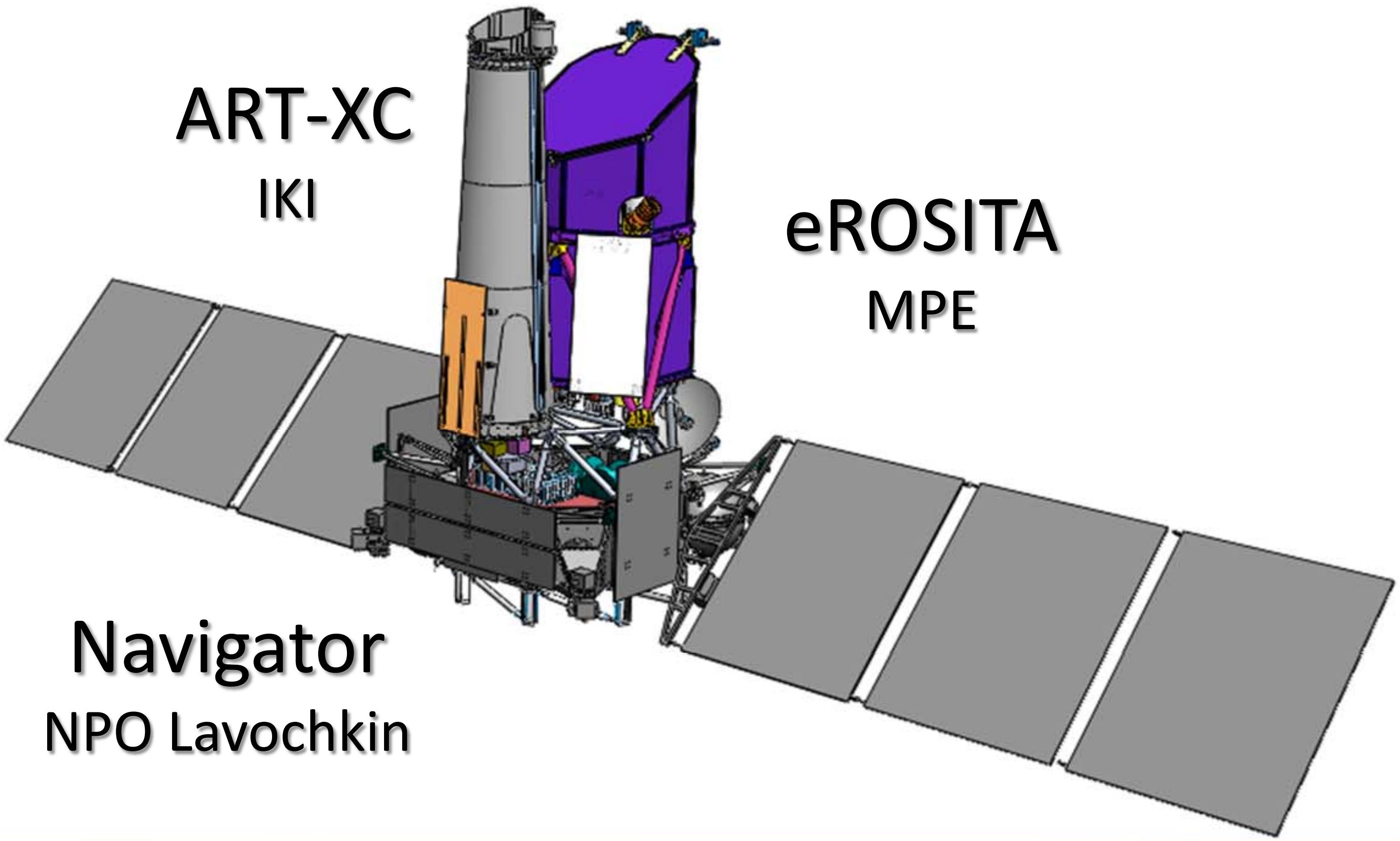


+ 500.000 Stars

+ 3.000.000 AGN

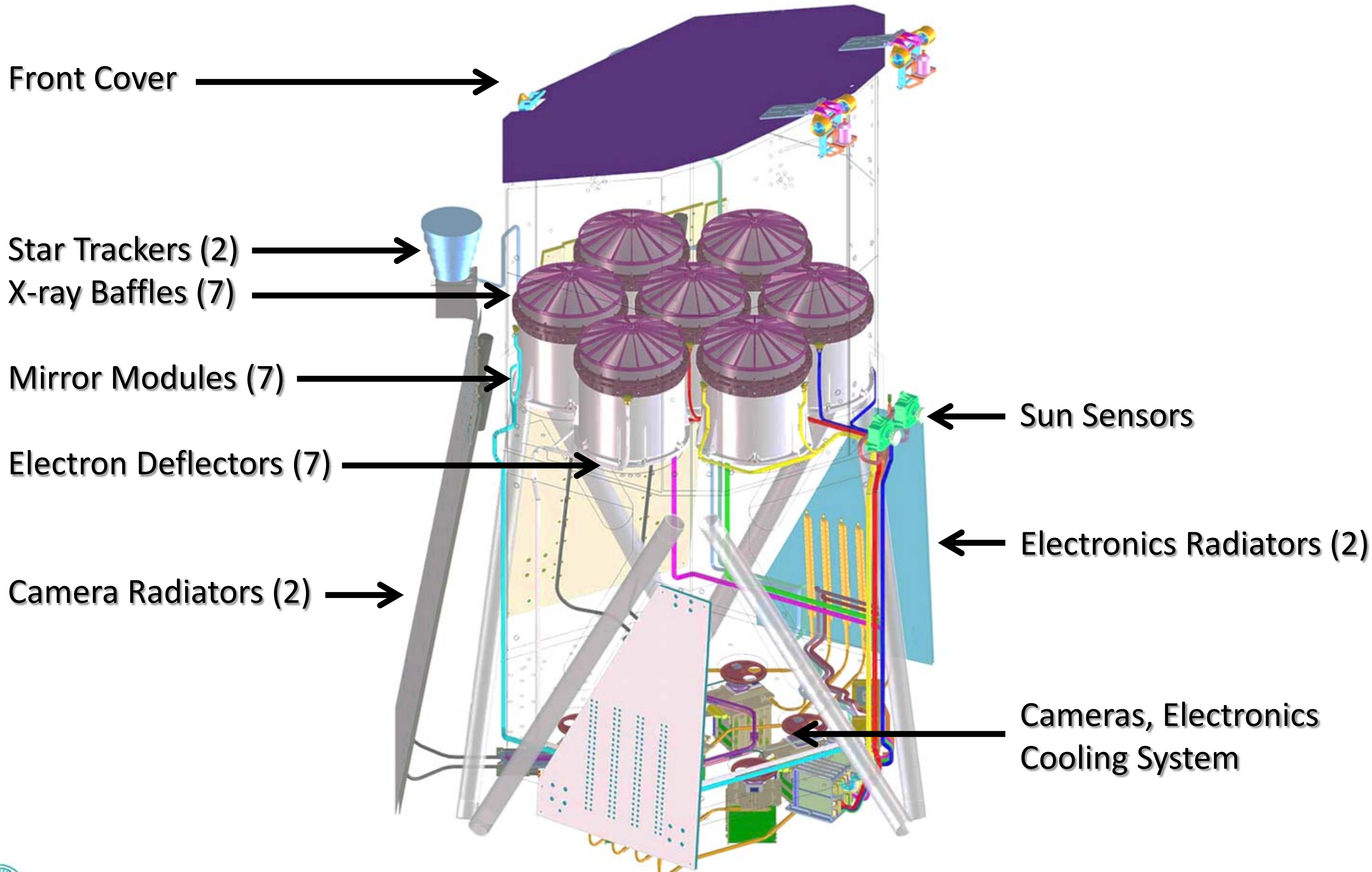
+ many other objects

Spektrum Rentgen Gamma (SRG)



Launch to L2 from Baikonur with a Zenit-Fregat, beginning 2016
ground stations in Russia

eROSITA: Telescope Scheme



eROSITA CCD Cameras and E-Boxes

7 PNCCD cameras:

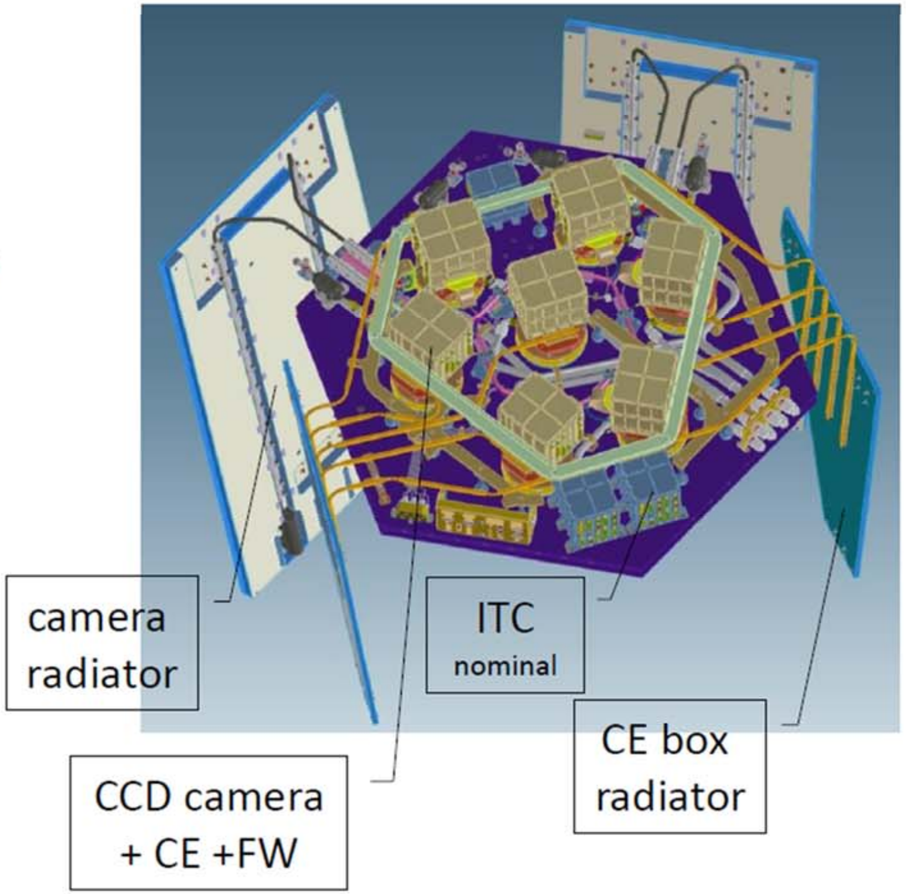
spectroscopy and imaging: 0.3 keV - 10 keV

time resolution: 50 ms

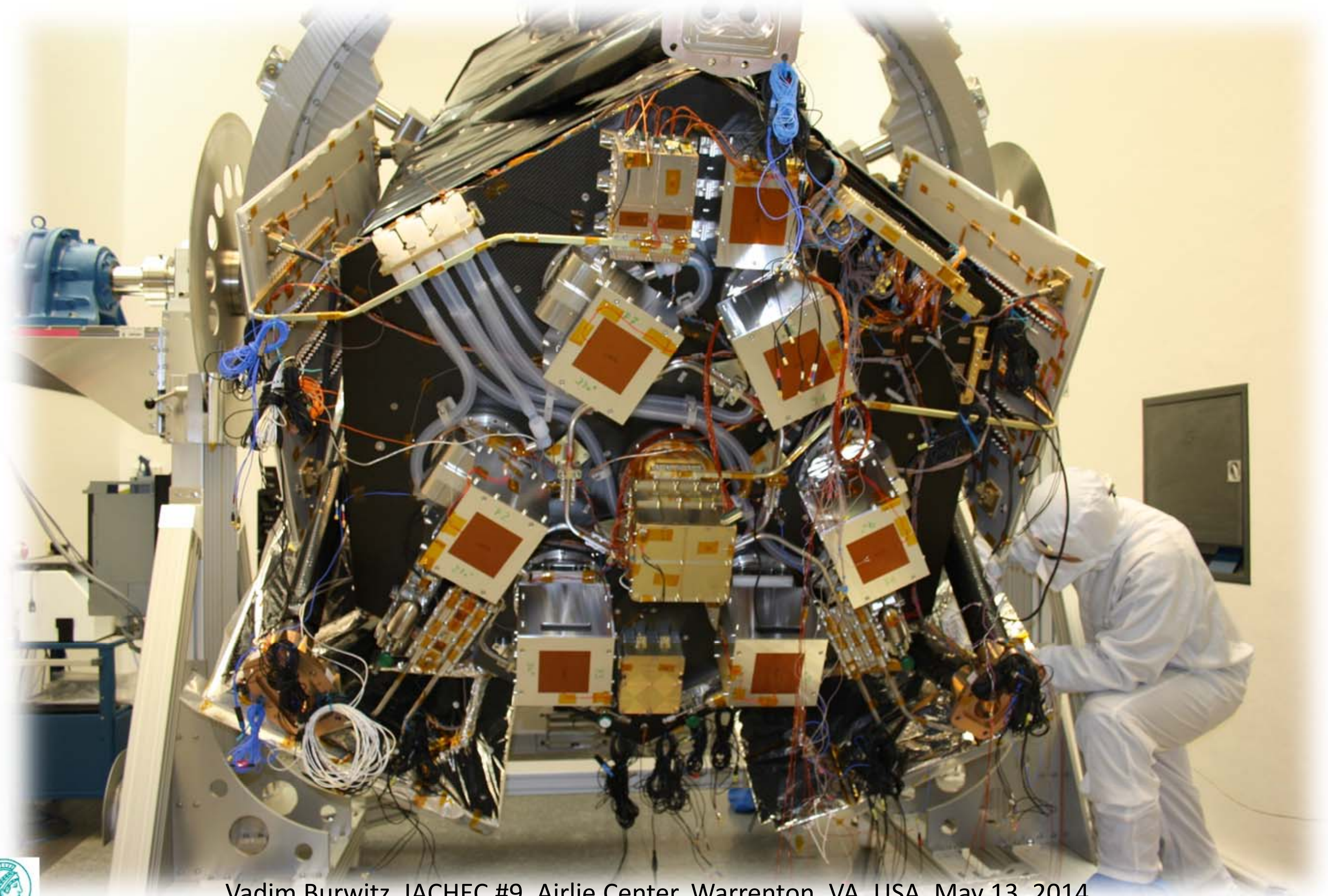
Image: 384 x 384 pixel

pos. res. < pixel ≈ 10 arcsec

FWHM(5.9keV) ≤ 138 eV (w/o rad. damage)

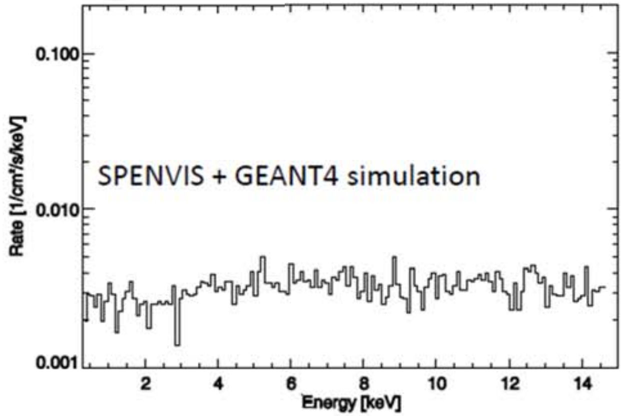


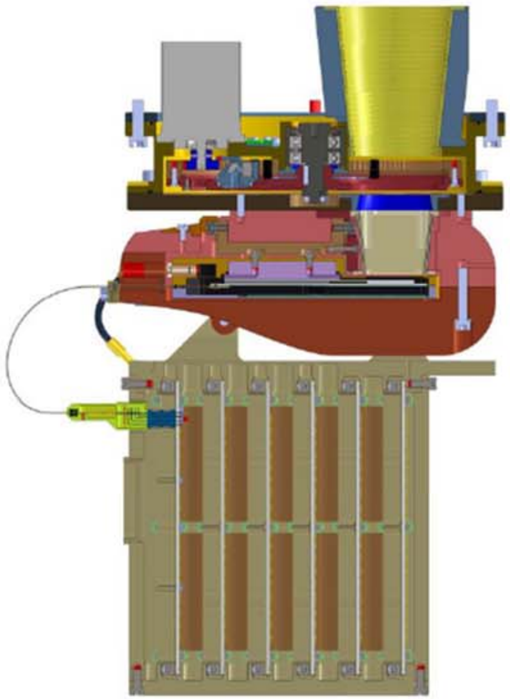
Complex Cooling pipe system for 7 CCDs



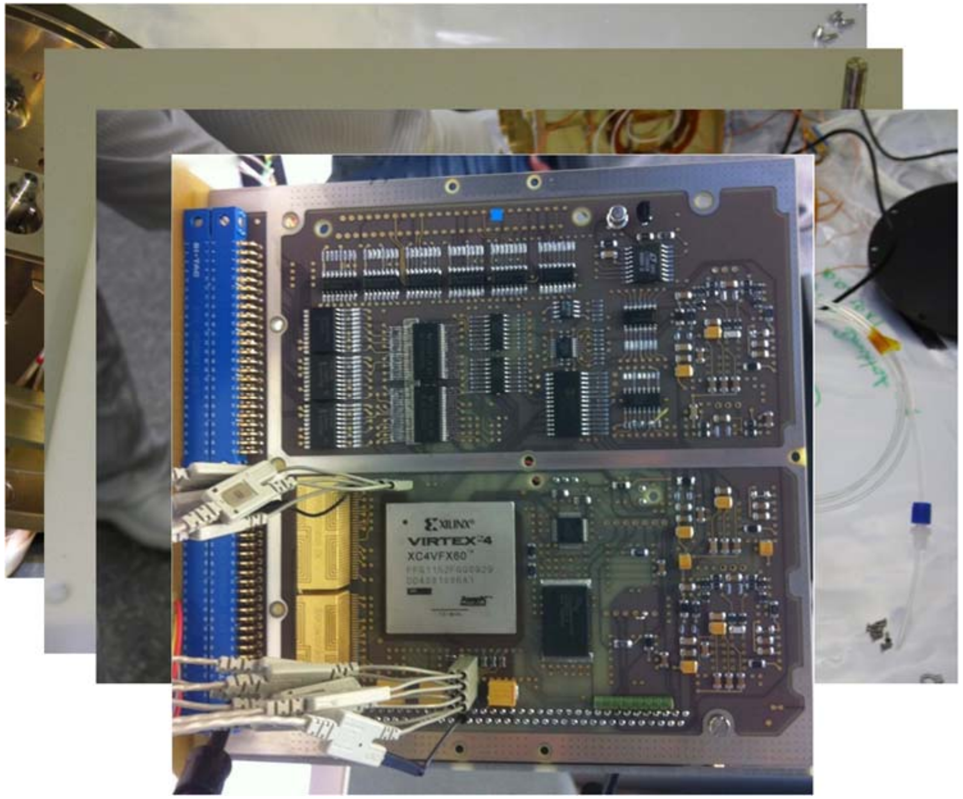
CCD Camera Design

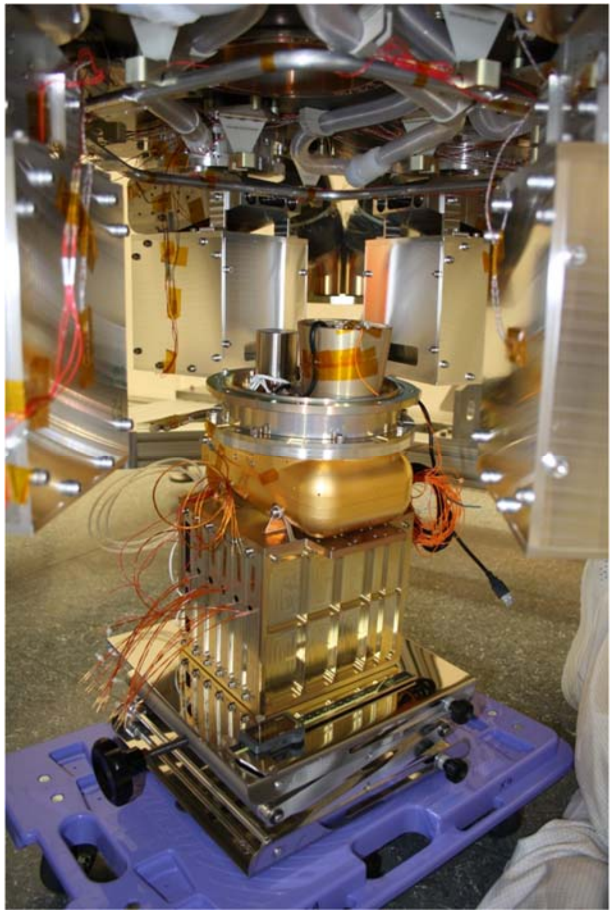
- req1: **graded Z shield**: Cu – Al – Be / B_4C
  → minimizes instr. background
- req2: detector active heat load: 0.7 W; incl. parasitics 2 W
  → $T_{CCD} \approx -95°C$
- STM camera: exp. test of structural and thermal design
- all **FM detector housings** produced
- all **FM proton shields** in production





Cameras and Electronics





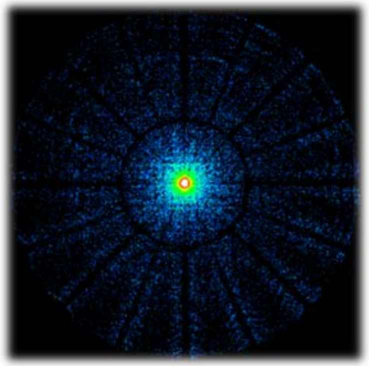
7×

Filterwheels
CCDs
Cameras
Camera Electronics

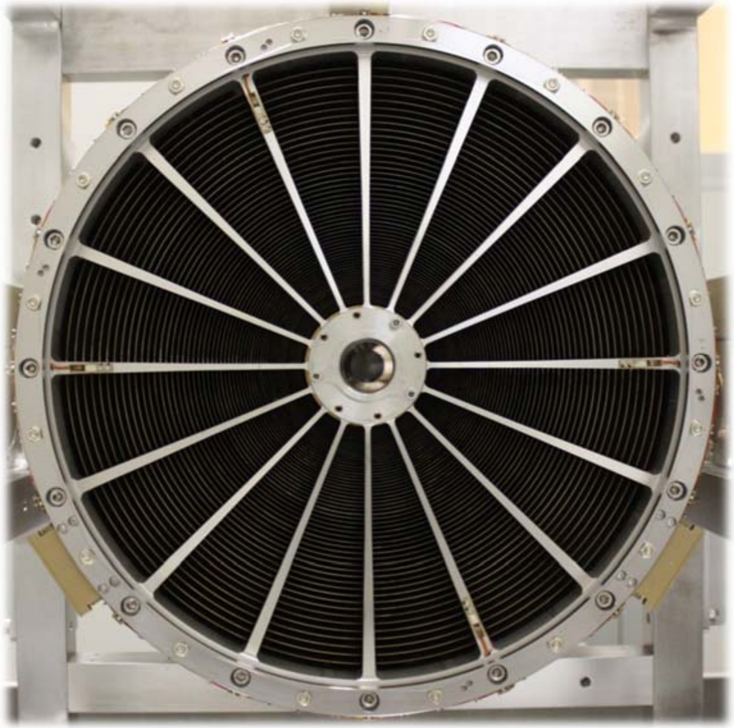
60 printed circuit boards
~35.000 electronics components
(radhard, highrel) **ITAR !!!**

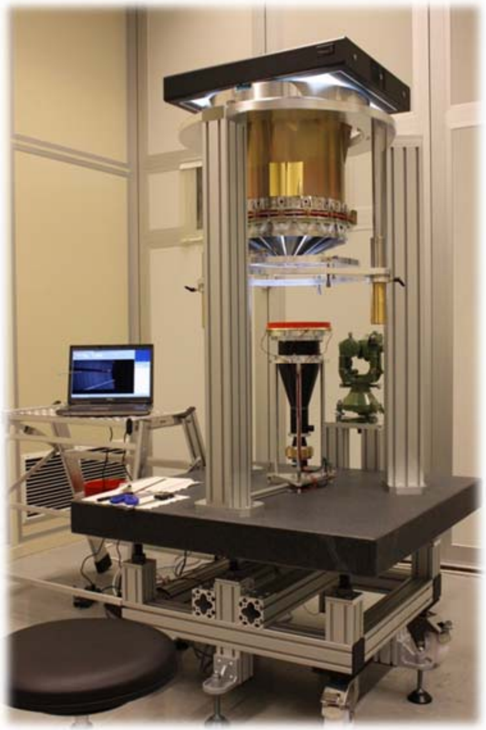
PSFs of the eROSITA Flight Mirror Modules

Mirrors shells produced and integrated at Media Lario Technologies and the X-ray Baffles at MPE



Photon energy	Goal	Measurement							
		FM 1	FM 2	FM 3	FM 4	FM 5	FM6	FM7	FM 8
HEW Al-K (1.49 keV)	≤15’’	16.1 ±0.2	16.8 ±0.3	15.7 ±0.3	16.0 ±0.3	16.2 ±0.3	16.3 ±0.3	15.6 ±0.3	17.1 ±0.3
HEW Cu-K (8.04 keV)	≤ 20’’	15.2 ±0.1	15.4 ±0.3	16.7 ±0.4	16.3 ±0.3	16.2 ±0.3	16.2 ±0.3	16.6 ±0.3	18.4 ±0.4





Mirror Performance

- PANTER measurements -

	Specification		Acceptance Test							
	Orbit	Derived for PANTER	FM 1	FM 2	FM 3	FM 4	FM 5	FM 6	FM 7	FM 8
			Dec 2012 / Jan 2013	Mar 2013	May 2013	Sep 2013 / Oct 2013	Sep 2013	Dec 2013	Dec 2013	Jun 2013
HEW Al-K (1.49 keV)	< 15″	< 15″	16.1″±0.2″	16.8″±0.3″	15.7″±0.3″	16.0″±0.3″	16.2″±0.2″	16.3″±0.3″	15.6″±0.3″	17.1″±0.3″
HEW Cu-K (8.04 keV)	< 20″	< 20″	15.2″±0.1″	15.4″±0.3″	16.7″±0.4″	16.4″±0.3″	16.2″±0.3″	16.2″±0.3″	16.6″±0.3″	18.4″±0.4″
W90 C-K (0.28 keV)	< 90″	< 90″	~89.8″	~106.5″	~107.9″	~106.7″	~119.6″	~127.3″	~107.9″	~123.6″
Eff. Area[1] Al-K	> 350 cm^2	> 363.6 cm^2	391.9 cm^2 ± 16.1 cm^2	391.1 cm^2 ± 20.6 cm^2	392.6 cm^2 ± 15.5 cm^2	369.4 cm^2 ± 24.8 cm^2	387.9 cm^2 ± 19.2 cm^2	378.4 cm^2 ± 19.2 cm^2	391.6 cm^2 ± 24.8 cm^2	389.6 cm^2 ± 20.5 cm^2
Eff. Area[1] Cu-K	> 20 cm^2	> 21.0 cm^2	24.8 cm^2 ± 0.8 cm^2	24.8 cm^2 ± 1.1 cm^2	25.1 cm^2 ± 1.2 cm^2	23.8 cm^2 ± 0.9 cm^2	24.1 cm^2 ± 0.6 cm^2	25.1 cm^2 ± 1.1 cm^2	25.0 cm^2 ± 0.9 cm^2	24.2 cm^2 ± 1.0 cm^2
Micro-roughness	< 0.5 nm	Scattering Cu-K < 15.7%	Scattering Cu-K 10.8%	Scattering Cu-K 11.2%	Scattering Cu-K 10.7%	Scattering Cu-K 12.0%	Scattering Cu-K 13.3%	Scattering Cu-K 11.3%	Scattering Cu-K 11.7%	Scattering Cu-K 11.4%
Focal length	1600±10 mm	1600±10 mm (with lens equation)	1600.94 ±0.5 mm	1600.90 ±0.5 mm	1600.77 ±0.5 mm	1600.93 ±0.5 mm	1601.14 ±0.5 mm	1601.80 ±0.5 mm	1600.93 ±0.5 mm	1601.21 ±0.5 mm
Optical axis alignment	< 30″	< 30″	0″±21″	30″±14″	110″±14″	47″±14″	72″±14″	61″±14″	38″±14″	105″±14″

HW-Status: Overview FM

Telescope Structure, Front Cover incl. Mechanism	ready, tested (qualified)
MLI	ready, some parts to be refurbished
Mirror System	
FM-1	ready with X-ray Baffle, tested (acc, baf, vib, ptv, tel)
FM-2, 3, 4, 5, 6, 7, 8	ready with X-ray Baffle, tested (acceptance)
X-ray Baffle	
FM-1, 3, 4, 5, 6, 7, 8, 9	ready, integrated onto each mirror module
Mirror Assemblies (Mirror + X-ray Baffle)	
FM-1, 2, 3, 4, 5, 6, 7, 8	ready, all still need to be calibrated in X-rays
Electron Deflector FM 1-8	ready, tested (qualified)
E-Box Radiators (2)	ready, tested (qualified)
Camera Radiators	ready, tested (qualified)
Heatpipe System Camera	Integrated and tested sucessfully in March
Heatpipe System Electronics	Integrated and tested sucessfully in March
Cameras (Meidinger et al. SPIE 8859-10)	
CCDs	QM test close to completion
Detector	QM test close to completion
Electronics	EM tests in progress
Interface & Thermal Control Electronics	EM tests in progress
Harnesses	Completed waiting for outgassing

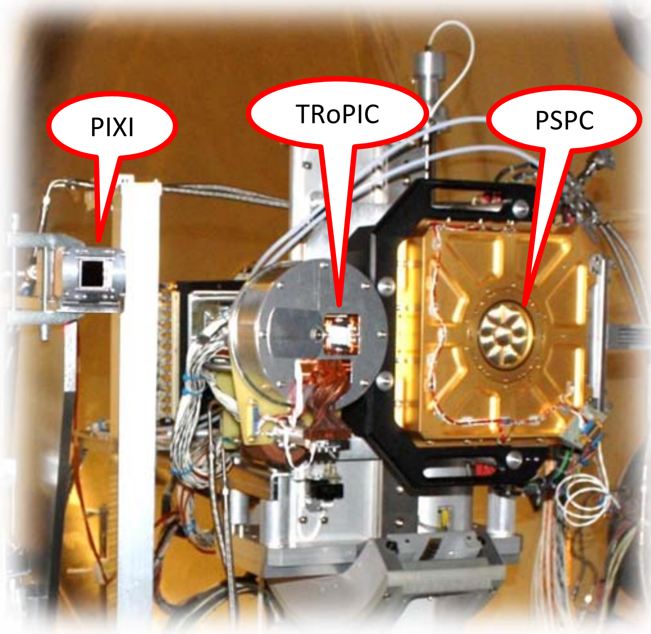
Calibration

device	process	signal	characteristic properties	
telescope	reflection (scattering)	*photon [eV]*	effective area (E,φ) point spread function (E,φ) field of view (FOV) boresight	collecting area, reflectivity, vignetting mirror quality focal length, detector geometry, plate scale alignment
filter	absorption		transmission (E) contamination (E,t)	
CCD	charge release	*charge [e⁻]*	charge splitting low energy threshold	**patterns** (singles, doubles, triples, quadruples, invalid..)
			contaminating effects quantum efficiency (QE) energy resolution (ΔE)	**pile-up** (single pixel, pattern) **photon background** (fluorescence, optical loading) **particle induced background** (soft protons, MIPs) **detector induced background** (noise, bright pixels)
	charge transfer		charge transfer loss (CTI) pattern migration	**trap saturation** due to photons and particles **charge transfer noise** **threshold induced charge loss** reemission, charge diffusion, charge splitting
	charge readout	*pulse height amplitude [adu]*	readout noise amplification ('gain')	non-linear gain, also dependence of the "apparent" gain on threshold(!) dependence on energy, temperature, time
on-board data processor	signal processing	*event [bit]*	energy offsets (offset map) common mode correction signal extraction MIP suppression	**restrictions likely due to limitations in on-board computing power and telemetry** (low energy threshold, MIPS..)

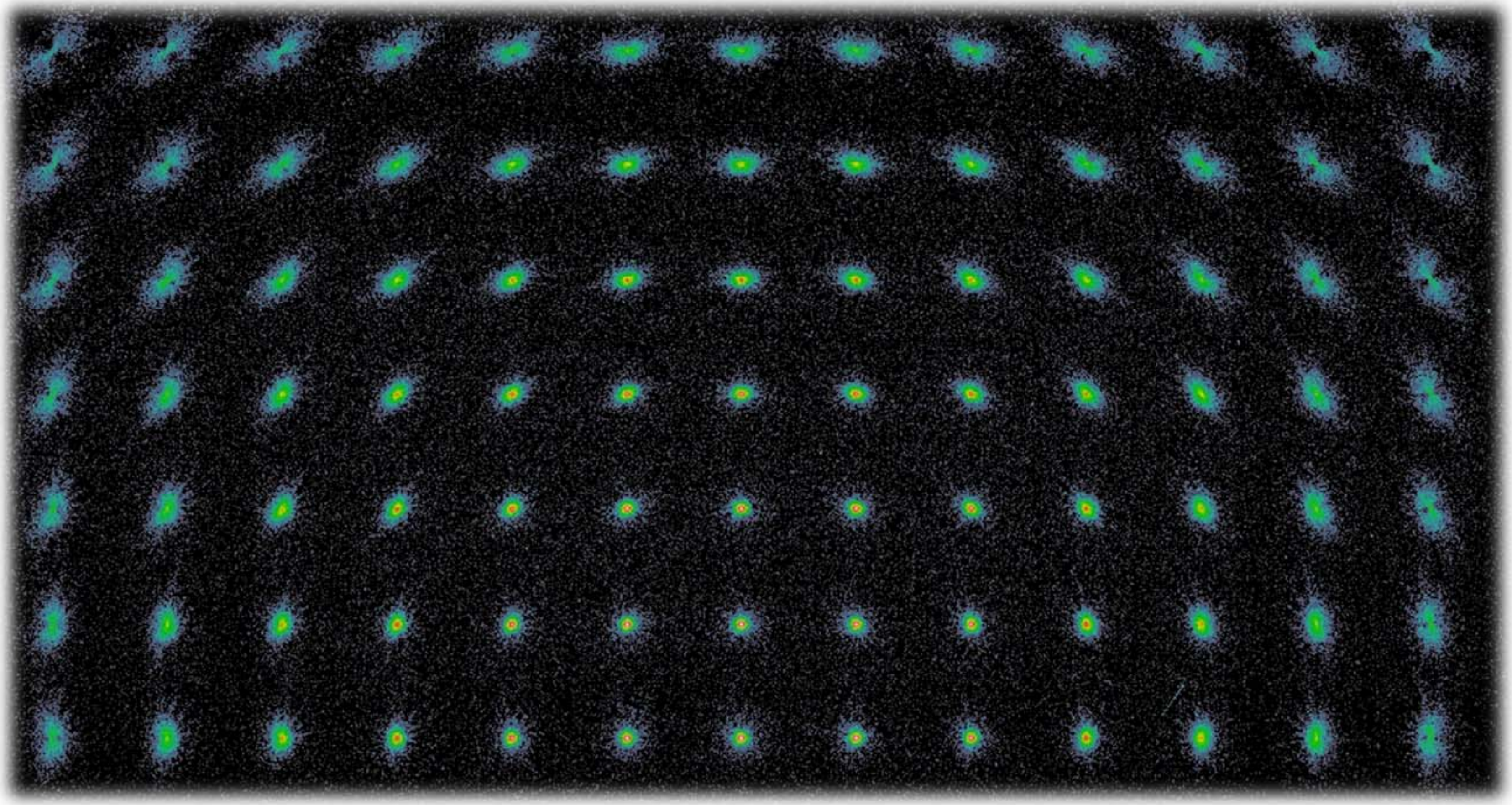
court. K. Dennerl

The MPE PANTER X-ray Test Facility

- **The X-ray test Facility**
  - **Length 132 m extendible to 145 m**
  - **Main intrument chamber 3.5 m diameter**
  - **Large cleanroom for handling X-ray optics**
- **Detectors**
  - **PSPC : Position Sensitive Proportional Counter**
  - **TRoPIC : Single photon counting CCD camera**
  - **PIXI : Integrating CCD Camera**
- **X-ray Sources**
  - **Multi target electron impact source**
  - **Seifert closed X-ray source**
  - **X-ray Monochromators**
- Beam Monitors
  - Proportional counters
  - Drift Chamber
- Manipulators
  - X, Y, Z translation stages
  - Tip-tilt, rotation stages



The of Axis PSF of eROSITA (Survey PSF)



Half the focal plane scanned In 5 arcmin steps

eROSITA Mirror Calibration

FM1 went through the following tests for qualifiction

- an X-ray acceptance test
  - HEW and effective area
- Integration of the baffle unit
- X-ray test after baffle integration
  - HEW and effective area
- Environmental tests (thermal cycling and vibration)
- Telescope module Test / X-ray test in space like envirement.

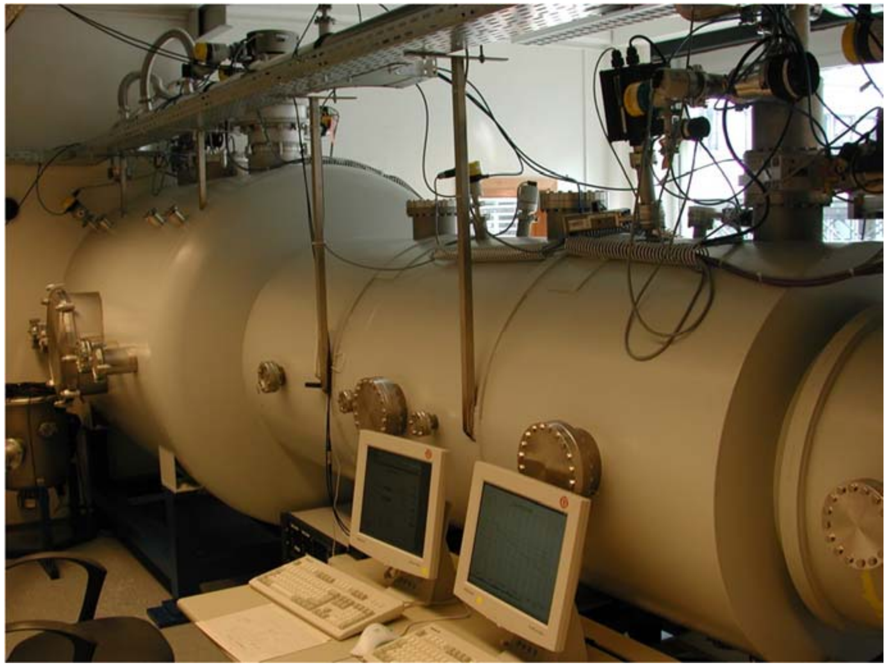
FM2-FM8:

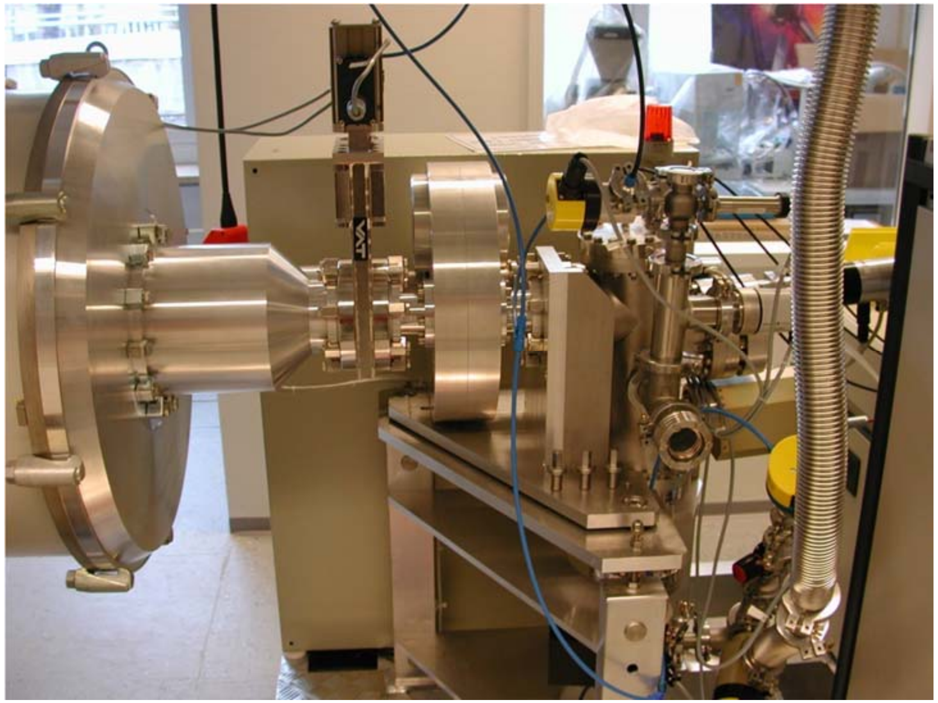
- went through an X-ray acceptance test
  - HEW and effective area

FM1-FM8:

- Final calibration tests to measure the:
  - PSF on-axis / off-axis in the energy range 0.18 – 8.04 keV
  - effective area in the energy range 0.18 – 8.04 keV
  - contribution of scattering

PUMA Facility

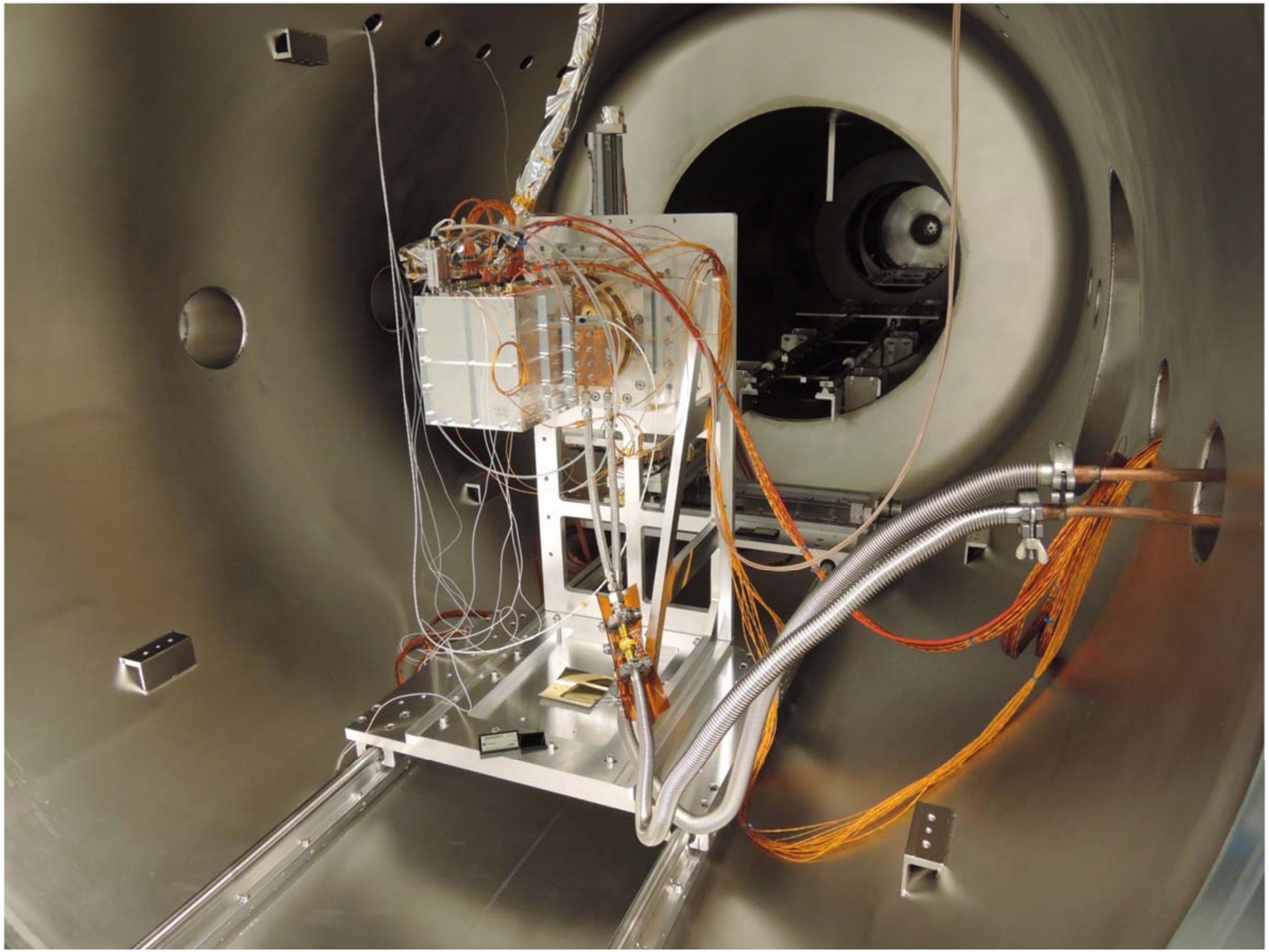




Vacuum: p = 2×10^{-7} mbar
StirlingCooler: T < -120°C
2nd cooler for electronics

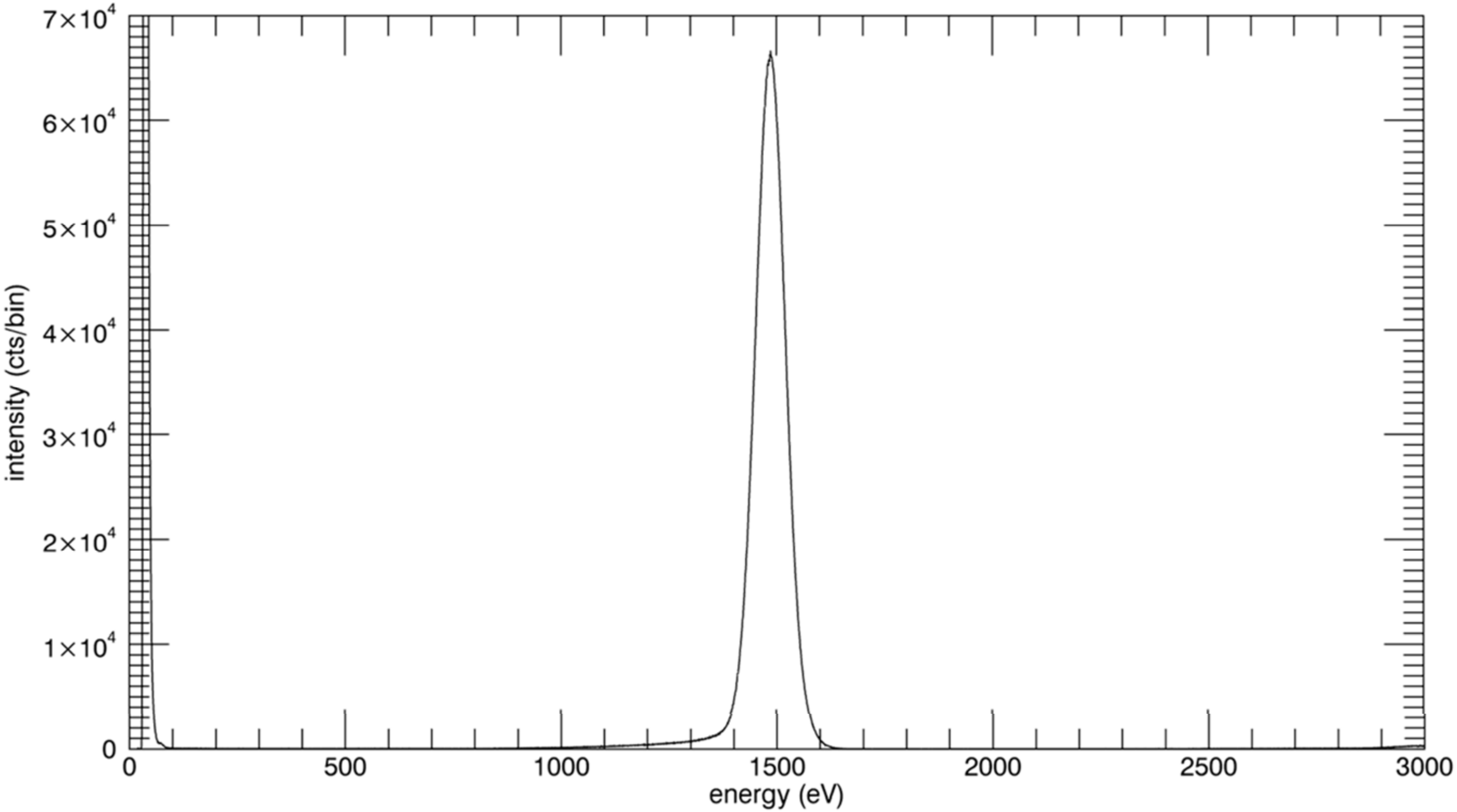
Multitarget X-ray Source
Double Filterwheel
charact. lines 0.3keV – 10keV

PUMA CameraTest

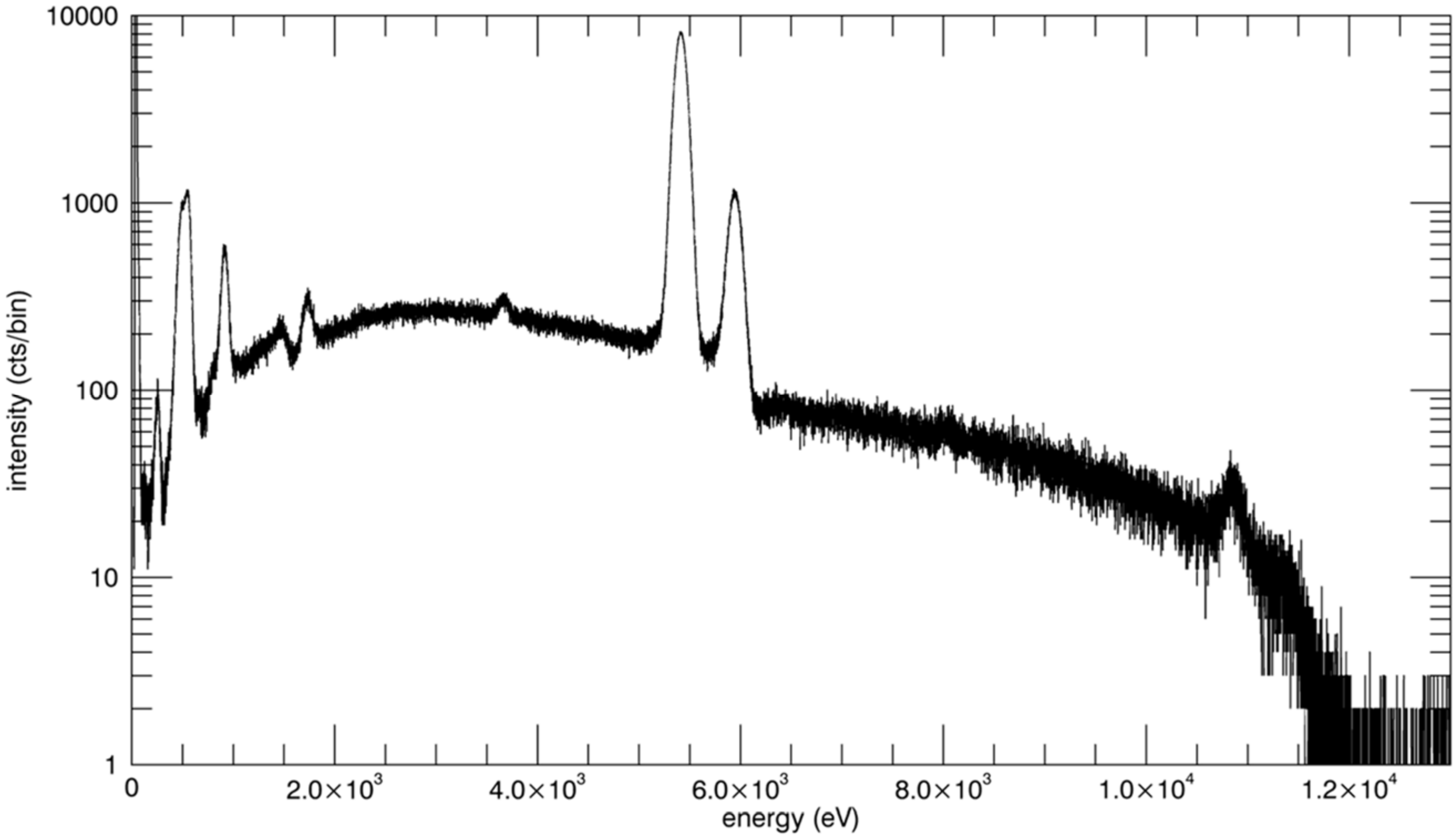


A boring result?

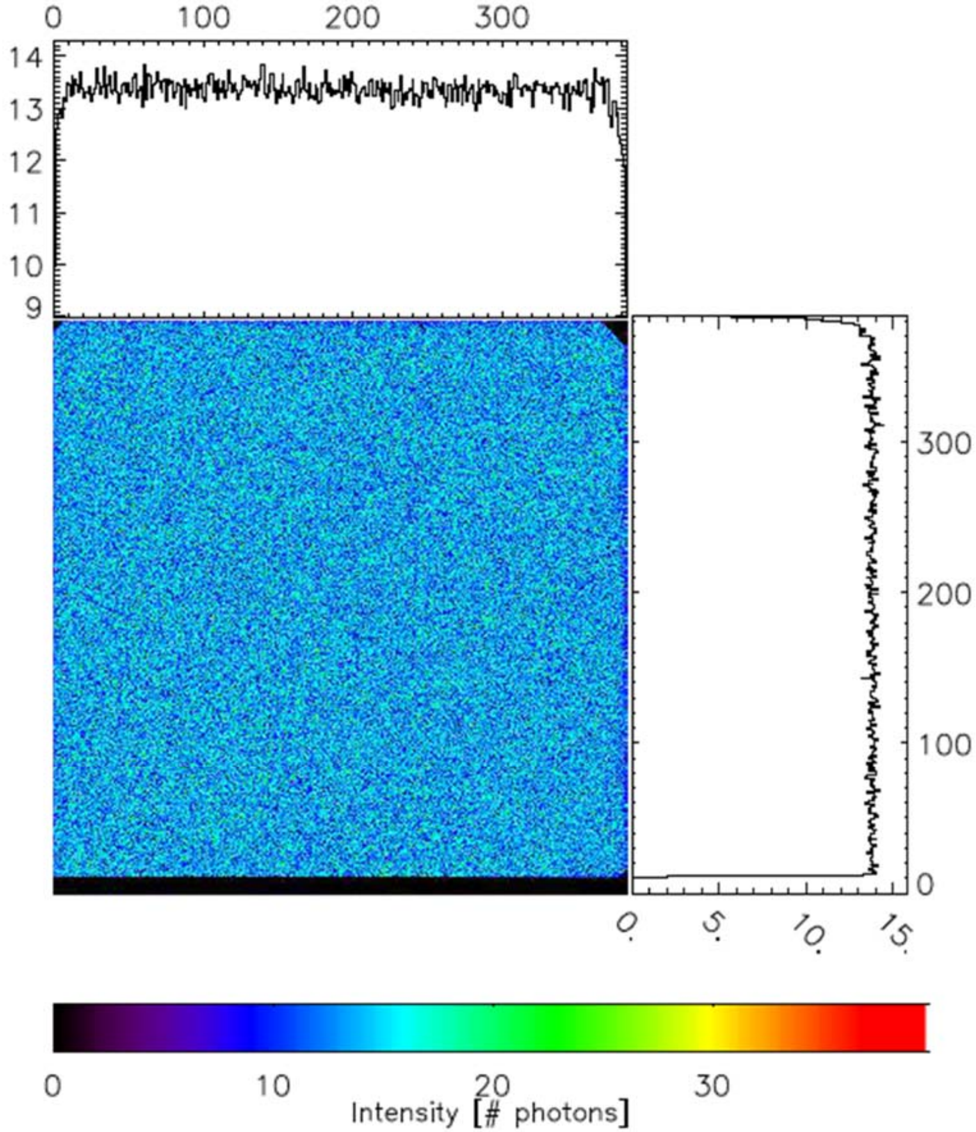
Al-Kα spectrum, 80eV FWHM



Cr-Kα 136eV FWHM
Cu-L 70eV FWHM

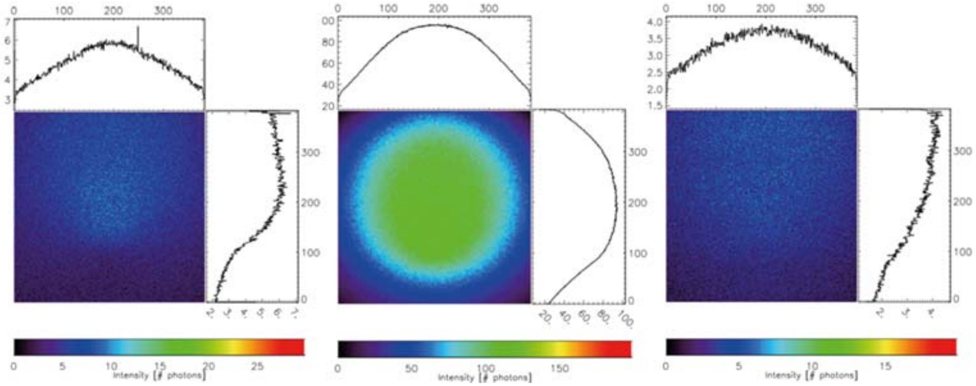


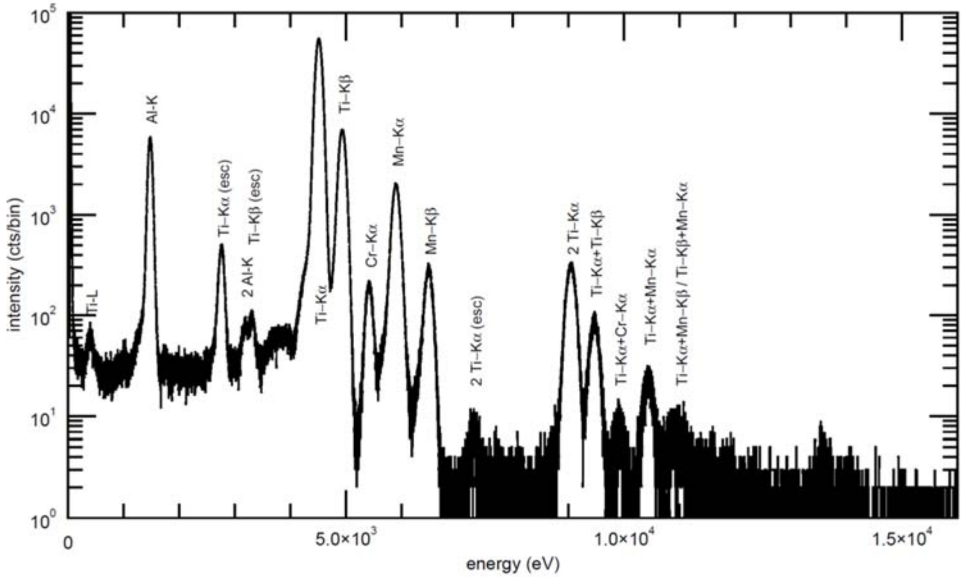
Perfect Uniformity



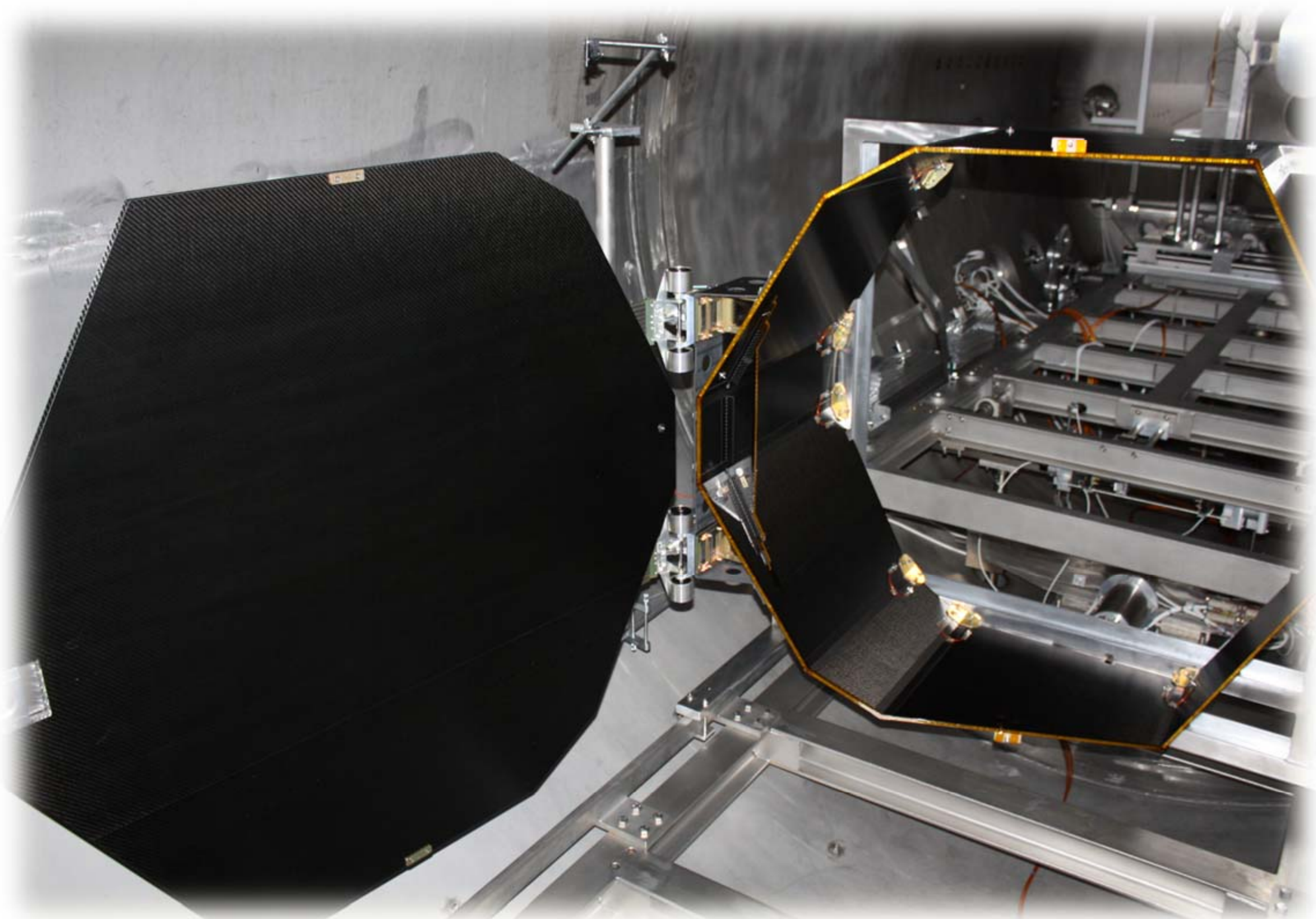
Onboard Calibration Source

Al Kα Ti Kα Mn Kα



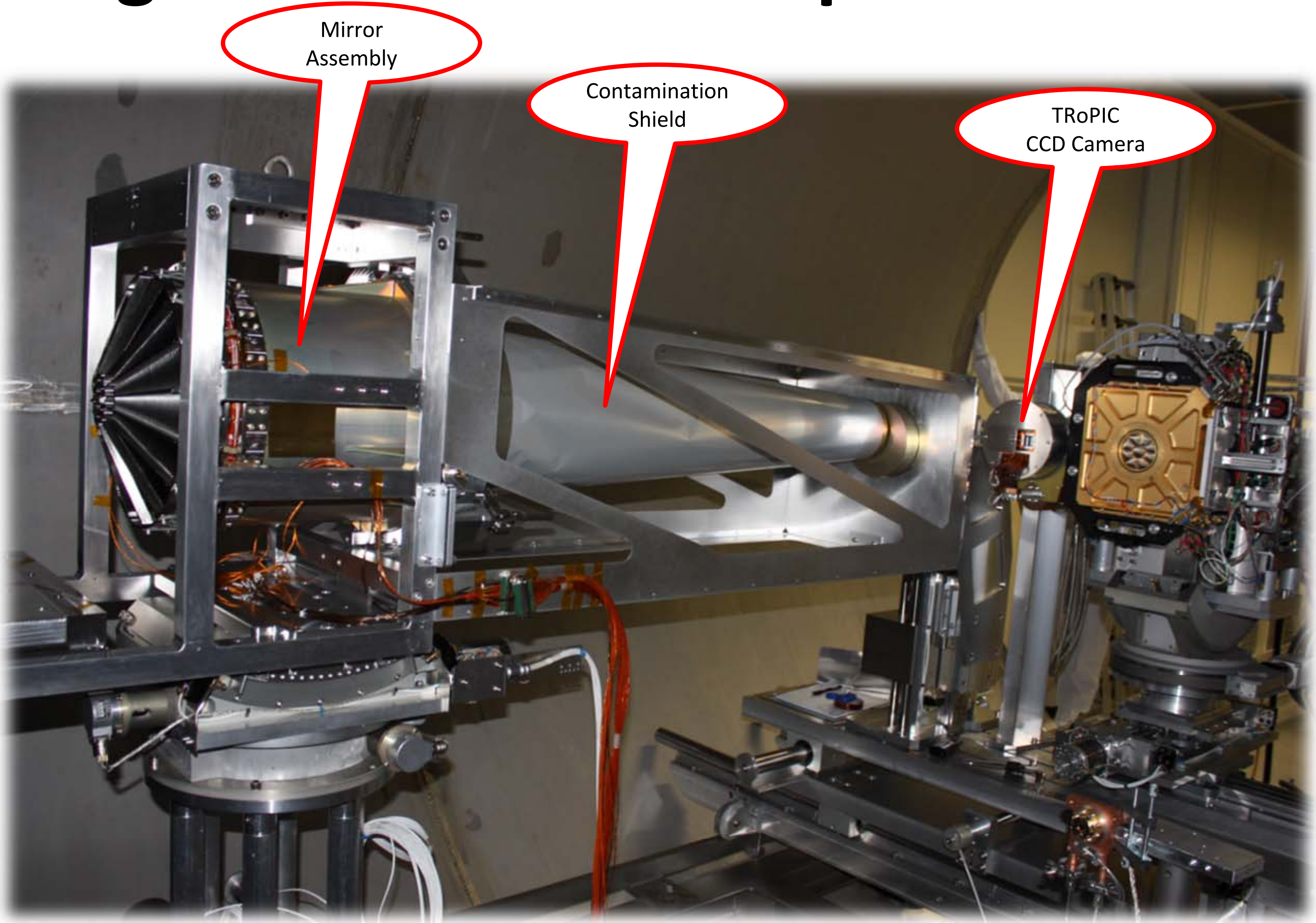


eROSITA Cover Test I at PANTER

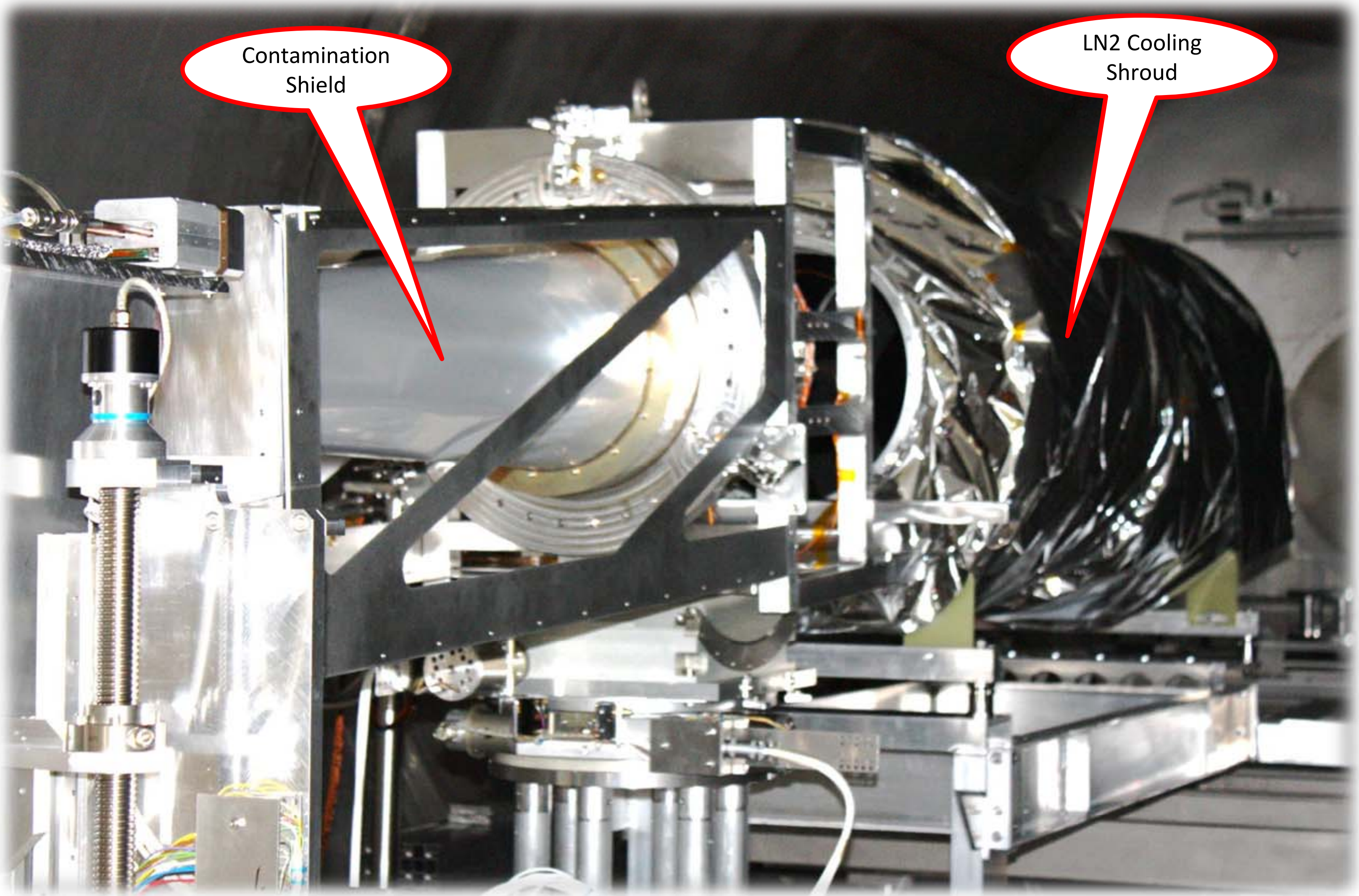


To perform a functional test in vacuum of the eROSITA telescope cover opening mechanism the top part of the sunshield together with the cover were installed in the large PANTER vacuum chamber

Single eROSITA telescope in PANTER



Space Simulation with Cooling Shroud



Thermal Tests: CCD Camera Heatpipe Cooling System Test & „End2End Test“ test

The complete telescope setup including 4 radiators that remove the heat from the cameras and the electronic boxes through a complex heat pipe system are placed in a thermal shroud in the vacuum chamber which has a liquid N_2 cooled radiators that are placed opposite the telescope radiators to simulate „cold space“.

In Febr.-Mar. 2014 this test successfully demonstrated that it is possible to cool all 7 CCDs down to at least -93^{o} C, the optimal temperature for operating the cameras. And also maintain the electronic boxes at the nominal Temperature of 20°C.

eROSITA „End to End“ Test at PANTER

- The last „end to end test“ of the eROSITA telescope before delivery to Russia will be performed at PANTER. In this critical test all systems, both hardware and software, will be checked out.

- As eROSITA will be placed upright into PANTER the on board Fe55 calibration sources will be used to illuminate the CCDs.

- The PANTER X-ray Test Facility is ideally suited for this „end to end“ test because it is the cleanest large vacuum chamber available to us for such a test that also provides the cooling capability for the radiators.

eROSITA status Summary

- We have 8 excellent Mirror Modules
- We have a perfectly working X-ray camera
- The telescope and its subsystems are qualified

  → „end to end test“ test at PANTER succesfull in Febr.-March 2014
- X-ray Mirror Assembly (Mirror + X-ray Baffle) Calibration

  →beginning next week, completion end of this summer
- CameraS → CCDs are all characterised and Calibration begins as soon electronics fabrication is completed
- After „end to end test“ in PANTER mid 2015 before delivery to Russia for a Launch beginning 2016