INAF
Osservatorio Astronomico di Palermo
Giuseppe S. Vaiana

Attività Strumentale nel Campo della Astrofisica delle Alte Energie

Marco Barbera

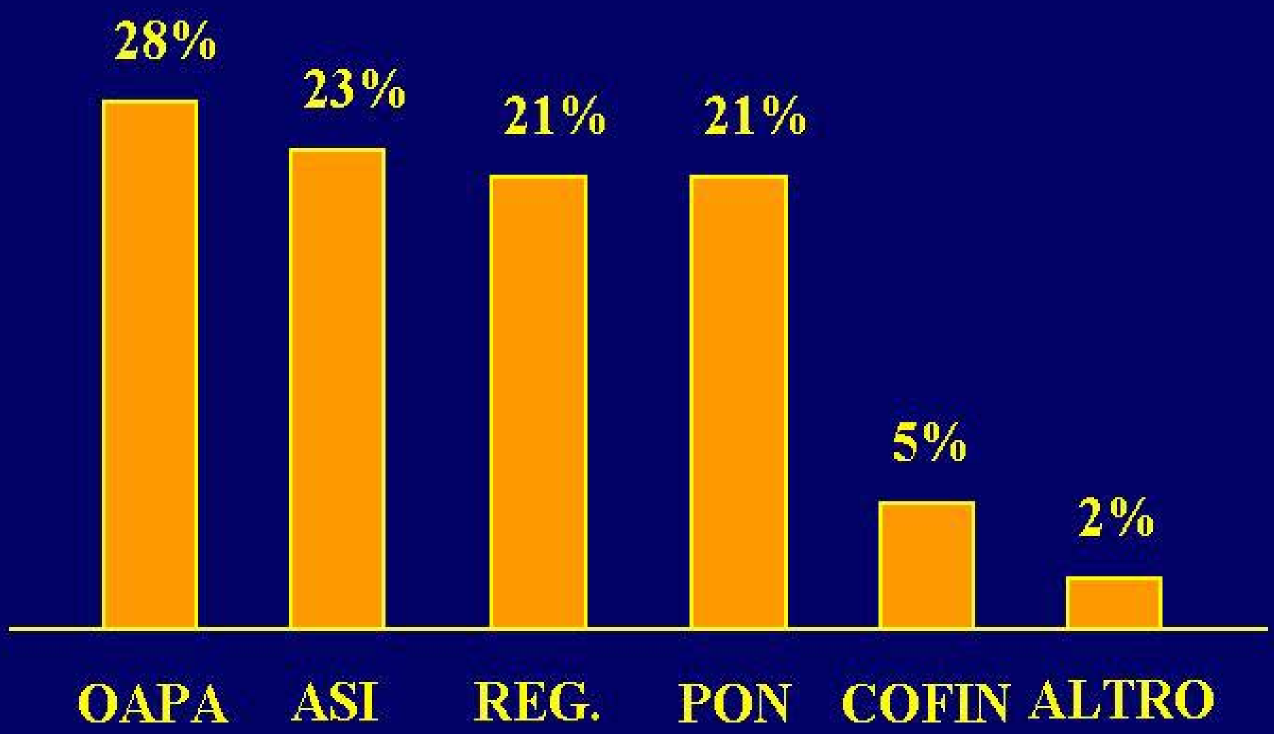
INAF-OAPA Attività Strumentale in Astrofisica delle Alte Energie

PROGETTI SPAZIALI	R&D	SVILUPPO LABORATORIO	Anno
Chandra		XACT	1989
			1991
	Filter Testing and Calibration	X-ray beamline	
			1993
Newton-XMM			
		XACT-Upgrade I	1995
	Optical Constants		
JET-X	Silica Glasses		
			1997
	Microcalorimeters	ADR Cryostat	
			1999
	Plastic X-ray Optics		
B-MINE	EBIT	Vacuum-control	
			2001
Solar-B			
Con-X	Bioastronomy	XACT-Upgrade II	2003
XEUS			

INAF-OAPA Attività Strumentale in Astrofisica delle Alte Energie

PROGETTI SPAZIALI	R&D	SVILUPPO LABORATORIO	Anno	Personale (Sc/Tec)	Fondi di Ricerca (KE)
Chandra		XACT	1989	1 / 2	400 (Reg. Siciliana) 30 (ASI) 100 (OAPA)
		X-ray beam	1991	2 / 2	100 (ASI) 100 (OAPA) 20 (CNR)
	Filter Testing and Calibration	Upgrade I	1993	2 / 2	200 (Reg. Siciliana) 100 (ASI) 100 (OAPA)
Newton-XMM			1995	2 / 2	120 (ASI) 100 (OAPA)
JET-X	Optical Constants		1997	2 / 3	50 (CRA) 120 (ASI) 100 (OAPA)
	Silica Glasses Microcalorimeters	ADR Cryostat	1999	2 / 3	70 (COFIN) 90 (ASI) 100 (OAPA)
B-MINE	Plastic Optics EBIT	Vacuum control	2001	2+2 / 3	70 (COFIN) 110 (ASI) 100 (OAPA)
Solar-B	Bioastronomy	Upgrade II	2003	2+2 / 3	60 (ASI) 630 (PON) 30 (Reg. Siciliana) 100 (OAPA)
					~ 3000

Fondi di Ricerca (%)



SVILUPPO LABORATORIO

The X-ray Astronomy Calibration and Testing facility (XACT)

- Facility for the development, test and calibration of instrumentation for soft X-ray Astronomy.

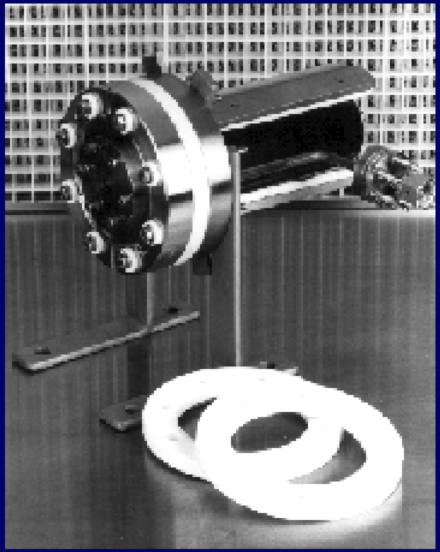
- Transmissivity, reflectivity, and quantum efficiency measurements in the UV and soft X-ray band (0.01 - 10 keV).

- Test and calibration in full imaging mode of moderate angular resolution (PSF > 10” FWHM), and small diameter (< 40 cm) grazing incidence X-ray optics.

X-Ray Beamline

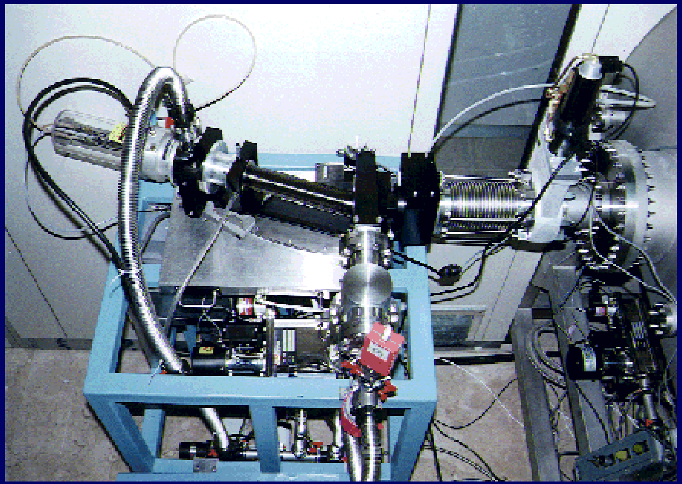
XACT - Upgrade I

GSPC detector

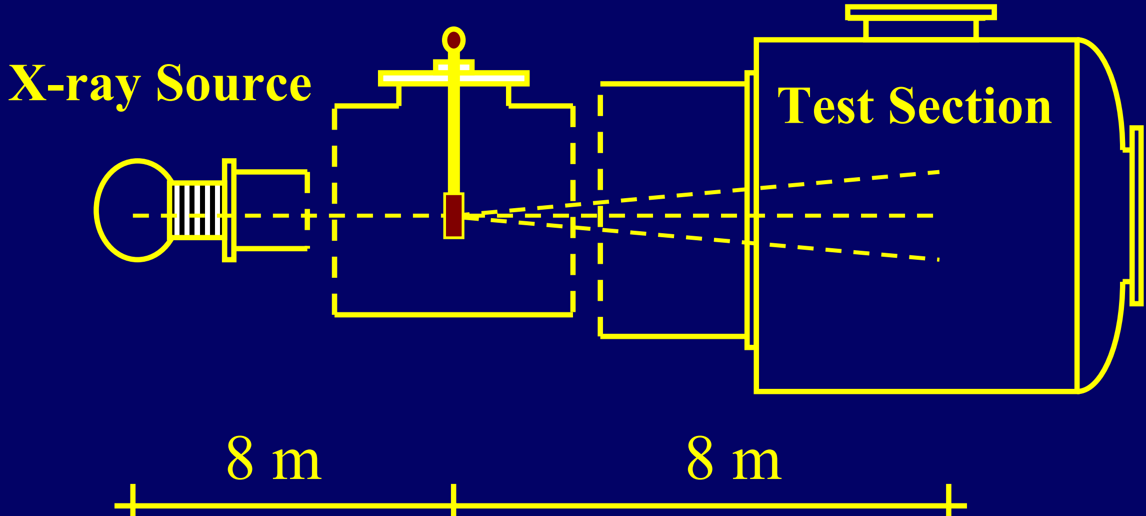


MCP detector

UV Beamline



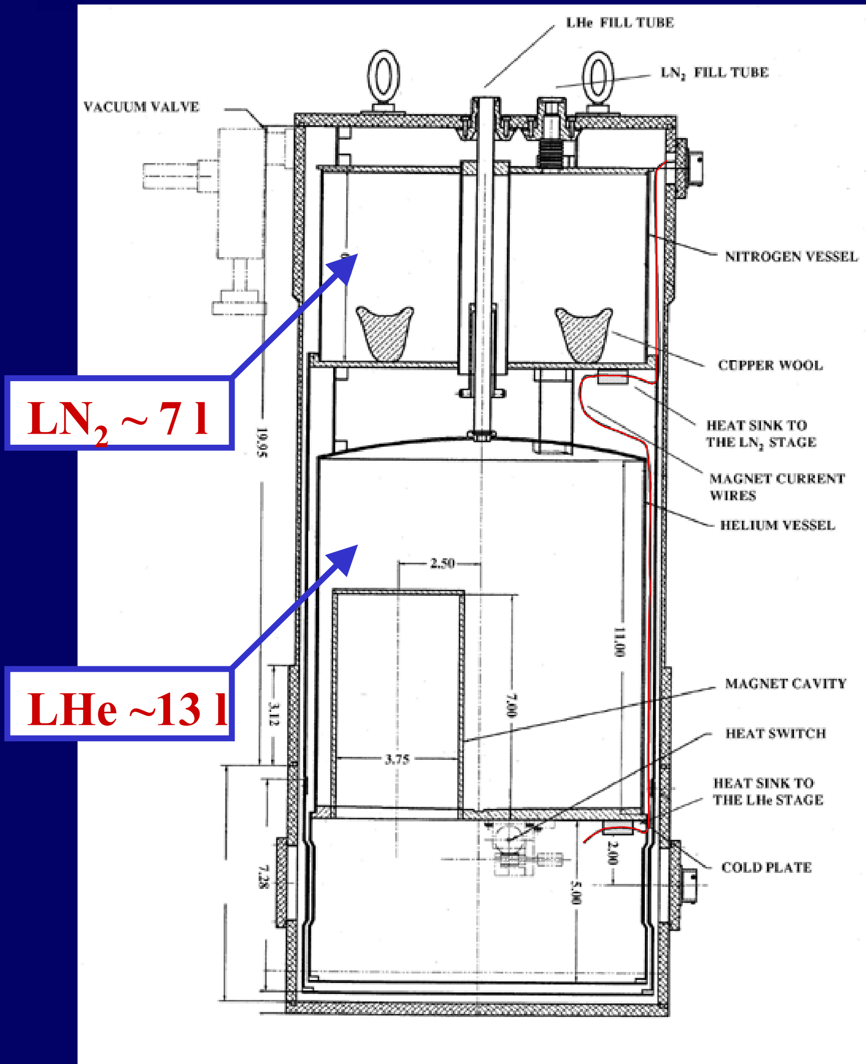
X-Ray Transmission grating Monochromator



Clean Room

Adiabatic Demagnetization Refrigerator

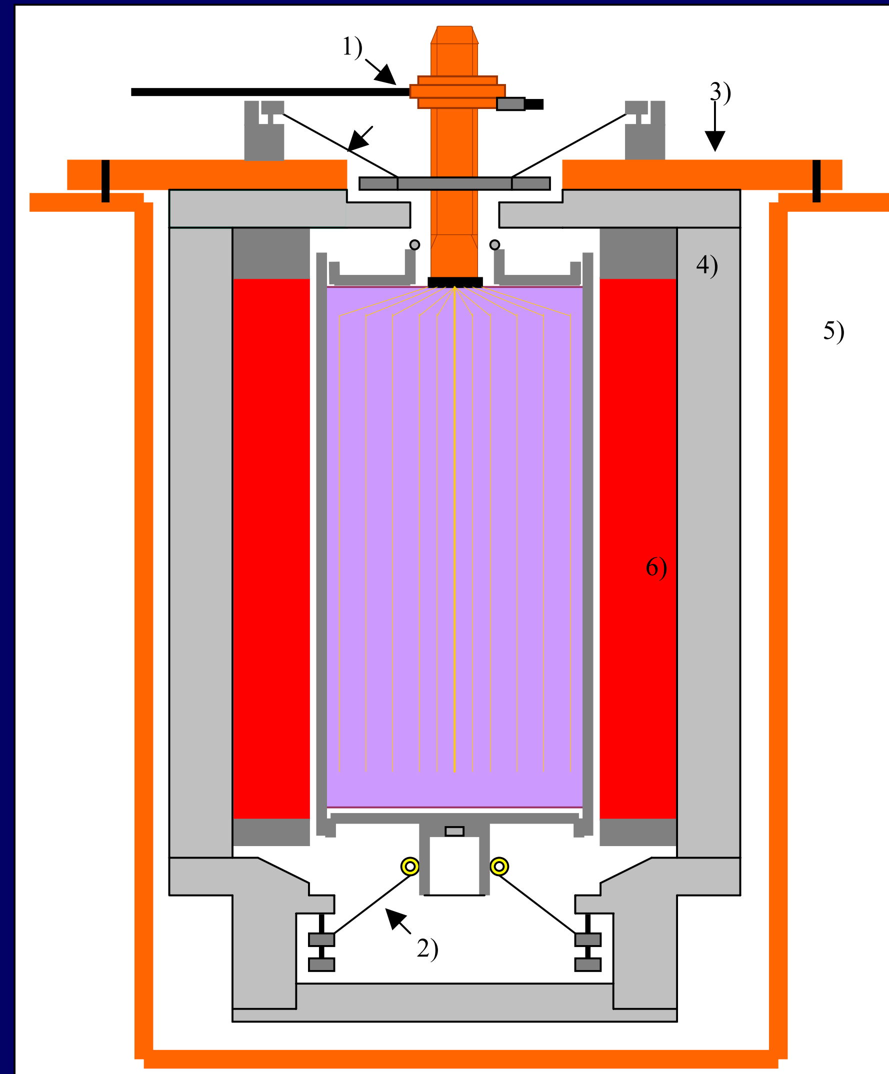
Liquid He Dewar



LN2 hold time ~ 48 hours

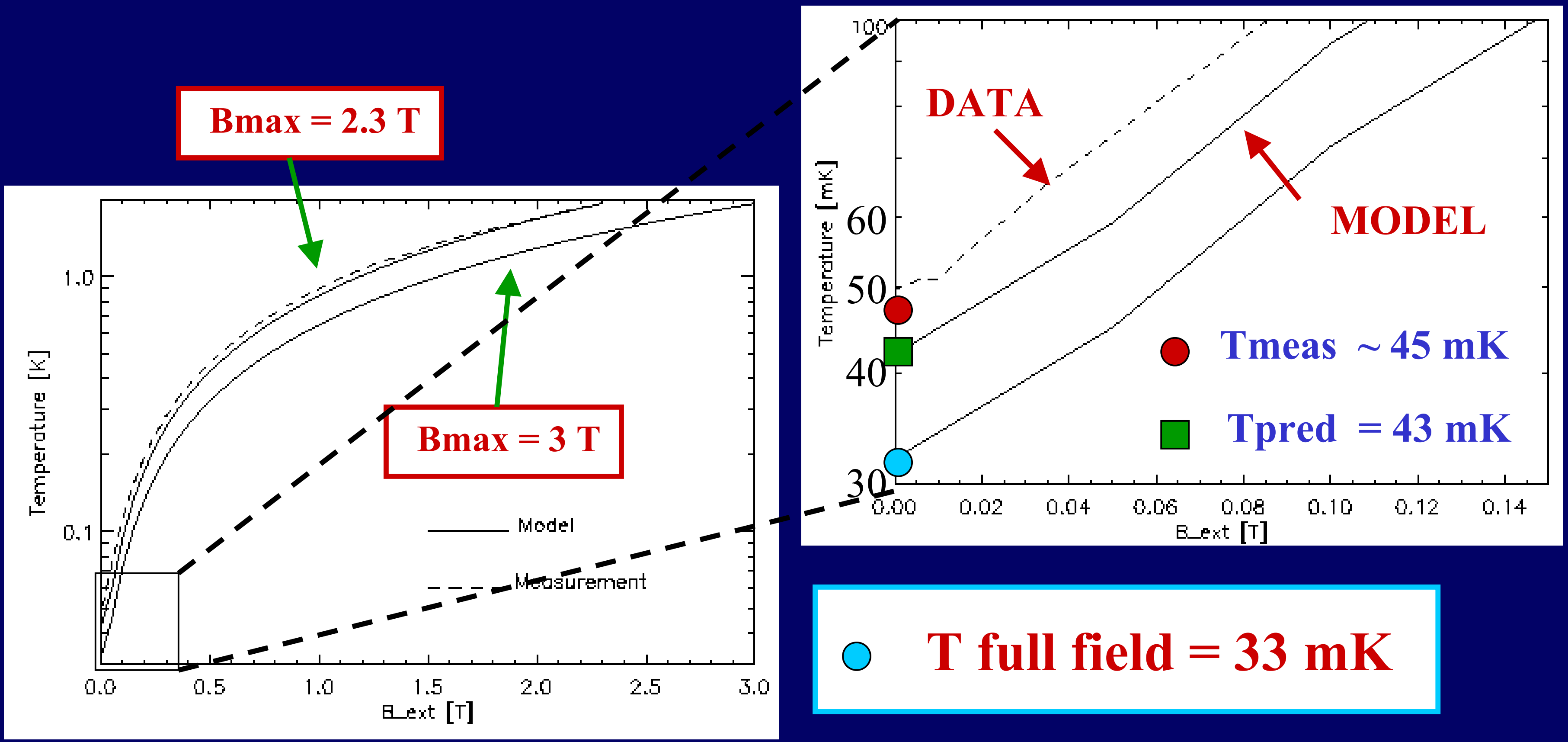
LHe hold time ~ 50 hours

ADR Insert



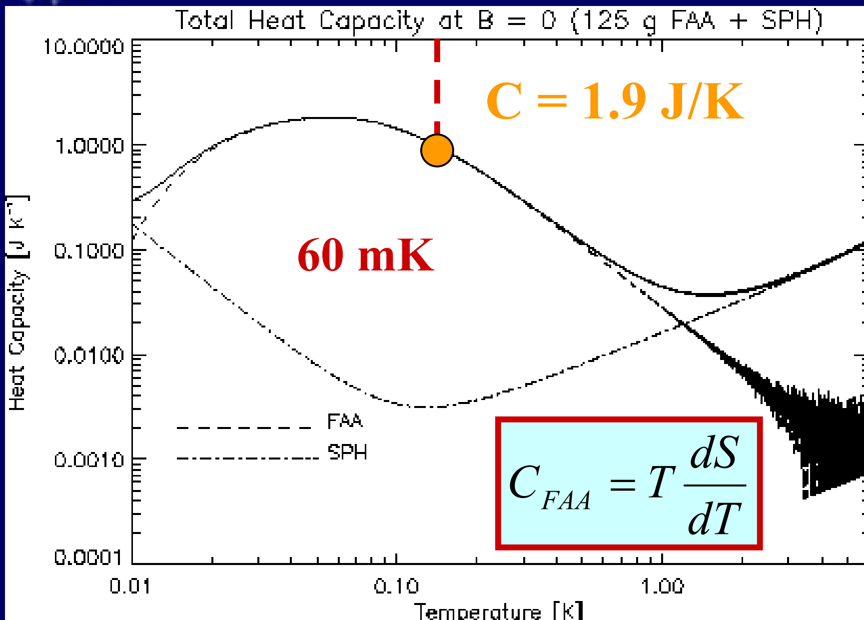
Laboratory Tests: Cooling down

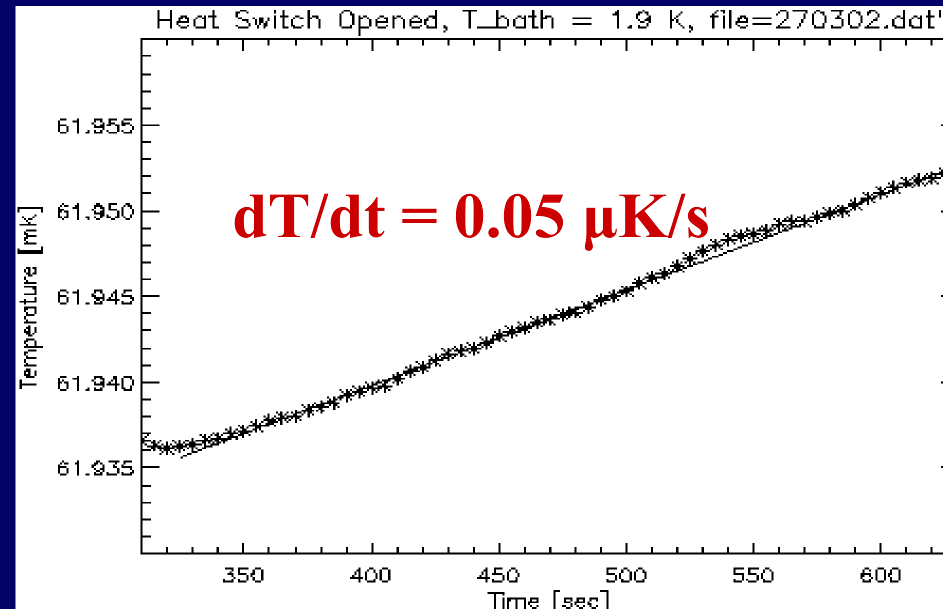
1. **Pumping on LHe and LN_2** (2 hours)
2. **Isothermal Magnetization** (2 hours)
3. **Adiabatic Demagnetization** (10 min)



T full field = 33 mK

Laboratory Tests: Heat Load





Measured Heat Load @ 60 mK

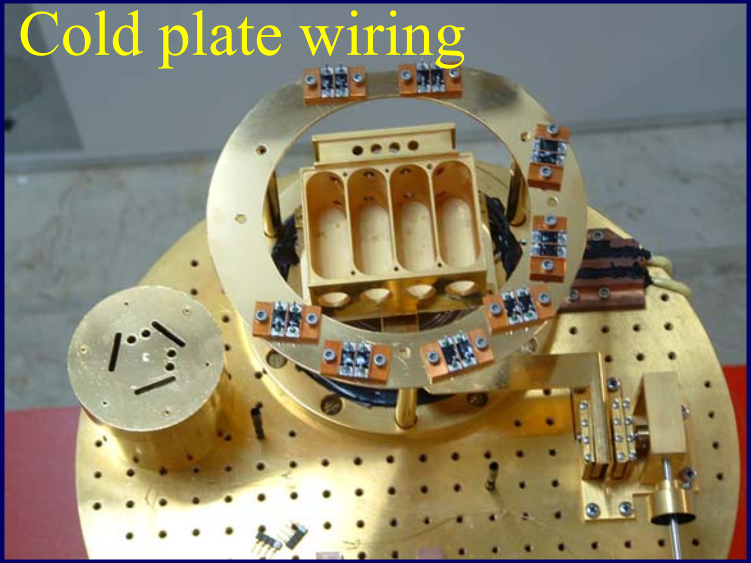
$$\frac{dQ}{dt} = C_{FAA+SPH} \frac{dT}{dt} = 0.1\ \mu\text{Watt}$$

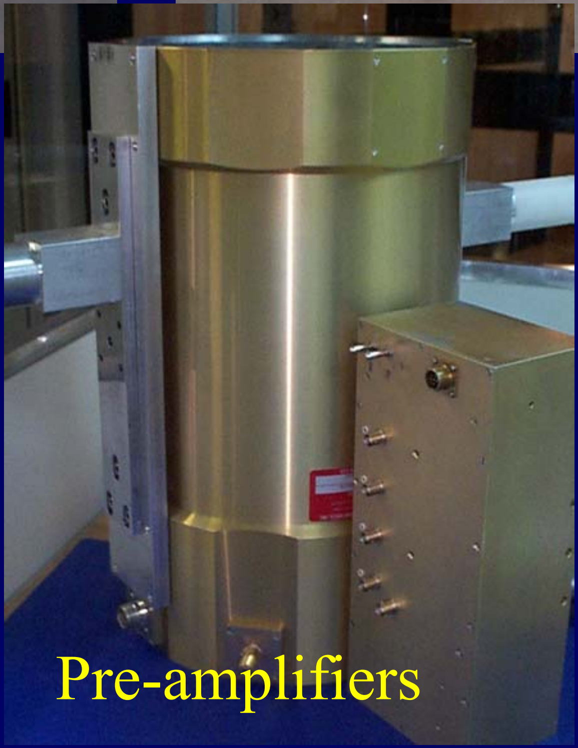
Hold Time @ 60 mK ~ 95 hours

Predicted Heat Load @ 60 mK

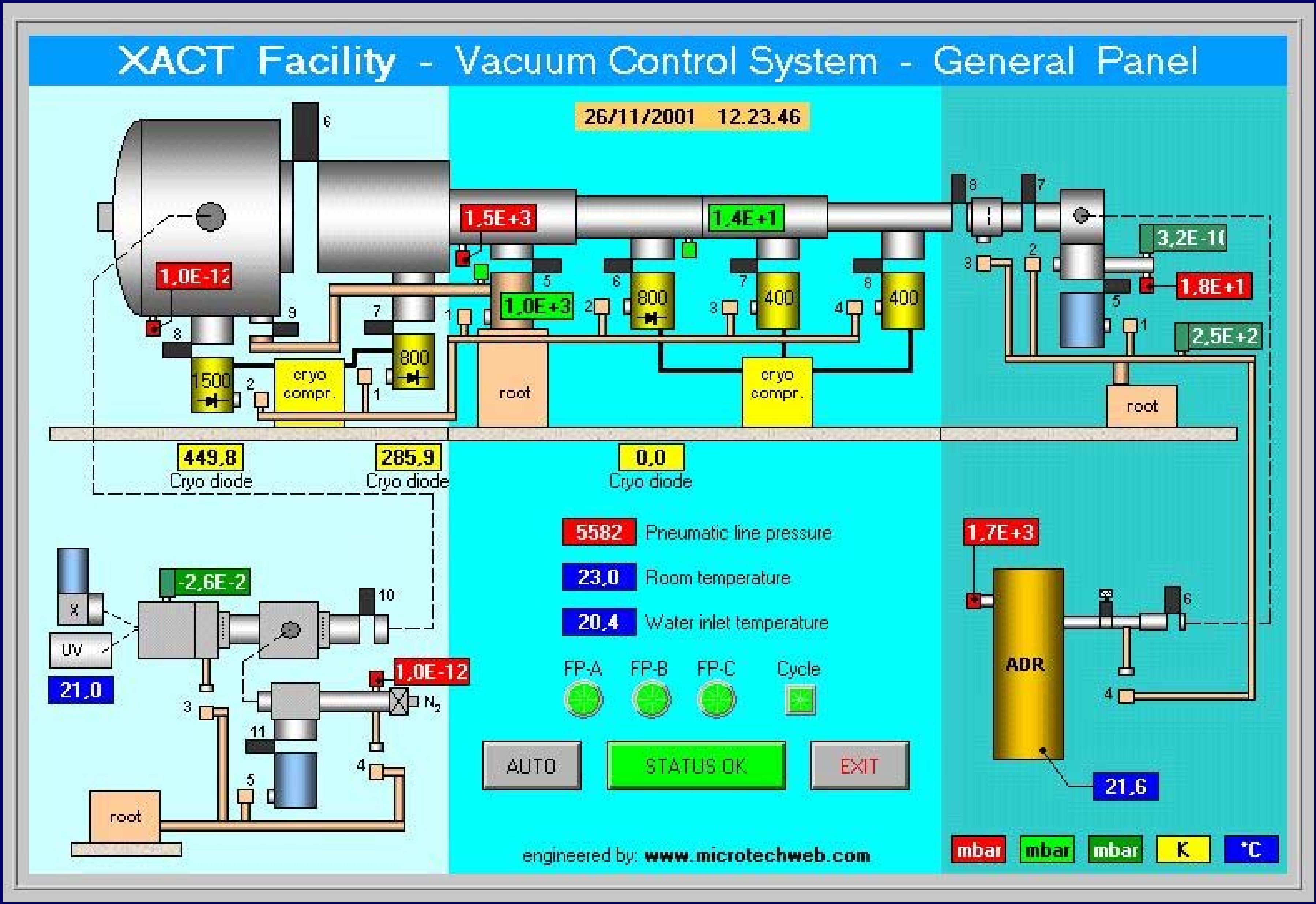
Source	(μWatt)
Thermom. Wires	0.005
Kevlar Wires	0.15
Radiation	0.002
Eddy Currents	0.008
TOTAL	**0.165 μWatt**

Set-up to test microcalorimeters





Vacuum Control System



XACT - Upgrade II

Bando MIUR N. 68 del 23.01.2002 - PON 2000-2006 - "Ricerca Scientifica, Sviluppo Tecnologico ed Alta Formazione", Misura II.1a "Potenziamento della dotazione di attrezzature scientifico-tecnologiche". Progetto biennale approvato dal MIUR (inizio 11.02.2003) per un importo pari a 768.000 Euro.

1) Expansion of the Machine Shop

2) Extension of the X-ray beamline

3) Development of an X-ray reflect. monochromator (0.1-20 keV)

4) Expansion of the instrumentation to test microcalorimeters

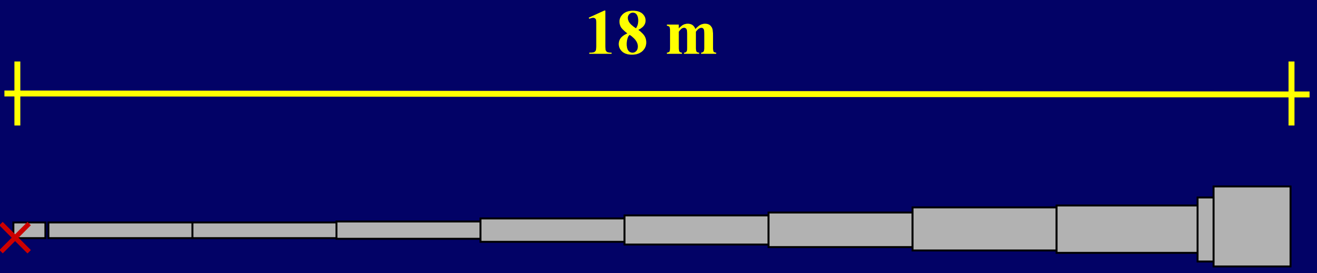
5) Upgrade of the control and data acquisition systems

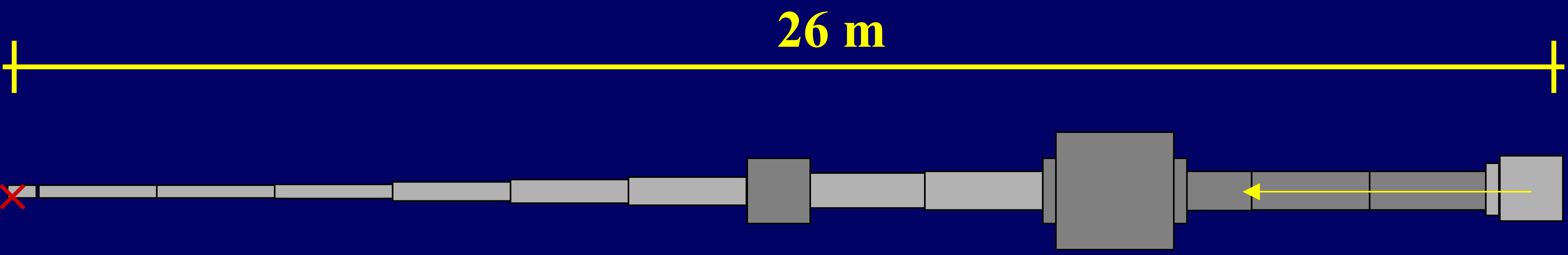
1) Expansion of the Machine Shop

CNC Lathe model CMT URSUS 500 TC
- Max working length 150 cm
- Max diameter 50 cm
- Precision 10 µm

CNC Milling machine model FAMUP 700
- Working Travell 700×500×640 cm
- Max speed 8000 rpm
- Precision 5 µm

2) Extension of the X-ray beamline





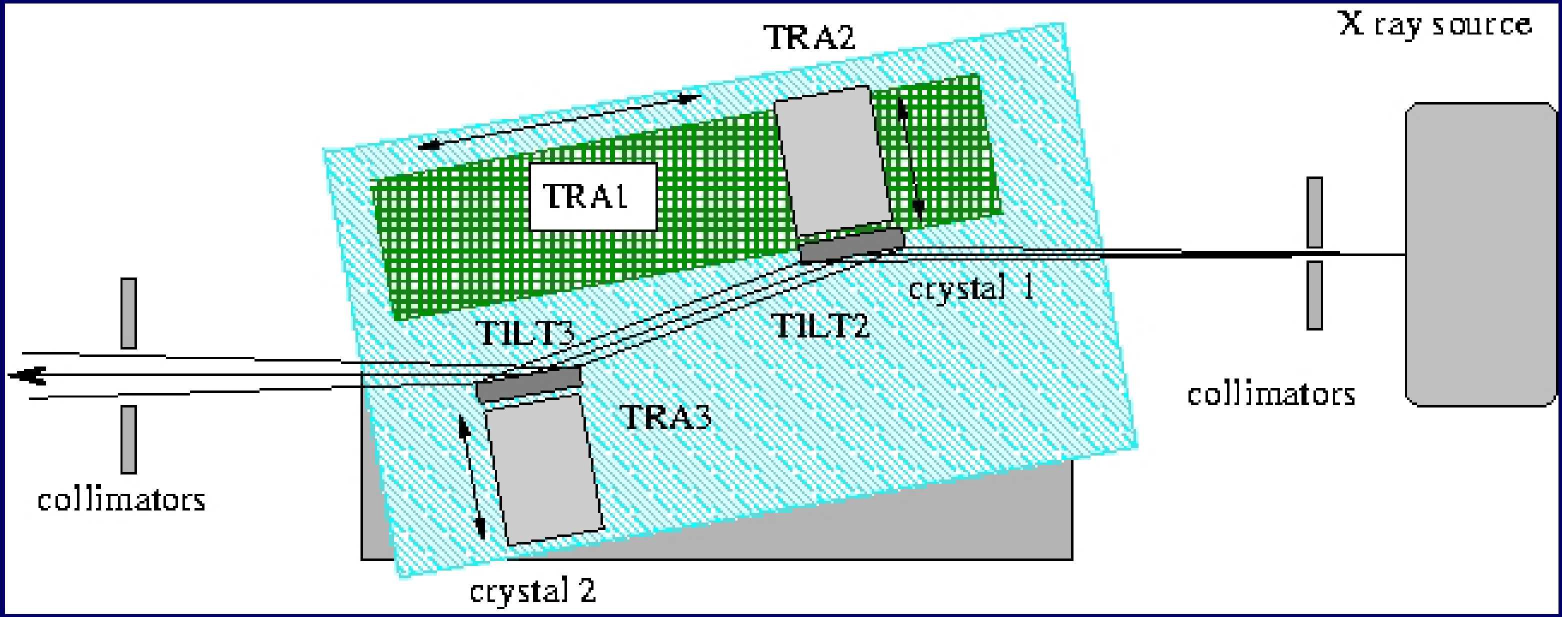
. Six axis (X,Y,Z,α,δ,φ) stages to accurately position the telescope

. Linear stage to position detectors at telescope focus (F.L. 3 ÷ 11 m)

3) Development of an X-ray Monochromator

Goals: - energy range 0.1-20 keV,
- fixed exit beam,
- large available beam at 20 m.

Baseline: Double crystal monochormator with use of different Bragg diffractors to cover the full energy range (e.g. natural crystals, mosaic crystals, gratings, bent crystals)



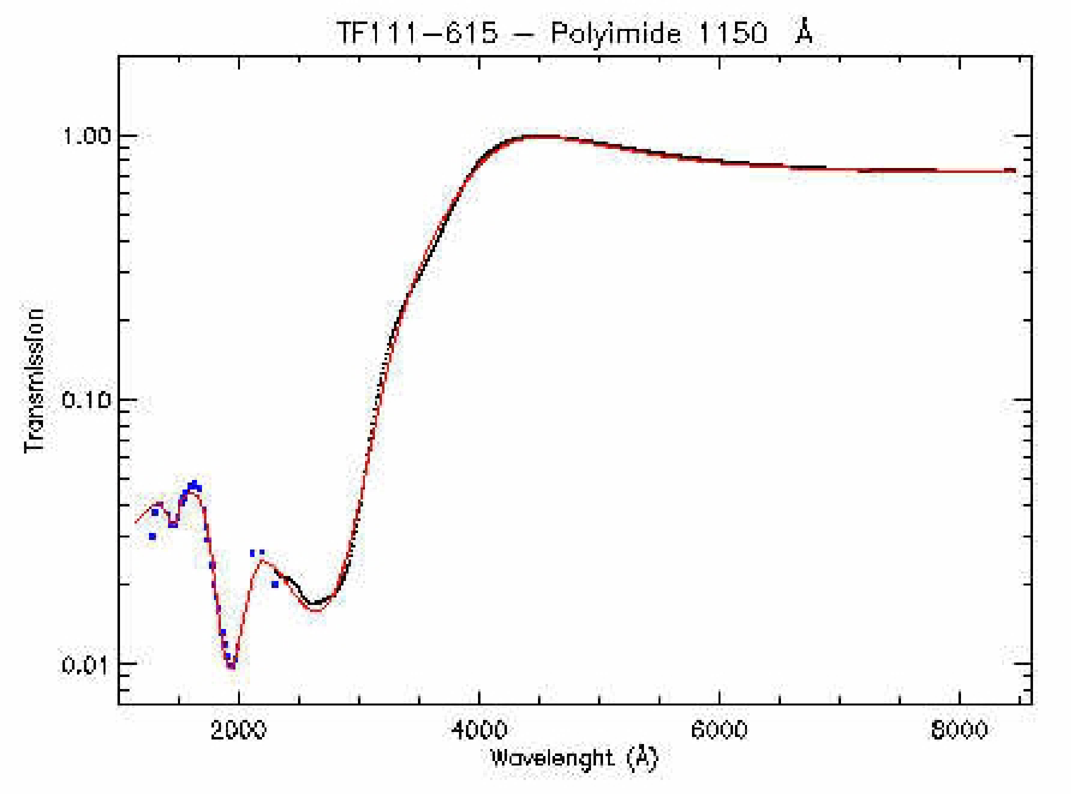
Research & Development

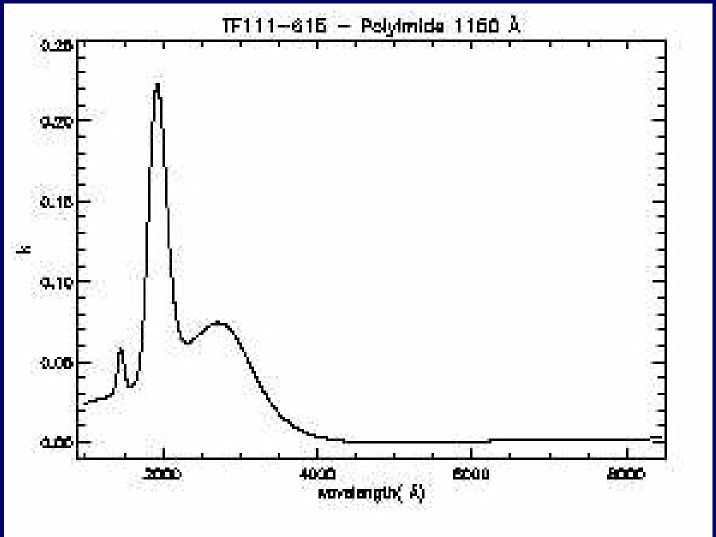
Filter Testing and Calibration

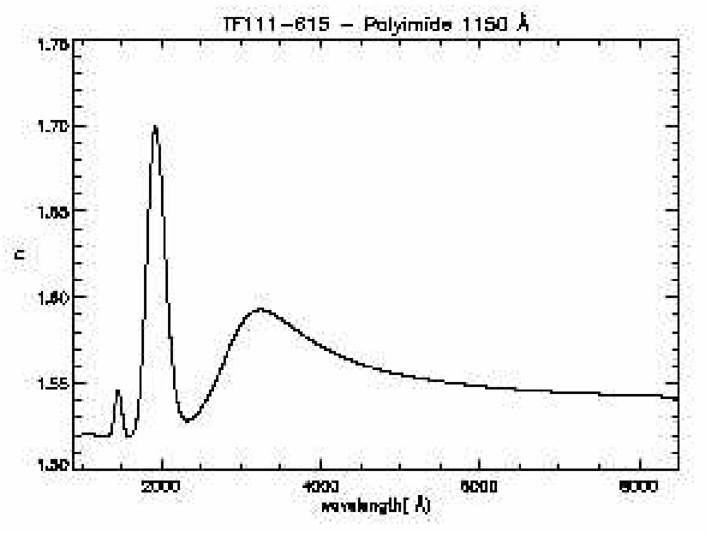
- Chandra
- Newton-XMM
- JET-X
- Solar-B

Measurement of the UV/Visible refractive index of filter materials

- Transmission measurements of monolayer films
- Parametric model of the extinction coefficient K







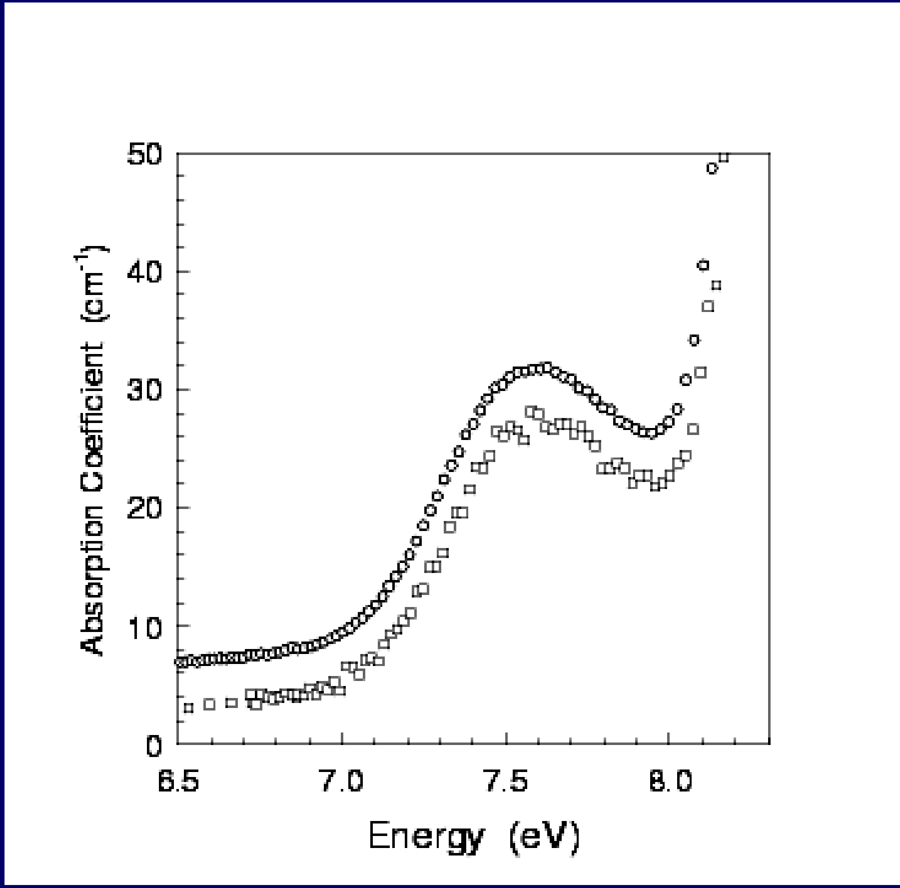
Vacuum UV absorption features in Silica Glasses

(Collaboration with DipSFA-UNIPA, Unità INFM Palermo)

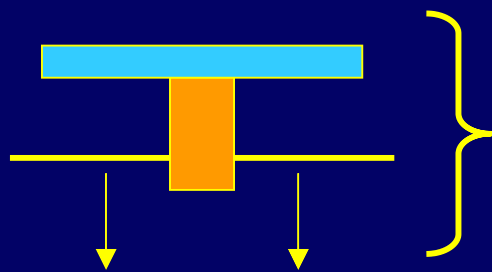
• Characteriziation of the optical activity of the silica (a-SiO_2) in the vacuum ultraviolet (VUV).

• Transmission measurements in the 1200-2300 Å are performed on natural or synthetic silica samples, with different content of OH groups irradiated with different doses of Gamma rays or neutrons.

• Very accurate results with respect to those obtained with a much more expensive set-up at Synchrotron facilities.



NTD Ge X-ray microcalorimeters
(Collaboration with SAO and LBNL)



$C \sim 5 \cdot 10^{-14}$ J/K

$G \sim 10^{-10}$ J/sec K

$T \sim 0.06$ K

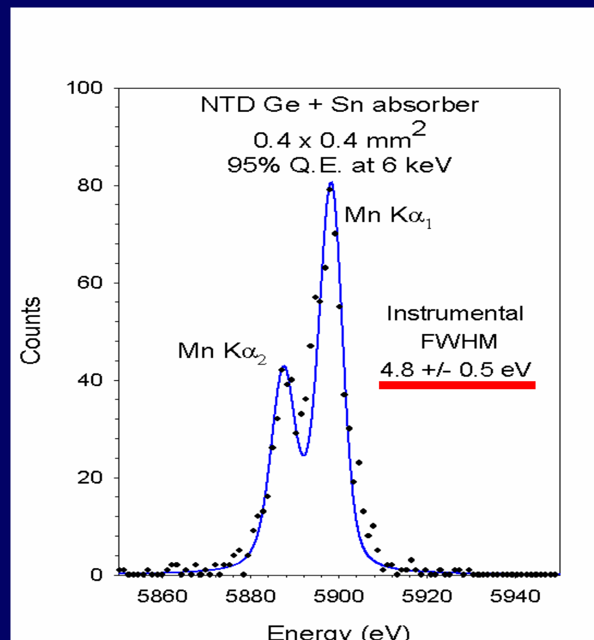
- **ABSORBER:** Superconducting Metal (Tin)
  (350 μm x 350 μm x 7 μm)
- **THERMISTOR:** NTD Germanium
  (75 μm x 50 μm x 150 μm)

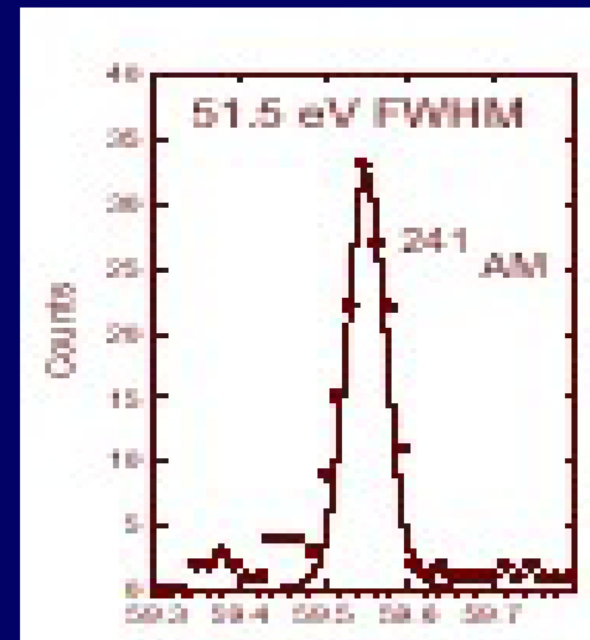
Theoret. Energy Resolution: $\Delta E_{FWHM} = 2.35\, a\, (k_B T^2 C)^{1/2} \cong 1$ eV

Some Recent Results

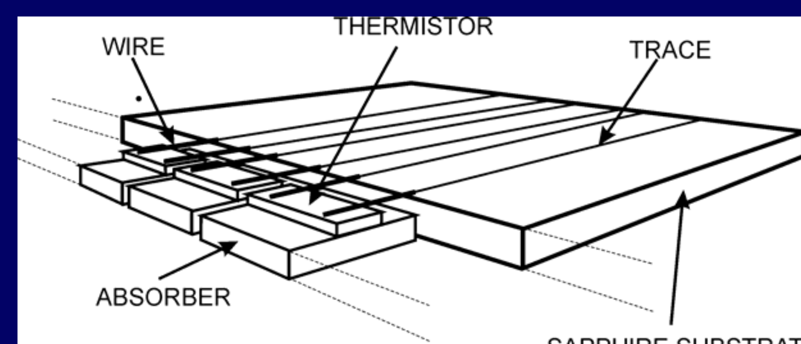
- **Energy Resolution**

5 eV FWHM at 6 keV — **50 eV FWHM at 60 keV**





- **Array Technology**
  - Read-out Multiplexing
  - 2-D arrays by stacking linear arrays



Modeling the Energy Thermalization in superconducting absorber

MICROSCOPIC ANALYSIS

Energy Trapping in QP
Variable Heat Capacity
Position Sensitivity

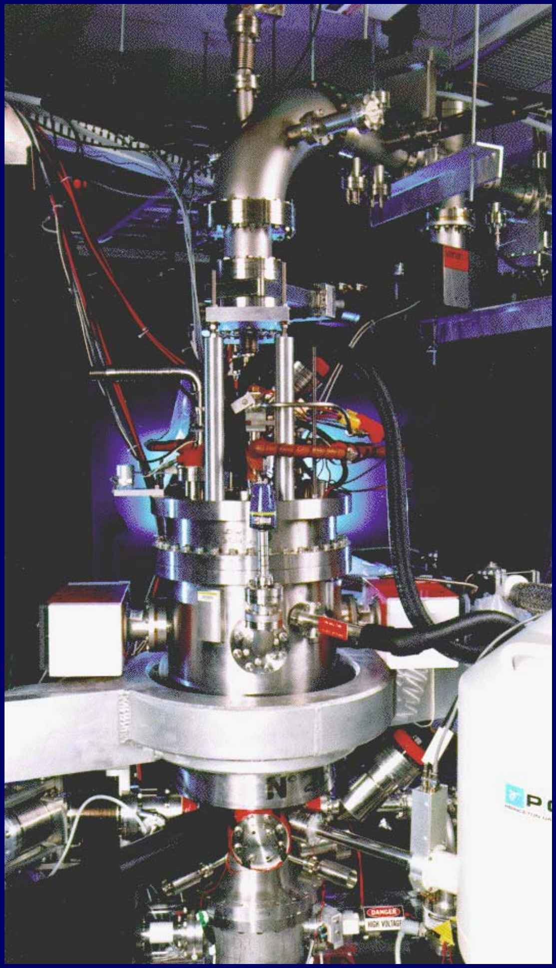
Design and construction of new detectors with different absorber materials. Experimental tests to be performed in the near future.

X-ray Spectroscopy of Laboratory Plasmas

(Collab. with SAO, NIST, LBNL, NRL)

Electron Beam Ion Trap (EBIT)

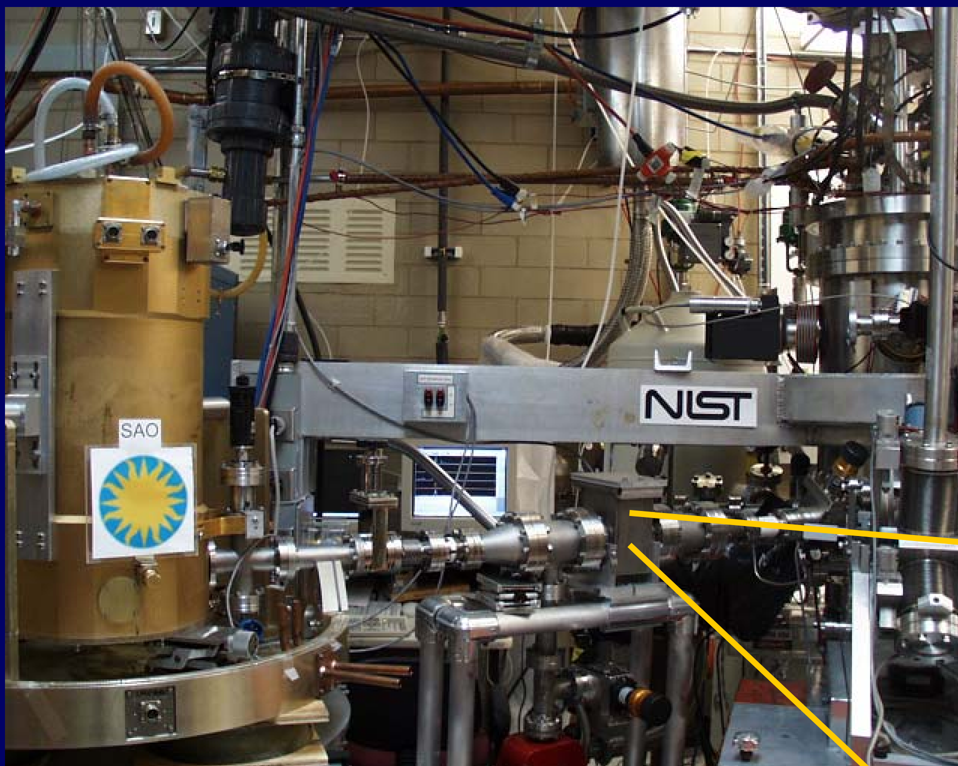
- Small scale laboratory device to create highly charged ions
- High purity of the selected species
- Fine control of charge states, excitation levels, electron density
- Plasma conditions similar to active regions of the Solar Corona
    - ion density: 10^9 cm^{-3}
    - electron energy: 0.6 - 30 keV
    - electron density: 10^{12} cm^{-3}
    - ion temperature: 100 eV - 1 keV



~ 1 m

~ 0.5 m

SAO NTD-Ge microcalorimeters at the EBIT of NIST Gaithersburg, MD



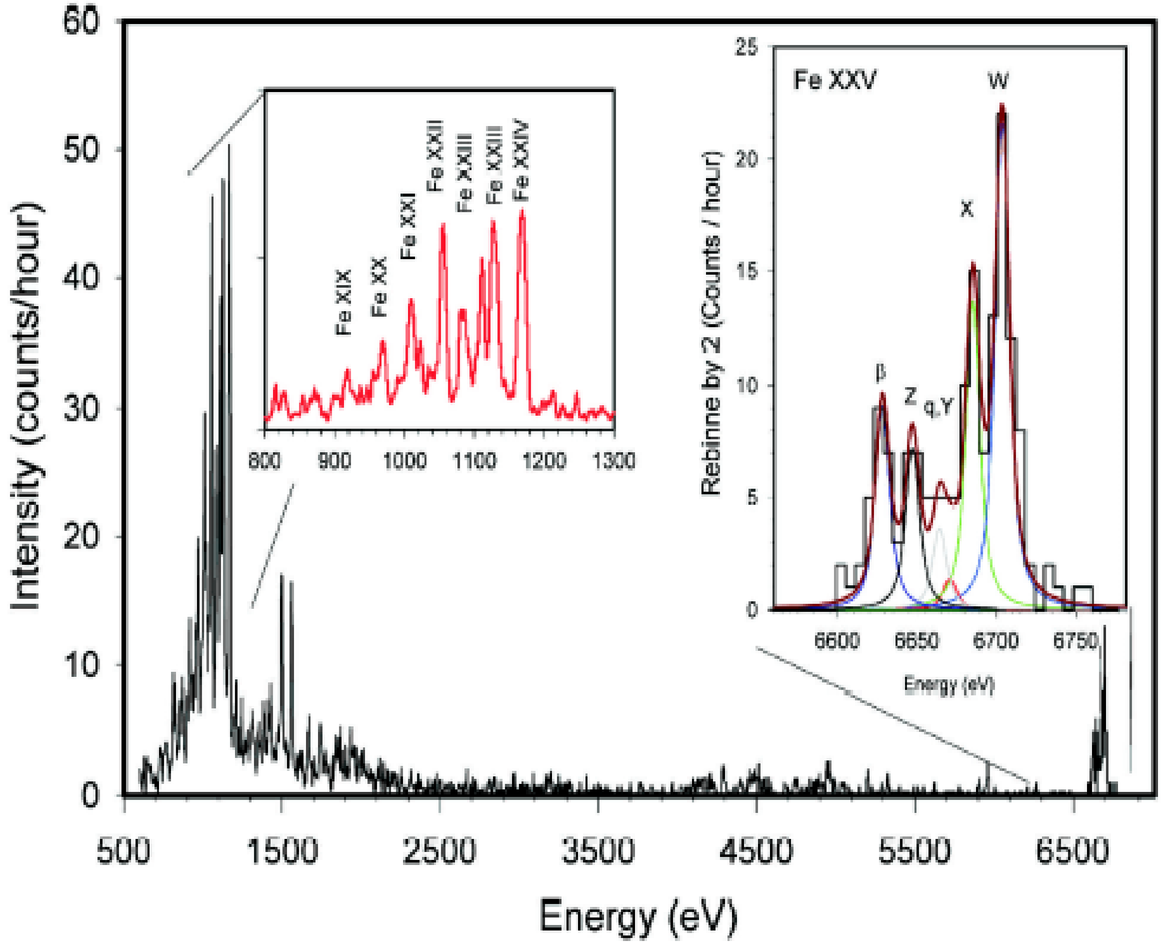
- High energy resolution
- High quantum efficiency
- Large spectral coverage
- Low sensitivity to polarization

Simultaneous observation of K and L transitions

NTD-Ge Microcalorimeter Spectrum of Highly Ionized Fe in EBIT Plasma

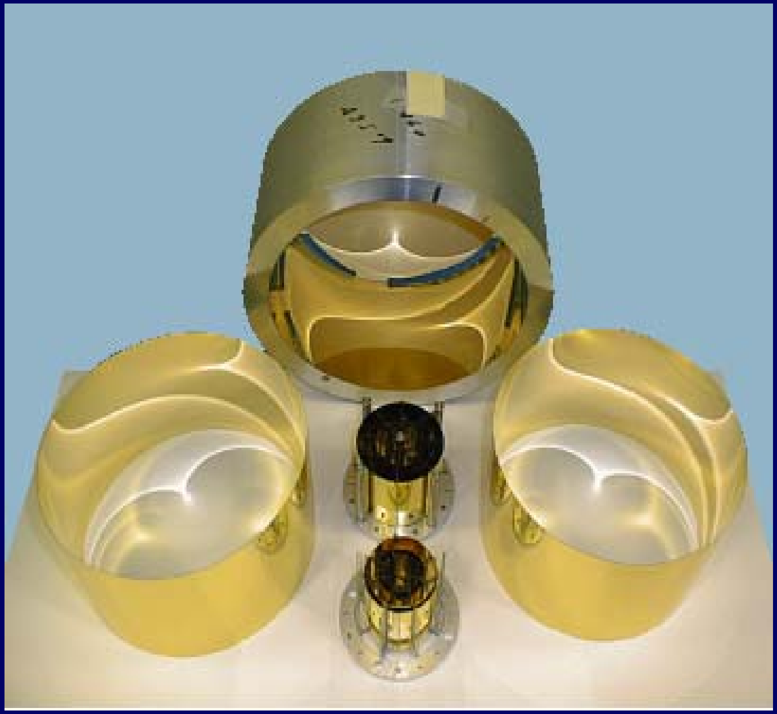
Approx L Shell Ionization Balance

Fe XXIV	1.0
Fe XXIII	1.0
Fe XXII	0.7
Fe XXI	0.2



I(w) / I(β) = 2.38
“ 1.6 x 10^6 K”

Plastic foils grazing incidence X-ray Optics
(Collaboration with SAO and DSRI)



- Plastic is very light, elastic, cheap

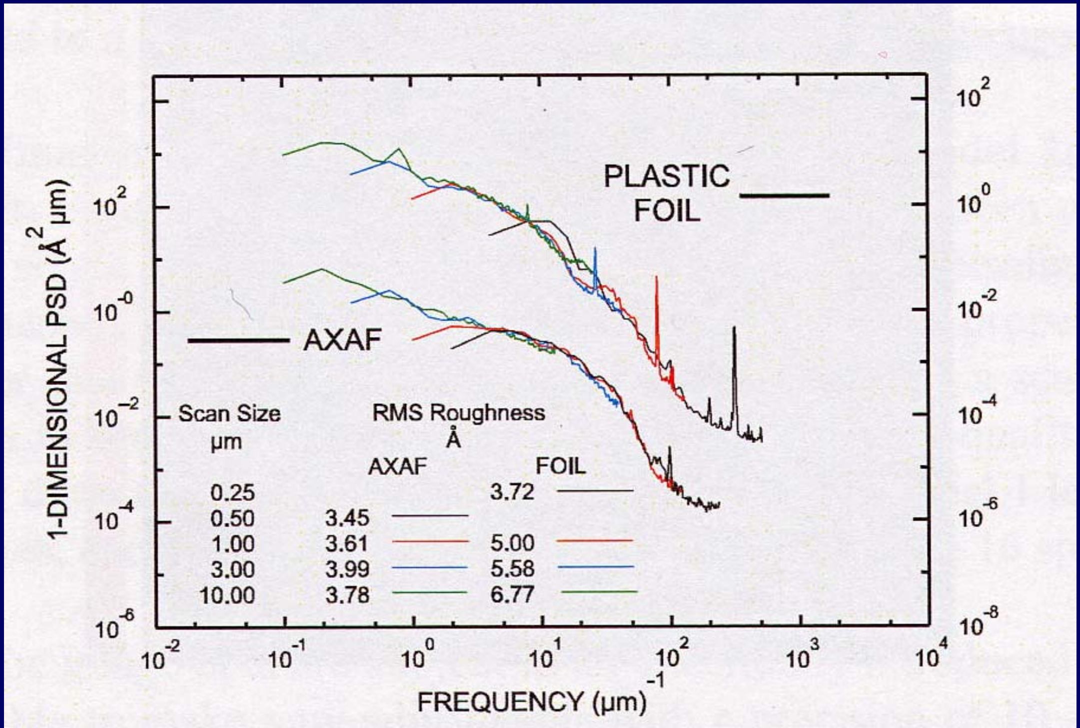
- Plastic foils from common industrial applications have high surface smoothness by a combination of stretching and rolling

- Plastic foils replicate the figure of the mandrel but not the smoothness. Expensive superpolished mandrels not required

- Plastic has strong affinity to coating (single and multilayer)

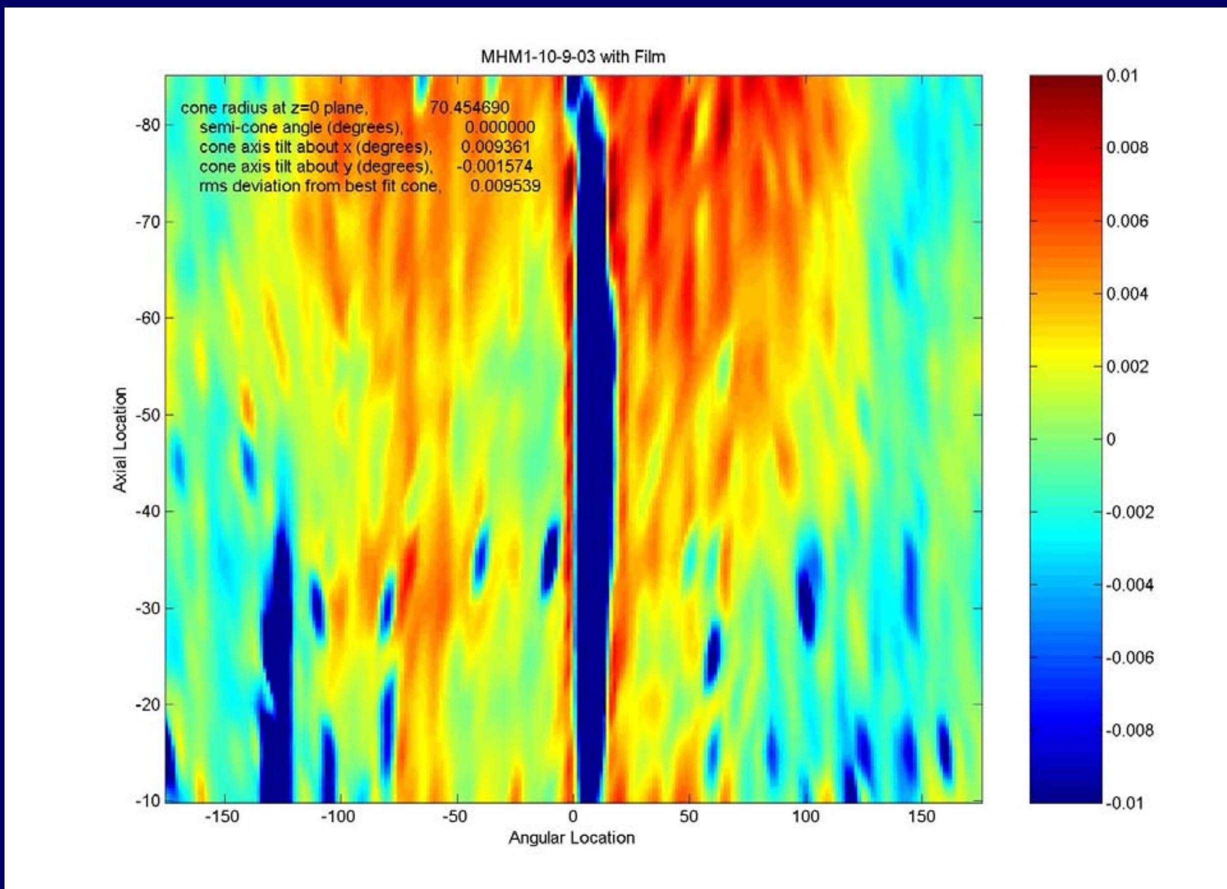
Some Recent Results

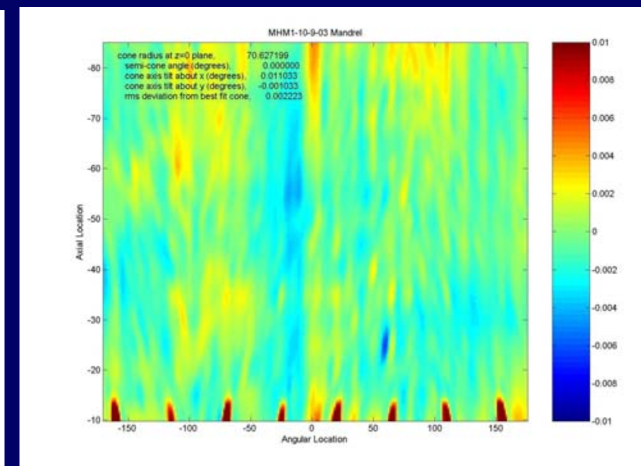
- **Surface Roughness**



AFM measurements show micro roughness of uncoated foils of 4 ÷ 7 Å (Chandra-HRMA has 3 ÷4 Å)

• Surface Profile





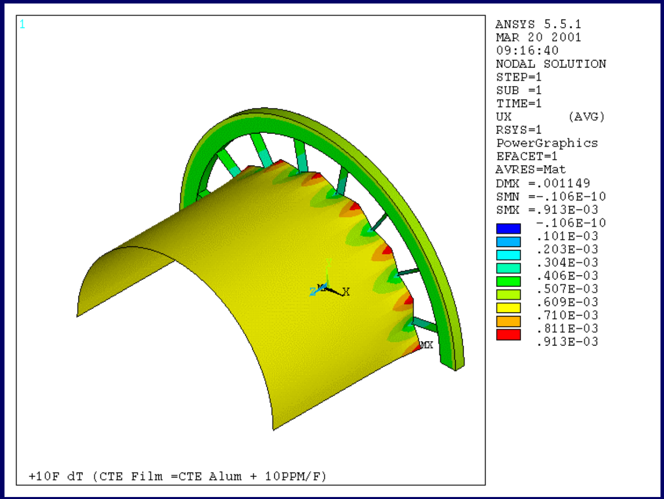
Microprofilometer measurements show surface profile smooth but thermal shaping under evaluation

• Mounting the foils

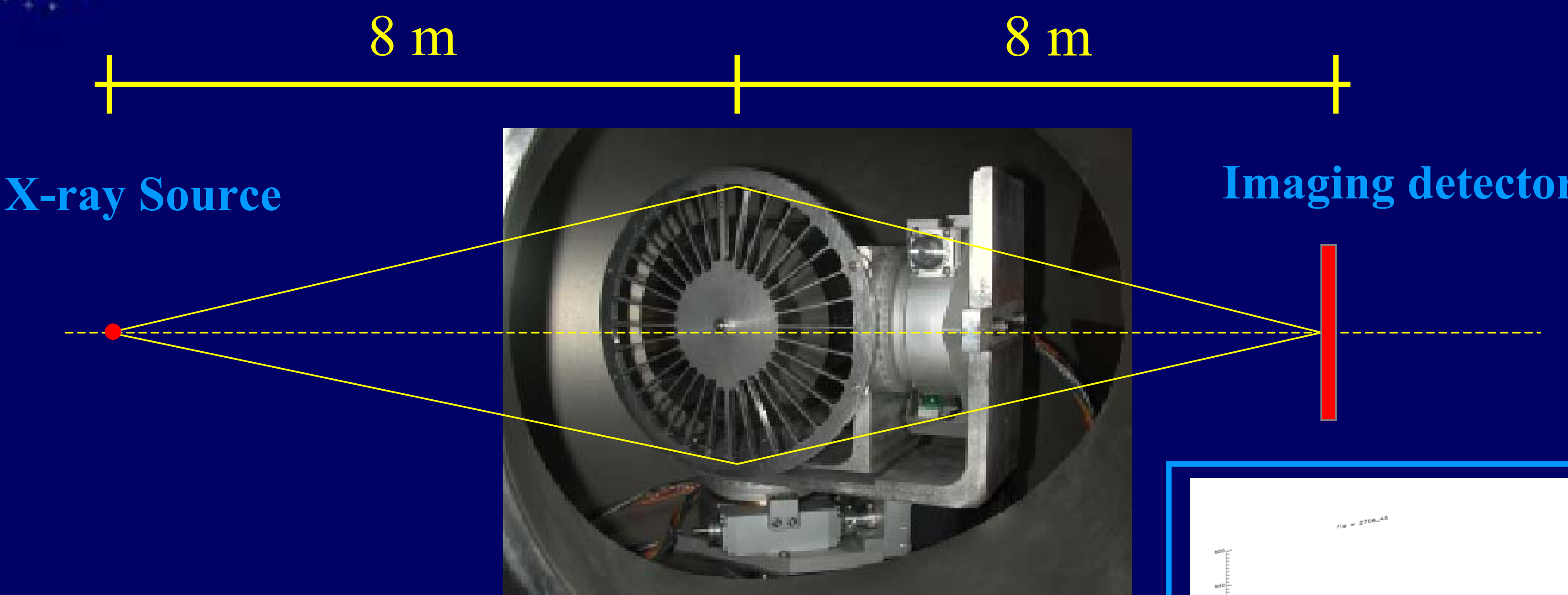
• Vacuum hold-down mandrels to form cylindrical or conical shells

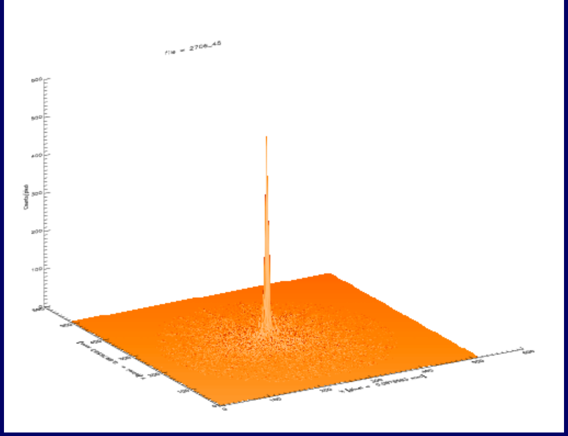
• Foils hold inside grooves of the supporting wheels

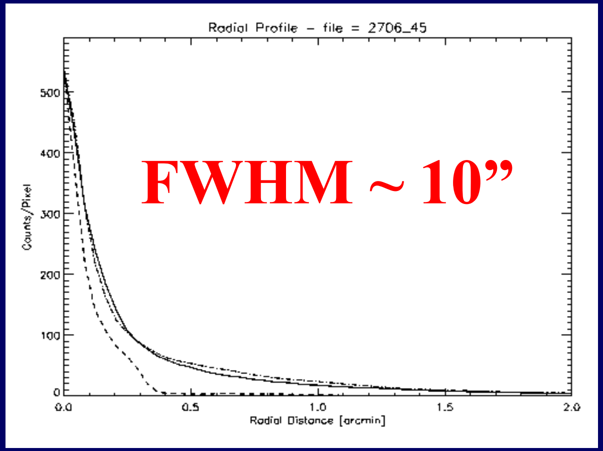
• Epoxy cured while foils are still inside the mandrel

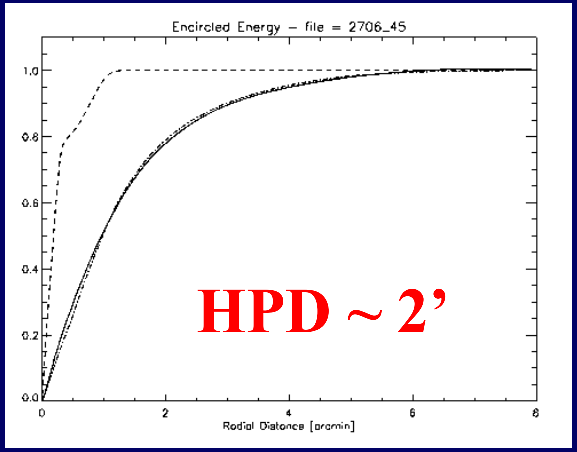


• X-ray imaging tests of Cylindrical optics at XACT









Next steps

- Thermal curing of plastic foils to try and improve replication of the mandrel figure

- Design, construction and test of conical optics, single and doubble reflection.

- Design and construction of multi shell optics

Effects of a young SUN X-ray radiation onto the life building blocks

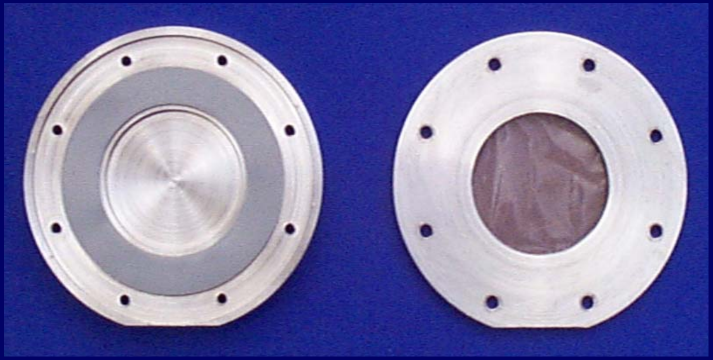
(Collaboration with ISMN-CNR (Bo), DipBAG-UNIFI, DipSFA-UNIPA)

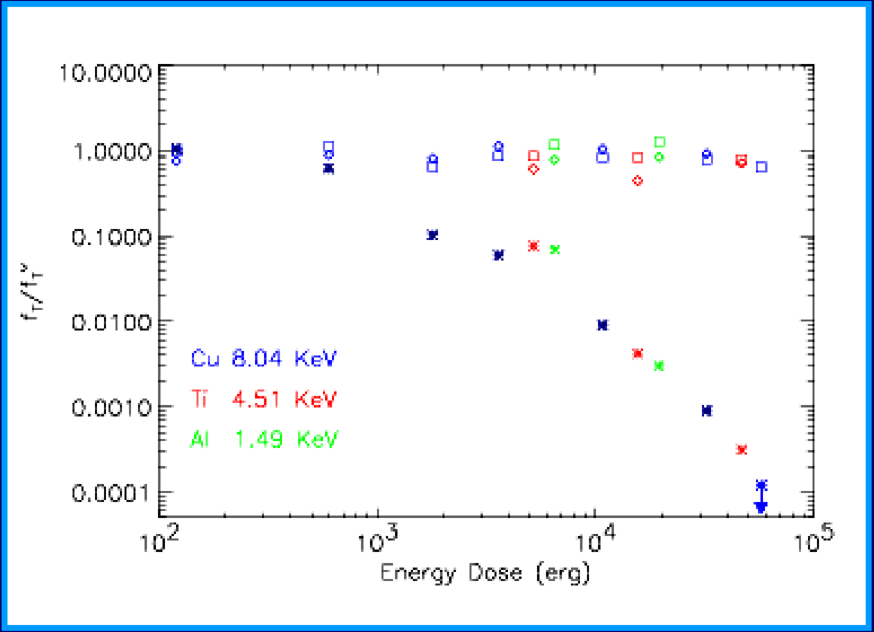
- X-ray irradiation of complex organic molecules with X-ray fluxes comparable to a young Sun.

- Biological transformations and IR spectroscopy to evaluate damages produced by the X-ray radiation.

- Free DNA severely damaged even at low doses. Clay adsorbed DNA is resistent to large doses.

- Ongoing program on simpler complexes, and comparison between UV and X-ray damages at same doses.





Partecipazione a Progetti Spaziali

Chandra HRC

Development of the UV/Ion shields

- Design, Vibrational and Acoustic tests, Calibration plan

★ UV transmission measurements of the UV/Ion shields

- Out of band rejection

★ X-ray transmission measurements of the UV/Ion shields

- X-ray Transmission modeling, XANES and EXAFS

X-ray QE measurements of MCP's at Daresbury Synchrotron

- CsI vs. KBr, X-ray QE modeling, Life tests

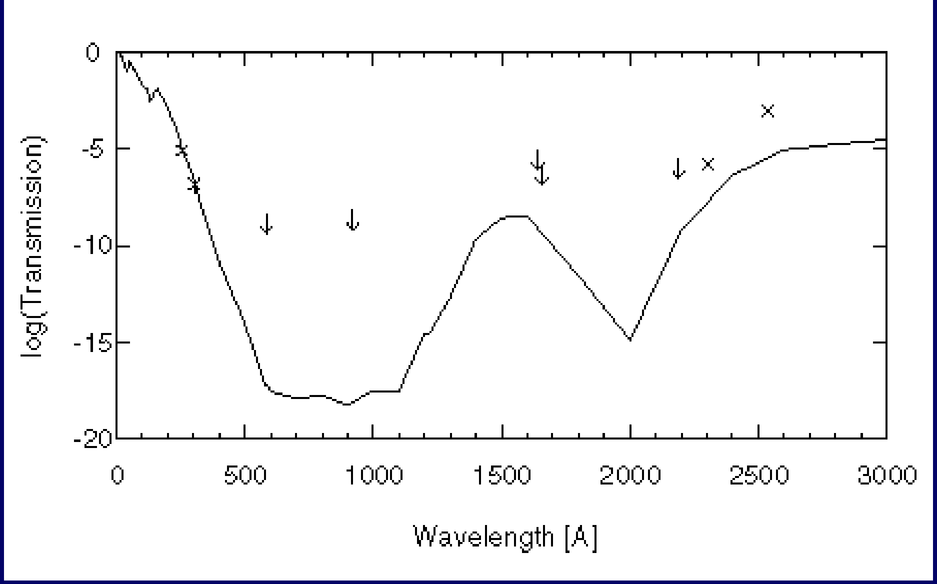
End to End test at Marshall Space Flight Center

- HRC-I +HRMA, HRC-S + HRMA + Gratings

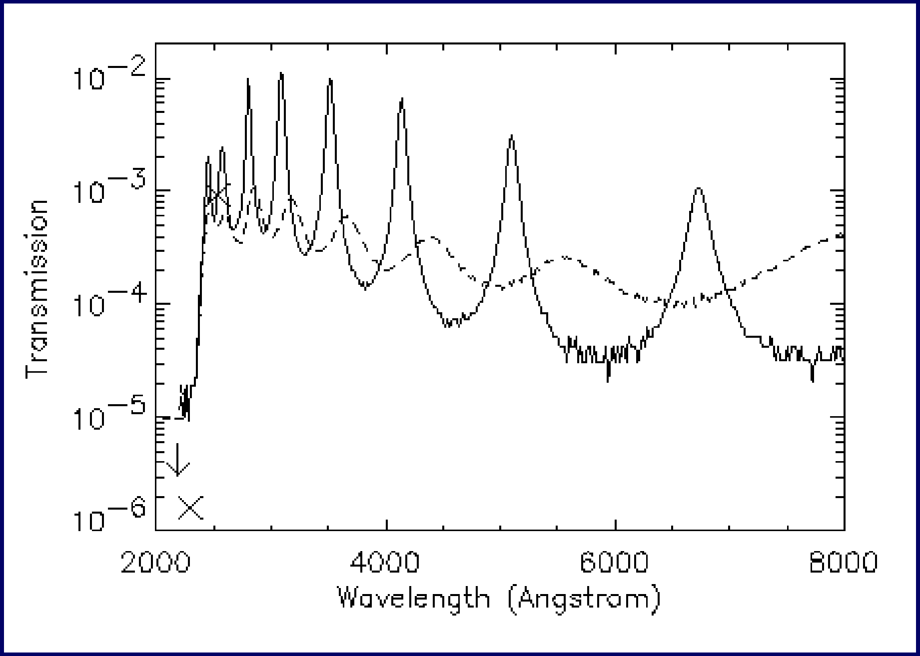
In Flight Calibration

- Out of band sensitivity

UV transmission measurements of the UV/Ion shields at XACT and DipSFA-UNIPA



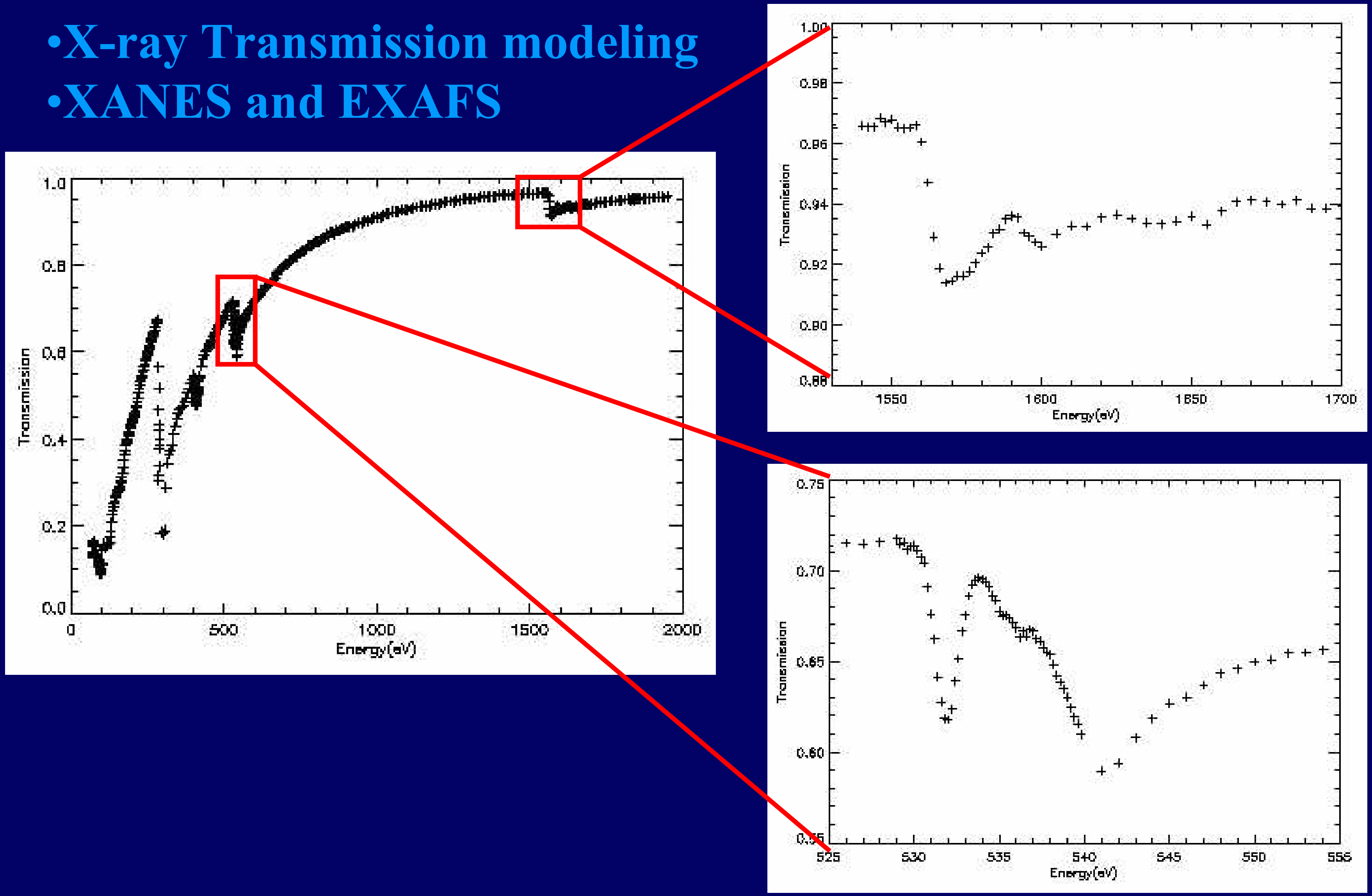
Aluminum oxidation and interferences



New filter design: Polyimide instead of Lexan, and single layer of aluminum (impact also on Chandra ACIS, Newton-XMM EPIC, JET-X CCD).

X-ray transmission measurements of the UV/Ion shields at Bessy Synchrotron

- X-ray Transmission modeling
- XANES and EXAFS



Newton-XMM EPIC

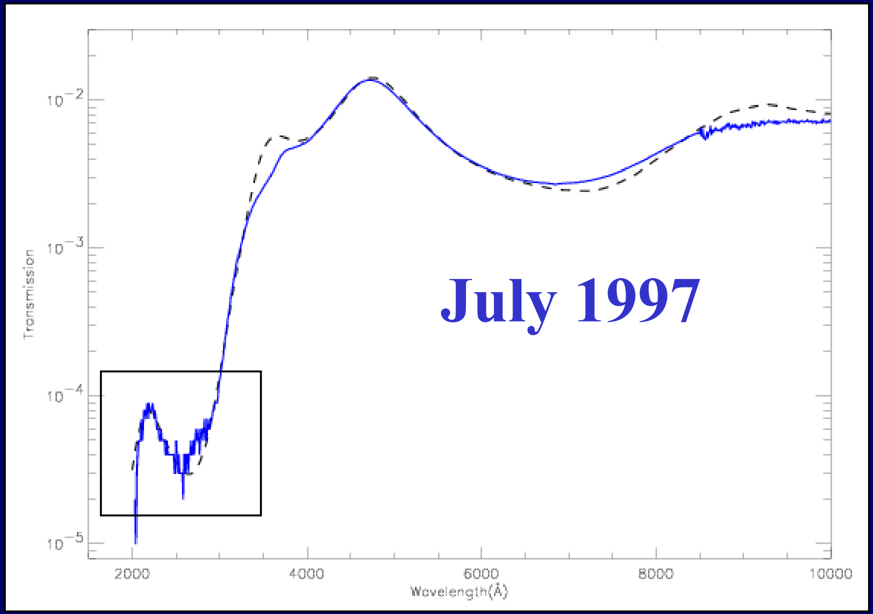
Medium and Thin Filter design and calibration plan

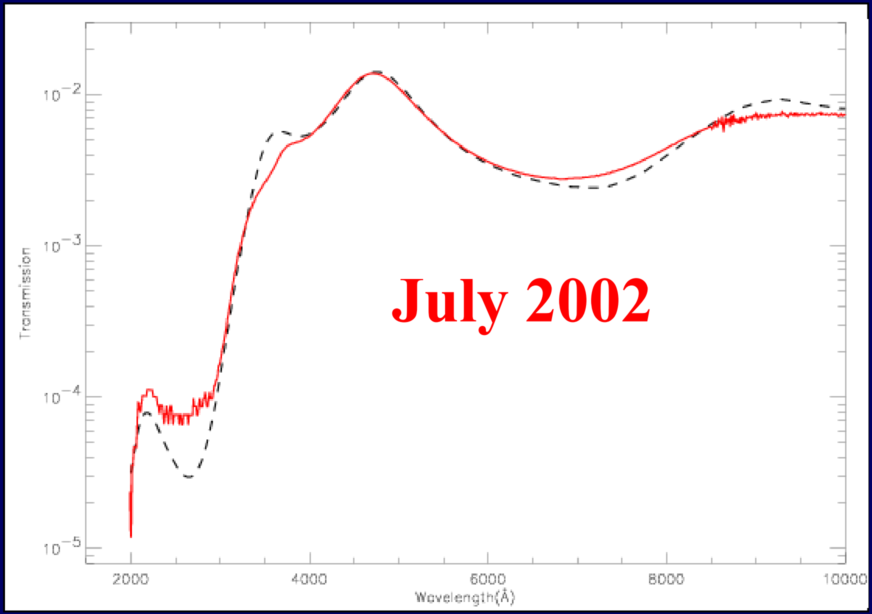
UV transmission measurements of Medium and Thin Filters
- Out of band rejection

X-ray transmission measurements of Medium and Thin Filters
- X-ray Shadowgraphs
- X-ray Transmission modeling, XANES and EXAFS

★ Monitoring ageing effects of Medium and Thin filters

Monitoring ageing effects of the Medium and Thin filters at the XACT facility and DipSFA-UNIPA





Slight increase in transmission in a narrow band.

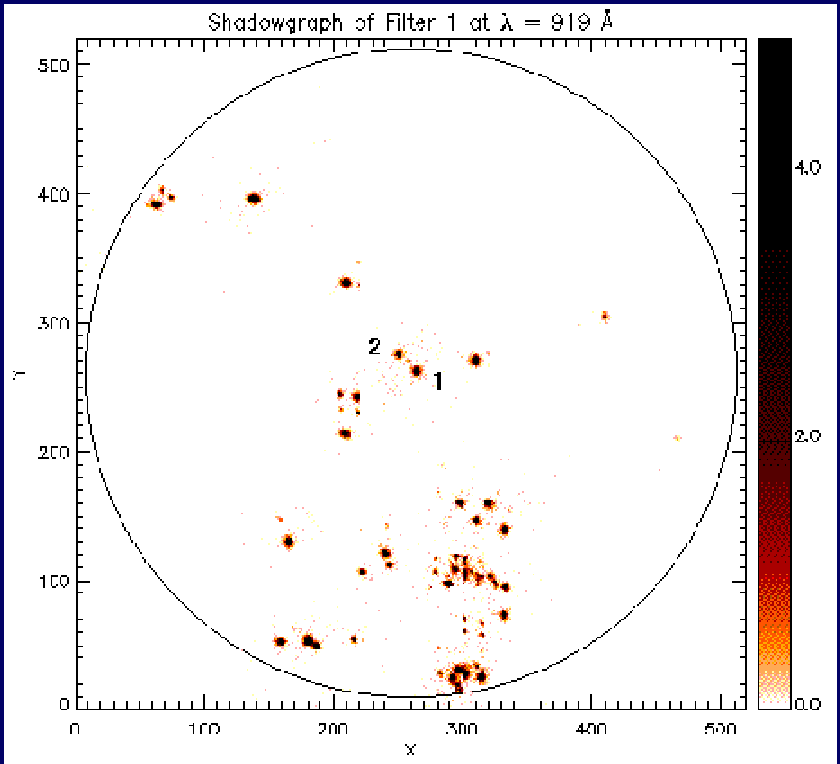
No significant impact on the science with EPIC

JET-X CCD

Support in the filter design

★ UV transmission measurements of sample filters at XACT

- Out of band rejection
- UV shadowgraphs (pinhole search)



XRT on board SOLAR-B

(PI: dr. Leon Golub, SAO, Cambridge, MA)

★ **Calibration of the Focal Plane Filters**

- X_ray shadowgraphs
- X-ray transm. measurements and modeling

  [Calibration of the first set of nine flight filters completed succesfully in May 2003]

★ **Calibration of the Telescope**

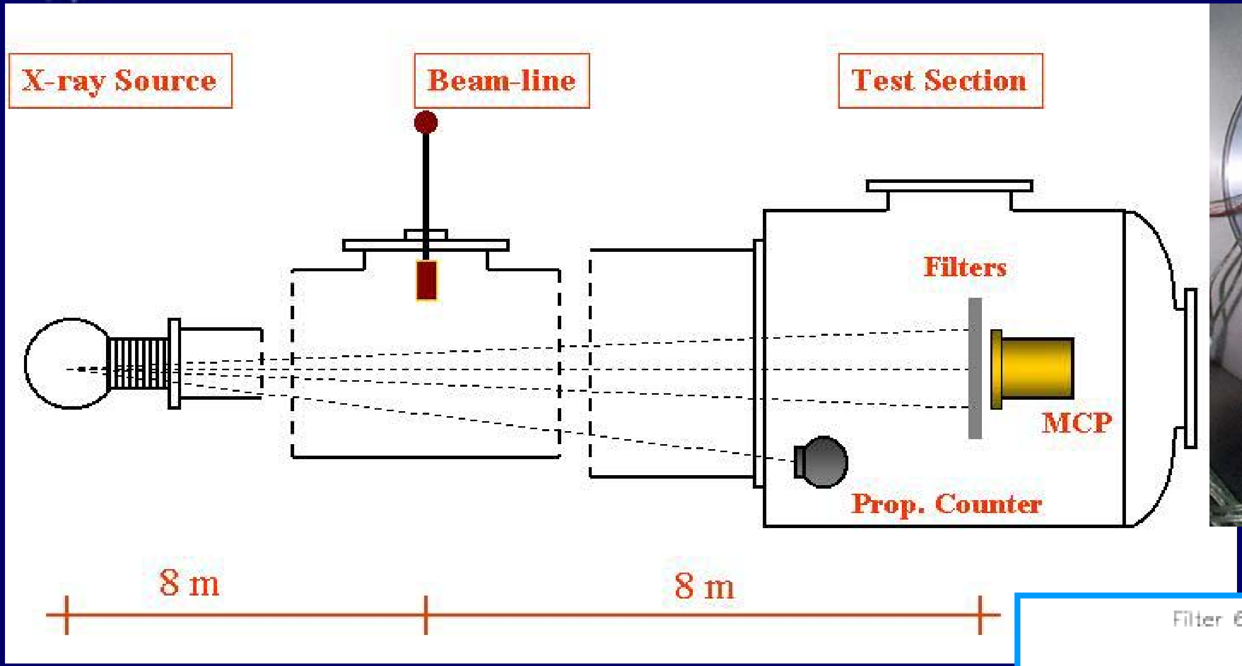
- Reflectivity measurements of flat mirror samples vs. energy and angle of incidence.

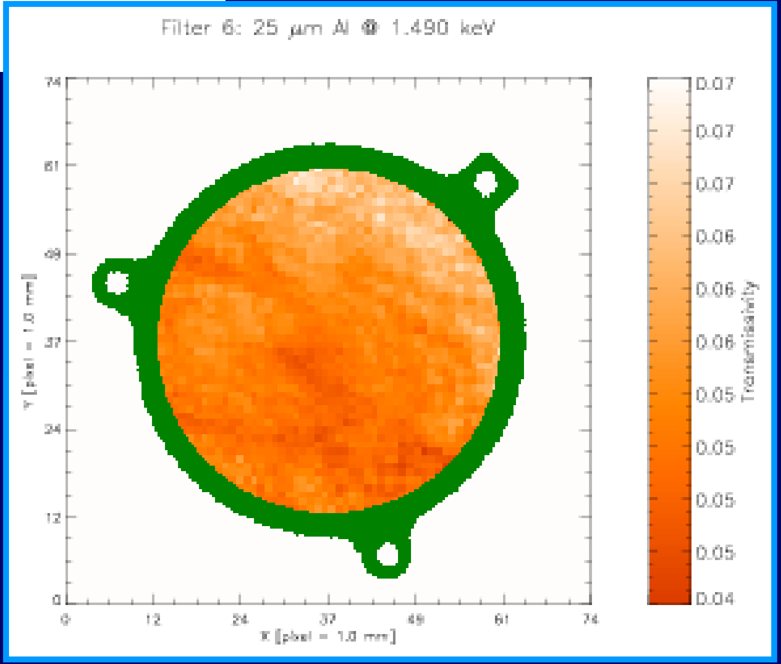
  [Ongoing Calibration Program]

Calibration of the Entrance Filters

- X-ray transmission measurements and modeling

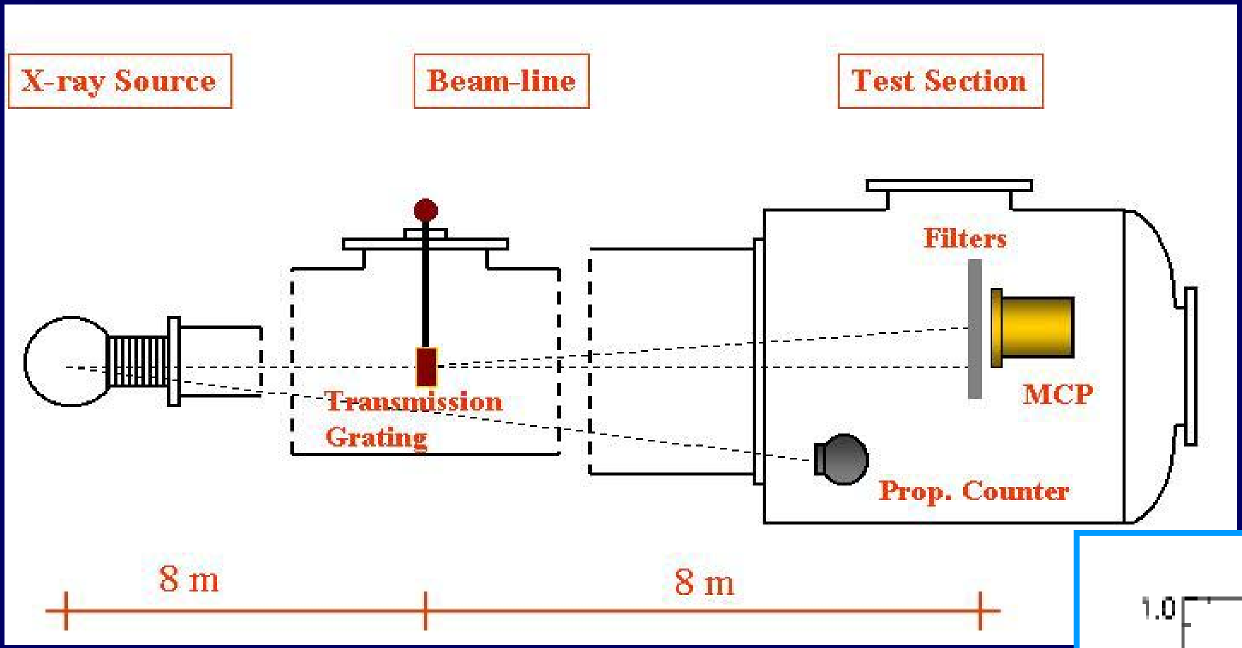
X-Ray Shadowgraphs

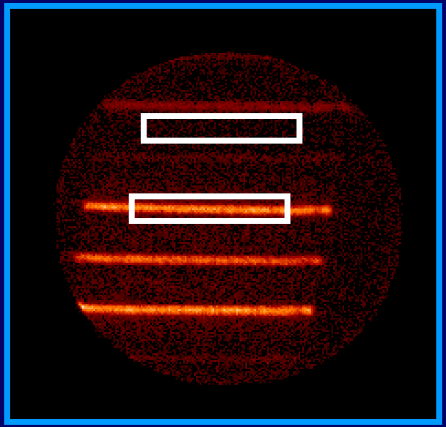


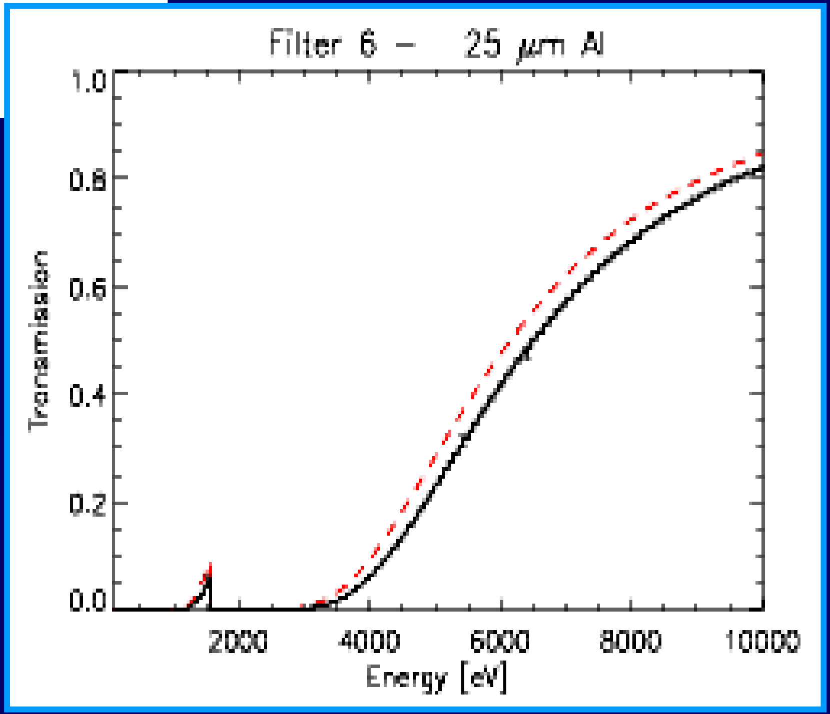


Es: Filtro 6 – 25 μm Al
Shadograph at 1.49 keV

X-Ray Transmission measurements and modeling

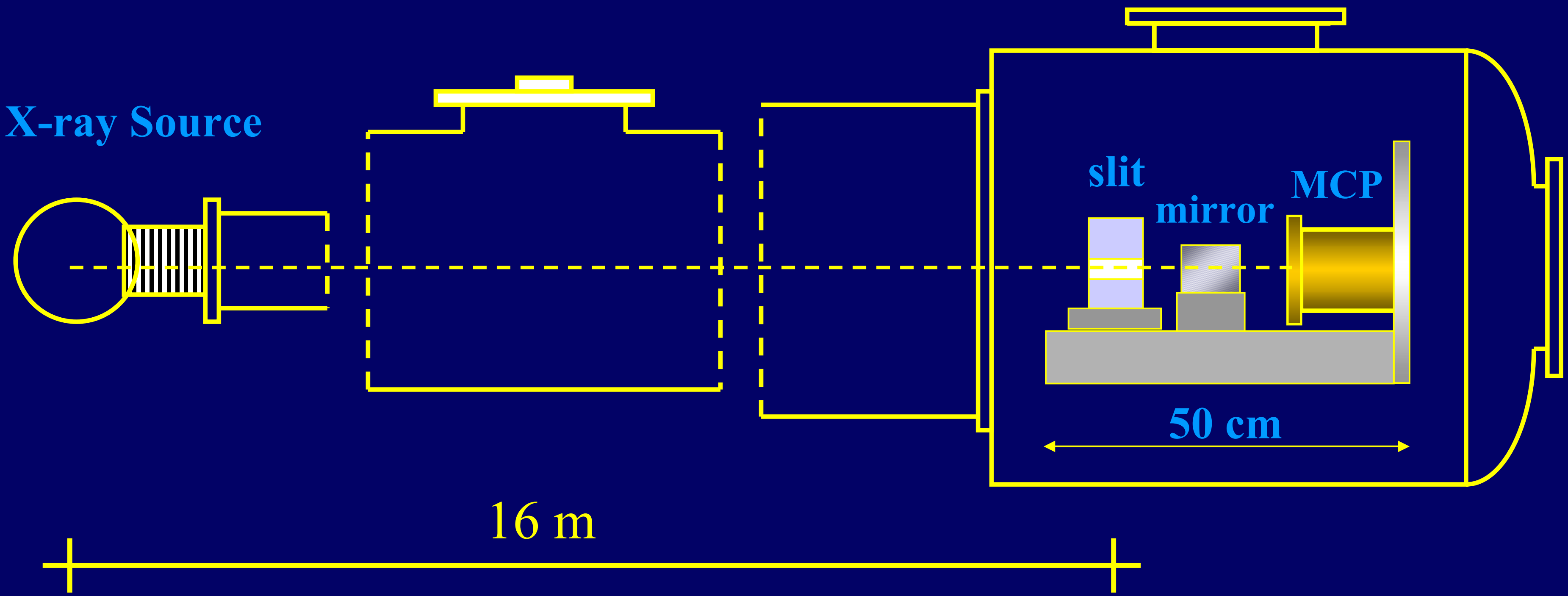






Es: Filtro 6 – 25 μm Al

Reflectivity vs. energy and angle of incidence of flat samples of the X-ray telescope [April-May 2004]



Baloon borne MIcrocalorimeter Nuclear line Explores
(PI dr. Eric Silver, SAO, Cambridge, MA)

- High resolution spectroscopy of ^{44}Ti Nuclear line in SNR
- Tuned multilayer 2-cone plastic foil X-ray telescope
- Array of 20x20 microcalorimeters