Ultra Thin Filters for X-ray Detectors in Space

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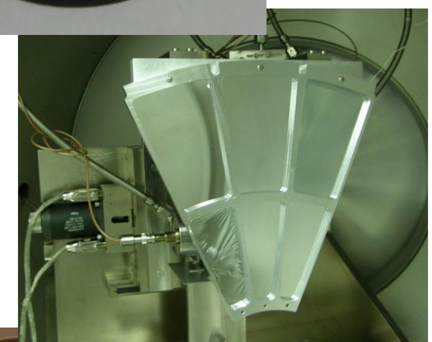
Outline

- **Ultra-thin filters for high energy Space missions**
  - **Heritage**
  - **Current Space Projects (Athena, eXTP, MUSE)**
- **Design and Modelling**
  - **Mechanical FEM**
  - **Thermal modelling**
  - **Photon Shot Noise simulation**
- **Experimental characterization**
  - **Synchrotron XAS**
  - **Synchrotron XPS**
  - **UV/VIS/IR spectroscopy**
  - **RF shielding effectiveness**
  - **Contamination vibration tests**
  - **Proton irradiation**

Heritage

- **Chandra HRC-I (NASA): UV/Ion Shield (93 mm x 93 mm)**

  HRC-I Aluminum 75 nm + Polyimide 570 nm



- **Newton-XMM EPIC (ESA): Thin and Medium Optical Blocking Filters (76 mm diam.)**

  Thin Aluminum 40 nm + Polyimide 180 nm
  Medium Aluminum 80 nm + Polyimide 180 nm

- **Simbol-X XRT (CNES/ASI): Telescope Thermal Shields**

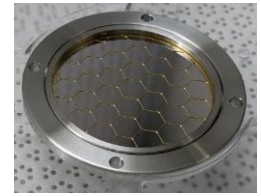
  Option 1 Aluminum 300 nm + Polyimide 2 µm + Ni mesh (80%)
  Option 2 Aluminum 300 nm + Polyimide 2 µm

- **LOFT LAD (ESA M3 candidate): Optical Blocking Filter (80 mm x 120 mm)**

  Option 1 Aluminum 40 nm + Polyimide 1 µm
  Option 2 Aluminum 40 nm + Polyimide 1 µm + SS mesh (90%)

Current projects - Athena

X-Ray Integral Field Unit (X-IFU)



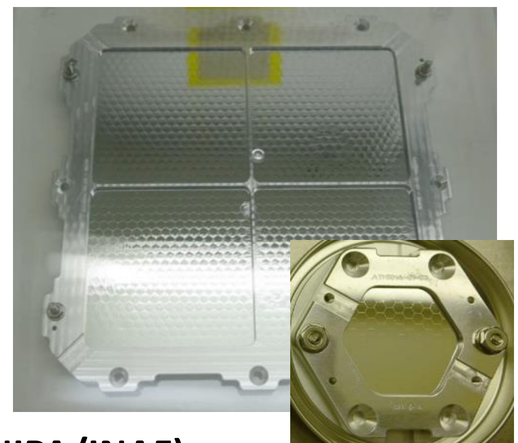
- **X-IFU Thermal Filters (Resp. of UNIPA/INAF)**

  Stack of 5 thin filters: Polyimide 45 nm / Aluminum 30 nm (diam. 26-130 mm)

- **X-IFU Optical Blocking Filters (Resp. of Univ. Geneva - designed by UNIPA/INAF)**

  thin filters: Polyimide 150 nm / Aluminum 30 nm (diam. 160 mm)
  medium filter: Polyimide 150 nm / Aluminum 70 nm (diam. 160 mm)
  thick filter: Polyimide 25 µm / Aluminum 100 nm (diam. 160 mm)

Wide Field Imager (WFI)



- **WFI Thin Optical Blocking Filters (Resp. of UNIPA/INAF)**

  LDA filter: Polyimide 150 nm / Aluminum 30 nm (168 mm x 168 mm)
  FD filter: Polyimide 150 nm / Aluminum 30 nm (diam. 35 mm)

- **WFI Thick Optical Blocking Filter (Resp. of Univ. Geneva - designed by UNIPA/INAF)**

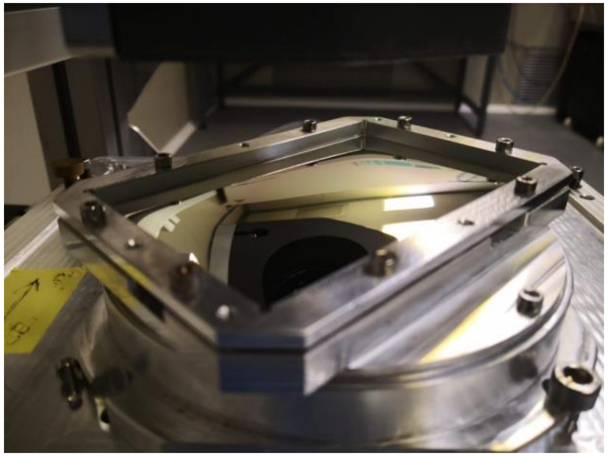
  1 filter: Polyimide 25 µm / Aluminum 100 nm (diam. 35 mm)

Current projects - eXTP

- **eXTP LAD (Chinese Academy of Sciences) Optical Blocking Filters (108.8 mm x 70.2 mm)**

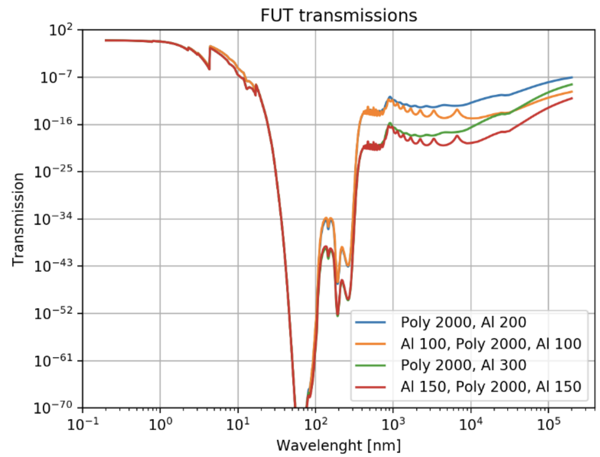
Aluminum 200 nm + Polyimide 2 µm

The Silicon Dirift Detectors used on the LAD detectors are sensitive to UV/VIS light. From simulations it turns out that 200 nm of Al are required on the filters in order to reduce the noise from the albedo in low Earth Orbit below three electron-hole pairs in the detector integration time (1 µs).



Filters will be manufactured in China by IHEP
INAF-OAPA/UNIPA have the responsibility of design and characterization

- X-ray spectroscopy
- Visible attenuation by use of a solar simulator
- Thermovacuum
- Differential pressure
- Vibration and Acoustic tests
- Atomic Oxygen



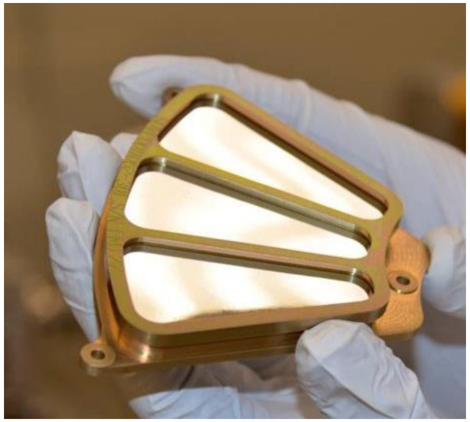
Current projects - MUSE

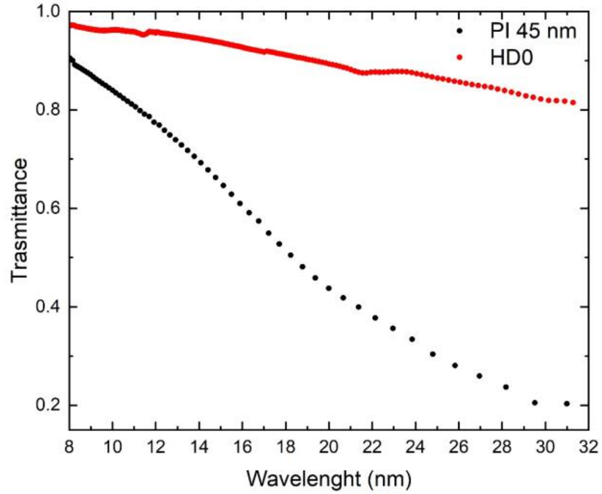
- **MUltislit Solare Explorer (NASA MIDEX) Optical Blocking Filters and Telescope Entrance Filters**

CNT + Zyrconium 50 nm
CNT + Aluminum 50 nm

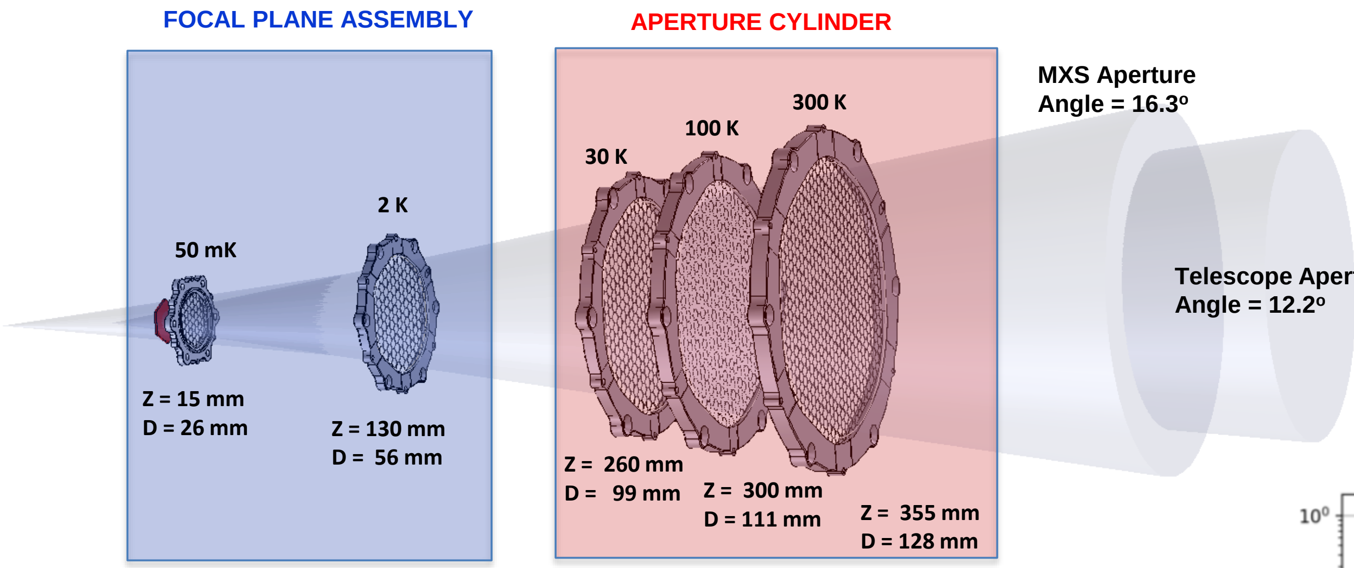
MUSE multilayer reflective optics and back illuminated CCD detectors designed for EUV sensitivity are also efficient at visible wavelengths, thus thin metallic filters will be needed to block 8-10 orders of magnitude of visible light. The use of CNT pellicles has been proposed by the Palermo team to get maximum EUV transmission.

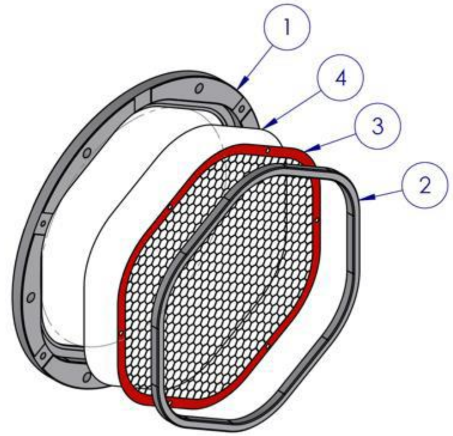
Filters will be manufactured in Finland
INAF-OAPA/UNIPA have the responsibility of design, procurement and characterization

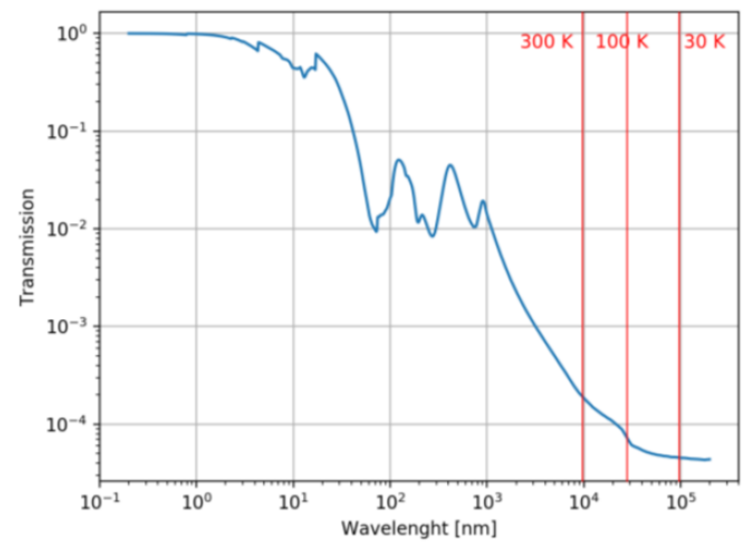




Design and Modelling: Out of Band Rejection



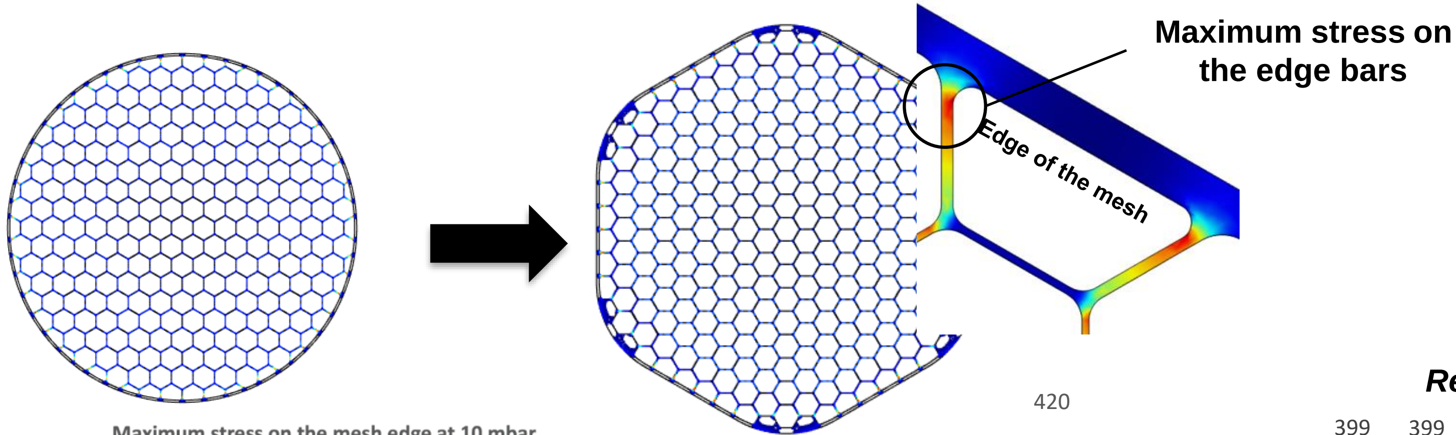


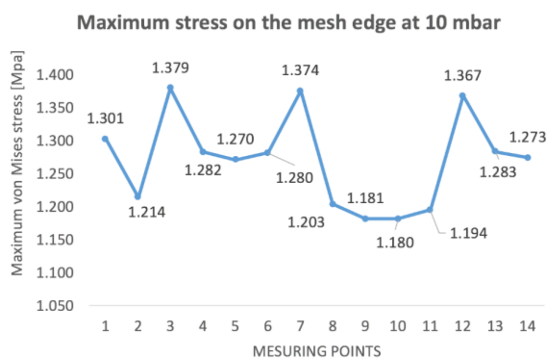


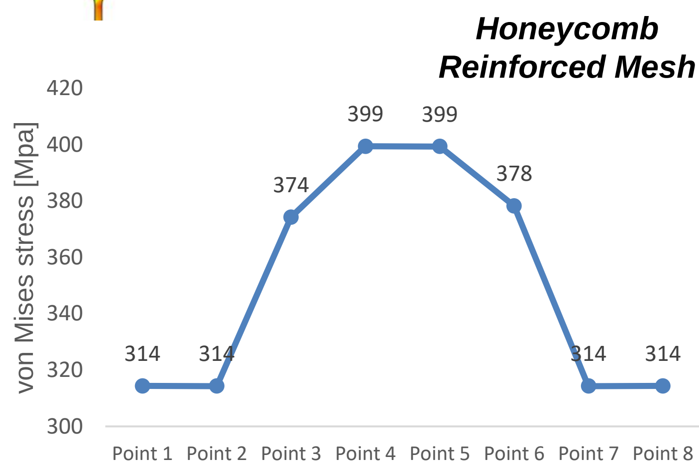
Design and Modelling: Mechanical FEM

Main Goals

- Optimize frame design and choice proper materials;
- Optimize mesh design to reduce stress under static and dynamic loads.





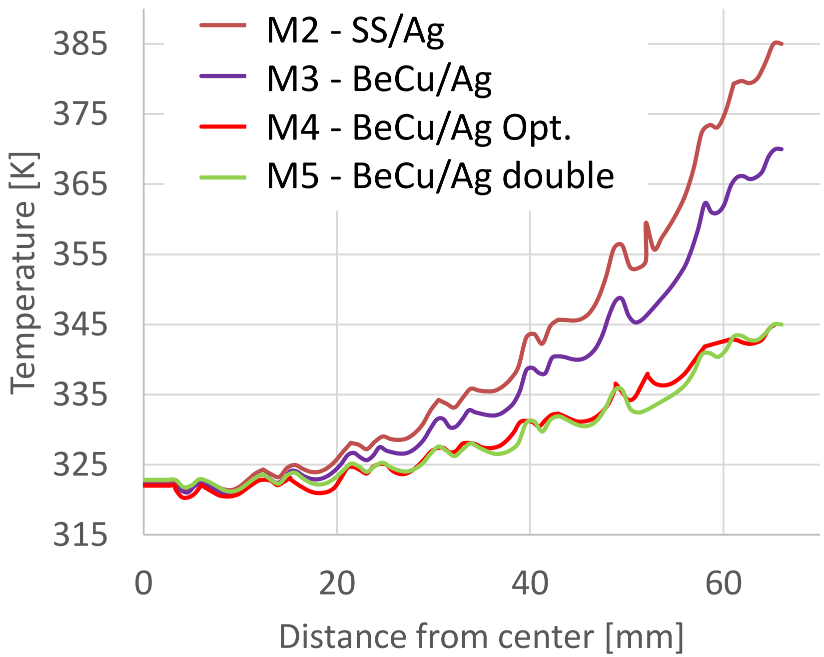


Going from circular to hexagonal frame, with a honeycomb reinforced mesh, allows to have a lower and more uniform distribution of the mesh stress and thus allow to use meshes with thinner wires (smaller Blocking Factor) and larger diameters.

Design and Modelling: Thermal

Main Goals

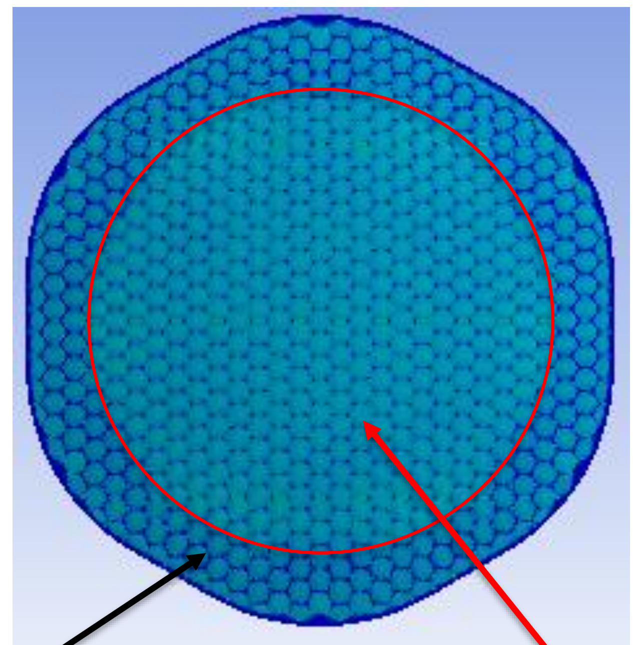
- Optimize frame and mesh design and choice of proper materials;
- Model Filter Thermal profile.



BeCu alloy mesh optimized design

Wires: 40 µm x 80 µm

Silver plating: 15 µm



Reinforced mesh BF~4.5% (Calibration MXS beam)

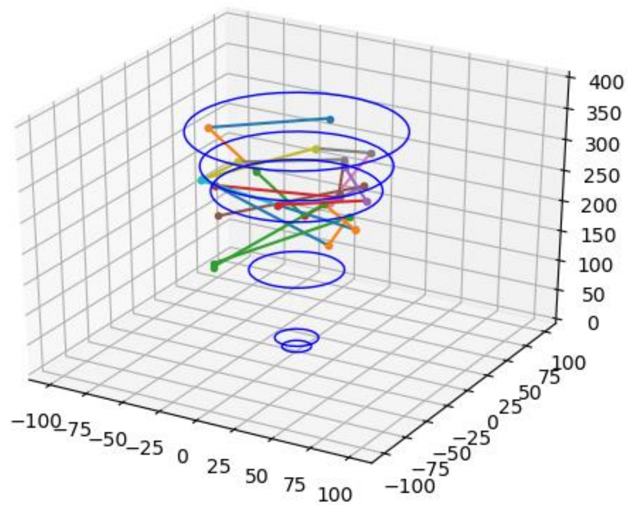
Inner mesh BF ~ 3.1% (Telescope beam)

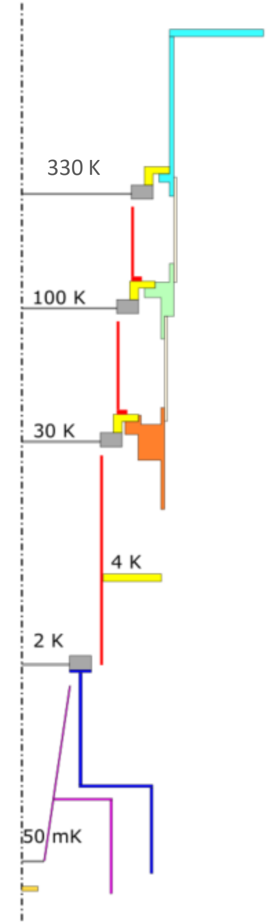
Design and Modelling: Photon Shot Noise

Implementation of a Ray-Tracing Code to calculate the Photon Shot Noise

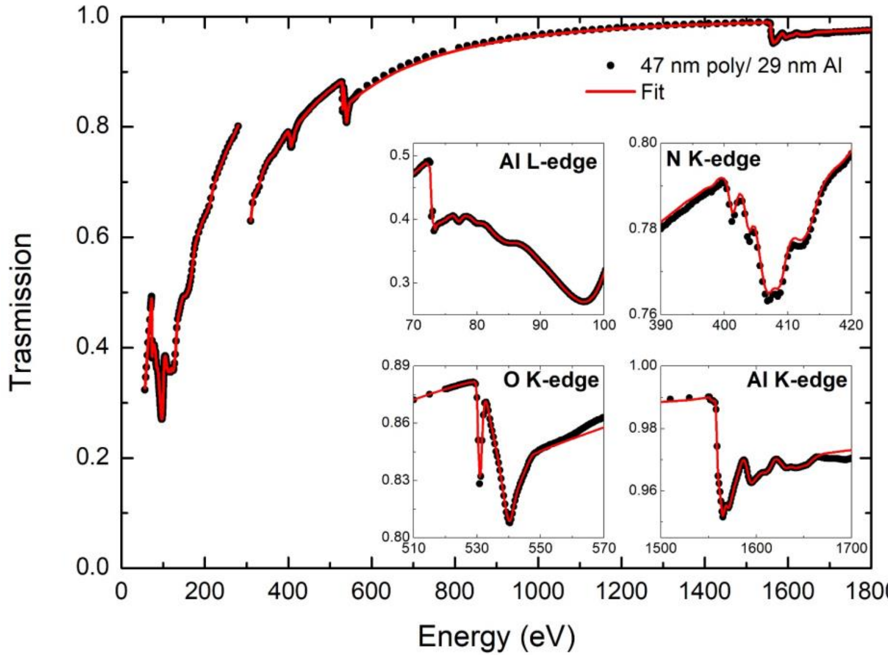
- More precise calculation of multiple reflections within cavities;
- Photons hitting the side walls are fully tracked;
- Walls reflectivity, filters emissivity and tilt angle as free parameters;

Validated with ESATAN.





Experimental Characterization: X-ray Absorption Spectroscopy



MAIN GOALS

- **Elemental analysis**
- **Filter materials areal densities**
- **Modelling of the absorption edges**
- **Spatial uniformity mapping**

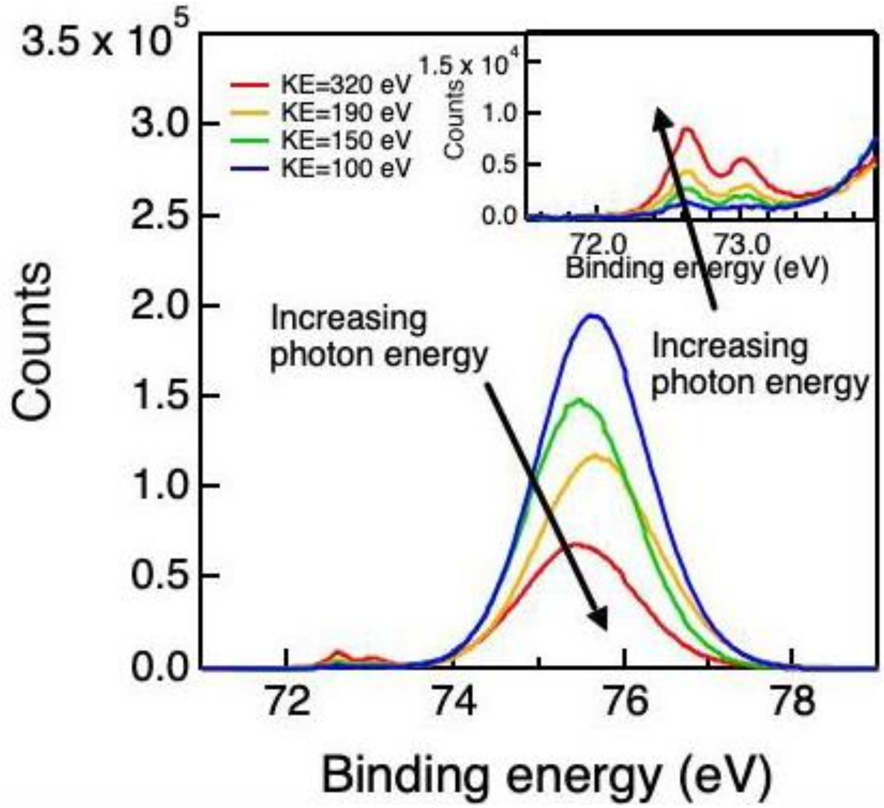
FACILITIES

- BEAR (40-1600 eV) beamline @ ELETTRA (Trieste, IT)
- PTB SX700 (50-1800 eV) beamline @ BESSY II (Berlin, DE)
- PTB FCM (1.75 -10 keV) beamline @ BESSY II (Berlin, DE)
- SIM (100-1800 eV) beamline @ PSI (Zurich, CH)

Experimental Characterization: X-ray Photoelectron Spectroscopy

MAIN GOALS:

- **Elemental analysis**
- **Chemical analysis**
- **Oxidation state**
- **Layer depth from the surface**



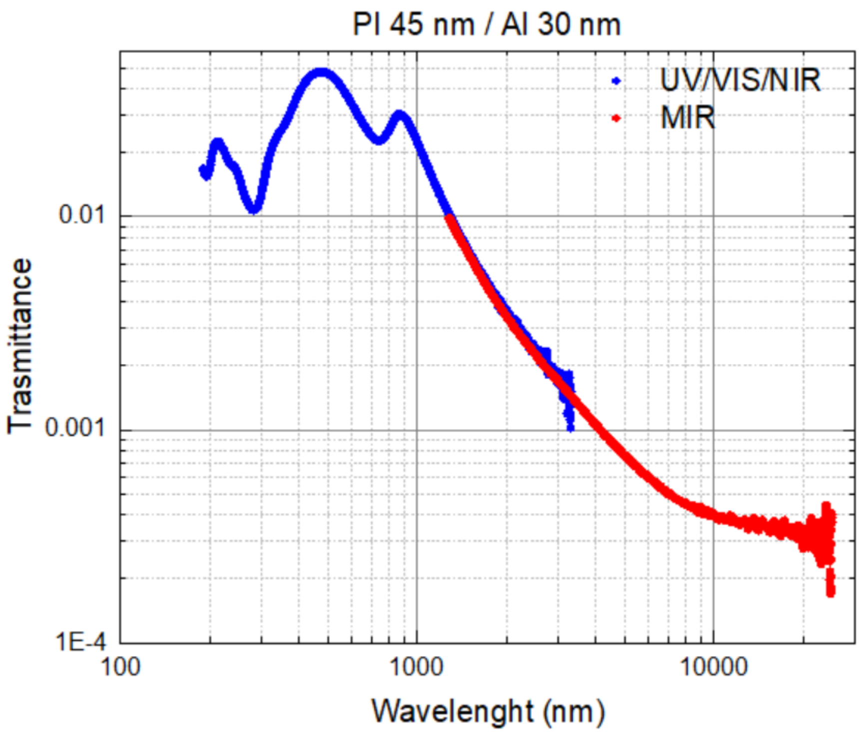
FACILITIES

- BACH beamline @ ELETTRA (Trieste, IT)

Experimental Characterization: UV/VIS/IR Spectroscopy

MAIN GOALS:

- **Measure the efficiency of the out of band rejection of thin membranes.**
- **Evaluation of material thicknesses, metal oxidation, contamination, and aging.**



FACILITIES

- XACT facility @ INAF-OAPA (Palermo, IT)

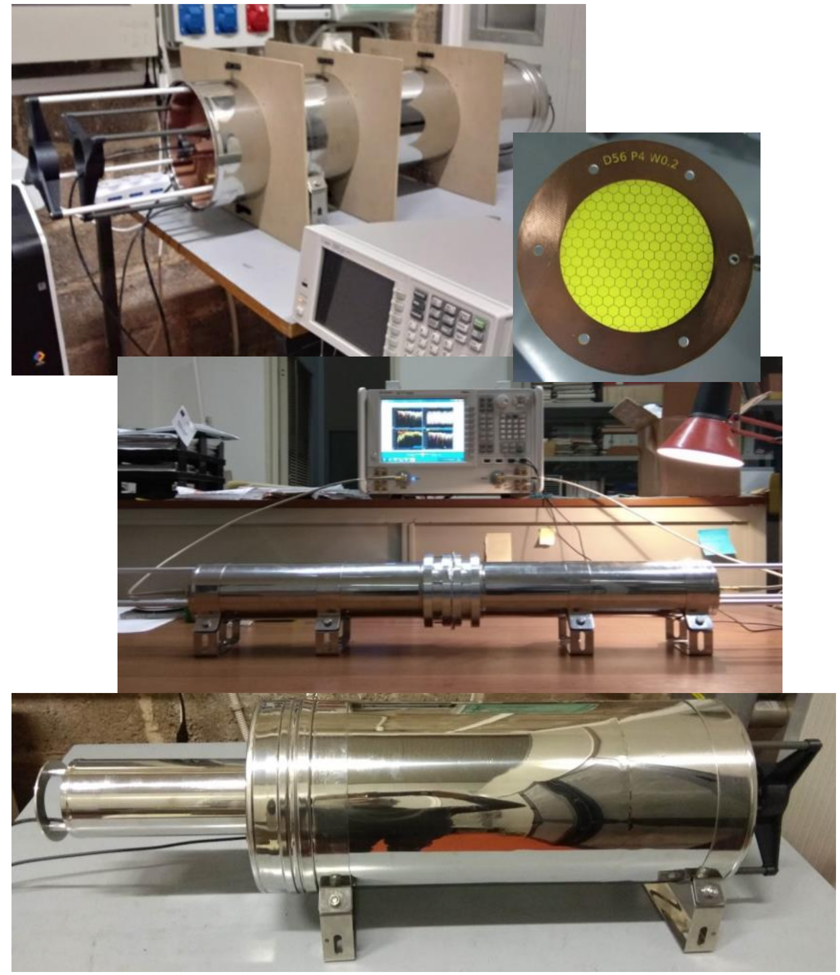
Experimental Characterization: Radio Frequency Attenuation

MAIN GOALS

- **Measure the Shielding Efficiency (SE) of a thin Al layer;**
- **Measure the SE of metal meshes;**
- **Measure the SE of combined stack of filters.**

FACILITY at UNIPA/INAF

- 100 mm I.D. wave guide (3 – 20 GHz)
- 250 mm I.D. wave guide (0.5 - 3 GHz)
- 250 mm I.D. wave guide (0.5 - 3 GHz) modified for multiple filters assembly



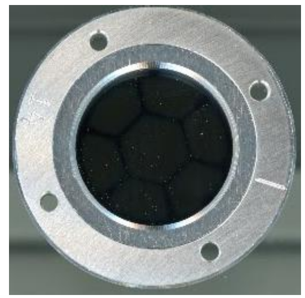
Experimental Characterization: Vibration Contamination Test

MAIN GOALS

- **Derive maximum size of acceptable particle contaminations;**
- **Identify requirements on clean standard for AIT activities.**

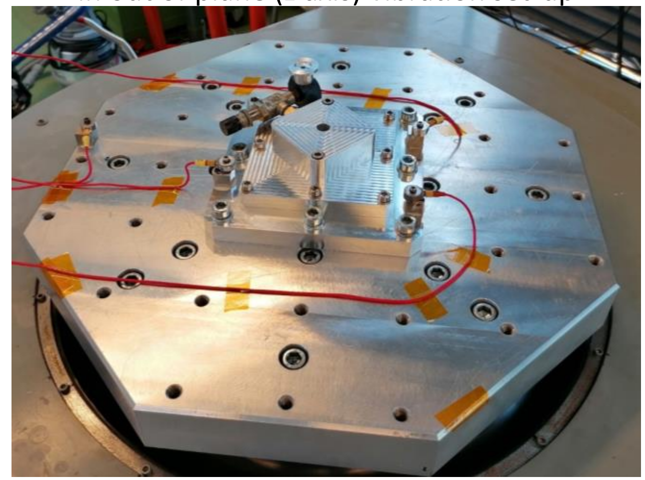
FACILITY

- Shaker @ MPE (Garching, DE)
- Shaker @ CSL (Liege, BE)



INTERFACE PLATE

in out of plane (z axis) vibration set-up

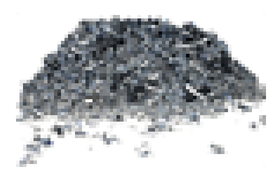


The head expander of the MPE shaker

Contamination Particles SS spheres

Diameters [µm]	Mass [µg]
27 - 31	0.06 - 0.09
39 - 47	0.2 - 0.3
57 - 67	0.6 - 0.9
95 - 105	3 - 4

Contamination Particles (Al shavings)

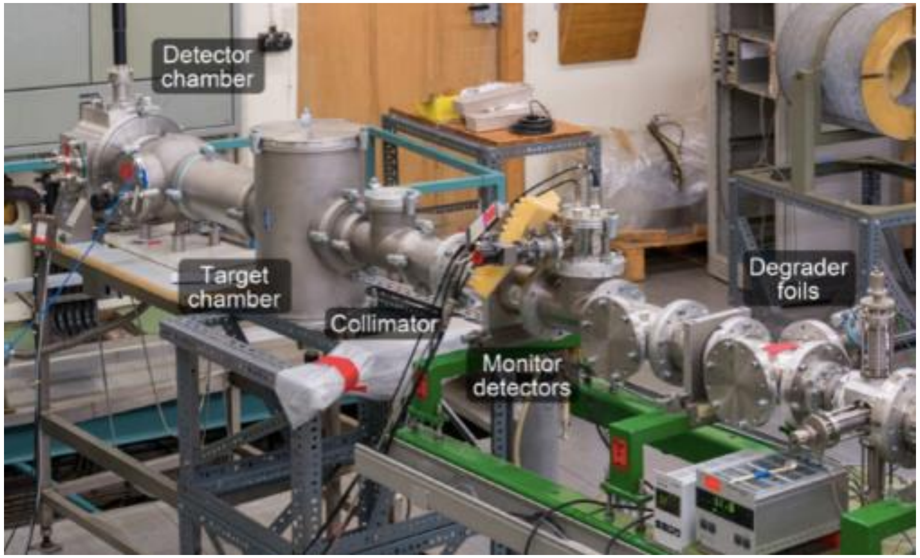


Particle Size [µm]
15
25
60
125

Experimental Characterization: Radiation Damage

MAIN GOALS

- **Verify radiation hardness of filters to doses comparable to those of a lifetime in Space.**



FACILITY

- Van der Graaf accelerator at the Johann Wolfgang Goethe-Universität Frankfurt am Main.

0.1 x QF	1 x QF	10 x QF	100 x QF	300 x QF
TO8 C2-4 TO8 C3-12	TO8 C2-5 TO8 C3-13	TO8 C2-2 TO8 C3-10	TO8 C2-3 TO8 C3-16	TO8 C2-7 TO8 C3-15

QF = $1.2*10^{10}$ cm^{-2} @ 1 MeV

People

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