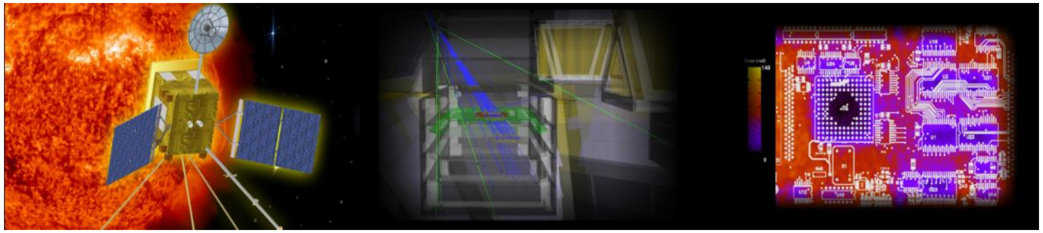
## Geant4 Space Users Workshop 2017

# Full X-ray micropore optics modelling for the BepiColombo MIXS instrument



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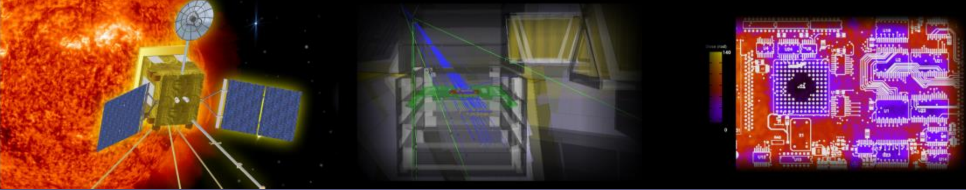

# OUTLINE

1. **BepiColombo Mission**
2. **MIXS instrument**
3. **Motivation**
4. **Objectives**
5. **3D modelling details MPO**
6. **Results**
7. **Conclusions**
8. **Future work**

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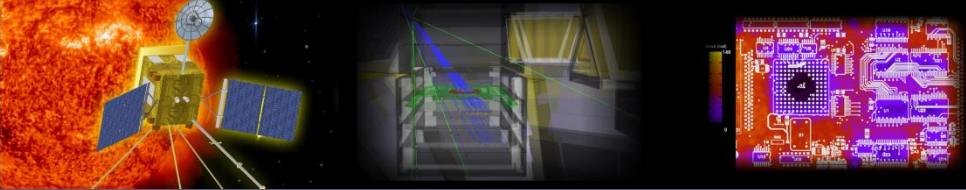
**BepiColombo** is a mission to the planet Mercury.

- European Space Agency (ESA).
- Japan Aerospace Exploration Agency (JAXA).

It will set off in October 2018 (arriving at Mercury in 2025).

Their objectives are:

- Study Mercury as a planet (form, interior, structure, composition…).
- Study Mercury's magnetosphere.
- Study the origin and evolution of a planet close to its parent star.



# 2. MIXS

**MIXS:** Mercury Imaging X-ray Spectrometer

- Measure fluorescent X-ray emission from Mercury's surface.
- It will reveal the elemental composition of the surface.

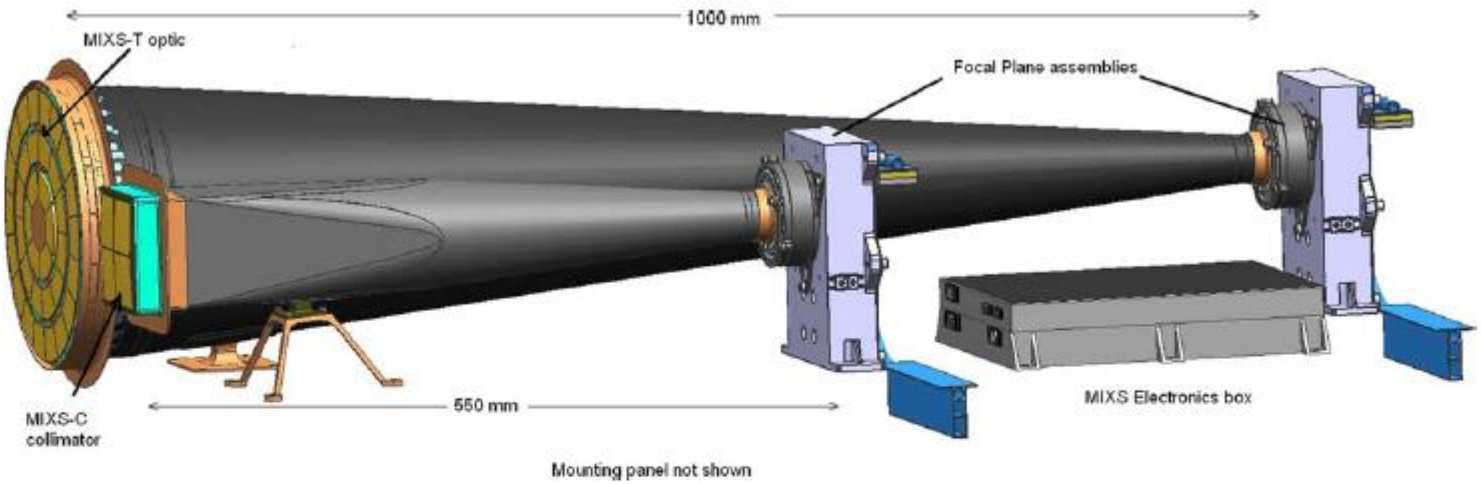



**Fig. 1.** A Schematic illustration of MIXS showing the adjacent MIXS-T and MIXS-C channels.

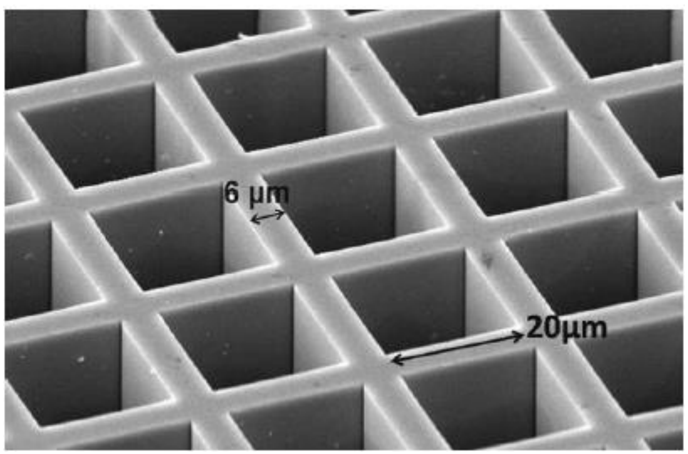
*Fraser, G.W et al. 2010. The mercury imaging X-ray spectrometer (MIXS) on bepicolombo. Planetary and Space Science 58 (2010) 79-95.*

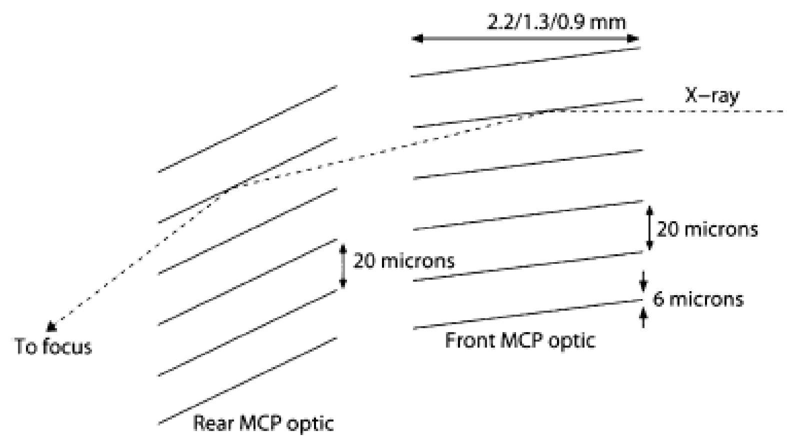
# 2. MIXS

- The MIXS-T is the main X-ray telescope and will make measurements on spatial scales of less than 10 km.

- That is achieved by low mass microchannel plate (MCP) X-ray optics.

- Wolter type I optical geometry.

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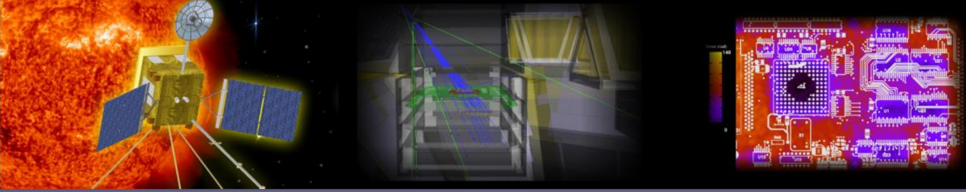
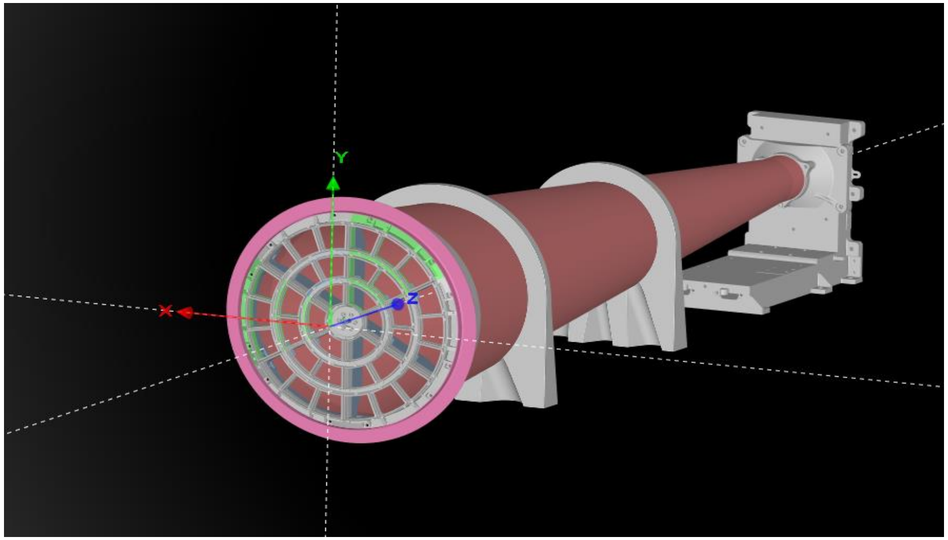


# 3. MOTIVATION

**Challenges**:

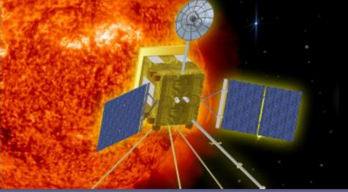
- Simulate in a **realistic** CAD-based **model of MIXS**.
- Combine both GDML model and C++/G4 MPO.
- More than $35x10^6$Si micropores coated with Ir.
- Propagate **X-ray reflection** and scattering at grazing angles.

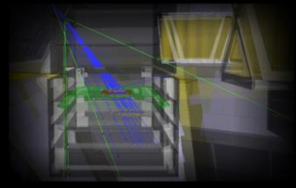
**CAD – model:**

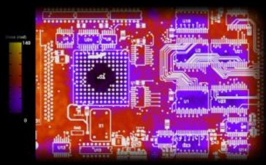



**MPO Geometry:**

Programmed via Geant4.







# 4. OBJECTIVES

- Develop an advanced 3D simulator of MIXS.
- Provide MIXS community with a useful open-source tool.
- Use this development for the future X-ray telescope simulators (ATHENA mission).

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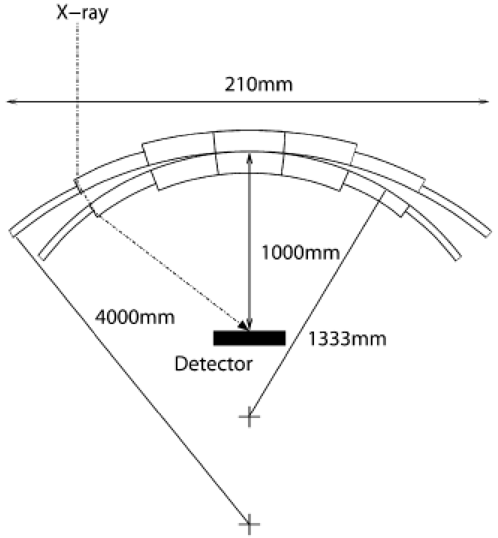
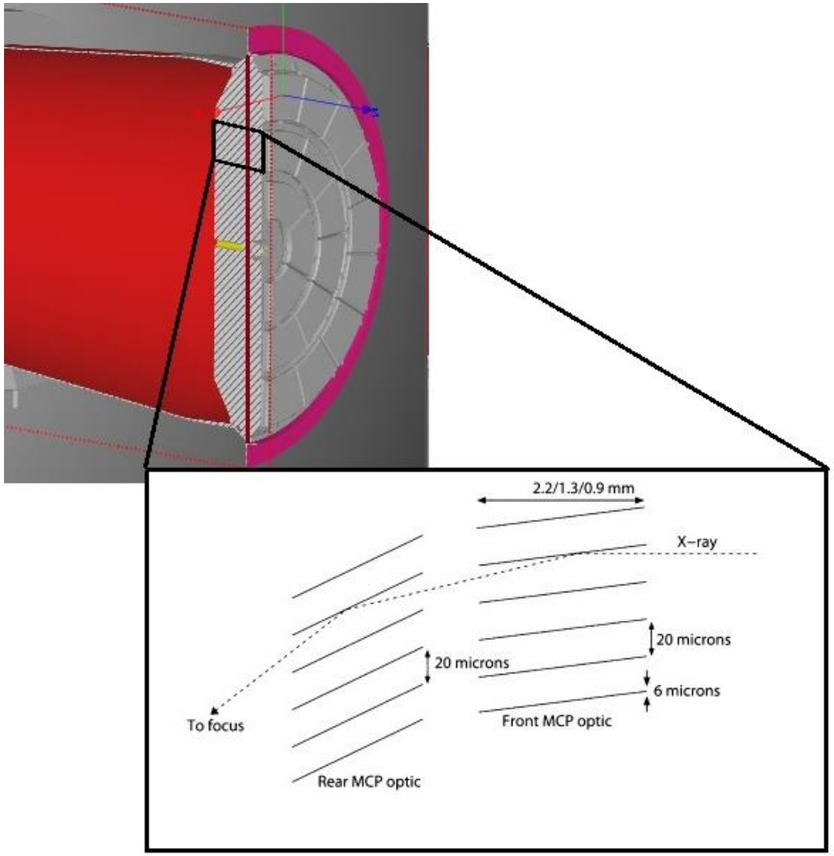
**MIXS-T DIAGRAM:**

- Three sections I / M / O.
- Thickness profile change with 1/r.
- Micropore inclination change with r.



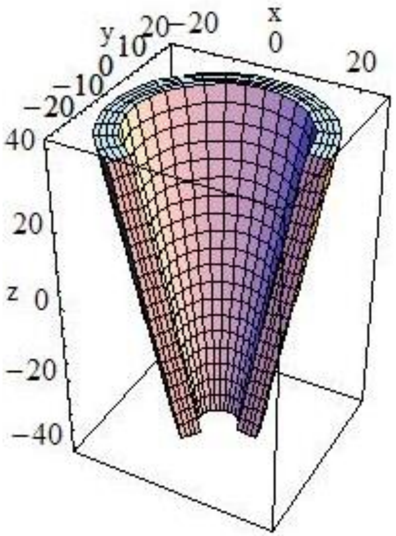




*Fraser, G.W et al. 2010. The mercury imaging X-ray spectrometer (MIXS) on bepicolombo. Planetary and Space Science 58 (2010) 79-95.*

**MIXS-T SIMULATION:**

How can we simulate this geometry?

- G4Sphere
  - ➢ Overlapping problems
- G4Box
  - ➢ Placement complexity
- G4Cons
  - ➢ Robust and flexible option
  - ➢ Good approximation



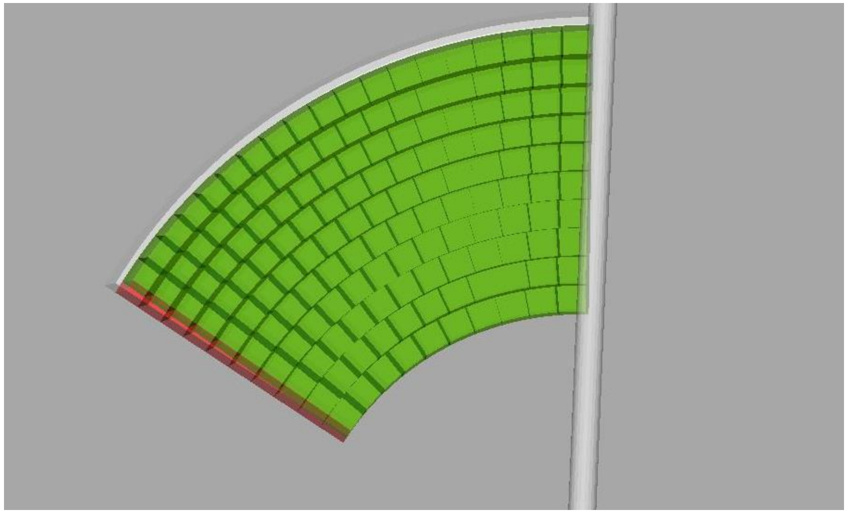
## MIXS-T SIMULATION:

- Recurrent calculation of the in MPO inclination.

- Use of G4Cons geometry.

Sectors (G4Cons/MotherVol.) [Si]
 / Rows (G4Cons) [Si]
  / G4PVDivision [Si]
   / G4PVDivision [Ir]
    / G4PVDivision [Vacuum]

- Good approximation to a Wolter Type I Geometry.



*Note: We use G4.10.01.p02 version, in later releases we have problems with the Division method*.

X-ray propagation: **XRTG4 (Cosine).**

- *E.J. Buis, G. Vacanti. 2009. X-ray tracing using Geant4. Nuclear Instruments and Methods in Physics Research A.*

Standard Fresnel equations.

$$R(\theta_i, E) = \left|\frac{sin\theta_i - n(E)sin\theta_t}{sin\theta_i + n(E)sin\theta_t}\right|^2$$

Real surface scattering factor added.

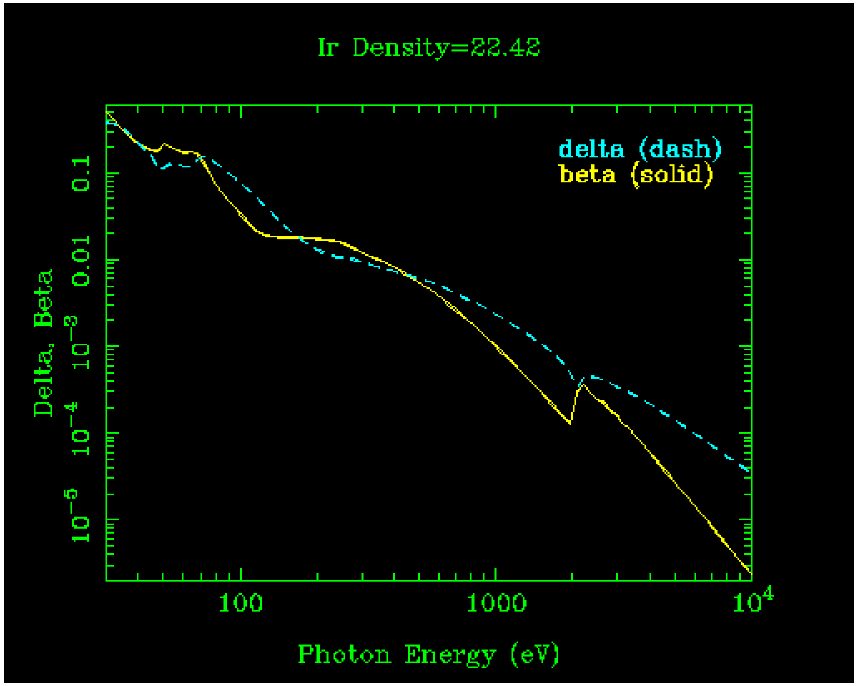
$$\exp\left(-\left(\frac{4\pi\sigma sin\theta_i}{\lambda}\right)^2\right)$$

Index reflection data:

- **CXRO Data Base**

Range = 30 – 10000 eV

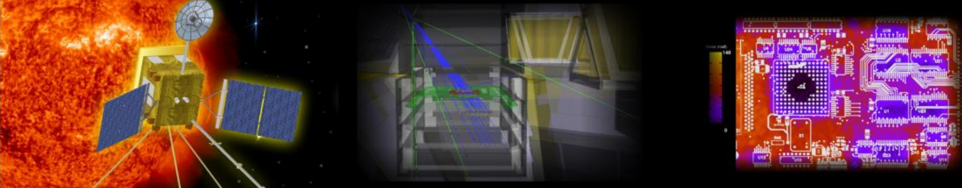
n = (1-delta) – i(beta)



# 6. RESULTS

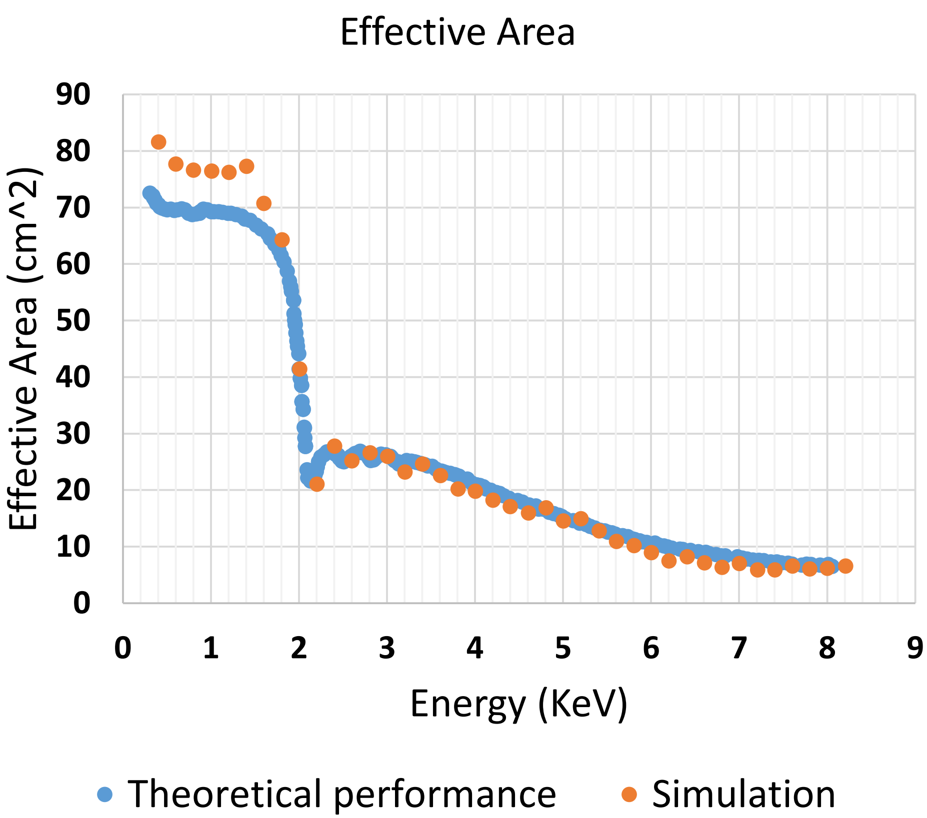
- Theoretical performance:
  - On axis effective area.
  - Calculated by Sequential Ray-Tracing (SRT) software.

- FM model tests:
  - Best focus
  - Angle tolerance

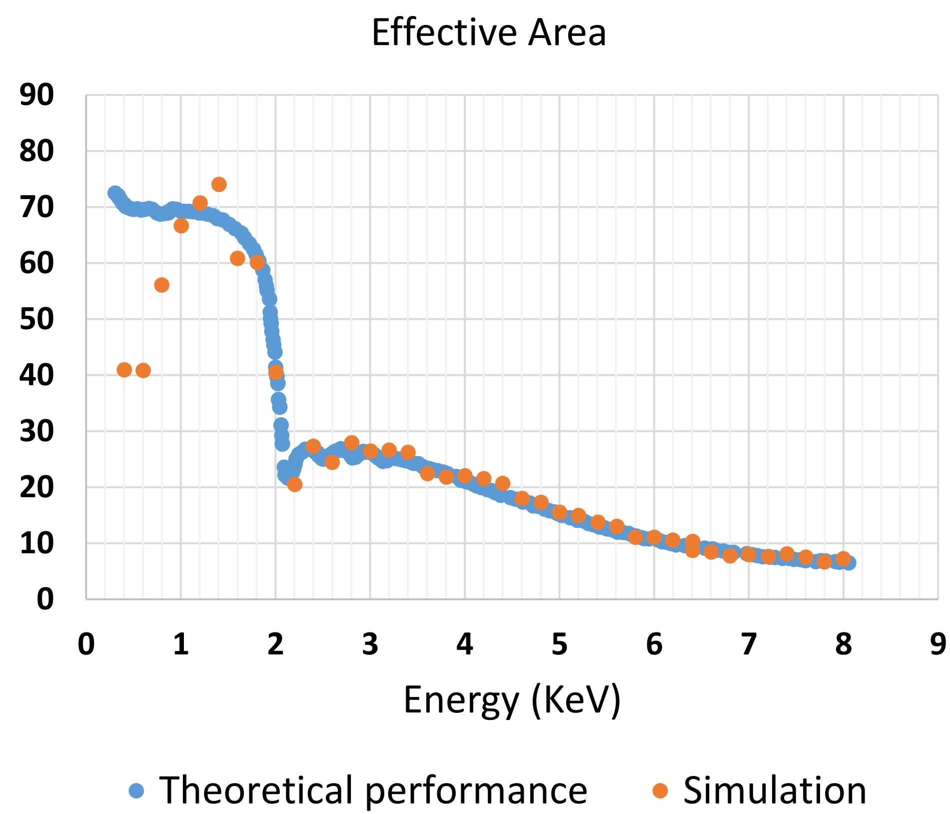


# 6. RESULTS: THEORETICAL PERFORMANCE

## MPO + Ideal Detector




## MPO + MIXS FM Model




*BC-MIX-TN-001. Calculations of MIXS-T performance.*

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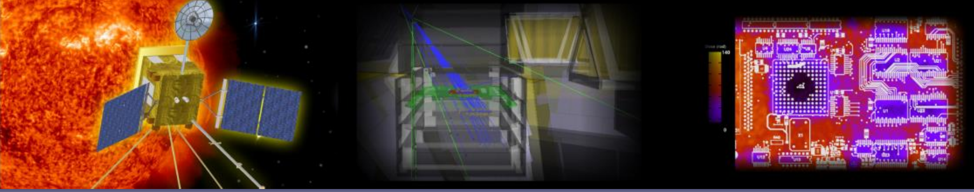
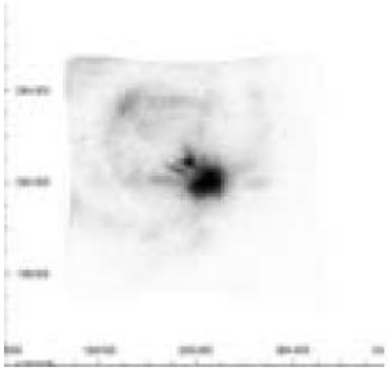


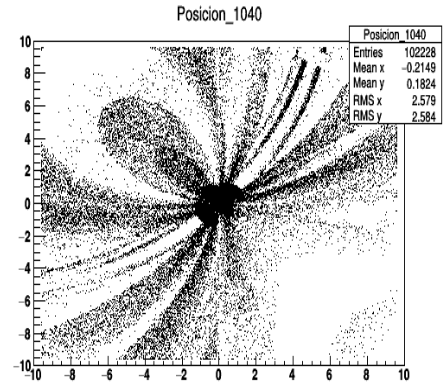
# 6. RESULTS: FM MODEL TESTS

**Focal plane position detector:**

- Experimentally: 1063 $\pm$ 5 mm
- Simulation: 1055 $\pm$ 5 mm.
- Error: < 1 %

**Angle tolerance (45’ phi, psi):**






**Differences analysis:**

- **Test / Simulation**
- Real source / simulated source
- MCP detector / flight detector

**Differences analysis:**

- **Test / Simulation**
- Instrument noise
- MCP detector angle efficiency

*BC-MIX-TN-232. X-ray test results of the Flight Optic MOMT005.*

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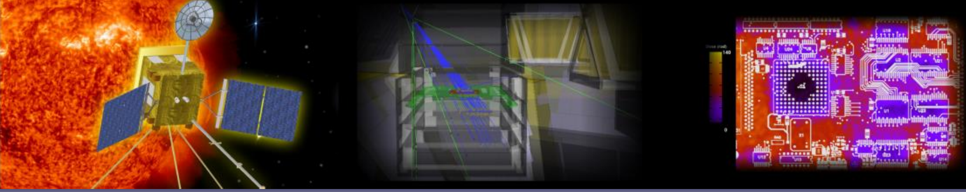

# 7. CONCLUSIONS

- Our first prototype, and the very first results look very promising.
- It provide **figures of merit similar to the MIXS X-ray TNOs.**
- It is necessary to **refine the reflection methods.**
- Study **the effect of the noise** in the results.
- Improve the **time efficiency of the simulation**.
- Analyze the importance of the **roughness** implementation.

# 8. FUTURE WORK

- Refine the r**eflection** methods; study and implementation of ***Parratt*** **formalism** in thin films and multilayer (Ir + Si).
- Compare different approximations for the **roughness behavior**: Debye – Waller, Nevot – Croce.
- Reproduce the MIXS-T behavior **against the expected X-ray flux from Mercury's surface** at the mission conditions.
- Collaboration with the **University of Leicester**.
- Provide a stable open-source version of this software to the MIXS community.