The Athena Optics

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On behalf of the SPO team

1st Athena Scientific Conference
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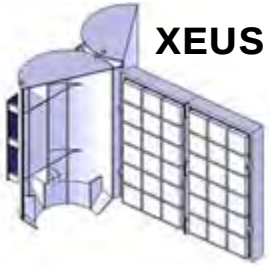
Background: Previous Studies



XEUS

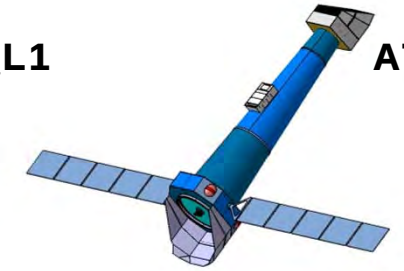
f = 50 m

IXO

f = 20 m

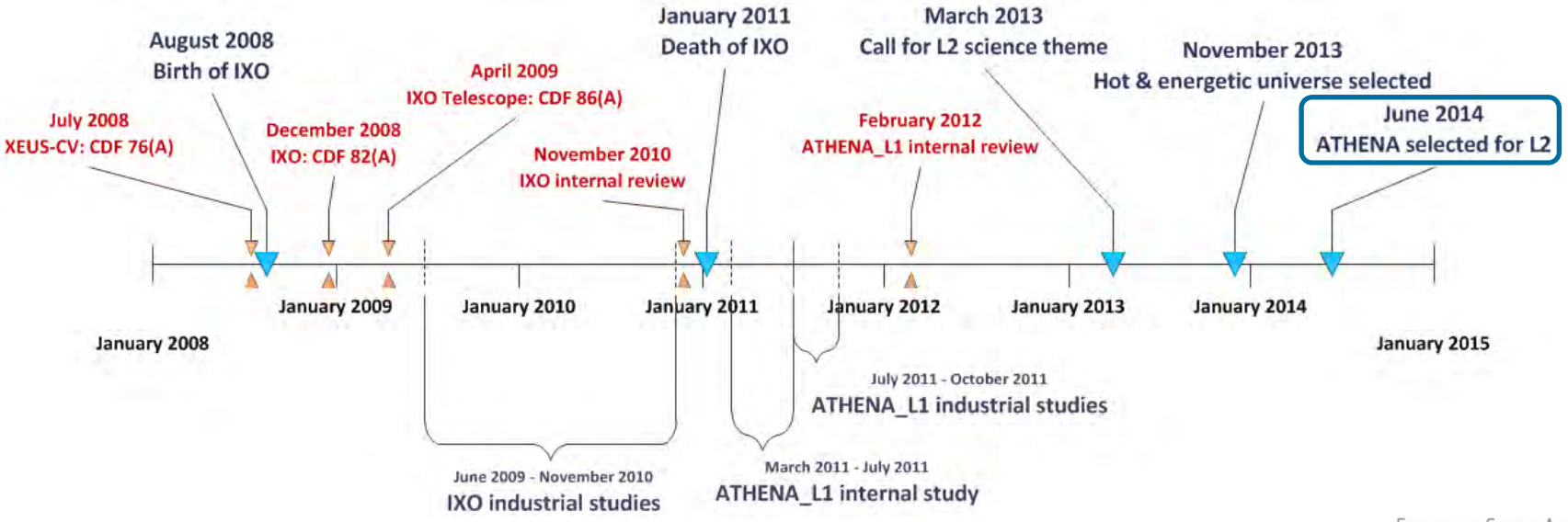
ATHENA_L1

f = 12 m

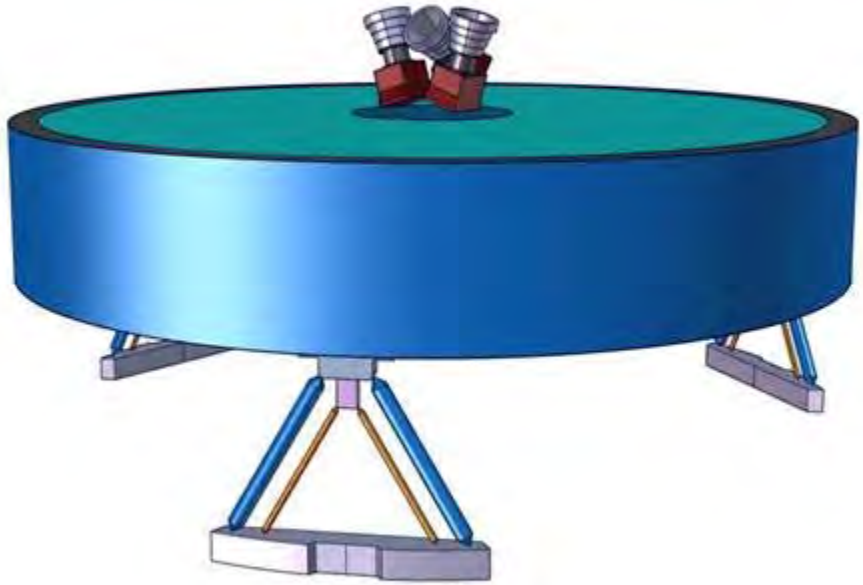


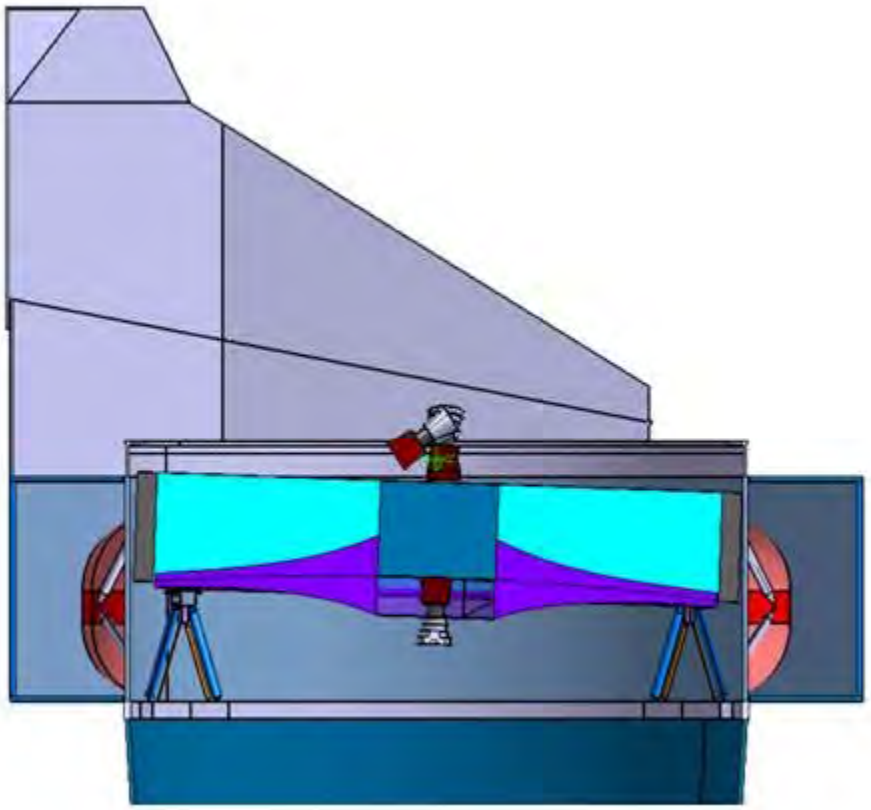
ATHENA

f = 12 m

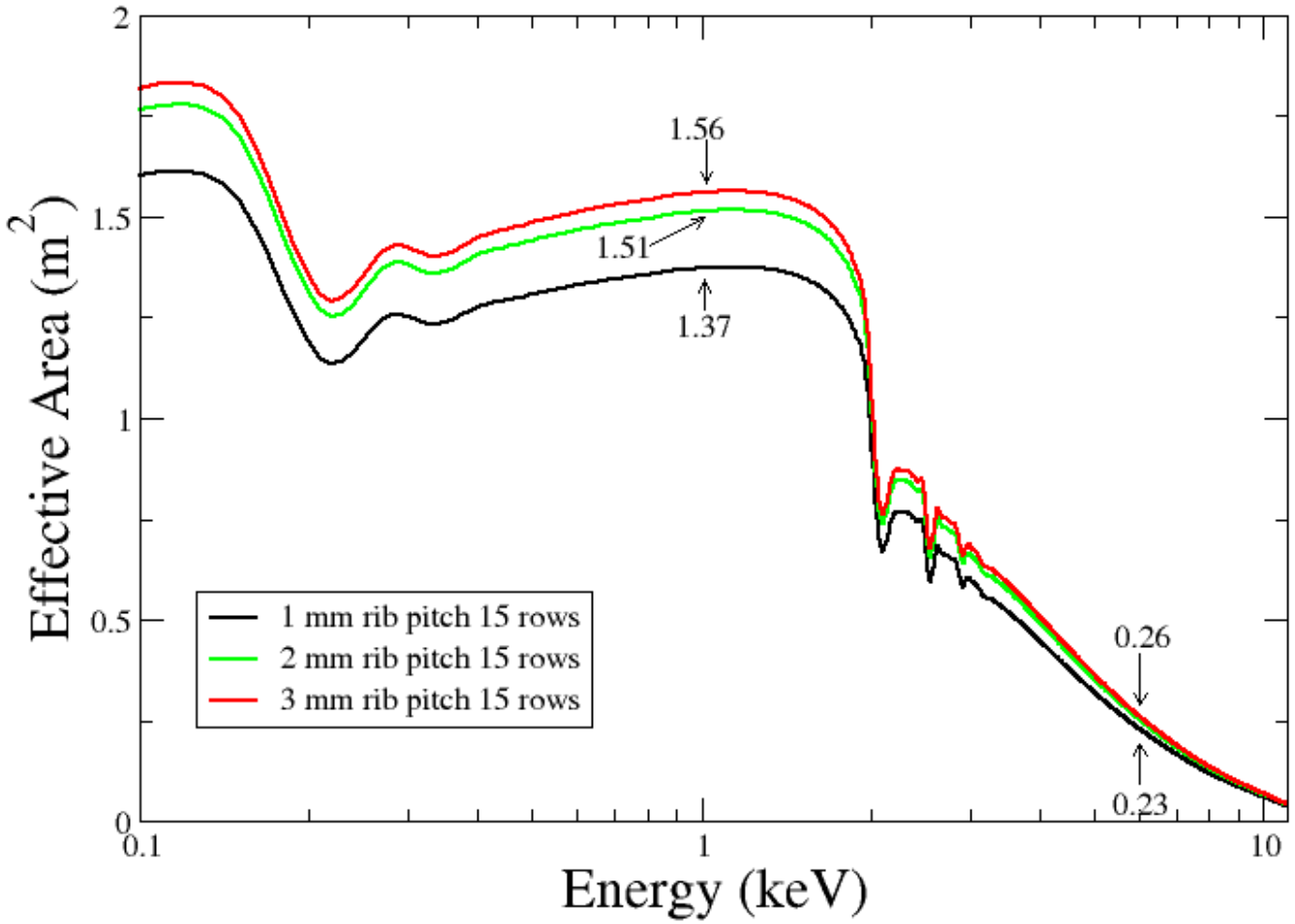


Athena CDF Study: Optics Accommodation

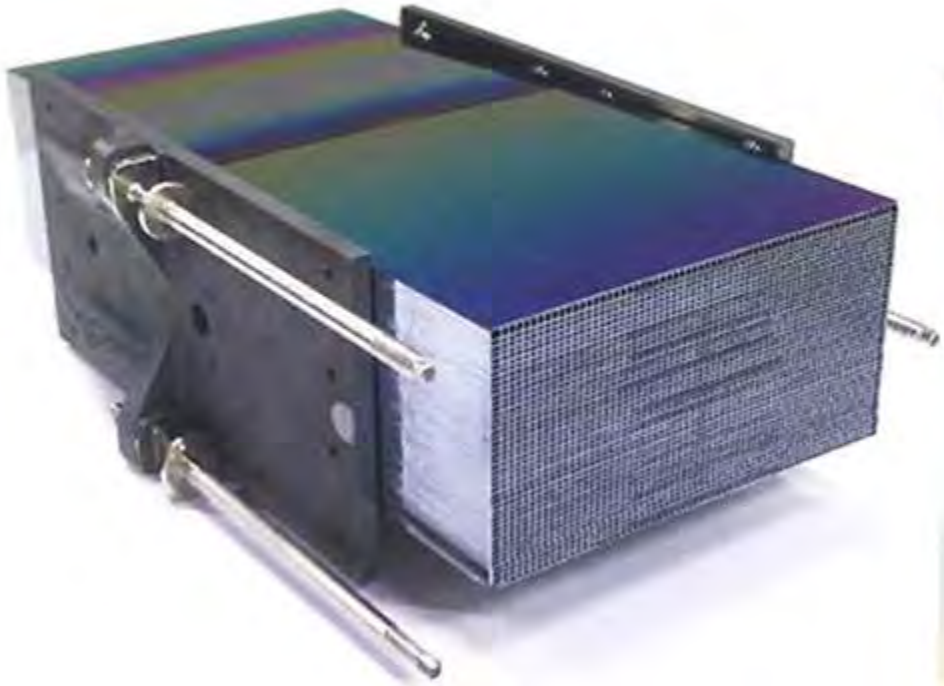


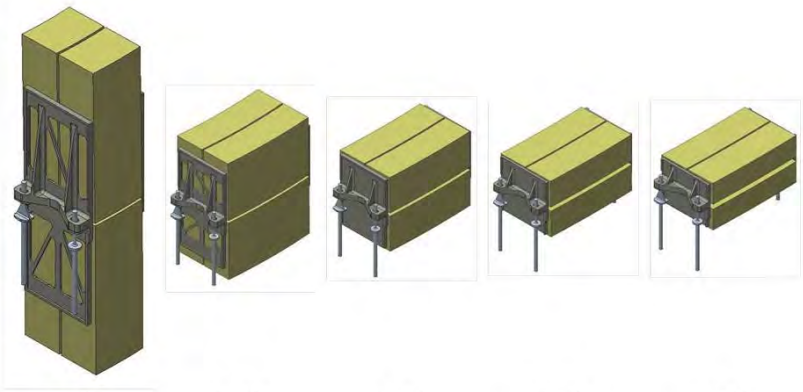


Athena CDF Study: Effective Area



Athena: Silicon Pore Optics

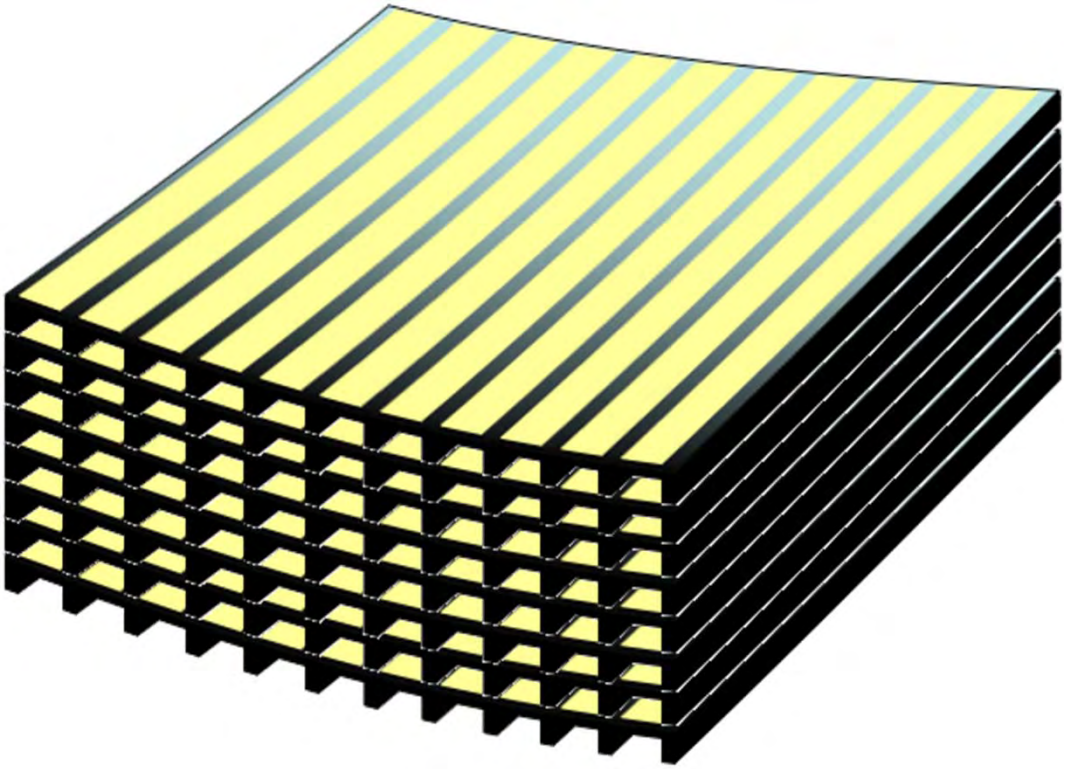


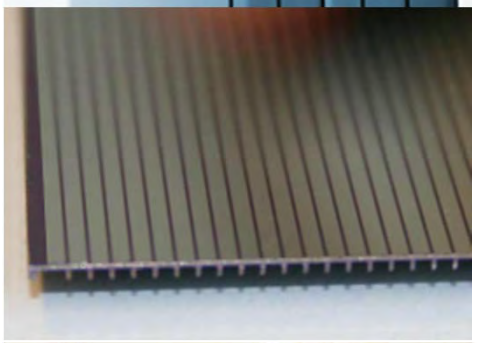


Row 01 Row 05 Row 10 Row 15 Row 20

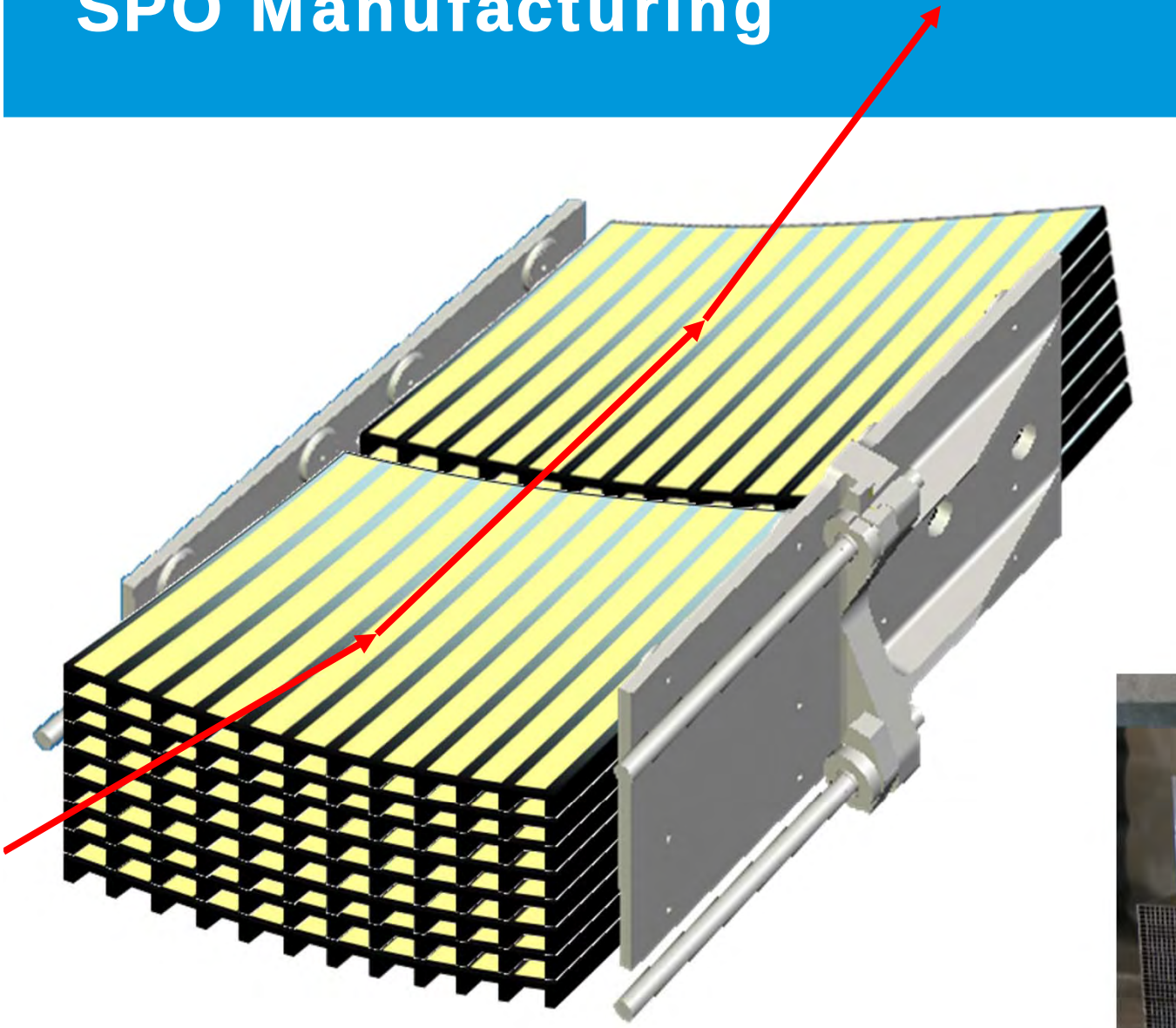
European Space Agency

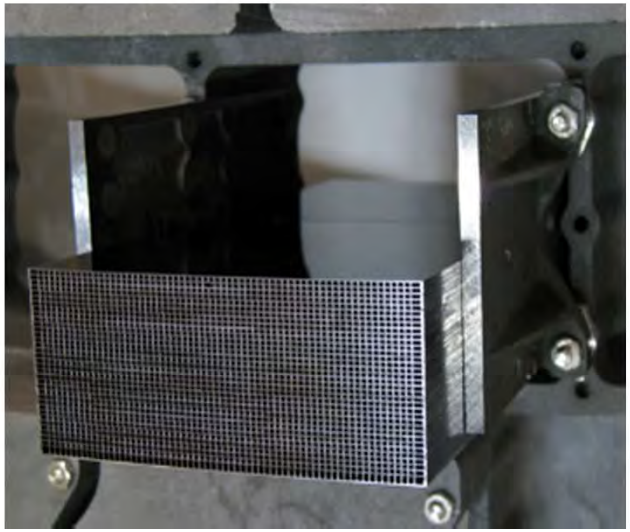
SPO Manufacturing



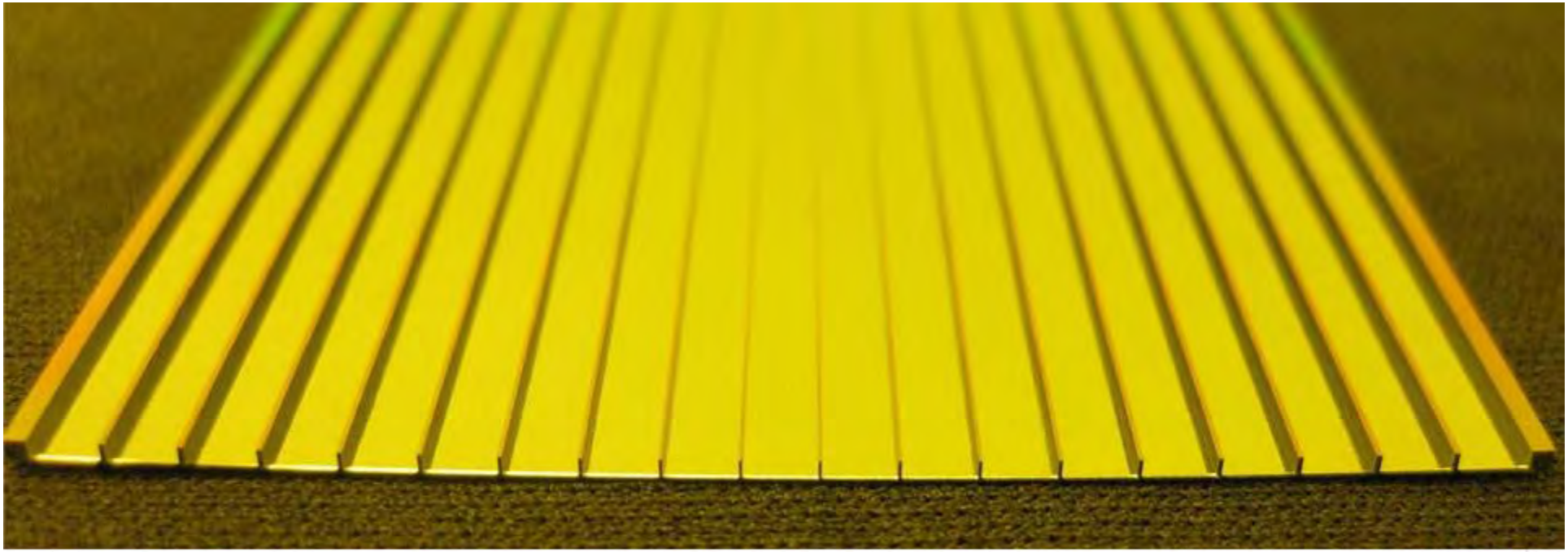


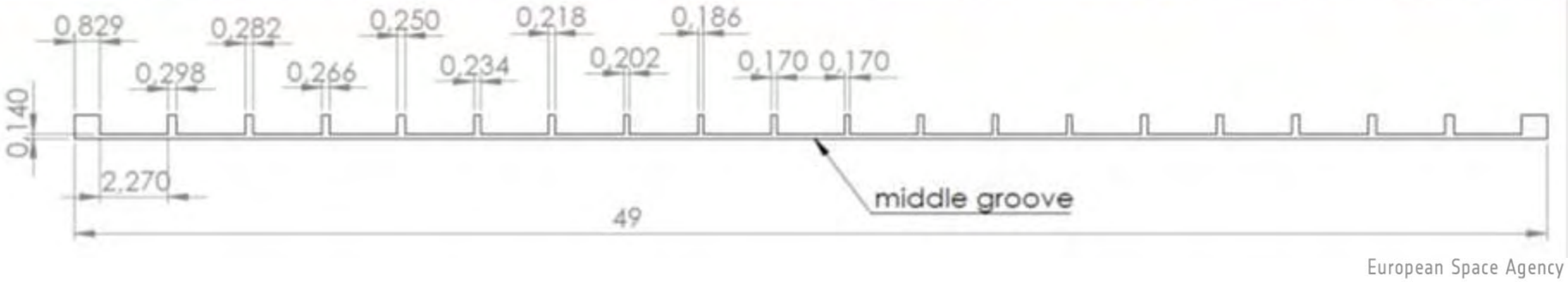
SPO Manufacturing



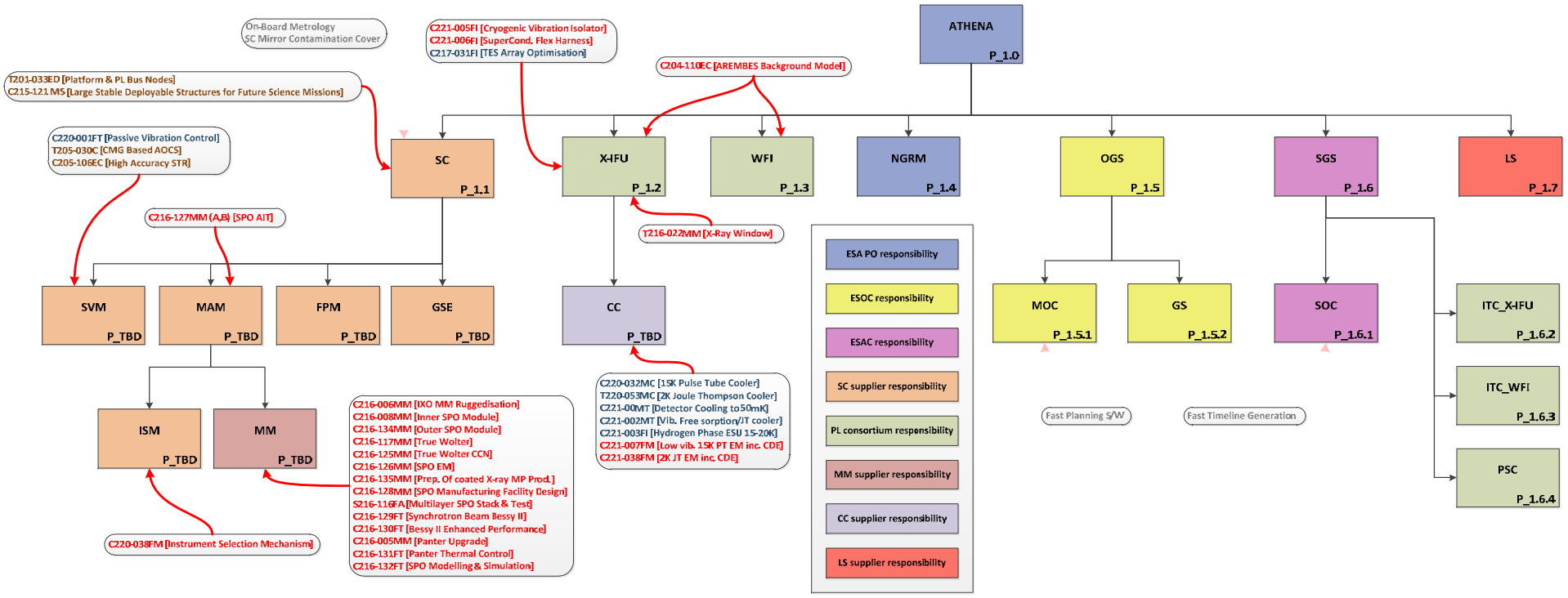


Athena: Inner Mirror Modules Mirror Plates

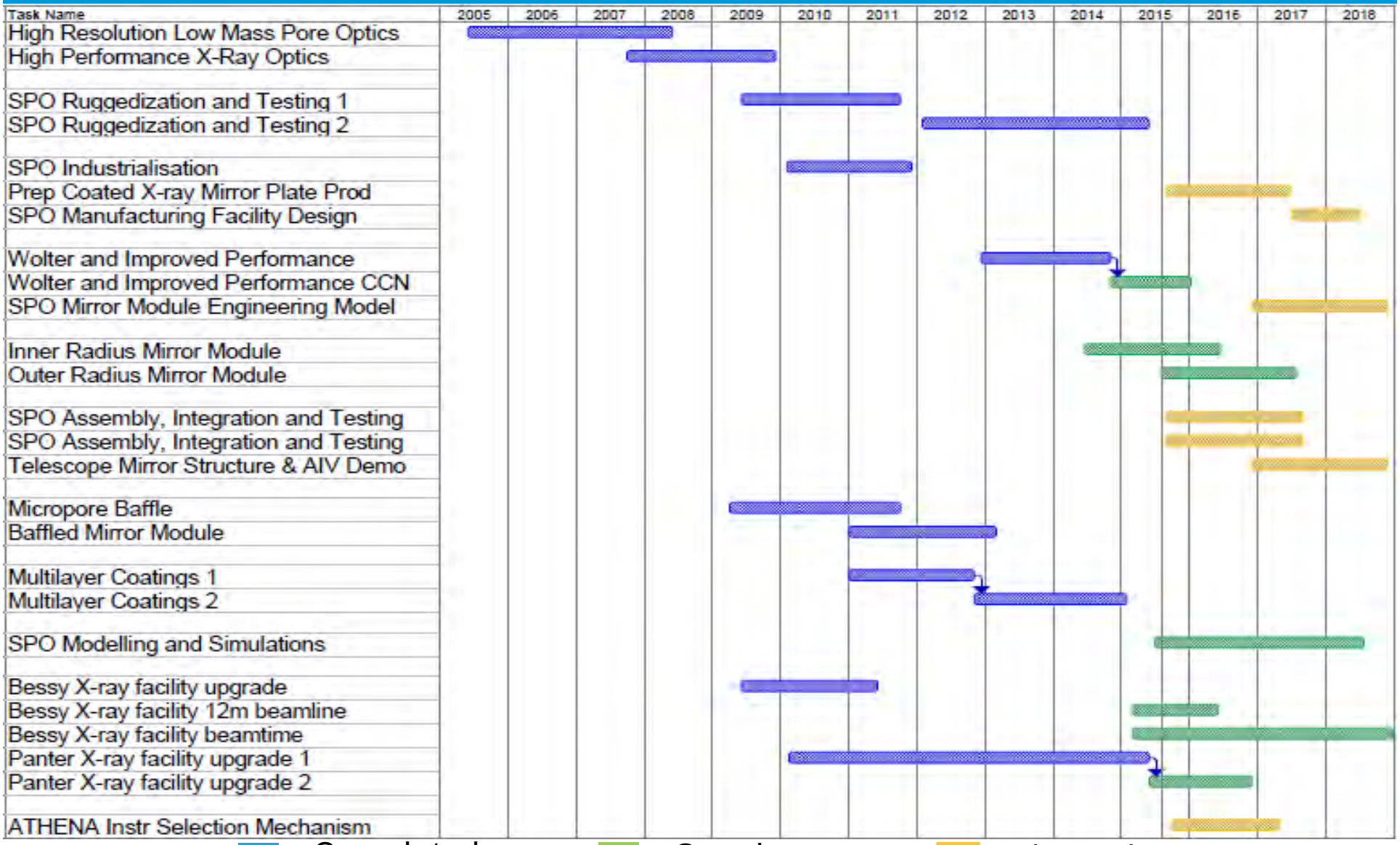




ATHENA top-level Product Tree with Technology Development Activities



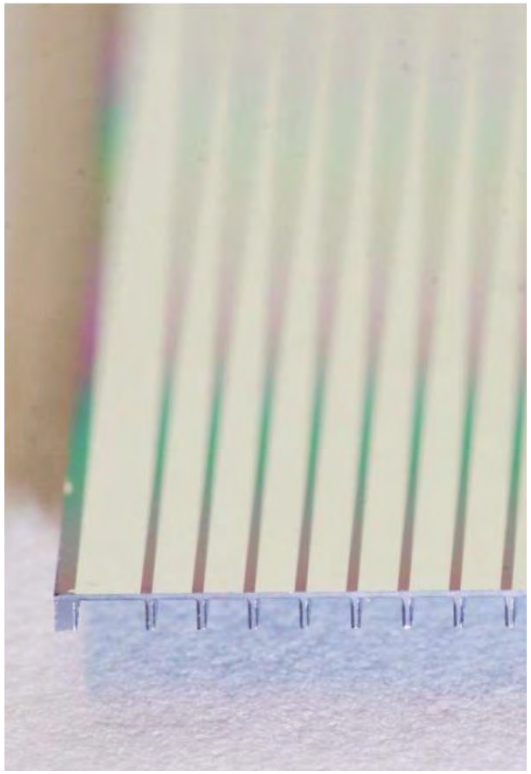
X-ray Optics Technology Development Activities

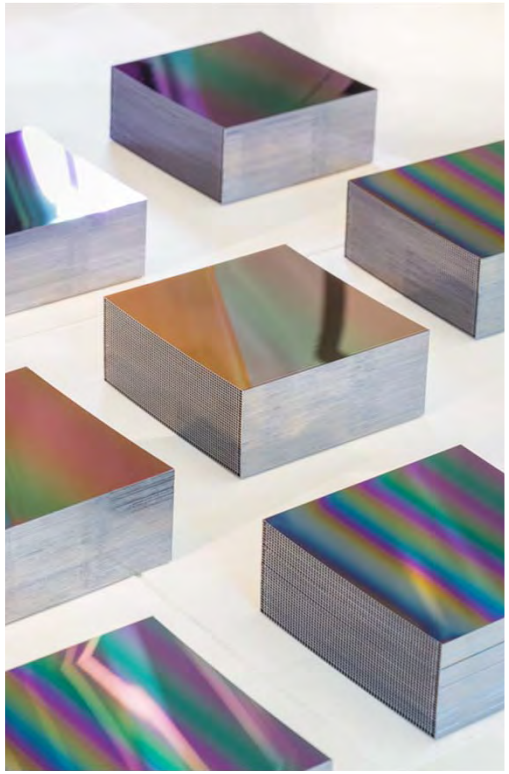


Main SPO Development Activities

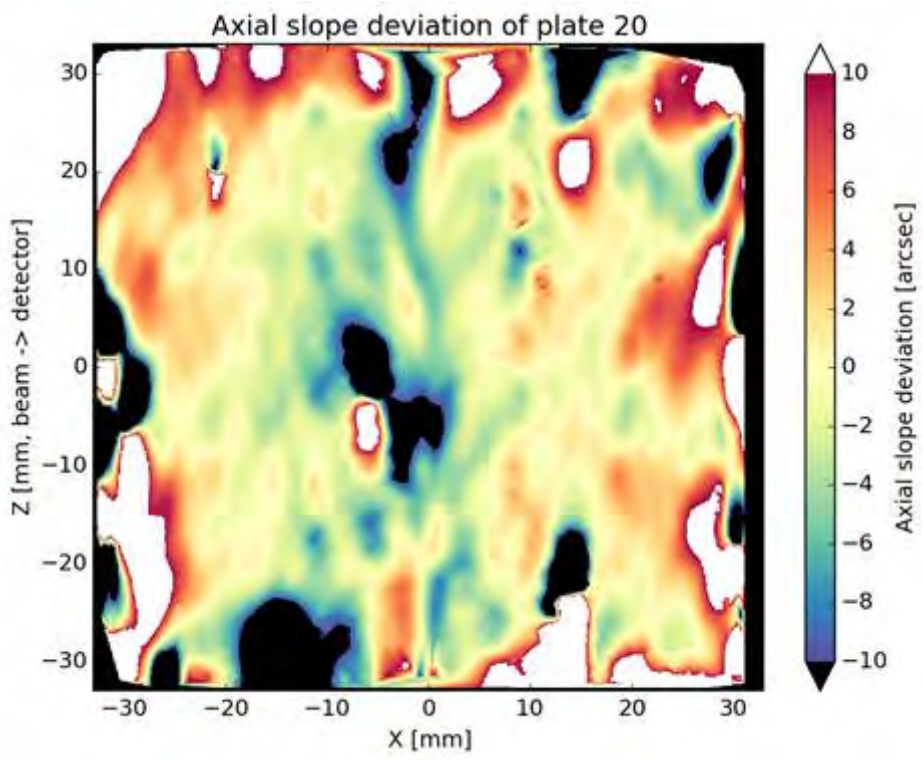
1st area: Improved Angular Resolution SPO Mirror Module (MM)

- Running activity WOLTER (CCN) aiming at 5” (Athena-L2, f = 12 m)
- Introducing secondary curvature (had conical approximation before)
- All steps of SPO MM production addressed
- Steps: 10” at f = 20 m -> 10” at 12 m -> 5” at 12 m

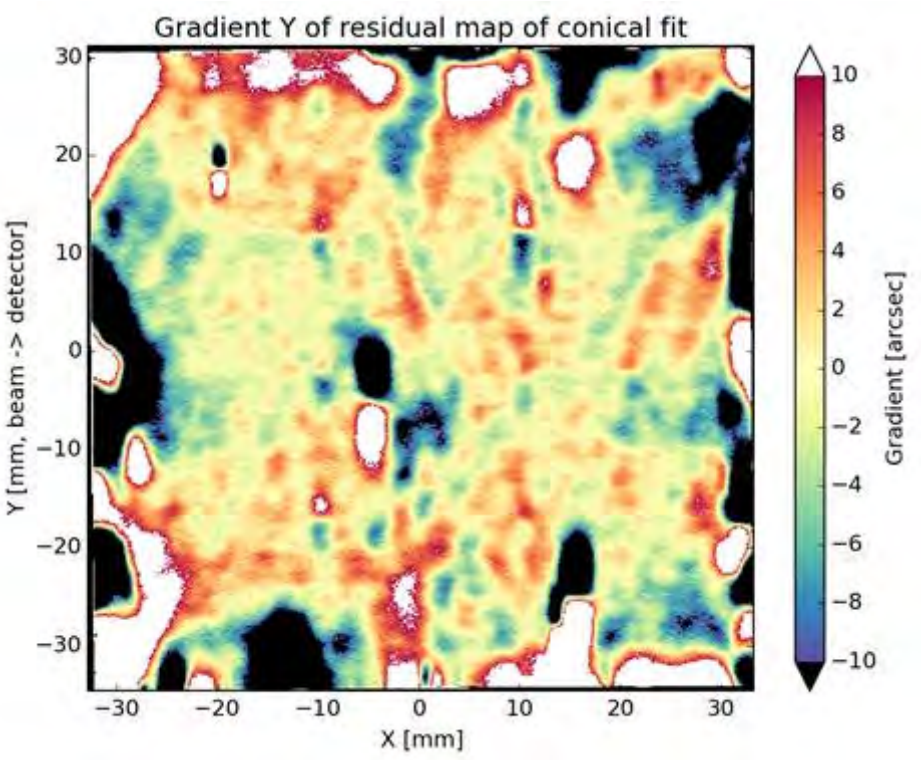




Surface Figure Metrology



X-ray Pencil Beam Scan
(Bessy II Facility)

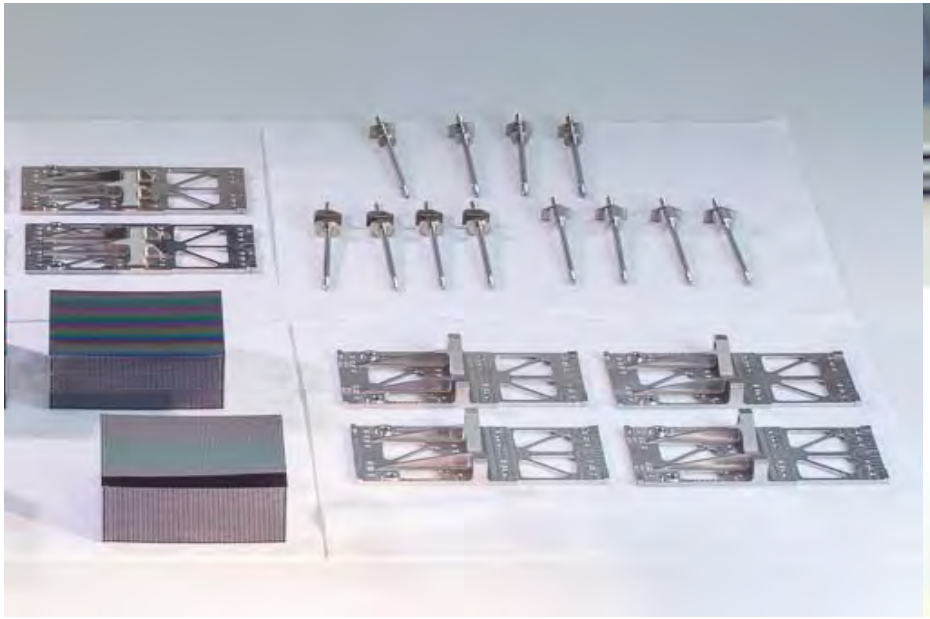


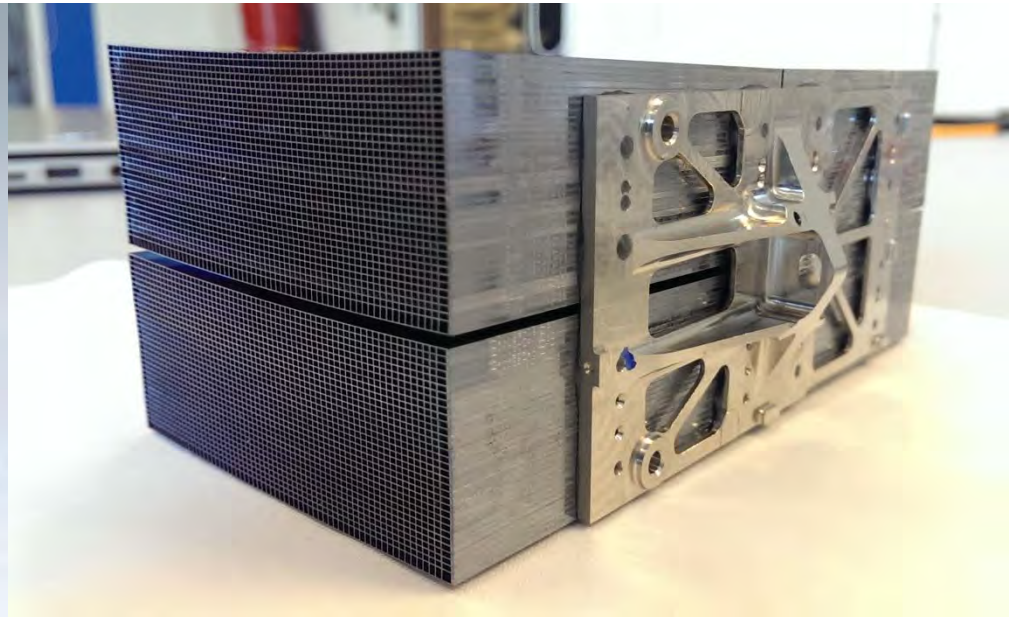
Fringe Reflection Technique
(stacking robot)

Main SPO Development Activities

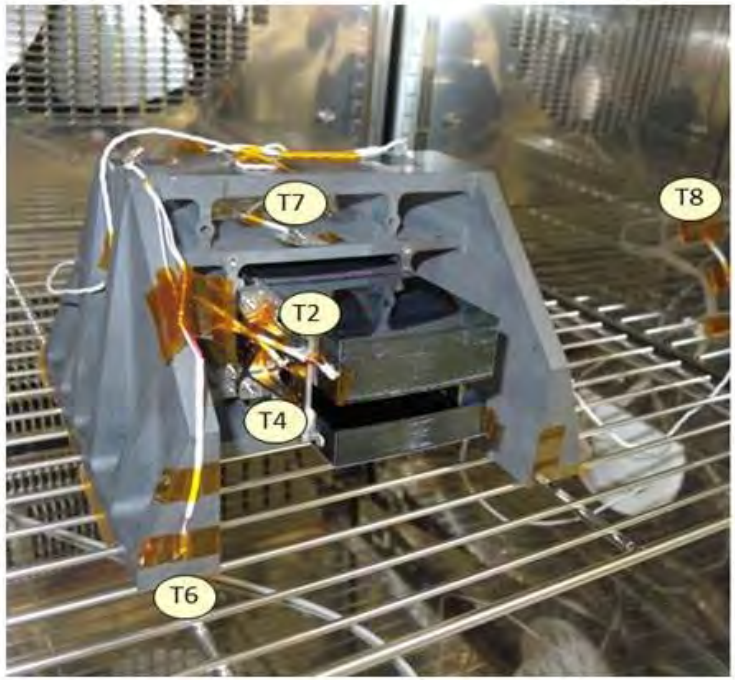
2nd area: Ruggedisation of Silicon Pore Optics

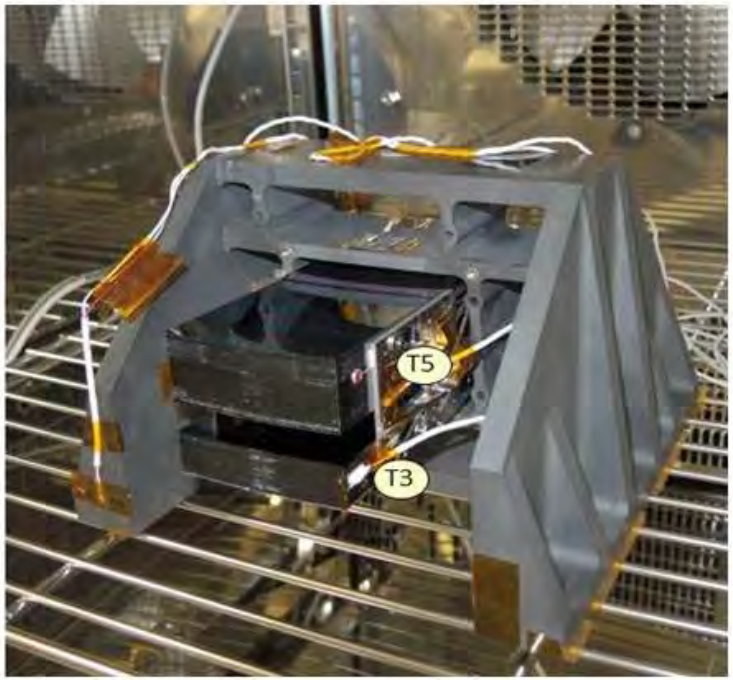
- Completed activity SPORT-2: conservative environmental assumptions
- Re-designed mirror brackets (now Invar), glue pads, pins etc
- Vibration, shock and thermal tests performed
- Planned activity: SPO MM Engineering Model

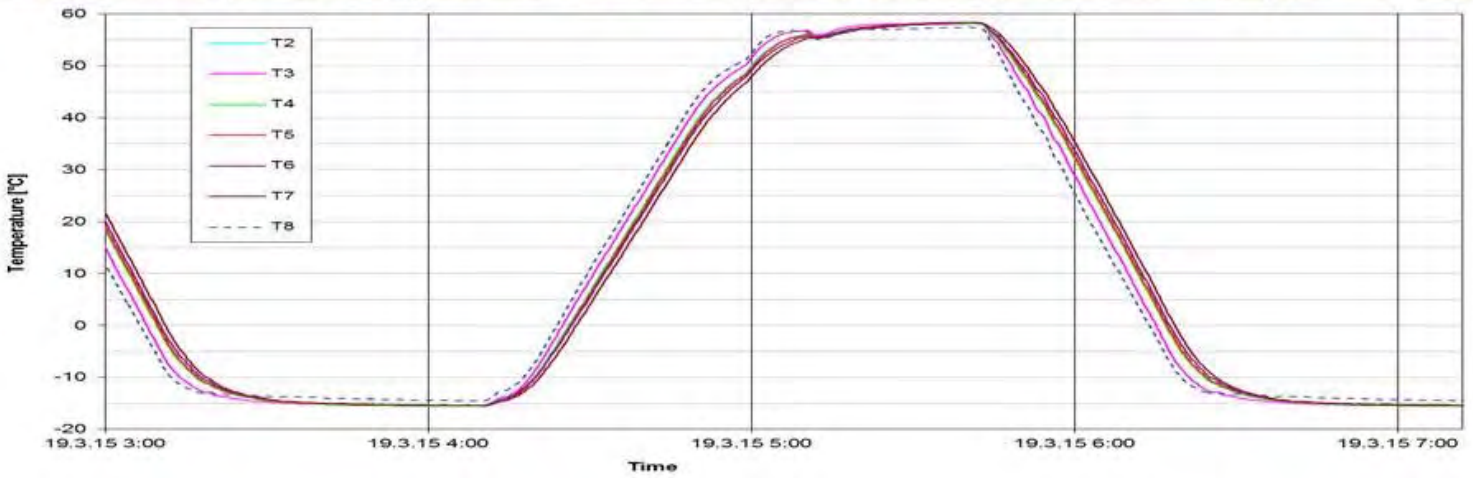




Thermal Cycling Tests







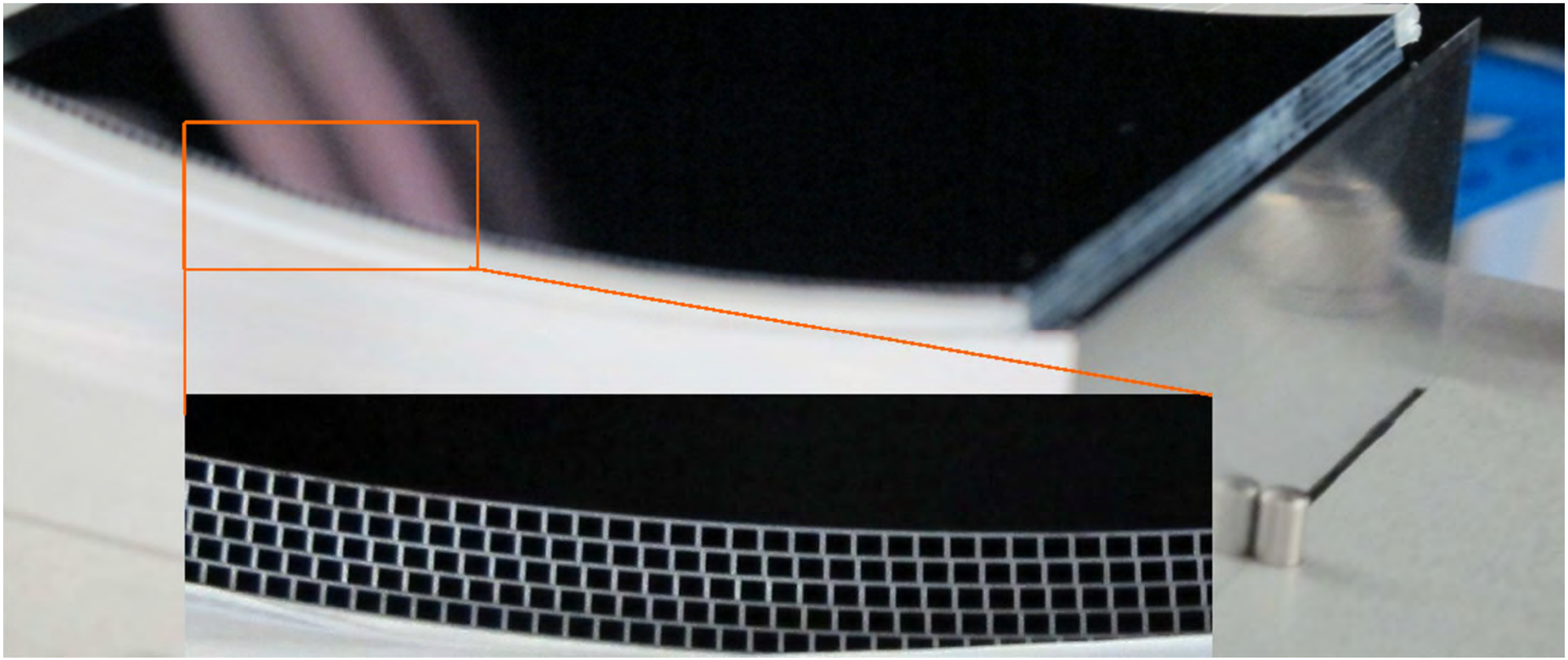
X-ray tests before and after show no changes

60 cycles
2°C per minute
-15 to +55 deg C

Main SPO Development Activities

3rd area: Demonstration of Inner/Outer Radius MM with f=12 m

- Started new development activity on Inner MM: SPIRIT
- New stacking machine and tools for f=12 m, r ~ 0.25 m
- Outer MM: contract placed, activity kicked-off



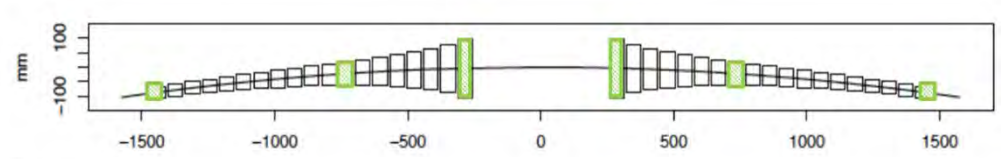
Inner and outer Mirror Modules

Inner Radius MMs (started 2014):

- Mirror plate design
- Smaller bending radius
- Larger plate wedges
- Passed CDR phase
- First results mid 2016

Outer Radius MMs (started 2015):

- Shorter/wider mirror plates
- Introduction of “mother plates”
- Kick-off in September 2015
- First results early 2017



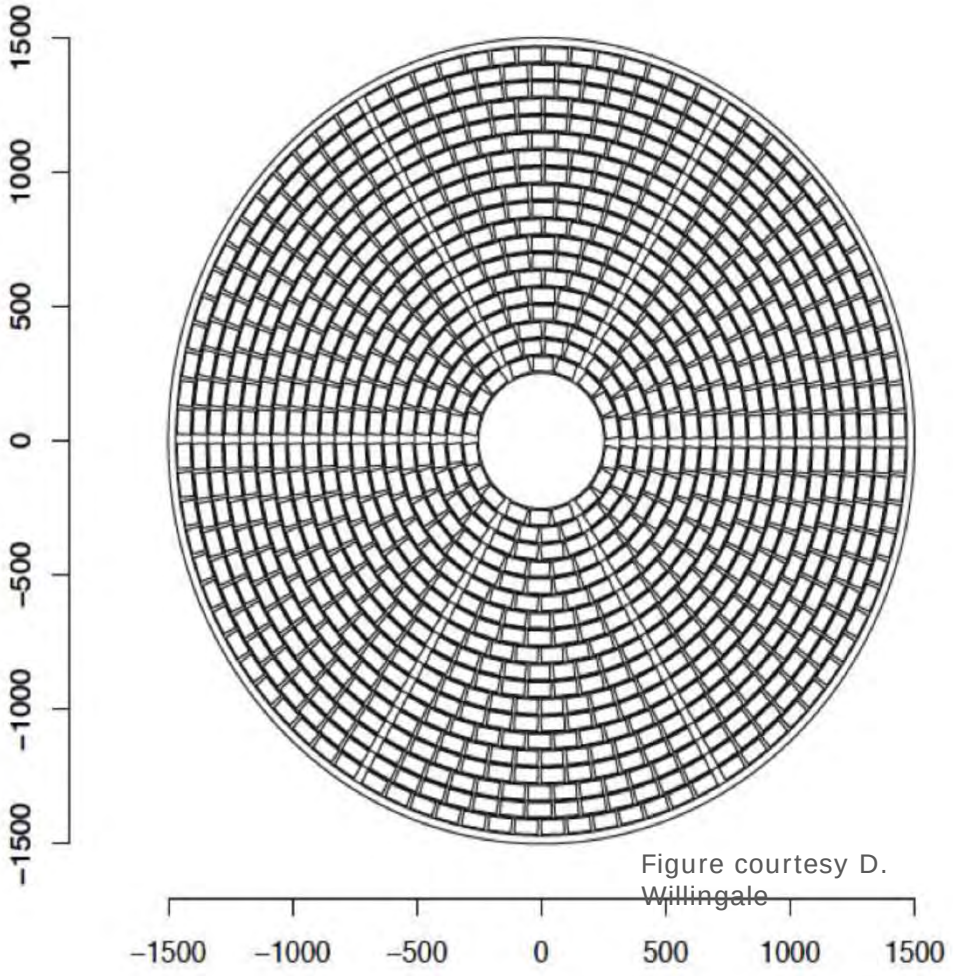
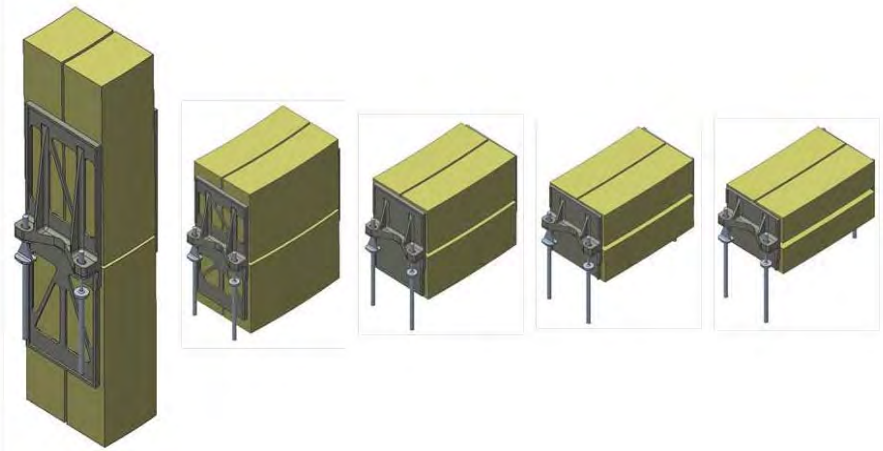


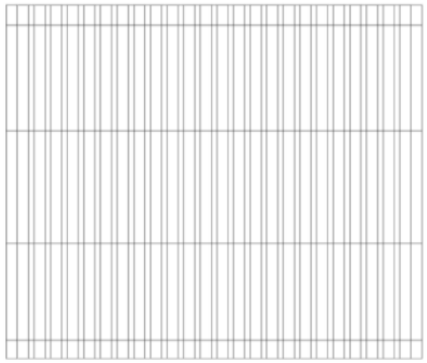
Figure courtesy D. Willingale

Outer radius plates

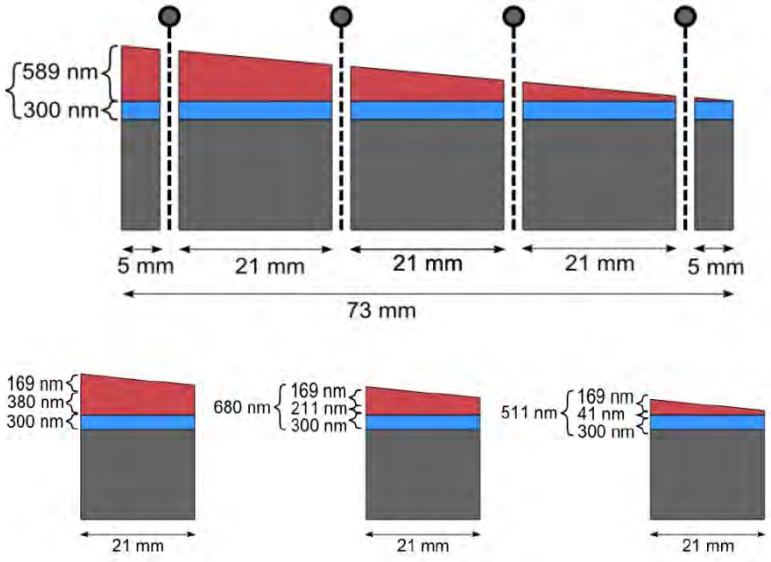
- Smaller length (~ 20 mm)
- Larger width (~ 100 mm)
- Dominating the telescope HE
- Edge effects more important

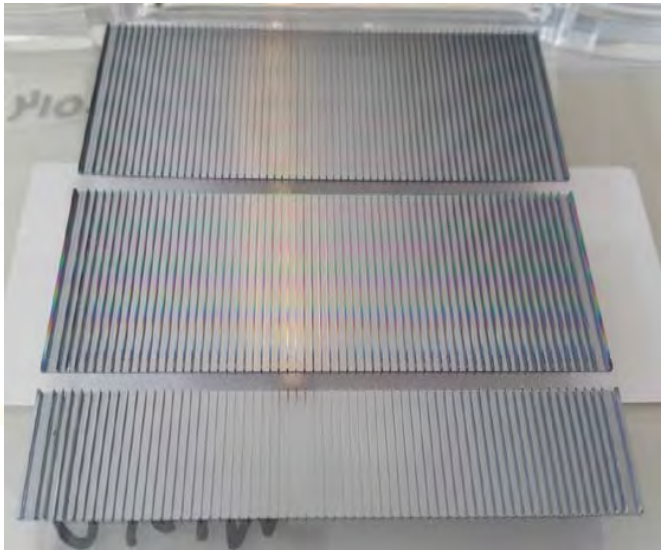


"mother-plate" 90x73.3 mm

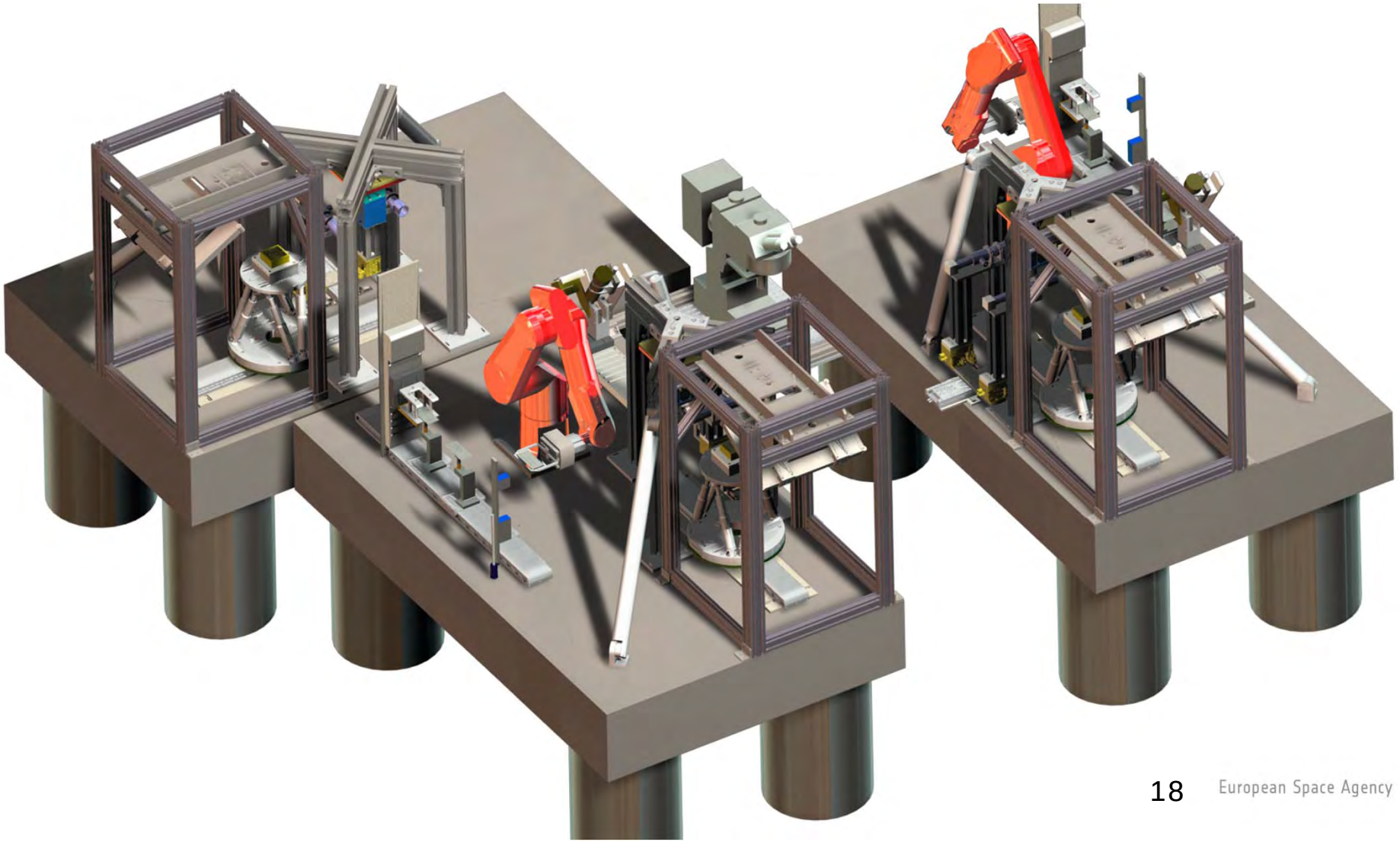


Final plate 90x21mm





Setting up inner and outer radii stacking robots

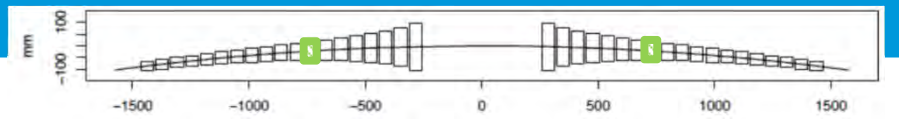


Main SPO Development Activities

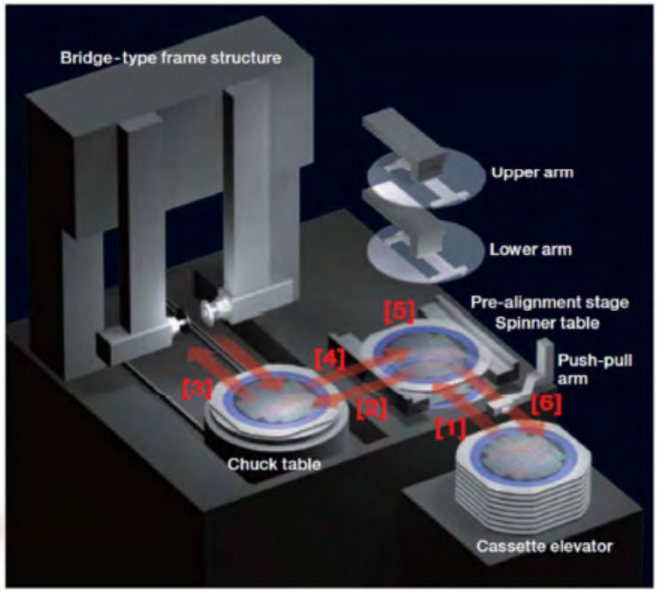
4rd area: Industrialisation Aspects

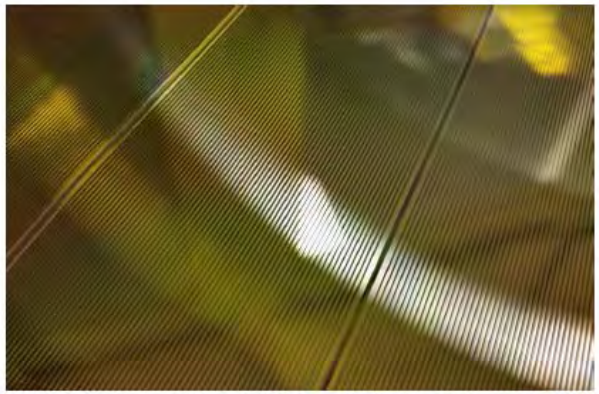
- Concluded SPO Industrialisation TDA: SPIN
- Issued ITT for coated mirror plate production
- Addressing industrialisation aspects in all activities
- Planned activity on SPO MM engineering model
- Planned activity on SPO manufacturing facility design

Middle radii – increasing plate production capabity



1. Increasing plate production capacity
   - Up to 1000 plates should become available for experiments in the coming 1.5 years
2. Results of first ribbing and dicing tests in one single run look promising
3. Investing also in
   - Automated wetbenches
   - Die upgrades
   - Additional mandrels
   - Stacking time reduction
   - Bond strength improvements

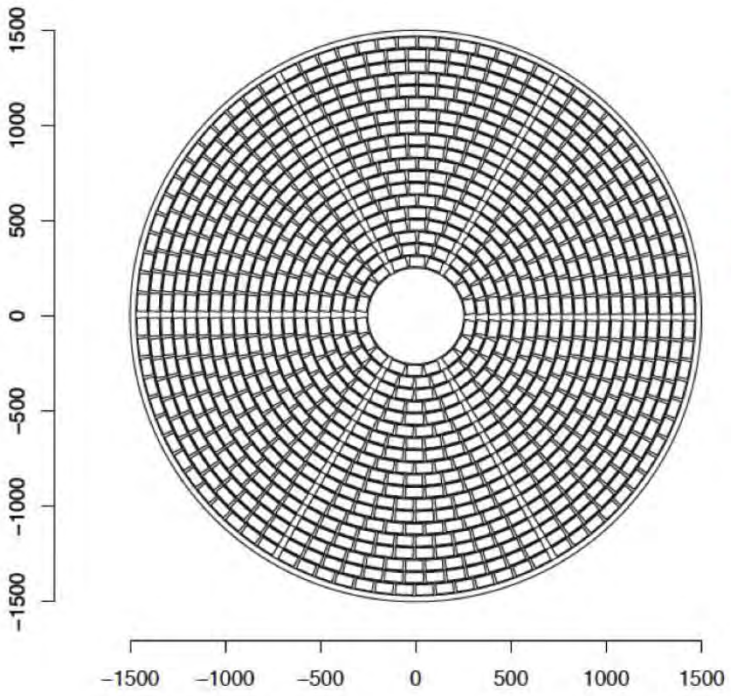


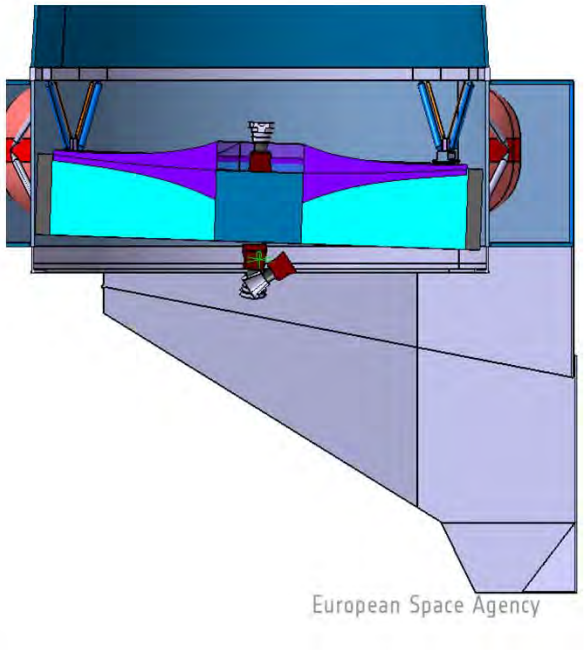


Main SPO Development Activities

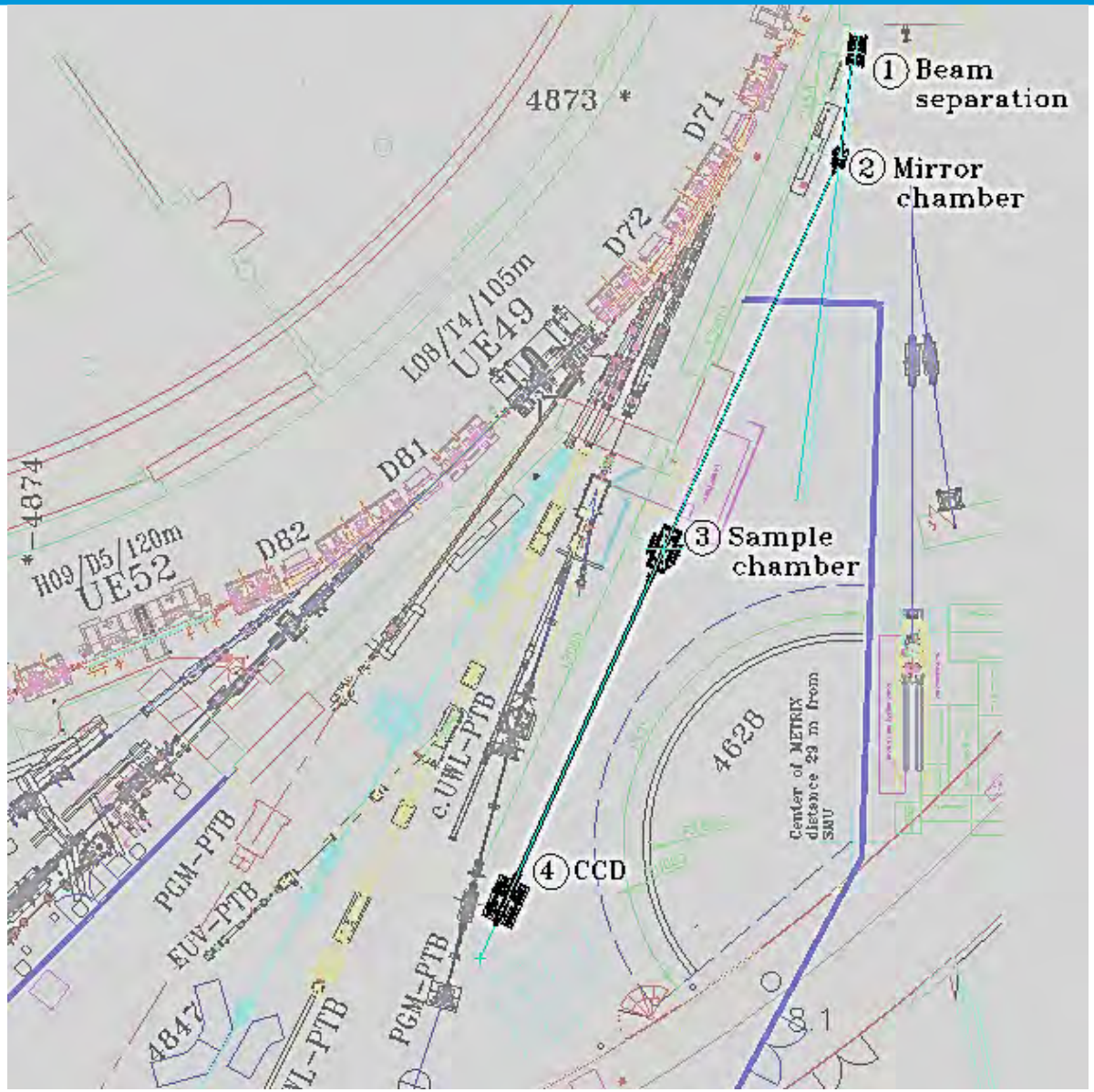
5th area: Accommodation and System Aspects

- Concluded SPO end2end TDA: HPO
- Placing activity on SPO MM AIT
- Issued ITT for Instrument Selection Mechanism
- Planned activity on telescope structure and optics integration
- Test facilities

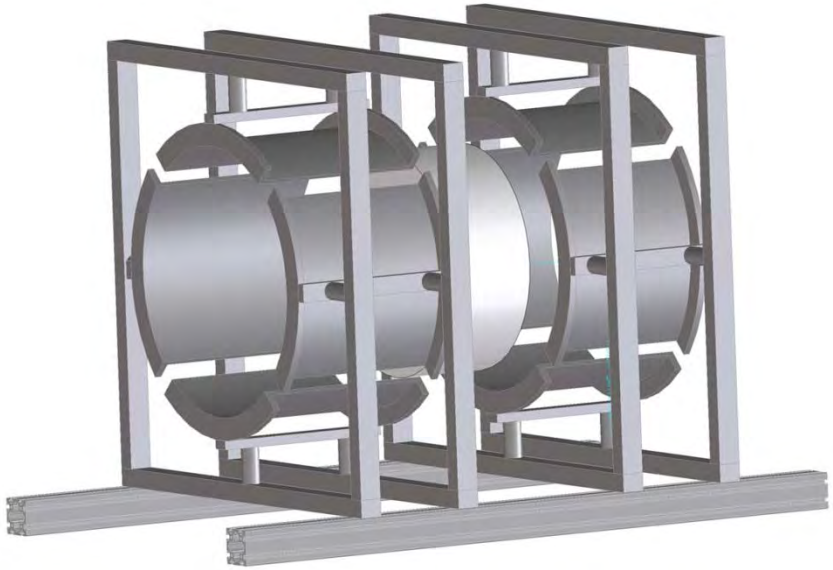


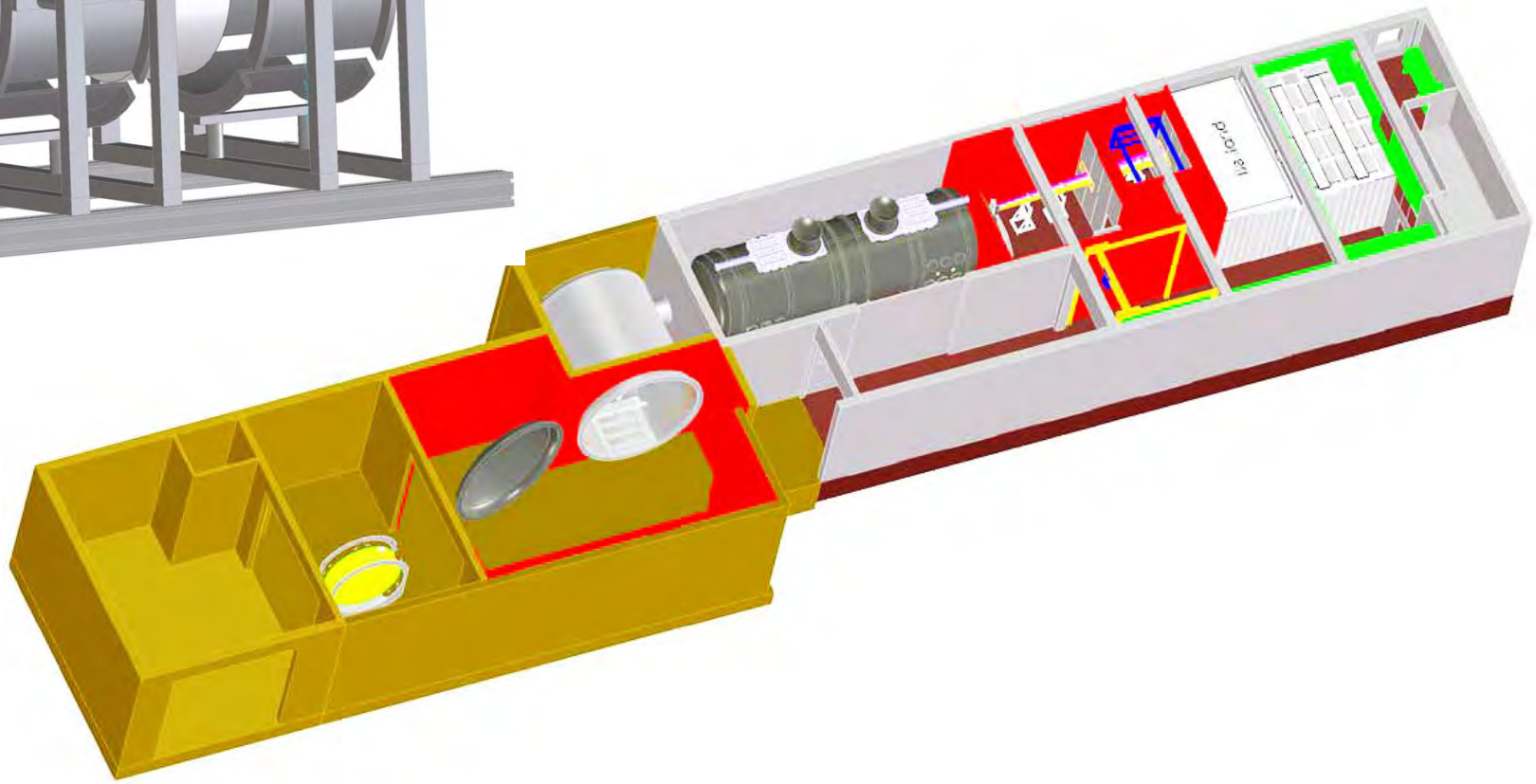


X-ray Test Facilities:
Bessy 12 m Beamline

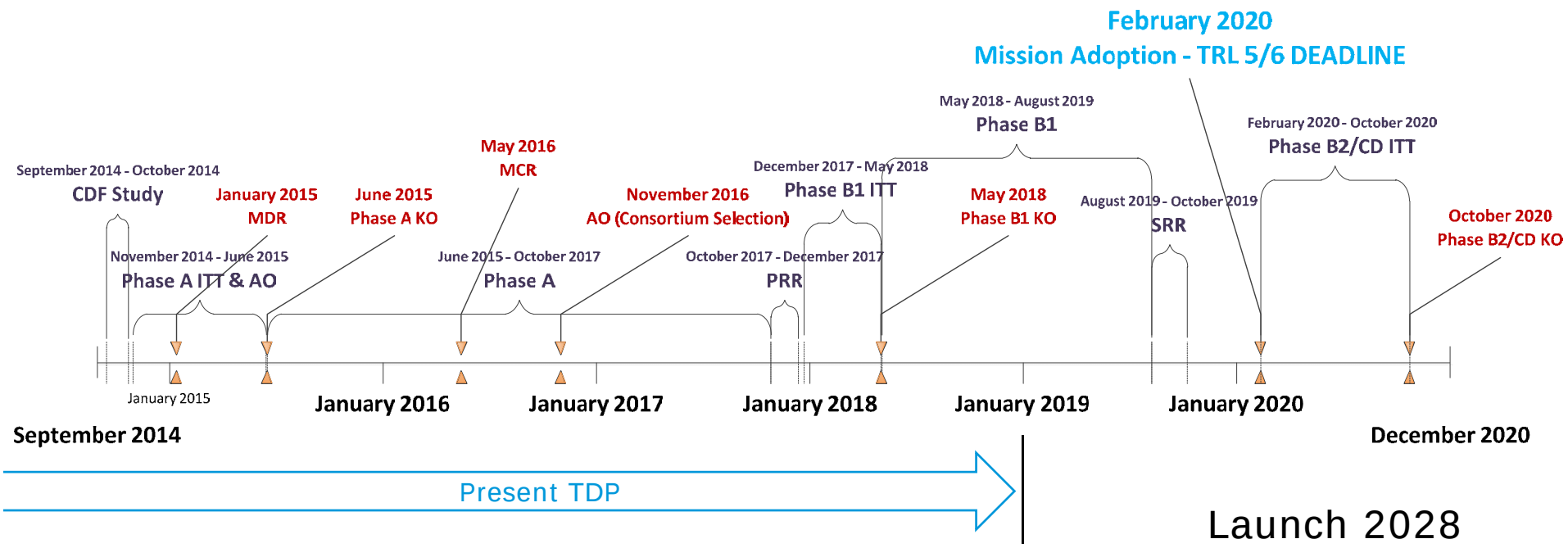


X-ray Test Facilities: Thermal Test Equipment and Large Optics Accommodation at Panter

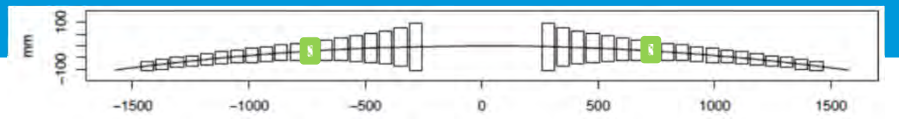




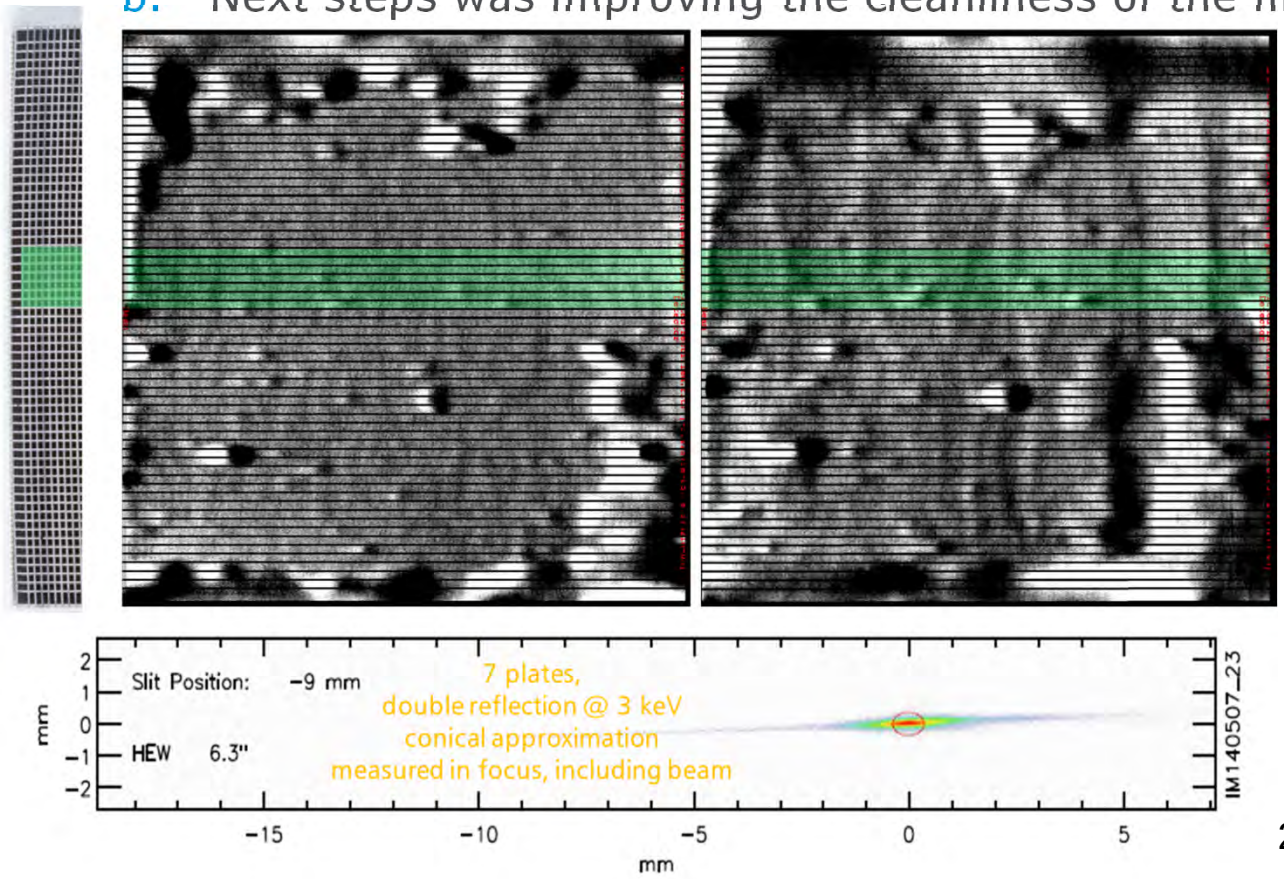
ATHENA TRL & Schedule Constraints



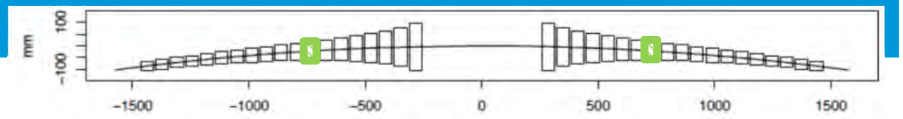
Middle radii – work on angular resolution



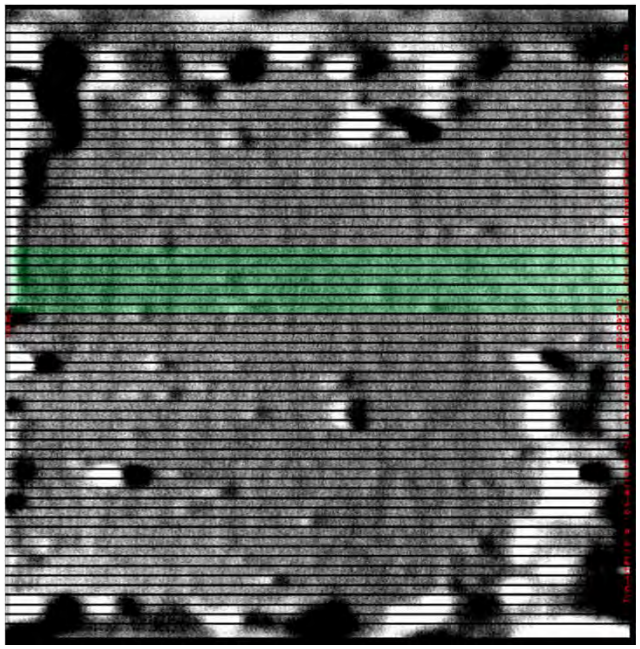
1. June 2014 Panter measurement gave 6.3” on 10% of small MM
    a. Had solved convex mandrel issue
    b. Next steps was improving the cleanliness of the mandrel

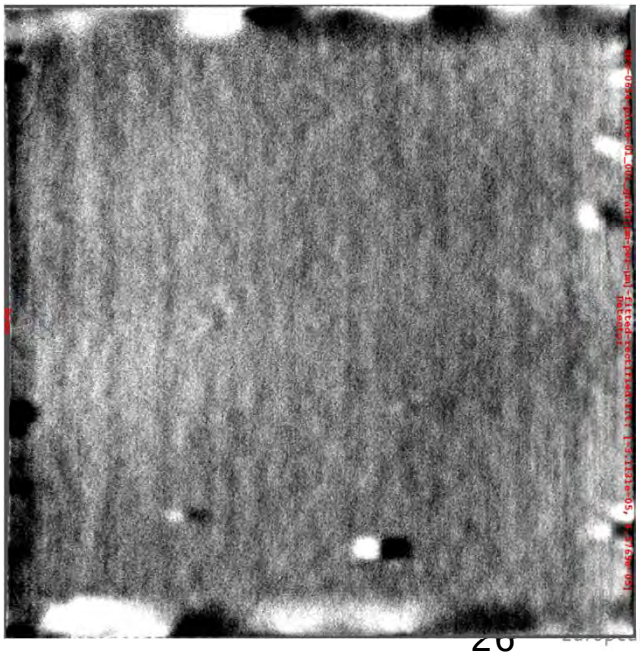


Middle radii – work on mandrels

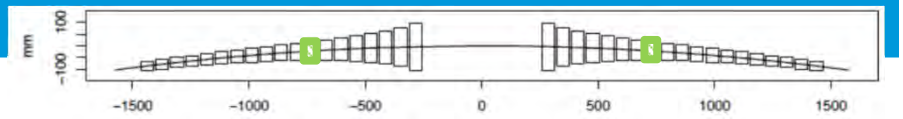


1. Mandrel had surface protrusions
    a. result of IBF process at Zeiss
2. Mandrel super-polishing introduced
    a. Resulted in much cleaner mandrel surface
    b. Unclear how super-polish affects figure of grooved mandrels

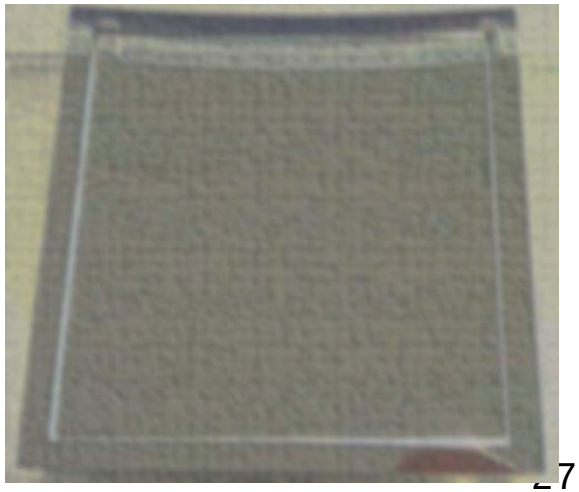




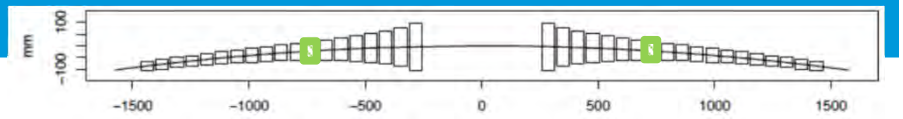
Middle radii – work on mandrels



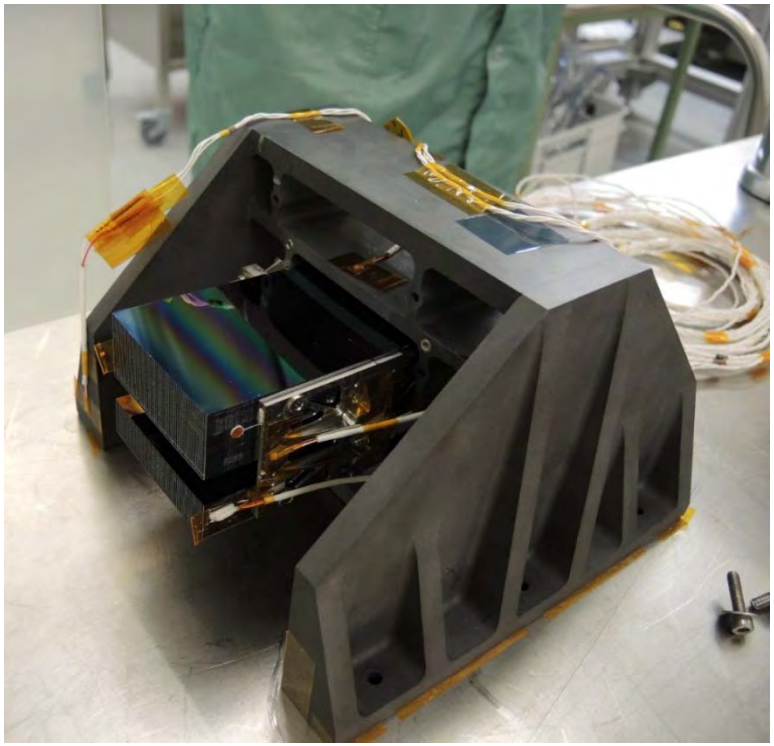
1. Grooved mandrels have some drawbacks
    a. can not be directly measured after grooving
    b. grooves are not simple to clean before stacking
2. Developed new generation of ‘holey’ mandrels
    a. Can be measured in X-rays and with cosine/Zeiss metrology
3. Drawback of improved cleanliness is bonding of stack to silicon mandrel
    a. Developing now passivation methods

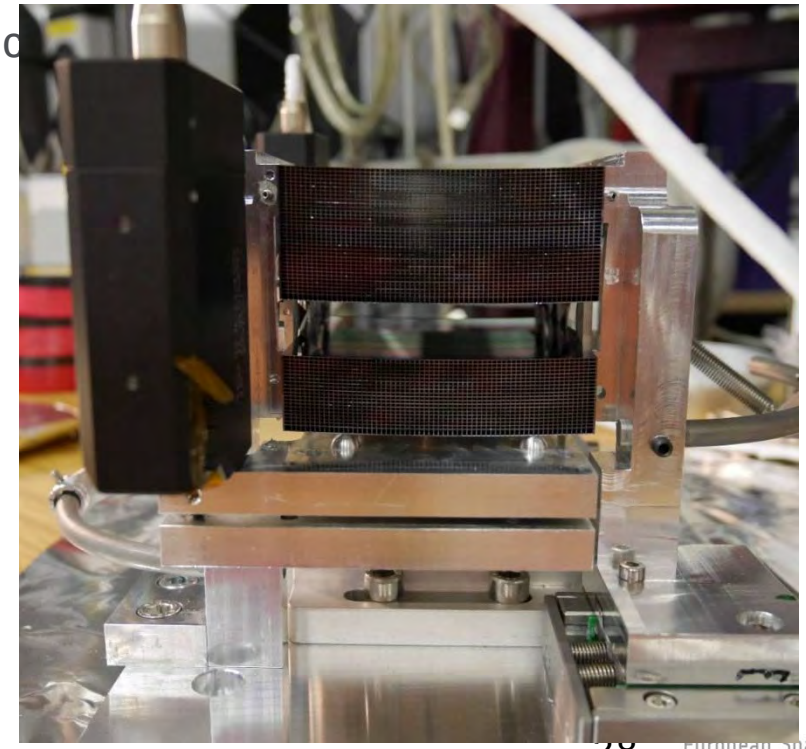


Middle radii – work on angular resolution

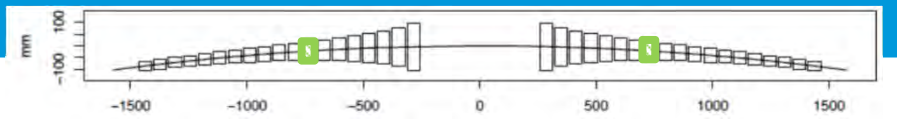


1. Assembled a test mirror module with stacks from holey mandrels
    a. Glued in January 2015, measured at BESSY and at PANTER
    b. Due to PANTER detector problem measured at 8 m intrafocal, at BESSY in focus

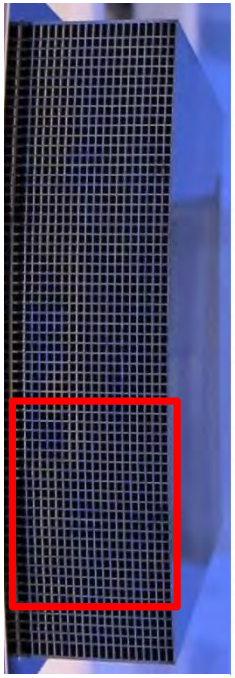


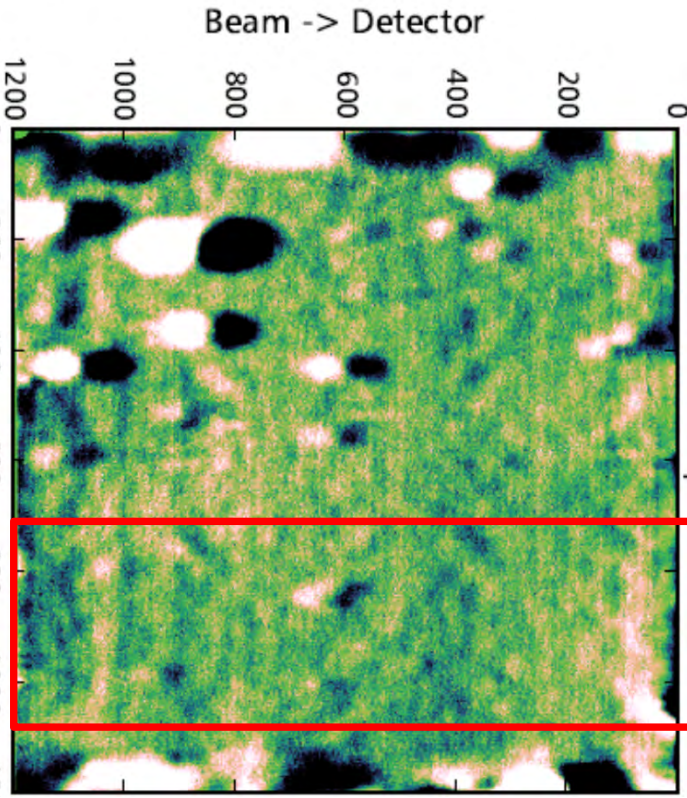


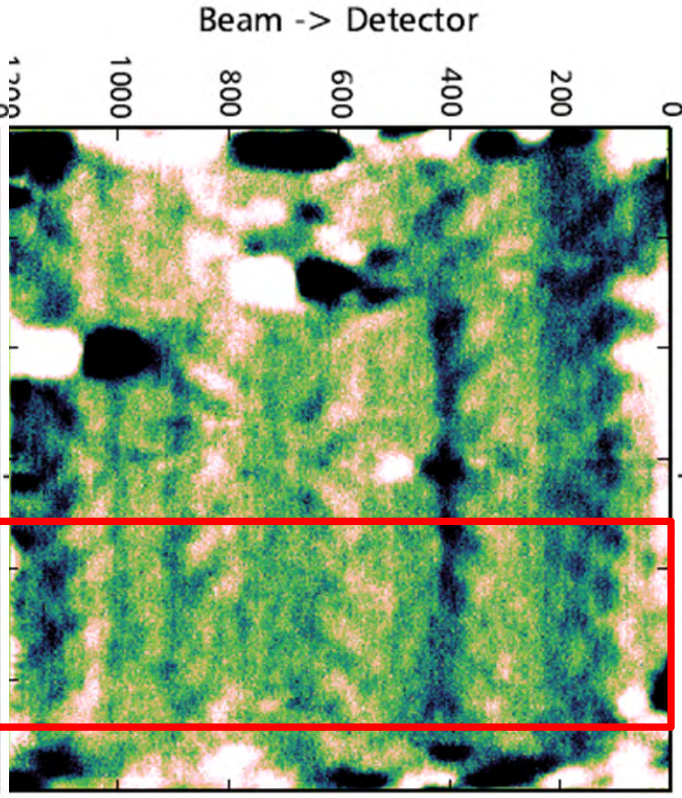
Middle radii – work on angular resolution



1. Metrology predicted good (clean and well bonded) area

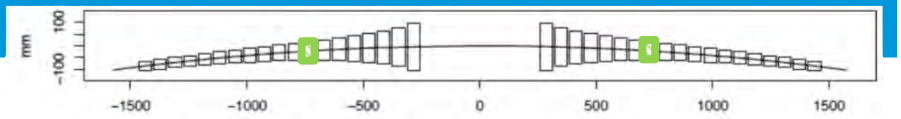




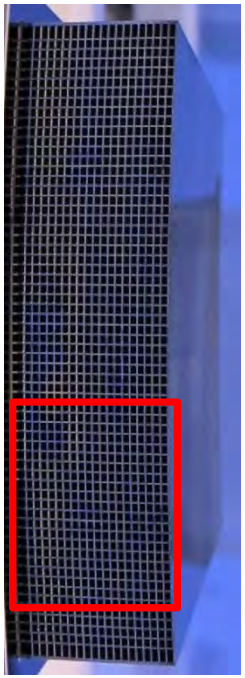


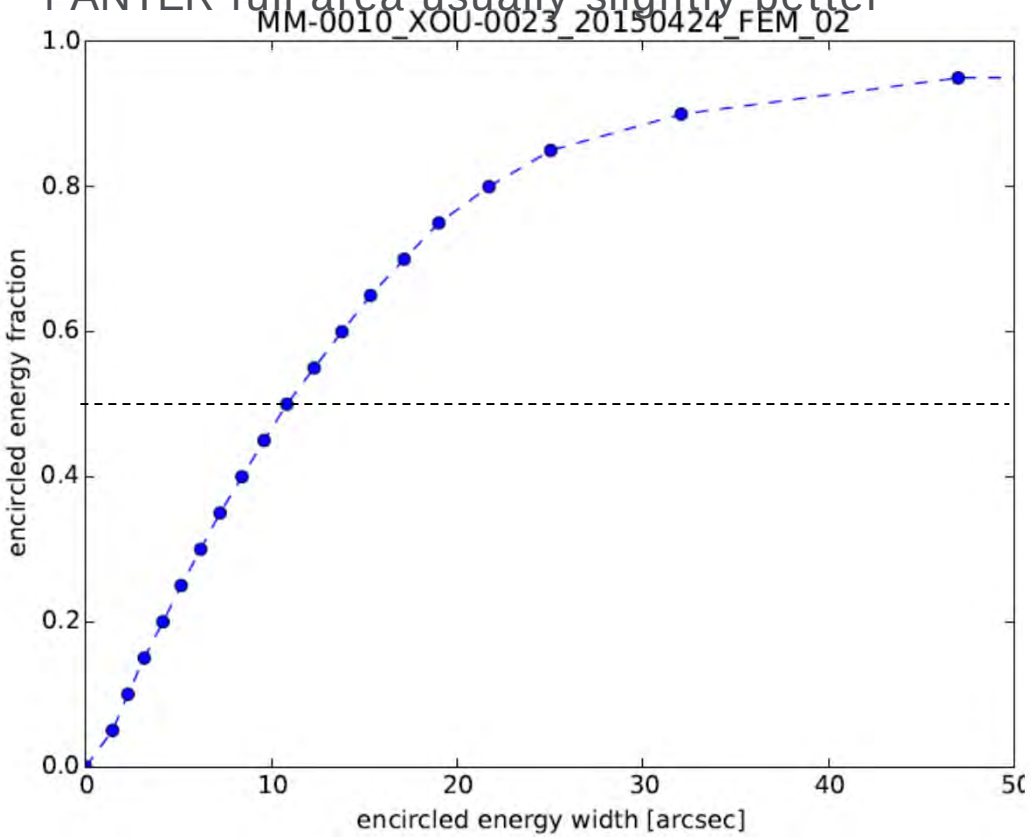
20 plates primary secondary

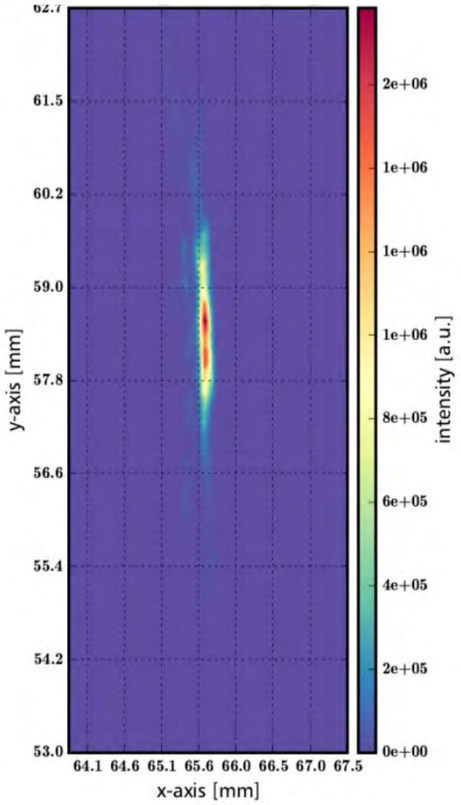
Middle radii – work on angular resolution



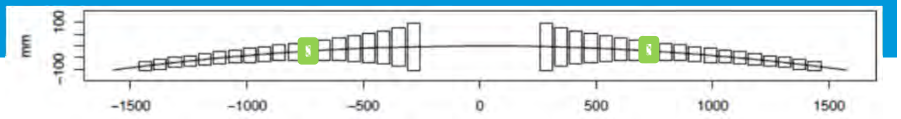
1. 1/3 of 20 plate MM has 10.5” @ 20 m
    a. measured at BESSY @ 3 keV, includes direct beam
    b. PANTER full area usually slightly better



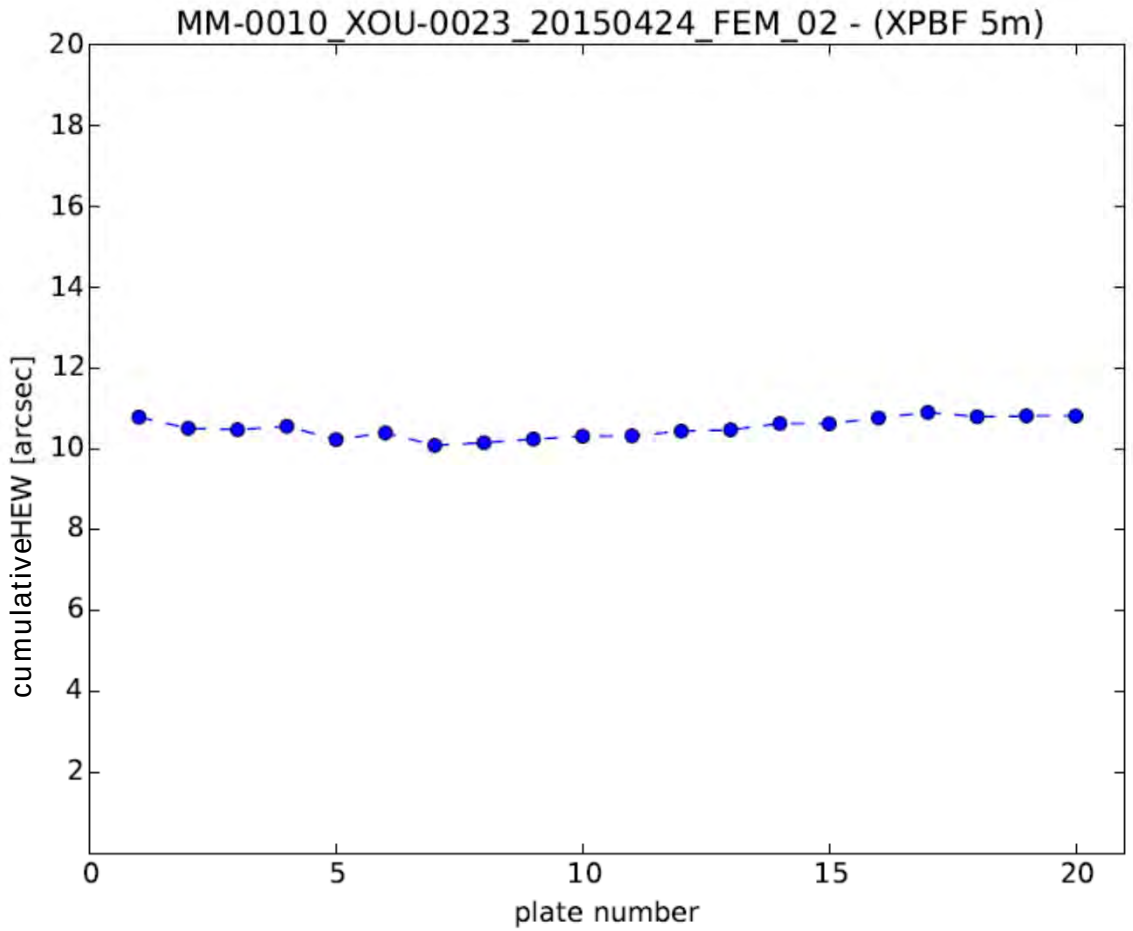




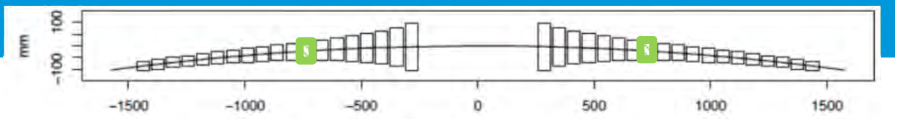
Middle radii – work on angular resolution



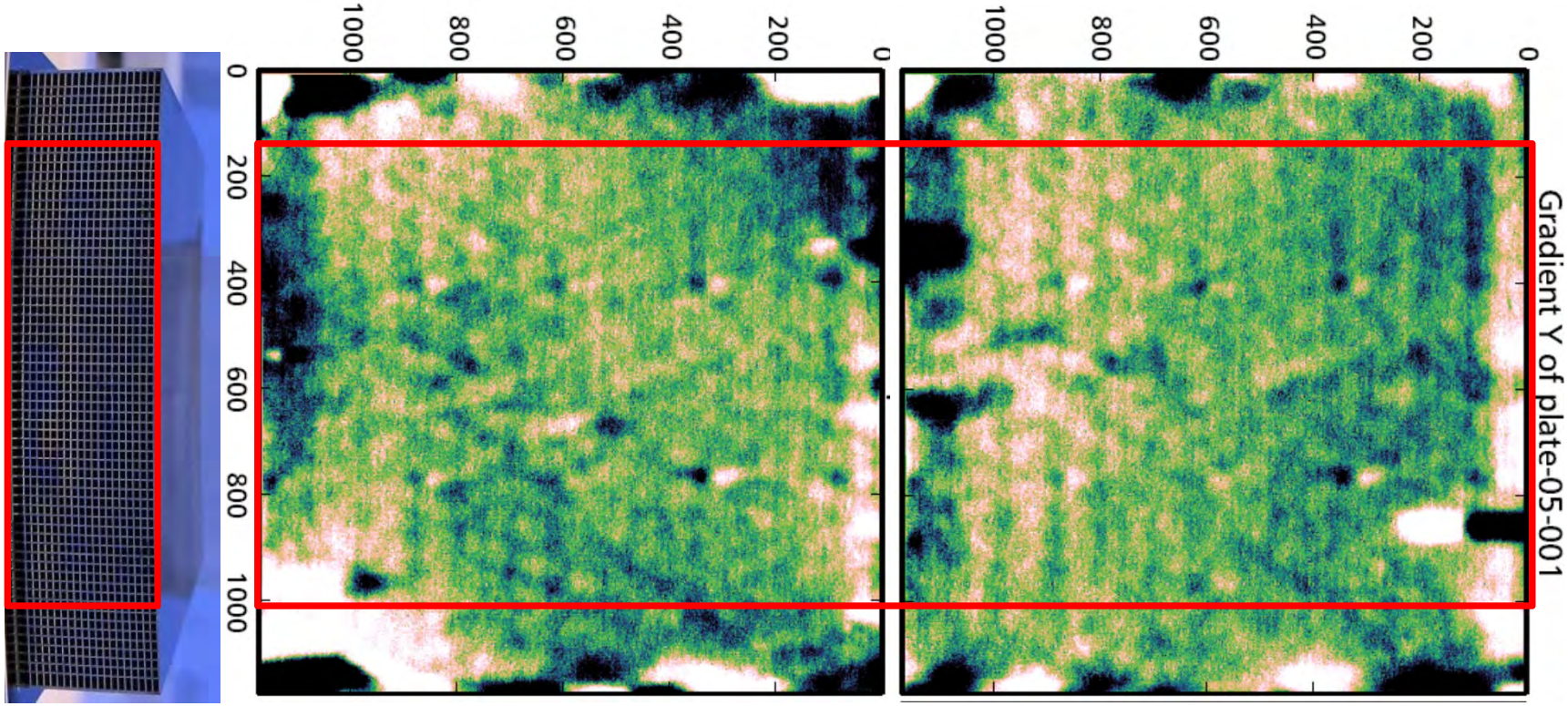
1. Found stack up errors to be strongly reduced



Middle radii – work on angular resolution



1. Further improvement of mandrel passivation process
   a. Leads to large completely clean area

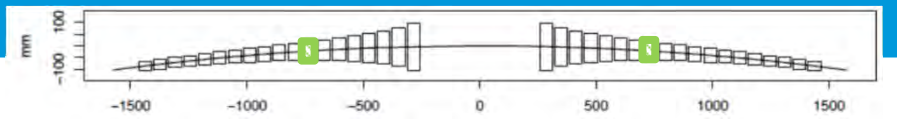


20 plates

primary

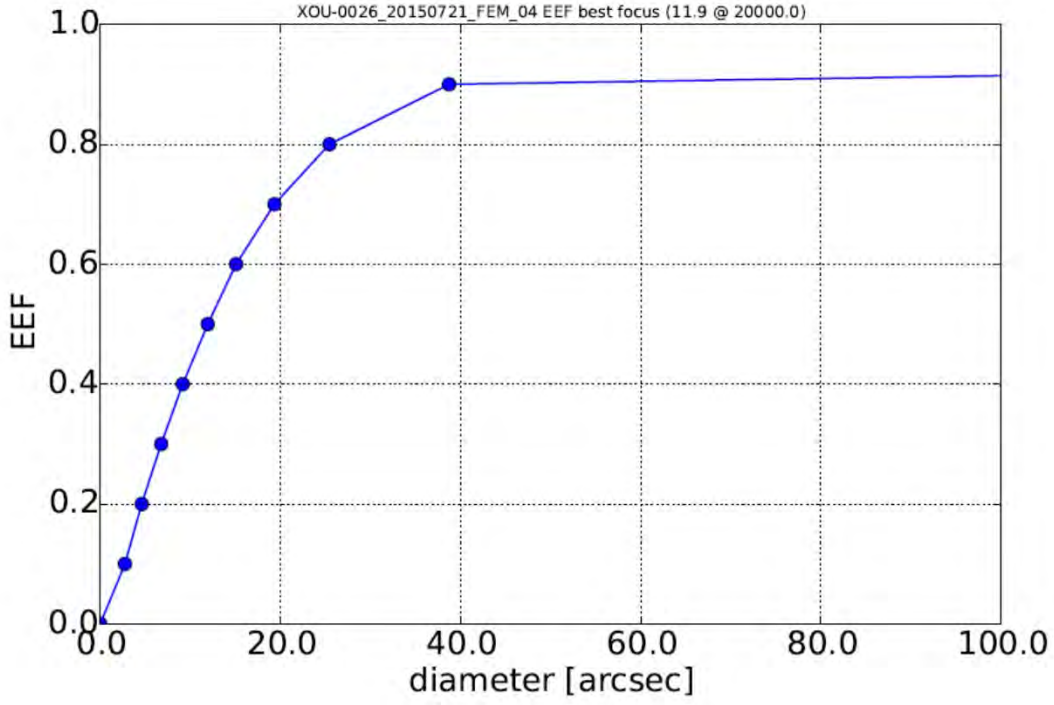
secondary

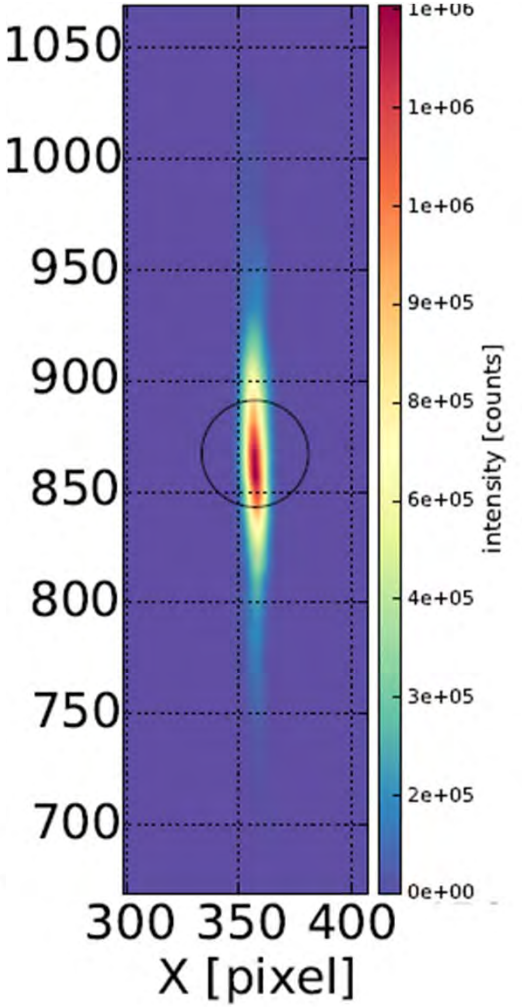
Middle radii – work on angular resolution



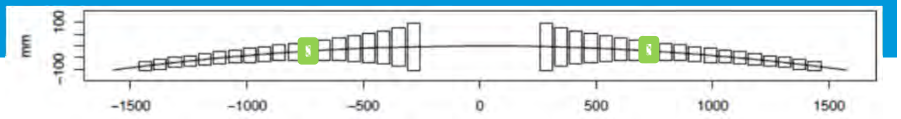
1. 70% of 20 plate MM has 11.9” @ 20 m
    a. measured at BESSY @ 3 keV, includes direct beam
    b. Not using secondary curvature mandrels yet
    c. PANTER full area usually slightly better

20 plates

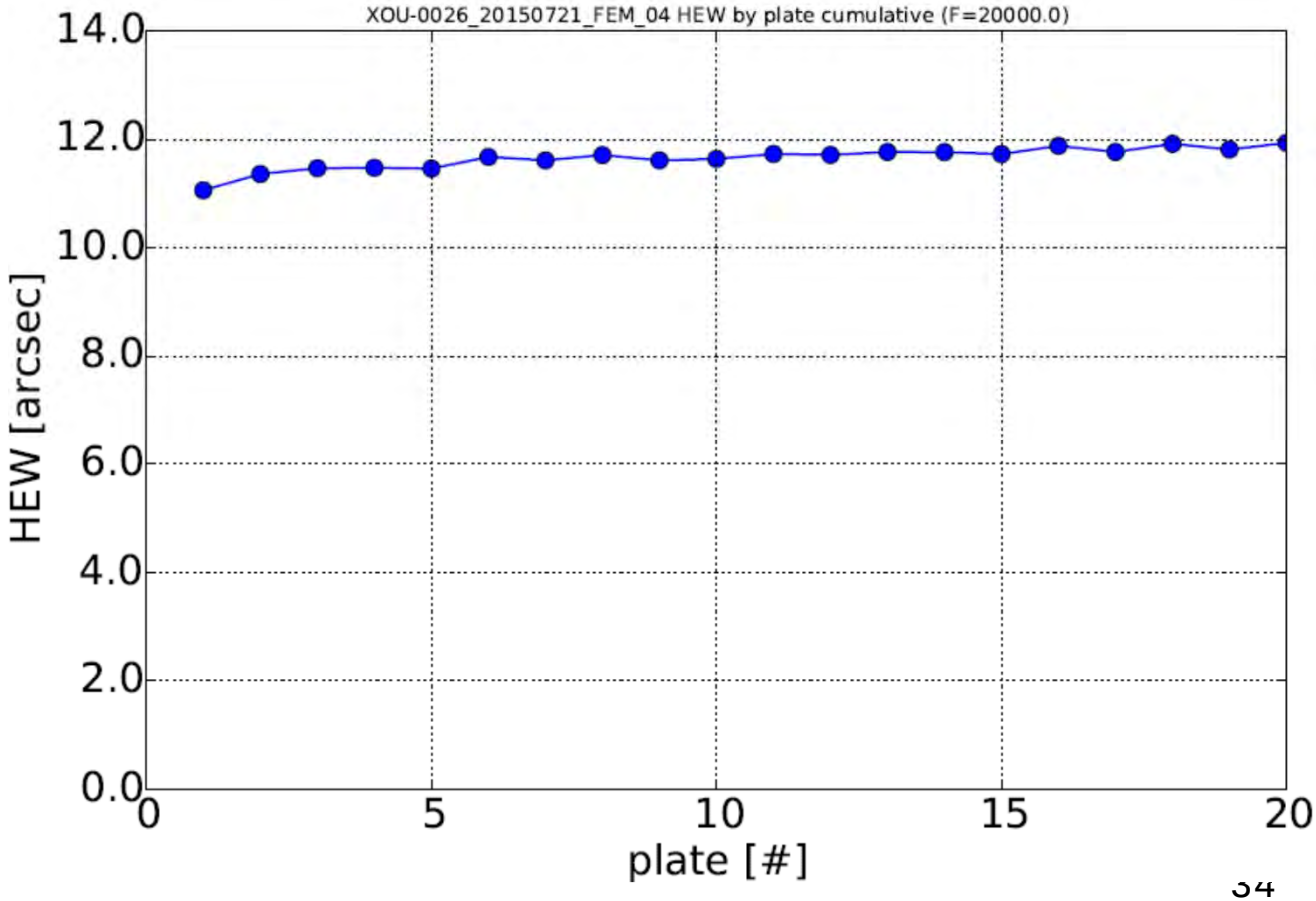




Middle radii – work on angular resolution



1. Again, we found stack up errors to be less than 1”



Status of the Optics for Athena

- Complementing the system level studies, the Athena **optics technology development continues** to follow the established and proven track (several new activities started or tendered),
- focusing on the **angular resolution**,
- the **environmental compatibility and industrialisation** for the middle, inner and outer mirror modules.
- In particular the **accommodation aspects** are gaining importance (e.g. AIT),
- and the required **X-ray test facilities** are being prepared.