Current Design of the Focusing Arrays onboard eXTP

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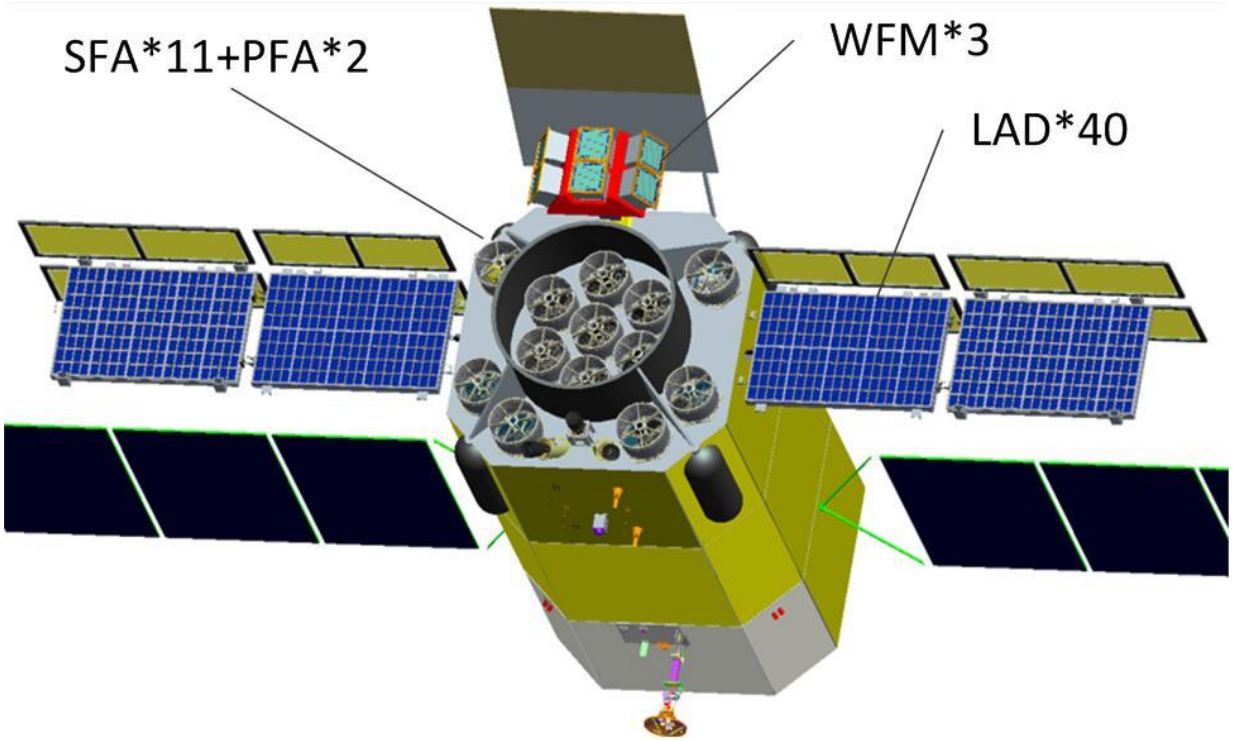
eXTP: enhanced X-ray Timing and Polarimetry Mission

- Payload characteristics
  - Short focal-length for multiple modules
  - Deployable panel for collimated modules
  - Independent polarimeters with imaging capability
  - Wide field monitor

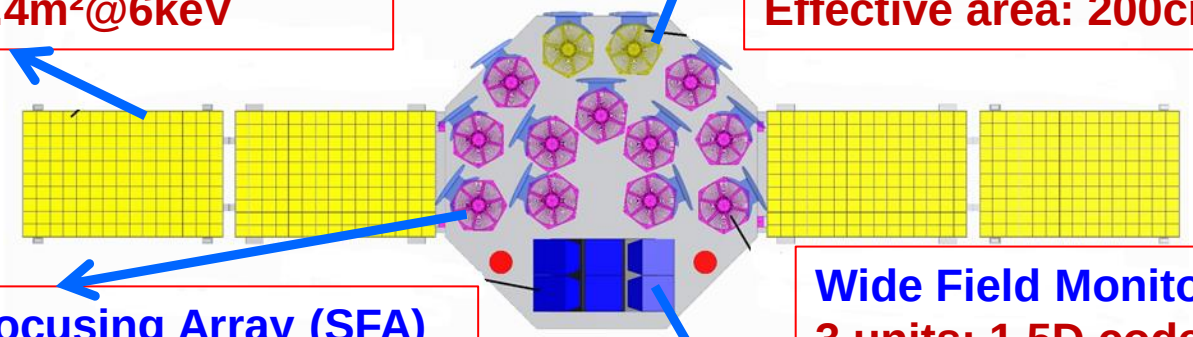
} Large eff. Area
High spectral res.
High throughput



Payload configuration

Large Area Detector (LAD)
40 modules: MCP collimator, SDD
Energy range: 2-30keV
Energy resolution: 250eV@6keV
Field of view: 1° (FWHM)
Time resolution: 10μs
Sensitivity: 10μCrab(10^4s)
Effective area: 3.4m²@6keV

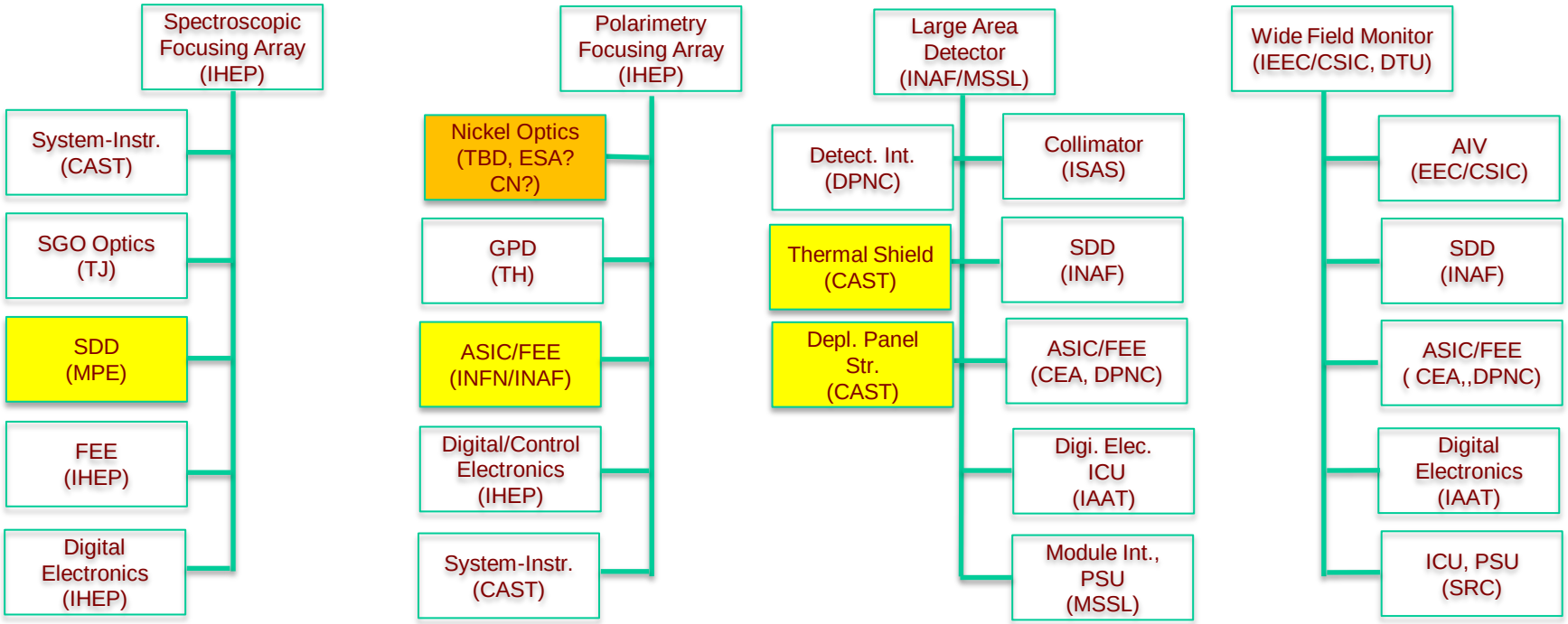
Polarimetry Focusing Array (FPA)
2 telescopes: FL4.5m, FoV12′, GPD
Energy range: 2-10(20) keV
Energy resolution: 1.8keV@6keV
Time resolution: 500μs
Angular resolution: 30″(HPD)
Sensitivity: 5μCrab(10^4s)
Effective area: 200cm²@2keV



Spectroscopy Focusing Array (SFA)
11 telescopes: FL 4.5m, FoV 12′, SDD
Energy range: 0.5-10keV
Energy resolution: 180eV@6keV
Time resolution: 10μs
Angular resolution: 1′(HPD)
Sensitivity: 0.16μCrab(10^4s)
Effective area: 0.6m²@6keV,
0.9m²@2keV

Wide Field Monitor (WFM)
3 units: 1.5D coded mask, SDD
Energy range: 2-50keV
Energy resolution: 500eV@6keV
Field of view: 3.2 Sr
Location accuracy: 1′
Angular resolution: 5′
Time resolution: 10μs
Sensitivity: 4mCrab(1day)
Effective area: 170cm²@6keV

Responsibilities of the instruments

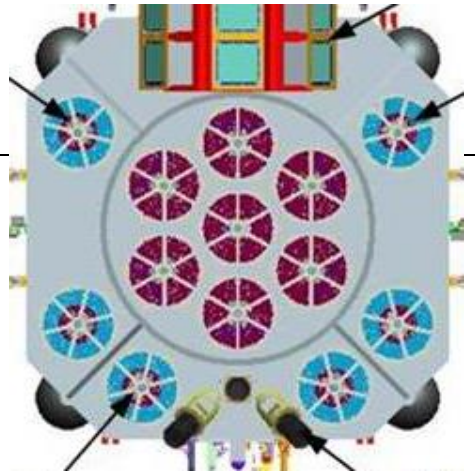


China
(originally from the XTP mission)

Europe
(originally from the LOFT mission)

A ‘new’ instrument team had been formed in November 2016, for the preliminary design of SFA and PFA, since HXMT was ready for delivery and the manpower was released.

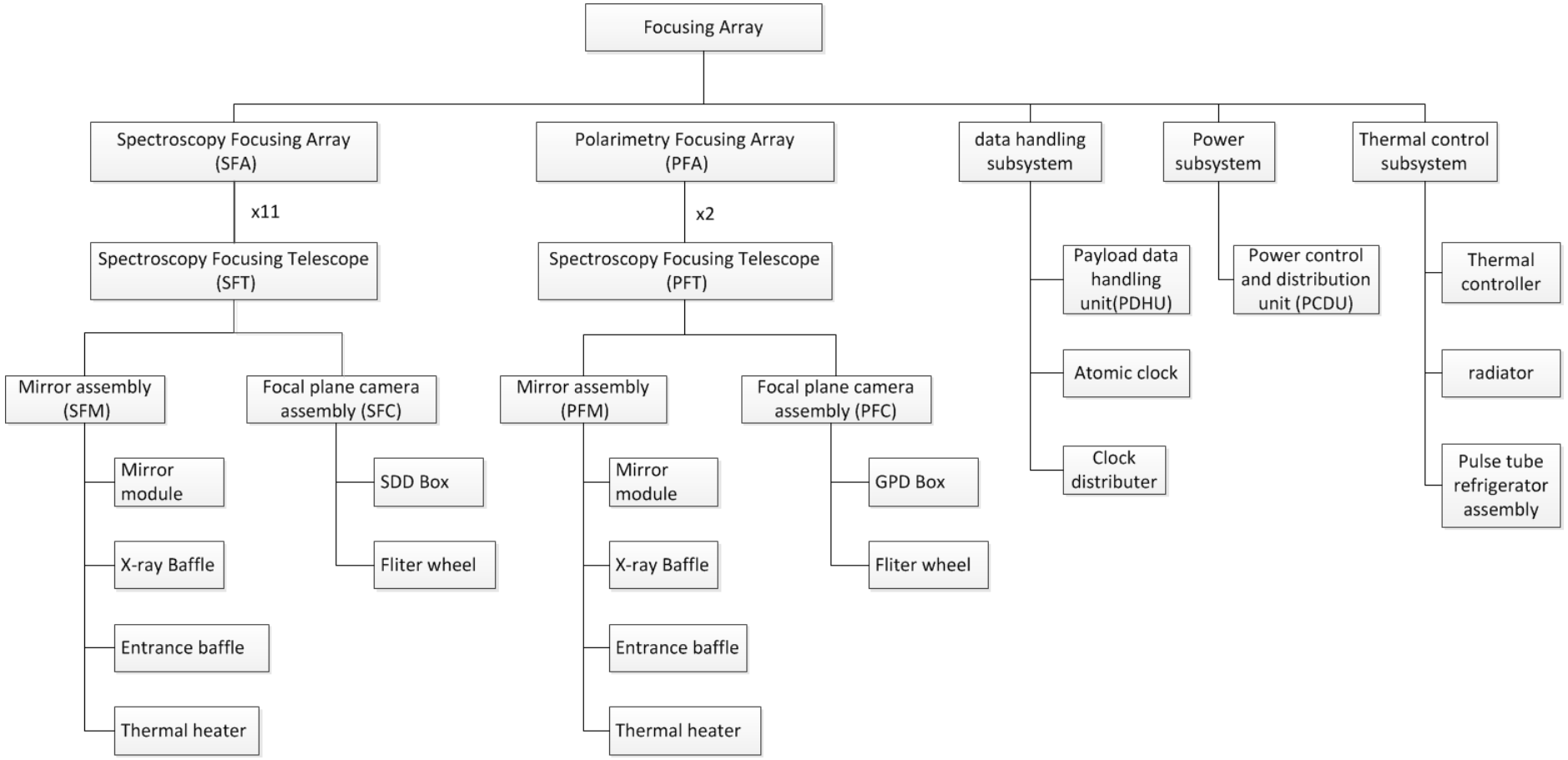
The focusing array



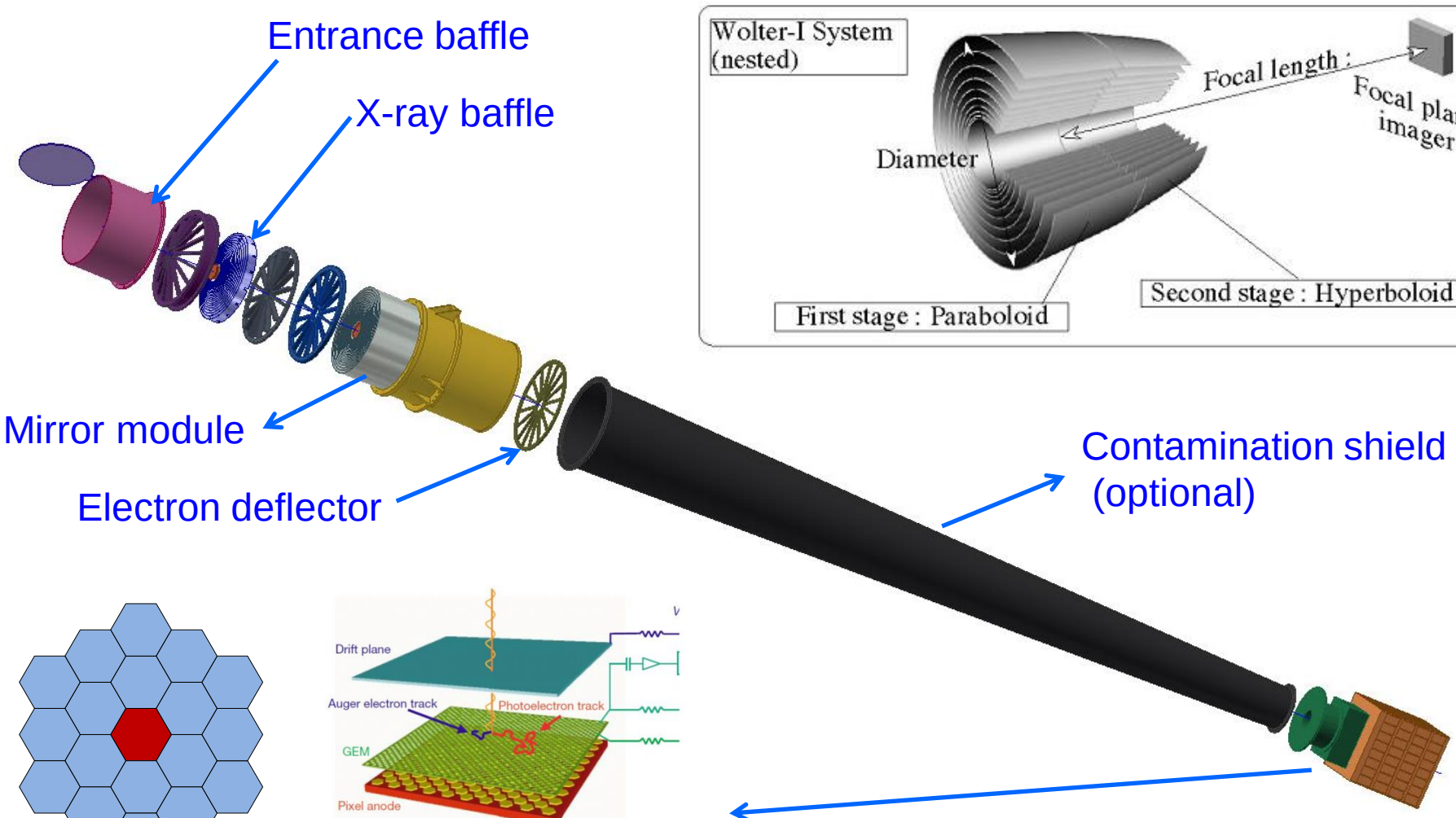
13 independent, co-aligned telescopes

- Spectroscopic Focusing Array (SFA)
  - 11 mirror assembly equipped with SDD detectors
- Polarimetry Focusing Array (PFA)
  - 2 mirror assembly equipped with imaging gas pixel photoelectric polarimeters
- Focal length: 4.5m, Field of view: 12′
- Mirror module envelope: ≤550mm in diameter
- Accommodation on spacecraft
  - All mirror assemblies mounted on a carbon-fiber optical bench, the mirror platform
  - All focal plane camera assemblies mounted on the instrument platform
- Alignment:
  - Mirror modules: <30″
  - Focal plane detectors : ＜0.5mm (lateral to Focal point)

Product tree (preliminary)



Preliminary design of the telescopes



SDD array for SFA

GPD for PFA

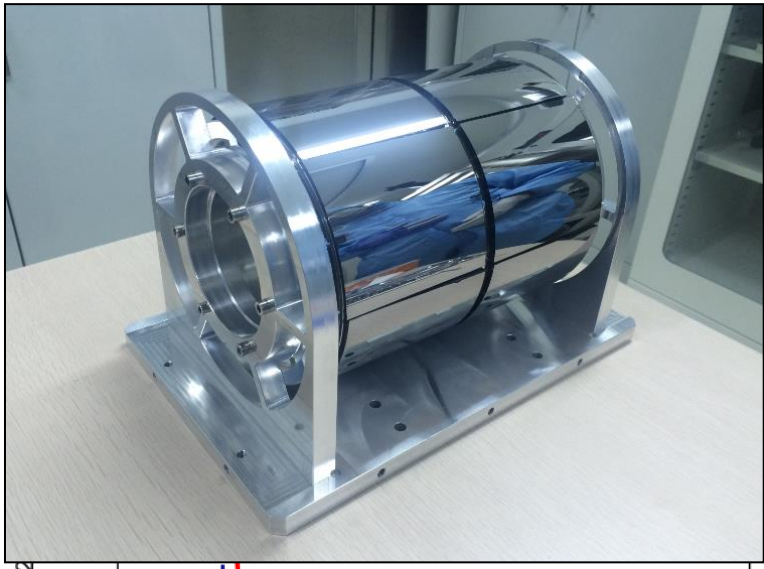
X-ray optics

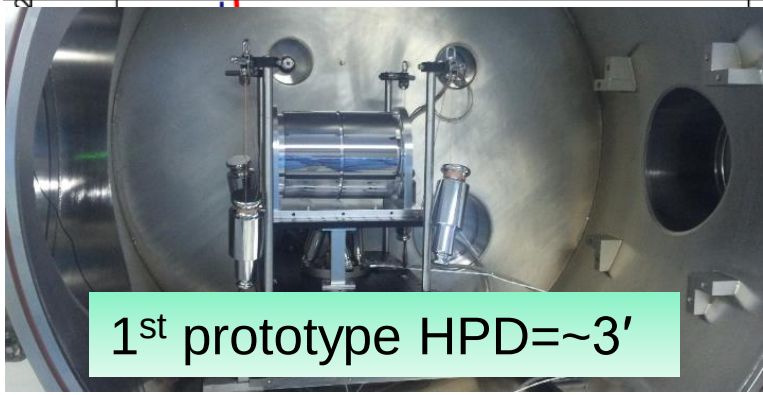
Item	SFA (11 modules)	PFA (2 modules)
Focal length	4.5 m	
Field of View	12′	
Angular res.	<1′ (HPD), 3′ (W90)	<30″(with a goal of 15″) (HPD)
Effective Area (total)	~0.9 m^2 @2 keV ~0.6 m^2 @6 keV	>200 cm^2 @2 keV (with a goal of 250 cm^2)
Mirror Effective Collecting Area (1 module)	>800 cm^2 @ 2 keV >500 cm^2 @ 6 keV	
Energy range	0.5 - 10 keV	2 - 10 keV
Envelope	≤550mm in diameter	
Working temperature	20±2℃	

- Solutions: Nested (conical) Wolter-I system
  - Slumped glass optics (SGO) for SFA (with a goal for PFA also)
  - Electro-formed Nickel replication (ENR) for PFA, backup for SFA

Slumped glass optics (SGO) (Tongji University)

- Optical design for SFA
  - Wolter-I conical approximation
  - Focal length: 4.5m
  - ϕ=100-450mm
  - Number of shells: 176
  - Mirror length: 2*100mm
  - θ = 0.15~0.71°
- Status
  - Development of slumping, metrology, simulation and assembly
  - Prototype development and test
  - Performance of free standing mirrors, improved from 140-220″ to 60-110″
- Details in Zhanshan Wang's talk
  - *Wednesday 12:15 – 12:30 Development of X-ray imaging telescope optics for eXTP mission*

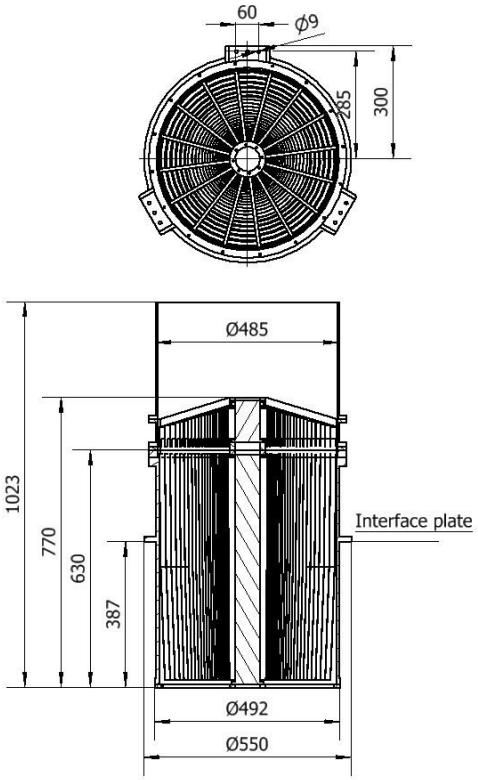


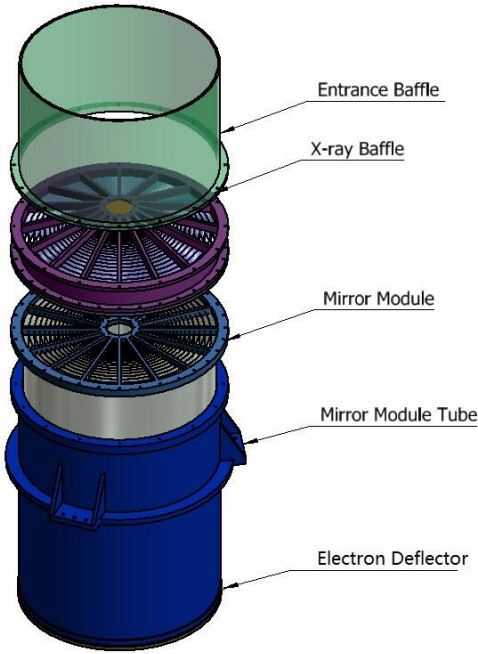


Electro-formed Nickel replication optics

- Nested Wolter-I system
- Focal length: 4.5m
- Field of view: 12′
- Angular resolution: 30″(15″)

- Status:
  - A proven technology in Italy, similar to XMM and eROSITA (OAB & Media Lario)
  - A study team had been formed at IHEP, for the optical design, mechanical design, metrology and calibration.

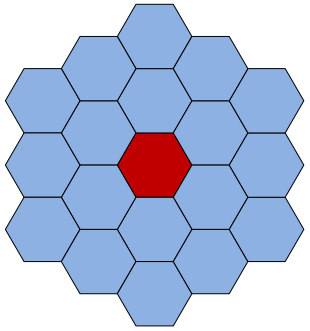




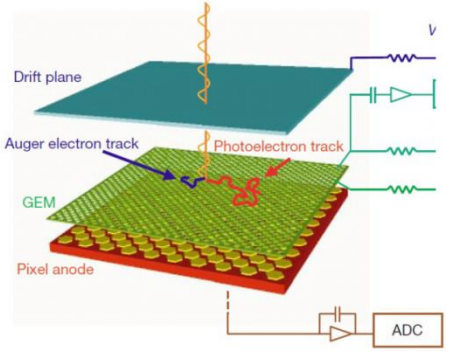
Preliminary design of the polarimetry focusing mirror assembly

Focal plane camera assemblies

	SDD for SFA	GPD for PFA
Sensitive area	≥16×16 mm^2 (12′)	15*15mm^2(11.5′)
Spatial resolution	=W90 (4mm,3′)	0.1mm (4.6″)
Number of pixels	19	~10^5
Energy range	0.5-20 keV	2-10 keV
Energy resolution	<180 eV@6keV	<1.8keV@6keV
Time resolution	< 10 μs	< 500μs



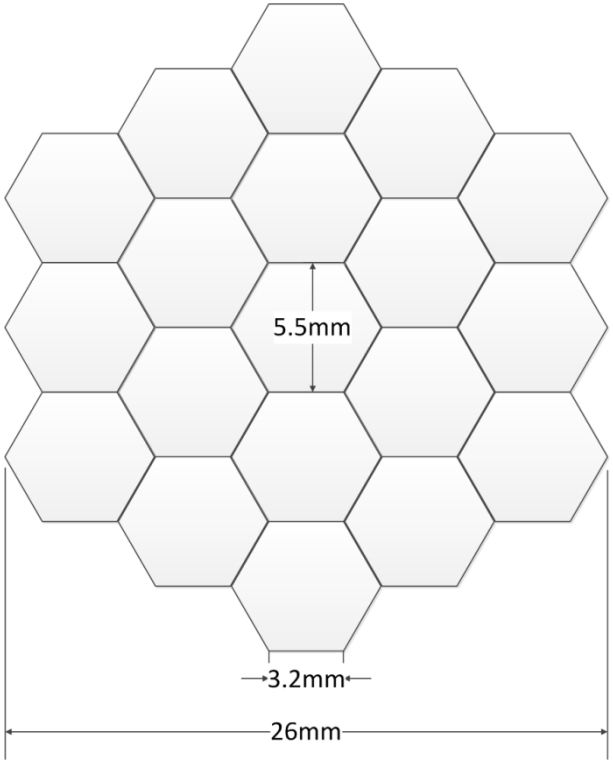
SDD array for SFA

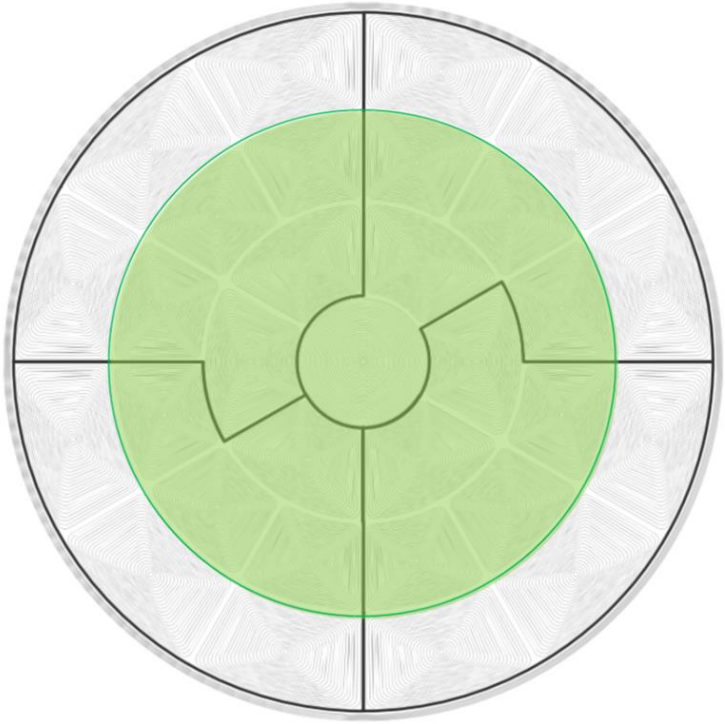


GPD for PFA

SFC: Layout of the SDD array

- Pixel size
  - W90(3′) = 4mm@4.5m FL + misalignment(±0.5mm) ➔ 4~5.5mm
- Layout: 2 solutions
  - 19 hexagon cells each with side length of 2.3~3.2mm and area of 13.7~26.6mm² (field of view: 14~19′)
  - Inherit the HTRS/IXO concept with cell area of 14.6mm²

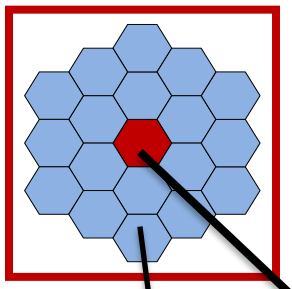


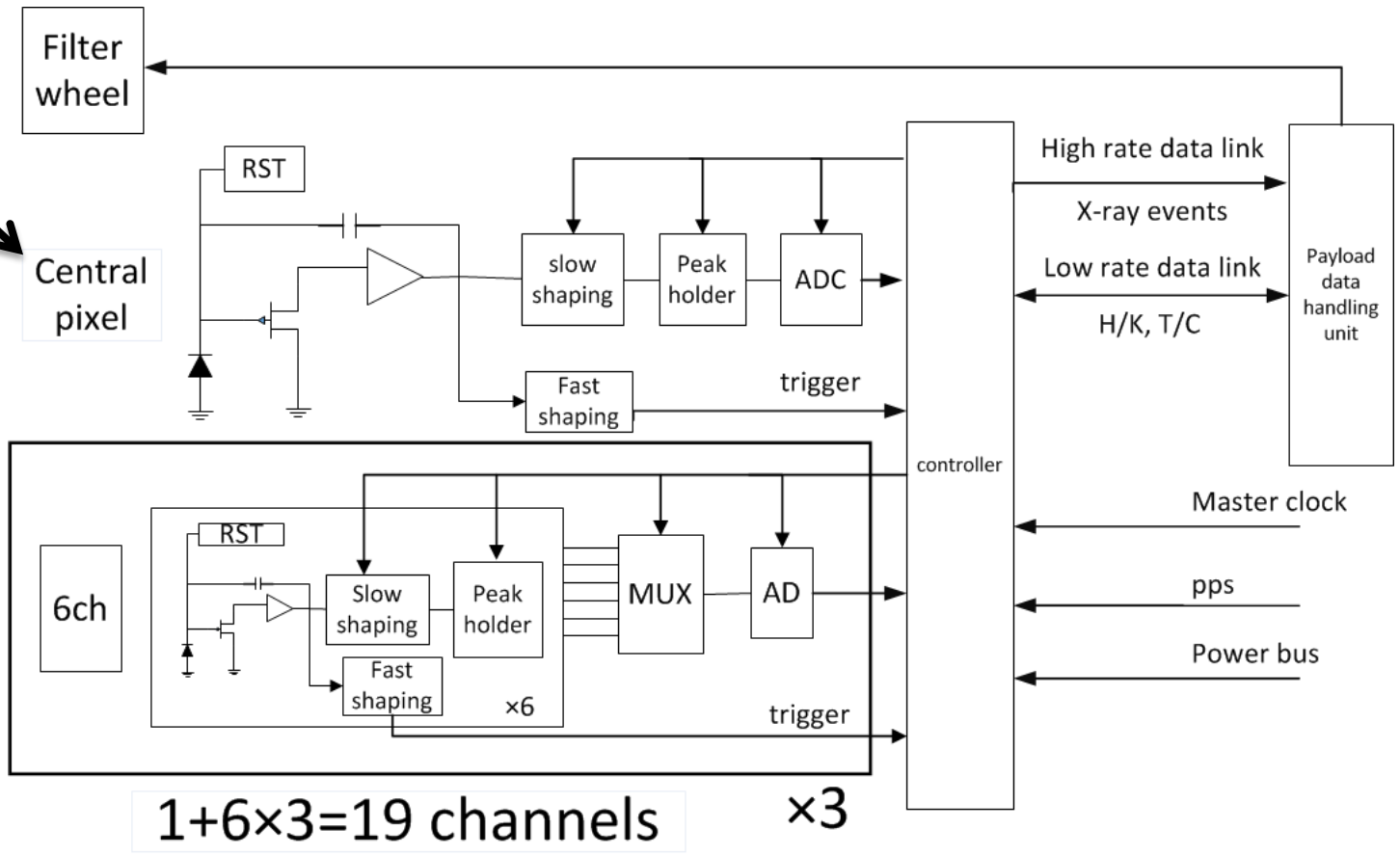


SFC: SDD & readout electronics features

- Requirements
  - Energy range: 0.5-20keV
  - Energy resolution: ＜180eV@6keV (end of life)
  - Time resolution: ~10μs
  - Life time: 5y + extension
- Solutions
  - Sensitive thickness：450μm
  - Low noise charge preamplifier
    - JFET on chip or monolithic cmos preamplifier (e.g. CUBE from XGLib)
  - Timing: atomic clock + GPS (accuracy better than 100ns)
  - Slow shaping time: ~μs, total processing time ≤10μs
    (throughput ≥ 95%@1Crab)　(1Crab ≈ 5kcps)
  - Fast shaping time: ≤ 200ns (pile up ≤ 0.1%@1Crab)
  - Light shield: 100~150nm Al on chip, and different filters on the filter wheel
  - Proton shielding: passive (Al case with composite materials)
  - Calibration: radioactive sources on filter wheel
  - Working temperature: 40±1℃ (goal: -100 ~ -80℃, ±0.5℃)

SFC functional block diagram

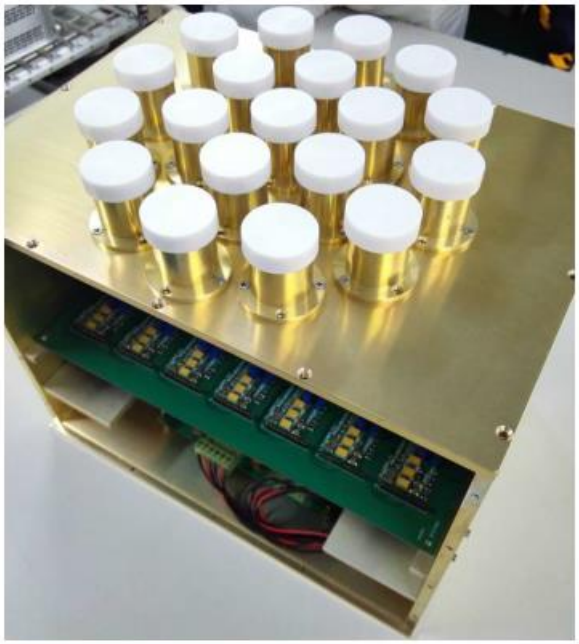




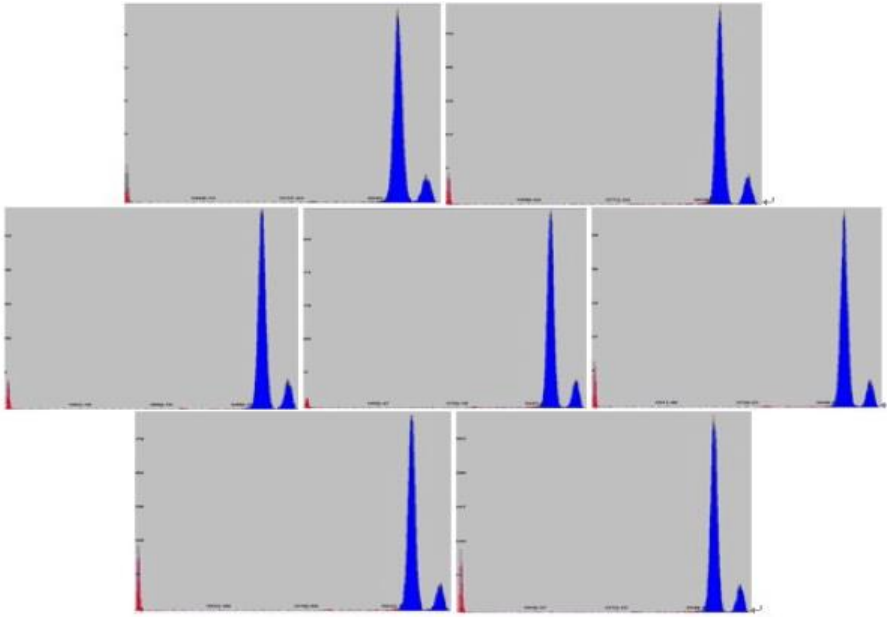
The 18 pixels out of focal point: Grouped to three 6-channel multiplexed readout circuit.

SDD readout electronics

- Prototype available based on discrete circuits
- Integrated solutions is under investigation



Prototype of a 19-pixel SDD array
Detector: 100mm², from KETEK



FWHM=189eV@5.9keV, -25℃

SFC working mode and data handling strategy

- Working mode：
  - Initial (keep room temperature for 1~2 weeks, functional test only)
  - Normal operation (aperture open, or with different filters)
  - Standby (aperture closed)
  - Calibration: 1.5/4.5/5.9keV (Fe55 + Al &Ti)
- Data handling:
  - High speed data link
    - Science events: *E* & *t* for each event
    - Data rate: 0.2Mbps@1Crab
  - Low speed data link
    - Binned data: spectrum for each pixel, ~10s
    - Light curves: for each pixel, ~1s
    - House-keepings: temperature, voltages, LV current, HV current, CSA reset frequency, status

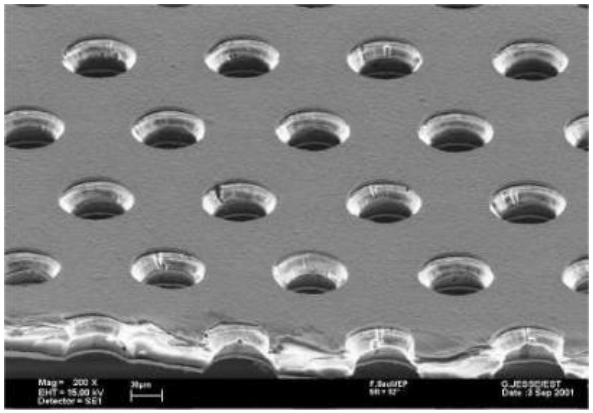
Polarimetry focal plane camera assembly (PFC)

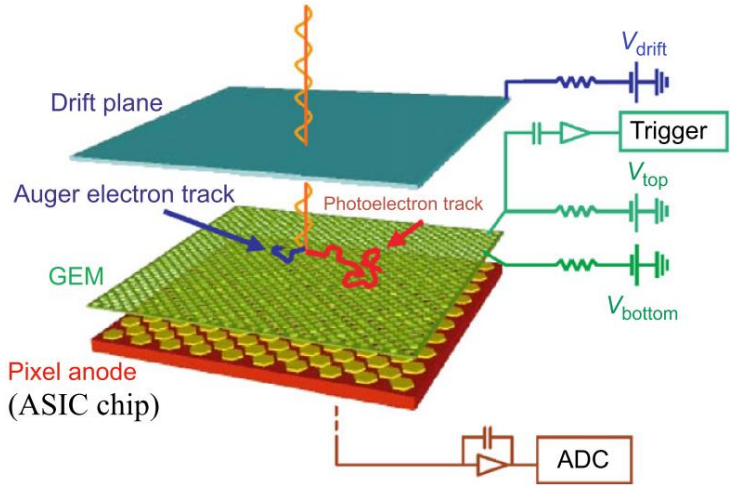
- Gas Pixel Detector (GPD) with imaging capability
- Prototype development
- Engineering model development

Gas pixel detector (GPD)

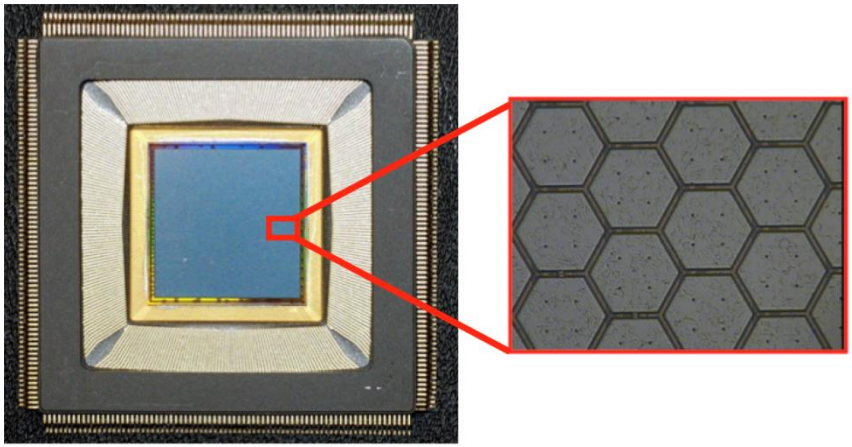
- Following the design by the INFN-Pisa group (Bellazzini et al.)
- Gas: DME (CH_3-O-CH_3) at 0.8 atm
- 50μm pitch (GEM foil and ASIC)

GEM foil





ASIC chip (1.5cm*1.5cm, 105k pixels)

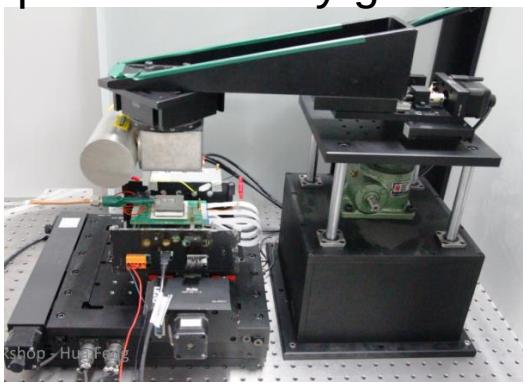


GPD prototype

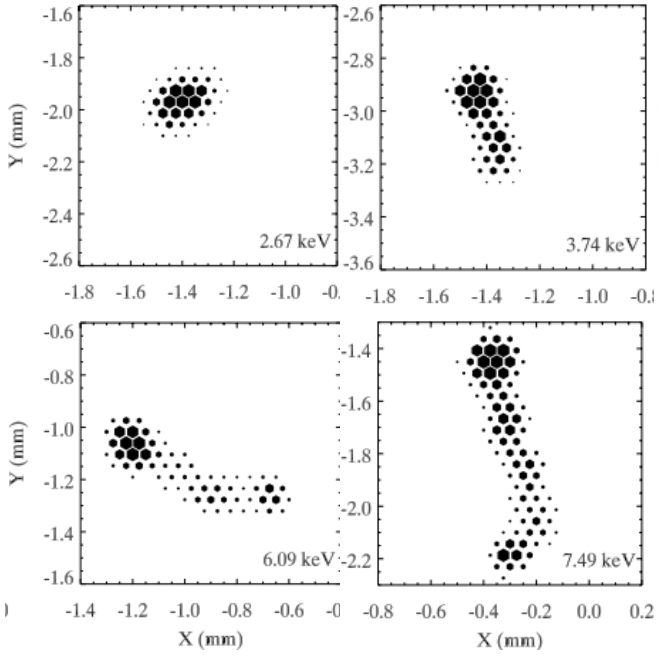
ASIC

Assembled GPD

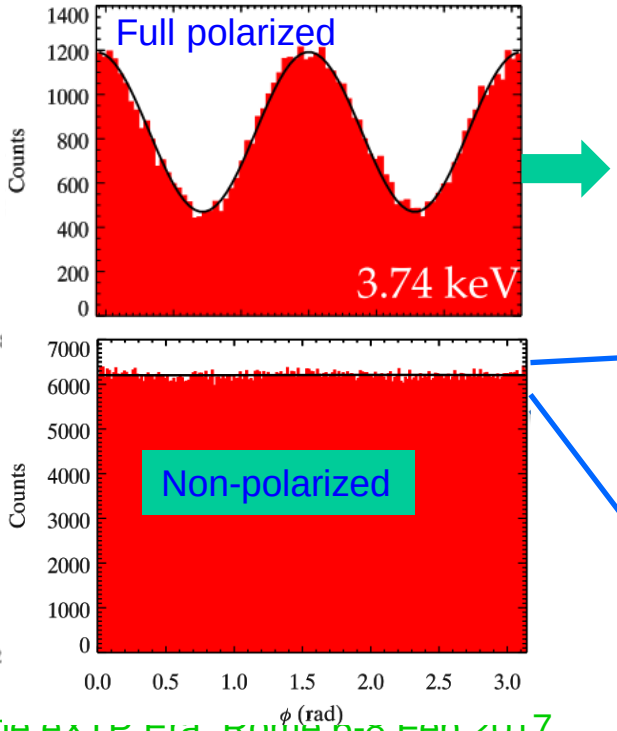
Fully polarized X-ray generator

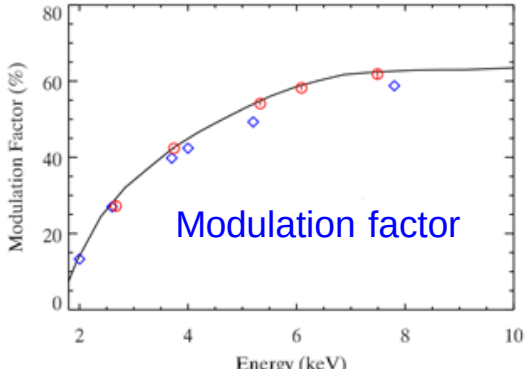


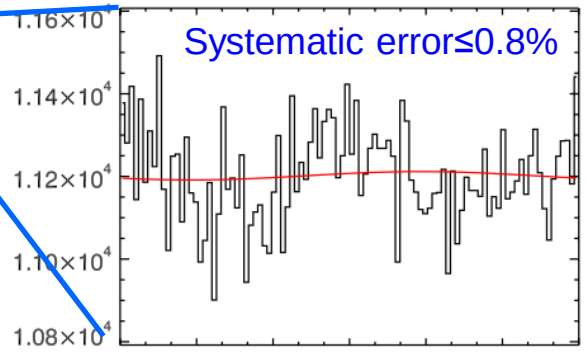
Photoelectron tracks



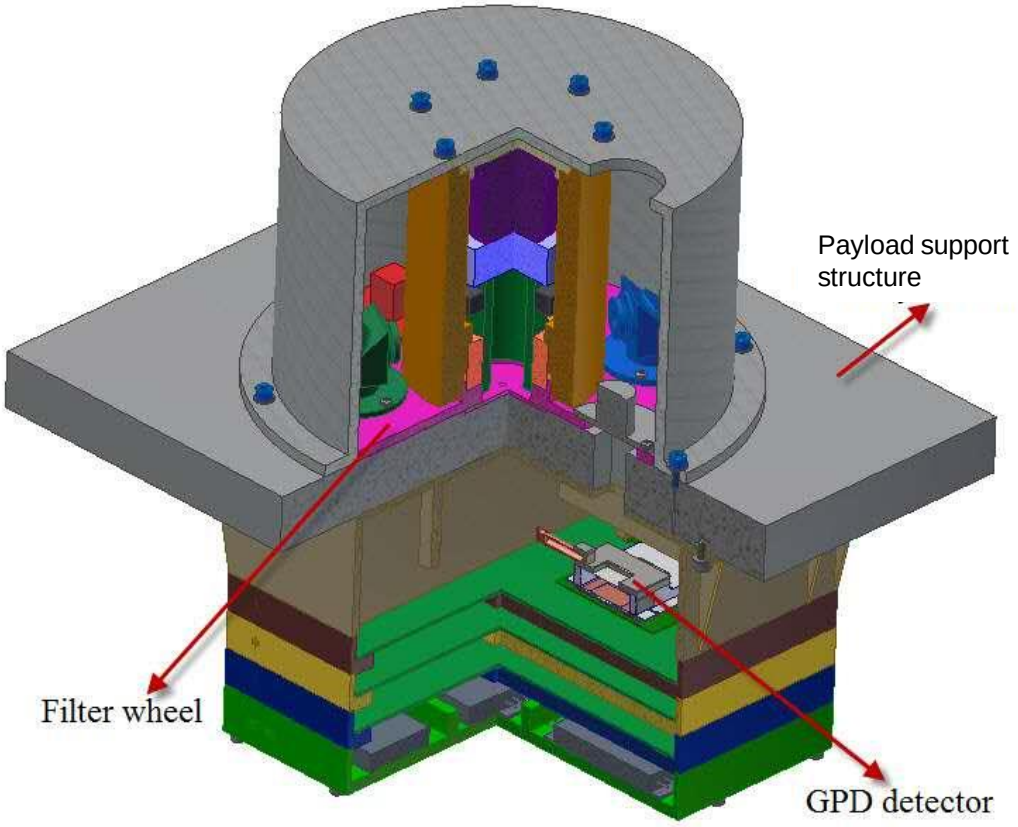
Modulation curve

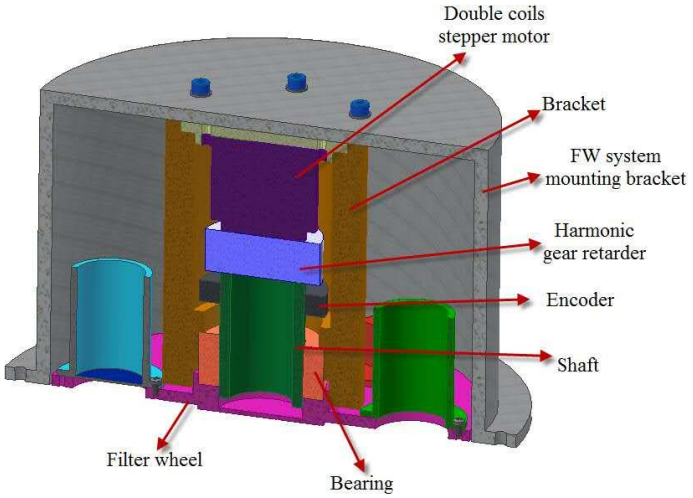


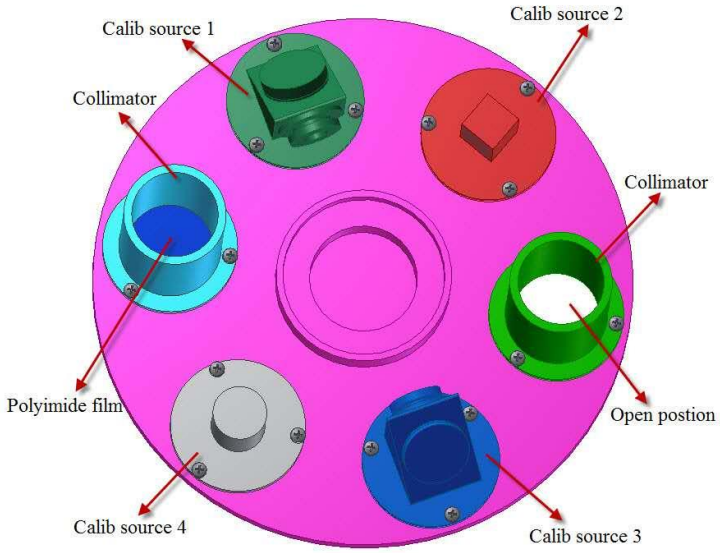




Preliminary design of the PFC

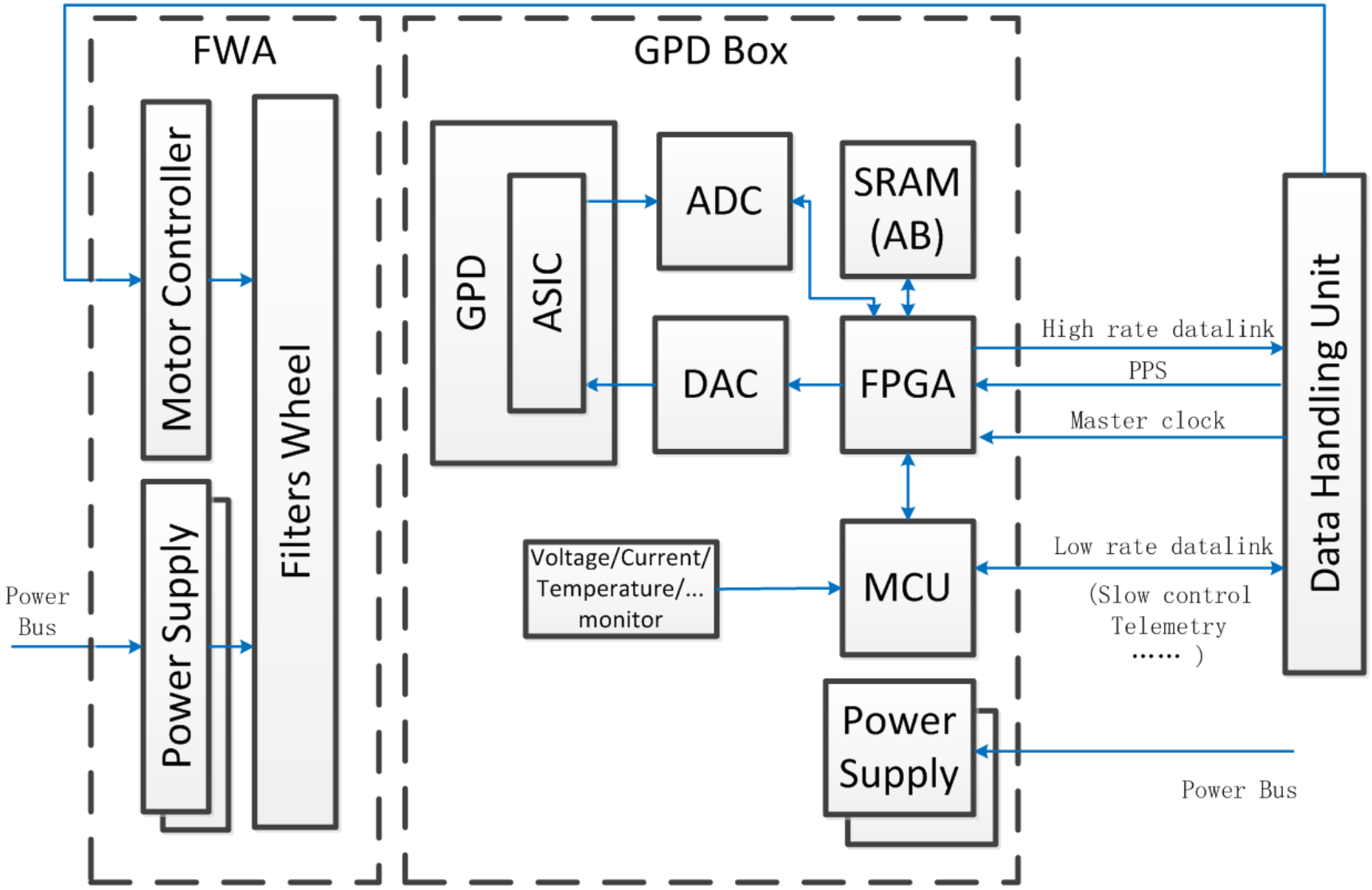




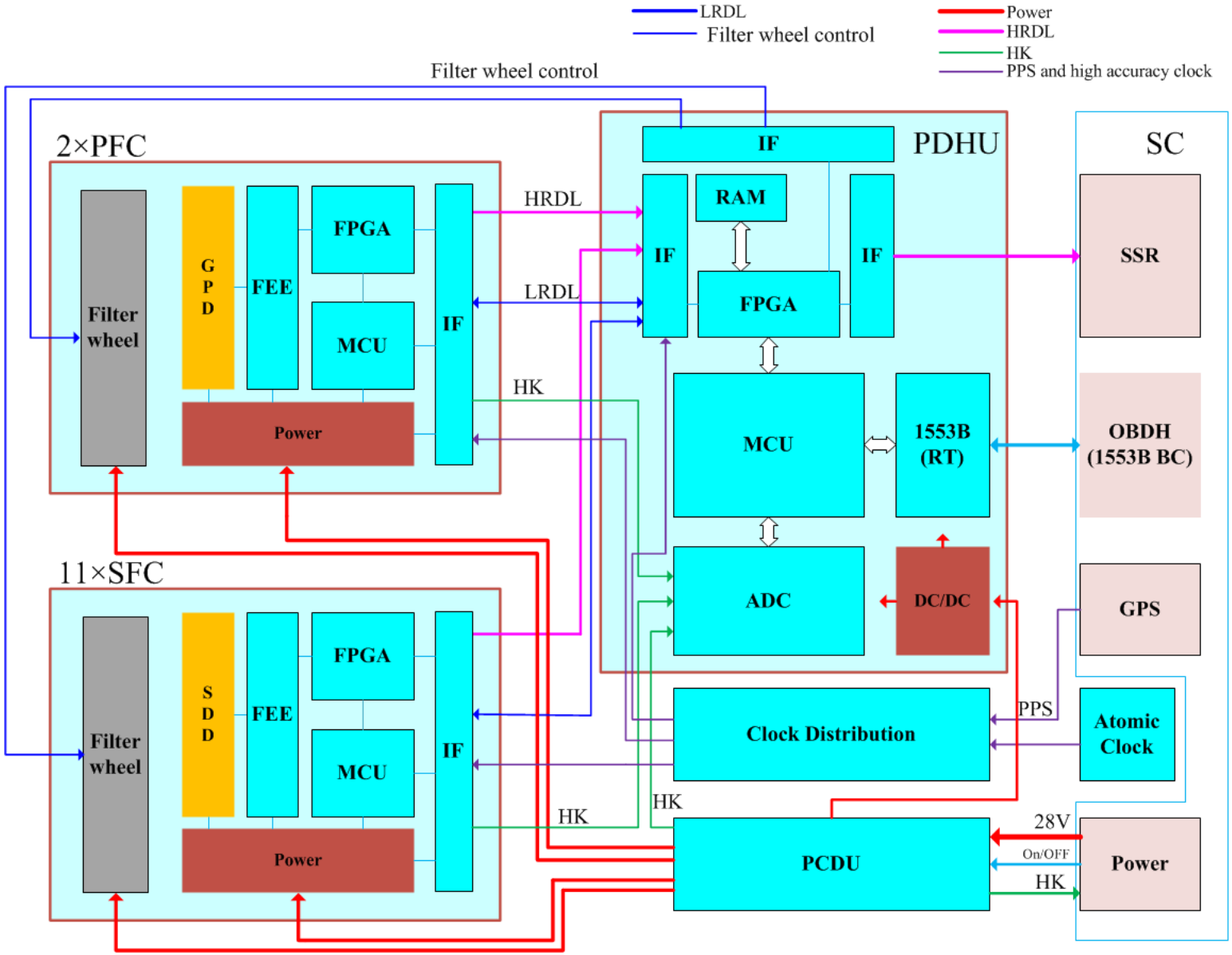


The polarimetry focal plane camera assembly is mounted back-to-back on the focal plane support structure

PFC functional block diagram



Data handling subsystem for SFA and PFA



Summary

- Status
  - Instruments (SFA & PFA) definition updated.
  - The instrument feasibility study is in progress.
- Plans in the near furture
  - Improve the optical design
  - Key technology development
  - Improve the spacecraft accommodation (collaborate with CAST)
  - Determine model philosophy & test matrix
  - Define the WBS
  - Engineering model development and space qualification test

==》Payload meeting, Beijing, March 21-23