X-ray Polarimetry Explorers (XPE)

Status and requests to INFN for 2017

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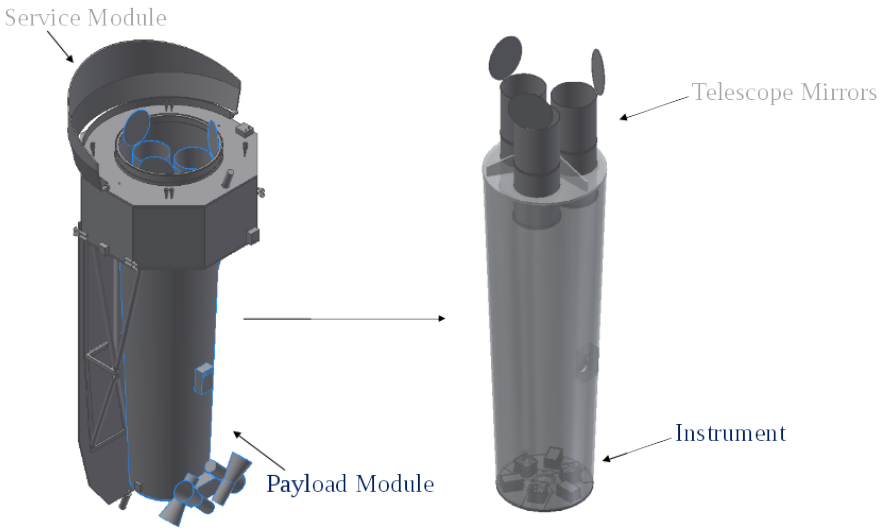
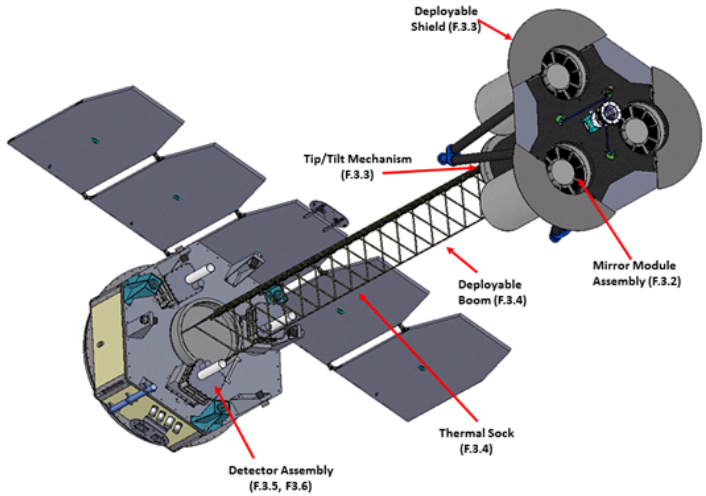
Next ESA/NASA candidate missions

XIPE (ESA M4)



IXPE (NASA SMEX)



P. Soffitta (INAF/IAPS)	Principal Investigator	M. Weisskopf (MSFC)
R. Bellazzini (INFN)	Co-Investigators	P. Soffitta (INAF/IAPS)
		R. Bellazzini (INFN)
400 M€	Cost envelope	125 M$
2000 kg (Vega)	Mass envelope	400 kg (Pegasus)
450 cm^2	Eff. area @2 keV	200 cm^2
April 2017	Down-selection date	February 2017
2025–2026	Launch date	2020–2021
$3 + 2$ years	Duration	$>$ 2 years

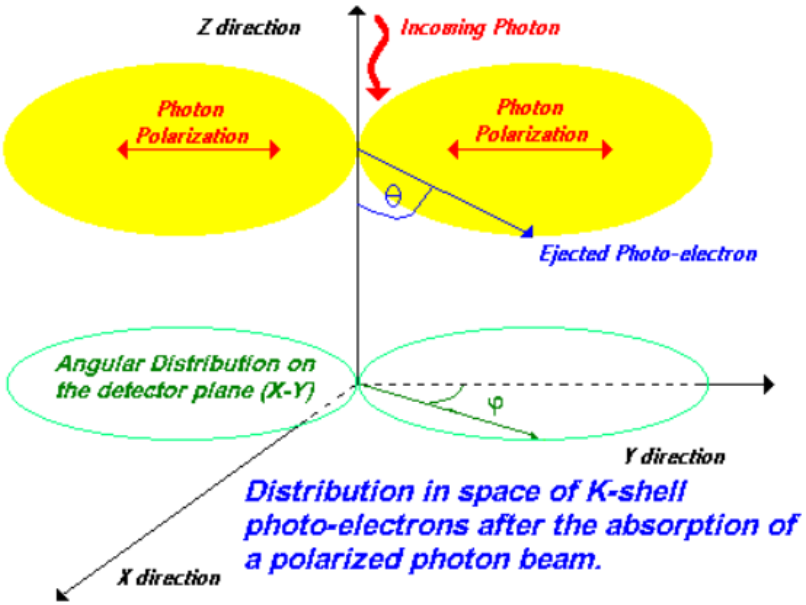
- 3 out of 6 missions in phase A study for the last ESA and NASA calls are entirely devoted to X-ray polarimetry.
- 2 of them based on INFN technology

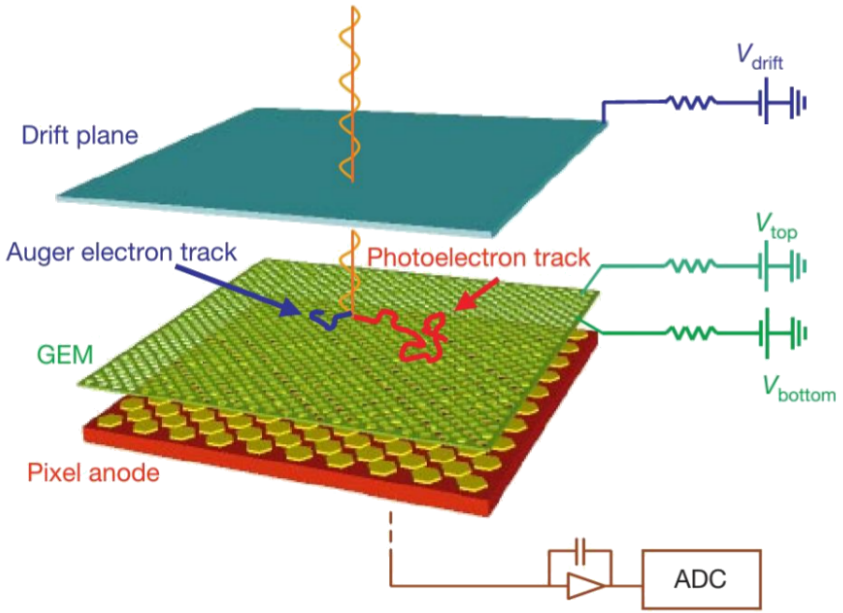
Recap of the science case and pointers

- Significant linear polarization expected in many diverse classes of X-ray sources:
  - Emission processes (synchrotron radiation and inverse Compton).
  - Geometry (scattering in aspherical geometries, propagation in magnetized plasmas).
  - Fundamental physics (strong gravitational and/or magnetic field, propagation over cosmological distances).
- Polarimetry would add two parameters to the phase space:
  - polarization degree;
  - polarization angle.
- XIPE/IXPE would effectively open a new observational window:
  - Measure polarization for > 100 sources.
  - Broad and diverse science case.

- XPE in CSN2:
  - September 23, 2015, Sestri Levante: scientific case, see https://agenda.infn.it/conferenceDisplay.py?confId=11614
  - April 4, 2016, Roma: technical aspects, see https://agenda.infn.it/conferenceDisplay.py?confId=11111
- XPE workshop in Torino, May 2016
  - https://agenda.infn.it/conferenceDisplay.py?confId=11412

Efficient photoelectric X-ray polarimetry

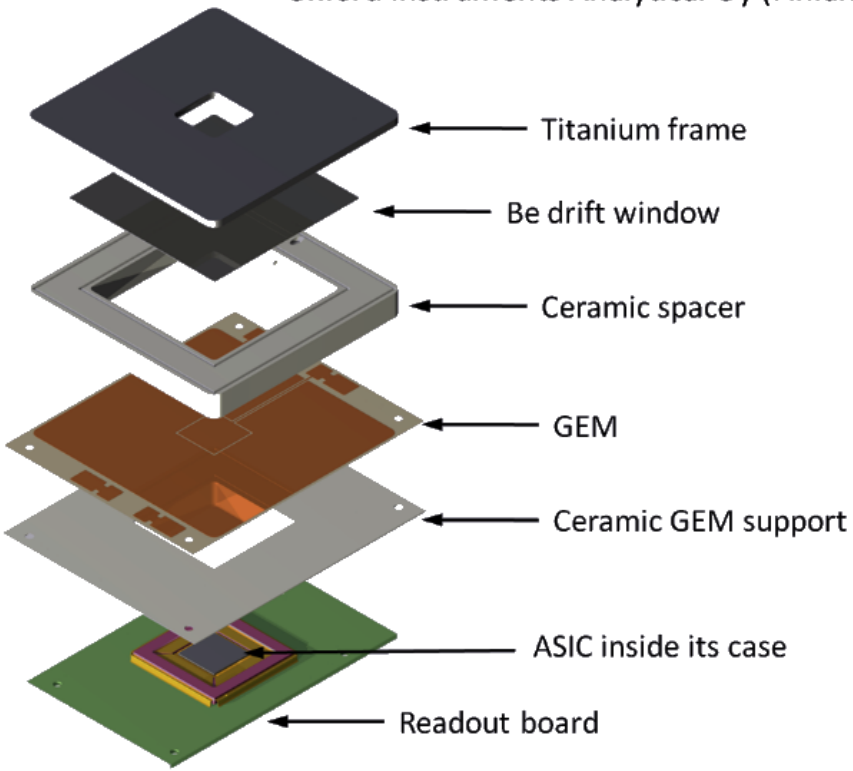


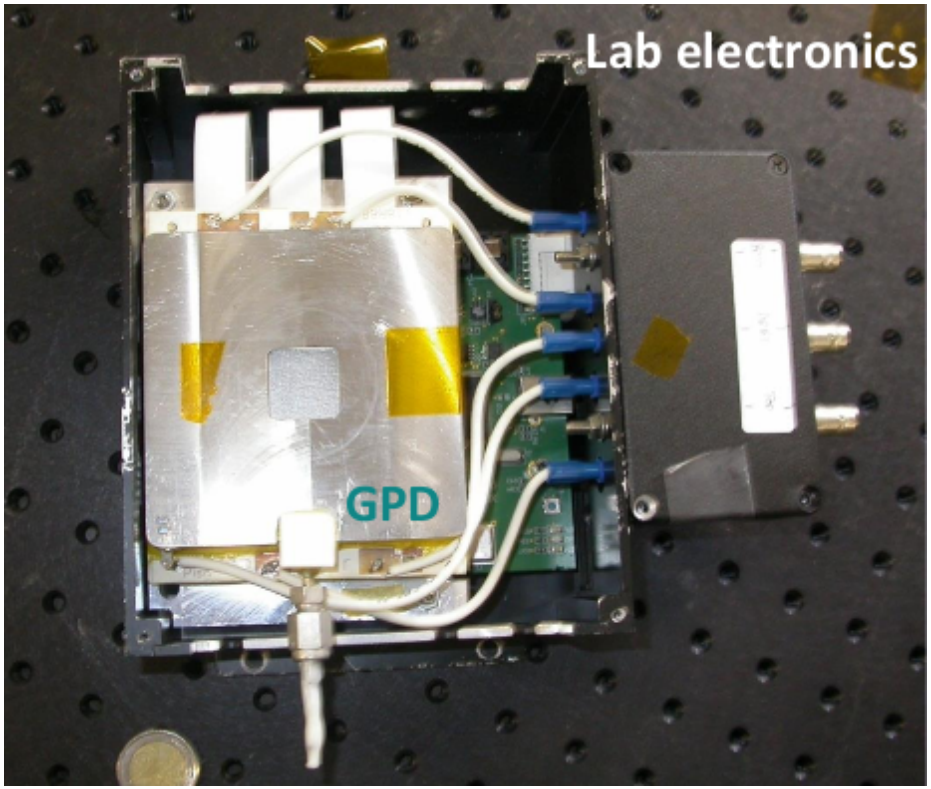


- The distribution of the direction of emission of a K-shell photoelectron is 100% modulated (if the incident radiation is 100% linearly polarized).
  - Main difficulty: at keV energies electrons propagate much less than photons in matter (need a gaseous absorption medium).
- The introduction of the Gas Pixel Detector (GPD) has paved the way to efficient X-ray photoelectric polarimetry.
- Key technology: custom ASIC used as a charge collecting anode.
  - entirely developed at INFN Pisa
  - Fully 2-dimensional, sufficient active area, low-noise.

The Gas Pixel Detector assembly

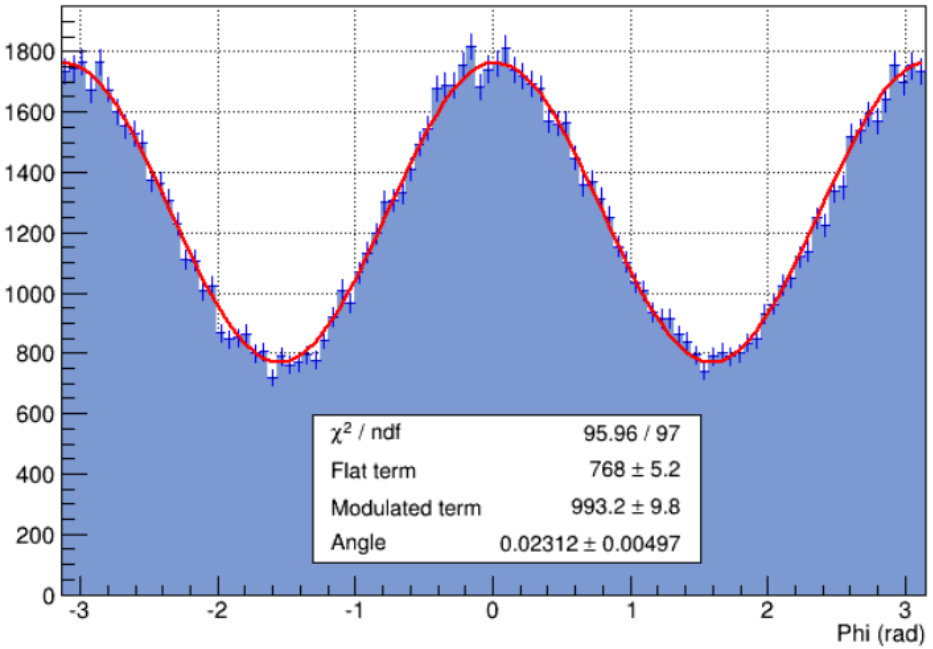
Collaboration with
Oxford Instruments Analytical Oy (Finland)

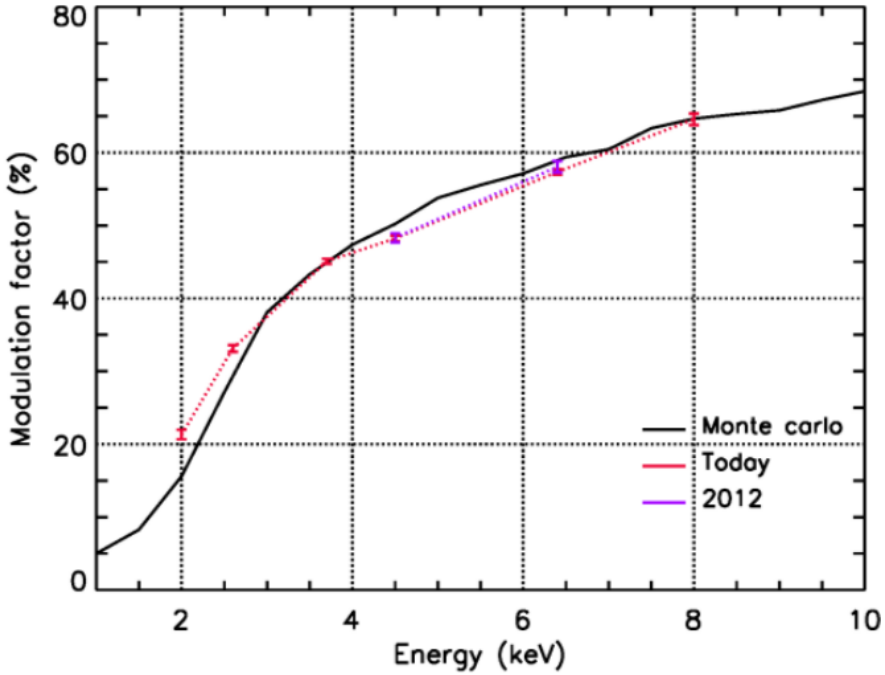




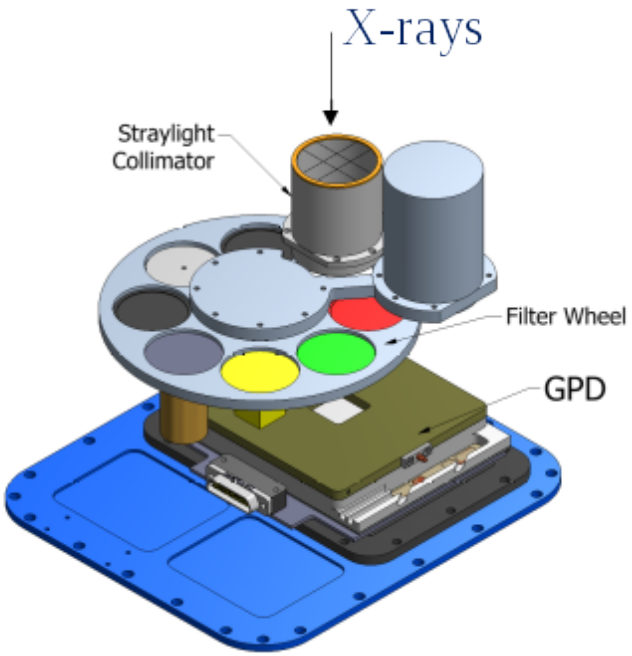
- Sealed detector, filled with He 20% + DME 80% at 1 bar, 1 cm absorption gap.
  - Optimized for the 2–10 keV energy range.
- ASIC mounted on a standard package and PCB (miniboard).
  - 105k hexagonal pixels, 50 μm pitch; self-triggering, automatic ROI selection.
- Sealed gas cell assembled at Oxford In. (Finland).
- GEM with 50 μm pitch/50 μm thick produced by SciEnergy (Japan).

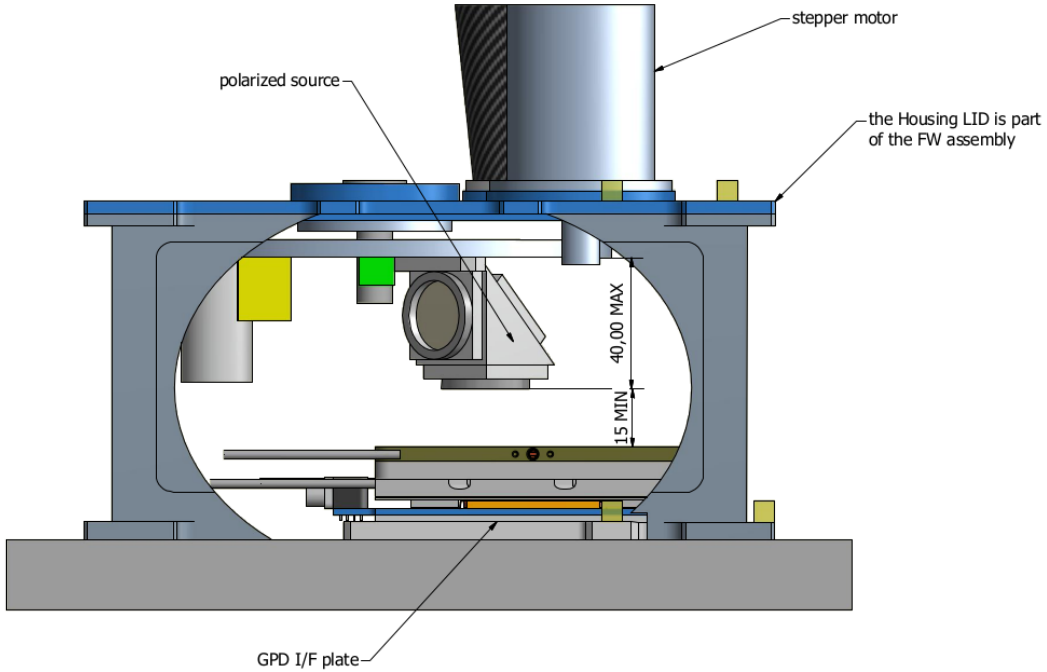
Performance of the GPD as a focal-plane detector





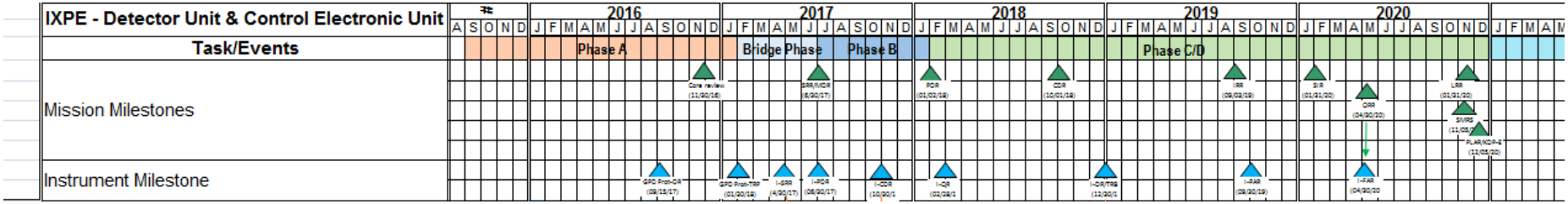
- Modulation factor: from 0.2 @ 2 keV to 0.7 @ 8 keV
  - Residual modulation for unpolarized radiation $\sim 0.1\%$
  - Performance stable in time over ~ 3 years
  - Fair agreement with the Monte Carlo simulation
- ~ 90 μm spatial resolution at 5.9 keV, measured ($\ll$ track length)
  - Good match for a 20 arcsec-type X-ray optics with 3.5 m focal length
- $\sim 15\%$ energy resolution (FWHM) at 5.9 keV
  - Enough for spectrally-resolved polarimetry (in a few energy bins) when statistics allow it
- μs-type time resolution
  - More than adequate for the shortest periodicity of interest





- Project Office (design, construction and test) will be INFN responsibility—in synergy with industrial partner(s).
- Detector units: Gas Pixel Detector (GPD), housing and cabling.
  - Note: both XIPE and IXPE have three detector units.
- Back-end electronics: DAQ boards (and low/high voltages).
- Calibration & qualification for space.

Schedule and milestones

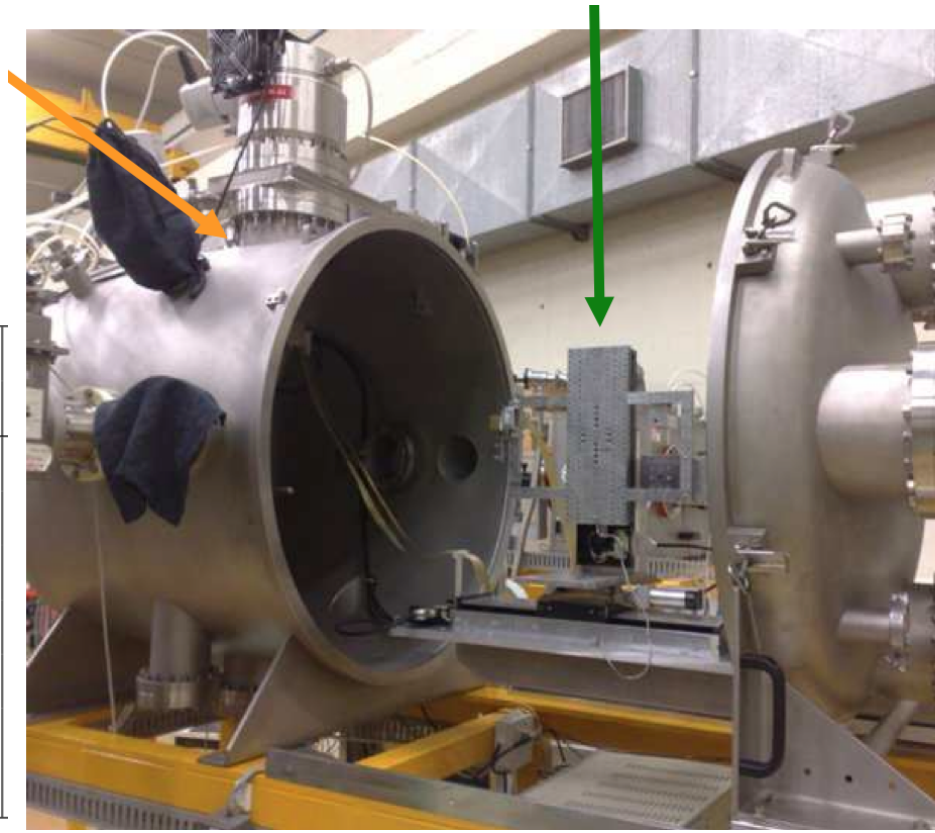


- IXPE (NASA) has tighter schedule than XIPE (ESA).
  - IXPE downselection spring 2017.
  - NASA site visit in November 2016 at MSFC
    - Need to provide a fully functional and calibrated GPD.
  - no interruption between phase A and phase B.
  - Critical Design Review in October 2017 (March 2021 for XIPE).
  - Delivery of all flight items by end of 2018
  - Launch in December 2020 (December 2025 for XIPE)
- Assume IXPE schedule, full GPD funding and team support for CSN2 requests
  - $\sim$ 1M in 5 years
  - ASI will cover industrial contracts, mirrors, contracts to support staff

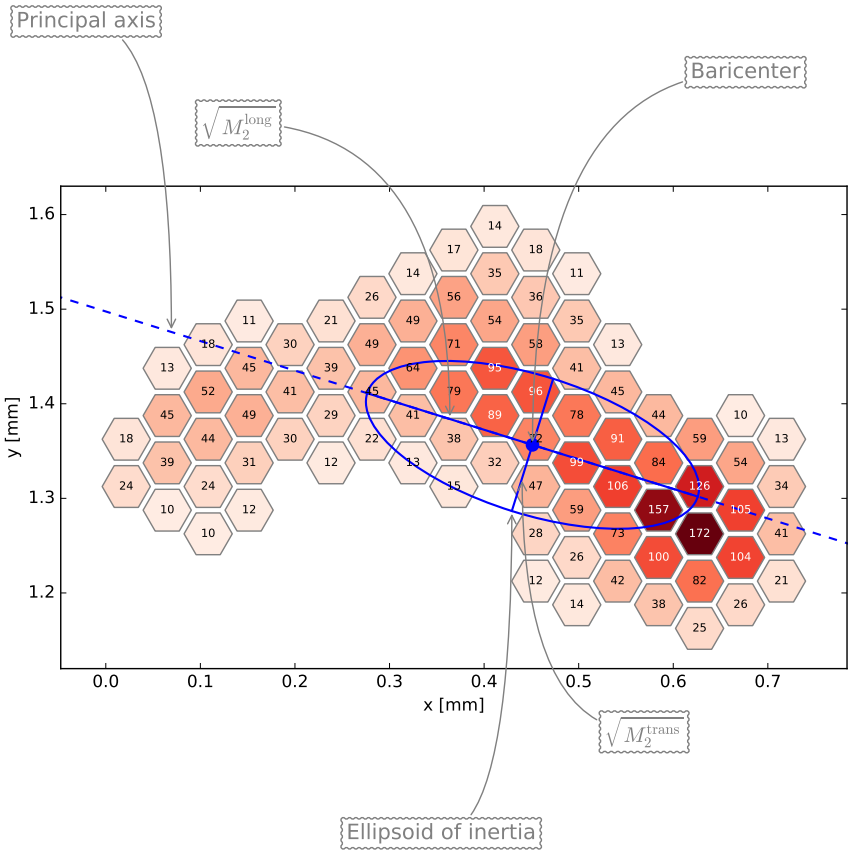
Phase A Activities at INFN (2016–2017)

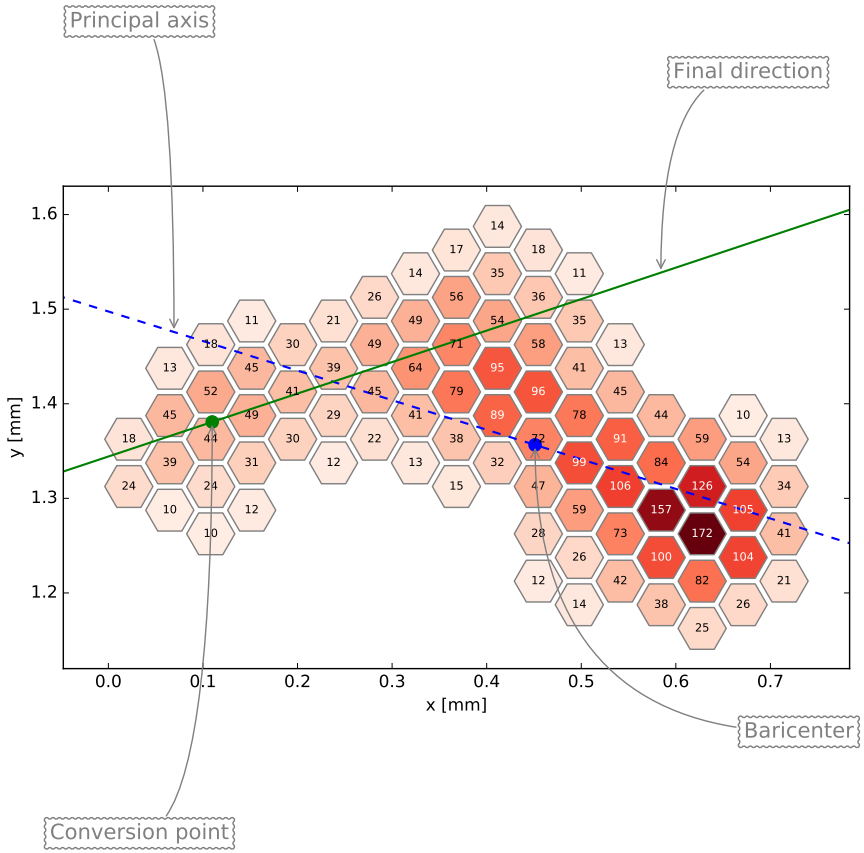
- Definition of the mission concept for Phase A report
  - Requirement definition - power, thermal, alignment, data handling
  - Interface definition - mechanical and electrical
  - Preliminary thermal and structural studies.
  - Production and test schedule definition and documentation.
  - Rough Order of Magnitude (ROM) costs (materials, tests, personnel).
- Build 2 lab-grade GPD prototypes in 2016 (for NASA and ESA site visits)
  - Assembly at Oxford In.
    - ASICs already in house for both missions.
    - Only 2 miniboards available, need to build a few more.
    - Only 1 GEM available, a new batch in production.
    - need to revamp GEM test setup
- Perform two test campaigns requested by ESA
  - ASIC irradiation test at LNL (dedicated miniboards needed).
  - Long-duration leakage test for the gas cell (details TBD).

Ion	Energy [MeV]	LET [MeV cm^2 mg^{-1}]	Flux [ions cm^{-2} s^{-1}]	Exposure time [hours]
^{28}Si	157	8.6	10^5	8.0
^{35}Cl	171	12.5	10^5	6.0
^{48}Ti	196	19.8	10^4	6.0
^{58}Ni	220	28.4	10^3	3.0
^{79}Br	241	38.6	10^3	3.5
^{107}Ag	266	54.7	10^3	3.5
^{127}I	276	61.8	10^2	2.0

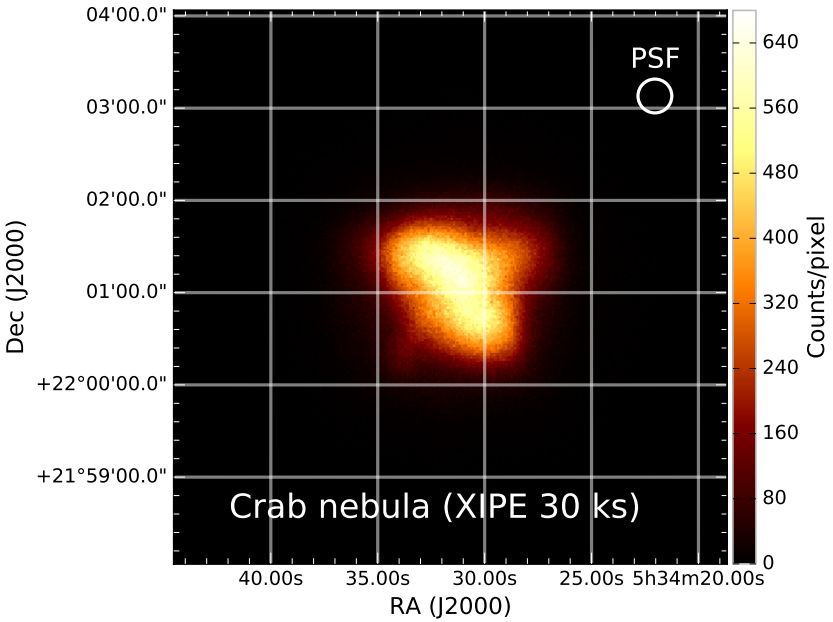


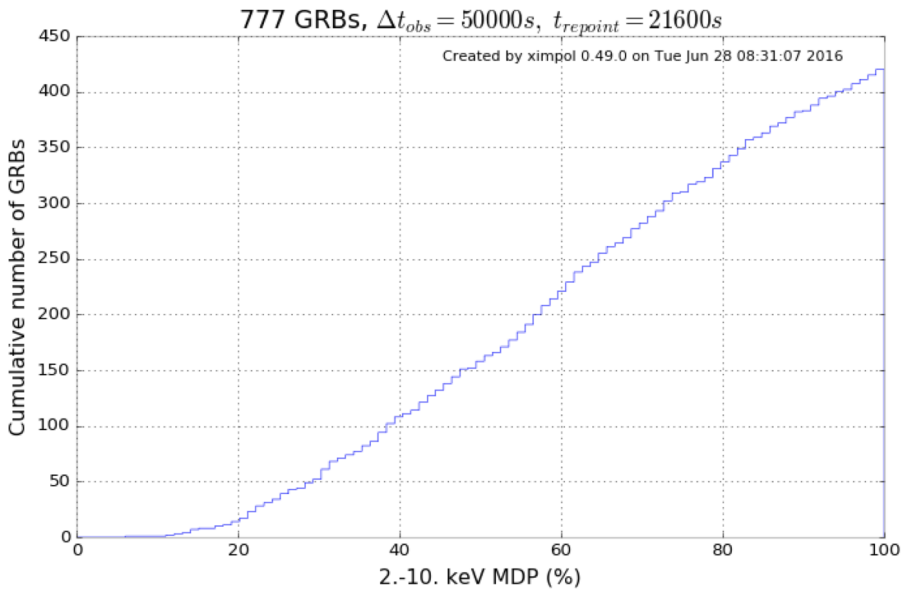
- Support ASIC SEE Irradiation test at LNL
  - Build mechanical interface between LNL vacuum chamber and XPE ASIC mininoards
  - Staff SEE tests
  - analyze and document test outcome
- Support procurement and test of GEM and flight grade handling mechanics
  - technical overview plus potential prototyping (TBD)





- Improve existing algorithms to determine impact point (imaging) and the emission direction (polarimetry).





- Use observation-simulation to estimate XIPE performance for specific targets
  - Gamma-Ray-Bursts (Swift sample)
  - Supernove Remnants

Gruppo XPE INFN-Torino

Nome	Affiliazione	%
Alvarez-Crespo N.	Dottoranda Università di Torino	50%
Bonino R.	Università di Torino	50%
Latronico L.*	INFN	30%
Massaro F.	Università di Torino	50%
Negro M.	Dottoranda Università di Torino	50%
	Totale FTE	2.3

- **Responsabile locale*
- *Sigla* INFN under discussion in CSN2 starting from July 20th meeting
- Responsabile locale may change in 2018 in case of selection
- Additional $\sim$ 5.2 FTE at INFN-Pisa (lead by Luca Baldini, national leader).

Richieste anno 2017

Capitolo	Voci specifiche	Subtotale [k€]	Totale [k€]
Missioni	2 settimane/uomo a MSFC	4	
	2 settimane/uomo gruppi lavoro Italia	2	
	2 settimane/uomo EU per assemblaggi	2	
			8
Consumo	Piastra supporto test irraggiamento	2	
	Piastra handling flight-grade	20	
			20
Apparati	10 GEM	25	
	sistema test GEM	10	
			35
		Totale	65
Lab. Tecnologico*	Progettazione	0.5 M/U	
	Lavorazioni meccaniche e installazione	1 M/U	

- * possibly at the end of 2016
- expect some fraction of SJ funding pending approval
- ASI currently supporting phase-A
  - $\sim$ 60 k€ for the 2 GPDs under construction, 2 TD (tecnologi) at INFN-Pisa