IXPE
Imaging
X-Ray
Polarimetry
Explorer

IXPE Status and Prospects

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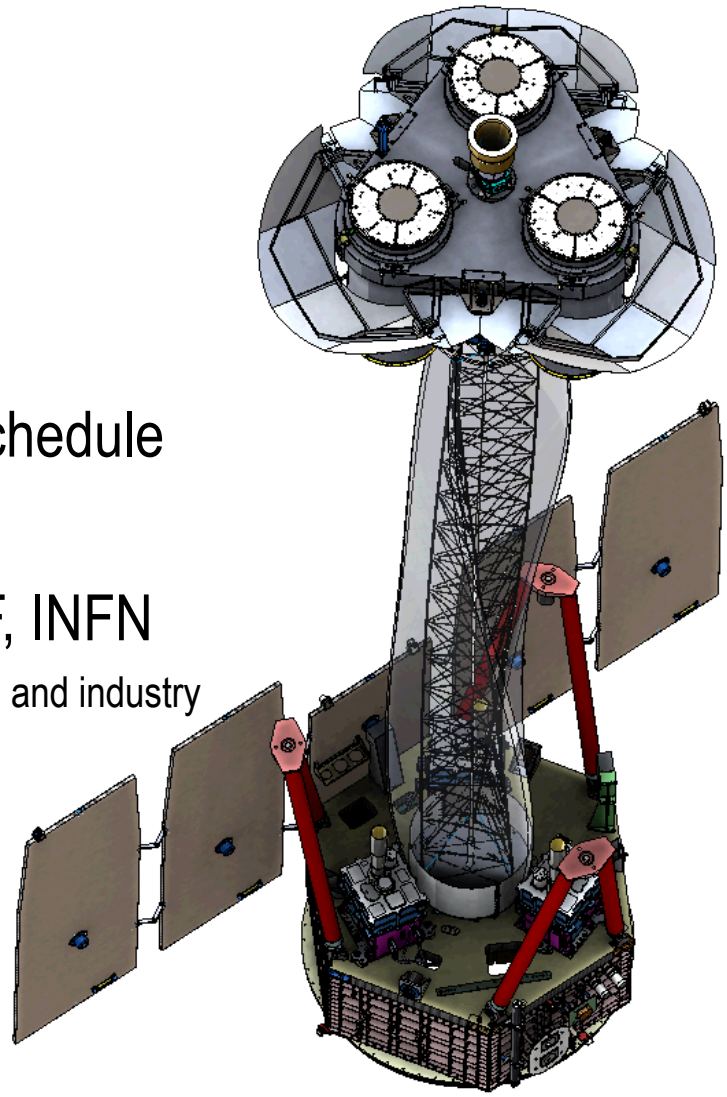
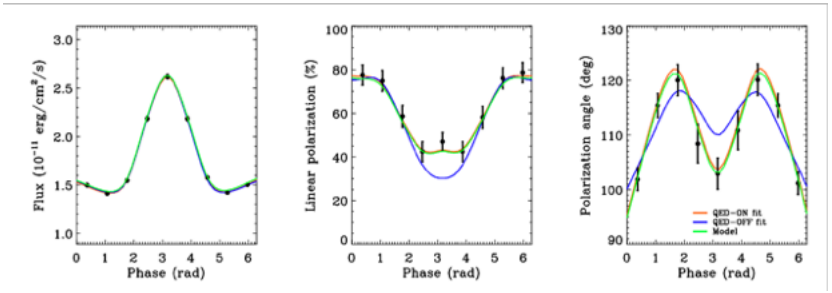
IXPE Mission Overview

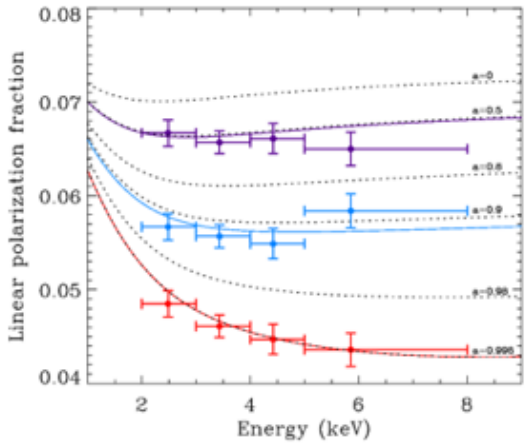
- IXPE is a NASA SMEX mission:
  - Selected January 2017
  - Italian contribution due December 2019
  - Launch April 2021
- Cost-capped (200M$) – rigid aggressive schedule
- Italian Contribution supported by ASI, INAF, INFN
  - ASI manages funding through 3 direct contracts to Institues and industry
    - OHB-I (FCW, DSU)
    - INFN (DU)
    - INAF (System Engineering and Calibration)

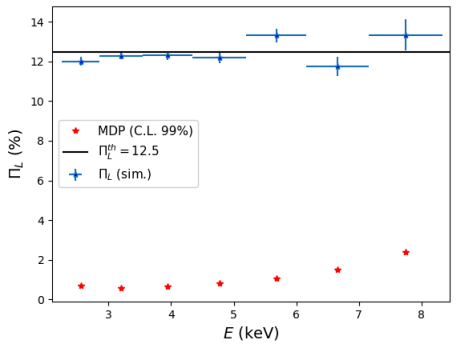


Why X-ray Polarimetry ?

- Polarized X-rays expected from most astrophysical systems
  - *Anything non spherical*
- Polarized X-rays bring insight into
  - emission processes
    - synchrotron, non-thermal bremsstrahlung, Inverse Compton
  - geometry
    - scattering in aspherical geometries, propagation in magnetized plasmas
  - fundamental physics
    - strong gravitation/magnetic fields (BH spin), QED vacuum birefringence, propagation through cosmological distances (LIV), unexpected polarization from photon-ALP mixing (Clusters)

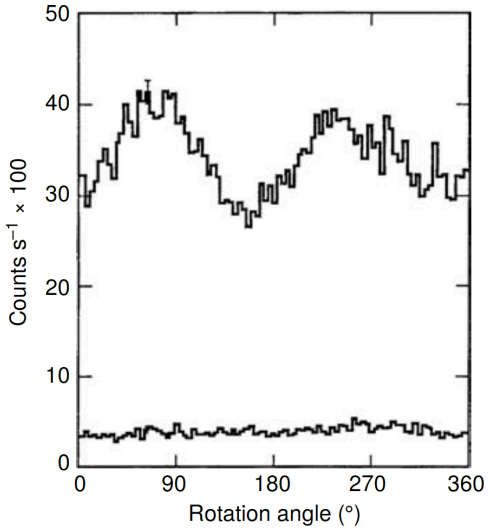


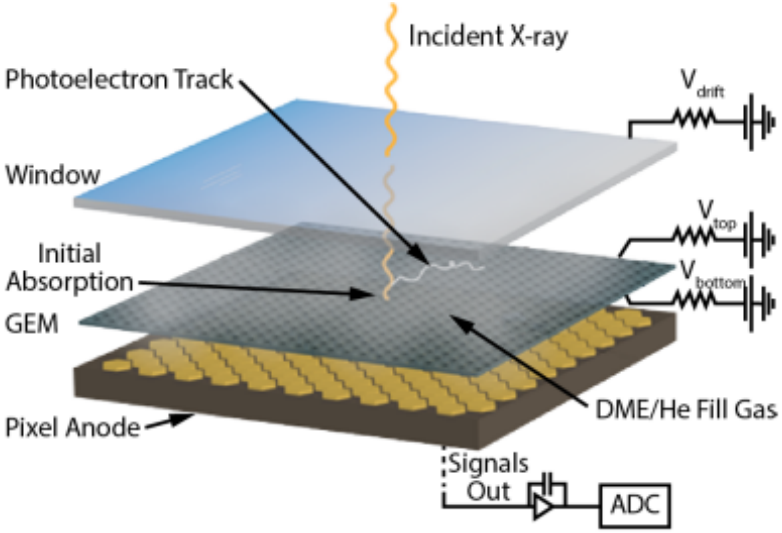


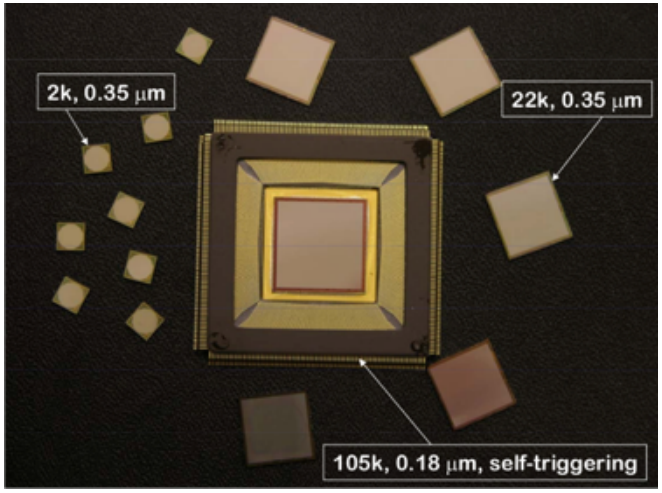


How X-ray Polarimetry ?

- Single historical (1978) measurement from the Crab Nebula
  - Through rotating angle-selective Bragg crystals in need of long exposure to achieve required large photon statistics
- INFN Gas Pixel Detector opens the way to X-ray polarimetry
  - 10+ years development of key detector parts (GEM, ASIC)
  - Measures direction of every single X-ray absorbed
  - Several mission proposals before IXPE

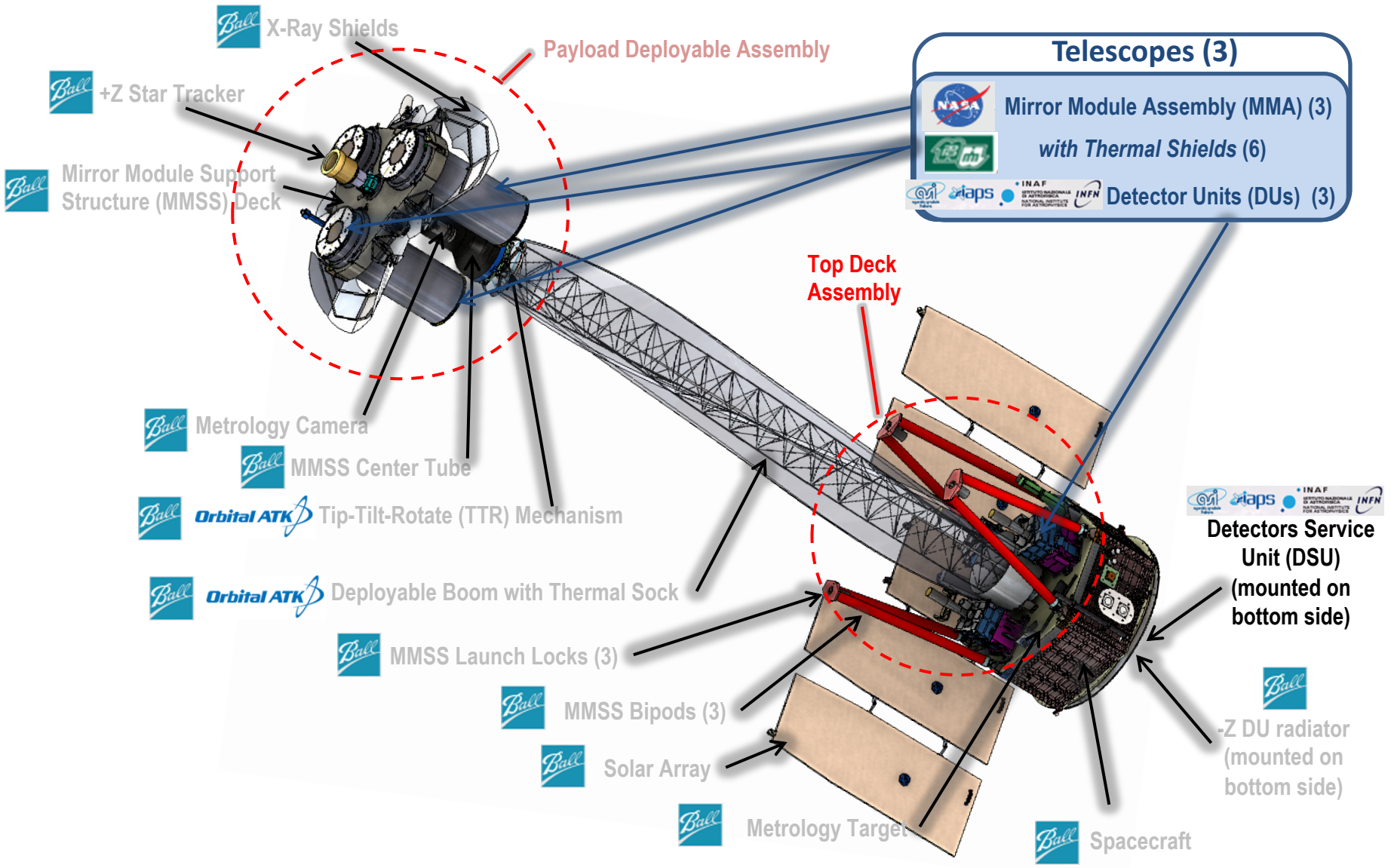






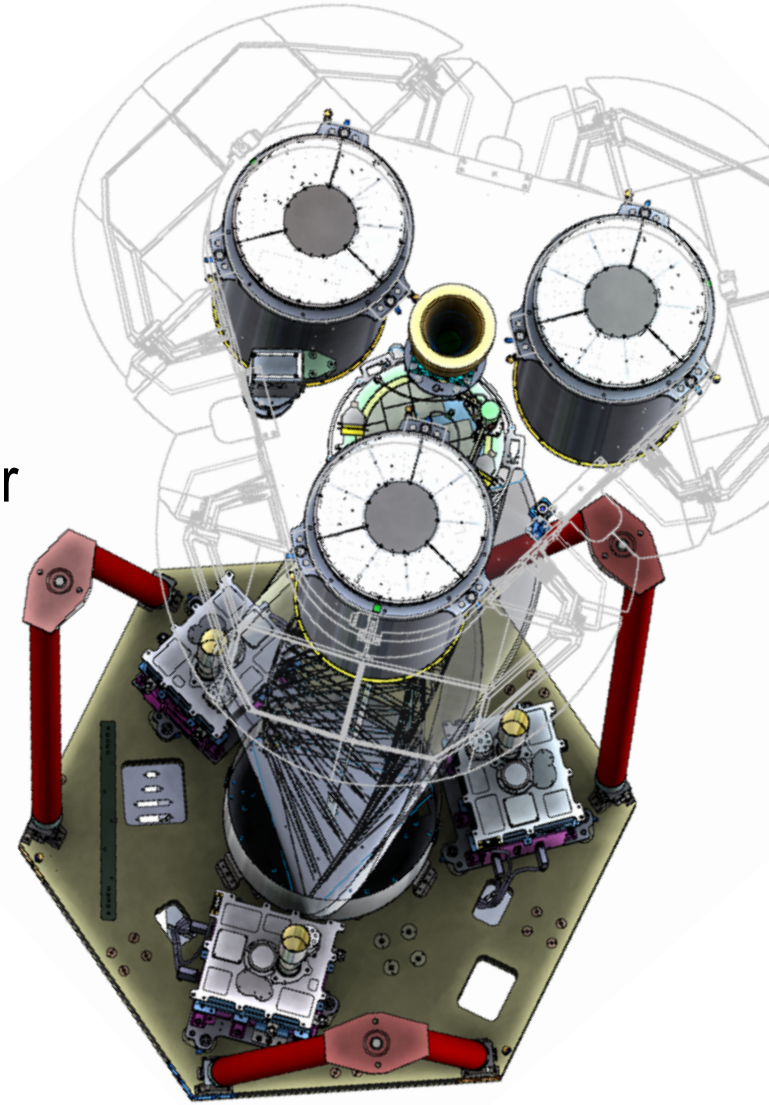
IXPE – From photons to data products

IXPE Observatory



IXPE Focal Plane Systems

- Design, Integration and Test at INFN
  - ~6.5M from ASI to INFN
  - INFN provides in-kind personnel (~1.5M) and facilities (CR, workshop), ~1M from CSN2
- Gas Pixel Detectors enabling technology for X-ray polarimetry invented at INFN
  - Luca Baldini Italian Co-PI
  - Luca Latronico Detector Unit Project Manager
- System level calibration, including Detector Service Unit, managed by INAF/IAPS
  - Paolo Soffitta Italian PI



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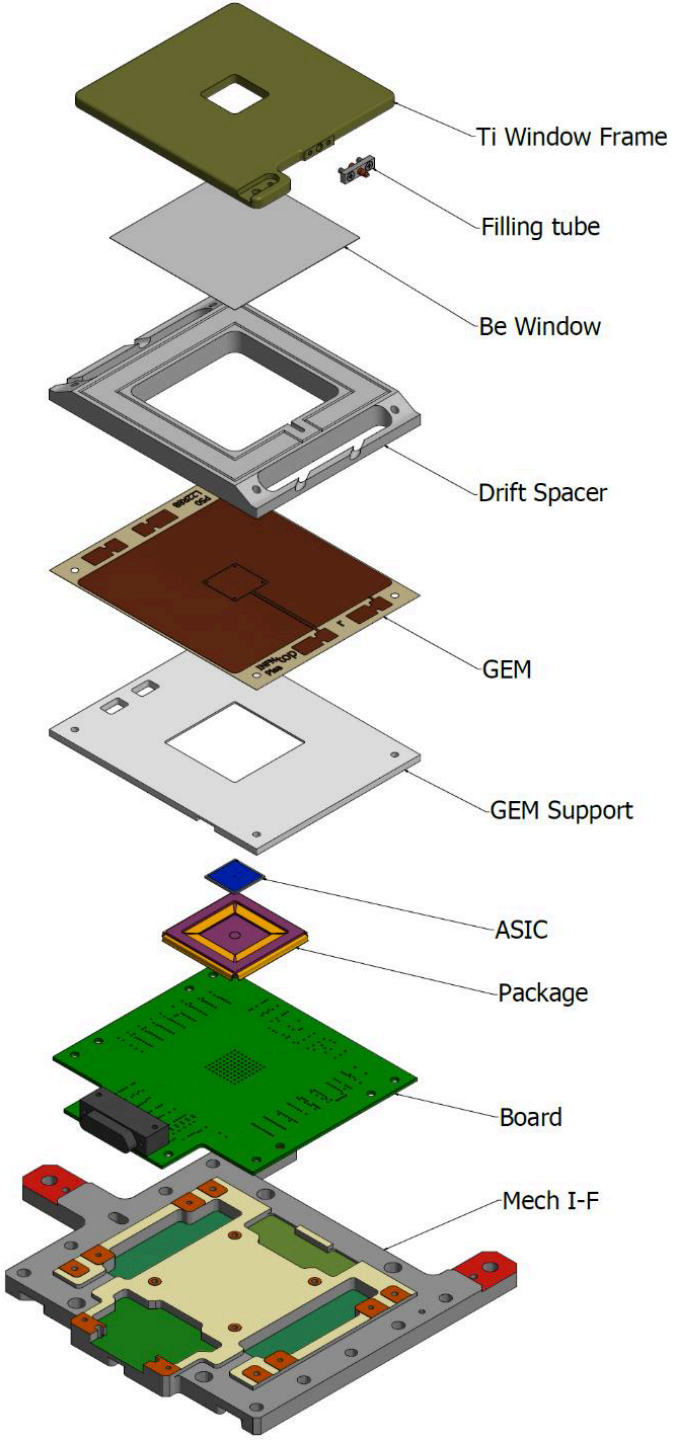
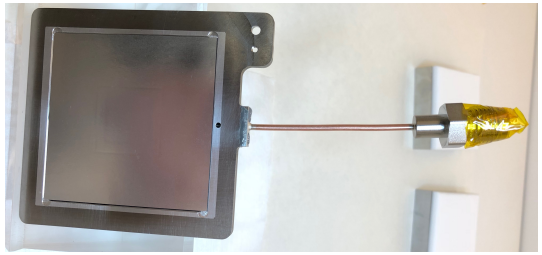
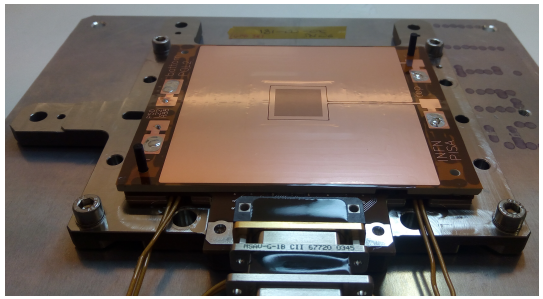
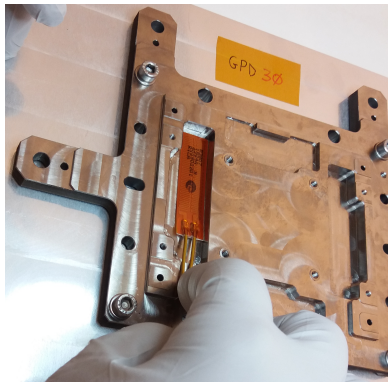
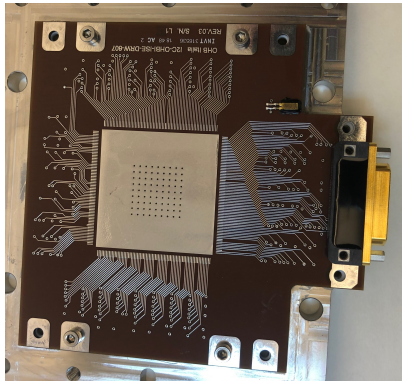
GPD - Gas Pixel Detector





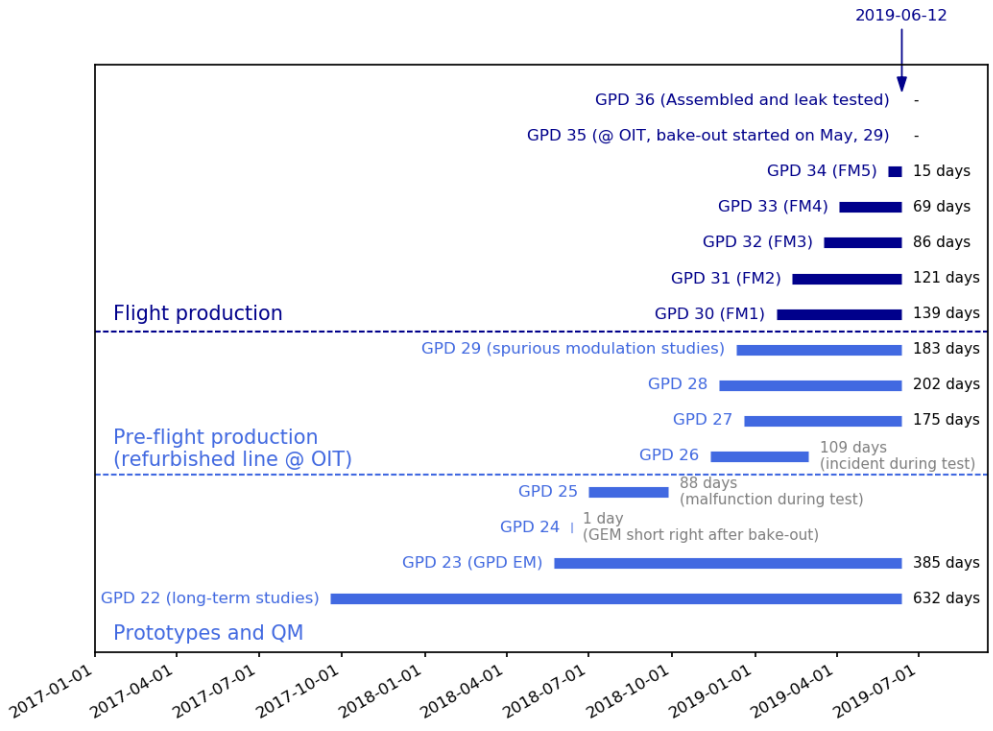




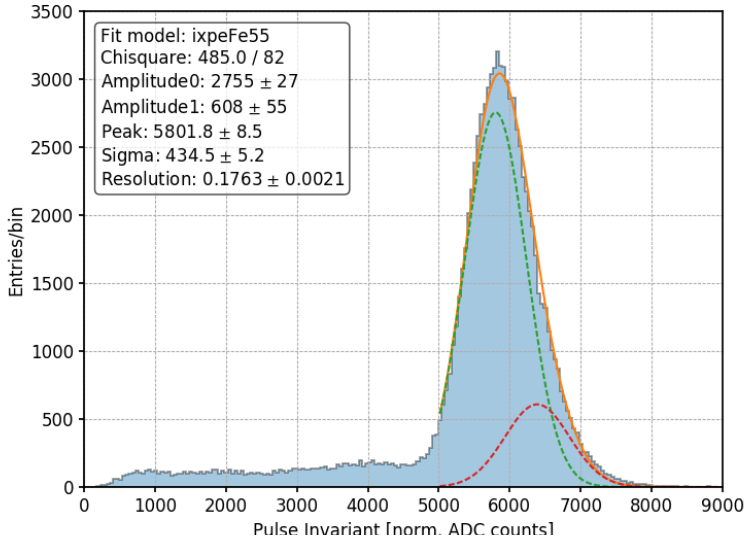


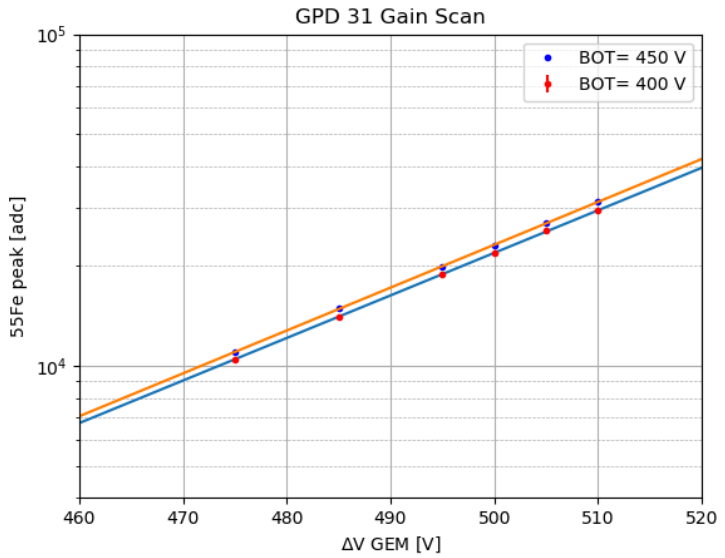
Designed and integrated at INFN

GPD production and performance testing

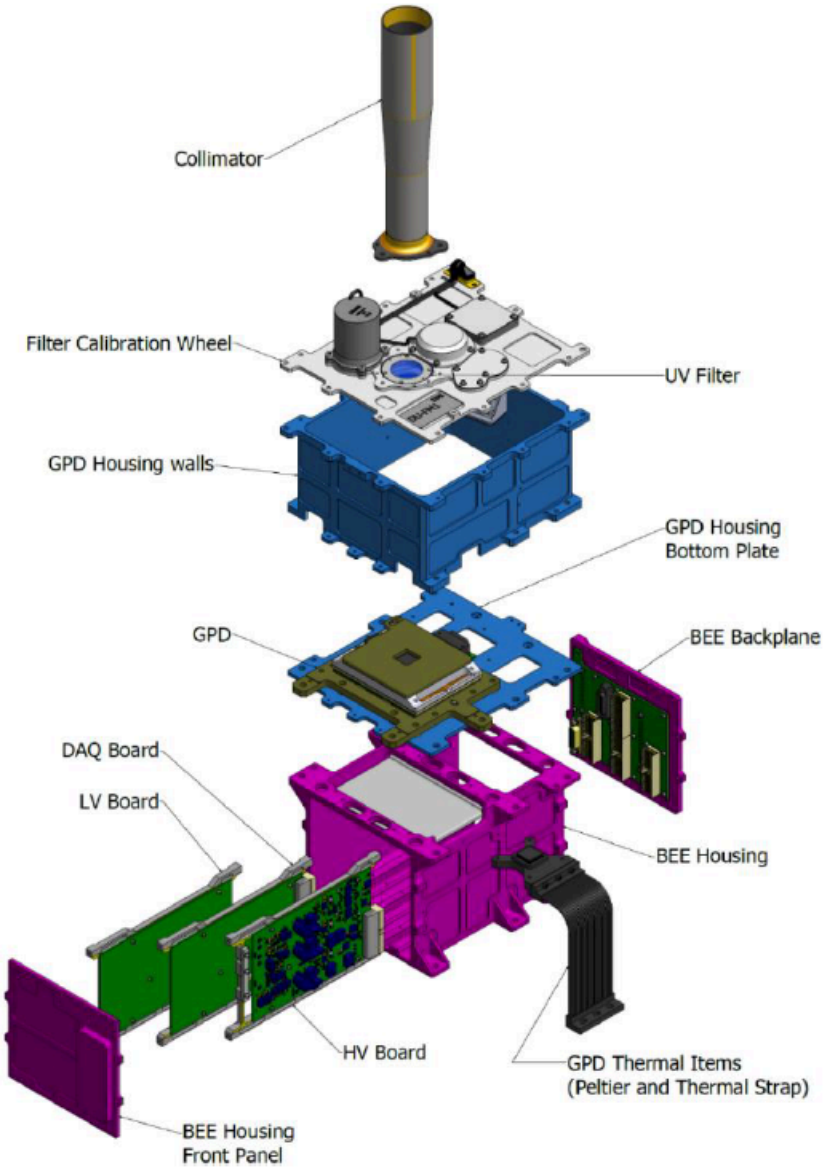


Acceptance and performance tests at INFN and IAPS, full calibration at DU level



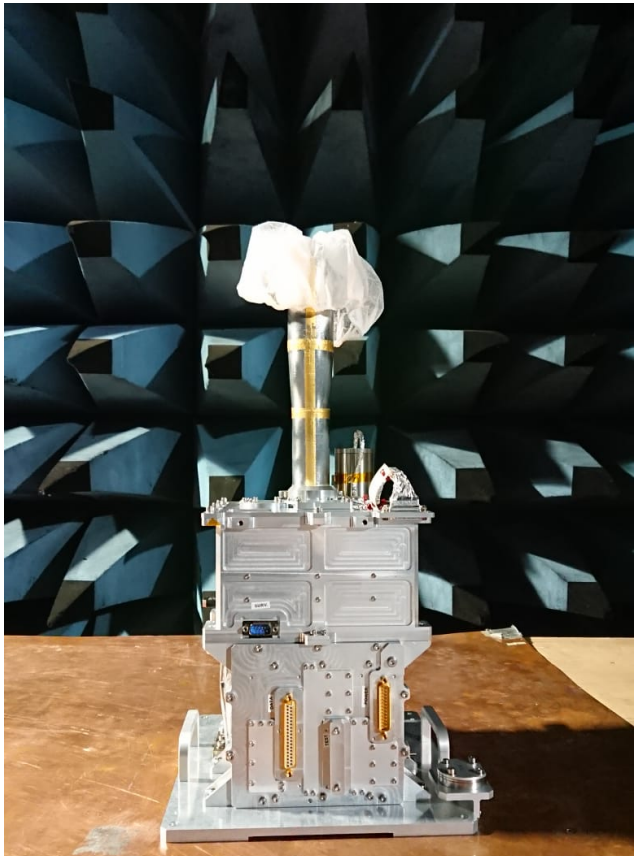


DU - Detector Unit

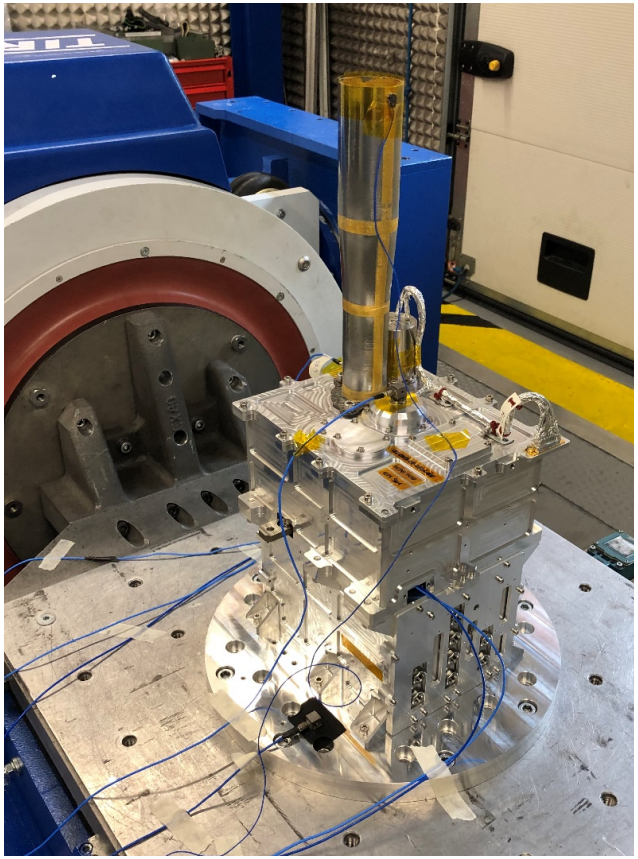


- INFN
  - GPD and associated thermal control
  - DAQ, Low-Voltage boards and associated backplane (OHB-I through INFN contract)
  - Stray-light collimator
  - DU Integration & Test
- IAPS
  - Calibration sources
  - UV filter
- OHB-I (through ASI contract)
  - High-voltage board
  - Filter and calibration wheel

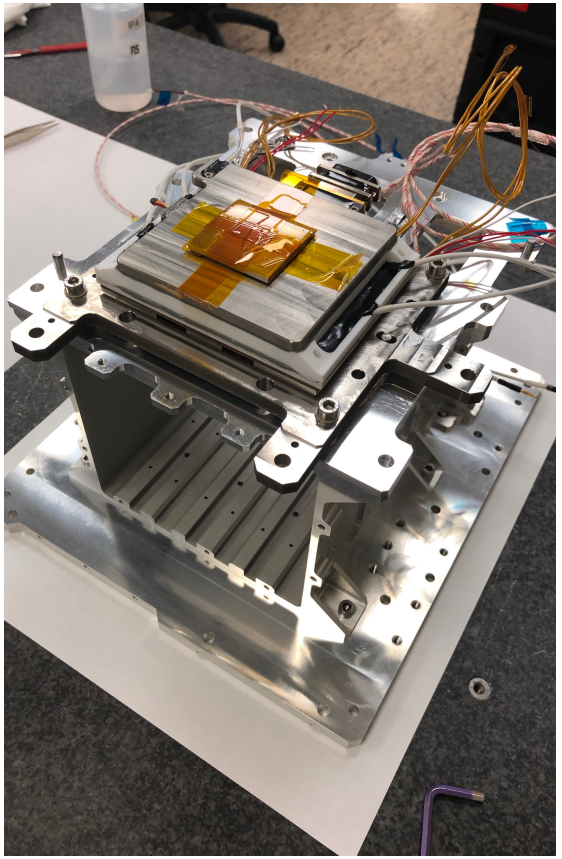
DU Assembly Integration & Test



DU Engineering Model
EMC Test

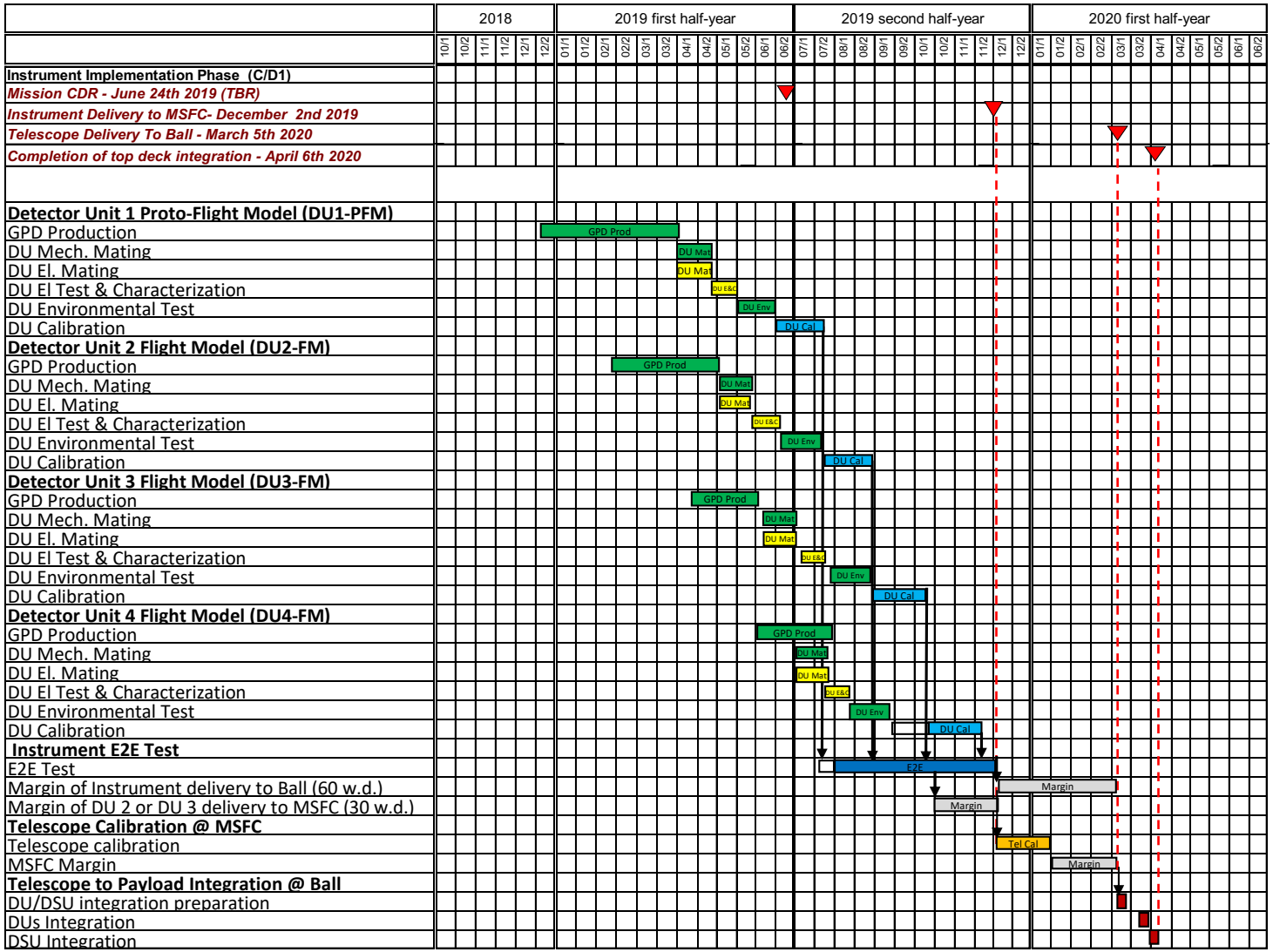


DU Structural Model
Vibrational qualification

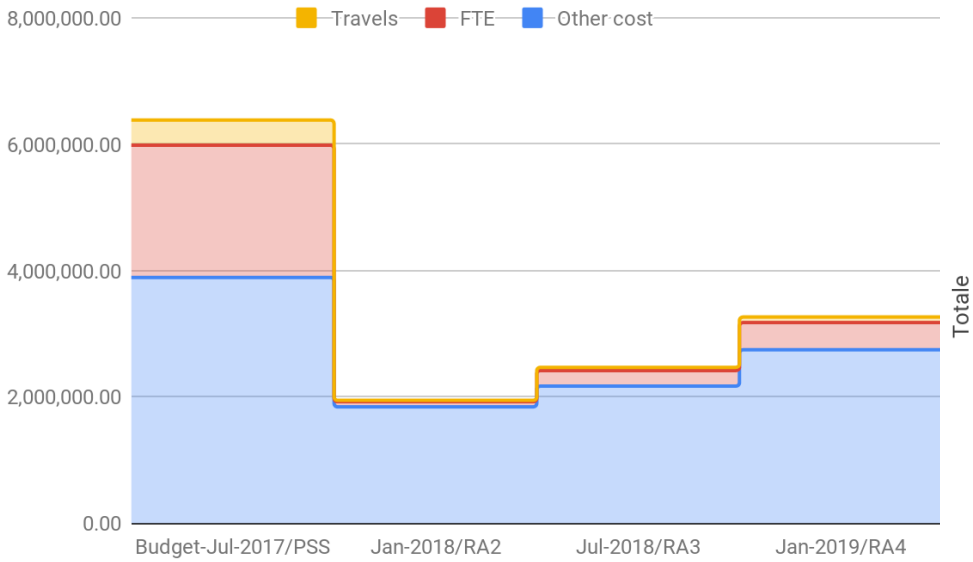


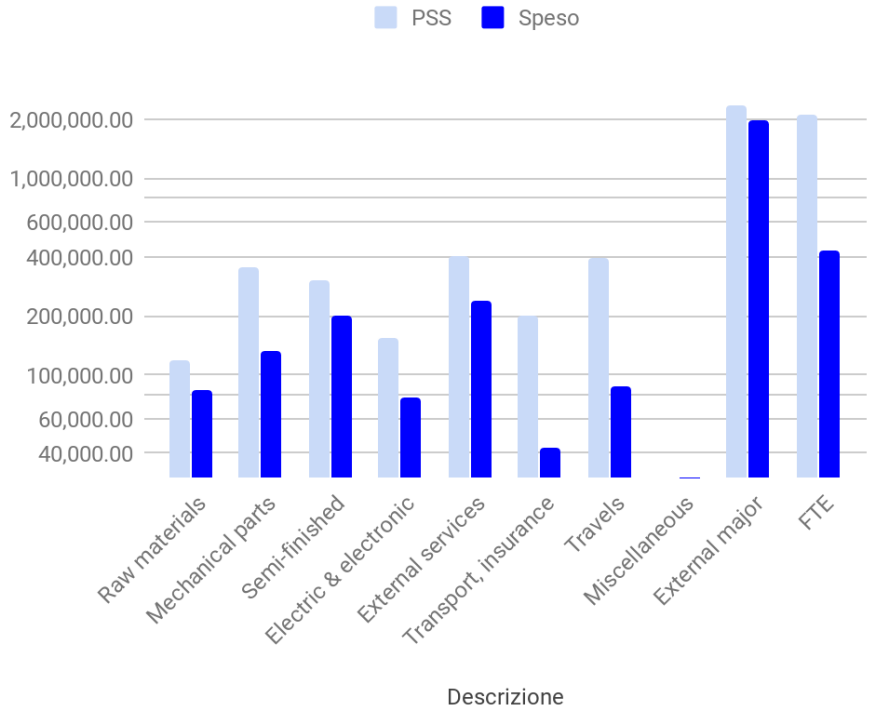
DU Flight Model 1
Integration

Instrument Schedule



IXPE Cash flow – ASI funds

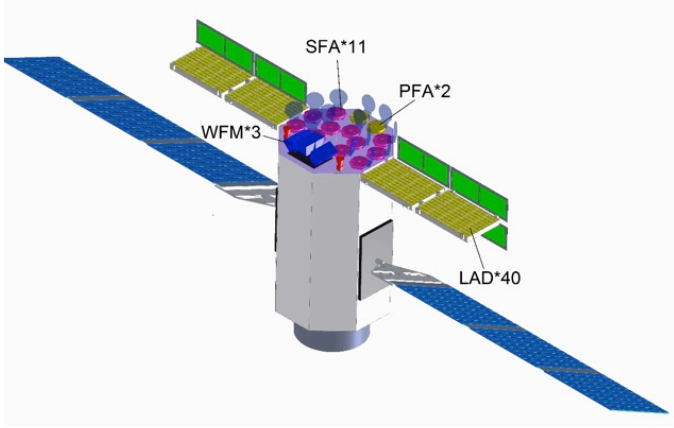




Procurement (tenders, orders) and personnel contacts managed through INFN administration

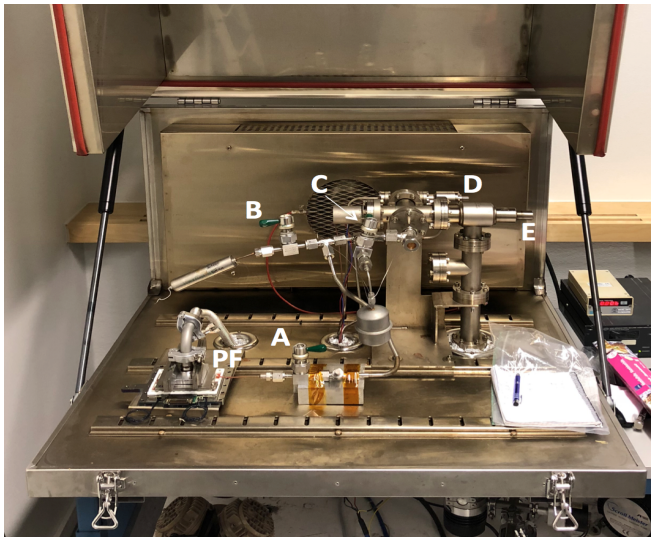
Prospects – beyond IXPE – call for volunteers

- Improve GPD performance for future missions
  - First window in 2026 with eXTP (China)
    - Large mission with several instruments for spectroscopy, imaging, timing and polarimetry



1. Solve systematics from spurious modulation
   - Complete test and qualification of alternative GEMs
   - Test new ASIC with dedicated readout systems
   - Evaluate new ASIC design and production

2. Consolidate GPD production line at INFN
   - Mechanics: build on existing design and derive more flexible parts for prototypes
   - Integration: build baking and sealing facility



GPD Spurious Modulation

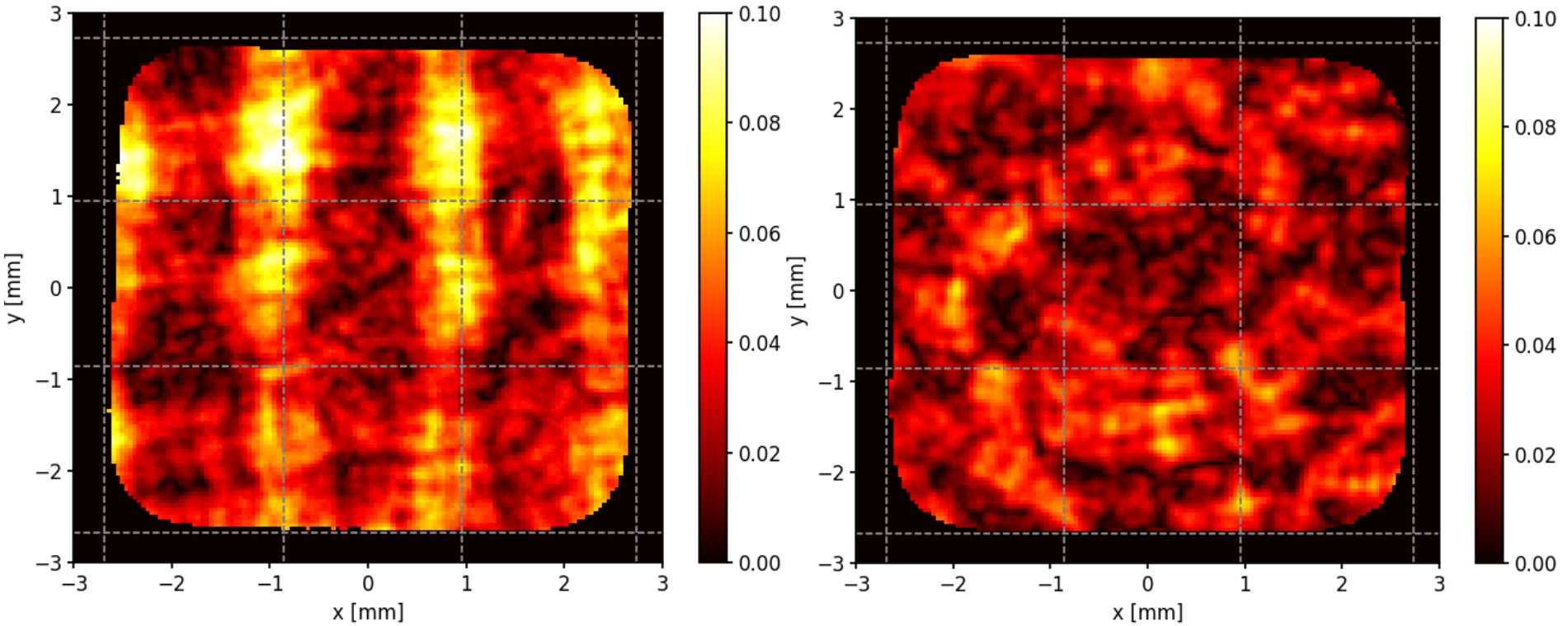
- IXPE GPDs exhibit energy- and position- dependent residual modulation of few % from unpolarized beams

- Measurements indicate a complex mixture of many tiny effects
  - GEM geometry (holes, pitch) and processing
  - ASIC (trigger digital lines activity, pedestal and gain pixel variations)
  - Readout electronics and processing software global effects
  - Residual source polarization

- Dedicated, successful effort to recover science requirements for IXPE
  - Through dedicated calibration and observation strategies (dithering and clocking)

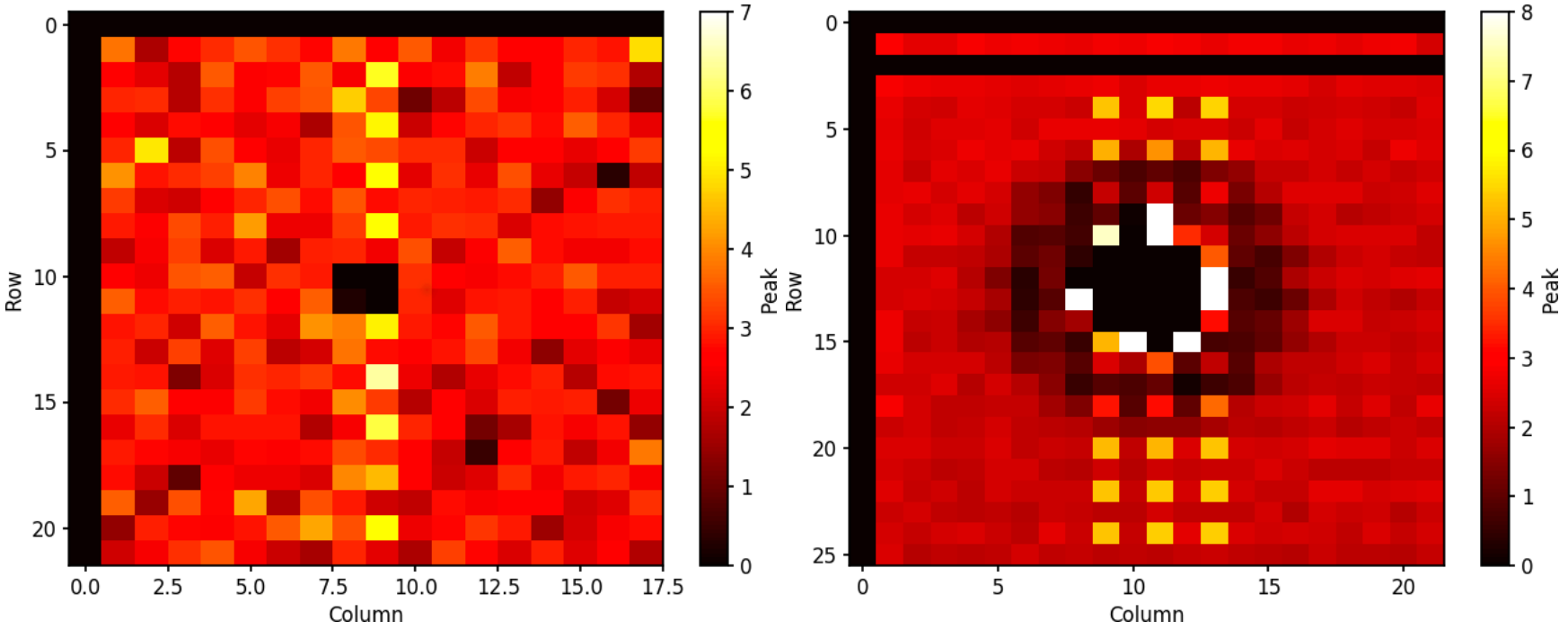
- Beyond IXPE – understand root cause inside GPD
  - Two years R&D program in parallel to IXPE mission

GPD Residual Modulation – GEM studies



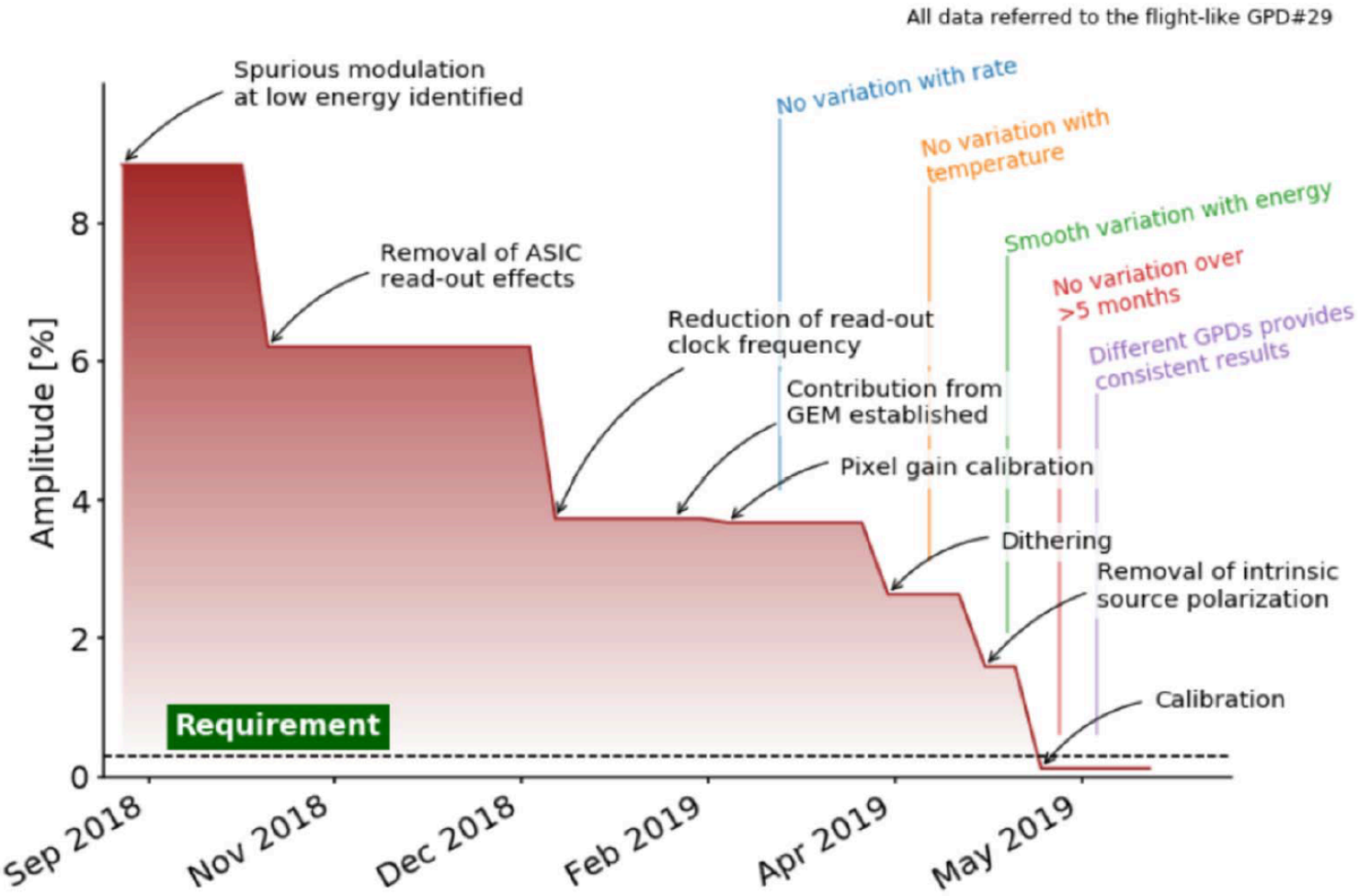
- GPD modulation correlates with GEM gain structures
  - after gain calibration
- Different GEM manufacturing technologies induce different modulation patterns

GPD Residual modulation – measured ASIC effects



- Readout (charge injection / physics) leaves few ADC counts asimmetries
- Tiny but coherent effect can produce ~% modukation
  - 2/3 ADC counts vs ~10 noise cts, vs ~1000 signal cts

IXPE GPD Residual modulation recovery



- Final goal is to solve root cause with new generation of GPDs for future missions

References

- https://ixpe.msfc.nasa.gov/ and papers therein
- Lectures on x-ray polarimetry and IXPE from
  - https://www2.pd.infn.it/astro/pers/asiago2018/index.html