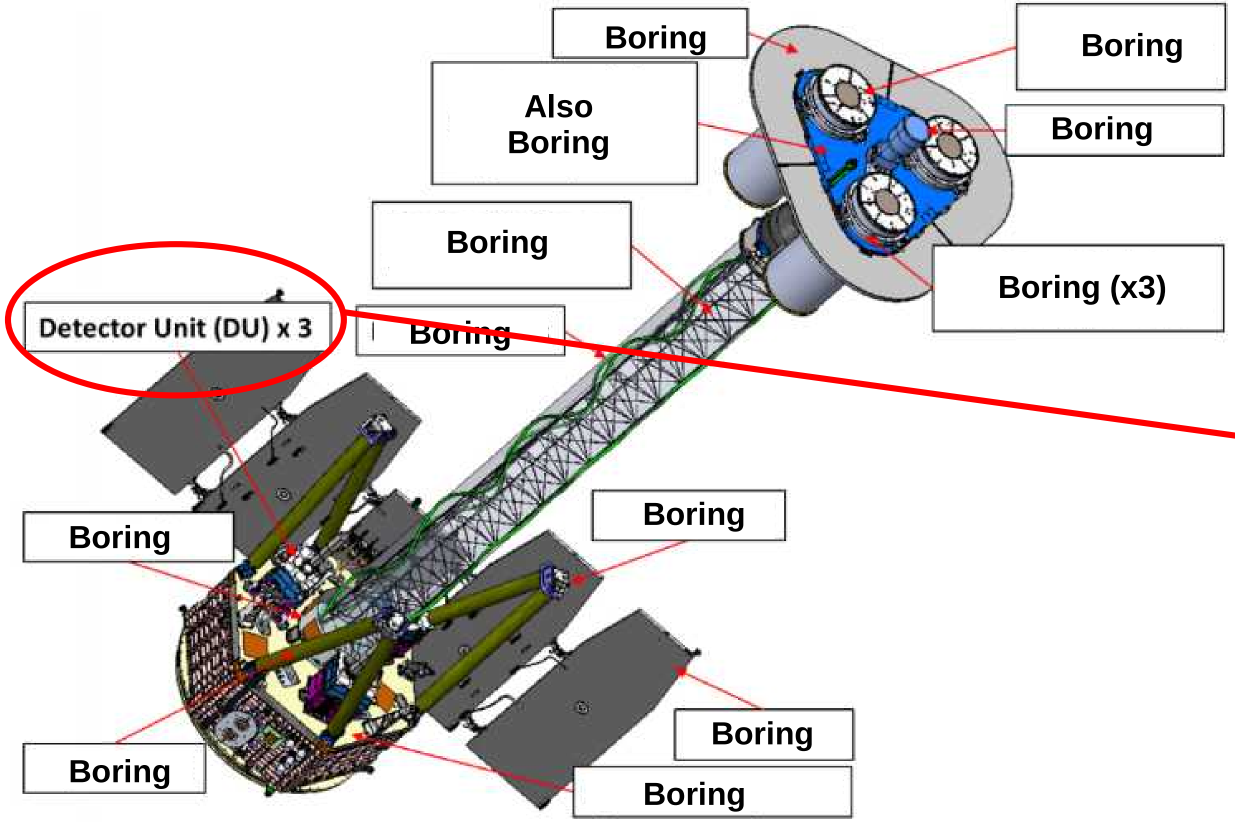
16th IACHEC Meeting,
Segovia (2024)

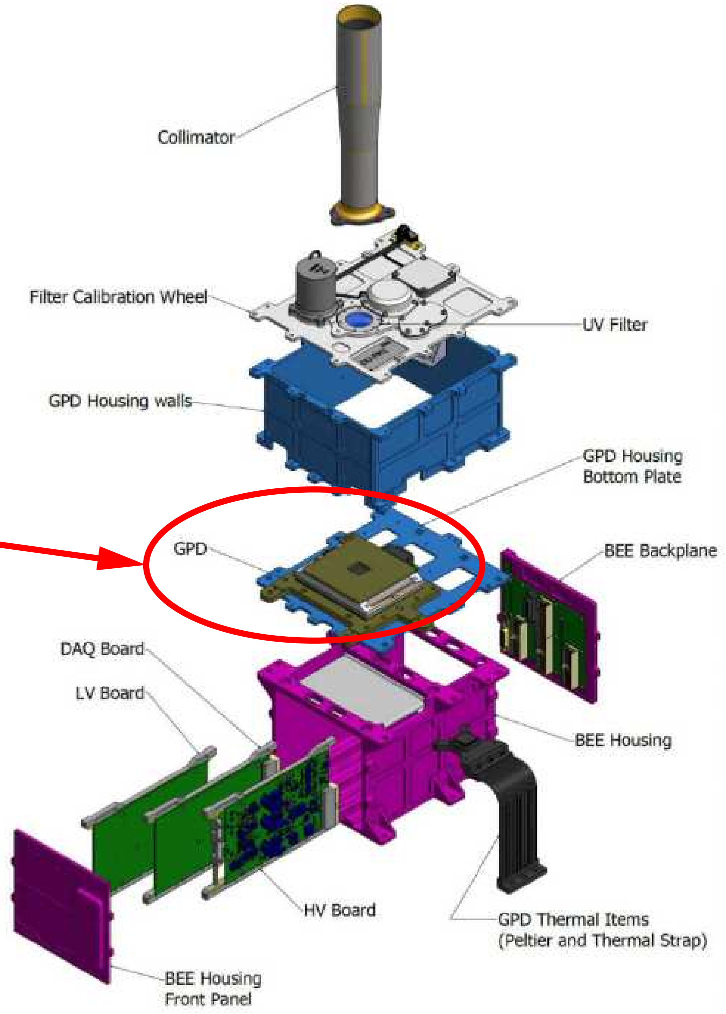
IXPE mission calibration updates

Stefano Silvestri
INFN and University (Pisa)
(On behalf of the IXPE team)

The IXPE telescope

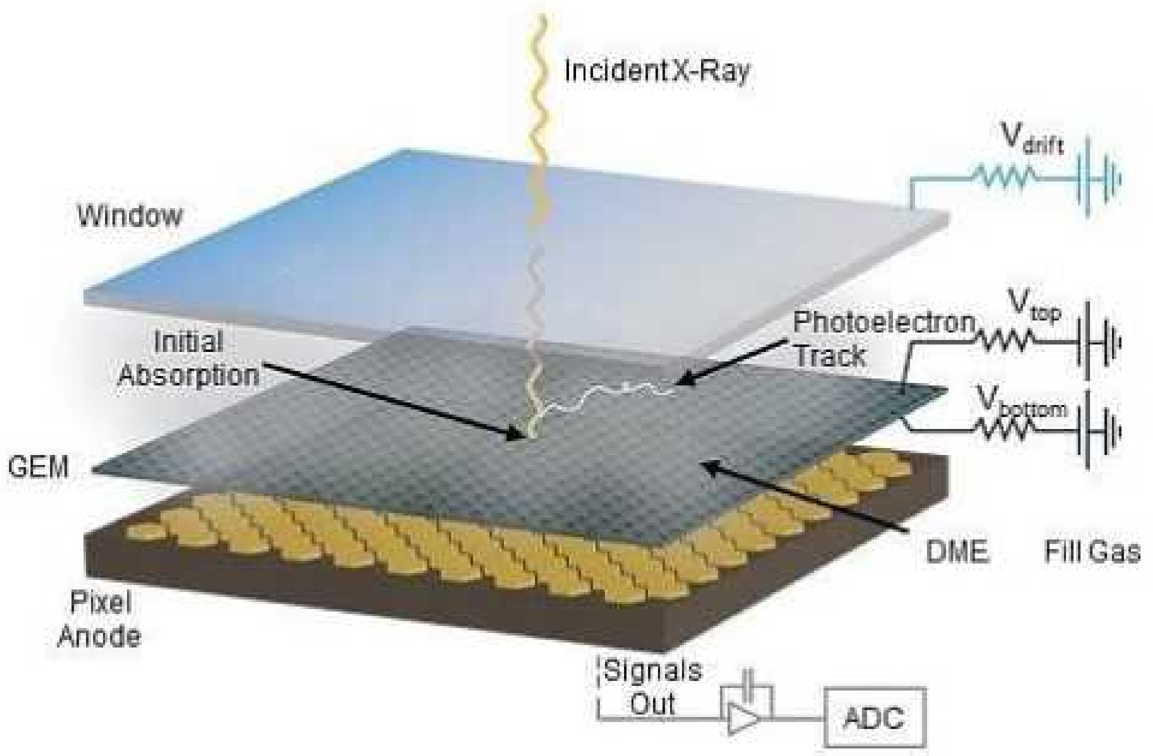
We have the usual Wolter Telescope focusing on a novel gas detector

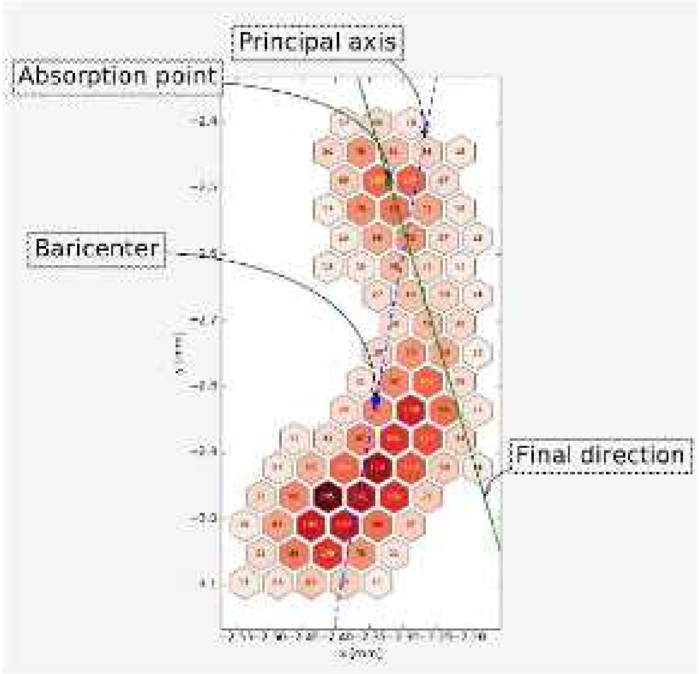




How IXPE detects polarisation

We get polarization from the shape of the track



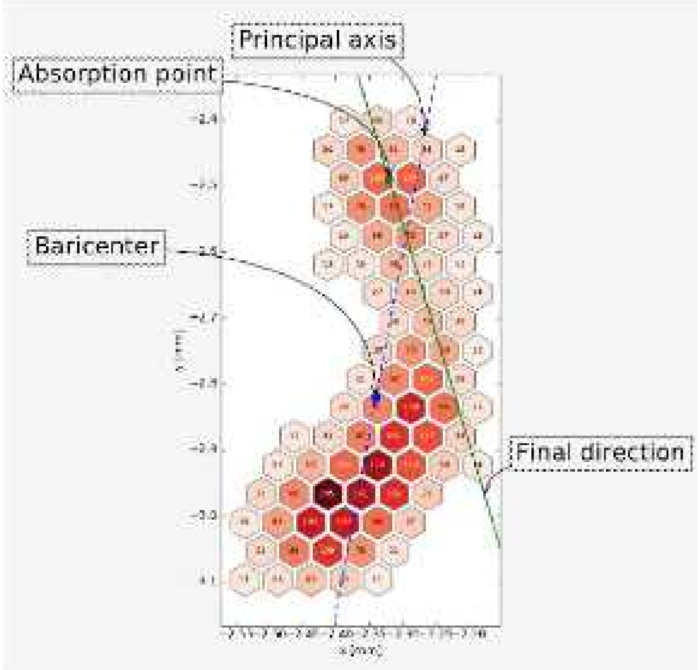


Photoelectron track analysis

How IXPE detects polarisation

A few stats

Parameter	Value
Sensitive area	15 mm × 15 mm (13 x 13 arcmin)
Fill gas and asymptotic pressure	DME @ 0.656 atmosphere
Detector window	50-µm thick beryllium
Absorption and drift region depth	10 mm
Spatial resolution (FWHM)	≤ 123 µm (6.4 arcsec) @ 2 keV
Energy resolution (FWHM)	0.57 keV @ 2 keV (∝ √E)
Useful energy range	2 - 8 keV

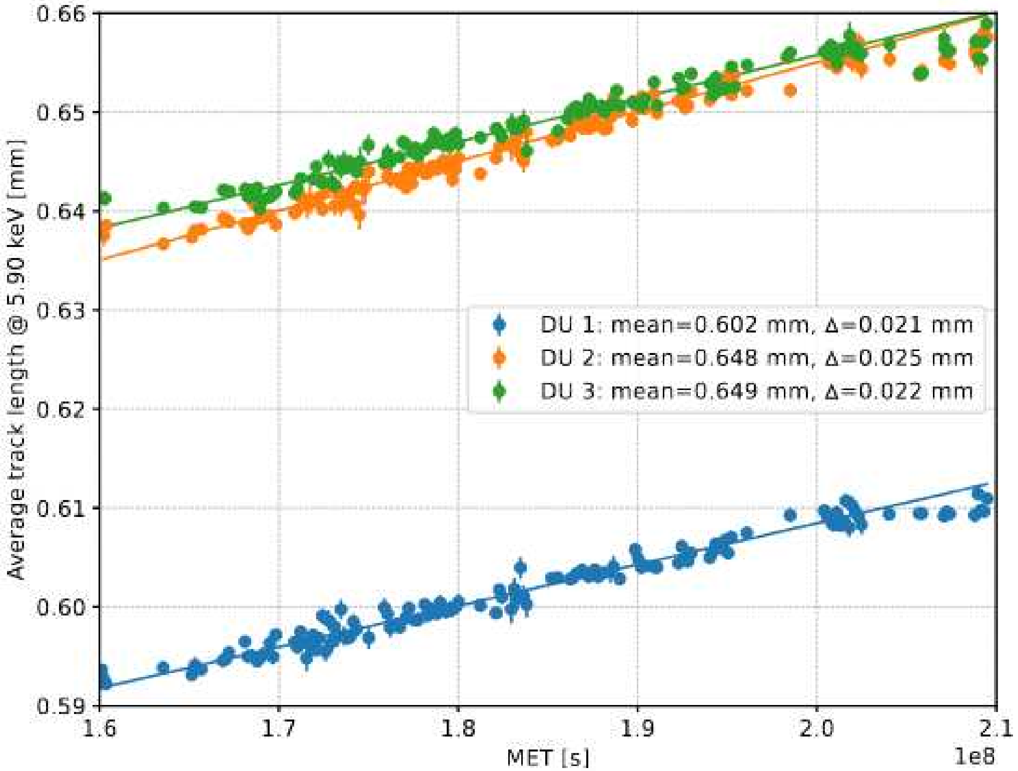


Photoelectron track analysis

Pressure variations

The gas is subject to slow pressure changes (**adsorption**) which result in a secular modification of the response functions

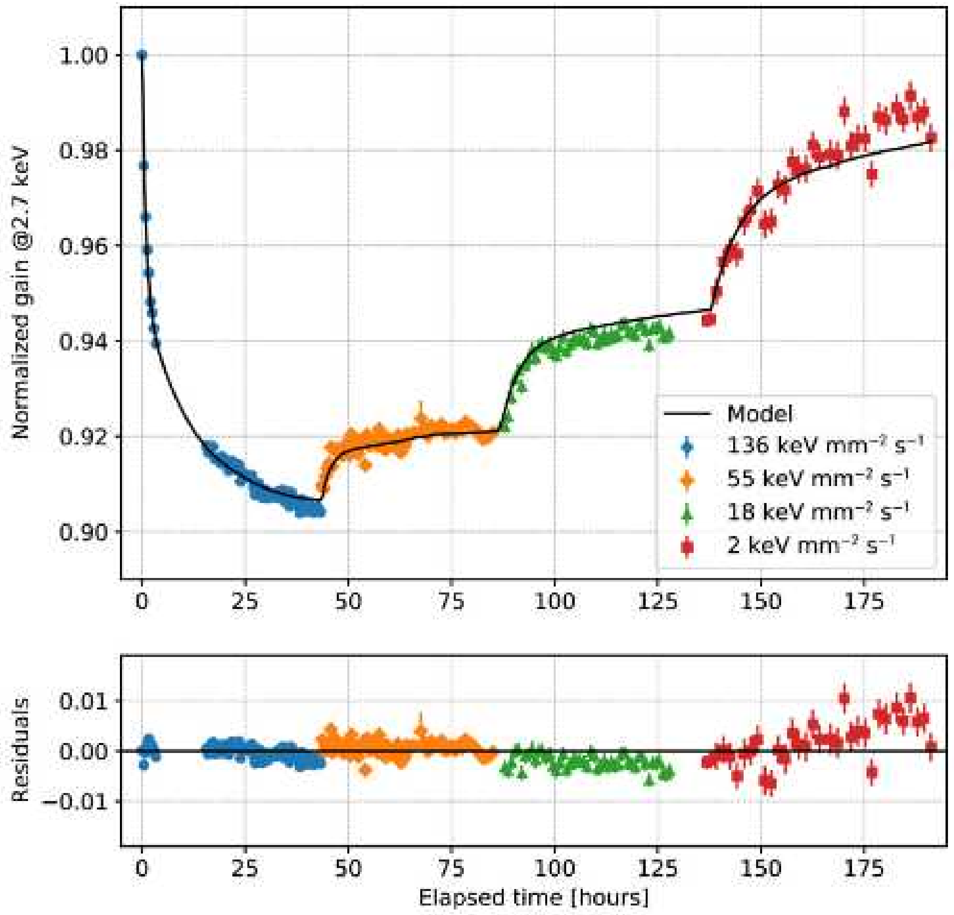
- Track length at a fixed energy is a proxy for the pressure of the gas (diffusion is the key)
- Over time, we detected an increased length of the tracks at a fixed energy
- This is also different depending on the detector unit
- Clear sign of the small internal adjustment of the gas pressure



Charging

The GEM is subject to charging which alters the amplification efficiency on a short timescale

- Roughly follows the physics of a capacitor
- The gain is rate-dependent
- The rate is coordinate dependent
- Ground calibration proved slightly inefficient (but was done sparsely due to time constraint of the mission)

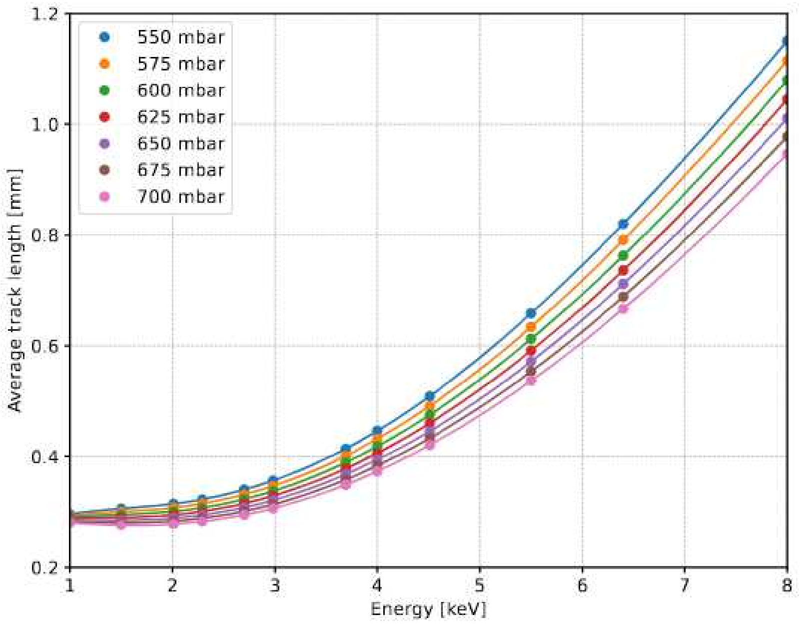


IXPE Imaging X-Ray Polarimetry Explorer

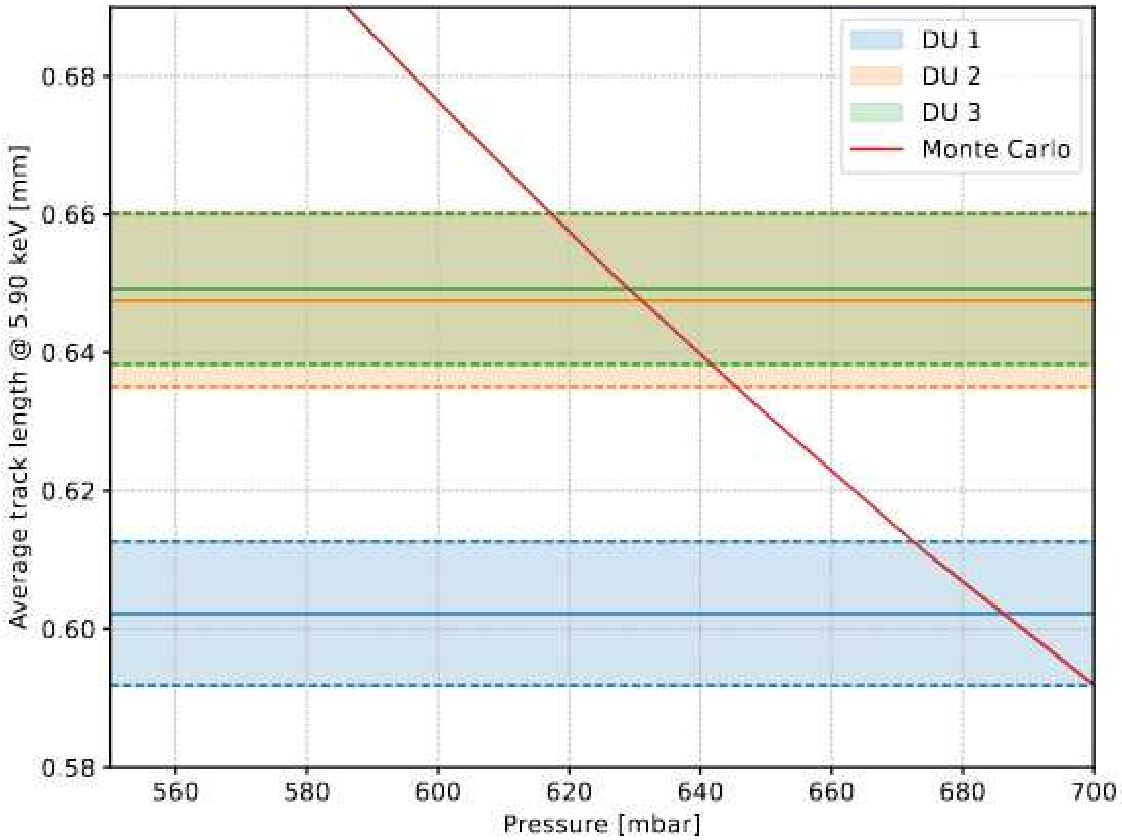
Year 2 on-orbit calibration

On orbit calibration of gas pressure

We have on-orbit lines from cal sources, and data from the simulations



Simulation: We simulate lines at different energies and observe track lengths as a function of the gas pressure



Cal sources: we can interpolate the plot on the left at fixed energy to see what track length we expect at different energies and correlate it with the oserved values for DU1 DU2 and DU3

- ➔ A significant pressure difference between DU1 and the others is observed, as we keep monitoring and updating the IRFs

On orbit calibration of gas pressure

The pressure is steadily dropping with the same rate (15/20 Mbar/yr) in all three Dus. The effect is small and we can fix it in the IRFs

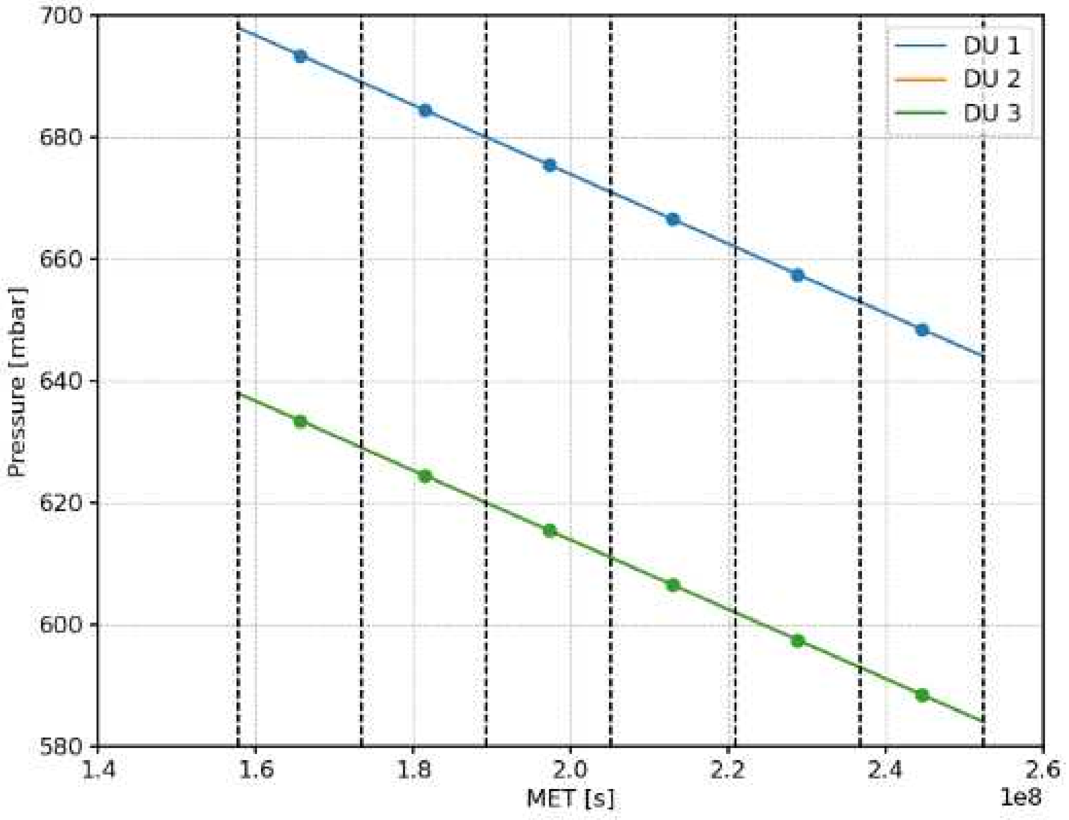
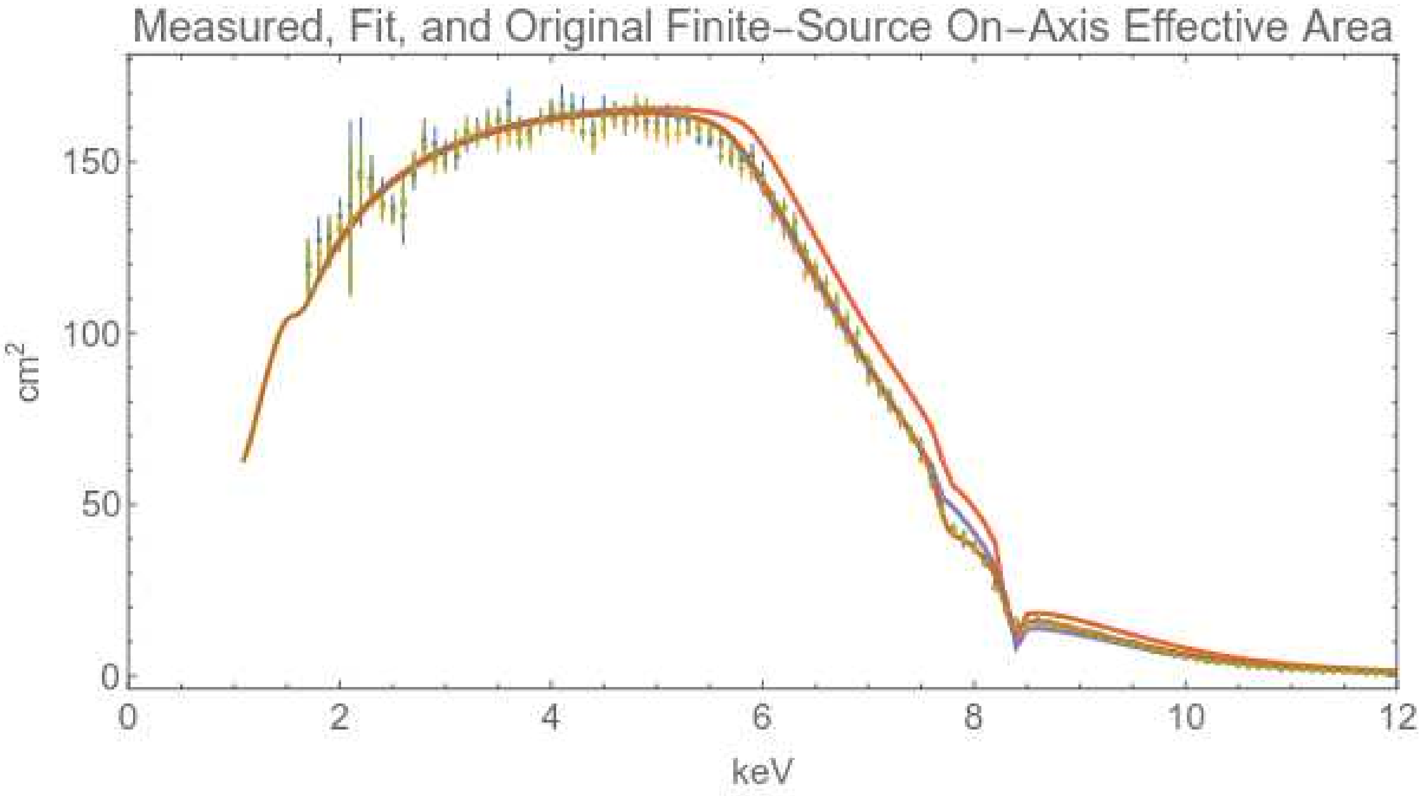


Figure shows that the pressure is roughly consistent in 6 months bins

- Monitor its variation and update the response functions every 6 months
- We now have different response function sets for each of the 6 months bins of previous observations
- IRFs have their start date encoded in the name now

MMA recalibration

We carried out a recalibration of the ARF using the Crab spectrum



Difference between the old and the new ARF comes from a better spectral fitting using slightly different parameters for on-ground calibration data

- Data points represent the observed spectrum
- Red line represents the old ARF
- Significant changes only at ~6 keV and above

Effective area at 4.5 keV

MMA	1	2	3	Total
Original	196.6	193.3	199.9	589.7
Revised	199.9	196.9	200.6	597.4
% Change	1.6	1.8	0.3	1.3

MMA temperature set point

We decreased the temperature set point to save power and extend mission duration

Half power diameters in arcseconds before (top) and after (bottom) the temperature set point change

- Baseline set after realignment of the optics
- Monitoring of the HPD estimates after set point change show no noticeable variation

DU1	DU2	DU3
25.4+/-0.5	31.5+/-0.5	30.0+/-0.5
26.3+/-0.5	32.6+/-0.5	30.2+/-0.5

On orbit calibration of charging

The ground-calibration under-corrects the charging

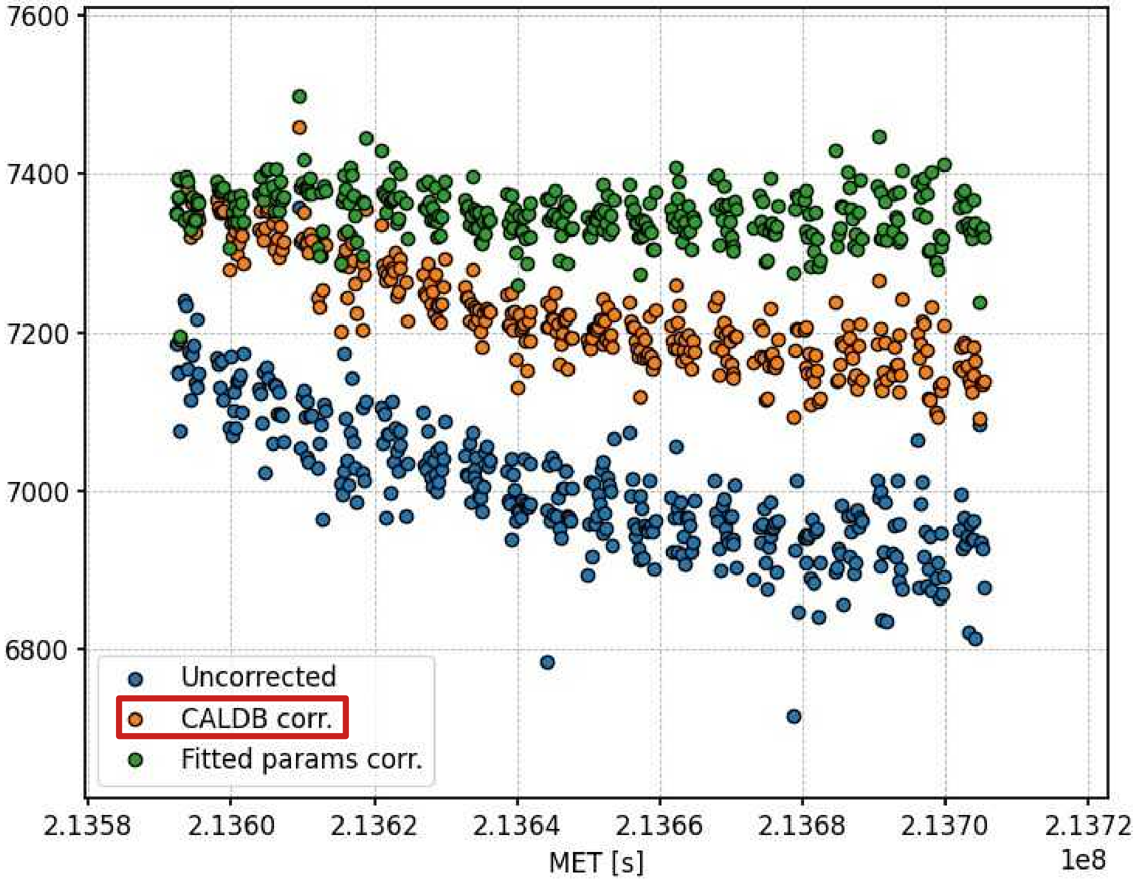


Figure shows mean PHA value over an observation of the Crab on DU2: although we are undercorrecting (CALDB corr) we know how to fix this (fitted parameters)!

- Charging is a local effect, so the the gain must be estimated on a grid, not on the overall detector
- Some events are not recorded by our detector but they physically alter its state nonetheless. For this reason, our charging map becomes increasingly unreliable over time without looking at the calibration sources
- The calibration is done when not observing, then we estimate the charging with a model that takes into account the (short scale) time averaged rate

On orbit calibration of charging

Once we have the initial state and we measure the rate in a time frame, the charging effect is estimated correctly, but over time it need to be calibrated

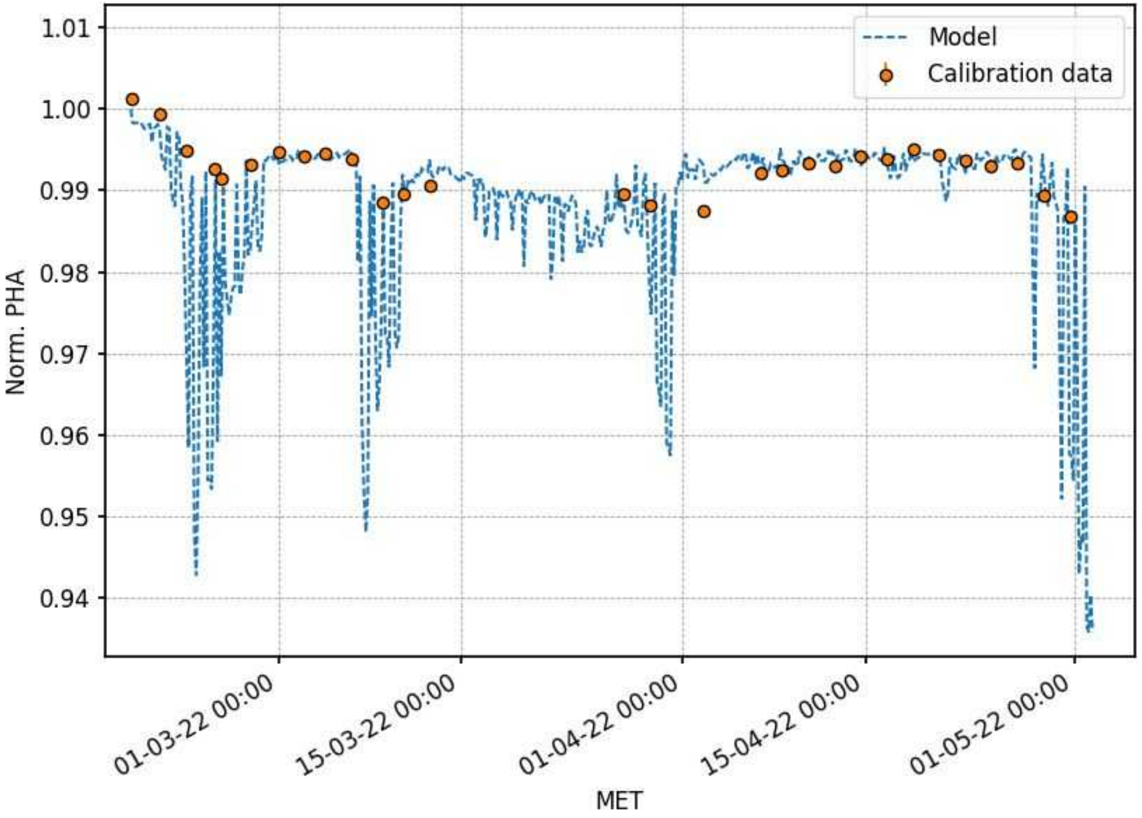
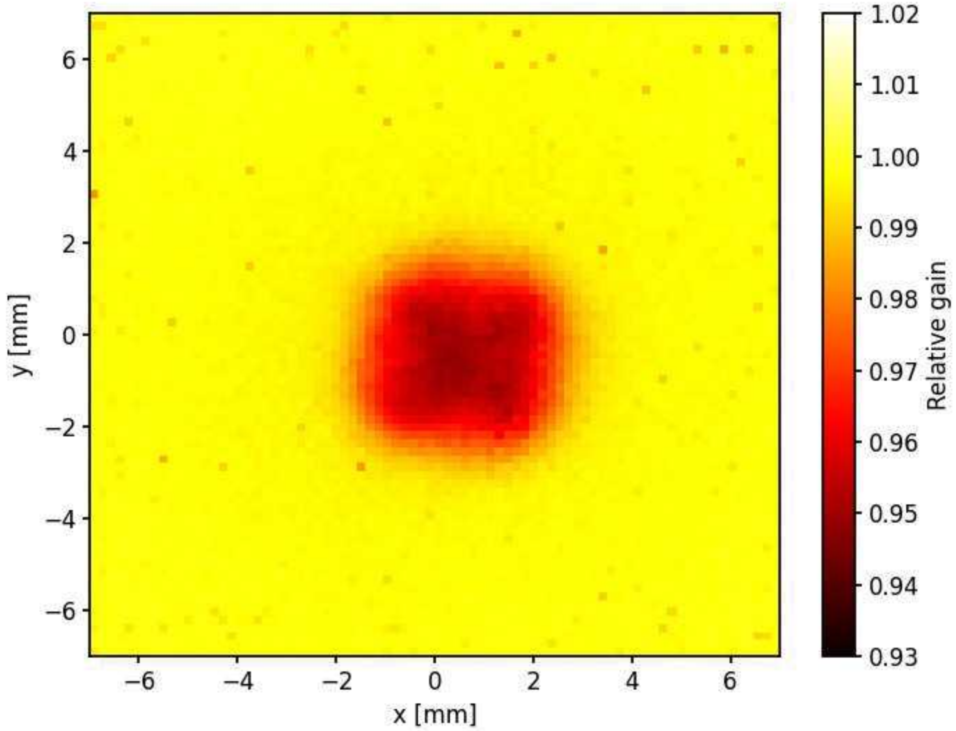


Figure shows that we can fit a model to the calibration data. The process really happens on a 2D grid which is not averaged out here

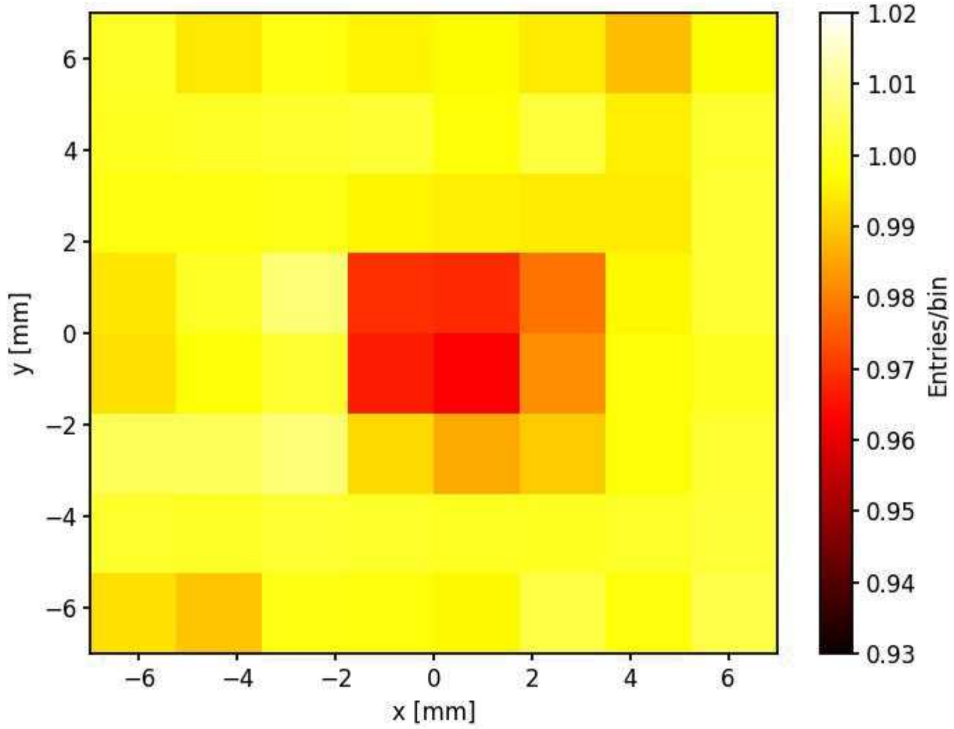
- Each time we have data from a calibration source we adjust the gain accordignly
- Once we have the calirated map we estimate its evolution and re-update it at the next calibration step

On orbit calibration of charging

The results are promising (on DU2) but the optimized correction is not yet in place, the current correction just undershoots the effect for ~few %



Estimated effect of charging on the gain



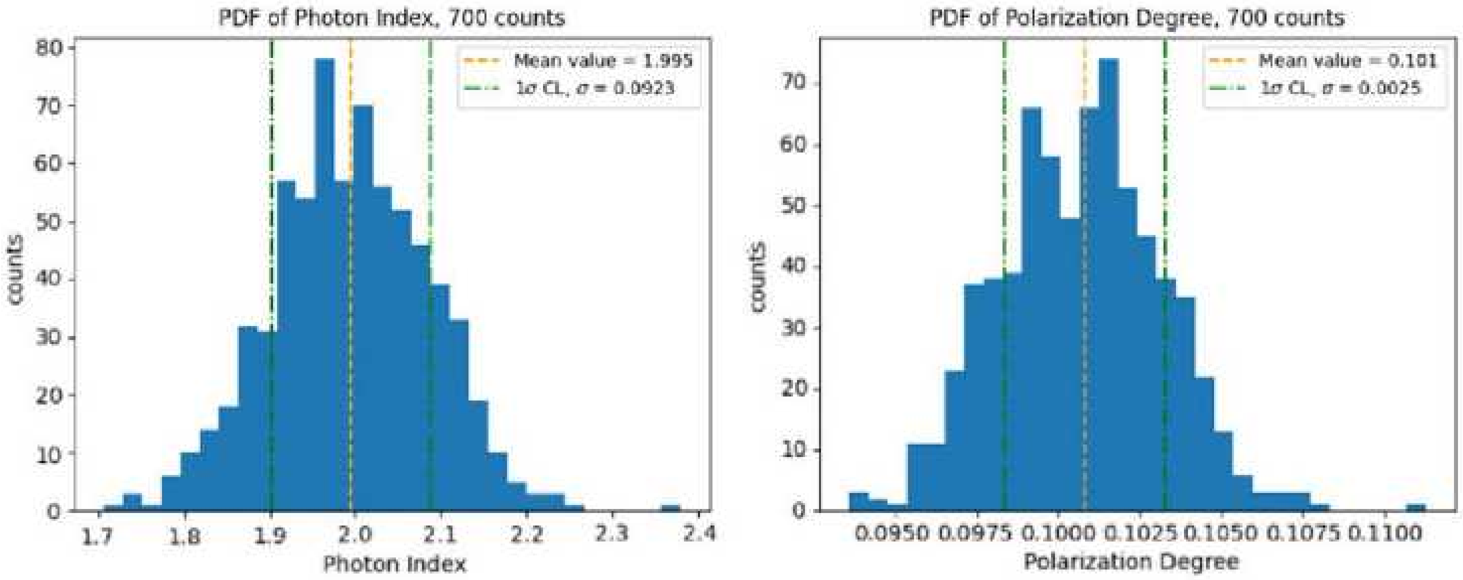
Observed effect through calibration sources

Throwback from last year's IACHEC

The effect of the charging on the estimate of the polarization had been already studied **with the exact asymptotic difference that we see in slide 5** (that was purely random)

Figure shows the result of the difference between estimated parameters with a perturbation of the energy scale by 2%

- Polarization degree is what matters and it is off from the input parameters by as little as 0.001
- Spectra are less relevant but also had other issues back then (old IRFS)



Parameter	Target	Result	Systematic PI
Ph. index	2	2.000 ± 0.001	1.995 ± 0.09
Normalization	10	10.00 ± 0.01	9.95 ± 0.6
Pol. degree	0.1	0.098 ± 0.0015	0.101 ± 0.0025

Summary

We are in good health

- We see a steady slight drop in pressure on the detector of the gas. We manage it through update IRFs, and its effect on the detection of polarization is negligible
- The new IRFs also contain an updated version of the ARF based on Crab data that provide a better fitting to spectra but does not impact our average ARF more than ~1%
- Our new processing pipeline include corrections for the themally induced boom oscillations and should soon include also a better charging correction. Its effect on the polarization as of now is <1%
- The decreased temperature from the heaters prolongs the mission duration without altering its sensitivity