STSM scientific report

Calibration of the GPD X-ray polarimeter/JET-X telescope assembly at the MPE Panter test facility

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Location: MPI für extraterrestrische Physik, 85748 Garching, Germany
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1 Purpose

The purpose of the STSM was to perform a calibration campaign dedicated to test the operation of the X-ray photoelectric polarimeter Gas Pixel Dedetector in the focus of a mirror module of the Joint European X-ray Telescope (JET-X). The measurements were carried out at the Max Planck Institute for Extraterrestrial Physics Panter X-ray Test Facility in Munchen (Germany) which was already used in the past for the calibration of the telescope. The calibration campaign is aimed at:

- measuring the Point Spread Function (PSF) of the GPD in the focus of the JET-X optics. The GPD can perform imaging polarimetry with a spatial resolution better than 40 um HEW (Soffitta et al., 2012 NIMA in press) but this is true for a beam which is incident perpendicular to the instrument. In case the GPD is placed in the focal plane of a X-ray telescope, the inclined direction of focussed photons is expected to add a contribution because the photons are absorbed in a gas cell 1 cm thick and not on a plane. Monte Carlo simulations suggest that the angular resolution is dominated by the telescope in normal conditions, but a real measurement will confirm this crucial point for future missions.
- placing an upper limit on the possible spurious polarization introduced by grazing reflection. This is an important issue for any polarimeter intended to be used in a focal plane as the GPD (or its competitor based on the Time Projection Chamber approach, Black et al. 2007 NIMA 581:755) and it is high debated because, although the effect according to Fresnel equations should be small and not detectable for the current generation of instruments, only a few estimates are available in the literature (Almeida et al. Applied Optics 32:4231 1993; Katsuta et al. NIMA 603:393 2009). Real measurements are threfore compelling.

2 Activities

The JET-X optics was built in the '90s for the original SPECTRUM-X-Gamma mission and then the first measurements were dedicated to confirm that the telescope performance has not degraded during the storage. The results, reported in the Figures below, are very encouraging.

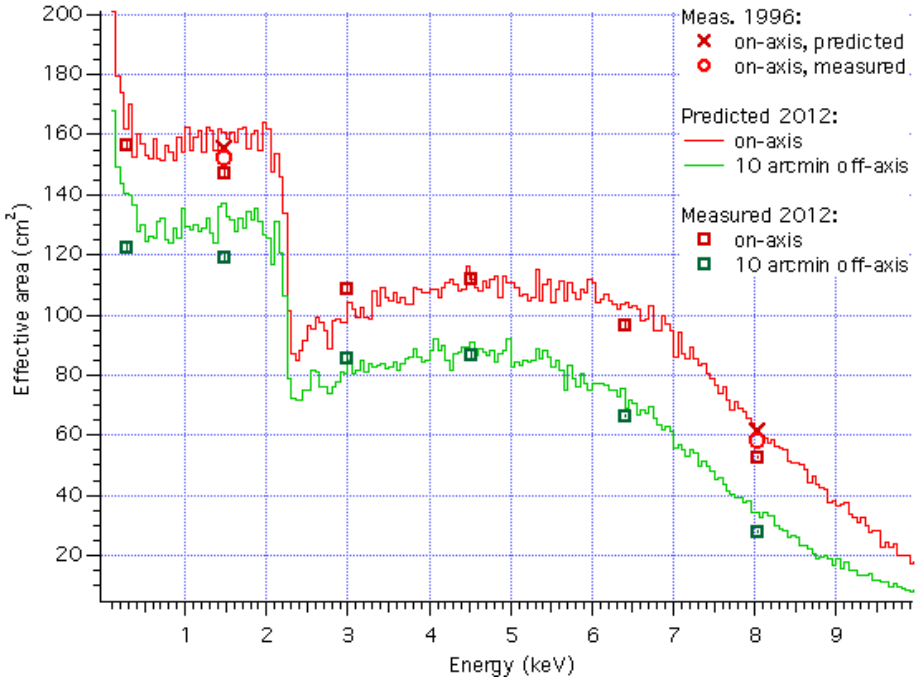

Figure 1 Comparison of the effective area of a JET-X mirror module measured in 2012 and 1996 calibration campaign (credit W. Burkert, G. Hartner, D. Spiga).

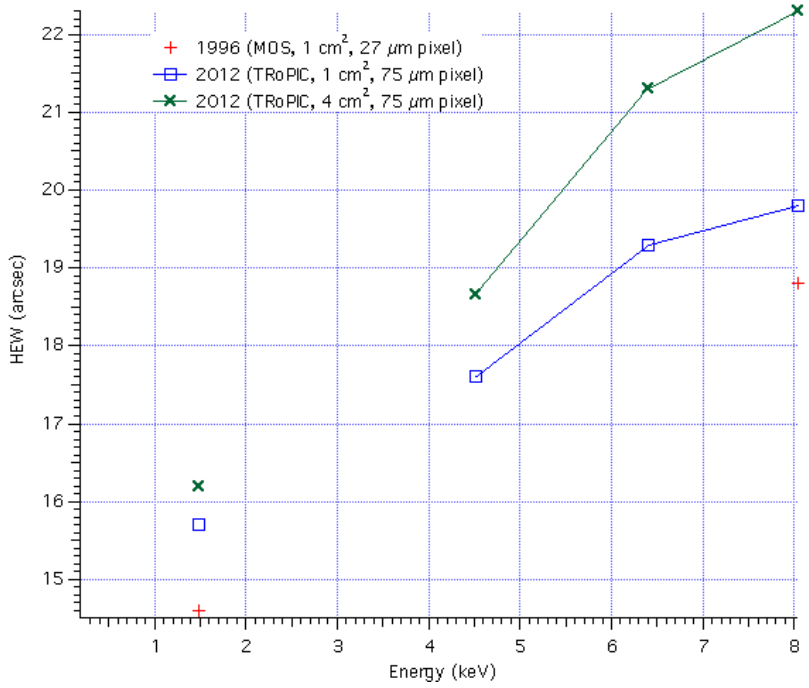

Figure 2 Comparison of the JET-X PSF. The data which can be compared directly to test the optics performance stability are those in red and blue (credit W. Burkert, G. Hartner, D. Spiga).

2.1 PSF on axis

The first measurements carried out with the GPD were dedicated to place the instrument in the focus of the telescope. The procedure is based on the minimization of the Half Energy Width, that is the radius which contains the half of the counts. We report in the figure below the HEW as a function of the position on the focal axis at 4.5 keV. The minimum value corresponds to 23.7 arcsec, which is fully consistent with the value expected considering the PSF and the inclined penetration of the photons in the gas cell (Fabiani et al. PoS(CRAB2008)027 2008). This confirms that the spatial resolution of the GPD is sufficient to fully exploit the quality of the mirrors.

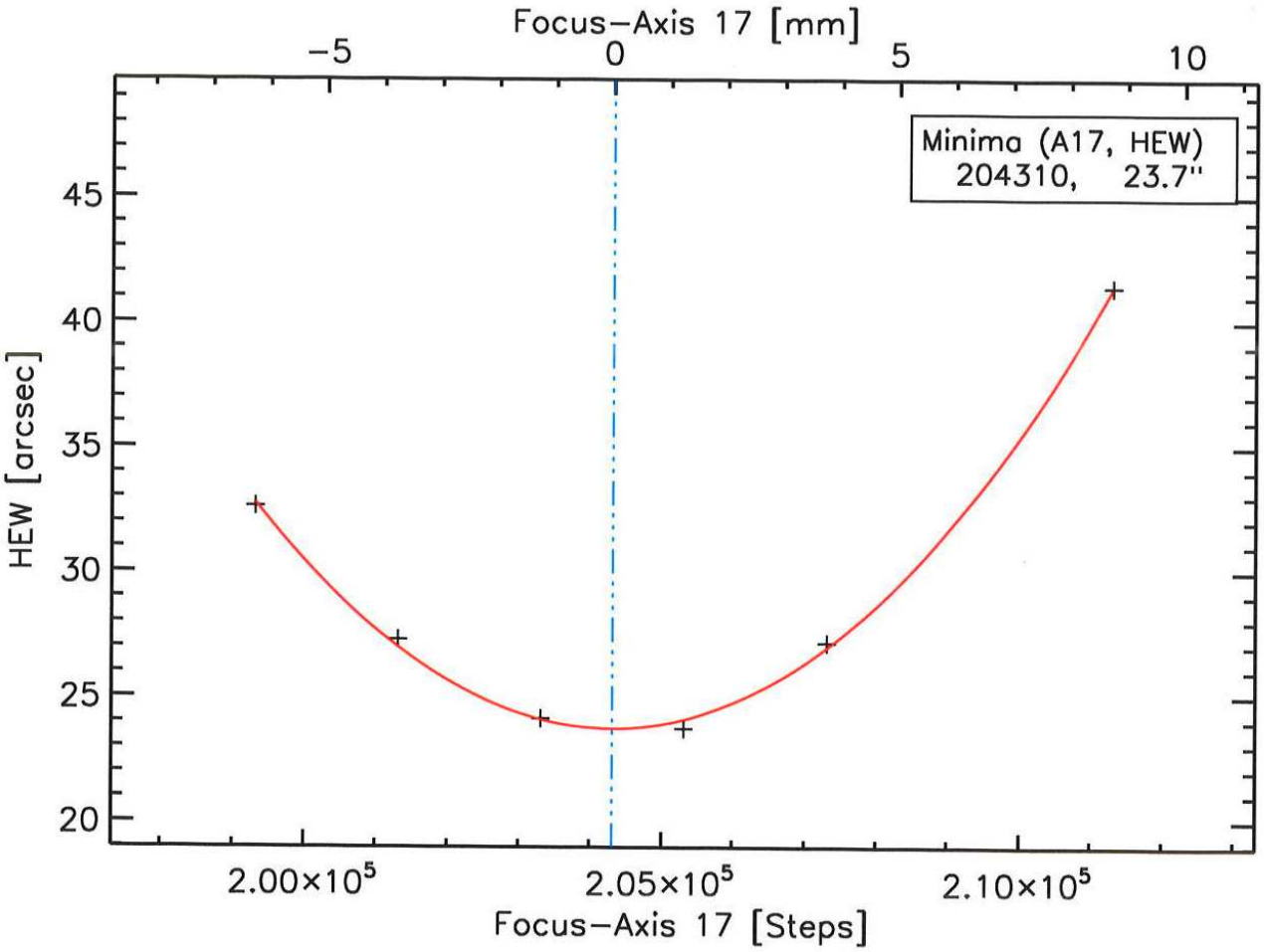

Figure 3HEW vs focal distance for the GPD+JET-X assembly at 4.5 keV.

We measured the HEW at three energies, that are 2.99 keV (corresponding to Ag L line), 4.5 keV(Ti K line) and 8.04 (Cu K line). The preliminary results are reported in the table. We also show in Figure 4 the PSF at 4.5 keV.

Energy (keV)	HEW (um) - preliminary	HEW (arcsec) – preliminary
2.99	401.9	23.0
4.51	410.8	23.7
8.04	514.5	29.5

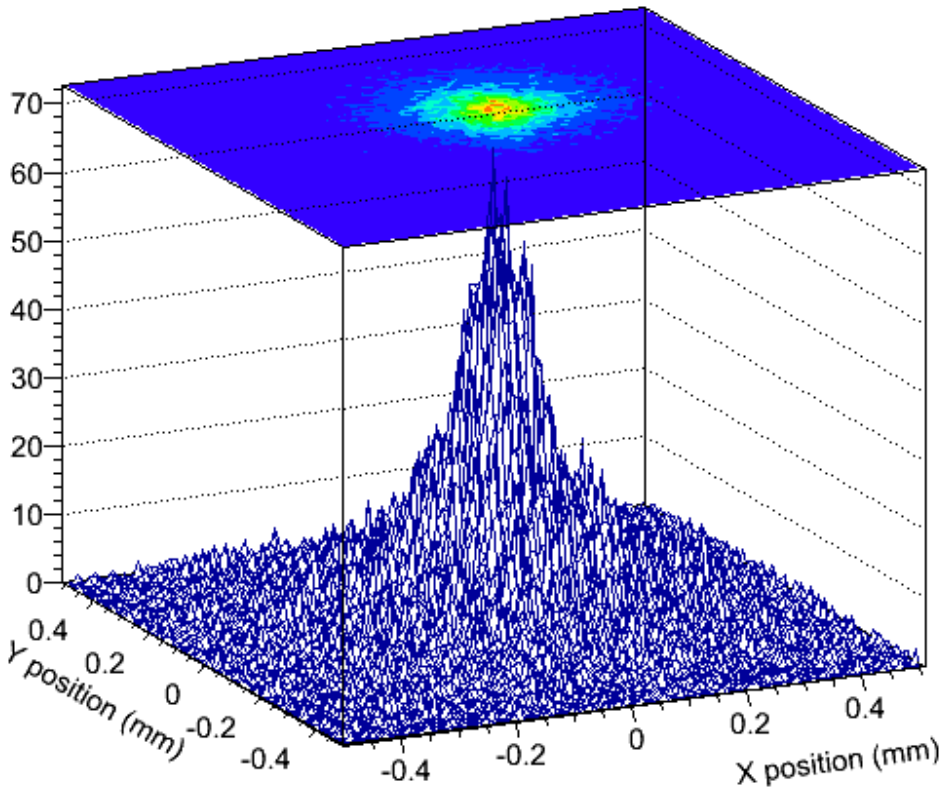

Figure 4 PSF at 4.5 keV.

2.2 PSF off-axis

We also measured the PSF in three positions off-axis, that are at (2.2;2.2) arcmin, (4.4;4.4) arcmin and (6.6;6.6) arcmin, and at three energies, that are 2.99, 4.51 and 8.04 keV. This is done by rotating and inclining the mirrors and then the image remains fixed in the center of the detector. No major distortion are detected, also because the field of view of the GPD is rather narrow (7.5x7.5 arcmin). In the figure below we report the PSF at 4.5 keV at (6.6;6.6) arcmin off-axis.

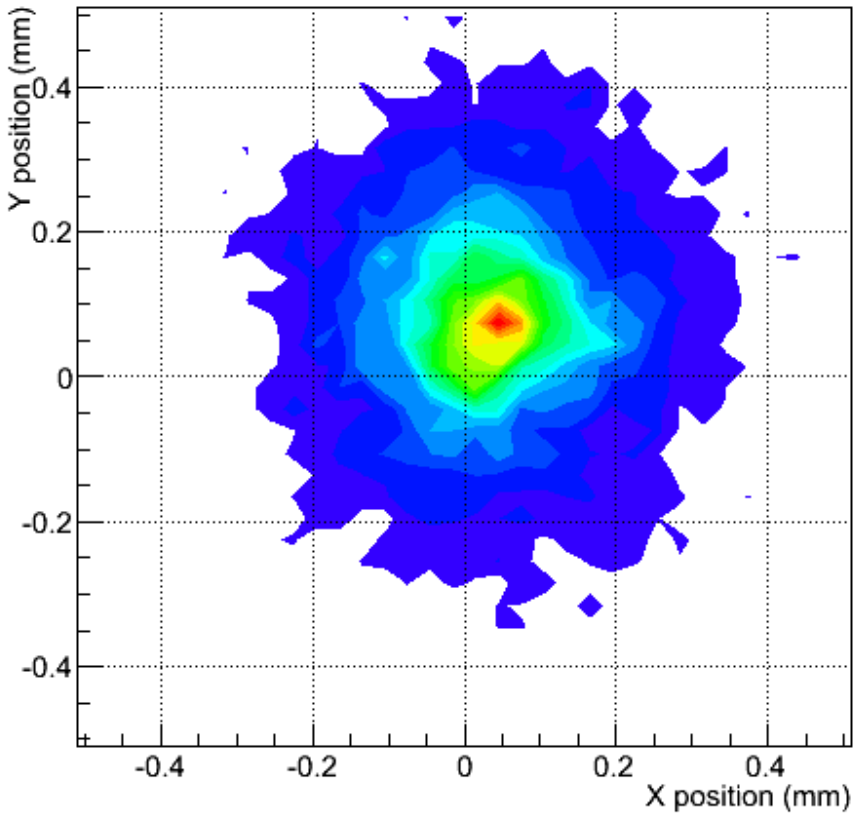

Figure 5 PSF at 4.5 keV and (6.6;6.6) arcmin off-axis.

2.3 Spurious modulation

The last measurement we performed was a long integration to explore the possible polarization induced by grazing reflection. We decided to perform such a measurement at 4.5 keV because at this energy the tracks are very well sampled and reconstructed by the instrument and then this energy is nearly at the peak of the sensitivity. A preliminary analysis of subset of the data shows that, selecting the events in which the difference between the beginning and the end of the track is more evident, we can exclude at the 99% that the telescope introduce the polarization at a level higher than 3.4%. A cosine square fit to the modulation curve provides a modulation of (0.53+/-0.56)% (see the figure below). A more refined analysis which take into account the polarization of the underlying bremsstrahlung and a better data selection which is on-going could improve this result.

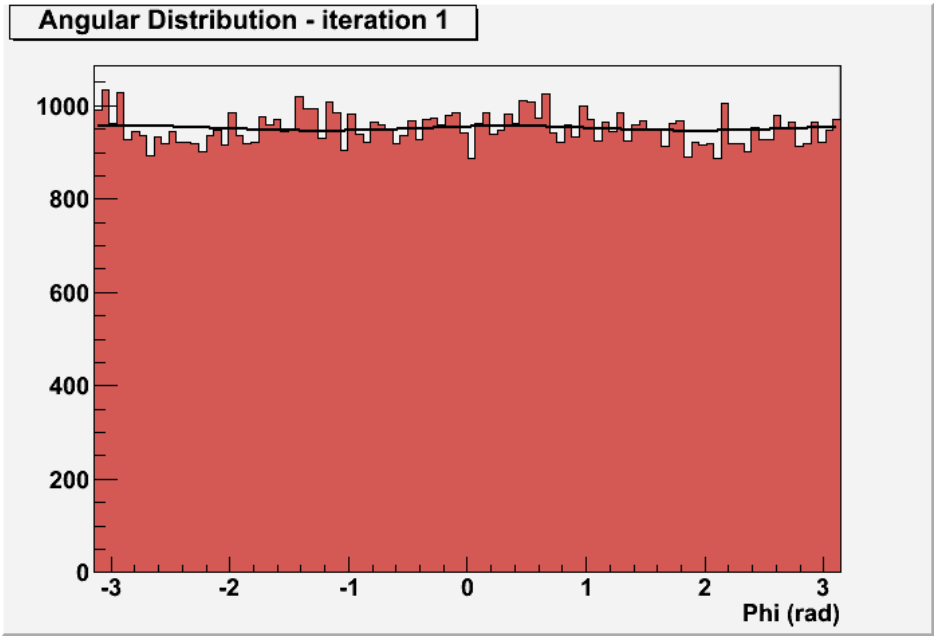

Figure 6 Modulation curve measured at 4.5 keV. A cosine square fit provides a modulation of (0.53+/- 0.56) %.

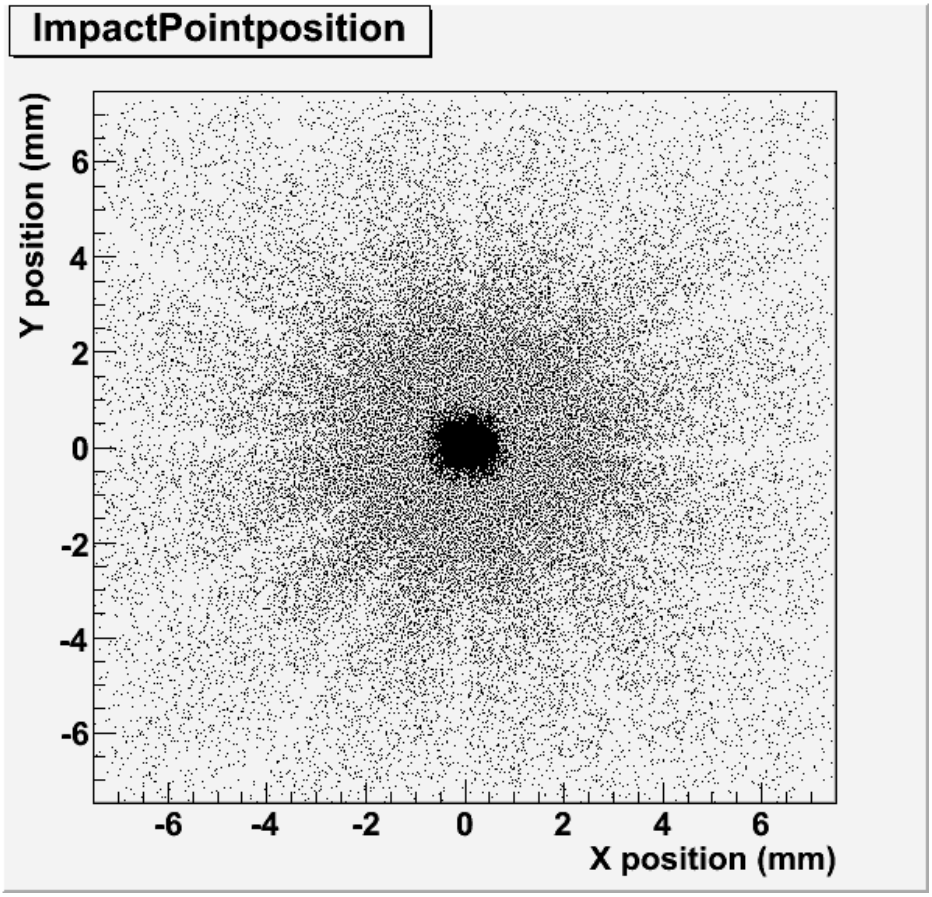

Figure 7 Image of the source. The large number of counts makes evident in the wings of the PSF the shadow of the structure supporting the shells of the mirror.

3. Conclusion

This calibration campaign allowed for the first time to study the behaviour of the GPD with an X-ray optics. We measured the PSF of the instrument in the focus of the JET-X optics at three energies and in 3 off-axis positions, thus covering almost completely the whole energy range and the field of view of the instrument. We also explored the possibility that grazing reflection may introduce a spurious modulation. A preliminary analysis shows that we can exclude any effect at a level higher that a few % and further work on the data may improve this result.
Further campaign will be performed in the future. A polarized and monochromatic source is being refurbished at the Panter Facility and this will allow us to repeat the measurements of the PSF and of spurious effects but with polarized light.
The results will be published on one or more articles on referred specialized journals.