Simbol-X calibration issues

A. Moretti & G. Malaguti

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From the calibration point of view Simbol-x presents 3 main non-standard issues

- Focusing optics at very high energy (End2End)
- Mirror and detector are not rigidly connected (End2End)
- Very large focal length (the most critical, Mirror Module + End2End)

Non-standard calibration: the energy band

Monochromatic energies in the 20-80 keV energy band

Few lines; mono-chromator (double crystal difractometer) is an option

Otherwise we could use only continuum

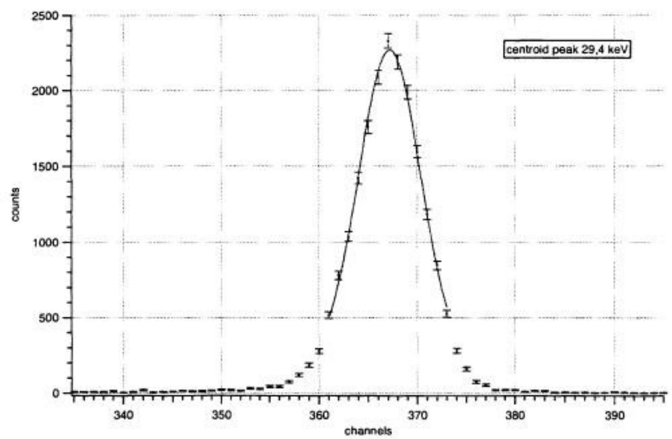


Figure 5. Line at nominal 30 keV obtained with the fixed-exit monochromator. See text.

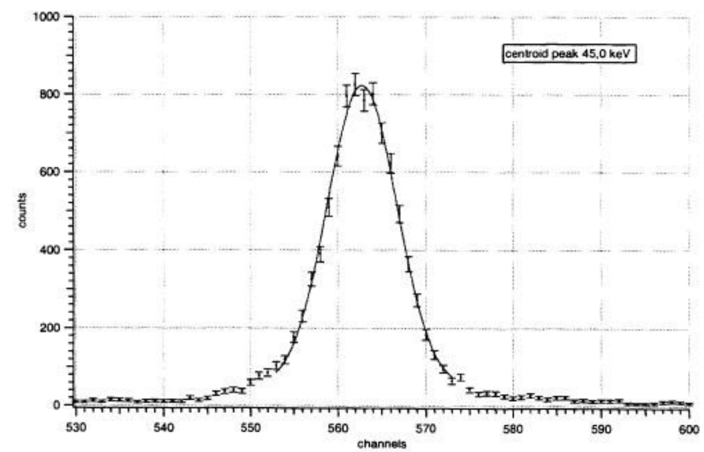
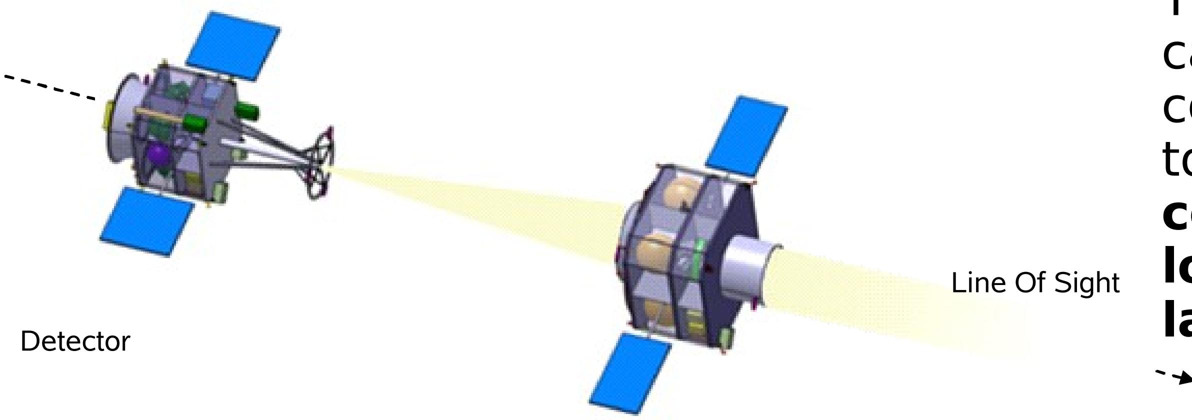
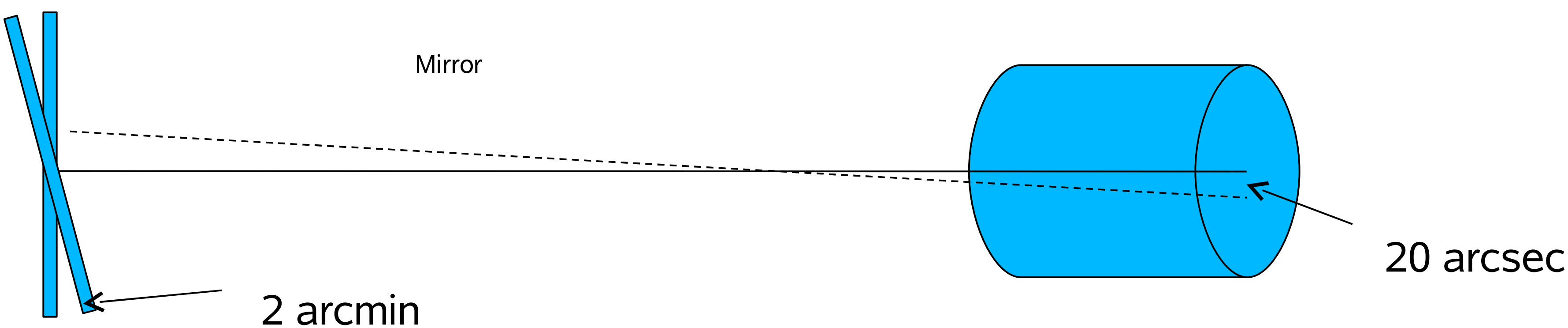


Figure 6. Line at nominal 45 keV obtained with the fixed-exit monochromator. See text.

Non-standard calibration: line of sight calibration



The detector satellite (DSC), carrying the focal plane assembly, controls its position with respect to the Mirror satellite within **control boxes of +/- 3 cm in longitudinal and +/- 0.5 cm in lateral.**



need to test for
- geometrical vignetting
- reflectivity vignetting (multilayer)
- occultation by auxiliary items

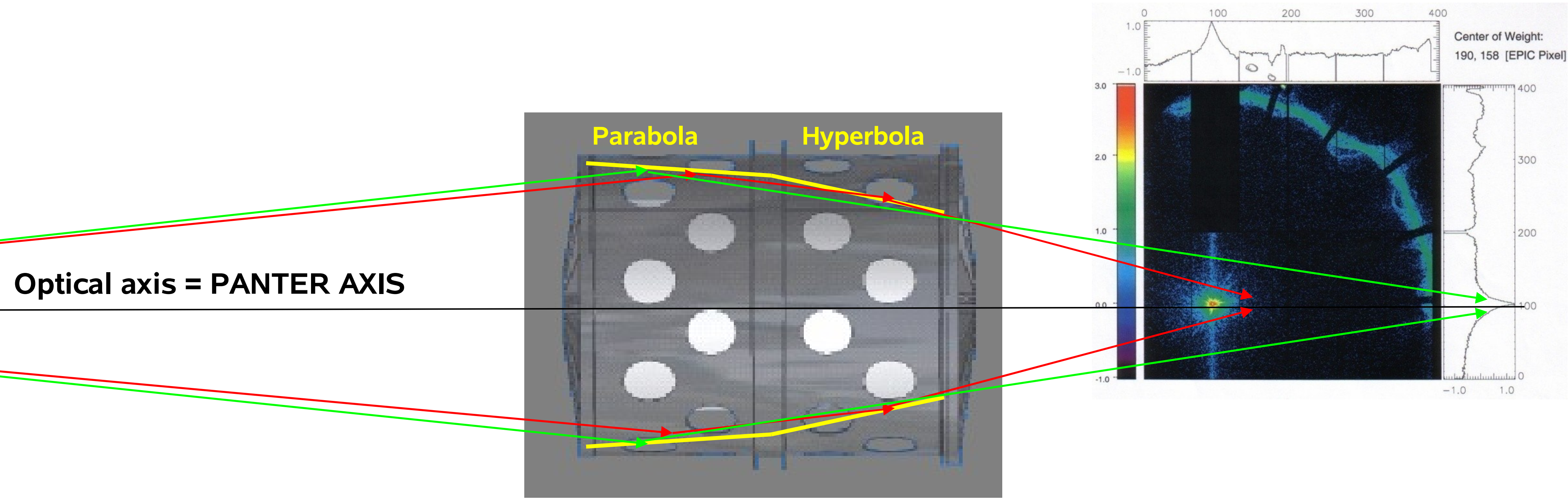
Non-standard calibration: the focal length
(*studied by O.Citterio, S.Basso, D.Spiga*)

Source finite distance problems (for large FL ~ 20m):

- A_eff loss (single reflection)

- Parabola angle ≠ hyperbola angle
- FP displacement
- Focal spot blurring

Problem 1: loss of effective area

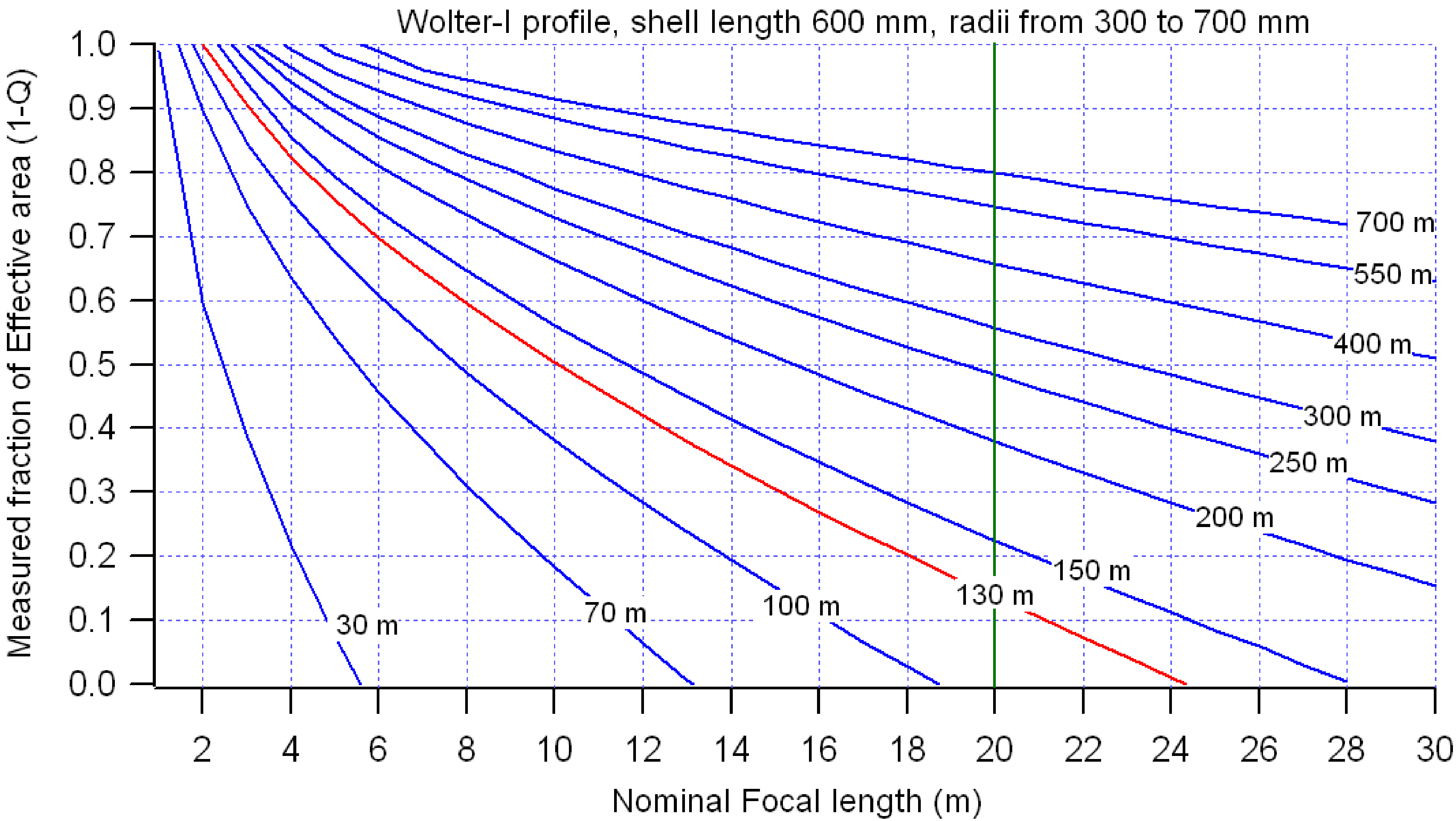


X-ray optic

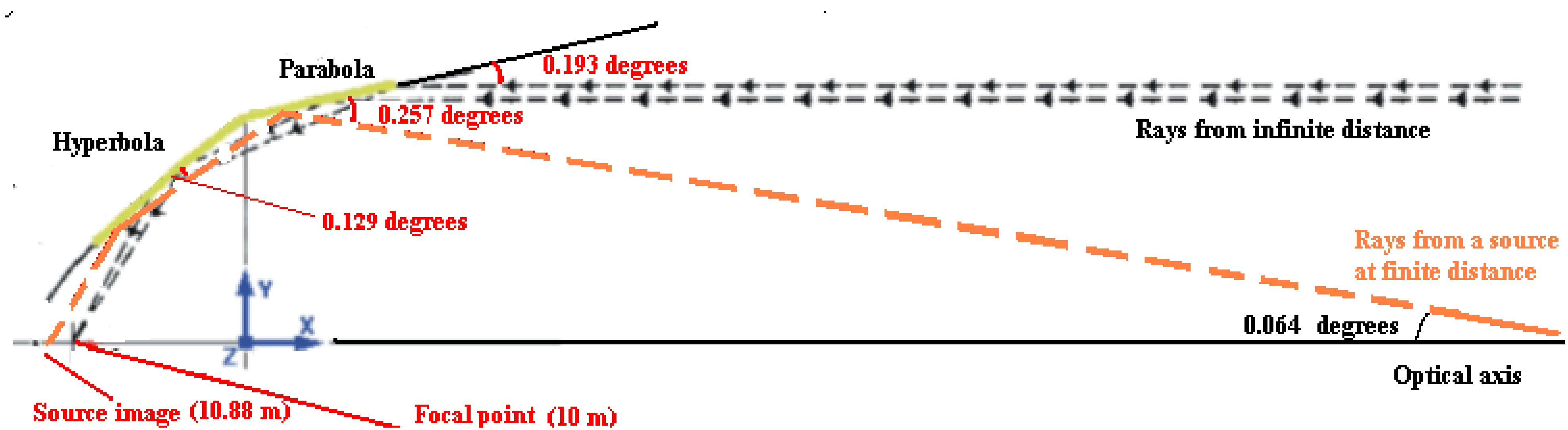
Focal plane

X-rays reflected near the parabola front-end do not undergo the reflection and are not focused on the X-ray detector this causes loss of effective area .

Problem 1: loss of effective area



Problem 2: different incidence angle



A source at infinity is focused by 2 reflections with the same angle α
(which is the angle between parabola and hyperbole)

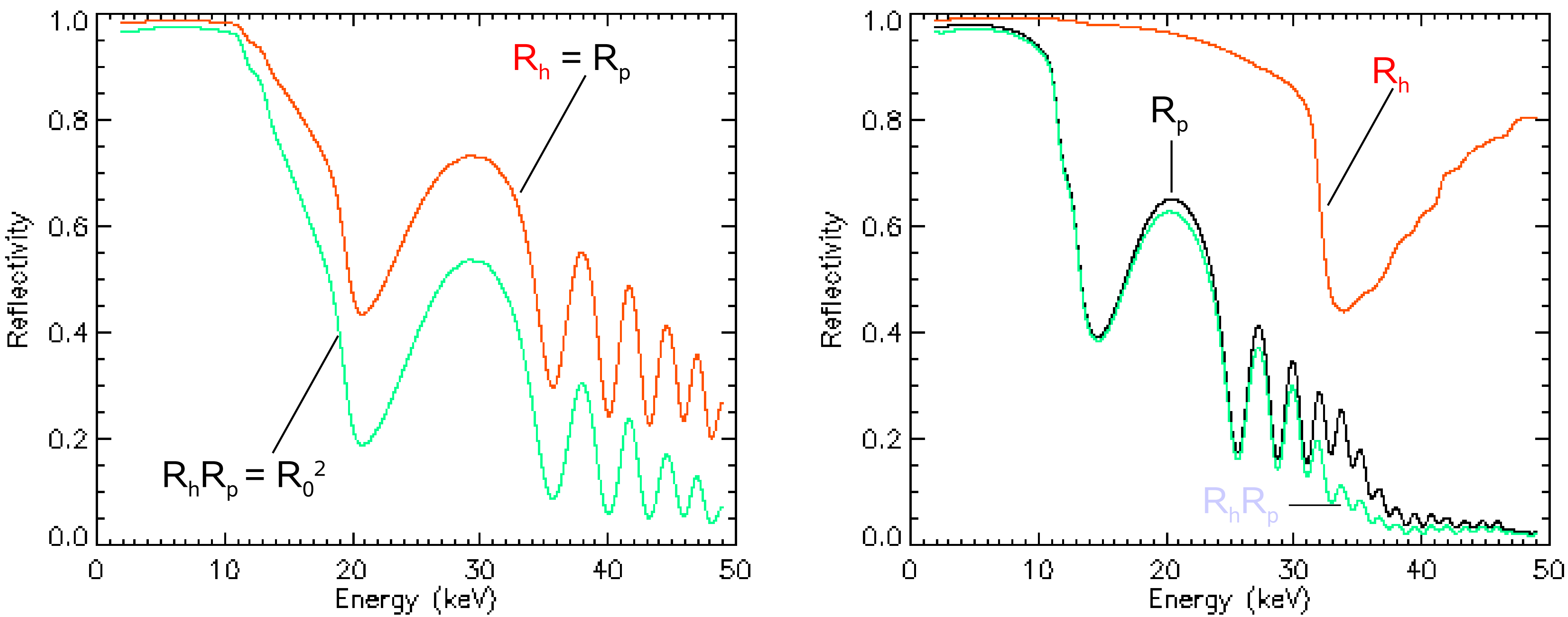
A source at distance D has a divergence of β = R/D at the entrance of a mirror with radius R.
The photon is reflected with 2 different angles α+β on the parabola and α-β on the hyperbole

Because β/α ~ 4 x focal length/ source distance in the case of Simbol X at Panter this effect is not negligible

Problem 2: different incidence angle means different reflectivity

W/Si graded multilayer, α = 0.16 deg

Source at infinity | Source at 120 m (r = 115 mm)



The departure of the actual incidence angles from the nominal one has to be considered when interpreting the effective area data, as it changes significantly the measured reflectivity.

Other problems

Increase of the focal length with respect to the nominal one:

$$f_1 = \frac{Df}{D - f}$$

D = distance mirror-source; e.g. f = 10 m, f_1= 10.88 m,

f = 20 m, f_1= 24.44 m

A *slight* blurring of the image even at the focus f_1

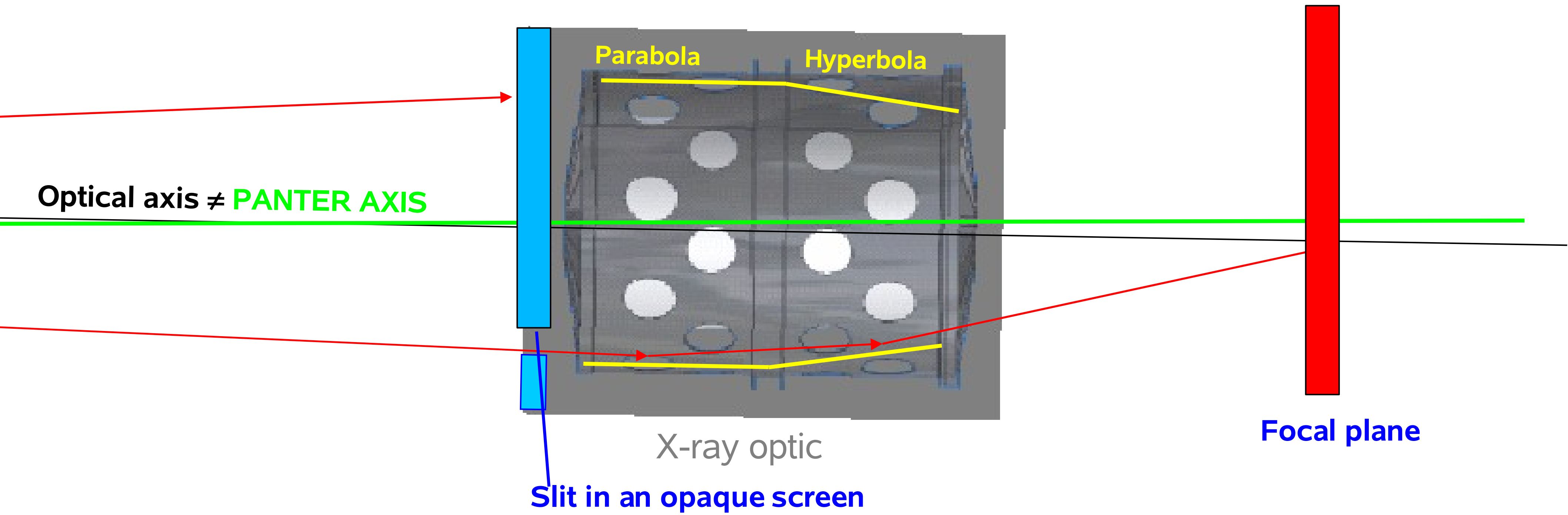
$$HEW_D = 4\frac{L_p}{f}\tan\left[\alpha\left(\frac{f}{D}\right)^2\right]$$

L_p = length of the parabola, α = nominal incidence angle;

e.g. L_p = 30 cm, f =10 m, α = 0.2 deg, HEW_D= 0.6 arcsec

e.g. L_p = 30 cm, f =20 m, α = 0.2 deg, HEW_D= 1.1 arcsec

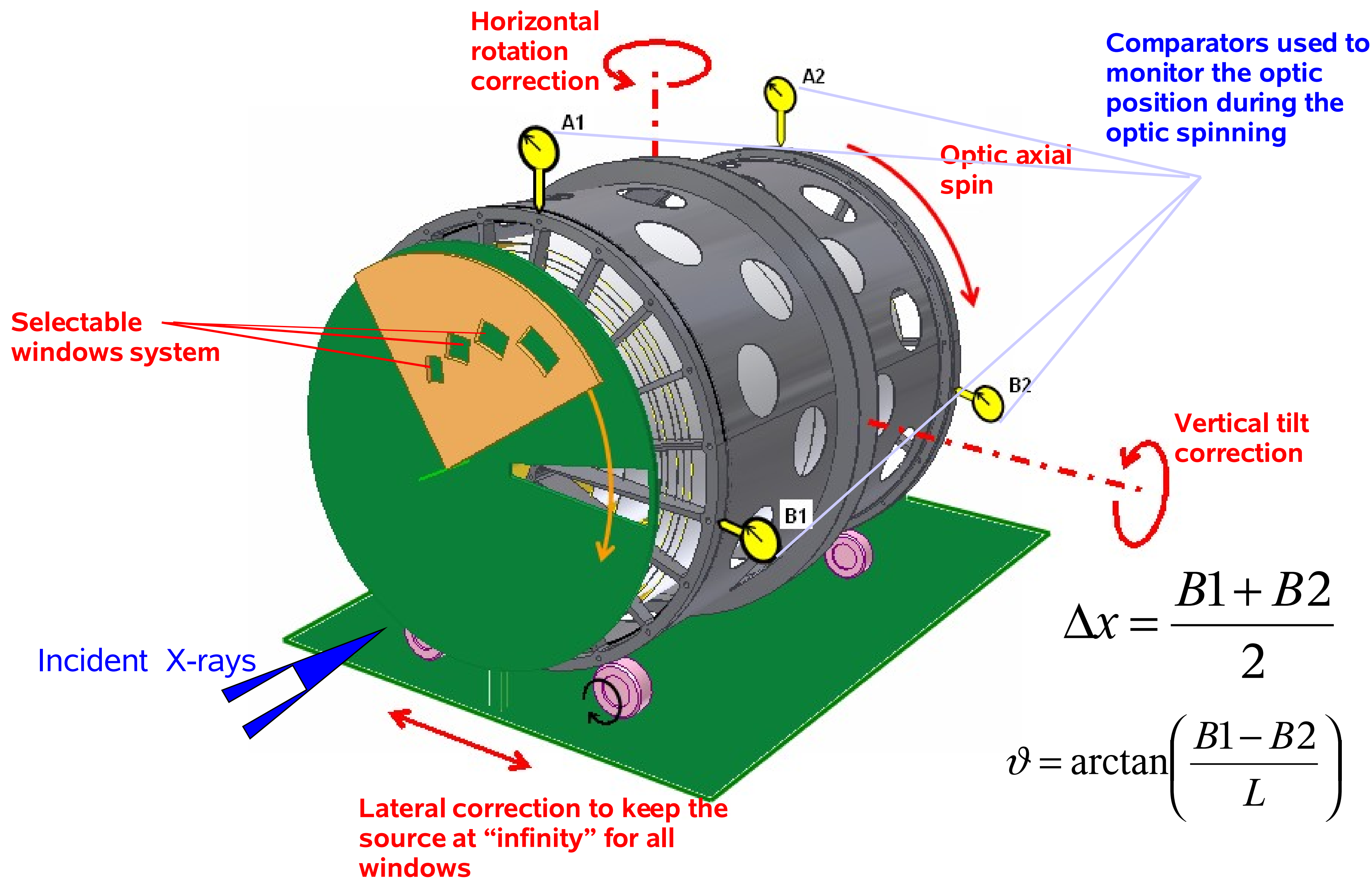
Solution for a single shell



If we adopt a pencil beam setup, we can select a thin beam (a few 10 arcsec divergence) and correct the beam divergence for a shell sector in order to make the two incidence angles equal (and equal to the on-axis incidence angle!)

Once the correct angles are set, all the optic performance (focusing + effective area) can be measured by spinning the optic around its axis, illuminating all sectors under the same conditions, and superposing all the images in the focal plane.

Solution for the whole optical module: the jig



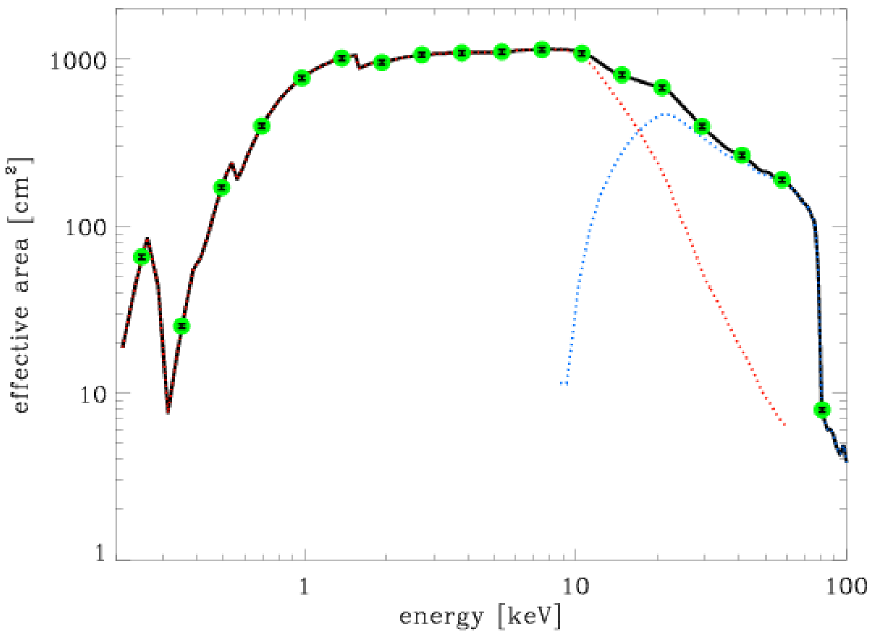
$$\Delta x = \frac{B1 + B2}{2}$$

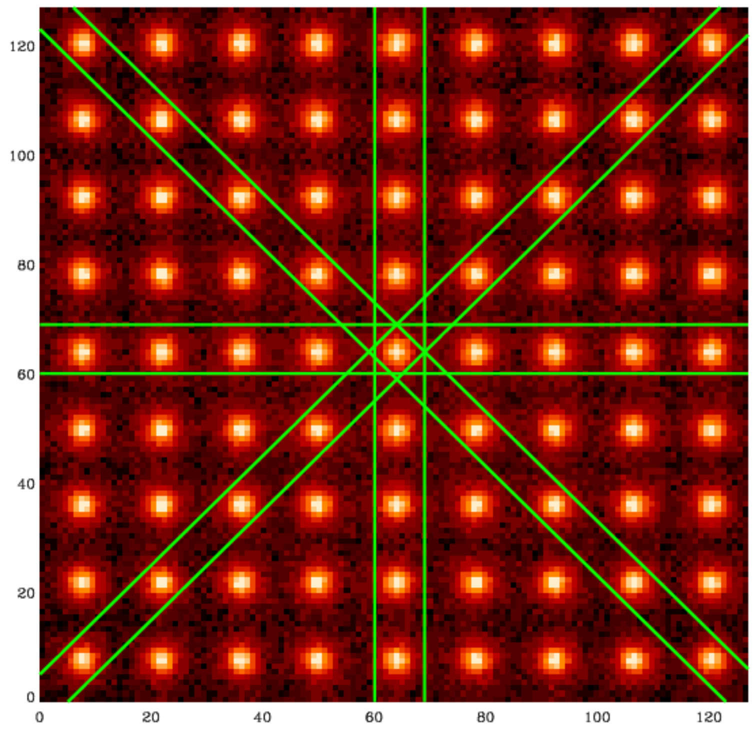
$$\vartheta = \arctan\left(\frac{B1 - B2}{L}\right)$$

End2End calibration dataset (the swift scheme)

DATASET:

· 20 energies
· 33 positions
· 10000 photons



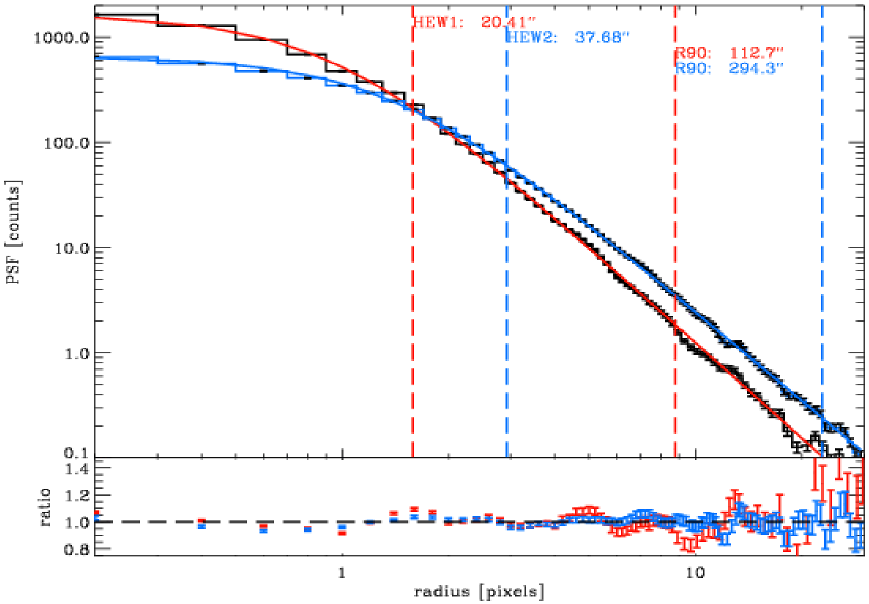


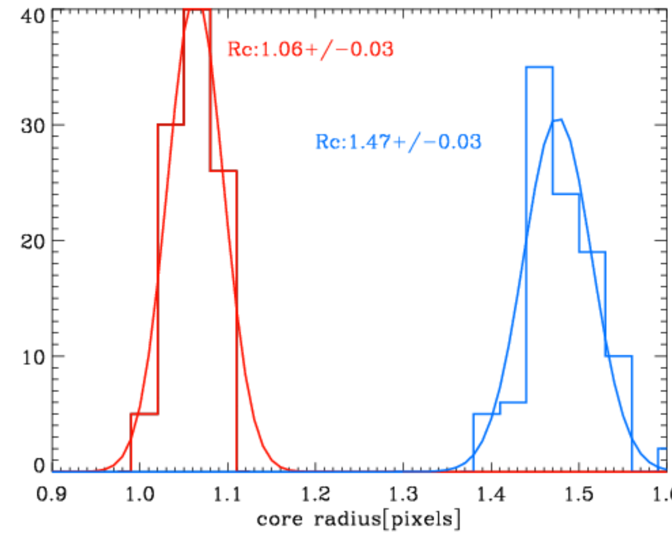
OUTPUT:

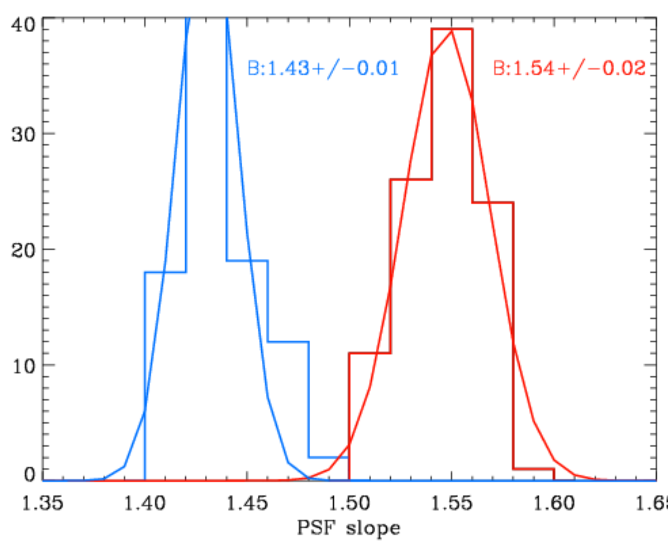
· PSF Model
· Effective Area
· Energy resolution
· ARF + RMF

with 5% of accuracy

Standard calibration IIa: the PSF calibration



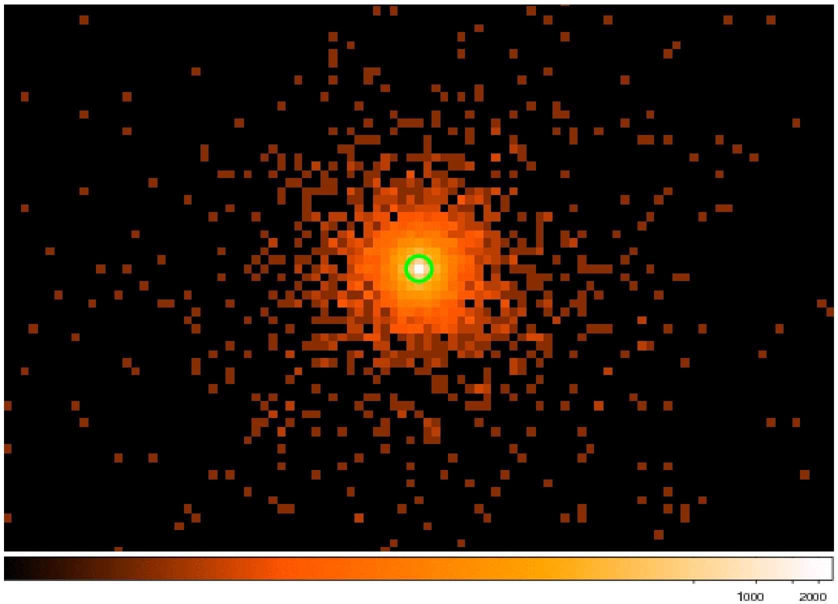




Given ~10000 counts, for each energy and position, the accuracy in the PSF model reconstruction is < 5%

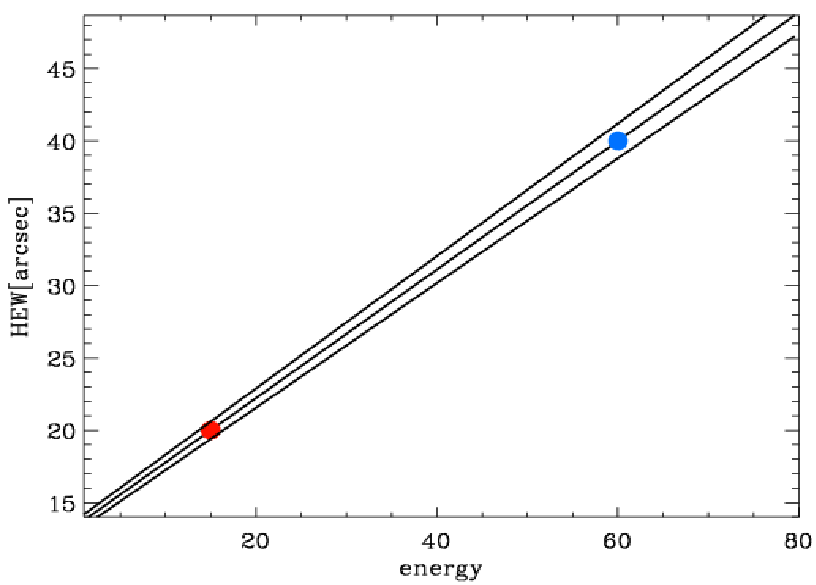
Assuming a King profile
A speculation more than a simulation….

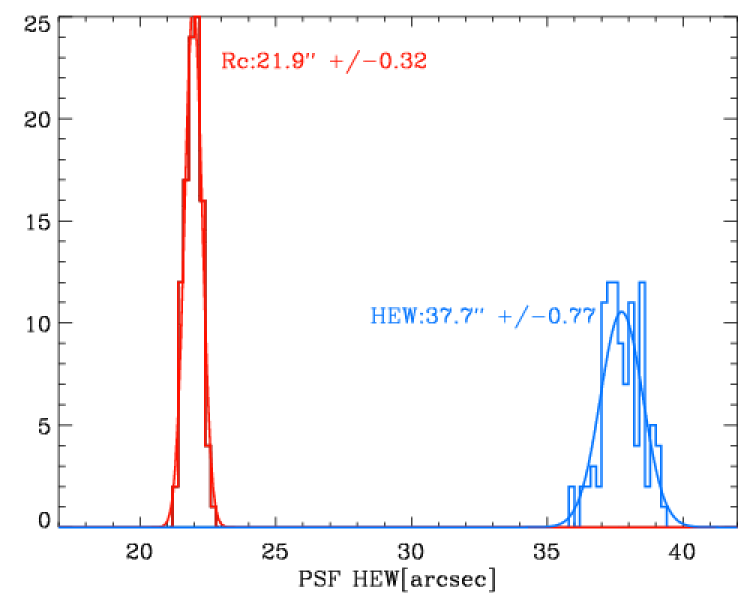
Standard calibration IIb: HEW verification



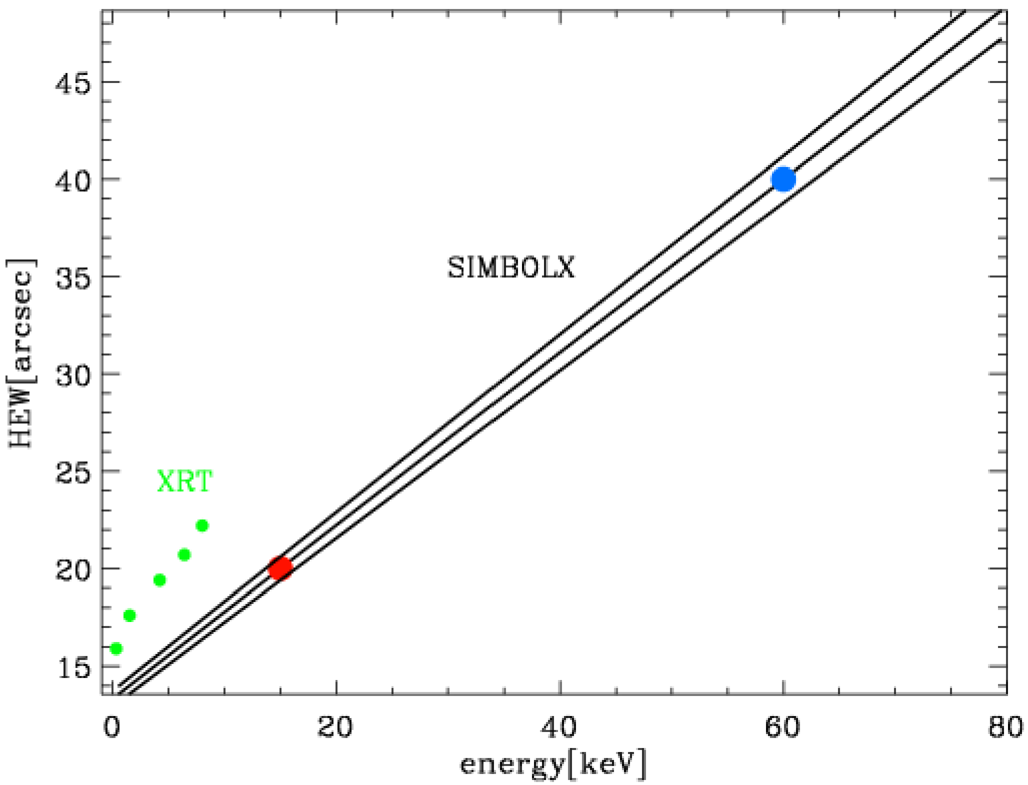
Given ~10000 counts, the accuracy in the HEW measurement is < 5%

Assuming a King profile:
A speculation more than a simulation....





PSF model importance



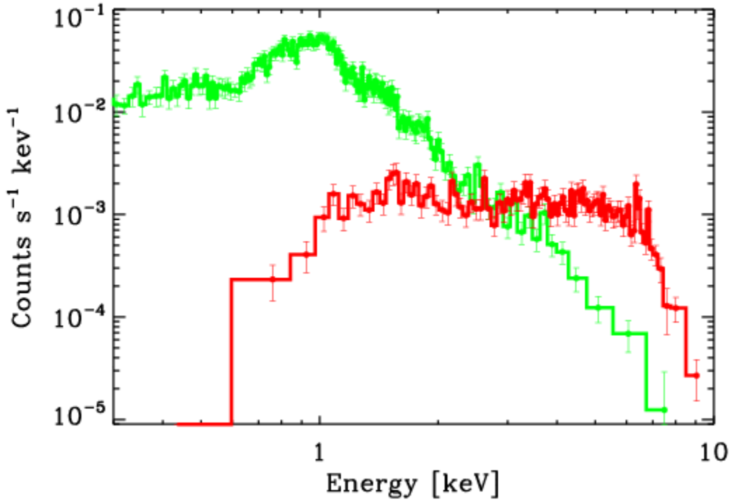
In XRT the dependence of the PSF from the off-axis angle is very shallow, because the telescope is de-focussed

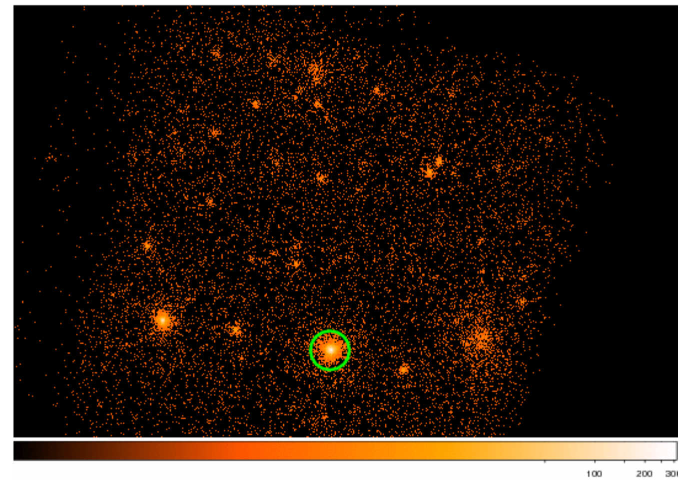
The energy dependence is also very shallow, because the effective area is all concentrated in a small energy band (0.5,2.0 keV)

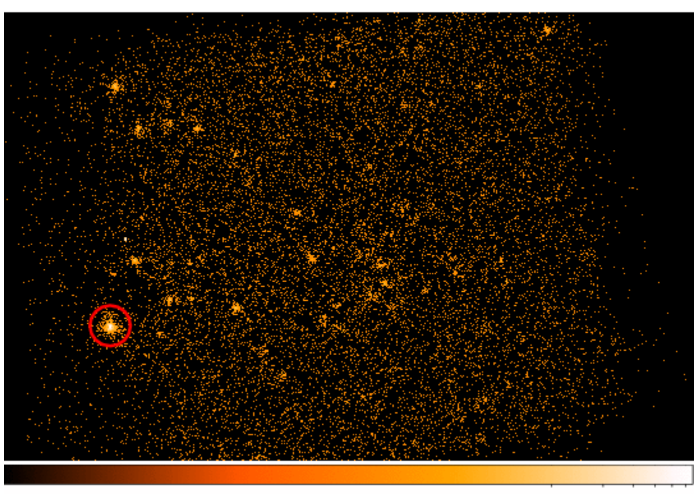
For SIMBOL-X the situation is very different: it will collect photons over a wide energy band. Therefore the PSF calibration as function of energy will be very important.

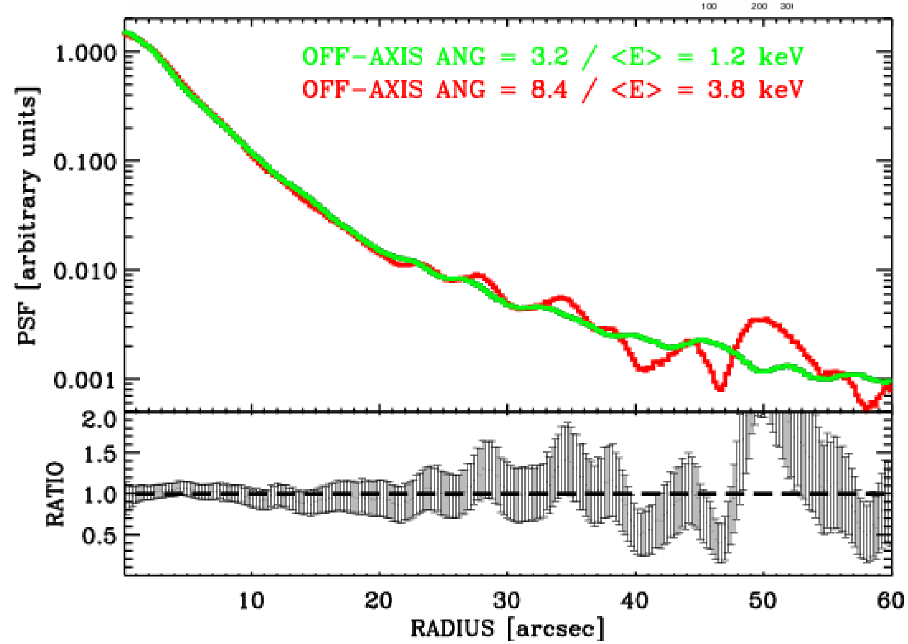
SWIFT XRT PSF in orbit

2 different sources, with different spectra and off-axis angle , but same



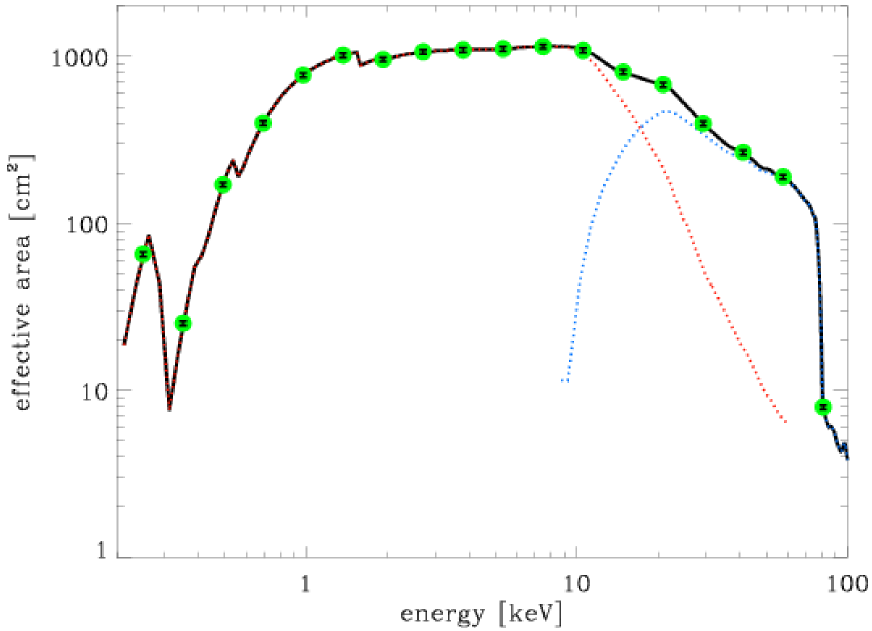






For XRT It is very easy to model the off-axis angle and energy dependence, because this dependence is very shallow

Standard calibration: effective area

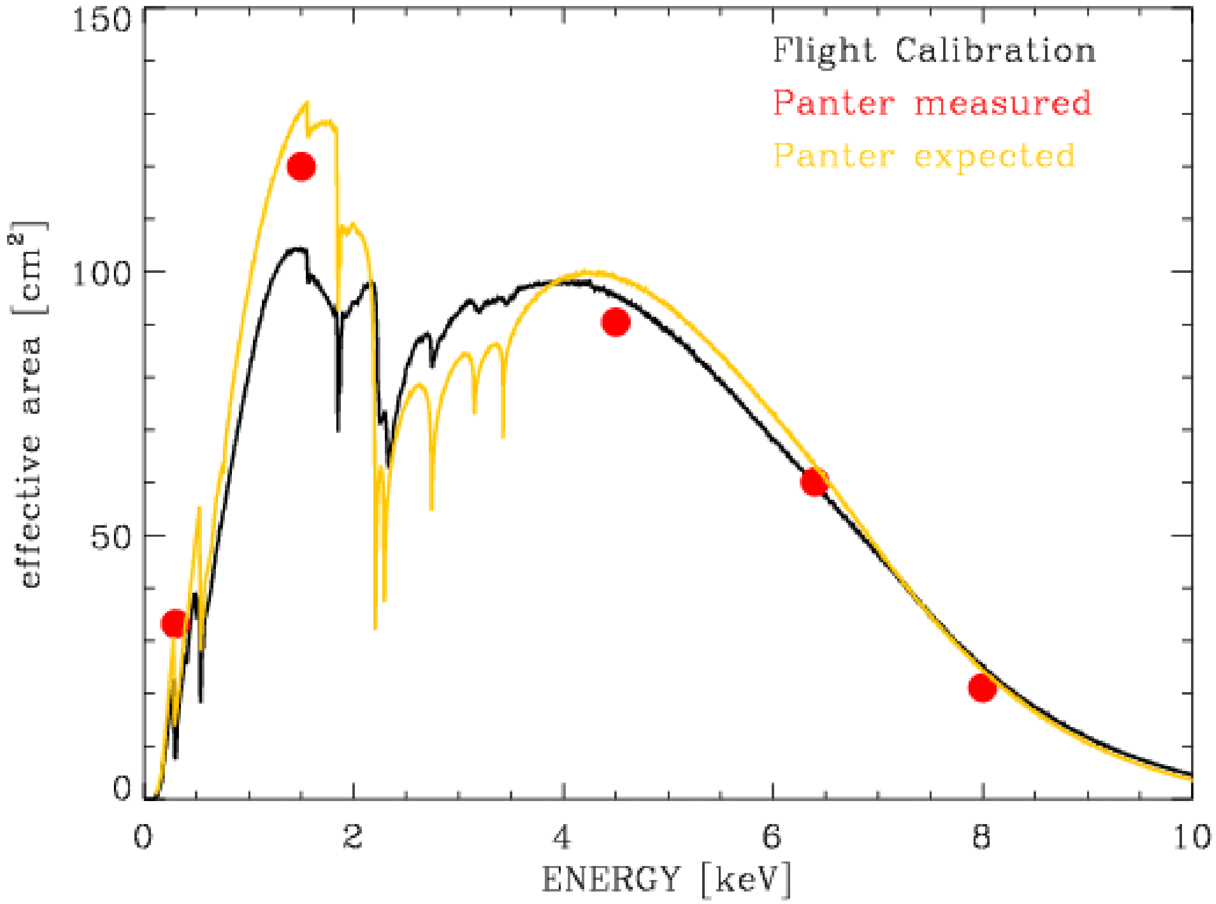


~10000 counts,
ch energy the statistical uncertainties in the effective are ~ 1%

we have to take into account:

ures between calibration energies
ertainties in the input spectrum and count rate

Swift-XRT Effective area from ground to orbit



TIMING REQUIREMENTS

Total time = N_ene * N_pos * counts / rate@ccd+[N_ene * dt_ene + N_pos *dt_pos]

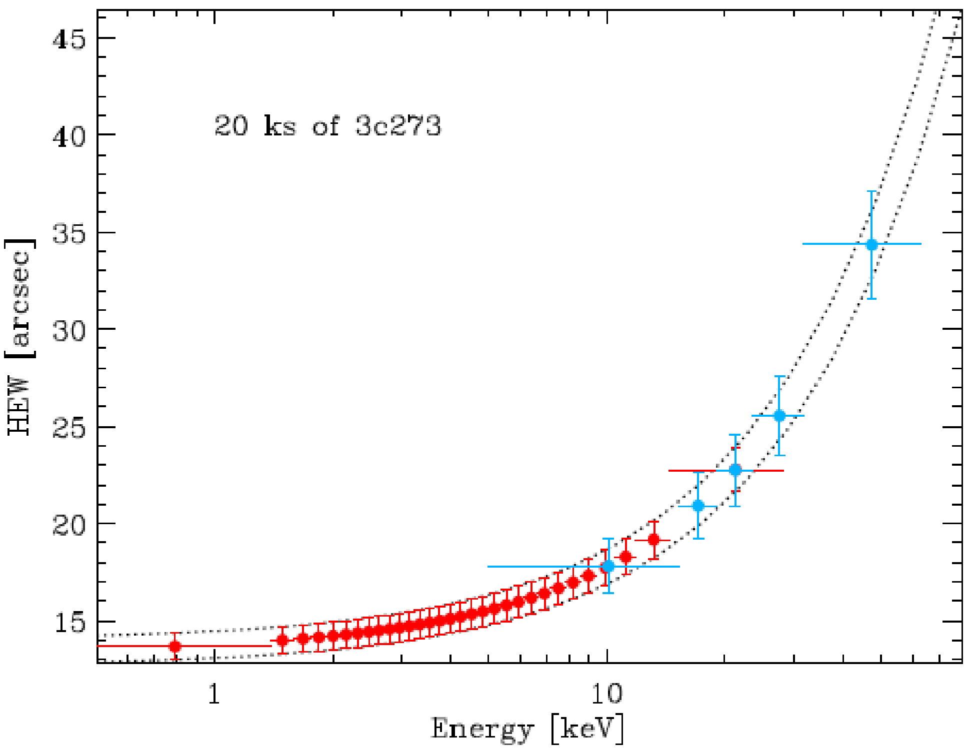
N_en. =20 N_pos=33 counts=10000 rate_at_ccd =1000.

➔ total time [**standard**] = 2 hrs + dead time

➔ total time [**pencil beam**] = 100*(total standard time) = 200 hrs + dead time pencil beam

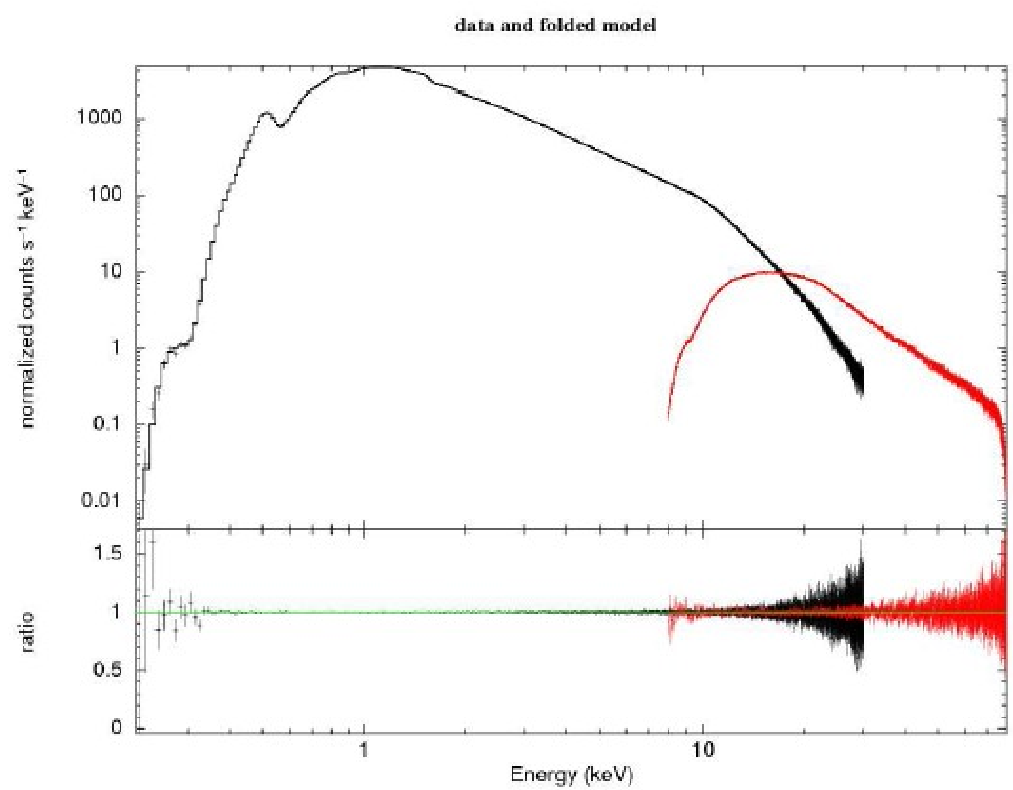
➔ total time [r**elative position**] = 5*(total pencil beam) = 1000 hrs + dead time relative position

In-flight Calibration



PSF: 3C 273
LED: 150 c/s
CZT: 1.2 c/s

Effective area: Crab
LED: 8000 c/s
CZT: 160 c/s



DA calibration (model) philosophy

What (model)	Why (Goal)	When
Breadboard	EMI/EMC compatibility tests	End 2008
Demonstrator	Separated chains functionality validation	End 2009
SM	Structural validation	2008-2009
STM	Mechanical, thermal and integration validation	2009-2010
EM	Electrical design validation	mid-2010
QM	**Qualification**	**2011**
FM	**Fly**	**2012**

MU calibration (model) philosophy

What (model)	Why (Goal)	What	When
STM	Optical validation after Mechanical & thermal cycles	4 “standard” + 96 dummy shells	End 09
QM	**Scientific performance validation**	10 “standard” shells + 90 “dummy” shells	**11**
FM	**Fly**		**12**