Optical properties of Laue lenses for hard X-rays (>60 keV)

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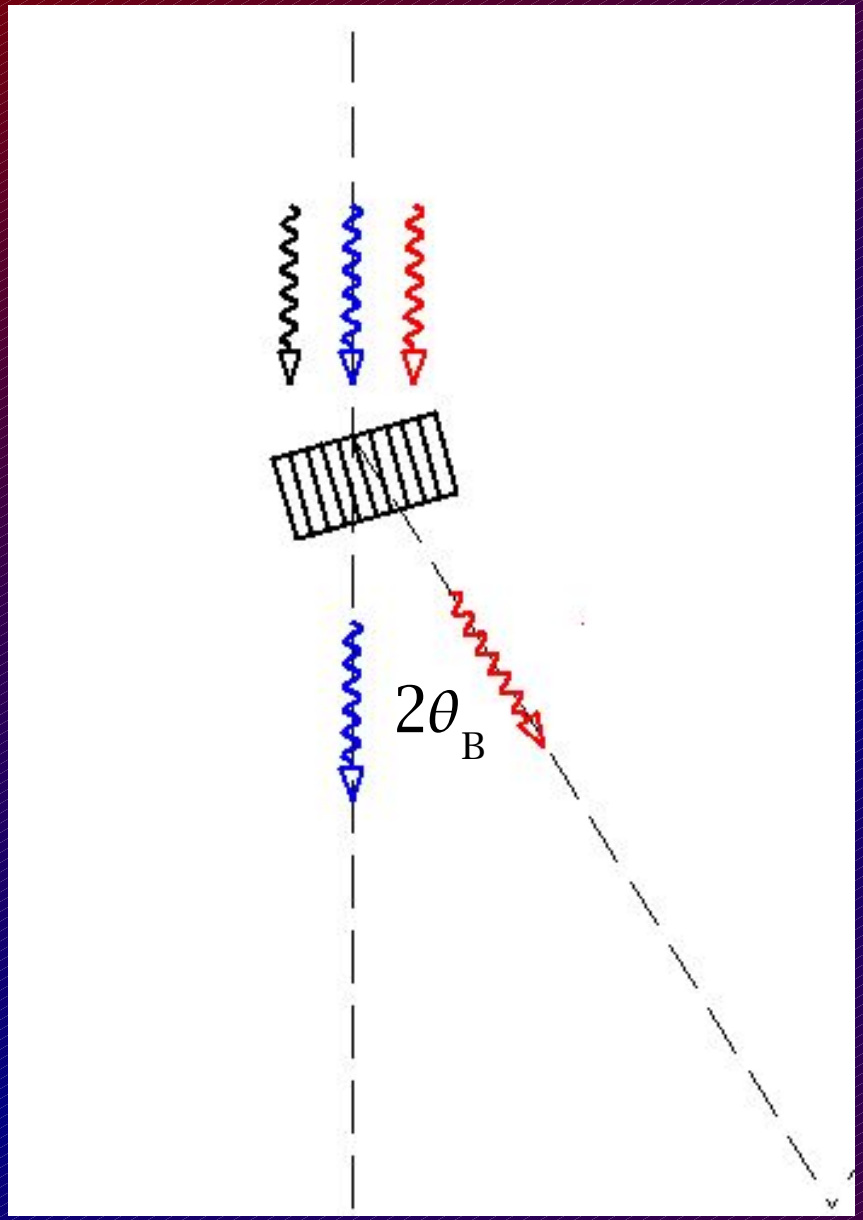
on behalf of a large collaboration

Laue lens working principle



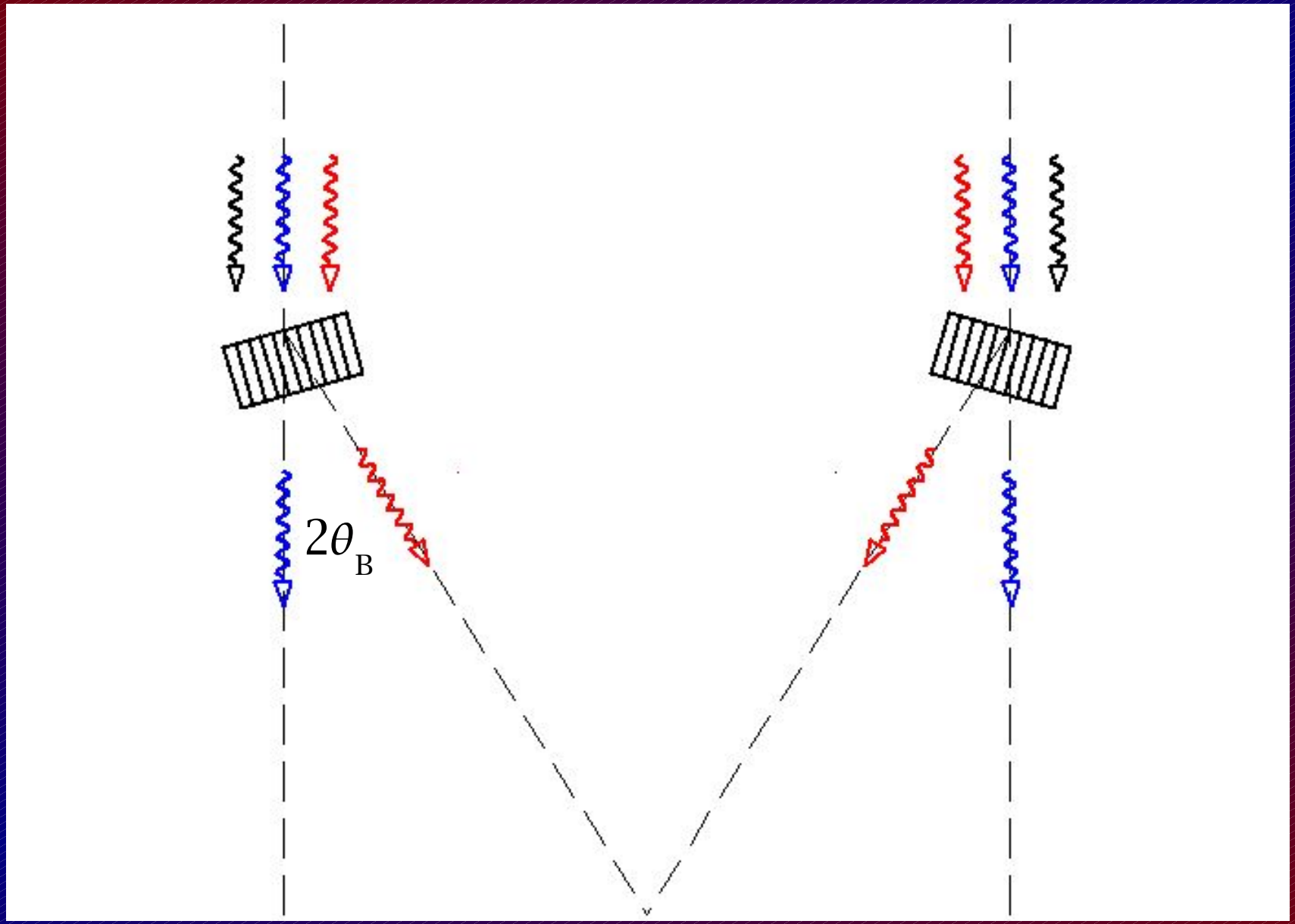
A crystal, through Bragg diffraction, can deviate photons of an angle $2\theta_B$

The process is energy selective

Some photons proceed undiffracted

Some are absorbed

Laue lens working principle



Laue lens examples

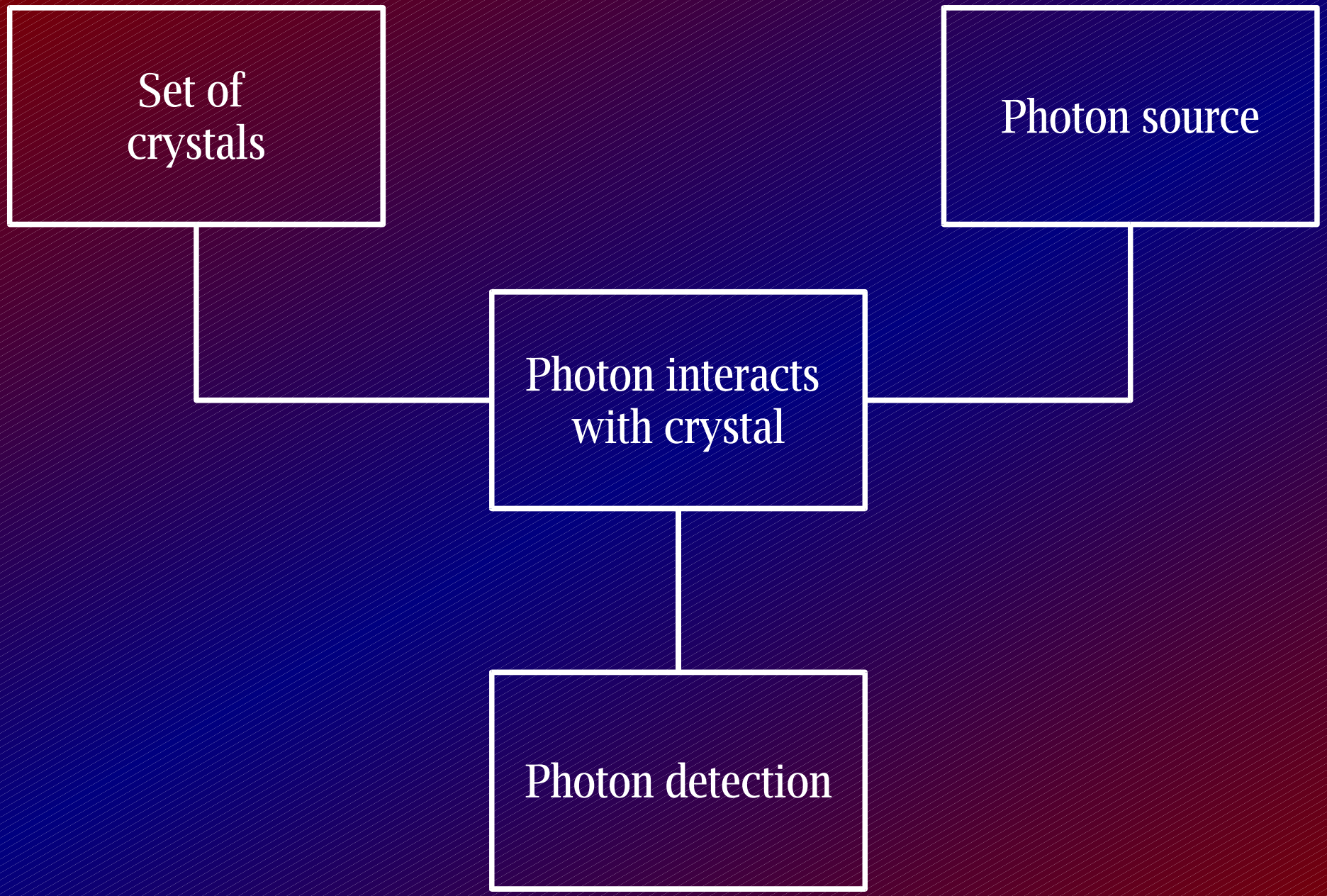
Broad band Laue lenses (HAXTEL)
Smooth response in a broad energy band (>60 keV) to investigate the continuum source spectra
(see talk by F. Frontera)

Nuclear lines Laue lenses (MAX)
Very high thoughput in a narrow energy band to investigate nuclear lines
(see talk by P. von Ballmoos)

Lens optical properties

Even if some properties of Laue lenses can be calculated analitically or with good approximation, full knowledge of the lens response can be obtained only with Monte Carlo simulations.

Monte Carlo concept



Monte Carlo software

Coded objects

Optics
- Crystal materials
- Crystal properties
- Crystal disposition

Crystal
- Material
- Size
- Position
- Orientation
- Mosaic spread

Photon
- Wavevector
- Position
- Source

Builtin methods to make the object interact with each other
(resonant scattering, photoelectric, Compton, ...)

Monte Carlo software

Developed in Python

- Object oriented
- Data types
- Scientific libraries (scipy[1], xraylib[2],...)
- Interaction
- Code readability
- Rapid development

1 - www.scipy.org
2 - Spectrochimica Acta Part B 59 (2004) 1725– 1731

Possible outputs via data analysis

- Photon history
- PSF on-axis and off-axis for different energies
- Diffracted photon spectrum
- Diffraction efficiency
- Effective area
- Sensitivity

Crystal disposition and characteristics

- One ring of Cu (111) crystals with the same orientation
- 20 m focal length
- Crystal size $1 \times 1 \times 0.2$ cm^3
- FWHM 1 arcmin

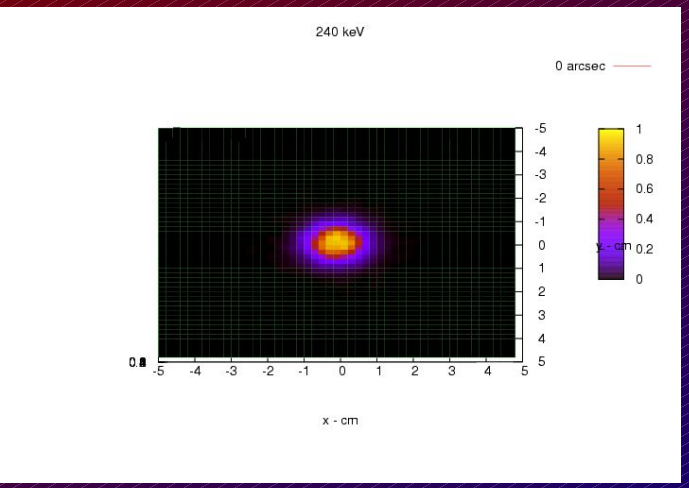
Photon source

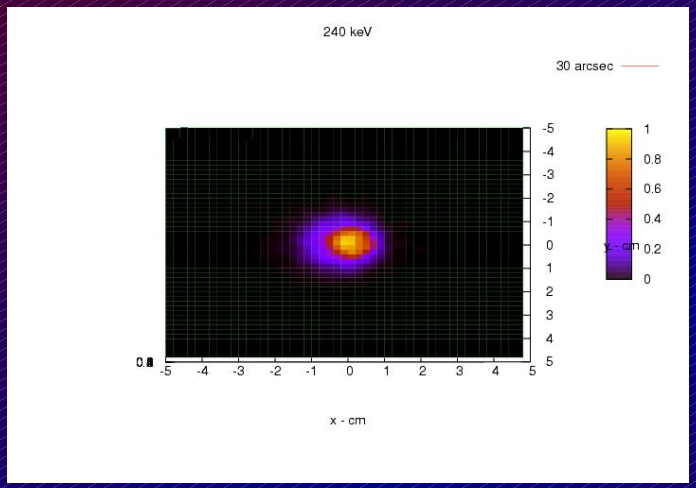
- Flat spectrum in a narrow energy band centered around the optimal energy for on-axis photons
- Photon offset 0, 0.5, 1, 1.5, 2., 2.5, 3. arcmin

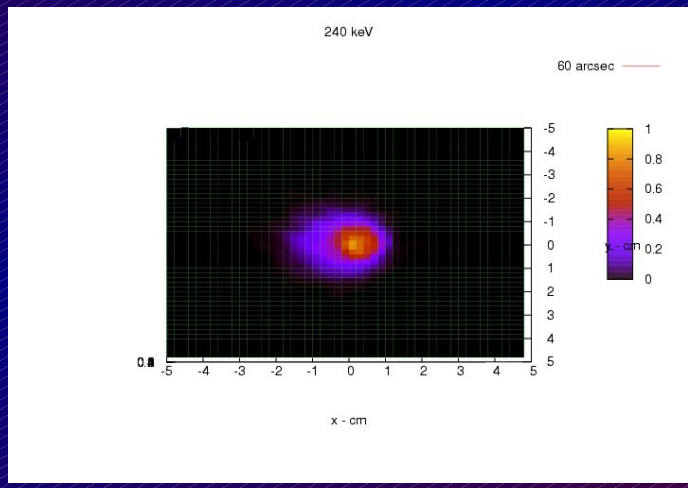
Point Spread Function (PSF)

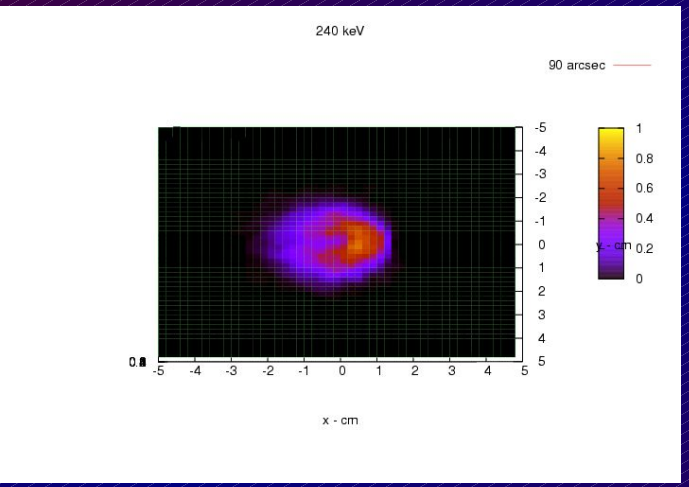
- Peak point for off-axis sources
- Standard deviation of photon distribution

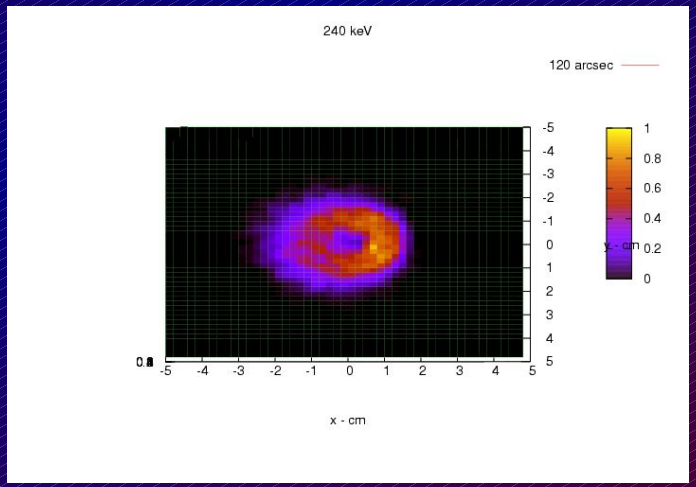
Focal spot shape

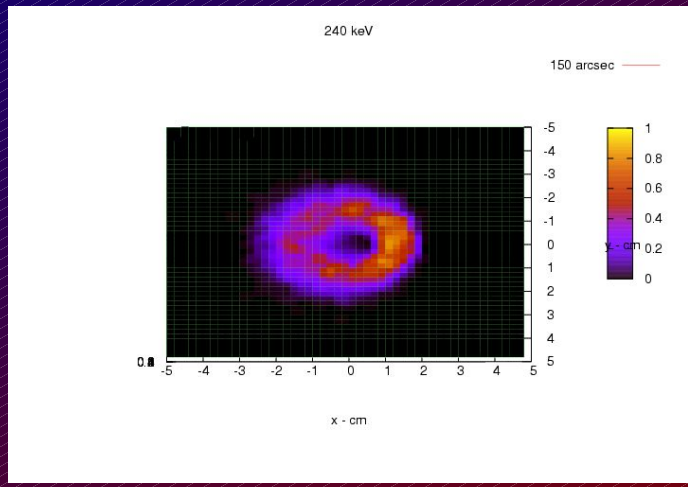


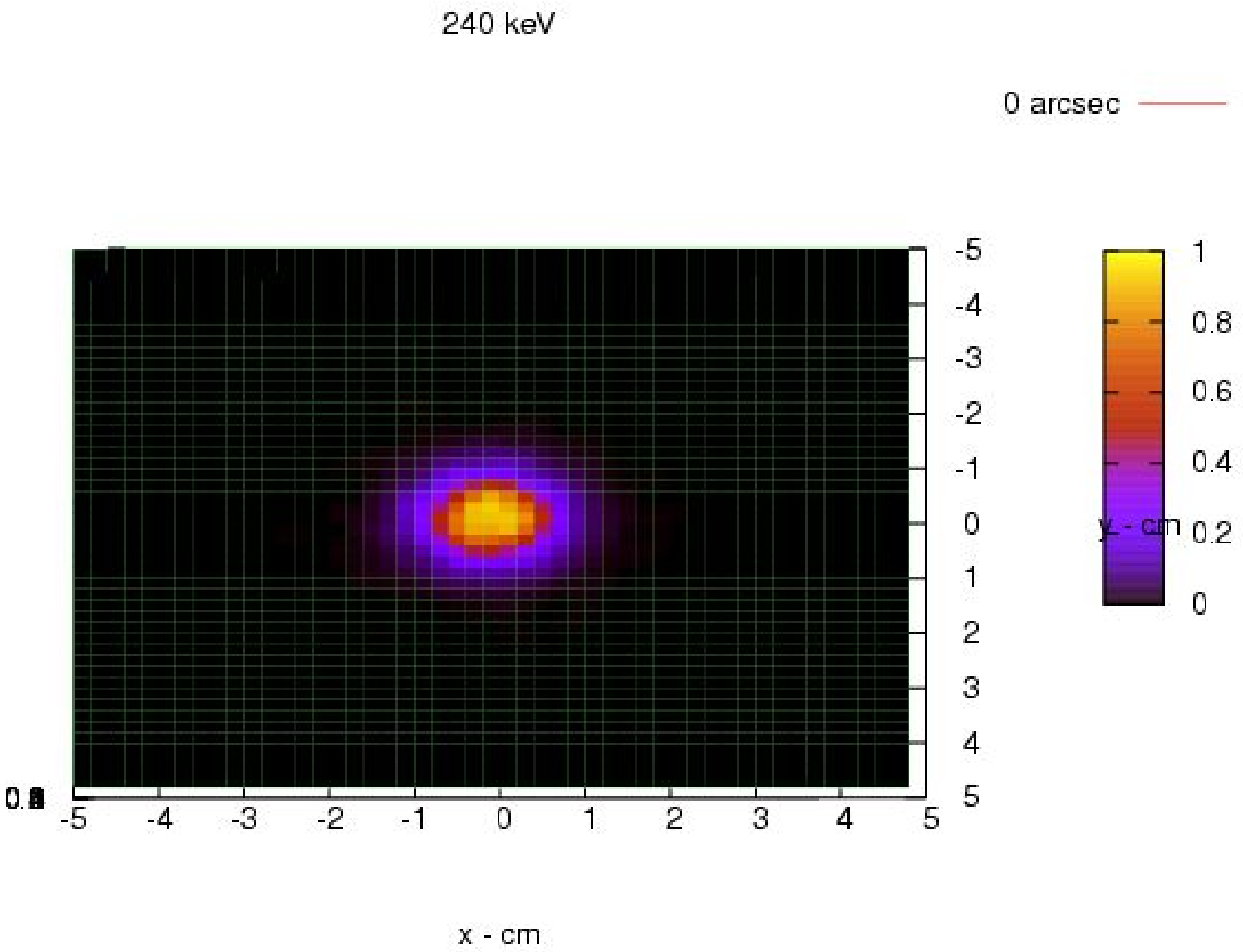


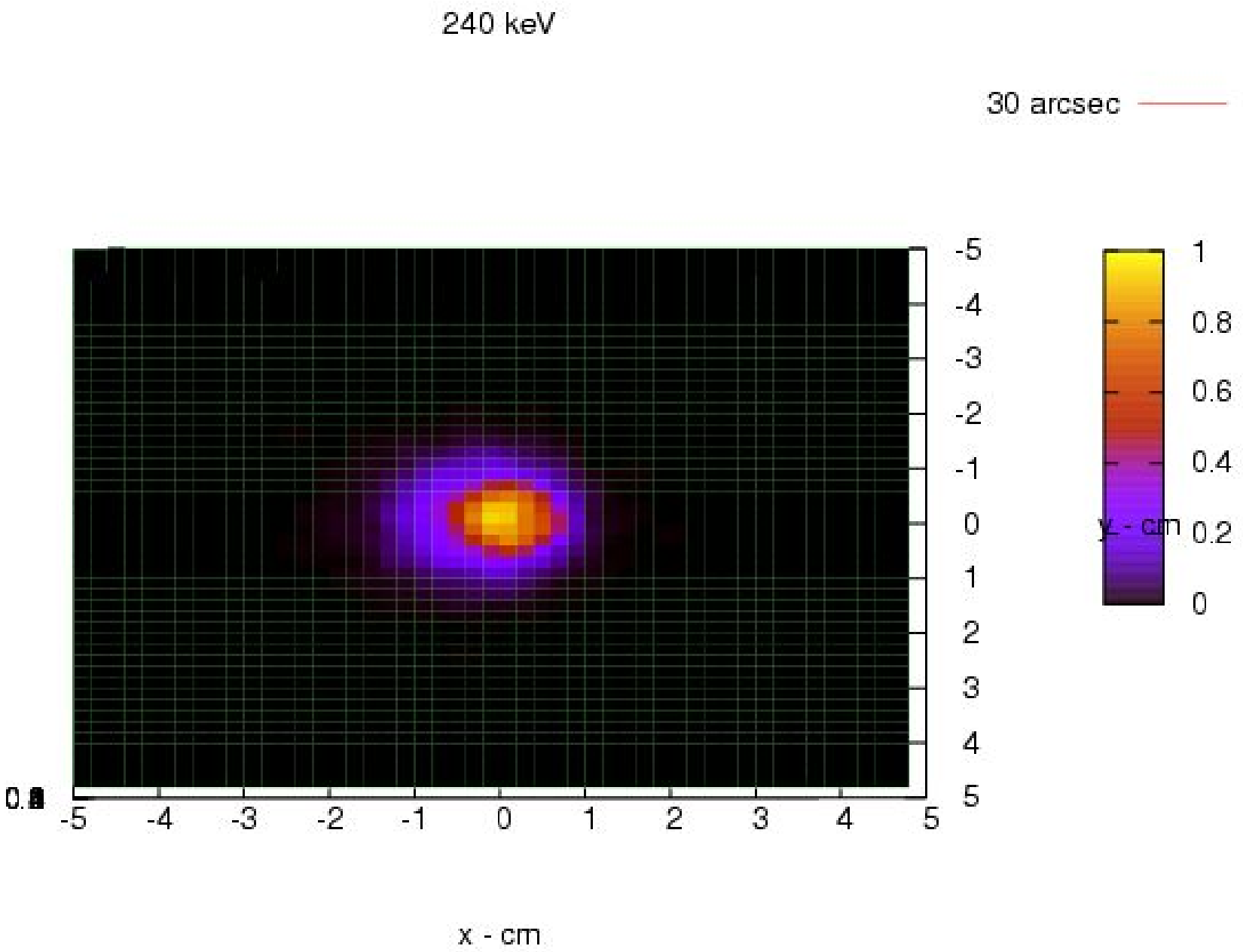


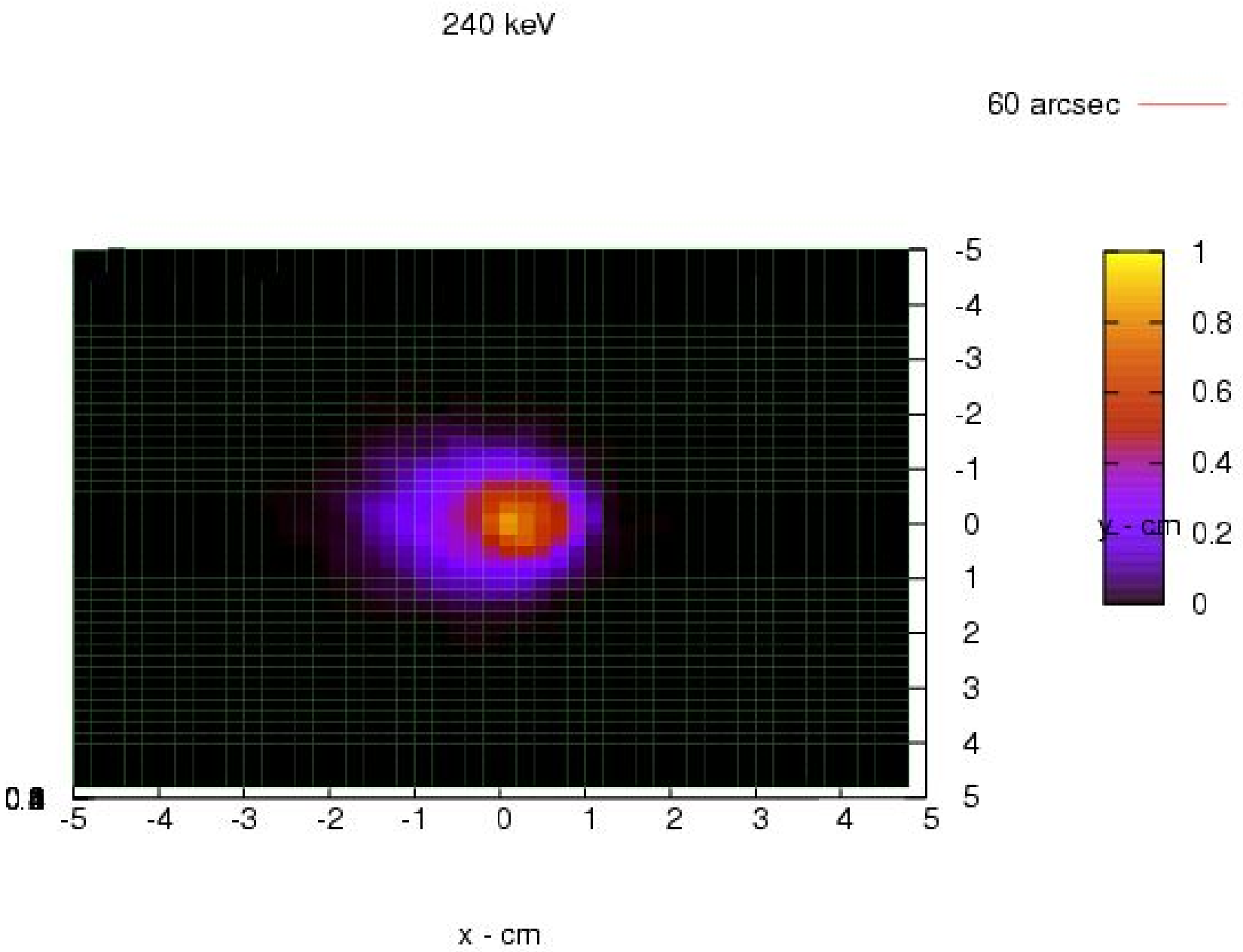


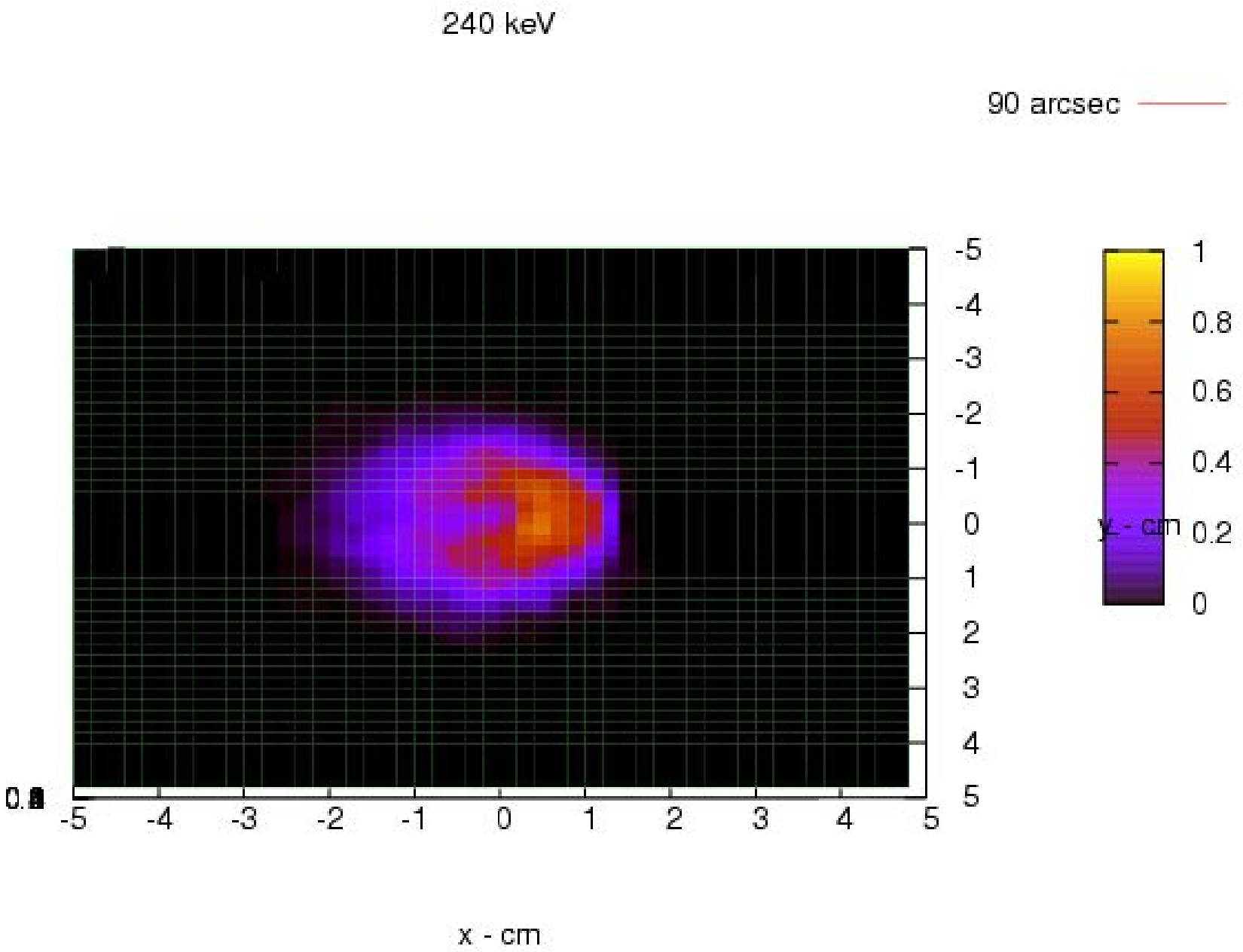


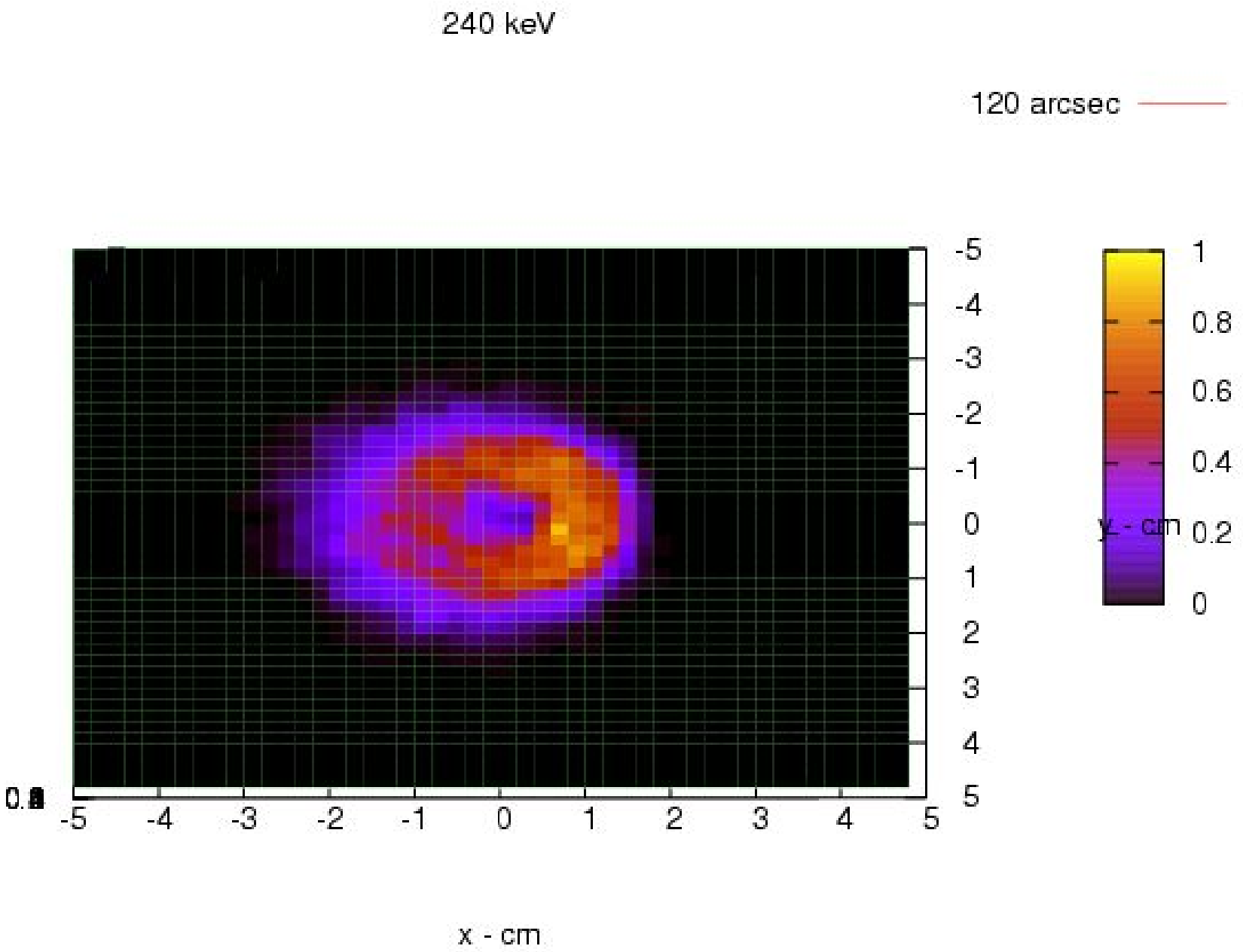


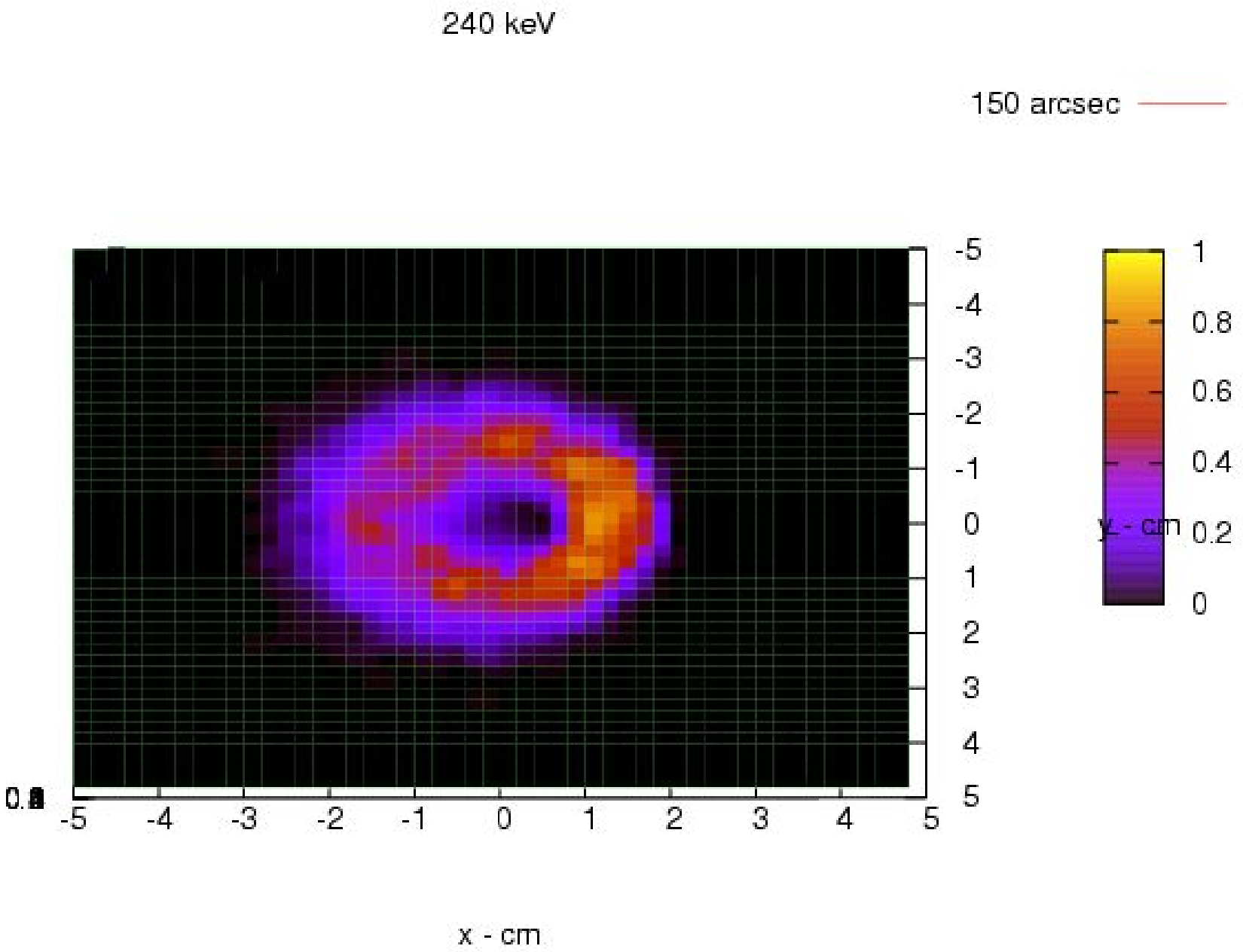

240 keV
0 arcsec
-5
-4
-3
-2
-1
0
1
2
3
4
5
-5
-4
-3
-2
-1
0
1
2
3
4
5
x - cm
y - cm
1
0.8
0.6
0.4
0.2
0

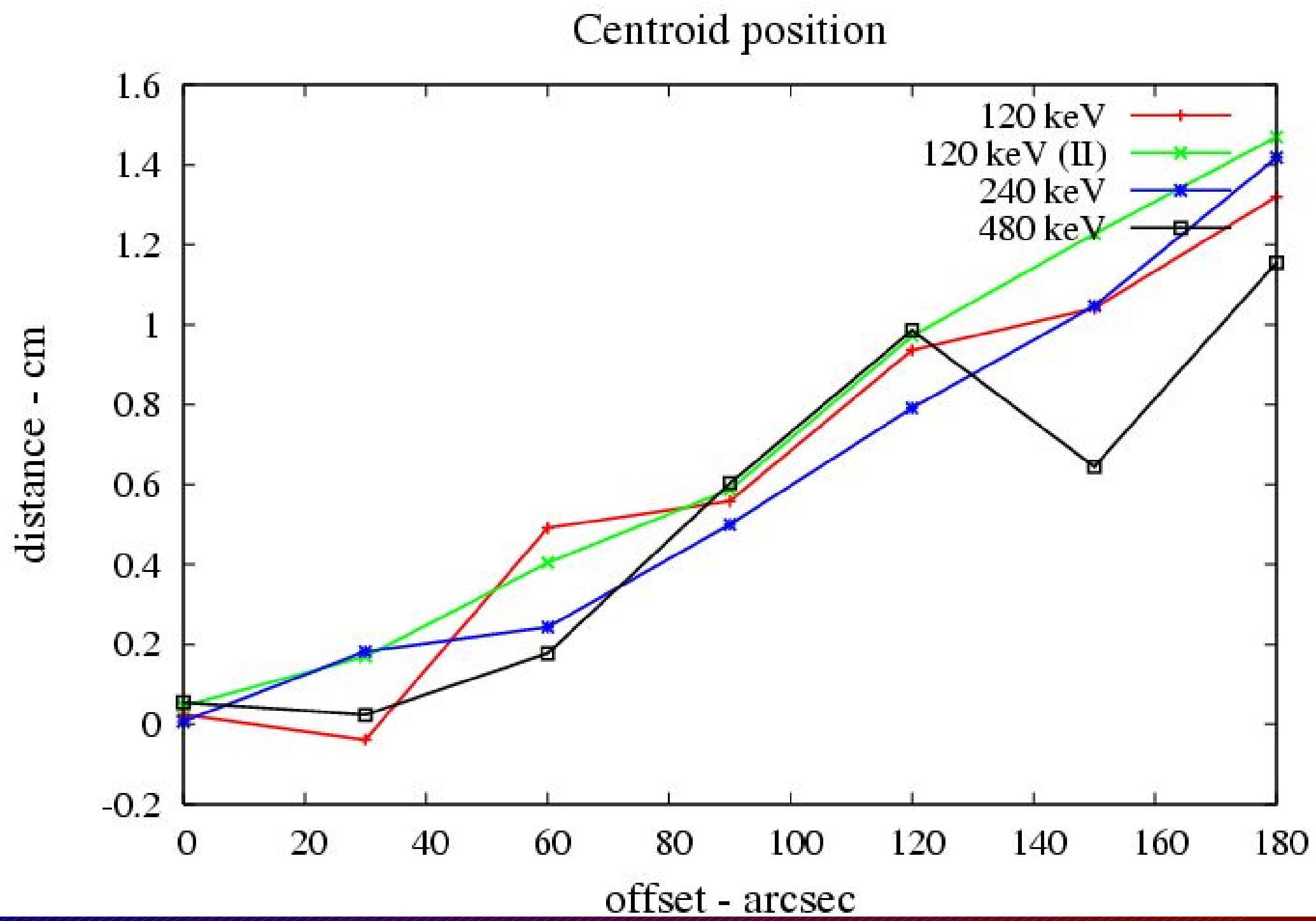

240 keV
30 arcsec
-5
-4
-3
-2
-1
0
1
2
3
4
5
x - cm
y - cm
1
0.8
0.6
0.4
0.2
0

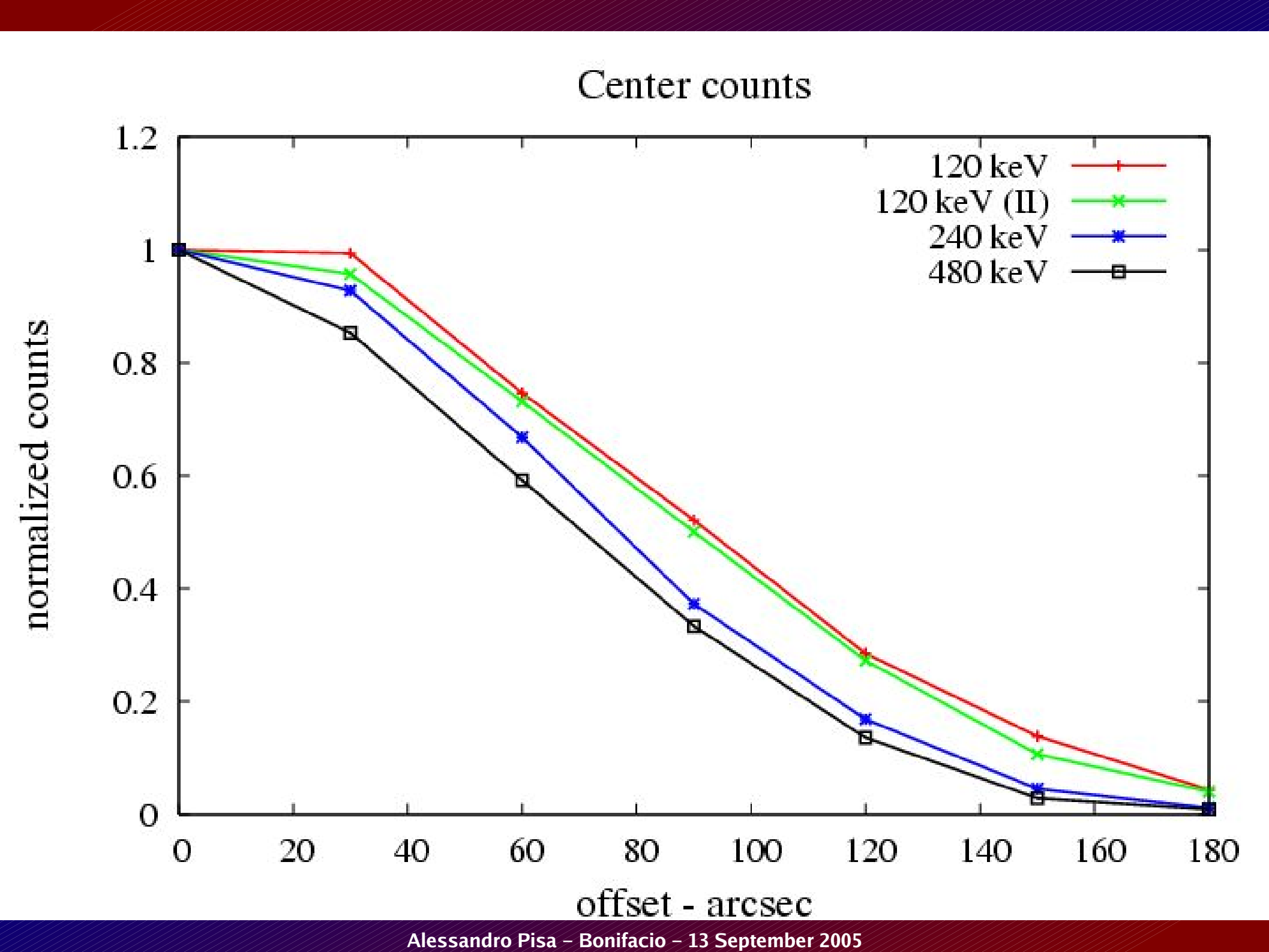

240 keV
60 arcsec
-5
-4
-3
-2
-1
0
1
2
3
4
5
x - cm
y - cm
1
0.8
0.6
0.4
0.2
0


240 keV
90 arcsec
-5
-4
-3
-2
-1
0
1
2
3
4
5
1
0.8
0.6
0.4
0.2
0
y - cm
x - cm

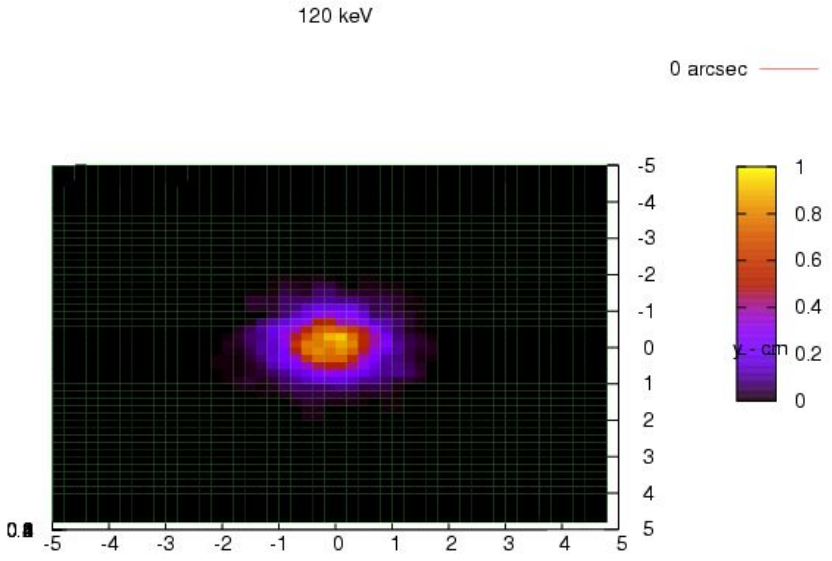

240 keV
120 arcsec
-5
-4
-3
-2
-1
0
1
2
3
4
5
1
0.8
0.6
0.4
0.2
0
y - cm
x - cm

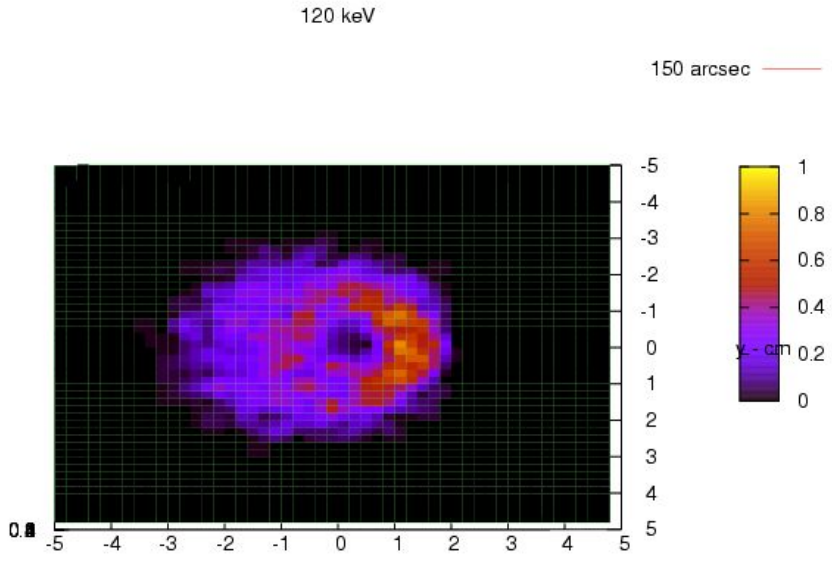

240 keV
150 arcsec
-5
-4
-3
-2
-1
0
1
2
3
4
5
1
0.8
0.6
0.4
0.2
0
y - cm
x - cm

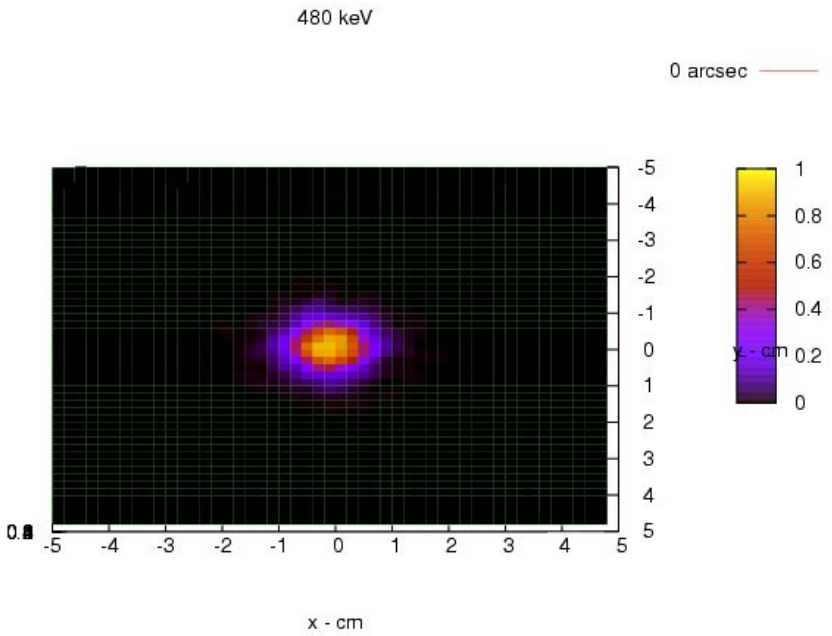

Centroid position
120 keV
120 keV (II)
240 keV
480 keV
distance - cm
offset - arcsec
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
20
40
60
80
100
120
140
160
180

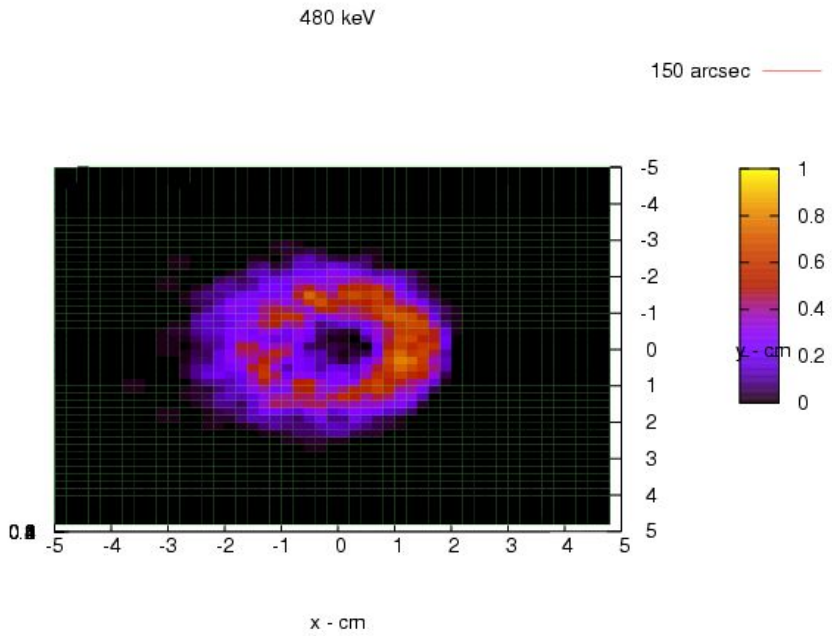

Center counts
120 keV
120 keV (II)
240 keV
480 keV
normalized counts
offset - arcsec
0
0.2
0.4
0.6
0.8
1
1.2
0
20
40
60
80
100
120
140
160
180

Focal spot at different energies









Focal spot at different diffraction orders