ASTENA Narrow Field Telescope: focal plane detector simulations

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on behalf of the AHEAD/ASTENA collaboration

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AHEAD SWG - IIth progress meeting - Universidade de Coimbra - April 18-19 , 2018

Summary

Astena WFI and NFT main features

Goals of this progess activity

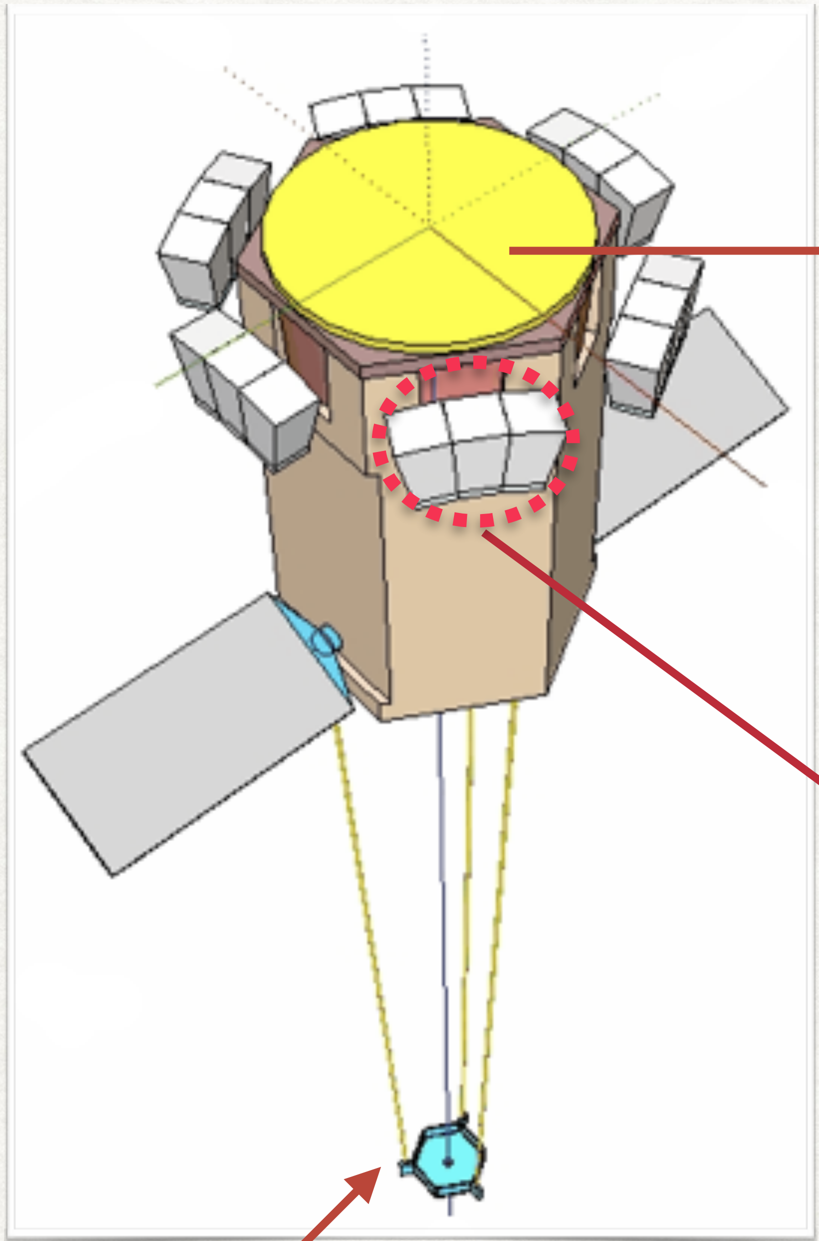
Laue lens sensitivity discussion

New features in the Laue lens optics

NFT detector geometry

MEGAlib simulations

Advanced Surveyor of Transient Events and Nuclear Astrophysics (ASTENA)



Narrow Field Telescope (NFT)

broad band
large collection area

LAUE lens

Wide Field Monitor Spectrometer (WFM/S)

6 blocks
18 modules
total detector area ~ 18000 cm^2
1 keV - 20 MeV
>1 sr FoV

focal plane detector
3D CZT

ASTENA Narrow Field Telescope (NFT)

optics configuration

pass-band 50 - 700 keV

20 m focal length

Si 111 + Ge 220

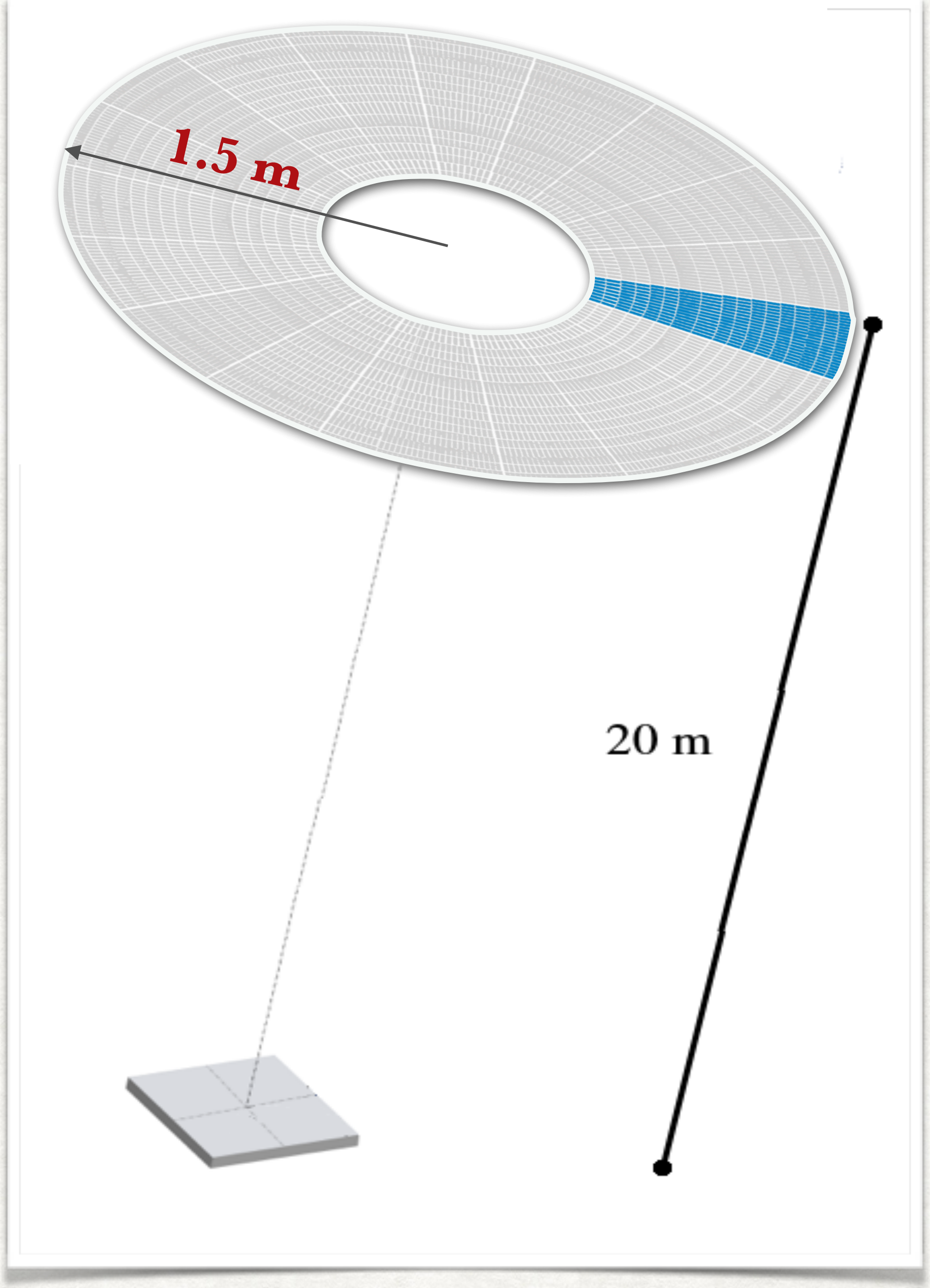
crystal dimensions: 30 x 10 x (optimized thickness) mm^3

43 rings

Rin/out= 18 cm / 149 cm

Filling Factor 93%

Total Geometric Area 69800 cm^2 ~ 7 m^2 !!



focal plane detector requirements

detection efficiency > 80% @ 700 keV

3D imaging capability = 300 µm (x, y, z direction)

fine spectroscopy response 1 % @ 511 keV

Goals of this progress activity

Laue lens optics

Definition of:

- optimized **crystal size** and **crystal dimensions**

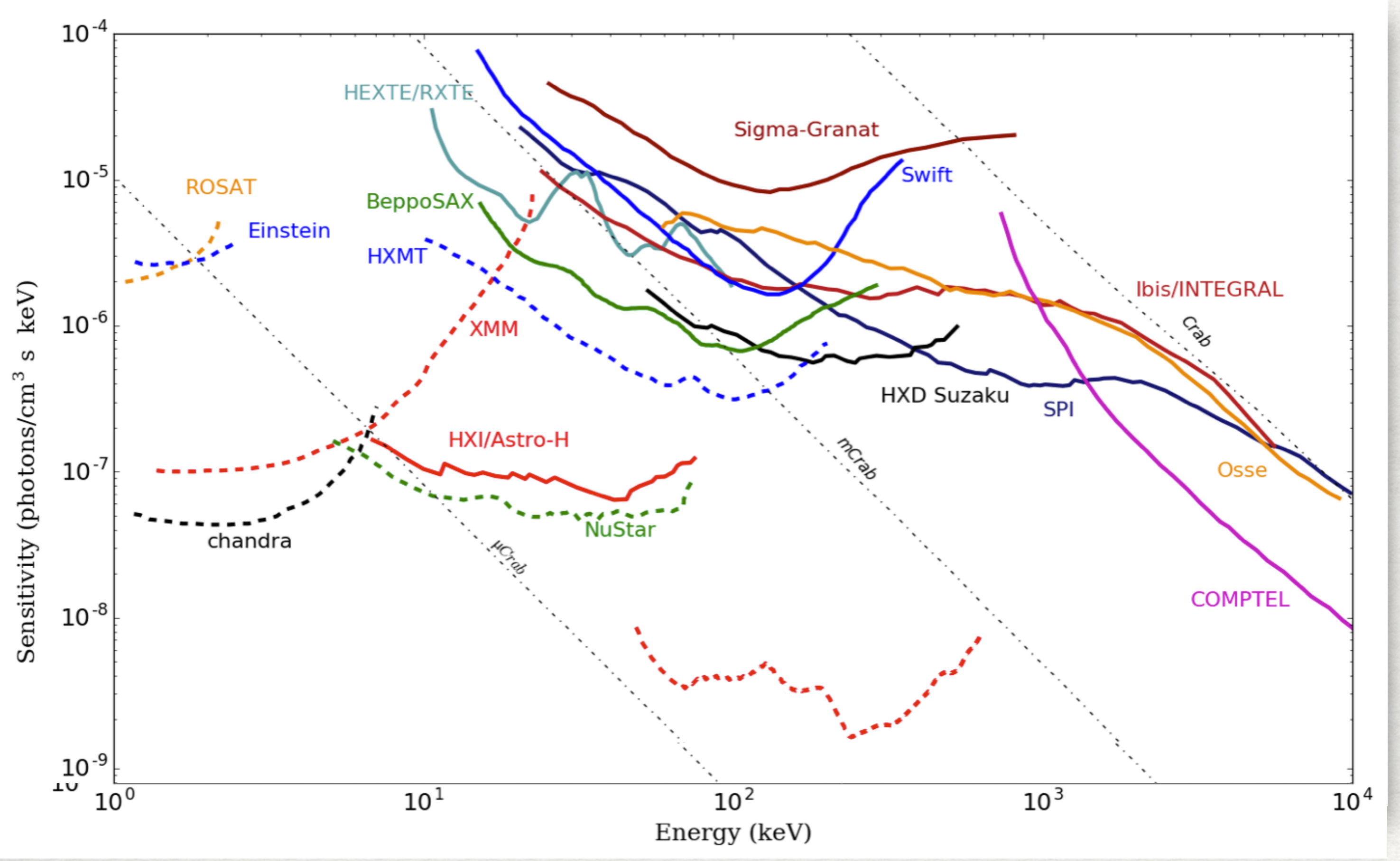
- instrument **field of view**

Focal plane detector

Definiton of:

- detector geometry (layers, thickness)
- detector material
- detection area

Laue lens sensitivity



All mission compared:

$$\Delta E = \frac{E}{2}$$

$$T = 10^5 s$$

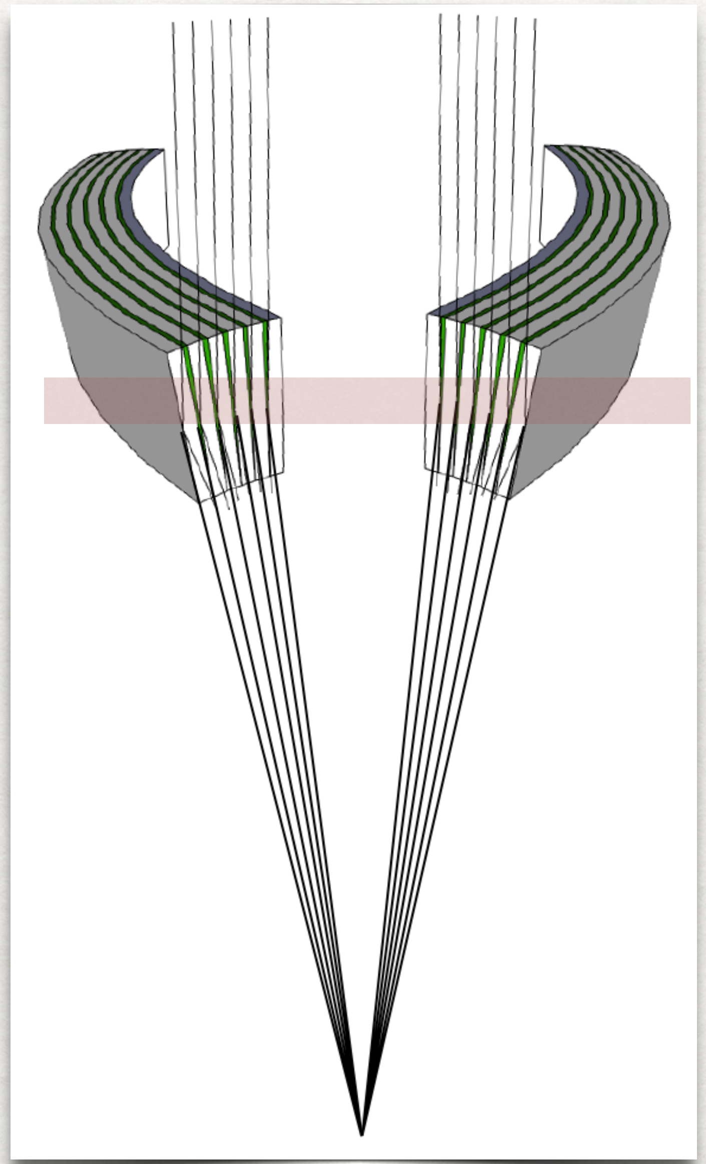
$$3\ \sigma$$

Due to the effect of integration above the Effective area A_{eff}

Laue lens optics updates

Laue Lens Library (LLL): SILC (Barriere et al.) geometry implemented

SILC tests in @ LARIX facility - Ferrara (within **WP4** AHEAD TransNational Access program)



- flat mosaic
- flat perfect
- bent mosaic
- bent perfect crystal
- stack of flat crystals
- **SILC**

link between WP4 and WP9

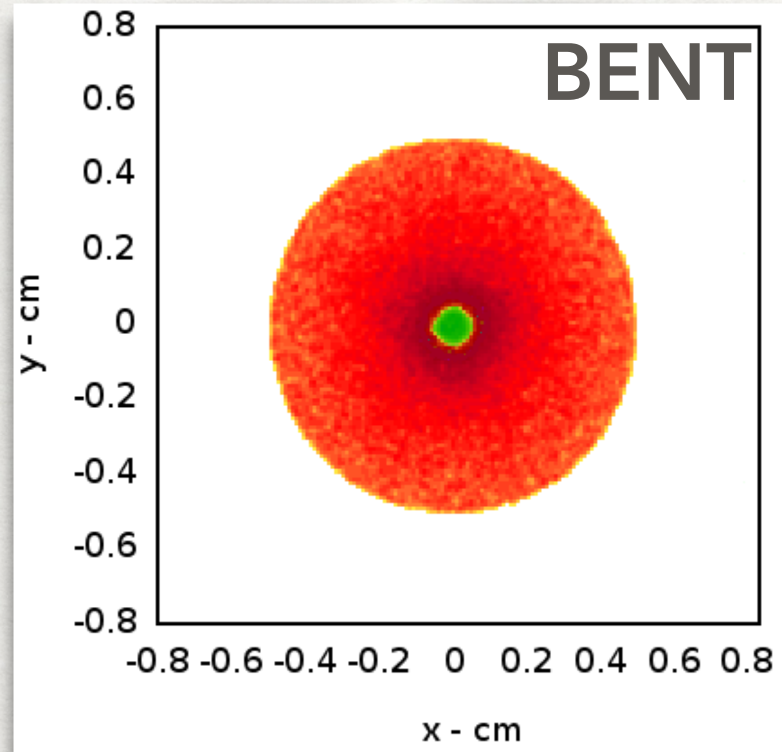
real comparison between simulations and experiments

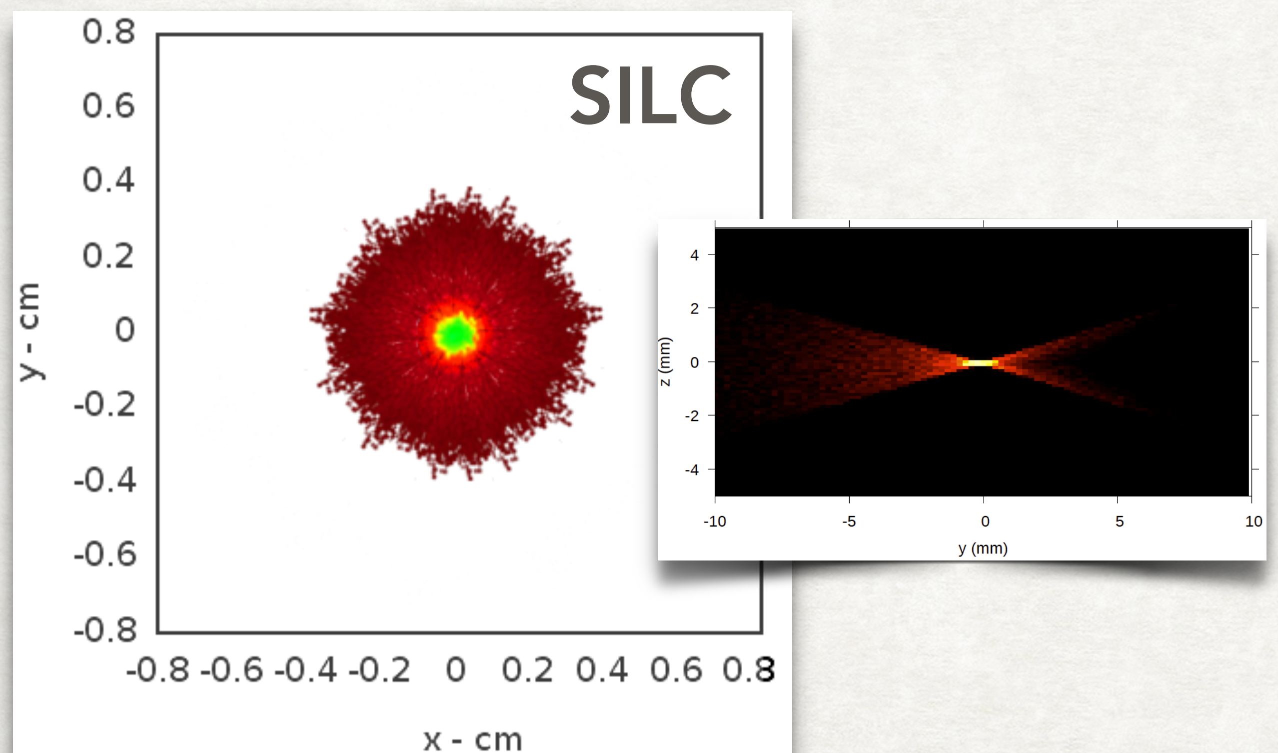
quite easy inclusion in LLL being it already conceived for modular elemens

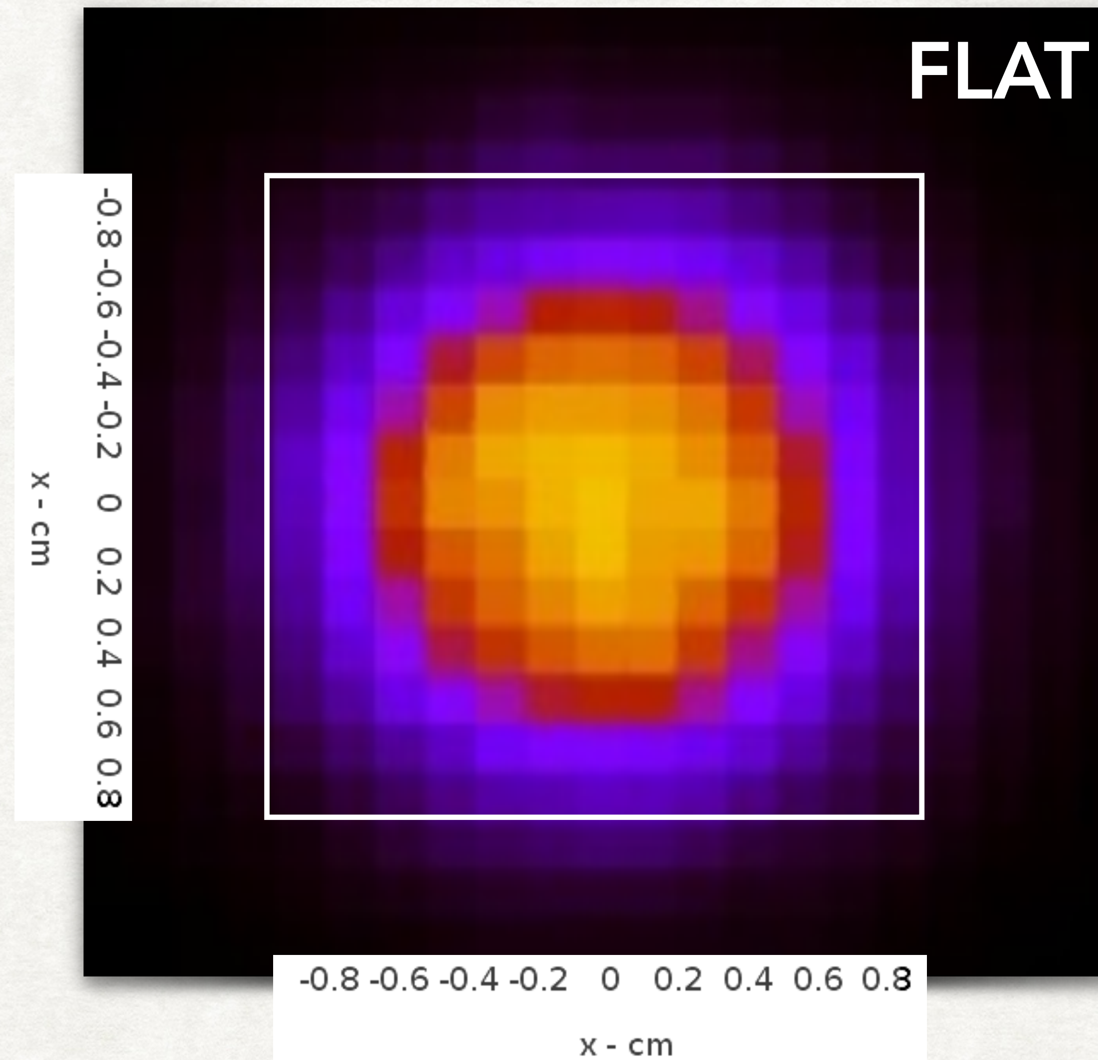
credits to **Cosine measurement systems** http://www.cosine.nl/

taken and adapted from Girou et al. (2017) SPIE Optical Engineering + Applications, 2017

Laue Lens Library (LLL): SILC (Barriere et al.) geometry implemented

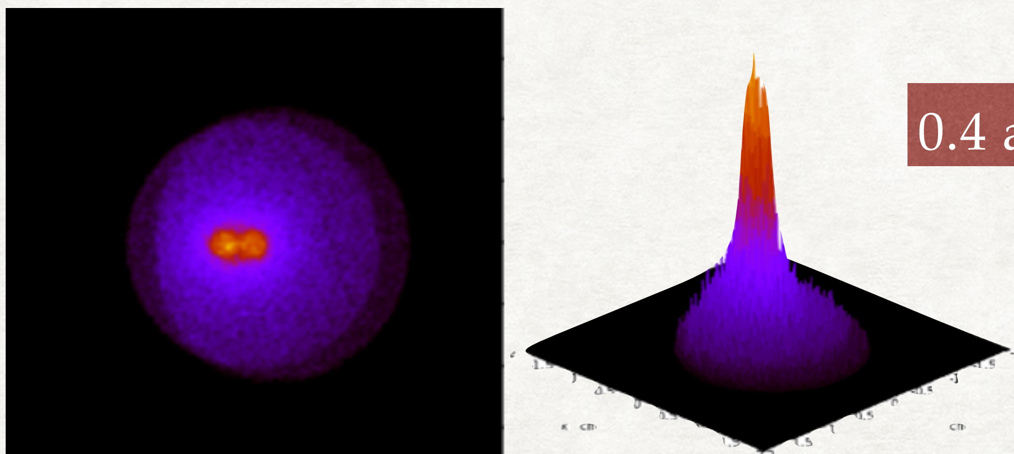




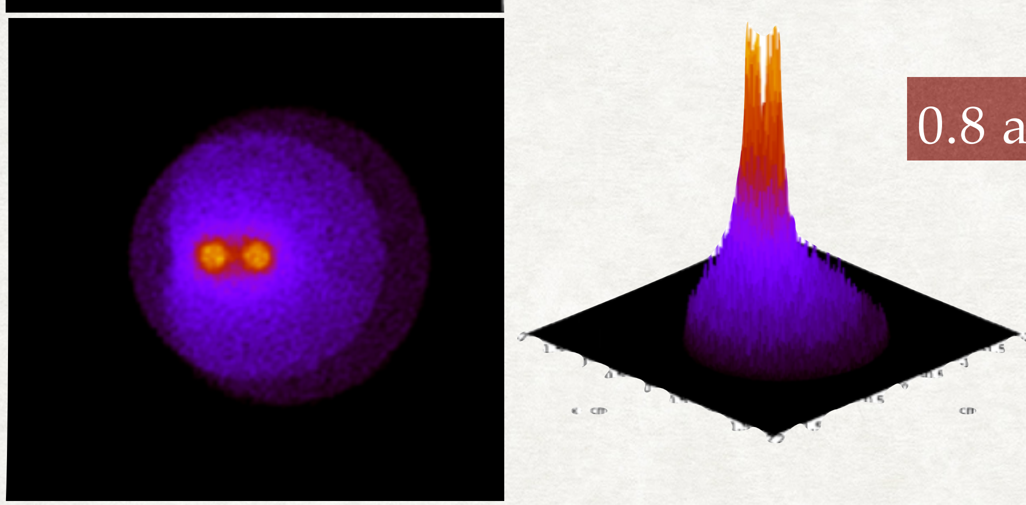


NFT - field of view

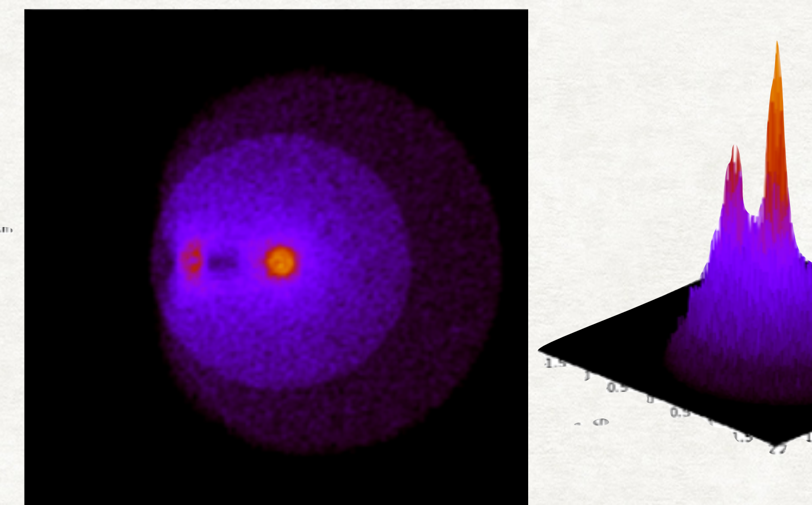
NFT - FoV is limited by aberration effects of the Laue optics. Bent crystals help to reduce this effect with respect to flat crystals.



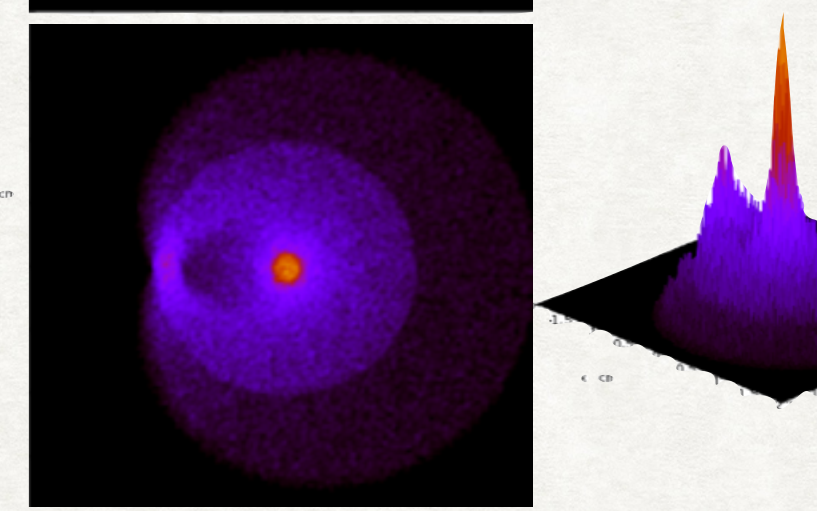
0.4 arcmin



0.8 arcmin



1.4 arcmin



1.8 arcmin

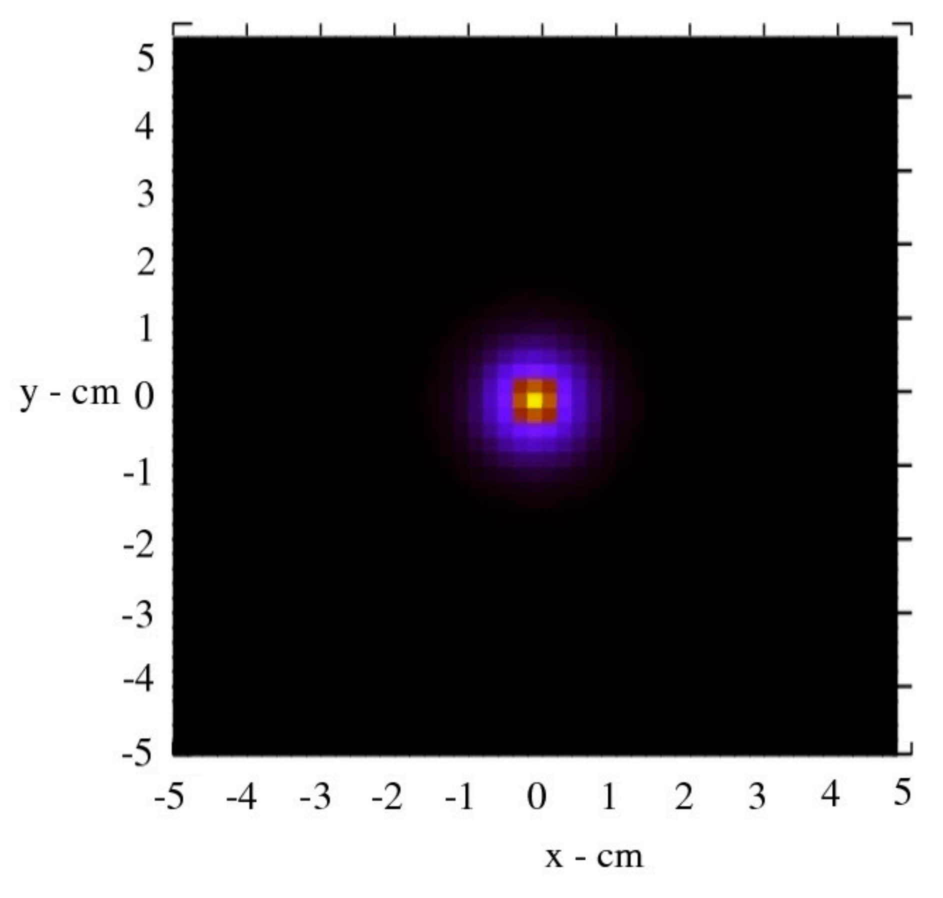
FoV = 3.6′ corresponds to a **minimum** detector size of 24 x 24 mm^2

Focal plane detector simulations

Starting point

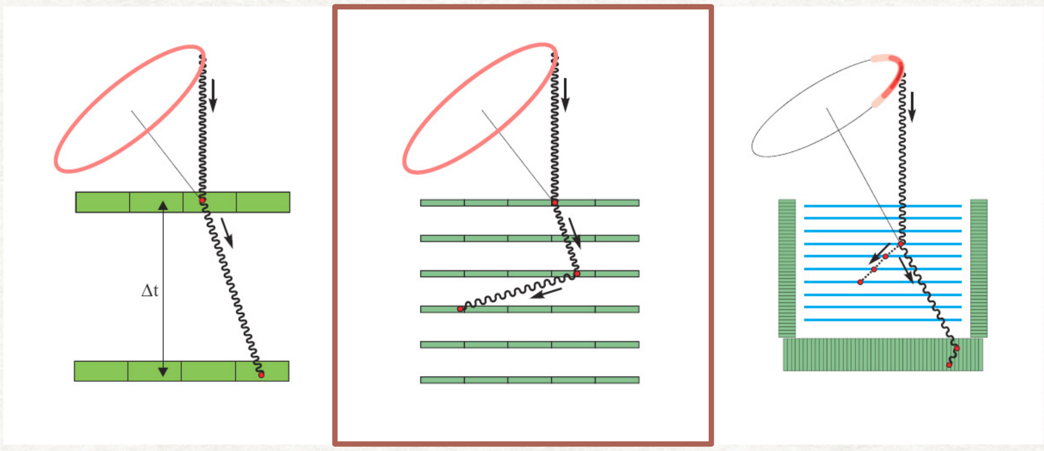
Ideal PSF (only lens focusing contribution)

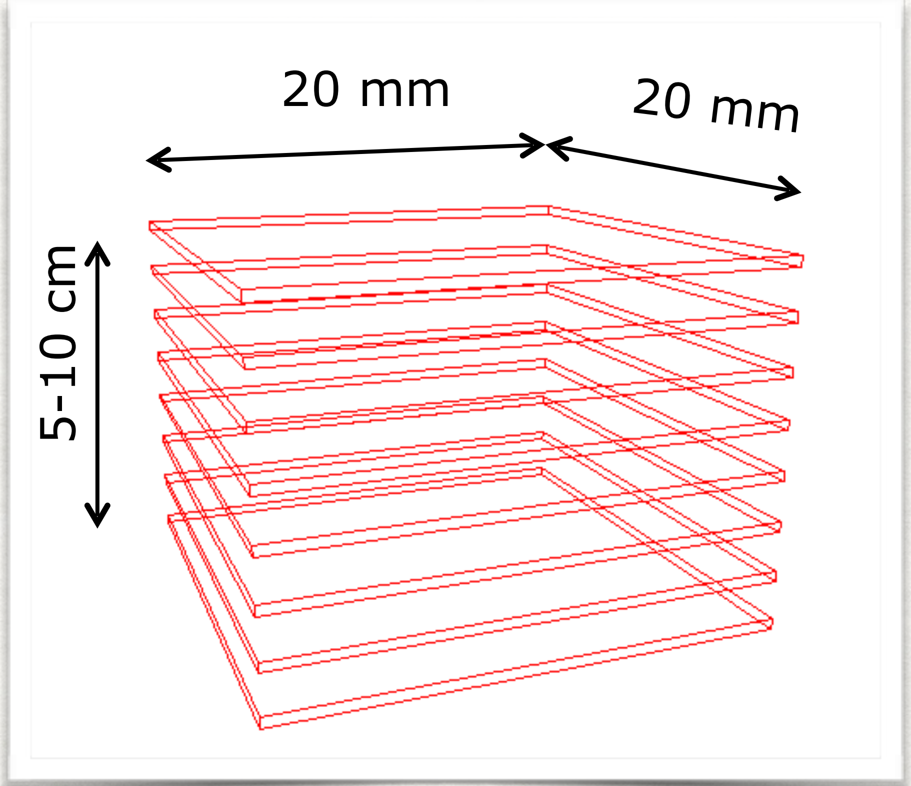
Focal plane reconstruction and dependance on energy.



MEGAlib simulations

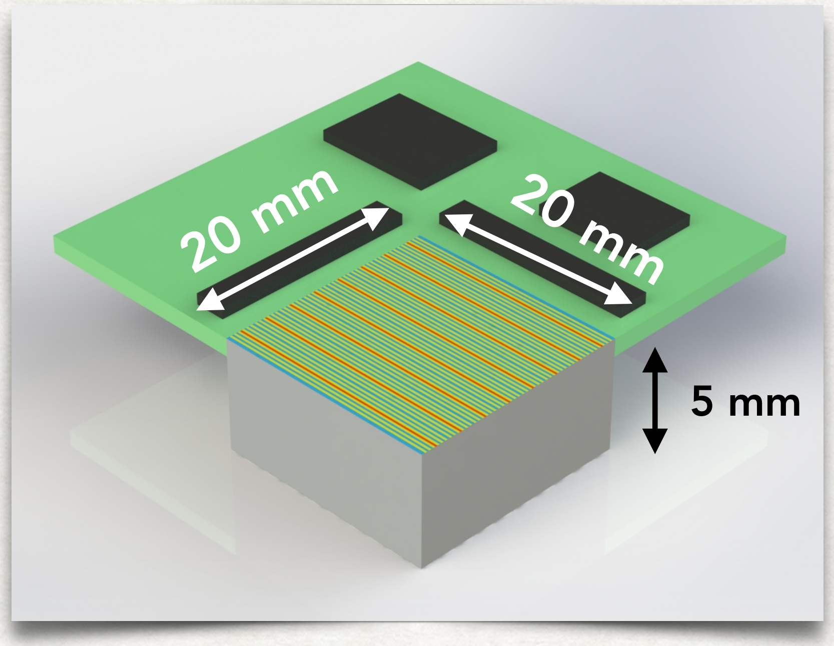
GEOMETRY AND DETECTOR INFORMATION → SIMULATION → EVENT SELECTION AND TRACK RECONSTRUCTION → IMAGE RECONSTRUCTION



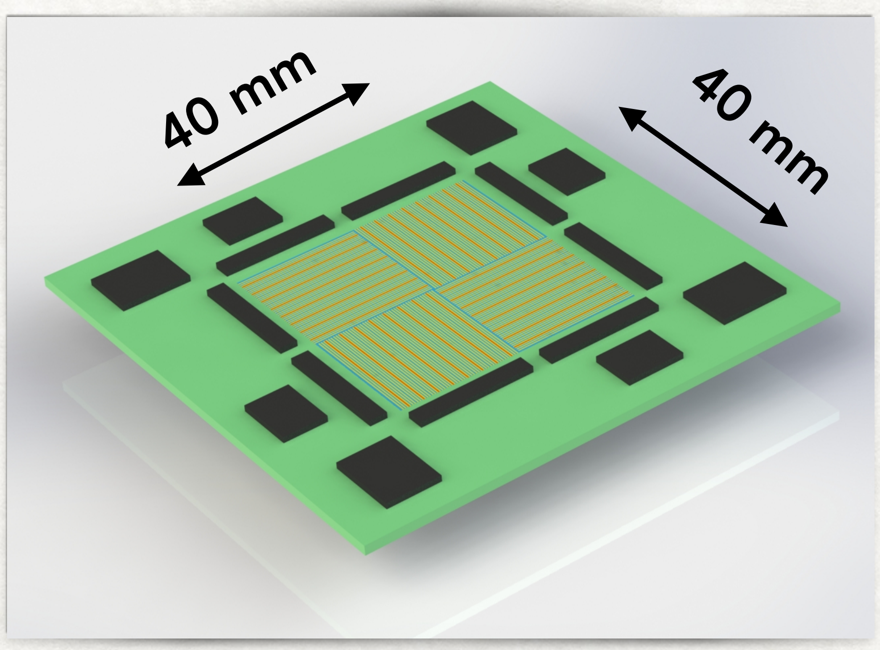


Detector optimization geometry

4 CdZnTe modules required to complete the NFT - FoV



Single CZT unit 20 x 20 x 5 mm
+ read out electronics



4 CZT packed units

MEGAlib: GEOMEGA input parameters

Detector parameters and optimization

at present a simple detector geometry is considered

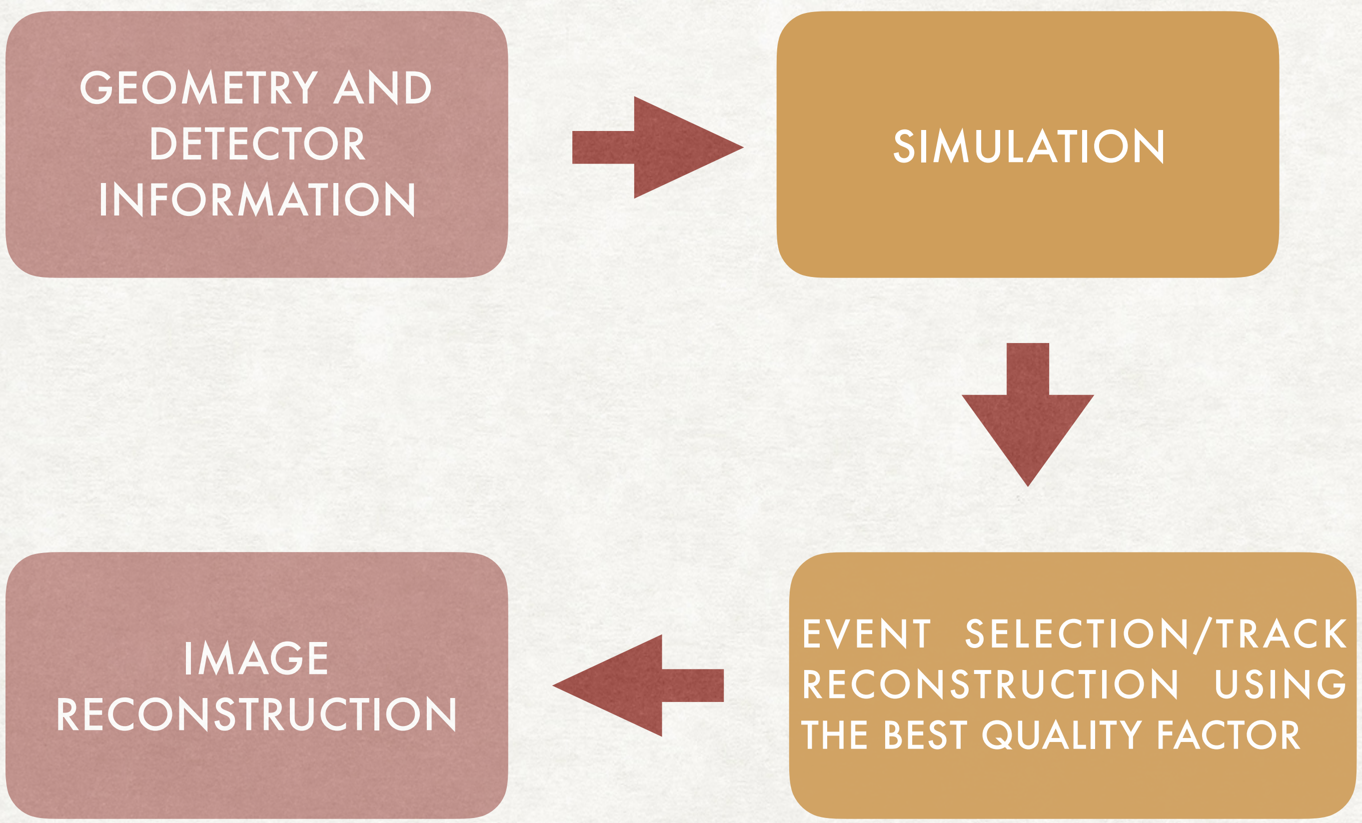
no electron tracking selected

Voxel 3d 300 x 300 x 300 μm^3

Number of layers: 2 - 20

layers **distance**: 0.5, 0.75, 1.0 cm

MEGAlib simulations



COSIMA setup

Triggered events = 10^4

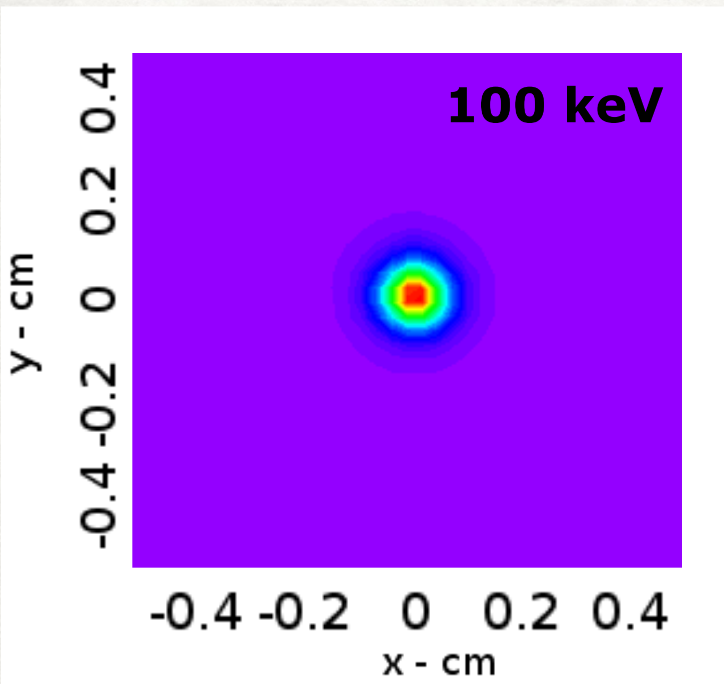
Single lines: 90, 250, 511, 650 keV

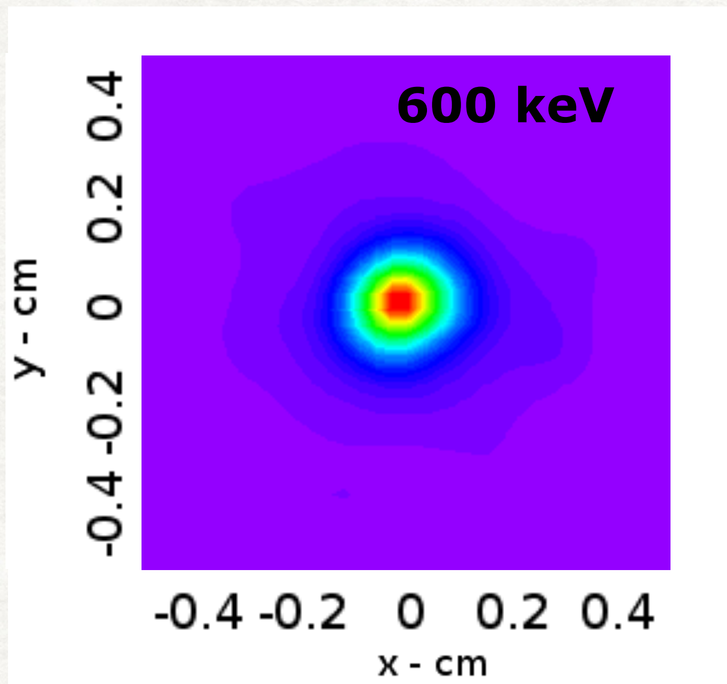
Polichromatic spectrum: 90 — 600 keV

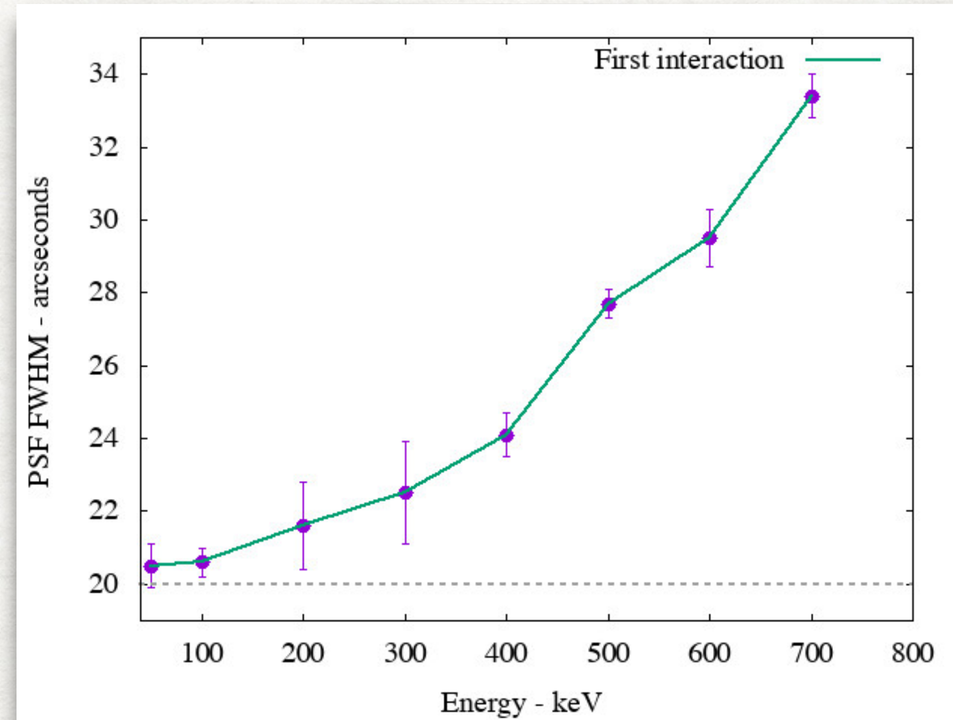
only on axis source

On axis source

using only first **interaction**



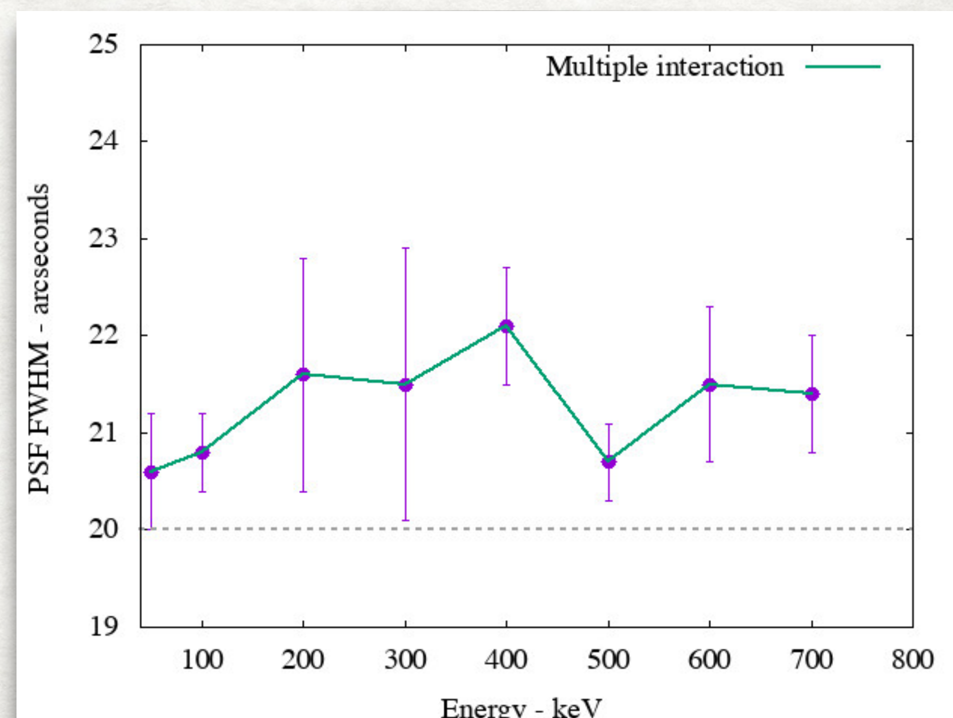




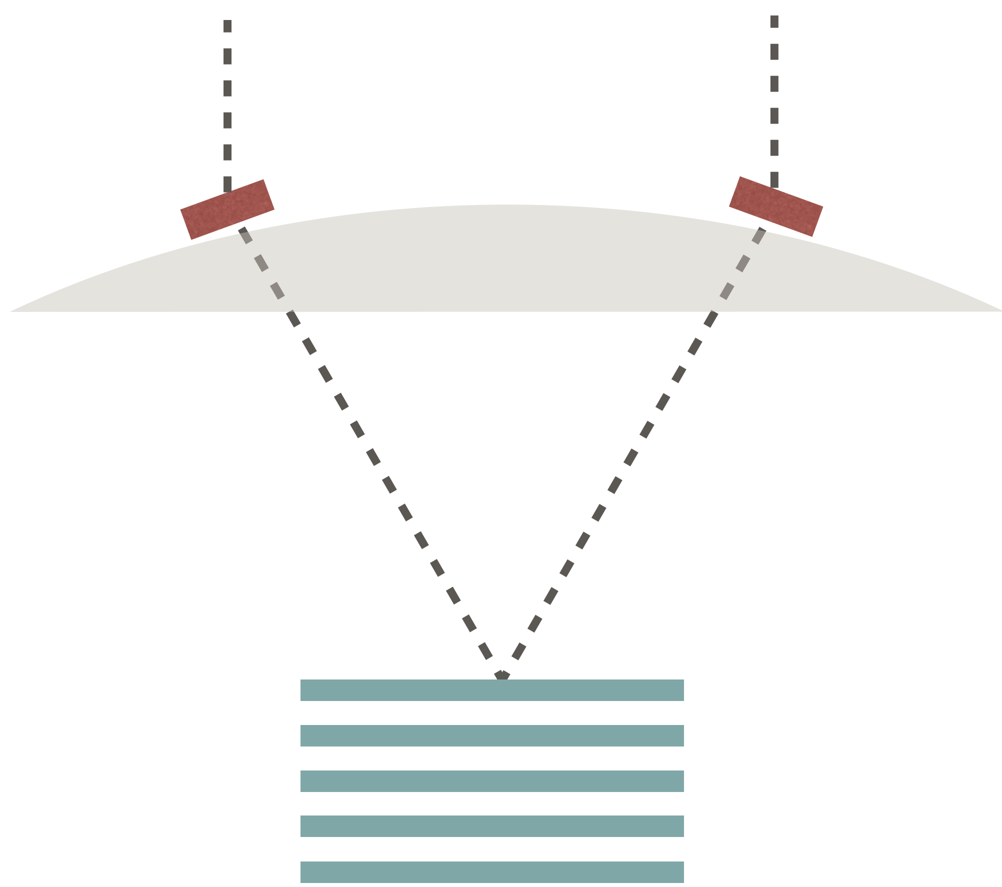
Number of layers: 10

layers **distance**: 0.5 cm

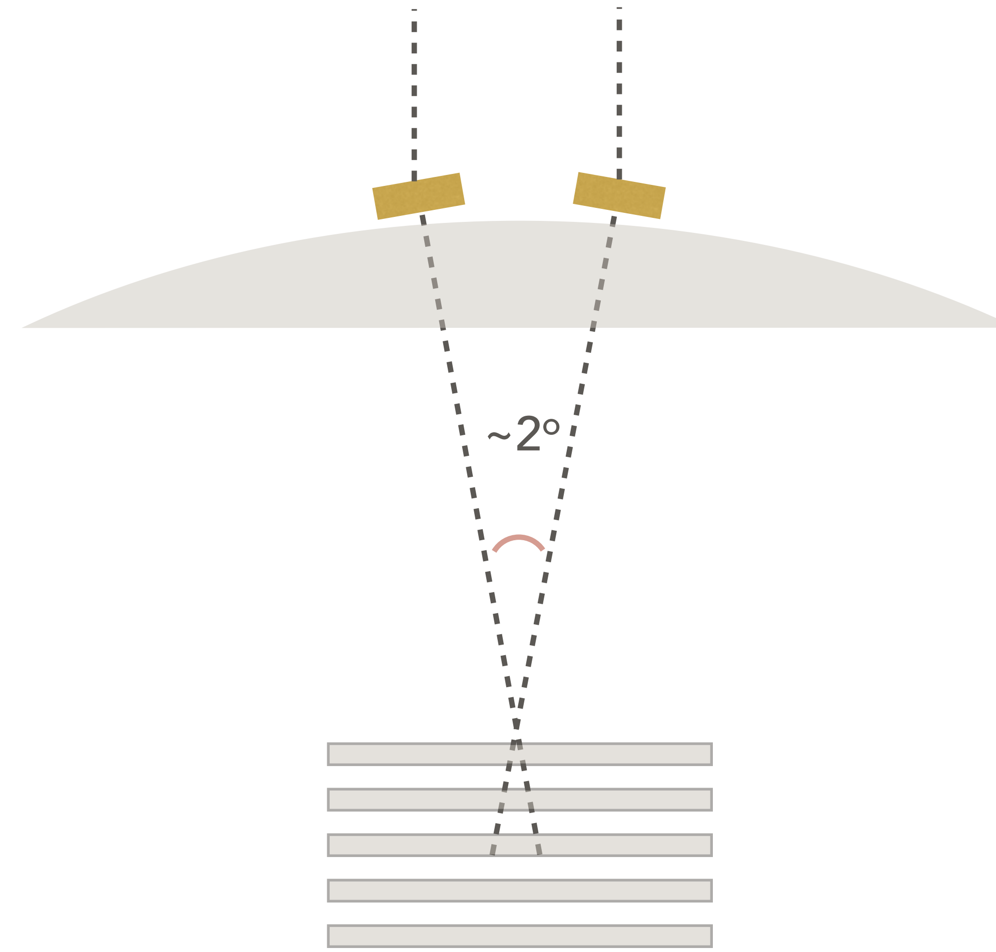
using all interactions



low energies (90 keV)



high energies (600 keV)



Different effects act in opposite manner

1. **Low energy** photons are photoelectrically absorbed at outward layers

2. **Low energy** photons come from outer radii (large diffraction angles)

~2° —> if the interaction occur at:

10 mm depth: —> ~ 4″
20 mm depth: —> ~ 7″

Next steps

- Complete the NFT geometric model (to be defined in DTU next July)
- Continuum sensitivity with real detector efficiency (until now used 0.9)
- Move to the science case (e.g. diffuse 511 keV emission, blazars spectra)

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Technical University of Denmark DTU

UNIVERSITÀ DEGLI STUDI DI FERRARA

Paper 10699-81 SPIE. The international society for optics and photonics

Austin Convention Center Austin, Texas, United States 10 - 15 June 2018

The advanced surveyor of transient events and nuclear astrophysics (ASTENA) mission within the AHEAD project

P. Rosati[1], E. Virgilli[1], F. Frontera[1], C. Guidorzi[1], E. Caroli[2], J. B. Stephen[2], N. Auricchio[2], L. Amati[2], M. Orlandini[2], F. Fuschino[2], L. Bassani[2], R. Campana[2], C. Labanti[2], A. Malizia[2], I. Kuvvetli[3], C. Budtz-Jørgensen[3], S. K. Brandt[3], G. Ghirlanda[4], R. Gilli[2], R. M. Curado da Silva[5]

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APPROVED TALK

Abstract

Within the AHEAD consortium a mission concept named ASTENA (Advanced Surveyor of Transient Events and Nuclear Astrophysics) is proposed to address the top-priority themes identified by the AHEAD Science Advisory Group: Gamma-Ray Bursts and Nuclear Astrophysics. With the wide field monitor/spectrometer (WFM/S, 1 keV - 20 MeV) we expect to accurately determine the energy spectrum of all type of Gamma Ray Bursts (GRBs) prompt emission in the broadest band ever achieved with a single instrument, to measure the gamma-ray polarization of, at least, the brightest GRBs and to search for electromagnetic counterparts of Gravitational Waves triggers. With the narrow field telescope based on Laue lenses (NFT, 50 – 700 keV), which is at least 100 times more sensitive at a few hundred keV than any other past or planned mission, we can carry out for the first time a long-sought study of the afterglow spectrum of GRBs up to high energies (600/700 keV), including its polarization level.

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The Narrow Field Telescope on board the ASTENA mission

E. Virgilli[1], P. Rosati[1], F. Frontera[1], E. Caroli[2], L. Amati[2], J. B. Stephen[2], N. Auricchio[2], Cr. Guidorzi[1], M. Orlandini[2], L. Bassani[2], A. Malizia[2], S. Silvestri[2], A. Basili[2], I. Kuvvetli[3], C. Budtz-Jørgensen[3], R. M. Curado da Silva[4], C. Labanti[2], F. Fuschino[2], R. Campana[2], S. K. Brandt[3]

[1] University of Ferrara (Italy);
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[3] Technical University of Denmark (Denmark);
[4] Universidade de Coimbra (Portugal);

APPROVED TALK

Abstract

The ASTENA mission, conceived in the AHEAD framework, consists of two coaligned instruments, a broad band Wide Field Monitor/Spectrometer WFM/S and a broad band Narrow Field Telescope (NFT). In the NFT a large geometric area Laue lens (3 m diameter, 20 m focal length) allows to focus the radiation of the 50 - 700 keV energy pass-band. Differently from other proposed Laue lenses in the past, the NFT is made of optimised thickness bent crystal tiles, made with Silicon and Germanium. With these assumption we have optimised the instrument Field of View (FoV) to 3.5 arcmin with the angular resolution of 20”. The Laue lens is coupled with a high efficiency (>80% above 600 keV) focal plane position sensitive detector, with 3D spatial resolution of at least 300 μm in the (X,Y) plane and fine spectroscopic response (1% @511 keV) and with polarization sensitivity.In this SPIE contribution we will discuss the NFI geometry and its simulated performances.

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EX LABORE FRUCTUS

Paper 10699-214 SPIE. The international society for optics and photonics

Austin Convention Center Austin, Texas, United States 10 - 15 June 2018

The wide field monitor and spectrometer instrument on board the ASTENA satellite mission concept

F. Fuschino[2], L. Amati[2], R. Campana[2], E. Caroli[2], G. De Cesare[2], F. Frontera[1], C. Labanti[2], M. Orlandini[2], P. Rosati[1], E. Virgilli[1]

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POSTER SESSION

Abstract

The ASTENA mission concept under study in the framework of the H2020 AHEAD project includes a wide field monitor (WFM), mainly dedicated to GRBs. The instrument is sensitive in the range 1 keV - 20 MeV. The total isotropic detection area of the will be ~ 1.8 m2 with a FOV of at least 1 sr. The WFM will allow the detection, both spectroscopic and polarimetric characterization of all classes of GRBs. Each module is a coded mask telescope that will allow the source localization within few arcmin up to 50/100 keV. The detector core is based on the coupling of low-noise, solid-state Silicon Drift Detectors (SDDs) with CsI(Tl) scintillating bars. Low-energy and high-energy photons are discriminated using the on-board electronics. The instrument design and preliminary experimental characterizations are reported and discussed.

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Laue lenses made with bent mosaic crystals: comparison between simulations and experimental results

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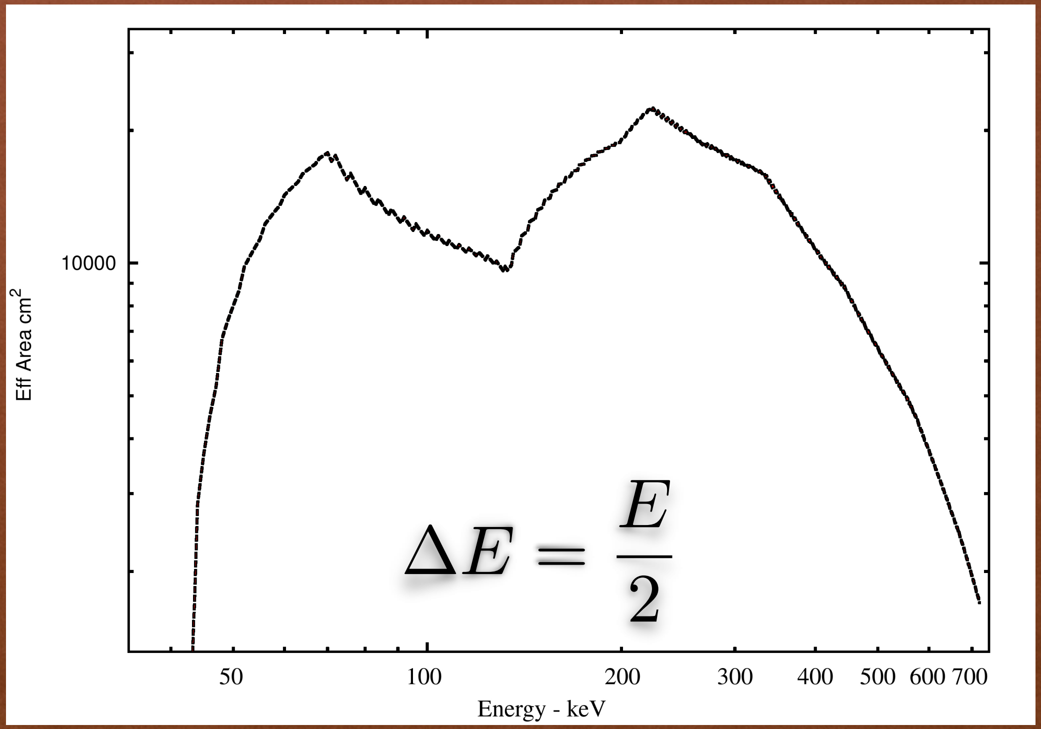
IN PROGRESS

ABSTRACT

Context. Laue lenses made with bent crystals represents a challenging way to focus the radiation from the Gama ray sky. Investigate the possibility of using bent crystals represents a new window that only recently started to be a real possibility.
Aims. It is shown that the crystals curvature radii represent a very important parameter to be carefully investigated, given that is capable to minimize the PSF. The distortion of the photon distribution on the focal plane detector due to the effects of crystal misalignment and radial distortion with respect to the nominal curvature are dicussed.
Methods. A software named laue lens library LLL has been developed for the purposes. In the Monte Carlo code, all the main parameters have been takein into account. The ray tracer
Results. We have found that a radial distortion of 5-10% with respect to the nominal curvature radius can be accepted to turn into a worsening of the on-axis PSF of about 10%. In this paper we have shown our method to realize a prototype with an unprecedent accuracy and stability in long time monitoring.
Conclusions.

Key words. Focusing telescopes; X-ray diffraction; Laue lens; Experimental astronomy; High energy instrumentation


Eff Area cm^2
10000
50
100
200
300
400
500
600
700
Energy - keV
$\Delta E = \frac{E}{2}$

we are performing simulations

coupling simulations with experimental activity (e.g. SILCS)

we are matching simulations of the detector with the state-ot-art detctors for focusing instruments

300 x 300 x 300 is the goal of DTU activity