v1.1

PHEMTO: MEGAlib Simulations

José Sousa

12-11-2025

Overall Assumptions: detectors

CZT/CdTe Detectors performance:

density = 5.79 g/cm3
threshold = 4 keV
noise = 0.5 keV
dx dy = 0.25mm
Energy resolution:

```
CZTcal5mm_U.EnergyResolution Gauss   40    40   1.8   // values borrowed from Alex
CZTcal5mm_U.EnergyResolution Gauss  100   100   2
CZTcal5mm_U.EnergyResolution Gauss  500   500   2.5
CZTcal5mm_U.EnergyResolution Gauss  1000  1000  5
CZTcal5mm_U.EnergyResolution Gauss  2000  2000  10
CZTcal5mm_U.EnergyResolution Gauss  5000  5000  25
```

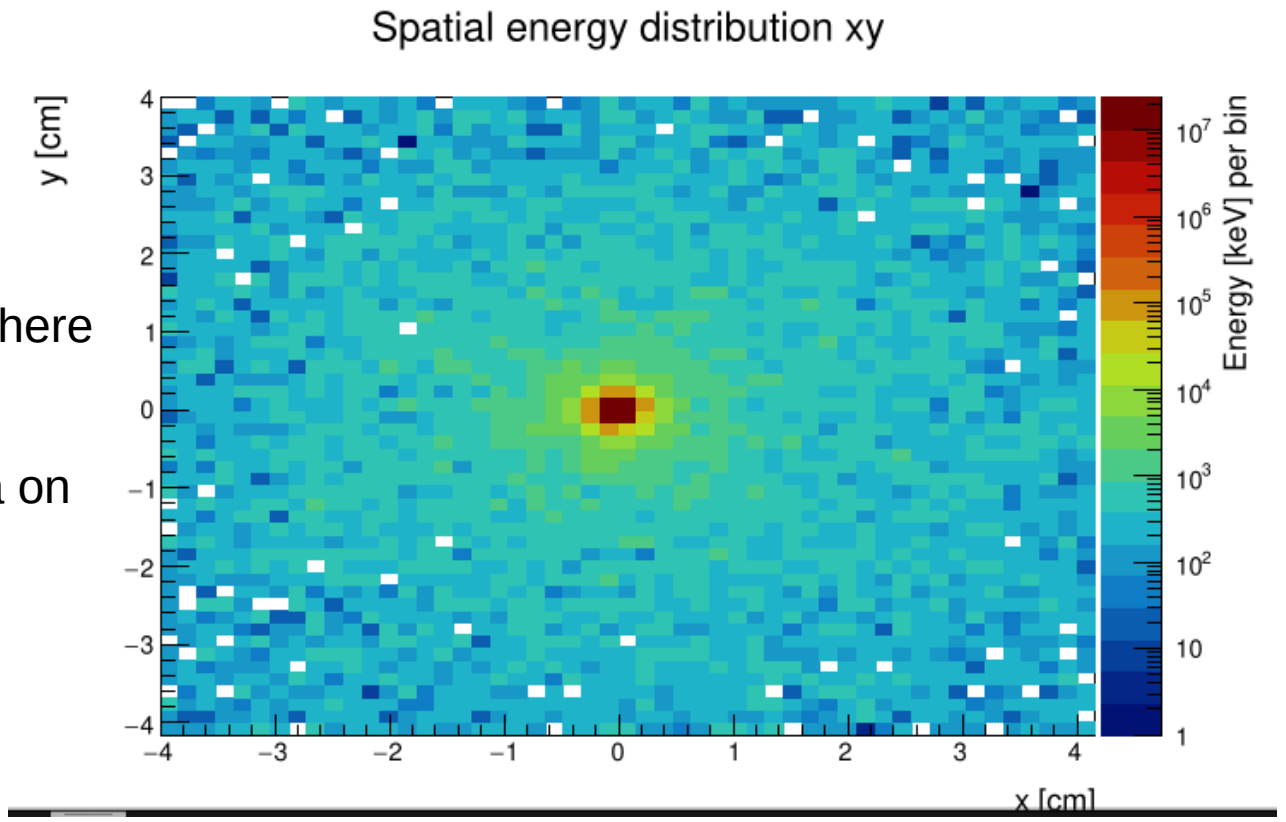
Overall Assumptions: sources

Example Source:

- Laue Lenses
- 1.5mm diameter focus [1,2]
- monochromatic 104keV

This simulations only for energies where laue lenses operates, [50, 700]keV

For E<50keV, used detector eff data on Laurent excel

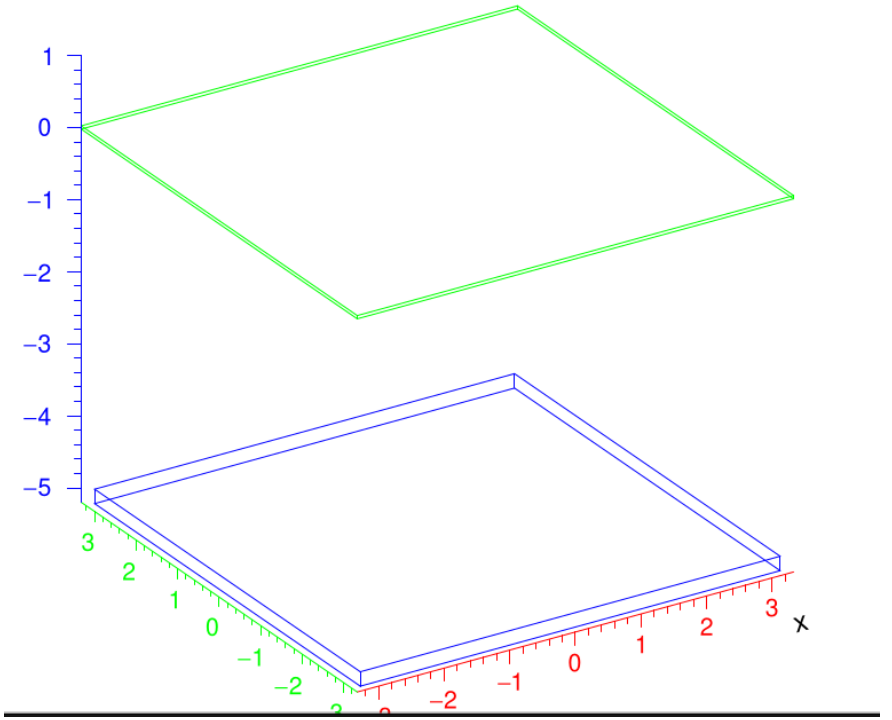


CONFIG 1

Si (green):
6.65x6.65cm2, 450um thick

CdTe (blue):
6.4x6.4cm2, 2mm thick

5cm spacing

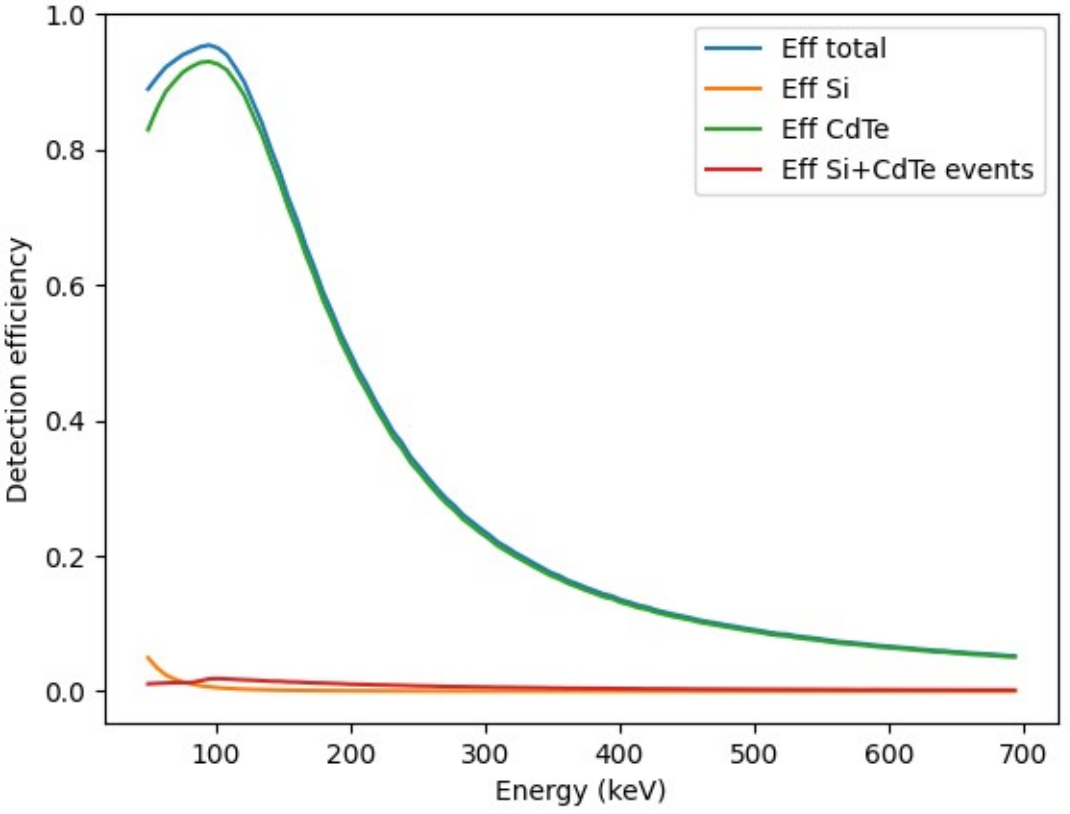


CONFIG 1

Simulated efficiency
for Energies:

```
E_init = 50
Log_E=[]
while E_init <= 693.5:
    Log_E.append(E_init)
    E_init = E_init + 6.5
```

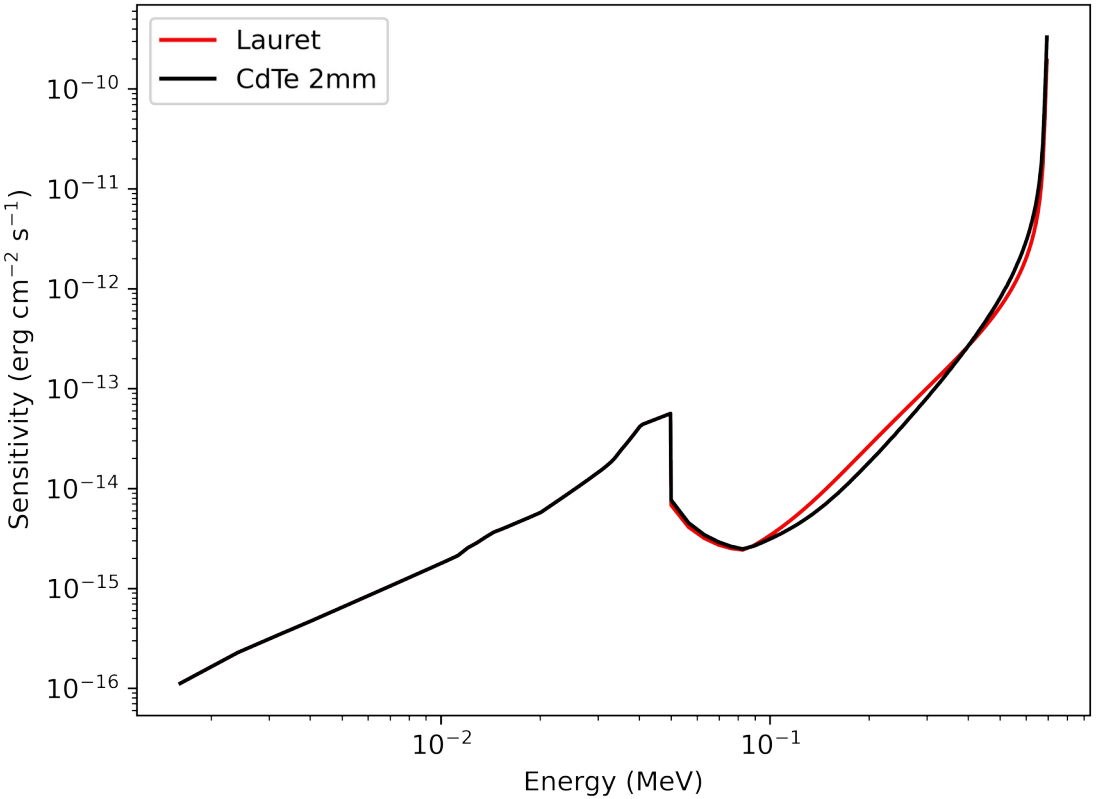
To be compliant with
Laurent Excel



CONFIG 1

Sensitivity Comparison:

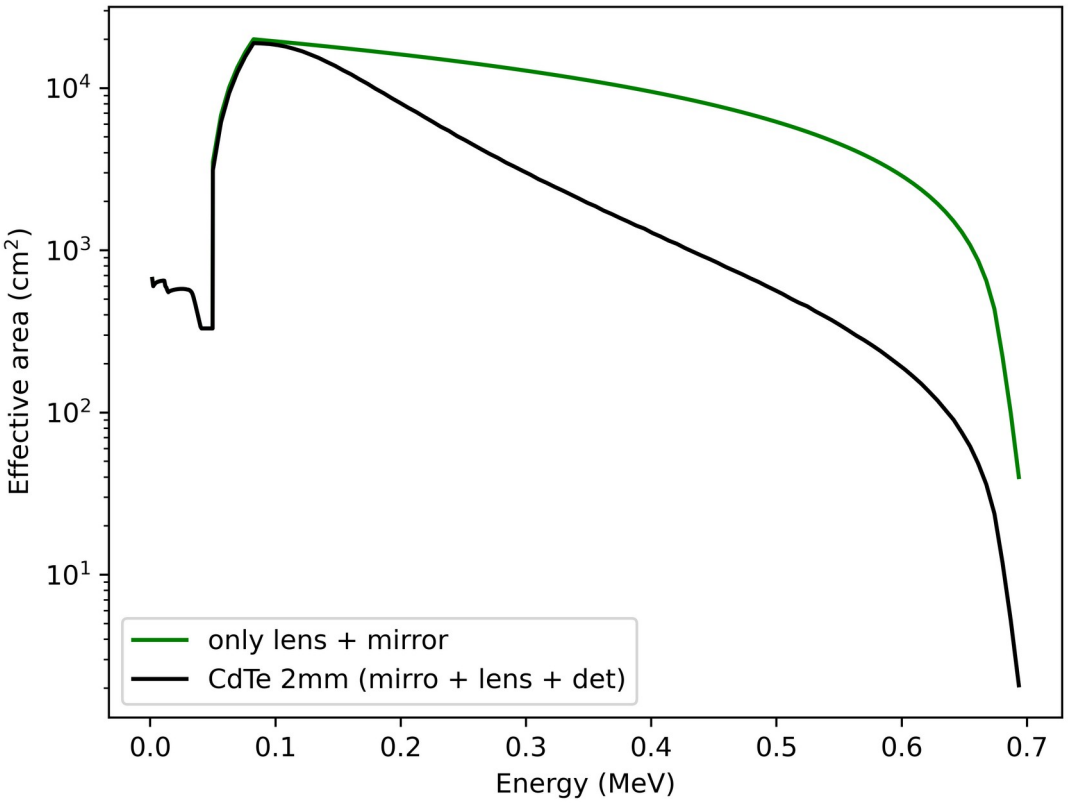
- Red, Laurent det eff Assumption (used 6.06 CdTe ro)
- Black, MEGAlib simulated eff from 50kev to 700kev



CONFIG 1

Effective Area using:

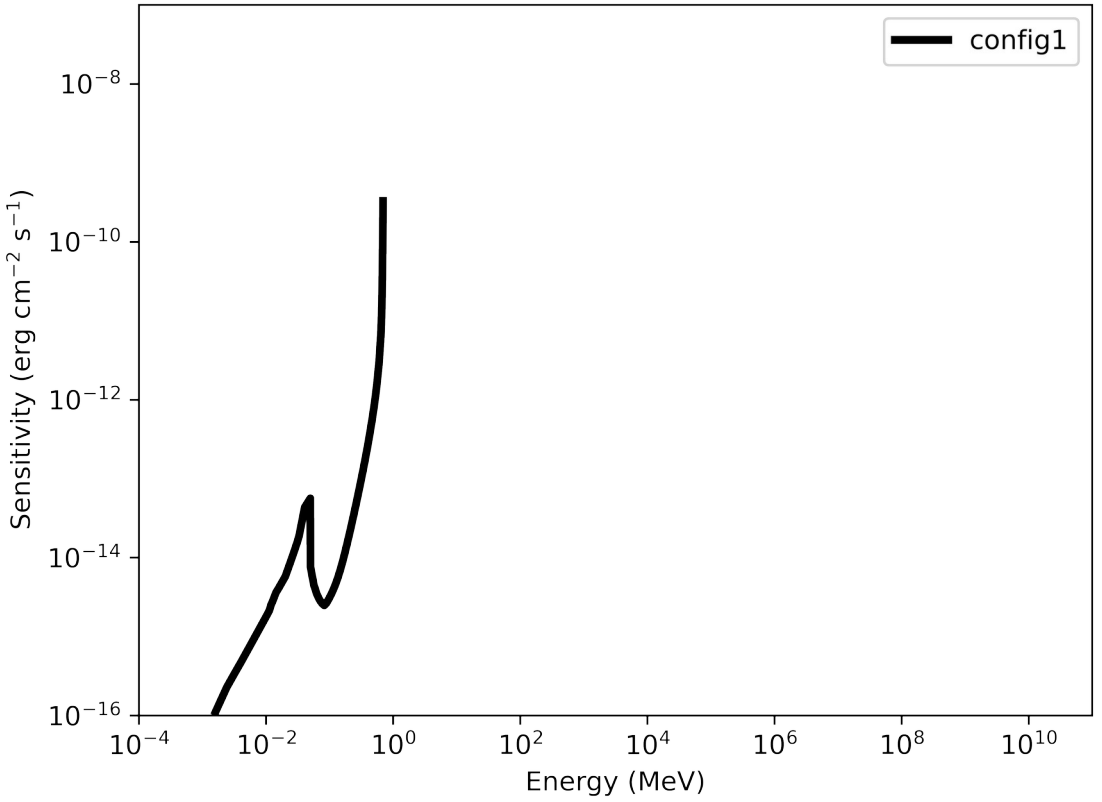
- Area lenses from Laurent excel
- multiply det_Eff x area

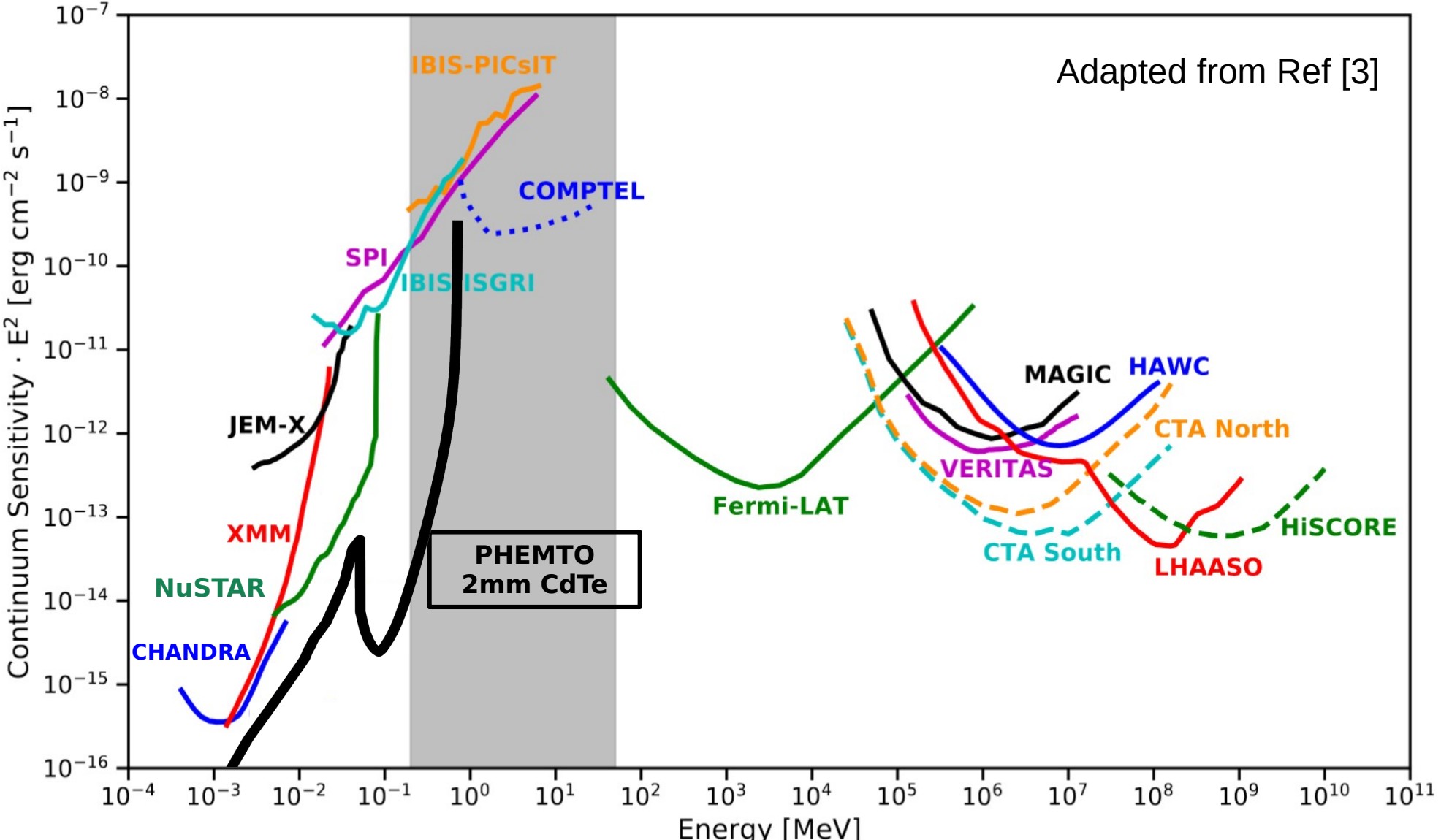


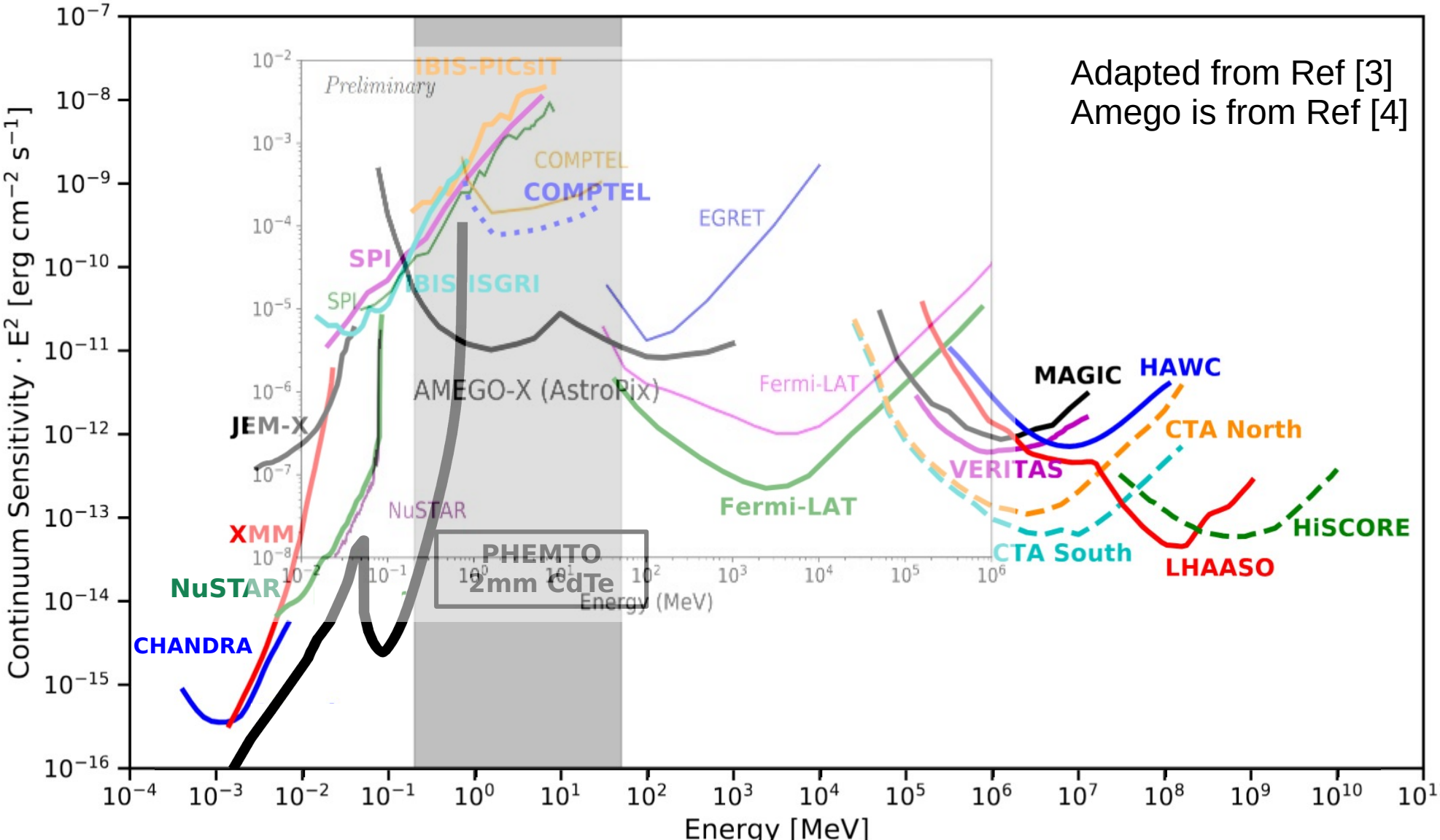
CONFIG 1

Sensitivity using:

- simulated det effs (Si + CdTe)
- used Laurent excel for lenses eff




Adapted from Ref [3]
Continuum Sensitivity · E² [erg cm⁻² s⁻¹]
Energy [MeV]
IBIS-PICsIT
COMPTEL
SPI
IBIS ISGRI
JEM-X
XMM
NuSTAR
CHANDRA
PHEMTO
2mm CdTe
Fermi-LAT
MAGIC
HAWC
CTA North
VERITAS
CTA South
HiSCORE
LHAASO

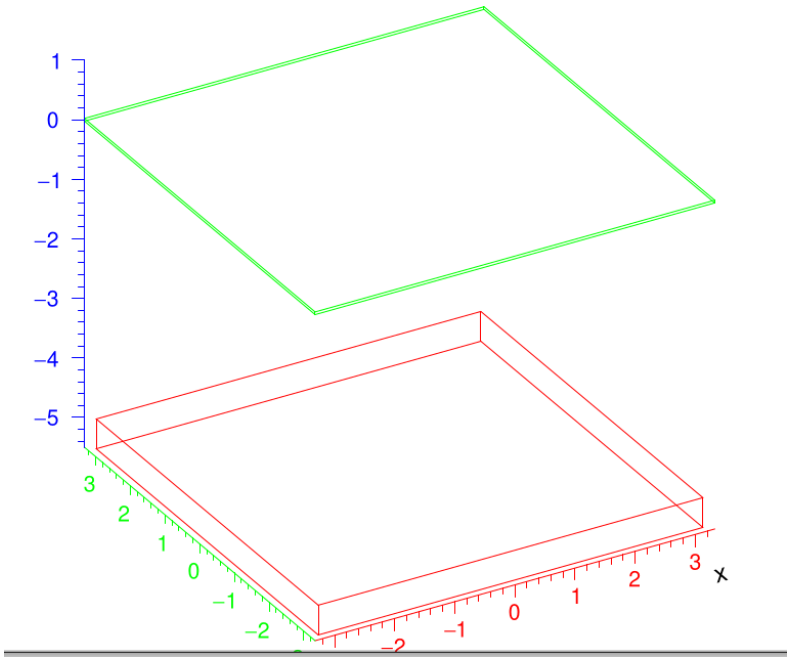

Adapted from Ref [3]
Amego is from Ref [4]
Continuum Sensitivity · E² [erg cm⁻² s⁻¹]
Energy [MeV]
Preliminary
IBIS-PICsIT
COMPTEL
COMPTEL
EGRET
SPI
IBIS-ISGRI
SPI
AMEGO-X (AstroPix)
JEM-X
Fermi-LAT
MAGIC
HAWC
CTA North
VERITAS
Fermi-LAT
NuSTAR
XMM
PHEMTO
2mm CdTe
HiSCORE
CTA South
LHAASO
NuSTAR
CHANDRA
Energy (MeV)

CONFIG 2

Si (green):
6.65x6.65cm2, 450um thick

CdTe (red):
6.4x6.4cm2, 5mm thick

5cm spacing

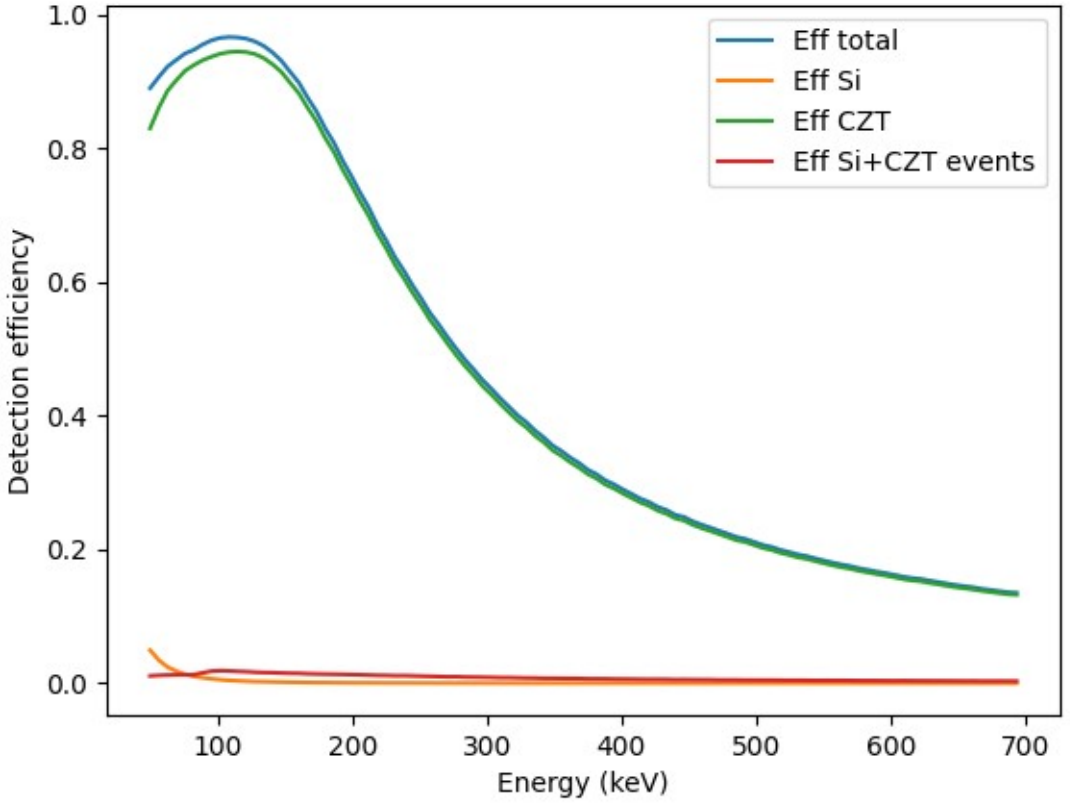


CONFIG 2

Simulated efficiency
for Energies:

```
E_init = 50
Log_E=[]
while E_init <= 693.5:
    Log_E.append(E_init)
    E_init = E_init + 6.5
```

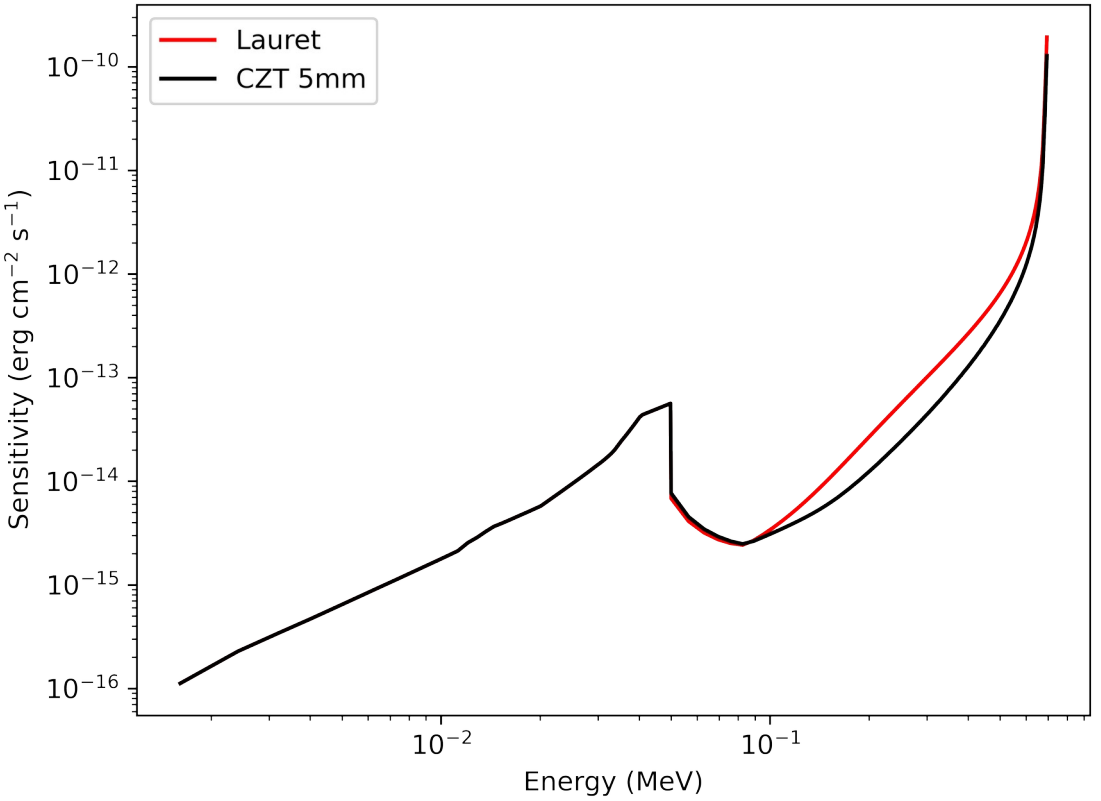
To be compliant with
Laurent Excel



CONFIG 2

Sensitivity Comparison:

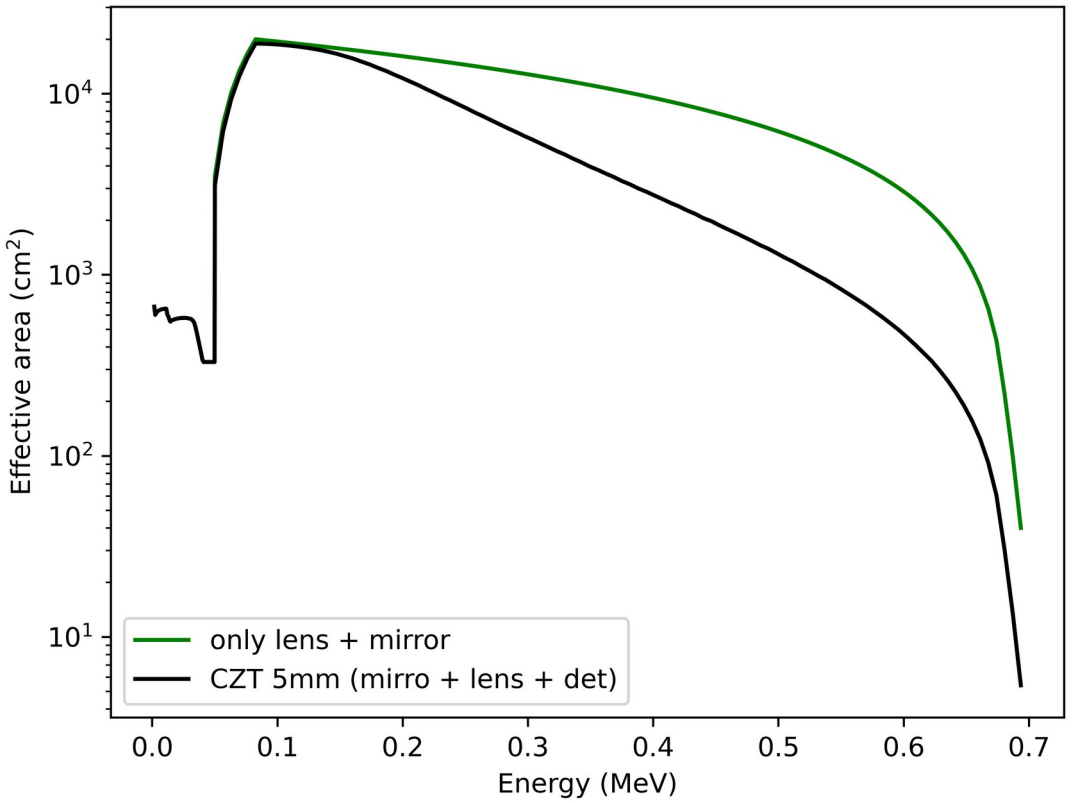
- Red, Laurent det eff Assumption (used 6.06 CdTe ro)
- Black, MEGAlib simulated eff from 50kev to 700kev



CONFIG 2

Effective Area using:

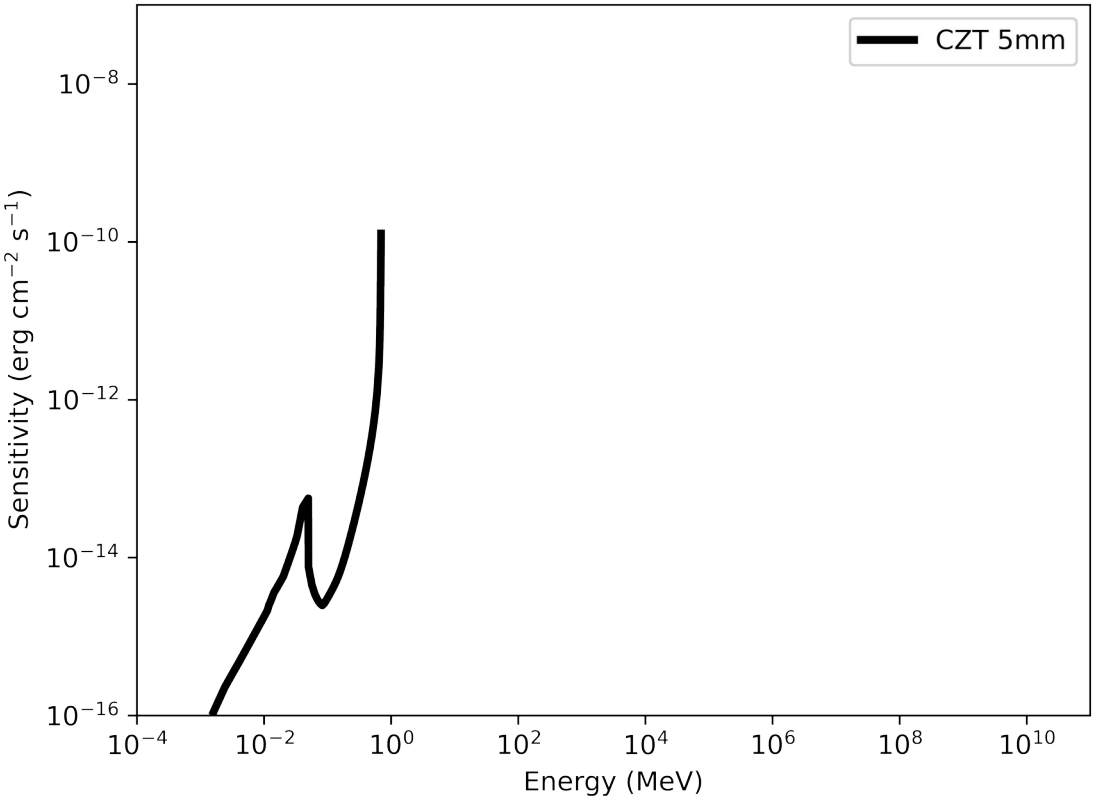
- Area lenses from Laurent excel
- multiply det_Eff x area

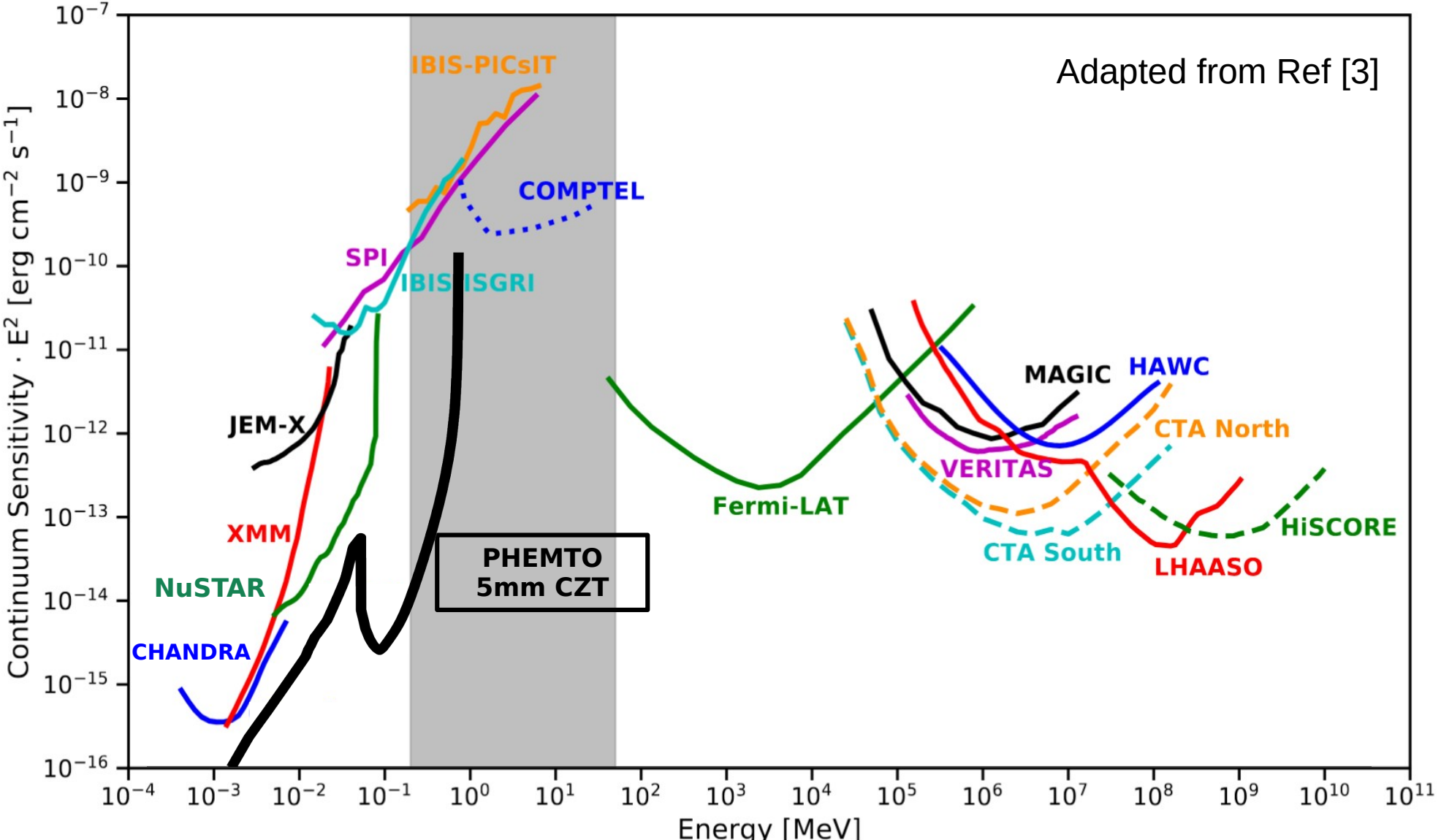


CONFIG 2

Sensitivity using:

- simulated det effs (Si + CdTe)
- used Laurent excel for lenses eff



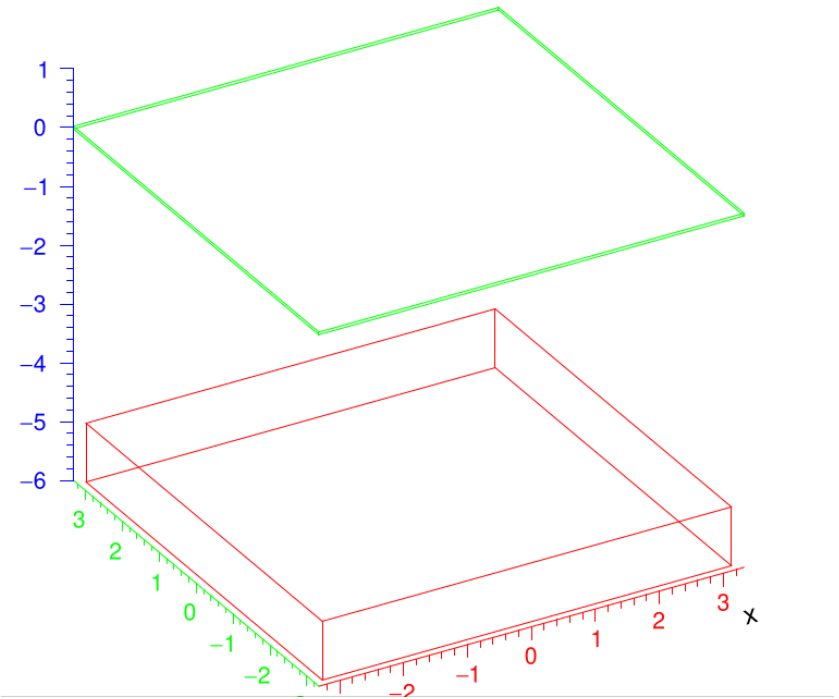

Adapted from Ref [3]
IBIS-PICsIT
COMPTEL
SPI
IBIS ISGRI
JEM-X
XMM
NuSTAR
CHANDRA
PHEMTO
5mm CZT
Fermi-LAT
MAGIC
HAWC
CTA North
VERITAS
CTA South
LHAASO
HiSCORE
Continuum Sensitivity · E² [erg cm⁻² s⁻¹]
Energy [MeV]

CONFIG 3

Si (green):
6.65x6.65cm2, 450um thick

CdTe (red):
6.4x6.4cm2, 10mm thick

5cm spacing

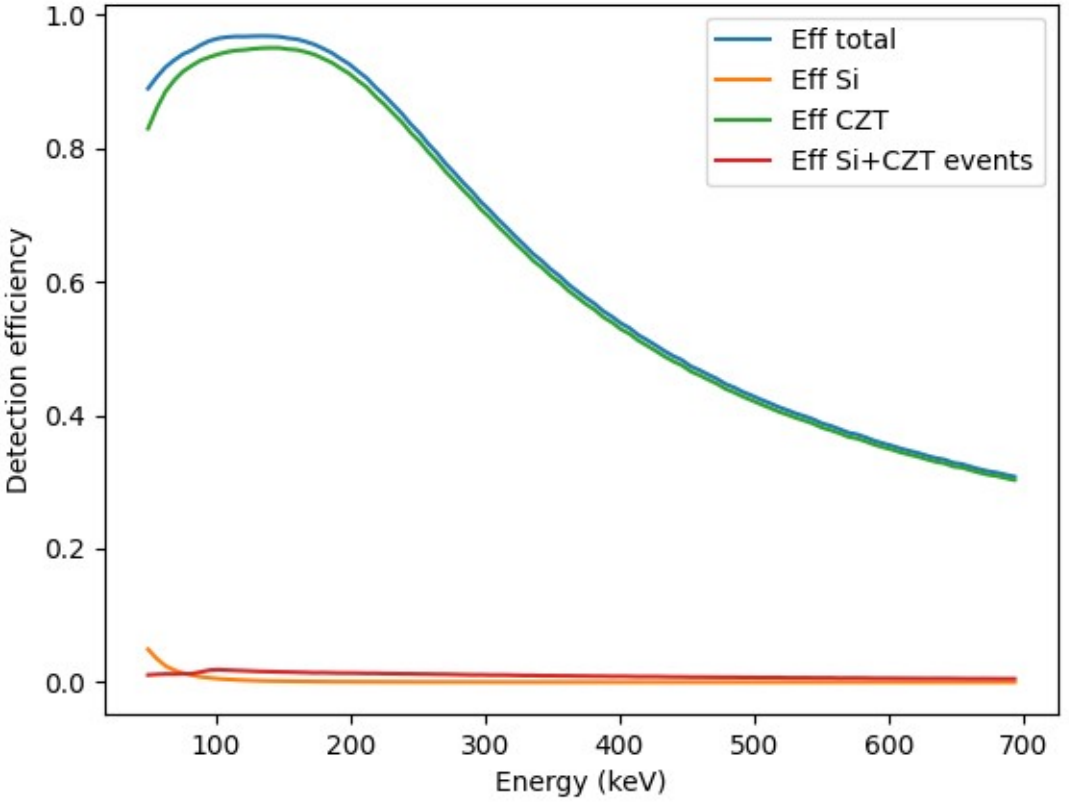


CONFIG 3

Simulated efficiency for Energies:

```
E_init = 50
Log_E=[]
while E_init <= 693.5:
    Log_E.append(E_init)
    E_init = E_init + 6.5
```

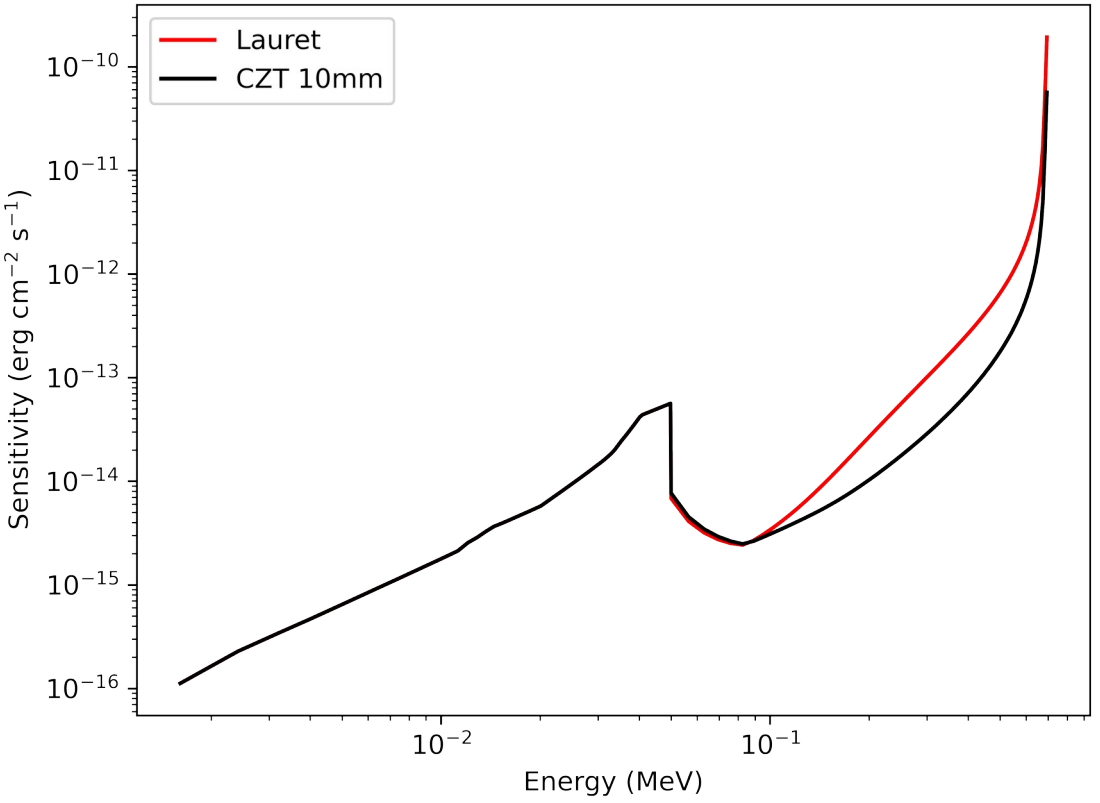
To be compliant with Laurent Excel



CONFIG 3

Sensitivity Comparison:

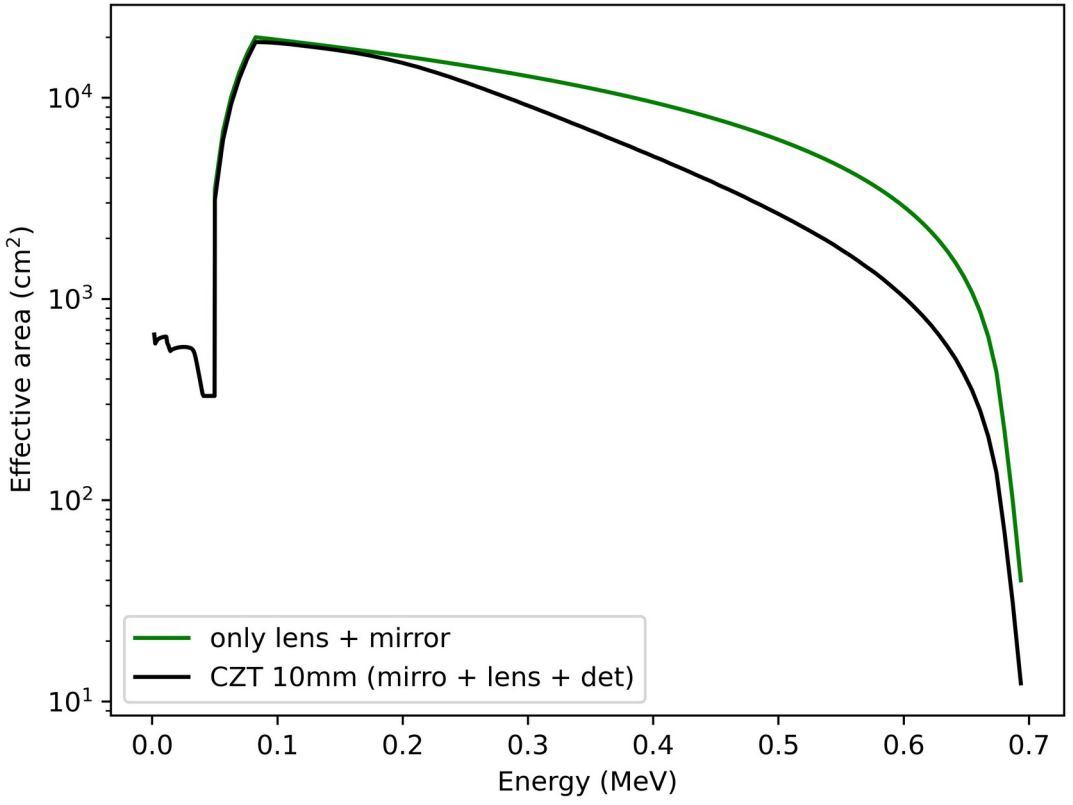
- Red, Laurent det eff Assumption (used 6.06 CdTe ro)
- Black, MEGAlib simmulated eff from 50kev to 700kev



CONFIG 3

Effective Area using:

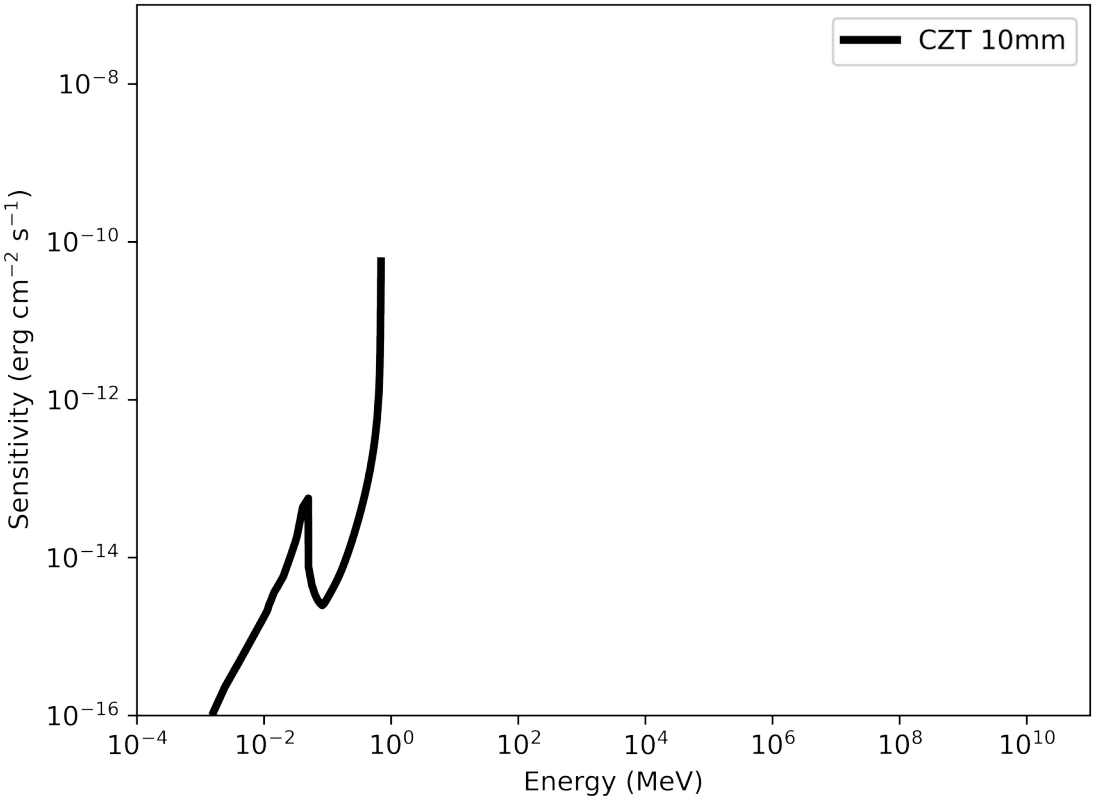
- Area lenses from Laurent excel
- multiply det_Eff x area

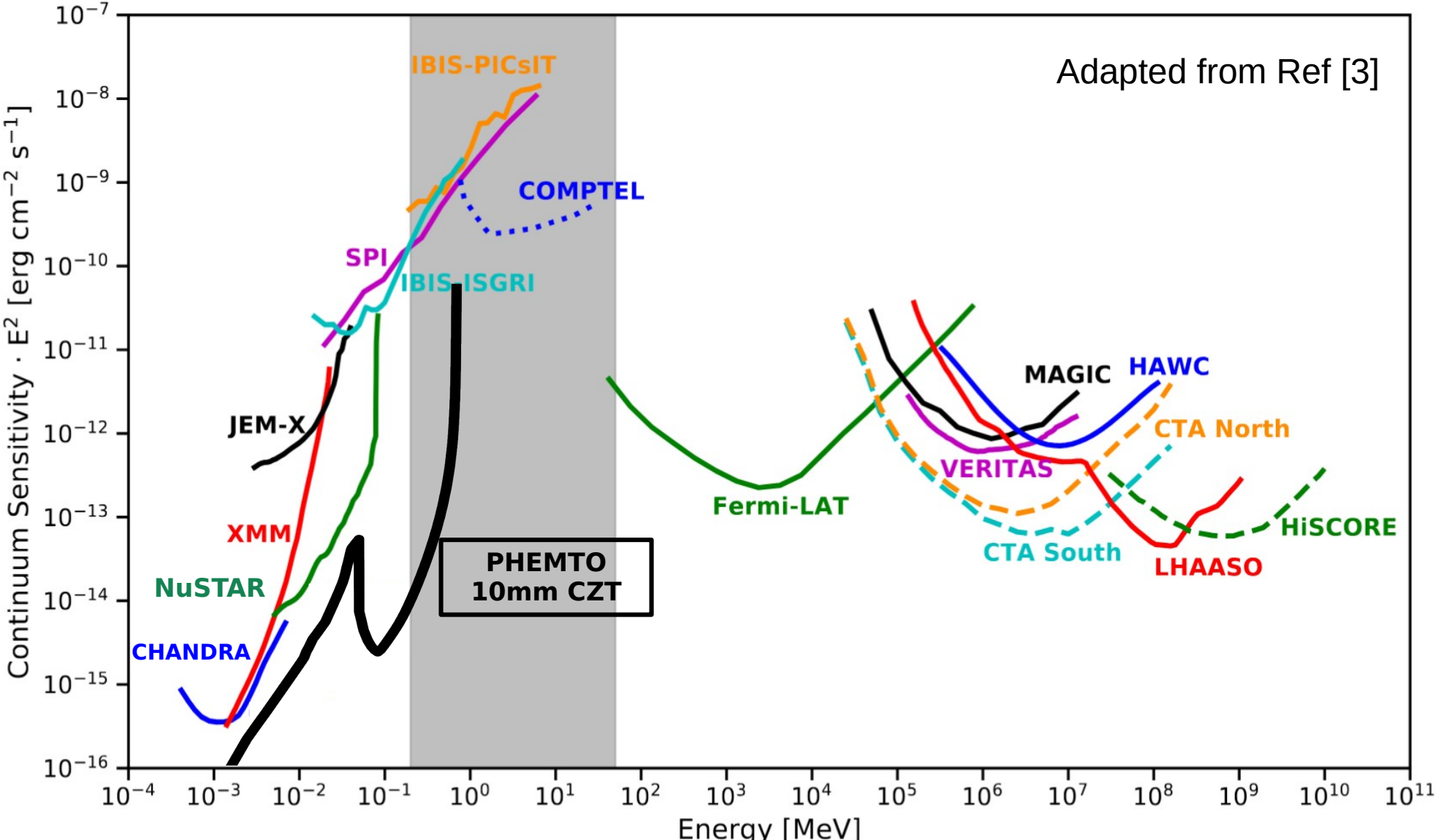


CONFIG 3

Sensitivity using:

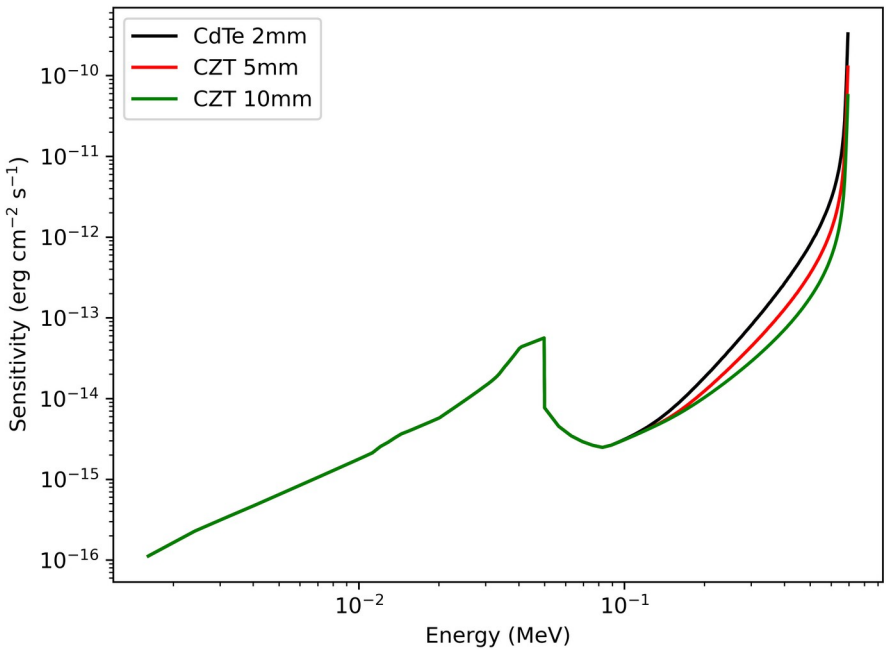
- simulated det effs (Si + CdTe)
- used Laurent excel for lenses eff



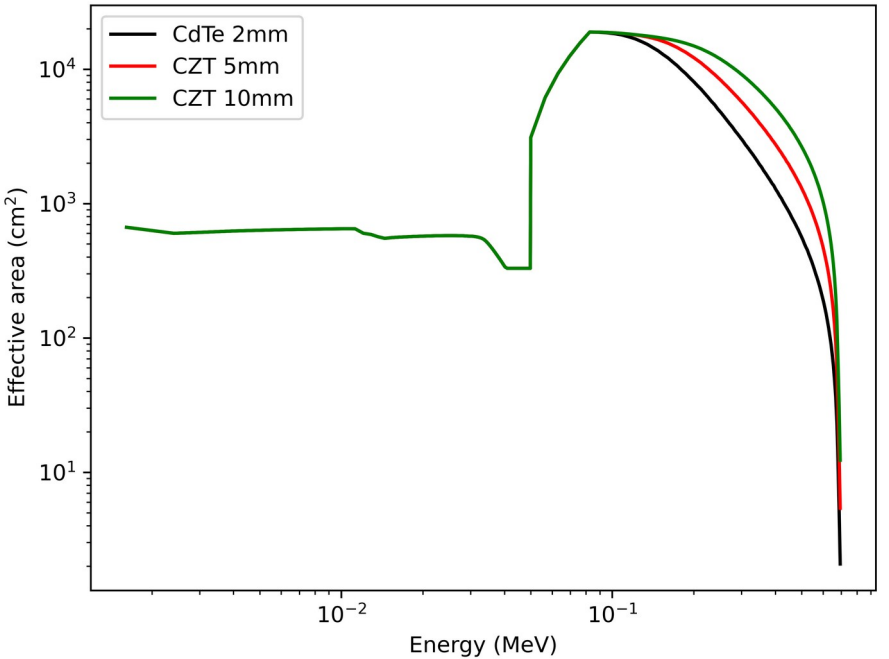

Adapted from Ref [3]
Continuum Sensitivity · E² [erg cm⁻² s⁻¹]
Energy [MeV]
IBIS-PICsIT
COMPTEL
SPI
IBIS-ISGRI
JEM-X
XMM
NuSTAR
CHANDRA
PHEMTO
10mm CZT
Fermi-LAT
MAGIC
HAWC
CTA North
VERITAS
CTA South
HiSCORE
LHAASO

Comparison between configs

Sensitivity



Effective Area



Future Work

Detectors:

- get more realistic CZT and CdTe energy resolution (simulations from Jose or use MC2 values from Hugo Allaire/Alline)
- get more realistic Si energy resolution (see newAthena WFI instrument)

Alternative Configurations:

- check how the PSF of Laue/mirror is on side detector of config4 and config5 (see last slide for figure of config4 and config5)

New Instrument Geometry:

- Add Pb (0.13 cm thick) collimator
- Add anti-coincidence detector (for particle rejection, in case particles are simulated on the background model)
- Understand the impact of the Collimator on config4 and config5

Sources:

- get x-ray optics point spread functions (can be an approximation)
- update Laue source for collimated source with double Gaussian.
- use [5] for background simulations

Future Work

Polarimetry:

- analysis for inter-plane compton (high energy polarimetry)
- analysis for on side CZT plane polarimetry (config4, config5), 20keV goal (low energy polarimetry

References

[1] Ferrari, E., Ferrari, C., Virgilli, E., Caroli, E., Auricchio, N., Stephen, J. B., Ferro, L., da Silva, R. C., and Moita, M. (2025). Correction: Imaging performance of laue lenses made of ge and si bent crystals for future gamma-ray astrophysics telescopes. Aerotecnica Missili amp; Spazio.

[2] Frontera, F. (2025). Hard x-ray/soft gamma-ray laue lenses for high energy astrophysics.

[3] Lucchetta, G. et. al. (2022). Introducing the MeVCube concept: a CubeSat for MeV observations. doi:10.1088/1475-7516/2022/08/013

[4] https://doi.org/10.48550/arXiv.2108.02860

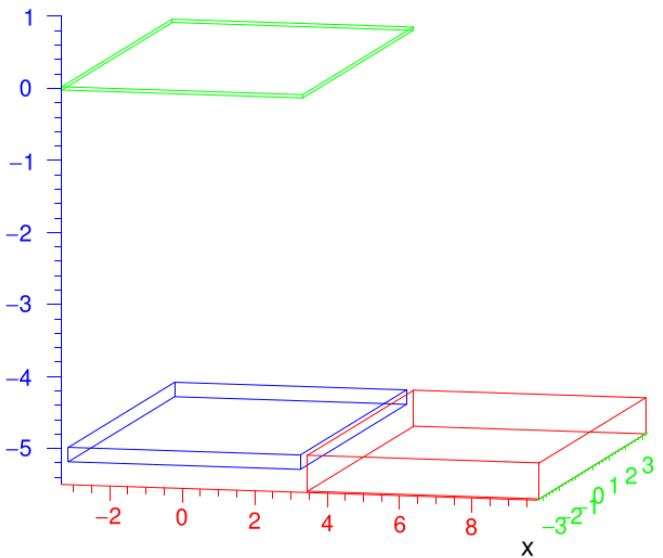
[5] Cumani, P., Hernanz, M., Kiener, J. et al. Background for a gamma-ray satellite on a low-Earth orbit. Exp Astron 47, 273–302 (2019). https://doi.org/10.1007/s10686-019-09624-0

Extra Configs

(moving optics to focus on Red detector)

Config4:

green Si
Blue 2mm CdTe
Red 5mm CZT



Config5:

green Si
Blue 2mm CdTe
Red 10mm CZT