Gamma-ray detectors for INTEGRAL and Fermi space telescopes

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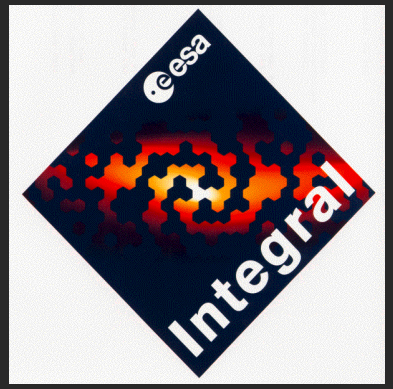
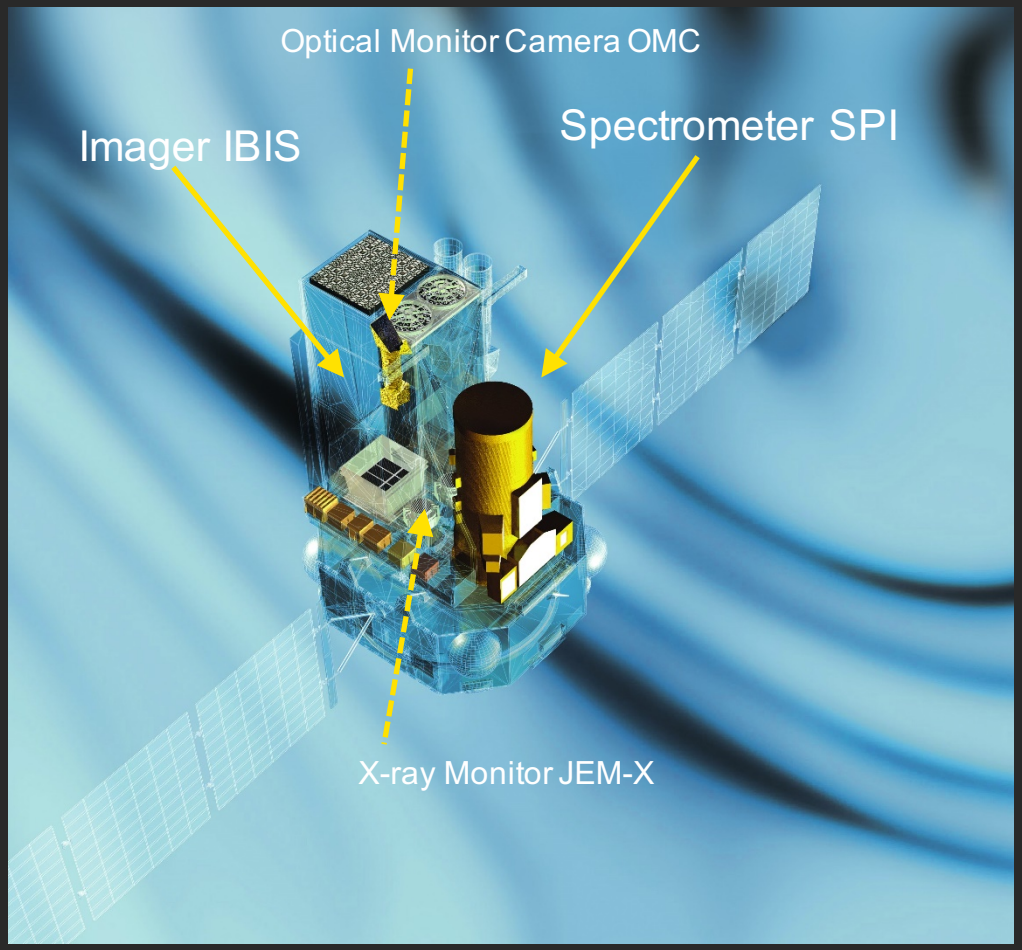
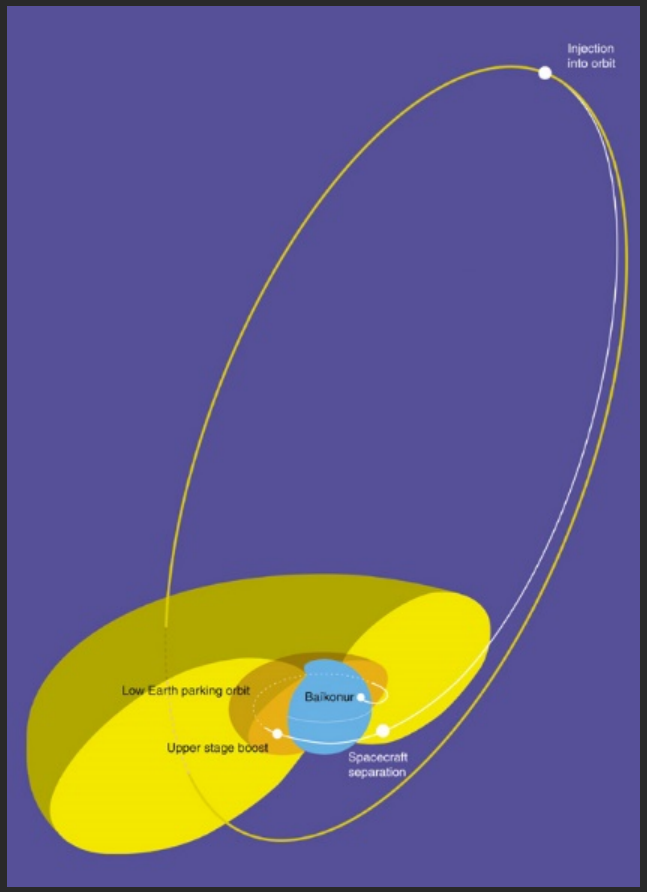


INTEGRAL spacecraft & scientific payload





- Launched 17. Oktober 2002

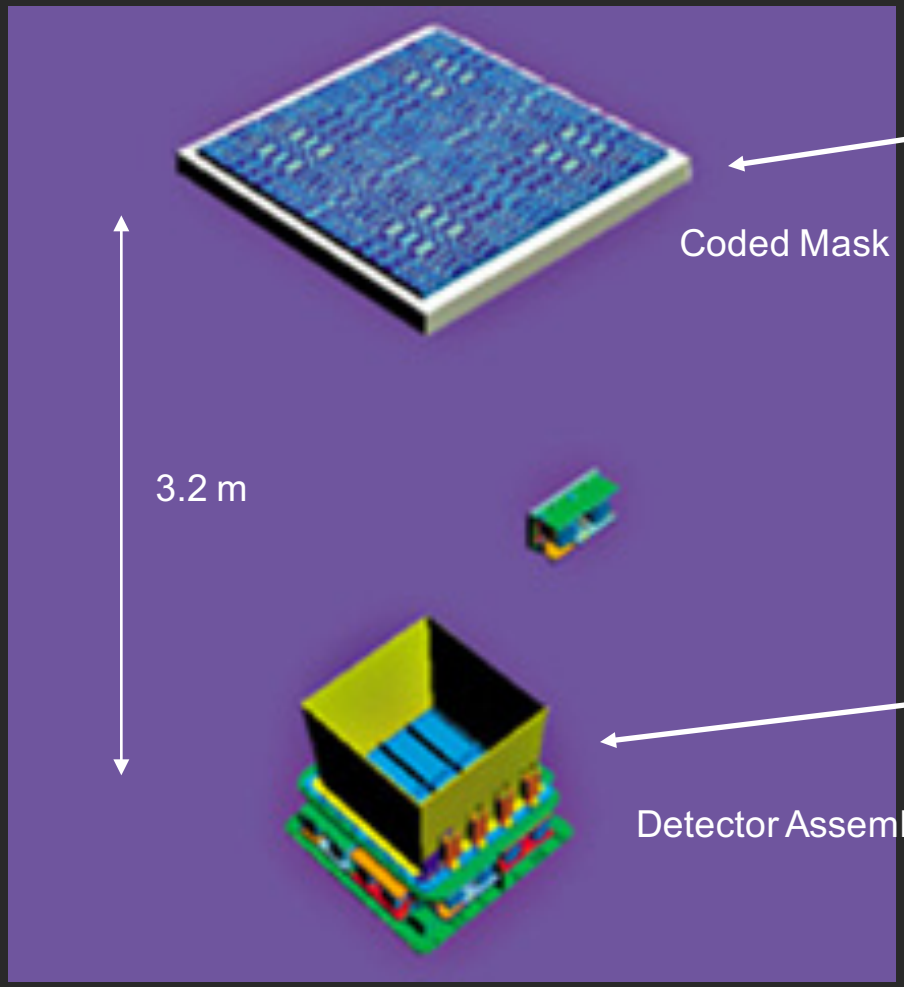
The Four INTEGRAL Instruments

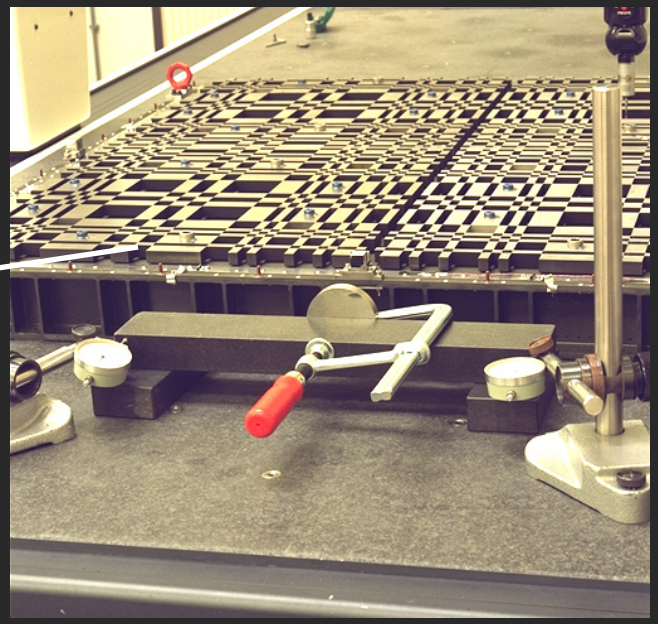
Instruments	Energy / E-Res.	Main purpose
Spectrometer **SPI**	20 keV– 8 MeV 2.3 keV @ 1.3 MeV	Fine spectroscopy of narrow lines Study of diffuse emission on > 1° scale
Imager **IBIS**	15 keV – 10MeV 9 keV @ 100 KeV	Accurate point-source imaging Broad lines and continuum
X-ray Monitor **JEM-X**	3 – 35 keV 1.2 KeV @ 10 KeV	Source ID, monitoring @ X-rays
Opt. Mon. Camera **OMC**	500 – 600 nm	Optical Monitoring of high energy sources

The Four INTEGRAL Instruments

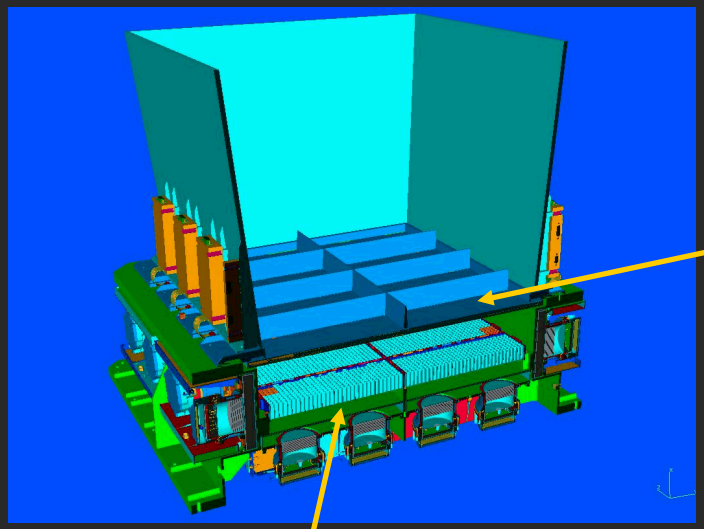
Instruments	**FoV** / Ang.-Res.	**Main purpose**
Spectrometer **SPI**	16° (corner to corn.) 2.5° (point source)	Fine spectroscopy of narrow lines Study of diffuse emission on > 1° scale
Imager **IBIS**	9° x 9° 12’	Accurate point-source imaging Broad lines and continuum
X-ray Monitor **JEM-X**	4.8° 3’	Source ID, monitoring @ X-rays
Opt. Mon. Camera **OMC**	5° x 5° 25”	Optical Monitoring of high energy sources

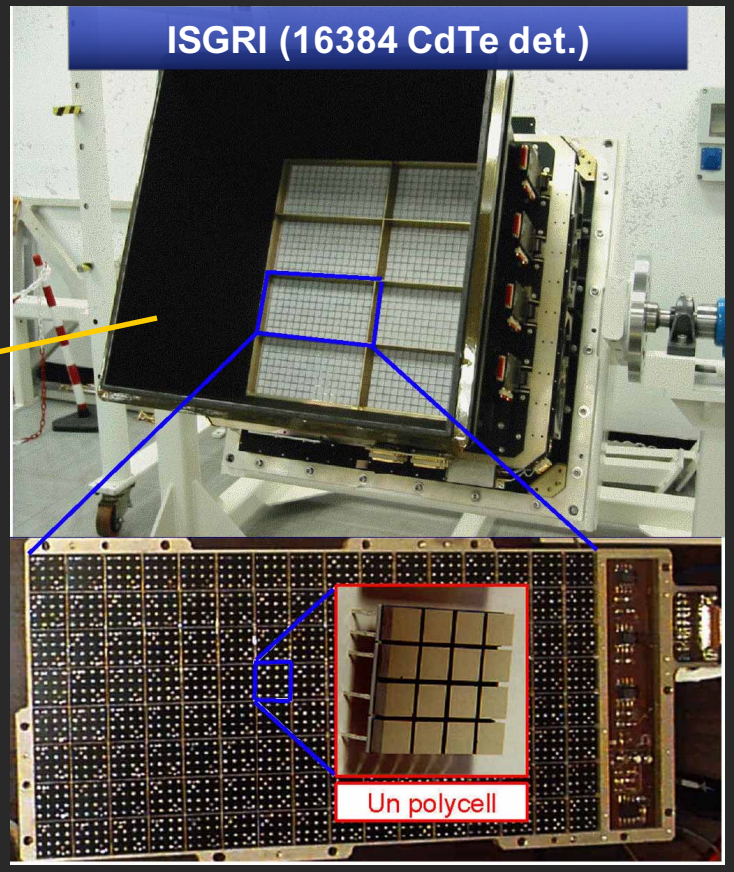
Imager IBIS

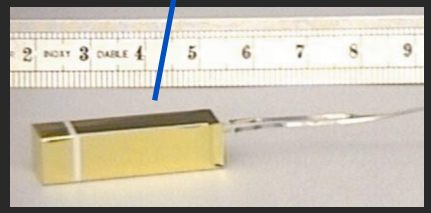




Imager IBIS

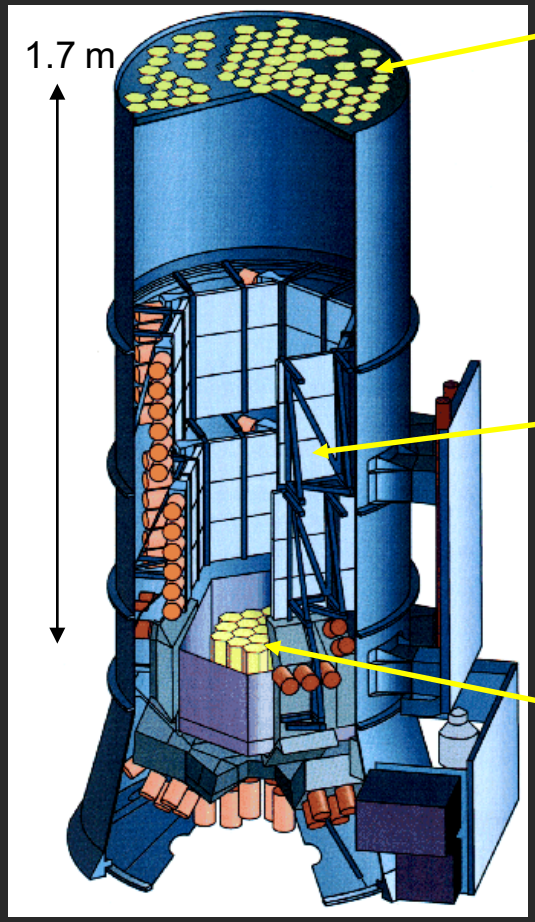




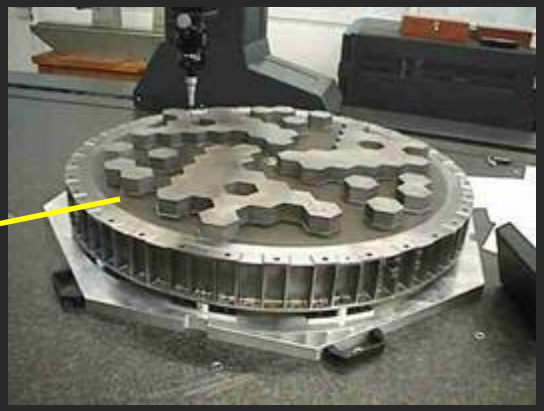


- Energy Range 15 - 10000 keV
- Angular Resolution 12 arcmin
- Two Detector Planes
  - 2600cm^2 CdTe Detector Pixels 4x4x2 mm (ISGRI)
    - E-range from 15 keV to about 500 keV
  - 3100cm^2 CsI Detector Pixels 9x9x30mm (PICSIT)
    - E-range from 15 keV to 10 MeV

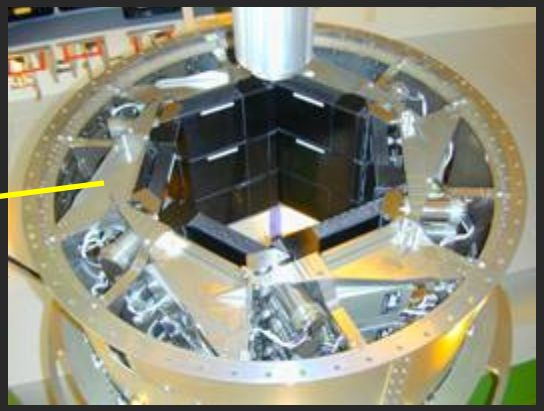
Spectrometer SPI



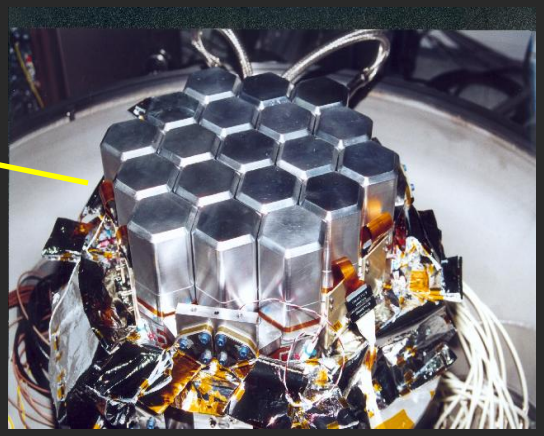
Coded Mask



Veto Shield

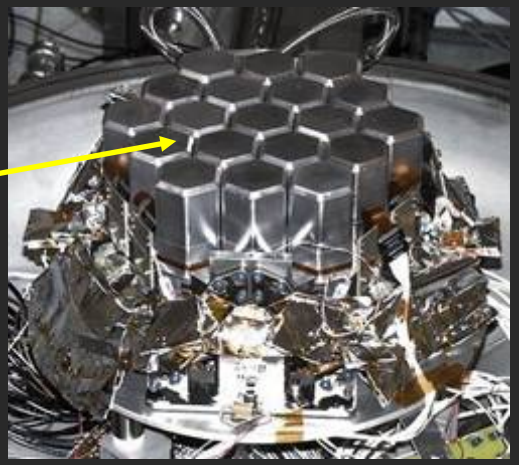


19 Germanium Detectors

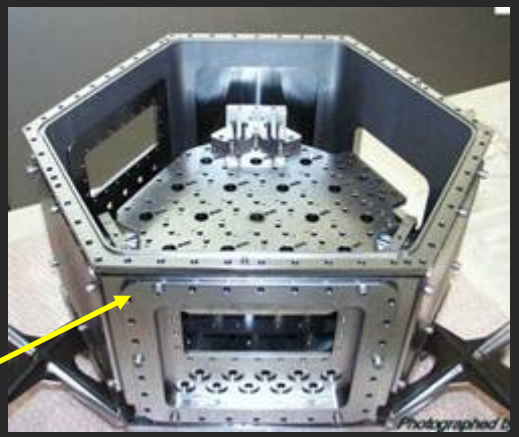


Detector array of SPI

- 19 n-type germanium detectors
  - Total geometric detection area: 500 cm^2
  - Center-to-center distance: 6 cm



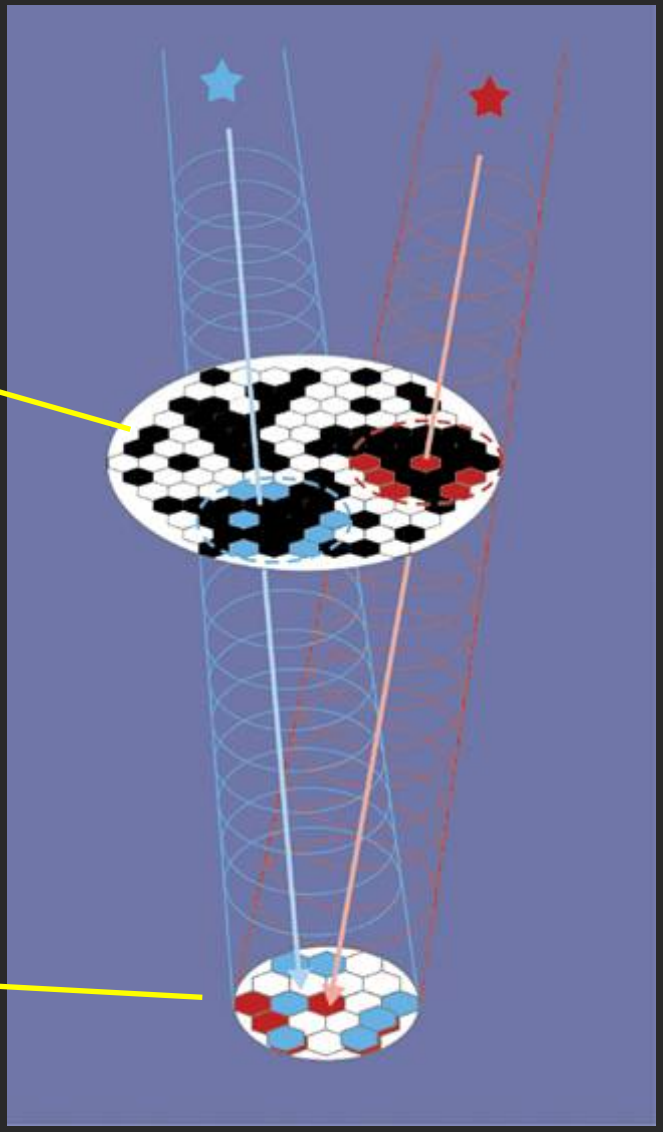
- Individual detector:
  - Hexagonal shape
  - 3.2 cm on a side
  - 7 cm deep



- Cryostat
  - Ge detector array mounted on a Beryllium plate at ~ 90 K
  - Cooled by Stirling cryo coolers
  - Enclosed by Beryllium cryostat at ~ 210 K

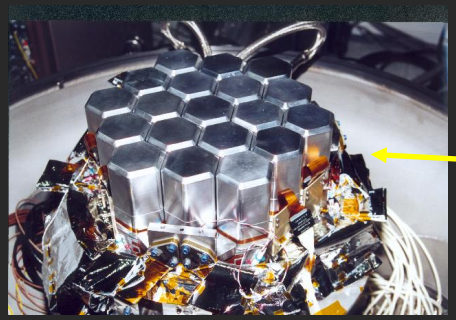
Imaging with coded mask (SPI)

Coded Mask



Coded-Mask Imaging: By decoding the signals from 19 germanium detectors an image is generated

- Angular Resolution ~2˚
- Field-of-View 16˚x16˚

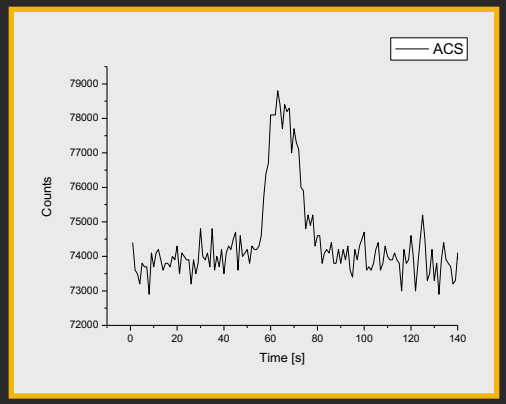


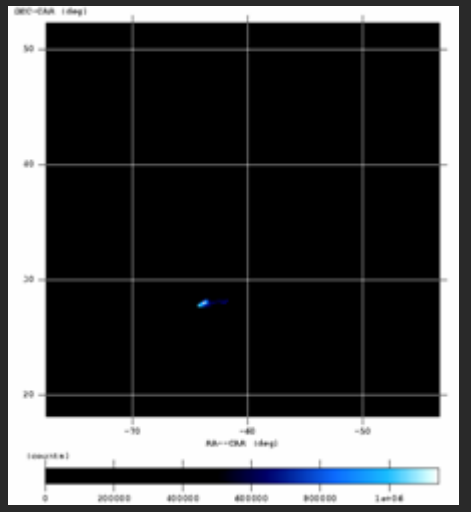
19 Germanium Detectors

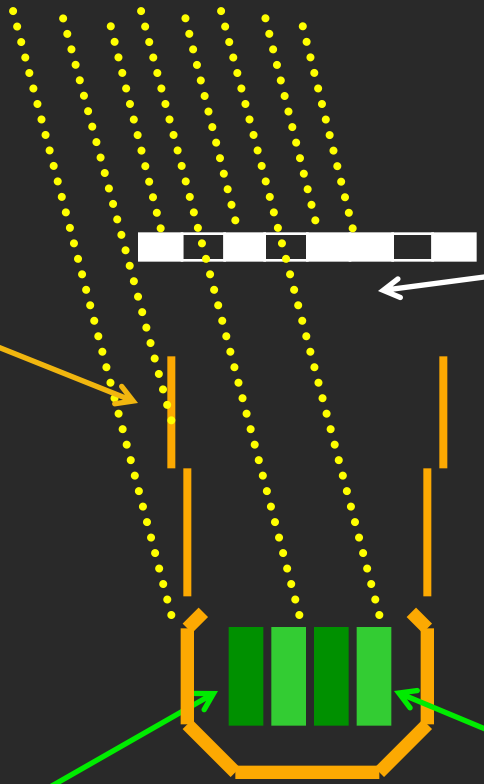
GRB021125 – detected by SPI

GRB 021125

GRB seen by ACS

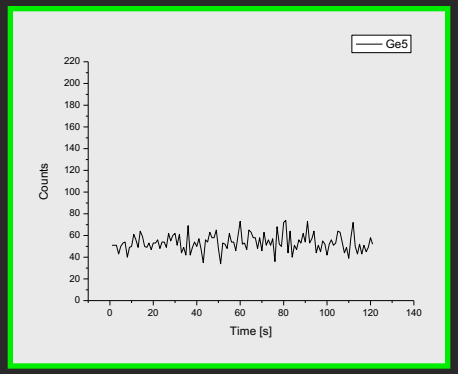




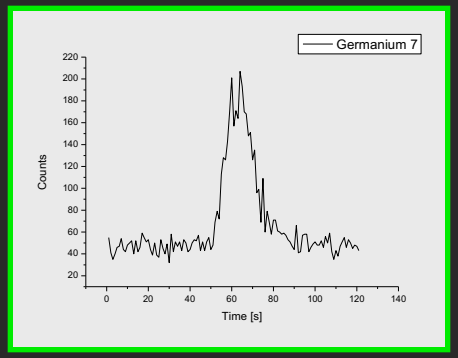


"Shadows"
from coded mask

Shadowed detector !

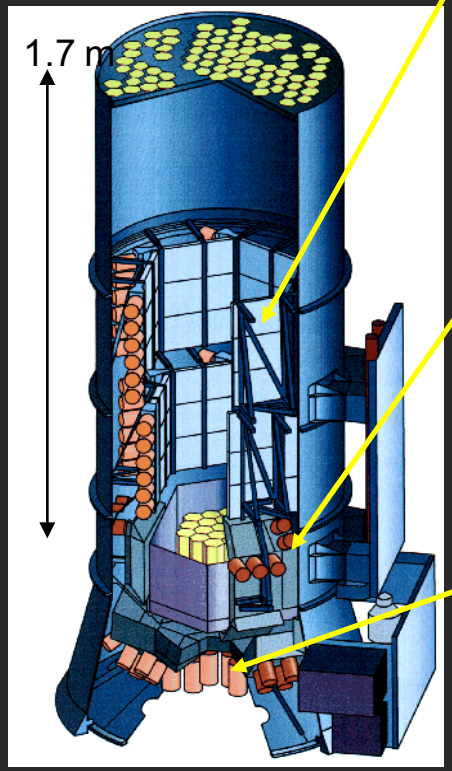


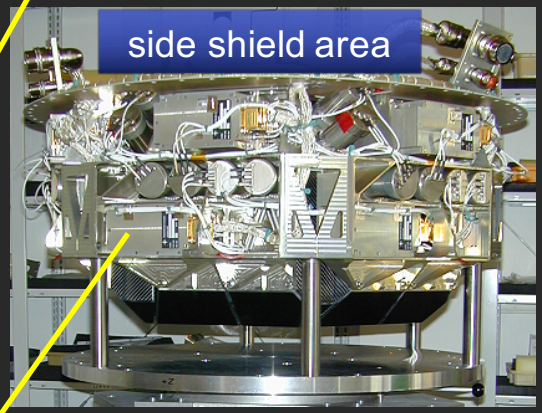
GRB seen by a
Germanium detector

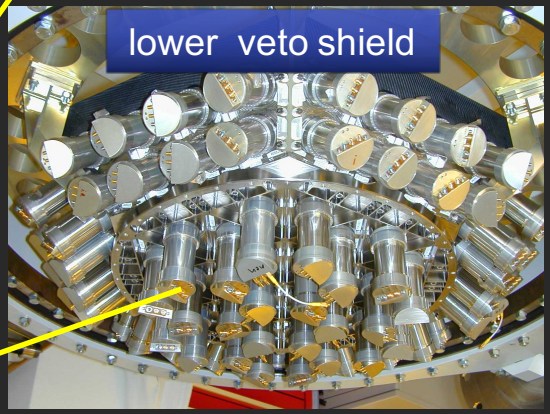


Anticoincidence shield ACS

- German contribution to SPI
  - DLR: financial support (~20 M€)
  - MPE: scientific lead
  - Astrium, Jena Optronik: industrial contractors
- 91 BGO-crystals arranged in
  - 2 Collimator Rings UCR + LCR
  - Side-Shield Area SSA
  - Lower Veto Shield LVS
  - ⇨ **512 kg of BGO !**
- 181 PMTs
- 91 FEEs
- VCU (main/redundant)
  - ⇨ **Generating 1 ORed Veto**
- No spectral information



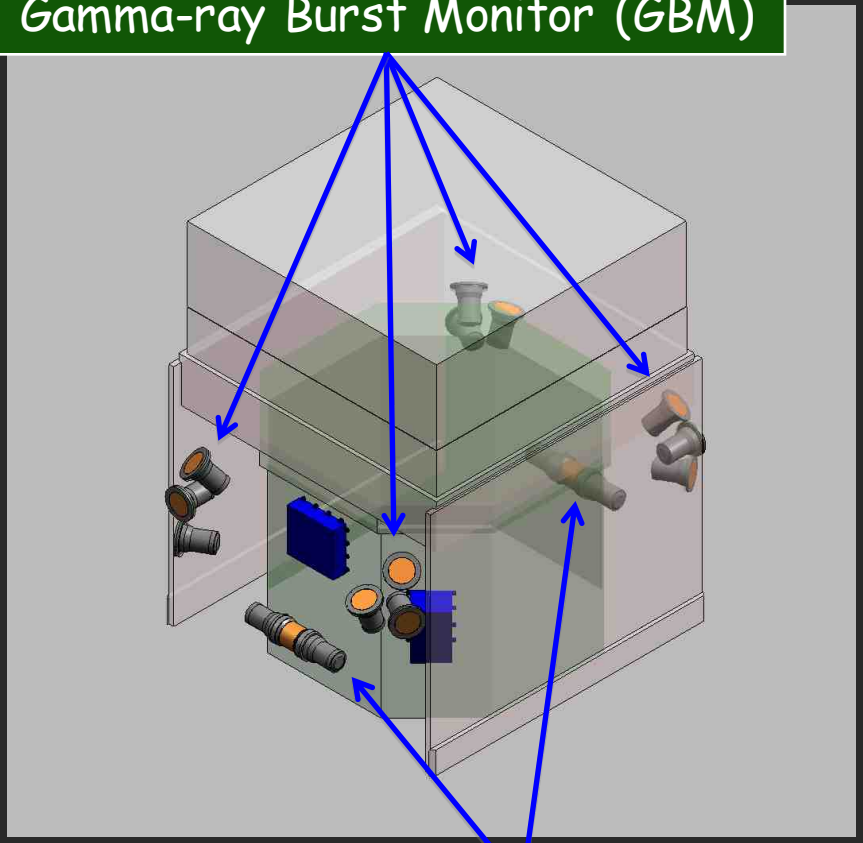




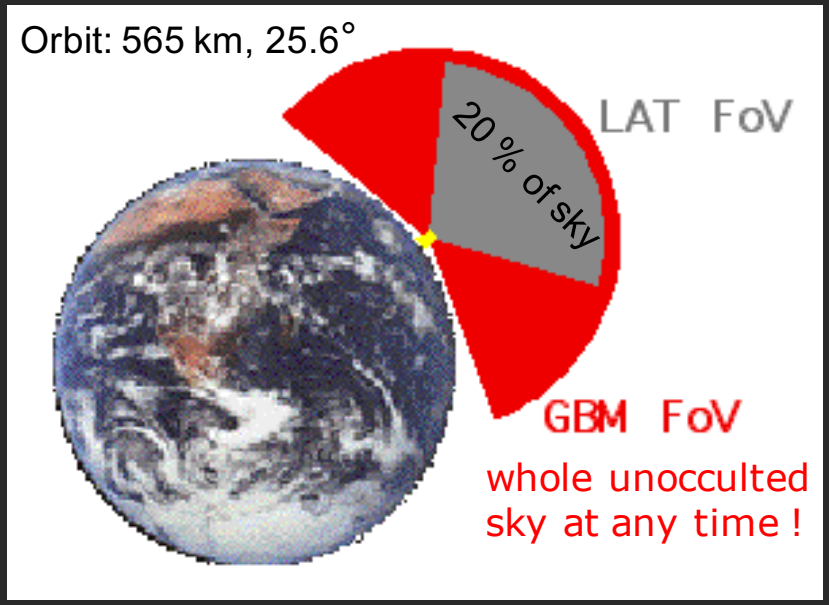
The *Fermi* Observatory

Large Area Telescope (LAT)

Gamma-ray Burst Monitor (GBM)



GBM detectors

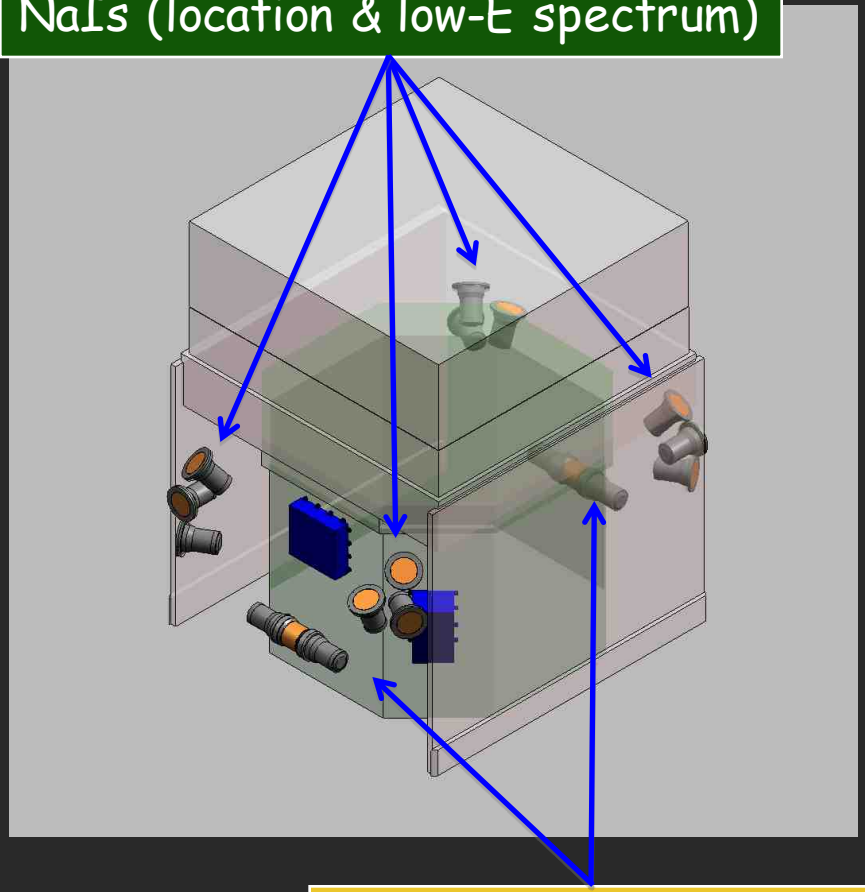


- Launched 11. June 2008

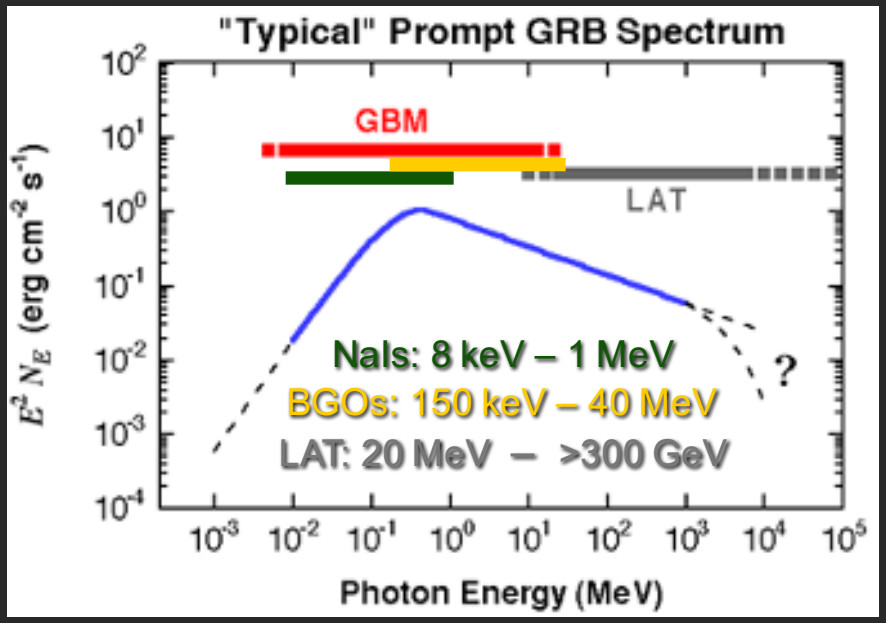
The *Fermi* Observatory

LAT (high-E spectrum)

NaIs (location & low-E spectrum)



BGOs (mid-E spectrum)



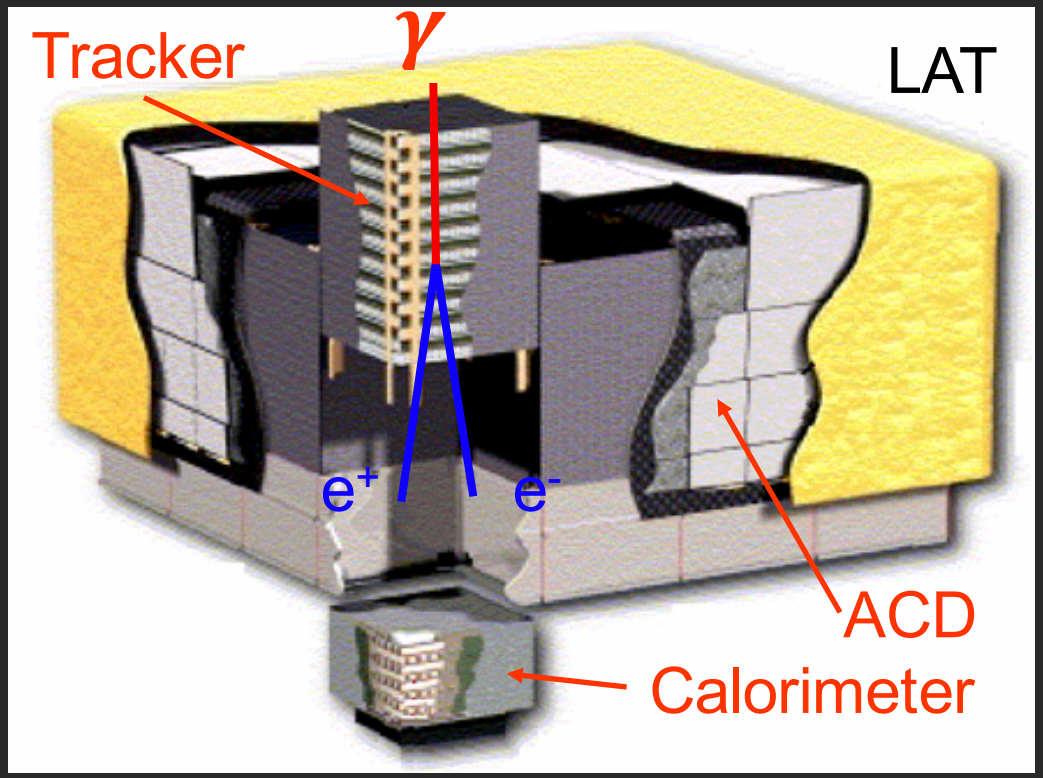
Fermi Large-Area Telescope (LAT)

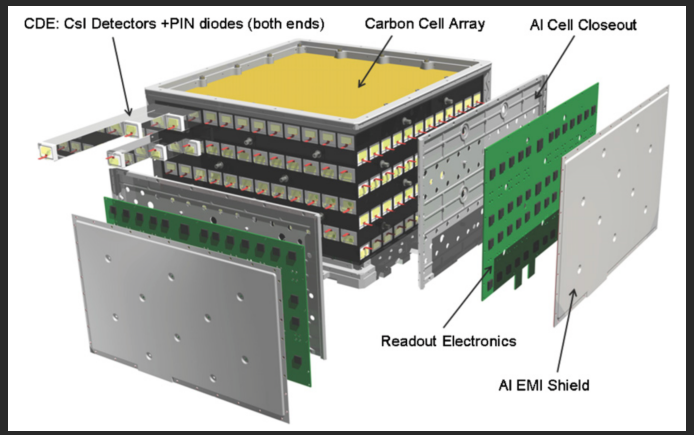
Pair Conversion: Detect photons between ~20 MeV - > 300GeV

Tracking system: Silicon-Strip Detectors (880000 channels)

Calorimeter: CsI Crystals (8.4 r.l., hodoscopic array)

Anticoincidence: Segmented ACD veto counters





GLAST Burst Monitor

12 x Sodium Iodide NaI(TL) scintillation detectors

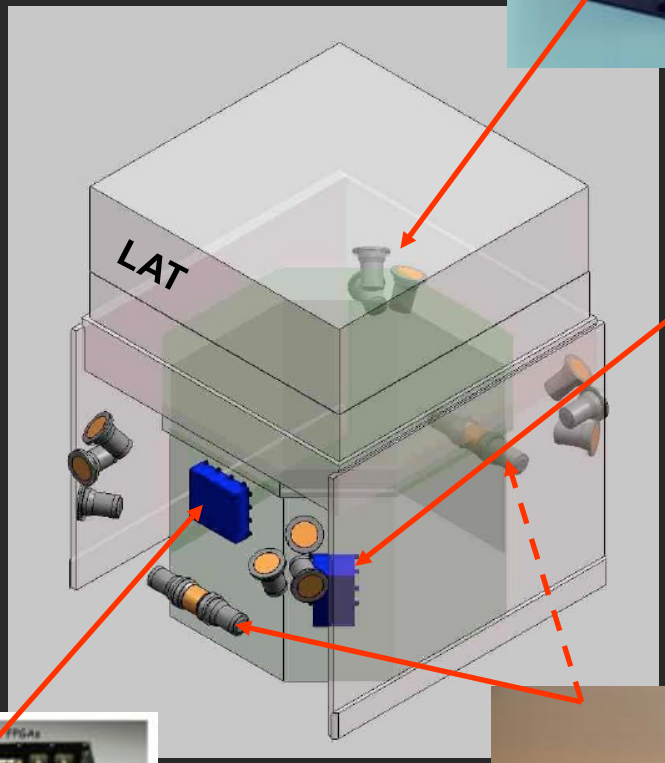
- Wide Field of View
- Burst Trigger
- Coverage of typical GRB spectrum: 10 keV – 1 MeV

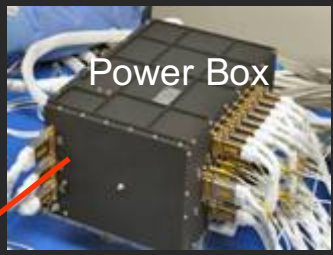
2 x Bismuth Germanate (BGO) scintillation detectors

- Spectral overlap with the LAT: 150 keV-30 MeV

1 x Power Box (PB)

1 x Digital Processing Unit (DPU)





Fermi Gamma-Ray Burst Monitor

NaI detectors:

Diameter: 12.7 cm (5”)

Thickness: 1.27 cm (0.5”)

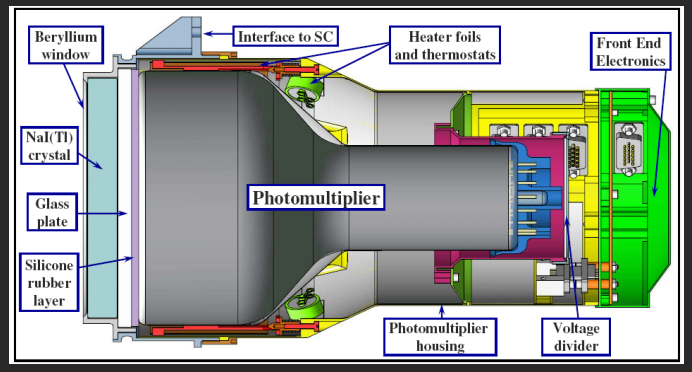
Energy range: 10 keV – 1 MeV

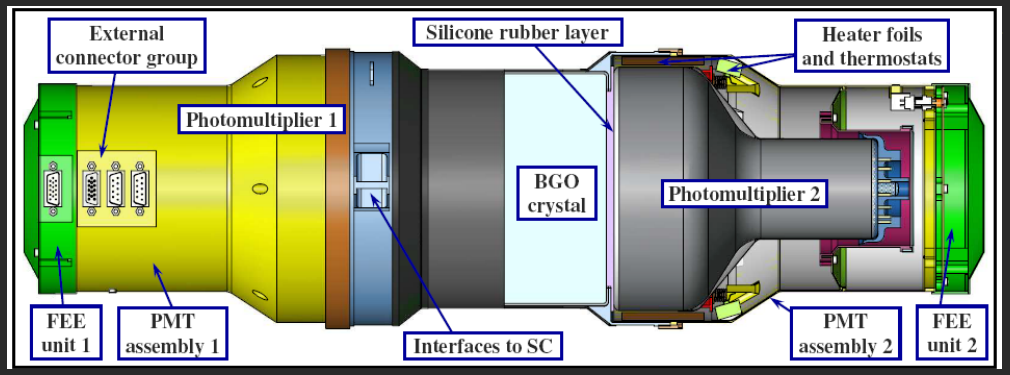
BGO detectors:

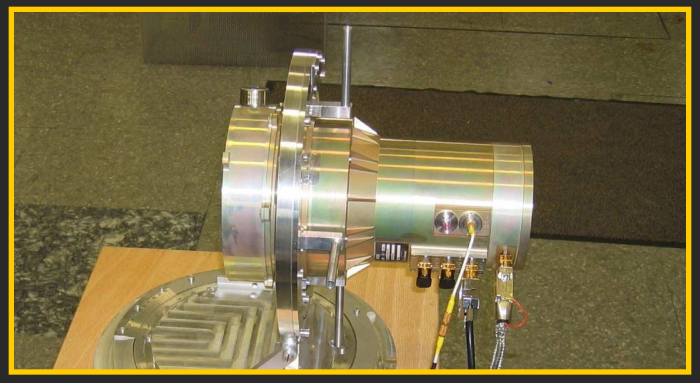
Diameter: 12.7 cm (5”)

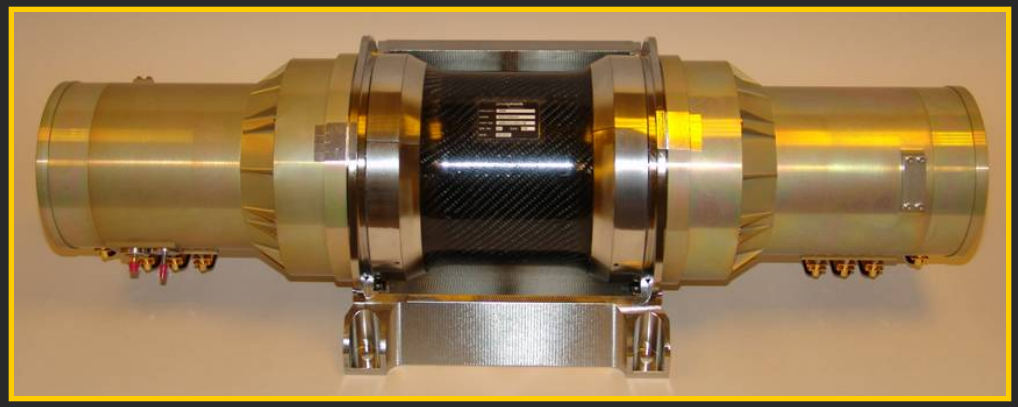
2.7 cm (5”)

Thickness: 12.7 cm (5”)

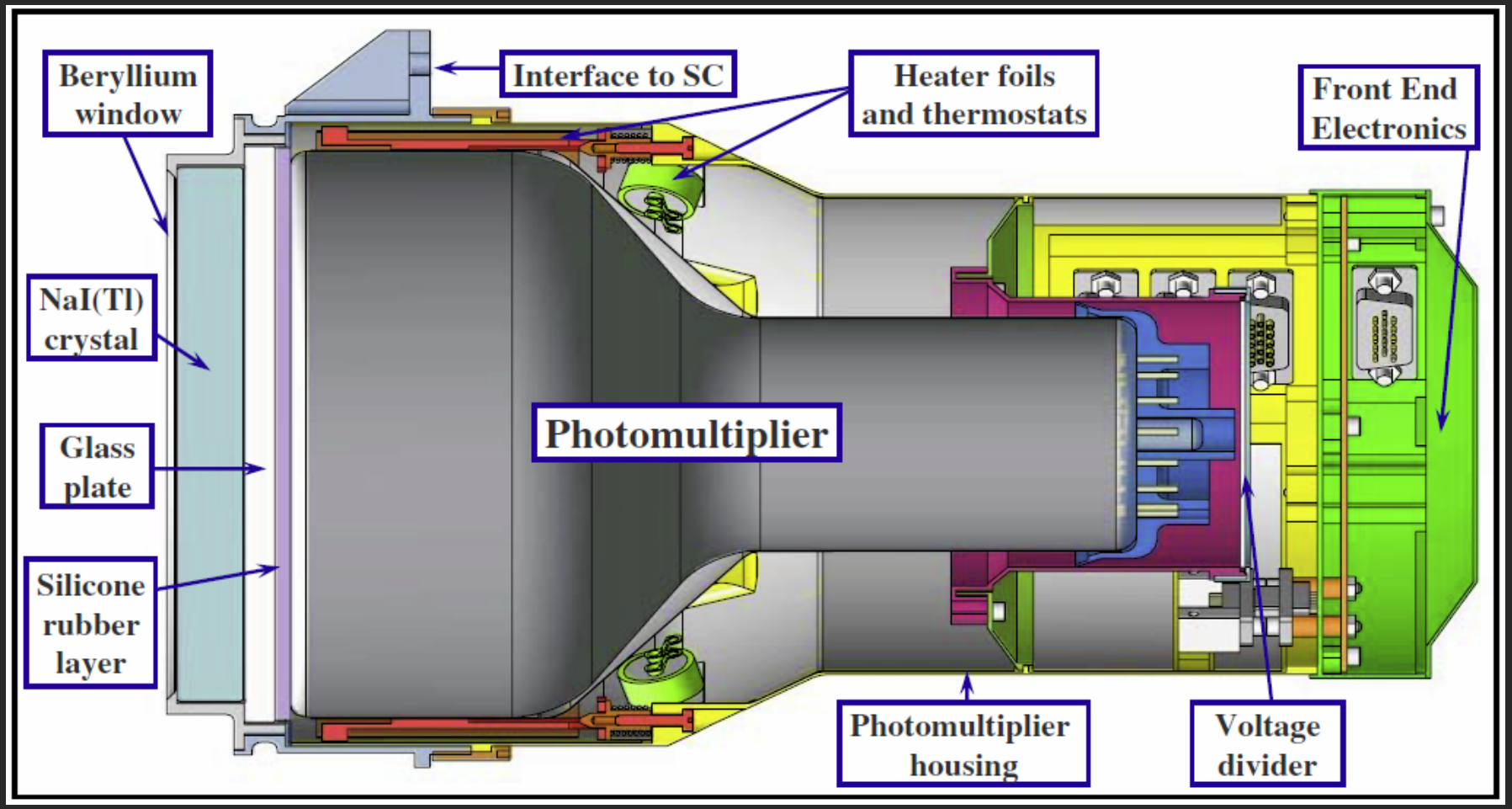








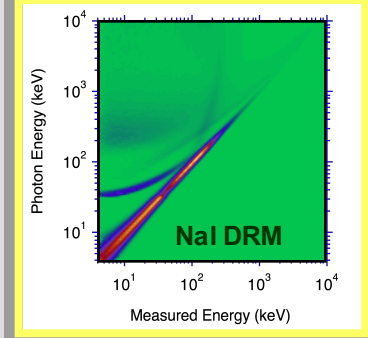
GBM NaI Detector



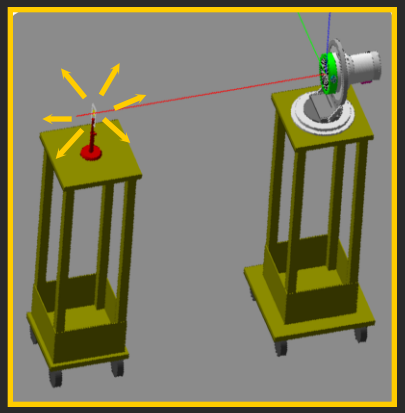
Instrument response: Detector-Level Calibration

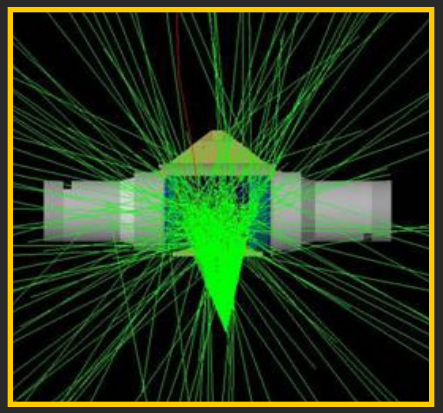
- Purpose of Calibration:
  - Performance verification of
    - Energy calibration
    - Energy resolution
    - Effective area
  - Provide accurate data
    - Comparison with simulated detector response data
    - Scientific analysis

MPE contribution:
DRM determination



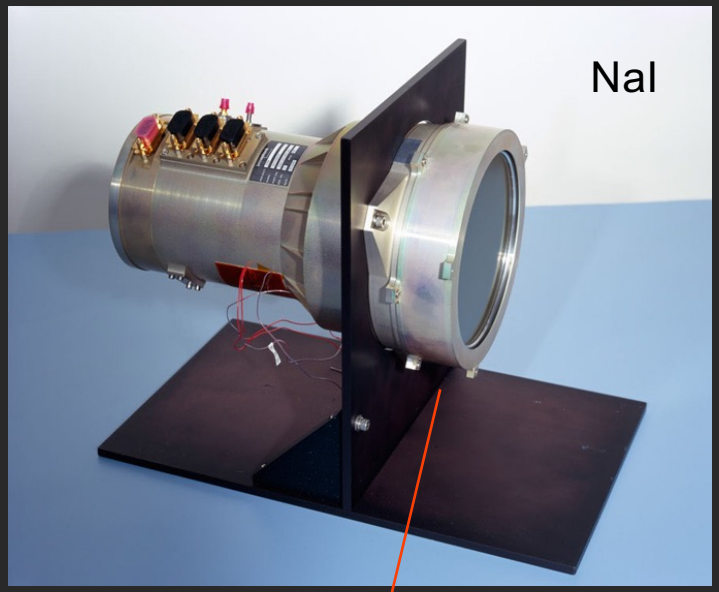
Calibration campaign at MPE (2005)

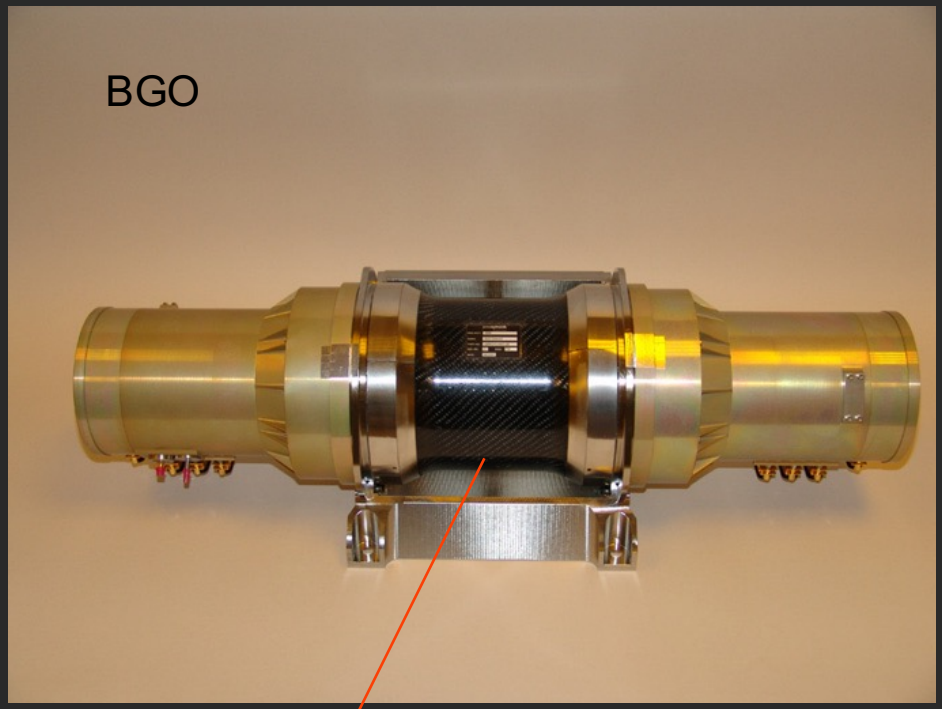


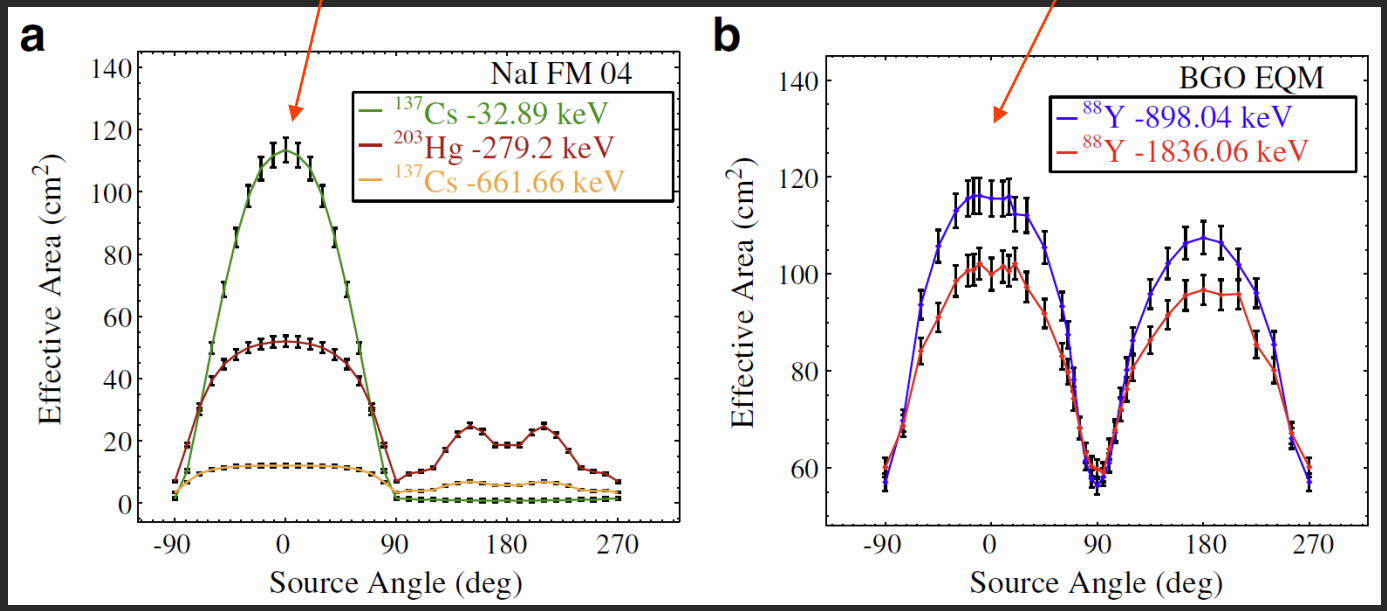


Detector and laboratory simulations by H. Steinle

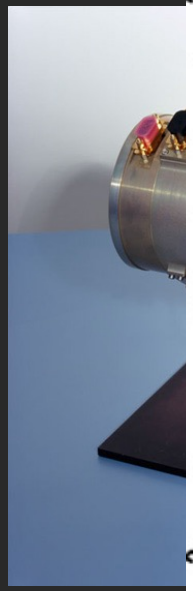
GBM Detectors

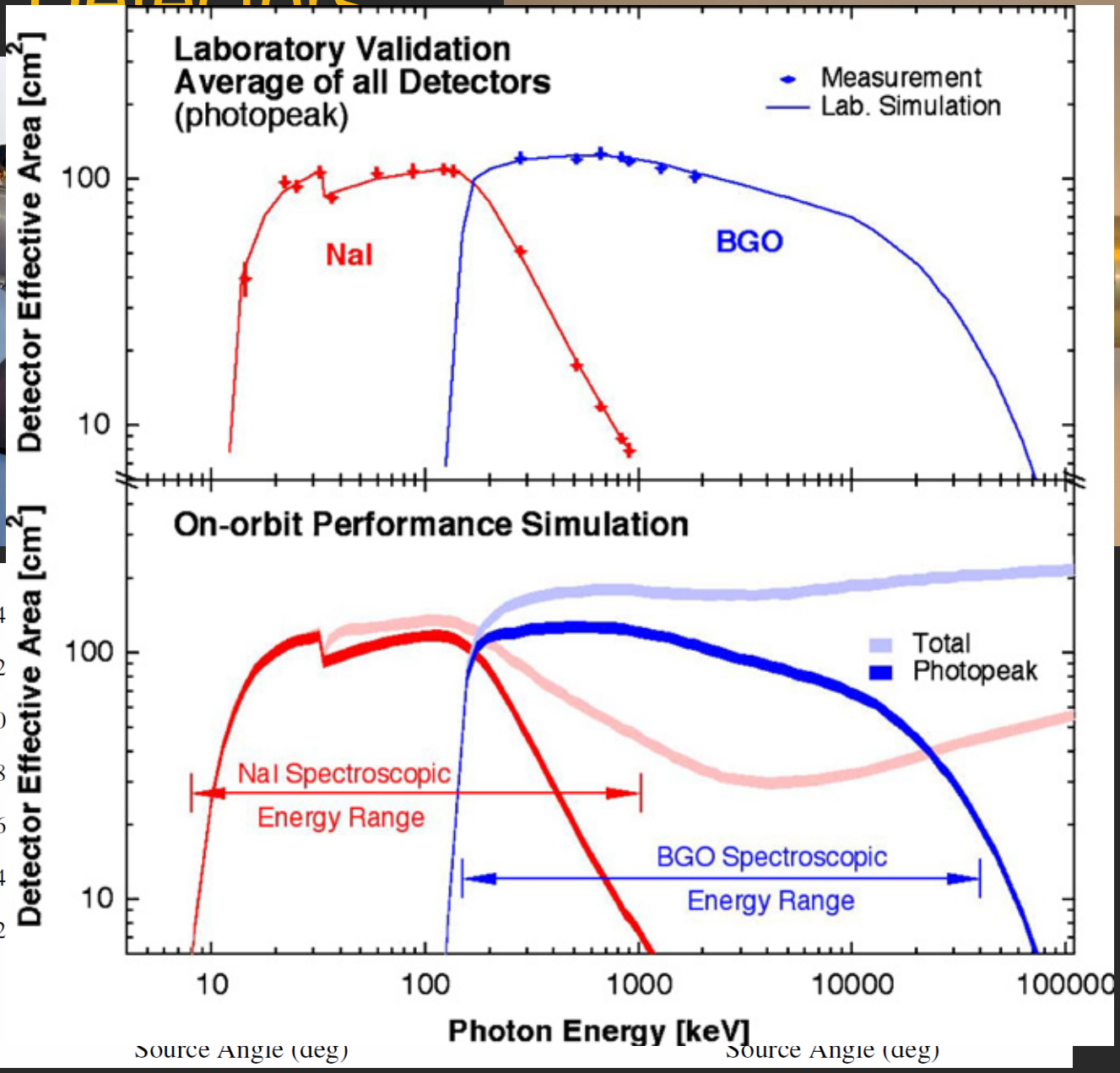




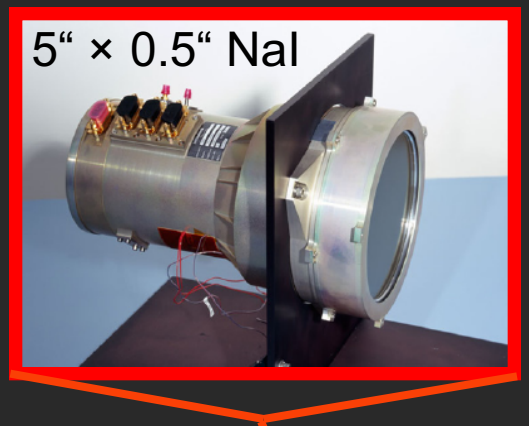


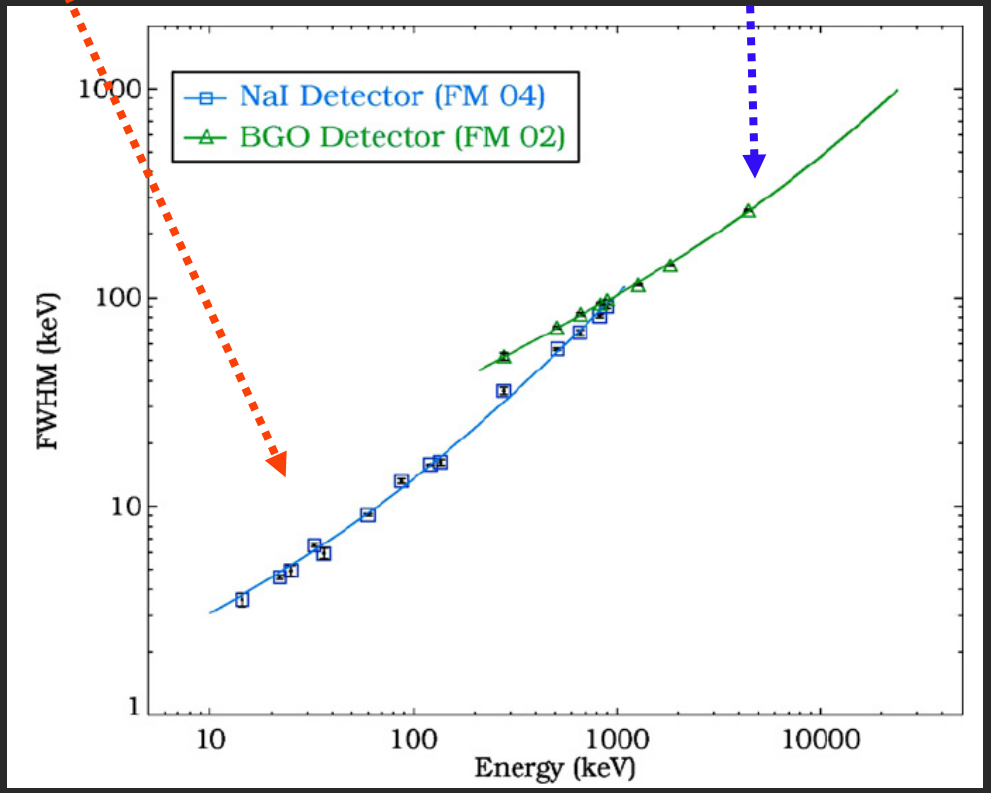
GBM Detectors





Fermi GBM Performance: Detectors



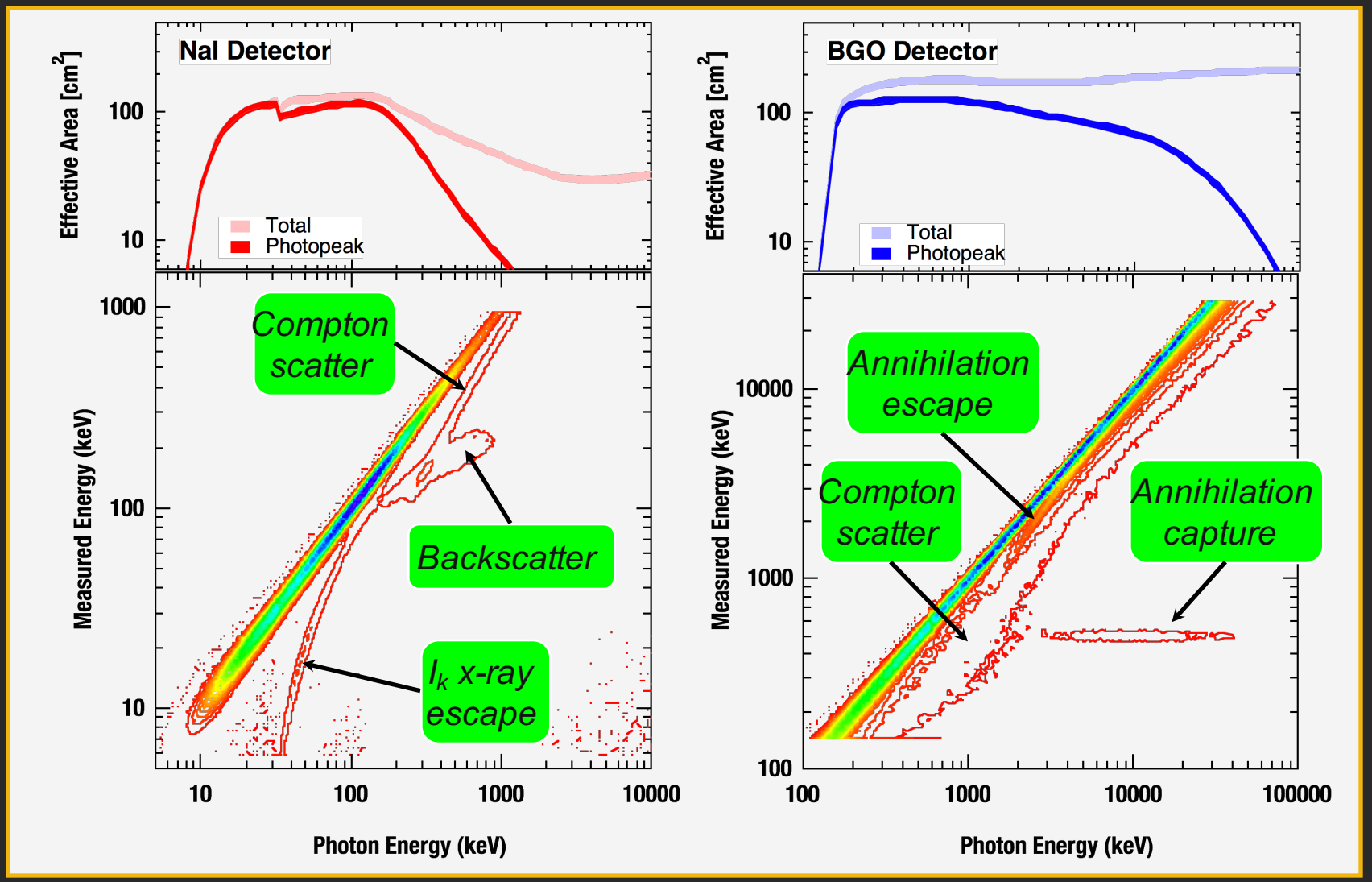


Energy resolution:

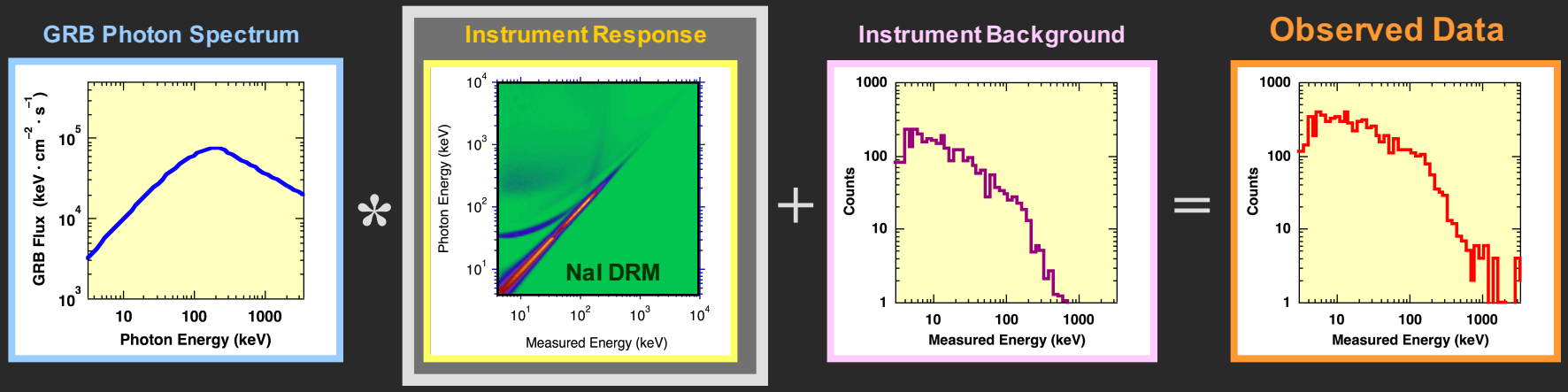
~15% at 100 keV

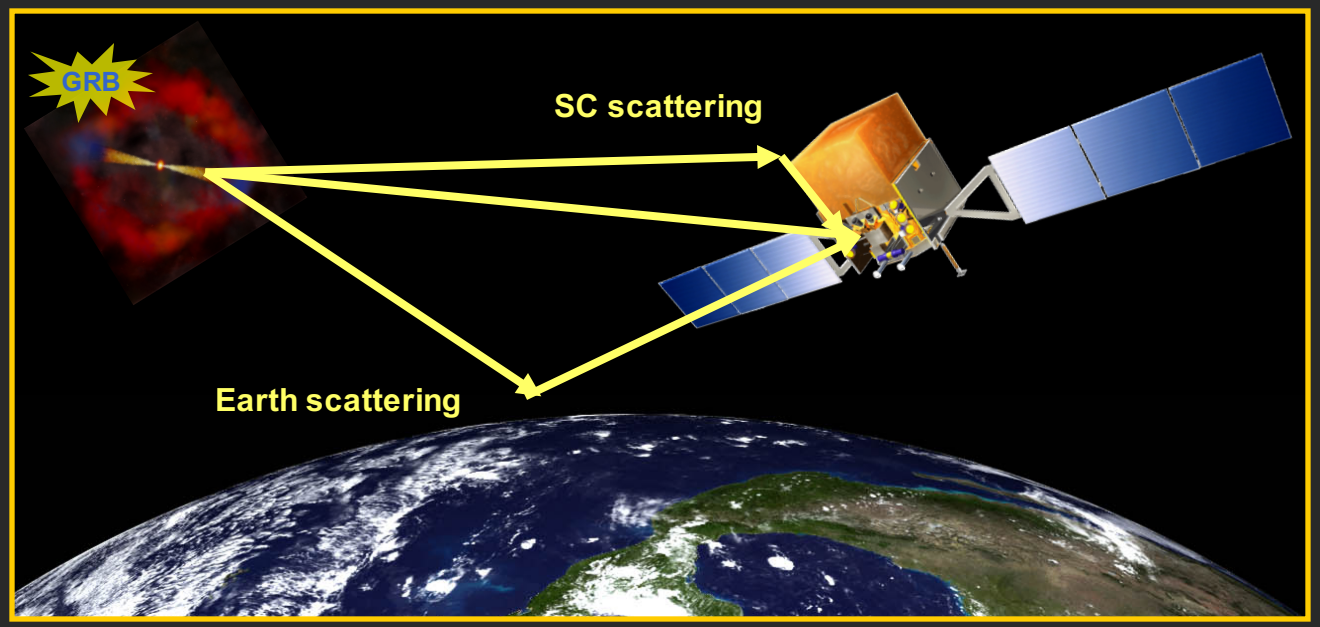
~ 10% at 1 MeV

GBM Detector Response

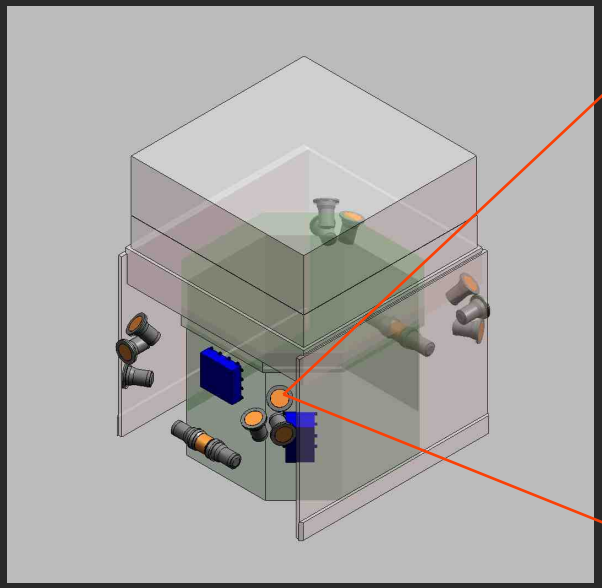


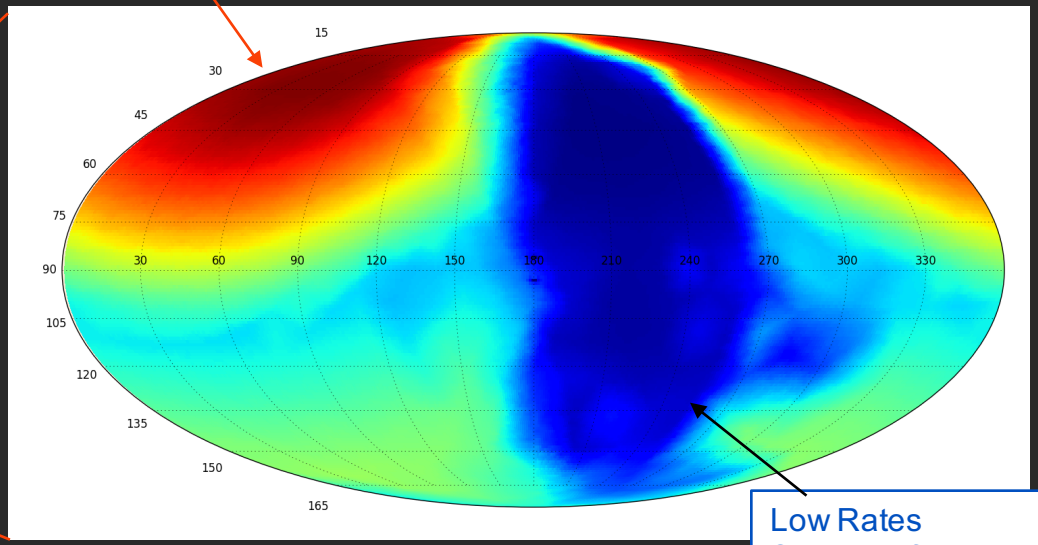
GBM response to GRBs





GBM Localization Method





- Localization is performed by comparing the relative observed rates from the GRB in each detector to the expected rates on a 1 degree grid
- This requires an assumption of the spectrum, and the sky grid limits to a statistical minimum uncertainty of 1 degree radius

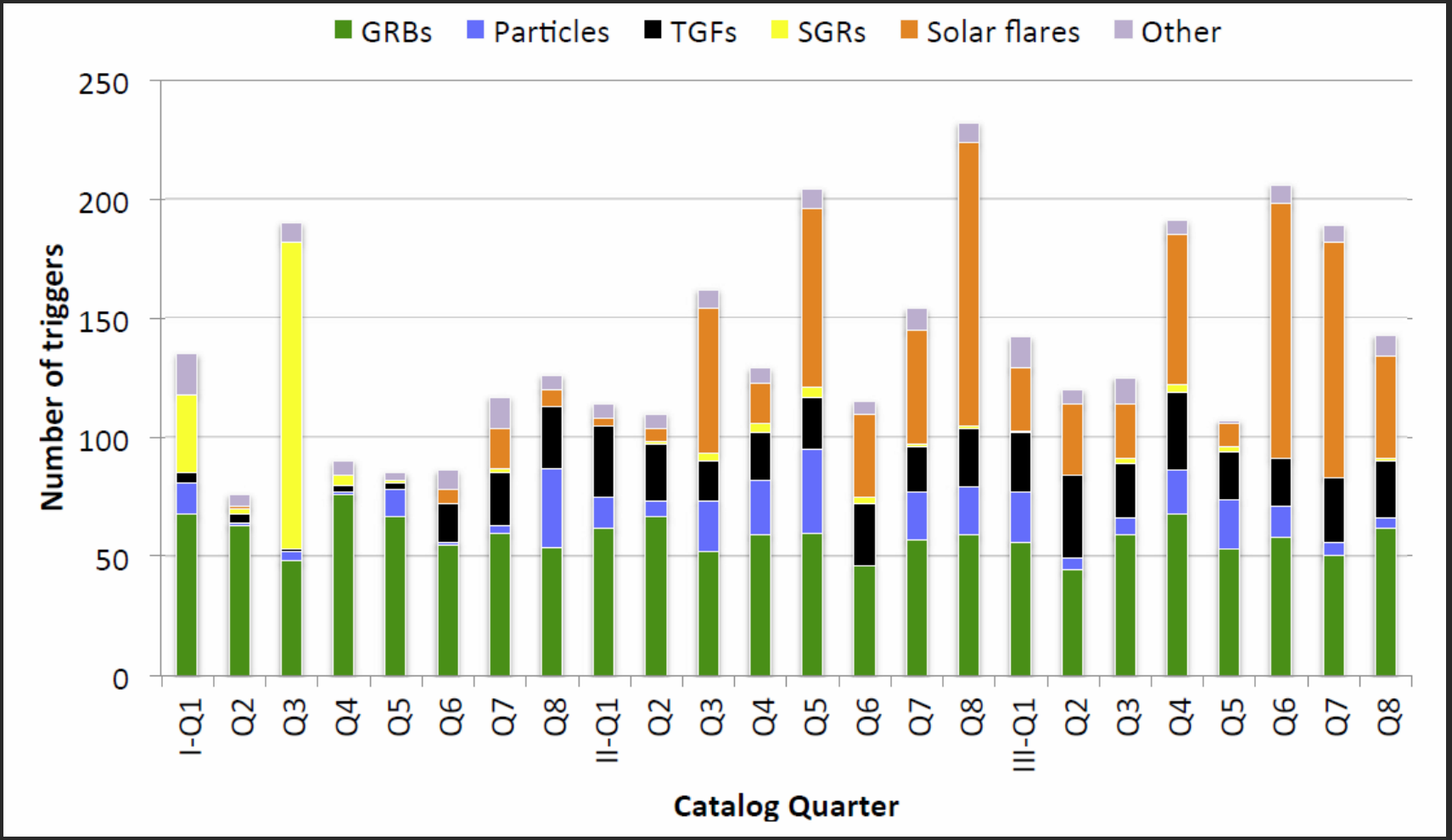
GBM On-Board Triggering

- GBM triggers when 2 or more detectors exceed background by n sigma over t timescale in e energy band.
- 70 algorithms operating simultaneously.
  - $4.5 \leq n \leq 7.5$
  - $16\ \text{ms} \leq t \leq 8.096\ \text{s}$
  - e = one of 25 - 50 keV, 50 - 300 keV, 100 - 300 keV, > 300 keV

⇨ What does GBM trigger on?

What does GBM see?

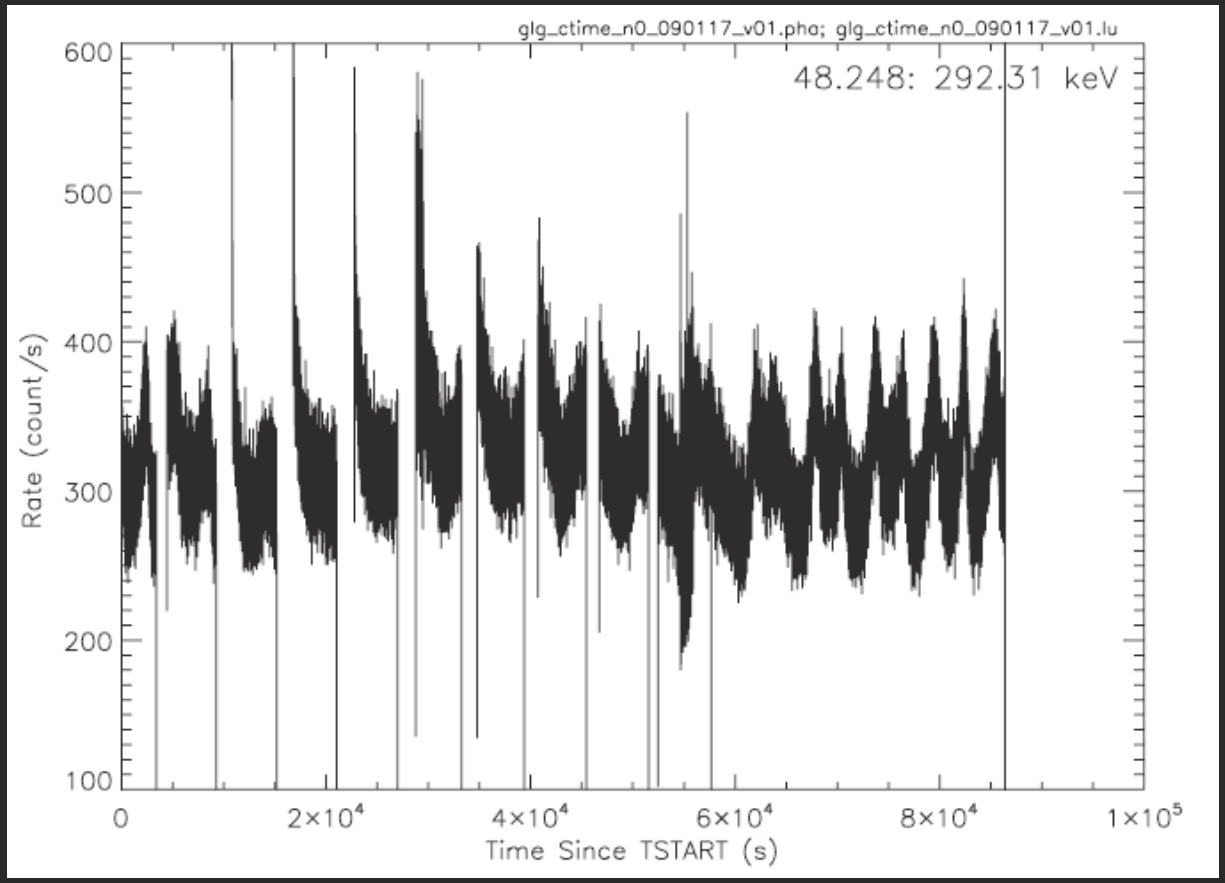
Lots of stuff



What does GBM see?

Continuous data: CSPEC (4.096 s, 128 energy channels),

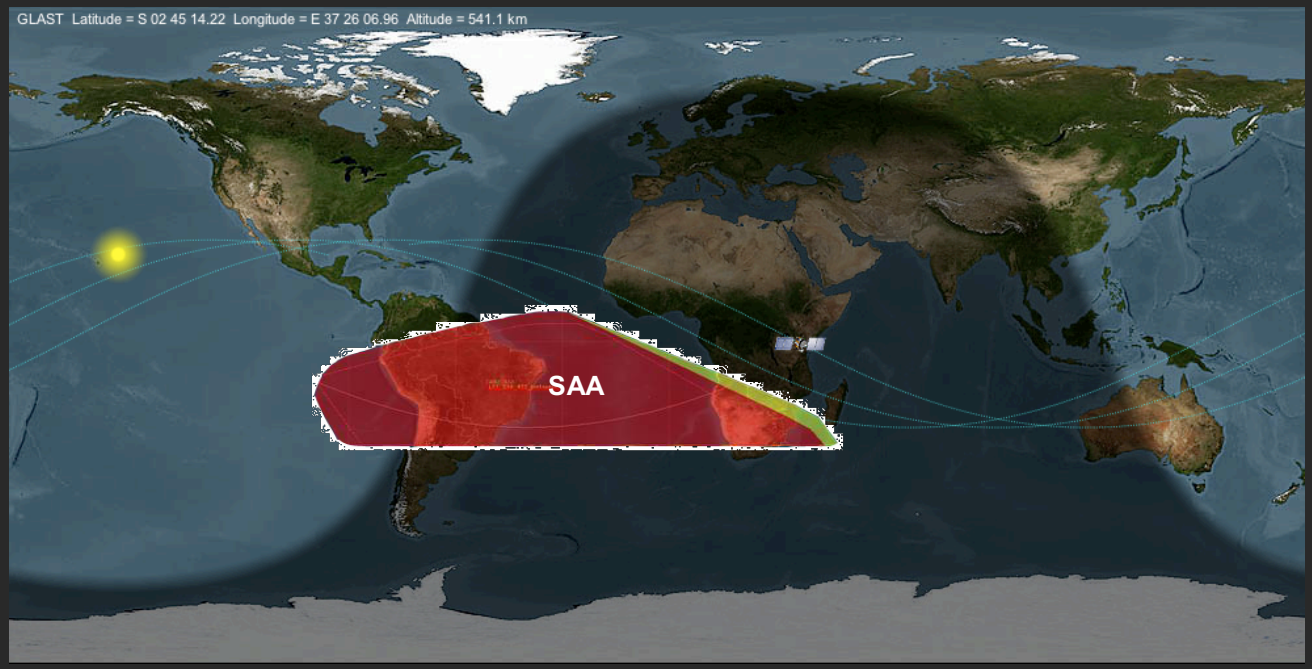
CTIME (0.256 s, 8 energy channels).



1 day time interval

NaI detector background rates in the 50 – 300 keV energy range

The *Fermi* Orbit

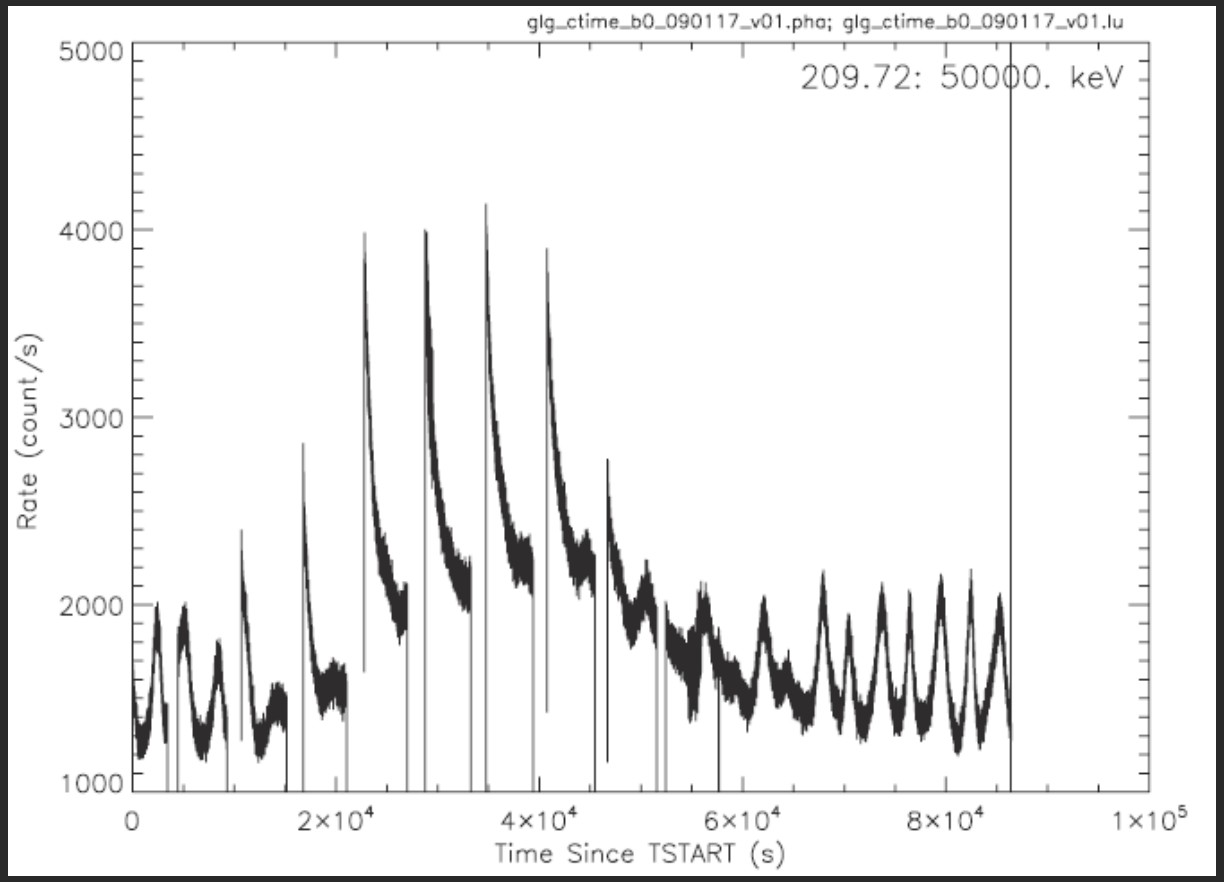


Fermi is now in 25.6^{o} orbit 565 km above Earth with 96 min orbit.

What does GBM see?

Continuous data: CSPEC (4.096 s, 128 energy channels),

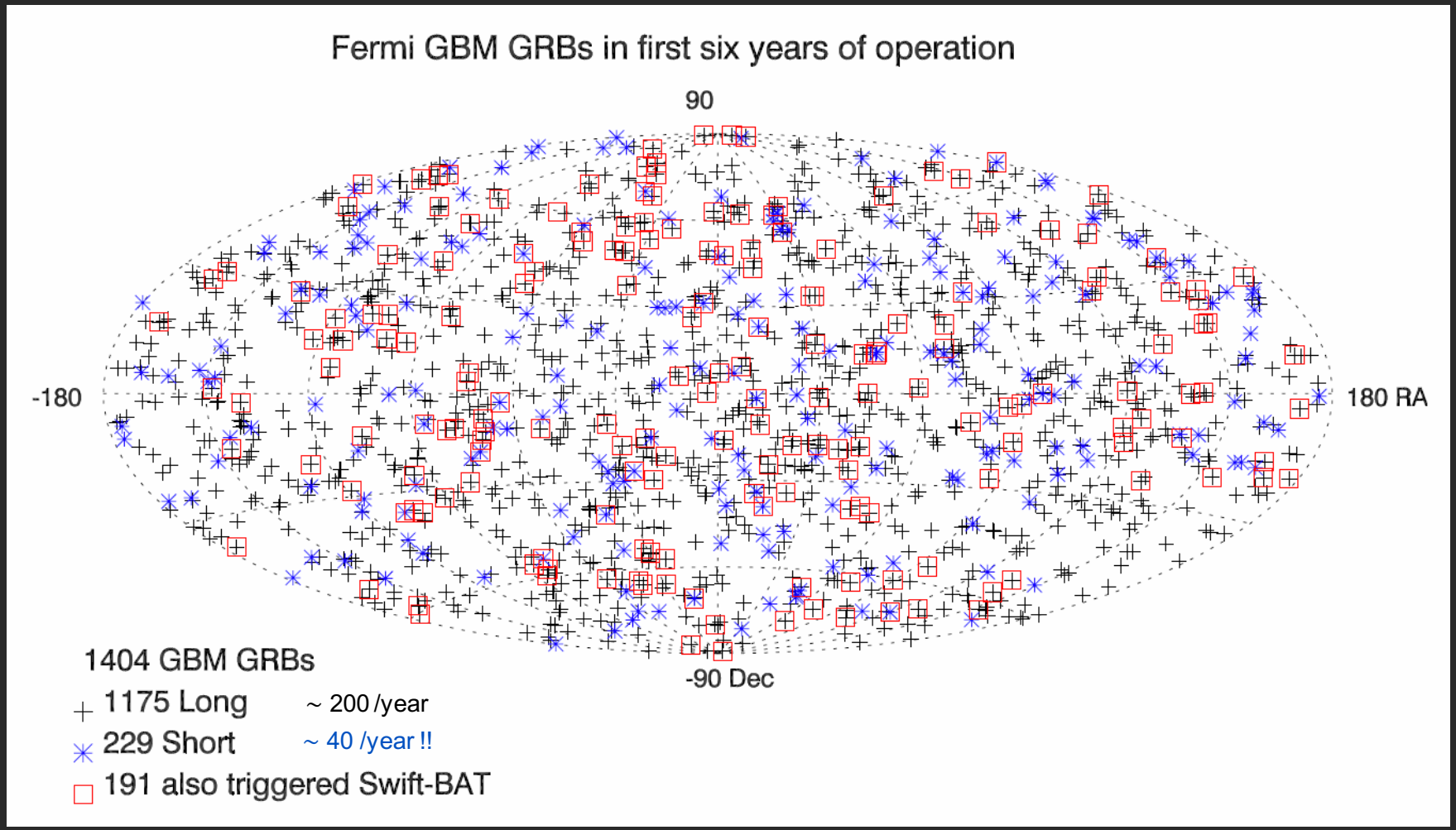
CTIME (0.256 s, 8 energy channels).



1 day time interval

BGO detector background rates over the full BGO energy range

Fermi GBM in first six years of operation



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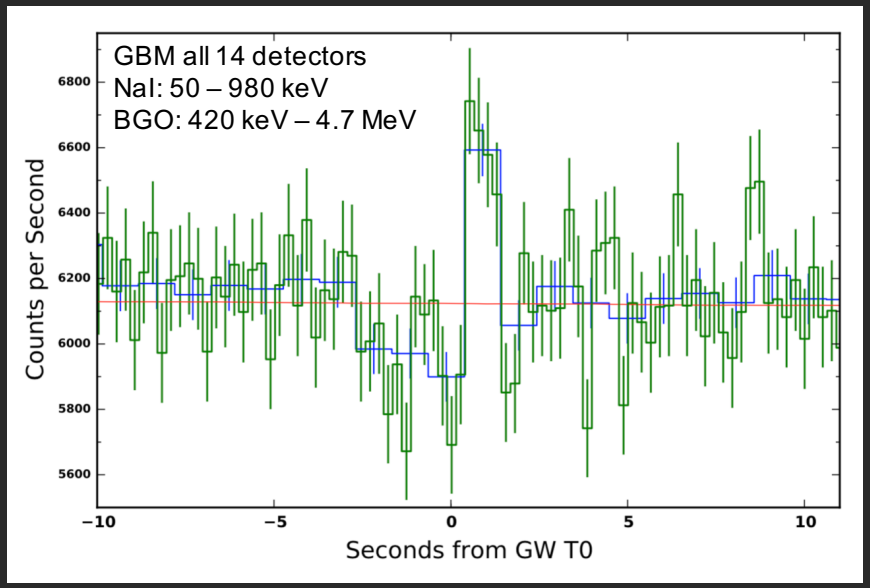
(arXiv 1602.03920, ApJL accepted)

Fermi GBM Observations of LIGO Gravitational Wave Event GW150914

V. Connaughton*,[1], E. Burns[2], A. Goldstein+,[3], L. Blackburn[4,5], M. S. Briggs[6,7], B.-B. Zhang[7,8], J. Camp[9], N. Christensen[10], C. M. Hui[3], P. Jenke[7], T. Littenberg[1], J. E. McEnery[9], J. Racusin[9], P. Shawhan[11], L. Singer+,[9], J. Veitch[12], C. A. Wilson-Hodge[3], P. N. Bhat[7], E. Bissaldi[13,14], W. Cleveland[1], G. Fitzpatrick[7], M. M. Giles[15], M. H. Gibby[15], A. von Kienlin[16], R. M. Kippen[17], S. McBreen[18], B. Mailyan[7], C. A. Meegan[7], W. S. Paciesas[1], R. D. Preece[6], O. J. Roberts[18], L. Sparke[19], M. Stanbro[6], K. Toelge[14], P. Veres[7]

Did GBM detect an electromagnetic (EM) counterpart ?

GW150914-GBM



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GW150914