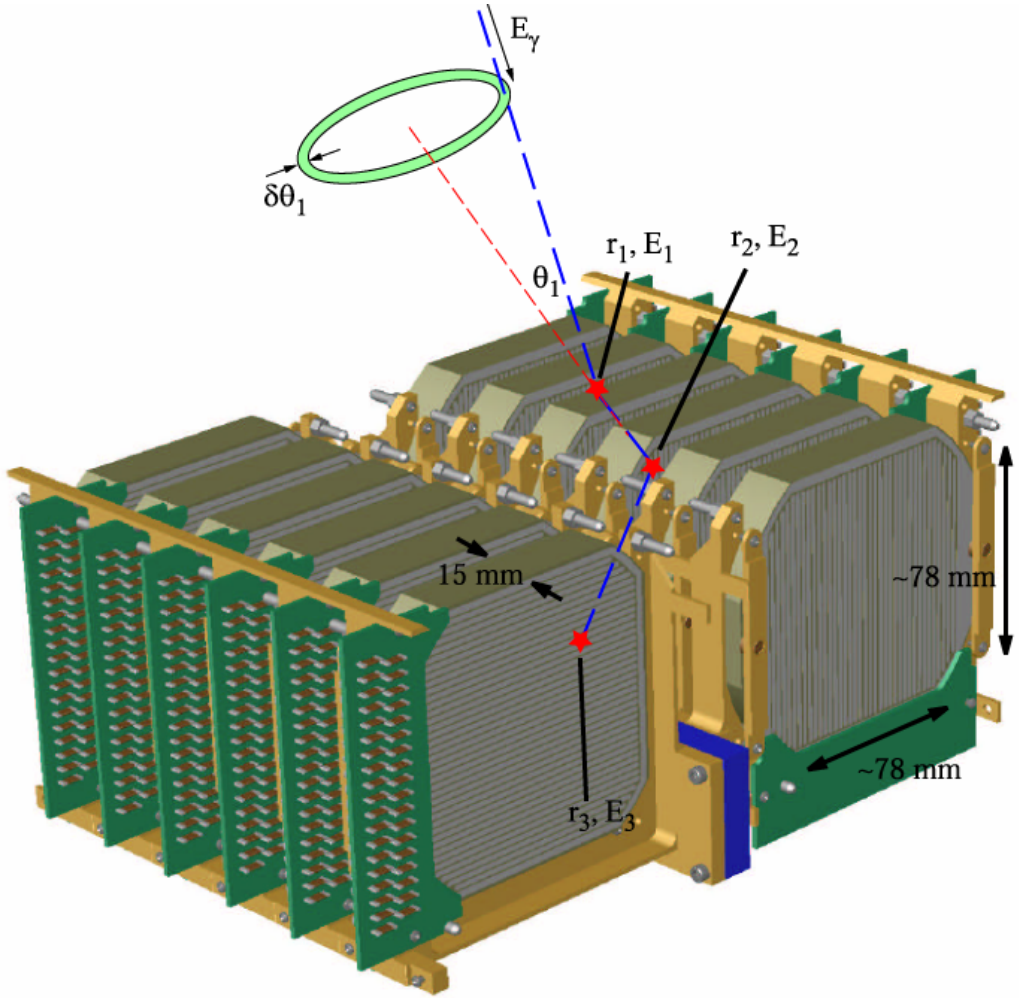
Compton Imaging for Astrophysical Observations



- 0.2-10 MeV (nuclear lines)
- wide FoV
- direct imaging (sorta)
- background rejection

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Compton Gamma-Ray Observatory
(1991-2000)

COMPTEL
(0.8-30 MeV)

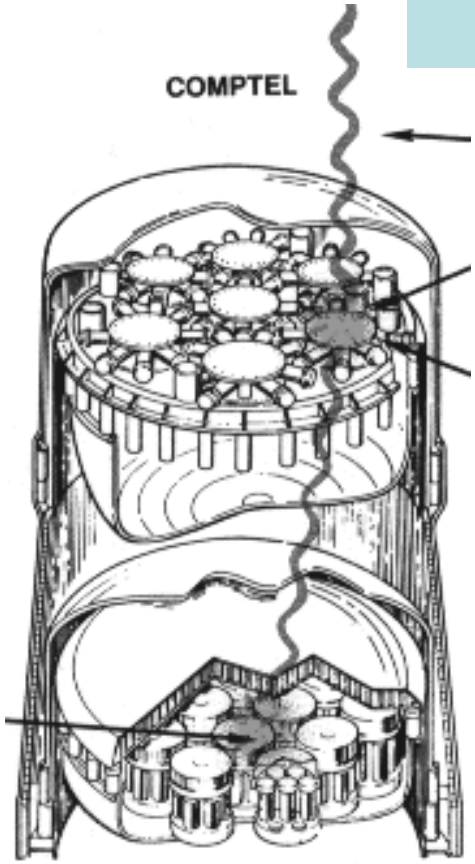
OSSE
(50 keV – 10 MeV)

BATSE
(20-600 keV)

EGRET
(20 MeV – 30 GeV)

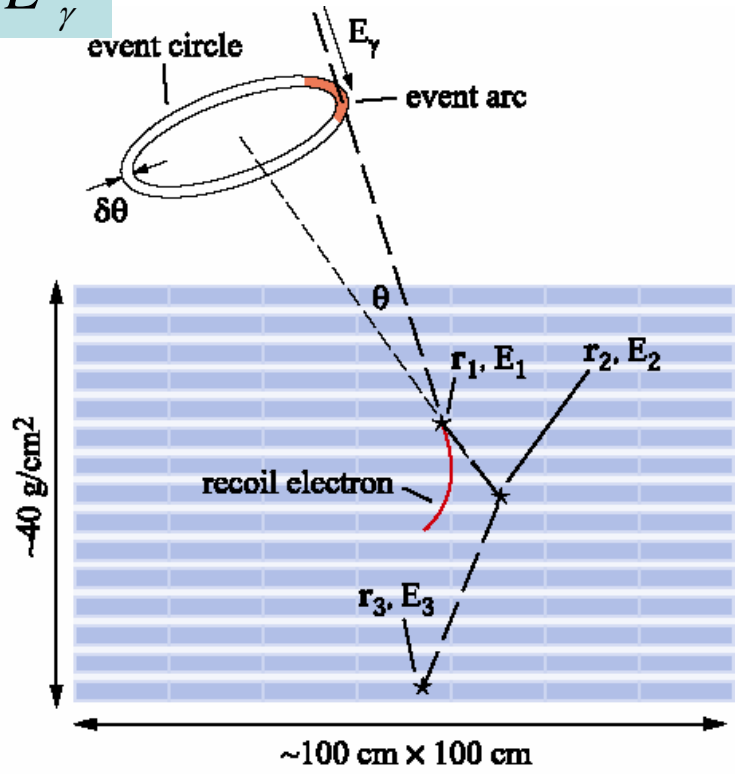
Compton Telescopes: Then & Now

$$\cos\theta = 1 + \frac{m_e c^2}{E_\gamma} - \frac{m_e c^2}{E'_\gamma}$$



CGRO/COMPTEL
- ~40 cm^3 resolution
- $\Delta E/E$ ~ 10%
- 0.1% efficiency

3 decades…

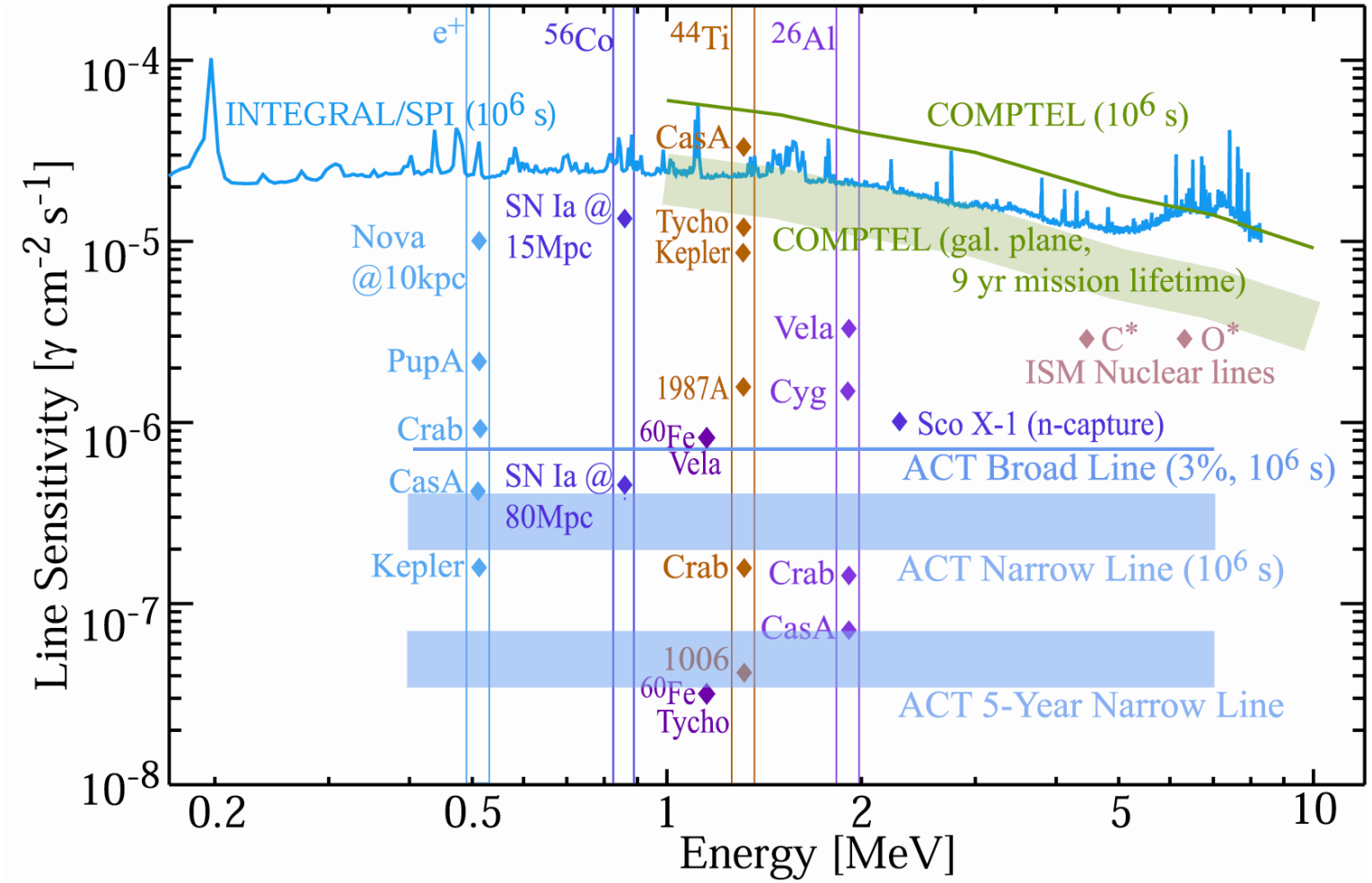


Modern Telescopes
- 1 mm^3 resolution
- $\Delta E/E$ ~ 0.2-1%
- 10-20% efficiency
- background rejection
- polarization

NASA's Advanced Compton Telescope:

Nuclear Line Spectroscopy

Primary science requirement: systematic study of SNIa spectra, lightcurves to uniquely determine the explosion mechanism, ^{56}Co (0.847 MeV) abundances.



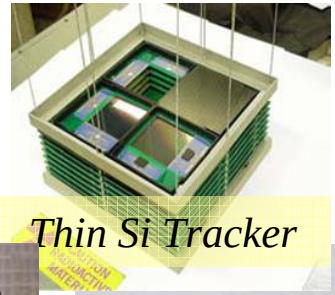
ACT Enabling Technologies

NASA ACT Vision Mission study identified the most promising detectors and highest priority technology developments.

Highest recommendations:

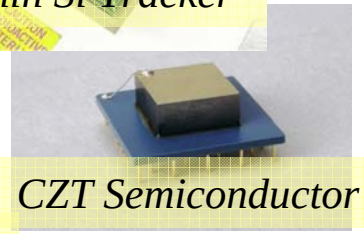
- low-power readouts
- Ge, thick Si, (LXe?)
- ~1m^2 area, ~40 g/cm^{2}depth


Liquid Xe


Thin Si Tracker


Si Semiconductor


Ge Semiconductor

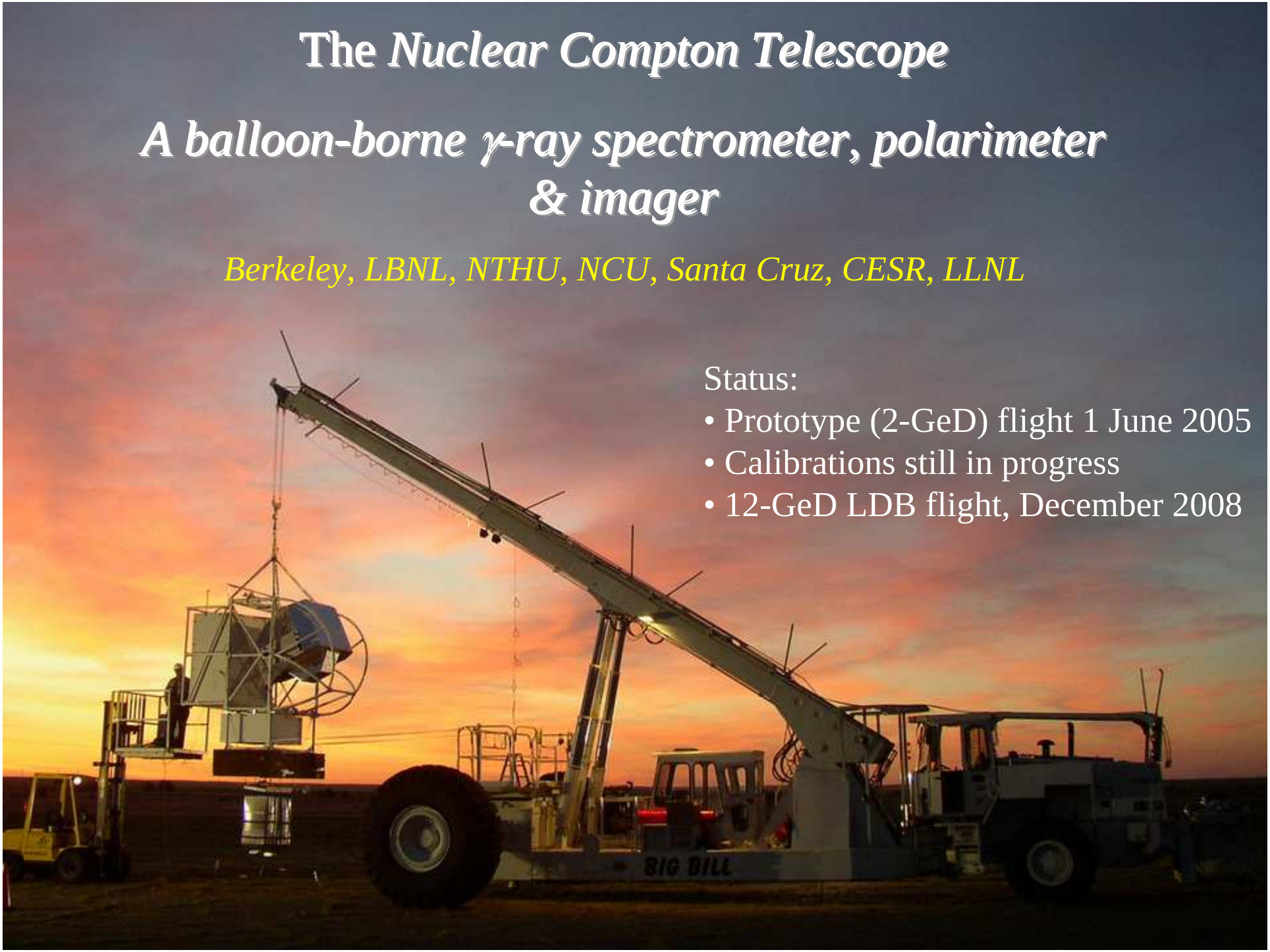

CZT Semiconductor

Property	Ge Strip	Si Strip	Liquid Xe	CZT Strip	Xe μWell
ΔE/E (1 MeV)	0.2-1%	0.2-1%	3%	1%	1.7%
Spatial Resol.	<1-mm^3	<1-mm^3	<1-mm^3	<1-mm^3	0.2-mm^3
Z density	32 5.3 g/cm^3	14 2.3 g/cm^3	54 3.0 g/cm^3	48 8.3 g/cm^3	54 (3 atm) 0.02 g/cm^3
Volume (achvd.)	130 cm^3	60 cm^3	3000 cm^3	4 cm^3	50 cm^3
Operating T	-190º C	-30º C	-100º C	10º C	20º C

The *Nuclear Compton Telescope*

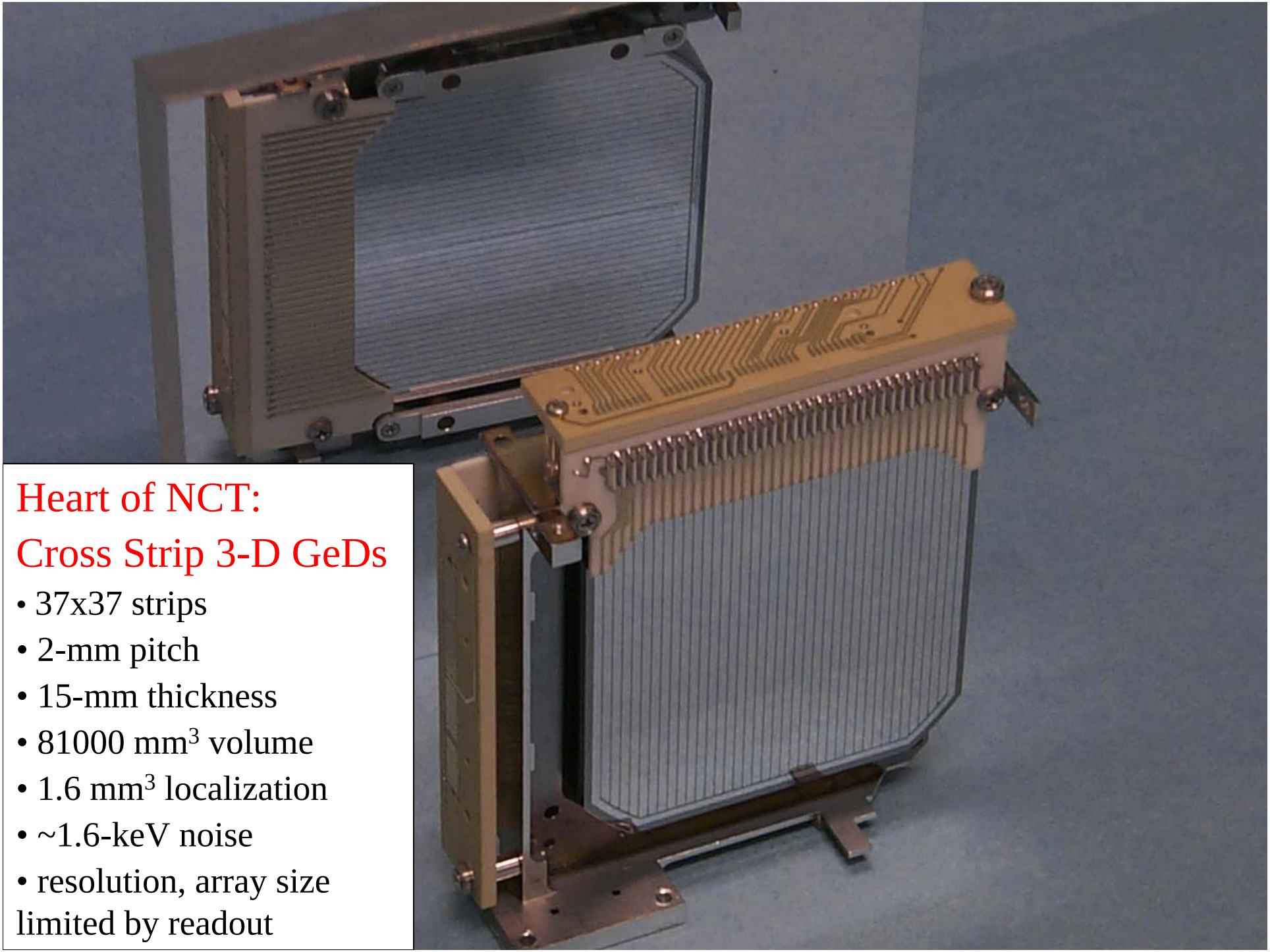
A balloon-borne γ-ray spectrometer, polarimeter & imager

Berkeley, LBNL, NTHU, NCU, Santa Cruz, CESR, LLNL



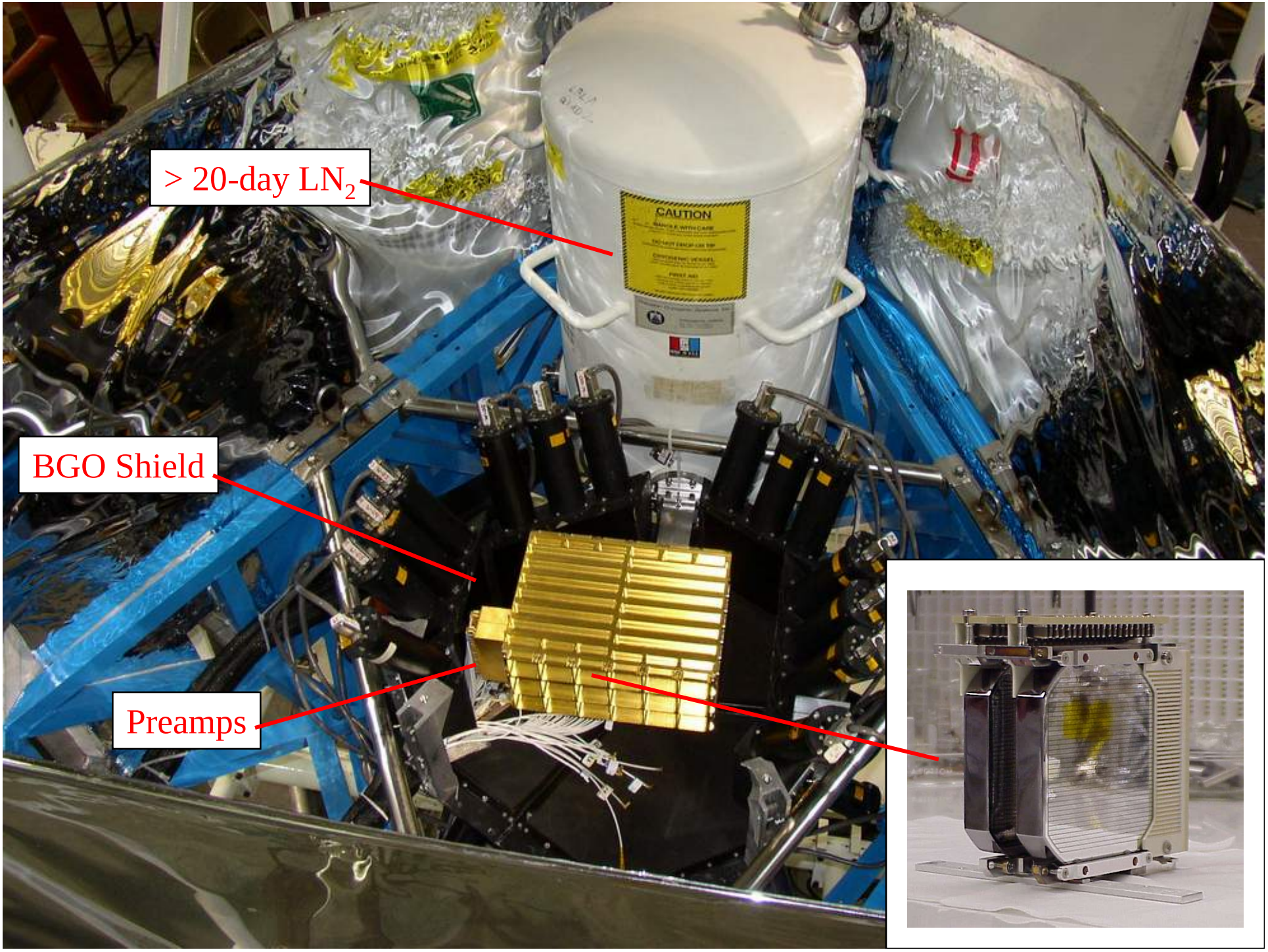
Status:

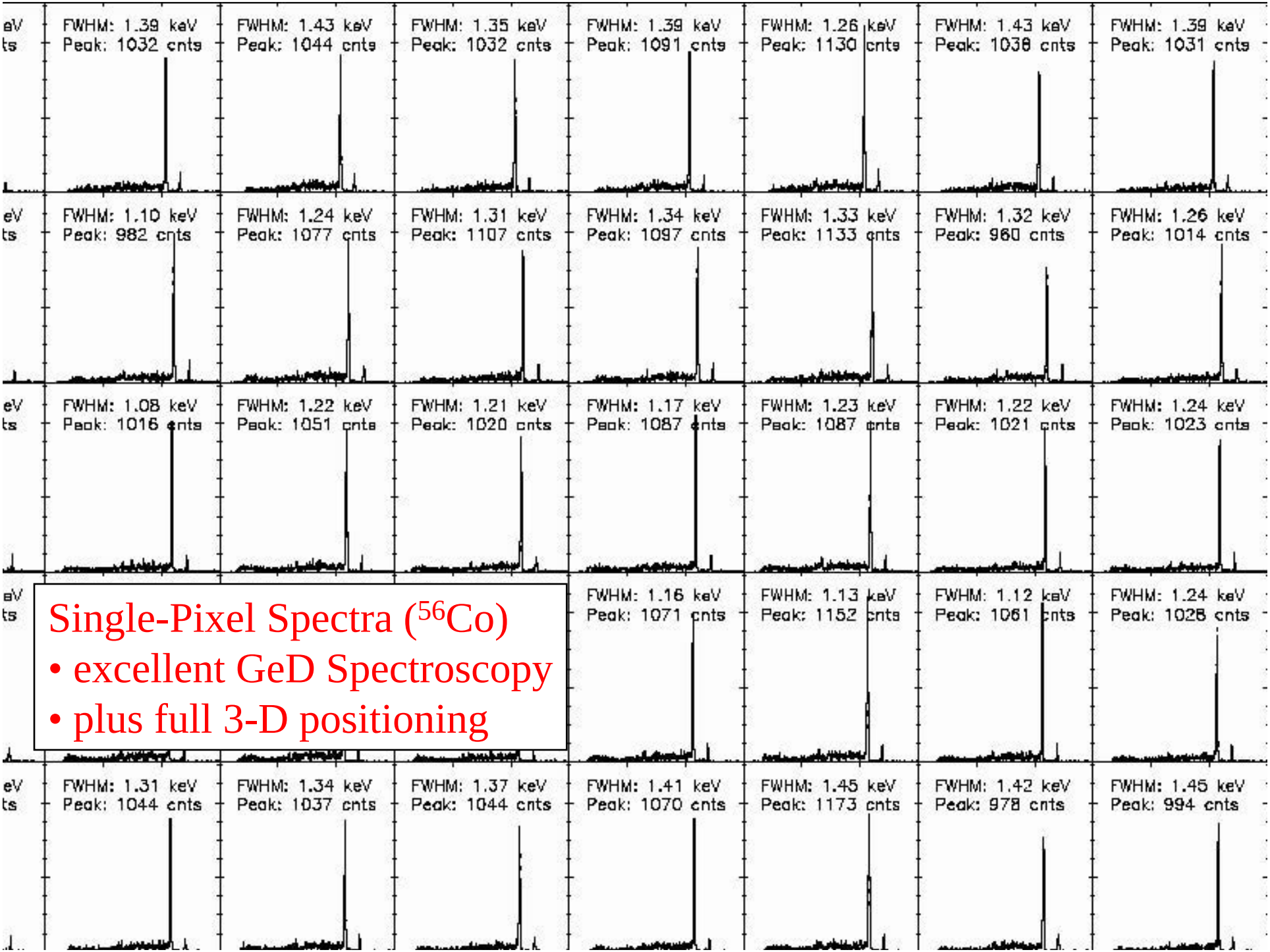
- Prototype (2-GeD) flight 1 June 2005
- Calibrations still in progress
- 12-GeD LDB flight, December 2008



Heart of NCT:
Cross Strip 3-D GeDs

- 37x37 strips
- 2-mm pitch
- 15-mm thickness
- 81000 mm^3 volume
- 1.6 mm^3 localization
- ~1.6-keV noise
- resolution, array size limited by readout

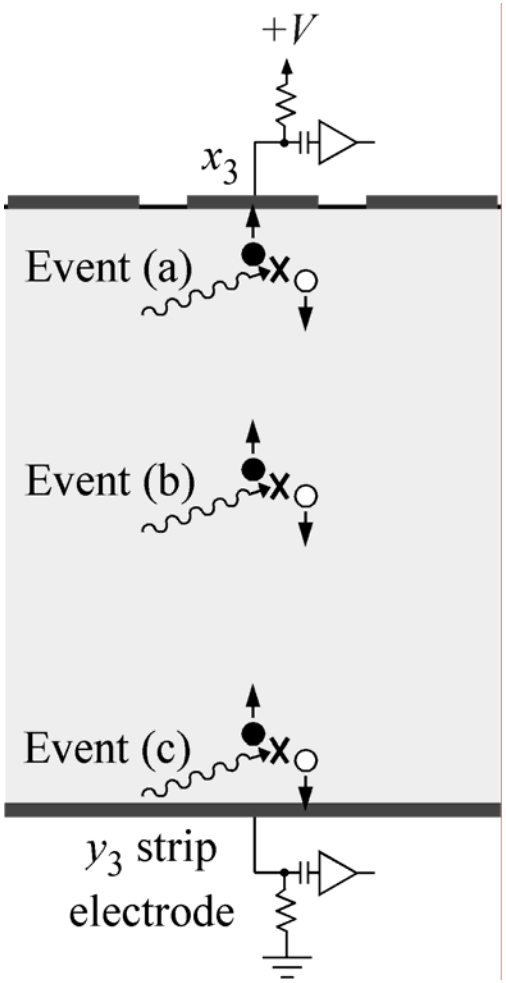

> 20-day LN_2
BGO Shield
Preamps
CAUTION

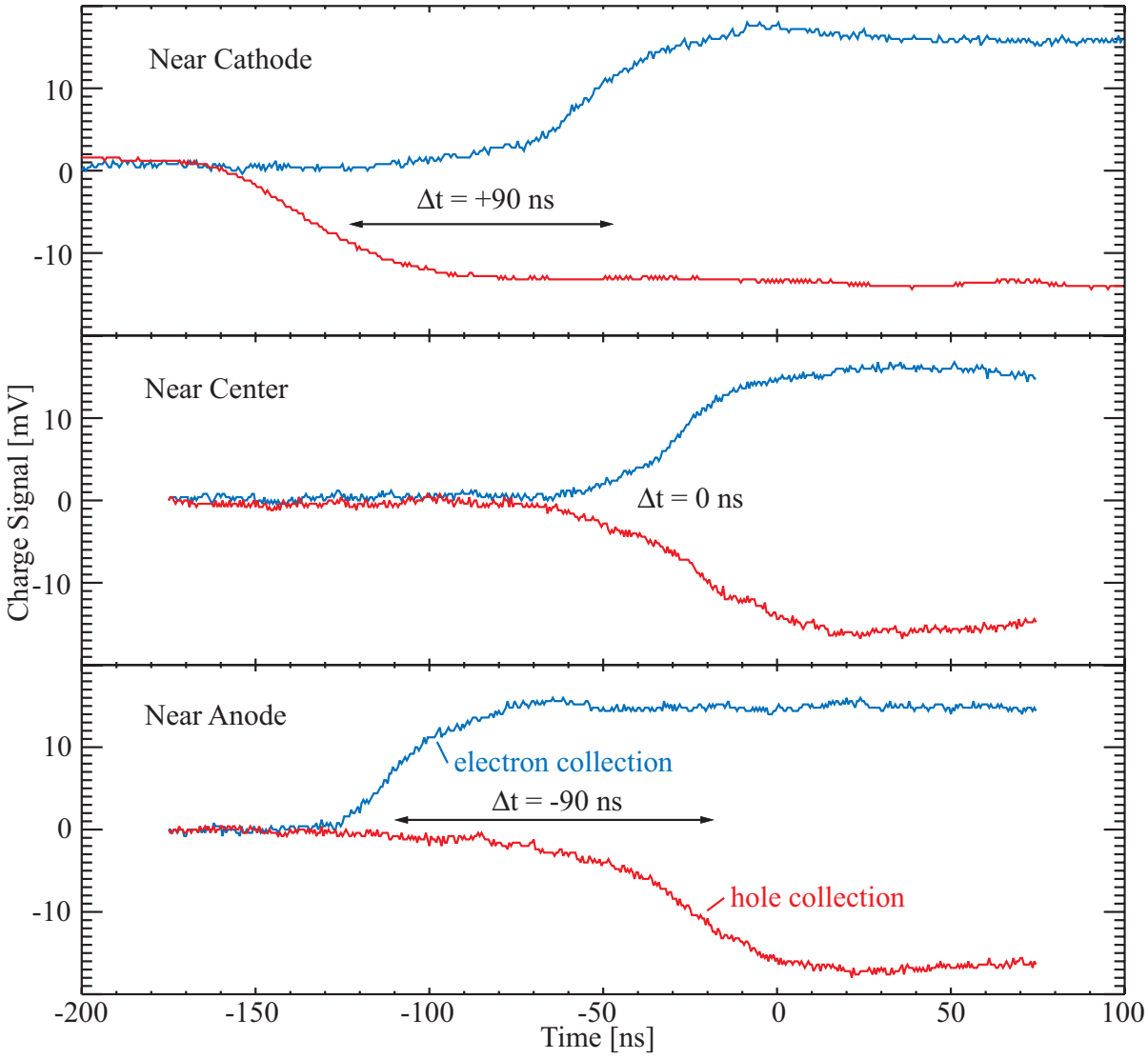


Single-Pixel Spectra (^{56}Co)

- excellent GeD Spectroscopy
- plus full 3-D positioning

3-D Positioning

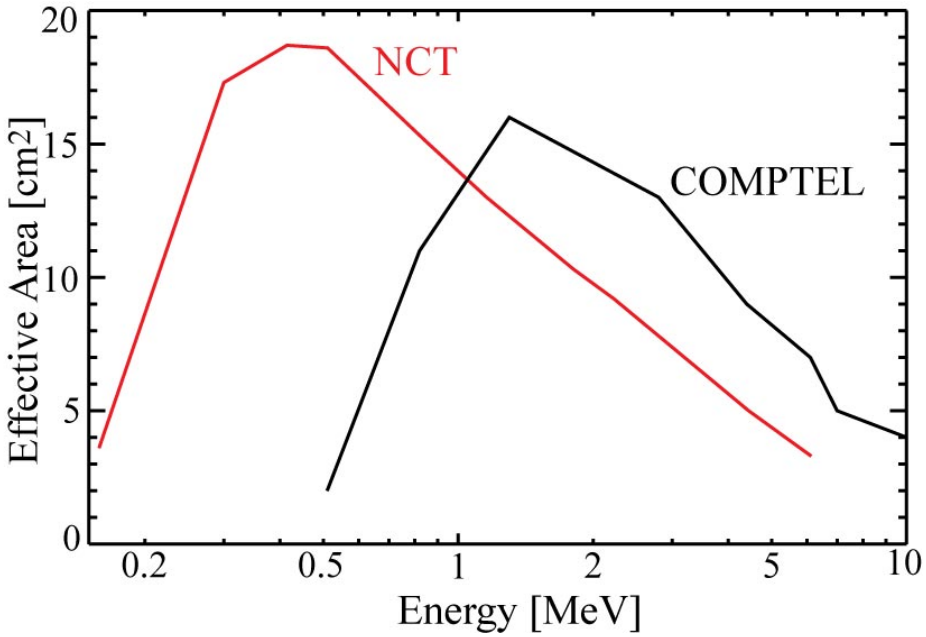




(Amman & Luke, NIM A452, 2000.

Amrose et al., IEEE, 2001.)

- ~0.4 mm FWHM
- limited (currently) by strip pitch

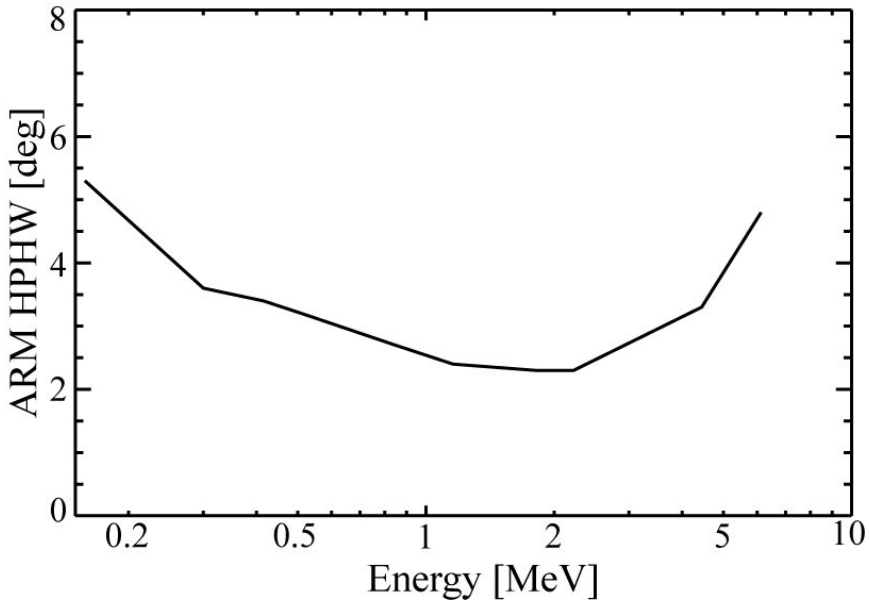


Effective Area:

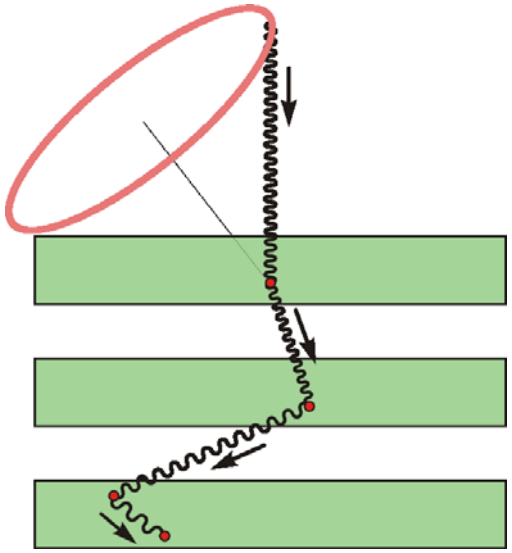
<1% COMPTEL detector volume

Angular Resolution:

~1° achievable, limited currently by 1.6 mm^3 resolution (>0.5 MeV)

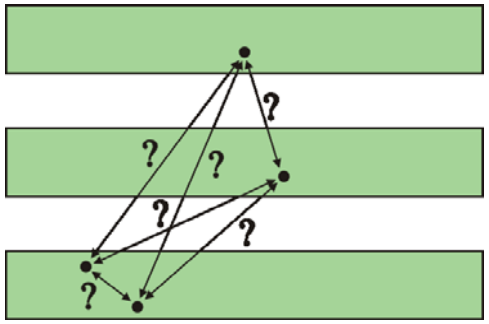


Step 1



"Tracking" Measurement
- 3D positions
- energy depositions

Step 2



Event Reconstruction
- interaction order
- photopeak ID
- background rejection

Step 3

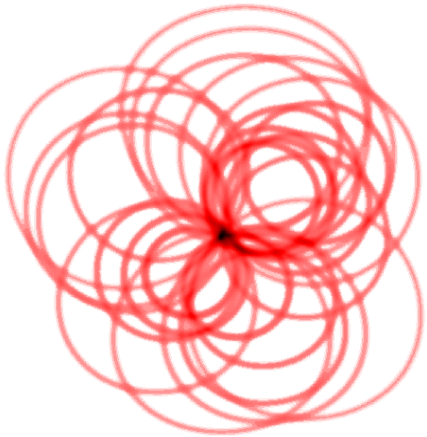
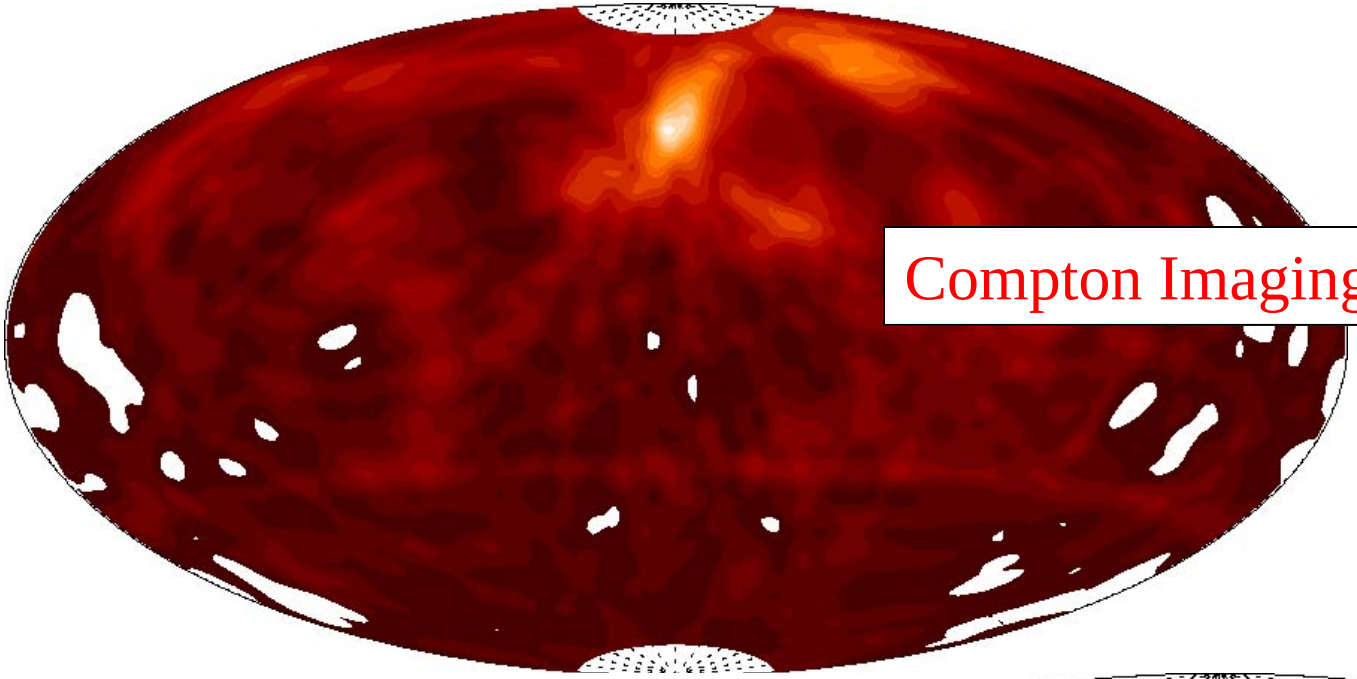


Image Reconstruction
- "list-mode"
- backprojection
- maximum likelihood
- ???

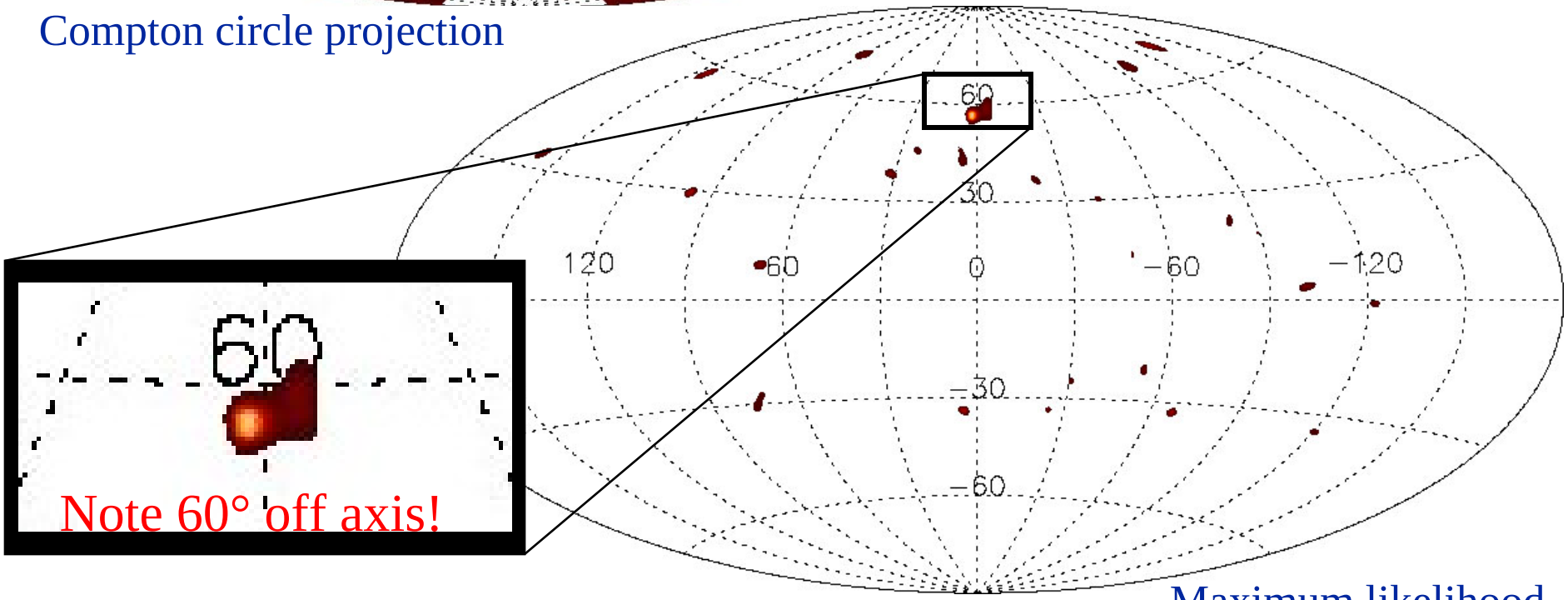
(figures A. Zoglauer)

(Boggs & Jean, A&A 2001; Zoglauer et al., New Astr. Rev., 2006)

Compton Imaging ^{60}Co (1.173 MeV)



Compton circle projection



Maximum likelihood