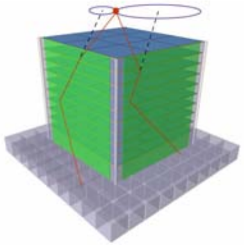
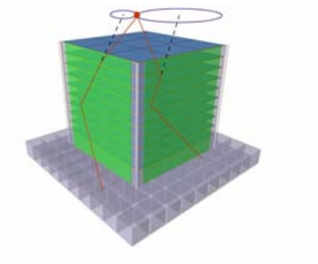


# Nuclear data for gamma ray telescope simulations

Bernard Phlips

Naval Research Laboratory
Washington DC



# Introduction

- MeV Gamma ray astrophysics involves satellites in space
- Space radiation environment, mostly protons and secondary neutrons, activates all materials

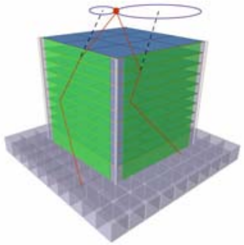
Internal detector background can be 100 x larger than bright sources

- Earth glows in gamma rays (atmosphere)
- Spacecraft glows in gamma rays
- Shielding material glows in gamma rays

} Often use active shields made of scintillators

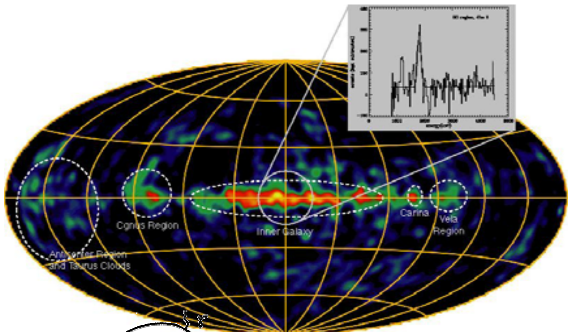
Sensitivity of instruments extremely dependent on internal radioactive background

To optimize the design, need good simulation tools with radioactive activation of instrument



# Compton Imager

$$\cos\varphi = 1 - m_e c^2 \left( \frac{1}{E_2} - \frac{1}{E_1} \right)$$



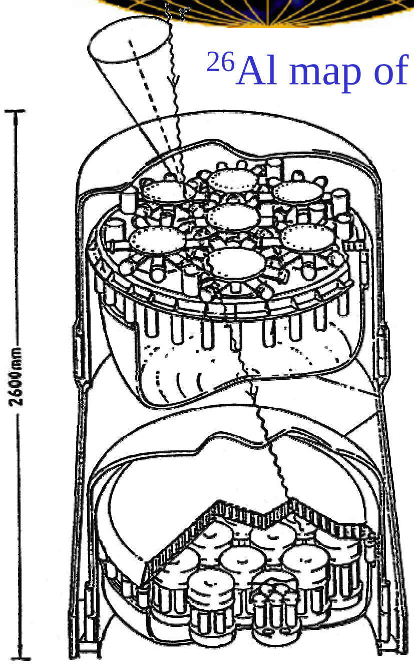

$^{26}$Al map of the Galaxy

## Technique for detection of penetrating photons (MeV):

- Scatter gamma ray in first detector
- Absorb gamma ray in second detector
- Measure position and energy in both detectors
- Use Compton formula to reconstruct a cone of directions
- Many cones generate an image

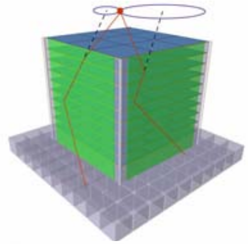
## Ongoing programs for:

- Homeland Security: detection of shielded nuclear materials
- Gamma ray astrophysics
- Solar physics

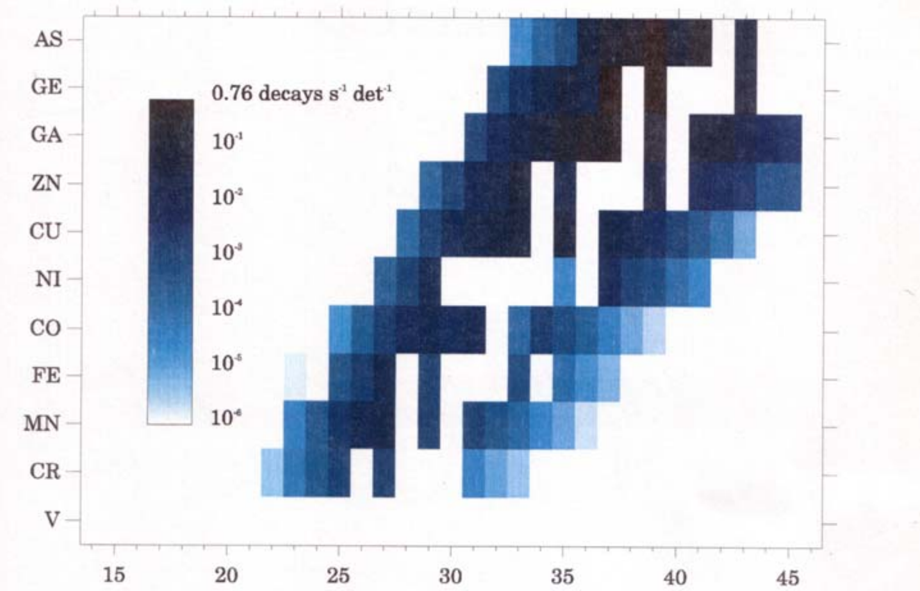


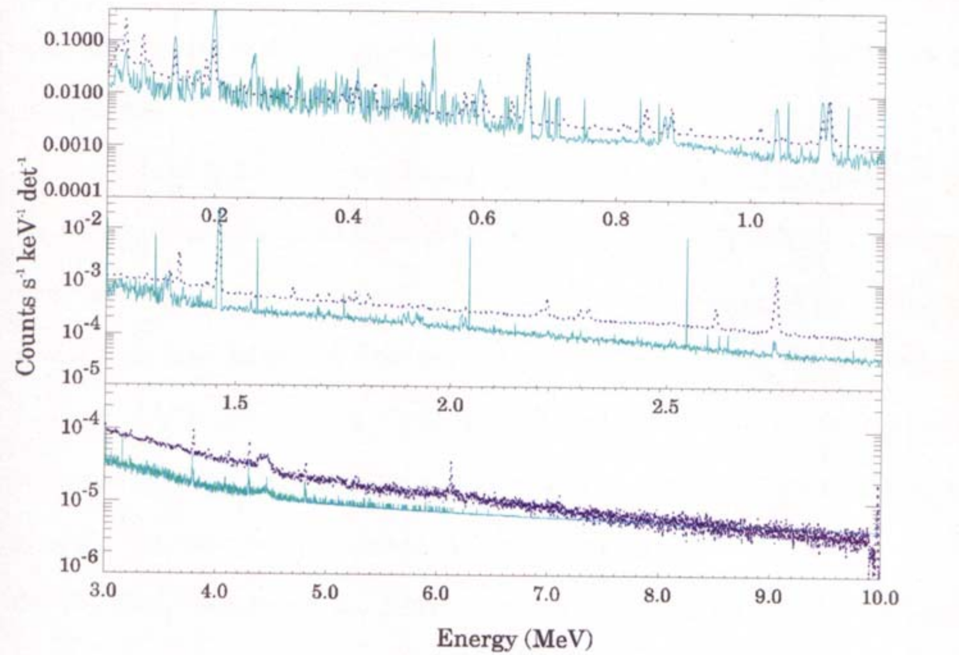

COMPTEL Instrument, 1991-1999

1700mm



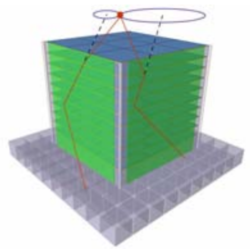
# EGS-ALICE-ENSDF Package (NRL)



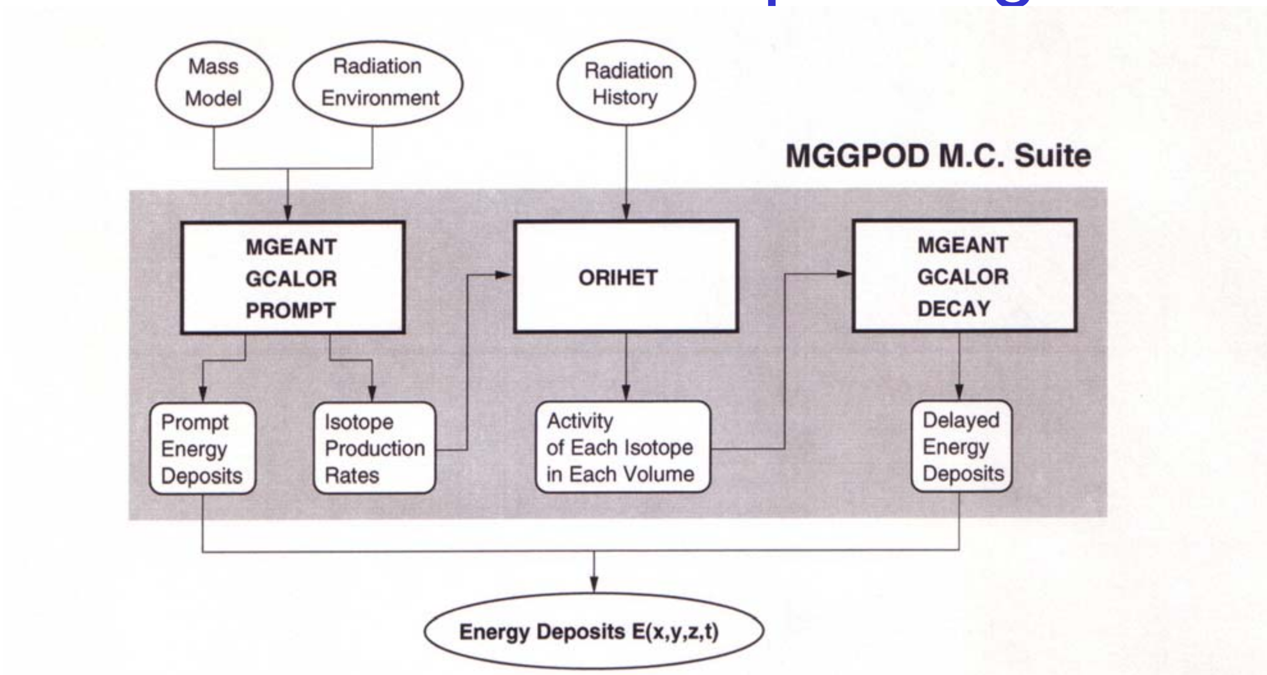




Started with EGS and made homegrown package:

- Added ENSDF decays to EGS
- Added ALICE (<200 MeV) and Yield-X (>200 MeV) for spallation cross sections
- Neutron and proton transport in GEANT 3
- Validated package on Ge crystal spectrometer that flew in space (HEAO 3)



# GEANT3-based package

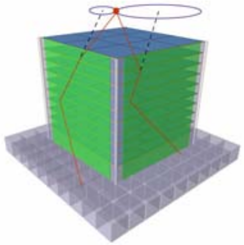



Currently using MGGPOD [Weidenspointner et al. 2003,A&A 411 L113]:

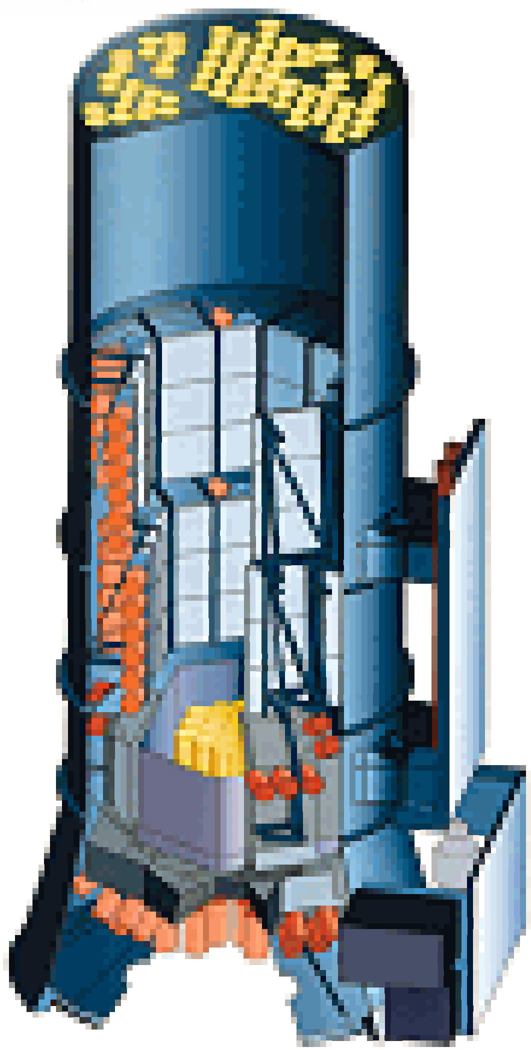
- Combination of NASA (GSFC) variation of GEANT and GGOD (U. Southampton)
- **MGEANT**: Shell on GEANT with various radiation inputs [Sturner et al.]
- **GCALOR**: Hadronic interaction (>1 MeV) and low energy neutron ($10^{-5}$ eV) [Zeitnitz & Gabriel]
  NMTC, FLUKA, MICAP, Scaling model
- **PROMPT**: Prompt photon emission after neutron capture, inelastic scattering or spallation
- **ORIHET**: Build-up and decay of radioactivity
- **DECAY**: decay schemes

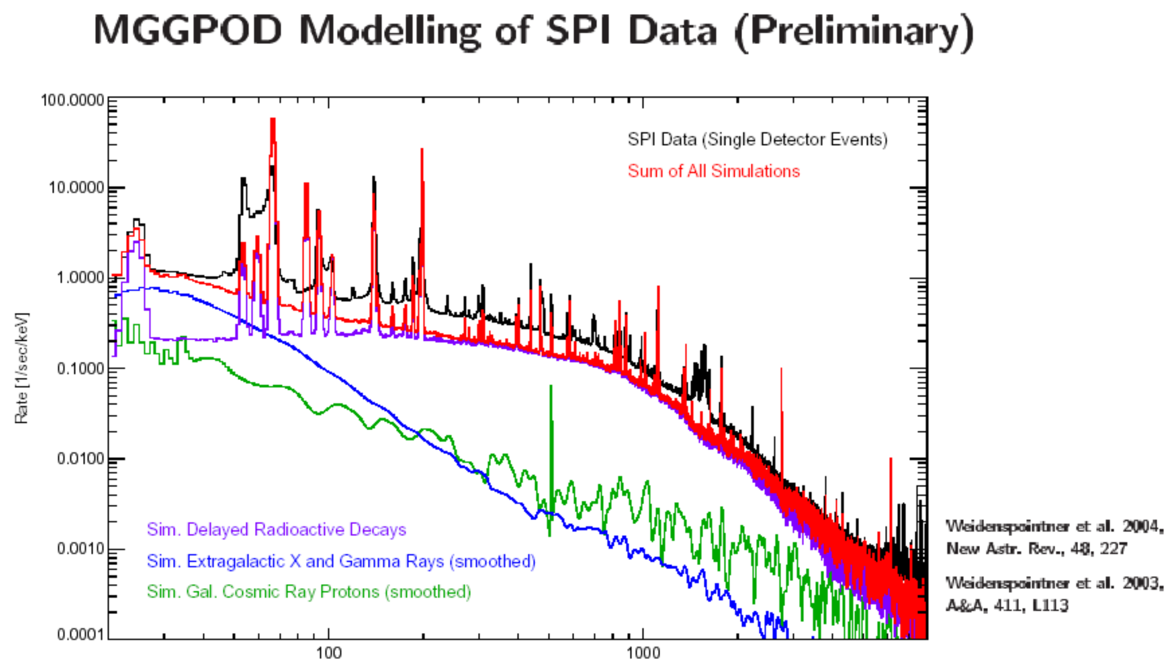
ENDF/B, JENDL

ENSDF

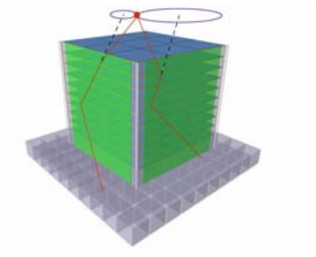


# INTEGRAL SPI Background






- ESA-led mission, currently in-orbit
- 19 Ge coaxial detectors
- 1 Ton BGO active shield
- Hexagonal Coded Aperture
- Pretty good fit between measurements and simulations

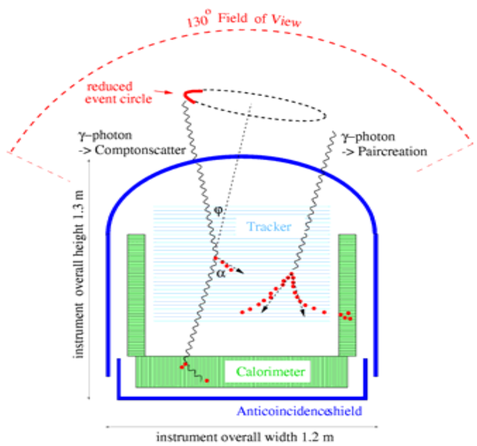


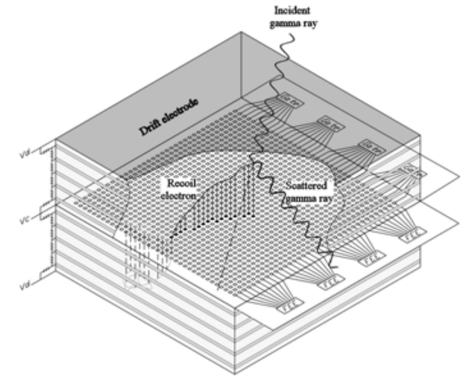
# ACT- Compton Telescope Options

NASA Mission Concept study (PI: S. Boggs, Berkeley)

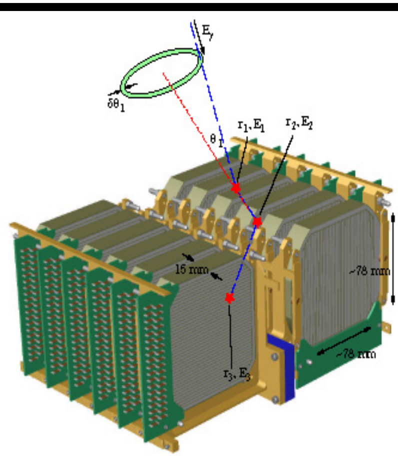
MEGA

Si-CsI




**Xe 3-dimensional track imager using pixelized gas micro-well detectors (MWDs)**




Nuclear Compton Telescope (NCT),
Ge strip detectors

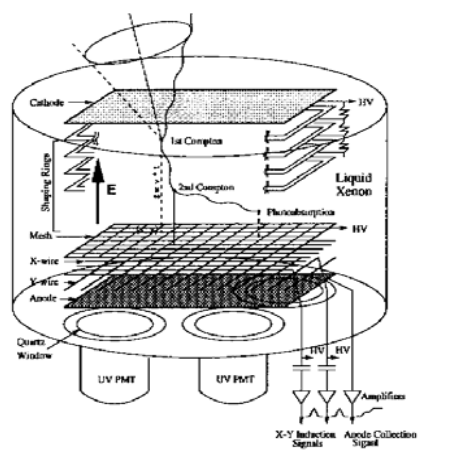
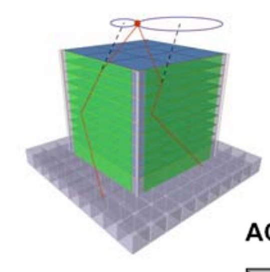



**FIGURE 1.** Schematic of the liquid xenon time projection chamber

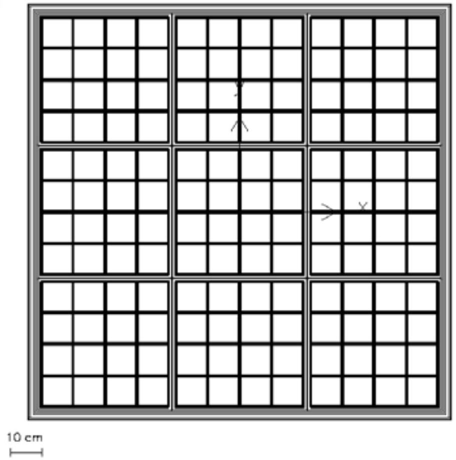
LXeGRIT

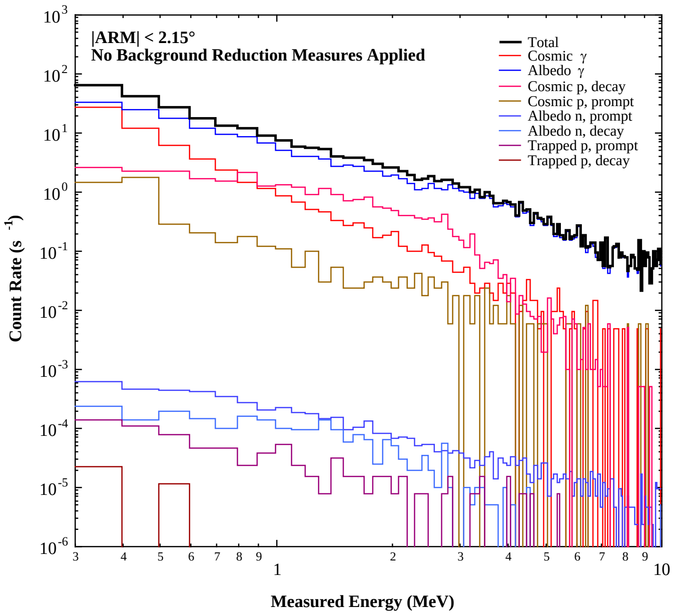


# ACT Design

## ACT Simulations led by M. Kippen of LANL

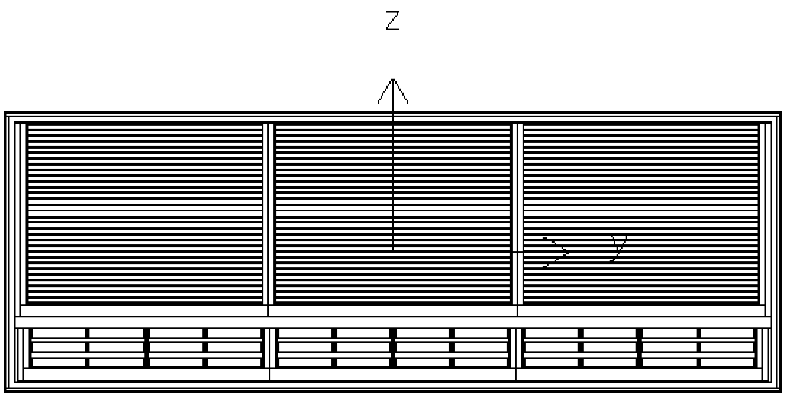
ACT - Si/Ge Instrument Concept 01



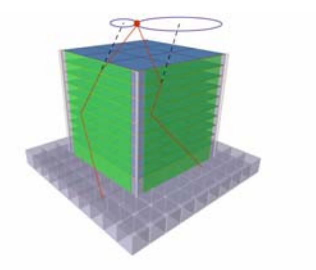




**32 layers of 2mm thick Si detectors**

**3 layers of 1.5cm thick Ge detectors**

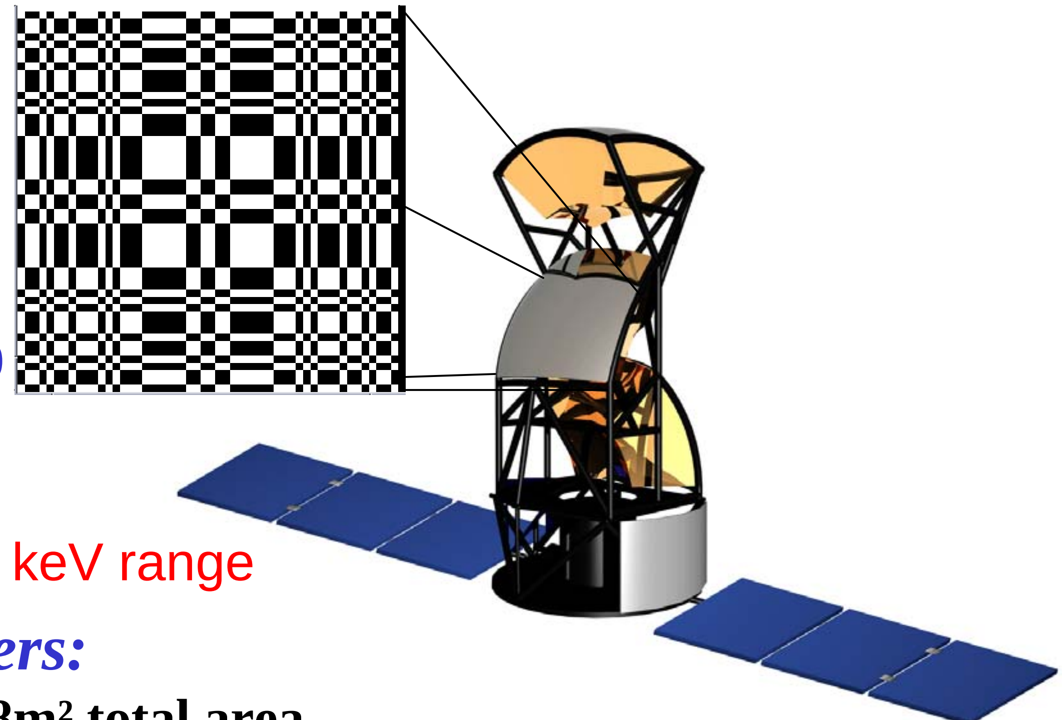



- Instruments require coincidence for trigger: Previous success no guarantee
- More passive material within active volume
- Different materials within active volume
- Different orbit



# EXIST

NASA Mission Concept study (PI: S. Josh Grindlay, Harvard)

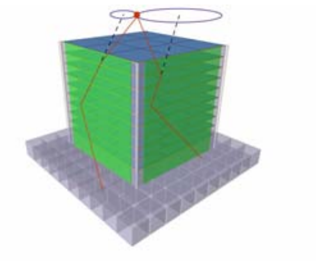


- All-sky imaging (5’ resolution) every 95min
- 5 sr filed of View
- Energy range:10-600 keV
- High-Z material coded mask (W, Ta, Pb)
- Scintillator shields (NaI, CsI)
- CdZnTe pixel detectors

Need to model $\Delta E$ in 10-600 keV range

## *Mission Parameters:*

- **CZT tiled arrays: 8m² total area**
- **Passive and active shielding; 25º x 20º collimation/module**
- **Mass, power, telemetry: 8500kg, 1200W, 1.2mbs (X-band)**
- **Delta-IV launch**
- **>2010 launch**



# Simulated materials

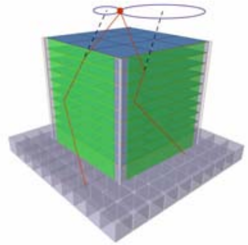
## Detector materials:

Semiconductors: Ge, Si, Cd, Zn, Te, Ga, As, In, P, C
Scintillators: Na, Cs, I, Bi, O, Lu, Gd, Y, Ba, F, La, Cl, Br, H
Gas: Ar, Xe

two coincident interaction sites: $(\beta,\gamma)$, $(\gamma,\gamma)$, $(\gamma,\gamma')$

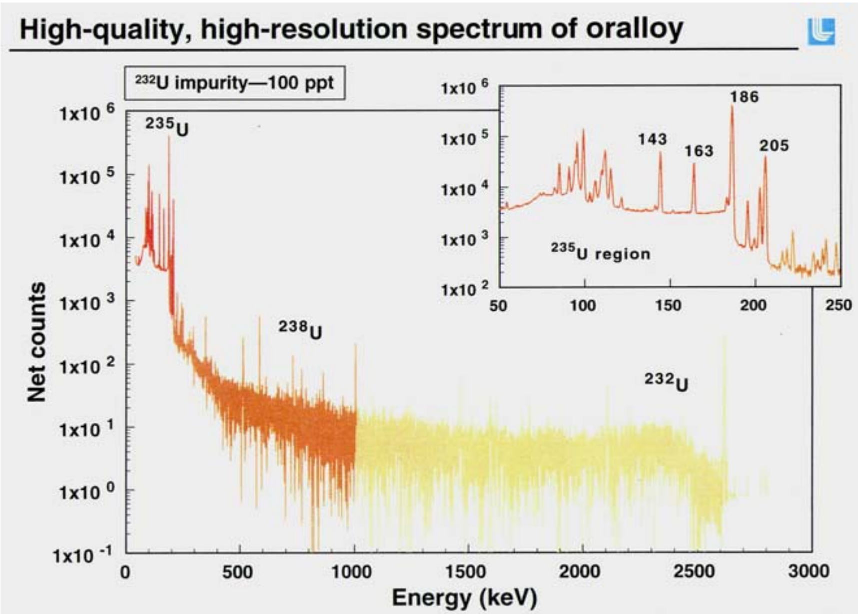
## Passive materials:

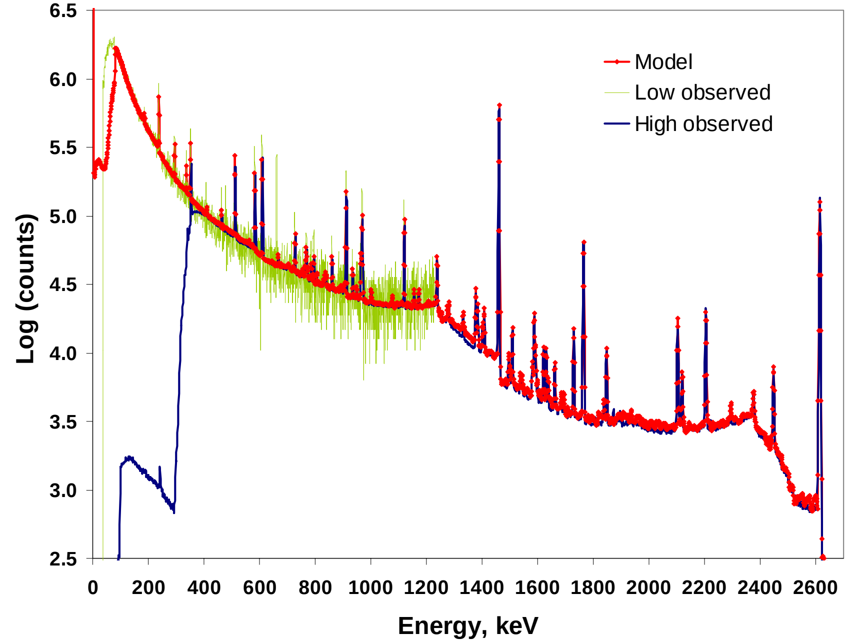
Structural: Al, Cu, Ti, Mg, Be, Fe
Shielding: W, Pb, Ta, Mo, Sn
Batteries/fuel: Ni, K, Li, N, S



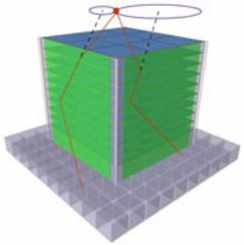
# *Homeland Security: Detecting Fissile Materials*

## Problem: Detection of shielded enriched uranium

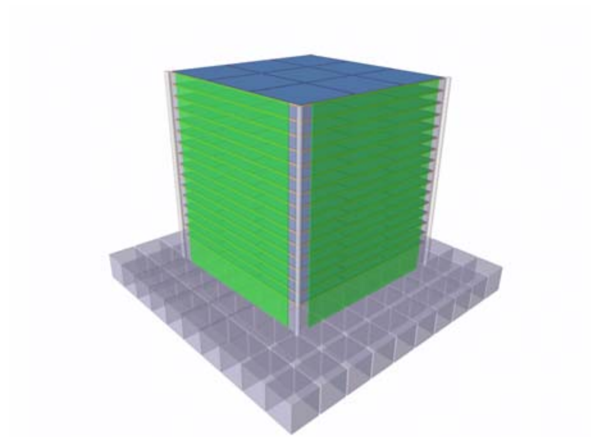


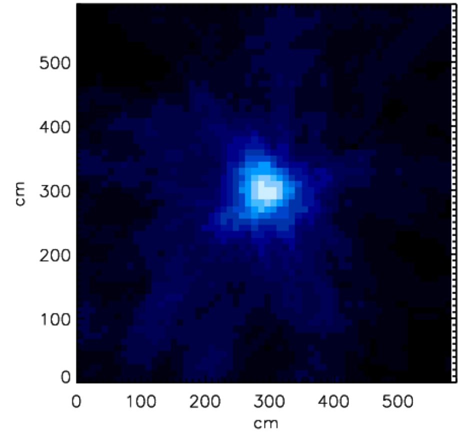




- Easy to shield < 200 keV lines from U-235
- Focus on 2.6 MeV line from U-232
- Need to differentiate from background 2.6 MeV flux
- Background is location dependent
- Use imaging
- Model sources and diffuse background



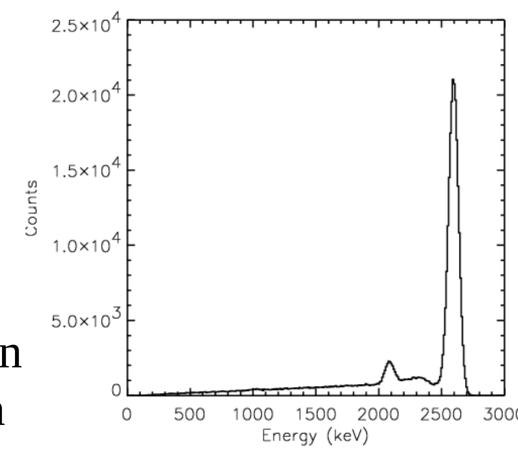
# Compton Imagers for shielded U-235

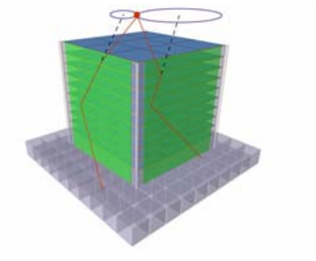





## Department of Homeland Security:

- BAA for portals meeting ANSI 42.35 portal standards
    - Detection at 6 meters
    - Detection in ~ 6 seconds
- Design could detect ~ 2 kg of shielded material, assuming 100 parts per trillion U-232 (conservative)
- Scintillator-based design could give (1 ft)$^3$ imaging resolution
- Silicon detectors would improve image and energy resolution





# Conclusions

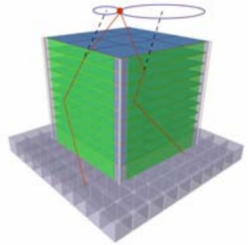
For space-based gamma ray telescope sensitivity predictions, need to model internal gamma ray background. Need:

- p and n transport (i.e. reaction cross sections)
- radioactive isotope generation
- radioactive decays
- prompt gammas
- He, C, N, O cosmic-rays not negligible: reaction cross sections (GeV/n) ?
- IC electron data incomplete from ENSDF?

For solar modeling, need: p and n (5 - 50 MeV) on Fe, Mg, Si and want $\gamma$ continuum

For homeland defense applications: no immediate need, but with active interrogation, might need:

- photonuclear cross sections
- prompt gammas with neutron production
- prompt gammas with fission



# Future

Simulations are switching over to GEANT 4.

ENSDF already built in

What software packages or databases should/**should not** be included?