Astro-E2 Hard X-ray Detector (HXD-II)

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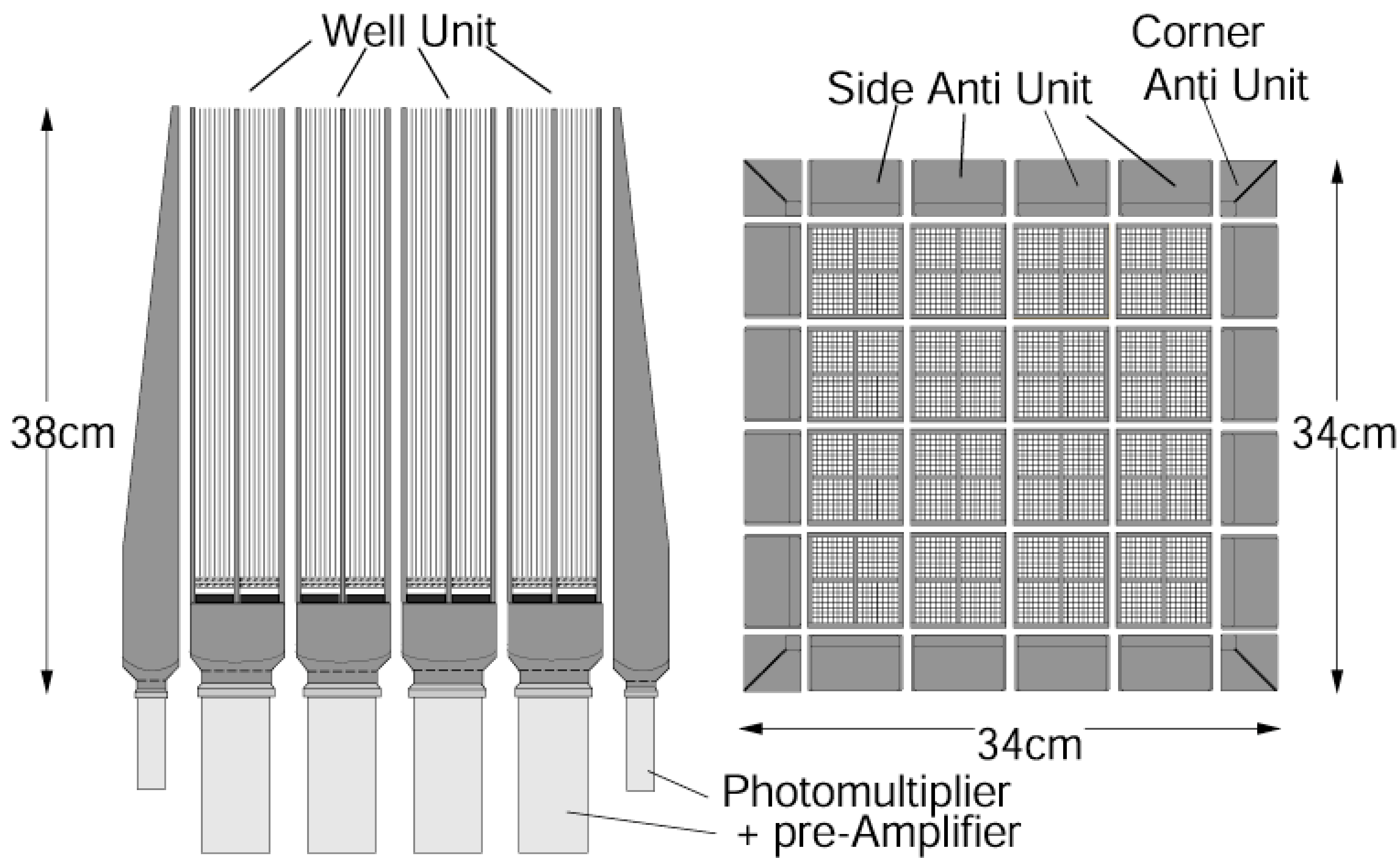
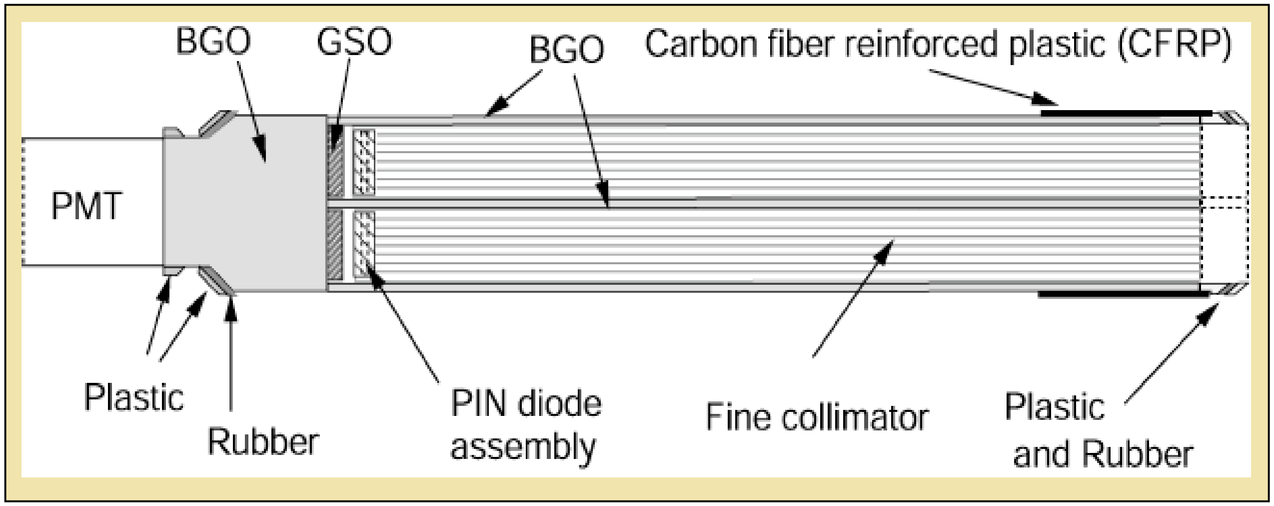
HXD: Detector design

- The Hard X-ray Detector is a non-imaging, collimated instrument sensitive from ~7 keV to ~600 keV, thus dramatically extending Astro-E2's bandpass
- It is a well-type, modular phoswitch detector surrounded by an active shield
- The sensor part of each module actually consists of <u>two</u> parts: the GSO/BGO scintillator counter (read-out by photomultiplier tubes), sensitive over the 30 - 600 keV band, and the Si PIN diode, sensitive over 7-70 keV band
- The HXD consists of 16 (4x4) modules, actively collimated to 4.5^o x 4.5^o, and passively collimated to 0.5^o x 0.5^o; each module in turn has four small sensors
- Field of view depends on energy: at E < 100 keV, the passive collimator is opaque, but above 100 keV, it becomes transparent, opening the FOV to full 4.5^o x 4.5^o

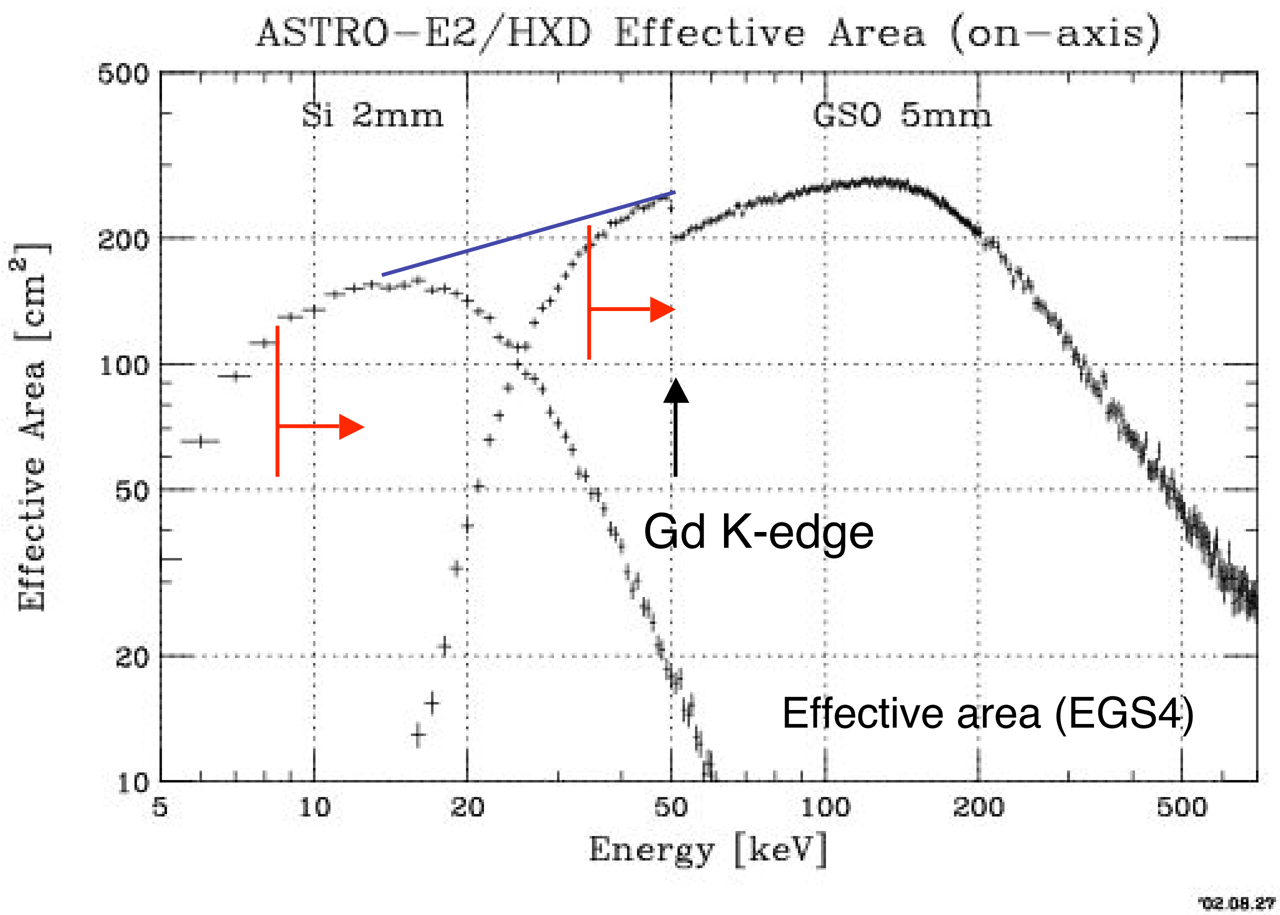
Physical layout of the HXD-II sensors



Schematic and photograph of a single HXD sensor unit

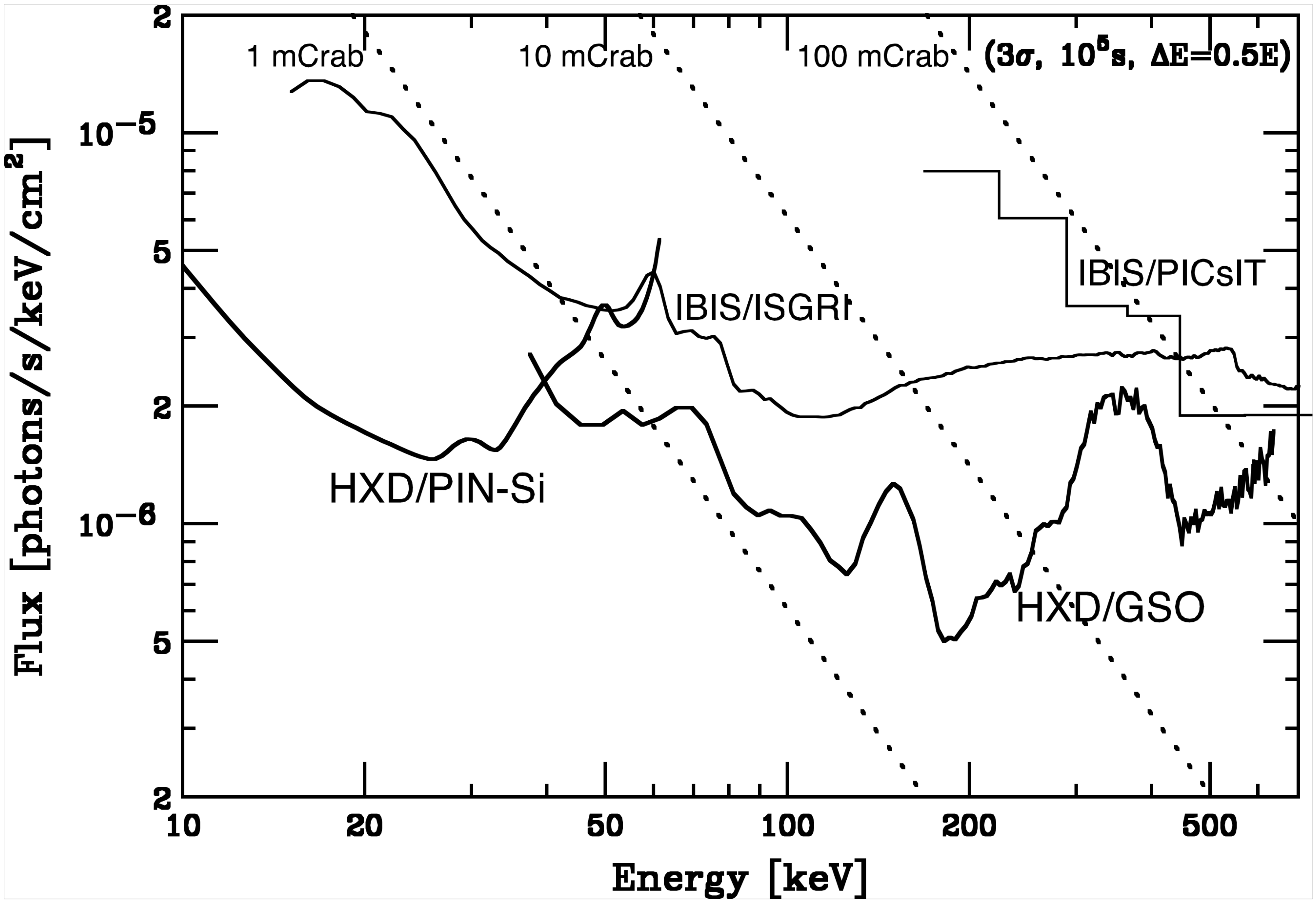


Effective area of the HXD



Overlap of bandpasses (within the HXD, but also with other Astro-E2 instruments) will be important in cross-calibration

HXD continuum sensitivity:, 3 σ, 100,000 s, over a band ΔE = _ E

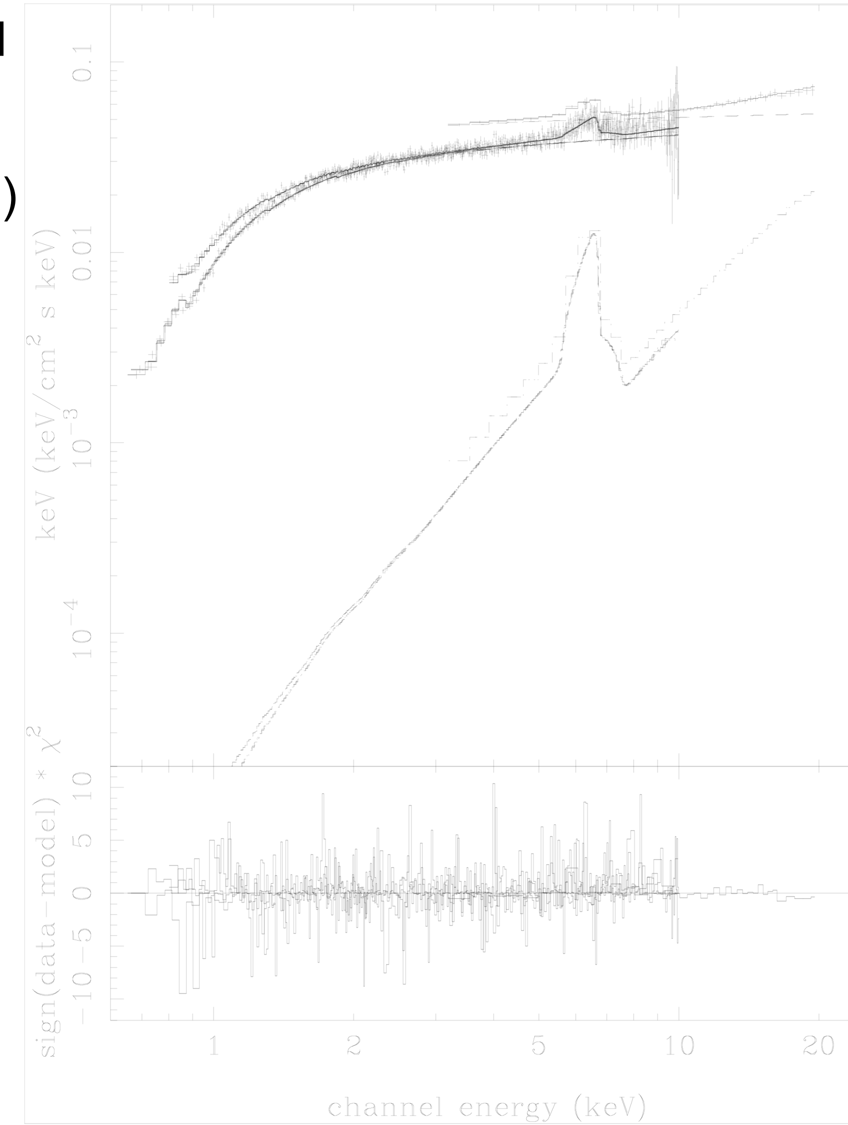


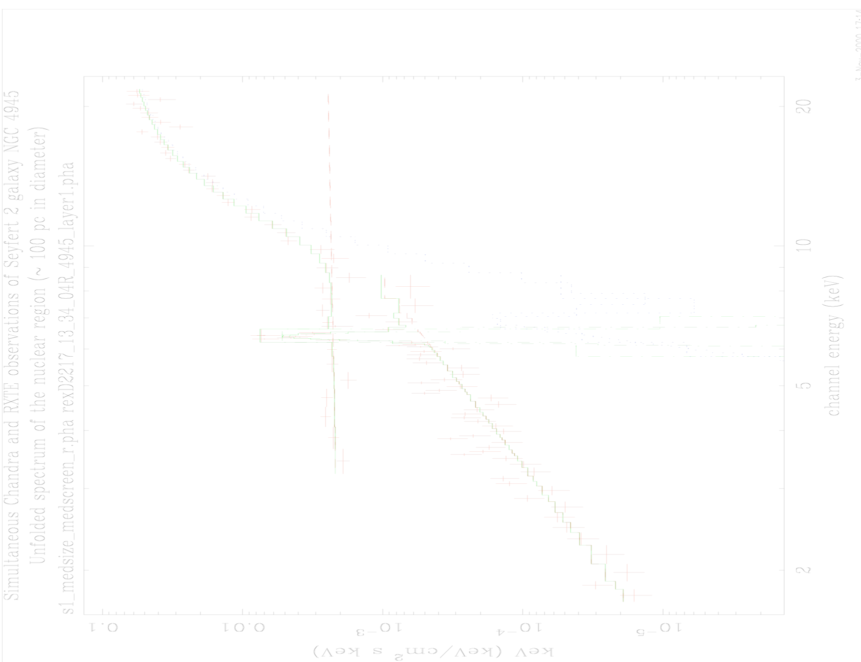
Science with the HXD

- The good sensitivity of the HXD will allow studies of a wide range of astrophysical sources
- Even in the XRS phase of Astro-E2 lifetime, there is significant overlap regarding the science
- Typical observation length needed to get good XRS data (for line spectroscopy) is ~ 100 ks
- For a ~ 3 mCrab source, in 100 ks, the HXD will measure the continuum up to ~ 200 keV

Science with the XHD

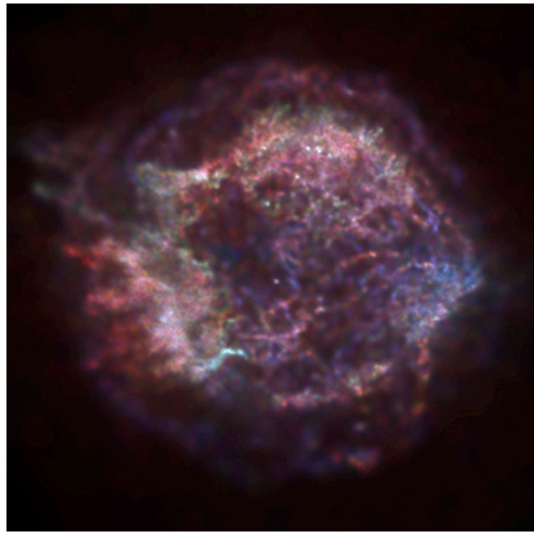
- This includes compact sources (AGN and binaries), where the measurement of the continuum will reveal the nature of the Compton reflection component (IC 4329a)
- It will allow a study of the hard, absorbed continuum in Seyfert 2s, and will help in assessing their contribution to the CXB above 10 keV (NGC 4945)

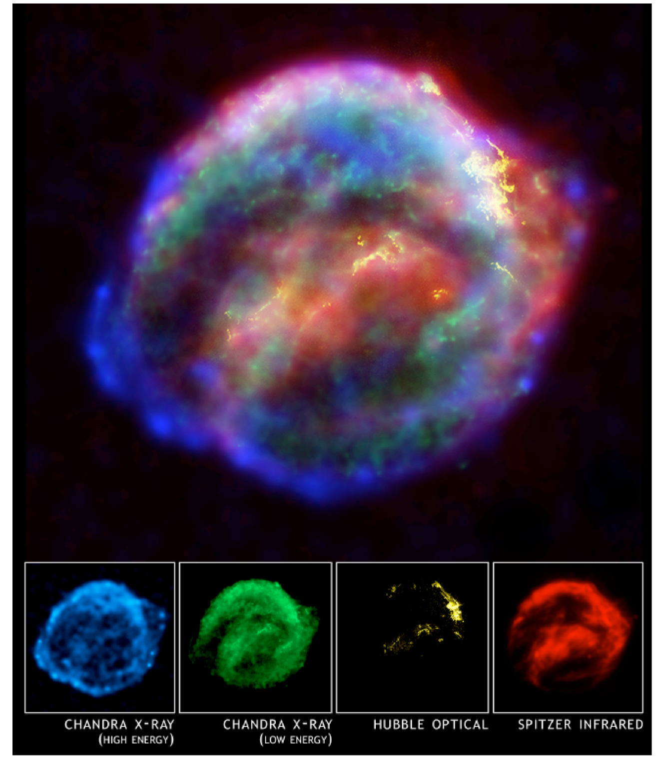




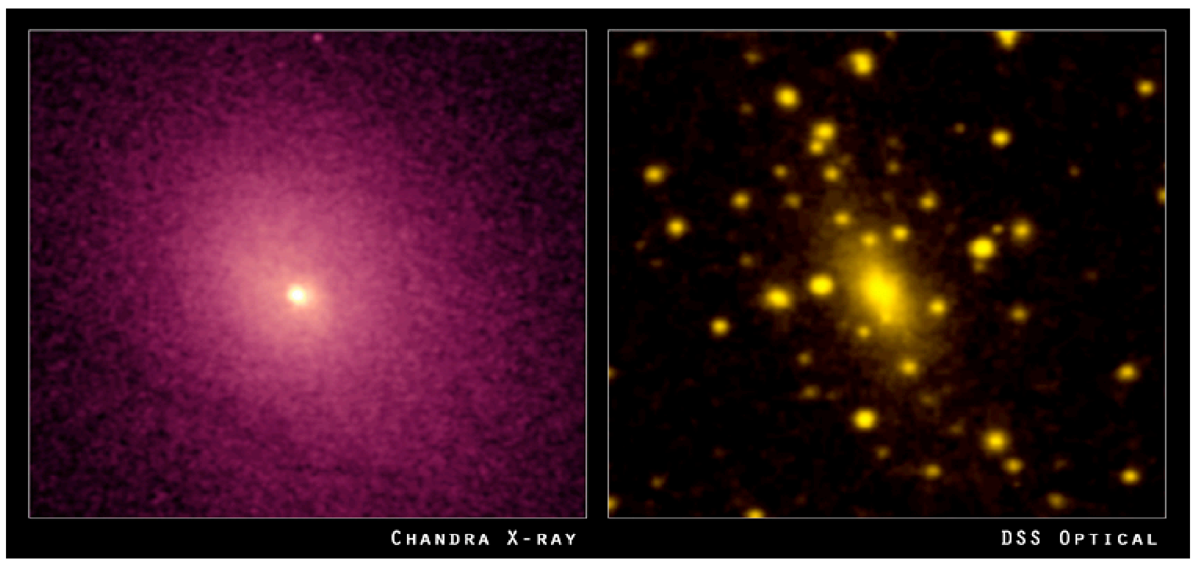
Science with the HXD

- Diffuse sources are also great targets:
- In supernova remnants, hard X-rays might point to the origin of cosmic rays
- Examples: Cas-A, Kepler on the right



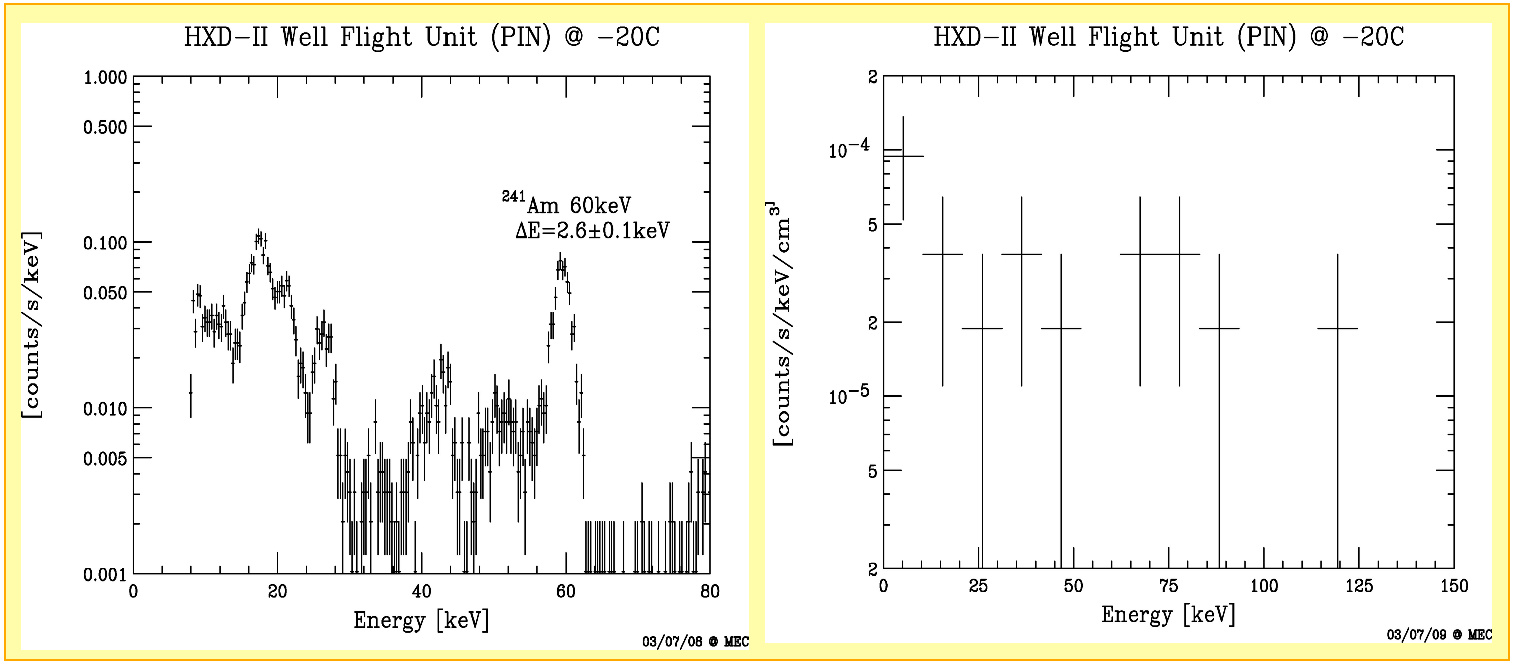


- Hard X-ray emission from clusters is also expected – via energetic electrons (inferred from radio data) by Compton-scattering the CMB (see Abell 2029 on the right)



HXD-II PIN silicon sensors

- Silicon PIN diodes are thin (2 mm) slices, located in front of the GSO sensors
- They absorb & detect photons below ~ 40 keV, but become transparent above that, allowing detection in the GSO
- Major recent change (over HXD-I) is the reduction of electronic noise and thus improvement of energy resolution (from 3.5 to 2.6 keV FWHM), allowing the extension of bandpass to ~ 7 keV from ~ 10 keV



Energy spectrum of the PIN diode (left) and background spectrum of the PIN diodes under the quasi-flight configuration

HXD-I: Energy resolution ~ 3.6 keV

Goal for the HXD-II: lower the low energy threshold to ~ 7 – 8 keV

Achieved via reduction of electronic noise, which improved the energy resolution (to 2.6 keV) and allowed lowering the threshold

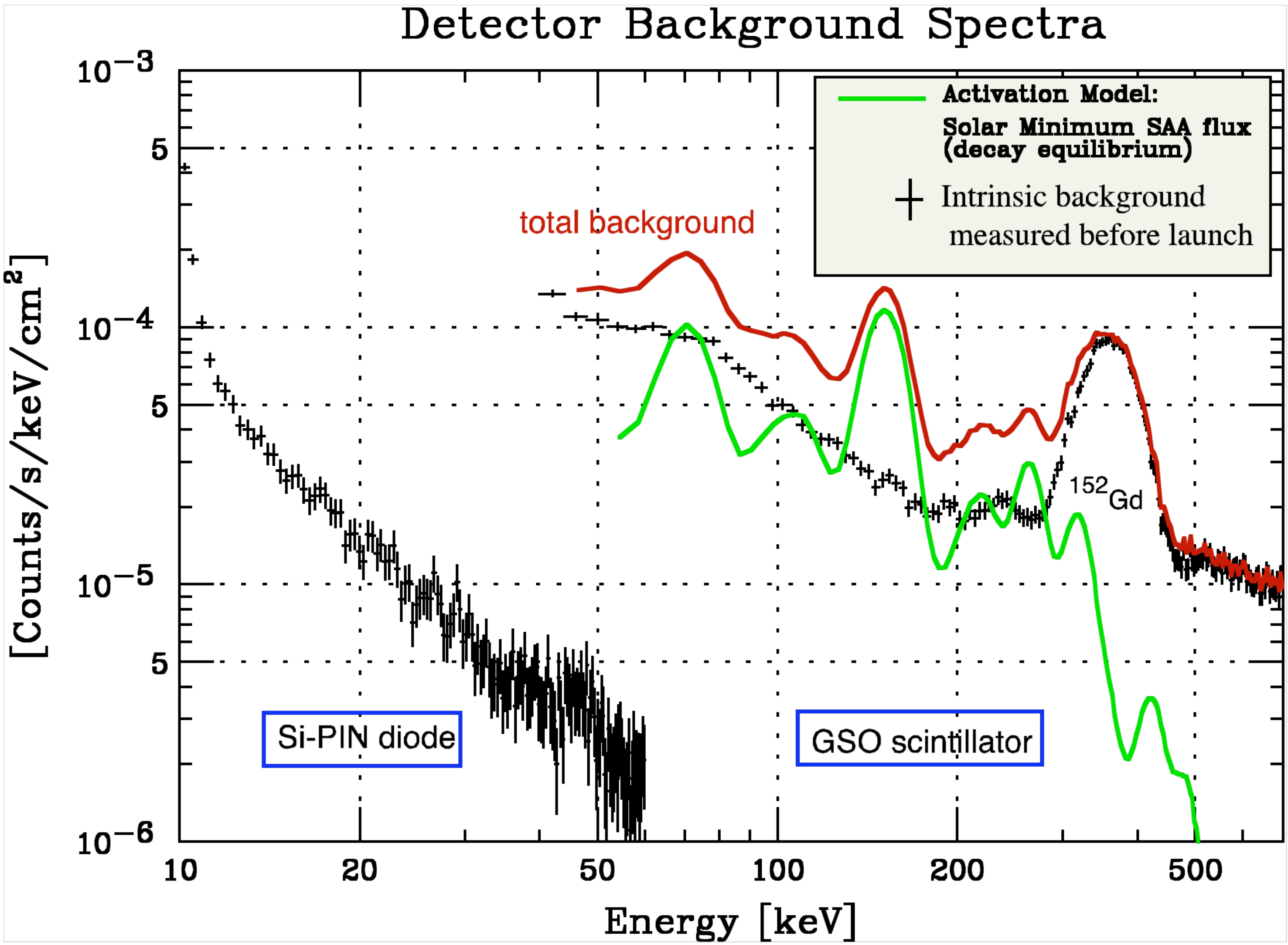
GSO sensors: Design details and the background rejection

- Energy resolution of the GSO units is about 10%, measured at 662 keV (using ^{137}Cs source)
- The “well” design allows much better background rejection than was possible in previous schemes
- The “good photon” detector is actually GSO (Gadolinium Silicate) and it is surrounded by five sides of BGO (Bismuth Germanate)
- The signal from the GSO/BGO units is read out by photomultiplier tubes

GSO sensors: background rejection

- For the GSO/BGO sensors, the technique employed here relies on different rise/decay times τ for the two materials: BGO has τ of ~ 700 ns while GSO has τ of ~ 120 ns
- Thus an event associated with a photon or a particle that interacts with the shield can be easily identified and rejected – this applies to both the GSO/BGO units and in the Si PIN diode data
- HXD will *not* “rock” to measure the background (as was the case for HEXTE)
- The residual background will be predicted from modeling, using the particle dose history, etc.

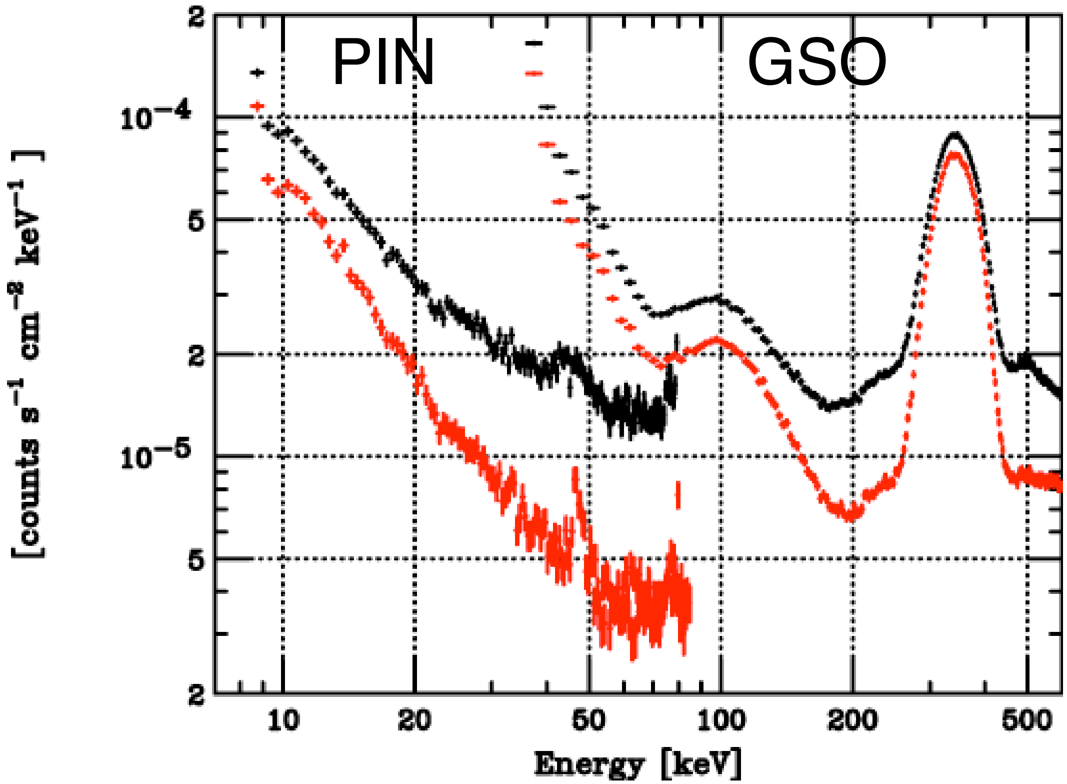
Expected HXD background



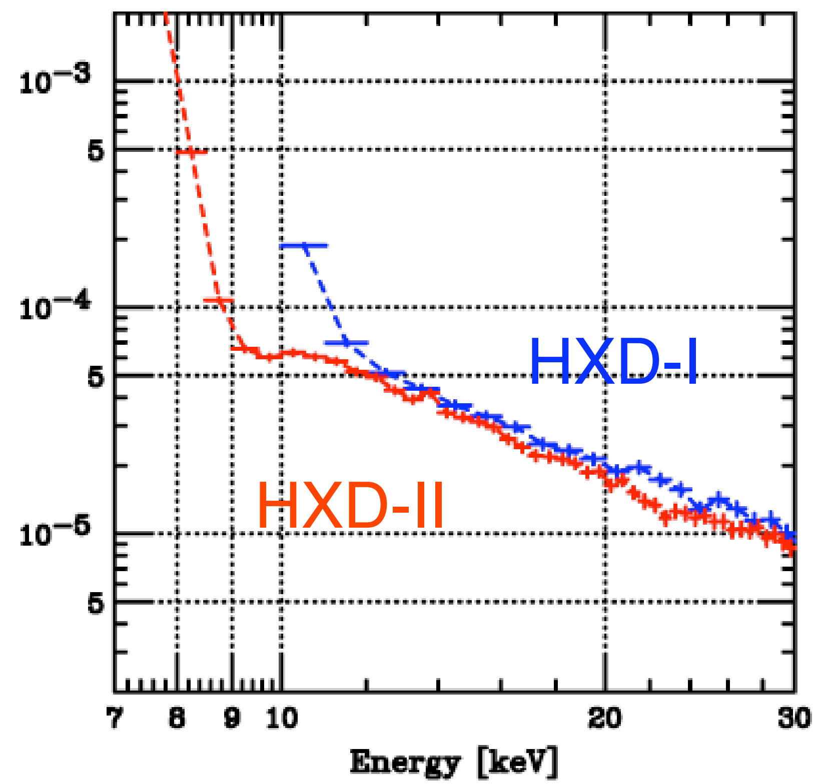
Intrinsic Background

PSD only

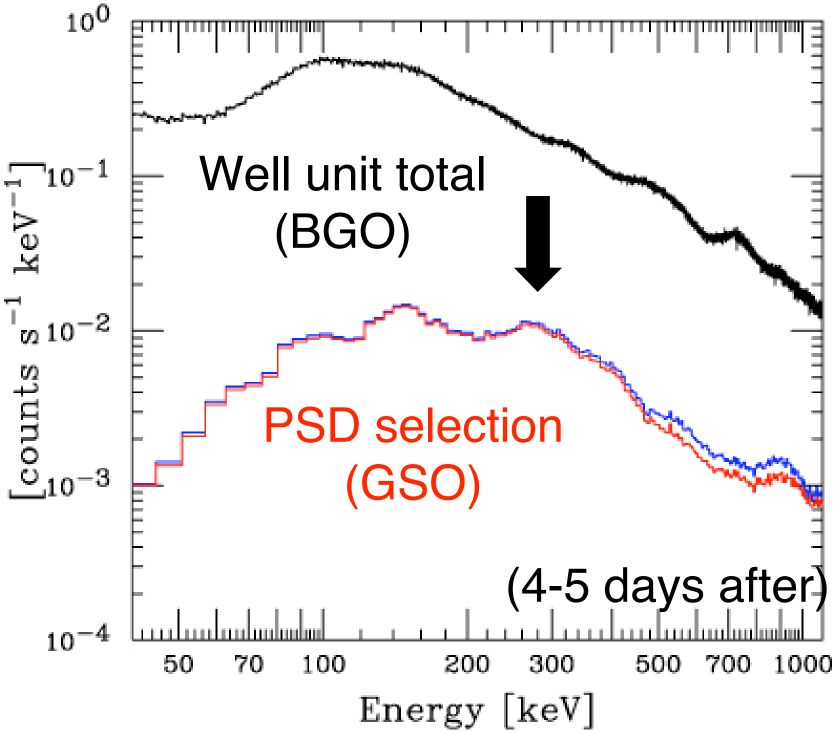
/w Hit-pattern rejection (4units)

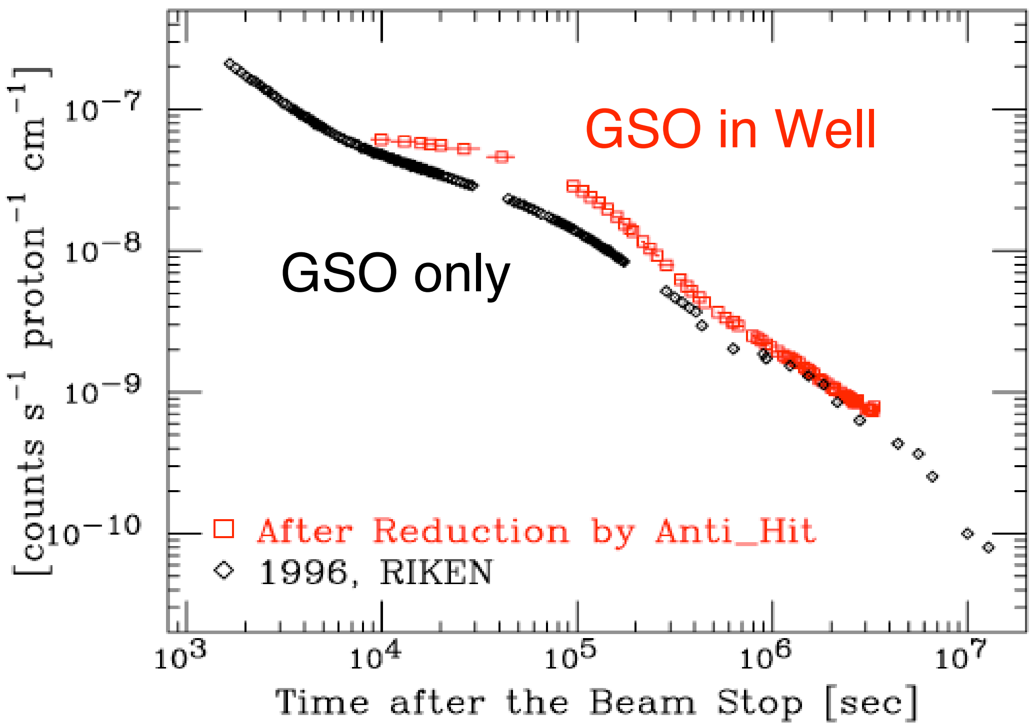


Lower threshold can be < 10 keV



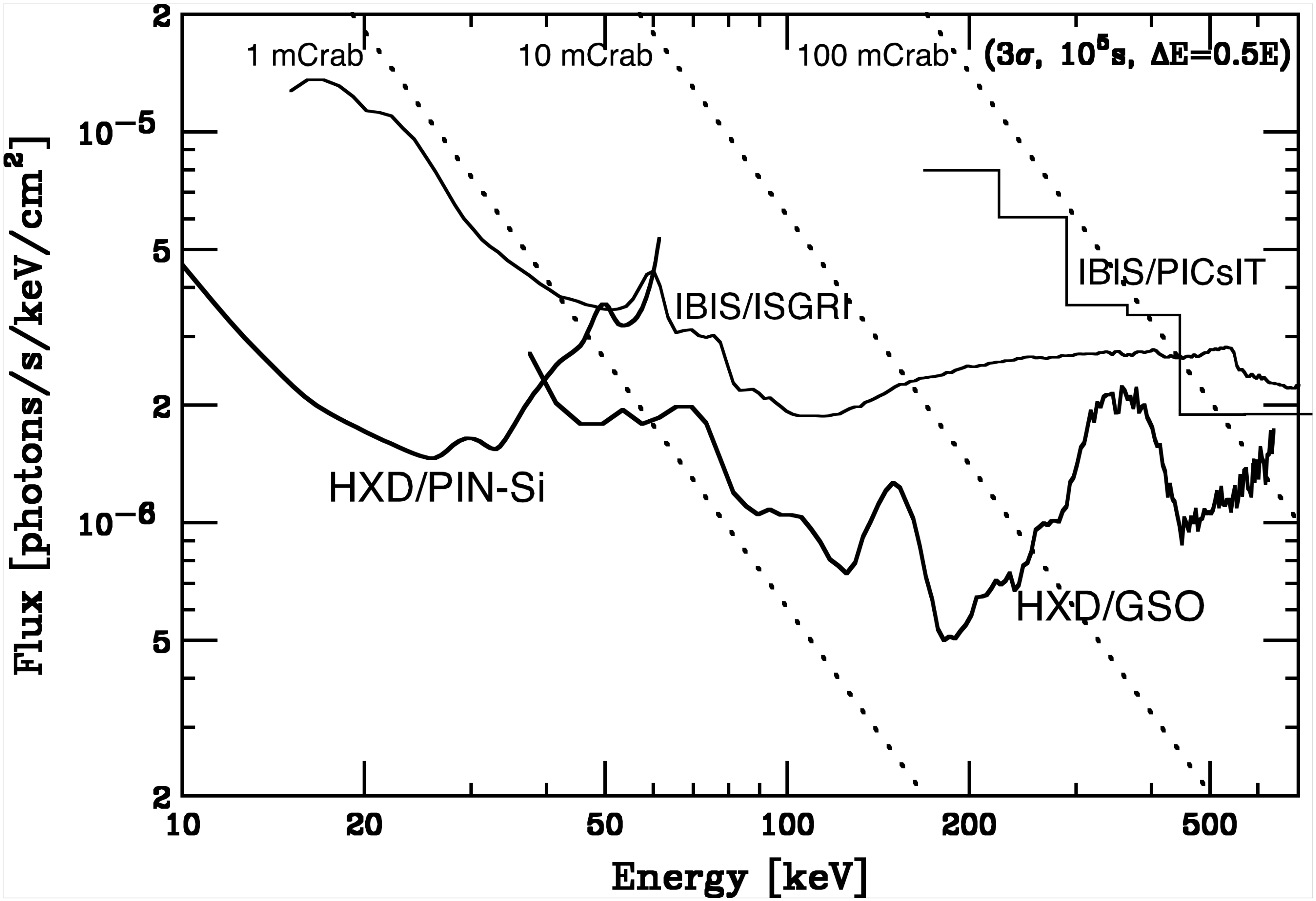
Activation measurement



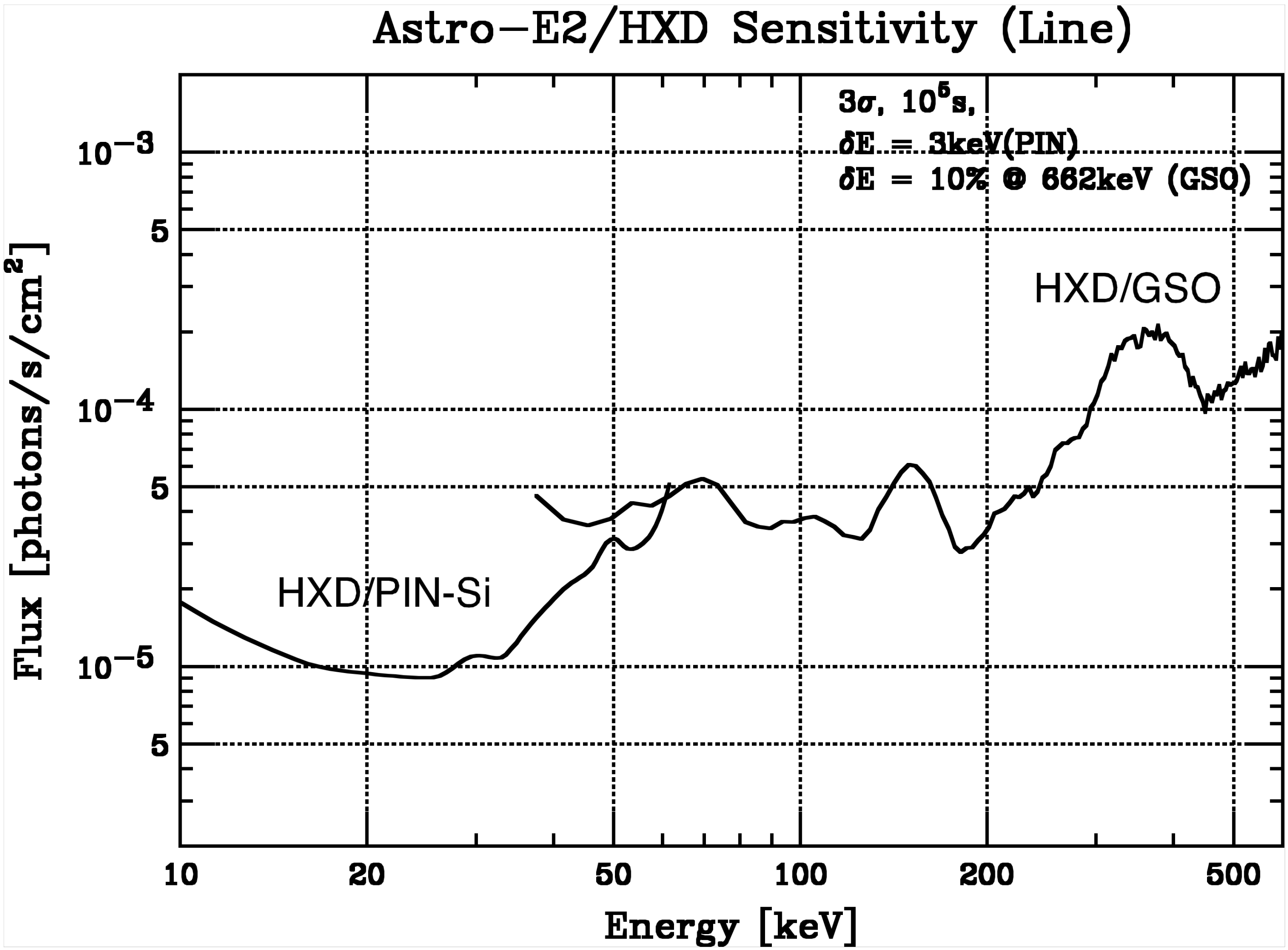


- Activation measured by irradiating with the RIKEN cyclotron, 3×10^9 100 MeV protons
- Active BGO shield is very efficient in reducing the activation background
- Activation of the BGO well itself does not affect the long-term background in orbit

HXD continuum sensitivity:, 3 σ, 100,000 s, over a band ΔE = _ E



HXD line sensitivity:, 3 σ, 100,000 s, ΔE = 3 keV (PIN), 60 keV (GSO/BGO)

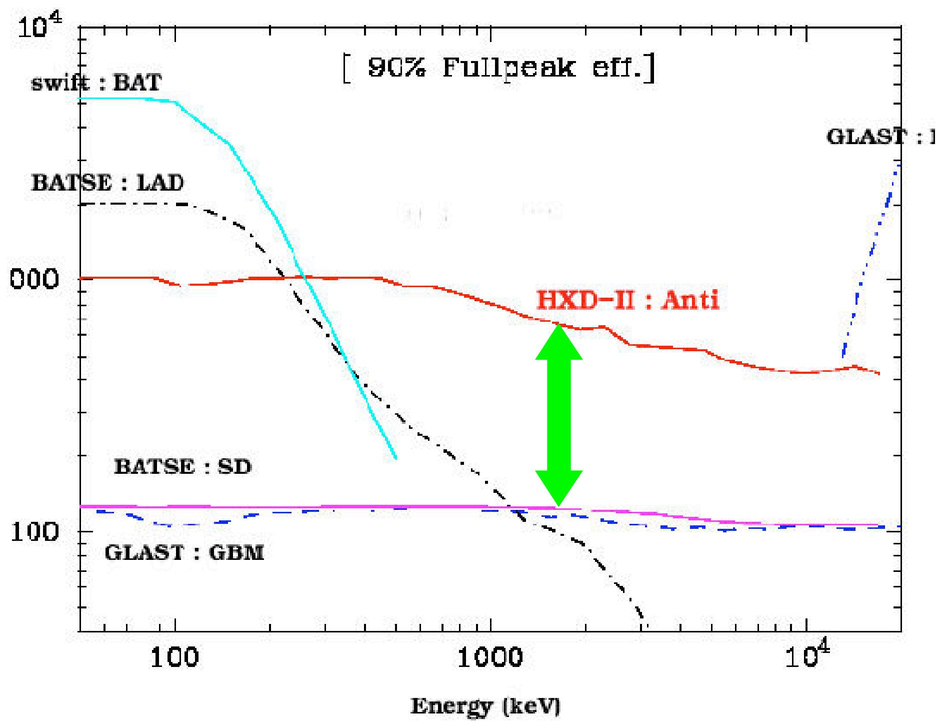


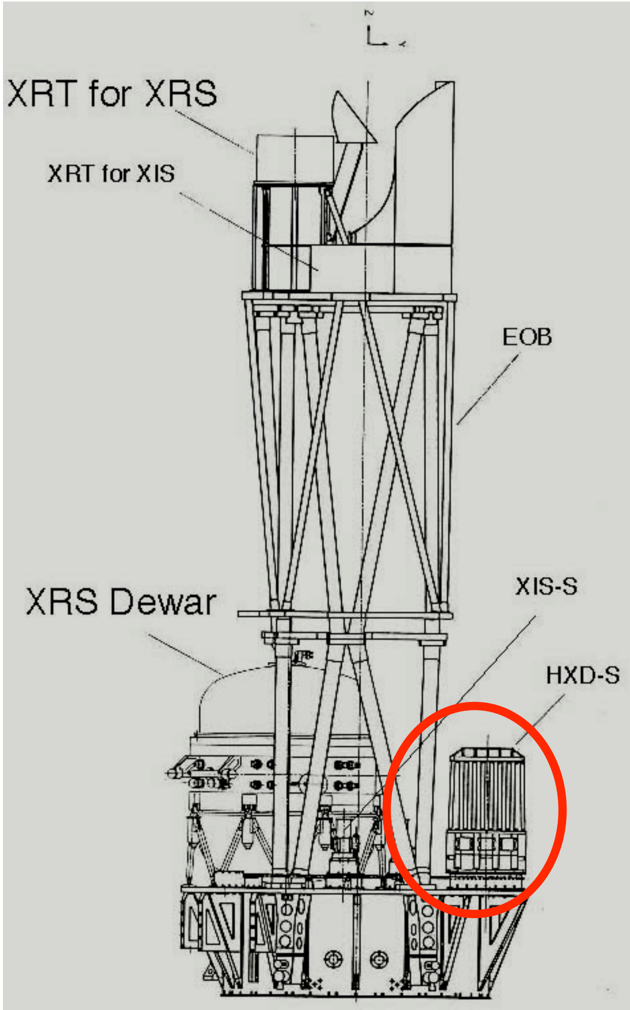
HXD In-Orbit Verification / calibration plan

- The most important cal observation of the HXD will be made using the Crab, but the observations will have to wait several months after the planned June launch until the Crab is visible
- This includes the “boresight,” effective area, as well as the off-axis response
- Cen-A and 3C273, might be used for this purpose; Mkn 421 will be used for search for “hidden spectral features” and PSR B1509-58 will be useful for verification of timing etc.
- Other calibration targets will include the Lockman Hole (for background)

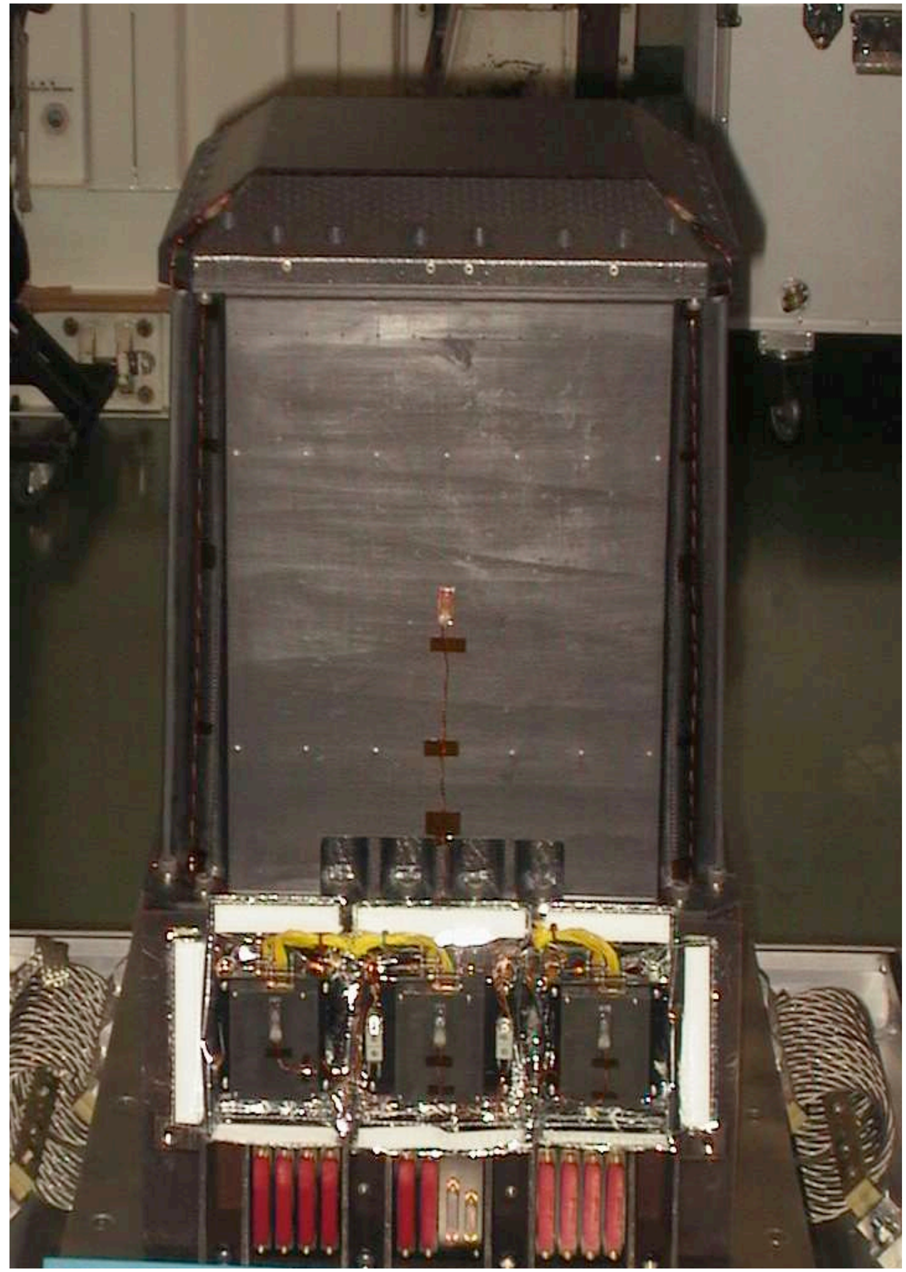
HXD Anti-coincidence shields can be used as GRB detectors

- Large Effective Area ～800 cm^2
- Wide Field of View ～2π sr
- Energy range 50 keV – 5 MeV
- Expect ~ 2 bursts/week
- Crude position (3^o) by relative count rate





Hard X-ray Detector before installation into Astro-E2



HXD team (June.30.2004 at ISAS/JAXA)