Effects of Neutrons on HXD-PIN Background onboard *Suzaku*

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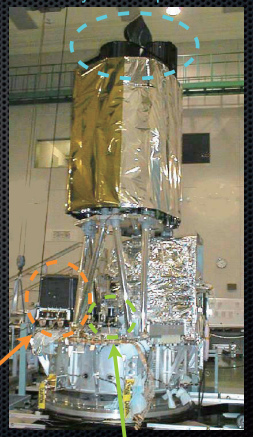
1. *Suzaku*/HXD introduction
2. HXD photon response construction
3. HXD-PIN background estimation

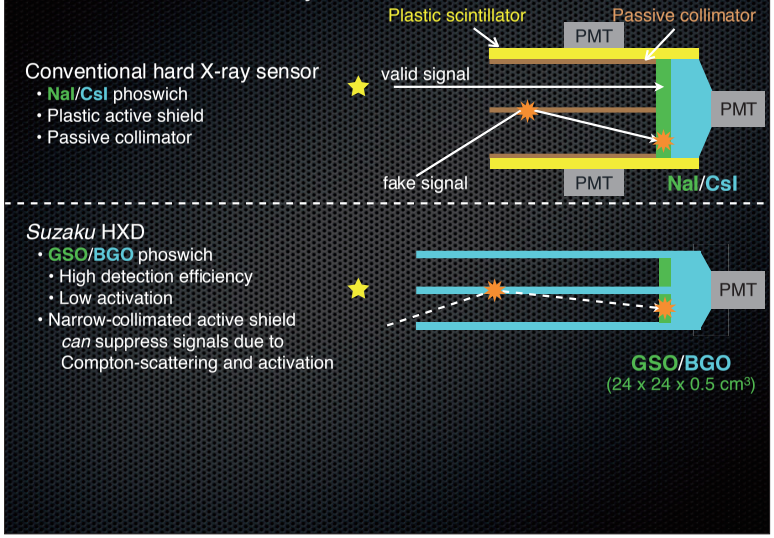
1.1 *Suzaku* Satellite

- Japanese 5th cosmic X-ray observatory
- Launch on 10/07/2005 in Japan
- Altitude: 580 km, Inclination: 34 deg
- Active mission



Suzaku characteristics
- Wide energy range of 0.2-600 keV
- Low and stable background
  → Suitable for detecting low-flux objects

1.2 Hard X-ray Detector onboard *Suzaku*



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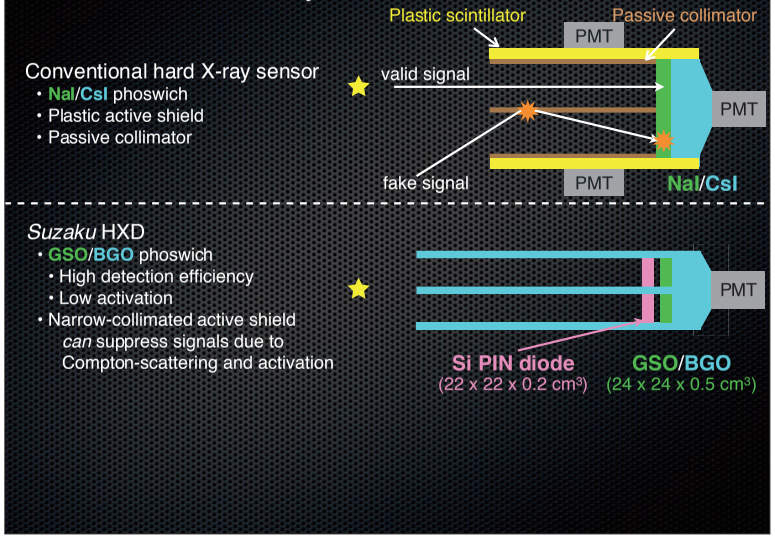

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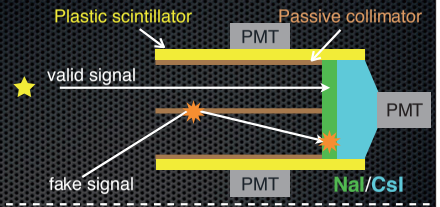
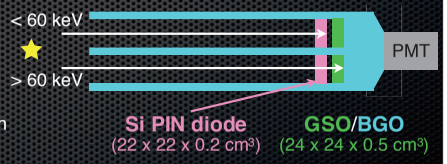
Conventional hard X-ray sensor
- NaI/CsI phoswich
- Plastic active shield
- Passive collimator



Suzaku HXD
- GSO/BGO phoswich
  - High detection efficiency
  - Low activation
- Narrow-collimated active shield
  can suppress signals due to Compton-scattering and activation



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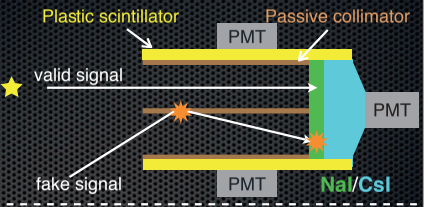

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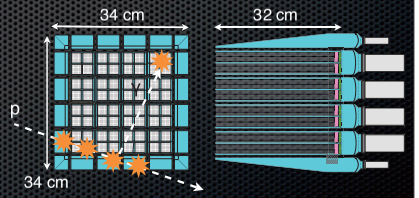
  - Anti-coincidence
  - Large effective area with low dead time



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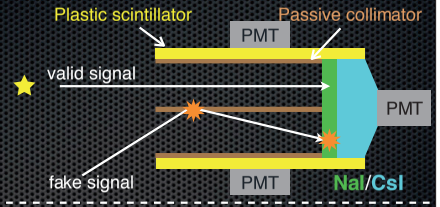

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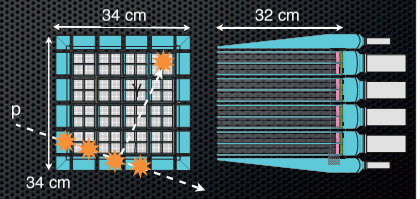
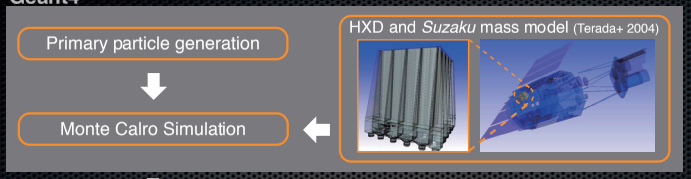


Need to understand HXD's responses to cosmic X-ray signals and radiation background

1.3 ***simHXD*** (Monte Calro Simulatior for HXD)

Geant4



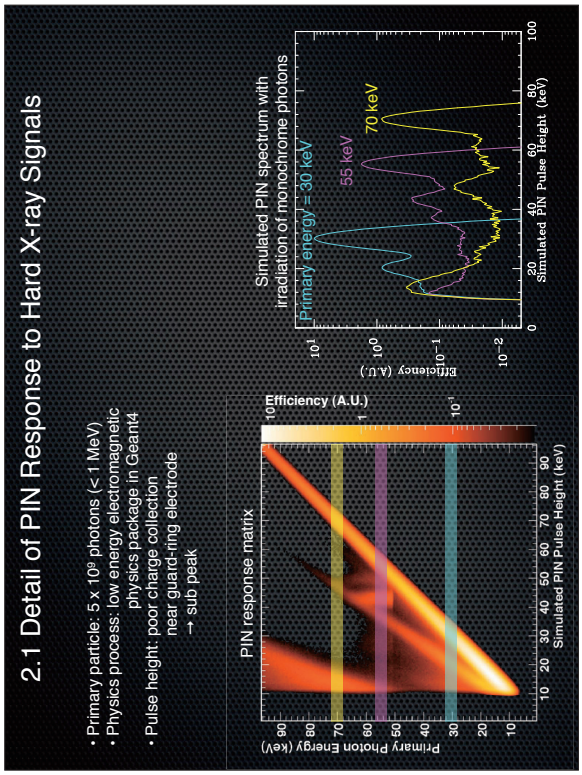
Simulated onboard hardware
- Energy to ADC channel
- Trigger generation

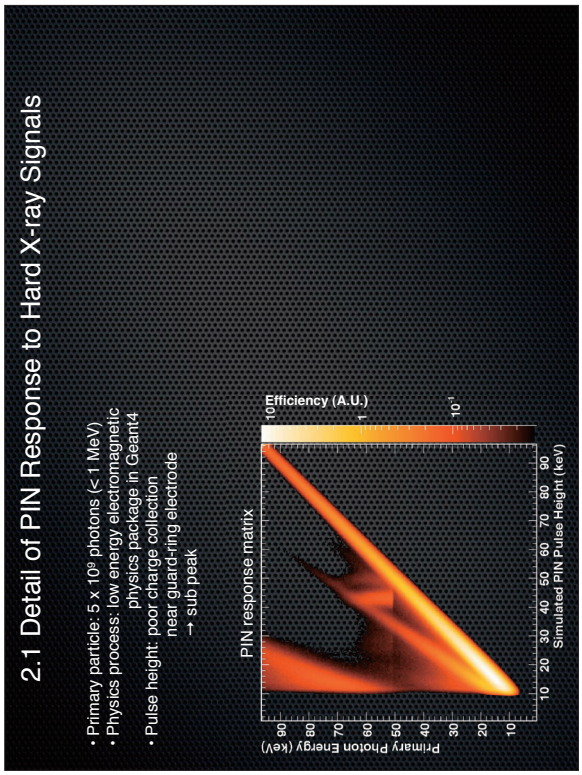
Simulated event list

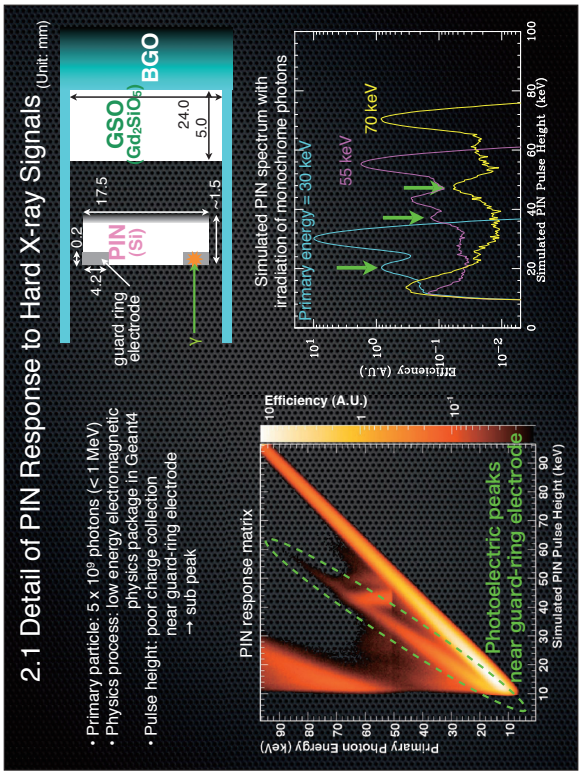
Same analysis as actual data
- Fine event selection
- Histogram extraction

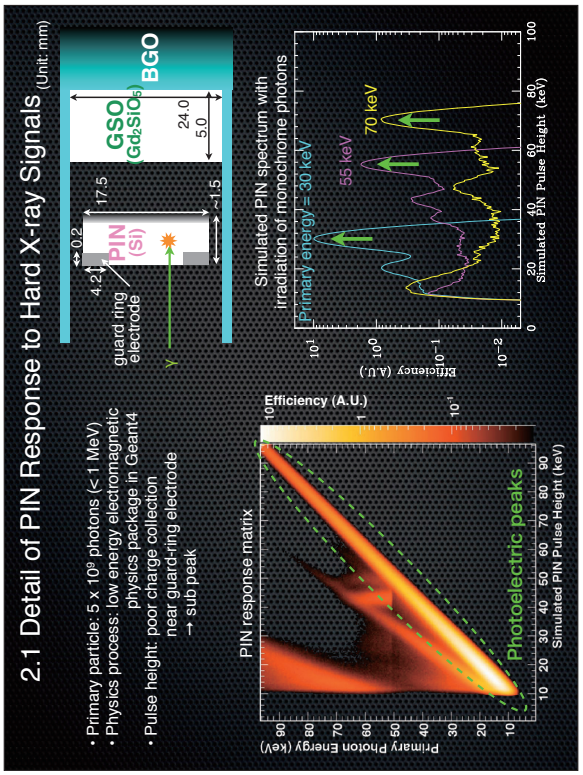
Database
- Hardware calibration
  - Sensor characteristics
  - Electronics response
- Hardware settings
  - Trigger level
  - Anti-coincidence level

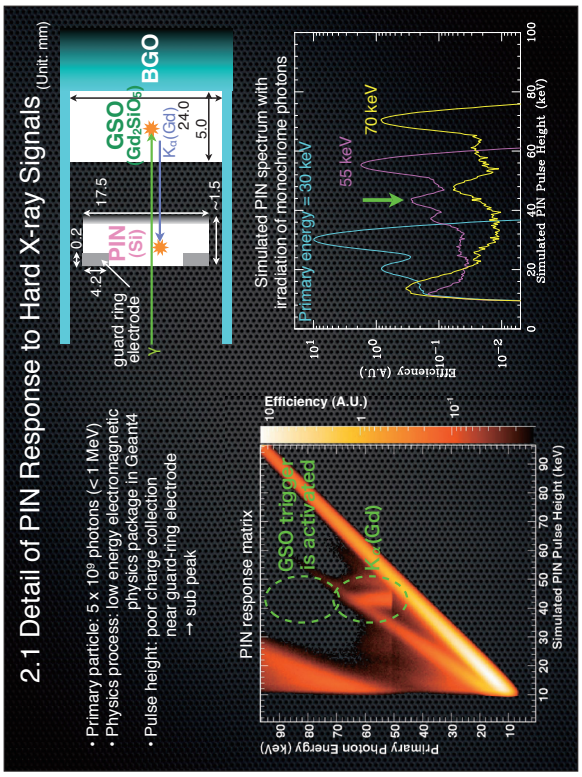
Products
- Detector response
- Simulated energy spectrum

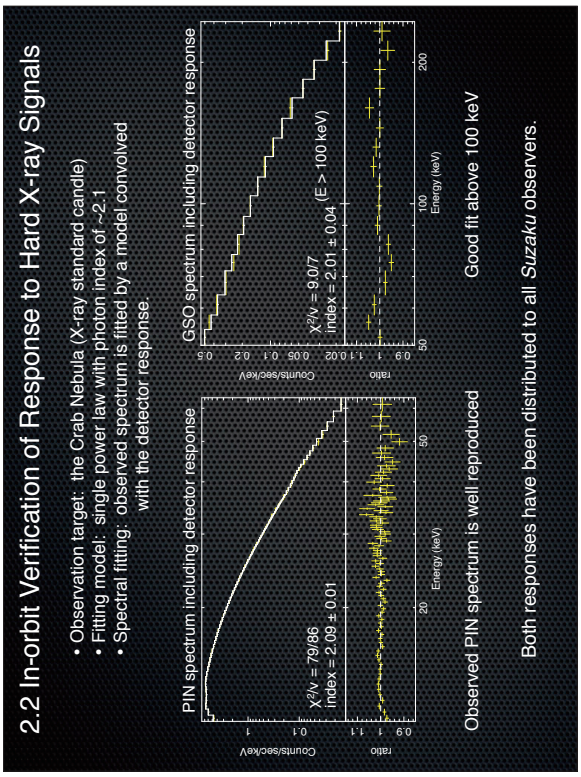


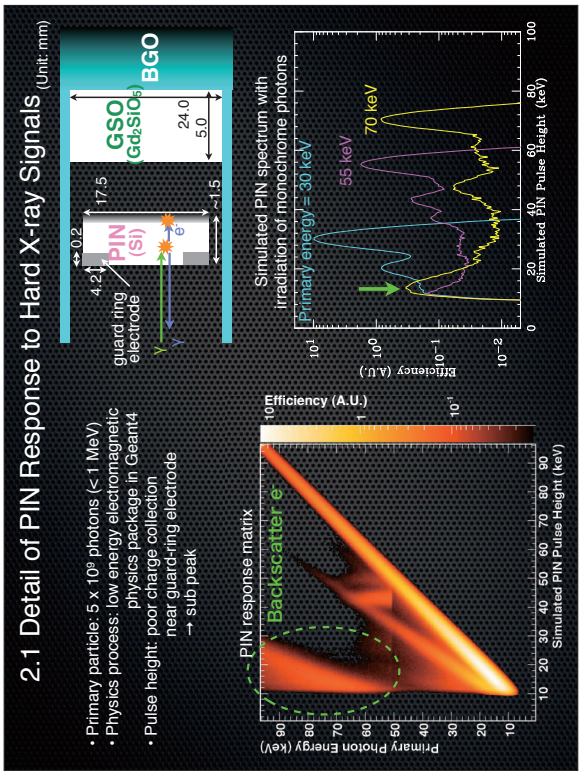


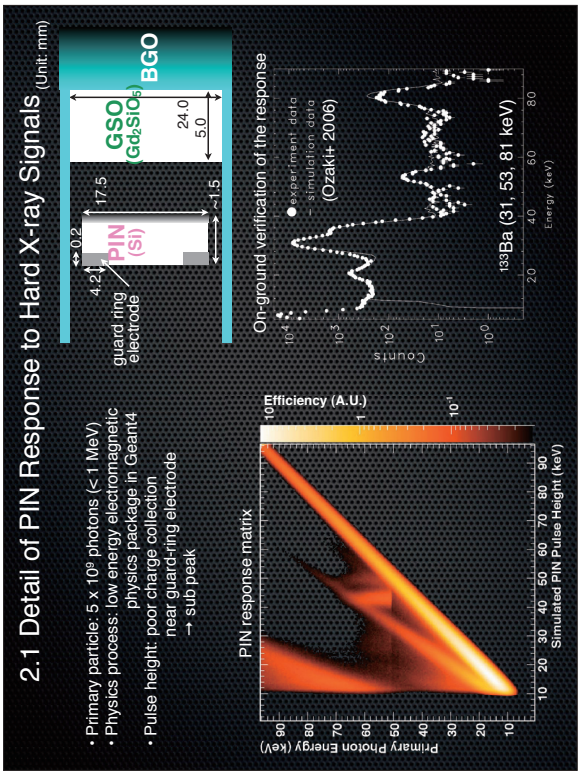








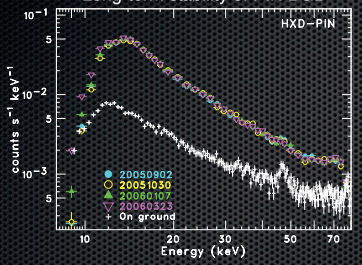




3.1 In-orbit PIN Background

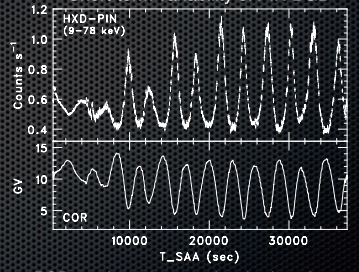
- S/B ~ 0.1 → need for high accuracy of BGD subtraction
- Database observed during earth occultations → HXD BGD model
- High sensitivity of the HXD → high reproducibility of the BGD model
  → full understanding of the BGD origin

Long-term stability of PIN BGD



In-orbit BGD is an order of magnitude higher than ground measured one, but has neither long-term (over one month) build-up nor activation lines.

Short-term variability of PIN BGD



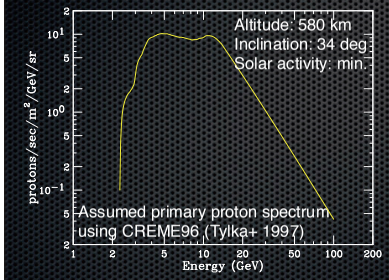
BGD rate is ~0.6 cps and varies by a factor of 2 anti-correlated with cut-off rigidity (COR).

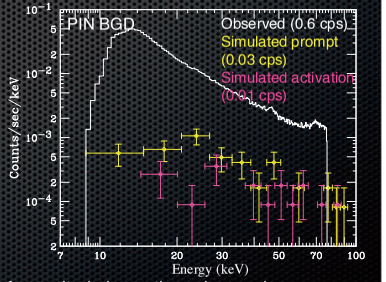
What is the origin of PIN background and its variation?

3.2 Simulation of Backgrounds by Cosmic Ray Protons

Prediction
- The negative correlation with COR → primary cosmic ray protons?
- Active shield vetoes most of the prompt BGD by charged particles
  → short-lived radioisotopes from nuclear activation?

Simulation using MGGPOD (Weidenspointner+ 2005) based on Geant3
- Designed for background simulation of in-orbit gamma-ray detectors
- Calculate activation as well as prompt signals by inputting radiation history
- Verification on *WINDS*, *INTEGRAL*, and *RHESSI* satellites



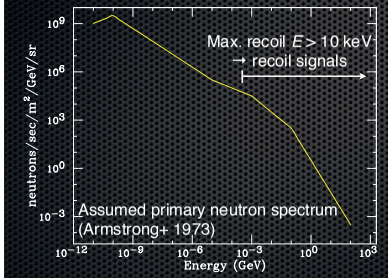


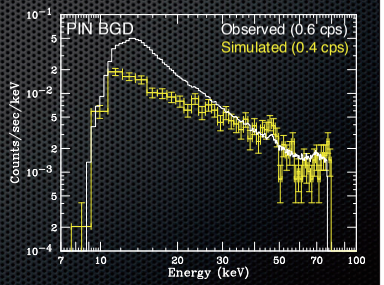
- Prompt and activation BGD is an order of magnitude lower than observed one.
- Prompt BGD is mostly caused by elastic scattering of secondary neutrons.

3.3 Simulation of Backgrounds by Albedo Neutrons

Prediction
- Cosmic ray protons produce neutrons in the atmosphere
- The neutrons elastically collide with Si nuclei → recoil signals
- Expected BGD rate ~ 1 cps/cm² x 1 barn x 1 mol = 0.1 cps (observed ~ 0.6 cps)

Simulation
- Physics process: G4NeutronHPorLElastic (< 20 MeV)
  G4HadronElastic (> 20 MeV)





Albedo neutrons can explain a large fraction of the PIN background

Summary

- Using Monte Carlo simulation, we evaluated detector responses of the HXD onboard the *Suzaku* satellite to hard X-ray, cosmic ray protons, and albedo neutrons.
- The detector responses of HXD-PIN and HXD-GSO to hard X-ray signals has been verified on the actual Crab Nebula data.
- Cosmic ray protons and albedo neutrons produce ~10% and ~70% of the observed HXD-PIN background, respectively.