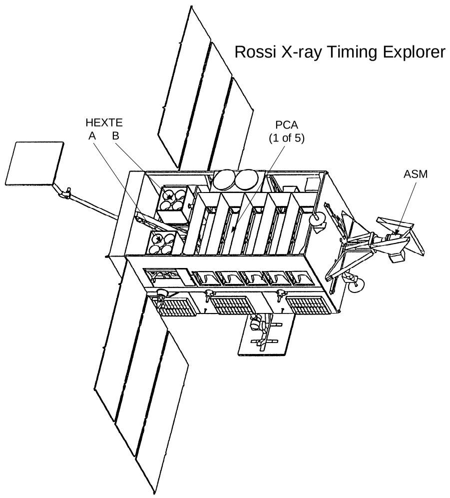
Example: RXTE-PCA

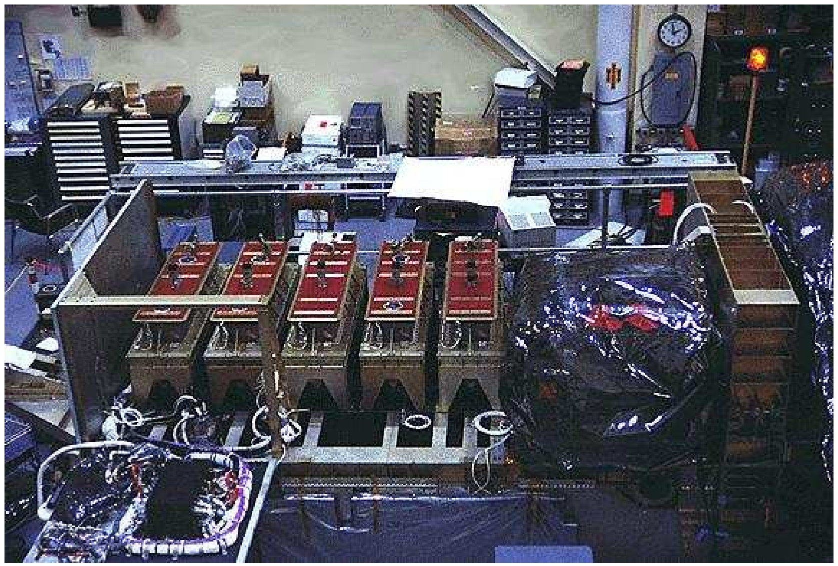


Rossi-X-ray Timing Explorer, Launch 30.12.1995, 3 instruments:

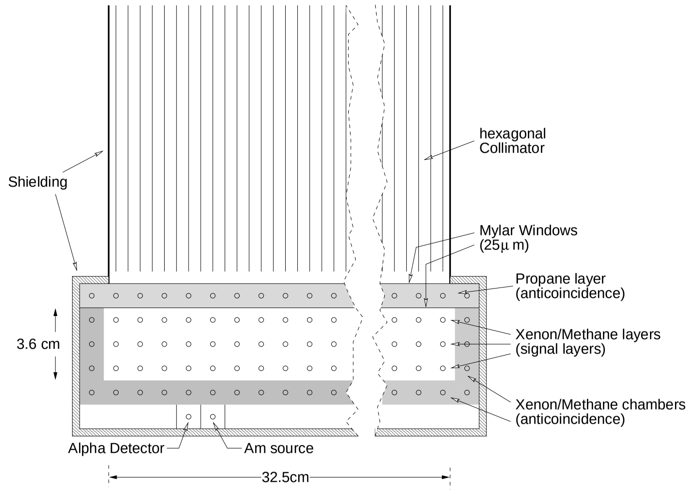
- Proportional Counter Array (PCA, 2–100 keV),
- High Energy X-ray Timing Experiment (HEXTE, 15–250 keV),
- All Sky Monitor (ASM, 2–10 keV)

PCA and HEXTE have μsec timing resolution

Example: RXTE-PCA



Example: RXTE-PCA



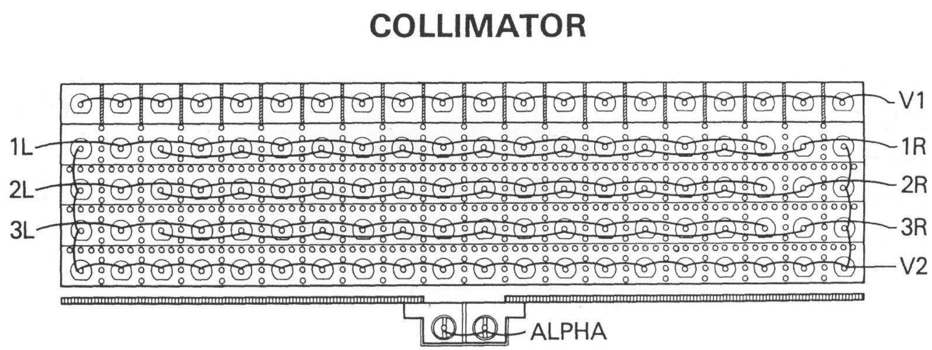
PCA consists of 5 Proportional Counter Units (PCUs), 1 atm pressure

Propane and outer anodes in Anti-Coincidence $\Longrightarrow$ Background reduction

BeCu-Collimator to limit field of view to $\sim 1^\circ$

^{241}Am-source for energy calibration
(simultaneous emission of 59.6 keV γ's and α-particles $\Longrightarrow$ coincidence measurements).

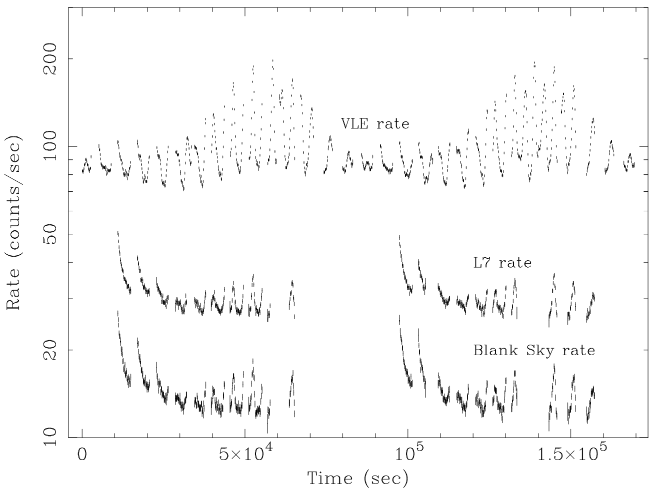
Example: RXTE-PCA



(Jahoda et al., 2006)

Wiring schematics of one proportional counter unit of the *RXTE*-PCA;
V2 is the veto anode

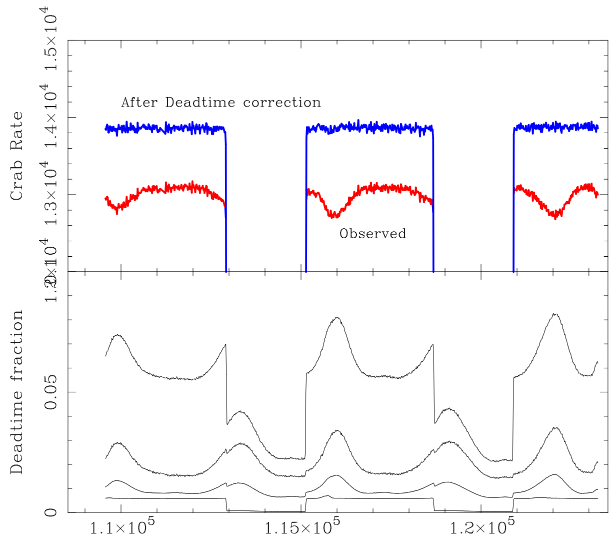
Example: RXTE-PCA



High-energetic particles produce a strong and time-varying background in the detector.

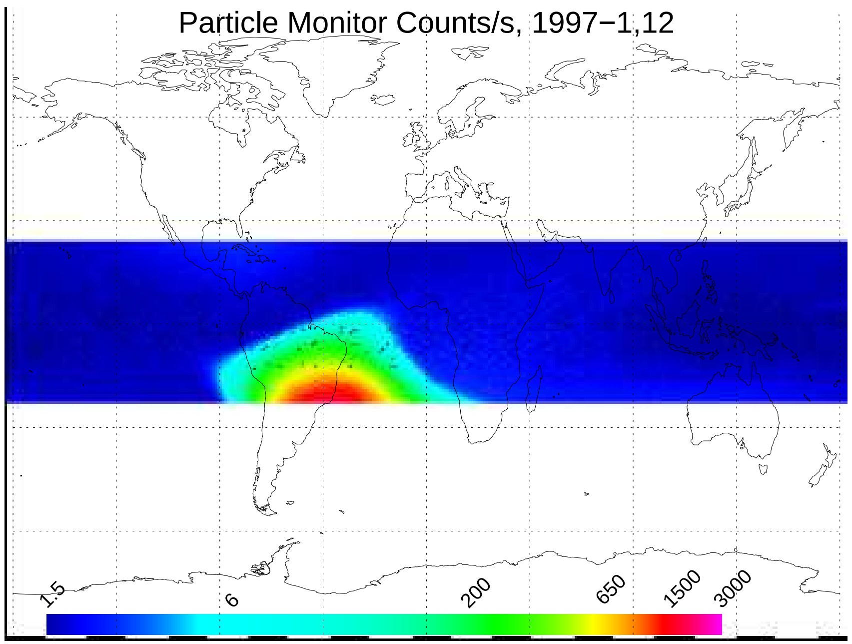
Jahoda et al. (2006; Fig. 25)

Example: RXTE-PCA



Non-photonic events due to particle background of the satellite cause deadtime in the detector countrate which has to be corrected.

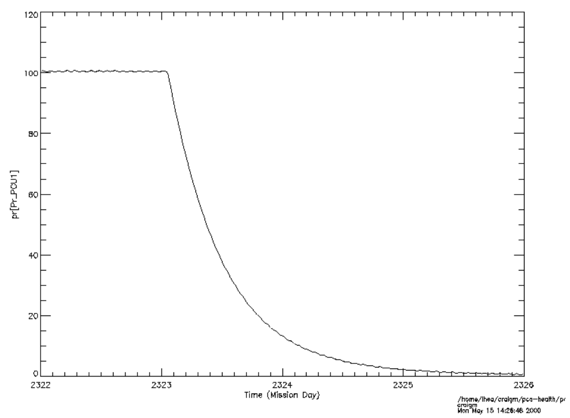
Jahoda et al. (2006; Fig. 30)



Fürst et al., in prep.

Background at ∼500 km height: note the South Atlantic Anomaly

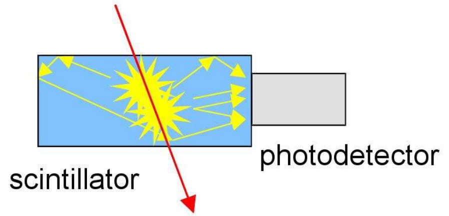
Example: RXTE-PCA



. . . this is what happens once a Mylar window starts having a hole in space

In addition ageing ⟹ Reduction of high voltage, alternate use of different PCUs.

Introduction



Scintillation detectors: ionizing particle deposits energy
$\Longrightarrow$ generates scintillation light
$\Longrightarrow$ light scatters in detector
$\Longrightarrow$ is detected and amplified

Two types of scintillation detectors:

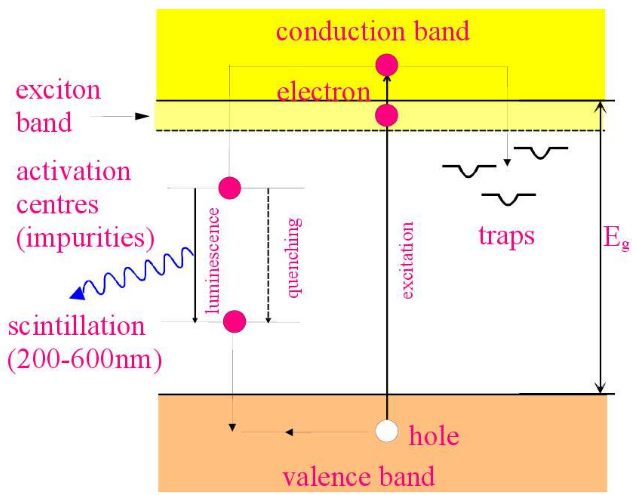
anorganic scintillators (e.g., NaI, CsI) : up to 40000 photons/MeV, high Z, ns to μs pulse durations, radiation hard

organic scintillators (plastics [and liquids)]: up to 10000 photons/MeV, low Z, low ρ, ns pulse durations, medium radiation hard

For space applications: typically use anorganic scintillators

Plastic scintillators are used in anticoincidence setups.

Anorganic Scintillators, I

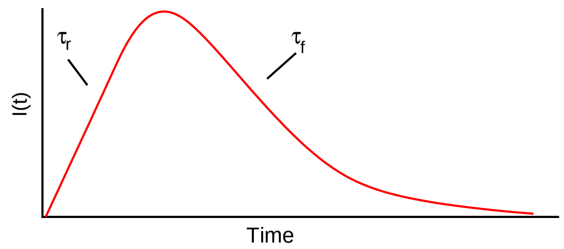


Generation of scintillation light:

- ionizing particle excites electron (and phonons)
- partial de-excitation to an activation center
- de-excitation by emission of scintillation light

CERN/C. D'Ambrosio

Anorganic Scintillators, II



Typical pulse shape:

$$I(t) = I_0 \left(e^{-t/\tau_f} - e^{-t/\tau_r} \right) \quad (3.7)$$

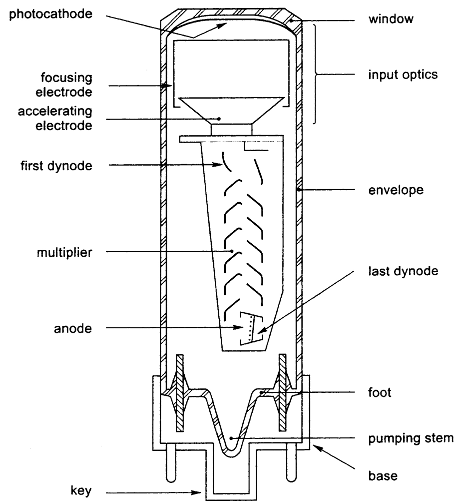
where τ_r, τ_f are the time constants.

Properties of typical scintillators:

Material	ρ g cm^{-3}	λ_{max} Å	τ_f [μs]
NaI(Tl)	3.67	4100	0.25
CsI	4.51	3100	0.01
CsI(Tl)	4.51	5650	1.00
BGO	4.88	4800	0.30

BGO: Bismuth-Germanate; note that there are many more scintillator materials available, the above are the ones typically used in space applications.

Photomultipliers, I



Primary scintillation signal is amplified with a photo-multiplier tube (PMT).

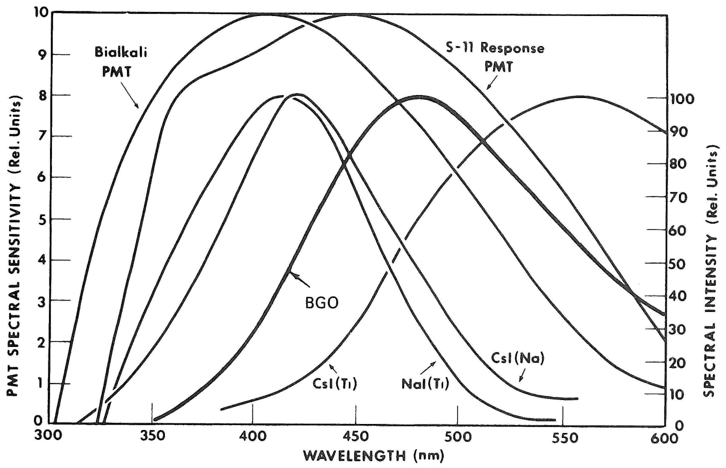
Technical considerations:

- Match PMT to scintillator crystal
  light losses at contact point between scintillator and PMT [scattering!], sensitivity of photocathode must be matched to peak of scintillation light,. . .
- Magnetic shielding
  Typical numbers: 25% decrease in efficiency if a PMT is operated in a 1 mT field!

Alternatives to PMTs: e.g., microchannel plates

Philips Photonics after H. Spieler

Photomultipliers, II



Knoll

Spectrum of several scintillators and efficiency of typical photocathode materials.

Typical Numbers

Typical numbers for a scintillator / PMT system for a 511 keV gamma-ray (after Spieler):

- 25000 photons at scintillator
- 15000 photons hit photocathode
- 3000 electrons at first dynode
- 3×10^9 electrons at anode

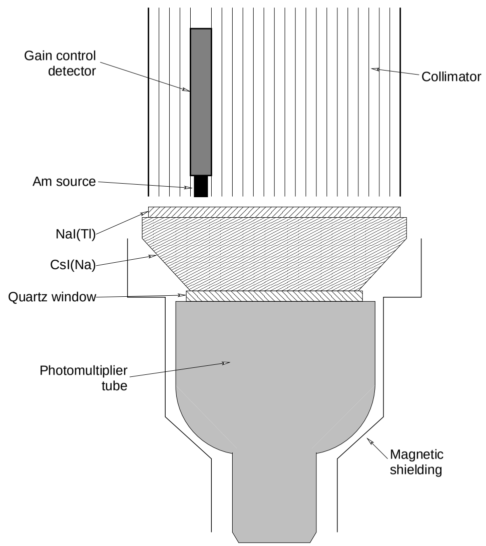
giving 2 mA peak current.

Energy resolution determined from smallest "quanta", i.e., here the number of electrons at the first dynode. Therefore for this example

$$\frac{\Delta E}{E} \sim \frac{2.35}{\sqrt{3000}} = 5\% \text{ at } 511\,\text{keV} \quad (3.8)$$

Typically scintillators are a factor 1.5 worse because of nonuniformities.

HEXTE

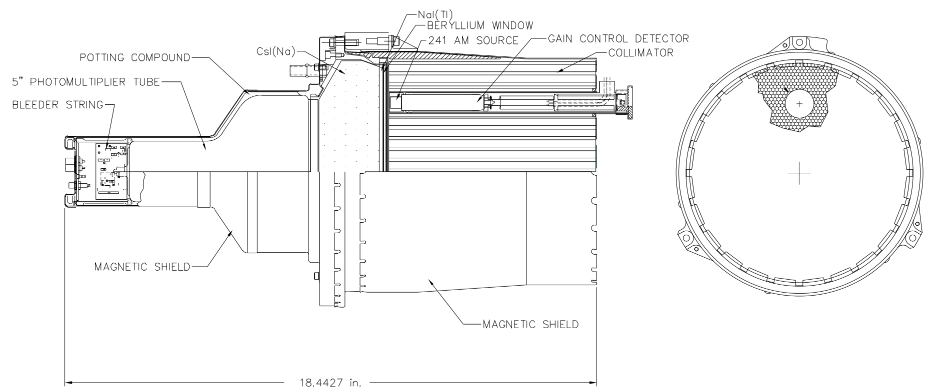


Phoswich: Combination of two scintillators with different decay times
$\Longrightarrow$ background discrimination!

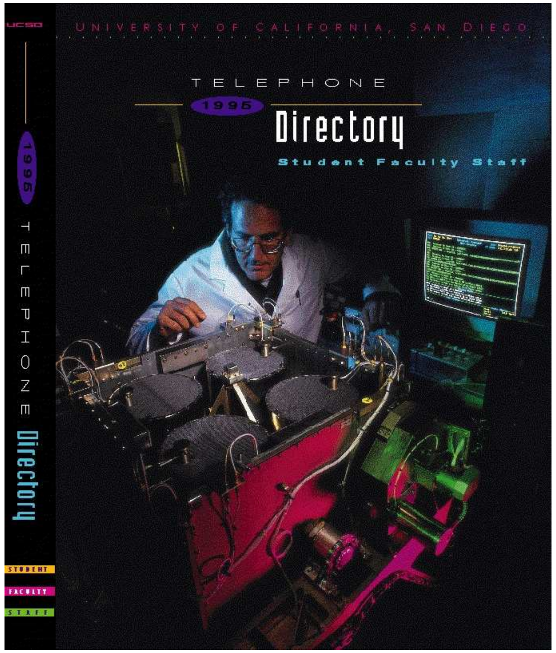
Most common: NaI(Tl) and CsI(Tl)

Example: High Energy X-ray Timing Experiment on *RXTE* (HEXTE), sensitive ~20 keV–200 keV.

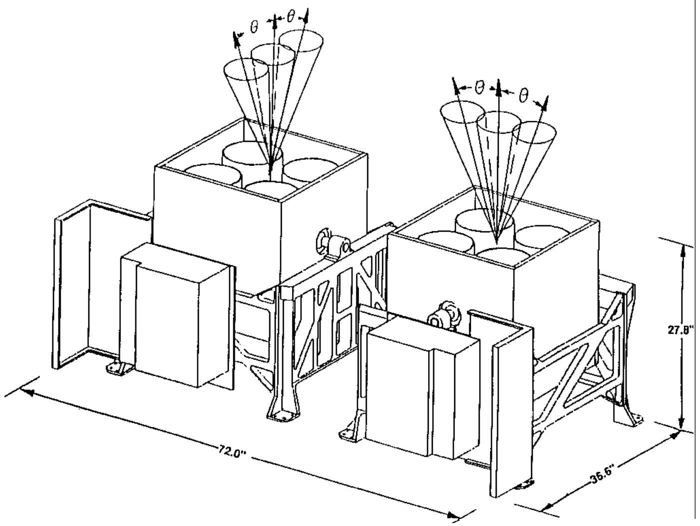
HEXTE



Rothschild et al., 1998



HEXTE



To allow background subtraction, HEXTE clusters perform source–background–rocking (typical timescales: 16 s or 32 s).

NASA/UCSD