Segmented Gamma-Ray Scintillator Detectors with Directional Capabilities

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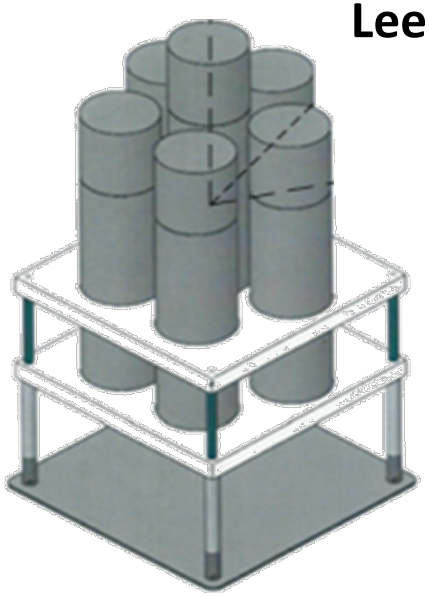
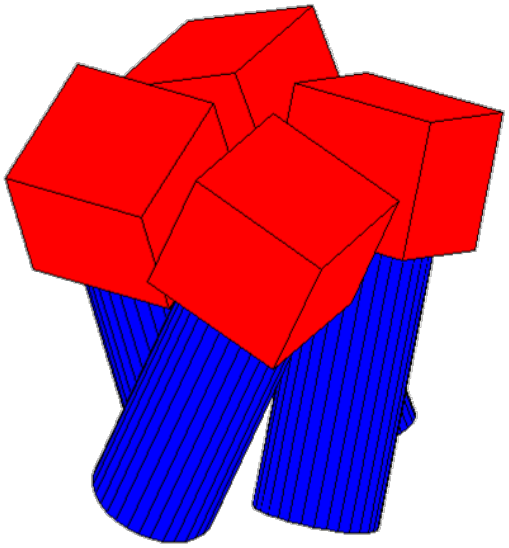




Motivation: Sub-MeV Transient Astronomy

- EM Counterparts
  - Gravitational waves (NS-NS merger - short GRBs?)
  - High energy neutrinos (Hadronic processes?)

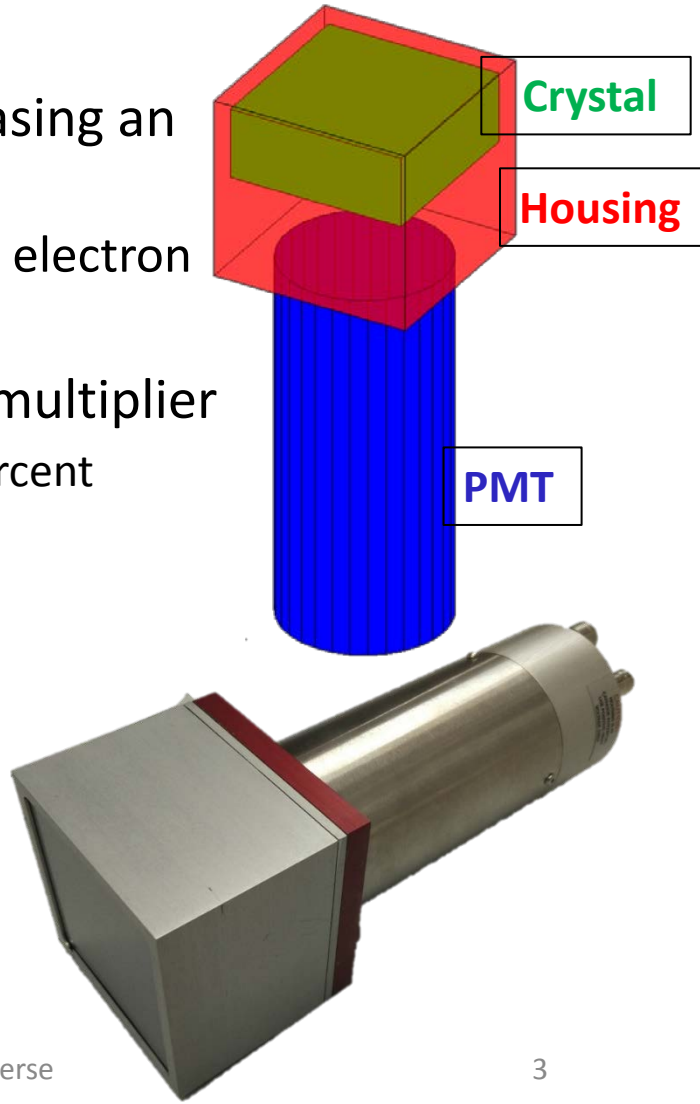
- And:
  - GRBs
  - Soft gamma-ray repeaters

Crystal Scintillator

- Crystal absorbs/scatters γ-ray photon, releasing an electron that generates scintillation
  - Scintillation intensity is proportional to the electron energy
- Light is reflected and collected by a photo-multiplier
  - Electron energy can be analyzed up to a few percent
  - **Photon direction information is lost**

- 4π sr response

  → Source analysis requires significant flux of photons.

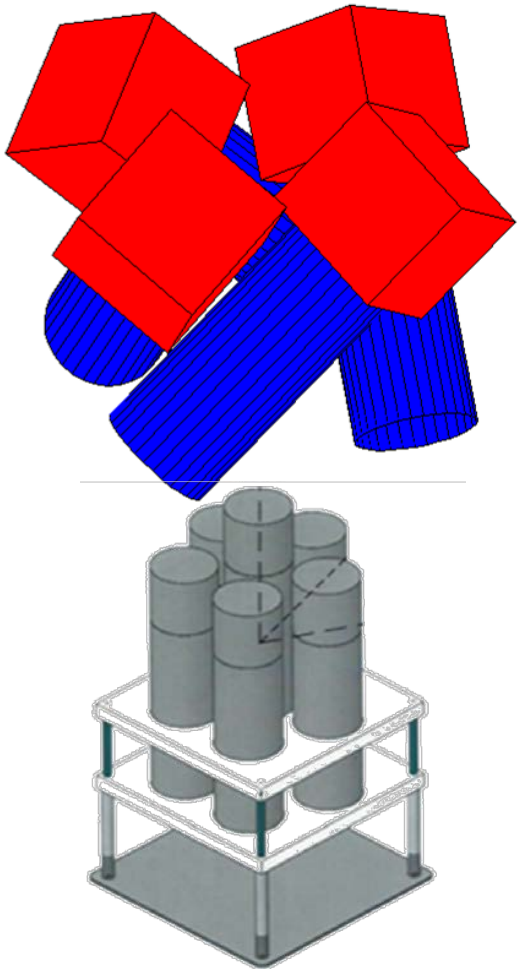


Segmentation

Directionality can be achieved by segmentation

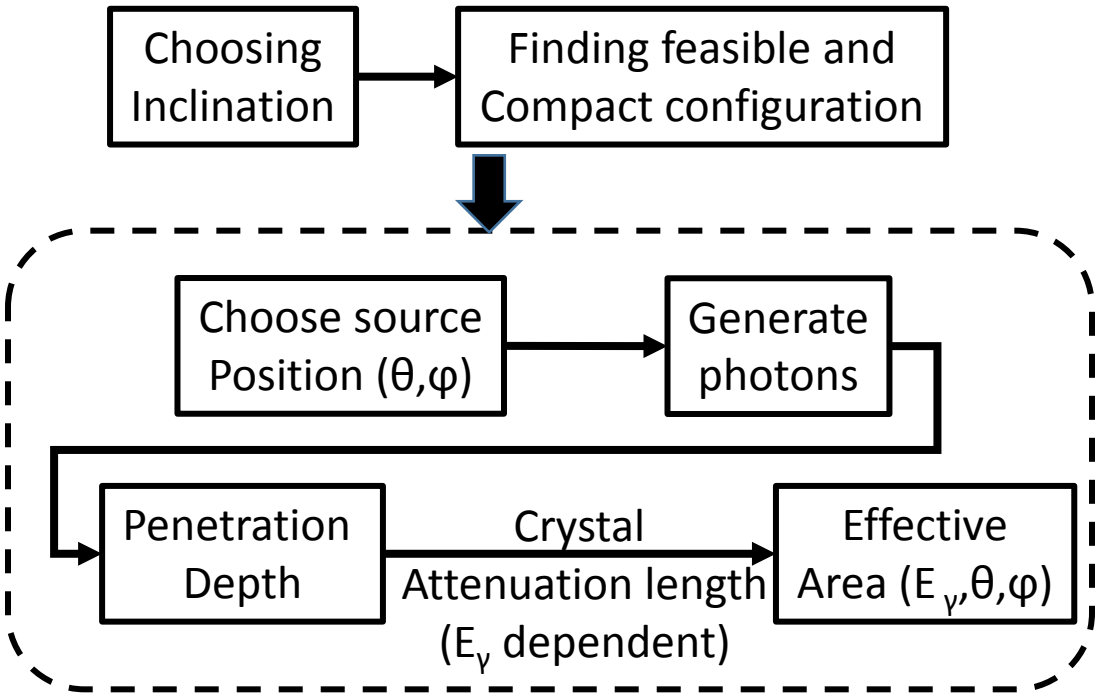
- Segments shade each other
- Inclination of the segments
  - ✓ Provides directionality at higher latitudes
  - ✓ Allows to distribute the effective area over the field of view

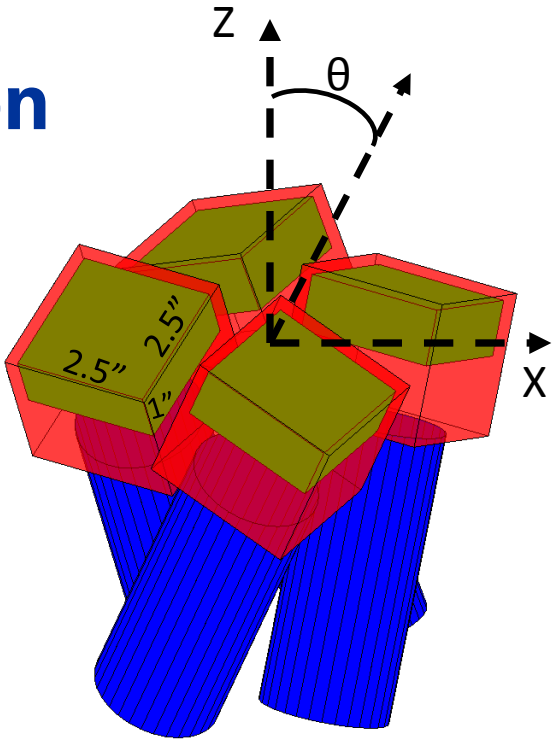
- Having many independent segments reduces false triggers by coincidence

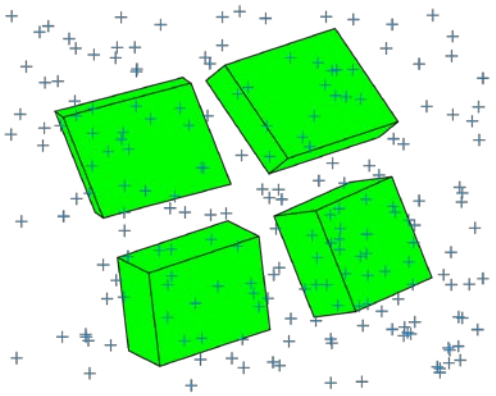


4 segments simulation

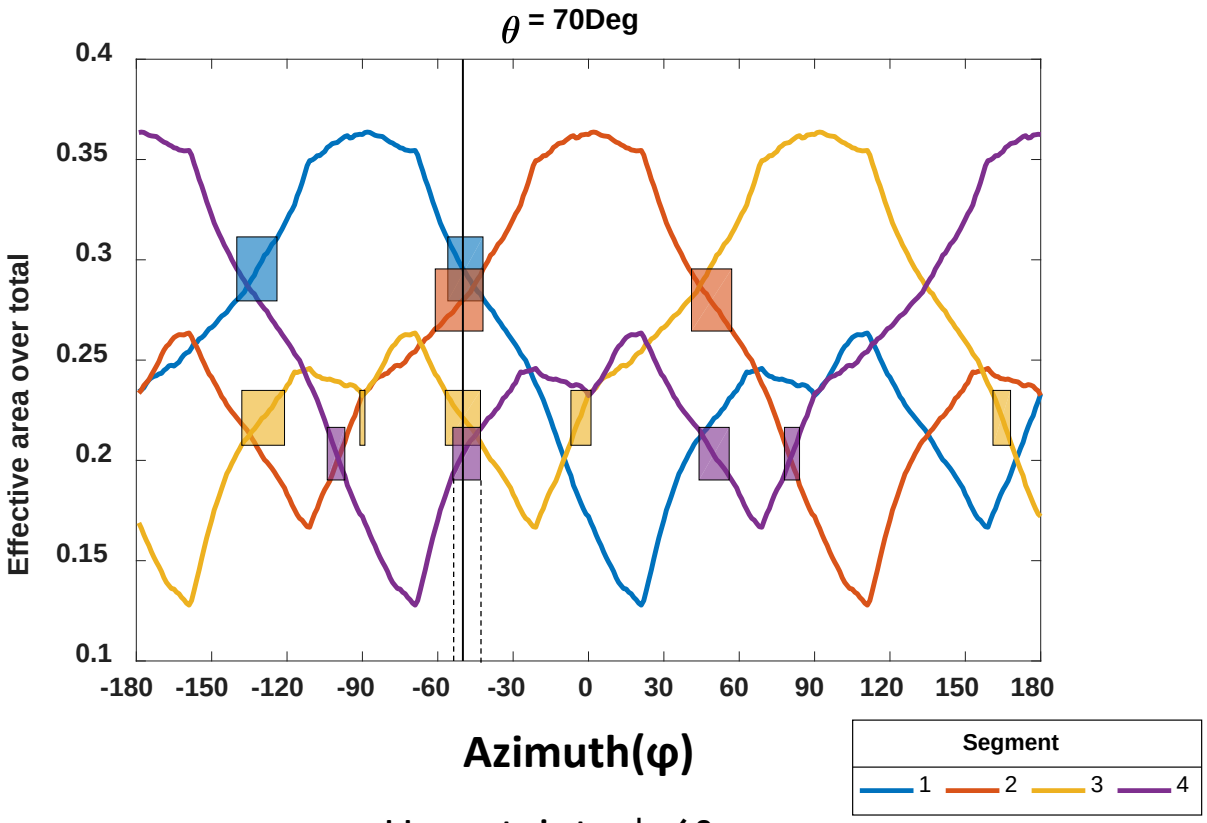
- 4 Crystals of 2.5X2.5X1”





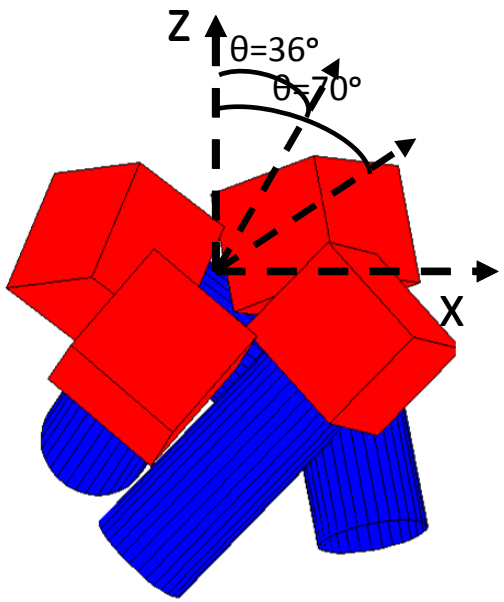


Angular Response

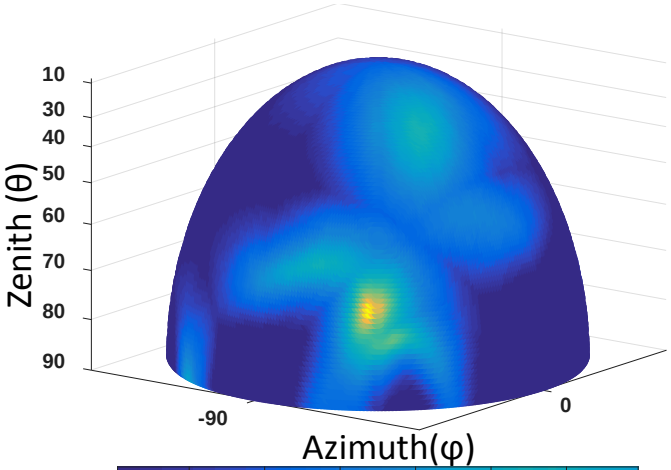


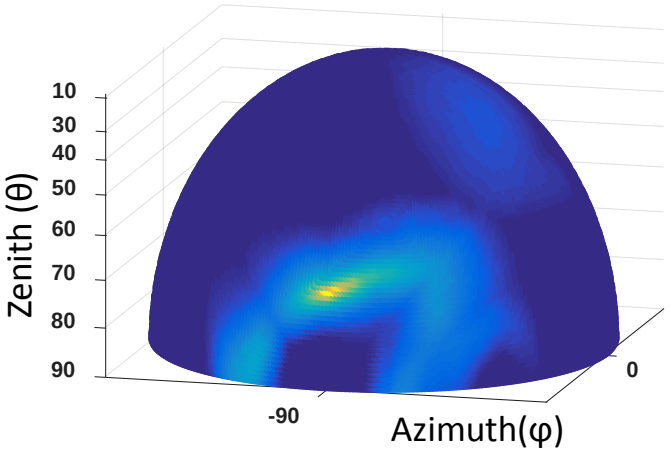
Uncertainty ± 6°

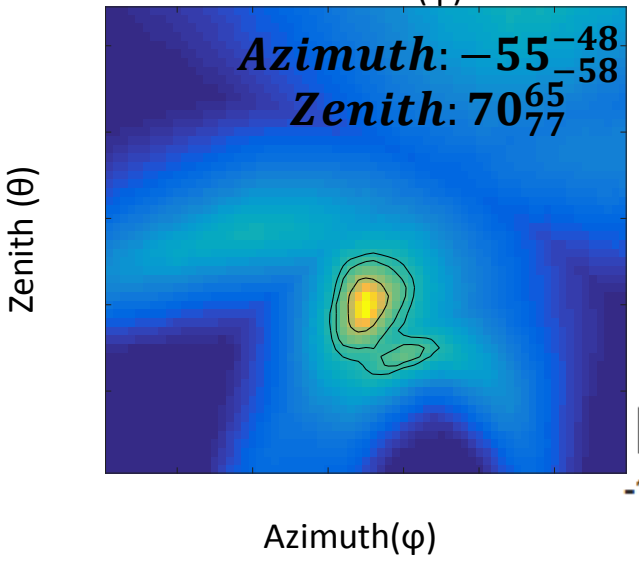
45° segment inclination

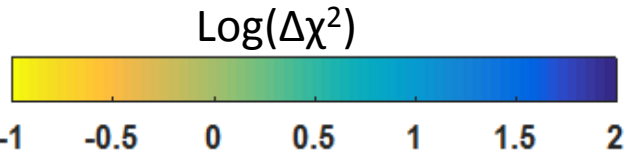


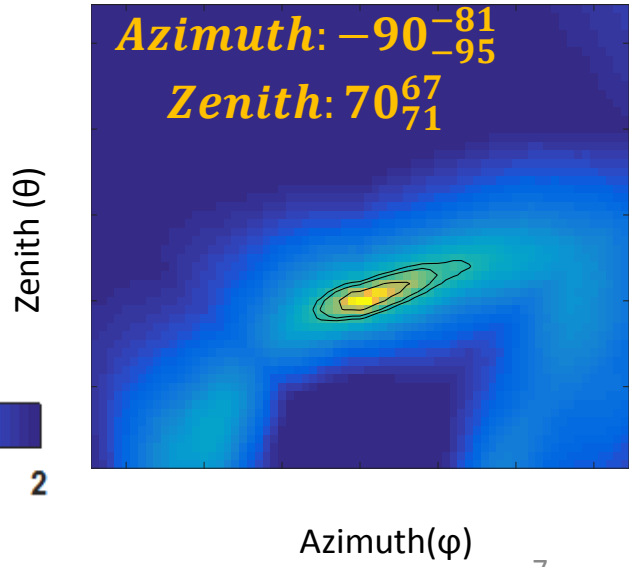
Angular Resolution





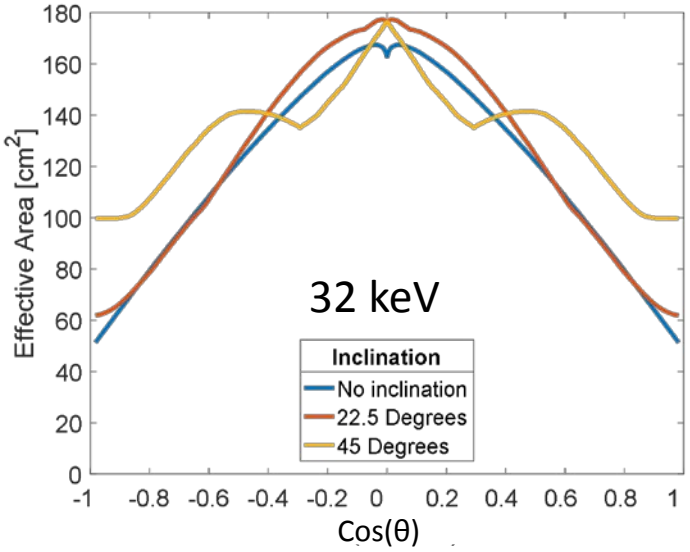


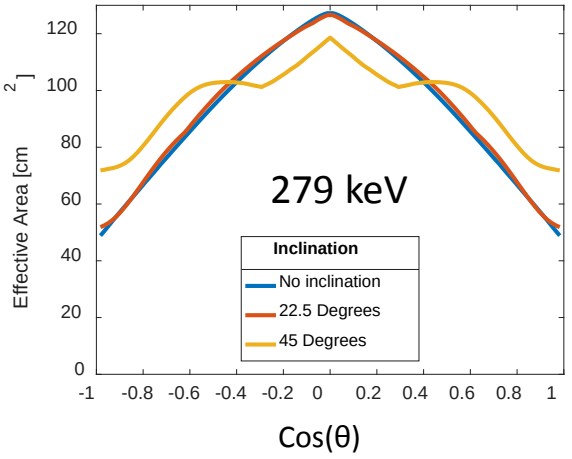




Effective Area

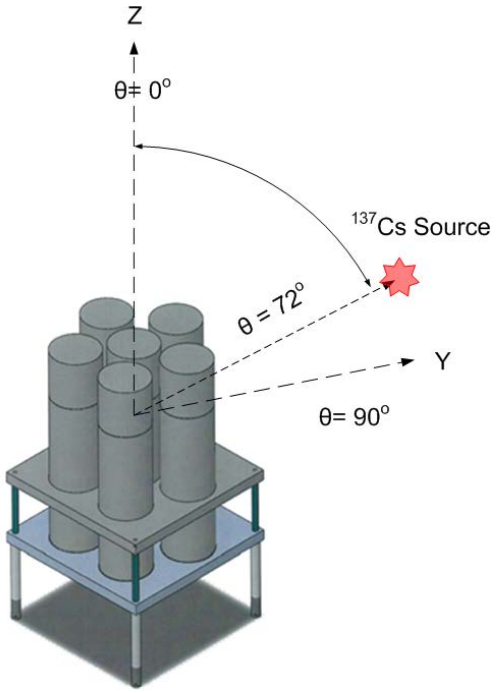
- Segments inclination allows to increase effective area at lower latitude angles
  - More uniform sensitivity over the field of view
  - A four 2.5”X2.5”X1” segments will detect ~50 GRBs per year, comparable to a single Fermi-GBM element.

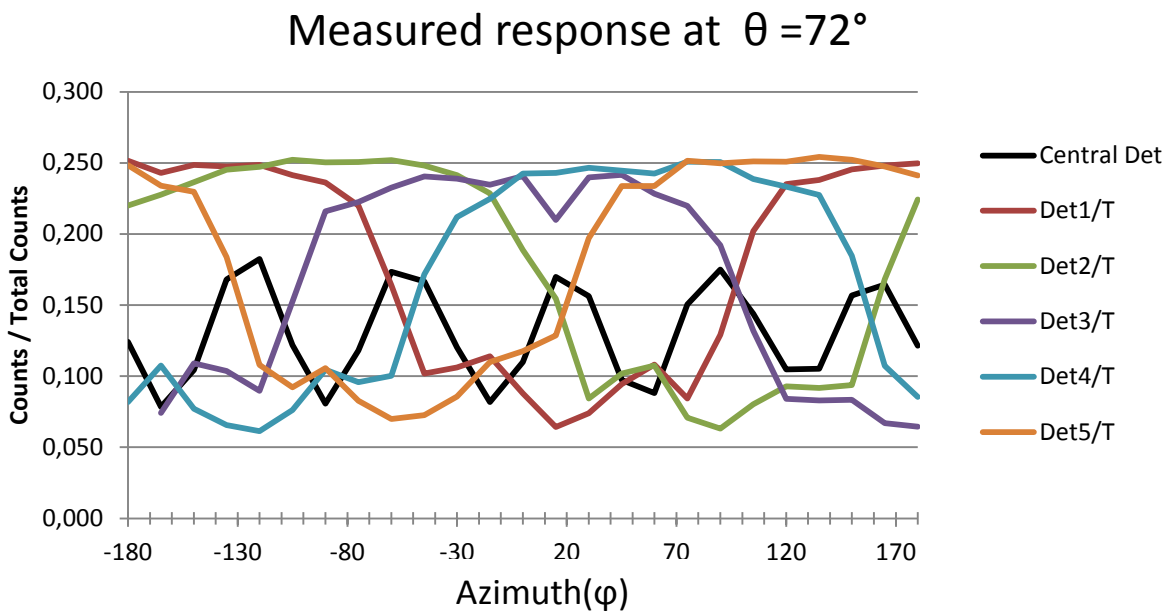




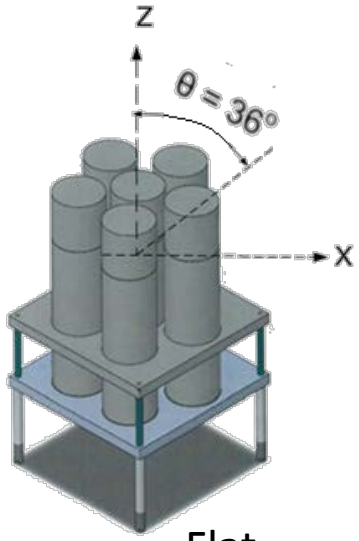
Lab Experiments with cylindrical detectors

- Simpler and tighter configuration
  - 6/7 segments in a “flower” shape
  - 1” diameter BGO detectors
- Results:
  - Very Good angular response at low latitude (high θ)

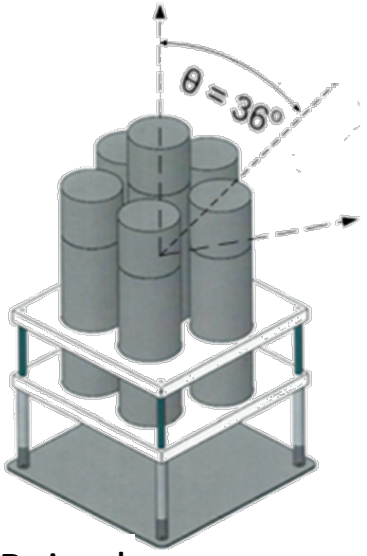


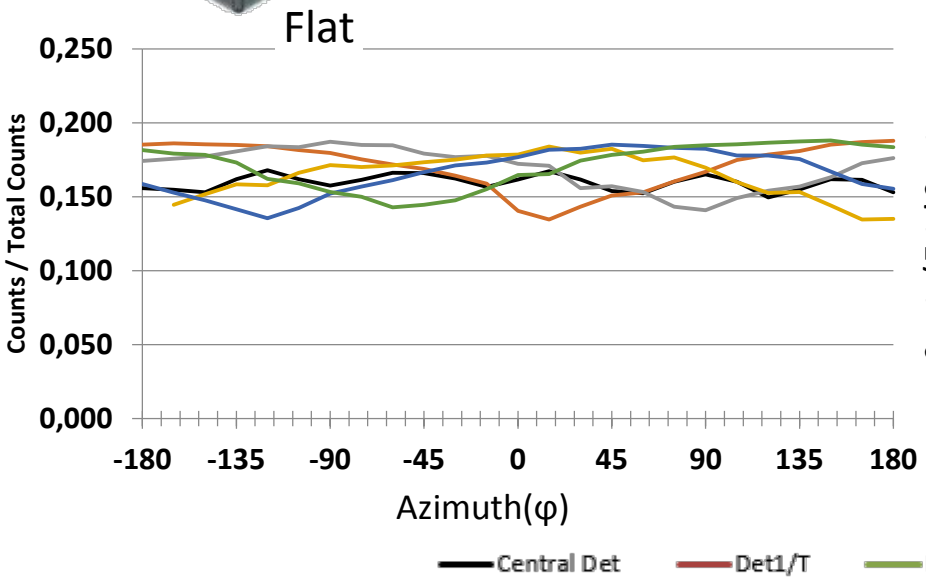


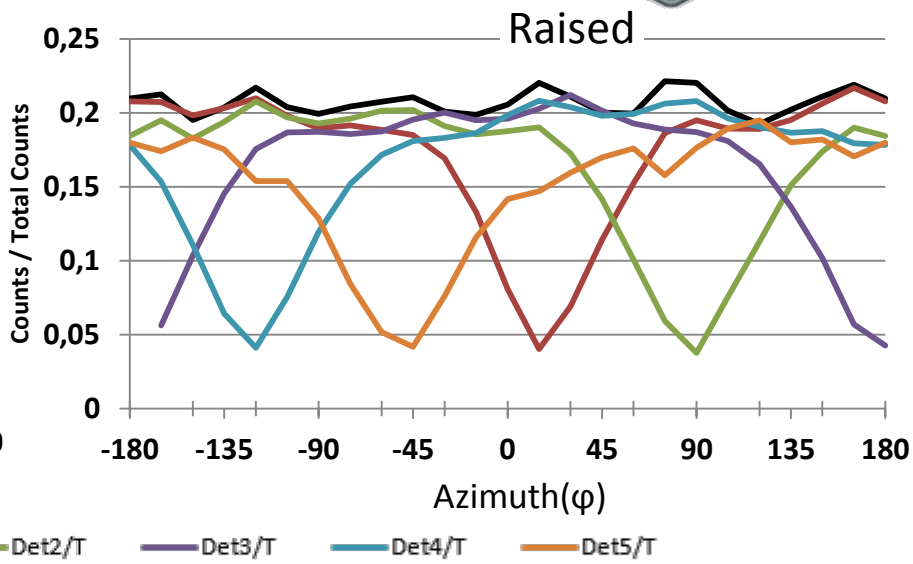
Lab Experiments with cylindrical detectors



- At high latitudes (small θ):
- Flat configuration – poor angular response
- Raised central segment - improved angular response

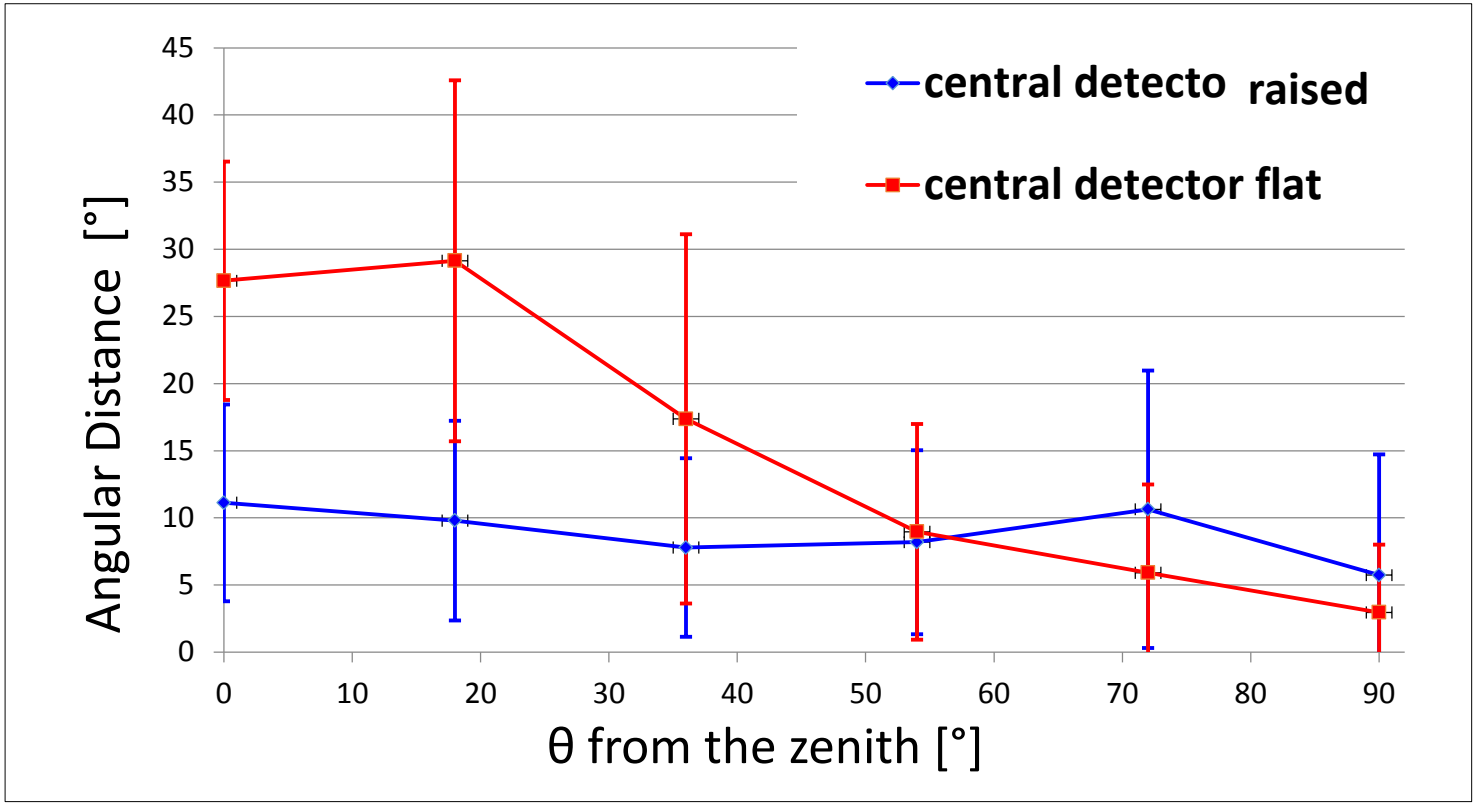


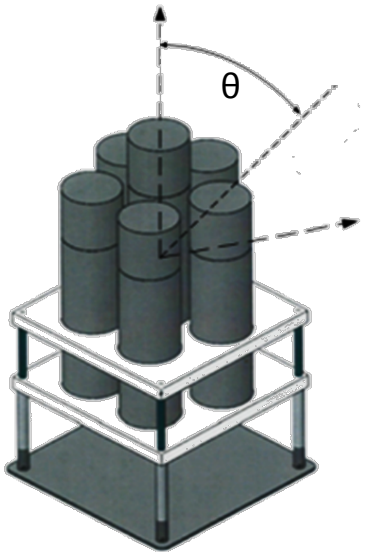




Central Det Det1/T Det2/T Det3/T Det4/T Det5/T

Angular Resolution



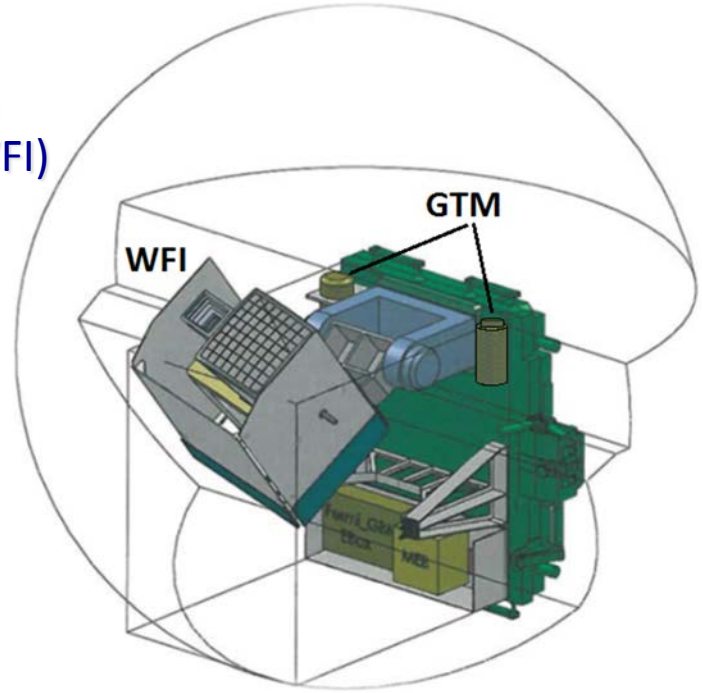


Gamma-ray Transient Monitor on board TAO-ISS

- Transient Astronomy Observatory (TAO) mission proposed as Mission of Opportunity (MoO) by NASA/GSFC for the ISS

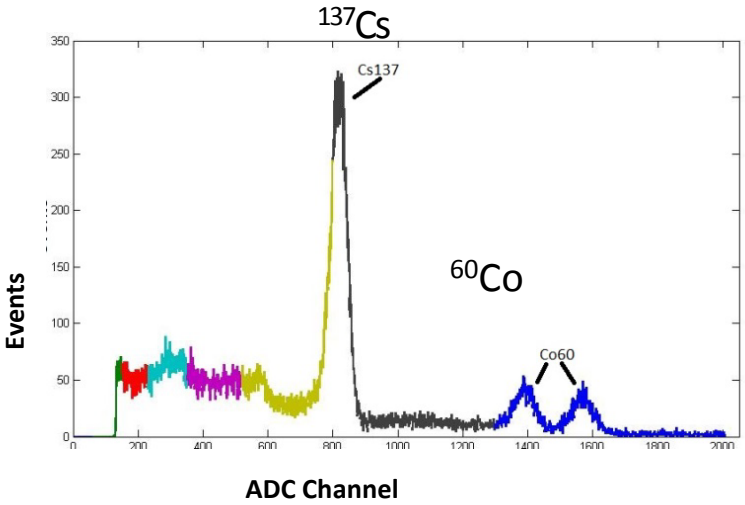
- Payload:
  - Lobster X-ray (0.3-5keV) Wide Field Imager (WFI)
  - **Gamma-ray Transient Monitor (GTM)**

- **Role of GTM**
  - **To extend TAO spectrum up to MeV**
  - **Trigger for WFI pointing**
    - → **Advantage to GTM directional capability**
  - **Time coincidence with GW events**

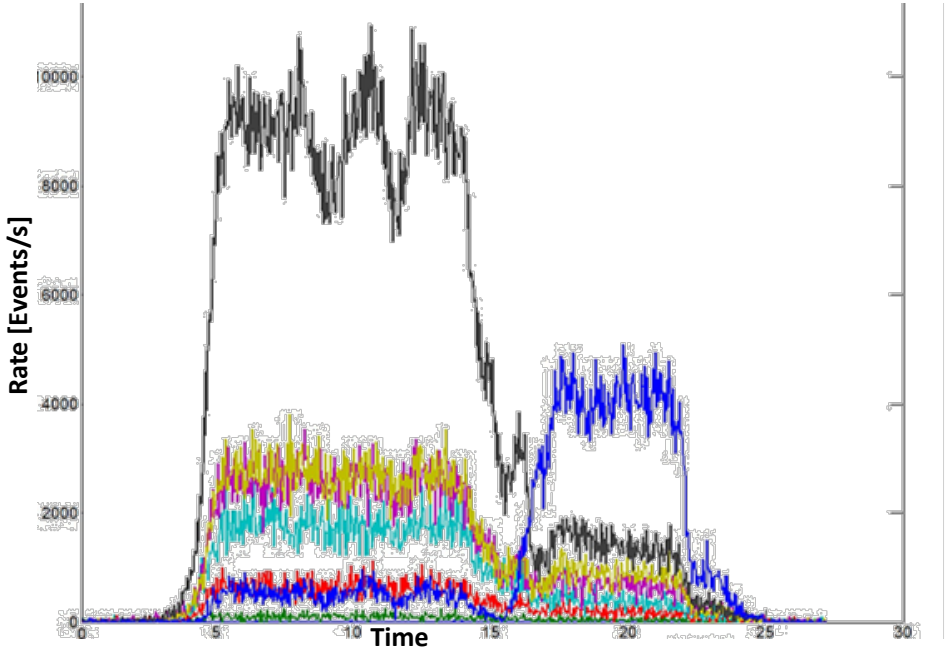


GTM Laboratory Demonstrator

- Single unit laboratory demonstrators already built:
  - 4-segments detector is on construction
  - FPGA based readout
  - Two analog processing channels

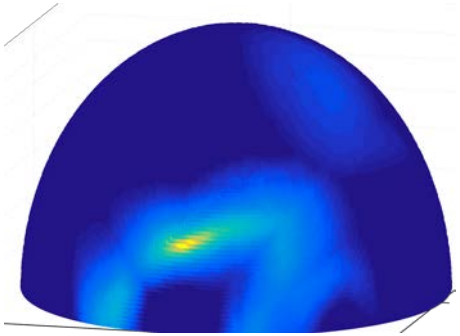


Demonstration of the energy bands of the light-curves. Characteristic peaks of ^{60}Co and ^{137}Cs can be seen



Demonstration of the light-curves we generate. While moving the sources with respect to detector.

Conclusions



- Segmented scintillators can reach angular resolution of a few degrees without loss of effective area
  - Depending on latitude, signal
  - Enough to direct other facilities
- Segmentation distributes the effective area more uniformly across the FOV.
- Segmentation reduces false triggering
- Angular resolution has been demonstrated in laboratory
- **We hope to build segmented detector for TAO-ISS soon**

Thank You

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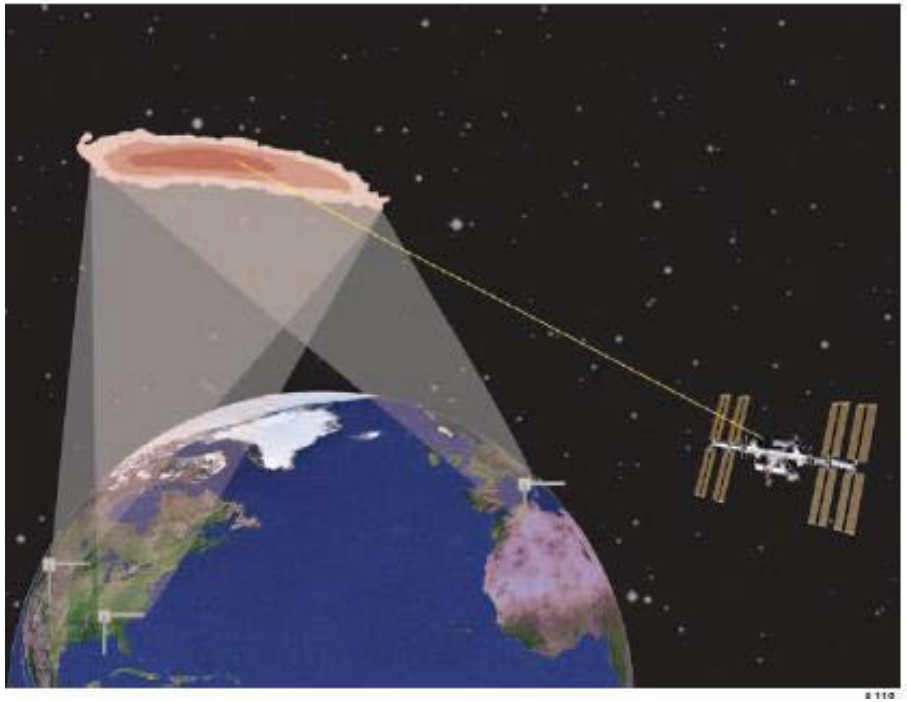
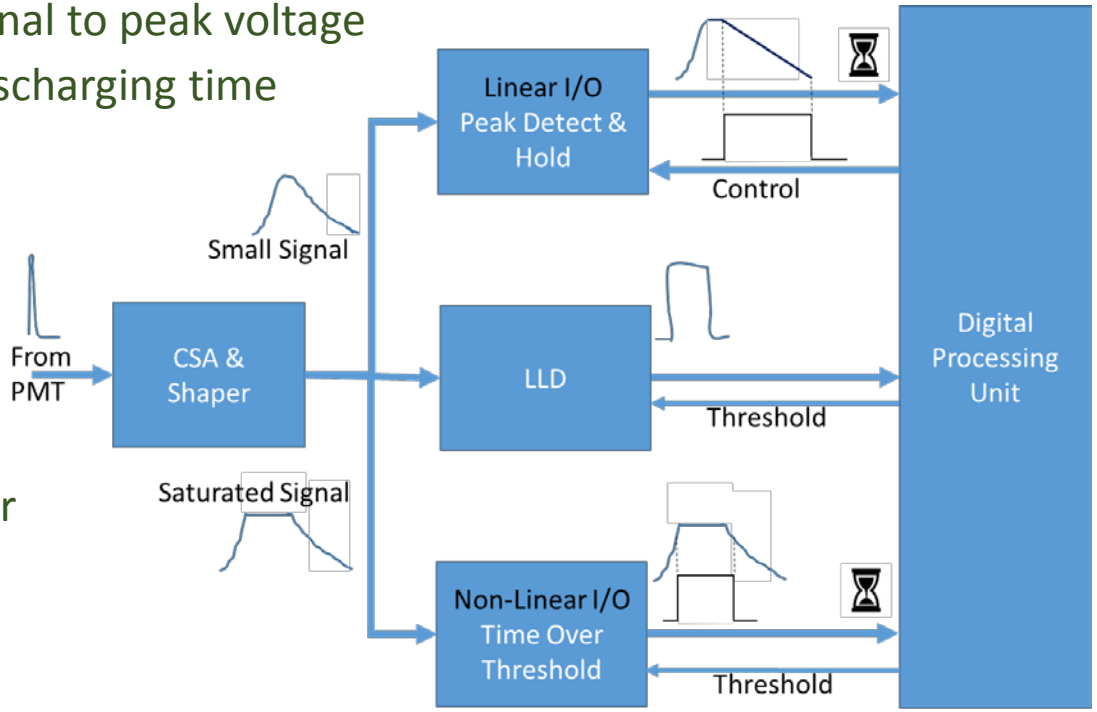
Lobster - Method of Operation

- Search for EM-counterparts of LIGO Gravitational Waves (GW)
  - NS-NS coalescences are believed to generate the most significant GW signal at earth as well as short-GRB
  - Repointing in respond to LIGO
- Transient x-ray astronomy
  - Scan >50% of the sky twice a day
- Early universe GRB studies
- Main science targets:
  - **Gravitational Wave sources**
  - High-z gamma ray bursts
  - Supernovae shock breakouts
  - Supermassive BH Tidal Disruption Events
  - High energy neutrino events



Pulse readout – Two Cahnnels

- Peak Detect & Hold – latches on voltage peak, linearly discharge
  - Discharging time proportional to peak voltage
  - By Firmware: measuring discharging time



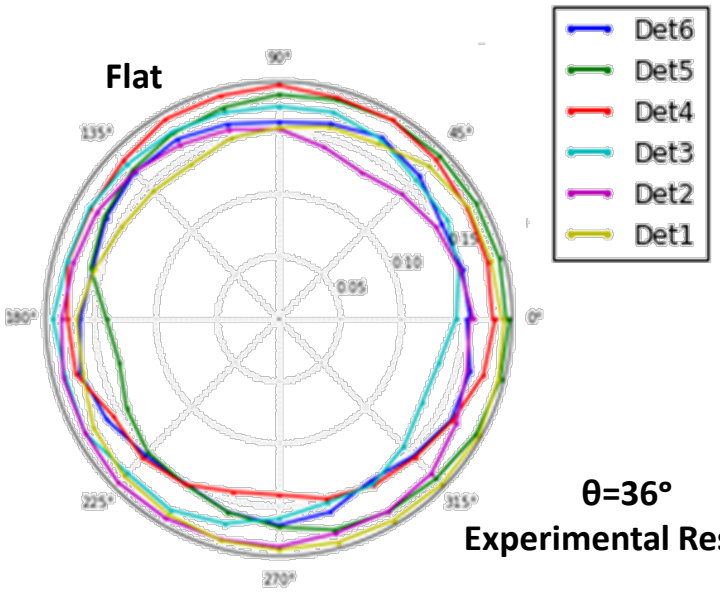
- Time Over Threshold – Signal that saturate the amplifier can be measured by the time above a threshold level

Dynamic range

- 290 with PKDT alone
- 470 with both
- Indication of >1000 with both

Lab Experiments with cylindrical detectors

- Simpler configurations with 1” diameter BGO detectors
- 6/7 segments in “flower” configuration
  - Shading at low latitudes
- Central segment can be raised
  - Shading at high latitudes



θ=36°
Experimental Results