Gamma-ray performance study of the HERD payload

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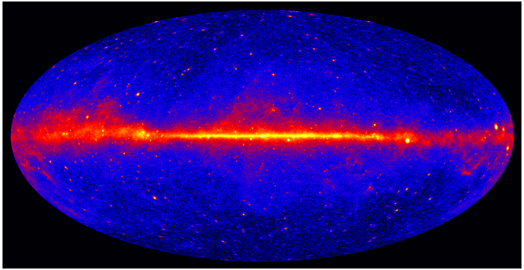
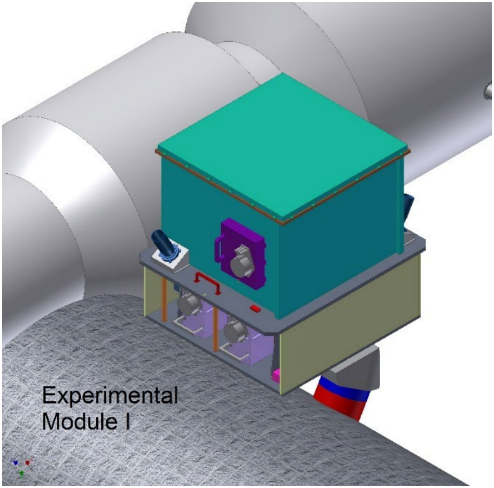
Outline

Gamma-ray astronomy from space



- *Fermi*-LAT:
  - already $>10\,\mathrm{yr}$, >5000 sources detected
  - Fermi bubbles
- Need continuity of space observations
- Work with next generation of ground observatories (CTA, LHAASO)
- Also current and future generation of observatories in other messengers (IceCube, KM3NeT, LIGO/Virgo, ...)

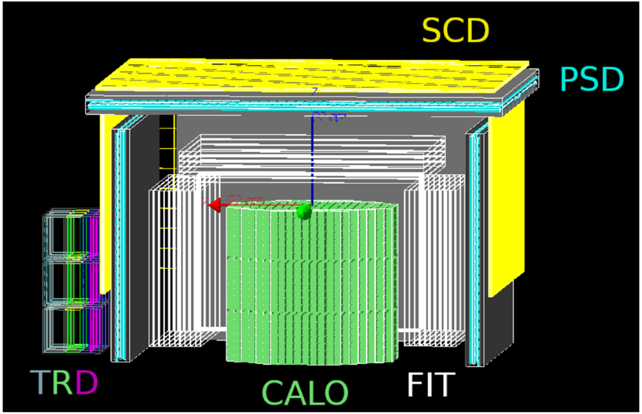
HERD: the High Energy Radiation Detector



- γ, e^-, CR detector
- To be installed $\sim$ 2027 on the CSS
- HERD Collaboration:

- γ energy resolution down to 1% at 200 GeV, γ PSF down to 0.1 deg at 10 GeV
- Science goals (γ):
  - Search for DM
  - Transients monitoring, alert & followup (GRBs, GWs,...)
  - Disentanglement of Galactic point-source/diffuse emissions

Geometry and Subdetectors[1]



SCD	Charge reconstruction
PSD	Charge reconstruction, γ identification
FIT	Direction reconstruction, charge identification
CALO	Energy reconstruction, e/p discrimination
TRD	Calibration of CALO to TeV p

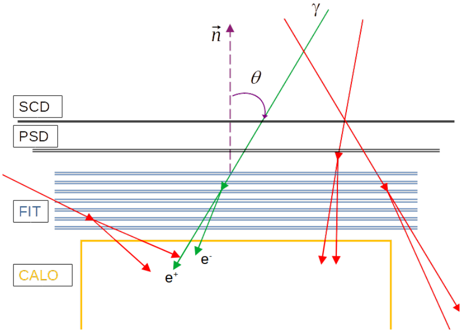
[1]More details in F. Gargano's Highlight Talk "The High Energy cosmic-Radiation Detection (HERD) facility on board the Chinese Space Station: hunting for high-energy cosmic rays"

MC sample generation

- Produced using the official HerdSoftware toolset
- GGS (based on Géant4)
  - Generate uniform γ flux
  - Determine interactions and energy depositions according to detector geometry
- EventAnalysis framework
  - Digitize signals in each subdetector
  - General analysis
- Samples:
  - Two runs for faces Z (“top”) and Ypos (“lateral”)
  - Energy range: 0.01–100 GeV
  - Total: 4×10^7 γs

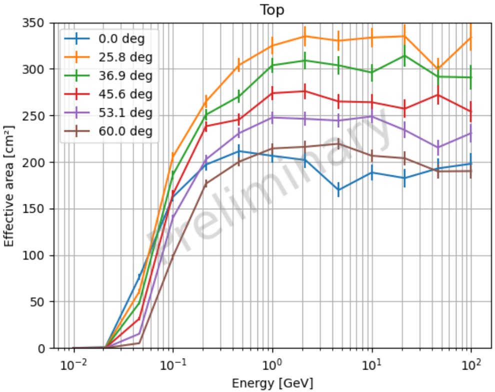
Event selection

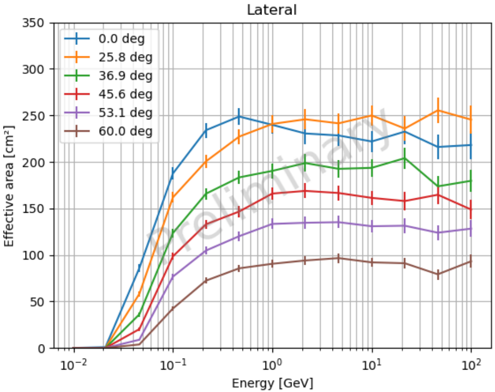
- Enter through the face under study
- Conversion happens inside the FIT
  - Conversion point from MC truth
- Enough hits in FIT to reconstruct the track
  - At least 3 hits for the e^-, e^+ in X/Y layers
- $> 50\%$ energy deposition in CALO



$$A_{eff}(E, \theta) = \frac{N_{sel}(E, \theta)}{N_{gen}(E, \theta)} A_{gen}(\theta)$$

Effective area results



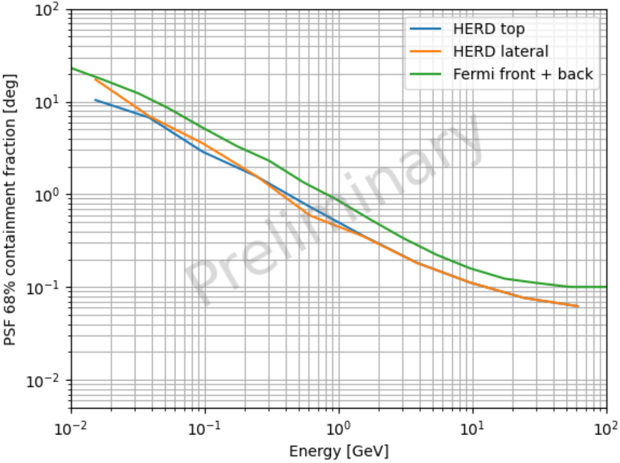


(Acceptance $\sim 10-20$x lower than *Fermi*-LAT's; HERD has no W foils but better FOV)

A proxy for the track reconstruction algorithm

- Retrieve the e^+e^- pair's interactions with the sensitive FIT elements from the MC truth
- Look for pairs of hits on consecutive X/Y layer pairs
- Smear their positions to a precision of 250 µm
- Reconstruct a combined hit:
  - Normal coordinate: average for both layers
  - Coordinates in detector plane: from the layer sensitive to it
- Fit two lines to the points from the e^+ and the e^-
- Average both tracks to obtain the reconstructed γ track
- Calculate the angle between the reconstructed and the true γ tracks
- Report the 68% containment fraction

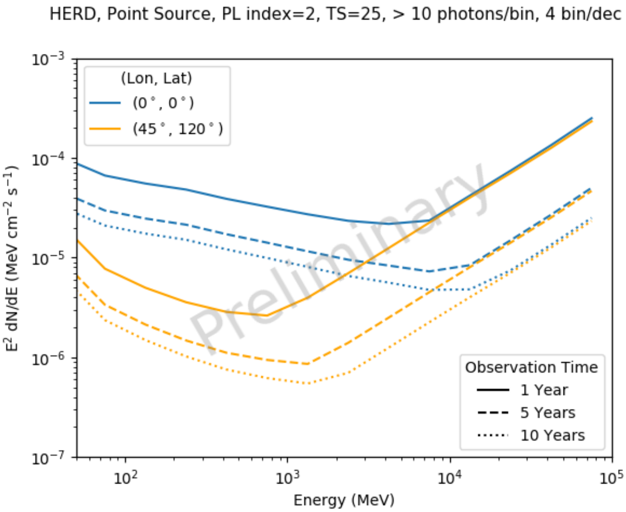
PSF results


HERD top
HERD lateral
Fermi front + back
Preliminary
PSF 68% containment fraction [deg]
Energy [GeV]
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}

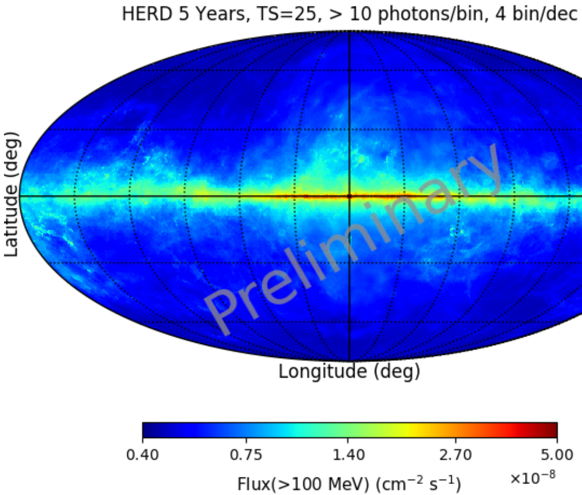
Sensitivity computation using the fermitools

- Differential sensitivity: minimum flux for a 5σ detection in a certain energy bin
- Four bins per decade
- Require at least 10 γs to report detection
- Source: point-like, PL with index 2
- Background:
  - *Fermi* galactic emission model `gll_iem_v07.fits`
  - *Fermi* isotropic bkg `P8R3_SOURCE`
- Using HERD A_{eff}
- Using *Fermi* PSF3 as it is most similar to HERD one

HERD sensitivity to low-E gamma-rays



HERD 5-year skymap



Conclusions

- We have determined HERD baseline capabilities for gamma-ray detection in the range $\sim$30 MeV - 100 GeV
- To be done: detector optimization + gamma-ray specific trigger
- HERD will have 5 sensitive faces and very wide field of view
- HERD will feature superior energy and angular resolutions
- HERD will be the reference gamma-ray instrument in space in the CTA+LHAASO era