GammaTPC: a new MeV Gamma Ray Instrument Concept

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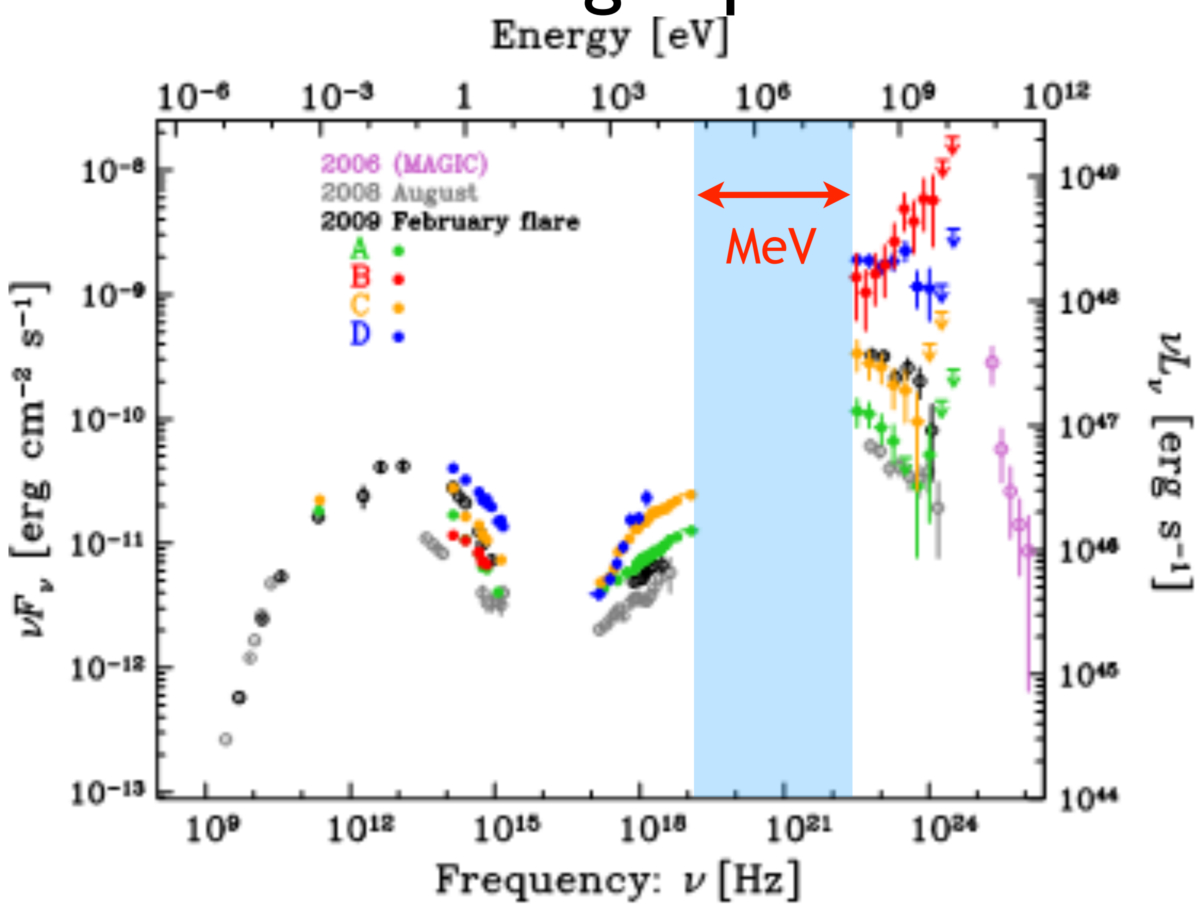
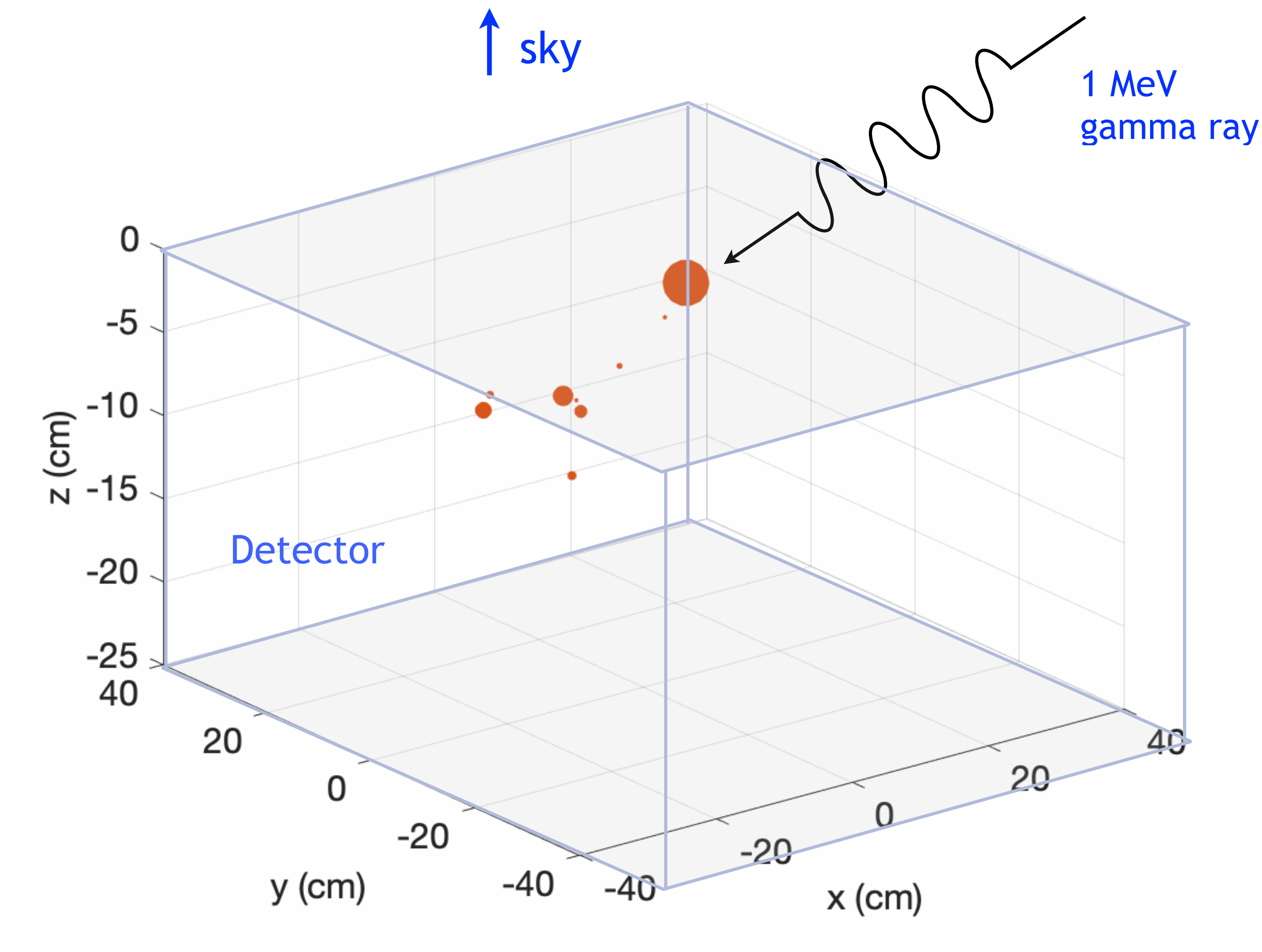
Astrophysical MeV Gamma Rays

- MeV gamma ray sky largely unexplored
- Rich set sources: black holes, neutron stars, supernovae
- Powerful multi-messenger probe

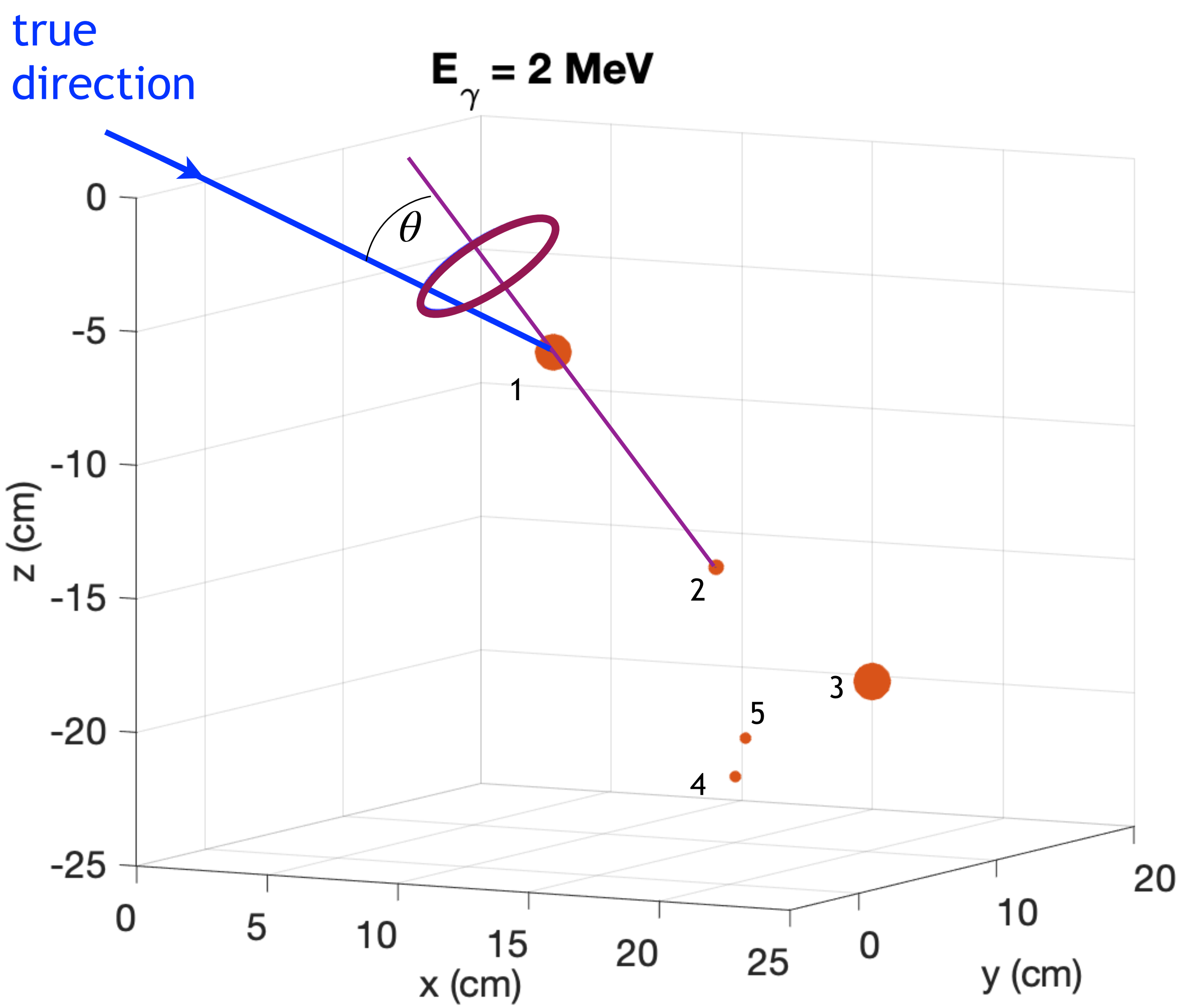


blazar 3C279

MeV Gamma Ray Measurement



Compton Event Reconstruction

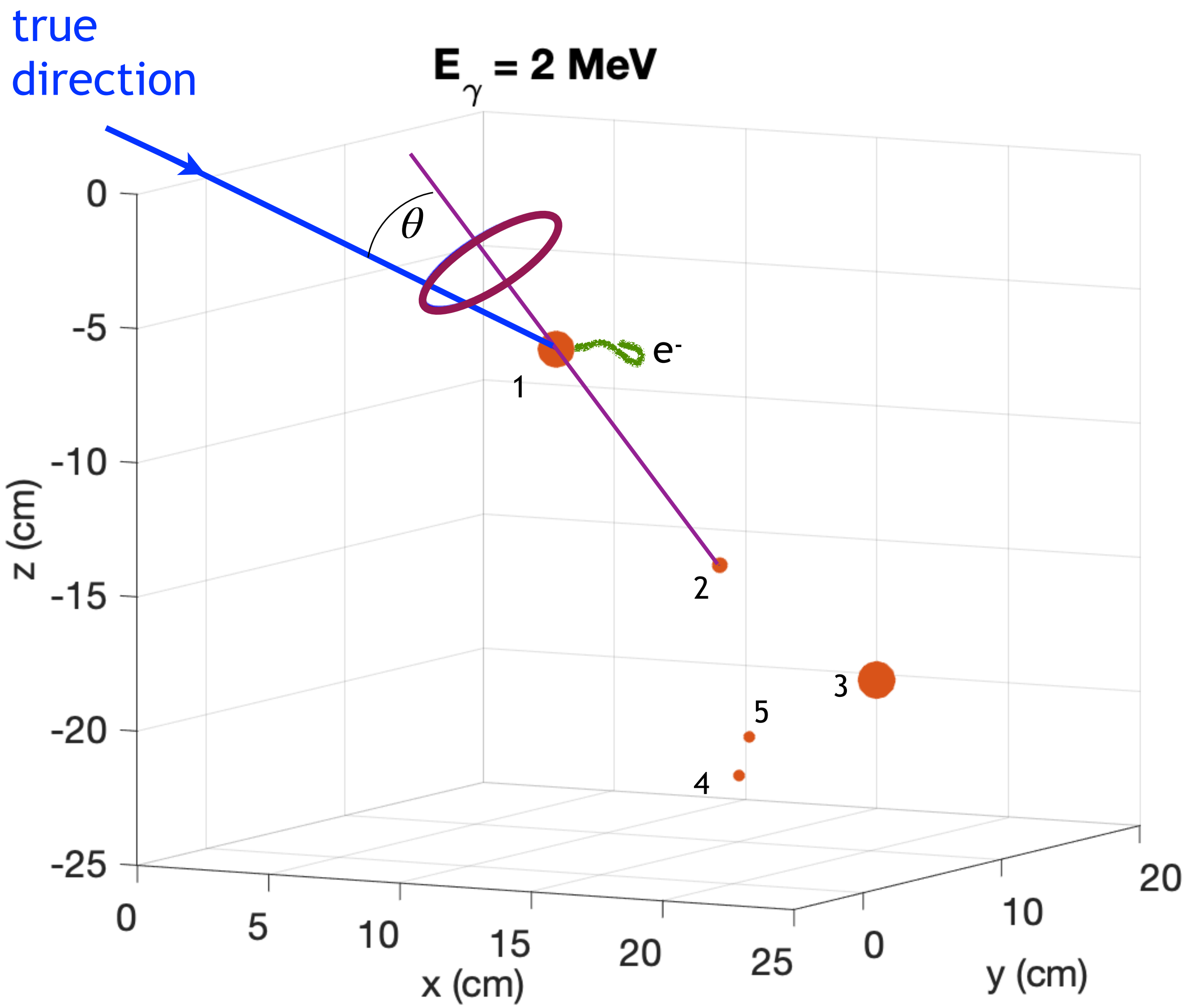


Images:
AMEGO

e⁻ track unmeasured

Compton Event Reconstruction

Images: AMEGO



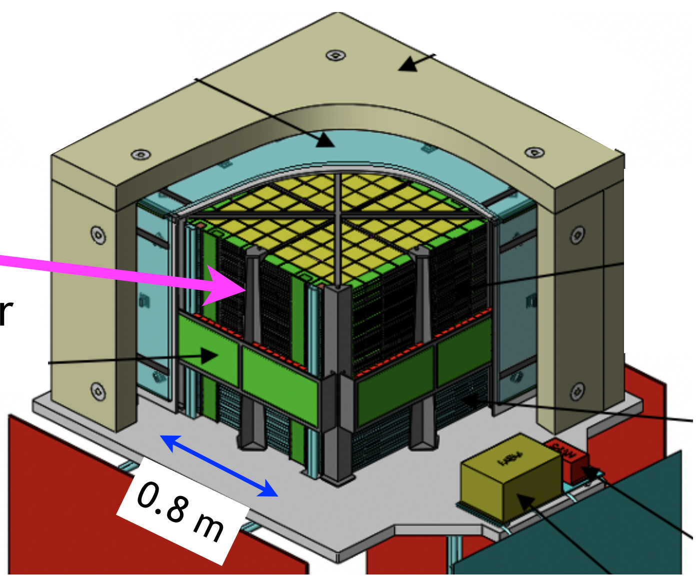
e$^-$ track unmeasured

e$^-$ track measured

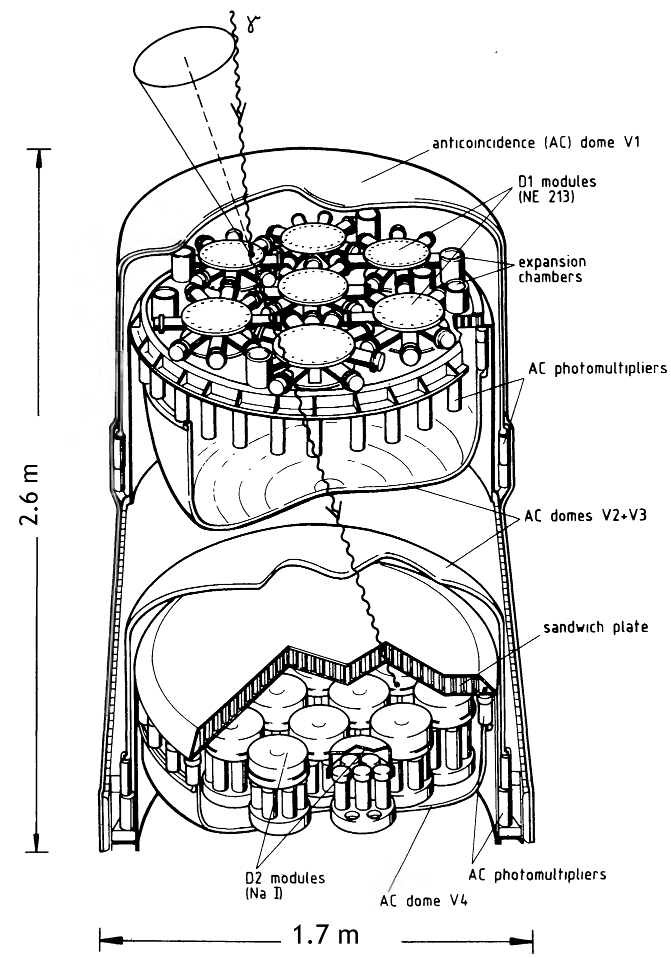
Detector Requirements

- Much larger than ~(30cm)^3
- 3D, sub-mm spatial readout *of head of electron track*
- Good energy resolution
- Very low passive mass
- High uniformity

60 Si strip
layers
~ 5 cm LAr

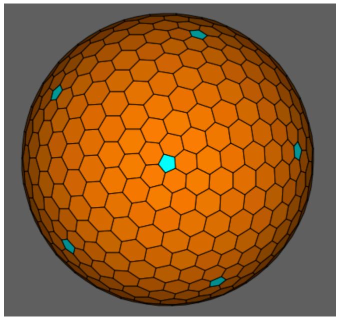


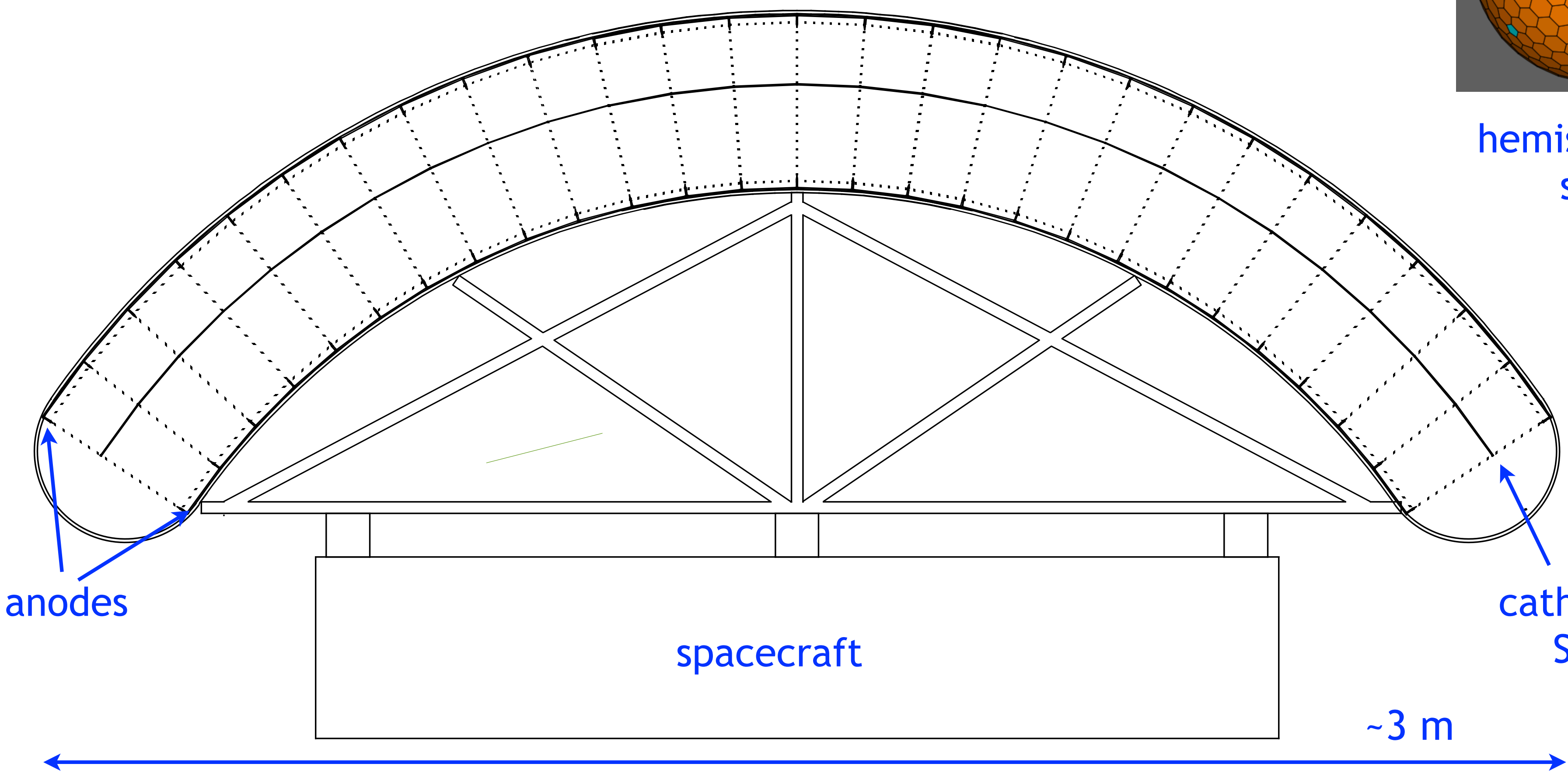
AMEGO - proposed Probe-class mission



COMPTEL 1991 - 1999

GammaTPC

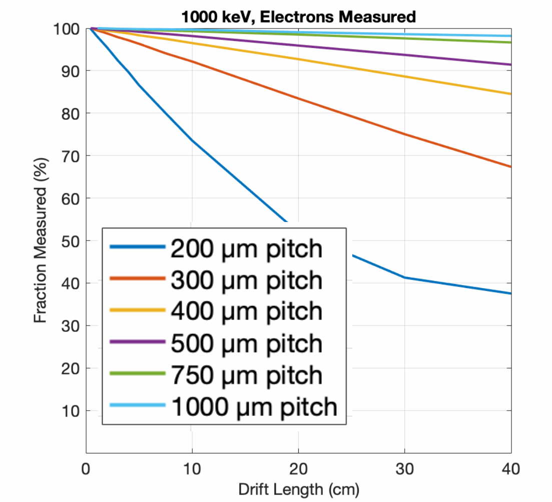




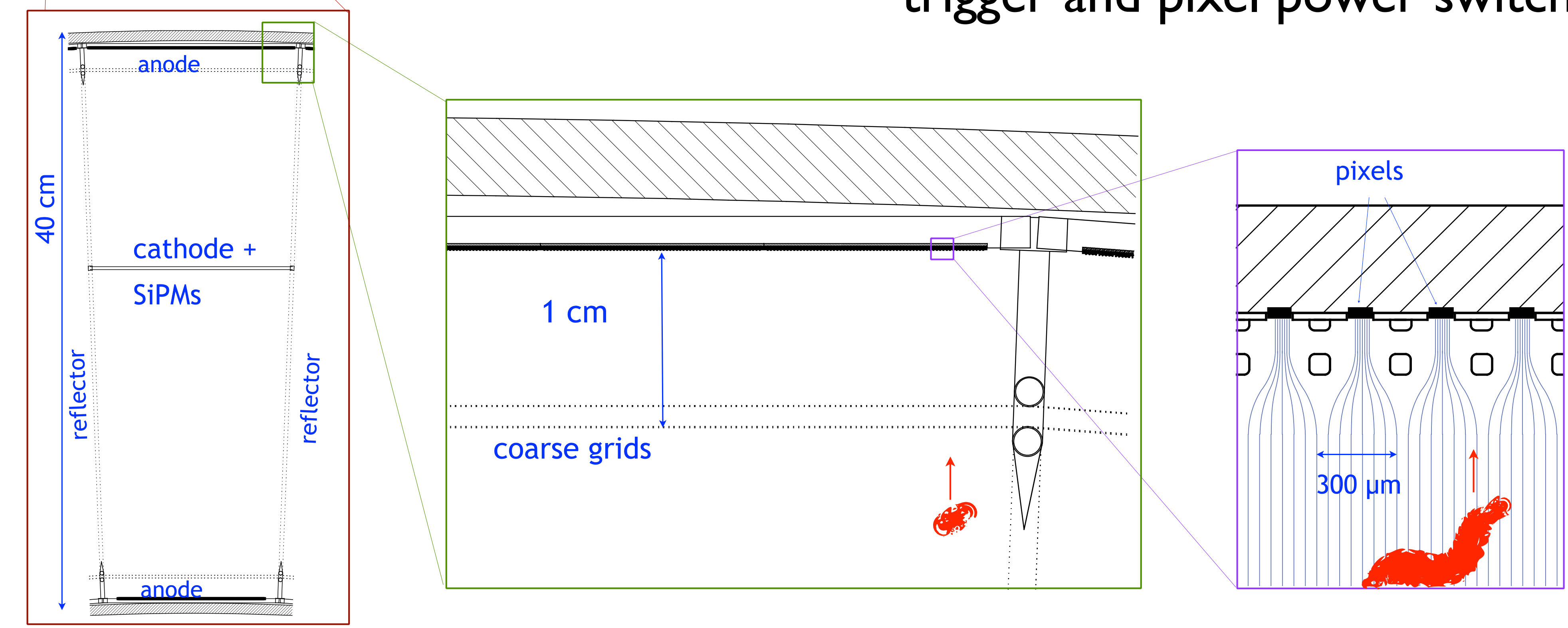
- Segmented TPCs in ~40 cm thick carbon fiber shell
- LAr at ~120 K
- 10 m^2, ~3 ton configuration shown - takes advantage of dropping costs of mass in space

Charge Readout

Charge fraction measured in pixels



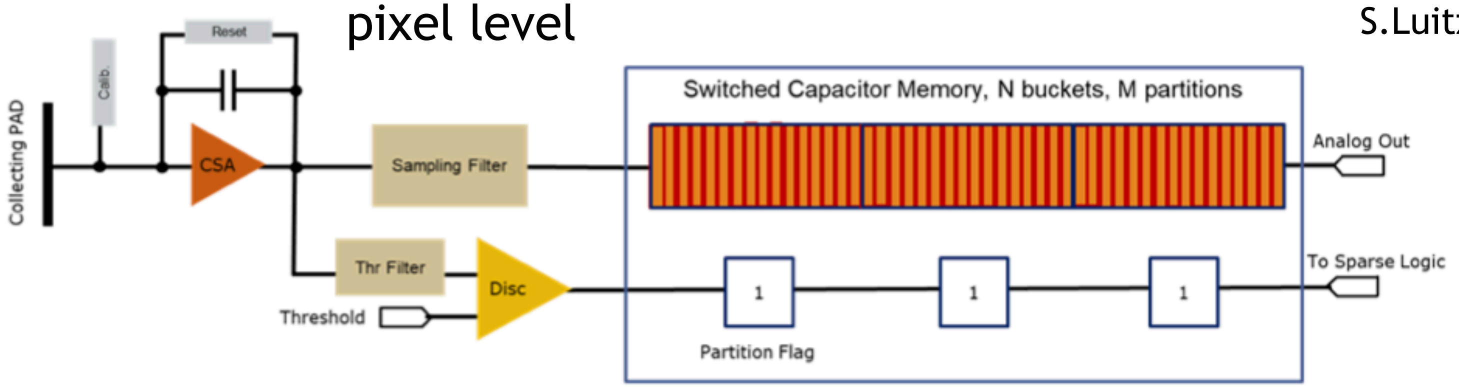
- Sub-mm charge readout loses charge to sub-threshold sensors with ~mm diffusion
- "Coarse" grids + pixels - eliminates charge loss, allows ~10^4 power reduction with coarse grid trigger and pixel power switching



Pixel readout

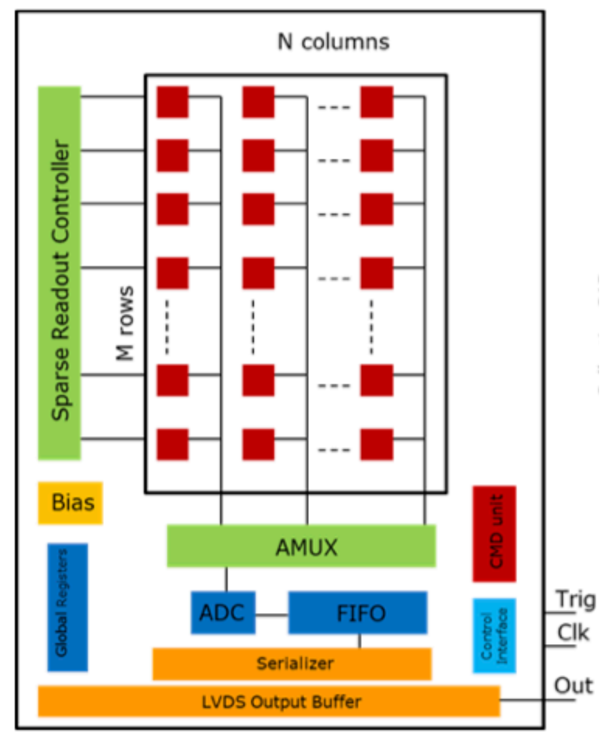
A Peña Perez, A. Dragone, S.Luitz, G. Haller, T. Shutt

pixel level



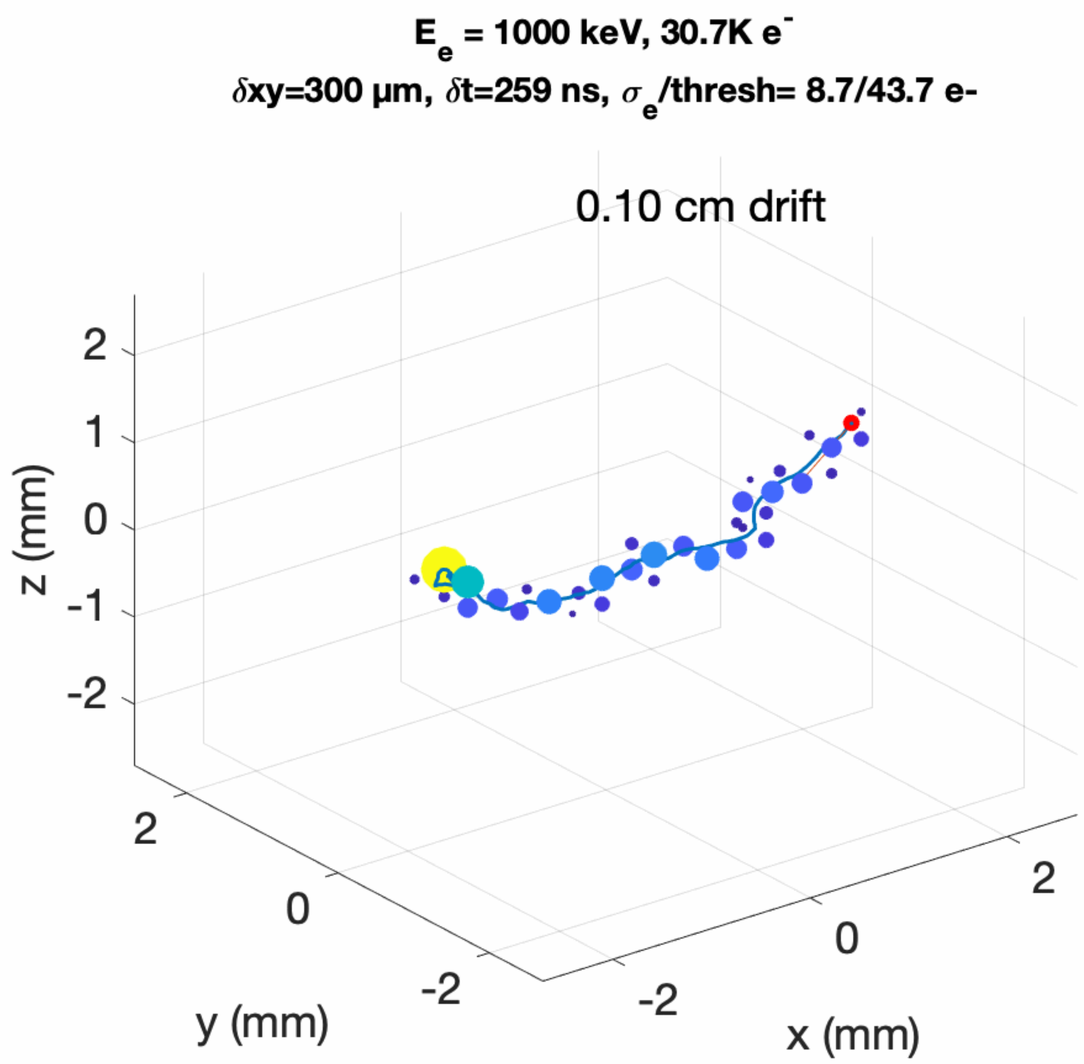
- Custom ASIC with analog memory buffer
- Coarse grid trigger turns on chips: ~10^4 power reduction
  - Need novel fast power switching scheme
- Noise ~ *few electrons*
- Builds on developments for DUNE + nEXO

chip level

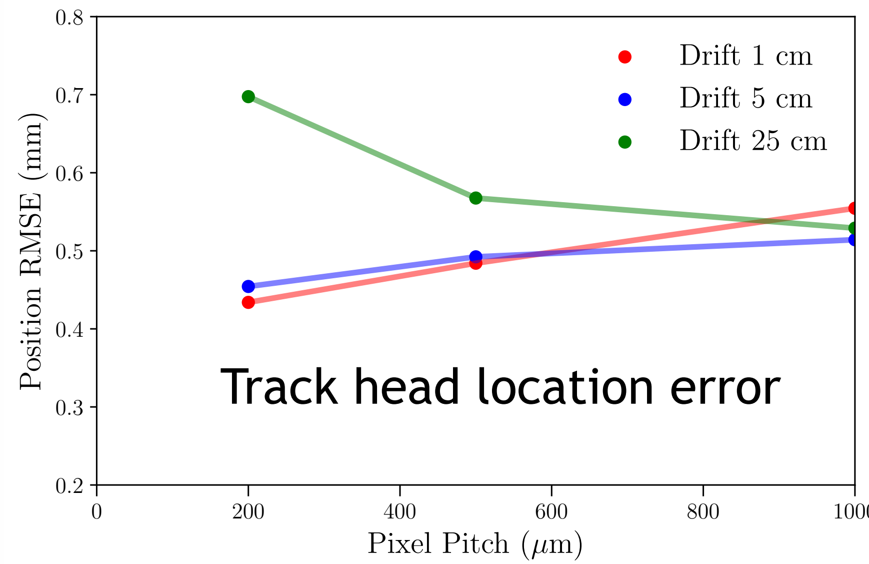


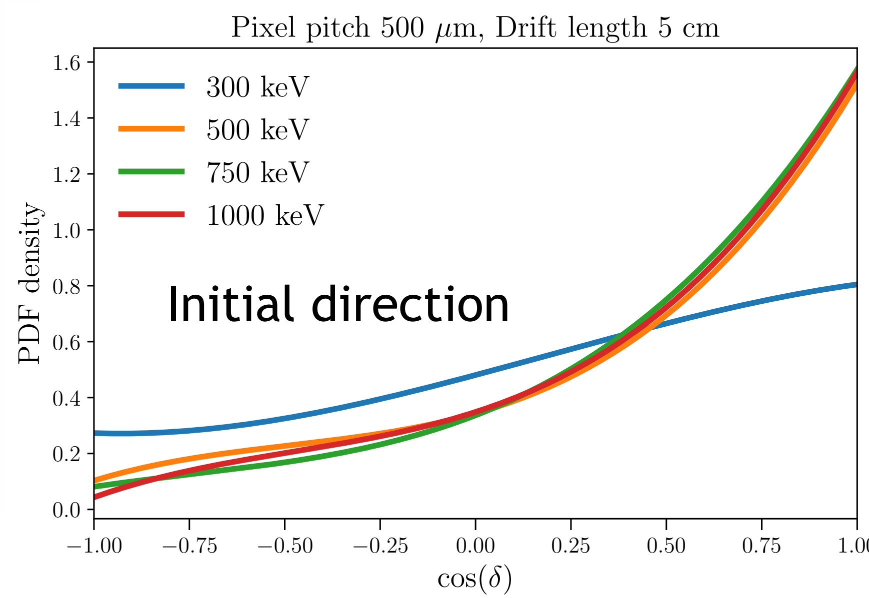
First look at pixel performance promising

ML approach - M. Buuck



1 MeV recoil electron



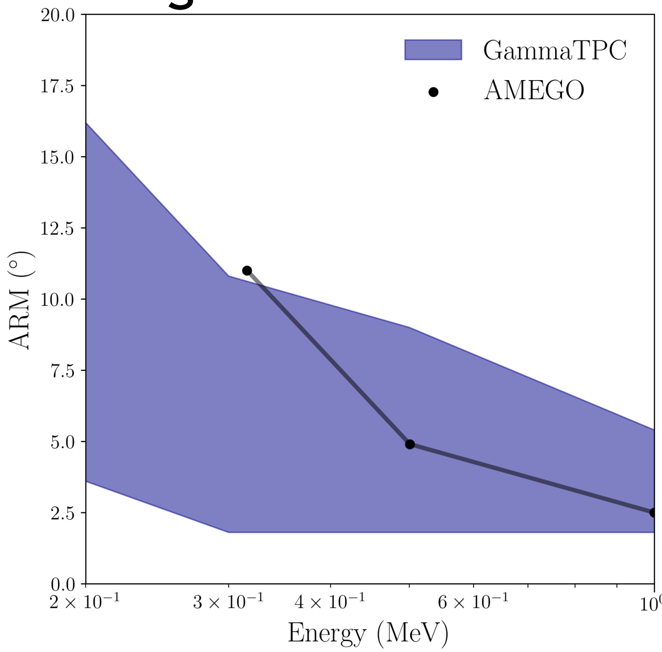


Space Deployment

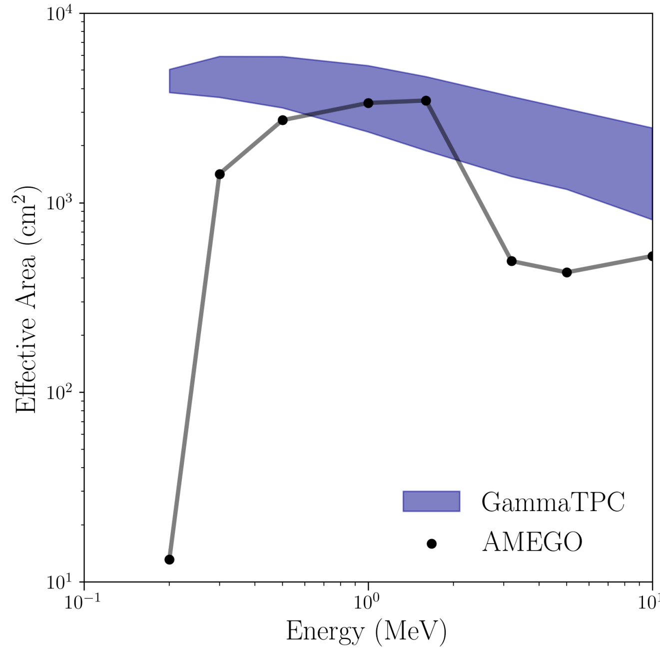
- Space charge from slow ion drift + particle background
  - Need charge injection scheme.
  - On paper, photocathode with qe ~ 10^{-4} will allow this
- Cryogenics: cryo-cooler with ~10s of W cooling power looks feasible. Passive cooling perhaps possible.
- Liquid - Gas separation: expandable bellows, or spin space craft.

First look at performance

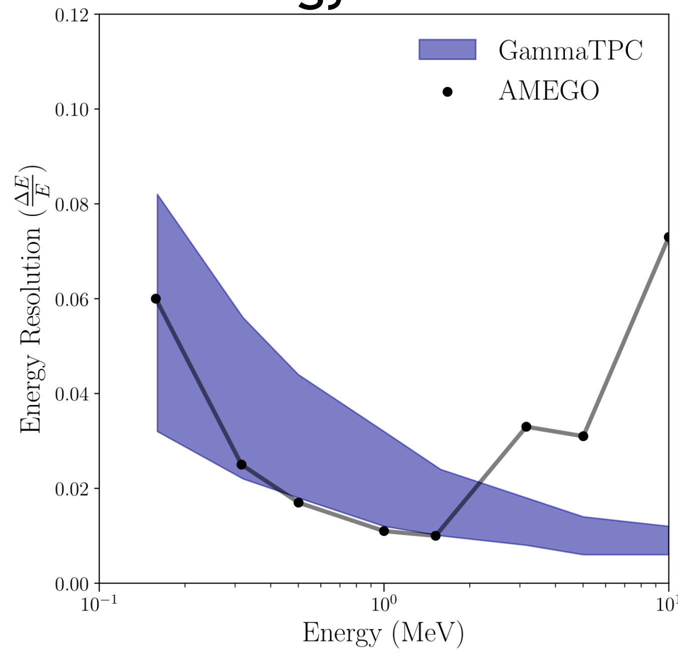
Angular resolution



“Effective Area”



Energy resolution



- Appears at least comparable performance to probe-class AMEGO proposal, for same ~1 m^2 instrument
- GammaTPC promises much larger instrument at lower cost

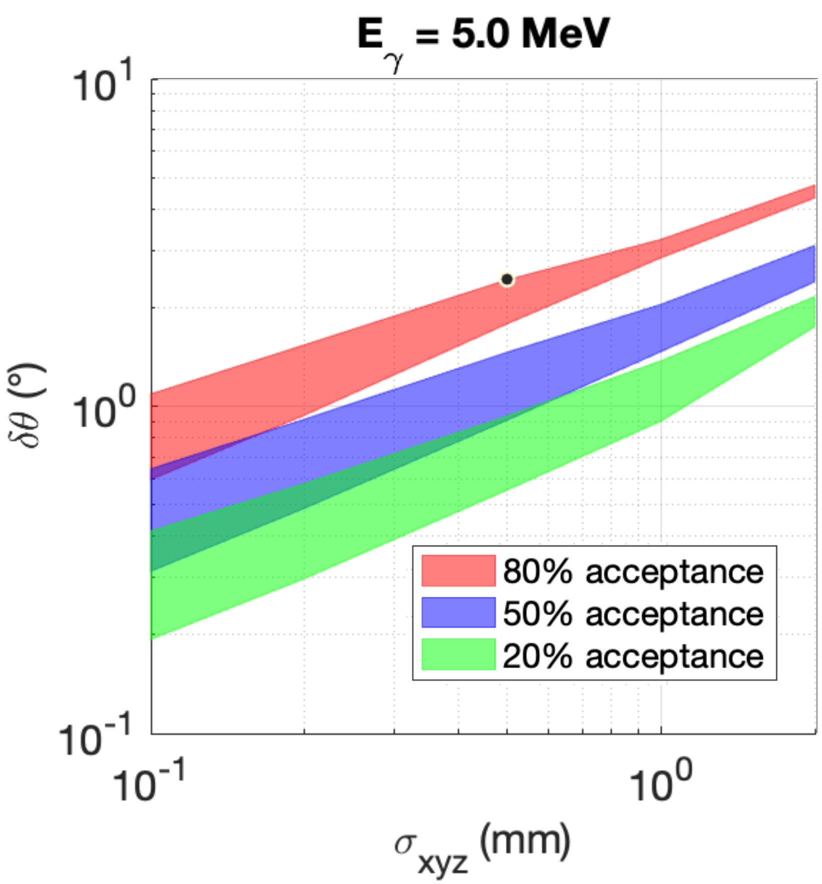
Conclusion

- Compelling new science with new MeV gamma ray instrument
- LAr TPC a promising technology
- Leverages communities development of liquid nobles, and DOE investment in DUNE
- Takes advantage of reduced costs to launch
- Many challenges to solve
- GammaTPC could be transformational instrument

backup

Performance

Point spread function



Band widths - range of energy resolution response

Energy Resolution