Advanced Energetic Pair Telescope for Medium-Energy Gamma-Ray Polarimetry

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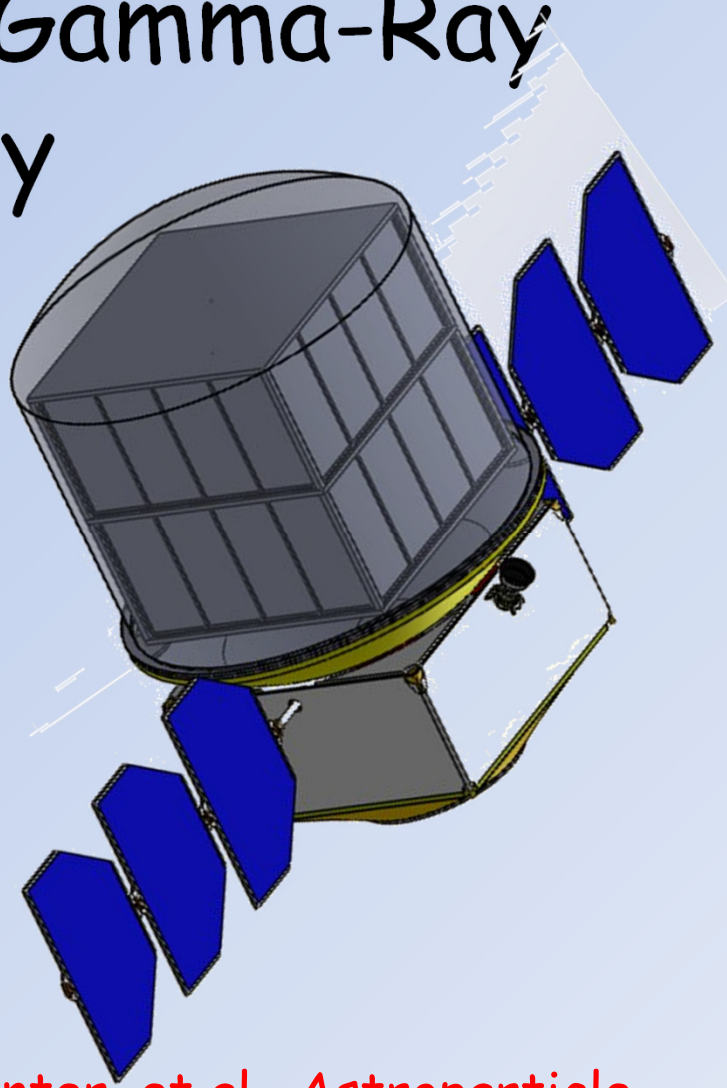


Hunter, et al., Astroparticle Physics, 59, 18-28 (2014)

Gamma-Ray Workshop

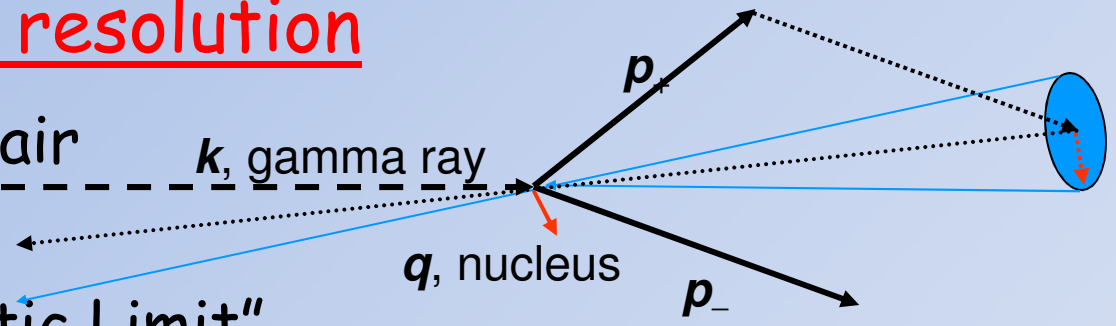
- Future Space-Based Gamma-Ray Observatories
  - NASA/GSFC, Feb 5-7, 2015
- Main themes for future gamma-ray missions
  - **Nuclear Lines and Polarization**
- AdEPT instrument and mission
  - Optimized for angular resolution and polarization
  - Mature mission and instrument concept
    - GSFC IDL/MDL runs
    - Viable Explorer mission

AdEPT Science, 5-200 MeV

- AdEPT will reveal the geometry of the most energetic accelerators in the Universe
- Explore fundamental processes of particle acceleration in active astrophysical objects
  - Pulsars, pulsar nebulae, supernova remnants, active galactic nuclei, magnetars, accreting binaries, gamma-ray bursts, …
- Map the transition from electron to hadronic processes in the Galactic diffuse emission
- Probe the universe for exotic processes
  - Dark matter
  - Lorentz invariance violation

AdEPT Design Philosophy

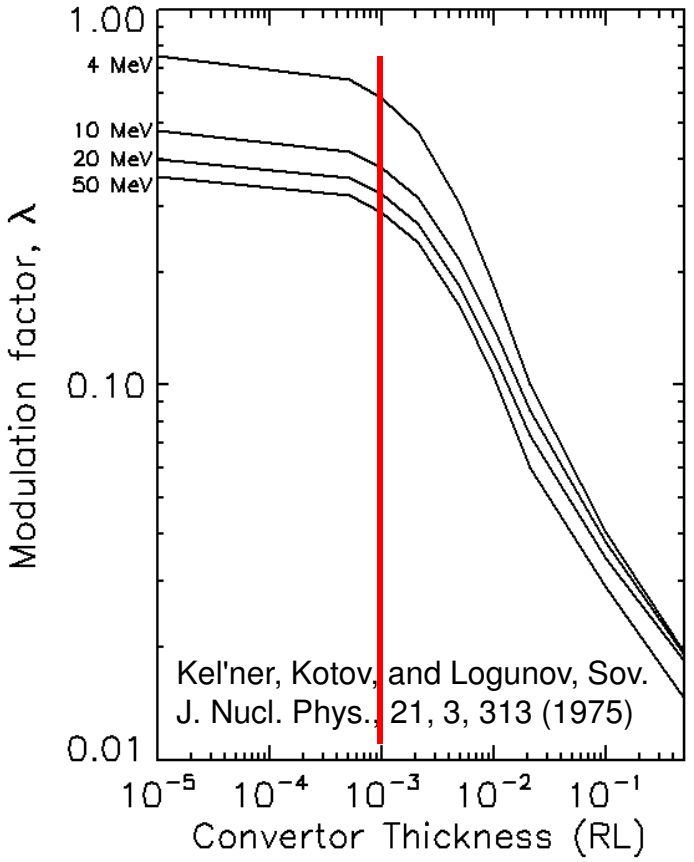
- Optimize for angular resolution
  - Angular resolution of pair telescope limited by nuclear recoil, "Kinematic Limit"



- Optimize for polarization sensitivity
  - Modulation factor, λ, decreases exponentially with thickness of tracking medium above ~1 mRL

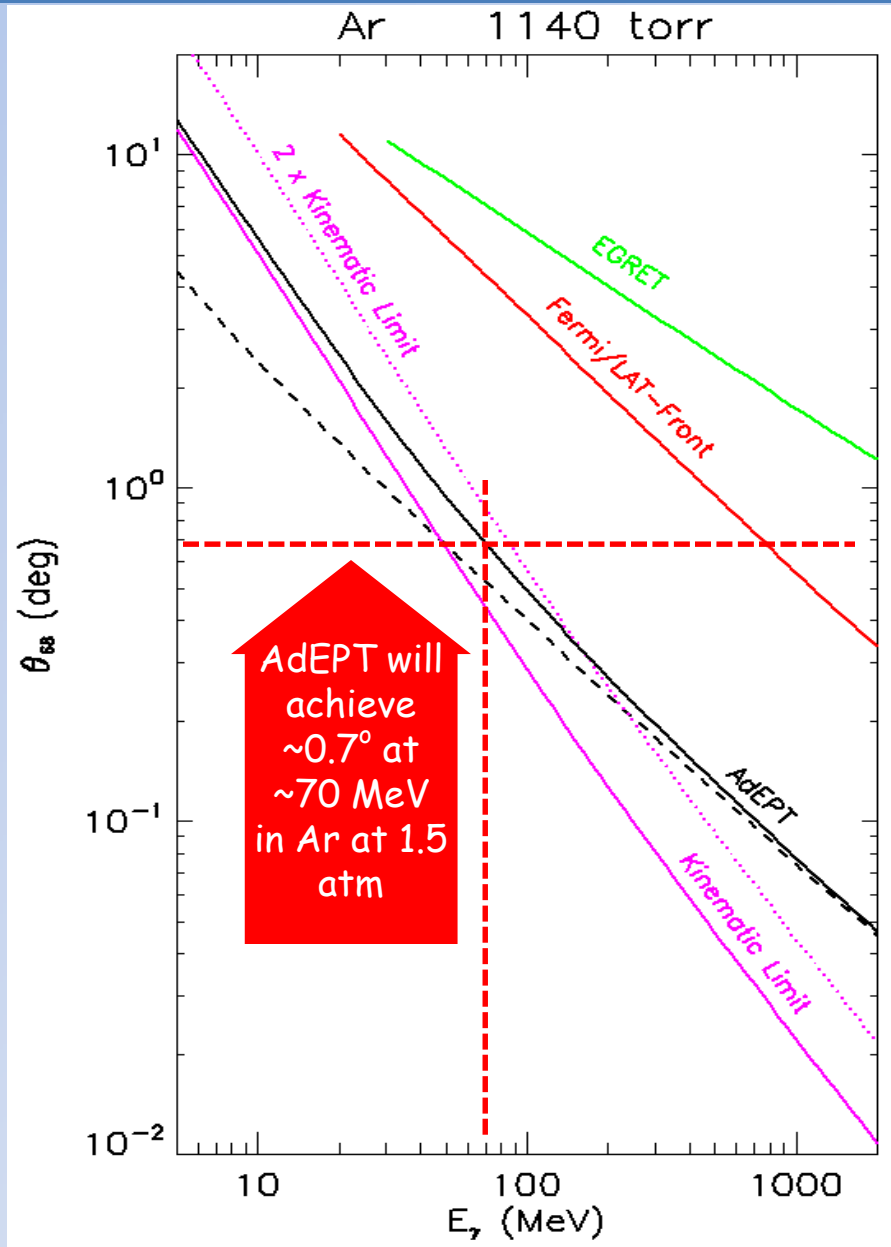
$$\sigma(\Psi_+) = \frac{\sigma_0}{2\pi}[1 + P\lambda\cos^2(\Psi_+ - \Psi_0)]$$

  - Measure e- and e+ directions in ≲1 mRL
    - ~100 μm of Si, ~8 cm of Ar at 1.5 atm



AdEPT Angular Resolution

- Continuous, low density, conversion and tracking medium
  - ~5 mg/cm^3 *i.e. a Gaseous medium*
- Angular resolution better than twice the Kinematic Limit up to ~200 MeV
- Low density enables detection of Triplet interactions
  - Low-energy angular resolution limited by spatial resolution, better than kinematic limit
  - Enhanced polarization sensitivity



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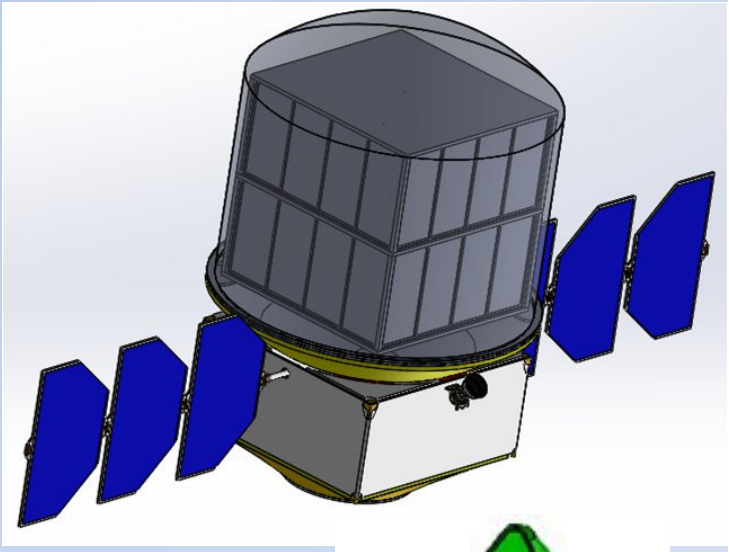
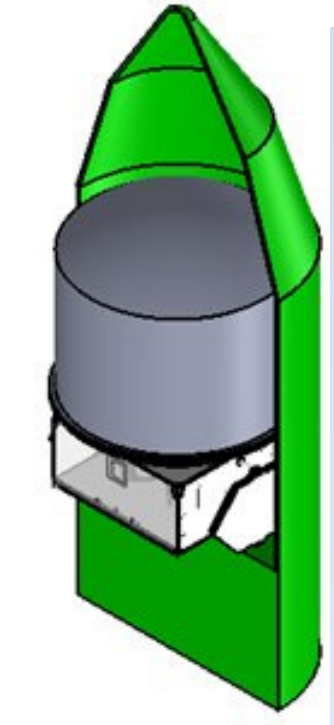
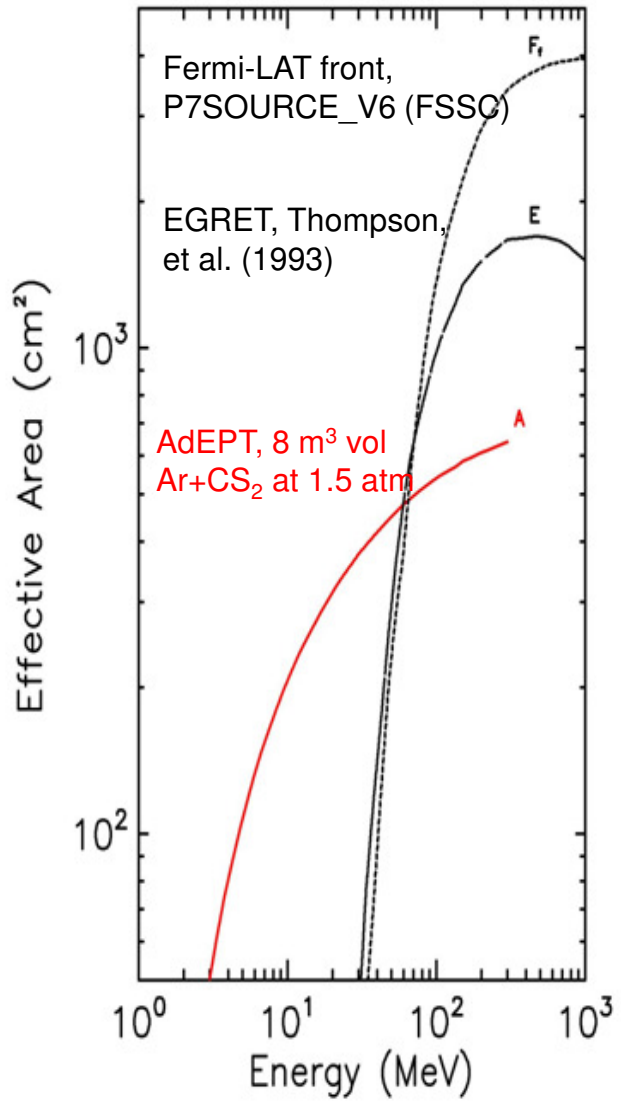
AdEPT is a Viable Gaseous G-ray Polarimeter!

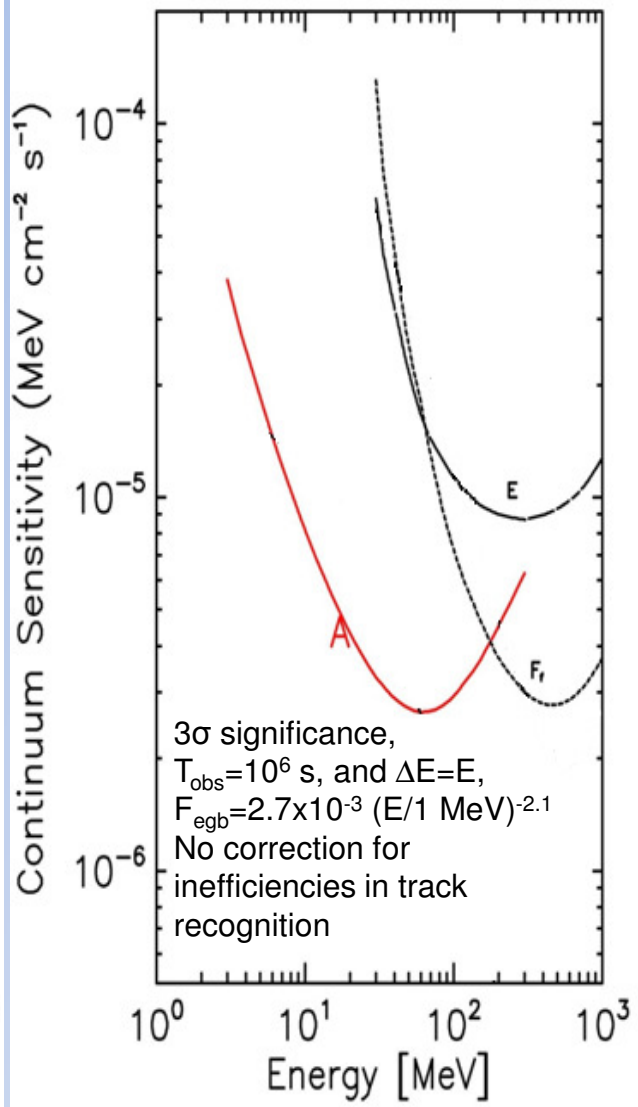
- Baseline design studied in GSFC IDL/MDL
- 2×2×2 array of 1 m^3 3-DTI modules
  - A_{geom}: 4 m^2, ~40,000 channels
- Ar (1100 torr) + CS_2 (40 torr), 25° C
- Pressure vessel: Al, 4 mm thick, ~300 cm diameter, ~530 kg
- Instrument power: ~500 W,
  mass: ~320 kg w/o s/c, pv
- Spacecraft: zenith pointed, 3-axis stabilized, scanning mode
- Orbit: near equatorial, ~550 km altitude
- Athena launch vehicle
- Fits within mission constraints: **Mass, power, & cost**

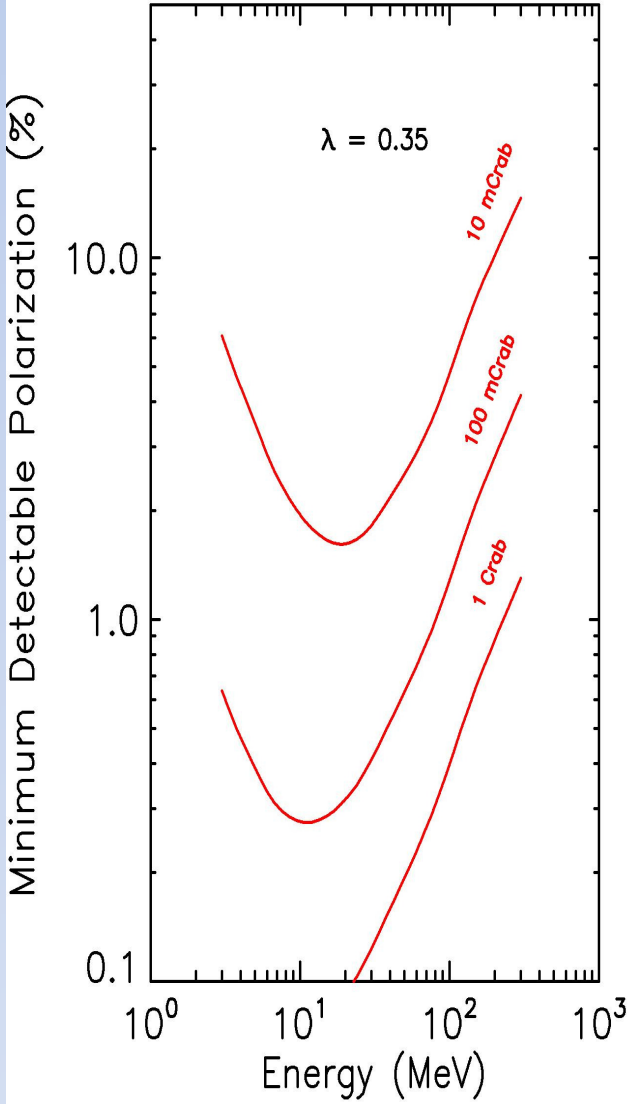




AdEPT Baseline Performance

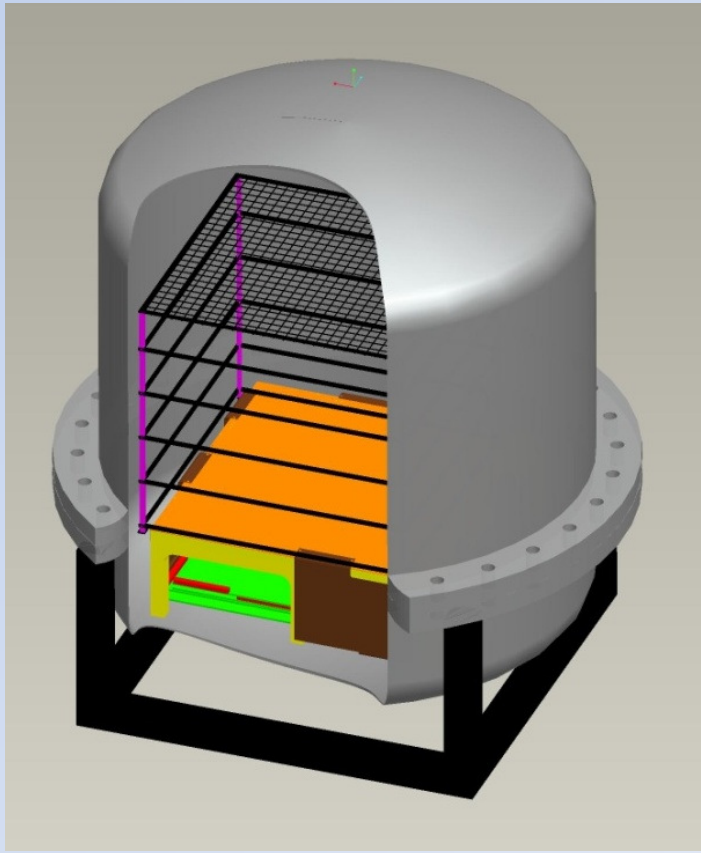






AdEPT Instrument Development

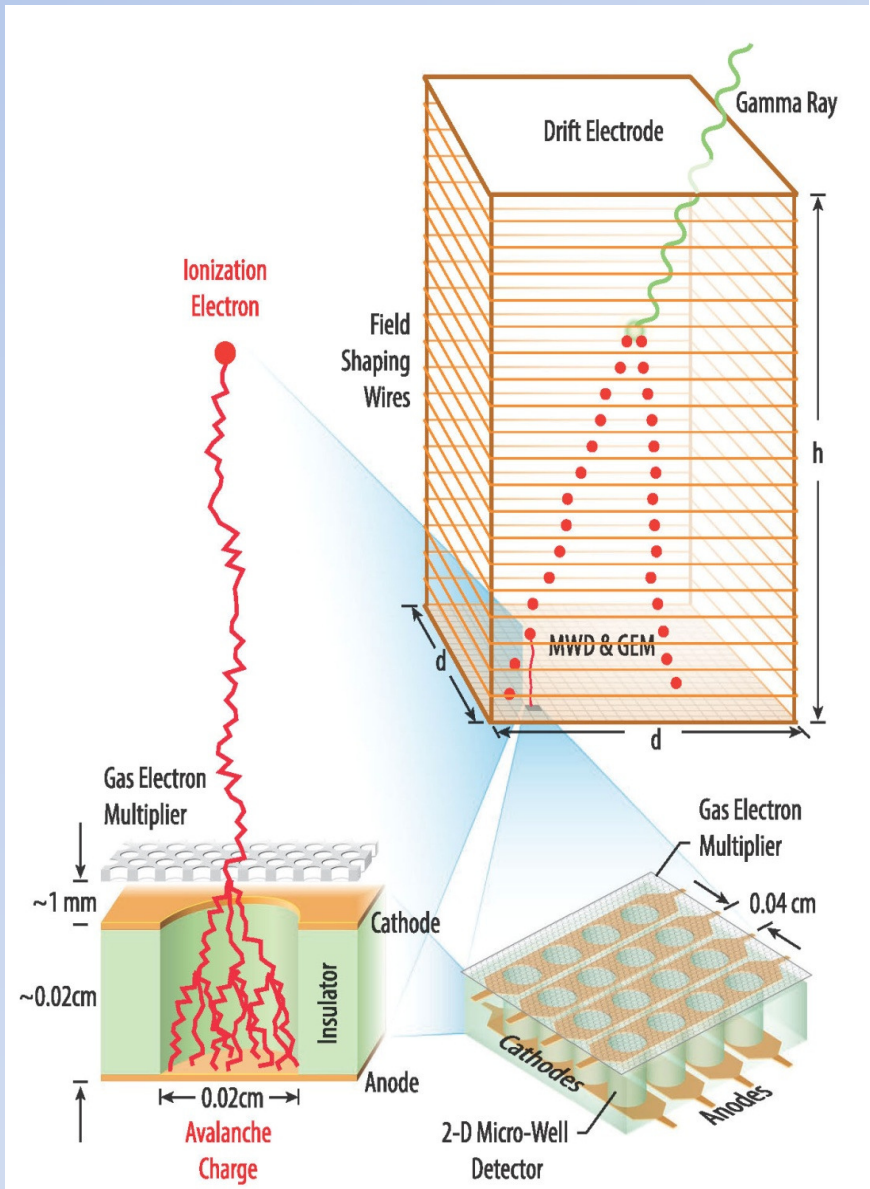
- 2015-18 ROSES-APRA
  - 50 x 50 x 100 cm^3 AdEPT prototype
    - Multi-core processor to discriminate gamma-rays from background
      - Determine gamma-ray direction, energy, polarization, and time of arrival
    - Large area MWD integration
    - FEE ASIC
  - Calibrate at accelerator with polarized gamma rays, 5 - ~90 MeV
    - Determine electron energy from Coulomb scattering
    - Measure angular resolution
    - Polarization sensitivity
- Future NASA mission!



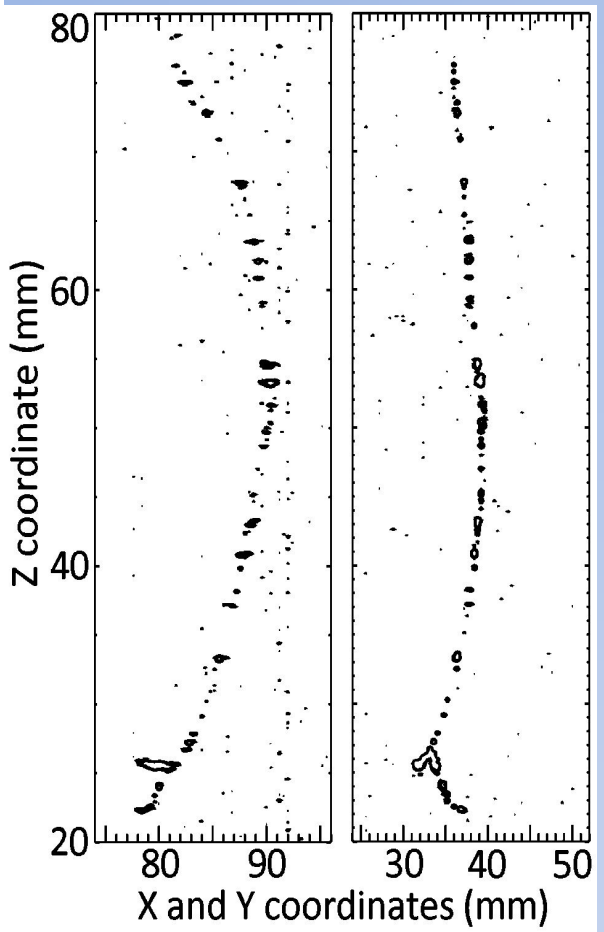
BACK-UP MATERIAL

3-Dimensonal Track Imager (3-DTI)

- AdEPT Enabling Technology
  - Large-volume gas **time projection chamber** (TPC)
    - Low density, homogenous, 100% active particle tracking
    - Thermal diffusion achieved with negative ion drift
  - **2-D readout**, 2-D micro-well detector (MWD) + GEM
    - Active detector, 0.4 mm pitch
    - GEM provides additional gain lost to negative ion drift
  - Scalable to large area



Electron Tracking in 3-DTI



X-Z, & Y-Z projections of single electrons from ^{90}Sr in Ar +CS_2 with 0.4 mm resolution

X-Z projection of 6.129 MeV gamma interaction in 80% P-10 + 20% CS_2