



 γ -ray astronomy with magnetic-field-free active targets: Optimal measurement of charged particle momentum from multiple scattering with a Bayesian analysis of filtering innovations

D. Bernard & M. Frosini, LLR, Ecole Polytechnique, CNRS/IN2P3

<u>Science Case</u> (1) Compton telescopes

(2) Pair telescopes

• Electron Tracking Compton Camera (ETCC) provides well defined, small PSF (small SPD)

• Si-wafer and gas TPC, high performance telescope development.

eASTROGAM V1.1 (PAIR), E = 100 MeV, theta = 30 deg., Event ID (N = 22) = 144







T. Tanimori *et al.*, Sci. Rep. **7**, 41511 (2017)

A_{eff} drops above 0.5 MeV, e⁻ escapes measurement.
Measure e⁻ momentum in TPC itself ?



A 100 MeV γ ray in the eASTROGAM detector

- V. Fioretti, Geant4 Space Users' Workshop G4SUW, Guildford, 2017
- Low density (wrt Tungsten-based Fermi-LAT) \rightarrow large volume
- $e^{+,-}$ momentum measurement a mass budget issue (calorimeter, magnetic spectrometer, TRD (transition radiation detector))
- Measure momentum in tracker from multiple scattering deflections ?

D. Bernard, Nucl. Instrum. Meth. A 701, 225 (2013)

Momentum from multiple measurements of multiple scattering

State of the art

• Deflection angle distribution approx. Gaussian, with RMS :

$$\theta_0 \approx \frac{p_0}{\beta p} \sqrt{\frac{\Delta x}{X_0}},$$

• Any deflection measurement is a momentum measurement.

G. Molière, Zeitschrift Naturforschung A 10 (1955) 177.

• Used in emulsion detectors an liquid argon TPC (muon detectors)

Kalman filter

- "Process noise" (multiple scattering)
- "Measurement noise" (detector resolution)
- Optimal estimation of the state vector (track) if noise matrices (momentum) are known
- \bullet Momentum estimated from maximum value of the Bayesian probability function p(s),

- Track segmented in tracklets
- Angle (deflection) measured on each tracklet.
- $\bullet \, \mathrm{d} E / \, \mathrm{d} x$ management along track with Kalman filter
- State vector "augmented" to (x, y, dx/dz, dy/dz, 1/p)

M. Antonello et al. [ICARUS Collaboration], JINST 12 (2017) no.04, P04010

- *p* both in state vector and noise matrix : "not appropriate estimates" J. Duník *et al.* IFAC **42** (2009) 372-377.
- Optimality ?

Results

• Unbiased momentum measurement





denis.bernard@in2p3.fr

$$s \equiv \left(\frac{p_0}{p}\right)^2 \frac{\Delta x}{lX_0}$$

s average multiple-scattering angle variance per unit track length,



p(s) distribution for a 50 MeV in the e-ASTROGAM Si-detector.

Performance for the Si-wafer e-ASTROGAM detector

• Si detector : method usable up to 1 GeV/c.

http://llr.in2p3.fr/ dbernard/polar/harpo-t-p.html