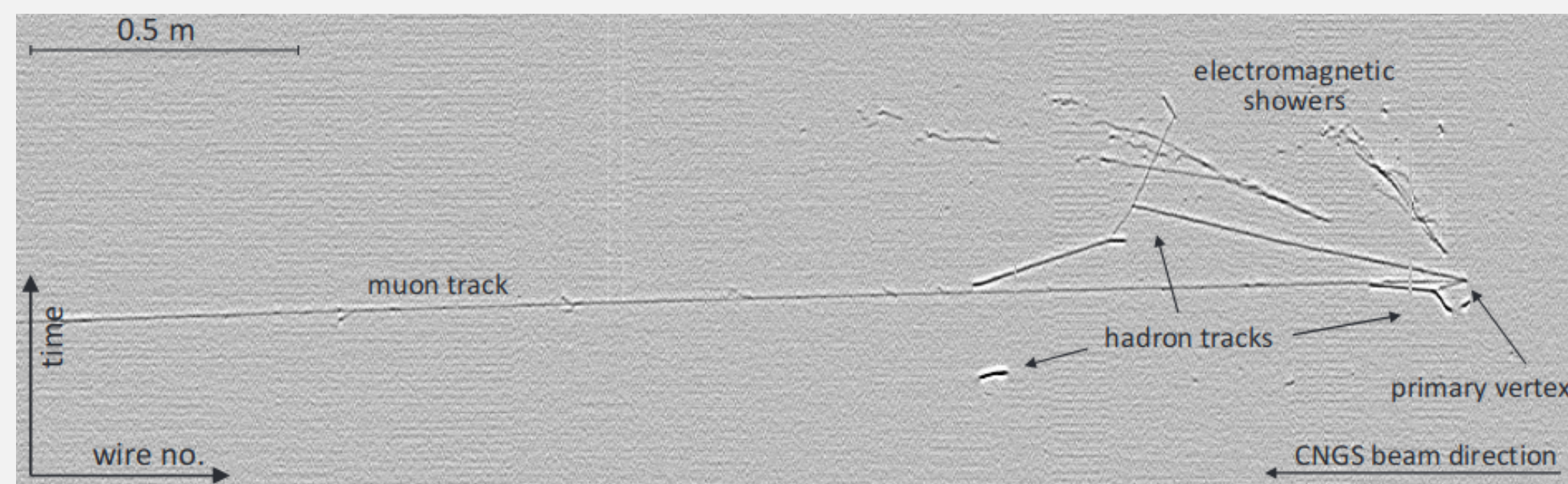


Kalman meets Molière: Optimal measurement of charged particle momentum from multiple scattering by Bayesian analysis of filtering innovations

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

(1) Long-base-line Large lAr TPC ν detectors

- Huge liquid-argon TPC projects (DUNE)
- Need μ momentum measurement in non-magnetized homogeneous detector



ν_μ charged-current interaction in the ICARUS T600 liquid argon TPC

M. Antonello *et al.*, *Adv. High Energy Phys.* **2013** (2013) 260820 [arXiv:1210.5089].

Multiple measurements of multiple scattering

- 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.
- Used in emulsion detectors and liquid argon TPC (muon detectors)

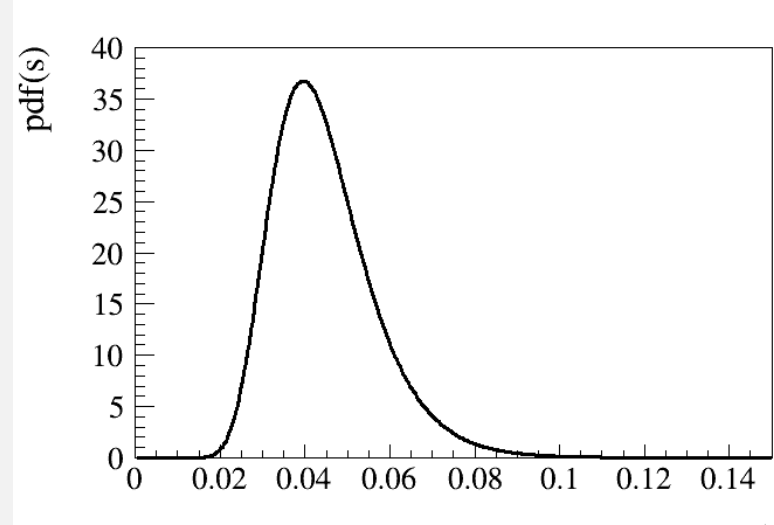
G. Molière, *Zeitschrift Naturforschung A* **10** (1955) 177.

Kalman filter

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

P. Matisko and V. Havlena, *Int. J. Adapt. Control Signal Process.* **27** (2013) 957.

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

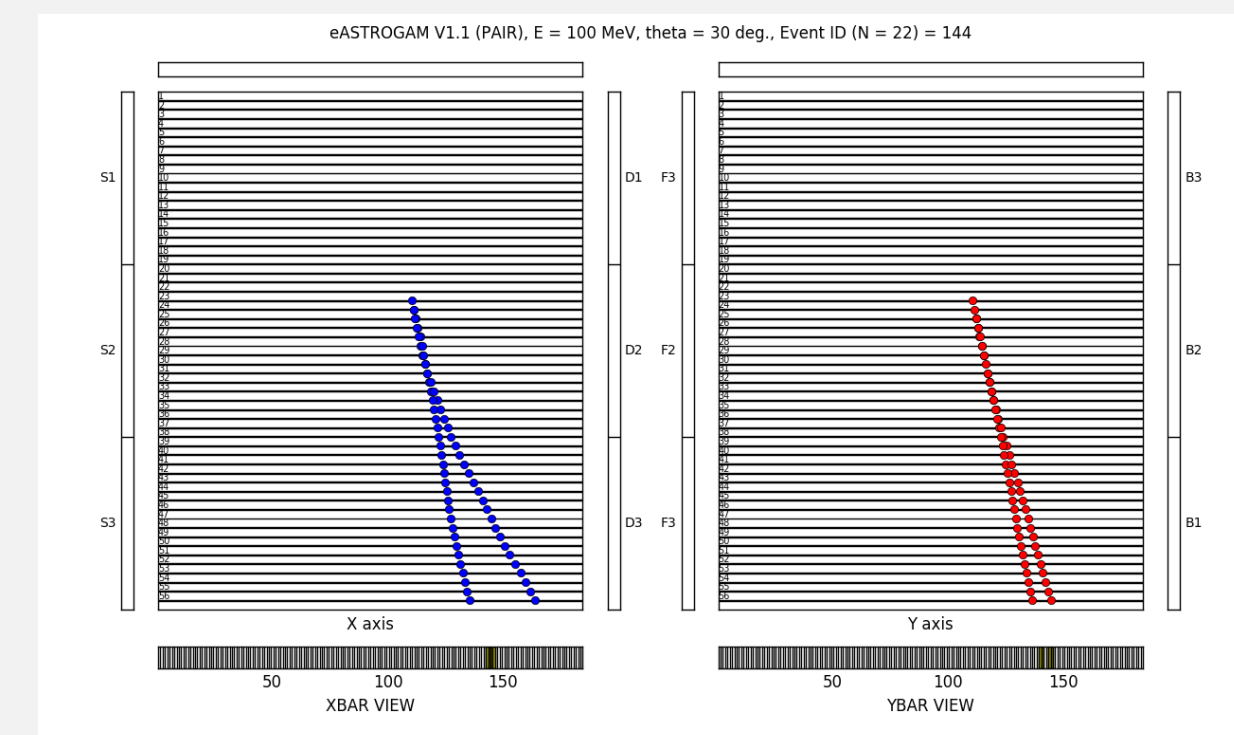


$$s \equiv \left(\frac{p_0}{p}\right)^2 \frac{\Delta x}{lX_0}$$

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

(2) Pair telescopes

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



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 ..)
- Measure momentum in tracker from multiple scattering deflections ?

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

State of the art

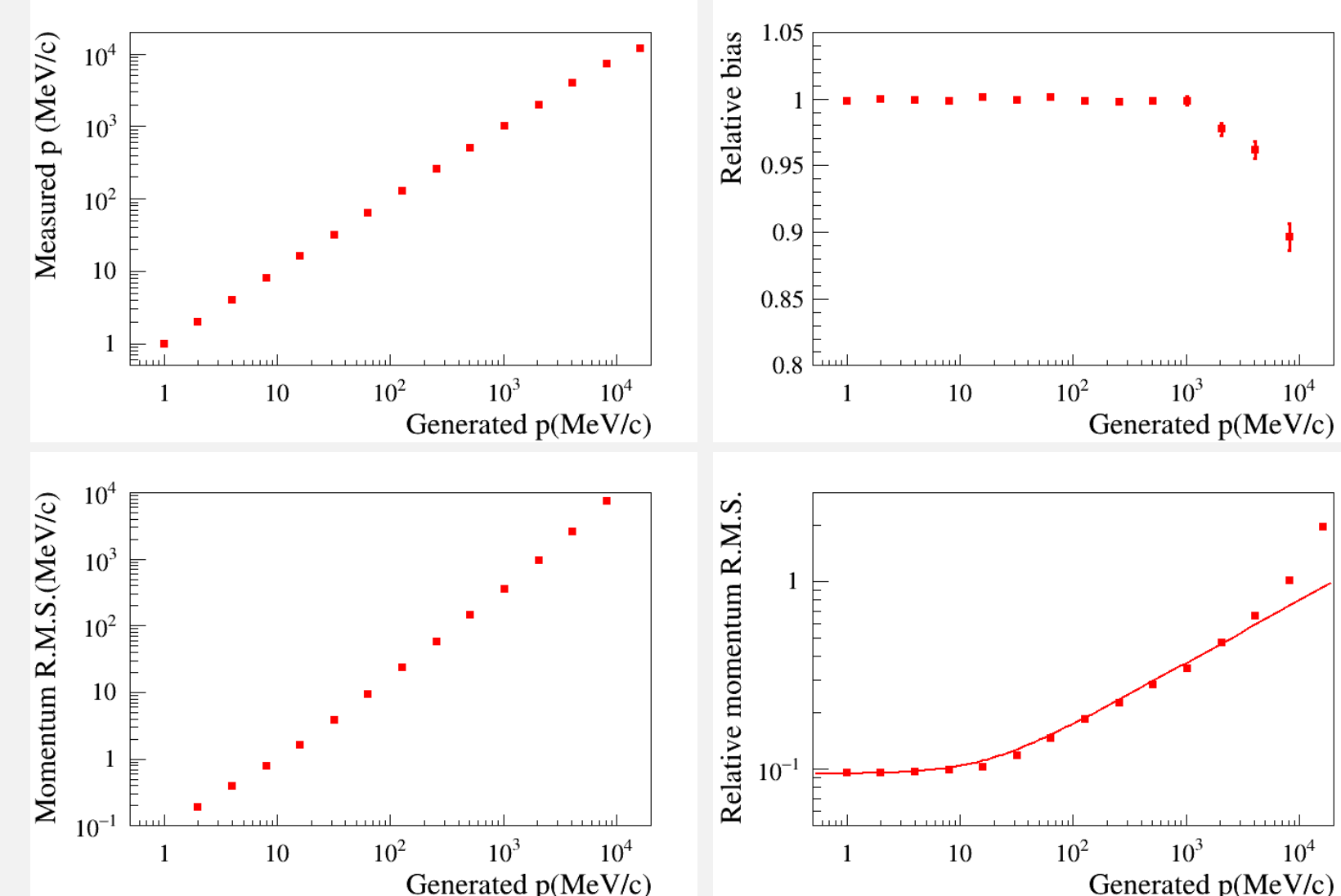
- Track segmented in tracklets
- Angle (deflection) measured on each tracklet.
- dE/dx management along track with Kalman filter
- State vector “augmented” to $(x, y, dx/dz, dy/dz, 1/p)$
- p both in state vector and noise matrix : “not appropriate estimates”
- Optimality ?

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

J. Dunik *et al.* *IFAC* **42** (2009) 372-377.

Results

- Unbiased momentum measurement



Performance for the Si-wafer e-ASTROGAM detector

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