Particle Tracking with Gempix - a Timepix Based Gas Detector

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Particle Tracking with Gempix - a Timepix Based Gas Detector

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How does the Gempix Work?

- Initial electrons created by an interaction are transported by electric fields to the GEM foils.
- Each GEM foil creates up to 40 output electrons for each electron in, three GEM foils give gains up to 10⁵ (depending on the gas)
- These electrons are collected by the Timepix, ~1000 electrons is enough to trigger a pixel (high gain operation)



Quad Timepix ASIC

(A) Photon interaction, (B) Electron multiplication, (C) Detection/Readout



GEM Detectors

- A GEM consists of a large kapton sheet with both sides metallized
- A potential is placed across both sides and tiny holes etched in the detector
- Electrical fields can reach ~100 kV/cm inside the holes, allowing for a **localised** electron avalanche



The Gempix - An Ultra Pixellated Gas Detector



(1) Gas Supply
(2) High Voltage
(3) Entrance Window
(4) GEM Foils
(5) FITPix Readout

Sensitive area = 3×3 x 1.2 cm³

The Timepix Pixel



- Medipix (pulse counting)
- TOA (Time of arrival)
- TOT (Charge surrogate measurement as a Wilkinson ADC)
- TOA/TOT achieved with an on chip clock synchronised to all pixels (up to 100 Mhz, but 50 stable)

Typical Frame - ⁵⁵Fe (5.9 keV)



Gas Mix = Ar:CO₂CF₄ (45:15:40), Gain = $1350V = 2.10^{4}$

Spectra - ⁵⁵Fe (5.9 keV)



18.3% Energy Resolution on the corrected Fe Peak

Typical Frame - ⁵⁵Fe (5.9 keV)



Response of 8x8 pixel regions

Mapped average response from gaussian fit

Maximum Count Rate (Xray tube, 40 kVp)

- Single interaction defined with clusterable data
- Maximum count rate ~10⁷/s (10⁶/cm²/s)
- Some room for optimisation by changing asic settings (factor 2 variation)
- Possibly an effect of the relatively high gain needed to readout the Timepix?



Particle tracking (CERN SPS MIP's)



Total dT ~ 400 nS

Effect of Chamber Gain



Measurement of Drift Velocity (vary drift field)

Track top/bottom delta times (morphological operator for time walk correction) Drift Velocity (mean from gaussian fit of curves on left)







Spatial Resolution



 $R = 170 \,\mu\mathrm{m}$ $R_{px} = 17 \,\mu\mathrm{m}$

(mostly because the time resolution is poorer than the spatial resolution)

Mixed Mode Operation



Note, TOA pixels are doubled in lateral size for visual effect

Gempix Energy Deposition Spectrum



PAI -> Geant4 PAI model, range cut = 0.1 mm, mono energetic 3 GeV 2/3 proton, 1/3 pi+ pencil beam on 24 mm ArCO₂CF₄ **Gaussian + PAI** -> Smearing following: $\sigma = A\sqrt{\Delta E(\text{keV})}$

^[1] J. Apostolakis et al, "An implementation of ionisation energy loss in very thin absorbers for the GEANT4 simulation package", NIM A, Volume 453, Issue 3, 21 October 2000, Pages 597–605

Angular Reconstruction - Mixed vs TOA



Avalanche Statistics



B factors not constant - threshold effects?

Plot of intercept parameter from left (charge cloud width 'just' from GEM structure)

An Application - Microdosimetery

- The study of radiation interactions at the scale of cellular structure
- The number of atoms in a 5 mm path in gas is about the same as in a cellular nucleus
- Typical instrumentation is a single low pressure gas
 volume or silicon volume
 volume 250 silicon volume

50

 Gas pixel detectors offer the ability to examine each track individually



50





An Advert!



- Aurora Tamborini
- Carbon therapy beam monitoring with GEMPix
- MIC Poster session IV (Friday at 16:30), M5DP-252