

High tracking performance in 3D

with gaseous pixel detectors based on the Timepix3 chip.

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TIPP2017, Beijing, May 25th 2017

Outline

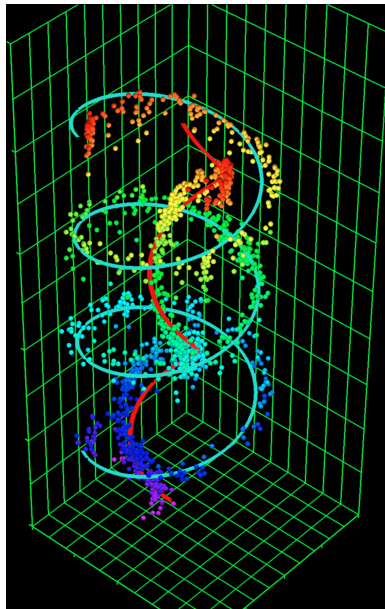
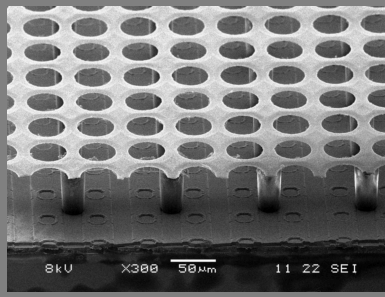
- Gaseous pixel detectors
- Detector construction
- Testbeam
- Analysis
 - Timewalk correction
 - Tracking performance
- Conclusions



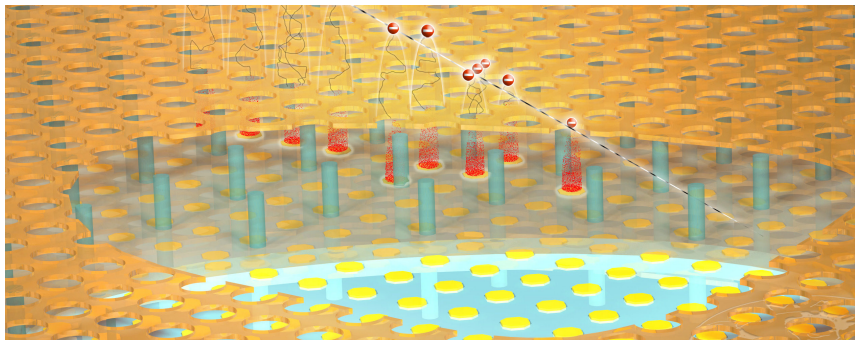
Micropattern gaseous pixel detectors

- Low material budget
- Less radiation damage
- Single electron detection
- High position resolution
- 3D track reconstruction

Under microscope



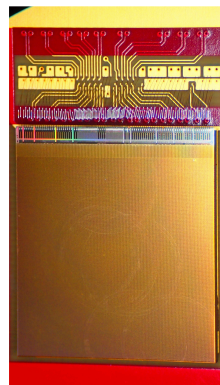
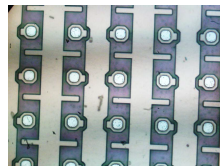
Working principle



- Ionisation in drift gap
- Electrons drift towards amplification gap ($50\text{ }\mu\text{m}$)
- Avalanche multiplication
- Induced signal on pixels
- Pixel position gives (x,y)
- Drift time gives z

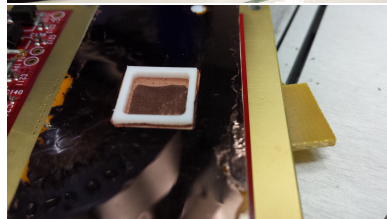
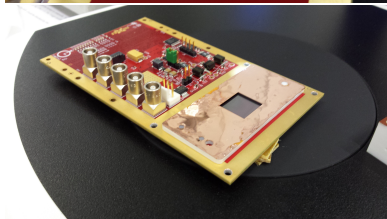
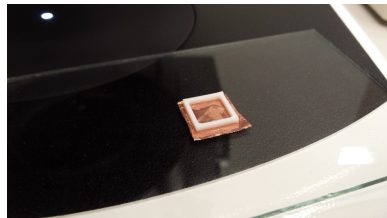
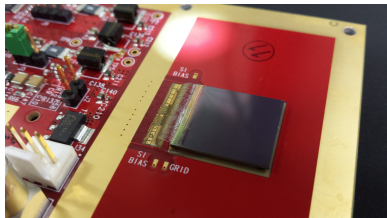
Timepix3 chip

- Designed by Medipix collaboration, CERN
- Matrix of 256×256 pixels
- $55 \mu\text{m}$ pixel pitch
- High resolution TDC per pixel
- Rise-time $< 25 \text{ ns}$, 1.562 ns resolution
- Simultaneous ToA & ToT measurement
- Low threshold, $6\sigma_{\text{noise}} \approx 500 \text{ e}^-$
- Readout rate up to 80 MHits/s per chip



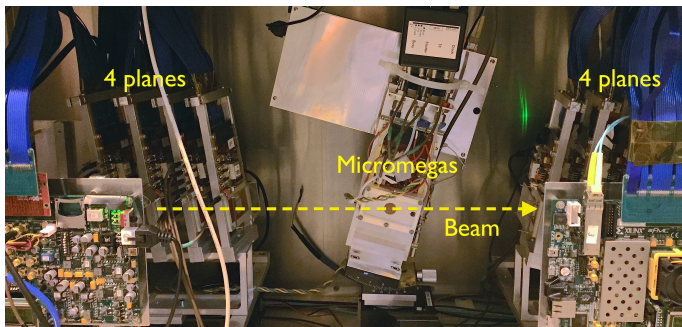
Detector construction

- Delayed production of InGrids on top of Timepix3 chip
- At that time, only Micromegas foils were available.
- Not integrated - manually placed



Testbeam set-up

- CERN SPS/H8A
- Muon and hadron beams
- Scintillators for ext. trigger
- Spidr readout

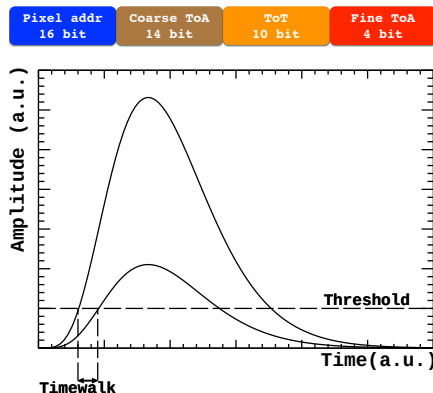


Timepix3 silicon telescope (LHCb VELO group)

Motivation

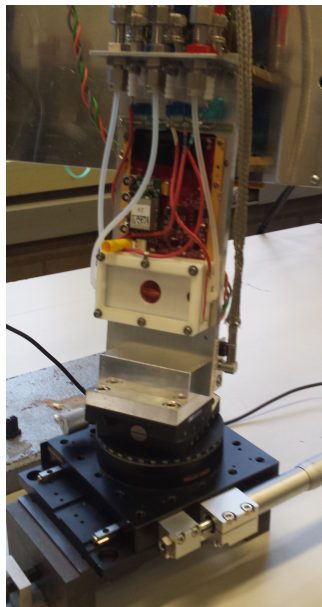
Offline correction for the “timewalk” effect

- All chips suffer from “timewalk”
- Gas gain fluctuations and/or rise-time variations
- Timepix3 chip enables such a correction
- Simultaneous measurement of ToT & ToA
- Measure the impact on the tracking performance



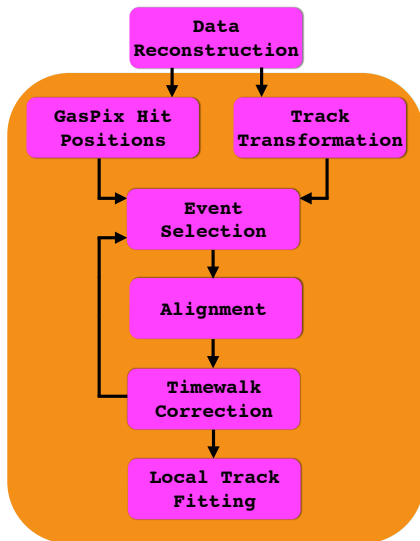
Detector settings

- CO₂/DME (50%/50%)
- $E_{\text{Drift}} = 1 \text{ kV/cm}$
- Drift gap $\approx 14 \text{ mm}$
- $V_{\text{grid}} = 550 \text{ V}$
- Gas gain $\approx 1.5\text{-}2.0\text{k}$
- 500 e^- threshold!
- Hadron beam (180 GeV/c)
- Rotation angle of 20°



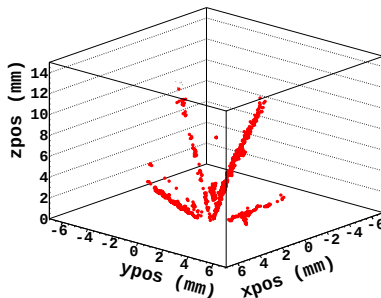
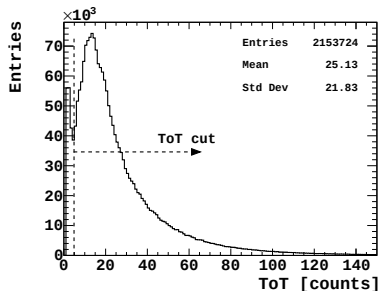
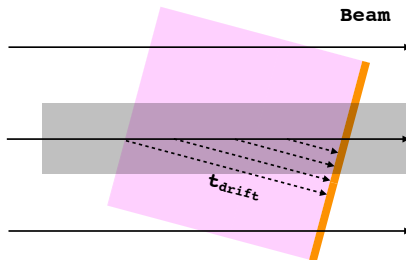
Analysis strategy

- Synchronise & merge telescope and GasPix data
- Transform telescope tracks to the GasPix frame
- Alignment based on hits
- Iterative procedure
- Fit the corrected hit positions with a straight line



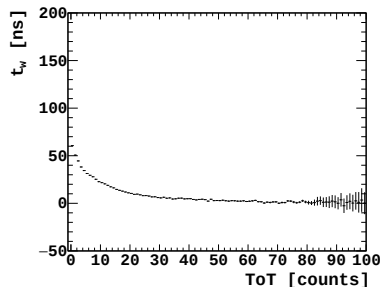
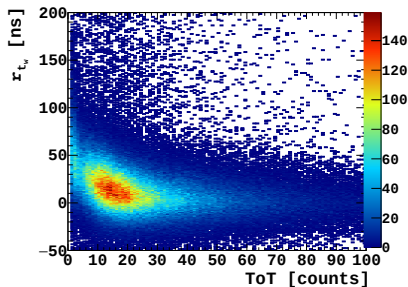
Event selection

- Accept tracks within a fiducial volume
- Reject events with large number of hits
- Reject noise hits



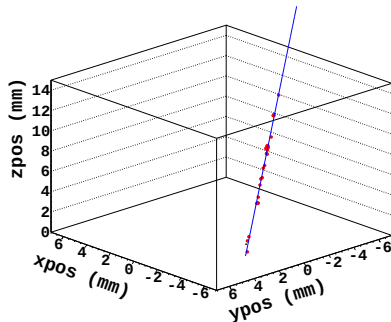
Timewalk correction

- Convert hit-residuals in time-residuals
- 2D histogram of the time-residuals against ToT
- Fit each slice with a gaussian
- Obtain timewalk (mean) and its error (sigma)
- Calculate corrected z'_h



Single hit resolution

- Hit position in 3D (x_h, y_h, z'_h)
- $\sigma_{x_h}^2 = \sigma_{y_h}^2 = \frac{d_g^2}{12} + D_T^2 z$
- $\sigma_{z'_h}^2 = \frac{(t_{TDC} v_d)^2}{12} + D_L^2 z + (v_d \sigma_{t_w}(\text{ToT}))^2$
- Obtain D_T, D_L from data



z [mm]	σ_x [μm]	σ_y [μm]	σ_z [μm]
0.0	17.3	17.3	36.2
1.0	34.3	34.3	46.7
2.0	45.2	45.2	55.3
5.0	68.3	68.3	75.4
10.0	95.0	95.0	100.2

GasPix event fitting

- Straight line fit (bivariate)

$$x = b_x + m_x z$$

$$y = b_y + m_y z$$

- Obtain b , m , χ^2 and the covariance matrix

$$\begin{pmatrix} \sigma_{b_x}^2 & 0 \\ 0 & \sigma_{m_x}^2 \end{pmatrix}$$

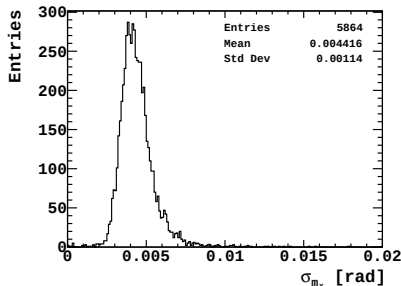
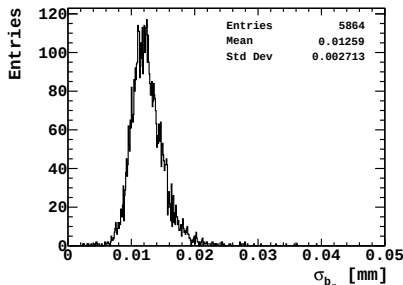
- At the center of gravity:

$$\sigma_{b_x}^2 = \sigma_{T_x}^2 + m_x^2 \sigma_{T_z}^2$$

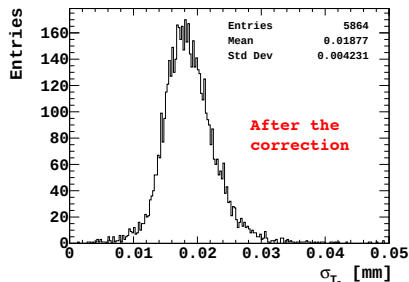
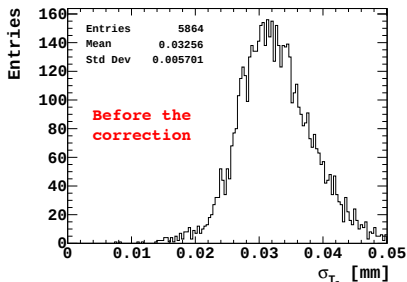
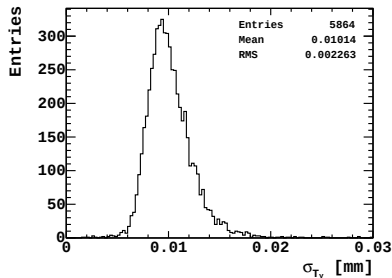
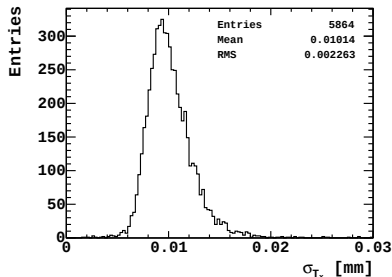
$$\sigma_{b_y}^2 = \sigma_{T_y}^2 + m_y^2 \sigma_{T_z}^2$$

- Track resolution:

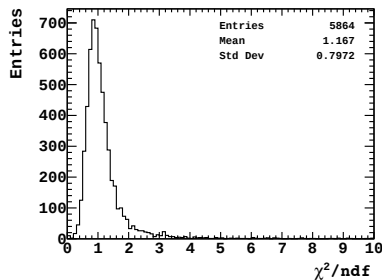
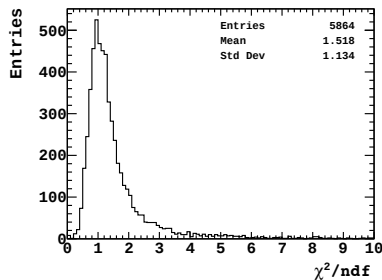
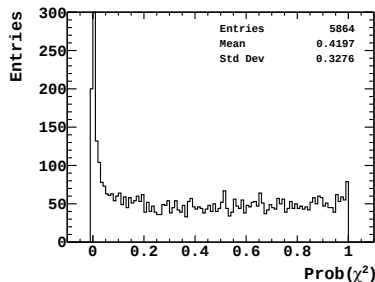
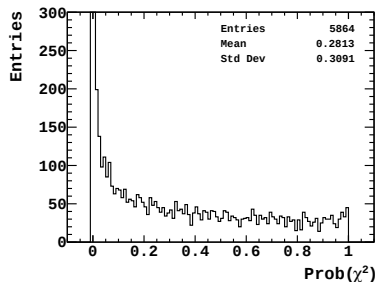
$$(\sigma_{T_x}, \sigma_{T_y}, \sigma_{T_z}) \text{ and } (\sigma_\alpha, \sigma_\beta)$$



Detector track resolution



Fit quality

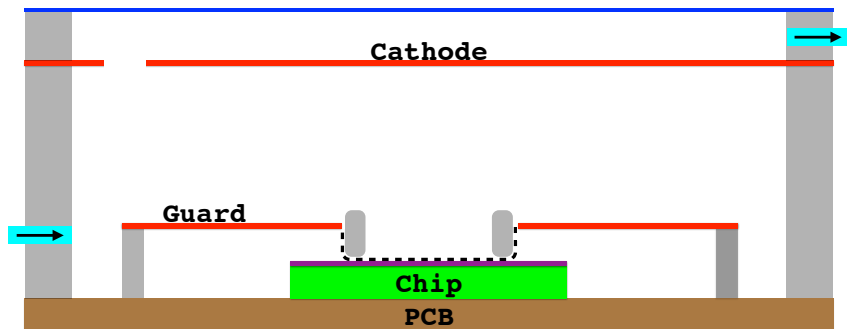


Concluding remarks

- We run at the minimum threshold for Timepix3 $\sim 500e^-$
- First correction for Timepix3 based on real particle data
- Tracking resolution: $(\sigma_{T_x}, \sigma_{T_y}, \sigma_{T_z}) = (10, 10, 19) \mu\text{m}$
- Angular resolution about 4.5 mrad for xz, yz projections
- Most precise detector to date for measuring the creation position of individual ionisation electrons

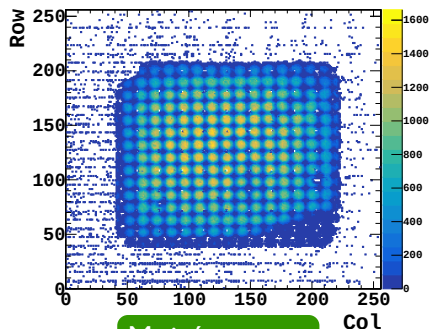
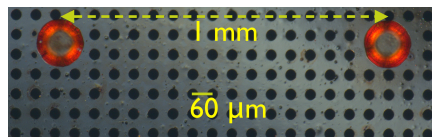
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Backup



Backup

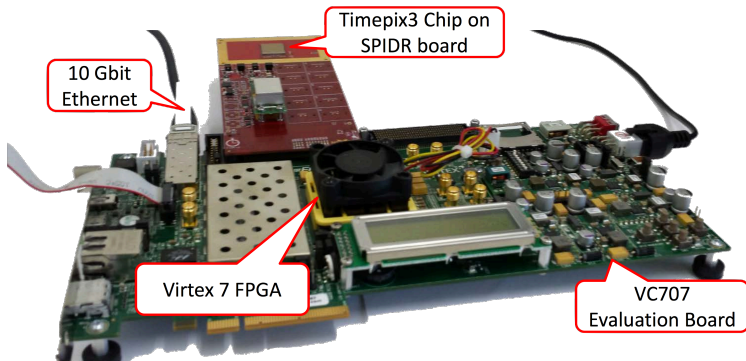
- 50 μm high pillars every 1 mm
- Hole diameter $\sim 35 \mu\text{m}$
- $d_g = 60 \mu\text{m}$, grid-hole pitch
- $d_p = 55 \mu\text{m}$ pixel pitch
- Mismatch = $\frac{60}{60-55} = 12$ pixels



Moiré pattern

Backup

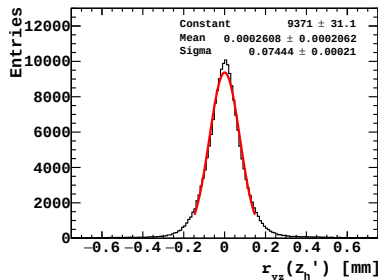
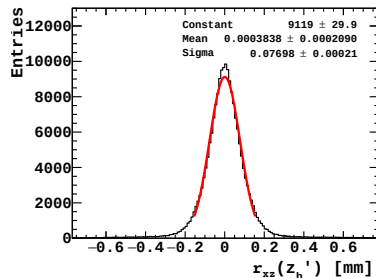
- Speedy Pixel Detector Readout (SPIDR)
- Based on Xilinx VC707 evaluation board



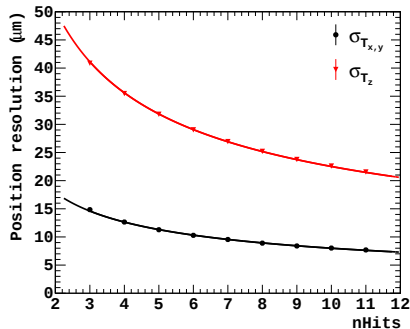
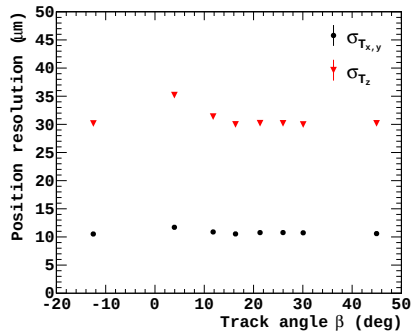
Backup

- Based on hits and not tracks
- Use events/tracks within the selection
- Update alignment constants iteratively

	Units	Value	Correction
T_x	mm	7.04	-0.41
T_y	mm	7.04	-1.88
T_z	mm	283	-1.94
α	rad	0.262	0.002
β	rad	0.349	0.002
γ	rad	0.	-0.011

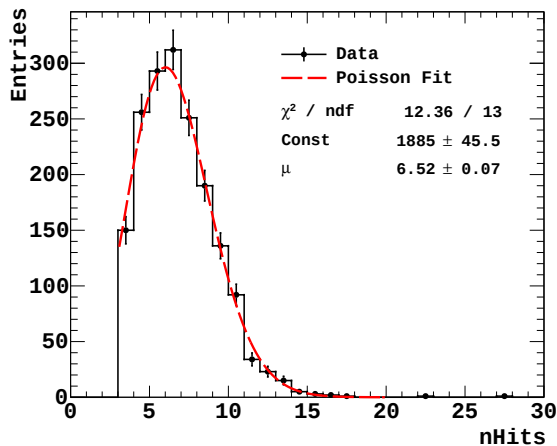


Backup



Nucl. Instr. and Meth. A 795 (2015) 309 – 317.

Backup



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