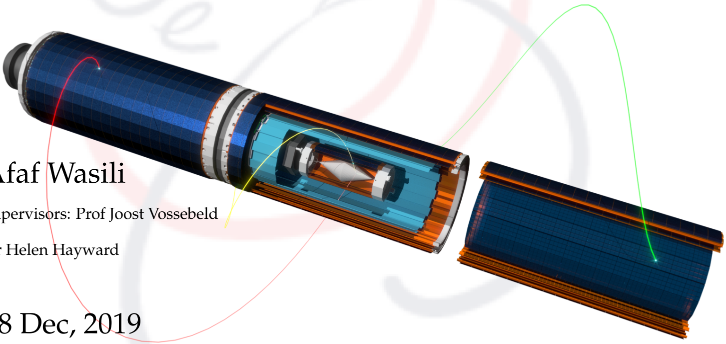
Xmass Meeting, University of Liverpool

Update on the performance study of a MuPix Detector Search with Mu3e Experiment $\mu^+ \rightarrow e^+e^+e^-$ at PSI



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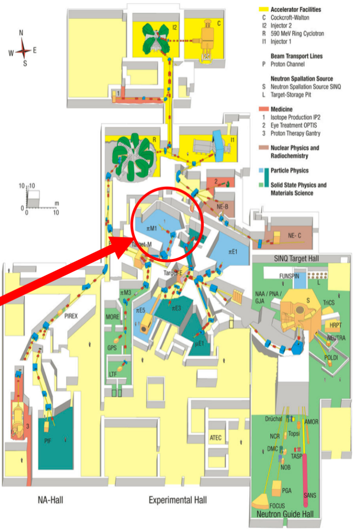
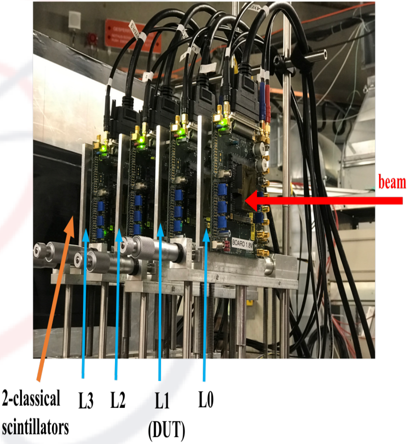
Test-beam is very useful to test the detector components such as MuPix prototypes on a smaller scale before using in the final Mu3e experiment



PSI Facility provides a mixed beam (e^{-},π,μ)
($P = 270$ MeV and $I = 1860.10$ μA) by
using πM1 area test-beam

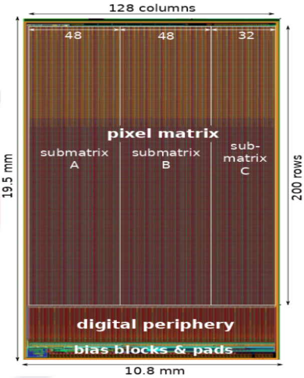
- What MuPix Telescope is?
  1. 3-layers of MuPix8 sensors with DUT layer
  2. DUT is layer 1, test-beam has been performed for MuPix8 and 9 as DUT.
  3. 2-classical trigger scintillators −(10 ps)
  4. All PCBs were connected to a HV power supply, and set to - 60 V for all measurements
- MuPix8 Telescope Configurations

Layer	Sensor ID	Board ID	Distance [mm]	Resistivity (Ωcm), Thickness(μm)
0	265-3-9	242-3-19	0	200,100
1	265-3-1	242-3-33	68.4	80,100
2	265-3-16	242-3-13	138	200,100
3	265-2-16	242-3-16	211	200,100



- What MuPix8 sensor?

1. First large prototype in MuPix group
2. Pixels have a size of $81 \times 80 \mu m^2$
3. Pixels are arrayed in 128×200 pixel matrix

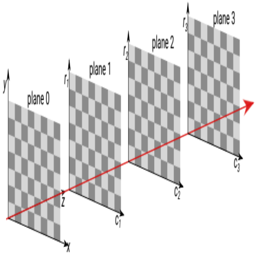


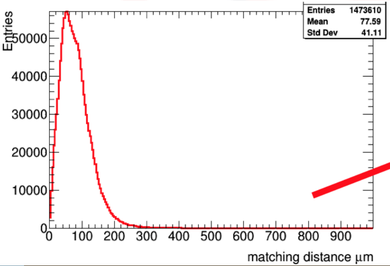
- Online selection cuts:

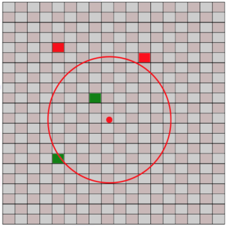
1. Calibration of Threshold −(set it till we see small noise)
2. Remove all hot pixels. During run, any pixel has 5% of the total hits, it will be rejected by eye on the online monitor histograms
   »» the number of hot pixels depends on threshold

Threshold mV	hot pixels removal out of 9600 pixels
545	120
570	13
650	0

- offline cuts and analysis procedure:
  1. Define coordinate systems, and fit track by (SLM) with ignoring MS and DUT layer:
  $$\mathcal{X}^2 = \sum_{i=1}^{n} \left(\frac{(x_i - (x_0 + a_x \cdot z_i))^2}{\sigma^2_{x_{m_i}}} + \frac{(y_i - (y_0 + a_y \cdot z_i))^2}{\sigma^2_{y_{m_i}}} \right)$$
  2. T_{window} = 100 ns, chi^2 = 100
  3. Search for ROI within $r_{matching}$ = 400 μm and match closest hit:
  $$(t_{\text{inters},x} - h_{\text{pos},x})^2 + (t_{\text{inters},y} - h_{\text{pos},y})^2 \leq r^2_{\text{cut}}$$

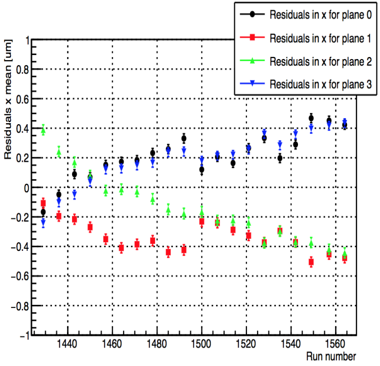


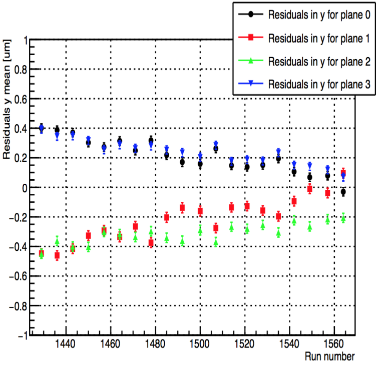




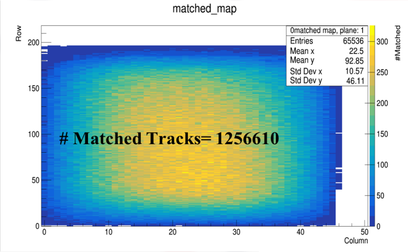
MuPix Telescope Test-Beam Highlights

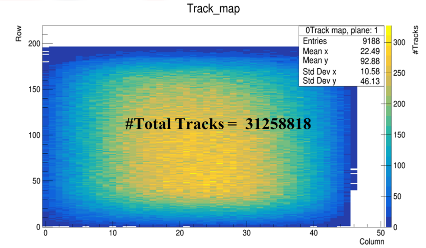
- X/Y-residuals vs the run number for each layer, the residuals are stable between 1 and -1 μm over the complete run set





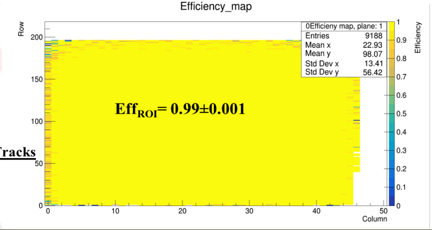
- The efficiency and noise of the DUT layer are given:
  (e.g efficiency of run 1429 with threshold 545 mV)



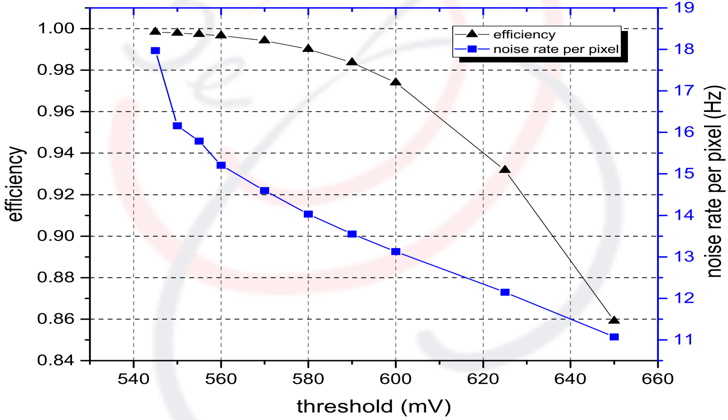


$$\mathrm{Eff}_{ROI} = \frac{\#\ \text{Matched Tracks}}{\#\ \text{Total Tracks}}$$

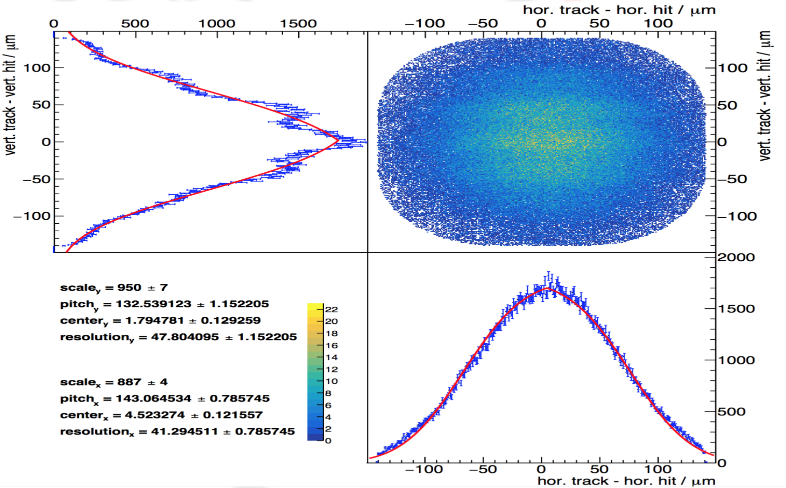
$$\text{Noise rate per pixel} = \frac{\#\text{hits} - \#\text{Matched Tracks}}{\text{runtime} \cdot \#\text{pixels}}$$



- Efficiency and noise rate per pixel scan vs threshold for different DAQ runs



- The pointing resolution of DUT layer is totally based on spatial resolution of the telescope. It is given via Gaussian Smeared Box fit– 41 μmx47μm

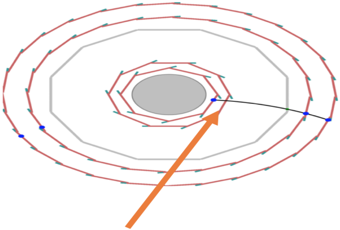


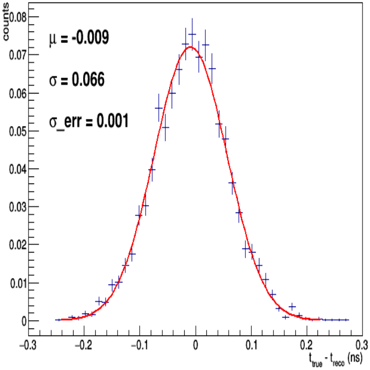
- Hardware: MuPix8 Telescope is powerful tool for test-beam studies, it can study efficiency, noise, and resolution
- Analysis of the timing performance for MuPix8/9 Telescope
- Understand noise rate from other test-beam

- Simulation: Timing studies for timing detectors of Mu3e detector to suppress C-bkg have been studied

Timing resolution	$chi2_{timing}$	suppression factor
fibre = 260 ps	7	IM+2IC = 105
tile = 66 ps	7	2M+1IC = 6500

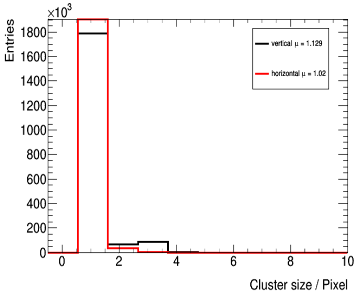
- Work to reconstruct tracks with missing hits
- Study predicated limits of C_{LFV} with realizing detector conditions

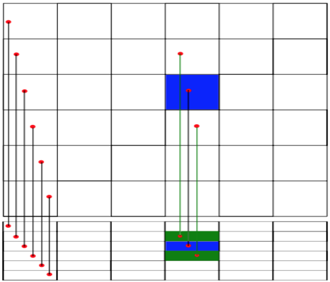




Thanks for listening!

- This plot shows that why better spatial resolution vertically have more than horizontally due to cross-talk. In the principle, 2-cluster size (set of hits are located at pixel edges) has better spatial resolution but horizontally less 2-cluster size have.





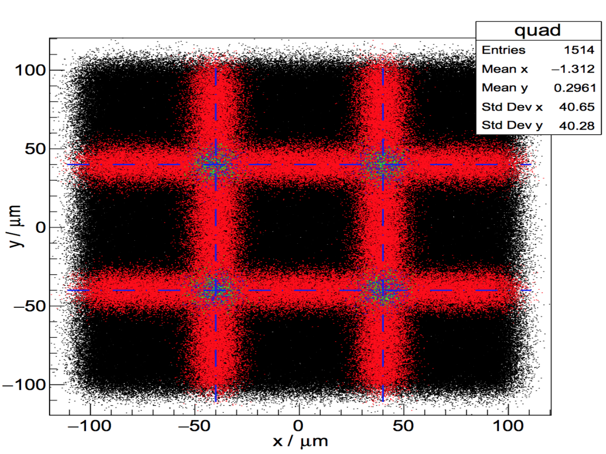


Figure: Single, double, triplet, quadruple cluster sizes

- The Gaussian smeared box fit is given via following equation in which worse resolution can spoil the edges, it can described as an error function which is indicated as s-curve:

$$\mathrm{erf}(x) = \frac{2}{\sqrt{\pi}} \cdot \int_0^x e^{-y^2} dy \tag{1}$$

This is an error function can be described only for one pixel edge located at position x = 0, in order to fit both edges with one fit, following function is used:

$$f(x) \approx A \left[\mathrm{erf}\left(\frac{w/2 - |x - c|}{\sigma\sqrt{2}} \right) + 0.5 \right] ; (w >> \sigma) \tag{2}$$

w: the width of the box c: the pixel center position A: the scaling factor