Track reconstruction for CMOS detectors in the upgraded ATLAS detector

Aim: Use simplified Geant 4 model of nine-layer CMOS pixel detector to investigate track reconstruction efficiency

Will lack of double layers significantly impair performance?

Conclusions (May 2017)

- With pile up = 100. 10% dead modules, find:
  96% muons, 95% pions, 2.6% ghosts
- With pile up = 100. No dead modules, find:
  99% muons, 98% pions, 0.9% ghosts
- With pile up = 50. 10% dead modules, find:
  98% muons, 95% pions, 0.8% ghosts

Geant 4 geometry

Adapted from model by Todd Huffman and Charles Jackson

Nine cylinder layers. Pixels modelled as silicon blocks.

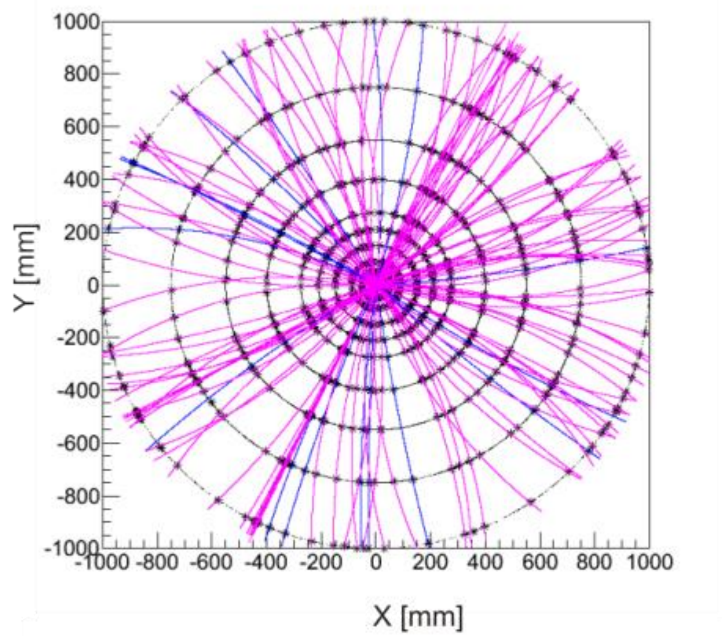
Parameter	Detector Layer								
	0	1	2	3	4	5	6	7	8
Layer radius [mm]	50.5	88.5	150	210	275	400	500	750	1000
Layer length [m]	2.4	2.4	1.5	1.5	1.5	2.8	2.8	2.8	2.8
Pixel length (parallel to beamline) [µm]	250	400	400	400	800	800	800	800	800
Pixel width (in Rϕ direction) [µm]	40	40	40	40	40	40	40	40	40
Pixel thickness [µm]	300	300	300	300	25	25	25	25	25
Inner dead layer [µm]					125	125	125	125	125
Outer dead layer [mm]	2	2	2	2	2	2	2	2	2

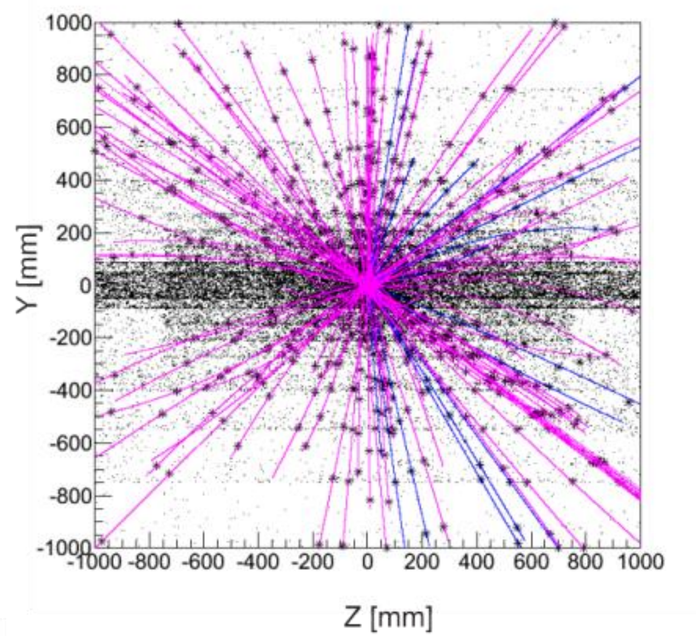
Total material (η=0): 20mm / 0.21 rad. lengths / 0.043 nucl. int. length

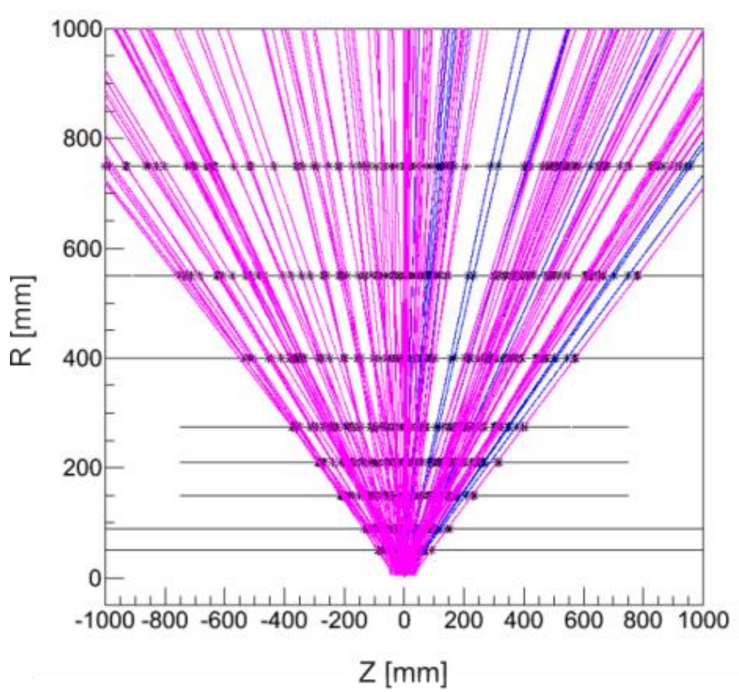
- Pythia 8.2 simulates pp-collisions at 13 TeV → Z' bosons.
- + 'artificial' muons – random energy (below 10GeV) and direction.

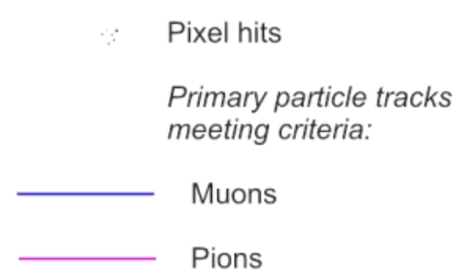
Reference truth track criteria:

- Muon or pion
- Originating from primary vertex on beamline (x=y=0) $|z|<45$mm
- $P_T > 1$ Gev
- $|\eta| < 1.15$ (to cover the range where particle tracks pass through all nine layers)
- Interacts with at least 6 layers









5000 GeV Z' decay
+ 25 artificial muons
+ 100 softQCD decays

Event with pileup

Results with ×100 pileup

$\sqrt{X^2/N}$ Cut	Track recognition efficiency		Ghosts
	Muons	Pions	
<1.175	519/533 (97.4%)	4520/4716 (95.9%)	1601 (30.5%)
<0.459	513/533 (96.2%)	4493/4716 (95.2%)	294 (5.6%)
<0.343	510/533 (95.7%)	4476/4716 (94.9%)	138 (2.6%)
<0.161	490/533 (91.9%)	4234/4716 (89.8%)	20 (0.4%)

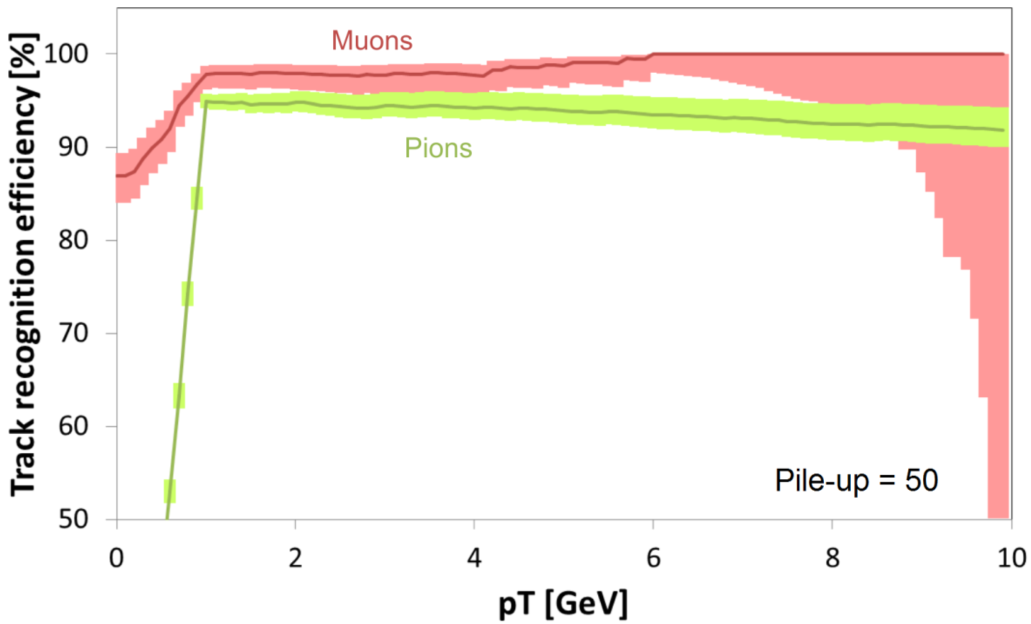
With no dead modules:

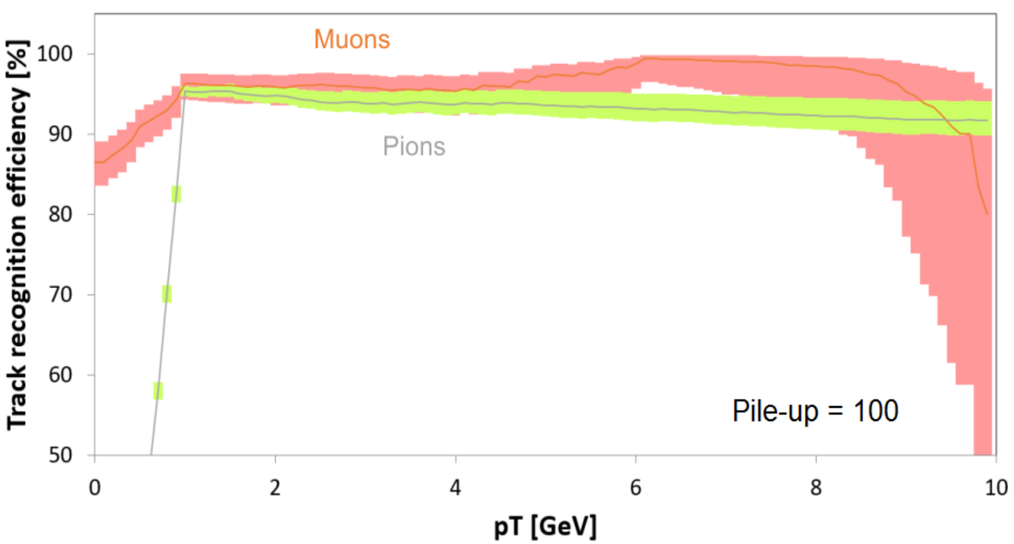
$\sqrt{(X^2/N)}$ Cut	Track recognition efficiency		Ghosts
	Muons	Pions	
<0.488	531/537 (98.9%)	4657/4757 (97.9%)	46 (0.9%)
<0.221	522/537 (97.2%)	4560/4757 (95.9%)	10 (0.2%)

Results: Impact of pile up

Pile up	$\sqrt{X^2/N}$ Cut	Track recognition efficiency		Ghosts	Processing time [h:m]
		Muons	Pions		
10	<1.307	558/569 (98.1%)	1959/2047 (95.7%)	21 (0.8%)	1:09
20	<0.459	543/553 (98.2%)	2255/2364 (95.4%)	16 (0.5%)	2:31
50	<0.459	525/537 (97.8%)	3018/3180 (94.9%)	31 (0.8%)	8:38
100	<0.343	510/533 (95.7%)	4476/4716 (94.9%)	138 (2.6%)	44:51

Efficiency against pT





Fit helical track to list of clusters by minimising χ^2

$$\chi^2 = \sum_{l=0}^{8} \chi_{xy}^2(l) + \chi_z^2(l)$$

$$\chi_{xy}^2 = \frac{(x_c - x)^2 + (y_c - y)^2}{\sigma_{xy}^2 + \sigma_s^2(R,l)} \qquad \chi_z^2 = \frac{(z_c - z)^2}{\sigma_z^2 + \sigma_s^2(R,l)}$$

Pixel resolution (σ_{xy}^2)

Scattering resolution ($\sigma_s^2(R,l)$)

- Main improvements by tweaking calculation of scattering resolution
- Optimisation likely to lead to further improvements

How this could be further improved

- Better clustering of pixel hits
- Better calculation of threshold parameters in initial search for prototracks
- More accurate resolution calculation
- Separate search for straight tracks