Fast Pixel Detectors in STAR

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September 27th, 2007

Efficiency Calculations in a high hit density environment

The probability of associating the right hit with the right track on the first pass through the reconstruction code is:

P(good association) $= 1 / (1+S)$

where $S = 2\pi\, \sigma_x\, \sigma_y\, \rho$

P(bad association) $= (1 - \text{Efficiency}) = S / (1 + S)$

and when S is small

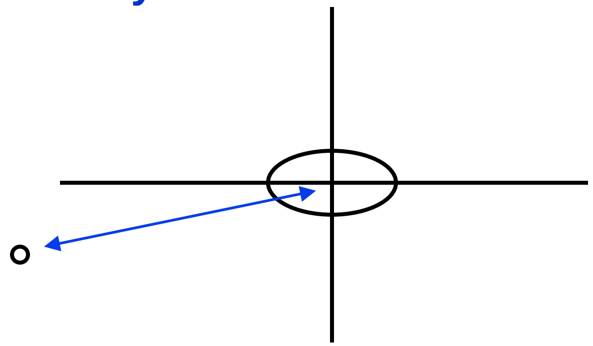
P(bad association) $\approx 2\pi\, \sigma_x\, \sigma_y\, \rho$

σ_x is the convolution of the detector resolution and the projected track error in the 'x' direction, and ρ is the density of hits.

The largest errors dominates the sum

$$\sigma_x = \sqrt{(\sigma^2_{xp} + \sigma^2_{xd})}$$

$$\sigma_y = \sqrt{(\sigma^2_{yp} + \sigma^2_{yd})}$$



Asymmetric pointing resolutions can be very inefficient

TPC Pointing at the PXL Detector

- **The TPC pointing resolution on the outer surface of the PXL Detector is greater than 1 mm …** **but lets calculate what the TPC can do alone**
  - **Assume the new radial location at 8.0 cm for PXL-2, with 9 μm detector resolution in each pixel layer and a 200 μsec detector**

Radius	PointResOn (R-ϕ)	PointResOn (Z)	Hit Density
8.0 cm	1.4 mm	1.5 mm	6.0
2.5 cm	90 μm	110 μm	61.5

  - **Notice that the pointing resolution on PXL-1 is very good even though the TPC pointing resolution on PXL-2 is not so good**

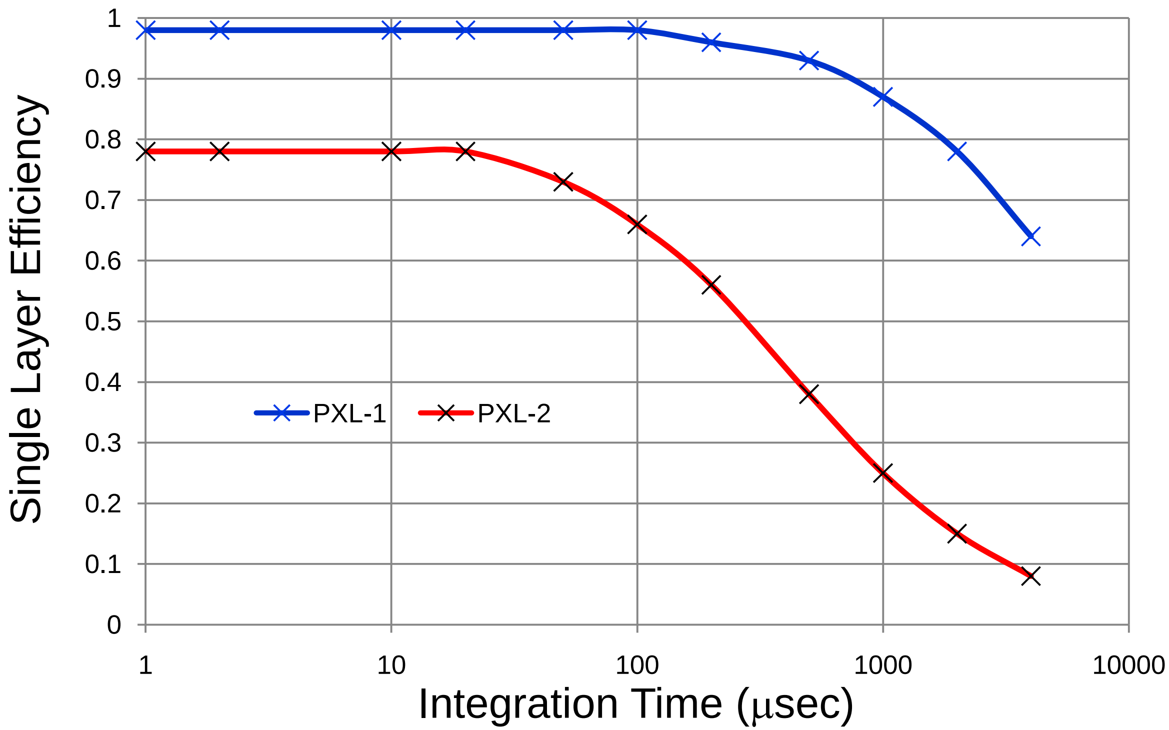
- **The probability of a good hit association on the first pass**
  - **56% on PXL2** The purpose of the intermediate tracking layers is to make 56% go up to ~100%
  - **96% on PXL1** All values quoted for mid-rapidity Kaons at 750 MeV/c

This is a surprise: The hard work gets done at 8 cm!

The performance of the TPC acting alone

- **The performance of the TPC acting alone depends on the integration time of the PXL chip**

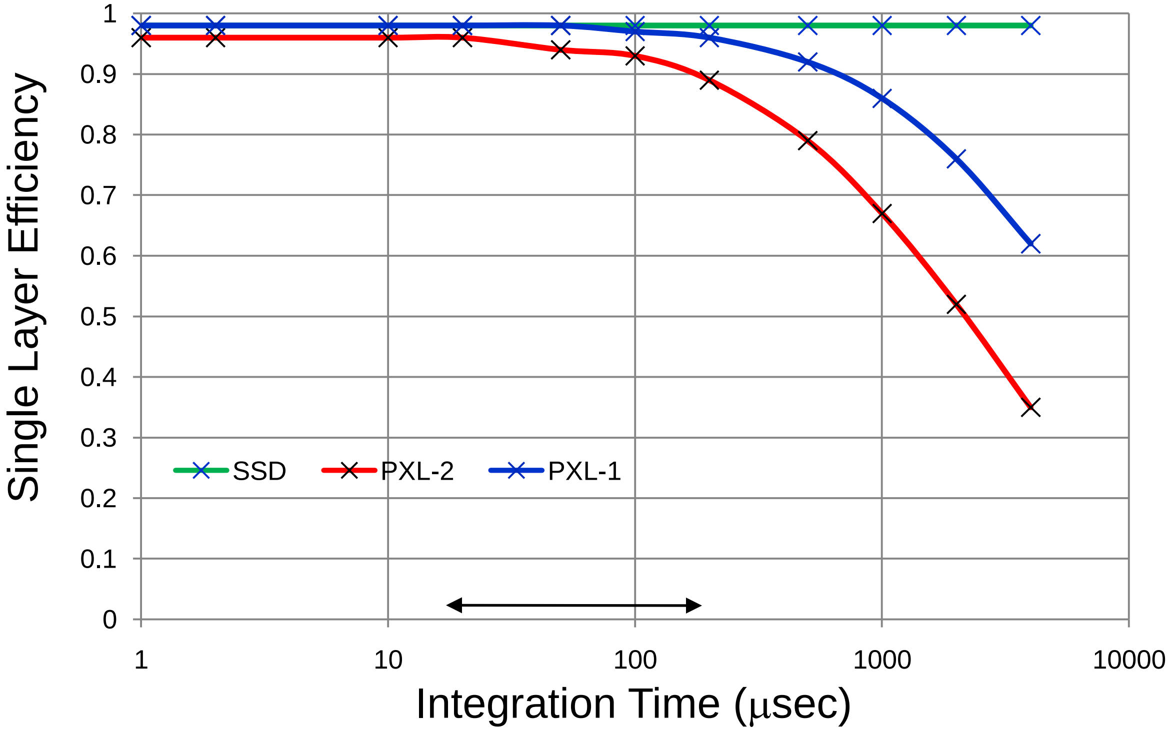
P(good association) = 1 / (1+S) **where $S = 2\pi\, \sigma_x\, \sigma_y\, \rho$**



The performance of the TPC + SSD

- **The performance of the TPC + SSD acting together depends on the integration time of the PXL chip … and its very good**

P(good association) = 1 / (1+S) **where $S = 2\pi\, \sigma_x\, \sigma_y\, \rho$**



The purpose of additional intermediate tracking layers is to make 94% go up to ~100%

Subtle things to discover

- **The total single-track efficiencies depend on the detector configurations**
  - **RHIC II Luminosity at 200 μsec and PXL2 at 7 cm radius (Au-Au)**
    - **pxl1+pxl2+tpc — 46%**
    - **pxl1+pxl2+ssd+tpc — 80%**
    - **pxl1+pxl2+ist1+ssd+tpc — 84%**
    - **pxl1+pxl2+ist1+ist2+ssd+tpc — 72%**
  - **RHIC II Luminosity at 200 μsec and PXL2 at 8 cm radius (Au-Au)**
    - **pxl1+pxl2+tpc — 56%**
    - **pxl1+pxl2+ssd+tpc — 84%**
    - **pxl1+pxl2+ist1+ssd+tpc — 84%**
    - **pxl1+pxl2+ist1+ist2+ssd+tpc — 72%**
    - **pxl1+pxl2+ist1+ist2+tpc — 51%**
  - **RHIC II Luminosity at 2 μsec and PXL2 at 8 cm radius (Au-Au)**
    - **pxl1+pxl2+tpc — 76%**
    - **pxl1+pxl2+ssd+tpc — 92%**
    - **pxl1+pxl2+ist1+ssd+tpc — 88%**
    - **pxl1+pxl2+ist1+ist2+ssd+tpc — 74%**

Long strips in the intermediate tracker hurt us at short integration times due to ambiguous hit associations; these same long strips help us at long integration times.

Conclusions

- **A fast Si detector associates the right hit with the right track more efficiently than a slow Si detector**
  - **pile up is less in a fast PXL detector**
- **The TPC acting alone is a good pointing device for a fast Si PXL detector**
  - **76% efficient – standalone mode**
  - **92% with the addition of the SSD**
- **Long strips in an intermediate detector are inefficient**
  - **The additional load due to ambiguous hits on long conventional strips overwhelms the gain due to the increased pointing resolution that the strips provide**
  - **Long strips add ambiguous hits to the reconstruction task so either the track is lost … or if its recovered on the repass – the long strips weren't needed in the first place because the inner layers did the work**

Next week I will propose detector modifications that may be achievable and may be very appealing