Ultimate position resolution of pixel clusters with binary readout for particle tracking

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Motivation

- There is significant literature on the position resolution obtained from interpolation of charge measurements.
- A comprehensive study of the resolution obtainable with binary readout is lacking and commonly assumed to be $\text{pitch}/\sqrt{2}$, which is the worst case upper limit.
- We study the best achievable resolution for minimum ionizing particles in binary readout pixels using simulation.

Why is $\text{pitch}/\sqrt{2}$ a worst case upper limit?

A. The cluster distributions that the hit belongs to.
B. Approximate incidence angles of the track producing the hit.

Resolution and the variety of clusters

- The resolution is best when Pr(Most Probable Shape) is small.
- $50 \times 50 \times 150 \mu m^3$ pixel sensor

Shape classification and RMS calculation

- Tracks near the edge of the pixel will produce 2-pixel clusters instead of 1-pixel clusters.
- The RMS of the actual distribution is $0.78 \times \text{pitch}/\sqrt{2}$.
- The resolution envelopes for different $\phi$ are always below 90% $\text{pitch}/\sqrt{2}$ across the entire $|\eta|$ range.

Position Resolution in the x and y direction

- Resolution was calculated for the peaks and valleys of the Pr(Most Probable Length).
- Large pixel: peak depends little on the size and $|\eta|$; valley depends strongly on the size and $|\eta|$.
- Small pixel: both the peak and valley depend strongly on the size and $|\eta|$, and the resolution can even exceed $\text{pitch}/\sqrt{2}$.
- Resolution in the x (non-zero $\phi$ incidence) benefits significantly from the longer cluster-size as $|\eta|$ increases.

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