Some vertexing and PID plans

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Past and present activities

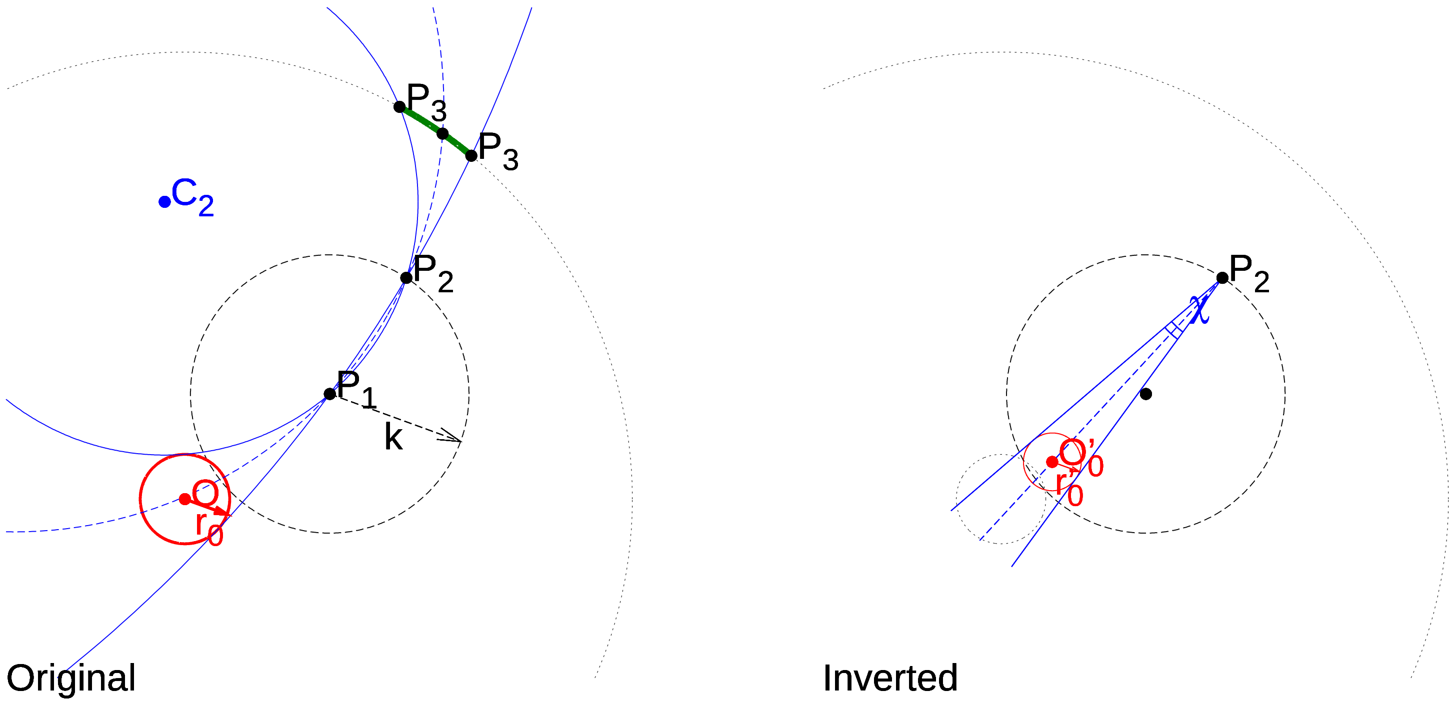
- Very small group
  - Ferenc Siklér, senior research fellow
  - Krisztián Krajczár, PhD student
  - Interest in mathematics, development of new algorithms, mostly silicon related

- Topics
  - Tracking
    * Down to very low p_T
    * With low fake rate
  - Vertexing
    * Fast vertexing using hit shape
    * Efficient vertexing even in high pile-up
  - Particle identification of low momentum hadrons
    * Based on tracking only (multiple scattering and lost energy, Kalman)
    * Based on deposited energy, even in case of few hits

Within CMS, leading role in QCD hadron physics

Tracking – down to very low p_T

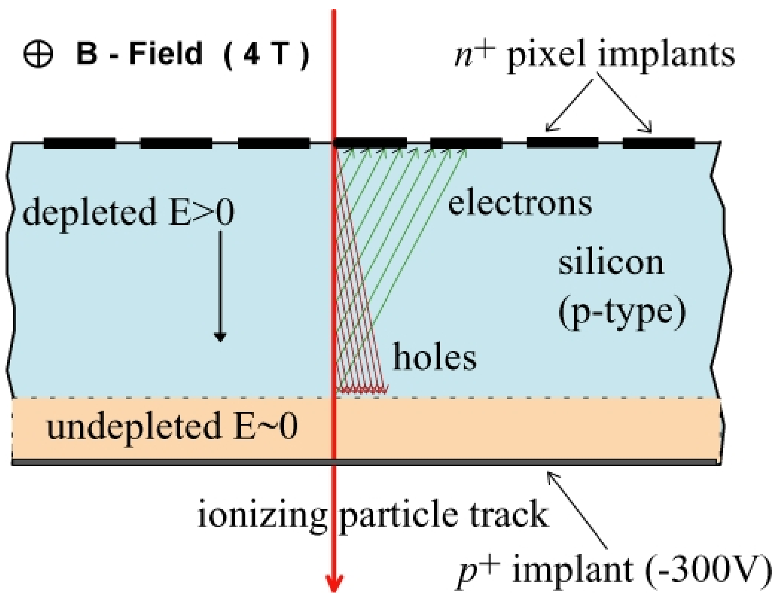
- Seed building, hit triplets
  - take hits from two barrels (P_1 and P_2)
  - find two limiting circles touching r_0, and passing though P_1 and P_2
  - inversion with center P_1 and radius $k = P_1P_2$
  - possible third hits are on arc $P_3 - P_3$

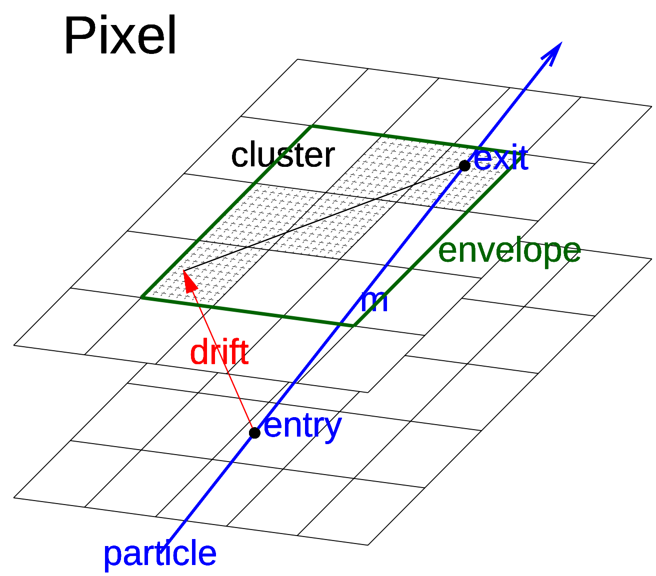


CMS AN-2006/100

Tracking – with low fake rate

- Problem
  - too many hits, which one belongs to which particle?
- Help
  - silicon is "thick" (300 μm) wrt the size of pixels (e.g. 150×100 μm^2)
  - the shape of the cluster is connected to the direction of the incoming particle
  - use look-up table based on cluster envelope to check compatibility, data driven





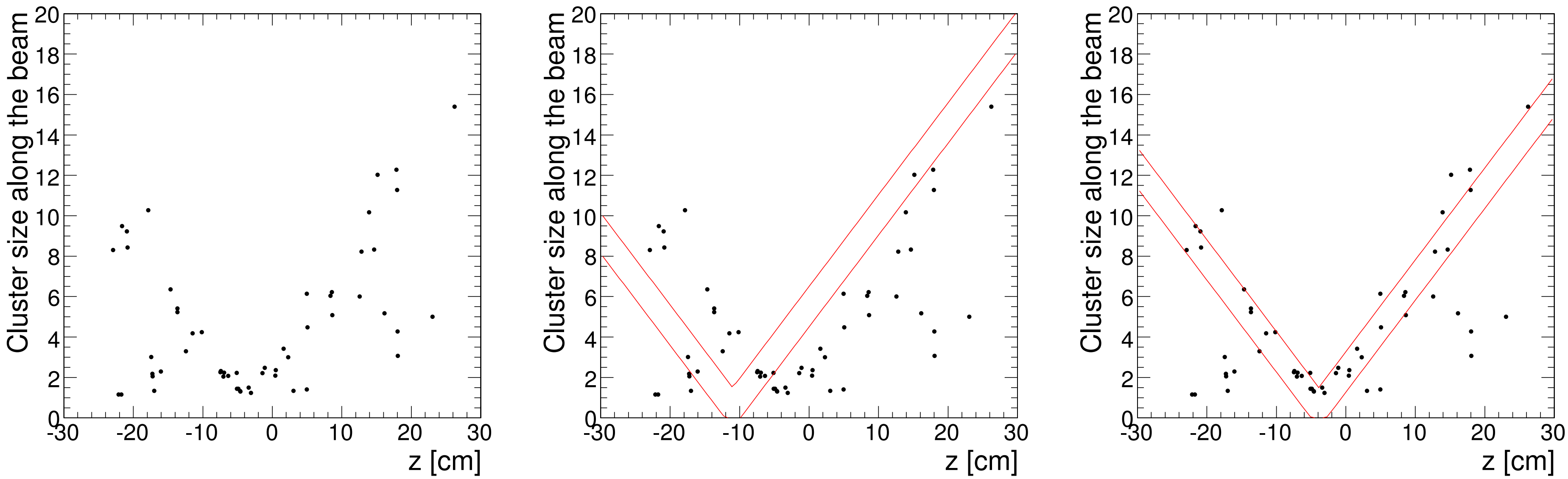
J Phys G **35** (2008) 104150

Efficient filter

Vertexing using hits only

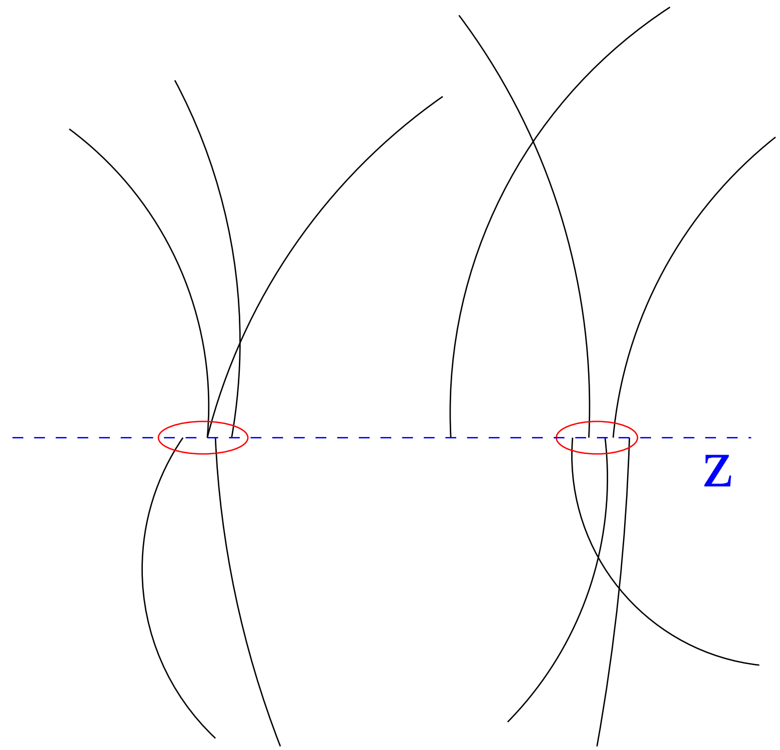
- Fast vertexing without tracks
  - primary particles: the length l of the cluster along the beam direction is proportional to its relative z position, $l = d/r \cdot z$
  - backgrounds (secondaries, decay products, loopers) do not obey this relation

- How to do it?
  - slide a V-shaped window and pick z if most hits are contained, or χ^2 optimal



KK et al, in JHEP 02 (2010) 041

Vertexing with track clustering



- Search for interaction points
  - z coords of tracks at closest approach to the beam-line and its estimated σ_z
  - 1D clustering with beam spot constraint

- How to do it better, wrt divisive clustering?
  - algos: agglomerative clustering, neighbor joining
  - classifications: k-Means, Gaussian mixture model

Vertexing with track clustering

- Agglomerative clustering (fast pairwise nearest neighbor, fPNN)
  - distance d of two particles

$$d^2 = \frac{(z_i - z_j)^2}{\sigma_i^2 + \sigma_j^2}$$

  - first each particle is a cluster
  - in each step we search for the closest clusters and join them
  - the new cluster will have

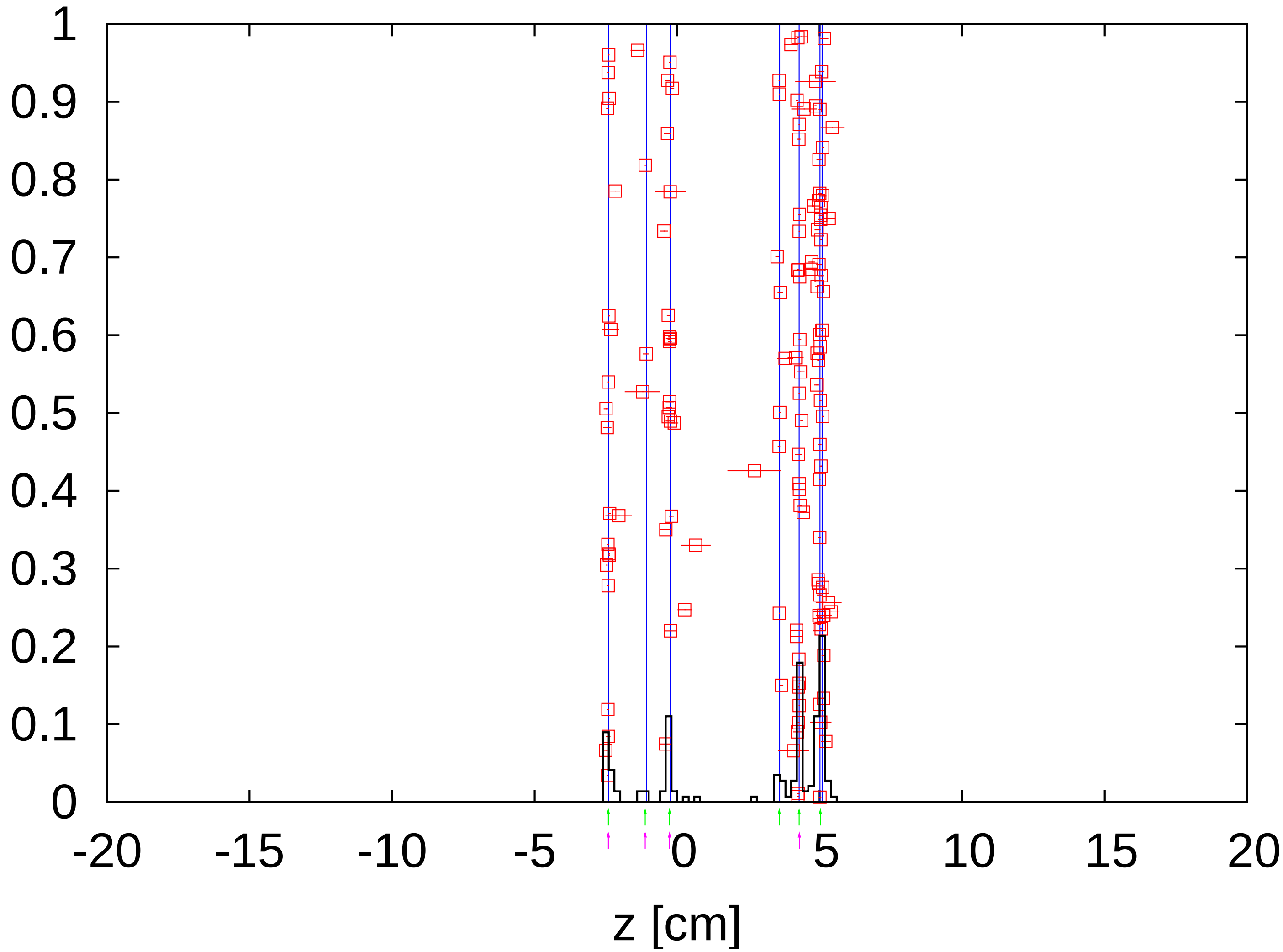
$$z = \frac{z_i/\sigma_i^2 + z_j/\sigma_j^2}{1/\sigma_i^2 + 1/\sigma_j^2}, \qquad \sigma^2 = \frac{1}{1/\sigma_i^2 + 1/\sigma_j^2}$$

  - do this until K clusters (vertices) remain

We get a distance graph or tree

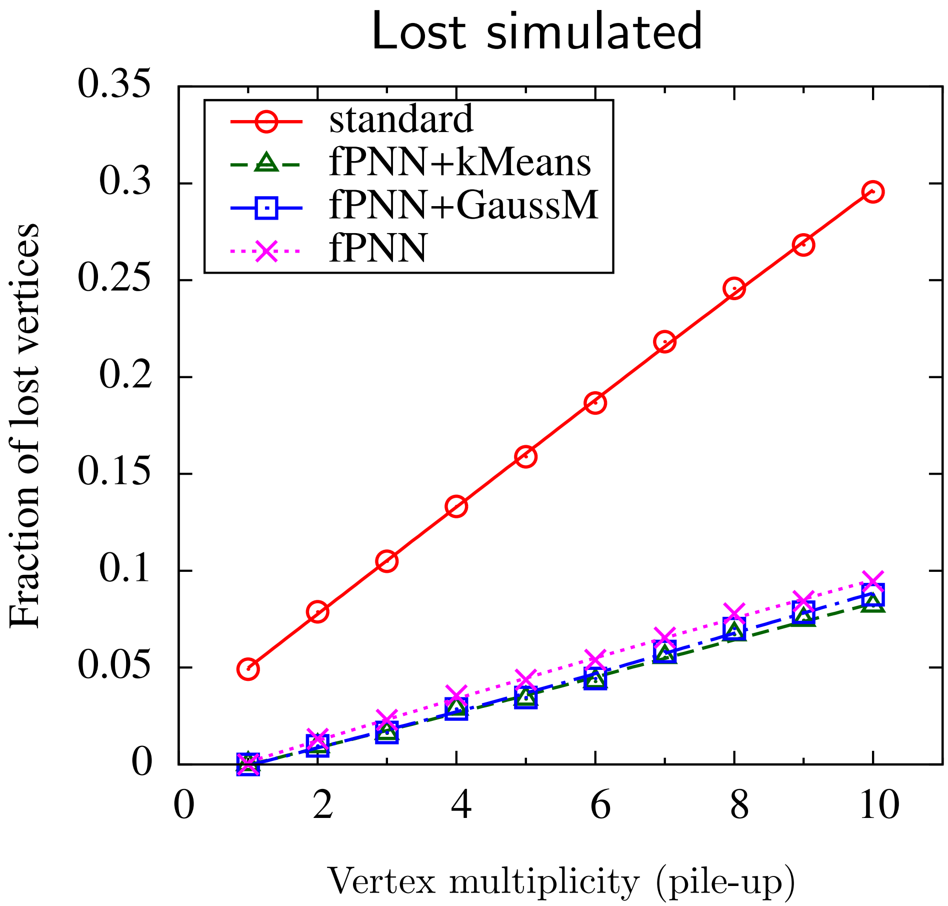
But how much is K? Where to stop with cluster merging?
Start with $K = 1$, look how $\chi^2(K)$ changes with increasing K

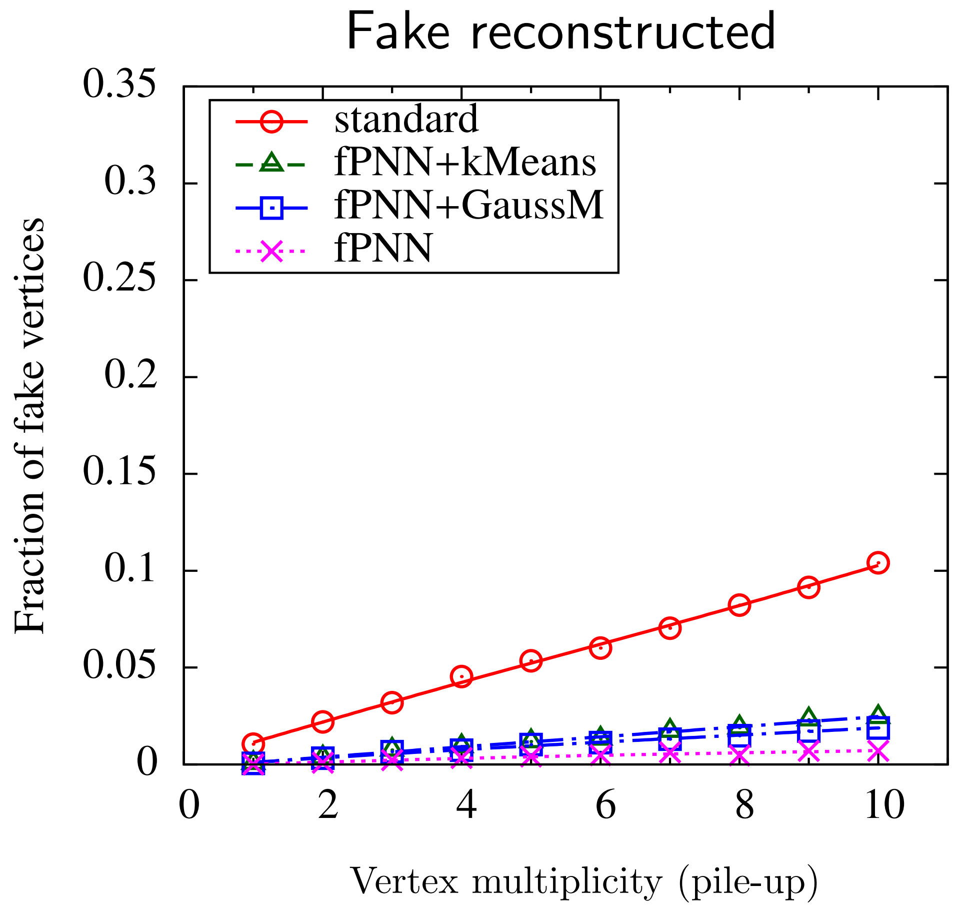
Vertexing with track clustering – example



z and σ_z; purple – standard, green – new

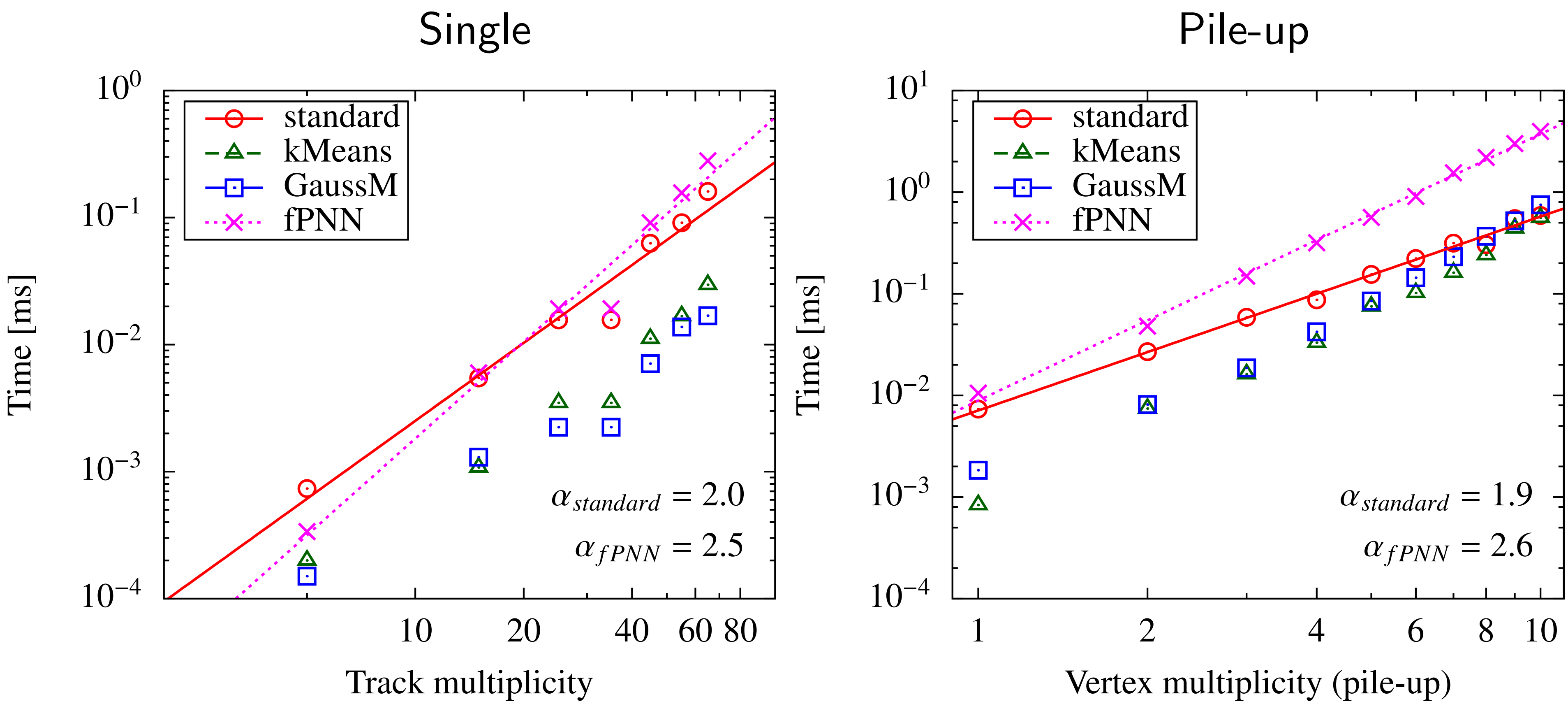
Vertexing with track clustering – performance





Better efficiency in case of 1 vertex
1/3 lost vertices, 1/5 fake vertices

Vertexing with track clustering – timing



In case of single vertex, timing scales similarly: exponents 2.3 and 2.6
For pile-up the new method is slower, still some ms

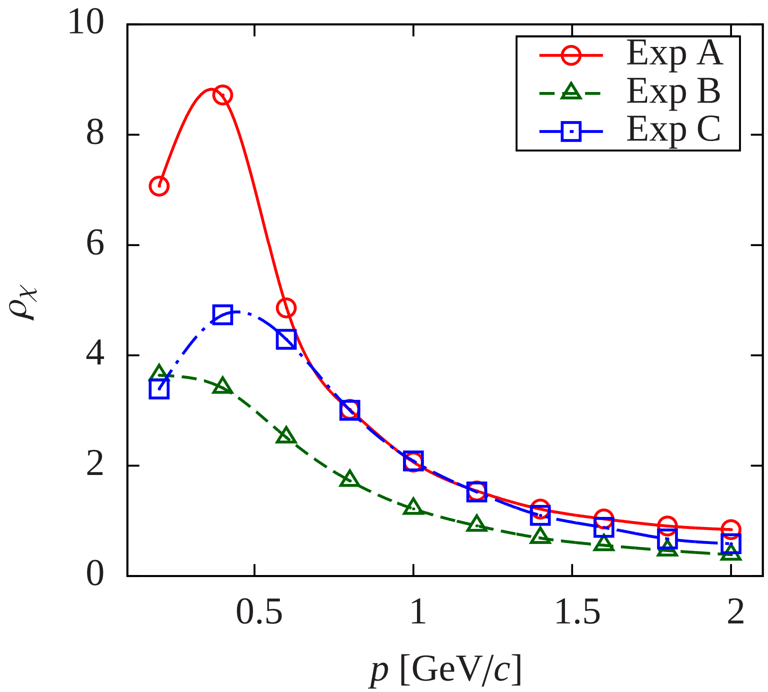
Most of the time is spent for making the distance graph or tree

FS, Nucl. Instrum. Meth. A **621** (2010) 526-533

PID based on tracking

- Where can that be useful?
  - particle identification, or at least unfolding of yields
  - dE/dx is not always available (e.g. ATLAS pixel detector)
  - supplementary measurement

- How to do that?
  - multiple Coulomb scattering, energy loss, Kalman

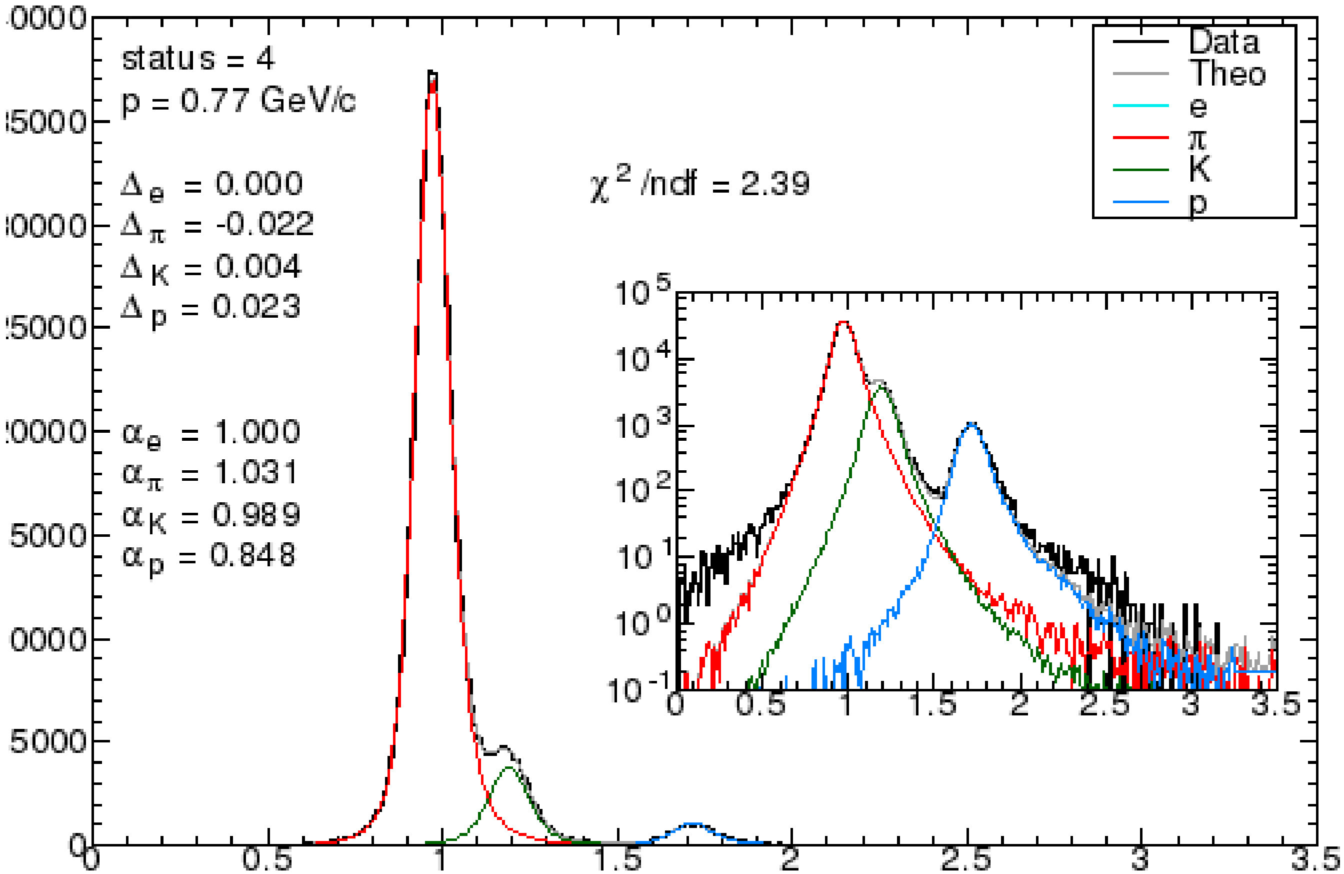


Separation power

$$\rho_\chi \approx 2\sqrt{2r-1}\,\frac{1-\beta(m)/\beta(m_0)}{\sqrt{1+[\beta(m)/\beta(m_0)]^2}}$$

FS, Nucl. Instrum. Meth. A **620** (2010) 477-483

PID based on deposited energy



Sometimes only few hits on track → Gaussian limit is too far

Estimation of "average" dE/dx, with help of an analytical model

Summary

- Areas
  - CMS motivated
  - Some general algorithms for vertexing in pile-up
  - Some seeding or PID ideas

Could be interesting for high density environment, low momentum physics