Belle II Reconstruction Software and Performance

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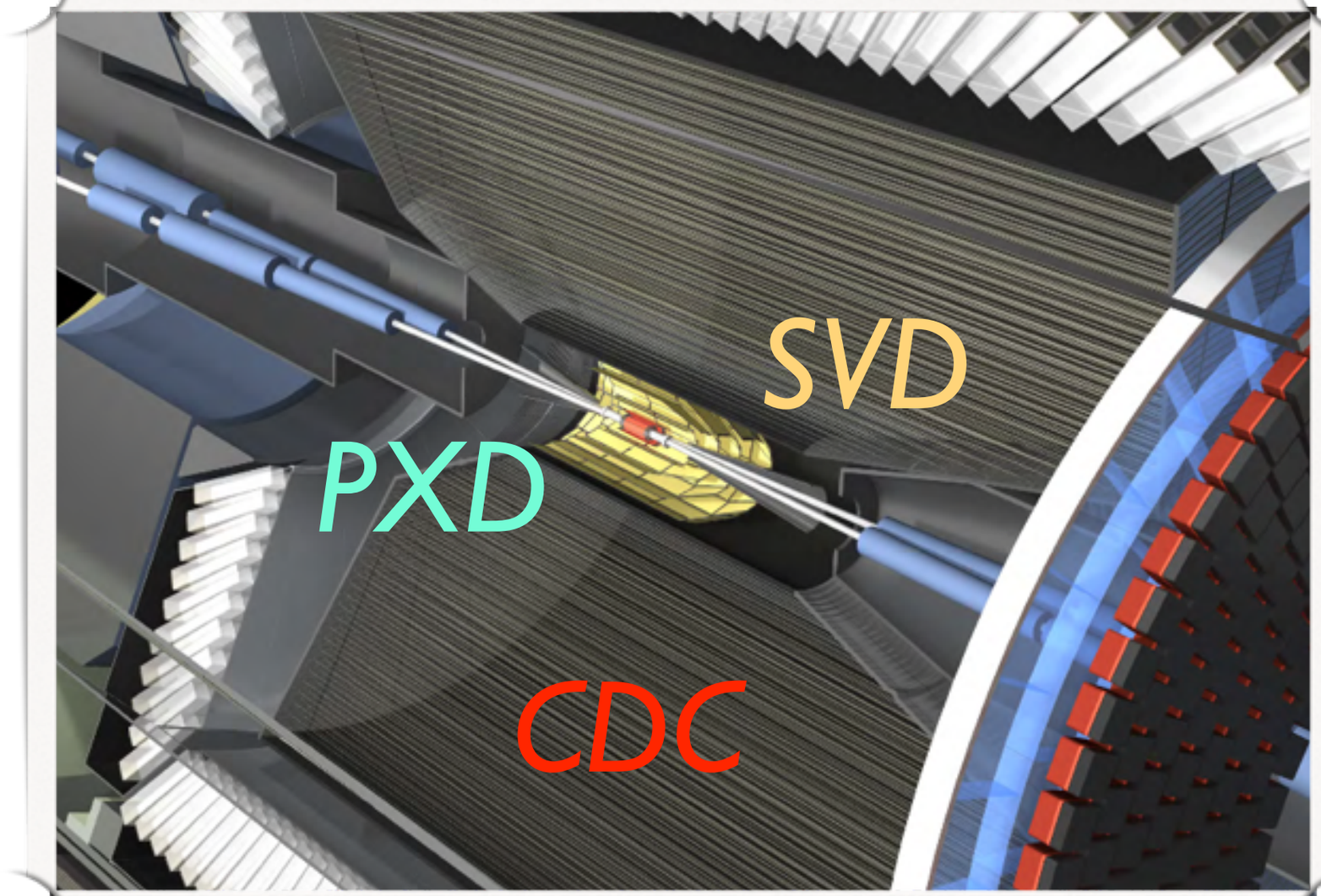
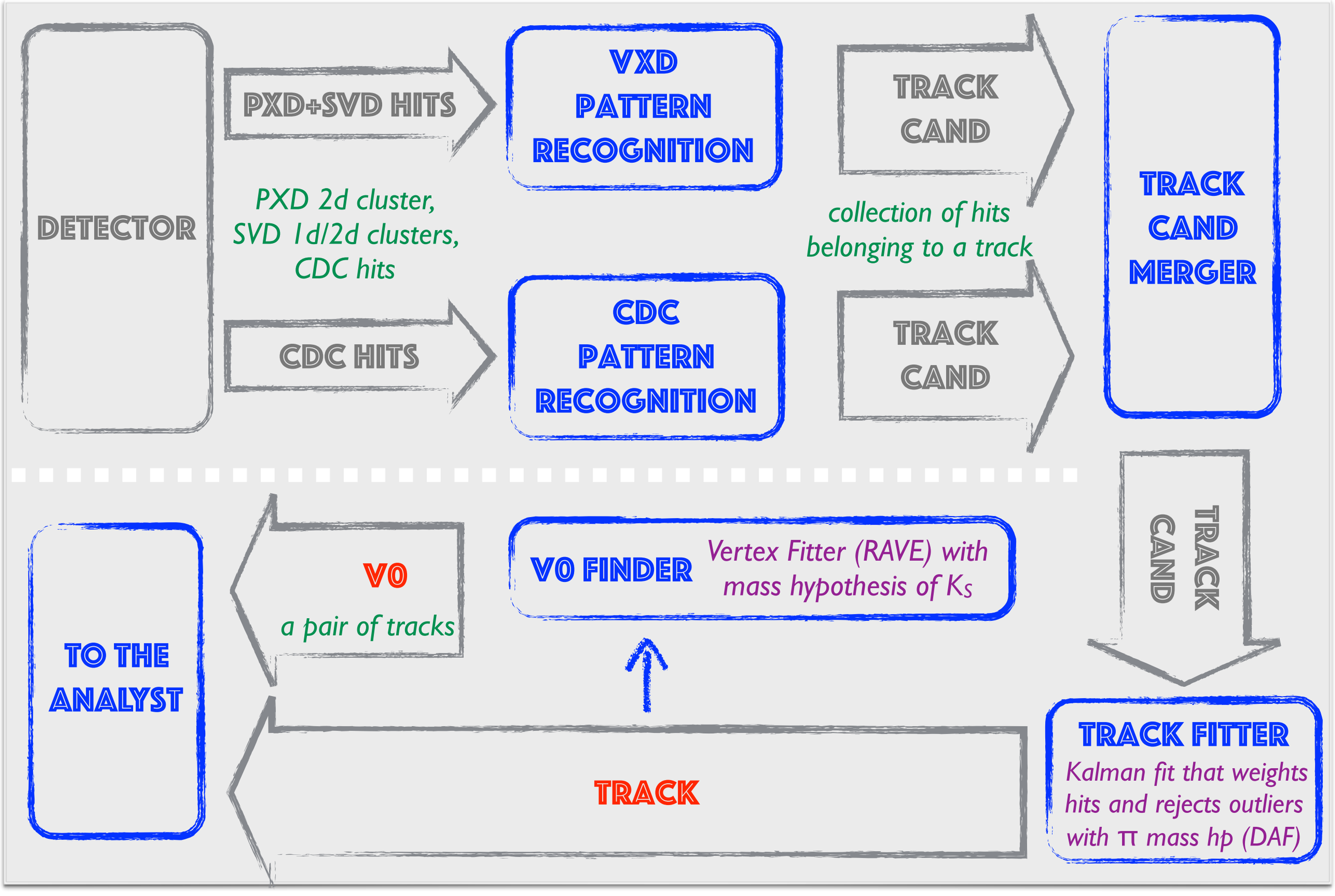
Outline

- ☑ *Tracking*
- ☑ *Calorimeter Reconstruction*
- ☑ *Charged Particle Identification*
- ☑ *Neutral Particle Identification*



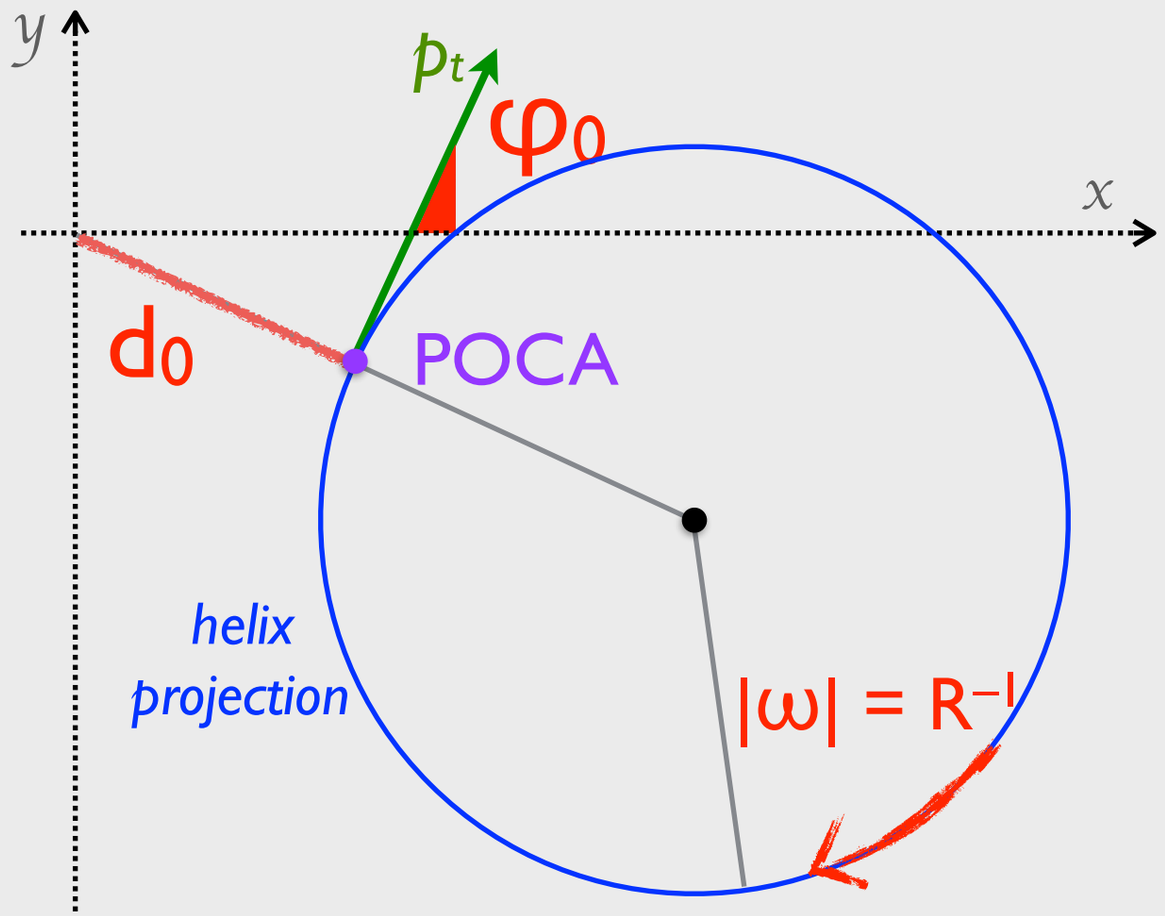
Tracking

Offline Tracking Reconstruction



Track Parameterisation

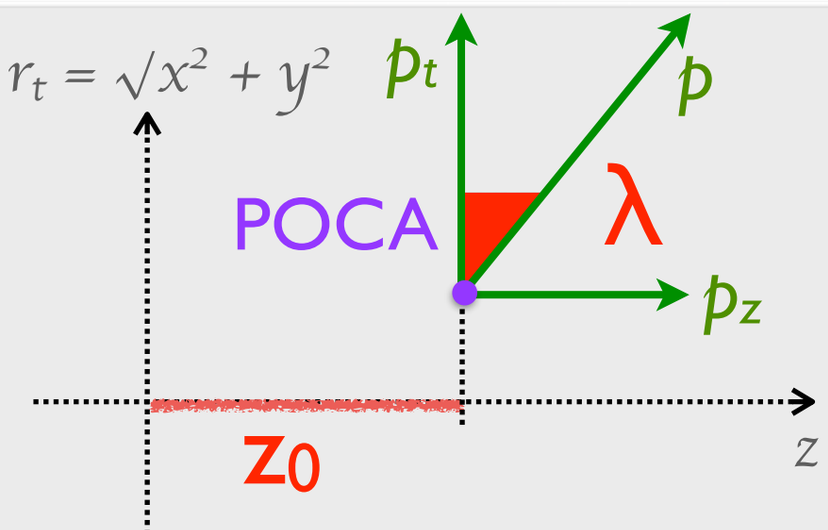
TRANSVERSE PLANE



- POCA = Point Of Closest Approach
- d_0 is the 2d signed distance of the POCA from the z axis, the sign depends on the angular momentum of the track (>0 in the fig.)
- φ_0 is the angle between p_t and the x axis at the POCA, $\varphi_0 \in [-\pi,\pi]$
- the sign of ω, the curvature, is the same as the charge of the track (>0 in the fig.)

LONGITUDINAL VIEW

- $\tan\lambda$ is the ratio of p_z and p_t, $\lambda \in [-\pi,\pi]$
- z_0 is the signed distance of the POCA from the transverse plane

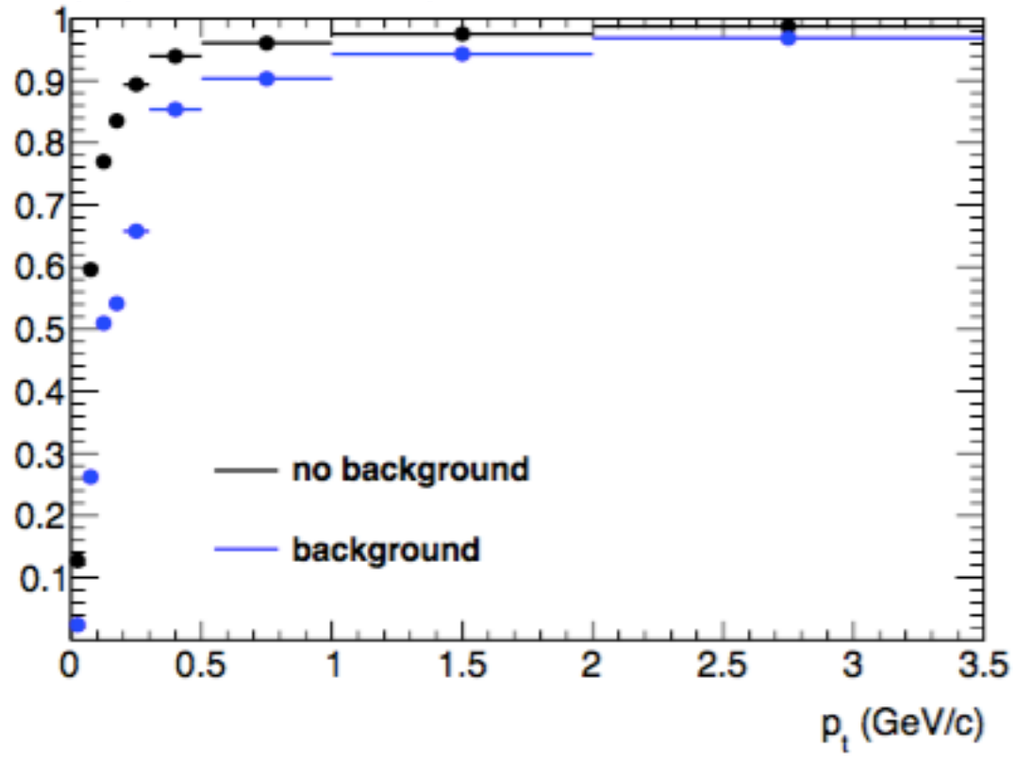


Tracking Efficiency

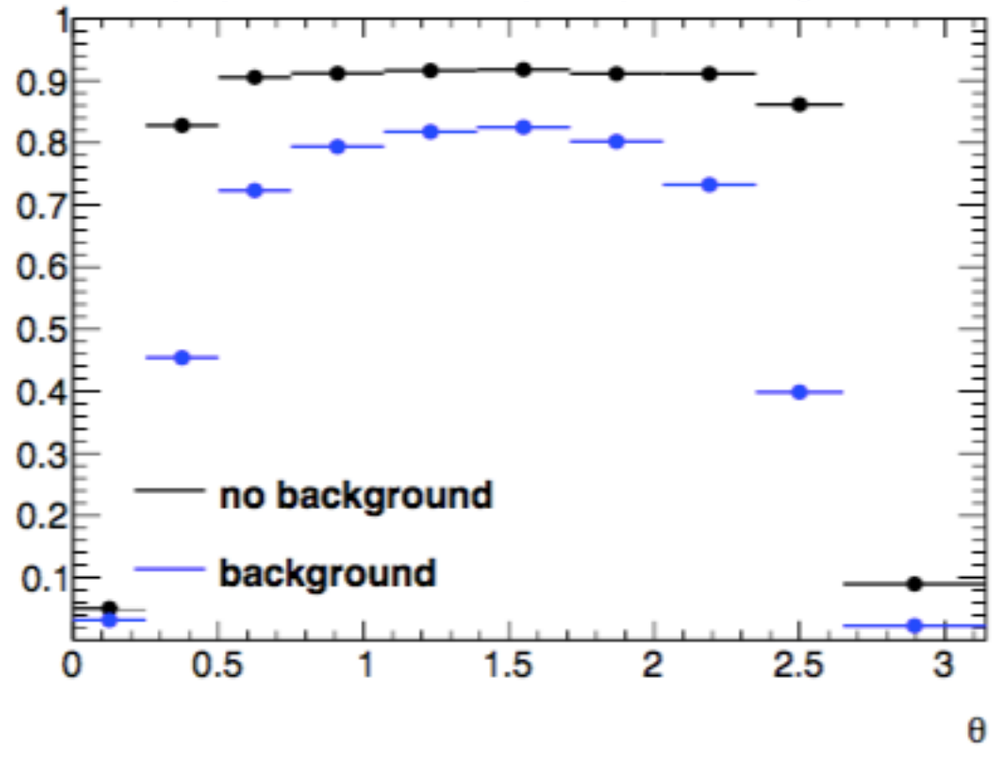
- *Current* tracking performance, caveat:
  - all PXD hits participates in pattern recognition
  - VXD pattern recognition is being redesigned, improvements expected
  - single pion mass hypothesis
  - inward and outward track extrapolation for additional hit finding are not included

efficiency (%) (no bkg)	release-00-07-00
physical	85.2±0.1
geom. accept. & det. ineff. factored out	93.7±0.1
pattern recognition	94.5±0.1

physical efficiency vs transverse momentum

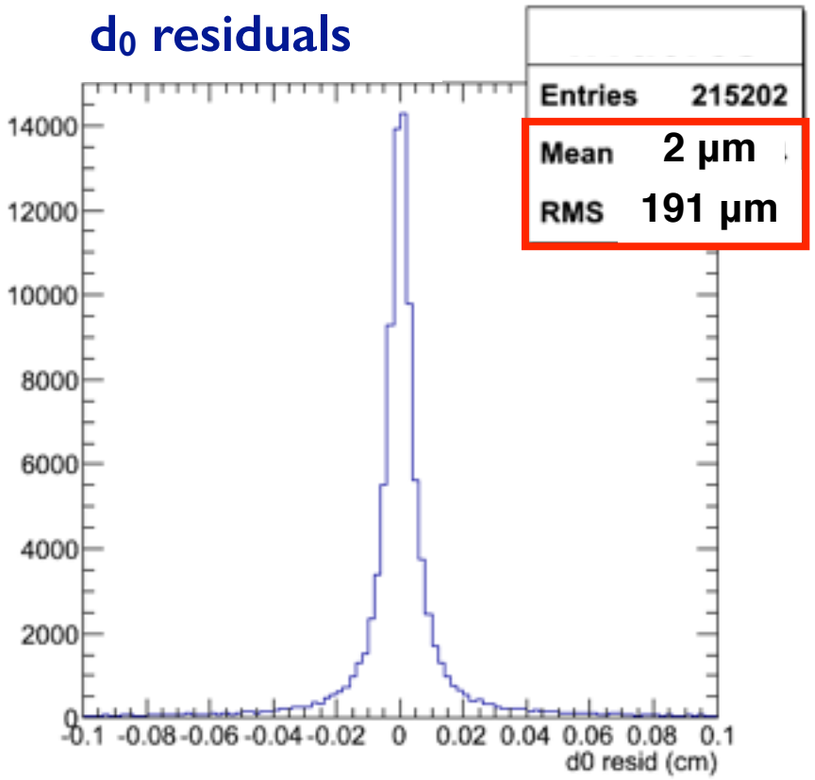


physical efficiency vs polar angle

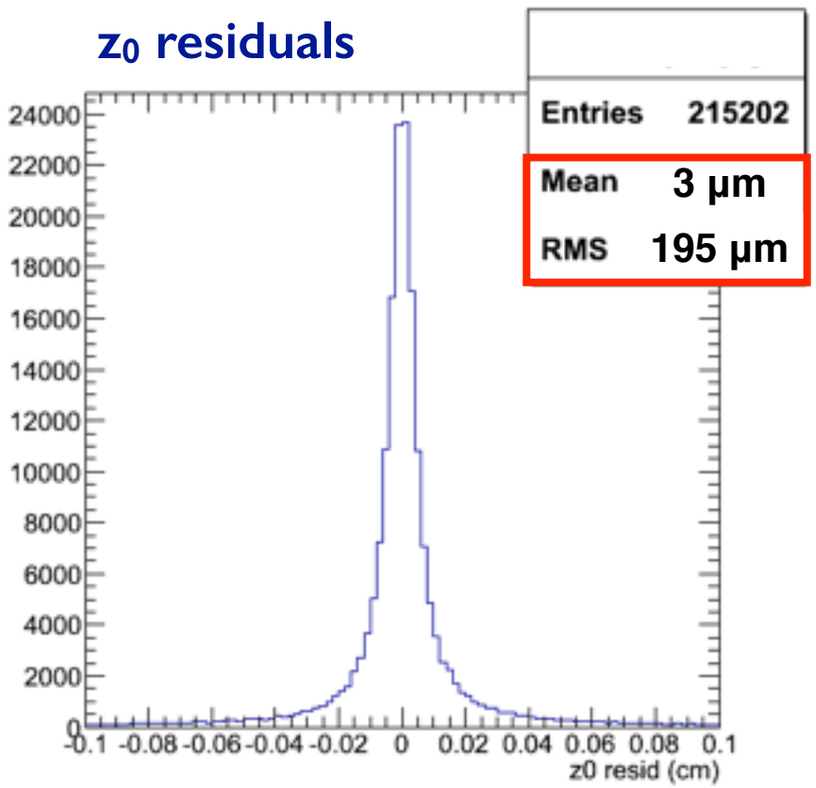


Track Quality

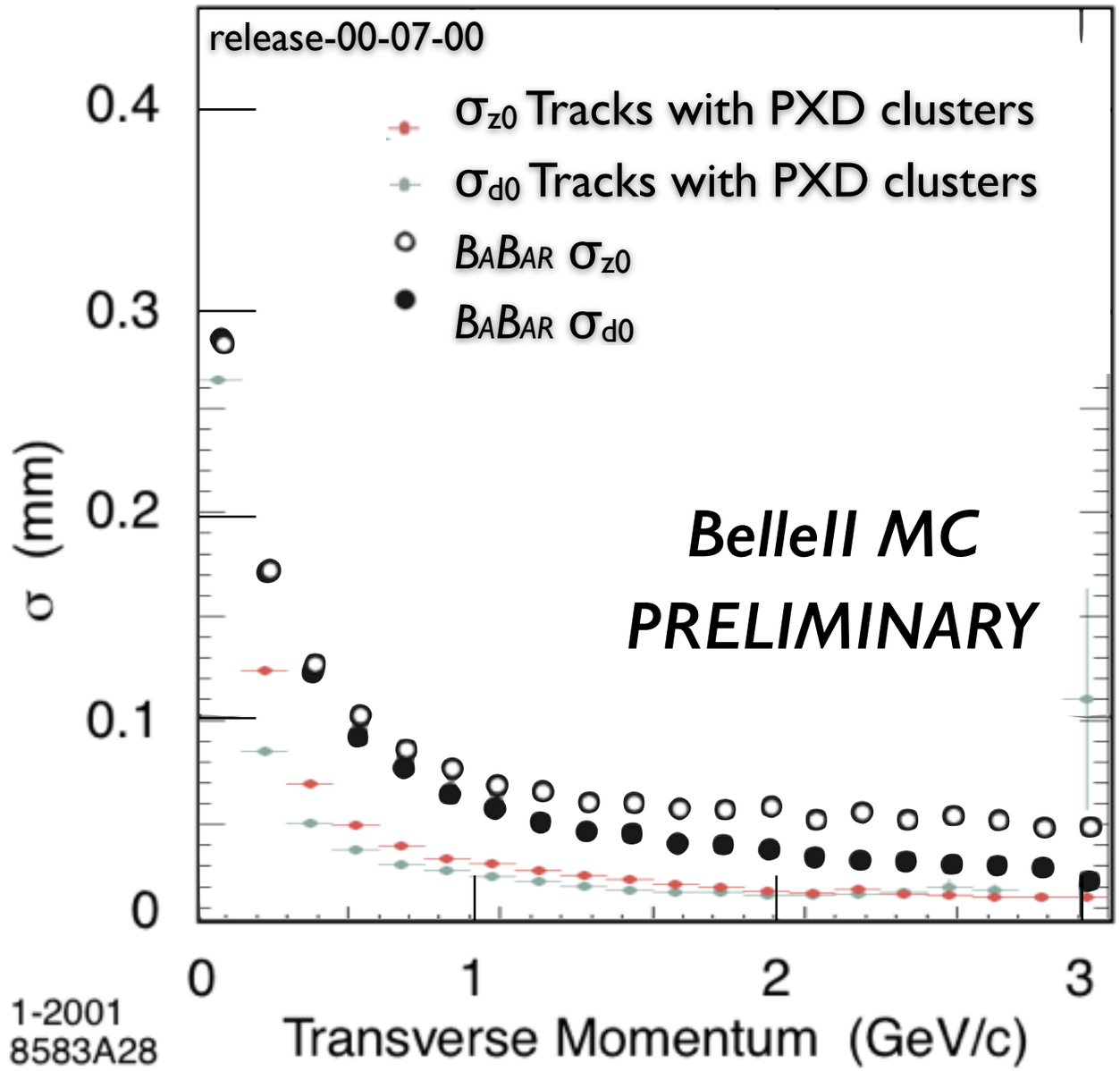
d_0 residuals



z_0 residuals



error on impact parameters VS transverse momentum

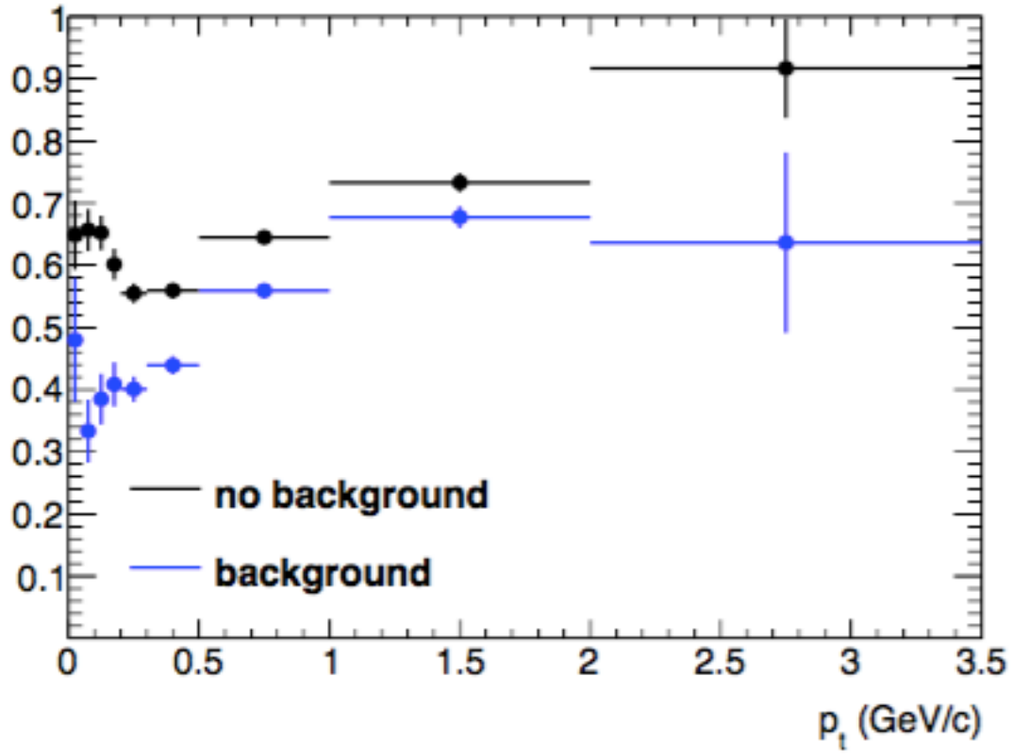


➡ *Belle II* VXD Tracking performs twice better than *BABAR*, when PXD clusters are attached to the track (75% of tracks have PXD cluster attached)

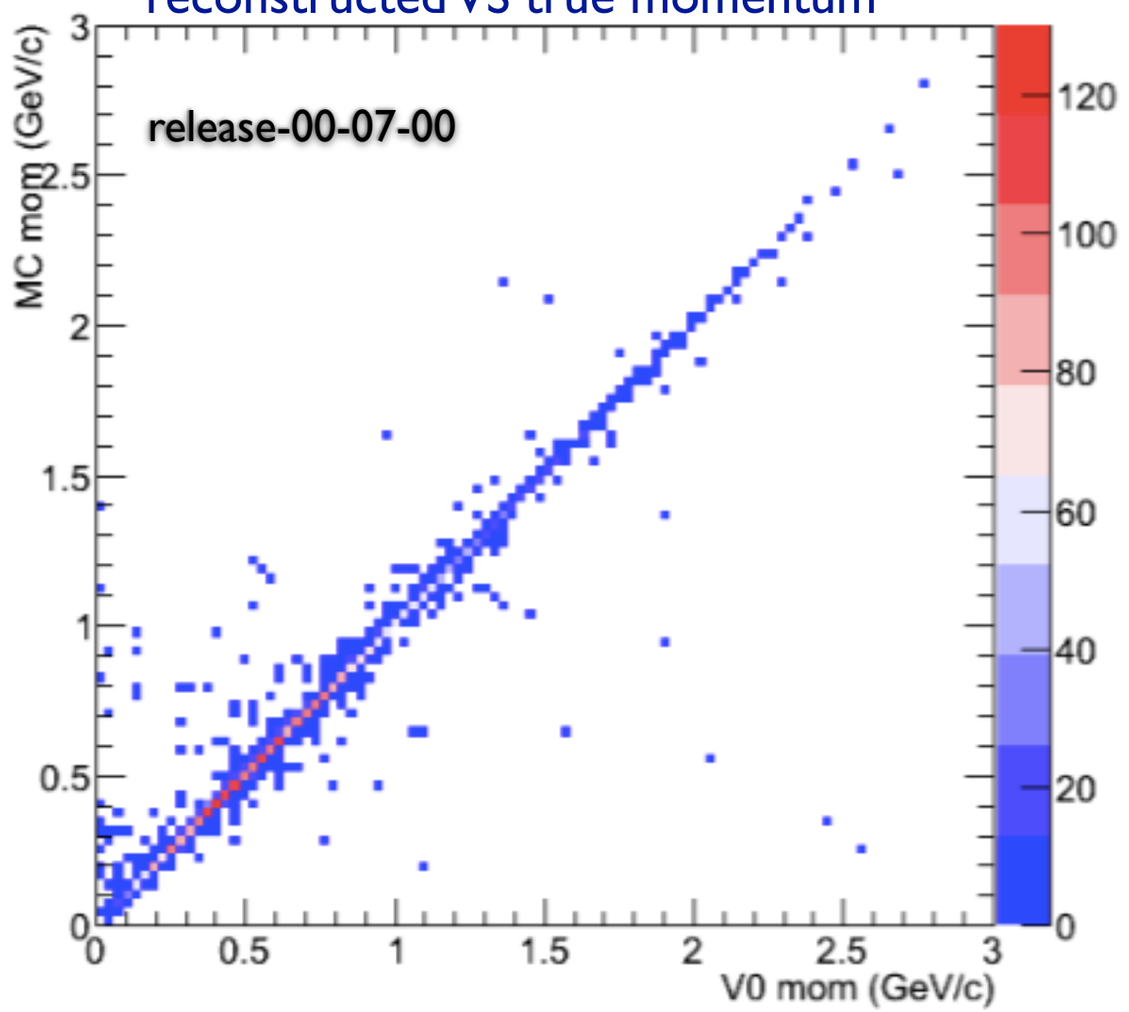
K_S Reconstruction

- Dedicated algorithm to reconstruct long-lived particles decaying outside the beam pipe
  - $K_S \rightarrow \pi\pi$ is implemented, converted $\gamma \rightarrow ee$ and $\Lambda \rightarrow \pi p$ will come
- Exploits the complete set of information belonging to the track (i.e. detector hits)
  - detailed hits information are lost after tracking reconstruction, are not available to the analyst
  - allows to improve the determination of the V0 (K_S) vertex and momentum

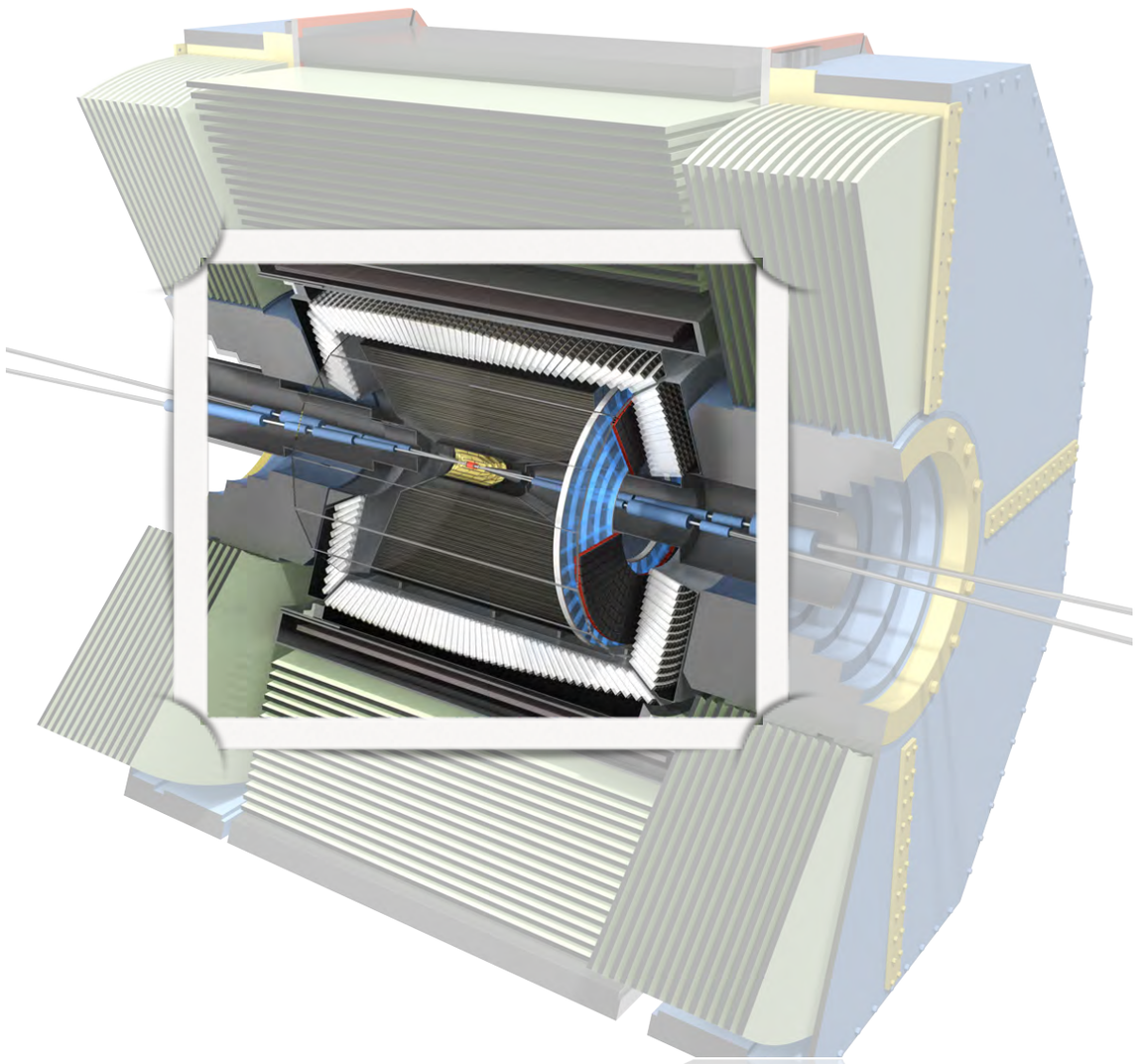
V0 efficiency vs transverse momentum



reconstructed VS true momentum



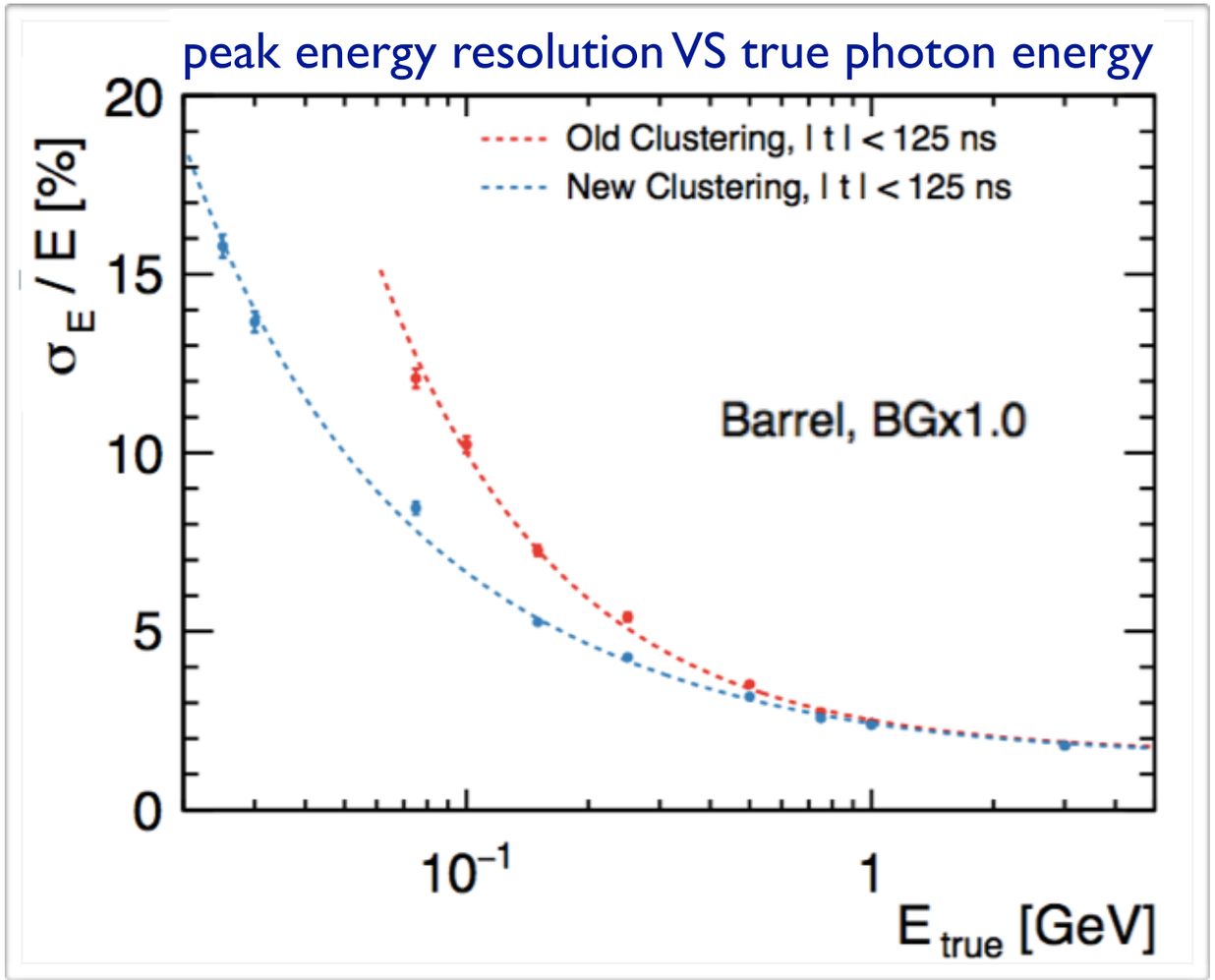
NOTE: *post-tracking K_S reconstruction is always possible and at the moment it yields higher efficiency*

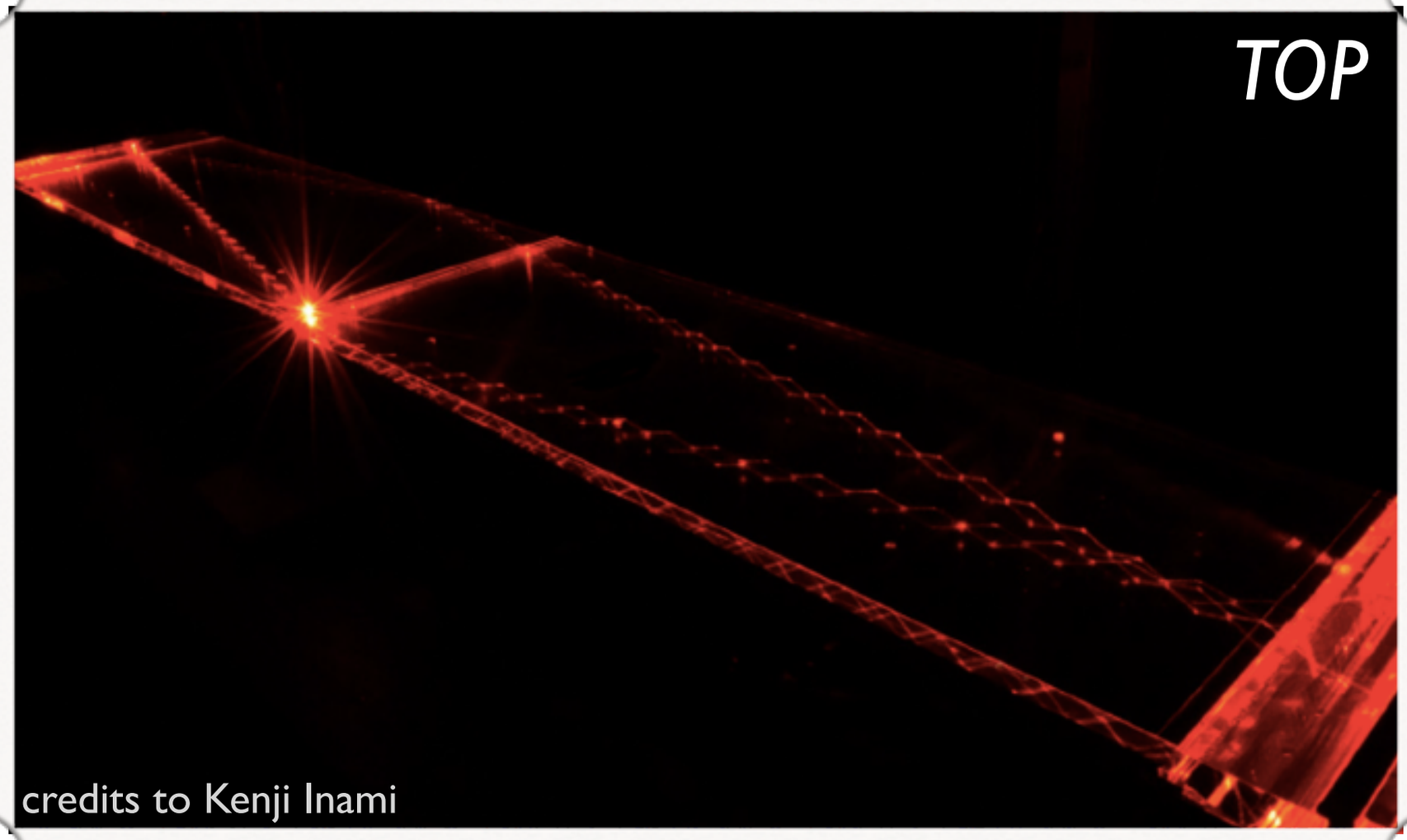


Calorimeter Reconstruction

ECL Reconstruction

- Tasks
  - reconstruct energy and position from neutral and charged particles
  - particle ID for electron muons, charged and neutral hadrons and photons based on shower shape variables and tracks matched to clusters
- Current **clustering** is an adaption of Belle clustering (old clustering)
  - algorithm:
    - seed crystal is a local energy maximum with at least 10 MeV
    - crystals are added up to a maximum cluster size of 5x5
    - centroids are computed as: $\vec{x} = \frac{\sum_i E_i \vec{x}_i}{\sum_i E_i}$
    - cluster position is corrected
    - cluster are matched to tracks using GEANT extrapolation
- *New clustering* is developed and already included for the future release-00-08-00





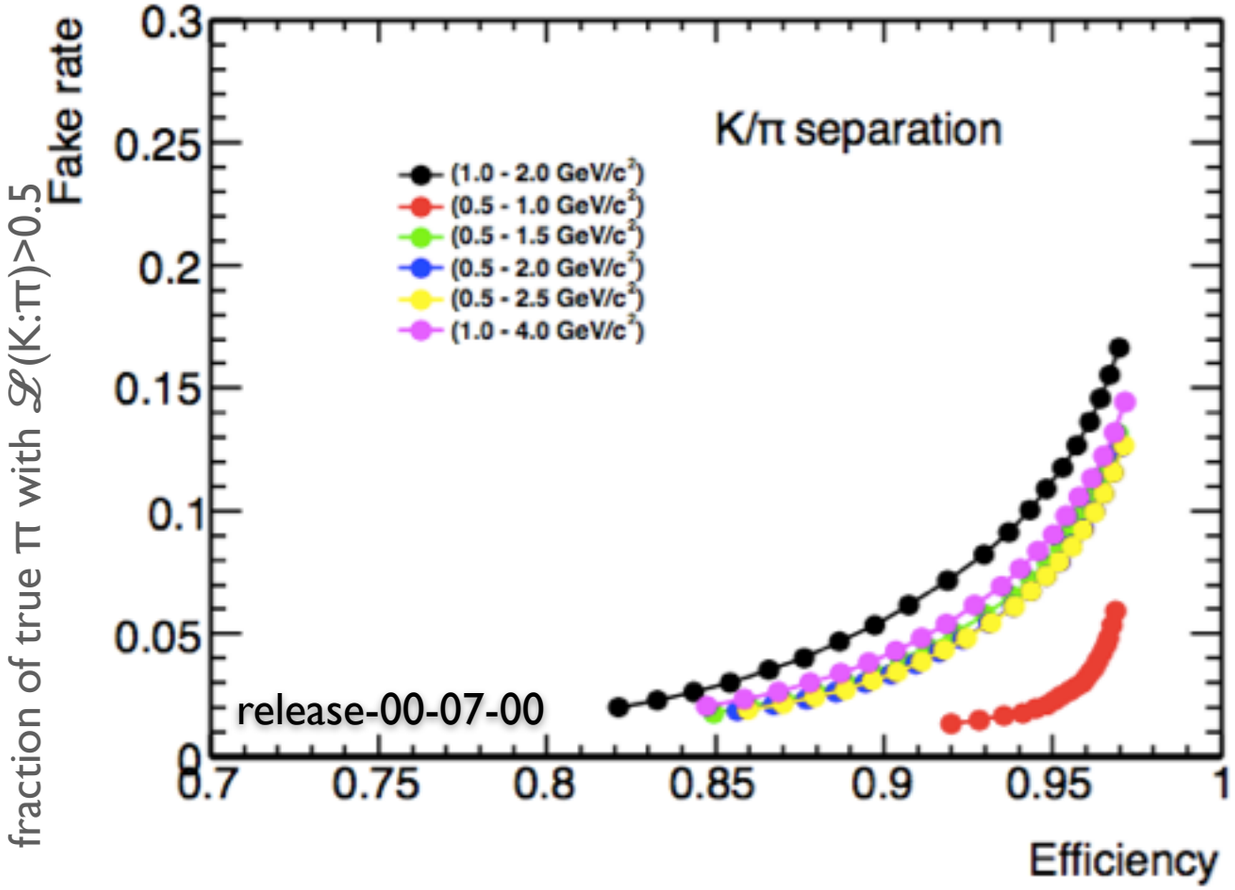
TOP, ARICH, dE/dx from CDC and SVD, ECL for eID and KLM for μID

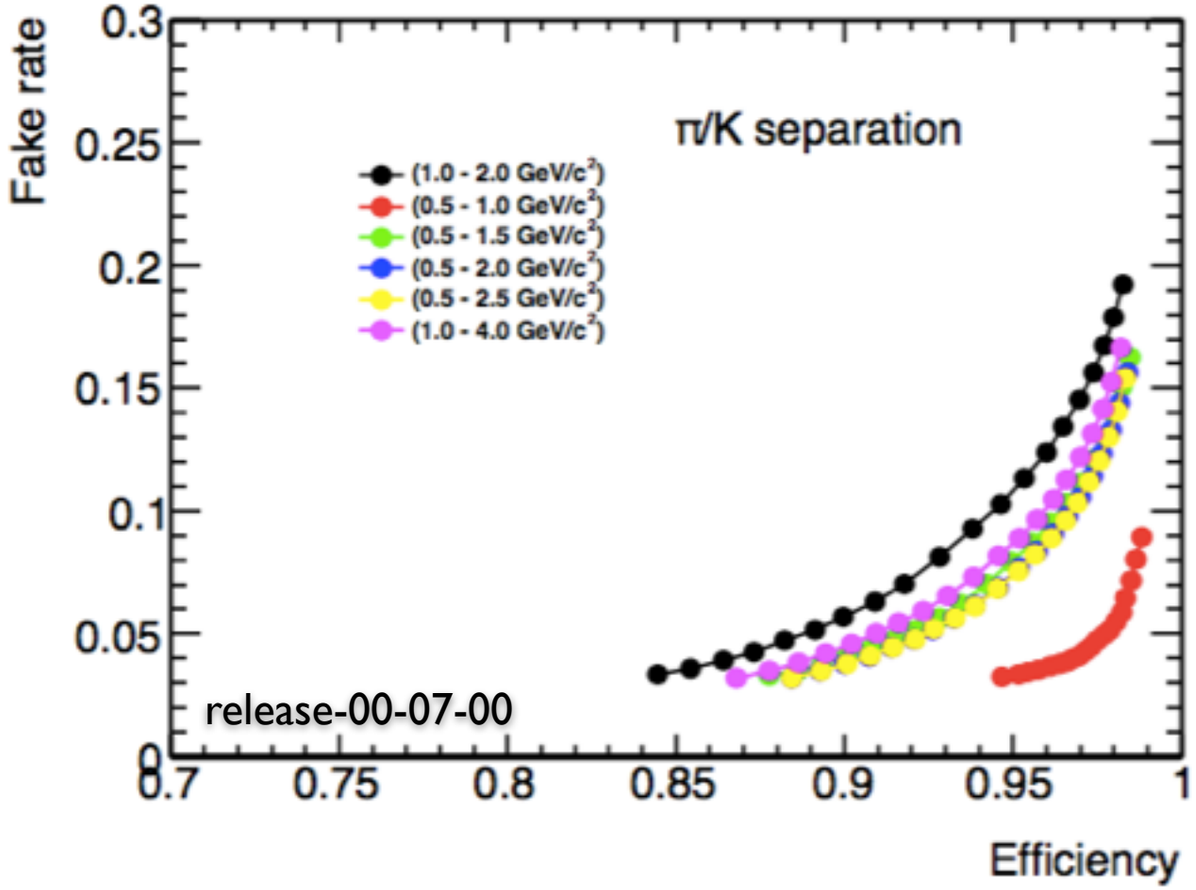
Charged Particle Identification

PID Performances

- information from each PID system is analyzed independently to determine a likelihood for each charged particle hypothesis
- likelihoods are then combined and difference in log likelihood between two particle hypotheses is used to construct a PID value:

$$\mathcal{L}(\alpha:\beta) = \frac{1}{1+e^{\ln\mathcal{L}_\alpha - \ln\mathcal{L}_\beta}}$$





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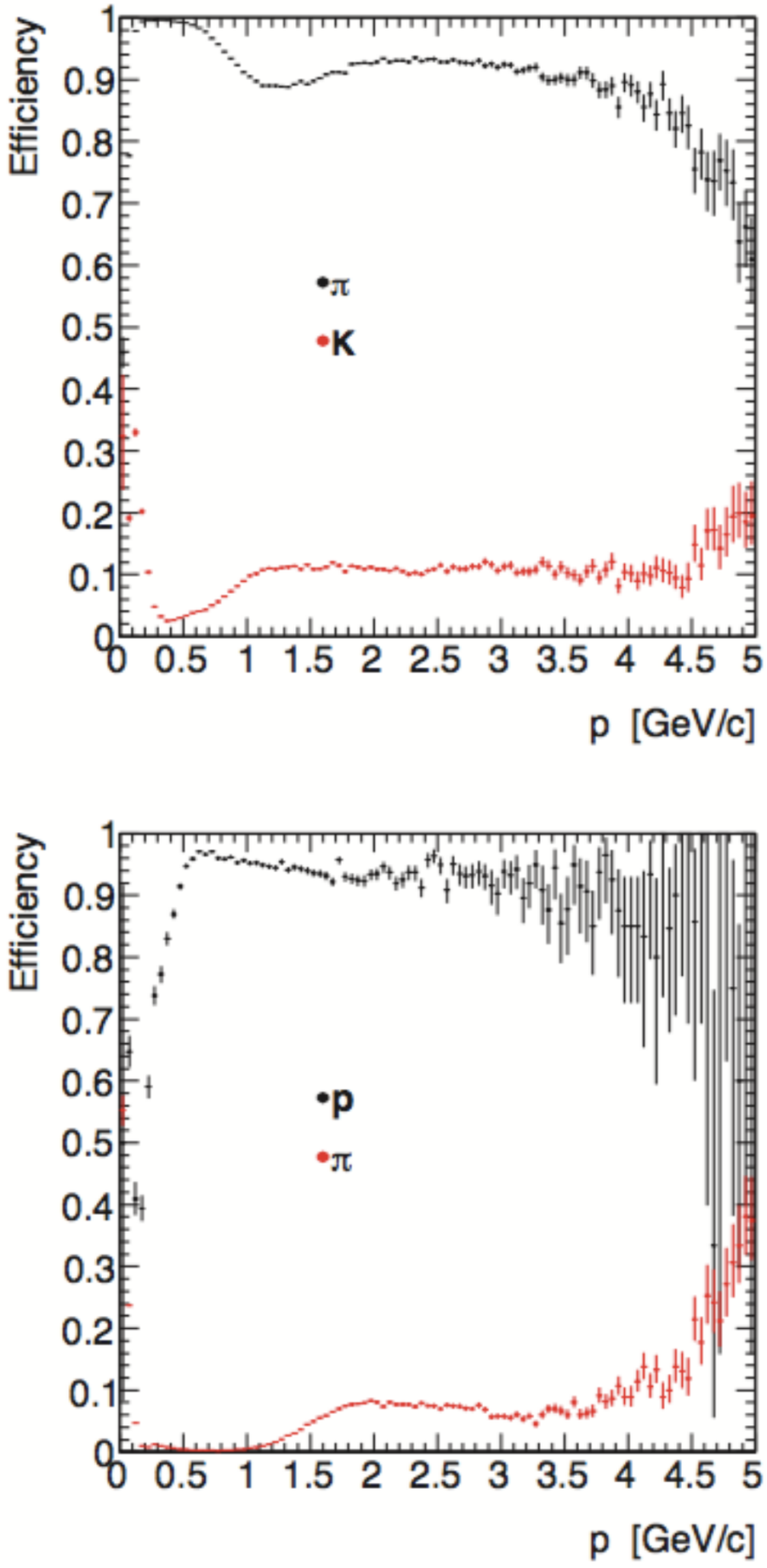
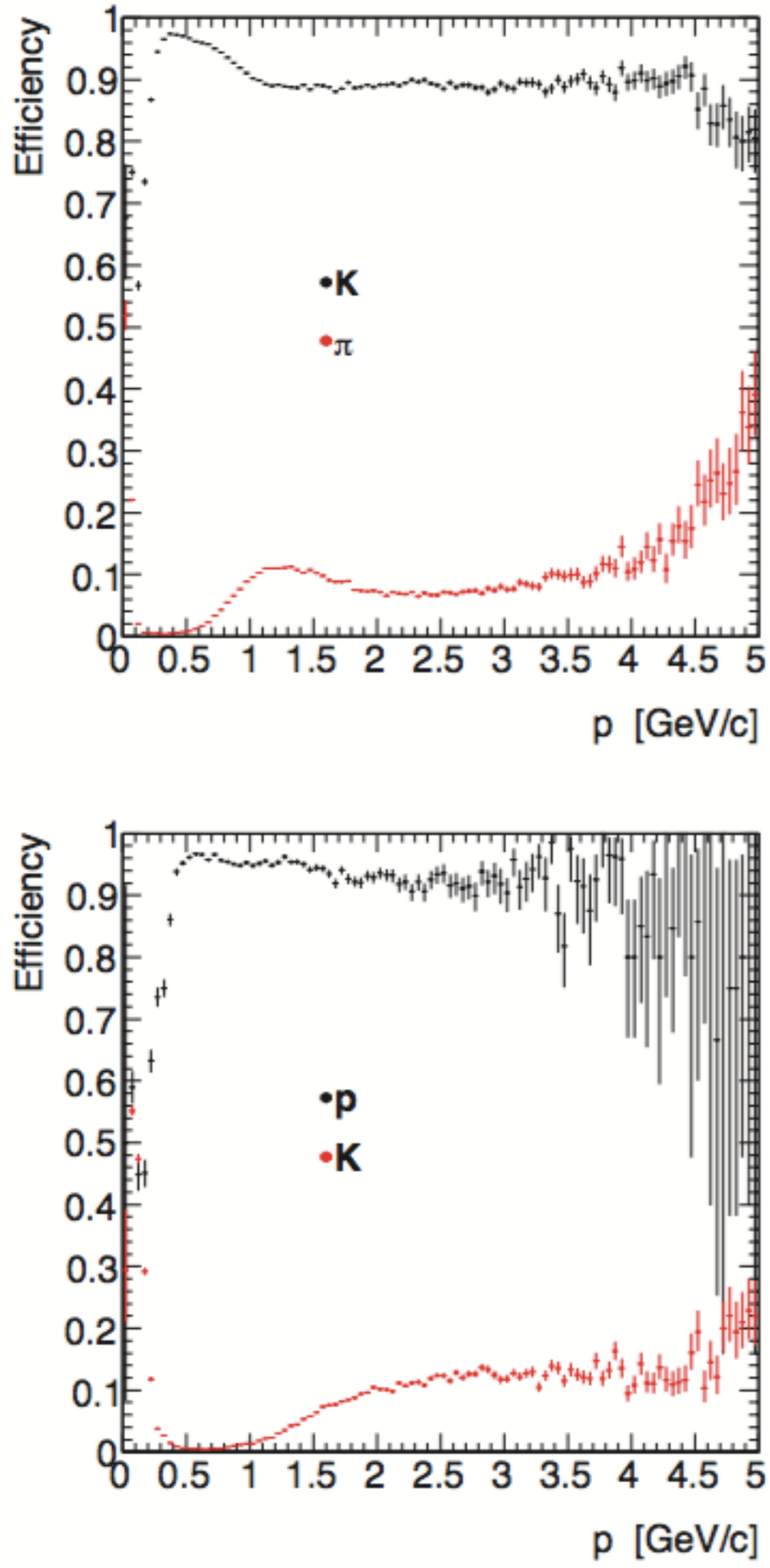
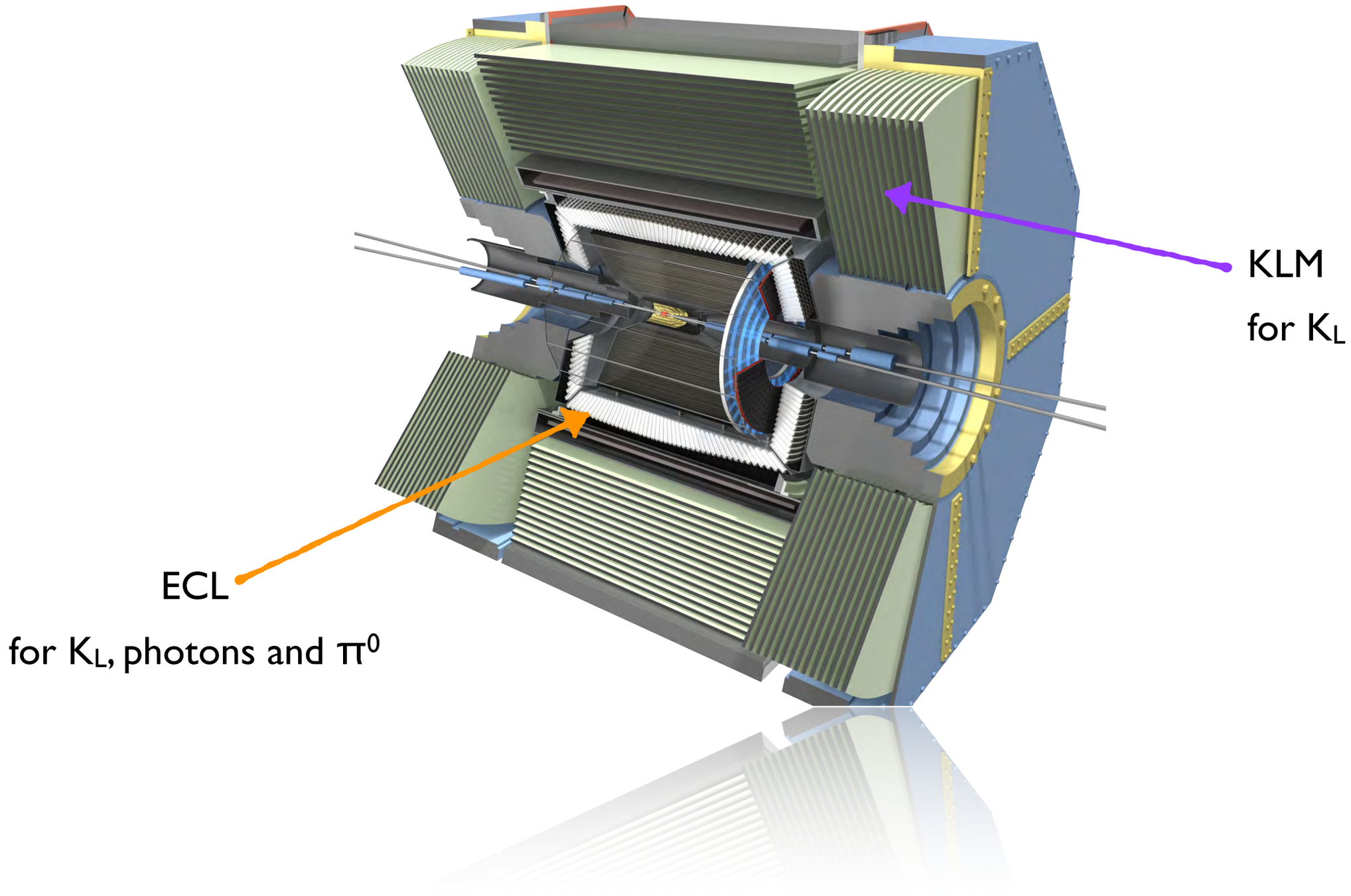
PID Efficiency



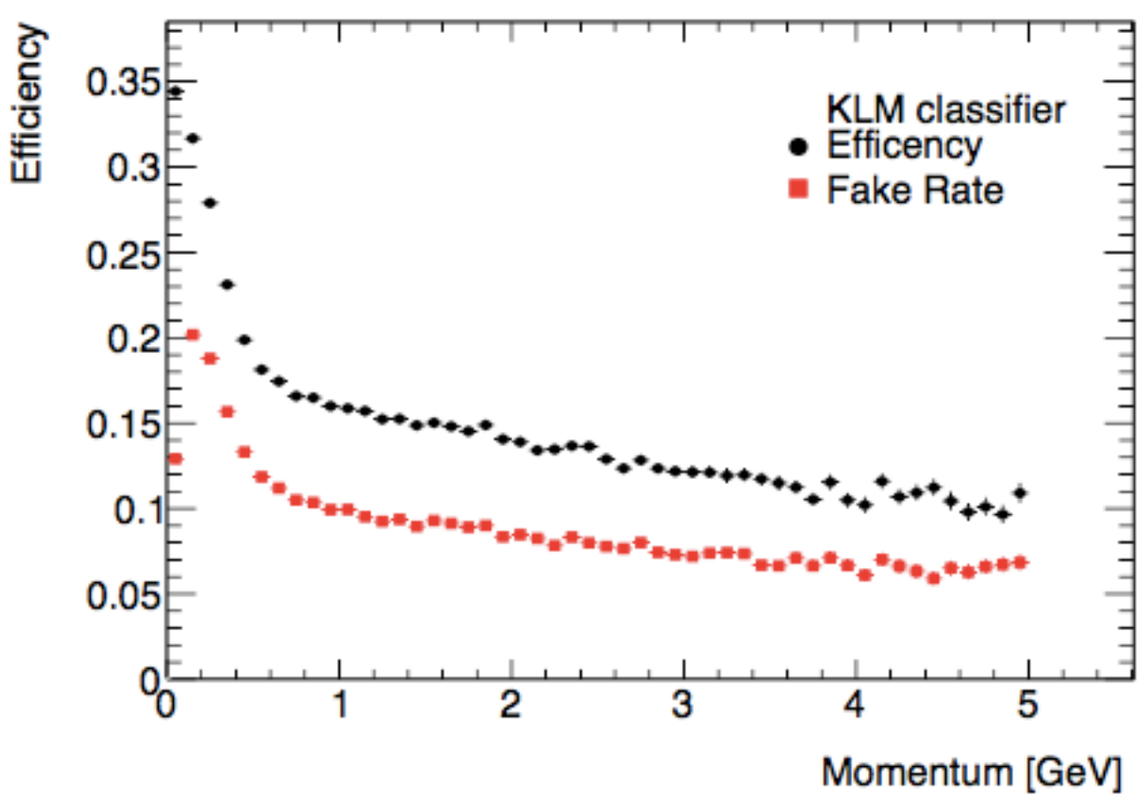


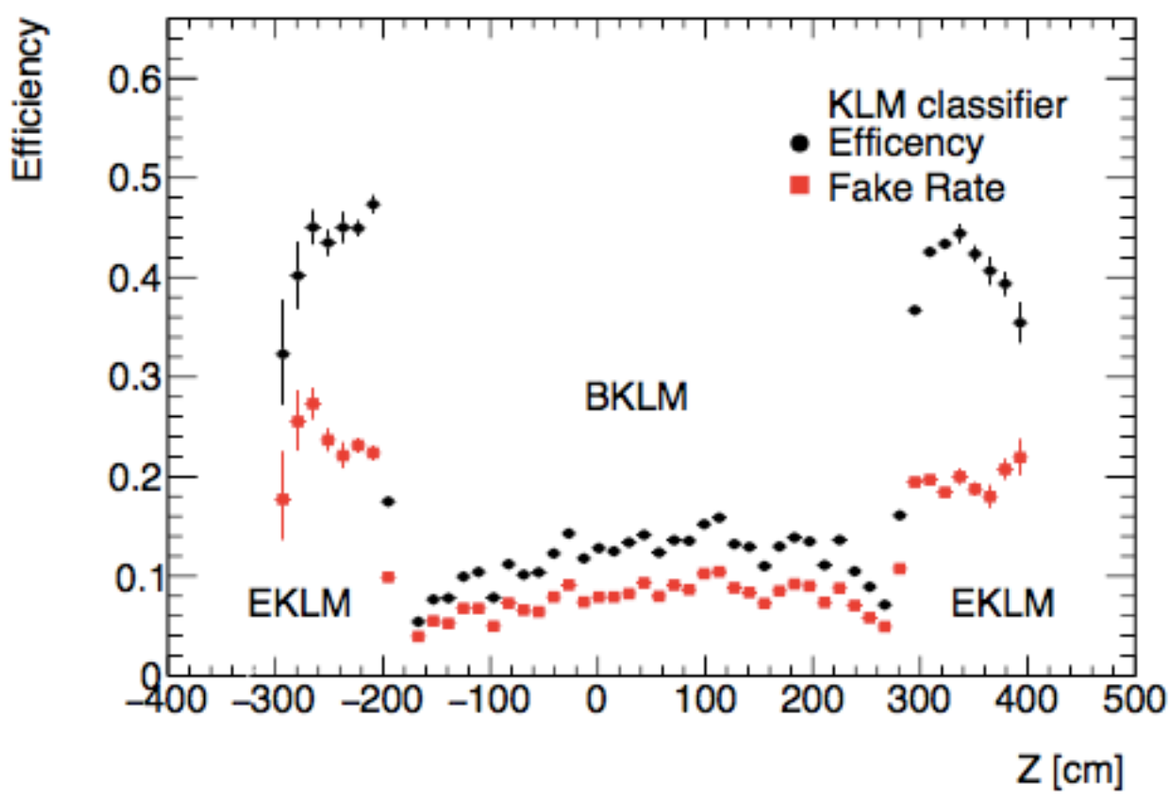


Neutral Particle Identification

K_L Identification

- Based on information coming from the KLM (>3.9 λ_0) and ECL (0.8 λ_0)
- A multivariate method is used to classify clusters according to their probability to originate from a K_L
- The optimal cut on the classifier output depends on the desired performance and the type and size of background
  - KLM classifier performance shown below for a cut yielding 30% – 40% purity





π^0 Identification

- Photon identification is based on the shape of the ECL clusters not matched to tracks

- π^0 are reconstructed from $\pi^0 \to \gamma\gamma$
  - if E < 2.5 GeV the combination of 4-momenta of the photon yields the π^0 momentum, the direction is inferred assuming that it comes from the IP
    - ✓ a mass-constrained improves energy resolution

energy threshold on both photons	50 MeV	30 MeV	20 MeV
π^0 efficiency	76%	93%	98%

  - if E > 2.5 GeV the clusters of the two photons overlap and they do not have local minima anymore
    - ✓ the new ECL reconstruction will allow to defer the π^0 energy from the shower shape

Conclusions

- ☑ *BelleII reconstruction software allows to perform reasonable feasibility and sensitivity studies*
- ☑ *The software is in development and we expect improvements in the future*
  - *new ECL clustering*
  - *redesigned VXD pattern recognition algorithm*