D^0 Reconstruction Using Microvertexing Techniques in the STAR Experiment

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- Physics Motivation
- STAR Detector
- Microvertexing Technique (Silicon info +secondary vertex fitting)
- Reconstruction of $D^0 \rightarrow K^-\pi^+$ in Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV

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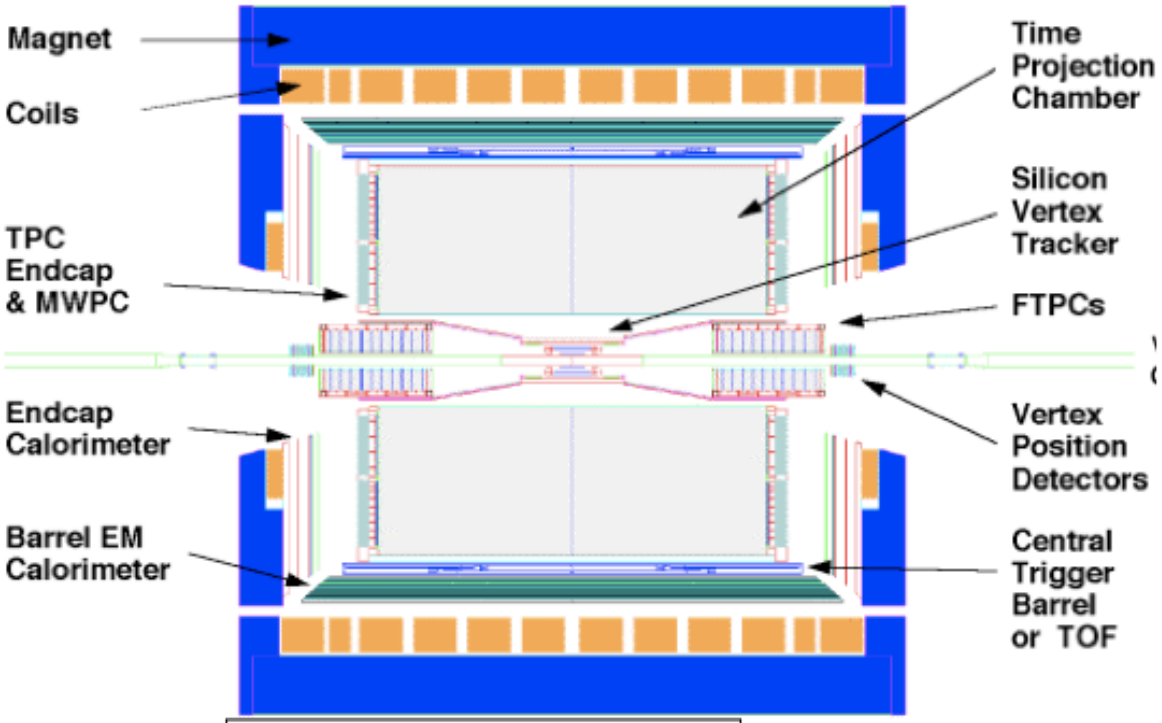
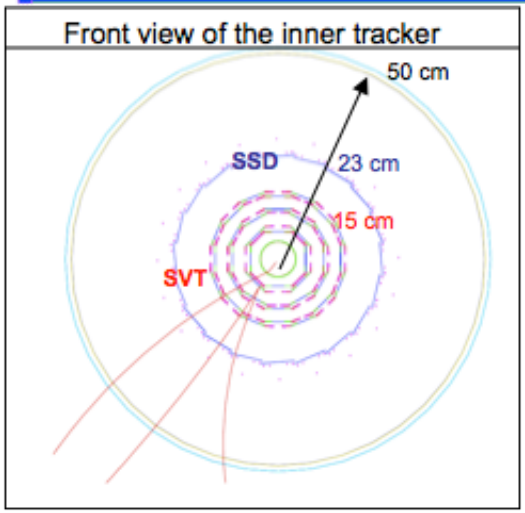
Motivation

- Heavy flavor quarks are produced early in collisions
- Provide insights to the properties of the medium created
  - Nuclear form factor R_{AA} → energy loss in the medium
- Measurement
  - Indirect using semi leptonic decays [1]:
    - $D^0 \rightarrow e^+ + X$, BR : 6.9 %
  - Direct using topological reconstruction [2]:
    - D^0 ($\bar{D}^0$)$K^-\pi^+$($K^+\pi^-$)BR : 3.8 %
- To separate c and b contributions, use full topological reconstruction of decaying particle
  - Challenging because D^0 decay length is small $c\tau(D^0) \approx 124\mu m$

[1]Adare A et al. (PHENIX) 2010 (Preprit1005.1627)
[2] dAu :Phys. Rev. Lett. 94 (2005)
AuAu :STAR arXiv:0805.0364
CuCu **:** preliminary

STAR Detector





- Time Projection Chamber (TPC)
- Silicon Detectors
  - Single Layer Silicon Strip Detector (SSD)
  - 3 Layer Silicon Drift Detector (SVT)
  - System Pointing Resolution of about 280μm in transverse direction [1]

[1] *Fisyak Y V et al. 2008 J. Phys. Conf. Ser. 119 032017*

Strategy

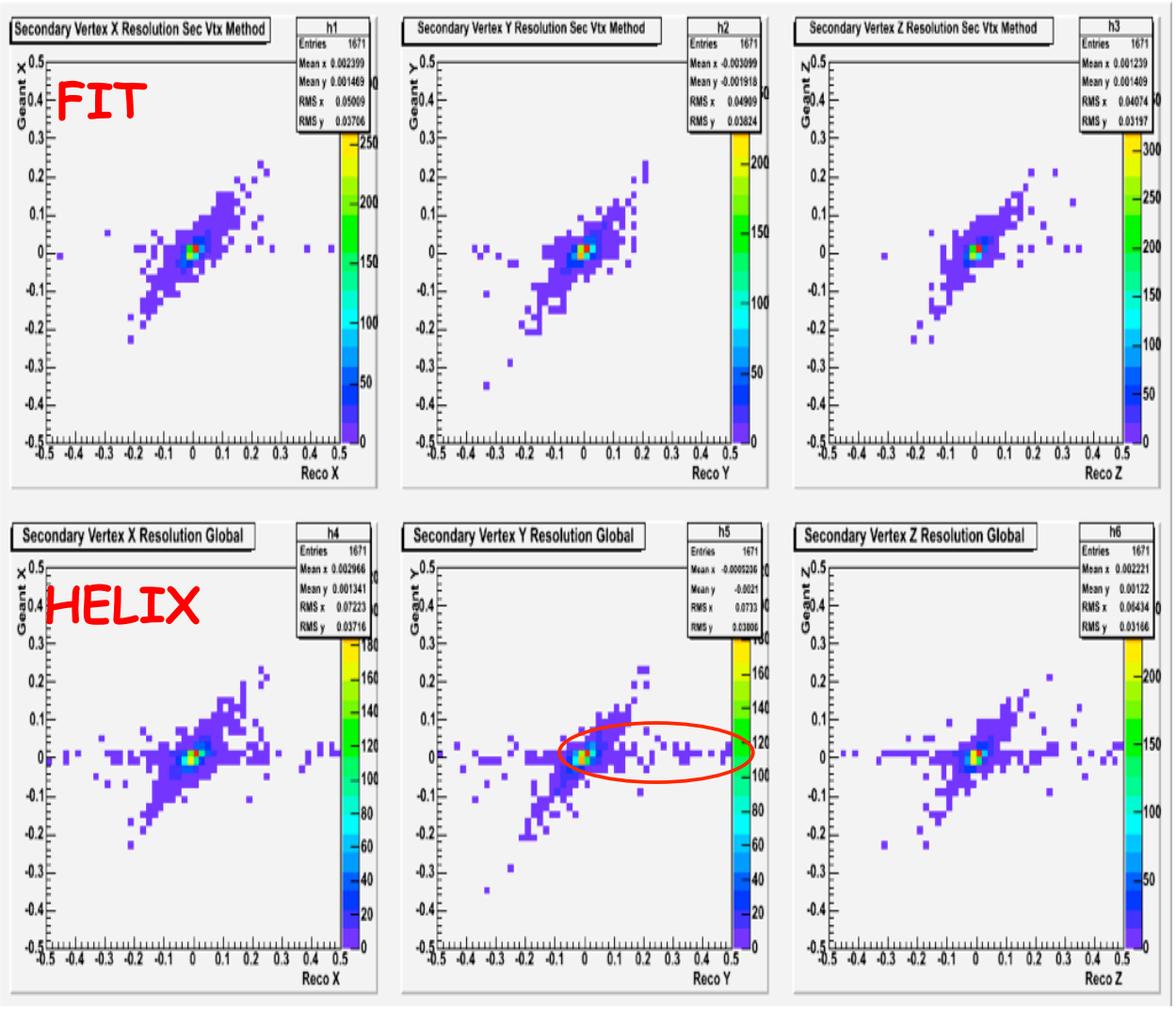
- Apply cuts both in reconstruction code and analysis to reduce the combinatorial background and select good quality tracks and pairs.

1. EVENT level :
   - Primary vertex position and its error (ensured by trigger detectors).
2. TRACKS level
   - Number of hits in the vertex detectors : **SiliconHits>2** (tracks with sufficient DCA resolution).
   - Number of fitted **TPC hits > 20** (avoid splitting tracks).
   - Particle identification : ndEdx : **$|n\sigma_K|<2$, $|n\sigma_\pi|<2$** (select kaon and pion candidates).
   - Pseudo-rapidity : **$|\eta|<1$** (Silicon detector acceptance).
   - DCA to Primary vertex (transverse) **DCA_{xy}< .1 cm** (remove tracks compatibles with strange particles decays).
3. PAIR ASSOCIATION level
   - Sum of momentum of pairs (individual track momentum cut).
   - results given by the secondary vertex fit.
   - Pairs with opposite charges.

- Least square fit of the decay vertex [1] :
  a) In 2 body decay, combination of 2 tracks + kinematic constraints driven by physical considerations.
  b) The Kalman fitter machinery allows the knowledge with high precision of tracks near the primary vertex (by taking into account the MCS due to the silicon layers).

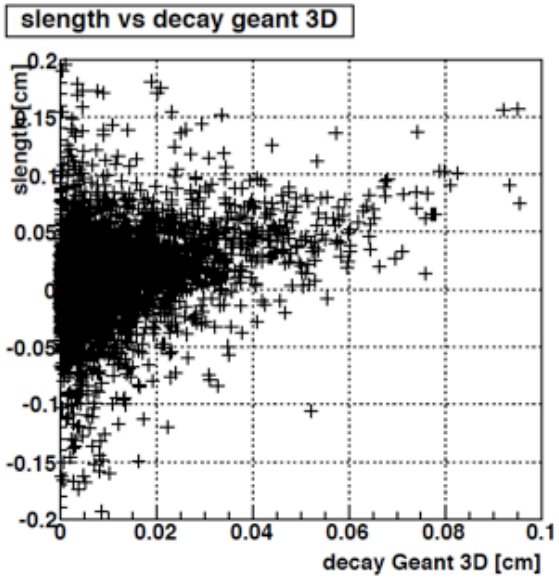
[1]Decay Chain Fitting with a Kalman Filter,W. D. Hulsbergen (arxiv:physics, 0503191)

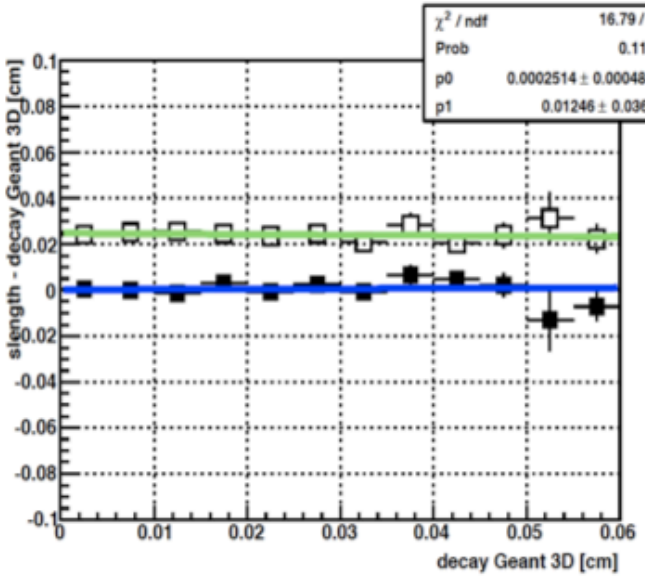
Secondary Vertex Resolution



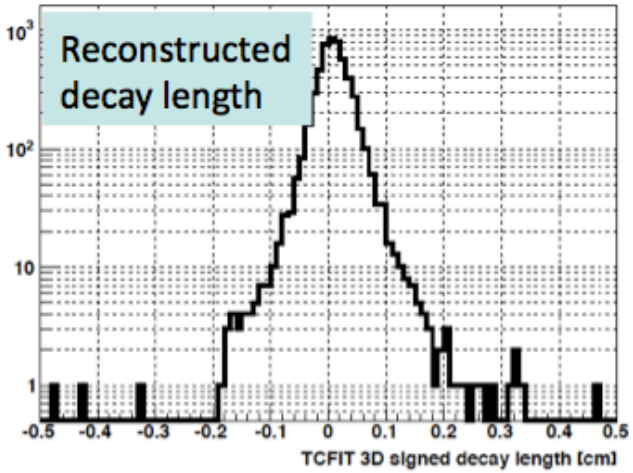
1. Evaluate Resolution in x,y,z
2. Compare Traditional helix swimming reconstruction method to Secondary Vertex Fit Method
3. Helix swimming method struggles more with near parallel tracks and has lower resolution.

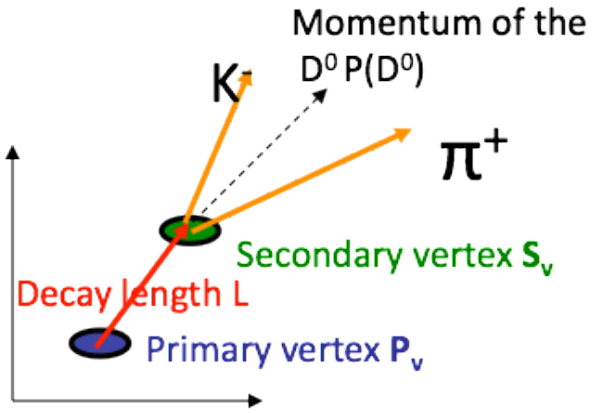
Secondary vertex fit (MC sample)





- There is no systematic shift in reconstructed quantities.
- The standard deviation of the distribution is flat at ~ 250 μm , which is of the order of the resolution of (SSD+SVT).





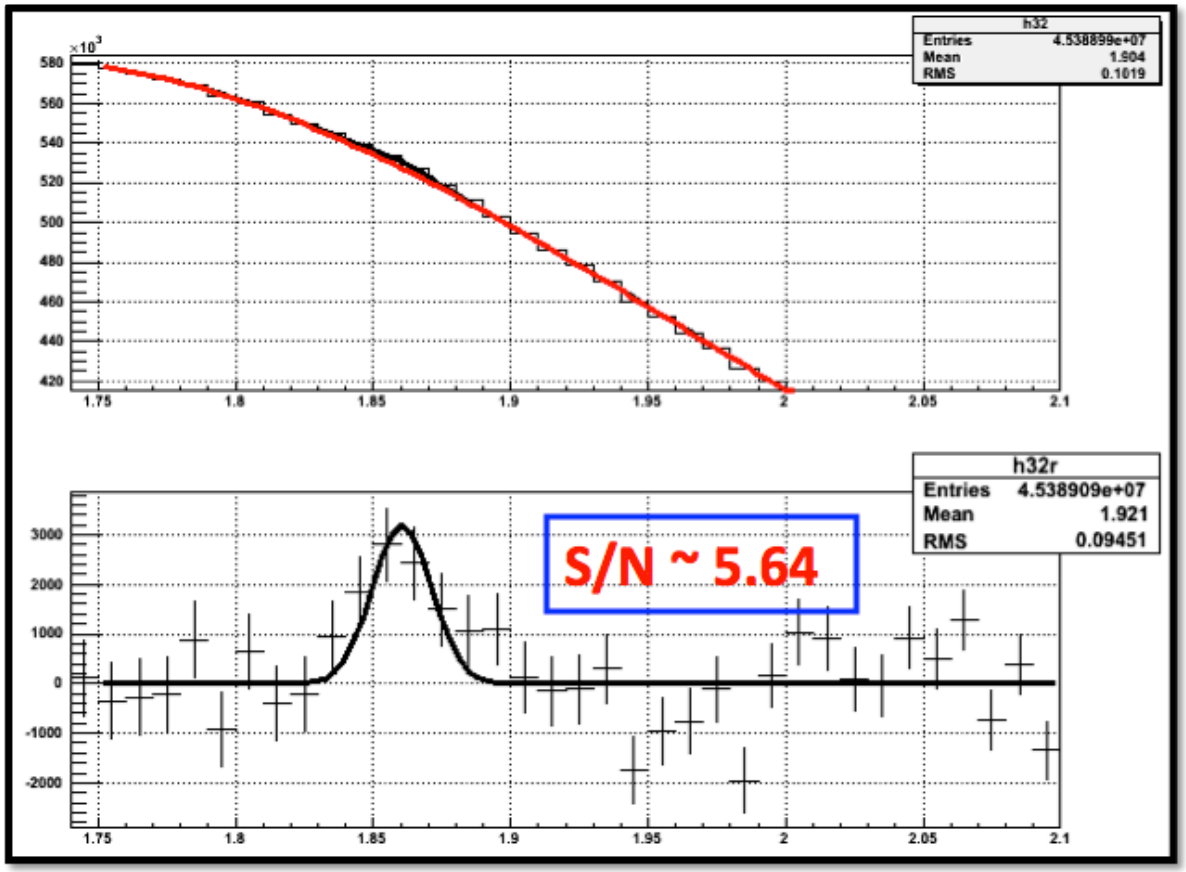
- Reconstructed decay length can be positive or negative.
- Real signal expected for positive decay length.
- Use the decay length significance.

Old Silicon Detectors have marginal capabilities but served as a playground for gaining Alignment, Fitting etc experience.

$D^0 \rightarrow K^-\pi^+$ in Au+Au@200GeV MinBias data

- Used 35M events.
- Multiplicity > 50
- 50μm < L < 400μm
- DCA btw daughters < 200 μm
- DCA of D^0 to primary vertex < 300μm
- $p_T^{kaon} > 0.7GeV/c$
- $p_T^{pion} > 0.7GeV/c$

•The signal remains stable by varying cuts.



Some physics seems possible

Summary

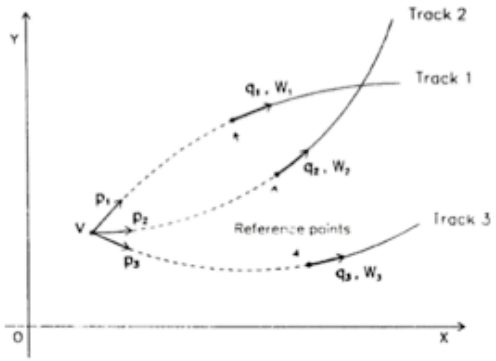
- Obtained D^0 signal with direct topological reconstruction
- Ongoing effort:
  - to tune cuts to maximize S/N
  - estimate efficiency corrections (to get pt spectra)

Inner tracker system

	Number of layer (radius)	technology	Sensor size (mm^2)	Intrinsic resolution (design)	Radiation length
SSD	1 (23 cm)	Double sided silicon strips	42 x 73	r/φ ~ 20 μm Z ~ 700 μm	~1% X_0
SVT	3 (6.8 cm ; 10.8 cm ; 14.8 cm)	Silicon drift	60 x 60	r/φ ~ 20 μm Z ~ 20 μm	~1.5% X_0 per layer

Decay fitting

decay tree

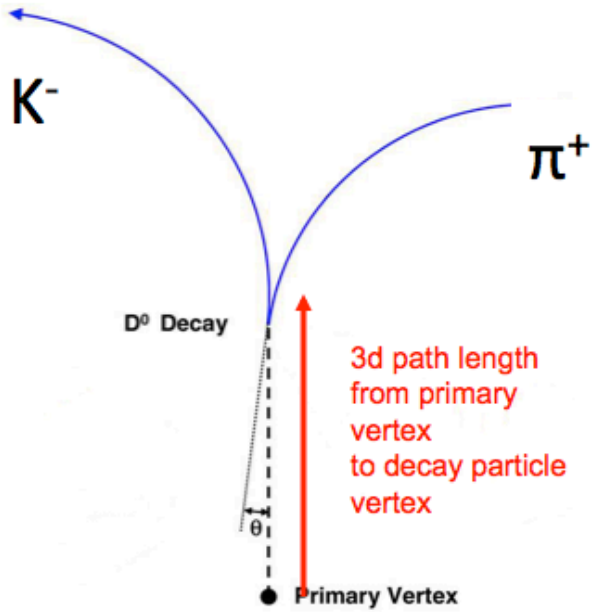


Vertex position

$$\chi^2 = \sum_{\text{tracks } i} (q_i - h(x,p_i))^T \, V^{-1}_i \, (q_i - h(x,p_i))$$

- measured track parameters
- Parametrisation of the track (helix)
- covariance matrix of measured track parameters

- Least square fit of the decay vertex [1] :
- In 2 body decay, combination of 2 tracks + addition of the constraint that they're coming from a common point.
- The Kalman fitter machinery allows the knowledge with high precision of tracks near the primary vertex (by taking into account the MCS due to the silicon layers)
- Method :
  1. Form pair of tracks and use TPC PID of K and π
  2 .Compute the position of the secondary vertex associated to each pair.



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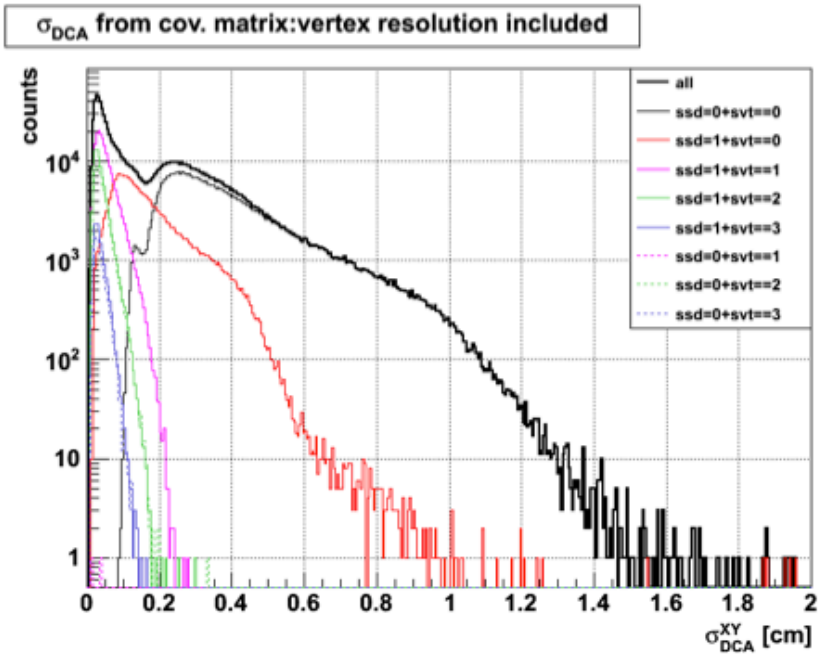
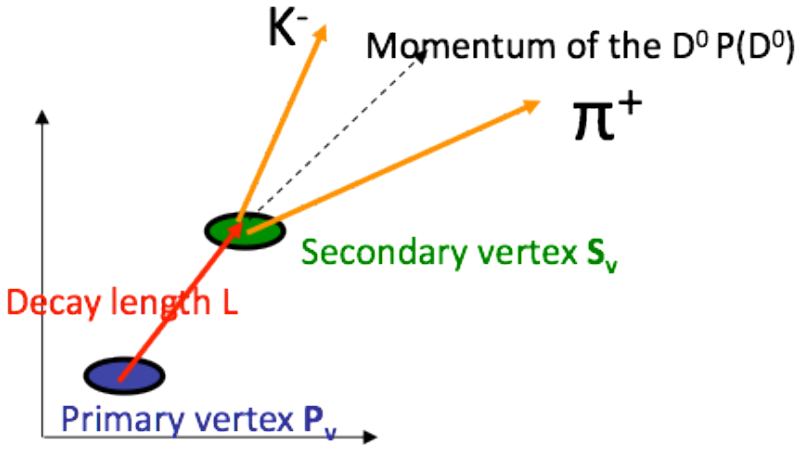
Some definitions

Single track resolution σ_{DCA} : it is taken from the track covariance matrix, augmented by the vertex resolution

$$\sigma_{DCA}^{XY} = \sqrt{\sigma_{DCA}^{XY}{}_{(\text{cov matrix})}^{2} + \sigma_{\text{vertex (XY)}}^{2}}$$





$$L = \frac{(\mathbf{S_v} - \mathbf{P_v}).\mathbf{P}(D^0)}{|\mathbf{P}(D^0)|}$$

σ_L : error associated to the calculated decay length L

$S_L = L / \sigma_L$