# Vertexing : An indispensable tool for precision Physics

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Vertexing
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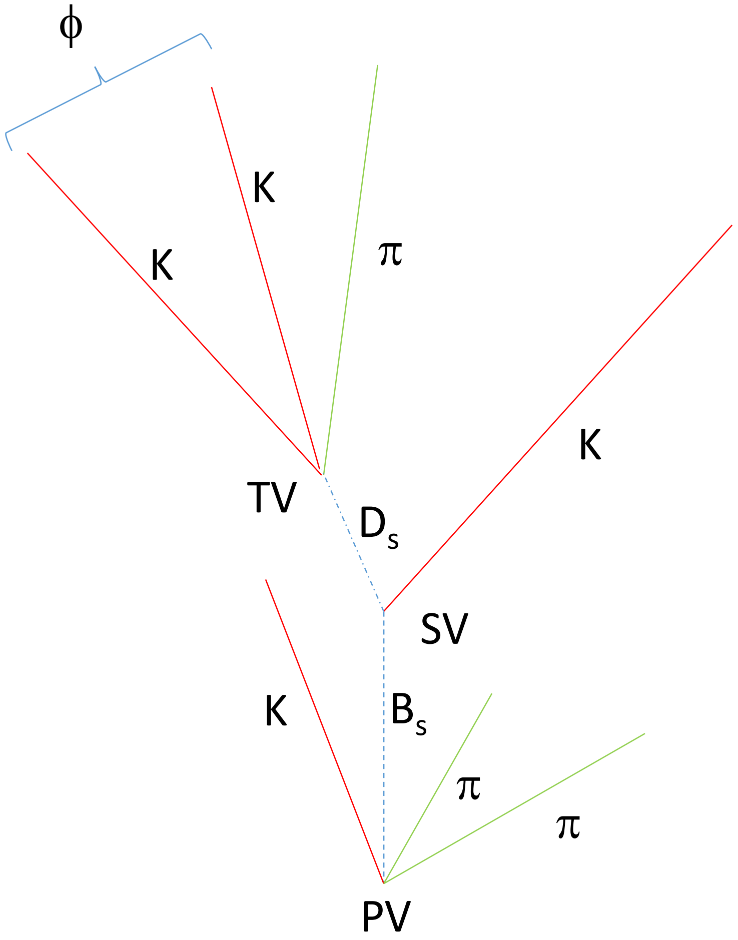
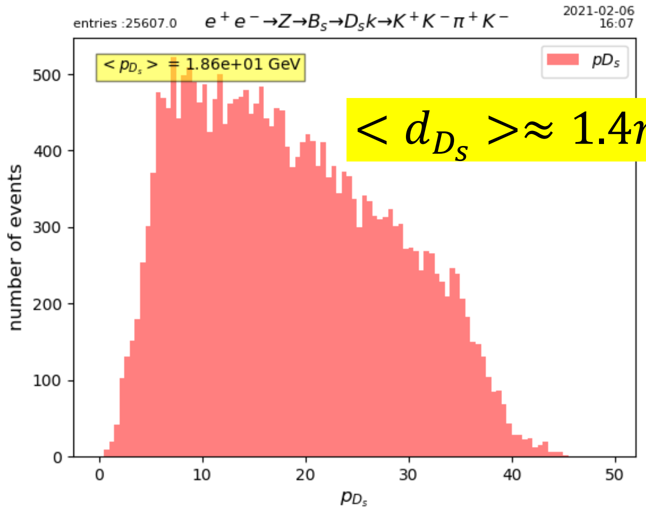
- Time dependent measurements (e.g. CP violation studies…)
  - B flight distance measurement
  - B-Tagging
- Electroweak and Higgs Physics
  - b-tagging, c-tagging, $\tau$-tagging
- Rare decays
  - Limiting the combinatorial background
  - Reconstruction of final states with neutrinos
- ….

# Time dependent measurements

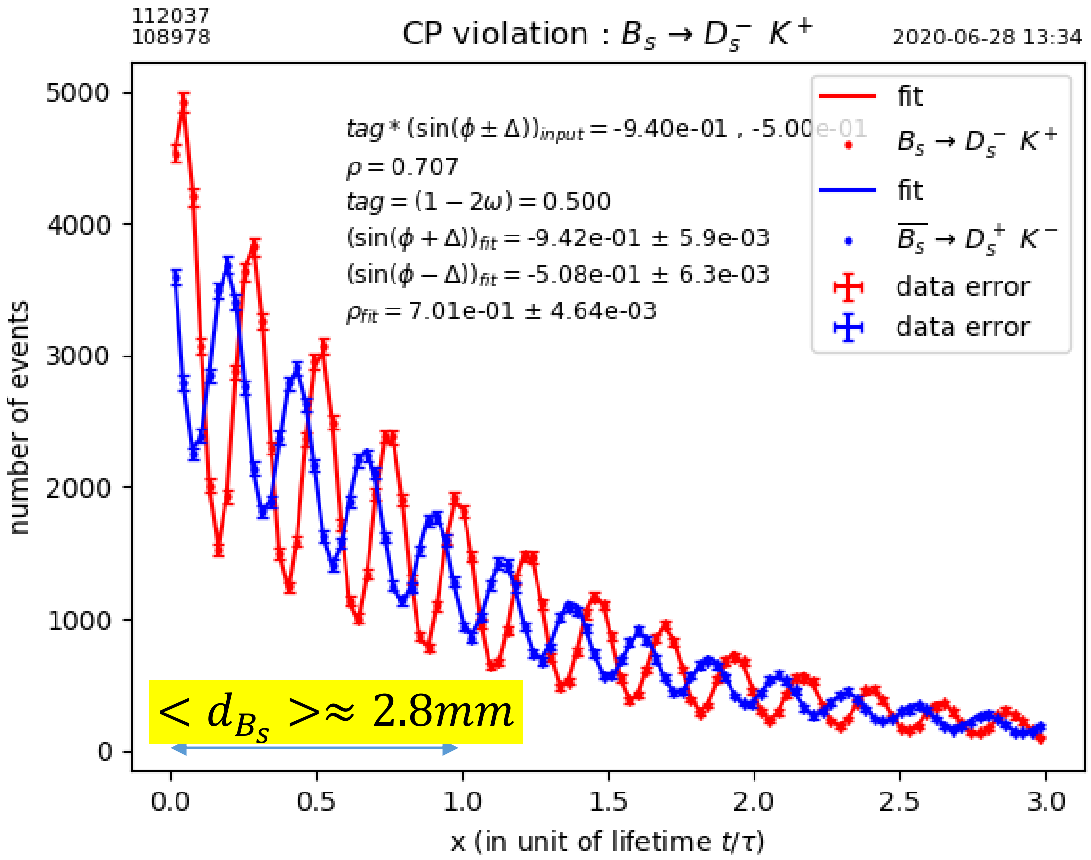
$$B_s \rightarrow D_s K \rightarrow \phi \pi K \rightarrow K K \pi K$$




Identification of all vertices (PV, SV, TV) necessary to make correct time dependent studies. It is also required for imposing intermediate mass constraints

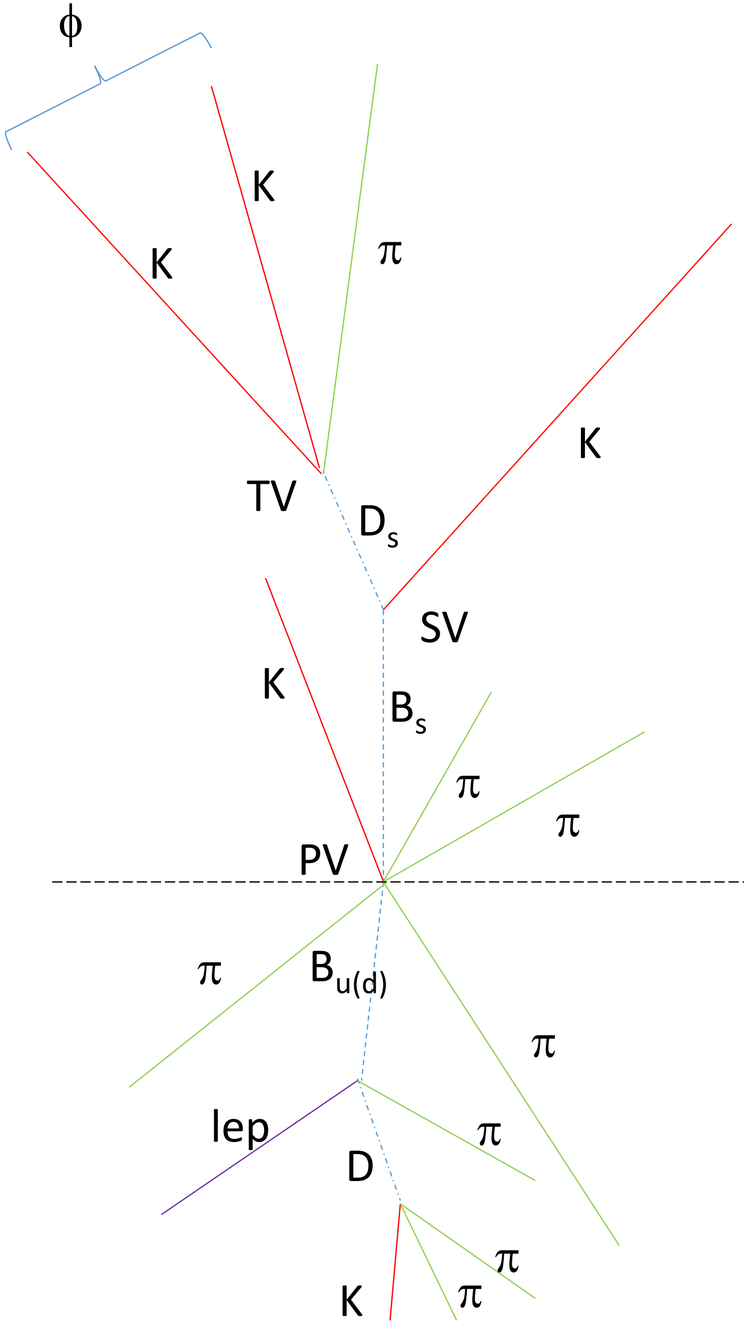



$< d_{D_s} > \approx 1.4mm$

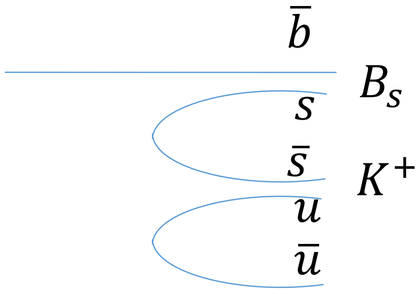



**Resolution on B-flight distance < 30μm very useful to have negligible smearing (minimizing deconvolution errors)**

# Same and Opposite side tagging




Same side tagging done using the identification of most energetic K from primary vertex .




Kaon is the first fragmentation particle taking largest fraction of remaining energy
Its sign same as b quark

Opposite side tagging is greatly facilitated by reconstructing the topology. It eases the identification of

- prompt lepton from B
- secondary lepton and K from D
- Overall weighted charge of the hemisphere

# Electroweak and Higgs Physics

Development of powerful flavor tagging essential for precision Higgs and Electroweak physics

- $H \rightarrow b\bar{b}, c\bar{c}, \tau^+\tau^-$ have different topologies in which vertexing plays an important role

  In general, main features :

  - $b\bar{b}$ : PV, 2SV, 2TV with larger flight distances, higher mutiplicity, multiple kaons, ....
  - $c\bar{c}$ : PV, 2SV with medium flight distances, lower mutiplicity , multiple kaons, …
  - $\tau^+\tau^-$ : 2SV with small flight distances, lower multiplicity, small number of kaons, …

- Measurement of $V_{cb}$ @ $e^+e^- \rightarrow W^+W^-$ with $W^+ \rightarrow c\bar{b}$

  Present error $\delta(V_{cb}) = (42.26 \pm 0.58) \times 10^{-3}$ $(i.e.\ \ \delta(V_{cb})/V_{cb} = 1.4\%)$

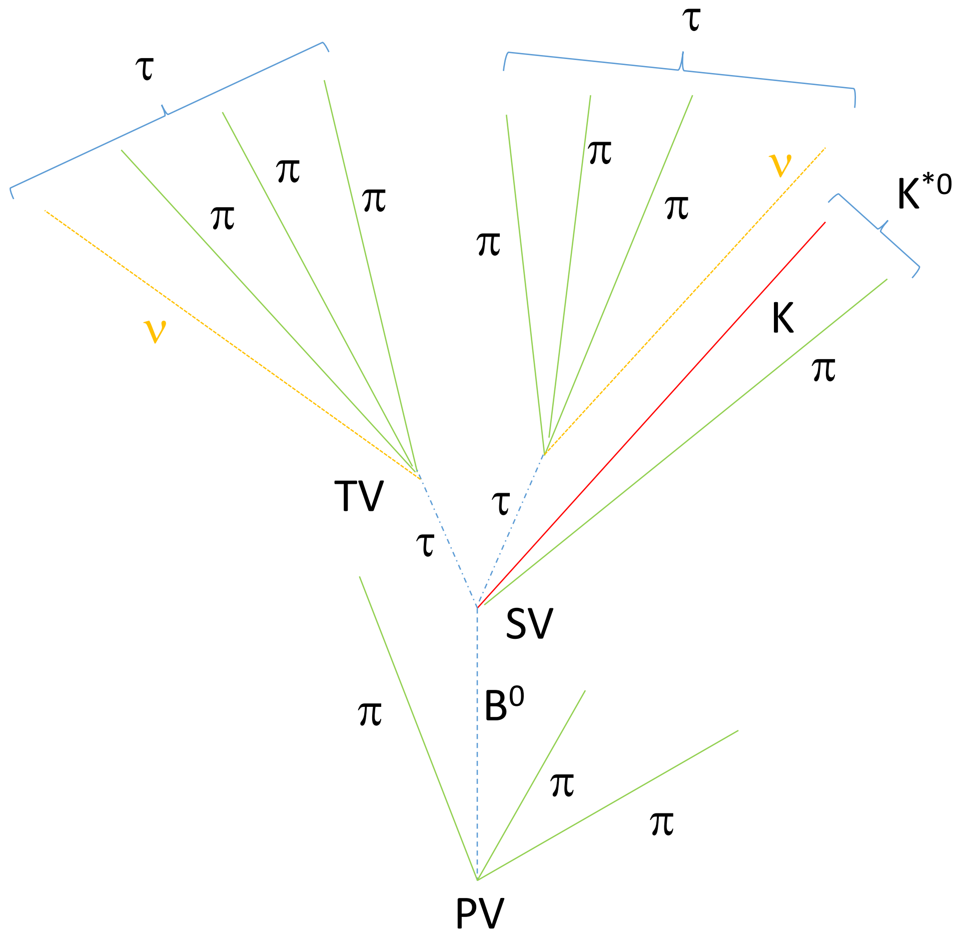
  Very clean (no decay constant uncertainty $f_{B_c}$) compared to $B_c \rightarrow \tau\nu$ … but very challenging

  $W^+ \rightarrow u\bar{d} : c\bar{s} : u\bar{s} : c\bar{d} : c\bar{b} \approx 1 : 1 : 0.05 : 0.05 :$ **$0.0019$**

  If $10^8$ W produced@FCC , 2 $10^5$ $W \rightarrow c\bar{b}(b\bar{c})$ , potential statistical error $\delta(V_{cb})/V_{cb} = 0.13\%$!

e.g. $B^0 \to K^{*0}\tau^+\tau^- \to (K^+\pi^-)_{K^{*0}}(\pi^+\pi^-\pi^+)_\tau(\pi^-\pi^+\pi^-)_\tau$

# Rare decays

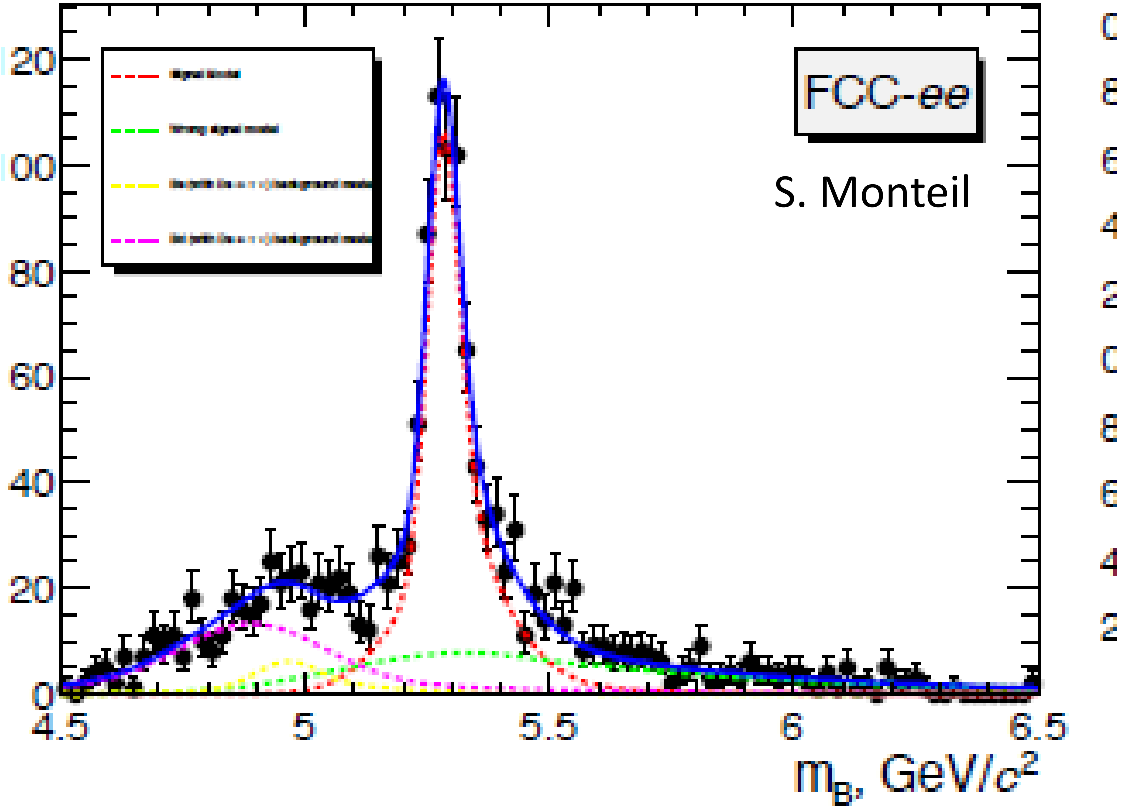



Two missing neutrinos but possible to reconstruct B, thanks to the knowledge of B and τ's directions (4 vertices)

Very interesting mode for probing lepton unviversality
By comparing to $B^0 \to K^{*0}\mu^+\mu^-$ and $B^0 \to K^{*0}e^+e^-$

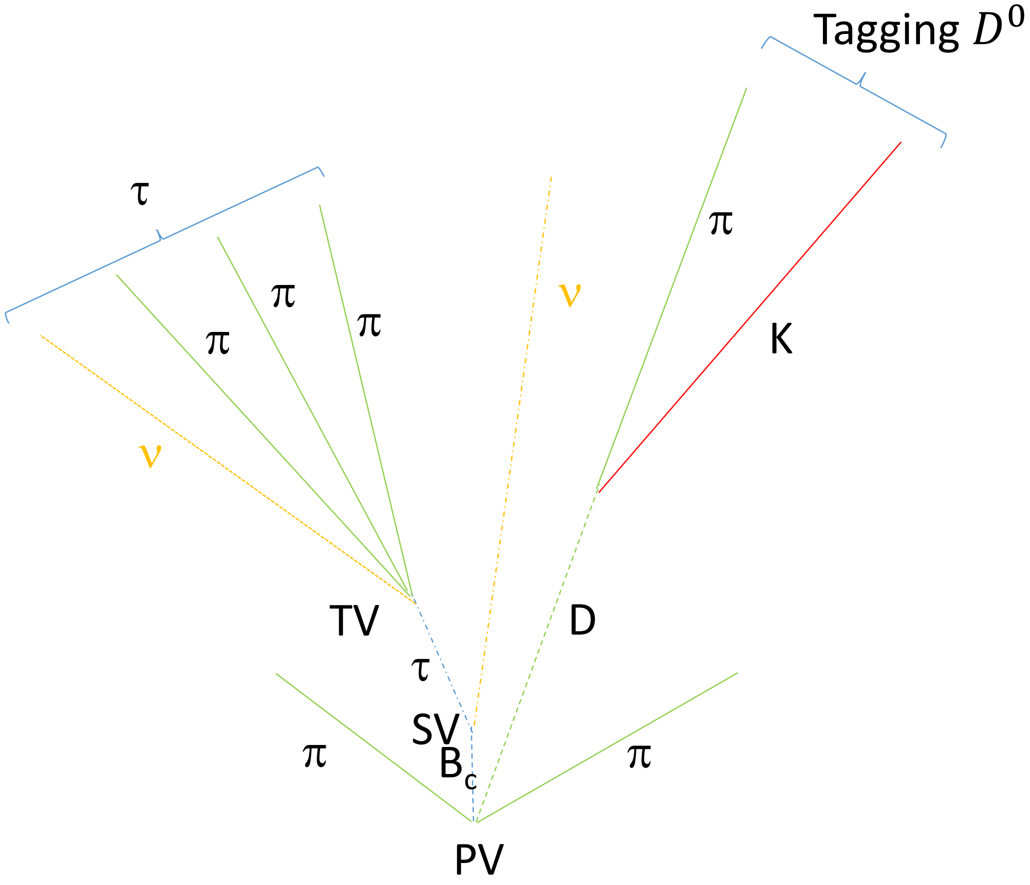
**Superb resolution on PV, SV, TV fundamental good B mass resolution for background suppression.**

τ flight distance is rather short ($c\tau \approx 90\mu m$)
error on τ direction generates larger B-mass resolution



# Rare decays

$B_c^{\pm} \to \tau^{\pm}\nu$




$Br(B_c^{\pm} \to \tau^{\pm}\nu) \approx 5\%$

$\frac{N(B_c^{\pm})}{N(B_u^{\pm})} \lesssim 10^{-3}$

$\Rightarrow \;\; \approx 4 \cdot 10^7 \; B_c^{\pm} \to \tau^{\pm}\nu$

$< p_\tau > \approx 19 \; GeV, < d_\tau > \approx 0.9mm$

Two missing neutrinos and no information on SV but some interesting features to reduce background:

- Tagging b in opposite side
- Same side tagging with D
- $B_c$ flight very short ($c\tau \approx 150\mu m$) compared to $B^+ \to \overline{D^0}\tau^+\nu$ or $B^0 \to D^-\tau^+\nu$ (very dangerous background (> x $10^2$)

# Conclusion

Vertexing is a vital tools in variaty of precision measurements @ FCC

Let's get to work