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Measuring γ at LHCb using $B^{\pm} \to D^0(\to K^0_S \pi^+\pi^-)\, K^{\pm}$

Dan Johnson, on behalf of the LHCb collaboration

Introducing γ and B→DK

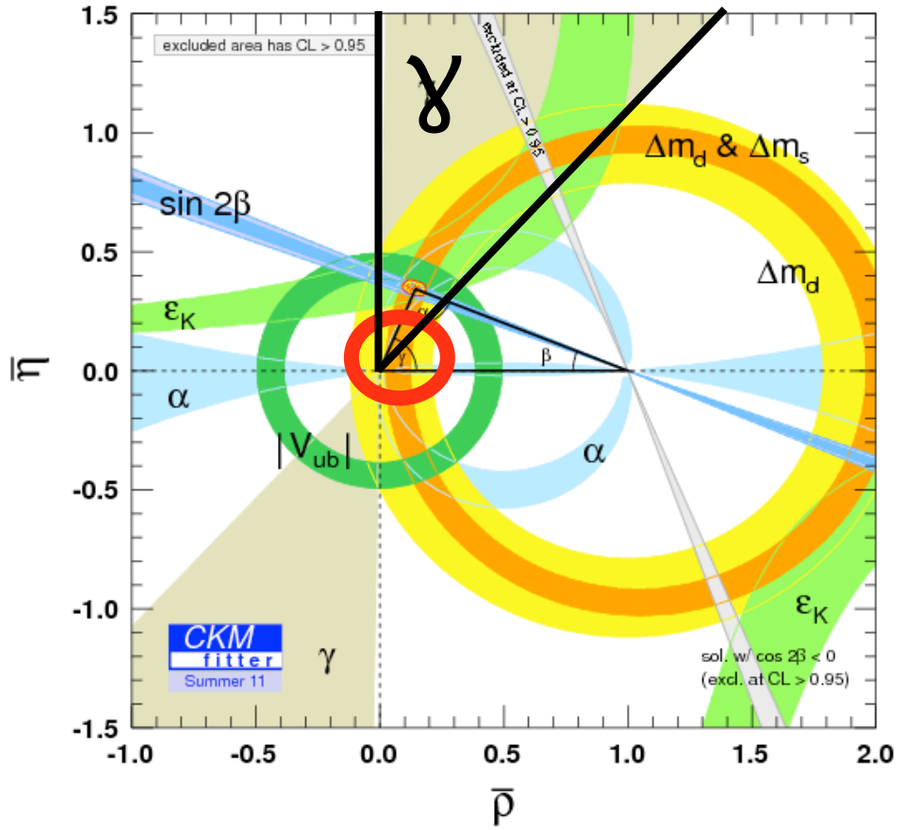
- Standard Model CP violation parameterised by CKM phase γ

Why measure γ?

- This is the least well known CKM phase:

$$\gamma = (68^{+10}_{-11})^\circ$$
B→DK

- Improved precision may allow over-constraining of the 'unitarity triangle' shown



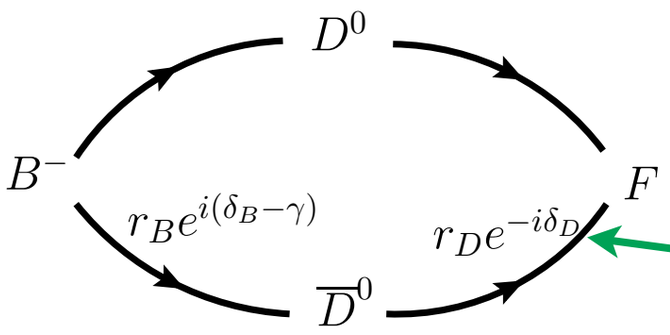
And how?

- Crucial mode: $B \to \{D^0 / \overline{D}^0\}(\to f)\, K$
  - interference between $D^0 \to f$ and $\overline{D}^0 \to f$ (f = final state)
  - tree level ⇒ theoretically clean

- Use several final states f of the $\{D^0/\overline{D}^0\}$ to:
  - increases statistical power
  - reduces ambiguities in γ result

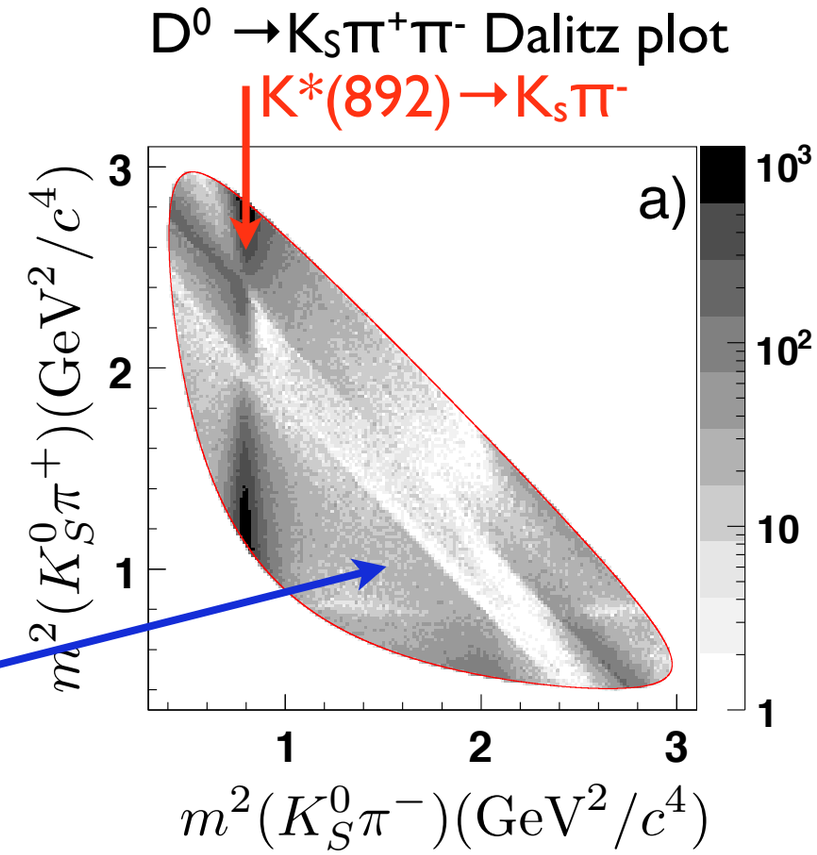
$B \to (K_S\pi\pi)_D K$

- Sensitive to γ through interference in $D^0/\overline{D}^0$ decay

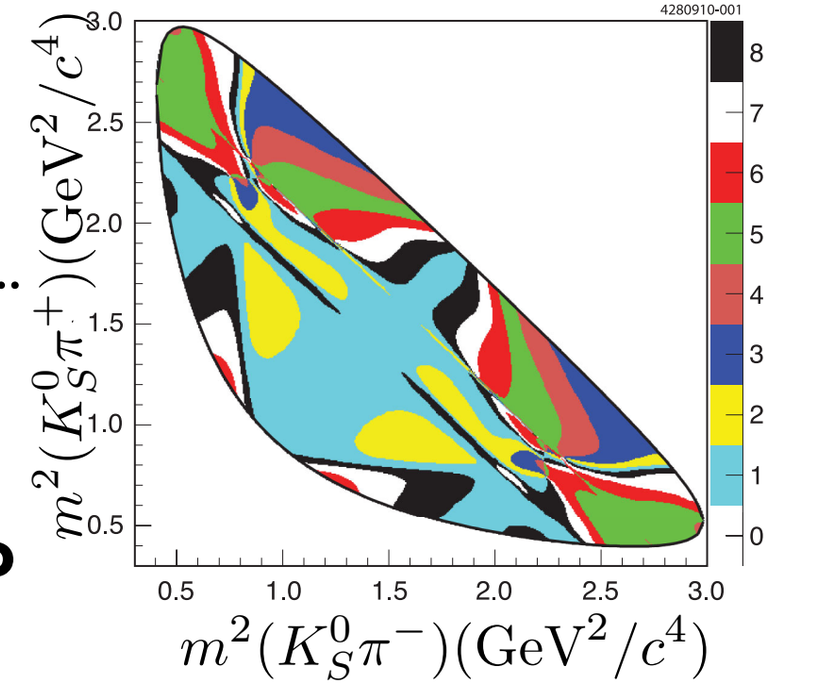


However, the D^0 decays through various resonances...

... and the strong phase depends on Dalitz position



- Can take strong phase from a model (but incur model systematic)
- **Better**: divide data into Dalitz plot 'bins' of similar strong phase and determine average strong phase elsewhere
  ⇒ model **independent**
- In a single bin, the number of $B^+(B^-)$ decays depends upon γ(-γ) ... ... but also on the CP-conserving strong phase which varies across the Dalitz space
- Need to know average strong phase in a bin i
  ('c_i' = $\langle\cos(\delta_D)\rangle_i$, 's_i' = $\langle\sin(\delta_D)\rangle_i$) ⇒ **look to CLEO**



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- This approach was employed by Belle to measure γ in 2011:
  $\Rightarrow \gamma = (77.3^{+15.1}_{-14.9} \pm 4.2 \pm 4.3)^\circ$ (c_i s_i uncertainty)
  ArXiv: 106.4046

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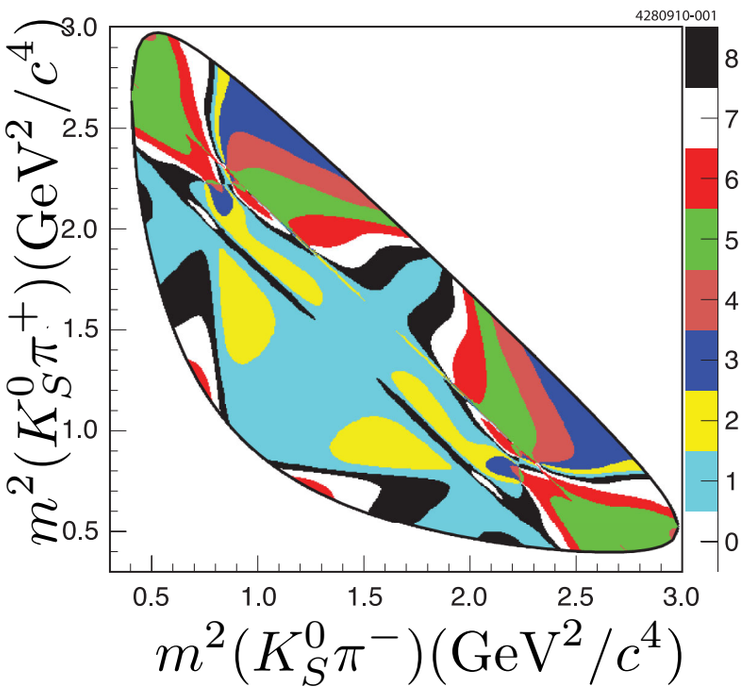
Input from CLEO

Input from CLEO

Cornell Electron Storage Ring

The CLEO experiment

- Cornell University, NY state
- Active ~1980 → 2008
- $e^+ e^-$ collisions at $\Psi(3770)$ resonance (CLEO-c)
- Bin-by-bin yields of 'CP-tagged' $D_{CP} \to K_S\pi^+\pi^-$ decays at CLEO allow access to required strong phase in each bin



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CP tagging at CLEO

$\Psi(3770)$

(1) CP+

D_1 D_2

'Quantum correlated' D mesons

(2) CP state (e.g. K^+K^-; CP+)

'Tagged' CP state **(3)**

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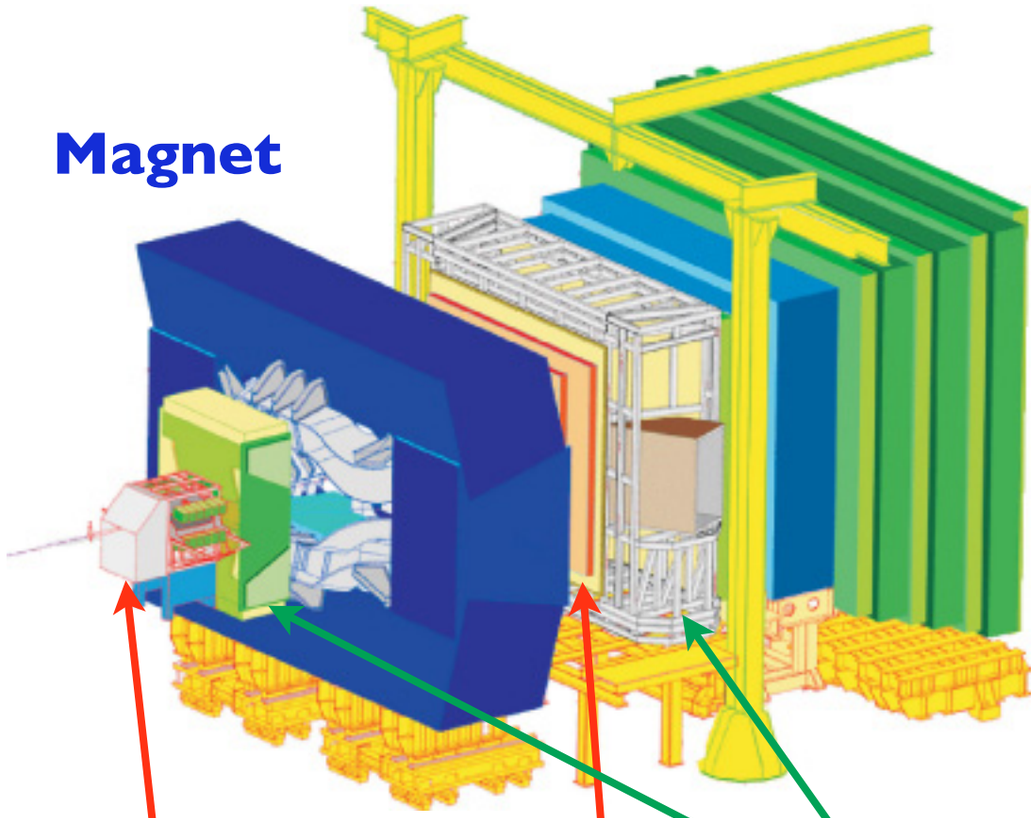
LHCb steps in

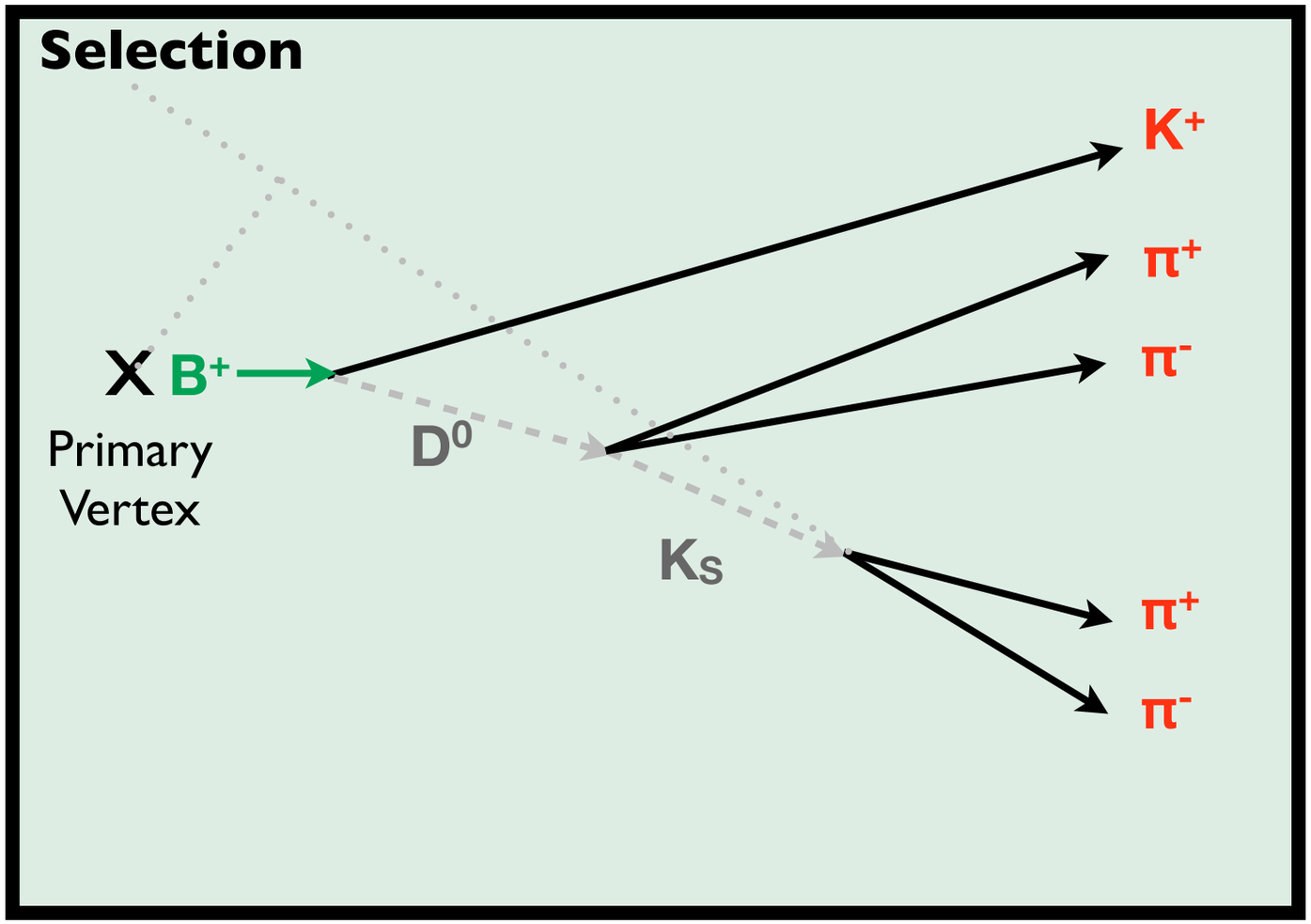
The LHCb experiment 1/2

- **Select** $B^{\pm} \to D^0(\to K_S\pi\pi)K^{\pm}$ and $B^{\pm} \to D^0(\to K_S\pi\pi)\pi^{\pm}$, to use as a control mode
  - no CP violation expected in $B^{\pm} \to D^0\pi^{\pm}$ decay
    - so control mode used to find selection efficiency in each bin and 'correct' $B^{\pm} \to D^0K^{\pm}$ bin yields for efficiency effects



Vertex Locator and Si strip/straw trackers:
Precision vertexing, tracking and momentum resolution

RICH detectors:
Excellent K/π separation over large momentum range



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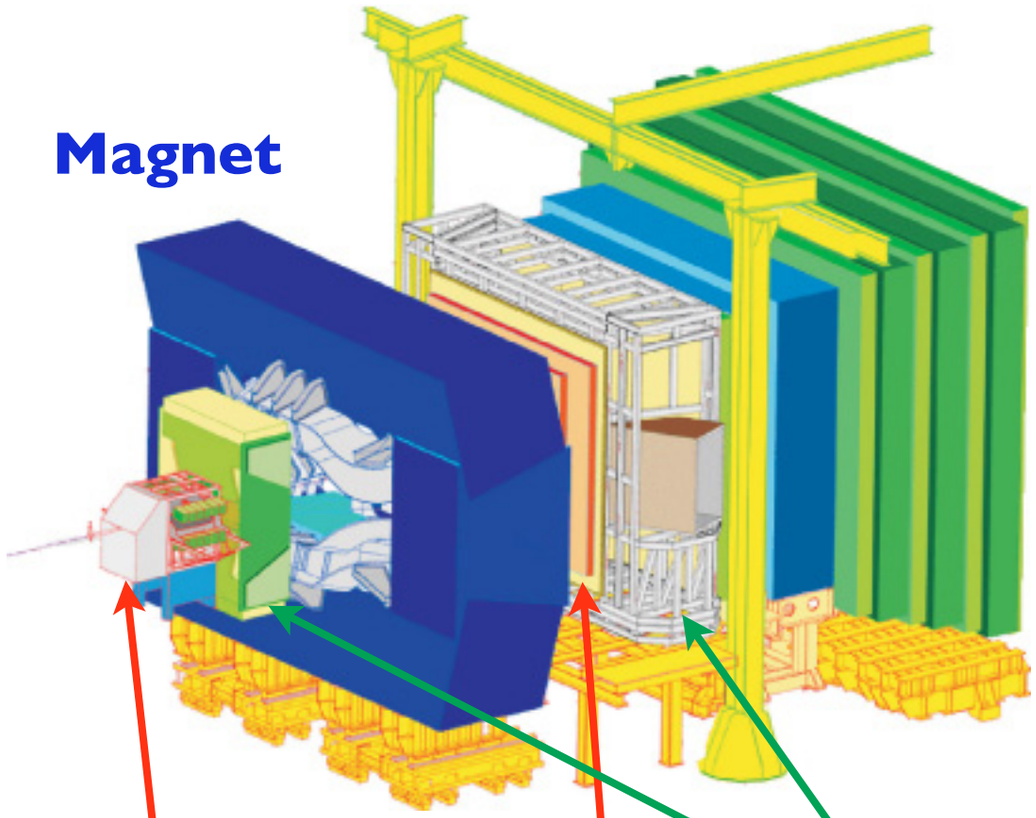

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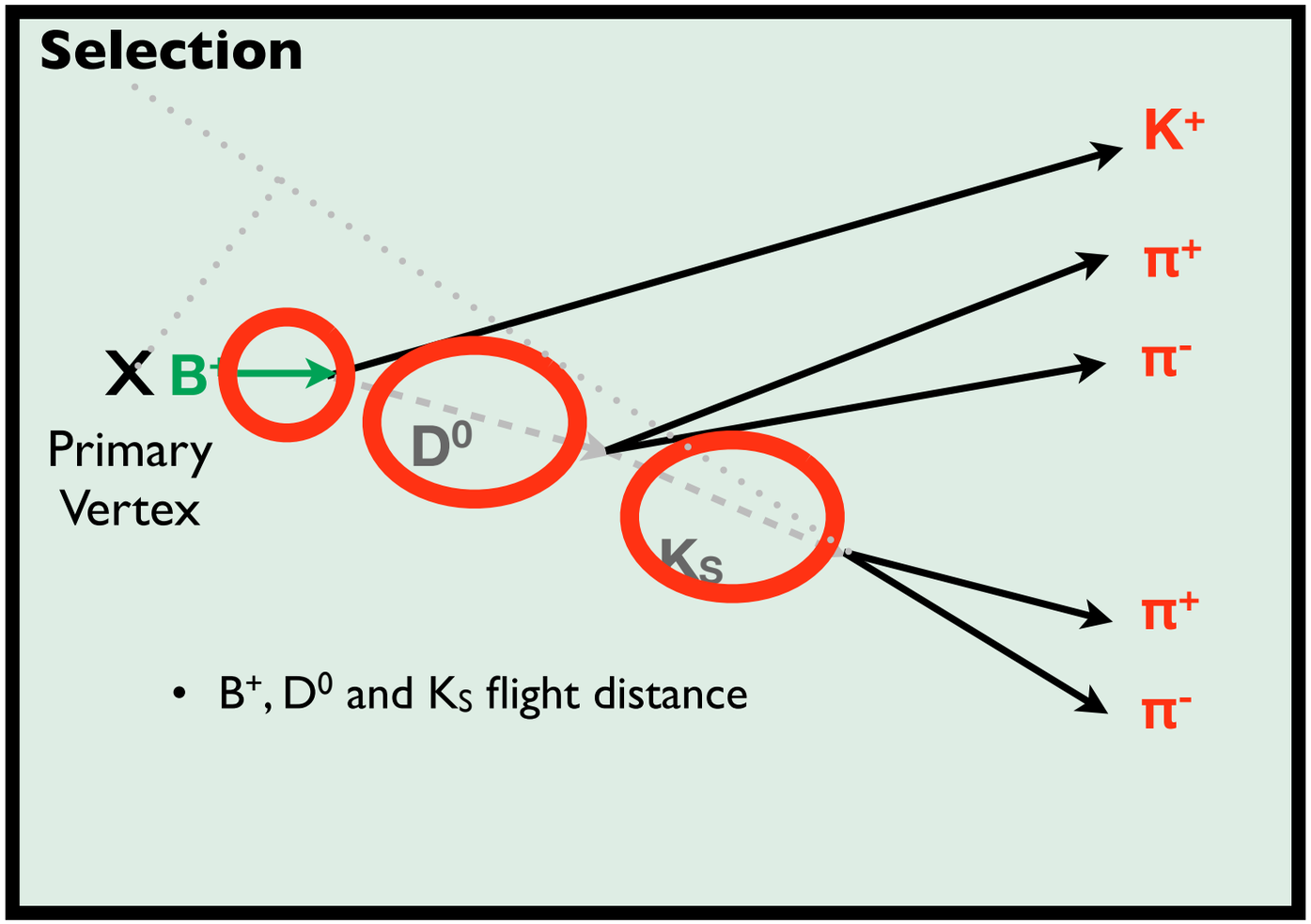

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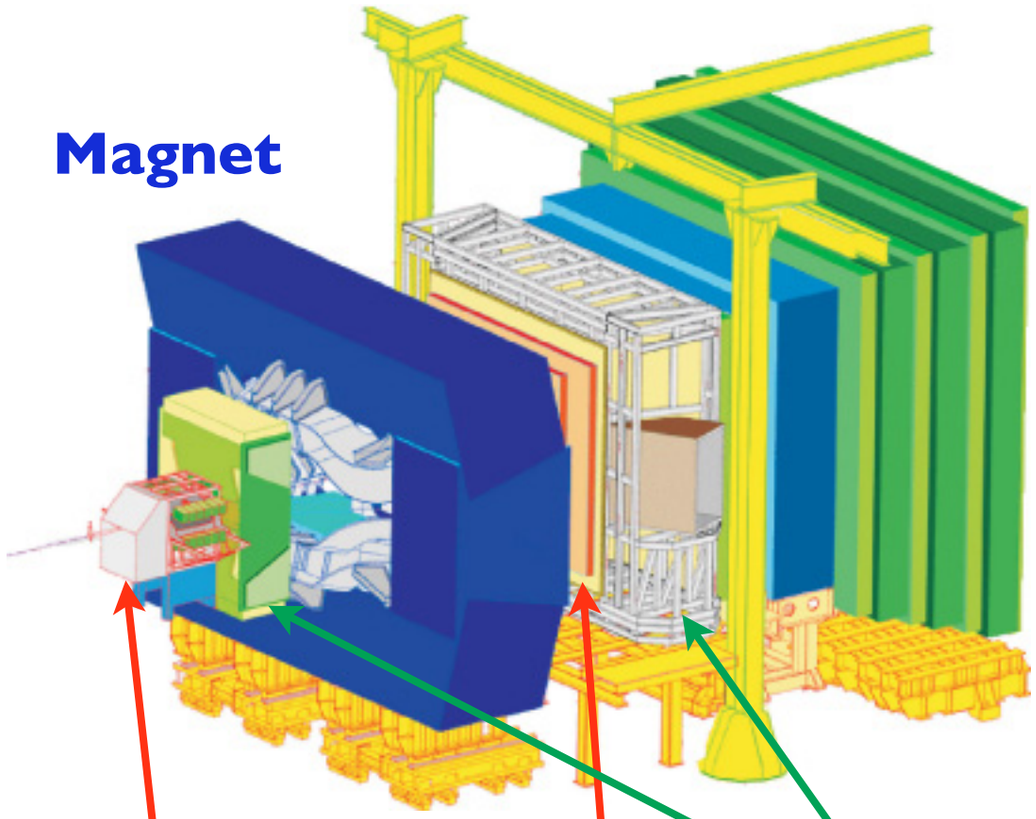

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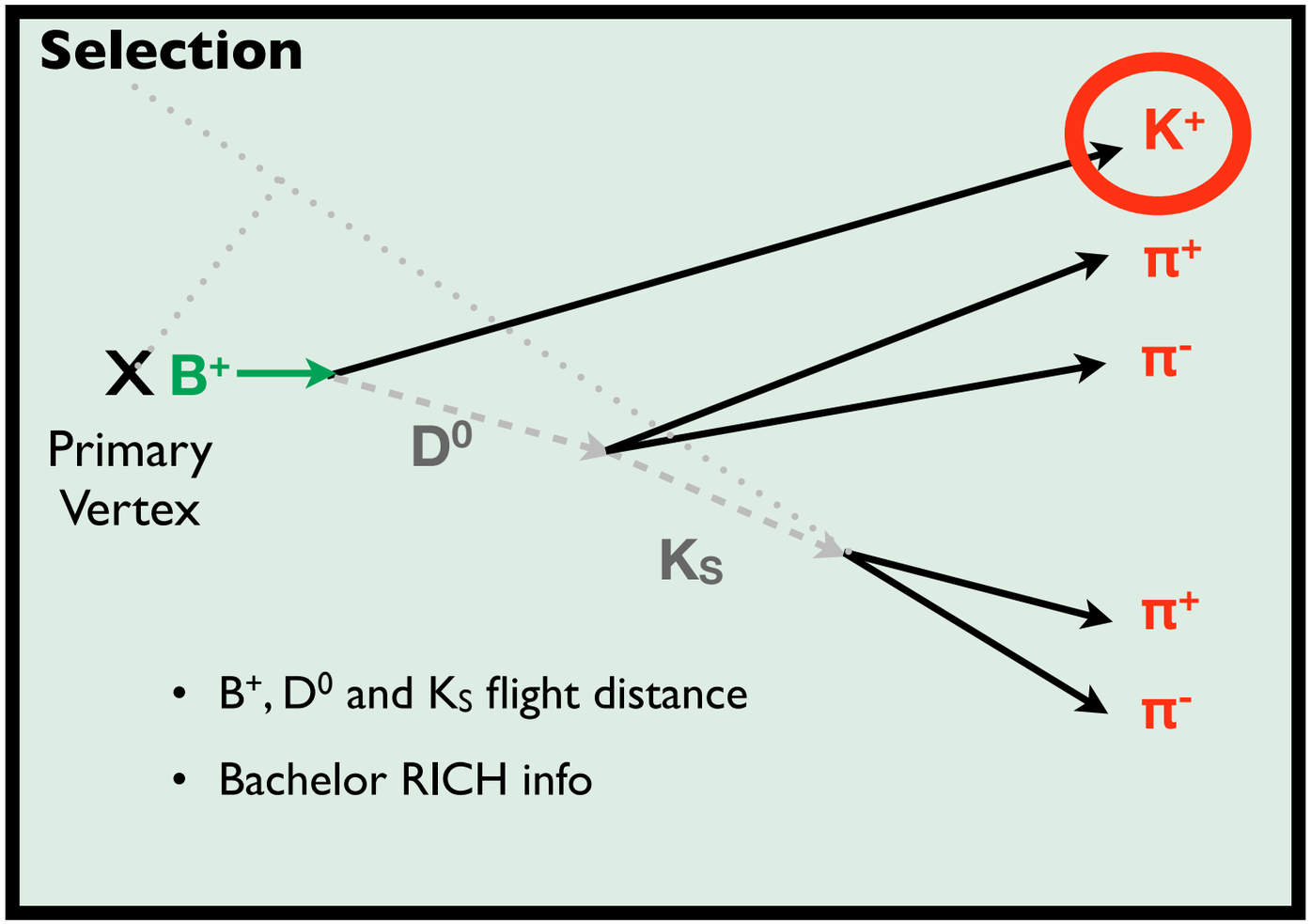

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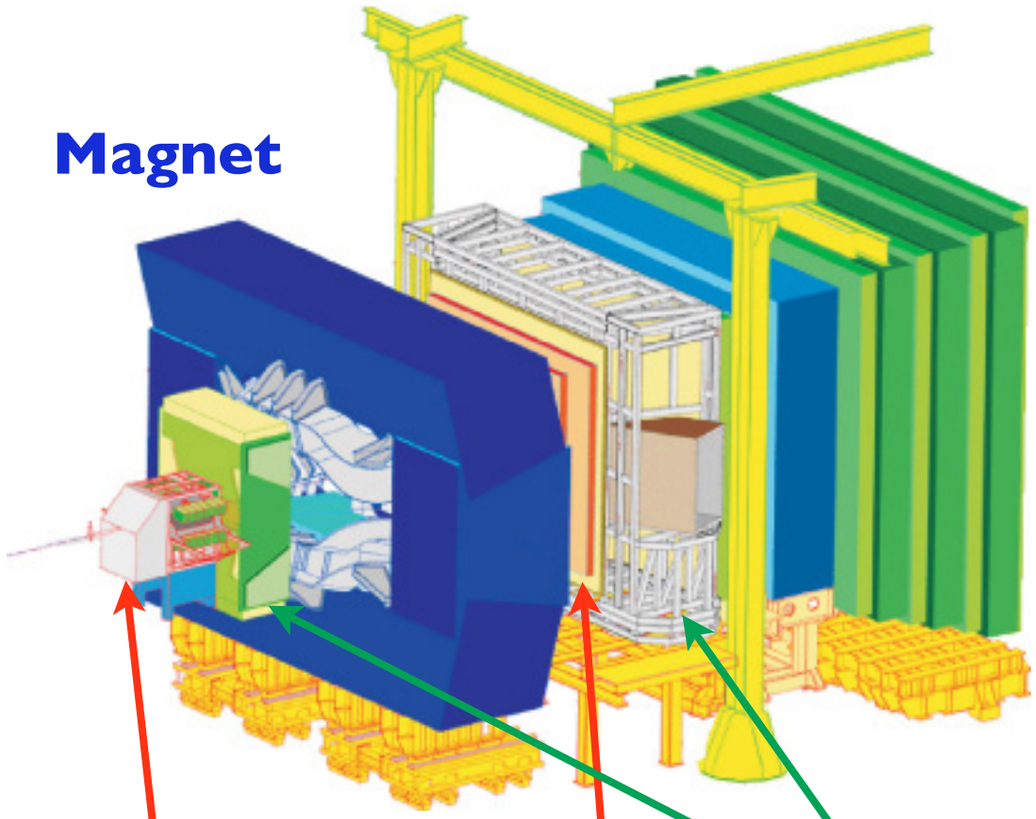

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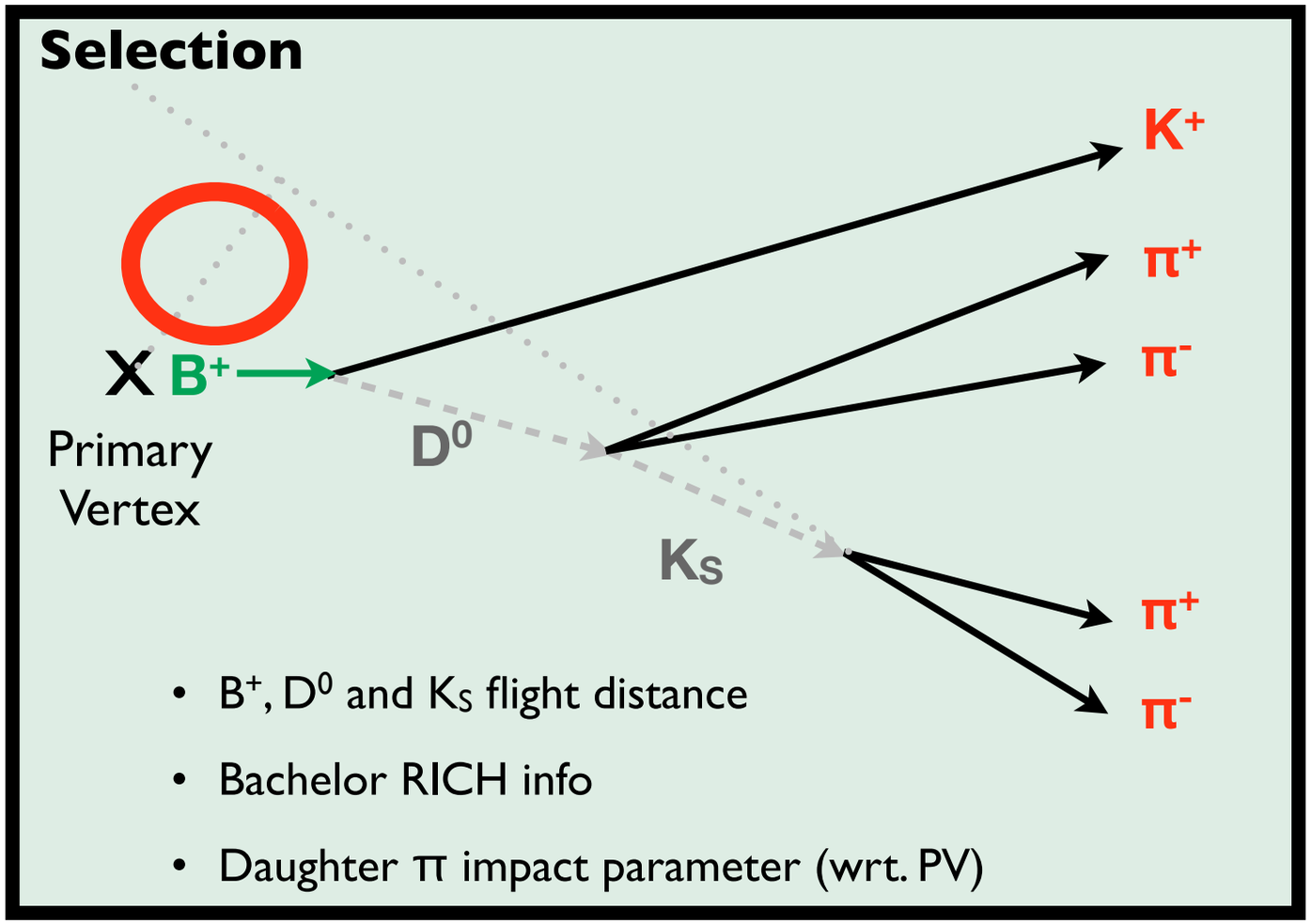
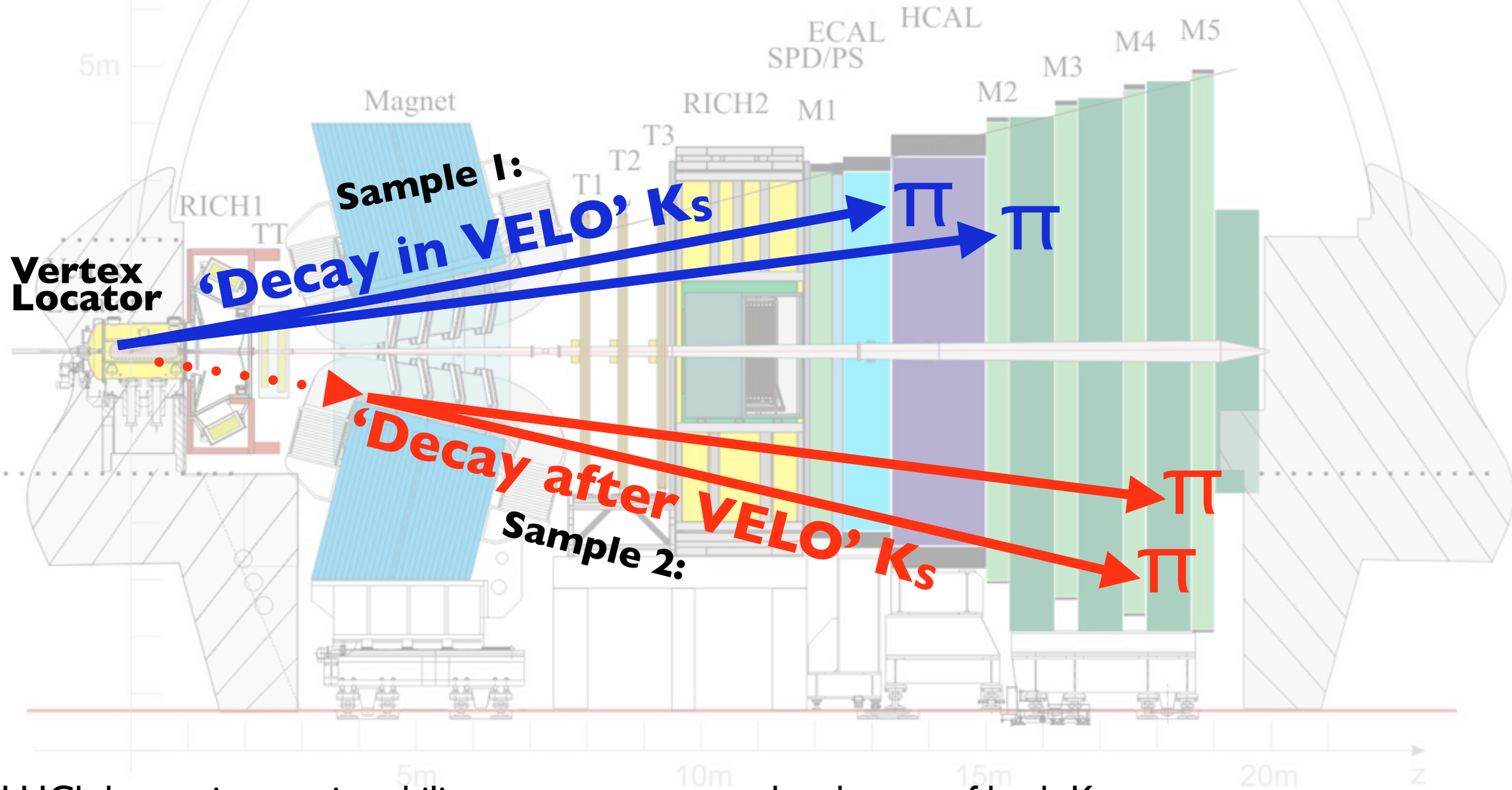


The LHCb experiment 2/2

- Reconstruct separately where K_S decays inside or beyond the precision silicon tracker ('Vertex Locator')



- LHCb has an impressive ability to reconstruct and make use of both K_S types

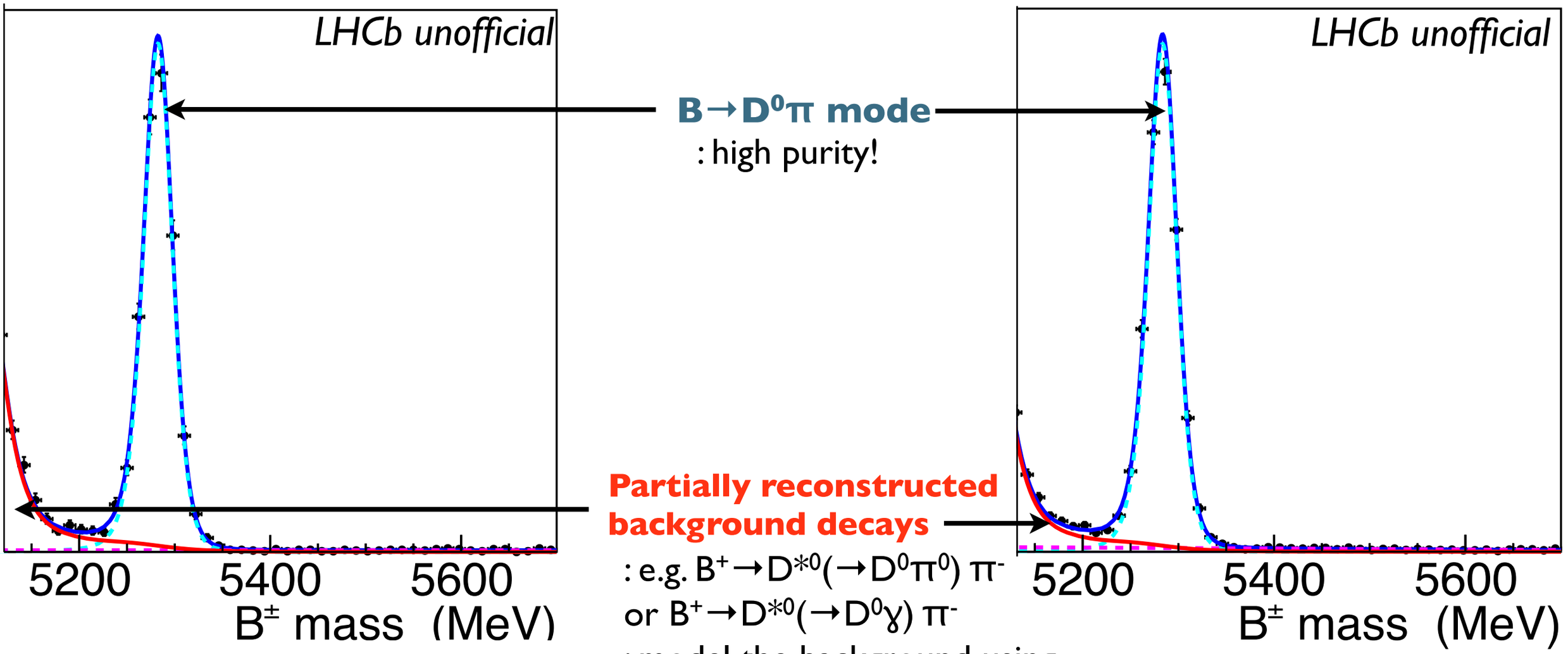
Current status at LHCb

- A sub-sample from 2011 LHCb dataset

K_s decays inside VELO

B → Dπ **Control** mode

K_s decays after VELO



But of course, **we're interested in B→D⁰K**, so make use of LHCb RICH to suppress B→D⁰π and find B→D⁰K…

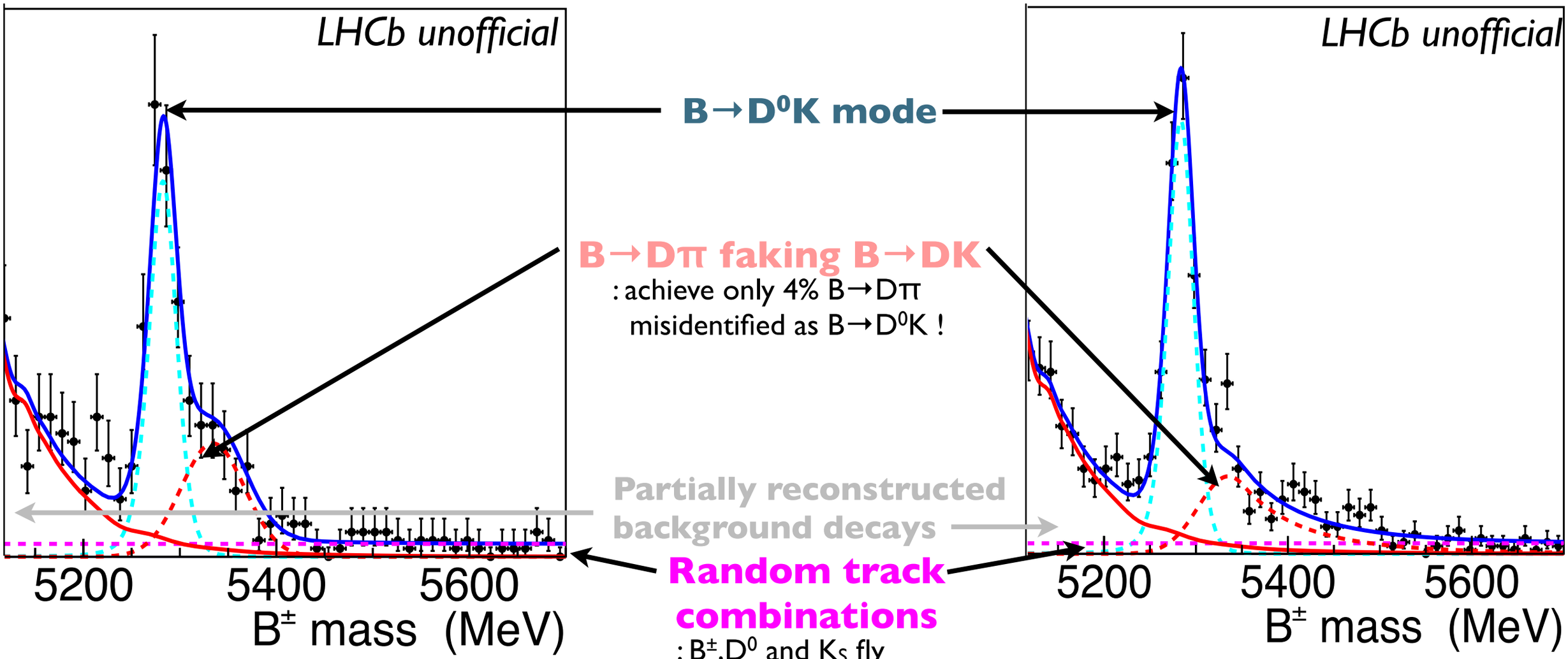
Current status at LHCb

- A sub-sample from 2011 LHCb dataset

K_s decays inside VELO

B →DK **Signal** mode

K_s decays after VELO

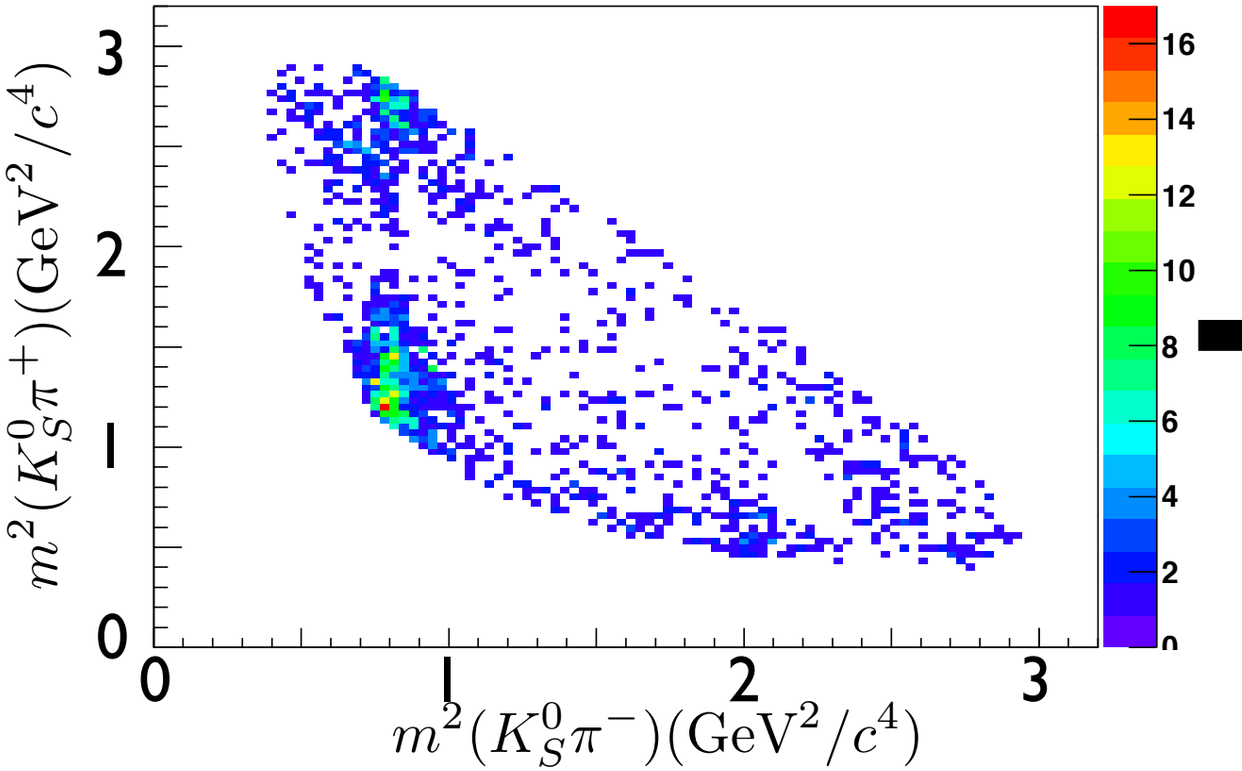


Simultaneous fit for B^+ and B^- ($\rightarrow D^0K$) yields in **all 16** Dalitz bins to find γ. But before that...

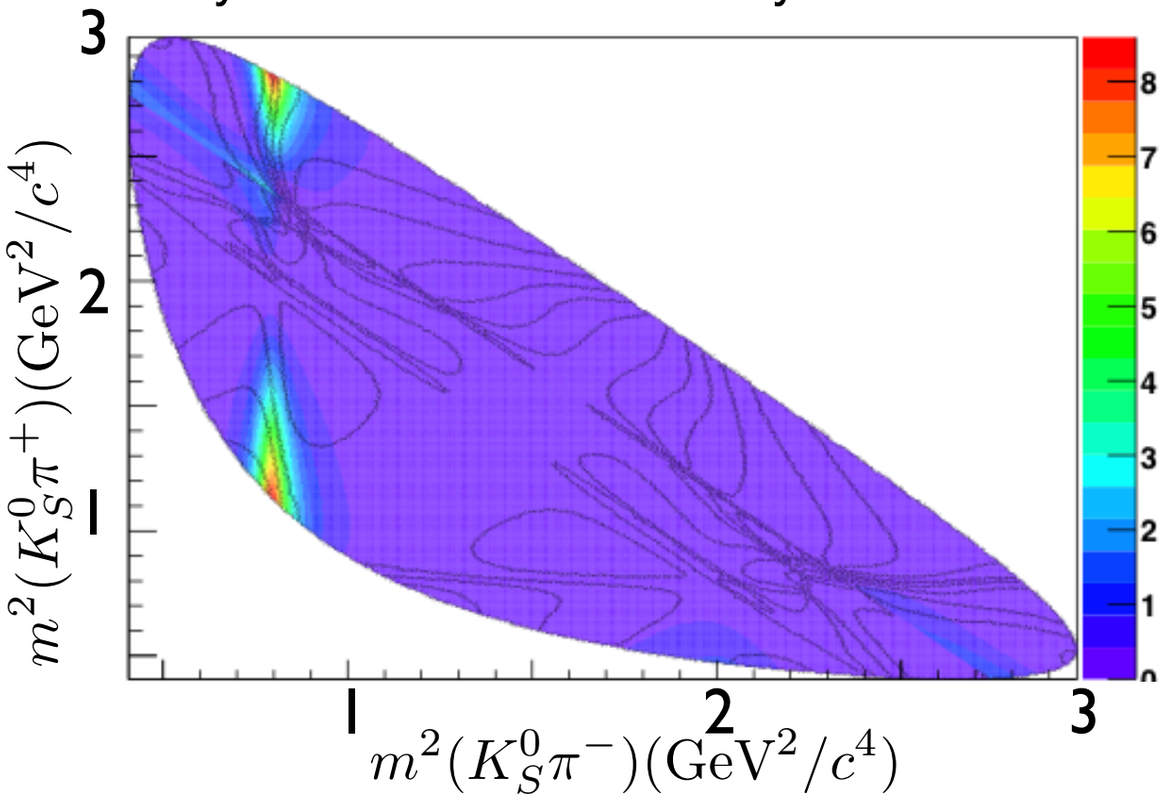
Efficiency across Dalitz plot

- Correct the $B^{\pm} \to D^0 K^{\pm}$ yields in each bin for reconstruction/selection efficiency effects which vary across the Dalitz space

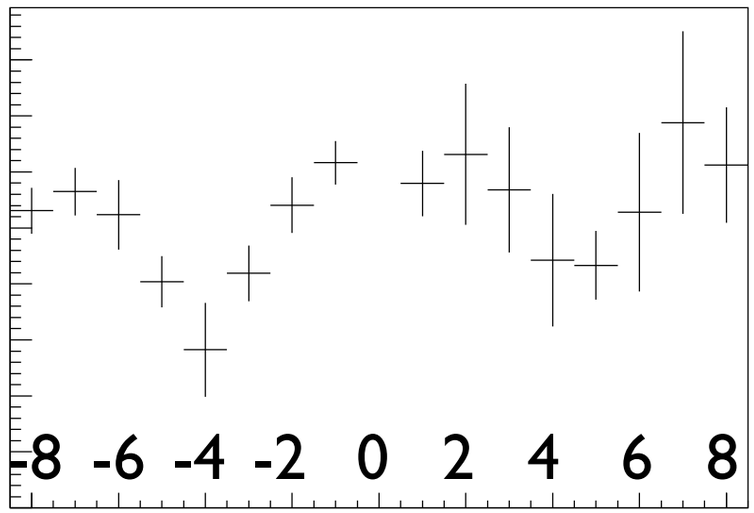
Divide $B^{\pm} \to D^0 \pi^{\pm}$ DATA yields (no CPV)...



...by LARGE SIMULATED yields...



...to find the efficiency in each Dalitz bin



Conclusion

Next steps

- Detailed **background** studies
- **Fitter** to extract γ
- **Systematics** studies
  - e.g. c_i, s_i CLEO uncertainties, PDF shapes used in fit to mass distribution
- Consider simple extension to less abundant $B^{\pm} \to D^0(\to \mathbf{K_S KK})K^{\pm}$ mode
- 2012: increased integrated luminosity and superior trigger ⟹ higher statistics

Conclusion

- CKM phase **γ poorly known**
- Can access γ with very small theoretical uncertainty in **$B^{\pm} \to D^0(\to K_S\pi\pi)\, K^{\pm}$** decays at LHCb
- Take information about the D^0 decay from the **CLEO experiment**
- Preparation underway for **measurement of γ** in this mode using LHCb data