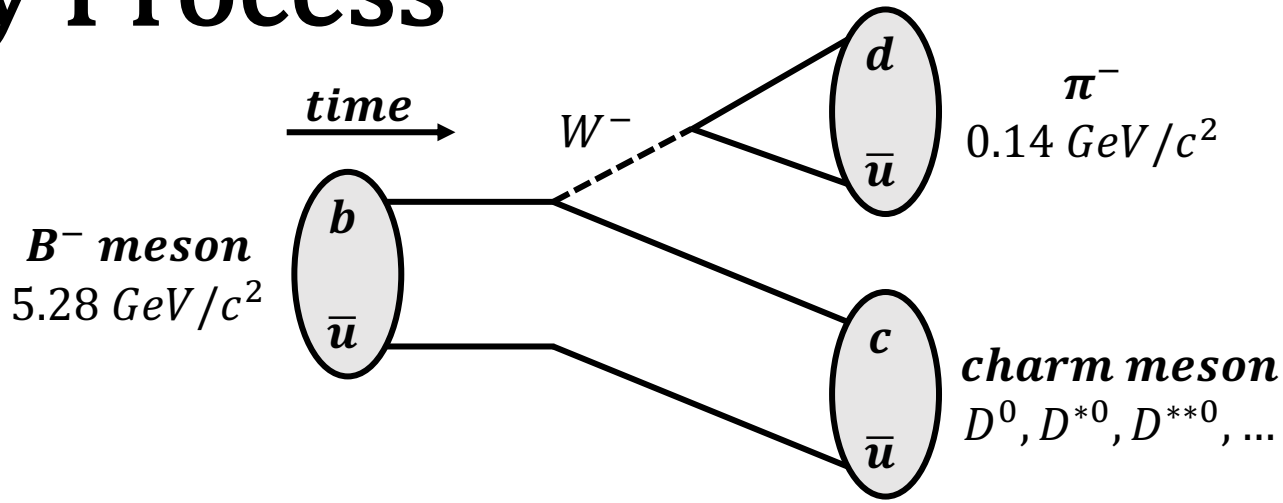
Measuring $B(B^- \to D^{**0}\pi^-)$ using the Missing Mass Method

Alex Gale

University of Cincinnati

Decay Process

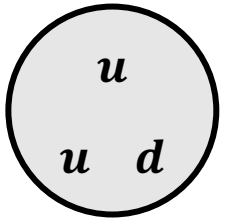


$\boldsymbol{B^-}$ **meson**
$5.28\ GeV/c^2$

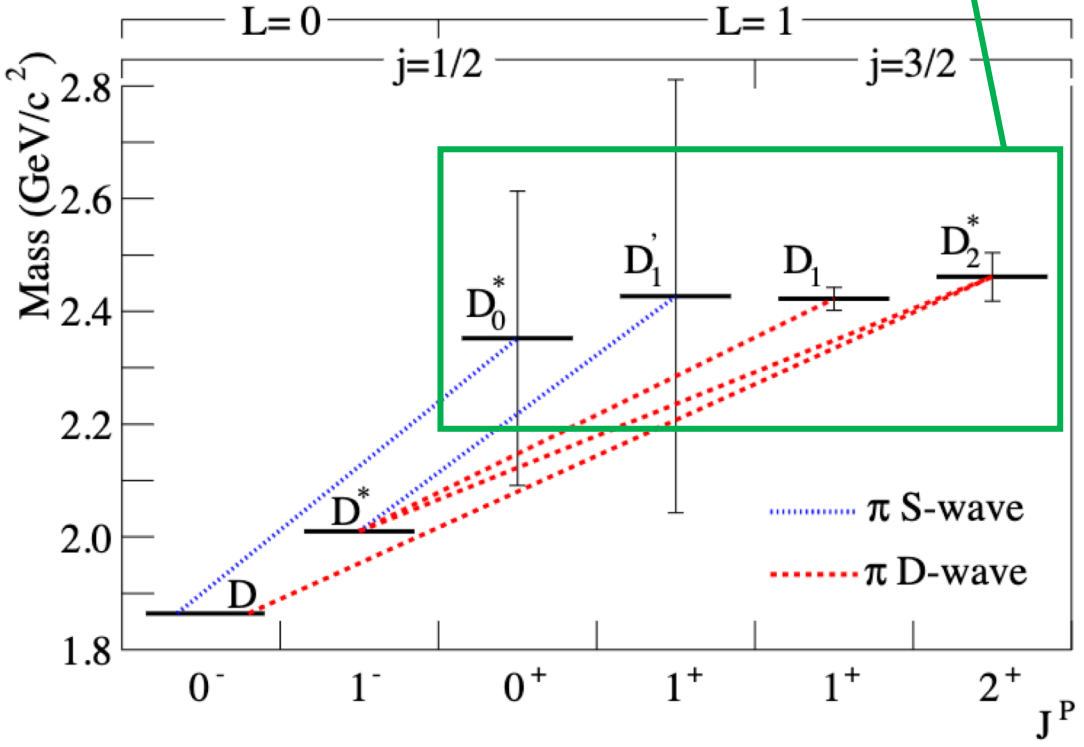
$\boldsymbol{\pi^-}$
$0.14\ GeV/c^2$

charm meson
$D^0, D^{*0}, D^{**0}, \ldots$

For reference:
Proton mass $\approx 0.94\ GeV/c^2$



4 different D^{**0} mesons



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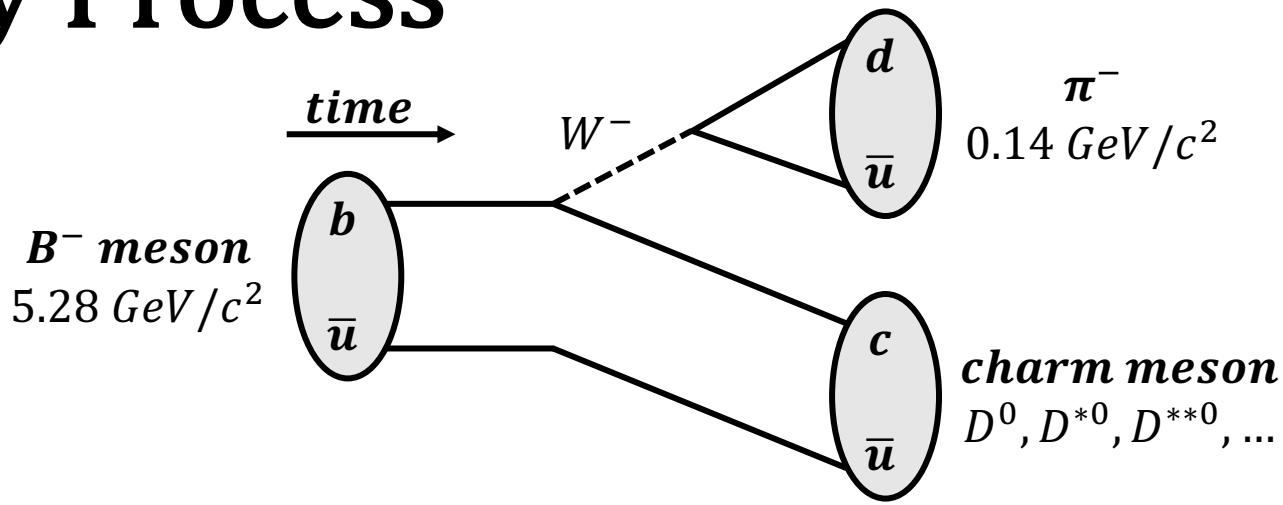

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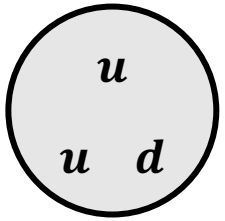
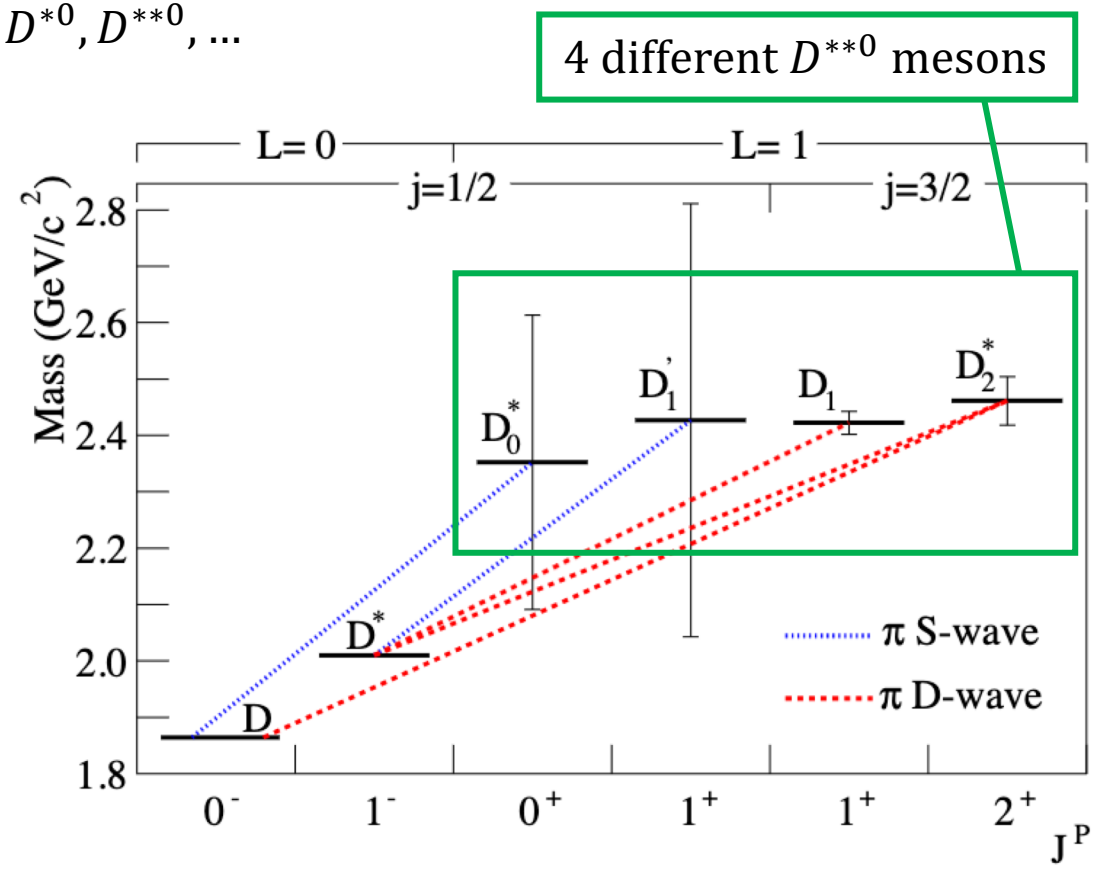


Decay Mode		Branching Fraction
Γ_{54}	$D^0\pi^-$	$(4.61 \pm 0.10)\times10^{-3}$
Γ_{131}	$D^{*0}\pi^-$	$(5.17 \pm 0.15)\times10^{-3}$
Γ_{151}	Combined $D^{**0}\pi^-$	$(5.6 \pm 1.2)\times10^{-3}$
From the Particle Data Group		



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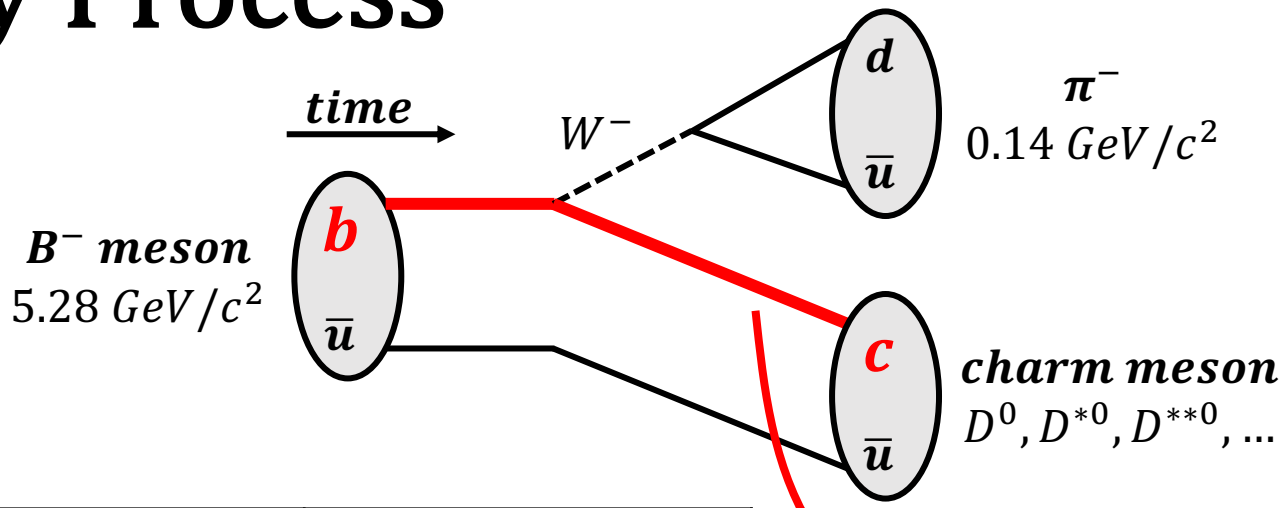

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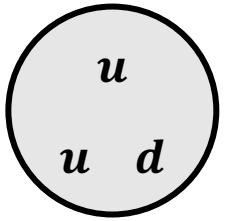

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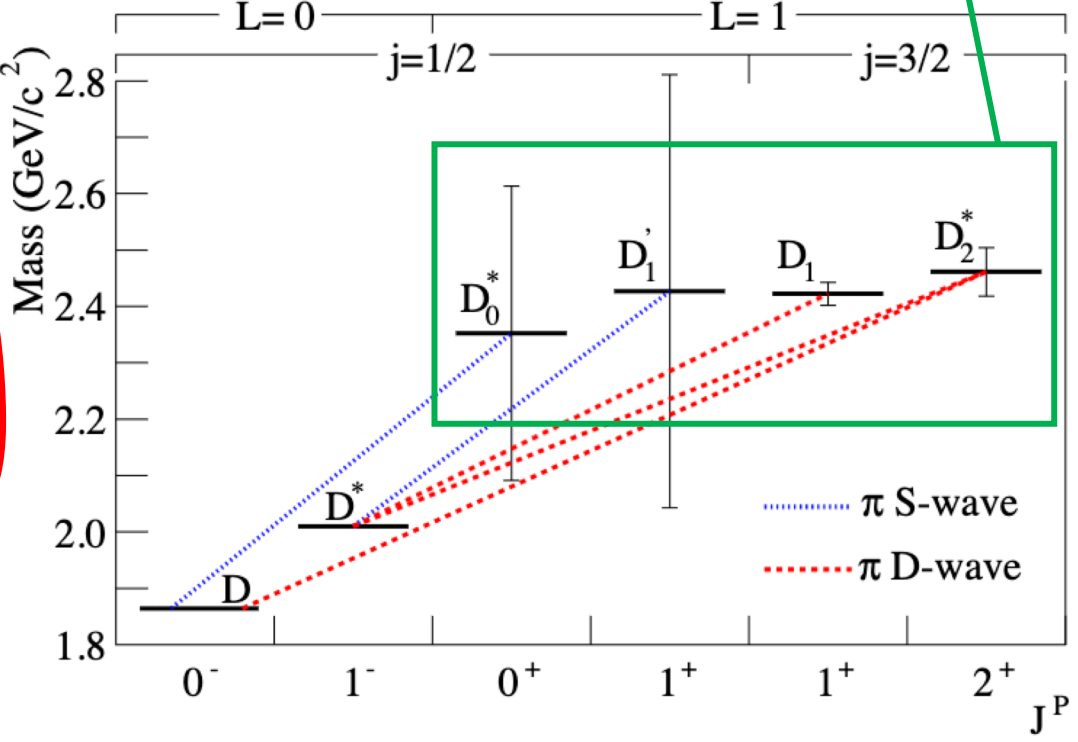
From the Particle Data Group		

- All rates above related to $|V_{cb}|$
- Relative rates related D^0, D^{*0}, D^{**0} wavefunctions

CKM Matrix

$$\begin{bmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{bmatrix}$$

4 different D^{**0} mesons



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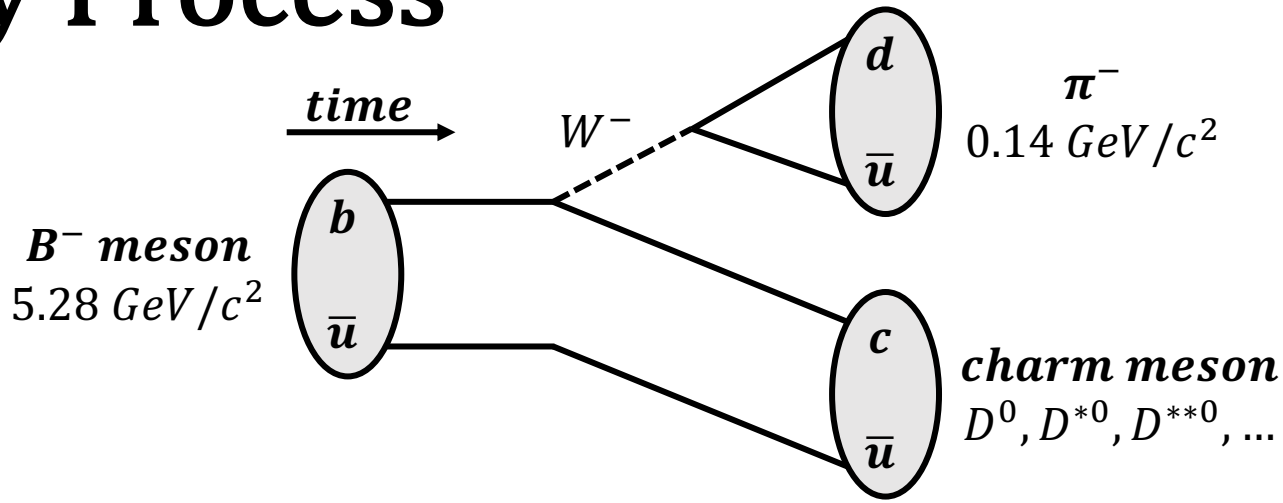

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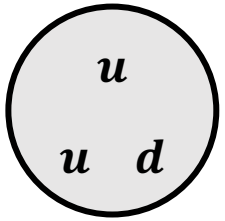

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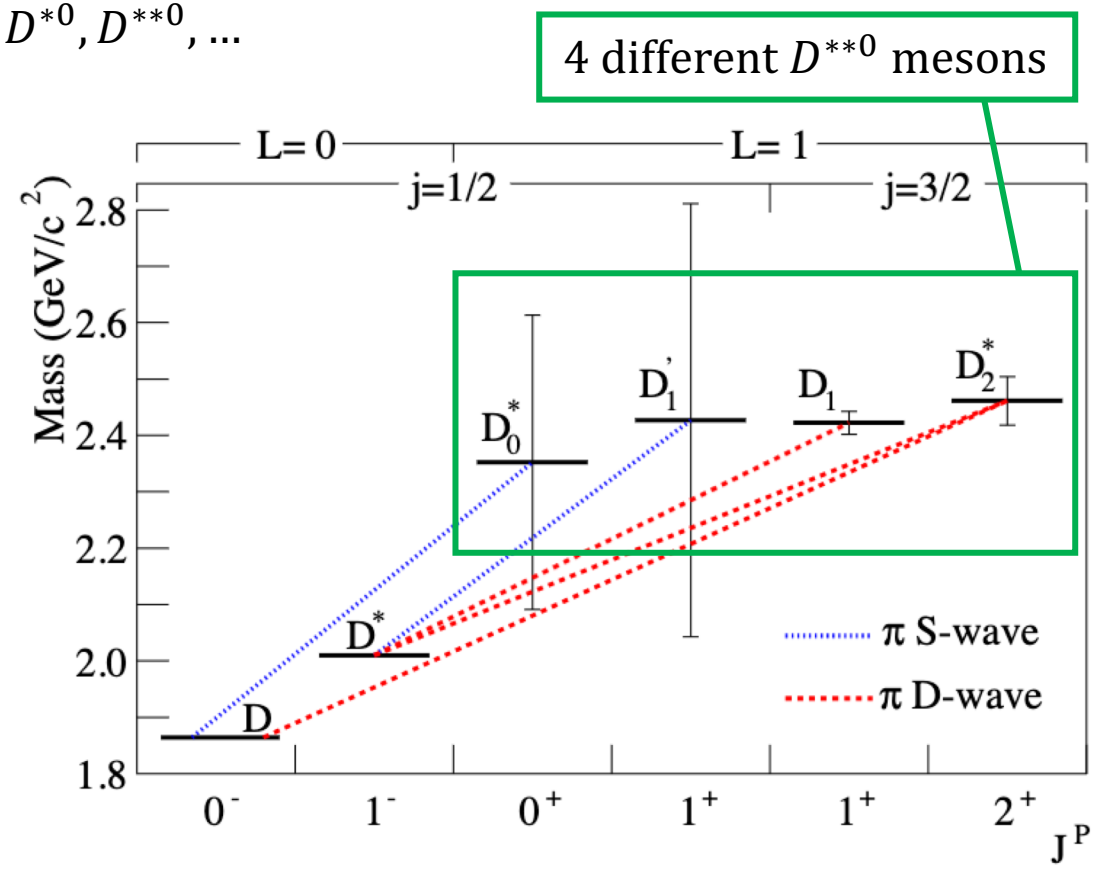
- BABAR measured combined $D^{**0}\pi^-$ branching fractions
- We want to measure each individually



Collisions and B Mesons

- Collide e^+e^- $\rightarrow$ produce $B\overline{B}$ meson pair
  - Each collision is an event!

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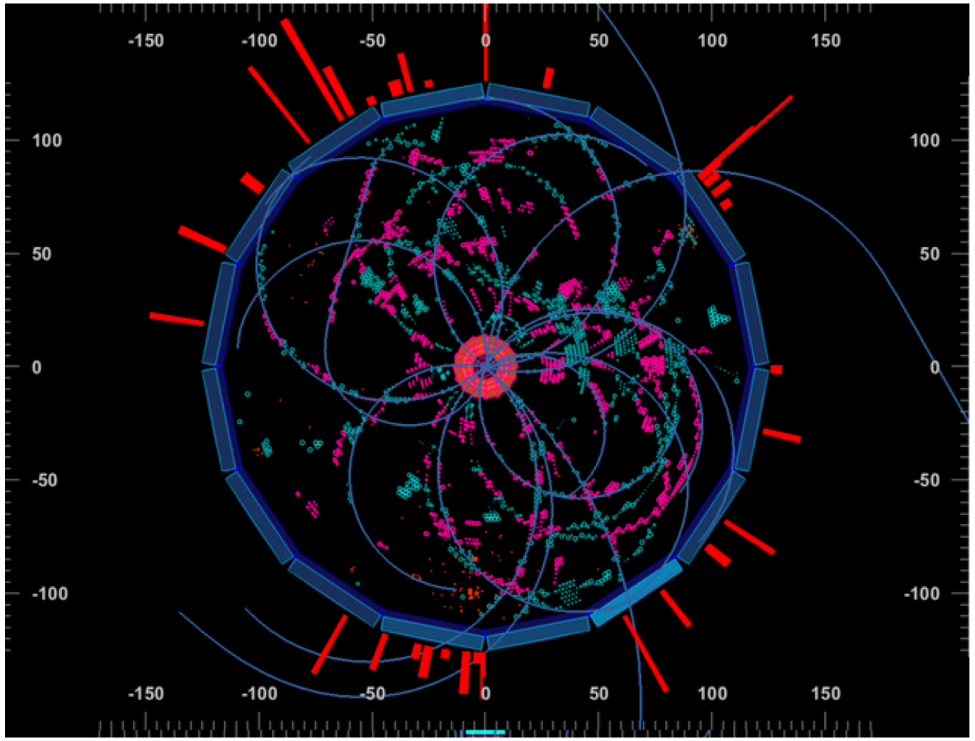

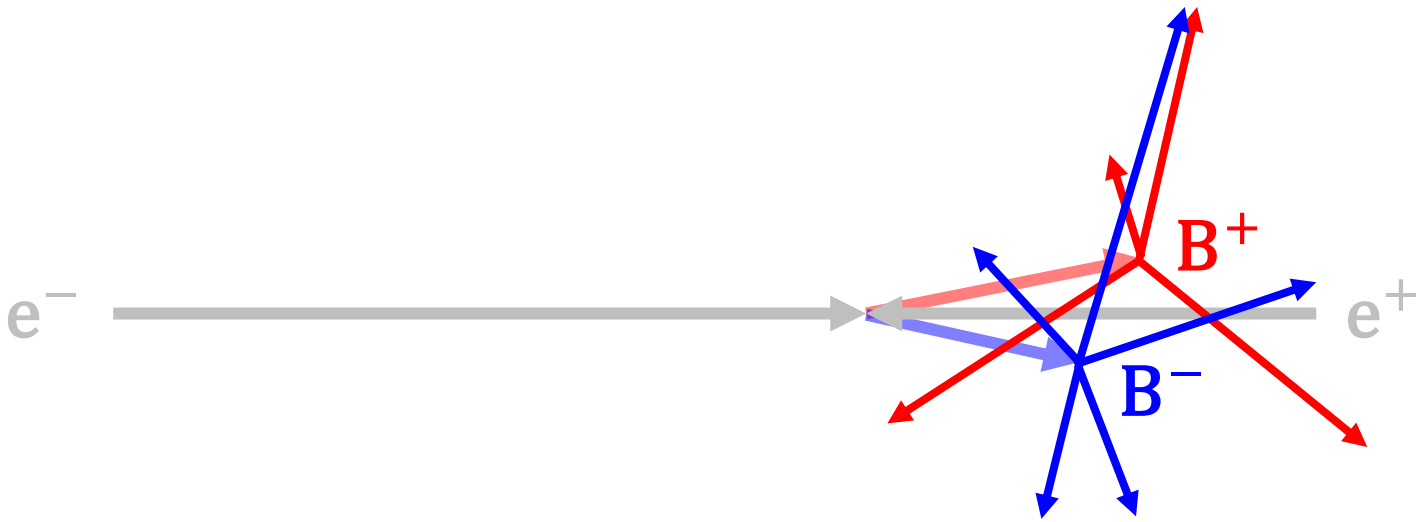

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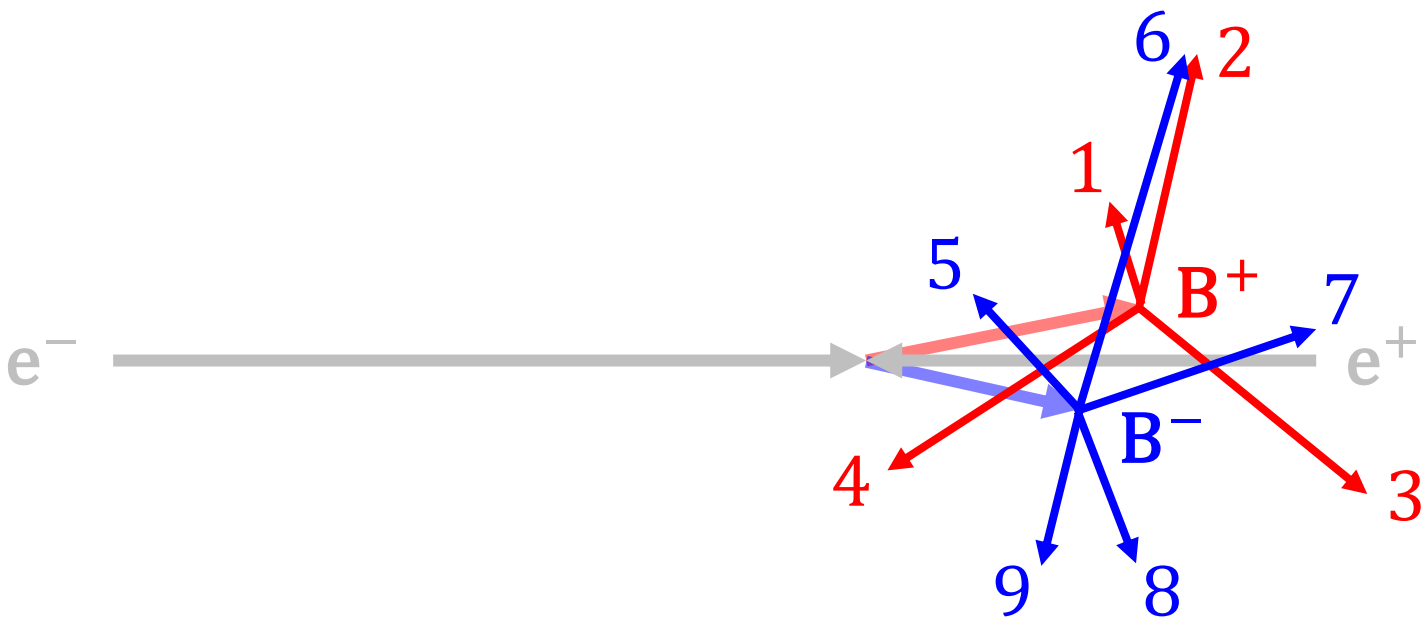

Each is a B candidate

5 1 6	
2 4 6 7	
2 7 3 5	
3 6 1 8 9	
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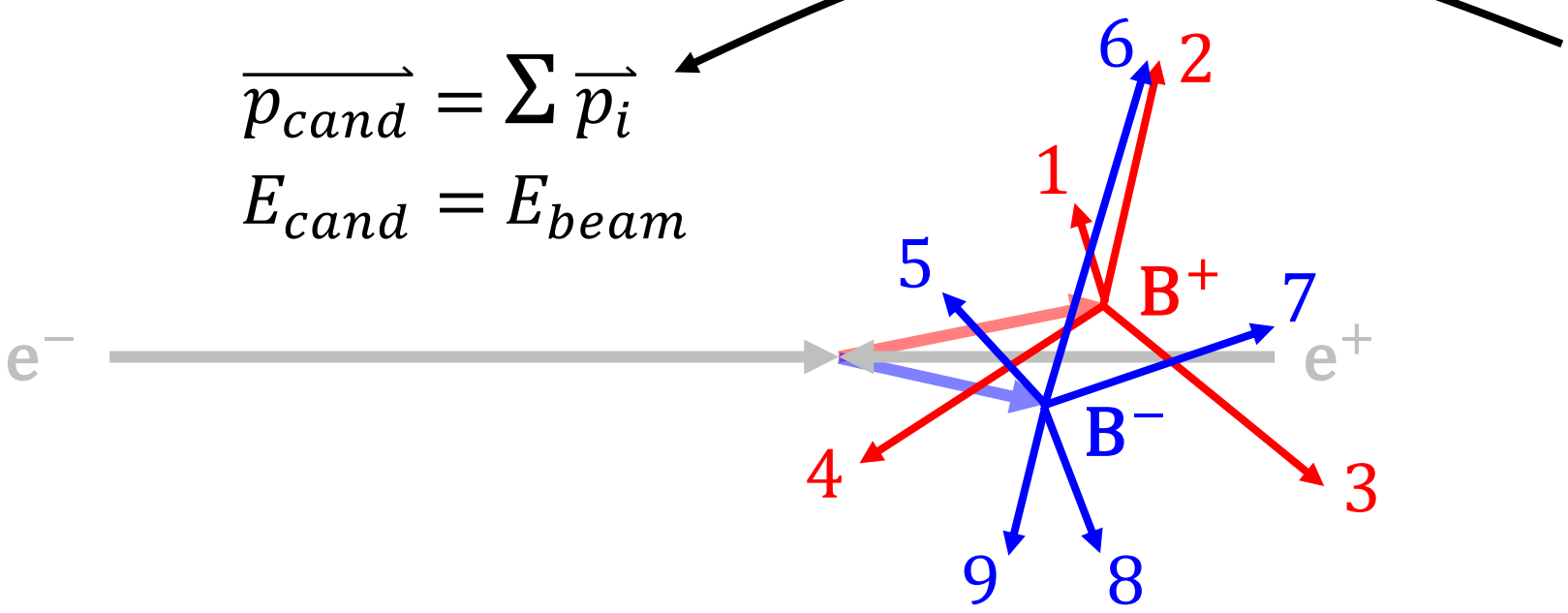
$$\overrightarrow{p_{cand}} = \sum \overrightarrow{p_i}$$

$$E_{cand} = E_{beam}$$



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2	4	6	7						
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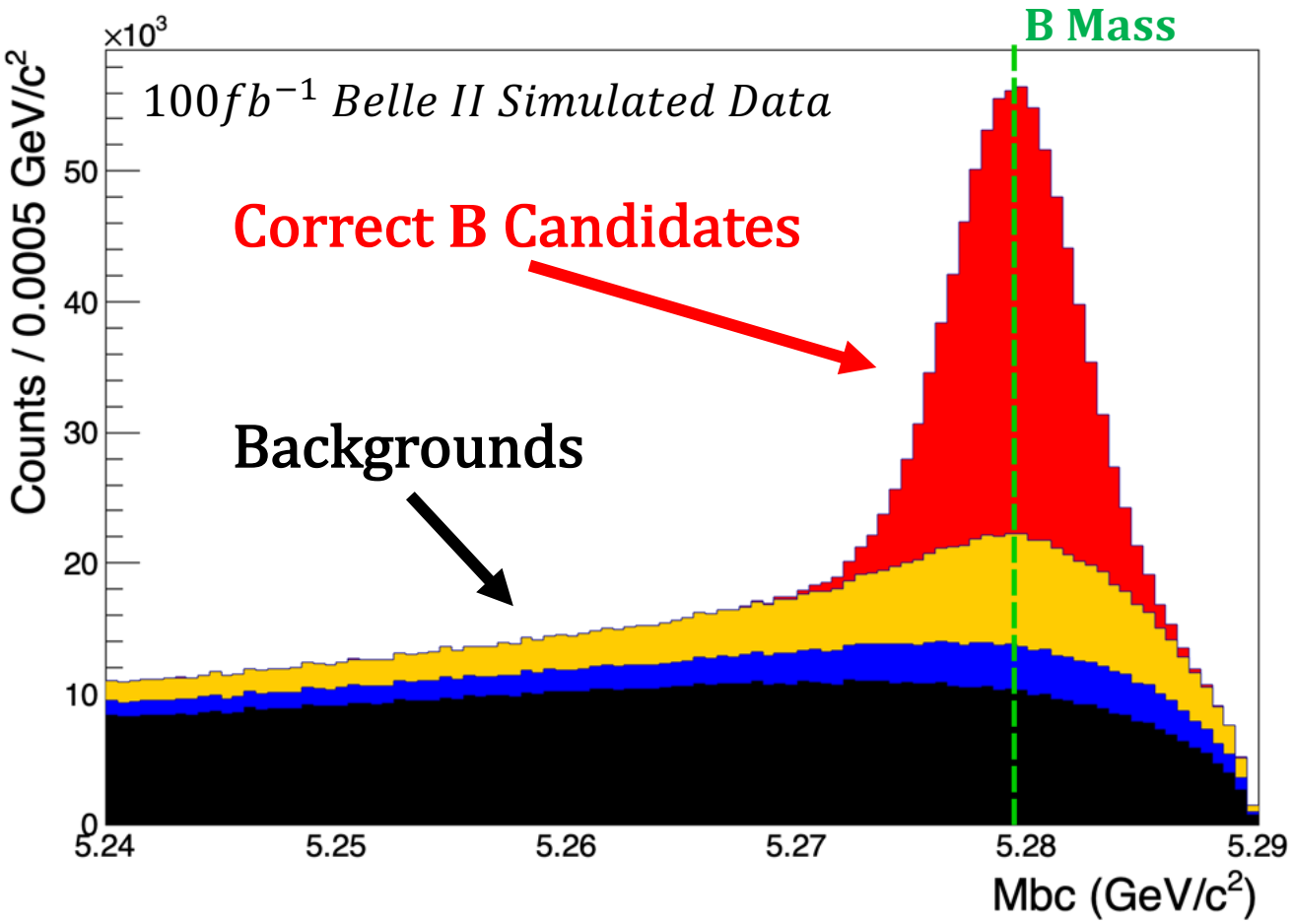
Beam Constrained Mass

- Use simulated data
  - Generated to look like real Belle II data
  - ≈ 100 million $B\overline{B}$ events
- Calculate beam constrained mass for each B candidate:

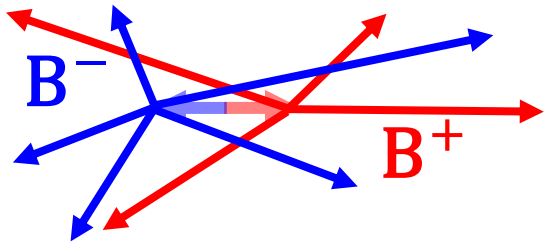
$$E_{cand} = E_{beam} \quad \overrightarrow{p_{cand}} = \sum \overrightarrow{p_i}$$

$$M^2c^4 = E^2 - |\vec{p}|^2c^2$$

$$M_{bc} = \frac{\sqrt{{E_{beam}}^2 - |\overrightarrow{p_{cand}}|^2c^2}}{c^2}$$



Missing Mass



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  - Look for $D^{**0}\pi^-$ in B^- decay

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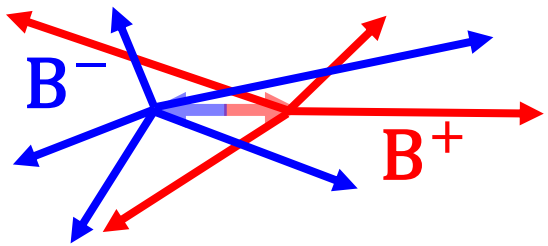

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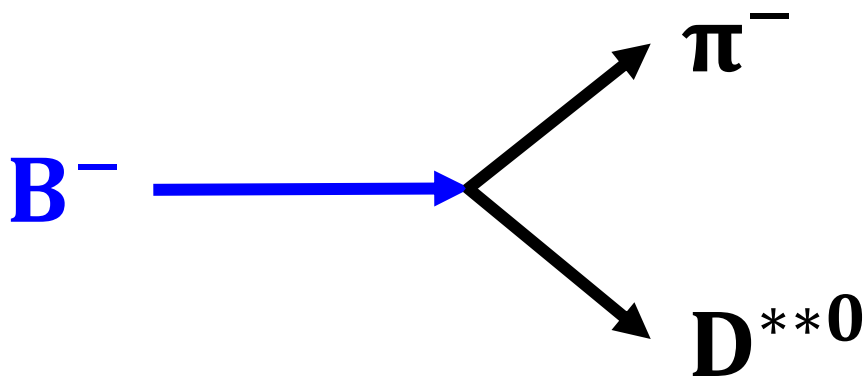
In center of mass frame:

$$\overrightarrow{p_{B^-}} = -\overrightarrow{p_{cand}}$$

$$E_{B^-} = E_{beam}$$



measure E_{π^-} and $\overrightarrow{p_{\pi^-}}$

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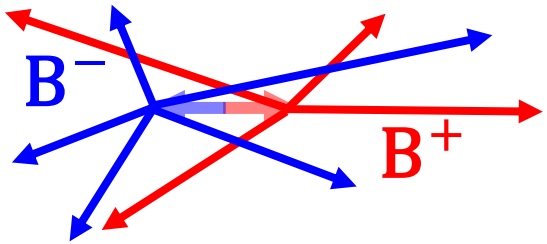

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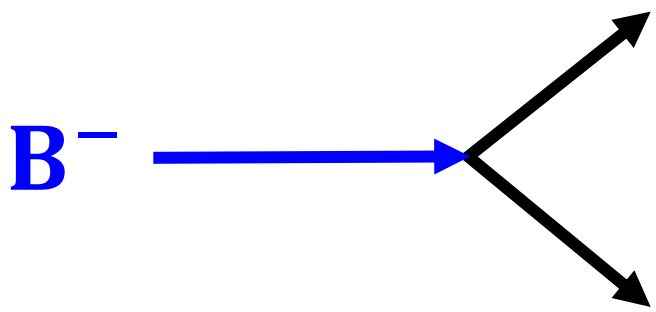

π^- measure E_{π^-} and $\overrightarrow{p_{\pi^-}}$

$$\overrightarrow{p_{D^{**0}}} = \overrightarrow{p_{B^-}} - \overrightarrow{p_{\pi^-}}$$

$$E_{D^{**0}} = E_{B^-} - E_{\pi^-}$$

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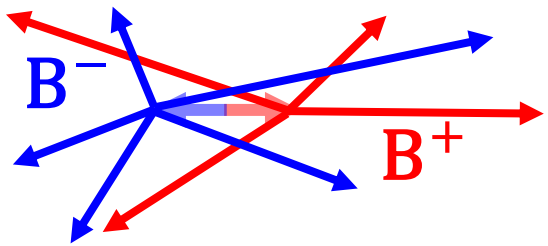

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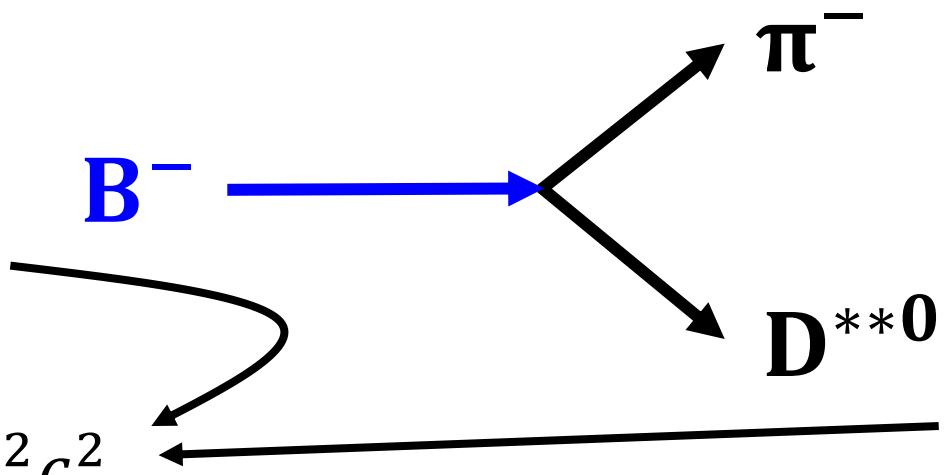

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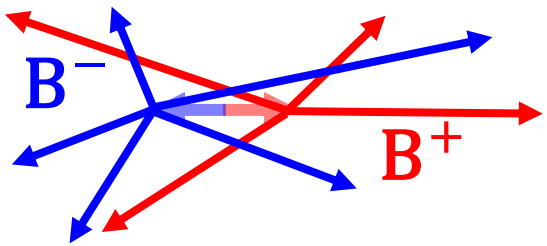

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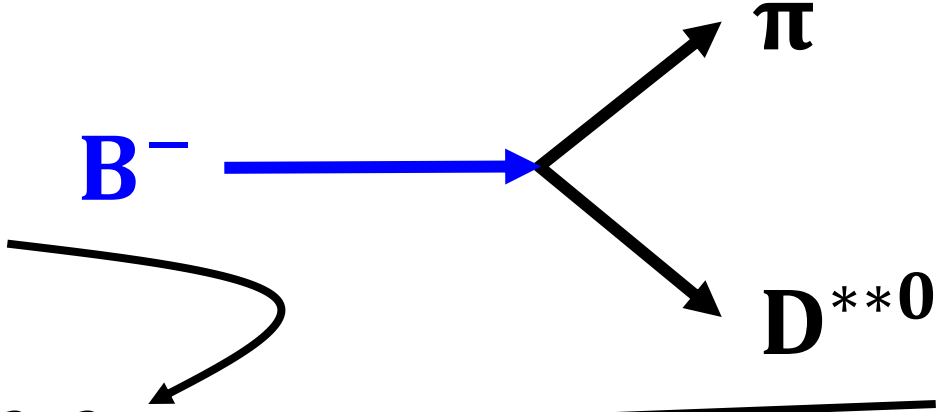

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$$M_{missing} = \frac{\sqrt{(E_{beam} - E_{\pi^-})^2 - |-\overrightarrow{p_{cand}} - \overrightarrow{p_{\pi^-}}|^2 c^2}}{c^2}$$

Missing Mass and Branching Fractions

$$M_{missing} = \frac{\sqrt{(E_{beam} - E_{\pi^-})^2 - |-\overrightarrow{p_{cand}} - \overrightarrow{p_{\pi^-}}|^2 c^2}}{c^2}$$

Calculate branching fraction:

$$\boldsymbol{B}(B^- \to D^0\pi^-) = \frac{N_D}{N_{tags} * \varepsilon_D}$$

$$= \frac{1495}{462973 * 0.730}$$

$$= (4.42 \pm 0.10)\times 10^{-3}$$

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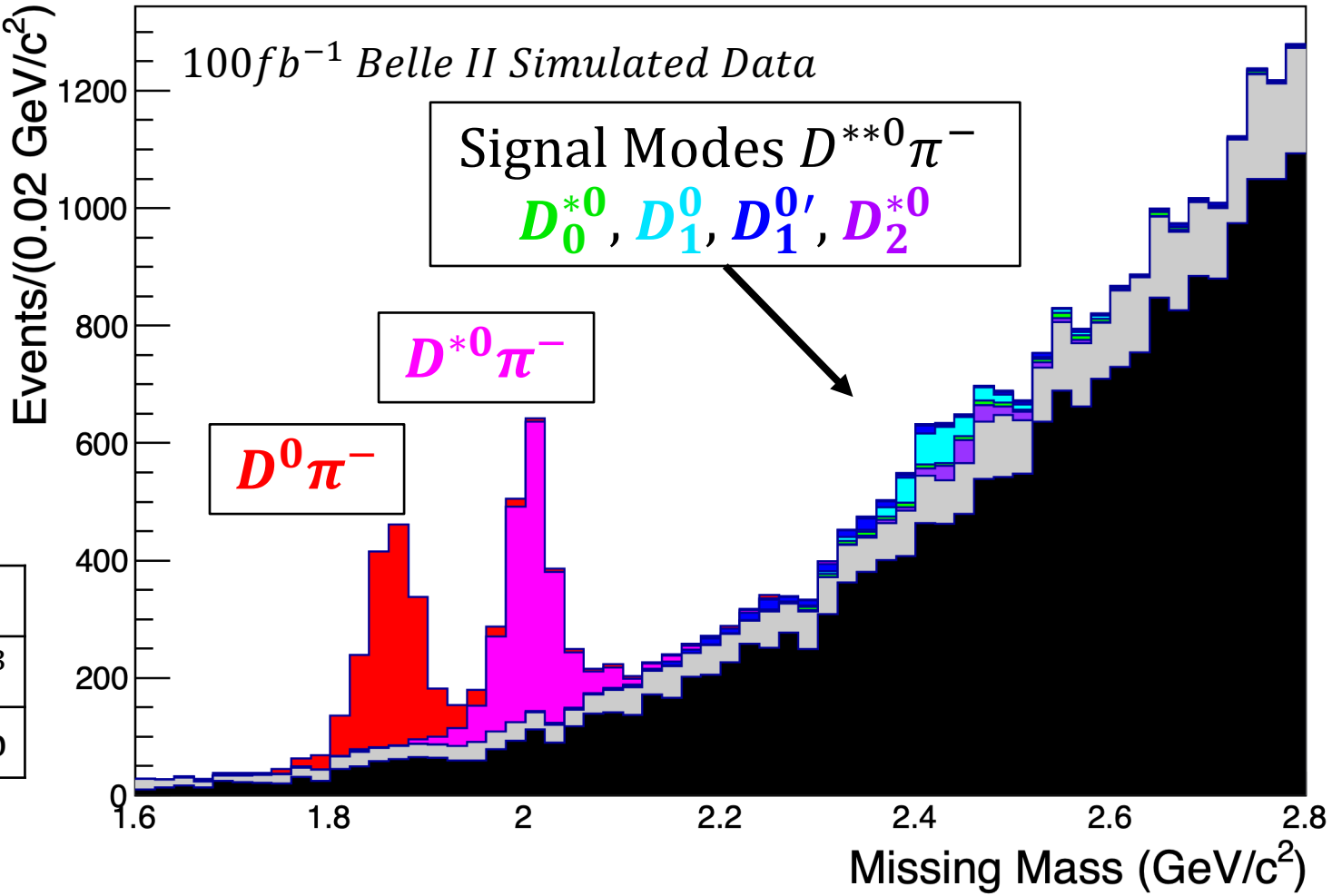
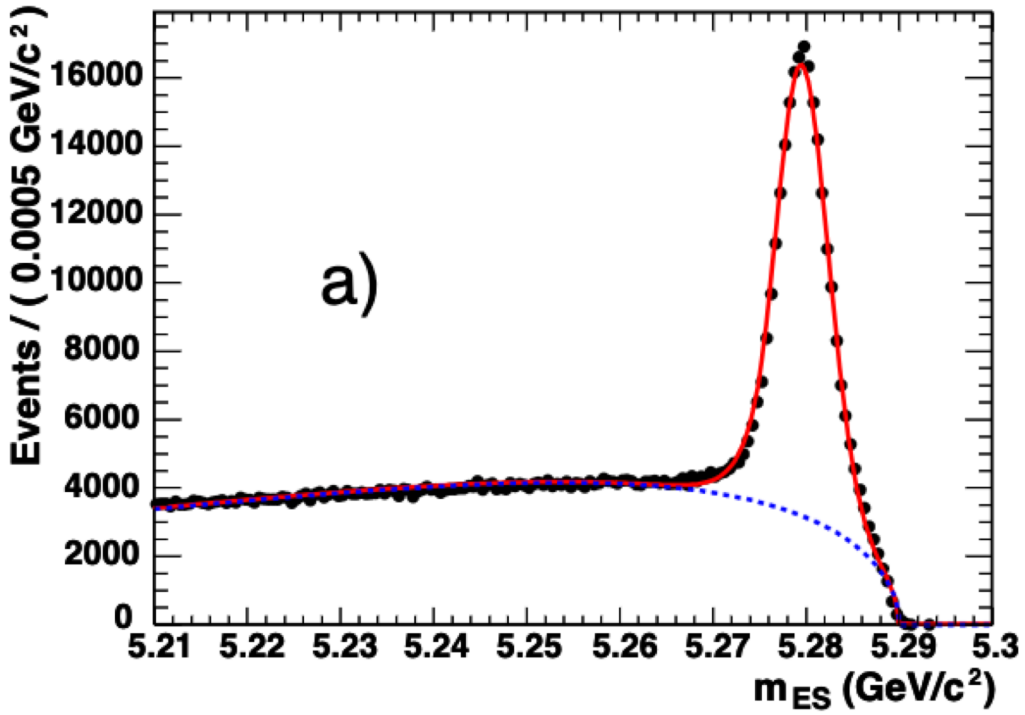


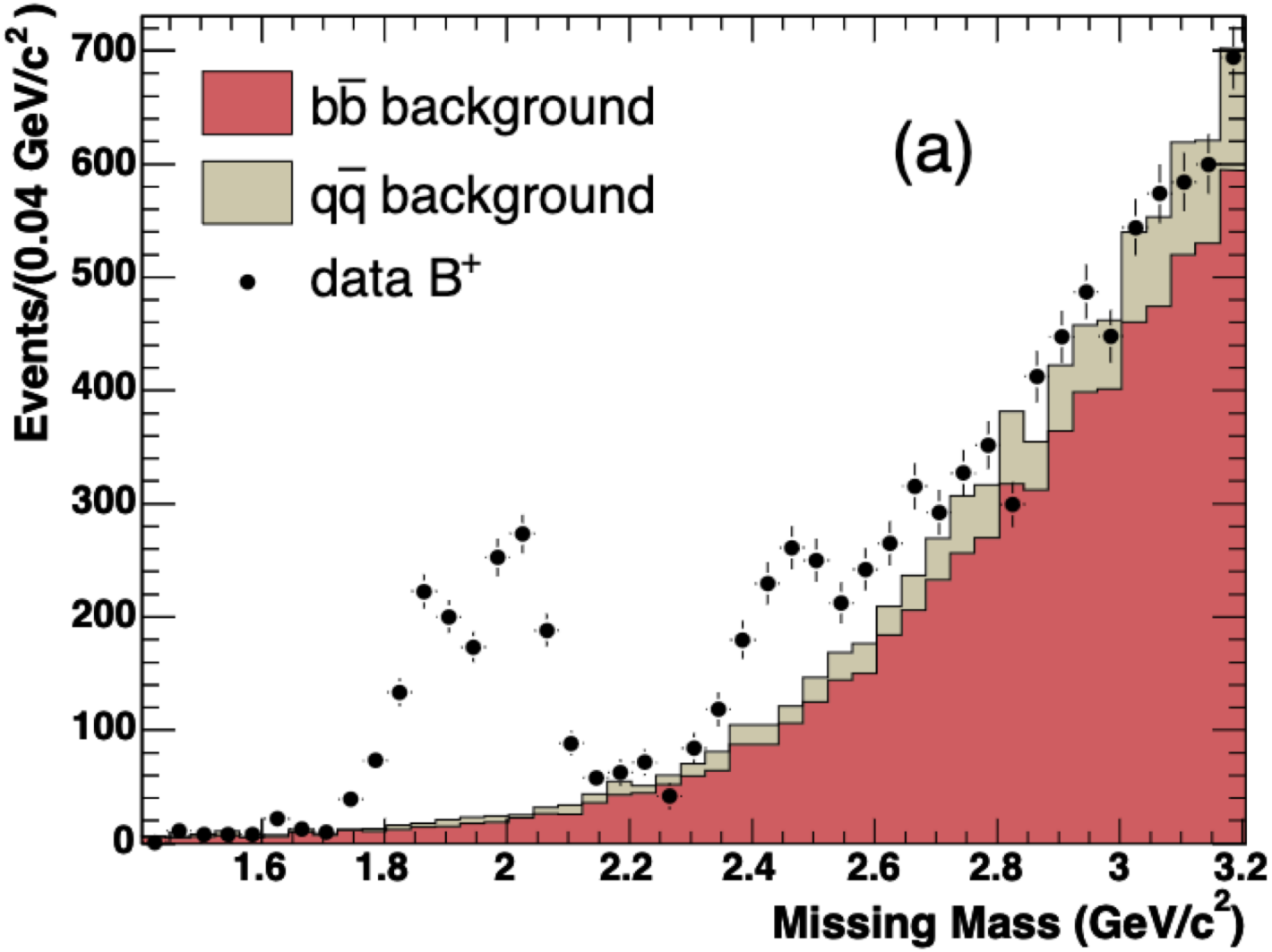
Questions?

BABAR Measurement

- 210fb^{-1} BABAR Data
  ≈ 210 million B$\overline{\text{B}}$ events

Decay mode	Yield	Efficiency	$\mathcal{B}(10^{-3})$
$B^- \to D^0\pi^-$	677 ± 32		4.49±0.21±0.23
$B^- \to D^{*0}\pi^-$	774 ± 33	0.796±0.007	5.13±0.22±0.28
$B^- \to D^{**0}\pi^-$	829 ± 78		5.50±0.52±1.04





BABAR Paper: https://arxiv.org/pdf/hep-ex/0609033