Angular analysis of the decay $\Lambda_b^0 \to \Lambda \ell^+ \ell^-$ at high q^2

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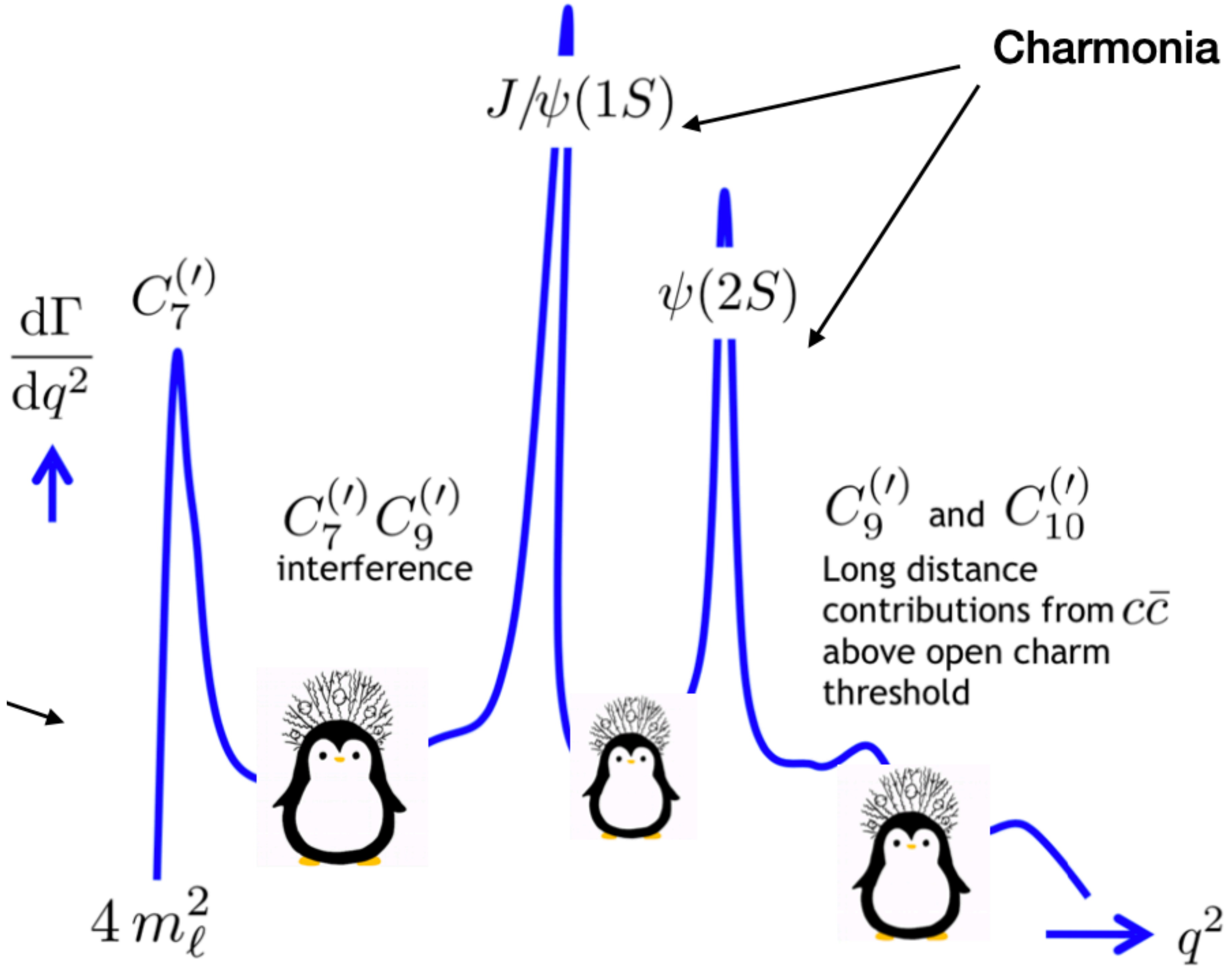
MOITIVATION

- FCNC sensitive to new physics → $\mathscr{B}(b \to s\ell^+\ell^-) \propto 10^{-6}$
- For $\mathscr{B}$ extremely difficult to disentangle Wilson coefficients C_j



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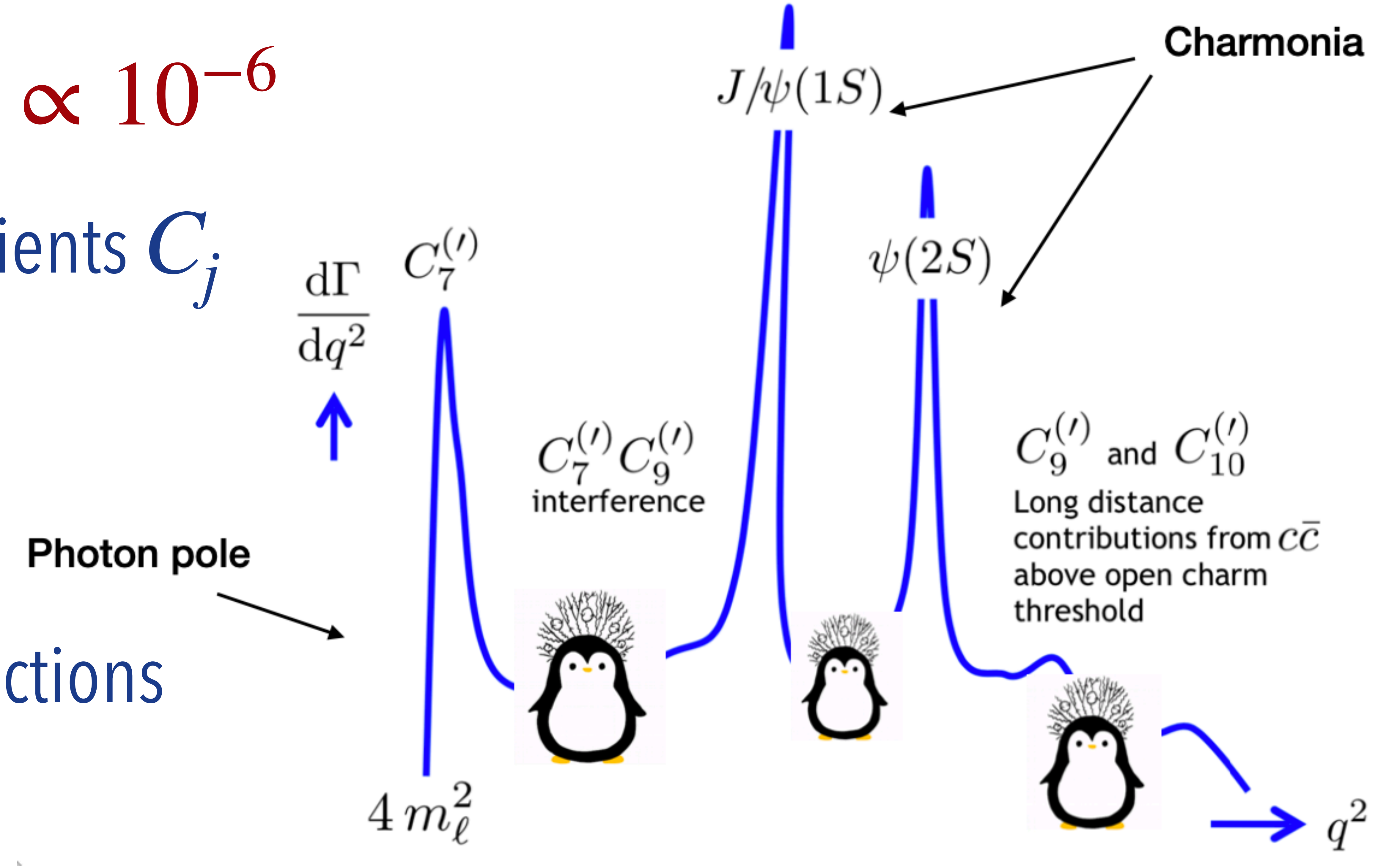
- Angular analyses are interesting since:
    1. they allow us to test form factor (FF) predictions
    2. extract limits on Wilson coefficients C_j



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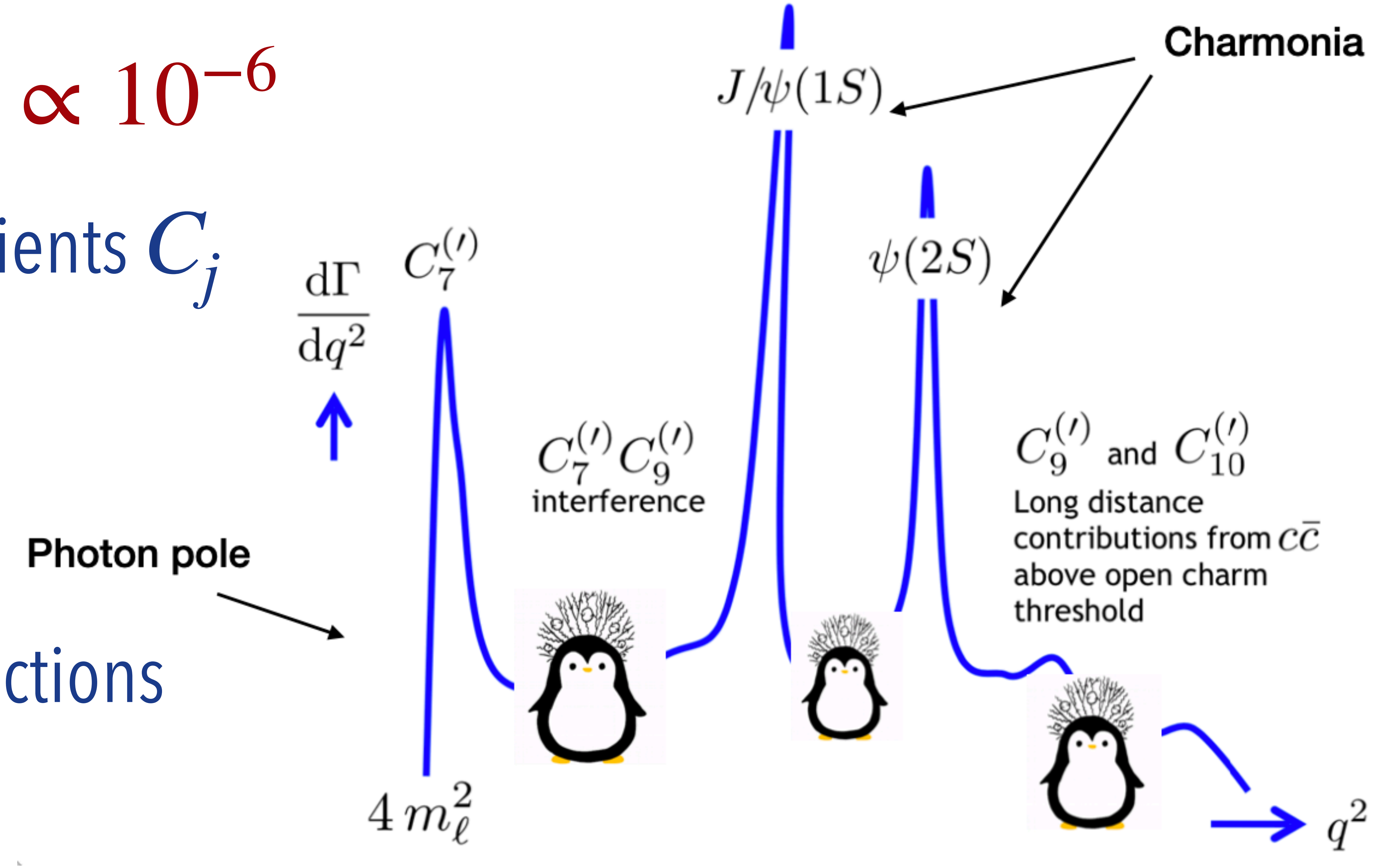


- $\frac{d\Gamma}{dq^2} = \sum_\lambda |A_\lambda|^2$ with A_λ being transversity amplitudes
- $A_\lambda(H_i(FF), C_j)$ depend on Wilson coefficients and helicity amplitudes H_i

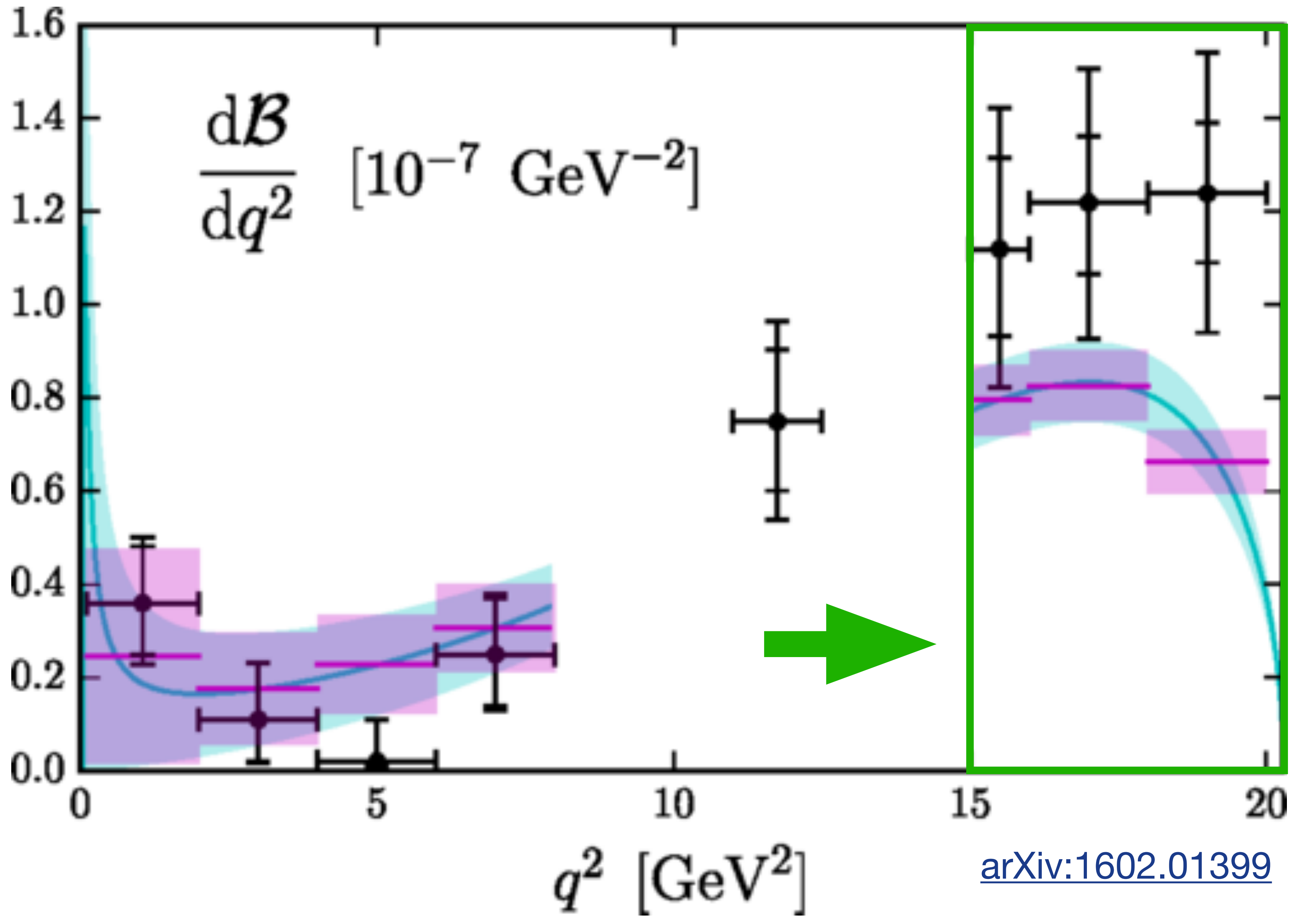
  $\rightarrow$ non-local FF contributions introduce q^2 dependence

Λ_b^0 ANGULAR ANALYSIS

- Most signal at high $q^2 \rightarrow$ focus of analysis
- Analysis with electron and muon mode
- Only muon mode observed

$\rightarrow$ factor ~4 smaller yield for electron

Differential branching fraction $\Lambda_b^0 \rightarrow \Lambda\mu^+\mu^-$



arXiv:1602.01399

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- Analysis with electron and muon mode
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  $\rightarrow$ factor ~4 smaller yield for electron
- Rich angular structure due to subleading weak decay

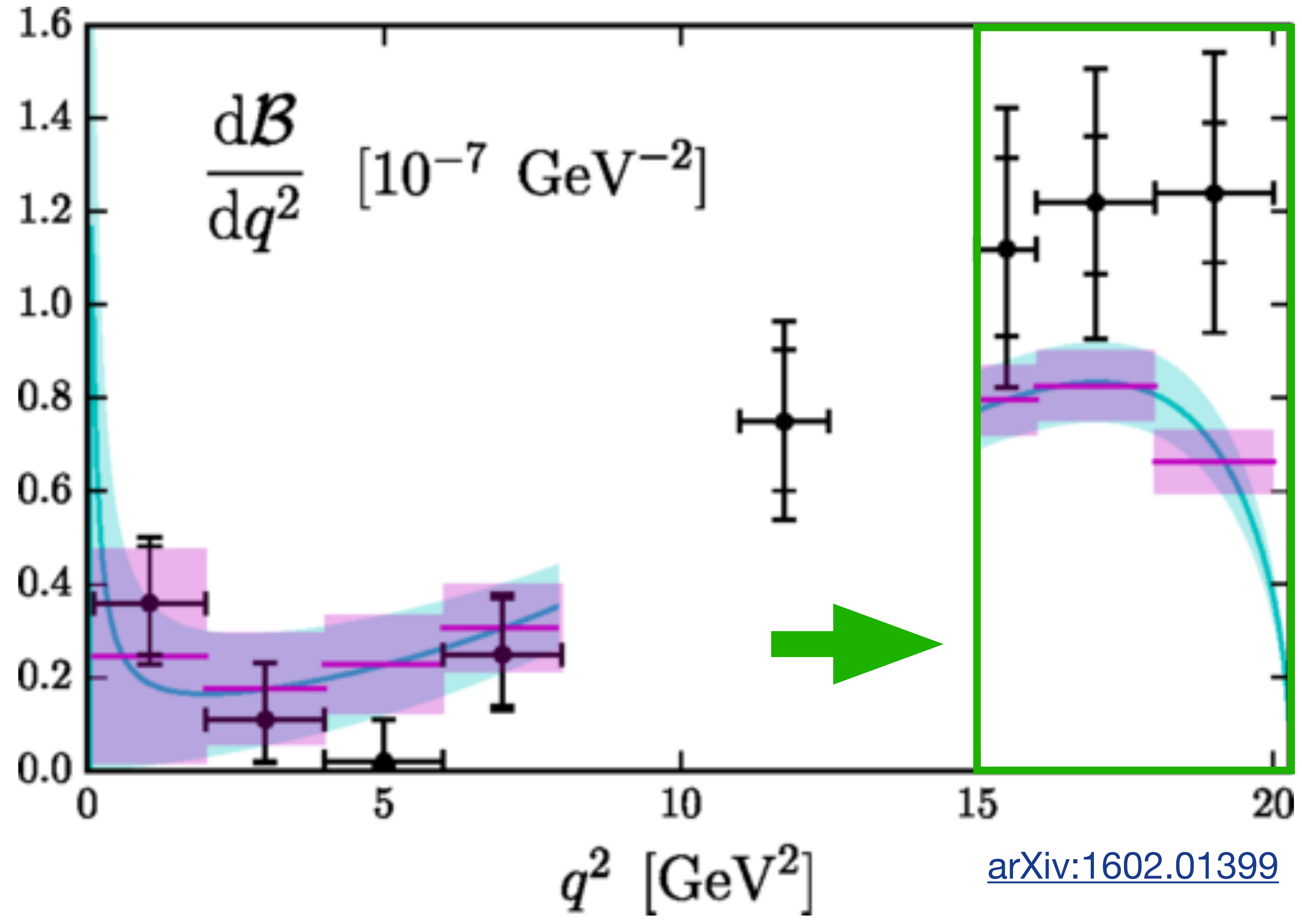
$$\Lambda_b^0 \rightarrow \Lambda(\rightarrow p\pi^-)\,\ell^+\ell^-$$

- Using both lepton types enables

  $\rightarrow$ independent LFU test: $K_i^{\text{LFU}} = K_i(\mu) - K_i(e)$

  $\rightarrow$ to mostly remove charm loop contribution

Differential branching fraction $\Lambda_b^0 \rightarrow \Lambda\mu^+\mu^-$



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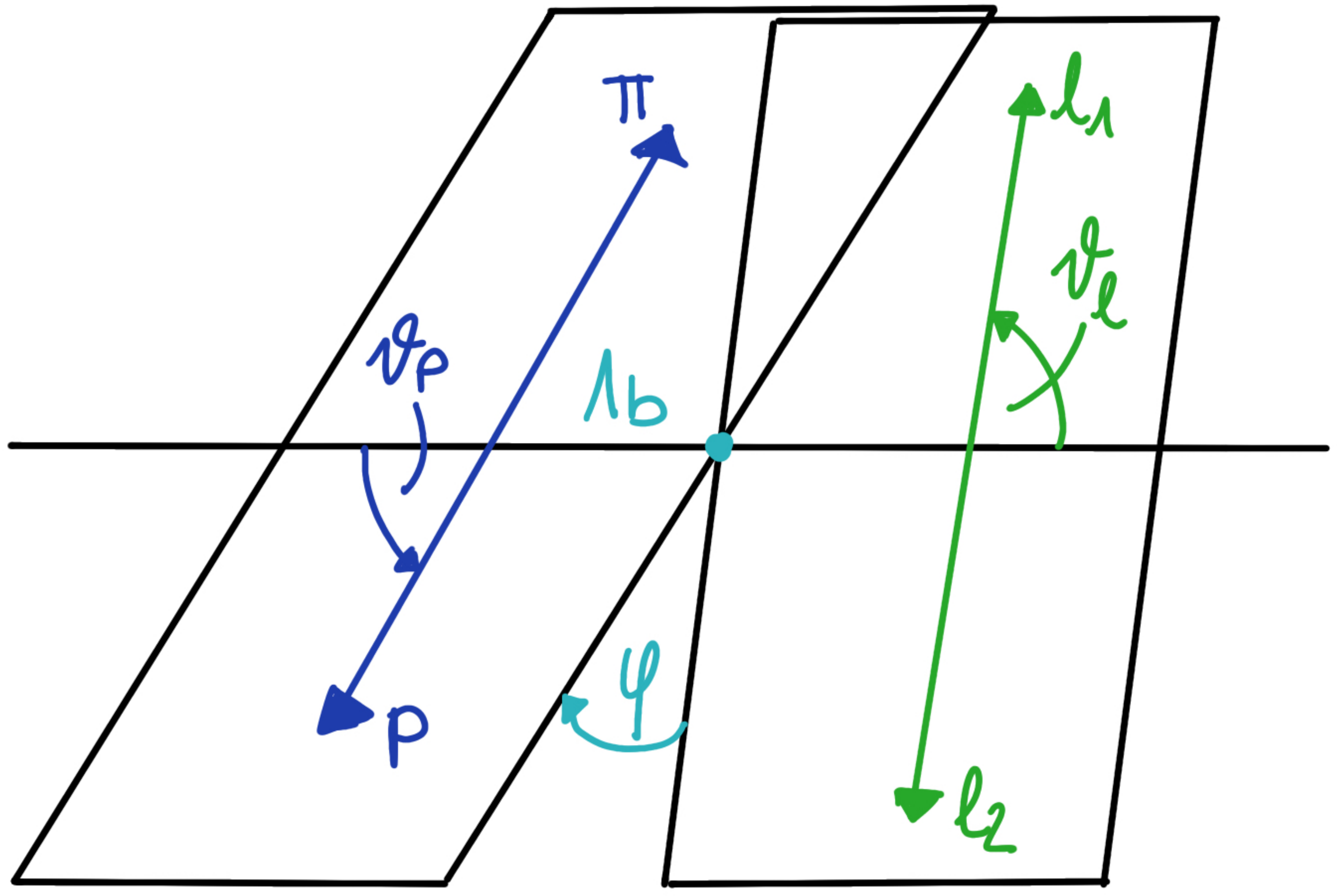
- Assuming an unpolarised Λ_b^0
- The full angular distribution is

$$\begin{aligned}K(q^2,\varphi,\cos\vartheta_\ell,\cos\vartheta_\Lambda) &= \frac{8\pi}{3}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\mathrm{d}\varphi\mathrm{d}\cos\vartheta_\ell\mathrm{d}\cos\vartheta_\Lambda}\\ &= \big[(K_{1ss}\sin^2\vartheta_\ell + K_{1cc}\cos^2\vartheta_\ell + K_{1c}\cos\vartheta_\ell)\\ &+ (K_{2ss}\sin^2\vartheta_\ell + K_{2cc}\cos^2\vartheta_\ell + K_{2c}\cos\vartheta_\ell)\cos\vartheta_\Lambda\\ &+ (K_{3sc}\sin\vartheta_\ell\cos\vartheta_\ell + K_{3s}\sin\vartheta_\ell)\sin\vartheta_\Lambda\sin\varphi\\ &+ (K_{4sc}\sin\vartheta_\ell\cos\vartheta_\ell + K_{4s}\sin\vartheta_\ell)\sin\vartheta_\Lambda\cos\varphi.\end{aligned}$$



- Coefficients K_i can be measured normalised

  as CP even $S_i = \frac{K_i + \bar{K}_i}{\frac{\mathrm{d}\Gamma}{\mathrm{d}q^2} + \frac{\mathrm{d}\bar{\Gamma}}{\mathrm{d}q^2}}$ or CP asymmetries $A_i = \frac{K_i - \bar{K}_i}{\frac{\mathrm{d}\Gamma}{\mathrm{d}q^2} + \frac{\mathrm{d}\bar{\Gamma}}{\mathrm{d}q^2}}$

- A_{1ss} and A_{1cc} cannot be accessed via transformation of the angles

  $\longrightarrow$ needs flavour-tagged analysis (which is possible)

Λ_b^0 ANGULAR ANALYSIS

- Likelihood fit analysis with LHCb dataset of $9\ \mathrm{fb}^{-1}$ in high q^2 bin

- Cut-based preselection and BDT to remove combinatorial
    - Preselection selects only real Λ
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- Cut-based preselection and BDT to remove combinatorial
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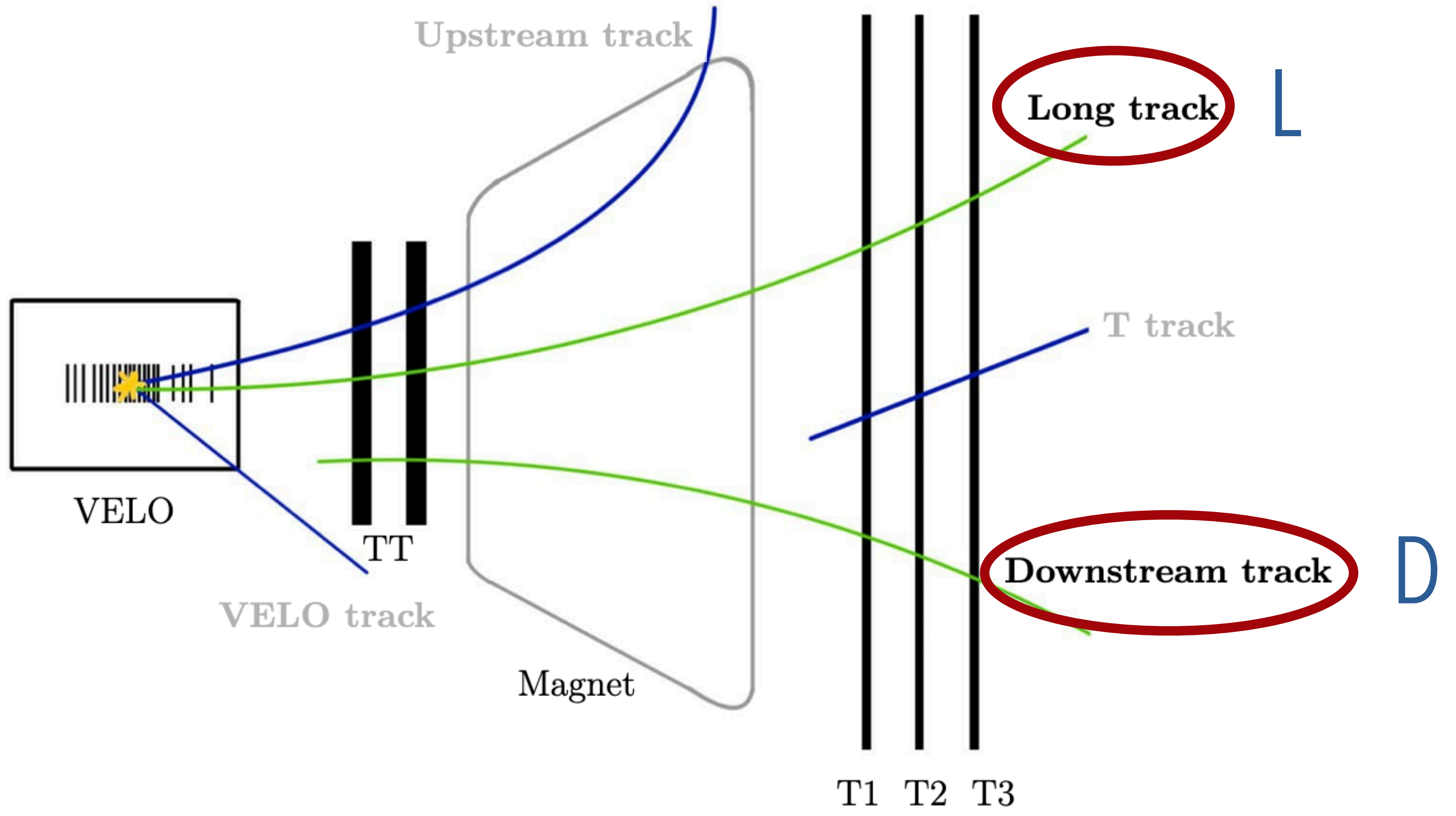
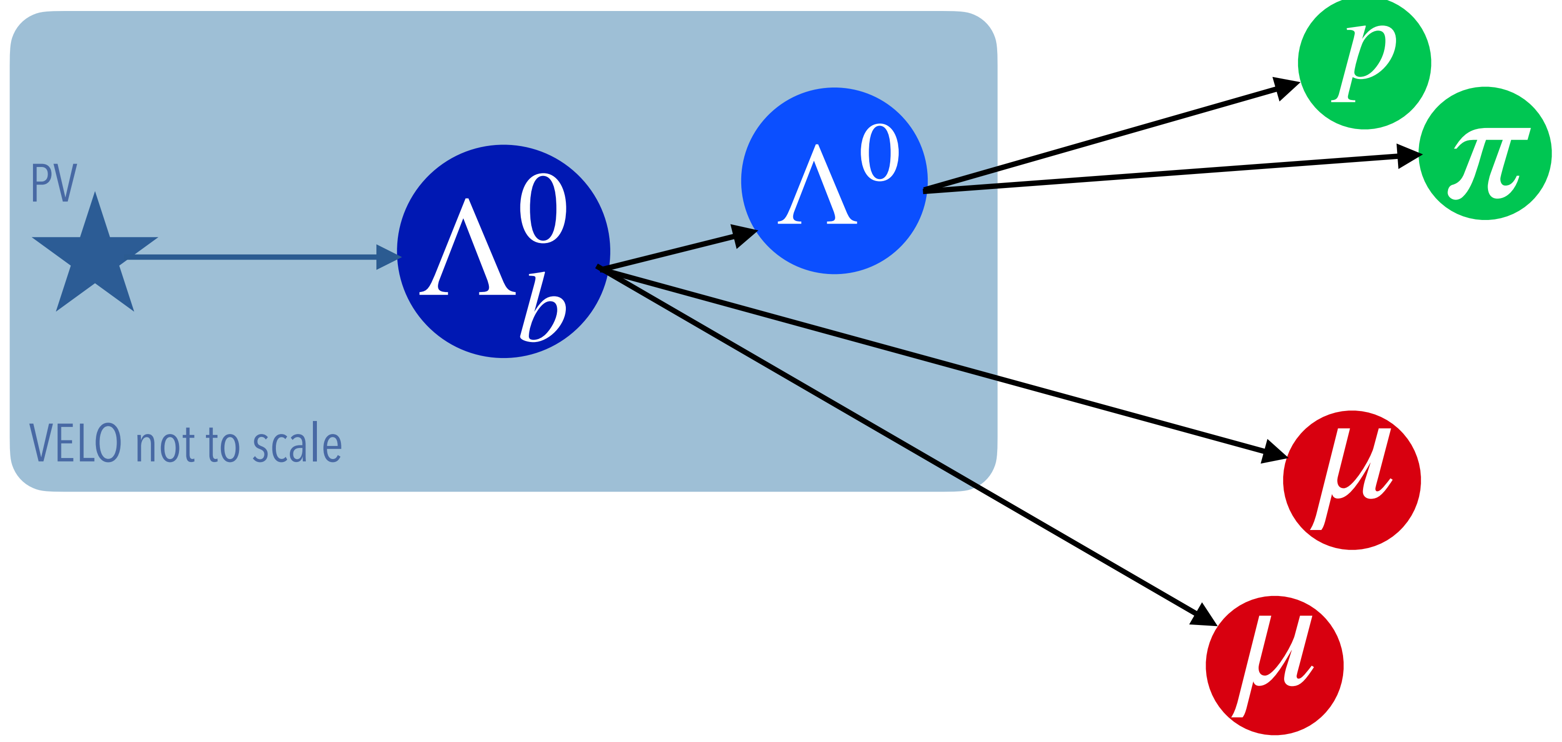
  - After full offline selection only combinatorial remaining
- Hyperon decay $\Lambda \to p\pi$ within or outside of VELO

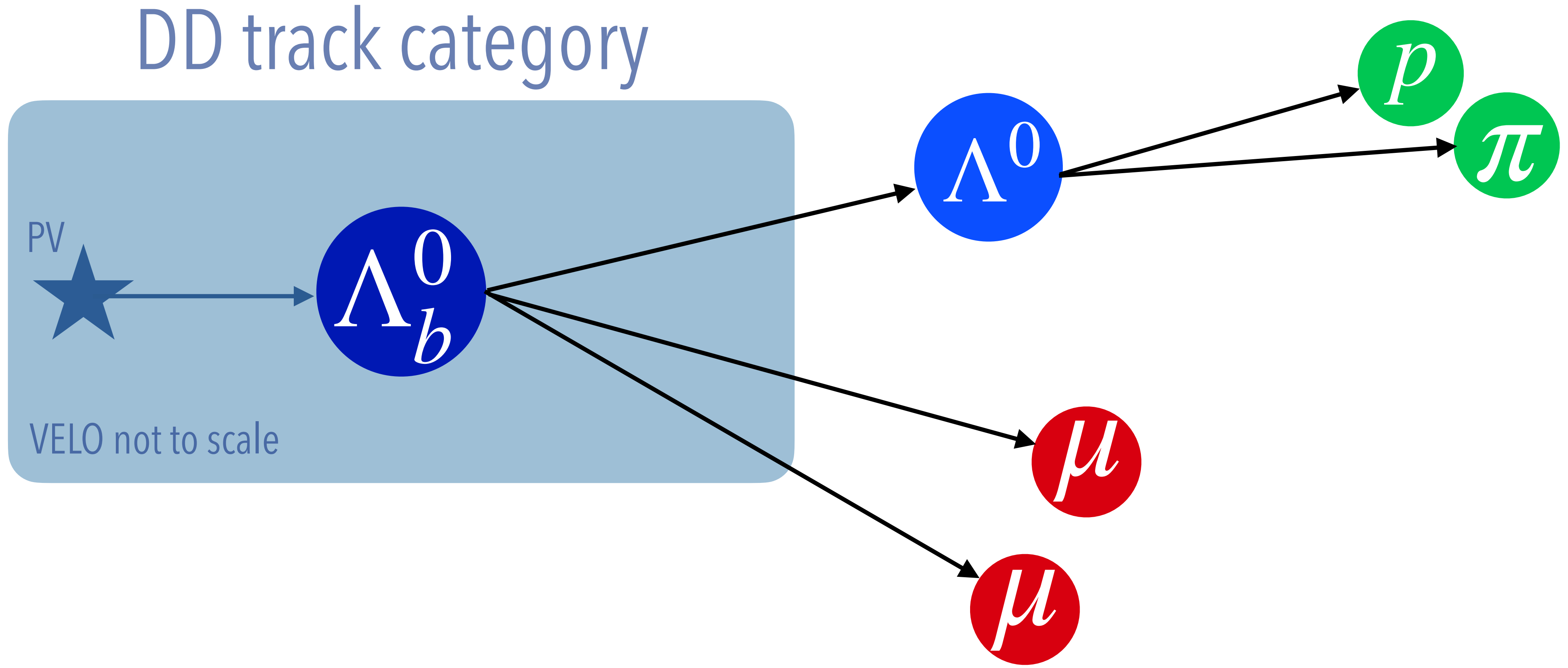
$\to$ check, if splitting in track categories necessary



LL track category



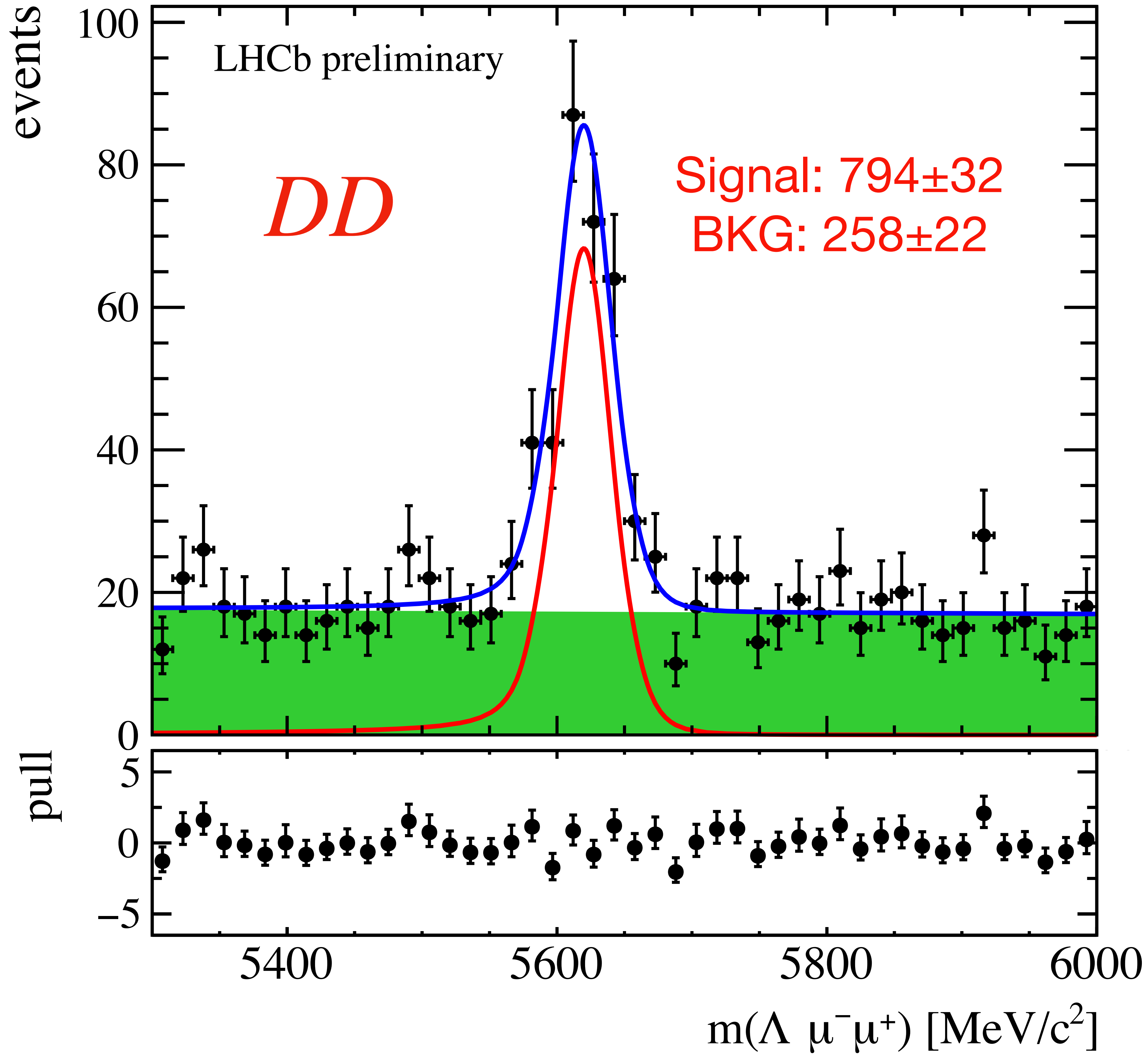
DD track category

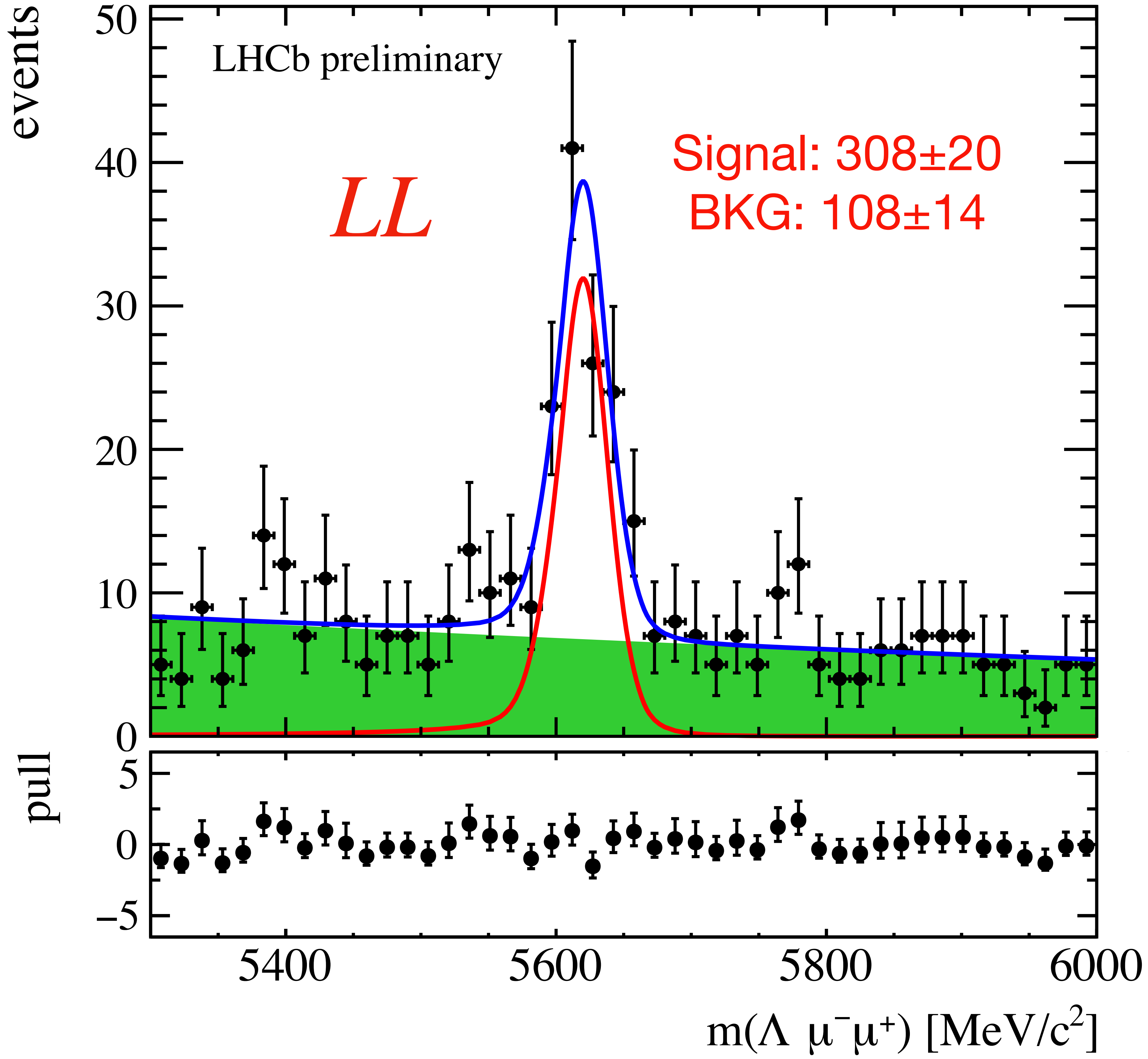


CROSS-CHECK MASS FIT

- Linear sum of **two double sided Crystal Ball** PDFs with shared mean
- Tail parameter as well as the fraction of the widths fixed to MC
- Background modelled with **exponential**
- Yields, BKG slope, mean and widths kept floating

BDT cut optimised independently





TOWARDS THE ANGULAR FIT

- If possible perform flavour-tagged angular analysis for muon mode

  $\longrightarrow$ extract CP even and odd angular coefficients

- If only combinatorial BKG, the total PDF is:

$$f_{sig} \times \text{PDF}_{sig}(\vartheta_l, \vartheta_\Lambda, \varphi)\text{PDF}_{sig}(m) + (1 - f_{sig}) \times \text{PDF}_{bkg}(\vartheta_l, \vartheta_\Lambda, \varphi)\text{PDF}_{bkg}(m)$$

- Total PDF needs to be efficiency ϵ corrected

$$\text{PDF}_{sig}(\vartheta_l, \vartheta_\Lambda, \varphi) \rightarrow \text{PDF}_{sig}(\vartheta_l, \vartheta_\Lambda, \varphi) \times \epsilon(\vartheta_l, \vartheta_\Lambda, \varphi)$$

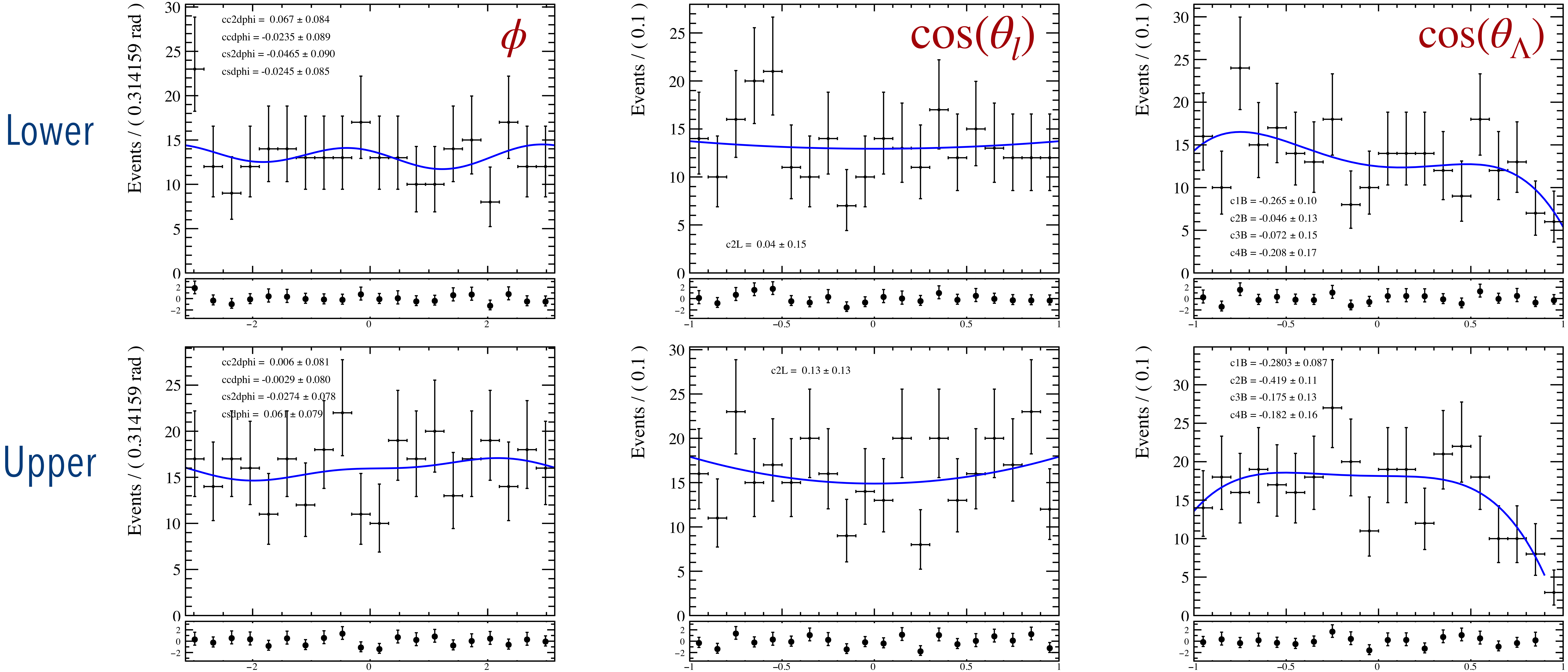
  $\longrightarrow$ angular acceptance accounts for detector effects, reconstruction and selection effects

CROSS-CHECK BKG ANGLES DD

- Testing if upper and lower BKG sidebands compatible

  → allows to check if no physics BKG remained

No significant difference



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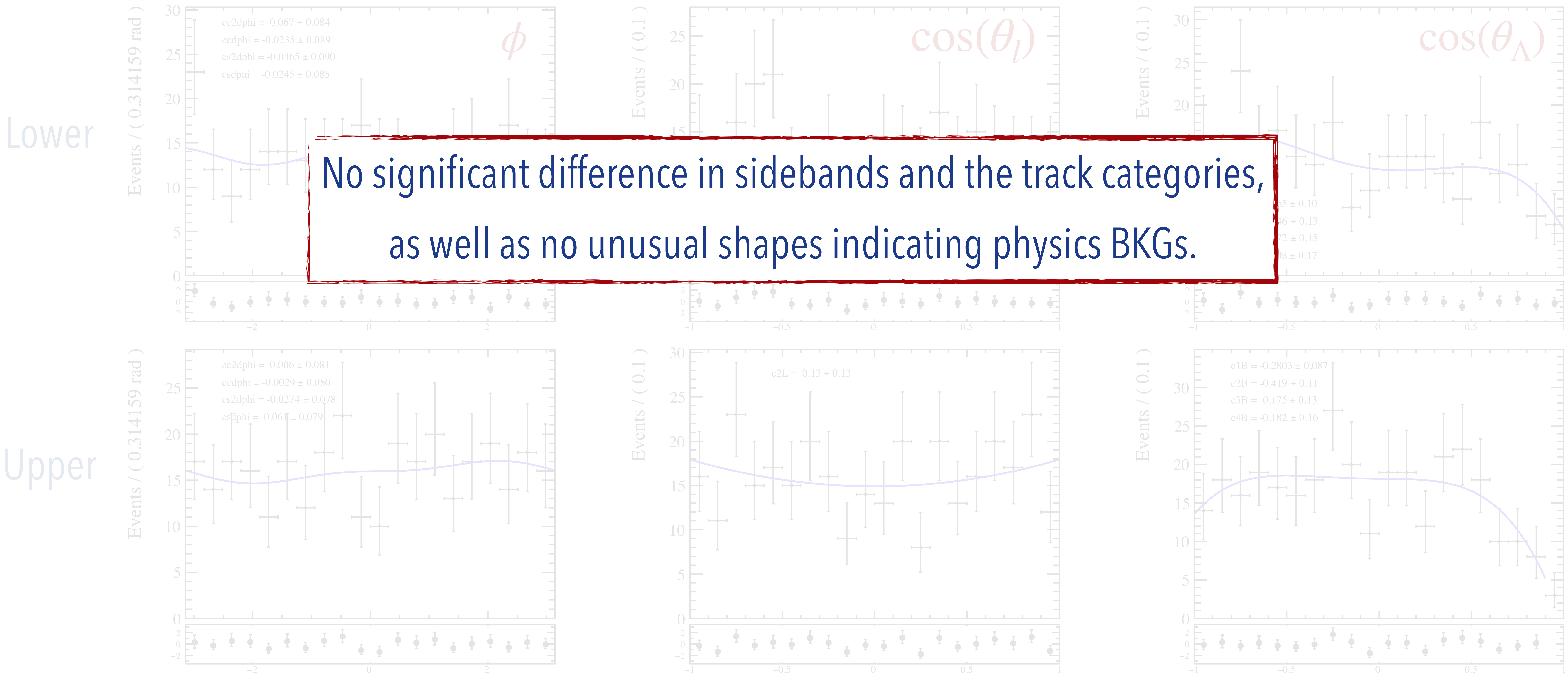


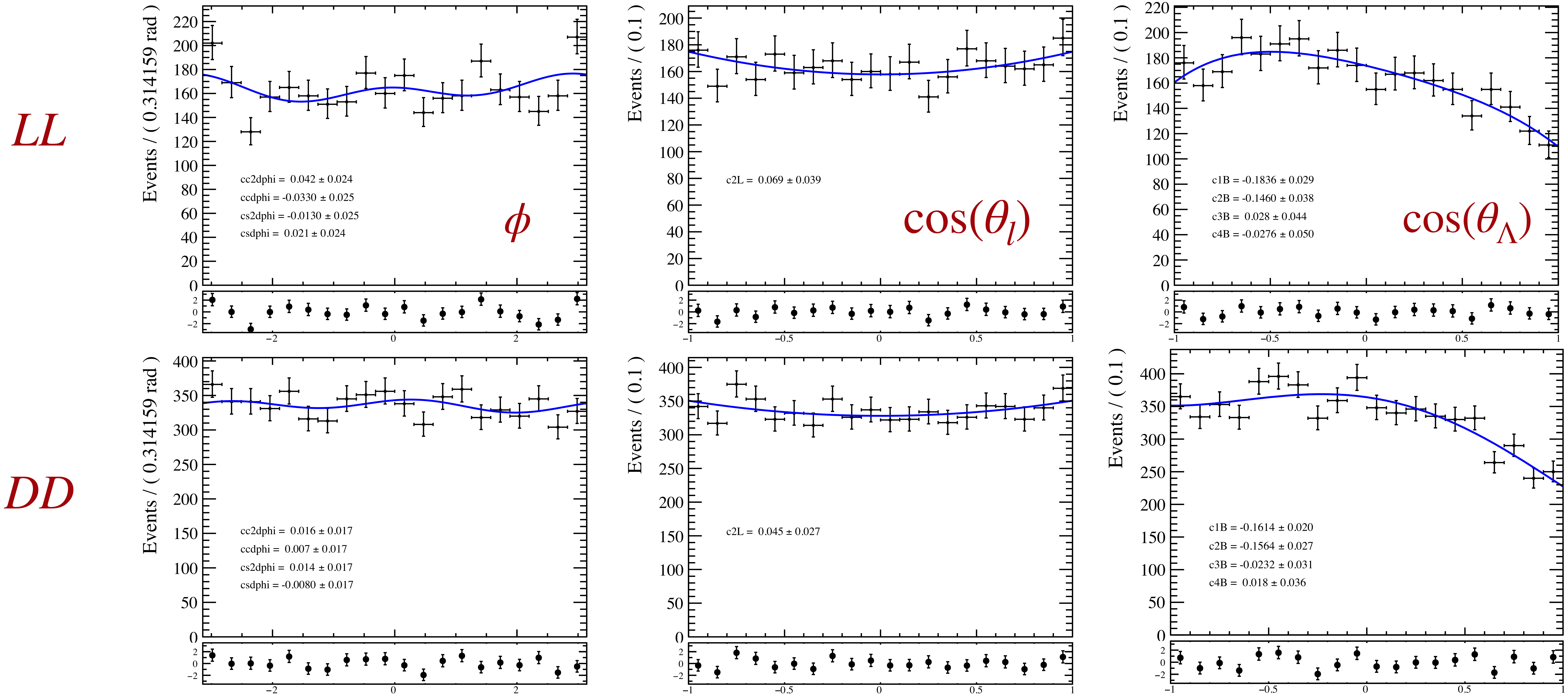
No significant difference in sidebands and the track categories, as well as no unusual shapes indicating physics BKGs.

ANGULAR ACCEPTANCE

- Angular acceptance fits with Legendre polynomial

  → supports to not split in track categories

In Agreement within 1σ



OUTLOOK

- Produce the toys to study full PDF

  → enables first sensitivity studies on the angular LFU test

- No splitting in track categories needed

  → study if full 3D angular fit can be accessed (flavour-tagged)

  → study if same assumption holds for electrons

- Stay tuned for the results!

BACKUP

MOTIVATION

- Stringent test of B anomalies in meson sector
- Enable to test possible spin dependence of NP

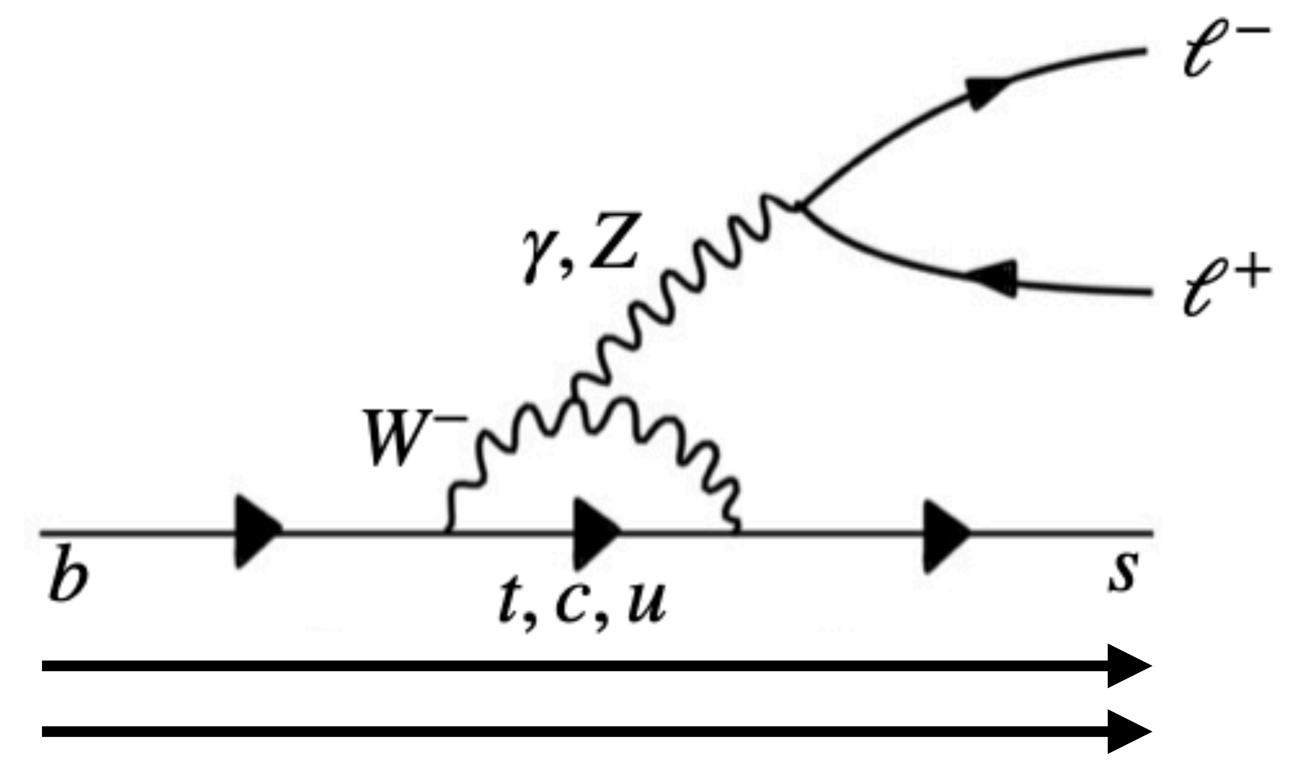
  → baryon half-integer spin

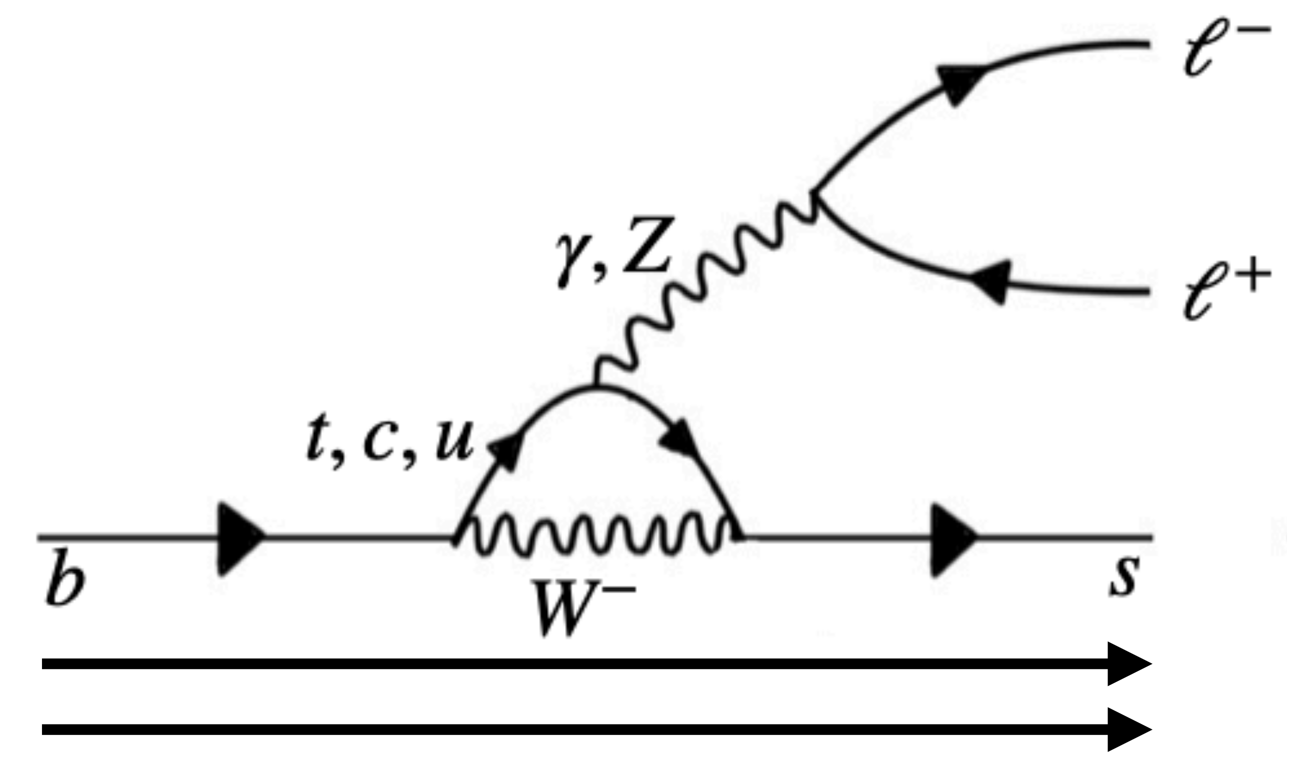
- Four weakly decaying baryons with one b quark

Λ_b^0	$b\,u\,d$	$f_{\Lambda_b^0} = 18\,\%$
Ξ_b^0	$b\,s\,u$	$f_{\Xi_b^0} = 1.5\,\%$
Ξ_b^-	$b\,s\,d$	$f_{\Xi_b^-} = 1.5\,\%$
Ω_b^-	$b\,s\,s$	$f_{\Omega_b^-} = 0.5\,\%$

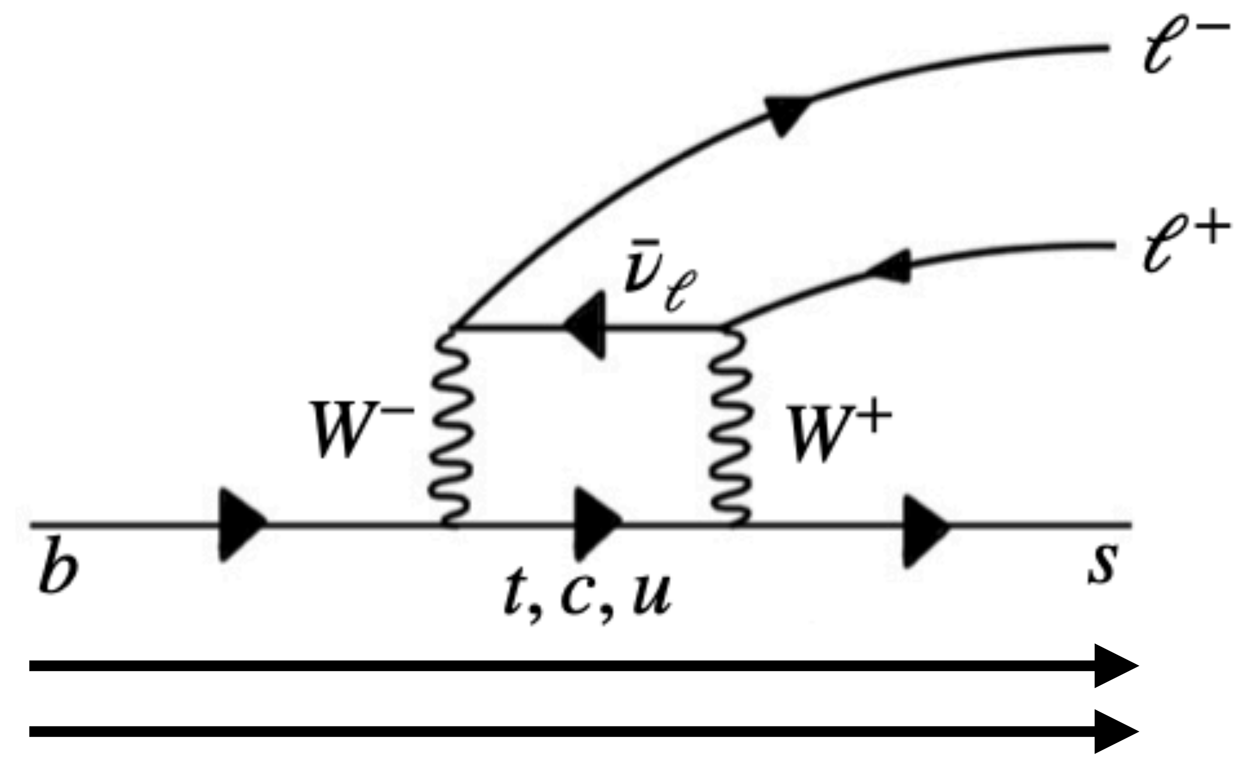
But very small production probability f_i

→ focus on Λ_b^0 decays





Two spectator quarks



BACKUP - ANGULAR COEFFIENCTS

- Assuming an unpolarised Λ_b^0
- The full angular distribution is

$$
\begin{aligned}
K(q^2,\varphi,\cos\vartheta_\ell,\cos\vartheta_\Lambda) &= \frac{8\pi}{3}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\mathrm{d}\varphi\mathrm{d}\cos\vartheta_\ell\mathrm{d}\cos\vartheta_\Lambda} \\
&= \big[(K_{1ss}\sin^2\vartheta_\ell + K_{1cc}\cos^2\vartheta_\ell + K_{1c}\cos\vartheta_\ell) \\
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\end{aligned}
$$

$$
\begin{aligned}
K_{1ss}(q^2) &= \frac{1}{4}\left[|A^R_{\perp_1}|^2 + |A^R_{\|_1}|^2 + 2|A^R_{\perp_0}|^2 + 2|A^R_{\|_0}|^2 + (R \leftrightarrow L)\right] \\
K_{1cc}(q^2) &= \frac{1}{2}\left[|A^R_{\perp_1}|^2 + |A^R_{\|_1}|^2 + (R \leftrightarrow L)\right] \\
K_{1c}(q^2) &= -\mathrm{Re}\left\{A^R_{\perp_1}A^{*R}_{\|_1} - (R \leftrightarrow L)\right\} \\
K_{2ss}(q^2) &= +\frac{\alpha}{2}\mathrm{Re}\left\{A^R_{\perp_1}A^{*R}_{\|_1} + 2A^R_{\perp_0}A^{*R}_{\|_0} + (R \leftrightarrow L)\right\} \\
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K_{3sc}(q^2) &= +\frac{\alpha}{\sqrt{2}}\mathrm{Im}\left\{A^R_{\perp_1}A^{*R}_{\perp_0} - A^R_{\|_1}A^{*R}_{\|_0} + (R \leftrightarrow L)\right\} \\
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