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Weak decays of heavy-quark baryons

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On behalf of the LHCb Collaboration

Young Scientist Forum

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Supported by:

Weakly decaying b-baryons

* based on CDF measurement with 16 events
Phys. Rev. D 80 (2009), 072003

Four weakly decaying b-baryons with one heavy quark

Λ_b^0 $b\,u\,d$ $f_{\Lambda_b^0} \sim 18\ \%$

Ξ_b^0 $b\,s\,u$ $f_{\Xi_b^0} \sim 1.5\ \%$

Ξ_b^- $b\,s\,d$ $f_{\Xi_b^-} \sim 1.5\ \%$

Ω_b^- $b\,s\,s$ $f_{\Omega_b^-} \sim 0.5\ \%$*

- Ω_b^- least studied b-baryon
  $\longrightarrow$ large uncertainties on e.g. **mass** $m(\Omega_b^-)$
- **Production fraction** $f_{\Omega_b^-}$ needed to measure absolute branching fractions
  $\longrightarrow$ never measured at the LHC

$$R = \frac{f_{\Omega_b^-}}{f_{\Xi_b^-}} \times \frac{\mathscr{B}(\Omega_b^- \to \Omega^- J/\psi)}{\mathscr{B}(\Xi_b^- \to \Xi^- J/\psi)}$$

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- Both decay modes hyperon decay chain:
  → cannot be mimicked by any mesonic decay

$$\Omega_b^- \to J/\psi(\to \mu^+\mu^-)\Omega^-(\to \Lambda K^-)$$
$$\Xi_b^- \to J/\psi(\to \mu^+\mu^-)\Xi^-(\to \Lambda \pi^-)$$

with $\Lambda \to p\pi^-$

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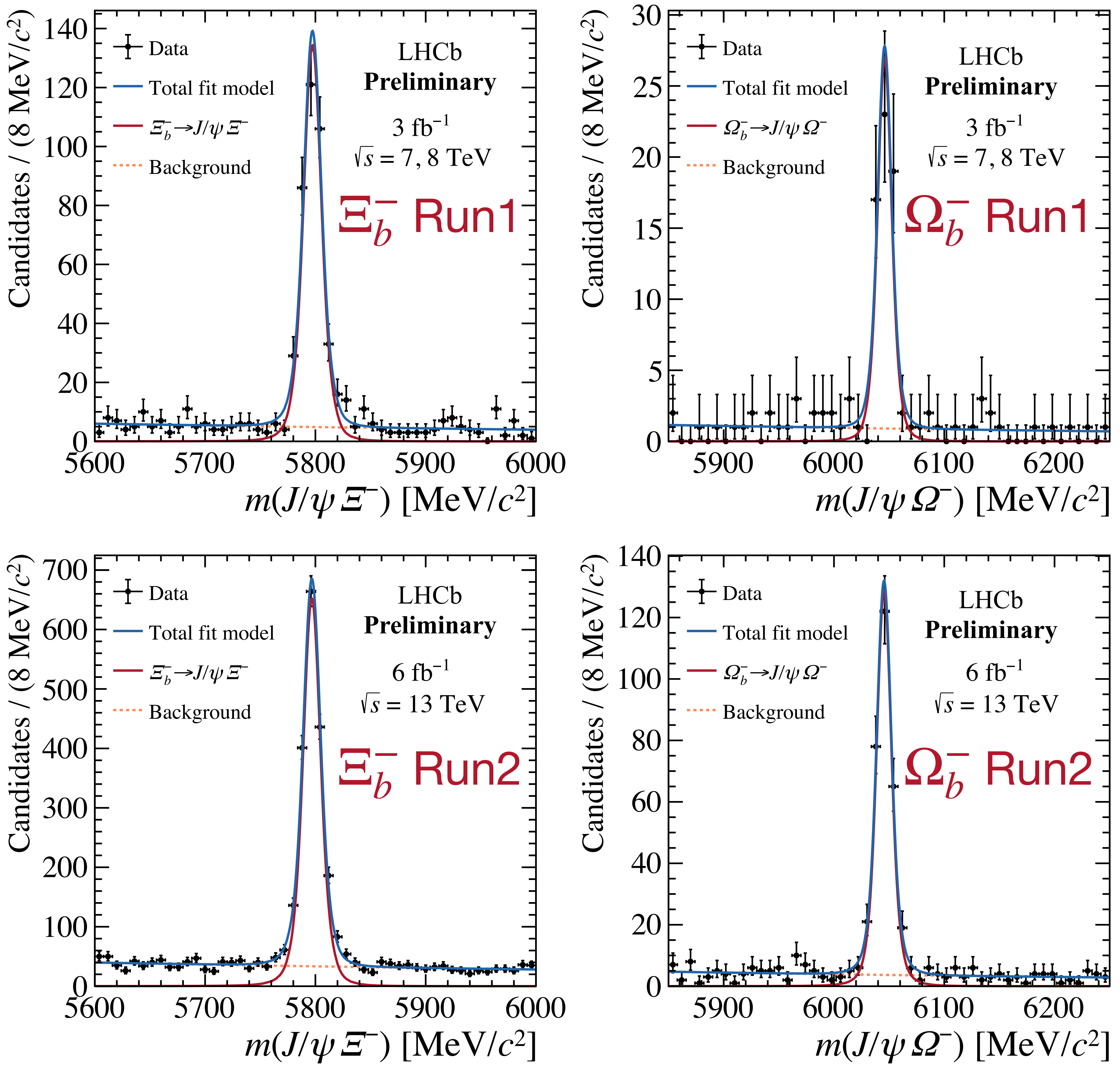
with $\Lambda \rightarrow p\pi^-$

- $\tau_\Lambda \sim 0.263$ ns $> \tau_{\Xi^-} \sim 0.164$ ns $> \tau_{\Omega^-} \sim 0.082$ ns :
  $\rightarrow$ Ω_b^- more often in LHCb acceptance, both decays low energy release
- Fully cut-based selection in fiducial phase-space

Ω_b^- mass measurement



LHCb-PAPER-2022-053 in preparation

- Extract the **mass difference** $m(\Omega_b^-) - m(\Xi_b^-)$
  → cancels dominant systematic uncertainty: abs. mom. scale
- Mass difference kept floating

$$m(\Omega_b^-) - m(\Xi_b^-) = 248.54 \pm 0.51\ (\text{stat}) \pm 0.38\ (\text{syst})\ \text{MeV}/c^2$$

- Dominant systematic uncertainty: hyperon masses

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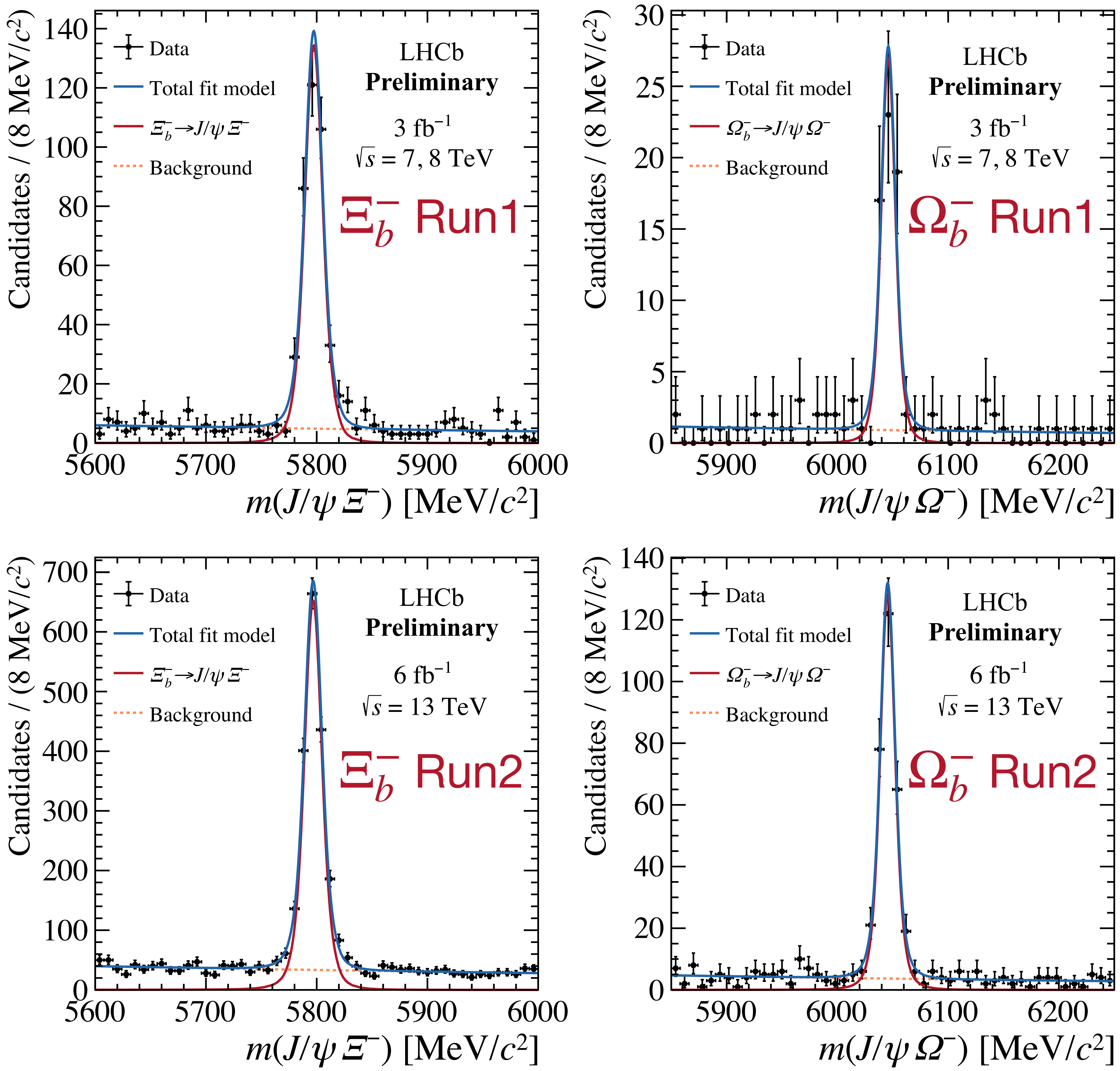

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- Using $m(\Xi_b^-)$ from $\Xi_b^- \to \Xi_c^0\pi^-$ Phys. Rev. D 103 (2021) 012004

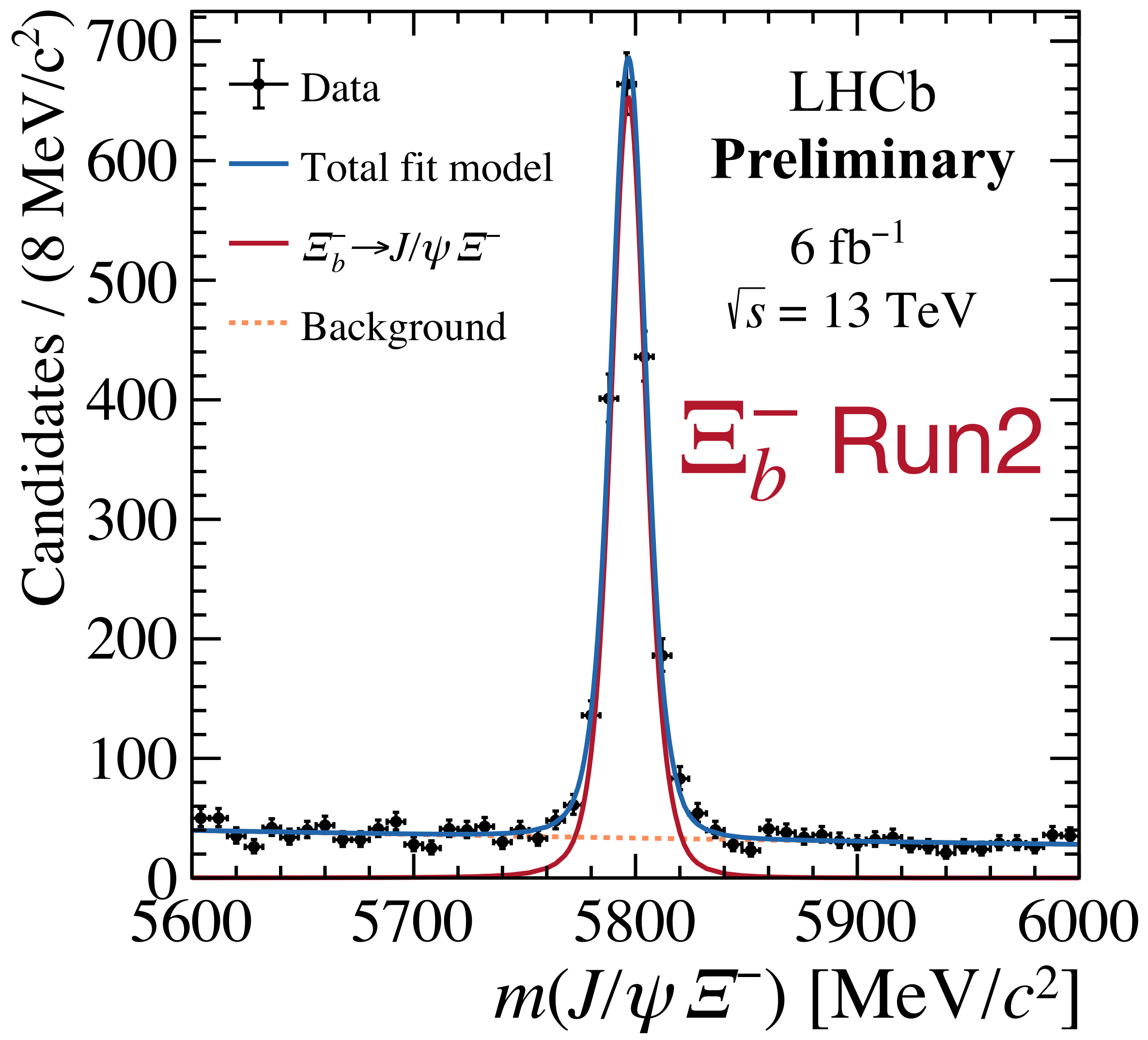
$$m_{LHCb}(\Xi_b^-) = 5797.33 \pm 0.24\ (\text{stat}) \pm 0.29\ (\text{syst})\ \text{MeV}/c^2$$

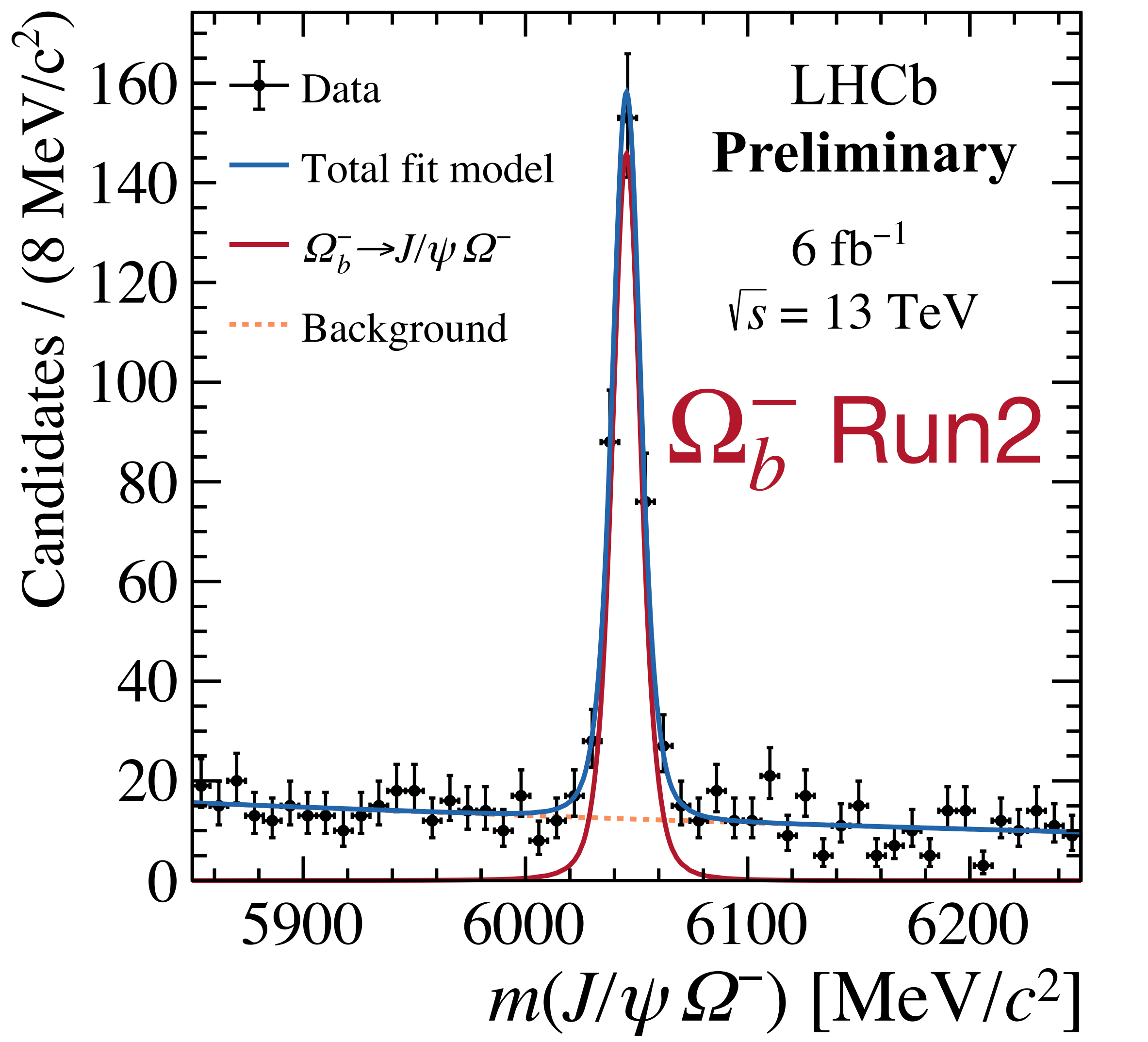
$$m(\Omega_b^-) = 6045.9 \pm 0.5\ (\text{stat}) \pm 0.6\ (\text{syst})\ \text{MeV}/c^2$$

- Factor 2 improvement wrt. previous best measurement

Phys.Rev.D 104 (2021) L091102

Relative production fraction





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- Simultaneous fit to Run2 ($\sqrt{s} = 13$ TeV) only

  $\rightarrow$ R kept floating

- Dominating systematic uncertainties: simulation calibration and b-baryon lifetimes

$$R = \frac{f_{\Omega_b^-}}{f_{\Xi_b^-}} \times \frac{\mathcal{B}(\Omega_b^- \to \Omega^- J/\psi)}{\mathcal{B}(\Xi_b^- \to \Xi^- J/\psi)} = 0.120 \pm 0.008\ (\text{stat}) \pm 0.008\ (\text{syst})$$

- In agreement within 1.2σ with CDF measurement but differs by a factor 2

  $R_{CDF} = 0.27 \pm 0.12\ (\text{stat}) \pm 0.01\ (\text{syst})$ Phys. Rev. D 80 (2009), 072003

- Production cross-sections ratio not expected to match between production environment at Tevatron and LHC

Conclusion

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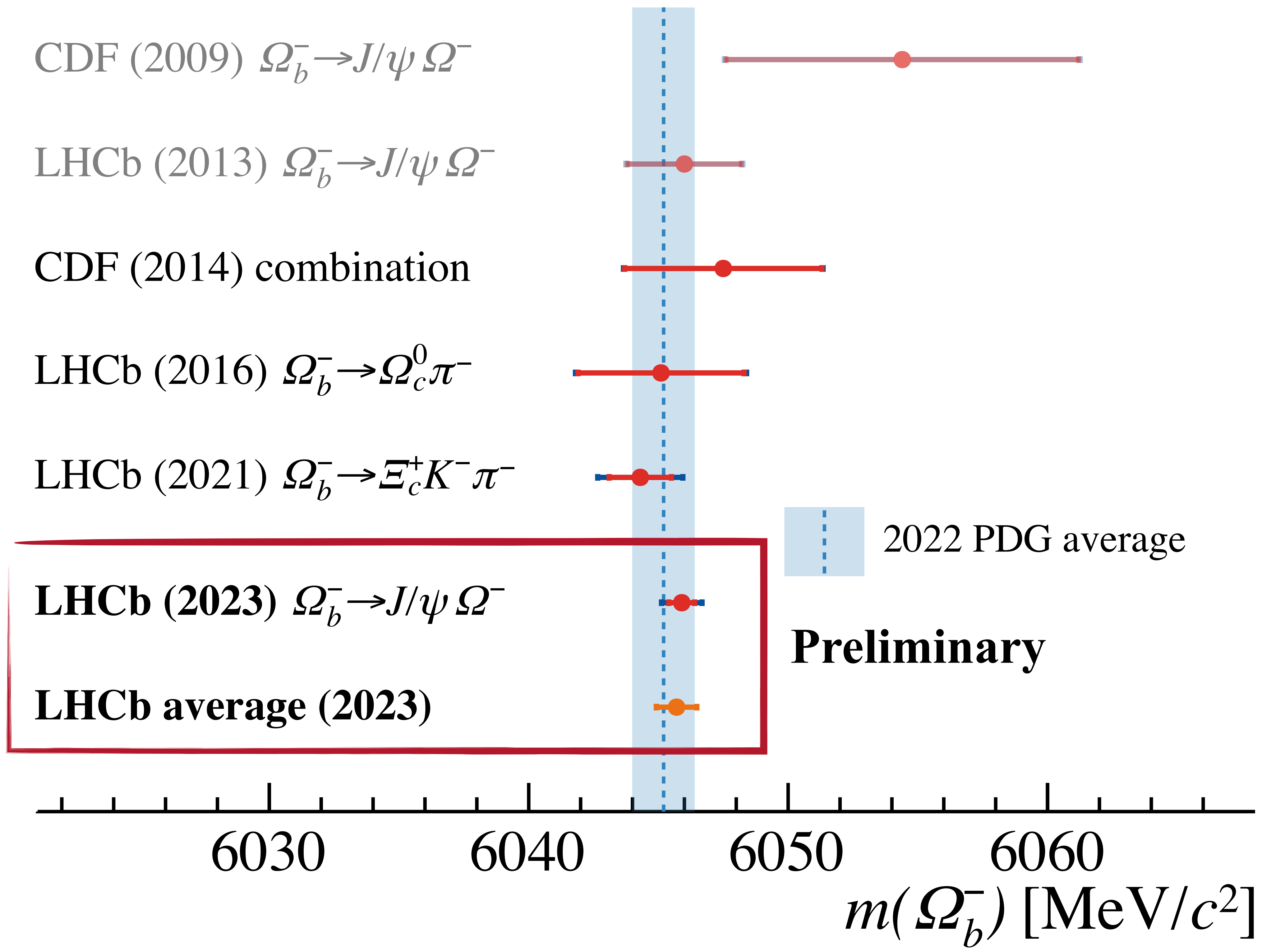

- **Most precise measurement of the Ω_b^- mass** with an LHCb dataset corresponding to $9\ \text{fb}^{-1}$
- Measurement in agreement with world average and previous measurements

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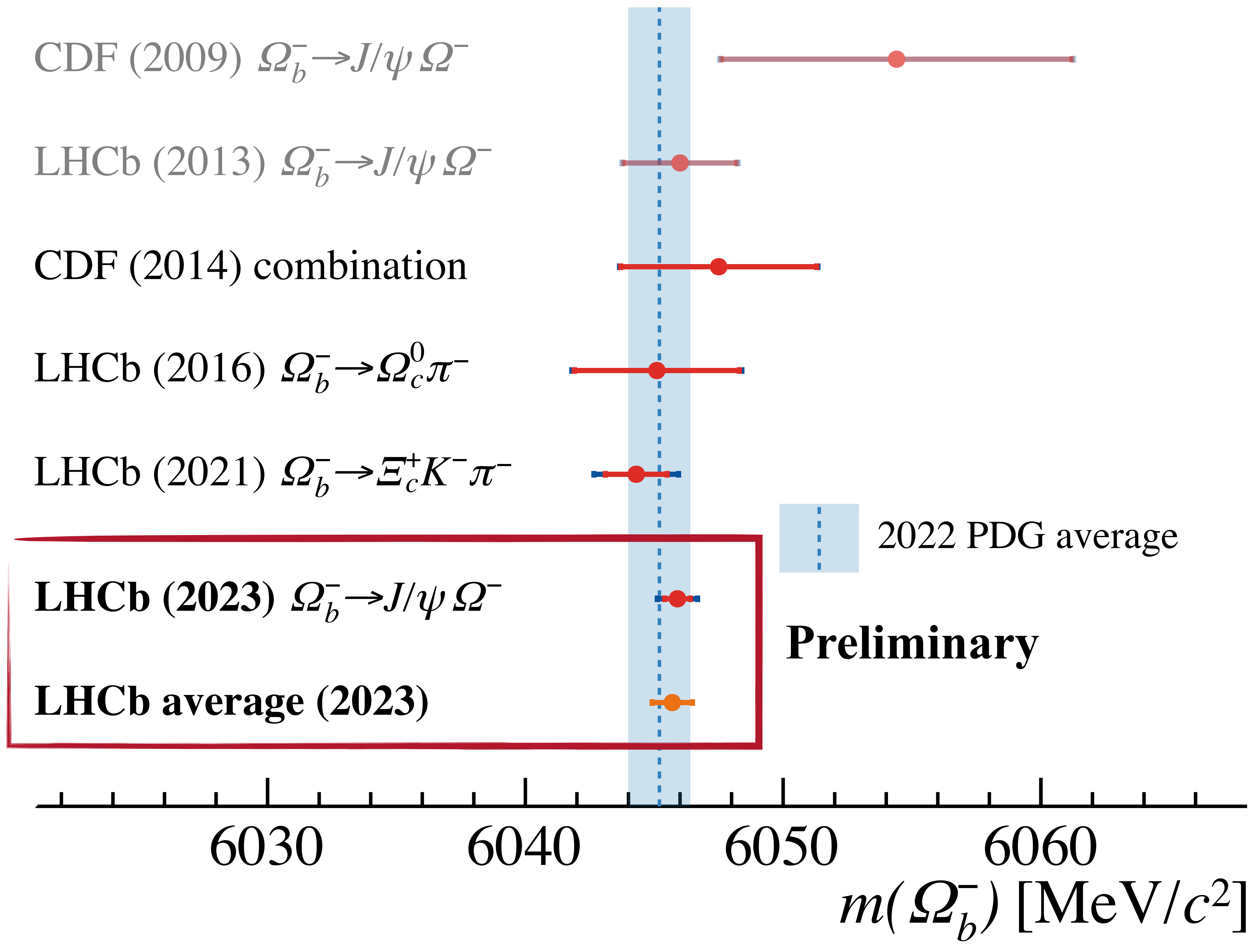


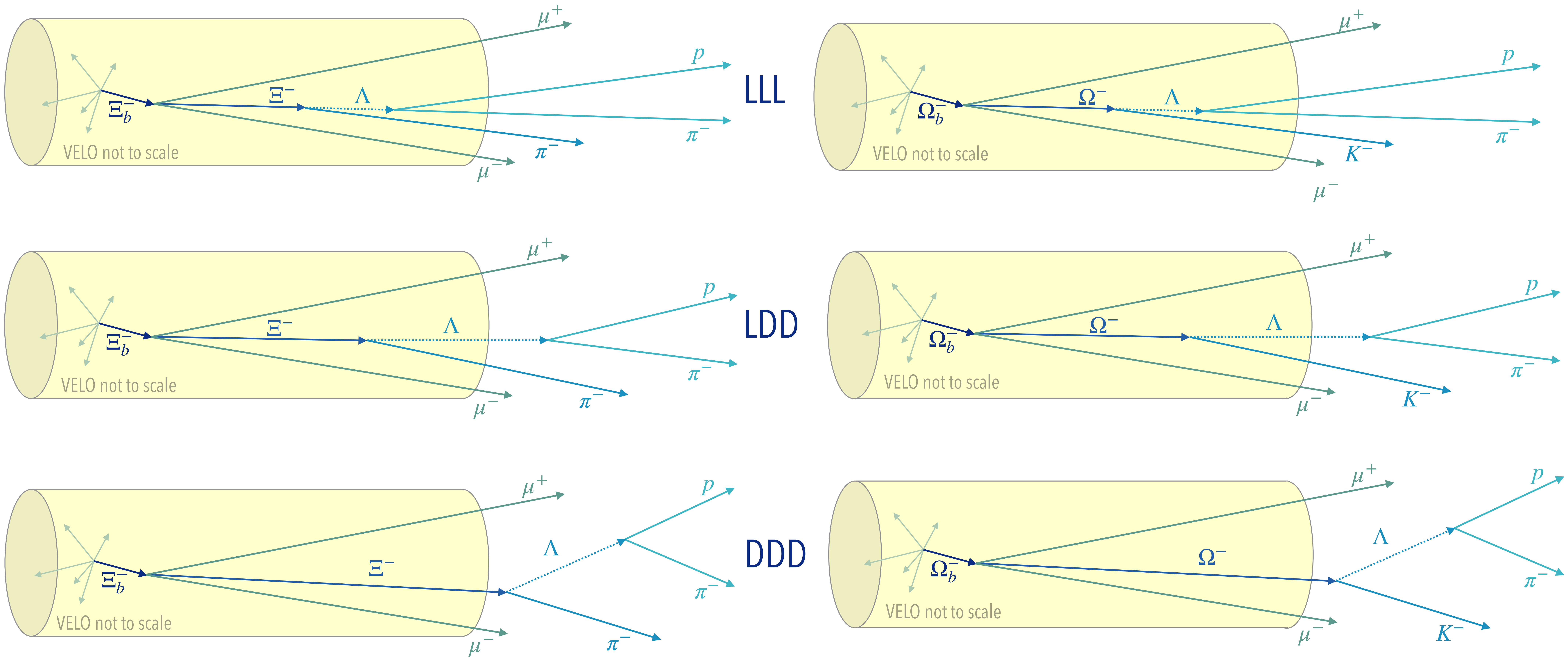
- **Most precise measurement of the Ω_b^- mass** with an LHCb dataset corresponding to $9\ \text{fb}^{-1}$
- Measurement in agreement with world average and previous measurements
- **First determination of the relative production fraction** of the Ω_b^- at the LHC at $\sqrt{s} = 13$ TeV

$$\frac{f_{\Omega_b^-}}{f_{\Xi_b^-}} \times \frac{\mathcal{B}(\Omega_b^- \to \Omega^- J/\psi)}{\mathcal{B}(\Xi_b^- \to \Xi^- J/\psi)} = 0.120 \pm 0.008\ \text{(stat)} \pm 0.008\ \text{(syst)}$$

- **Input from theory needed** to disentangle production fraction ratio from ratio of branching fractions

Track categories

- Possible track categories based on Velo information available long track (L) or not downstream track (D)
- $\tau_{\Lambda} \sim 0.263$ ns $> \tau_{\Xi^-} \sim 0.164$ ns $> \tau_{\Omega^-} \sim 0.082$ ns : More long tracks for Ω_b^- decays,



Uncertainties

Systematic uncertainties on mass difference

Type	Value, MeV/c^2
Momentum scale knowledge	0.09
$\mathrm{d}E/\mathrm{d}x$ correction	0.01
Hyperon mass knowledge	0.35
$\Lambda_b^0 \to J/\psi \Lambda$ background	0.10
Fit bias	0.06
Full fit model	0.01
Total	0.38

Systematic uncertainties on production fraction x BF

Type	Value [%]
Size of simulated samples	0.3
Calibration of simulation	5.5
Selection criteria	0.1
Lifetimes of b-baryons	3.1
Material interactions	0.7
Fit model	0.8
External input ($\mathcal{B}$)	1.0
Total	6.5