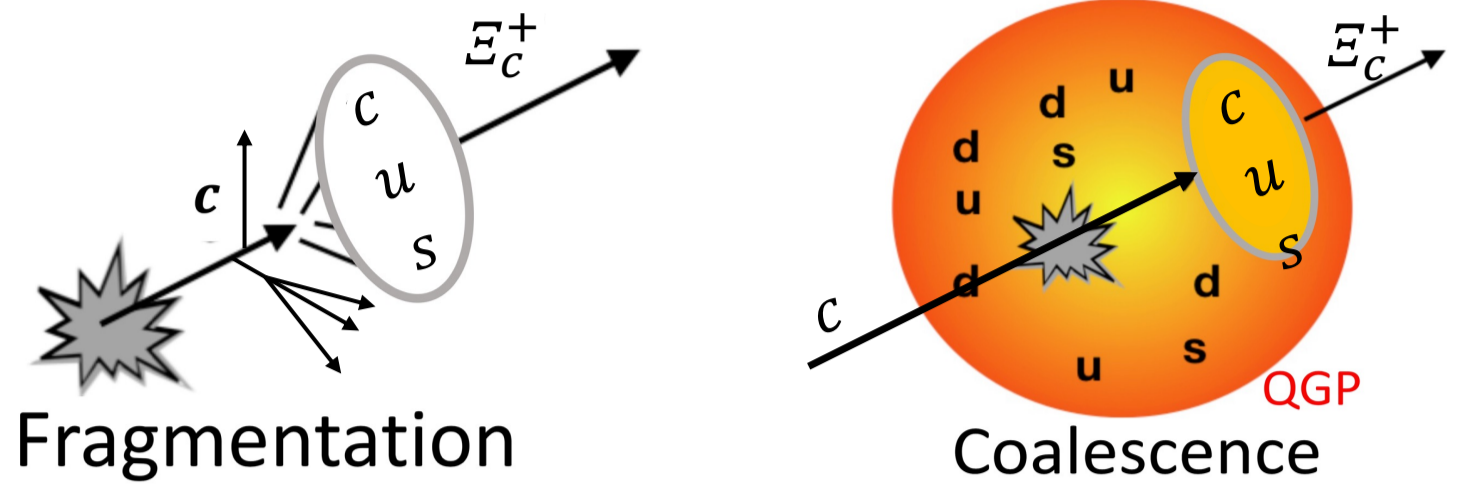


1. Introduction

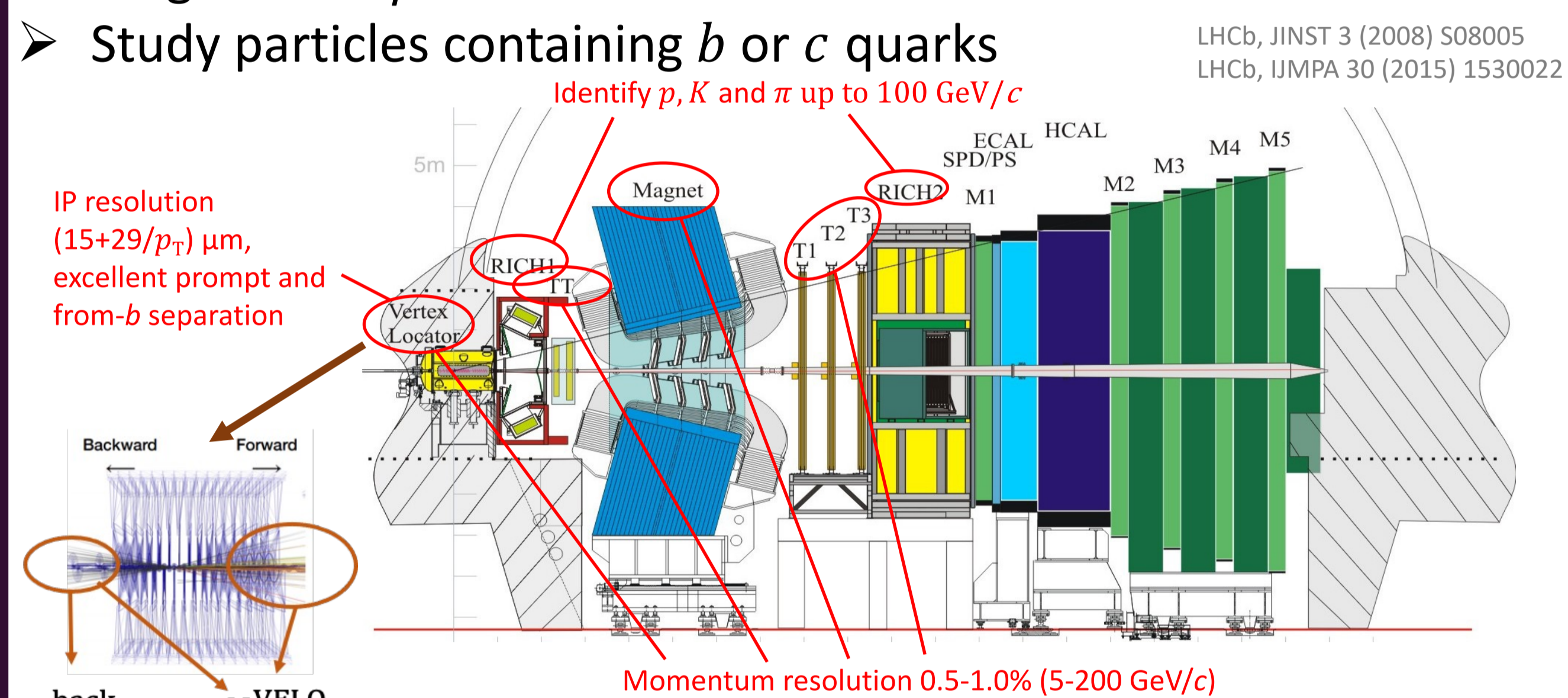
- Enhancement of strange particle production in heavy-ion collisions is considered as a signature of quark gluon plasma (QGP)
 - Strange quarks are abundant in QGP medium
 - Quark coalescence may dominate the hadronization mechanism as particle density becomes larger



- Fragmentation: initial high energy partons produce other partons from the vacuum and neutralized by produced partons
- Coalescence: quarks that are produced near each other combine to form colour-neutral hadrons
- Enhanced strangeness production has been observed in nucleus-nucleus collisions and small systems, which arouses discussions on whether one fluid rules all systems
- LHCb provides opportunities on investigating whether strangeness enhancement exists for heavy flavor in unique forward regions

2. The LHCb detector

- A single-arm forward spectrometer, covering the pseudorapidity range of $2 < \eta < 5$
- Study particles containing b or c quarks



- Particle multiplicity characterized with the track multiplicity of the Vertex Locator (VELO), and normalized multiplicity and charged particle density can be derived then

3. Observables

- Double differential cross-section

$$\frac{d^2\sigma}{dp_T dy^*} = \frac{N}{\mathcal{L} \times \epsilon_{\text{tot}} \times \mathcal{B} \times \Delta p_T \times \Delta y^*}$$

- N : prompt signal yield
- \mathcal{L} : integrated luminosity
- ϵ_{tot} : total efficiency
- \mathcal{B} : branching fraction
- $\Delta p_T = 1 \text{ GeV}/c$, $\Delta y^* = 0.5$
- Integrate over y^* or p_T to get one-dimensional cross-sections

- Stranged production ratio

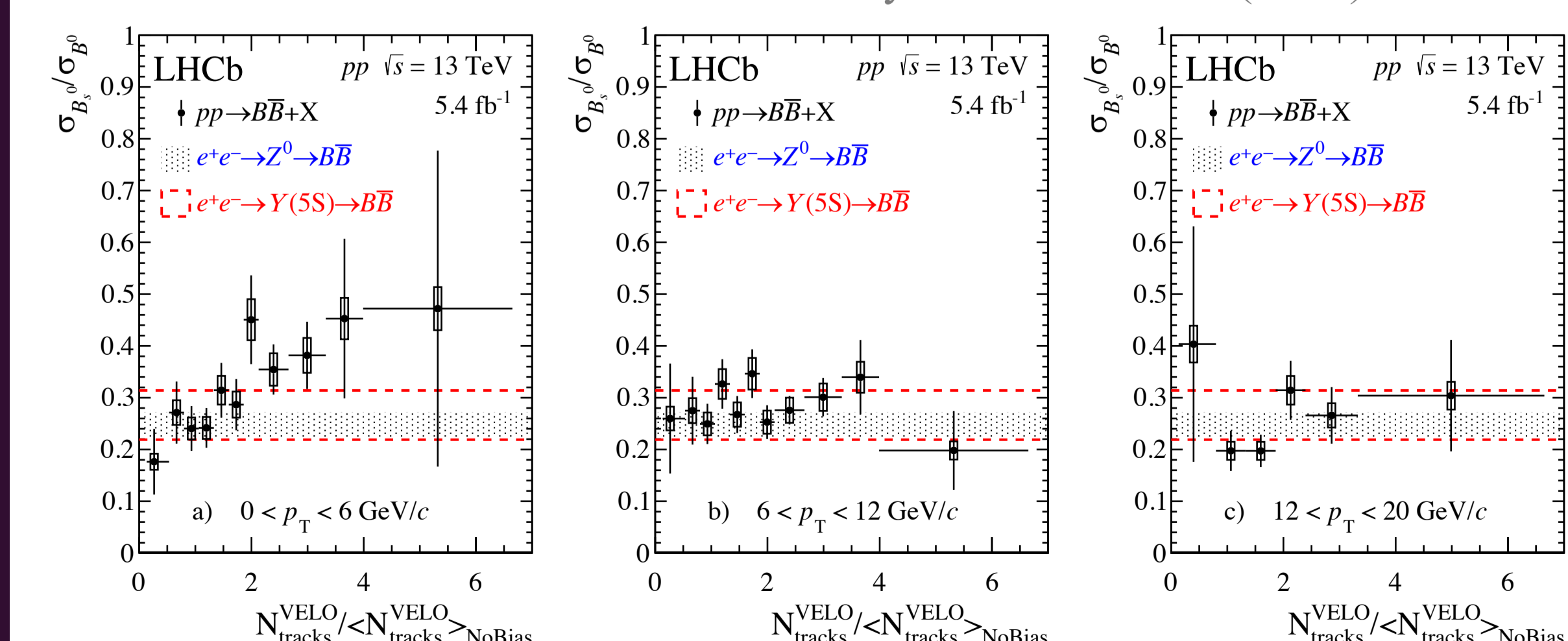
$$R_{S/N}(p_T, y^*) = \frac{d^2\sigma_S(p_T, y^*)/dp_T dy^*}{d^2\sigma_N(p_T, y^*)/dp_T dy^*}$$

4. B_s^0/B^0 production ratio in $p\text{Pb}$

- $R_{B_s^0/B^0}$ v.s. multiplicity in different p_T intervals

Phys. Rev. Lett. 131 (2023) 061901

$B^0: \bar{b}d$
 $B_s^0: \bar{b}s$



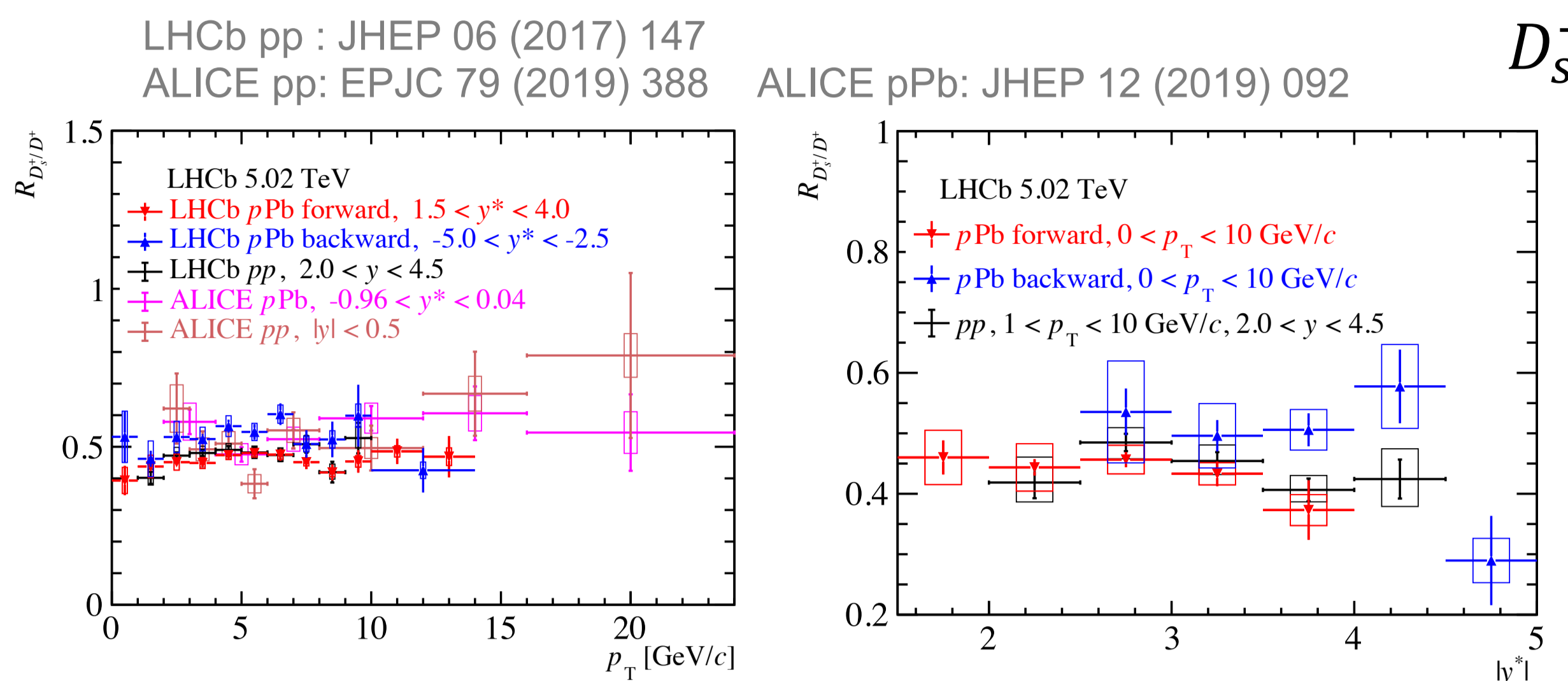
- Increasing trend with a slope significance of 3.4σ at low p_T , qualitatively consistent with expectations from coalescence model
- Flat trend vs. multiplicity at high p_T in agreement with e^+e^- , where fragmentation becomes dominant

5. Prompt D_s^+/D^+ production ratio in $p\text{Pb}$

- $R_{D_s^+/D^+}$ v.s. p_T and y^* @ 5.02 TeV

JHEP 01 (2024) 070

$D^+: c\bar{d}$
 $D_s^+: c\bar{s}$

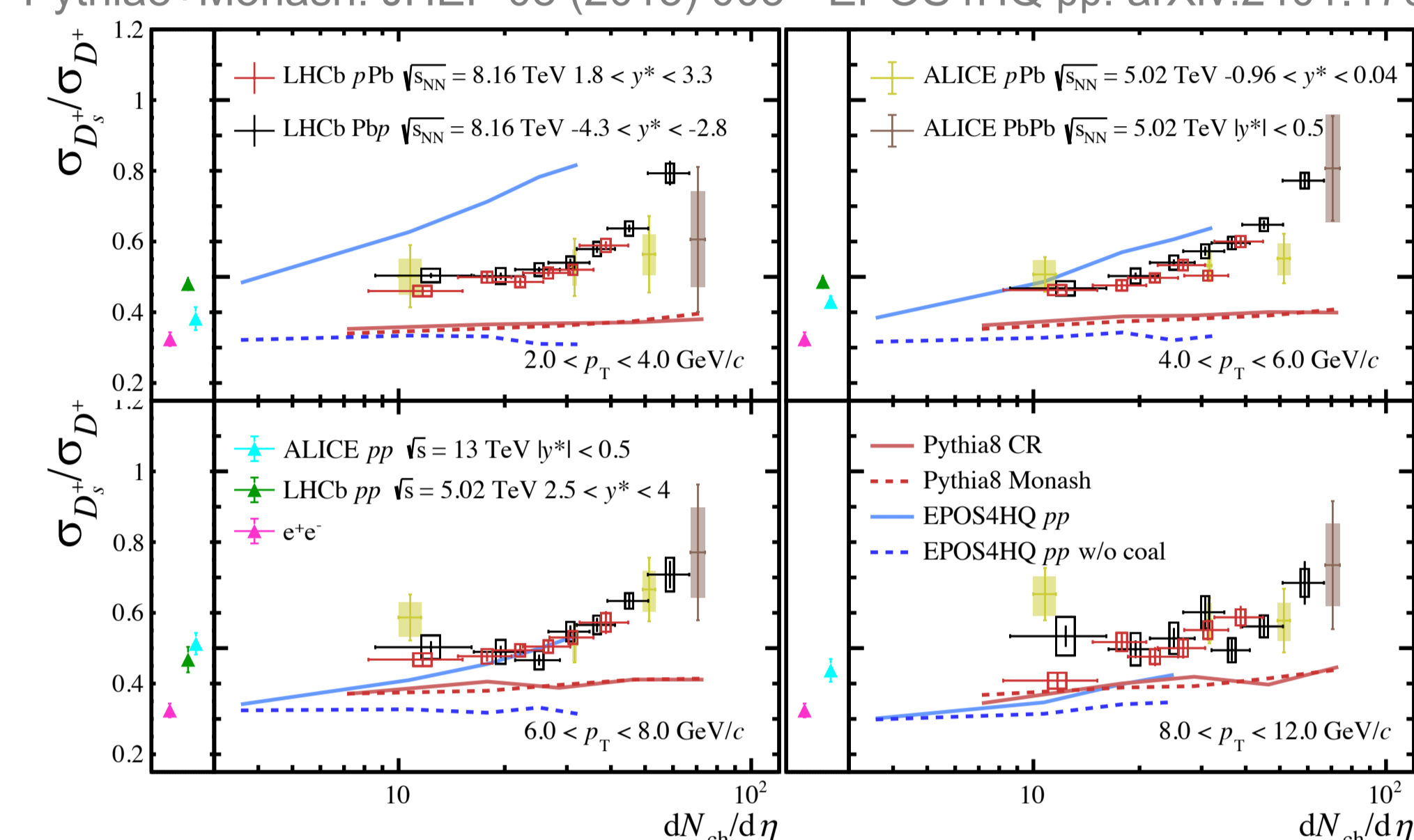


- No significant strangeness enhancement observed, limited by the statistics

- $R_{D_s^+/D^+}$ v.s. $dN_{\text{ch}}/d\eta$ @ 8.16 TeV

Phys. Rev. D 110 (2024) 3, L031105

Pythia8+CR: EPJC 74 (2014) 3024
Pythia8+Monash: JHEP 08 (2015) 003 EPOS4HQ pp: arXiv:2401.17096



- Thanks to the large statistics, $R_{D_s^+/D^+}$ can be measured as a function of charged particle density $dN_{\text{ch}}/d\eta$.
- **First observation** ($> 6\sigma$ at intermediate p_T w.r.t flat distribution) of strangeness enhancement in charm mesons
- Similar rising trend with multiplicity at forward, backward and mid rapidity (ALICE), suggesting that final-state effects dominate the enhancement
- EPOS4HQ+coalescence gives the best description on data except for low p_T , indicating possible coalescence contribution in charm quark hadronization

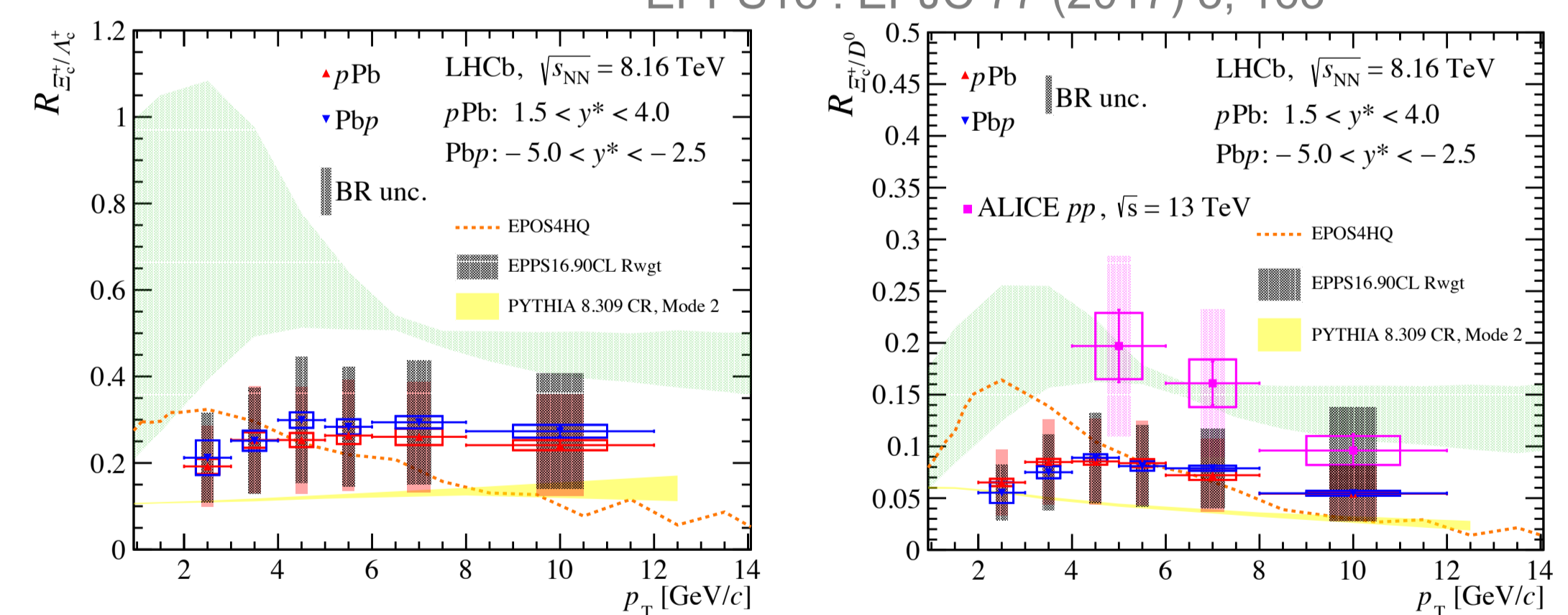
6. Prompt Ξ_c^+ production in $\sqrt{s_{\text{NN}}} = 8.16 \text{ TeV } p\text{Pb}$

- **First measurement** of Ξ_c^+ baryon in $p\text{Pb}$ collisions

Phys. Rev. D 110 (2024) 3, L031105

- $R_{\Xi_c^+/\Lambda_c^+}$ and $R_{\Xi_c^+/D^0}$

EPPS16: EPJC 77 (2017) 3, 163



$\Xi_c^+: cus$
 $\Lambda_c^+: cud$
 $D^0: c\bar{u}$

- Strangeness enhancement and modification of baryon-to-meson ratio can be studied at the same time
- No significant dependence on p_T and enhancement seen for $R_{\Xi_c^+/\Lambda_c^+}$ and $R_{\Xi_c^+/D^0}$
- In generally agreement with HELAC-onia calculation incorporating EPPS16 nPDF

7. Summary

- Evidence for increased B_s^0/B^0 ratio in pp at low p_T , in agreement with the expectation from coalescence model
- First observation of strangeness enhancement in charm hadron production in small systems, D_s^+/D^+ ratio generally reproduced by theoretical predictions incorporating quark coalescence
- Enhanced Ξ_c^+ production not seen, consistent with nPDF model
- Stay tuned for more results on strangeness productions with LHCb Run2 and Run3 data!