Heavy flavour and exotic production at LHCb

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on behalf of the LHCb collaboration

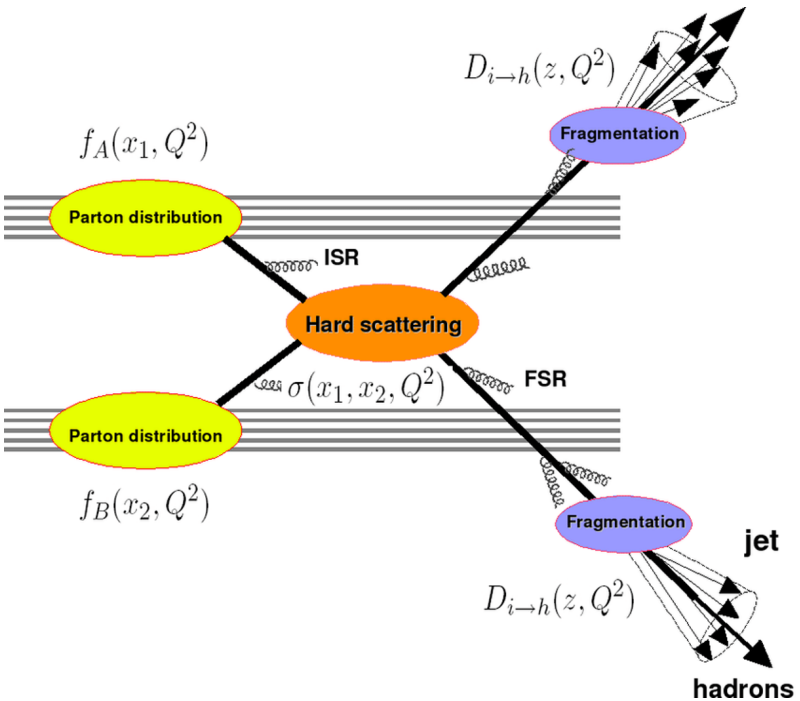
ICHEP 2022

July 7, 2022

Heavy-flavour production at LHCb

Heavy quarks in heavy-ion collisions

- The large quark mass allows pQCD calculation on the heavy-flavour production.

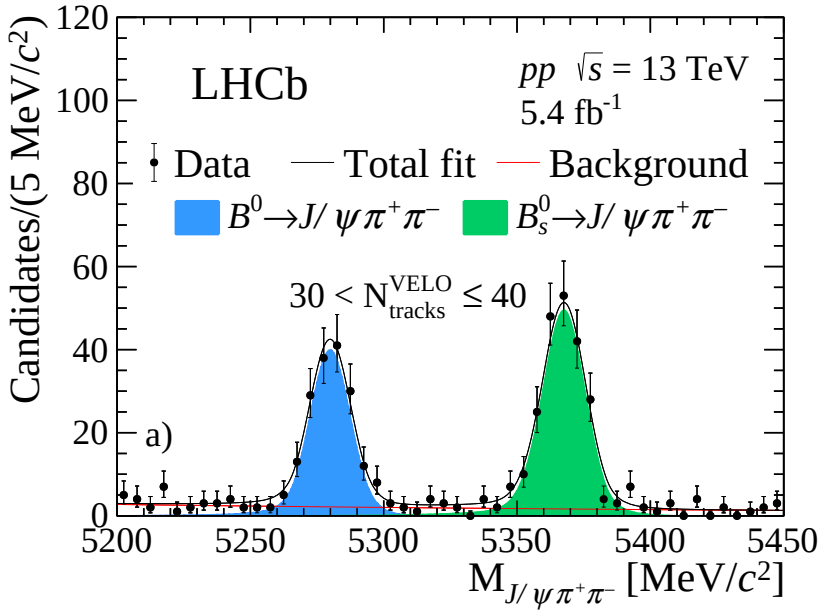


- Initial-state effects
  - nPDF $f(x,Q^2)$
  - Initial-state energy loss
- Interaction with medium created in the collision
  - Final-state energy loss
  - Collective behaviour
- Hadronisation mechanisms
  - Fragmentation
  - Coalescence

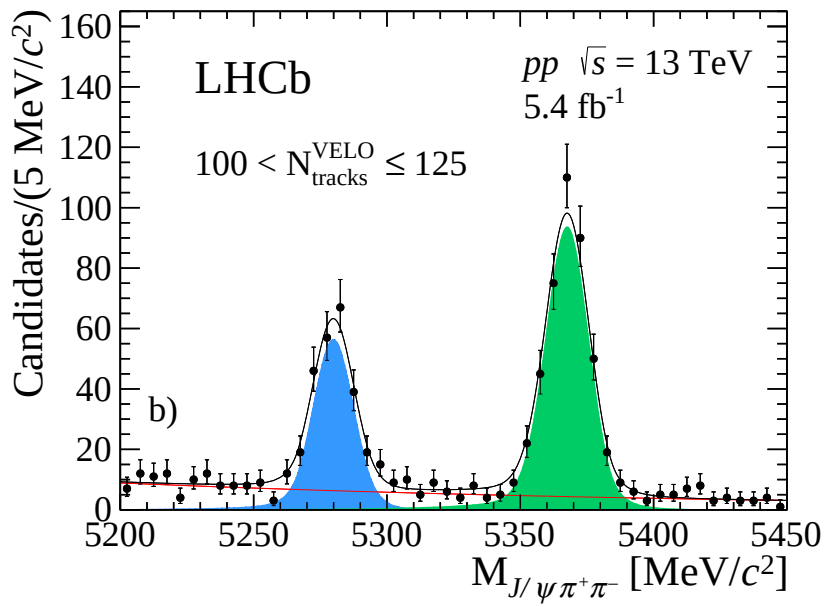
B_s^0/B^0 ratio *vs.* multiplicity in pp at 13 TeV

arXiv:2204.13042

- Test strangeness enhancement with multiplicity and possible hadronisation of b quark via quark coalescence.
- B_s^0 and B^0 candidates reconstructed via common final state $J/\psi\,\pi^+\pi^-$.



Low multiplicity

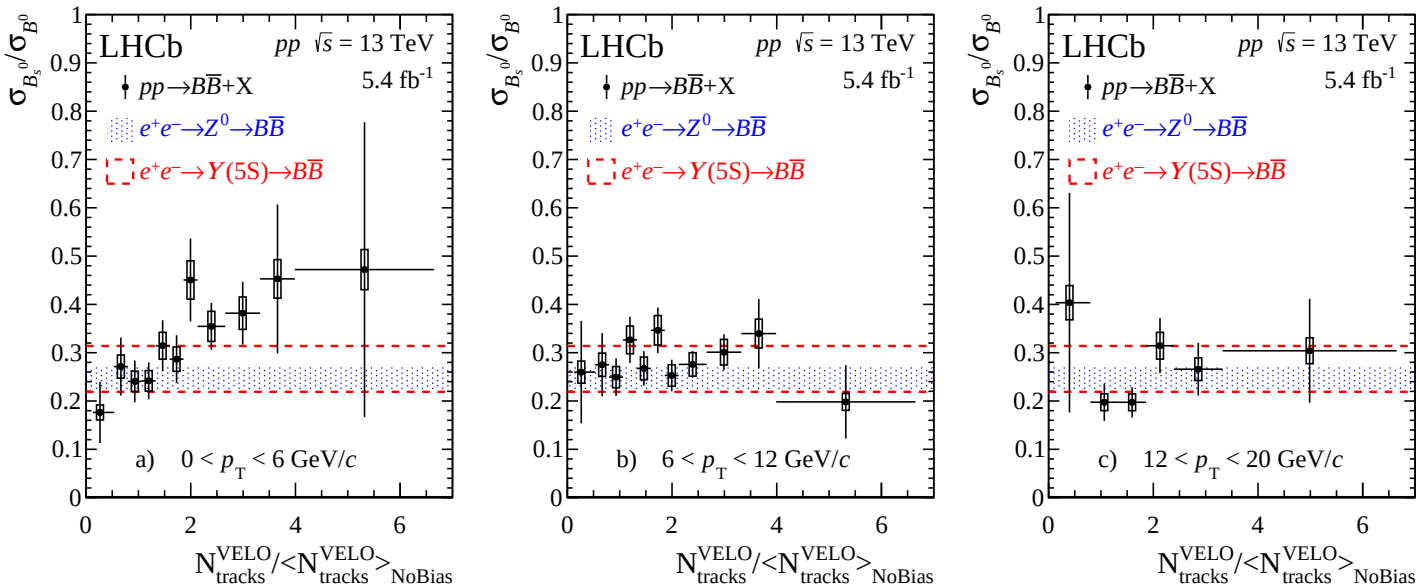


High multiplicity

B_s^0/B^0 ratio *vs.* multiplicity

arXiv:2204.13042

- B_s^0/B^0 ratio in different p_{T} regions:

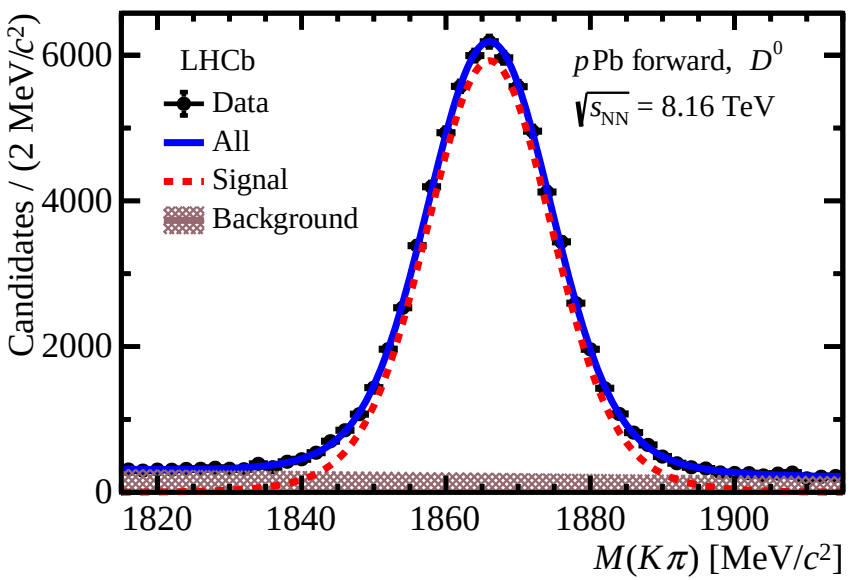


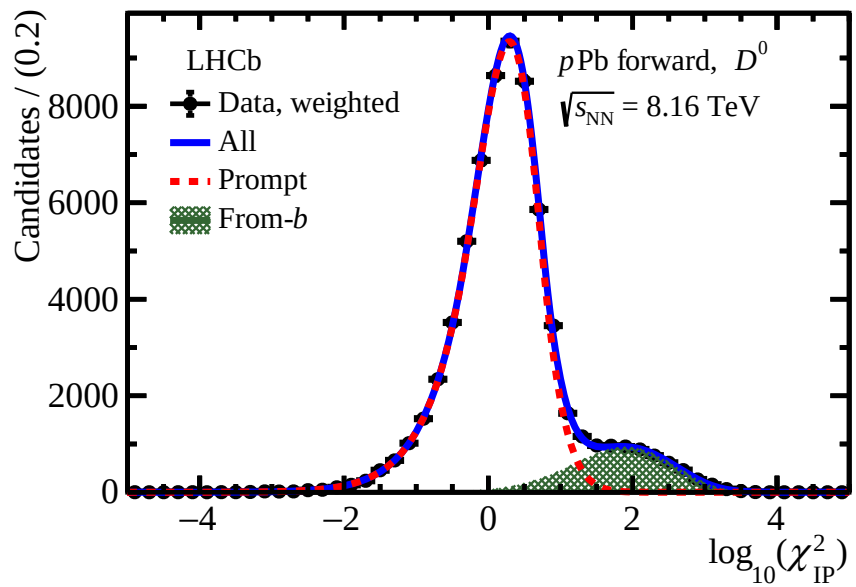
- B_s^0/B^0 ratio increases with multiplicity at low p_{T}, with a slope significance of 3.4σ, qualitatively consistent with expectations from the coalescence model.
- Flat trend *vs.* multiplicity at high p_{T}, in agreement with e^+e^- results.

Prompt D^0 production in pPb at 8.16 TeV

arXiv:2205.03936

- Measurement of D^0 production for both forward and backward rapidity regions down to $p_{\mathrm{T}} \sim 0\,\mathrm{GeV}/c$.
- Approximately 20 times more statistics compared to 5 TeV.
- Fit to background-subtracted impact parameter distribution to extract prompt D^0 yields.

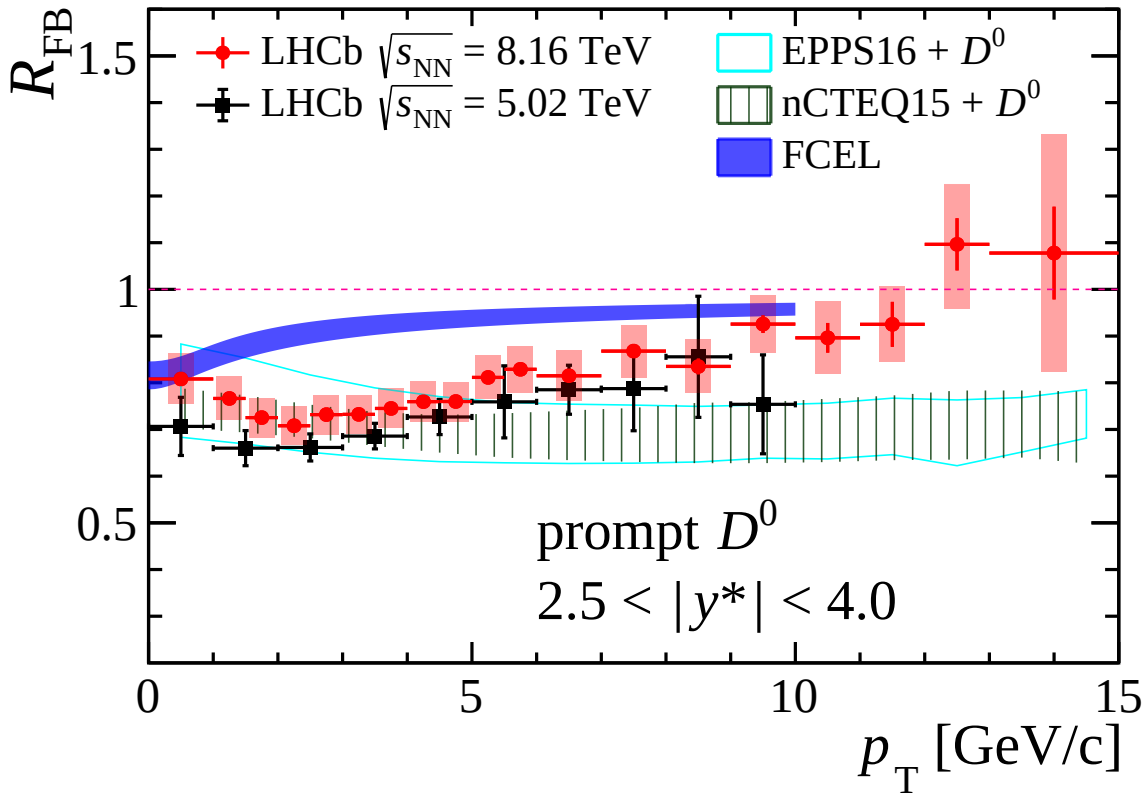


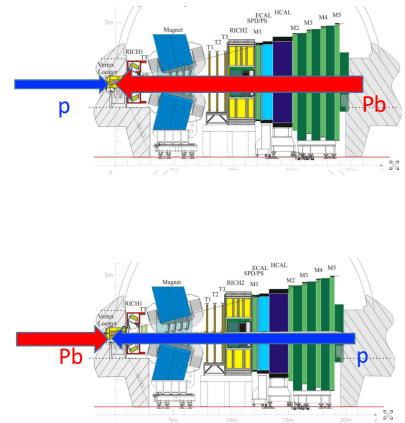


Forward-backward ratio R_{FB}

arXiv:2205.03936

- Comparing the cross-sections between forward and backward regions:



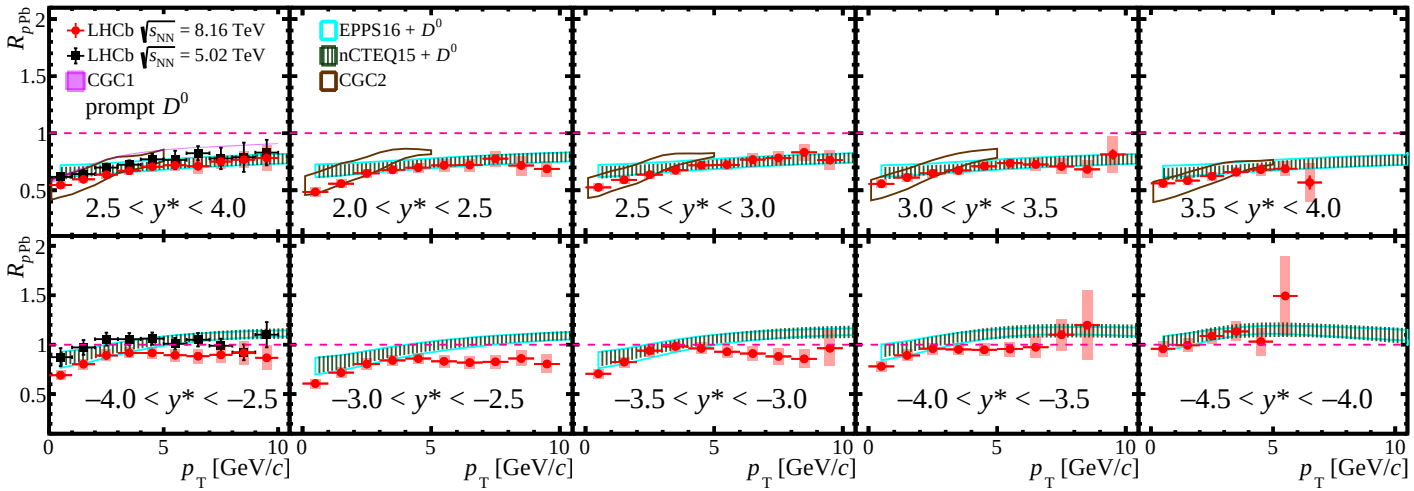


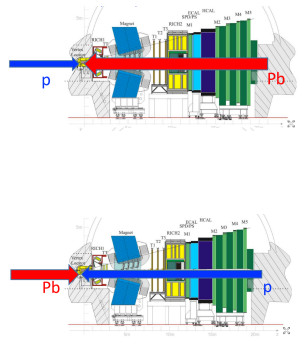
- Significant asymmetry between forward and backward.
- Rising trend over nPDF calculation at high p_{T}.

Nuclear modification factor $R_{p\mathrm{Pb}}$

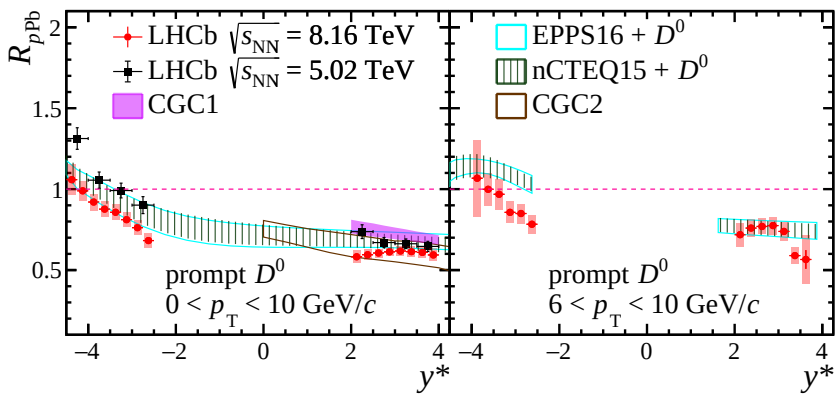
arXiv:2205.03936

- Consistent with theories and 5 TeV results in forward rapidity.





- Lower than nPDF calculations at high p_T in backward rapidity.

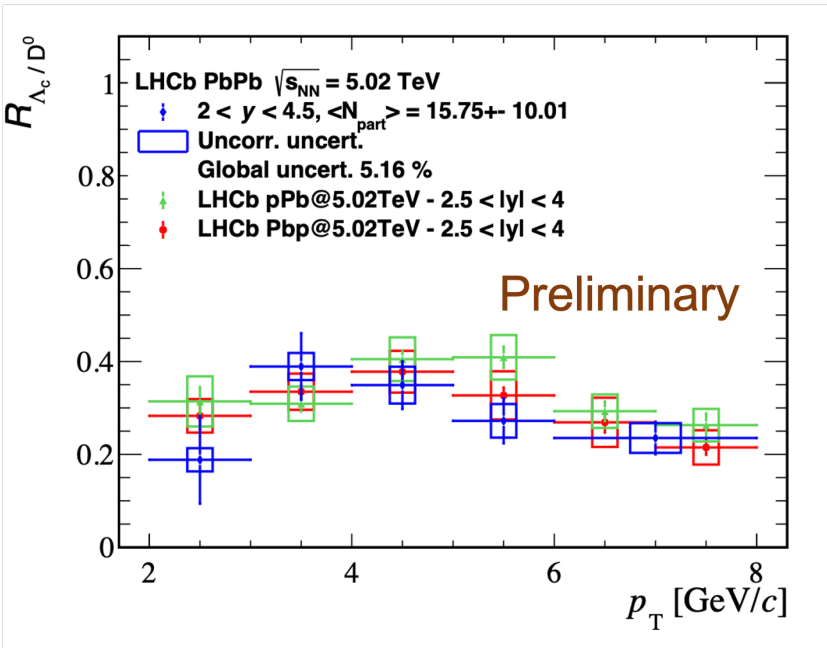


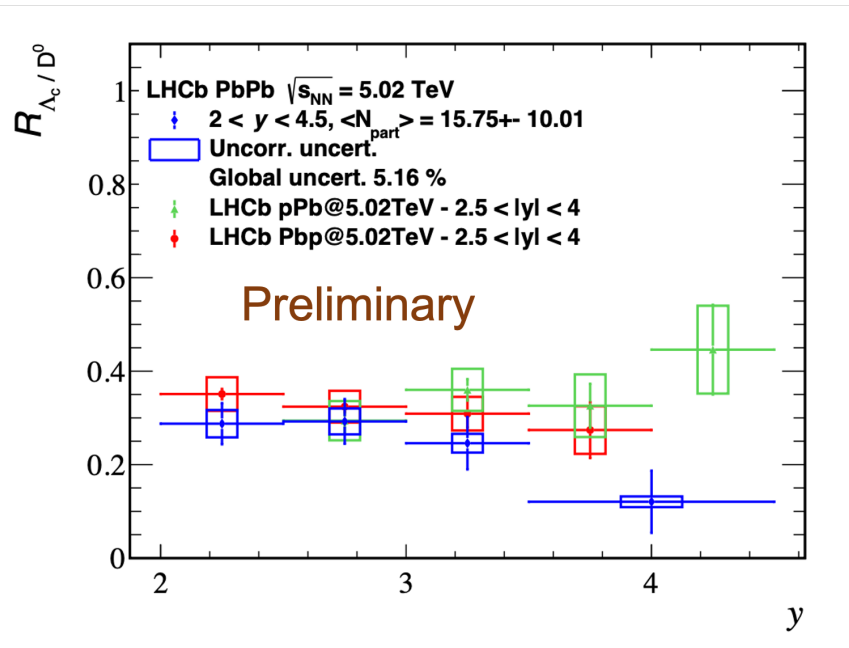
- Possible initial/final-state effects?

Prompt Λ_c^+/D^0 ratio in peripheral PbPb at 5 TeV

LHCb-PAPER-2021-046, in preparation

- First Λ_c^+/D^0 ratio measurement in peripheral PbPb collisions at forward rapidity, up to $\sim 60\%$ centrality.
- Baryon to meson ratio sensitive to hadronisation mechanism.



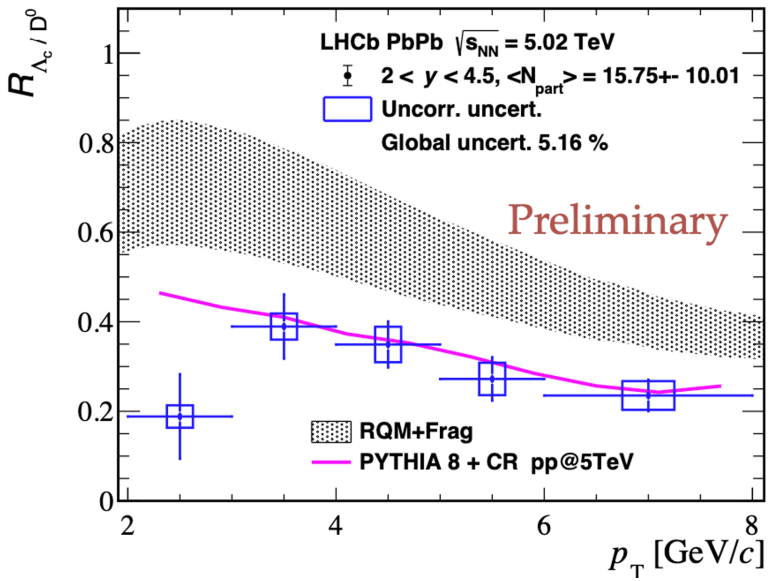


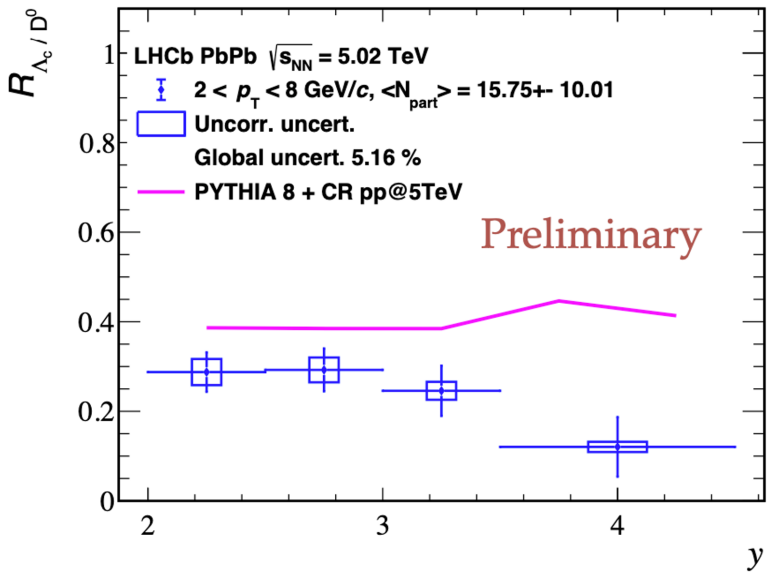
- A relative enhancement at intermediate p_{T}.
- Consistent with LHCb results in pPb at $\sqrt{s_{\mathrm{NN}}}$ =5.02 TeV.

Prompt Λ_c^+/D^0 ratio in peripheral PbPb

LHCb-PAPER-2021-046, in preparation

- Comparisons with theoretical calculations:



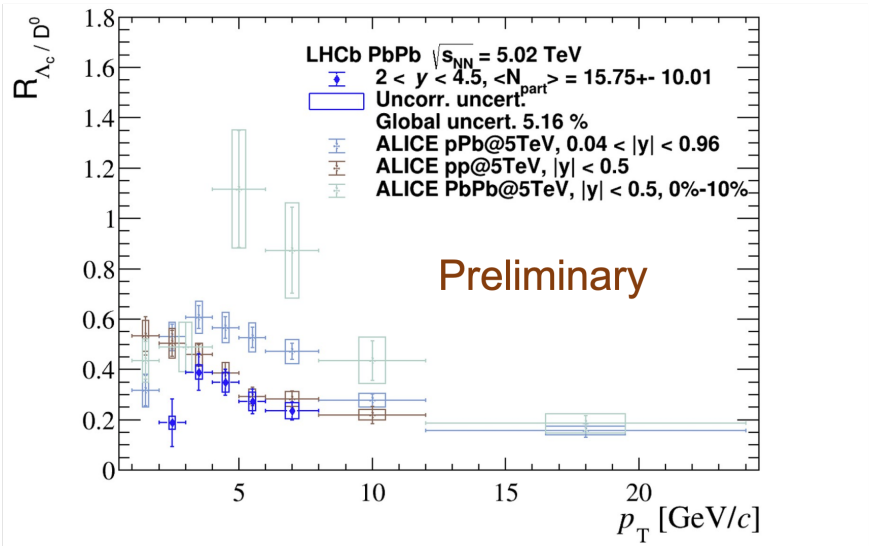


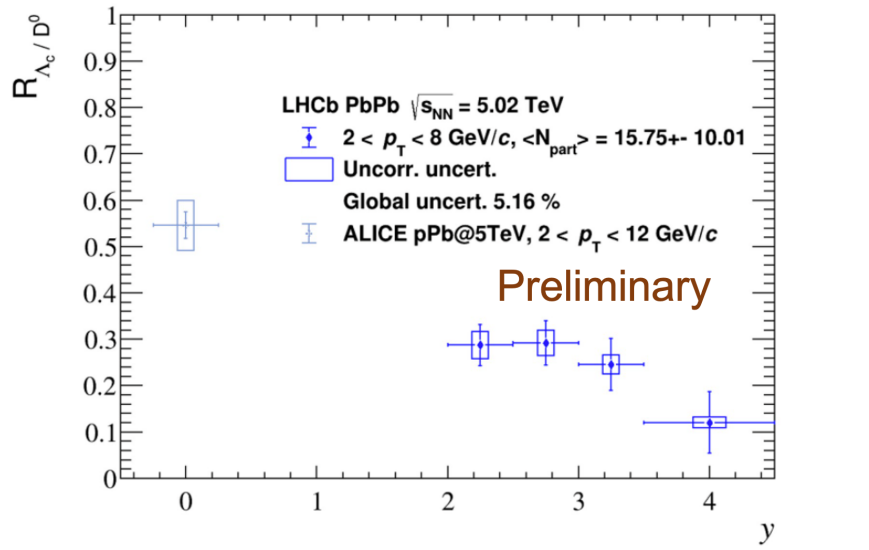
- Compatible with PYTHIA 8 + Colour reconnection prediction for $p_{\mathrm{T}} > 4\,\mathrm{GeV}/c$.
- Standard Hadronisation Model does not reproduce the data.

Prompt Λ_c^+/D^0 ratio in peripheral PbPb

LHCb-PAPER-2021-046, in preparation

- Comparisons with measurements from ALICE:



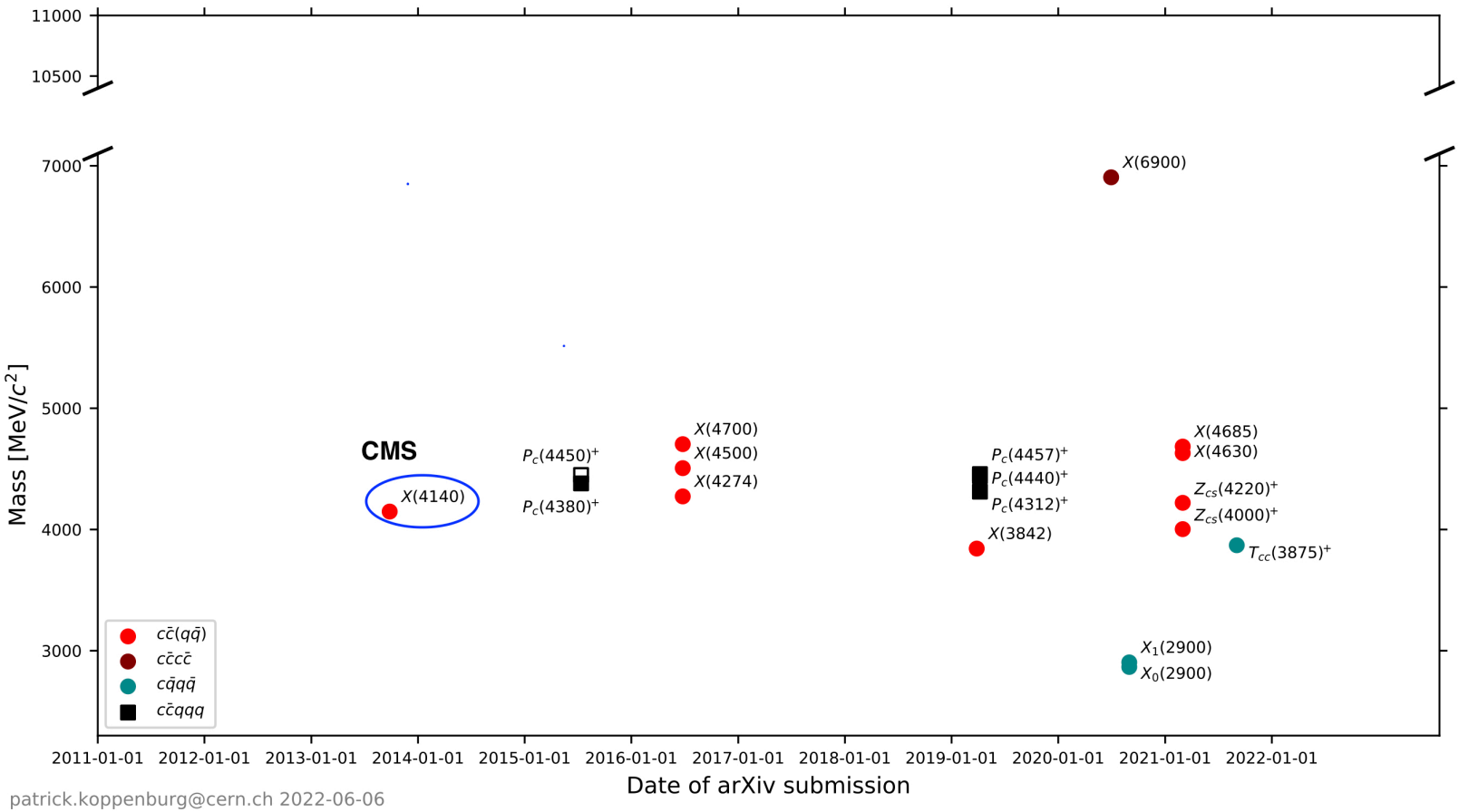


- Similar p_{T} trend with ALICE for $p_{\mathrm{T}} > 4\,\mathrm{GeV}/c$.
- $R_{\Lambda_c^+/D^0}$ *vs.* y at forward rapidity lower than ALICE results at mid rapidity.

Exotic production at LHCb

Exotic production at LHCb

- LHCb is very active in studying exotic states.
- Exotic states observed at the LHC.
  - All but one observed by LHCb.

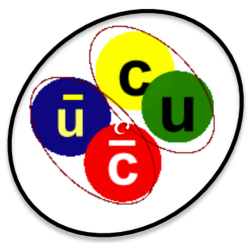


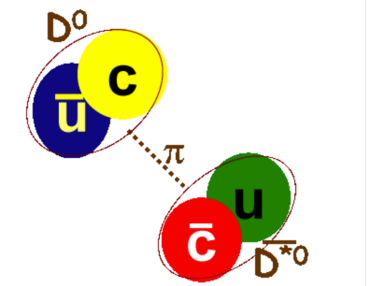
Link

$\chi_{c1}(3872)$ structure

- The structure of $\chi_{c1}(3872)$ state still not clear: compact tetraquark / hadronic molecule ?

  Compact tetraquark Hadronic molecule





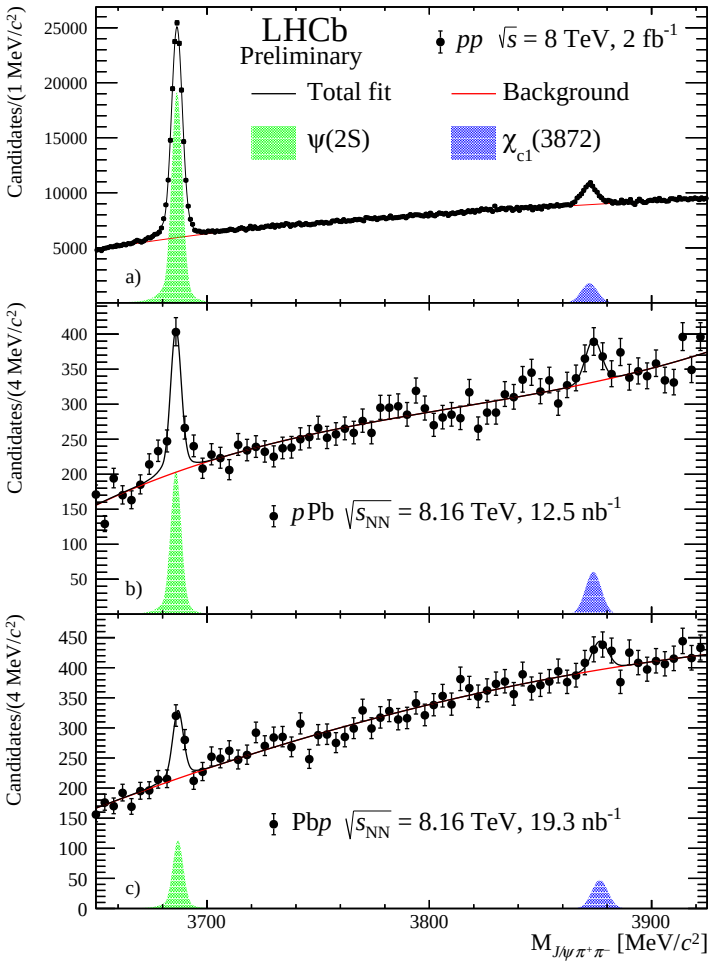
- Or superposition of different states:

  $\chi_{c1}(3872) = a|c\bar{c}\rangle + b|c\bar{c}q\bar{q}\rangle$?

- Compare the $\chi_{c1}(3872)$ state with conventional $c\bar{c}$ meson $\psi(2S)$.
- Probe the final-state effects on $\chi_{c1}(3872)$ according to comover/coalescence model.

$\chi_{c1}(3872)$ and $\psi(2S)$ signal

LHCb-CONF-2022-001

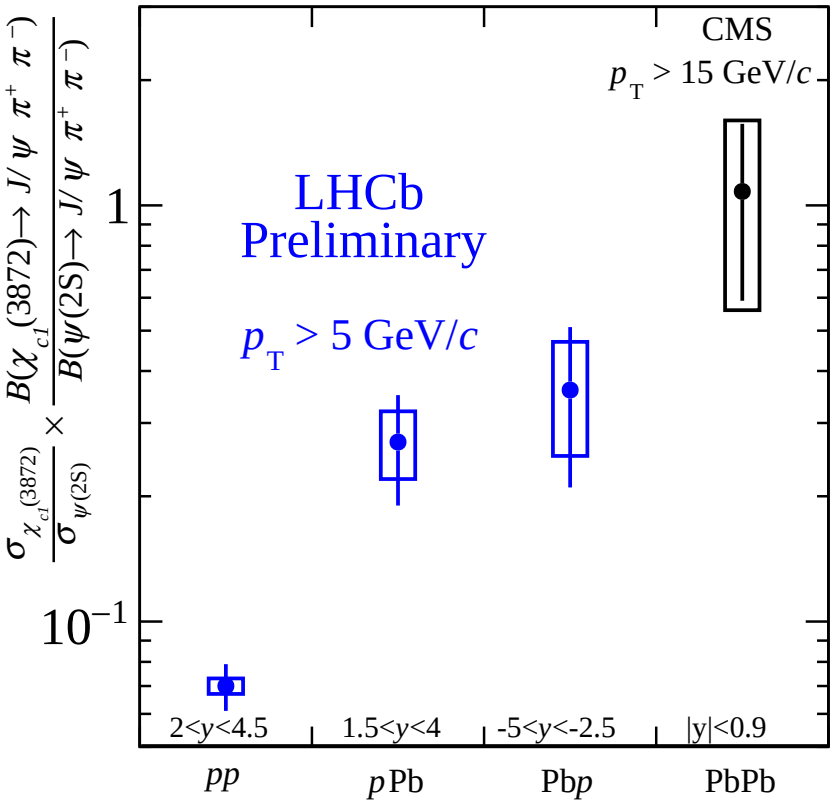


- First measurement on $\chi_{c1}(3872)$ in pPb collisions.
- $\chi_{c1}(3872)$ and $\psi(2S)$ states reconstructed via common final states $J/\psi\,\pi^+\pi^-$.
- Use pseudo decay-time $t_z = (z_{\text{decay}} - z_{\text{PV}}) \cdot M/p_z$ to select prompt components.

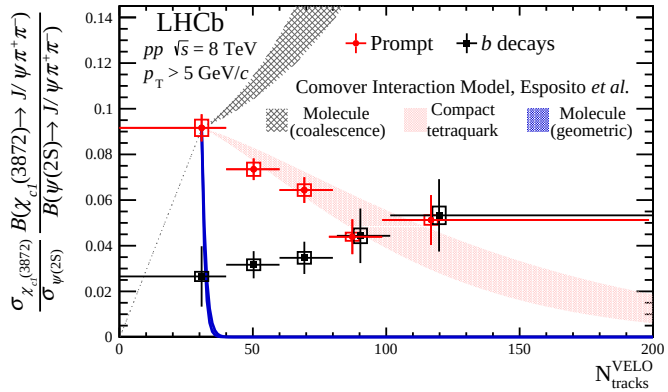
System	Rapidity	Energy	Luminosity
pp	$2 < y < 4.5$	8 TeV	$2\,\text{fb}^{-1}$
pPb	$1.5 < y_{\text{cm}} < 4$	8.16 TeV	$12.5\,\text{nb}^{-1}$
Pbp	$-5 < y_{\text{cm}} < -2.5$	8.16 TeV	$19.3\,\text{nb}^{-1}$

$\chi_{c1}(3872)/\psi(2S)$ ratio across collision systems

LHCb-CONF-2022-001
Phys. Rev. Lett. 126, (2021) 9, 092001



- Initial-state effects largely cancelled in ratio
- Final-state effects dominant



- The ratio increases with the system size, different from the decreasing trend as multiplicity in pp
- Indicate that coalescence may dominate the $\chi_{c1}(3872)$ production in pPb?
- $R_{p\mathrm{Pb}}$ in preparation

Summary and outlook

- LHCb has strong capabilities to study heavy flavour.
  - B_s^0/B^0 ratio in pp increases with the particle multiplicity at low-p_{T}, qualitatively consistent with expectations from the coalescence model.
  - Tension between prompt D^0 $R_{p\mathrm{Pb}}$ and nPDF predictions at high-p_{T} in Pbp.
  - Prompt Λ_c^+/D^0 ratio in peripheral PbPb is consistent with LHCb results in pPb while lower than ALICE results at mid rapidity.
- LHCb is very active in studying exotic states.
  - Prompt $\chi_{c1}(3872)/\psi(2S)$ ratio increases with the collision system size, different from the decreasing trend with multiplicity in pp.
- Stay tuned for more results from Run2 data.
- More opportunities for heavy-ion physics at Run3 and beyond.

Thanks

Backups

LHCb detector

JINST 3 (2008) S08005
IJMPA 30 (2015) 1530022

- A single-arm forward spectrometer, covering the pseudo-rapidity range of $2 < \eta < 5$.
- Designed for studying particles containing b or c quarks.
- A general purpose detector measuring pp/pPb/PbPb.