Heavy flavour and exotic production at LHCb

Sara Sellam* on behalf of the LHCb Collaboration

DIS2022

Santiago de Compostela, Spain

*sara.sellam@cern.ch

Topics:

Heavy Flavour:

- B_s^0/B^0 production versus multiplicity in pp at 13 TeV.
  arXiv:2204.13042

- Λ_c^+/D^0 ratio in peripheral PbPb collisions.
  LHCB-PAPER-2021-046 (in preparation)

- Open-charm production in pPb collisions.
  LHCb-PAPER-2022-007 (in preparation)

Exotic production:

- $\chi_{c1}(3872)$ and $\psi(2S)$ production in pp collisions with particle multiplicity.
  Phys.Rev.Lett. 126 (2021) 9, 092001

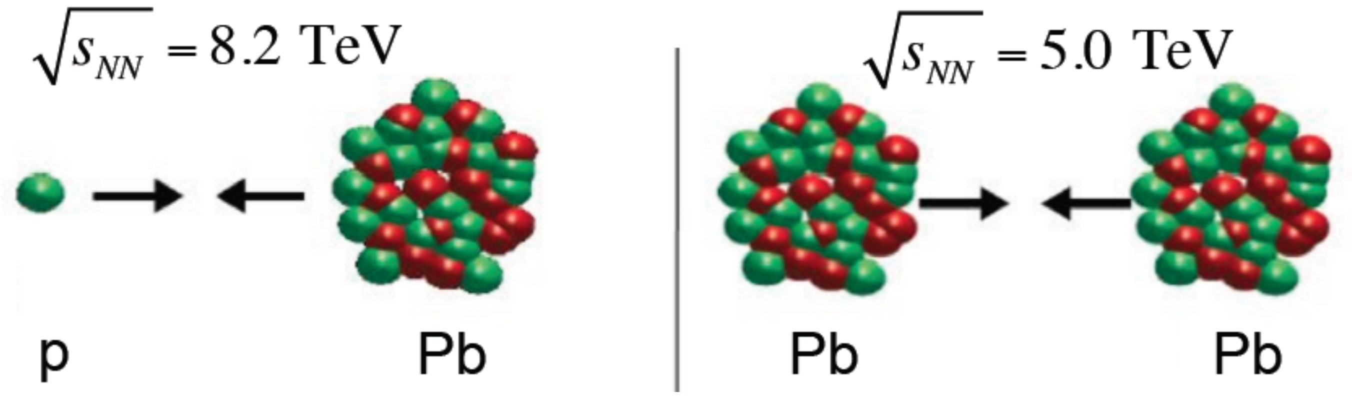
- Production of $\chi_{c1}(3872)$ and $\psi(2S)$ in pPb collisions.
  LHCb-CONF-2022-001

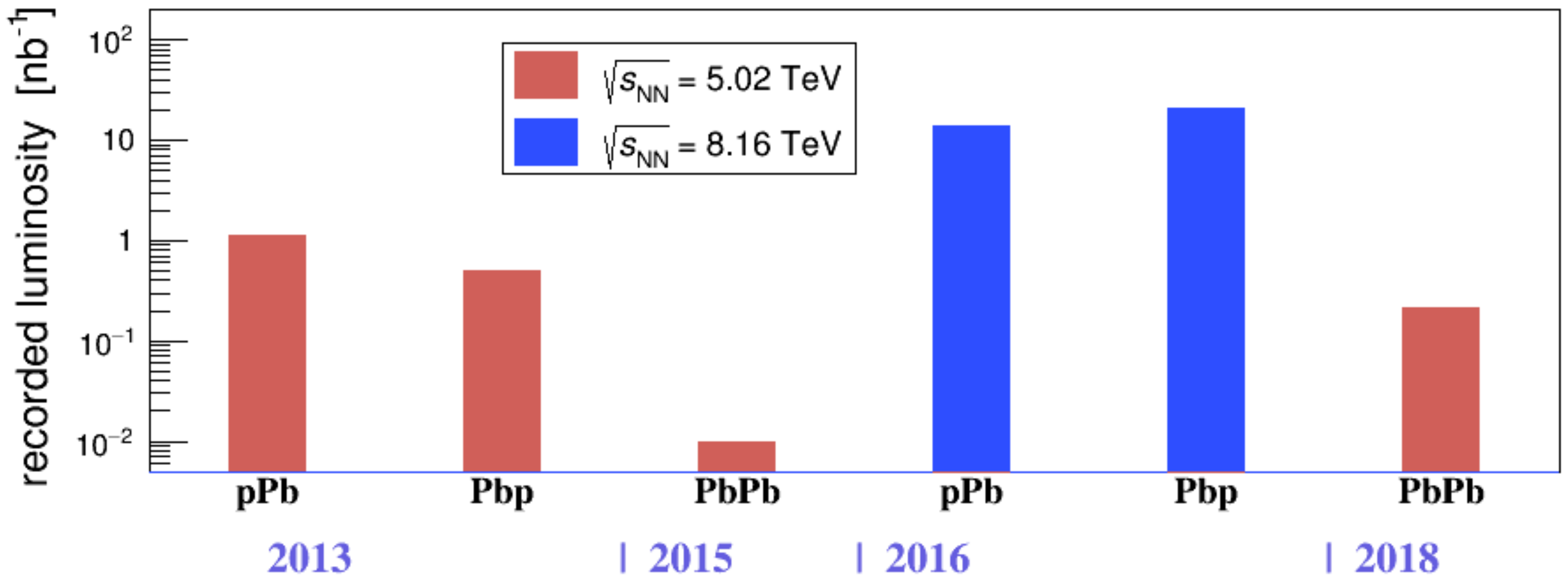
- Doubly charmed T_{cc}^+ tetraquark.
  arXiv:2109.01056 (accepted for publication in Nature Communications)

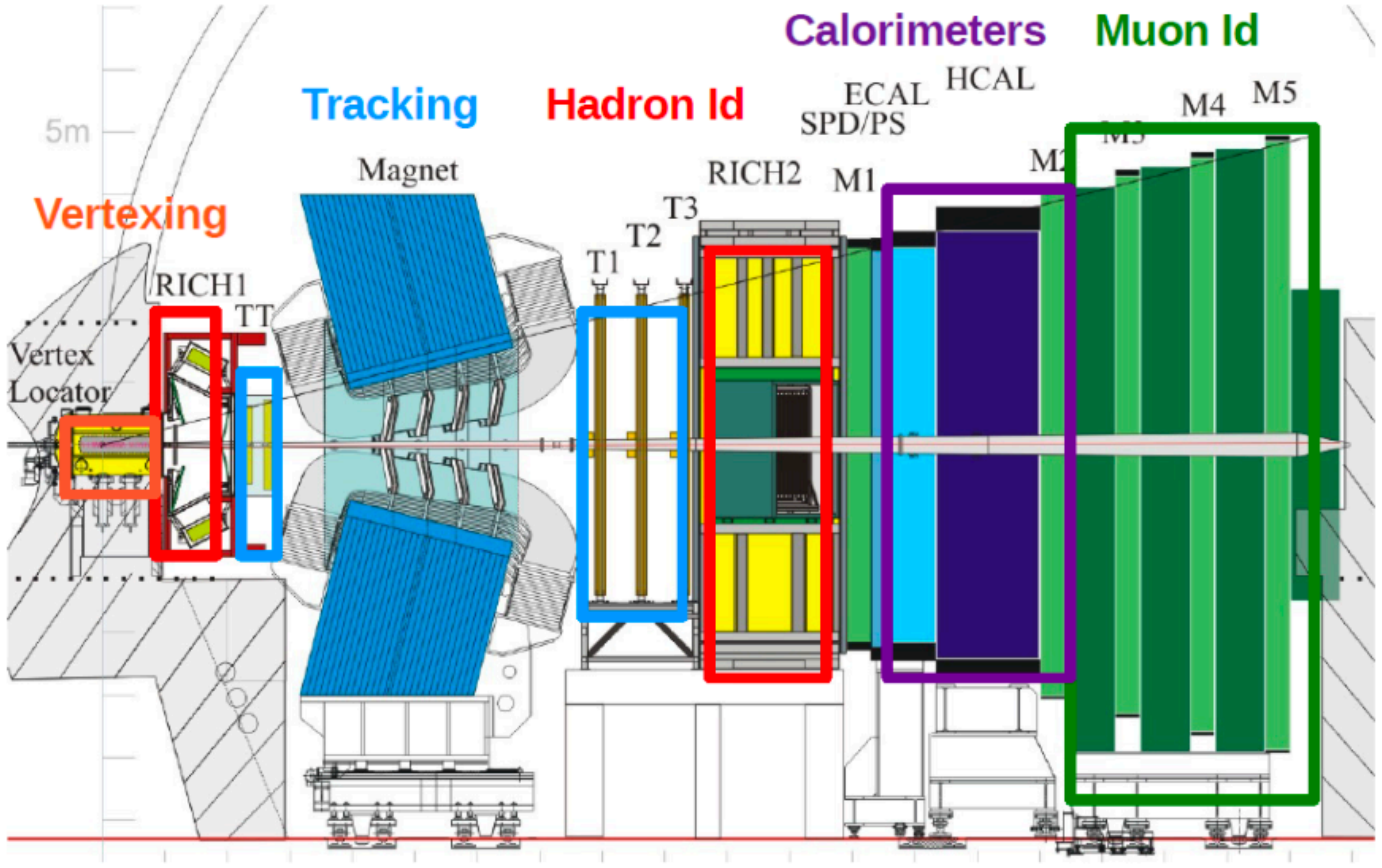
LHCb data set

In addition to *pp* collisions:

Collider mode







JINST 3 (2008)S08005

B_s^0/B^0 production versus multiplicity in pp at 13 TeV

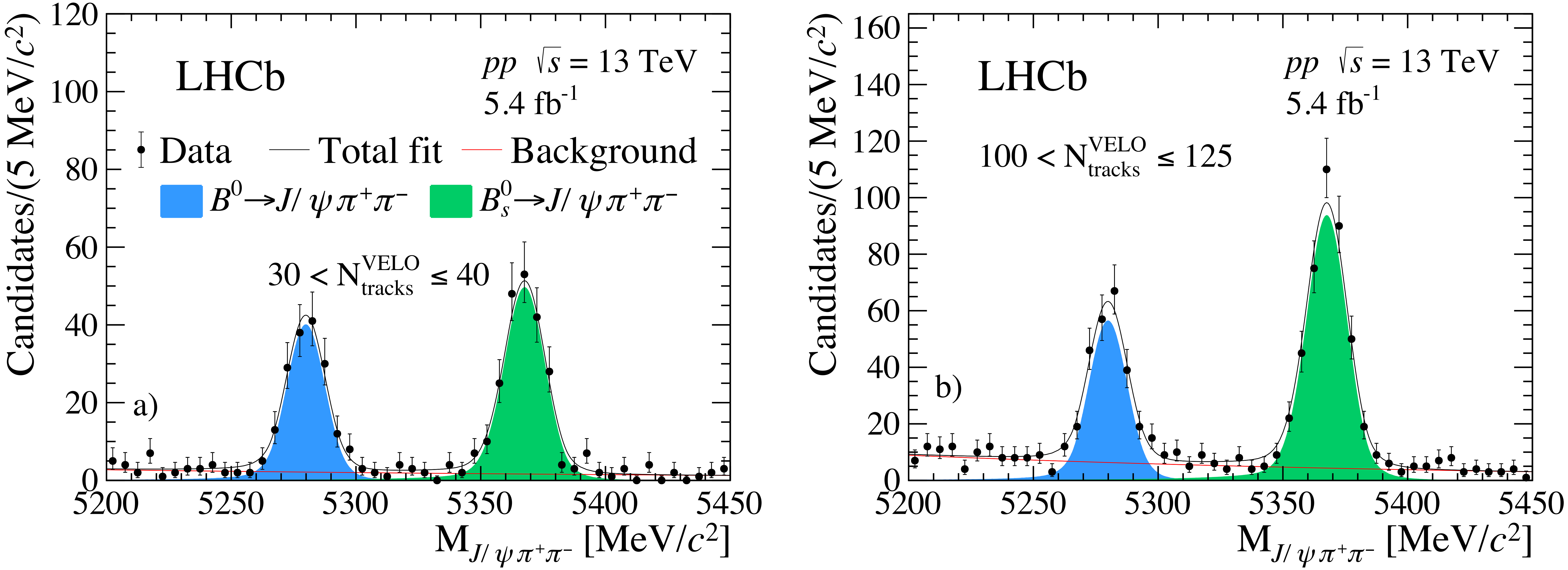
arXiv:2204.13042

Motivation:

- B_s^0/B^0 vs multiplicity: probe hadronization via coalescence.

N_{Tracks}^{VELO} : the number of VELO tracks.

$30 < N_{tracks}^{VELO} \leq 40$ $100 < N_{tracks}^{VELO} \leq 125$



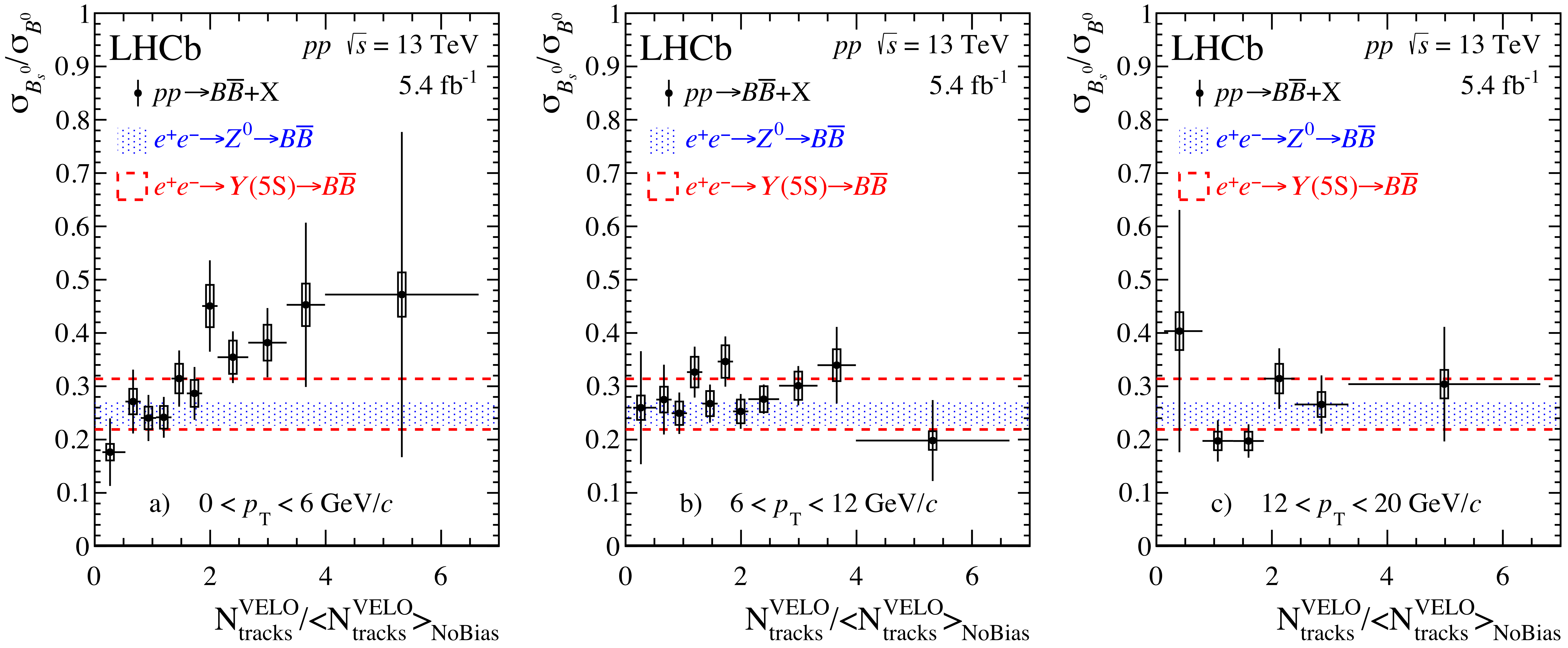
An increase of the B_s^0 yield relative to the B^0 yield in high multiplicity

B_s^0/B^0 production versus multiplicity in pp at 13 TeV

arXiv:2204.13042

N_{Tracks}^{VELO} : the number of VELO tracks.

$< N_{Tracks}^{VELO} >_{noBias}$: the mean number of tracks in NoBias events.

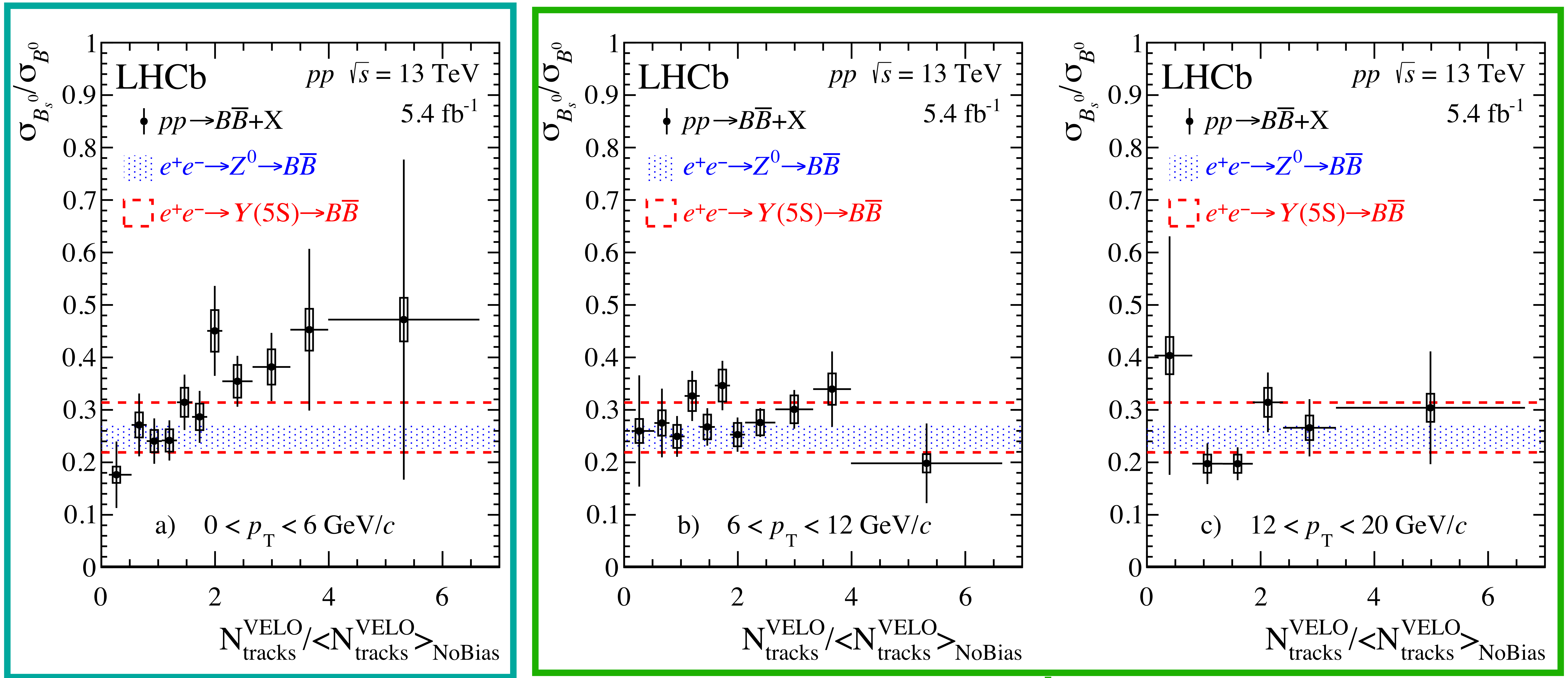


$0 < p_T < 6\ GeV/c$ $6 < p_T < 12\ GeV/c$ $12 < p_T < 20\ GeV/c$

B_s^0/B^0 production versus multiplicity in pp at 13 TeV

N^{VELO}_{Tracks} : the number of VELO tracks.

$< N^{VELO}_{Tracks} >_{noBias}$: the mean number of tracks in NoBias events.



- $\sigma(B_s^0)/\sigma(B^0)$ is consistent with values measured in e^+e^- collisions at low p_T.
- The ratio increases with multiplicity.

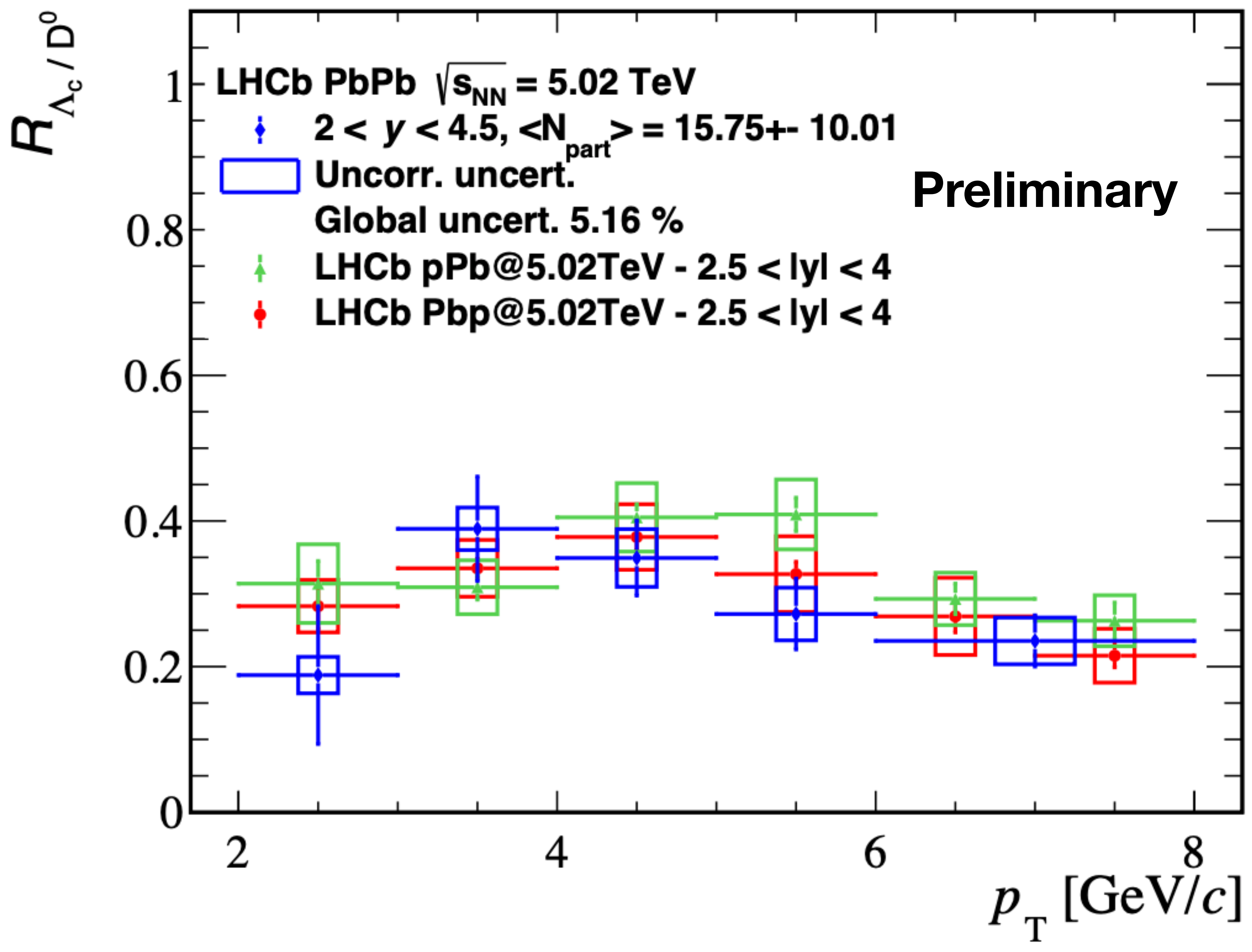
- No significant dependence on multiplicity is observed.
- Results consistent with e^+e^-.

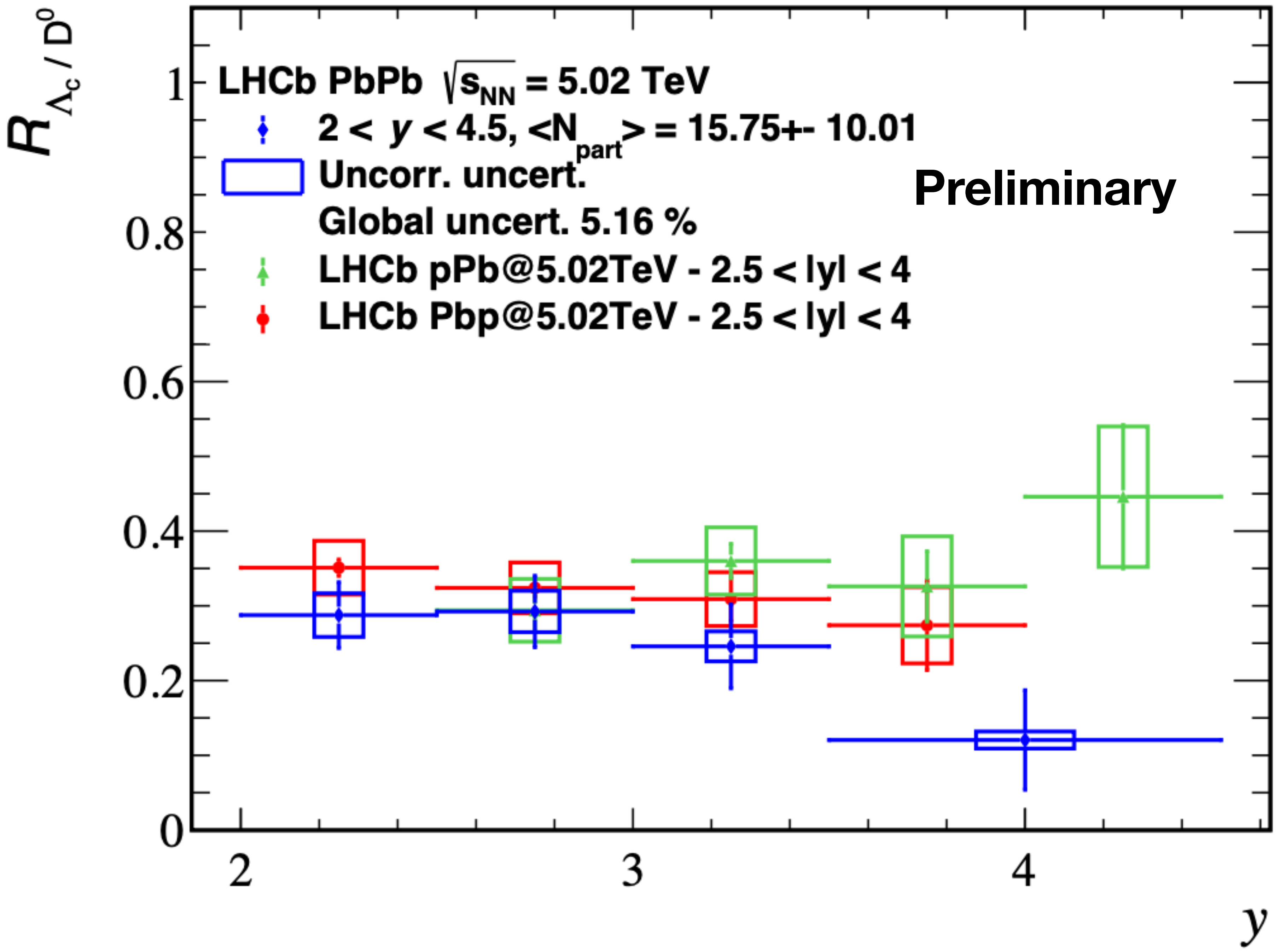
Λ_c^+/D^0 ratio in peripheral PbPb collisions

LHCB-PAPER-2021-046
(in preparation)

Motivation:

- Baryon/meson sensitive to hadronization mechanism.





- The Ratio Lc/D0 is compatible with previous LHCb measurements in pPb.

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

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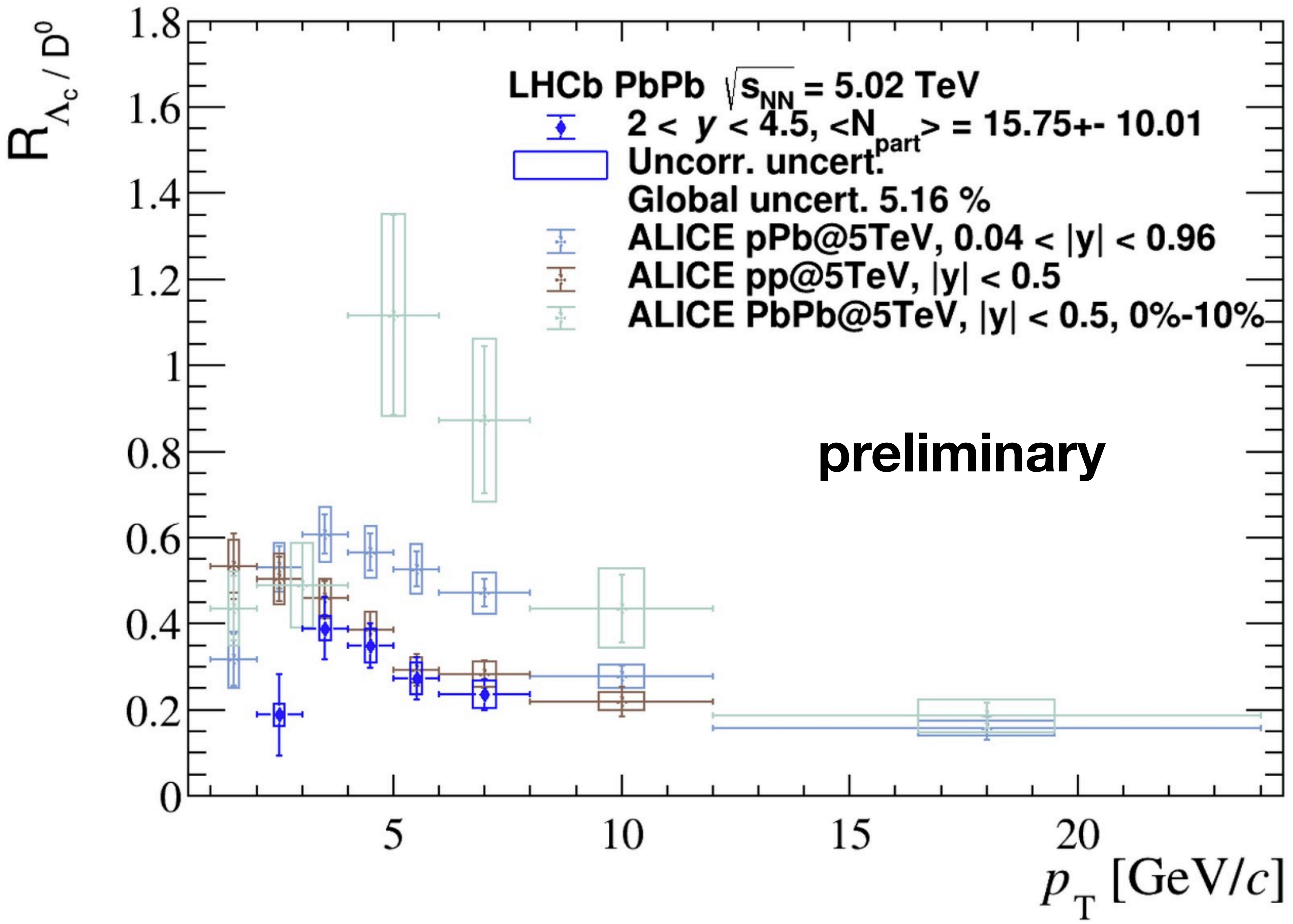
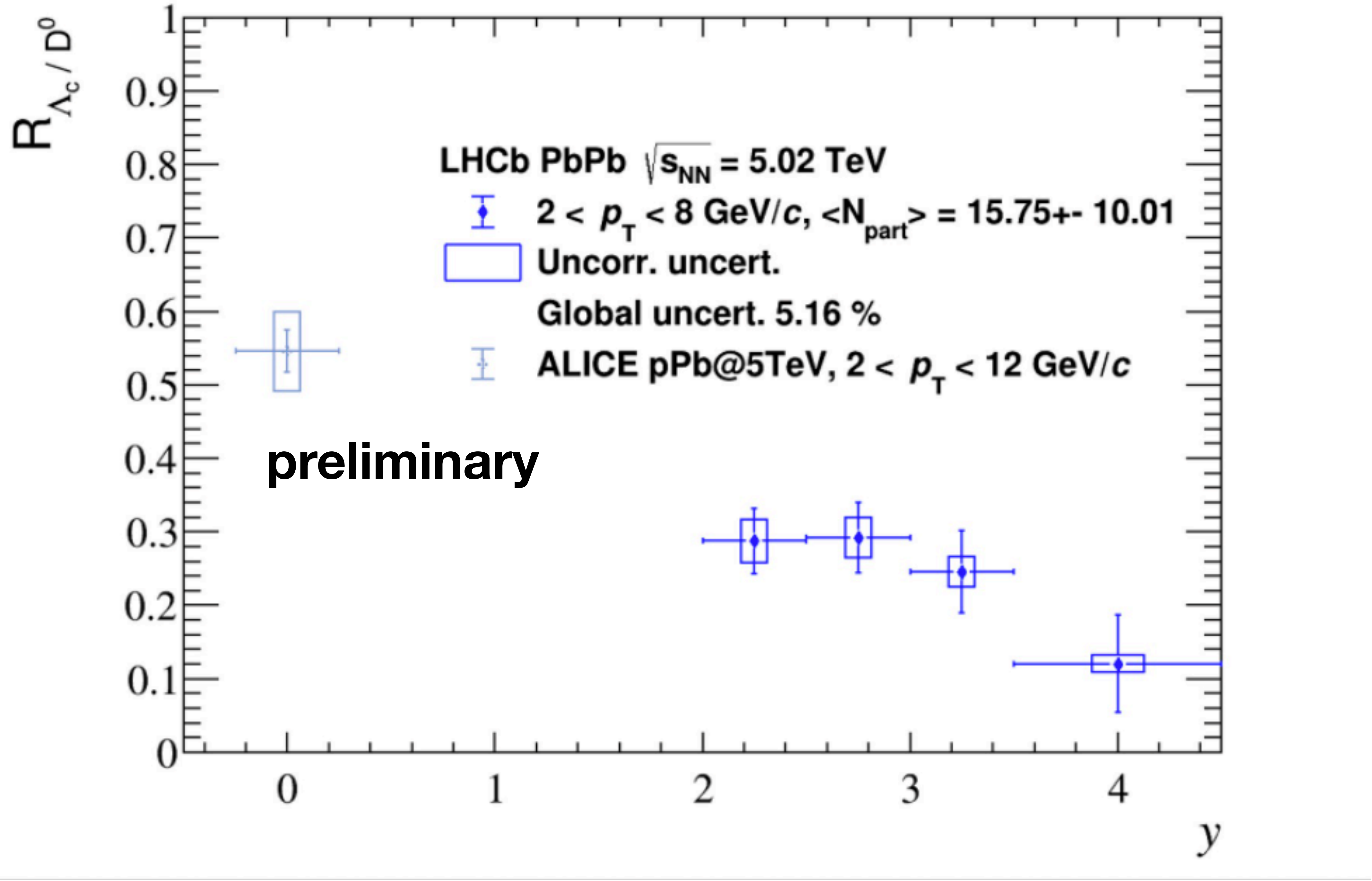
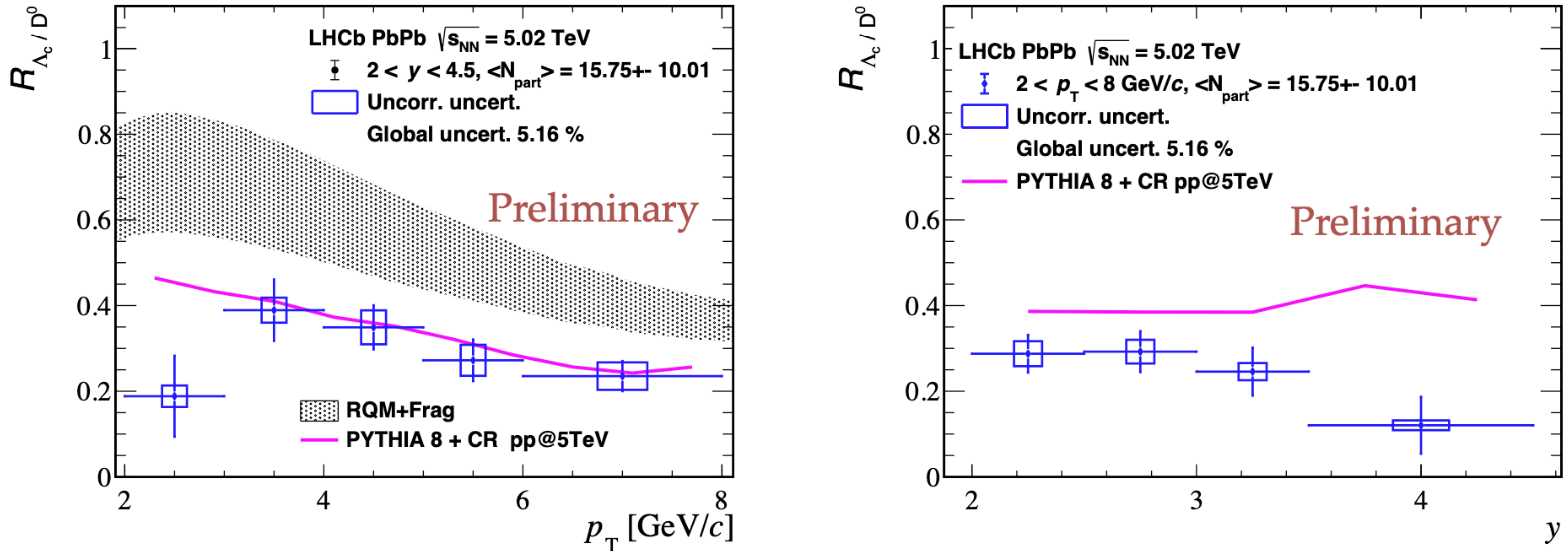




- $R(\Lambda_c^+/D^0)$ follows a similar trend as ALICE.
- Lc/D0 ratio is lower in forward rapidity than ALICE in midrapidity.

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

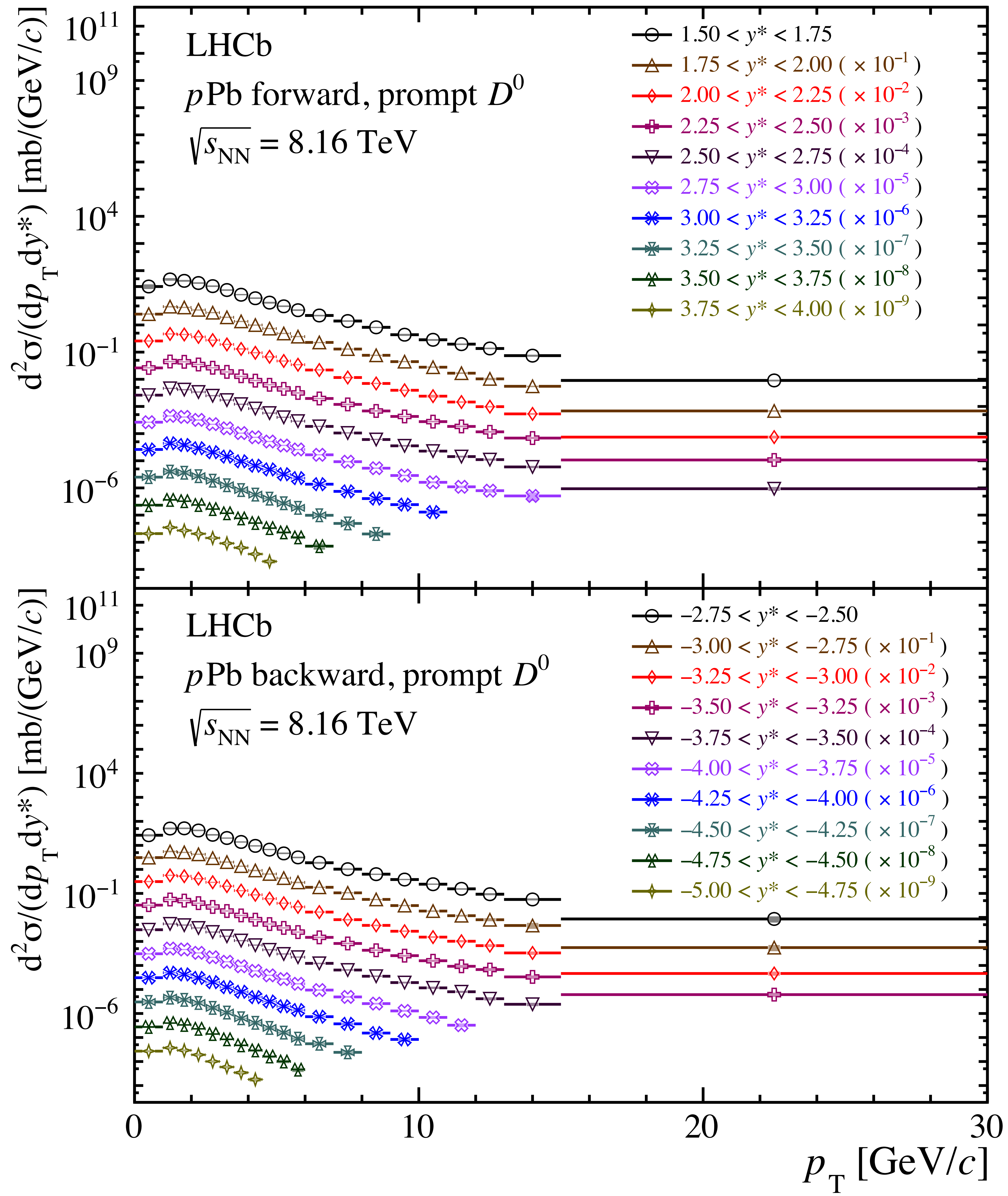
LHCB-PAPER-2021-046
(in preparation)

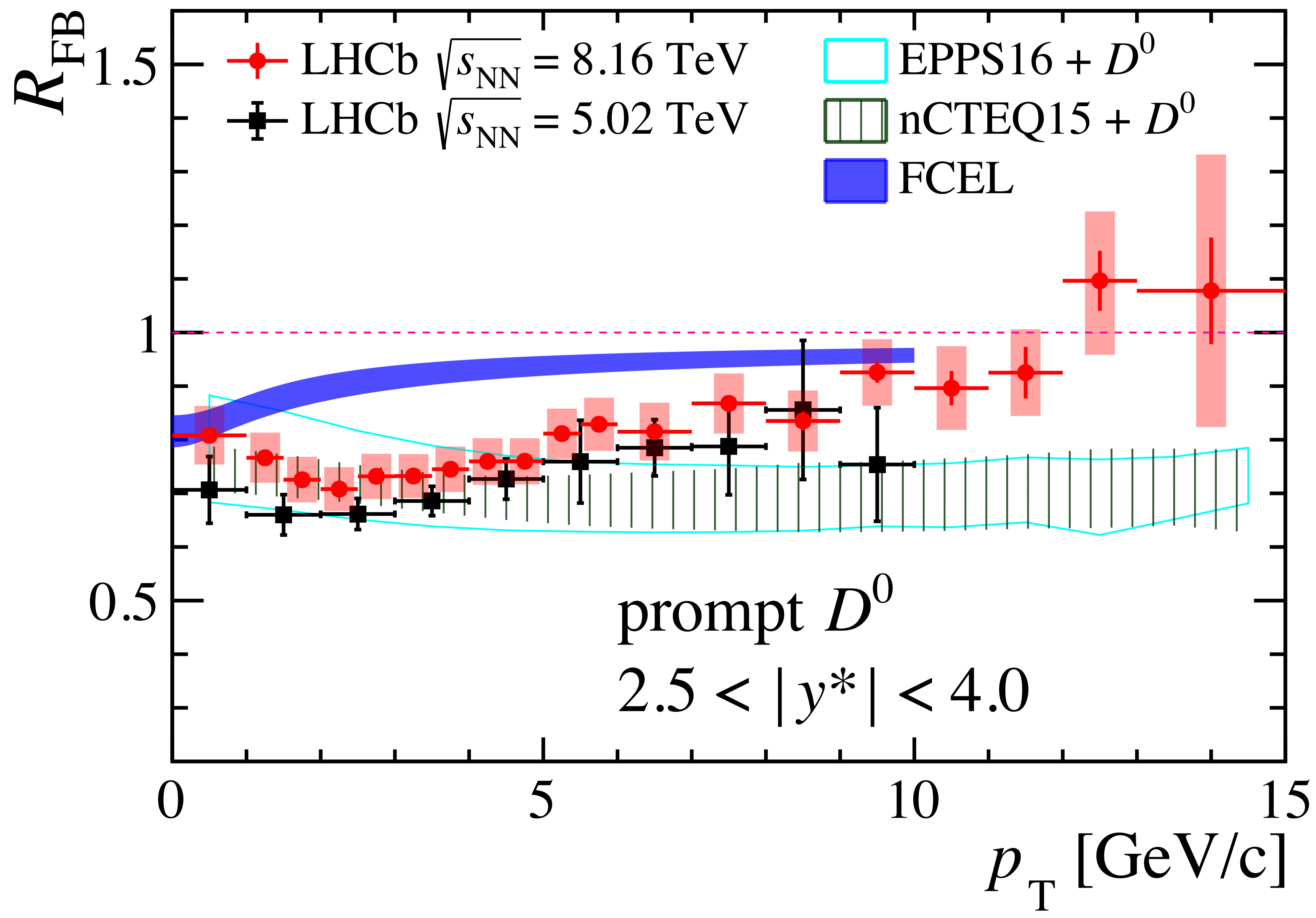


- $R(\Lambda_c^+/D^0)$ show an enhancement at intermediate p_T.
- PYTHIA8 + Colour reconnection describes the data for $p_T > 5$ GeV/c.
- Standard Hadronization Model does not reproduce the data.

D^0 production in pPb collisions

LHCb-PAPER-2022-007 (in preparation)

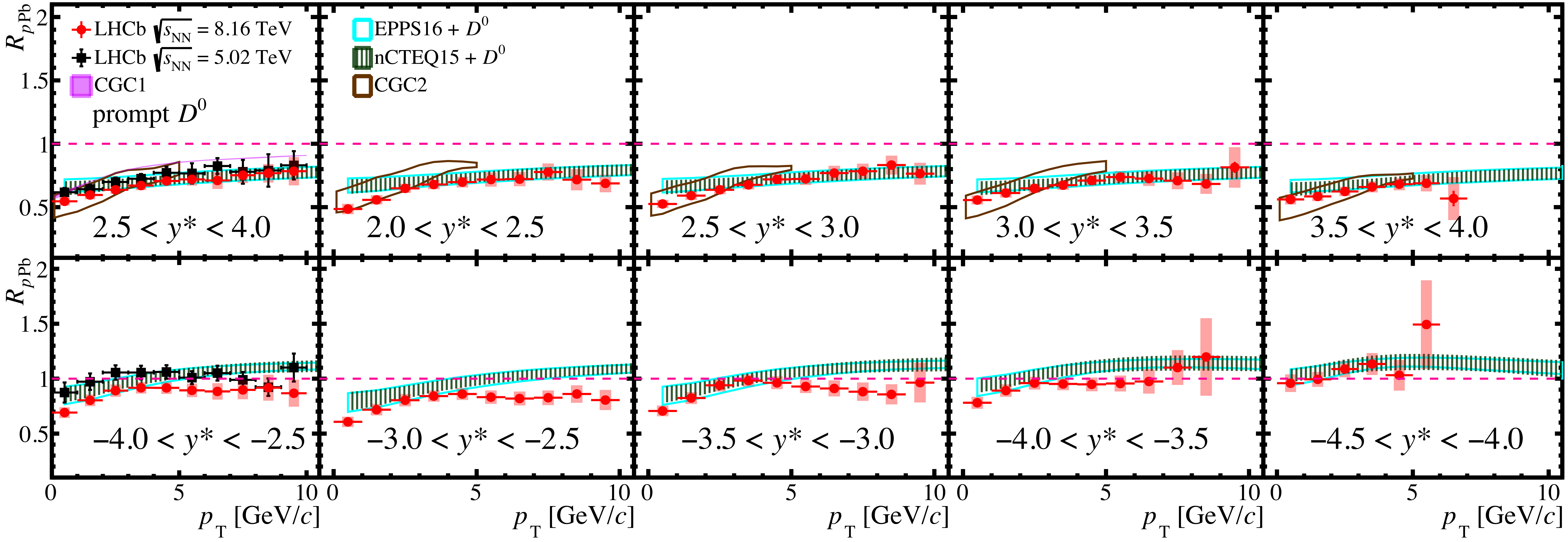




- Tension between data and theory predictions at high p_T.
- D^0 cross-section measurement in pPb/Pbp that covers $0 < p_T < 30$ GeV/c.

Most precise measurement of the prompt D^0 production in pPb collisions from the LHC to date.

D^0 production in pPb collisions



- The measurement of R_{pPb} provides a stringent test of nPDFs down to small x regions.
- Tension between data and theory predictions at high p_T.

Most precise measurement of the prompt D^0 production in pPb collisions from the LHC to date.

Exotic Production at LHCb

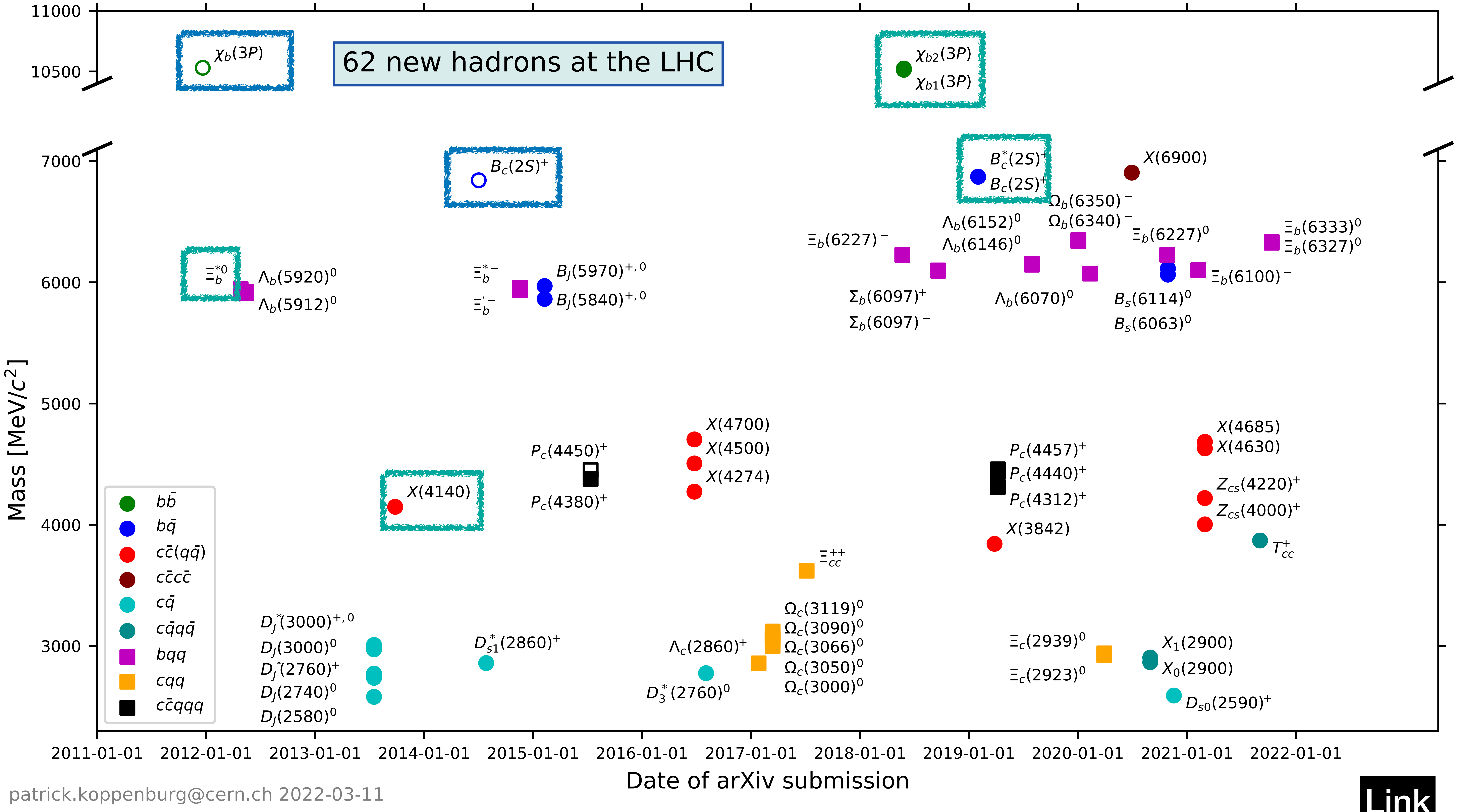
A forest of new states

A powerful tool for heavy hadron spectroscopy.

CMS

ATLAS

52 Hadrons discovered by LHCb



Link

A forest of new states

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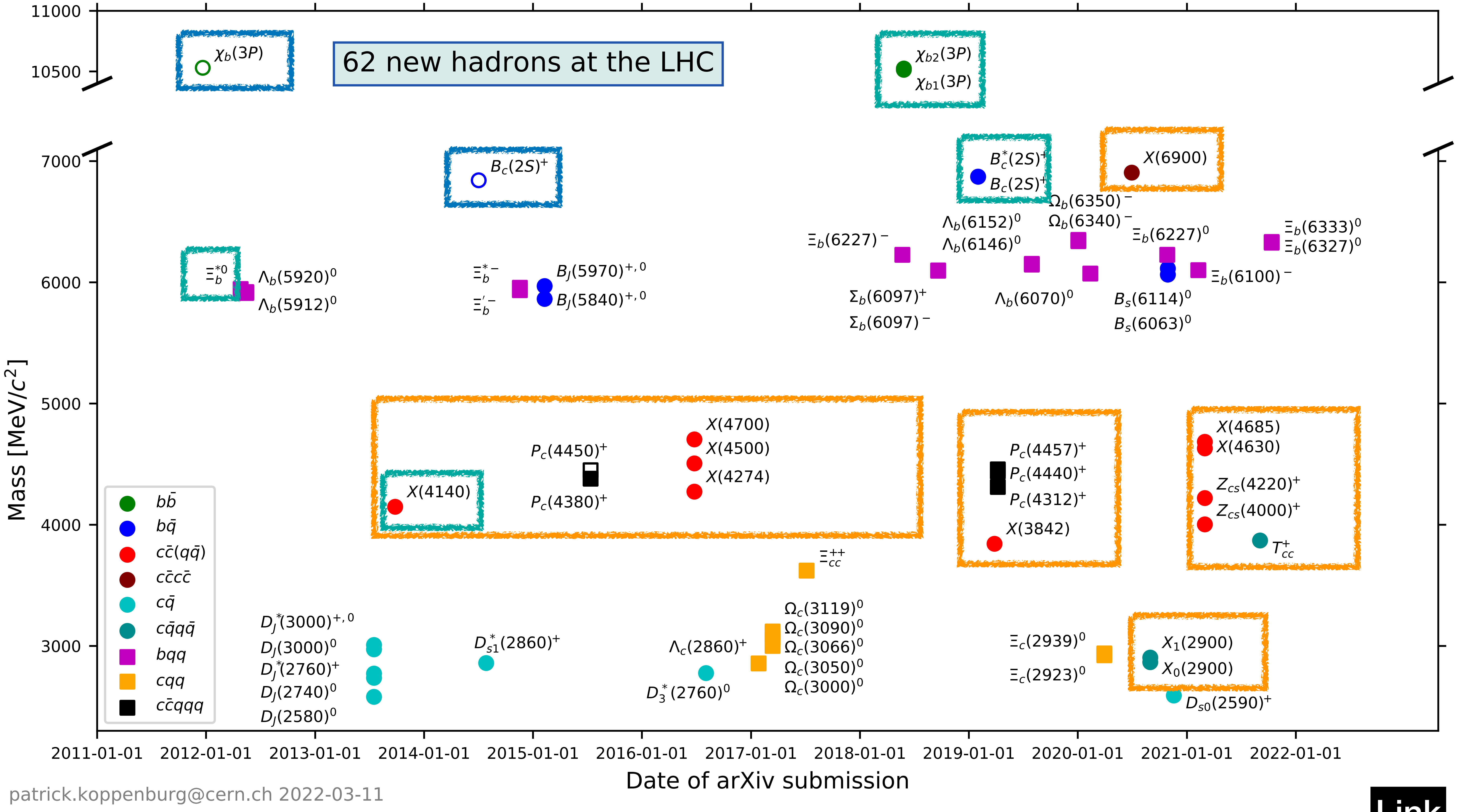
Exotic



Link

$\chi_{c1}(3872)$ structure

<u>Exotic:</u> hadrons with >3 valence quarks.

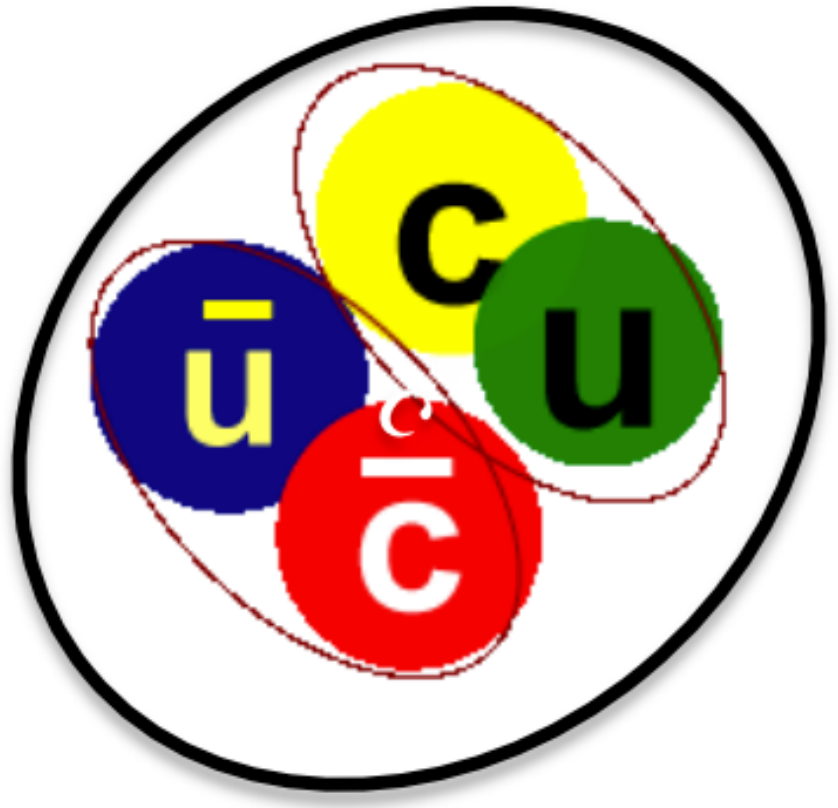
$\psi(2S)$ is a $c\bar{c}$ state

The nature of $\chi_{c1}(3872)$ is still intriguing :

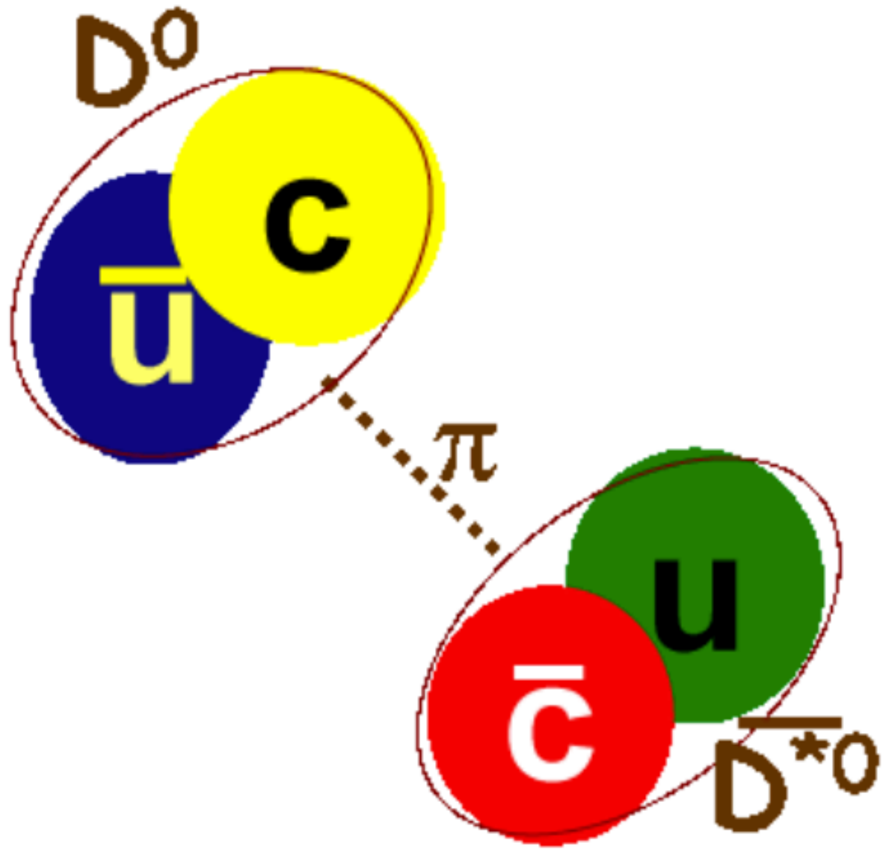
Mixture

$$X = a|c\bar{c}> + b|c\bar{c}q\bar{q}>$$

Tetraquark



Molecule



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

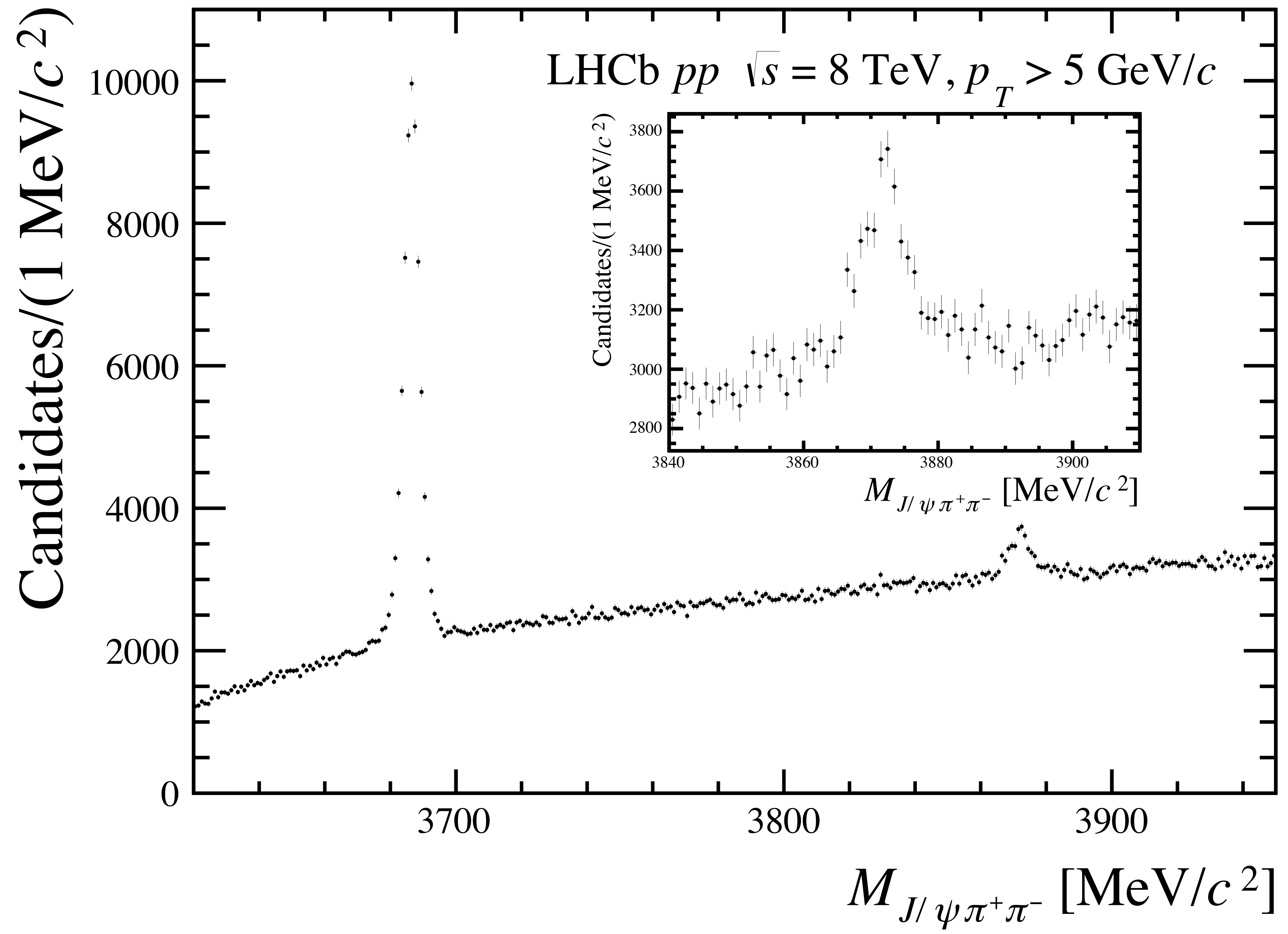
Phys.Rev.Lett. 126 (2021) 9, 092001

Reconstruct the hadrons from the decays :

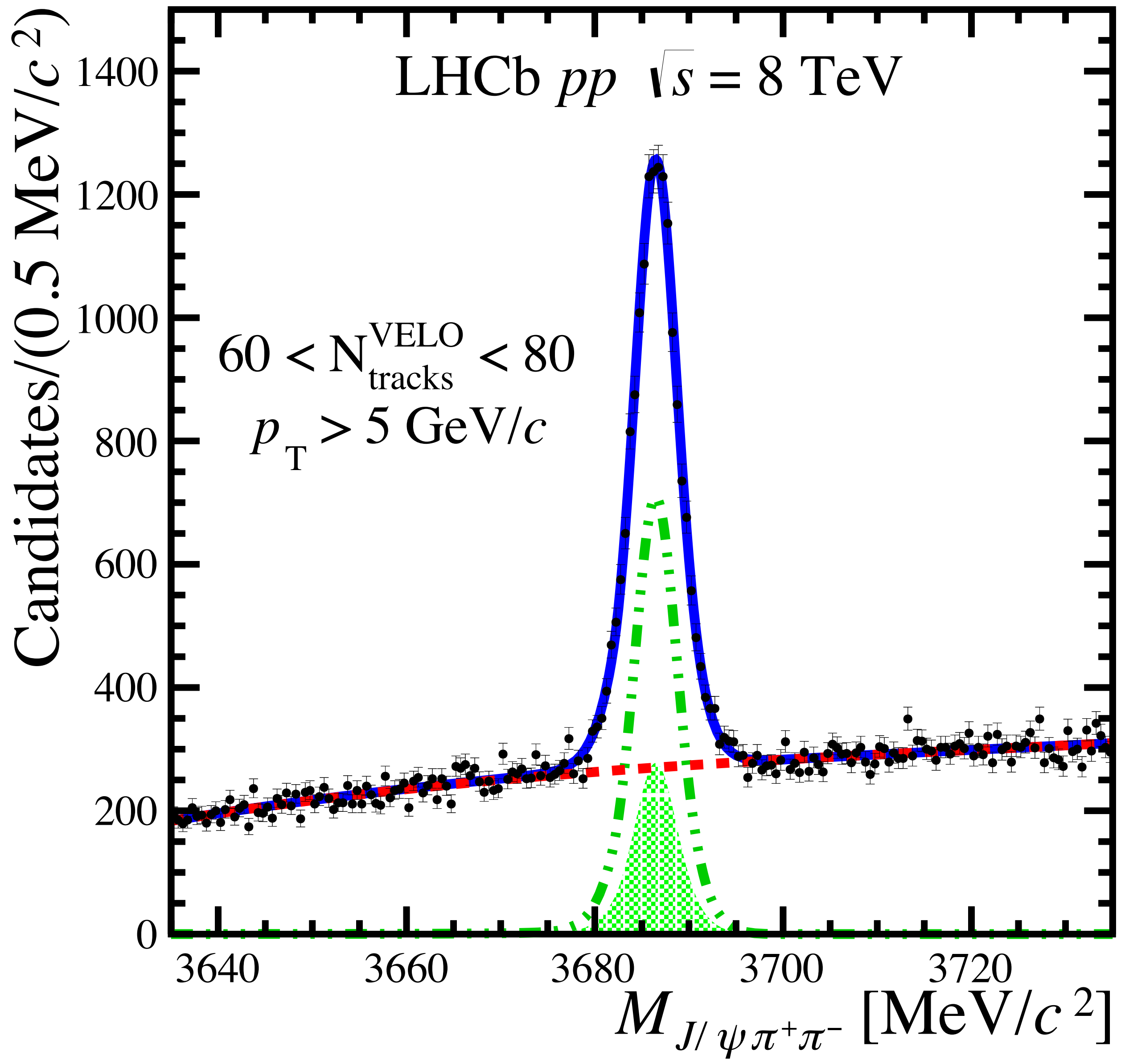
$\chi_{c1}(3872) \rightarrow J/\psi\pi^+\pi^-$

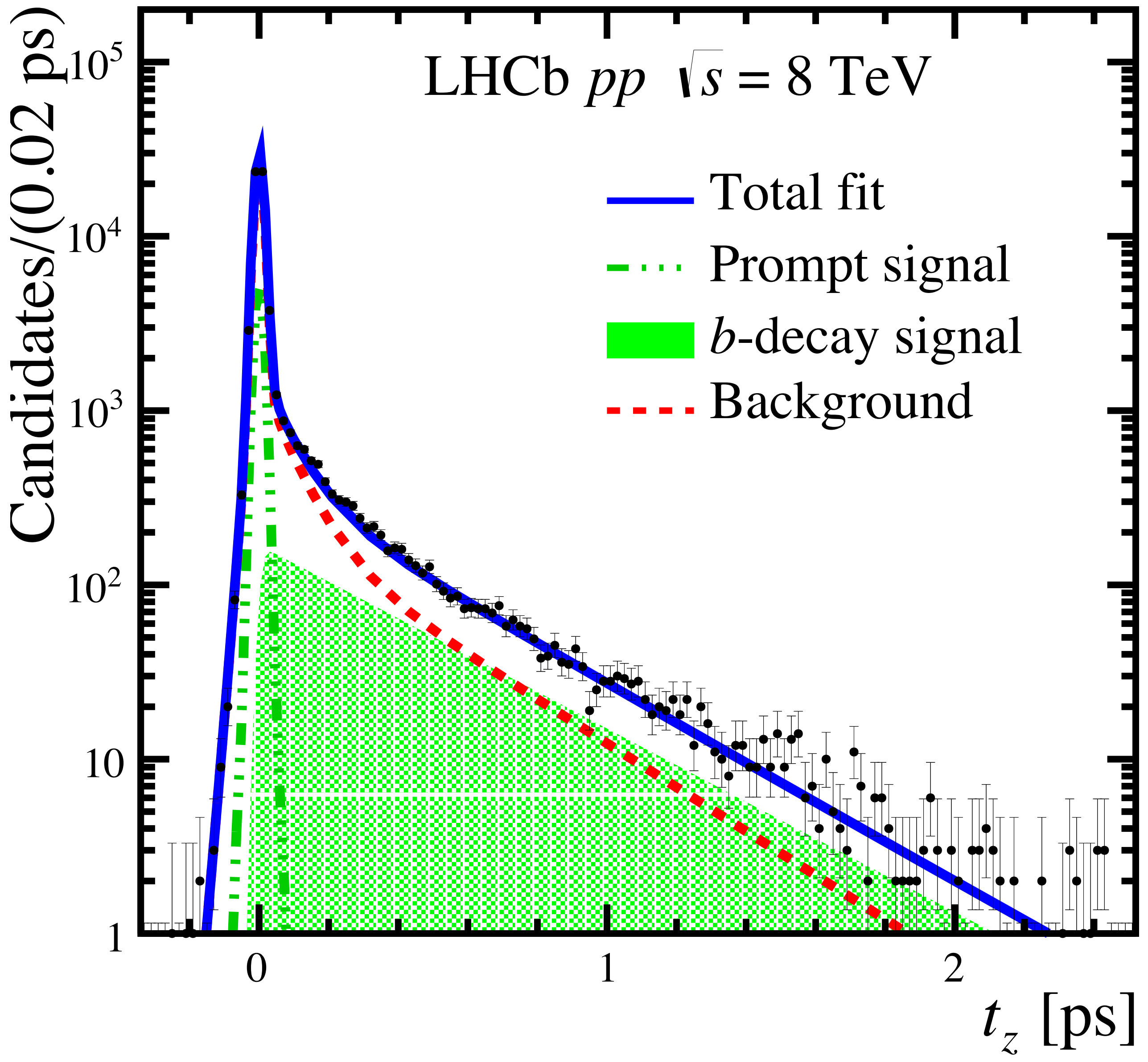
$\psi(2S) \rightarrow J/\psi\pi^+\pi^-$

Selected events are required to originate from a common vertex and the dimuon mass is constrained to the known J/ψ mass.



$\psi(2S)$





$$t_z = (z_{\psi(2S)} - z_{PV})\frac{m(\psi(2S))}{p_z(\psi(2S))}$$

Prompt and not prompt hadrons are separated by fitting the pseudo-decay-time t_z.

Multiplicity Dependence of $\chi_{c1}(3872)$ and $\psi(2S)$

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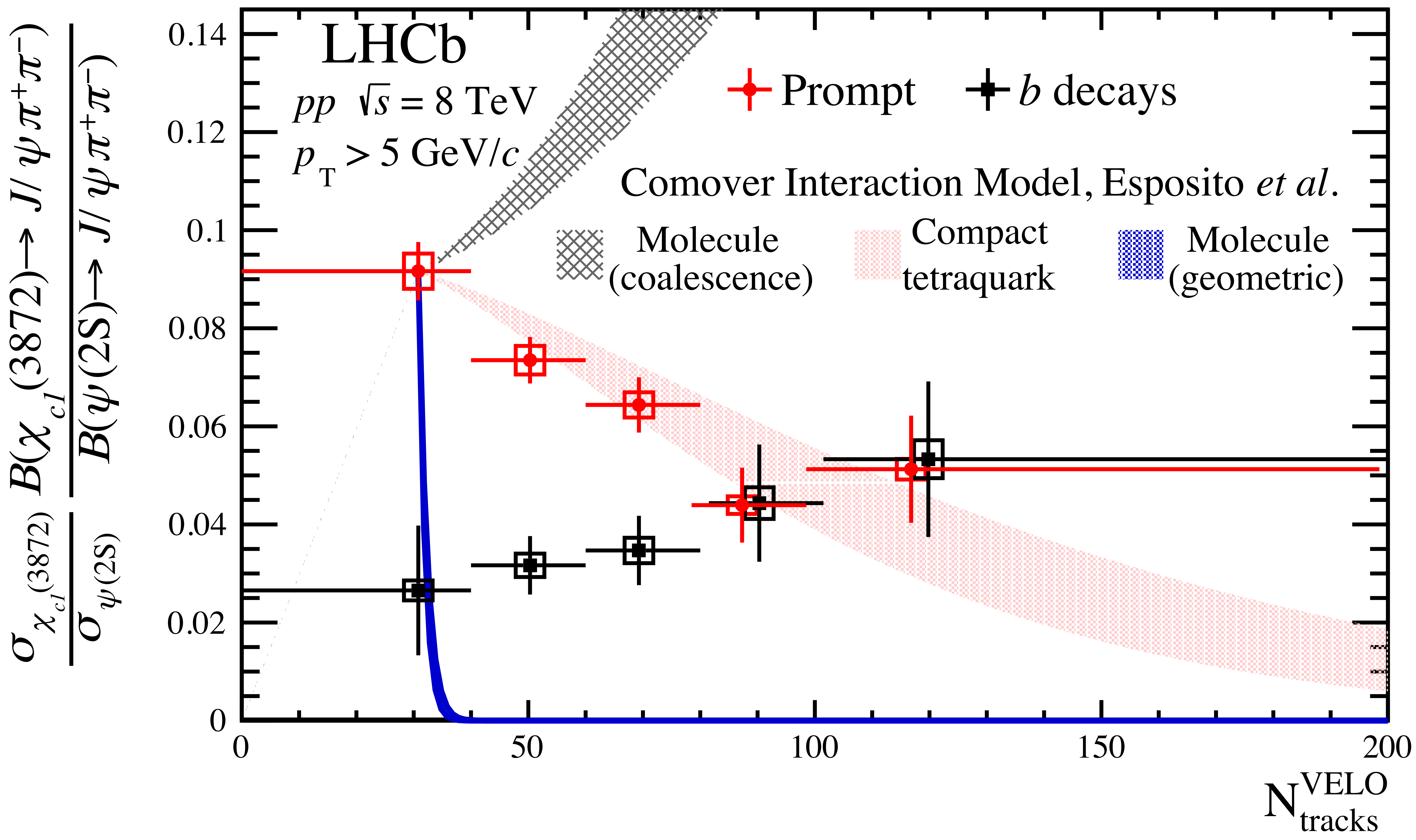
With the increasing multiplicity:

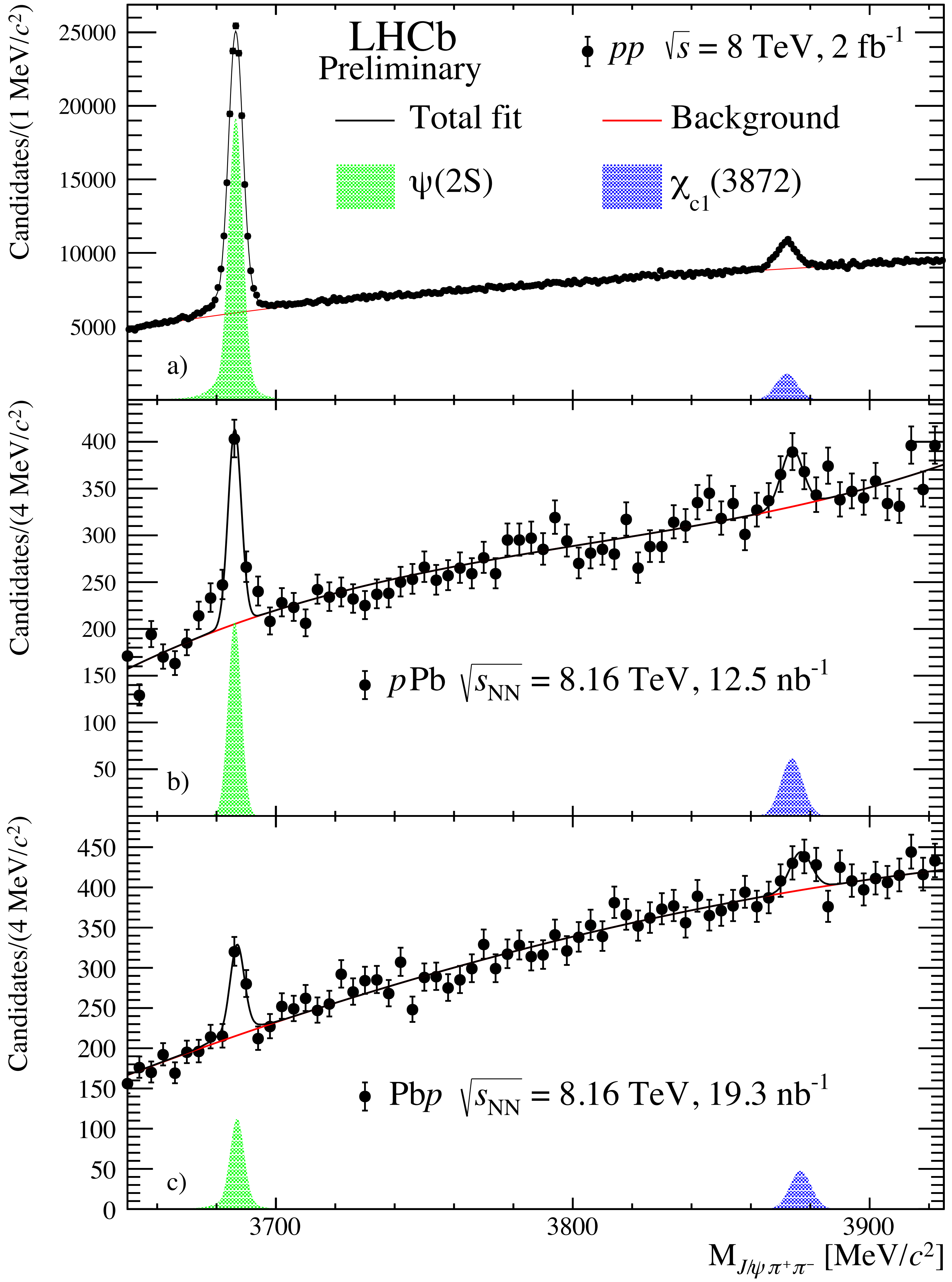
- The prompt production of $\chi_{c1}(3872)$ is suppressed relative to prompt $\psi(2S)$ production.
- No significant change in the non-prompt production, as expected for decays in a vacuum.

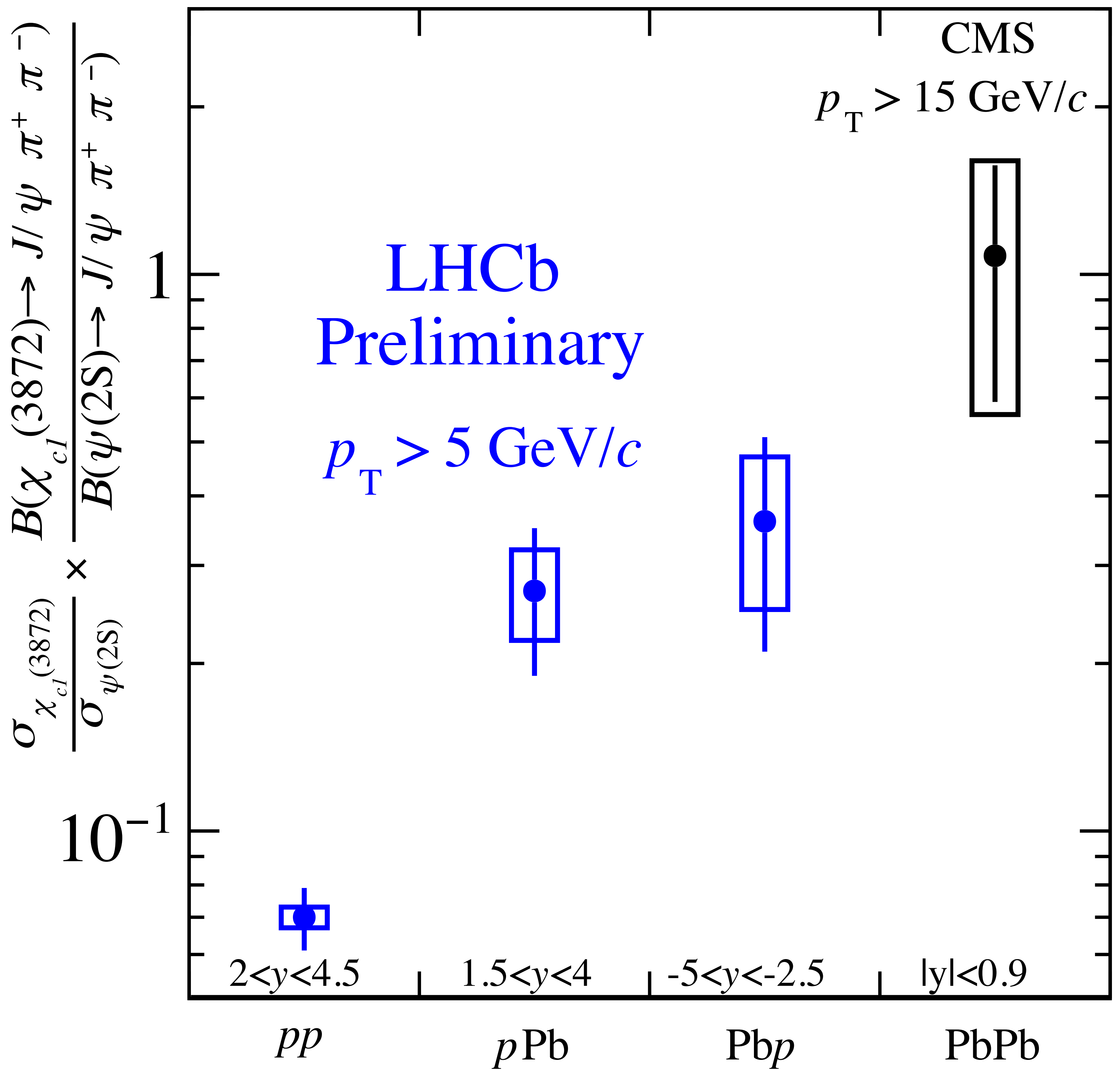


Production of $\chi_{c1}(3872)$ and $\psi(2S)$ in pPb collisions

LHCb-CONF-2022-001

Expand $\chi_{c1}(3872)$ and $\psi(2S)$ production in *pp* collision to *pPb*:





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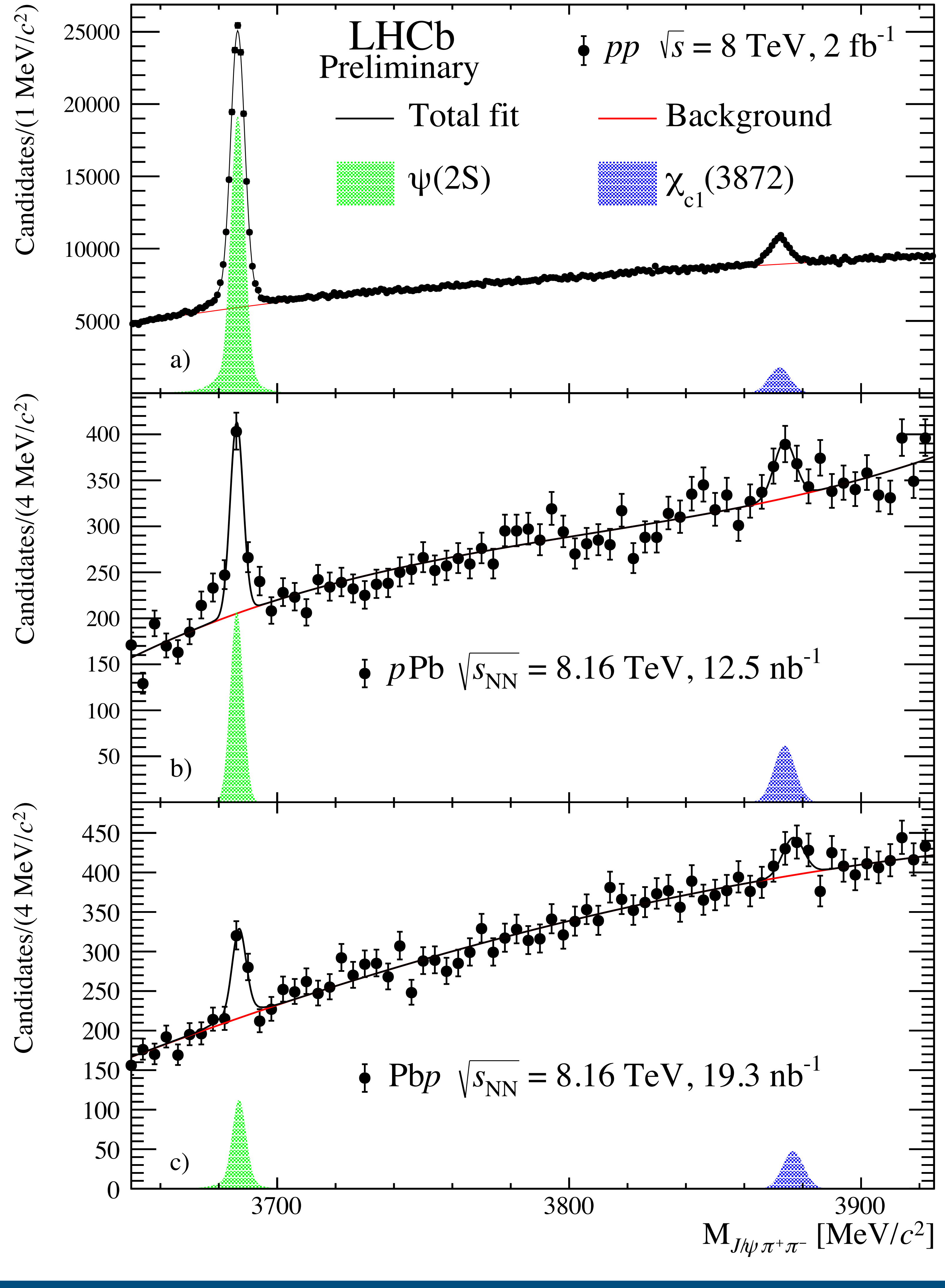
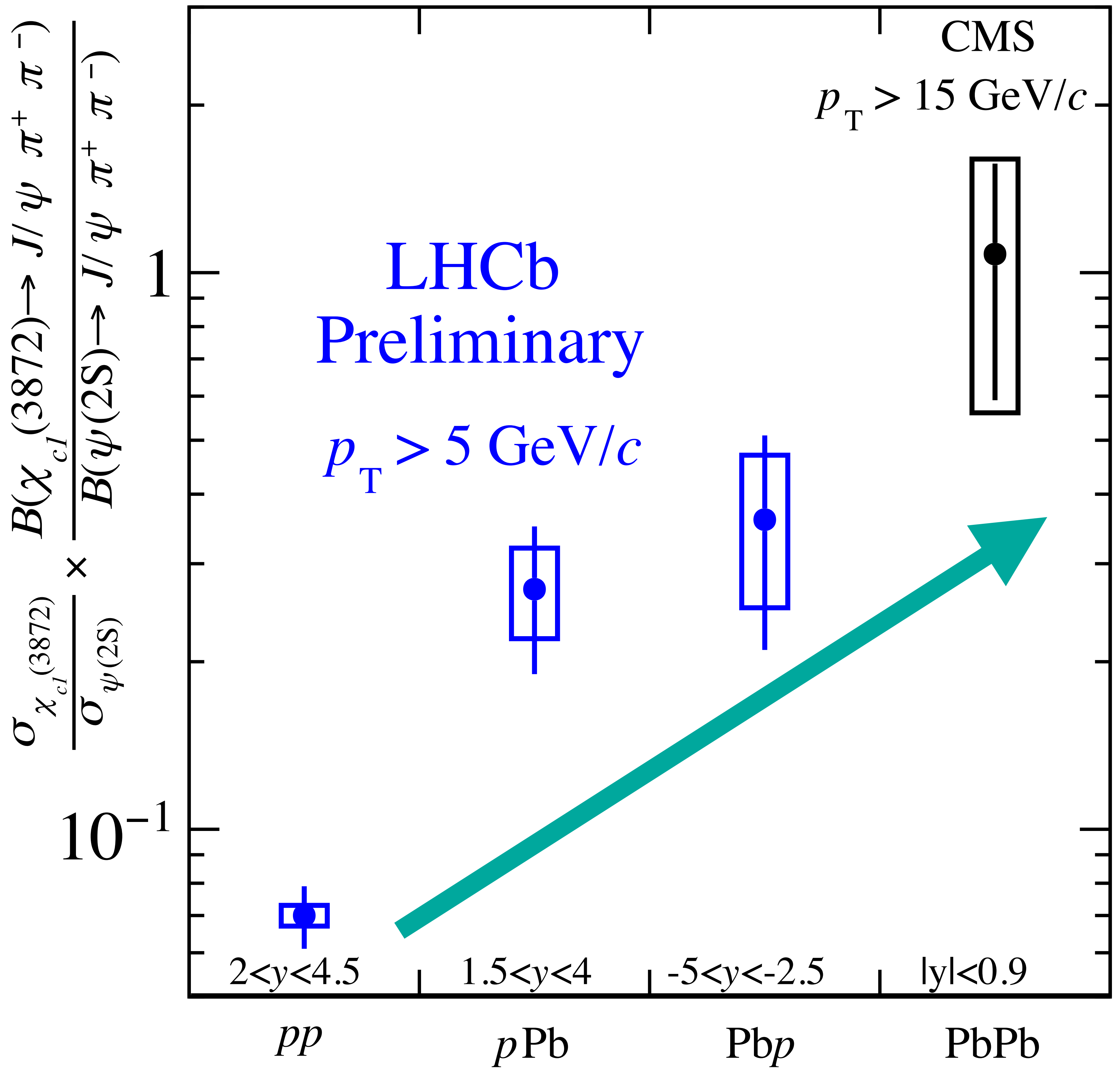




- Initial state effects should largely cancel in ratio.
- Final state effects dominate.
- The ratio increases with the system size.

$T_{cc}^{+}[cc\bar{u}\bar{d}]$ observation

arXiv:2109.01056

$D^0 \to K^-\pi^+$

$T_{cc}^+ \to D^0 D^0 \pi^+$

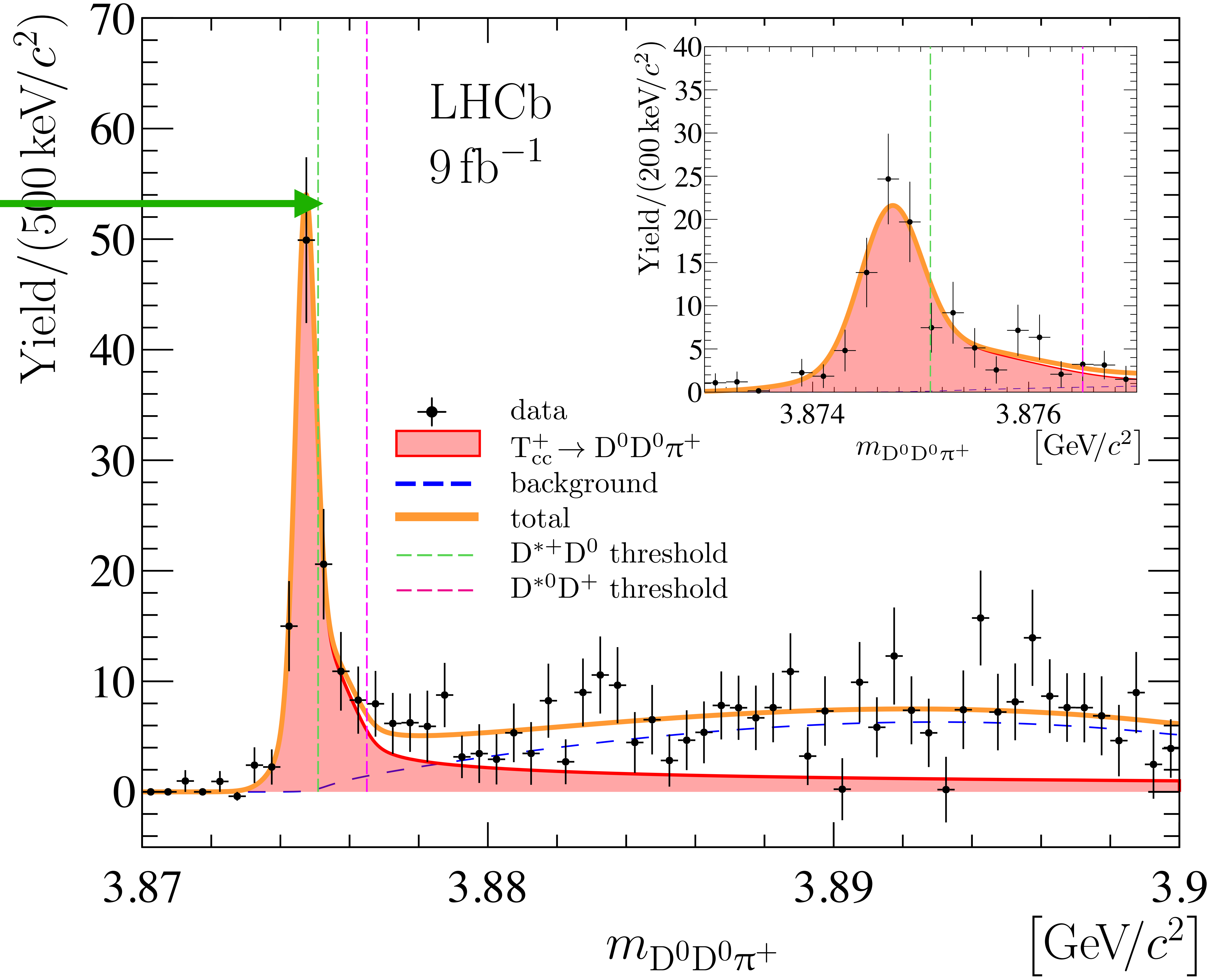
Found to be below the $D^{*+}D^0$

→ compatible with T_{cc}^+ being a tetraquark with $cc\bar{u}\bar{d}$.

$$\delta m_U = m_U - m_{D^{*+}} - m_{D^0}$$

Parameter	Value
N_{sig}	186 ± 24
δm_U	$-359 \pm 40\text{keV}/c^2$

- pp : 9fb^{-1} @7,8,13TeV



- The narrowest exotic state observed to date.

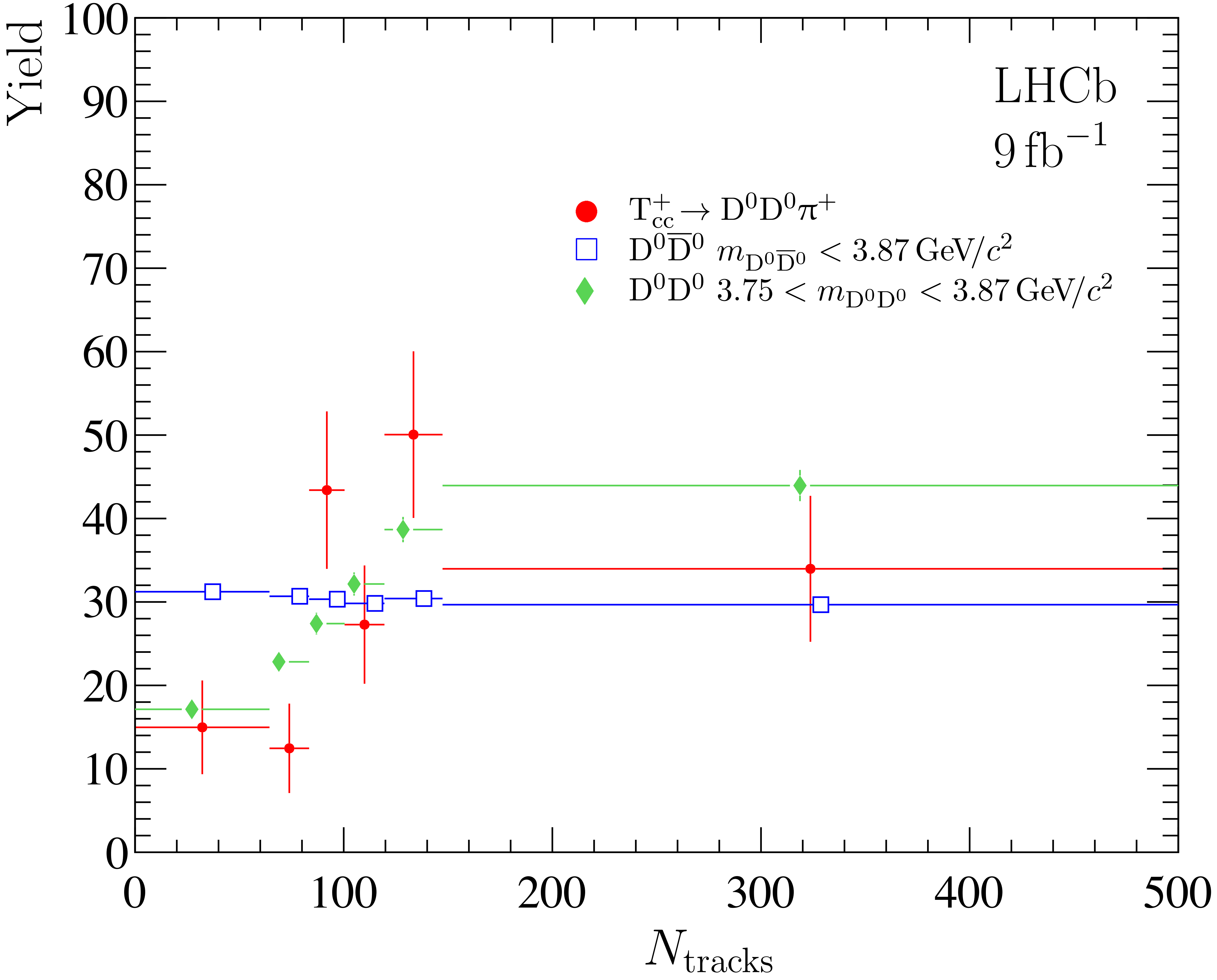
Compare T_{cc}^{+} yield with :

D^0D^0 dominated by double parton scattering.

$D^0\bar{D}^0$ dominated by single parton scattering.

- Yield increases with high multiplicity collisions.

  → Similar to the D^0D^0



Conclusion

Heavy Flavour:

- B_s^0/B^0 ratio increases with particle multiplicity.
- Tension between data and theory predictions at high p_T for D^0 production in pPb collisions.
- $R(\Lambda_c^+/D^0)$ show a strong rapidity dependence, as well as the ratio is compatible with previous LHCb measurements in pPb but the difference with ALICE remains.

Exotic hadrons:

- $\sigma(\chi_{c1}(3872))/\sigma(\psi(2S))$ increases with the collision system.
- Theoretical calculations are compatible with $\chi_{c1}(3872)$.

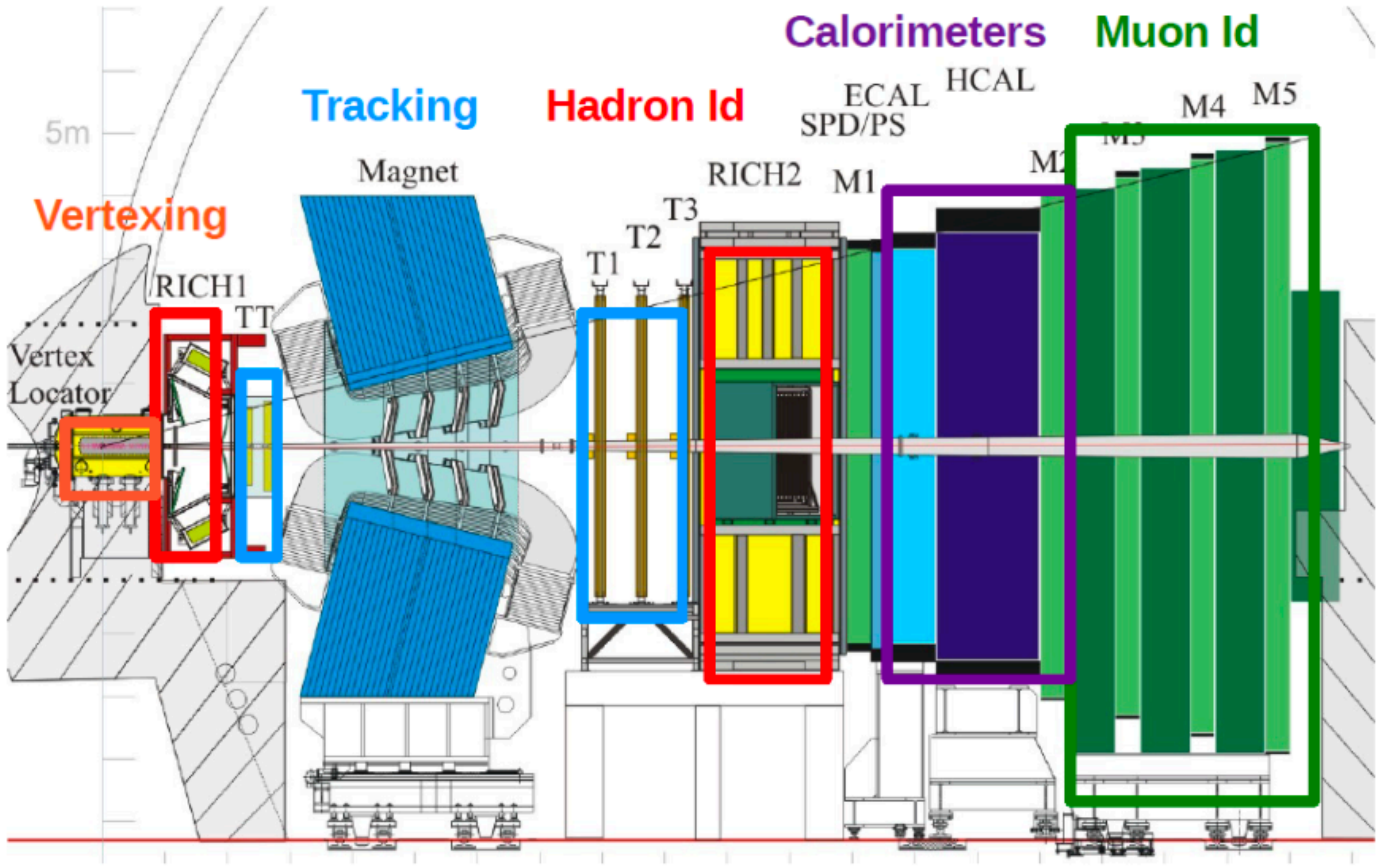
More precise spectroscopic measurements from the LHCb experiment and, hopefully, some discoveries should follow with the analysis of Run 3 data.

More LHCb results can be found here.

Backup

LHCb Detector

- From heavy flavour physics to a general-purpose detector in the forward region.
- Forward detector fully instrumented in $2 < \eta < 5$.
- Excellent tracking, momentum resolution, and particle identification.



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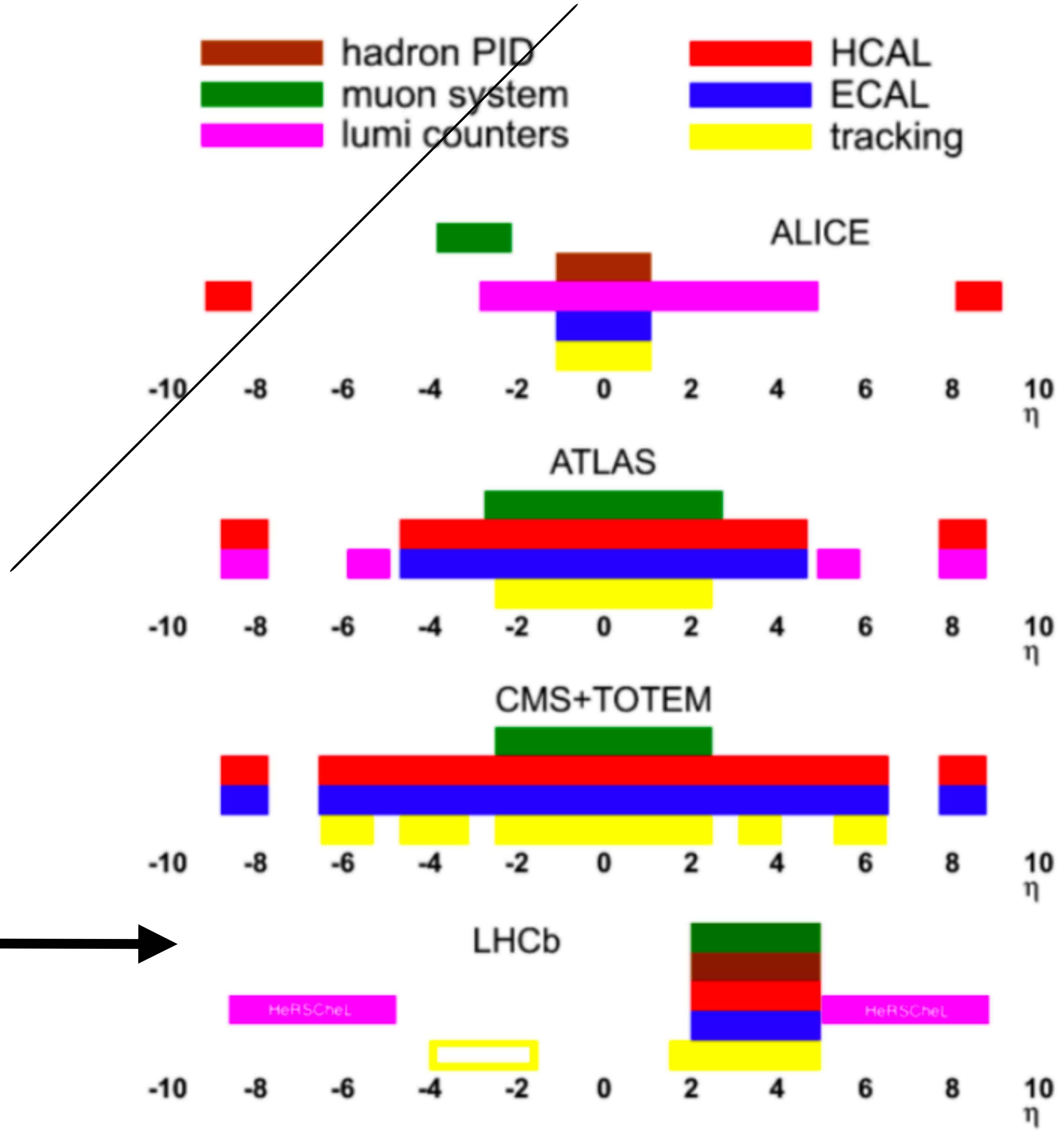

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