Search for nuclear modifications of B^+ meson production in pPb collisions at $\sqrt{s_{NN}} = 8.16$ TeV

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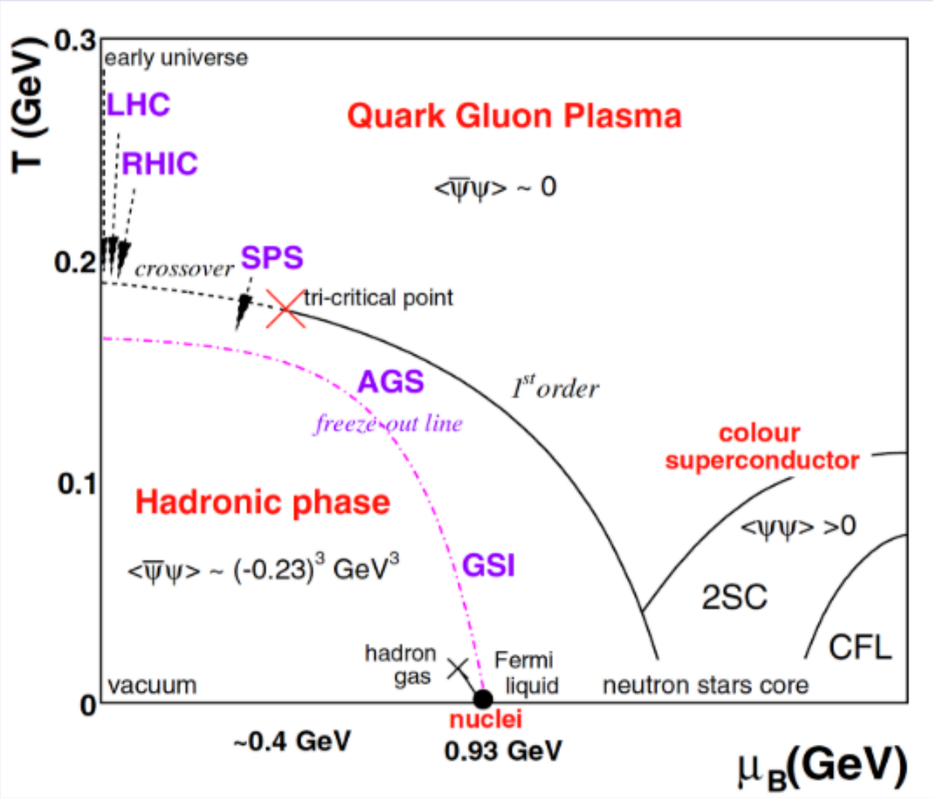
Camilo J. Torres Castaño (BUAP-FCFM)

Some insights in b-mesons nuclear modification factor and multiplicity studies.



The schematic phase diagram of QCD in terms of T, showing the QGP state. [1]

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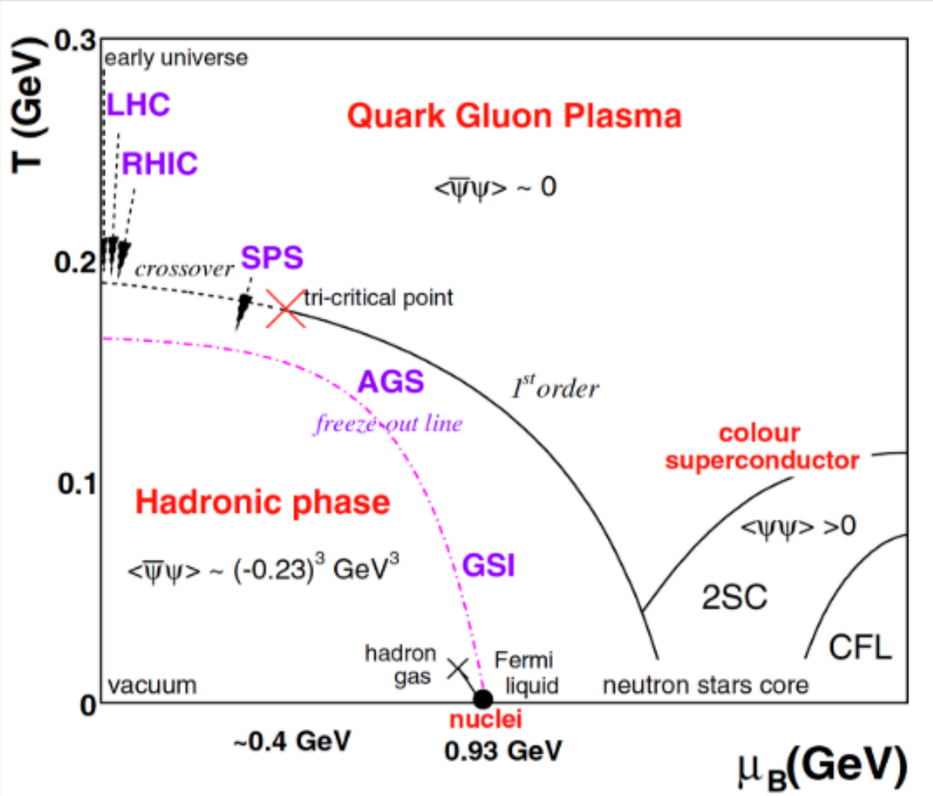
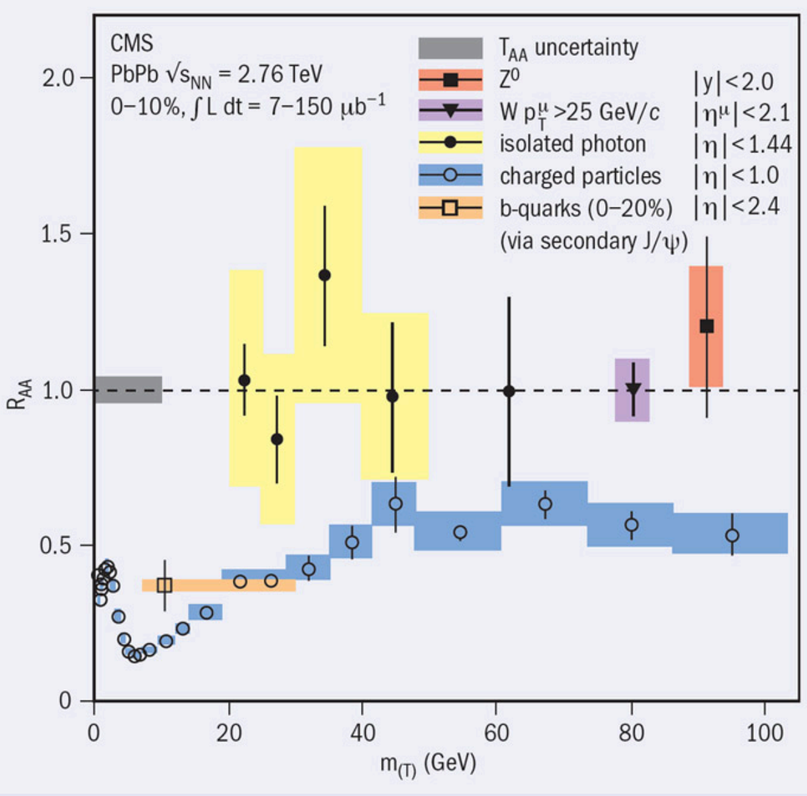


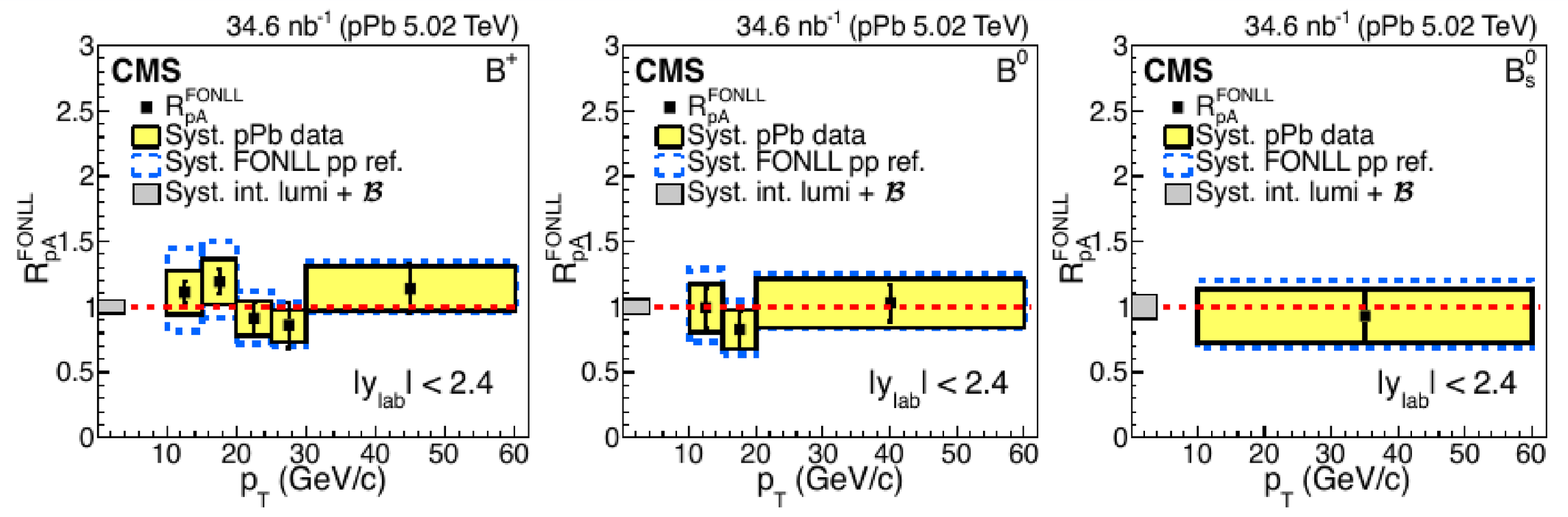


The schematic phase diagram of QCD in terms of T, showing the QGP state. [1]

The nuclear modification factor is a quantity that measures the production suppression due to in-medium collective effects. [2]

Study of B meson production in pPb collisions at 5.02 TeV using exclusive hadronic decays

[3] CMS HIN-14-004
Phys. Rev. Lett. 116 (2016) 032301



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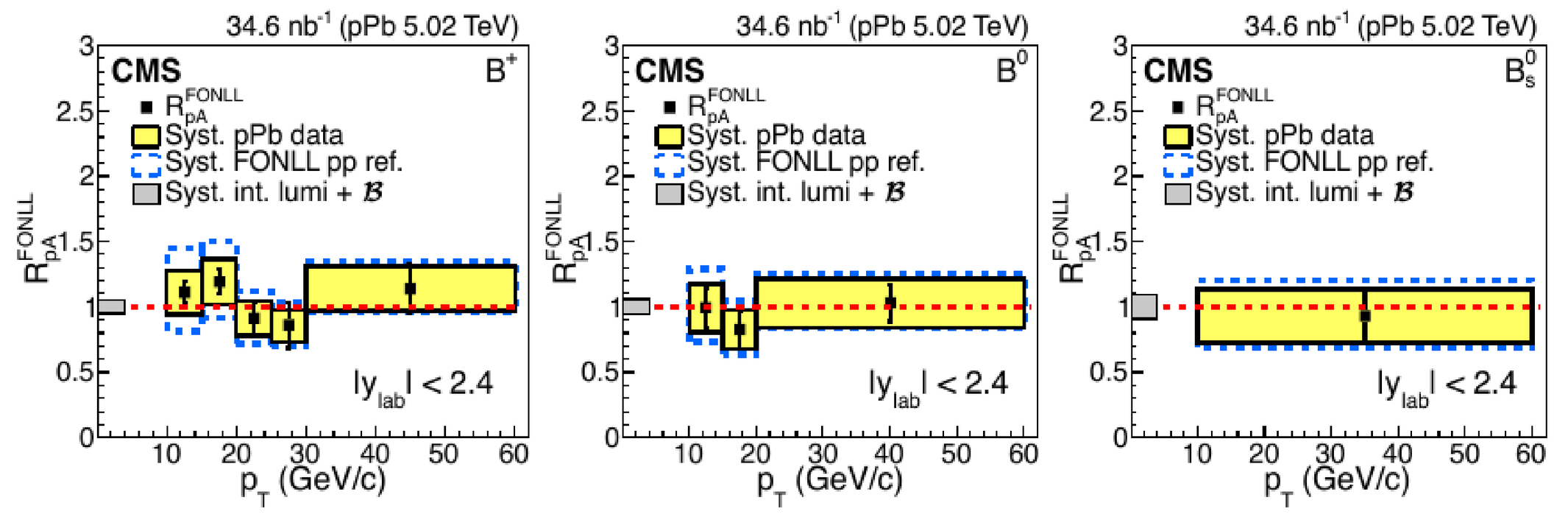
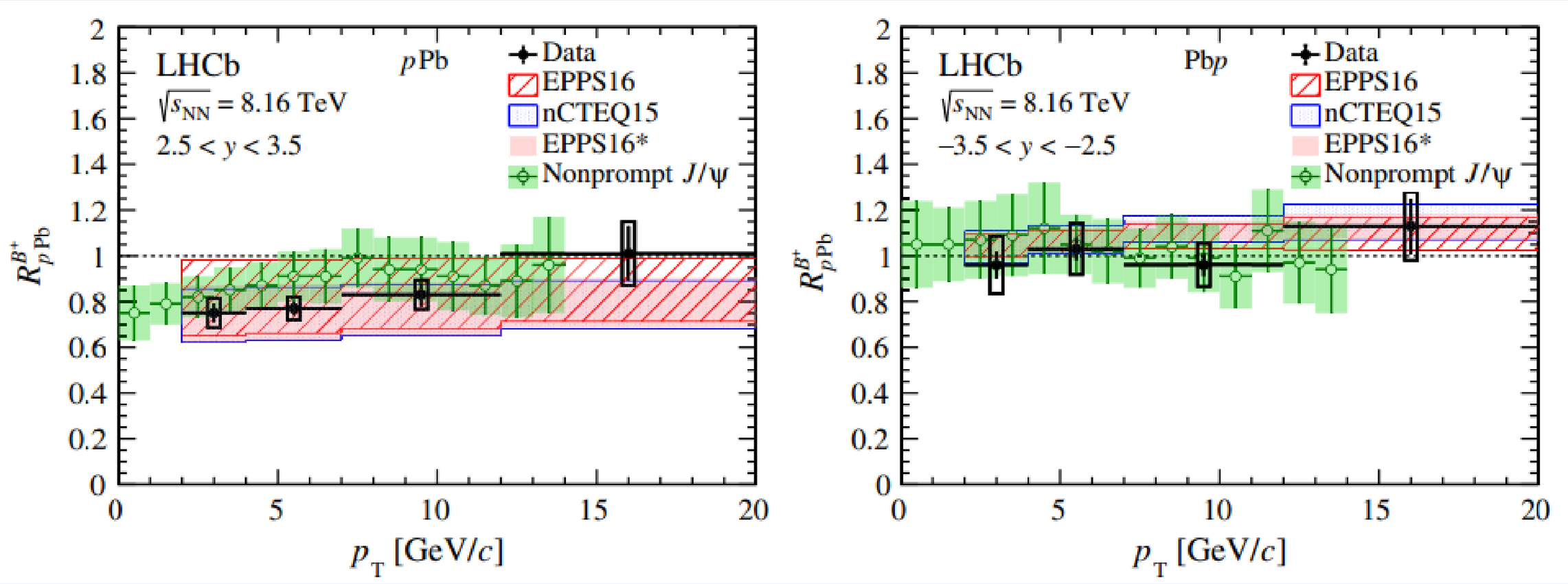


- The nuclear modification factors of the three B mesons do not show evidence for modification of pPb data compared to the FONLL reference
- These results provide a baseline for the study of in-medium b quark energy loss in PbPb collisions.

Nuclear modification factor in pPb collisions for B+ mesons as function of y and as a function of pT

[4] LHCb Collaboration
Phys. Rev. D 99, (2019) 052011



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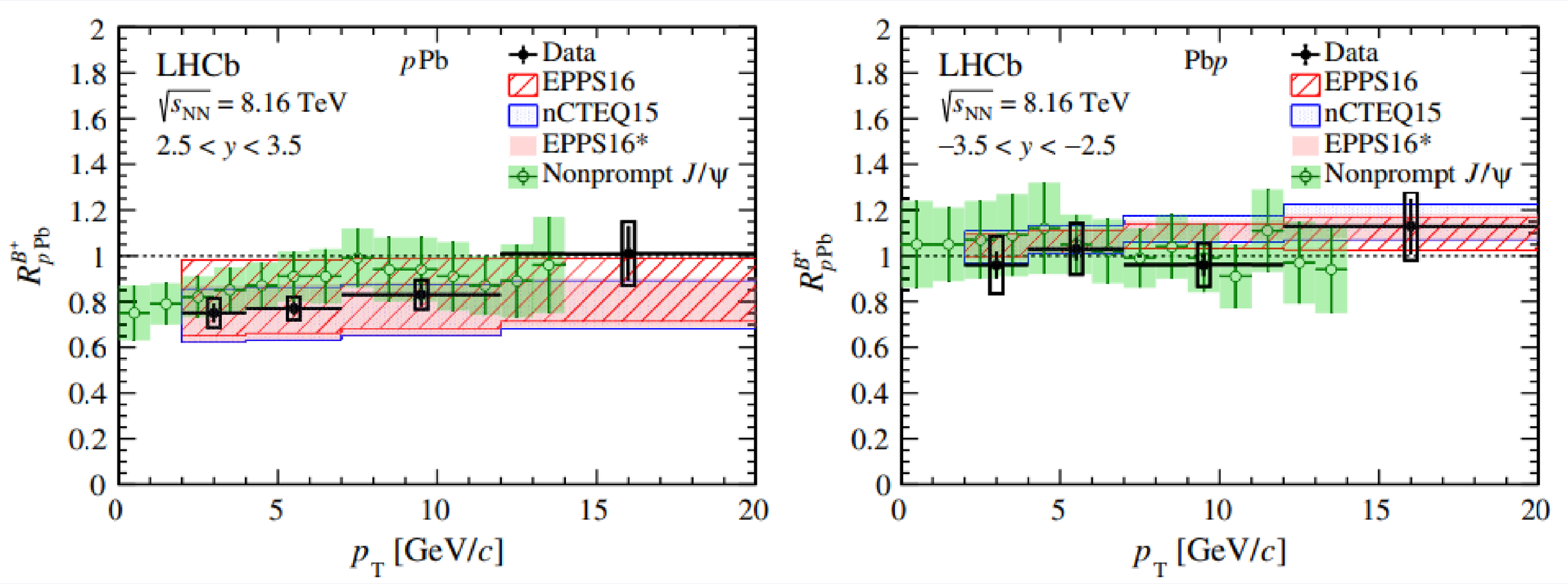
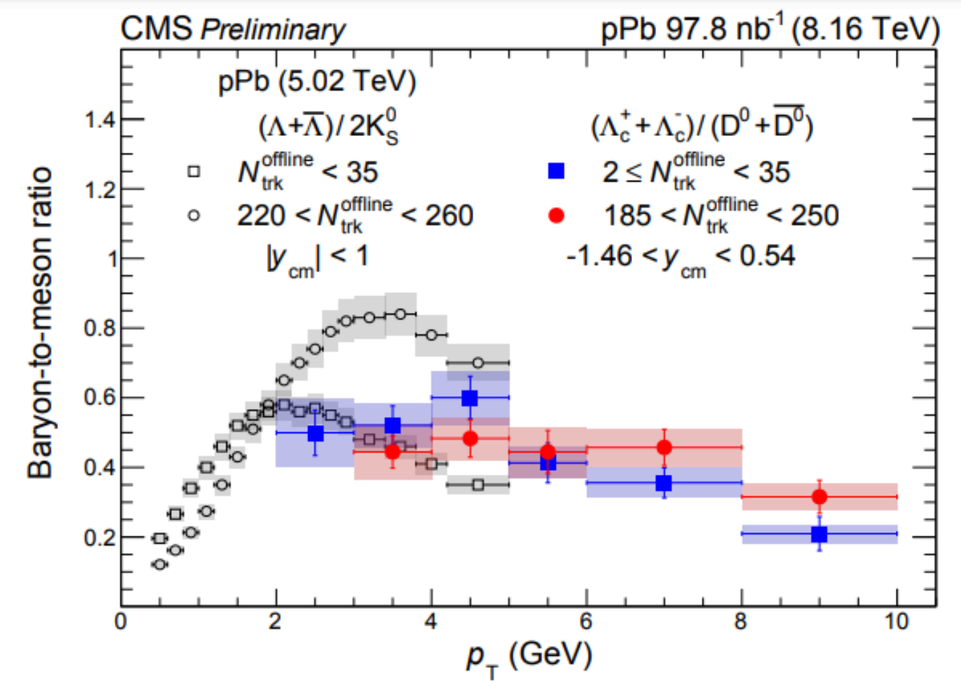
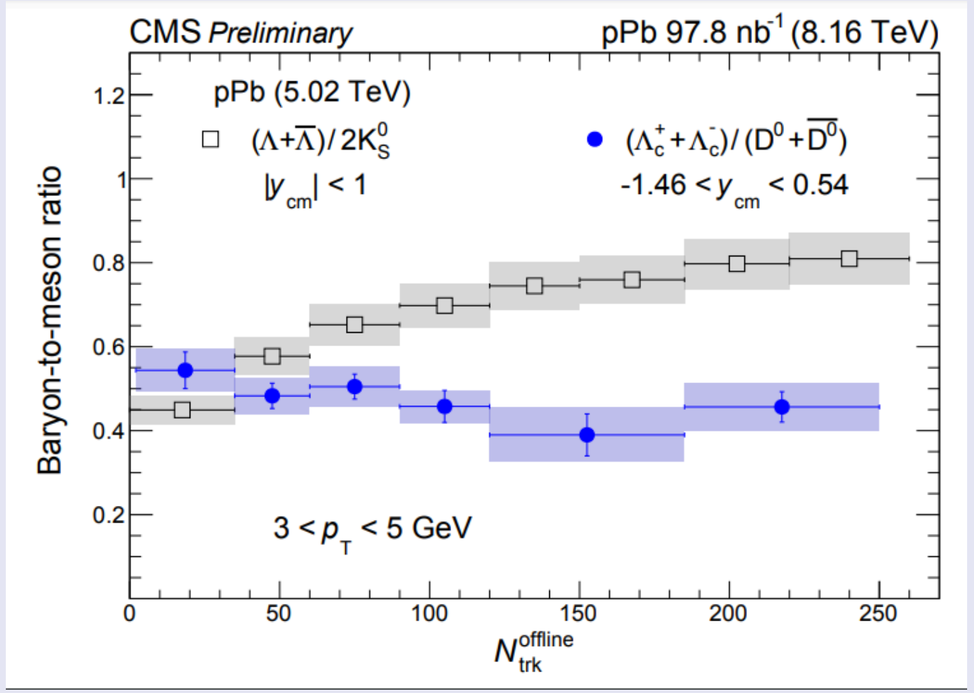


- Forward-to-backward nuclear modification factors indicate a significant nuclear suppression at positive rapidity.

Multiplicity dependence of charm baryon and meson production in pPb collisions at 8.16 TeV

[5] CMS-PAS-HIN-21-016





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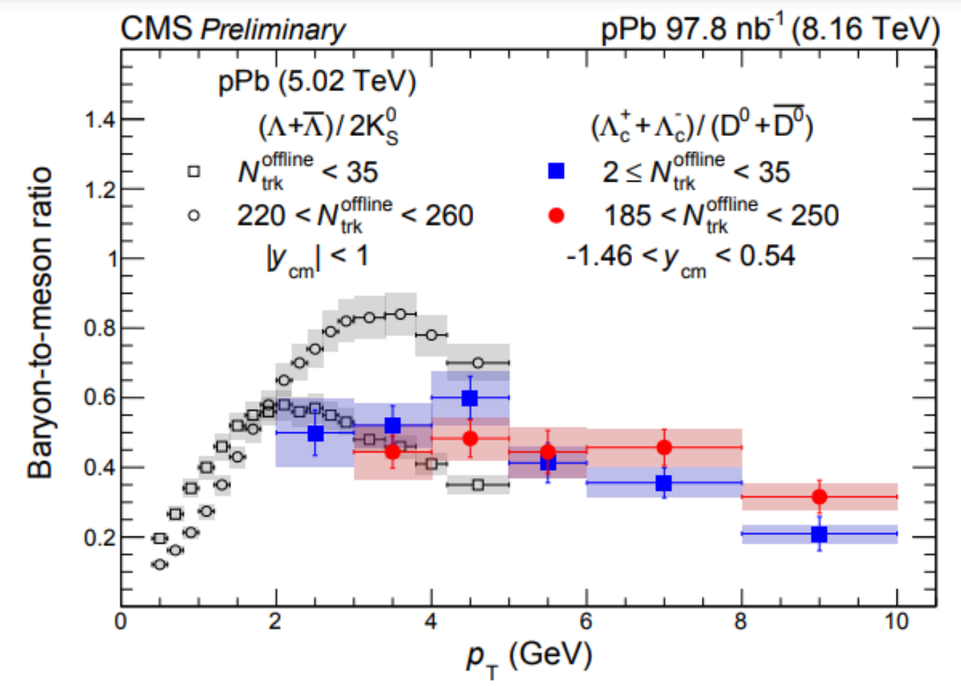

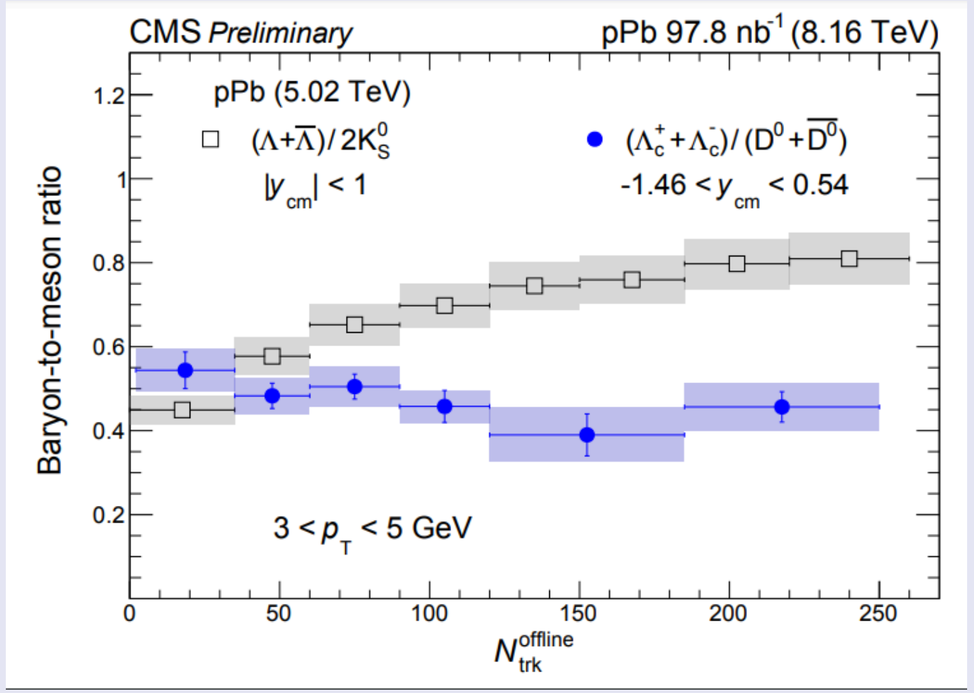

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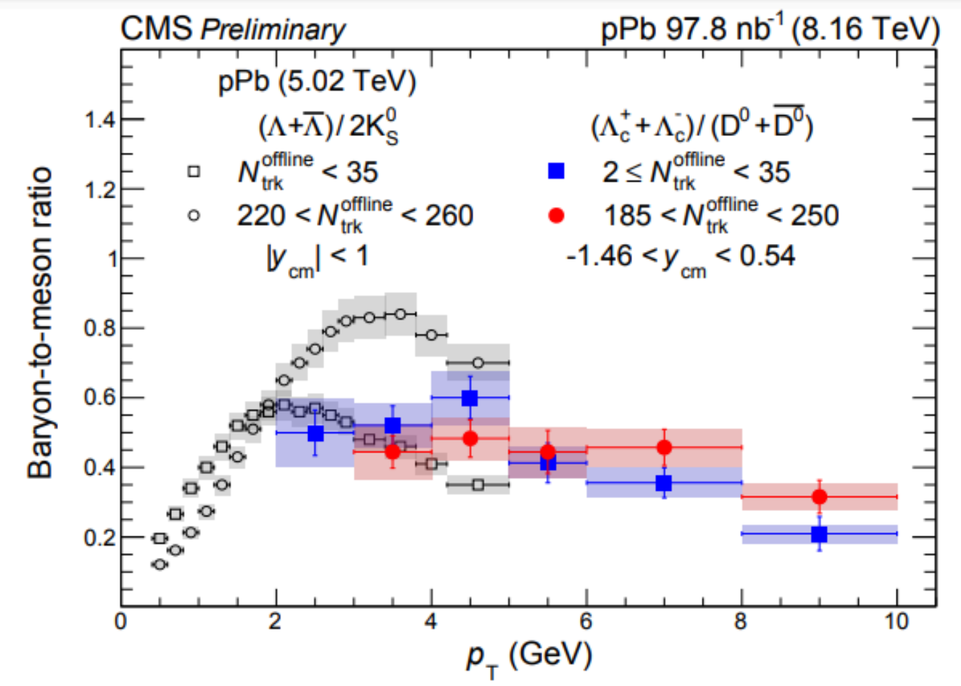

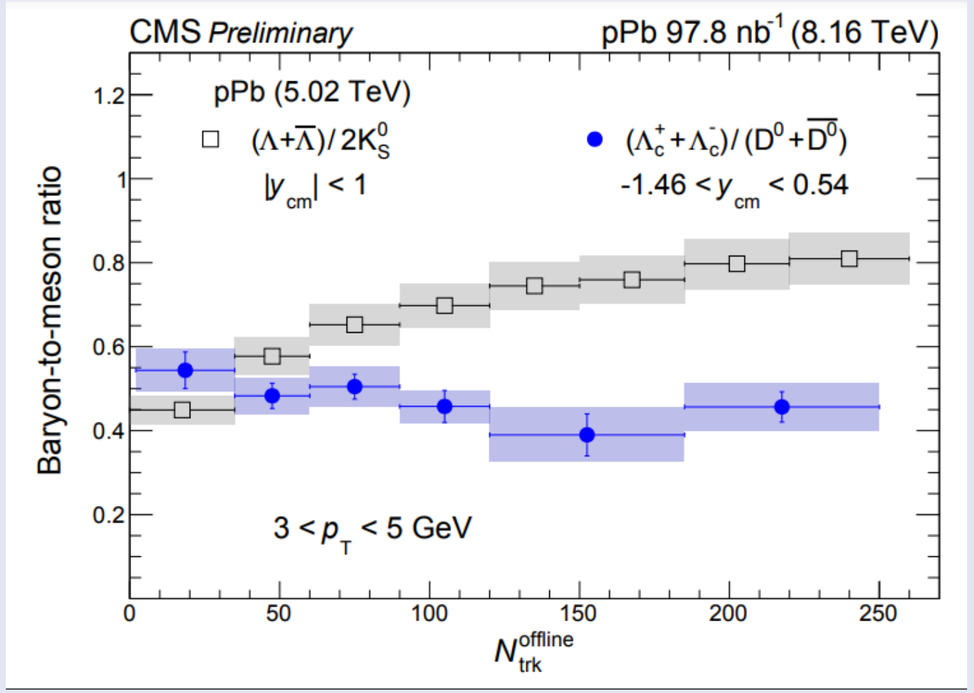

- Evidence of charm hadronization mechanism possibly in presence of a dense medium produced in high-multiplicity pPb collisions.
- Reported results may indicate different event multiplicity evolution of hadronization mechanism for charm quarks than light flavor strange quarks

[6] CMS-HIN-22-001

[7] arXiv:2407.05402

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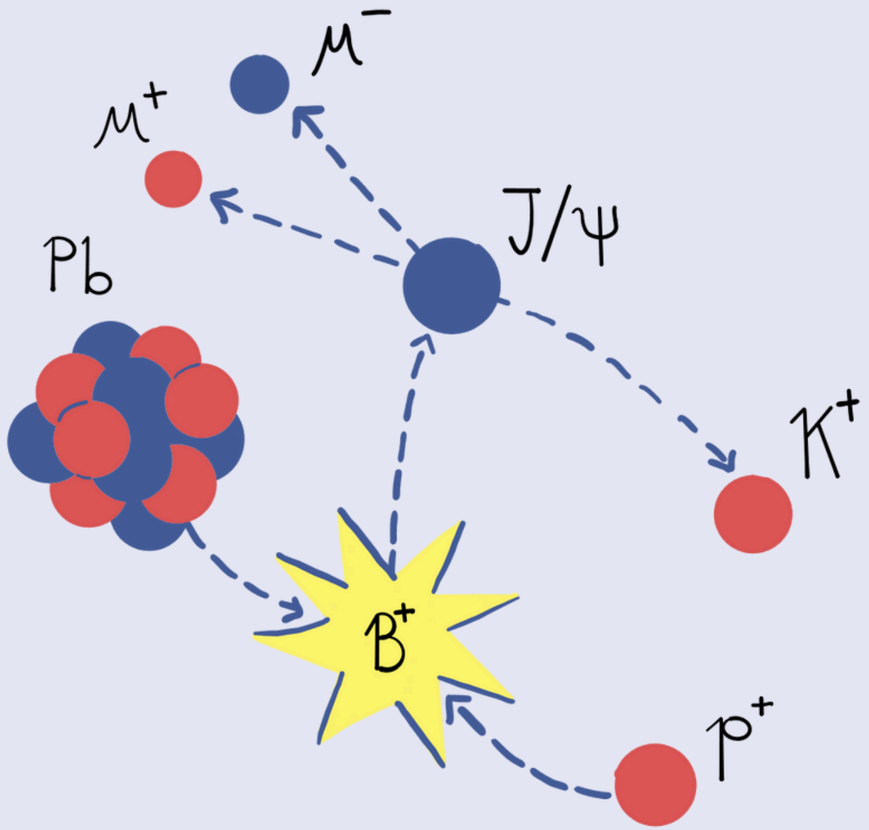

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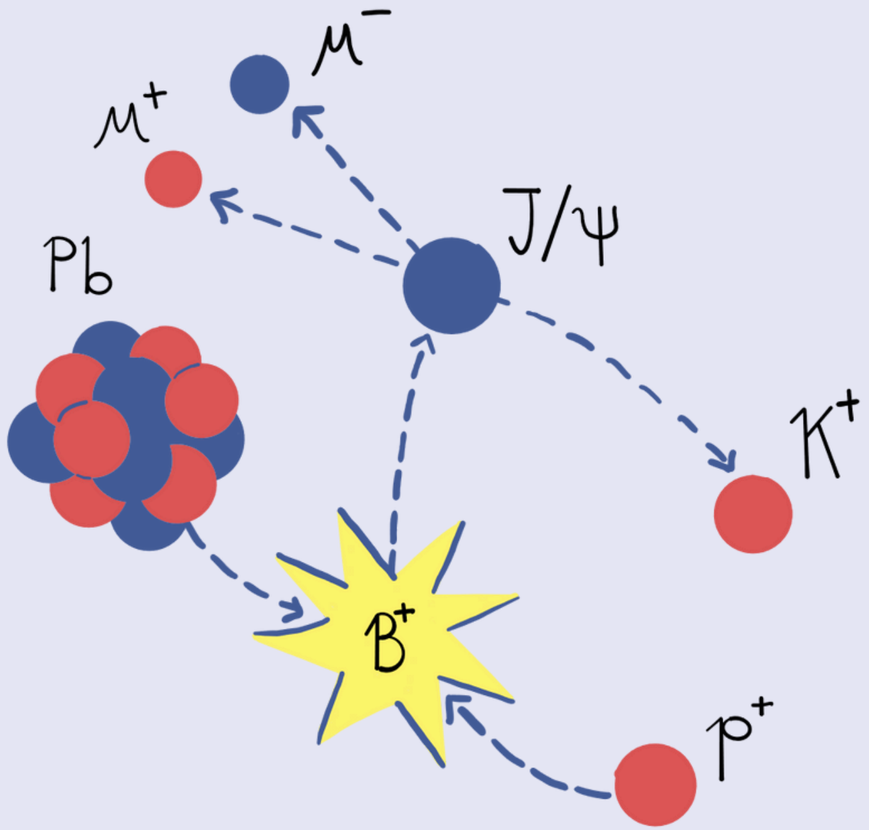
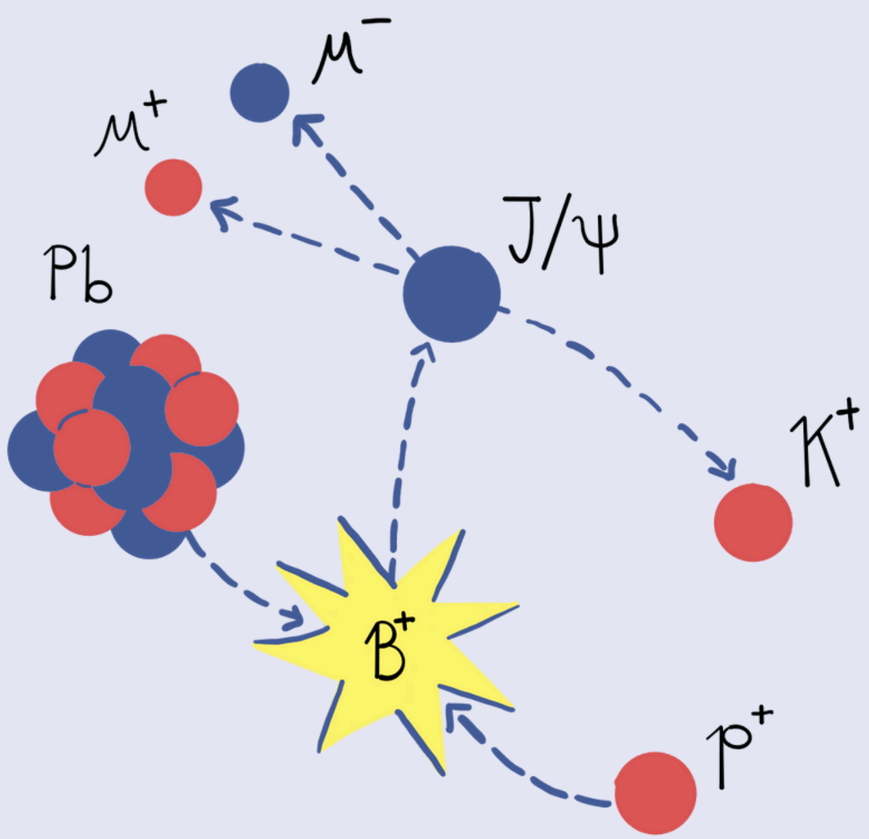


Recent observations of QGP-like phenomena in small collision systems, such as pp and pPb collisions, challenge our understanding of high-energy heavy ion physics.

Data sets and selection details

CMS-HIN-22-001



$$B^+ \rightarrow J/\psi\, K^+$$

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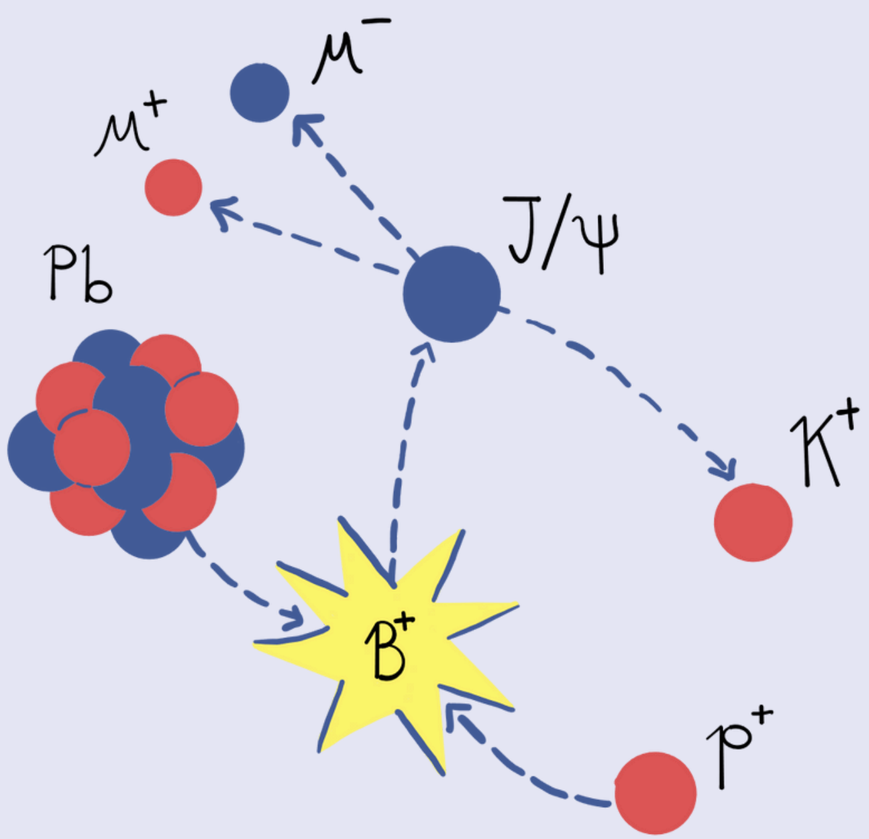

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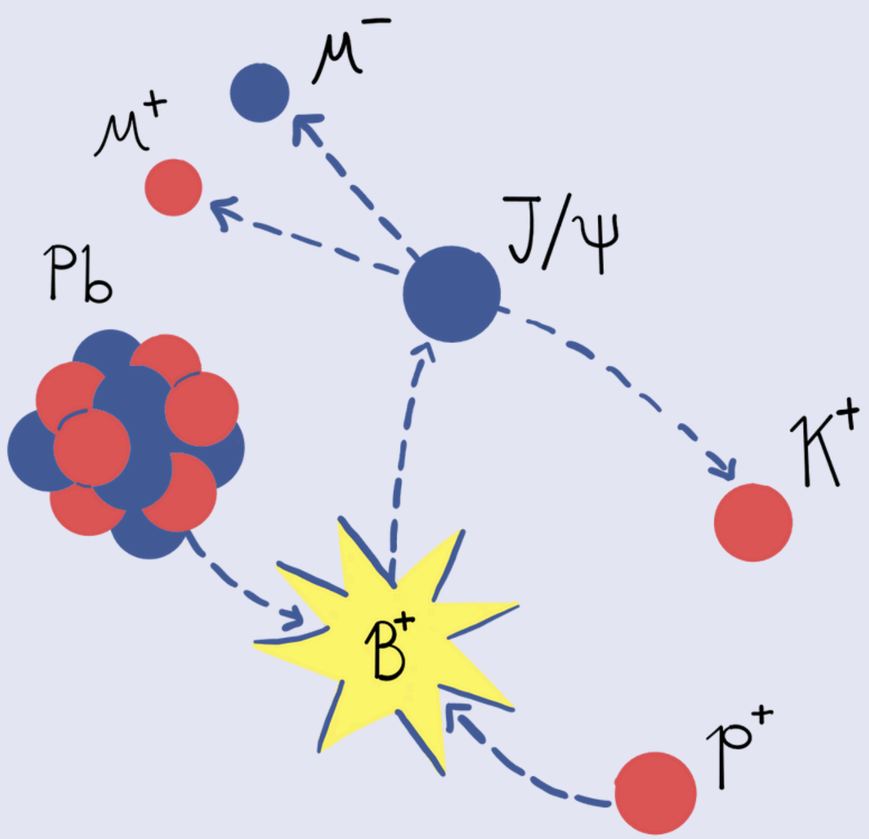

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J/ψ selection details:

- $\text{Prob}\,(\text{vtx}) > 0.01 \;\; (1\%)$
- $2.9 < \text{Mass}\,(J/\psi) < 3.3$ GeV
- $p_T\,(\mu) > 2.0$ GeV ; $\quad |\eta\,(\mu)| < 2.4$
- **Soft Muon ID**

Dimuon trigger

CMS-HIN-22-001

Trigger

Open Double Moun Trigger

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$$|\max \eta| < 2.4$$

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year	part of the run	$\mathcal{L}_{\mathrm{int}}$ $\left(\mathrm{nb}^{-1}\right)$
2016	for pPb	62.65
2016	for Pbp	111.92
	Total Luminosity	174.57

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Charged-particle multiplicity

CMS-HIN-22-001

- Number of charged particles produced in a collision.

Multiplicity class	Fraction (%)	$\langle N_{ch} \rangle$
$2 \leq N_{ch} < 250$	100.0	102 ± 2
$2 \leq N_{ch} < 60$	19.5	43 ± 1
$60 \leq N_{ch} < 85$	21.1	73 ± 2
$85 \leq N_{ch} < 110$	20.4	97 ± 2
$110 \leq N_{ch} < 250$	39.1	149 ± 4

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$$\epsilon_{trk}(\eta, p_T) = \frac{AE}{1 - F}$$

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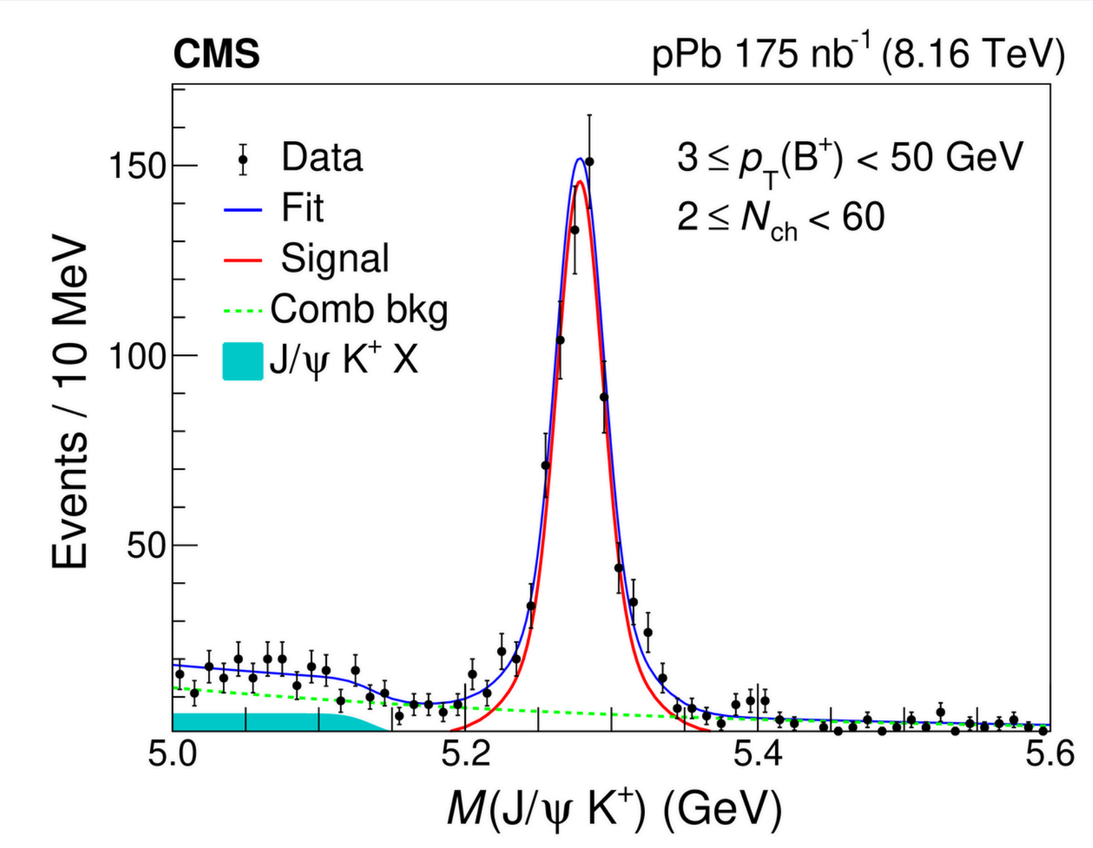
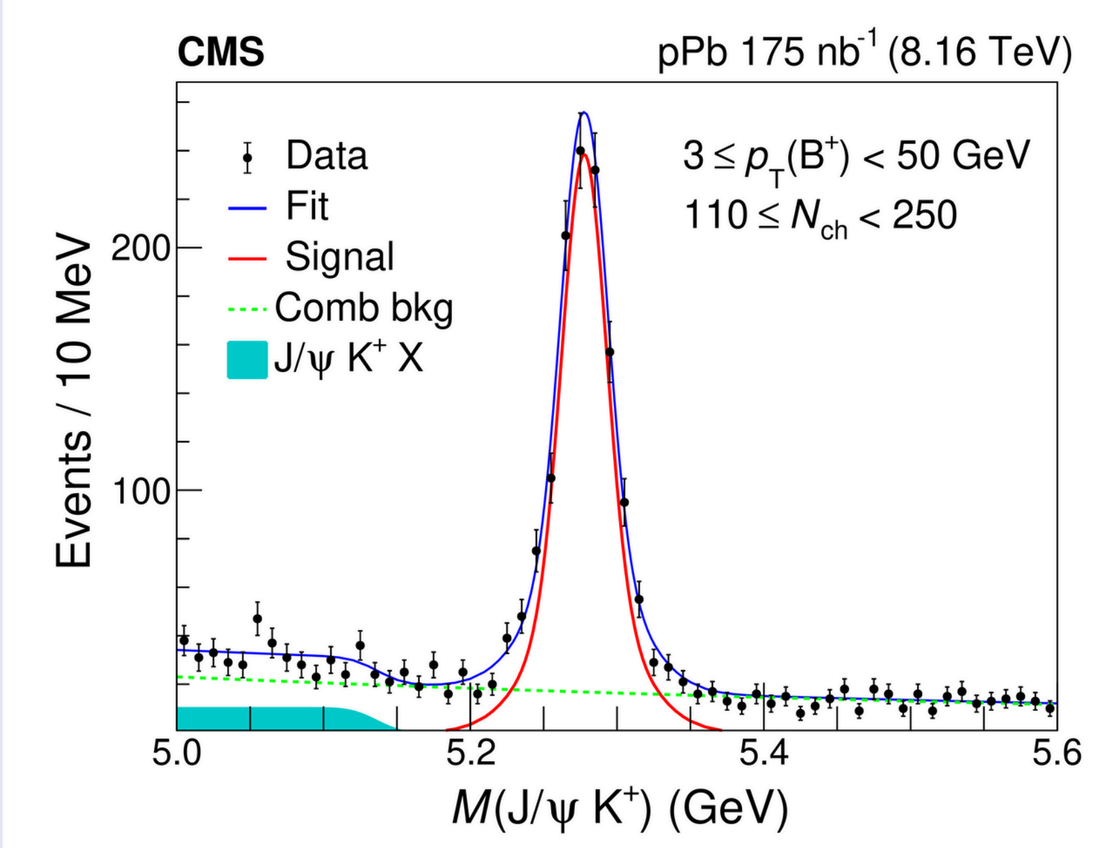
First B^+ meson studies at different charged particle multiplicities in pPb collisions.

Invariant mass distribution

CMS-HIN-22-001





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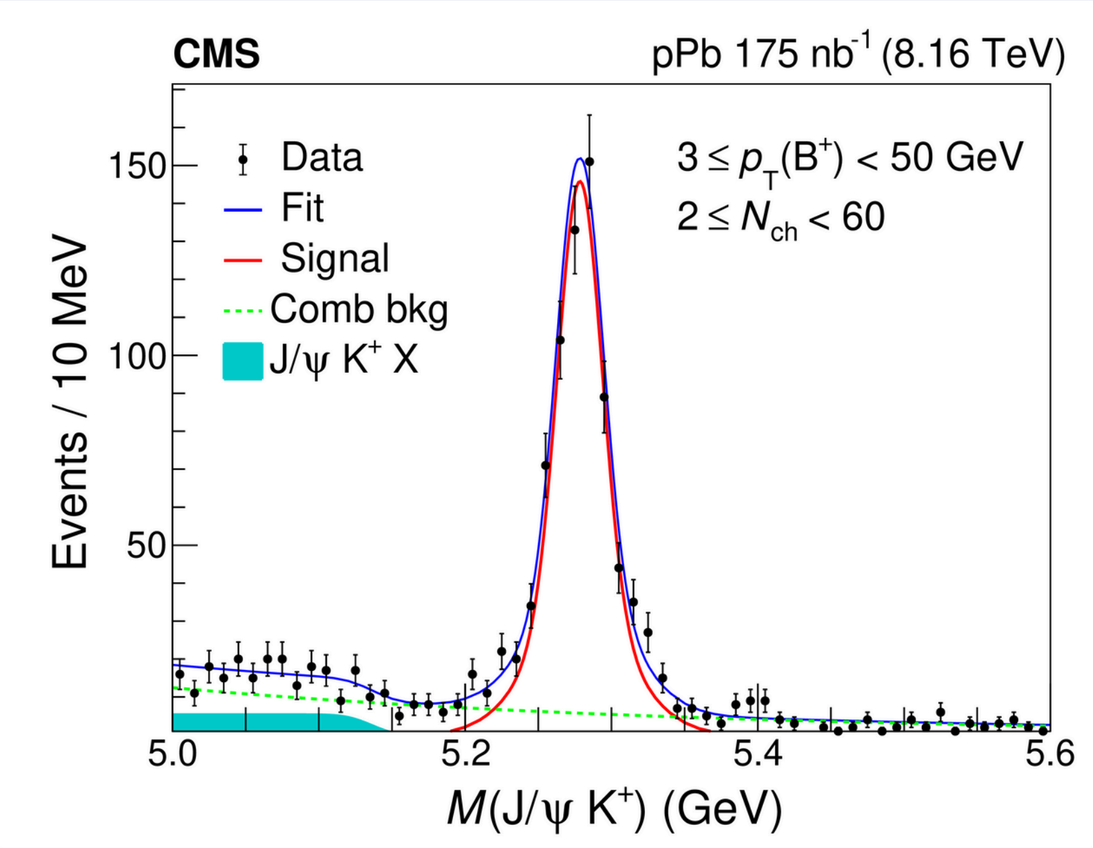

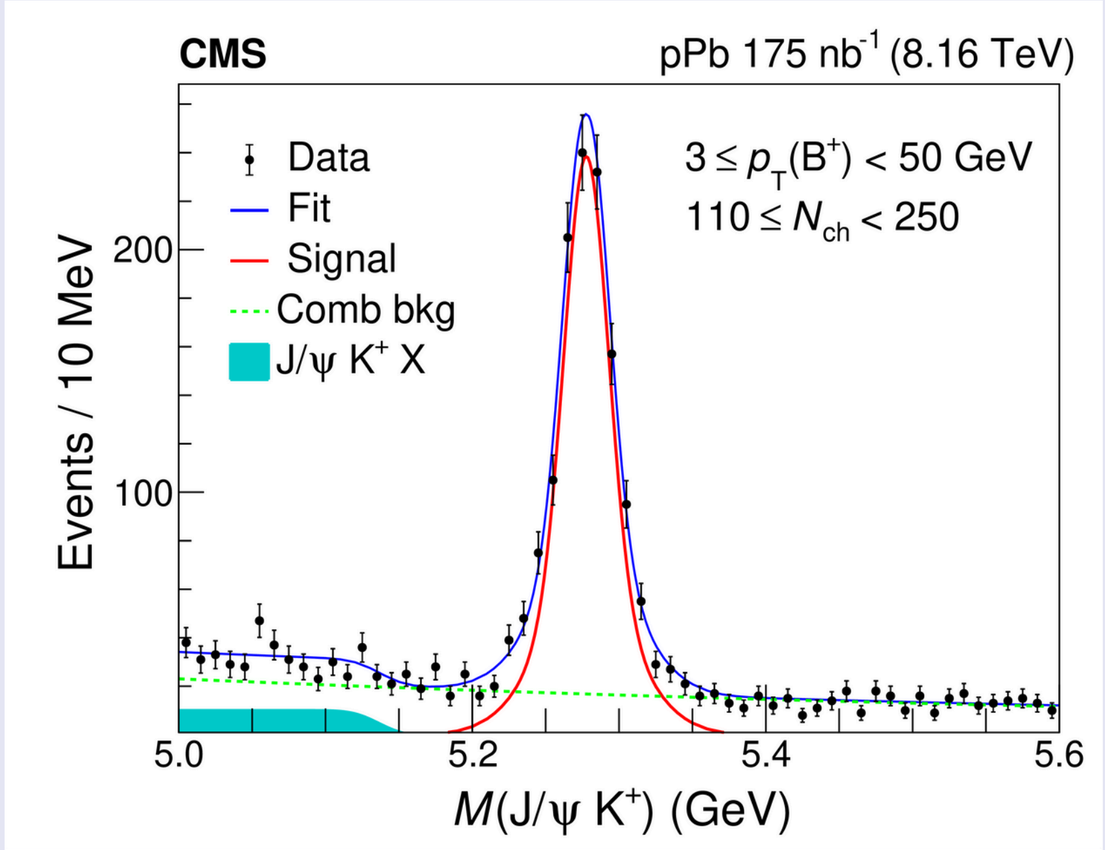

- B$^+$ yields are obtained by unbinned maximum likelihood.

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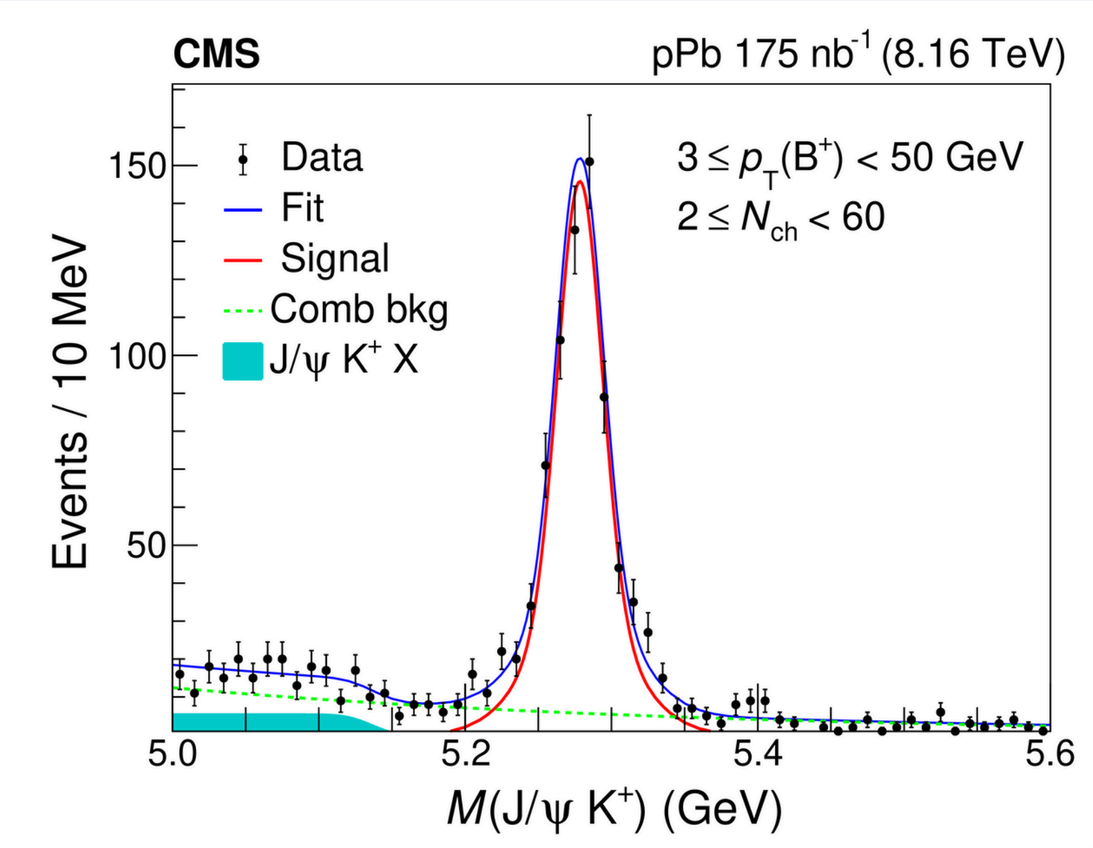

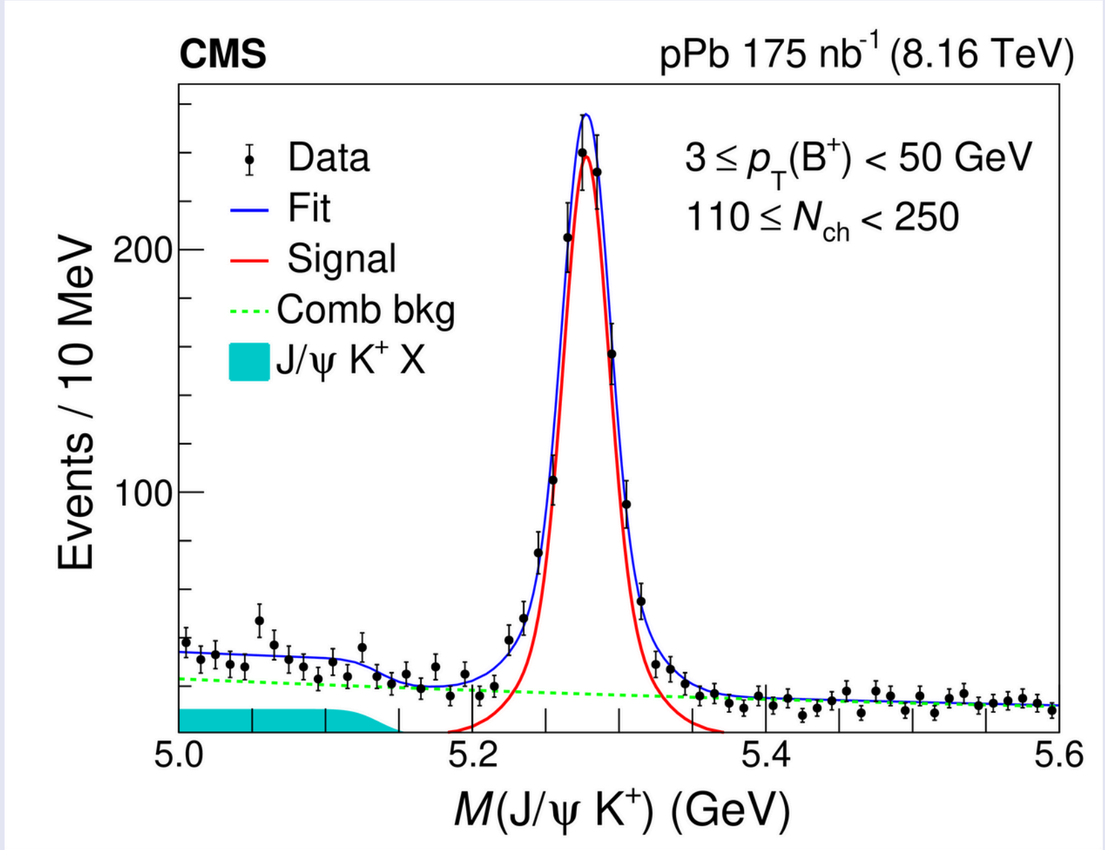

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- Signal modeled by: double-gaussian; backgroud by: error function and exponential.

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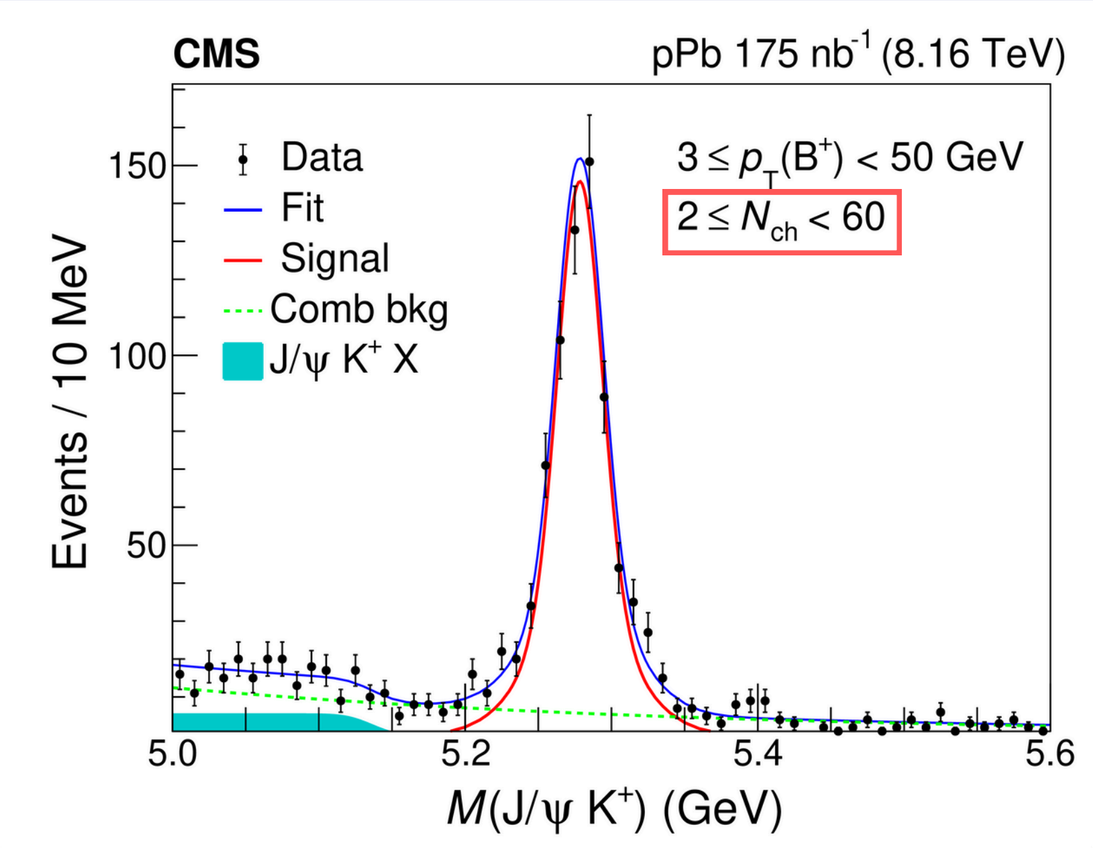

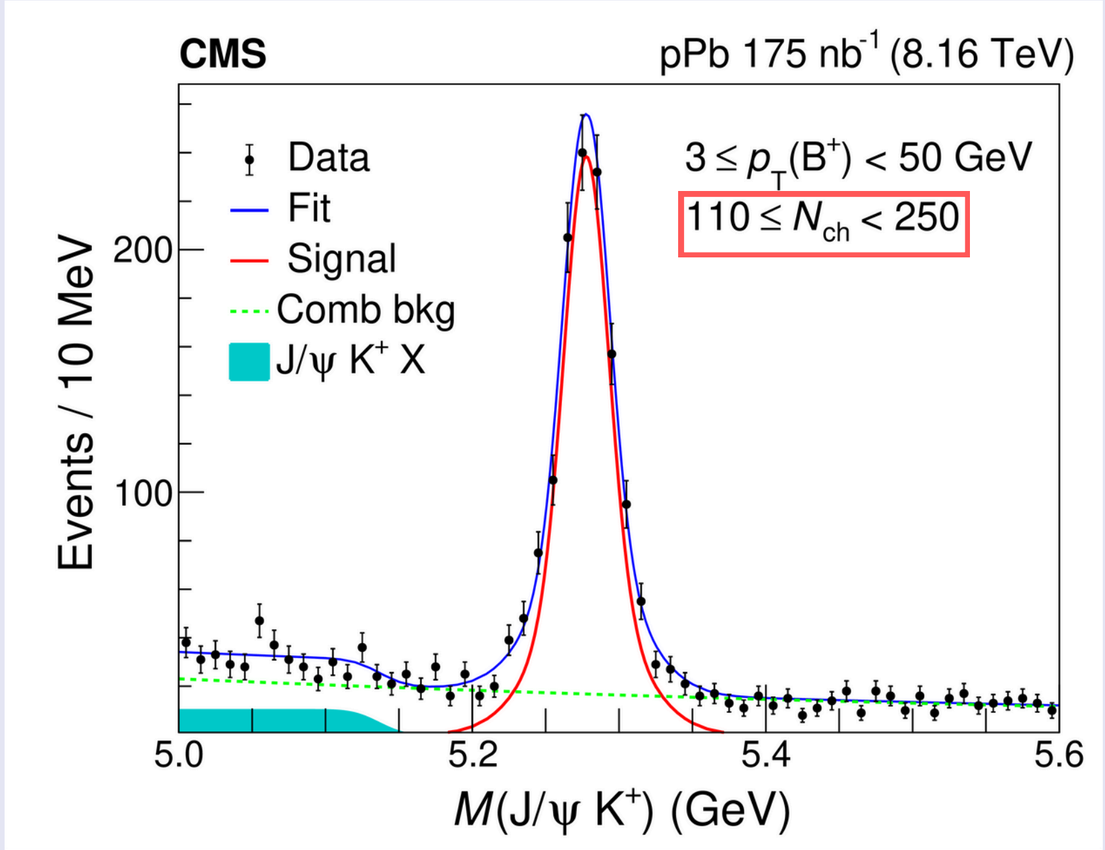

- B$^+$ yields are obtained by unbinned maximum likelihood.
- Signal modeled by: double-gaussian; backgroud by: error function and exponential.
- Results are obtained for 6 p_T bins and 4 multiplicity classes.

Differential cross section

CMS-HIN-22-001

$$\frac{\mathrm{d}\sigma}{\mathrm{d}p_{\mathrm{T}}} = \frac{1}{2}\frac{1}{\Delta p_{\mathrm{T}}}\frac{N(p_{\mathrm{T}})}{\epsilon\,\mathcal{B}\mathcal{L}}$$

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- $\mathcal{B}$ product world-average branching fractions.
- ϵ is the total efficiency.
- $\mathcal{L}$ is the integrated luminosity.
- Δp_{T} transverse momentum bin width.

Differential cross section

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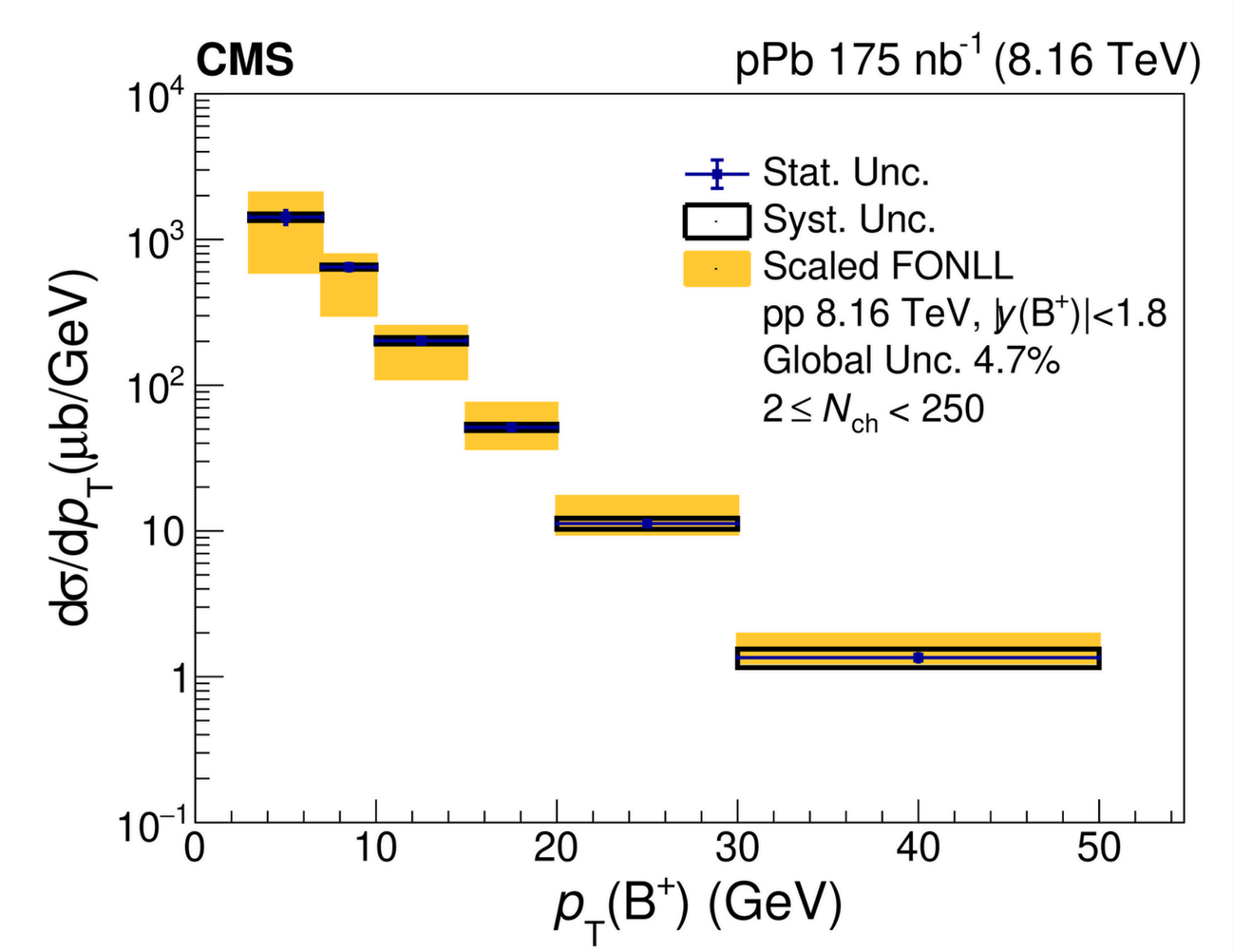

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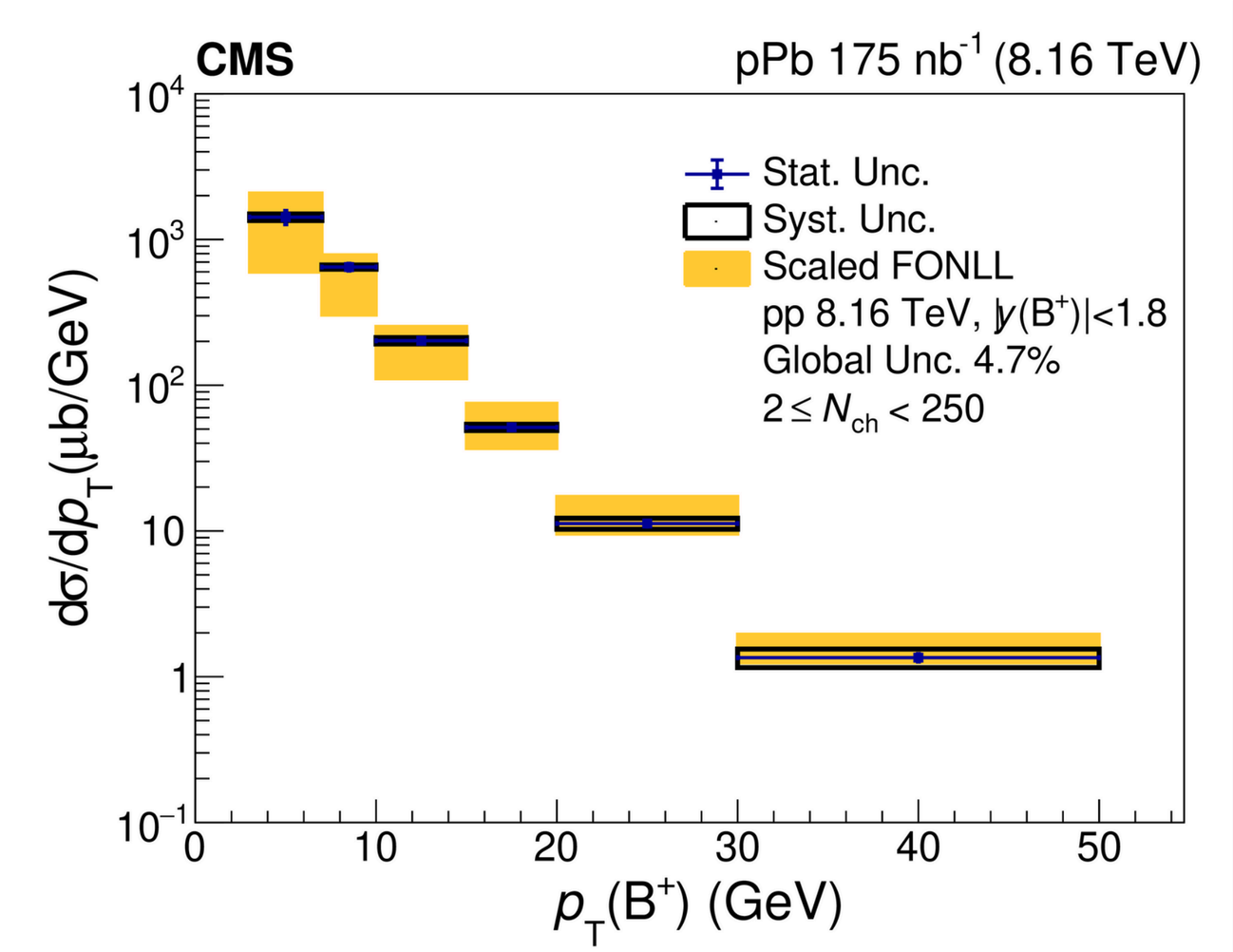

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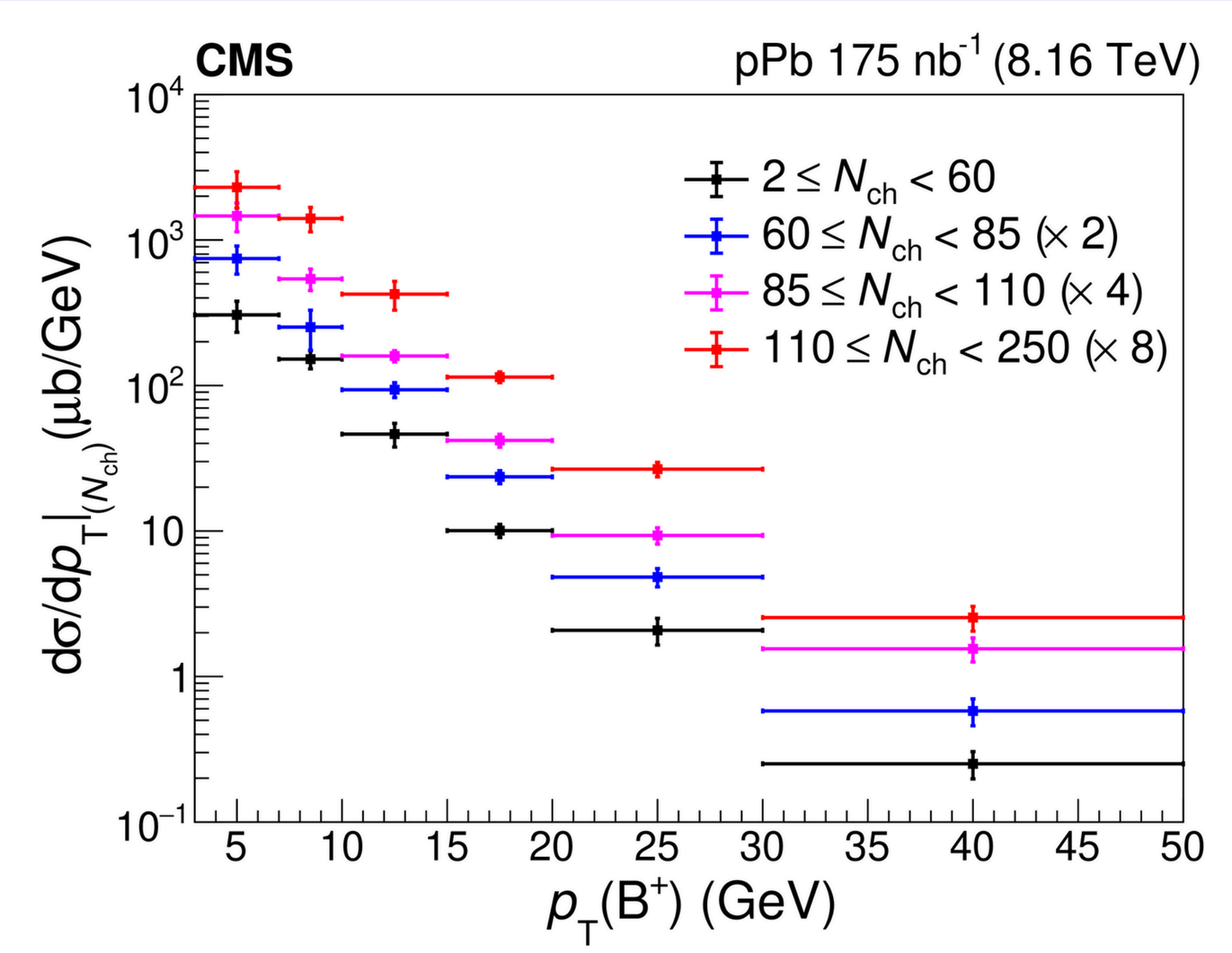
The theoretical predictions of FONLL are in good agreement with the measurements

B^+ cross section in multiplicity classes

CMS-HIN-22-001



- Cross section in p_T bins and charged-particle multiplicity classes.
- Total uncertainties are shown.

B^+ cross section in multiplicity classes

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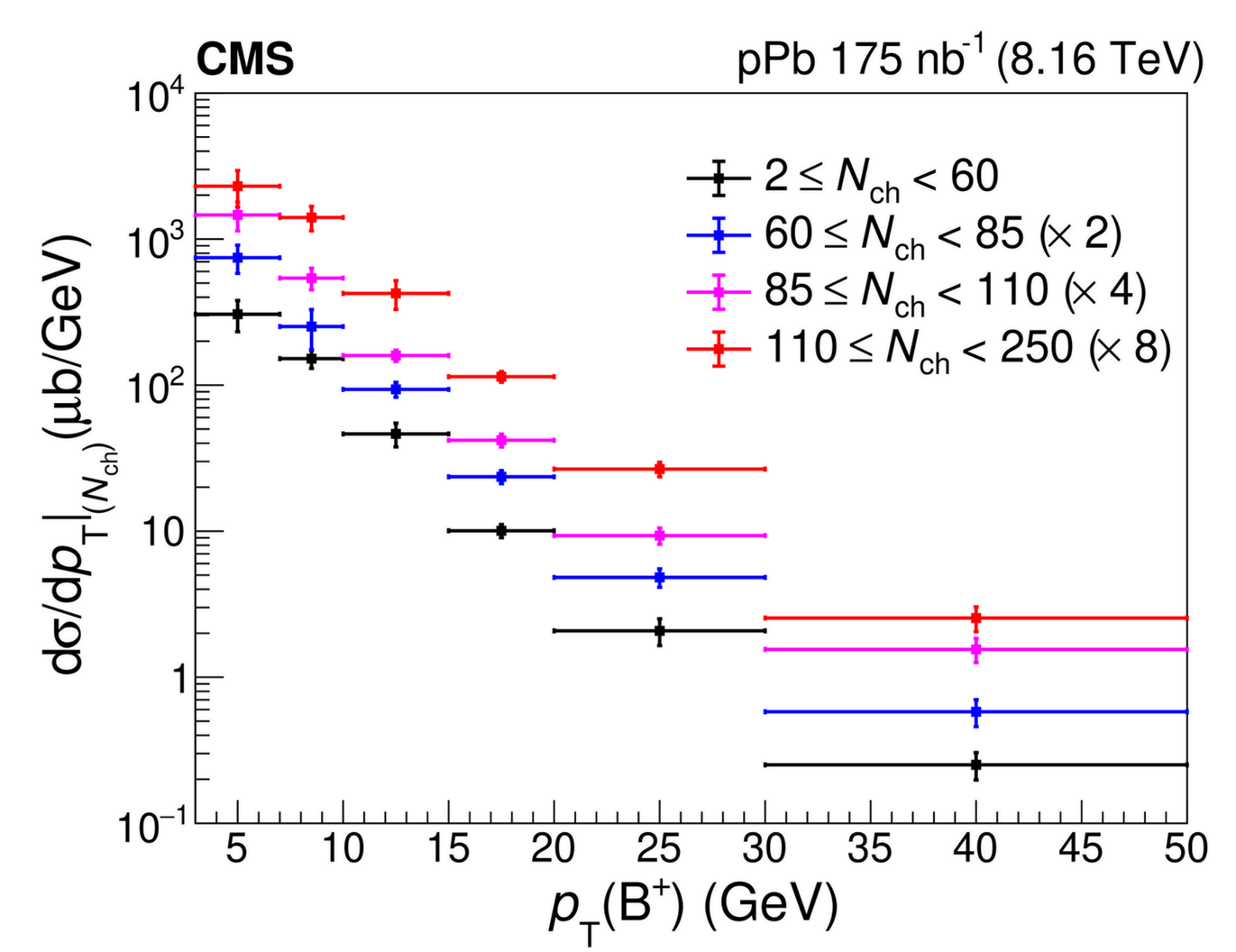

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For the first time in pPb collisions.

Study of in-medium nuclear effects

CMS-HIN-22-001

- Bad understanding in pPb medium effects to generete Glouver MC and no pp reference data available.

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- Definition of a new observable to measure of in-medium nuclear effects

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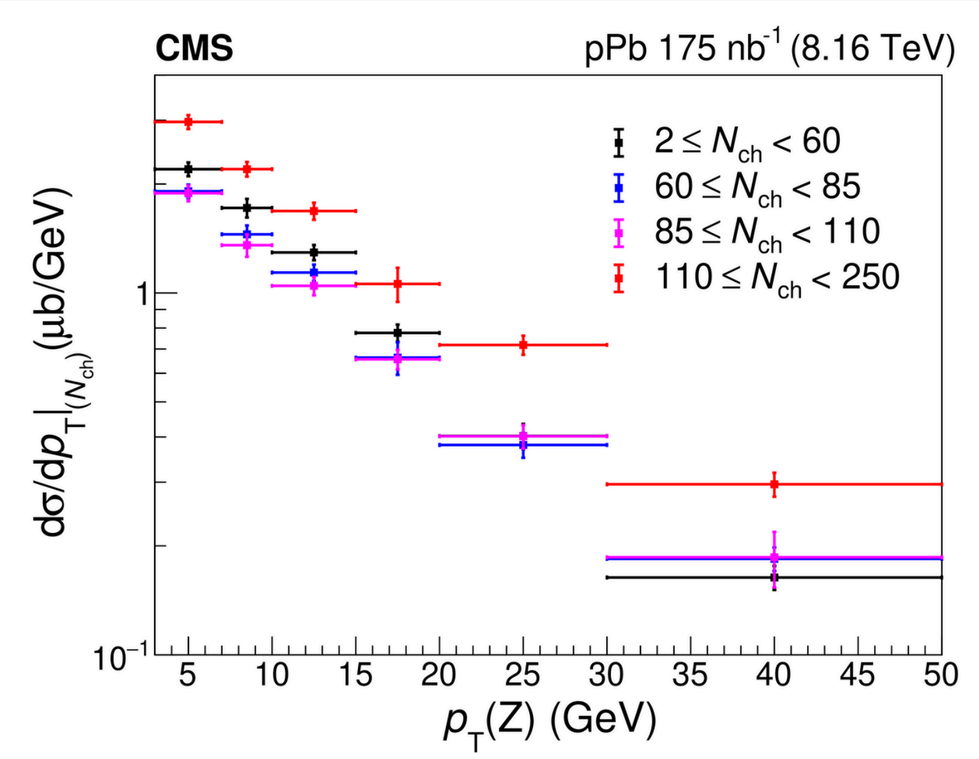

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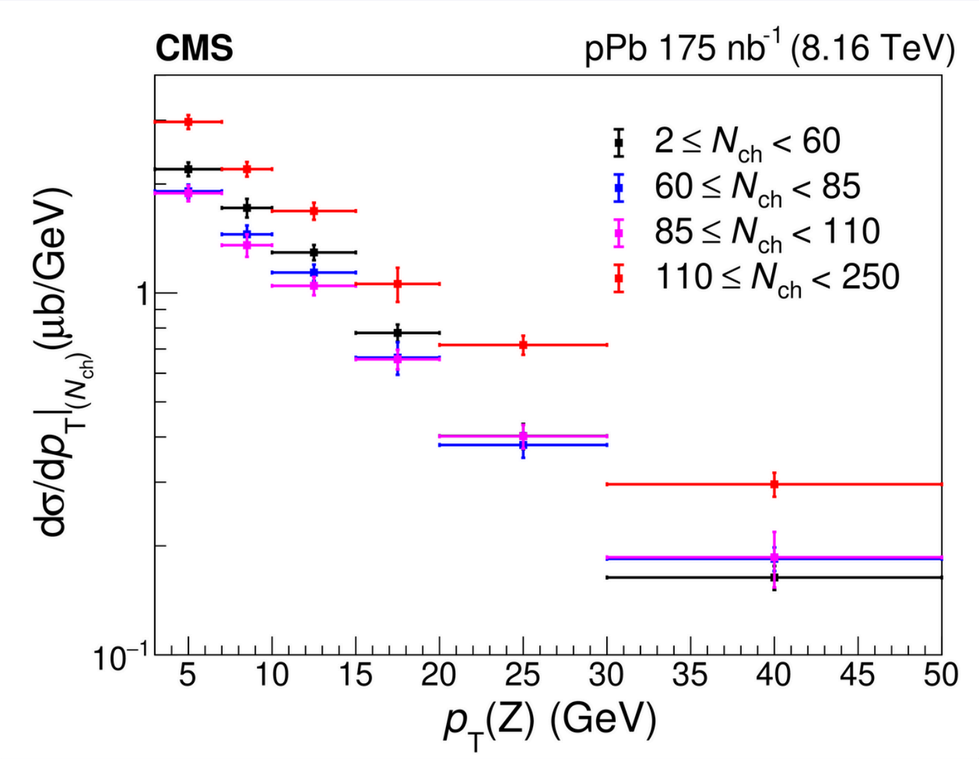


$$R^{\mathrm{Z}}_{\mathrm{HL}} = 1 \quad \rightarrow \quad R_{\mathrm{HL}} = \frac{R^{\mathrm{B}^+}_{\mathrm{HL}}}{R^{\mathrm{Z}}_{\mathrm{HL}}}$$

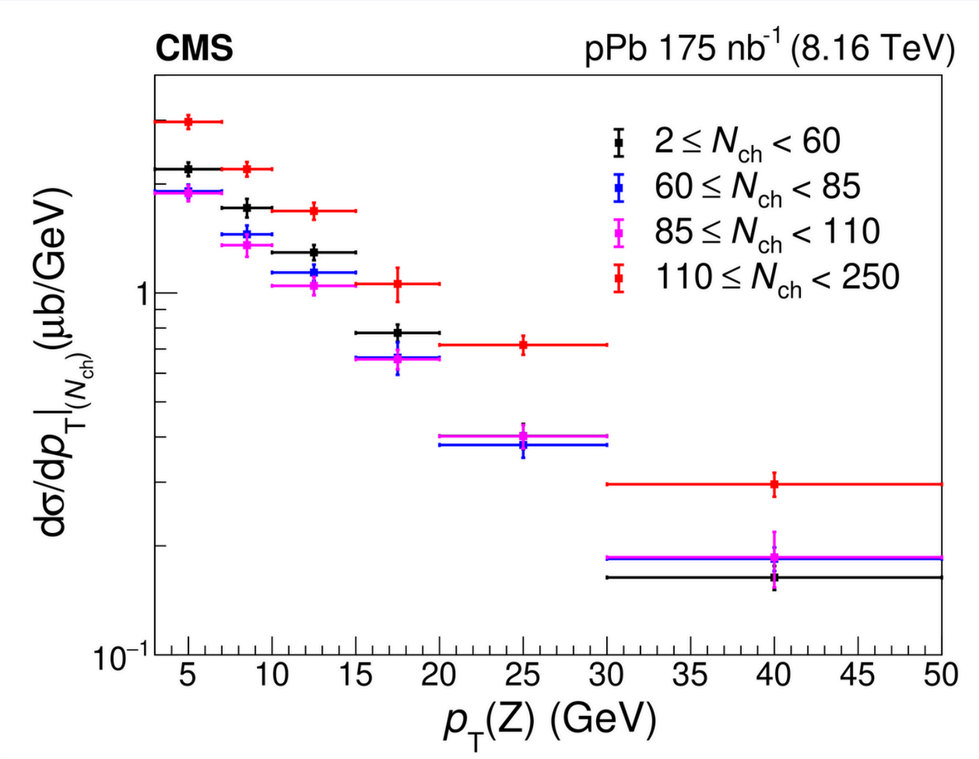
Study of in-medium nuclear effects

CMS-HIN-22-001

- Bad understanding in pPb medium effects to generete Glouver MC and no pp reference data available.
- Definition of a new observable to measure of in-medium nuclear effects
- **Diferential cross section of Z boson in the same events.**

$$R_{\mathrm{pPb}} = \frac{1}{\langle N_{\mathrm{coll}} \rangle} \frac{(\mathrm{d}\sigma/\mathrm{d}p_{\mathrm{T}})|_{\mathrm{pPb}}}{(\mathrm{d}\sigma/\mathrm{d}p_{\mathrm{T}})|_{\mathrm{pp}}}$$

$$R_{\mathrm{HL}} = \frac{\langle N_{\mathrm{coll}} \rangle|_{\mathrm{low}}}{\langle N_{\mathrm{coll}} \rangle|_{\mathrm{high}}} \frac{(\mathrm{d}\sigma/\mathrm{d}p_{\mathrm{T}})|_{\mathrm{high}}}{(\mathrm{d}\sigma/\mathrm{d}p_{\mathrm{T}})|_{\mathrm{low}}}$$

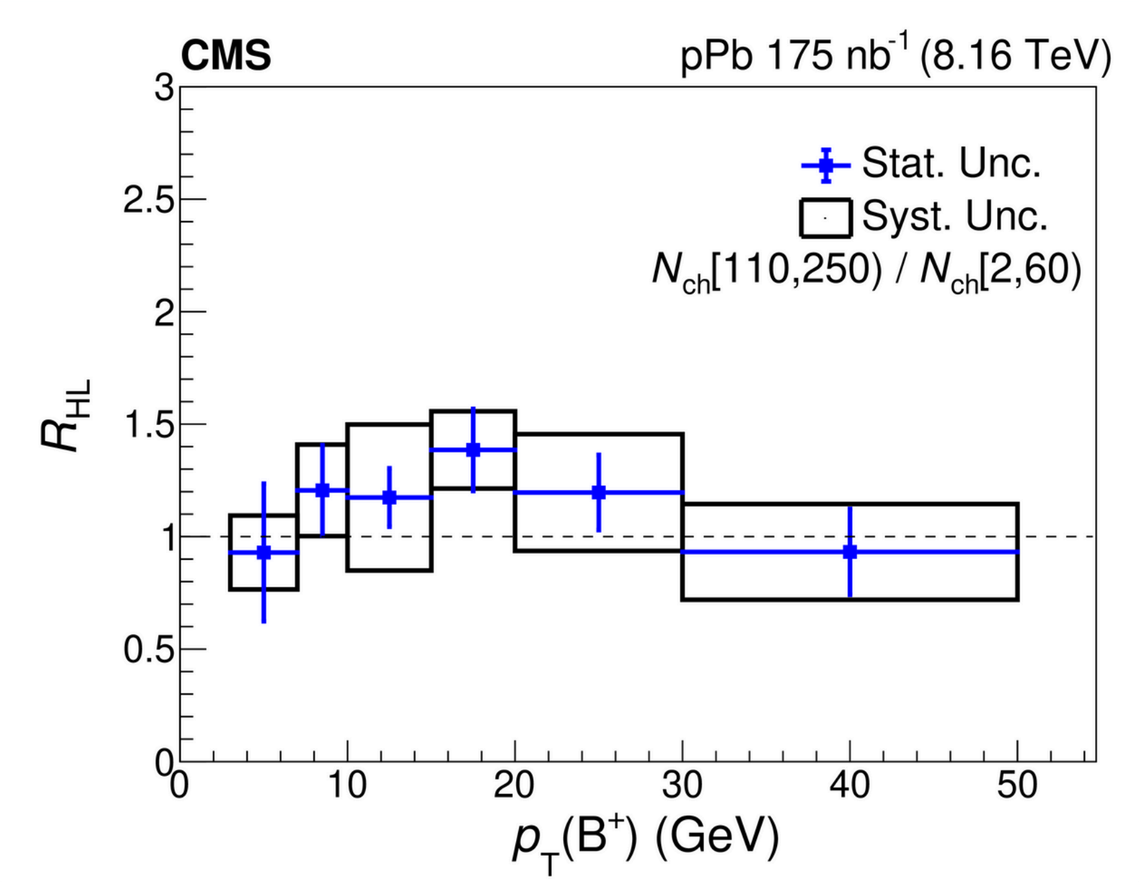


$$R^{\mathrm{Z}}_{\mathrm{HL}} = 1 \quad \rightarrow \quad R_{\mathrm{HL}} = \frac{R^{\mathrm{B}^+}_{\mathrm{HL}}}{R^{\mathrm{Z}}_{\mathrm{HL}}}$$

$$R_{\mathrm{HL}} = \frac{\left(\mathrm{d}\sigma^{\mathrm{B}^+}/\mathrm{d}p_{\mathrm{T}}\right)|_{\mathrm{high}}}{\left(\mathrm{d}\sigma^{\mathrm{B}^+}/\mathrm{d}p_{\mathrm{T}}\right)|_{\mathrm{low}}} \Big/ \frac{\left(\mathrm{d}\sigma^{\mathrm{Z}}/\mathrm{d}p_{\mathrm{T}}\right)|_{\mathrm{high}}}{\left(\mathrm{d}\sigma^{\mathrm{Z}}/\mathrm{d}p_{\mathrm{T}}\right)|_{\mathrm{low}}}$$

Study of in-medium nuclear effects

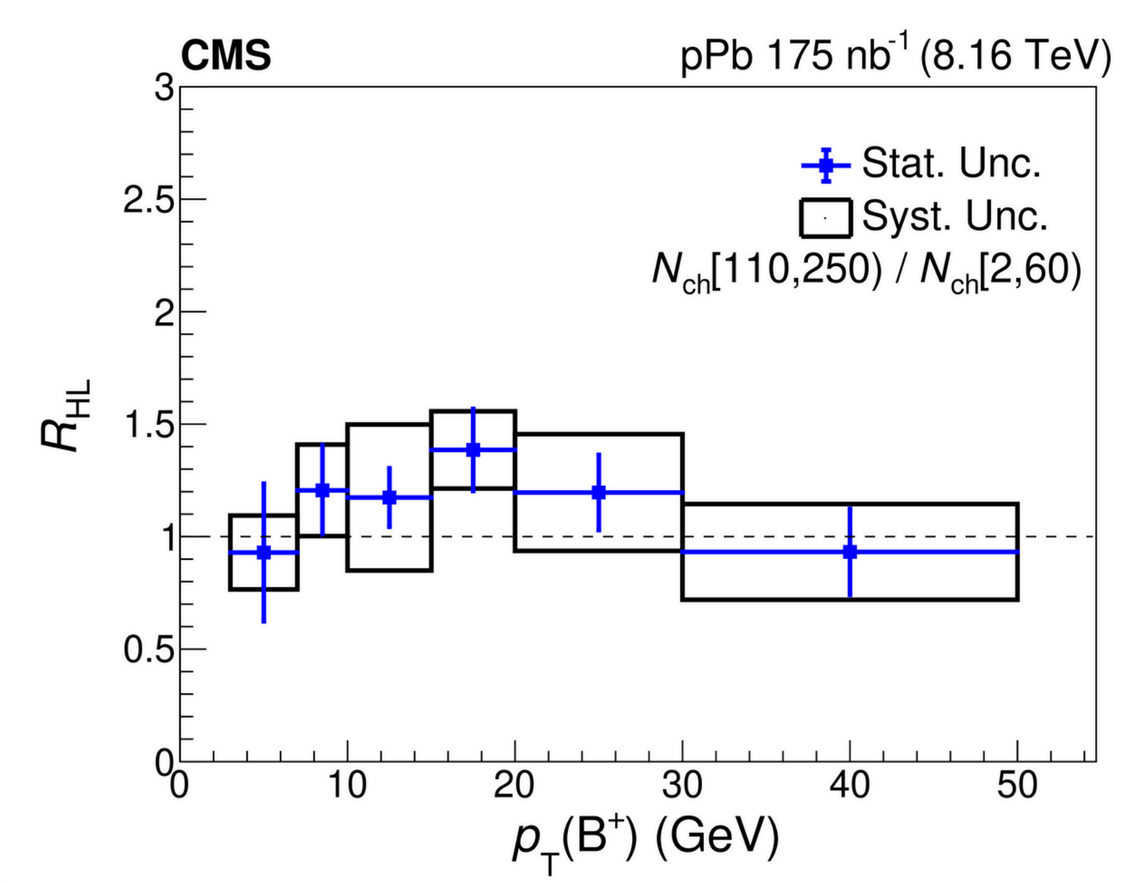
CMS-HIN-22-001



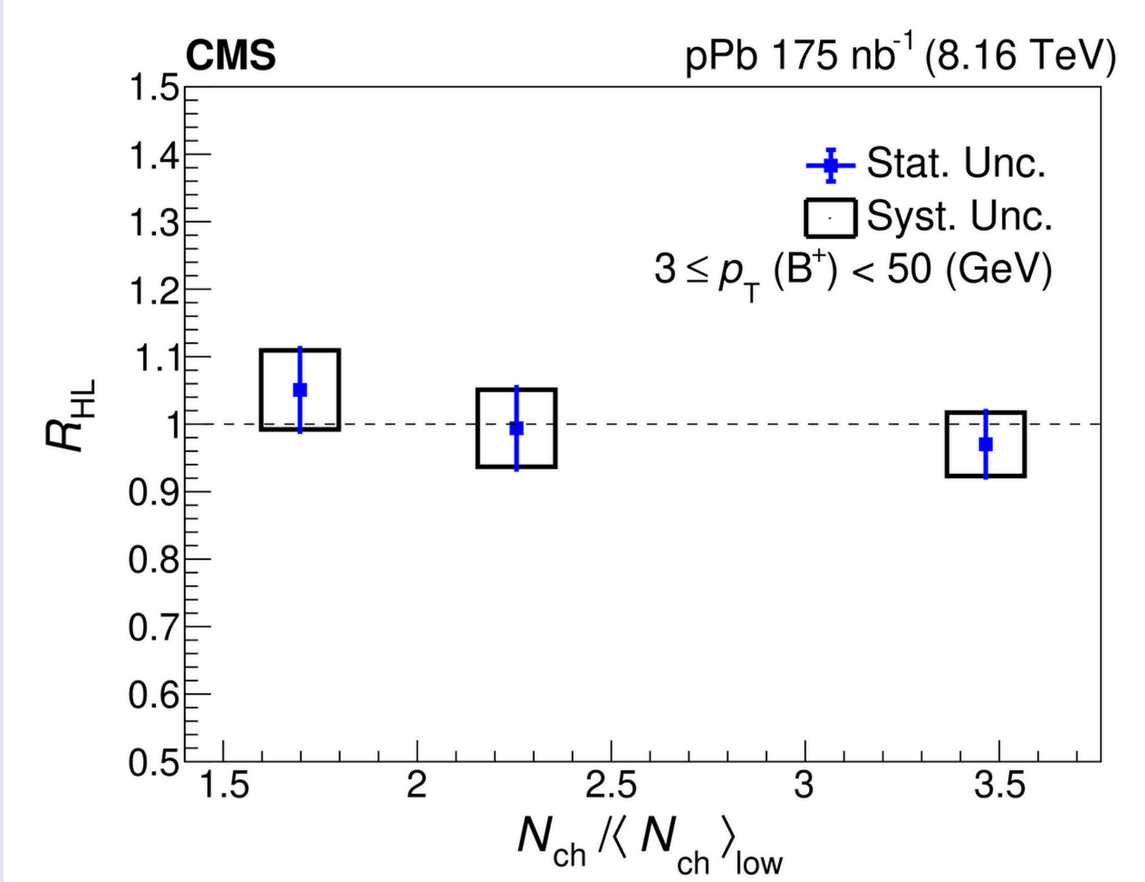
The R_{HL} for B^+ in p_T bins for the highest and lowest multiplicity classes

Study of in-medium nuclear effects

CMS-HIN-22-001



The R_{HL} for B^+ in p_T bins for the highest and lowest multiplicity classes

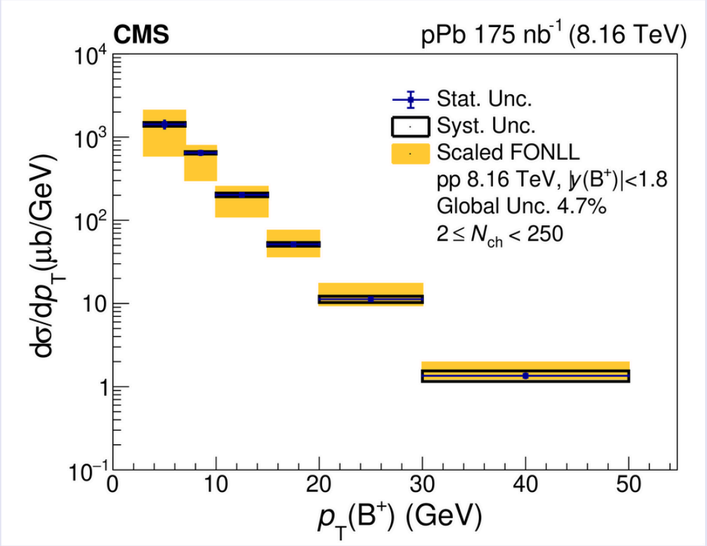


The R_{HL} for B^+ in the full p_T range and as a function of the multiplicity density

Conclusions

CMS-HIN-22-001

- B^+ differential cross section measurement is in good agreement with the theoretical predictions.



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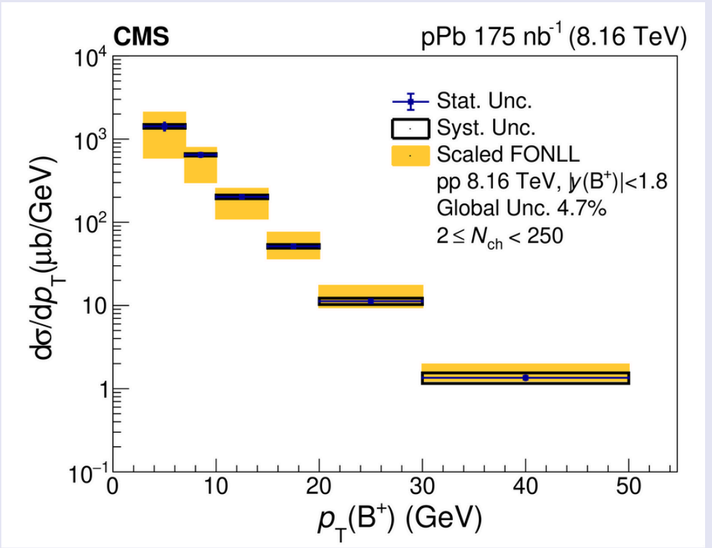
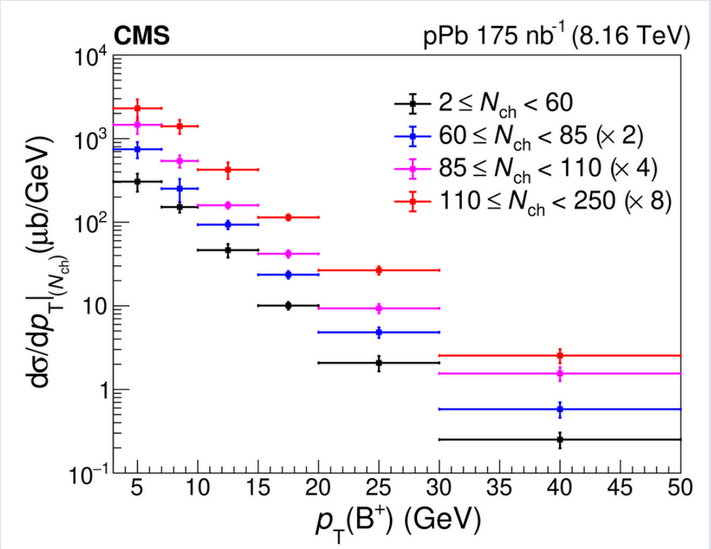
CMS-HIN-22-001

- B^+ differential cross section measurement is in good agreement with the theoretical predictions.
- First measurement of B^+ differential cross section in multiplicity classes in pPb collisions.

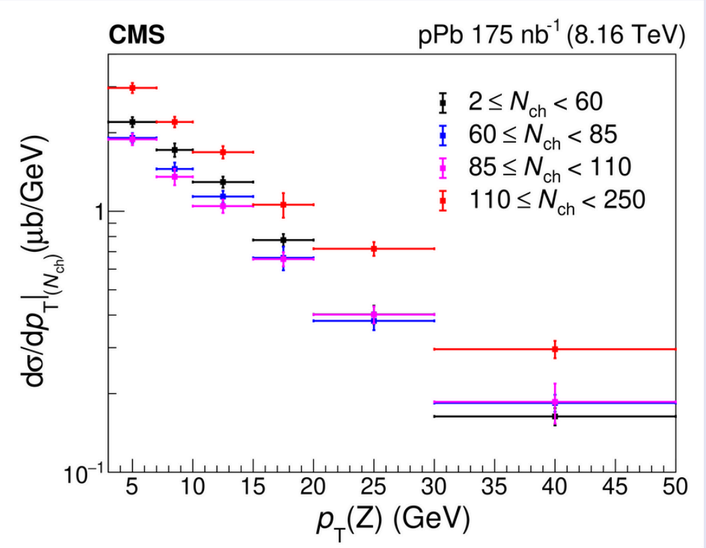


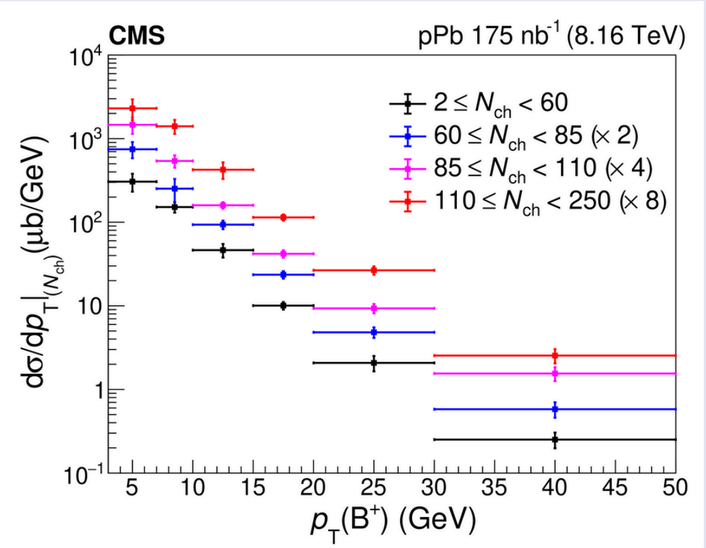


Conclusions

CMS-HIN-22-001

- B^+ differential cross section measurement is in good agreement with the theoretical predictions.
- First measurement of B^+ differential cross section in multiplicity classes in pPb collisions.
- The novel approach relying on the Z boson measurements to extract the scaling factors provides future opportunities for medium effect searches, particularly in small collision systems.





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CMS-HIN-22-001

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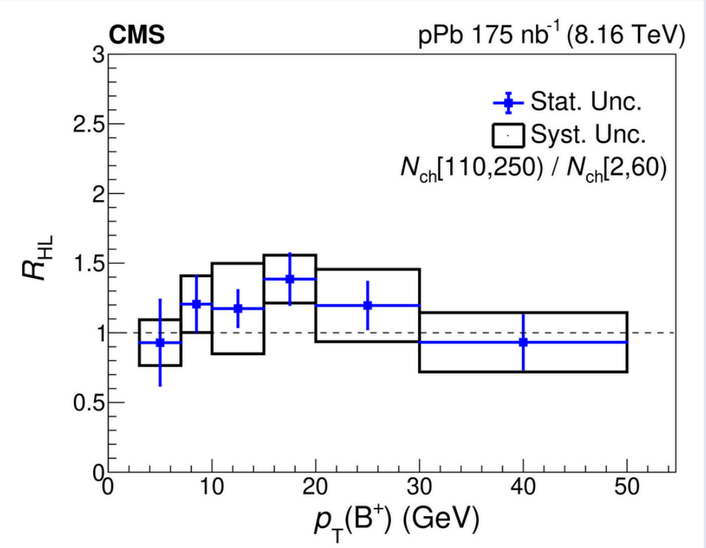
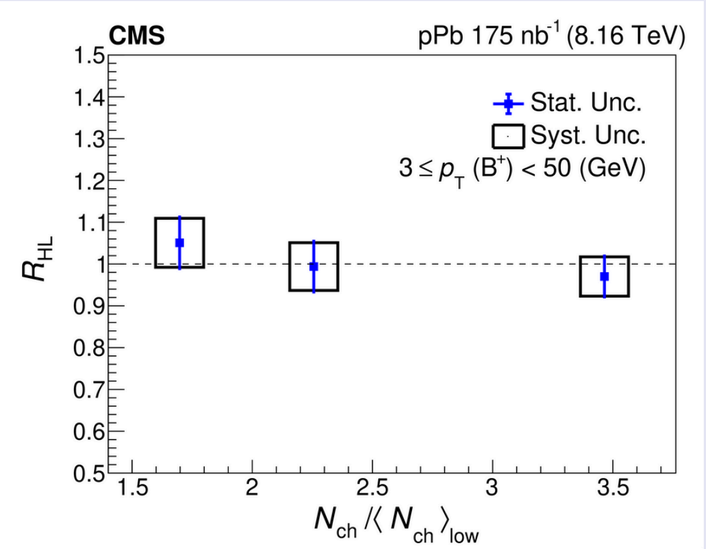
- The observed ratios are consistent with unity within uncertainties.

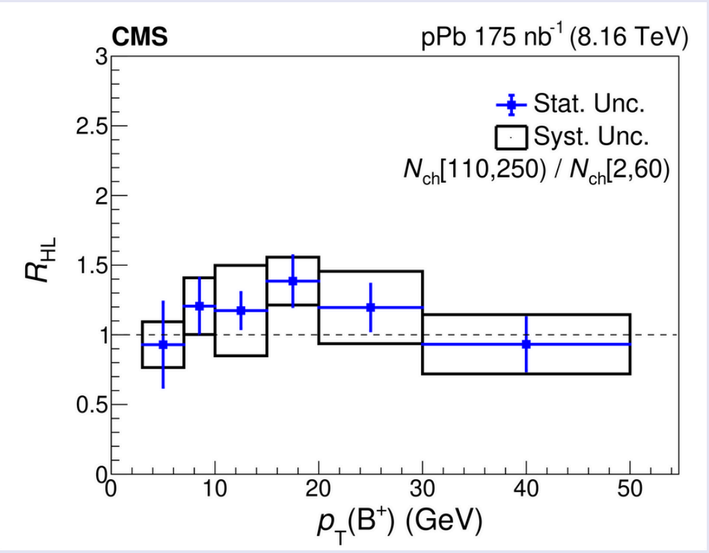


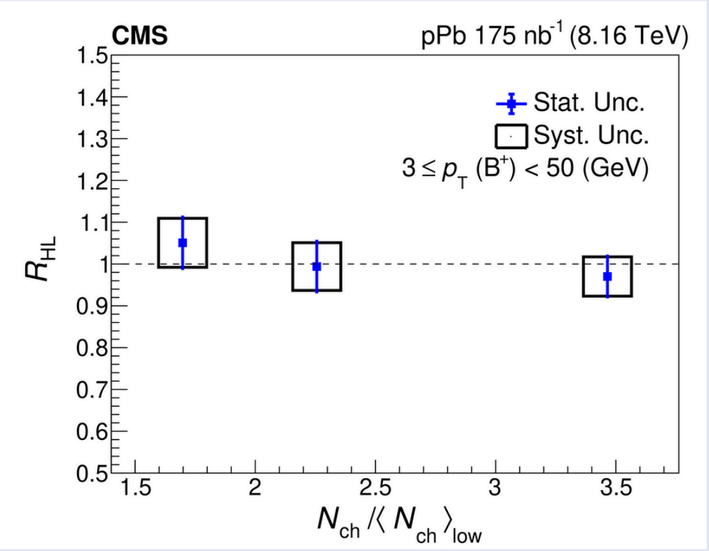


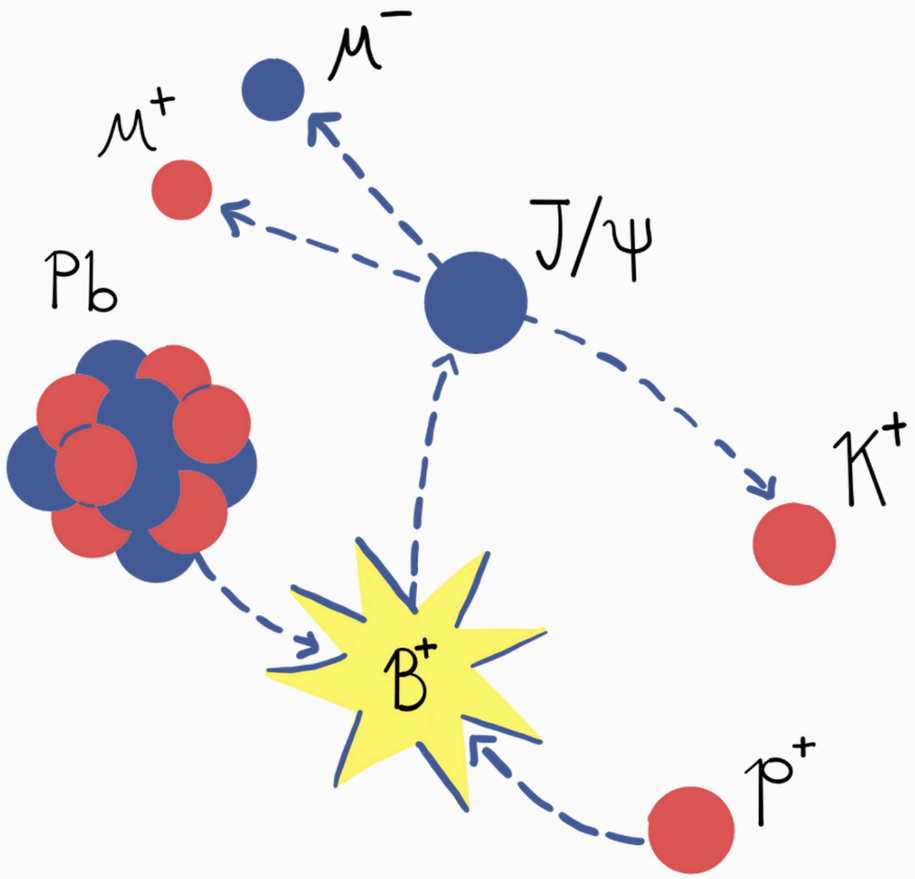
Conclusions

CMS-HIN-22-001

- B^+ differential cross section measurement is in good agreement with the theoretical predictions.
- First measurement of B^+ differential cross section in multiplicity classes in pPb collisions.
- The novel approach relying on the Z boson measurements to extract the scaling factors provides future opportunities for medium effect searches, particularly in small collision systems.
- The observed ratios are consistent with unity within uncertainties.
- Constraints on possible presence of medium effects in the B^+ meson production.







Thanks for listening!

Back-up

Monte Carlo and Efficiency

CMS-HIN-22-001

Monte Carlo

- MC samples generated with PYTHIA, EVTGEN, PHOTOS, EPOS and GEANT 4.
- Correction with **Tag and Probe** scale factors derived from efficiency ratio between the data and the MC in J/ψ analysis for each muon (RECO).
- Slightly discrepancies between data and MC in kinematic distributions. Corrected with reweighting (RECO).

Total Efficiency

$$\epsilon = A \times \epsilon_R$$

Acceptance A

Number of events passing the so called pre-filtercuts is divided by the number of events generated.

Reconstruction Efficiency ϵ_R

Number of reconstructed events after the full selection divided with respect to the number of generated b decays.

Summary table of differential cross sections of B^+ in pPb

p_T (GeV)	$d\sigma/dp_T$	Stat. Unc.	Syst. Unc.
3–7	1423	157	73
7–10	647	39	22
10–15	202	7	10
15–20	51.4	2.0	2.6
20–30	11.3	0.5	1.0
30–50	1.35	0.09	0.20

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[7] CMS Collaboration, "Search for nuclear modifications of B^+ meson production in pPb collisions at √sNN = 8.16 TeV". arXiv:2407.05402 (2024)