Measurement of the B^+ differential cross section as a function of transverse momentum and multiplicity density in pPb collisions at 8.16 TeV

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Documentation

CADI line:
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CMS Draft Analysis Note

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Measurement of the differential cross section of B^+ as a function of transverse momentum and multiplicity in pPb collisions at $\sqrt{s}$ =8.16 TeV.

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DRAFT
CMS Paper

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Measurement of the B^+ differential cross section as a function of transverse momentum and multiplicity density in pPb collisions at $\sqrt{s} = 8.16$ TeV

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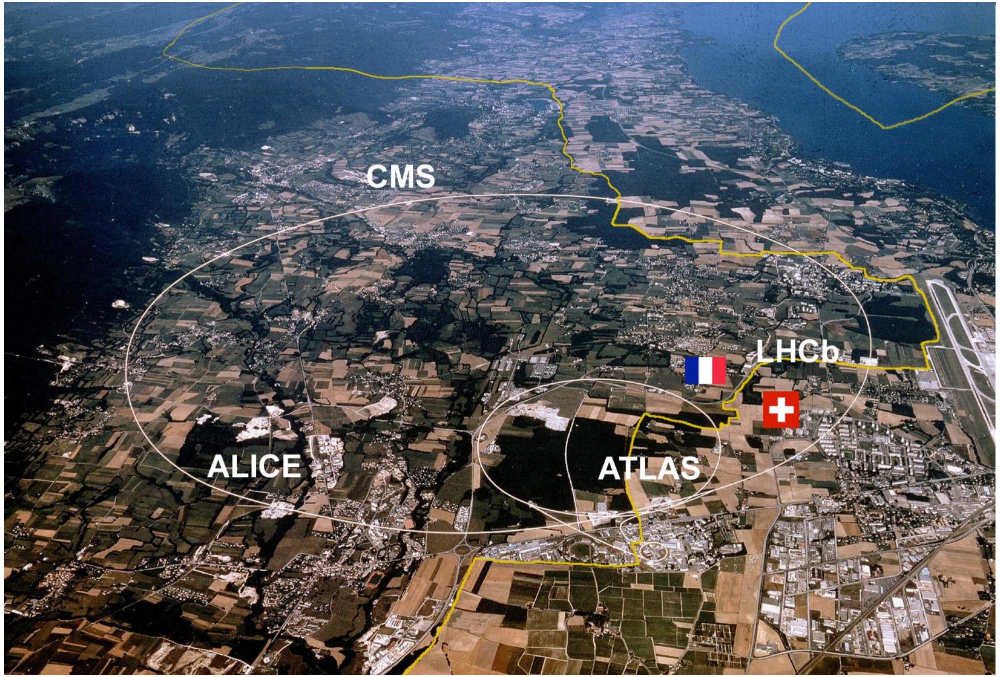
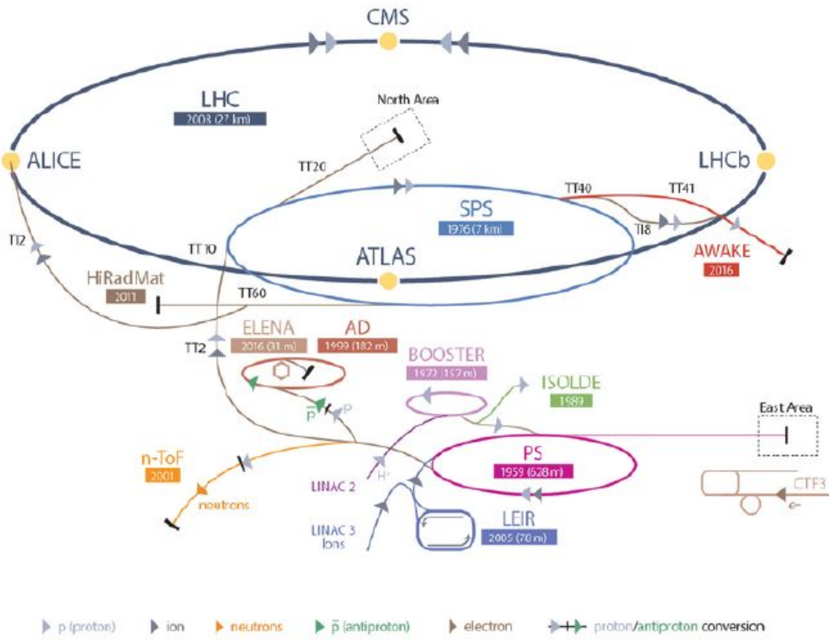
PDFAuthor:	Camilo Torres, Rogelio Reyes, Irais Bautista, Jhovanny Mejia, Gabriel Ayala, Horacio Crotte, Ivan Heredia De La Cruz, Heriberto Castilla
PDFTitle:	Differential multiplicity studies on B+ Production in pPb collisions at 8.16 TeV
PDFSubject:	CMS
PDFKeywords:	CMS, your topics

Please also verify that the abstract does not use any user defined symbols

Note: This analysis is part of the preliminary results presented to publish an article with The CMS Collaboration. For the current date the analysis is being reviewed by the Analysis Review Committe (ARC) and move to the approval and publication with the usual channels of CERN.

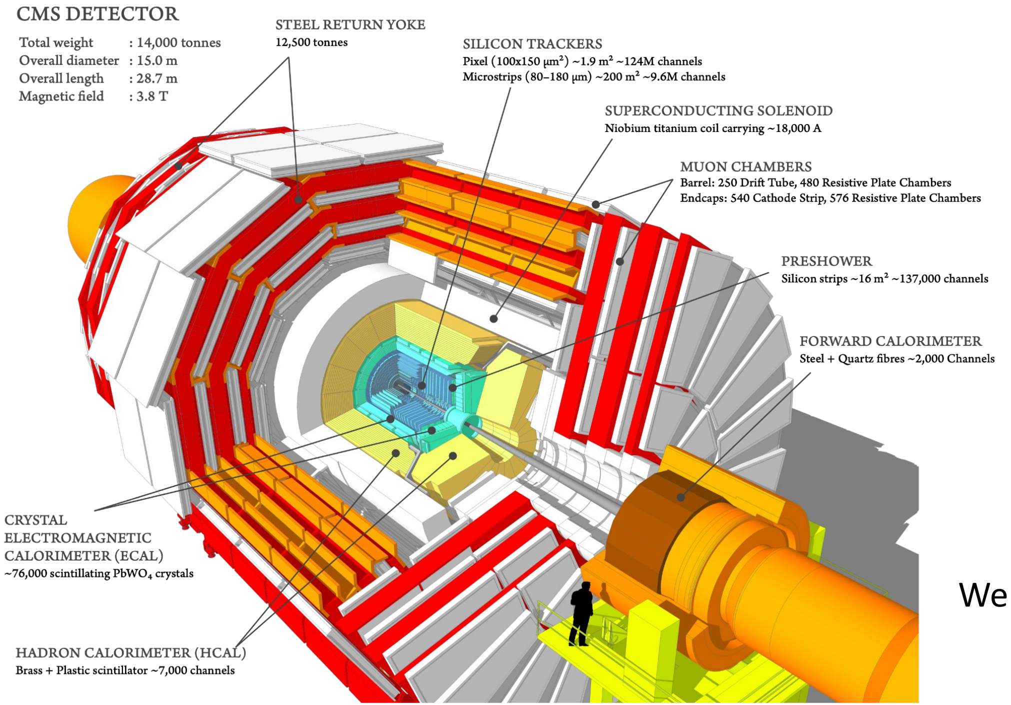
The Large Hadron Collider

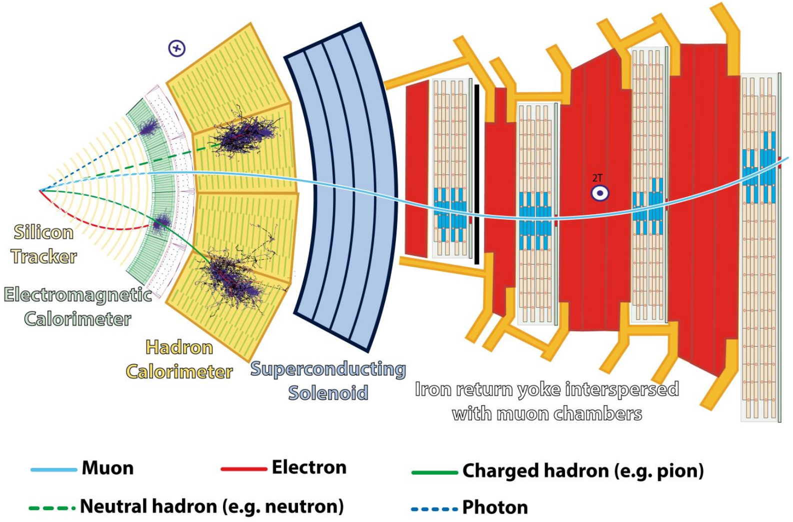




The world's largest and most powerful particle accelerator.

CMS Experiment

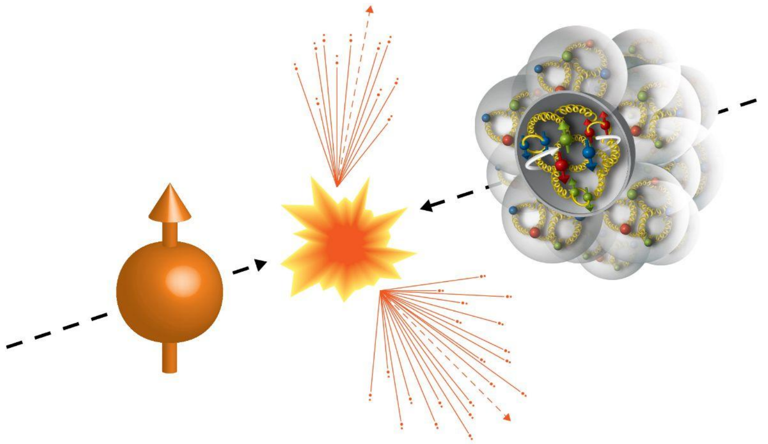




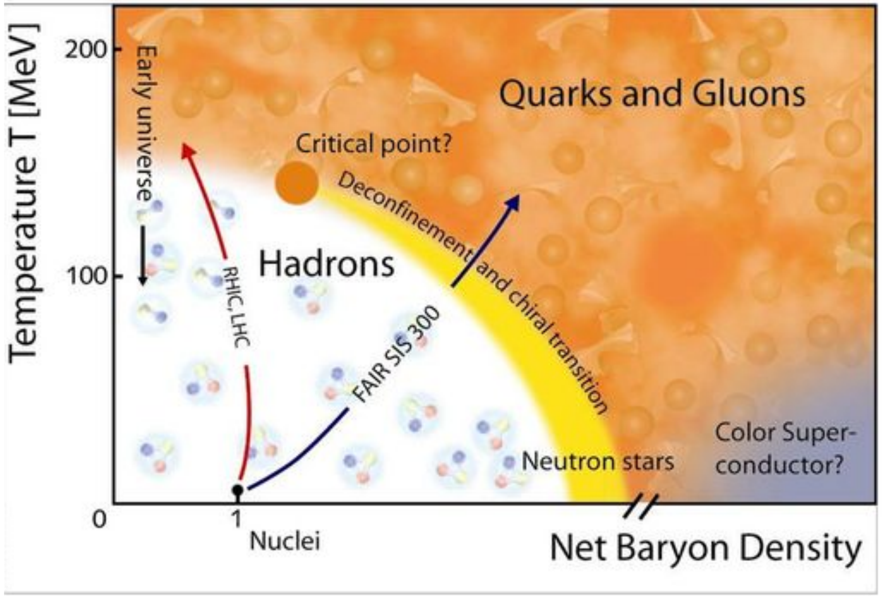
We are using Silicon Trackers and Muon Chambers.

Heavy Ions Collisions and Quark-Gluon Plasma

- After the Big Bang the universe was filled with a mixture dominated by quarks and by gluons.
- At high temperatures, quarks and gluons were bound only weakly. (Quark-gluon plasma)
- Powerful accelerators make collisions as proton-lead or lead-lead.



Motivation

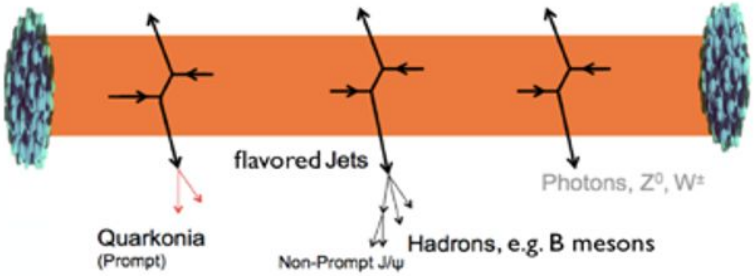


- *c* and *b* quarks may probe the QGP state.
- They interact strongly with the medium via elastic collisions and gluon radiation, losing energy.

- Measurement of the production of strange beauty mesons can provide fundamental insights into the relevance of mechanisms of beauty recombination in the quark-gluon plasma.

- A complete understanding of the interactions of heavy quarks in the deconfined medium formed in heavy ion collisions requires a thorough knowledge of their production in proton-nucleus collisions.

Heavy Flavor states are are ideal "hard probes" for studying the properties of the created medium



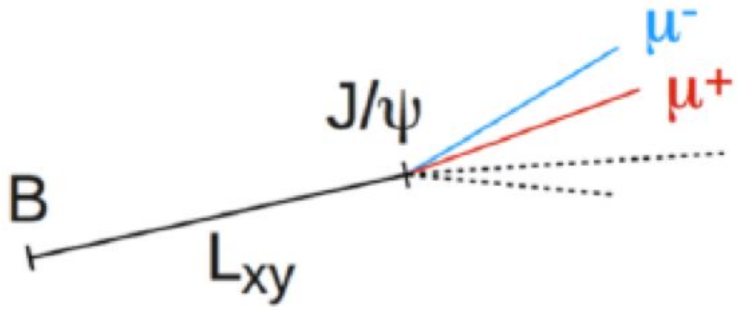
Data and Monte Carlo samples, Trigger and Online selection

Decay channel

The decay channels used for this analysis are:

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

$$J/\psi \rightarrow \mu^+\mu^-$$



2016 Data Sets and Selection Details

Datasets

/PADoubleMuon/PARun2016A-PromptReco-v1/AOD
/PADoubleMuon/PARun2016B-PromptReco-v1/AOD
/PADoubleMuon/PARun2016C-PromptReco-v1/AOD
/PADoubleMuon/PARun2016D-PromptReco-v1/AOD

J/ψ selection details:

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

Data quality:

Cert_285479-285832_HI8TeV_PromptReco_pPb_Collisions16_JSON_NoL1T.txt
Cert_285952-286496_HI8TeV_PromptReco_Pbp_Collisions16_JSON_NoL1T.txt

Dimuon Trigger

Trigger:

HLT_PAL1DoubleMuOpen_v1

Trigger details:

|Max η| < 2.4

min pT = 0.0

Table 2.1: Integrated luminosity's.

year	part of the run	L_{int} (nb^{-1})
2016	for pPb	62.65
2016	for Pbp	111.92
	Total luminosity	174.57

This trigger requires two muon candidates found in the muon detectors at level-1 (L1) trigger with loosest possible selections to maximize the detection efficiency. During 2016 pPb run, this trigger was operated without any pre-scale.

Integrated Luminosity:

- 8TeV pPb Luminosity: 64.41 /nb
- 8TeV Pbp Luminosity: 115.28 /nb
  Luminosity: 179.69 /nb (2016) (PdmV2016Analysis)
- The luminosity sections were selected based on the certified list, validated by the different Detector Performance Groups (DPGs) and Physics Object Groups (POGs).

Official MC Samples

Monte Carlo (MC) samples of pPb (Pbp) collisions are generated in this analysis for efficiency studies, analysis selection, and cross-check of other potential detector effects.

- **PYTHIA 8:** Production and hadronization.
- **EVENTGEN:** Decaying b hadrons.
- **PHOTOS:** The QED final state radiation.
- **GEANT4:** Simulation of the CMS detector.
- **EPOS:** Simulation of collective effects in pp, pA and AA collisions.

Generator	Dataset
EPOS	/ReggeGribovPartonMC_EposLHC_pPb_4080_4080_DataBS/pPb816Summer16DR-MB_80X_mcRun2_pA_v4-v2/AODSIM
EPOS	/ReggeGribovPartonMC_EposLHC_PbP_4080_4080_DataBS/pPb816Summer16DR-MB_80X_mcRun2_pA_v4-v2/AODSIM
PYTHIA +EVTGEN	/BPlusToJpsiK_pThat5_pPb-Embed_8p16TeV_TuneCUETP8M1_Pythia8_EvtGen/pPb816Summer16DR-80X_mcRun2_pA_v4-v2/AODSIM
PYTHIA +EVTGEN	/BPlusToJpsiK_pThat5_Pbp-Embed_8p16TeV_TuneCUETP8M1_Pythia8_EvtGen/pPb816Summer16DR-80X_mcRun2_pA_v4-v2/AODSIM
PYTHIA +EVTGEN	/NonPromptPsi1S2S_pPb-EmbEPOS_8p16TeV_Pythia/pPb816Summer16DR-pPbEmb_80X_mcRun2_pA_v4-v2/AODSIM
PYTHIA +EVTGEN	/NonPromptPsi1SPsi2S_PbP-EmbEPOS_8p16TeV_Pythia/pPb816Summer16DR-PbPEmb_80X_mcRun2_pA_v4-v2/AODSIM

Transverse Momentum Analysis

$$p_T\left(B^+\right)$$

Data Mass Fit

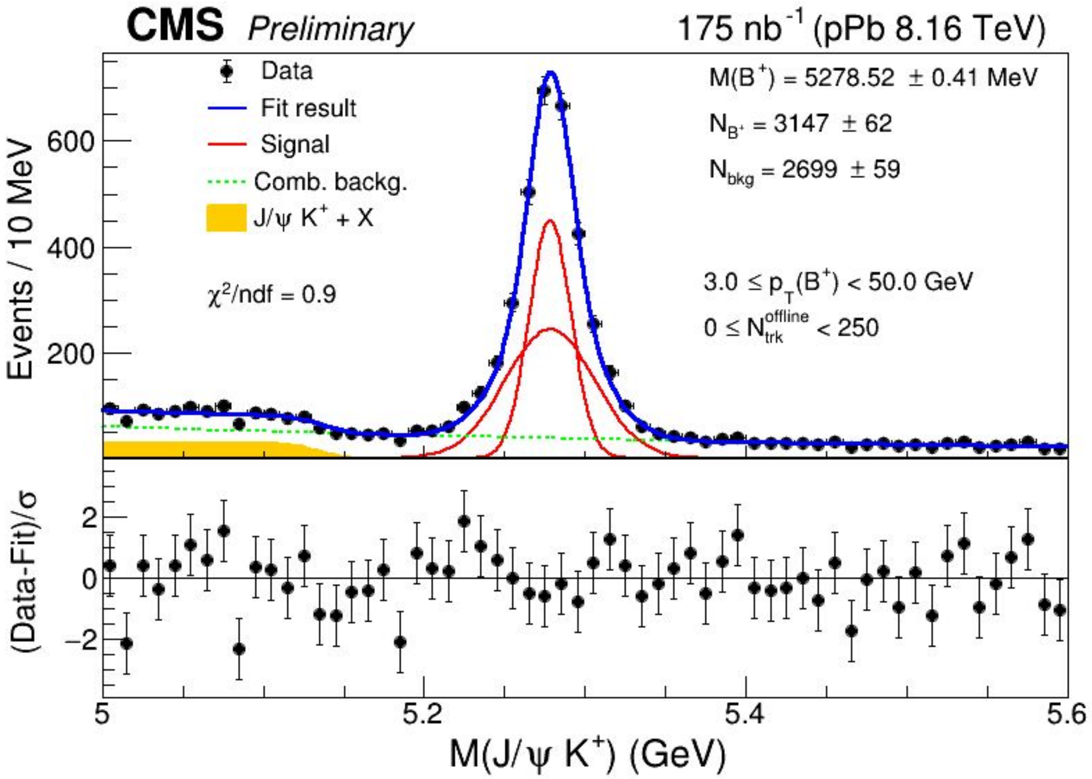
Following HIN-14-004. Meson Production in p+Pb Collisions at 5.02 TeV

(Phys. Rev. Lett. 116, 032301)

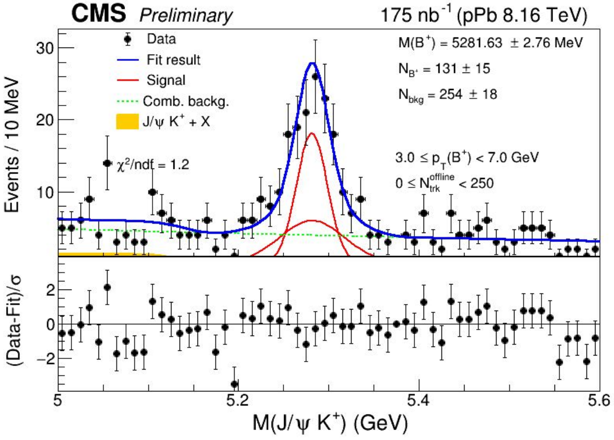
The B^+ yields are extracted using unbinned maximum likelihood estimations to the reconstructed $J/\psi K^+$ invariant mass distributions.

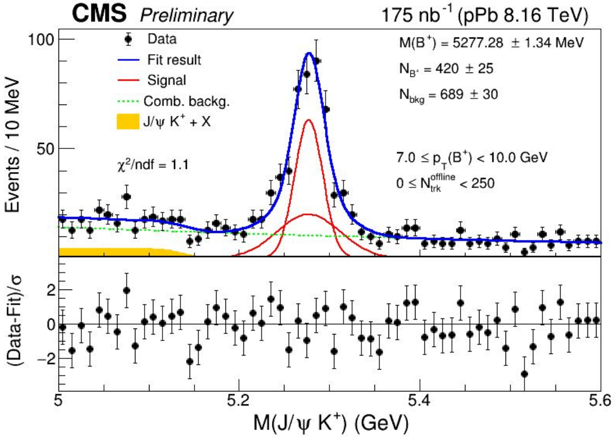
Fit function:

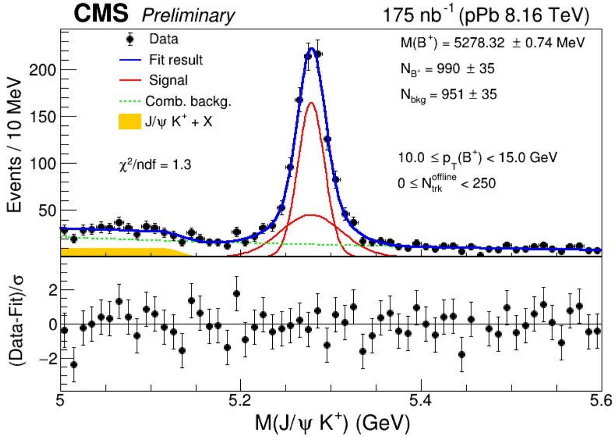
- Sum of two Gaussians with common mean and different widths
- $B^+ \to J/\psi K + X$ decays modeled with an error function.
- Combinatorial background modeled with an exponential function

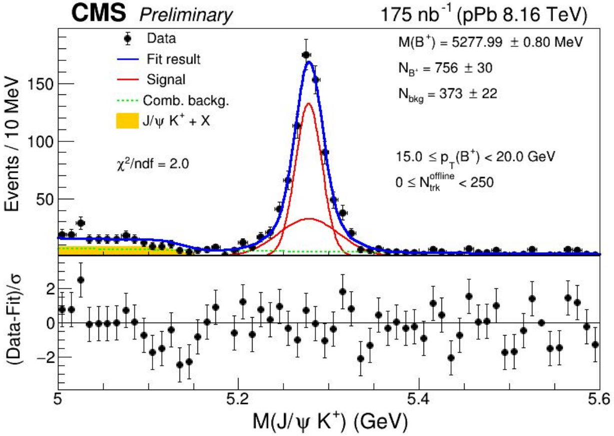


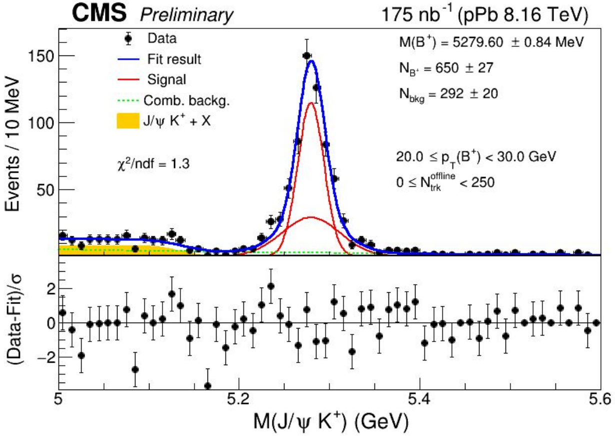
pT Analysis

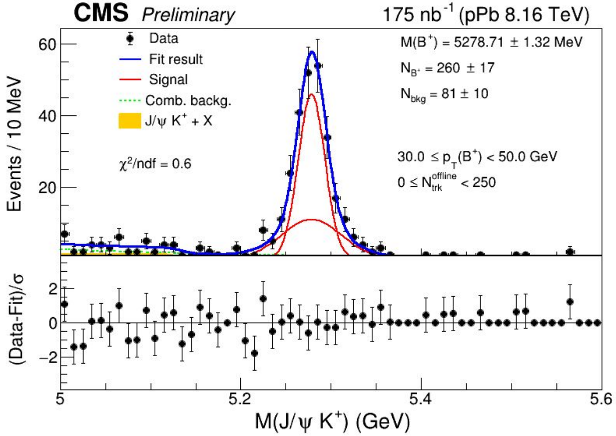

CMS Preliminary
175 nb^-1 (pPb 8.16 TeV)
Data
Fit result
Signal
Comb. backg.
J/ψ K+ + X
M(B+) = 5281.63 ± 2.76 MeV
N_B+ = 131 ± 15
N_bkg = 254 ± 18
χ2/ndf = 1.2
3.0 ≤ p_T(B+) < 7.0 GeV
0 ≤ N_trk^offline < 250
Events / 10 MeV
(Data-Fit)/σ
M(J/ψ K+) (GeV)


CMS Preliminary
175 nb^-1 (pPb 8.16 TeV)
Data
Fit result
Signal
Comb. backg.
J/ψ K+ + X
M(B+) = 5277.28 ± 1.34 MeV
N_B+ = 420 ± 25
N_bkg = 689 ± 30
χ2/ndf = 1.1
7.0 ≤ p_T(B+) < 10.0 GeV
0 ≤ N_trk^offline < 250
Events / 10 MeV
(Data-Fit)/σ
M(J/ψ K+) (GeV)

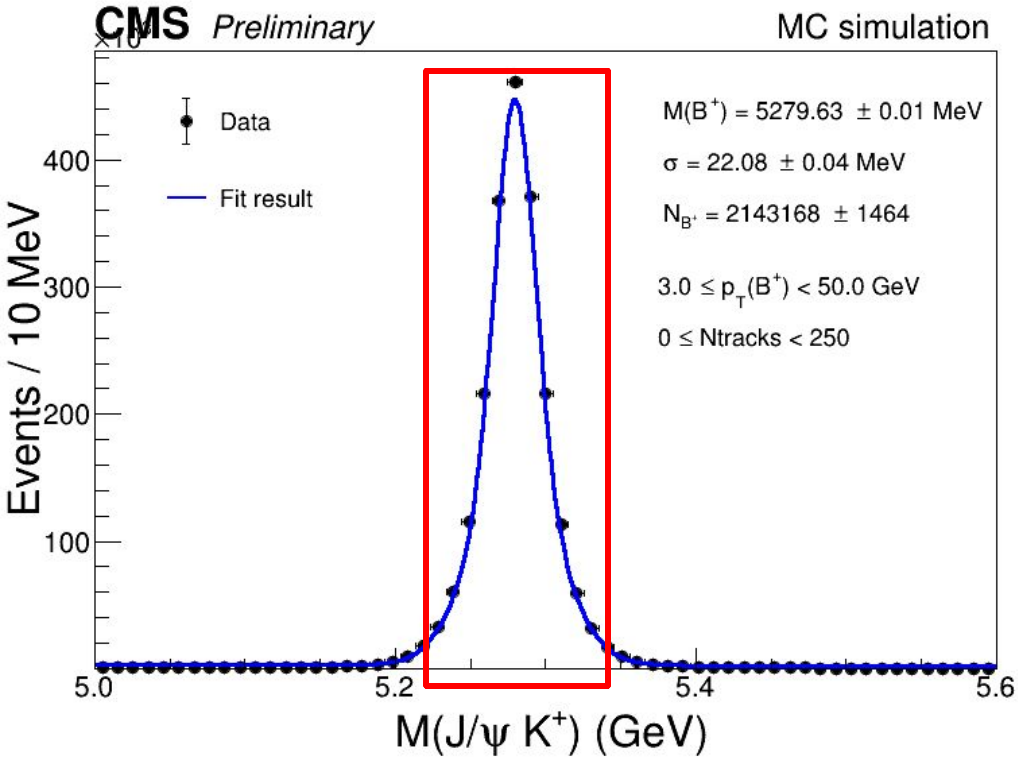

CMS Preliminary
175 nb^-1 (pPb 8.16 TeV)
Data
Fit result
Signal
Comb. backg.
J/ψ K+ + X
M(B+) = 5278.32 ± 0.74 MeV
N_B+ = 990 ± 35
N_bkg = 951 ± 35
χ2/ndf = 1.3
10.0 ≤ p_T(B+) < 15.0 GeV
0 ≤ N_trk^offline < 250
Events / 10 MeV
(Data-Fit)/σ
M(J/ψ K+) (GeV)


CMS Preliminary
175 nb^-1 (pPb 8.16 TeV)
Data
Fit result
Signal
Comb. backg.
J/ψ K+ + X
M(B+) = 5277.99 ± 0.80 MeV
N_B+ = 756 ± 30
N_bkg = 373 ± 22
χ2/ndf = 2.0
15.0 ≤ p_T(B+) < 20.0 GeV
0 ≤ N_trk^offline < 250
Events / 10 MeV
(Data-Fit)/σ
M(J/ψ K+) (GeV)

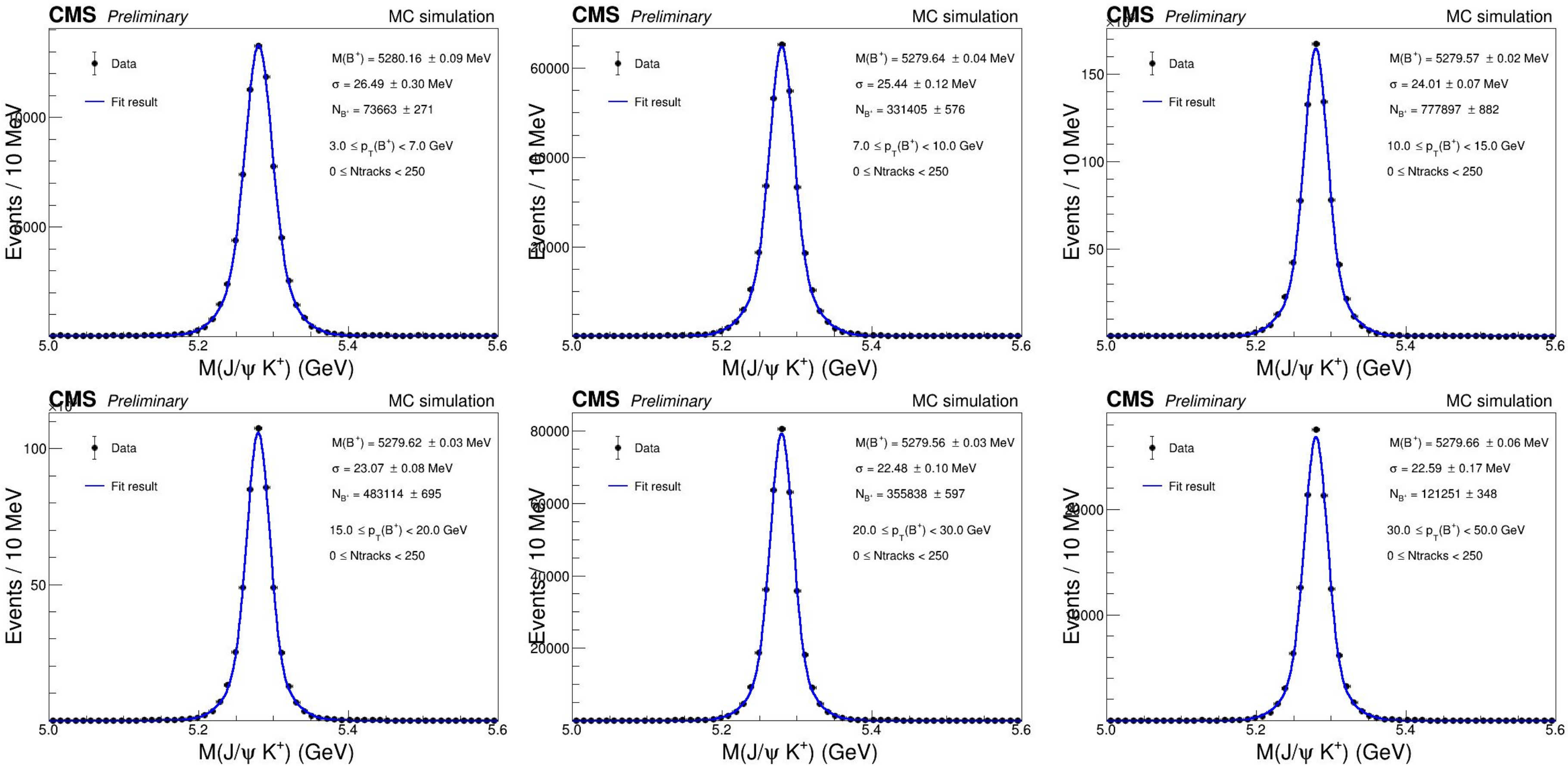

CMS Preliminary
175 nb^-1 (pPb 8.16 TeV)
Data
Fit result
Signal
Comb. backg.
J/ψ K+ + X
M(B+) = 5279.60 ± 0.84 MeV
N_B+ = 650 ± 27
N_bkg = 292 ± 20
χ2/ndf = 1.3
20.0 ≤ p_T(B+) < 30.0 GeV
0 ≤ N_trk^offline < 250
Events / 10 MeV
(Data-Fit)/σ
M(J/ψ K+) (GeV)

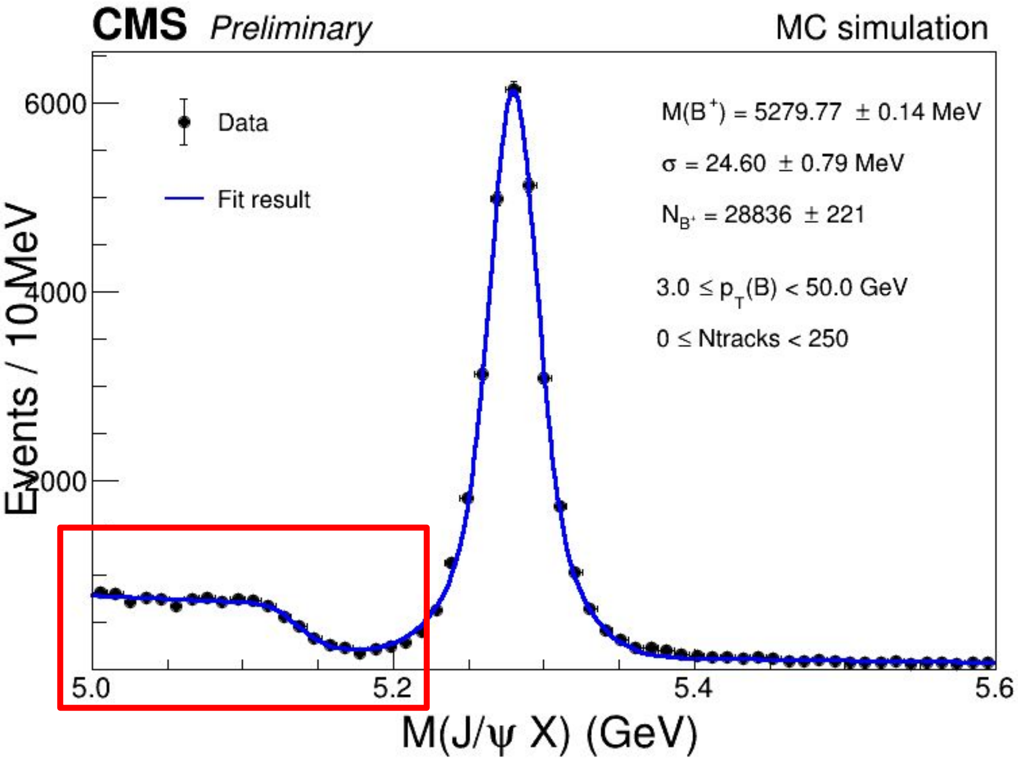

CMS Preliminary
175 nb^-1 (pPb 8.16 TeV)
Data
Fit result
Signal
Comb. backg.
J/ψ K+ + X
M(B+) = 5278.71 ± 1.32 MeV
N_B+ = 260 ± 17
N_bkg = 81 ± 10
χ2/ndf = 0.6
30.0 ≤ p_T(B+) < 50.0 GeV
0 ≤ N_trk^offline < 250
Events / 10 MeV
(Data-Fit)/σ
M(J/ψ K+) (GeV)

Monte Carlo Mass Fits



The widths of the fit function Gaussians of the data are fixed to the values obtained from a fit performed to the J/ψK^+ invariant mass in the pure-signal MC sample.


CMS Preliminary
MC simulation
Data
Fit result
M(B⁺) = 5280.16 ± 0.09 MeV
σ = 26.49 ± 0.30 MeV
N_B⁺ = 73663 ± 271
3.0 ≤ p_T(B⁺) < 7.0 GeV
0 ≤ Ntracks < 250
M(B⁺) = 5279.64 ± 0.04 MeV
σ = 25.44 ± 0.12 MeV
N_B⁺ = 331405 ± 576
7.0 ≤ p_T(B⁺) < 10.0 GeV
0 ≤ Ntracks < 250
M(B⁺) = 5279.57 ± 0.02 MeV
σ = 24.01 ± 0.07 MeV
N_B⁺ = 777897 ± 882
10.0 ≤ p_T(B⁺) < 15.0 GeV
0 ≤ Ntracks < 250
M(B⁺) = 5279.62 ± 0.03 MeV
σ = 23.07 ± 0.08 MeV
N_B⁺ = 483114 ± 695
15.0 ≤ p_T(B⁺) < 20.0 GeV
0 ≤ Ntracks < 250
M(B⁺) = 5279.56 ± 0.03 MeV
σ = 22.48 ± 0.10 MeV
N_B⁺ = 355838 ± 597
20.0 ≤ p_T(B⁺) < 30.0 GeV
0 ≤ Ntracks < 250
M(B⁺) = 5279.66 ± 0.06 MeV
σ = 22.59 ± 0.17 MeV
N_B⁺ = 121251 ± 348
30.0 ≤ p_T(B⁺) < 50.0 GeV
0 ≤ Ntracks < 250
Events / 10 MeV
M(J/ψ K⁺) (GeV)



MC fit of the non prompt Jpsi MC samples to extract the parameters of the error function to fit the **J/ψ / K⁺ + X** background in data with these parameters.

Efficiencies

The efficiency is the number of reconstructed B events after the full selection divided by the number of generated B decays in the fiducial region of the analysis specified by the B kinematic window:
3 < pT(B) < 50 GeV and **|y(B)| < 2.4**

➔ **It includes the acceptance and offline selection.**
➔ **It is determined from MC simulations, using 2 samples per channel:**

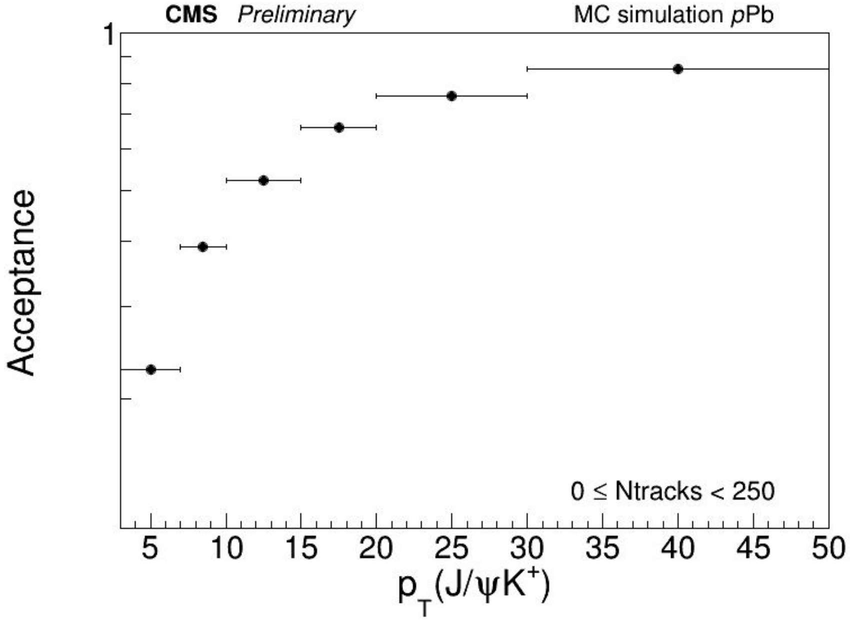
- The first sample has no cuts (with gen-info only).
- The second sample has the gen filter cuts: **$|\eta(\mu)|<2.5$**, **$|\eta(K)|<2.5$**, **$pT(\mu)>1.5$ GeV** and **$pT(K)>0.4$ GeV**.

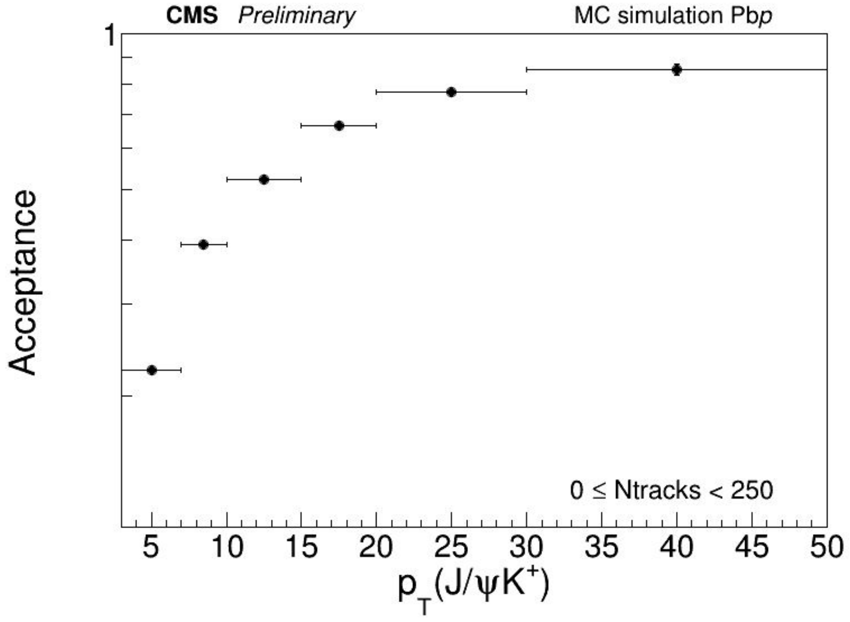
➔ **The efficiency is split into two terms:**

- The "**pre-filter efficiency**" or "**acceptance**" measures the efficiency of the gen pre-filter.
- The "**efficiency of reconstruction**" measures the event selection efficiency given the pre-filter selection.
- The "**total efficiency**" is the product of the two efficiencies above.

Pre-filter Efficiency

$$\epsilon_1^i = \frac{N(B^+ \to J/\psi K^+; |y_{B+}^{gen}| < 2.4, c < p_T^{gen}(B^+) < d, \text{filter cuts})}{N(B^+ \to J/\psi K^+; |y_{B+}^{gen}| < 2.4, c < p_T^{gen}(B^+) < d)}$$

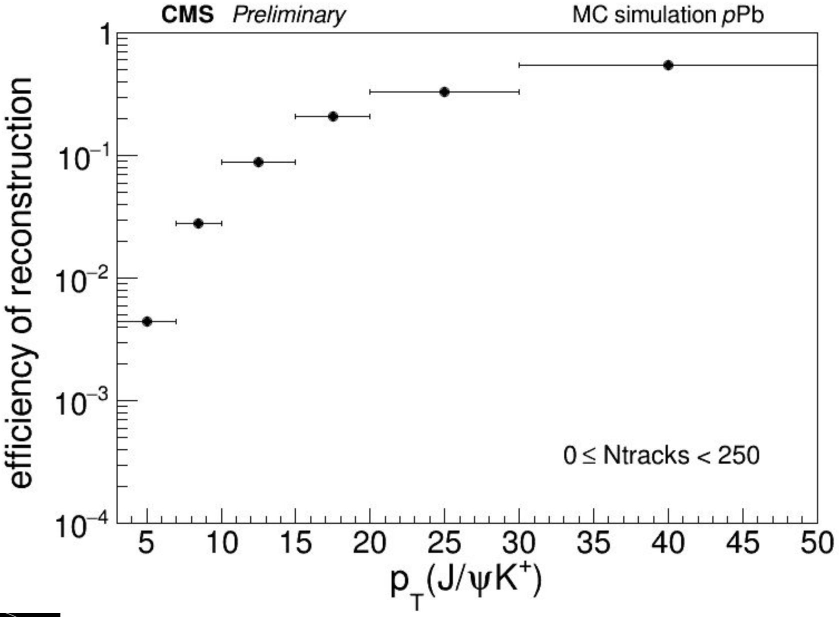


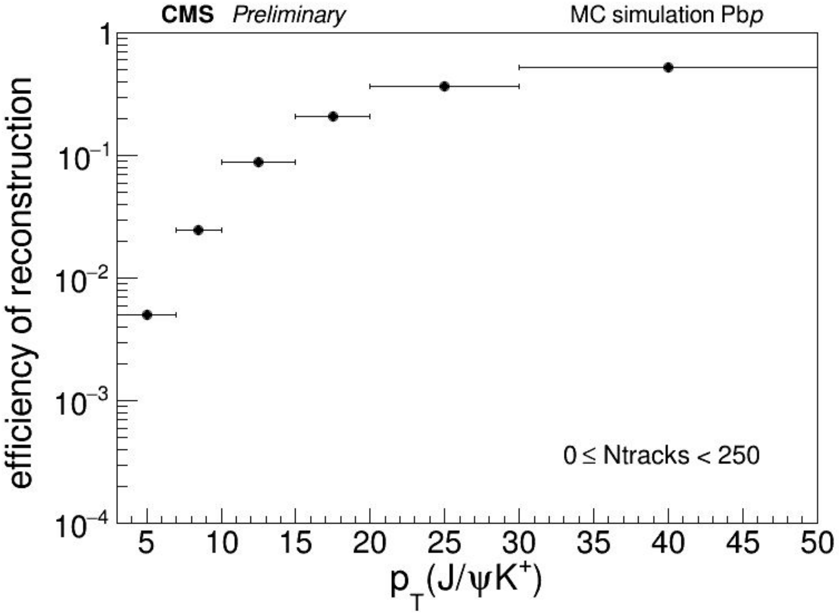


Reconstruction Efficiency

$$\epsilon_2^i = \frac{N(\mathrm{B}^+ \to \mathrm{J}/\psi\mathrm{K}^+, |y_{\mathrm{B}^+}^{\mathrm{reco}}| < 2.4, c < p_{\mathrm{T}}^{\mathrm{reco}}(\mathrm{B}^+) < d, \text{filter cuts, full selection})}{N(\mathrm{B}^+ \to \mathrm{J}/\psi\mathrm{K}^+, |y_{\mathrm{B}^+}^{\mathrm{gen}}| < 2.4, c < p_{\mathrm{T}}^{\mathrm{gen}}(\mathrm{B}^+) < d, \text{filter cuts})}$$

Reconstruction efficiency reweighted and with Tag and Probe weights.

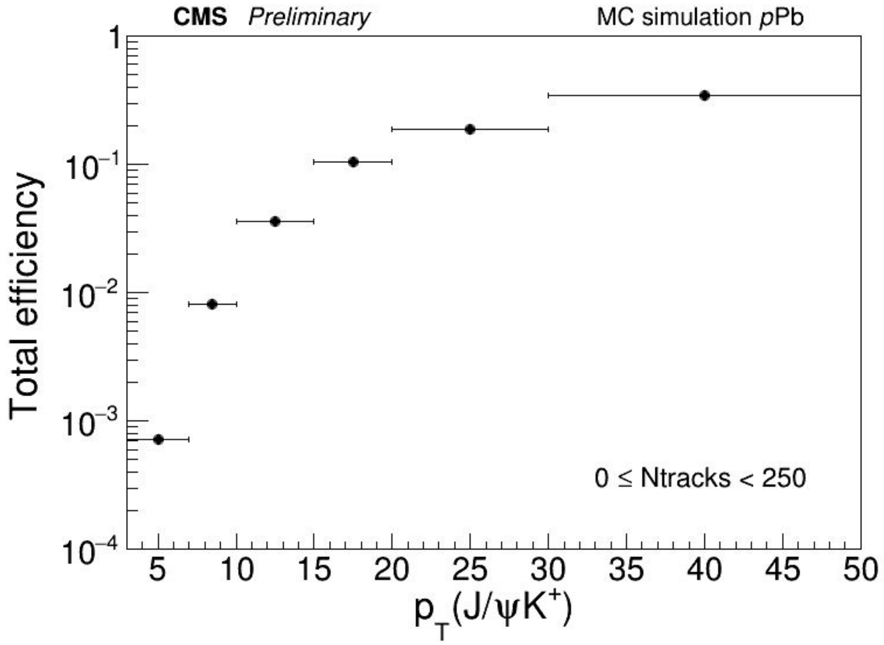


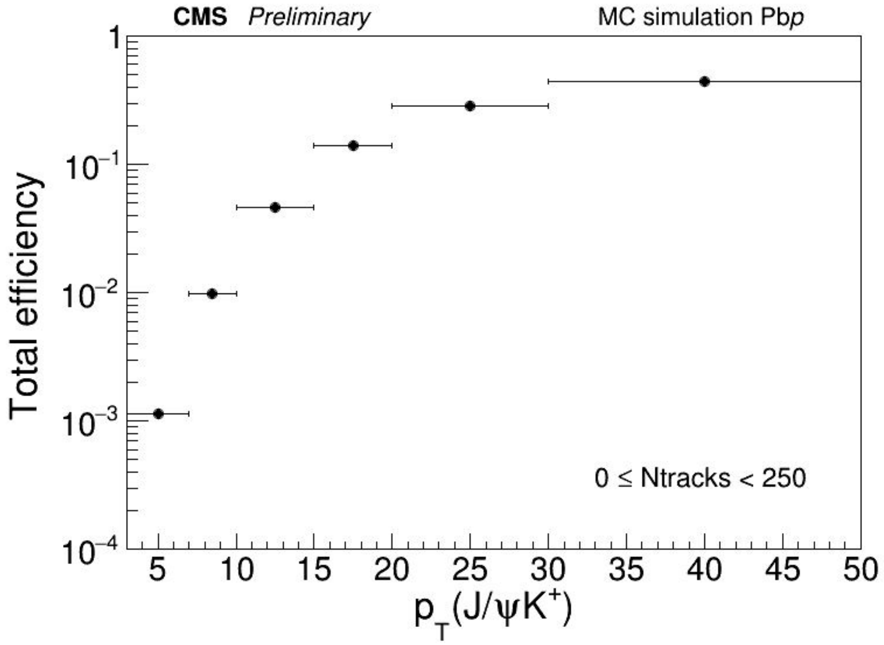


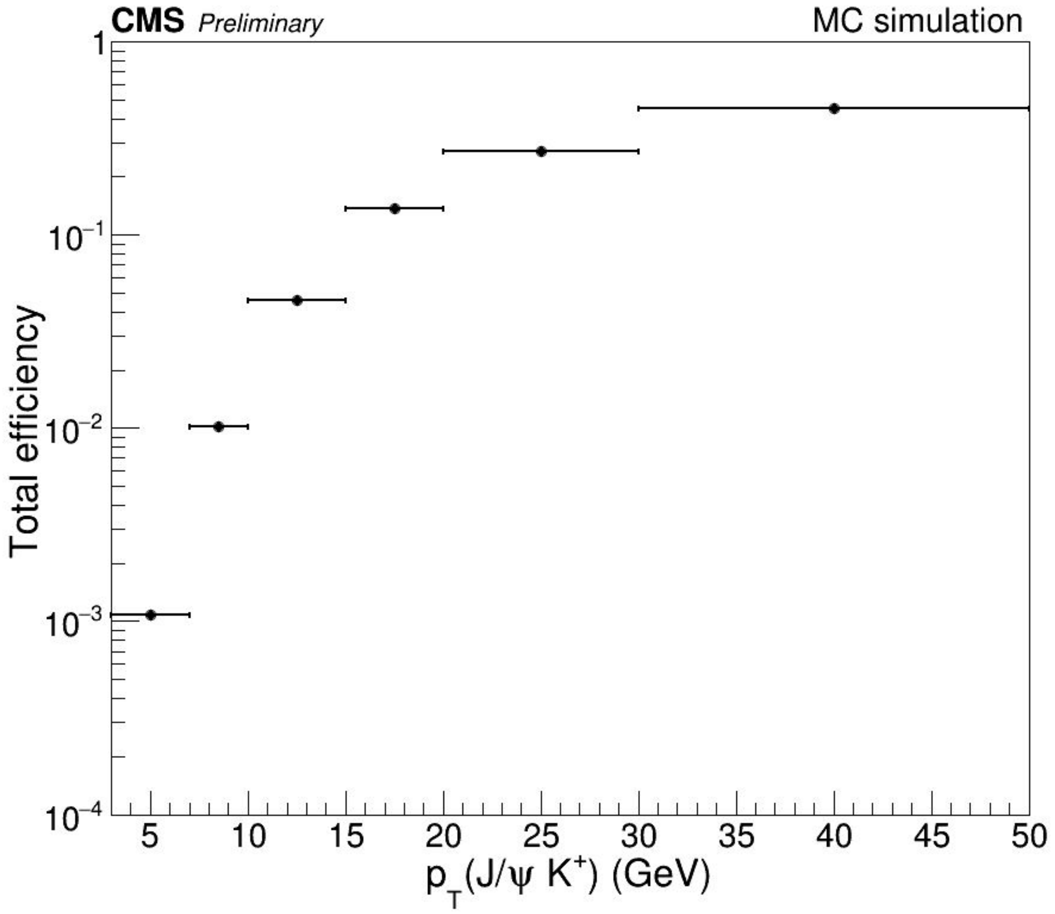
Total Efficiencies

$$(\epsilon = \epsilon_1 \times \epsilon_2)$$

Total efficiency reweighted and with Tag and Probe weights.







Total Efficiency weighted by luminosity.

$$\epsilon_T = \frac{\mathcal{L}_1 \epsilon_{T_1} + \mathcal{L}_2 \epsilon_{T_2}}{\mathcal{L}_1 + \mathcal{L}_2}$$

Total Efficiency error.

$$\Delta\epsilon_T = \frac{\sqrt{\mathcal{L}_1^2\, \Delta\epsilon_{T_1}^2 + \mathcal{L}_2^2\, \Delta\epsilon_{T_2}^2}}{\mathcal{L}_1 + \mathcal{L}_2}$$

Where ϵ_T is the total efficiency,
$\Delta\epsilon_T$ its respective error,
and $\mathcal{L}$ the integrated luminosty.

Cross Section

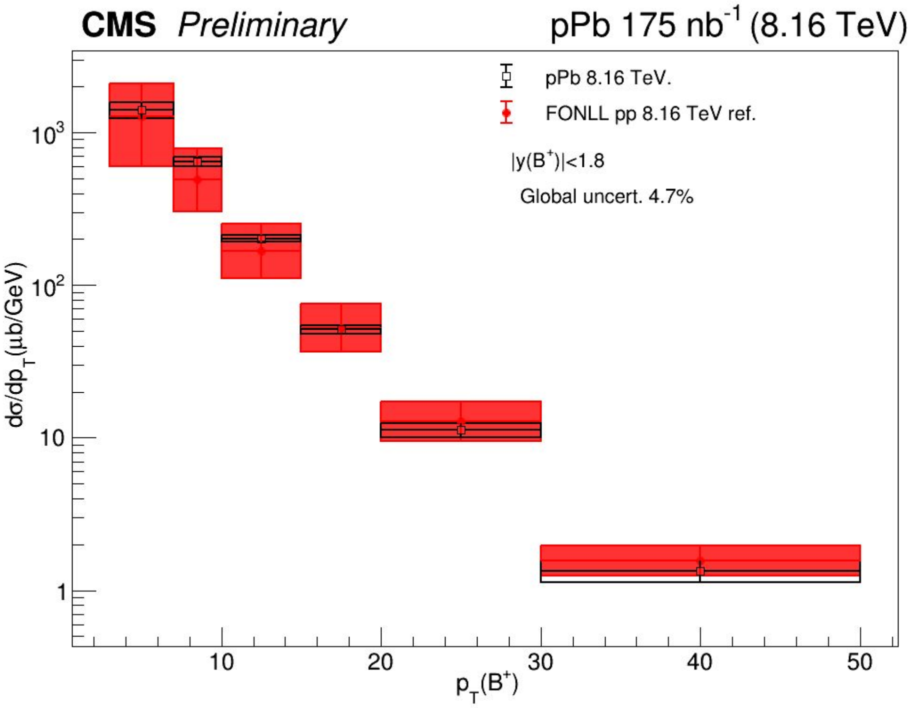
$$\left.\frac{d\sigma}{dp_T}\right|_{|y_{\rm lab}|<2.4} = \frac{1}{2}\frac{1}{\Delta p_T}\frac{N(p_T)_{|y_{\rm lab}|<2.4}}{(\mathrm{Acc}\ \epsilon)_{|y_{\rm lab}|<2.4}\mathcal{B}\mathcal{L}}$$

B Meson Production in p+Pb Collisions at 5.02 TeV
HIN-14-004 **(Phys. Rev. Lett. 116, 032301)**

BR($B_u \rightarrow J/\psi K$)	**(1.026 +/- 0.031)e-3**
BR($J/\psi \rightarrow \mu^+\mu^-$)	**(5.961 +/- 0.033)e-2**

FONLL Heavy Quark Production

The pT differential cross sections of B+ were derived by scaling the FONLL predictions for the generic B meson and baryon admixture by the PDG measured fractions, 40.2%. The results are multiplied by the number of nucleons in the Pb nucleus A=208. **(AN2013_322. Section 8.)**



Systematic Uncertainties

Table 24: Systematic uncertainties on $d\sigma/dp_T$ from alternative Bu fitting strategies described in the text. The total systematic uncertainty is the sum in quadrature of the individual uncertainties. Statistical uncertainty is shown too.

p_T (GeV)	B^+ signal	Bu bkg	MC size	Tracking	Tag and Probe	Total Systematic uncertainty (%)	Statistical uncertainty (%)
3 – 7	4.9	0.60	0.9	2.4	0.04	5.6	11.1
7 – 10	1.1	0.40	0.6	2.4	0.29	2.8	6.0
10 – 15	2.1	1.31	0.6	2.4	1.26	3.7	3.6
15 – 20	1.5	0.34	0.9	2.4	3.98	5.0	3.9
20 – 30	3.3	0.56	1.0	2.4	8.15	9.2	4.2
30 – 50	0.8	0.34	1.6	2.4	14.26	14.6	6.5

Preliminary results.

Summary of Cross Section Measurements

Table 30: Summary table of the pT-differential cross sections of B^+ in pPb collisions at $\sqrt{s_{NN}} =$ 8.16 TeV.

pt (GeV)	$d\sigma/dp_T$ ($\mu b\ GeV^{-1}$)	stat. error ($\mu b\ GeV^{-1}$)	sys. error ($\mu b\ GeV^{-1}$)	$d\sigma/dp_T$ (FONLL) ($\mu b\ GeV^{-1}$)	FONLL error ($\mu b\ GeV^{-1}$)
3 – 7	1409.36	156.93	78.88	1275.39	+806.48 -677.37
7 – 10	646.01	38.69	17.67	494.46	+289.87 -191.16
10 – 15	201.72	7.23	7.07	167.28	+85.55 -56.31
15 – 20	51.31	2.02	2.56	52.51	+22.57 -15.70
20 – 30	11.24	0.47	1.03	12.83	+4.39 -3.29
30 – 50	1.35	0.09	0.20	1.57	+0.39 -0.32

Preliminary results.

Multiplicity Analysis

$$N_{trk}$$

Definition of Charged-Particle Multiplicity

The event-by-event charged-particle multiplicity Ntrk is defined using primary tracks, tracks that satisfy the high-purity criteria and criteria to improve track quality and ensure that the tracks come from the primary vertex.

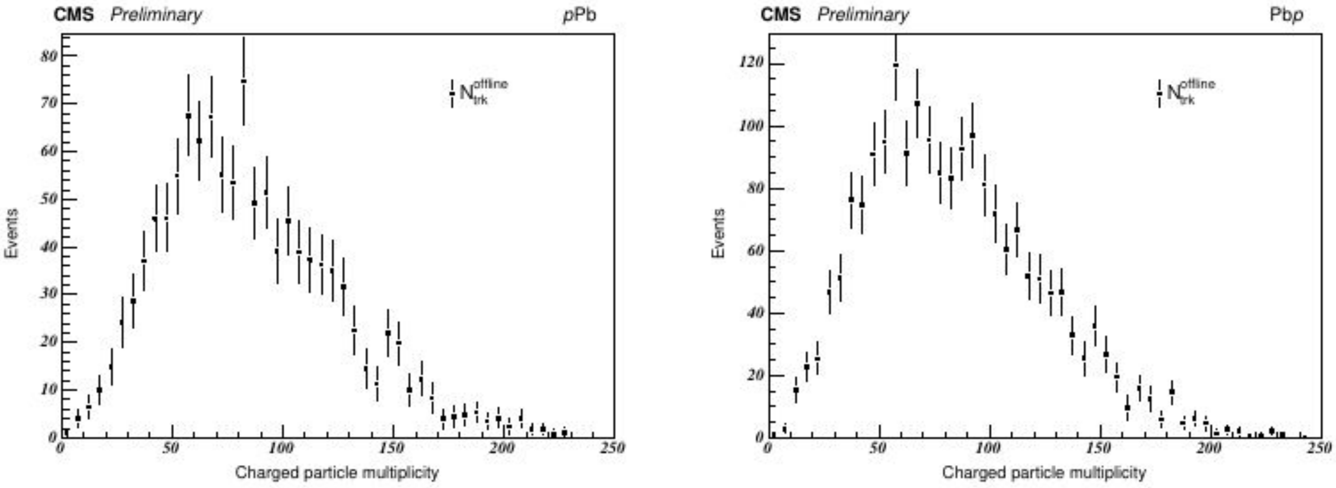


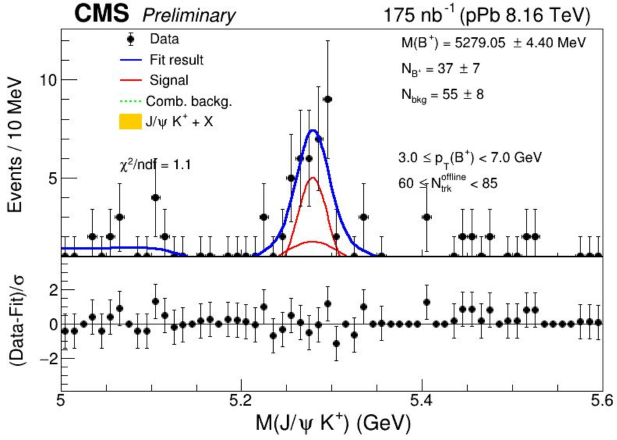
Figure 7: N_{trk} distribution of the events selected in this analysis, for pPb (left) and Pbp (right) samples.

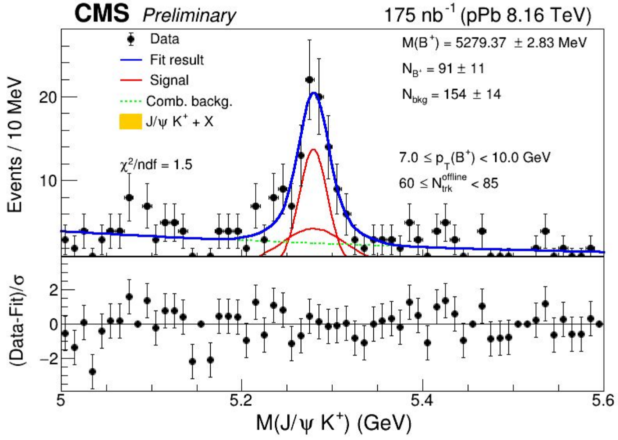
Data are divided into classes based on N_{trk} The quantity is $N_{\mathrm{trk}}^{\mathrm{corrected}}$ the corresponding multiplicity corrected in the same kinematic region

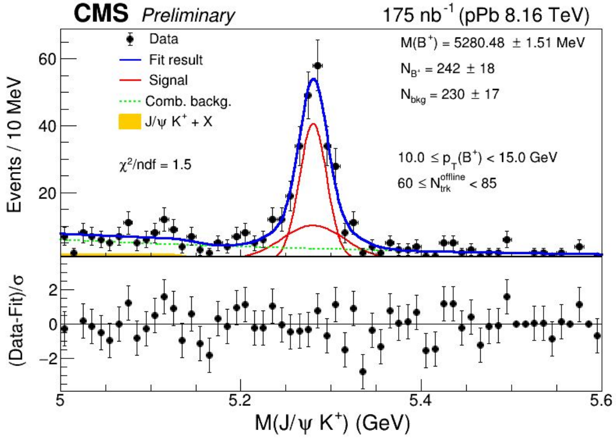
- $|\eta| < 2.4$
- pT > 0.4

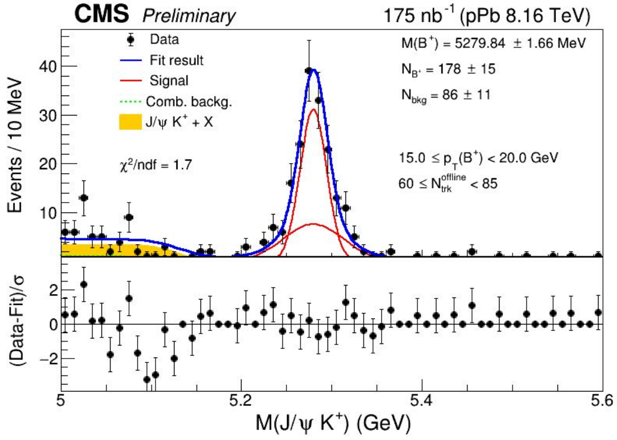
Table 4: Fraction of the full event sample for each multiplicity class. The last two columns show the observed and corrected multiplicities, respectively, of charged particles with $|y| < 2.4$ and $p_T > 0.4$ GeV/c. Systematic uncertainties are given for the corrected multiplicities, while statistical uncertainties are negligible.

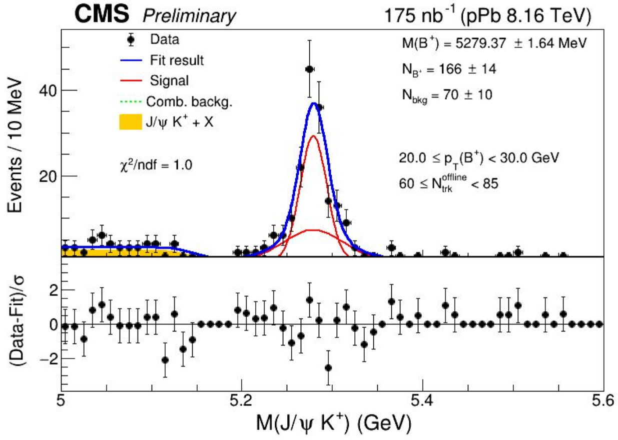
Multiplicity class (N_{trk})	Fraction(%)	$\langle N_{trk} \rangle$	$\langle N_{trk}^{corrected} \rangle$
$2 \leq N_{trk} < 250$	100.0	88	102 ± 2
$2 \leq N_{trk} < 60$	27.5	42	49 ± 1
$60 \leq N_{trk} < 85$	24.1	72	84 ± 2
$85 \leq N_{trk} < 110$	20.6	96	112 ± 3
$110 \leq N_{trk} < 250$	27.7	140	163 ± 4

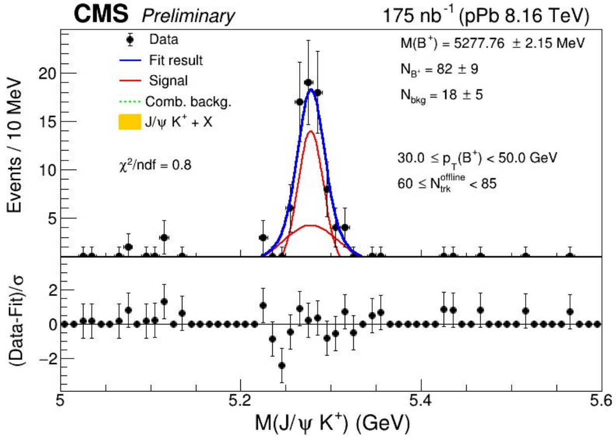

CMS Preliminary
175 nb-1 (pPb 8.16 TeV)
Data
Fit result
Signal
Comb. backg.
J/ψ K+ + X
M(B+) = 5279.05 ± 4.40 MeV
NB+ = 37 ± 7
Nbkg = 55 ± 8
χ2/ndf = 1.1
3.0 ≤ pT(B+) < 7.0 GeV
60 ≤ Ntrk offline < 85
Events / 10 MeV
(Data-Fit)/σ
M(J/ψ K+) (GeV)


CMS Preliminary
175 nb-1 (pPb 8.16 TeV)
Data
Fit result
Signal
Comb. backg.
J/ψ K+ + X
M(B+) = 5279.37 ± 2.83 MeV
NB+ = 91 ± 11
Nbkg = 154 ± 14
χ2/ndf = 1.5
7.0 ≤ pT(B+) < 10.0 GeV
60 ≤ Ntrk offline < 85
Events / 10 MeV
(Data-Fit)/σ
M(J/ψ K+) (GeV)

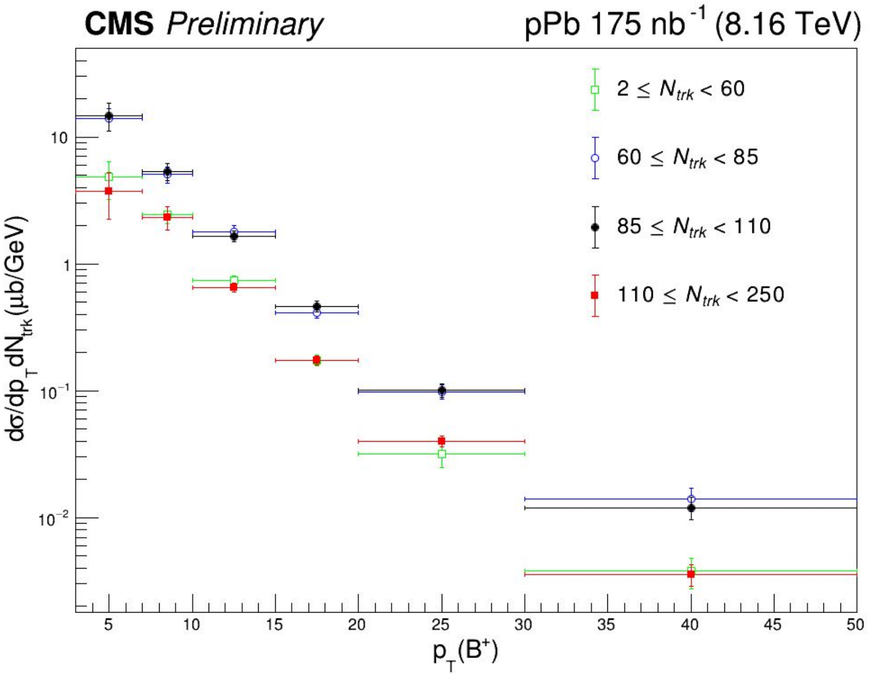

CMS Preliminary
175 nb-1 (pPb 8.16 TeV)
Data
Fit result
Signal
Comb. backg.
J/ψ K+ + X
M(B+) = 5280.48 ± 1.51 MeV
NB+ = 242 ± 18
Nbkg = 230 ± 17
χ2/ndf = 1.5
10.0 ≤ pT(B+) < 15.0 GeV
60 ≤ Ntrk offline < 85
Events / 10 MeV
(Data-Fit)/σ
M(J/ψ K+) (GeV)

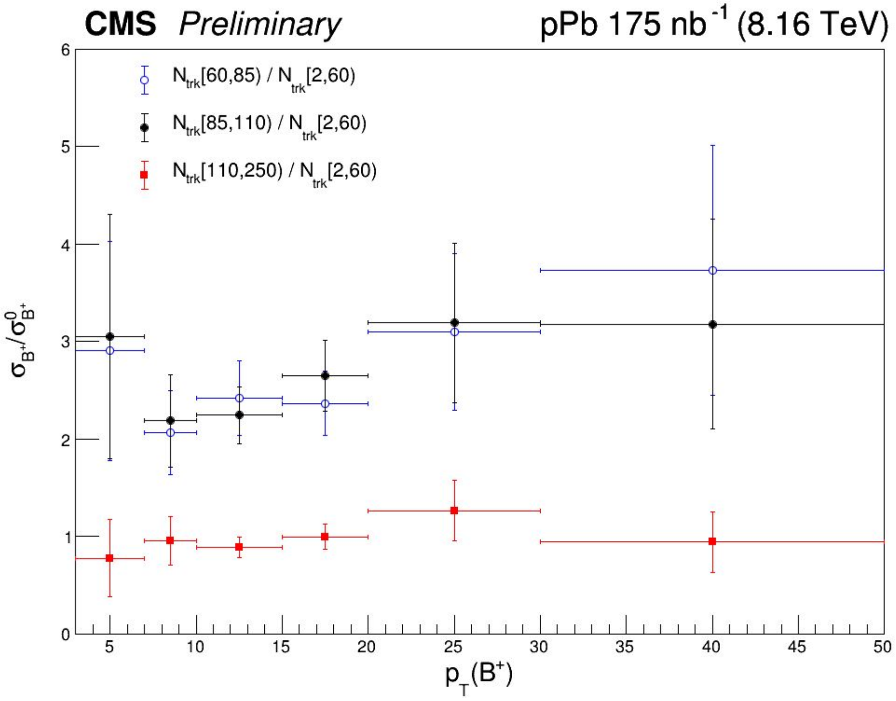

CMS Preliminary
175 nb-1 (pPb 8.16 TeV)
Data
Fit result
Signal
Comb. backg.
J/ψ K+ + X
M(B+) = 5279.84 ± 1.66 MeV
NB+ = 178 ± 15
Nbkg = 86 ± 11
χ2/ndf = 1.7
15.0 ≤ pT(B+) < 20.0 GeV
60 ≤ Ntrk offline < 85
Events / 10 MeV
(Data-Fit)/σ
M(J/ψ K+) (GeV)


CMS Preliminary
175 nb-1 (pPb 8.16 TeV)
Data
Fit result
Signal
Comb. backg.
J/ψ K+ + X
M(B+) = 5279.37 ± 1.64 MeV
NB+ = 166 ± 14
Nbkg = 70 ± 10
χ2/ndf = 1.0
20.0 ≤ pT(B+) < 30.0 GeV
60 ≤ Ntrk offline < 85
Events / 10 MeV
(Data-Fit)/σ
M(J/ψ K+) (GeV)


CMS Preliminary
175 nb-1 (pPb 8.16 TeV)
Data
Fit result
Signal
Comb. backg.
J/ψ K+ + X
M(B+) = 5277.76 ± 2.15 MeV
NB+ = 82 ± 9
Nbkg = 18 ± 5
χ2/ndf = 0.8
30.0 ≤ pT(B+) < 50.0 GeV
60 ≤ Ntrk offline < 85
Events / 10 MeV
(Data-Fit)/σ
M(J/ψ K+) (GeV)

Cross section

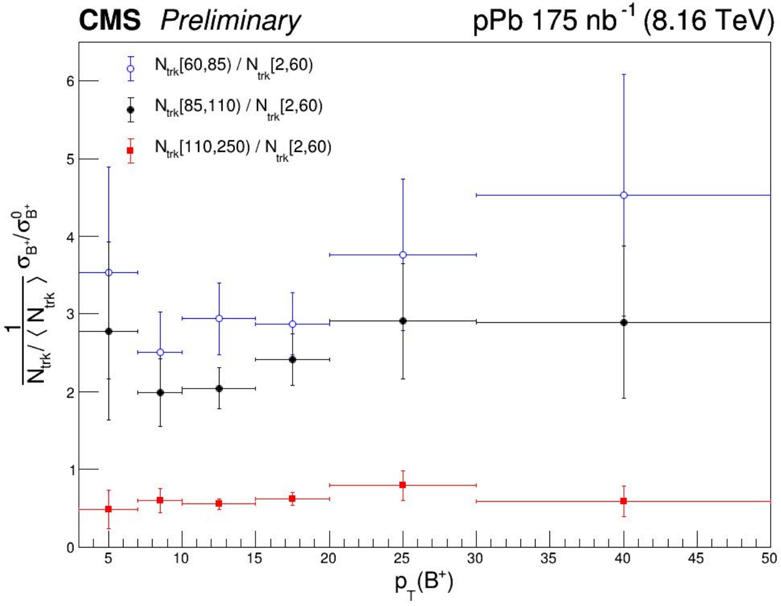




$$\frac{d\sigma}{dp_{\mathrm{T}}dN_{\mathrm{trk}}} = \frac{1}{2}\frac{1}{\Delta p_{\mathrm{T}}\Delta N_{\mathrm{trk}}}\frac{N(p_{\mathrm{T}}, N_{\mathrm{trk}})}{(\epsilon)\mathcal{B}\mathcal{L}}$$

CS ratios scaled by multiplicity density

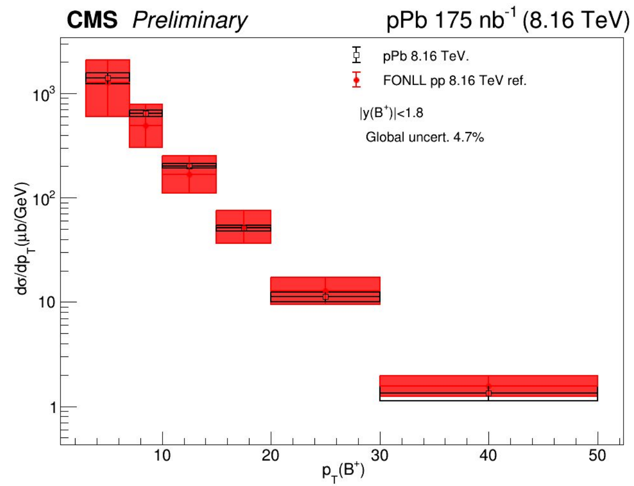
$$R^{B^+}_{pPb}|_{N_{ch}} / R^{B^+}_{pPb}|_{2-60} = \frac{1}{N_{coll}|_{N_{ch}}} \frac{\sigma^{B^+}|_{N_{ch}}}{\sigma^{B^+}|_{pp}} \Big/ \frac{1}{N_{coll}|_{2-60}} \frac{\sigma^{B^+}|_{2-60}}{\sigma^{B^+}|_{pp}} \approx \frac{1}{\langle N_{ch}\rangle / \langle N_{2-60}\rangle} \frac{\sigma^{B^+}|_{N_{ch}}}{\sigma^{B^+}|_{2-60}},$$

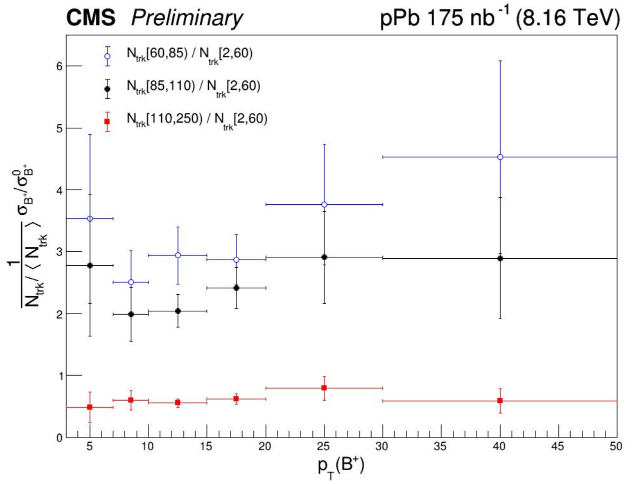


Conclusions

- The B+ ⟶ J/ψK+ is used to measure the production cross section and compared to FONLL calculation with good agreement.
- The corresponding cross-sections factor of B+, σB+/σB0+ , is found to show a trend to be suppressed in pPb high multiplicity collisions when compared to the small multiplicity bin as a reference.
- A more clear trend could be seen when taking into account normalization with the averaged multiplicity density in analogy as the one taking in the nuclear modification factor.
- These measurements establishes an important baseline to constraint models that describe the flavor dependence of the in-medium parton energy loss.

Next steps: Publication!





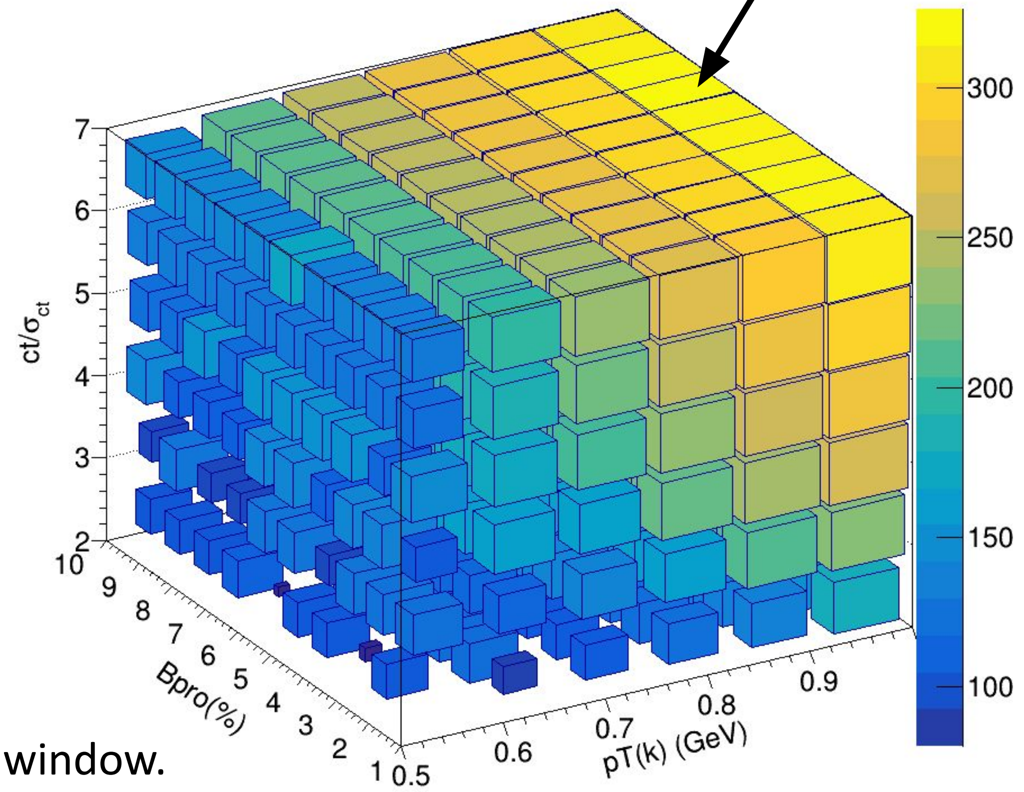
Thank you very much for the attention!

back-up

Significance optimization

Best significance for MC

Previously it was done with data. The suggestion was to move to use MC. It has been done.

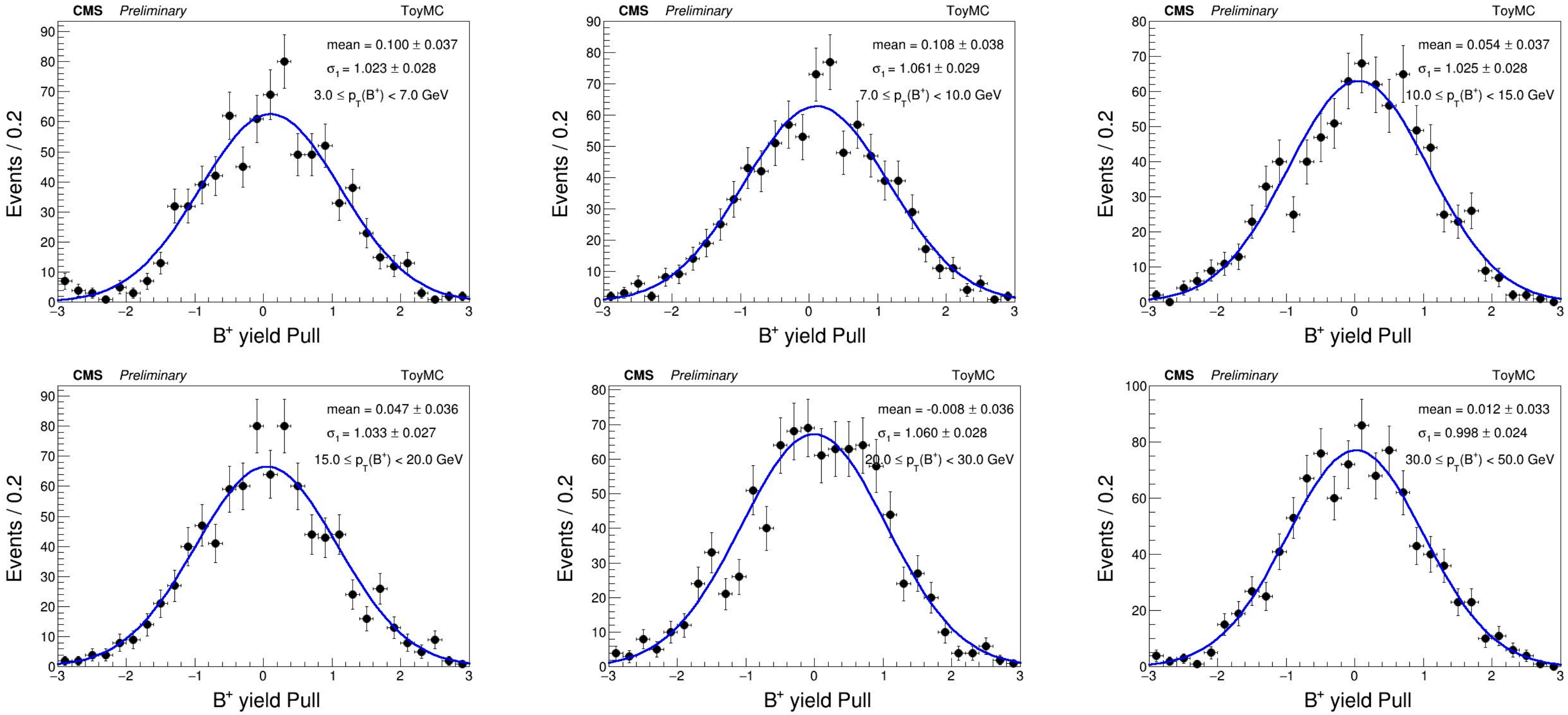


$$sig \approx Eff/\sqrt{B}$$

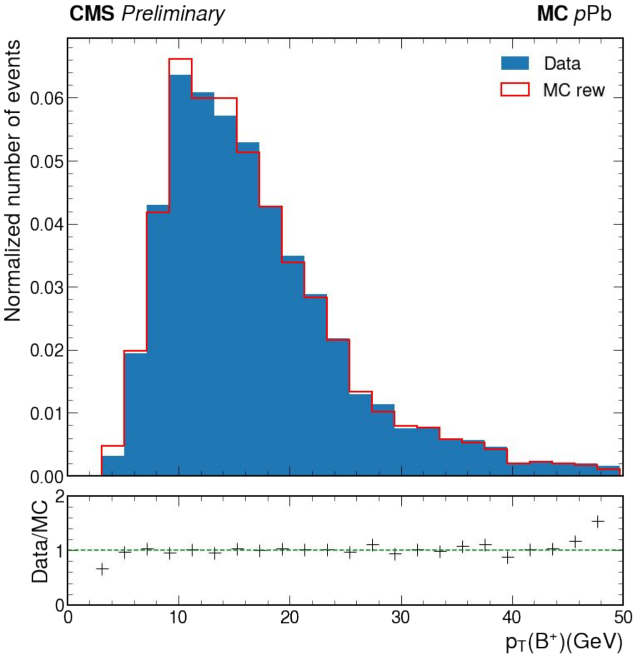
Eff: Efficiency.

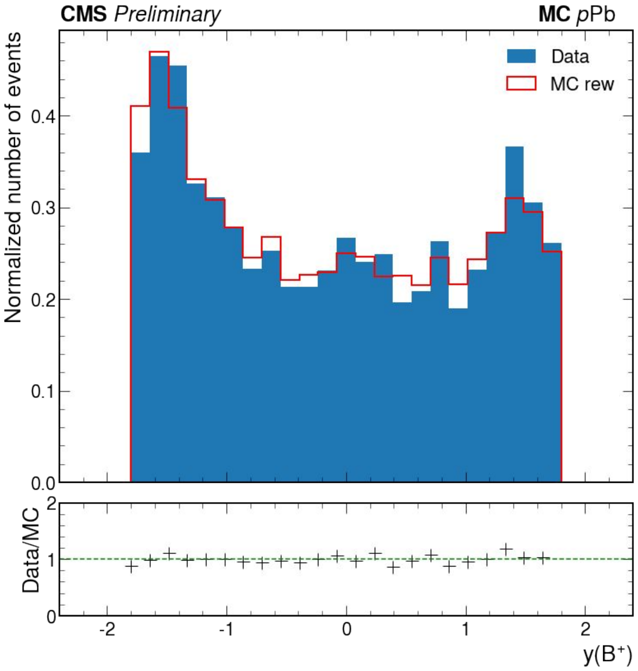
B: Background yields in mass window.

Pull Study with "Toy Monte Carlo"



Reweighting Process





2D reweighting in pT and y

The reweight was made event per event and the process in stopped when both histograms Data and MC reach a KS test greater than 0.5

Tag and Probe

We improve the efficiency by using a data-driven method of Tag and Probe (TnP) and scale factors (SFs), which are derived from the efficiency ratio between the data and the MC in the J/ψ analysis for each muon (https://twiki.cern.ch/twiki/bin/viewauth/CMS/ HIMuonTagProbe). The TnP SFs are applied as an additional weight (after the weight coming from reweighting procedure) to MC RECO candidates in order to correct the efficiency. In this analysis, we use the 2016 pPb TnP header file located at:

https://github.com/CMS-HIN-dilepton/MuonAnalysis-TagAndProbe/blob/80X_HI/macros/tnp_weight_lowPt.h

to determine the SF of each MC muon based on its kinematics (pT and η). Then, we multiply them together:

$$SF_{\mu^+\mu^-} = SF^{\mu^+} \times SF^{\mu^-},$$

and finally we use the $SF_{\mu+\mu-}$ as a weight to the MC for efficiency correction.

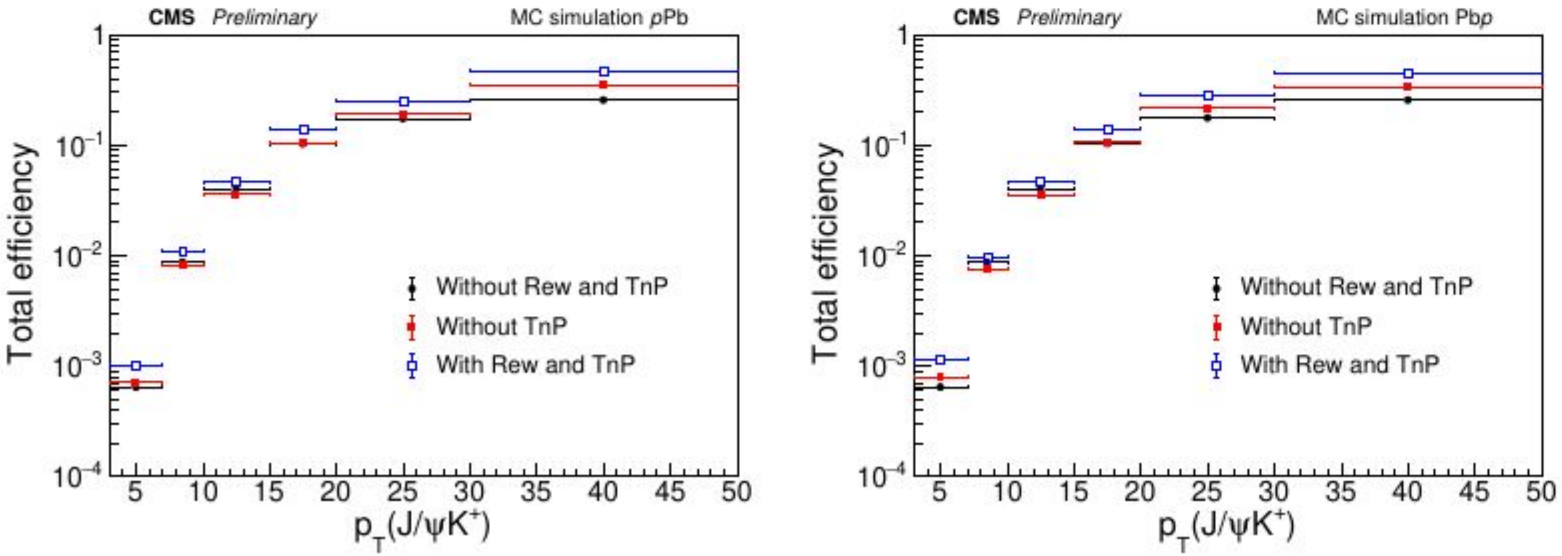


Figure 21: The total efficiency distributions are shown for pPb (left) and Pbp (right) samples in p_T bins. The efficiency distributions are shown before and after applying the reweighting procedure.

Multiplicity Corrections

Track reconstruction implies that the detector effect is present, so in order to get the actual number of charged particles a tracking efficiency correction is needed. Then each reconstructed track is weighted by the inverse of the efficiency factor $\epsilon_{\text{trk}}(\eta, p_{\text{T}})$

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

- Detector acceptance $A(\eta, p_{\text{T}})$.
- Reconstruction efficiency $E(\eta, p_{\text{T}})$: $recoToSimTracks/SimTracks$
- Fraction of misidentified tracks or the fake rate $F(\eta, p_{\text{T}})$: $NotRecoToSimTracks/recoTracks$

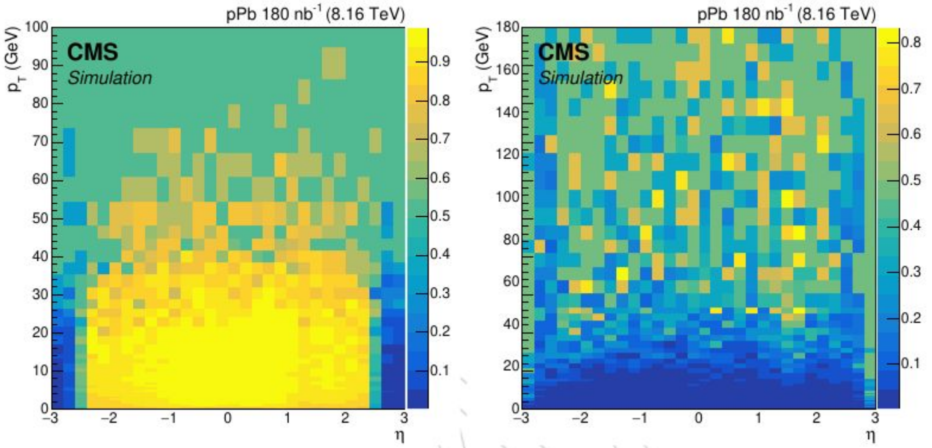


Figure 6: Reconstruction efficiency $E(\eta, p_{\text{T}})$ (left) and the fraction of misidentified tracks $F(\eta, p_{\text{T}})$ (right). The values were computed from MC samples.