

Λ_c^+ production in pp and PbPb collisions at 5.02 TeV with the CMS detector

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for the CMS Collaboration

Strangeness in Quark Matter 2019



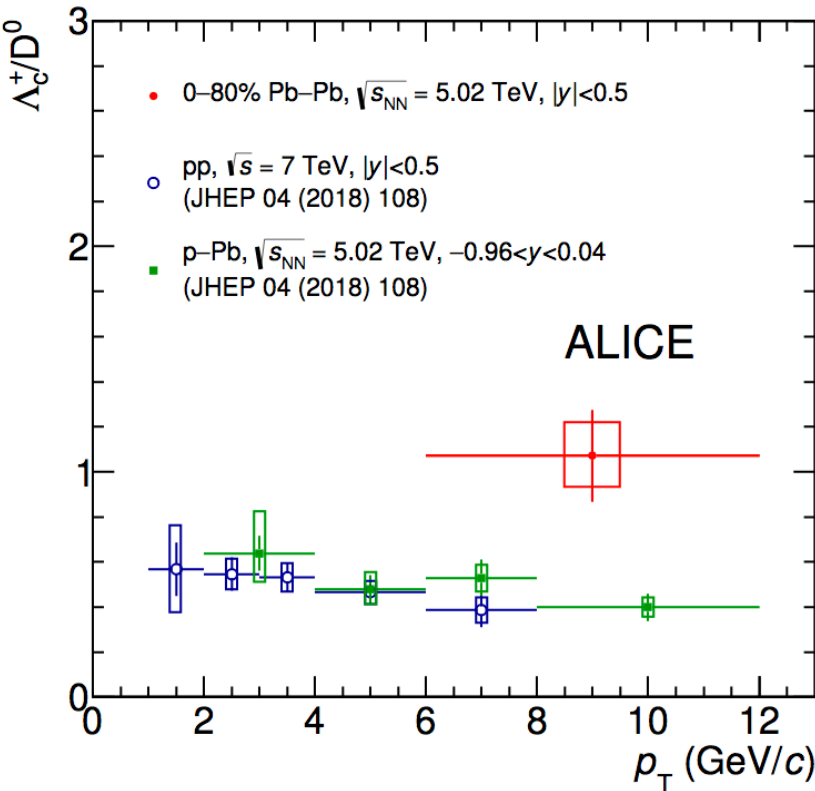
Motivation

- ❖ Heavy quarks are produced early and experience the full evolution of the medium.
- ❖ Involve a variety of E-loss mechanisms
 - Gluon radiation, collisional energy loss, collisional dissociation, ...
 - Allow further understanding of the medium properties.
- ❖ Λ_c^+ is essential for understanding:
 - Heavy quarks transport in QGP and hadronic phase of the medium
 - Charm quark hadronization including coalescence
 - Enhance Λ_c^+ / D^0 in AA over pp collisions
 - Measurements in broad p_T range needed



Motivation

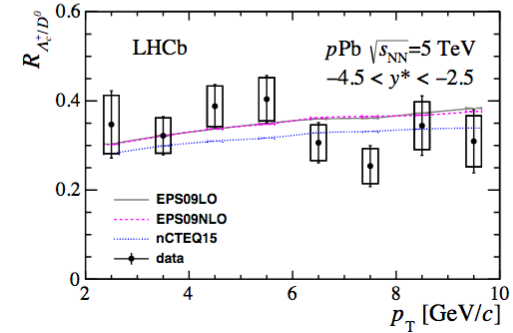
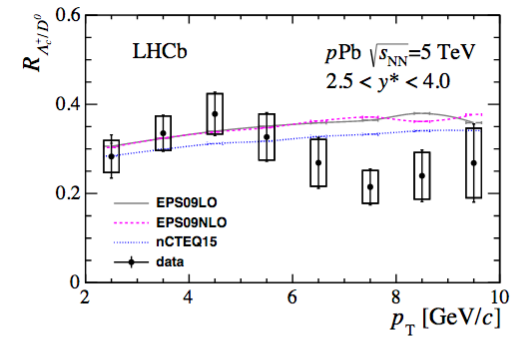
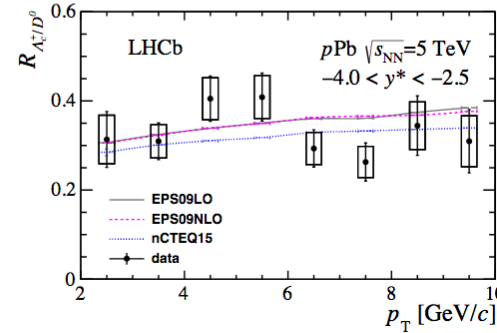
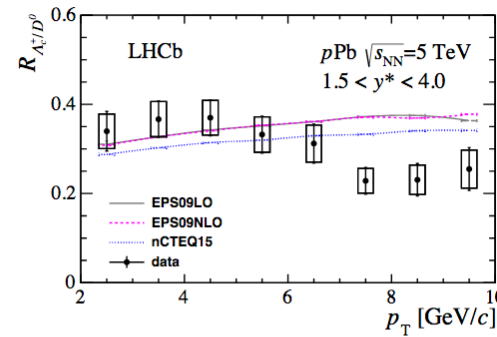
- ❖ ALICE ratios from pp and pPb are larger than LHCb ones.
- ❖ ALICE ratio for $6 < p_T < 12$ GeV/c in PbPb are larger than ALICE ratios in pp and pPb.



JHEP 04 (2018) 108

Phys. Lett. B 793 (2019) 212

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JHEP 02 (2019) 102



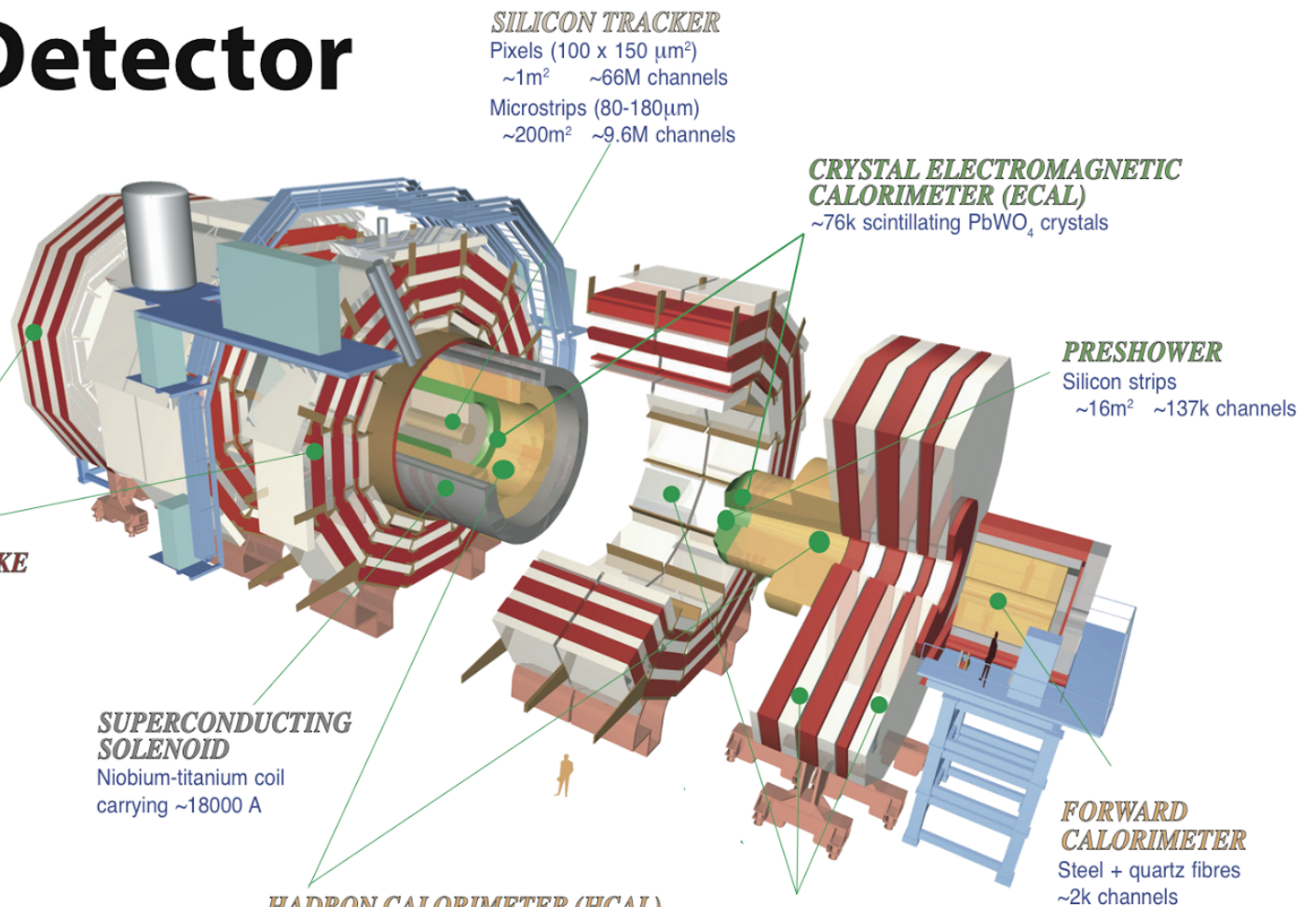
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CMS Detector

CMS Detector

Pixels
Tracker
ECAL
HCAL
Solenoid
Steel Yoke
Muons



SILICON TRACKER
Pixels (100 x 150 μm^2)
~1m² ~66M channels
Microstrips (80-180 μm)
~200m² ~9.6M channels

CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76k scintillating PbWO₄ crystals

PRESHOWER
Silicon strips
~16m² ~137k channels

FORWARD CALORIMETER
Steel + quartz fibres
~2k channels

MUON CHAMBERS
Barrel: 250 Drift Tube & 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip & 432 Resistive Plate Chambers

HADRON CALORIMETER (HCAL)
Brass + plastic scintillator
~7k channels

SUPERCONDUCTING SOLENOID
Niobium-titanium coil
carrying ~18000 A

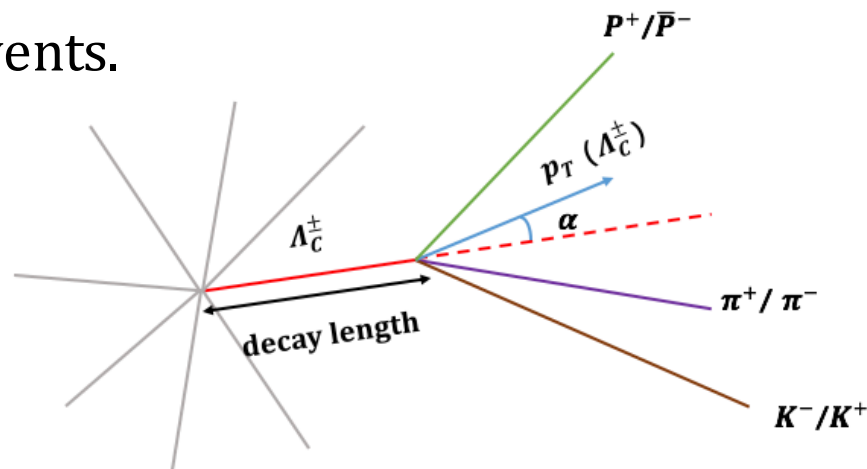
STEEL RETURN YOKE
~13000 tonnes

Total weight : 14000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T



Λ_c^+ reconstruction

- ❖ 2015 HI run at 5.02 TeV at LHC
- ❖ Both pp and PbPb: minimum bias events.
 - pp: 2B minimum bias events
 - PbPb: 300M minimum bias events.
- ❖ $c\tau (\Lambda_c^+) \sim 60 \mu\text{m}$
- ❖ $\Lambda_c^+ \rightarrow P^+ K^- \pi^+$ BR \sim 6.23%

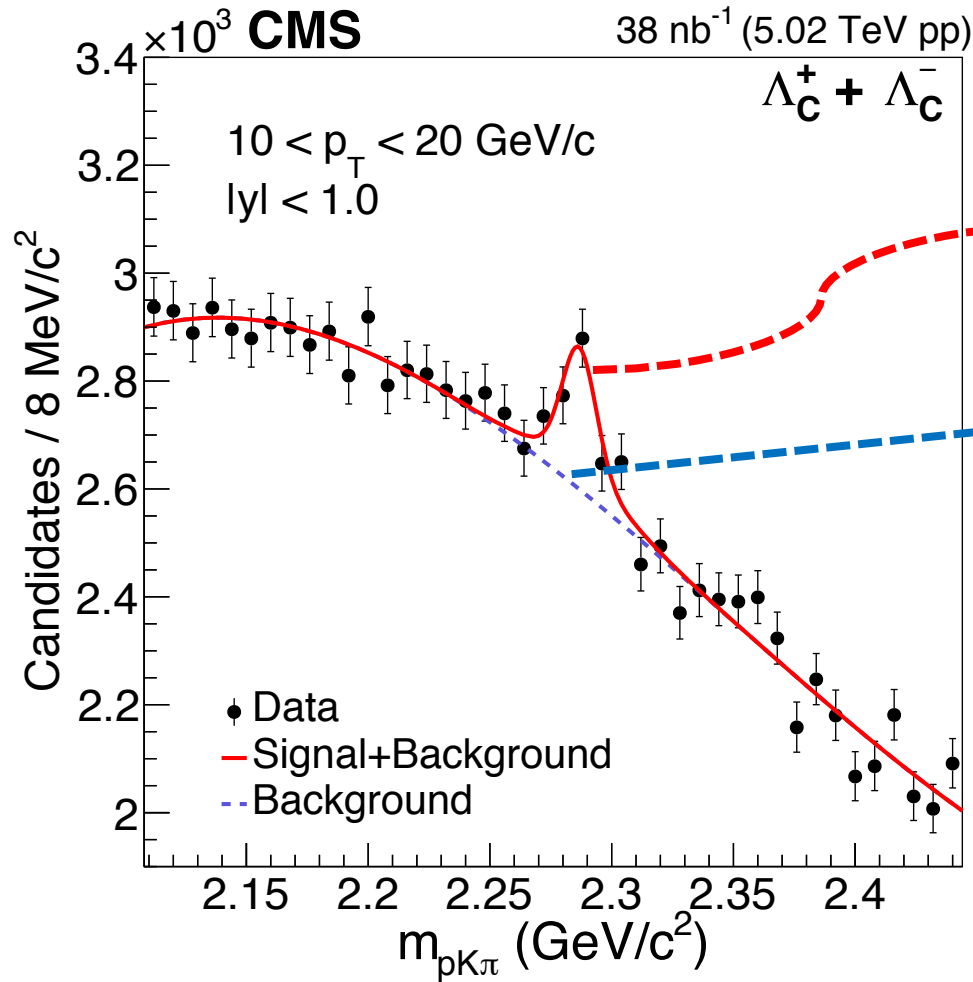


❖ Topological selections:

- pp
 - 2D decay length significance with respect to BS
 - Vertex probability
 - 2D pointing angle with respect to BS
 - Daughter track p_T ratio
- PbPb
 - 3D decay length significance with respect to PV
 - Vertex probability
 - 3D pointing angle with respect to PV
 - Daughter track p_T ratio



Λ_c^+ signal extraction



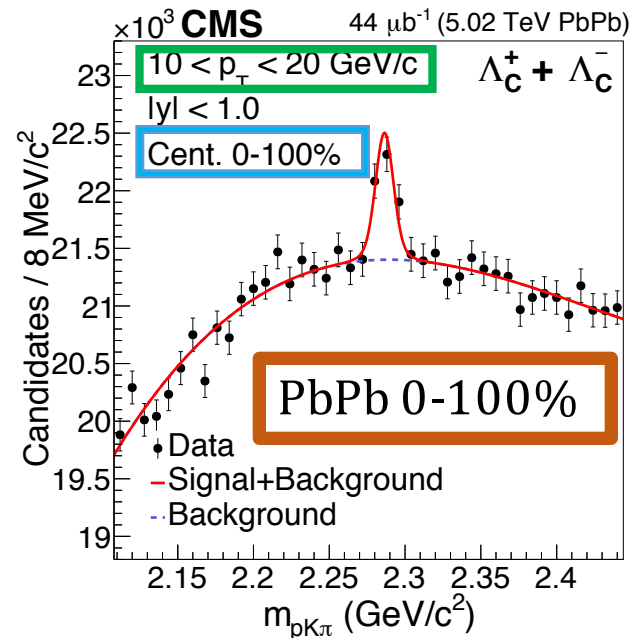
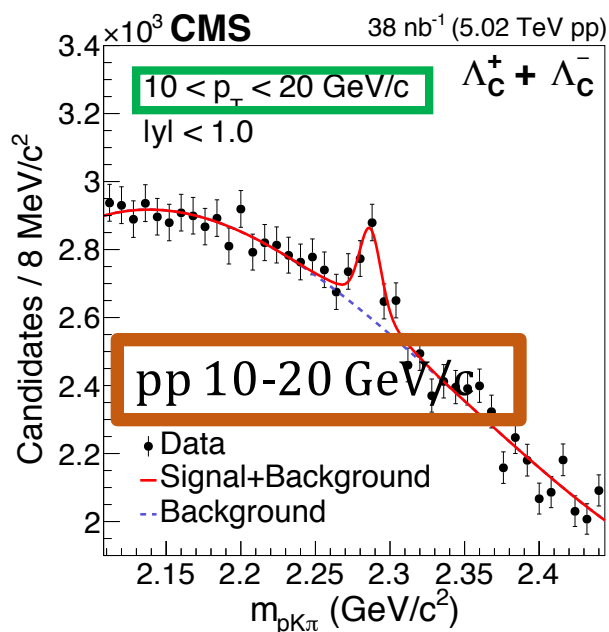
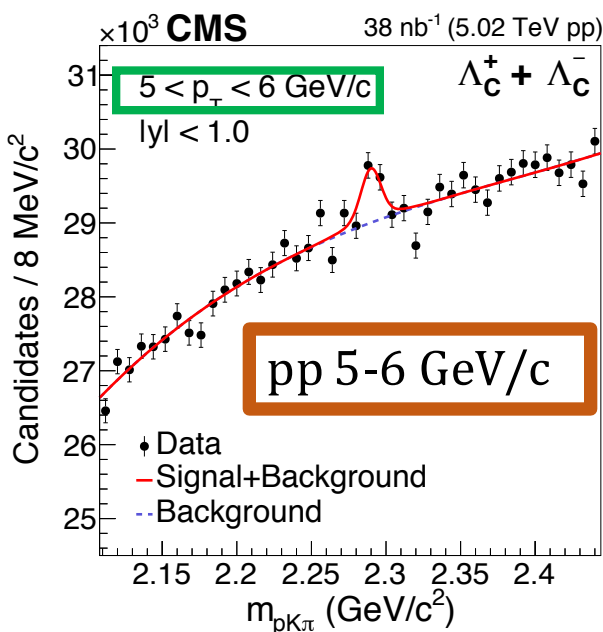
Invariant mass fitted with:

❖ Double Gaussian for signal

❖ 3rd order Chebyshev polynomial function for combinatorial background



Λ_c^+ signal extraction

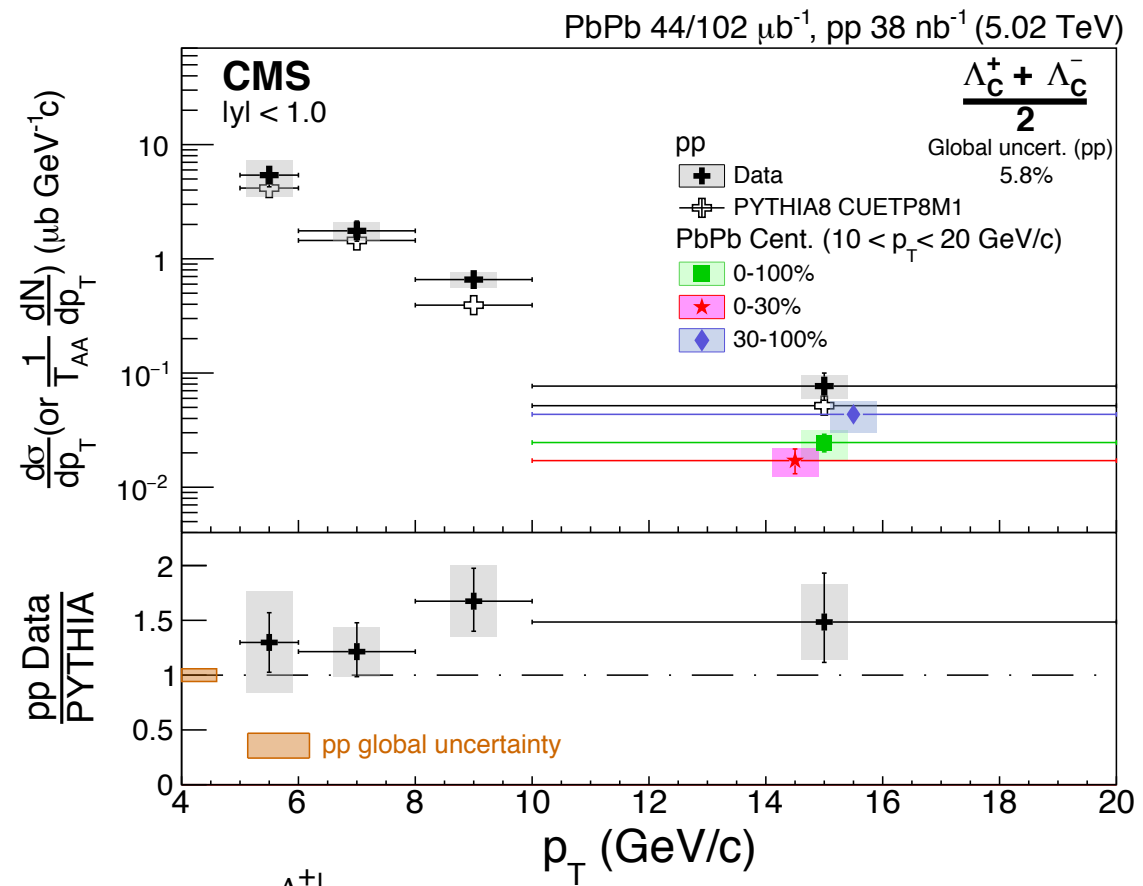


❖ Representative invariant mass plots.

arXiv: 1906.03322



p_T spectra



arXiv: 1906:03322

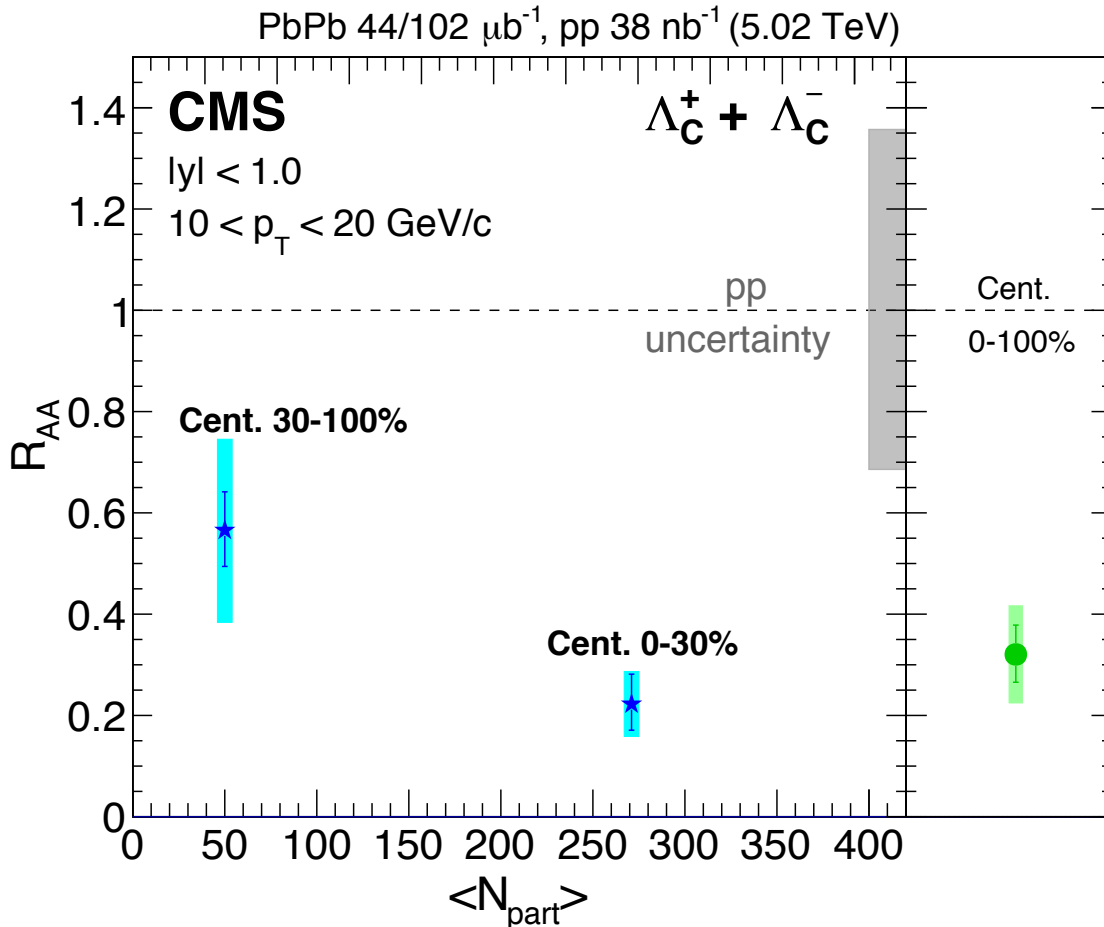
$$\frac{d\sigma_{pp}^{\Lambda_C^+}}{dp_T} \Big|_{|y| < 1.0} = \frac{1}{2\mathcal{L}\Delta p_T B} \frac{N_{pp}^{\Lambda_C^+} \Big|_{|y| < 1.0}}{A\epsilon}$$

$$\frac{1}{\langle T_{AA} \rangle} \frac{dN_{PbPb}^{\Lambda_C^+}}{dp_T} \Big|_{|y| < 1.0} = \frac{1}{\langle T_{AA} \rangle} \frac{1}{2N_{events} \Delta p_T B} \frac{N_{PbPb}^{\Lambda_C^+} \Big|_{|y| < 1.0}}{A\epsilon}$$

p_T distribution shape in pp collisions is consistent with PYTHIA8.



Nuclear modification factor R_{AA}



$$R_{AA}(p_T) = \frac{1}{\langle T_{AA} \rangle} \frac{dN_{PbPb}}{dp_T} / \frac{d\sigma_{pp}}{dp_T}$$

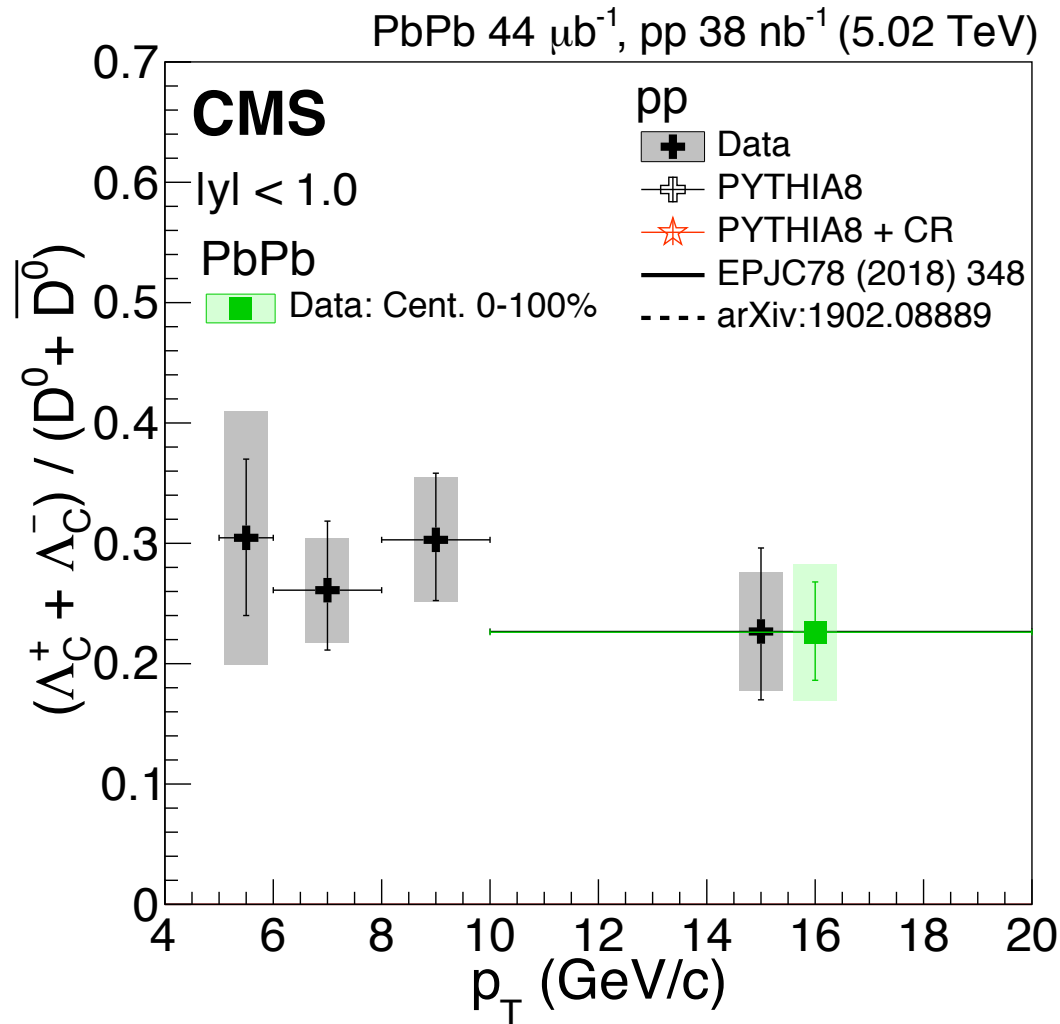
❖ Conclusion:

- A hint: the production of Λ_C^+ is suppressed in PbPb for $p_T > 10 \text{ GeV}/c$.
- Evidence: more suppression in the more central PbPb collisions.

arXiv: 1906.03322



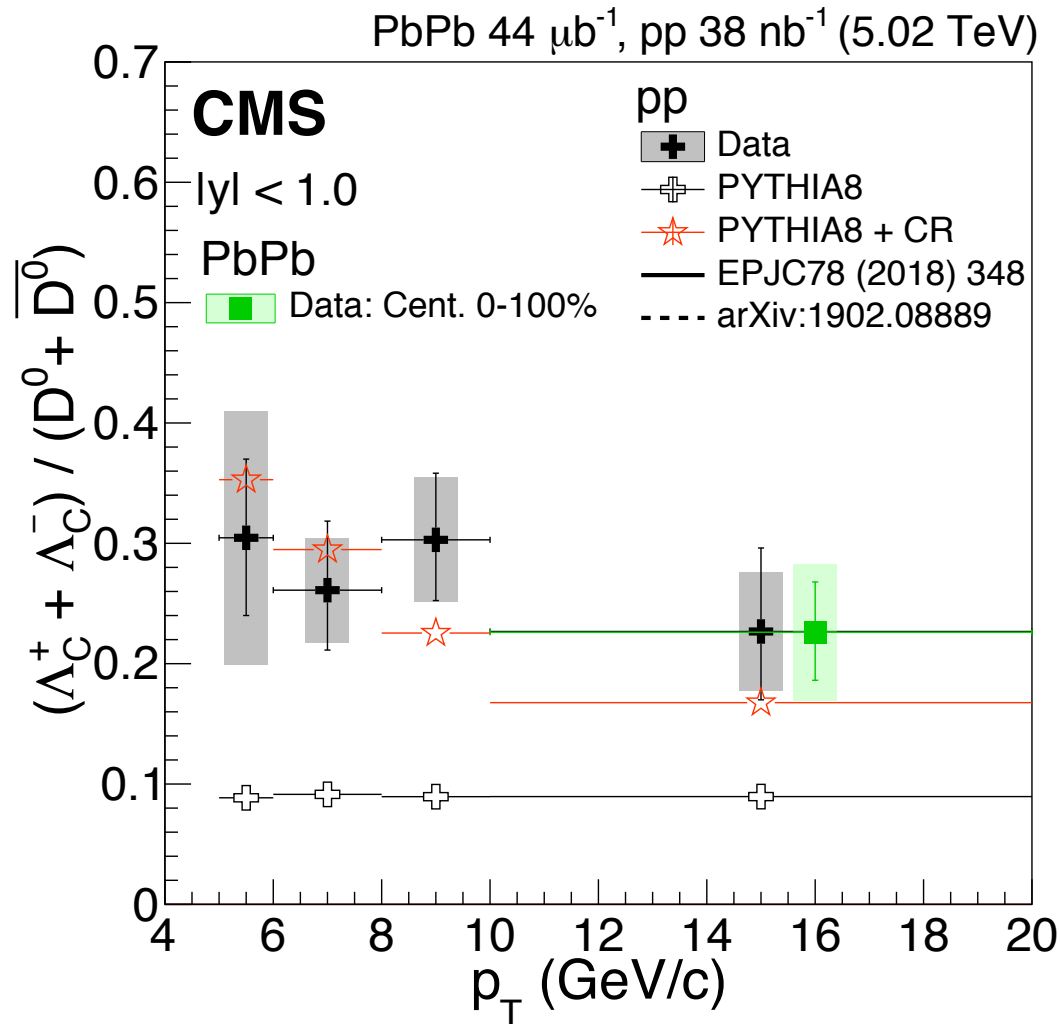
Λ_C^+ / D^0 production ratio



- ❖ PbPb \sim pp result in 10-20 GeV/c, suggests no significant contribution from coalescence in PbPb for $p_T > 10$ GeV/c.



Λ_C^+ / D^0 production ratio

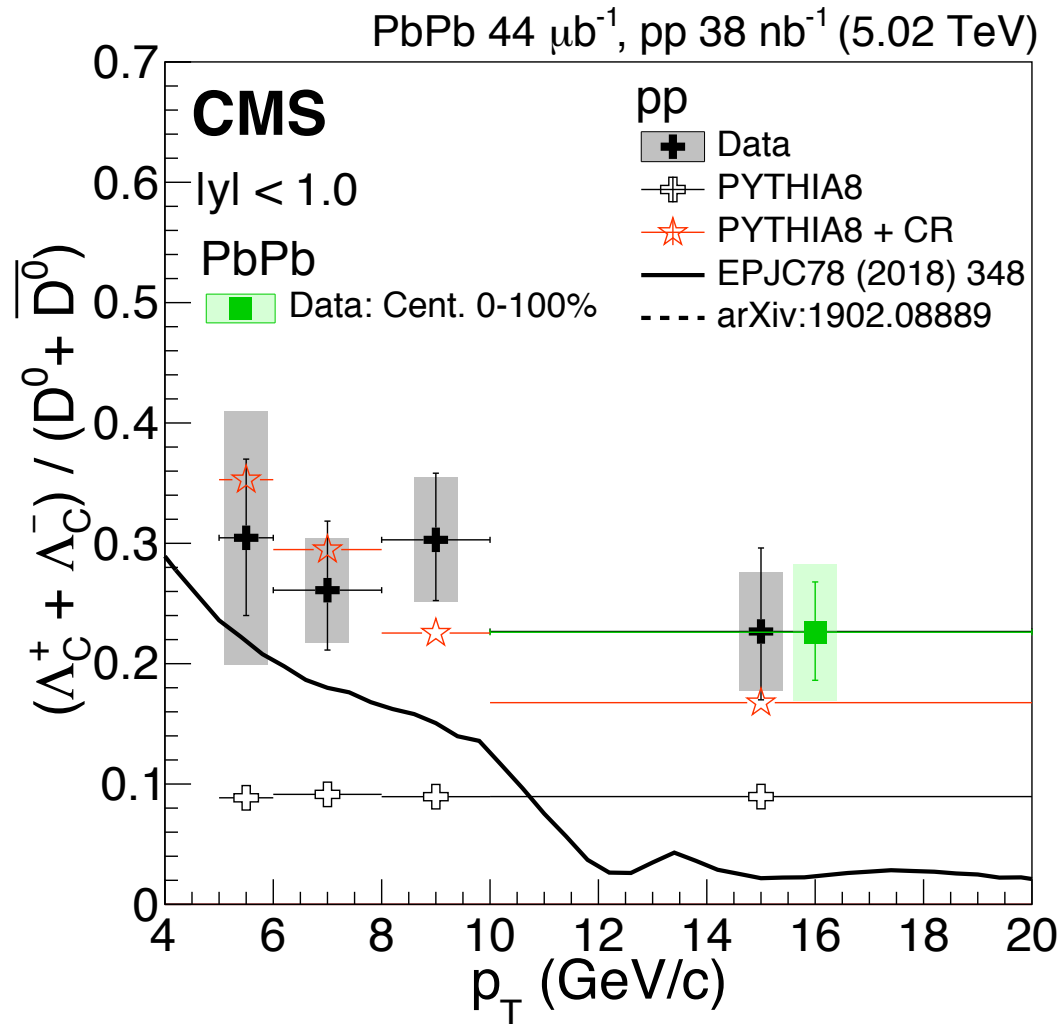


- ❖ PbPb ~ pp result in 10-20 GeV/c, suggests no significant contribution from coalescence in PbPb for $p_T > 10$ GeV/c.
- ❖ pp result ~ PYTHIA8 in shape (tune: CUETP8M1.)
- ❖ PYTHIA8 + color reconnection describes data.

JHEP 08 (2015) 003



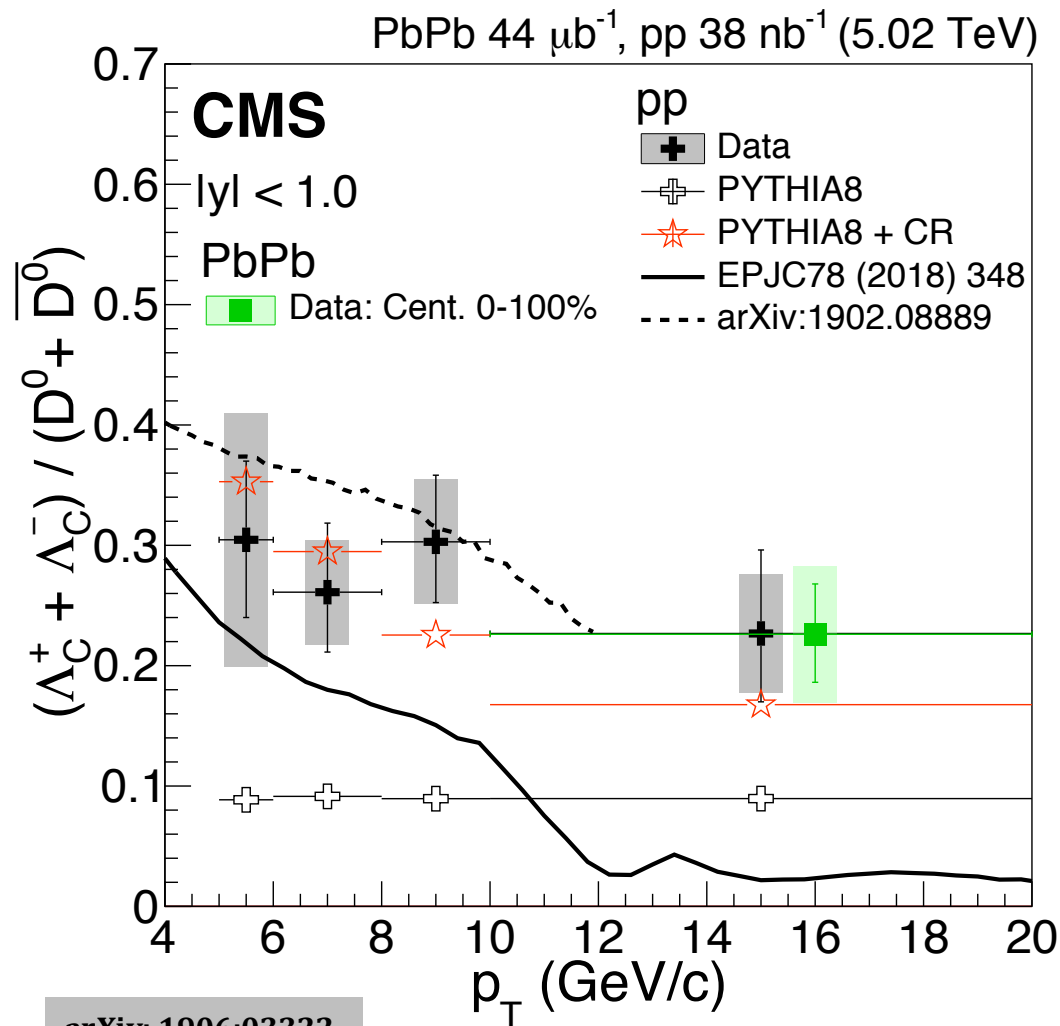
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- ❖ Solid line: predicts a stronger p_T dependence and underestimate $p_T > 10$ GeV/c.
 - Coalescence + fragmentation.
 - S. Plumari et al



Λ_C^+ / D^0 production ratio



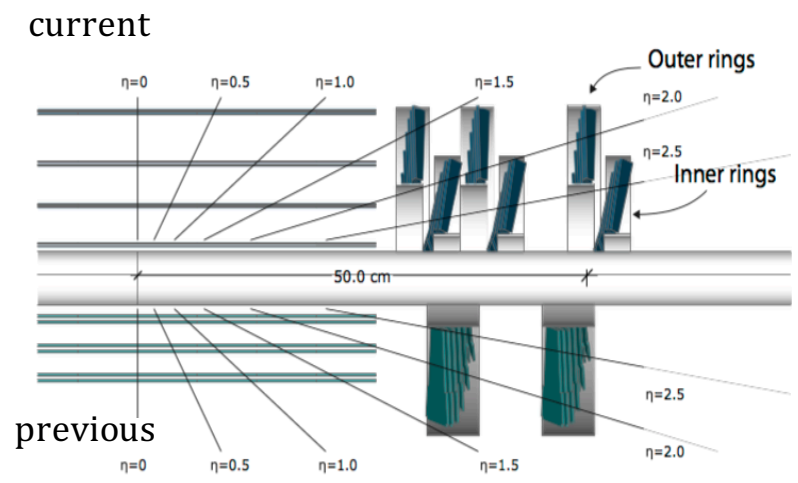
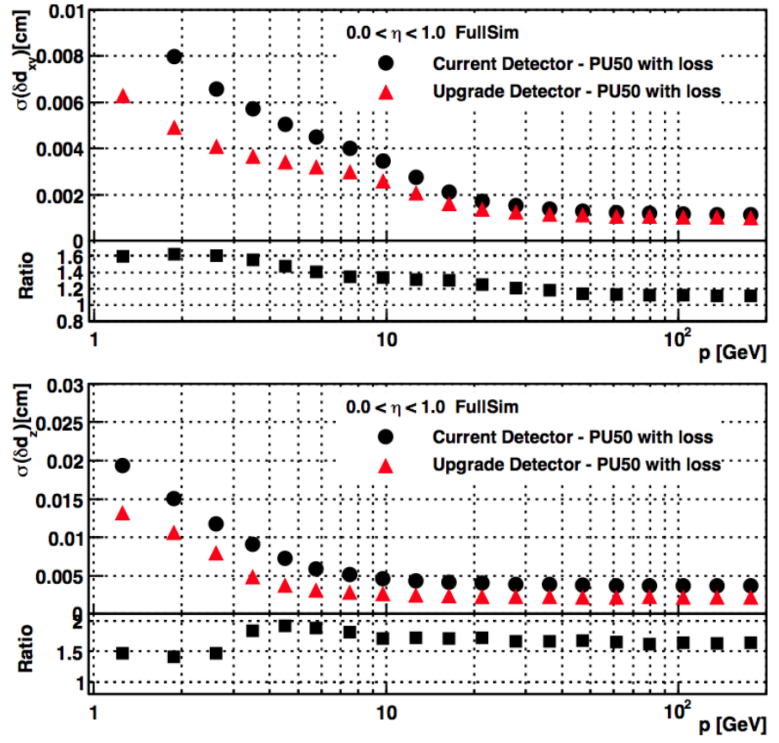
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- ❖ Solid line: predicts a stronger p_T dependence and underestimate $p_T > 10$ GeV/c.
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 - S. Plumari et al
- ❖ Dashed line: provide reasonable description of pp data $p_T < 10$ GeV/c.
 - Include excited charm baryons states beyond PDG.
 - M. He and R. Rapp



Outlook

❖ More precise with expanded p_T ranges in the near future.

- ~20X MB data statistics in year 2018
- Pixel detector upgrade: layers: 3 → 4



CERN-LHCC-2012-016

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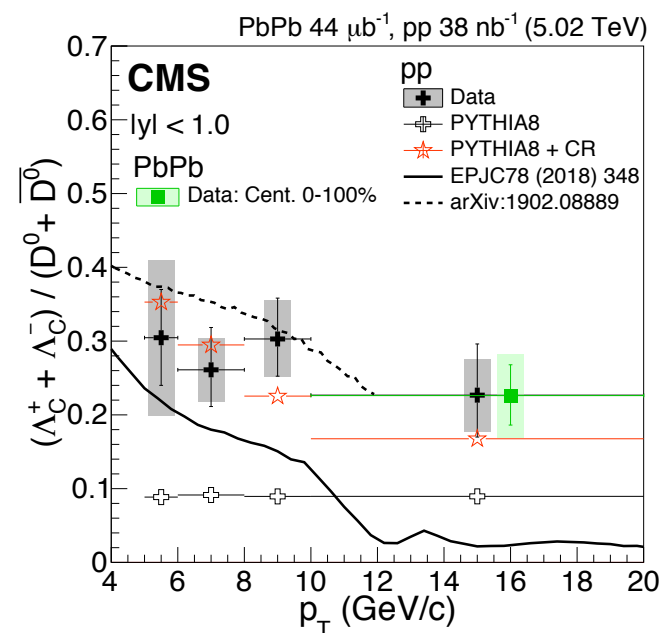
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Summary

- ❖ Λ_C^+ differential cross section is measured in pp and PbPb.
 - p_T distribution shape in pp collisions is consistent with PYTHIA8.
- ❖ $\Lambda_C^+ R_{AA}$ is measured in PbPb.
 - Evidence: more suppression in the more central collisions.
- ❖ Λ_C^+ / D^0 production ratio is measured in pp and PbPb.
 - PbPb result \sim pp in 10-20 GeV/c, suggests that there is no significant contribution from the coalescence process for $p_T > 10$ GeV/c in PbPb.
 - The standard color reconnection model is consistent with the pp result.
- ❖ More precise measurement with 2018 Run data.



Thank you !



Back Up



Systematic uncertainties

❖ Signal extraction systematics

- Changing the background fit function effect: 4-10% (pp) and 7-9% (PbPb).
- Changing signal fit function: 10-32% (pp) and 6-13% (PbPb).

❖ Systematic uncertainty on selection cut

- Comparing data and MC efficiency of different cut selections (6% for pp and 19% for PbPb).
- Tacking efficiency systematic.

❖ Systematic uncertainty for D^0 in CMS

❖ Systematic uncertainty on p_T shape

- Changing the MC p_T shape (0-10% for pp and 3-4% for PbPb).

❖ Branching ratio systematic

- 5.3% from PDG.
- Varying the branching ratio for each sub-channel in the uncertainty from PDG. (8% for pp and for PbPb).



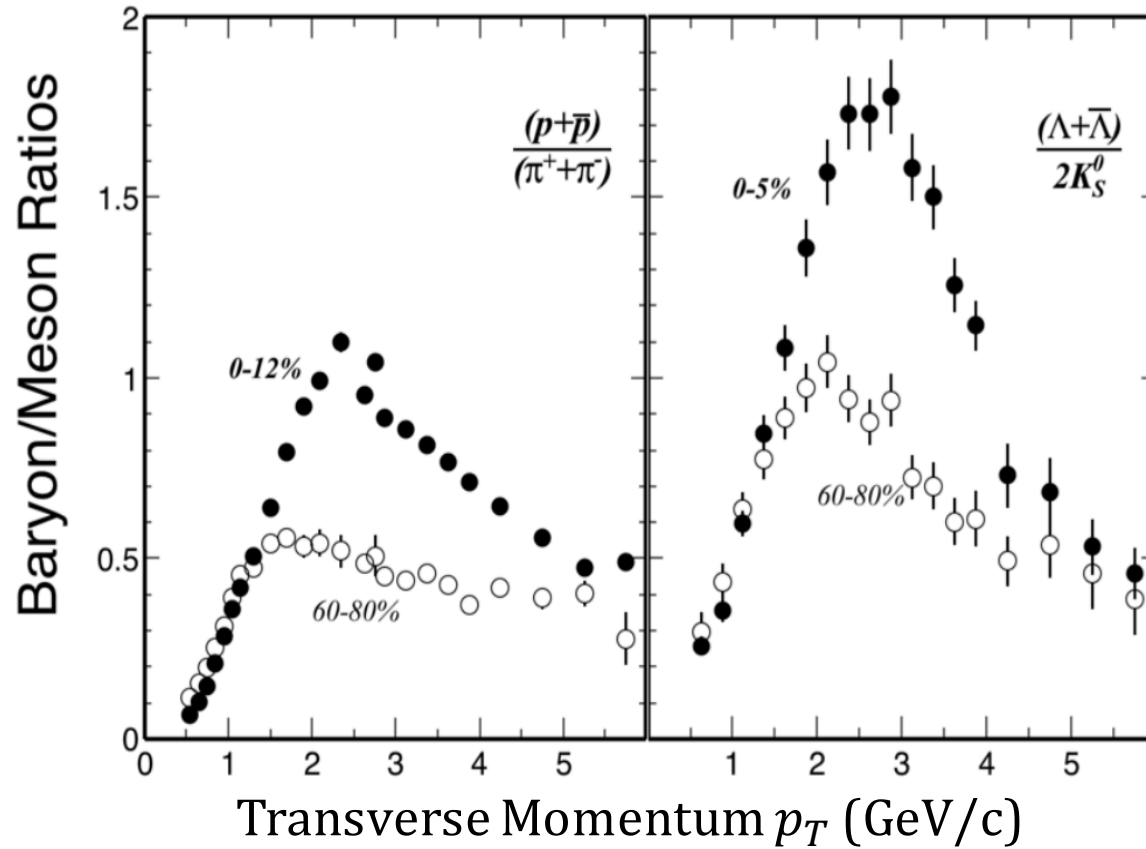
CR Modes parameters setting

Parameter	Monash	Mode 0	Mode 2	Mode 3
StringPT:sigma	= 0.335	= 0.335	= 0.335	= 0.335
StringZ:aLund	= 0.68	= 0.36	= 0.36	= 0.36
StringZ:bLund	= 0.98	= 0.56	= 0.56	= 0.56
StringFlav:probQQtoQ	= 0.081	= 0.078	= 0.078	= 0.078
StringFlav:ProbStoUD	= 0.217	= 0.2	= 0.2	= 0.2
StringFlav:probQQ1toQQ0join	= 0.5, 0.7, 0.9, 1.0	= 0.0275, 0.0275, 0.0275, 0.0275	= 0.0275, 0.0275, 0.0275, 0.0275	= 0.0275, 0.0275, 0.0275, 0.0275
MultiPartonInteractions:pT0Ref	= 2.28	= 2.12	= 2.15	= 2.05
BeamRemnants:remnantMode	= 0	= 1	= 1	= 1
BeamRemnants:saturation	-	= 5	= 5	= 5
ColourReconnection:mode	= 0	= 1	= 1	= 1
ColourReconnection:allowDoubleJunRem	= on	= off	= off	= off
ColourReconnection:m0	-	= 2.9	= 0.3	= 0.3
ColourReconnection:allowJunctions	-	= on	= on	= on
ColourReconnection:junctionCorrection	-	= 1.43	= 1.20	= 1.15
ColourReconnection:timeDilationMode	-	= 0	= 2	= 3
ColourReconnection:timeDilationPar	-	-	= 0.18	= 0.073

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Baryon/Meson Ratios



arXiv:nucl-ex/0601042

