$\Lambda_c^{\pm}$ production (and D and B) in pp and PbPb collisions at 5.02 TeV with the CMS experiment
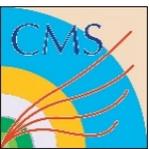
Rui Xiao

(Purdue University)
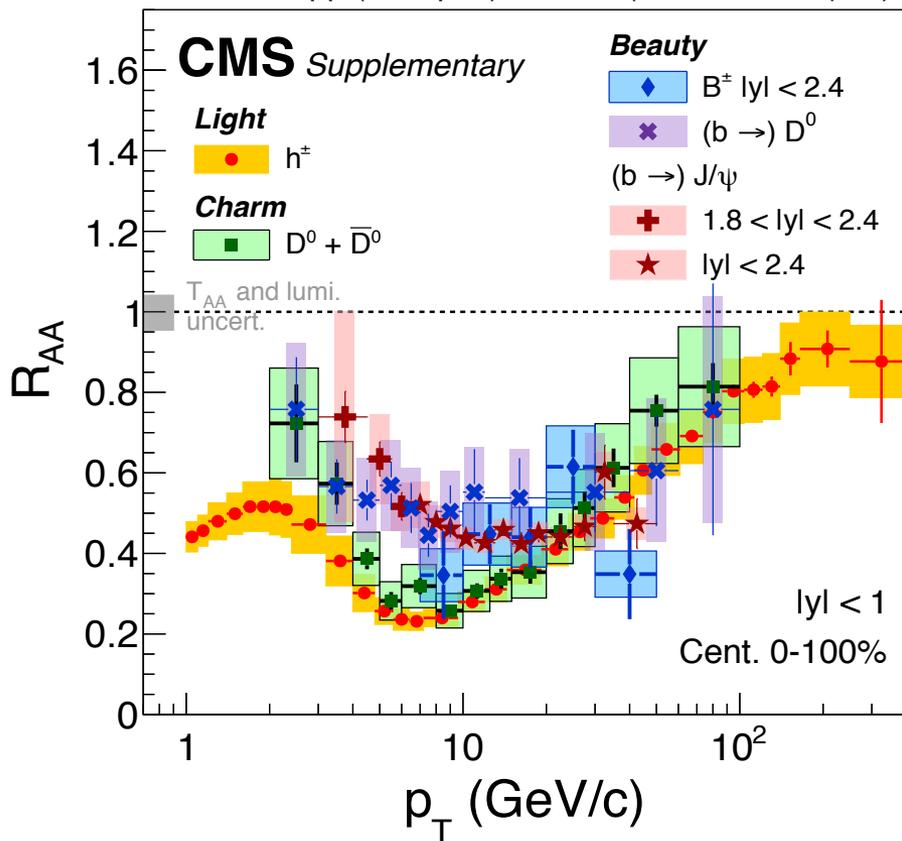*for the CMS Collaboration*
Hard Probes 2018

Physics 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 disassociation, ...*

❖ Cold nuclear effects

  ▪ *Gluon shadowing , Color glass condensate, ...*

❖ Sensitive to the gluon nPDF.

  ▪ *produced mostly from gluon fusion*

❖ A good reference to quarkonium production

R_{AA} of D and B meson at 5.02 TeV

5.02 TeV pp (27.4 pb^{-1}) + PbPb (530/404/368 μb^{-1})

**CMS** *Supplementary*

Light
h$^\pm$

Charm
D^0 + $\overline{D}^0$

T_{AA} and lumi. uncert.

Beauty
B$^\pm$ |y| < 2.4
(b →) D^0

(b →) J/ψ
1.8 < |y| < 2.4
|y| < 2.4

|y| < 1
Cent. 0-100%

- ❖ **p_T < 4 GeV/c:**
  - ▫ Hint of D^0 R_{AA} bigger than $h^\pm$ R_{AA}

- ❖ **p_T > 4 GeV/c:**
  - ▫ D^0 R_{AA} consistent with $h^\pm$ R_{AA}

- ❖ For the whole **p_T** range:
  - ▫ B^+ and D^0 R_{AA} consistent within uncertainties.
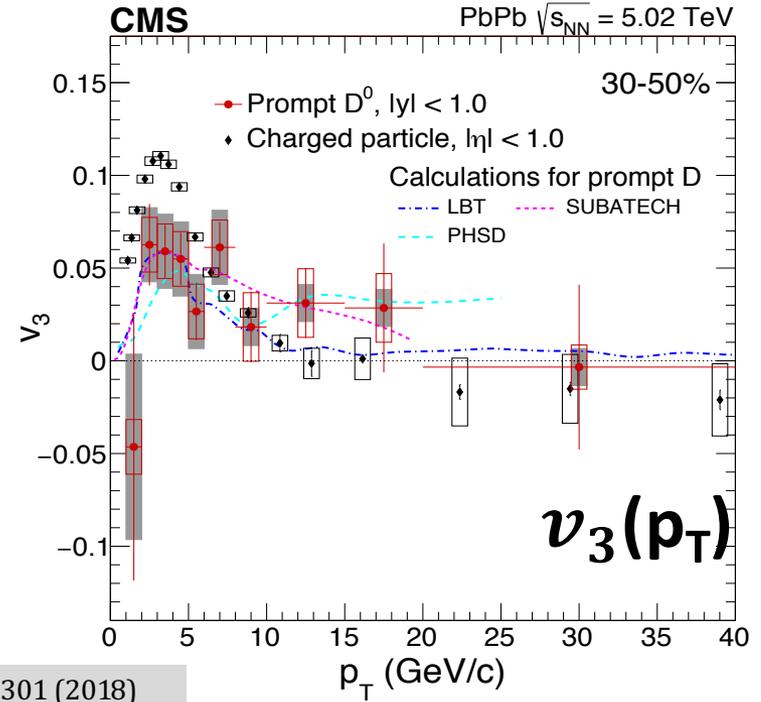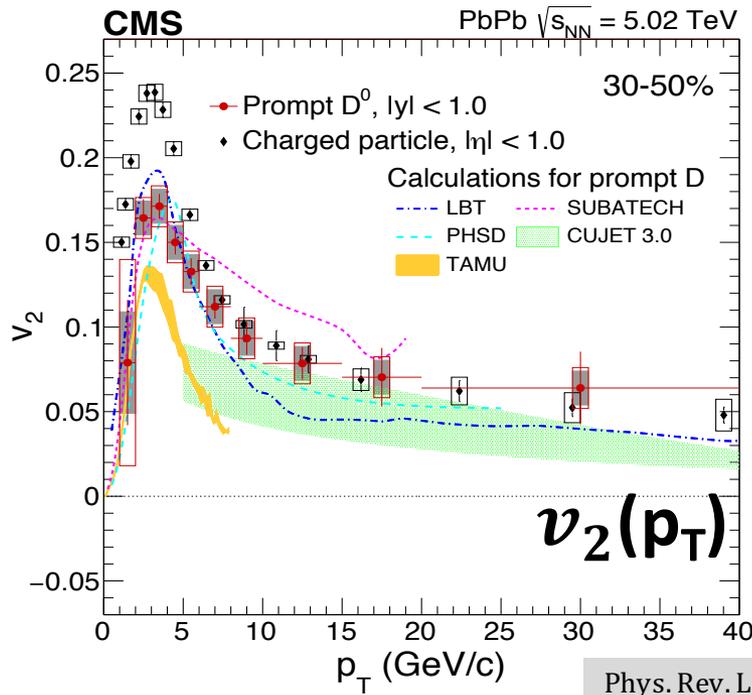 - ▫ $R_{AA}(D^0) < R_{AA}(B\rightarrow J/\psi)$

Eur. Phys. J. C 78 (2018) 509

Phys. Lett. B 782 (2018) 474

JHEP **04** (2017) 039

Phys. Rev. Lett. **119** (Oct, 2017) 152301

PURDUE
U N I V E R S I T Y
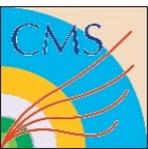
Elliptic (v_2) and triangular flow (v_3) of D^0 at 5.02 TeV

Phys. Rev. Lett. 120, 202301 (2018)

❖ $p_T < 6\,\mathrm{GeV}/c$:
- Smaller v_2 and v_3 for charm but p_T dependence similar to charged hadrons.

❖ $p_T > 6\,\mathrm{GeV}/c$:
- path length dependence of charm energy loss similar to light quarks.
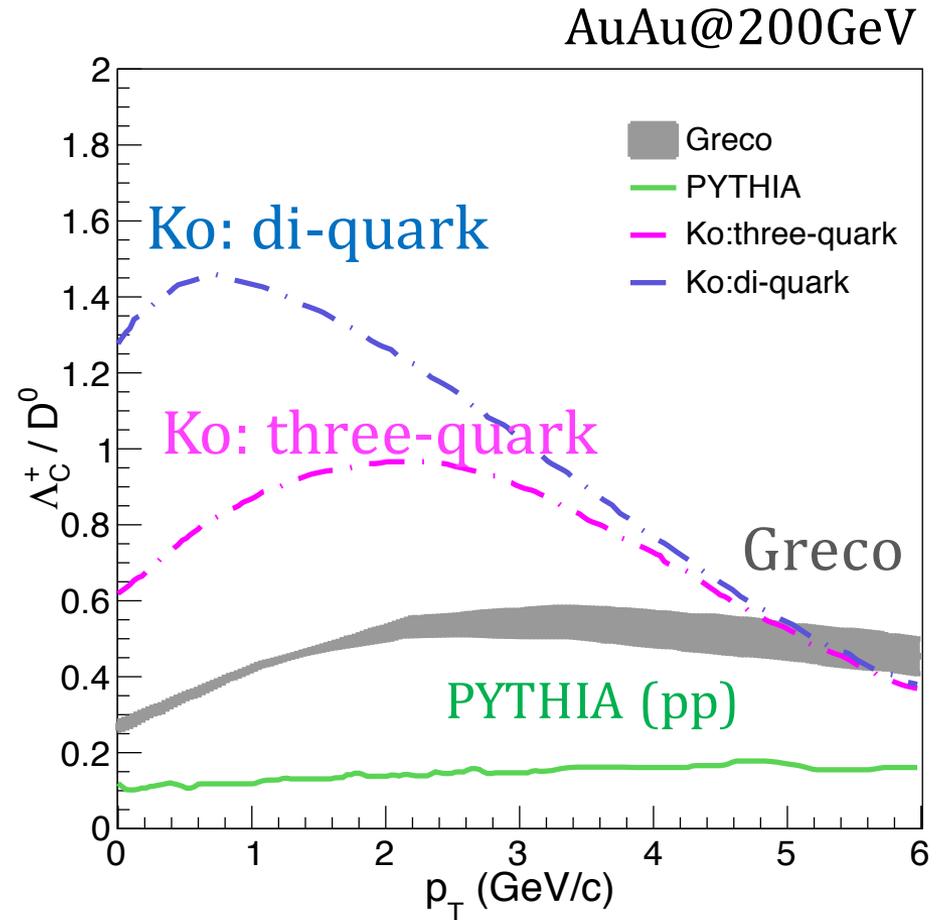
- Coll-E-loss + Rad.-E-loss: LBT, CUJET, SUBATECH
- Coll-E-loss: TAMU, PHSD
- Charm-medium interaction + coalescence
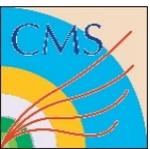- Charm quark collectivity

Charm baryon: $\Lambda_C^\pm$

$\Lambda_C^\pm$ is essential for understanding :

❖ heavy quarks transport in QGP and hadronic phase of the medium

❖ charm quark hadronization via coalescence

■ Enhances $\Lambda_C^\pm$ in PbPb over pp

■ Measurements in broad p_T range needed

AuAu@200GeV

Ko: di-quark

Ko: three-quark

Greco

PYTHIA (pp)

Legend:
- Greco
- PYTHIA
- Ko:three-quark
- Ko:di-quark

Λ_C^+ / D^0 vs p_T (GeV/c)

Ko model: Y. Oh, et. al. PRC 79,044905(2009)
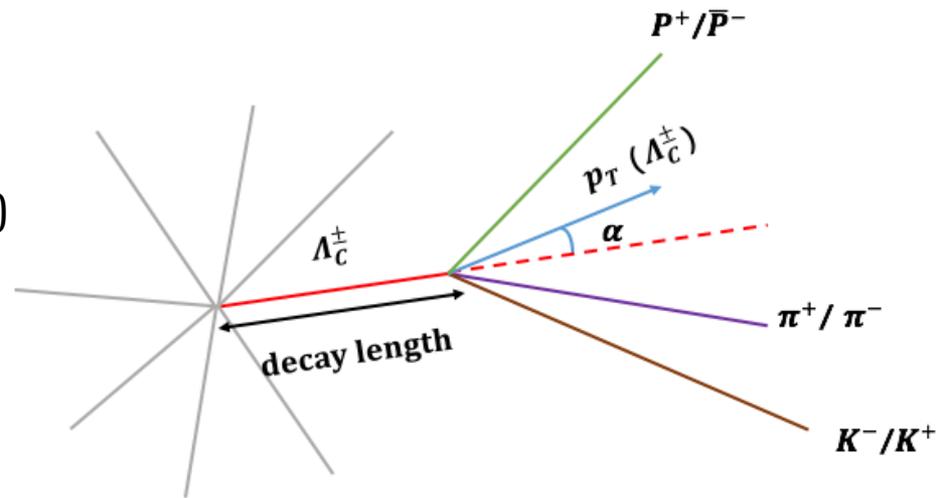Greco model: S. Ghosh, et. al. PRD 90,054017(2014)

PURDUE
U N I V E R S I T Y

$\Lambda_c^{\pm}$ signal extraction

❖ $c\tau\ (\Lambda_c^+) \sim 60\ \mu$m ➜ Hard to measure.

❖ $\Lambda_c^+ \rightarrow P^+\ K^-\pi^+$ BR~6.35%

- $P^+\bar{K}^*(892)^0 \rightarrow P^+K^-\pi^+ = 1.98\% \times \frac{2}{3} \sim 1.32\%$
- $\Delta^{++}\ K^- \rightarrow P^+K^-\pi^+ = 1.09\%$
- $\Lambda(1520)\pi^+ \rightarrow P^+K^-\pi^+ = 2.2\% \times 22.5\% \sim 0.495\%$
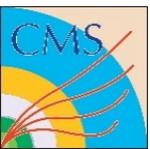- $Non\ resonance = 3.5\%$

❖ Topological selection:

- ➤ Decay length significance $(d_0/\sigma(d_0))$
- ➤ Secondary vertex probability
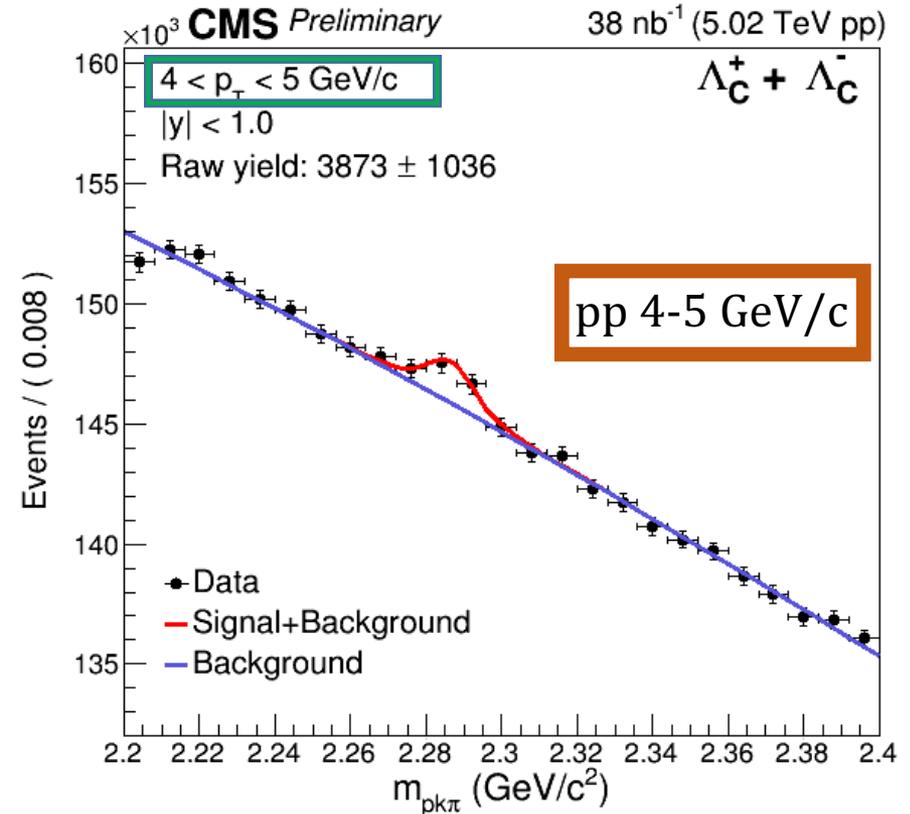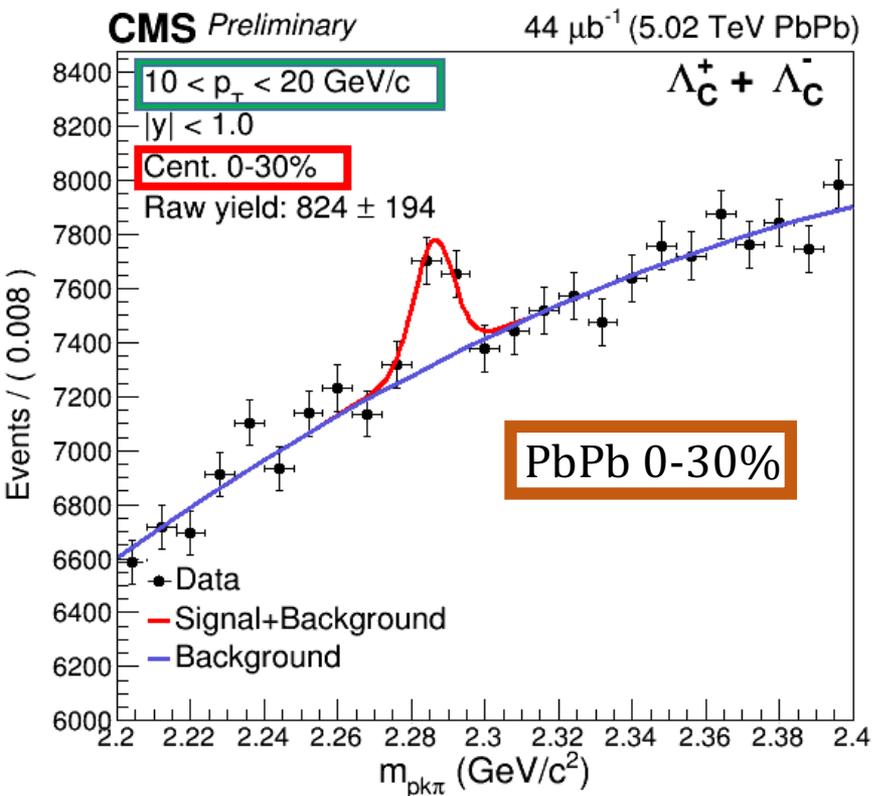- ➤ Pointing angle: α
- ➤ Daughter track p_T

$\Lambda_c^{\pm}$ signal extraction

❖ The optimal cuts are obtained by TMVA*.

  ▪ Rectangular cut as the classification method.

❖ The optimal cut values to maximize significance $s/\sqrt{s+b}$

❖ Signal:

  ▪ Obtained from true MC signal.

❖ Background:

  ▪ sideband from data

❖ TMVA ➜ much higher significance & lower p_T reach.

*Toolkit for Multivariate Data Analysis with ROOT

# Observation of $\Lambda_c^{\pm}$ signal in pp and PbPb

CMS *Preliminary* 44 μb⁻¹ (5.02 TeV PbPb)

$10 < p_T < 20$ GeV/c
$|y| < 1.0$
Cent. 0-30%
Raw yield: 824 ± 194

$\Lambda_c^+ + \Lambda_c^-$

PbPb 0-30%

Events / (0.008)

- Data
- Signal+Background
- Background

$m_{pk\pi}$ (GeV/c²)

CMS *Preliminary* 38 nb⁻¹ (5.02 TeV pp)

$4 < p_T < 5$ GeV/c
$|y| < 1.0$
Raw yield: 3873 ± 1036

$\Lambda_c^+ + \Lambda_c^-$

pp 4-5 GeV/c

Events / (0.008)

- Data
- Signal+Background
- Background

$m_{pk\pi}$ (GeV/c²)

❖ Significant signal observed
- 10-20 GeV/c in 0-30% PbPb, the signal significance is 4.2σ
- down to 4 GeV/c in pp, the signal significance is 3.7σ

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Outlook

❖   pp at 5.02 TeV in Run2017:

  ▪   trigger data: 305 pb^{-1} $\sim$ x10 of Run2015.

  ▪   Minimum-bias: 7.2 billion $\sim$ x2.5 of Run2015.

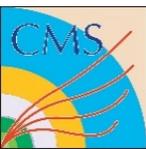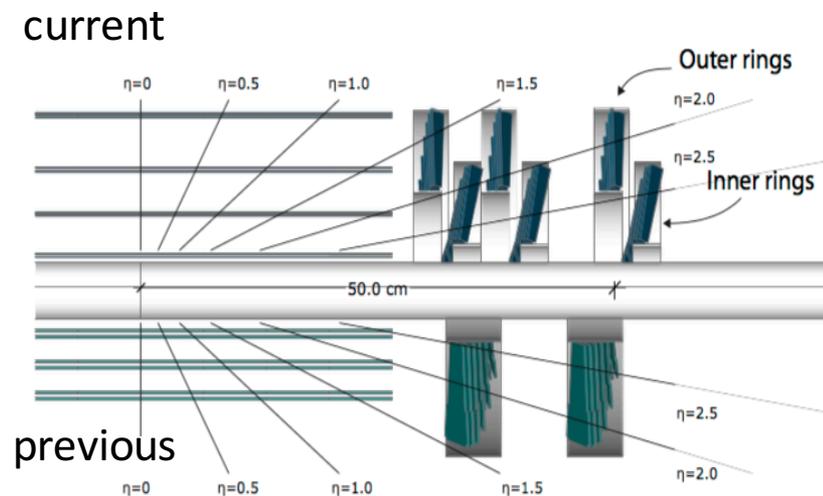❖   PbPb at 5.02 TeV in Run2018:
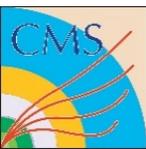
  ▪   ~20x Run2015.

Outlook

❖ pp at 5.02 TeV in Run2017:

- trigger data: 305 pb^{-1} ~ x10 of Run2015.
- Minimum-bias: 7.2 billion ~ x2.5 of Run2015.

❖ PbPb at 5.02 TeV in Run2018:

- ~20x Run2015.

❖ New CMS Phase-1 pixel detector in operation.

- 4 pixel barrel layers.
- Impact parameter resolution significantly improved.

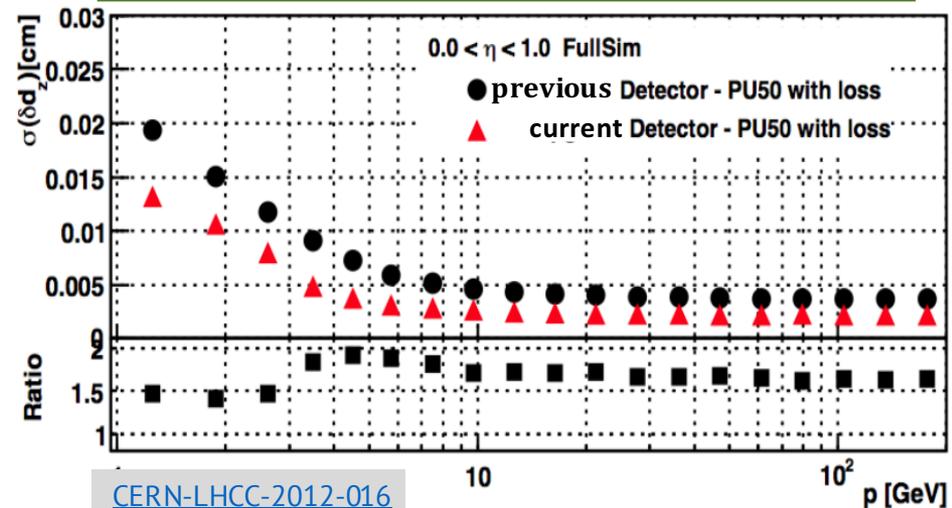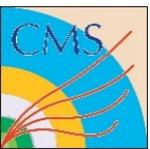❖ More precise measurements in near future.

Outlook

❖ New CMS Phase-1 pixel detector in operation.

  ▪ 4 pixel barrel layers.

  ▪ Impact parameter resolution significantly improved.

❖ More precise measurements in near future.

Transverse impact parameter resolution
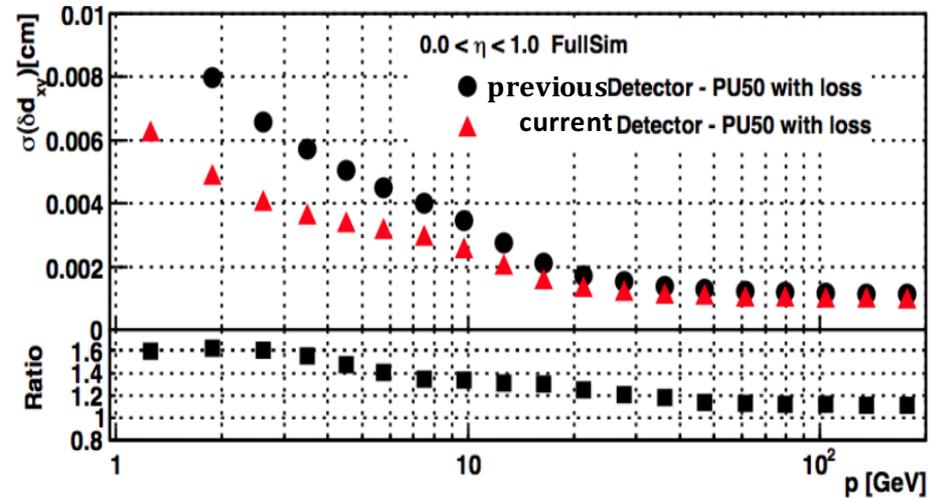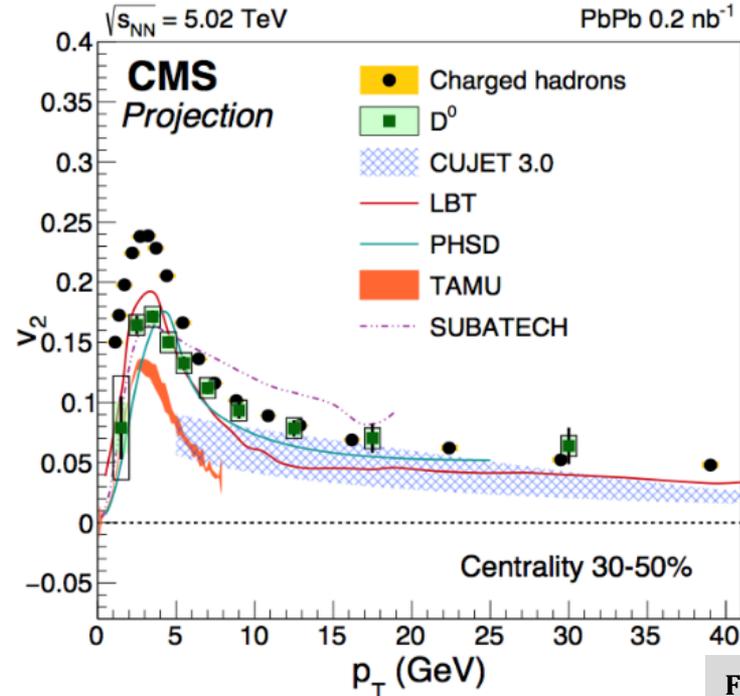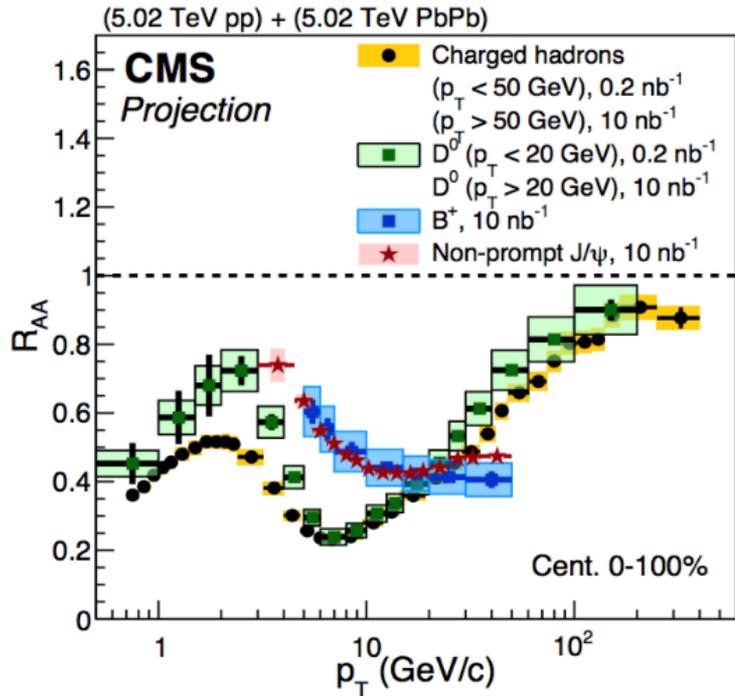

Longitudinal impact parameter resolution

CERN-LHCC-2012-016

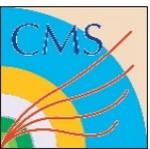# Outlook

- High-Lumi-LHC (~2025): ~10 nb^{-1} , ~20x Run2015

FTR-17-002 PAS

- ~16k $\Lambda_c^{\pm}$ in 0-30% PbPb
- High precision measurements in High-Lumi-LHC era

Summary

❖ Measurement of R_{AA} and v_n

➢ Hint of R_{AA}(beauty) > R_{AA} (charm) > R_{AA}(charged)

➢ v_n results: suggest collective motion of charm quark at low p_T and path-length dependence E-loss at high p_T.
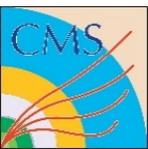
❖ Significant $\Lambda_C^{\pm}$ signal observed in PbPb and pp

➢ PbPb centrality 0-30%: 4.2σ

➢ pp 4-5 GeV: 3.7σ

❖ High(er) precision measurements with 2017/2018 and HL-LHC data.
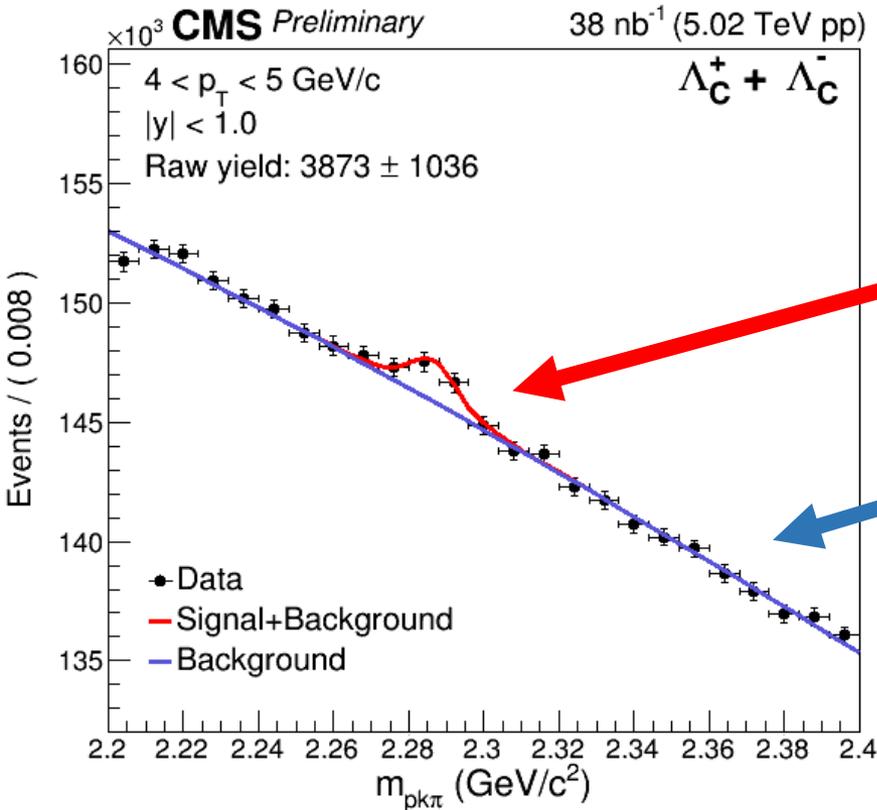
PURDUE
UNIVERSITY
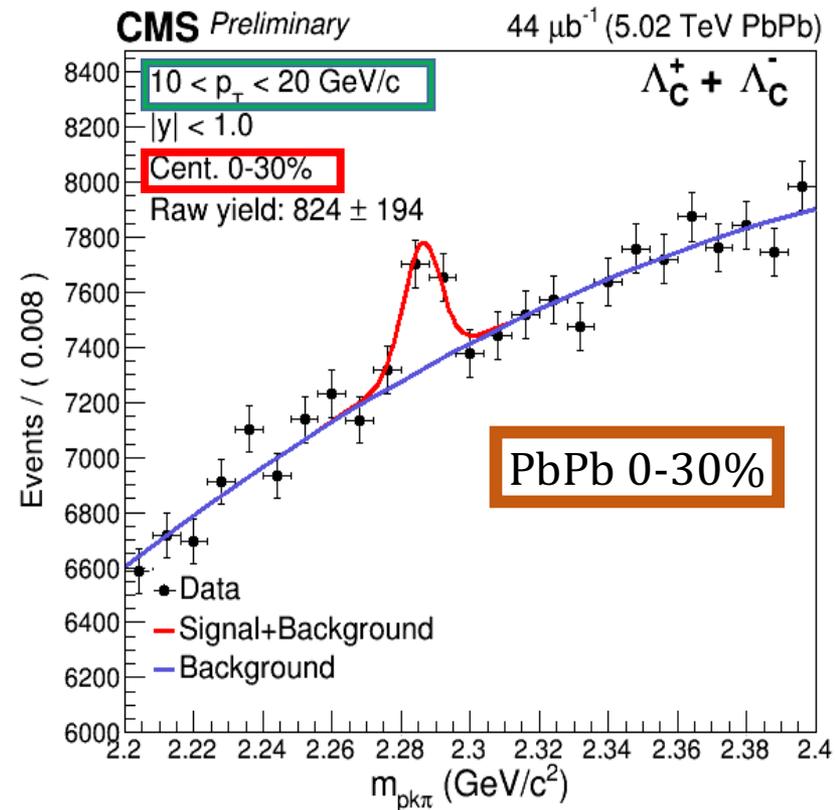
Thank you

Back Up

$\Lambda_c^{\pm}$ signal extraction

❖ **Unbinned fit procedure using RooFit.**

- Double Gaussian for signal.

- Second order Chebychev polynomial function for background.

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