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

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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

- $p_T < 4$ 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.
  - $R_{AA}(D^0) < R_{AA}(B\rightarrow J/\psi)$


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Elliptic ($v_2$) and triangular flow ($v_3$) of $D^0$ at 5.02 TeV

- $p_T < 6$ GeV/c:
  - Smaller $v_2$ and $v_3$ for charm but $p_T$ dependence similar to charged hadrons.

- $p_T > 6$ 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

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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**

![Graph showing $\Lambda_C^\pm$ vs. $p_T$](image)

- **Greco**
- **PYTHIA (pp)**

**Ko model:** Y. Oh, et. al. PRC 79,044905(2009)
**Greco model:** S. Ghosh, et. al. PRD 90,054017(2014)
\( \Lambda_c^\pm \) signal extraction

- \( c\tau (\Lambda_c^+) \sim 60 \mu m \) → Hard to measure.

- \( \Lambda_c^+ \rightarrow P^+ K^- \pi^+ \) \( \text{BR} \sim 6.35\% \)
  - \( P^+ K^*(892)^0 \rightarrow P^+ K^- \pi^+ = 1.98\% \times \frac{2}{3} \sim 1.32\% \)
  - \( \Delta^{++} K^- \rightarrow P^+ K^- \pi^+ = 1.09\% \)
  - \( \Lambda(1520) \pi^+ \rightarrow P^+ K^- \pi^+ = 2.2\% \times 22.5\% \sim 0.495\% \)
  - Non resonance = 3.5\%

- Topological selection:
  - Decay length significance \( (d_0 / \sigma(d_0)) \)
  - Secondary vertex probability
  - Pointing angle: \( \alpha \)
  - Daughter track \( p_T \)
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 $\Rightarrow$ much higher significance & lower $p_T$ reach.

*Toolkit for Multivariate Data Analysis with ROOT
Observation of $\Lambda_{C}^{\pm}$ signal in pp and PbPb

- Significant signal observed
  - 10-20 GeV/c in 0-30% PbPb, the signal significance is $4.2\sigma$
  - down to 4 GeV/c in pp, the signal significance is $3.7\sigma$
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.
Outlook

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

- More precise measurements in near future.
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Outlook

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

- \(~16k\, \Lambda^\pm_c\) in 0-30\% PbPb
- High precision measurements in High-Lumi-LHC era
Summary

❖ Measurement of $R_{AA}$ and $\nu_n$
  ➢ Hint of $R_{AA}$ (beauty) > $R_{AA}$ (charm) > $R_{AA}$ (charged)
  ➢ $\nu_n$ 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%: $4.2\sigma$
  ➢ pp 4-5 GeV: $3.7\sigma$

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

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

Events $(0.008)$

$\Lambda_C^+ + \Lambda_C^-$

$38$ nb$^{-1}$ (5.02 TeV pp)