Multiplicity and rapidity dependence of strange hadron production in pp, pPb, and PbPb collisions at LHC energies

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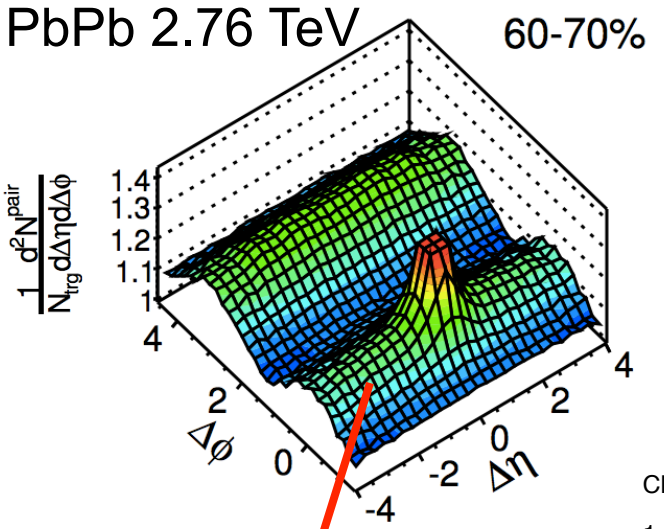
Motivation

EPJC 72(2012)
JHEP 09(2010) 091
PLB 718(2013) 795

PbPb 2.76 TeV

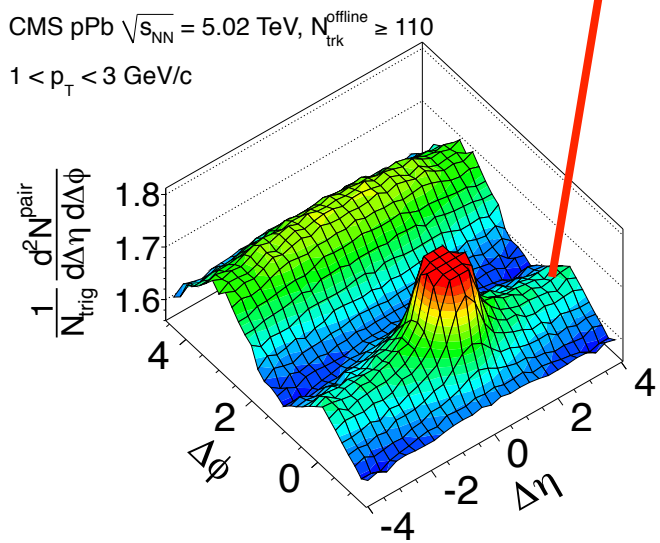
60-70%



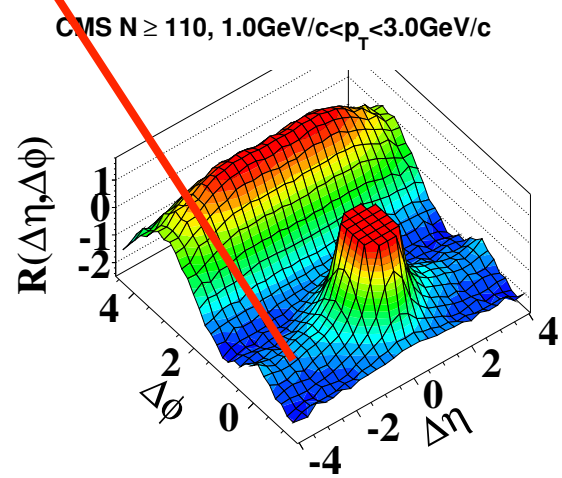
In smaller systems with high multiplicity

- Similar ridge structure as in AA collisions
- Also related to collective flow?

pPb 5.02 TeV



pp 7 TeV



- Ridge-like structure
- Collective flow

This analysis analyzes identified particle.
If it is collective flow, can we see mass effect?

Motivation

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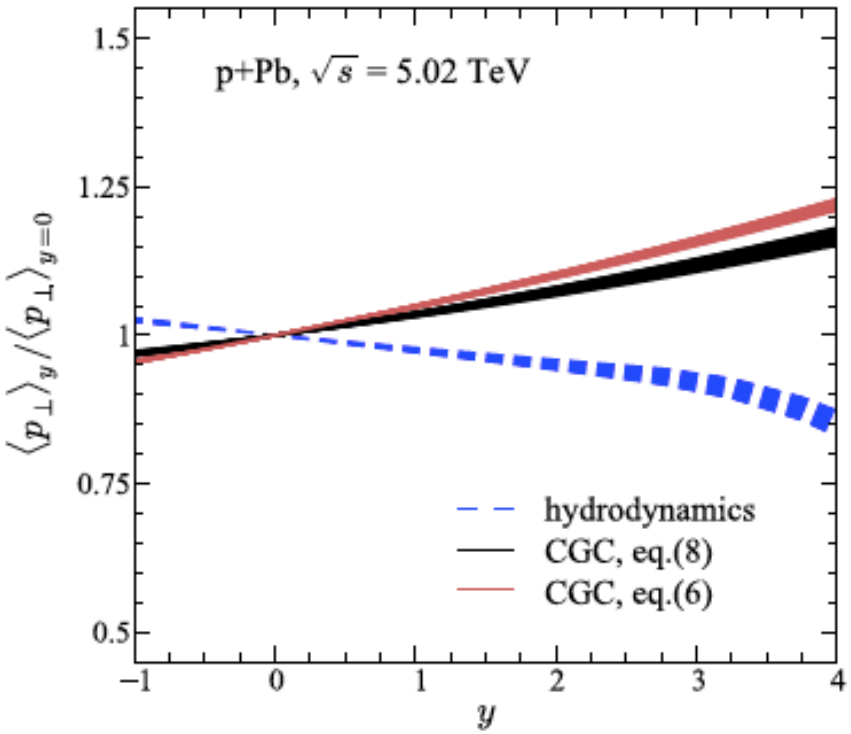


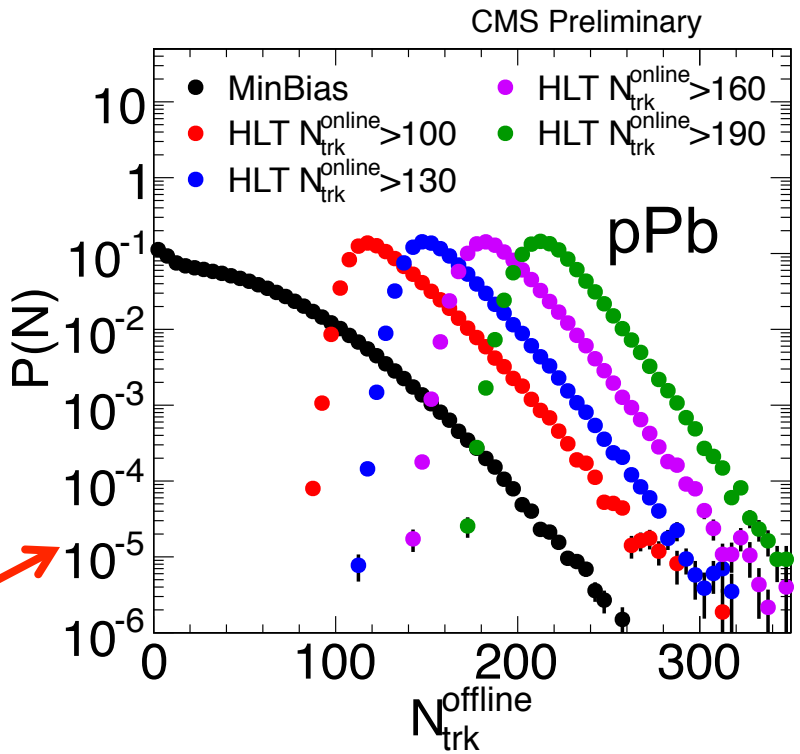
From Pb-going side to p-going side:

- In hydrodynamics, $\langle p_T \rangle$ gets smaller
  - ➢ Number of particles decreases
- Opposite trend in CGC (only) model.
  - ➢ Saturation momentum increases

With the large acceptance of CMS detector, what will we see in our result?

Data Sample

- pp
  - Data set: 2010 7 TeV
  - Event Selection:
    Minimum bias trigger
    High multiplicity triggers
- pPb
  - Data set: 2013 5.02 TeV
  - Event Selection:
    Minimum bias trigger
    High multiplicity triggers
- PbPb (50-100% Centrality)
  - Data set: 2011 2.76 TeV
  - Event Selection:
    Minimum bias trigger



Track multiplicity distribution for different triggers in pPb

V_0 and Ξ ($\Xi^- + \Xi^+$) Reconstruction

Decay Channel:

$K_s \rightarrow \pi^+ \pi^-$

$\Lambda^0 \rightarrow \pi^- p$

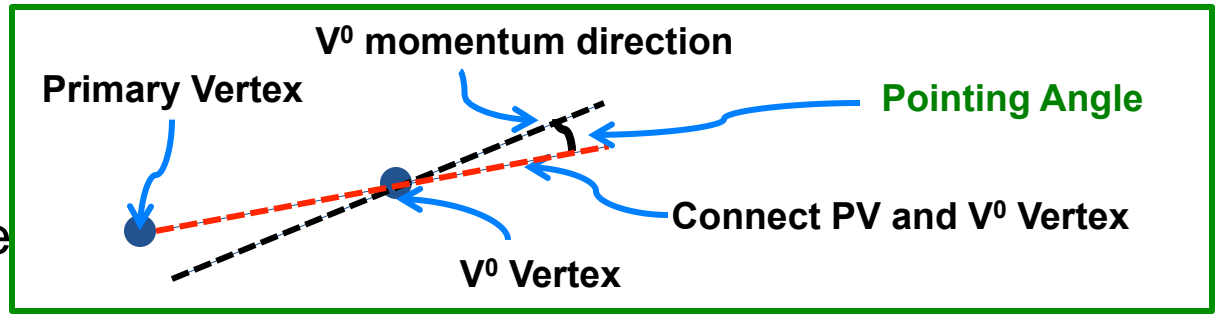
$\Xi^- \rightarrow \Lambda^0 \pi^-$

V^0

V^0s are reconstructed via combining a pair of oppositely charged tracks

Ξ^- candidates are reconstructed via combining Λ^0 candidate with an additional charged track with the proper sign

Candidates Selection:



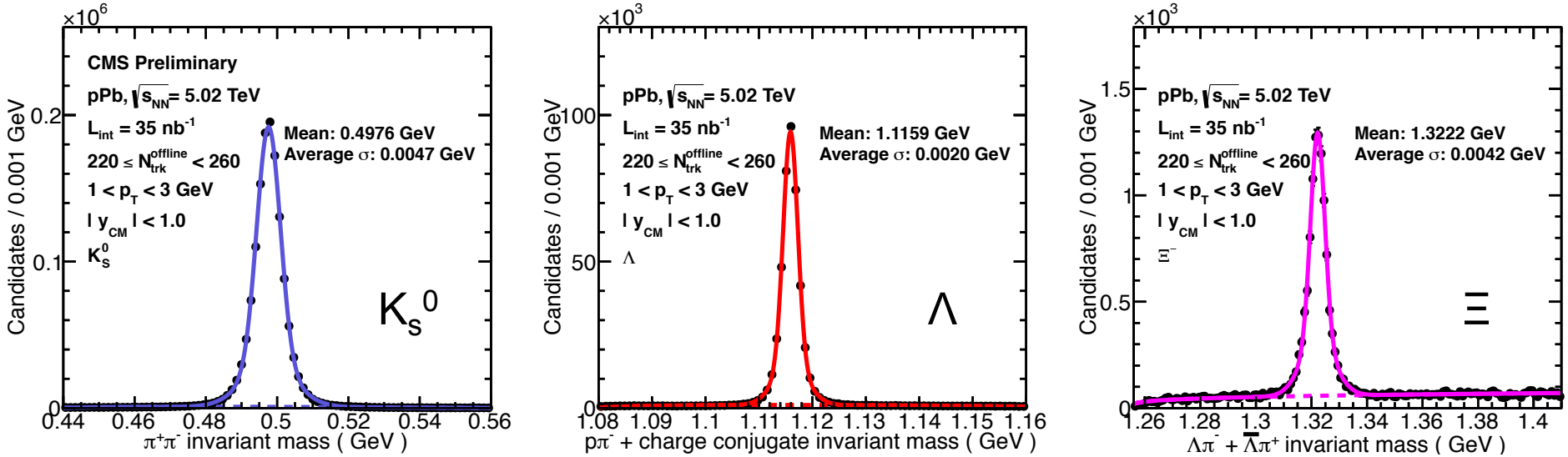
For V^0s

- Decay length significance
- Cos(pointing angle)
- 2D impact parameter significance of daughter tracks wrt PV

For Ξ^- Candidates

- 3D impact parameter significance of daughter tracks wrt PV
- 3D separation significance between Ξ^- or Λ^0 vertex wrt PV
- 3D impact parameter significance of Ξ^- candidate wrt PV

Invariant Mass Peaks

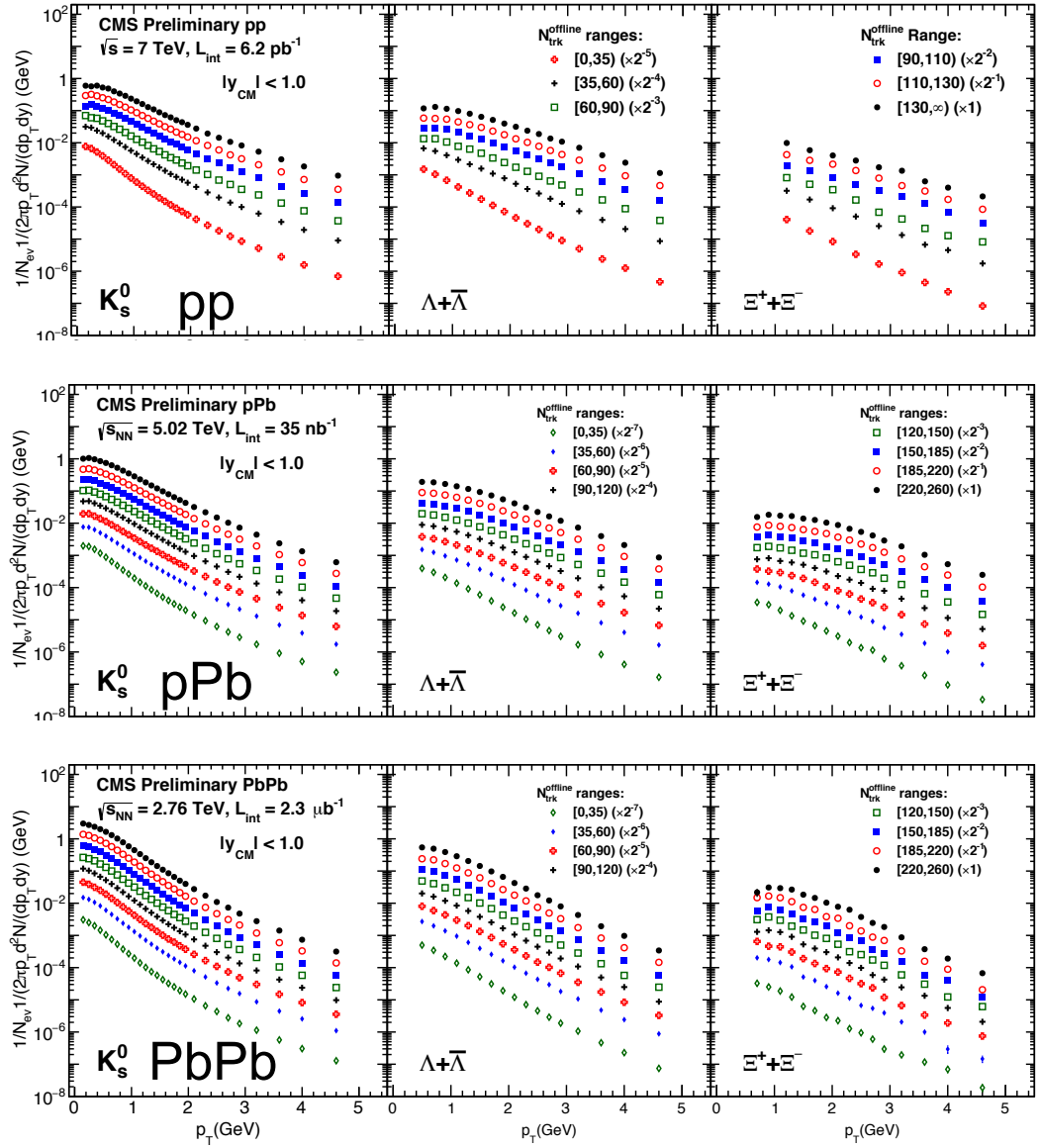


- Signal Function: Double Gaussian(with a common mean)
- Background Function:
  - quadratic function for K_s
  - $Aq^{3/2}+Bq^{1/2}$ for Λ, where $q = m - (M_p + M_\pi)$
  - Aq^B for Ξ, where $q = m - (M_\Lambda + M_\pi)$

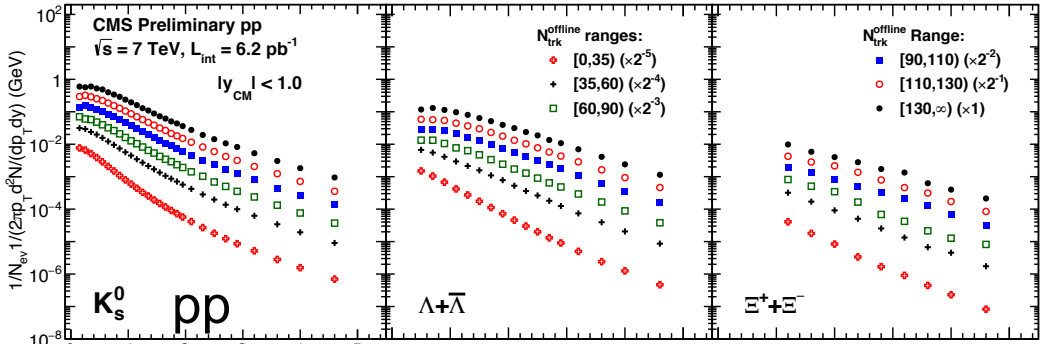
Yield Extraction

1. Implement Signal Fitting Function → Signal Counts * PDF
2. Obtain signal counts and statistical error from fitting parameters

Mid-rapidity Spectra

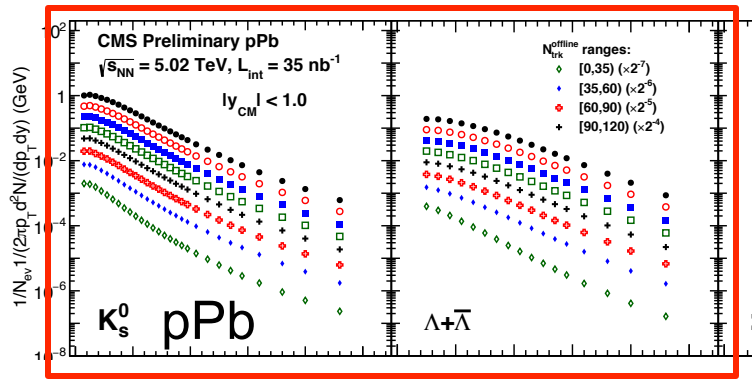


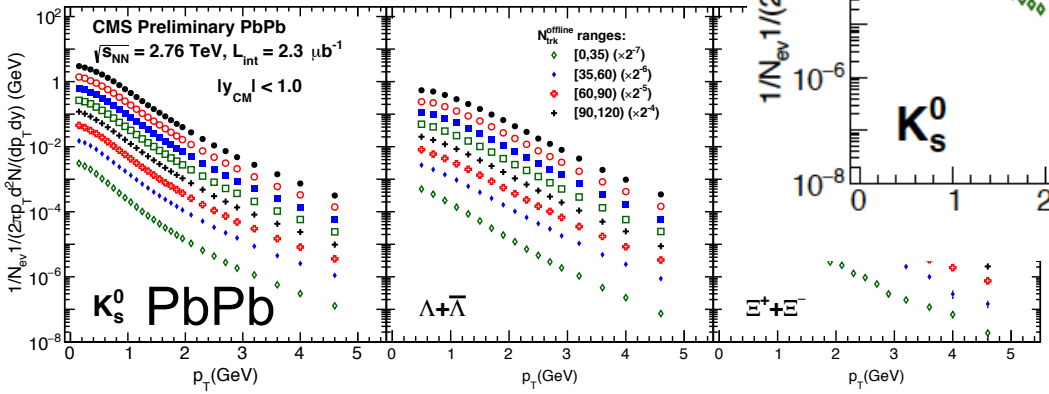
Mid-rapidity Spectra

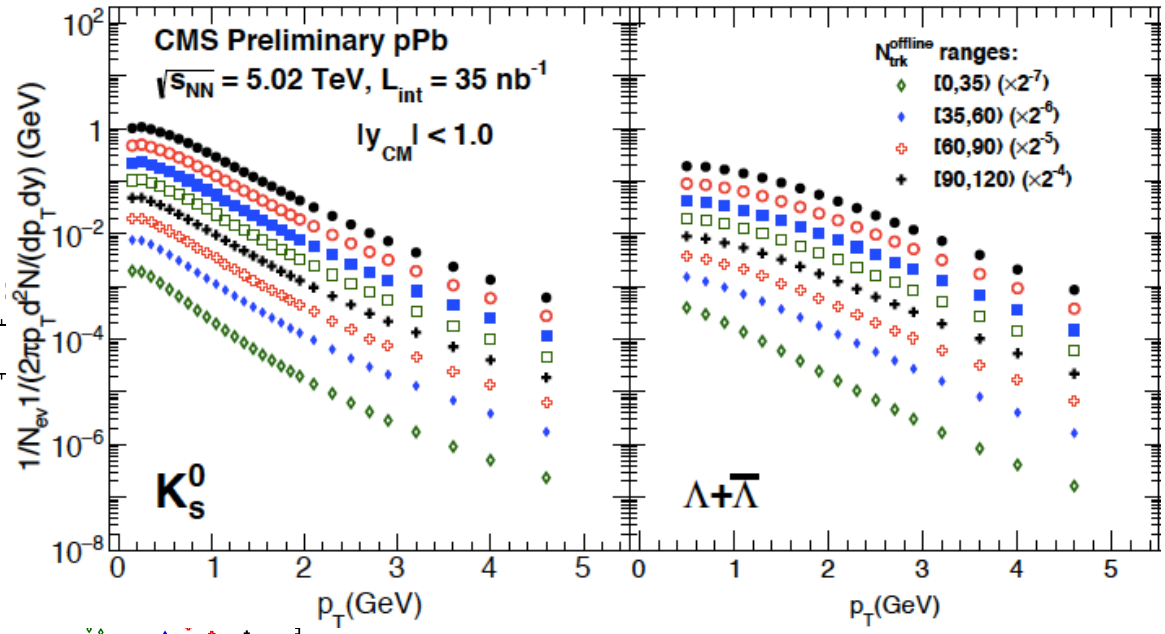


Evolution of Spectra Shape:

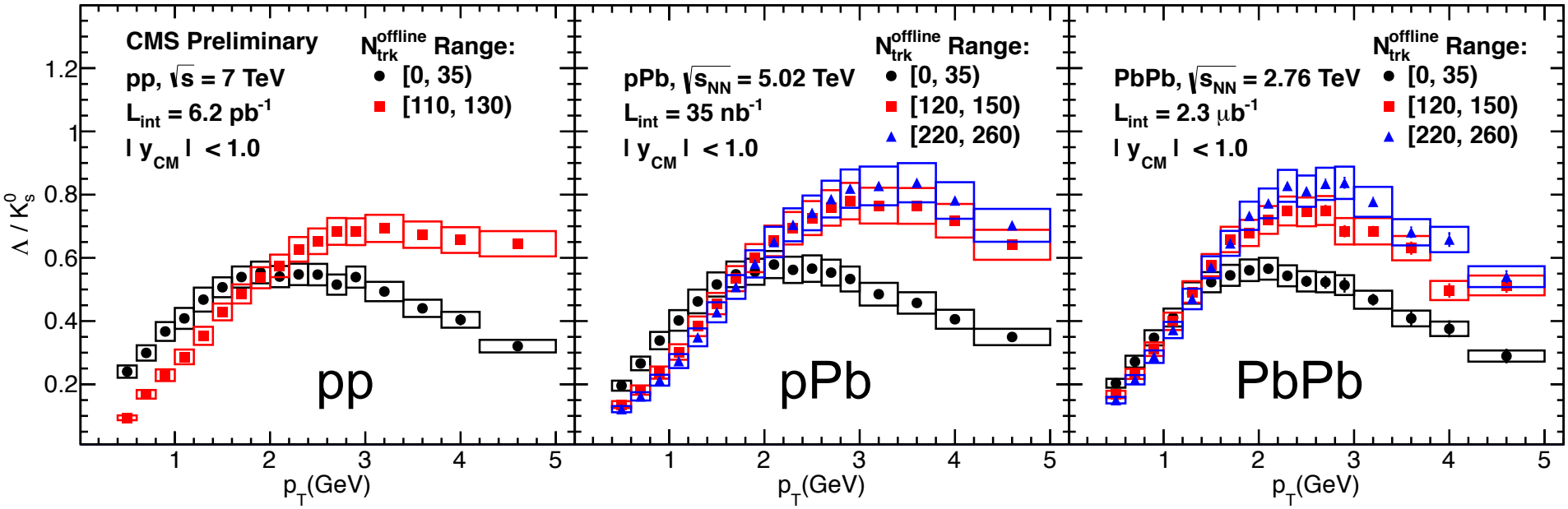
1. Spectra become harder as multiplicity increases
2. Heavier particles have harder spectra





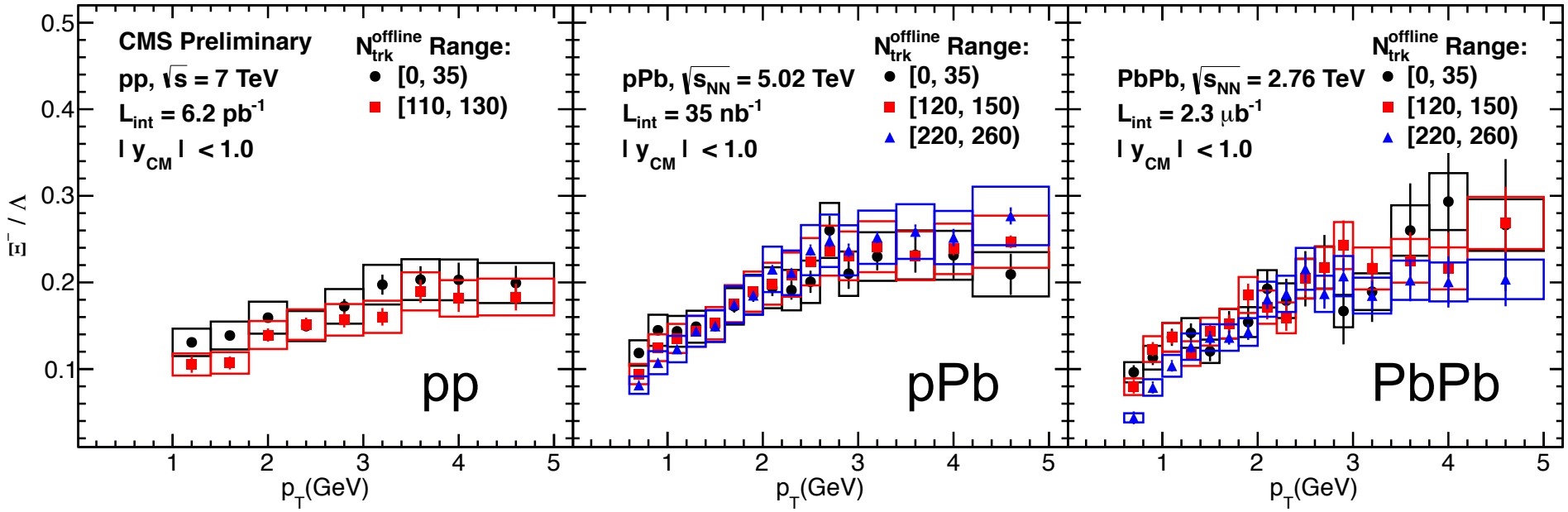


Λ / K_s Ratio



- For all multiplicity classes
  - Λ / K_s ratio reaches a maximum and then declines at higher p_T
  - Location of the maximum in p_T increases with multiplicity
- At low p_T region
  - In each system, at a given p_T, Λ / K_s ratio is smaller in higher multiplicity events
  - Difference between high and low multiplicity events is larger for smaller system

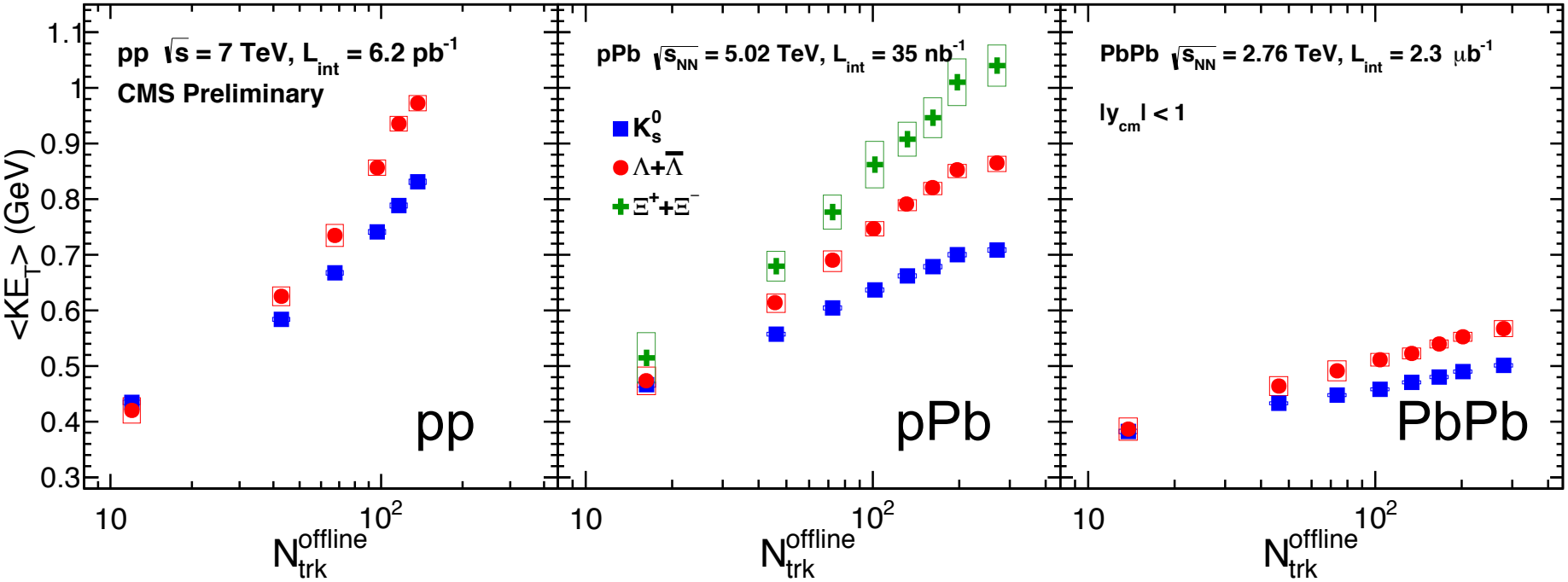
Ξ / Λ Ratio



- For all multiplicity classes
  - Ξ / Λ ratio increases with p_T and then reaches a plateau at around 3 GeV
- At low p_T region
  - Don't expect a large difference between high and low multiplicity events, because of small mass difference

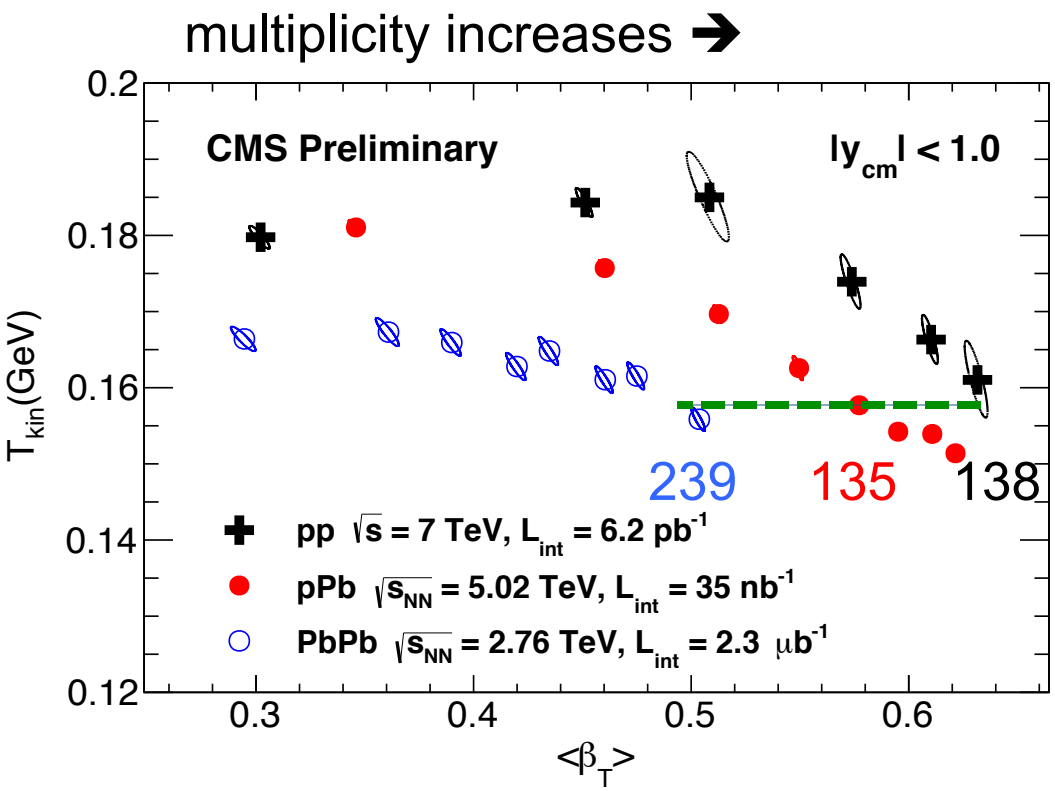
<KE$_T$> versus Multiplicity

$KE_T = m_T - m_0 = \sqrt{(p_T^2 + m_0^2)} - m_0$



- At the lowest multiplicity bin, <KE$_T$> for all particles are similar (m_T scaling)
- For all particles, <KE$_T$> increases as multiplicity increases
- For each system, <KE$_T$> of heavier particle species increases faster with multiplicity
  - In PbPb collisions, m_T-scaling breaking is the effect of radial flow.
- At similar multiplicities, larger separation for pp / pPb than PbPb

Simultaneous Blast Wave Fit



Simultaneous fit for K_s and Λ

T_{kin}:
kinetic freeze-out temperature
$\langle\beta_T\rangle$:
average radial flow velocity

Simultaneous Blast-wave model assumes:

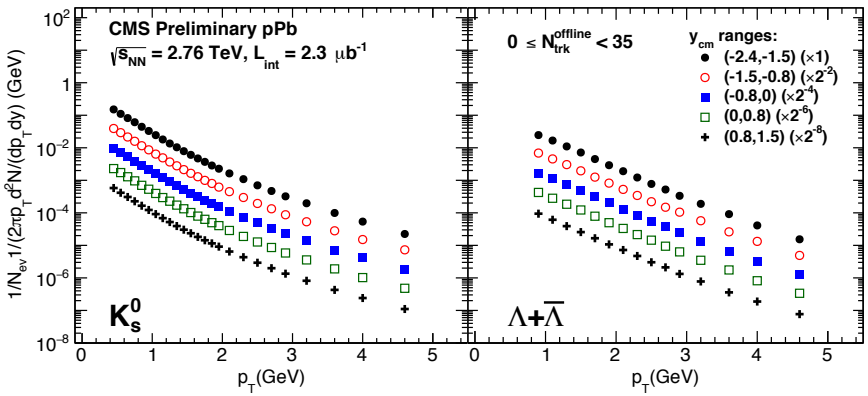
- common T_{kin}
- common $\langle\beta_T\rangle$

for all particle species

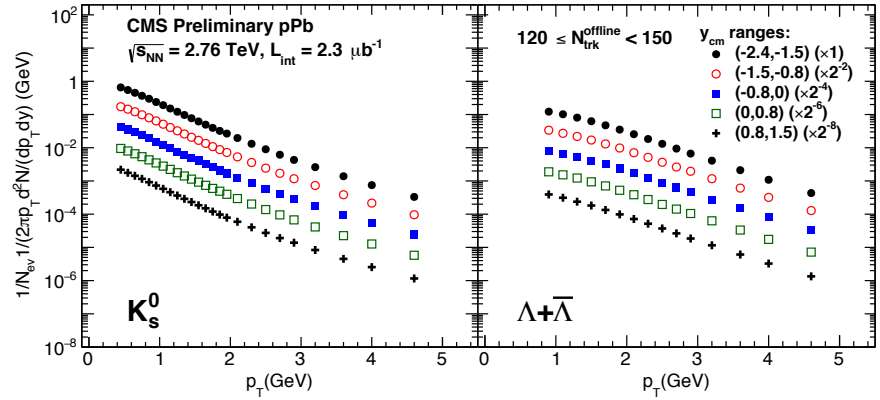
- Meaning of T_{kin} and $\langle\beta_T\rangle$ are model-dependent
- Provide a qualitative comparison of the spectra shape among three systems

Larger radial flow velocity for smaller system

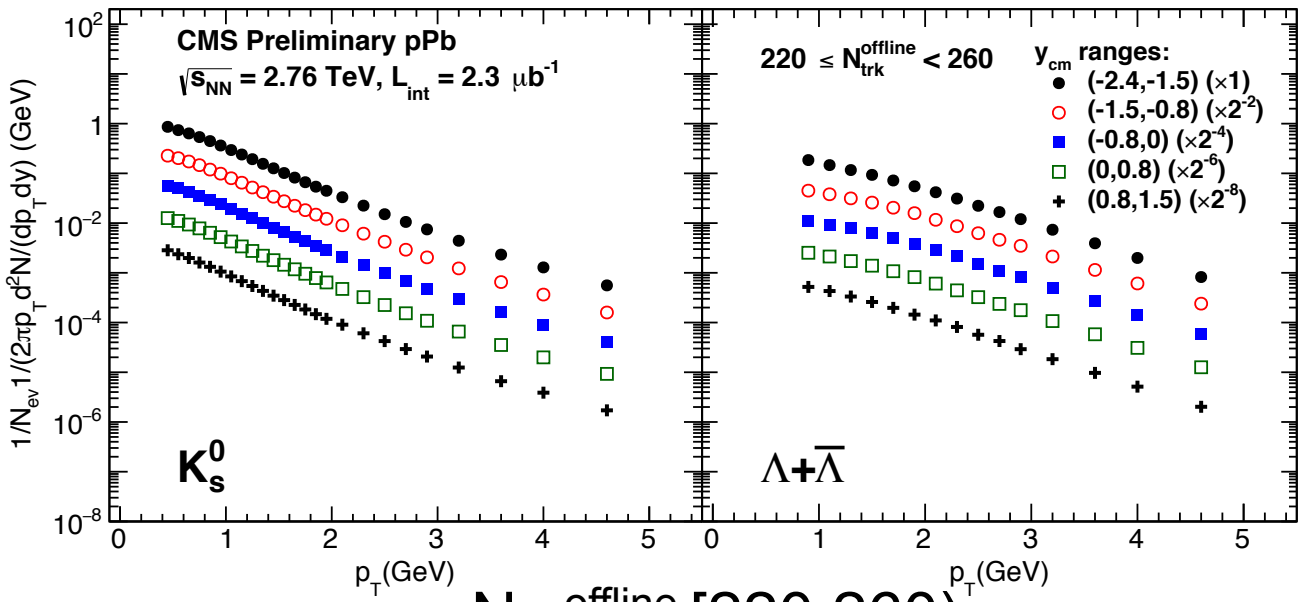
pPb Spectra in Different Rapidity Range

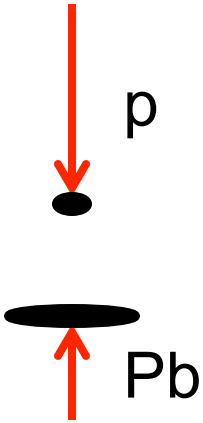


$N_{trk}^{offline}$ [0,35)



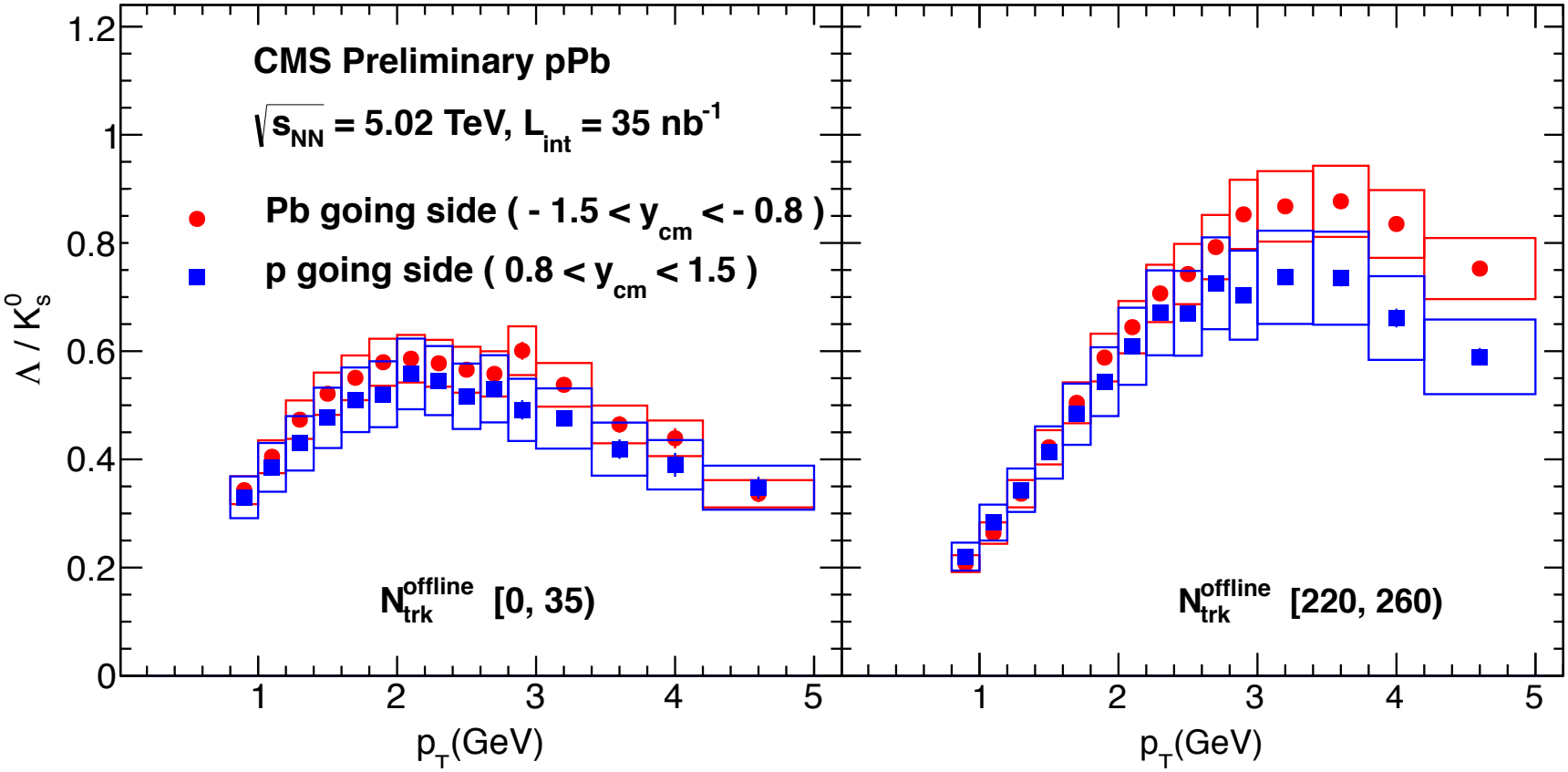
$N_{trk}^{offline}$ [120,150)





$N_{trk}^{offline}$ [220,260)

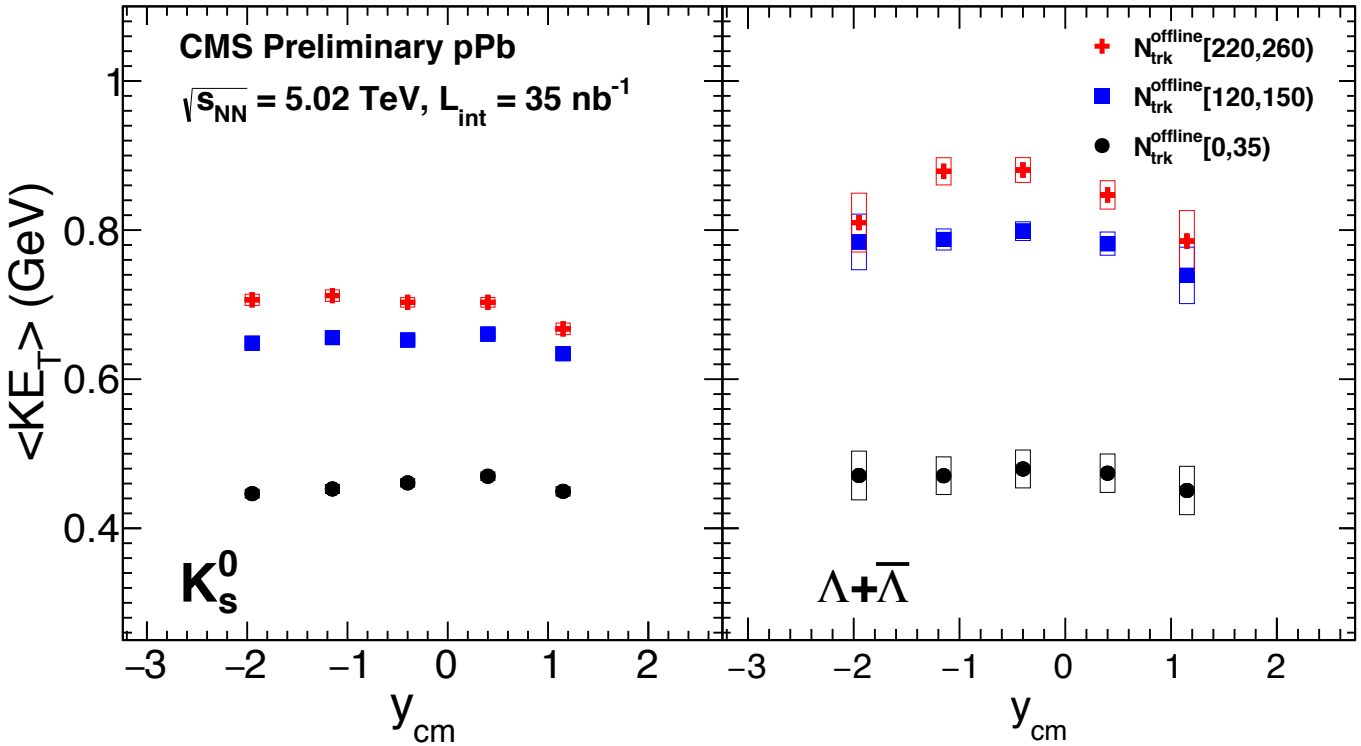
Λ / K_s Ratio in Pb-going Side versus p-going Side



Comparing Λ / K_s ratio in Pb-going side and p-going side:

- For low multiplicity events, two ratios mostly overlap within systematic uncertainties
- For high multiplicity events, ratio in Pb-going side is larger at higher p_T

$\langle KE_T \rangle$ versus y_{cm}



<KE$_T$> versus y$_{cm}$

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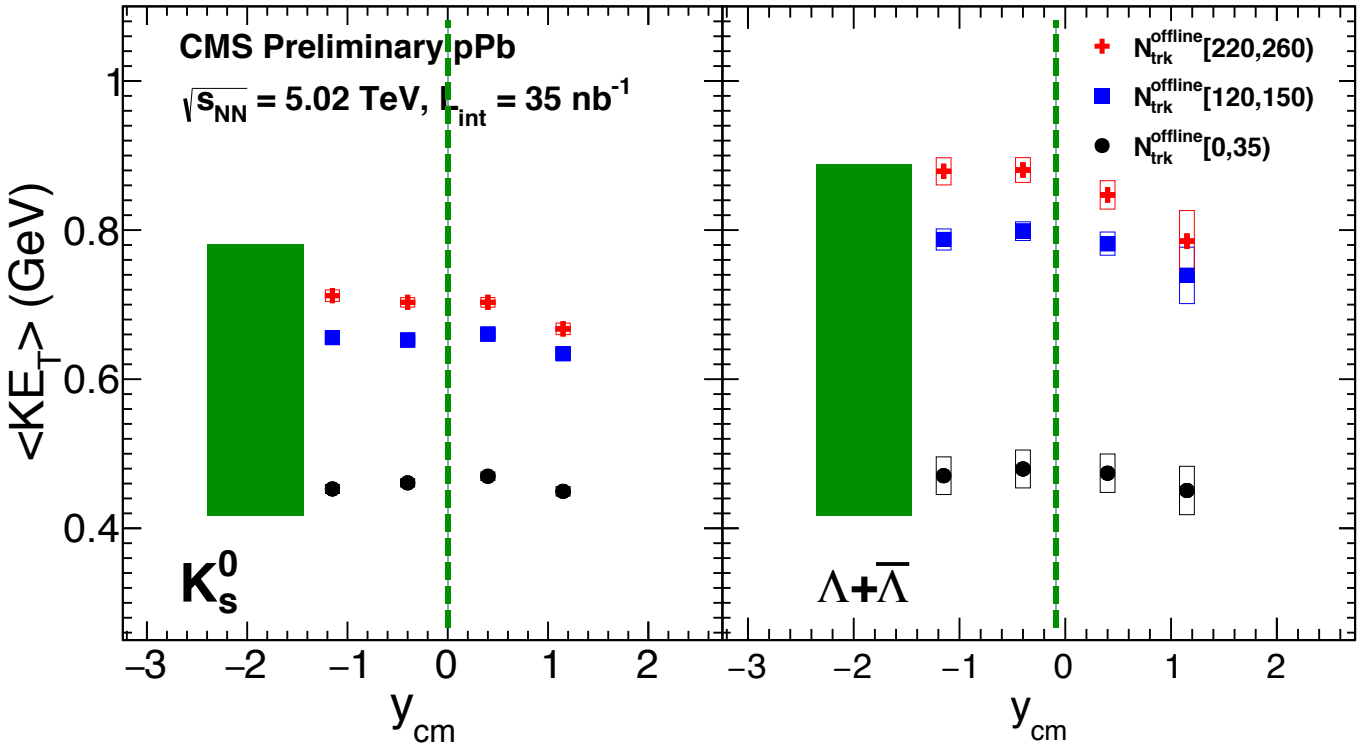
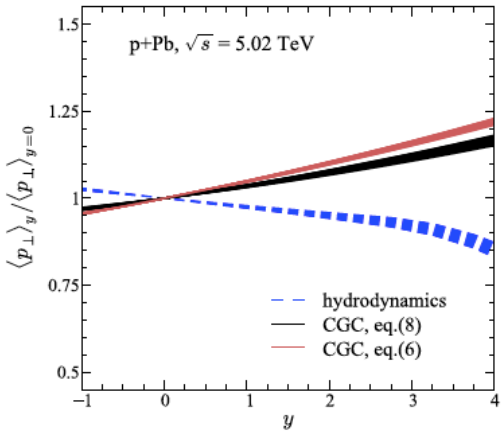




Comparing <KE$_T$> in Pb-going side and p-going side:

- Asymmetry develops as event multiplicity increases(Pb-going side larger)
- Trend of asymmetry is more evident for heavier particle species

The trend of data is similar as hydrodynamic model predicted.

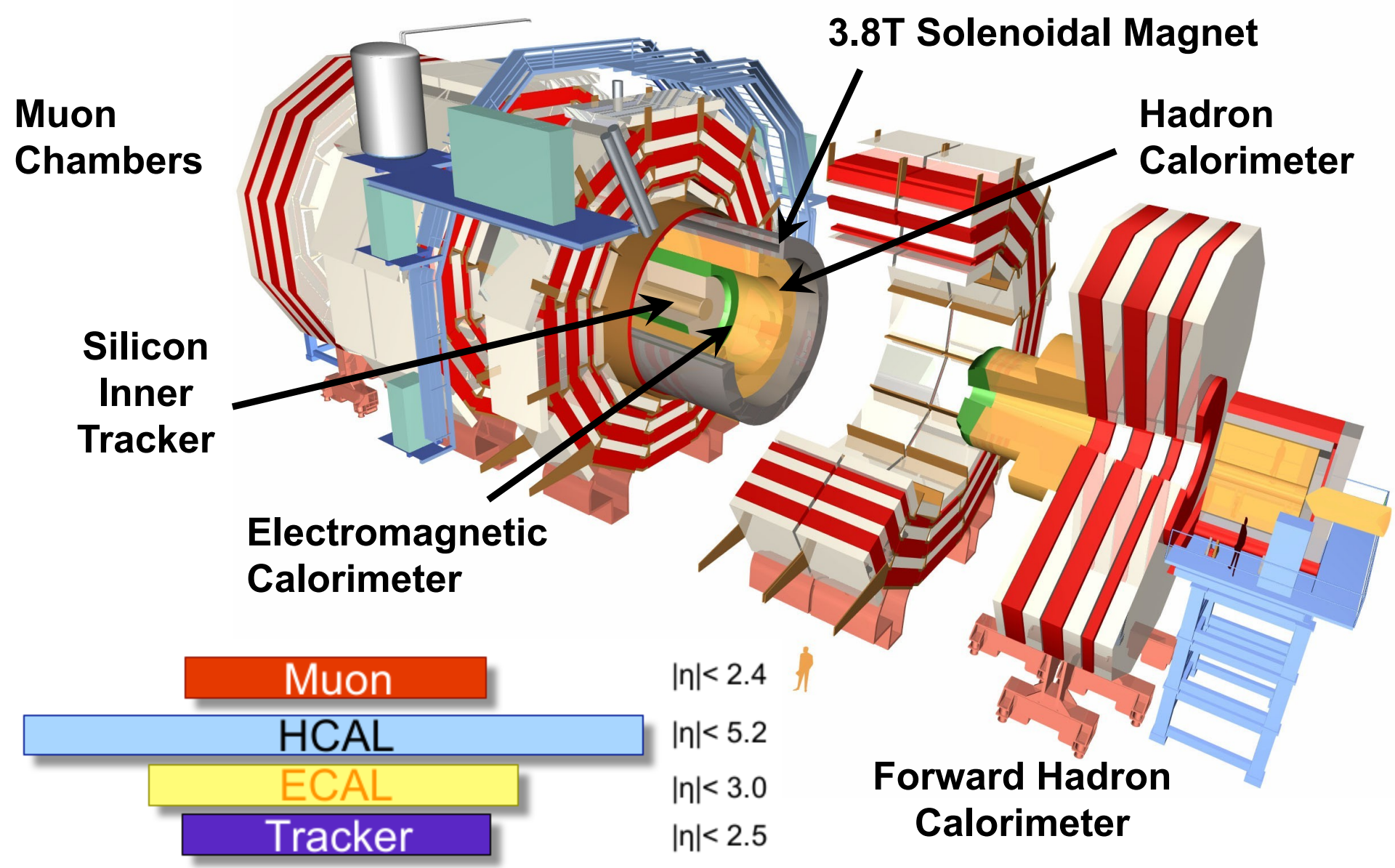
Summary

- K_s, Λ, and Ξ spectra are measured in three systems with high precision
- At similar multiplicities, particle ratios at low p_T show a larger difference between high- and low-multiplicity events in smaller system
- At similar multiplicities, "m_T-scaling" breaking is more significant for smaller system
- $\langle KE_T \rangle$ asymmetry develops as multiplicity increases, with a larger value at Pb-going side, especially for heavier particles

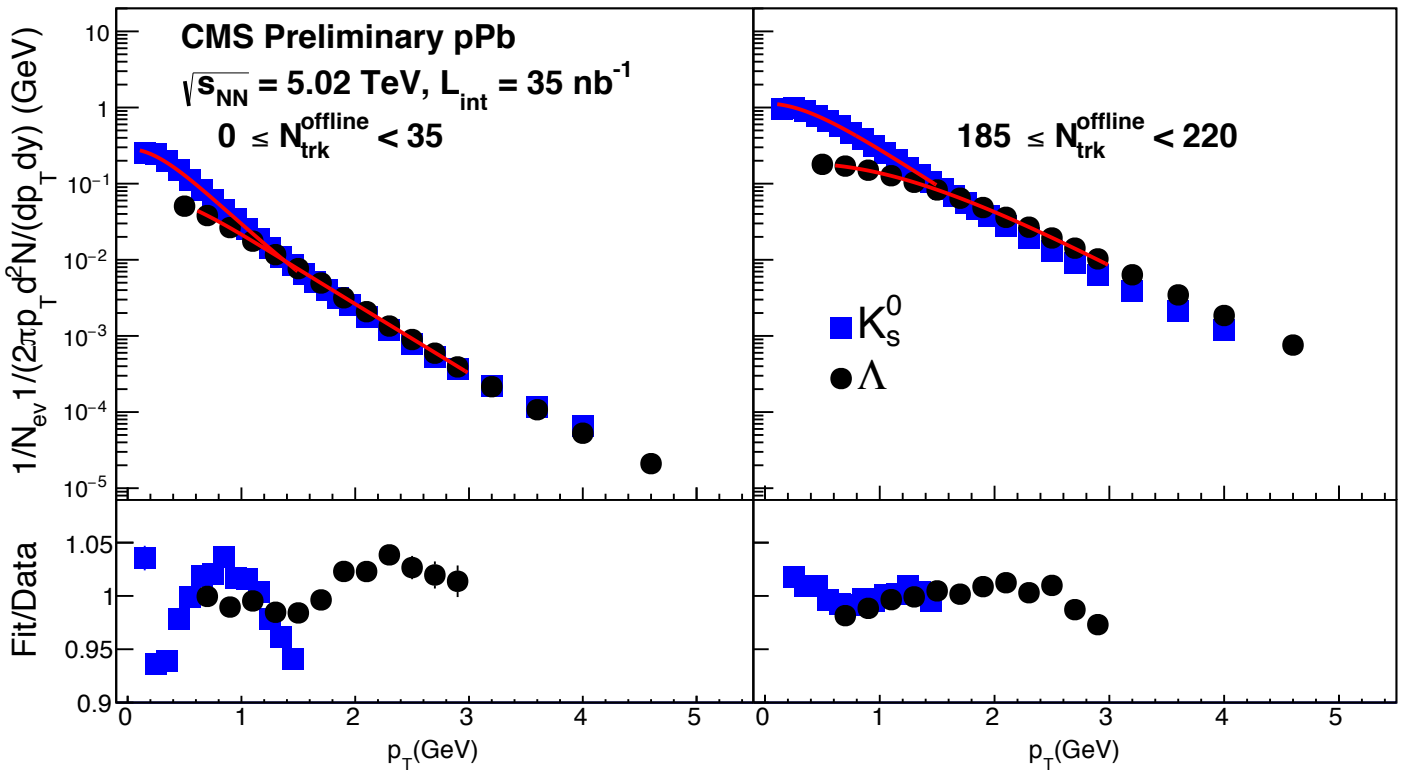
See Poster #0214
by Zhoudunming(Kong) Tu

Extra Slides

CMS Detector



Blast Wave Fit Quality



- Fit quality is good at high multiplicity events
- Fit quality is not so good at low multiplicity events (No “radial” flow effect)

Fitting Range:

K_s(0.1 to 1.5 GeV/c), Λ(0.6 to 3 GeV/c)

Simultaneous Blast Wave Fit with PYTHIA8