

Nuclear modification factors of strange and multi-strange particles in pPb collisions with the CMS experiment



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for the CMS Collaboration



VANDERBILT
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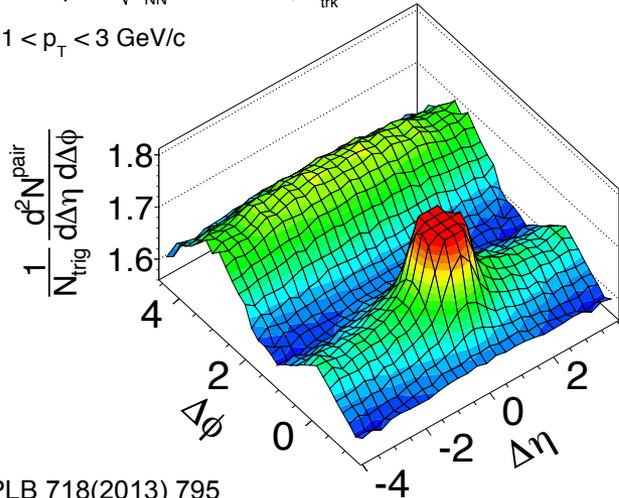
34th WWND, Guadeloupe

27th March, 2018



Motivation

CMS pPb $\sqrt{s_{NN}} = 5.02$ TeV, $N_{trk}^{offline} \geq 110$
 $1 < p_T < 3$ GeV/c

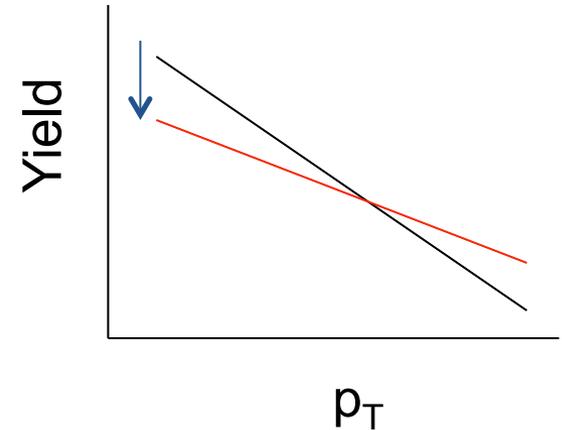


(b)

radial flow driven by
pressure gradient?



if yes, flattened spectra,
mass effect can be seen



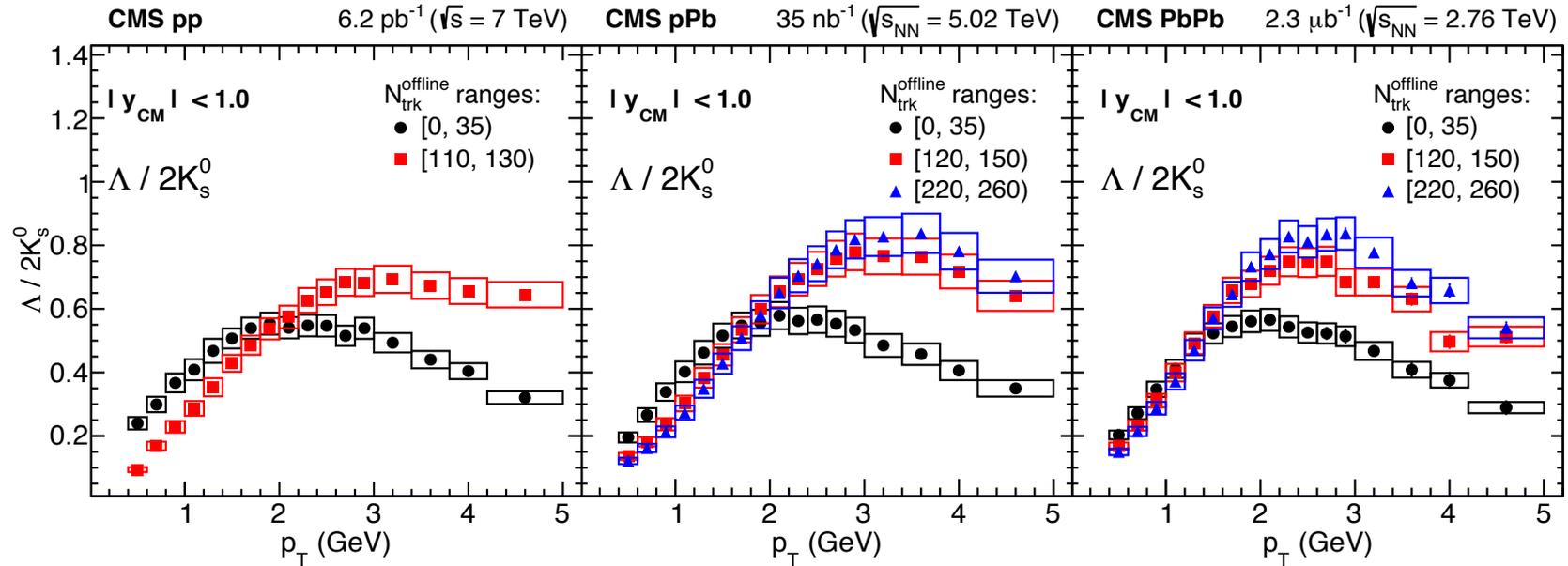
PLB 718(2013) 795

- Two particle correlations show “Ridge” structure in pA
- “Ridge” indicates collective effects may be present in small systems.
 - The nature of the “ridge” is still under intense debate.
- If radial flow \rightarrow flattened spectra \rightarrow dependence on the mass of hadrons

Motivation

PLB 768(2017) 103

Spectra ratios



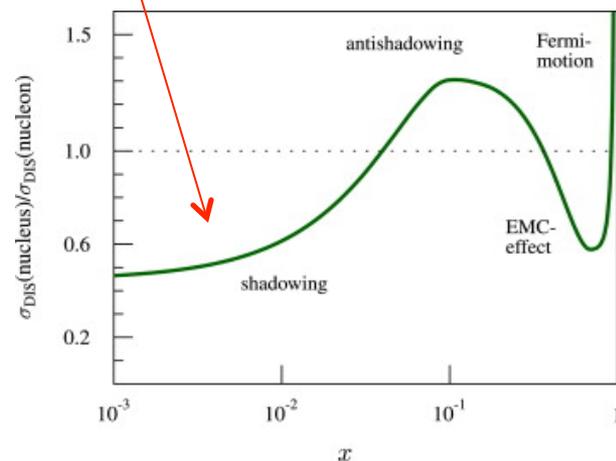
- Mass dependence in the strange particle spectra has been seen in CMS.
- What about strange particle spectra at higher p_T ?

Physics processes reflected in spectral shapes

What can modify particle spectra, besides radial flow?

- Radial flow
 - mass ordering
 - larger radial flow effect at Pb-going direction ✓ PLB 768(2017) 103
- Hadronization by quark recombination
 - dependence on number of valence quarks
- Shadowing in nPDF ($x < 0.02$ for this analysis)
 - larger R_{pA} at Pb-going side
 - $Y_{asym} > 1$
 - larger Y_{asym} at forward rapidities
- “Cronin” effect / multiple parton scattering
 - larger R_{pA} at p-going side
 - transverse momentum broadening of the initial partons inside the projectile

nPDF for DIS on a nucleus with A nucleons is smaller than the incoherent sum of the nucleon $A \cdot \text{PDF}$.



Observables

$$R_{AB}(p_T) = \frac{d^2N^{AB}/dp_T dy_{CM}}{\langle N_{coll} \rangle d^2N^{PP}/dp_T dy_{CM}}$$

$$Y_{asym}(p_T) = \frac{d^2N(p_T)/dy_{CM} dp_T|_{y_{CM} \in [-b, -a]}}{d^2N(p_T)/dy_{CM} dp_T|_{y_{CM} \in [a, b]}}$$

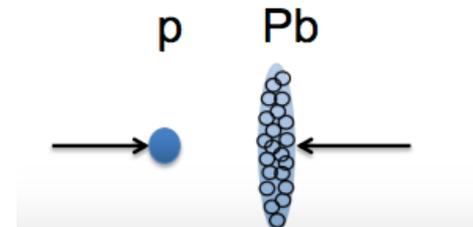
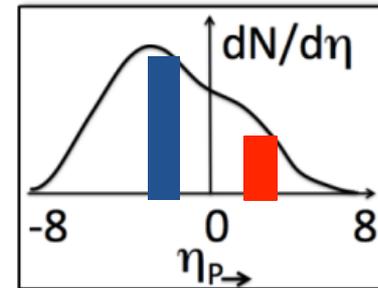
R_{pPb} will be unity, if pPb collision is just superposition of pp collision.

$$Y_{asym} = \frac{\text{Yield Pb-going}}{\text{Yield p-going}}$$

x : fractional momentum from a colliding nucleon carried by the parton

larger x at Pb-going side, smaller x at p-going side

With R_{pPb} and Y_{asym} , different x can be accessed.

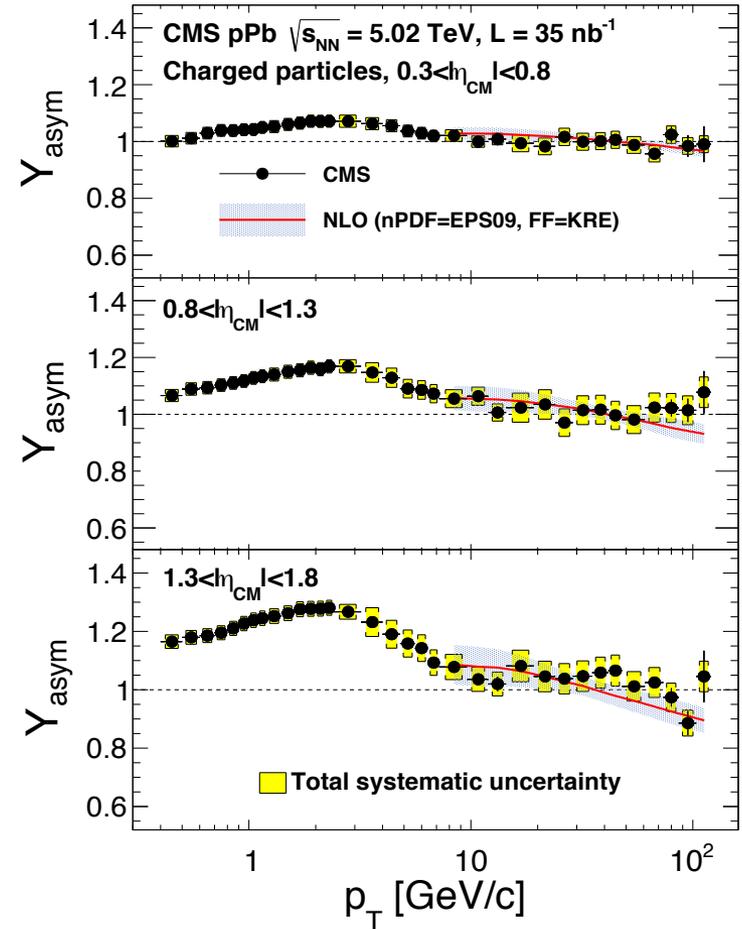
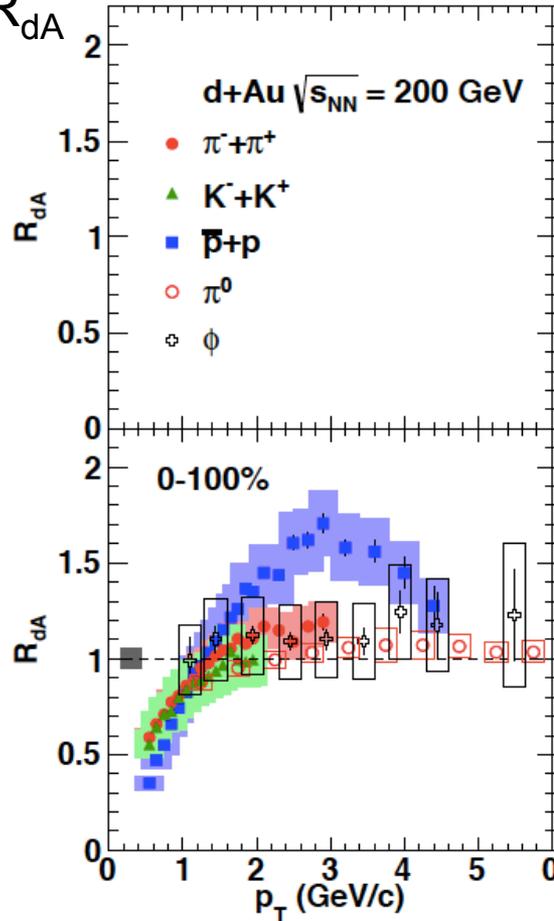


Previous measurements

PRC 88, 024906(2013)

EPJC 75 (2015) 237

PHENIX R_{dA}



- PHENIX R_{dA} : dependence of number of valence quarks(Recombination?)
- CMS charged hadron Y_{asym} : shadowing in nPDF larger at forward η_{cm} .
- What about identified strange particles in CMS?

K_s , Λ^0 , Ξ^- , and Ω^- reconstruction

Decay Channel:

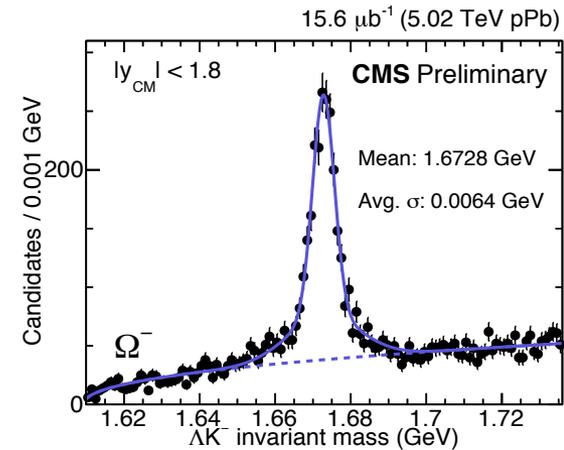
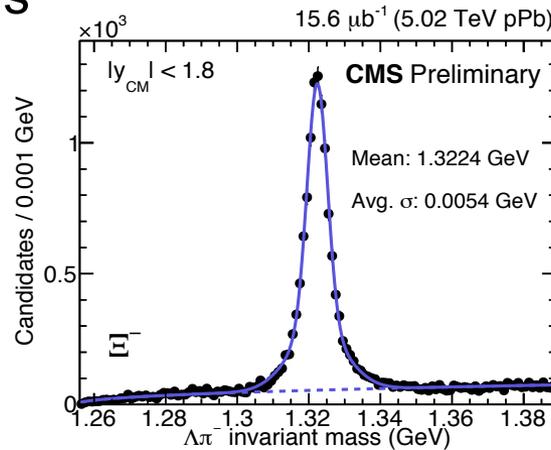
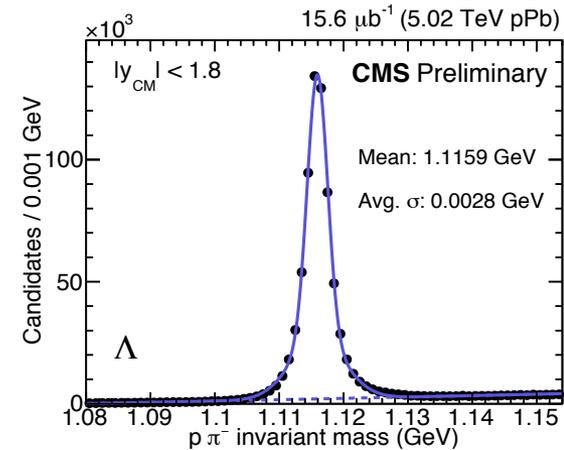
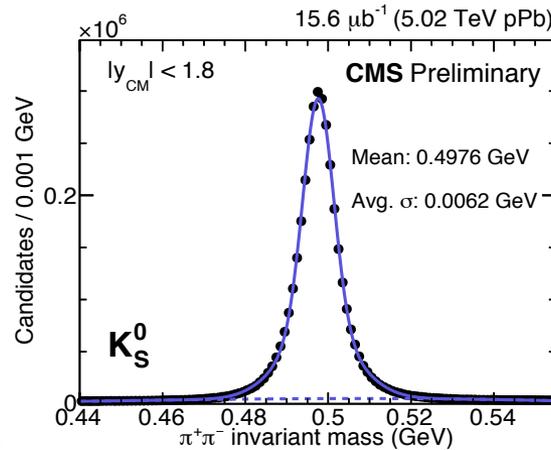


V^0

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

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

Invariant mass peaks



CMS PAS HIN-16-013

*particle-conjugate states are included throughout this analysis

Signal: double gaussian with a common mean

Background:

2nd order polynomial for K_S

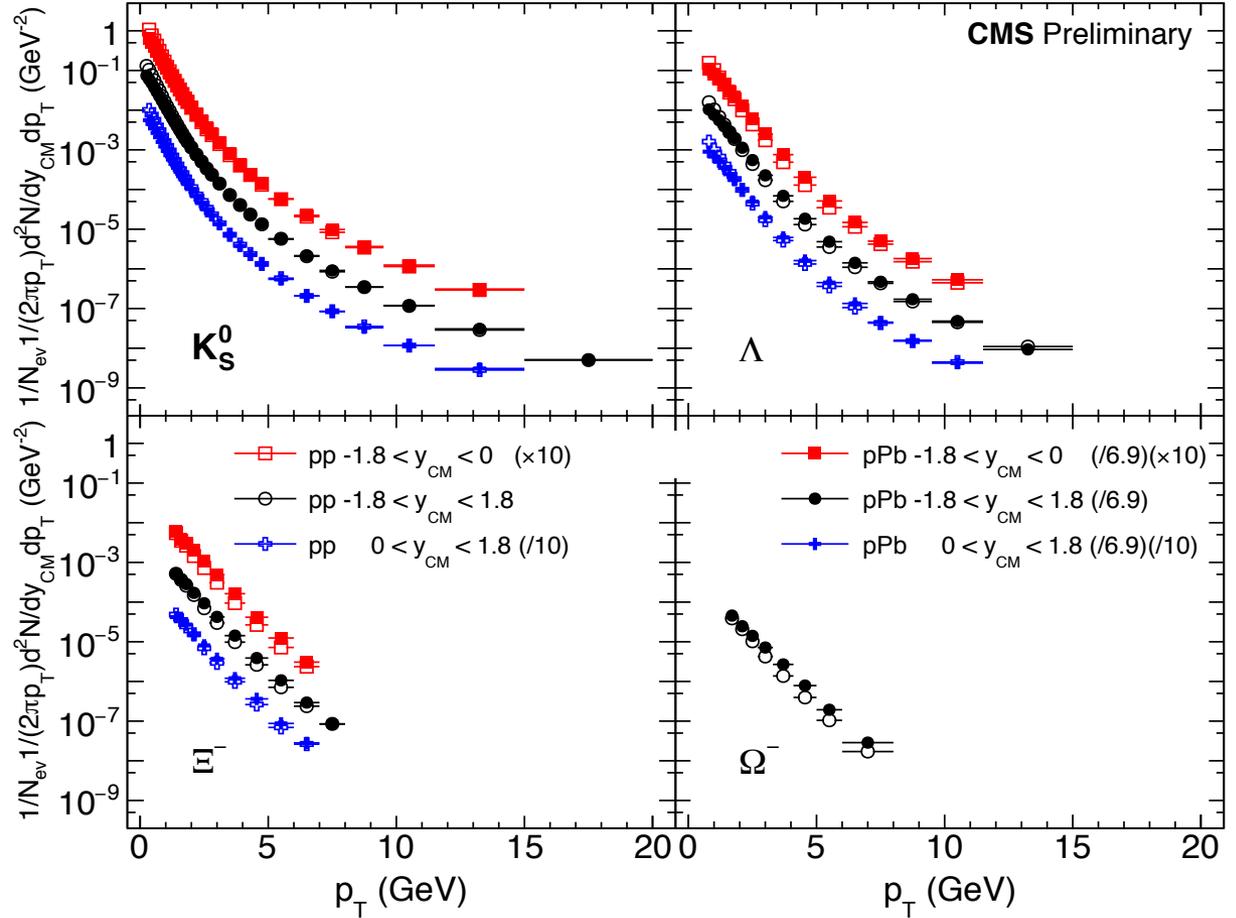
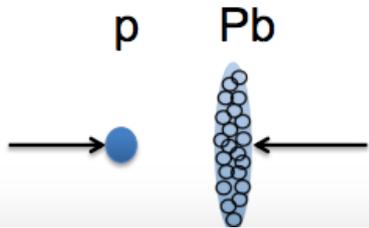
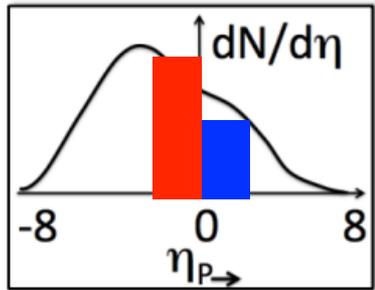
Aq^B for baryons, where $q = m_{\text{mother}} - (m_{\text{dau1}} + m_{\text{dau2}})$

R_{pA}

Spectra

CMS PAS HIN-16-013

40.2 nb⁻¹ (5.02 TeV pp), 15.6 μb⁻¹ (5.02 TeV pPb)

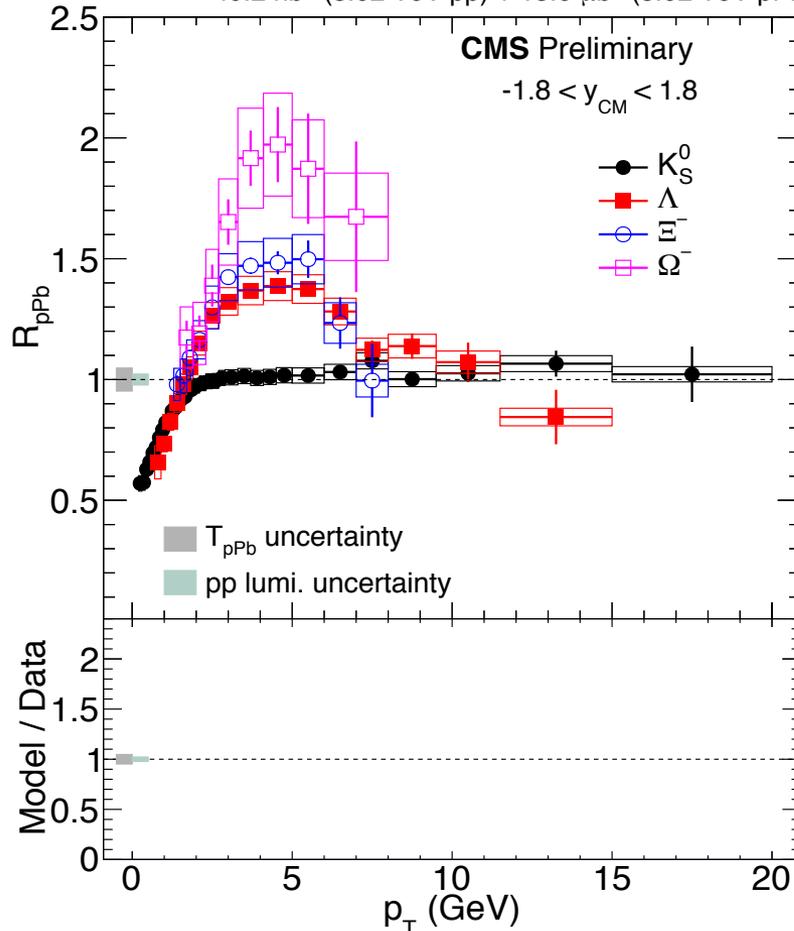


pPb spectra are divided by $\langle N_{coll} \rangle = 6.9$ from Glauber Model.

R_{pA} for $y_{CM} [-1.8, 1.8]$

CMS PAS HIN-16-013

40.2 nb⁻¹ (5.02 TeV pp) + 15.6 μb⁻¹ (5.02 TeV pPb)



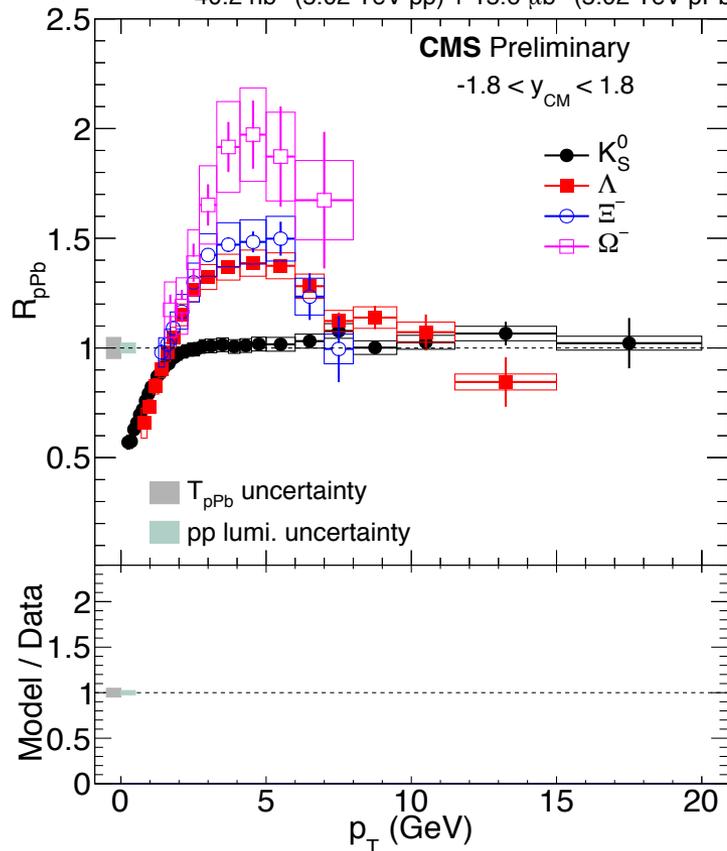
$$R_{AB}(p_T) = \frac{d^2N^{AB}/dp_T dy_{CM}}{\langle N_{coll} \rangle d^2N^{PP}/dp_T dy_{CM}}$$

- R_{pPb} of K_S is around unity for $p_T > 3\text{GeV}$
- Significant enhancement at intermediate p_T ordered by particle mass
- Mass dependence disappears at higher p_T

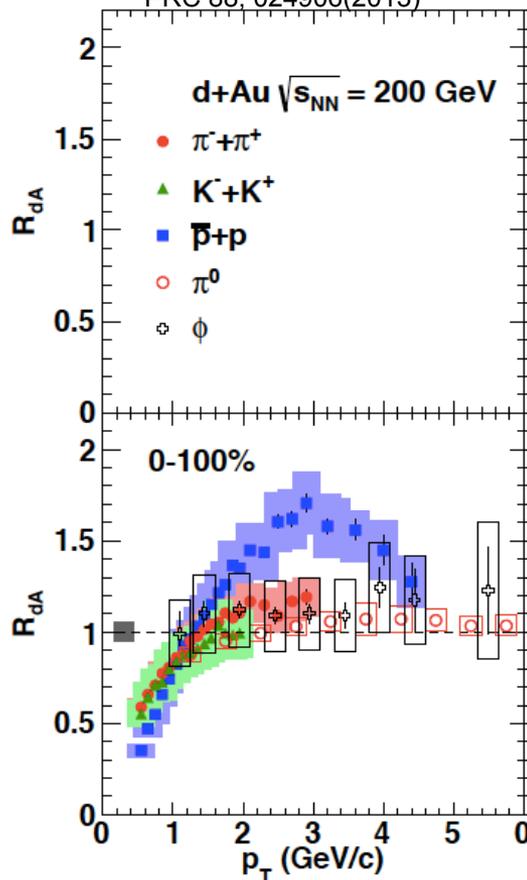
R_{pA} for $y_{CM} [-1.8, 1.8]$

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PRC 88, 024906(2013)

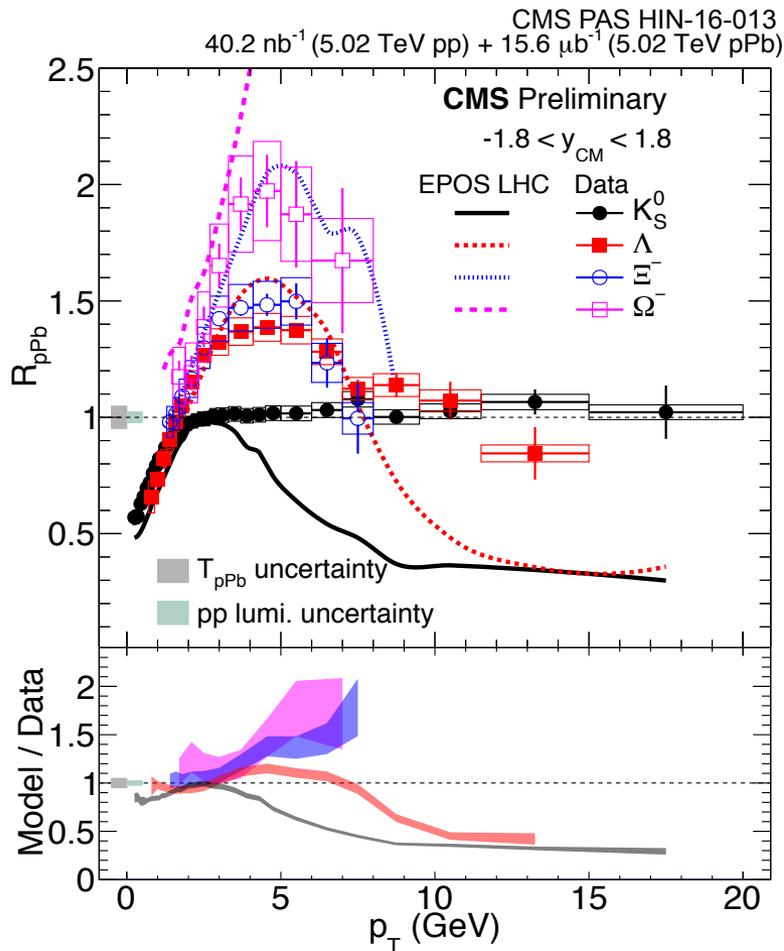


$M_{\text{proton}} \sim$
938.272 MeV

$M_{\phi} \sim$
1019.445 MeV

- Mass ordering of identified strange particle in CMS
- $M_{\text{proton}} \sim 938.272$ MeV, $M_{\phi} \sim 1019.445$ MeV, but $R_{dA}(\text{proton}) > R_{dA}(\phi)$
- These suggest both radial flow effect and recombination play a role

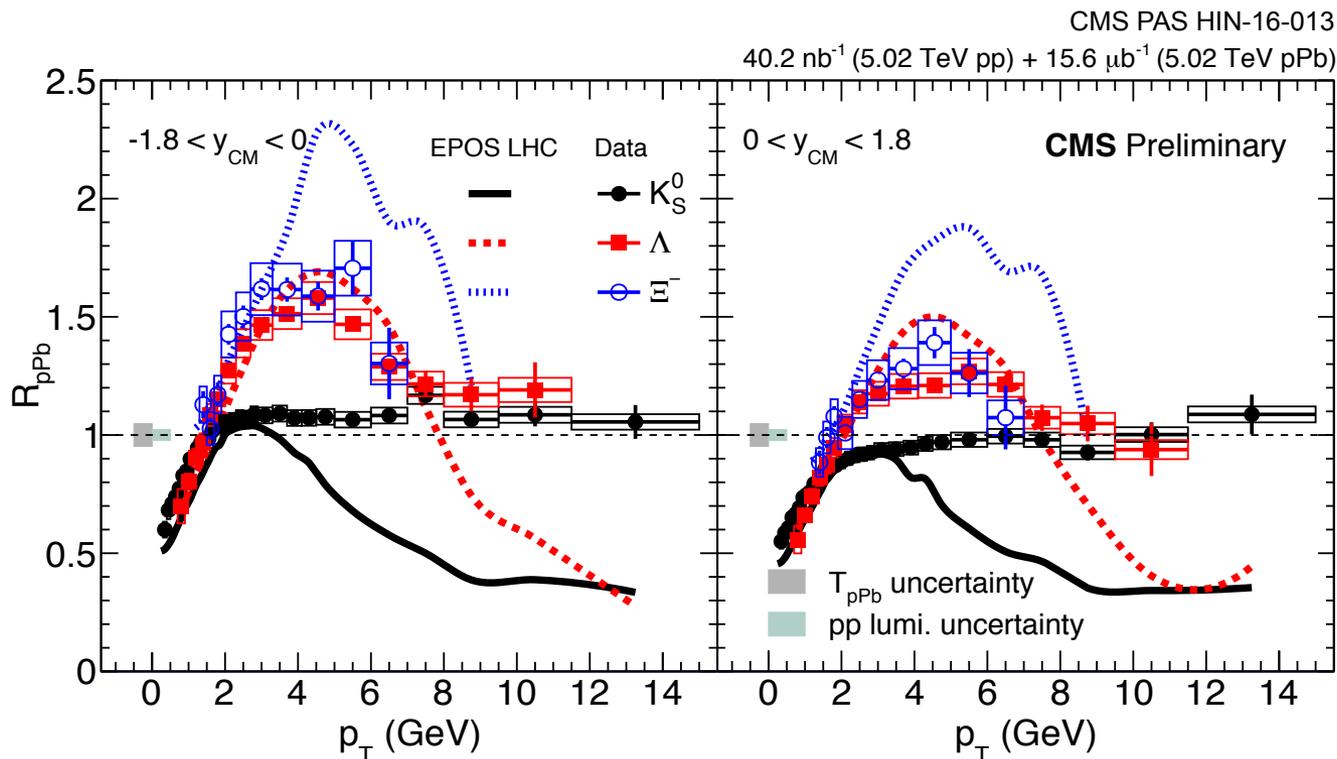
R_{pA} for $y_{CM} [-1.8, 1.8]$



- Comparison with EPOS LHC, which includes parametrized flow, is shown
- EPOS LHC prediction agrees with data up to 3 GeV.
- Data show less mass dependence than EPOS LHC

R_{pA} for $y_{CM} [-1.8,0]$ and $[0,1.8]$

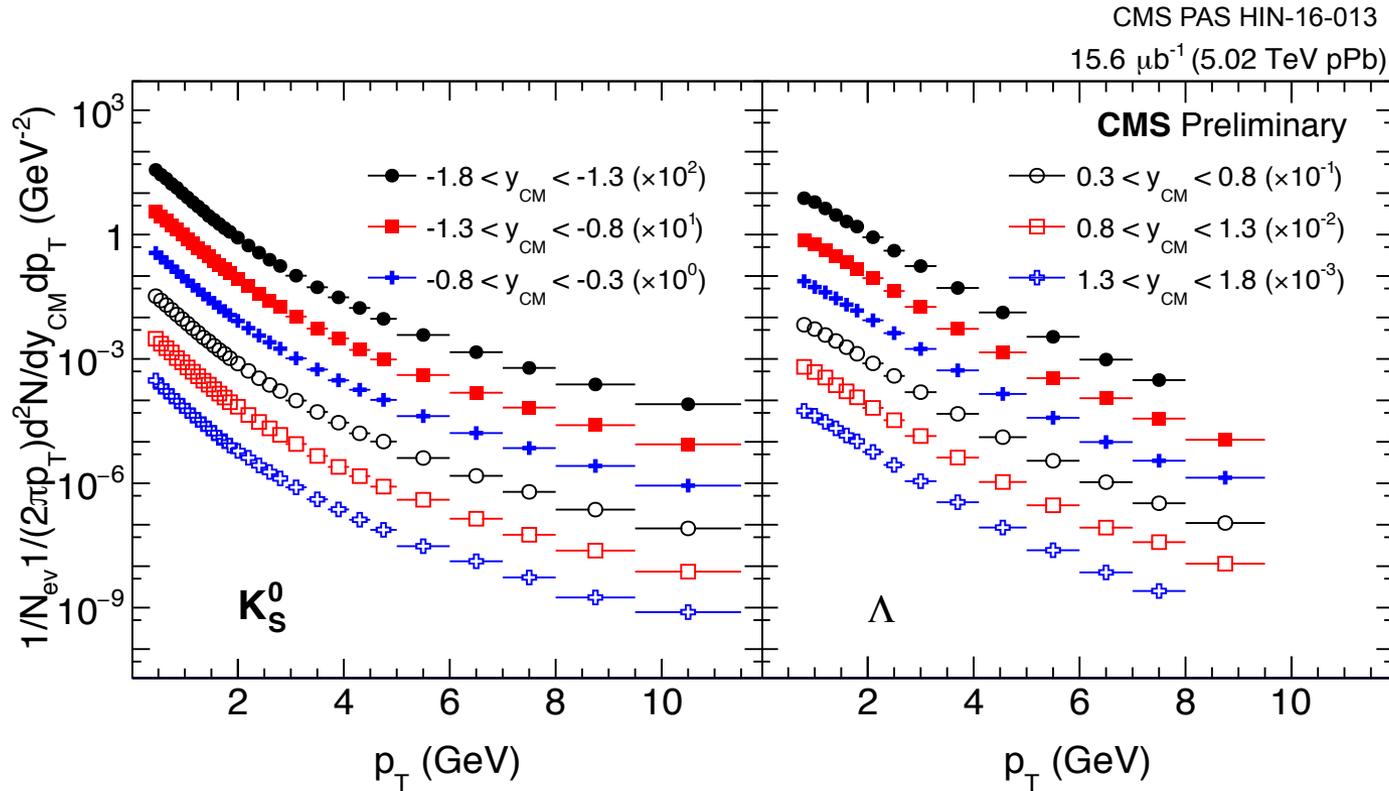
Pb-going



- R_{pA} in Pb-going direction is larger than p-going direction
- Radial flow ✓
- Shadowing in nPDF ✓
- “Cronin” effect / multiple parton scattering ✗
- EPOS LHC predicts that R_{pA} is larger on the Pb-going side, but overpredicts the mass dependence

Y_{asym}

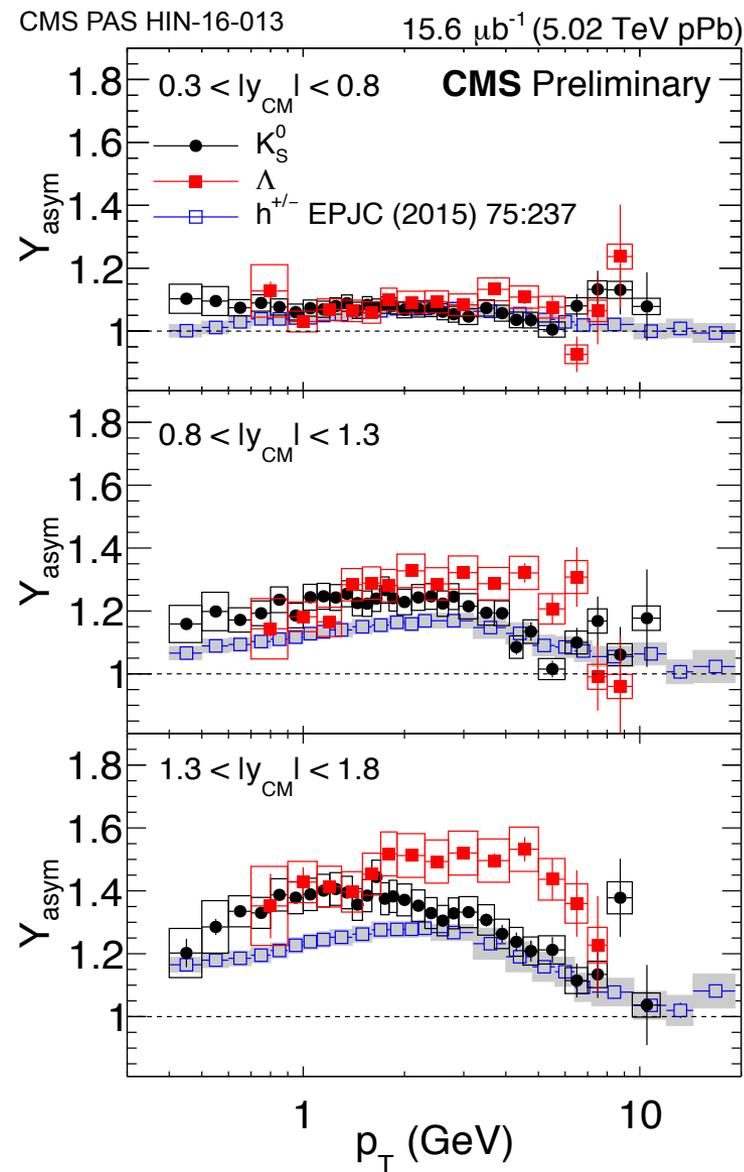
Rapidity dependence of spectra



Thanks to the large acceptance of CMS, we can measure V^0 s spectra in several different center of mass rapidity ranges.

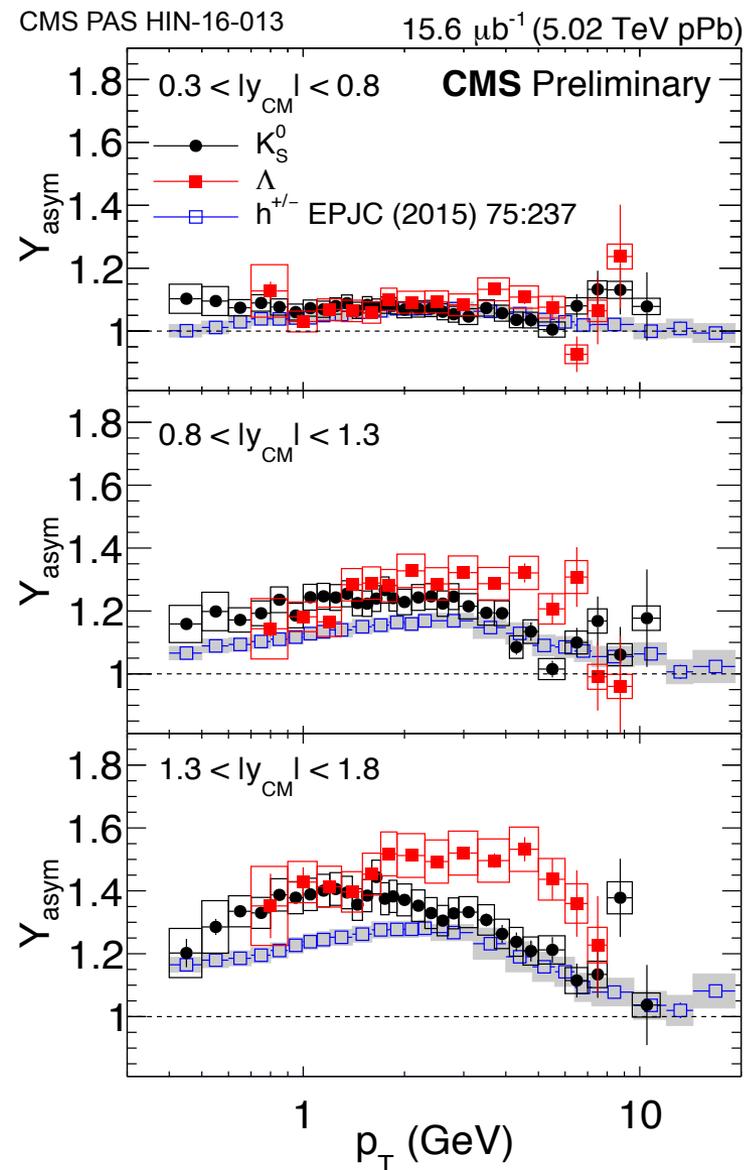
Y_{asym} of V^0 compared to charged particles

- $Y_{\text{asym}} > 1$ for all rapidity bins
- Consistent with radial flow effect and shadowing effect.



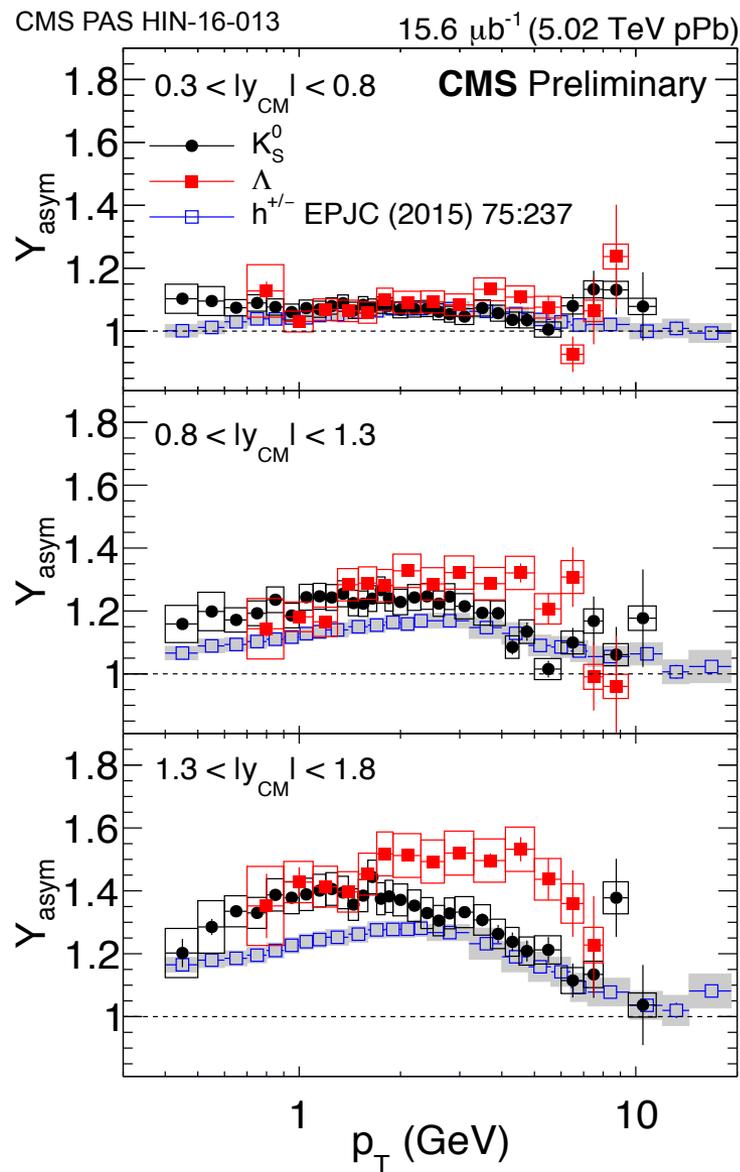
Y_{asym} of V^0 compared to charged particles

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- Y_{asym} of charged particles and V^0 s don't show much difference in $[0.3, 0.8]$



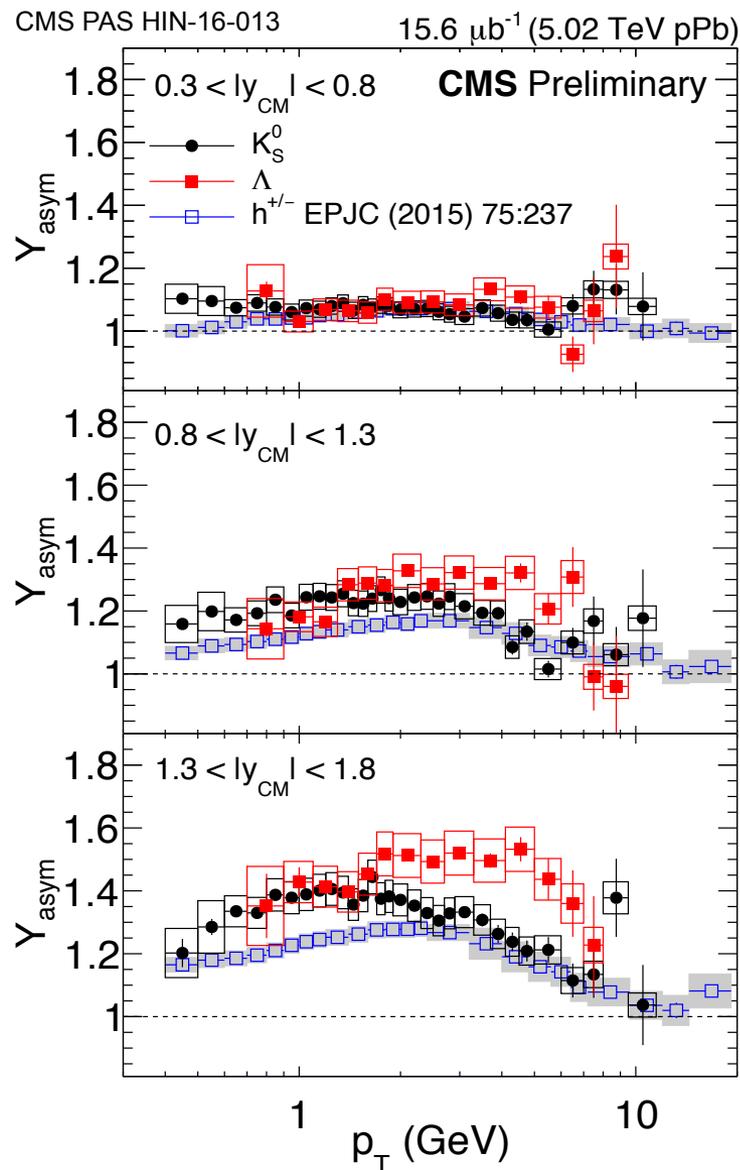
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- Y_{asym} of charged particles and V^0 s don't show much difference in $[0.3, 0.8]$
- In forward rapidity bins, peak value: $h^{+/-} < K_S < \Lambda$



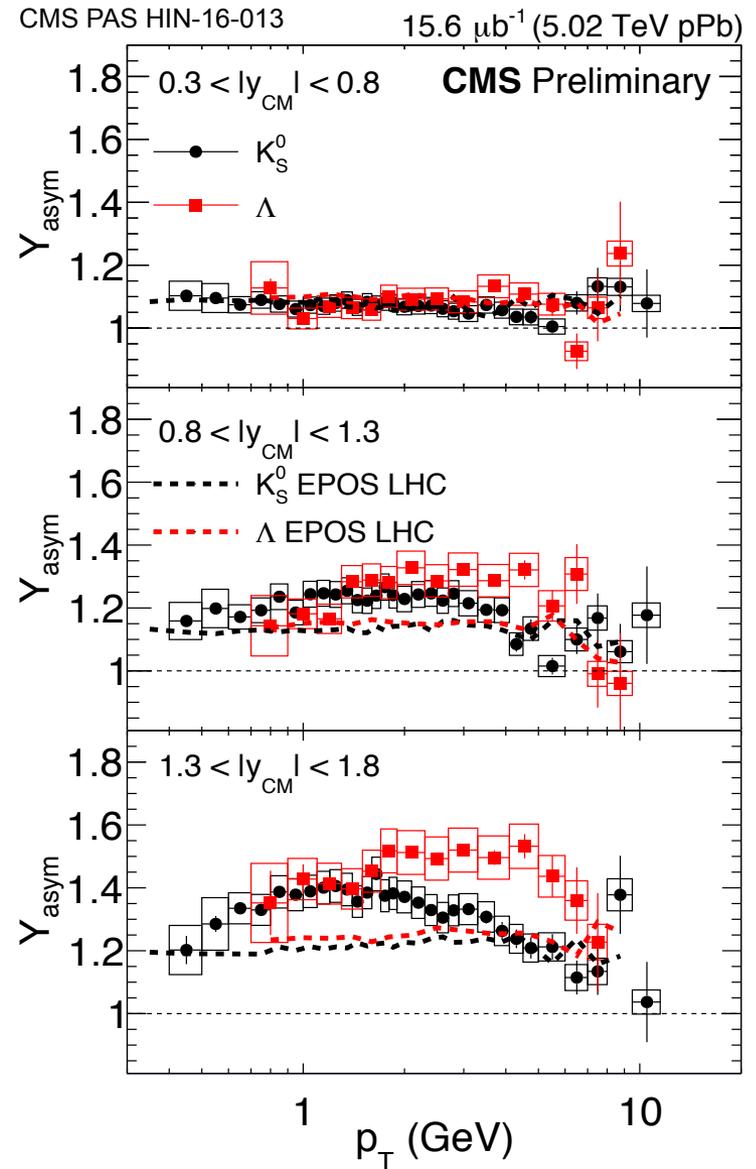
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- In forward rapidity bins, peak position: $K_S < h^{+/-} < \Lambda$



Y_{asym} of V^0 compared to charged particles

- Y_{asym} of V^0 calculated from EPOS LHC increase from mid-rapidity to forward rapidity. This trend is consistent with data
- However, EPOS LHC doesn't show much particle-species dependence.
- It would be very useful to see predictions from other models.



Summary

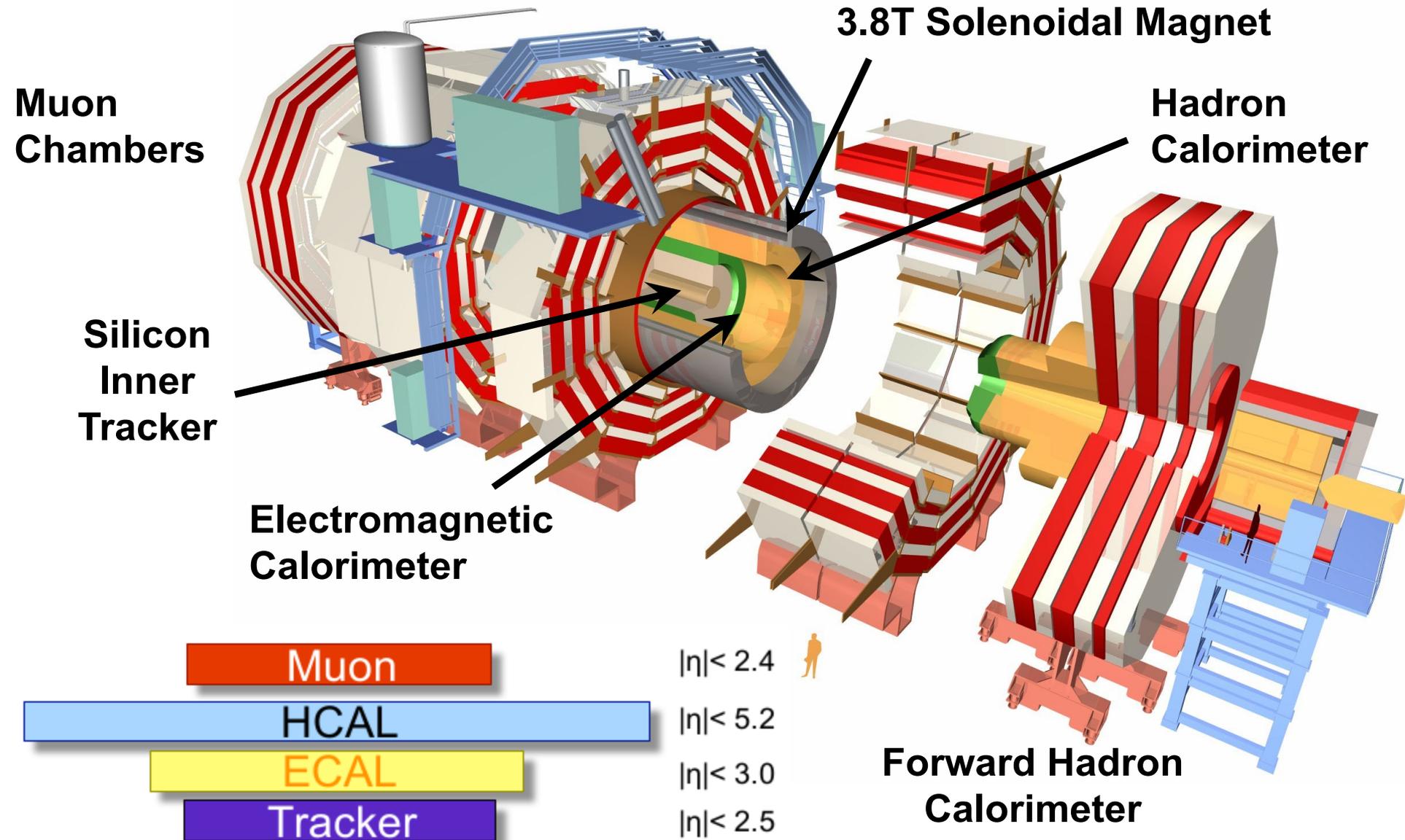
- Spectra of identified strange and multi-strange particles in several center of mass rapidity bins are measured in 5TeV pp and pPb with CMS.
- R_{pA} and R_{dA} from LHC and RHIC suggest that both radial flow and recombination play a role in particle production
- Larger R_{pA} at Pb-going side is consistent with radial flow and shadowing
- Y_{asym} of V^0 s are compared with charged hadrons.
 - In forward rapidity bins, peak value: $h^{+/-} < K_S < \Lambda$
 - In forward rapidity bins, peak position: $K_S < h^{+/-} < \Lambda$

Thank you!

Extra Slides



CMS Detector



Extra Slides

