Probing novel long-range correlation phenomena in pPb collisions with identified particles at CMS

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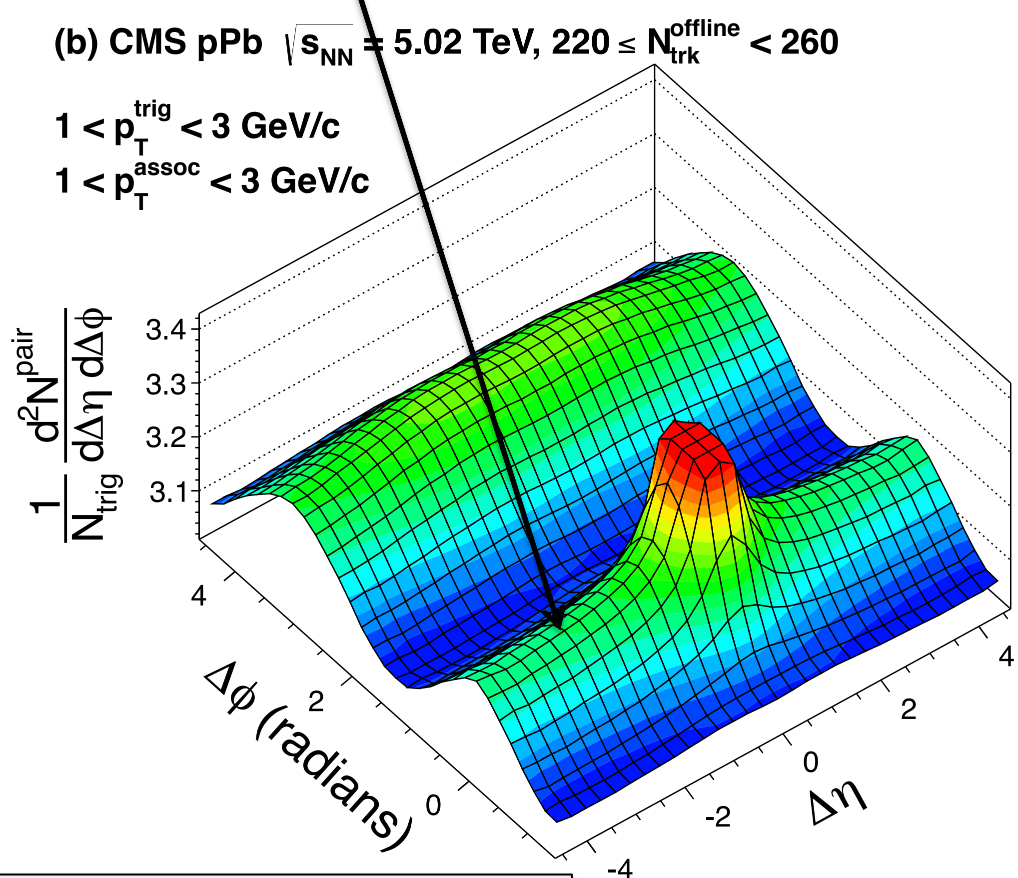
for the CMS Collaboration

Hot Quarks Workshop 2014

Discovery of long range “ridge” in pPb

Near side long range “ridge”, $\Delta\phi \sim 0$



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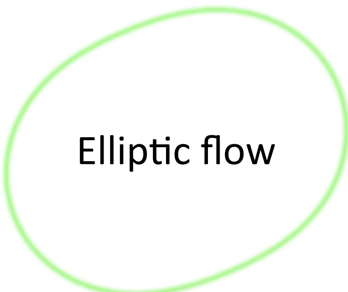
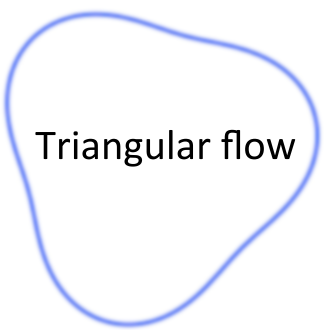
Long range rapidity correlations seen in AA collisions and only in high multiplicity pp and pPb collisions

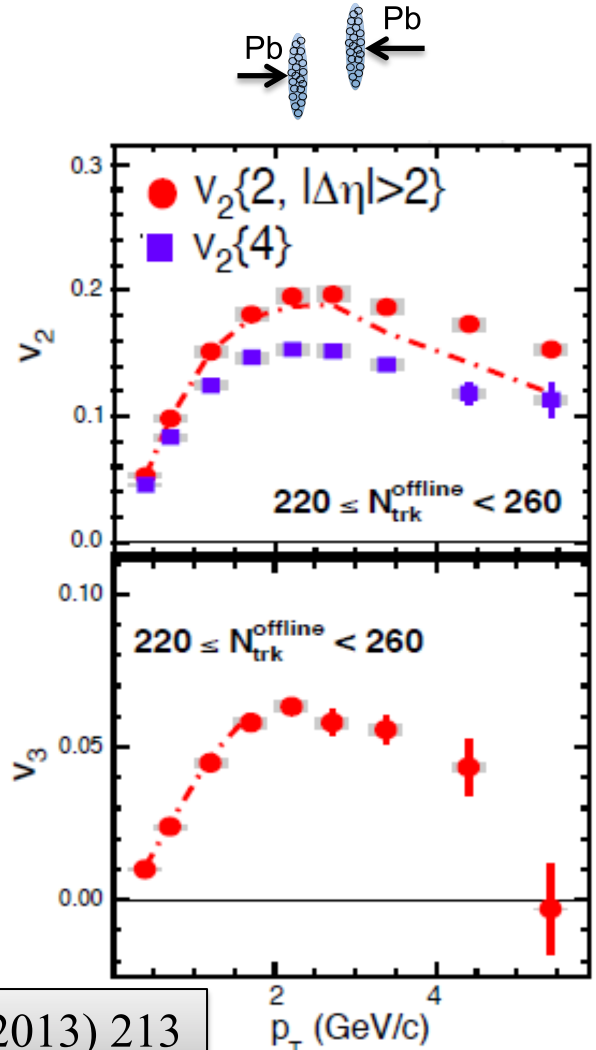
What could we learn from latest pPb run?

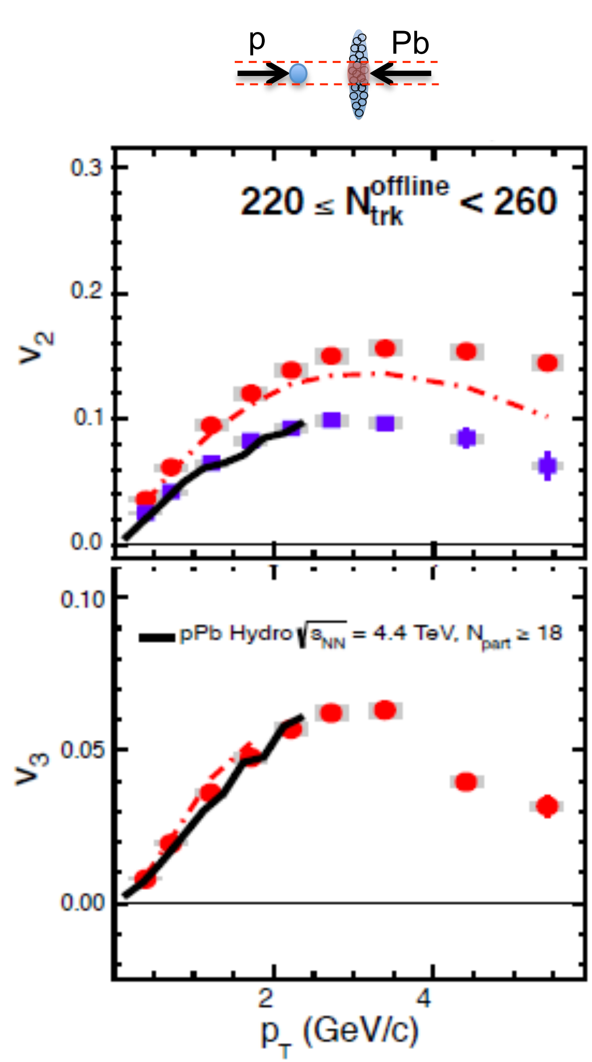
- In AA collisions, long range correlations arise from collective flow
- Are these correlations in pPb also related to hydrodynamic flow as in PbPb?

Similarity between pPb and PbPb collisions









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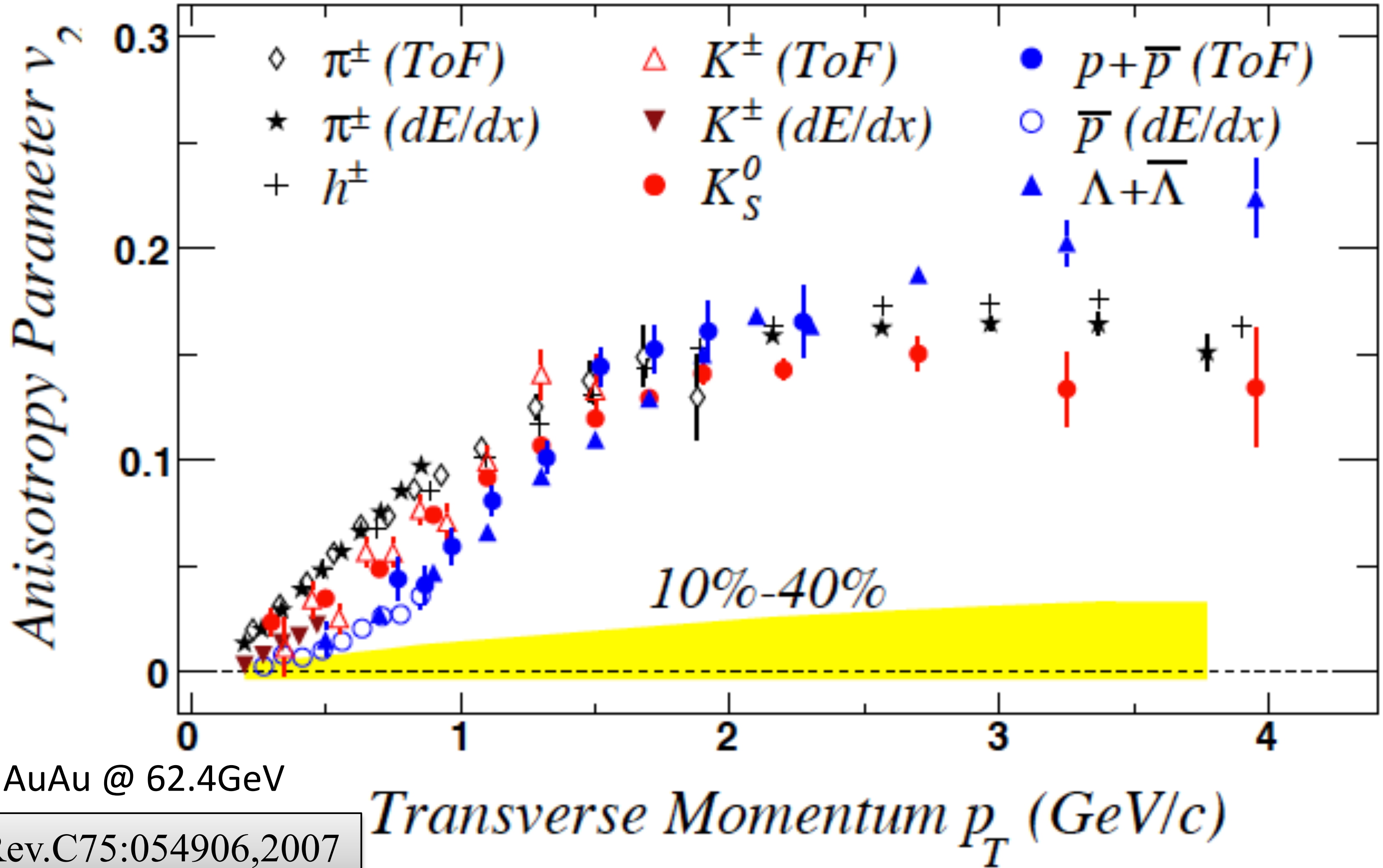
Remarkable similarities in pPb and PbPb for same multiplicities

Identified particle v_2 in AA collisions

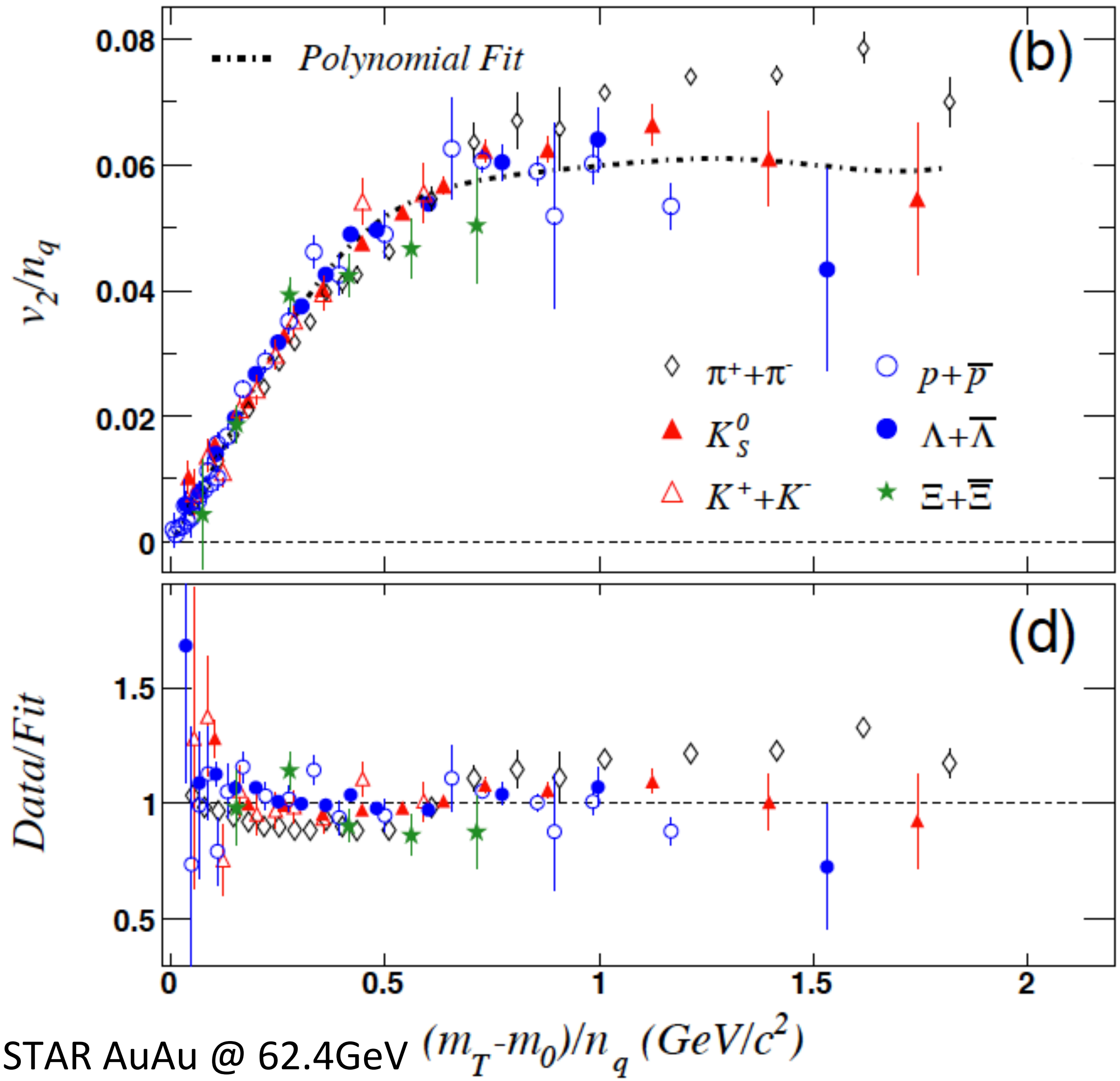


STAR AuAu @ 62.4GeV

Phys.Rev.C75:054906,2007

- Mass ordering at low p_T seen in AA collisions.
- A cross-over of v_2 observed at around 2 GeV

Quark Number Scaling



STAR AuAu @ 62.4GeV

Phys.Rev.C75:054906,2007

- Number of constituent quark scaling (NCQ) observed in AA collision.
- A possible indication of parton degree of freedom.

Study mass dependence and NCQ scaling for a wide p_T range in CMS:

- In high multiplicity pPb collision events
- Compare results with same multiplicity in PbPb collisions

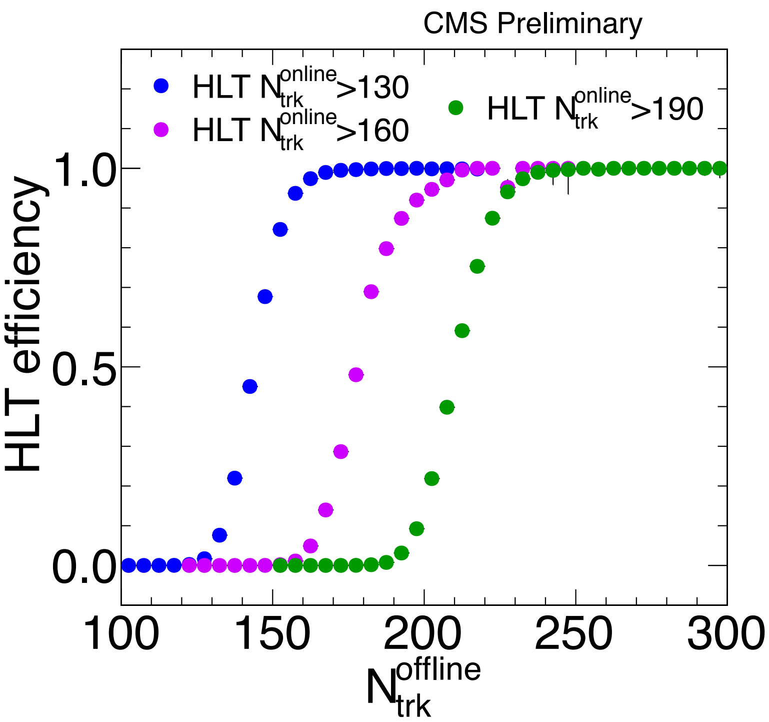
Data set, triggers and multiplicity distribution

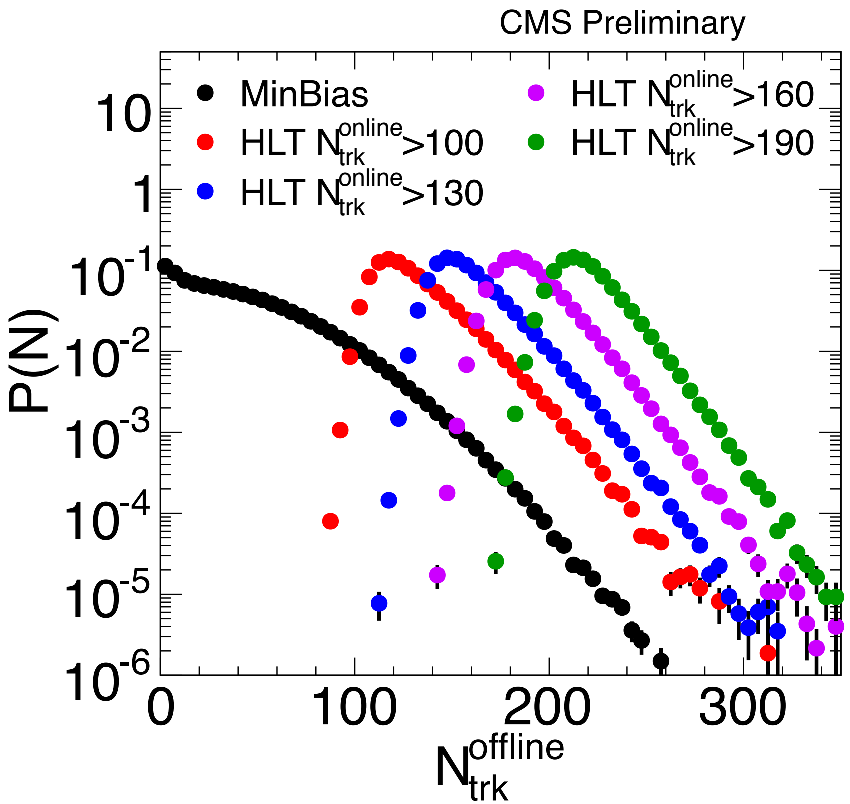
Data sets:

- 2013 pPb + Pbp, $35 nb^{-1}$
- 2011 PbPb, $2.3\ \mu b^{-1}$ (50-100%)

Triggers:

- High multiplicity triggers in 2013
- Minimum bias trigger

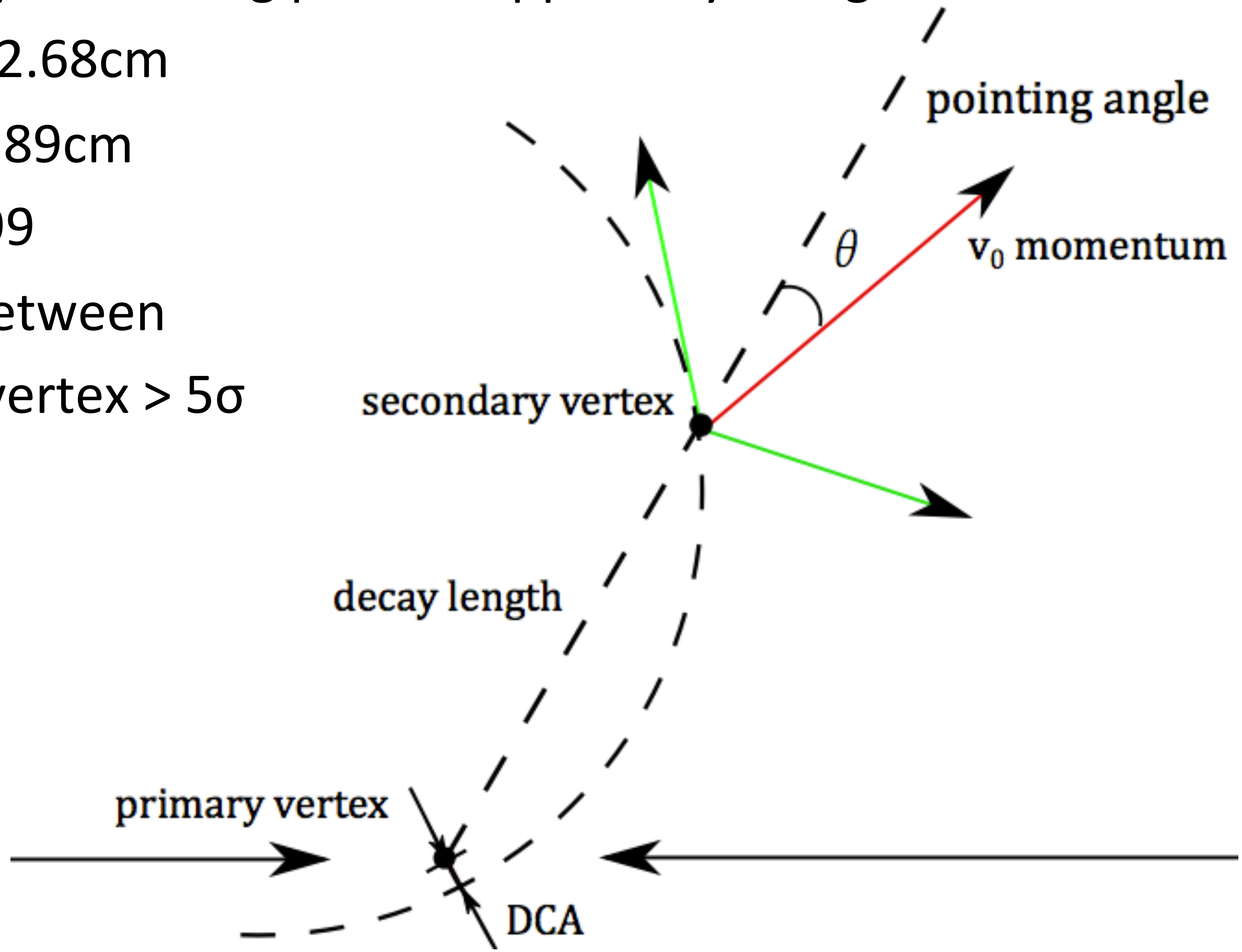




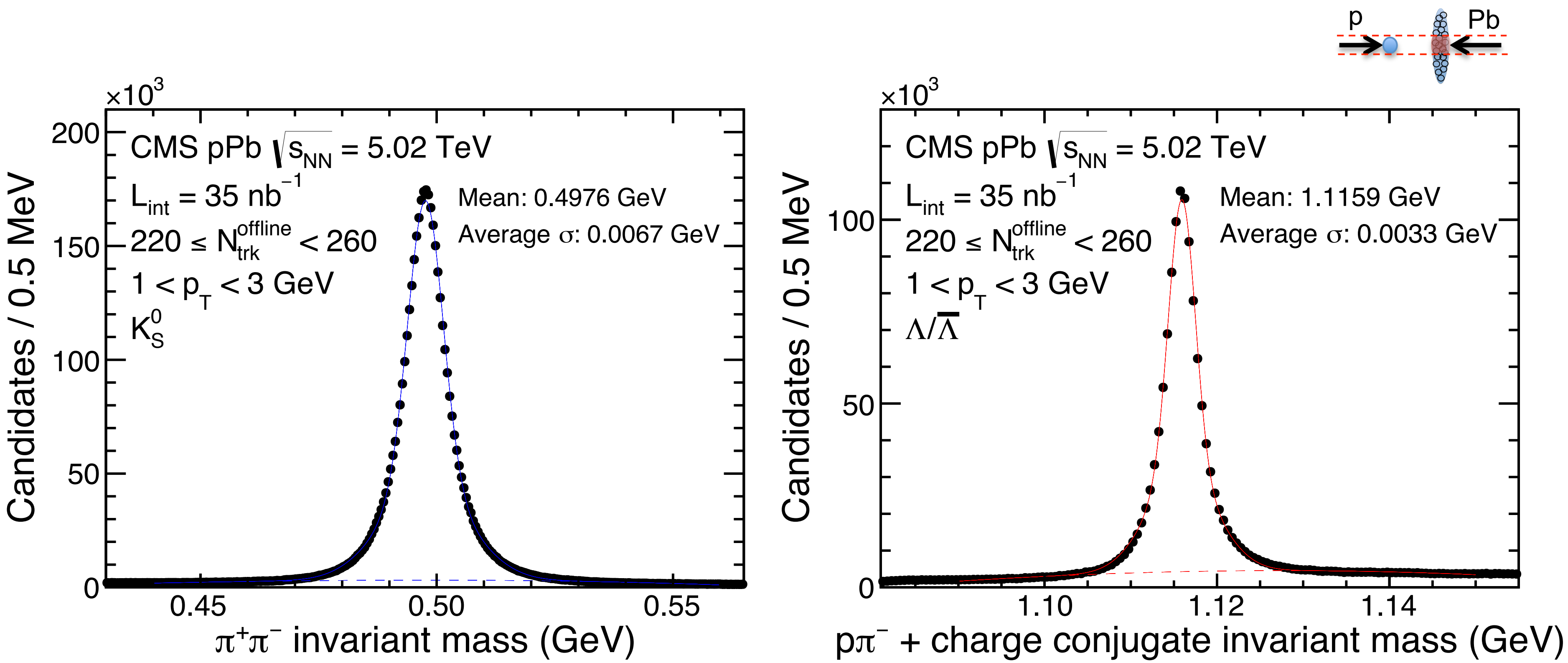
Track (p_T > 0.4 GeV, $|\eta|$<2.4) multiplicity distribution in pPb for different triggers

V^0 Candidates Reconstruction

- The K^0_S and Λ candidates (generally referred to as V^0) are reconstructed by combining pairs of oppositely charged tracks.
- $K^0_S \rightarrow \pi^+\pi^-$, $c\tau$ = 2.68cm
- $\Lambda \rightarrow p^+\pi^-$, $c\tau$ = 7.89cm
- $Cos(\theta^{point}) > 0.999$
- 3D separation between primary and V^0 vertex > 5σ

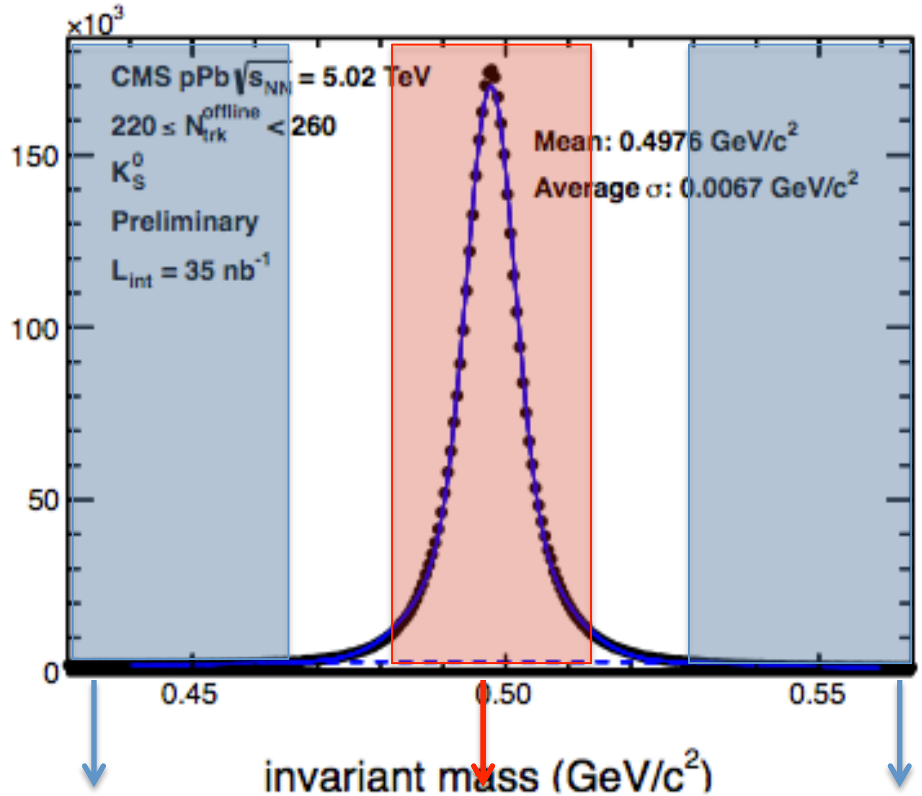


V^0 Candidates Reconstruction



- V^0 peaks can be clearly identified with little background for K^0_S and Λ constructed over wide range of p_T and η
- Mass values very close to PDG numbers

Extraction of v_n signal



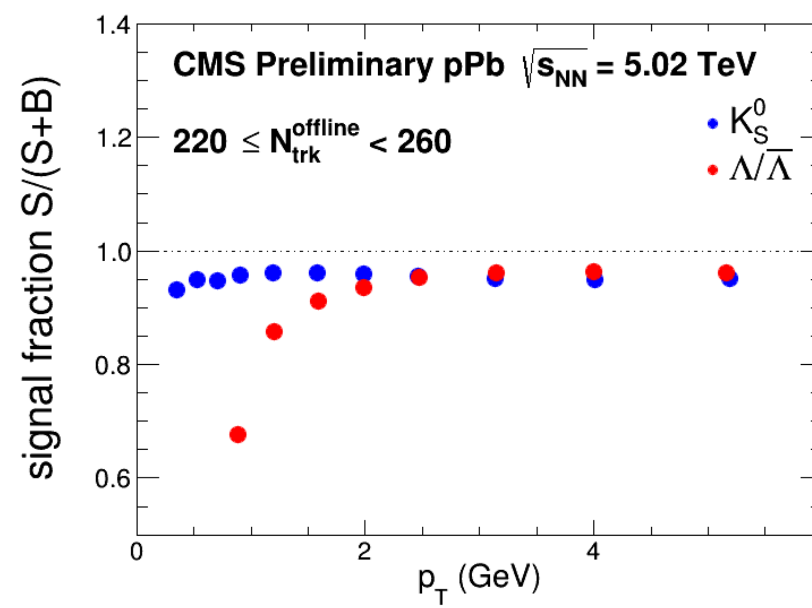
Sideband background region < -3σ

±2σ Peak region

Sideband background region > 3σ

Peak region:
Background + signal candidates,
Extraction of v_n^{obs},
Calculation of signal fraction
f = signal yield/total yield = S/(S+B)

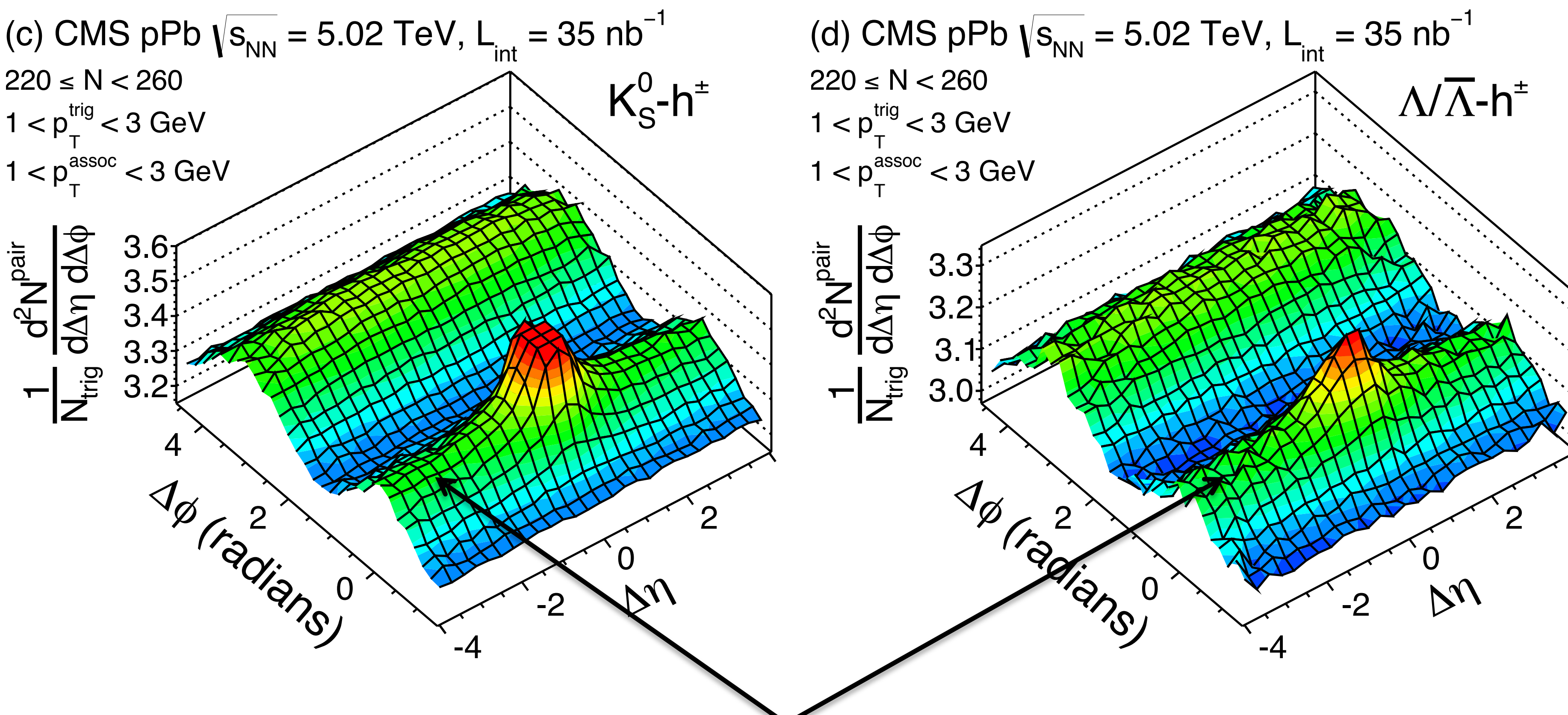
Sideband background region:
Only background candidates,
Extraction of v_n^{bkg}



$$v_n^{obs} = v_n^{sig} \cdot f + v_n^{bkg} \cdot (1-f)$$

Two-particle correlation function

- Two-particle correlation functions are constructed for:
  - K^0_S as trigger, inclusive charged hadron as associated, K^0_S-$h^{\pm}$.
  - Λ as trigger, inclusive charged hadron as associated, Λ-$h^{\pm}$.



Near side long range "ridge", $\Delta\phi \sim 0$

Extraction of v_n

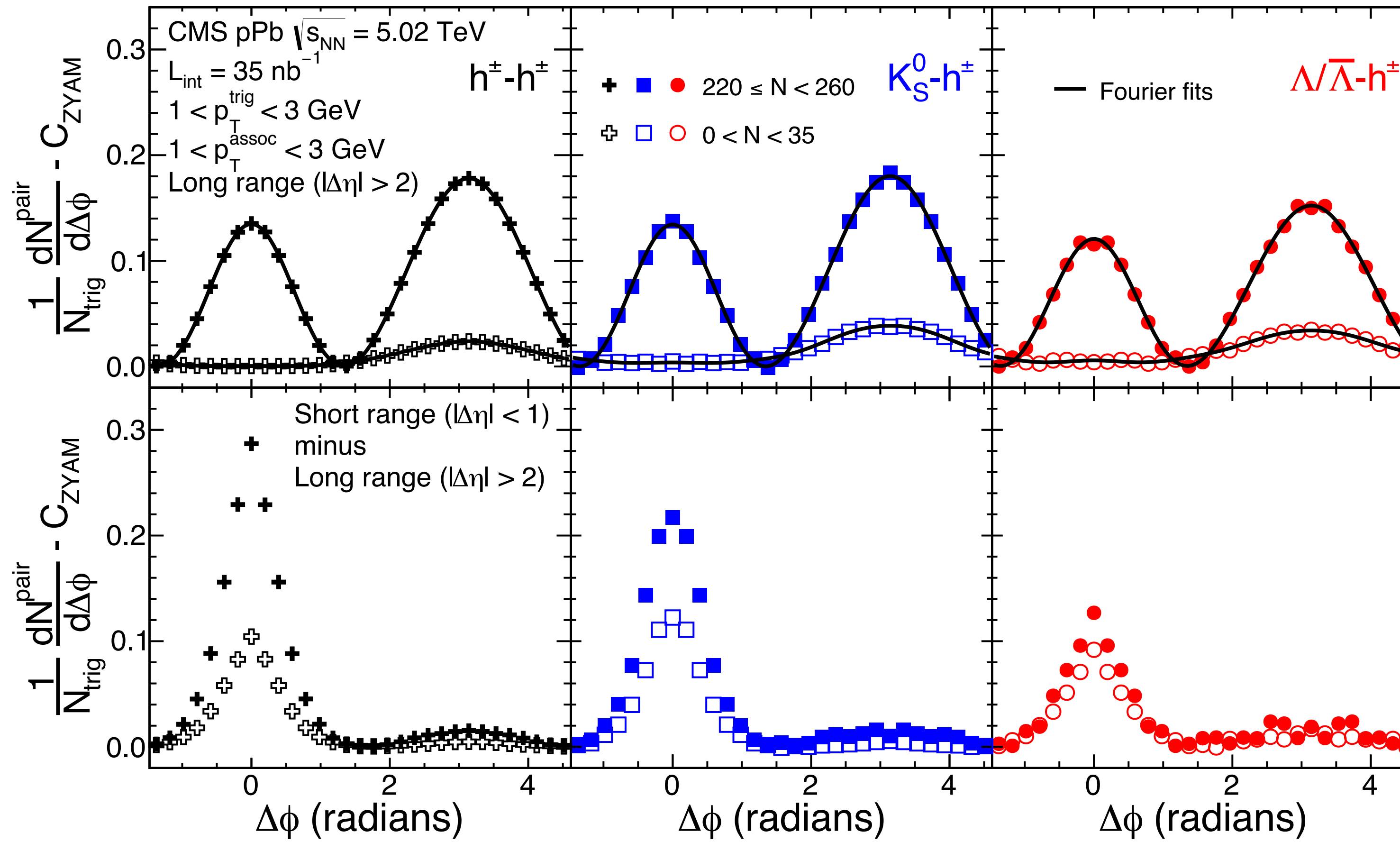
Two-particle correlation functions are projected in "ridge" range ($|\Delta\eta|>2$), fit by a Fourier decomposition to get $V_{n\Delta}$: $\frac{1}{N_{trig}}\frac{dN^{pair}}{d\Delta\phi} = \frac{N_{assoc}}{2\pi}\left\{1+\sum_n 2V_{n\Delta}\cos(n\Delta\phi)\right\}$

$$v_n^h = \sqrt{V_{n\Delta}^{h-h}}$$

Assume factorization

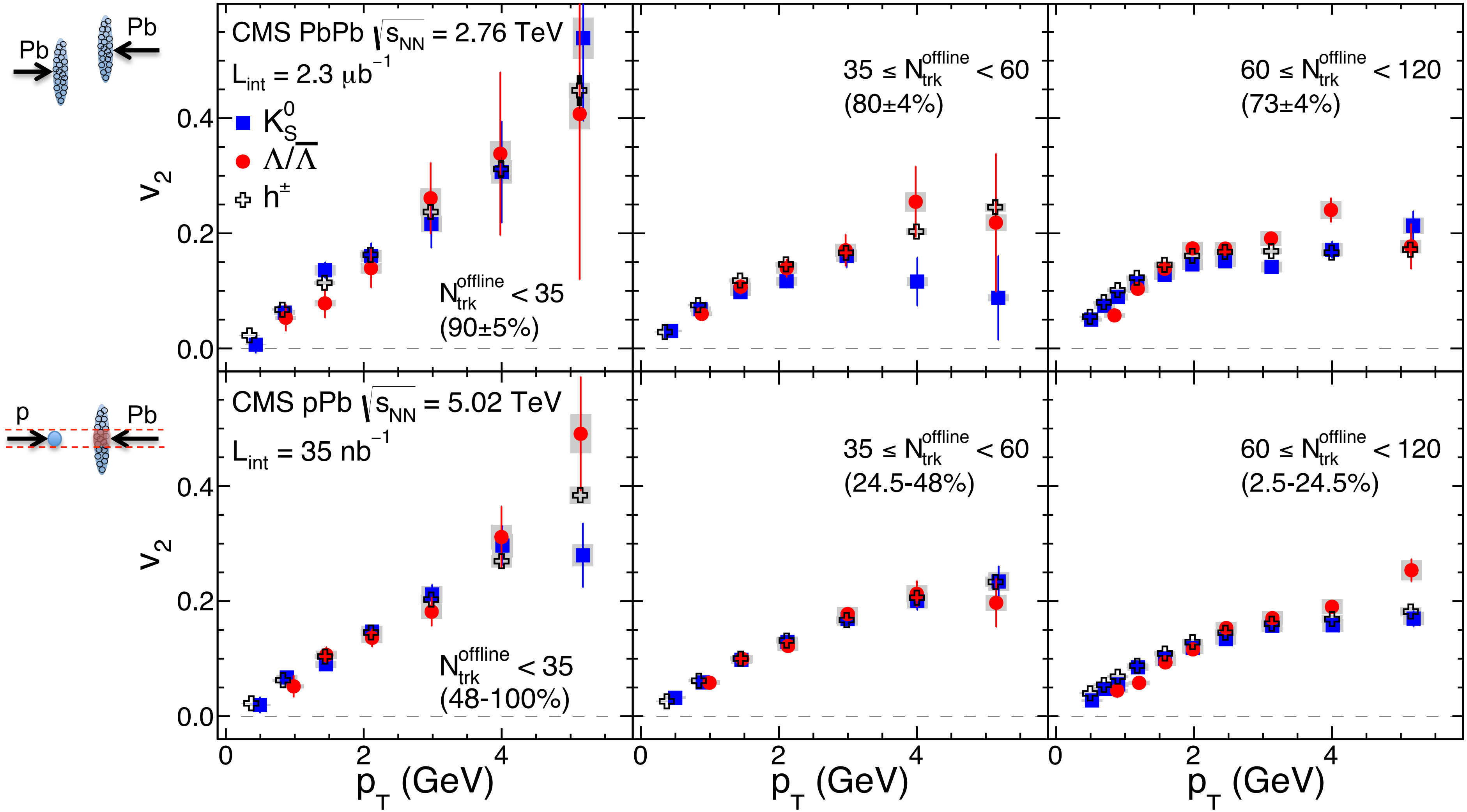
$$v_n^{K_s^0} = \frac{V_{n\Delta}^{K_s^0-h}}{v_n^h}$$

$$v_n^{\Lambda} = \frac{V_{n\Delta}^{\Lambda-h}}{v_n^h}$$



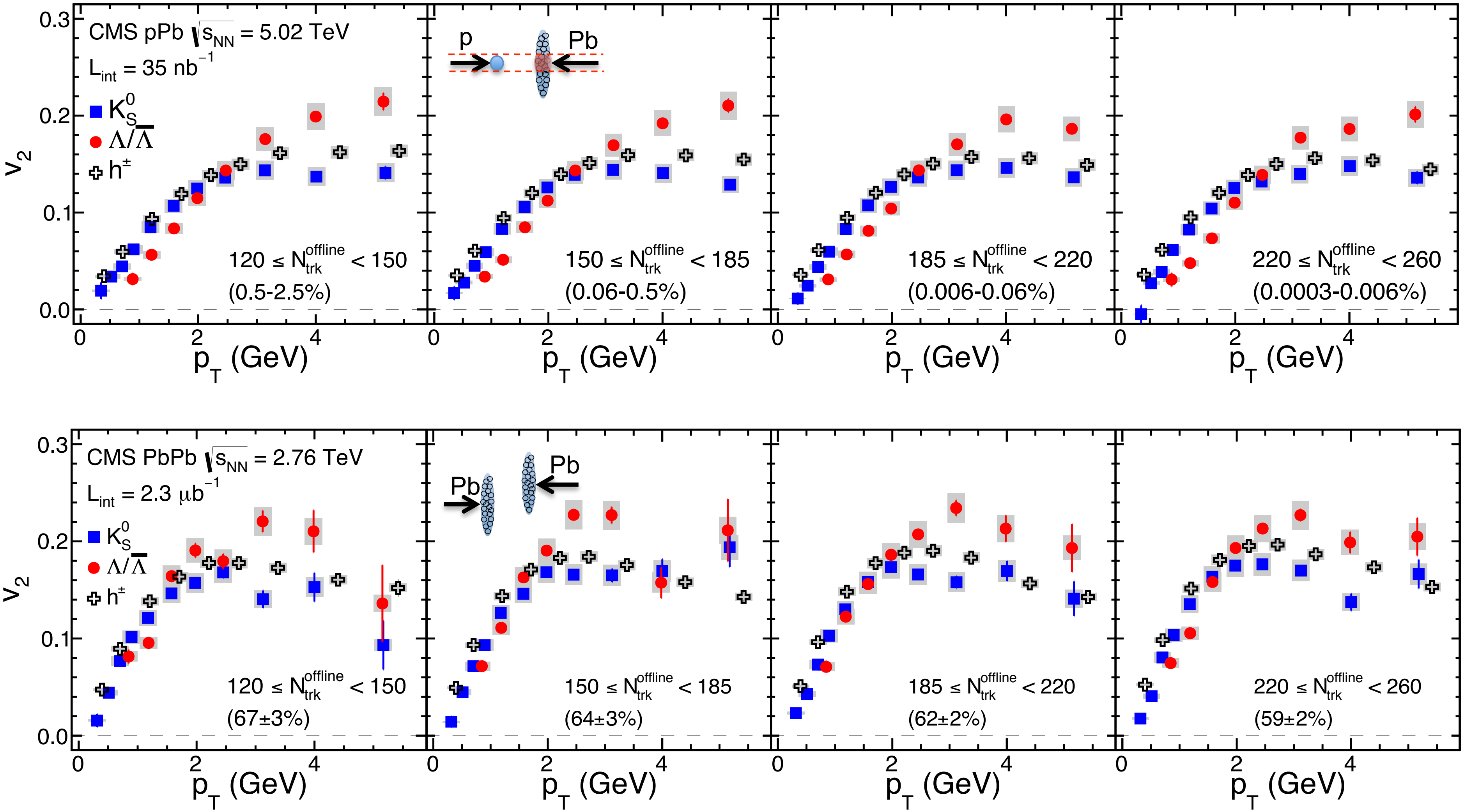
$v_n^{obs} = v_n^{sig} \cdot f + v_n^{bkg.} (1-f)$

Low multiplicity v_2 in pPb and PbPb



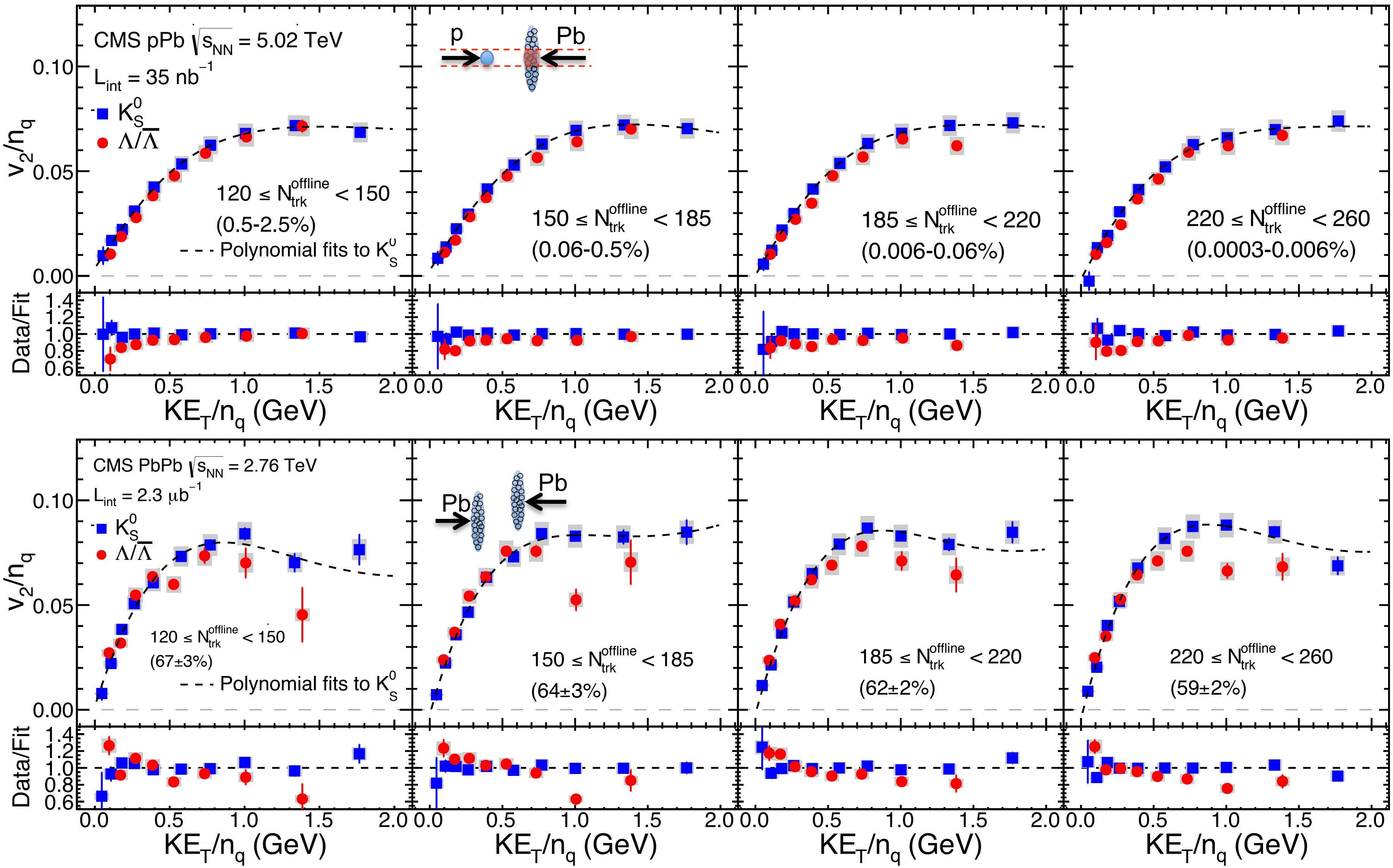
- v_2 patterns are compatible for K^0_S, Λ and inclusive charged hadron at low multiplicity (<60) for both pPb and PbPb
- At 60-120 multiplicity, a hint of a deviation of v_2 between K^0_S and Λ is observed.

High multiplicity v_2 in pPb and PbPb



Mass ordering below 2 GeV and a cross-over at around 2 GeV observed.

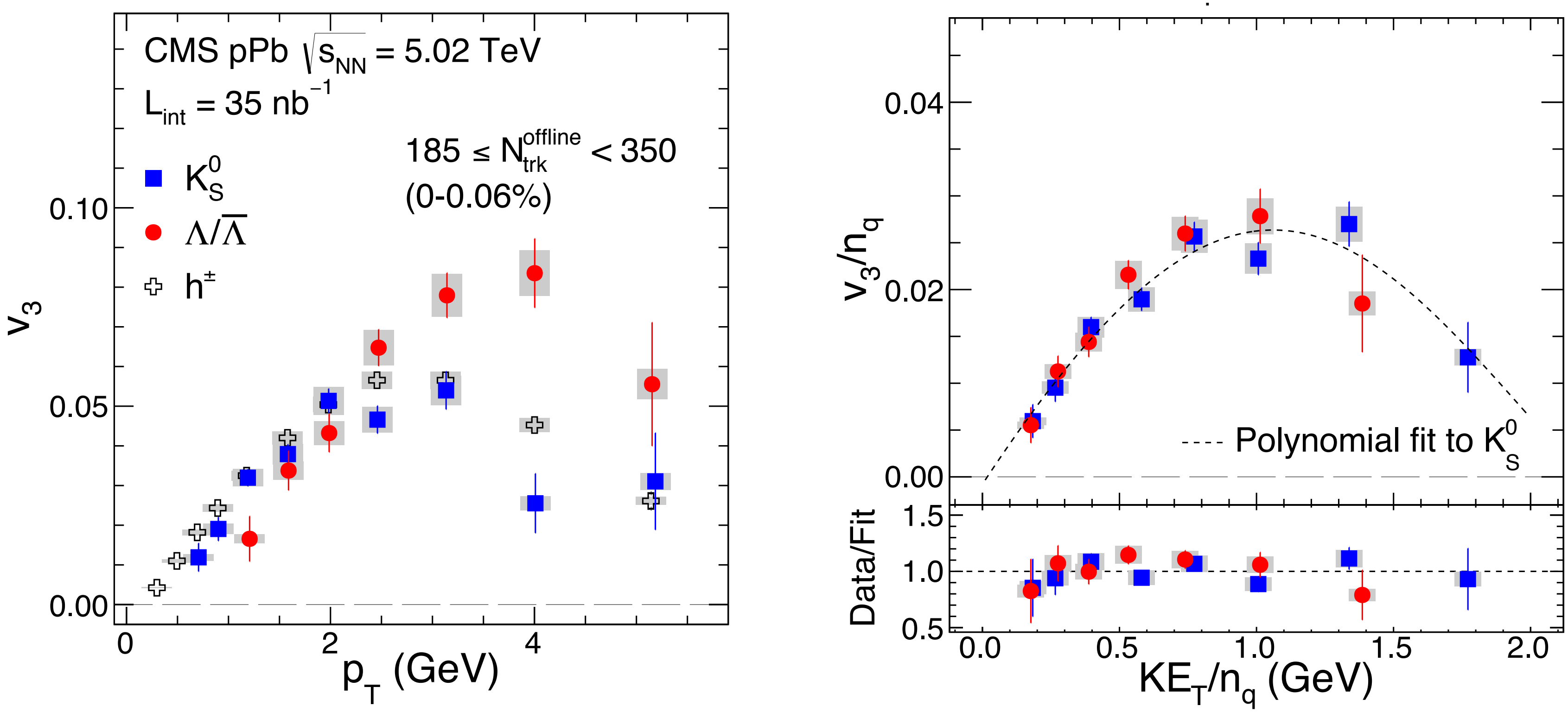
NCQ scaling of v_2 in pPb and PbPb



NCQ scaling holds within 10% in pPb, better than in PbPb (25%).

– Suggesting parton degree of freedom in pPb collision?

High multiplicity v_3 in pPb



Similarity between v_2 and v_3 in pPb:

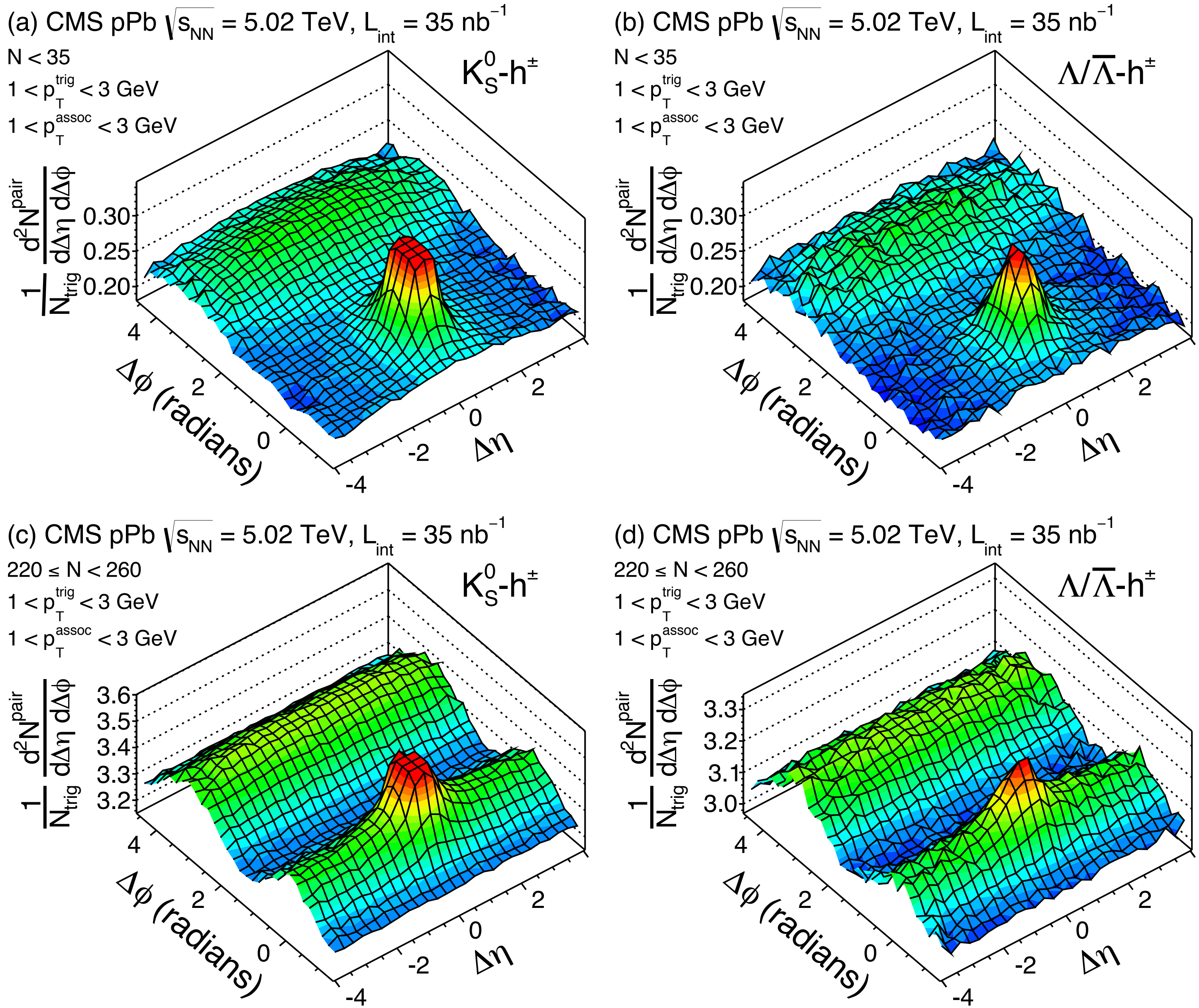
- Mass ordering below 2 GeV and a cross-over at around 2 GeV
- NCQ scaling holds within 20%

Conclusion

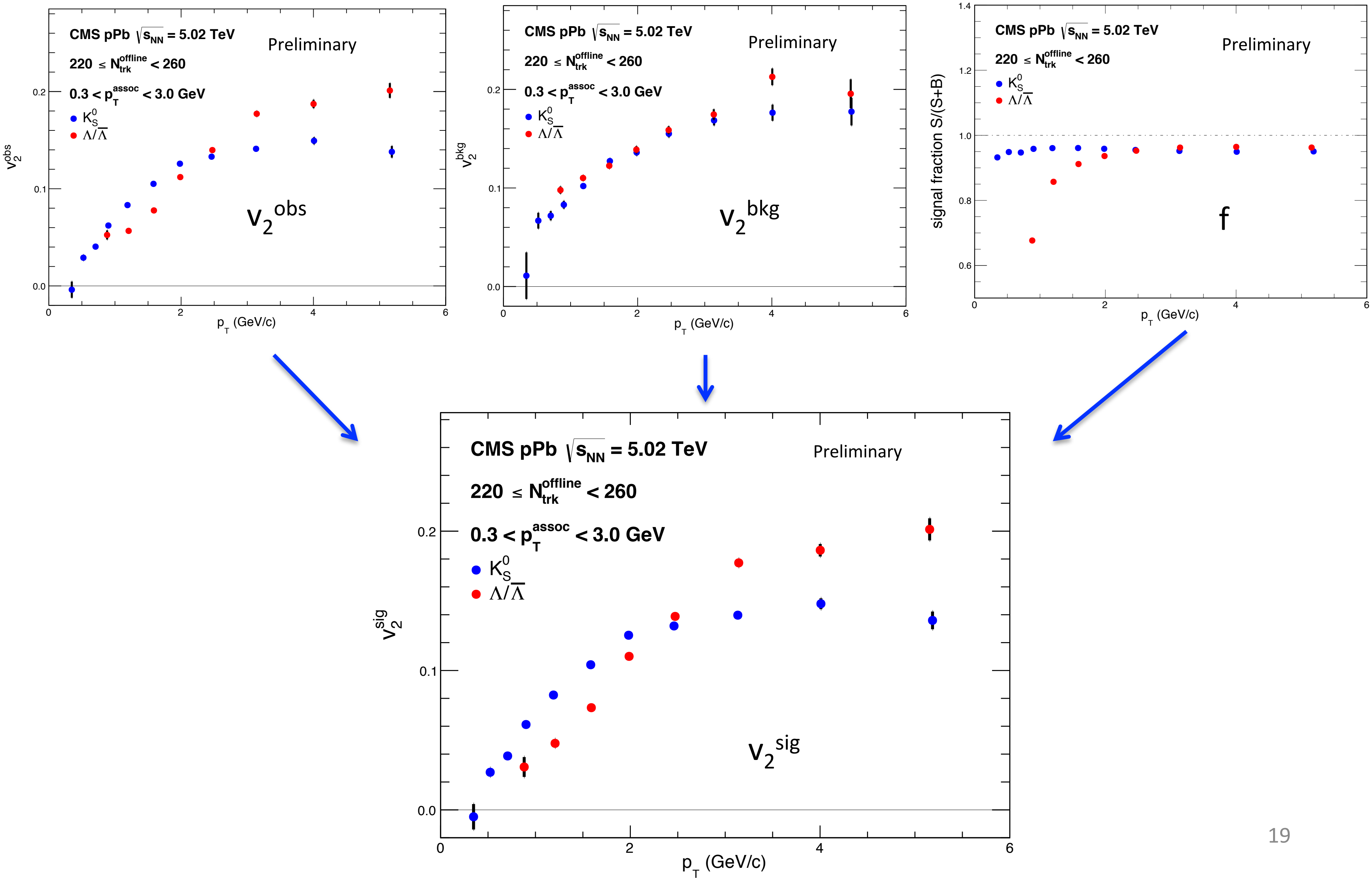
- Second-order (v_2) and third-order (v_3) anisotropy harmonics of K^0_S and Λ particles are presented over wide multiplicity range and broad p_T range in pPb collisions
  - Compared to PbPb results with same multiplicities
- Low multiplicity ($N_{trk}^{offline} < 60$)
  - v_2 are compatible for K^0_S and Λ in both pPb and PbPb collisions
- Higher multiplicity ($60 < N_{trk}^{offline} < 350$)
  - Mass ordering of v_2 and v_3 observed in pPb collision, more prominent than in PbPb collision at same multiplicities
  - A cross-over at around 2 GeV is observed for both pPb and PbPb collisions
- Number of constituent quark (NCQ) scaling of v_2 and v_3 observed in high multiplicity pPb collision
  - Holds better than in PbPb collision at same multiplicities

Back up

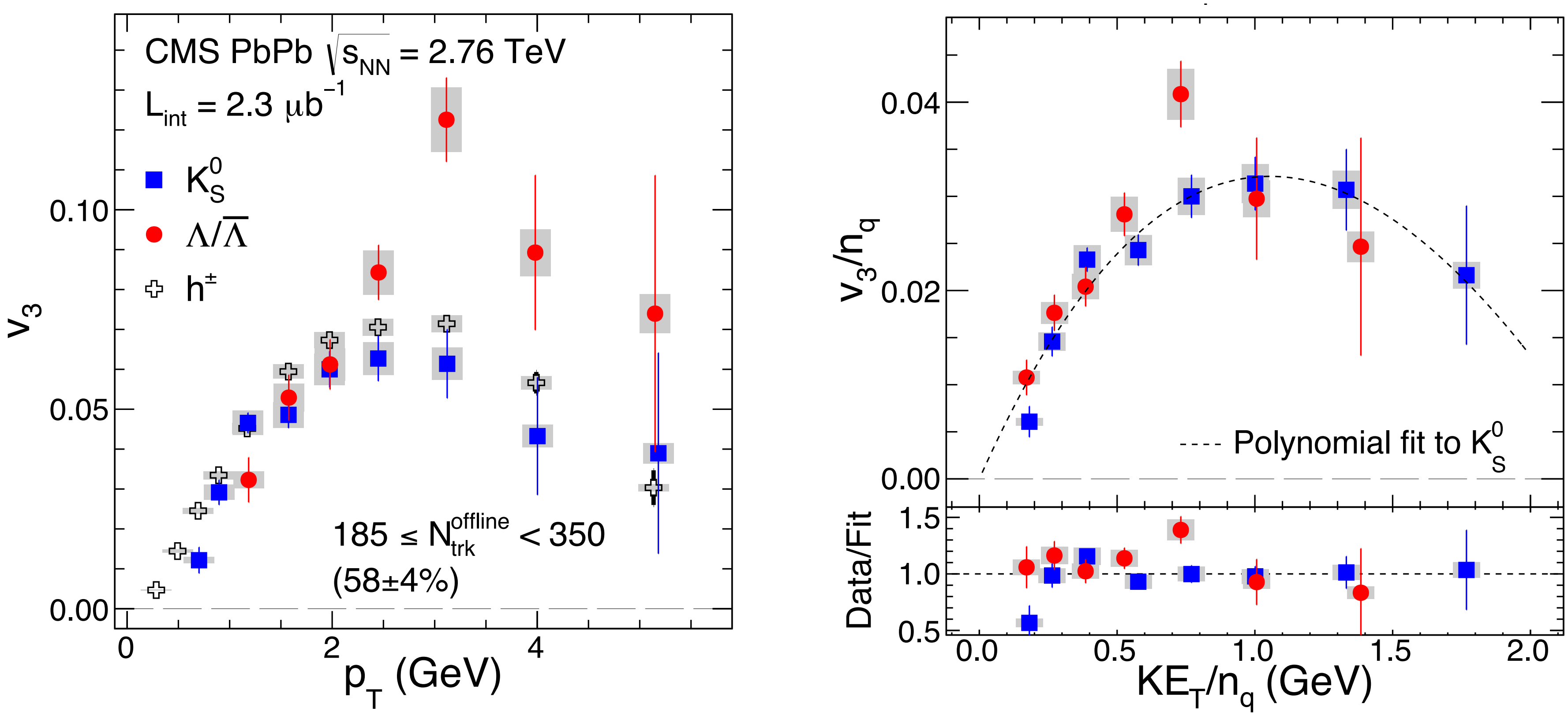
Two-particle correlation function



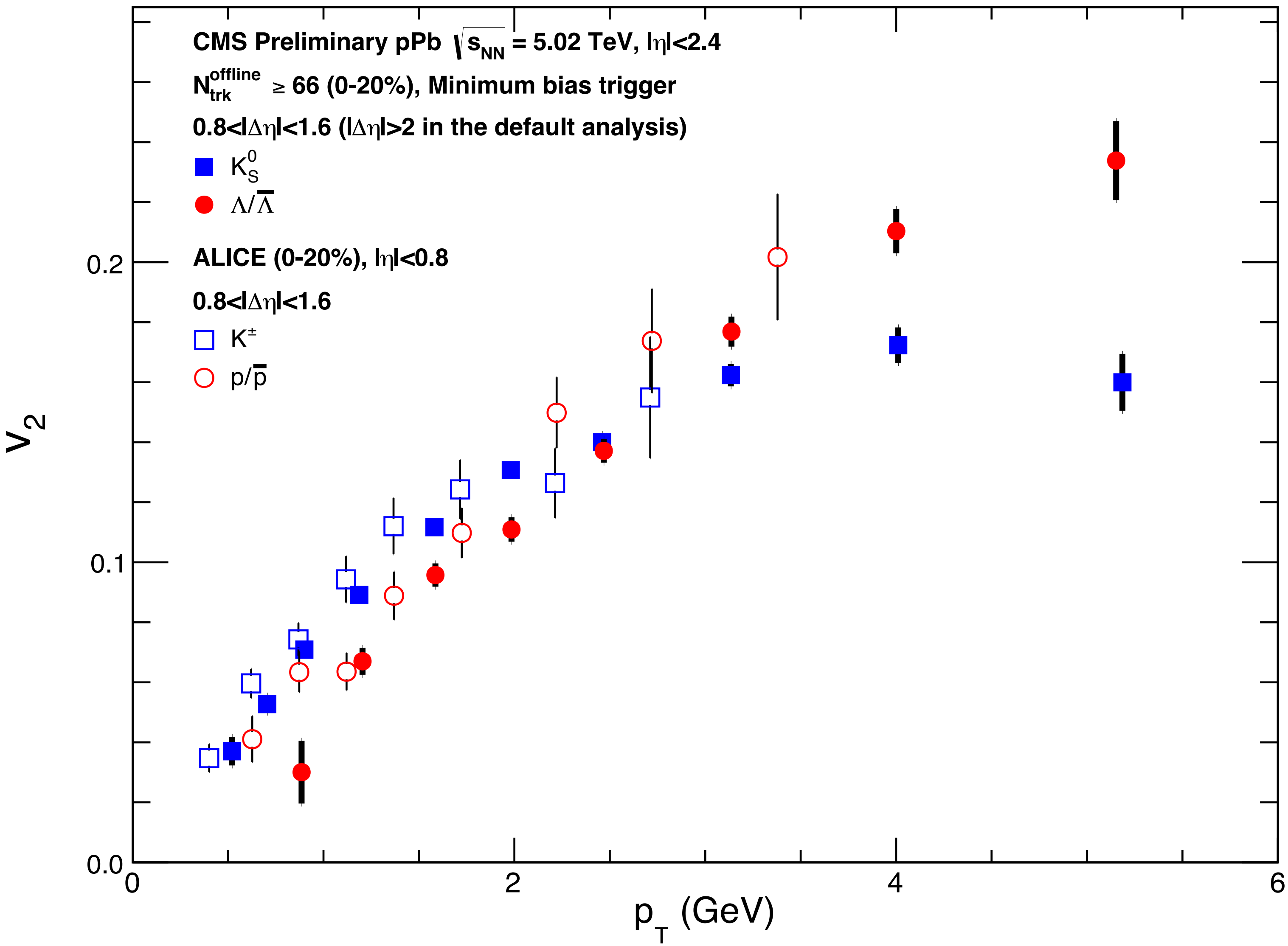
v_n^{signal} calculation



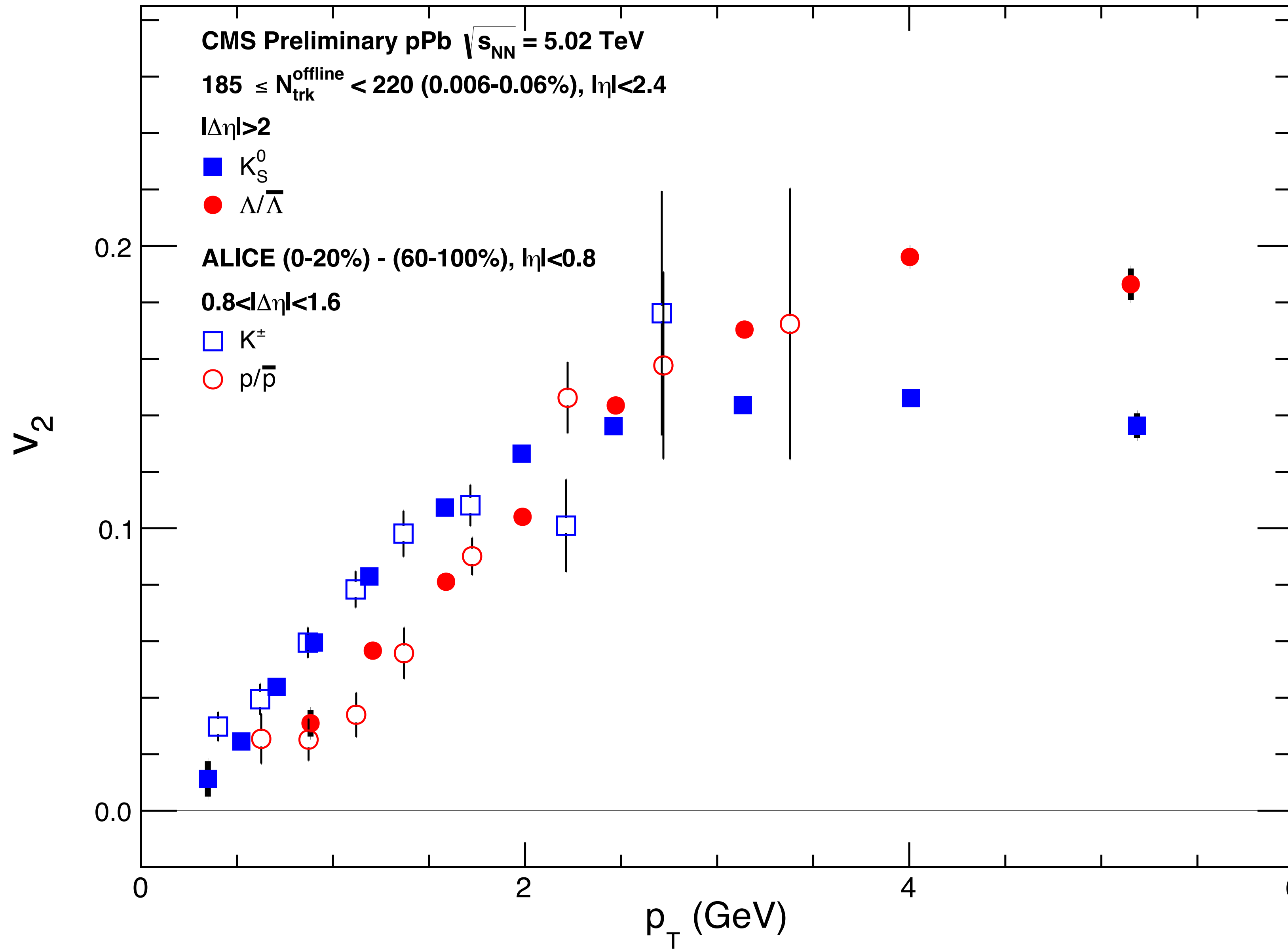
High multiplicity v_3 in PbPb



Comparison to ALICE result



Comparison to ALICE result



ALICE PbPb v2