Anisotropic flow of identified particles in Pb-Pb collisions at 2.76 TeV with the ALICE detector

You Zhou

Nikhef & Utrecht University

(on behalf of the ALICE Collaboration)

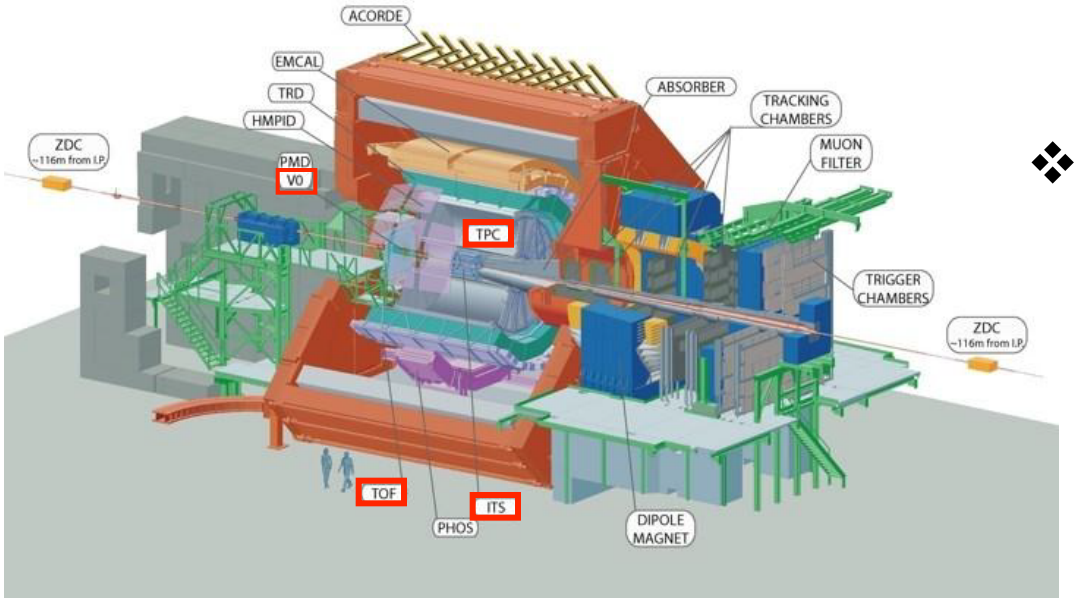
Motivation

- Anisotropic flow signals the presence of multiple interactions between the constituents of the medium created in the collision, its magnitude therefore is a detailed probe of the level of thermalization.
- Anisotropic flow:
  - quantified as the coefficients of the Fourier expansion of azimuthal transverse momentum distribution

$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{dp_T d\eta}(1 + \sum_{n=1}^{\infty} 2v_n(p_T, \eta)\cos[n(\varphi - \Psi_n)])$$

  - v_2 : elliptic flow; v_3 : triangular flow; v_4 v_5, …
- Anisotropic flow of identified particles allows to probe the freeze-out conditions of the system (temperature, radial flow, …)
  - test with π , K, p v_2 and v_3
  - describe all particles v_2 simultaneously (strange, multi-strange particles)?
- Identified particles v_2 (v_3) allow us to check the baryon meson scaling
  - indication of partonic collectivity ?

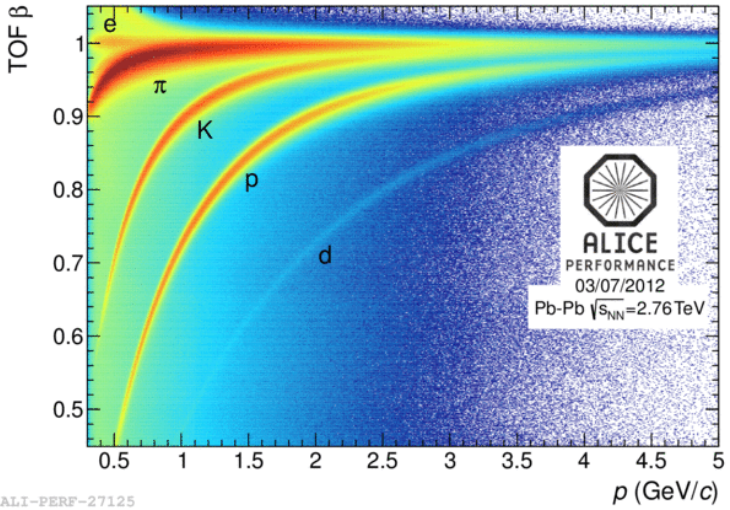
Analysis Details

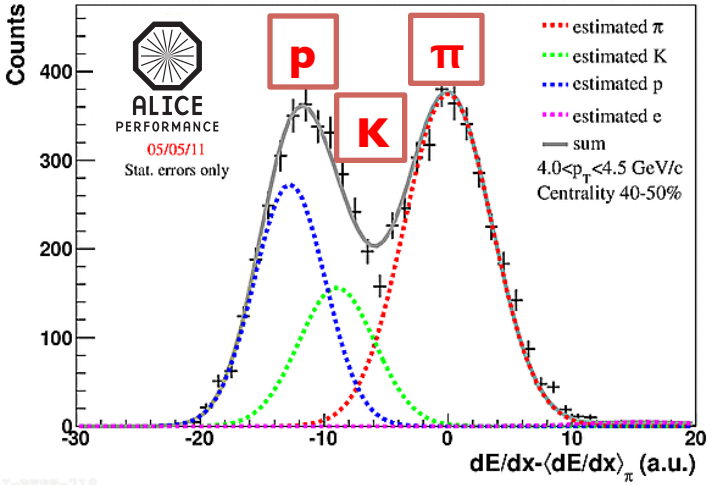


- Data sample:
  - Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV,
  - ~ 10 M Pb-Pb events,
  - minimum bias trigger,
  - acceptance: $-0.8 < \eta < 0.8$.
- Detectors used:
  - Inner Tracking System (tracking and vertexing).
  - Time Projection Chamber (tracking & particle identification),
  - Time-Of-Flight (particle identification),
  - VZERO detectors ($-3.7<\eta<-1.7$, $2.8<\eta<5.1$, centrality / event plane)

Identification of π, K, p

- Particle identification with TOF & TPC:
  - asymmetric β-cut in TOF and 2σ cut in the TPC dE/dx to select a high purity sample of π, K and p.
  - p_T range (in GeV/**c**):
    - π : $0.3 < p_T < 3.5$
    - K : $0.4 < p_T < 2.5$
    - p : $0.5 < p_T < 4.0$
  - purity > 90%
- Identification at high p_T with TPC:
  - purity cut on the TPC dE/dx signal:
  - p_T range (in GeV/**c**):
    - π and p: $3 < p_T < 16$
  - purity: pions > 90%, protons > 80%

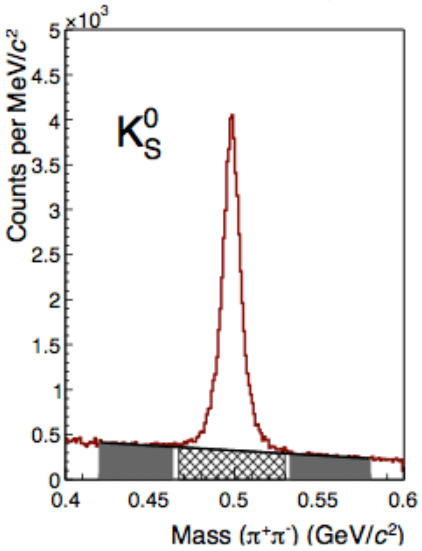


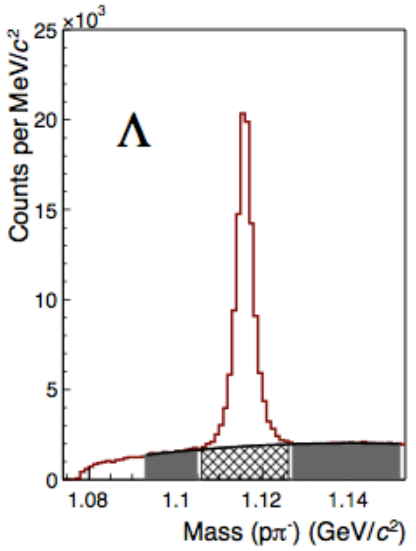


Topological reconstruction

arXiv:1307.5530
Today

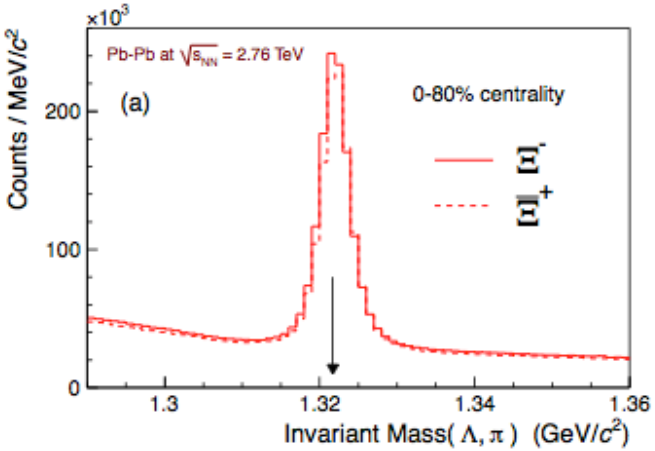
See Talk:
L. HANRATTY
25 Jul 2013,18:10-18:30

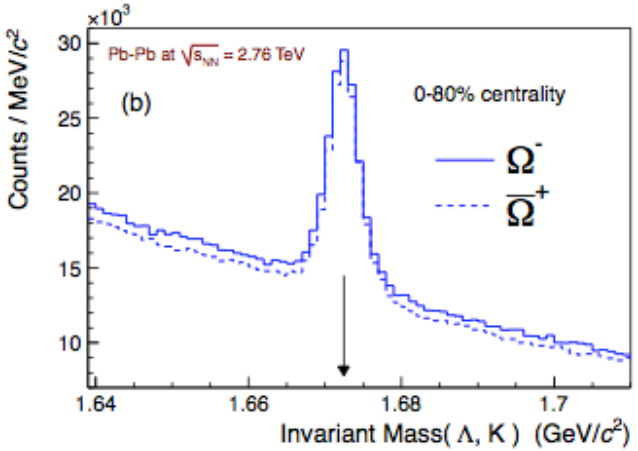




arXiv:1307.5543
Today

See Talk:
D. COLELLA
25 Jul 2013, 17:50-18:10





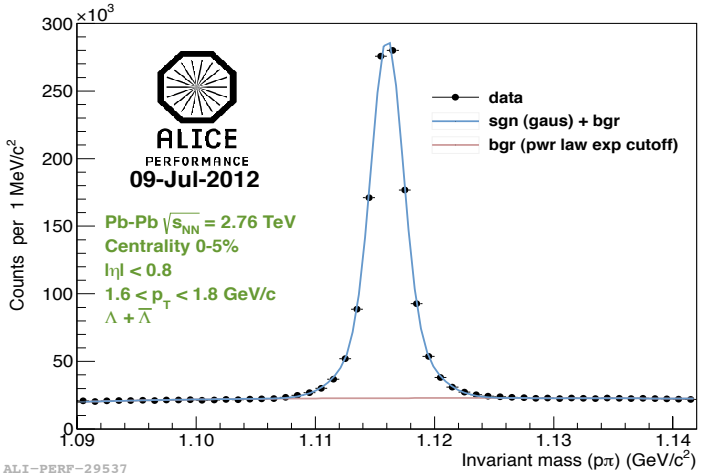
- Topological reconstructions for strange and multi-strange particles

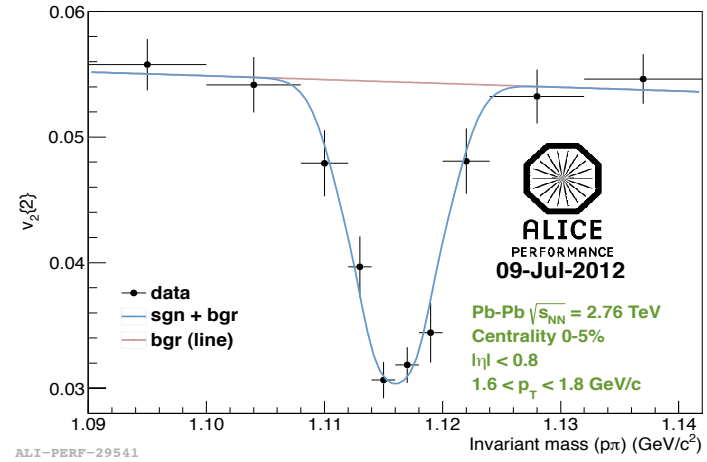
Flow Methodology

- Anisotropic flow of π, K, p is directly measured by *Q-cumulant, Scalar Product* and *Event Plane* method.
- We extract v_2 of K_S^0, Λ, Ξ and Ω, with v_2 *vs. invariant mass* method:

$$v_2^T(m_{inv}) = v_2^S \frac{N^S}{N^T}(m_{inv}) + v_2^B(m_{inv}) \frac{N^B}{N^T}(m_{inv})$$

  - the yields N^S, N^B are obtained from the fits of the invariant mass distributions.
  - the $v_2^T(m_{inv})$ is measured by *Scalar Product* and *Event Plane* method
  - the $v_2^B(m_{inv})$ is parameterized with the polynomial function
  - all necessary information to extract v_2^S is available





v_2 of π, K, p, K_S^0, Λ

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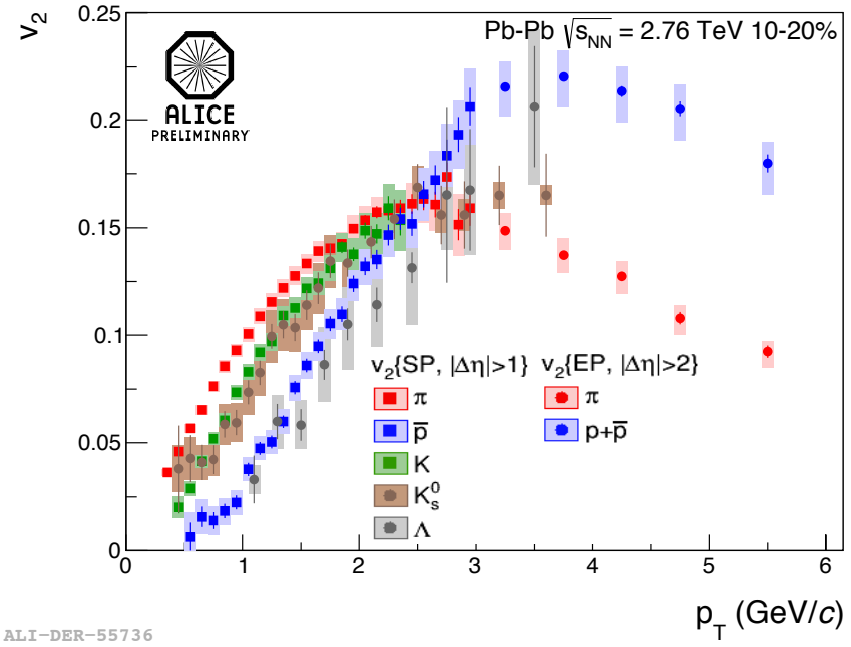

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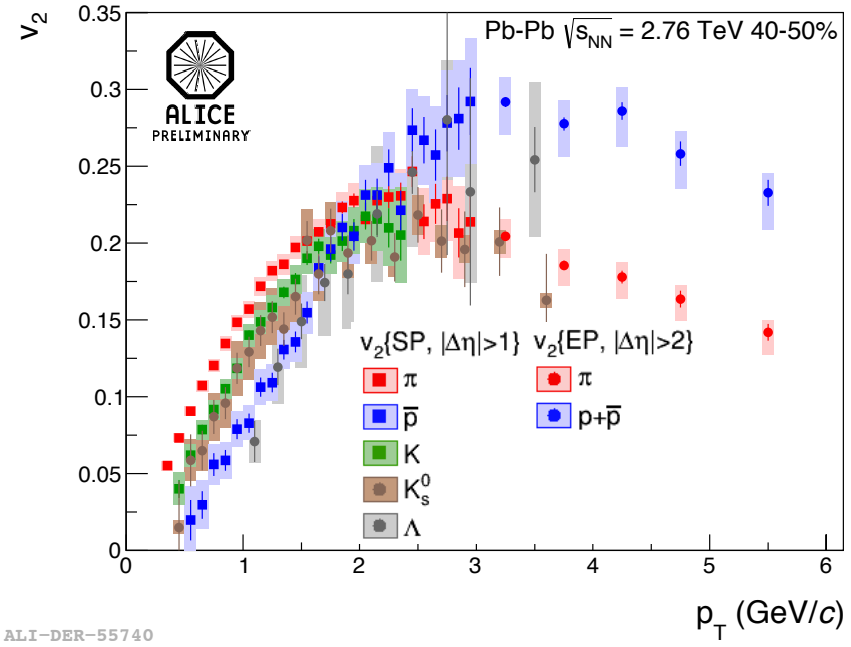

- v_2 is measured for a number of particles with light and strange quark contents
- The mass ordering is stronger in most central collisions.
  - indicative of stronger radial flow in more central collisions
- The v_2 of p is significantly different from that of π at higher p_T region

Comparison with hydrodynamic calculations

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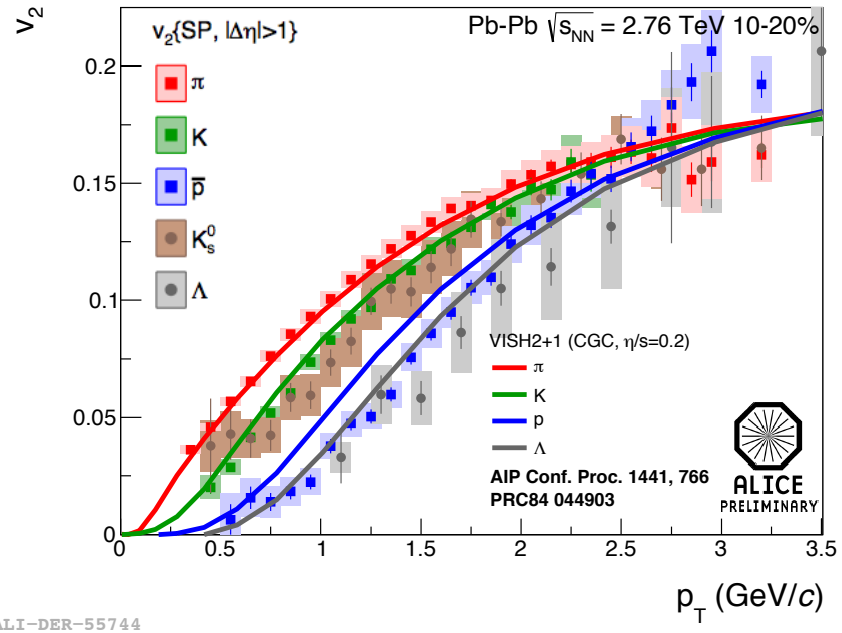

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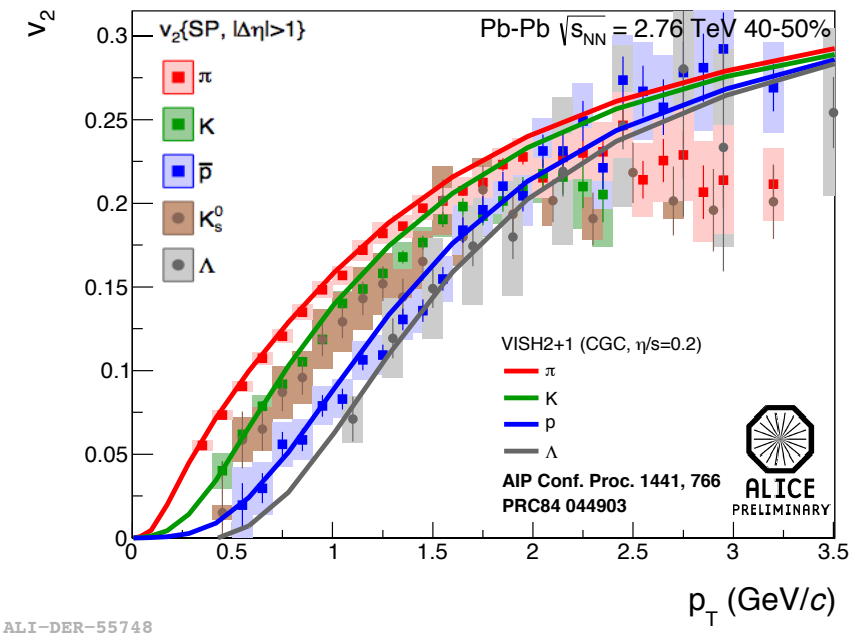
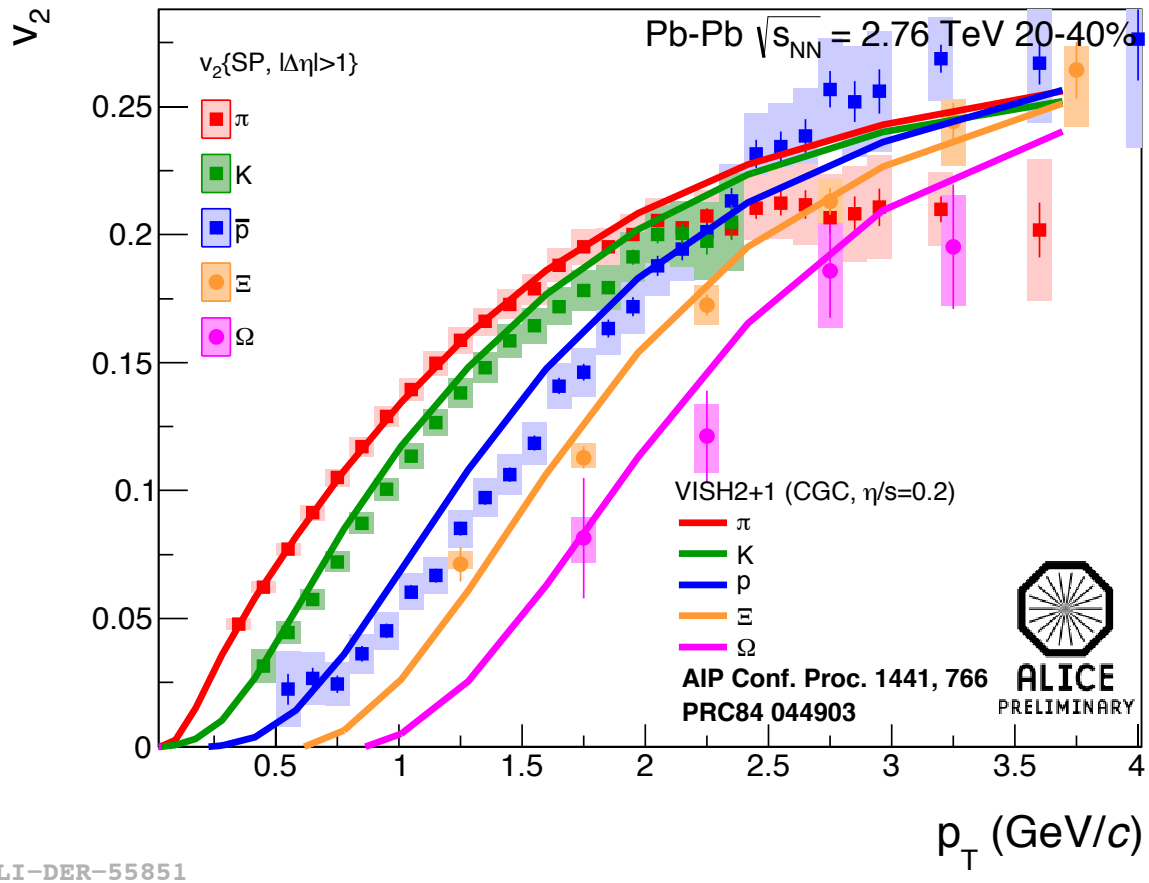


- hydrodynamic calculation, VISH2+1 (w/o afterburner) reproduces the main features of v_2 at low p_T range,
  - it describes the measurements better in peripheral than central collisions
  - it overestimates the p v_2 in central collisions.
  - the hadronic interactions might play an important role in reproducing p v_2

Multi-strange particles v_2



- We also observe clear mass ordering in Ξ and Ω v_2

NCQ scaling vs transverse momentum

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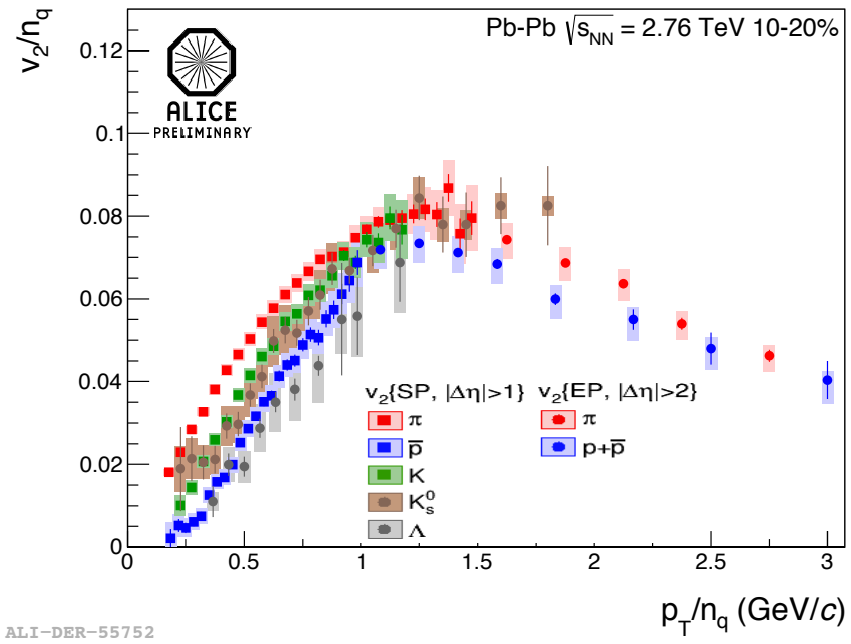

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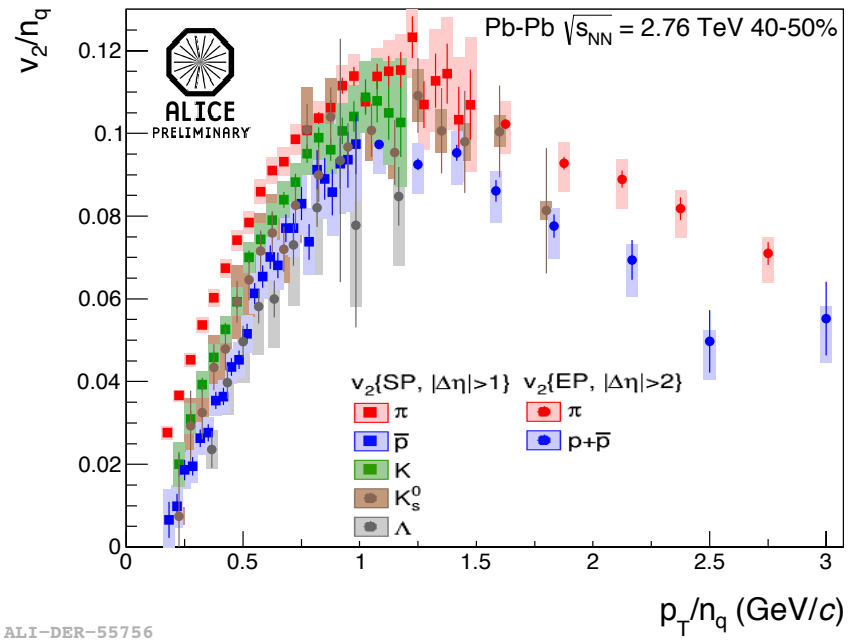

- NCQ scaling serves a test for the particle production via quark coalescence

NCQ scaling vs transverse momentum

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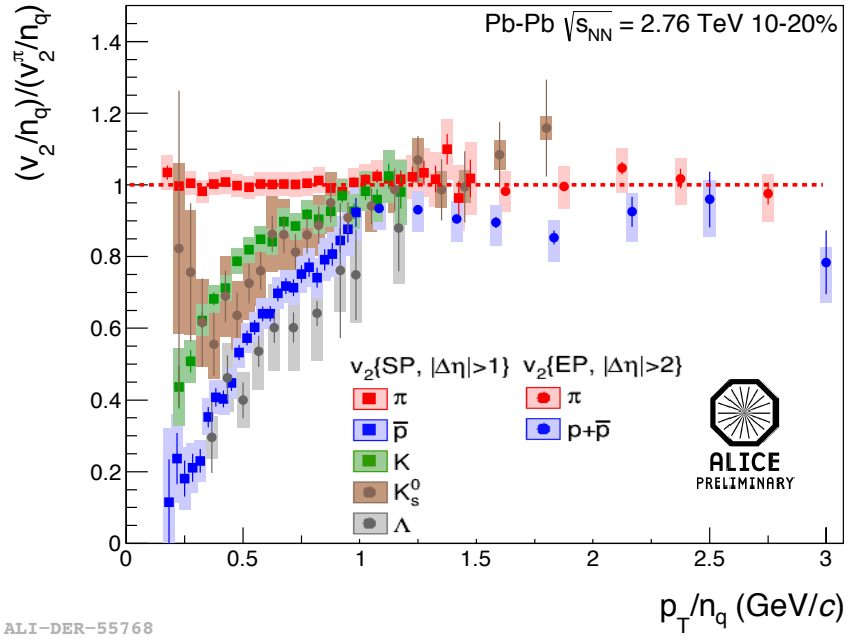

ALI-DER-55768

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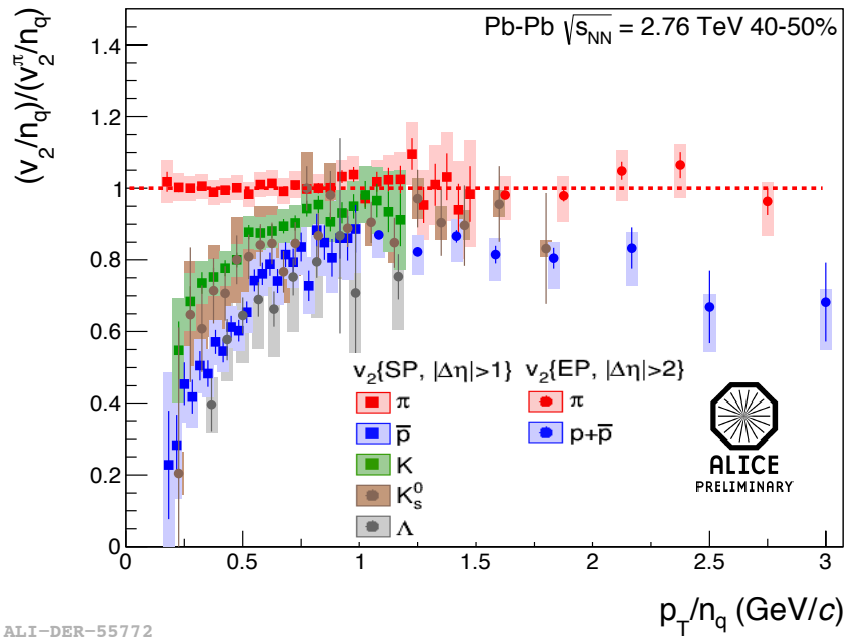
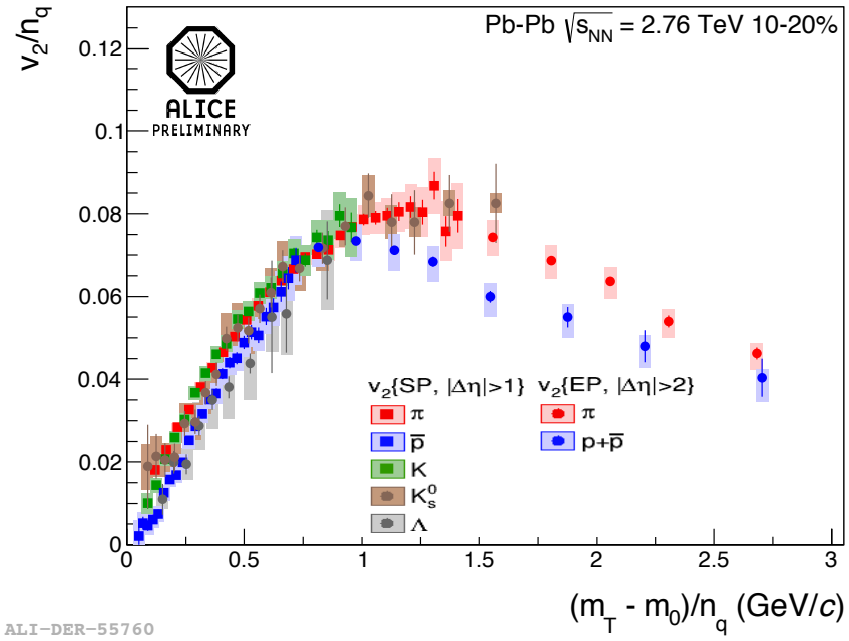


ALI-DER-55772

- The ratio of v_2/n_q for identified particle and v_2/n_q of π vs p_T/n_q have been shown.
- v_2/n_q vs. p_T/n_q (n_q: number of quarks per meson/baryon) shows that if such scaling exists it is only approximate (holds within 20%) at p_T/n_q~1.2 GeV/***c***

NCQ scaling vs transverse kinetic energy

10-20%



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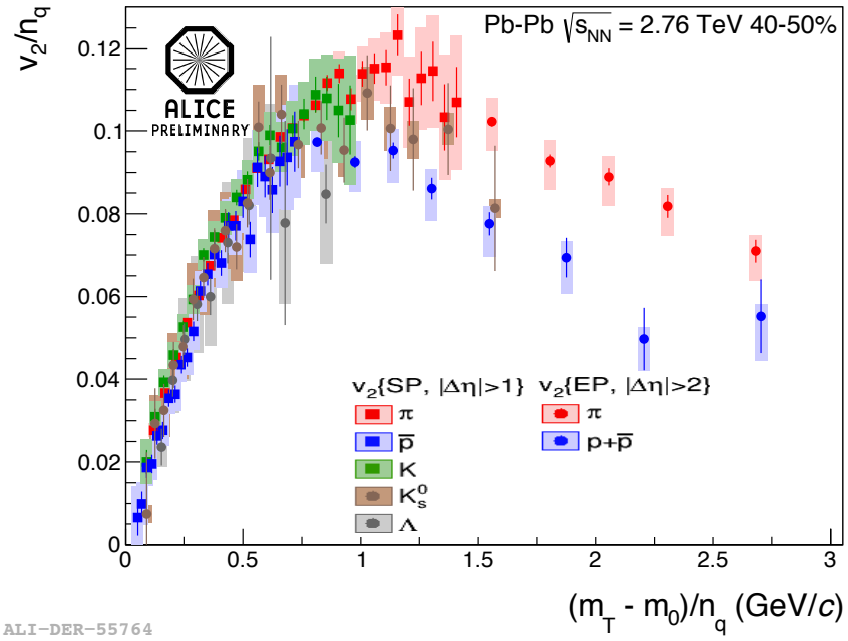
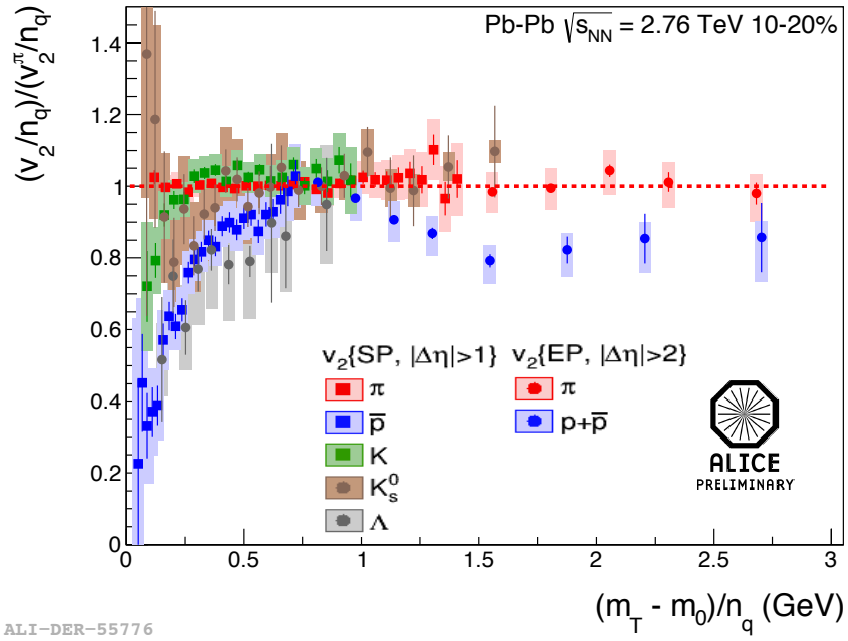


- NCQ scaling vs KE_T/n_q provides additional checks (and w/o mass effect) if the particle production is due to the quark coalescence picture.

NCQ scaling vs transverse kinetic energy

10-20%



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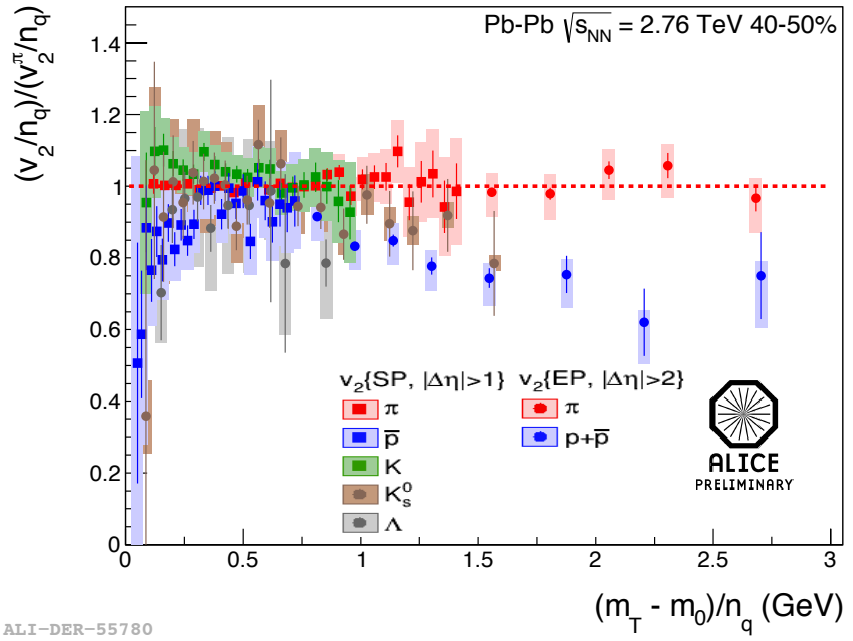
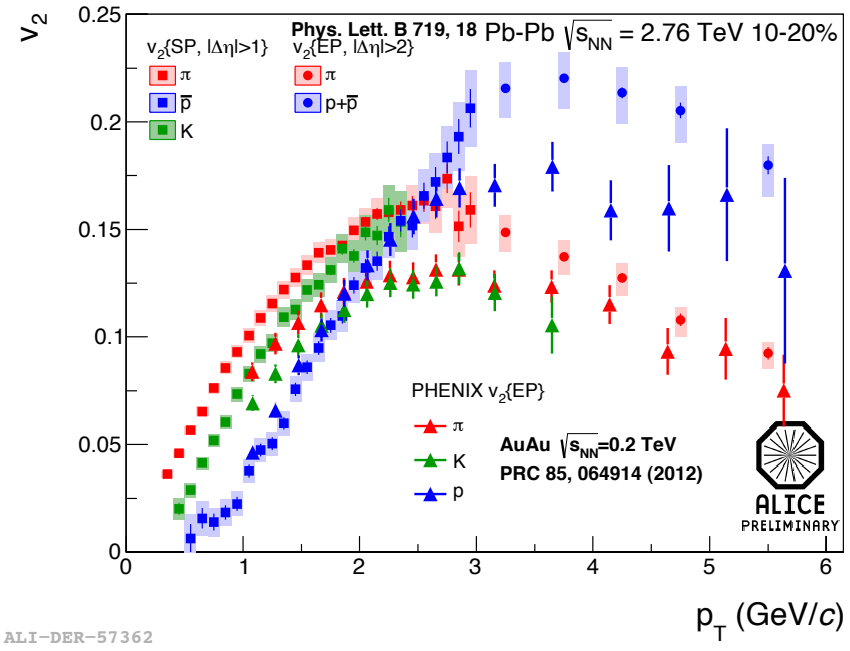


ALI-DER-55780

- For low KE_T/n_q: v_2/n_q together with KE_T scaling is violated at LHC
- For KE_T/n_q>1 GeV/**c** v_2 of p is lower than that of π

From RHIC to LHC

10-20%



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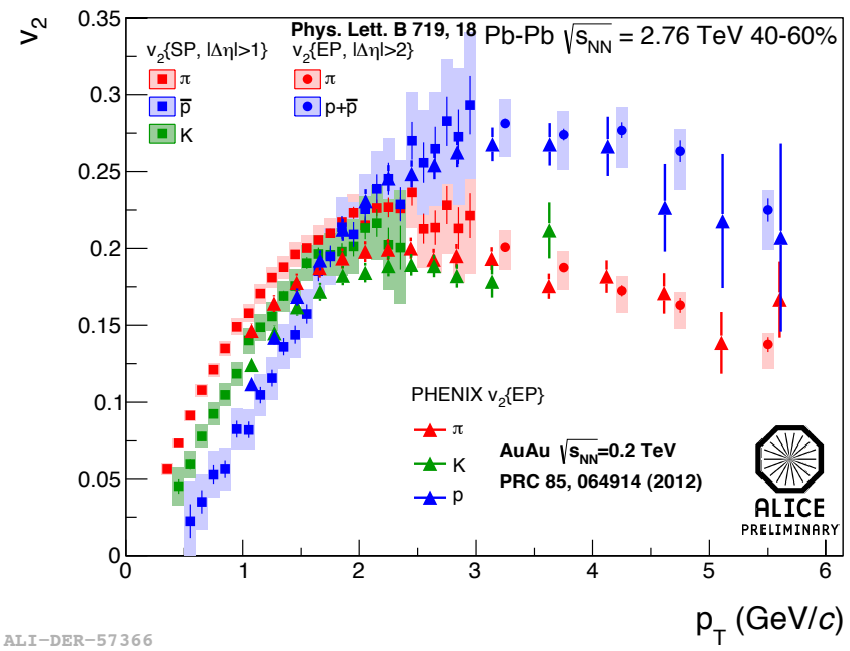
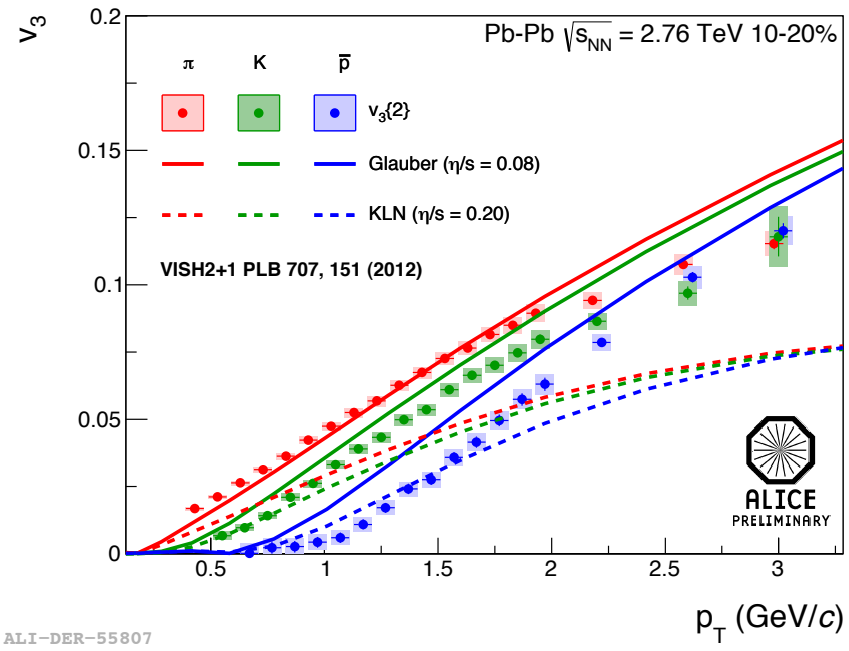


- v_2 measured at the LHC is slightly above the RHIC v_2 for π and K
- v_2 of p is lower at low p_T but higher at higher p_T at the LHC than at RHIC
  - reflects effect of larger radial flow at LHC

Triangular flow of π, K, p

10-20%



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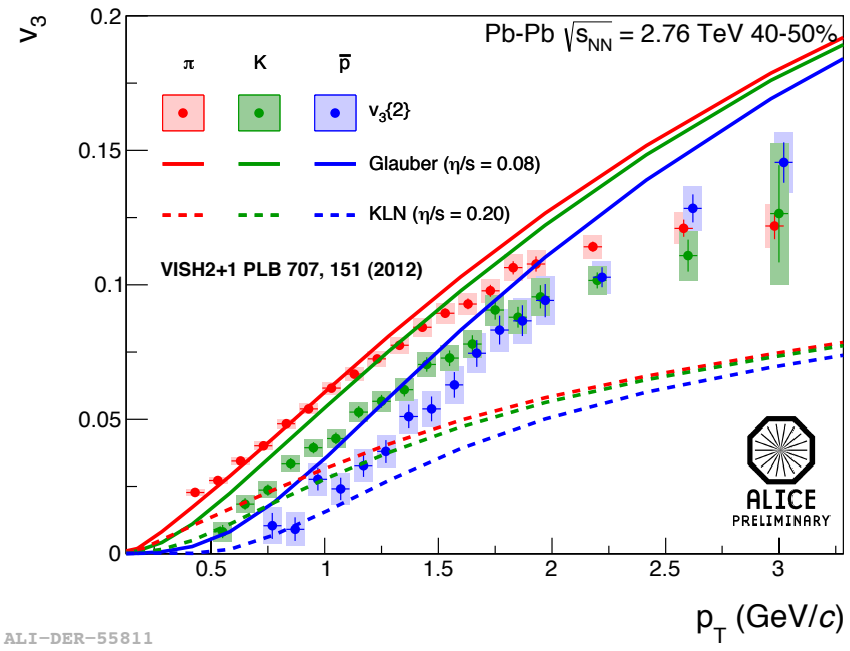

- At low p_T, we see mass ordering as expected from the hydro picture.
- v_3 of π and p cross at intermediate p_T as expected from coalescence.
- Further constrains for initial state models as well as the η/s.

KE_T scaling for v_3

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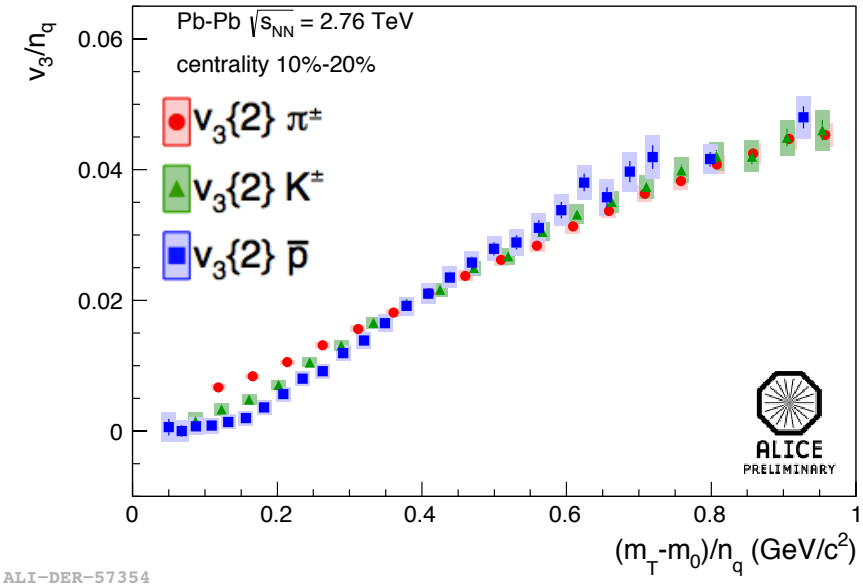

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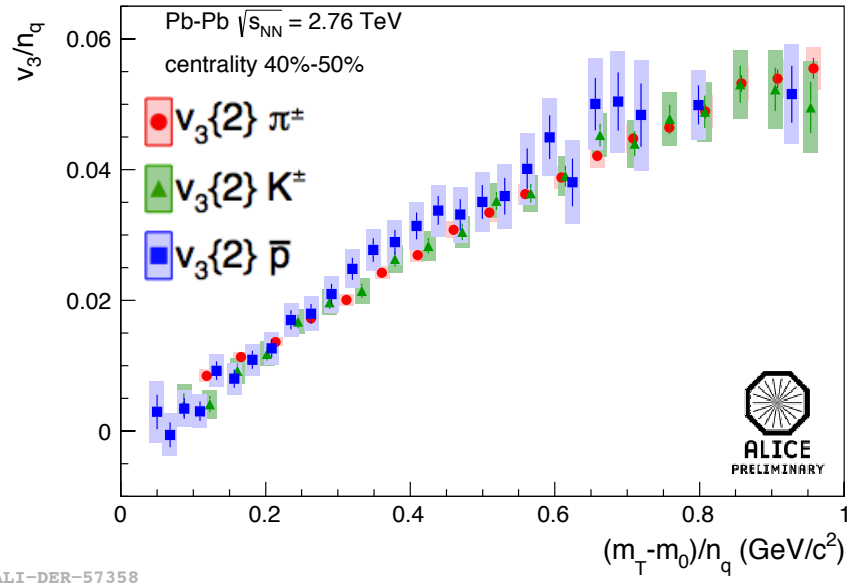
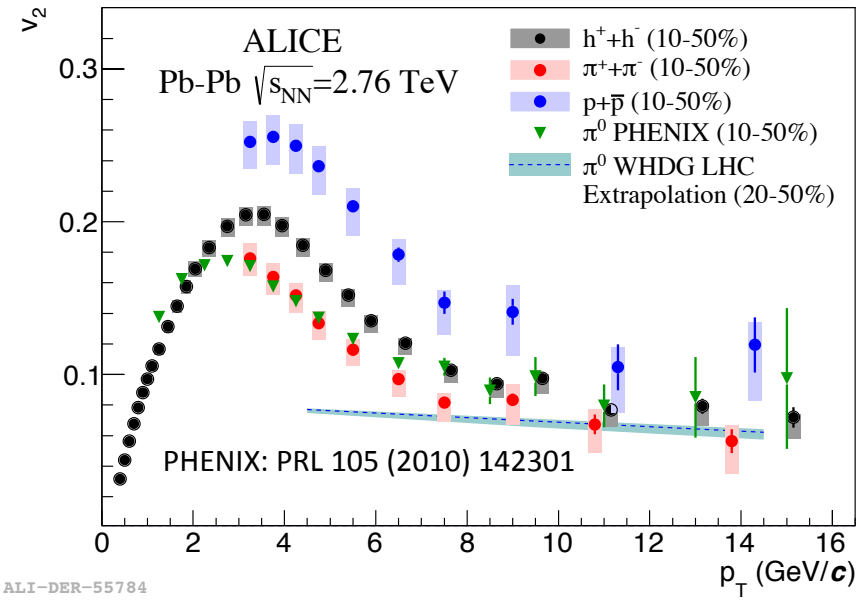


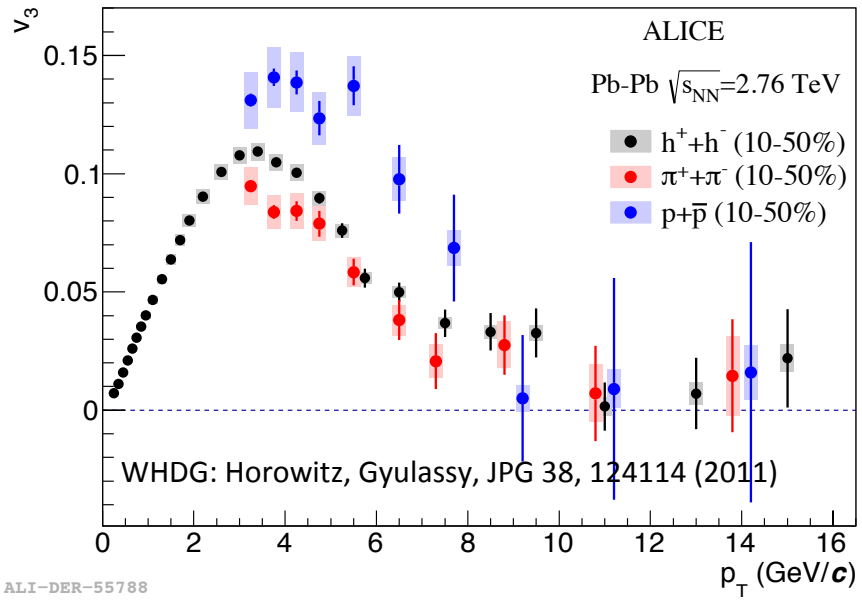
- NCQ scaling of v_3 works better than for v_2 but it is still only approximate

Elliptic flow and triangular flow at high p_T

ALICE: PLB 719 (2013) 18 v_2



ALICE: PLB 719 (2013) 18 v_3



- v_2 and v_3 of p are larger than that of π out to p_T = 8 GeV/c
  - agree with the picture that particle production includes interactions of jet fragments with bulk matter in this p_T region
- π v_2 is compatible with π^0 measured by PHENIX and π^0 calculation reproduced by WHDG for LHC
- π and p v_2 are consistent within uncertainties for p_T>10 GeV/c.

Summary

- Anisotropic flow of identified particles (including π, K, p, K_S^0, Λ, Ξ and Ω) are measured in 2.76 TeV Pb-Pb collision.
- For p_T < 3 GeV/***c*** :
  - observed mass dependence is reproduced by the hydrodynamic model calculations (VISH2+1)
  - The larger mass splitting of v_2 to higher p_T observed by ALICE is consistent with stronger radial flow at the LHC
  - v_3 of π, K, and p has a similar mass dependence and crossing point as that of v_2
- For p_T ~ 3-6 GeV/***c*** :
  - number of constituent quark scaling holds only approximately for v_2
  - KE_T scaling works better for v_3 than v_2
- For high p_T :
  - v_2 and v_3 of p are finite, positive and higher than that of π up to 8 GeV/***c***
  - v_2 of π and p are consistent within uncertainties for p_T >10 GeV/***c***

More flow studies in ALICE

ALICE contributions on PID Flow in SQM

- Heavy flavor decay μ v_2 (talk from X. Zhang)
  - 23 Jul 2013, 16:20-16:40, **Session:** Heavy Flavour 1
- D-meson flow (talk from E. Bruna)
  - 25 Jul 2013, 15:20-15:40, **Session:** Heavy Flavour 2
- PID $v_2\{2PC\}$ in pPb (talk from L. Milano)
  - 26 Jul 2013, 15:20-15:40**, Session:** p-A collisions
- Heavy flavor decay e v_2 (poster from A. Dubla)
  - 23 july 2013, 19:30-21:00, **Session**: poster

Thanks for your attention!