Linear, non-Linear flow and flow correlations at ALICE

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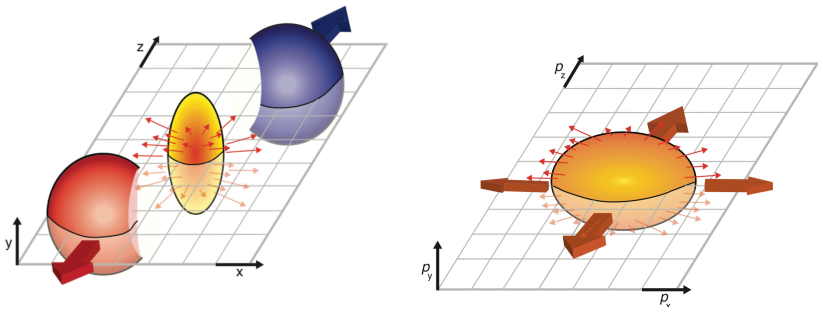
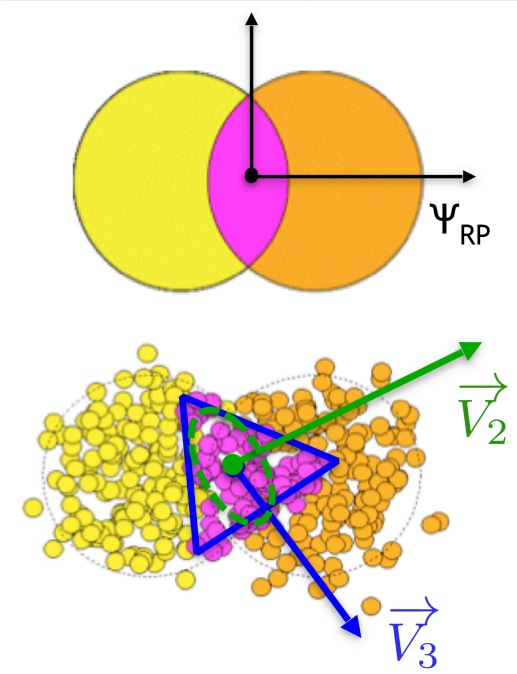
Flow and correlations



$$\frac{dN}{d\varphi} \propto \Sigma_{n=1}^{\infty} v_n(p_T) \cos(n(\varphi - \Psi_n))$$



- Flow harmonics constrain initial conditions and transport properties.
- Can be defined with particles correlations.

S. Voloshin, Y. Zhang, Z.Phys.C70:665-672,1996

Initial anisotropy and final state flow

$$V_n = V_n^{\mathrm{L}} + V_n^{\mathrm{NL}} \quad (n > 3)$$

Linear response

Non-linear response

$$V_4 = V_4^{\mathrm{NL}} + V_4^{\mathrm{L}} = \chi_{4,22}(V_2)^2 + V_4^{\mathrm{L}}$$

$$V_5 = V_5^{\mathrm{NL}} + V_5^{\mathrm{L}} = \chi_{5,32} V_3 V_2 + V_5^{\mathrm{L}}$$

$$V_6 = V_6^{\mathrm{NL}} + V_6^{\mathrm{L}} = \chi_{6,222}(V_2)^3 + \chi_{6,33}(V_3)^2 + \chi_{6,24} V_2 V_4^{\mathrm{L}} + V_6^{\mathrm{L}}$$

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Correlations between V_m and V_n

Symmetric Cumulant: SC(m,n)

$$SC(m,n) = \langle v_m^2 v_n^2 \rangle - \langle v_m^2 \rangle \langle v_n^2 \rangle$$

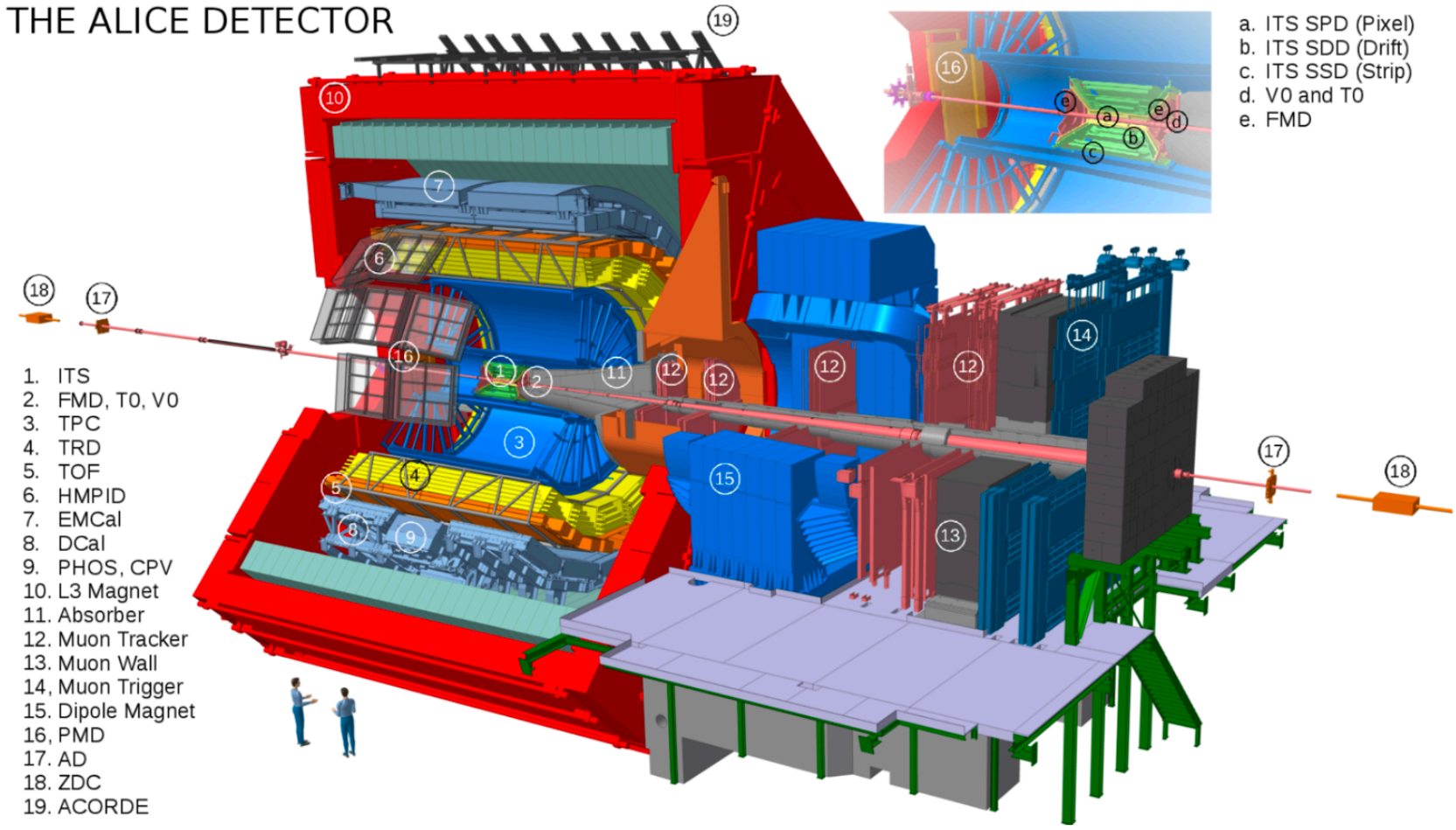
Normalized Symmetric Cumulant: NSC(m,n)

$$NSC(m,n) = SC(m,n)/\langle v_m^2 \rangle \langle v_n^2 \rangle$$

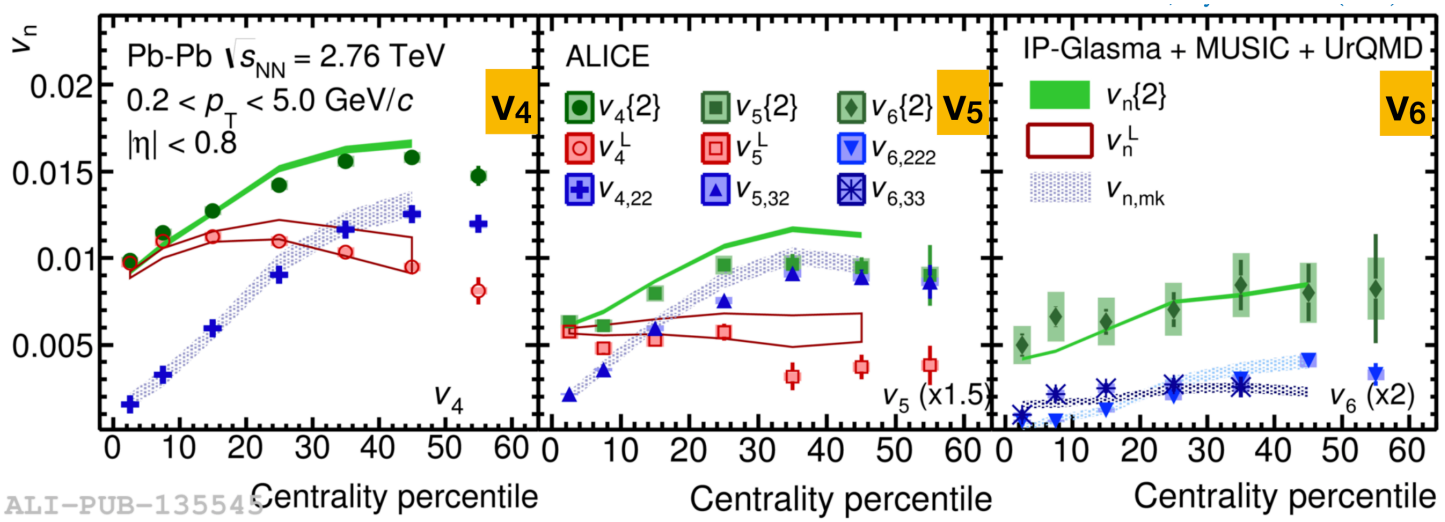
- sensitive to initial conditions and/or η/s.
- insensitive to non-flow effects.

PRC 89,064904 (2014)

ALICE detector

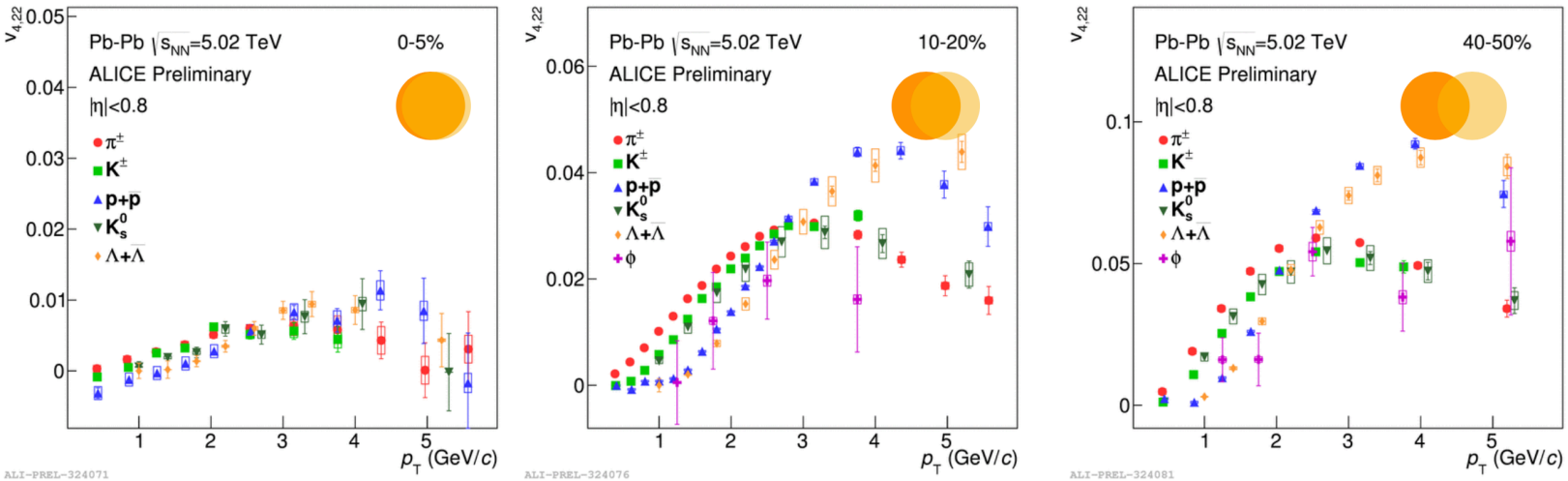


Linear and non-linear flow in Pb-Pb



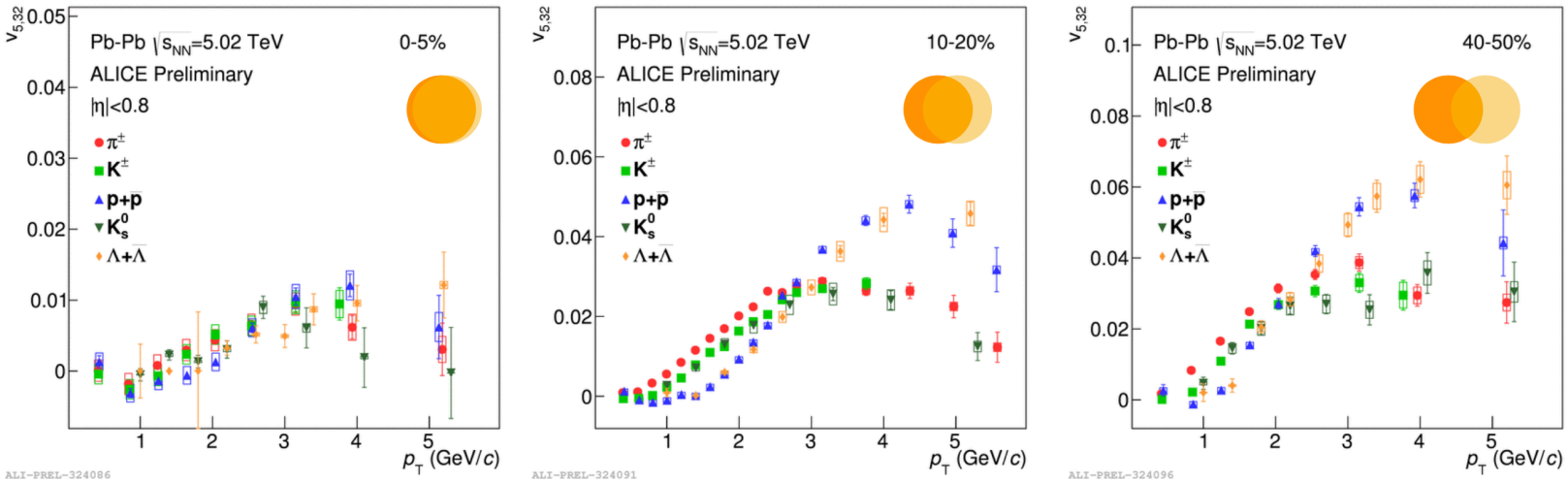
- Non-linear mode is increase with increasing centrality while linear is weakly centrality dependent.
- Well described by IP-Glasma + MUSIC + UrQMD.

$v_{4,22}$ for identified particles in Pb-Pb



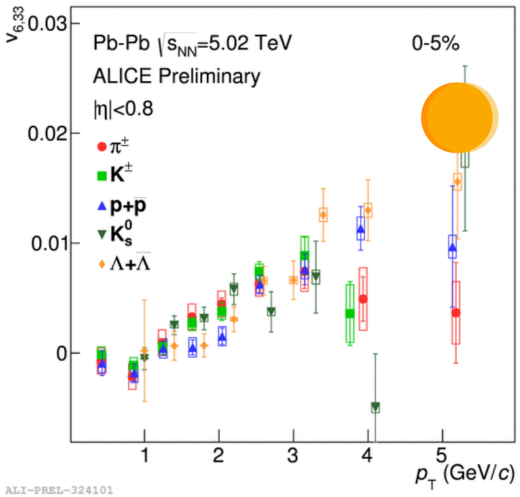
- Clear centrality dependence observed.
- Mass ordering in low p_{T} region and particle type grouping in the intermediate p_{T} region.

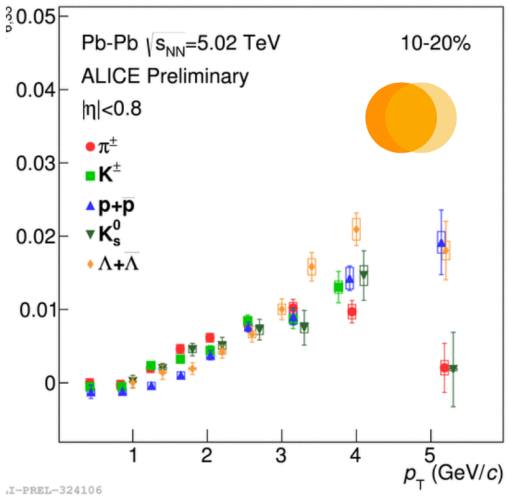
$v_{5,32}$ for identified particles in Pb-Pb

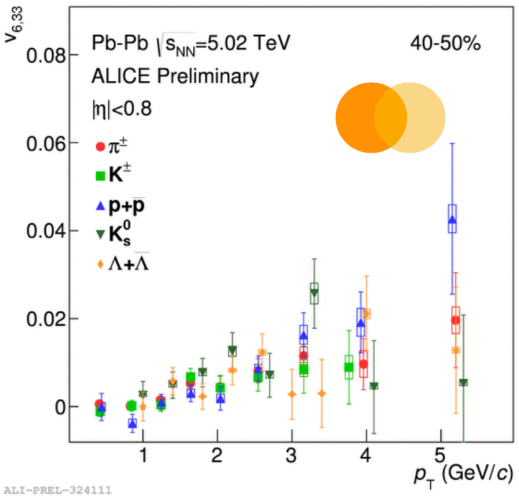


- Clear centrality dependence observed.
- Mass ordering in low p_{T} region and particle type grouping in the intermediate p_{T} region.

$v_{6,33}$ for identified particles in Pb-Pb

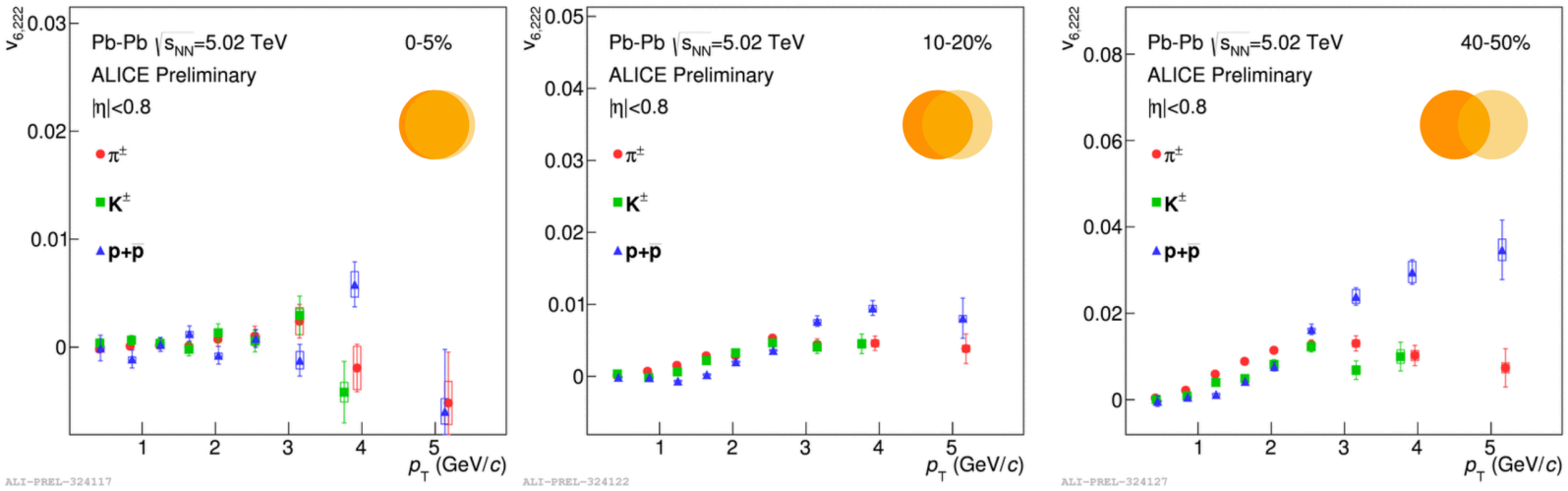






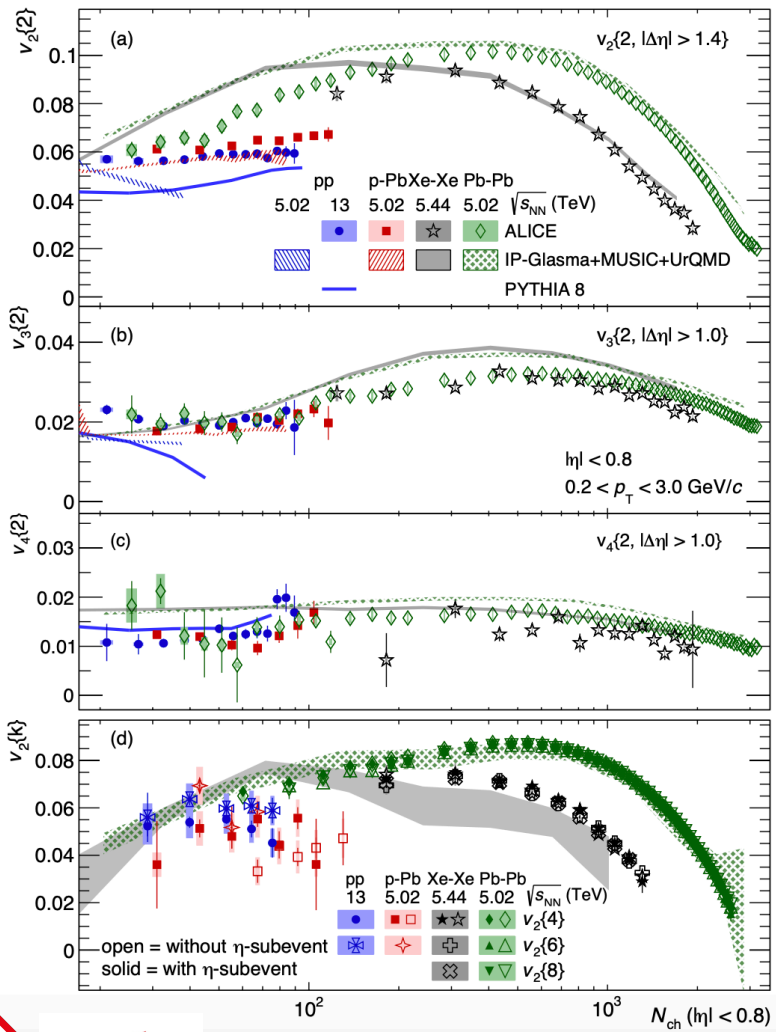
- No clear centrality dependence observed.
- No clear mass ordering particle type grouping.

$v_{6,222}$ for identified particles in Pb-Pb



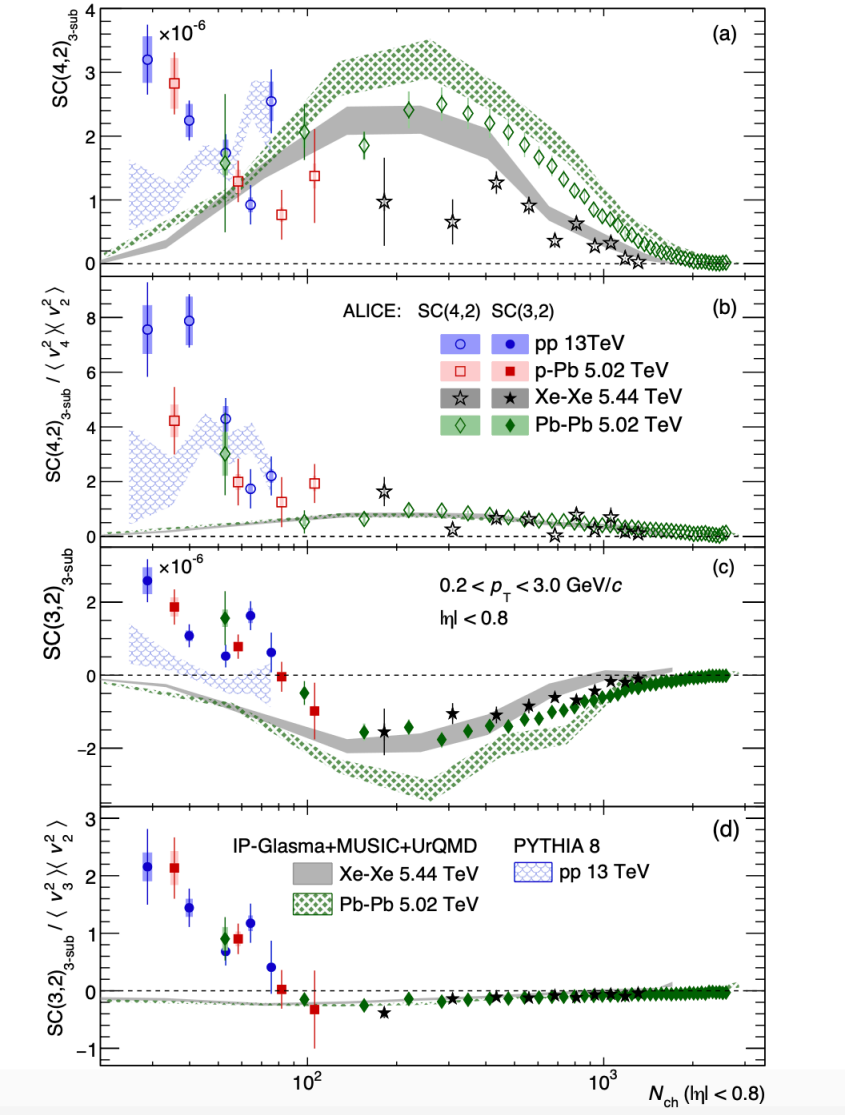
- Clear centrality dependence observed.
- Mass ordering in low p_{T} region and particle type grouping in the intermediate p_{T} region.

Anisotropic flow coefficients $v_n\{k\}$



- Measurements of anisotropic flow coefficients $v_n\{k\}$ of order n, obtained from k-particle correlations, in pp, p–Pb, Xe–Xe and Pb–Pb collisions.
- At low multiplicity, the magnitudes of v_n in large system are similar to those measured in pp and p–Pb collisions.
- In small collision systems, all the v_n coefficients exhibit a weak dependence on multiplicity.

Symmetric cumulants SC(m,n)



- Measurements of SC(4,2), SC(3,2) and the normalized ones, in pp, p–Pb, Xe–Xe and Pb–Pb collisions.
- The of trend SC(4,2) and SC(3,2) are reproduced by the IP-Glasma+MUSIC+UrQMD calculations.
- In small collision systems, at low multiplicity region, the SC(3,2) shows a positive sign.

Conclusion and perspectives

- Recent results of linear flow, non-linear flow and flow correlations are presented and discussed.
- More flow variables are needed to be measured across large and small systems to get a coherent understanding of flow.