WG3: High multiplicities (small systems)

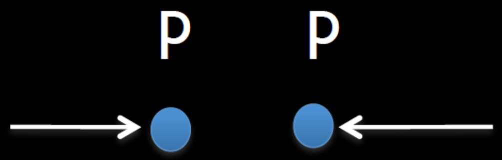
SUMMARY

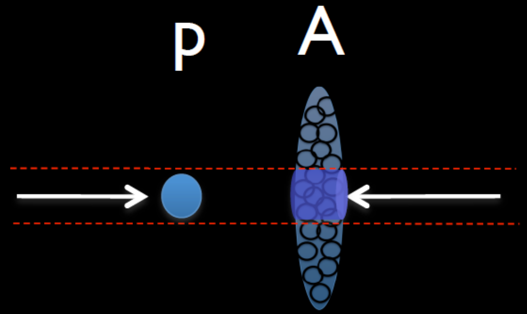
Carlota Andres
Małgorzata Anna Janik

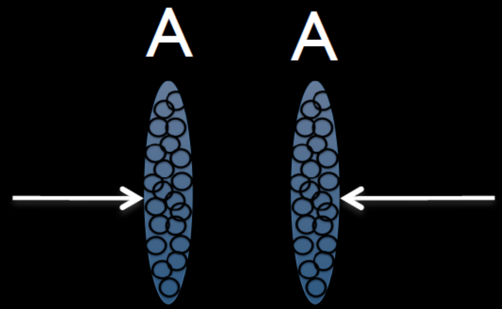
MPI@LHC Workshop

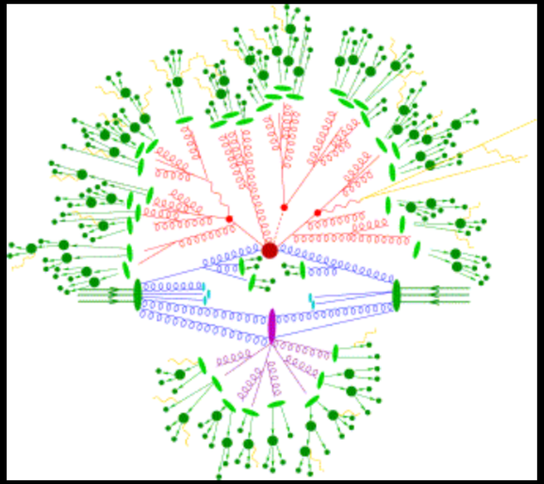
Madrid 14-18.11.2022

Using pp and pA to cleanse AA from initial state physics (early 2000's)

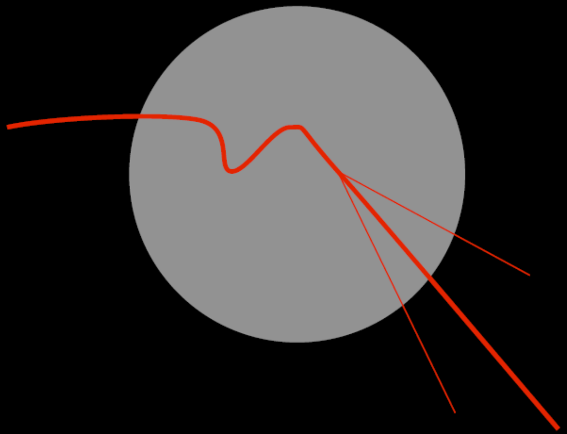




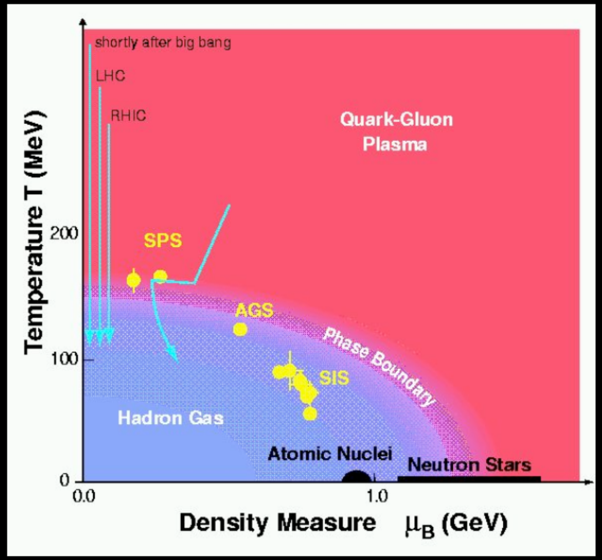




Local structure of QCD
vacuum

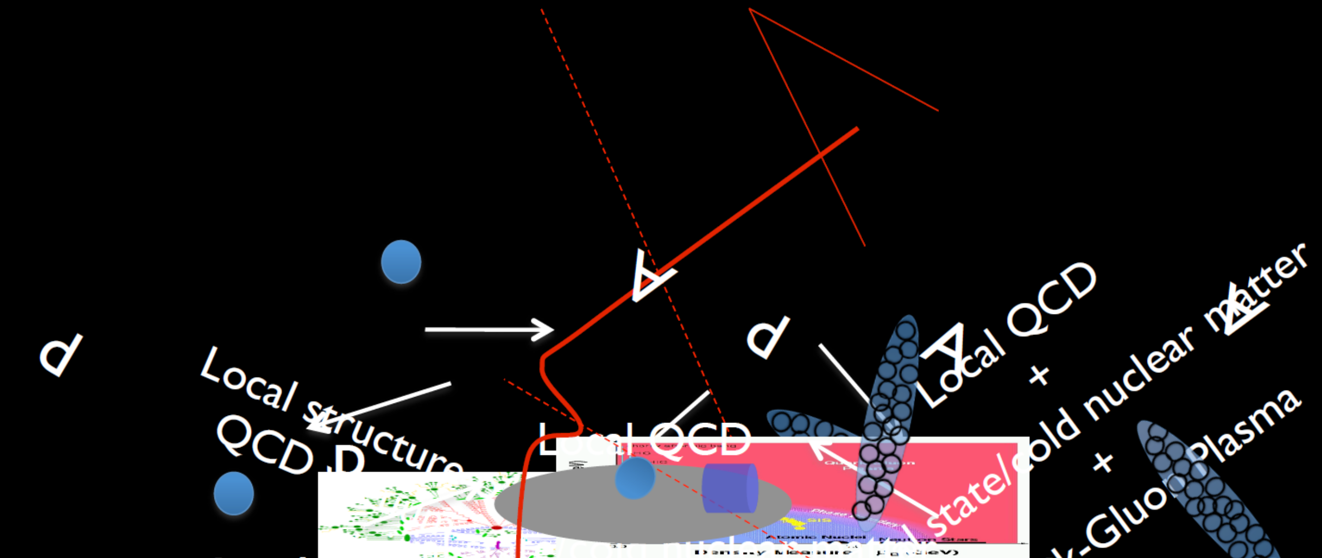


Local QCD
+
initial state/cold nuclear matter



Local QCD
+
initial state/cold nuclear matter
+
Quark-Gluon Plasma

Fig. G. Roland

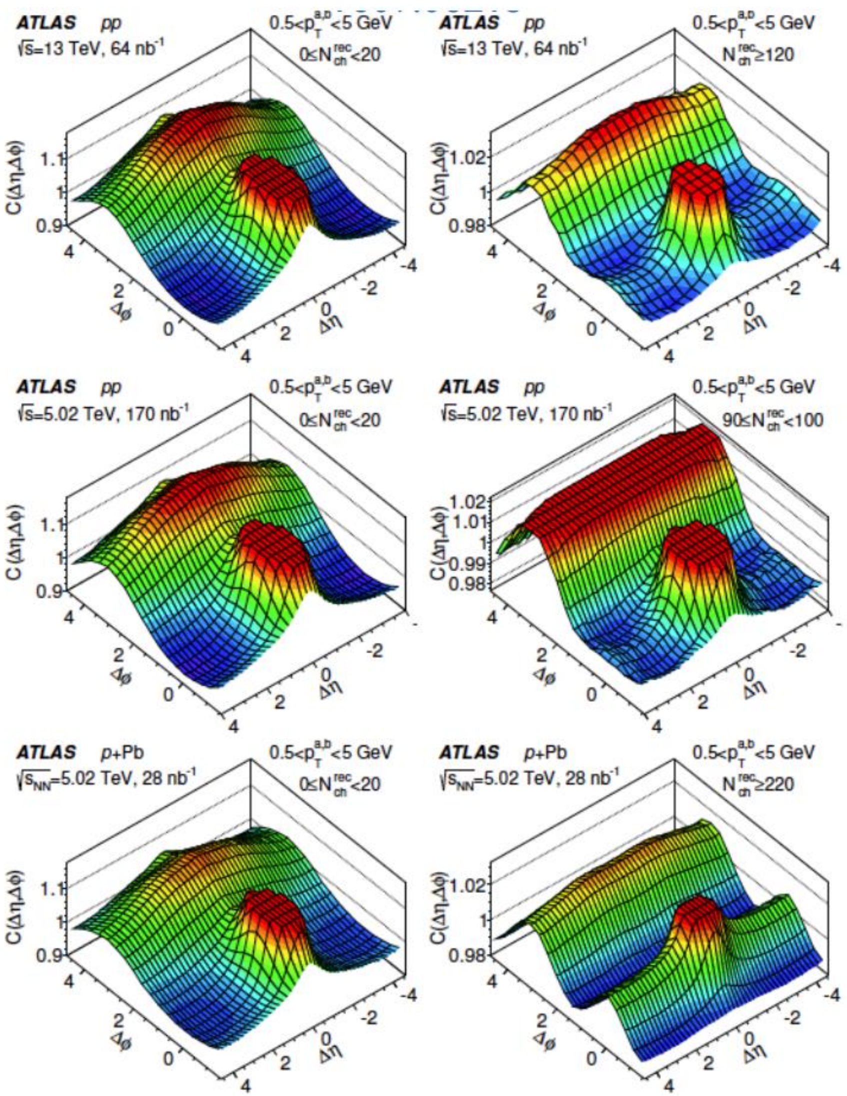


Using pp and pA to cleanse AA from initial state physics

Two particle correlations

Motivation: Ridge structure

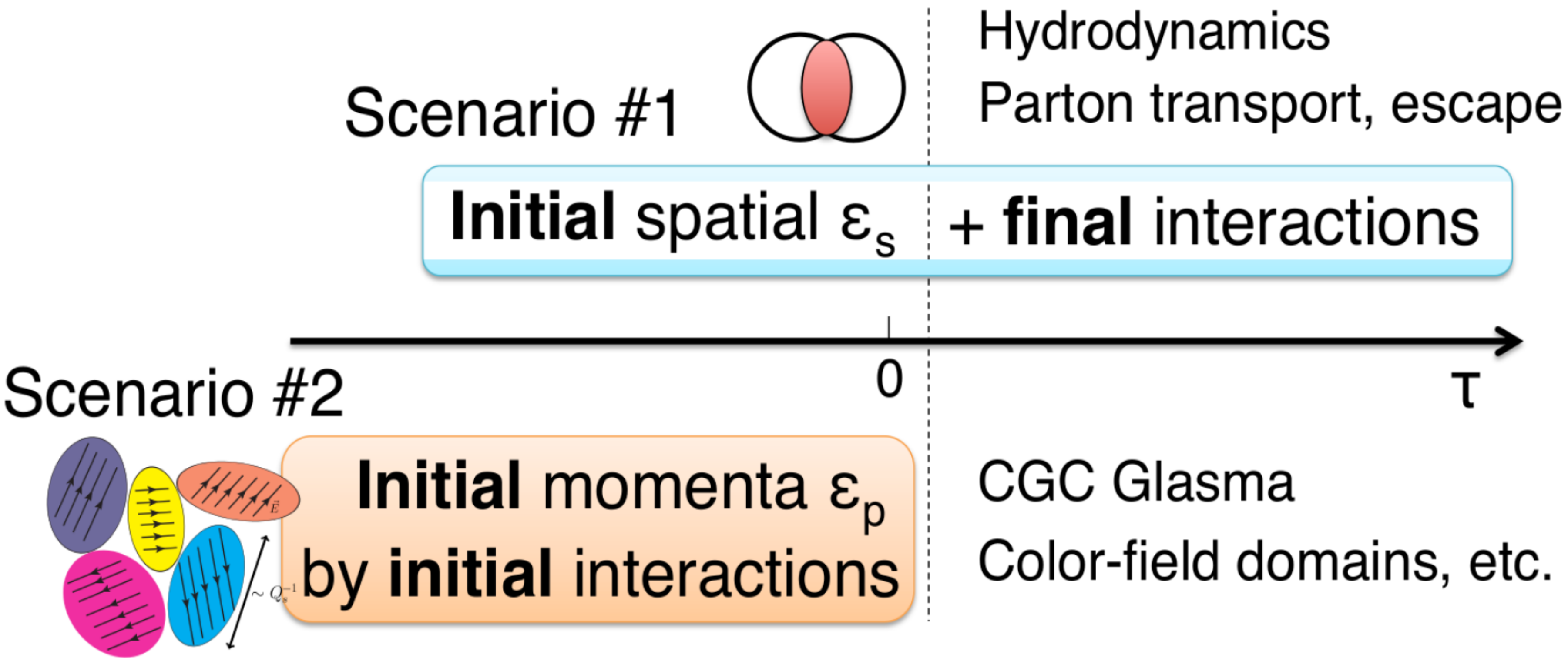
[ATLAS Collaboration - arXiv:1609.06213]



- *correlations between particles over large intervals of rapidity peaking at zero and π relative azimuthal angle.*
- observed first at RHIC in Au-Au collisions.
- observed at LHC for high multiplicity pp and pA collisions.

Collective-like effects in small systems

Lucia Olivia



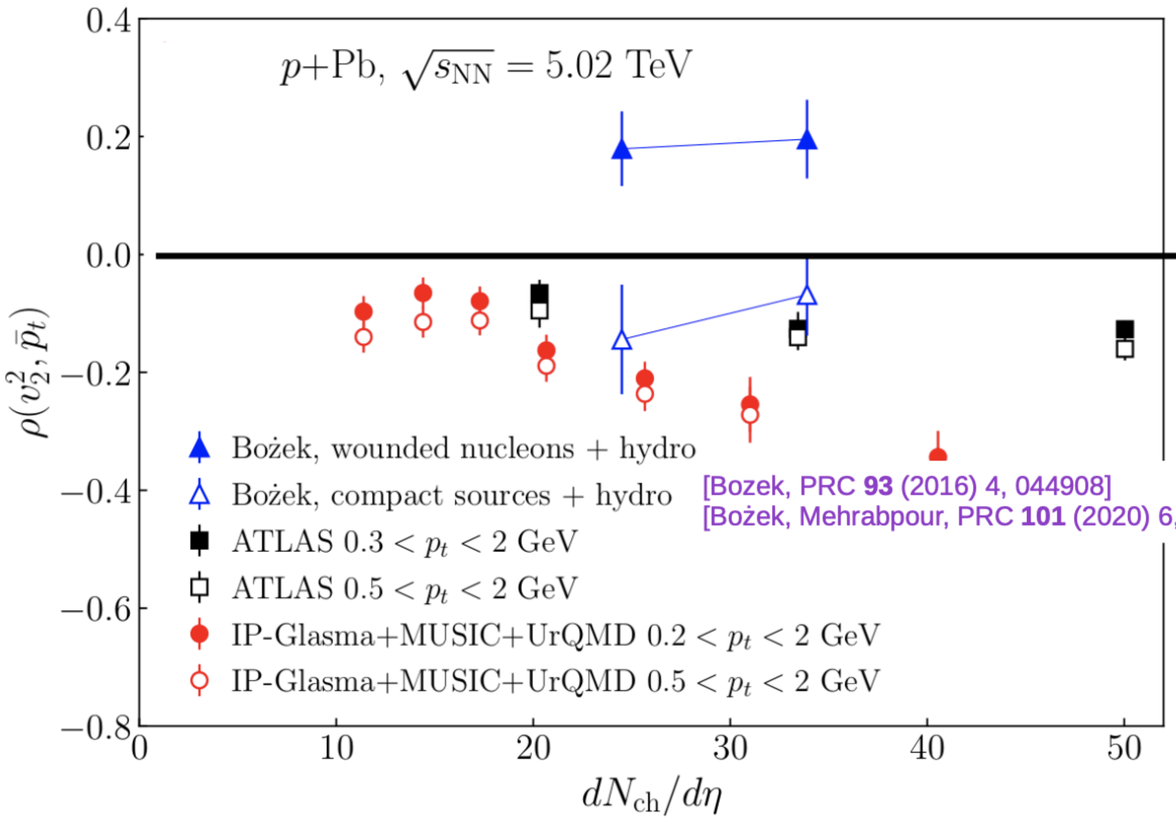
Tolga Altinoluk – CGC
Victor Vila – CGC

Collectivity in small systems

Giuliano Giacalone, Thu. 14:30

Small systems to study as a tool to study the onset of hydrodynamic behavior

[ATLAS collaboration, EPJC **79** (2019) 12, 985]



[Bozek, PRC **93** (2016) 4, 044908]
[Bożek, Mehrabpour, PRC **101** (2020) 6, 064902]

wounded nucleons

$$(T_A + T_B)$$

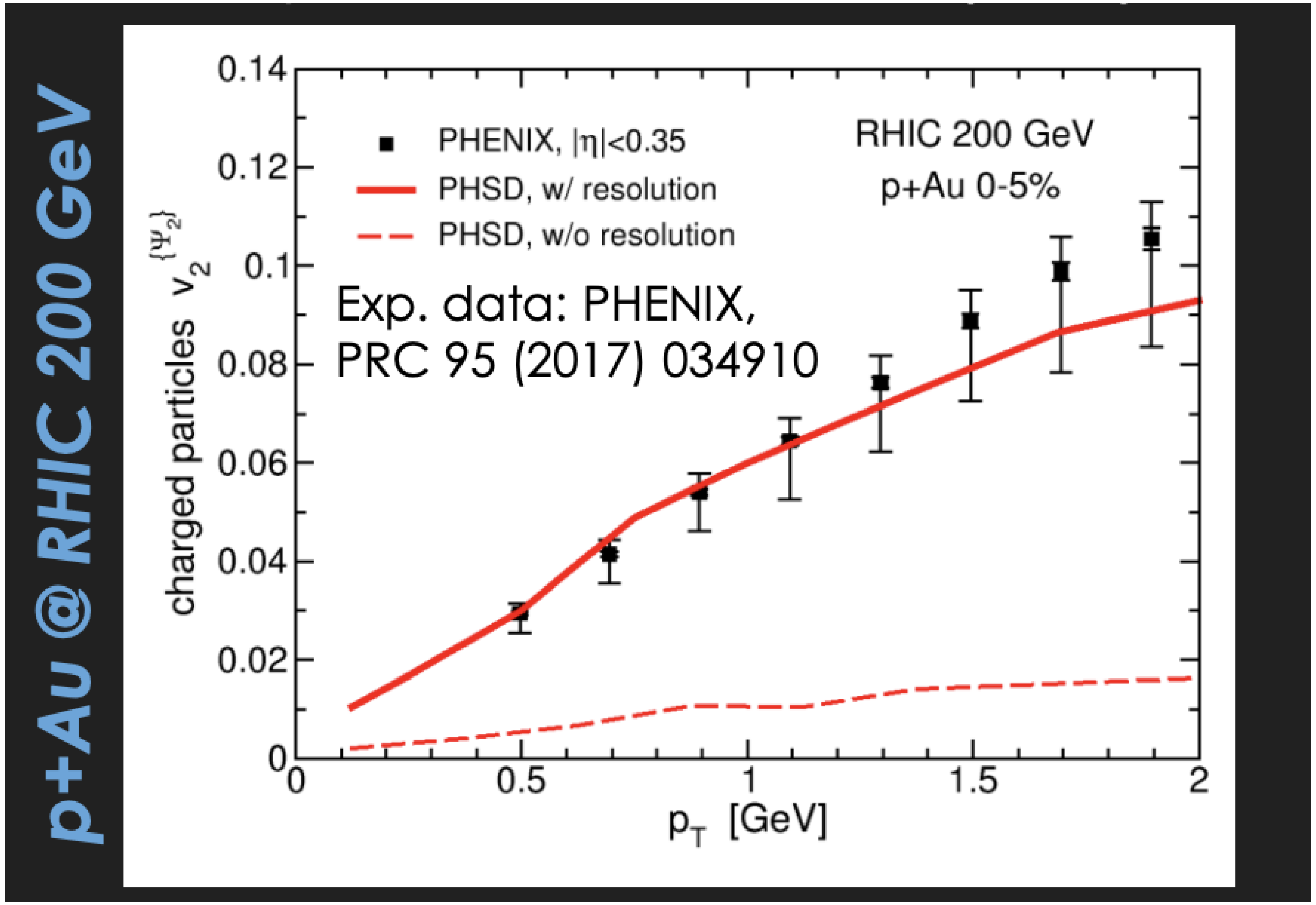
CGC- or TRENTo-like

$$\left(T_A(\mathbf{x})T_B(\mathbf{x})\right)^q$$

Signature of sub-nucleonic structure!

Collectivity in small systems: transport models

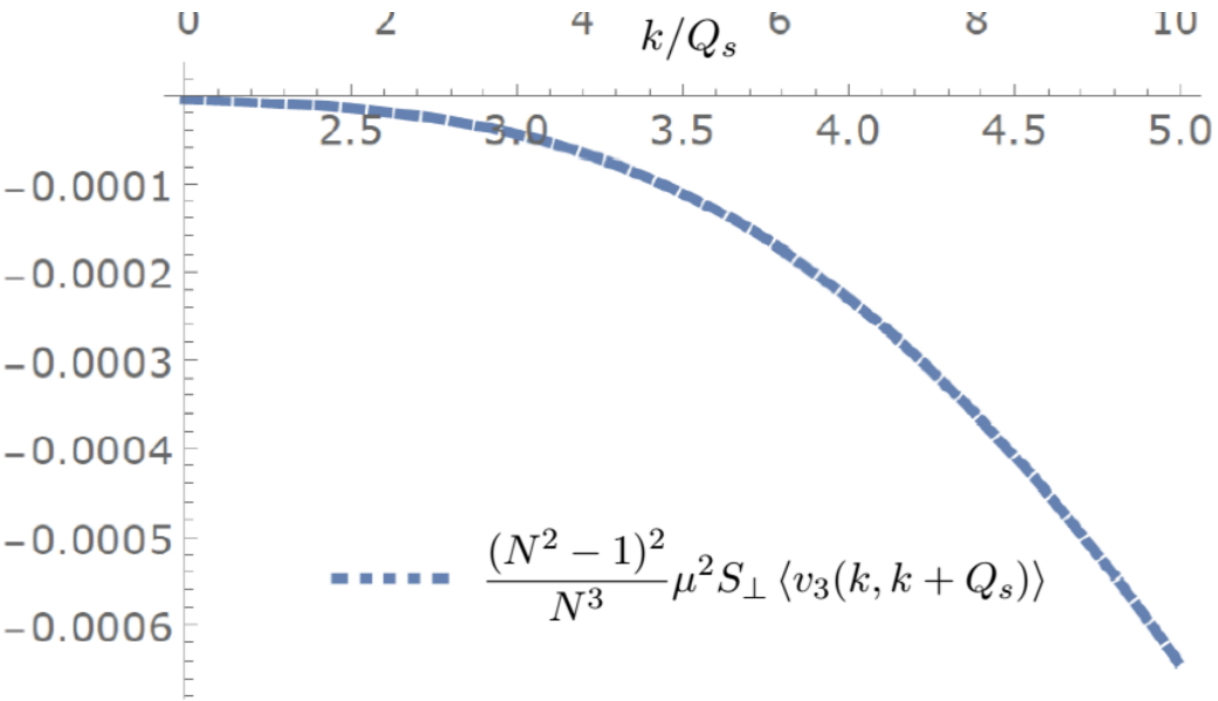
The elliptic flow in pA can be also described in transport models as the PHSD



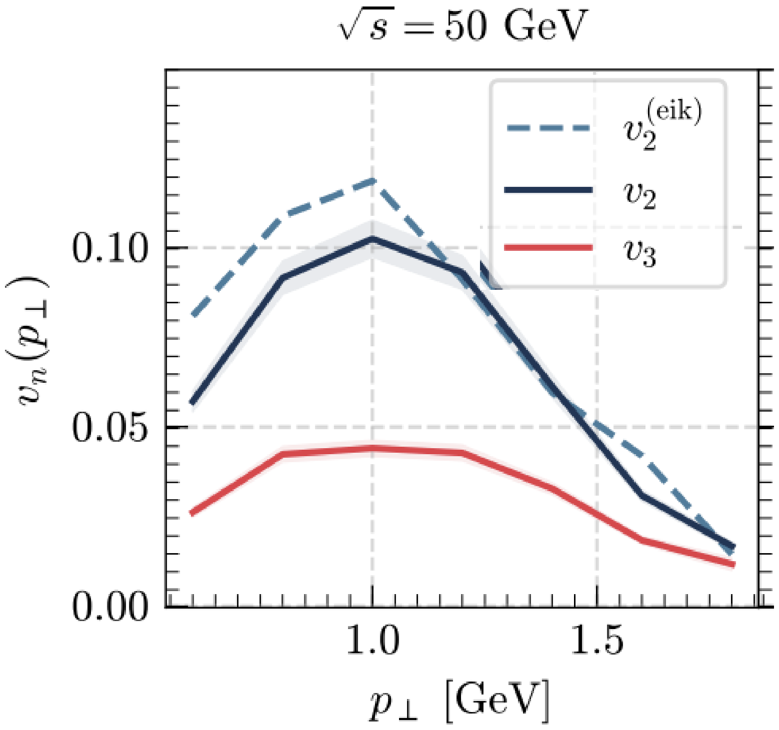
Lucia Oliva,
Mon 18:30

CGC calculations

- Generating non vanishing odd harmonics in the CGC
  - Going beyond the Glasma graph approximation in the projectile (Vila)
  - Going beyond eikonal in the target (Altinoluk)



Kendi ,Marquet, Vila, in preparation



Agostini, Altinoluk, Armesto, in preparation

Experimental results on flow on small systems

Elliptic flow in Pb-Pb

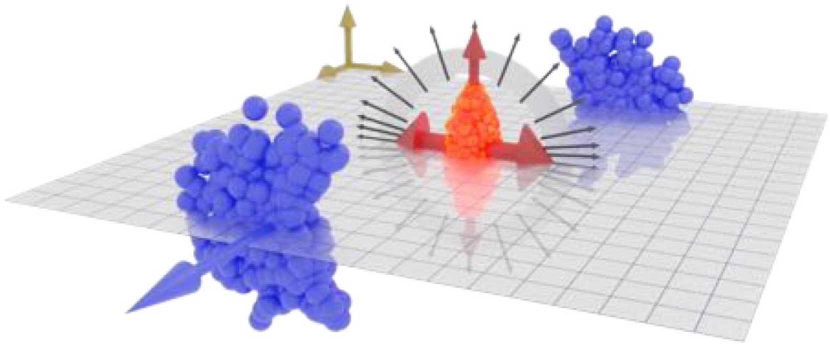


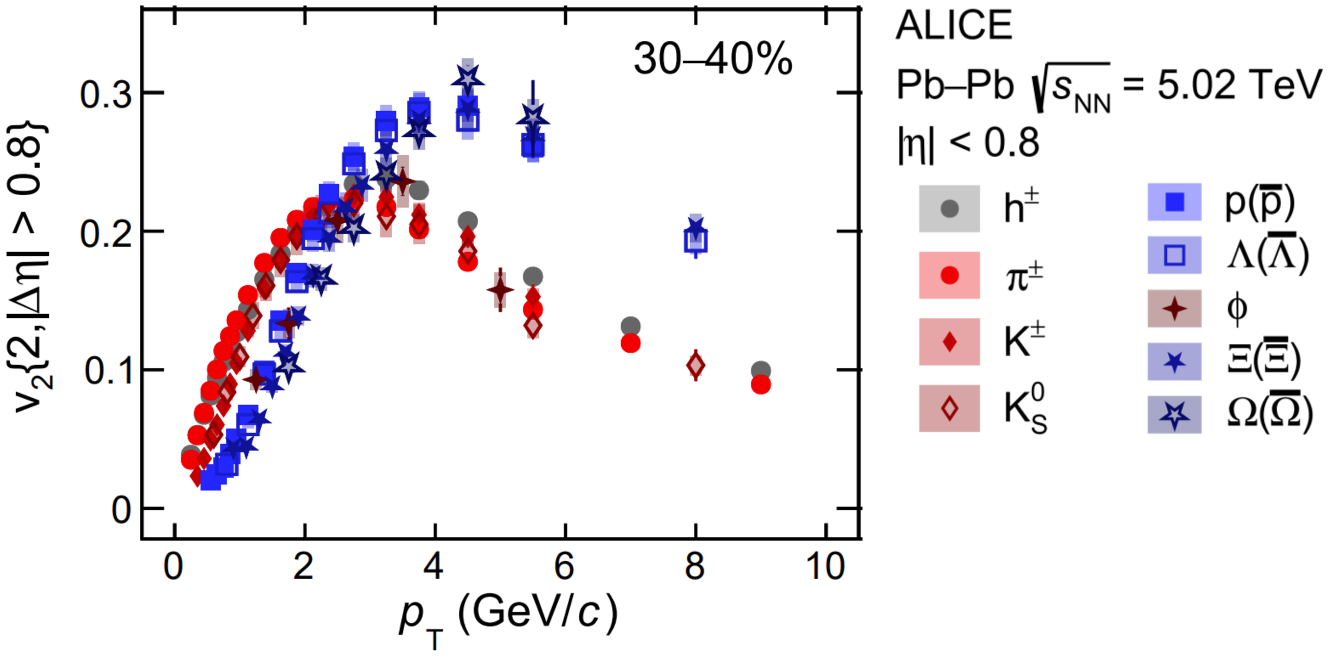
Fig. D. Chinnelato

v_2 – tool to study the flow of produced particles

- non-central collisions : elliptical geometry
- expansion (flow) → azimuthal modulation in momentum
- azimuthal mom. distribution → **decomposed into a Fourier expansion**, with anisotropic flow coefficients:

$$\frac{dN}{Nd\phi} = 1 + 2v_2\cos\left(2(\phi - \Psi_{RP})\right) + \textit{higher harmonics } (v_3, v_4, \ldots)$$

arXiv: 2206.04587



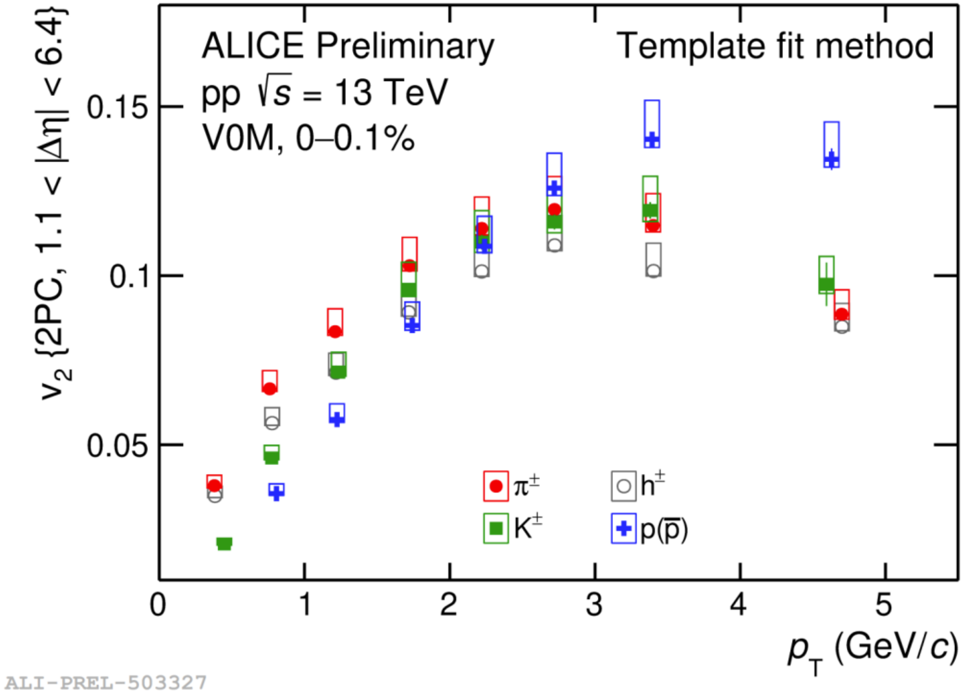
Mass ordering at low p_T:
described by hydrodynamics

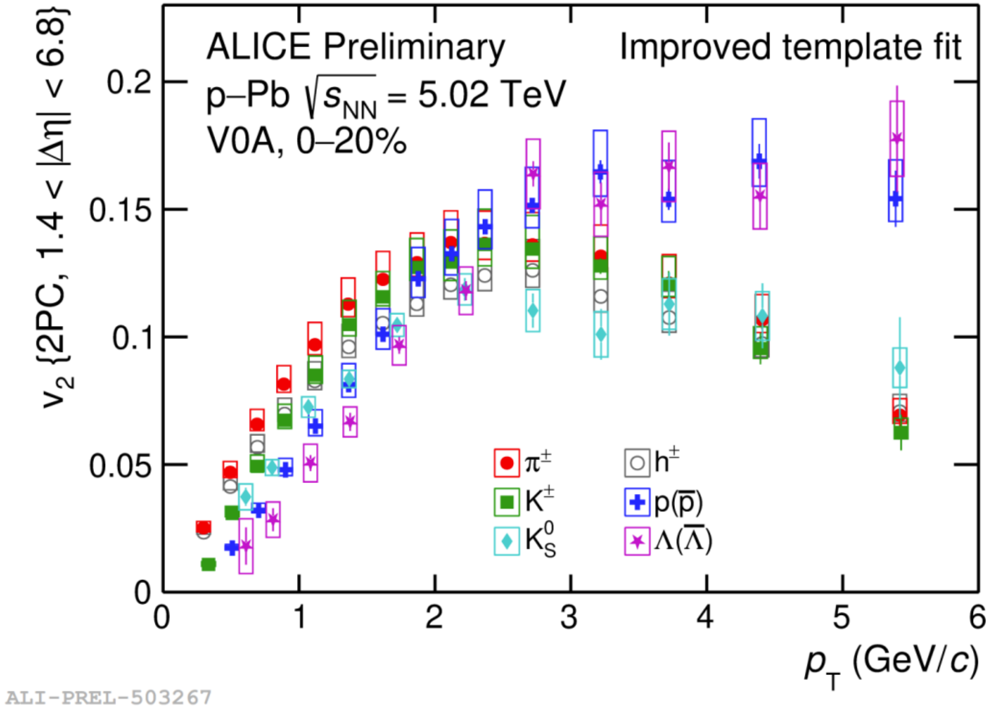
Baryon vs meson splitting **at high p_T:**
quark-level flow + recombination

Elliptic flow in small systems

Zuzana Moravcova, Thu. 16:30

- **Mass ordering at low p_T: described by hydrodynamics**
- **Baryon vs meson splitting at high p_T: quark-level flow + recombination**



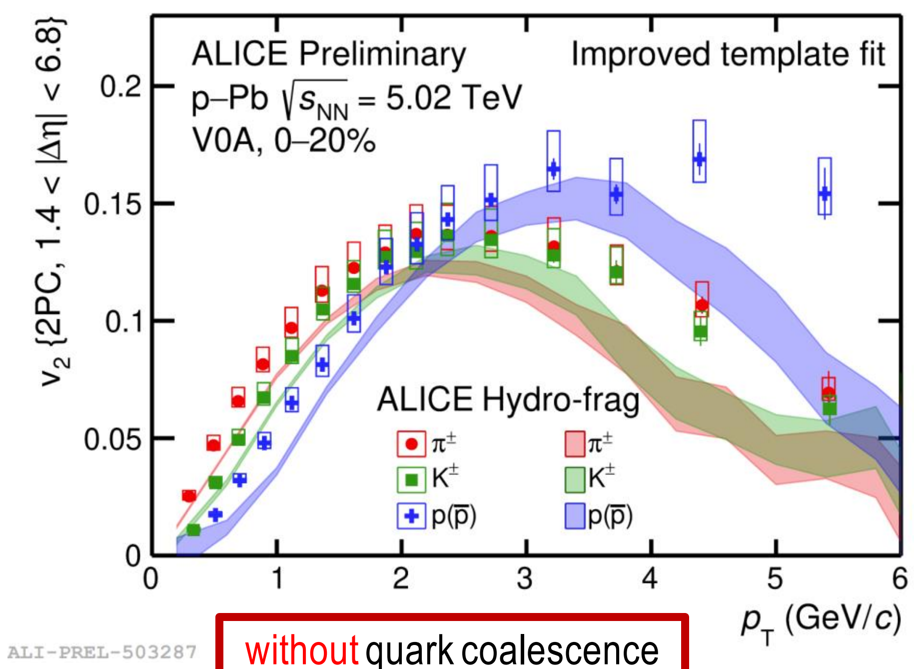


- **Characteristic flow behaviors of Pb-Pb have been observed in pp and p-Pb!**

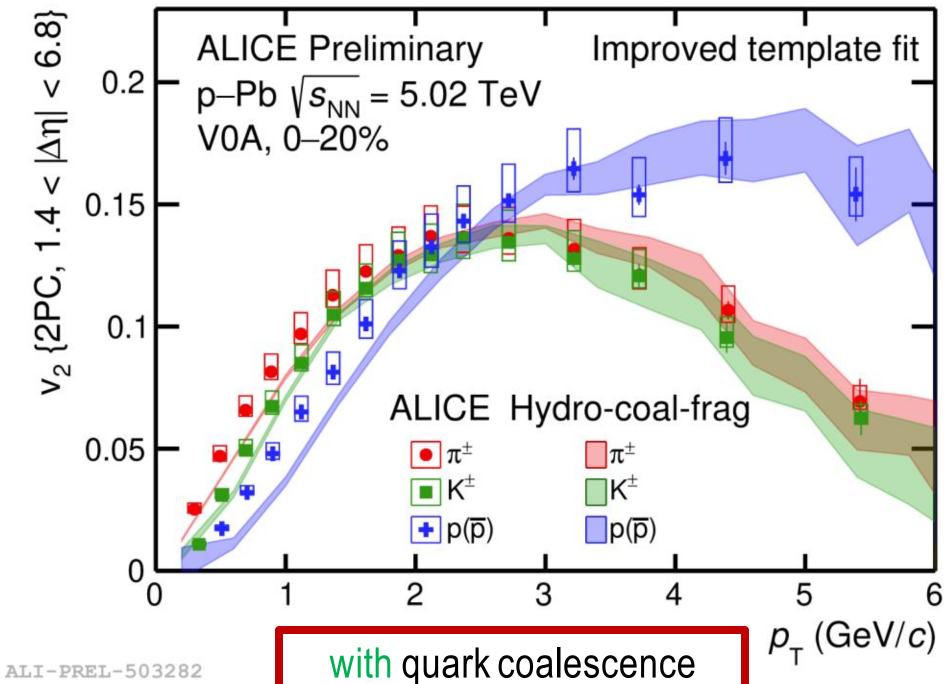
Flow of partons in small systems

Zuzana Moravcova, Thu. 16:30

- Mass ordering at low p_T: described by hydrodynamics
- Baryon vs meson splitting at high p_T: quark-level flow + recombination



without quark coalescence



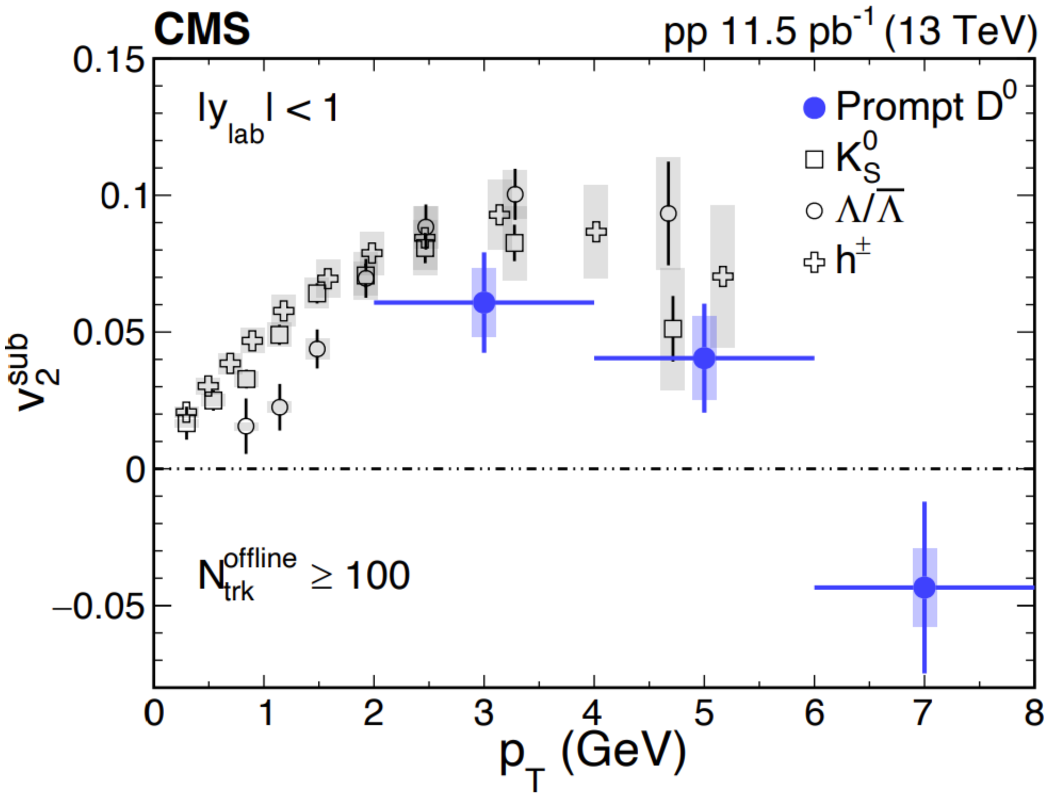
with quark coalescence

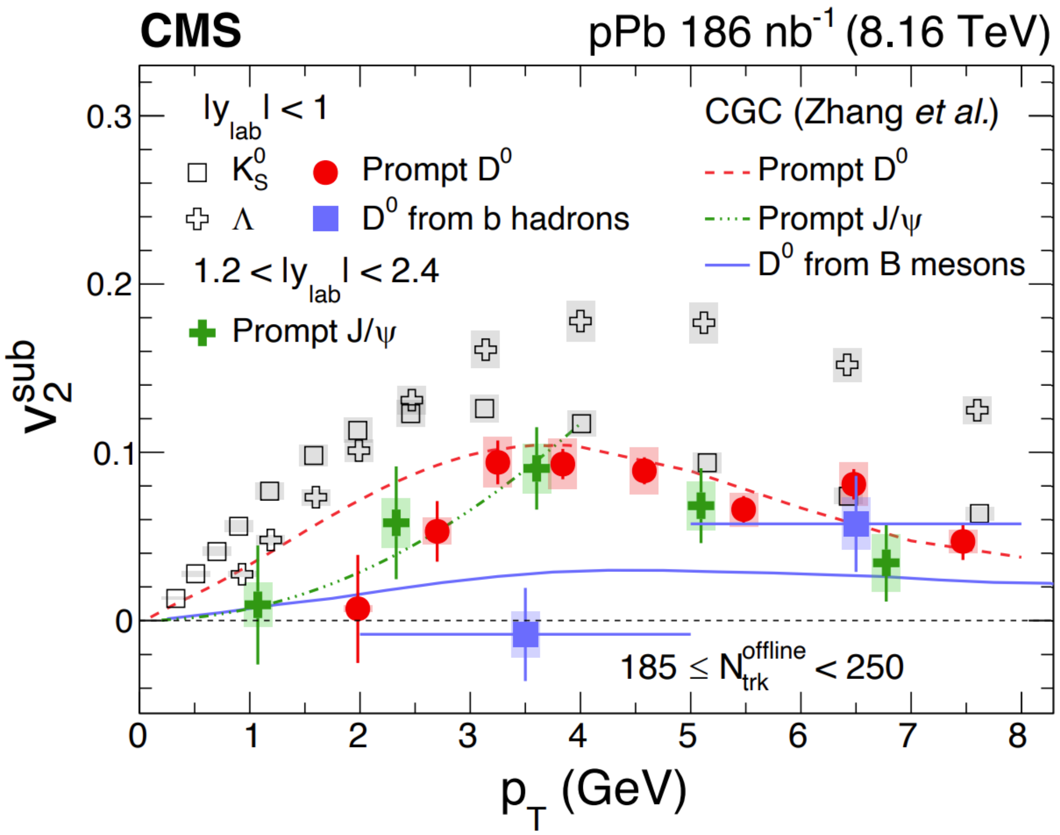
- Model without quark coalescence cannot qualitatively describe trends seen in data
- Indication of partonic flow in small systems

Flow of partons in small systems

Valentina Mariani, Tue. 10:30

- Mass ordering at low p_T: described by hydrodynamics
- for the first time for prompt D0 in pp and nonprompt D0 in pPb

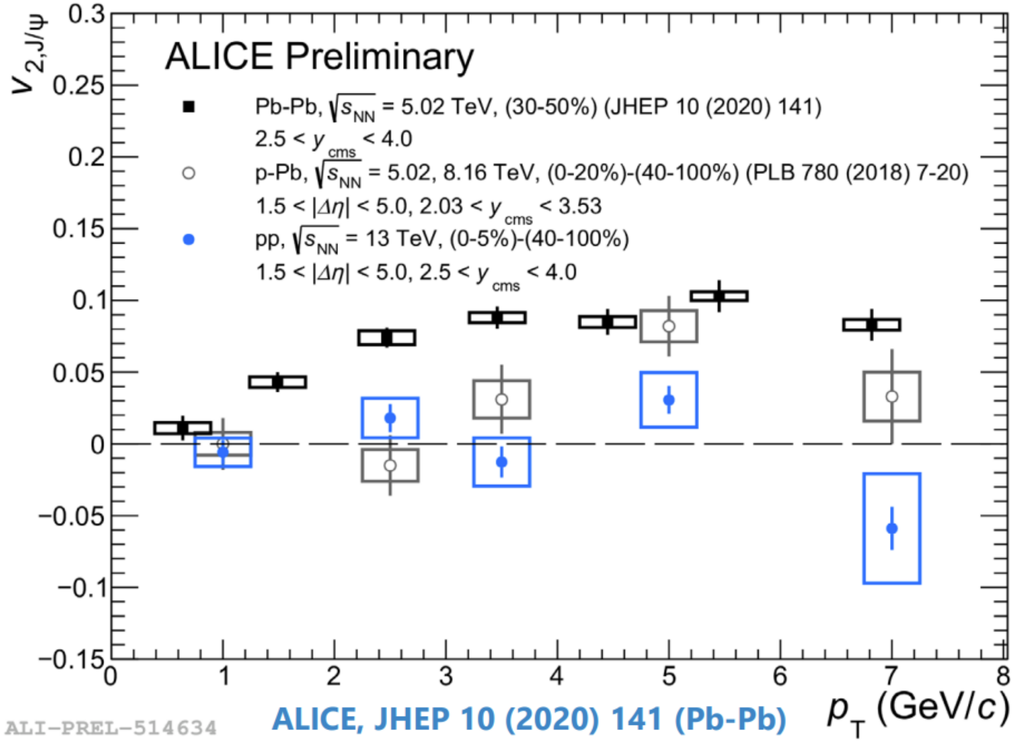




- indications of collectivity of charm quarks in pp collisions
- indications of mass dependence of heavy-flavor hadron v2 in the pPb

J/Ψ ELLIPTIC FLOW IN SMALL SYSTEMS

Fabio Colamaria, Thu. 12:30

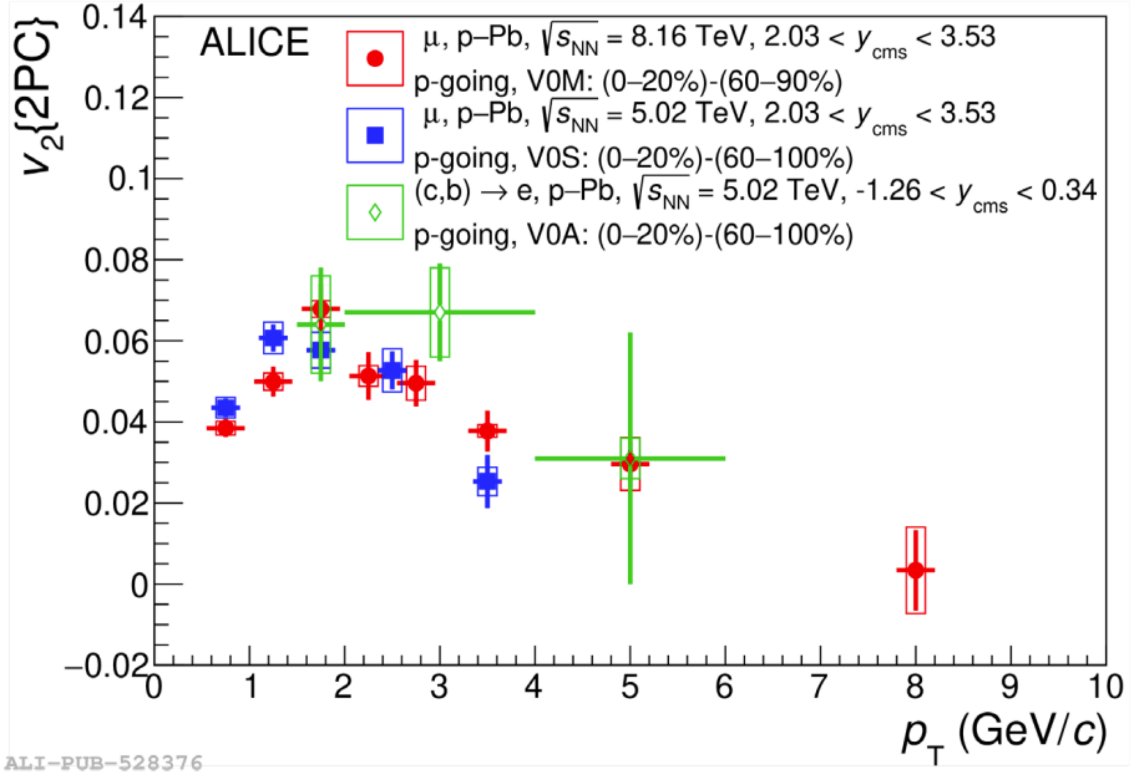


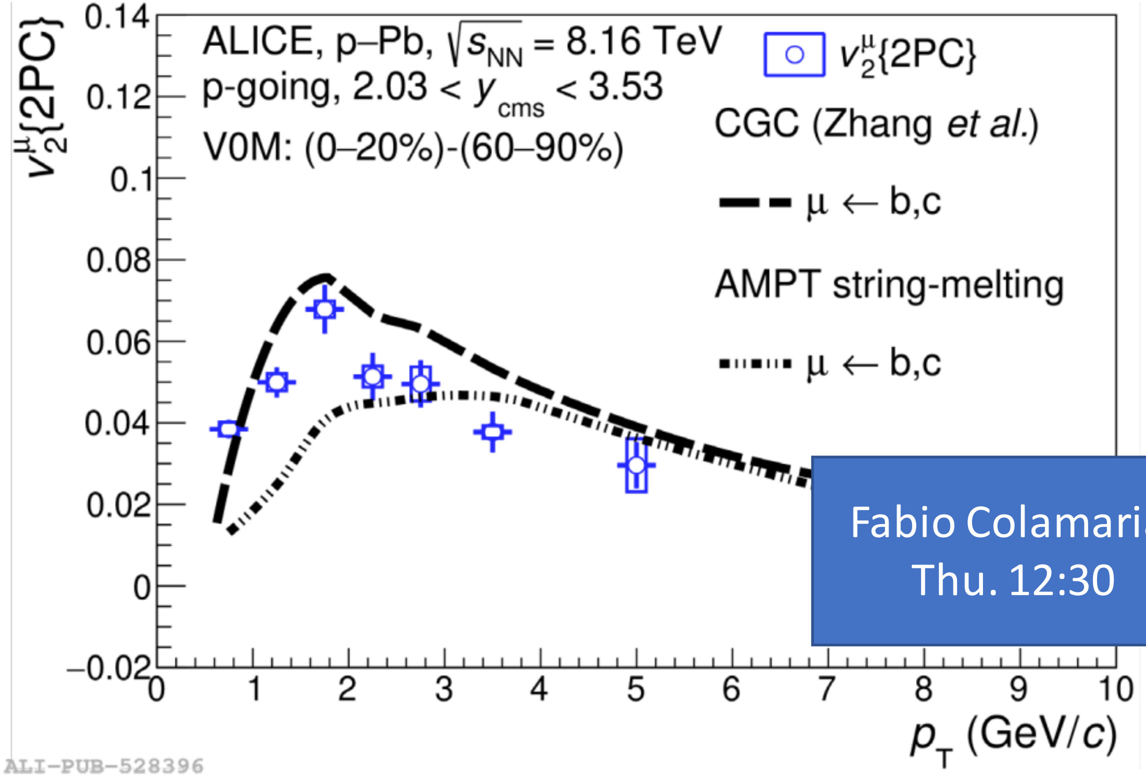
ALICE, JHEP 10 (2020) 141 (Pb-Pb)
ALICE, PLB 780 (2018) 7-20 (p-Pb)

- Investigate the presence of **collective motion in high-multiplicity pp and p-Pb** events for J/Ψ, and compare with Pb-Pb results
- **Pb-Pb collisions:**
  - Presence of **strong collective effects**
- **p-Pb collisions:**
  - **Significant flow** for p_T > 3 GeV/c, not explained by transport models
- **pp collisions (new):**
  - **No hints** of collective behaviour observed for J/Ψ within uncertainties

- Presence of **collective behavior** in **p-Pb** and **Pb-Pb**, suggesting a common mechanism at play, still to be understood, with a significant difference w.r.t. pp data
- p-Pb results support what previously observed for open heavy flavour (and light-flavour particles)

OPEN HEAVY-FLAVOUR ELLIPTIC FLOW IN SMALL SYSTEMS





Fabio Colamaria,
Thu. 12:30

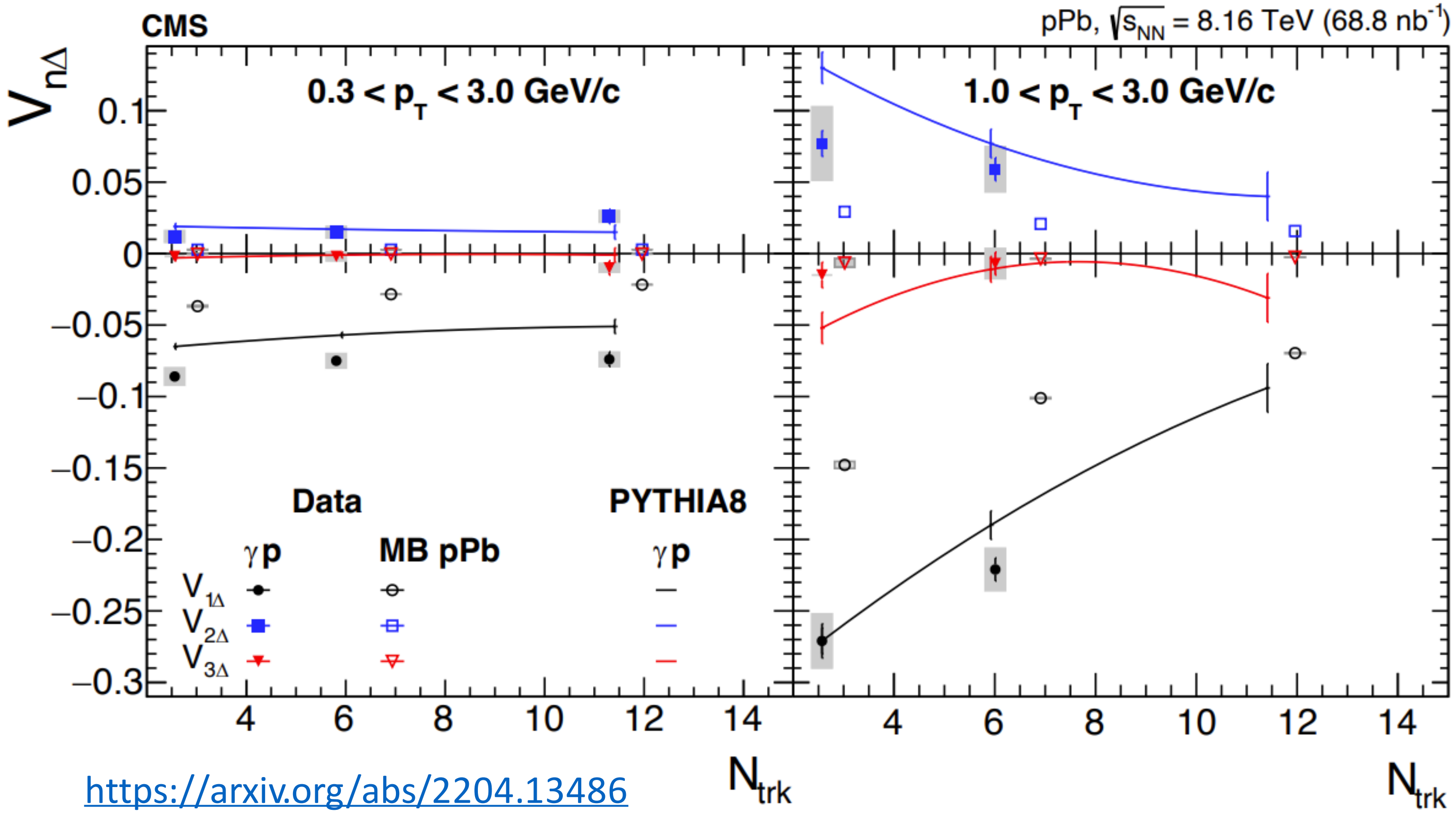
- **Positive v_2** for HF decay **muons** in high-multiplicity p-Pb, consistent with previous HF decay **electron** measurement
  - Feature observed for lower $_{pT}$ than for J/Ψ, but different quark→particle p_T scale + c,b → e,μ decay kinematics
  - Well described by CGC model, and by AMPT from p_T>2 GeV/c
- Collective motion in high-multiplicity p-Pb collisions due to **final-state effects** (QGP droplet)? Or behaviour related to **initial-state effects** (e.g. gluon saturation)?

Flow of partons in small(er) systems

γ-p collisions from CMS

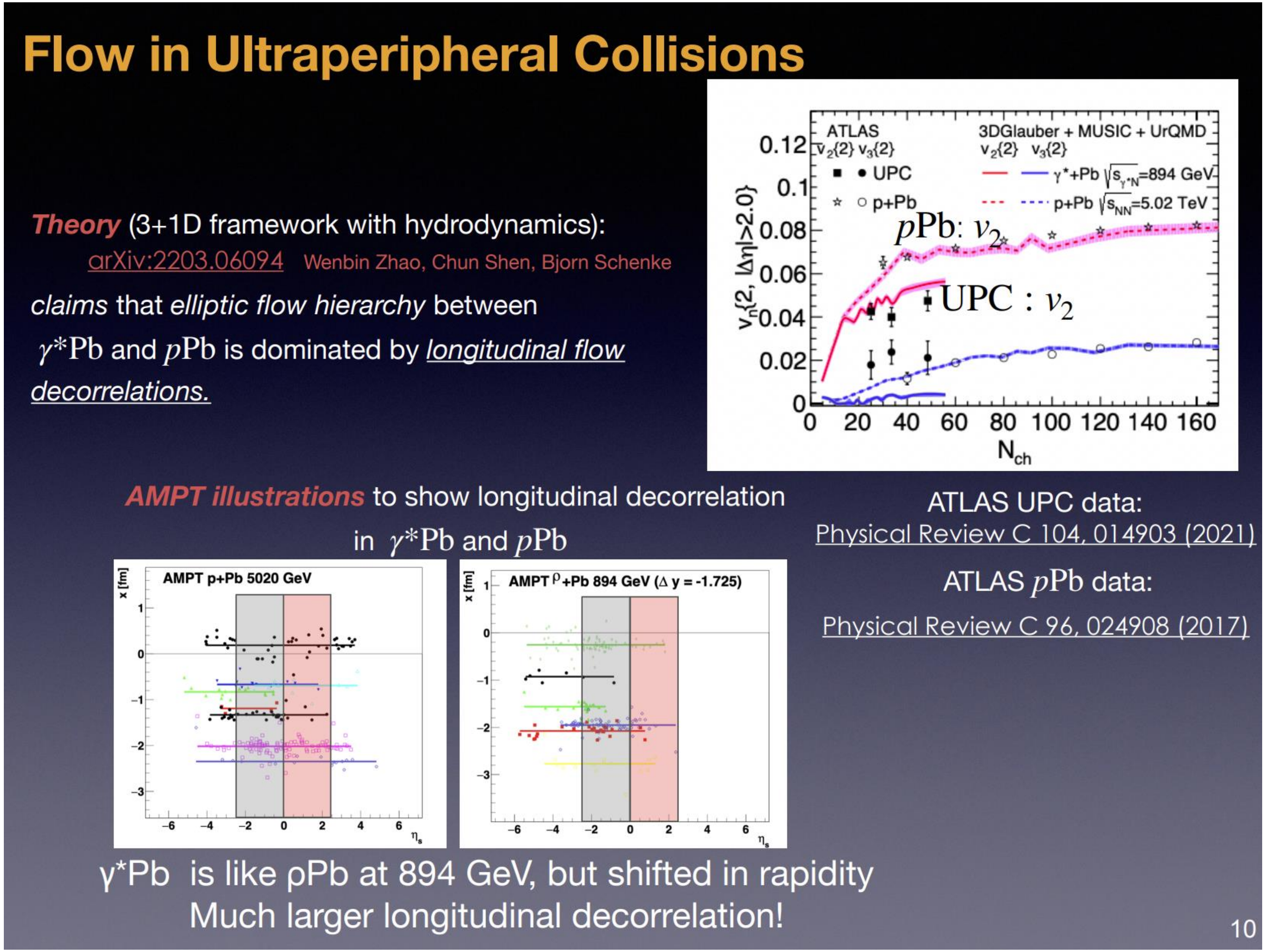
Valentina Mariani, Tue. 10:30

- For the first time long-range correlations have been studied in γ-p collisions, identified from collisions and studied
- No collectivity effect seen so far (data match the Pythia simulations)



- https://arxiv.org/abs/2204.13486

Flow of partons in small(er) systems



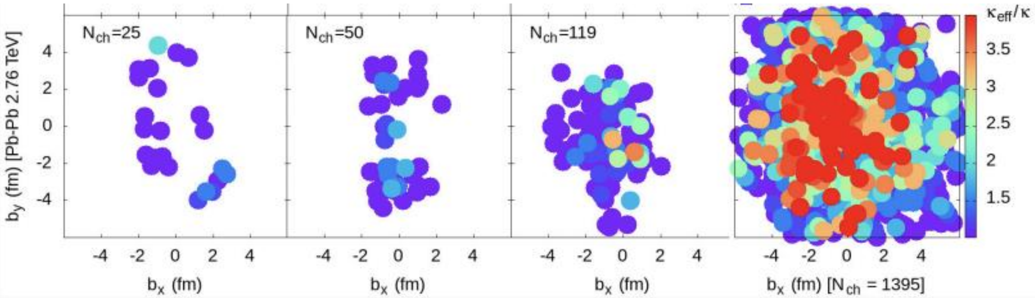
Sruthy Jyothi Das,
Tue. 10:50

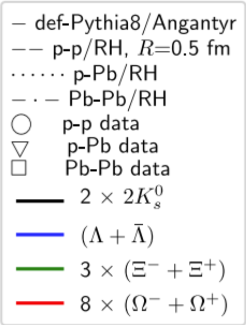
- **v2 measured also in UPC from ATLAS**

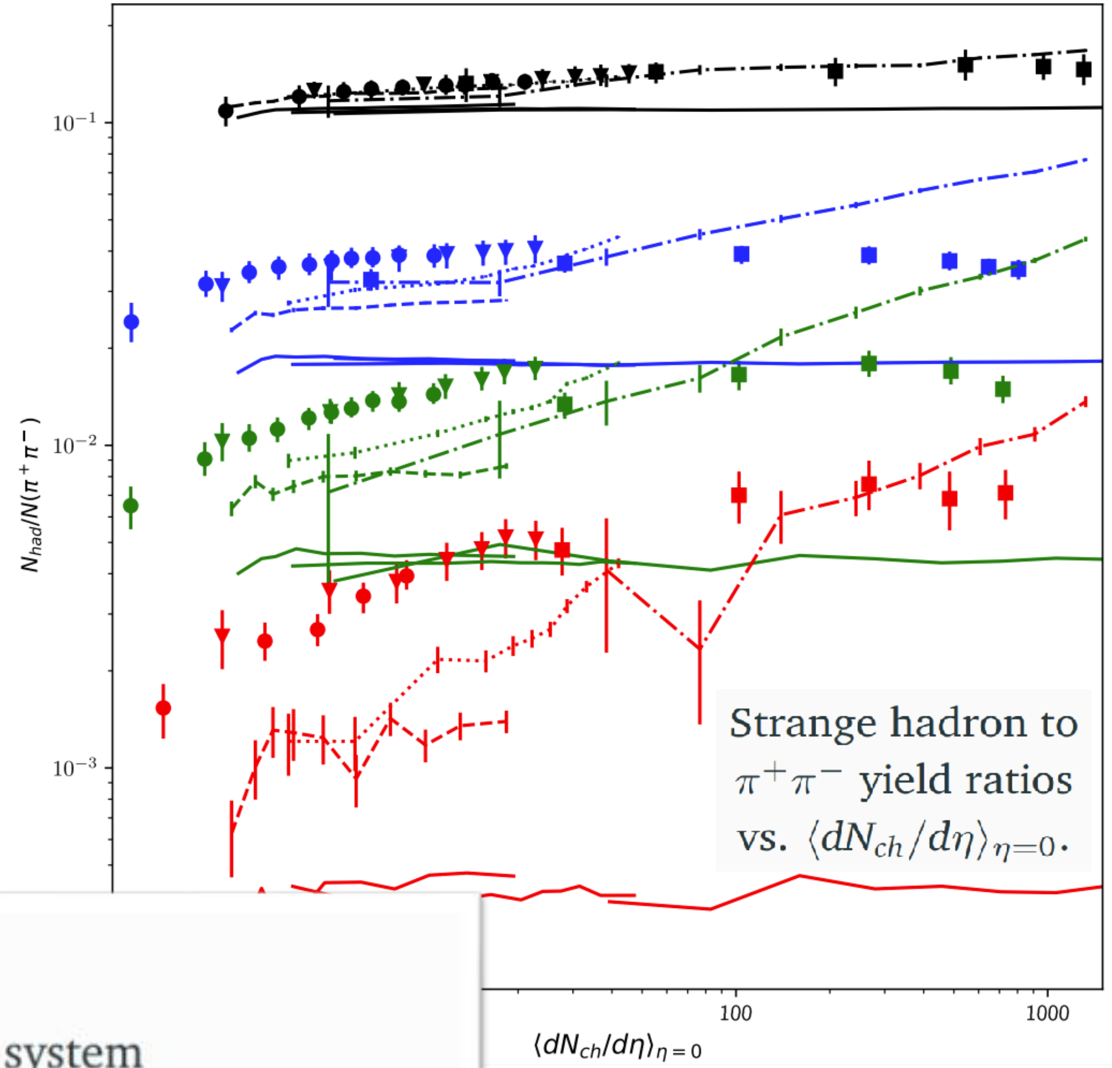
Strangeness enhancement in small systems

Pythia/Arganthyr

Pb-Pb@2.76 TeV







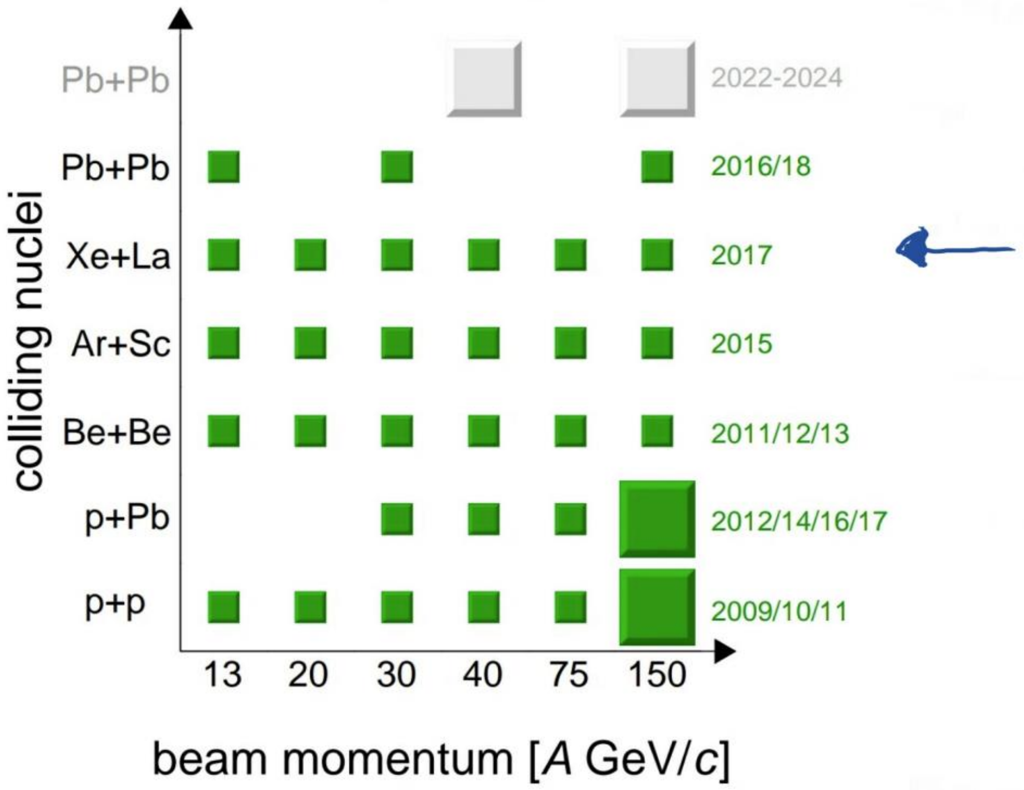
Conclusions:

- ✓ **Parallel frame formalism** includes all strings, regardless of the system
- ✓ **Rope hadronization** gives rise to **strangeness and baryon enhancement** across *all* systems, as well as in jets in p-p collisions
- ✓ **String shoving might solve high enhancement of strange baryons** in central A-A collisions

Smita Chakraborty, Tue. 11:10

Onset of collectivity, phase diagram

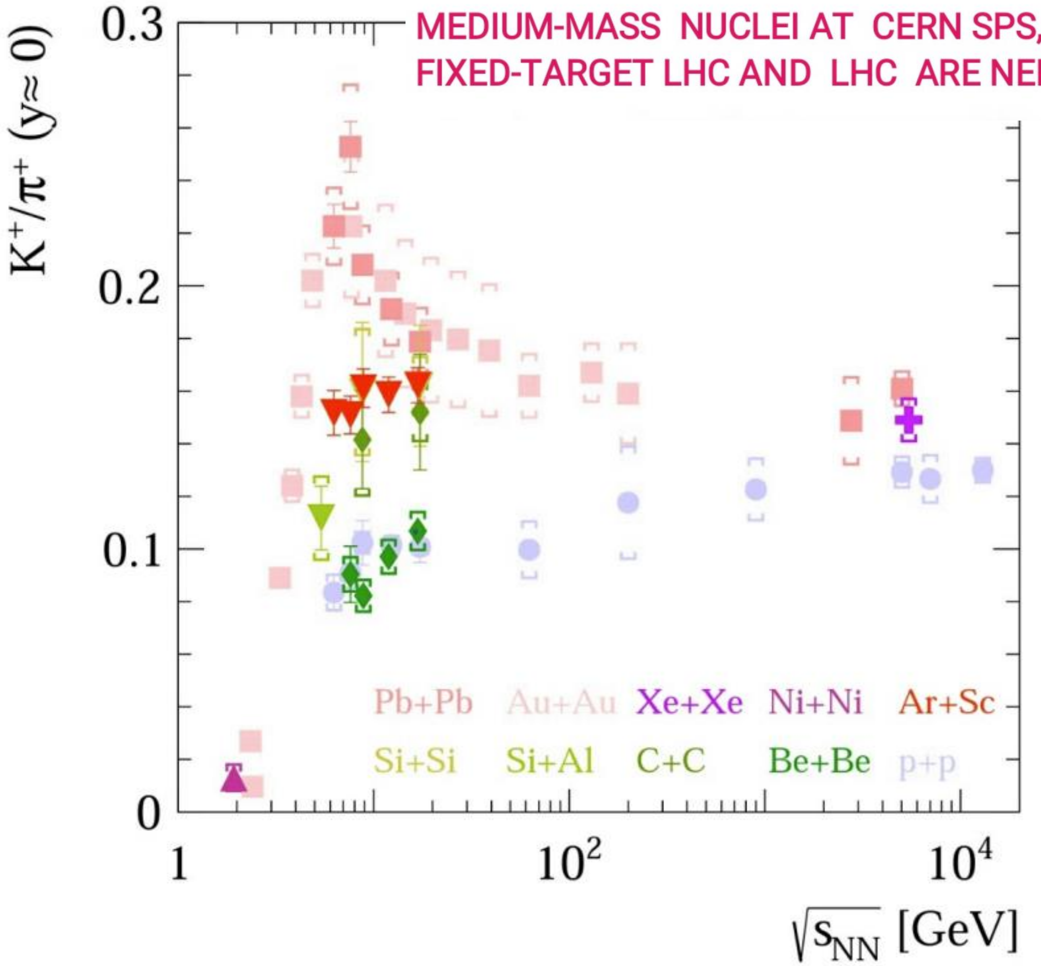
Marek Gaździcki, Mon. 17:50



$\sqrt{s_{NN}} \approx 5 \longleftrightarrow 17$ GeV

NA61/SHINE program

PRECISION DATA ON COLLISIONS OF LIGHT AND MEDIUM-MASS NUCLEI AT CERN SPS, FIXED-TARGET LHC AND LHC ARE NEEDED



Outlook

- Light nuclei more under control. Optimistic future

[https://indico.cern.ch/event/1078695/]

Nucleon-nucleon luminosity: $\mathcal{L}_{NN} = A^2 \cdot \mathcal{L}_{AA}$

optimistic scenario	O-O	Ar-Ar	Ca-Ca	Kr-Kr	In-In	Xe-Xe	Pb-Pb
$\langle L_{AA} \rangle$ (cm^{-2} s^{-1})	$9.5 \cdot 10^{29}$	$2.0 \cdot 10^{29}$	$1.9 \cdot 10^{29}$	$5.0 \cdot 10^{28}$	$2.3 \cdot 10^{28}$	$1.6 \cdot 10^{28}$	$3.3 \cdot 10^{27}$
$\langle L_{NN} \rangle$ (cm^{-2} s^{-1})	$2.4 \cdot 10^{32}$	$3.3 \cdot 10^{32}$	$3.0 \cdot 10^{32}$	$3.0 \cdot 10^{32}$	$3.0 \cdot 10^{32}$	$2.6 \cdot 10^{32}$	$1.4 \cdot 10^{32}$
$\mathcal{L}_{AA}$ (nb^{-1} / month)	$1.6 \cdot 10^{3}$	$3.4 \cdot 10^{2}$	$3.1 \cdot 10^{2}$	$8.4 \cdot 10^{1}$	$3.9 \cdot 10^{1}$	$2.6 \cdot 10^{1}$	$5.6 \cdot 10^{0}$
$\mathcal{L}_{NN}$ (pb^{-1} / month)	409	550	500	510	512	434	242