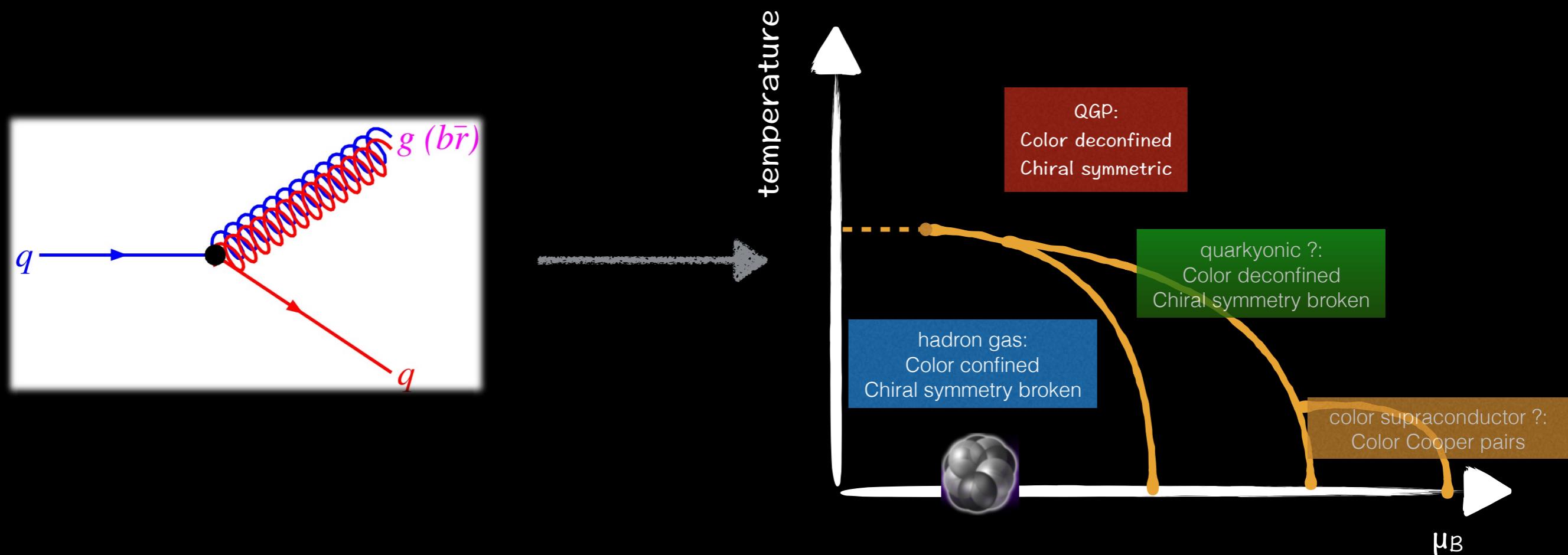


ALICE @ LHC

Probing the most perfect perfect-liquid in AA ... and pp,
pA collisions



Thermodynamics of strongly interaction matter



How do collective
phenomena and properties of
matter emerge from the
fundamental QCD
Lagrangian ?

Standard strategy

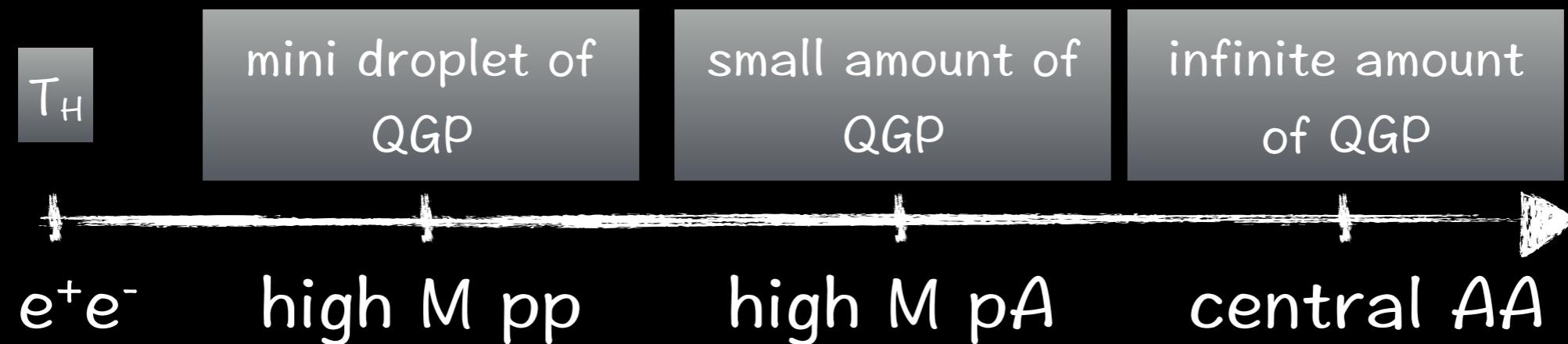
- Large and dense: heavy-ion physics
 - ▶ $\text{AA} \rightarrow \text{Npdf} + \text{pQCD} + \text{FF} + \text{collectivity}$
- Small and dilute: comparison measurement
 - ▶ $\text{pp} \rightarrow \text{pdf} + \text{pQCD} + \text{FF}$
 - ▶ $\text{pA} \rightarrow \text{Npdf} + \text{pQCD} + \text{FF}$

High multiplicity pPb and pp ! same as PbPb ?



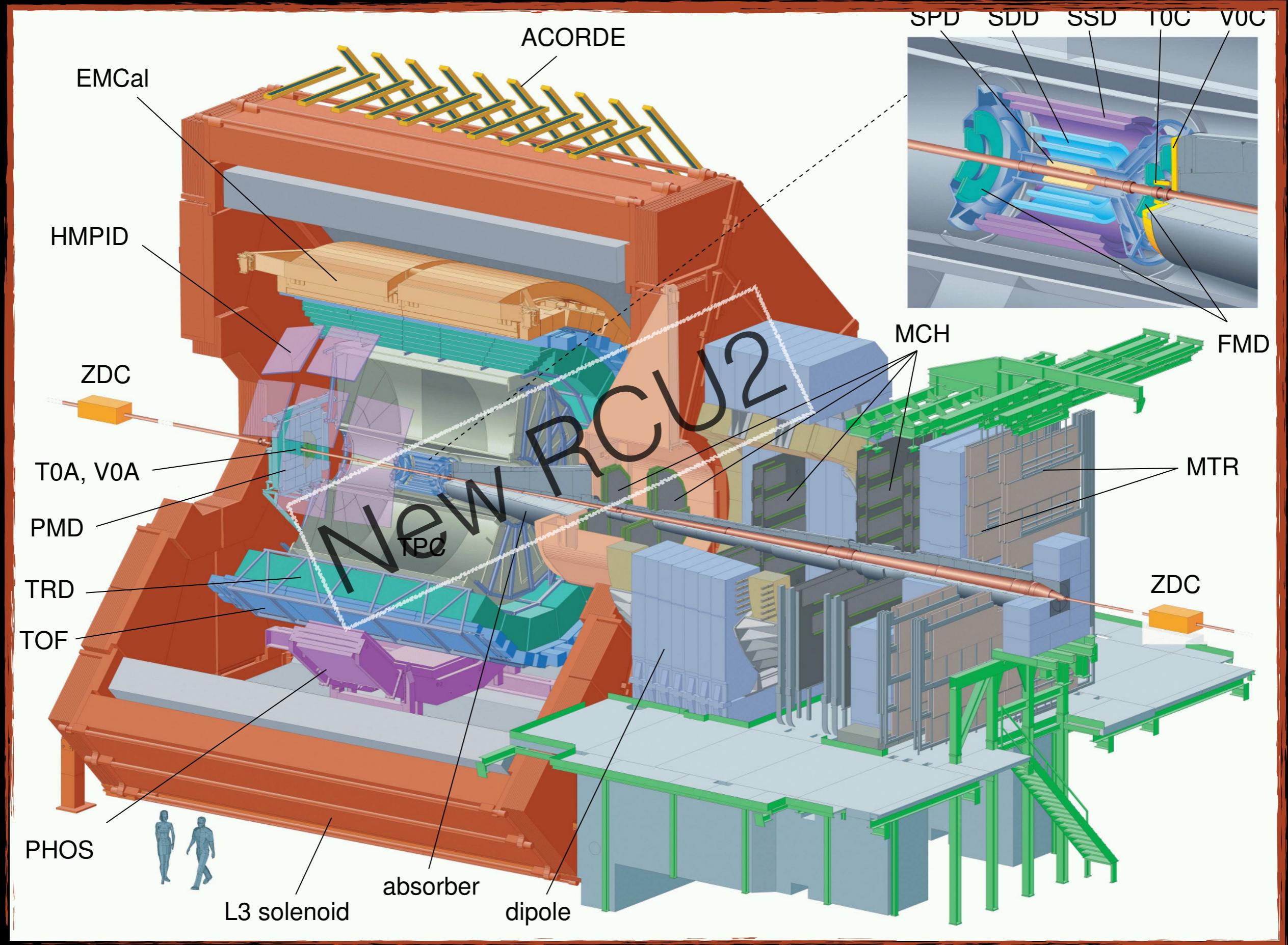
Toward a new paradigm ?

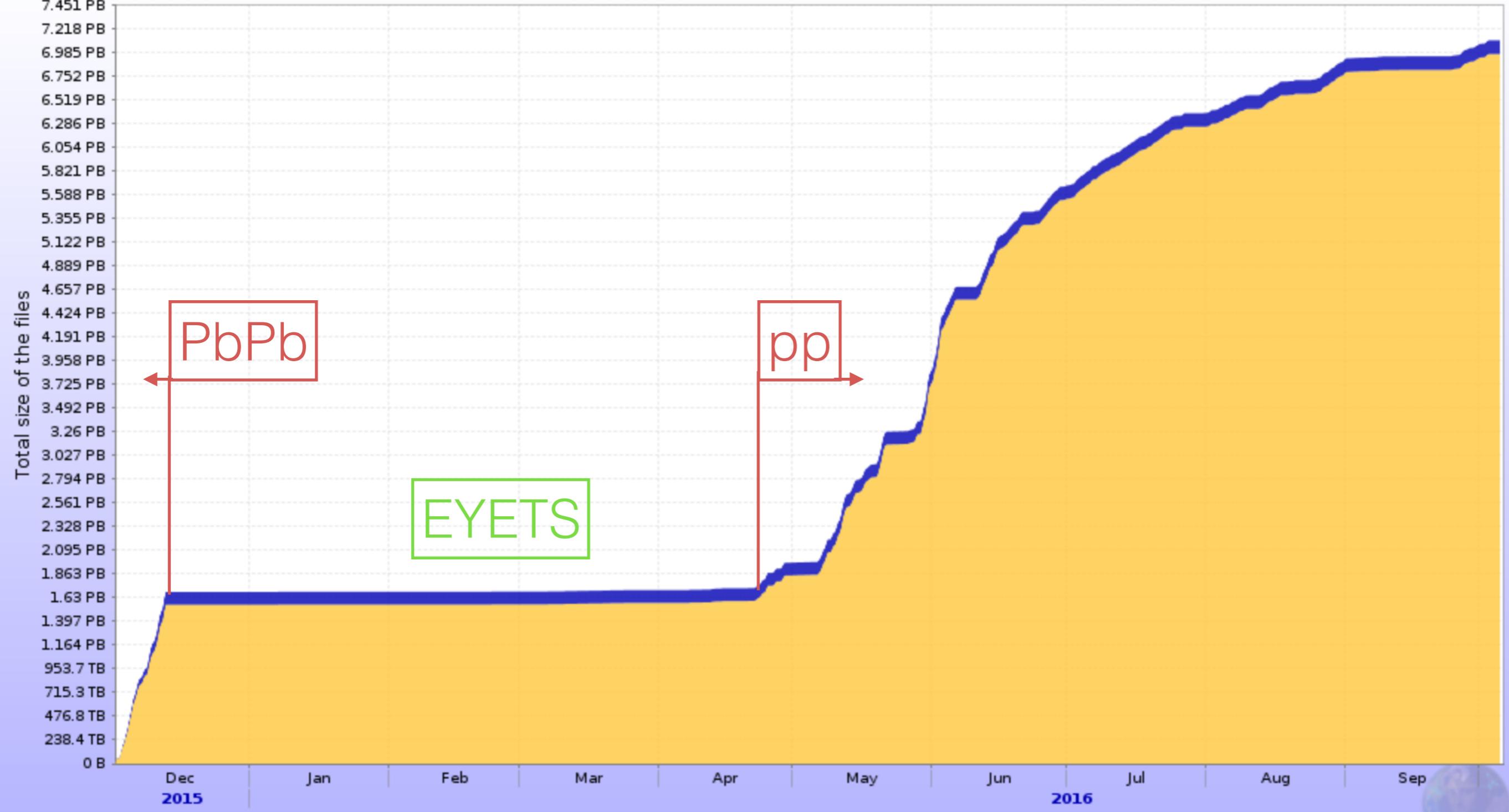
- Collectivity everywhere !



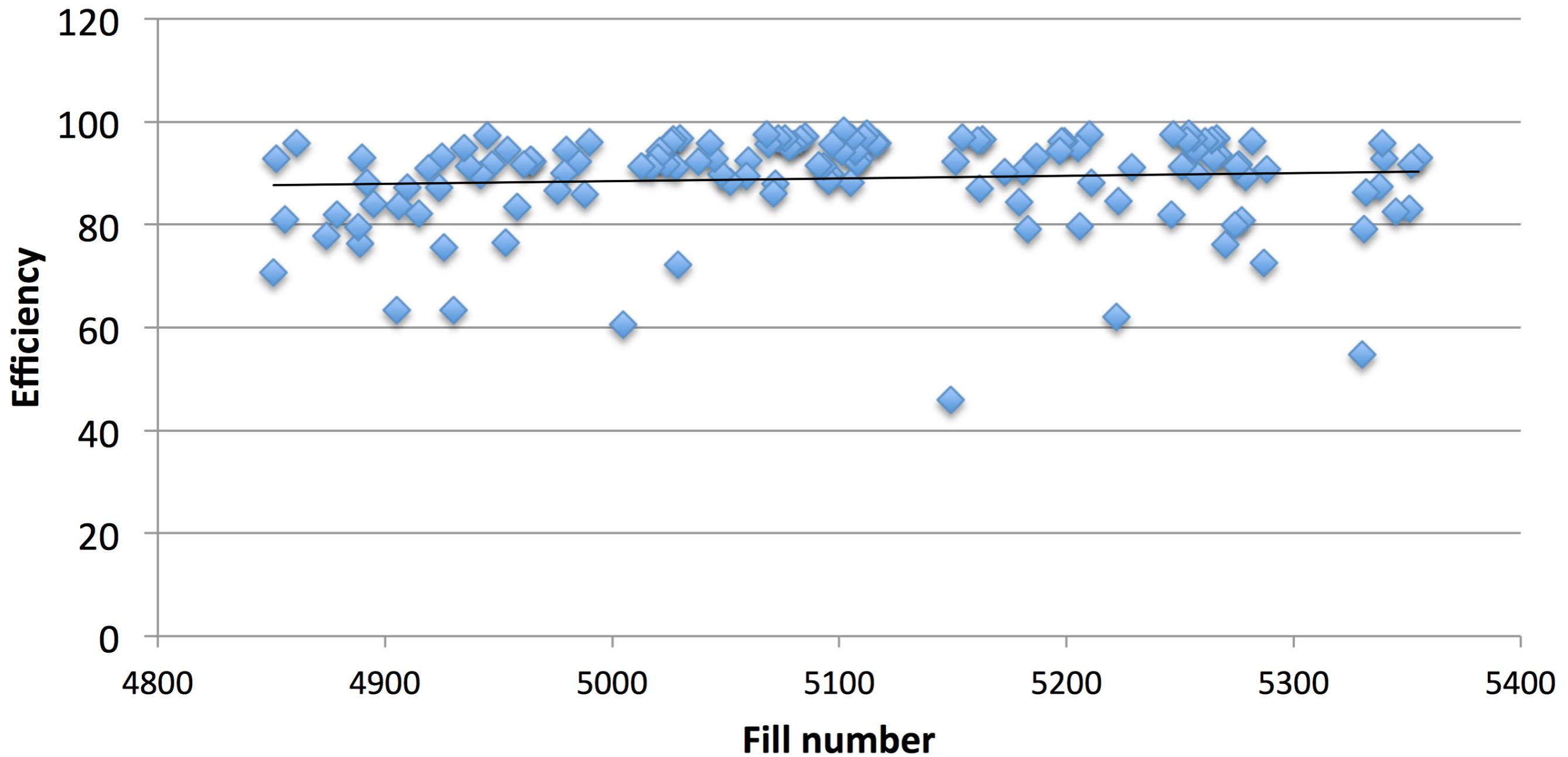
- A coherent experimental and theoretical approach to statistical QCD from e⁺e⁻ to AA

ALICE en 2016

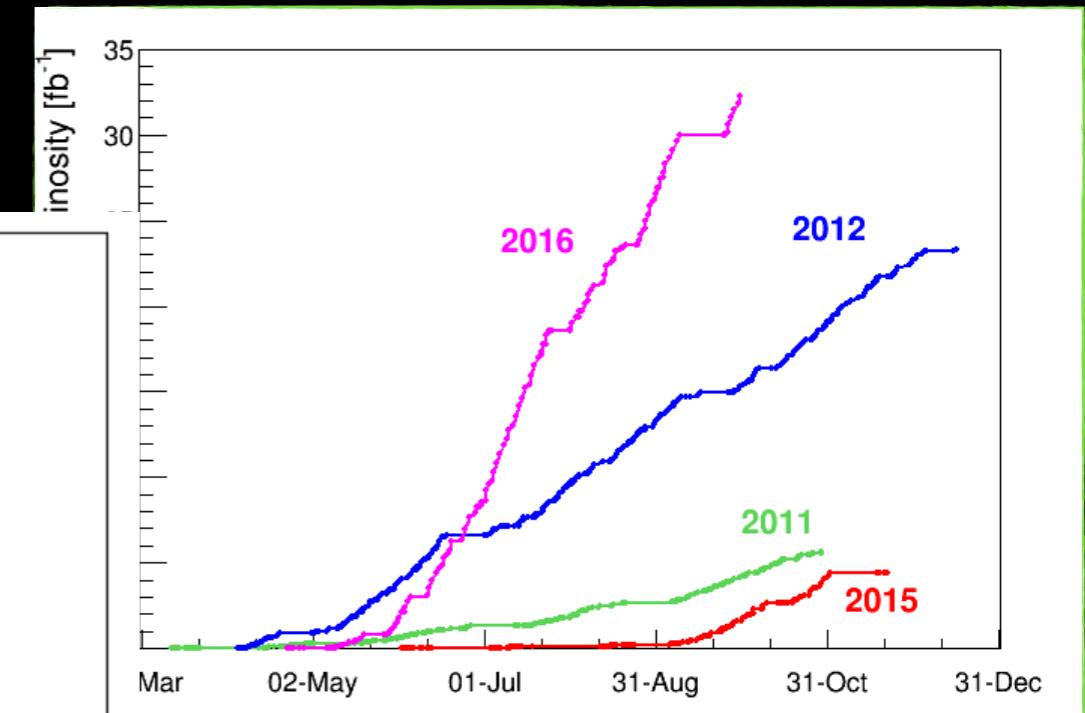
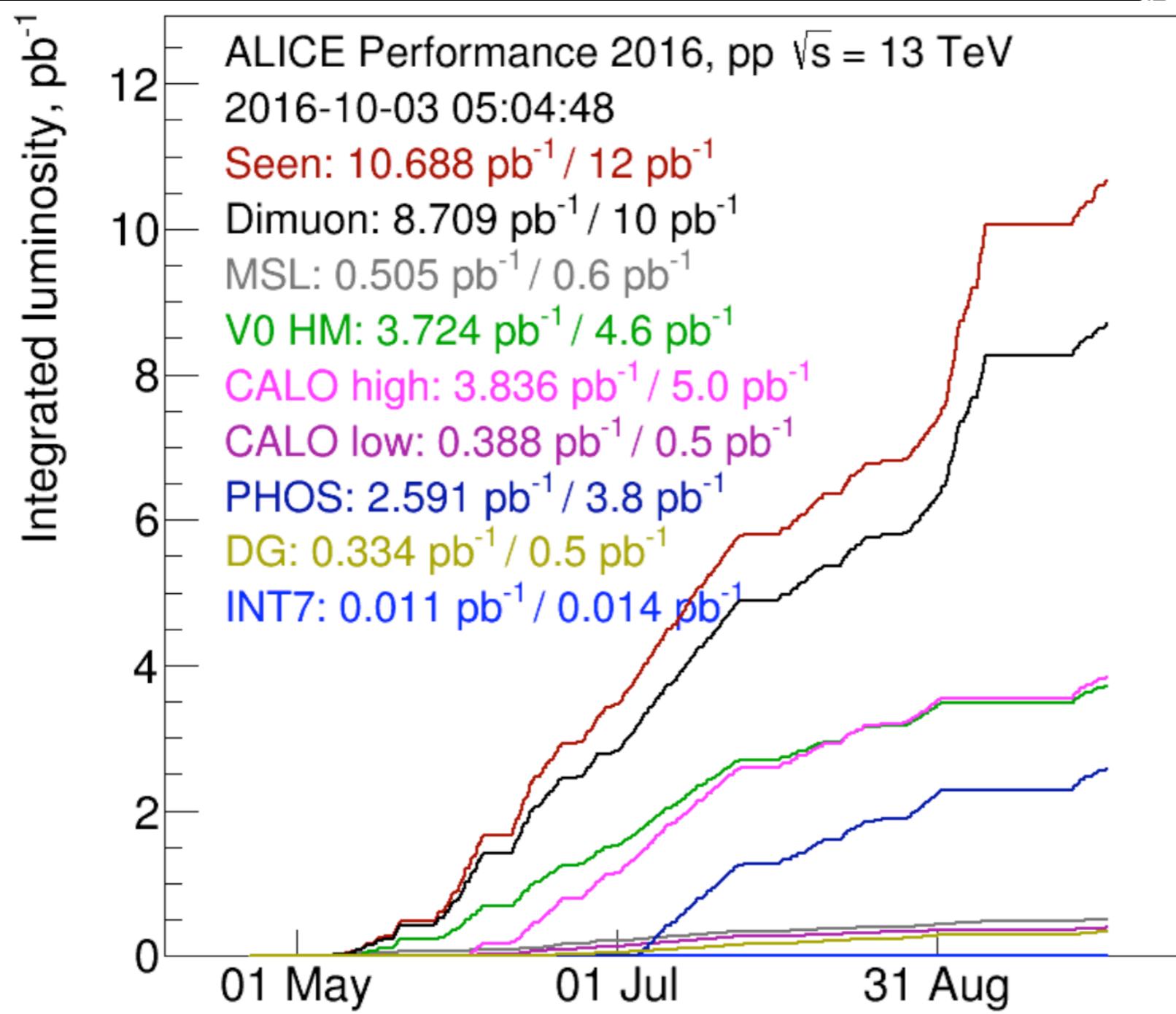




- very stable operation
- new HLT data compression



- very stable operation
- high efficiency > 92%

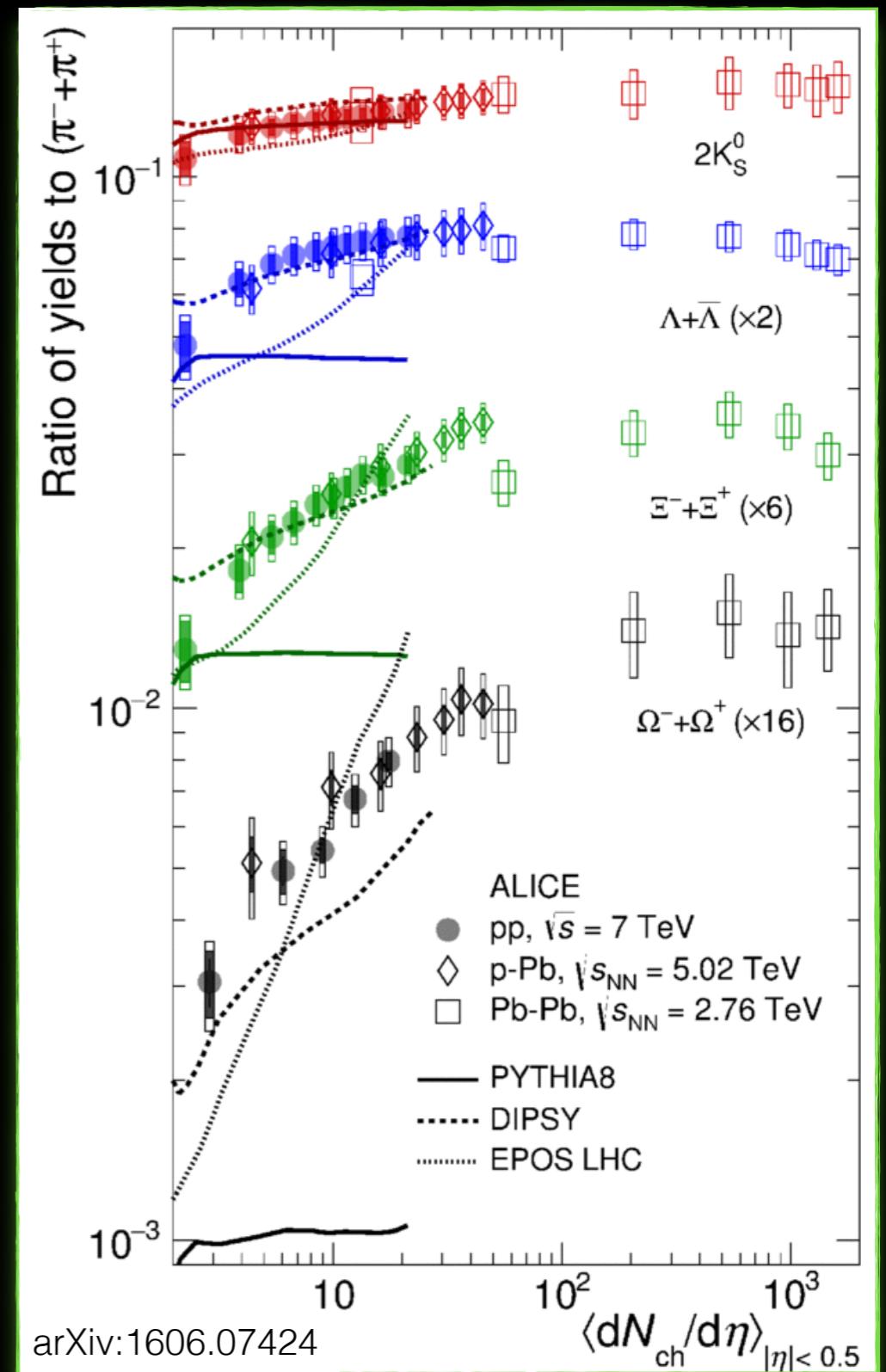


Well on the way for 2016 targets according to previously approved strategy

Final state

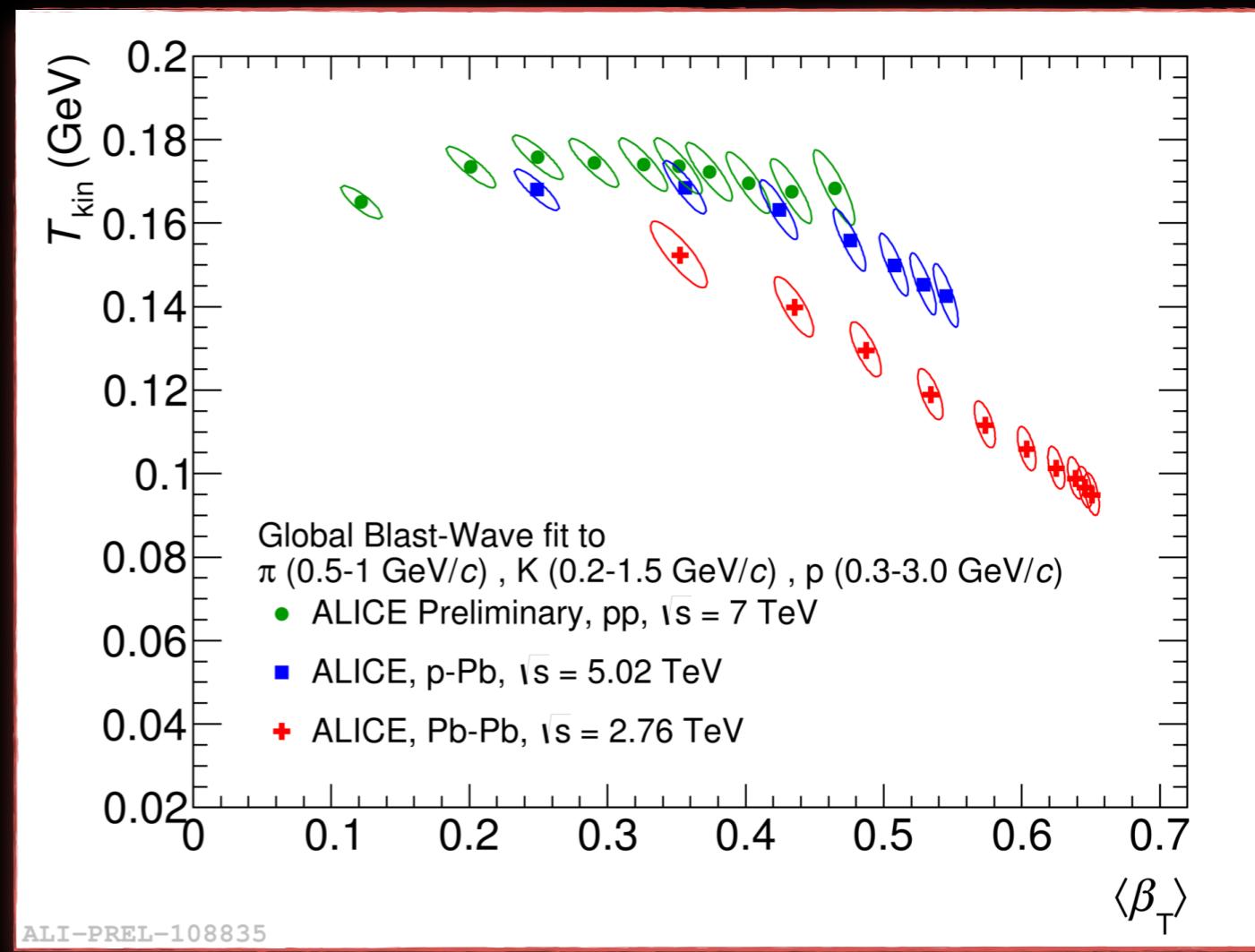
Final state: strangeness

- Smooth trend with centrality (charge particles density)
- Identical for pp, pA and AA
- Increase of strangeness production with charged - particle density
- From pp to AA same production mechanism at work ?



Final state: spectra

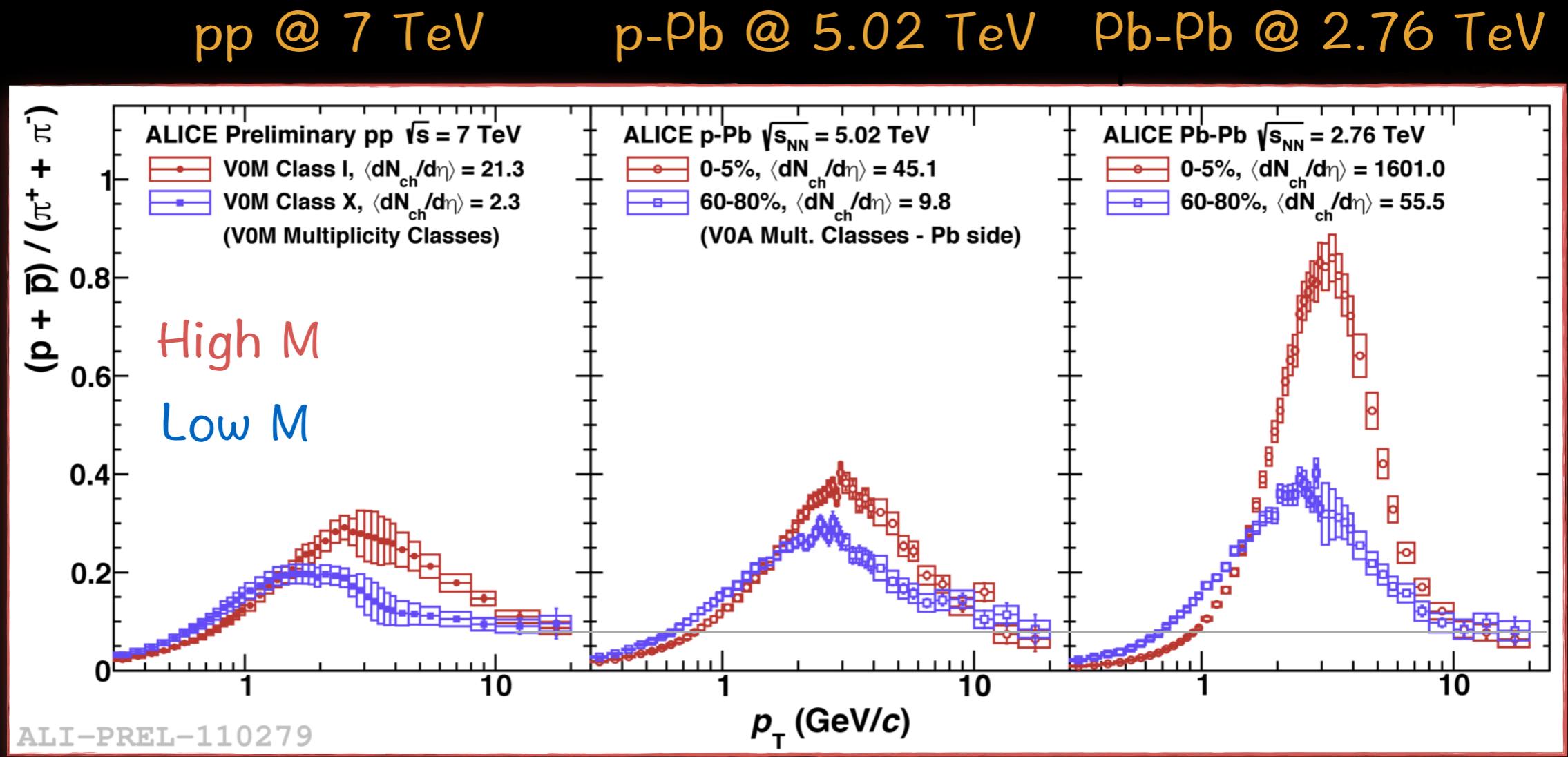
- Radial flow is
 - increasing with centrality
 - identical for pp, pA
 - larger in pp and pA at same multiplicity



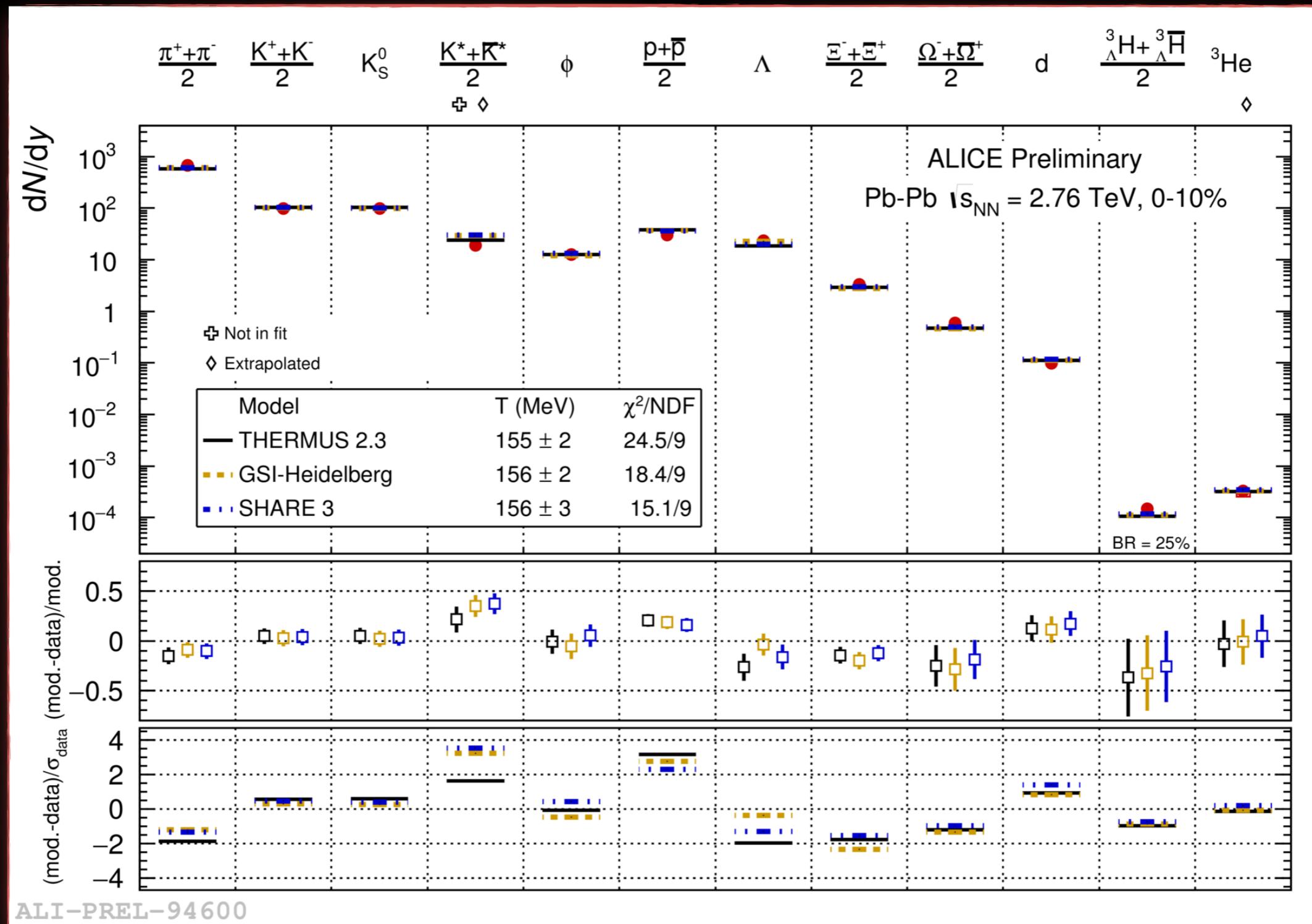
Flow dynamics everywhere !

Final state: baryon/meson

- Increasing ratio with centrality (radial flow)
- Coalescence: a new hadronization mechanism ? deconfined quarks ?



Final state hadrons: $T_H = 155$ MeV



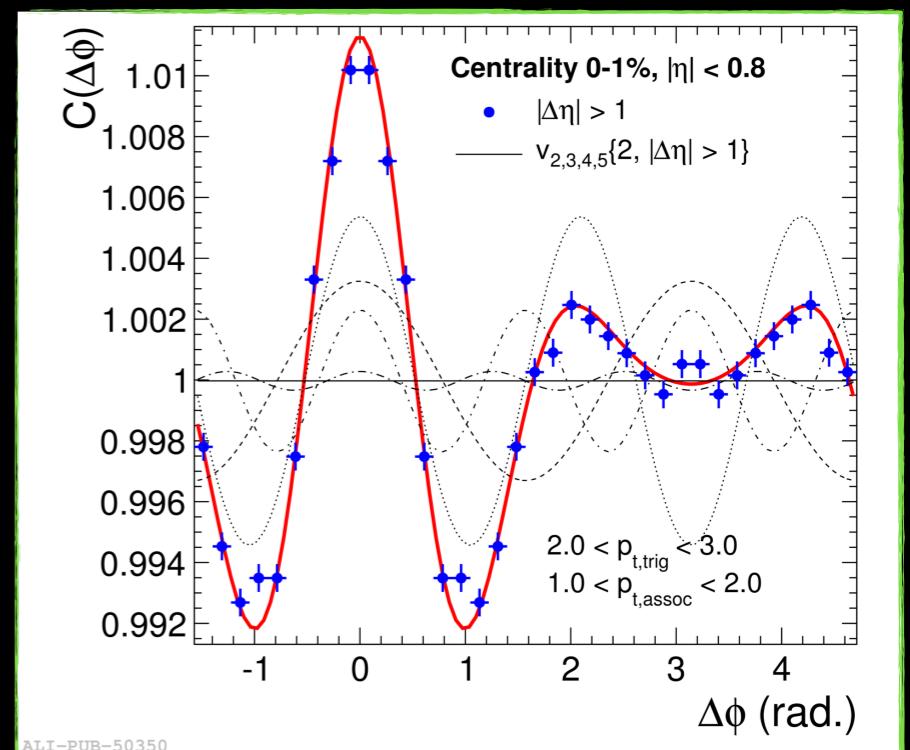
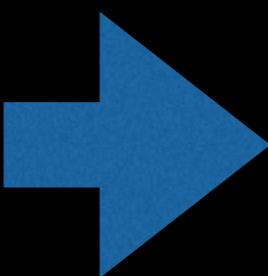
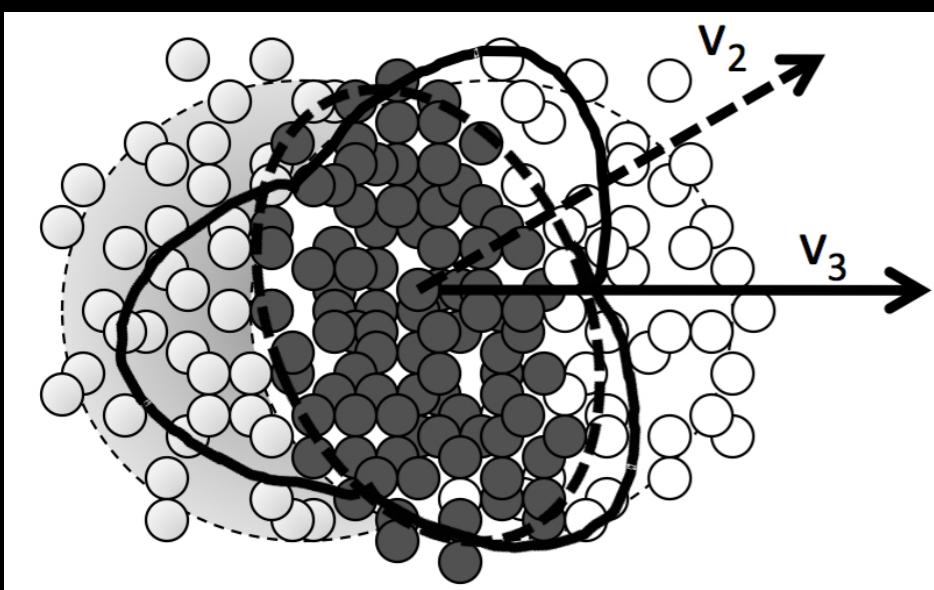
QGP

Characterization

Dissipation in the perfect liquid is minimal:

The QGP is transparent to fluctuations in the Initial State

non dissipative
hydro



1. Initial conditions

- non equilibrated
- oversaturate $f(x, p) \sim 1/a_s$
- anisotropic $p_T < p_L$

2. Pre-equilibrium stage → rapid hydro dynamisation

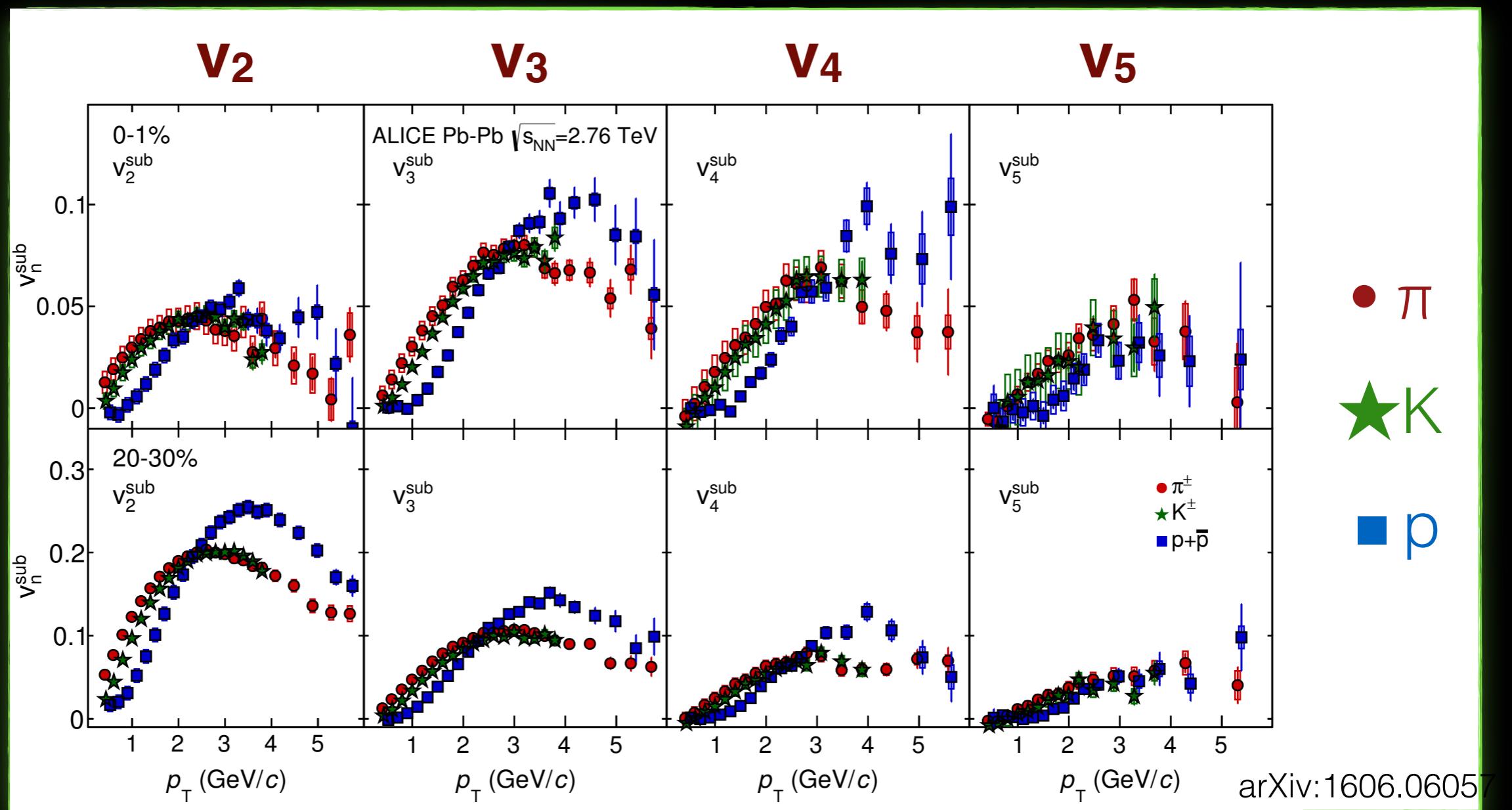
- determined by effective kinetic theory (if dynamics is perturbative)
- qualitatively understood in models of gauge-gravity duality (if dynamics is non-perturbative)

3. Hydrodynamics expansion

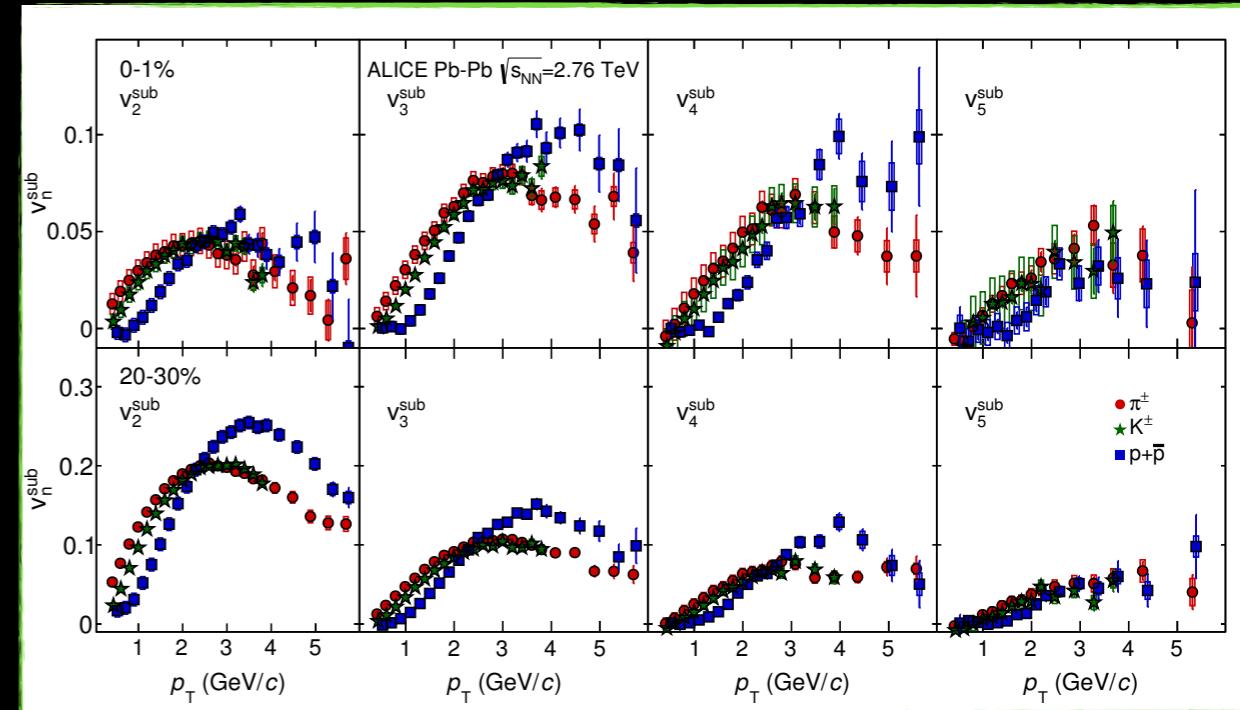
- determined by very few thermal equilibrium properties calculable from first principle in QCD)

QGP: flow harmonics

Pb-Pb @ 2.76 TeV



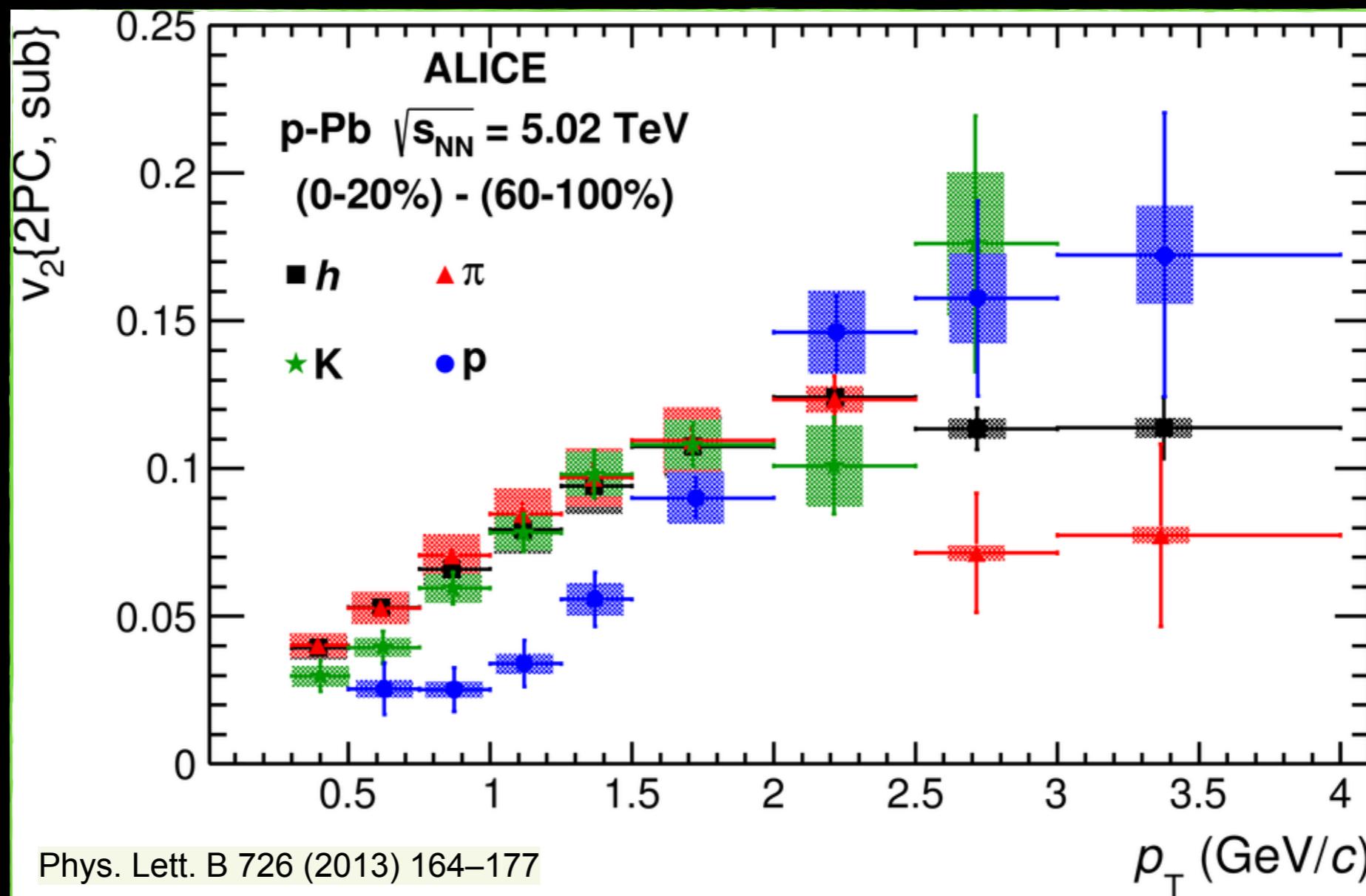
QGP: flow harmonics



- baryon/meson grouping → coalescence
- $v_2 \rightarrow$ geometry of the collision
- v_2 mass dependence → velocity of radial flow
- $v_{n>2} \rightarrow$ initial state geometrical fluctuations

QGP: flow harmonics

p-Pb @ 5.02 TeV high multiplicity



pA: hydro flow, as well ! the embarrassing success of hydro

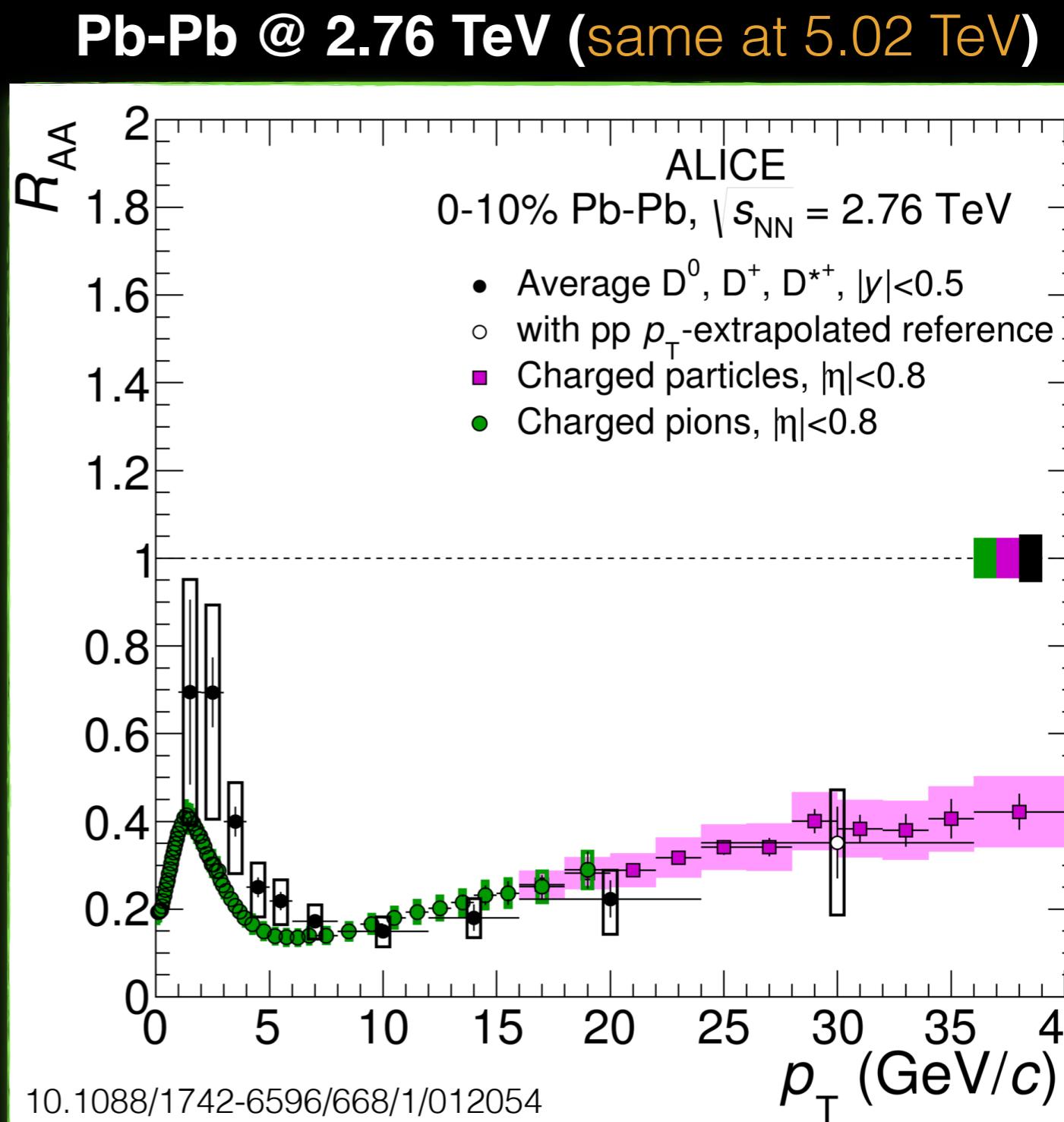
QGP

DoF at high resolution scale

QGP: nuclear modification, hadron

$$R_{xA}(p_T) = \frac{d^2 N_{ch}^{xA} / d\eta dp_T}{\langle T_{xA} \rangle d^2 \sigma_{ch}^{pp} / d\eta dp_T}$$

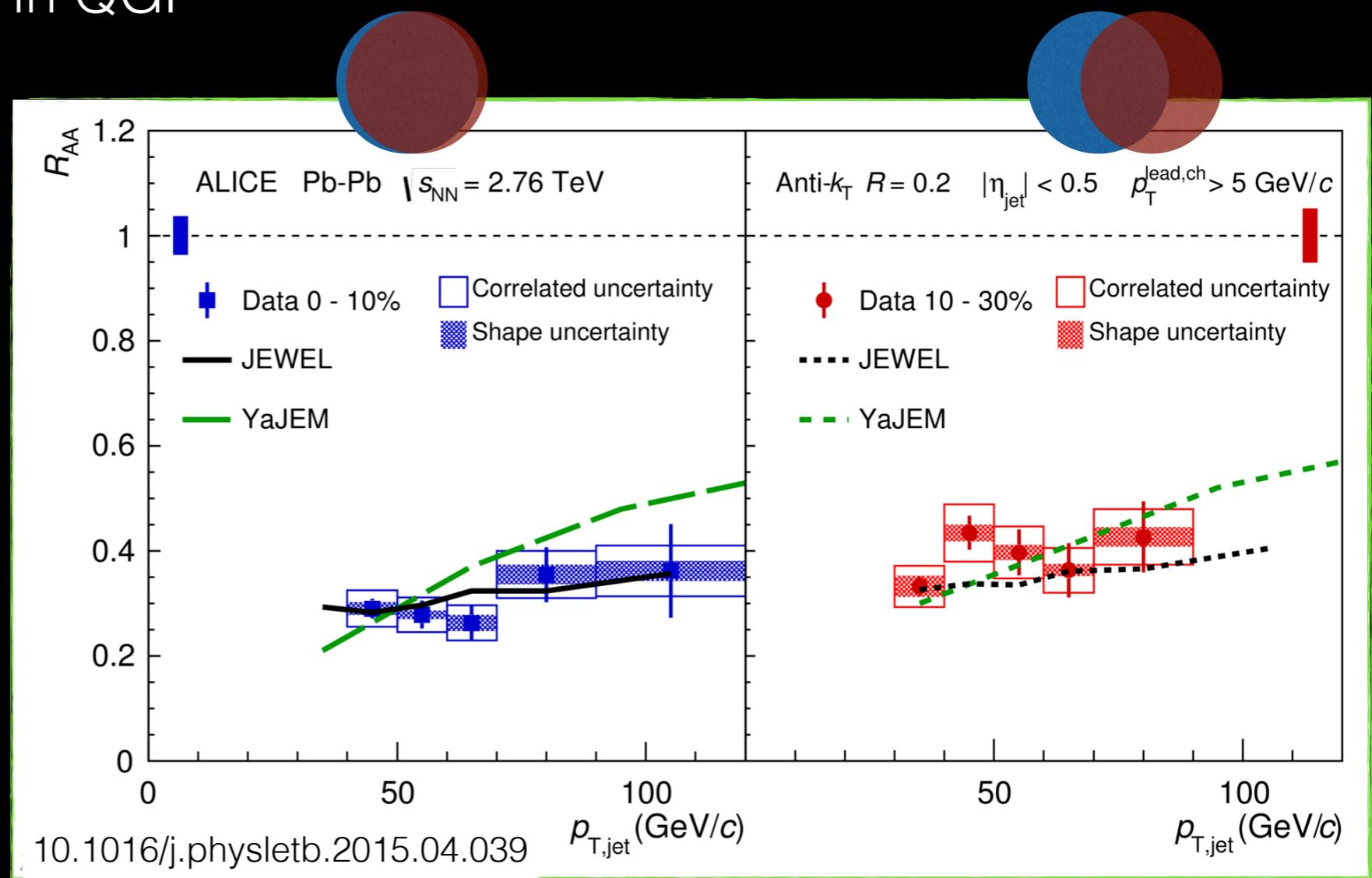
- parton energy loss in QGP
- light flavor and charm equally suppressed at higher p_T



QGP: nuclear modification, jet

- light flavor and charm equally suppressed at higher p_T
- parton energy loss in QGP

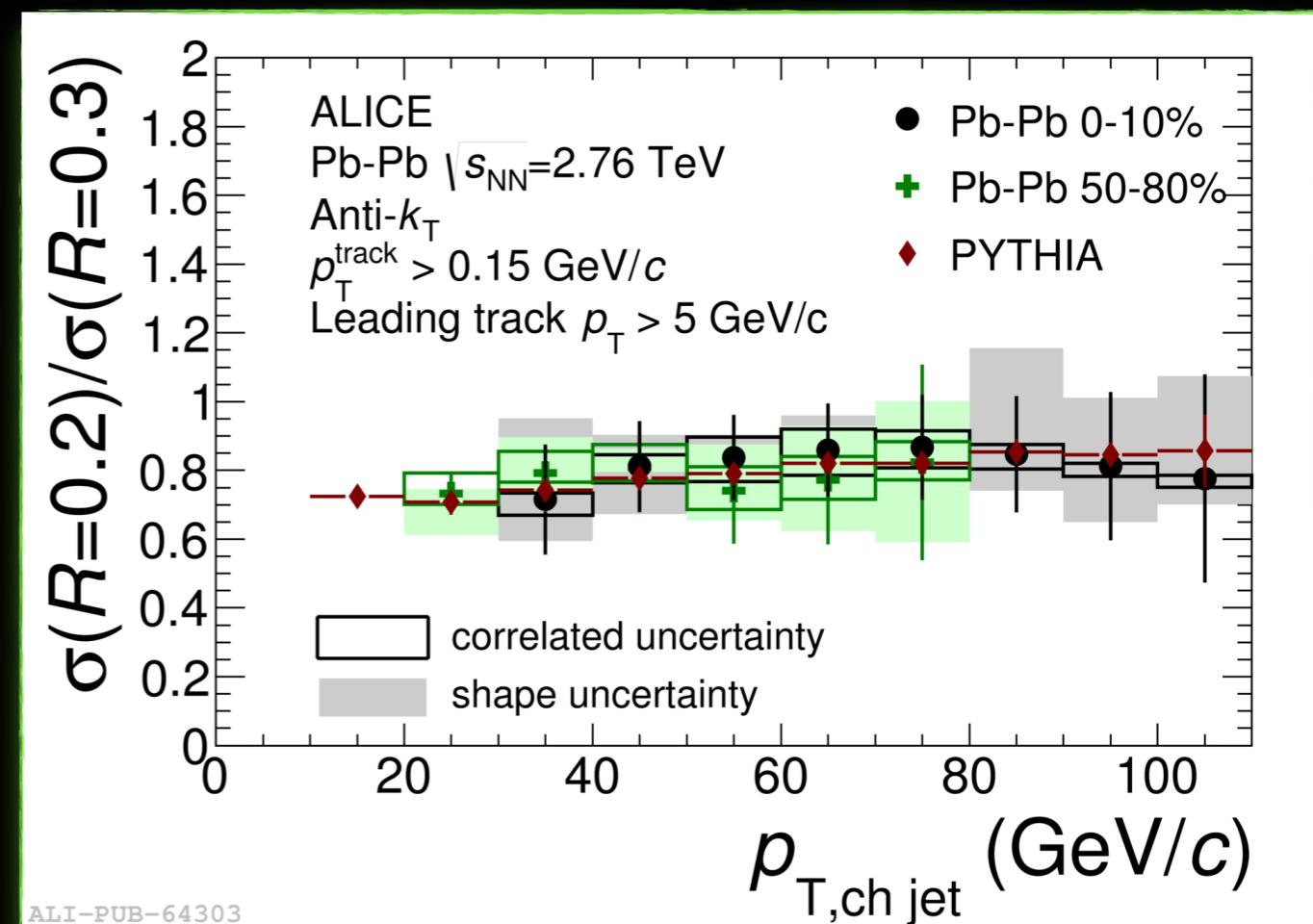
Pb-Pb @ 2.76 TeV



QGP: nuclear modification, jet

- Lost energy not recovered
- more differential measurements on going: energy flow, PID, j-h correlations

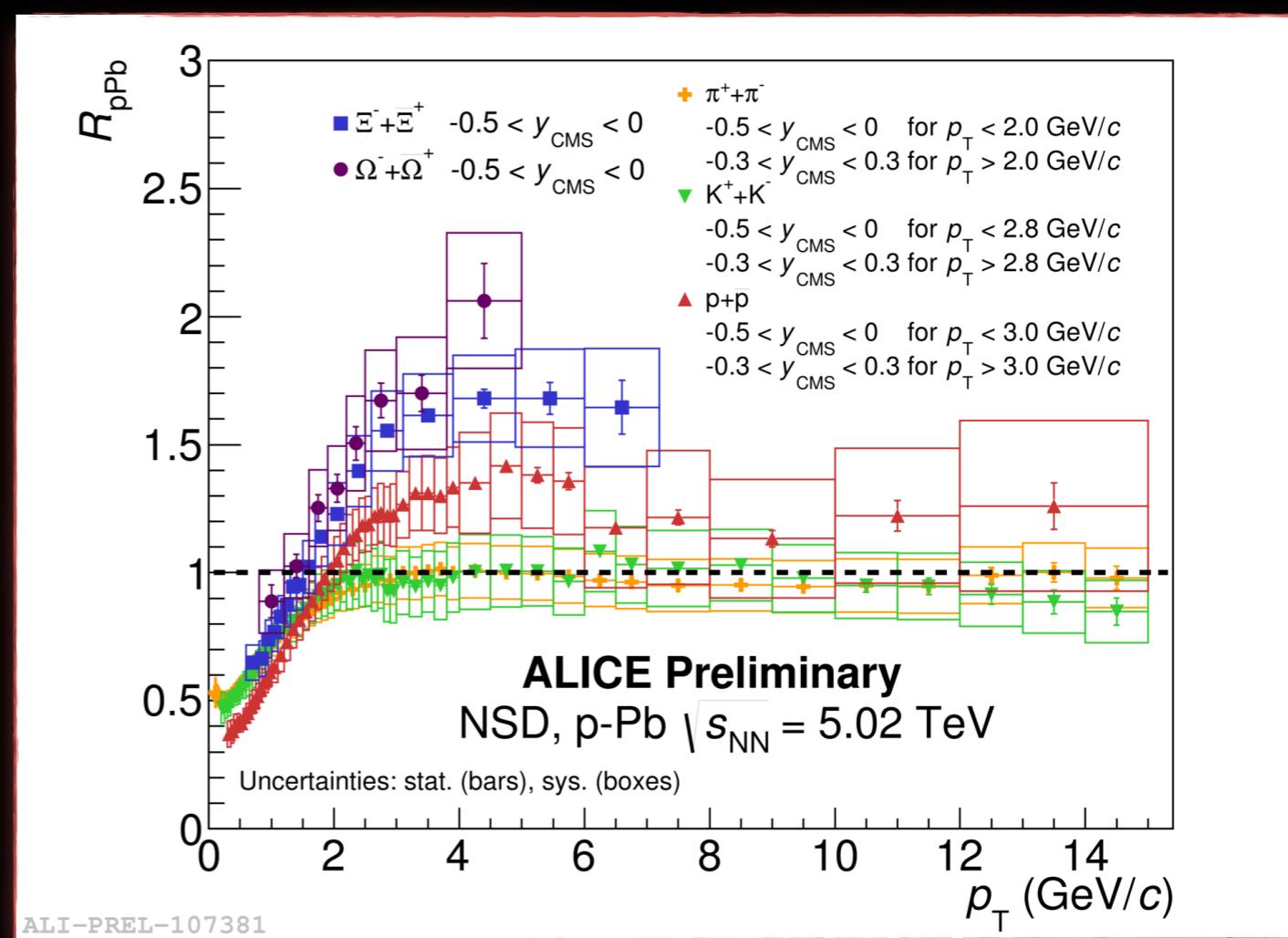
Pb-Pb @ 2.76 TeV



QGP: nuclear modification

p-Pb @ 5.02 TeV

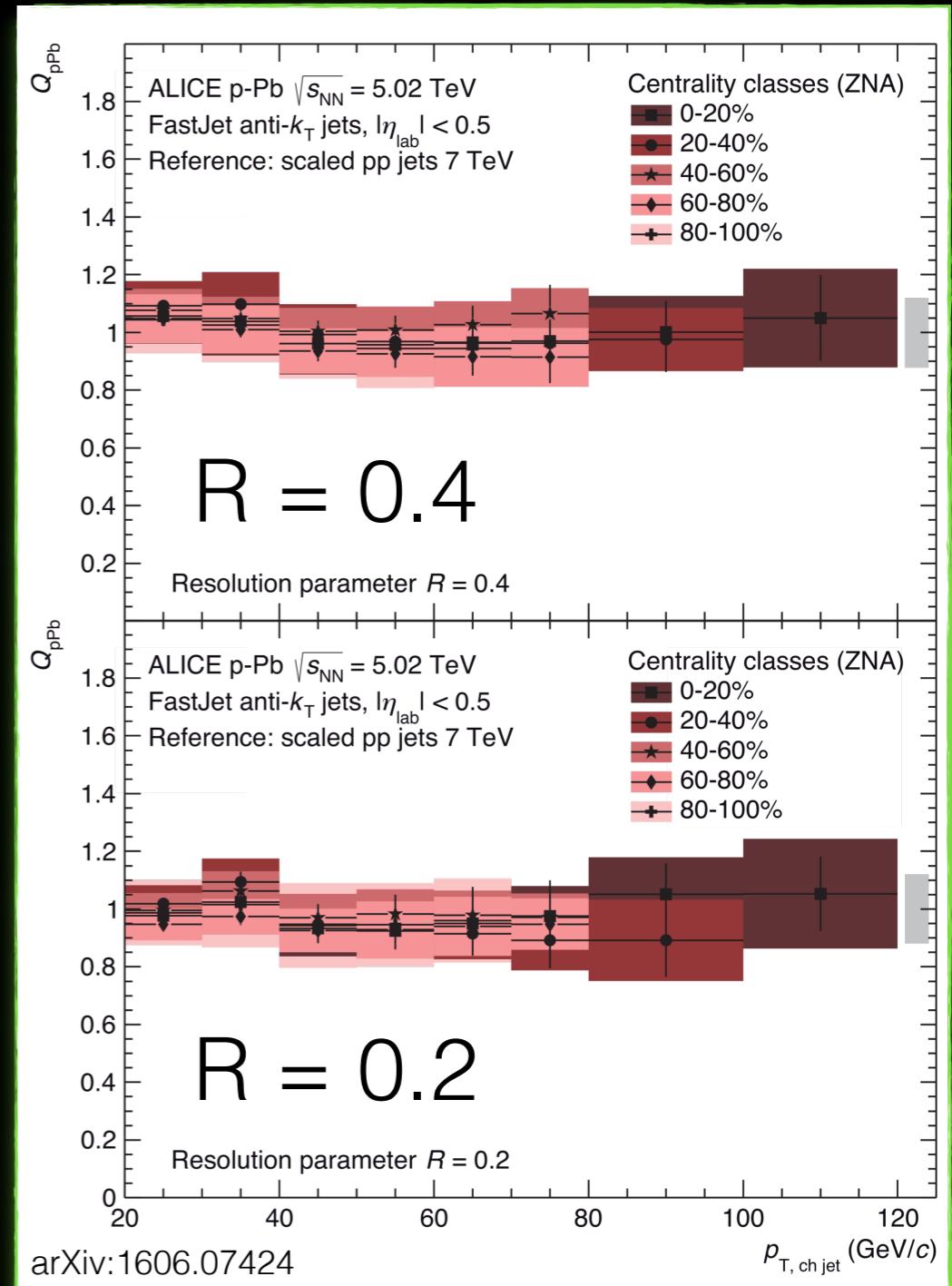
- high p_T , flavor-independent suppression in pA/pp
- no parton energy loss ?



QGP: nuclear modification, jet

p-Pb @ 5.02 TeV

- high p_T , flavor-independent suppression in pA/pp
- no parton energy loss ?



arXiv:1606.07424

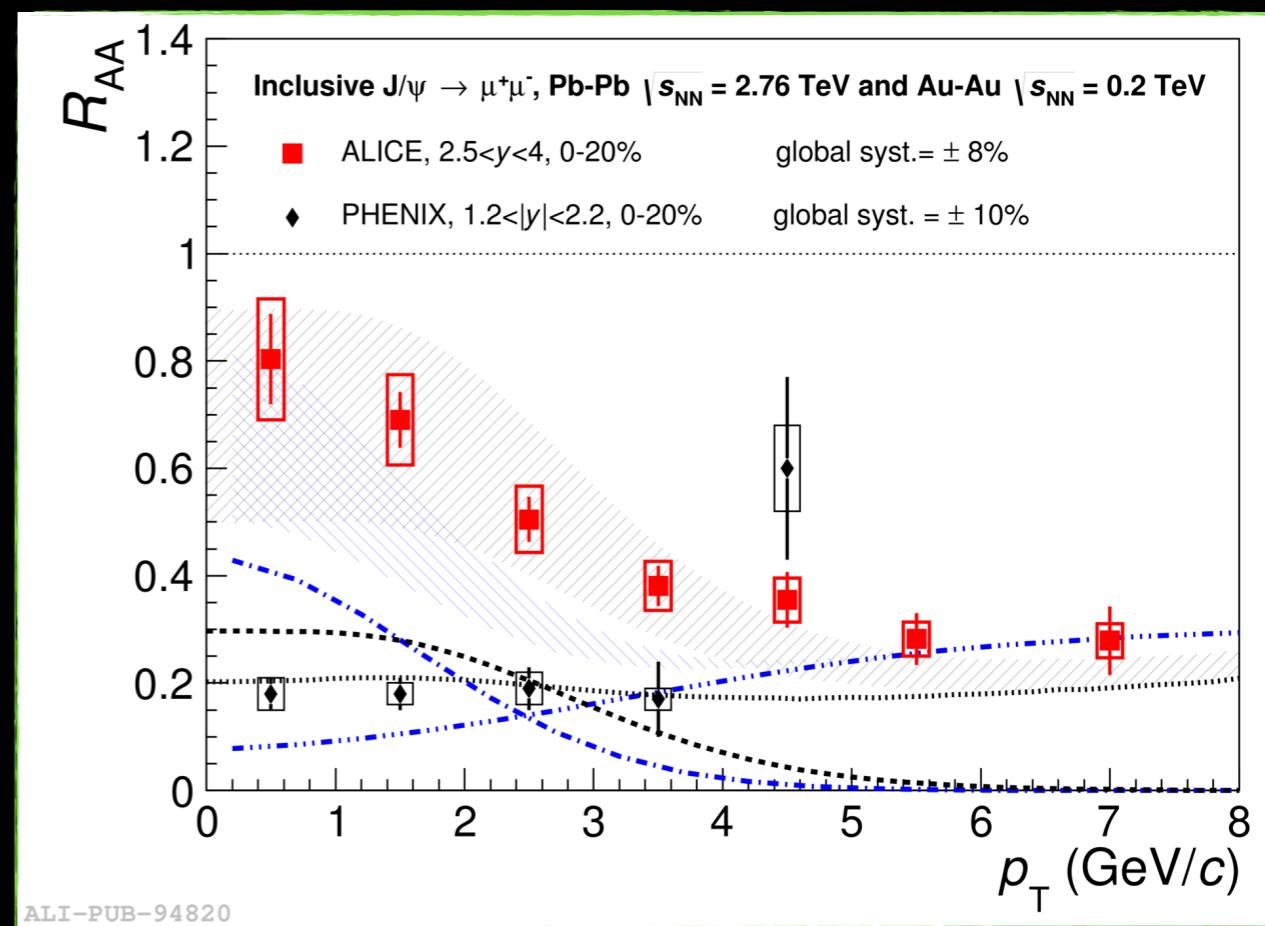
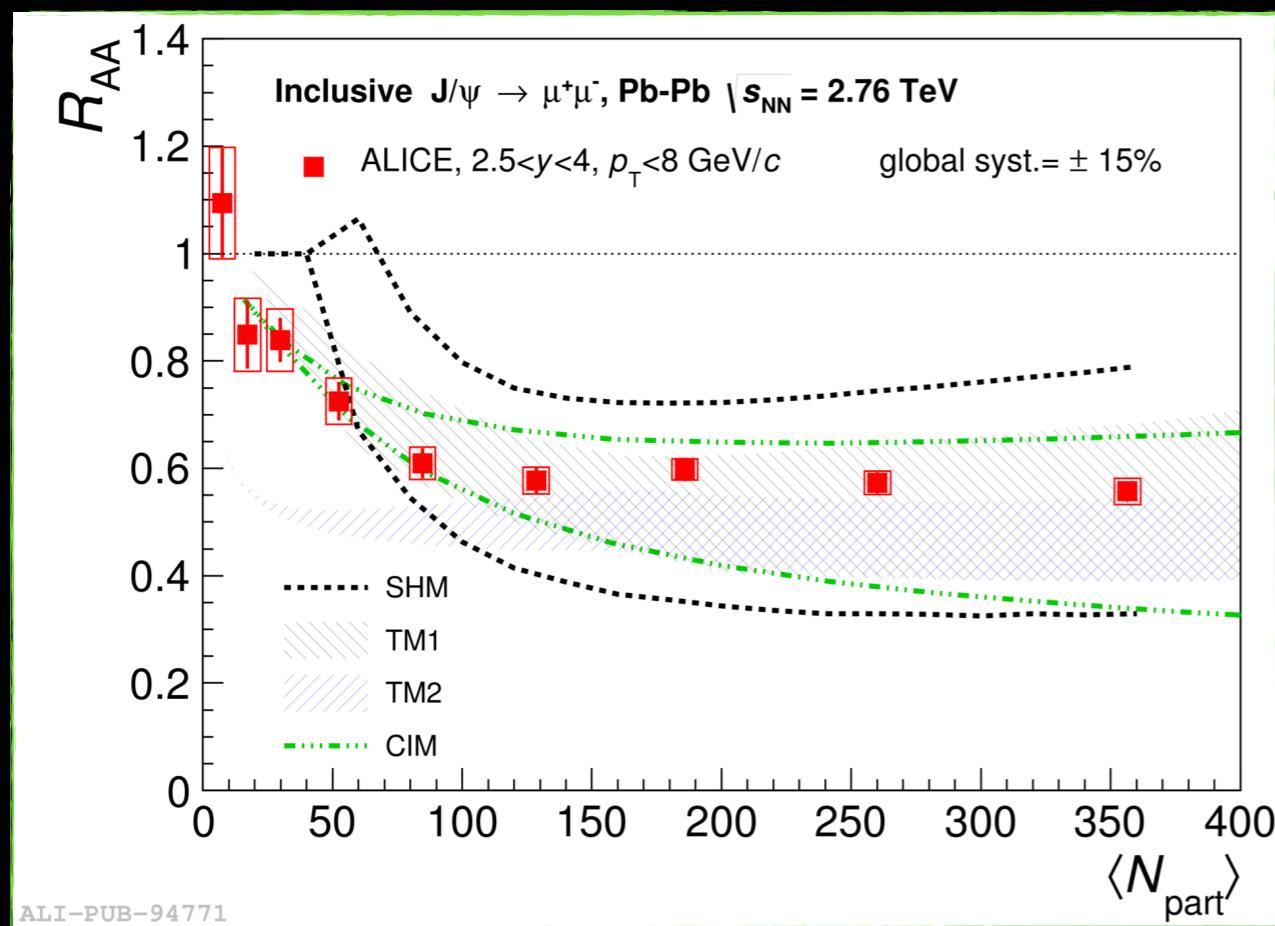
QGP

Transport properties & deconfinement

QGP: quarkonia, J/ψ

- Competition between recombination (low p_T) and dissociation (high p_T)
- \sqrt{s} dependence ($0.2 \text{ TeV} \rightarrow 2.76 \text{ TeV}$)

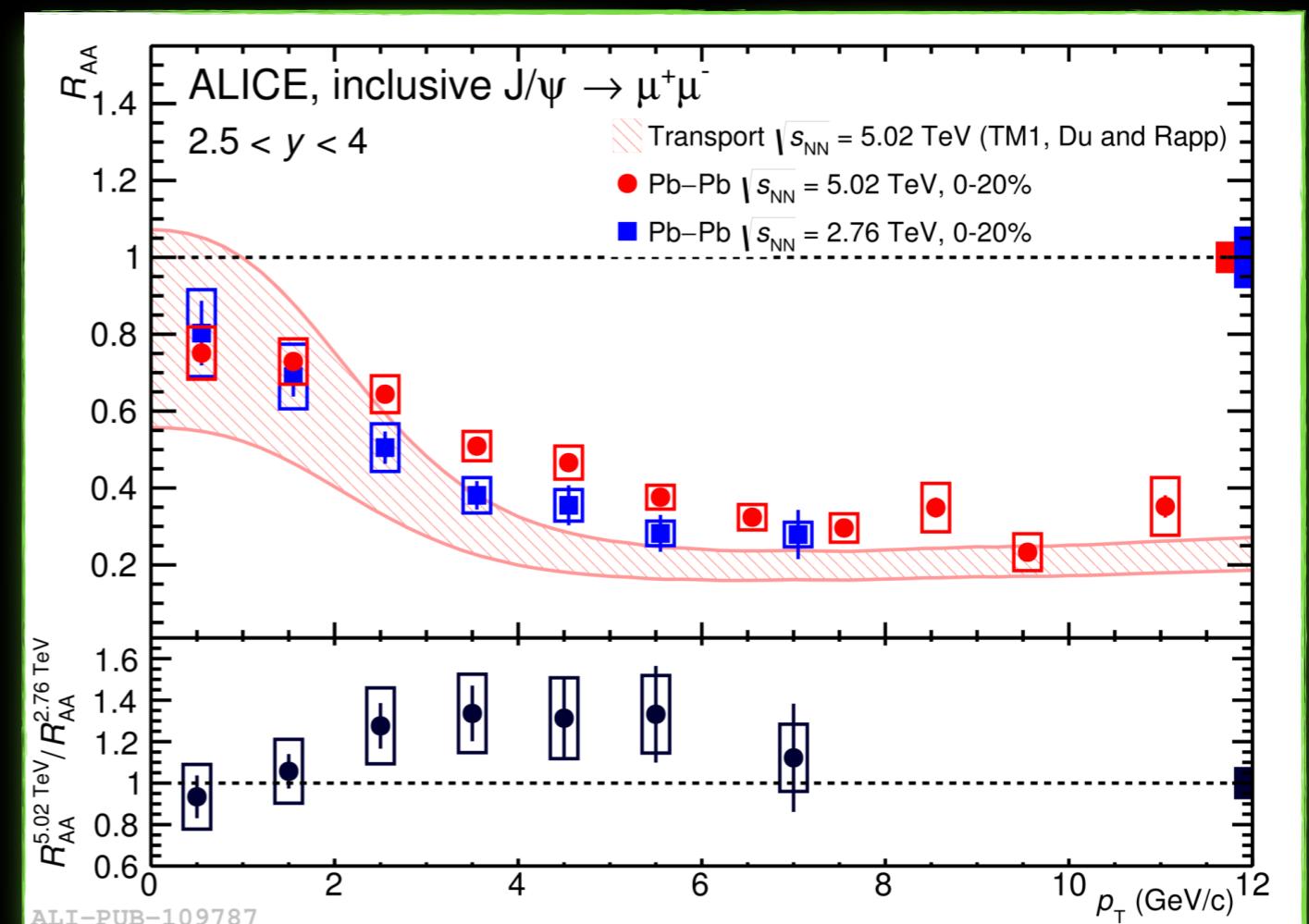
Pb-Pb @ 2.76 TeV



QGP: quarkonia, J/ψ

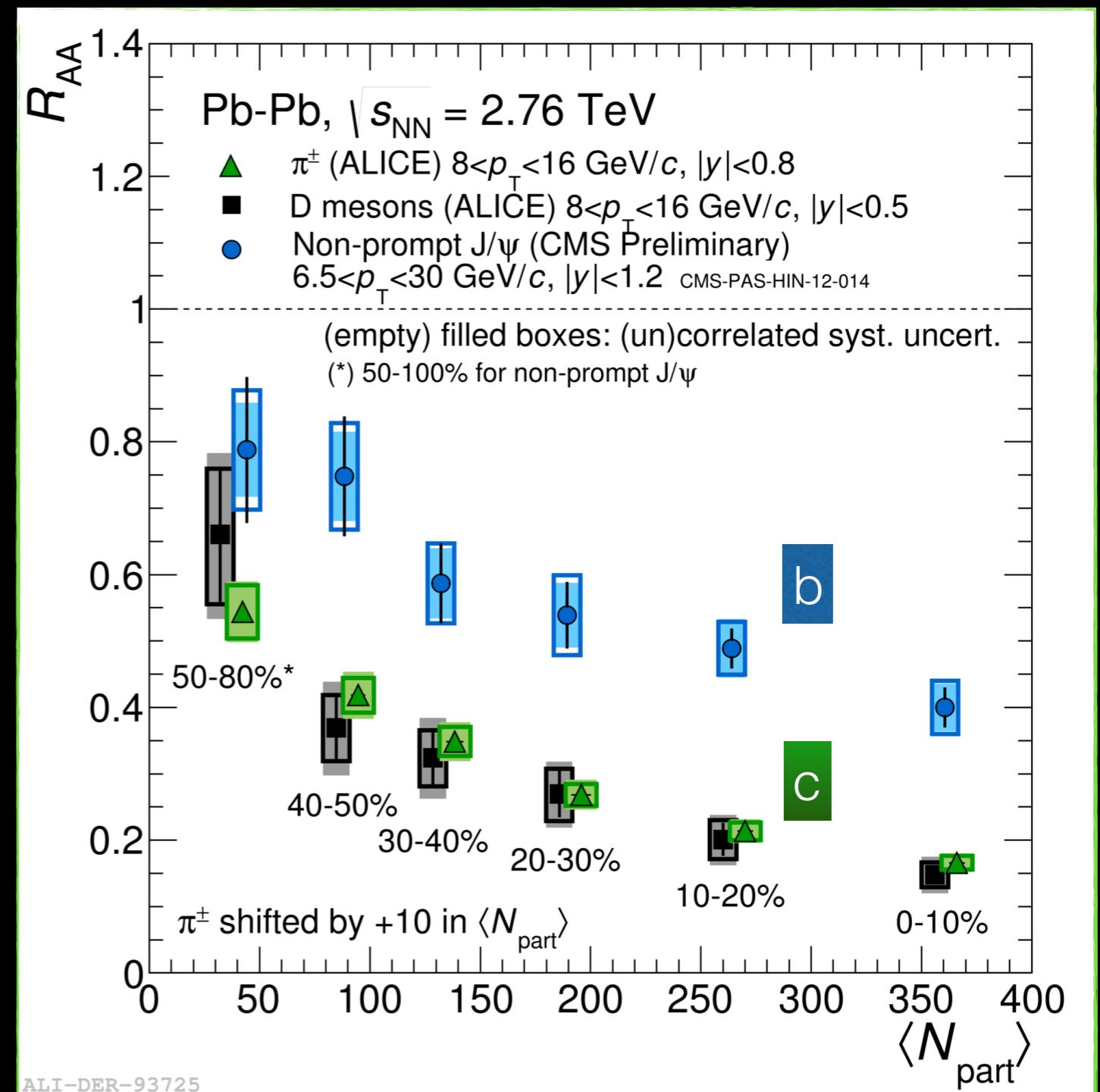
- Competition between recombination (low p_T) and dissociation (high p_T)
- \sqrt{s} dependence ($0.2 \text{ TeV} \rightarrow 2.76 \text{ TeV}$)
- Hint for less suppression at 5.02 TeV

Pb-Pb 2.76 TeV / 5.02 TeV



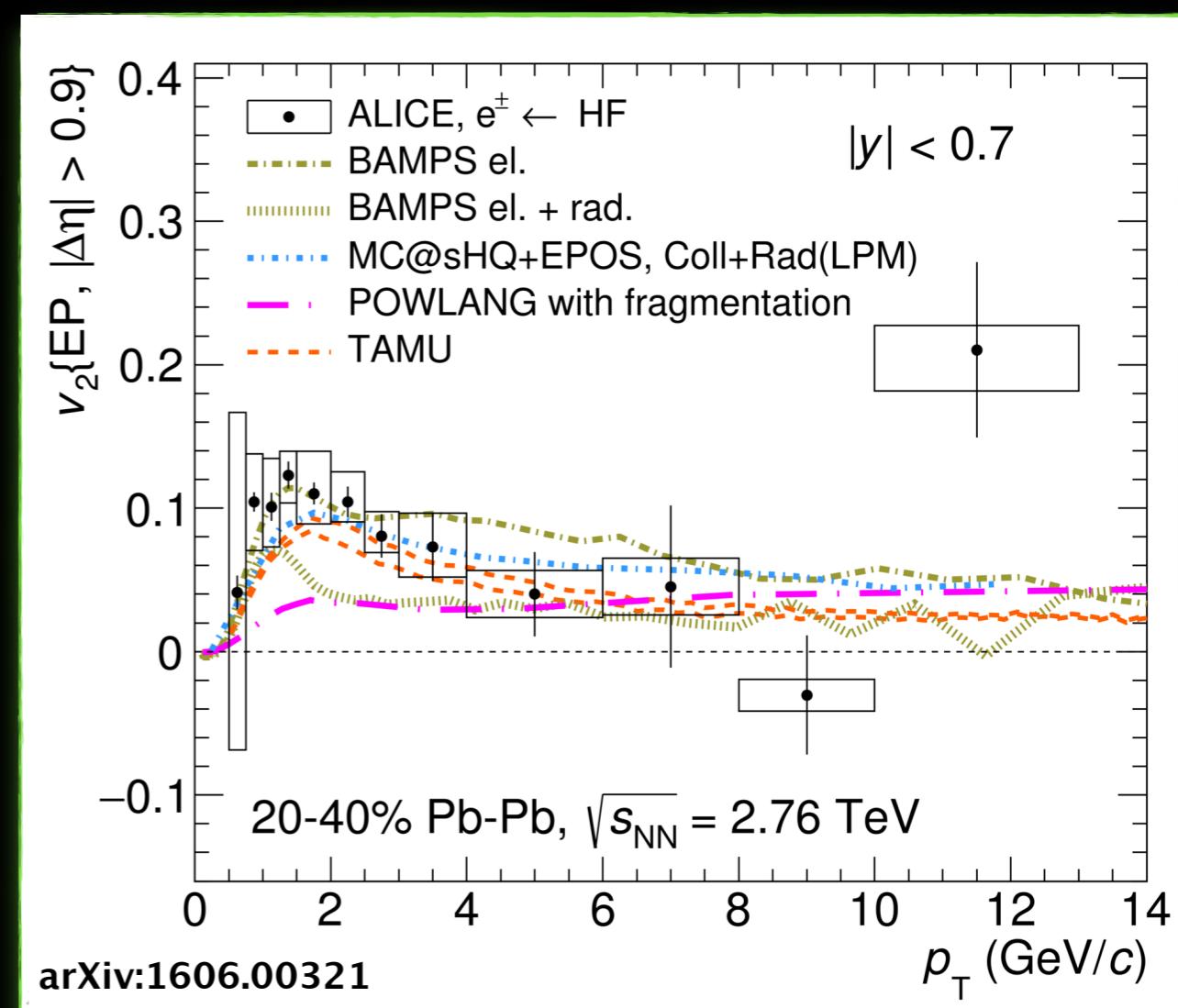
QGP: HF, c, b

- HF transport:
 - Mass dependance: ?



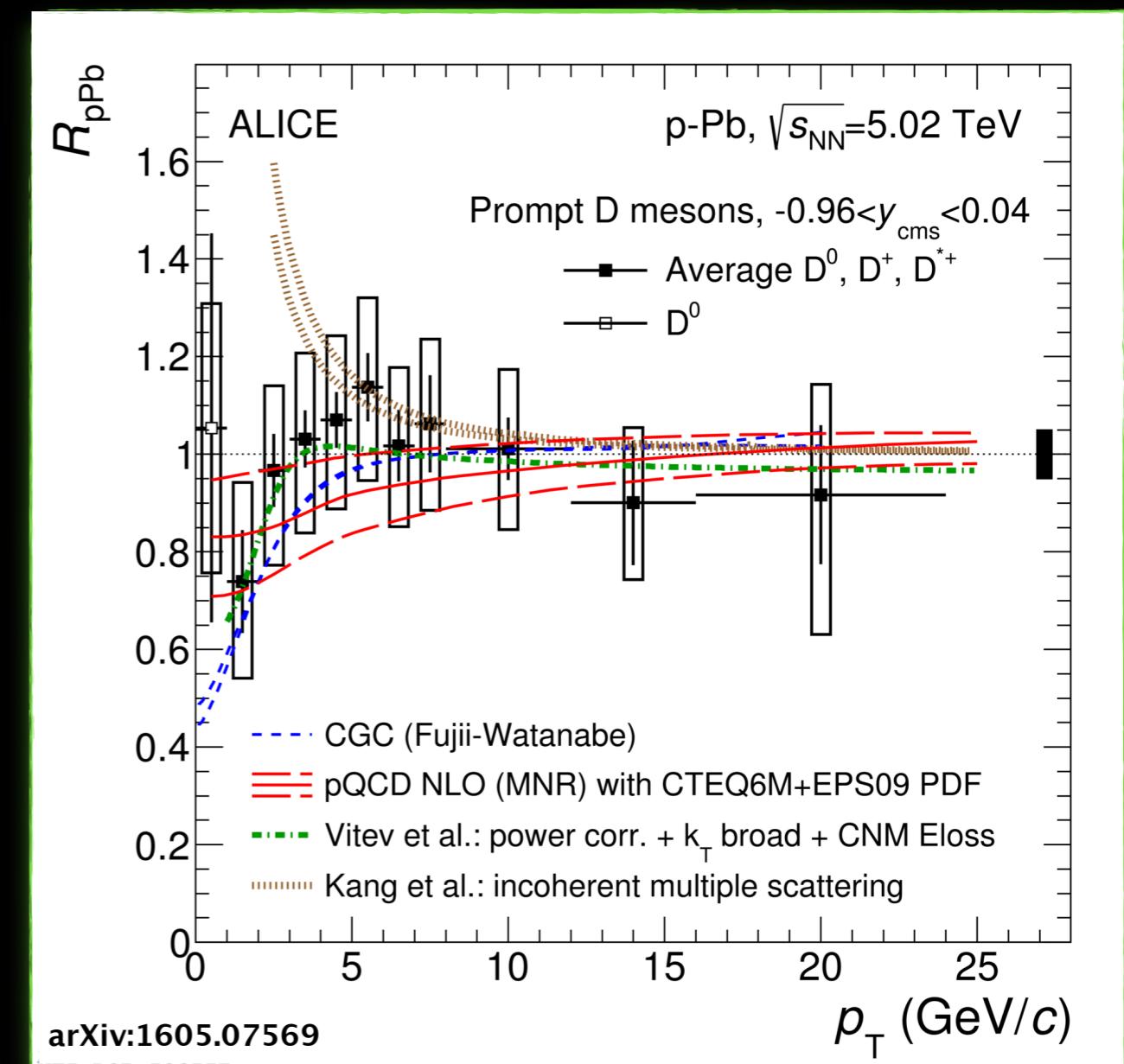
QGP: HF, c, b

- HF transport:
 - Mass dependence: ?
 - Thermalization: ?



QGP: HF, c, b

- HF transport:
 - Mass dependance ?
 - Thermalization: ‘
 - pA: No



ALICE at LHC

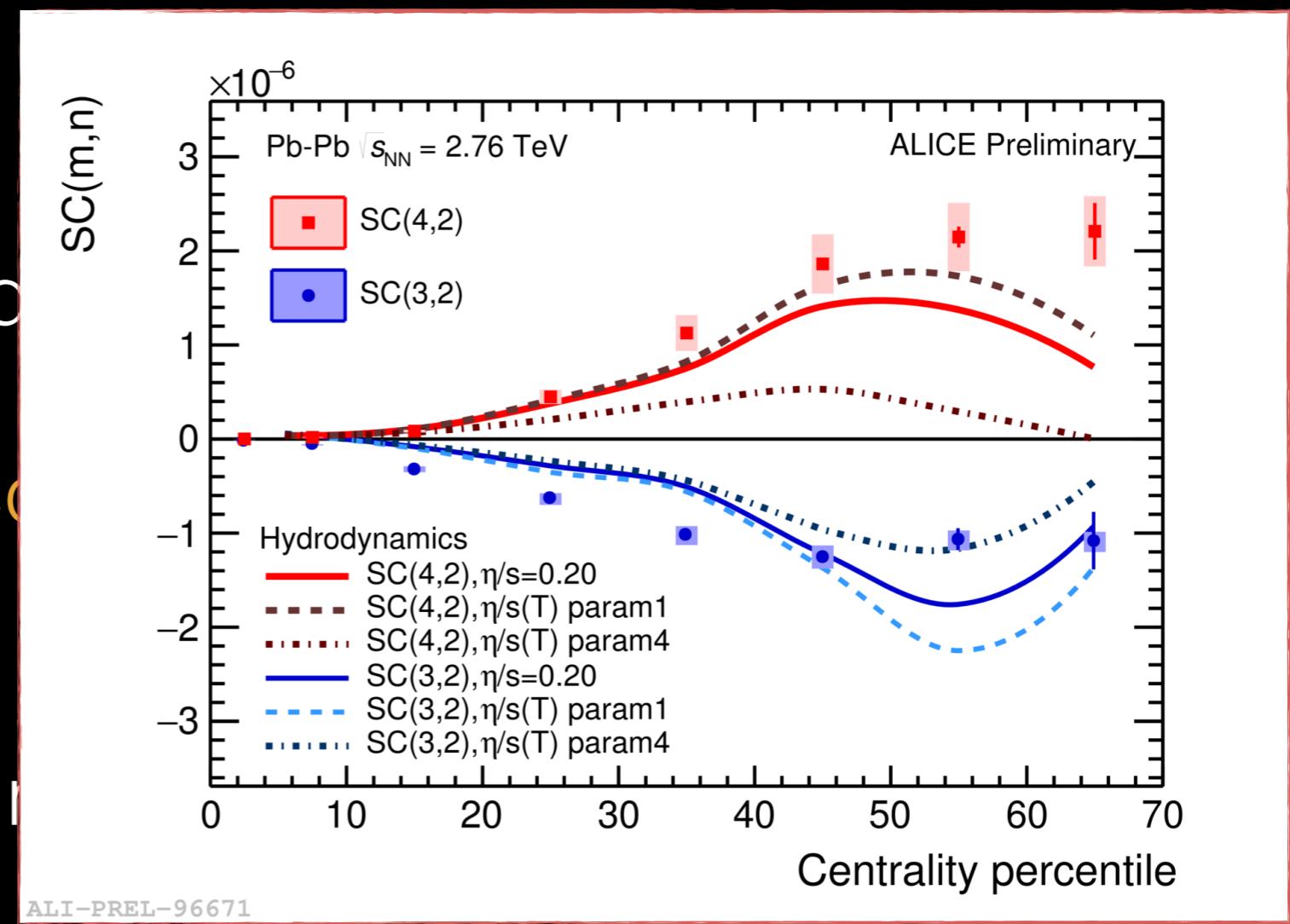
so far...

- Towards a full understanding of HI dynamics
- Bulk and microscopic of QGP properties being fine tuned
- Small systems: a new paradigm ?

ALICE at LHC

so far...

- Towards a full understanding
- Bulk and microscopic models fine tuned
- Small systems: a new era



- Entering precision era $\rightarrow \eta/S(T)$, minimum at T_c approaching $\hbar/4\pi k_B$

Open questions

- Interpretation of observables still complicated, e.g.:
 - jet quenching: little sensitivity of R_{AA} to color density; energy loss of heavy quarks
 - Azimuthal anisotropy: elliptic flow, higher harmonics, heavy quarks, viscosity
- New challenge: perform precision measurements of bulk properties with heavy quarks

More challenges

- Explore electroweak probes
 - thermal photon/dileptons
 - hard EW probes (γ/Z -jet)
- Initial state: gluon saturation ?

Looking forward....

- RUN 2: higher precision, more differential, correlations, $\mathcal{L}_{\text{int}} \times 10$
- RUN 3-4: upgraded ALICE, rare probes (c, b),
 $\mathcal{L}_{\text{int}} \times 100$
- ALICE is unique in low p_{t} /mass measurements and particle identification

Looking backward...



30 Years of Heavy ions : ...what next?

9 November 2016

CERN

Europe/Zurich timezone

There is a [live webcast](#) for this event.

<https://indico.cern.ch/event/457044/overview>

Overview

[Scientific Programme](#)

[Timetable](#)

[Registration](#)

[Participant List](#)

[Videoconference Rooms](#)



Starts 9 Nov 2016 14:00

Ends 9 Nov 2016 20:30

Europe/Zurich



CERN

500-1-001 - Main Auditorium



Materials



[HeavyIonCelebration_PosterFinal-print...](#)



Registration

Registration for this event is currently open.

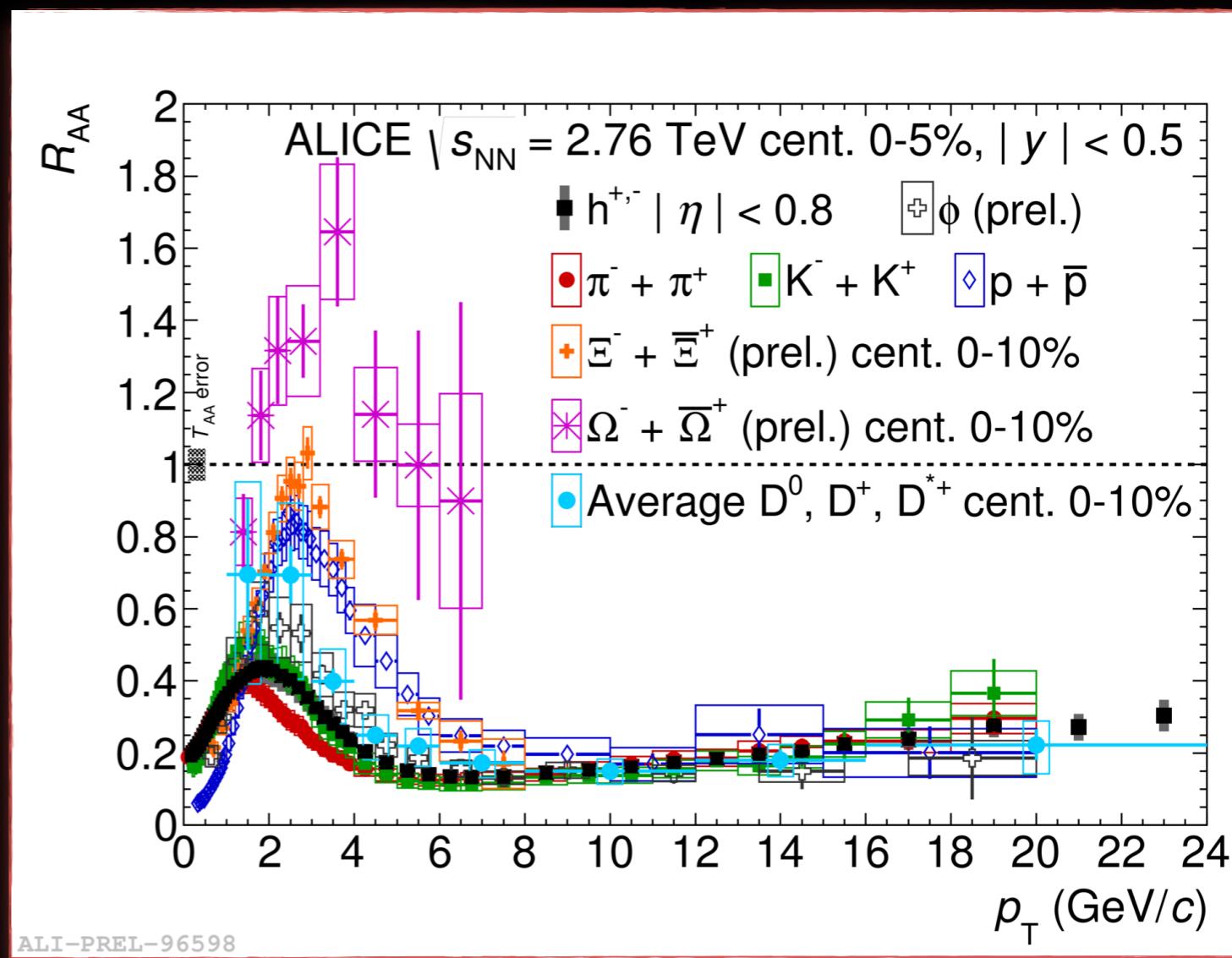
[Register now >](#)

QGP: nuclear modification, hadron

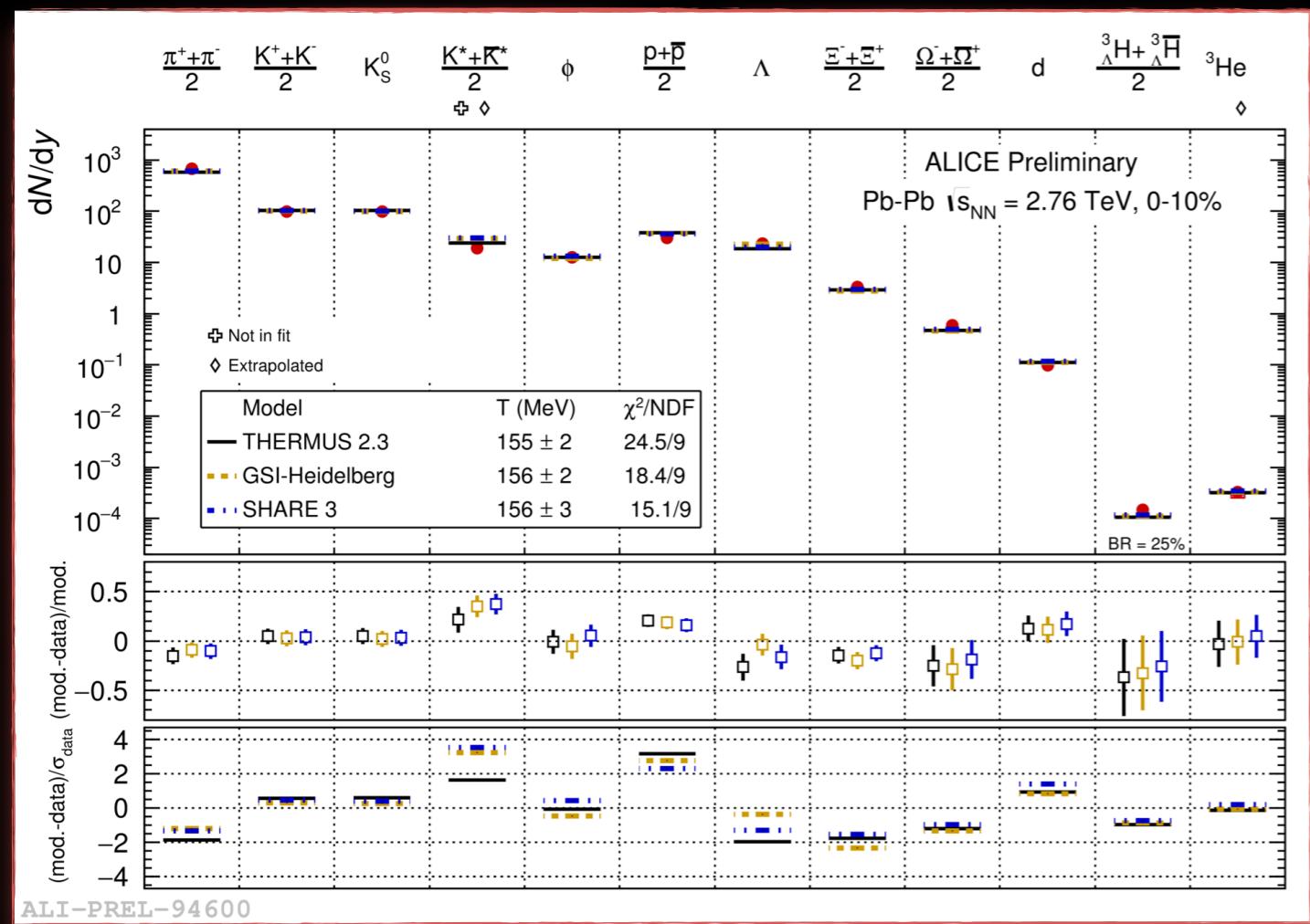
$$R_{xA}(p_T) = \frac{d^2 N_{ch}^{xA} / d\eta dp_T}{\langle T_{xA} \rangle d^2 \sigma_{ch}^{pp} / d\eta dp_T}$$

Pb-Pb @ 2.76 TeV (same at 5.02 TeV)

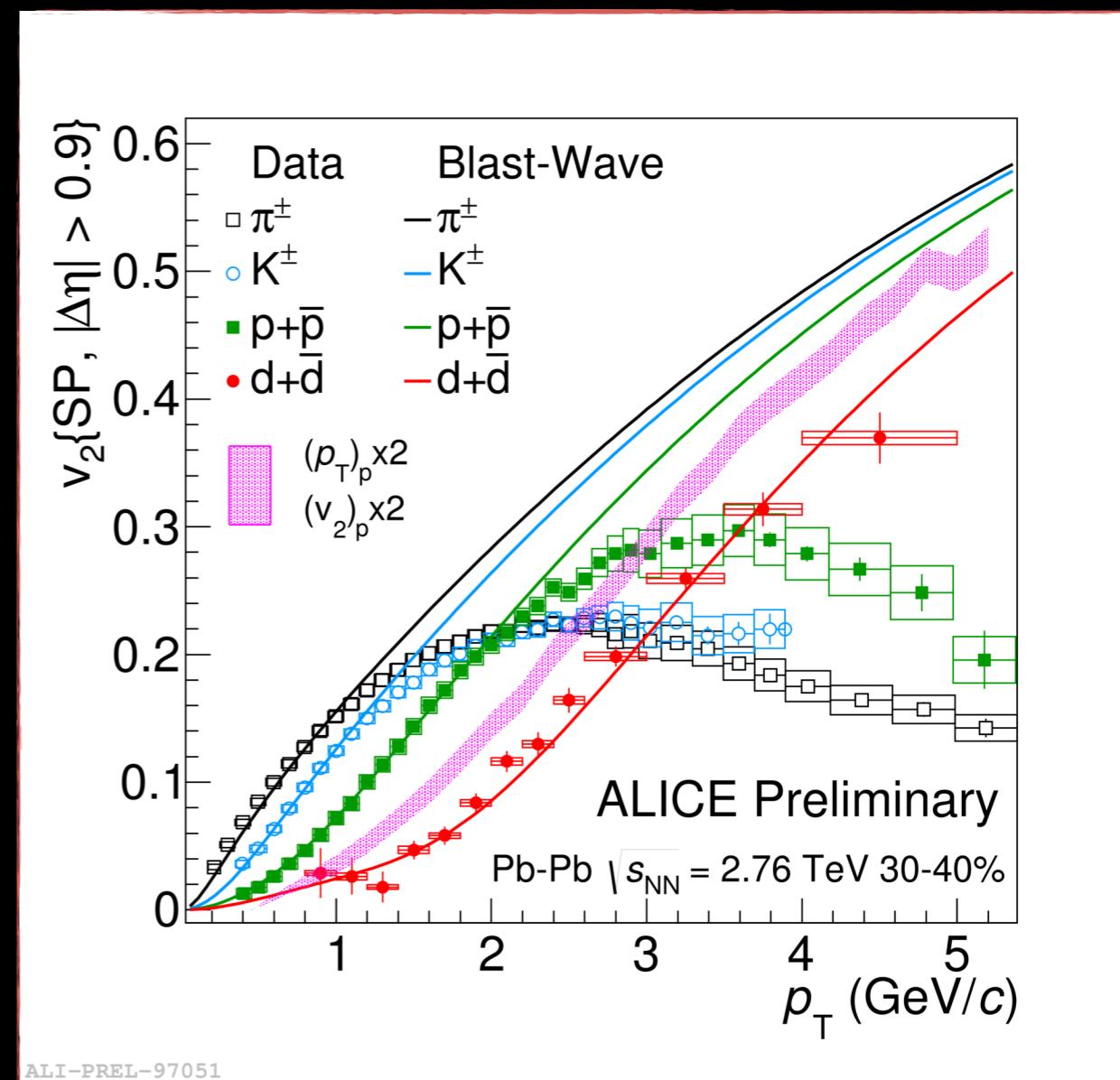
- light flavor and charm equally suppressed at higher p_T
- parton energy loss in QGP



Final state: hadrons & nuclei



> Similar production mechanism for h and d ?



Final state: ratio/strangeness

- Smooth trend with centrality (charge particles density)
- Identical for pp, pA and AA
- Increase of strangeness production with charged - particle density
- From pp to AA same production mechanism at work ?

