Relativistic Heavy-Ion Physics

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UKNPSS, Bristol, Sept 2013

Recap lecture 2

- Experimental Observations
  - Hadron spectrum yields consistent with T=160 MeV
  - Increased role for strange quark d.o.f.
  - Energy densities of at least 10 GeV/fm^3
  - Matter opaque to high p_T particles which are suppressed by a factor 5-10

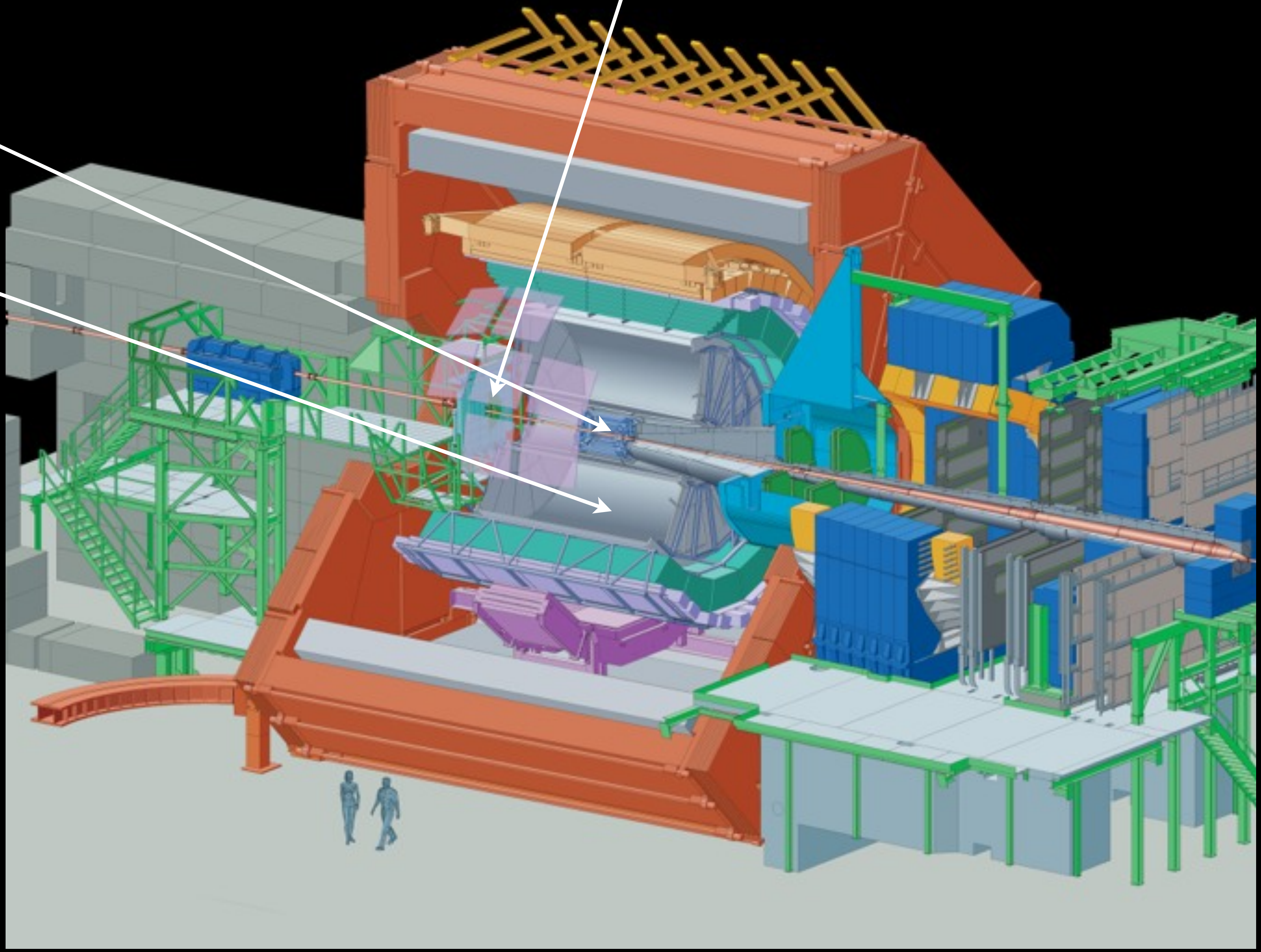
In this lecture

- Further investigation
  - Using identified particles, π, K, p …
  - Measuring Φ dependence
  - p+Pb collisions - control experiment or something new?

ALICE

Scintillator (V0)
for centrality and reaction plane

TPC and ITS
for tracking



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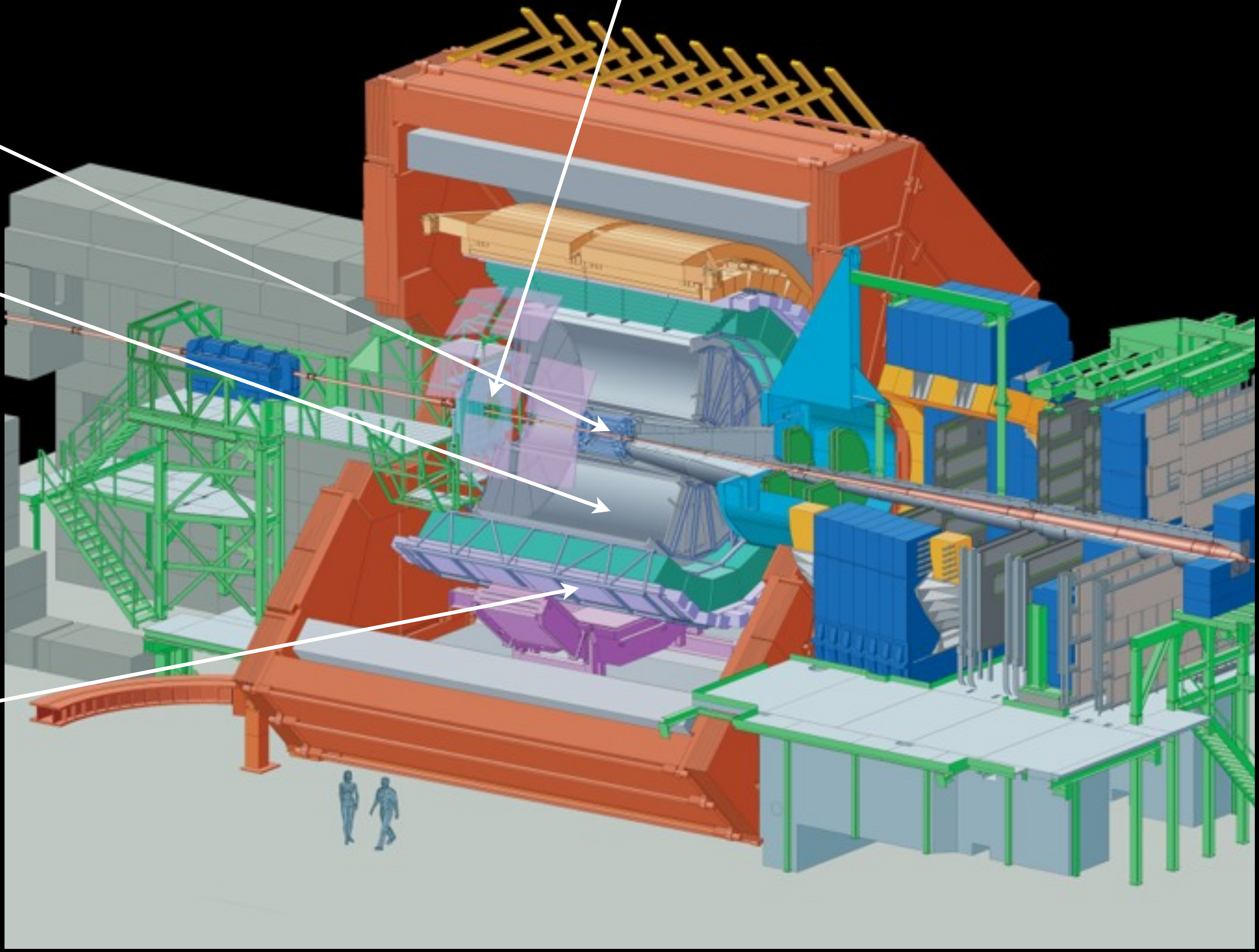

TPC, ITS and
TOF for PID

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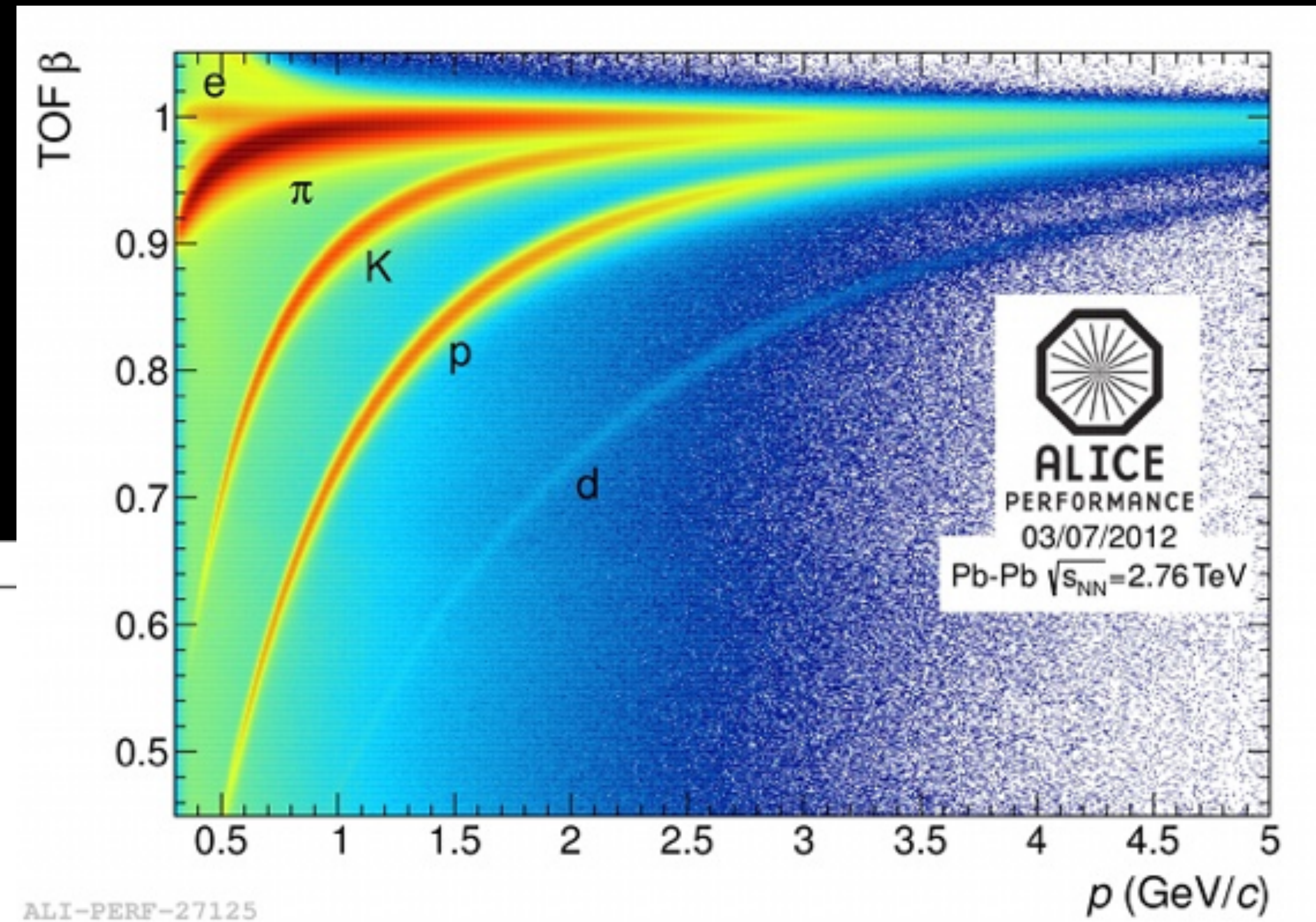
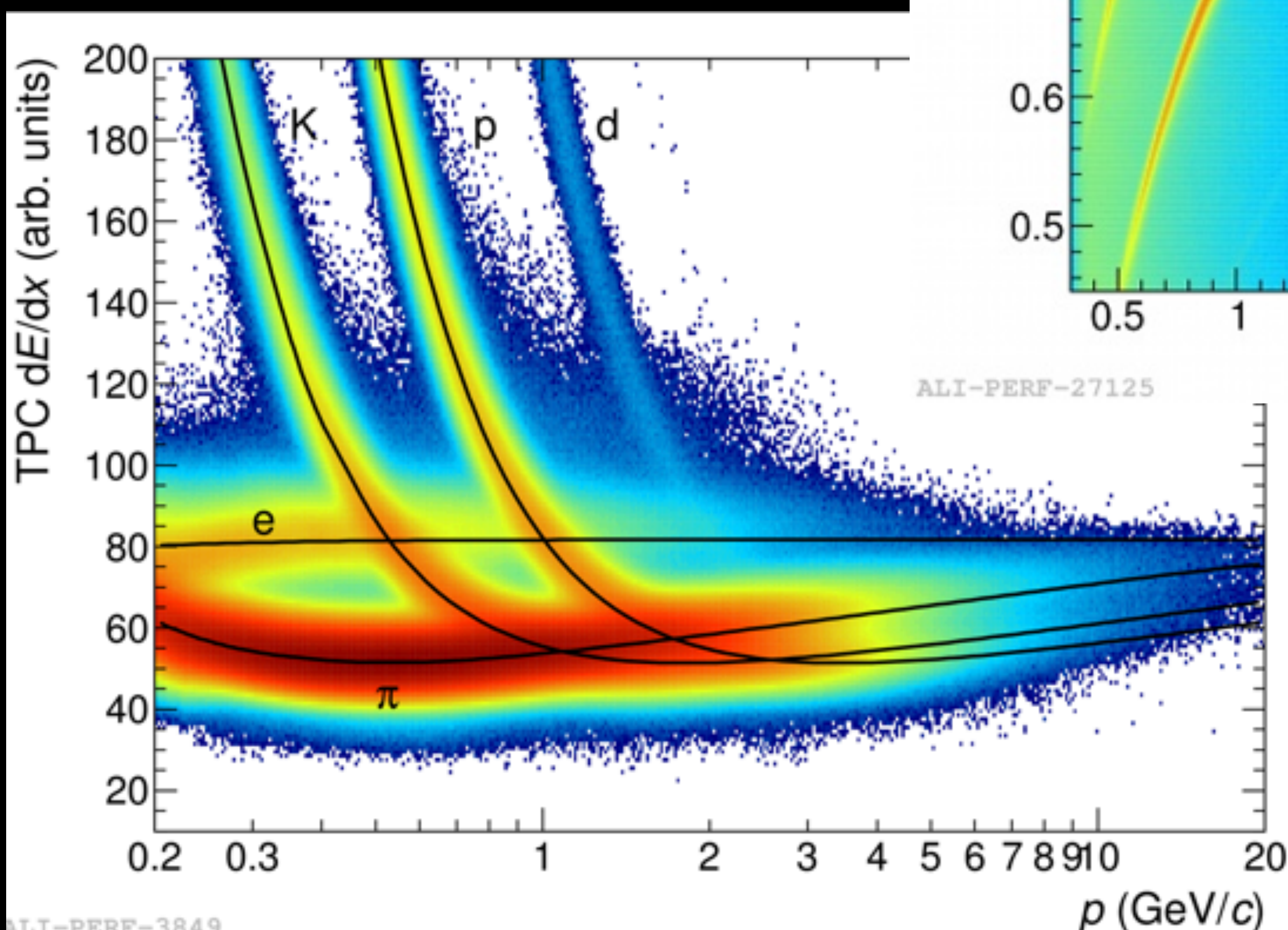
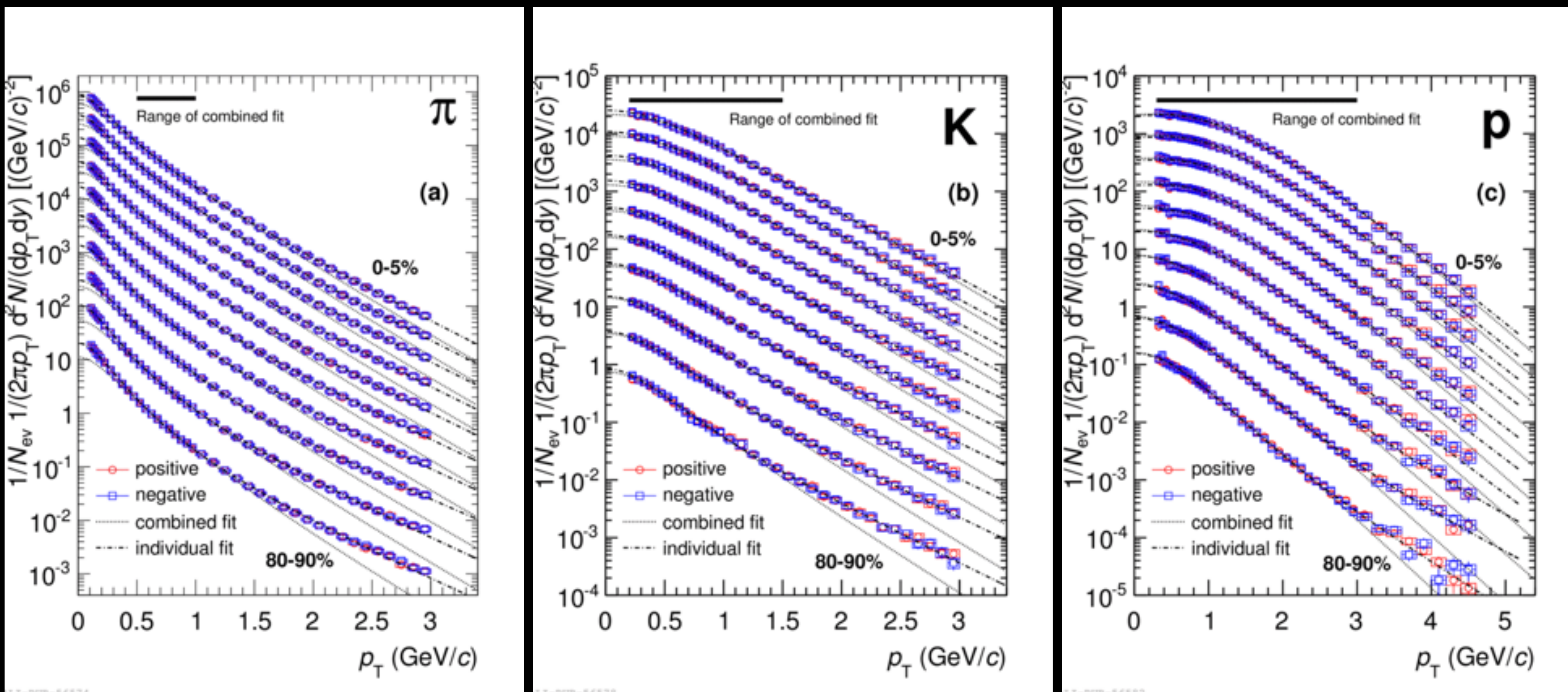
Identifying particles





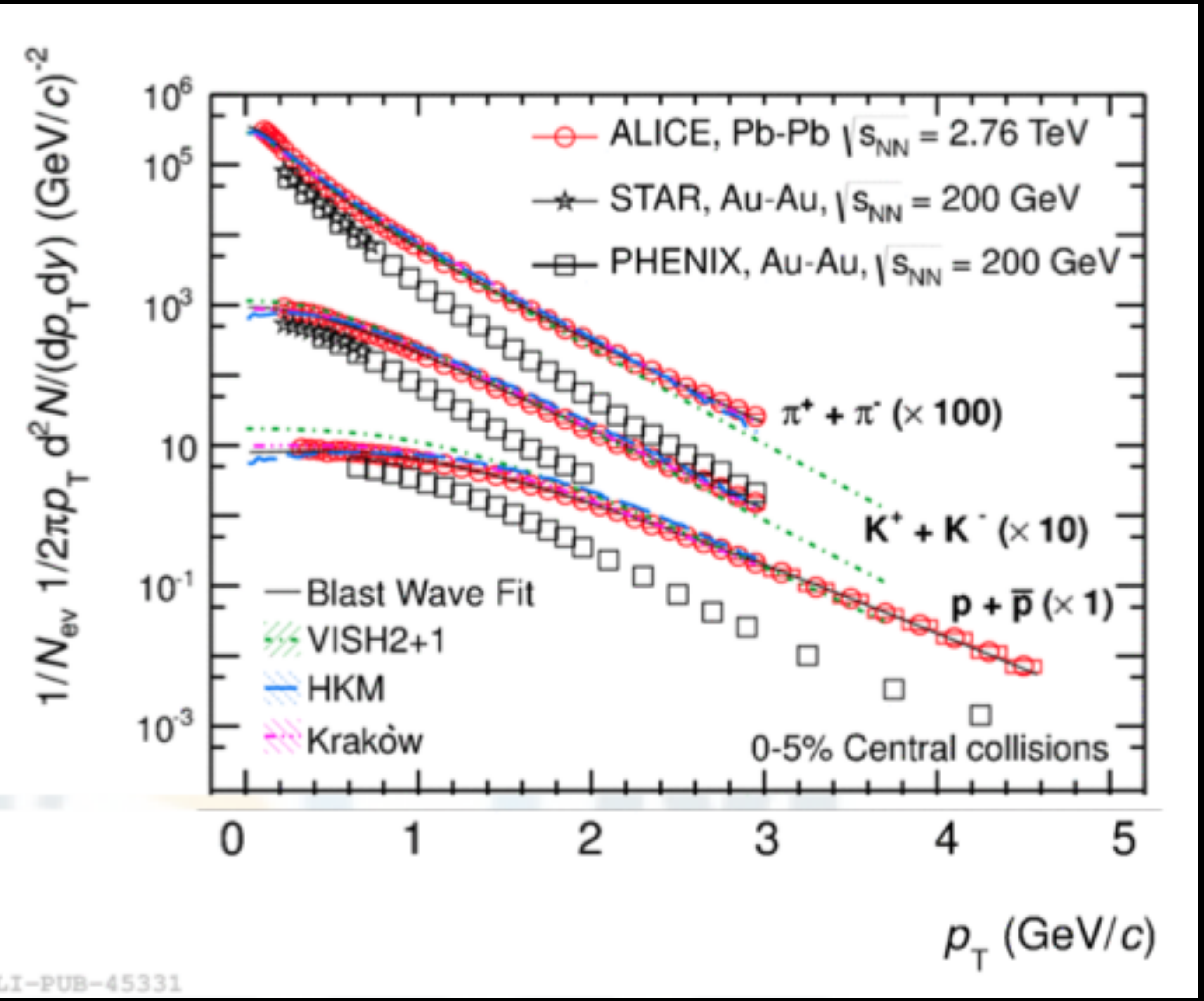
p_T spectra



Spectra changing shape with centrality

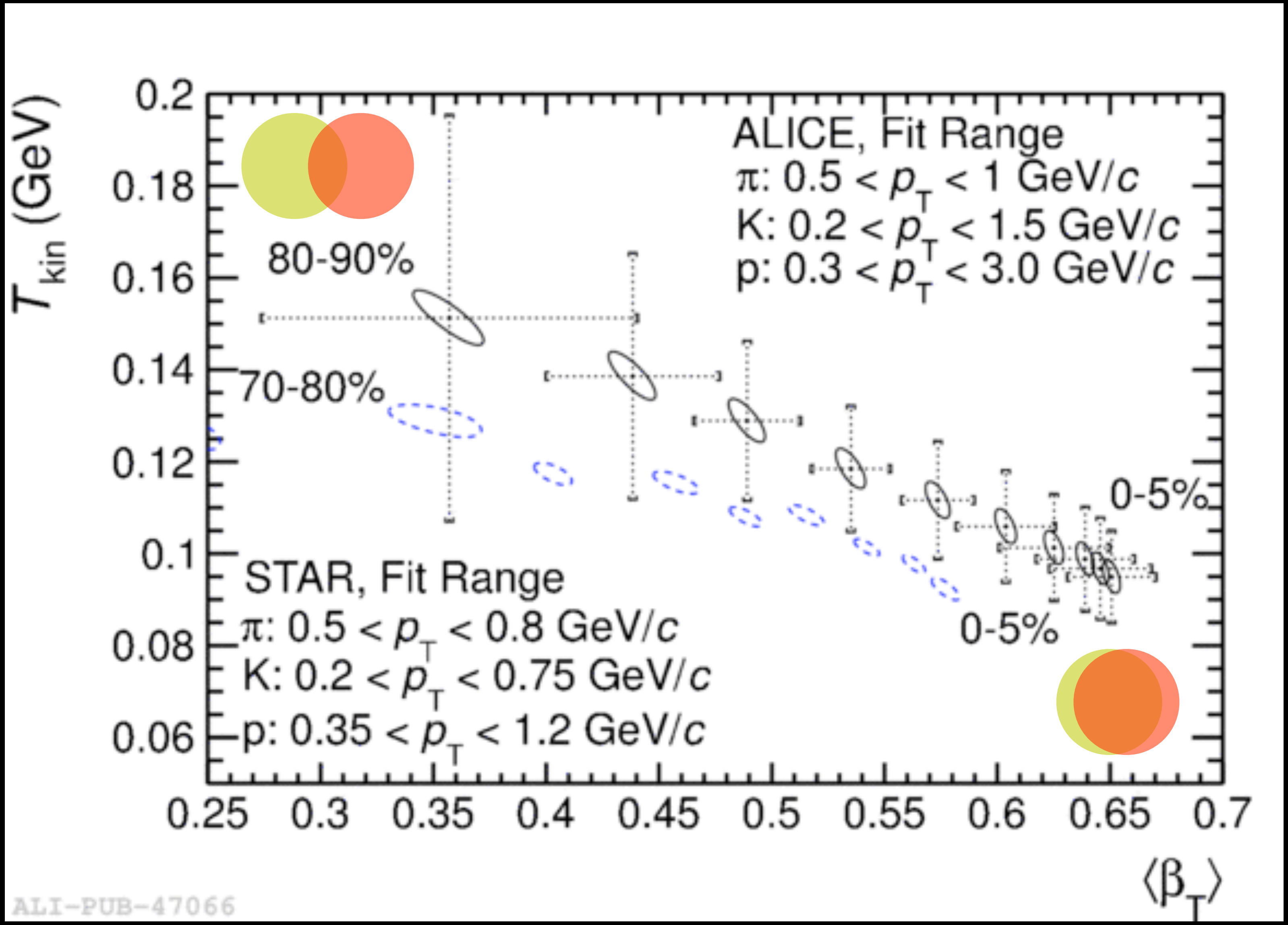
Collective motion

- Slope of p_T spectrum reflects temperature
  - but only for a **static** source
- Expanding source gives ‘boost’
  - particles with common **VELOCITY** move together in hydrodynamic flow

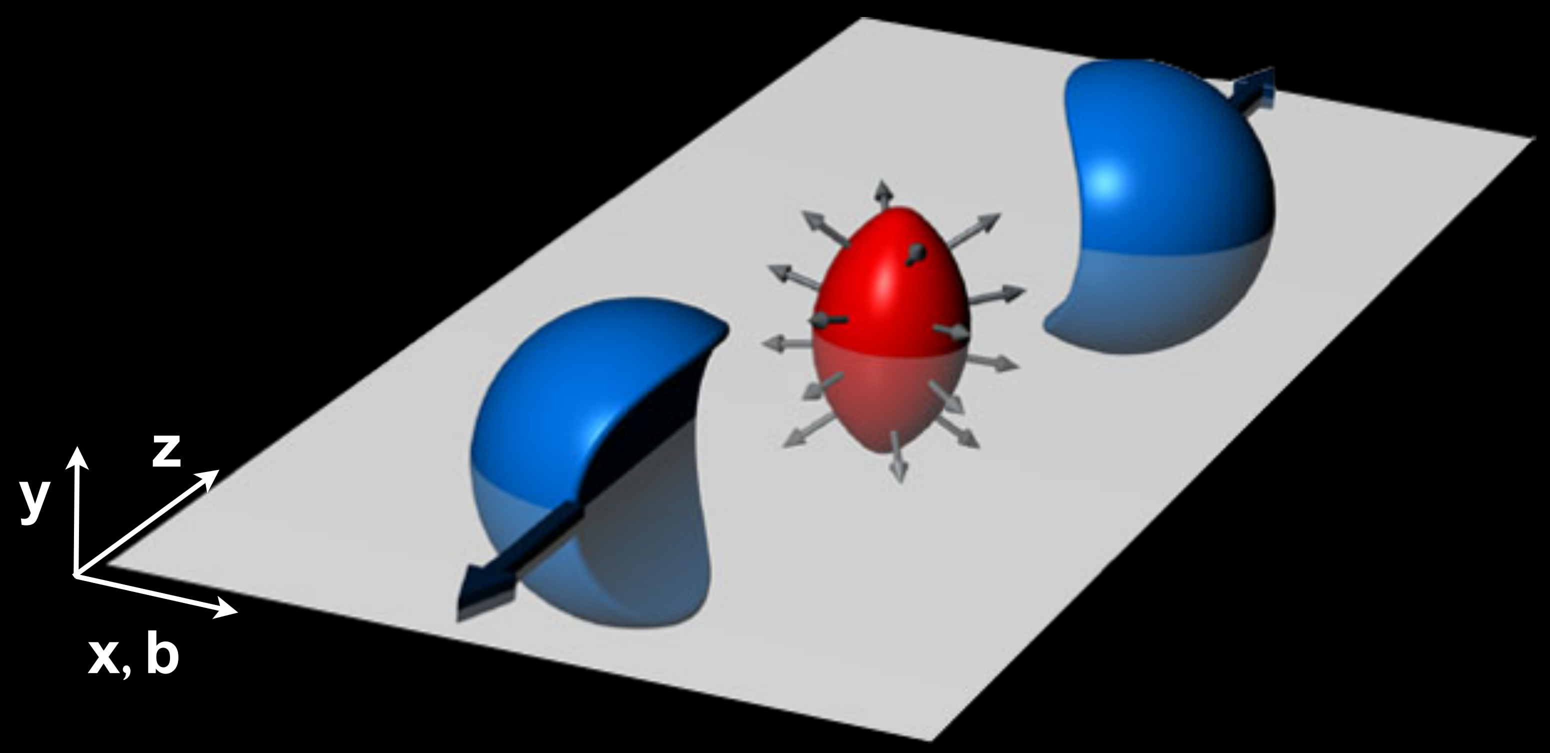


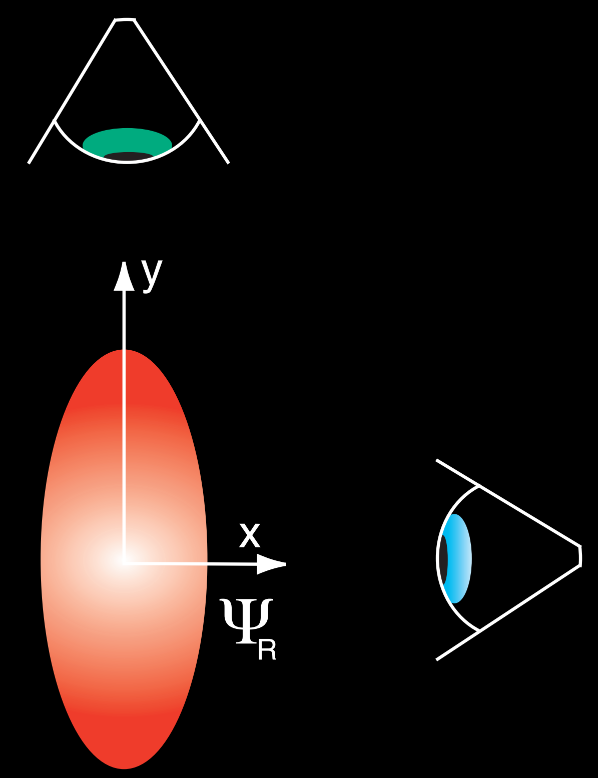
Blast-wave model

- Thermalized volume elements, expanding in a common velocity field
- Parameters:
  - T_{kin}
  - $\beta_T = \beta_S \cdot (r/R)^n$



The Reaction Plane

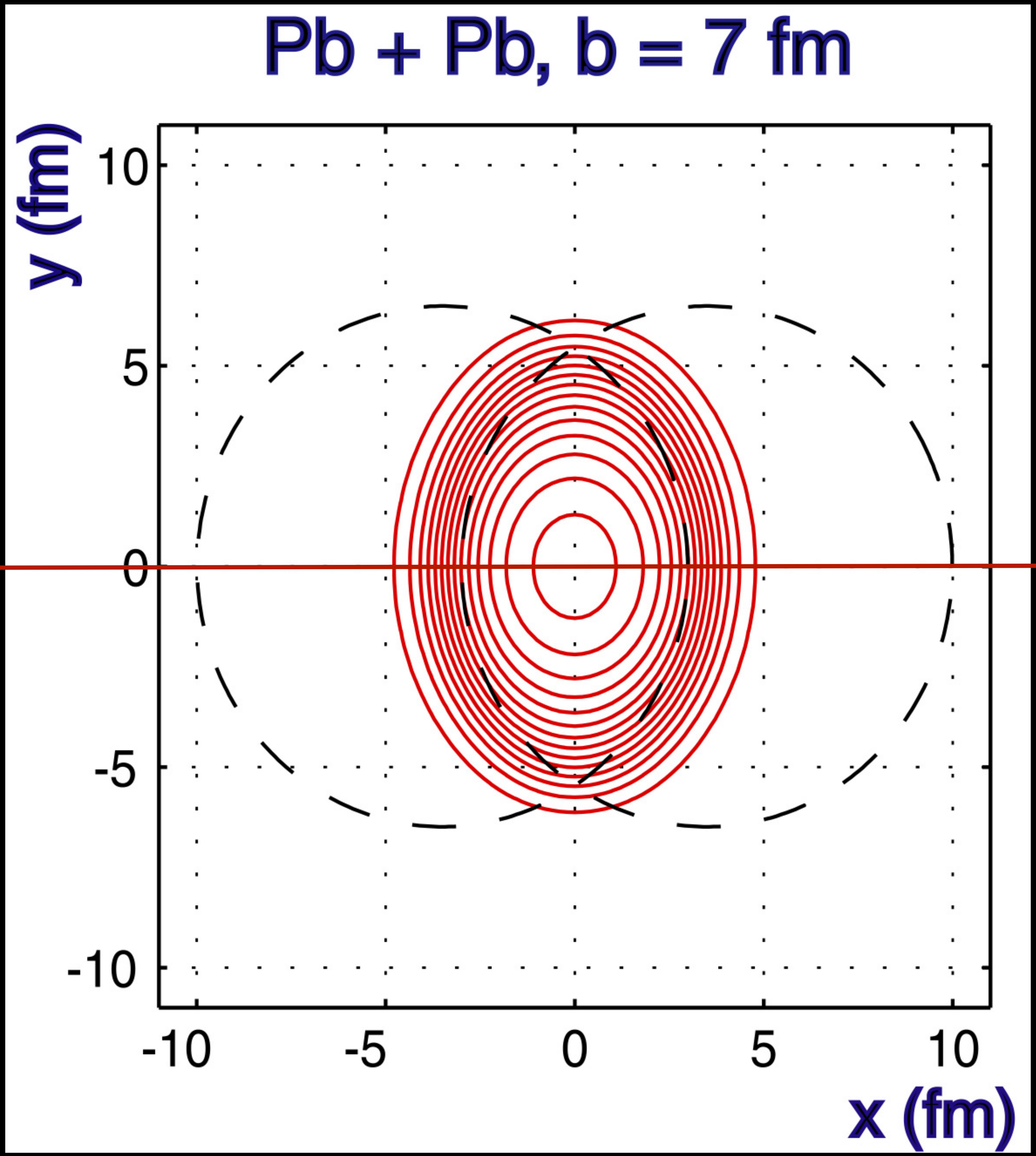




$$E\frac{d^3N}{d^3p} = \frac{d^3N}{p_t dp_t dy d(\phi - \Psi_R)}$$

determine the angle of the reaction plane ψ_R

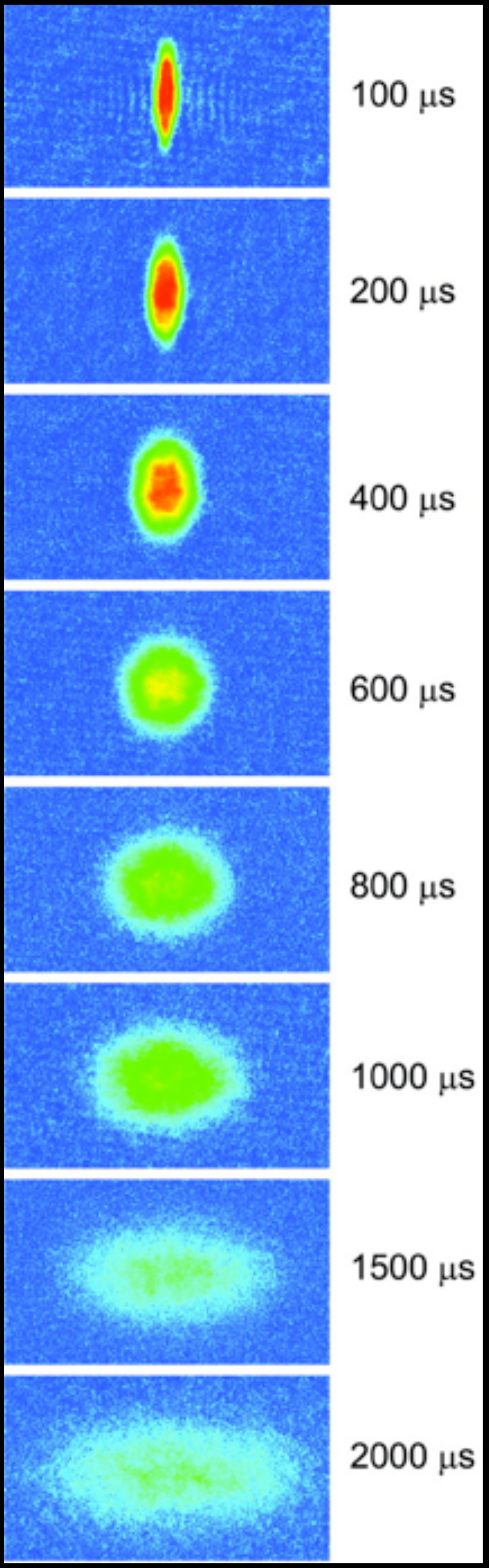
Elliptic Flow concept



Reaction plane

Example in another field

- Strongly coupled interacting Li^6 Fermi Gas
- Held in trap and released
- Expansion over time shown



Science 13 2002:
Vol. 298 no. 5601 pp. 2179-2182

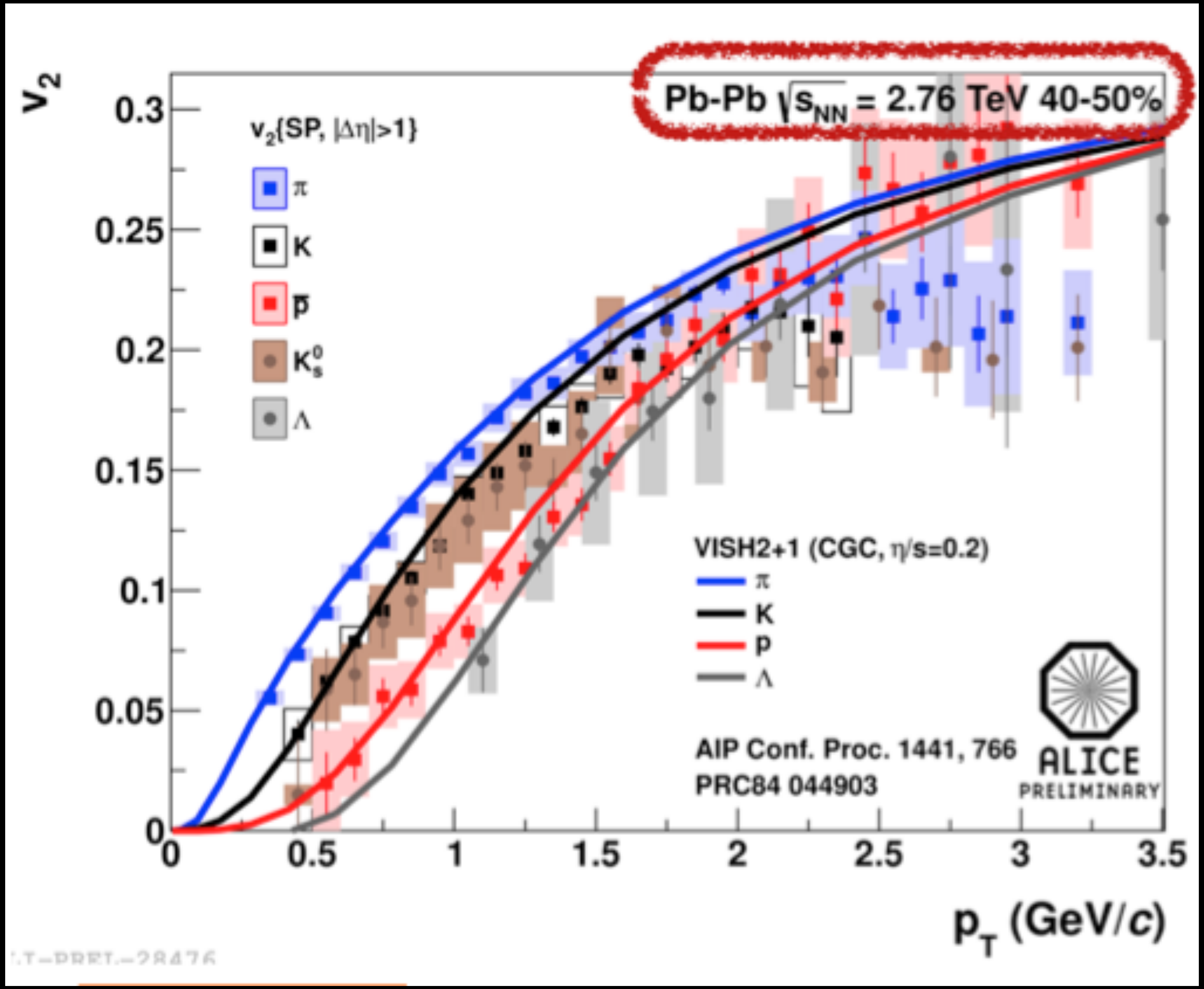
Elliptic Flow in experiment

$$E\frac{d^3N}{dp^3} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_t dy} 1 + \sum_{n=1}^{\infty} 2v_n \cos\left(n(\phi - \Psi_R)\right)$$

- v_2 coefficient known as 'elliptic flow'
- Get reaction plane angle from other detectors
- *or* invent fancy methods using correlations which eliminate it

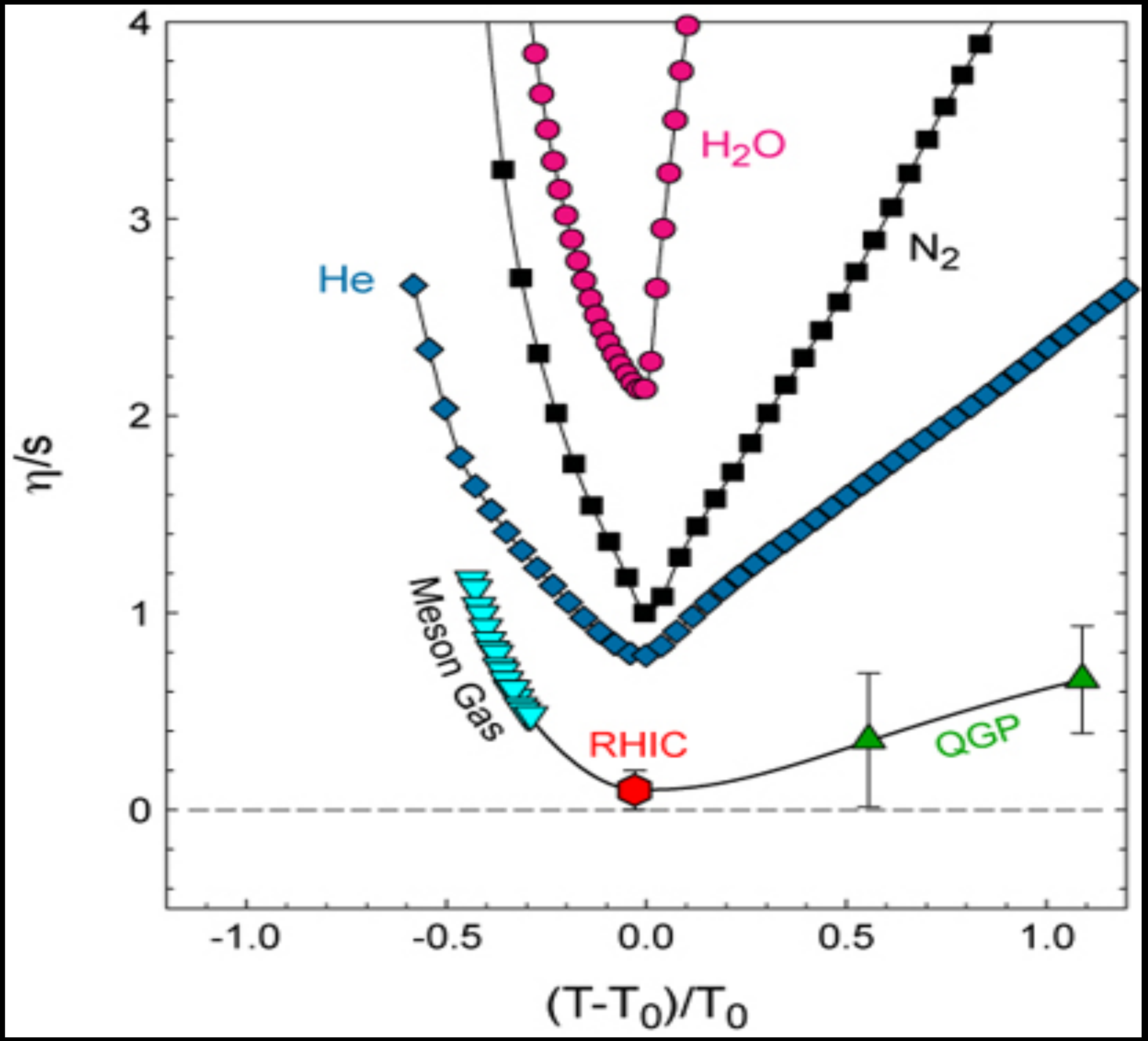
v_2 mass dependence

- Possible to do full hydrodynamic modelling with viscosity included



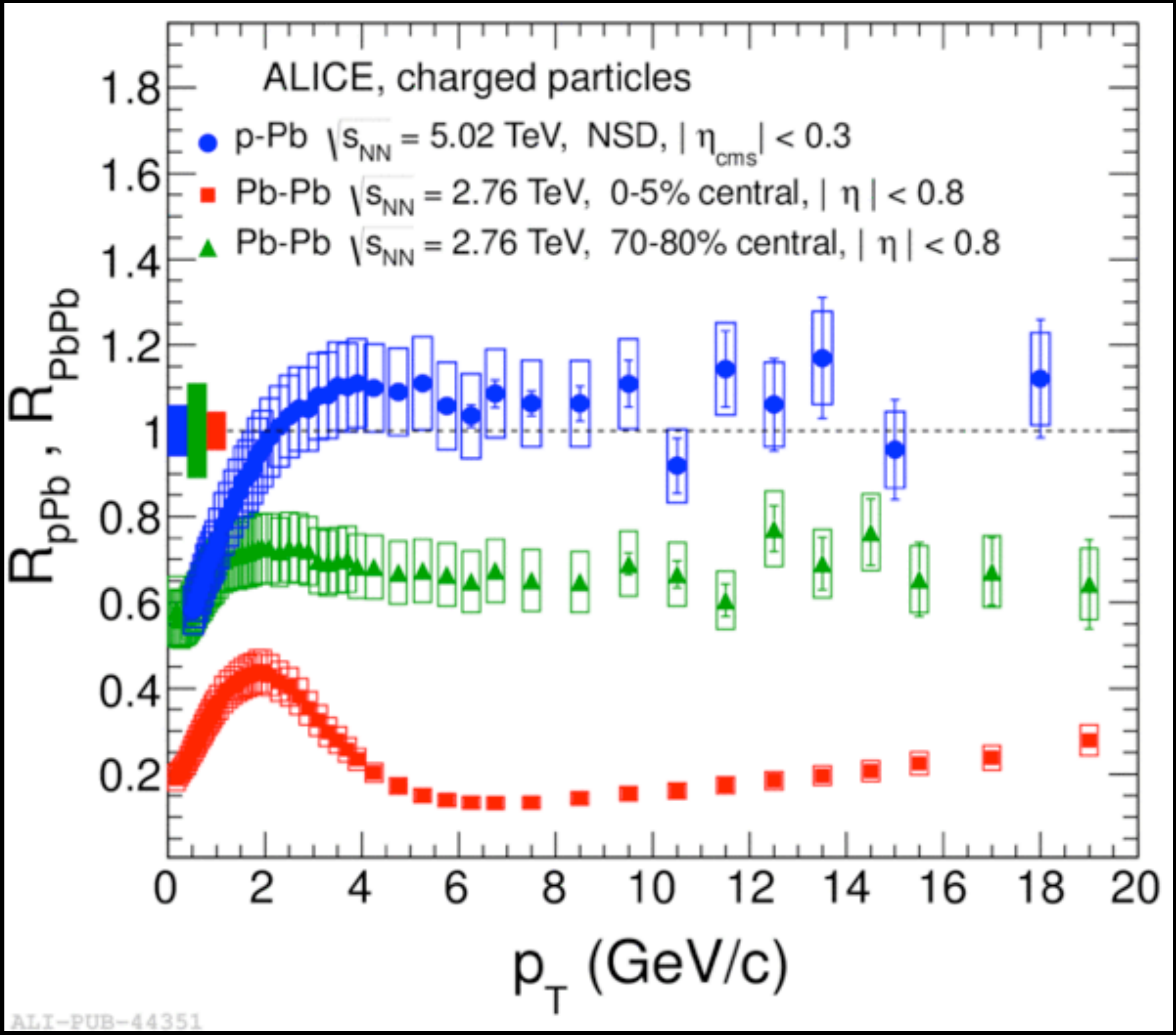
Viscosity

- Viscosity to entropy ratio can be calculated
- It comes out *very* small compared to all known liquids
- 'Perfect Liquid'



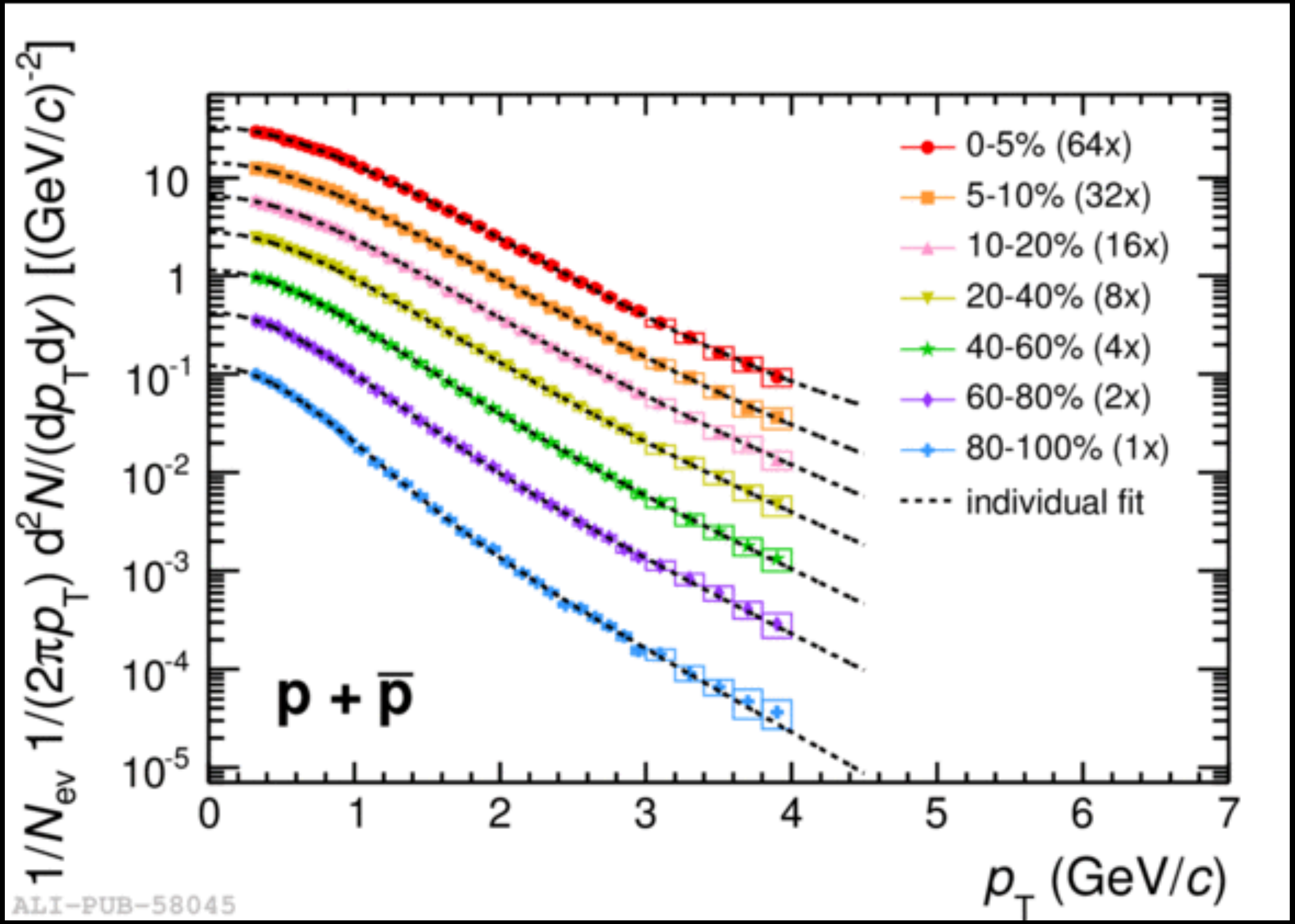
p+Pb collisions (1)

- Confirms validity of binary scaling



p+Pb collisions (II)

- Signs of multiplicity dependence of p_T spectra even in a ‘small’ system



Conclusions

- Progress in measuring and understanding the quark/gluon matter
- Still things to understand better and possible surprises eg p-Pb

Other hard probes (not covered)

- 'Hard' means ~calculable in pQCD
- Not only high-p_T also charmonium and bottomonium i.e. c-$\bar{c}$ and b-$\bar{b}$
- Bounds states can be disrupted by colour charge screening (Debye)

Acknowledgements

- My colleagues in the field for producing nice diagrams and illustrations. In particular:
  - Prof. Raimond Snellings (NIKHEF/U. Utrecht)
  - Prof. Peter Jones (U. Birmingham)
  - Dr Marek Bombara (P.J. Safarik U., Kosice, Slovakia)
  - Prof. Mike Lisa (Ohio State U.)
  - Dr Andrea Dainese (U. Padova)