LHCP 2013

Light flavour hadron production in pp and Pb-Pb collisions in the ALICE experiment at the LHC

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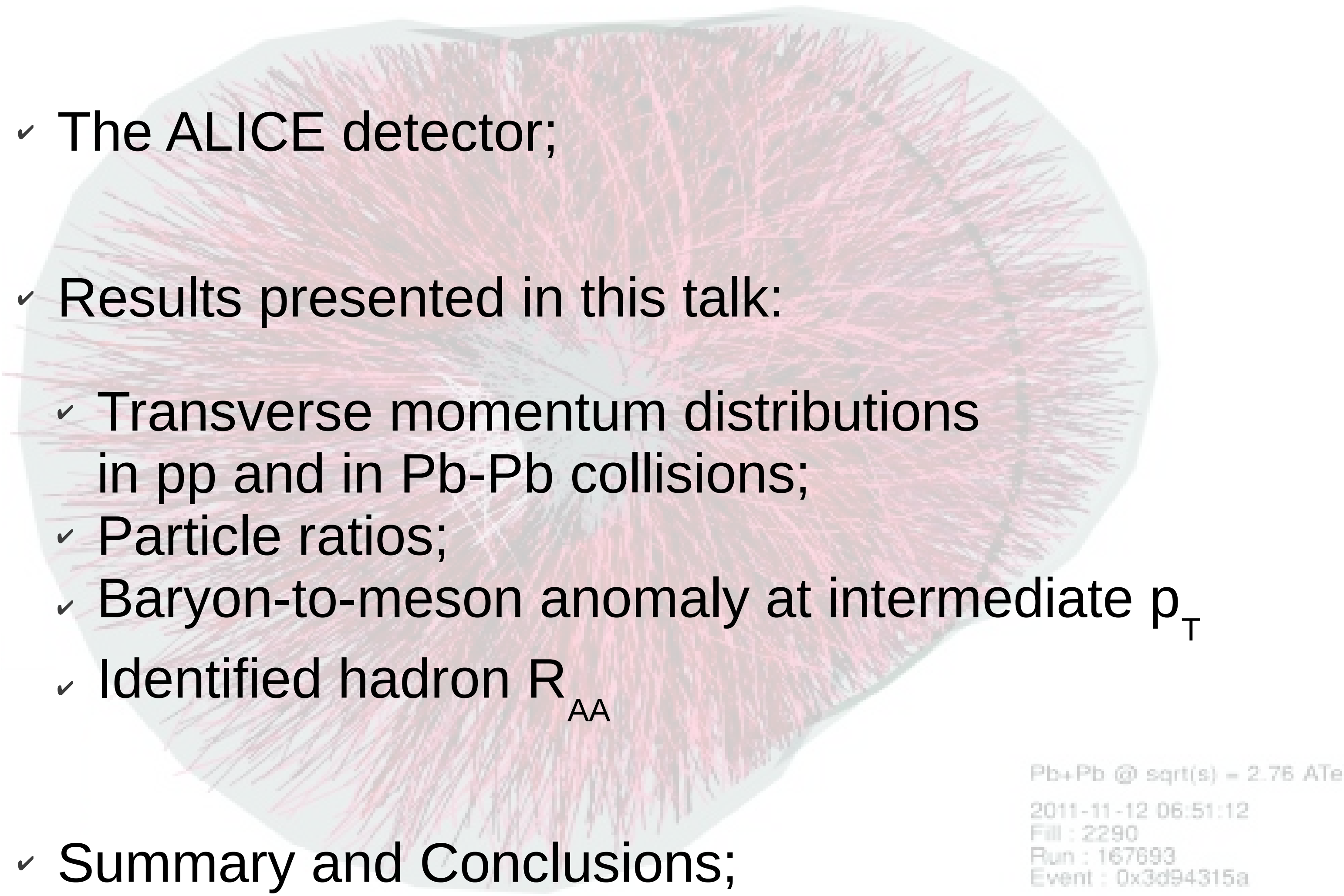
ALICE

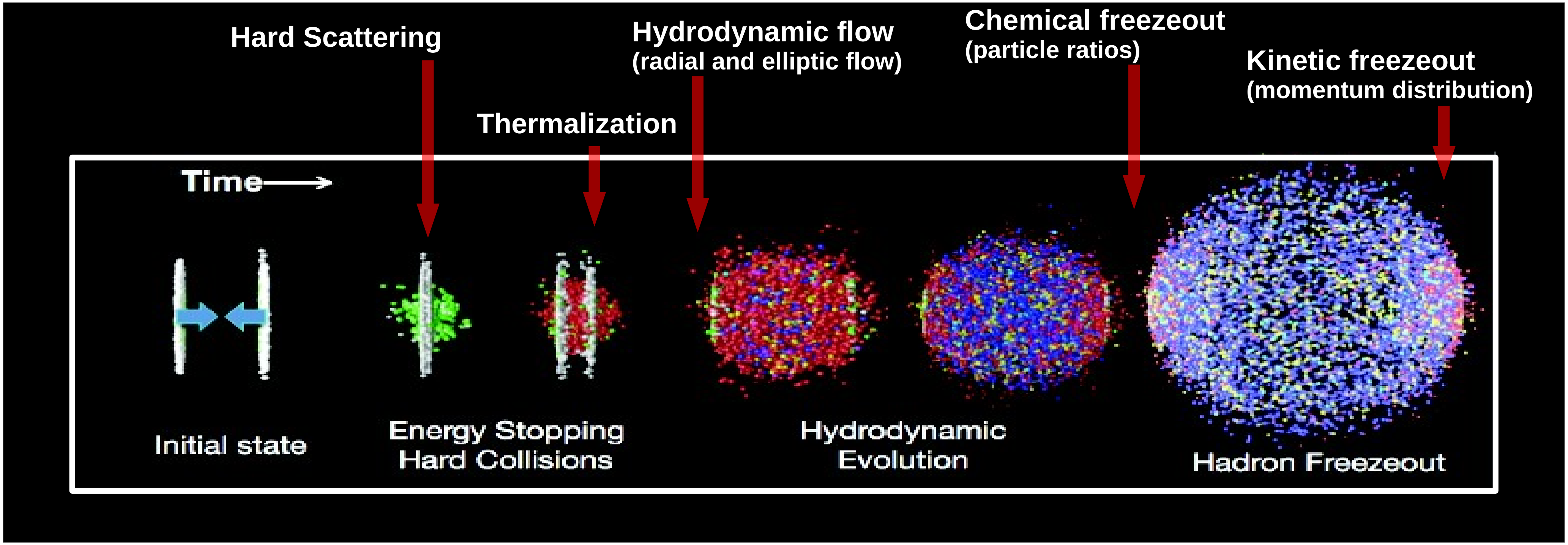
Outline

- Physics motivation;
- The ALICE detector;
- Results presented in this talk:
  - Transverse momentum distributions in pp and in Pb-Pb collisions;
  - Particle ratios;
  - Baryon-to-meson anomaly at intermediate p_T
  - Identified hadron R_{AA}
- Summary and Conclusions;



Physics motivation

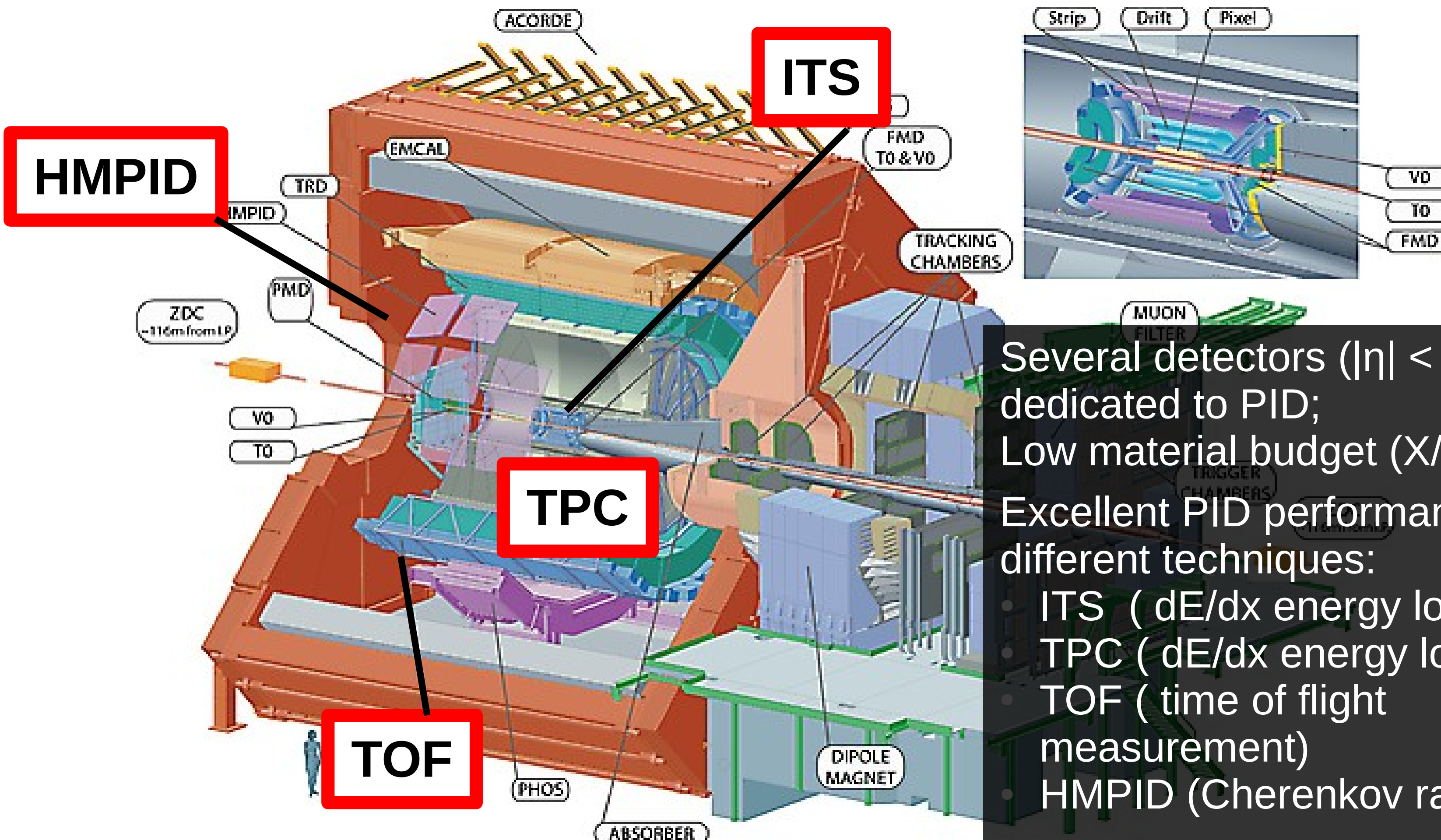
- Nuclear matter under extreme conditions can be investigated in ultra-relativistic heavy-ion collisions.
- Collective and thermal properties of the **Quark Gluon Plasma** inferred from **tranverse momentum (p_T) distributions and integrated yields** of identified particles;



Heavy Ion collisions dynamical evolution

The ALICE detector

The ALICE detector is a dedicated heavy-ion experiment at the LHC

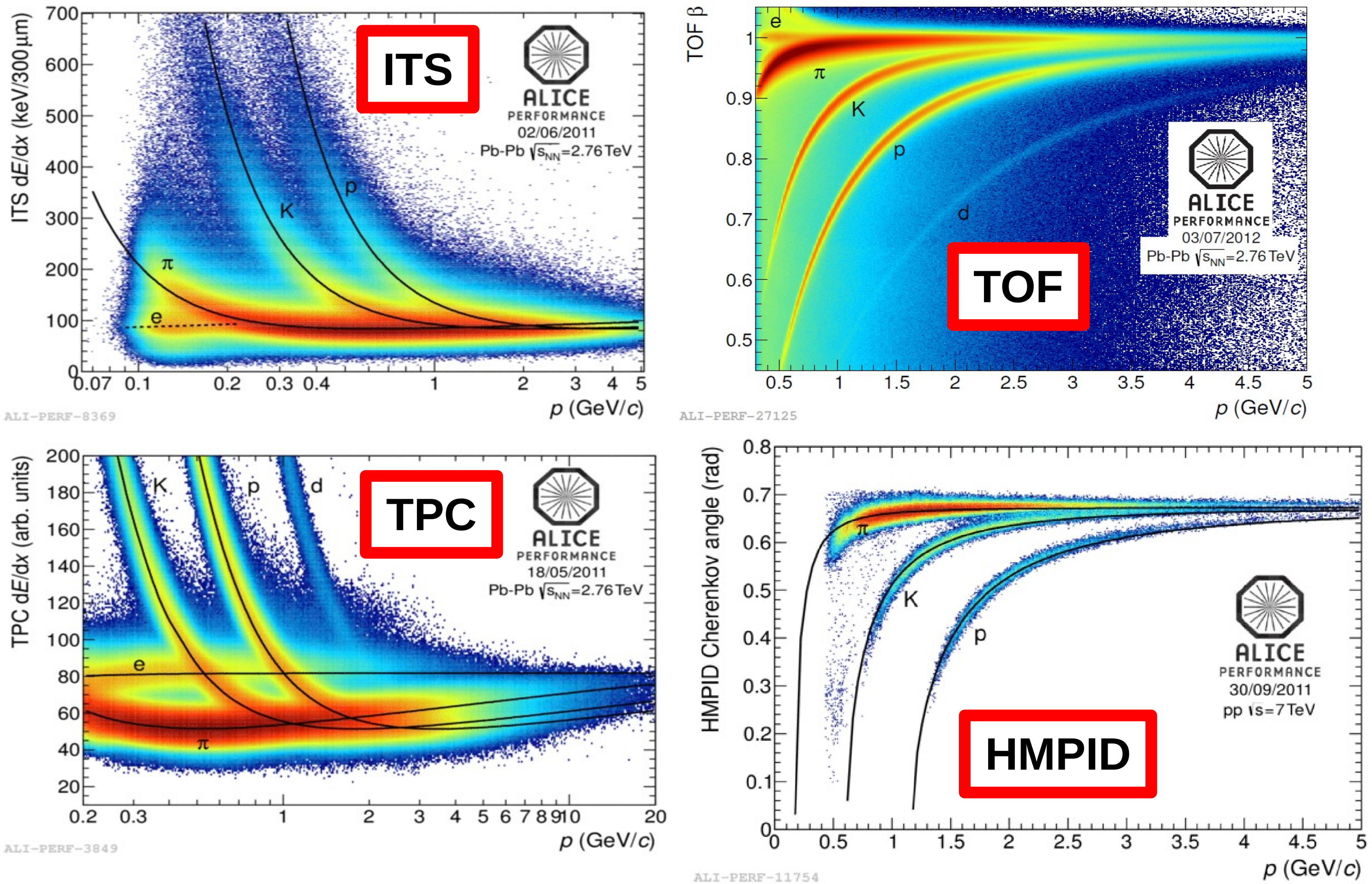


Several detectors ($|\eta| < 0.9$) dedicated to PID;
Low material budget ($X/X_0 \sim 0.1$);
Excellent PID performance using different techniques:

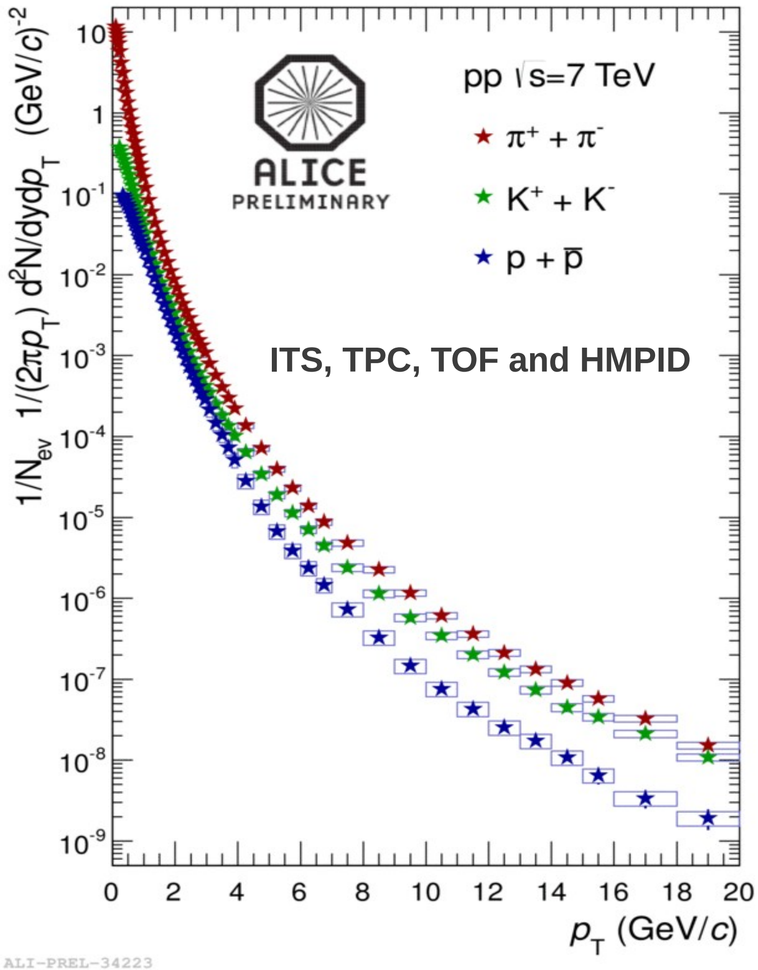
- ITS (dE/dx energy loss)
- TPC (dE/dx energy loss)
- TOF (time of flight measurement)
- HMPID (Cherenkov radiation)

The central barrel detectors are operated in a 0.5 T solenoidal field

PID Central barrel



Transverse momentum distributions in pp



LOW p_T

$p_T < 3$ GeV/c:

Bulk proprieties and flow

INTERMEDIATE p_T

$3 < p_T < 7$ GeV/c

Anomalous baryon enhancement

HIGH p_T

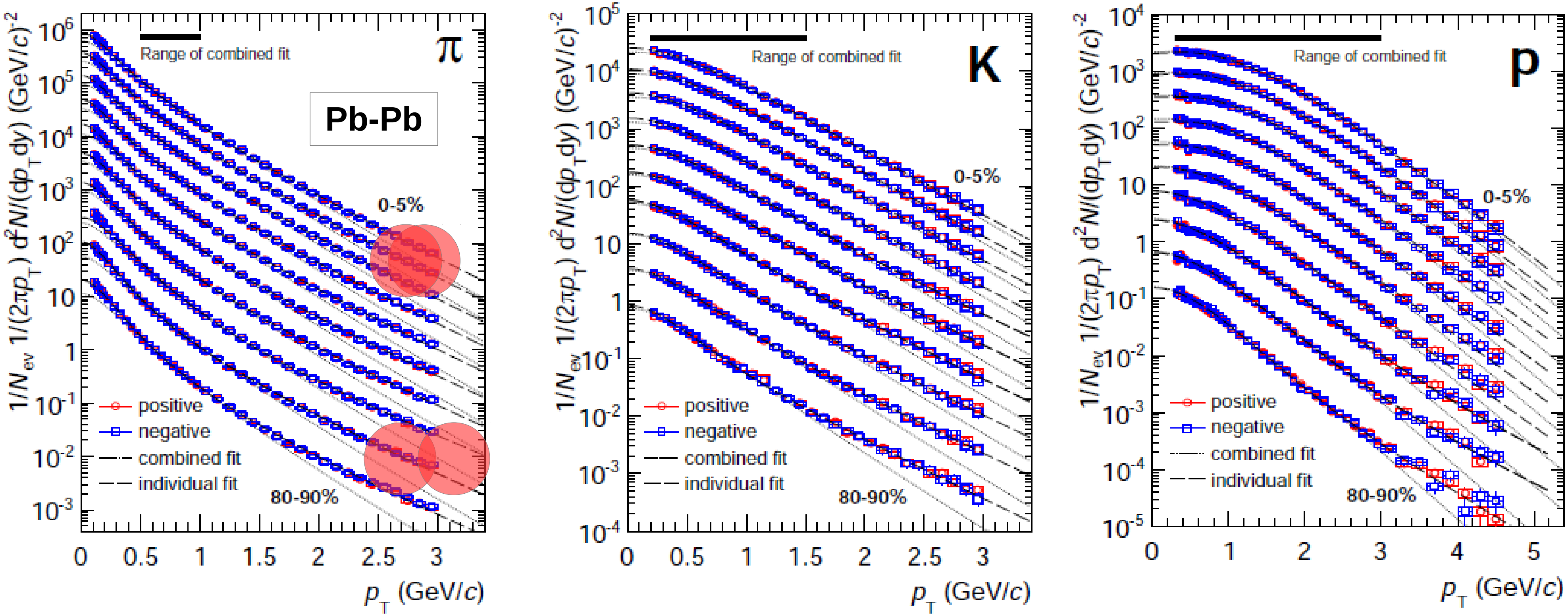
$p_T > 7$ GeV/c

"Jet Quenching": search for medium modification of fragmentation functions

PID from 100 MeV/c to 20 GeV/c

See B. Guerzoni's talk

Transverse momentum distributions at low p_T



arXiv:1303.0737v1

- Spectra at low p_T as a function of centrality.
- Different PID techniques used: ITS, TPC and TOF;
- The spectra get harder with increasing centrality → in hydrodynamic models, it is a consequence of the collective expansion → stronger radial flow with increasing centrality;

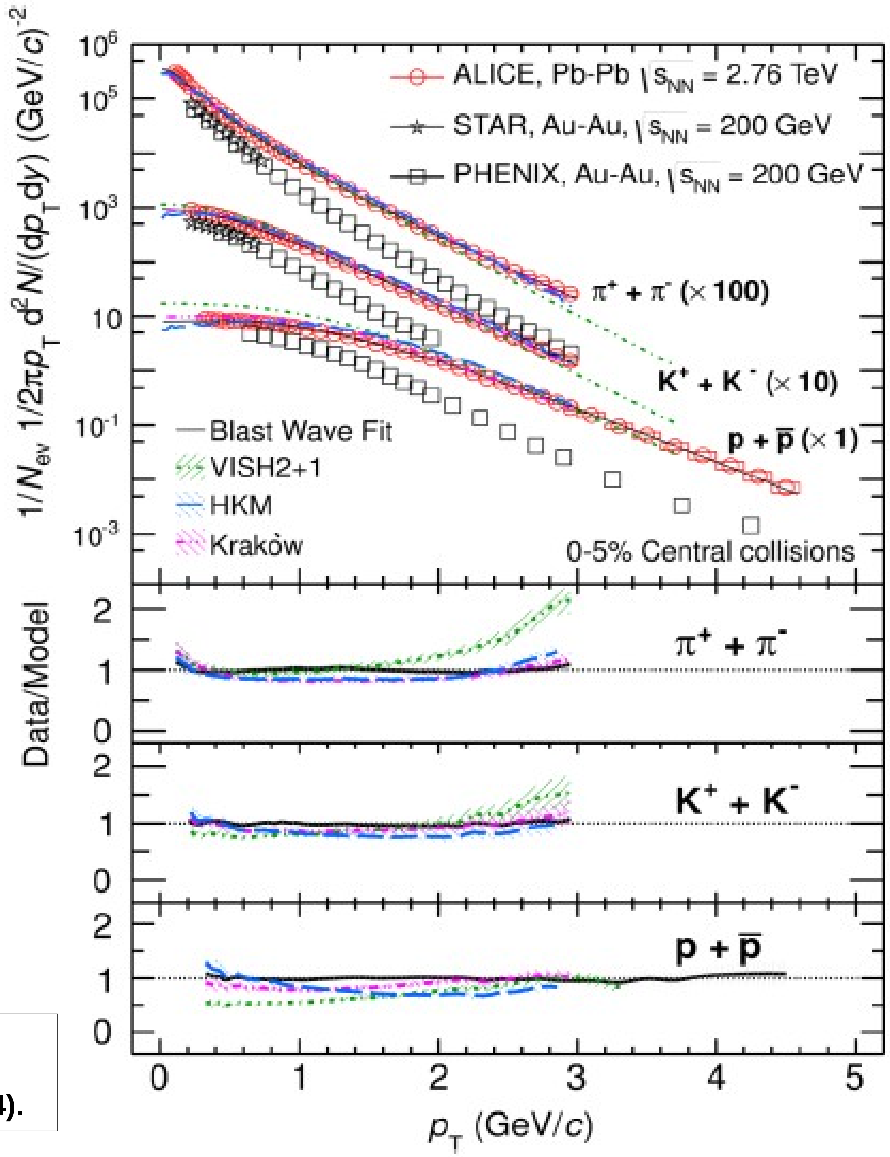
Transverse momentum distributions at low p_T

The Blast wave model: thermalized volume elements, expanding in a common velocity field.

The free parameters in the fit are:
- the kinetic freezeout temperature T_{Kin},
- the average transverse velocity $<\beta_T>$,
- the exponent of the velocity profile (*n*).

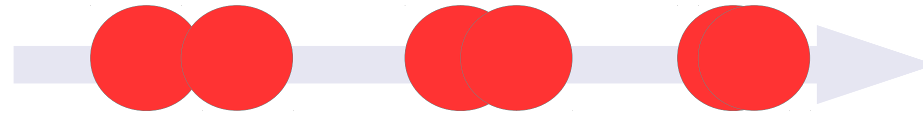
T_{kin} = 95 ± 10MeV → comparable with RHIC

$\langle \beta_T \rangle$ = 0.65 ± 0.02 → 10% higher than RHIC consistent with observation of increasing of mean p_T at LHC compared to RHIC for π, K, p, φ, K*



arXiv:1303.0737v1
(STAR Collaboration), Phys. Rev. C 79, 034909 (2009).
(PHENIX Collaboration), Phys. Rev. C69, 034909 (2004).

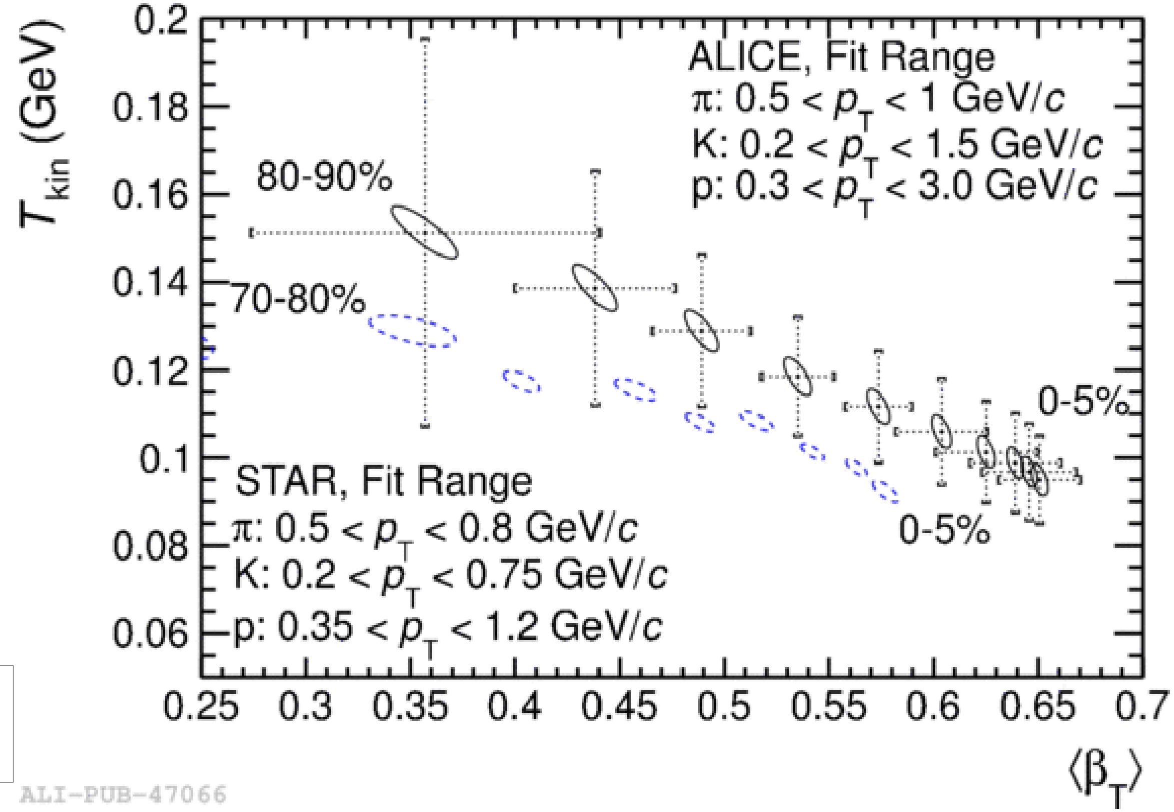
Kinetic freezeout



$\langle \beta_T \rangle$ increases with centrality

T_{kin} decreases with centrality

n ~ 0.7 in central collisions - increase towards peripheral collisions (spectrum not being thermal).



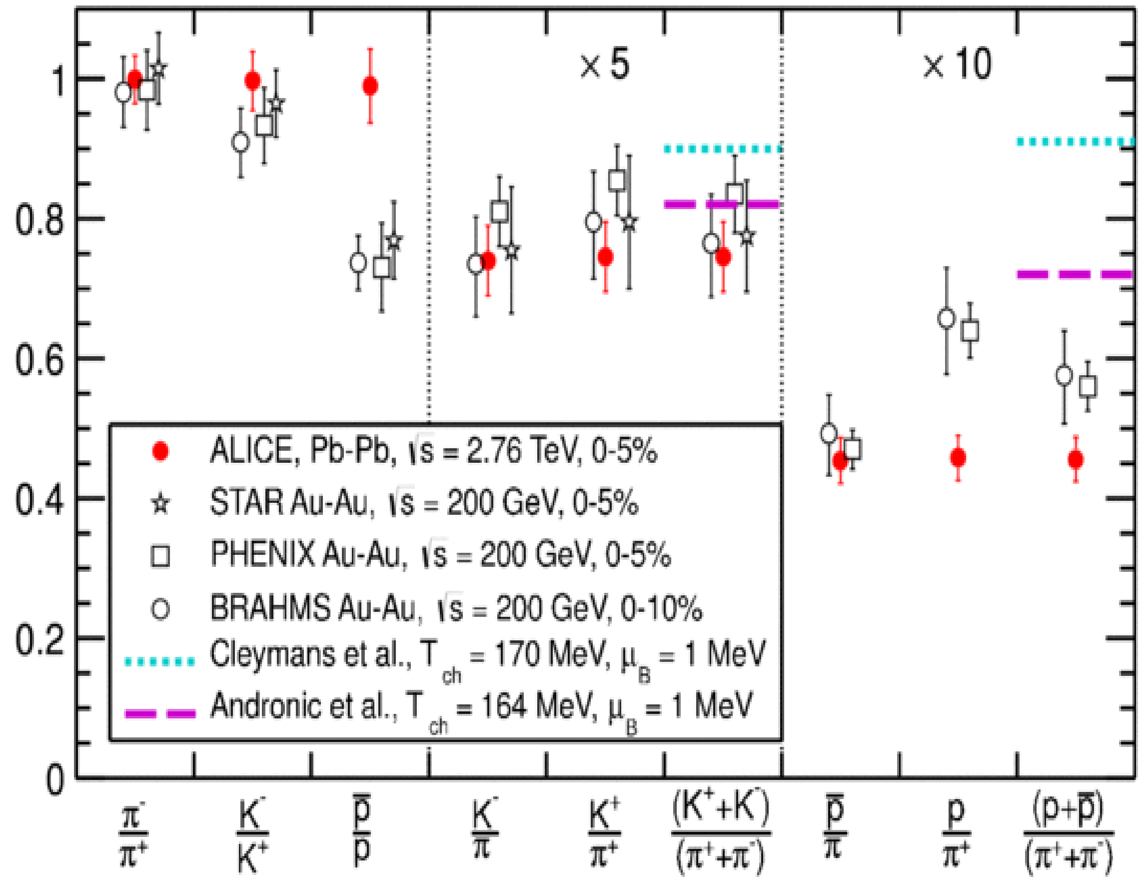
arXiv:1303.0737v1
(STAR Collaboration), Phys. Rev. C 79, 034909 (2009).
(PHENIX Collaboration),Phys. Rev. C69, 034909 (2004).

Possible indication of more rapid expansion with increasing centrality.
In peripheral collisions it is consistent with the expectation of a **shorter lived fireball with stronger radial gradients*.**

***U. W. Heinz, 165 (2004), aiXiv:0407360**

Particle ratios

Midrapidity particle ratios, compared to RHIC results and prediction from thermal models using μ_B = 1 MeV and T_{ch} of 164 MeV* and 170 MeV** for central Pb-Pb collisions at the LHC. μ_B extrapolated from lower energy data; T_{ch} obtained from fits to RHIC data (constant above a centre-of-mass-energy of a few tens of GeV)

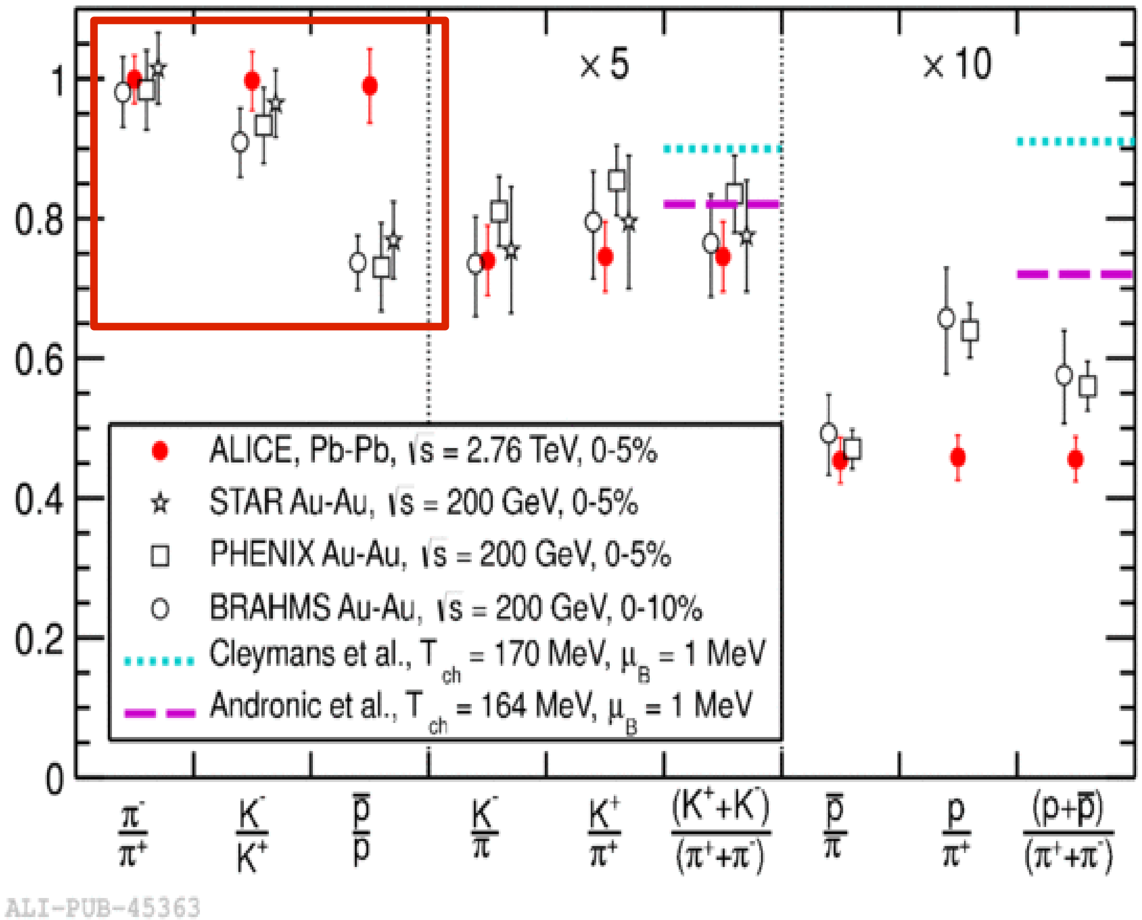


* A. Andronic, P. Braun-Munzinger, and J. Stachel, Phys.Lett. B 673, 142 (2009).
** J. Cleymans, I. Kraus, H. Oeschler, K. Redlich, and S. Wheaton, Phys. Rev. C 74, 034903 (2006).

Particle ratios

Neg/Pos particle yields are compatible
with unity for all centralities;

The anti-p/p ratio confirms vanishing baryon-number transport to mid-rapidity (0.8 at RHIC 200 GeV)



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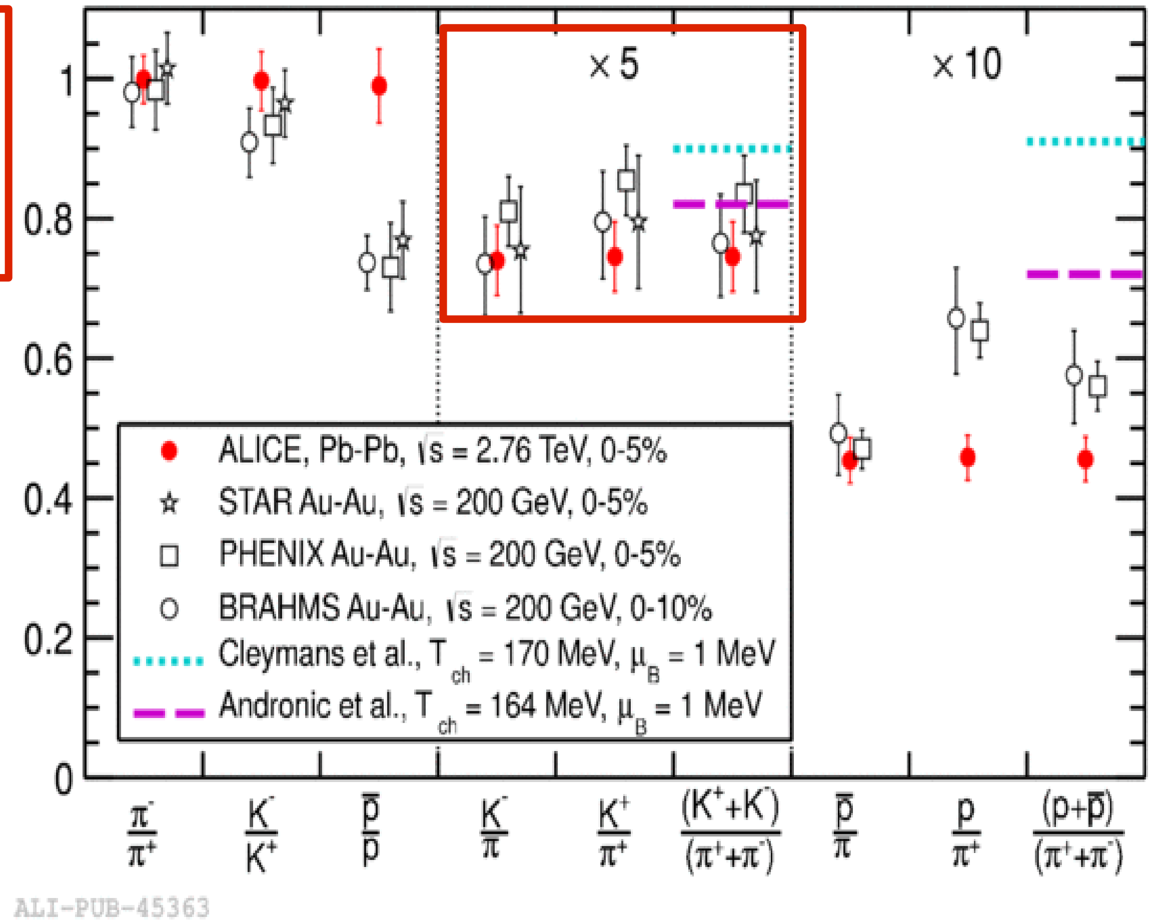
Particle ratios

K/π similar to the lower energy values, agree with the thermal model;



* A. Andronic, P. Braun-Munzinger, and J. Stachel, Phys.Lett. B 673, 142 (2009).
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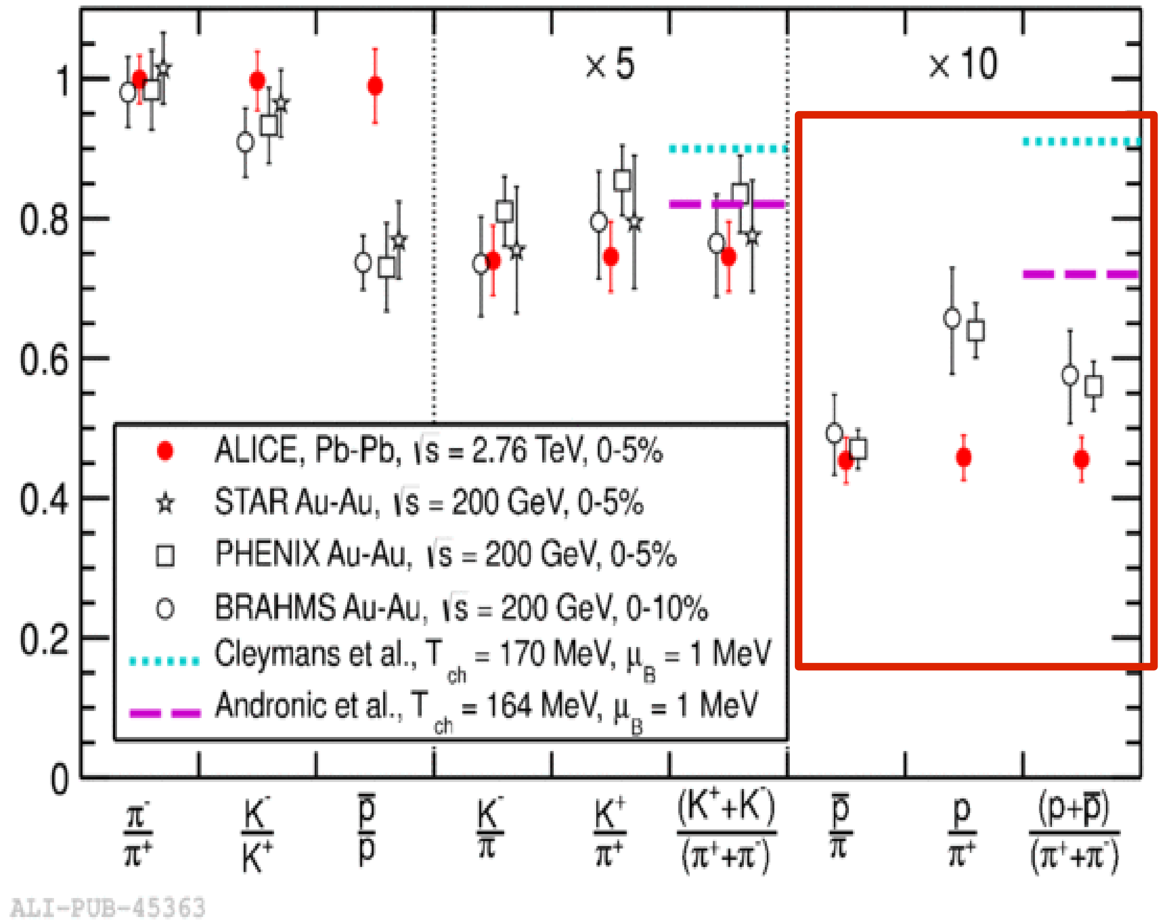
Particle ratios

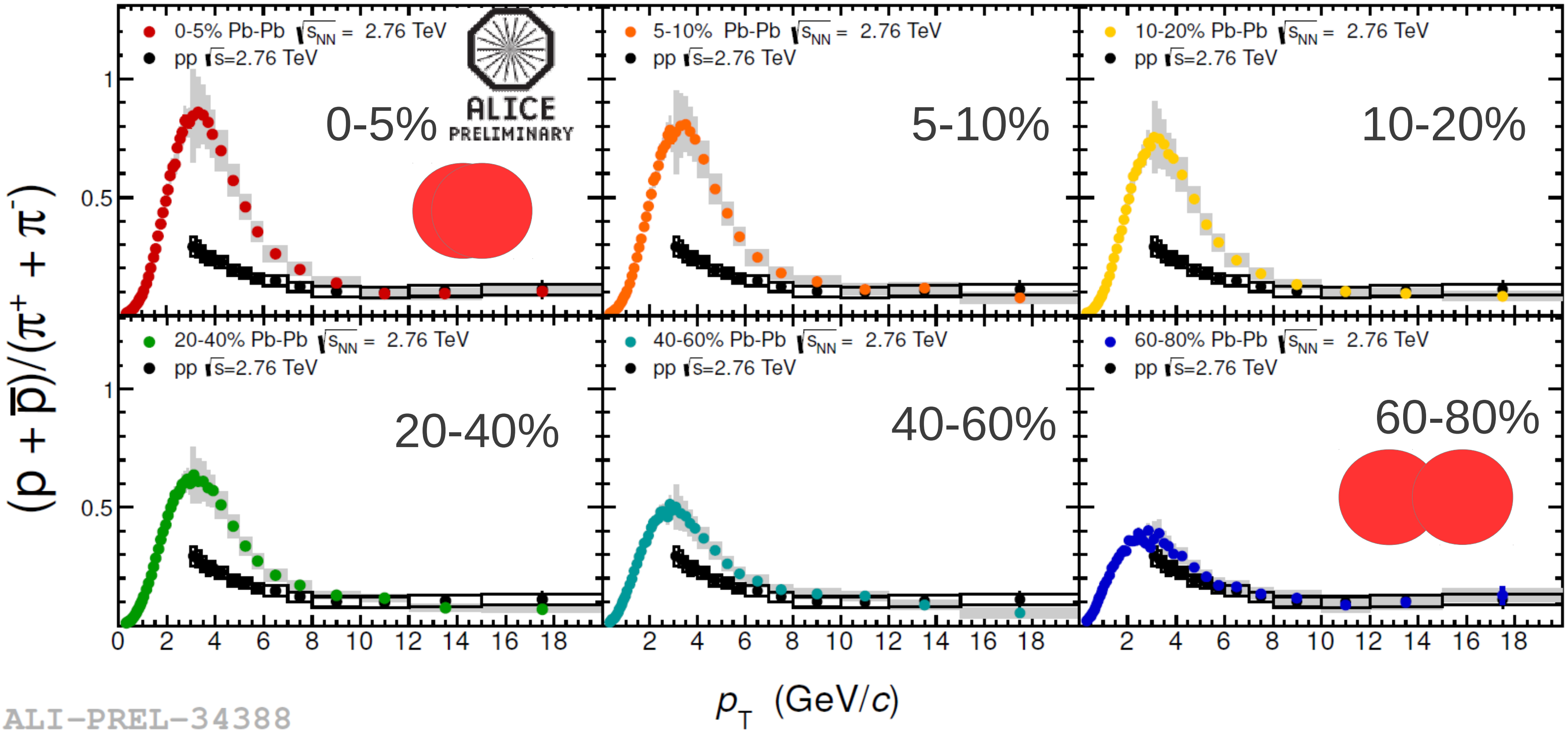
p/π lower than expected from thermal model
(by a factor ~1.5-1.9, ~1.2 with RHIC)

- Final state interactions in the hadronic phase (HKM model)*
- Flavour and mass dependent prehadronic bound states in not-equilibrium phase (recent lattice QCD and QCD-inspired models)**



* arXiv:1204.5351
** Phys. Rev. D 85, 014004 and arXiv:1205.3625

Baryon-to-meson ratio at intermediate p_T

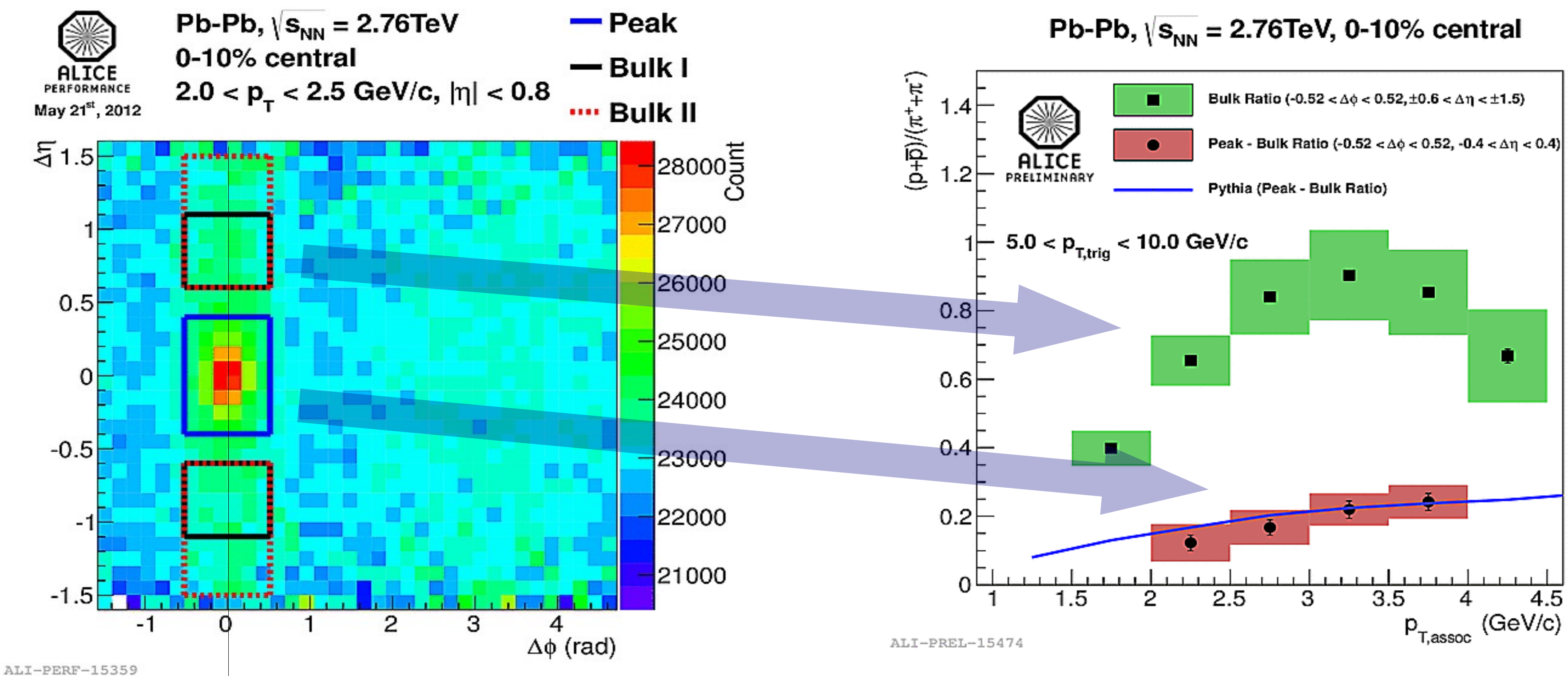


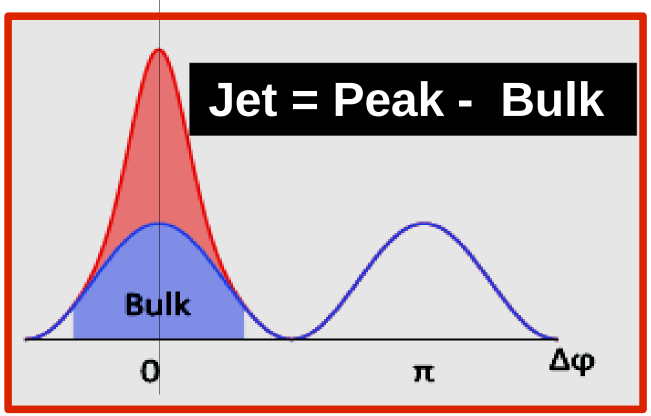
- For p_T > 10 GeV/c pp and Pb-Pb value are similar.
  - Parton fragmentation independent of particle species

- Enhancement of the baryon-to-meson ratio at intermediate transverse momentum (3-7 GeV/c) (at ~ 3 GeV/c up to 3x higher than in pp);

See M.Nicassio's talk

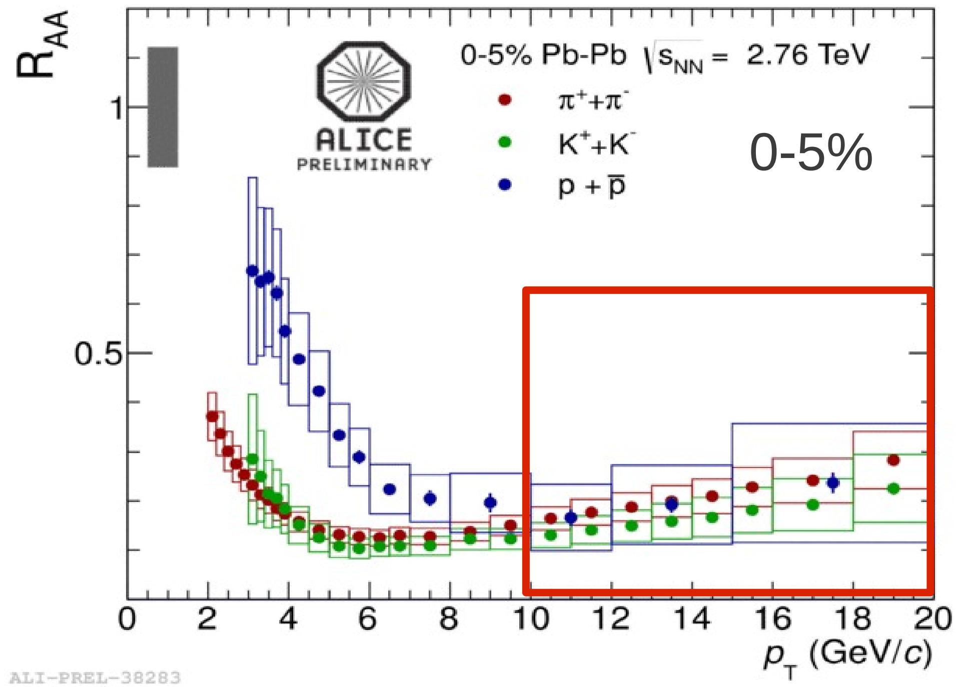
Baryon-to-meson ratio at intermediate p_T

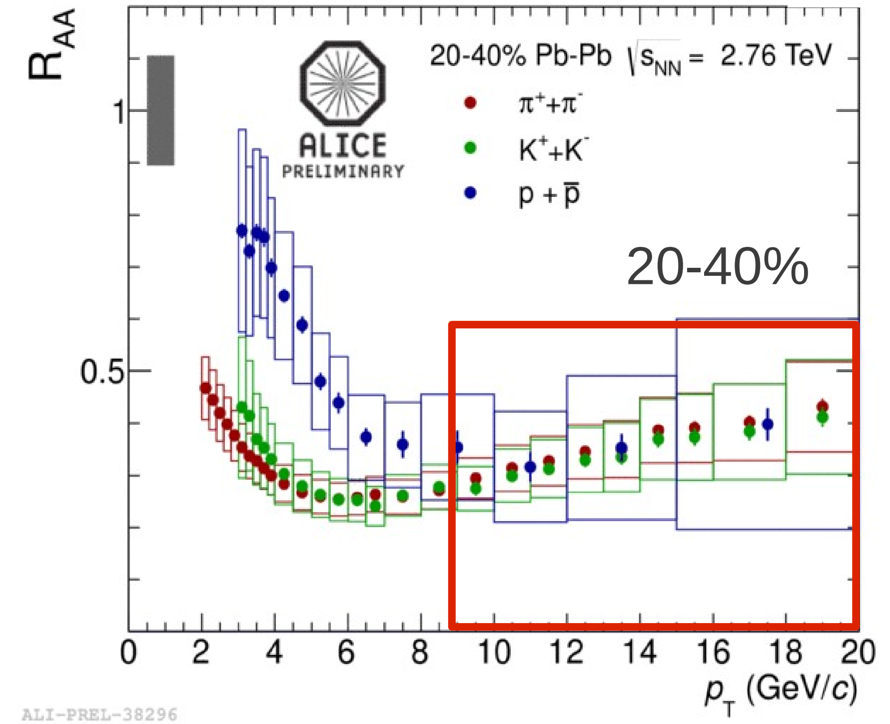




- Two particle correlation: p/π in the bulk and in the jet;
- Enhancement of the baryon-to-meson ratio:
  → The Baryon anomaly is an effect restricted to the bulk, absent in the jet!

Identified hadron R_{AA}





$$R_{AA} = \frac{AA}{\text{rescaled pp}} = \frac{d^2N_{AA}/dp_T dy}{\langle N_{coll}\rangle d^2N_{pp}/dp_T dy}$$

- ✓ R_{AA} (p) > R_{AA}(K) ~ R_{AA}(π)
- ✓ R_{AA} compatible for the three species at high p_T (p_T > 8- 10 GeV/c) within the uncertainties

→ no significant species dependence at high p_T

Summary and Conclusions

- Identified particle measurements allow the properties of the matter in the HI collisions to study;
- In this talk, some recent results in pp and in Pb-Pb have been reviewed:
  - hadron spectra → very strong radial flow;
  - baryon anomaly at intermediate p_T → only bulk effect;
  - Identified hadron R_{AA} → no particle species dependence of the R_{AA} at high p_T

Transverse momentum distributions at low p_T

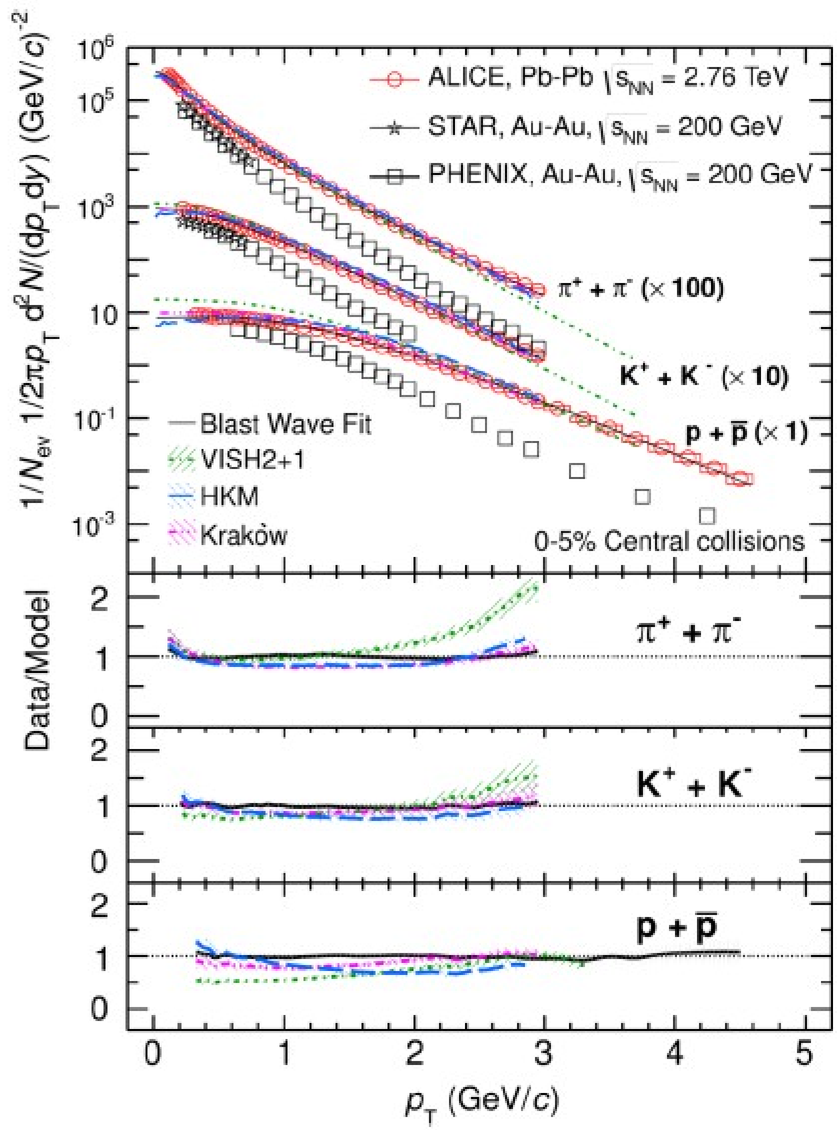
Hydro models:

VISH2+1: viscous hydrodynamics,
Difference: no description of hadronic phase in the model. Yield are taken to be thermal at Tch = 165 MeV
(Shen et al., PRC 84, 044903 (2011))

HKM: hydro+UrQMD*, hadronic phase builds additional radial flow, mostly due to elastic interactions, and affects particle ratios due to inelastic interactions
(Karpenko et al., arXiv:1204.5351)

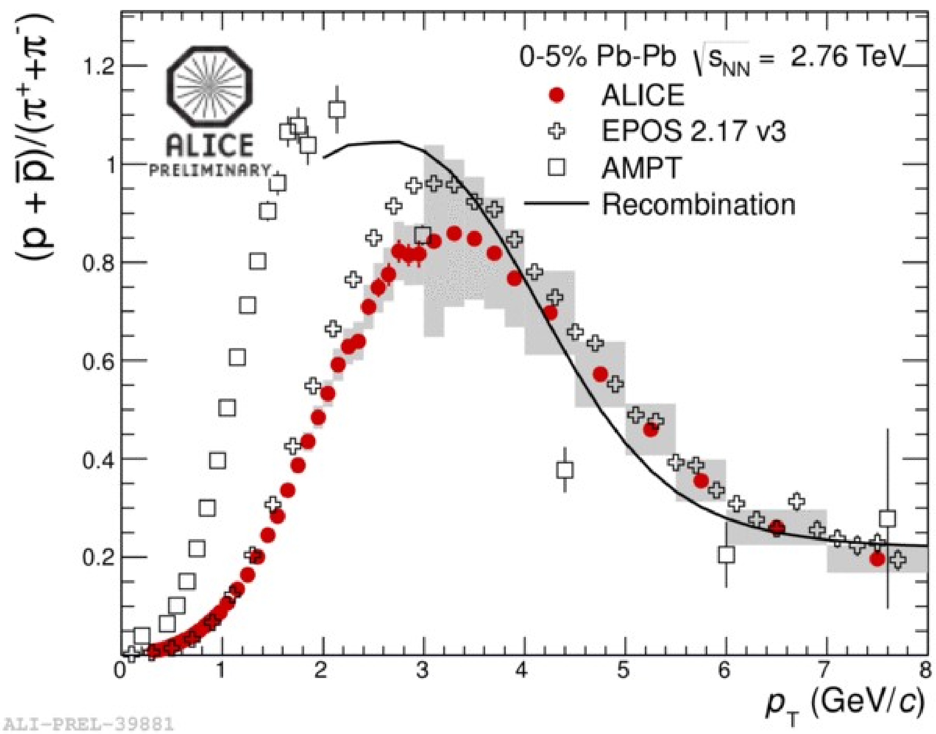
Krakow: introduces non equilibrium corrections due to viscosity at the transition from the hydrodynamic description to particles which change the effective Tch
(Bozek, PRC 85, 034901 (2012))

The last two models reproduce well the data supporting a hydrodynamic interpretation of the trasnsverse momentum spectra at the LHC.



*Hadronic cascade model

Baryon to meson ratio



- EPOS → "initial hard scattering creates a flux tubes which either escape the medium and hadronize as jet, or contribute to the bulk matter, described in terms of hydrodynamics. After hadronization, particles are transported with a hadronic cascade model (UrQMD)".
  - reproduces to the baryon-to-meson ratio
  - good agreement with data for central and semicentral.
  - late hadronic interaction is fundamental.