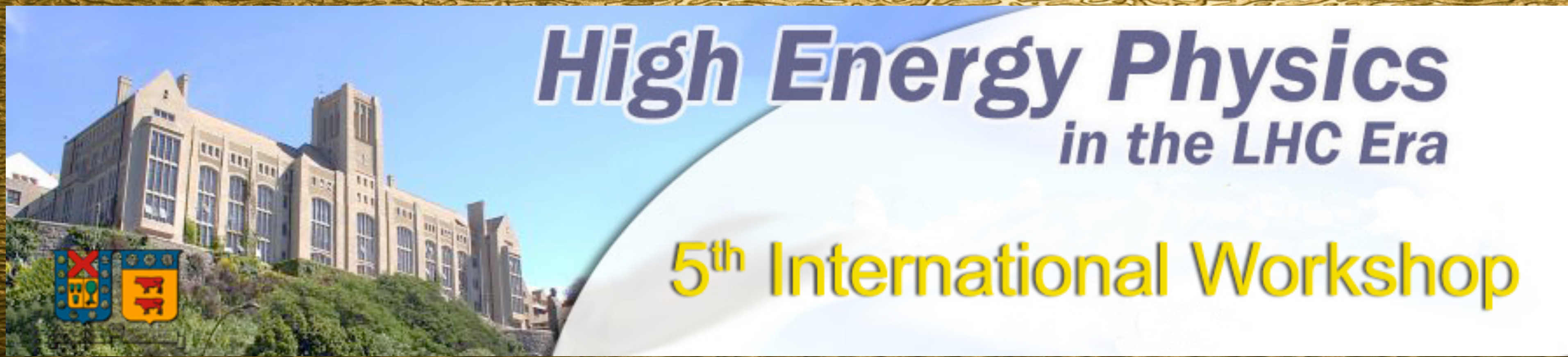


Charged pion, kaon and proton production in pp and Pb-Pb collisions measured with ALICE

Raúl Tonatiuh Jiménez Bustamante
for the ALICE Collaboration

ALICE

Instituto de Ciencias Nucleares UNAM

UNIVERSIDAD NACIONAL AUTONOMA D MEXICO
POR MI RAZA HABLARA EL ESPIRITU

= Outline =

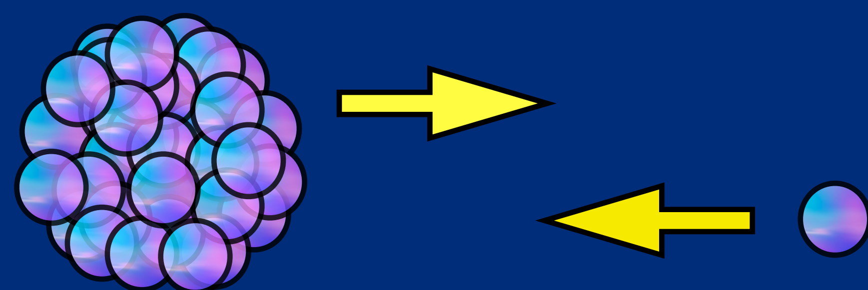
- Motivation
- ALICE detector
- Particle Identification (PID) Method
- Results:
  - Measurement of particle spectra and particle ratios in pp and Pb-Pb collisions.
- Conclusions

= Motivation =

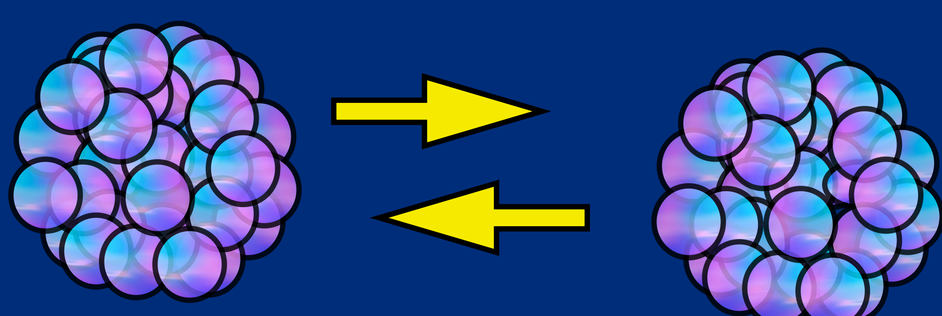
Information we obtain from transverse momentum, p_T, spectra in different systems: pp, p-Pb, Pb-Pb

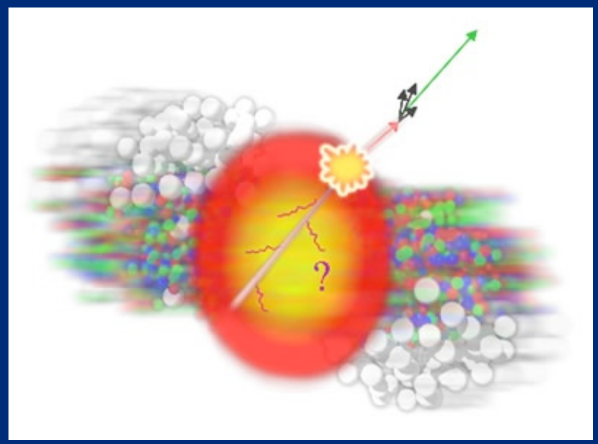
pp collisions: reference for Heavy Ion collisions, parton-parton interaction.

p-Pb collisions: reference for Heavy Ions, Formation of medium? collective effects?, radial flow?



Pb-Pb collisions: hot and dense medium . Sensitive to QGP effects: collective expansion, quark recombination, and jet quenching.





= Motivation =

$$R_{AA} = \frac{d^2N_{AA}/dp_{\mathrm{T}}dy}{\langle N_{coll}\rangle d^2N_{pp}/dp_{\mathrm{T}}dy}$$

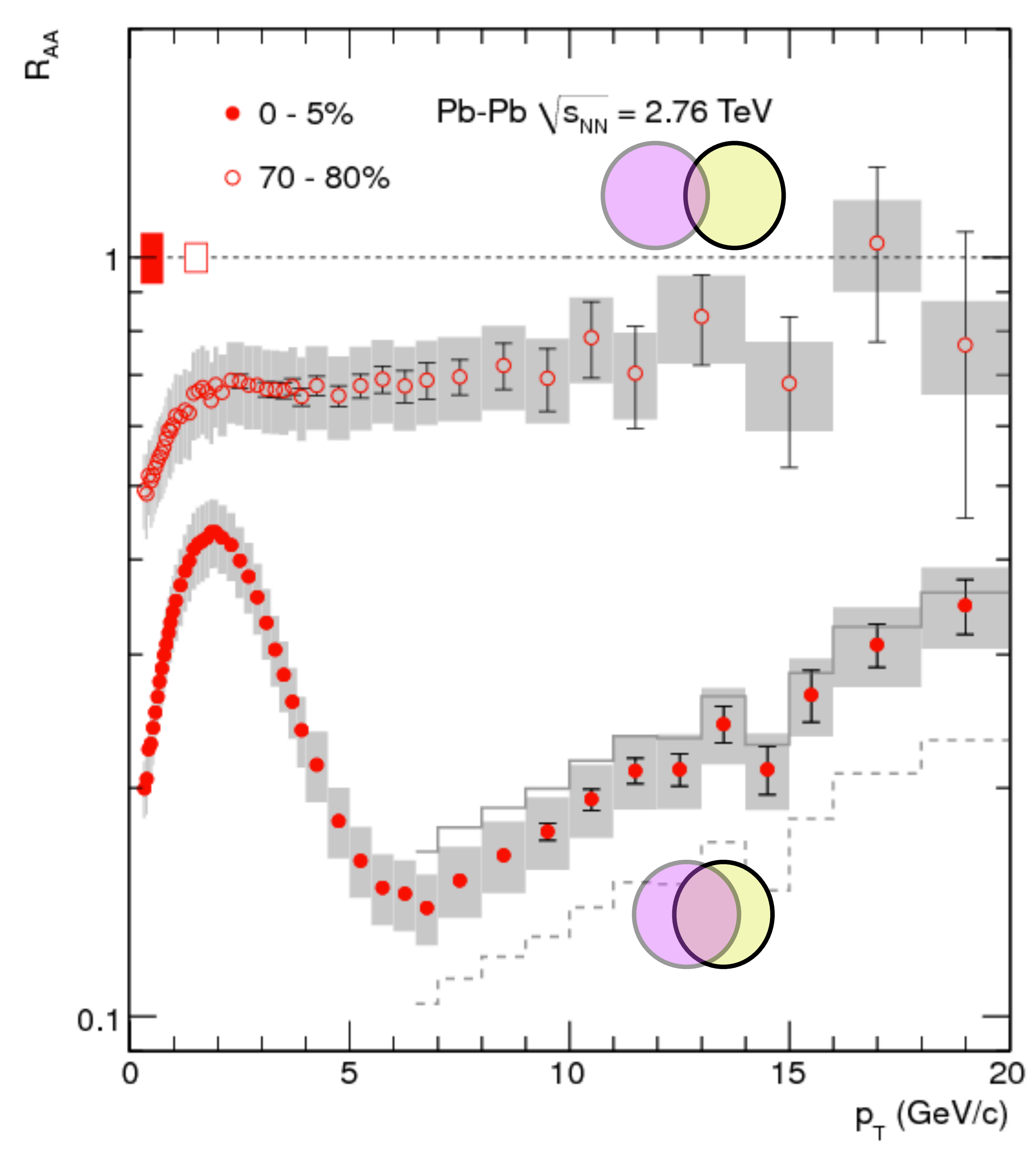
For pQCD processes:

$R_{AA}<1$: suppression

$R_{AA}=1$: no nuclear effects

$R_{AA}>1$: enhancement

The particle identifiaction is crucial to understand the medium effects



ALICE, Phys. Lett. B 696 (2011) 30-39

= Motivation =

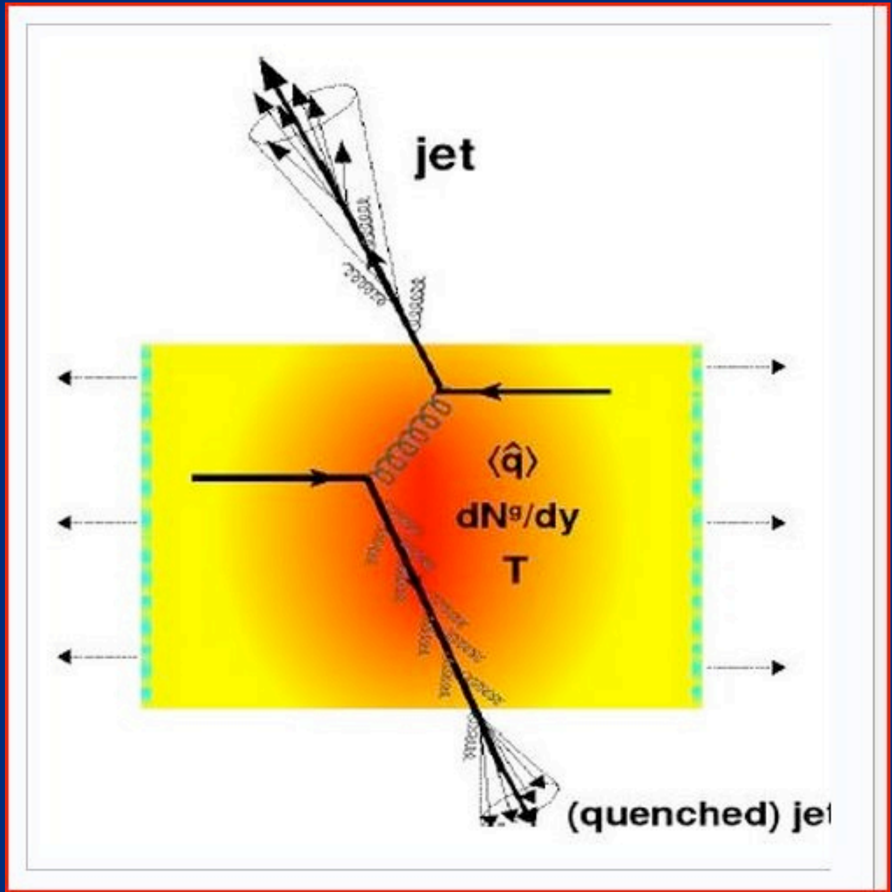
In particular at high p_T:

Measurements sensitive to the flavor of the initial hard scattered parton provide contraints into the jet quenching mechanism.

Does the interaction of hard partons with the medium modify the abundances of identified particles spectra?

e. g.

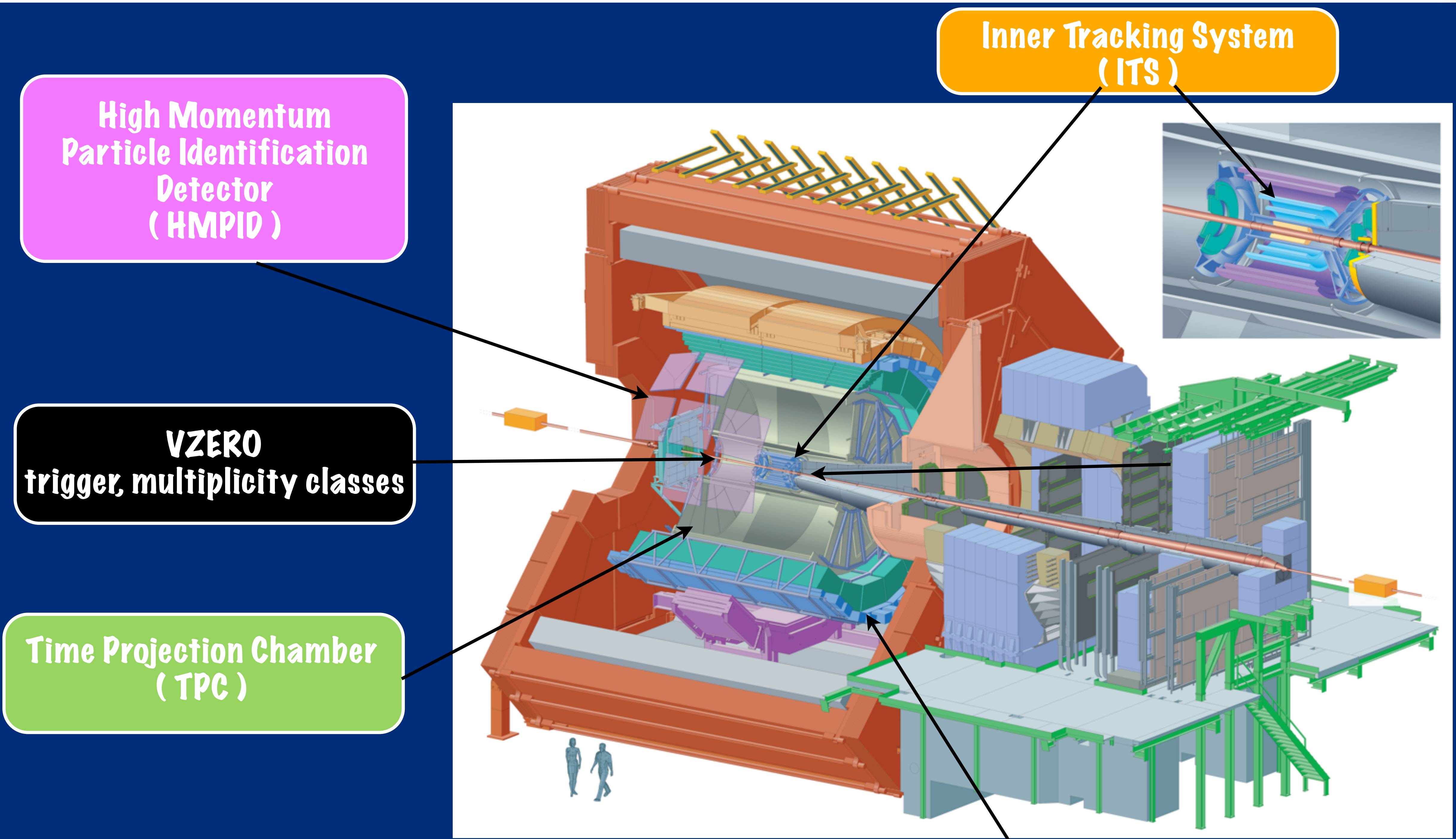
Interactions with the medium, enhanced by parton splitting.



Prediction: Modify the high p_T identified particle ratios in heavy ions versus pp collision (R_{AA})

S. Sapeta and U.A. Wiedemann, Eur.Phys.J. C55 (2008) 293

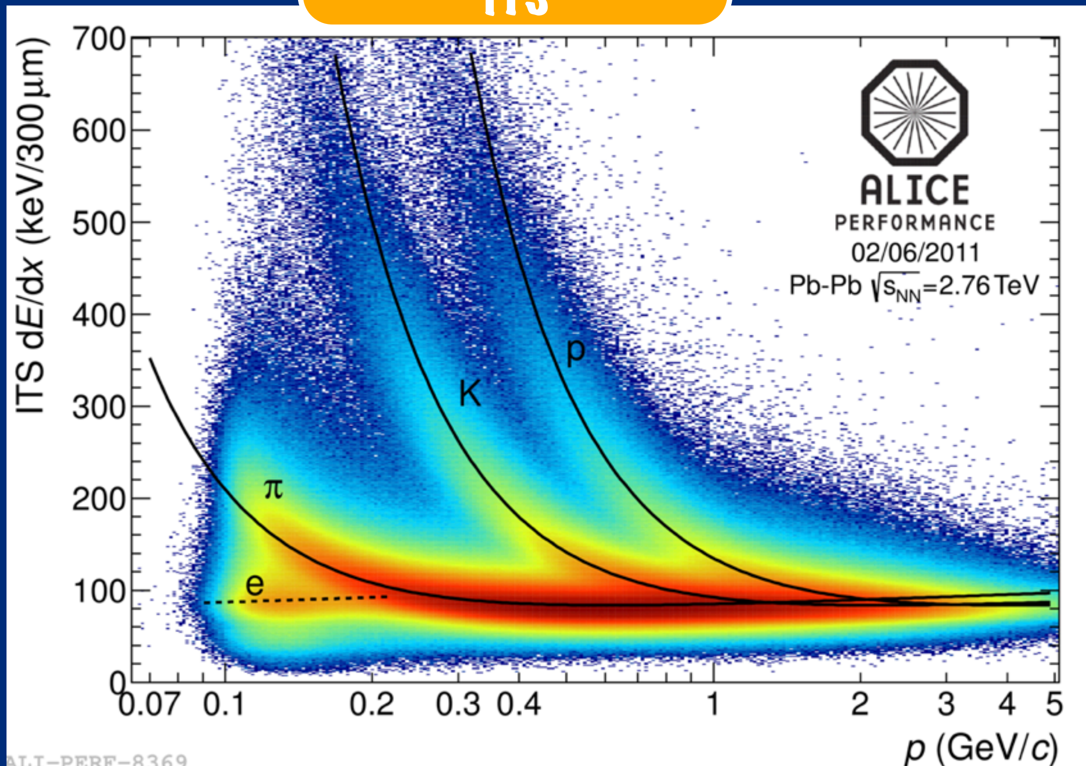
= ALICE detector =



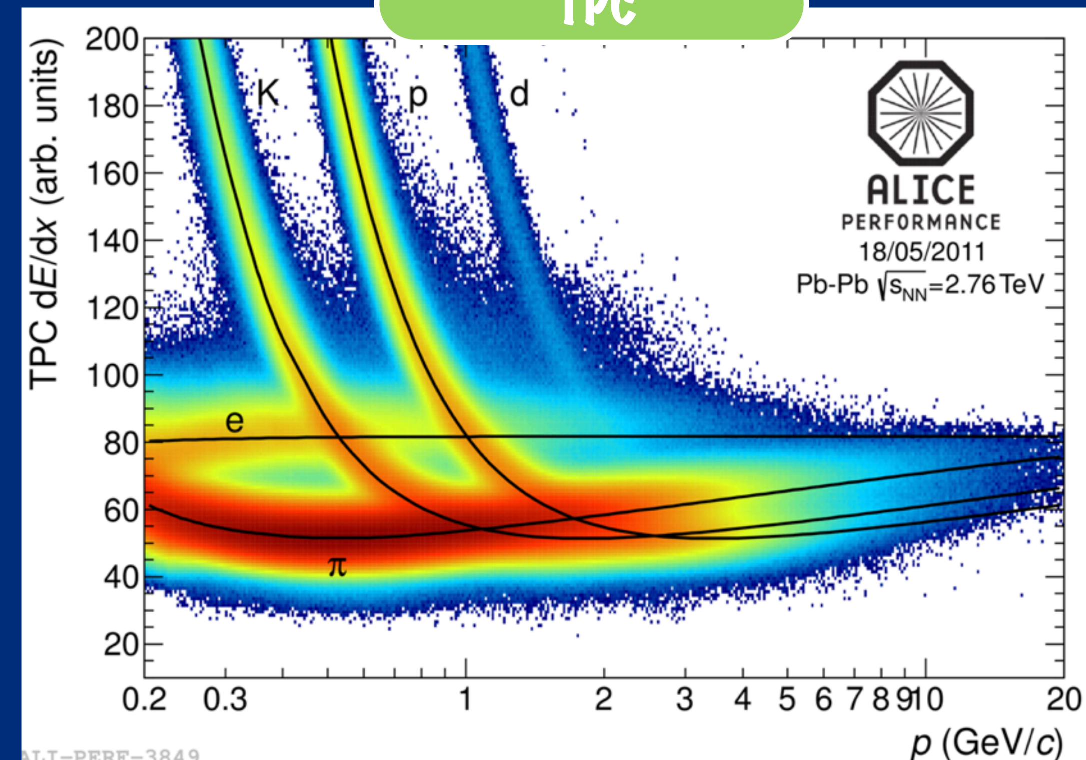
ALICE is optimized for charged Particle IDentification (PID) in the central pseudo-rapidity region $|\eta| < 0.9$

= PID in ALICE =

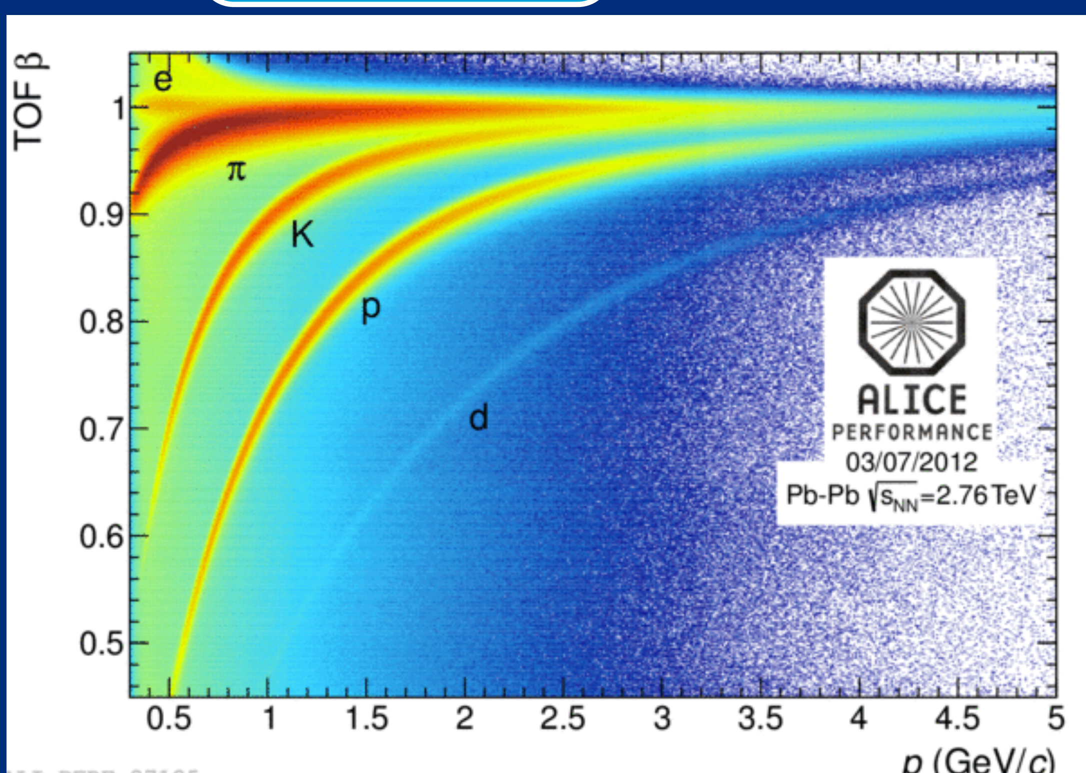
ITS



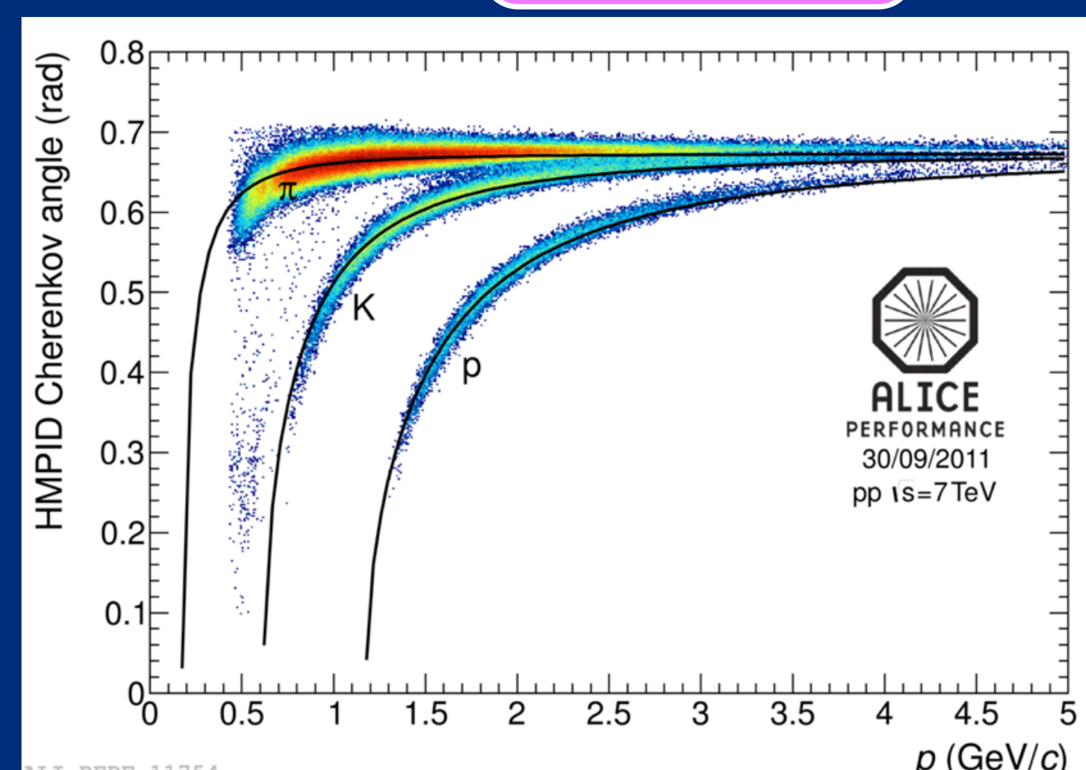
TPC



TOF

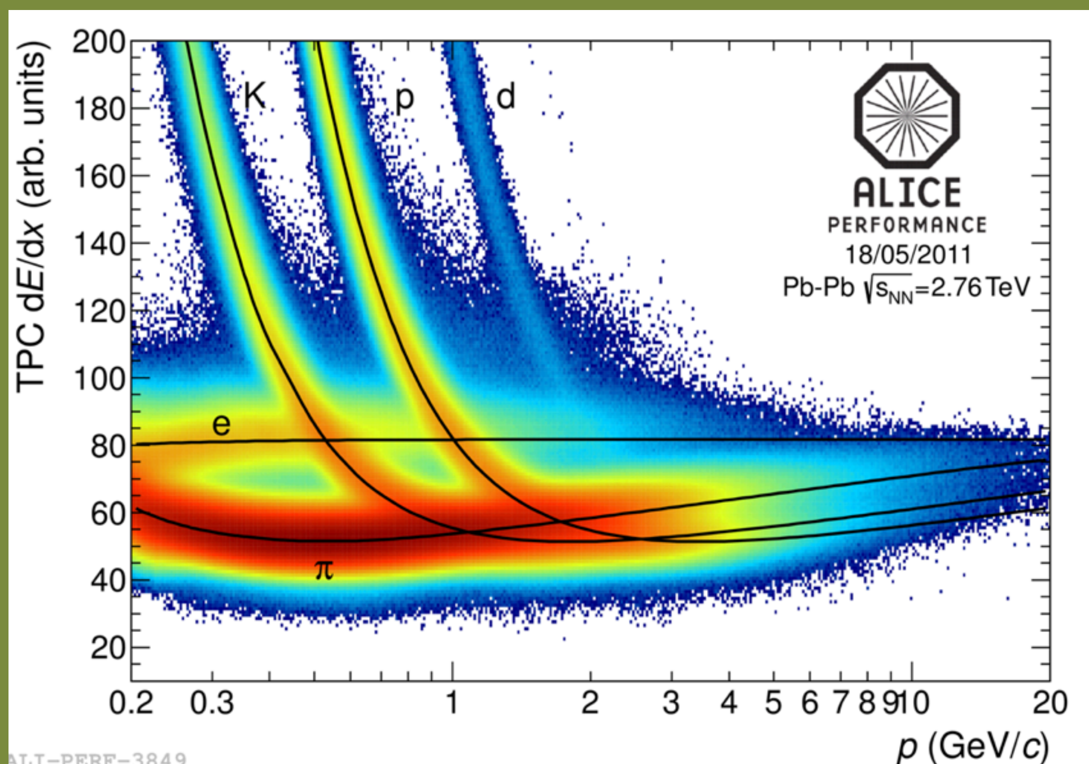


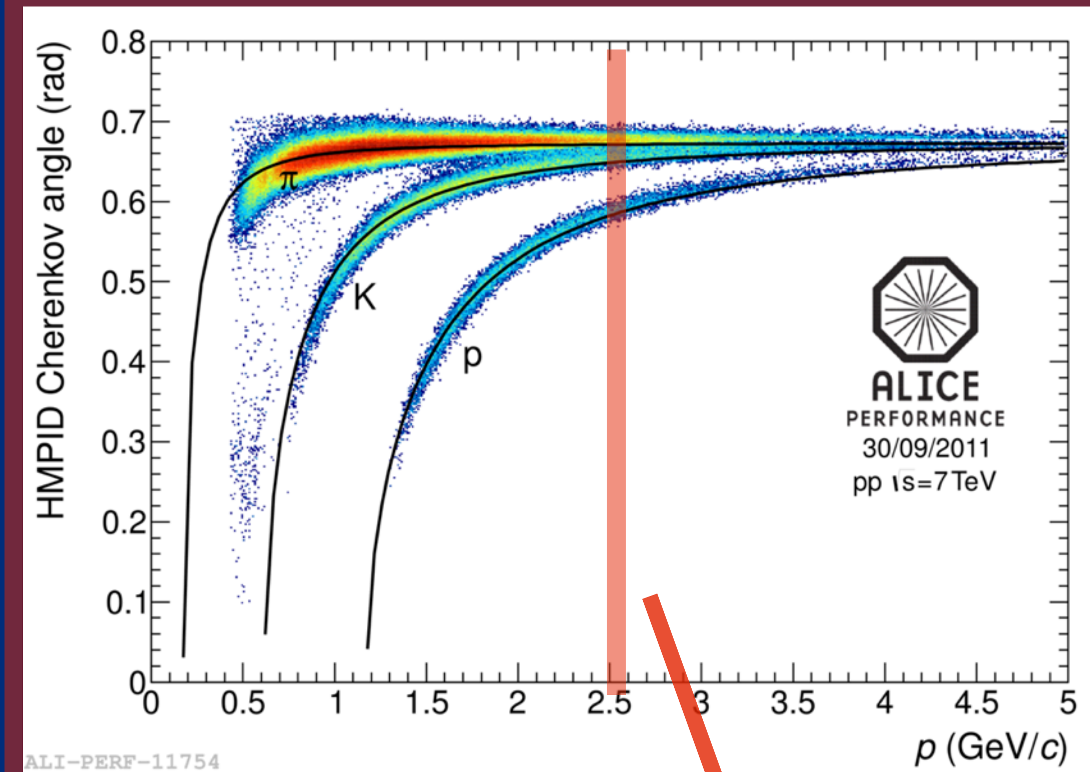
HMPID

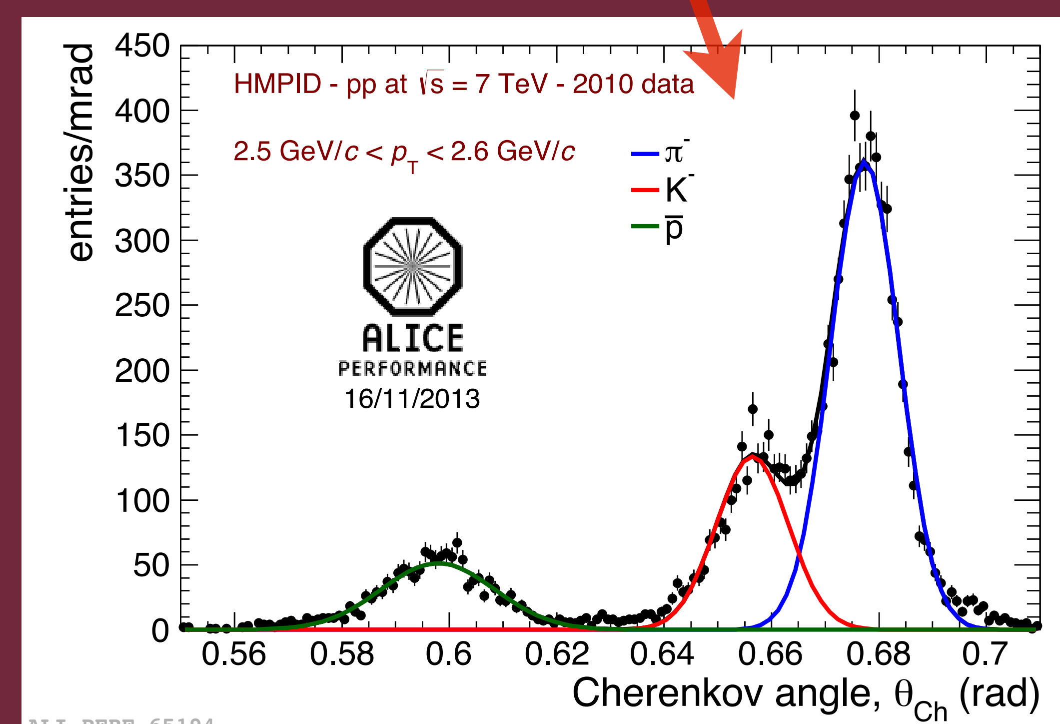


= PID methods =

Nsigma method: PID done track by track, selecting exclusive 3 sigma bands for each particle.



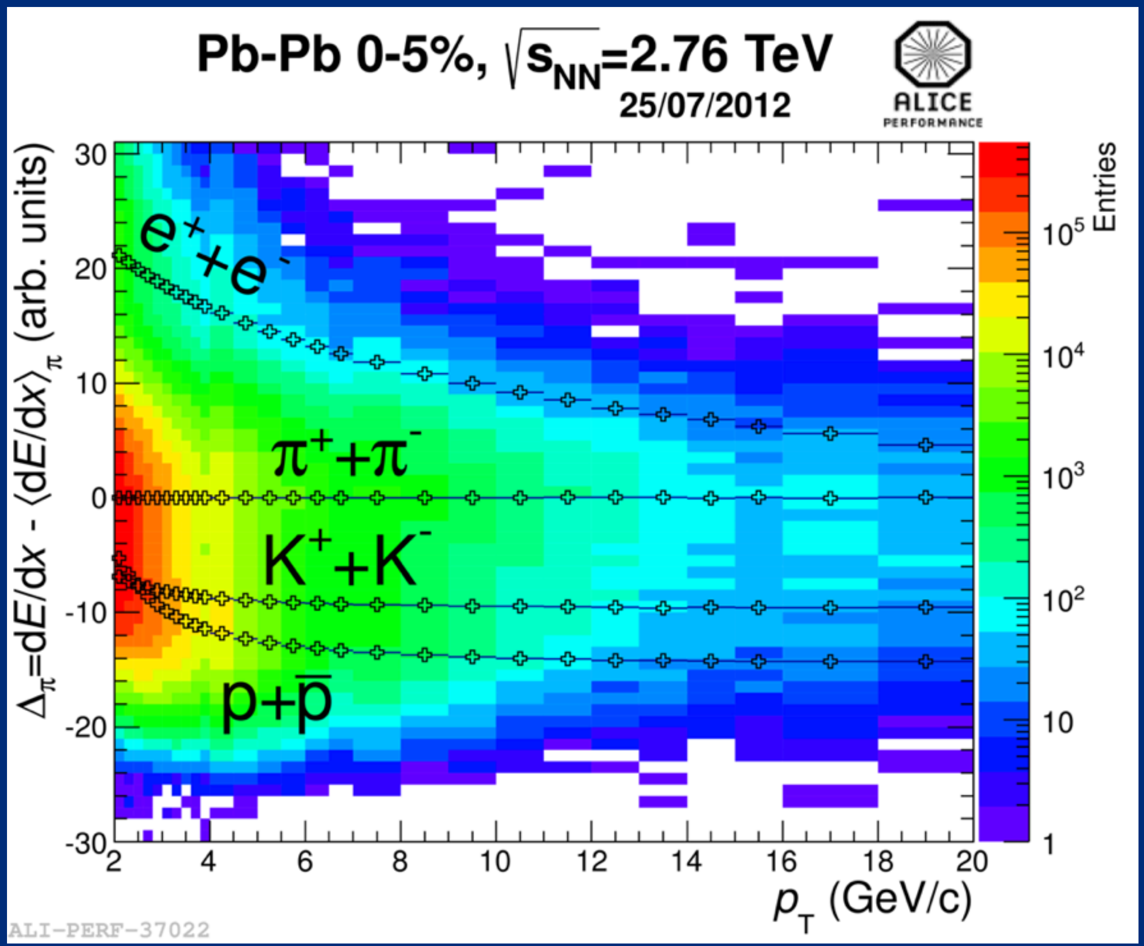


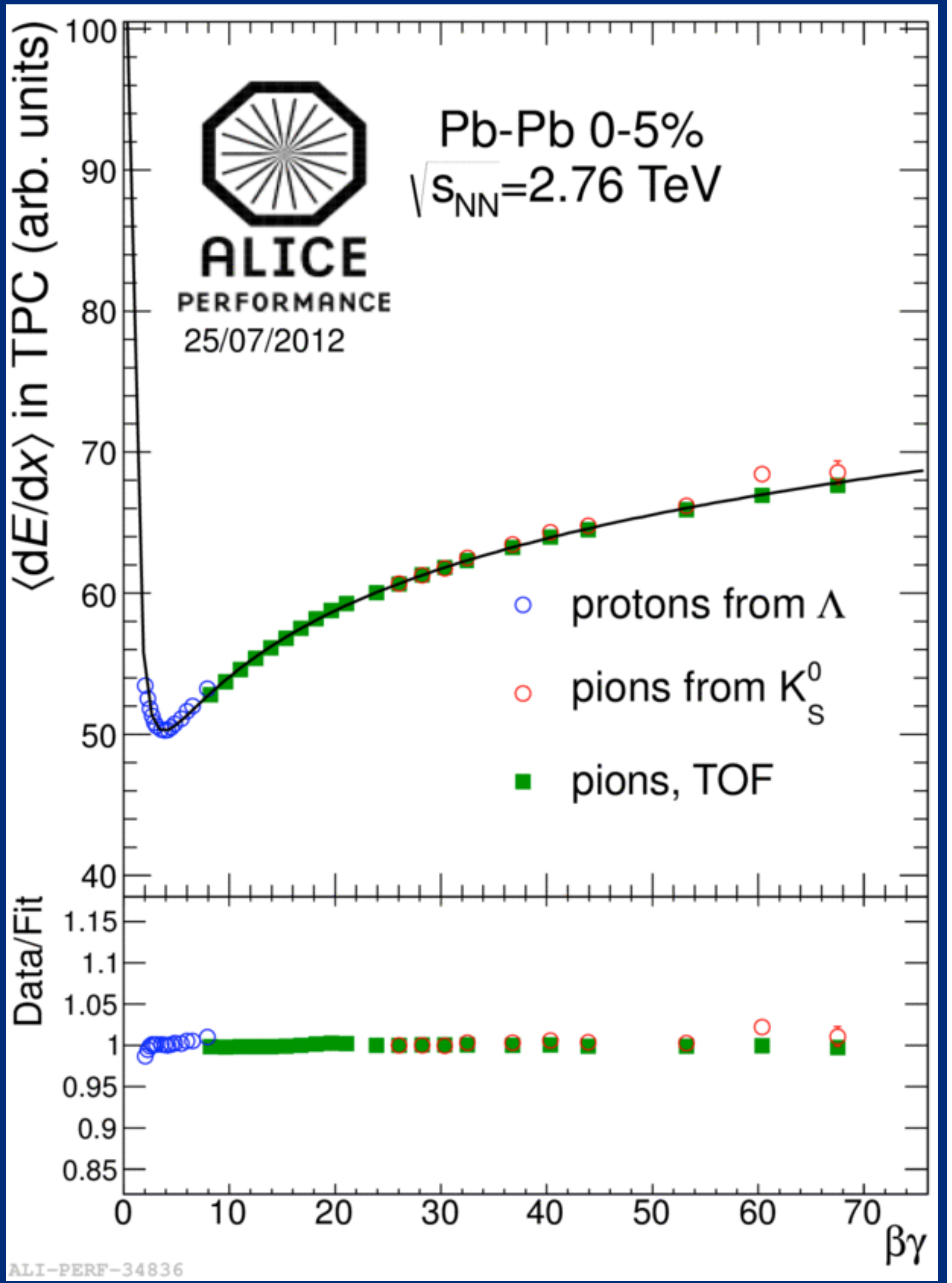


Statistical method: Select tracks with a PID signal (dE/dx, time, θ_{Ch}) close to the expected value and fit empirical functions (in p_T slices) to the PID signal distributions.

= High p_T PID method =

High pt PID: Done in the relativistic rise region of the BB curve where <dE/dx> separation between particles with different masses is nearly constant.

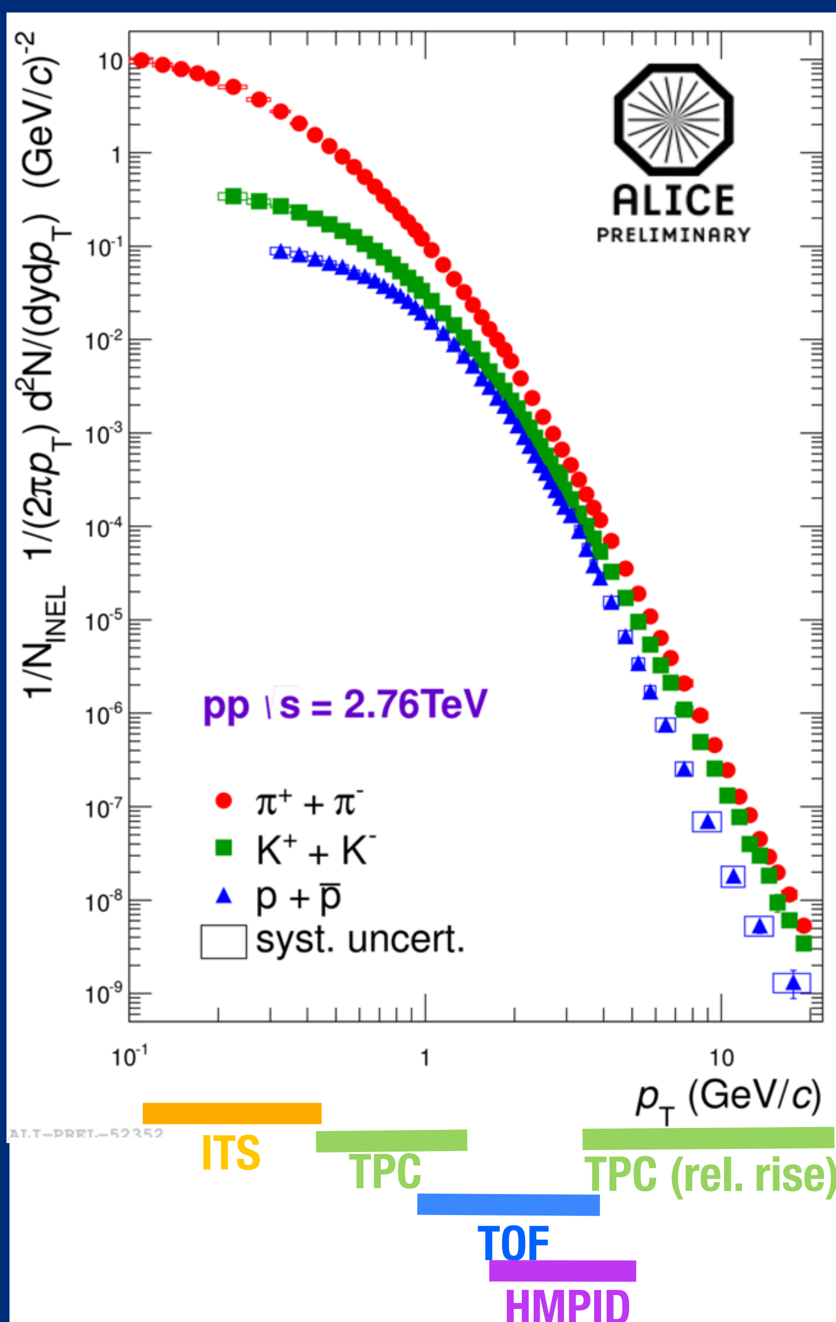


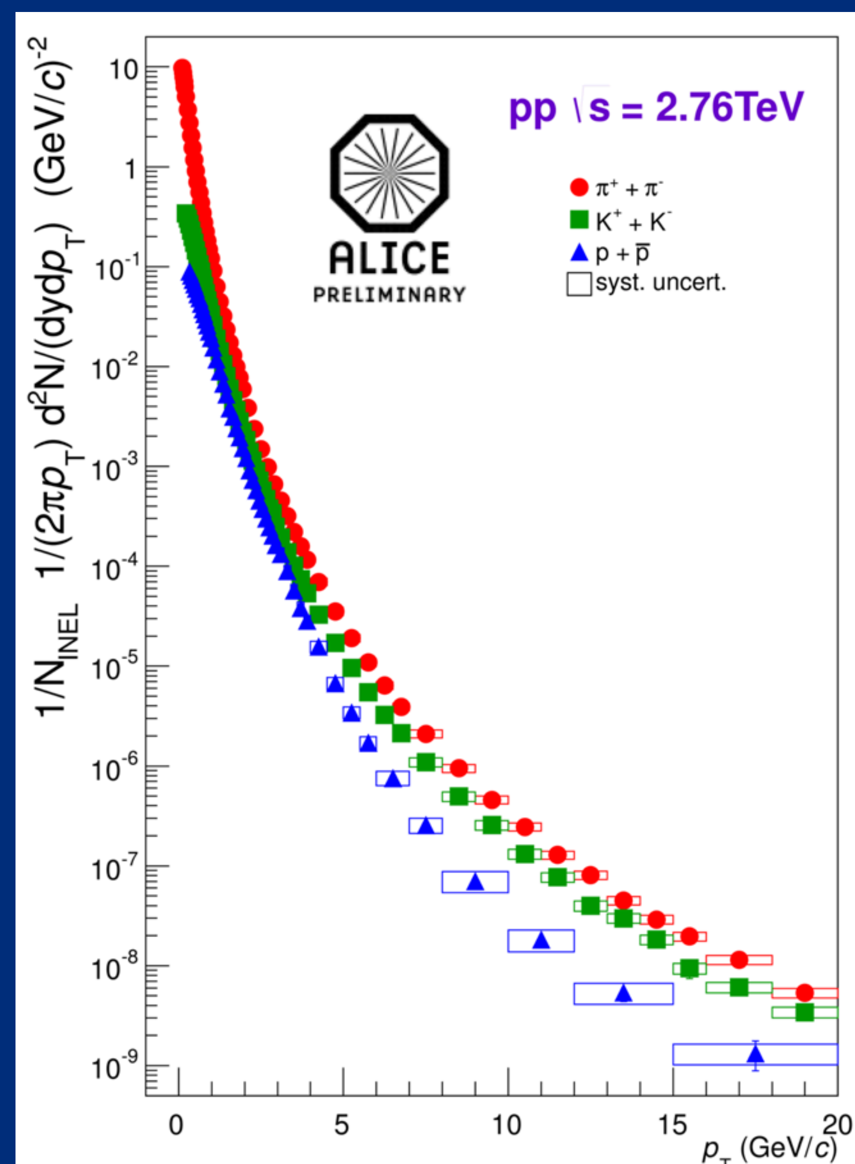


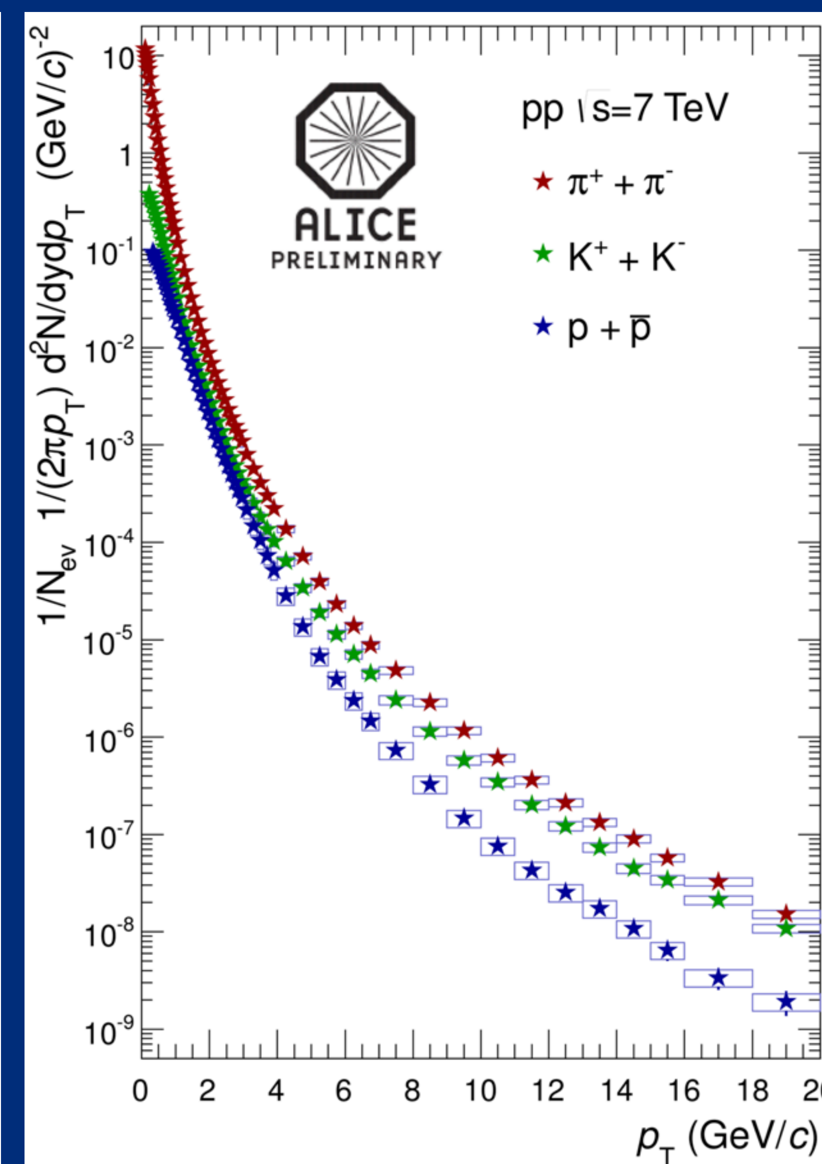
<dE/dx> (bγ) & σ (<dE/dx>) are extracted from data using V0s daughters and pions + electrons from TOF.

= Results: pp collisions =

Pions, Kaons, Protons full spectra is obtained combining the different PID methods and detectors.

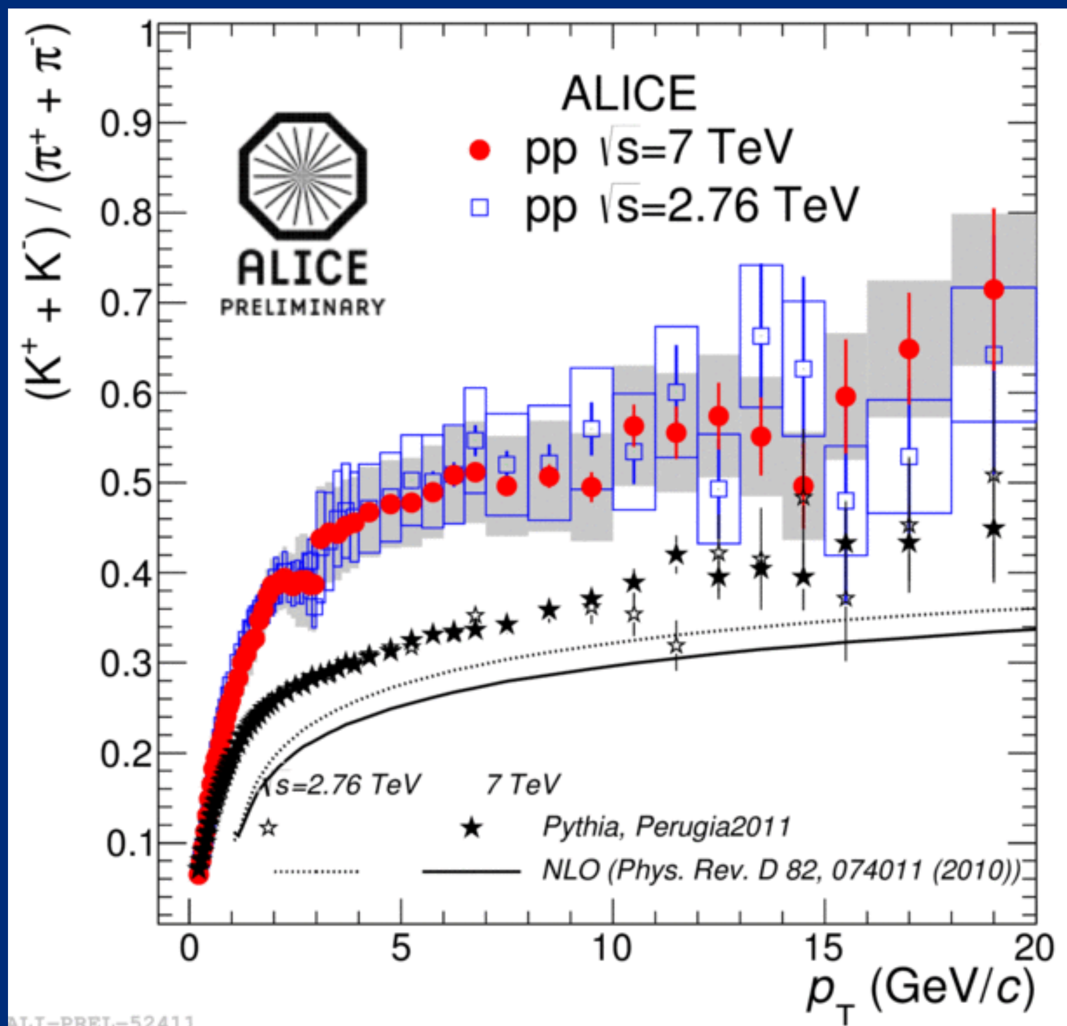


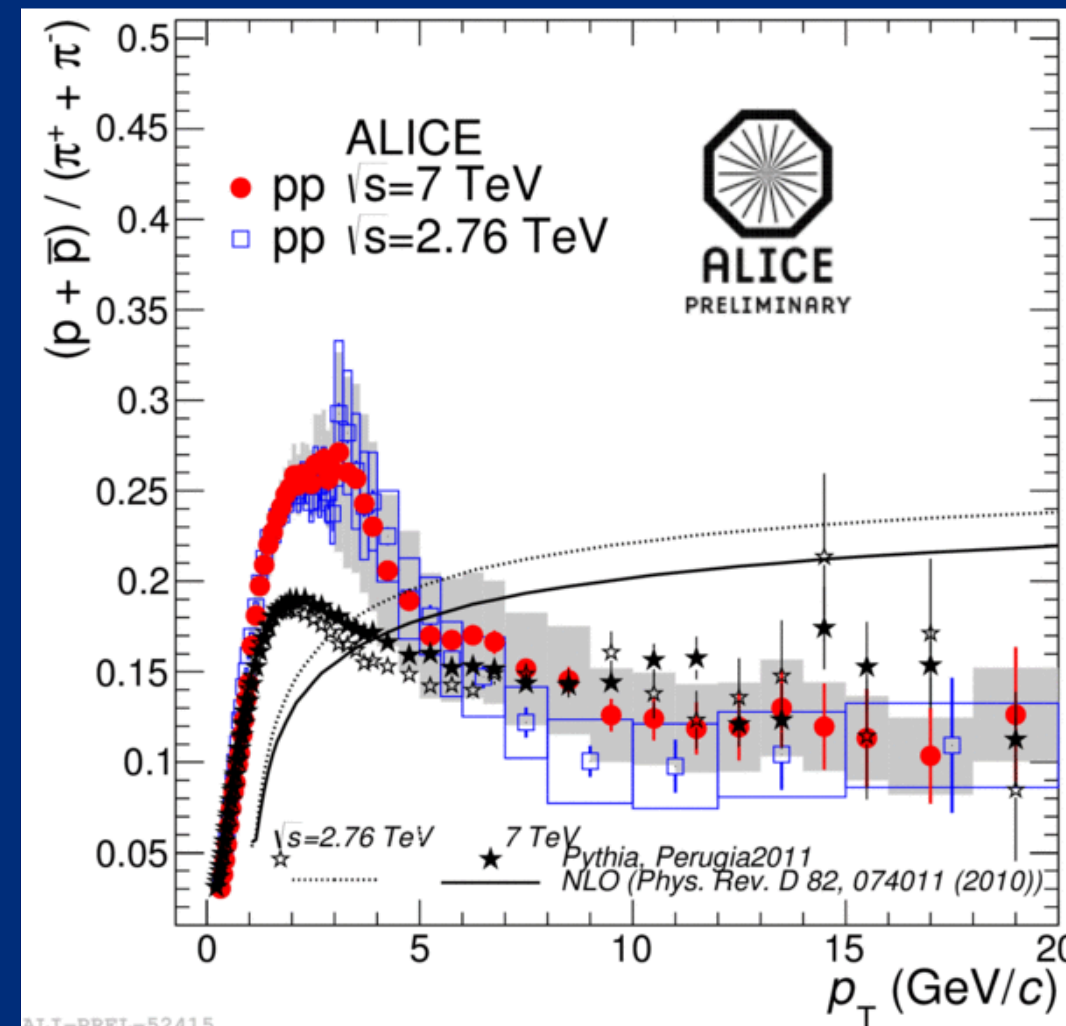




Full spectra at different energies in the
p_T range -> 100 MeV/c to 20 GeV/c

= Particle ratios =





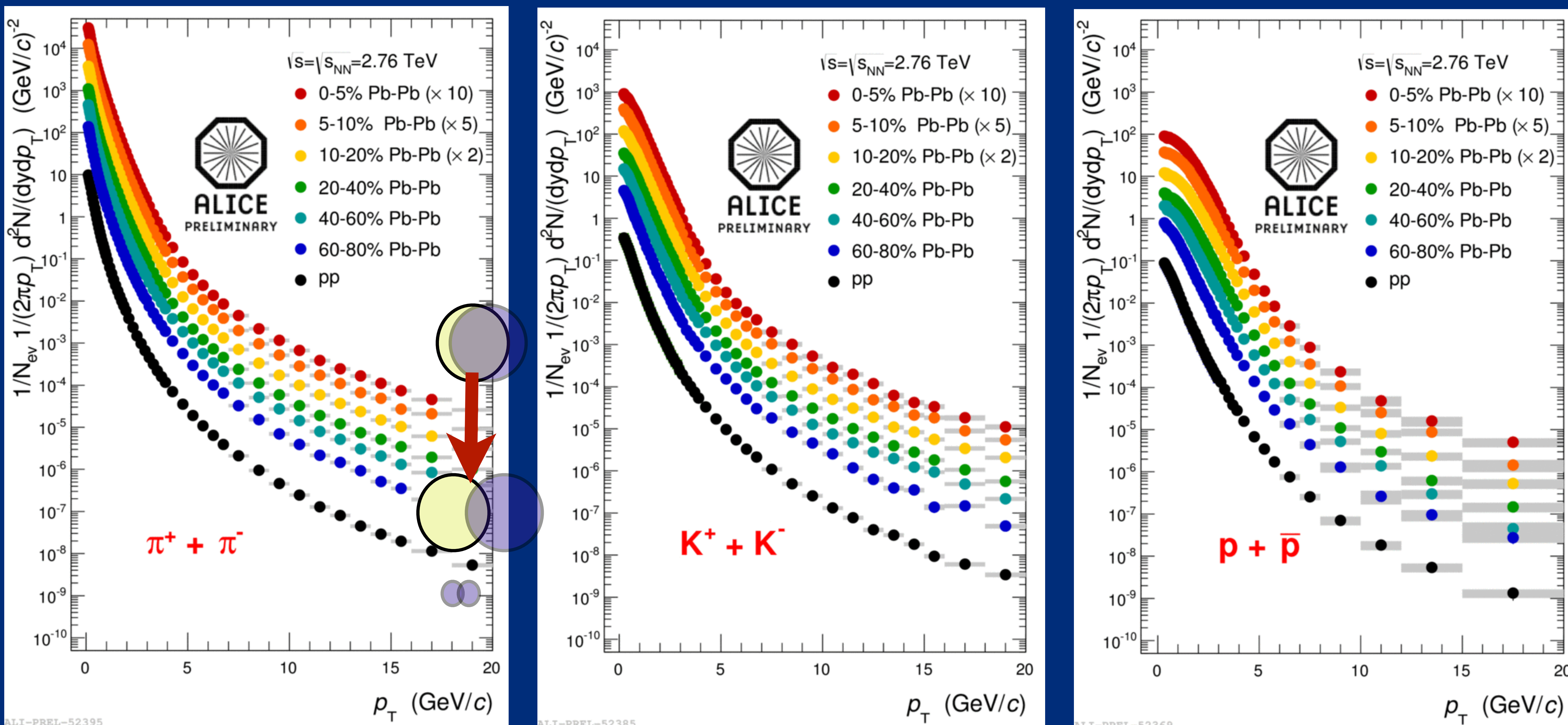
Ratios K/π and p/π at different energies are the same (within uncertainties)

Neither K/π nor p/π are reproduced by theory or MC models at p_T higher than 1 GeV/c.

Pythia 8 relates the peak in the p/pi ratio with color reconnection mechanism ->flow like mechanism.

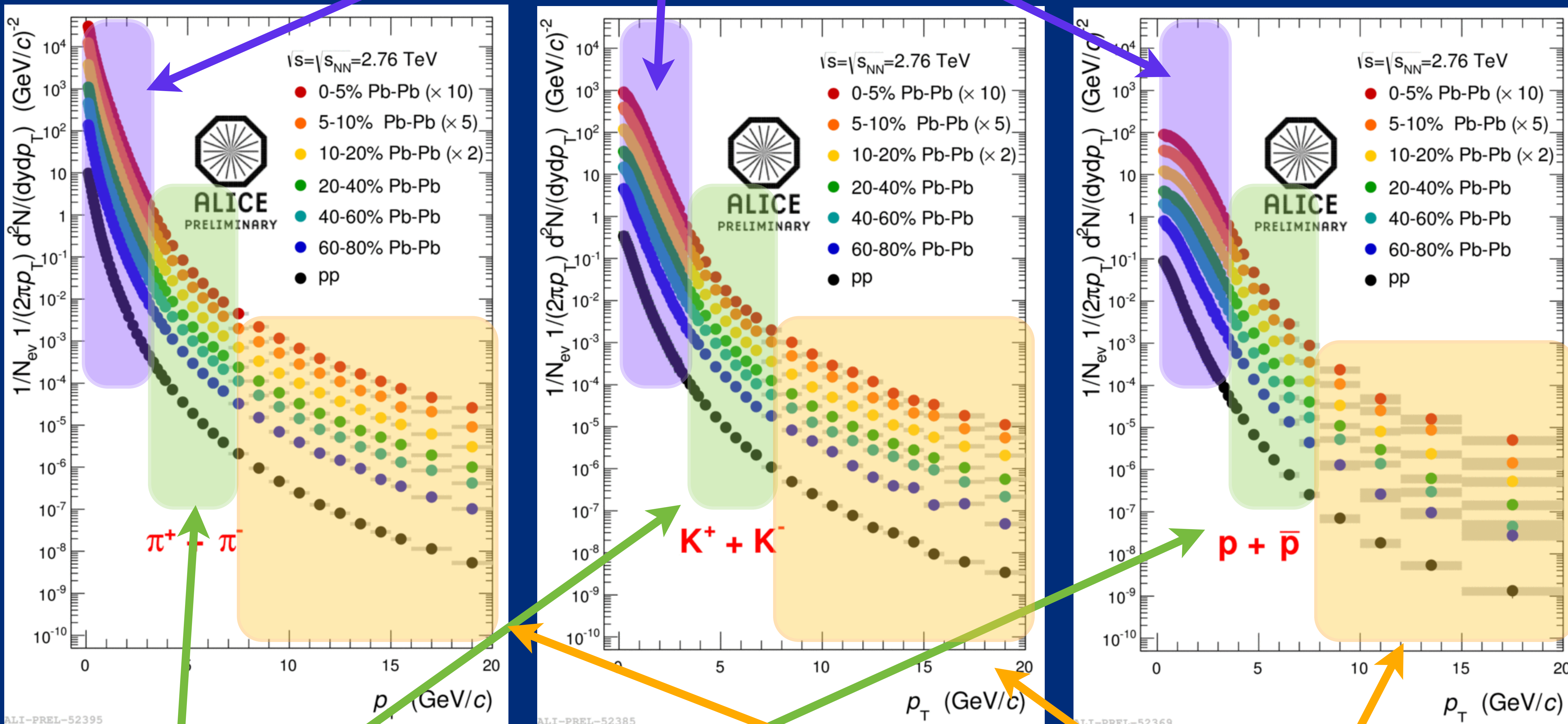
[Ortiz et al, PRL111, 042001 (2013)]

= Particle spectra =



= Particle spectra =

Radial flow (mass dependence)



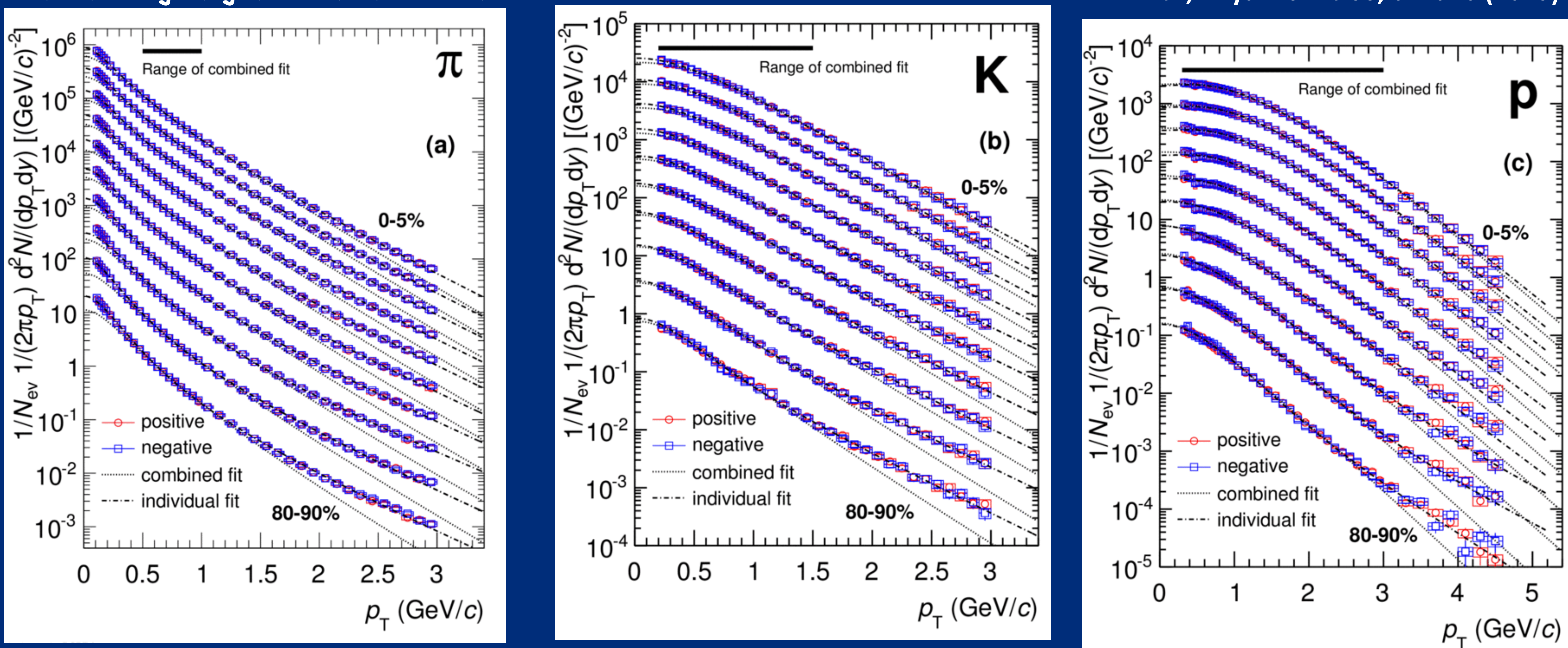
Mass anomaly

search for medium modification/ jet fragmentation

= Low p_T =

Blast wave fit: assumes a locally thermalized medium, expanding collectively with common velocity an undergoing into an instatanious freeze-out.

ALICE, Phys. Rev. C 88, 044910 (2013)



Individual fits describe data over the full p_T range.
Spectra well described by the Blast-wave model.
Extrapolation agrees with data in central collisions -> Purely hydrodynamical

$$\frac{1}{p_T}\frac{dN}{dp_T} \propto \int_0^R r\,dr\, m_T\, I_0\left(\frac{p_T \sinh\rho}{T_{kin}}\right) K_1\left(\frac{m_T \cosh\rho}{T_{kin}}\right)$$

Schnedermann et al, Phys. Rev. C 48, 2462 (1993)

Parameters: T_{kin}, $\beta_T = \beta_S\,(r/R)^n$

T_{kin} = kinetic freeze out
β_S = transverse expansion velocity
n = exponent of the velocity profile

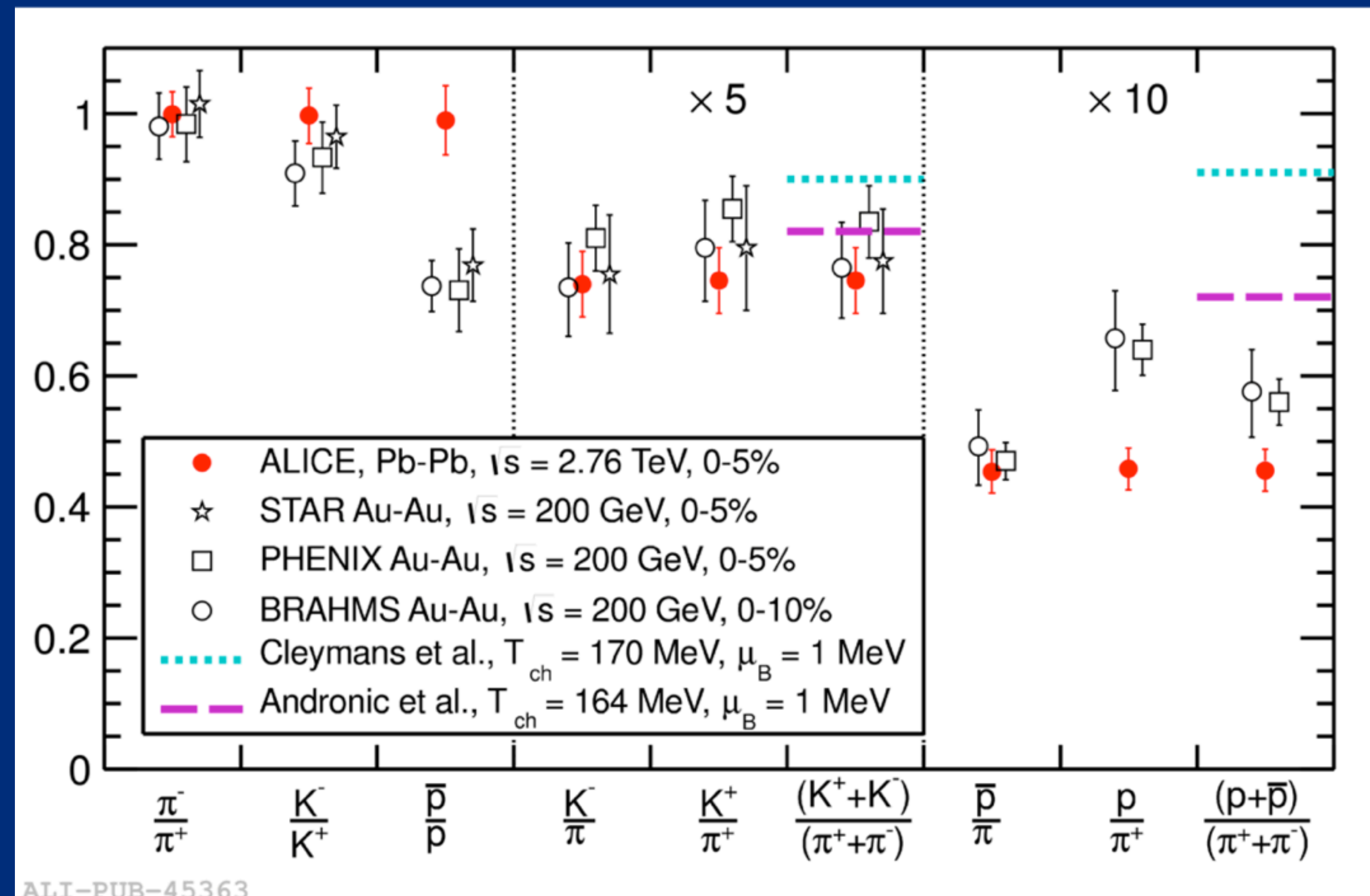
= Statistical model =

The integrated ratios can be interpreted in terms of the thermal models.

Statistical model calculations agrees with most ratios.

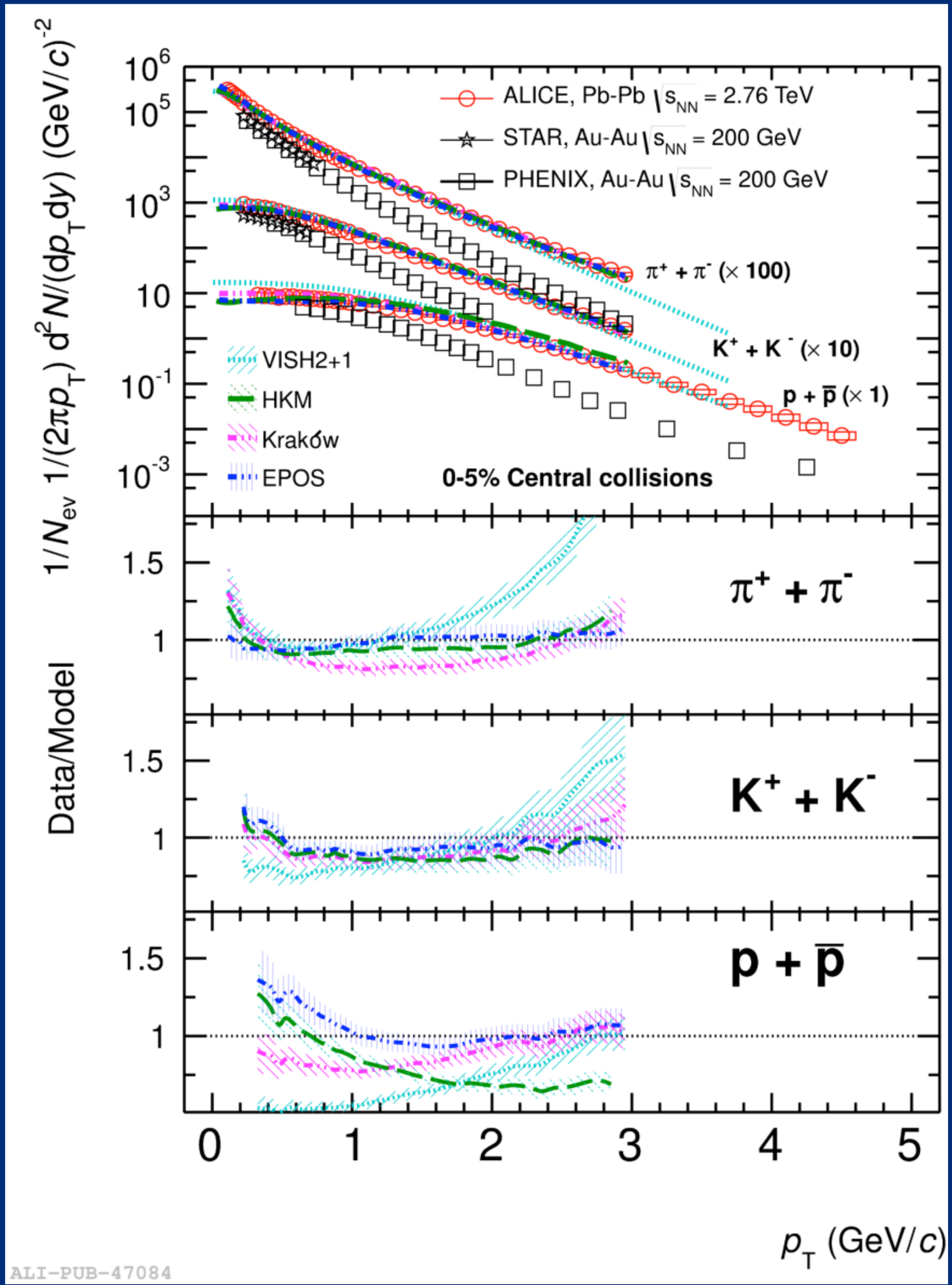
Ratio particle/antiparticle compatible with unity at LHC energies.

Bad description for protons.



ALICE, Phys. Rev C 88, 044910 (2013)

= Blast wave fit =



Low pT spectra for central collisions

Most of hydro models provide a reasonable description of the measured spectra at p_T lower than 3 GeV/c.

VISH 2+1: viscous hydrodynamics without description of hadronic phase. (low p_T). Thermal paricle yields with T_{ch}=165 MeV.

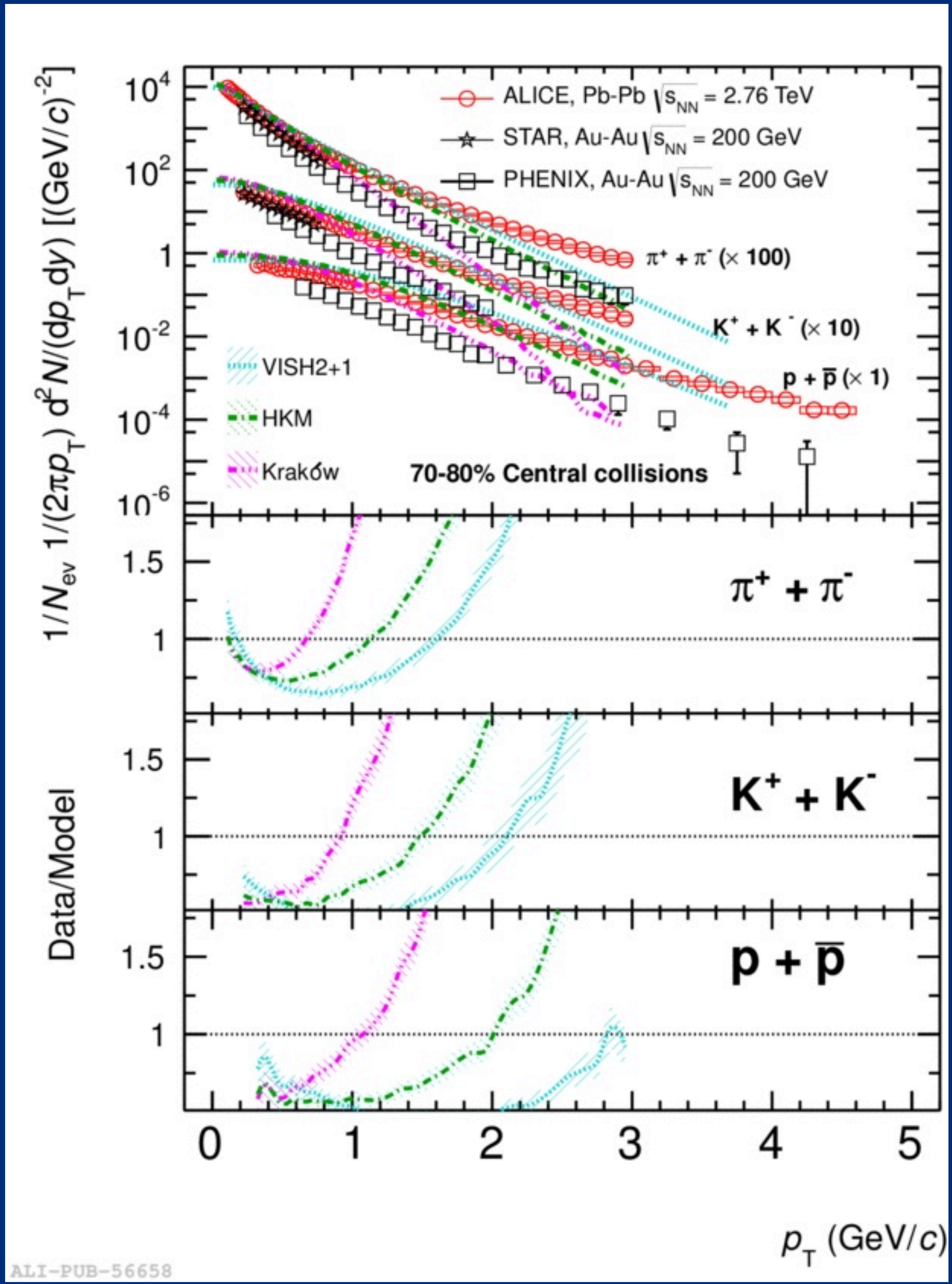
HKM: hydro+UrQMD, additional radial flow built by hadronic phase which also affects particle ratios as a result of inelastic interactions. (low p_T)

Kraków: introduces non equilibrium corrections due to the bulk viscosity at the transition from the hydrodynamic description to particles which changes the effective T_{ch}. (low p_T)

EPOS: uses breakup of the flux tubes created by initial hard scatterings. These flux tubes constitutes bulk matter and jets. Describe the spectra for all p_T.

ALICE, Phys. Rev. C 88, 044910 (2013)

= Blast wave fit =

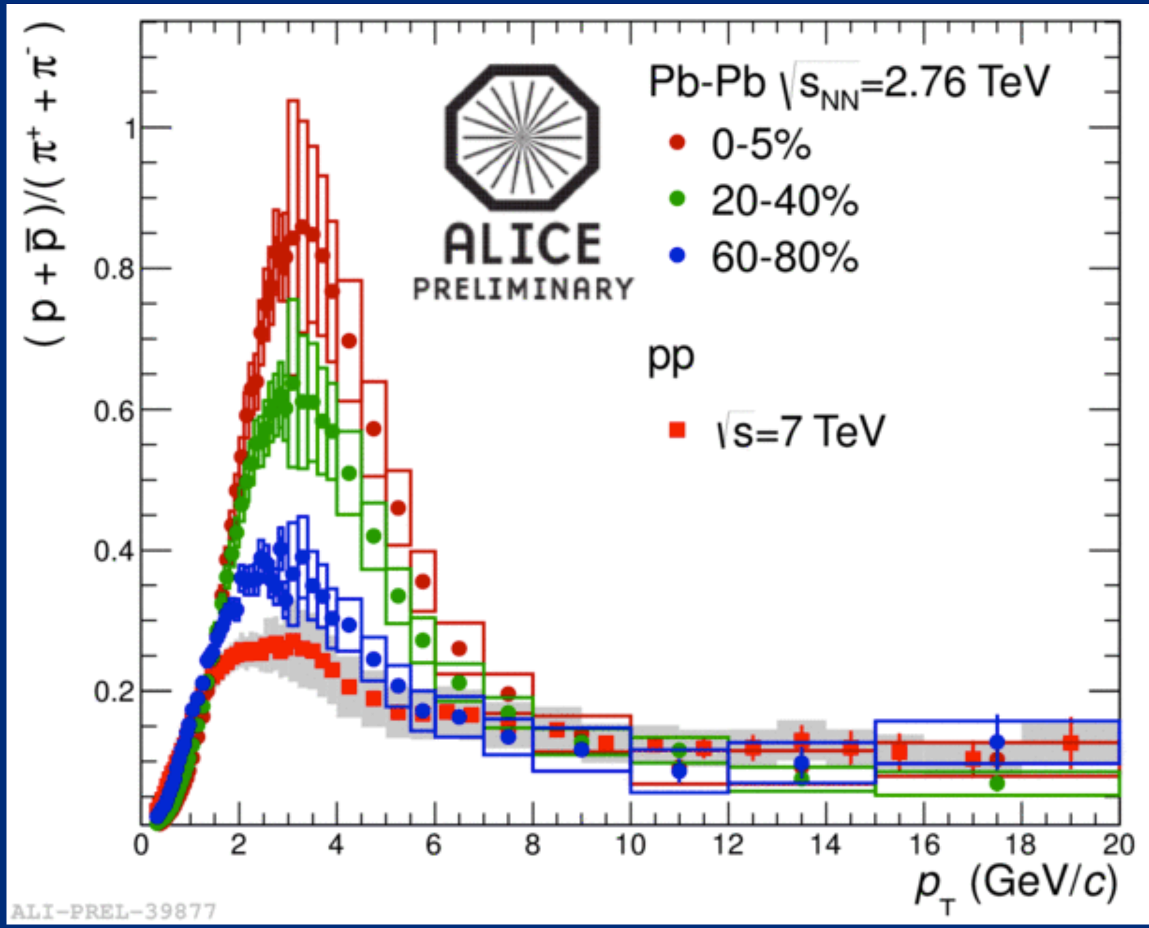


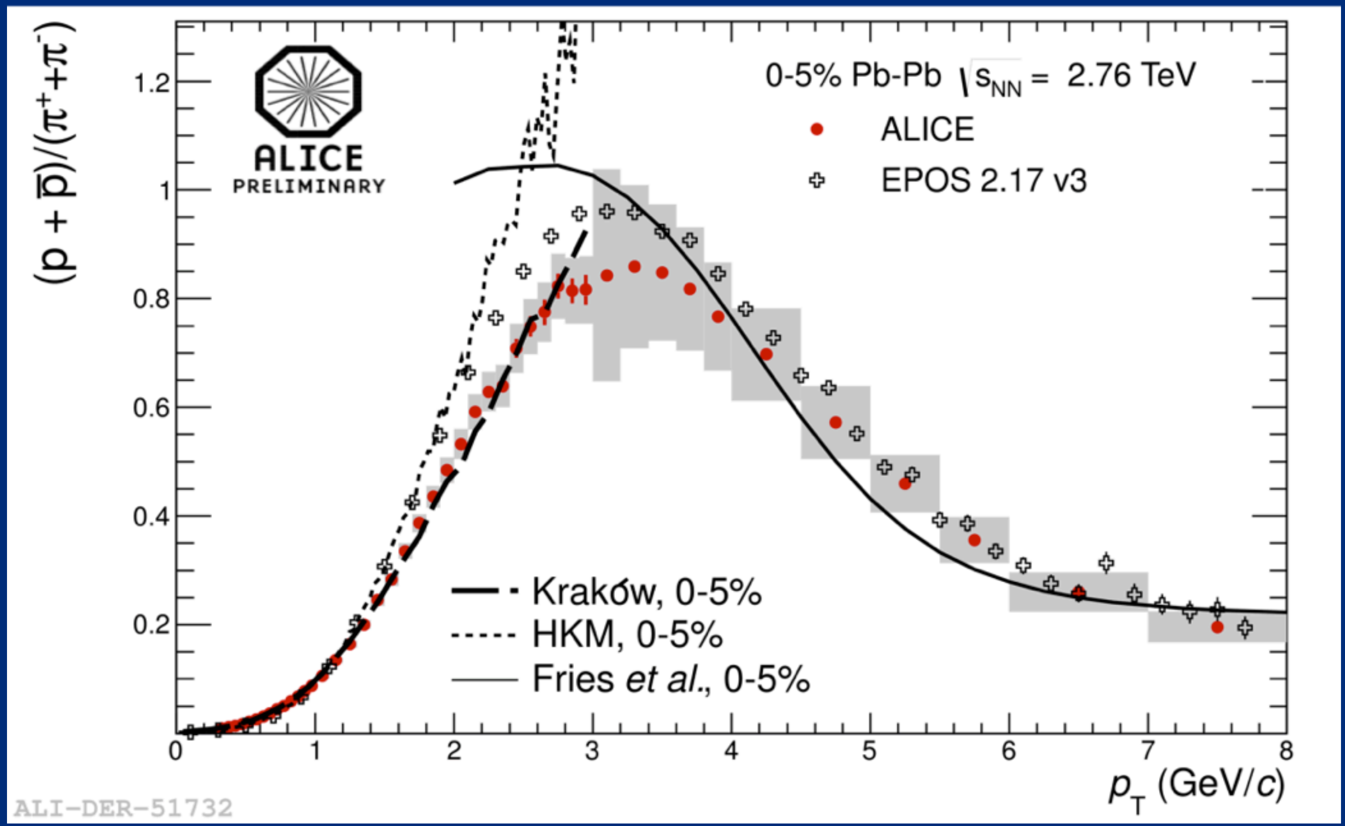
Low pT spectra for peripheral collisions

Hydro models fails in the description of data,

ALICE, Phys. Rev. C 88, 044910 (2013)

= Intermediate p_T =





p/pi enhancement around p_T 3 GeV/c.

Collective medium response.

Push from radial flow?

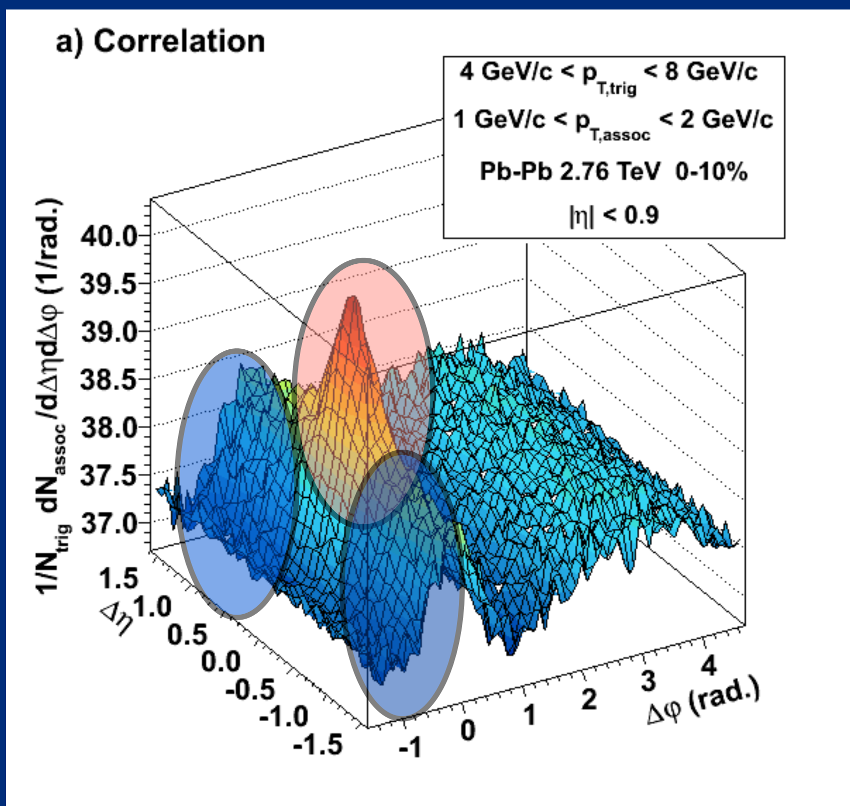
Decrease at high pT.

Low pT -> hydro models (Krakow & HKM)
Intermediate pT: recombination (FRIES)

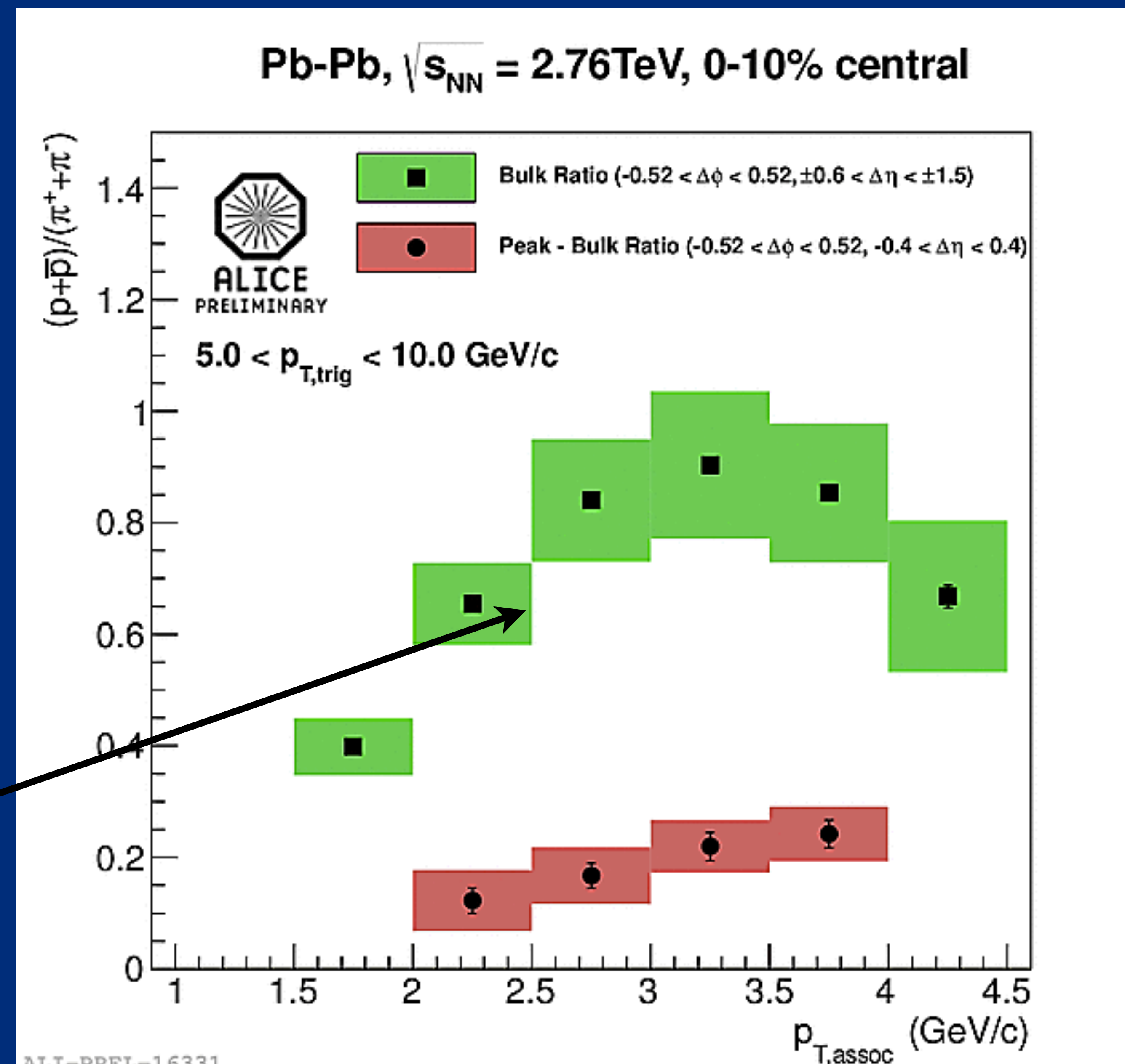
EPOS -> all pt range:
hydrodynamics (low pT)
medium modified fragmentation for quenched jets (intermediate pT)
vacuum fragmentation (high pT)

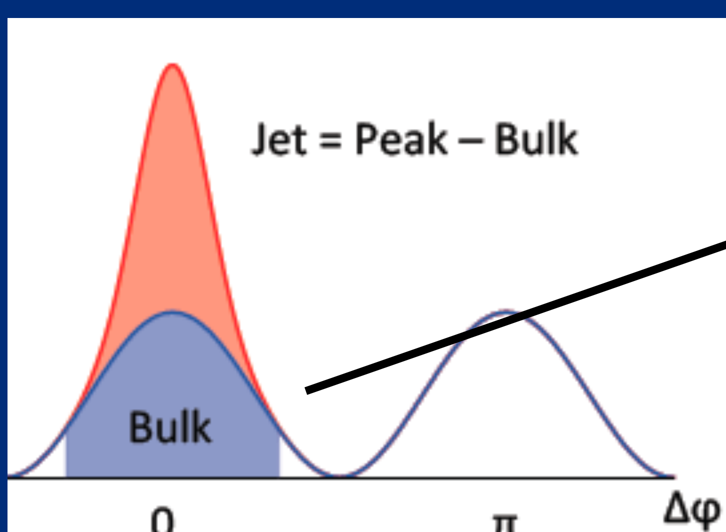
Still no perfect model for all pT regions that describes the data.

= Intermediate p_T =



p/pi ratio in the jet and bulk

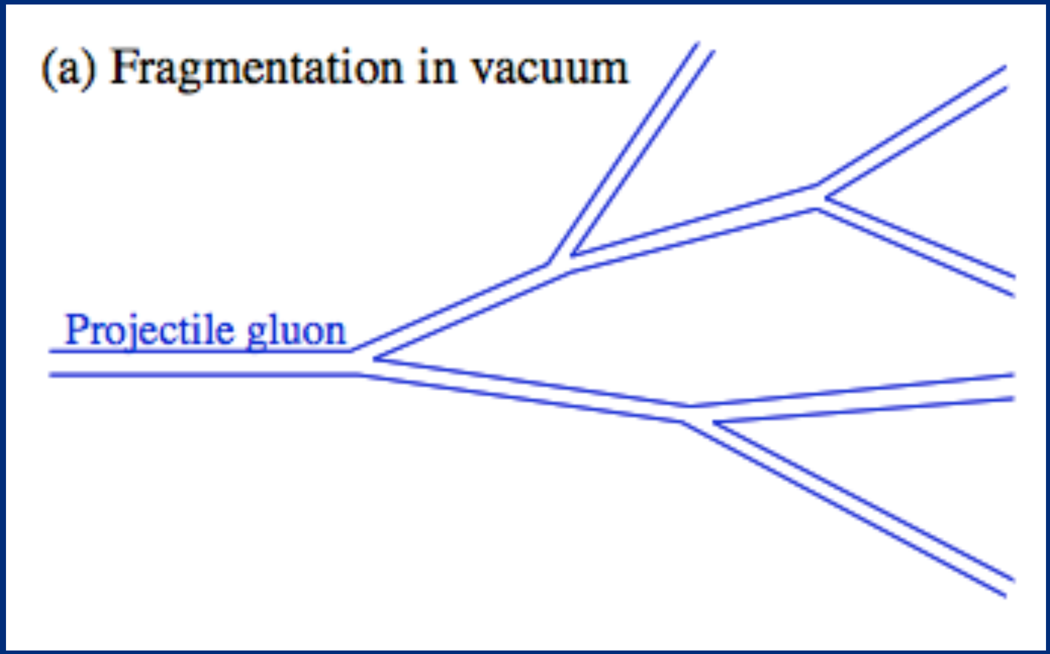


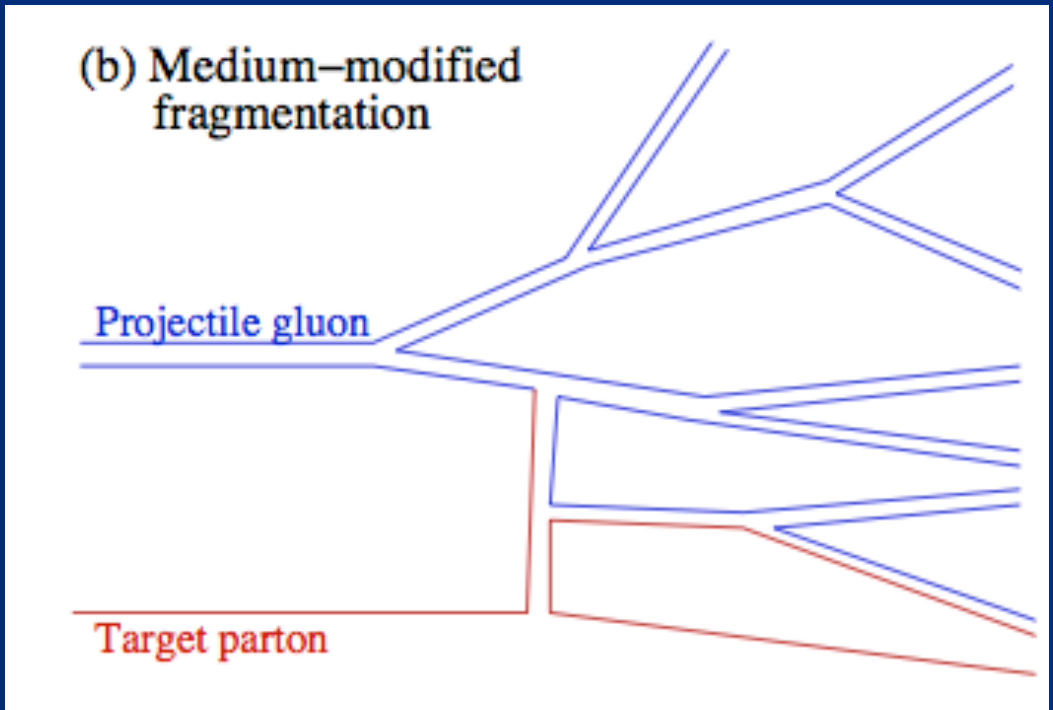


Baryon enhancement is a bulk effect!

Flavor dependence of the R_{AA}.

S. Sapeta and U.A. Wiedemann, Eur.Phys.J. C55 (2008) 293:





One expects energy loss affect jet hadrochemistry ->

All Models: the interaction of a parton with the QCD medium transfers color between partonic projectile and target.

Color flow in parton shower-> Affect hadronization.

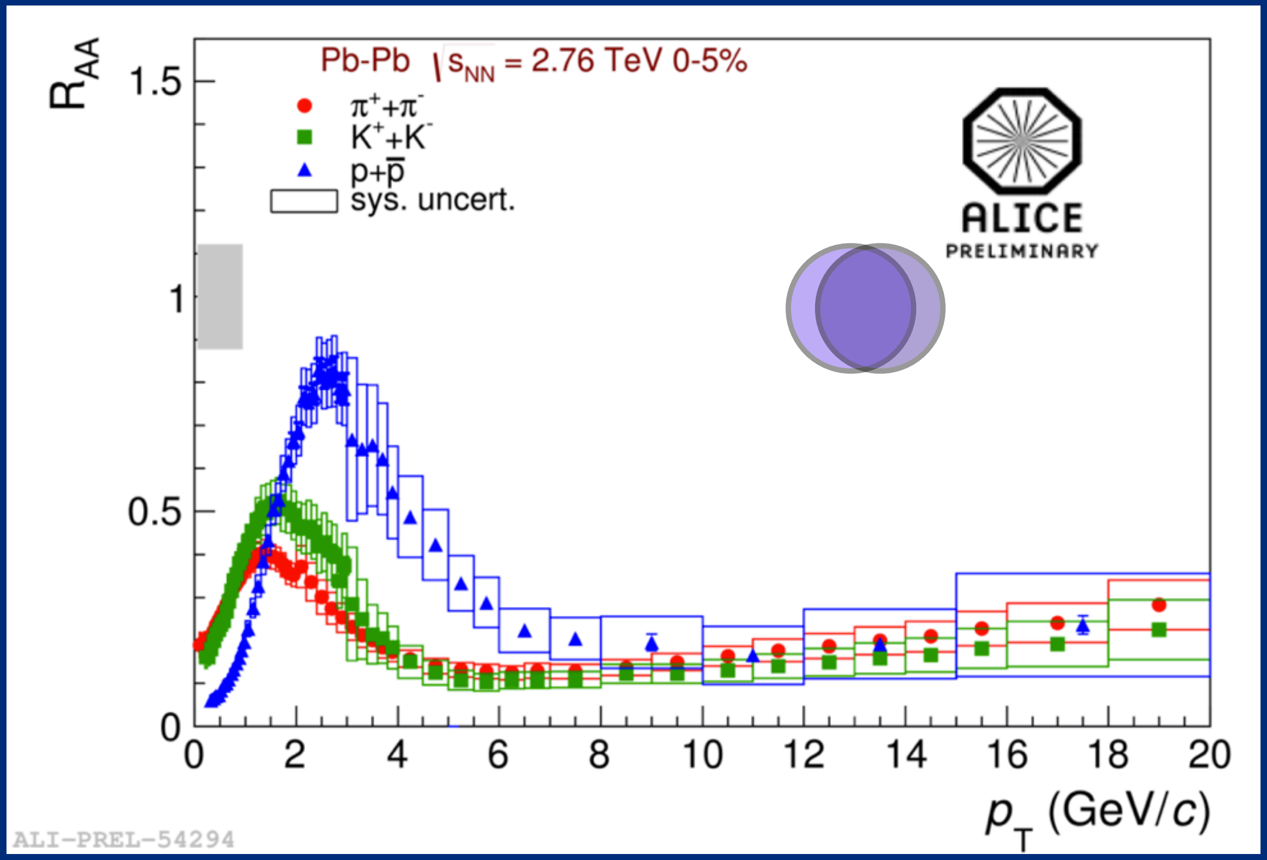
Flavor or baryon number can be exchanged between medium and projectile.

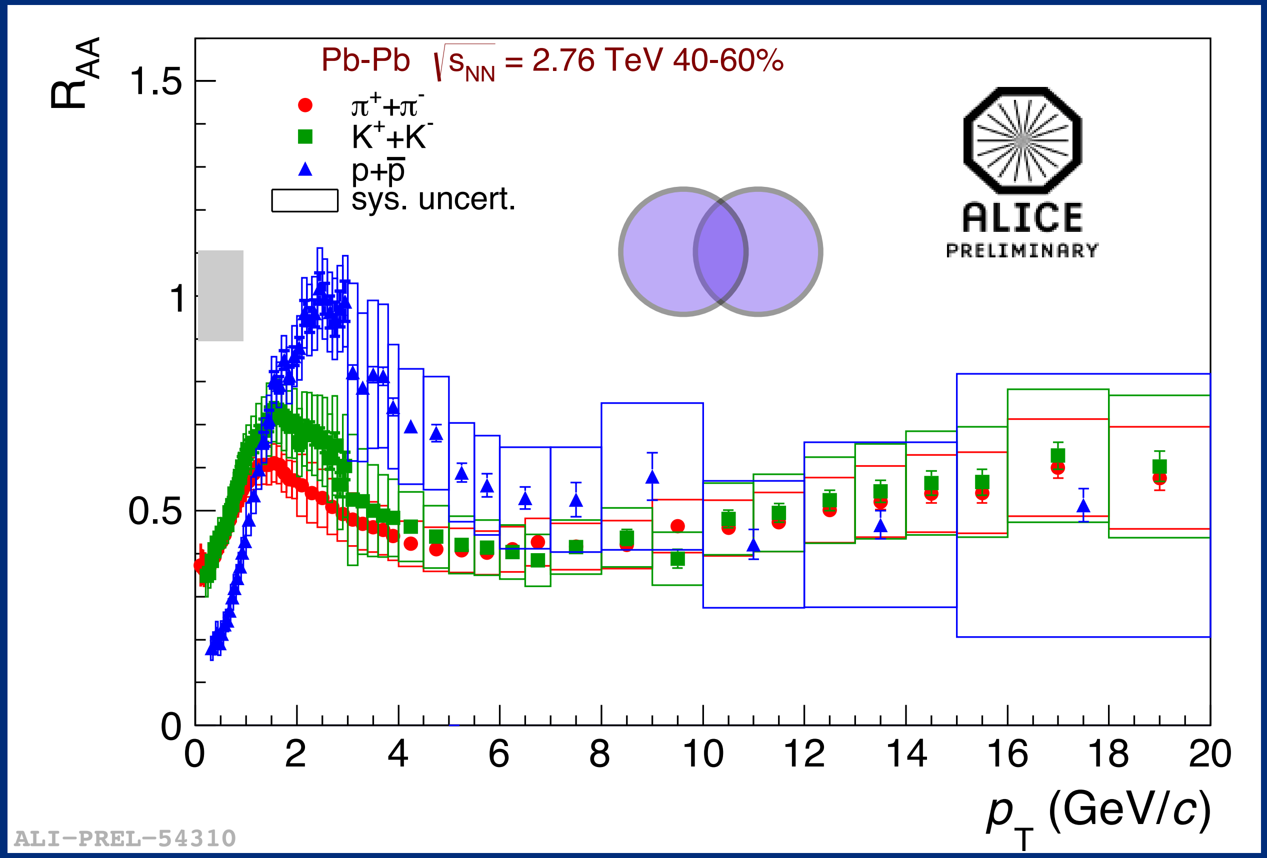
$$R_{AA} = \frac{d^2N_{AA}/dp_T dy}{\langle N_{coll}\rangle d^2N_{pp}/dp_T dy}$$

At high pT above 10 GeV/c the R_{AA} for pi, K and p are compatible.

No difference in energy loss.

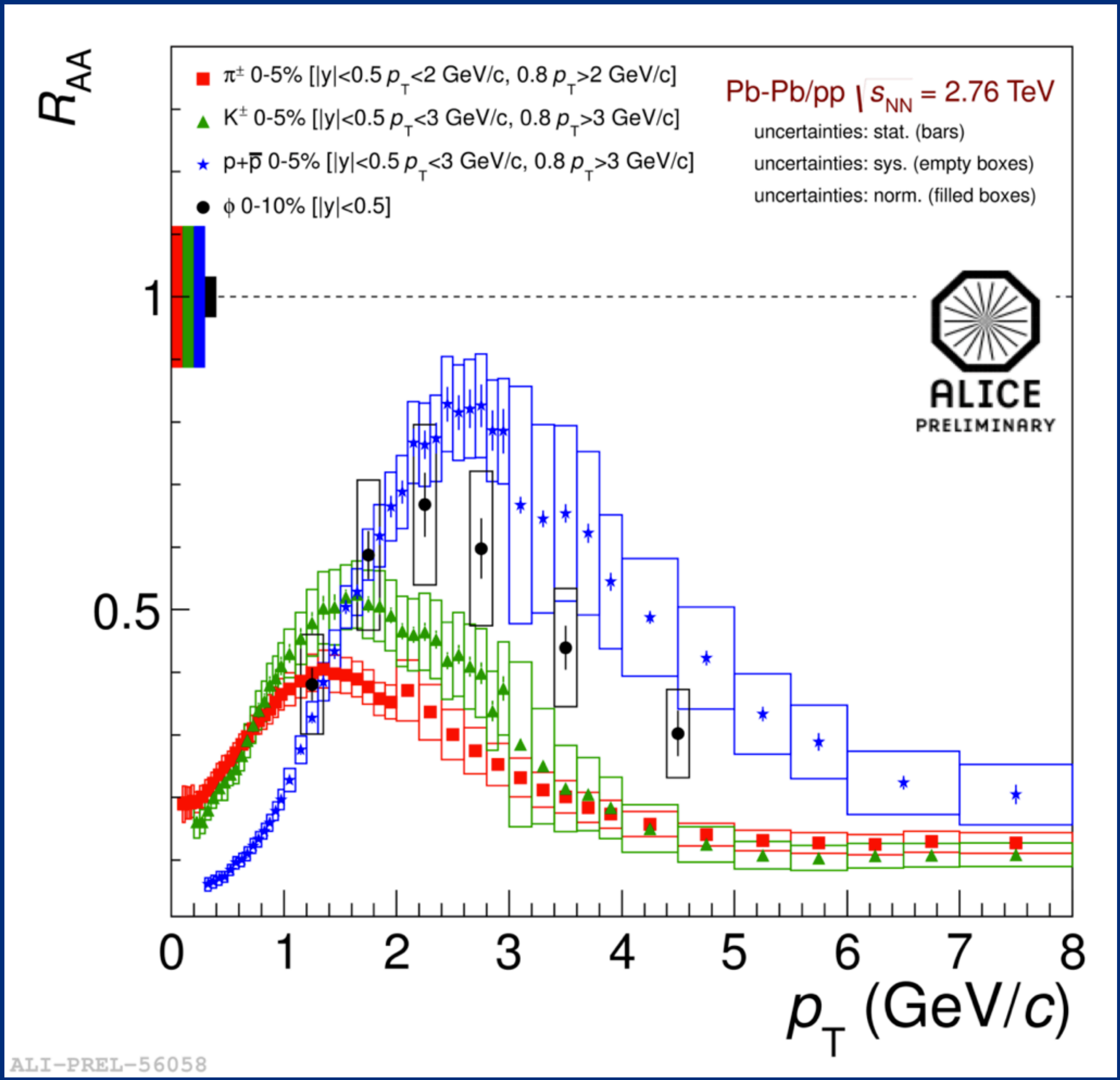
R_{AA} no flavor dependence at high p_T





Predictions of significant modifications of high-p_T particle hadrochemistry induced by jet quenching are disfavored

= RAA different mesons =

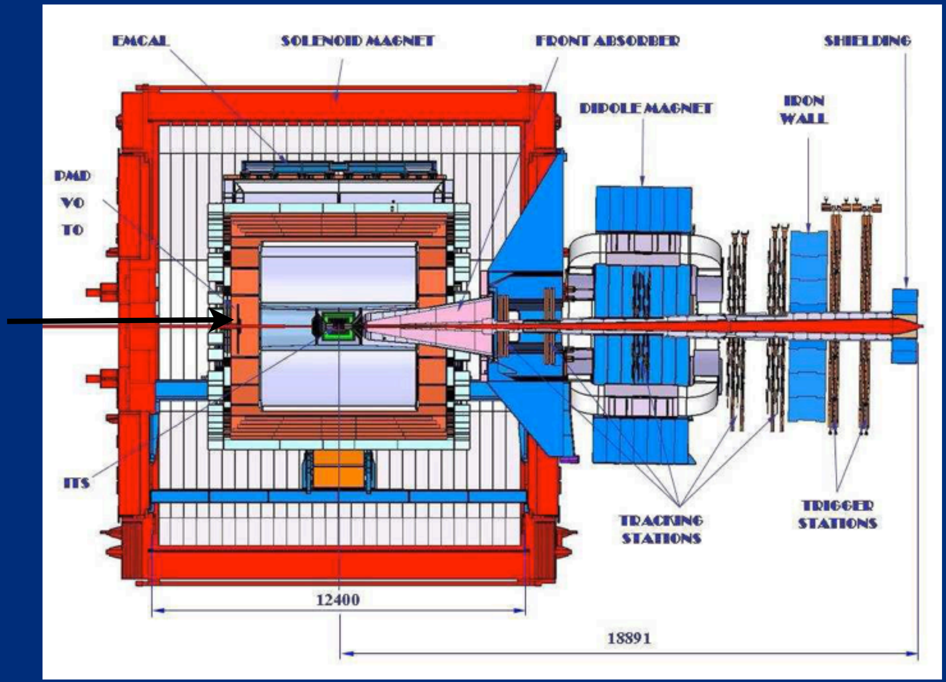


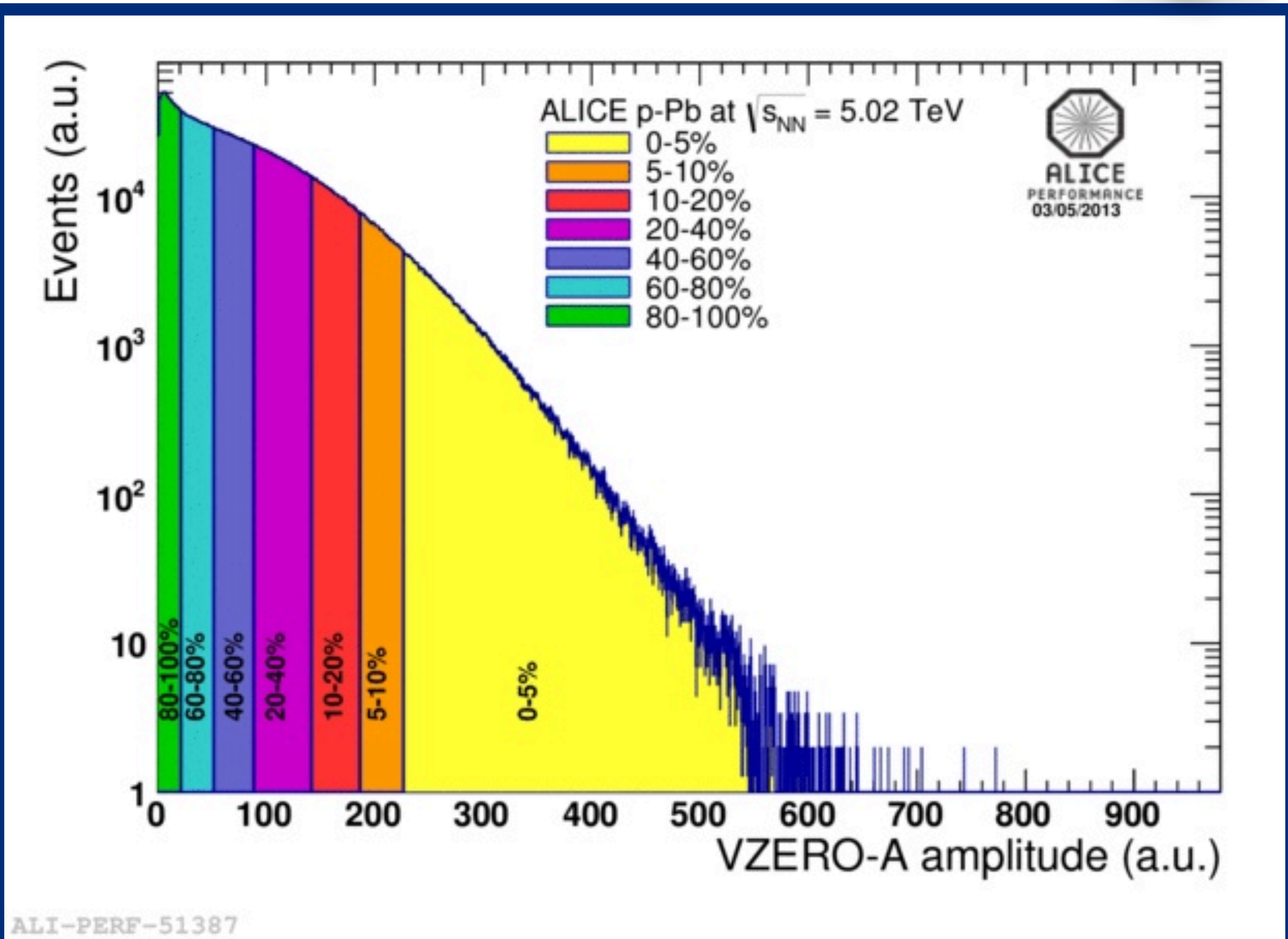
φ (1020) meson -> mass similar to proton.

The R_{AA} for φ mesons follows the same trend as protons for p_T < 2 GeV/c (hydrodynamic region)

For pT > 2 GeV/c we cannot conclude anything because of the large systematics.

= A Fast look to p-Pb results =





VZERO-A

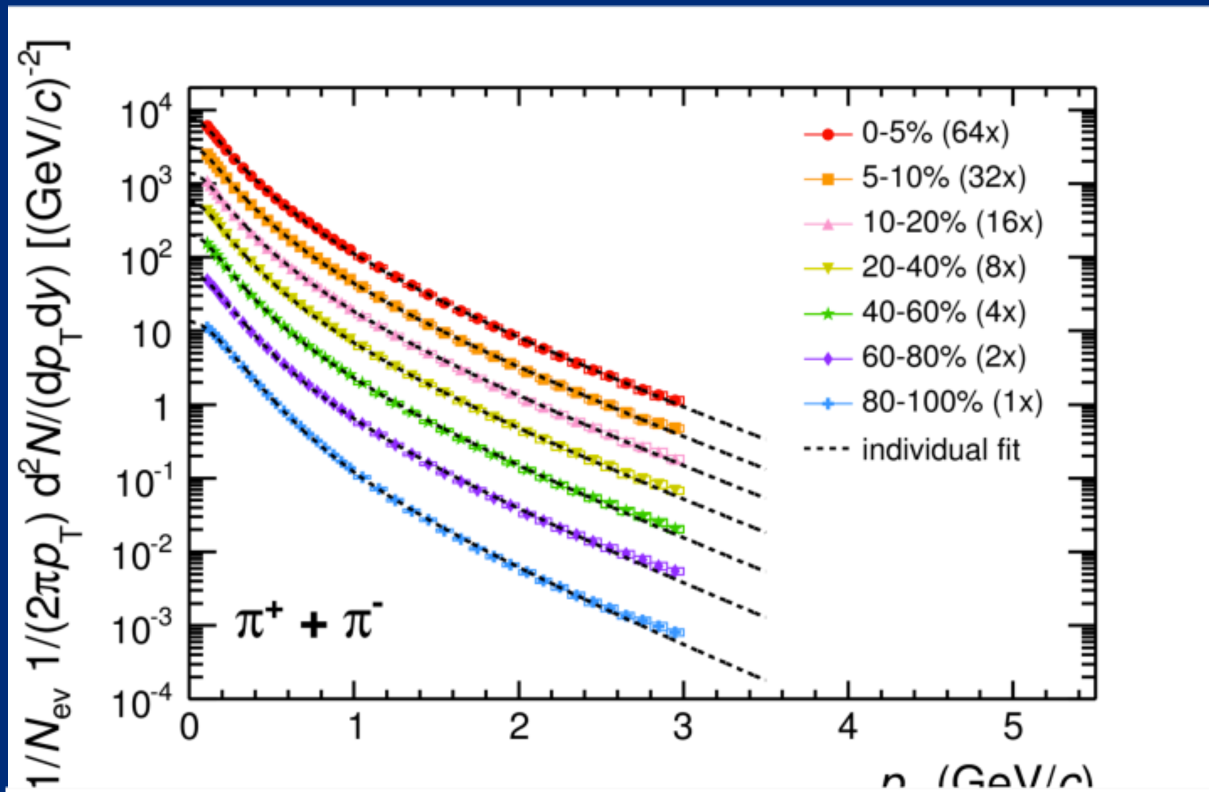
VZERO-A (in Pb dir)
$2.8 < |\eta_{lab}| < 5.1$
$y_{CMS} = y_{LAB} + 0.465$ in p-dir

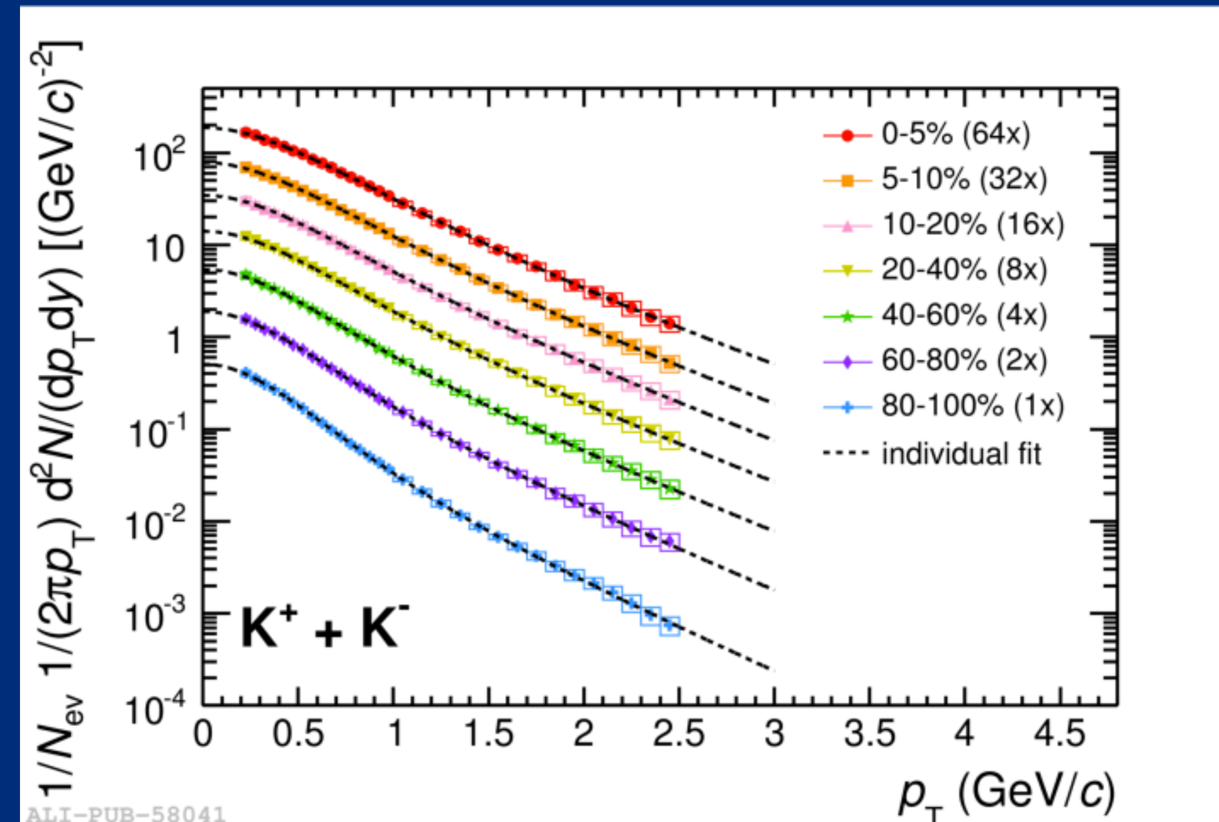
The correlation between p-Pb collision geometry and particle multiplicity is not trivial.

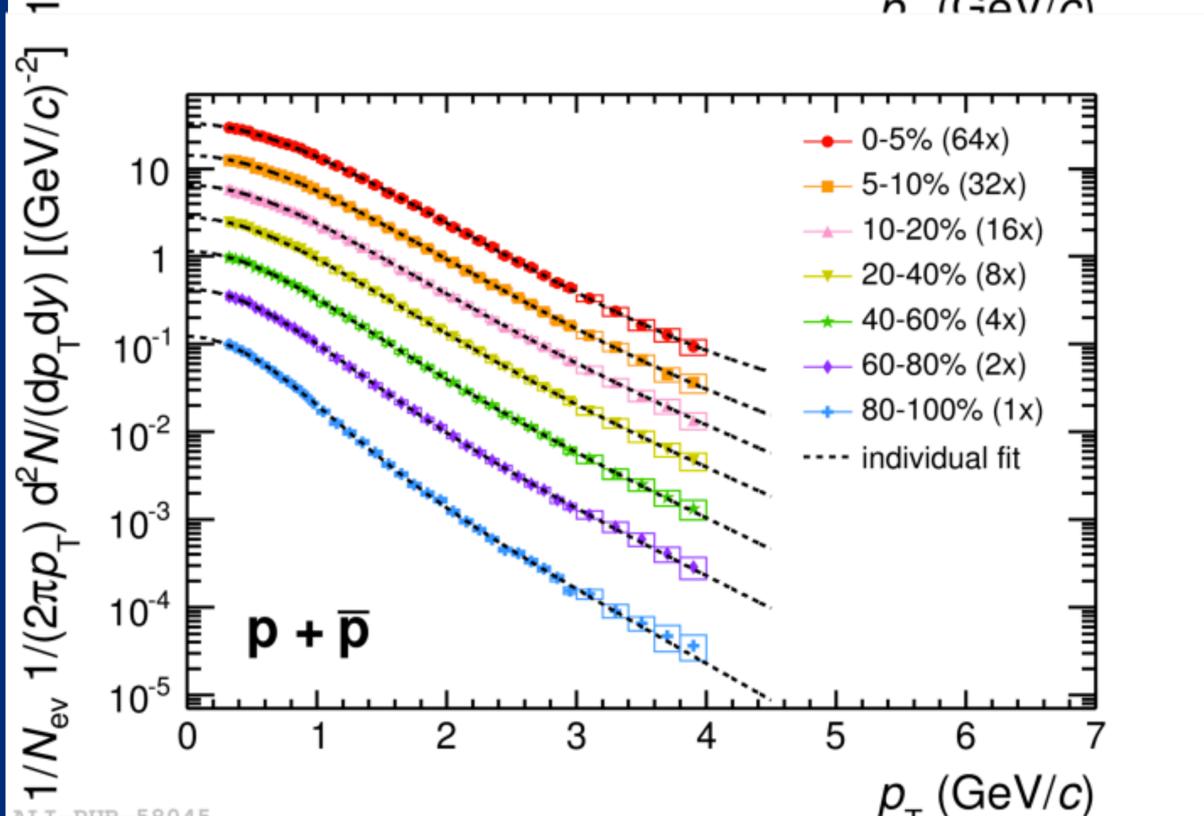
Seven p-Pb multiplicity event classes based on the amplitude of the signal of the VZERO-A.
VZERO-A signal proportional to charged particle multiplicity:

high multiplicity: 0-5%
low multiplicity: 80-100%

= p_T spectra π/k/p =







$0.0 < y_{cms} < 0.5$

Spectra with individual blast-wave fits

p_T coverage:

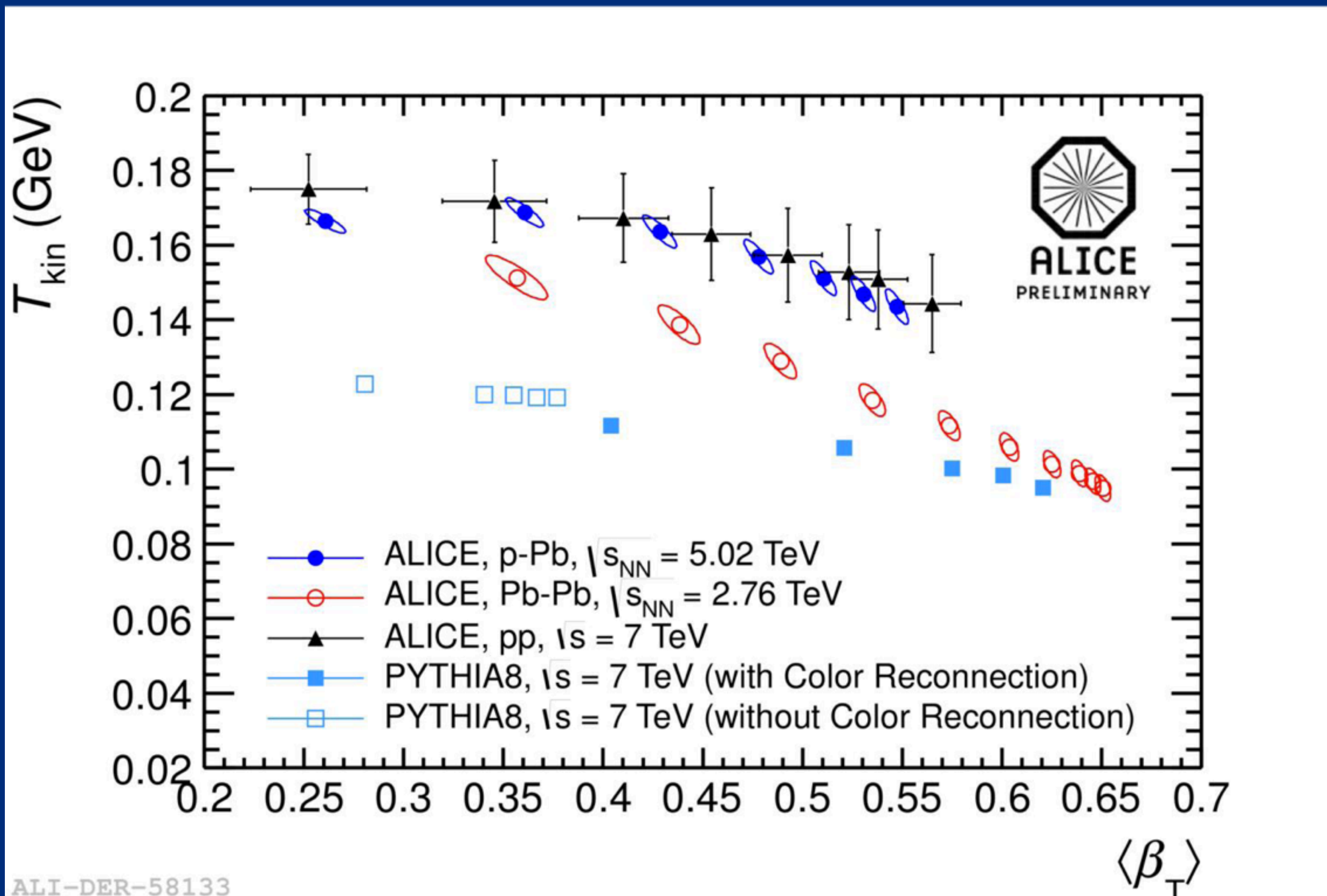
π: 0.2 < pT < 3.0 GeV/c

K: 0.25 < pT < 2.5 GeV/c

p: 0.45 < pT < 4.0 GeV/c

ALICE, arXiv:1307.6796

= Blast wave parameters =



ALICE, arXiv:1307.6796

Comparison between parameters for the 3 systems:

The pp, p-Pb and Pb-Pb data follows the same trend.

If the spectral shape changes (at low p_T) are elated to radial flow.

Flow in p-Pb and pp ¿?

PYTHIA 8 shows a similar trend with the Color Reconnection mechanism (CR) enabled.
CR-> flow-like effects without formation of a medium.

[Ortiz et al, PRL111, 042001 (2013)]

= Conclusions =

- The pT spectra of π /K/p for the 3 diffent systems were presented.
- Low pT spectra qualitatively well described by models with hydro:
  - pp & p-Pb - Not clear whether the description is hydrodynamical or due to other mechanism like CR. Blast-wave analysis shows similar trend as in Pb-Pb.
  - Pb-Pb Very strong radial flow, $\beta_{blast\text{-}wave} \simeq 0.65$.
- The intermediate p_T region still need a comprehensive model description. The PID provides essential information (particle ratios).
- "Baryon anomaly" is a bulk effect, strong constraints for models.
- At high p_T No flavor dependence of the R_{AA}, this suggest significant modifications of high-p_T particle hadrochemistry induced by jet quenching are disfavored.
- Still waiting for a model that describes the data in all p_T regions.

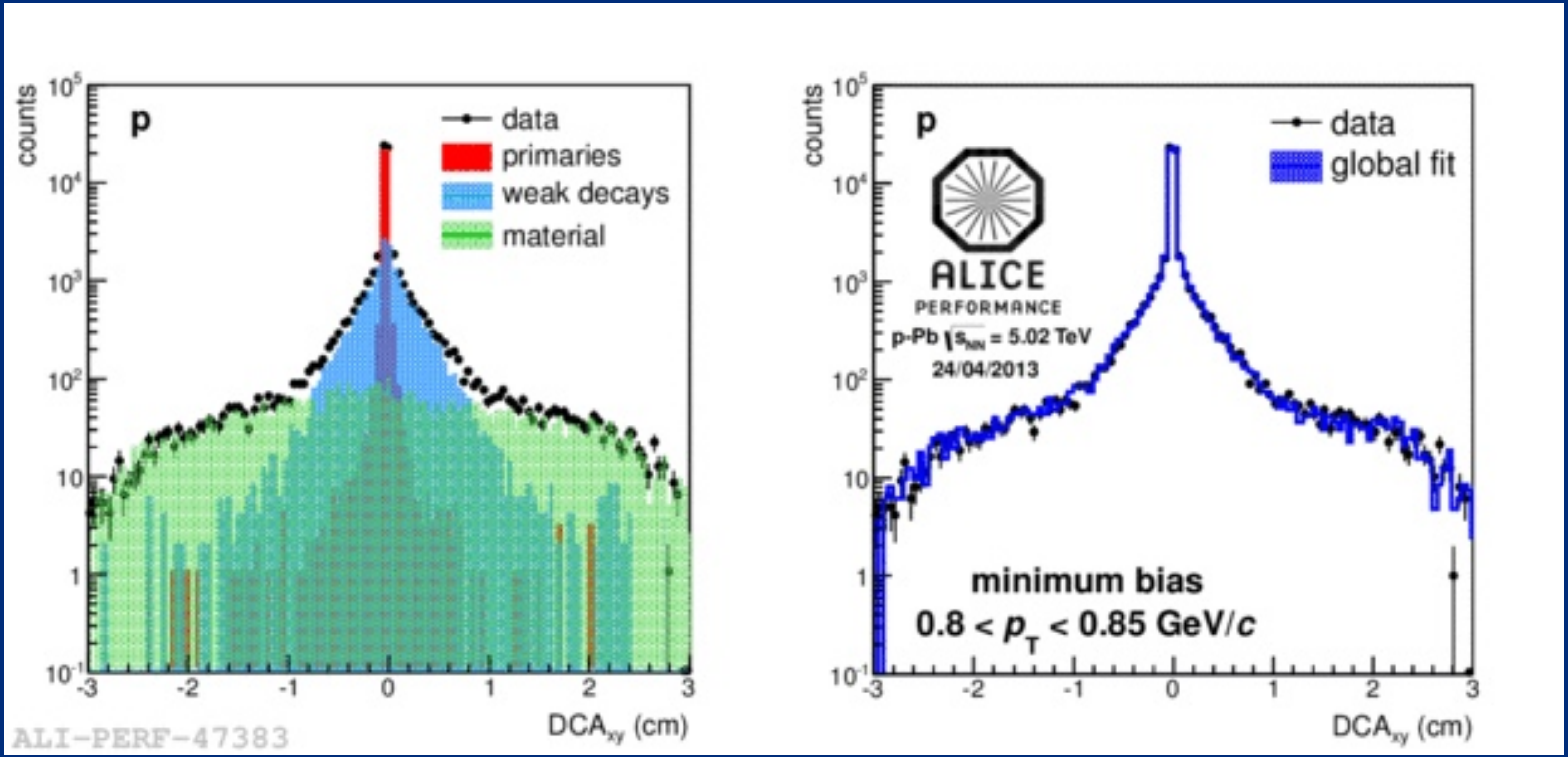
Thank you!

= Spares slides =

= Feed-down correction =

Secondaries correction with a driven method.

Applied to pions, antipions, protons and antiprotons.



= Color reconnection =

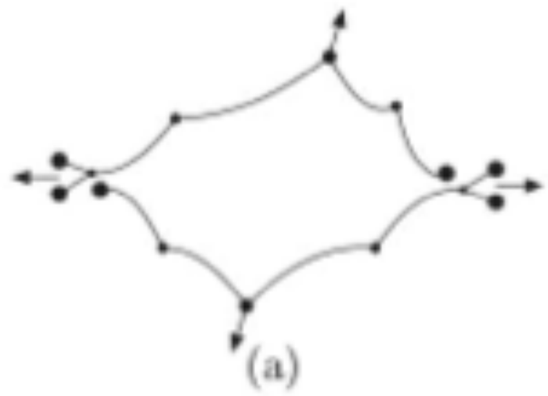
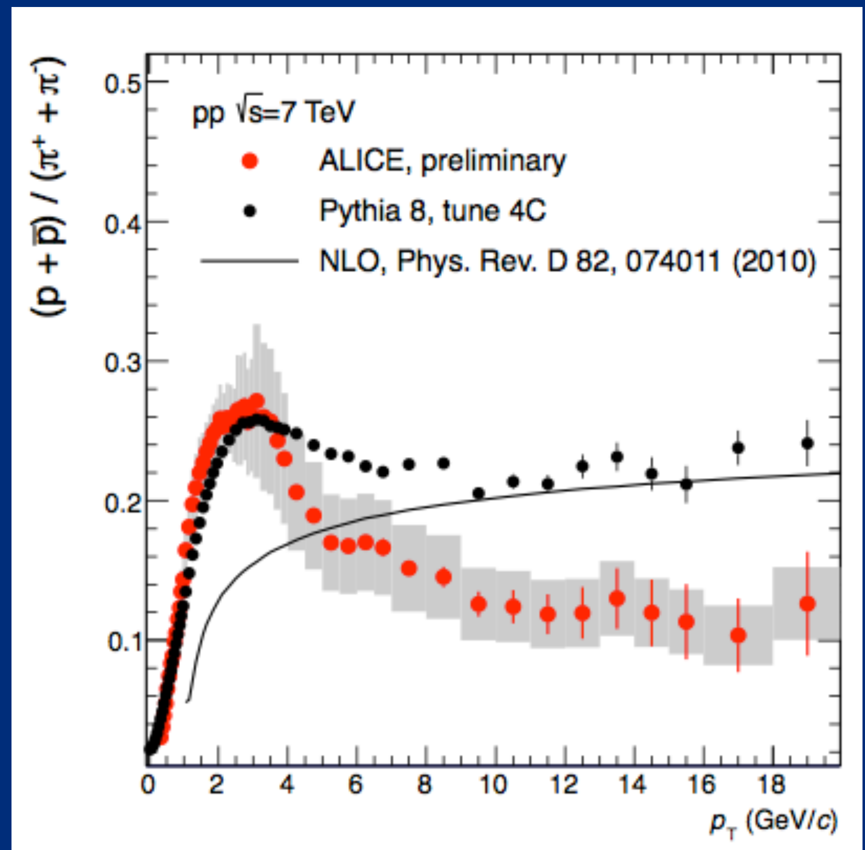


FIG. 2. Illustration of the color reconnection in the string fragmentation model (picture taken from [14]). The outgoing gluons color connected to the projectile and target remnants (a). The second hard scattering (b). Color reconnected string(c).

In Pythia, the final step at parton level before the hadronization.

"multiple hard subcollisions due to color string formations between final partons from independent hard scatterings"

[Ortiz et al, PRL111, 042001 (2013)]



= EPOS =

EPOS: Dynamical picture for all pT scales.

Hard scattering: Flux tubes produced in elementary collisions produce string segments. 3 possible scenarios;

- BULK MATTER - Matter evolve hydrodynamically and hadronize in soft hadrons.
- JET - Energy scape and consitute hadrons outside matter "Jet hadrons"
- JET- BULK - Energy inside matter or at surface, however it has enough energy to escape as jets. They interact with the flowing matter ("fluid-jet interaction")

"Considering transverse fluid velocities up to 0.7c and thermal parton momentum distributions, one may get a "push" of a couple of GeV to be added to the transverse momentum of the string segment. This will be a crucial effect for intermeadiate pT jet hadrons."