Hard Probes 2012

5th international Conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions

27 May – 1 June 2012, Cagliari (Sardinia, Italy)

High p_T identified particle production in ALICE

Peter Christiansen

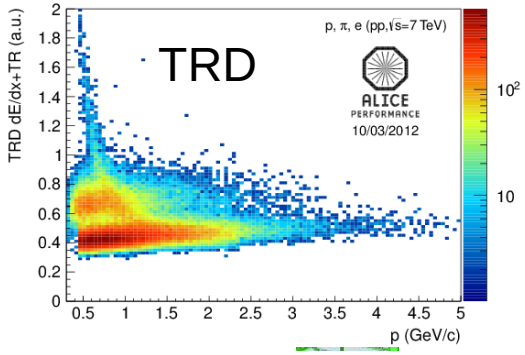
(Lund University)

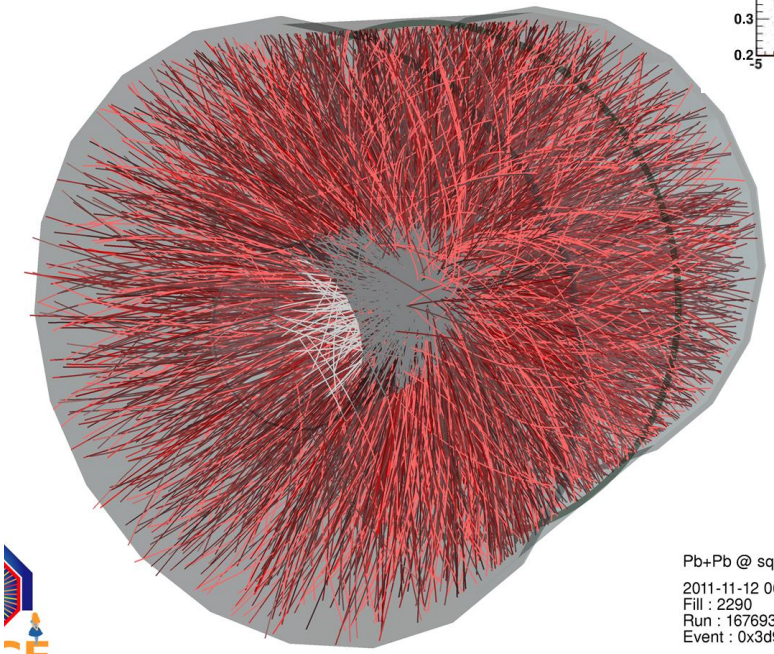
for the ALICE Collaboration

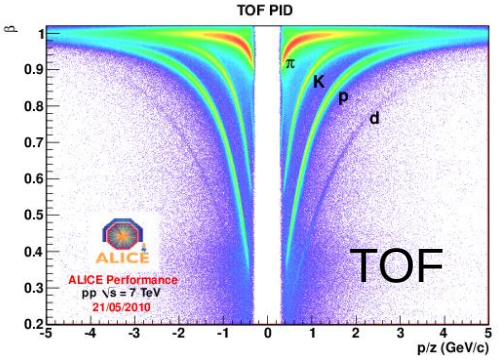
Outline of talk

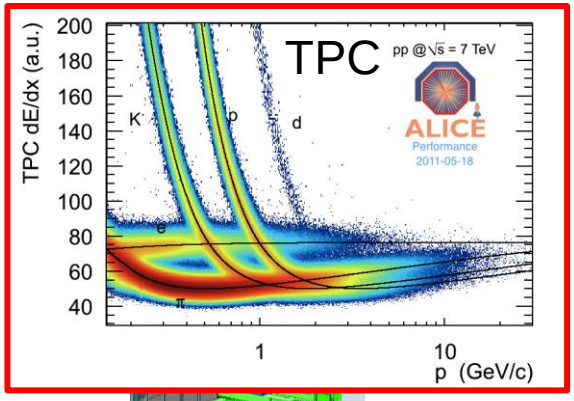
- The Particle IDentification (PID) capabilities of the ALICE experiment
- Short introduction to the different p_T regimes of particle species dependent physics
- Intermediate p_T results
  - Baryon to meson ratio at LHC
  - Identified elliptic and triangular flow
- High p_T results
  - Identified R_{AA} at $p_T > 6$ GeV/c
- Conclusions

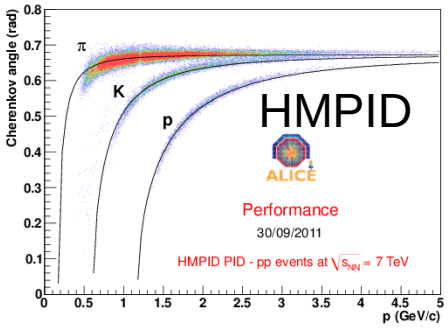
ALICE as a charged particle PID detector (central barrel)

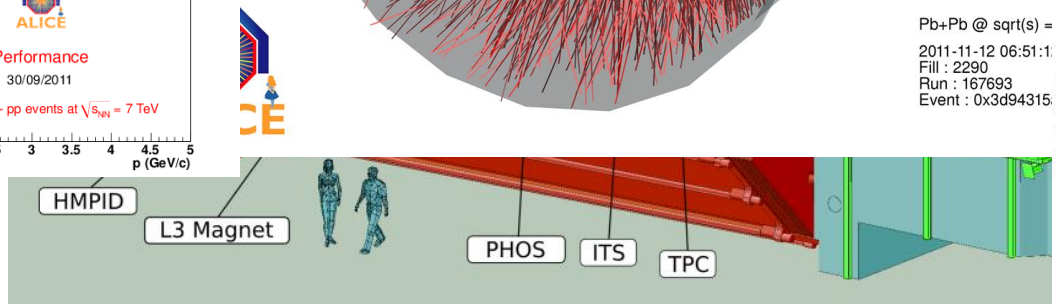


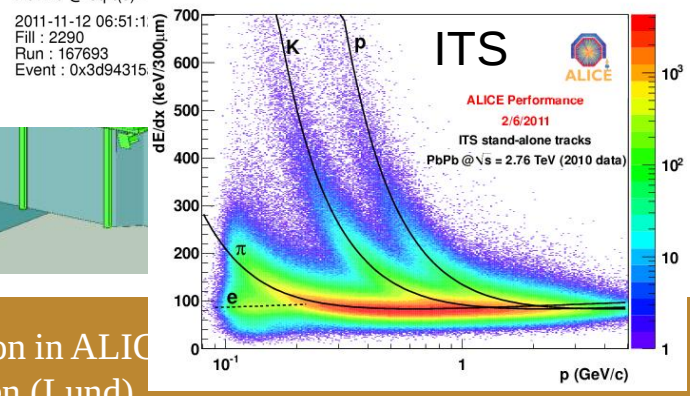






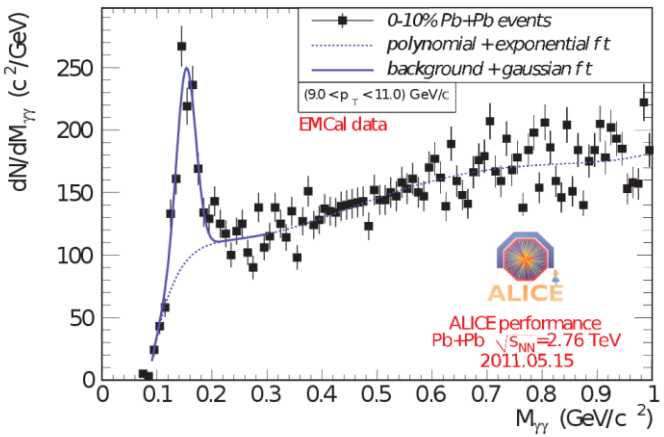




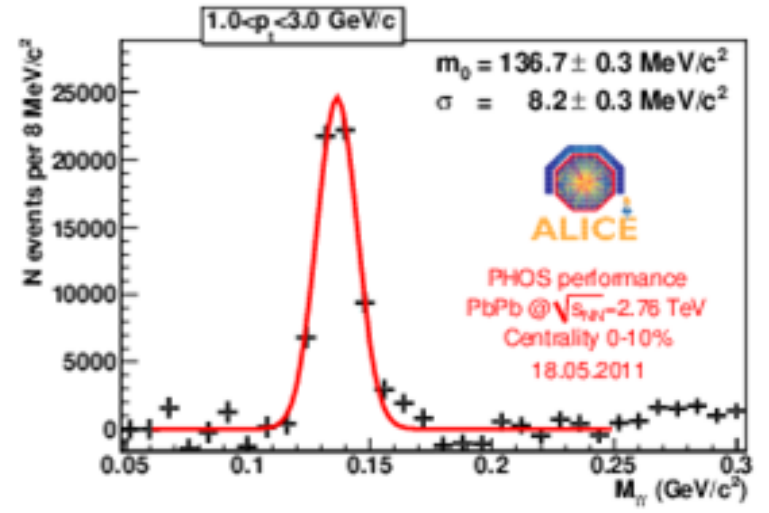


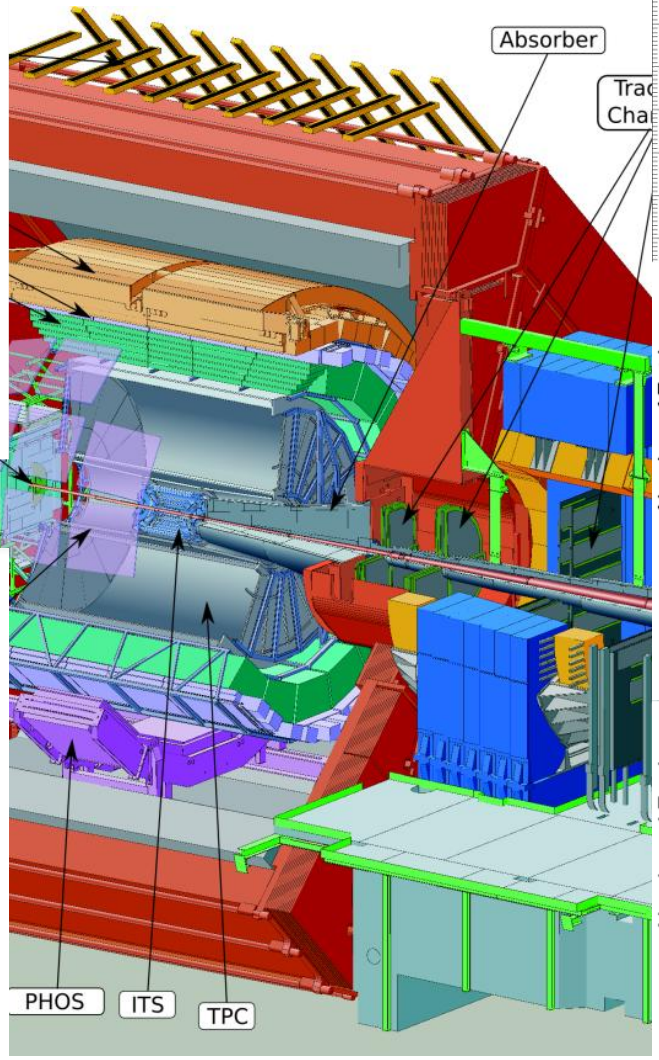
ALICE as a neutral particle PID detector

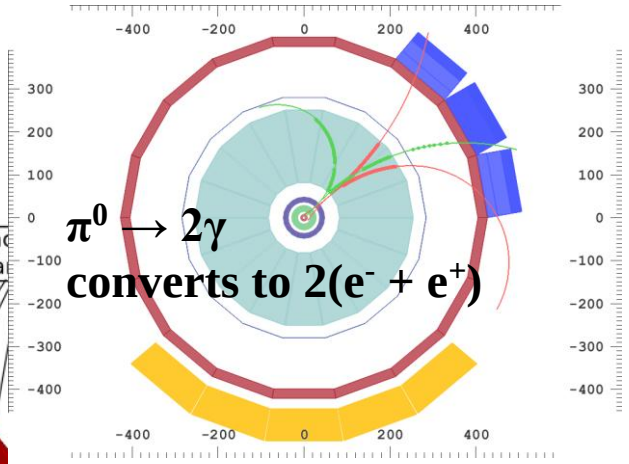
π^0 (EMCAL)

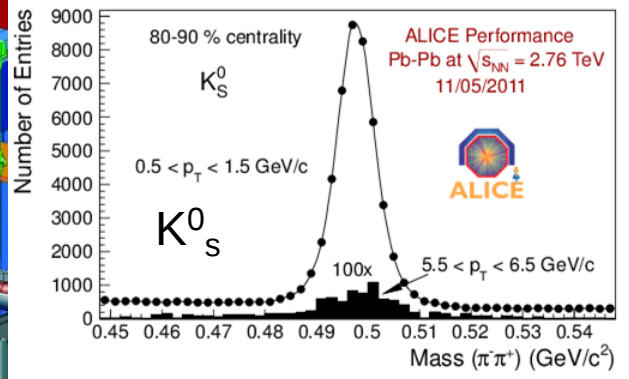


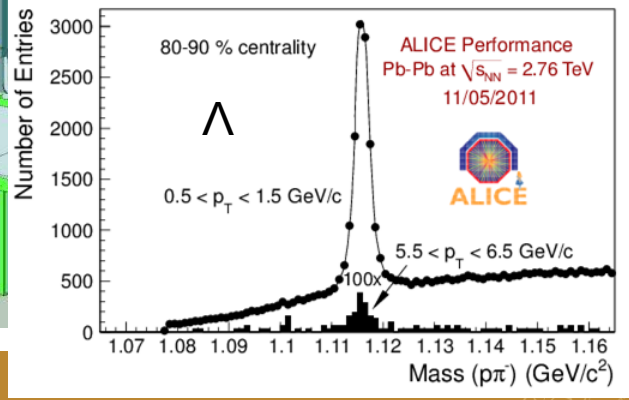
π^0 (PHOS)



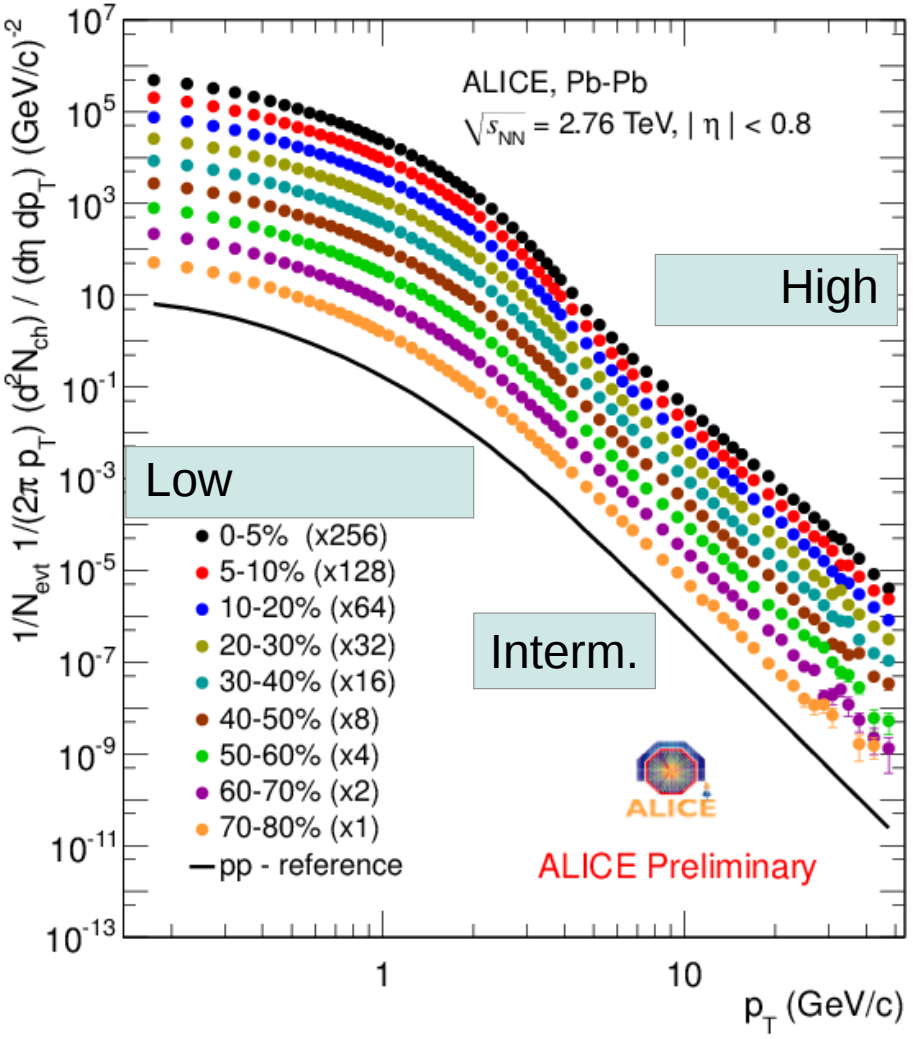








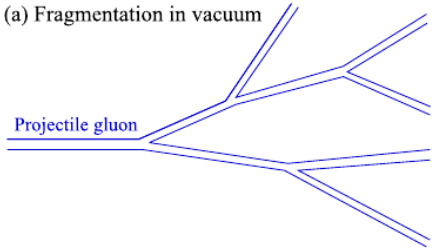
The 3 regimes of p_T and their particle species dependence

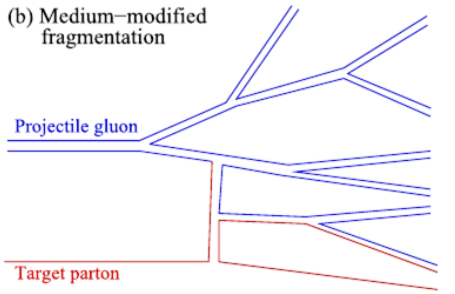


- Low: $p_T \leq 2$ GeV/c
  - Radial flow (mass dependence)
- Intermediate: $2 \leq p_T \leq 8$ GeV/c
  - Flow peaks (mass dependence)
  - Coalescence? (valence quark scaling)
  - Color anomalous baryon fragmentation? (string junction)
  - …..
- High: $p_T \geq 8$ GeV/c
  - Vacuum fragmentation?

Why do we expect particle species dependent modifications even at higher p_T?

- Large effects at intermediate p_T – does this effect just disappear?
- The low value of R_{AA} suggests that most hard partons interacts strongly with the medium

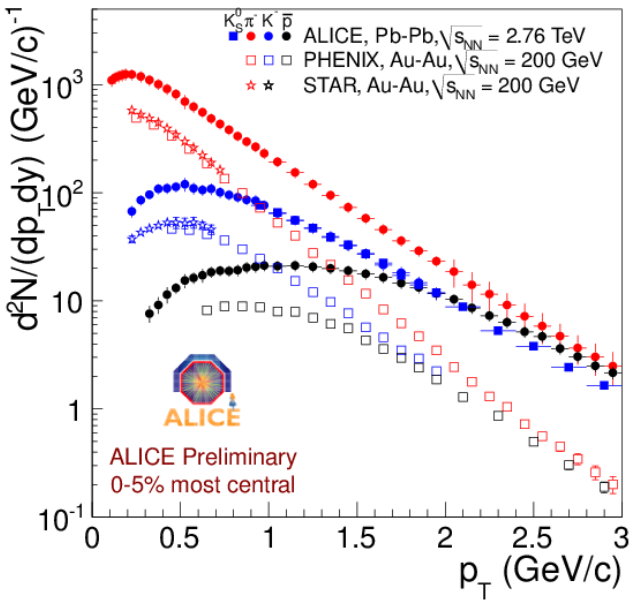


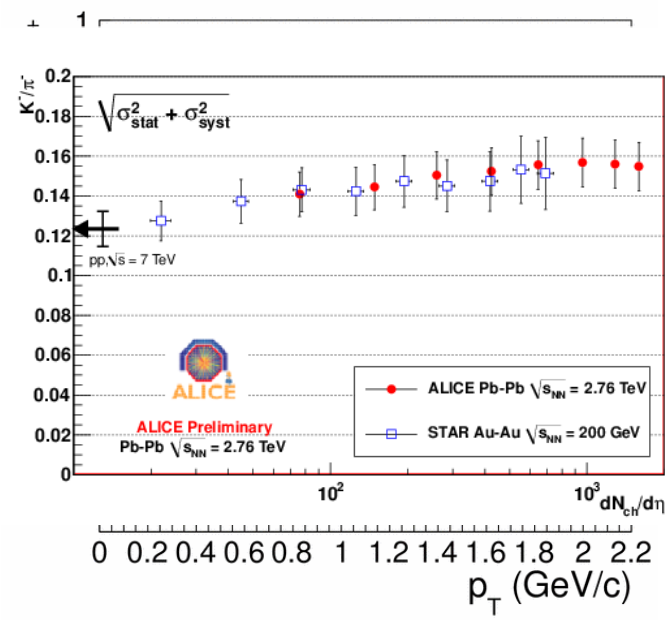


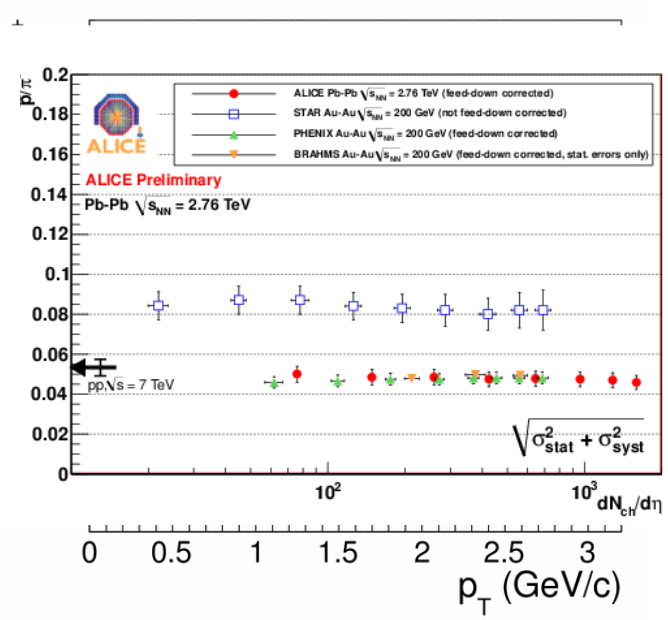
S. Sapeta and U.A. Wiedemann, Eur.Phys.J. C55 (2008) 293:

- Indirect
  - "in all models of radiative parton energy loss, the interaction of a parent parton with the QCD medium transfers color between partonic projectile and target. This changes the color flow in the parton shower and is thus likely to affect hadronization."
- Direct
  - "In addition, flavor or baryon number could be exchanged between medium and projectile."

Low p_T: spectra and particle ratios

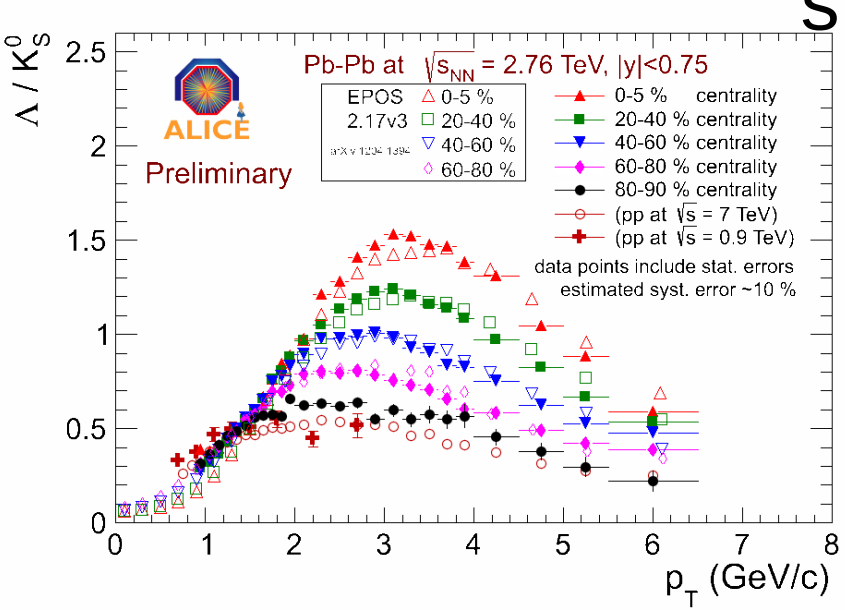


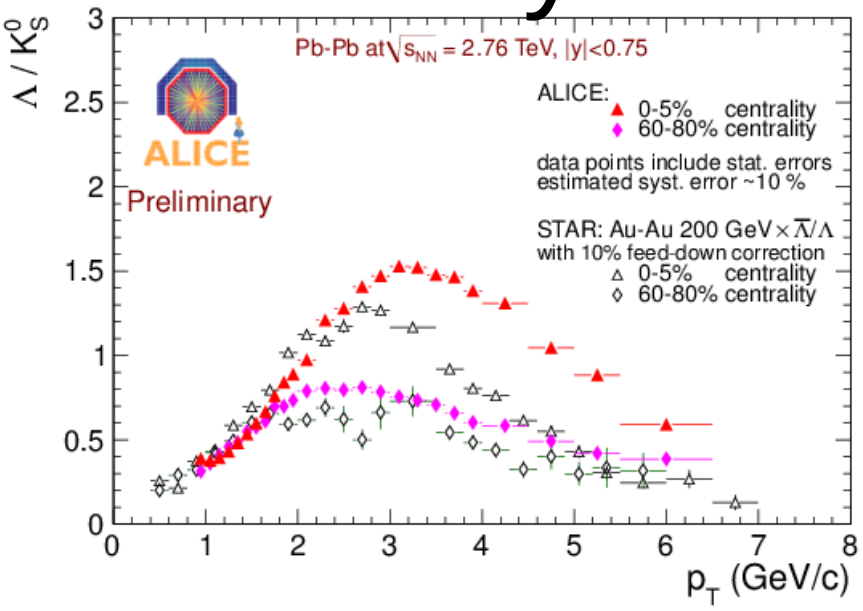




- Integrated particle ratios are similar at RHIC and LHC for K/π and p/π (feeddown corrected)
  - But protons are clearly ”pushed out” to higher p_T at LHC: stronger flow

Intermediate p_T: Λ/K^0_s vs. centrality

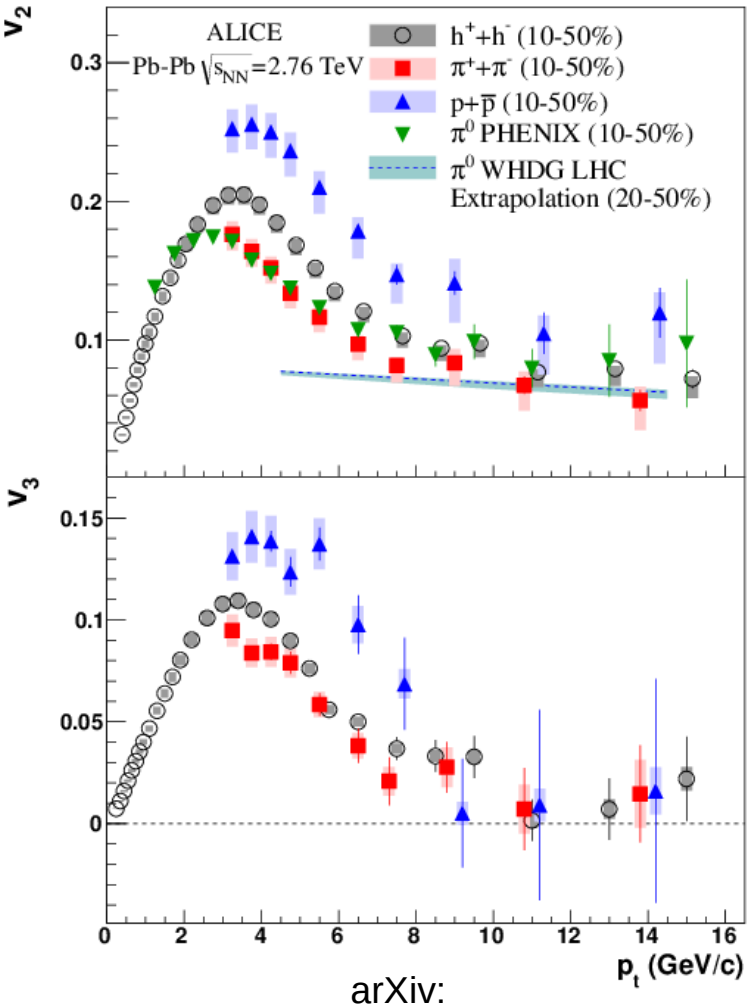




- The baryon to meson ratio is also enhanced at LHC
  - More so than at RHIC
- But much less than predicted in some coalescence models
  - R.C. Hwa and C.B. Yang, Phys. Rev. Lett. 97, 042301 (2006).
- Recent EPOS model calculation describes the data well:
  K. Werner, arXiv:1204.1394.

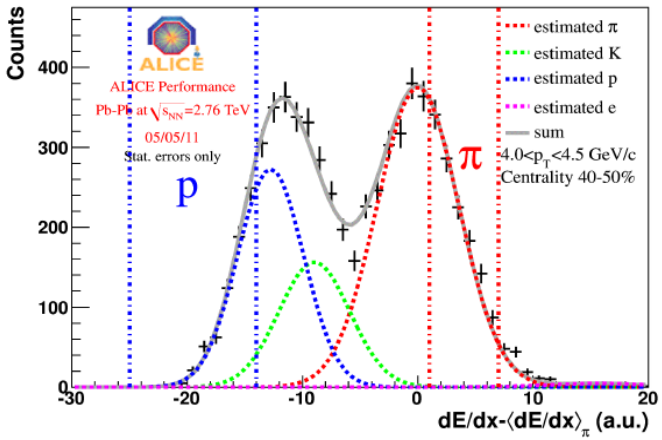
Bulk or jet effect?
Parallel talk:
Misha VELDHOEN
Monday 16:30

Elliptic and triangular flow for identified particles at high p_T



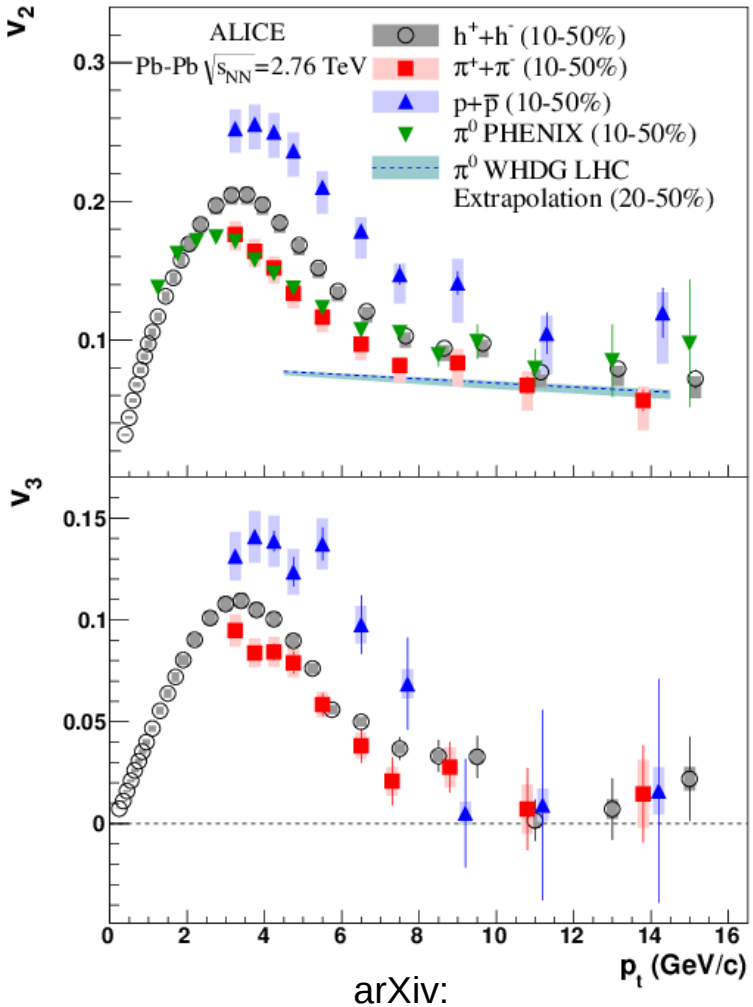
arXiv: 1205.5761

PID using TPC: dE/dx - <dE/dx>$_\pi$
$4.5 < p_T < 5.0$ GeV/c



- PID using “clean” regions of dE/dx on the relativistic rise

Elliptic and triangular flow for identified particles at high p_T



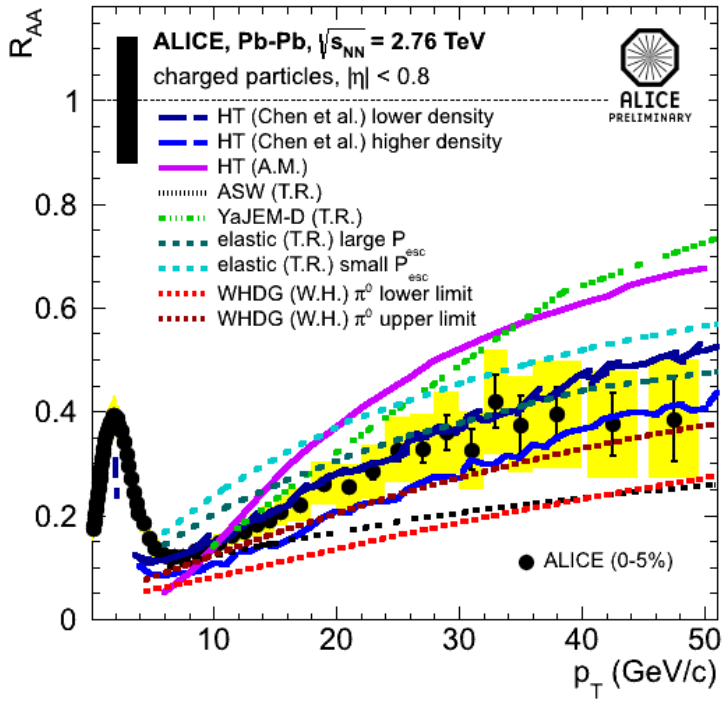
arXiv: 1205.5761

- The v_2 and v_3 also peaks in the intermediate p_T region
  - Large particle species dependence
- End of hydrodynamic flow for $p_T \geq$ 9-10 GeV/c ?
  - Triangular flow which is not sensitive to collision geometry becomes small
  - No or small particle species dependence for v_2 (little mass dependence)
  - And pion v_2 is well described by jet quenching prediction

Parallel talk:
Jan RAK
Monday 15:00

R_{AA} for unidentified charged particles

$$R_{AA} = \frac{d^2N^{AA}/dp_T d\eta}{\langle T_{AA}\rangle d^2\sigma^{pp}/dp_T d\eta}$$



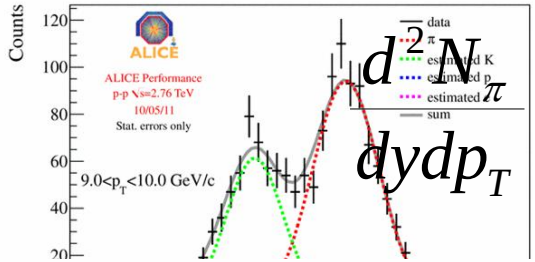
Parallel talk:
Michele FLORIS
Monday 17:50
Poster:
Philipp LUETTIG

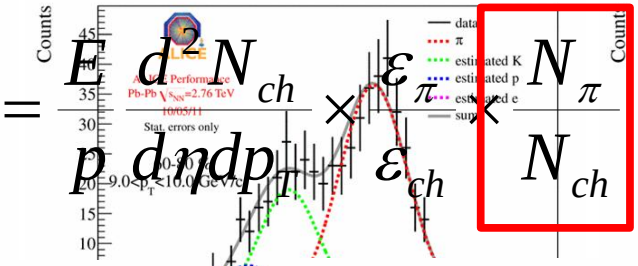
- Several models capture the essential features (but some miss absolute scale)
- The relative particle species dependent effects should be easier to describe as complicated space time dynamics probably falls out in the “double ratio”

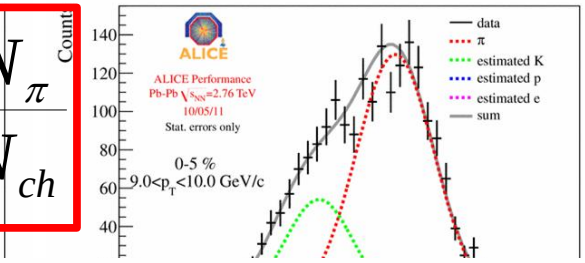
R_{AA} for identified particles can be obtained using the additional dE/dx info

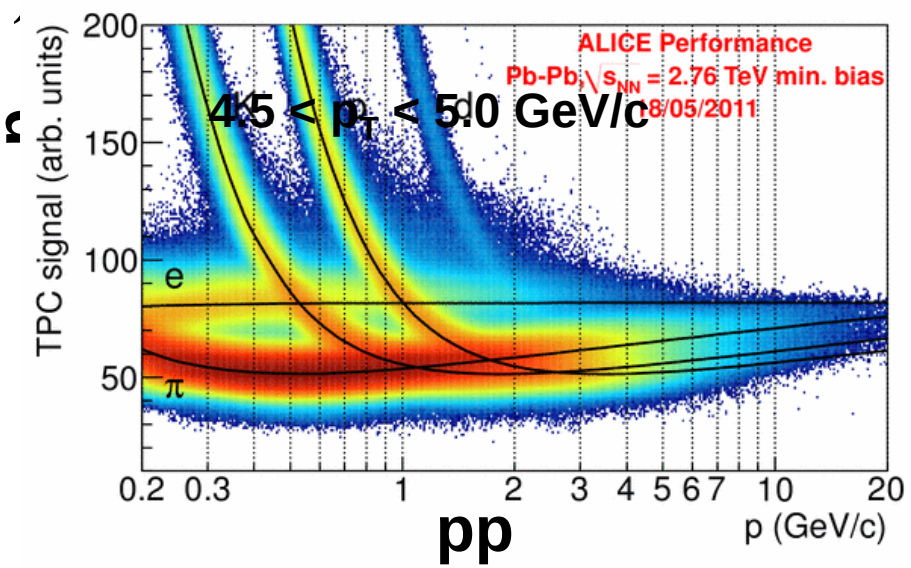
$9.0 < p_T < 10.0$ GeV/c

$$\frac{d^2N_\pi}{dydp_T} = \frac{E\,d^2N_{ch}}{p\,d\eta dp_T} \times \frac{\varepsilon_\pi}{\varepsilon_{ch}} \times \frac{N_\pi}{N_{ch}}$$

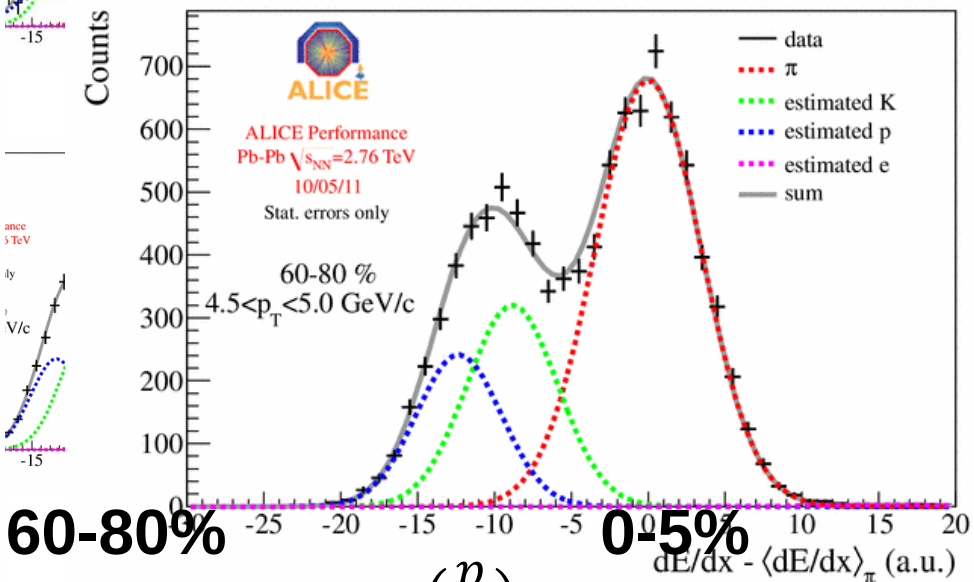








pp



60-80% **0-5%**

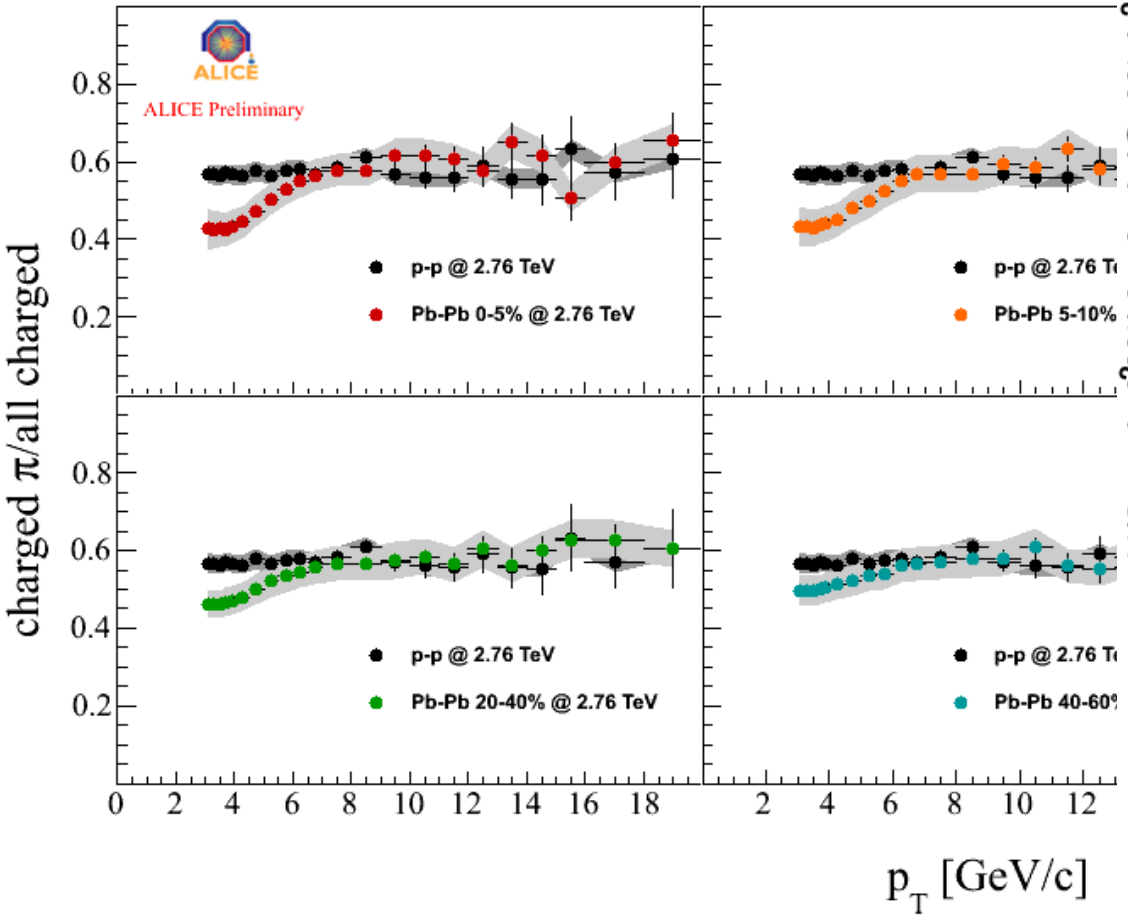
On the relativistic rise: $\langle dE/dx \rangle = k \log(\beta\gamma) = k \log\left(\frac{p}{m}\right)$

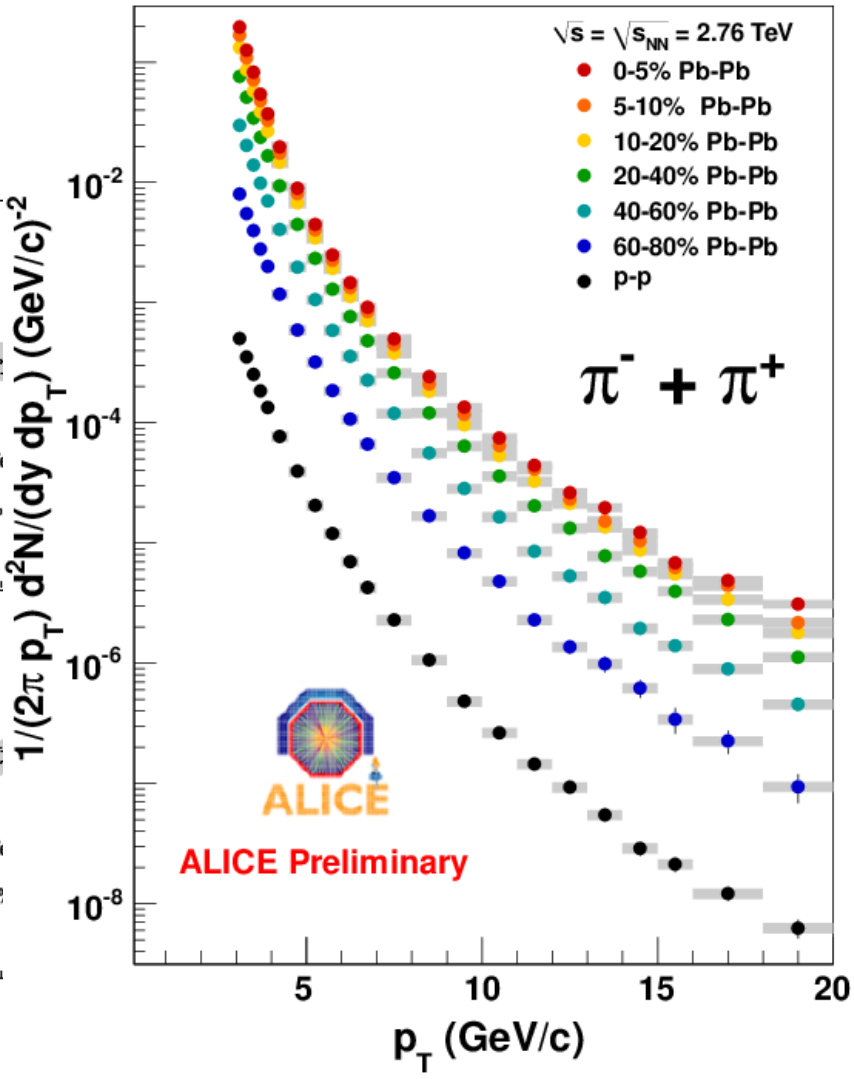
$$\langle dE/dx \rangle_1 - \langle dE/dx \rangle_2 = k \log\left(\frac{m_2}{m_1}\right) = \text{const}$$

pp → central PbPb

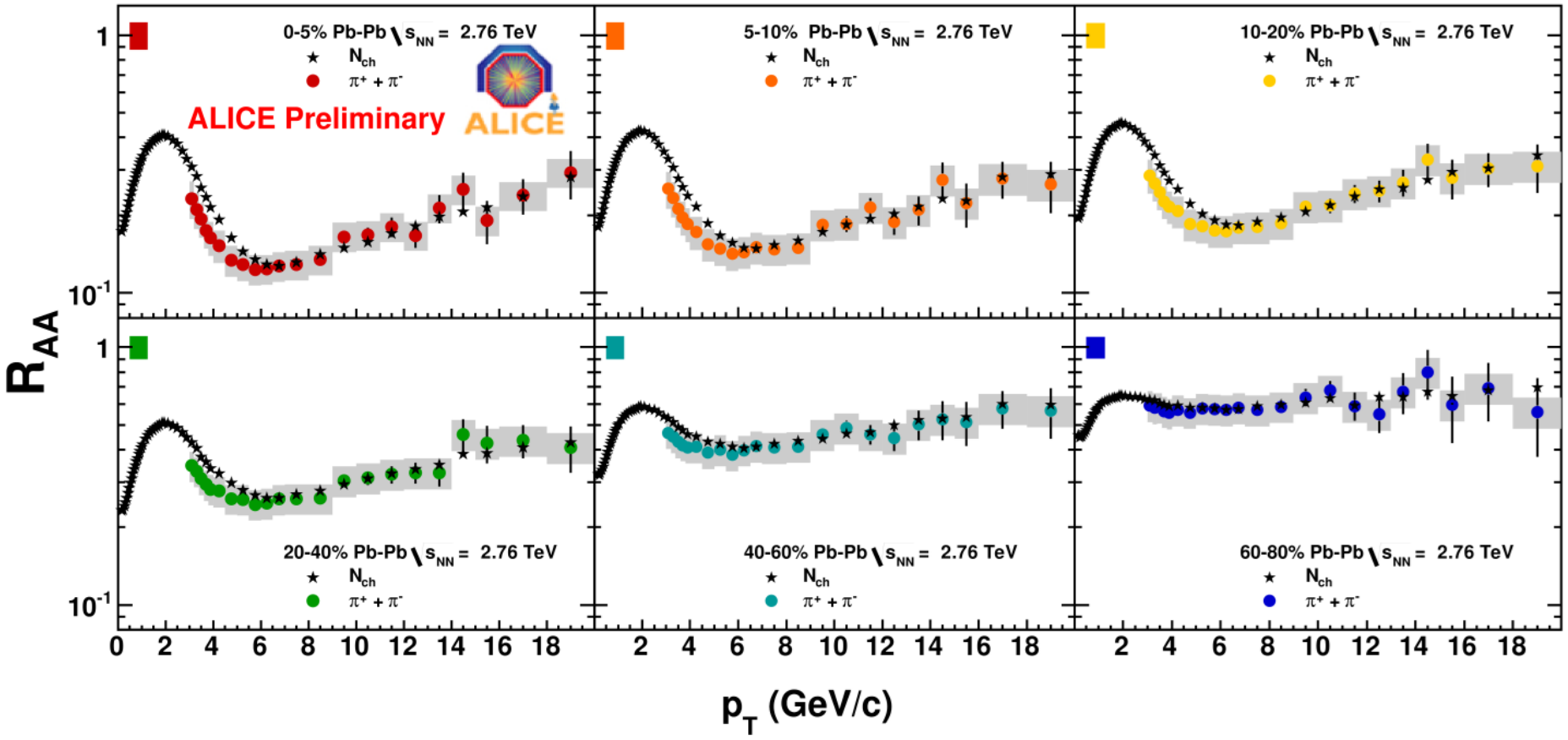
Charged pion spectra at high p_T

$$\frac{d^2N_\pi}{dydp_T} = \frac{E}{p}\frac{d^2N_{ch}}{d\eta dp_T} \times \frac{\varepsilon_\pi}{\varepsilon_{ch}} \times \frac{N_\pi}{N_{ch}}$$



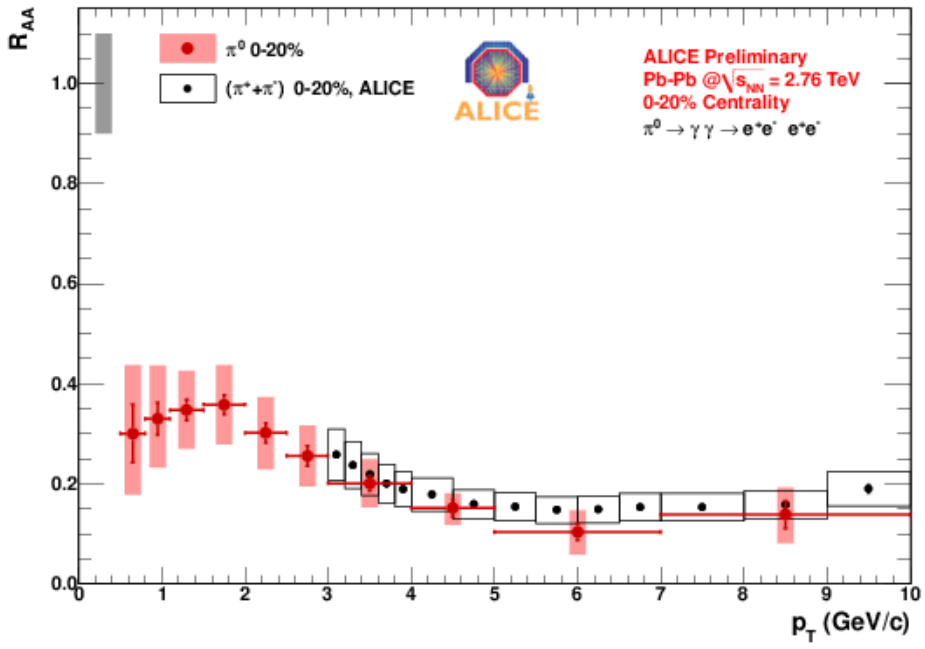


Charged pion R_{AA}



- Is smaller than charged particle R_{AA} for p_T < 6-8 GeV/c
- Agrees with charged particle R_{AA} for p_T > 6-8 GeV/c

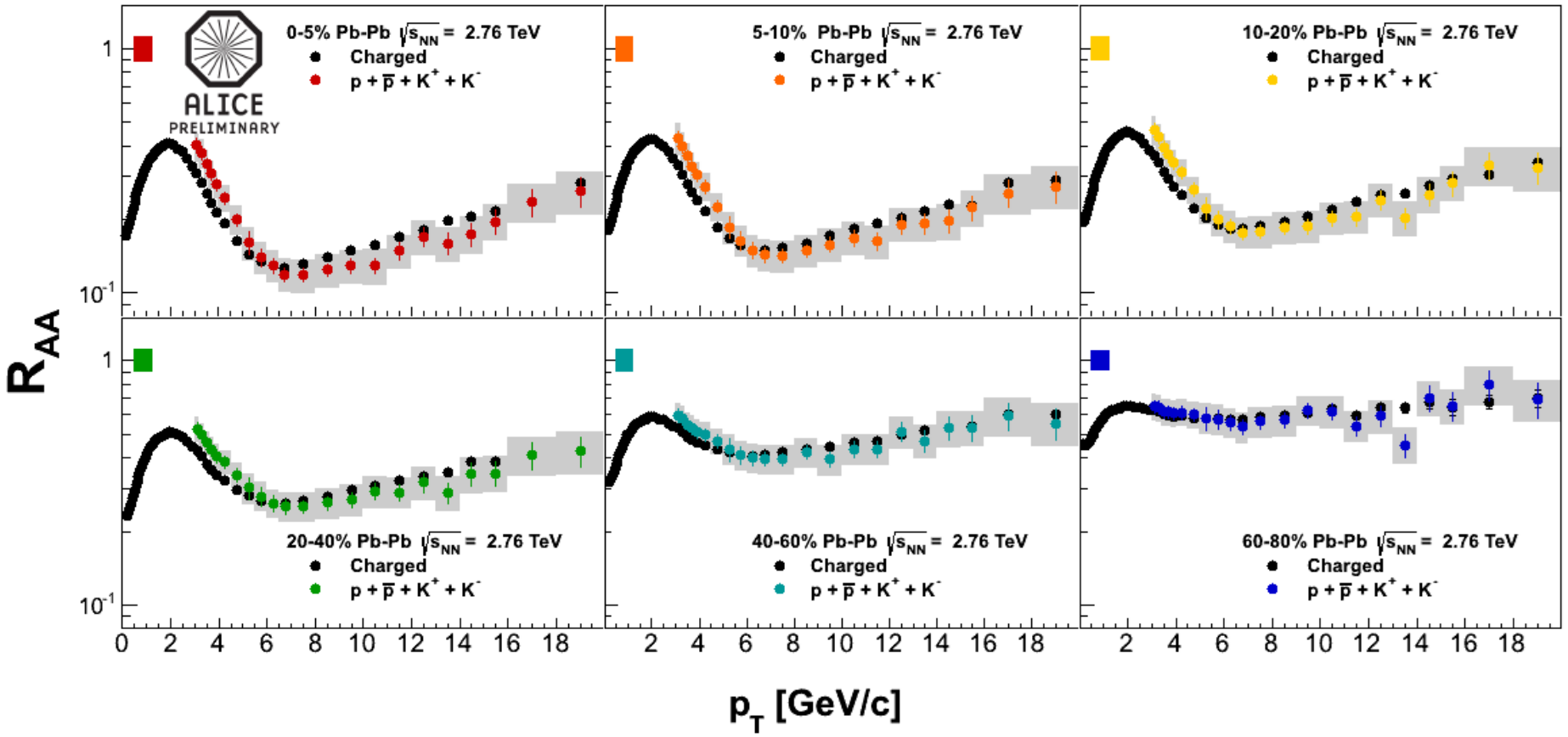
Comparison of charged and neutral pion R_{AA}



Parallel talk:
Yury KHARLOV
Monday 17:10

- Complementary analyses with different systematics
  - Important as these measurements will be limited at LHC by systematic errors

Charged kaon+proton R_{AA}



- Is <u>larger</u> than charged particle R_{AA} for p_T < 6-8 GeV/c
- Agrees with charged particle R_{AA} for p_T > 6-8 GeV/c

A general model with particle species dependent modifications

S. Sap

(a) Fragi

STAR data
Phys. Rev. Lett. 108 072302 (2012).

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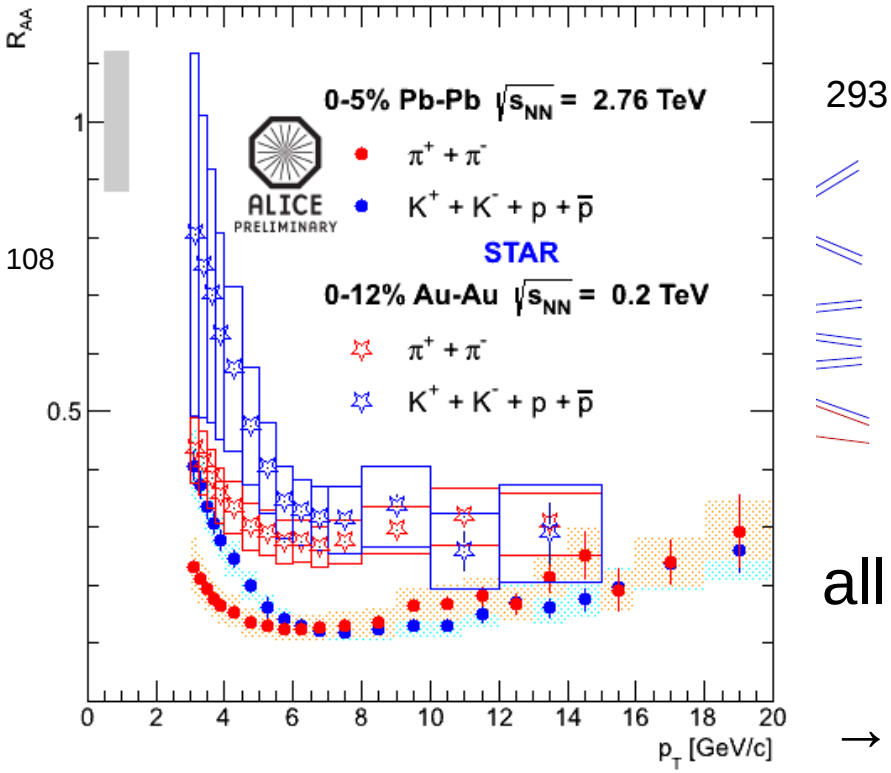
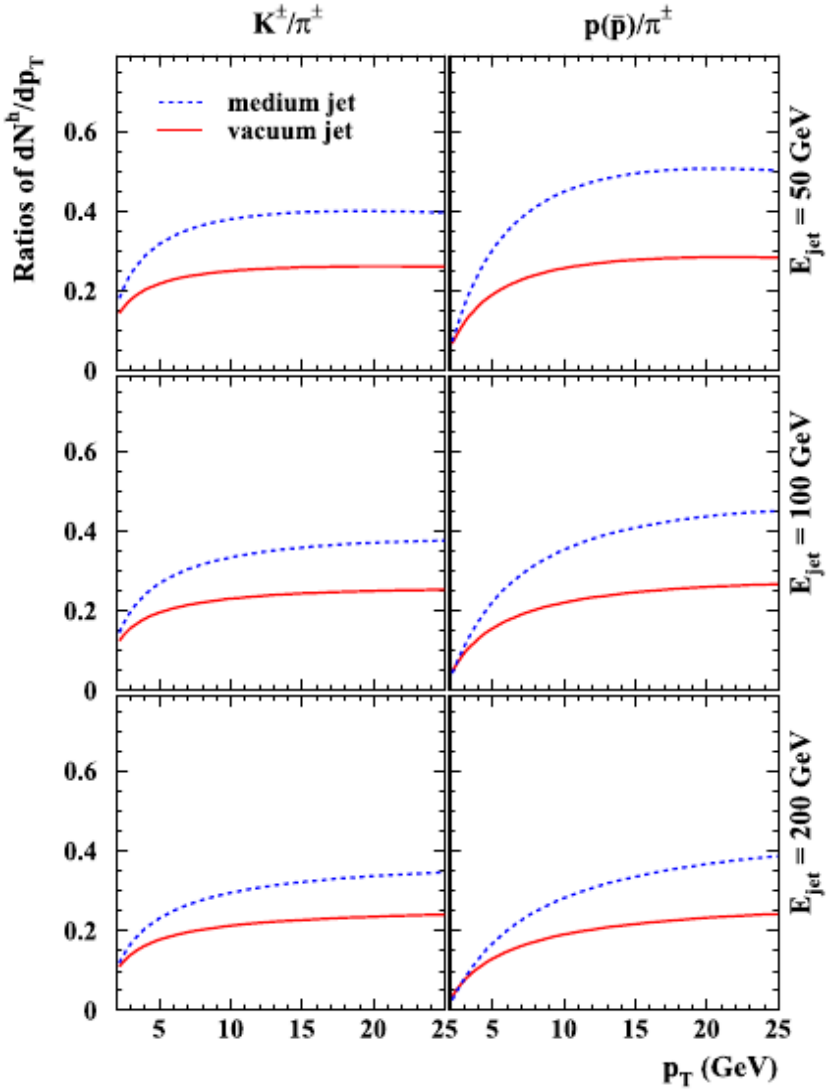
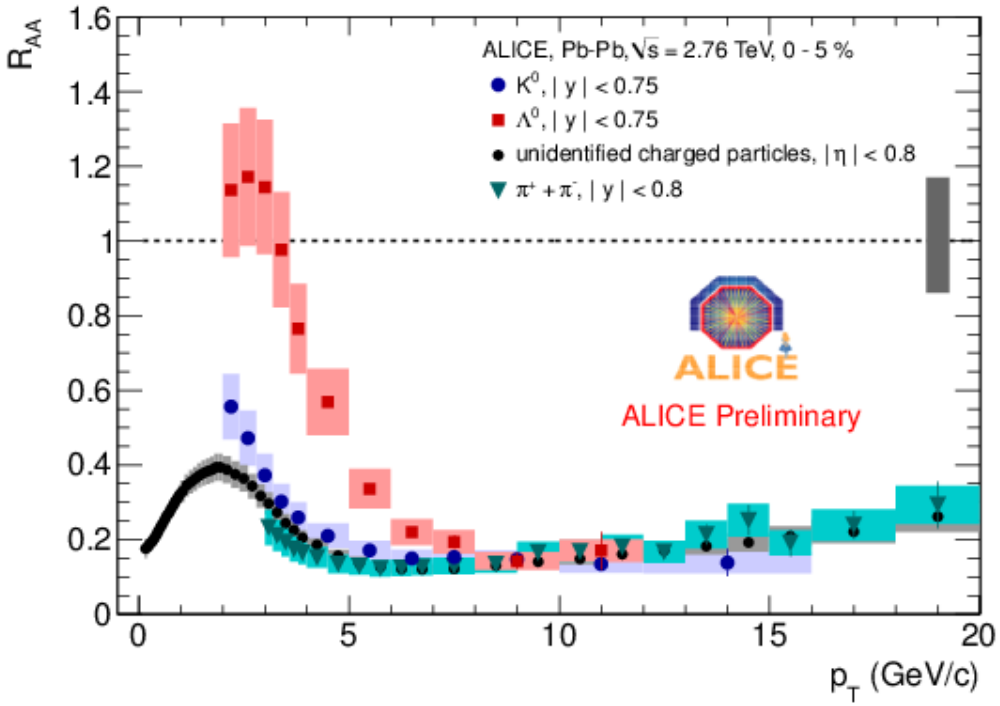


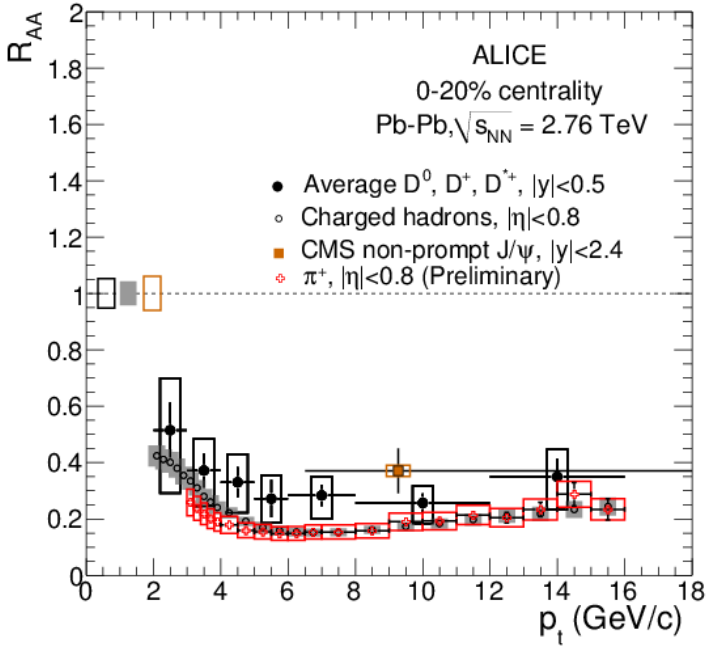
- Ef
- Bu all
  ha
- K/
  - (K+p)/π medium > vacuum →
  - K+p less suppressed than π
  - Question: what do we learn about the interaction between parton and medium?

Prediction incompatible with data



R_{AA} for light quark hadrons





arXiv: 1203.2160

- Light quark hadrons with p_T > 8 GeV/c are equally suppressed
- This seem to indicate that medium interactions do not affect fragmentation for p_T > 8 GeV/c - fragmentation occurs into vacuum
- Light quark results also provide a baseline for understanding heavy quark energy loss

Parallel talk:
Zaida CONESA DEL VALLE
Monday 16:30

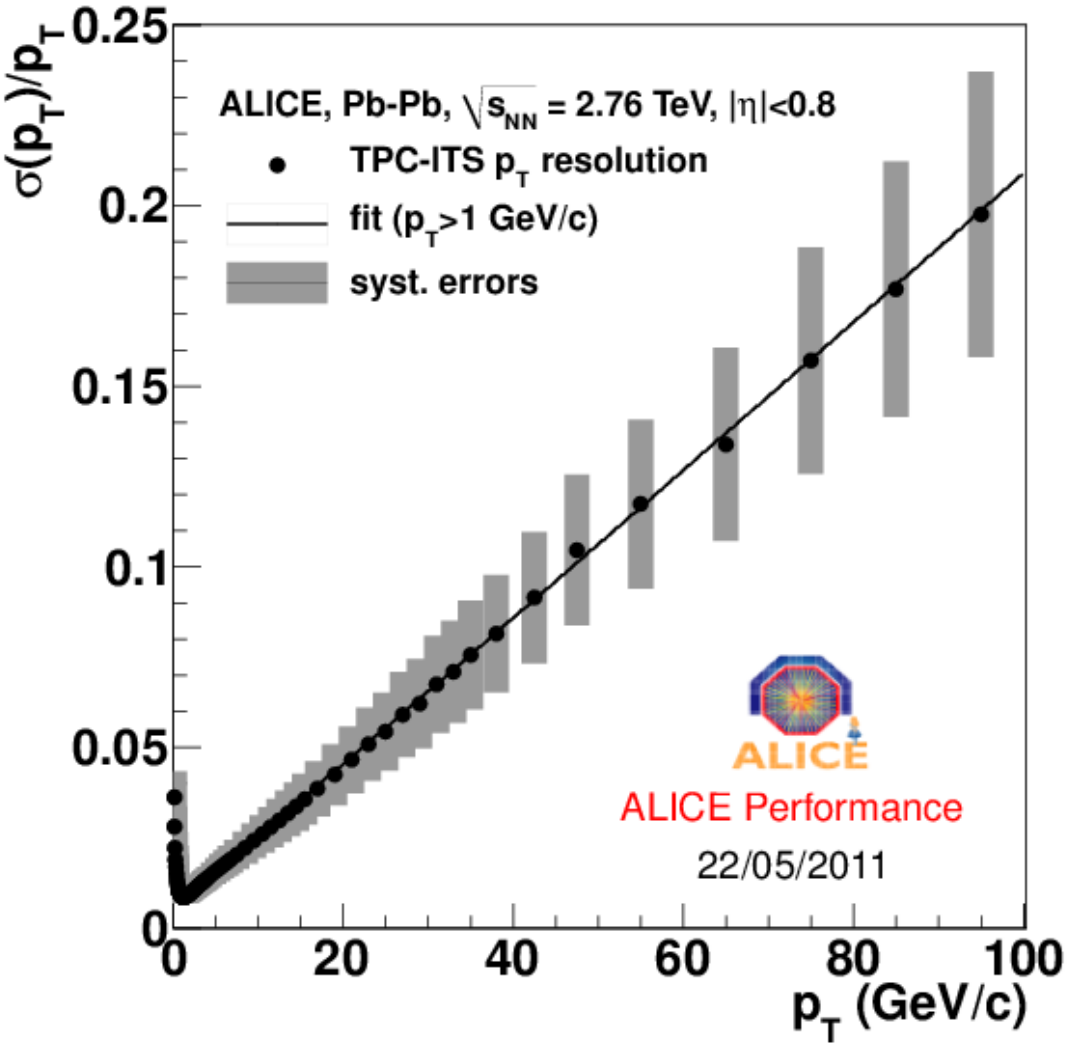
Conclusions

- The intermediate p_T region is rich in exciting physics where PID provides much additional information
  - Large baryon to meson ratios and large particle species dependent flow: v_2 and v_3
- The transition ($6 \leq p_T \leq 10$ GeV/c) to a hard high p_T region where particle species dependent effects are much smaller is observed both in the identified R_{AA} and v_2 and in the small value of v_3
- Longer term perspective: jet studies including PID

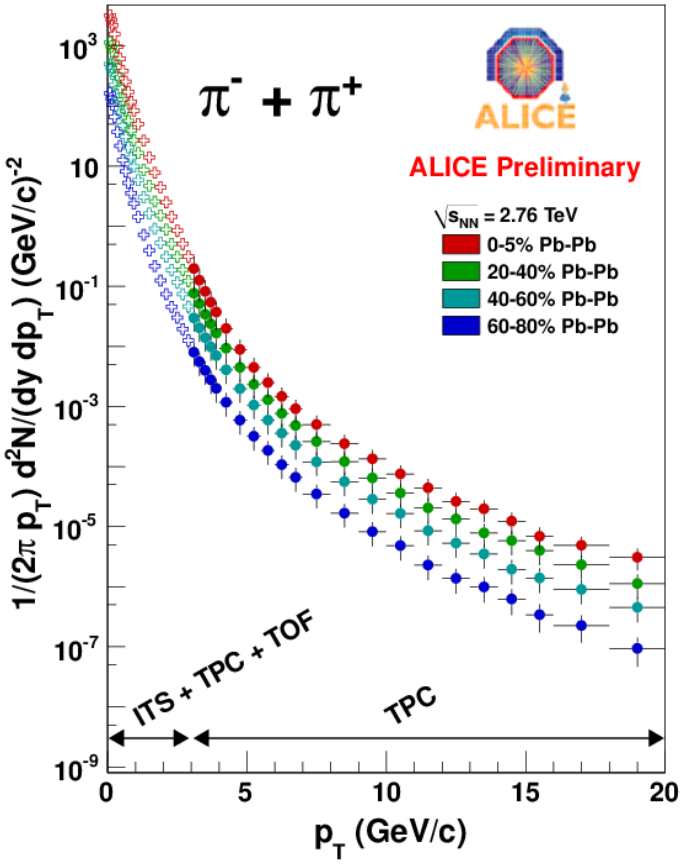
Thank you!

Backup slides

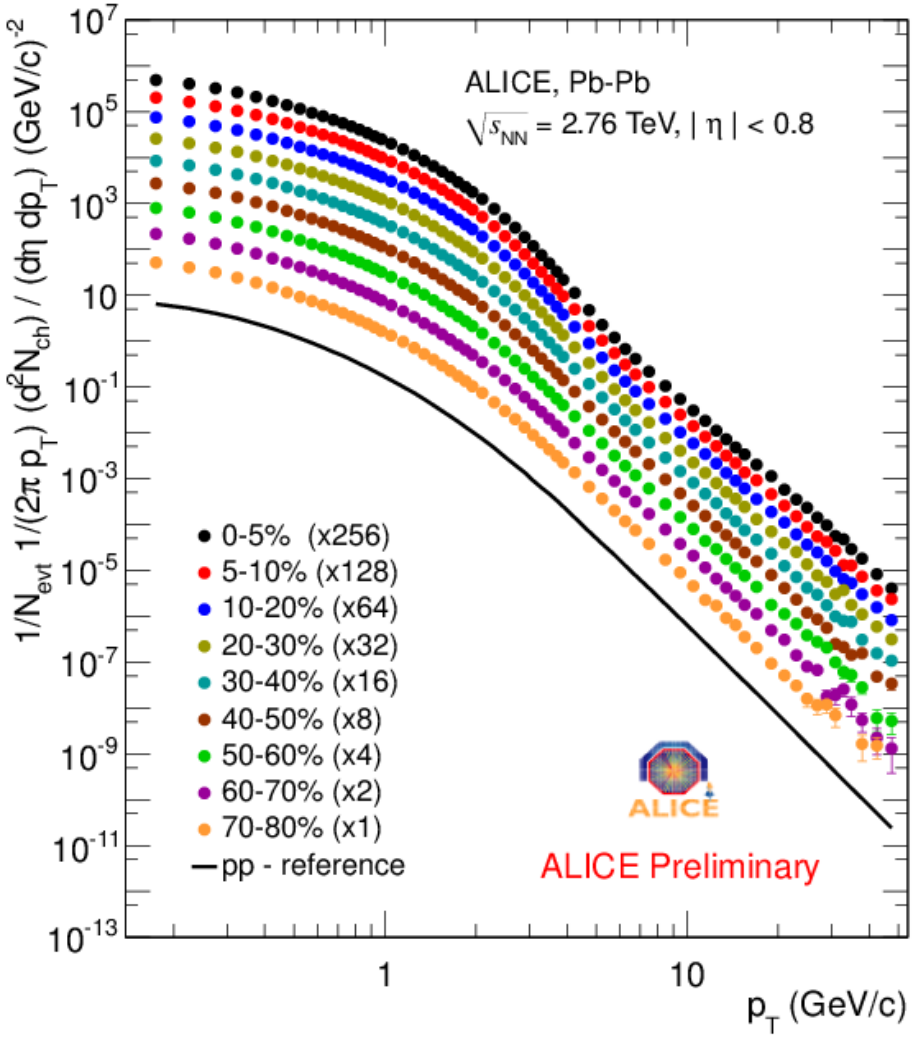
Transverse momentum resolution

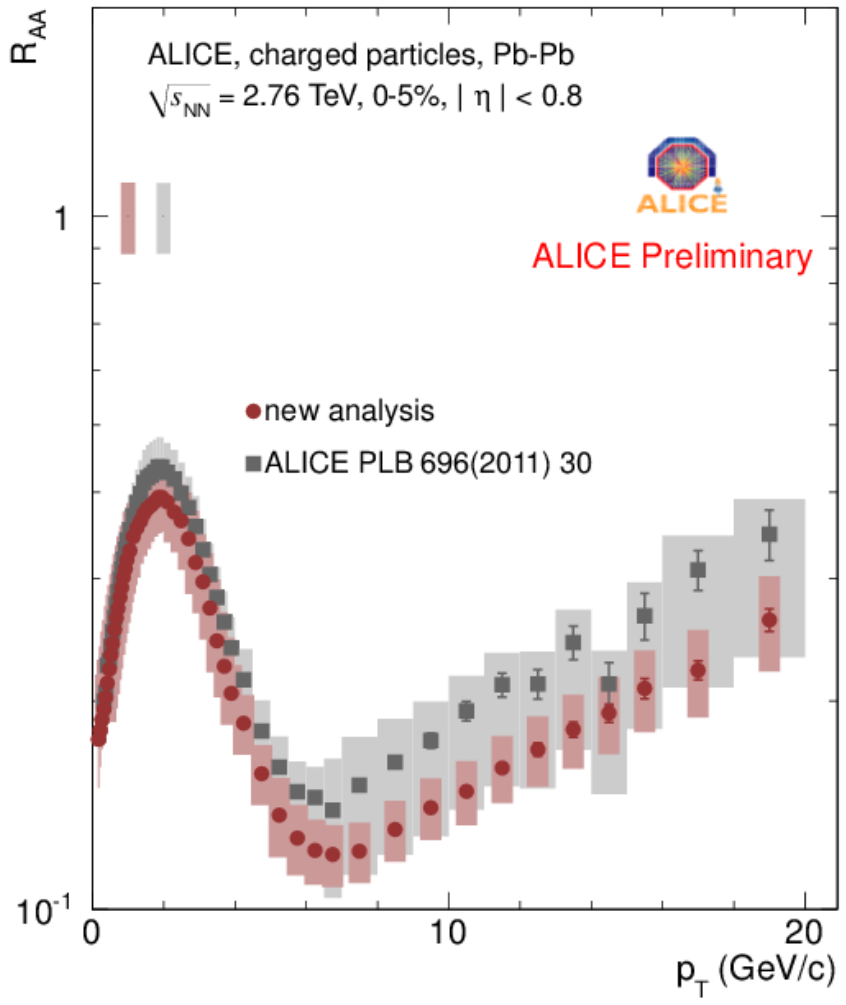


Comparison of low pT and high p_T charged pion spectra

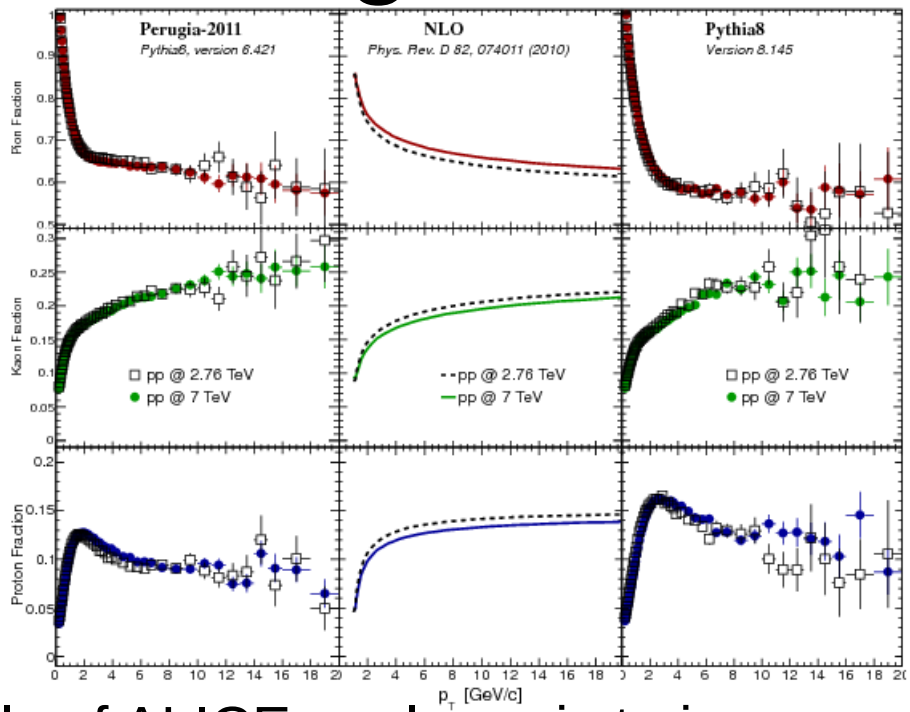


Spectra and RAA for unidentified particles



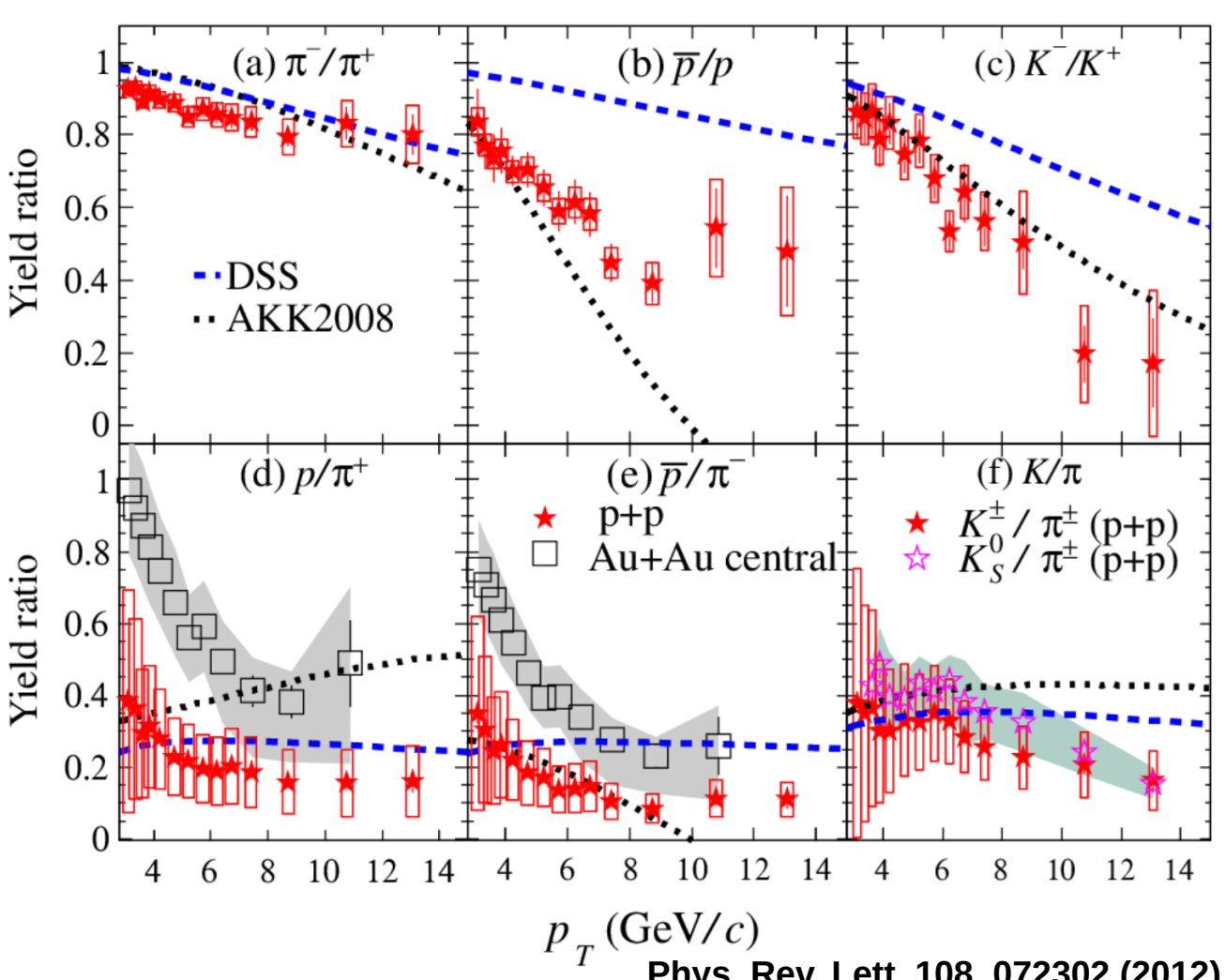


How well defined is PID fragmentation?



- One of the goals of ALICE analyses is to improve this (pp)
- But it also implies that we need to have an experimental baseline:
  - Unidentified vs. identified e.g. RAA
  - pp vs. AA e.g. Λ/K^0_s
  - beam energy variation e.g. LHC vs. RHIC

STAR results



Phys. Rev. Lett. 108, 072302 (2012).

Note there that
STAR ratios << 1
Valence quark fragments
at high p_T

Color anomalous baryons fragmentation

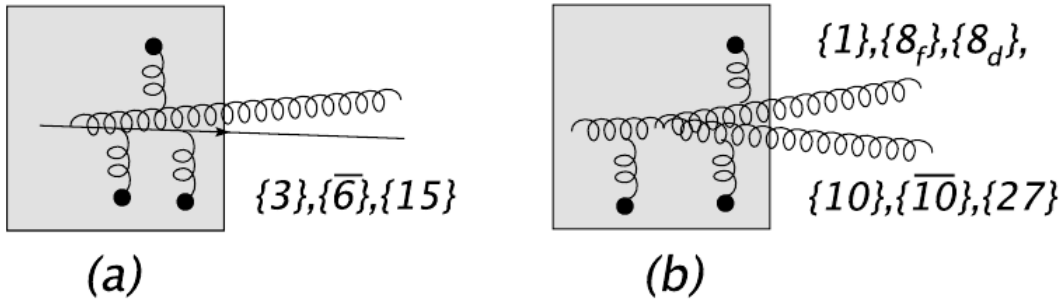


Fig. 1 The $q \rightarrow gq$ (**a**) and $g \rightarrow gg$ (**b**) transitions in the medium and possible color states of the final two parton systems

- Color anomalous baryon fragmentation (P. Aurenche, B.G. Zakharov, Eur.Phys.J. **C71** (2011) 1829.). The model is aimed at explaining the baryon anomaly but these effects persists out to higher p_T.
  - A hard scattered quark (triplet) can pickup a gluon from the medium → sextet state
  - a gluon (octet) can pick up another gluon → decuplet state
  - The fragmentation of these color states is very different from normal quark (triplet) and gluon (octet) states and relies on string junction (soft effect).