Recent results from ALICE

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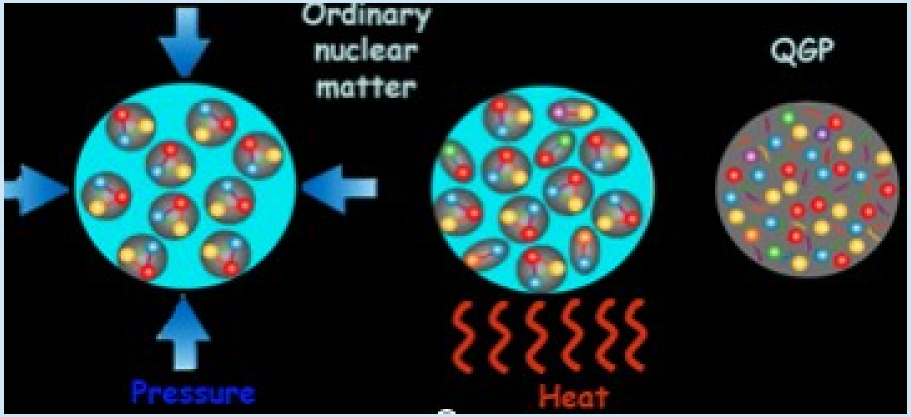
Outline

- Motivation: the QGP
- ALICE layout
- p-Pb results:
  - two particle correlations
  - π, K, p, Λ, K_s^0 spectra
  - heavy flavours
- Pb-Pb results:
  - π, K, p spectra
  - particle ratios
  - baryon/meson ratio
  - strangeness
  - light flavour R_{AA}
  - resonances
  - heavy flavours
  - (anti-) matter and hyper-matter
  - Summary

Motivation: the QGP

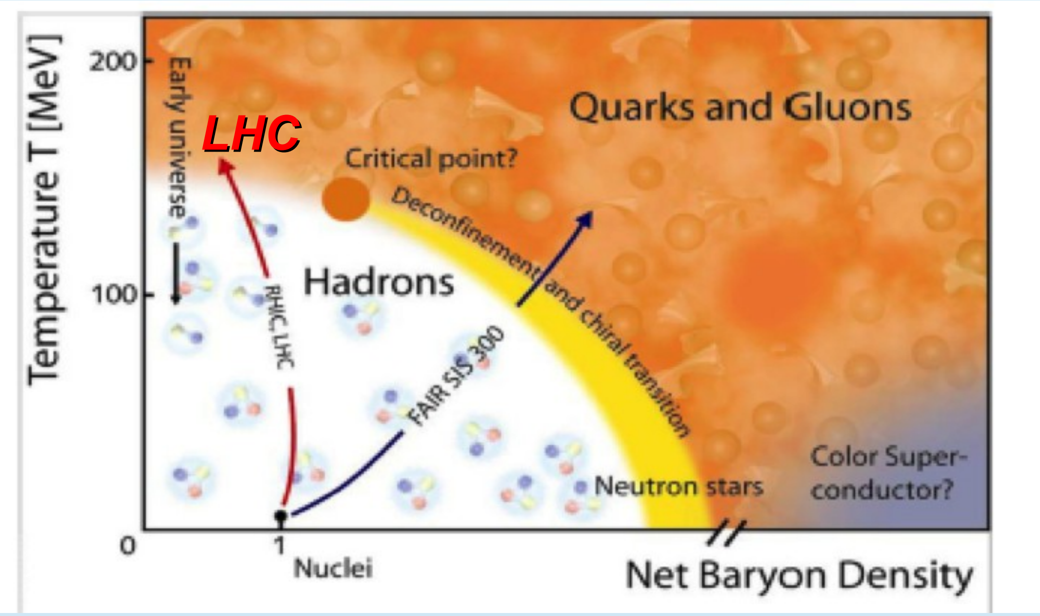


Quark-Gluon plasma:

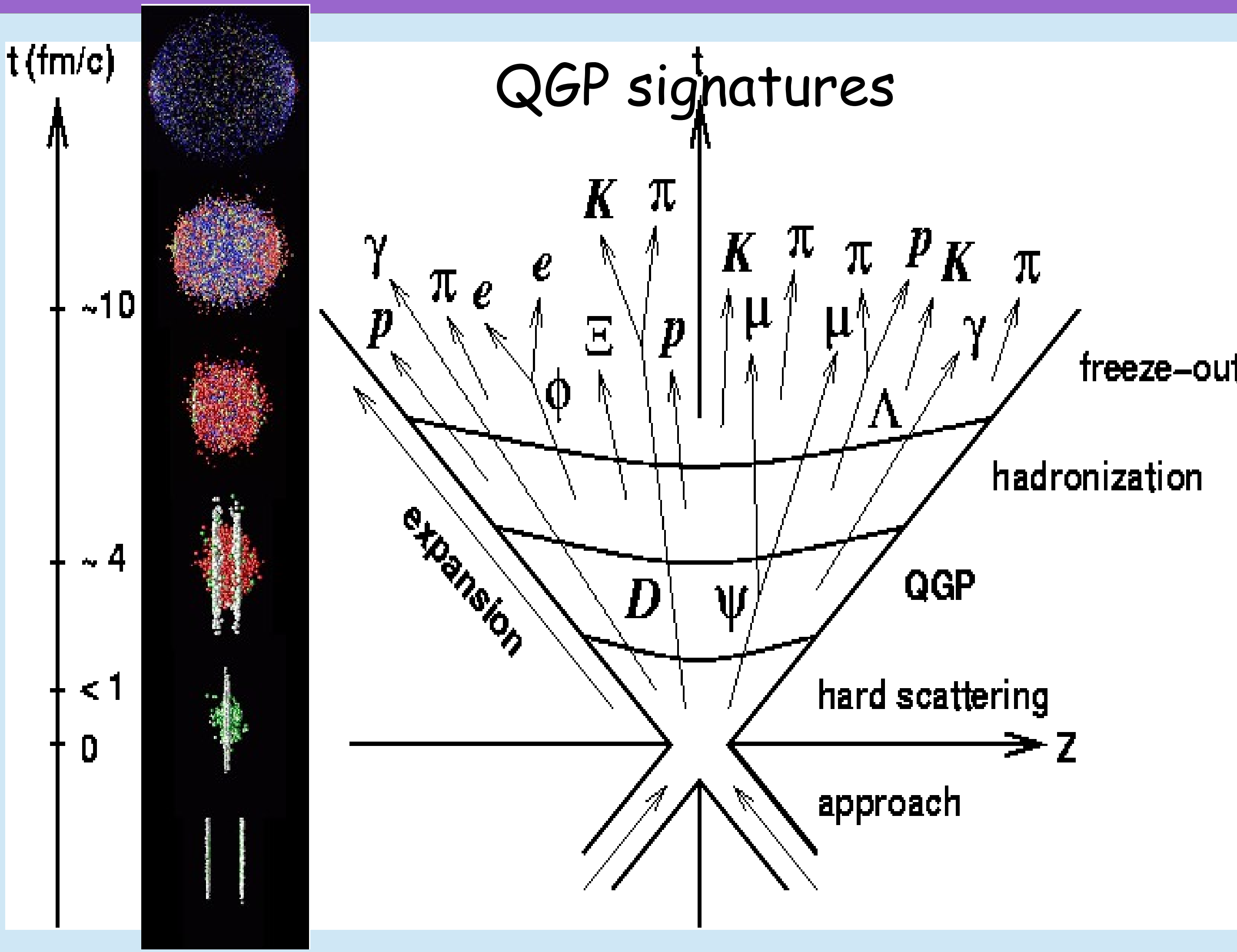
- Predicted by lattice QCD
- Deconfined quarks and gluons
- Partonic number of degrees of freedom

$T_c \sim 173$ MeV

$E_c \sim 0.7$ GeV/fm^3



Motivation: the QGP



Kinetic: no elastic collisions

Chemical: no inelastic collisions

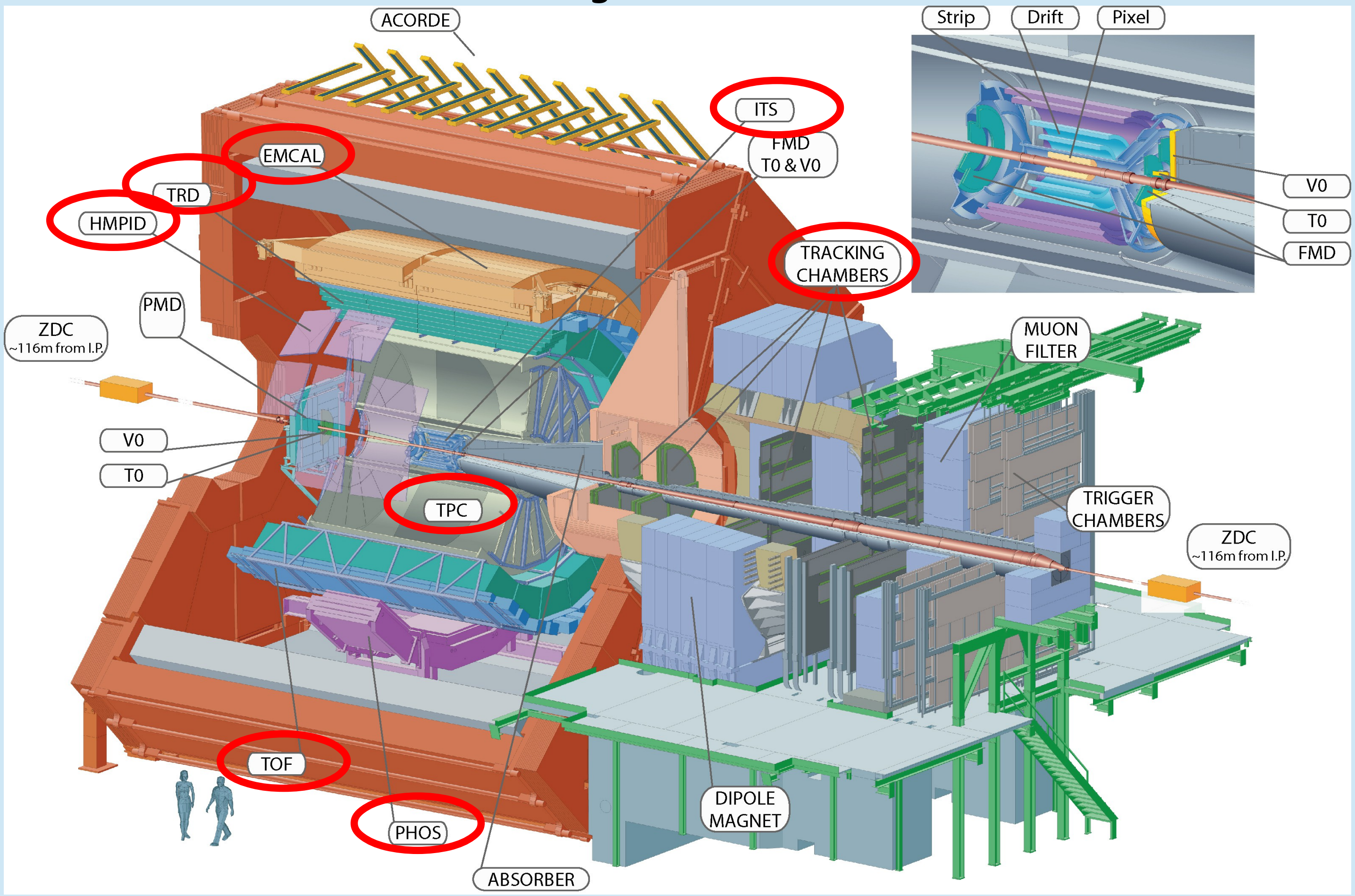
First bound states

Thermalized medium

Heavy quarks + jets + direct photons

ALICE layout

- Low material budget
- Excellent PID performance
- Low magnetic field

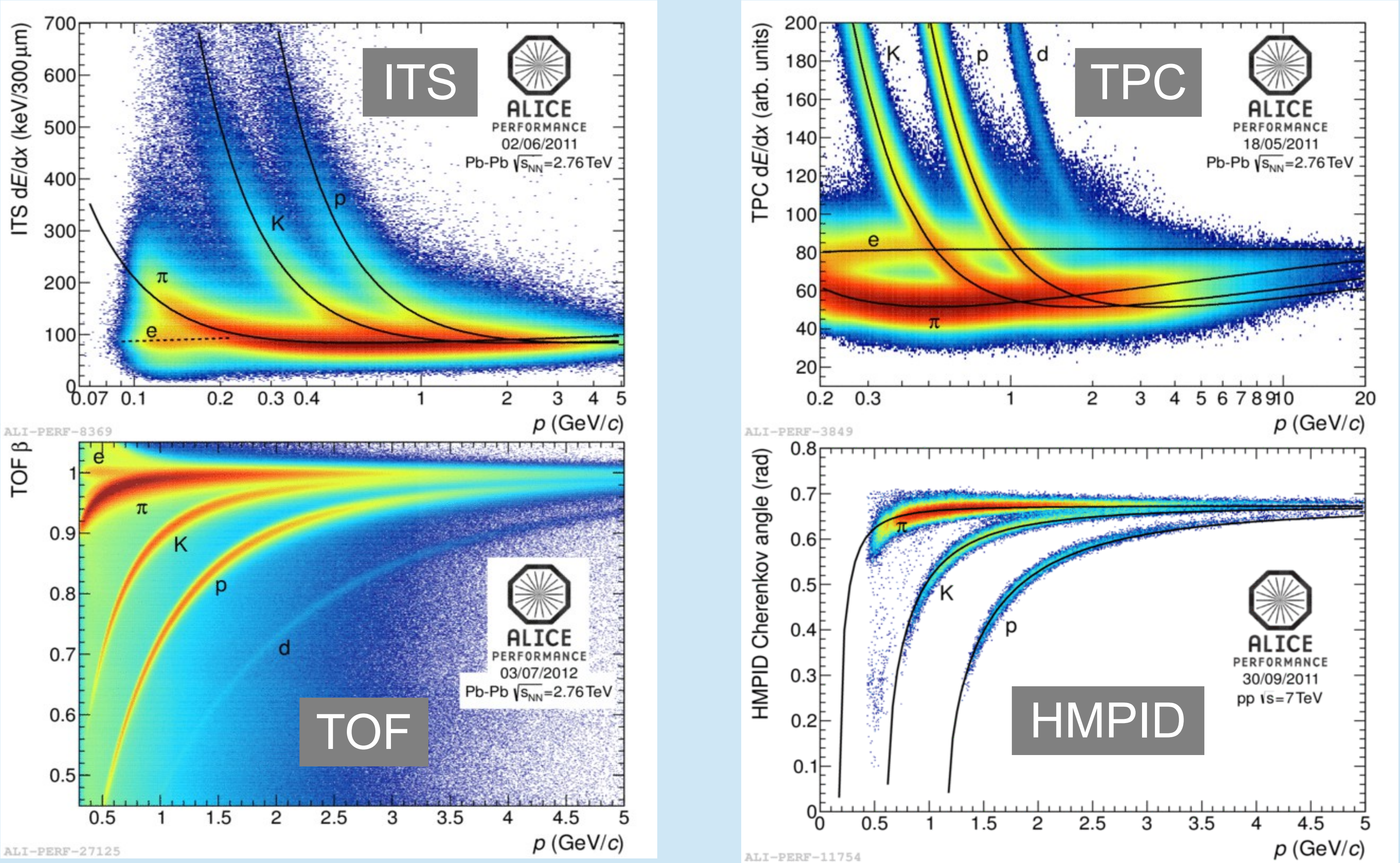


ALICE has several barrel detectors (|η|<0.9) dedicated to PID

- covering complementary p_T ranges
- using different PID techniques
  - ITS: dE/dx
  - TPC: dE/dx
  - TRD: Transition Radiation
  - TOF: Time-of-Flight
  - HMPID: Cherenkov Radiation
  - EMCal, PHOS: EM calorimeters

ALICE has a forward muon spectrometer (-4.0<η<-2.5) for muon ID

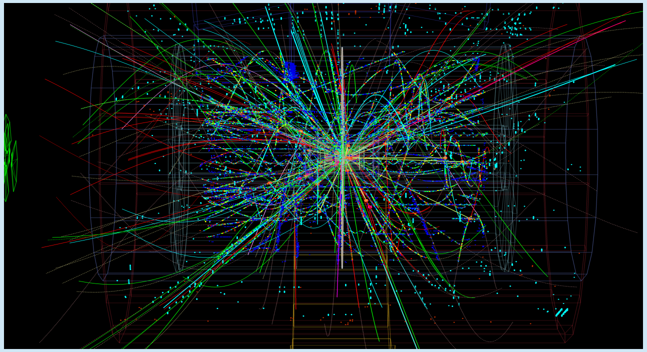
Main PID detector performance



Data taking

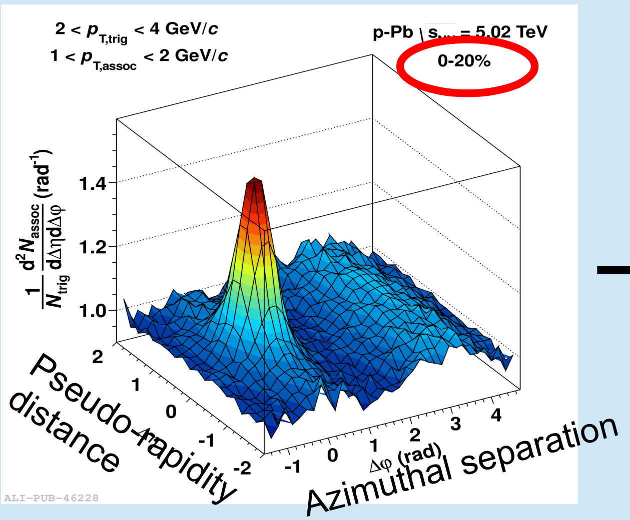
- **pp collisions** @ $\sqrt{s}$ = 0.9-2.76-7.0 TeV:
  - test QCD inspired models and tune MC models
  - provide reference for Pb-Pb data
  - complement other LHC experiment results
- **Pb-Pb collisions** @ $\sqrt{s_{NN}}$ = 2.76 TeV:
  - study the QGP
- **p-Pb collisions** @ $\sqrt{s_{NN}}$ = 5.02 TeV:
  - discriminate between initial (cold nuclear matter) and final (QGP) state effects
  - provide reference for Pb-Pb data
  - study properties of QCD at low parton fractional momentum x and high gluon densities

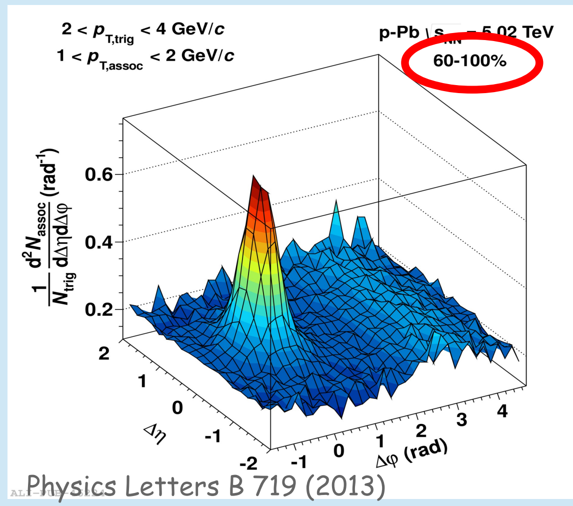
In this talk

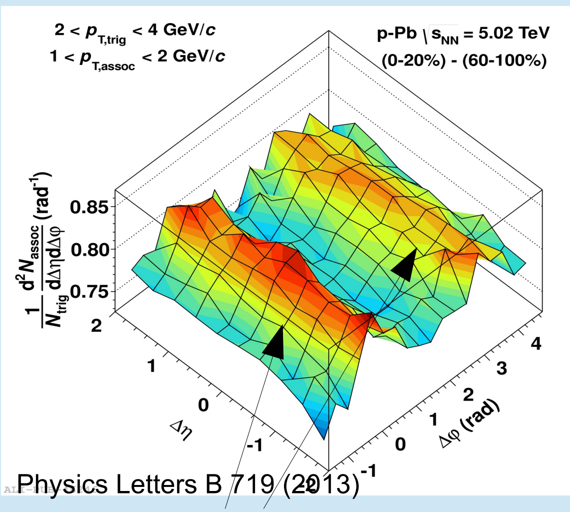


p-Pb: two particle correlations

to study the underlying mechanism and dynamics of particle production







long range structure on both near and away side

jet contribution reduced by subtracting low multiplicity events

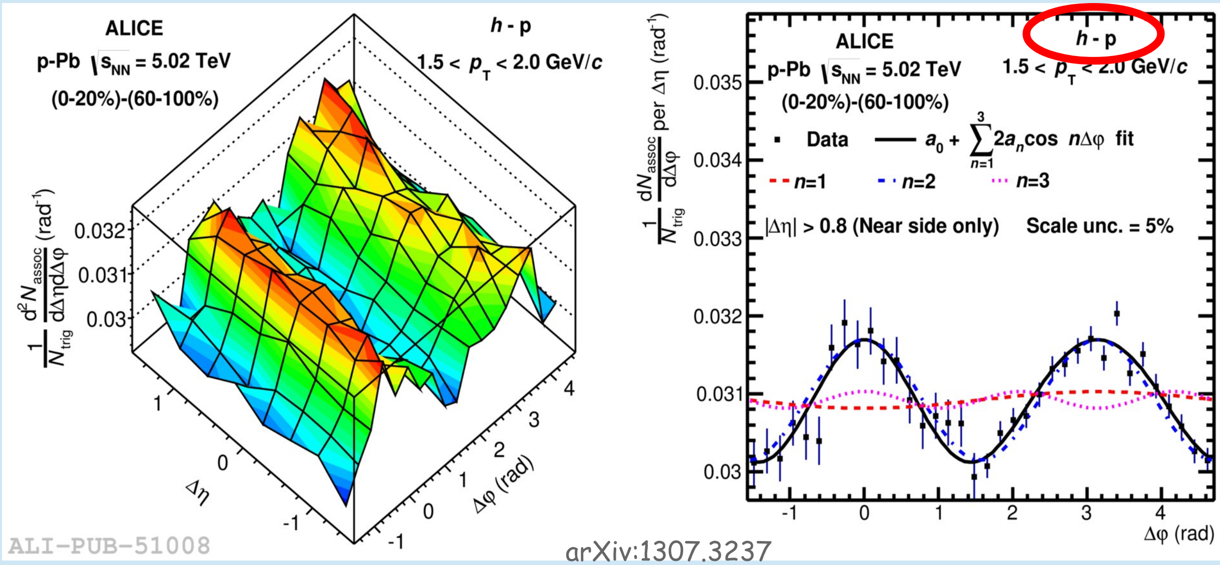
Double ridge in high multiplicity p-Pb like in Pb-Pb

Double ridge:

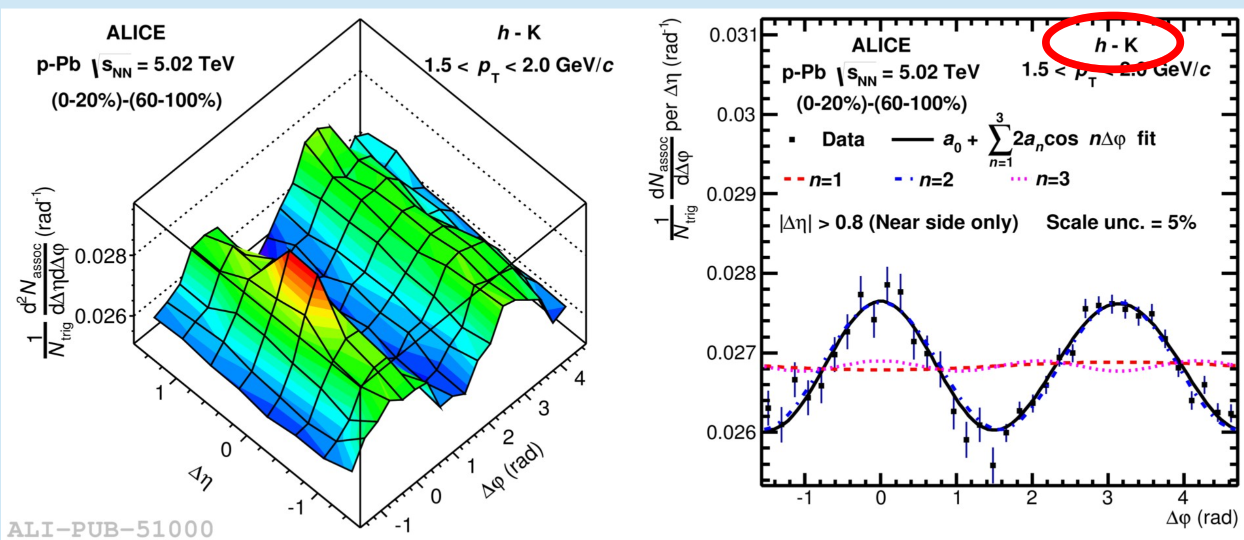
- Pb-Pb -> collective effects: hydrodynamics
- p-Pb -> - Initial state effect (CGC) ?
  - Final state effect (hydrodynamics) ?

Does it flow or not? Particle identification could help

p-Pb: two particle correlations



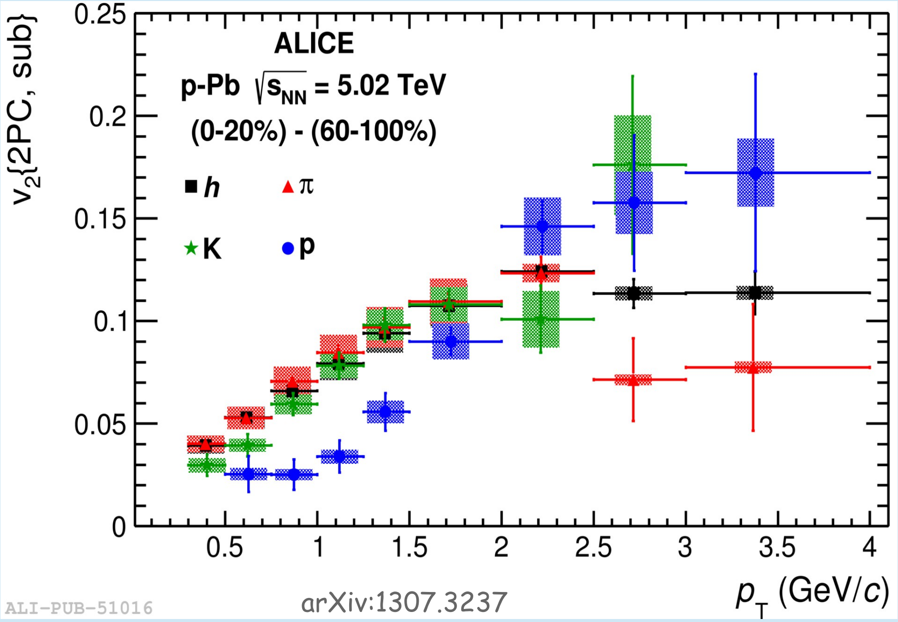
arXiv:1307.3237

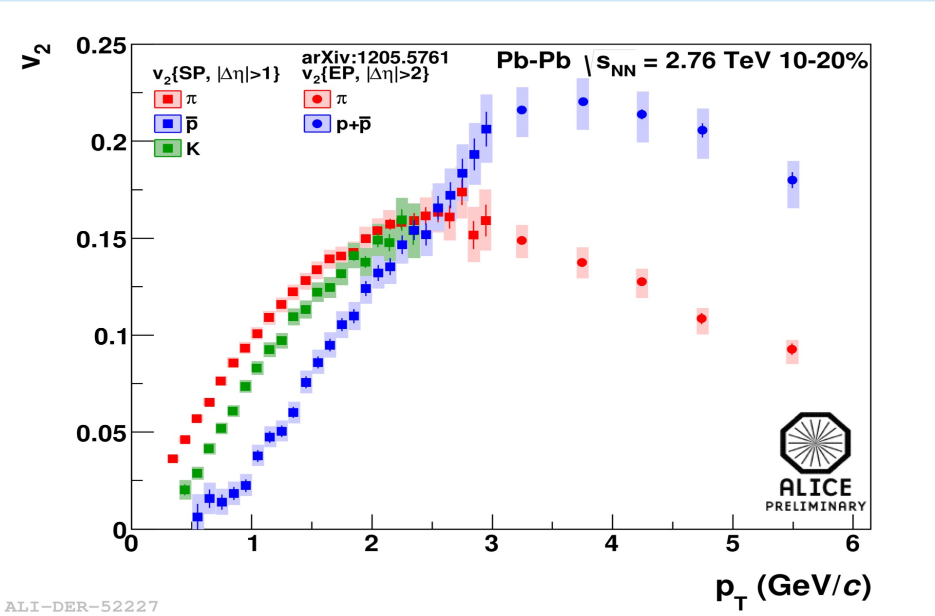


Harmonic decomposition of Δφ distribution

$$a_0 + \sum_{n=1}^{3} 2a_n \cdot \cos(n \cdot \Delta\varphi)$$

p-Pb: two particle correlations



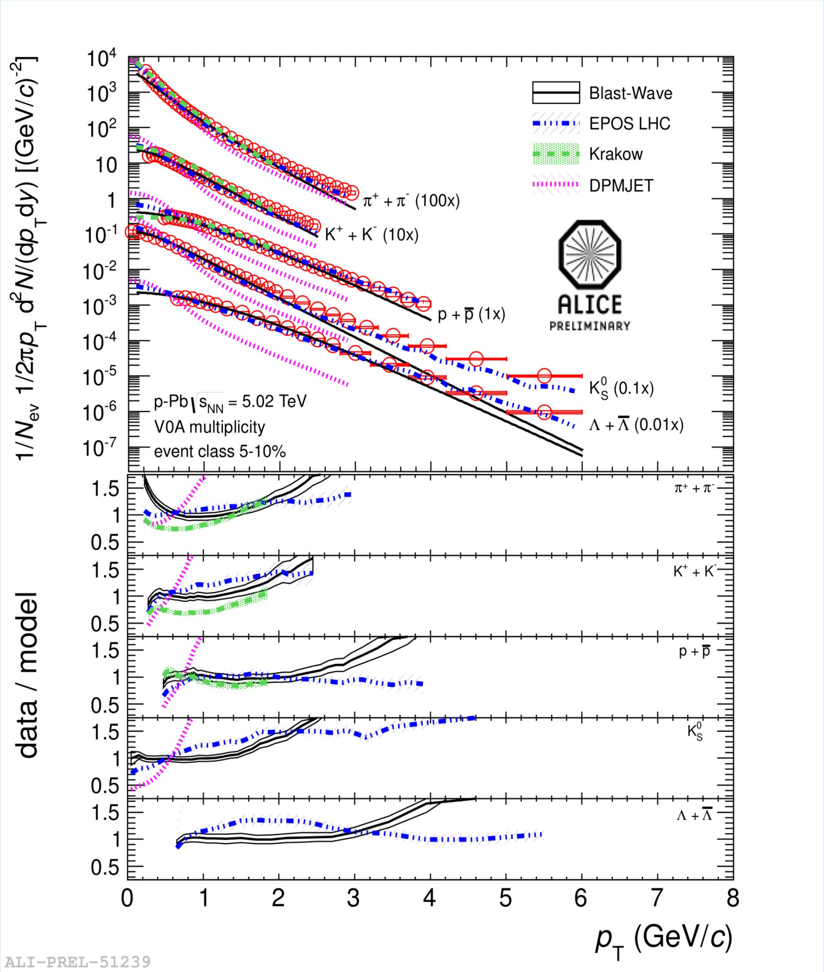


Similar features in p-Pb and Pb-Pb: mass ordering at low-p_T - in Pb-Pb ascribed to hydrodynamics

CGC description and model based on hydrodynamic flow give a satisfactory description of p–Pb correlation data -> the question "Does it flow or not?" is still open…

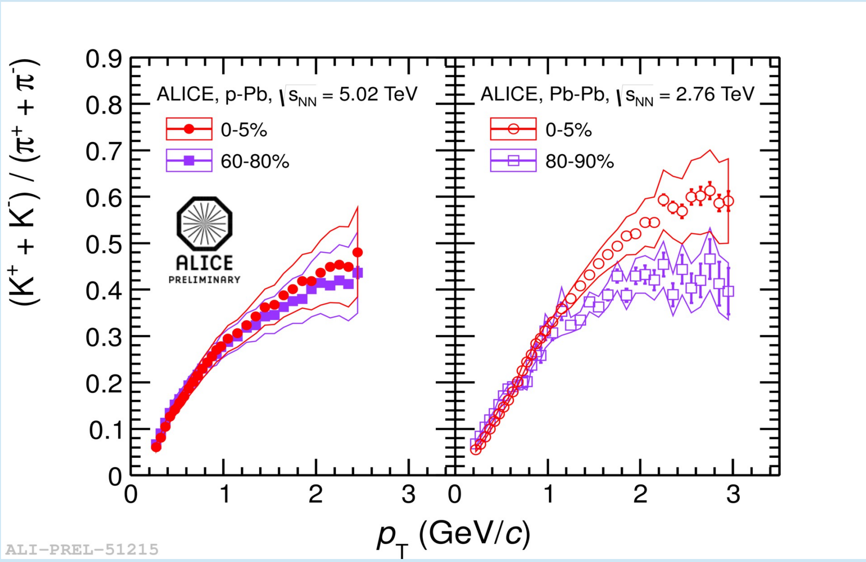
input from identified spectra?

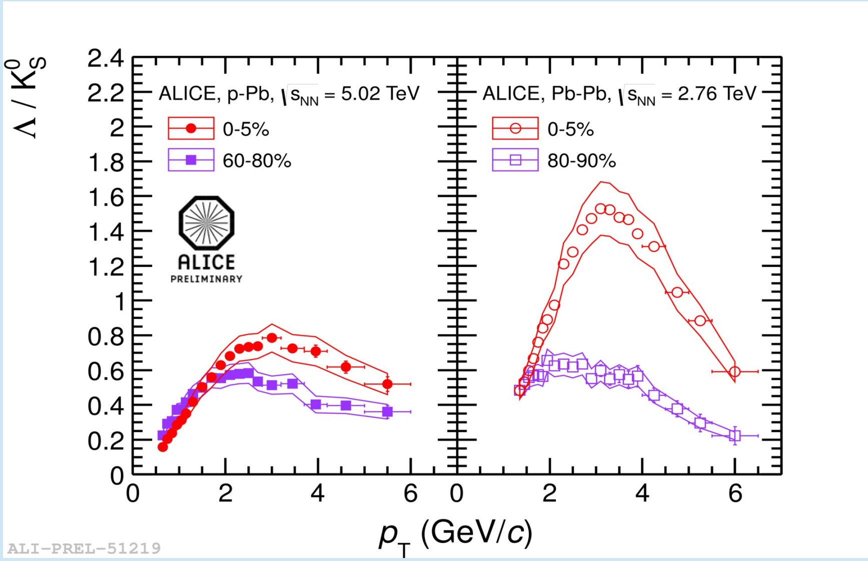
p-Pb: π, K, p, Λ, K_s^0 spectra

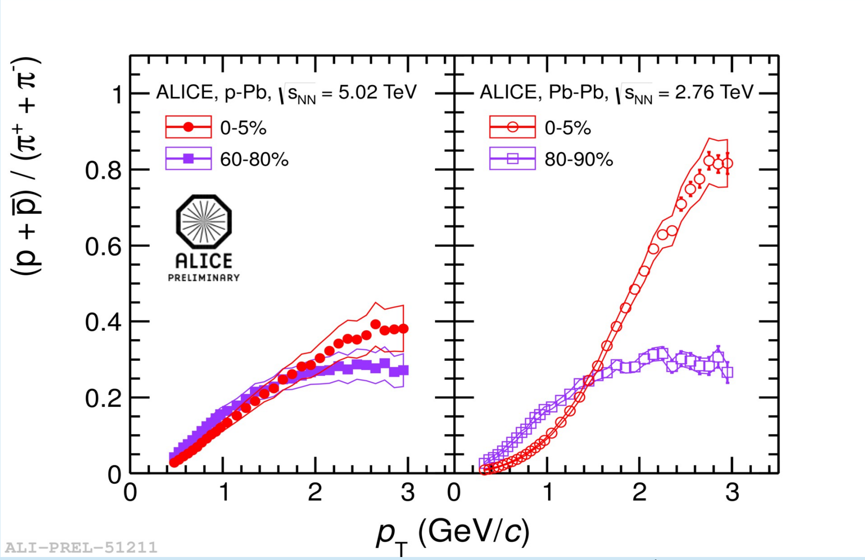


- DPMJET, QCD inspired generator: can not reproduce p_T distributions and $\langle p_T \rangle$ of charged particles.
- Krakow (Bozek, PRC85, 014911 (2012)), viscous hydro model: reproduces π and K for p_T < 1 GeV/c where hydro effects dominate. At higher p_T the observed deviations for pions and kaons are possibly due to non-thermal component. Good description of p.
- EPOS LHC (Pierog et al., arXiv:1306.0121 [hep-ph]), initial hard scattering creates "flux tubes" which either escape the medium and hadronize as jets, or contribute to the bulk matter, described in terms of hydrodynamics: it can reproduce π and p within 20% over the full measured range; larger deviations for kaons and lambdas.

p-Pb: π, K, p, Λ, K_s^0 spectra







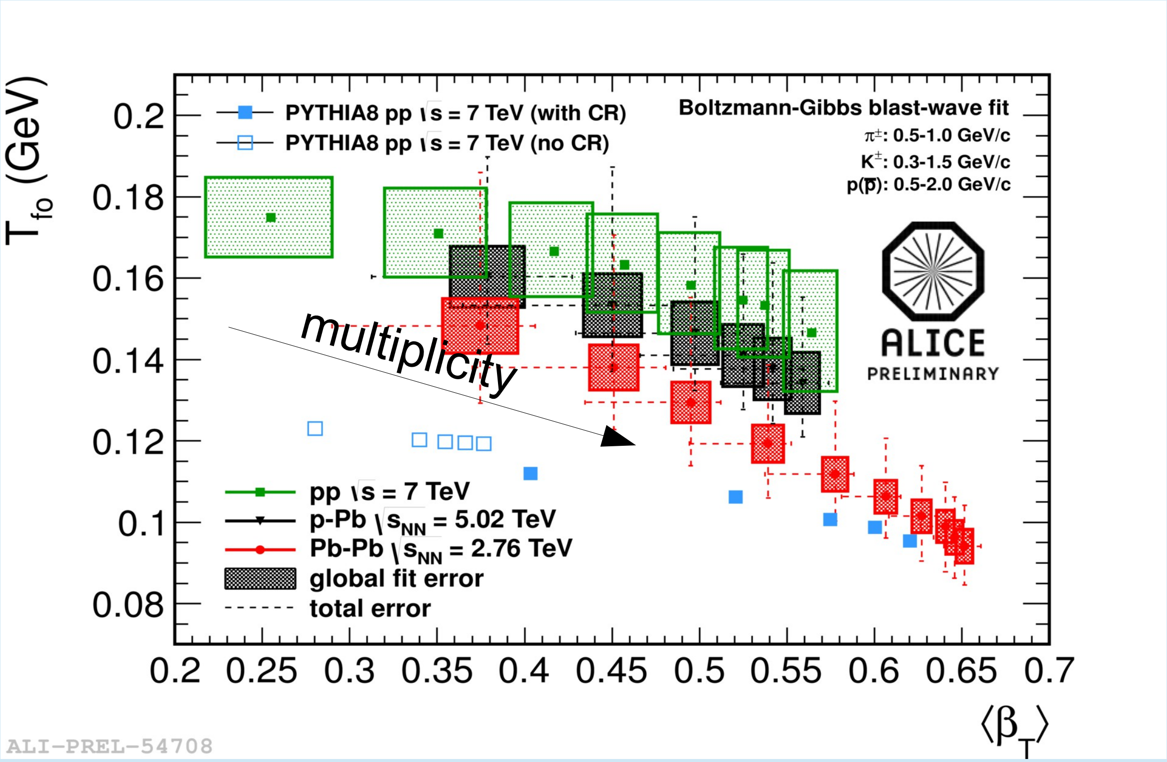
- *Spectra become harder as the multiplicity increases*
- *Mass dependence of spectral shape evolution with multiplicity*

Same behaviour as in Pb-Pb where it is explained in terms of collective radial expansion -> final state effects seem to be needed to describe the p-Pb data ??

p-Pb: π, K, p, Λ, K_s^0 spectra

How to compare spectral shapes and evolution in different collision systems?

-> spectra fitted with Blast wave function (Schnedermann et al., PRC 48, 2462 (1993))



Smaller fit range in p-Pb -> assumptions underlying the blast-wave model expected to be valid up to lower p_T values in p–Pb as compared to Pb–Pb due to the smaller system size

1-Similar trend for p-Pb and Pb-Pb -> consistent with radial flow in p–Pb

At similar $dN_{ch}/d\eta$:

- T_{kin} comparable for the two systems
- $\langle\beta_T\rangle$ higher in p-Pb collisions

→ stronger collective flow for smaller system size? Shuryak, arXiv:1301.4470 [hep-ph]

2-PYTHIA (no hydro-like collectivity implemented) shows similar features -> color reconnection (CR) produces flow-like patterns in pp

3-pp data have similar features

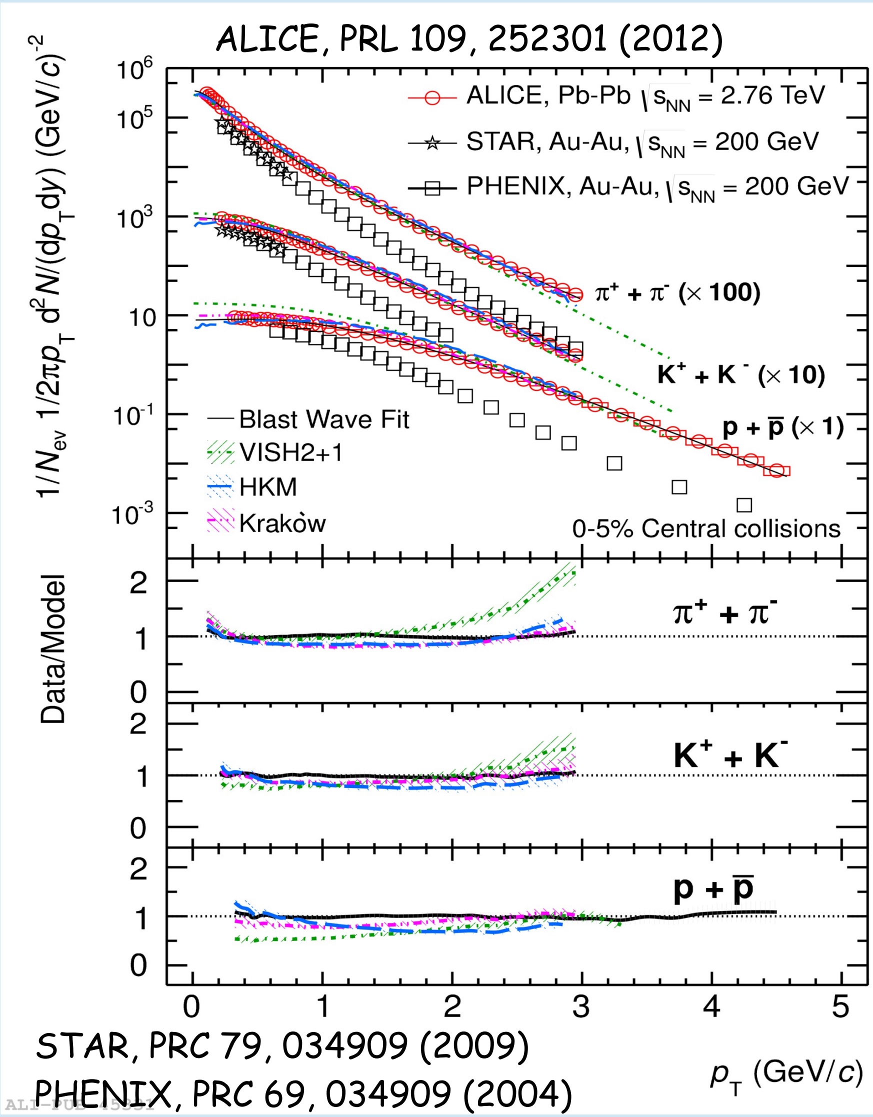
-> Blast-Wave spectral-shape analysis not yet conclusive

Pb-Pb bulk particles production: hadron spectra and yields

Fundamental to study collective and thermal properties of QGP -> signals produced in the QGP phase have to be folded with space-time evolution of the whole system

- p_T spectra: described by hydrodynamic models reflect conditions at "kinetic freeze-out" (no more elastic interactions) -> give information about:
  - collective transverse expansion (radial flow) -> average transverse velocity $\langle \beta_T \rangle$
  - kinetic freeze-out temperature T_{kin}
- particle abundances: described by thermal models (in thermal and chemical equilibrium) -> give information about:
  - chemical freeze-out temperature T_{ch}
  - baryochemical potential μ_B (net baryon content)
- baryon/meson ratio and strange particles production: provide info on bulk particles production mechanism

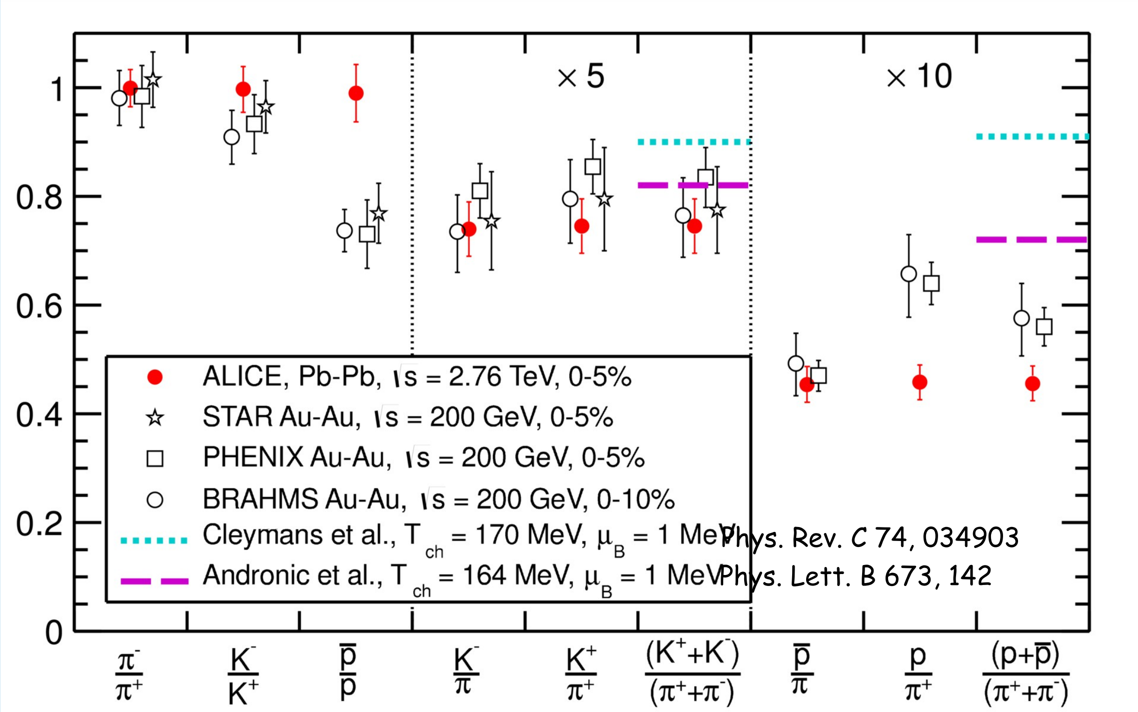
Pb-Pb: π, K, p spectra



Hydro models:

- VISH2+1: viscous hydrodynamics, no description of hadronic phase
  (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))

Pb-Pb: particle ratios



PRL 109, 252301 (2012)

T_{ch} obtained from fit to RHIC data

μ_B extrapolated from lower energies

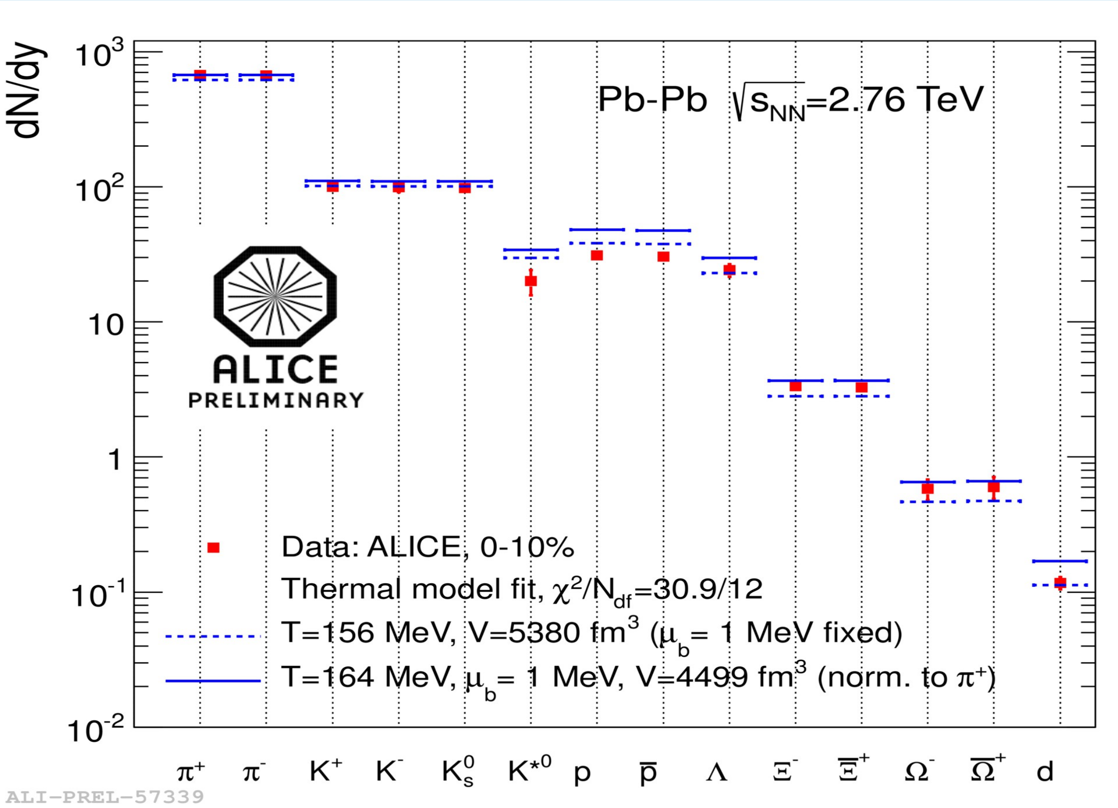
Comparison with 2 thermal model predictions (both models fit RHIC data):

- K/π in line with predictions
- p/π lower than expected by factor 1.5

Deviation from thermal ratio:

- final state interactions in hadronic phase (arXiv:1203.5302) (HKM model (arXiv:1204.5351))
- non equilibrium SHM (Eur. Phys. J. A 35)
- existence of flavor and mass dependent pre-hadronic bound states in the QGP phase (Phys. Rev. D 85, 014004 and arXiv:1205.3625)

Pb-Pb particle ratios



K* not used in the fit, resonances can interact with hadronic medium in final state

Thermal model predictions:

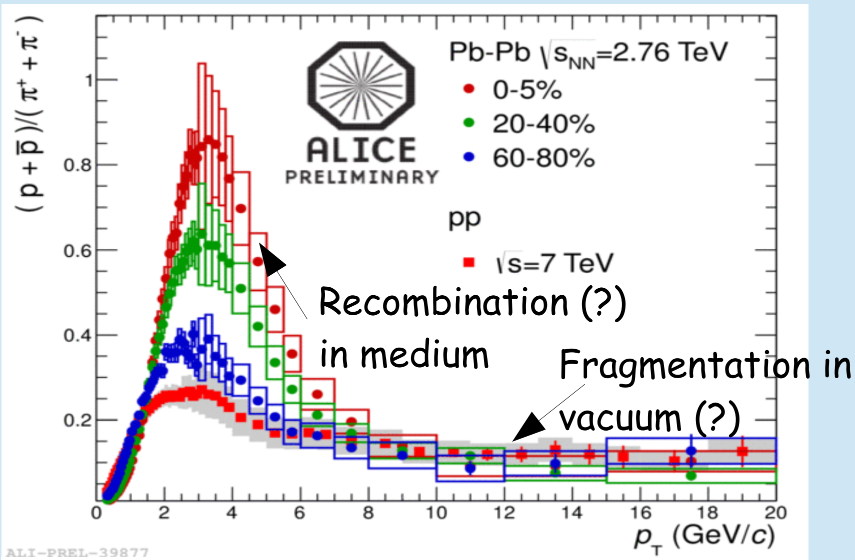
- T = 164 MeV from lower energies extrapolation
- T = 156 MeV from the fit

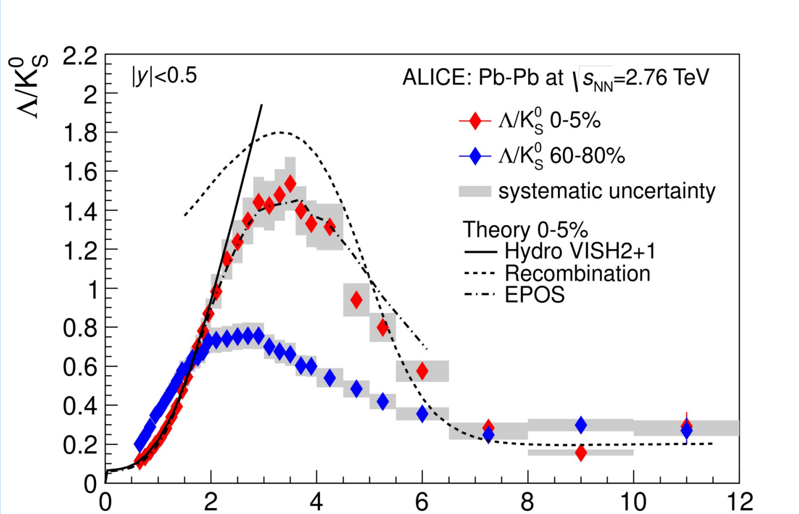
T = 156 MeV fit better than the expected T = 164 MeV

Tension between species: unique chemical freeze-out temperature does not describe p, Λ, Ξ, Ω

A. Andronic et al., Phys. Lett. B697 (2011) 203

Pb-Pb: baryon/meson ratio





ALICE arXiv:nucl-ex/1307.5530

2 GeV/c < p_T < 7 GeV/c

- enhancement respect to pp increases with centrality
- qualitatively consistent with hadron formation from medium constituents (coalescence)

p_T > 10 GeV/c

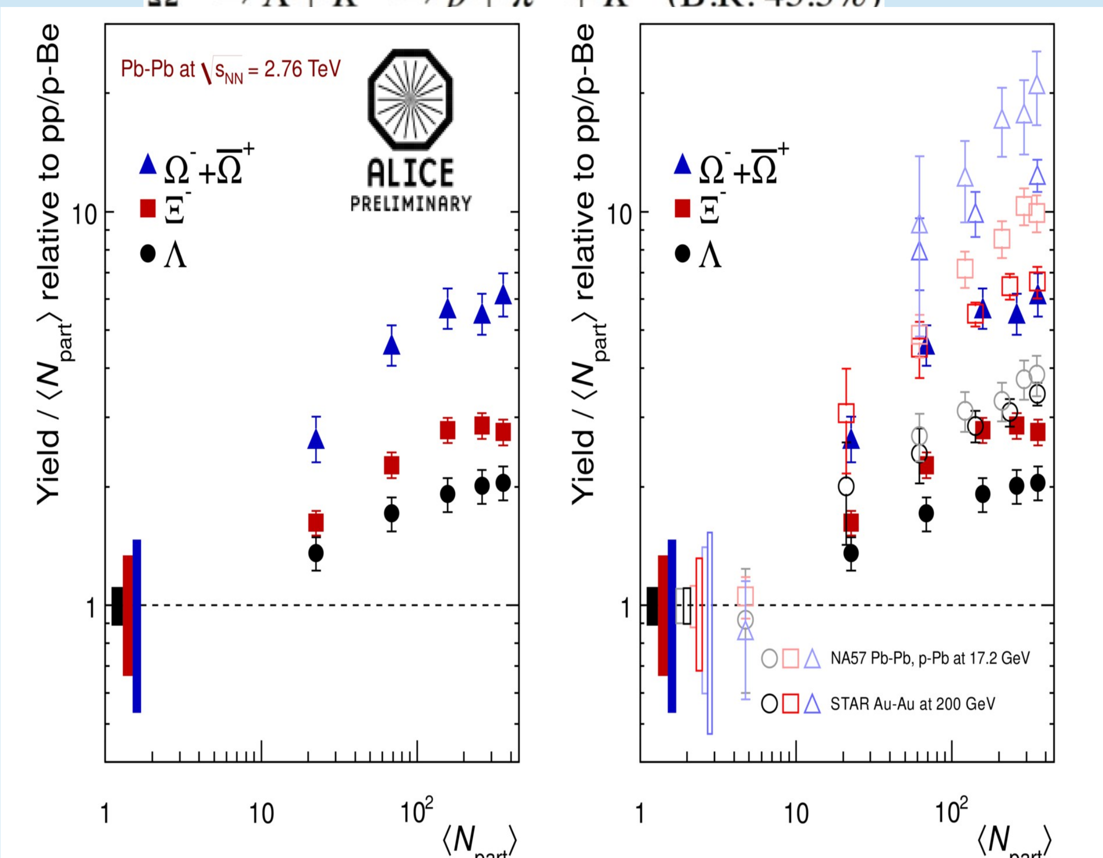
- ratio similar to pp value -> parton fragmentation (jet chemistry) not modified by the medium

- Λ/K^0_s of integrated yields constant with centrality -> baryons / mesons redistributed in p_T rather than enhanced / suppressed
- Hydro model works at p_T<2 GeV/c then additional processes are needed: a quantitative description is challenging
- Recombination calculation gets correct shape
- EPOS successfully describe transition

Hydro: Phys. Lett. B658, 279 (2008), Recombination: Phys. Rev. C83, 054912 (2011), EPOS: Phys. Rev. Lett. 109, 102301 (2012)

Pb-Pb: strangeness

$$\Xi^- \rightarrow \Lambda + \pi^- \rightarrow p + \pi^- + \pi^- \text{ (B.R. 63.9\%)}$$
$$\overline{\Xi}^+ \rightarrow \overline{\Lambda} + \pi^+ \rightarrow \overline{p} + \pi^+ + \pi^+ \text{ (B.R. 63.9\%)}$$
$$\Omega^- \rightarrow \Lambda + K^- \rightarrow p + \pi^- + K^- \text{ (B.R. 43.3\%)}$$
$$\overline{\Omega}^+ \rightarrow \overline{\Lambda} + K^+ \rightarrow \overline{p} + \pi^+ + K^+ \text{ (B.R. 43.3\%)}$$



NA57: J. Phys. G 32, 427 (2006), J. Phys. G 37, 045105 (2010)
STAR: Phys. Rev. C 77, 044908 (2008)

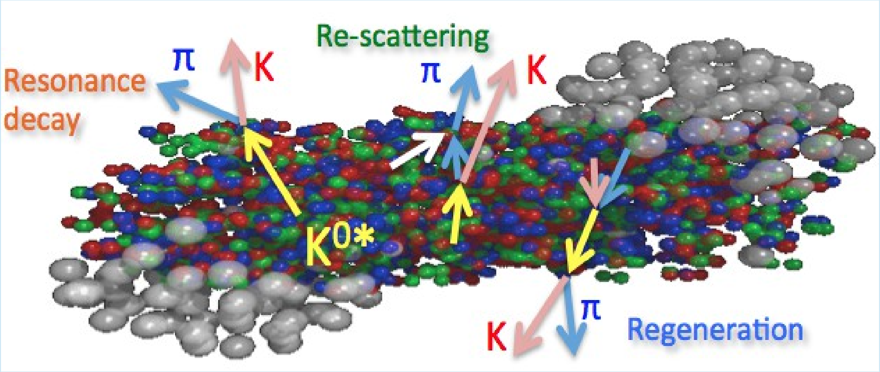
No net strangeness content in the colliding system -> s quarks light enough for thermal production in the QGP
- comparison with thermal models
- test strangeness enhanced production in Pb-Pb vs pp
- test particle production mechanism

Strangeness enhancement:

- Ratio increases with strangeness content
- decreasing trend with energy
- Multi-strange baryons (Ξ=ssd,Ω=sss) enhanced up to x7 wrt pp -> formed by recombination in a system with abundant s quarks?

Pb-Pb: resonances

See next talk from S.Kiselev

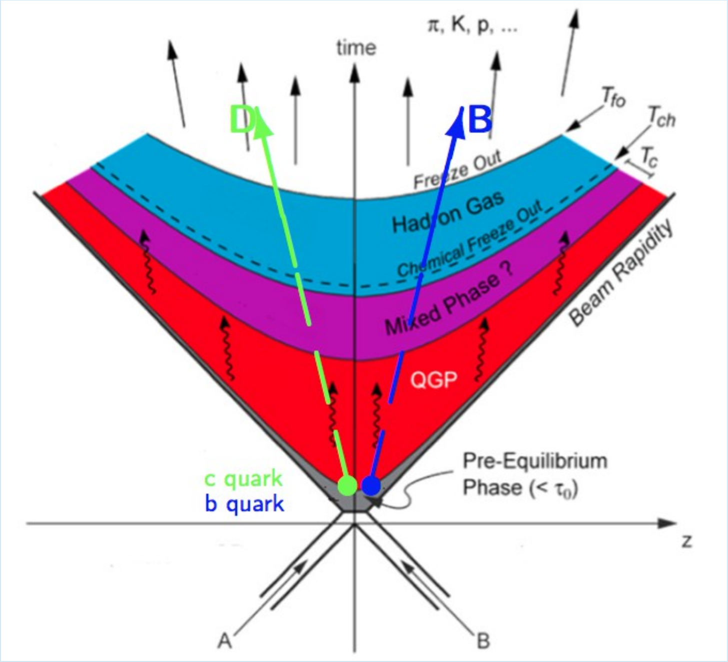


- Resonances provide information about the medium (mainly in hadronic phase):
  - investigation of rescattering of the decay products and resonance regeneration in the time between chemical and thermal freeze-out (hadronic medium) comparing resonant/non resonant particle ratio (most important for pT<2 GeV/c)
  - role of resonances production by quark coalescence in partonic phase wrt production by hadron coalescence in hadronic phase

  Φ/K independent on centrality -> production by kaon coalescence in hadronic phase disfavoured while K*/K slightly decrease with increase in centrality -> interaction in hadronic medium (rescattering of π ?)
- Resonances may decay when chiral symmetry was restored: mass shift and width broadening

  no effect seen up to now for the studied Φ and K* -> consistent with vacuum values)

Heavy flavours



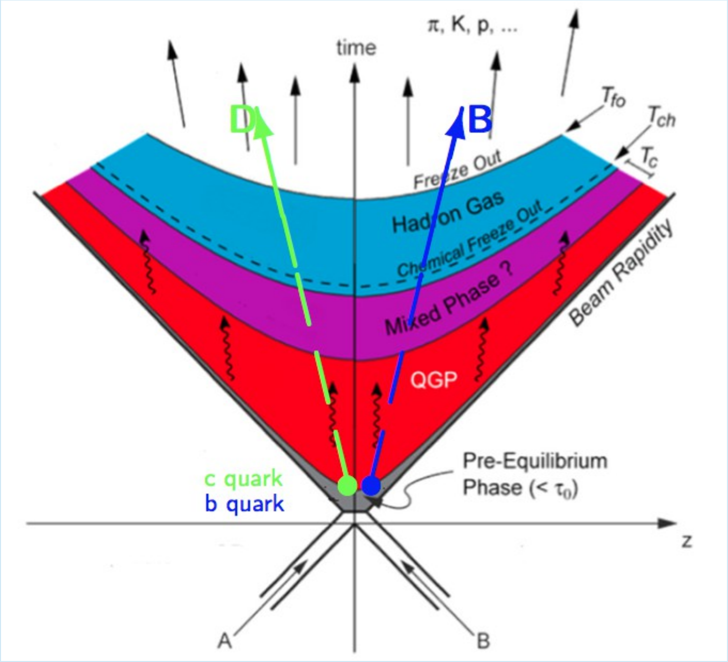
Quarkonium states and hadrons with open heavy flavors provide a means to study the QGP since:

- heavy quarks produced in the primary partonic scatterings -> exposed to the medium evolution
- no extraproduction at the hadronization

- We expect medium-induced gluon radiation depending on parton mass and color-charge

  $\Delta E_g > \Delta e_{u,d} > \Delta E_c > \Delta E_b$ -> $R_{AA}(B) > R_{AA}(D) > R_{AA}(\pi)$
- If in-medium quark re-combination is the dominant mechanism of charm hadron formation at low $p_T \rightarrow$ strange charm hadrons (Ds) expected to be largely enhanced
- Elliptic flow carries informations on medium transport properties (viscosity, energy loss)

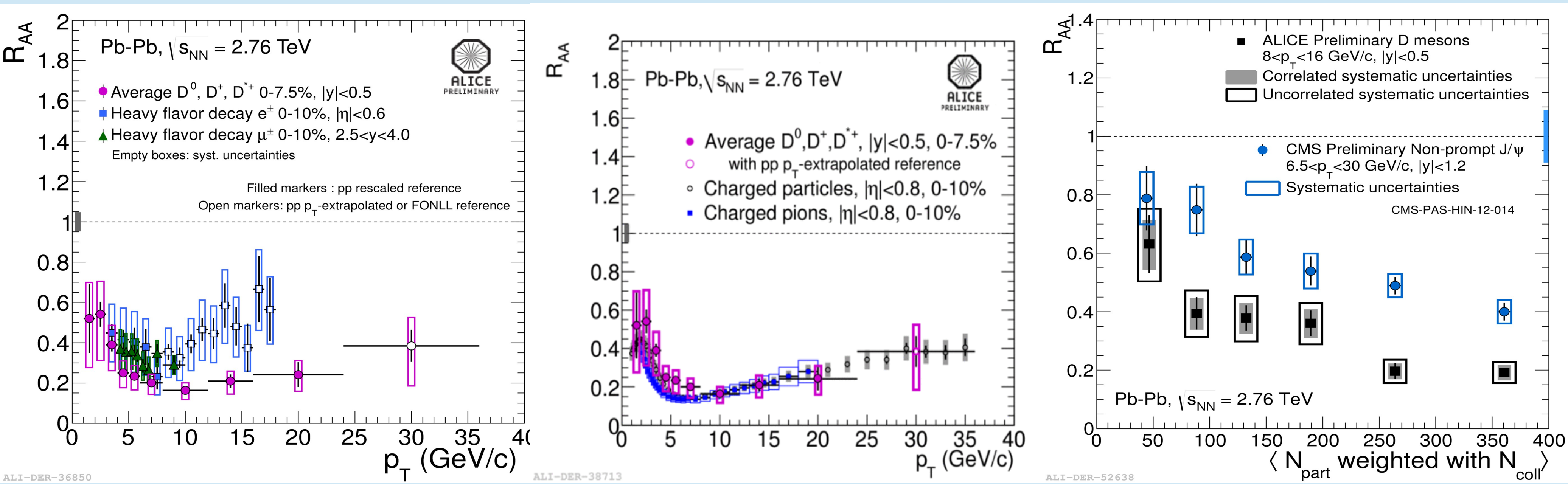
Heavy flavours



J/Ψ suppression:

- in-medium dissociation probability of quarkonium states provides an estimate of the initial T of the system (color-screening model).
- Increasing temperature -> maximum size up to which quarkonium states are bound decreases. Melting of the quarkonium states should follow a sequence defined by their size
- models have to take into account: direct J/Ψ production + dissociation due to Cold Nuclear Matter effects (CNM) + J/Ψ dissociation + regeneration from deconfined charm quarks in the medium

Pb-Pb: heavy flavours



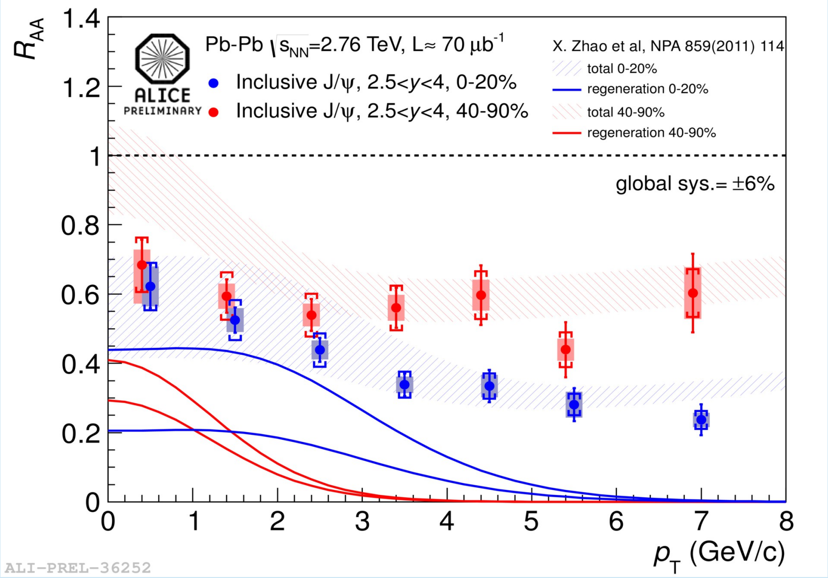
- R_{AA} of D^0, D^+, D^{*+} in agreement
- Enhancement of D^+_s due to strangeness content? data not conclusive yet
- Strong suppression in a wide p_T range
- R_{AA} (HF → leptons) similar in the most central collisions despite different rapidities

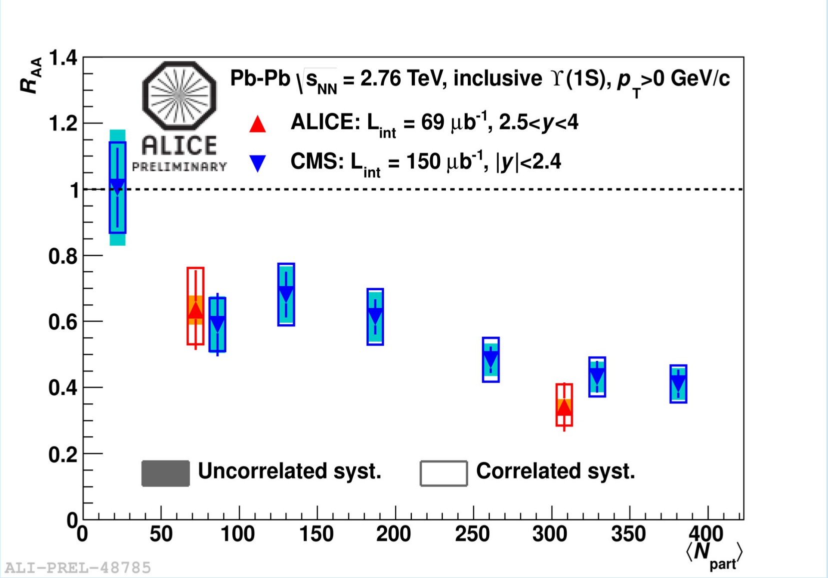
- D mesons R_{AA} similar to light hadrons in central collisions -> maybe hints of the hierarchy

  $R_{AA}(D) > R_{light}$ (more statistic needed)
- Indications for $R_{AA}(D) < R_{AA}(J/\Psi \leftarrow B)$ (but slightly different kinematical regions)
- More suppression in central wrt peripheral collisions

Pb-Pb: J/Ψ suppression

Inclusive J/Ψ -> μ+μ- At forward rapidity
Inclusive J/Ψ -> e+e- At mid rapidity





R_{AA} decrease with p_T mainly for central collisions

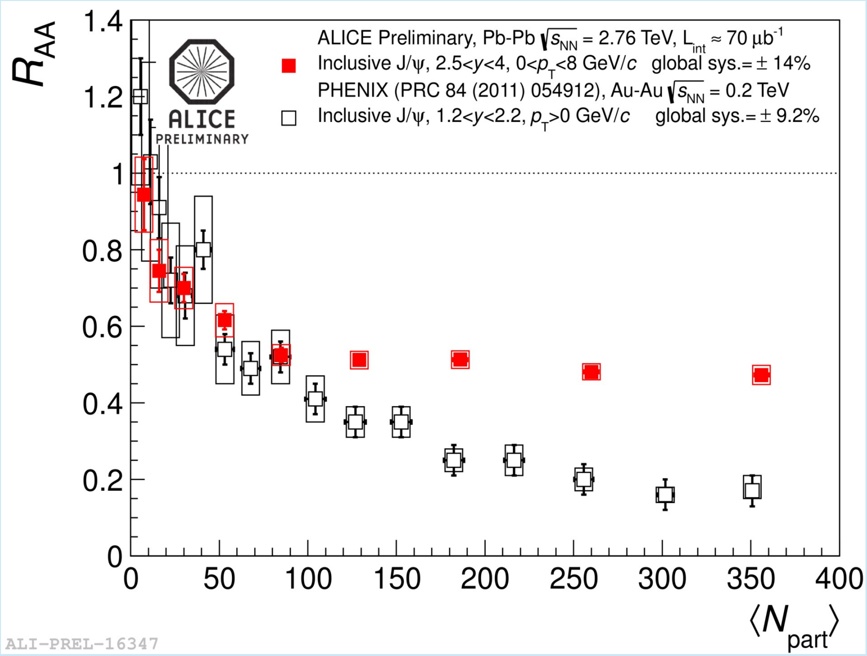
J/ψ are suppressed in QGP BUT are regenerated in the low p_T region from the large number of freely roaming charm quarks in the QGP

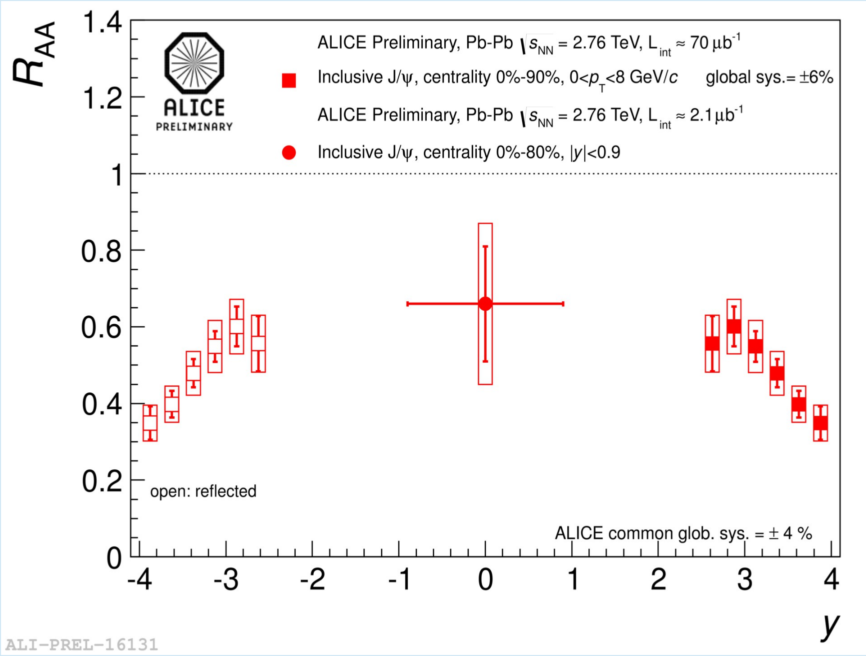
Υ(1S) suppression, similar in magnitude to the one observed by CMS at midrapidity

Hints of larger suppression in central collisions

Weak or no rapidity dependence: R_{AA} seems to remain quite constant over a large range.

J/Ψ suppression



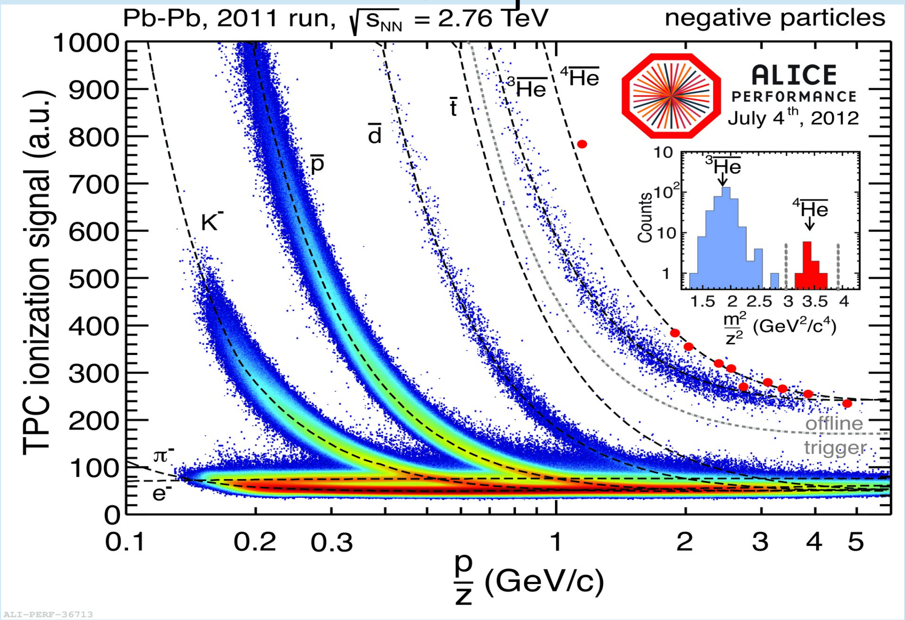


Pb-Pb: No centrality dependence for N_{part} > 70

R_{AA} decreases with rapidity -> density of charm quark grows from forward to mid rapidity -> J/Ψ production from charm quarks in QCD phase

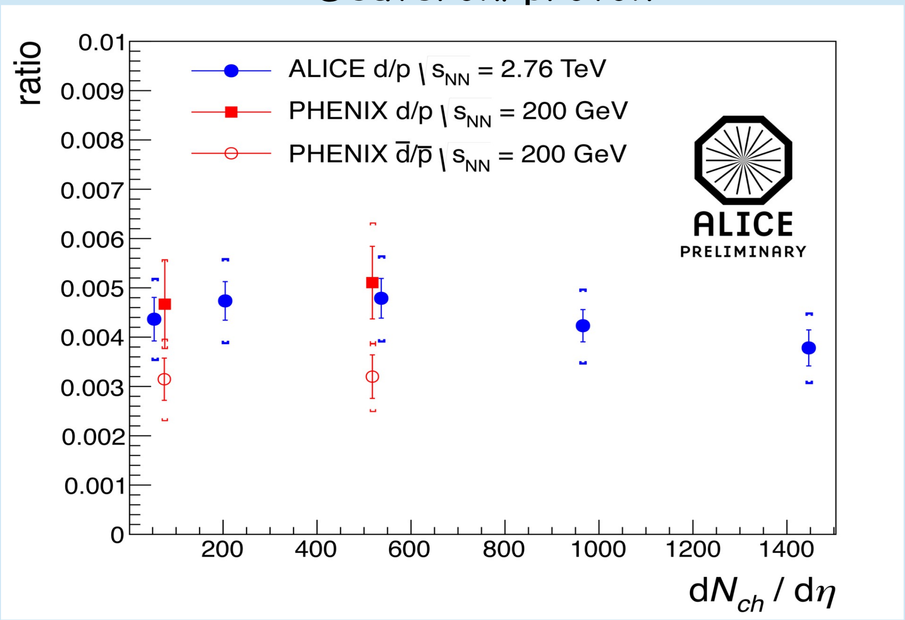
(Anti-) matter and hyper-matter

anti-alpha



10 anti-alphas identified
in the full 2011 statistic

Deuteron/proton



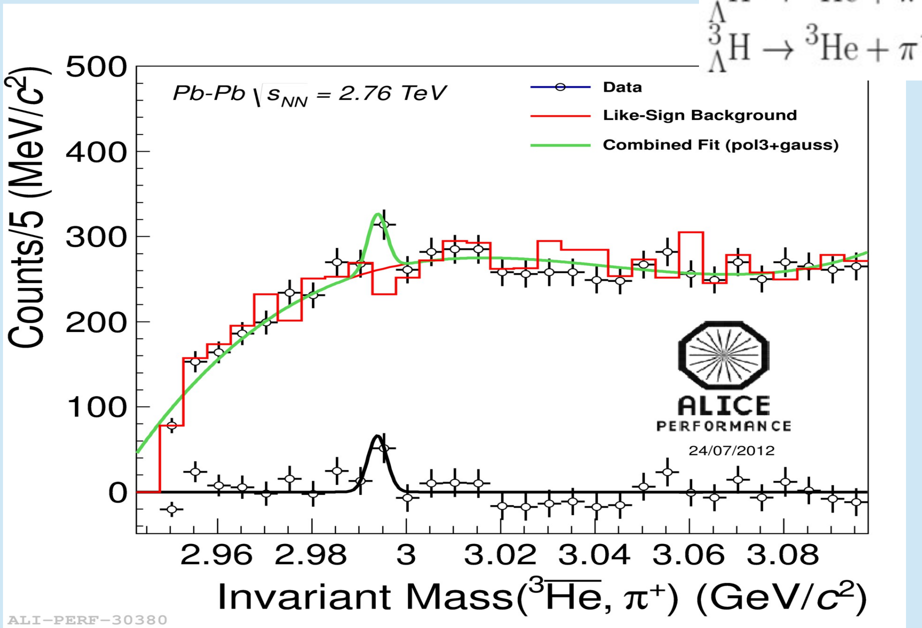
- no dependence on centrality
- no change between RHIC and LHC energies
- in contrast to LHC energies the baryochemical potential is not negligible at RHIC energies

(Anti-) matter and hyper-matter

Hyperons: baryons which have at least one s-quark as one of their 3 valence quarks (Λ, Σ, Ω, ...)
Hyper-nuclei: nuclei with at least one hyperon bounded in addition to the normal nucleons
Hyperons are unstable even if bounded in a nucleus

(anti)hypertriton

$$\overline{^{3}_{\Lambda}\mathrm{H}} \rightarrow \overline{^{3}\mathrm{He}} + \pi^{+}$$
$$^{3}_{\Lambda}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + \pi^{-}$$



Searches for exotica:

- ΛΛ hypothetical bound state of *uuddss*: H-Dibaryon
- Λn bound states

$$\Lambda n \longrightarrow d + \pi^{-}$$
$$\Lambda\Lambda \longrightarrow \Lambda + p + \pi^{-}$$

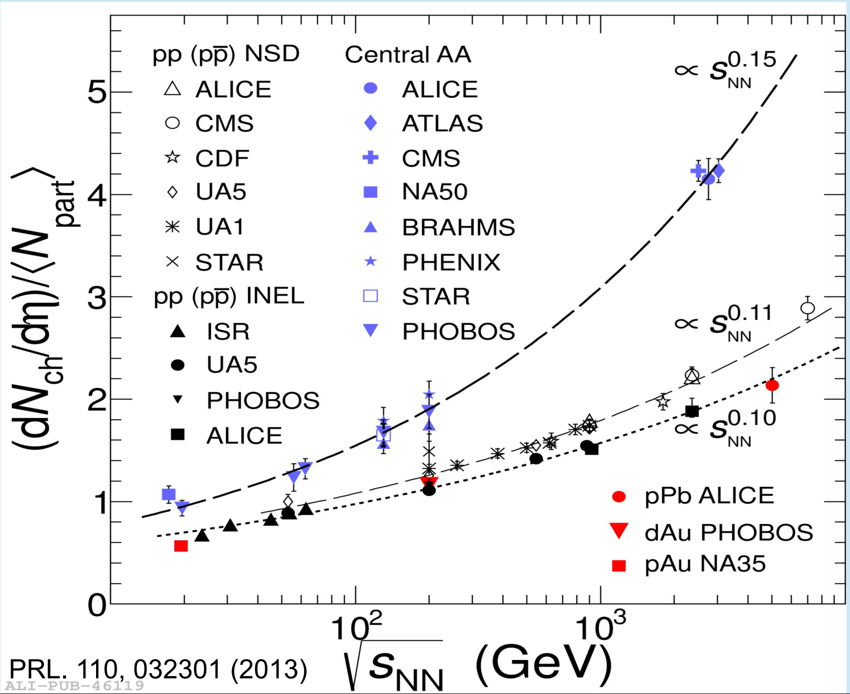
No signal visible in ALICE data -> upper limit on production rate
significantly below thermal model expectations

Summary

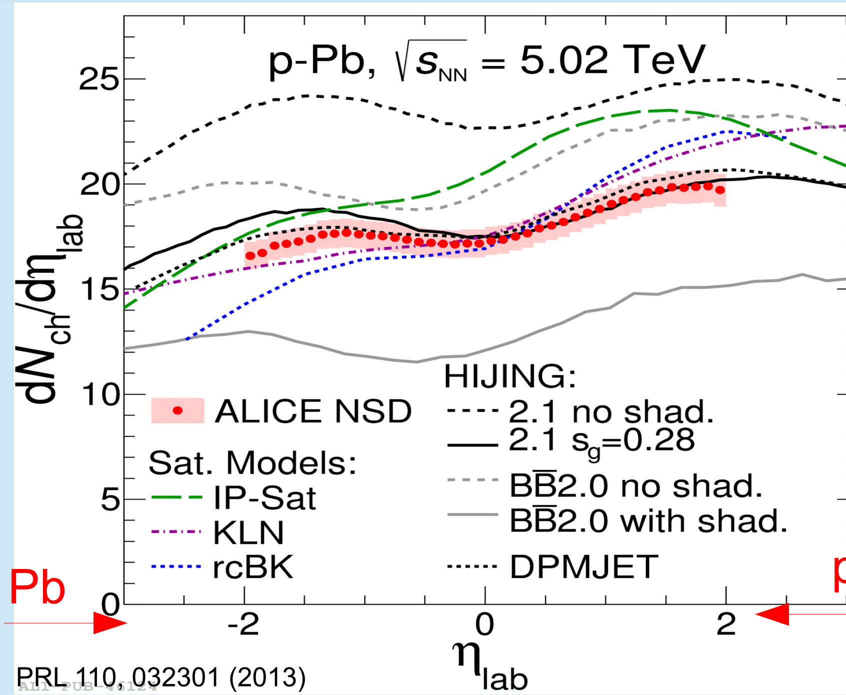
- The main target of ALICE is the study of the QGP produced in ultra-relativistic heavy ion collisions
- Some of the most recent Pb-Pb results have been shown:
  - hadron spectra, yields and baryon/meson ratio -> $\langle \beta_T \rangle$, T_{kin}, T_{ch}, μ_B and bulk particles production mechanisms
  - strange particles production -> test strangeness enhancement
  - heavy flavours -> medium interaction of the particles produced in the primary partonic scatterings, J/Ψ suppression
- p-Pb collisions provide a way to decouple initial and final state effect. Two particles correlations and spectra of identified particles seem to have similar properties as in Pb-Pb -> are final state effects needed to describe the p-Pb data? Further studies are needed!
- ALICE analyzes also pp data since they are a reference for Pb-Pb ones and give the possibility to tune QCD inspired models

Backup

p-Pb: primary particles multiplicity



Primary particles: prompt particles including decay products, except those from weak decays of strange particles



$(dN_{ch}/d\eta_{cms})$ = 16.81 ± 0.71 (syst.)

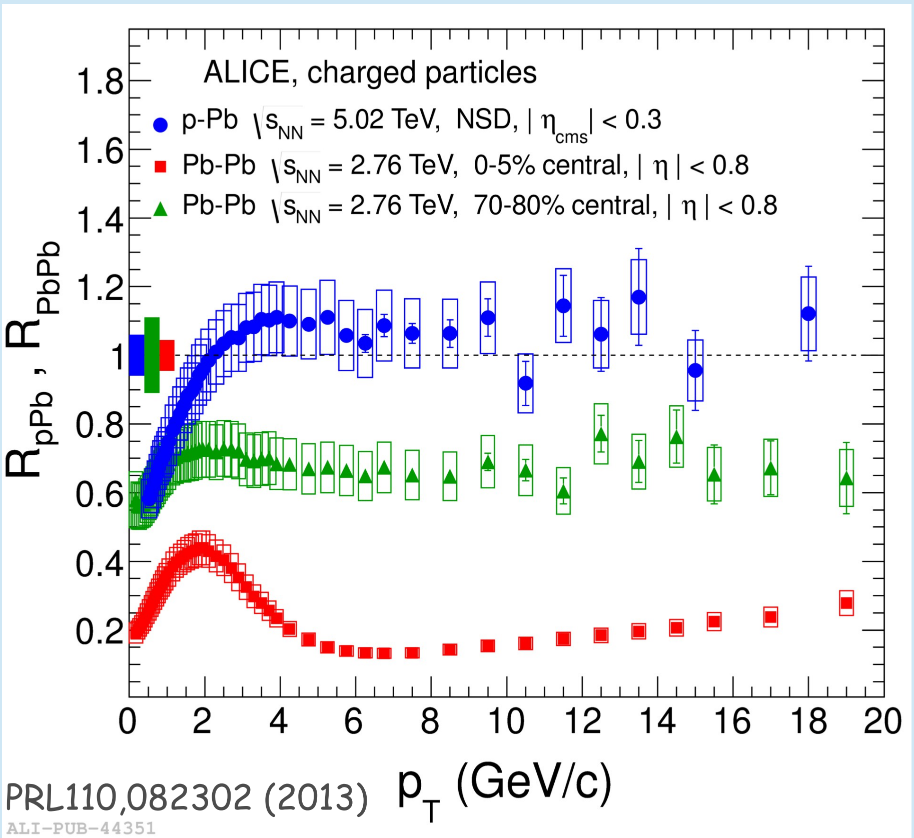
$(dN_{ch}/d\eta_{cms})/\langle Npart\rangle$ = 2.14 ± 0.17 (syst.)

- 16% lower than pp NSD
- consistent with inelastic pp collisions interpolated to $\sqrt{s_{NN}}$ = 5.02 TeV
- 84% higher than d-Au at $\sqrt{s_{NN}}$ = 0.2 TeV

- forward-backward asymmetry between proton and lead hemispheres: less particles in the proton direction
- most of the models that include shadowing or saturation predict the measured multiplicity values within 20%

p-Pb primary particles production

Does the initial state of the colliding nuclei play a role in the observed suppression of hadron production at high-p_T in Pb–Pb collisions?



PRL110,082302 (2013)

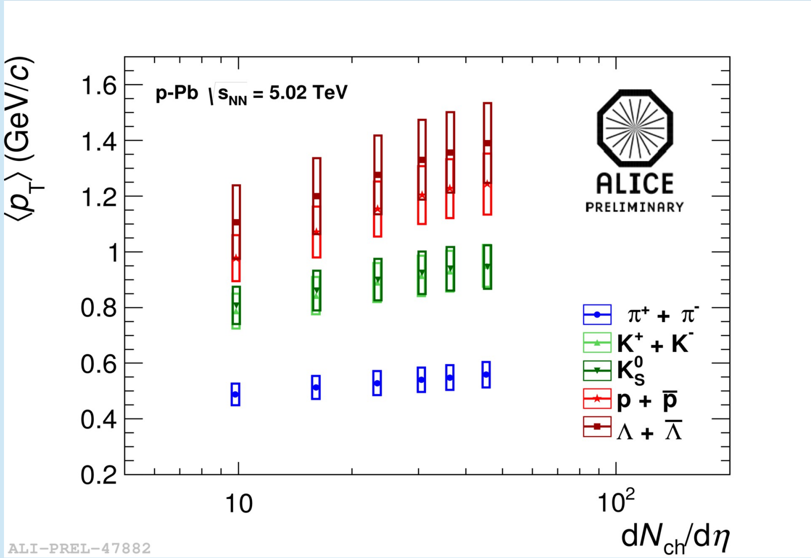
Nuclear modification factor R_{pPb}

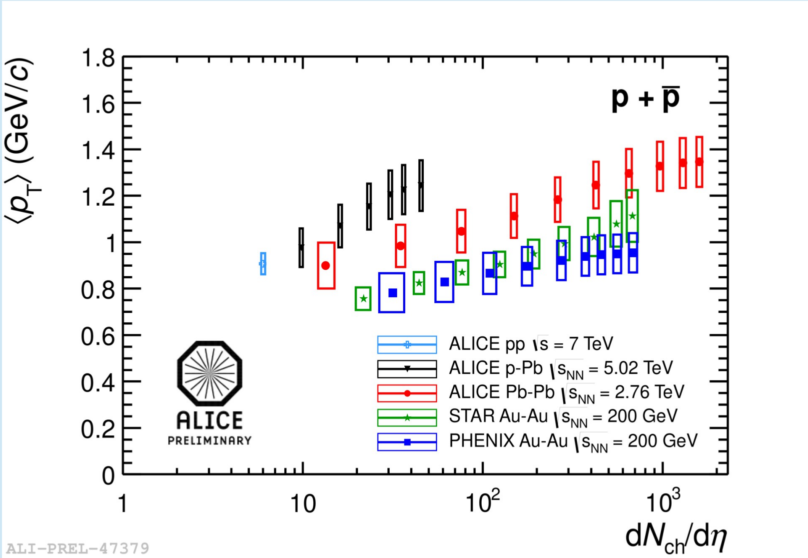
$$R_{\rm pPb}(p_{\rm T}) = \frac{{\rm d}^2 N^{\rm pPb}_{\rm ch}/{\rm d}\eta {\rm d}p_{\rm T}}{\langle T_{\rm pPb}\rangle {\rm d}^2\sigma^{\rm pp}_{\rm ch}/{\rm d}\eta {\rm d}p_{\rm T}}$$

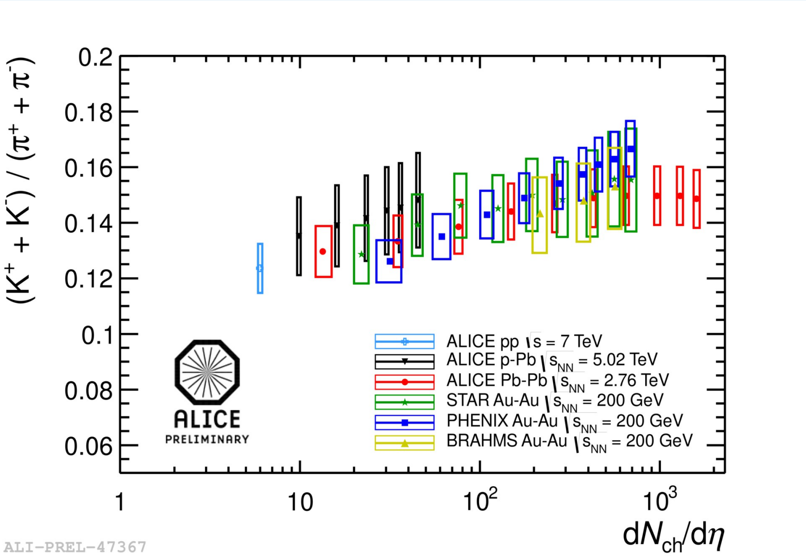
R_{pPb} = 1 for binary collision scaling

- R_{pPb} consistent with 1 for p_T>2 GeV/c -> strong suppression of hadron production at high p_T in Pb–Pb collisions is not due to initial-state effect but fingerprint of jet quenching in hot QCD matter
- R_{pPb} <1 at low p_T -> effect of gluon saturation/shadowing in the initial nuclear state + particle prod. dominated by soft processes (do not scale with Ncoll)

p-Pb: π, K, p, Λ, K_s^0 spectra

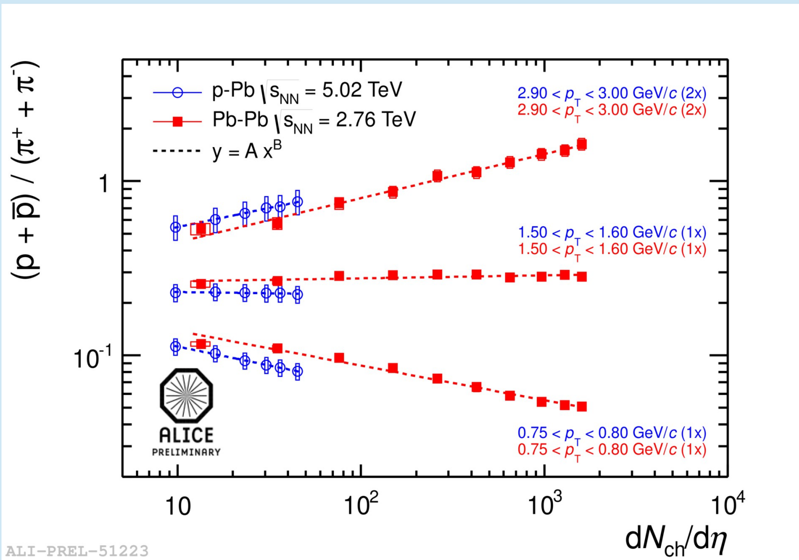


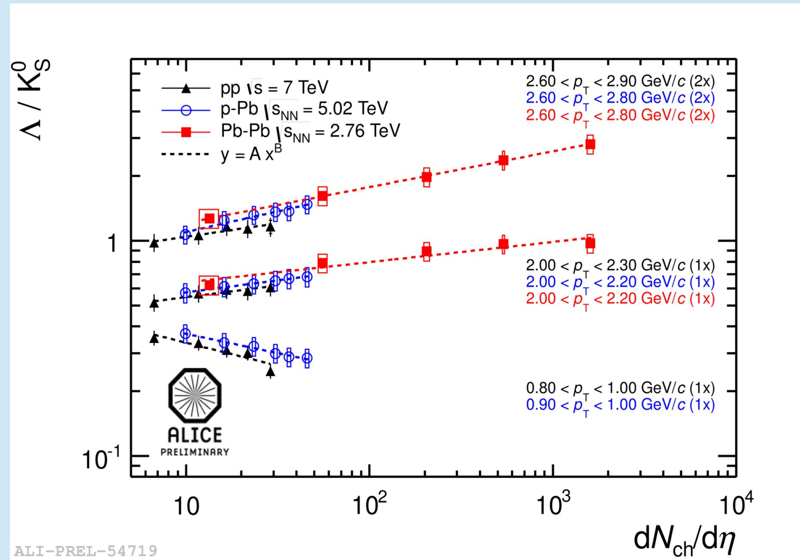




- Mass ordering of $\langle p_T \rangle$ increasing: stronger increase for heavier particles like in pp and Pb–Pb
- p-Pb values higher for similar Pb-Pb multiplicity → harder spectra
- p/π: no evolution from peripheral to central events
- K/π and Λ/π: small increase observed like in Pb–Pb, Au–Au and d–Au collisions -> reduced canonical suppression of strangeness production in larger freeze-out volumes or enhanced strangeness production in QGP

p-Pb: π, K, p, Λ, K_s^0 spectra

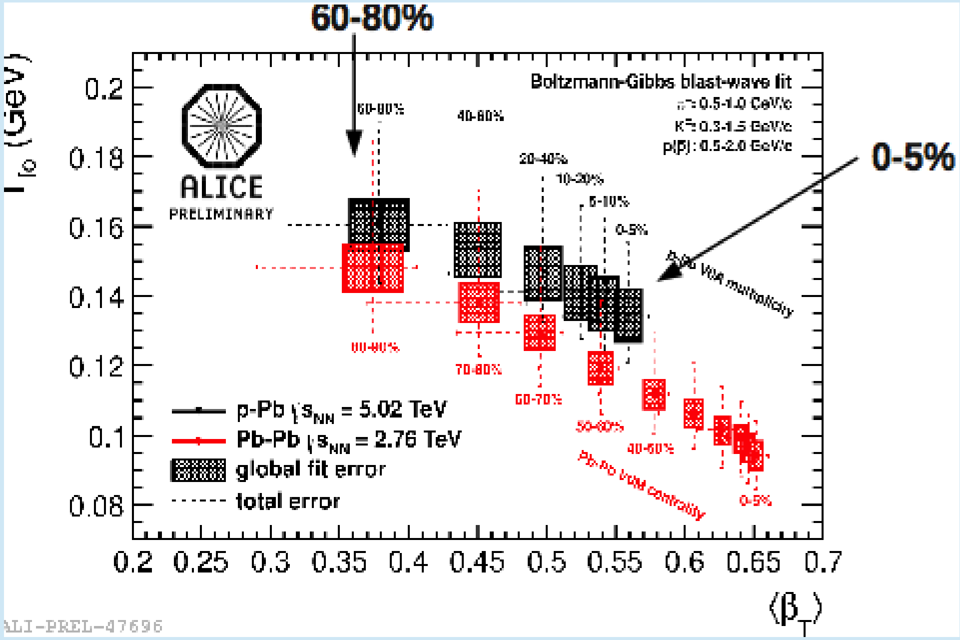


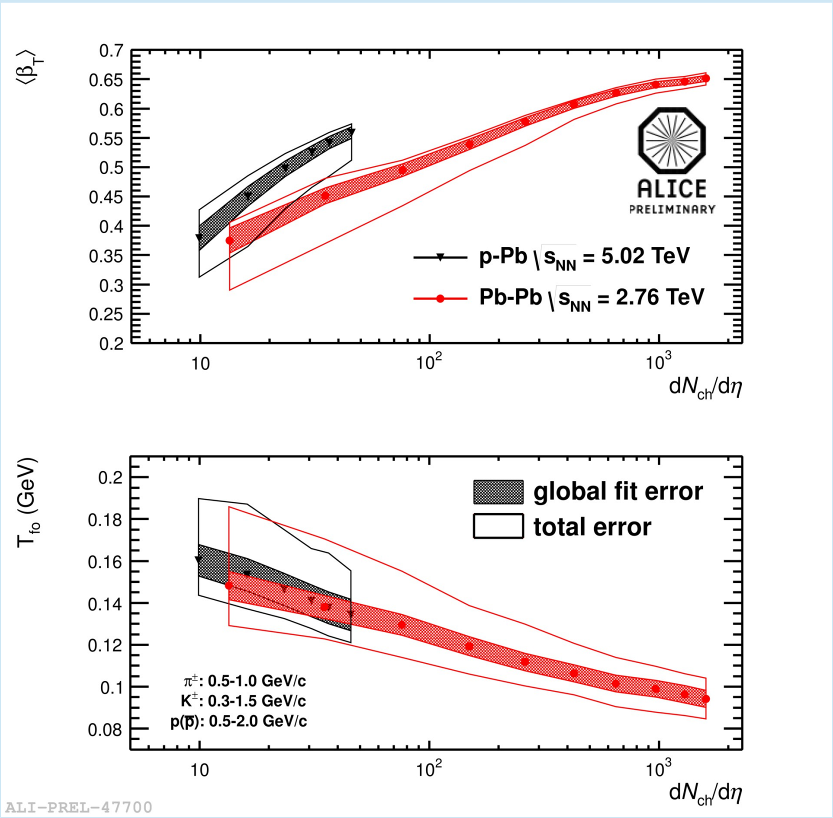


multiplicity dependence of p/π and Λ/K^0_s

(at given pT) independent of the colliding system

p-Pb: π, K, p, Λ, K_s^0 spectra





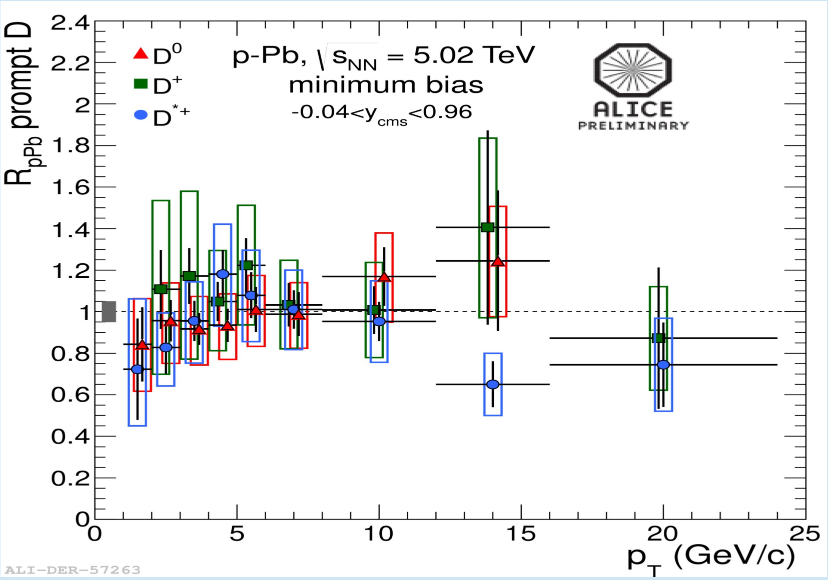
For the same multiplicity:

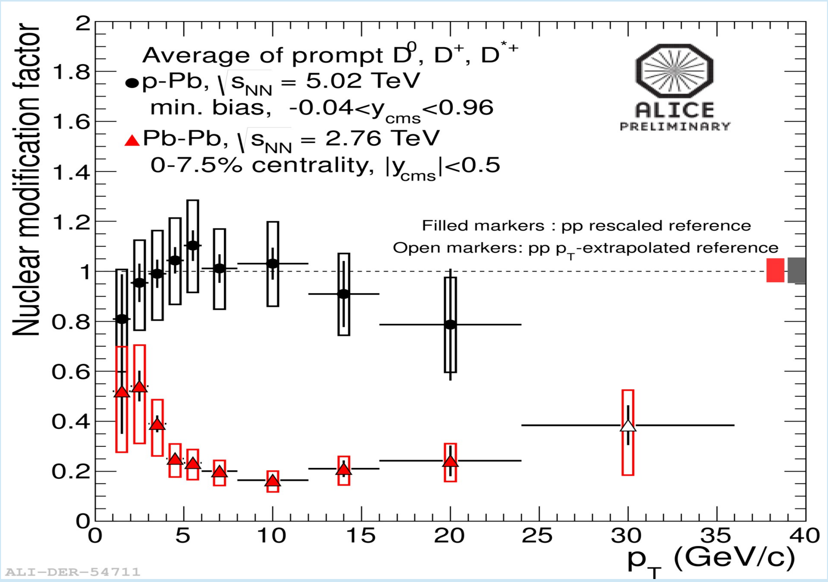
- T_{fo} similar in Pb-Pb and p-Pb
- $\langle\beta_T\rangle$ larger in p-Pb

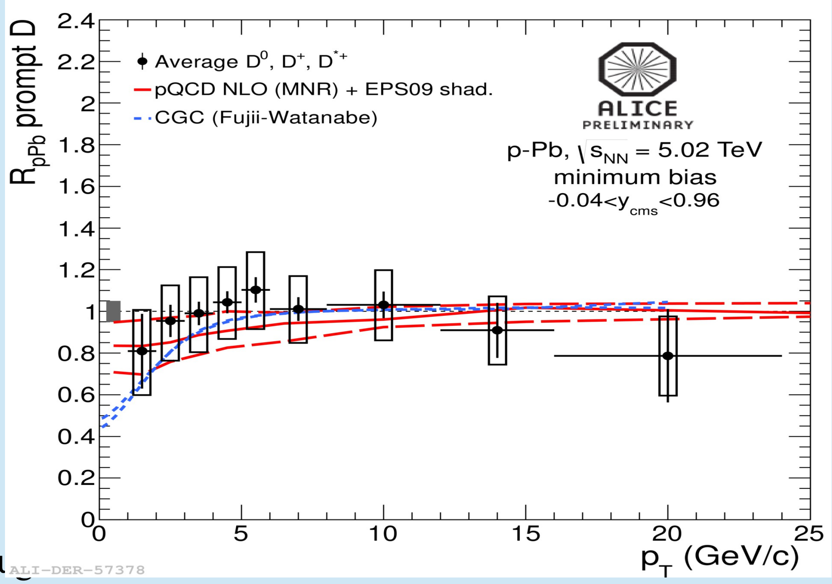
-> stronger collective flow for smaller system size?

Shuryak, arXiv:1301.4470 [hep-ph]

p-Pb: heavy flavours

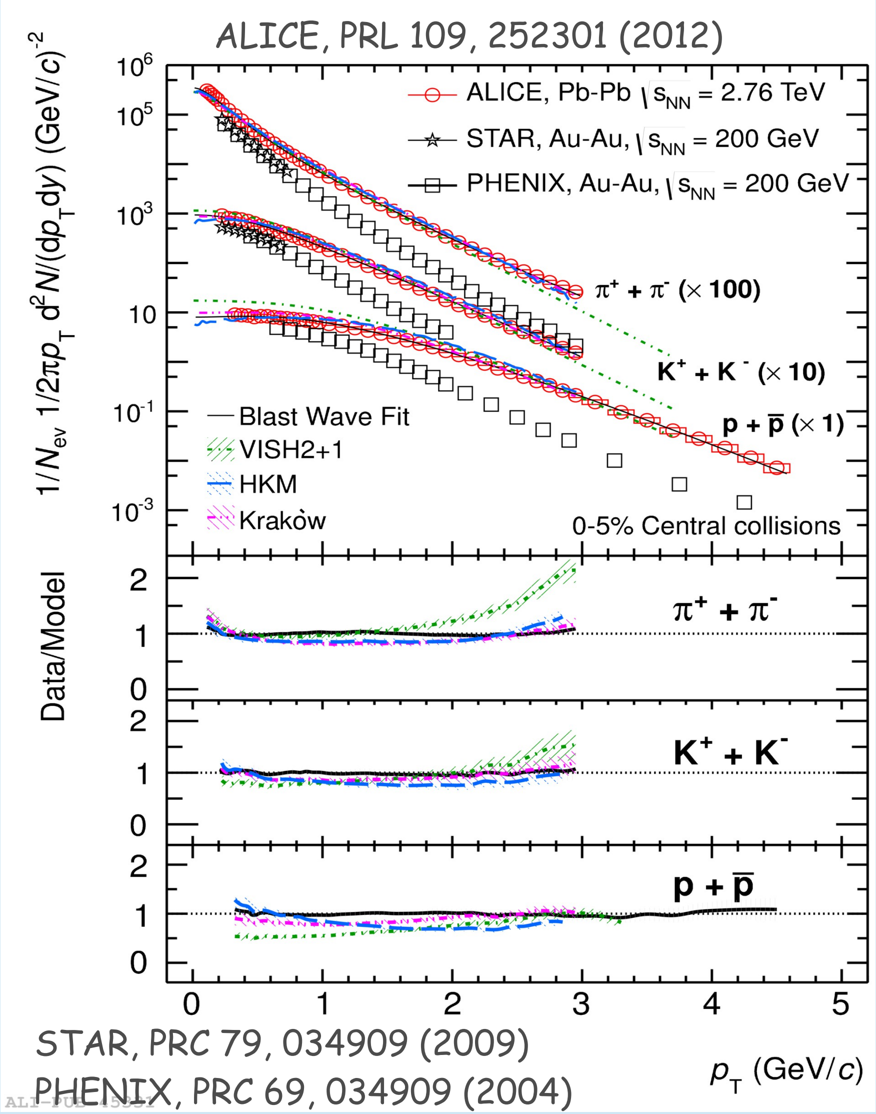






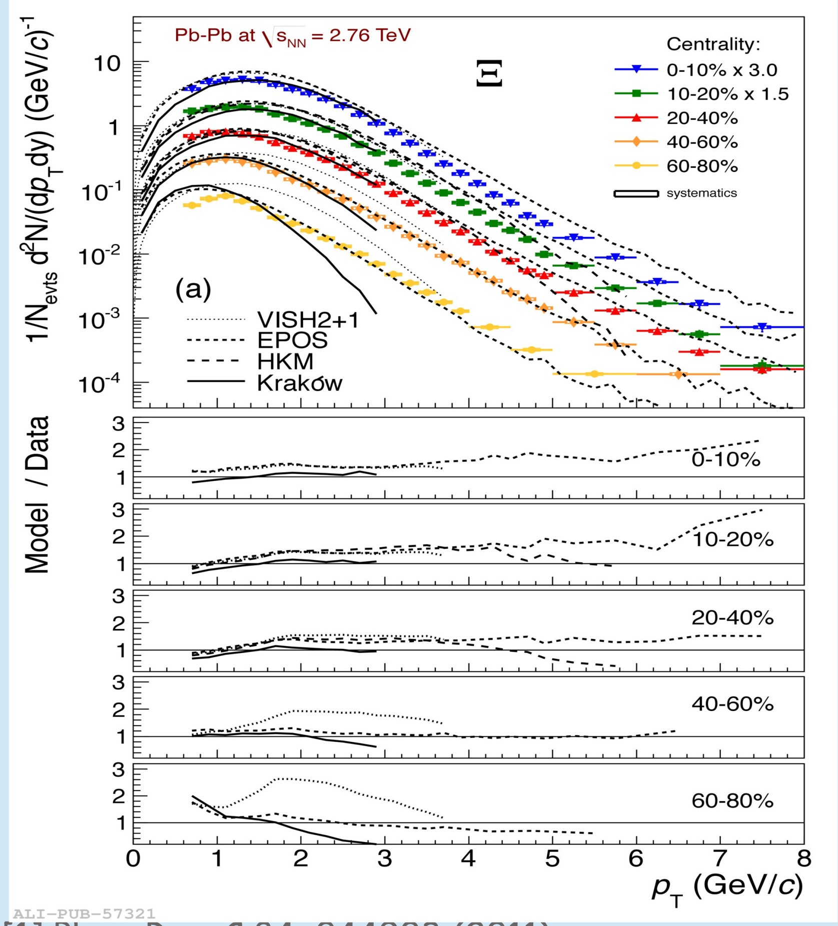
- R_{pPb} of D0, D+, D*+ and Ds compatible
- Expectation about initial state effects: shadowing, no energy loss
- R_{pPb} compatible with unity and well described by pQCD+EPS09 predictions (JHEP 0904 (2009) 065)
- Pb-Pb suppression is a final state effect

Pb-Pb: π, K, p spectra



- Harder spectra compare to RHIC -> stronger radial flow (in hydrodynamic models is a consequence of increasing particle density)
- Combined blast wave fit* :
  - $\langle \beta_T \rangle$ = 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*
  - T_{kin}= 95 ± 10MeV -> comparable with RHIC (sensitive to pion fit range due to contribution from resonance decays)

Pb-Pb: strangeness



Models:

- VISH2+1[1]: viscous hydrodynamic model
- HKM[2]: ideal hydro model, with hadron cascade (UrQMD)
- Kraków[3]: non-equilibrium corrections due to bulk viscosity in transition from hydrodynamics to particles
- EPOS[4]: incorporates hydrodynamics and models the interaction between high pT hadrons and expanding fluid, also use UrQMD as hadronic cascade model

- Kraków model provides a good description for both yields and shapes (pT < 3 GeV/c)
- EPOS gives the most successful description of spectra shape in a wider pT range

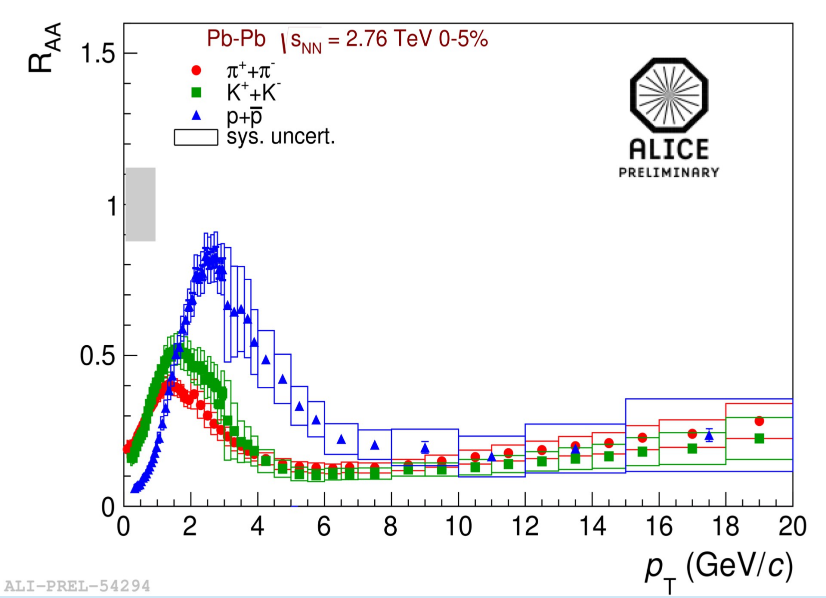
[1] Phys. Rev. C 84, 044903 (2011)

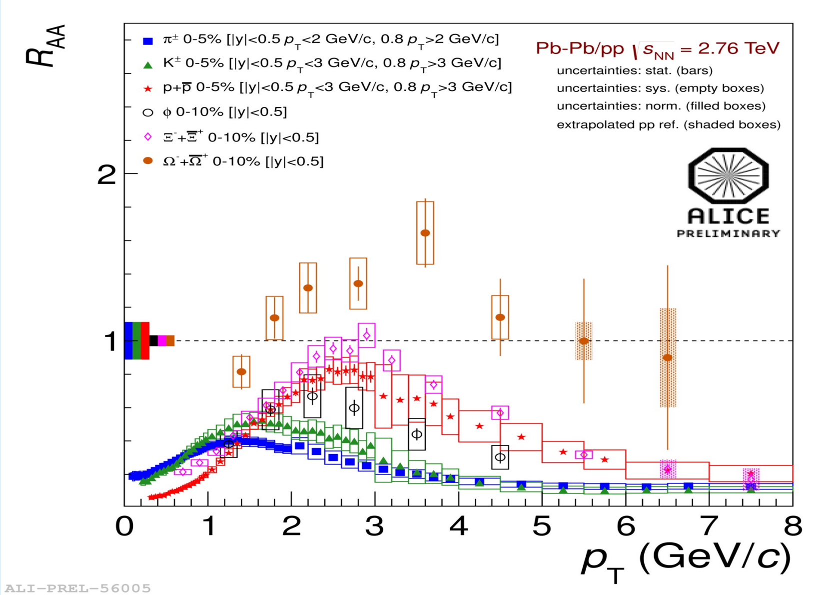
[2] J. Phys. G 38, 124059 (2011), 1204.5351 [nucl-th] (2012)

[3] Phys. Rev. C 85, 034901 (2012), Acta Phys. Pol. B 43, 4, 689 (2012)

[4] Phys. Rev. C 85, 064907 (2012), 1204.1394 [nucl-th], (2012) 1205.3379 [nucl-th] (2012)

Light flavour R_{AA}





- Mass ordering at mid-p_T
- At high p_T R_{AA} does not depend on particle's mass -> energy loss models should not show differential suppression for light species around 7 GeV/c
- Effect of strangeness enhancement on Ω (and Ξ)

Resonances in ALICE

Particle	Decay channel	Lifetime [fm/c]	pp@√s=900GeV	pp@√s=7TeV	PbPb@√s=2.76TeV
$\phi(1020)$	$K^+ + K^-$	45	published[1]	published[2,(3)]	paper in preparation[5]
$K^*(892)^0$	$\pi^\pm + K^\mp$	4.0		published[2]	paper in preparation[5]
$\rho(770)^0$	$\pi^\pm + \pi^\mp$	1.3		preliminary	
$\Delta(1232)^{++}$	$p + \pi^+$	1.6			
$\Sigma(1385)^\pm$	$\Lambda + \pi^\pm$	5.7		paper in preparation[4]	
$\Lambda(1520)^0$	$p + K^-$	13			
$\Xi(1530)^0$	$\Xi^- + \pi^+$	20		paper in preparation[4]	

1) K.Aamodt et al., EPJ, *C71* (2011) 1594

2) B.Abelev et al., EPJ, *C72* (2012) 2183

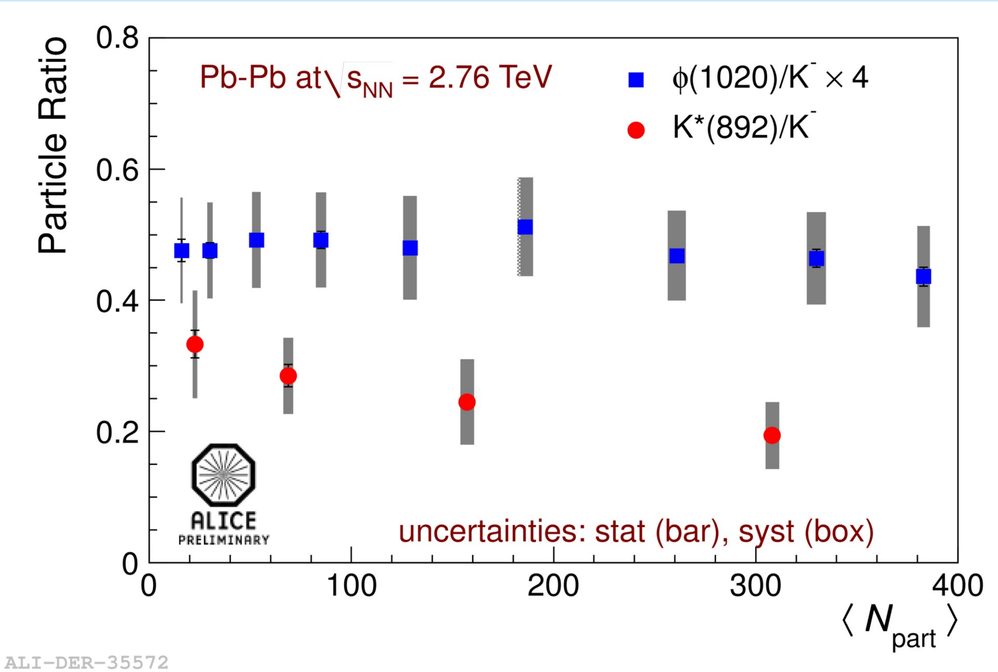
3) B.Abelev et al., PLB 710 (2012) 557-568

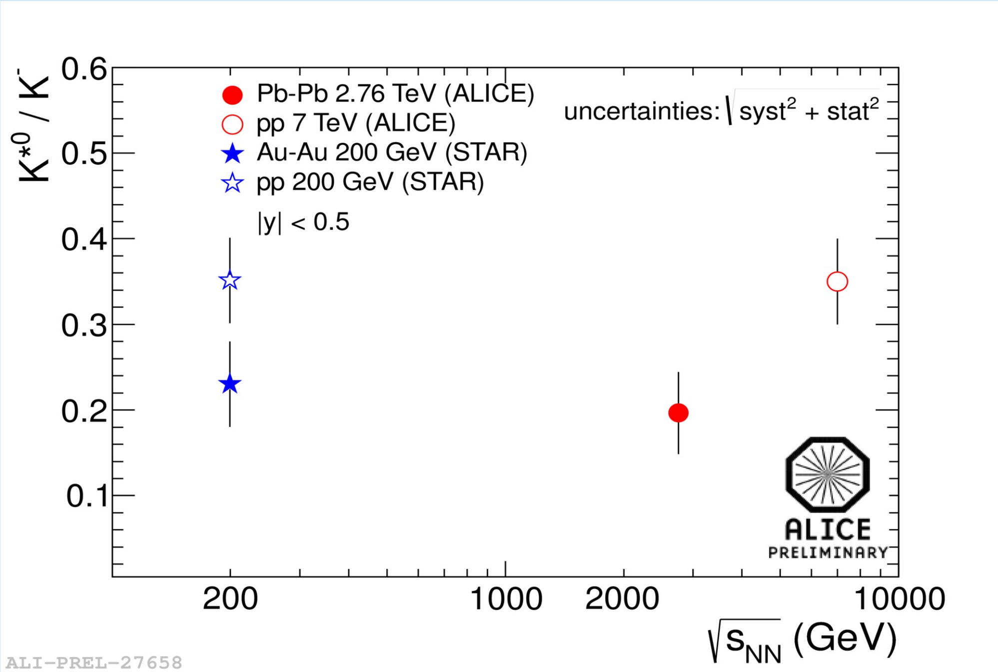
4) Production of ⅀(1385)± and X(1530)0 in proton-proton collisions at $\sqrt{s} = 7$ TeV with ALICE at the LHC, to be submitted

5) K(892)^0 and f(1020) resonances in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV at ALICE, to be submitted

Pb-Pb: Resonances

$\phi(1020) \rightarrow K^+ + K^-$
$K^*(892)^0 \rightarrow \pi^\pm + K^\pm$

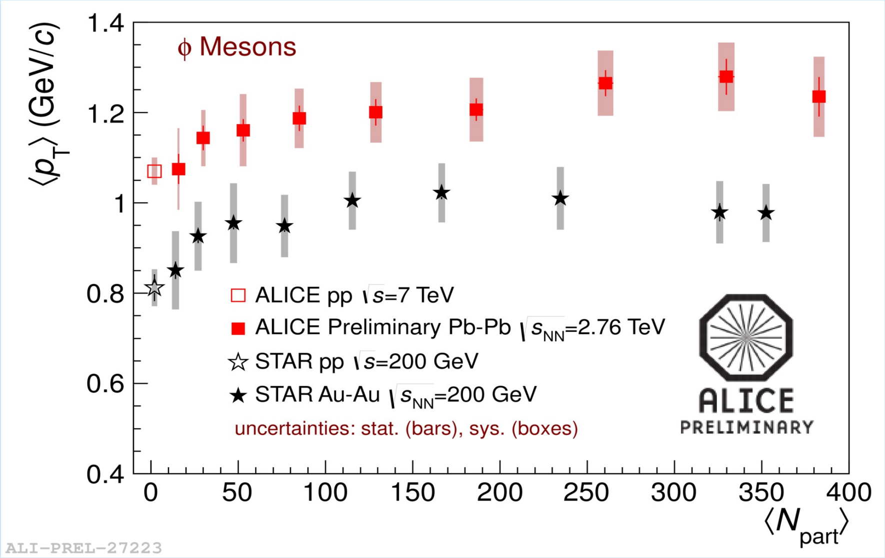


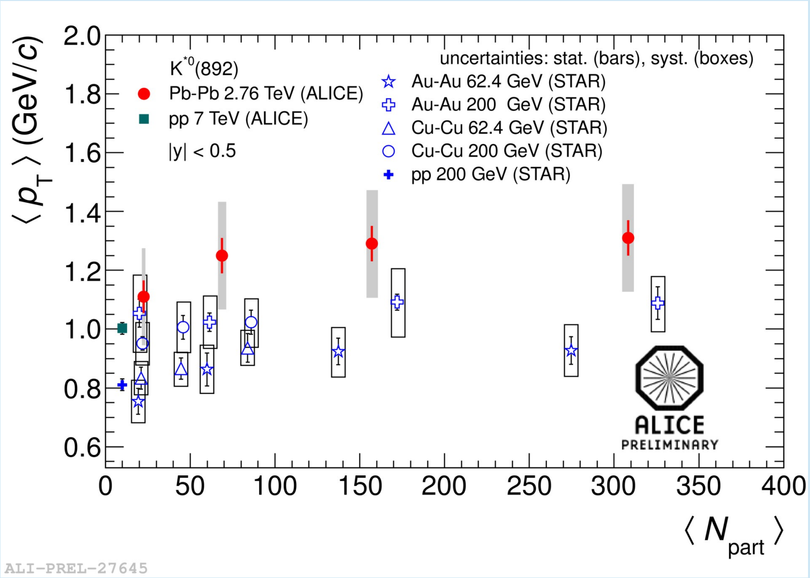


- Φ/K independent on centrality -> production by kaon coalescence in hadronic phase disfavoured -> Φ not affected by medium due to long lifetime
- K*/K slightly decrease with increase in centrality and $(K^*/K)_{AA} < (K^*/K)_{pp}$ -> interaction in hadronic medium
  - re-scattering of π (invariant mass info lost) ?
  - Thermal model (Torrieri and Rafelski, Phys.Lett.B509,239(2001)) with T=164 MeV + re-scattering predicts K^{0*}/K data for lifetime hadronic phase ≥ 4.5 fm/c

	Lifetime (fm/c)
K^{*0}	4
ϕ	45

Resonances in ALICE

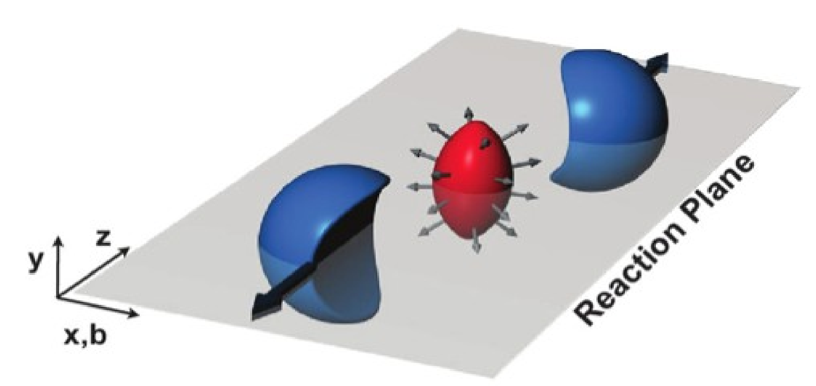


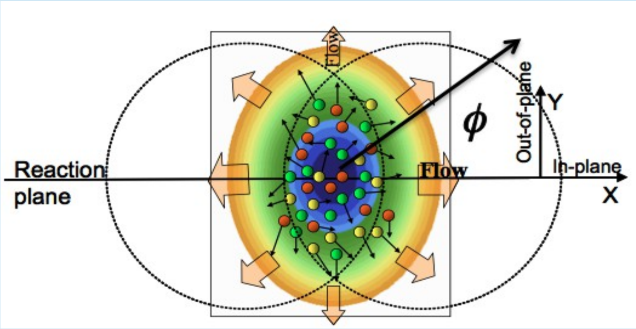


Radial flow

QGP anisotropic flow

Initial spatial azimuthal anisotropy of overlap region of colliding nuclei in non central collisions is converted, via interactions, into anisotropy in momentum space
Magnitude of anisotropy depends on centrality -> impact parameter determines eccentricity





Anisotropy from fourier expansion of particle yield

$$\frac{dN}{Nd\phi} \propto 1 + 2v_2 \cos\left(2(\phi - \Psi_{RP})\right) + \textit{higher harmonics } (v_3, v_4, \ldots)$$

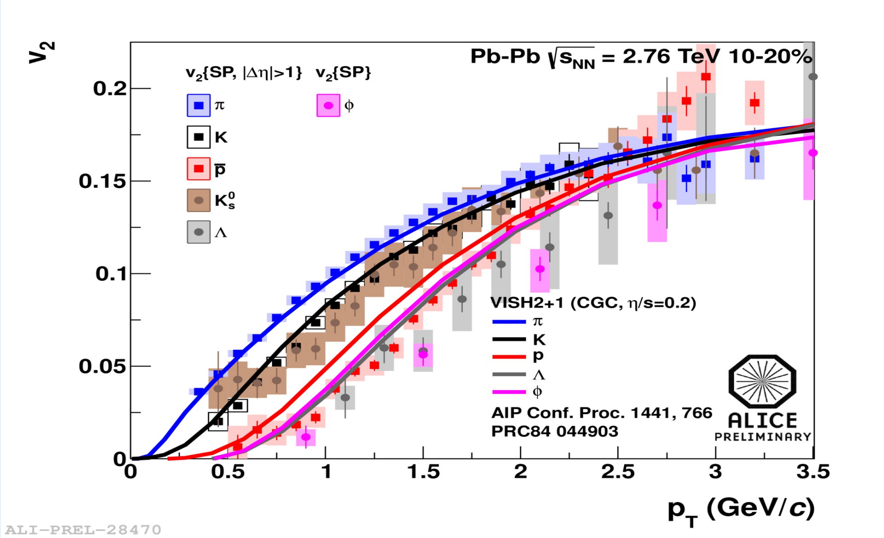
$$v_n = \langle \cos[n(\phi - \Psi_R)] \rangle$$

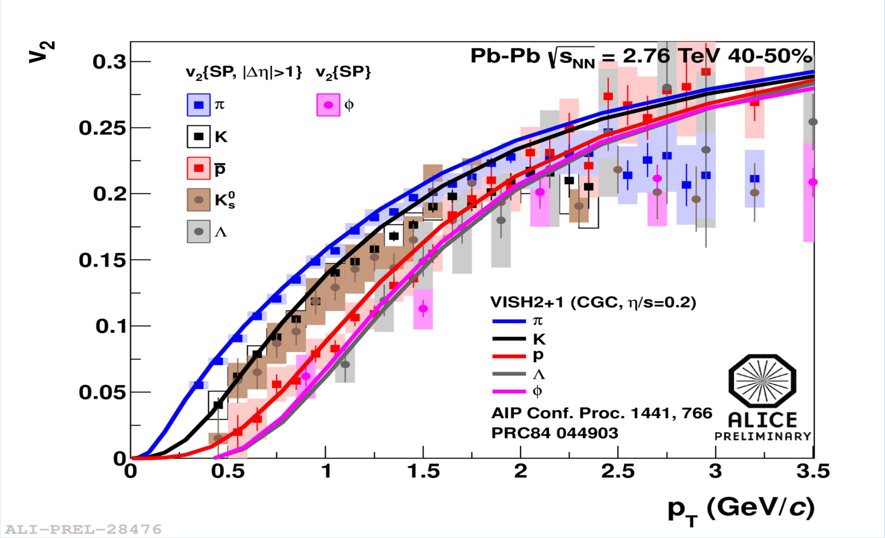
- v1 = directed flow
- v2 = elliptic flow (strength of collectivity)
- v3 = triangular flow

Initial shape fluctuations dependent by η/s (viscosity)

Hydrodynamic models seem to favour a low value of η/s at both RHIC and LHC energies

Elliptic flow

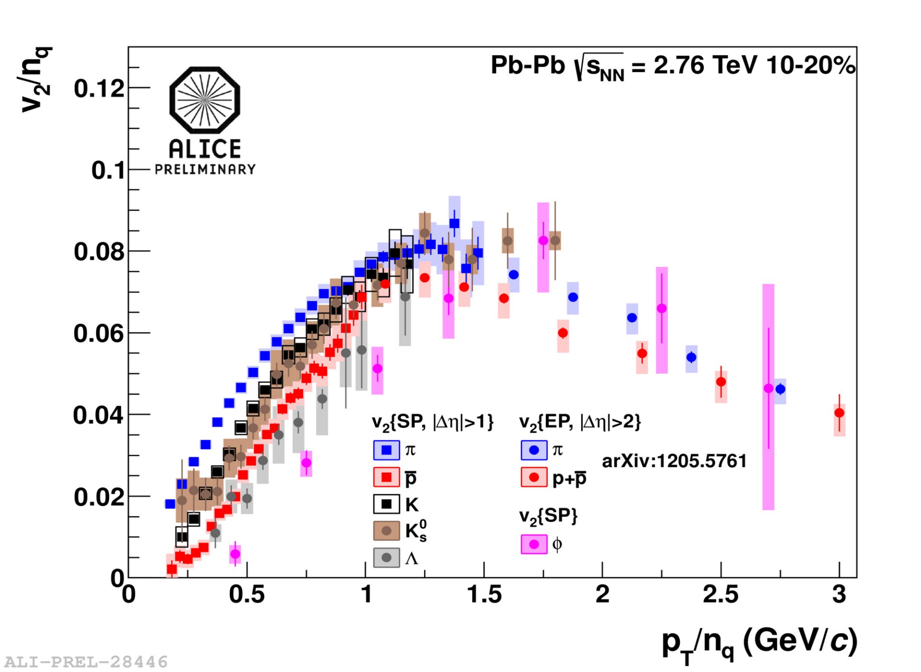


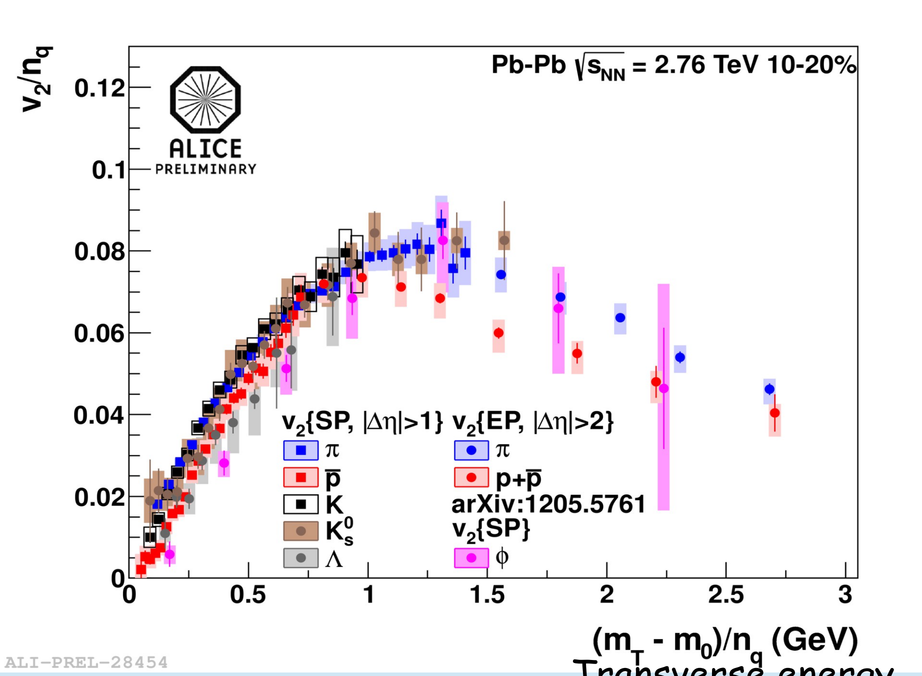


- Mass ordering
- Centrality dependence
- Mass splitting at LHC larger than at RHIC consistent with larger radial flow
- Comparison with viscous-hydro predictions
  - good agreement with VISH2+1 * (η/s=0.2) at low p_T in peripheral collisions but problem for heavier particles especially in central collisions
  - adding hadronic rescattering (UrQMD) after the hydro stage reproduces better v2

*Shen et al., PRC 84, 044903 (2011)

Elliptic flow



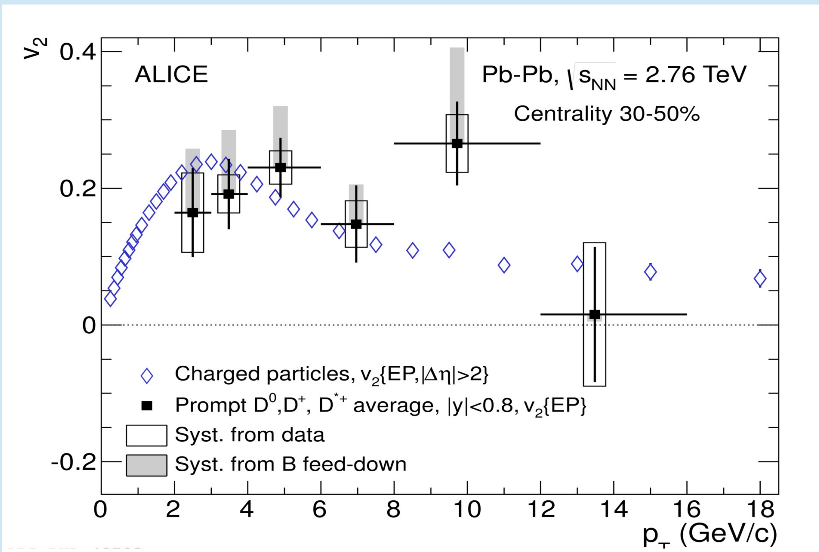


Transverse energy

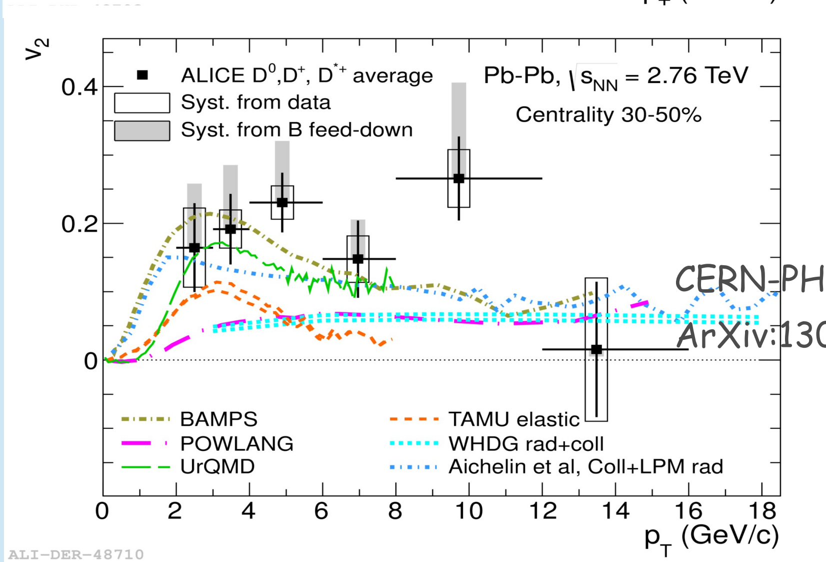
Mesons and baryons seem to scale differently with NCQ

v2 scales better with transverse energy

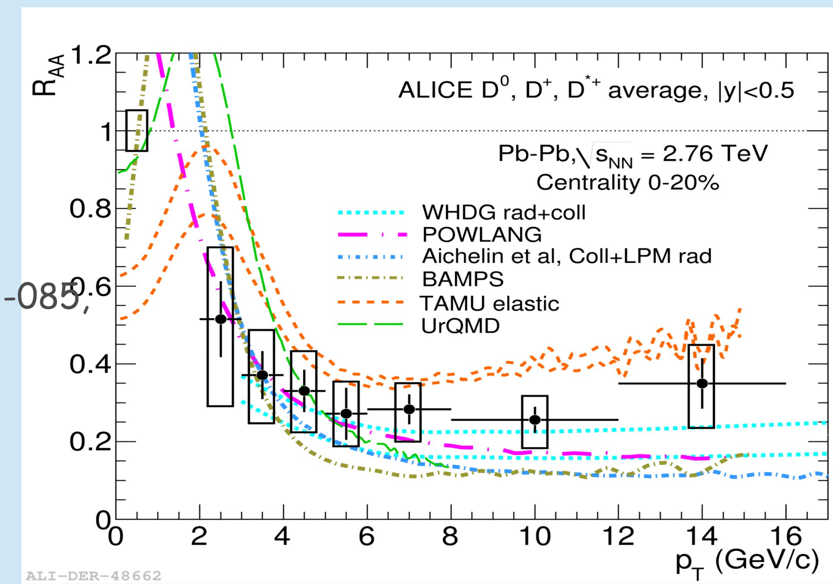
Pb-Pb: heavy flavours



- Non zero D mesons v2
- D meson v2 comparable with charged hadron v2 -> indication of charm thermalization in the medium
- Simultaneous description of D meson R_{AA} and v2 → understanding of heavy quark transport coefficients of the medium (challenging for models)



CERN-PH-EP-2013-085, ArXiv:1305.2707



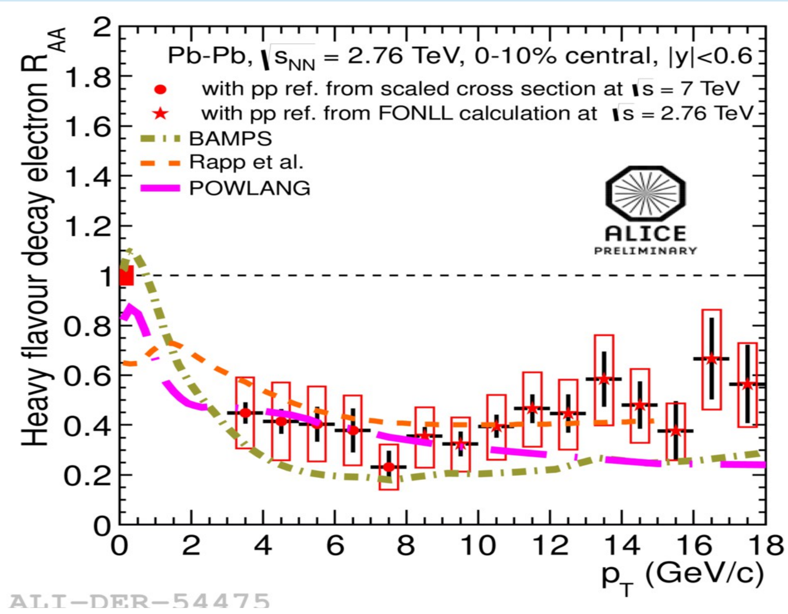
BAMPS: Uphoff et al. arXiv:1112.1559., O. Fochler, J. Uphoff, Z. Xu and C. Greiner, J. Phys. G38 (2011) 124152.

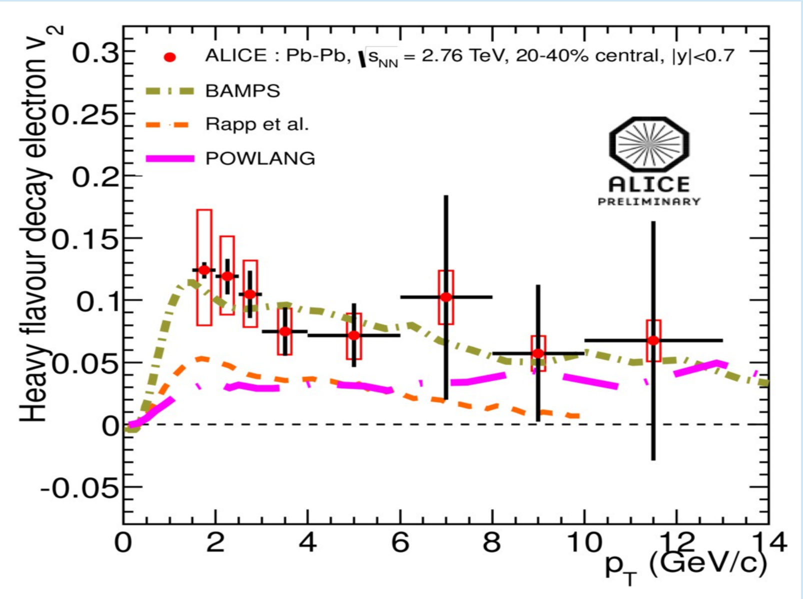
Aichelin et al. Phys. rev. C 79 (2009) 044906,

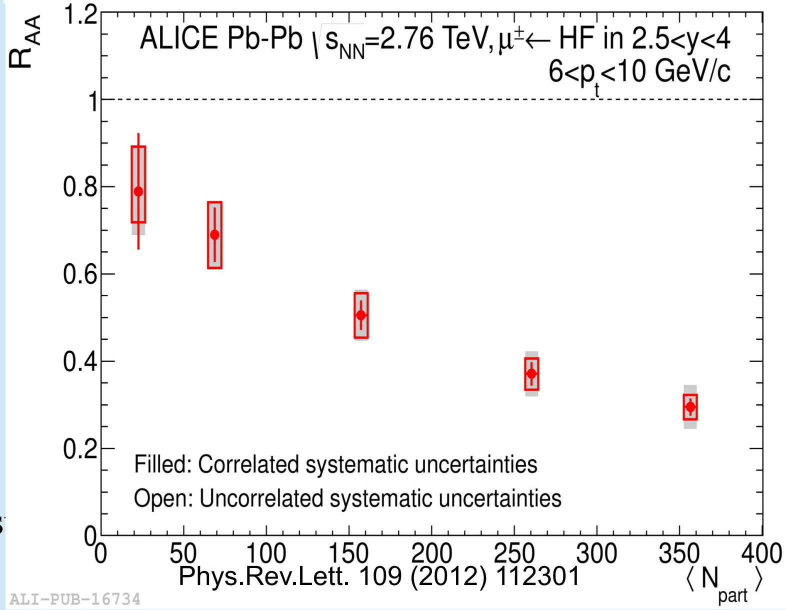
W.A. Horowitz et al. J. Phys. G38, 124064 (2011).,W. A. Horowitz and M. Gyulassy, J. Phys. G38 (2011) 124114.

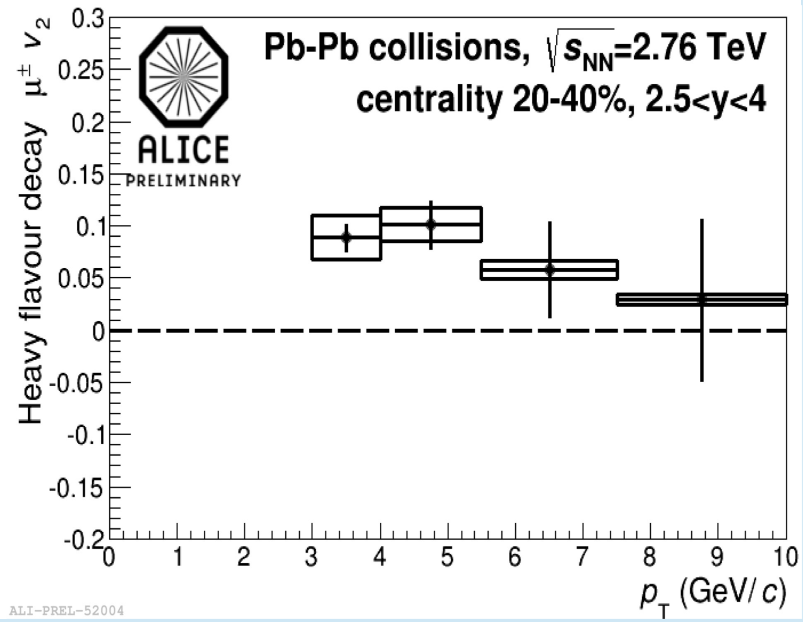
W. M. Alberico et al. Eur. Phys. J. C 71, 1666 (2011). M. He, R.J Fries and R. Rapp, arXiv:1204.4442 [nucl-th]

Heavy flavour decay leptons

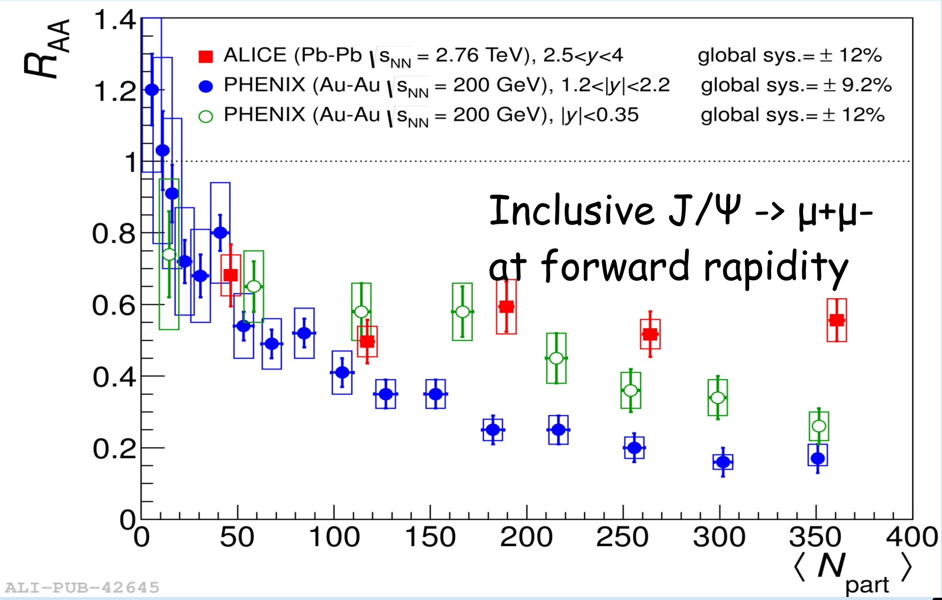


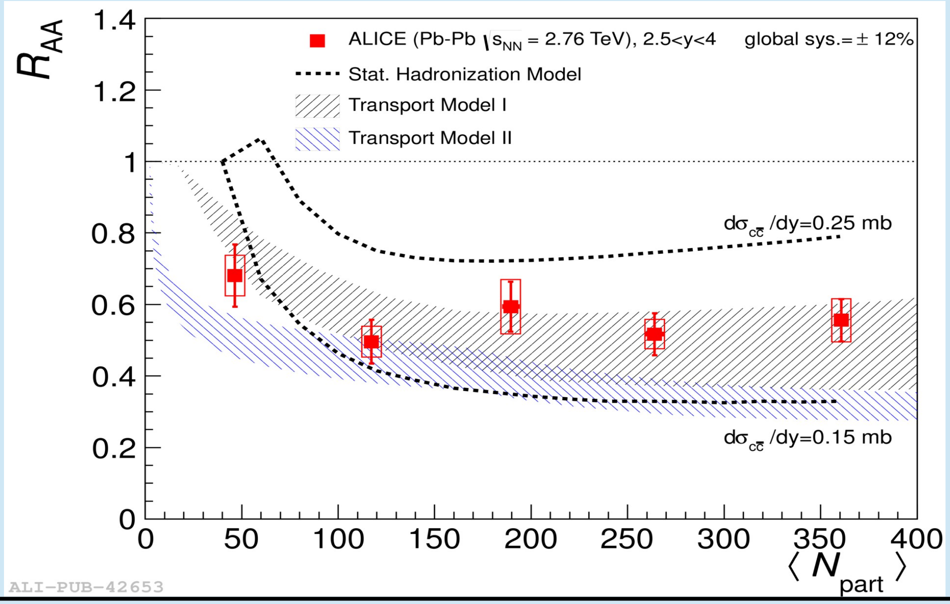






J/Ψ suppression

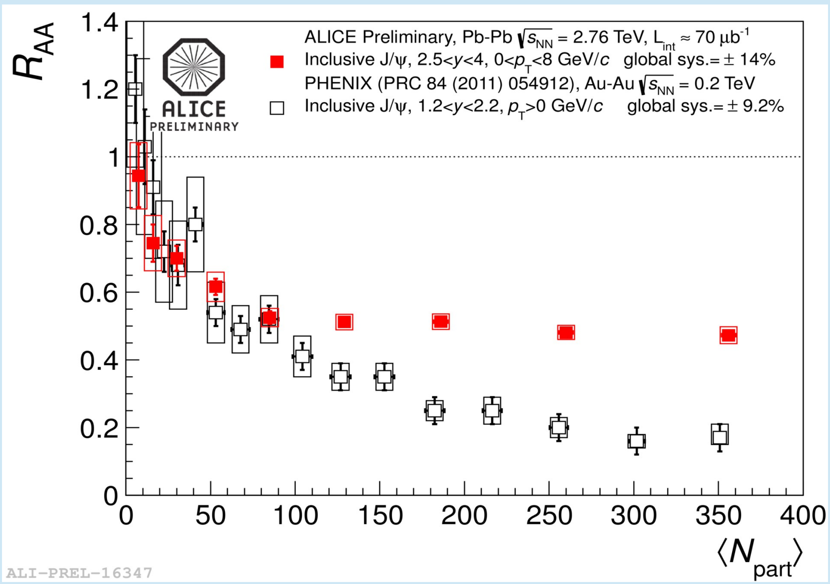


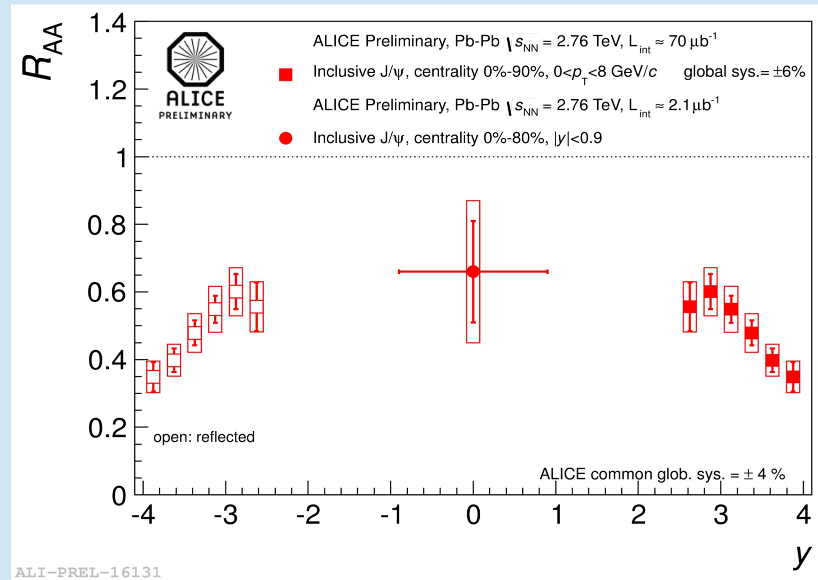


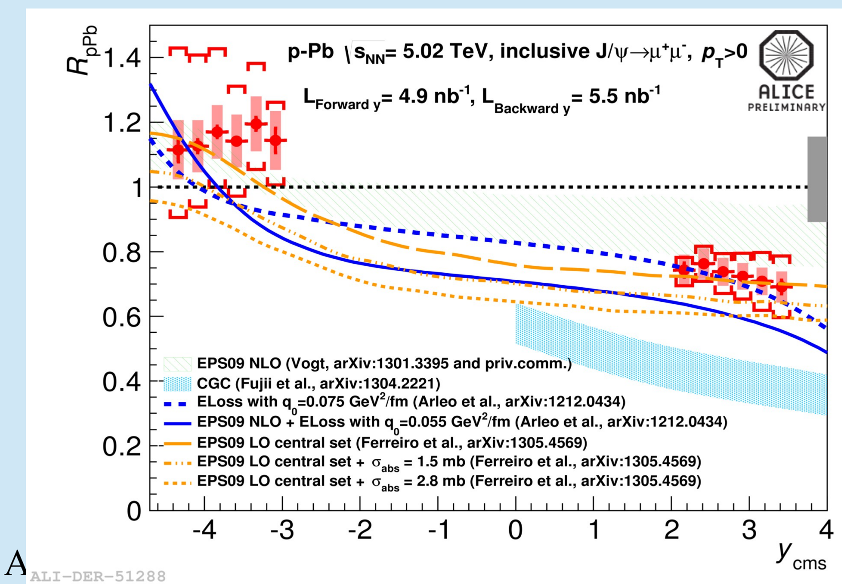
- No centrality dependence
- ALICE R_{AA}~3 times bigger than RHIC one at N_{part} > 180
- $R_{AA}^{0-80\%}$ = 0.545 ± 0.032(stat) ± 0.083 (syst)
- Inclusive J/Ψ ~ 10% B feed down

- ALICE data vs models that include J/Ψ regeneration component from deconfined charm quarks in the medium
- Stat. hadronization and transport models (full (partial) J/Ψ production from charm quarks in the QGP phase) can describe the data
- More precision in the CNM effects and in open charm cross section needed

J/Ψ suppression







Pb-Pb: No centrality dependence for N_{part} > 70

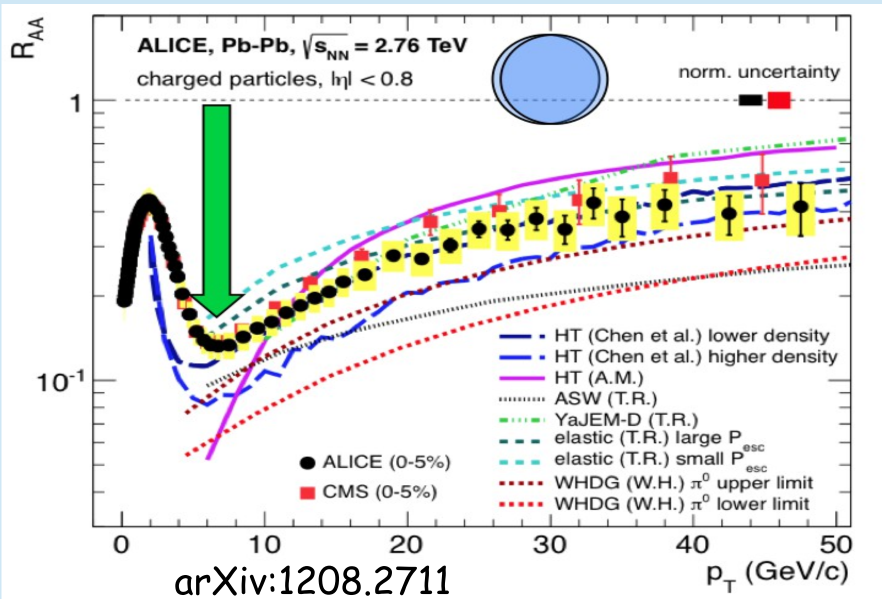
R_{AA} decreases with rapidity -> density of charm quark grows from forward to mid rapidity -> J/Ψ production from charm quarks in QCD phase

p-Pb: J/ψ production decreases with respect to pp collisions from backward to forward rapidity.

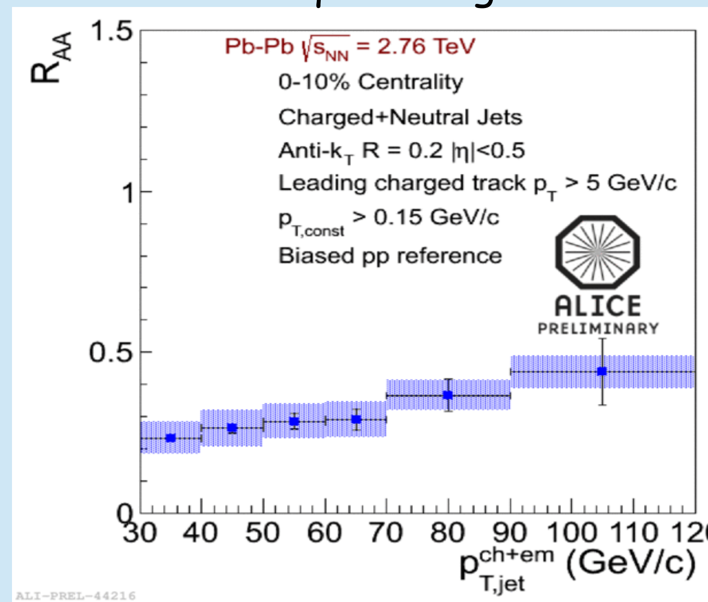
p-Pb: Data are in agreement with EPS09 NLO predictions (shadowing) and energy loss models, but not with CGC model

Jet quenching

single particle suppression



Jet quenching



Large suppression in charged-particles up to 50 GeV/c

Maximum factor: 7 at ~8 GeV/c

Qualitatively described by models with parton energy loss by medium-induced gluon radiation

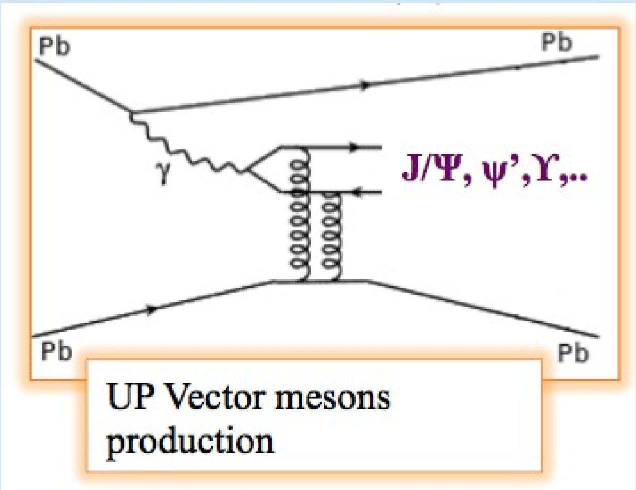
Jet yield suppressed by factor 3-5 -> consistent with single particle suppression, taking into account fragmentation

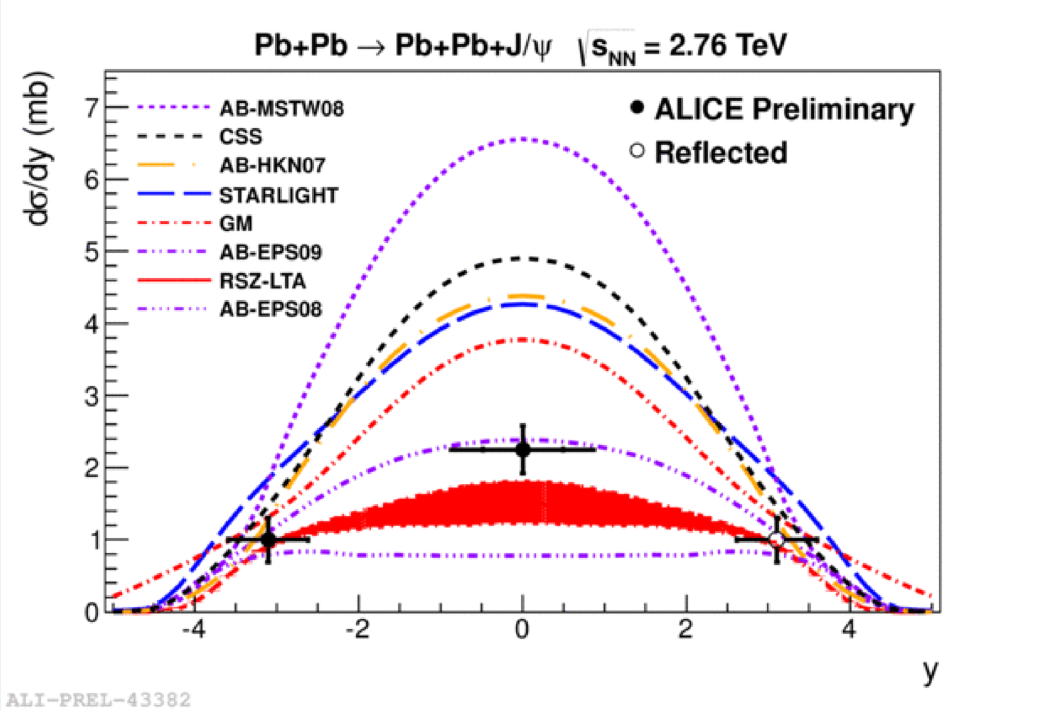
Suggests that "lost" energy is radiated at large angles, outside the jet (otherwise jets would be less suppressed than single particles)

J/Ψ photoproduction in UPC

J/ψ photoproduction in Ultra-Peripheral Collisions: Pb+γ -> Pb+J/ψ

probes nuclear gluon density, poorly known at low Bjorken-x (down to ~10^{-5})





Best agreement with models that include nuclear gluon shadowing; consistent with the recent EPS09 parameterization