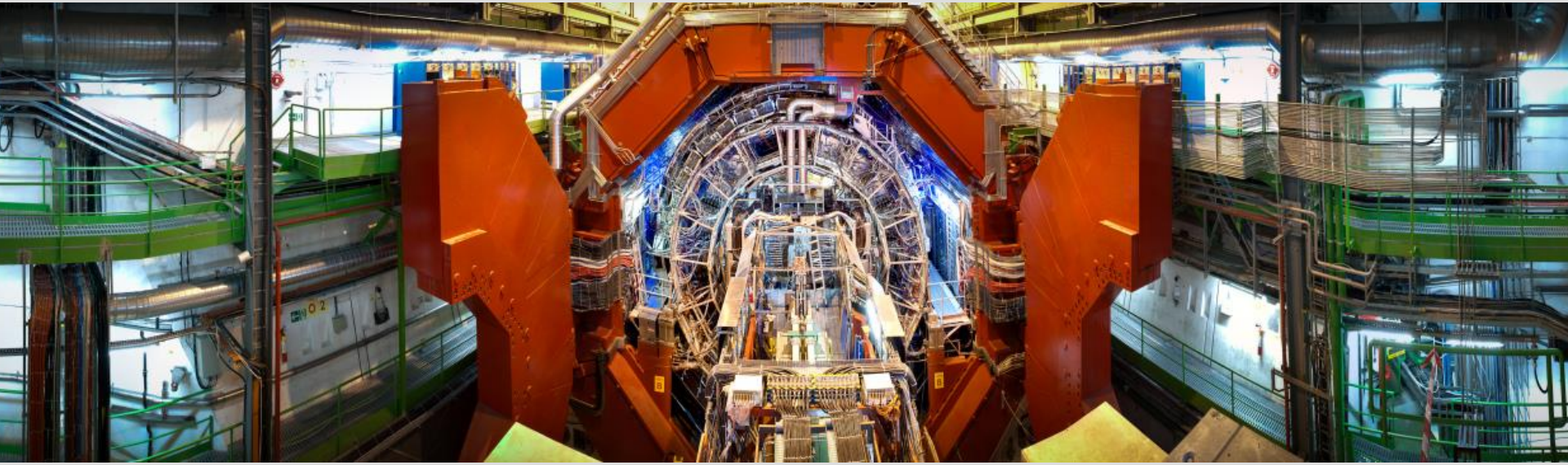


Helmut Oeschler

University of Heidelberg

For the ALICE Collaboration

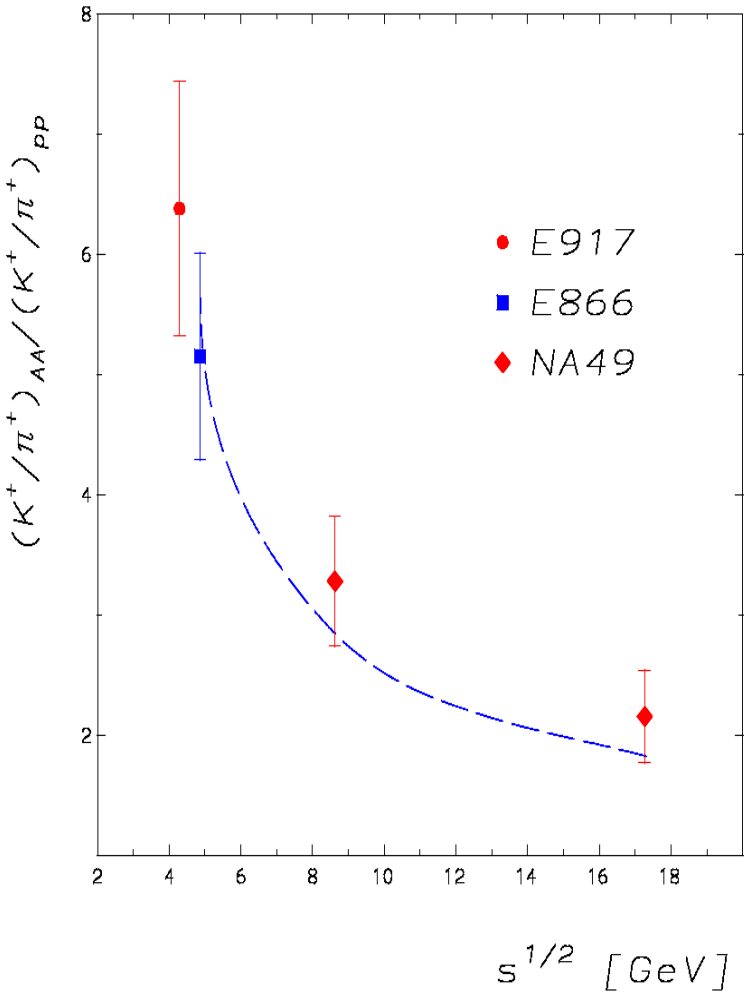
ALICE

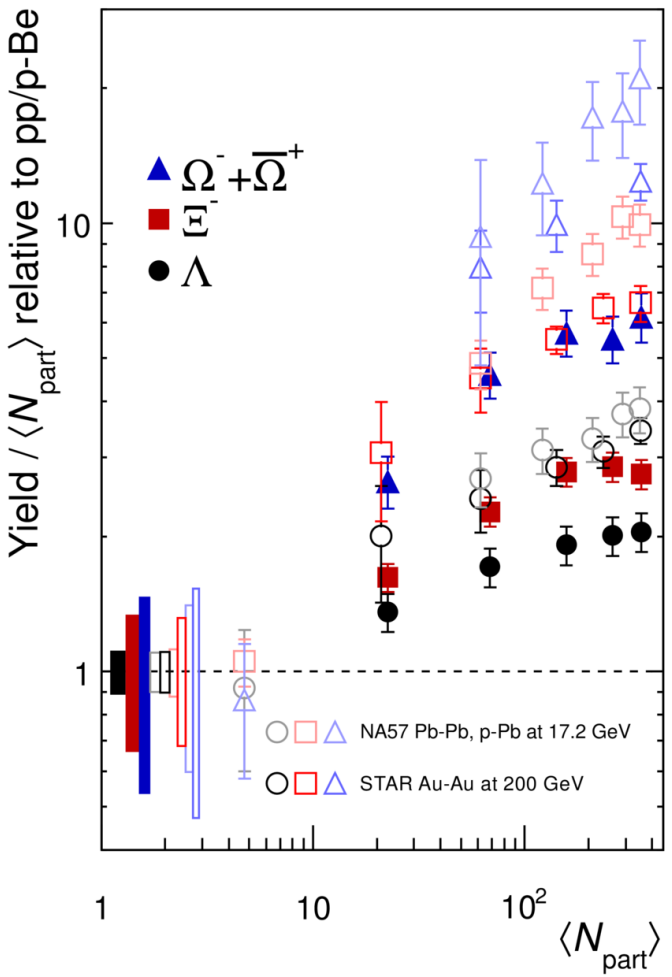
WWND-2014, April 7th, 2014

Outline

- Strangeness enhancement at LHC
- Comparison pp and heavy-ion collisions
- Chemical and kinetic freeze out vs. $\sqrt{s}$
- Do d, 3He and hypertritons fit in a thermal picture?
- Baryon-meson ratios: quark recombination or ?
- D_s vs. D mesons, are u, d, s „thermal“ when c is present?

Strangeness Enhancement PL B728 (2014) 216





SPS

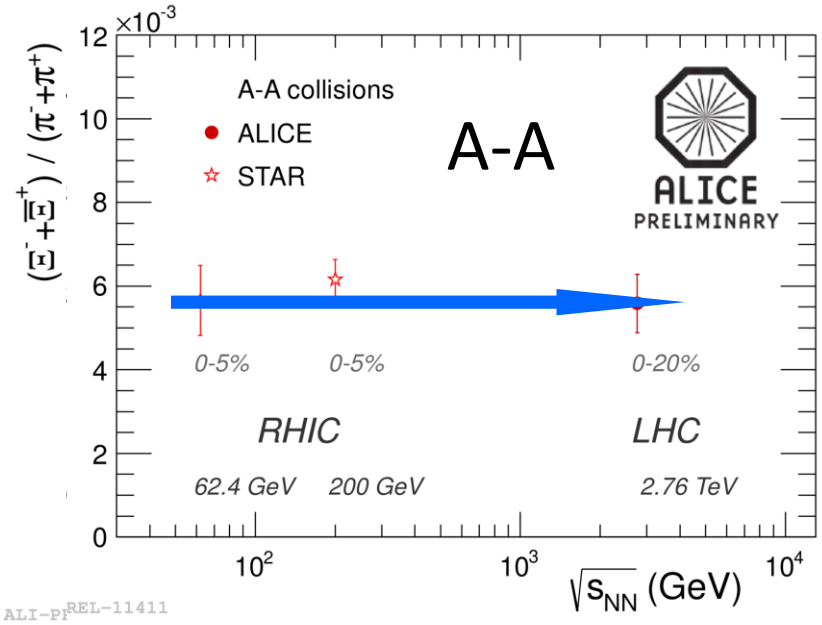
RHIC

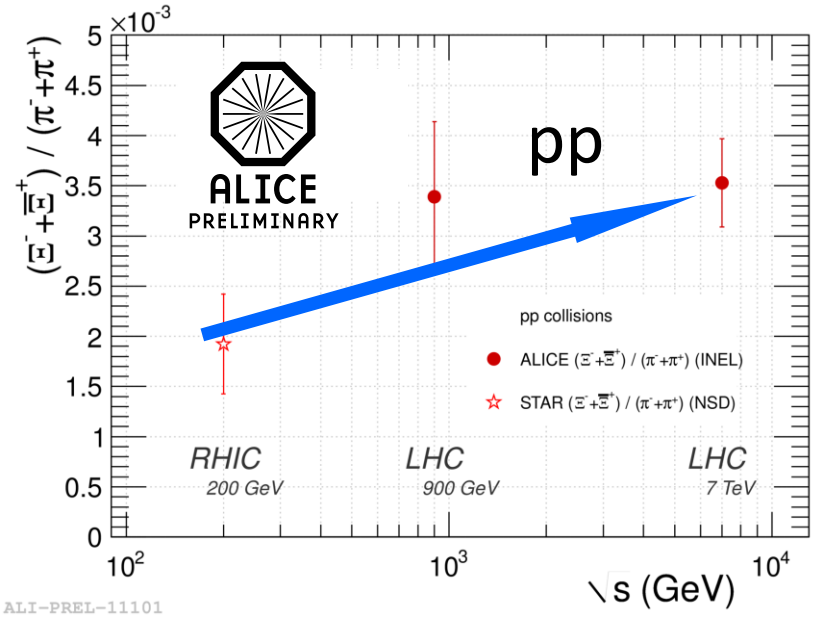
LHC

ALI-DER-57382

What causes the decrease? An increase in pp or a decrease in Pb-Pb

Strangeness in pp and Pb-Pb





In HIC, the ratio Ξ/π remains constant, while in pp it rises!

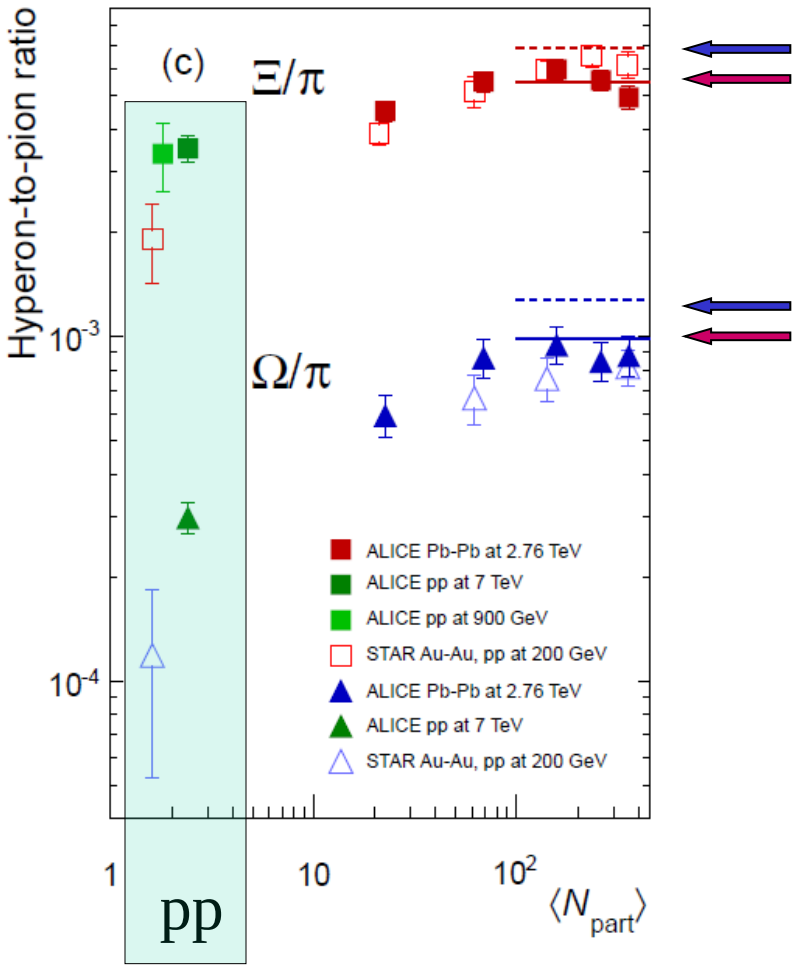
Enhancement well explained by thermal model!

No sign for QGP per se!

Centrality Depedence of Multistrange

ALICE Coll.

PL B728 (2014) 216

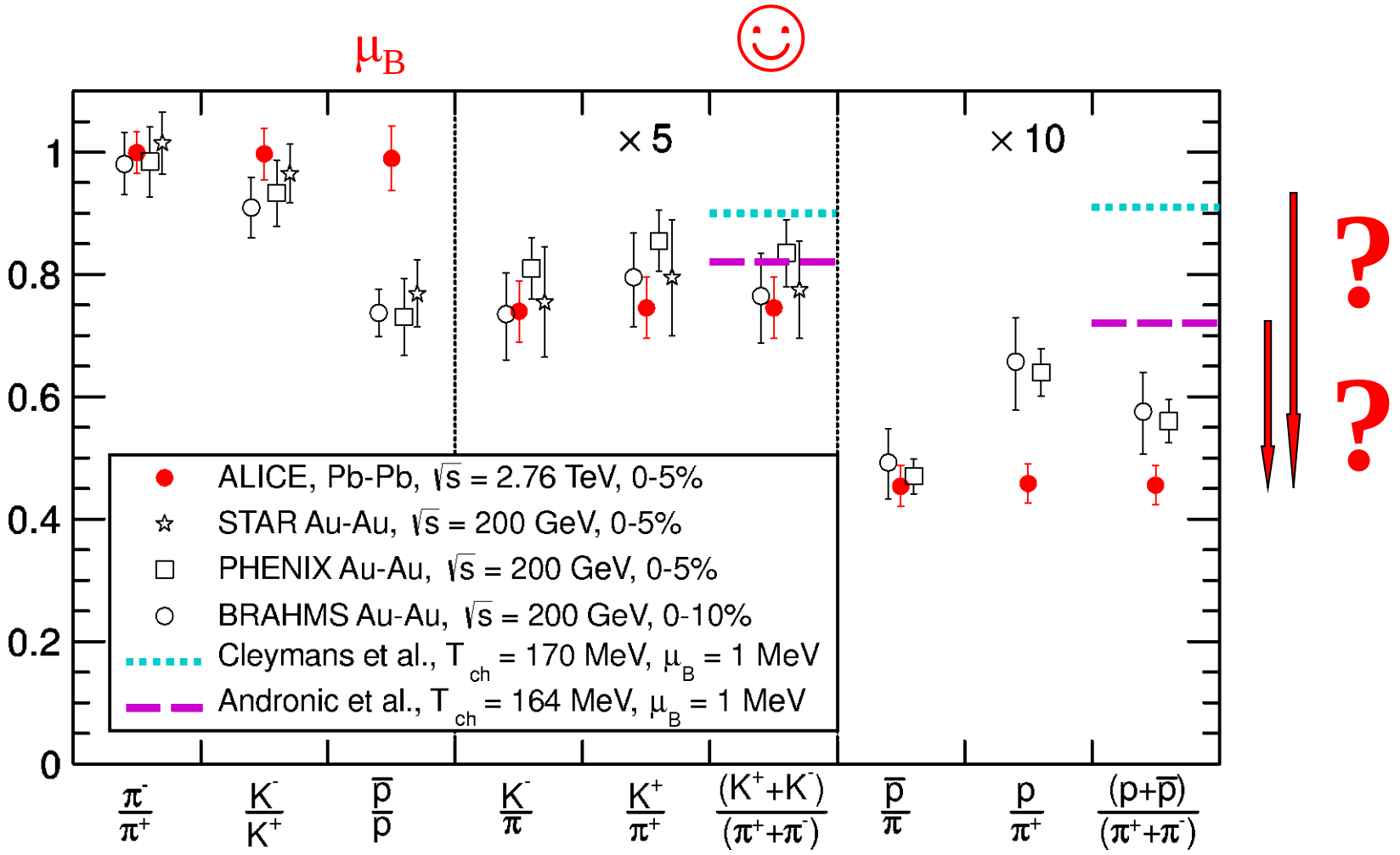


Predictions with

T = 170 MeV (J. Cleymans et al.)

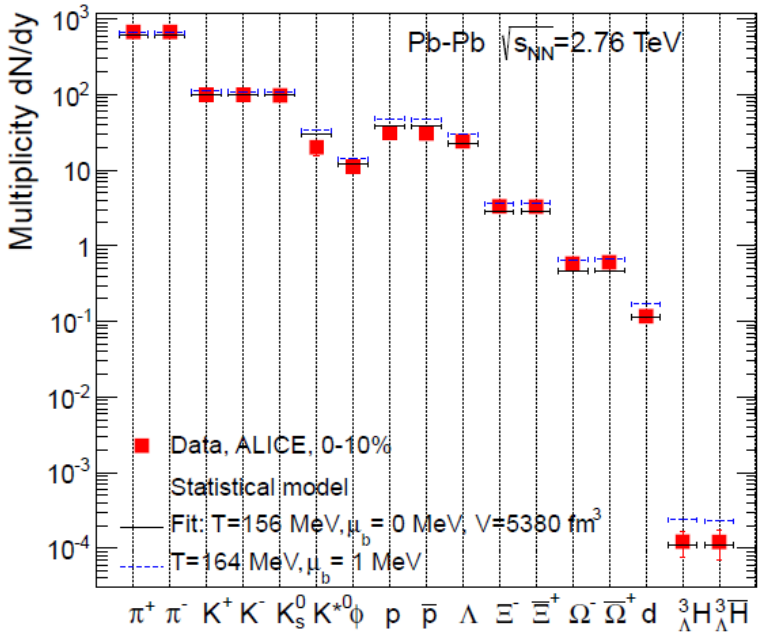
T = 164 MeV (A. Andronic et al.)

Particle ratios at LHC

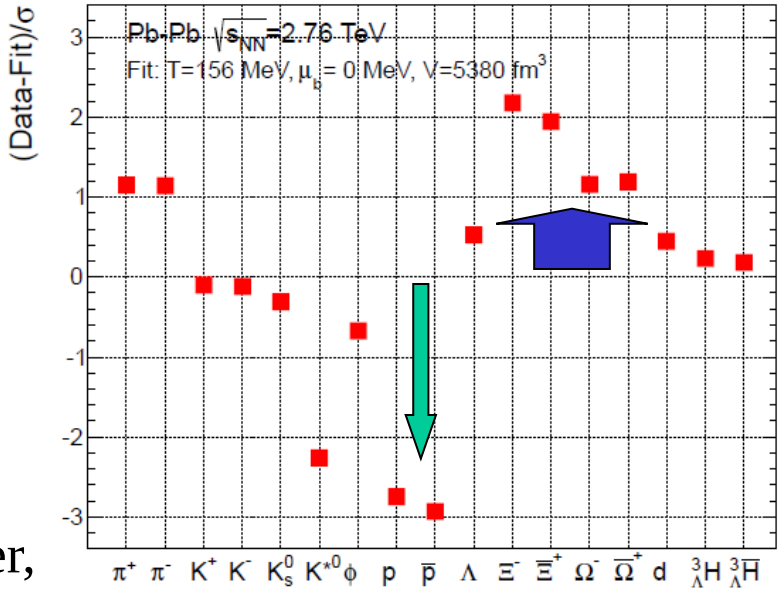


ALICE Coll., Phys. Rev. Lett. 109, 252301 (2012)

Central Pb-Pb Collisions at the LHC



The $\chi 2$ is reasonable, yet distinct deviations!

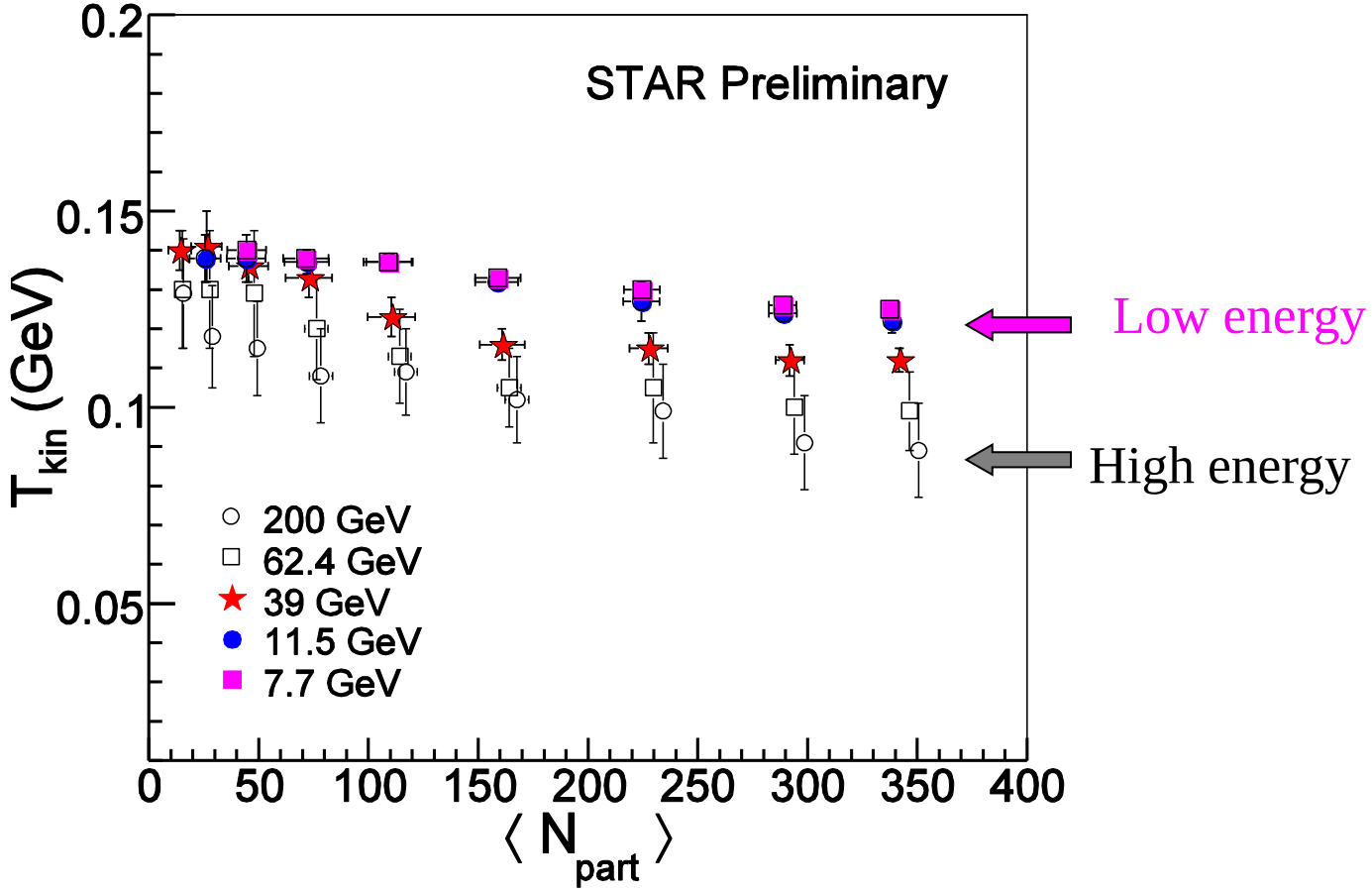


J. Stachel, A. Andronic, P. Braun-munzinger, SQM2013, arXiv: 1311.4662

Thermal fits in central Pb-Pb

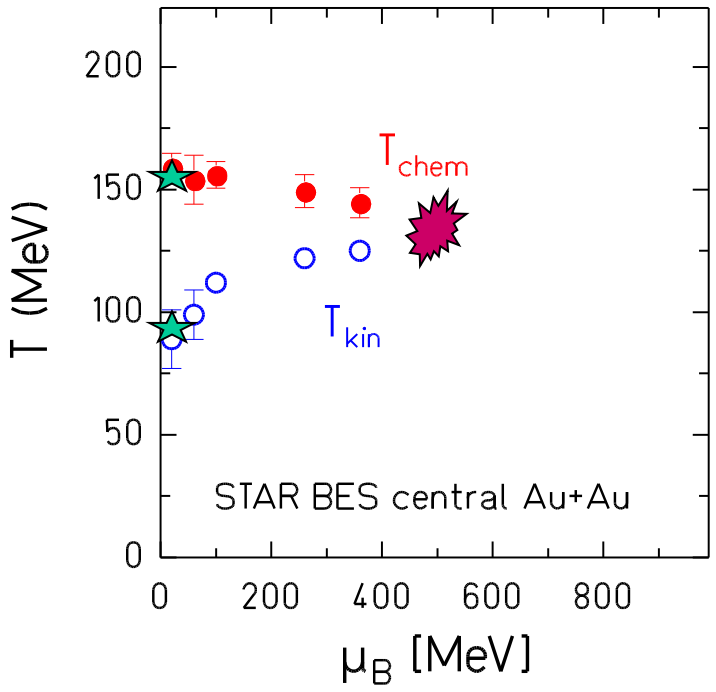
- General description, okay, T = 156 MeV
- Significant deviation for p (T ≈ 140 MeV)
- (multi-)strange baryons correspond more to T = 165 MeV
- Annihilation of p pbar between chemical and kinetic freeze out? Sound reasonable, but ….
- Two freeze-out temperatures, one for u,d and one for s?

Kinetic freeze out – STAR BES



From STAR Coll., CPOD 2011

At LHC?



In central Pb-Pb:

T_{chem} = 156 MeV (?)

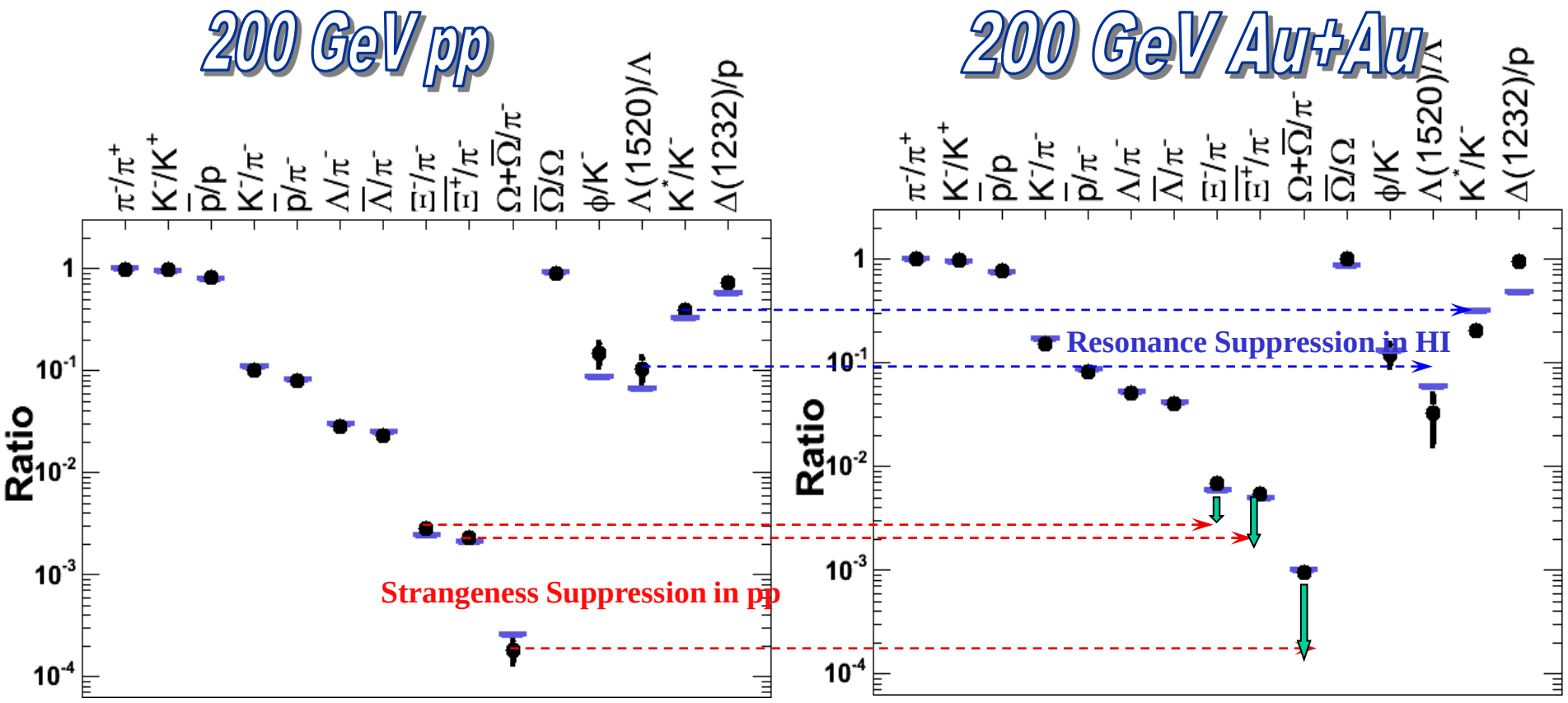
T_{kin} = 95 ± 10 MeV

ALICE

Phys. Rev. Lett. 109, 252301 (2012)

Long phase between chem. and kin. freeze out!!!

Difference between pp and HI Collisions



- In *pp* particle ratios are well described using canonical description
- In *Au+Au* only stable particle ratios are well described

STAR Collaboration

Canonical Approach

Pion density

$n(\pi) = exp(-E_\pi/T)$

Strangeness is conserved!

Kaon density

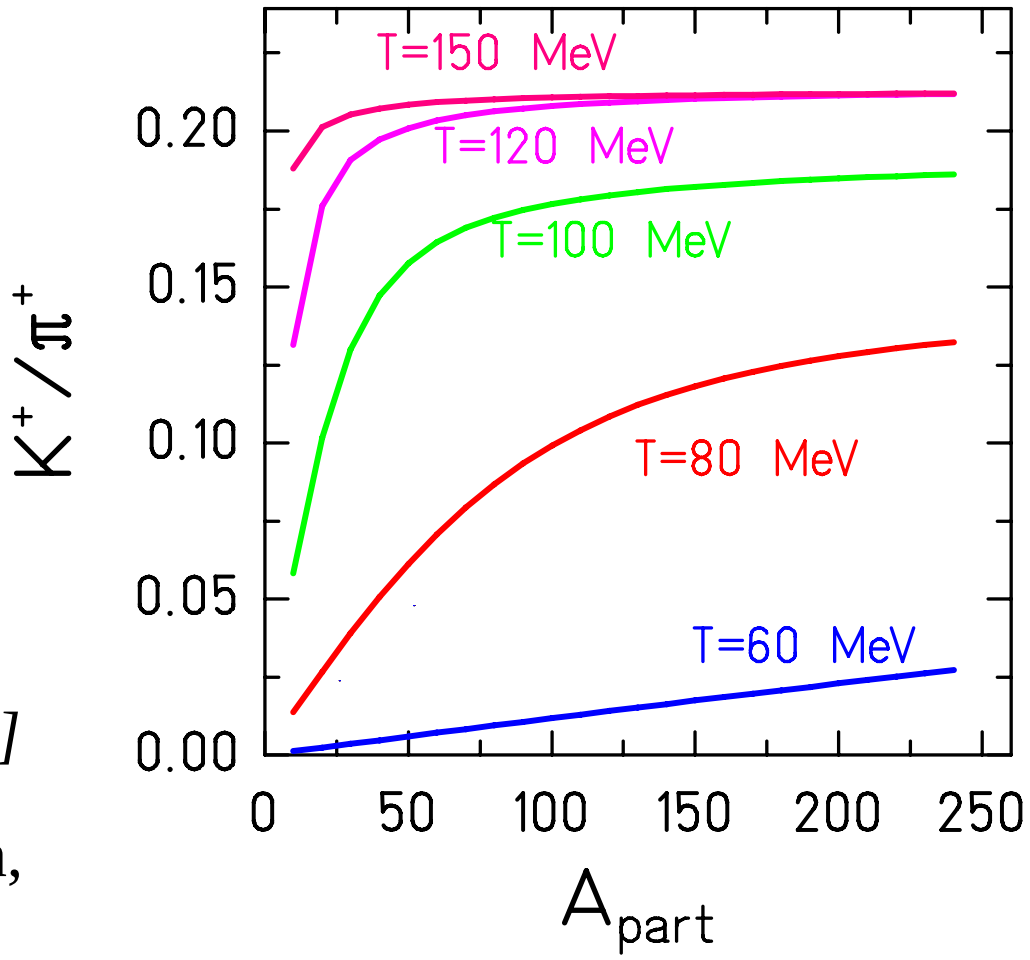
$NN \rightarrow N \Lambda K^+$

$n(K) = exp(-E_K/T)$

$[g V \int ... exp[-(E_\Lambda - \mu_B)/T]$

J. Cleymans, HO, K. Redlich,

PRC 60 (1999)

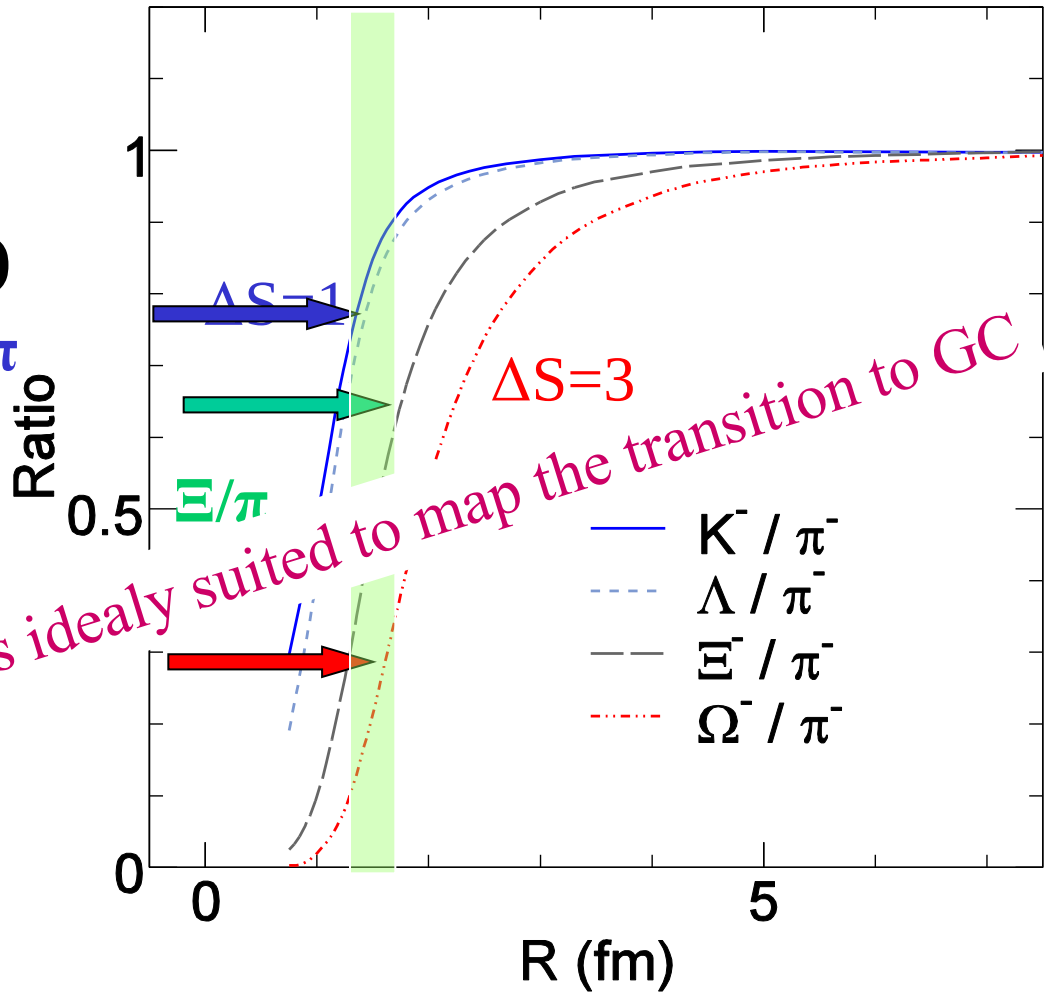


Equations in the model are different!

Testing Canonical Suppression at LHC

Calculated ratio:
can./grand can.

Measured ratio:
ratio(pp)/ratio(PbPb)



p-Pb collisions idealy suited to map the transition to GC

Example:

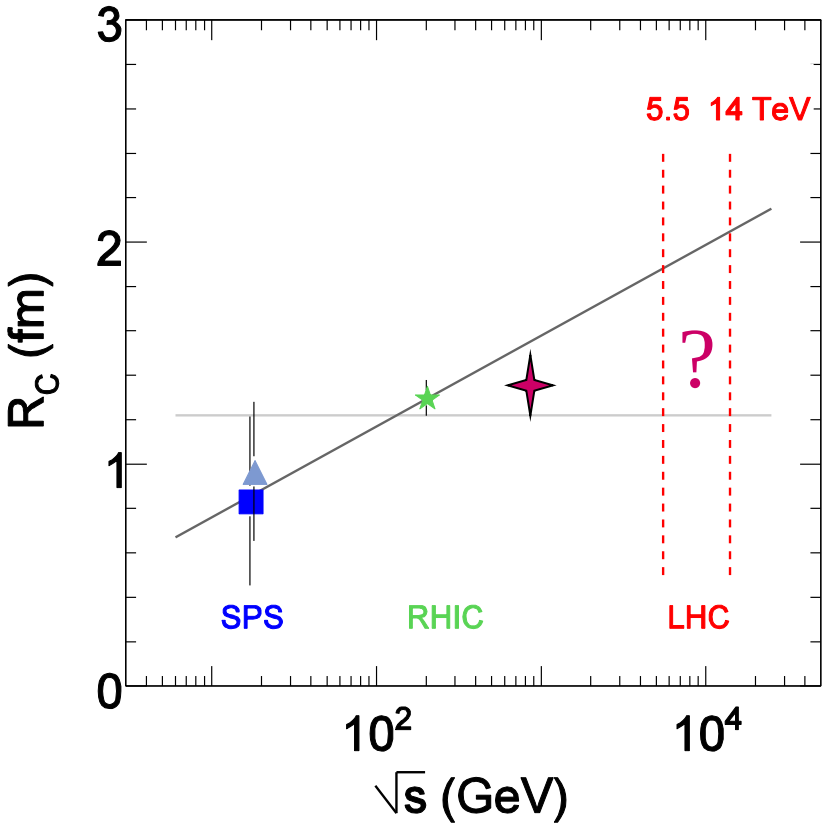
T = 170 MeV

μ_B = ´

Values for LHC

Prediction:I. Kraus et al., PR C 79 (2009) 014901

Correlation Radii at LHC

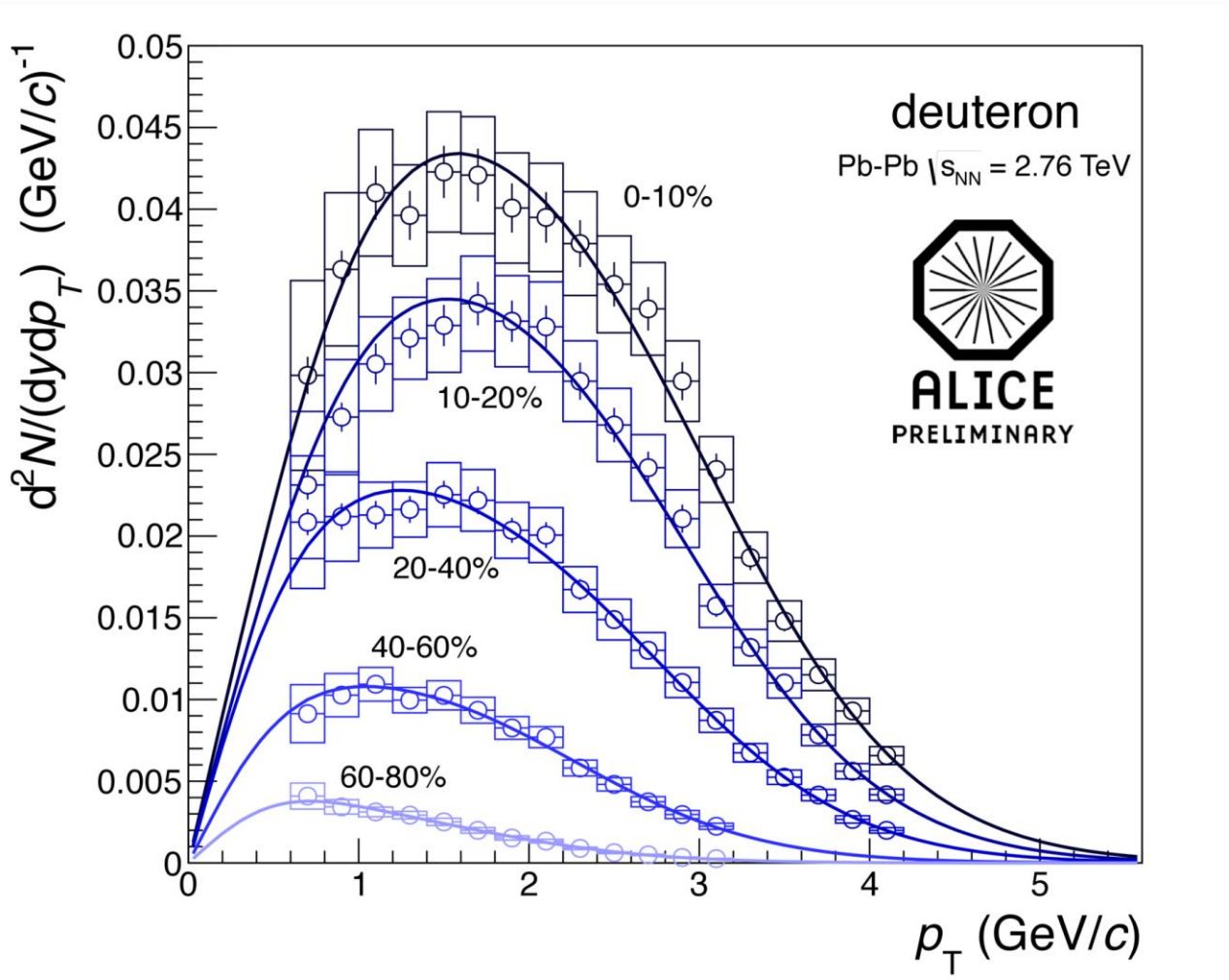


pp 900 GeV thermal fit: arXiv:1102.2745

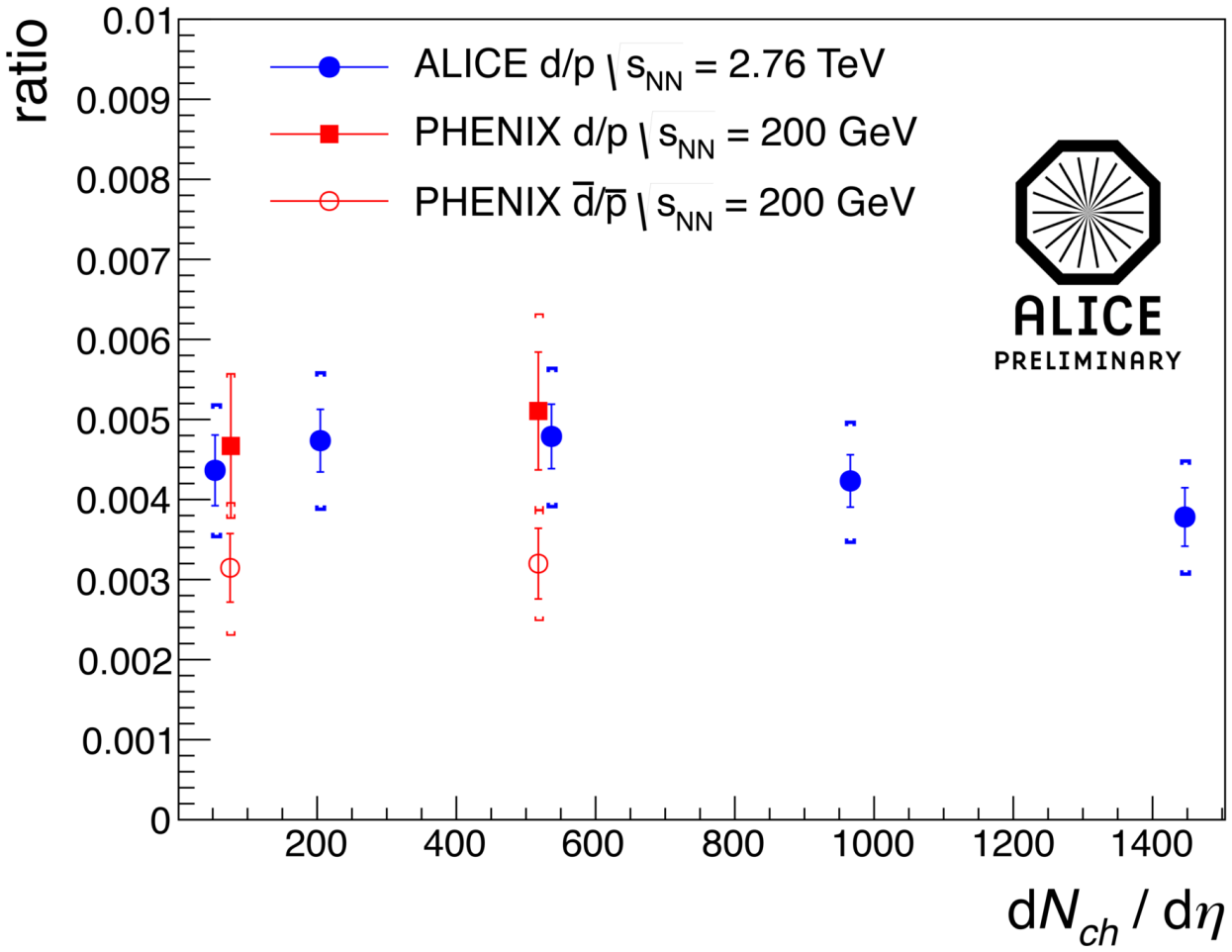
Next: high-multiplicity events in pp 7 TeV !!!???

Will pp collisions approach Grand canonical limit, i.e. HIC

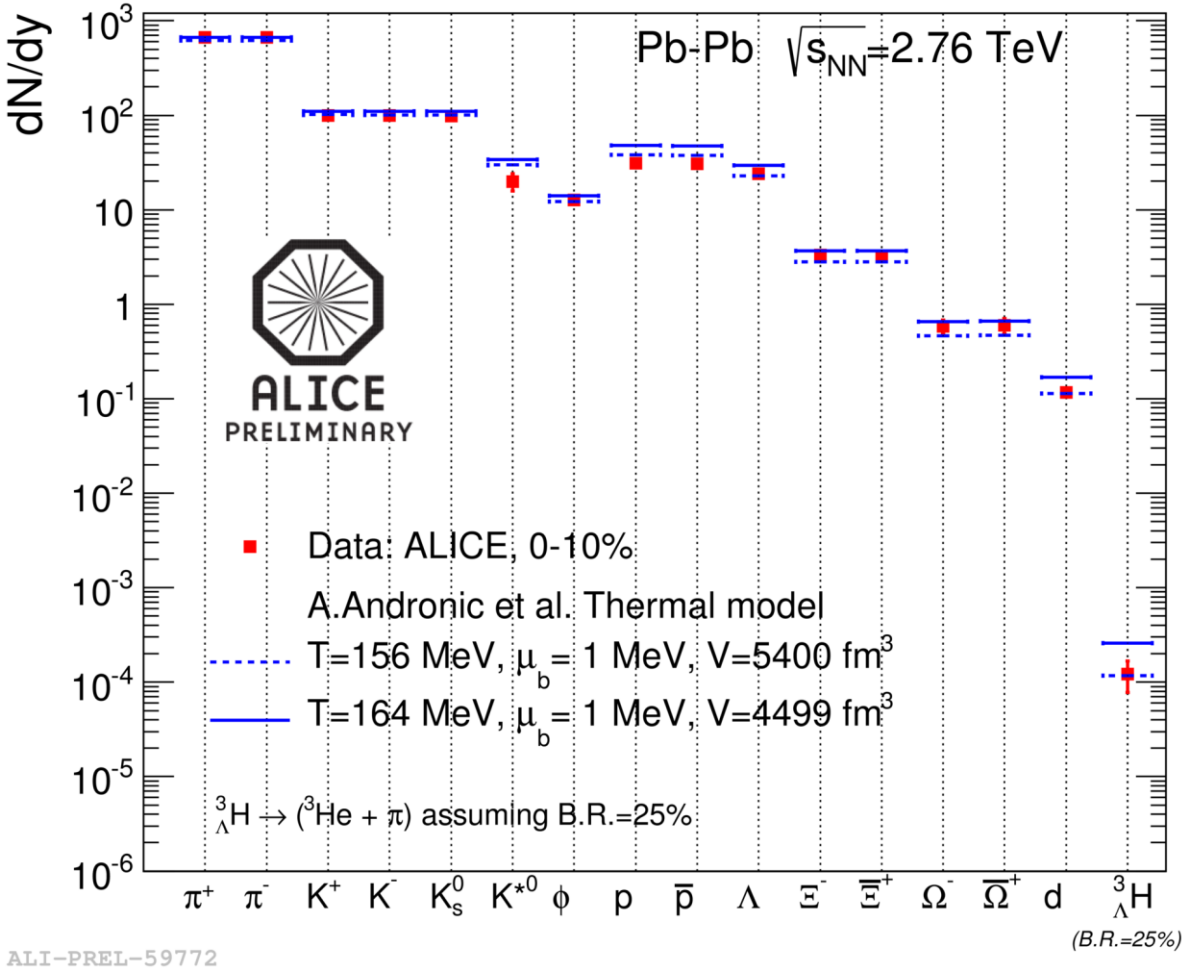
Measurement of (anti-)nuclei



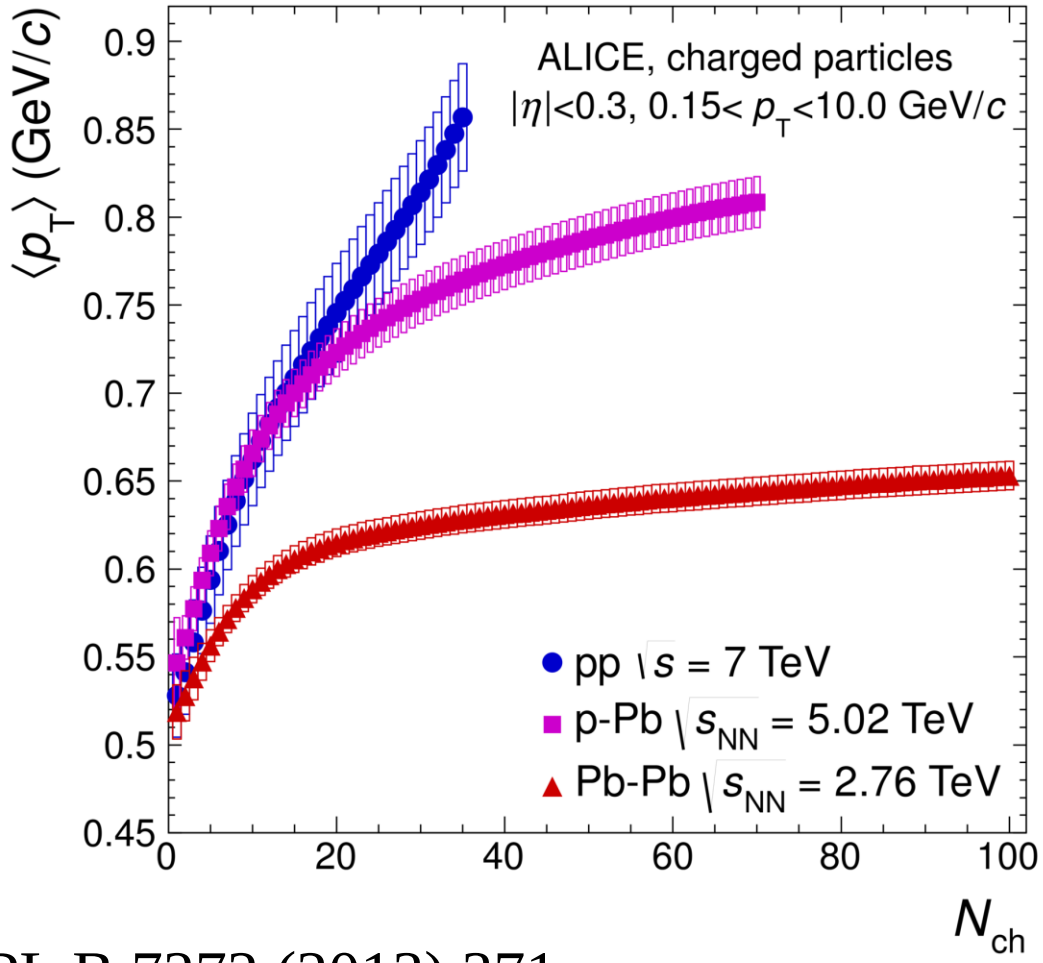
Does the d/p ratio vary with centrality?



Do hypertritons fit in a thermal picture?

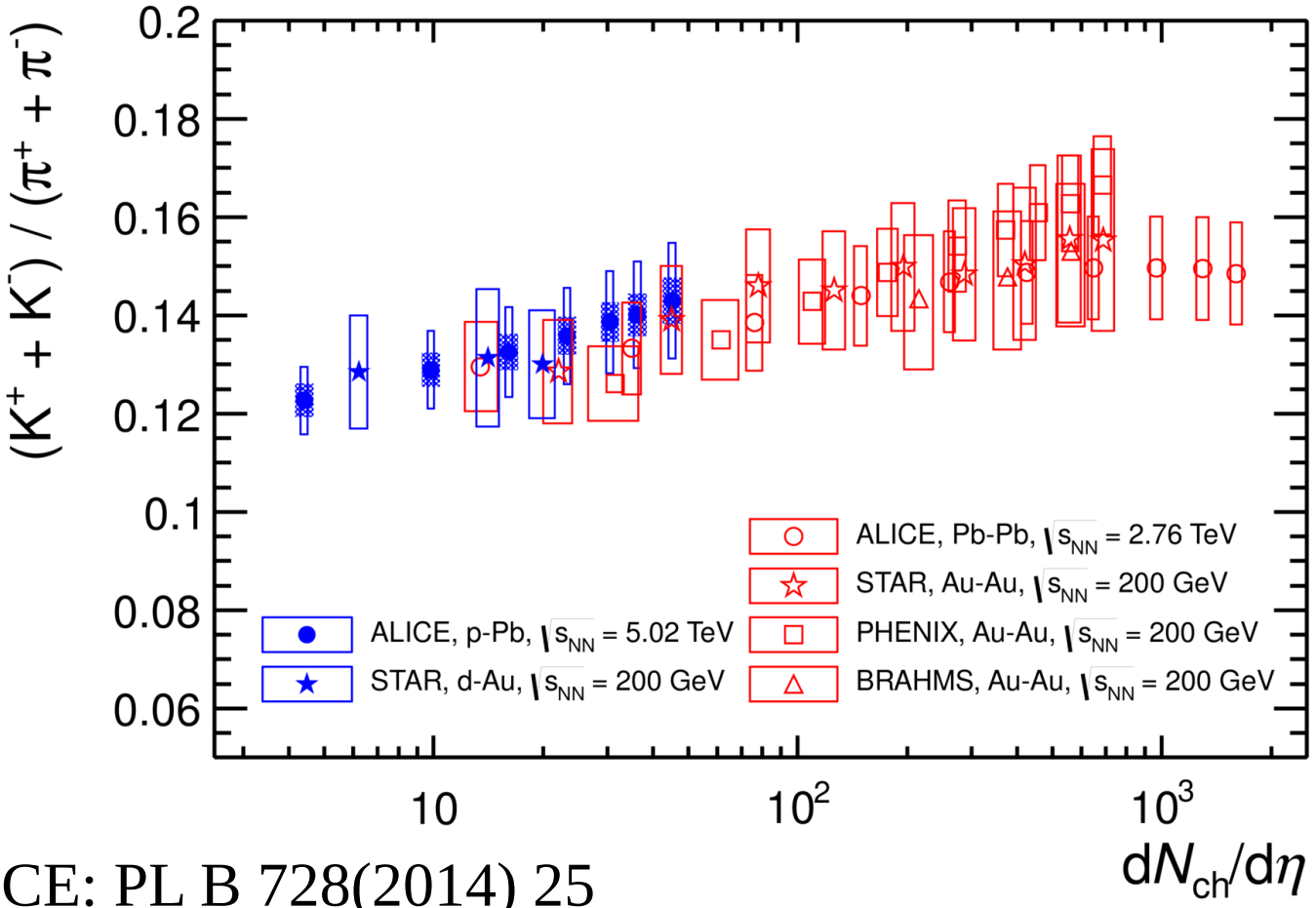


What can be learnt from a comparison pp, p-Pb and Pb-Pb?



ALICE: PL B 7272 (2013) 371

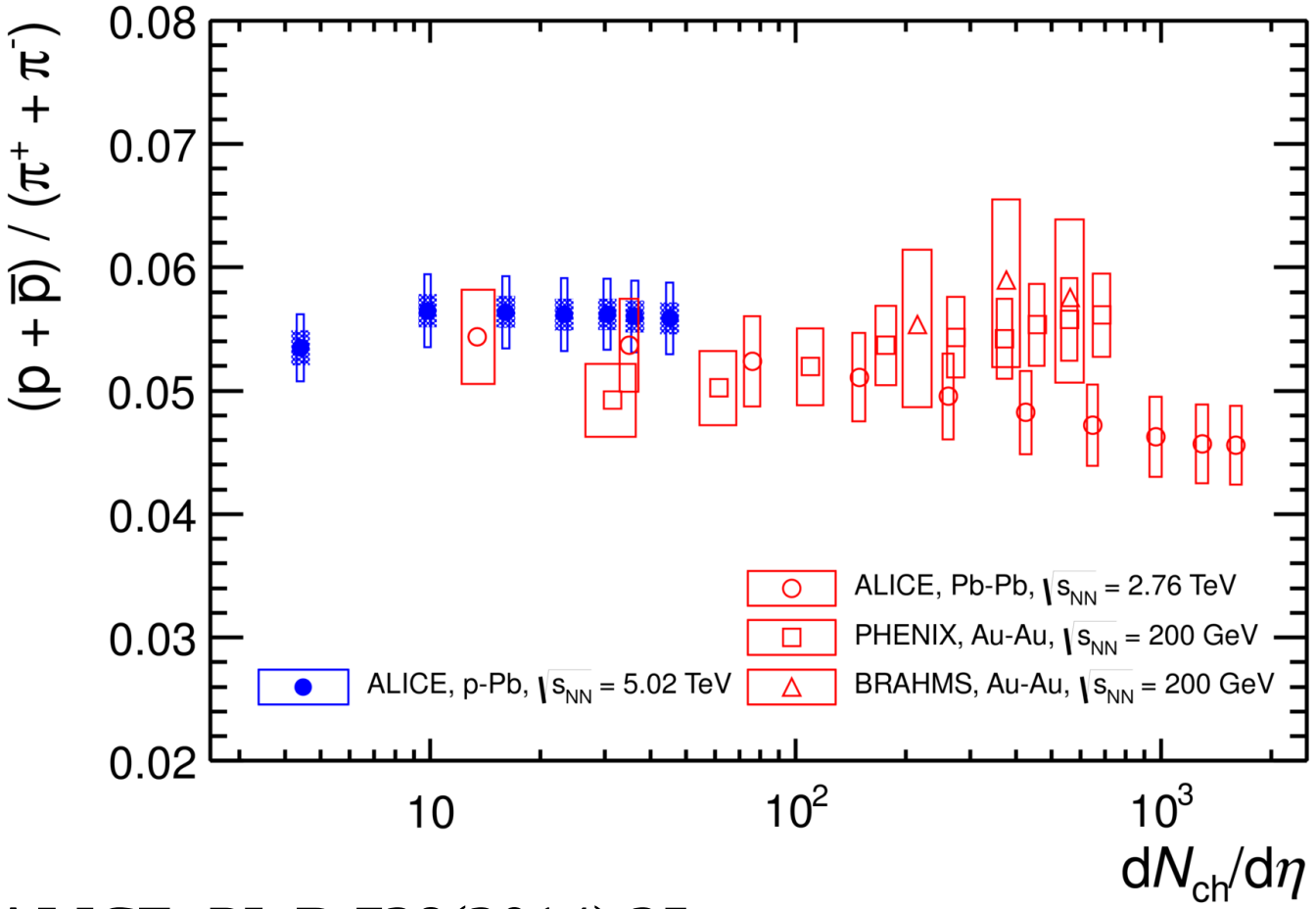
Centrality Dependence



ALICE: PL B 728(2014) 25

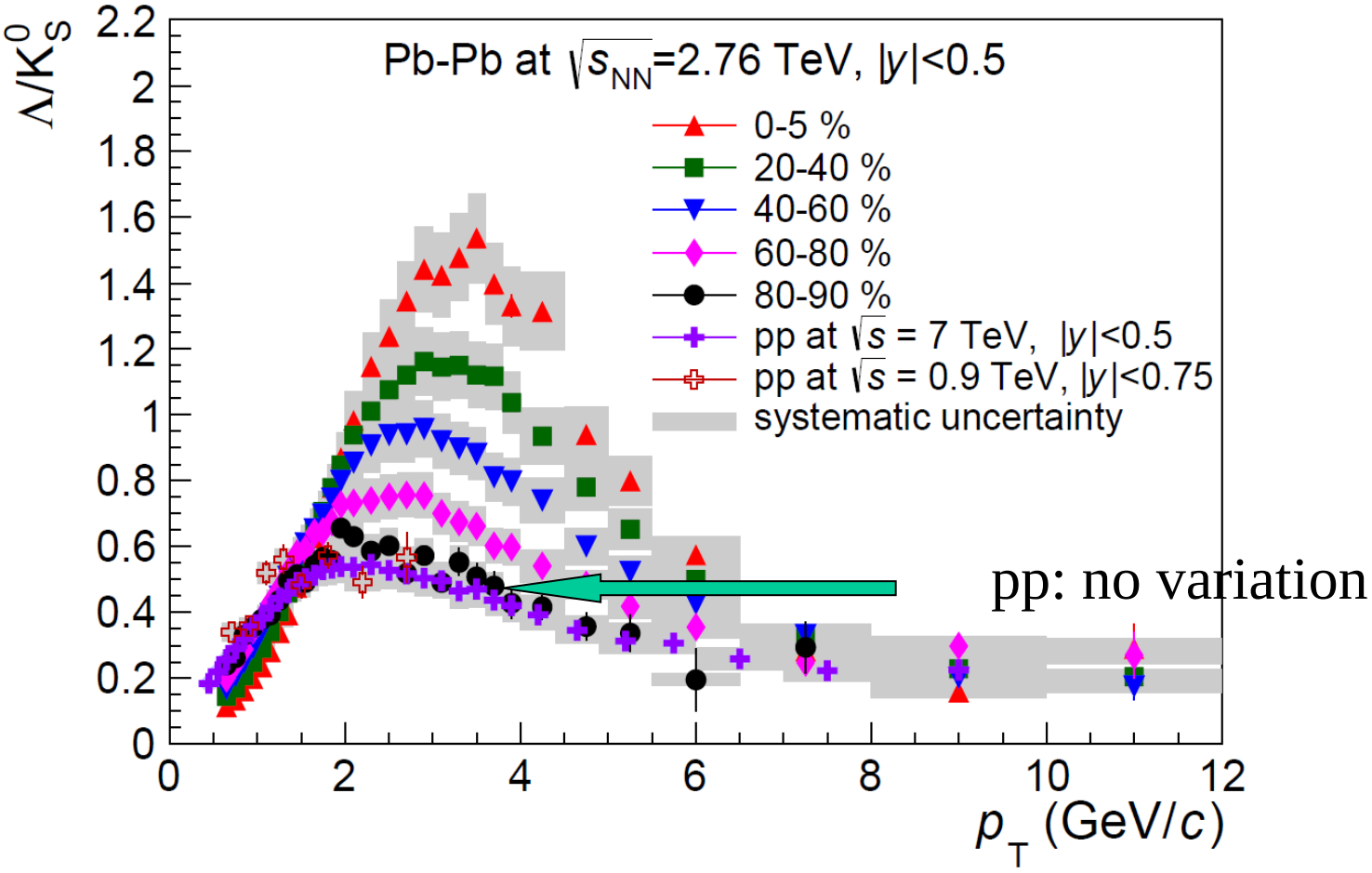
Influence of canonical suppression

Centrality Dependence



ALICE: PL B 728(2014) 25

Baryon-meson ratio

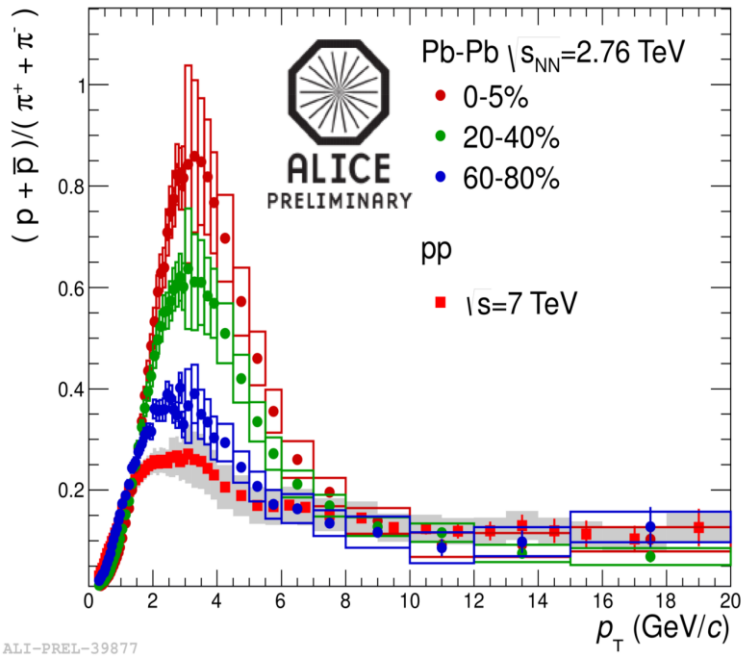


ALICE PRL 111 (2013) 222301 **similar STAR: PRL 108(2012)**

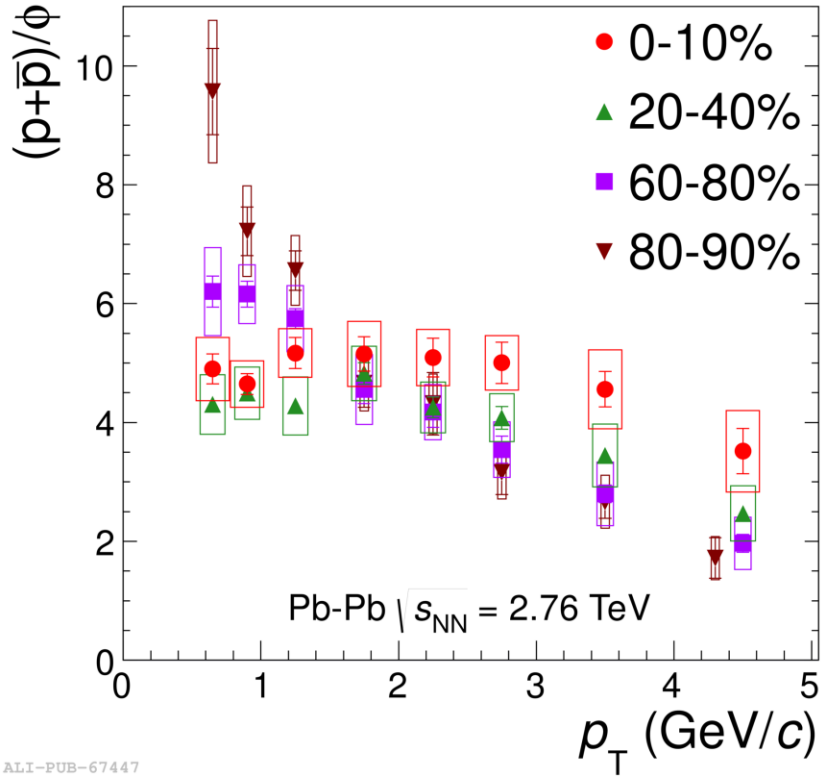
Speculation: recombination of two/three quark

Other Particle Ratios

Similar: arXiv:1401.1250



arXiv: 1404.0495



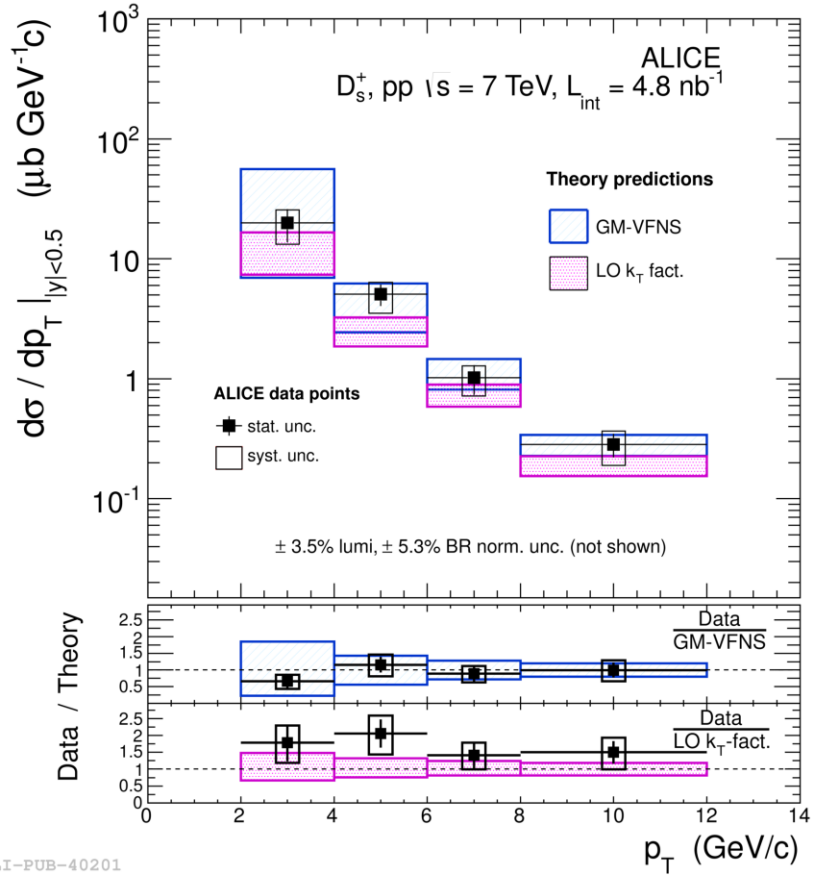
p and π, large mass difference, pronounced peak!

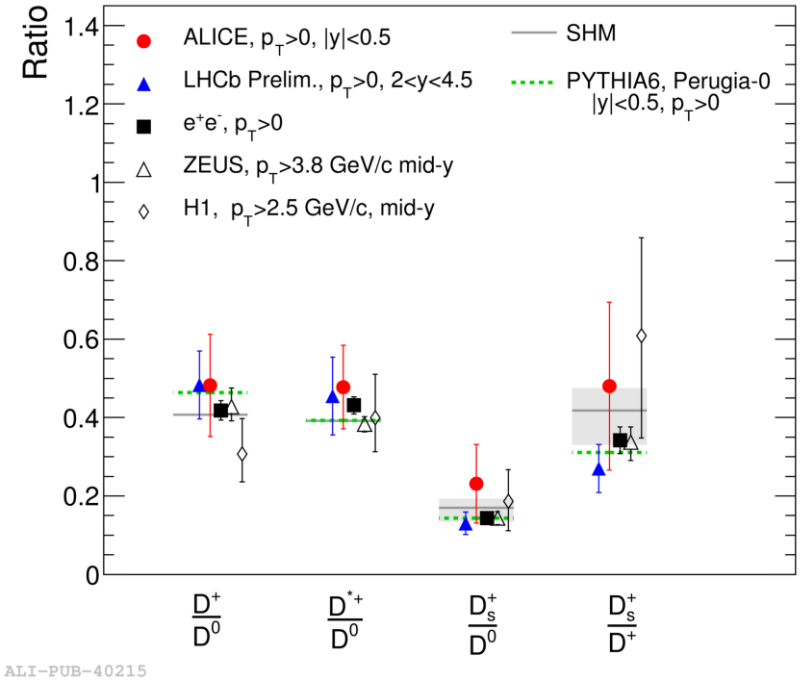
ϕ and p, same mass, flat for central collisions!

Strong argument against quark coalescence! What about v_2?

Distribution of s, u and d quarks when c quarks present?

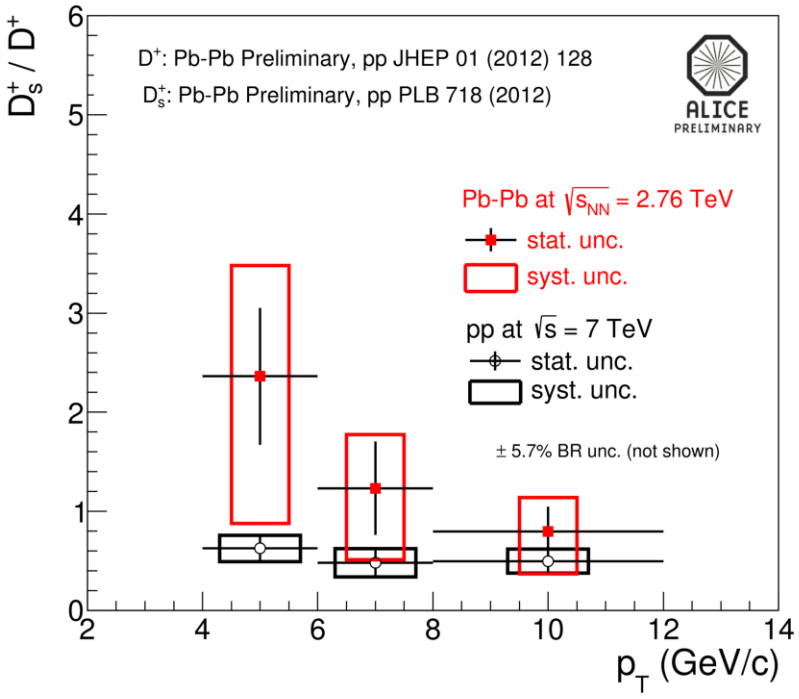
Ratio D_s/D^0 pp 7 TeV

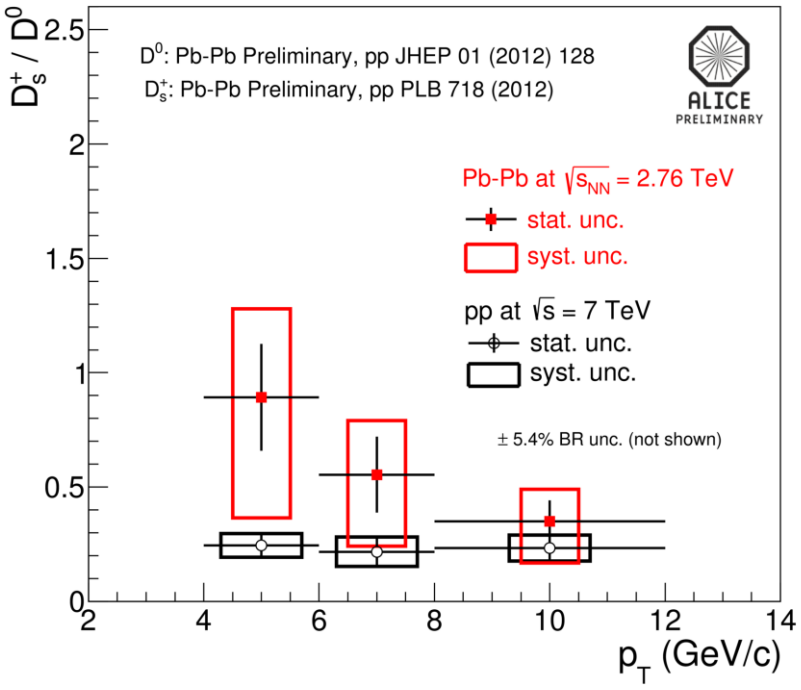




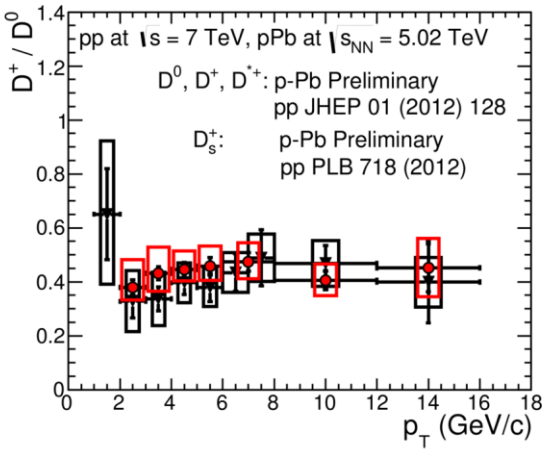
ALICE PL B 718 (2012) 279

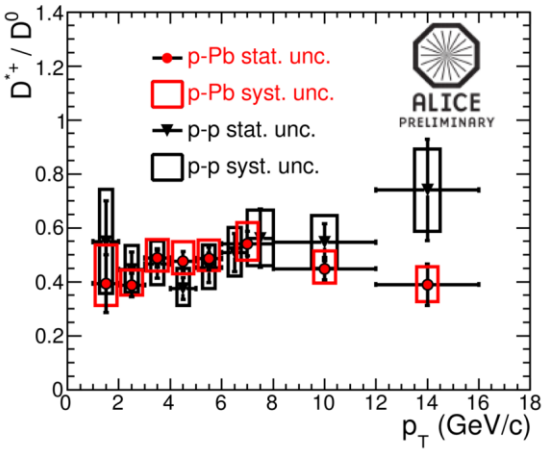
In Pb-Pb collisions

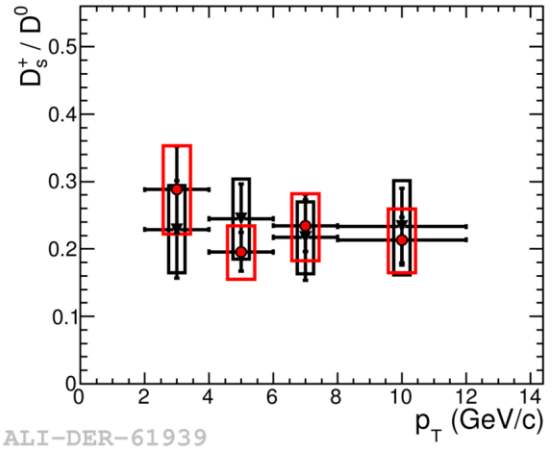


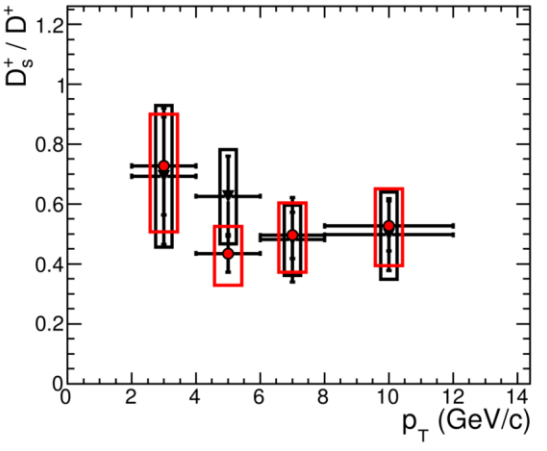


In p-Pb collisions









Review of strangeness

- Strangeness enhancement decreases with √s. Understood as disappearance of the canonical suppression in pp
- Particle ratios: okay, but devi… What do we learn from these deviatio…
- Also d, 3He … are well described by statistical mo…s. And what about coalescence?
- Meson-baryon anomaly: No anomaly -> radial flow
- Ratio D_s vs. D mesons, statistical equilibrium of u ,d, s also when c present, but not of c with u, d, s, ????

Many thanks!

Predictions for LHC

Prediction for heavy ions:

Grand can. (blue)

I. Kraus et al.,

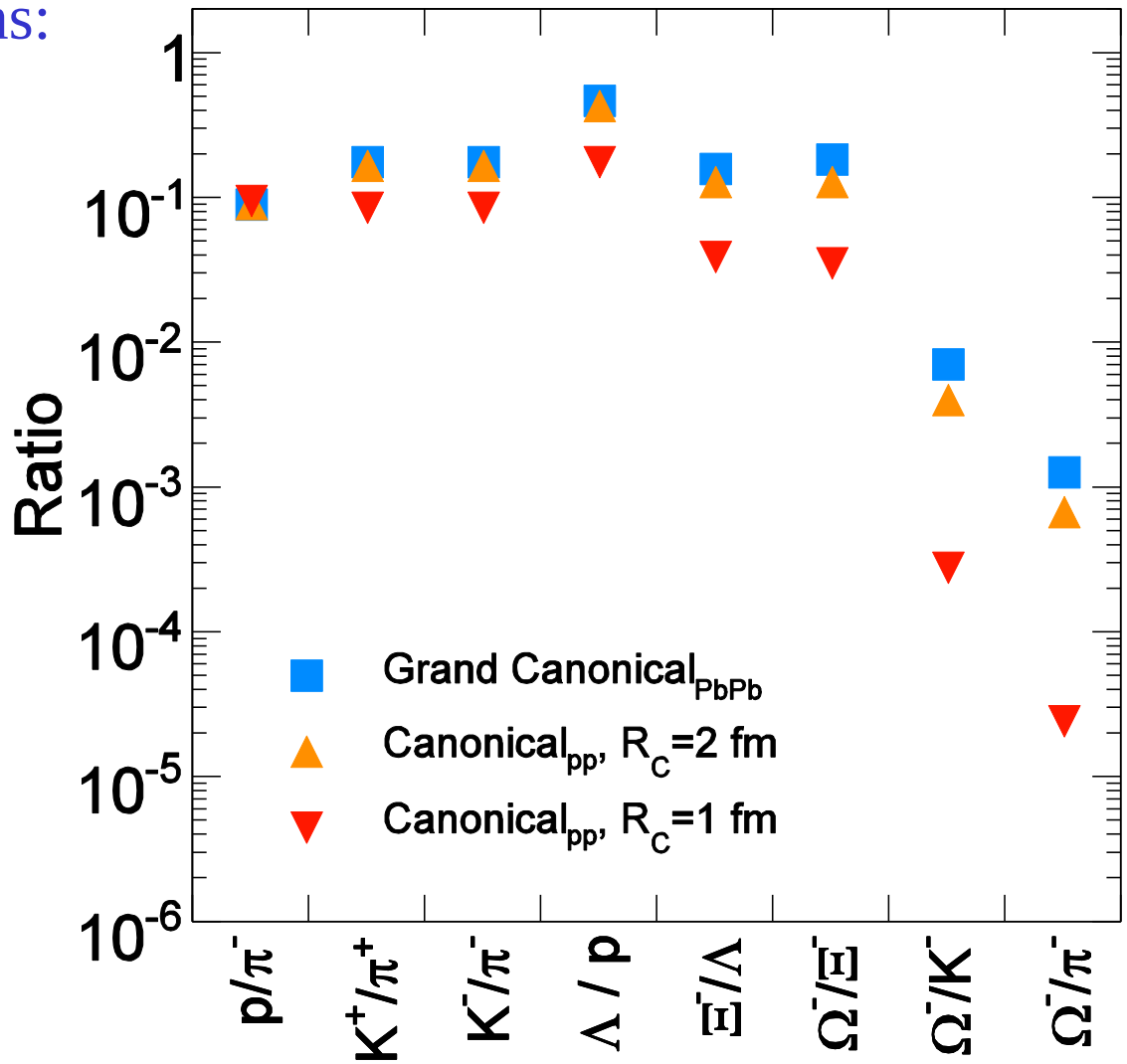
PRC 74 (2007)

For pp collisions:

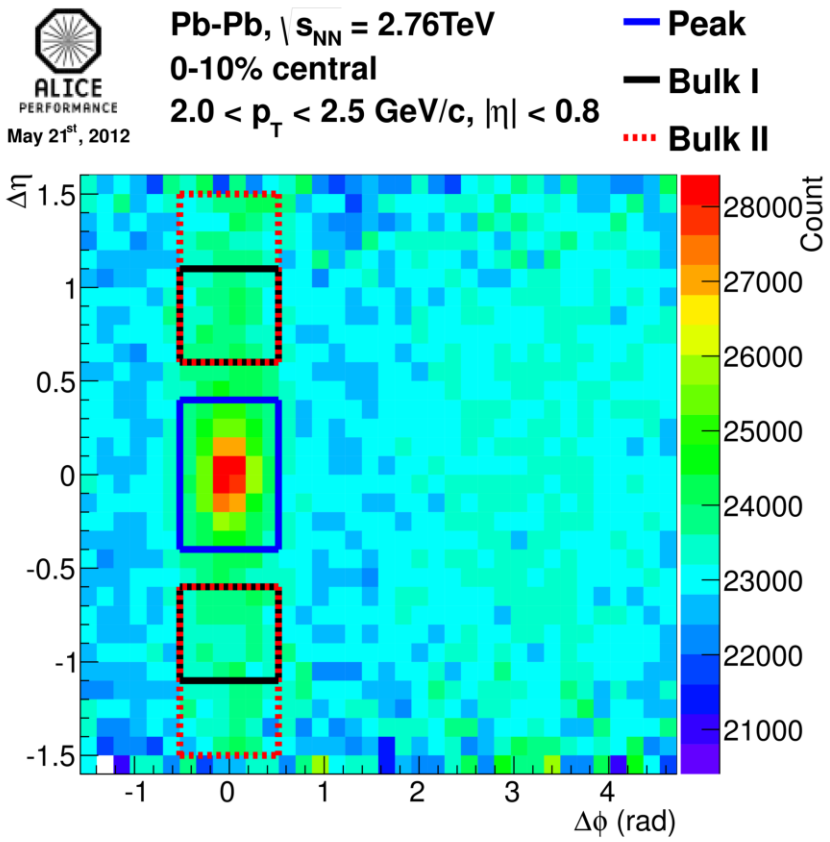
Canonical (yellow and red)

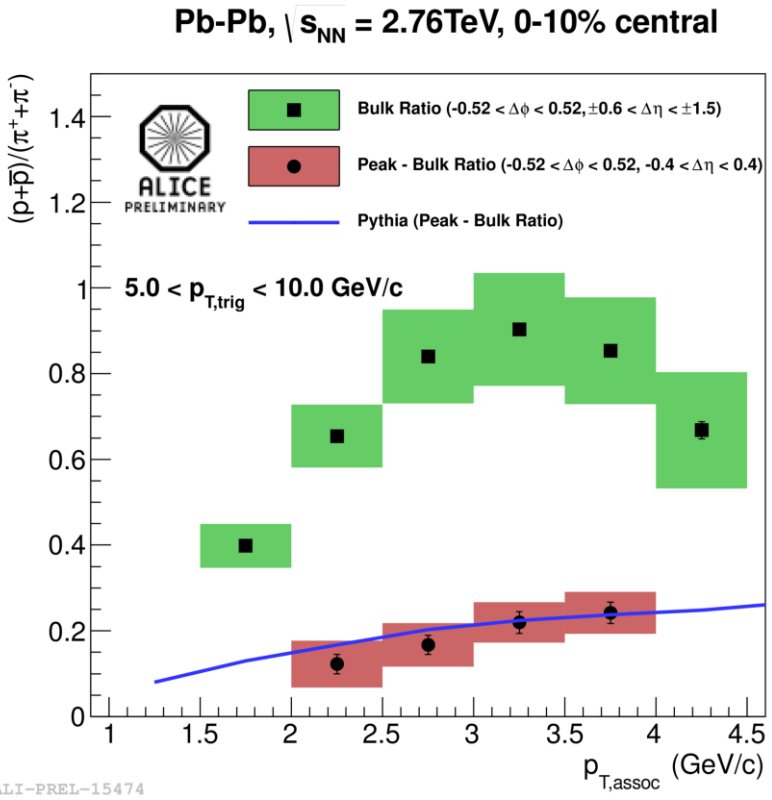
I. Kraus et al.,

PRC 79(2009)

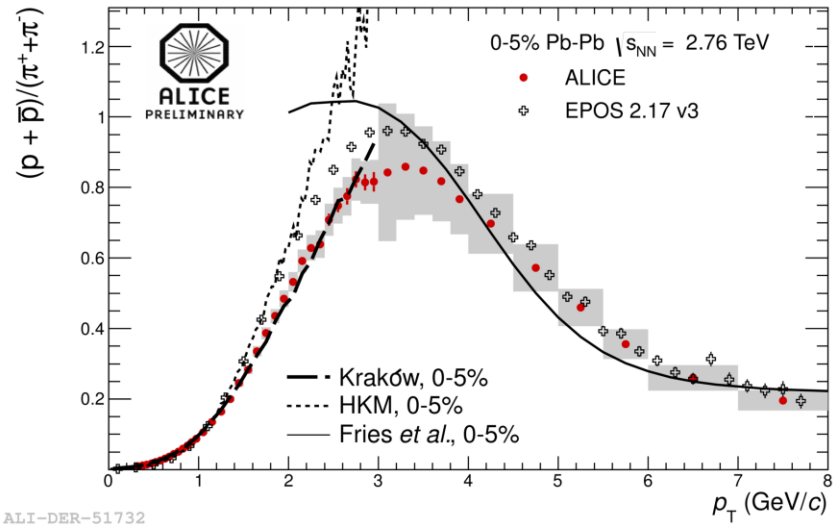


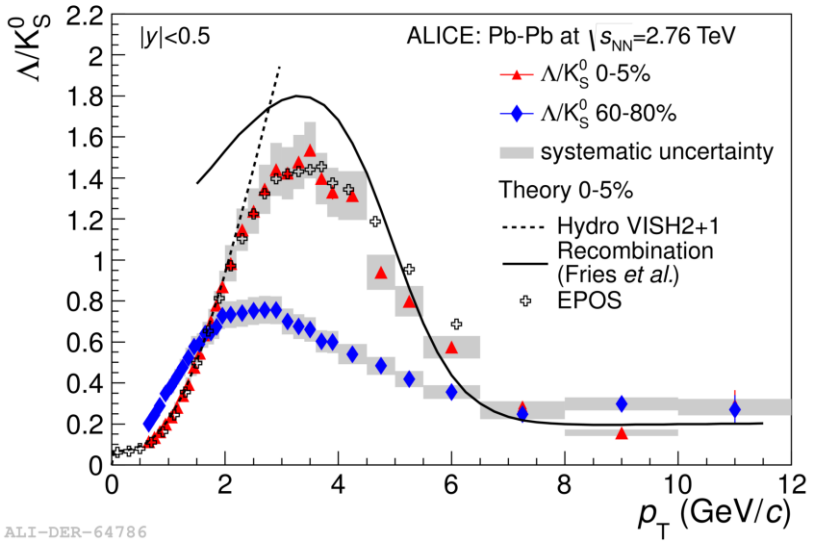
Particle Composition in Jets





Comparison with Theory



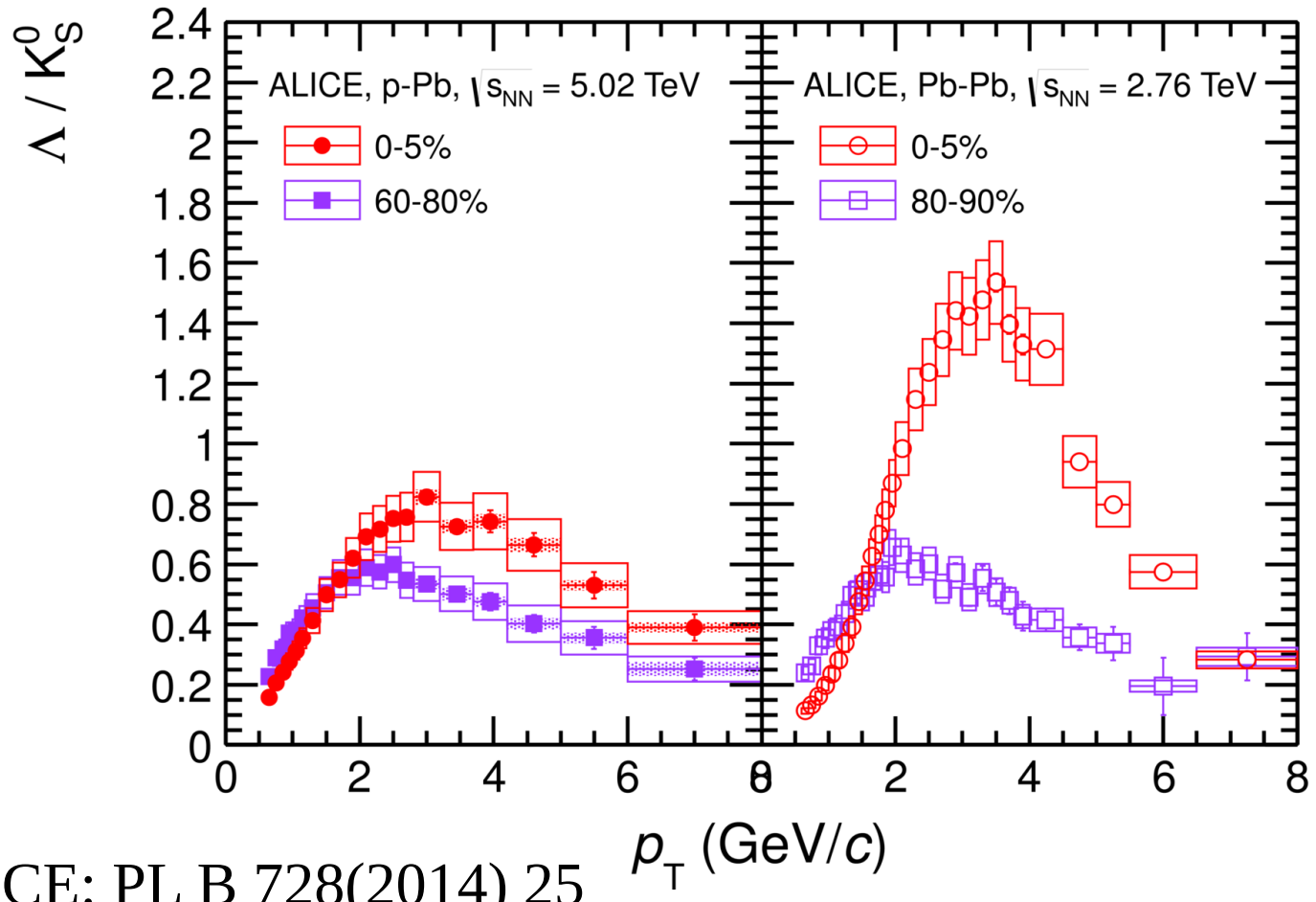


ALICE PRL 111 (2013) 222301

EPOS quite good

Hydro low p_T part -> radial flow

Λ/K^0 ratio p-Pb vs. Pb-Pb

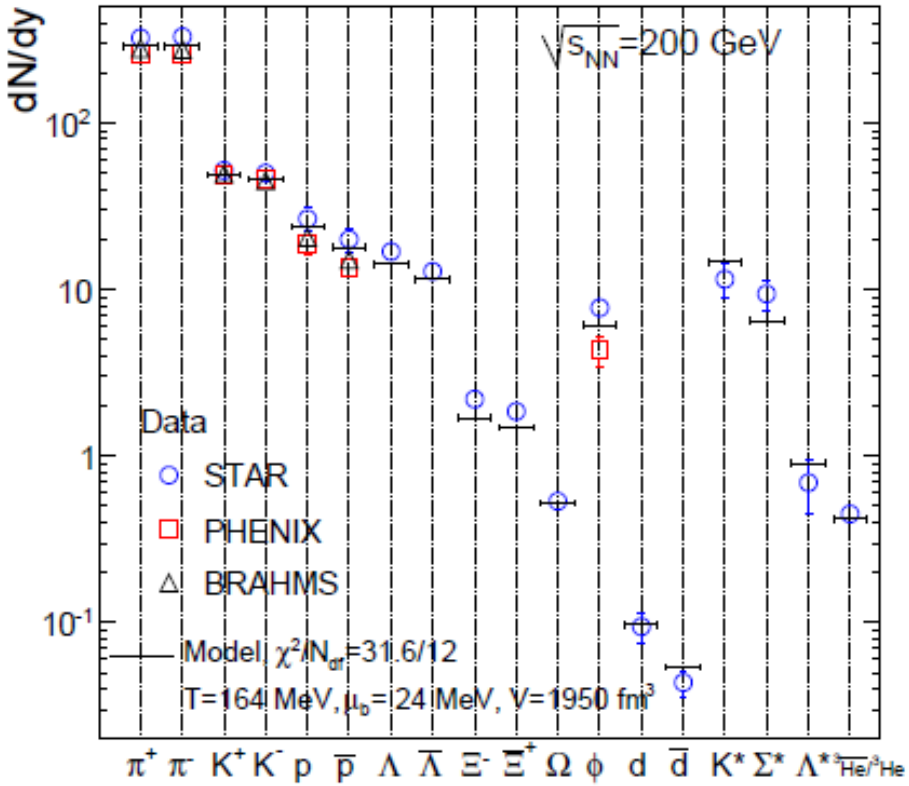


ALICE: PL B 728(2014) 25

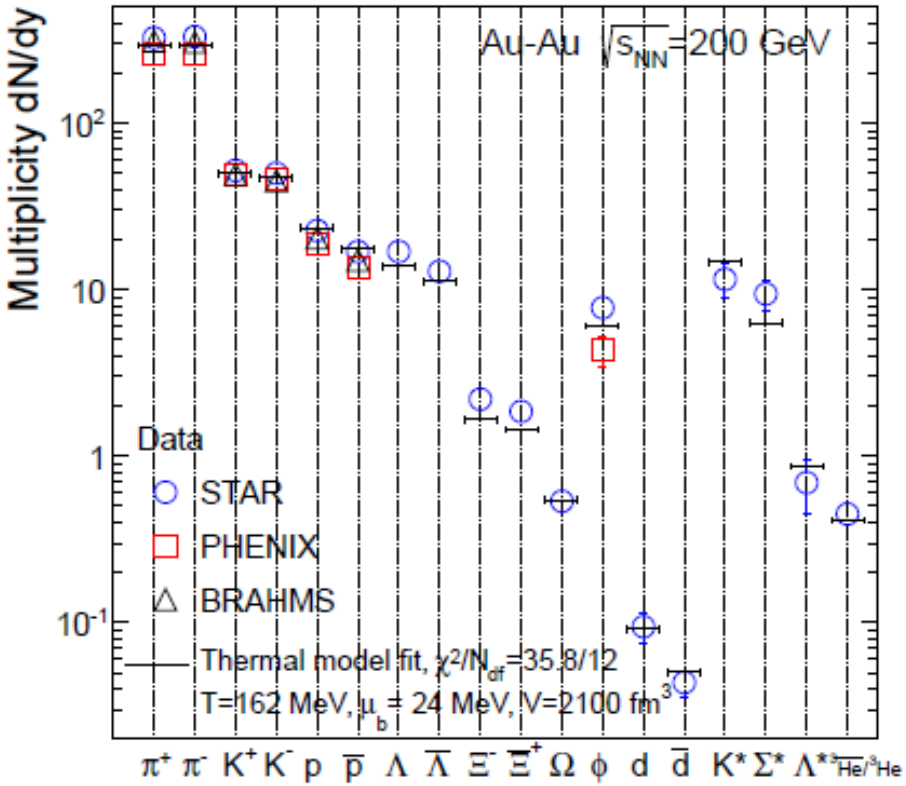
Slight increase with multiplicity. Flow or color reconnection or ?

RHIC, $\sqrt{s_{NN}}$=200 GeV, fit of average data

2008: STAR 2/3 p from w.d. corr.;
PHENIX, BRAHMS 2/3 π w.d. corr.



2012: STAR all p from w.d. corr.;
no BRAHMS π w.d. corr.

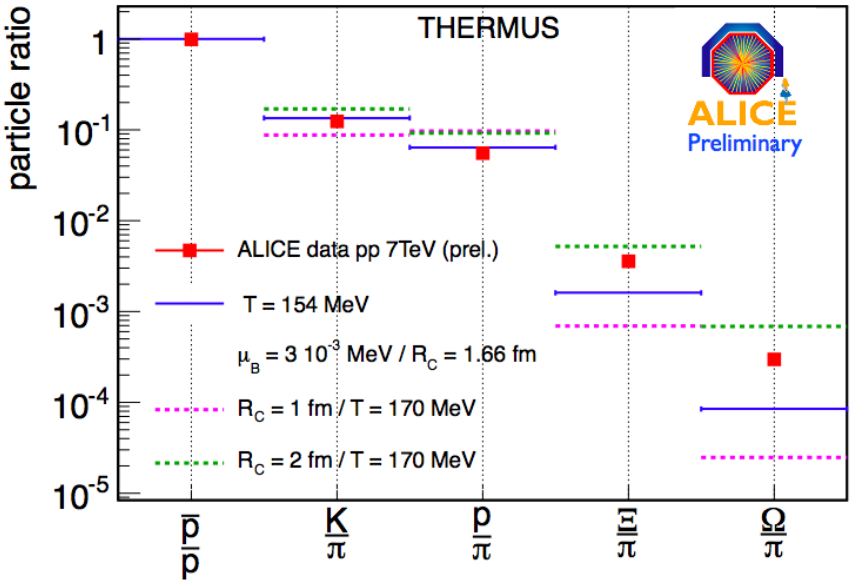


K^*, Σ^*, Λ^* not in fit

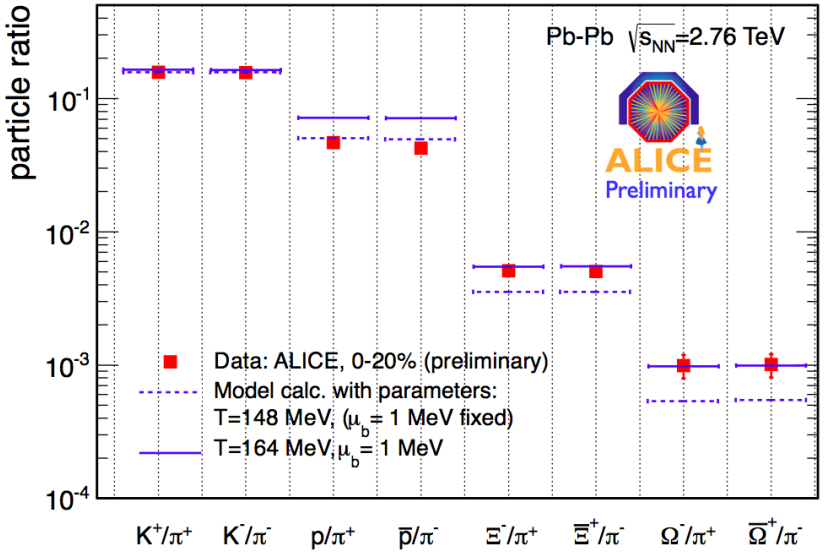
From Anton, QM 2012

LHC Energies

pp 7 TeV



Pb-Pb 2.76 TeV



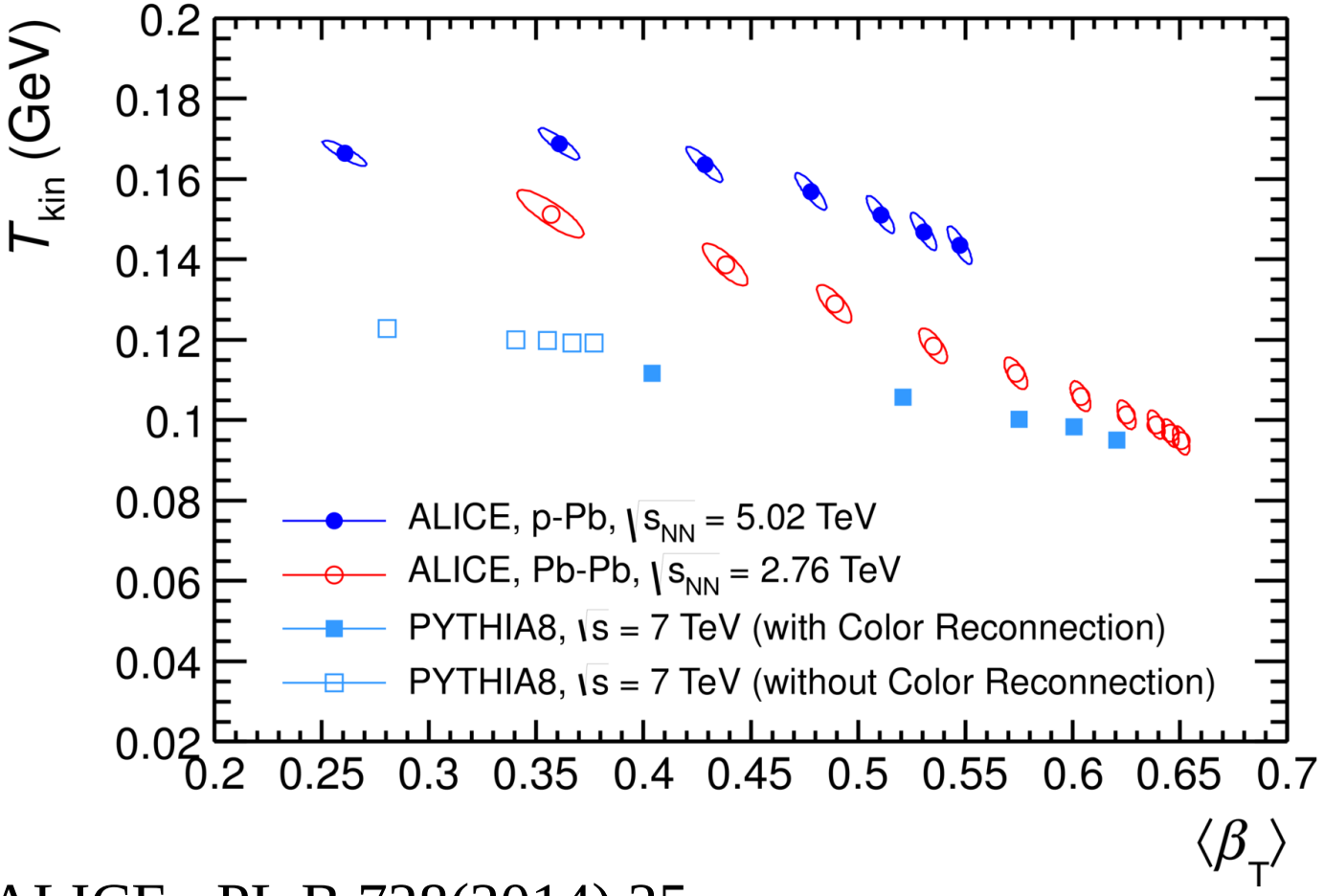
p/π the same in pp and Pb-Pb,

BUT lower than expected from stat. models

K/π in pp is lower than in Pb-Pb, expected from stat. model!

Strangeness is okay!

T – β Plane



ALICE: PL B 728(2014) 25