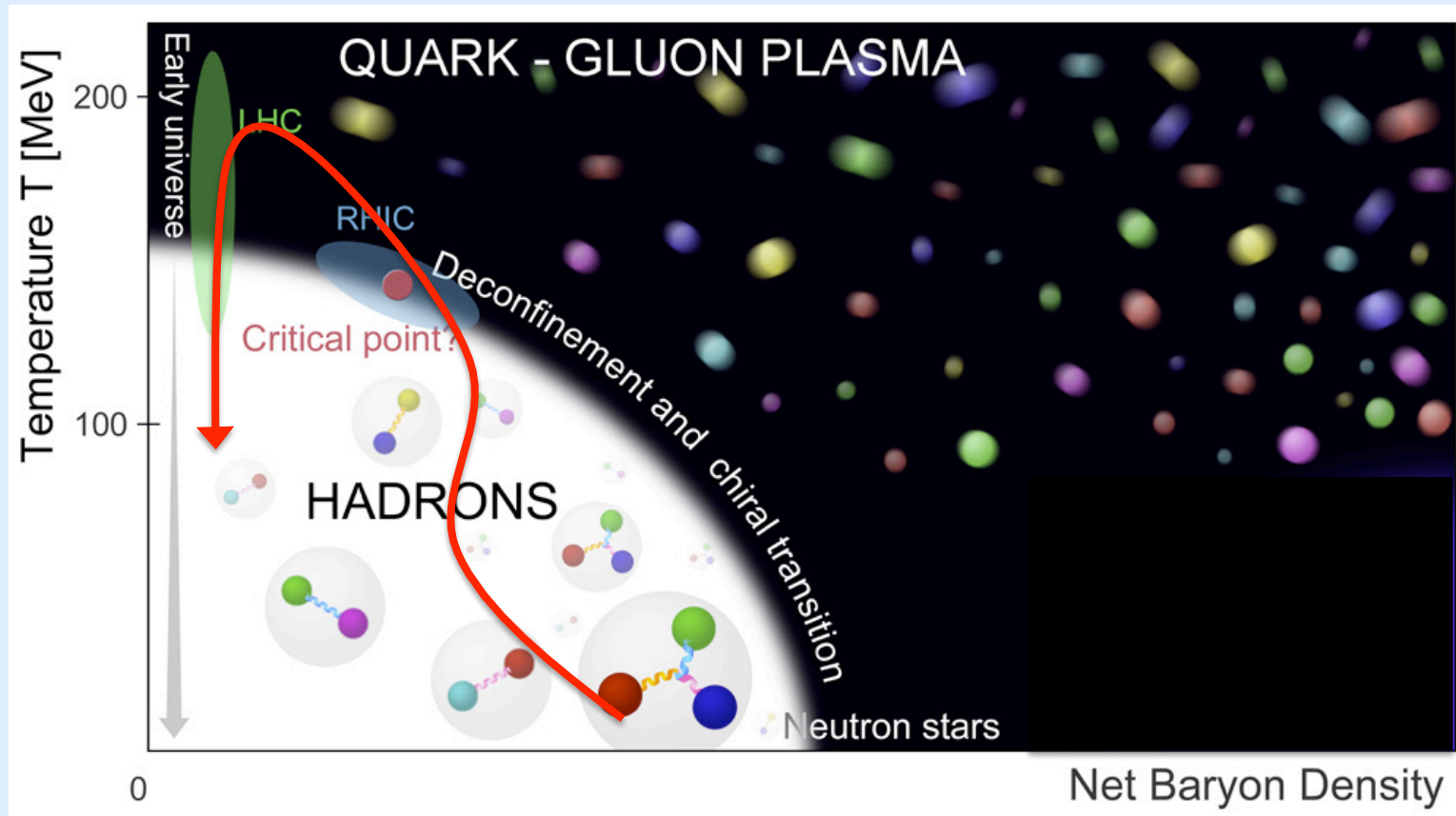# Resonances probing the small system of a p-Pb collision

Christina Markert
University of Texas at Austin
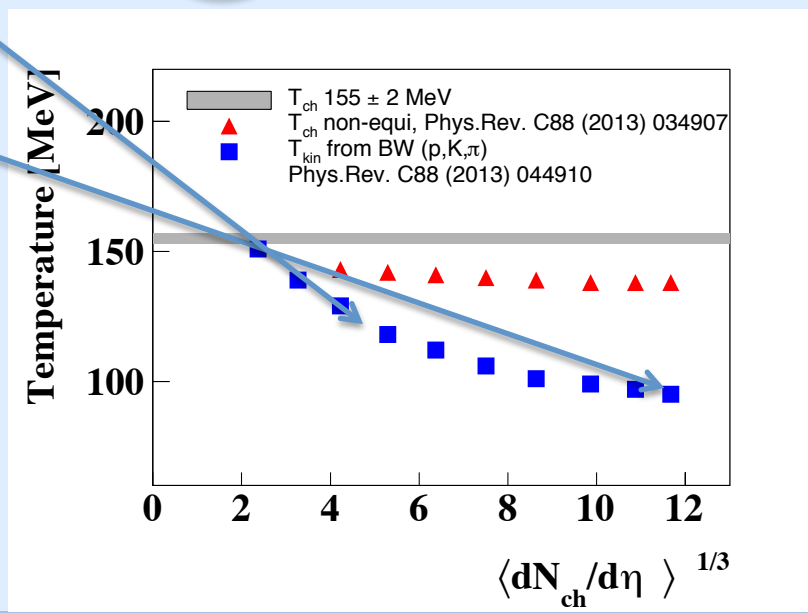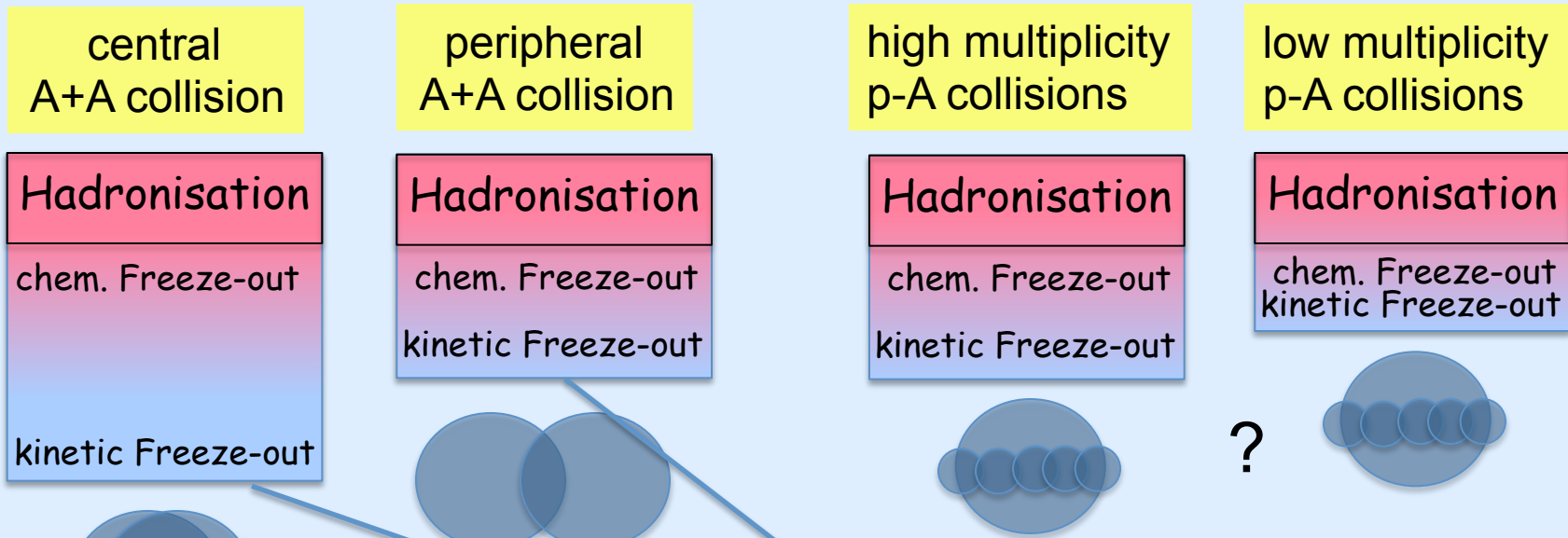
- Small systems
- Resonances
- hadronic phase
- partonic phase ?

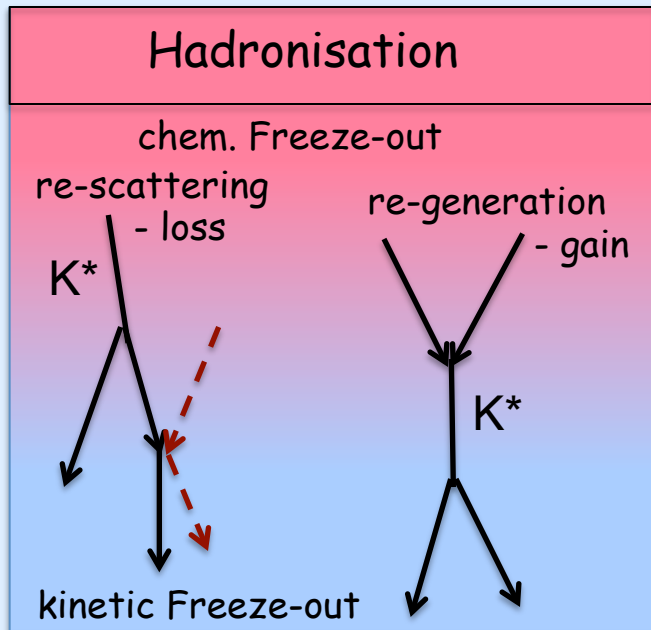# Phase diagram of nuclear matter (QCD)
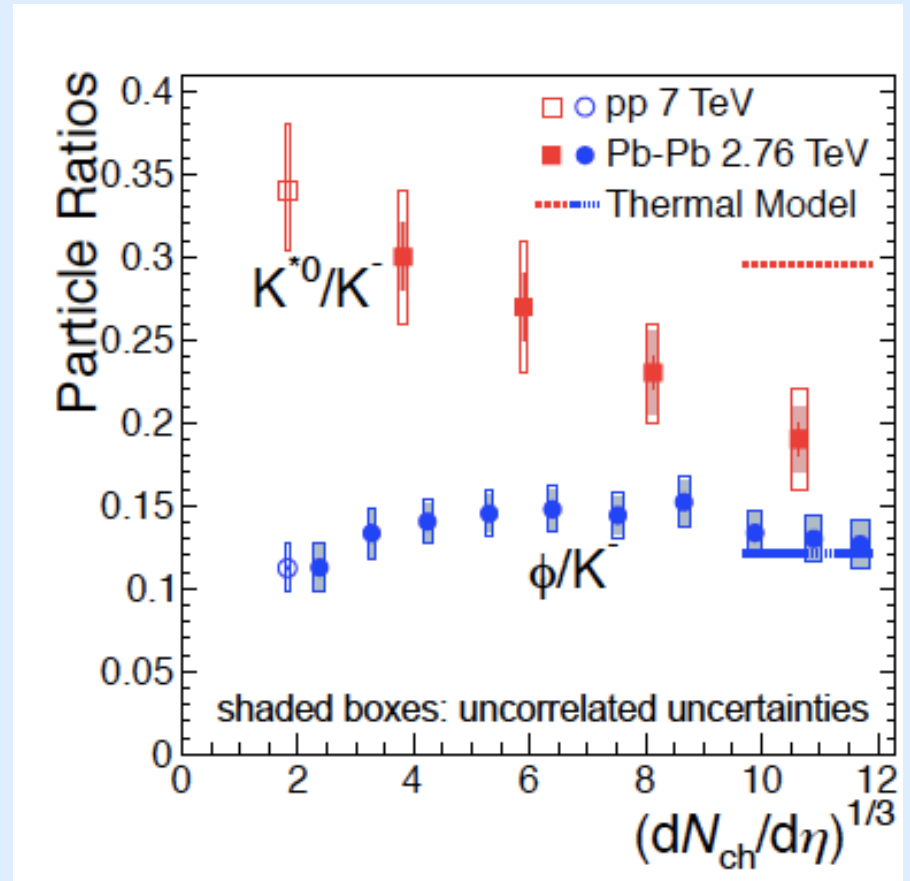
2T(time and temperature) of hadronic medium

central A+A collision	peripheral A+A collision	high multiplicity p-A collisions	low multiplicity p-A collisions
Hadronisation	**Hadronisation**	**Hadronisation**	**Hadronisation**
chem. Freeze-out	chem. Freeze-out	chem. Freeze-out	chem. Freeze-out
	kinetic Freeze-out	kinetic Freeze-out	kinetic Freeze-out
kinetic Freeze-out			

?

Legend in plot:
- T_{ch} 155 ± 2 MeV
- T_{ch} non-equi, Phys.Rev. C88 (2013) 034907
- T_{kin} from BW (p,K,π) Phys.Rev. C88 (2013) 044910

Temperature [MeV]: 200, 150, 100

x-axis: $\langle dN_{ch}/d\eta \rangle^{1/3}$ — 0, 2, 4, 6, 8, 10, 12

Resonance interaction in hadronic medium

central A+A collision

Hadronisation

chem. Freeze-out

re-scattering
- loss

re-generation
- gain

K*

K*

kinetic Freeze-out

Life-time [fm/c]
$\rho(770)$ = 1.3
$\Delta(1232)$ = 1.7
$K(892)$ = 4
$\Sigma(1385)$ = 5.7
$\Lambda(1520)$ = 13
$\phi(1020)$ = 44

Particle Ratios vs $(dN_{ch}/d\eta)^{1/3}$

- □ ○ pp 7 TeV
- ■ ● Pb-Pb 2.76 TeV
- Thermal Model

K^{*0}/K^-

ϕ/K^-

shaded boxes: uncorrelated uncertainties

Resonances in EPOS (+UrQMD)

AG Knospe, CM, K Werner, J Steinheimer, M Bleicher: **PRC93 (2016) 1, 014911**
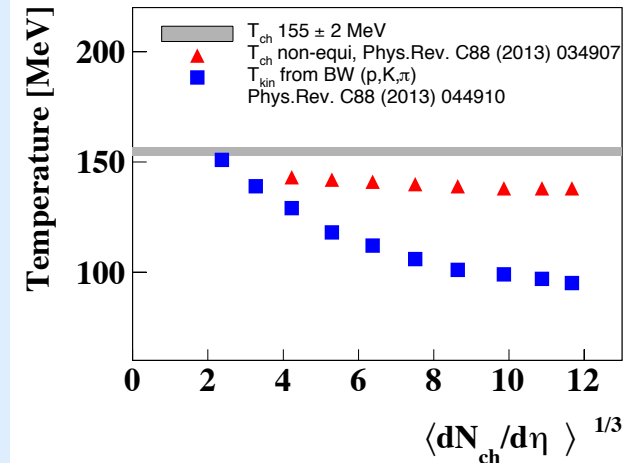
Count resonances:

1.) EPOS + UrQMD OFF (~ 168 MeV)
from core + corona contribution
core ~ thermal distribution

2.) EPOS + UrQMD ON
- follow decay particles in hadronic medium
- count resonance when all decay particles do not interact
  (elastic or pseudo-elastic)

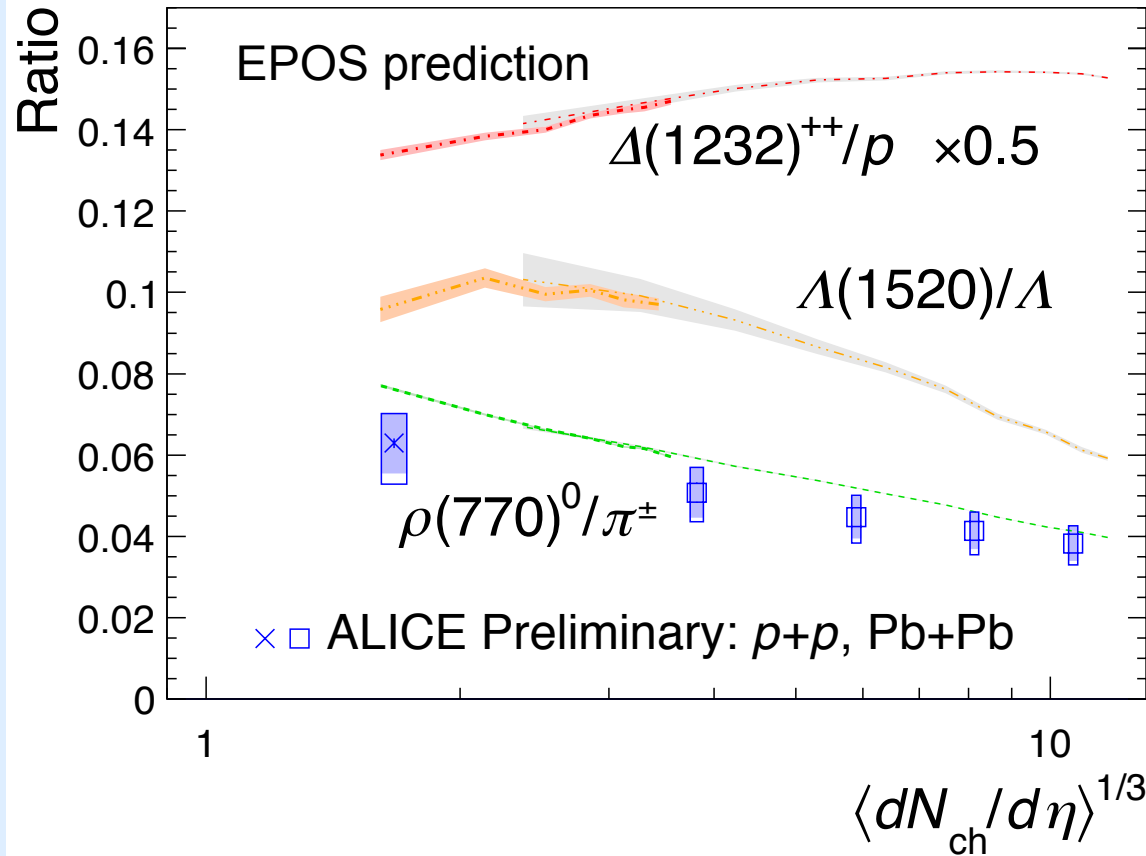Legend: T_{ch} 155 ± 2 MeV; T_{ch} non-equi, Phys.Rev. C88 (2013) 034907; T_{kin} from BW (p,K,π) Phys.Rev. C88 (2013) 044910

Y-axis: Temperature [MeV]; X-axis: $\langle dN_{ch}/d\eta \rangle^{1/3}$

Resonance	decay channel	branching ratio	lifetime (fm/c)
$\rho(770)^0$	$\pi^+ + \pi^-$	1	1.335
$K^*(892)^0$	$\pi^- + K^+$	0.67	4.16
$\phi(1020)$	$K^+ + K^-$	0.489	46.26
$\Delta(1232)^{++}$	$\pi^+ + p$	1	1.69
$\Sigma(1385)^+$	$\pi^+ + \Lambda$	0.870	5.48
$\Sigma(1385)^-$	$\pi^- + \Lambda$	0.870	5.01
$\Lambda(1520)$	$K^- + p$	0.225	12.54
$\Xi(1530)^0$	$\pi^+ + \Xi^-$	0.67	22

Resonance ratios (EPOS+UrQMD)

AG Knospe, CM, K Werner, J Steinheimer, M Bleicher

PRC91 (2015) 024609
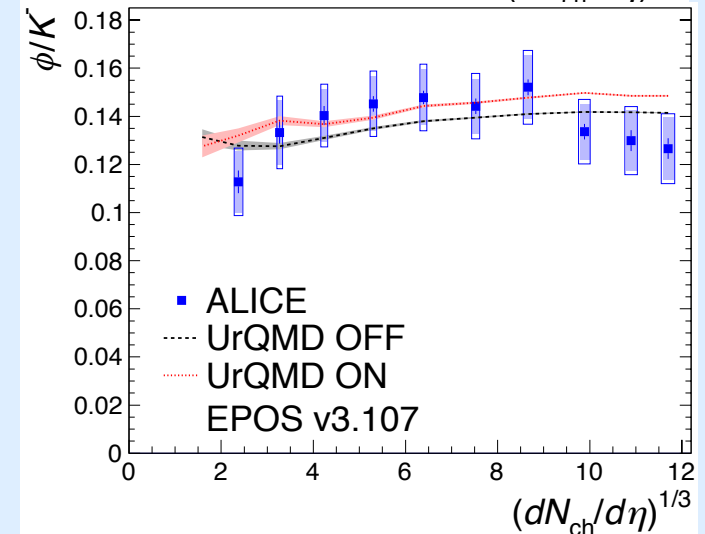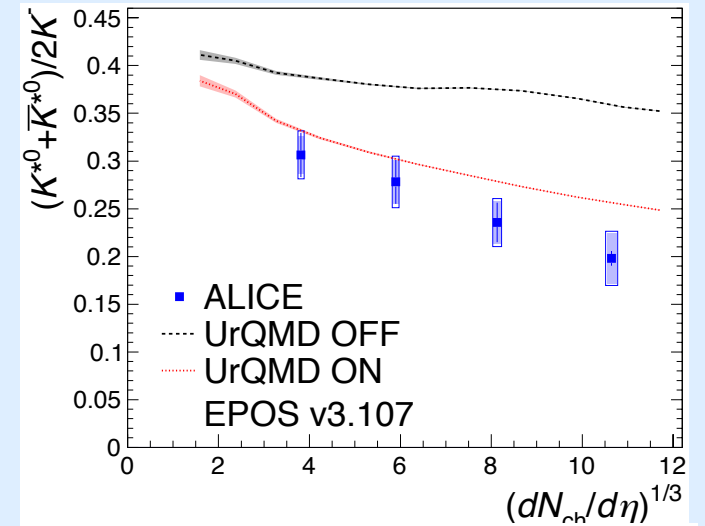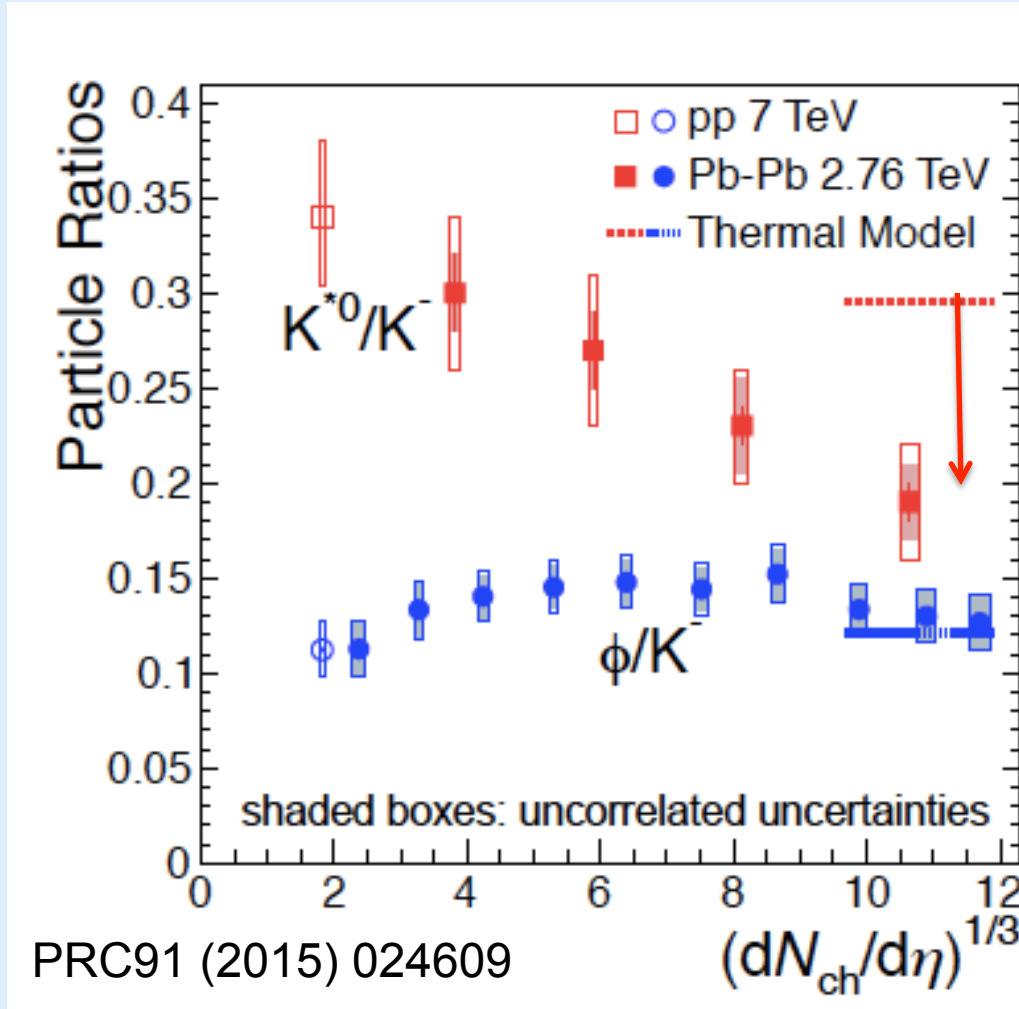
ρ(770) meson suppression in Pb–Pb

Life-time [fm/c]
ρ(770) = 1.3
Δ(1232) = 1.7
K(892) = 4
Σ(1385) = 5.7
Λ(1520) = 13
φ(1020) = 44

Trend of ρ resonance suppression with increasing centrality in agreement with EPOS model predictions.
→ Confirms extended hadronic medium
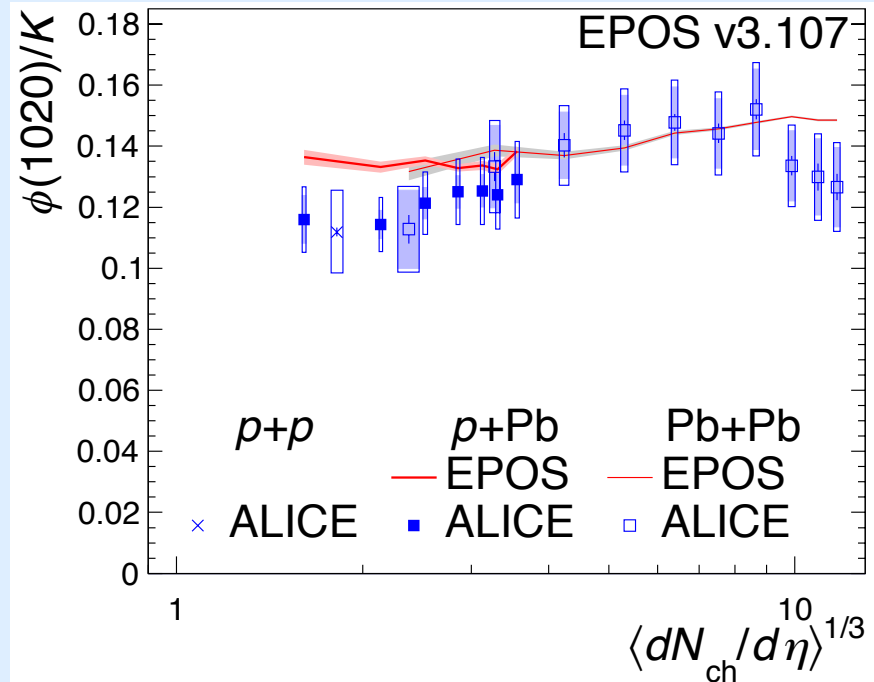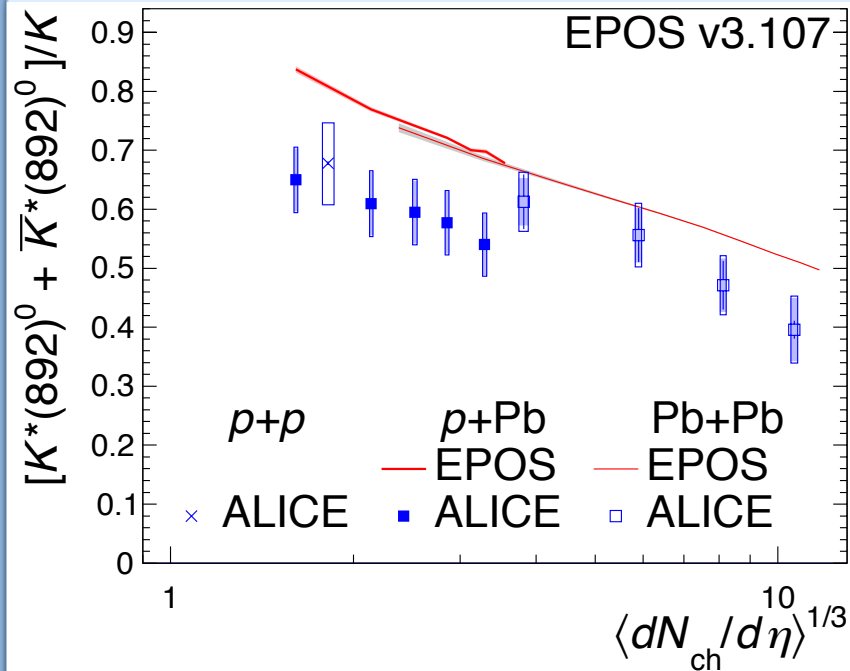
K(892) in PHSD at RHIC energies

A. Ilner, D. Cabrera, CM, E. Bratkovskaya
arXiv:1609.02778 submitted to Physical Review C
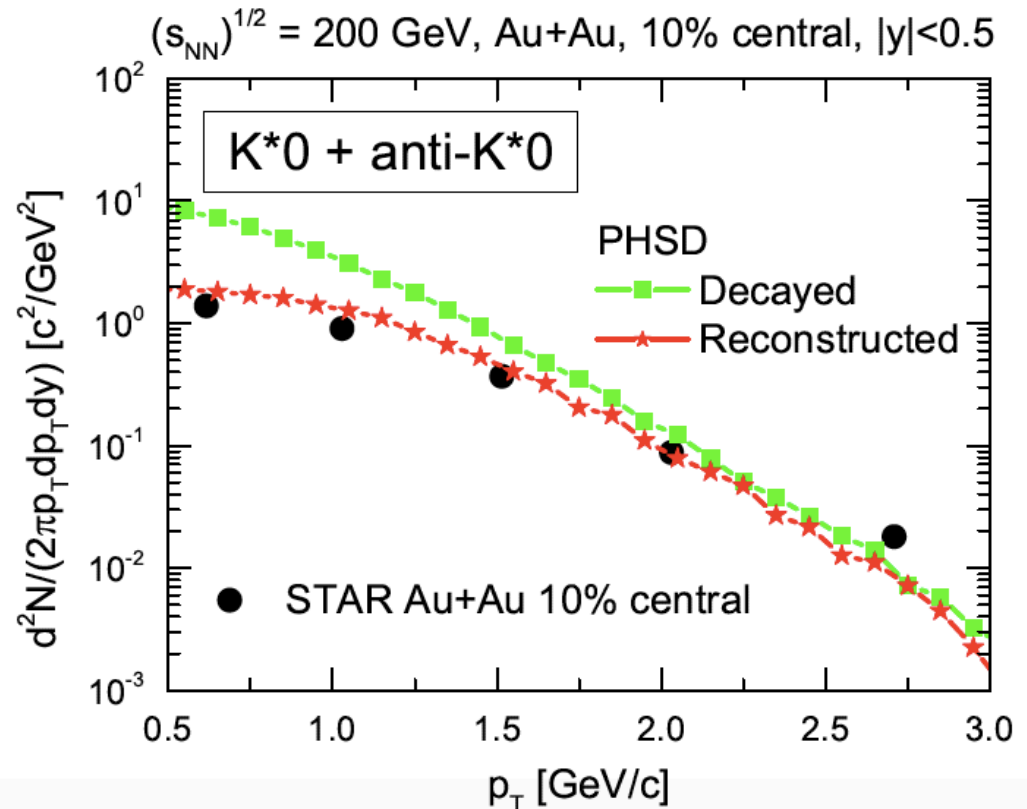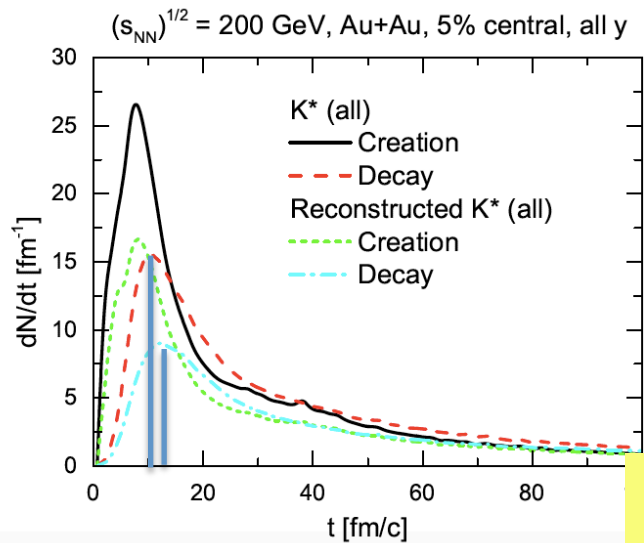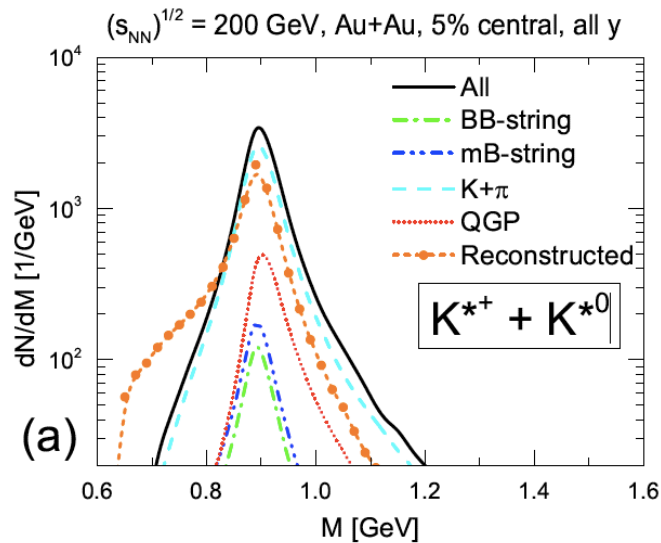
PHSD describes K(892) suppression in A+A collisions
→ Reconstructed K(892) from later time.

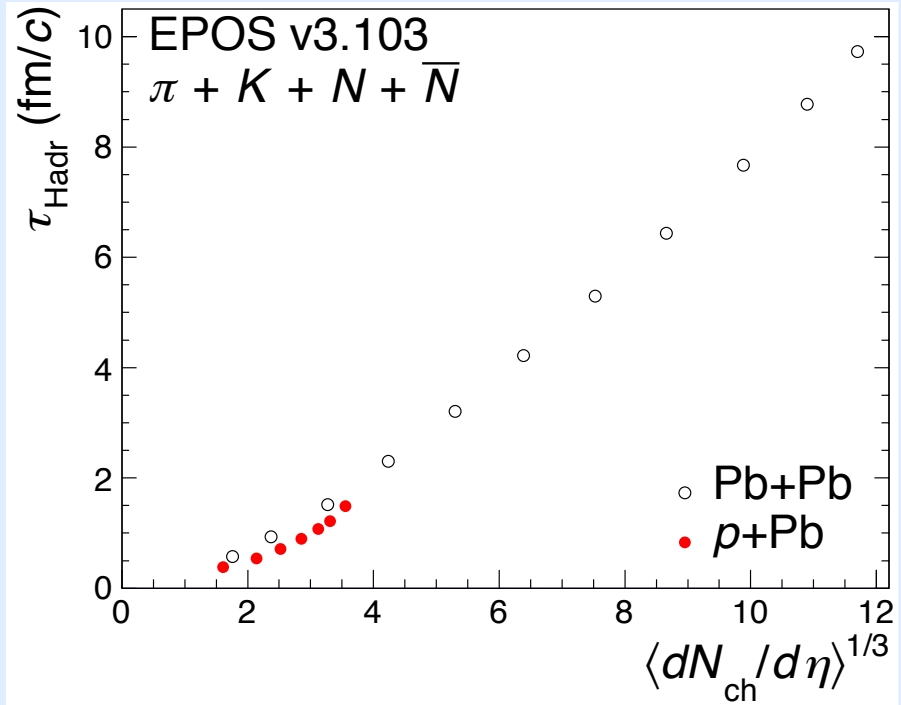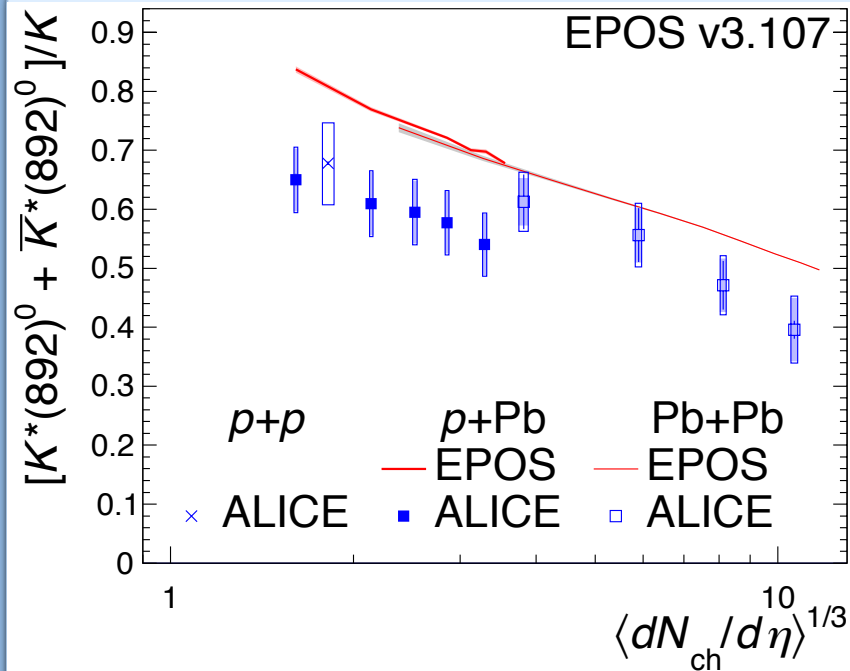# Medium in p-Pb collisions ?

Medium in p–Pb collisions ?

Data: Eur.Phys.J. C76 (2016) no.5, 245

K*/K in p-Pb shows similar behavior compared to low multiplicity Pb-Pb collisions
This is mainly a hadronic effect due to hadronic interactions (re-scattering)
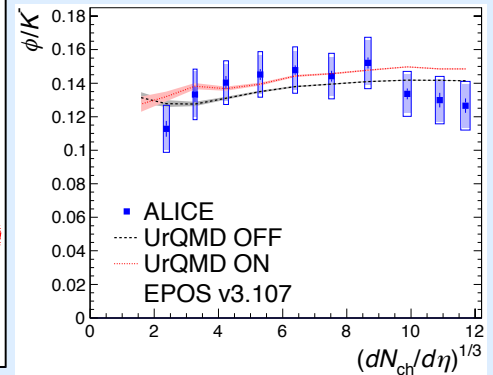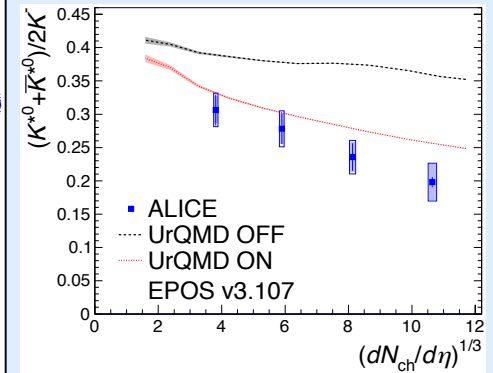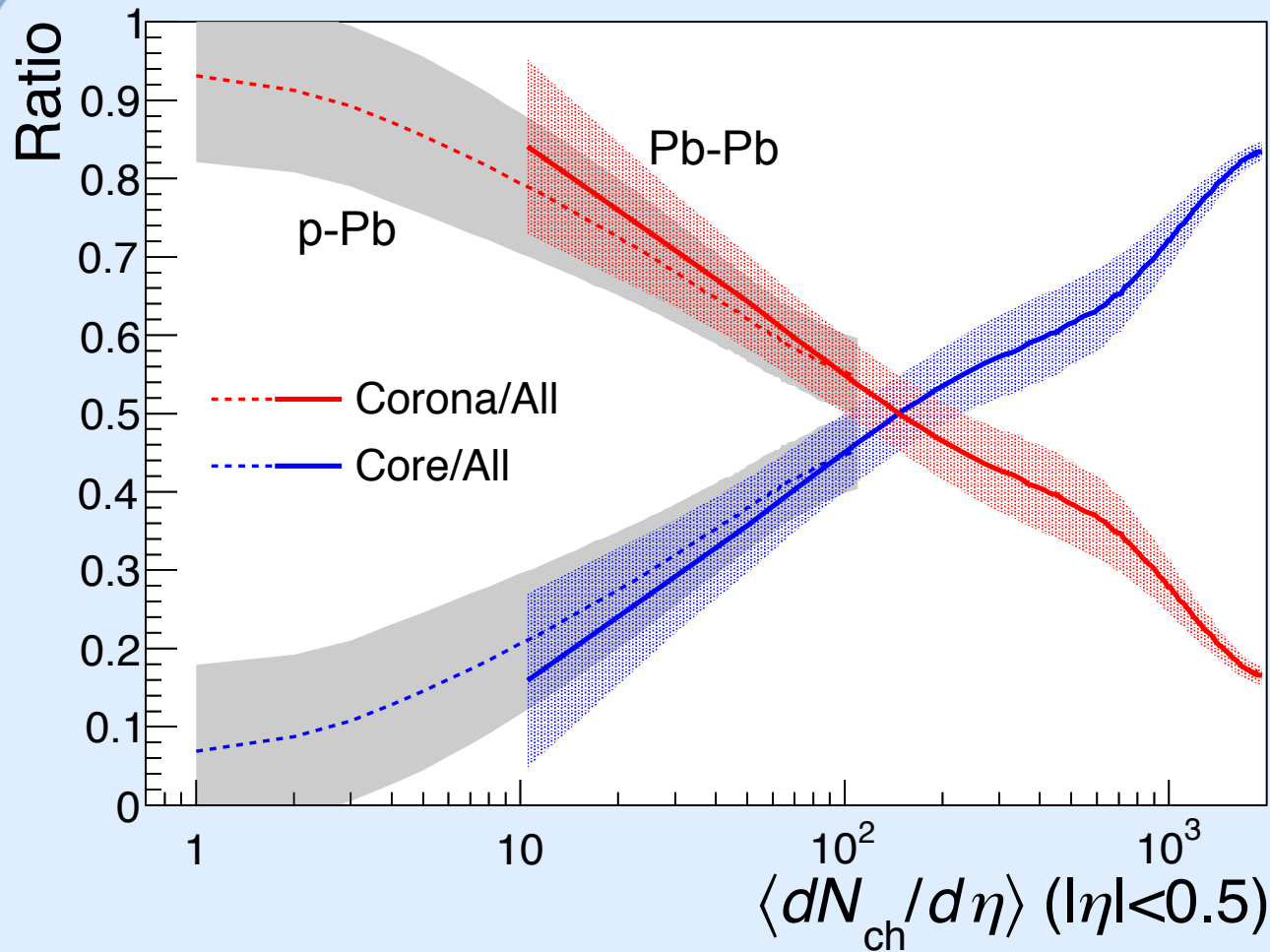→ Extended hadronic medium.

Medium in p-Pb collisions ?

K*/K in p-Pb shows similar behavior compared to low multiplicity Pb-Pb collisions
This is mainly a hadronic effect due to hadronic interactions (re-scattering)
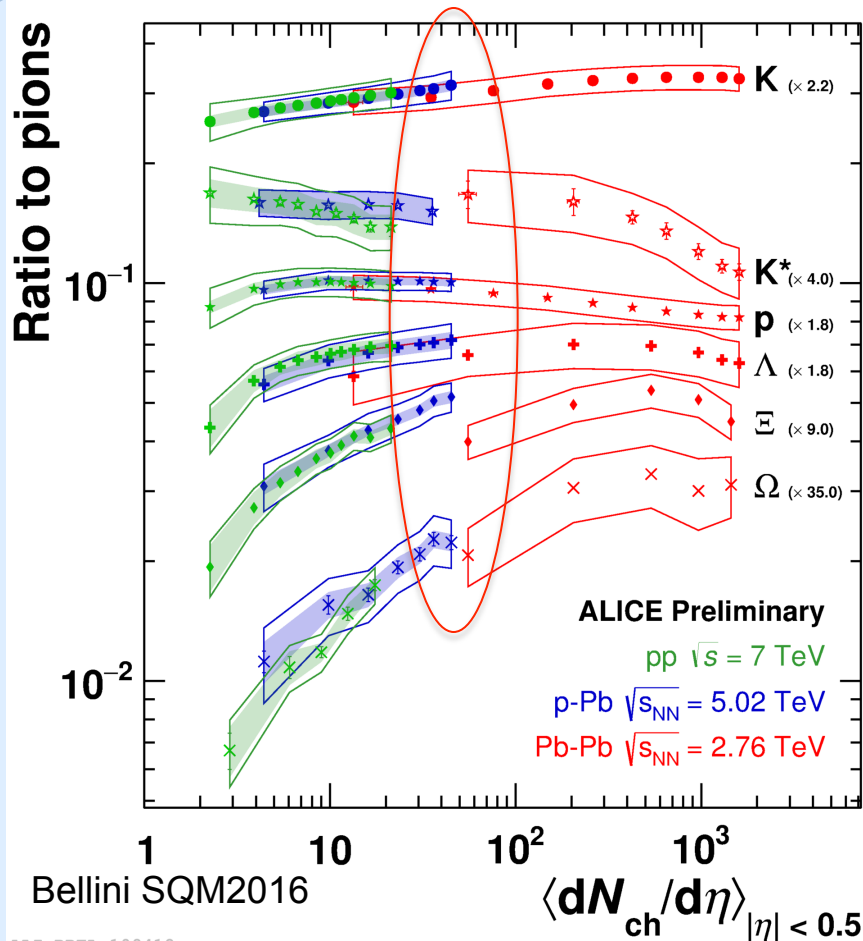→ Extended hadronic medium.
→ Hadronic lifetime is about 1.5 fm/c in 0-5% p-Pb collisions
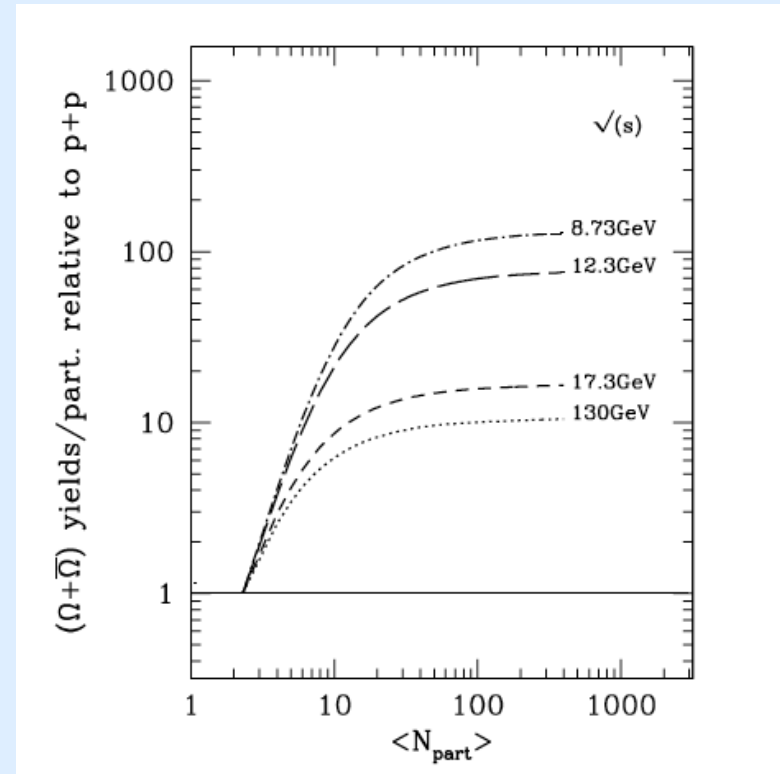
Core-corona contribution

Continues transition from p-Pb to pp (corona =1) and Pb-Pb collisions.
However with K*/K and phi/K we are not sensitive to partonic phase.
→ Same ratios independent of centrality and collisions system

Strangeness production in p-Pb (pp) Collisions

ALICE Preliminary
pp $\sqrt{s}$ = 7 TeV
p-Pb $\sqrt{s_{NN}}$ = 5.02 TeV
Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV

Bellini SQM2016

ALI-PREL-109418

A. Tounsi and K. Redlich,
B. J. Phys. G 28 (2002) 2095

p-Pb ratios fit into the transition from a canonical (pp) to a grand canonical system (Pb-Pb) (Ξ is a little off). Volume effect of strangeness suppression in small systems. Only hadronic effect.
Don't forget that we don't have evidence for strangeness enhancement in central Pb-Pb collisions

Christi...

13

Do we have same hadronic medium in 0-5% p-Pb and 60-80% Pb-Pb collisions ?
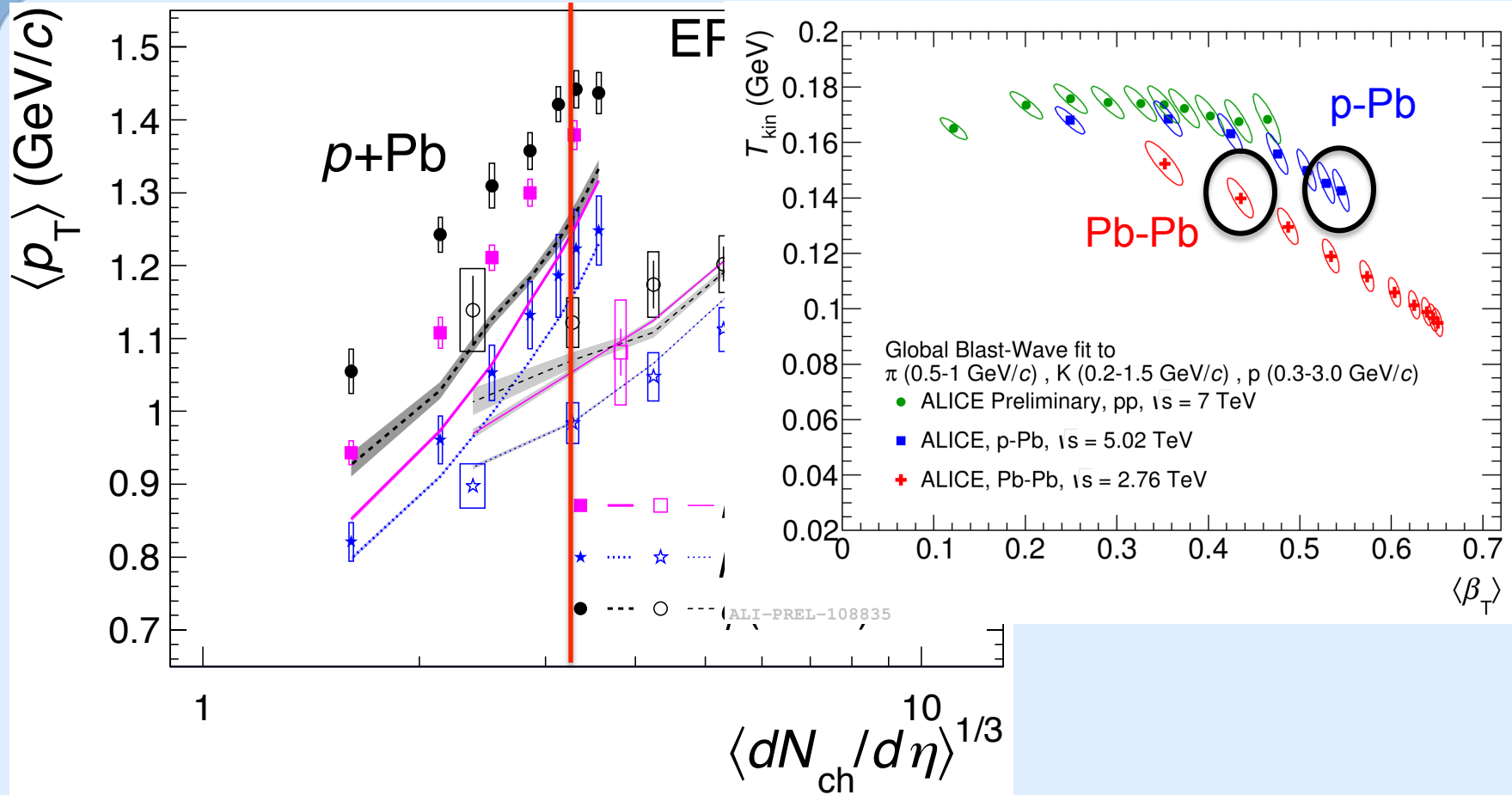
Mean p_T in small system size
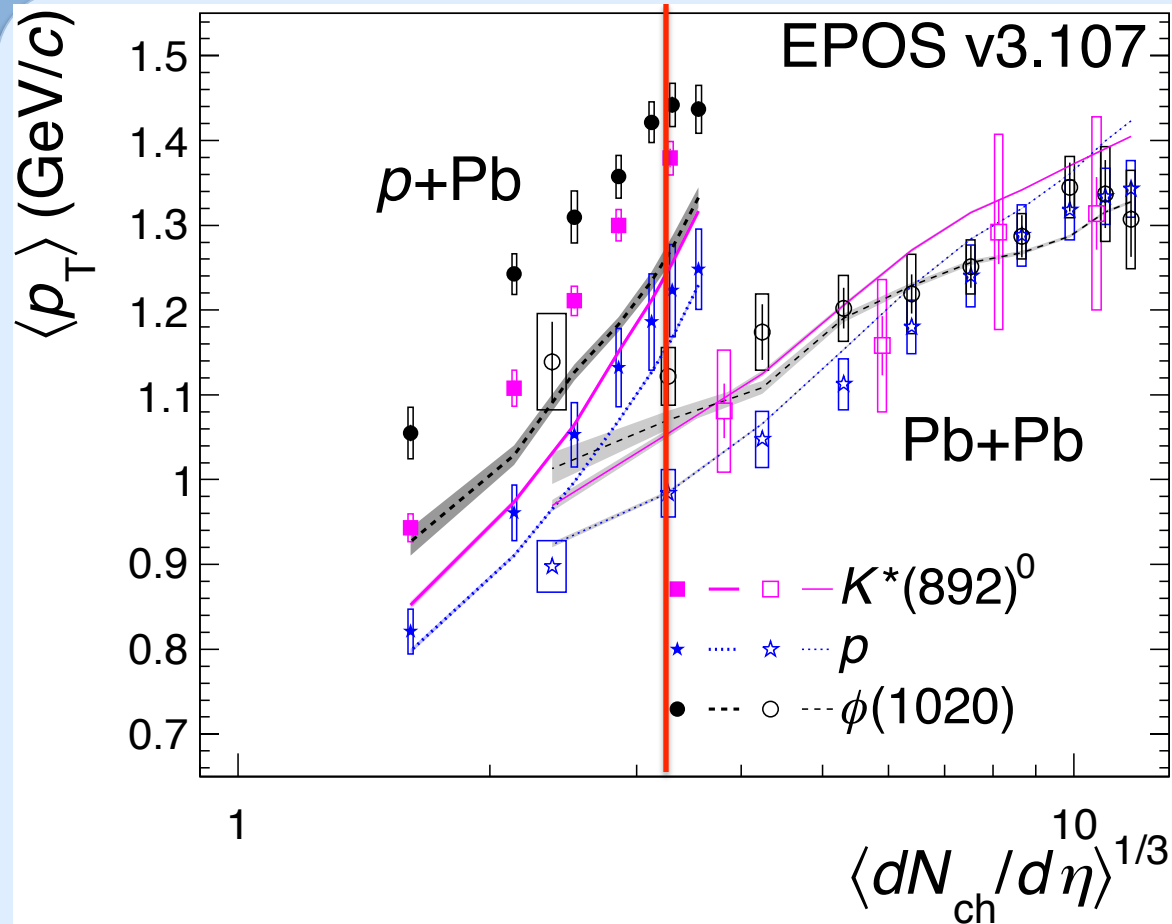
Larger mean p_T in p-Pb at same Pb-Pb multiplicity:
- More head on quark-quark scatterings ?
- More radial flow ?
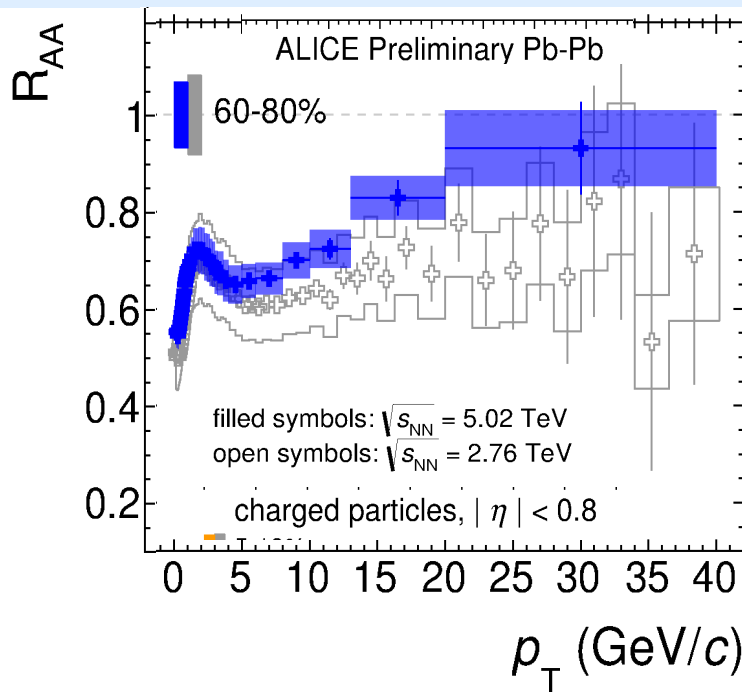→ Hadronic phases are different
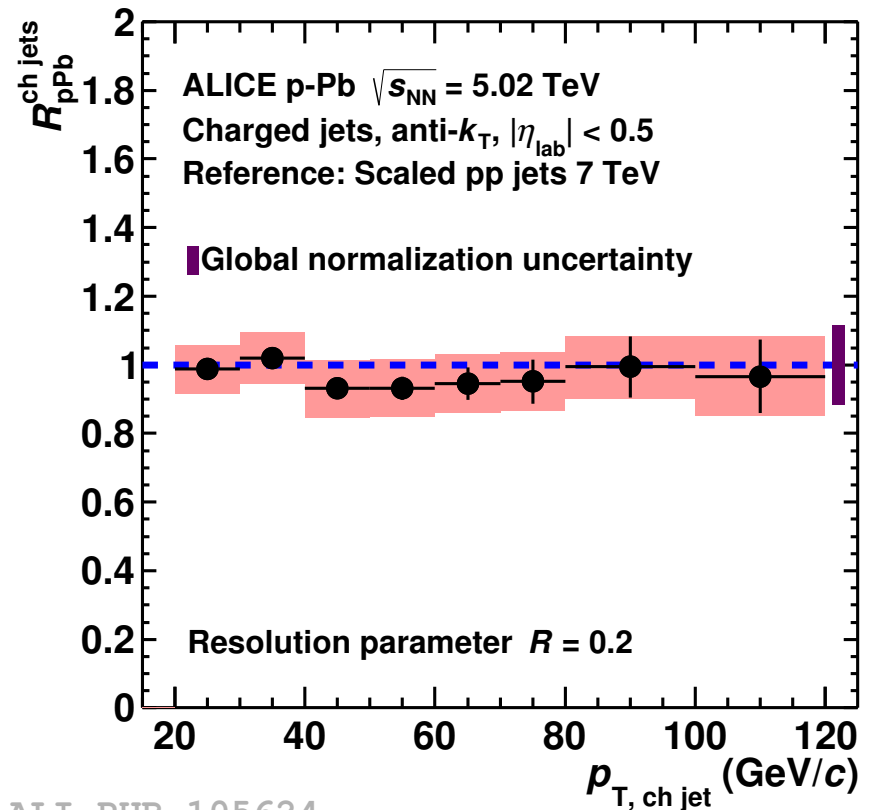
Mean p_T in small system size

Same kinetic freeze-out temperature, different expansion velocity (from p,K,π)
→ Different hadronic medium ?

Do we have evidence for partonic medium in high multiplicity p-Pb collisions?

Nuclear modification factor (p–Pb)

ALICE Preliminary Pb-Pb

60-80%

filled symbols: $\sqrt{s_{NN}}$ = 5.02 TeV
open symbols: $\sqrt{s_{NN}}$ = 2.76 TeV

charged particles, $|\eta| < 0.8$

R_{AA}

p_T (GeV/c)

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

$R_{pPb}^{ch\ jets}$

ALICE p-Pb $\sqrt{s_{NN}}$ = 5.02 TeV
Charged jets, anti-k_T, $|\eta_{lab}| < 0.5$
Reference: Scaled pp jets 7 TeV

Global normalization uncertainty
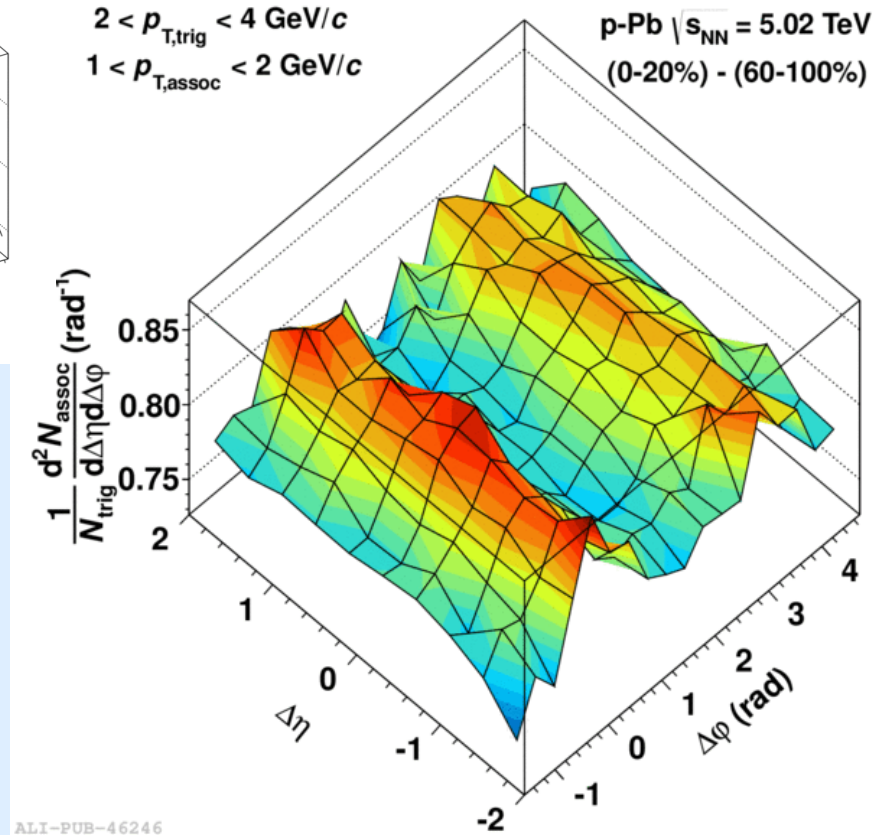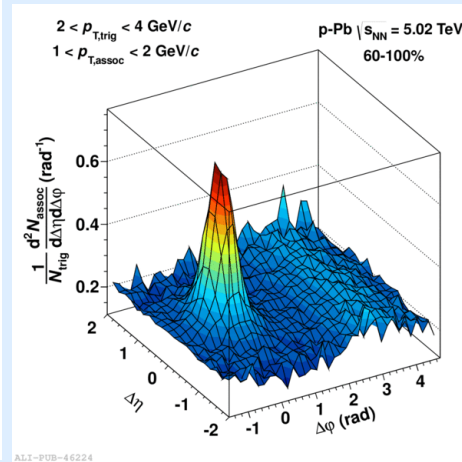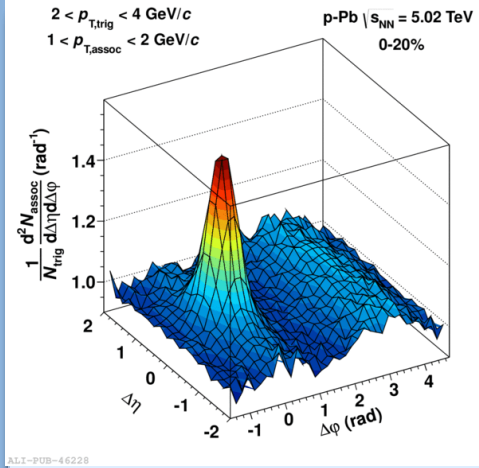
Resolution parameter R = 0.2

$p_{T,\ ch\ jet}$ (GeV/c)

ALI–PUB–105624

Phys. Lett. B749 (205) 68-811

R_AA 60-80% Pb-Pb shows suppression.
Binary collisions in p-Pb not easy to determine
No high pt jet R_pPb suppression in p-Pb (minbias)
→ Need jet R_pPb for 0-5% p-Pb collisions
→ No direct comparison → room for possible low pt suppression
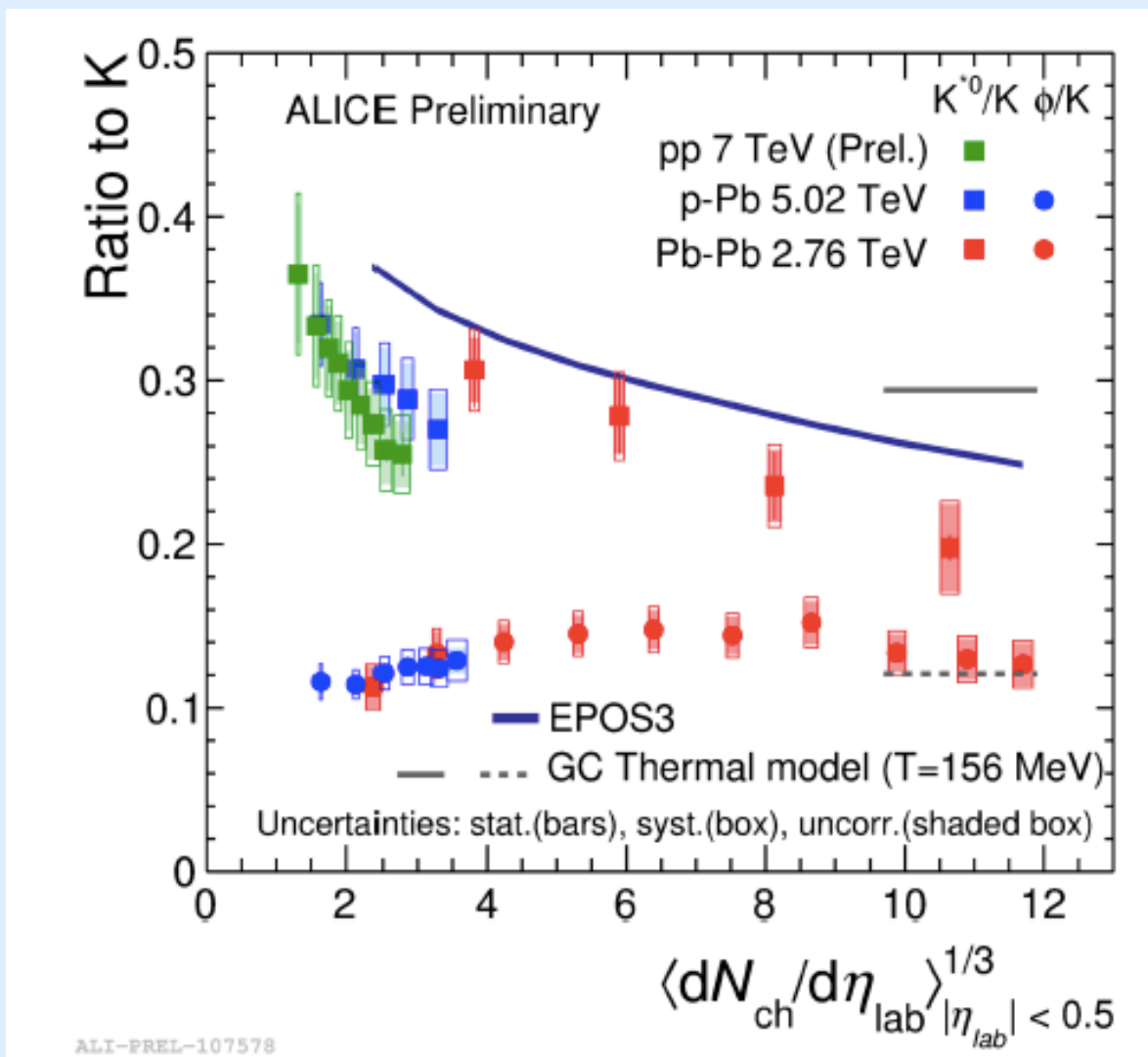
p–Pb collisions (correlations)

(0-20%) – (60-100%)

ALICE, PLB 719 (2013) 29
0-20% 60-100%
ATLAS, PRL 110 (2013) 182302

# Extended hadronic medium in pp collisions

My Conclusion

- Suppression of resonances in p–Pb → hadronic phase

- Increase of strangeness production in events with increasing multiplicity -> canonical to grand canonical system.

- Hadronic phase in different

- There are no signatures of partonic phase

- Maybe small hint from v2 of partonic phase

- Difficult to get R_pPb 0-5% (not sensitive right now)

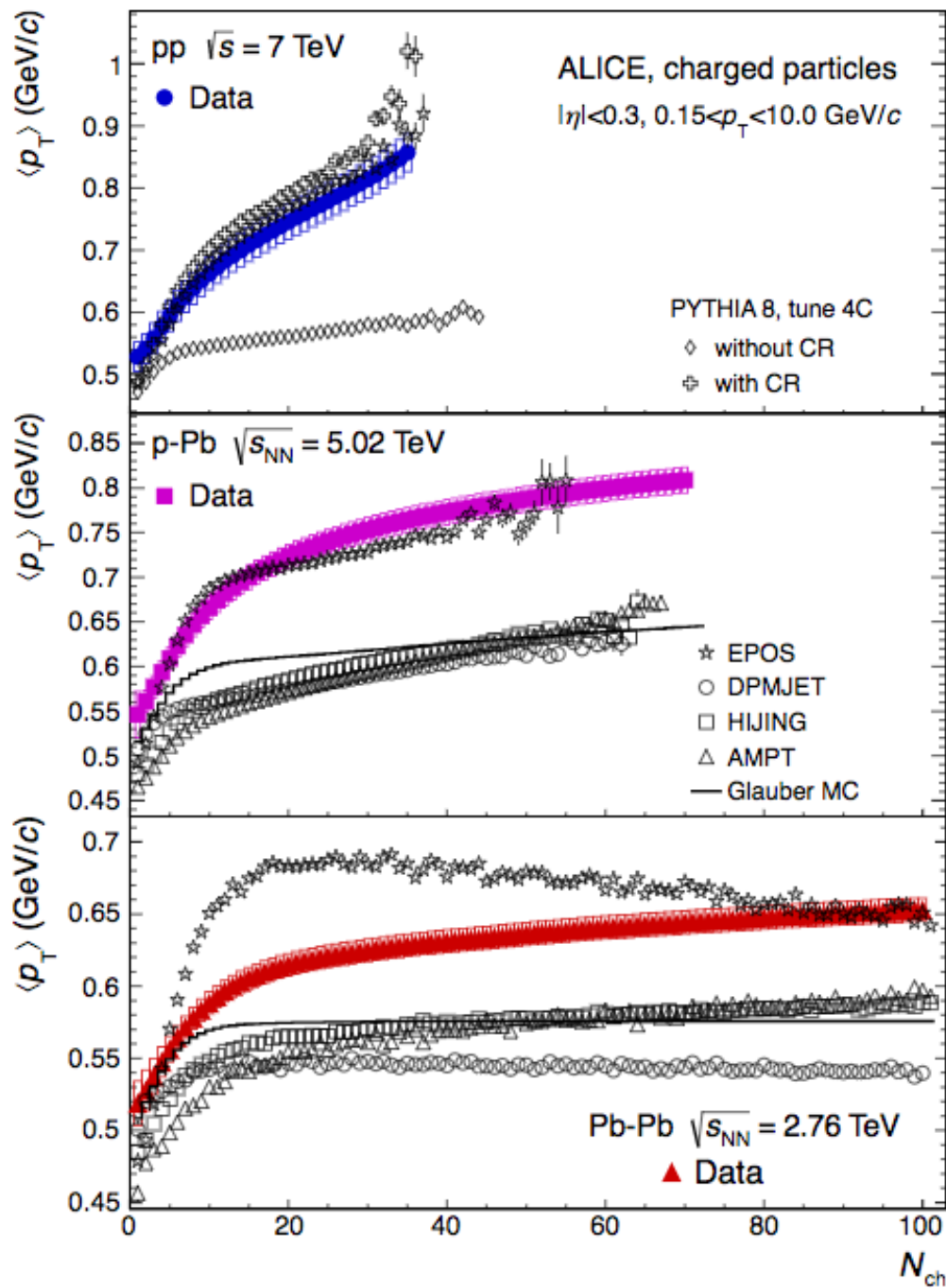# P- Pb
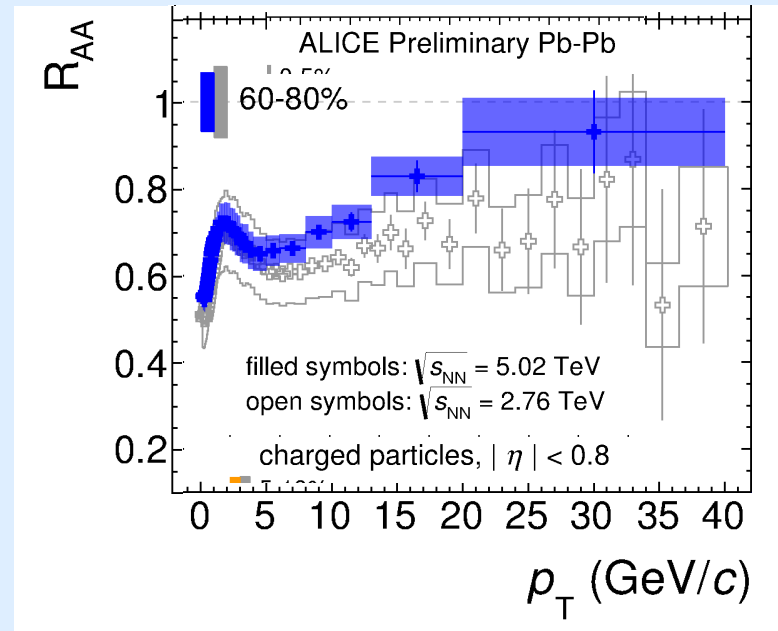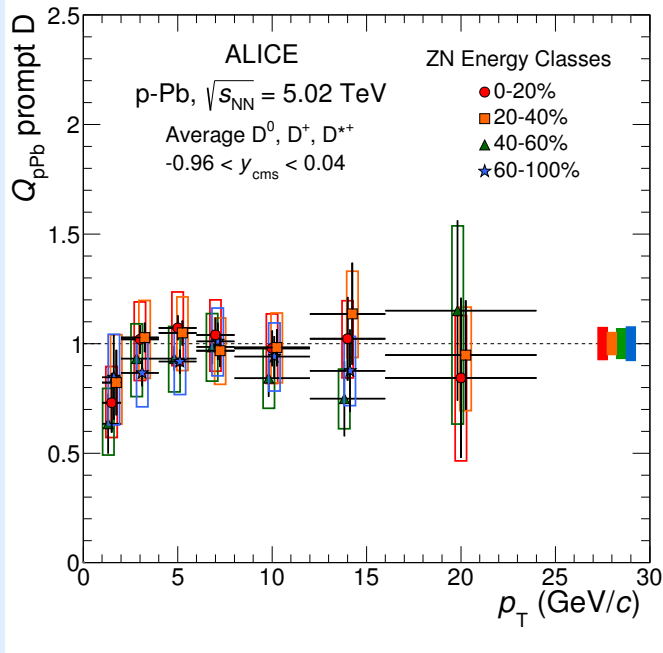
arXiv:1602.07240

P- Pb
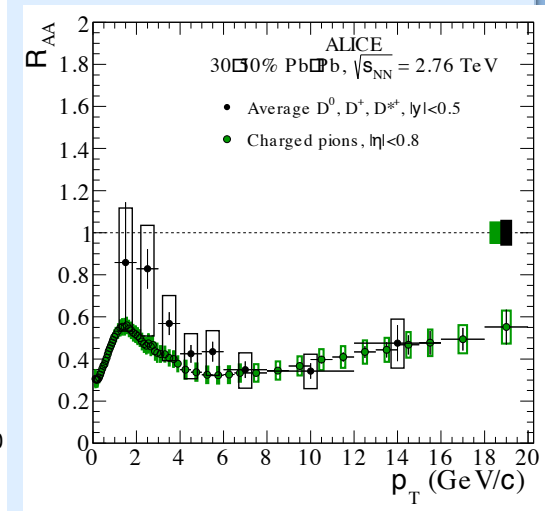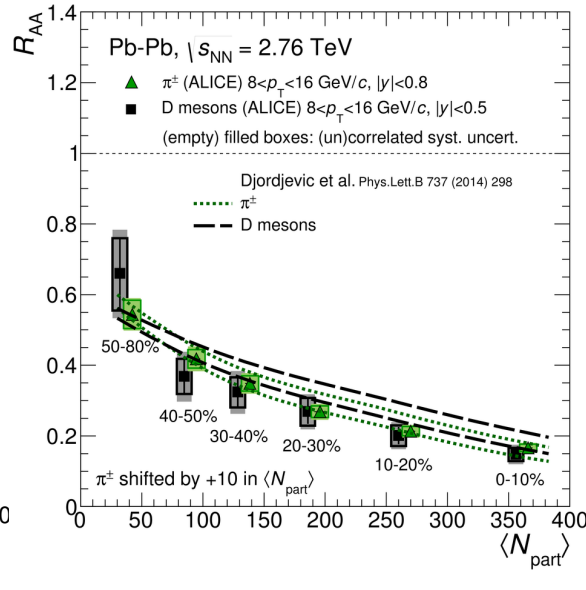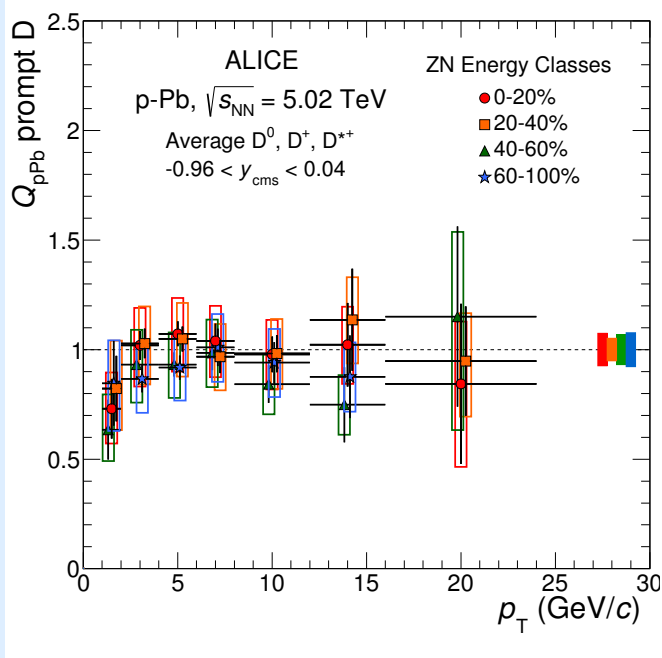
arXiv:1602.07240

arXiv:1506.06604

arXiv:1509.06888

Phys. Lett. B 727 (2013) 371-380

CR = color reconnection

K(892) in PHSD at RHIC energies

(s_{NN})$^{1/2}$ = 200 GeV, Au+Au, 5% central, all y

(a)

K^{*+} + K^{*0}

Legend: All, BB-string, mB-string, K+π, QGP, Reconstructed

dN/dM [1/GeV] vs M [GeV]

(s_{NN})$^{1/2}$ = 200 GeV, Au+Au, 5% central, all y

K* (all): Creation, Decay
Reconstructed K* (all): Creation, Decay

dN/dt [fm^{-1}] vs t [fm/c]

A. Ilner, D. Cabrera, CM, E. Bratkovskaya
arXiv:1609.02778 submitted to Physical Review C

(s_{NN})$^{1/2}$ = 200 GeV, Au+Au, 10% central, |y|<0.5

K*0 + anti-K*0

PHSD
Decayed
Reconstructed

STAR Au+Au 10% central

d^{2}N/(2πp$_T$dp$_T$dy) [c^2/GeV^2] vs p$_T$ [GeV/c]