Unidentified and identified hadron production in Pb-Pb collisions at the LHC with ALICE

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On behalf of the ALICE Collaboration

A Large Ion Collider Experiment
aliceinfo.cern.ch

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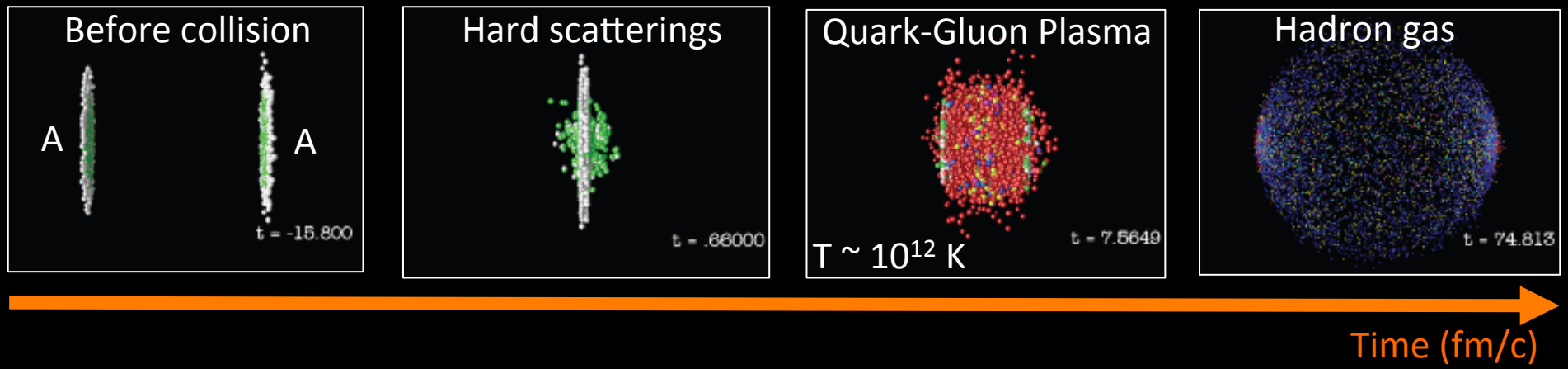
Outlook

Quest for the Quark-Gluon Plasma
(Cabibbo & Parisi 1975, Collins & Perry 1975)

https://www.youtube.com/watch?v=gslEZUTJyvc



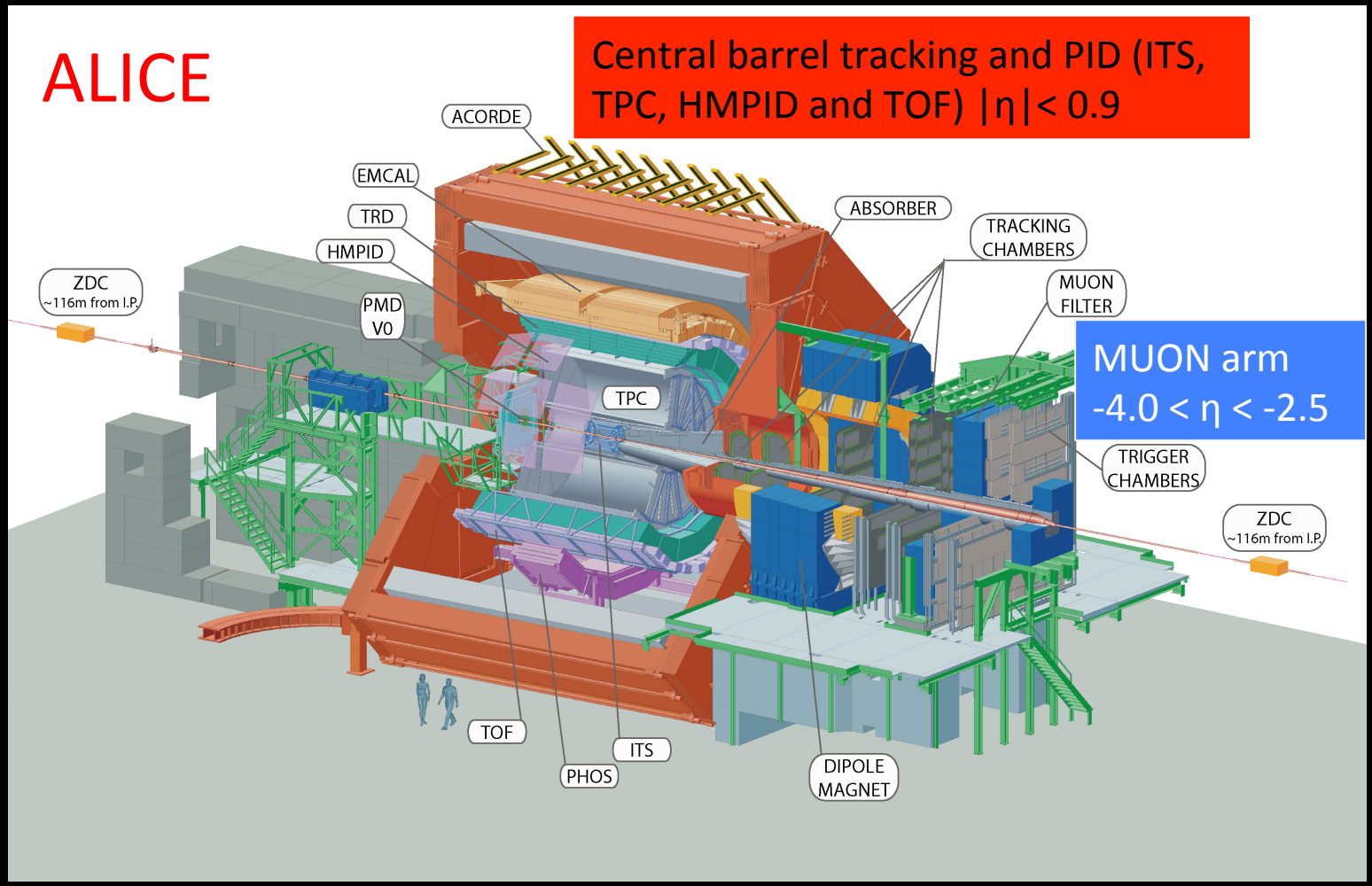
Particle production in hot/dense QCD matter

- Collective effects on p_T spectra (radial flow)
- Thermal particle production and role of the rescattering and regeneration in the hadronic phase
- Nuclear effects on particle production at high p_T

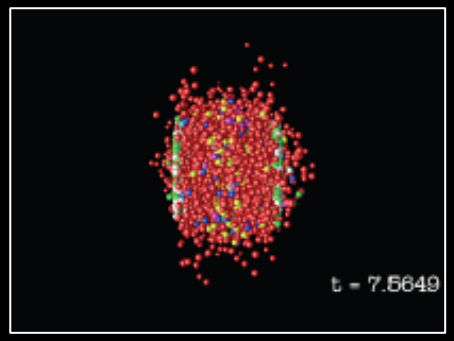
Focus on new results from Pb+Pb 5 TeV (Run 2)
vs Pb+Pb 2.76 TeV (Run 1)

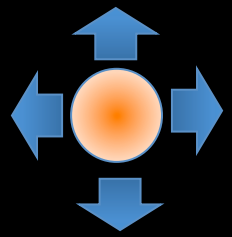
A Large Ion Collider Experiment

- Excellent particle identification capabilities in the large p_T range 0.1-20 GeV/c
- Good momentum resolution ~1-5% for p_T = 0.1-50 GeV/c

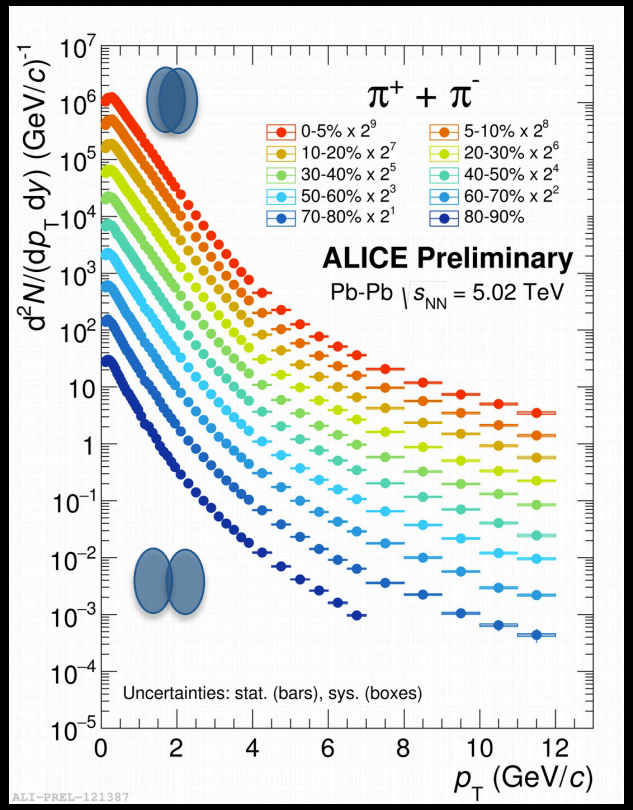


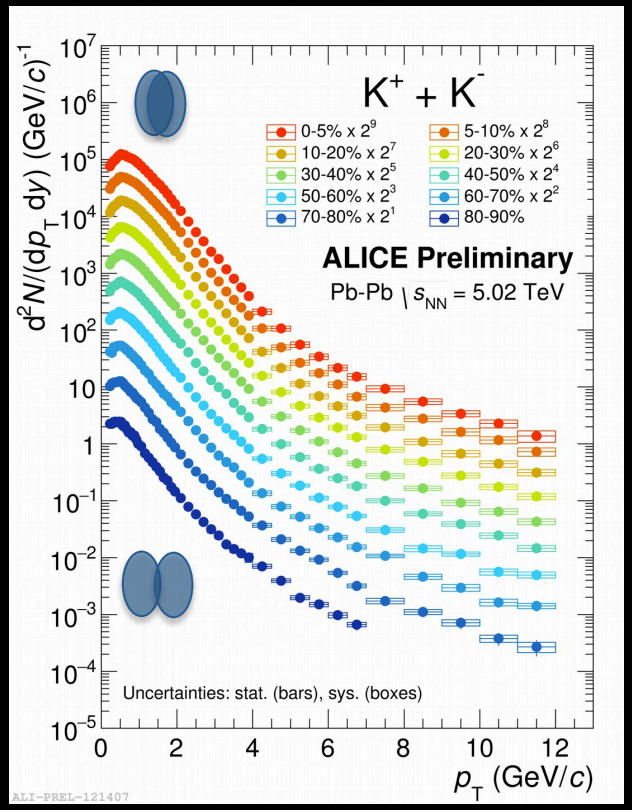
Collective effects on p_T spectra (radial flow)

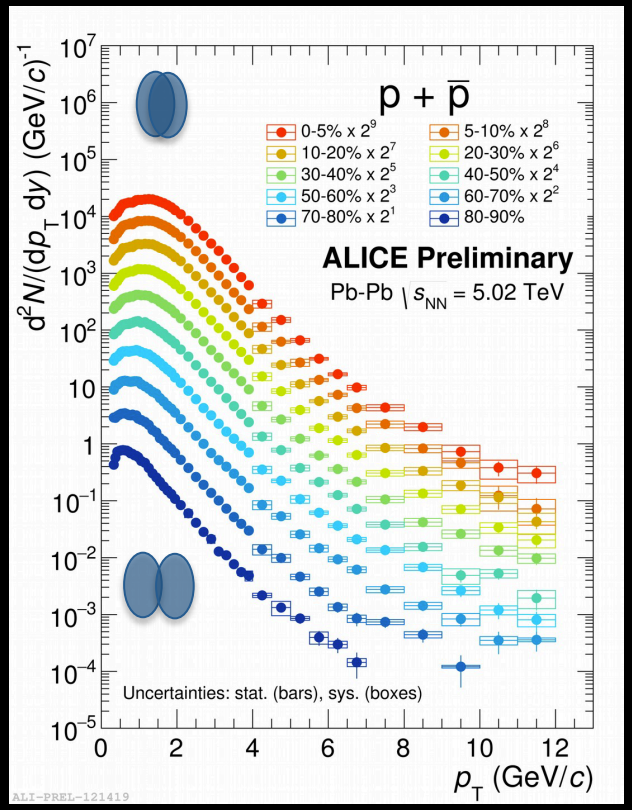




Charged π, K and p spectra

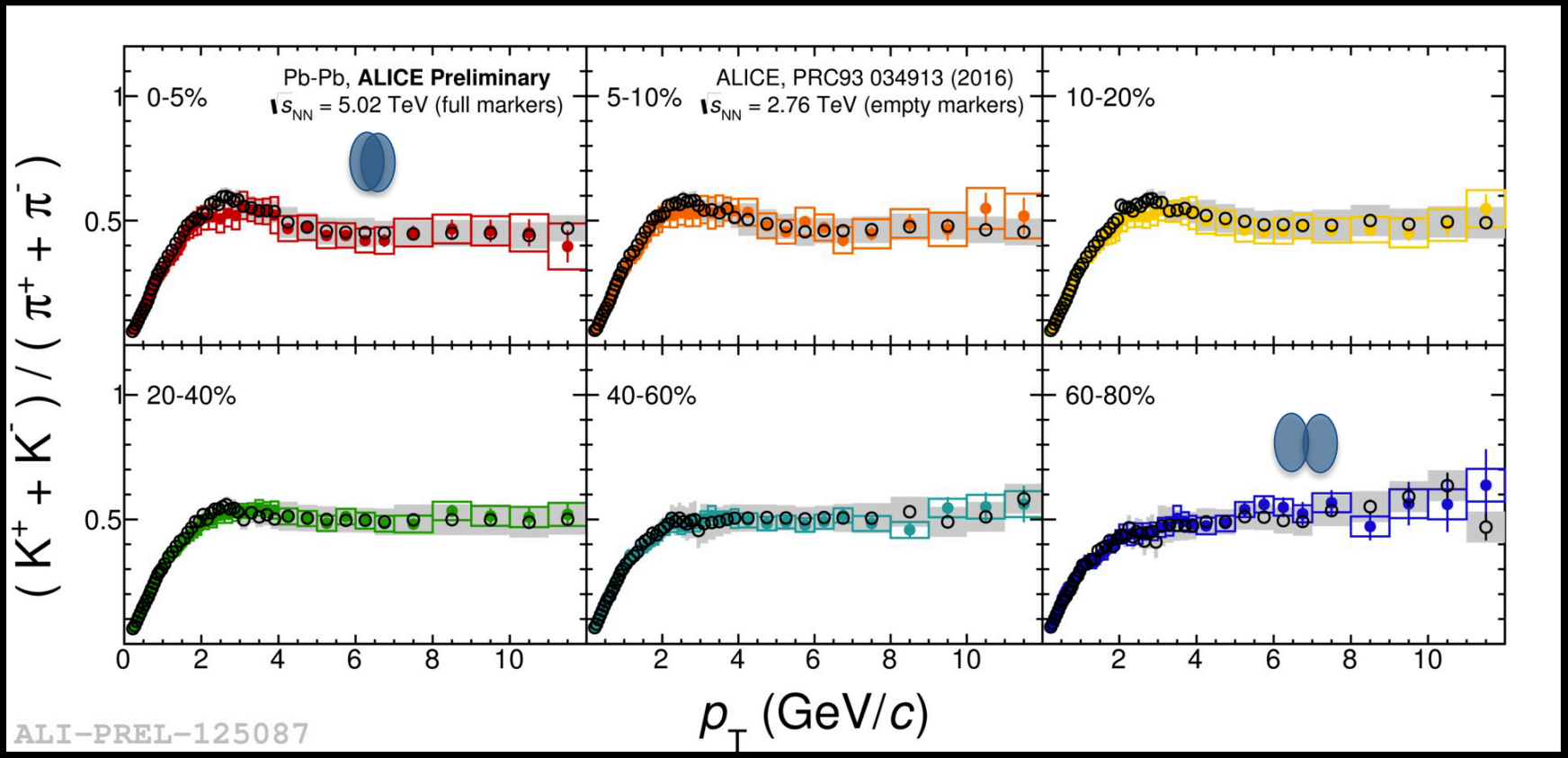






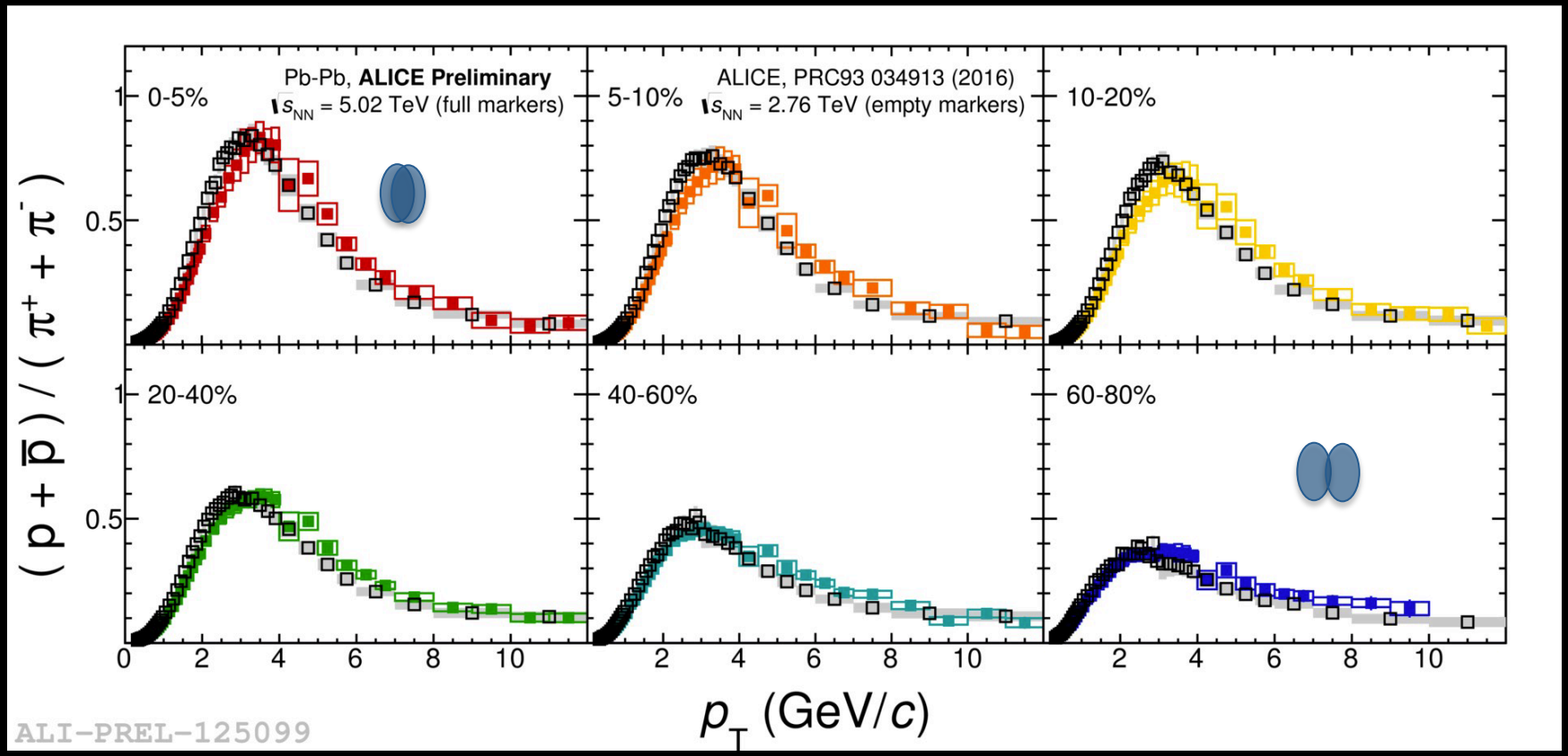
- Measured and identified with different analysis techniques: ITS, TPC, TOF, HMPID and topological identification of decaying charged kaons
- Mass dependent hardening of the spectra with increasing centrality

K / π ratio



- Different pattern in the K/π ratio, depending on centrality
- No significant change between the two energies $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV

p / π ratio



- Maximum in the p/π ratio due to radial flow
- Shift of the maximum of p/π to higher p_T with respect to lower energies (stronger radial flow)

Blast-Wave model

$$E\frac{d^3N}{dp^3} \propto \int_0^R m_T I_0\left(\frac{p_T \sinh(\rho)}{T_{Kin}}\right) K_1\left(\frac{m_T \cosh(\rho)}{T_{Kin}}\right) r\, dr$$

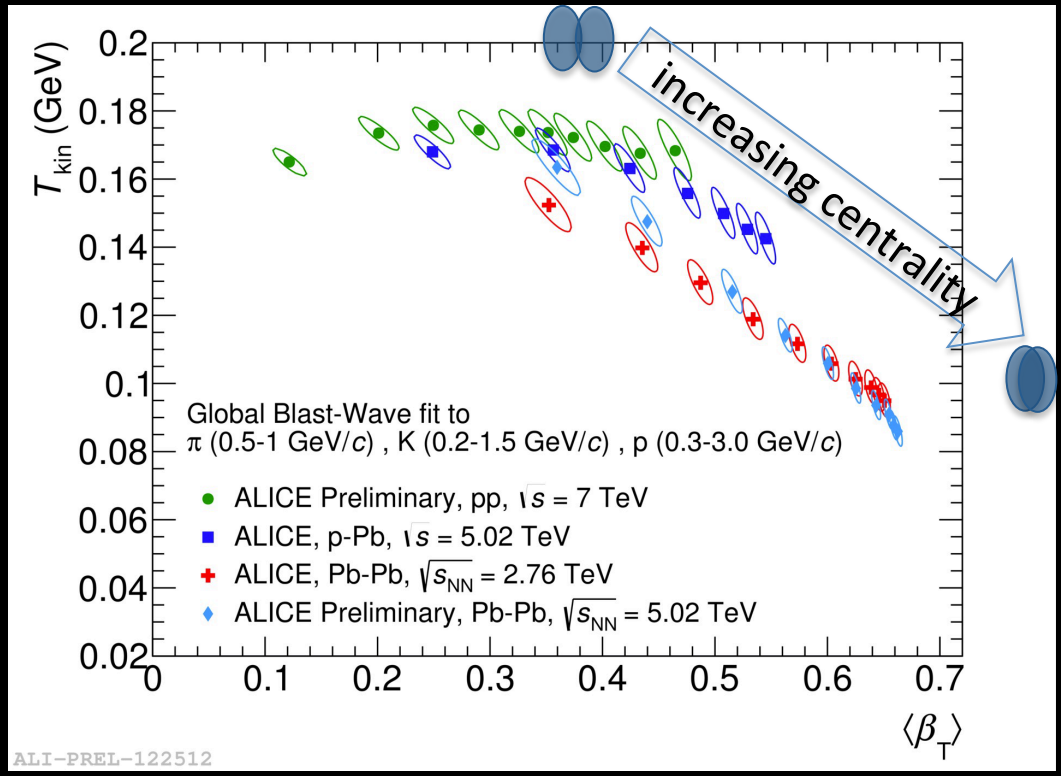
$$m_T = \sqrt{m^2 + p_T^2} \qquad \rho = \tanh^{-1}(\beta_T) \qquad \beta_T = \beta_s \left(\frac{r}{R}\right)^n$$

Schnedermann, Sollfrank and Heinz Phys. Rev. C 48, 2462

Simplified hydrodynamic model with 3 parameters:

- β_T - radial expansion velocity
- T_{kin} – kinetic freeze-out temperature
- n – velocity profile

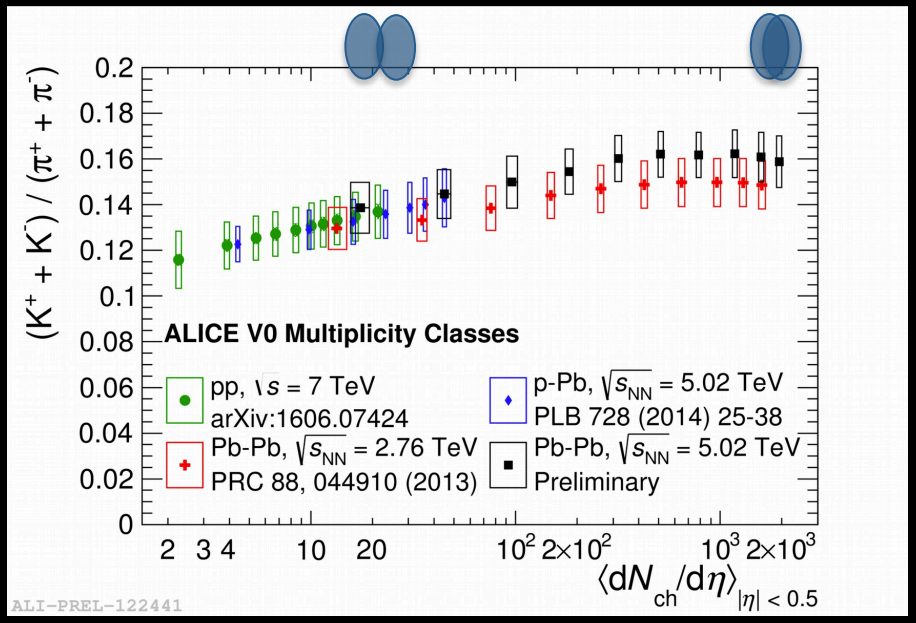
Simultaneous fit to the π, K, p spectra

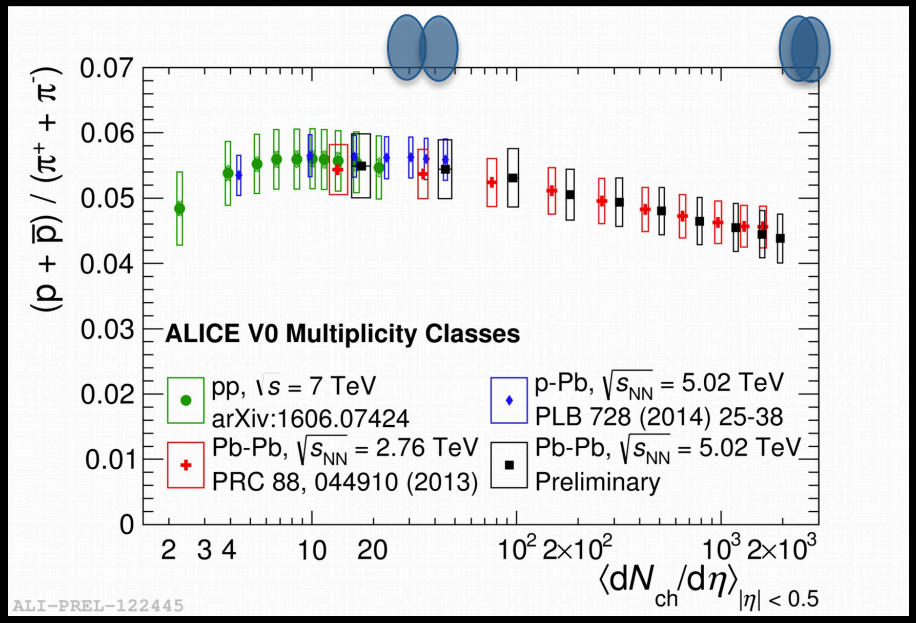


p–Pb Phys. Lett. B 760 (2016) 720
Pb–Pb Phys. Rev. C88 (2013) 044910

Blast-Wave model parameters follow trends observed at lower energy

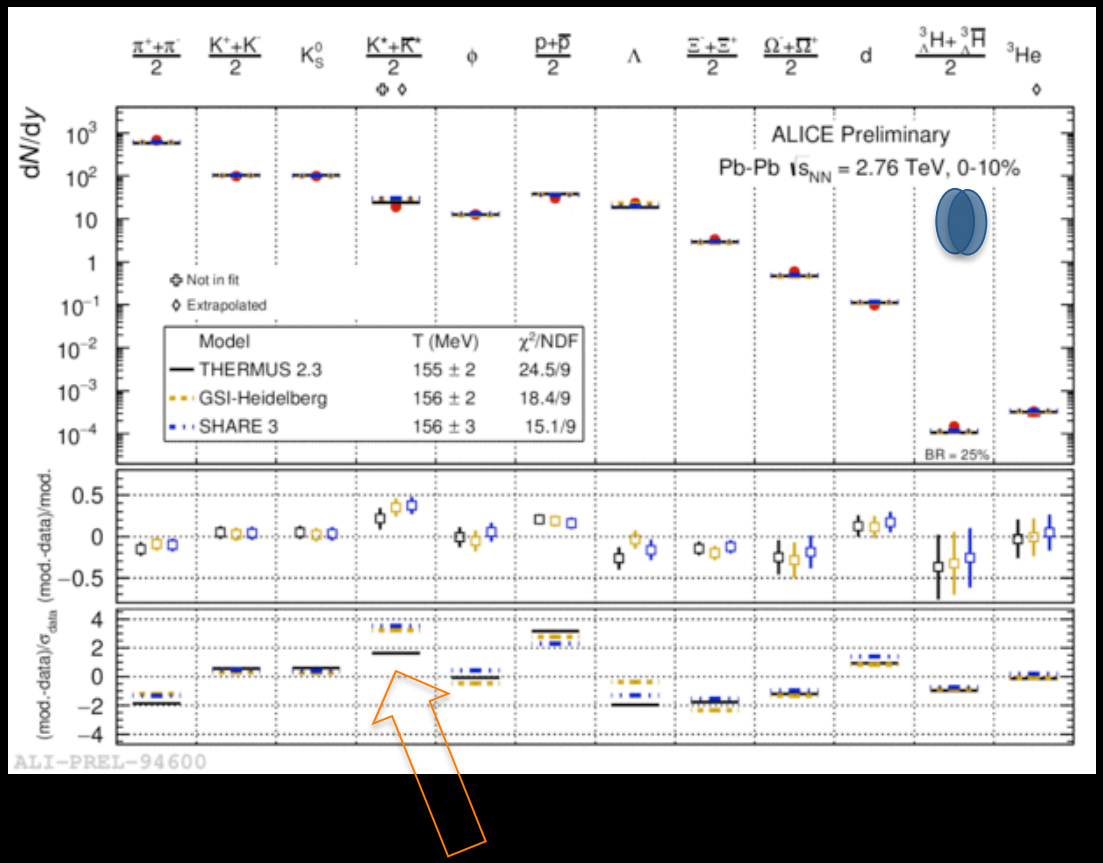
Ratios of p_T integrated yields

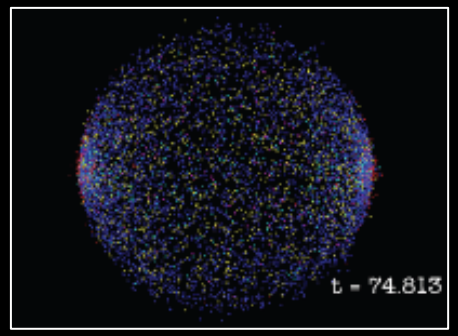


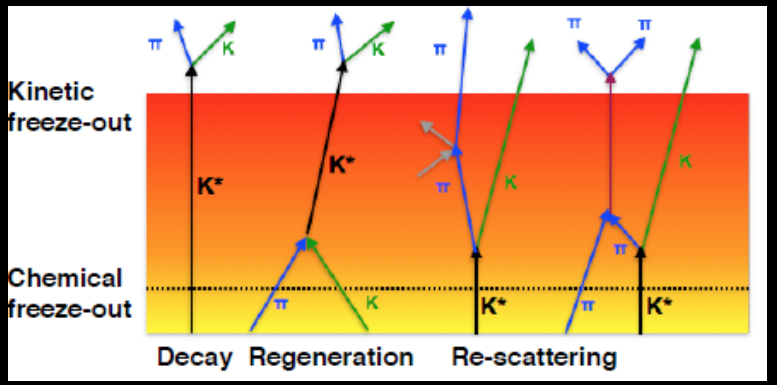


- No significant energy dependence is observed
- K/π and p/π measured in peripheral Pb-Pb collisions are consistent with the high-multiplicity pp and p-Pb values

Thermal particle production and role of the rescattering and regeneration in the hadronic phase

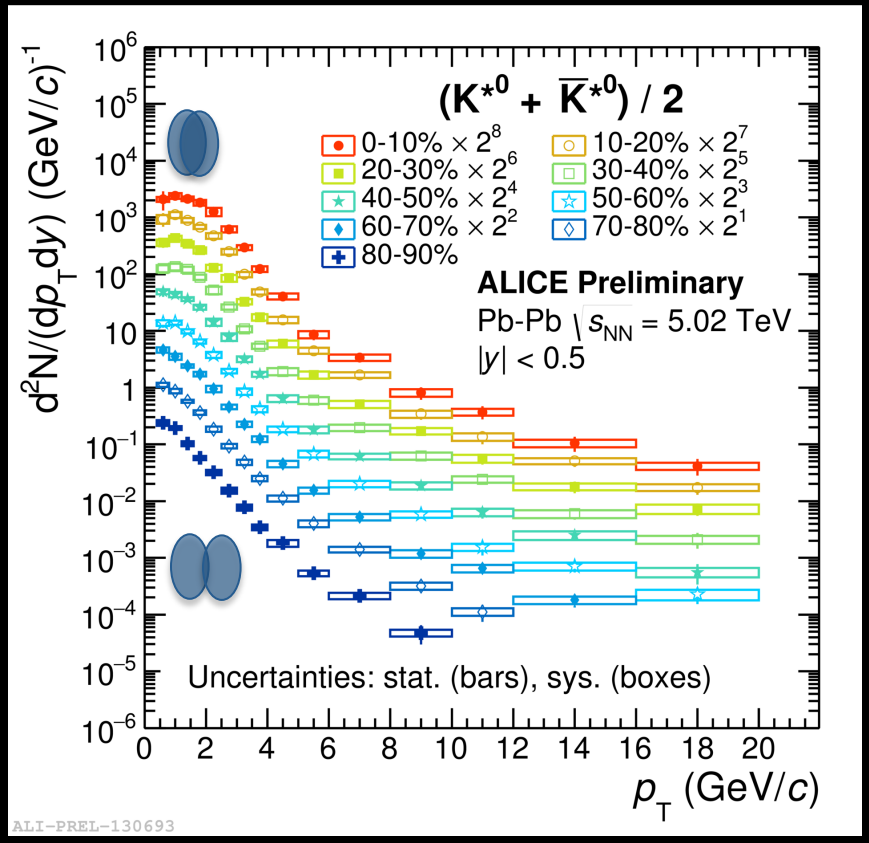


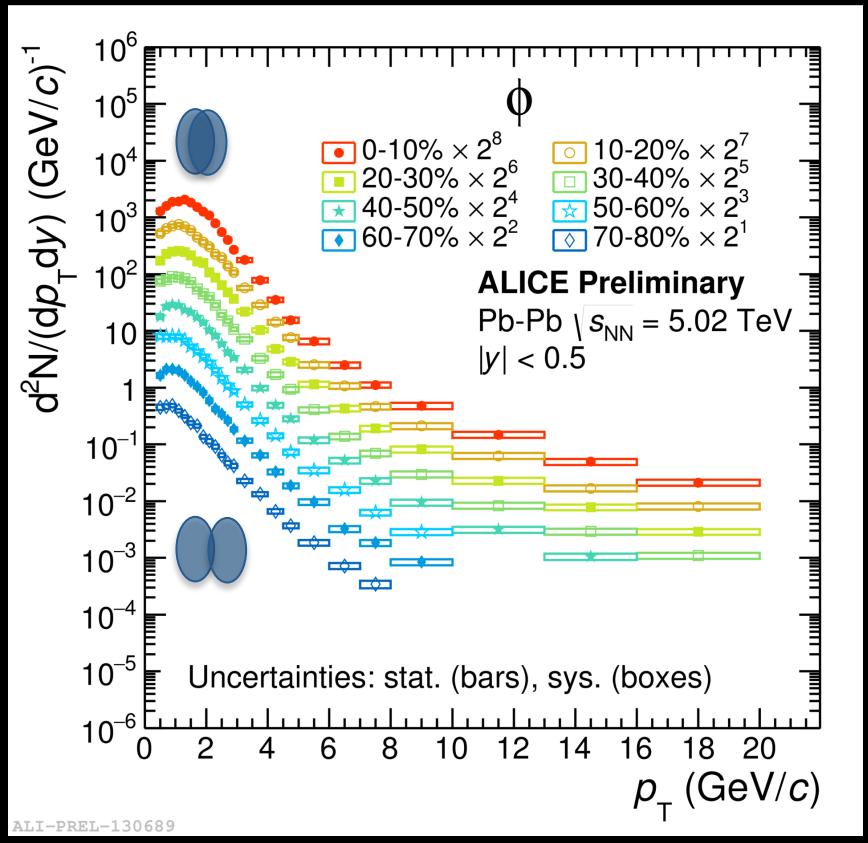




K* production overestimated by thermal models

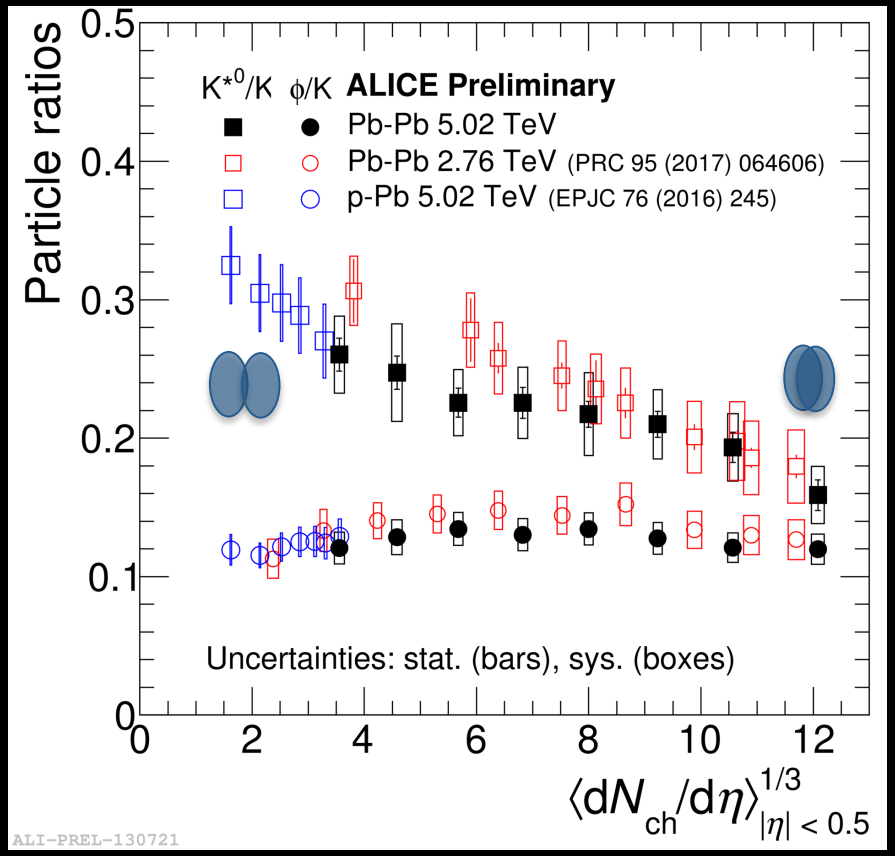
K*(892)^0, Φ(1020) resonances





- Mean lifetime: K*(892)^0 ~4.16 fm/c, Φ(1020) ~ 46.2 fm/c
- Measured using invariant mass (K*^{0}→πK, Φ→KK) and PID with different analysis techniques using TPC and TOF

Ratios of p_T integrated yields

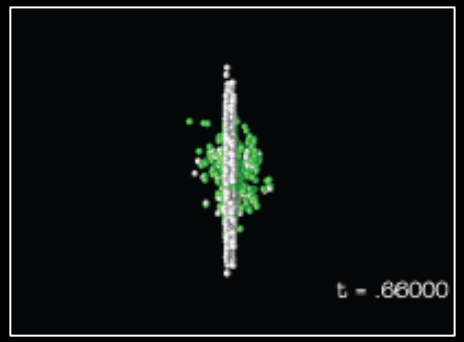


- K^{*0}/K decreases with collision centrality
- K^{*0}/K depends only on system size but not on collision energy
- no decrease is observed for Φ/K
- K^{*0}/K and Φ/K measured in peripheral Pb-Pb collisions are consistent p-Pb values

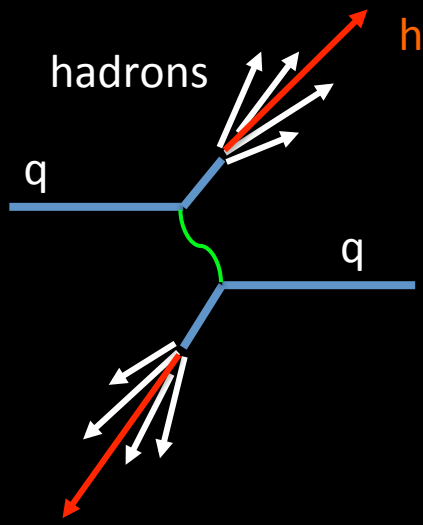
→ Dominance of rescattering over regeneration in the hadronic phase

Mean lifetime: $K^*(892)^0$ ~4.16 fm/c, $\Phi(1020)$ ~ 46.2 fm/c

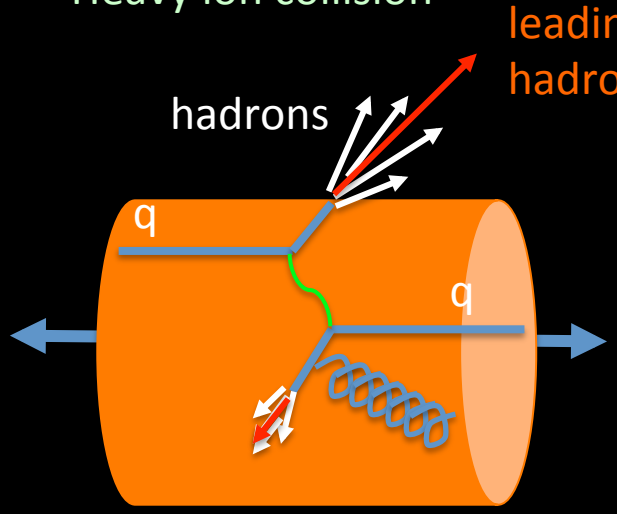
Nuclear effects on particle production at high p_T (quantify via nuclear modification factors R_{AA})



pp collision

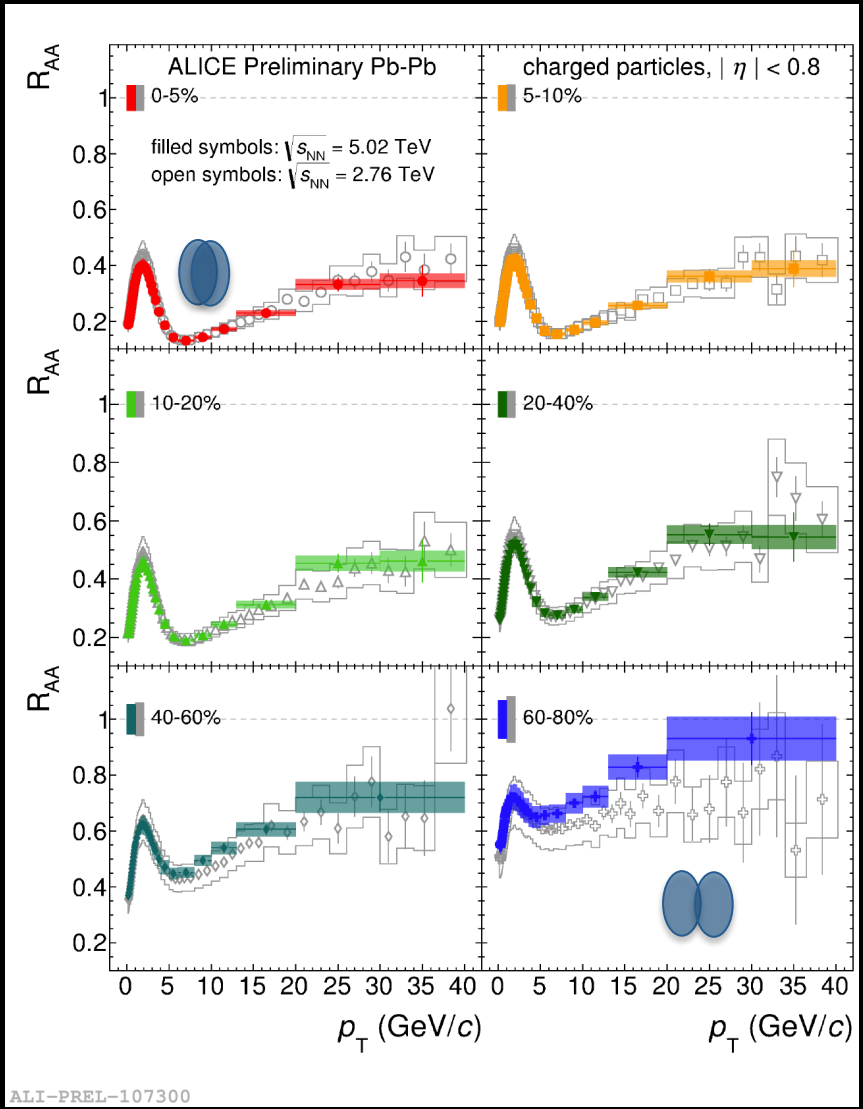


Heavy ion collision



Jet quenching

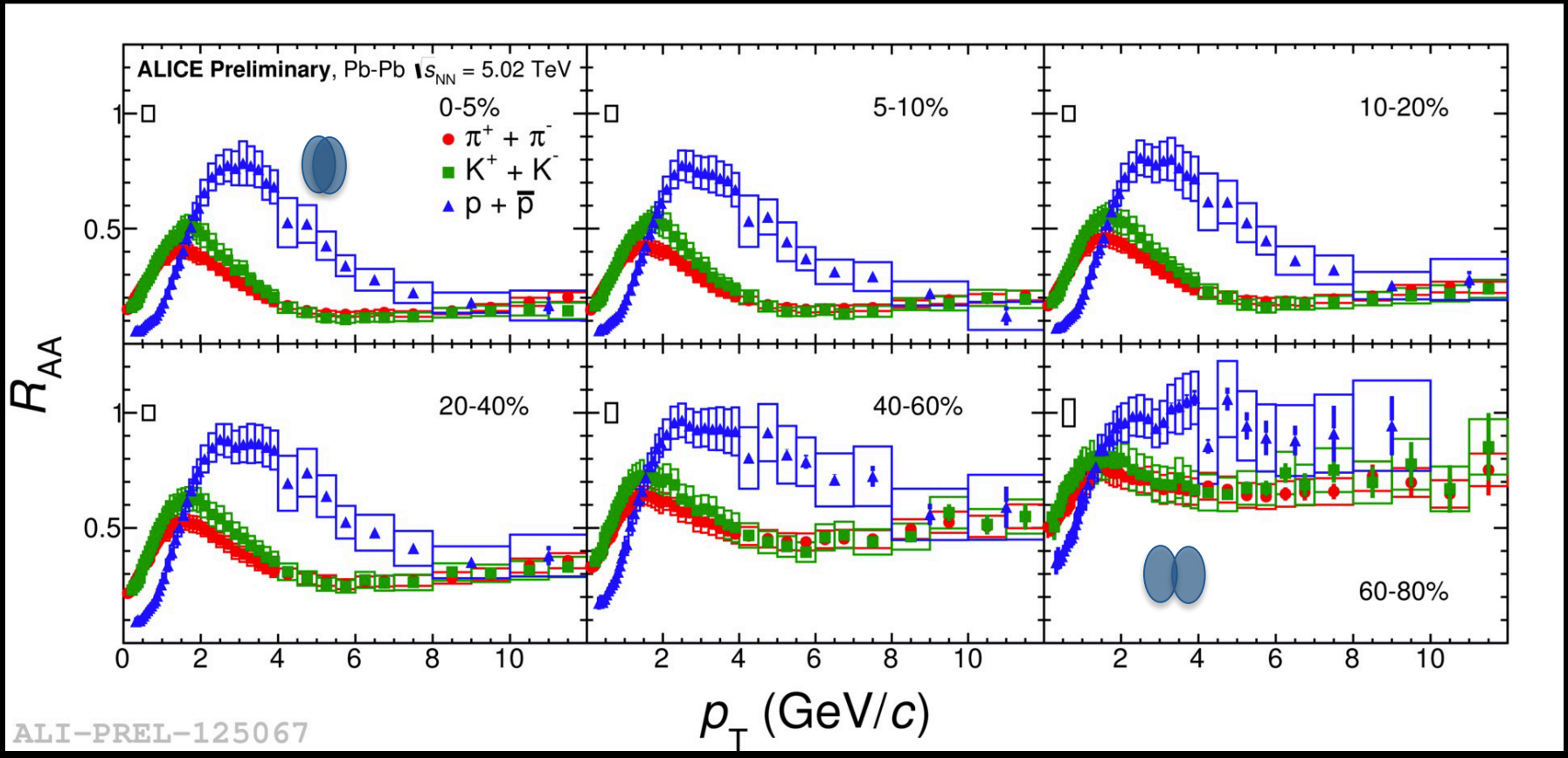
Charged-particle R_{AA}



$$R_{AA}(p_T) = \frac{1}{\langle T_{AA} \rangle} \frac{dN_{AA}/dp_T}{d\sigma_{pp}/dp_T}$$

- Measurement for $0.15 < p_T < 40$ GeV/c
- Different suppression pattern, depending on Pb-Pb collision centrality
- Maximum suppression by a factor of 7 ($6 < p_T < 7$ GeV/c) in the 0-5% collisions
- No significant evolution with collision energy is seen

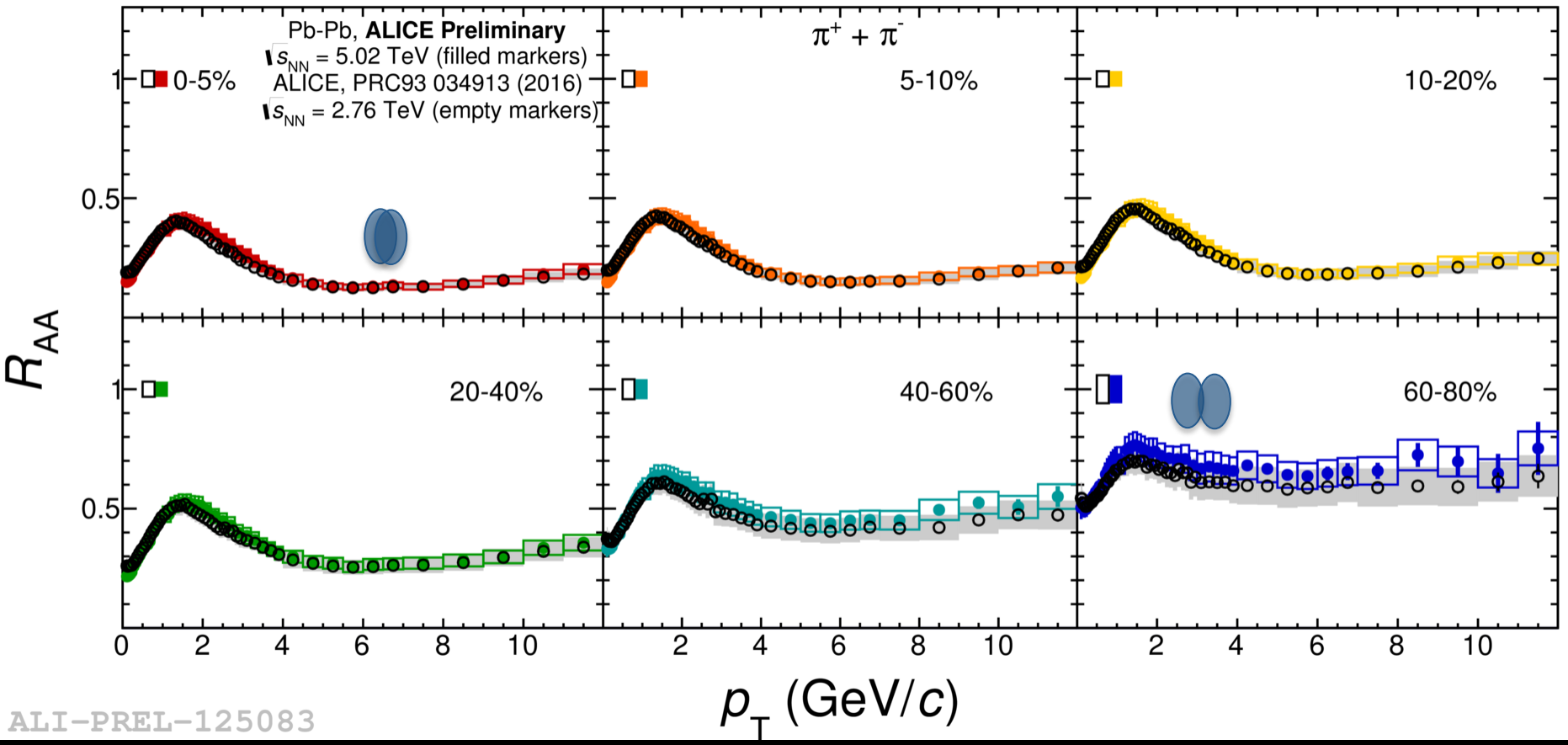
R_{AA} of π, K, p



pp Phys. Rev. Lett. B 760 (2016) 720

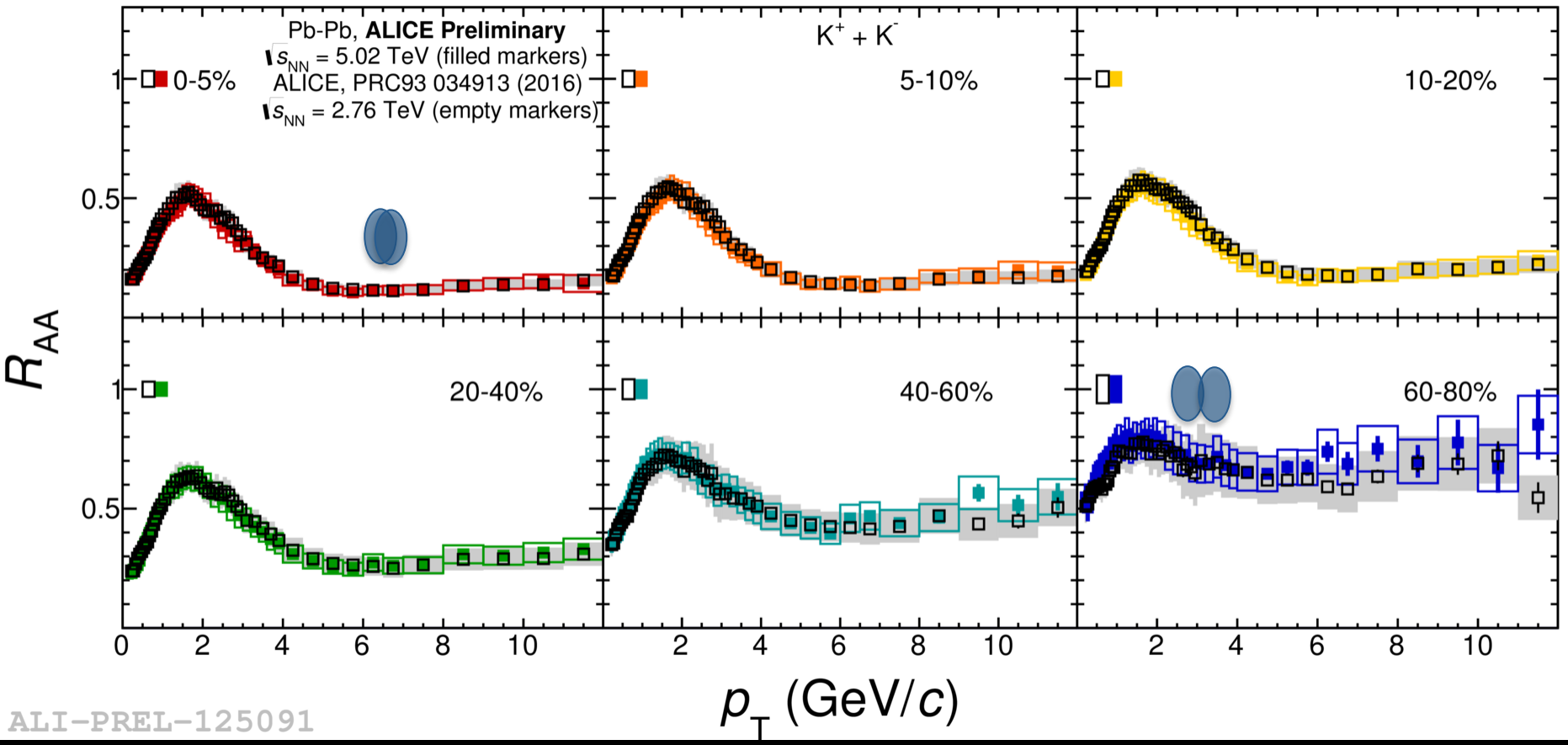
- In Pb–Pb collisions all three species are equally suppressed for all centralities at high p_T > 8 GeV/c
- Light–flavor independent energy loss at high p_T as observed at $\sqrt{s_{NN}}$ = 2.76 TeV

R_{AA} energy dependence



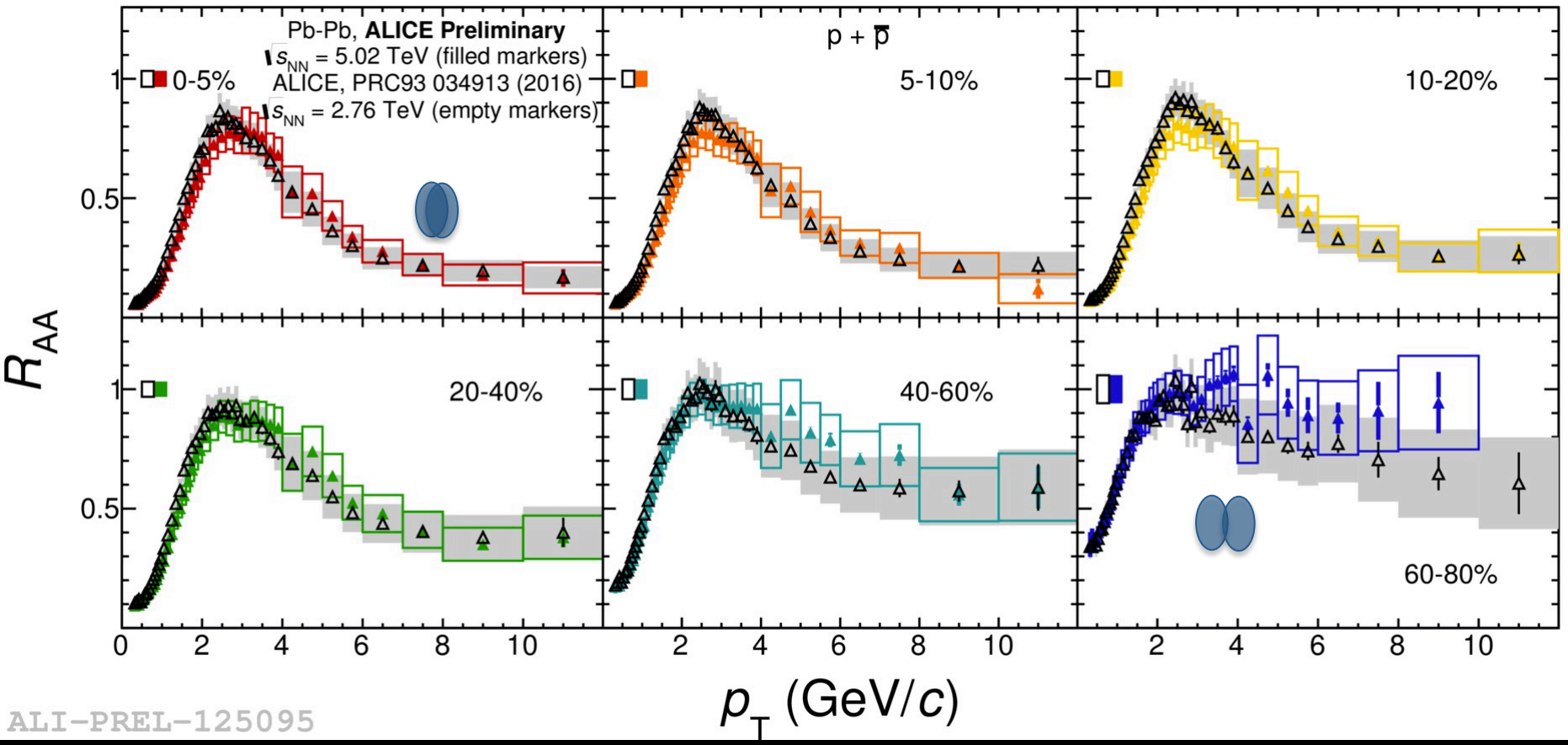
No significant evolution with collision energy is found

R_{AA} energy dependence



No significant evolution with collision energy is found

R_{AA} energy dependence



No significant evolution with collision energy is found

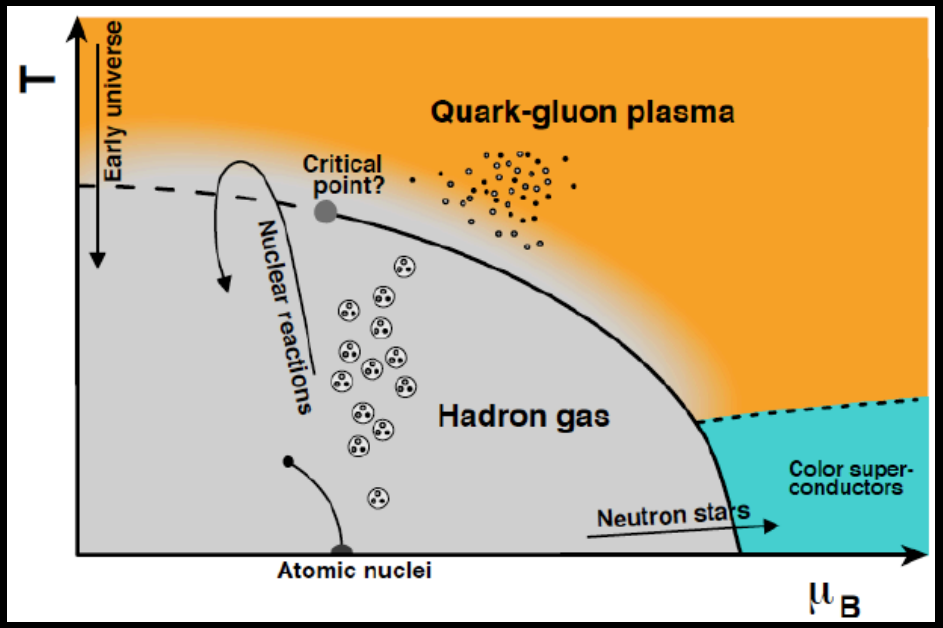
Summary and Outlook

- No significant change between particle production for the two energies $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV
- Similar yields and p_T dependence
- A bit stronger radial flow observed for 5.02 TeV collisions
- K/π and p/π as well as K^{*0}/K and Φ/K measured in peripheral Pb-Pb collisions are consistent with the high-multiplicity pp and p-Pb values
- K^{*0}/K decreases with collision centrality → dominance of rescattering over regeneration in the hadronic phase
- Nuclear modification factors show no energy dependence

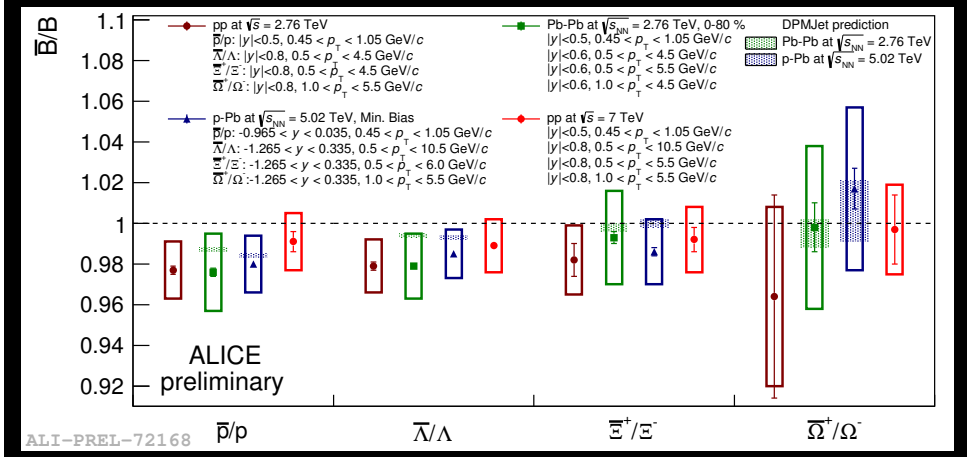
See also talks:
"Strangeness production in Pb-Pb collisions with ALICE at the LHC" - Peter Kalinak
"New results on the multiplicity and centre-of-mass energy dependence of identified particle production in pp collisions with ALICE" - Gyula Bencedi

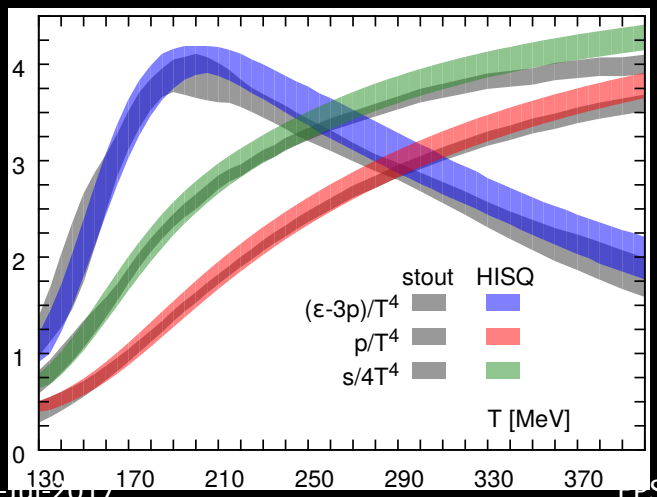
Backup

Phase diagram of QCD matter



ALICE, $\mu_B \sim 0$



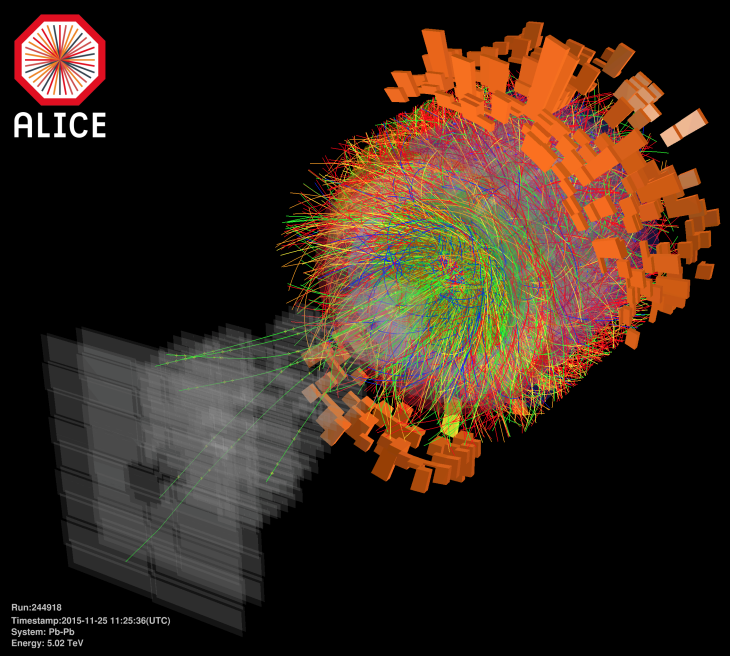


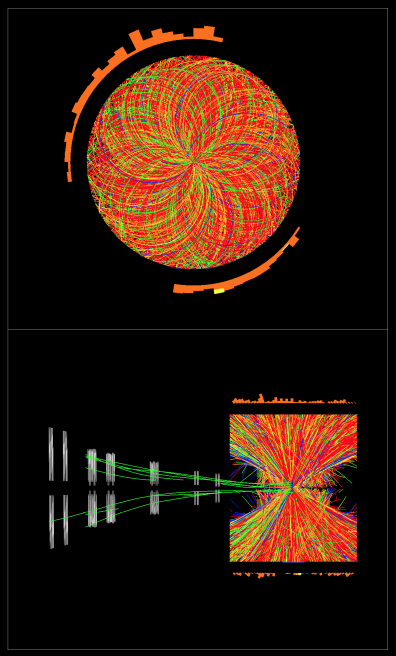
Bazavov et al. Phys. Rev. D 90 (2014) 094503

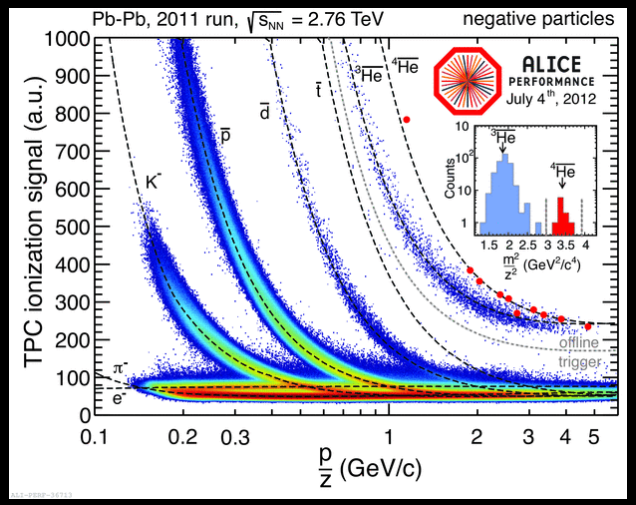
Lattice QCD ($\mu_B = 0$):

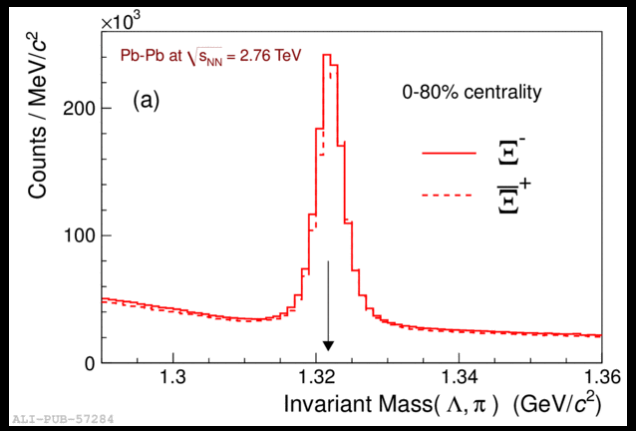
- Hadron gas <-> QGP (crossover)
- T_C = 145-163 MeV
- ε_C = (0.18-0.5) GeV/fm^3, (1.2-3.1) $\varepsilon_{nuclear}$

ALICE at work









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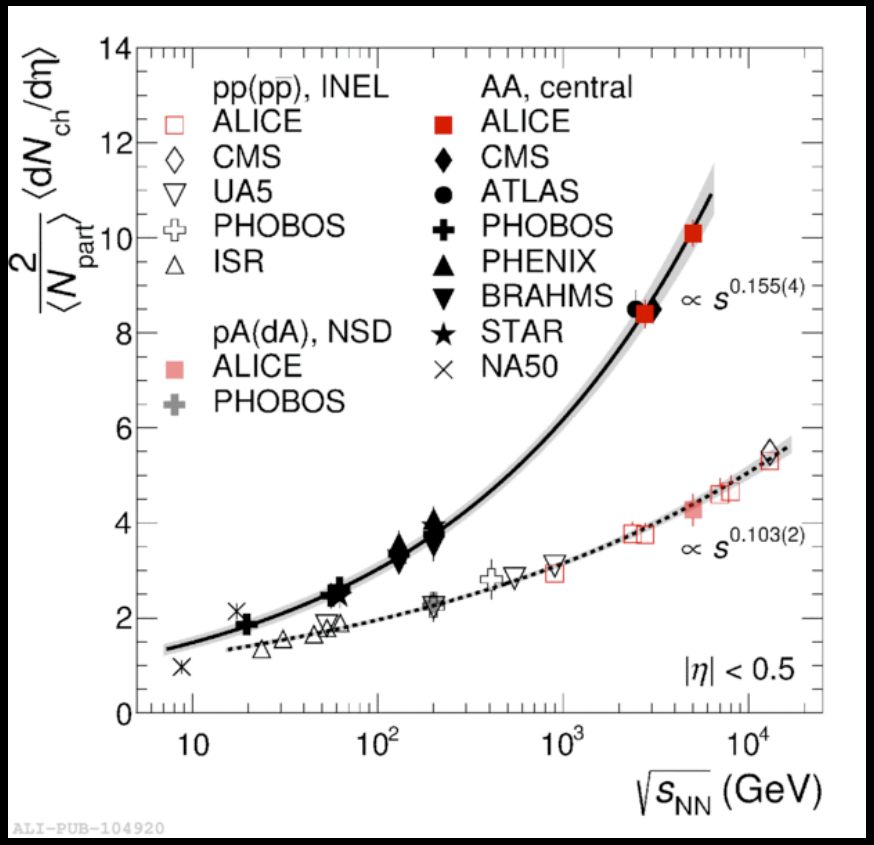
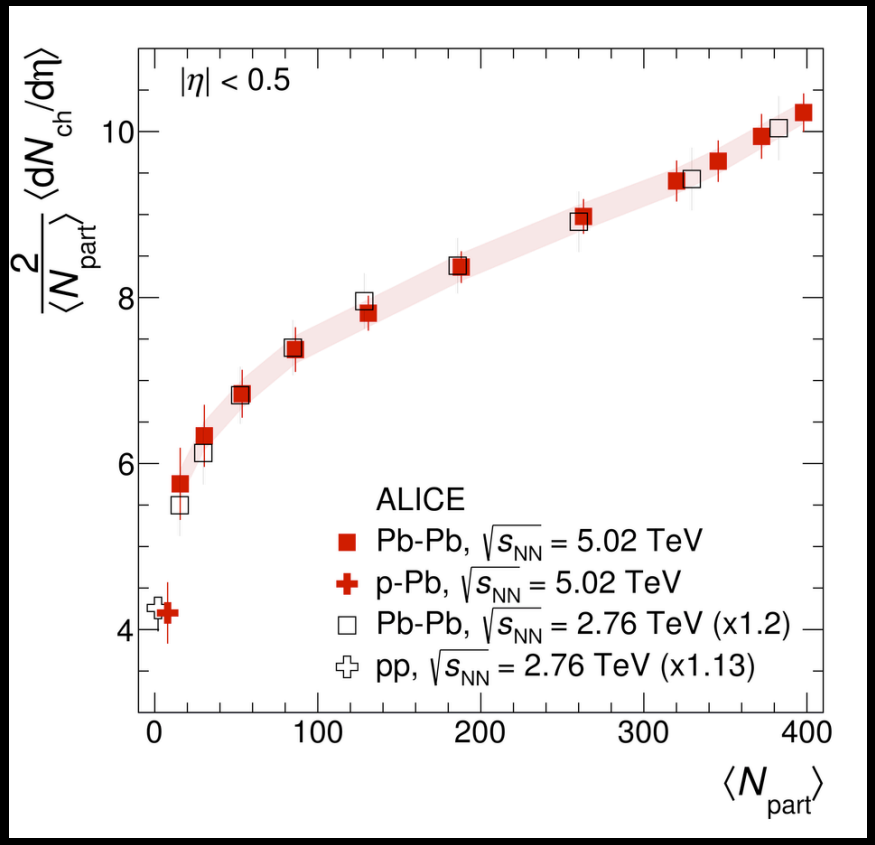
Run 1 (2009 - 2013)	Run 2 (2015 - now)
p+p $\sqrt{s}$=0.9, 2.36, 2.76, 7, 8 TeV	p+p $\sqrt{s}$=5.02,13 TeV
p+Pb $\sqrt{s_{NN}}$= 5.02 TeV	p+Pb $\sqrt{s_{NN}}$= 8.16 TeV
Pb+Pb $\sqrt{s_{NN}}$=2.76TeV	Pb+Pb $\sqrt{s_{NN}}$=5.02 TeV

Charged particle density $dN_{ch}/d\eta$

Phys. Rev. Lett. 116 (2016) 222302



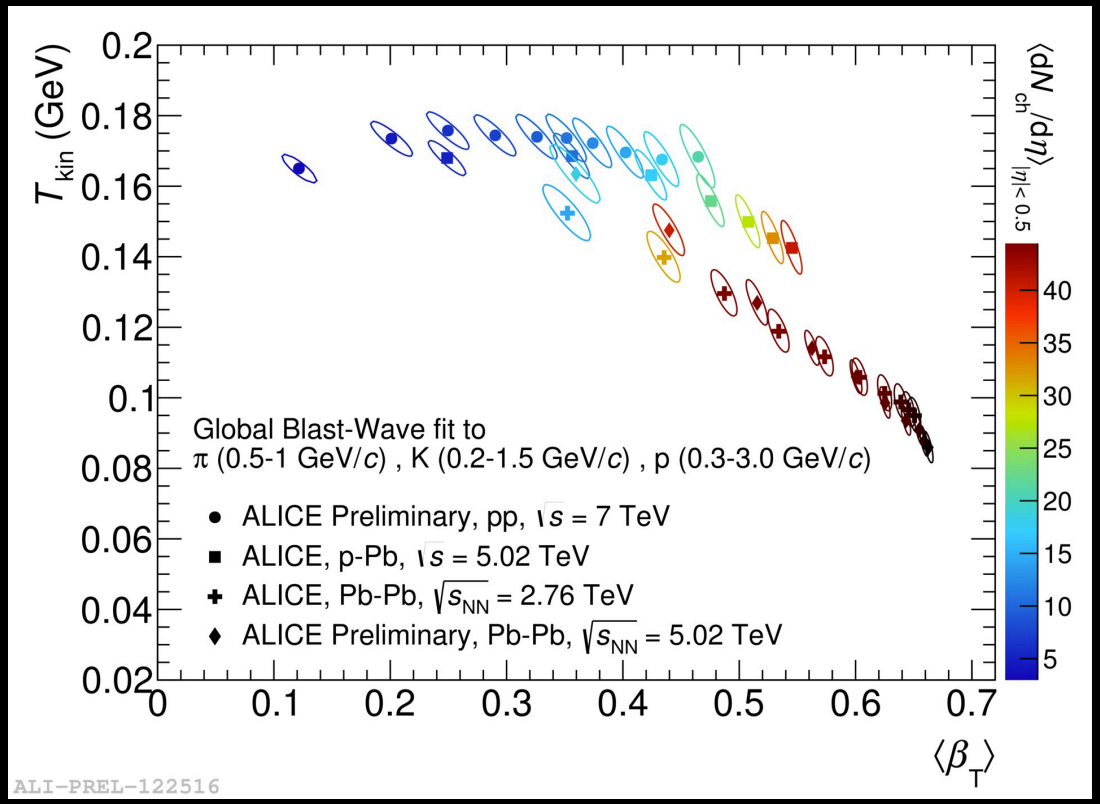


- $dN_{ch}/d\eta$ = 1943 ± 54 (Pb-Pb, 0-5%, 5.02 TeV)
- pp and p-Pb scales similarly with $\sqrt{s_{NN}}$
- Stronger rise in Pb-Pb than in pp and p-Pb (min. bias)

- Increase x1.2 ($s^{0.155}$ dependence) 2.76 TeV to 5.02 within 0-80% Pb-Pb centrality
- pp scaled by 1.13 ($s^{0.103}$ dependence)

Blast-Wave model

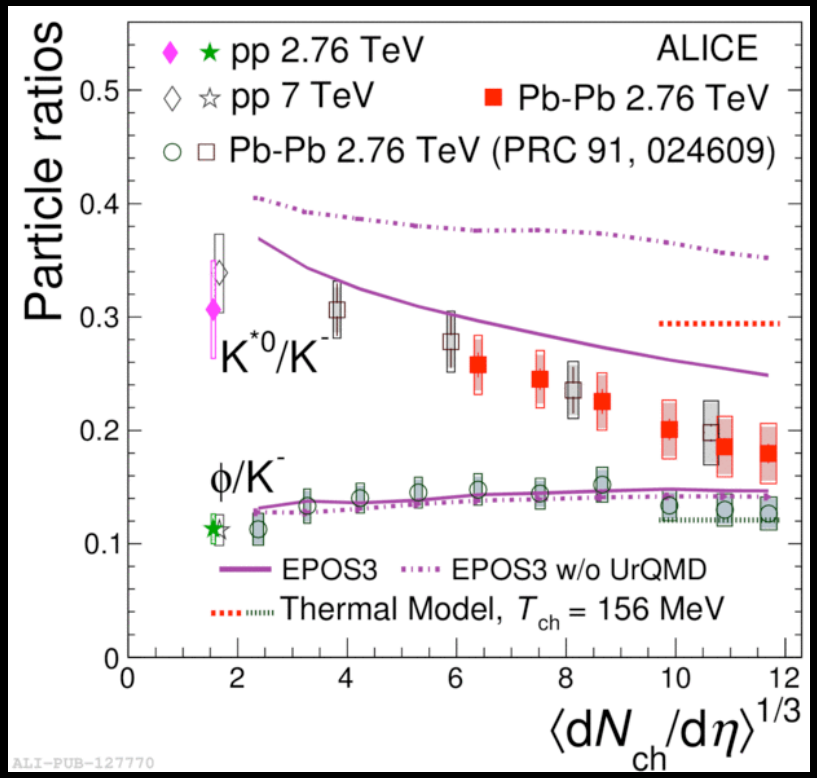
- In Pb–Pb at the two energies parameters are similar at comparable multiplicities
- Higher $<\beta_T>$ for smaller collision systems at comparable multiplicities



p–Pb Phys. Lett. B 760 (2016) 720
Pb–Pb Phys. Rev. C88 (2013) 044910

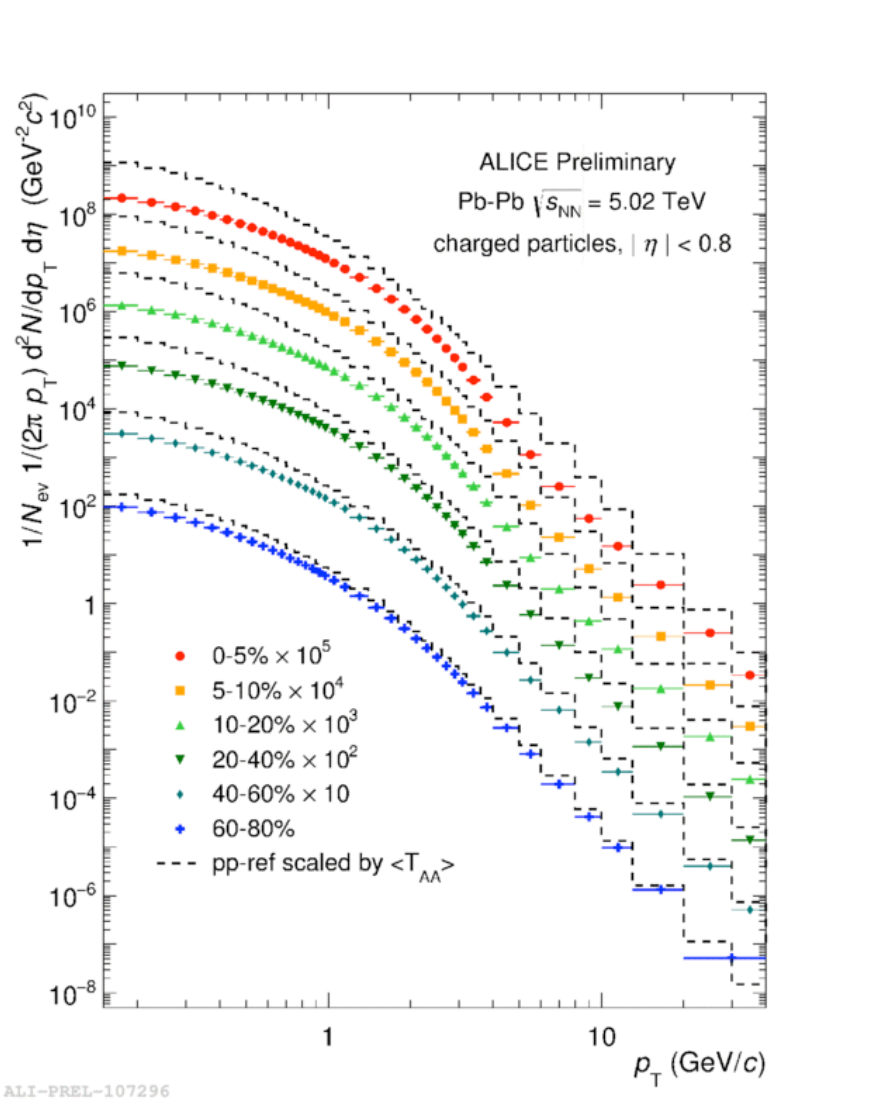
$K^*(892)^0$, $\Phi(1020)$ comparison to models

Phys. Rev. C 95, 064606 (2017)



- K^{*0}/K is not described by EPOS3 (w/, w/o UrQMD) as well as Thermal model, but EPOS3 with UrQMD describes decreasing trend.
- Φ/K well described by the models

Charged-particle spectra



pp reference measured at the same collision energy of √*s* = 5.02 TeV (Run 2)

pp reference for R_{AA} of identified particles

pp reference constructed for $\sqrt{s}$ = 5.02 TeV (Run 2)

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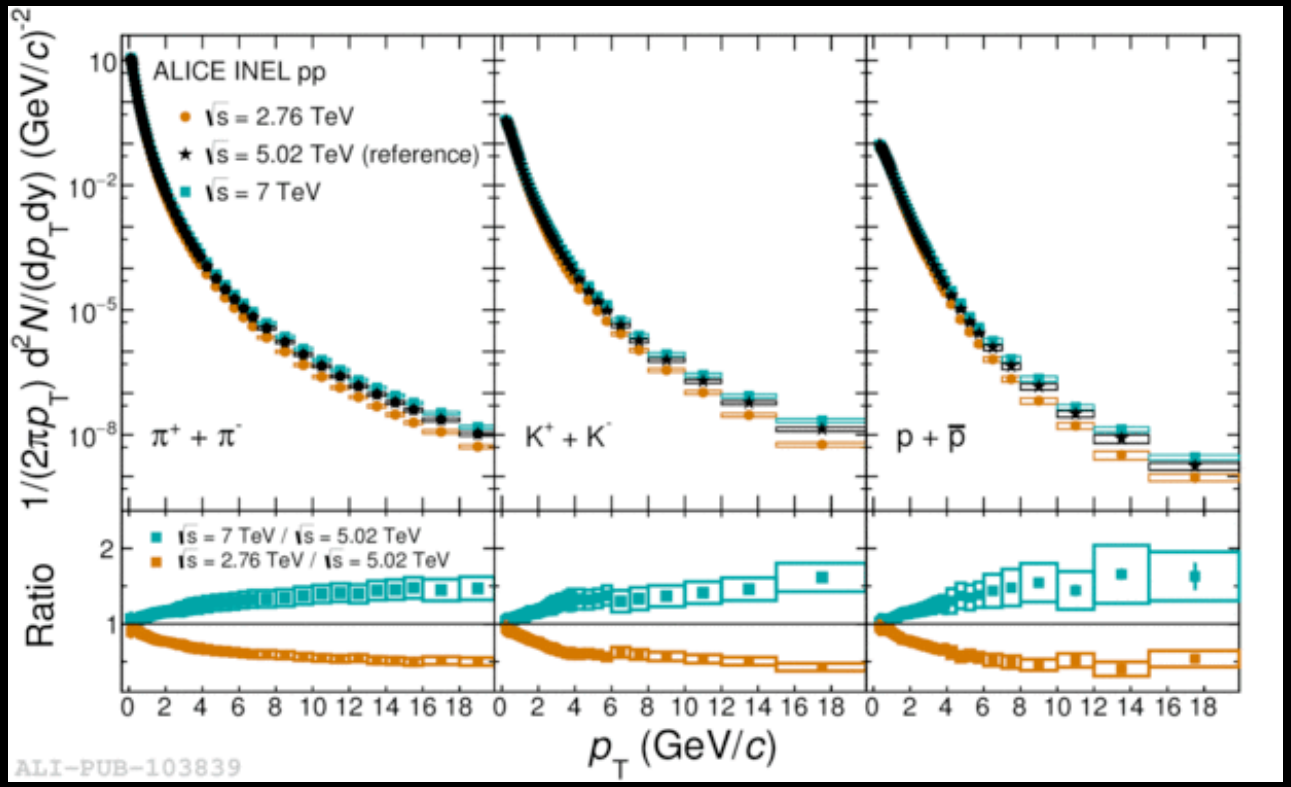
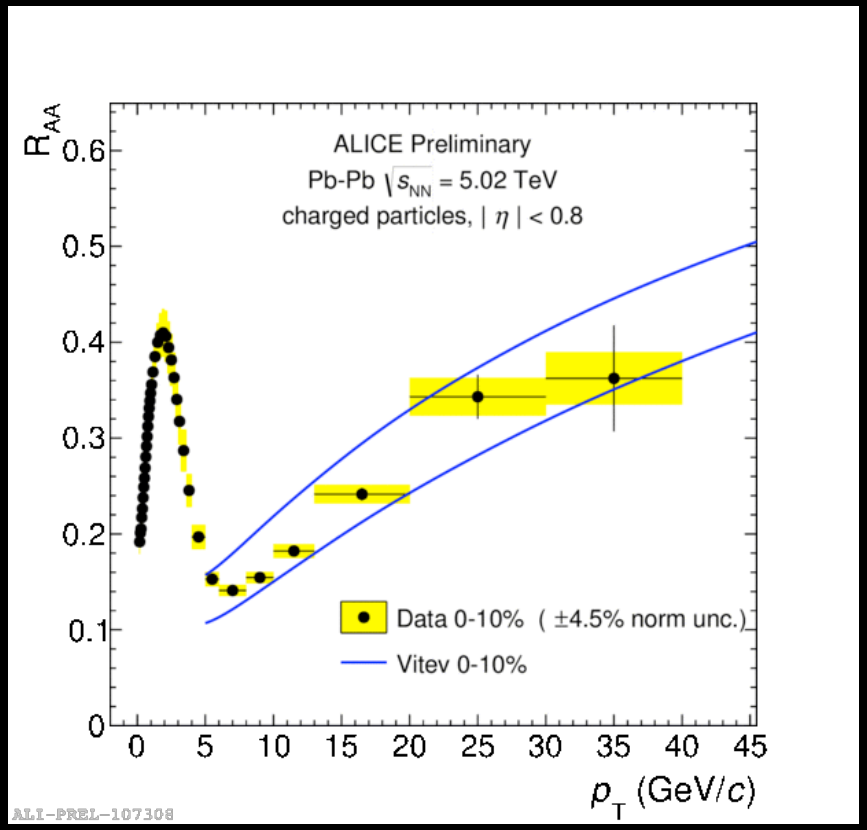
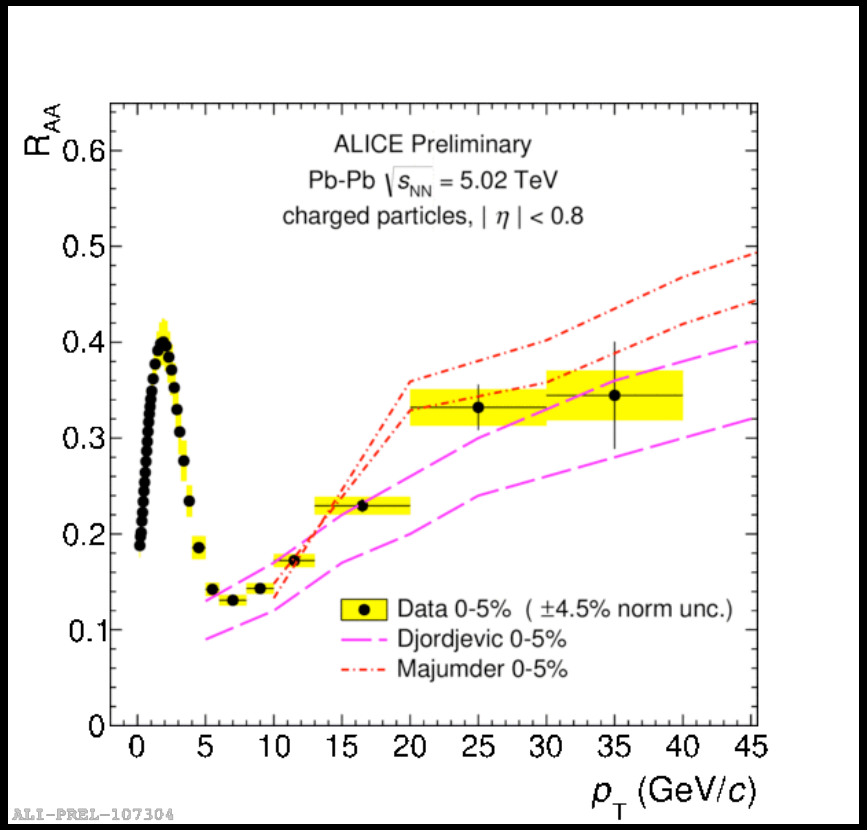


Charged-particle R_{AA} comparison to models





Vitev *et al.* Phys. Rev. D 93 (2016) 074030
Djordjevic *et al. Phys. Rev. C* 94 (2016) 044908
Majumder *et al.* arXiv:1702.00481