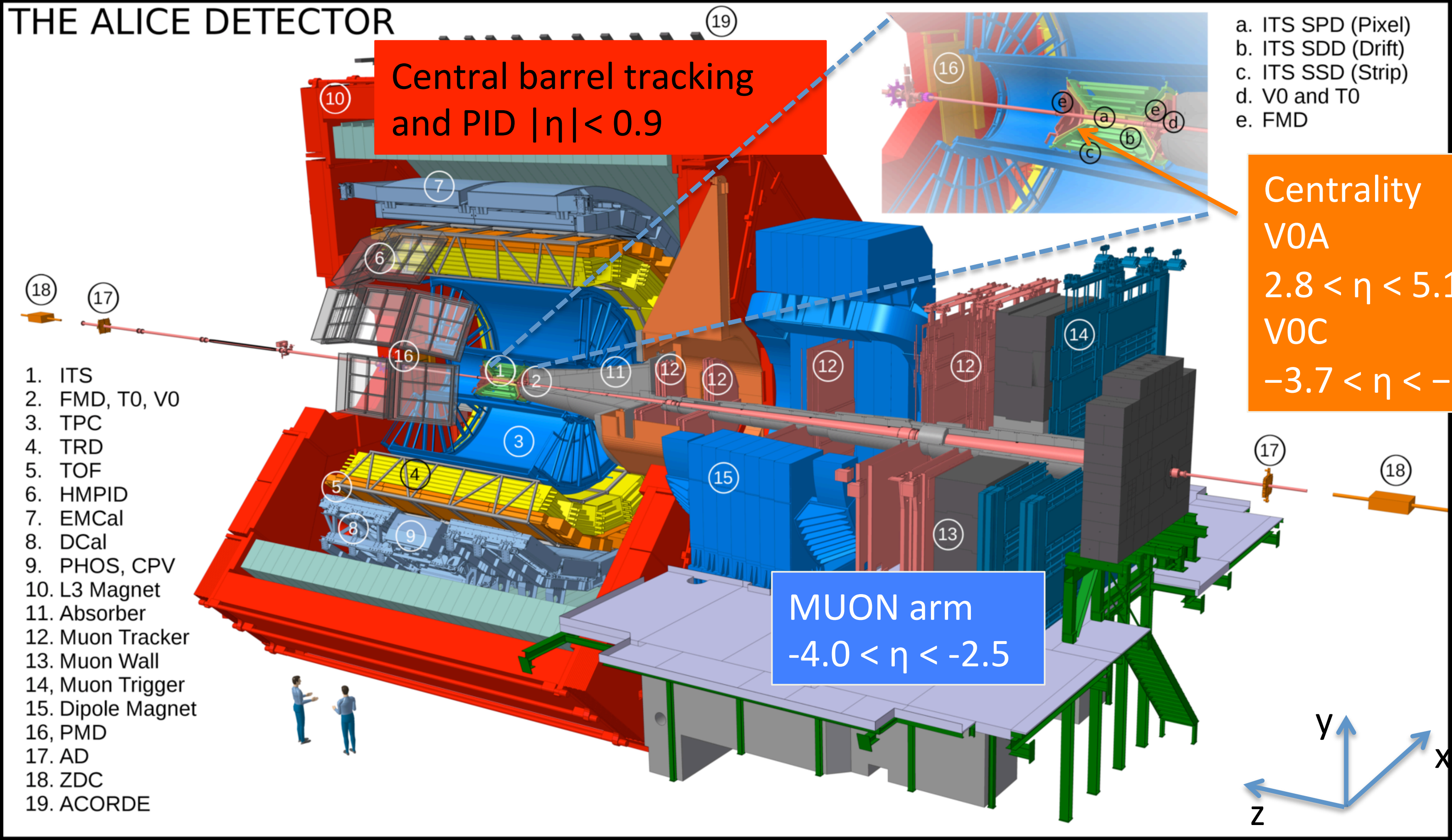
Production and flow of light-flavor hadrons and nuclei in small and large systems with ALICE

- Particle multiplicity, spectra and yields
- Radial flow and azimuthal anisotropy
- Nuclear modification factors

Jacek Otwinowski (IFJ PAN, Krakow)
On behalf of the ALICE Collaboration

A Large Ion Collider Experiment

- Excellent particle identification capabilities over a wide p_T range 0.1-20 GeV/c
- Good momentum resolution ~1-5% for p_T = 0.1-50 GeV/c

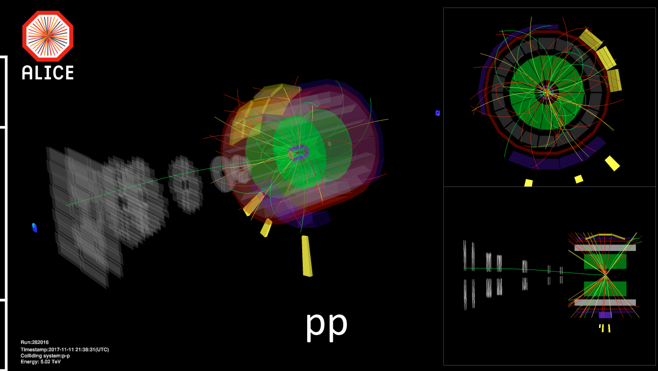


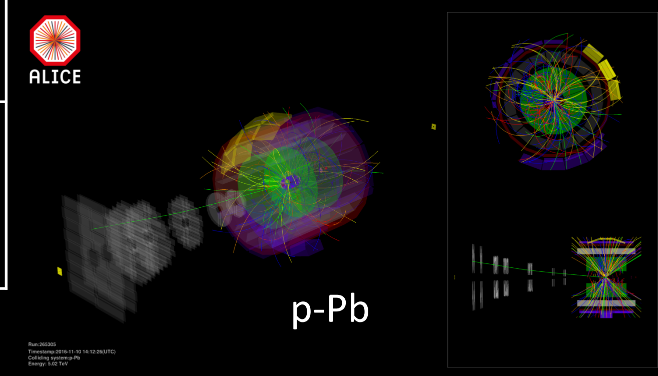
ALICE at work since 2009

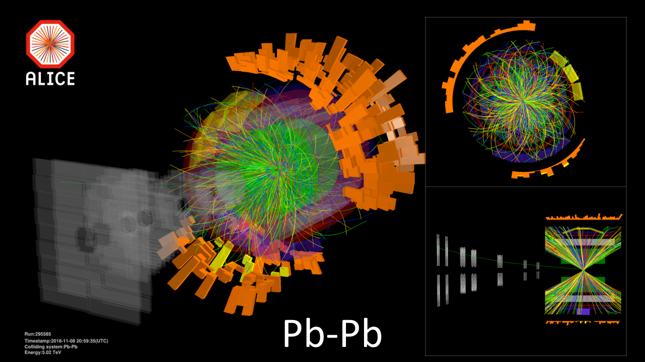
System	Year	$\sqrt{s_{NN}}$ (TeV)	L_{int}
Pb-Pb	2010-2011 2015 2018	2.76 5.02 5.02	~75 μb^{-1} ~250 μb^{-1} ~0.9 nb^{-1}
Xe-Xe	2017	5.44	~0.3 μb^{-1}
p-Pb	2013 2016	5.02 5.02, 8.16	~15 nb^{-1} ~3 nb^{-1}, ~25 nb^{-1}
pp	2009-2013 2015-2018	0.9, 2.76, 7, 8 5.02, 13	~200 μb^{-1}, ~100 μb^{-1}, ~1.5 pb^{-1}, ~2.5 pb^{-1} ~1.3 pb^{-1}, ~59 pb^{-1}

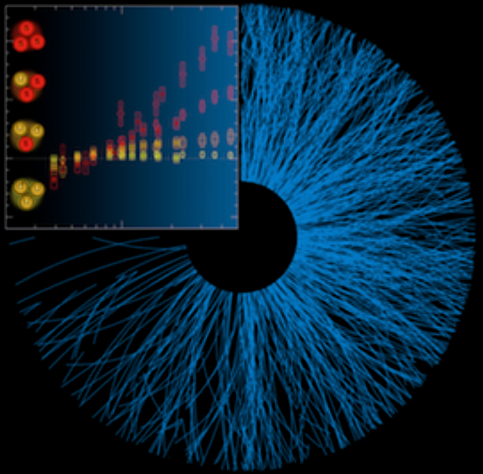
- Energy and system dependence studies of particle production are possible
- Large statistics of pp, p-Pb and Pb-Pb collisions at the same $\sqrt{s_{NN}}$
  - → **Precise comparison studies**

Quest for the Quark-Gluon Plasma





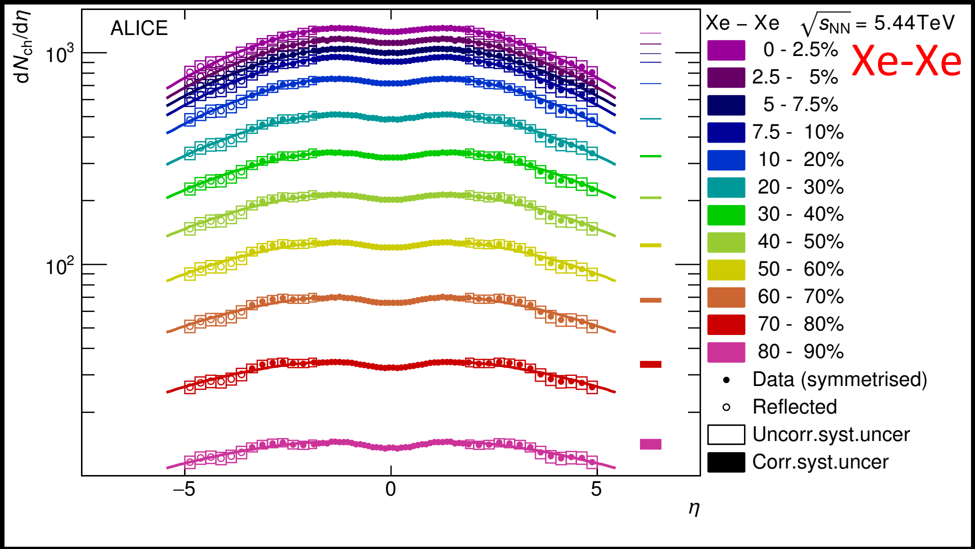


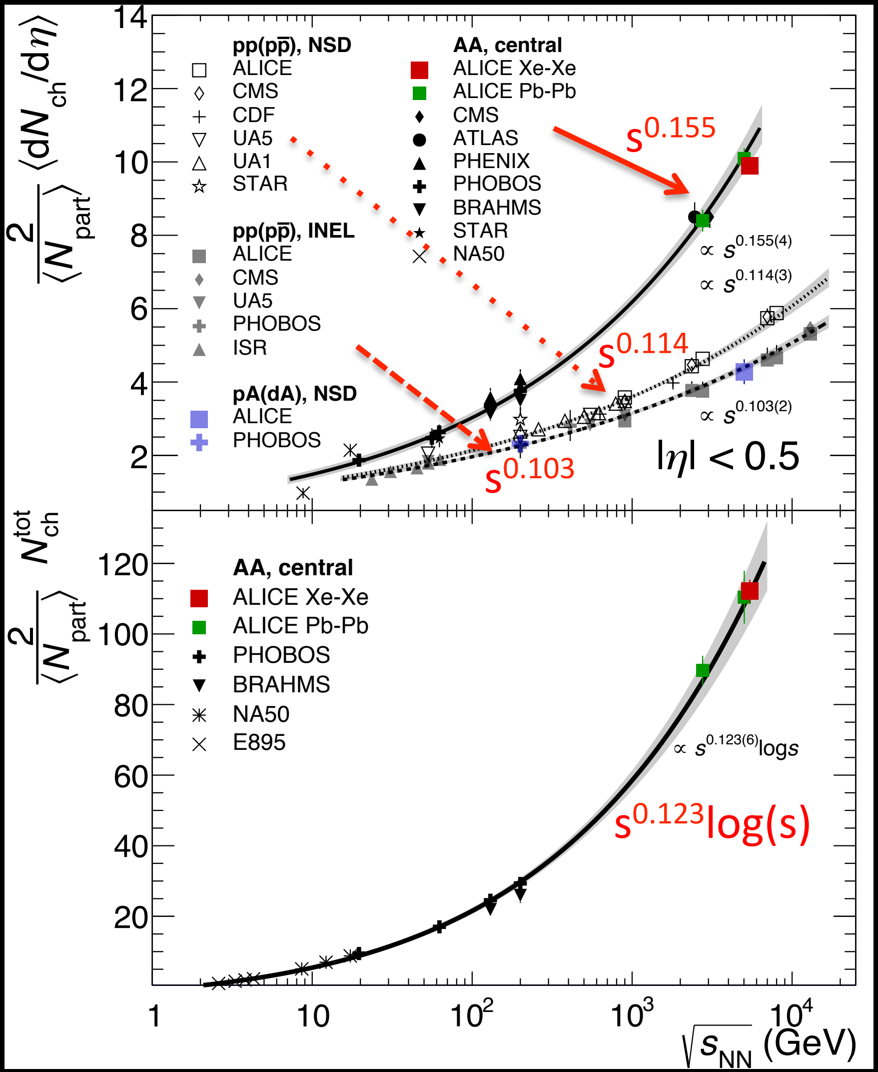


PARTICLE MULTIPLICITY, SPECTRA AND YIELDS

Charged-particle multiplicity in pp, p-Pb, Pb-Pb and Xe-Xe

Phys. Lett. B 790 (2019) 35



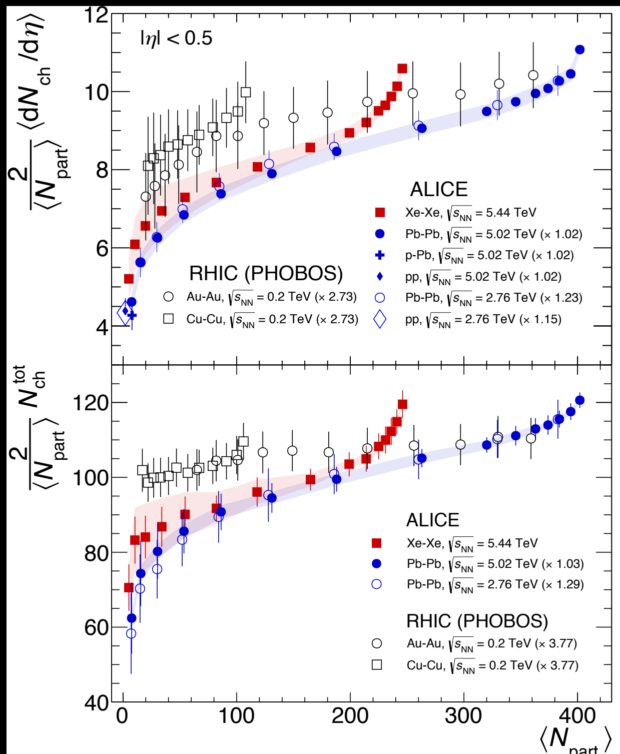


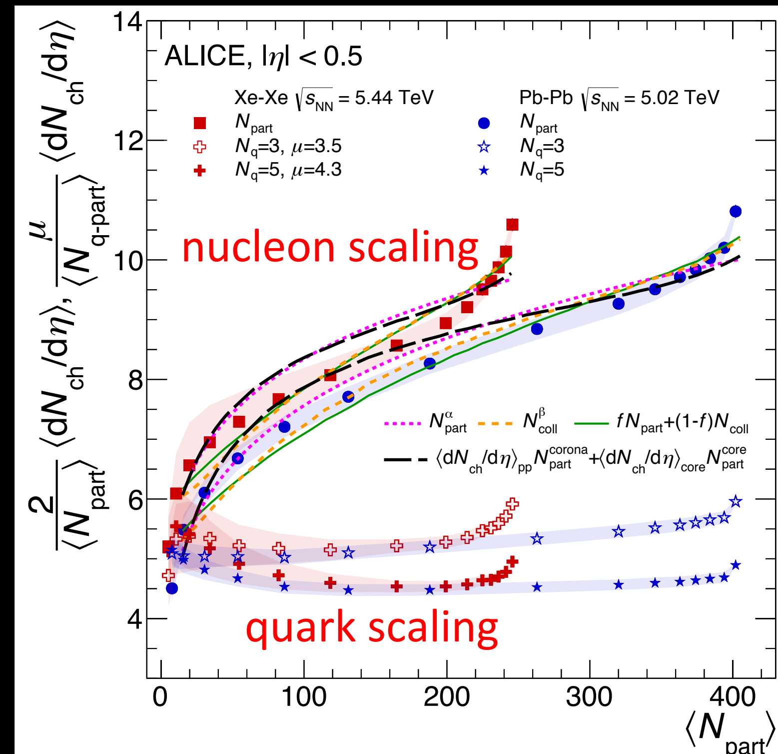
- Measurement in broad rapidity range and several centrality intervals
- √s dependence in A-A collisions differs from pp and p-Pb (no universal scaling)
- Total charged-particle multiplicity from extrapolation up to $\eta = \pm y_{beam}$ in unmeasured region

Charged-particle multiplicity vs N_{part} in pp, p-Pb, Pb-Pb and Xe-Xe

ALICE

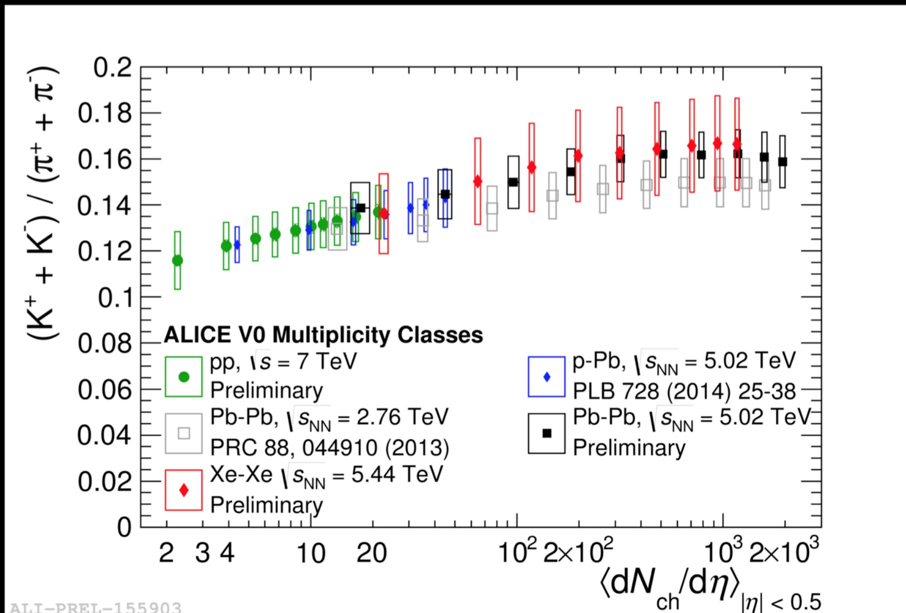
Phys. Lett. B 790 (2019) 35

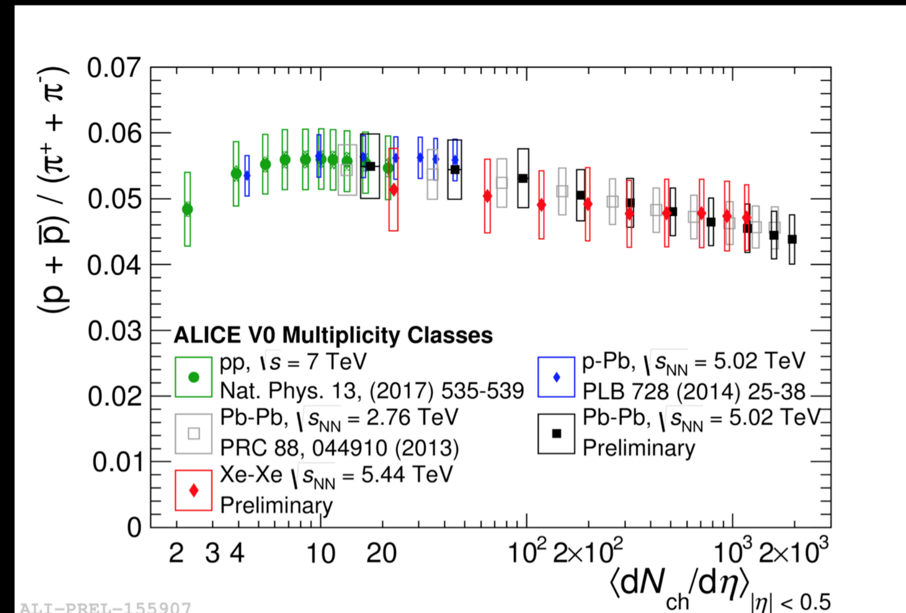




- Charged-particle multiplicity density and total multiplicity as a function of centrality
  - Deviation from N_{part} scaling
  - Steeper rise in most central Xe-Xe and Pb-Pb collisions due to upward fluctuations
- Comparison to scaling (~N_{part}, ~N_{coll}, core+corona, ~N_{qpart}) shows that collision geometry plays an important role in particle production

K/π and p/π in pp, p-Pb, Pb-Pb and Xe-Xe





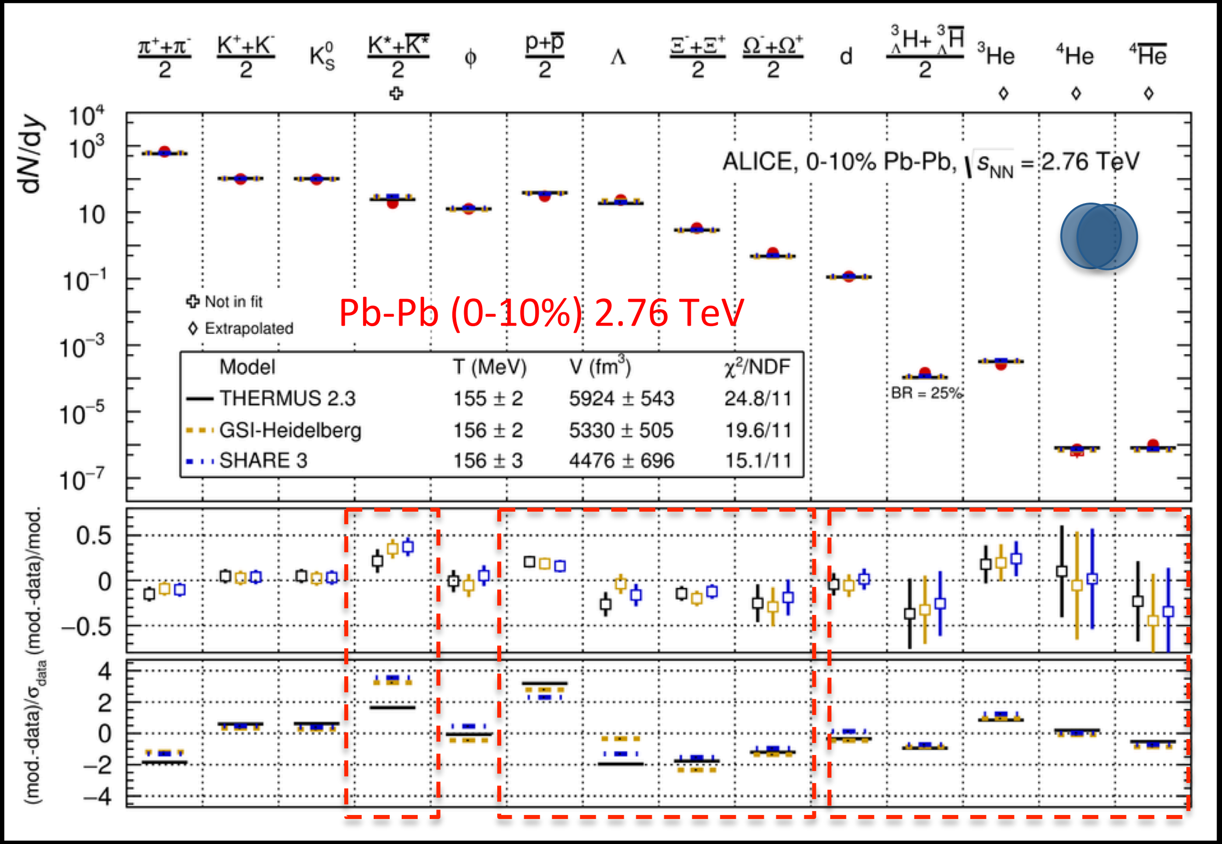
- No significant energy dependence is observed
- K/π and p/π are consistent for all collision systems at similar multiplicity

→ Particle production is driven by the characteristics of final state

M. Sefcik 11/06

Particle yields vs thermal models in Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV

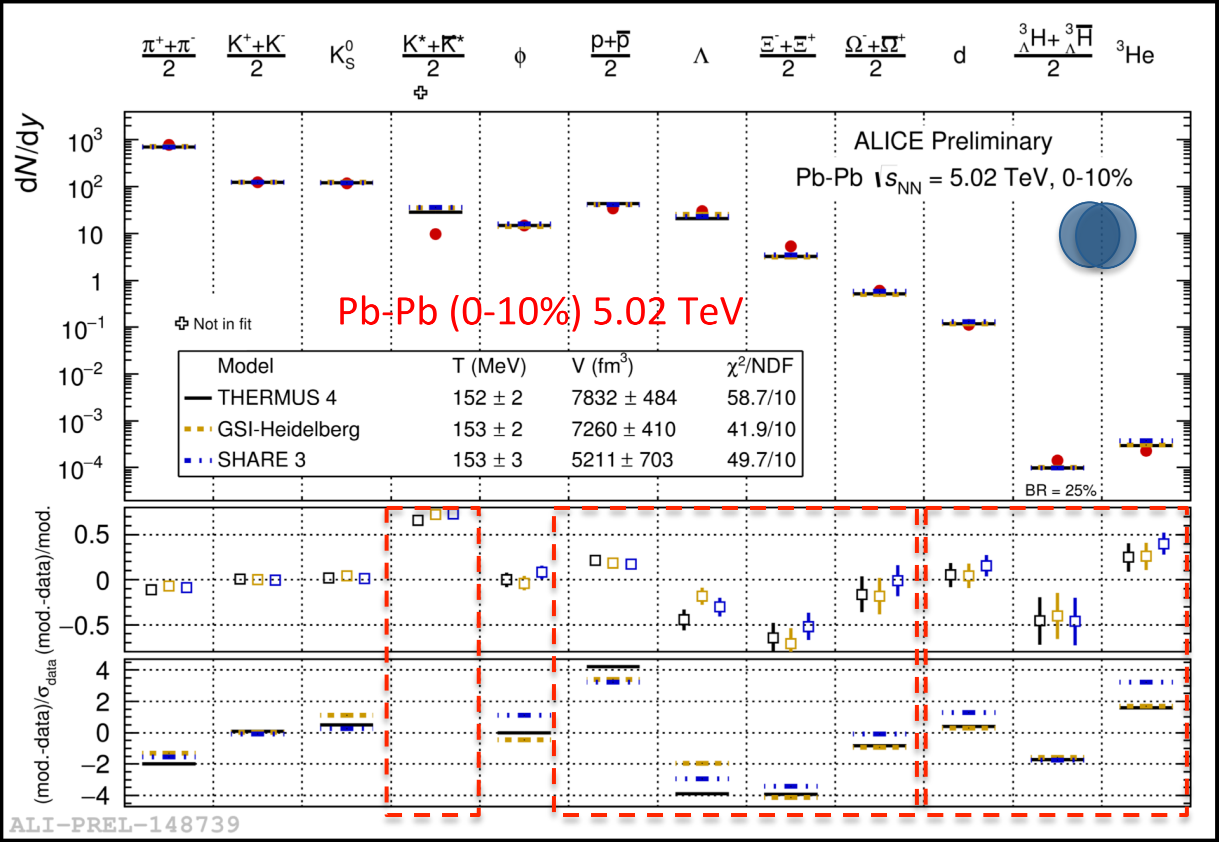
Nucl. Phys. A 971 (2018) 1



- Production of (most) hadrons well described at freezeout temperature T_{ch} ~ 156 MeV
- K^{*0} resonance (not included in the fit): production overestimated by thermal models
- Tension for protons and multi-strange baryons
- Light nuclei production described by thermal models (binding energy << T_{ch})?

THERMUS: Wheaton et al., Comput. Phys. Commun, 180 (2009) 84
GSI-Heidelberg: Andronic et al., Phys. Lett. B 673 142
SHARE: Petran et al., Comp. Phys. Commun. 195 (2014) 2056

Particle yields vs thermal models in Pb-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV



Model	T (MeV)	V (fm^3)	χ^2/NDF
THERMUS 4	152 ± 2	7832 ± 484	58.7/10
GSI-Heidelberg	153 ± 2	7260 ± 410	41.9/10
SHARE 3	153 ± 3	5211 ± 703	49.7/10

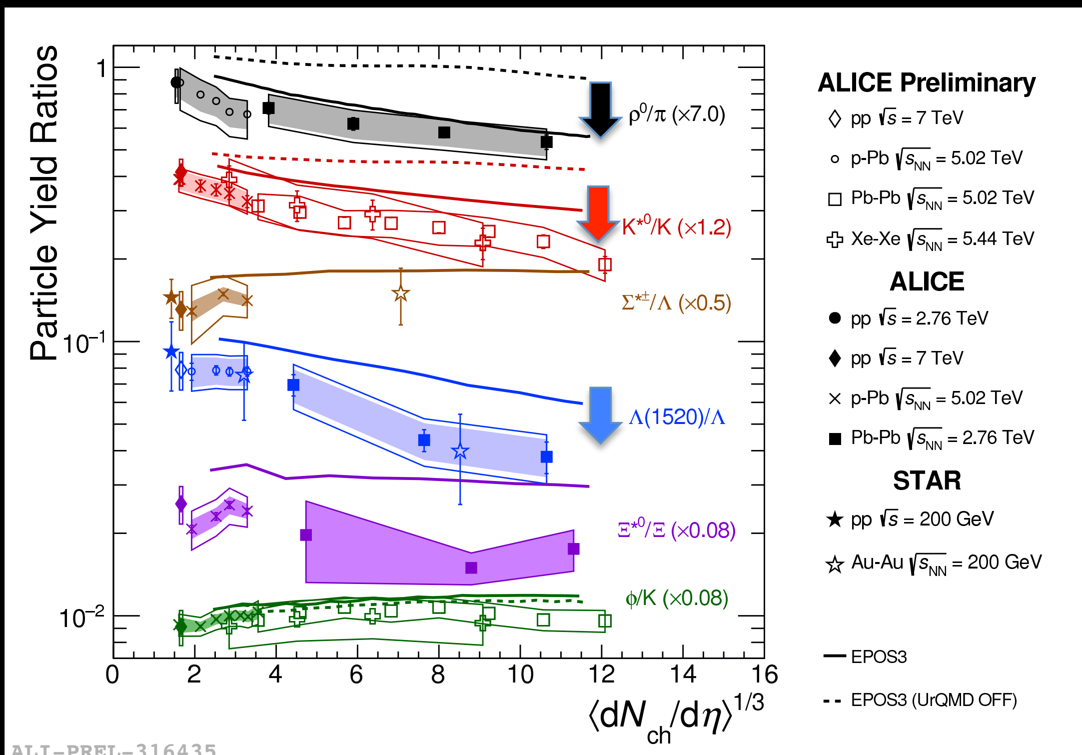
- Production of (most) hadrons well described at freeze-out temperature T_{ch} ~ 153 MeV (caused by protons)
- K^{*0} resonance (not included in the fit): production overestimated by thermal models
- Tension for protons and multi-strange baryons
- Light nuclei production described by thermal models (binding energy << T_{ch})?

Fit χ^2 worst than at 2.76 TeV (more precise data)

THERMUS: Wheaton et al., Comput. Phys. Commun, 180 (2009) 84
GSI-Heidelberg: Andronic et al., Phys. Lett. B 673 142
SHARE: Petran et al., Comp. Phys. Commun. 195 (2014) 2056

Relative resonance production in pp, p-Pb, Pb-Pb and Xe-Xe collisions

Resonance	ρ^0	K^{*0}	$\Sigma^{*\pm}$	$\Lambda(1520)$	Ξ^{*0}	ϕ
Lifetime (fm/c)	1.3	4.16	5.5	12.6	21.7	46.2



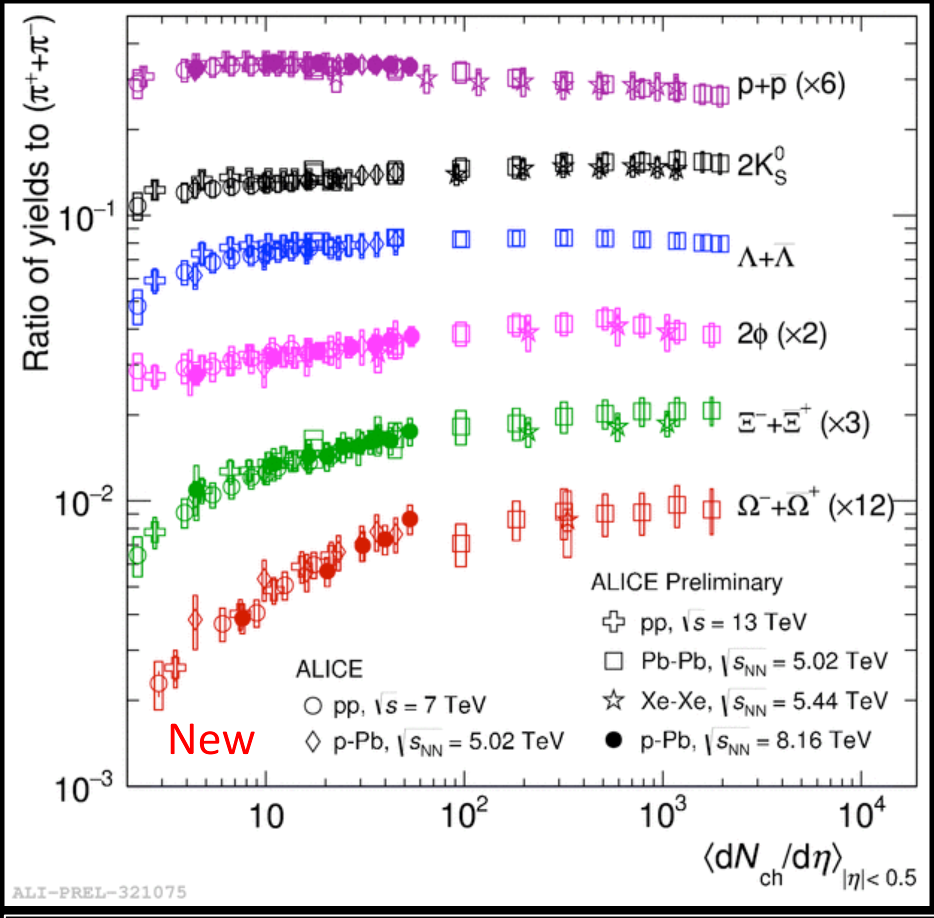
- Relative suppression of ρ^0, K^{*0}, $\Lambda(1520)$ with increasing multiplicity
- Σ^*/Λ, Ξ^*/Ξ, ϕ/K is independent of multiplicity
- Similar trend seen in all collision systems
- EPOS3 + UrQMD describes the trend of data

S. Tripathy 13/06

→ Dominance of rescattering over (re)combination in hadronic phase

ρ^0: Phys. Rev. C99, (2019) 064901
K^{*0}: Phys. Rev. C95, (2017) 064606
$\Lambda(1520)$: Phys. Rev. C99, (2019) 024905
STAR, Phys.Rev.C78 (2008) 044906
STAR, Phys. Rev. Lett. 97 (2006) 132301
ϕ: Phys. Rev. C91 (2015) 024609
Σ^*, Ξ^*: Eur. Phys. J. C 77 (2017) 389

Relative strangeness production in pp, p-Pb, Pb-Pb and Xe-Xe



Historically a signature of the QGP
Rafelski & Mueller, Phys. Rev. Lett. 48 (1982) 1066

- Smooth evolution from pp to Pb-Pb
- Enhancement increases with strangeness content
- No significant energy and system dependence is observed at similar multiplicity

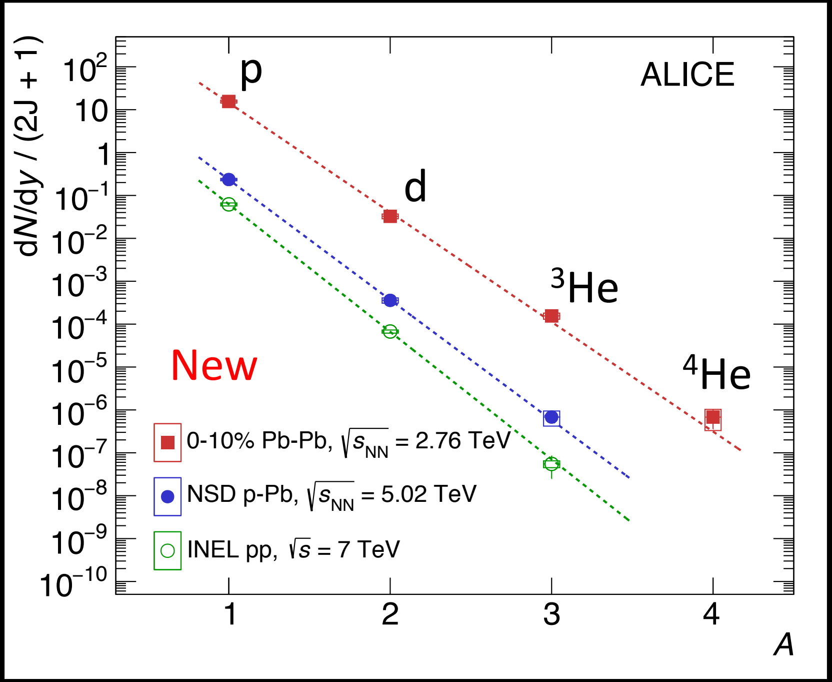
→ Strangeness production is driven by the characteristics of final state

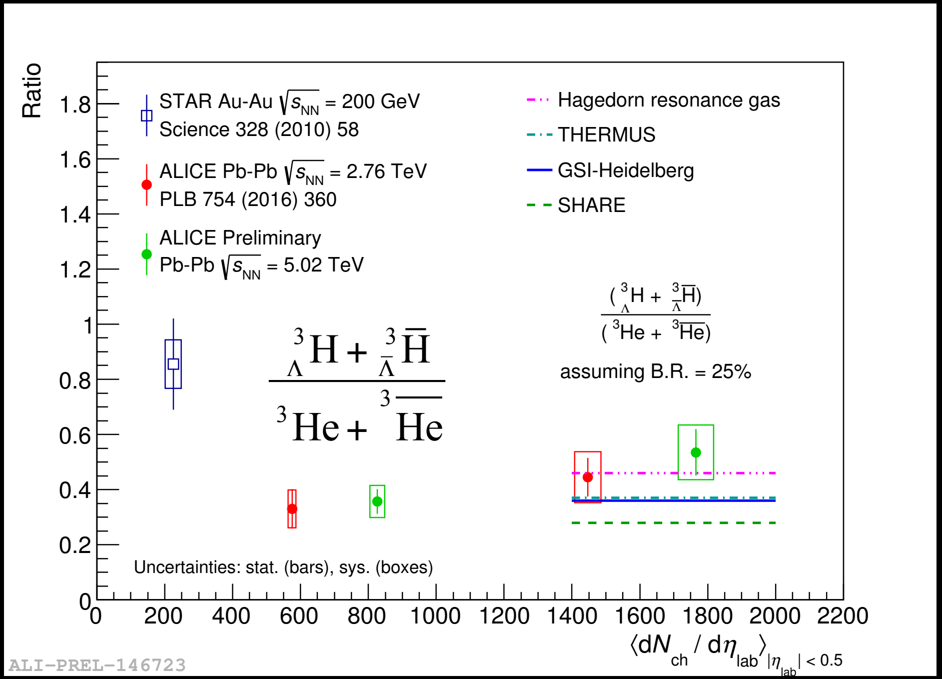
pp 7 TeV: Nature Physics 13 (2017) 535
p-Pb 5.02 TeV: Phys. Lett. B728 (2014) 25, Phys. Lett. B758 (2016) 389

E. Willsher 11/06

Nuclei production in pp, p-Pb and Pb-Pb

p-Pb: arXiv:1906.03136



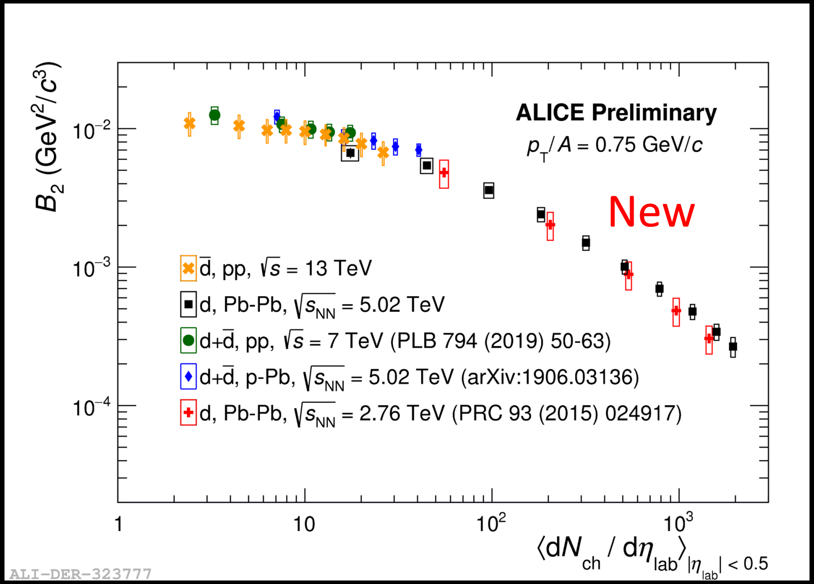


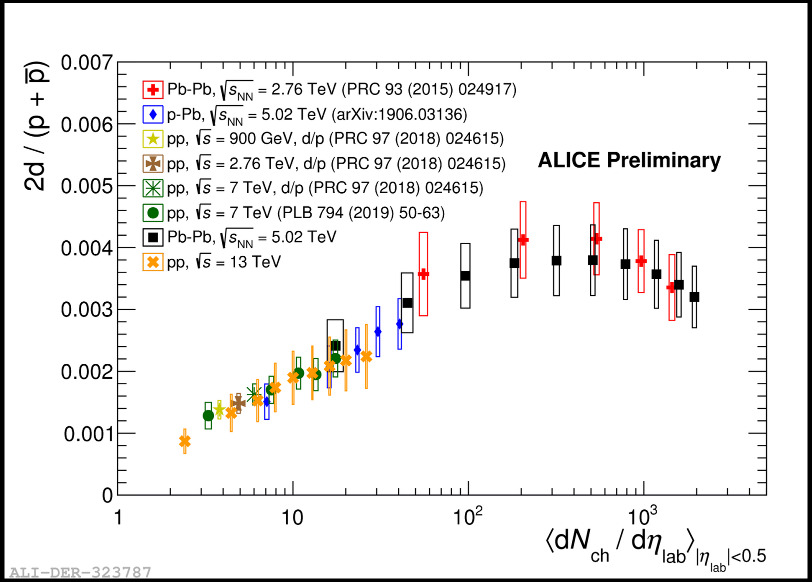
- Exponential decrease in nuclei rate in agreement with thermal model predictions
- Nuclei production rate decrease by factor of ~300 (Pb-Pb), ~600 (p-Pb) and ~1000 (pp) for each additional nucleon
- $^3_\Lambda$H production consistent with thermal model (binding energy ~0.13 MeV << T_{ch})
  → Production mechanisms: thermal vs coalescence?

L. Barioglio 11/06
S. Bufalino 13/06 ($^3_\Lambda$H life time)

pp: Phys. Rev. C97 (2018) 024615
Pb-Pb: Nucl. Phys. A 971 (2018) 1

Formation of light nuclei: (anti) deuterons





- Coalescence of baryons close in phase space (*A* - mass number)

$$E_A \frac{d^3 N_A}{dp_A^3} = B_A \left(E_p \frac{d^3 N_p}{dp_p^3} \right)^A$$

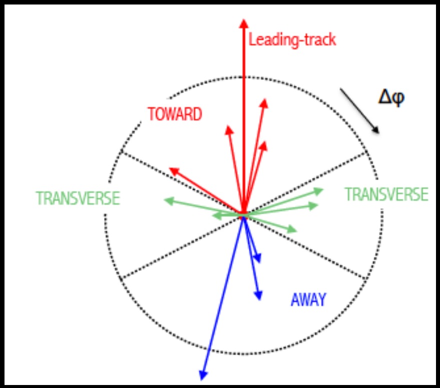
- B_2 shows dependence on multiplicity (no dependence on p_T)

- d/p vs multiplicity
  - Increase from pp to peripheral Pb-Pb consistent with coalescence model
  - No centrality dependence in high multiplicity Pb-Pb (yields consistent with thermal model)

→ Production mechanisms: thermal vs coalescence?

SPECTRA

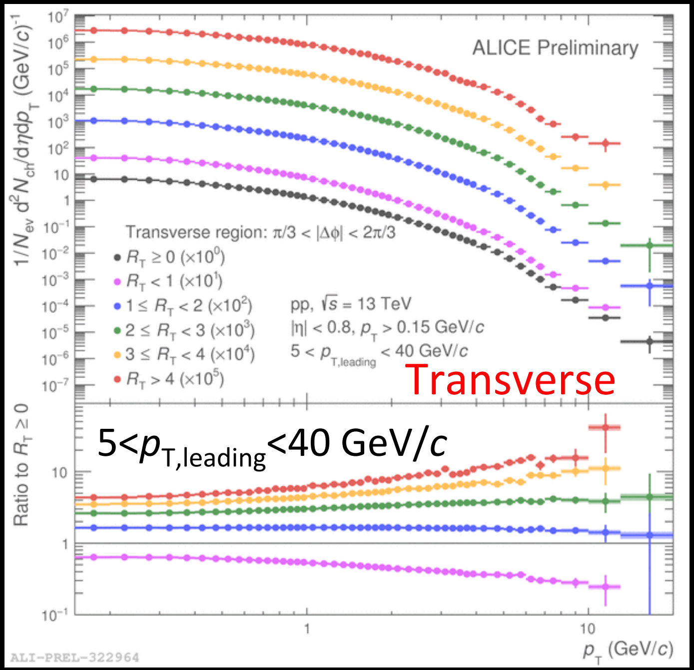
Transverse/toward p_T spectra in pp

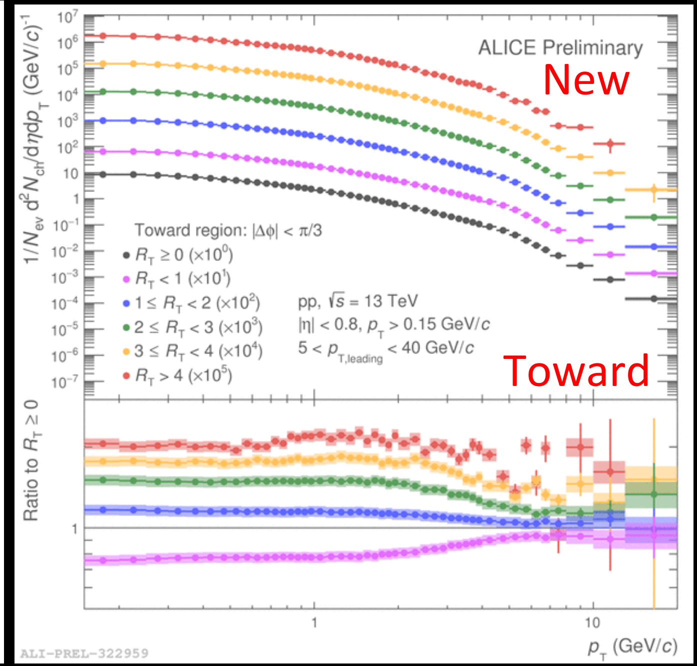


Transverse activity classifier:

- $R_T = N_{inc.} / \langle N_{inc.} \rangle$

Martin et al.
Eur. Phys. J.C 76 (2016) 299



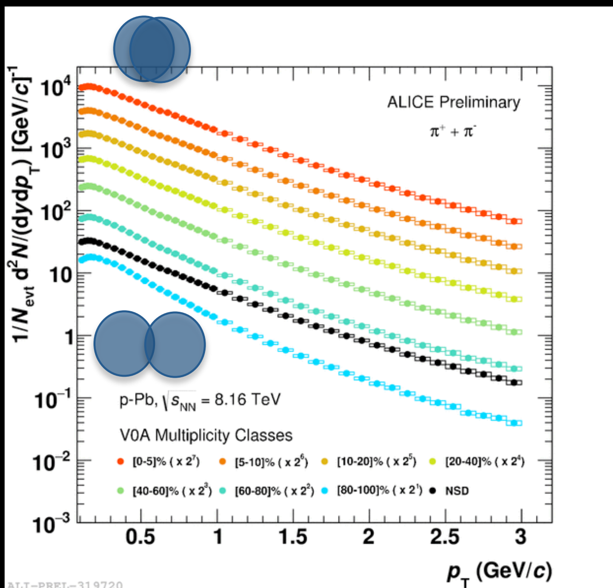


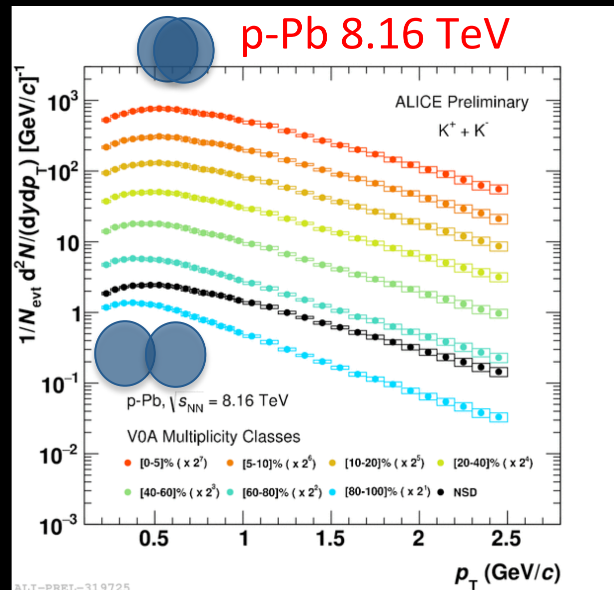
- p_T spectra in multiplicity intervals are biased due to correlations between low- and high-p_T particles → harder spectra in higher multiplicity events [ALICE, arXiv:1905.07208]
- R_T selection (jet free multiplicity estimator) can be used to reduce such biases and help to understand these correlations

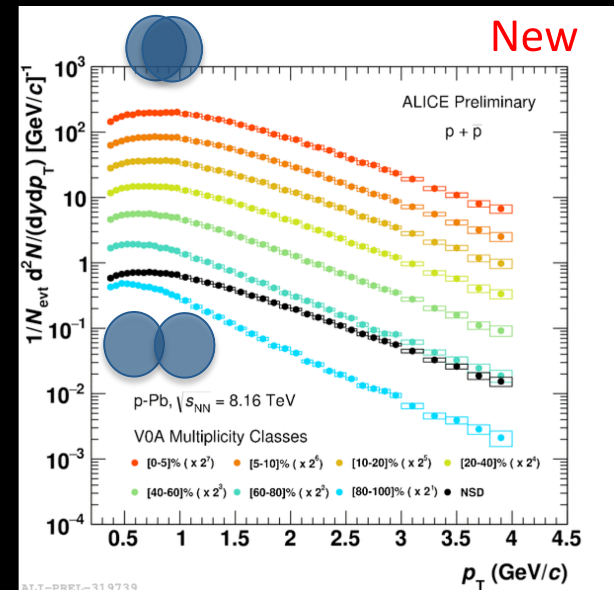
V. Zaccolo 11/06

- Opposite trend at high p_T for the transverse and toward spectra
- Convergence to the inclusive jets for the toward spectra at high p_T → separation between soft (UE) and hard (jet) part of the spectrum

p_T spectra of charged π, K and p in p-Pb

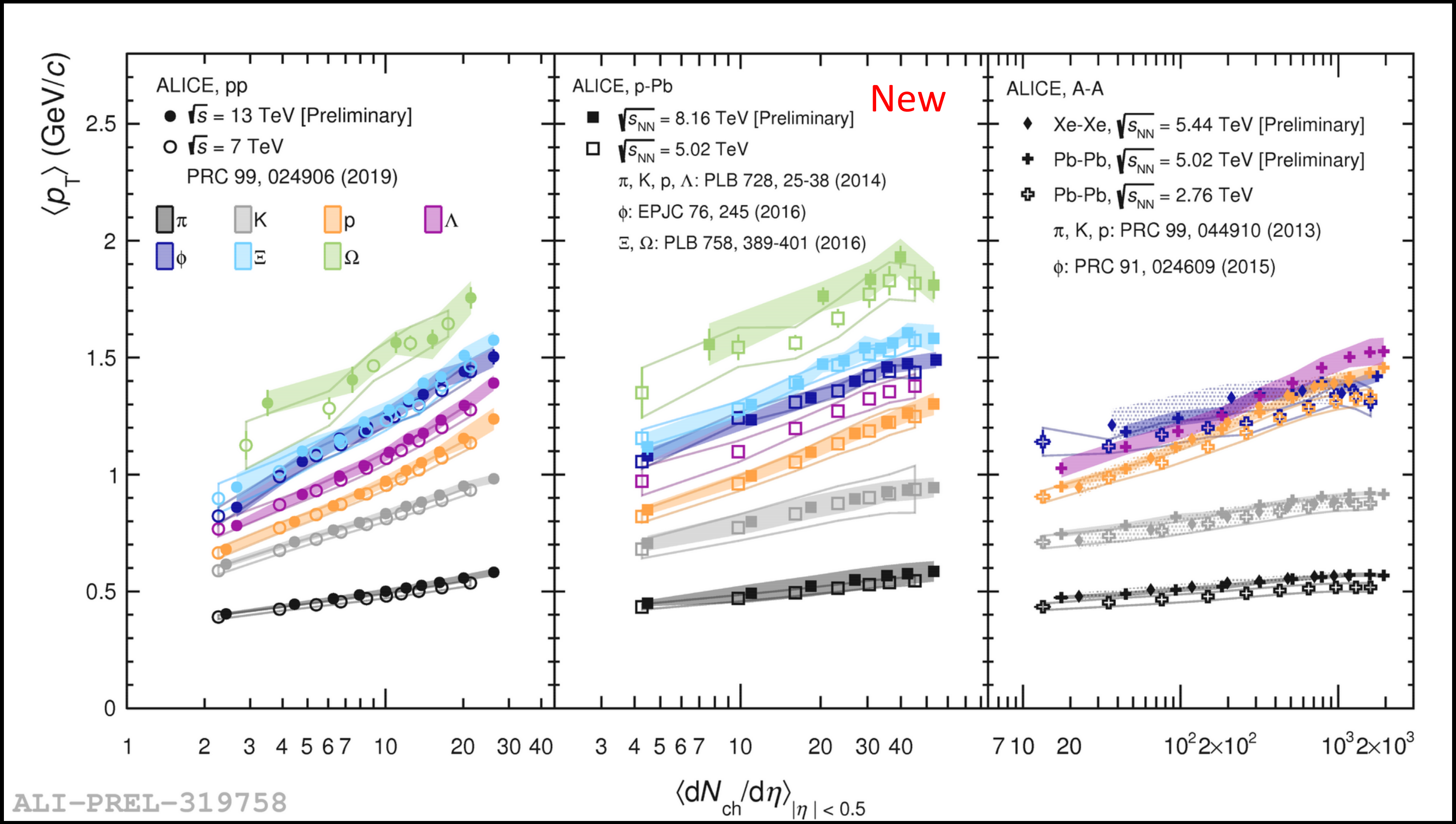






- Measured and identified with different analysis techniques: ITS, TPC, TOF, HMPID and topological identification of decaying charged kaons
- Mass dependent hardening of the spectra with increasing centrality
  → Collective radial expansion

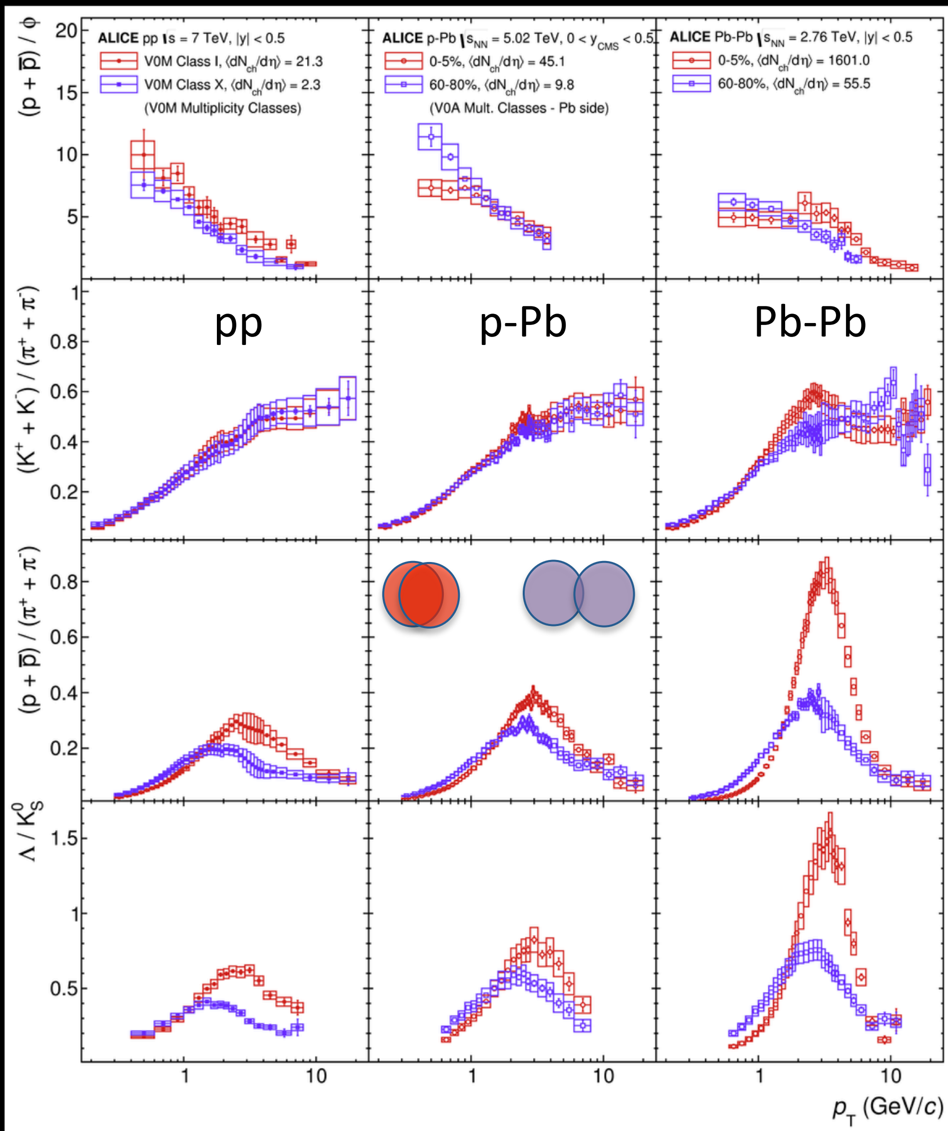
$\langle p_T \rangle$ vs centrality of hadrons in pp, p-Pb, Pb-Pb and Xe-Xe

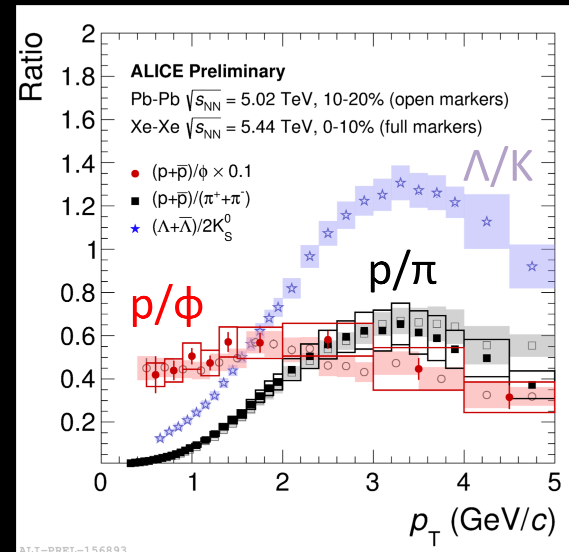


- $<p_T>$ increases with increasing centrality and mass
- Larger increase in smaller systems
  - → Collective radial expansion

Particle ratios in pp, p-Pb, Pb-Pb and Xe-Xe

Phys. Rev. C99, 024906 (2019)





- Similar evolution pattern of particle ratios from pp to Pb-Pb
- Similar values for Pb-Pb and Xe-Xe at similar multiplicity
- p/ϕ consistent with radial flow but also with (re)combination [Phys.Rev. C92 (2015)054904]

→ Particle production is driven by the characteristics of final state

→ Spectra at intermediate p_T determined by flow or recombination?

Blast-Wave fit to hadron p_T spectra

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

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

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

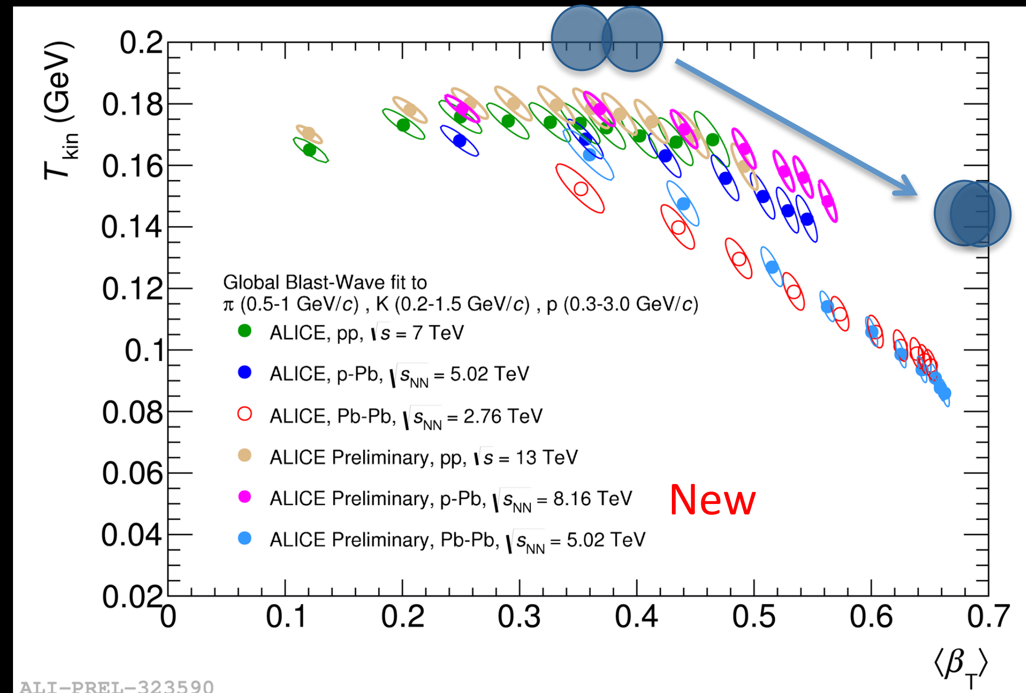
Simplified hydrodynamic model with 3 parameters:

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

→ Similar trend observed in pp, p-Pb and Pb-Pb collisions

→ Larger β_T in small systems at similar multiplicity

Simultaneous fit to the π, K, p spectra



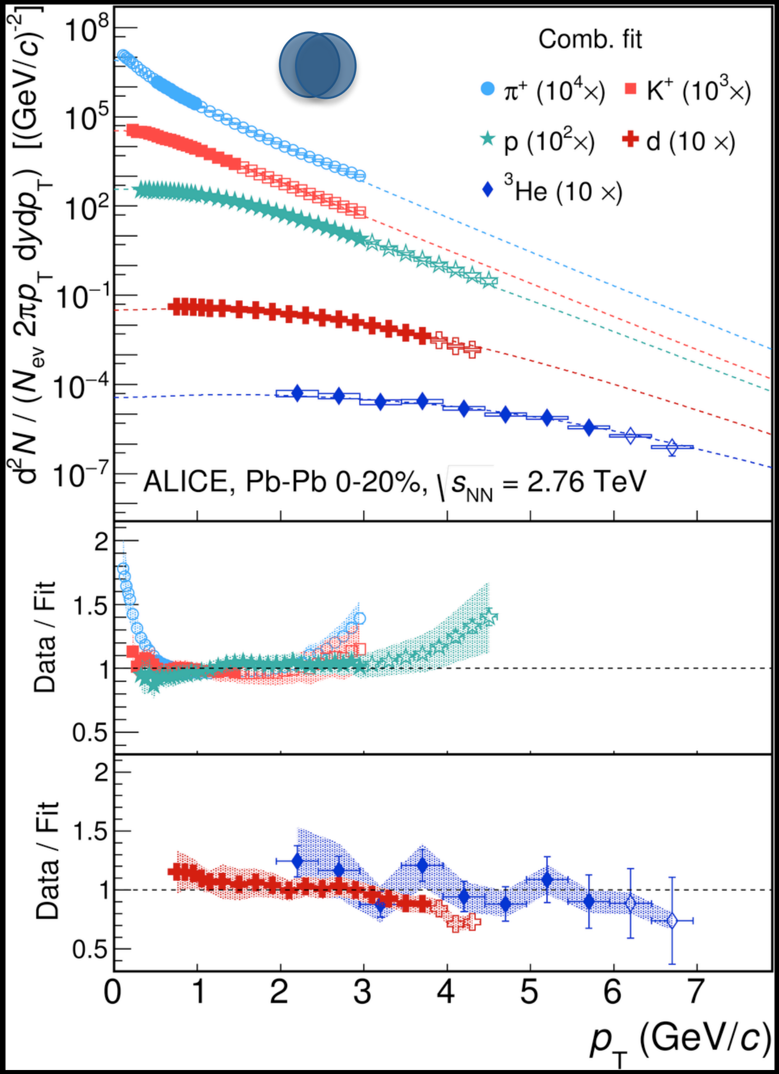
pp 7 TeV: Eur. Phys. J. C75 (2015) 226

p–Pb 5.02 TeV: Phys. Lett. B 760 (2016) 720

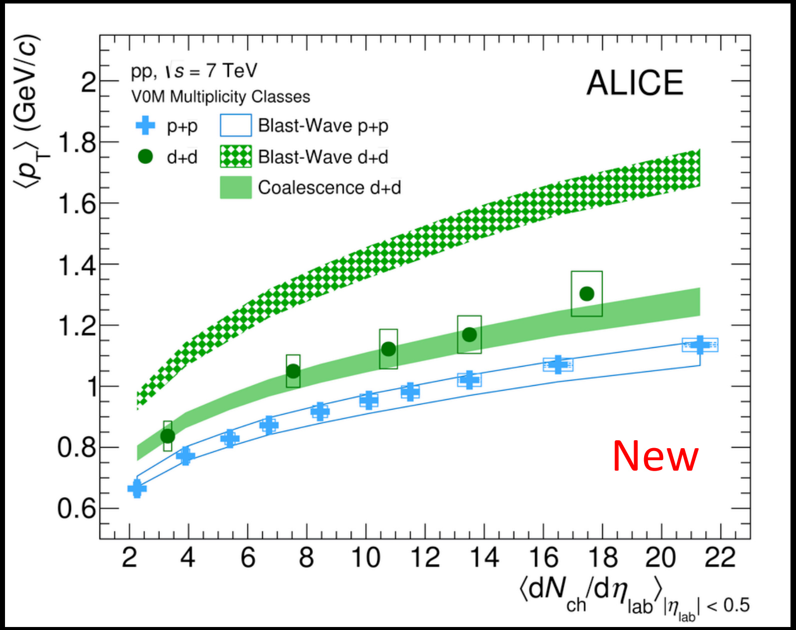
Pb–Pb 2.76 TeV: Phys. Rev. C88 (2013) 044910

Blast-Wave fit including nuclei

Phys. Rev. C 93 (2015) 024917



Phys.Lett. B794 (2019) 50



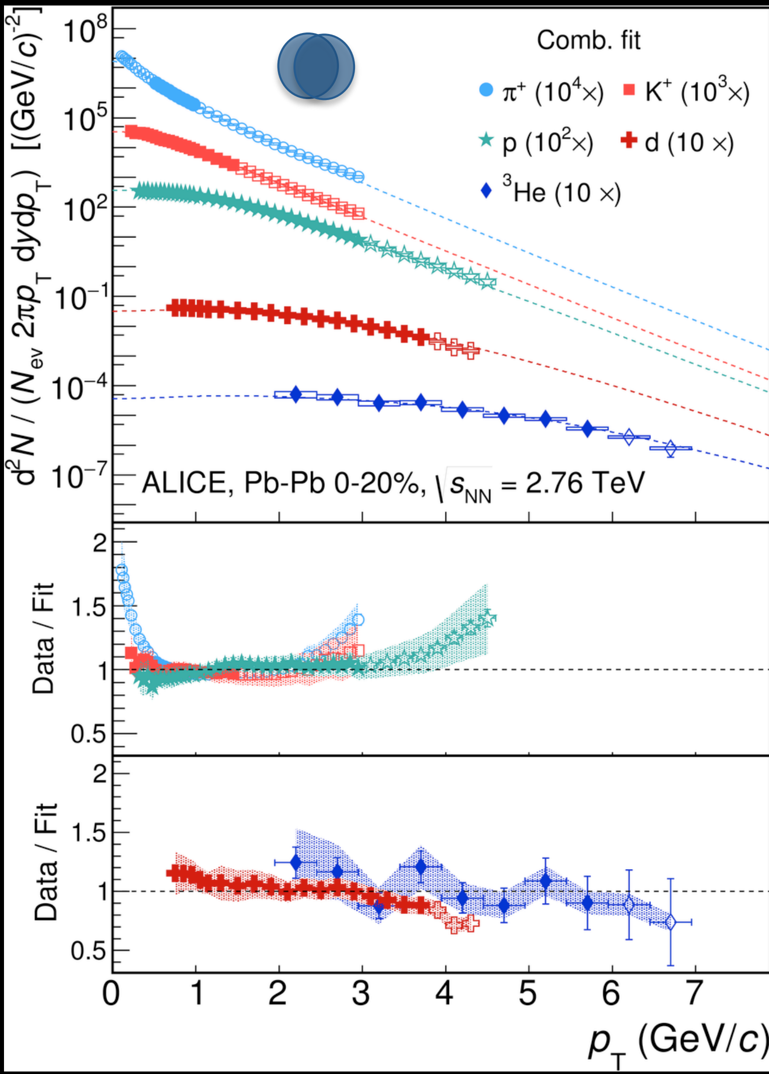
- Pb-Pb: nuclei participate in collective expansion with $<\beta_T>$~0.63 and T_{kin}~ 113 MeV (consistent with values for π, K, p)
- pp: Blast-Wave model does not reproduce $<p_T>$ of (anti)deuterons in contrast to Pb-Pb

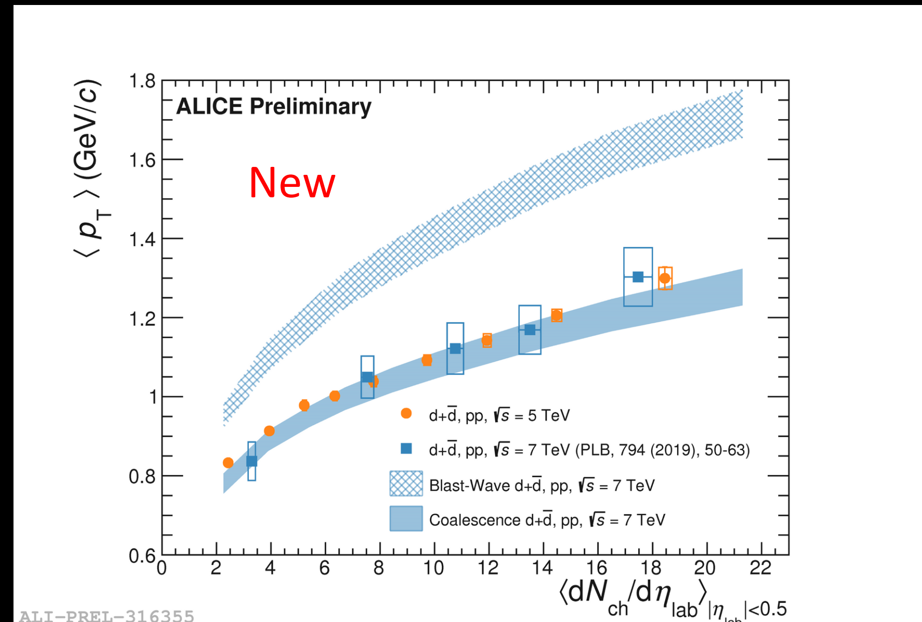
→ coalescence scenario favored for deuteron production in pp

Blast-Wave fit including nuclei

Phys. Rev. C 93 (2015) 024917

A. Balbino - Poster 11/06





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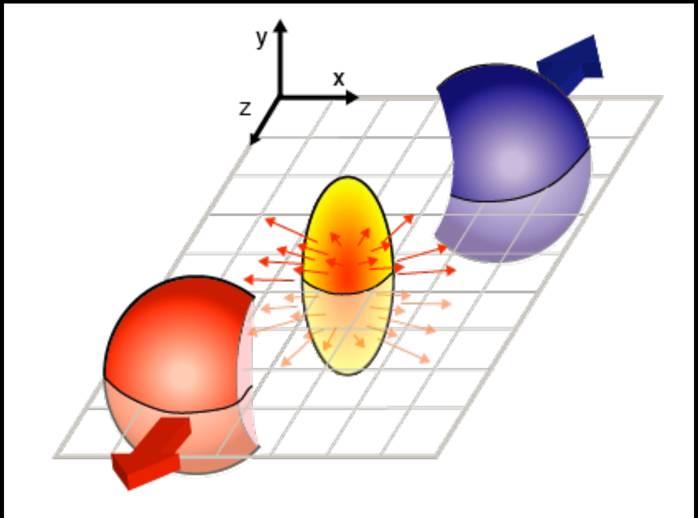
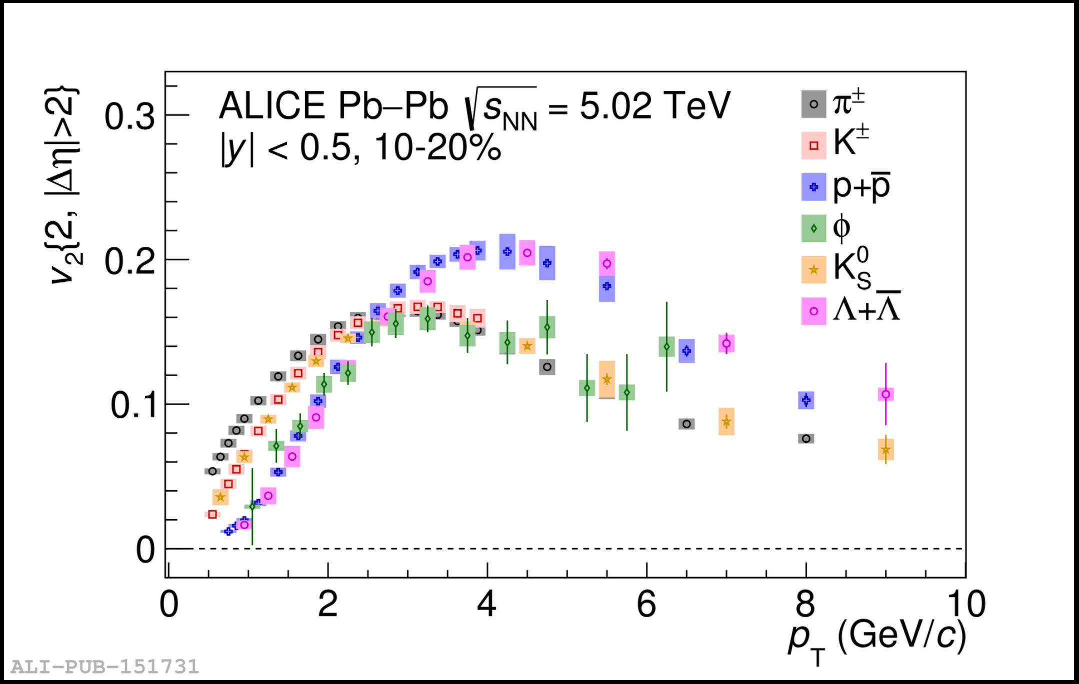
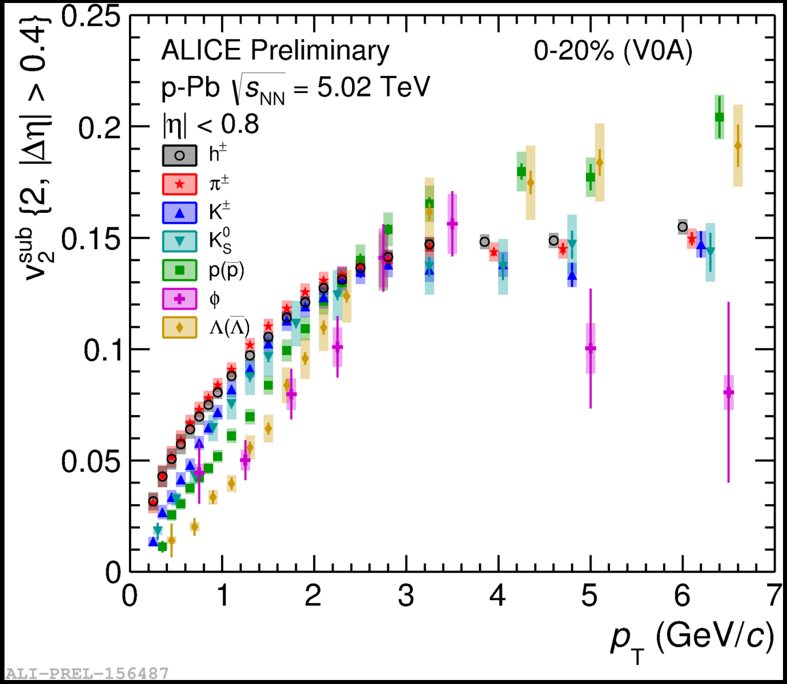


ANISOTROPIC FLOW

Identified particle v_2 in Pb-Pb and p-Pb

JHEP09 (2018) 006



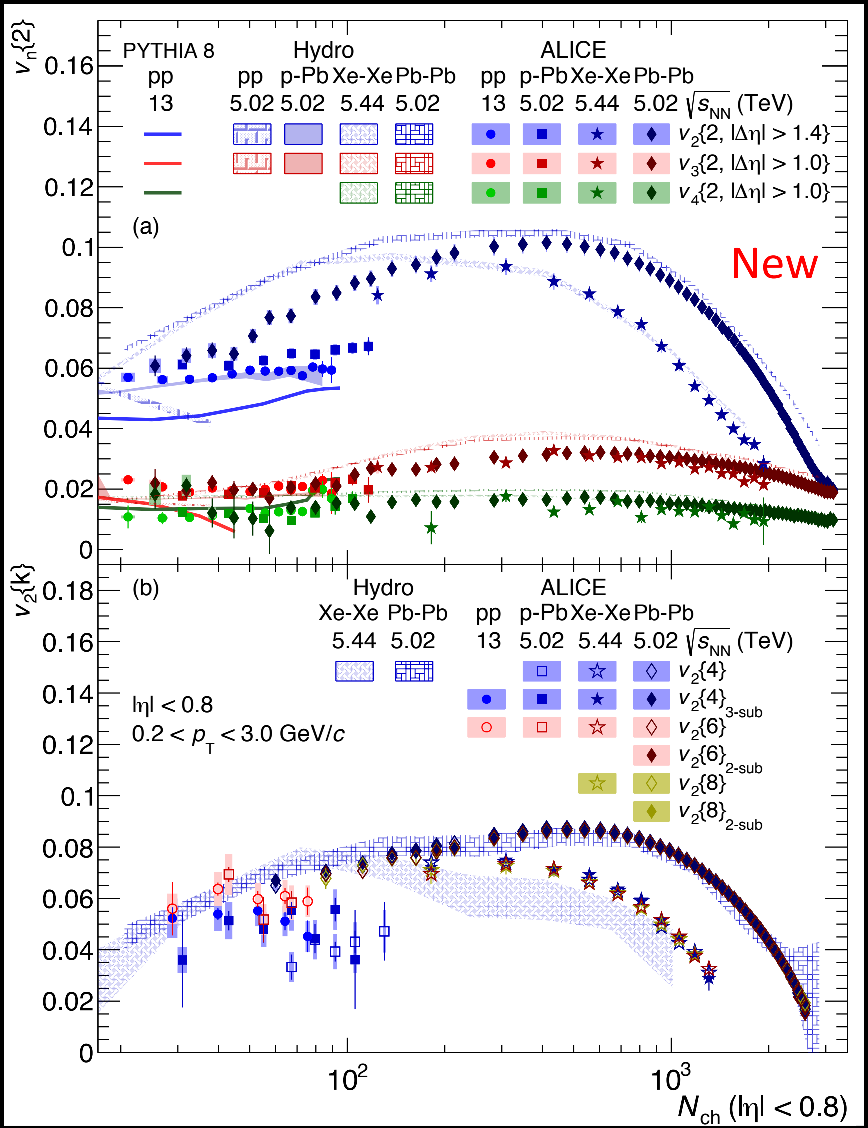


- p_T < 2 GeV/*c:* hadron mass ordering seen in Pb-Pb and p-Pb collisions
- p_T ~ 2.5 GeV/*c:* crossing between v_2 of baryons and mesons
- p_T > 2.5 GeV/*c*: baryons v_2 > mesons v_2 (flow driven by quark content)
- ϕ meson follows mass ordering at low p_T and quark content at intermediate p_T

→ Quantitative differences between systems

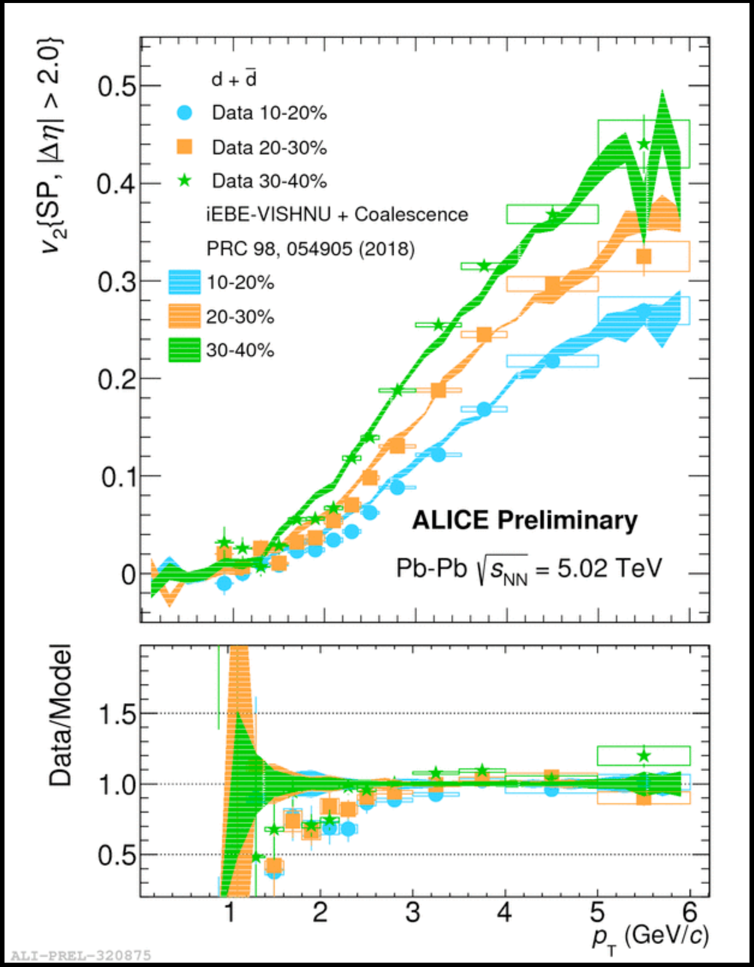
Charged-particle v_2, v_3, v_4 in pp, p-Pb, Xe-Xe and Pb-Pb

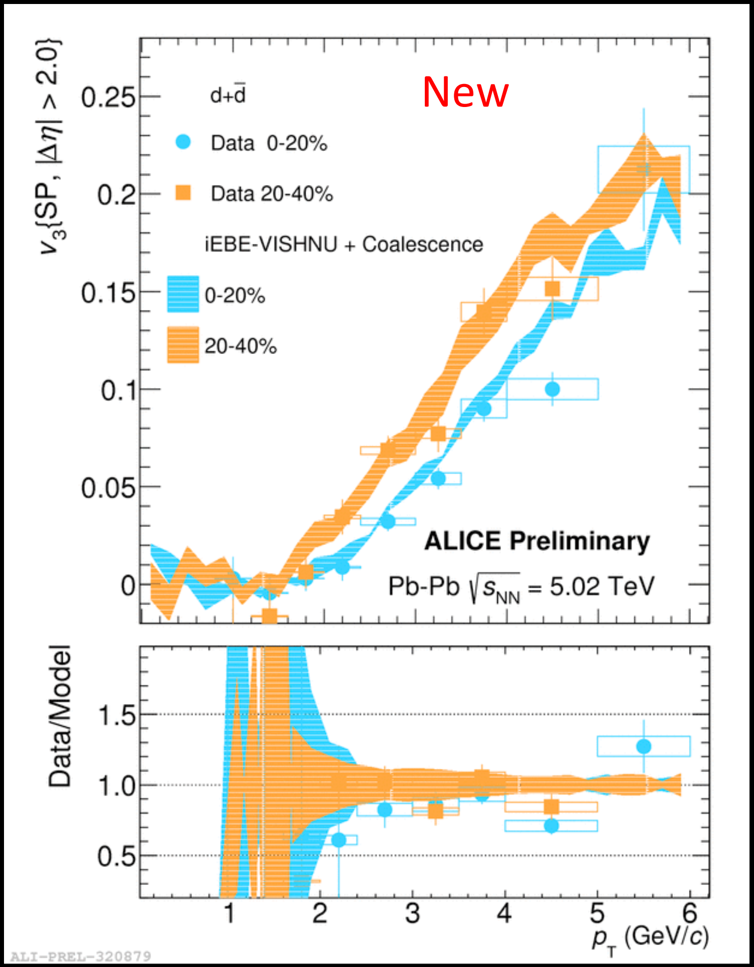
arXiv:1903.01790



- Two and multi-particle azimuthal correlations
- Similar ordering of $v_2 > v_3 > v_4$ seen in small and large systems
- Weak v_2 multiplicity dependence seen in pp and p-Pb
- Novel subevent method supports long-range multi-particle azimuthal correlations in high multiplicity pp and p-Pb
- PYTHIA8 and IP-Glasma+MUSIC+UrQMD cannot describe correlations in pp and p-Pb

(Anti)deuteron v_2 and v_3 in Pb-Pb

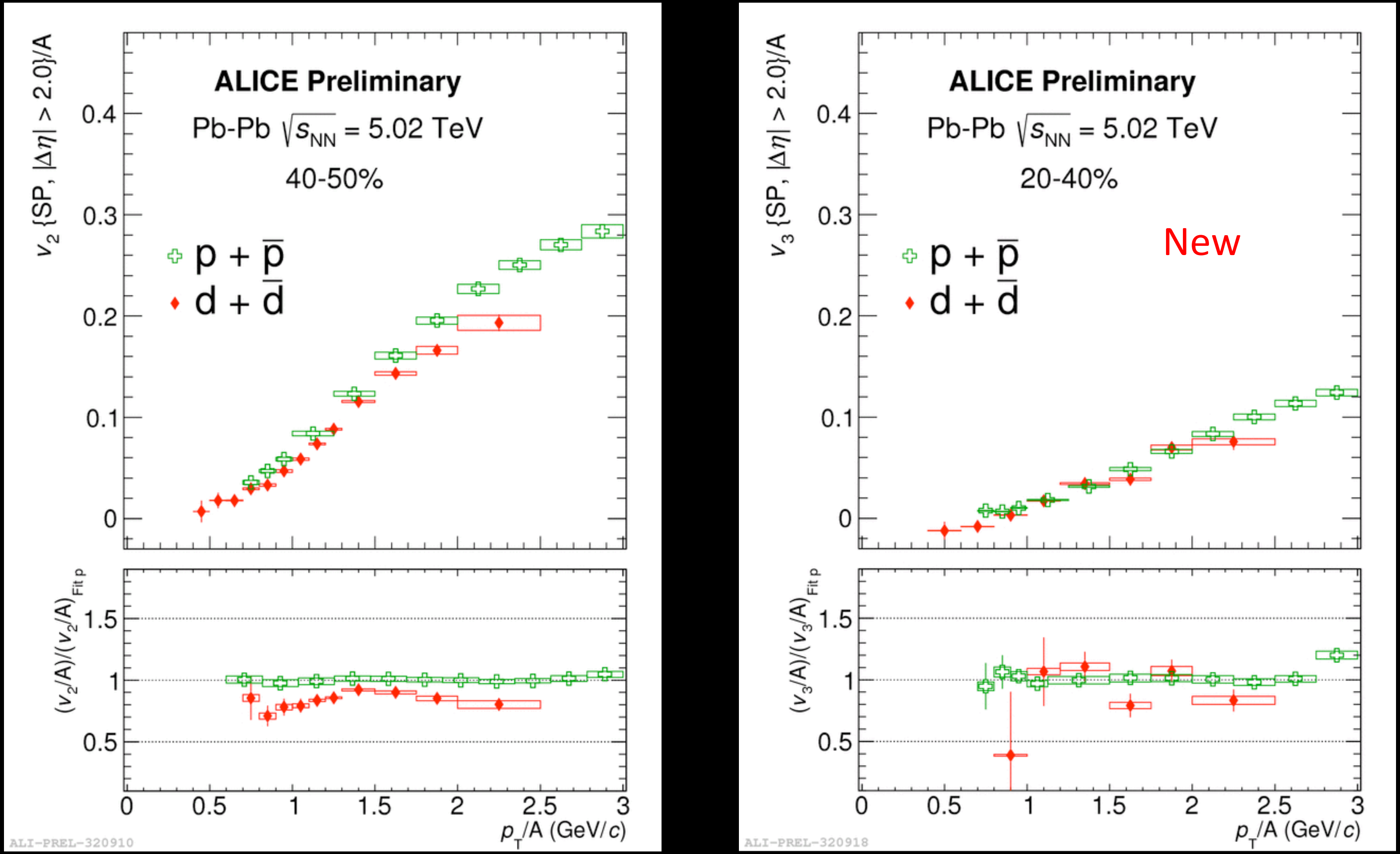




- Coalescence model with phase-space distributions of protons and neutrons from iEBE-VISHNU in agreement with data

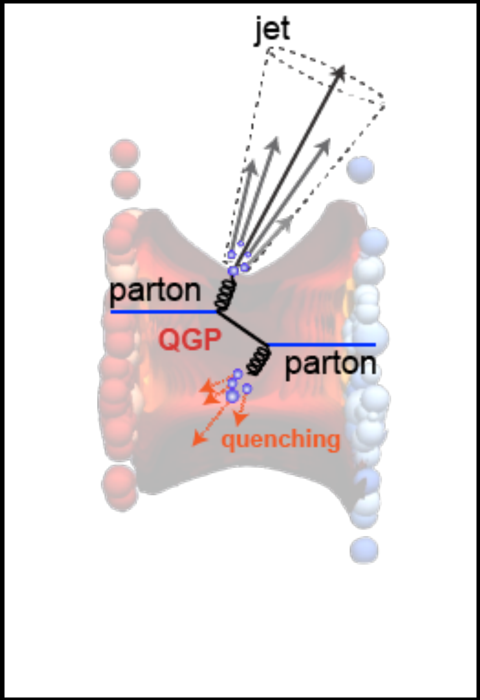
A. Caliva 11/06

(Anti)deuteron v_2 and v_3 in Pb-Pb



- Coalescence model with phase-space distributions of protons and neutrons from iEBE-VISHNU in agreement with data
- (Anti)deuteron v_2 and v_3 comparable to protons

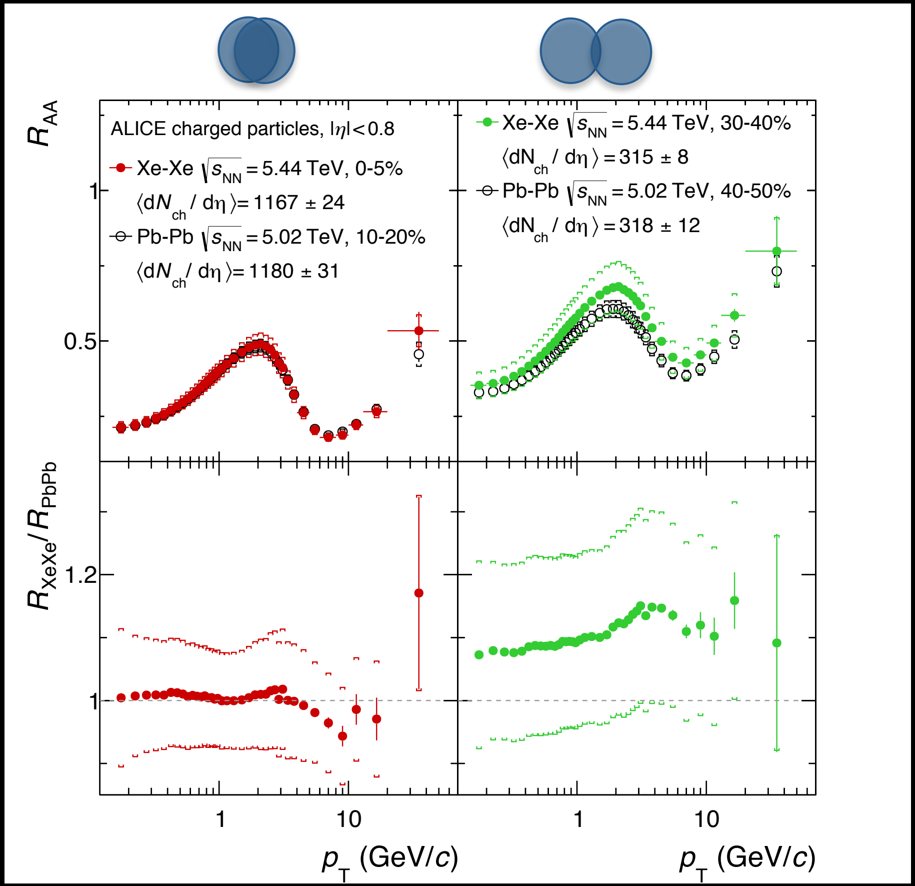
A. Caliva 11/06

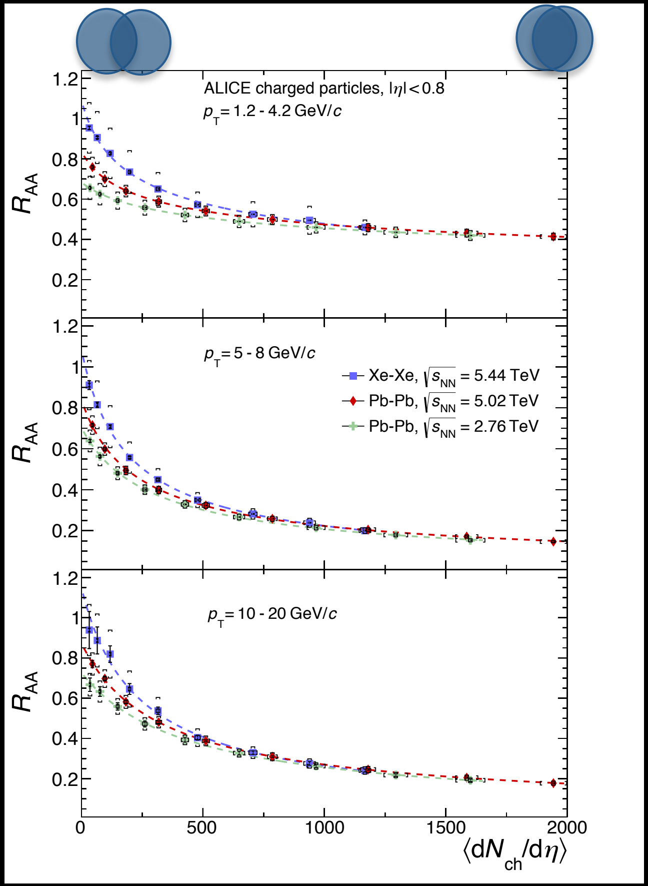


NUCLEAR MODIFICATION FACTORS AND JET QUENCHING

Charged-particle R_{AA} in Xe-Xe and Pb-Pb

Phys. Lett. B 788 (2019) 166

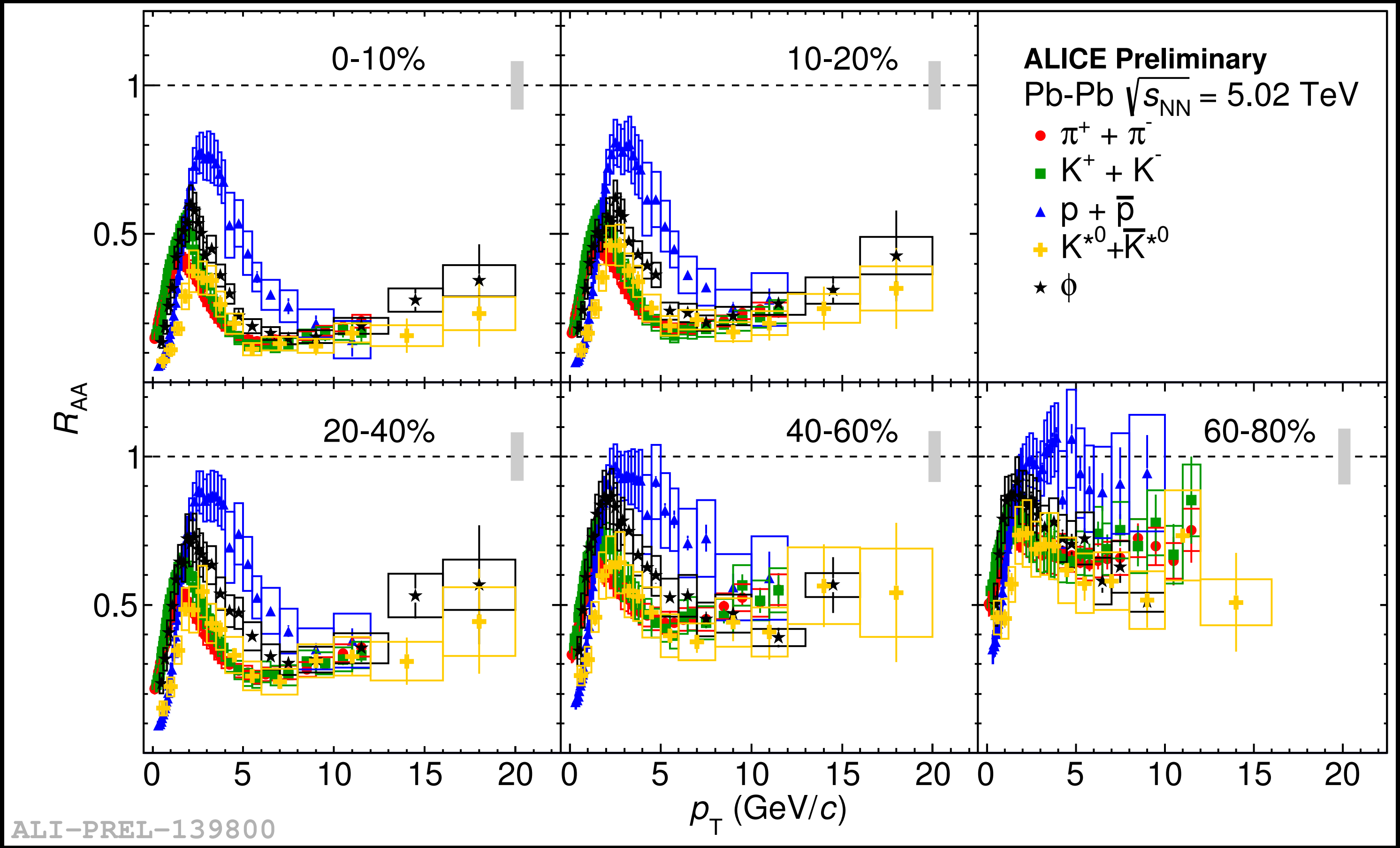




- Similar R_{AA} in central Xe-Xe and Pb-Pb collisions at similar multiplicity
- Different R_{AA} in more peripheral collisions

→ Result of interplay between geometry and path length dependence of parton energy loss

R_{AA} of identified hadrons in Pb-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV



- p_T > 10 GeV/c: the same strong suppression of light-flavor hadrons
  → high-p_T fragmentation function not affected by the medium
- p_T < 10 GeV/c: differences between light-flavor hadrons (difficult to interpret due to other effects e.g. radial flow, (re)combination,…)

Summary

- The collision geometry plays an important role in particle production
- Particle production is driven by characteristics of final state
- Several mechanisms of hadron and nuclei production: rescattering, (re)combination, coalescence etc.
- Strangeness enhancement seen in small and large systems (droplet of QGP?)
- NEW results: charged-particle p_T spectra vs. R_T, π,K,p in p-Pb at 8.16 TeV, nuclei production in pp and p-Pb

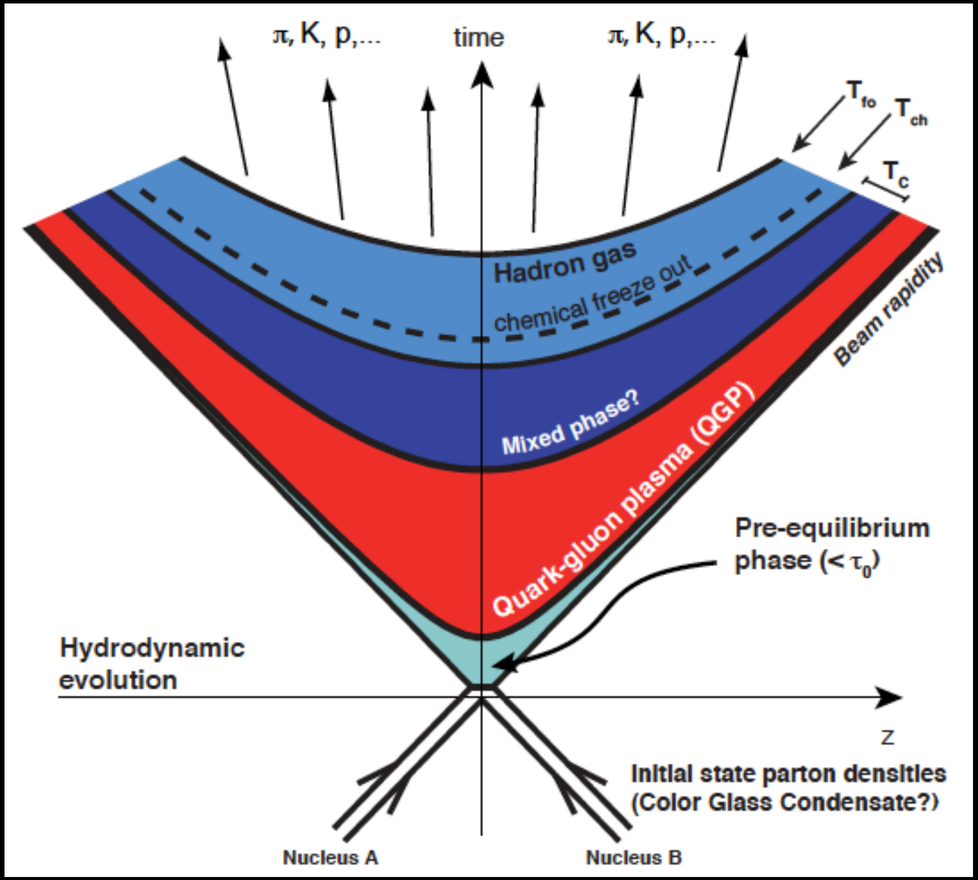
- Collective effects are observed in small and large systems
- Quantitative differences between flow coefficients in small and large systems (different underlying mechanisms?)
- NEW results: charged-particle v_2, v_3 and v_4 in pp, p-Pb, Xe-Xe and Pb-Pb, nuclei v_2 and v_3 in Pb-Pb

- Strong suppression of particle production in central Pb-Pb and Xe-Xe collisions (interplay between geometry and path length dependence)
- Suppression at high p_T independent of particle species

Backup

Stages of the relativistic heavy-ion collision

Bjorken 1983



Chemical and thermal freeze-out

Hadronization (T ~ T_C)

Quark-Gluon Plasma (thermalized matter?)

Pre-equilibrium, fast thermalization ~ 1 fm/*c*, glasma?

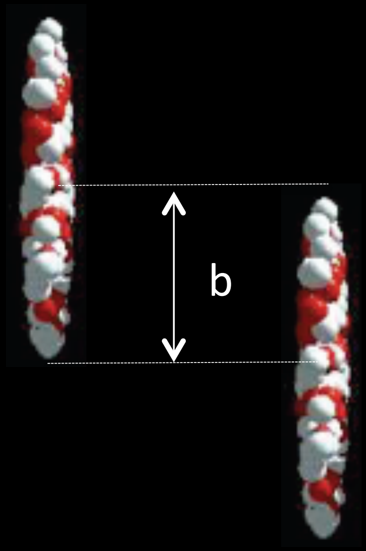
Hard collisions

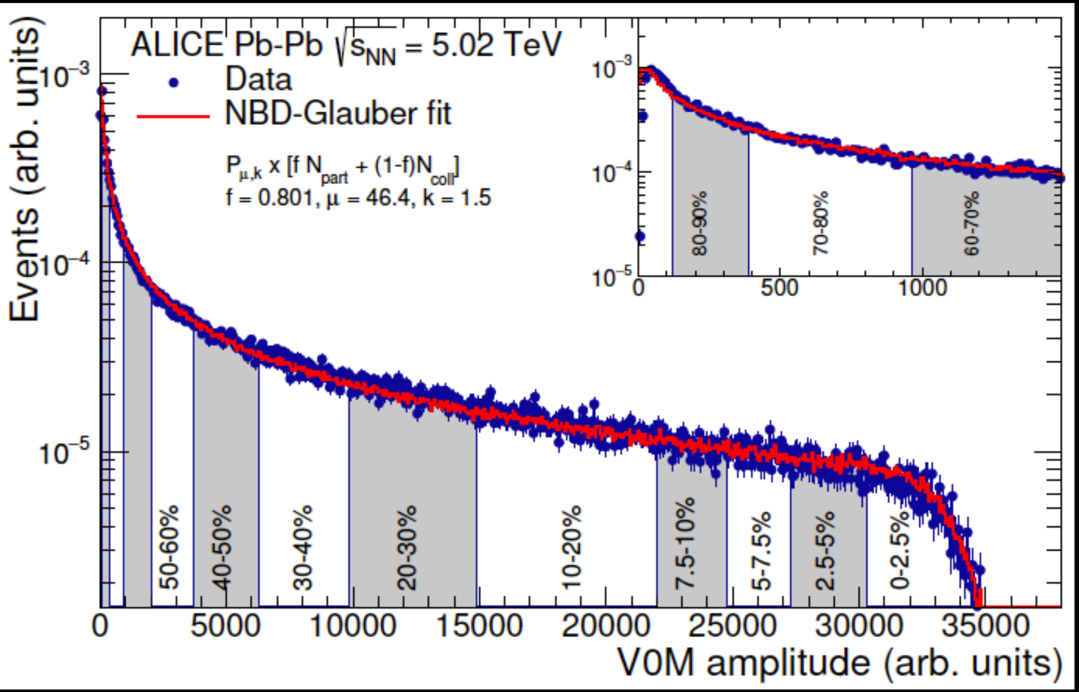
Lorentz-contracted ions (dense gluonic matter, Color Glass Condensate?)

- All stages in models of nuclear collisions
- QGP expansion modeled by relativistic hydrodynamics

Event Centrality Selection

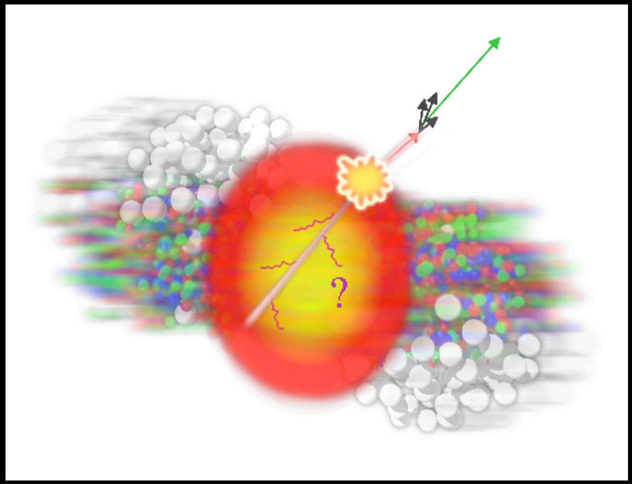
ALICE-PUBLIC-2018-011

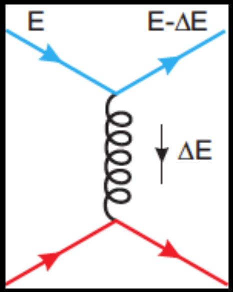




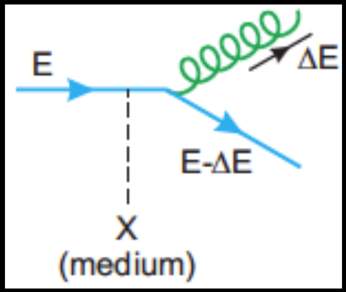
- Correlate particle multiplicity with collision geometry i.e. impact parameter, volume and shape (A. Białas et al. APPB 8 (1977) 389)
- N_{coll}, N_{part} and $T_{AA} = N_{coll} / \sigma^{NN}_{INEL}$ values determined by fitting NBD-Glauber coupled to two parameter model

Parton energy loss and jet quenching





collisional



radiative

Radiative and collisional parton energy loss:

$\Delta E = \Delta E_{coll} + \Delta E_{rad}$, ΔE (E, m, C_R; ρ_g, α_s, T, L)

D. d'Enterria, arXiv:0902.2011

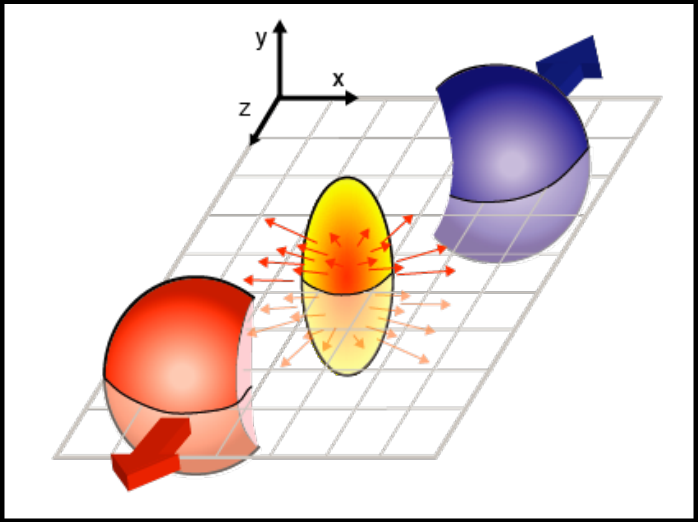
Radiative energy loss dominate at high-p_T:

- Color charge dependence C_R: $C_{R,g} > C_{R,q,Q}$
  → $\Delta E_g > \Delta E_{q,Q}$
- Mass dependence "dead cone": gluon radiation suppression at $\Theta < m_Q/E$
  → $\Delta E_q > \Delta E_Q$
  L. Dokshitzer & D.E. Kharzeev, PLB 519 (2001) 199

- In static medium: $\Delta E_{coll} \sim L$, $\Delta E_{rad} \sim L^2$
- Characterize medium transport properties via parton energy loss

$$\hat{q} \equiv \frac{m_D^2}{\lambda} = m_D^2 \rho \sigma$$

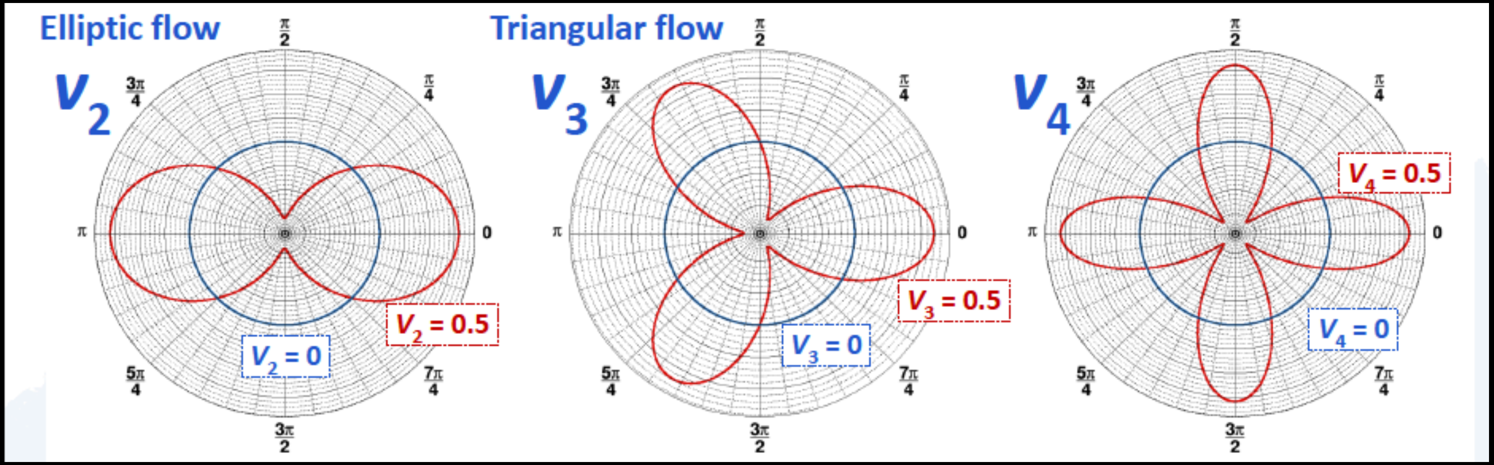
Anisotropic flow



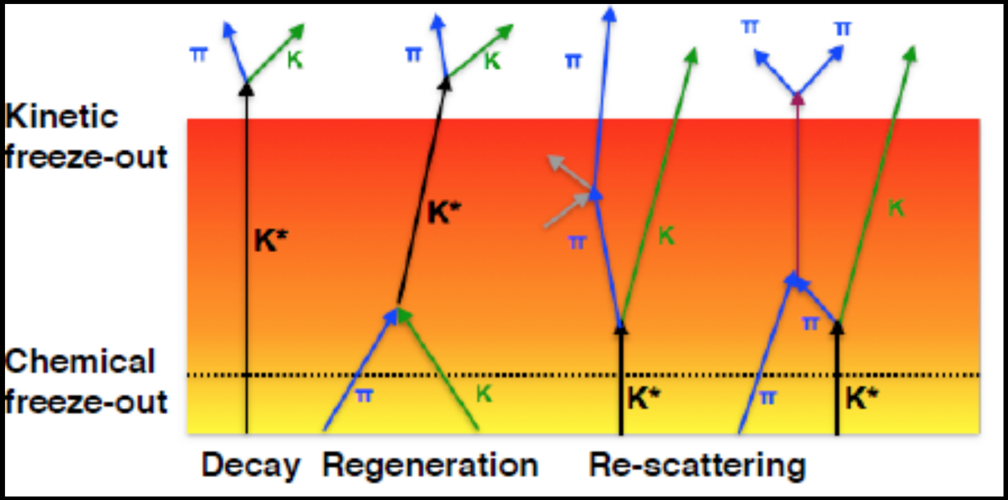
- Strongly interacting system:
  spatial anisotropy → momentum anisotropy
- Quantified in terms of Fourier coefficients v_n

$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left(1 + 2\sum_{n=1}^{\infty} v_n \cos[(\varphi - \Psi_n)]\right)$$

$$v_n(p_T, y) = \langle\cos[n(\varphi - \Psi_n)]\rangle$$



Resonance production



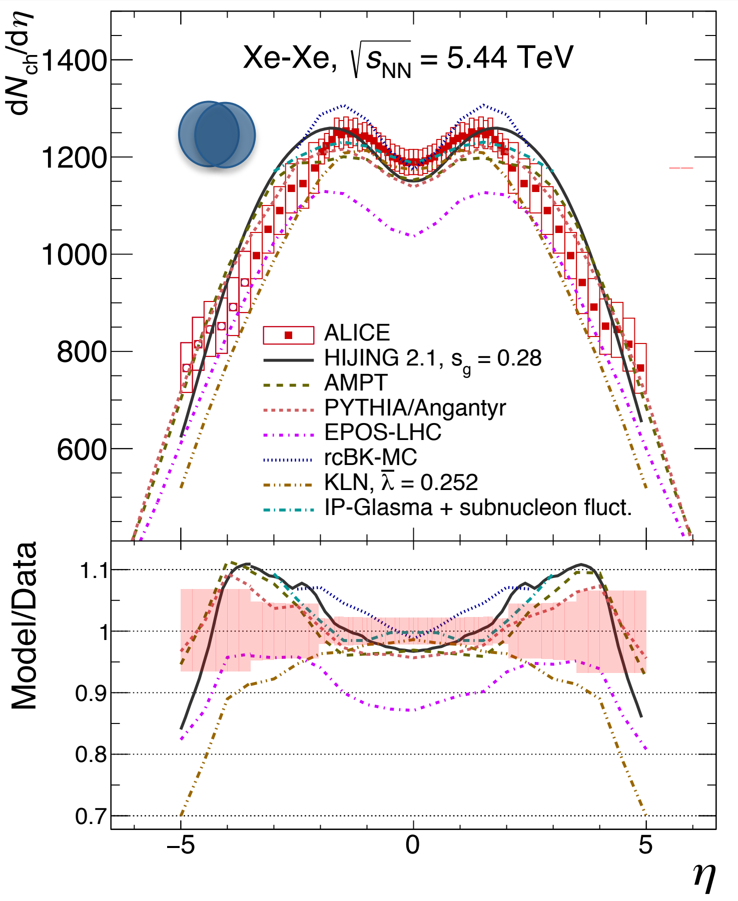
Rescattering and (re)combination in the hadronic phase influence the measured resonance yields

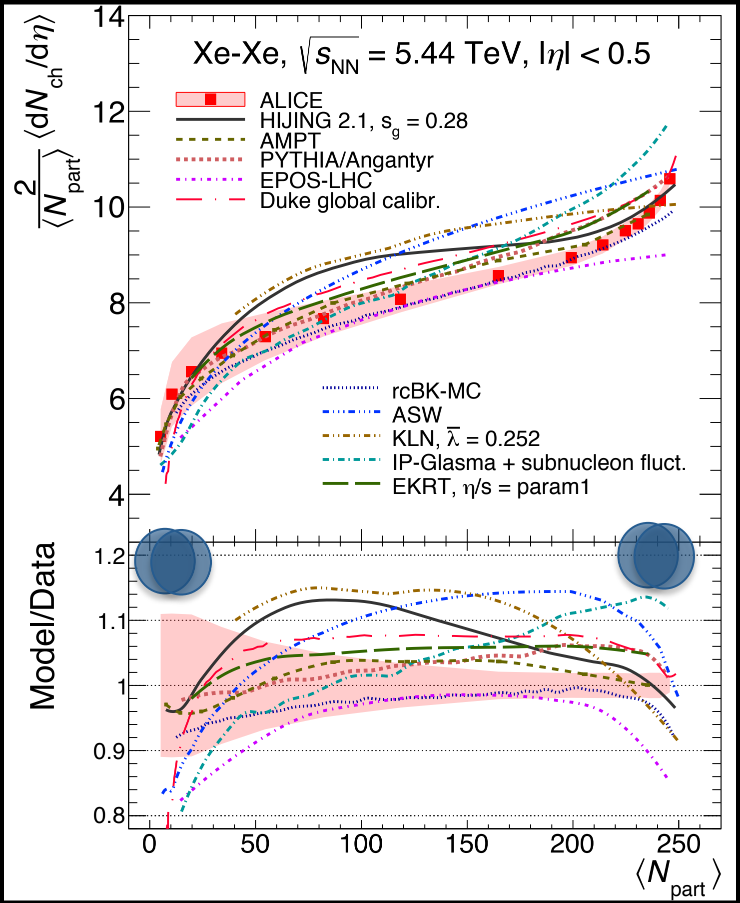
Final yields at kinetic freeze-out depend on:

- Initial yield after chemical freezeout
- Lifetime of hadronic phase
- Resonance lifetime
- Scattering cross-section of decay products

Charged-particle multiplicity vs models in Xe-Xe

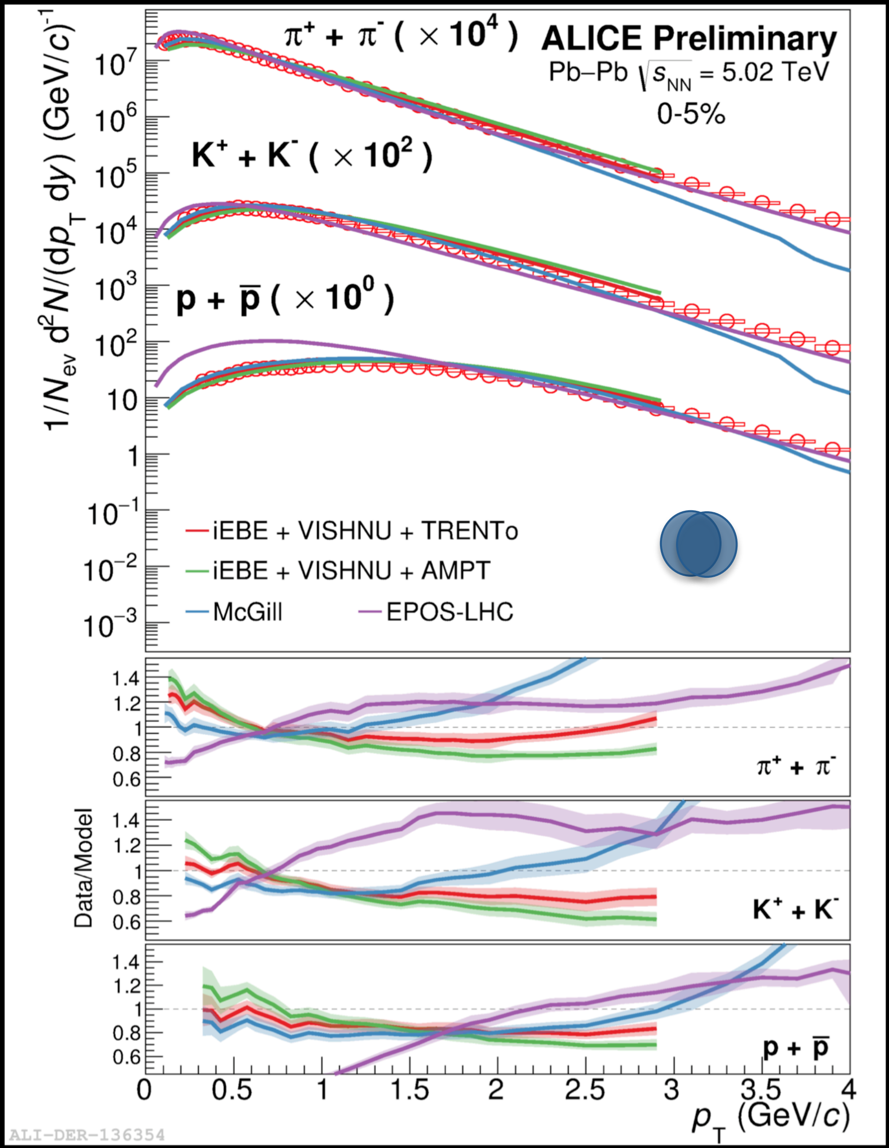
Phys. Lett. B 790 (2019) 35

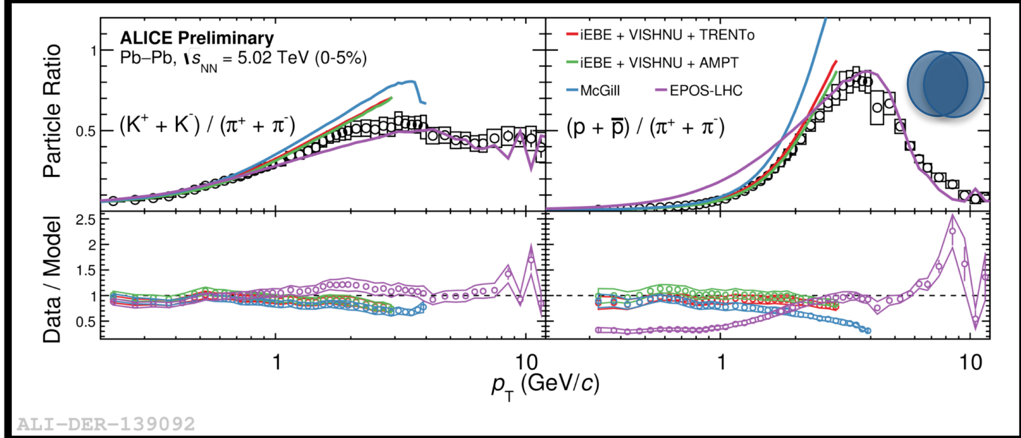




- Models do not describe charged-particle production in the whole rapidity range
- N_{part} dependence is best described by rcBK-MC: CGC saturation model based on Balitsky-Kovchegov gluon evolution equation

Comparison to hydro models – Pb-Pb (0-5%)



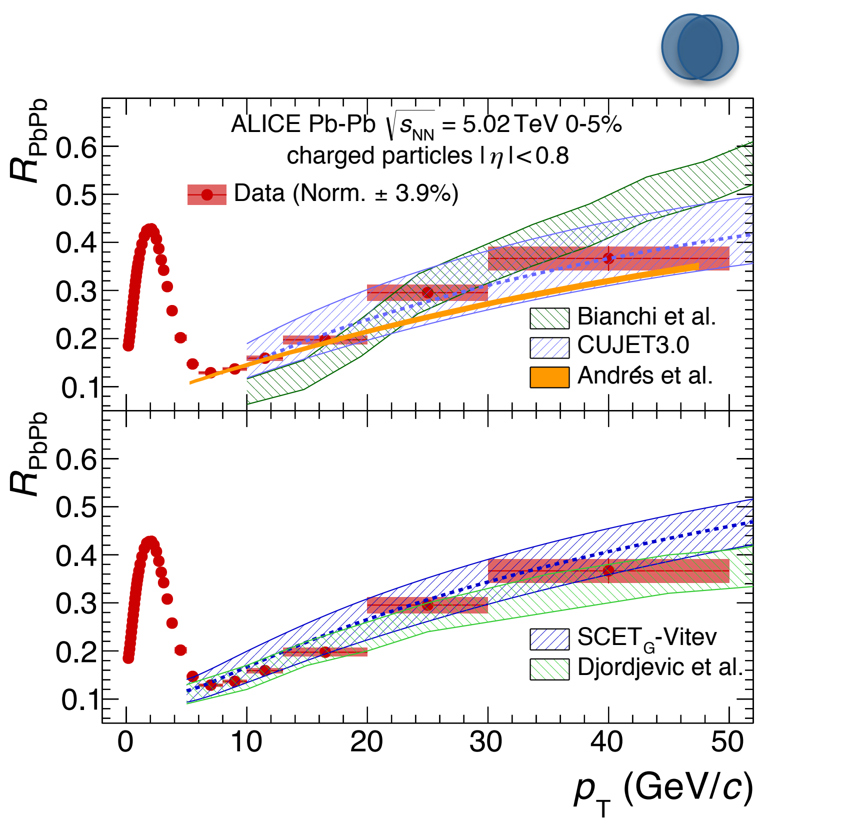


- iEBE-VISHNU (hydro+UrQMD) + TRENTo/AMPT initial conditions
- McGill: MUSIC (hydro) + IP glasma initial conditions
- EPOS LHC: hydro param. + hadronization [3]
- Models description within 20-40% for Pb-Pb central collisions
- Presented models give much worse description in peripheral collisions

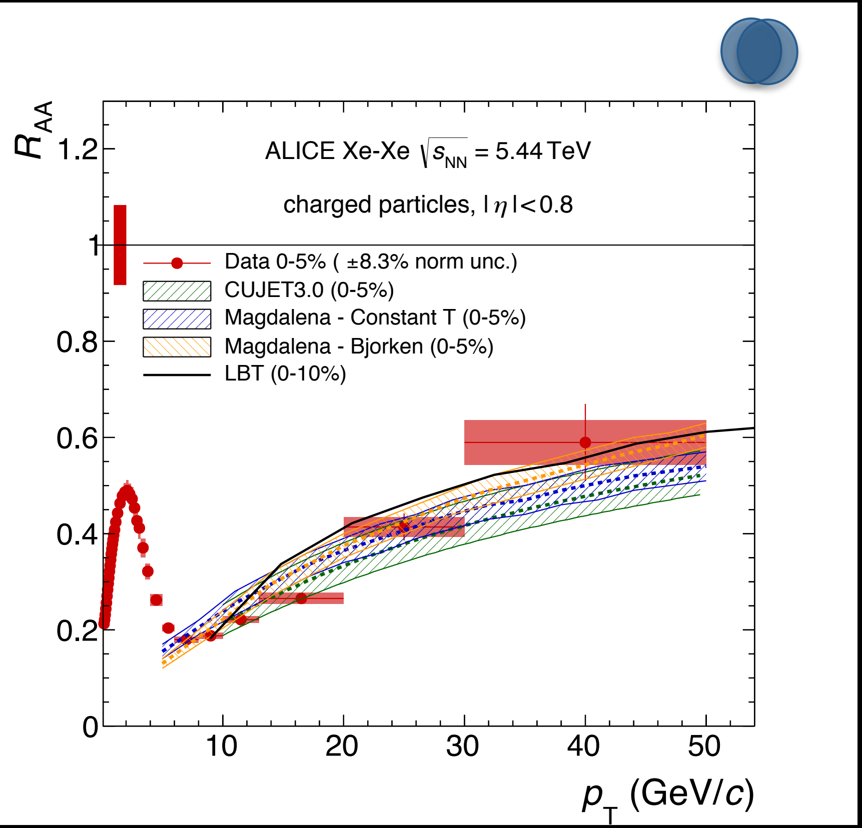
radial flow (hydro) - Navier-Stokes equations
iEBE-VISHNU: Eur. Phys. J C77 (2017) 645
McGill: Phys. Rev. C95 (2017) 064913
EPOS LHC: Phys. Rev. C92 (2015) 034906

Charged-particle R_{AA} vs models in Pb-Pb and Xe-Xe

JHEP 1811 (2018) 013



Phys. Lett. B 788 (2019) 166

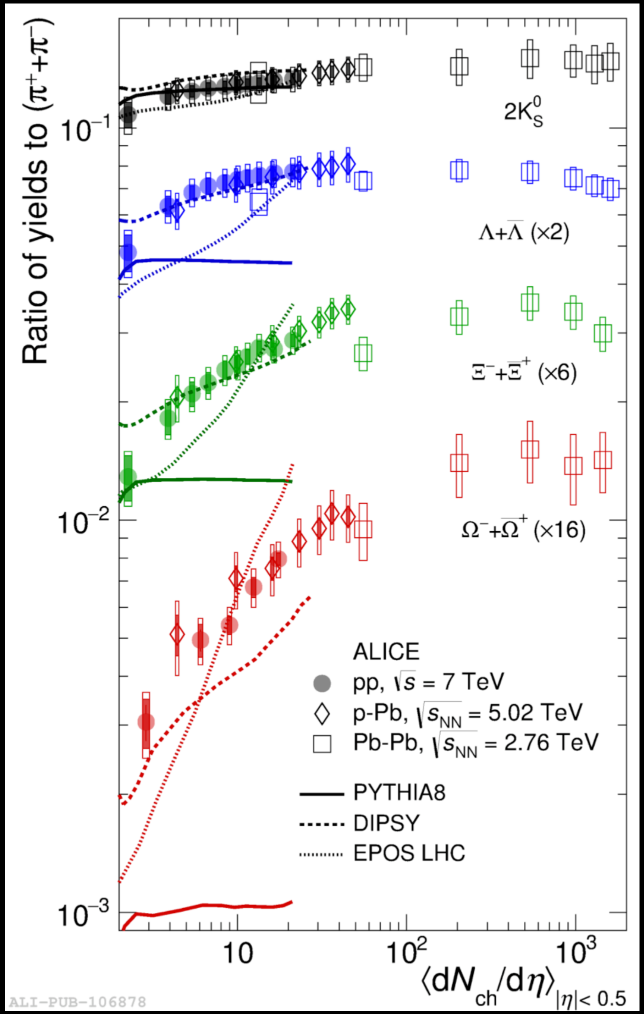


Models:

- All models include radiative energy loss
- CUJET3.0 and Magdalena Djordjevic models also include elastic energy loss
- Calculations are performed in dynamically expanding medium except that of Vitev et al.

Relative strangeness production in pp, p-Pb and Pb-Pb

ALICE, Nature Physics 13 (2017) 535



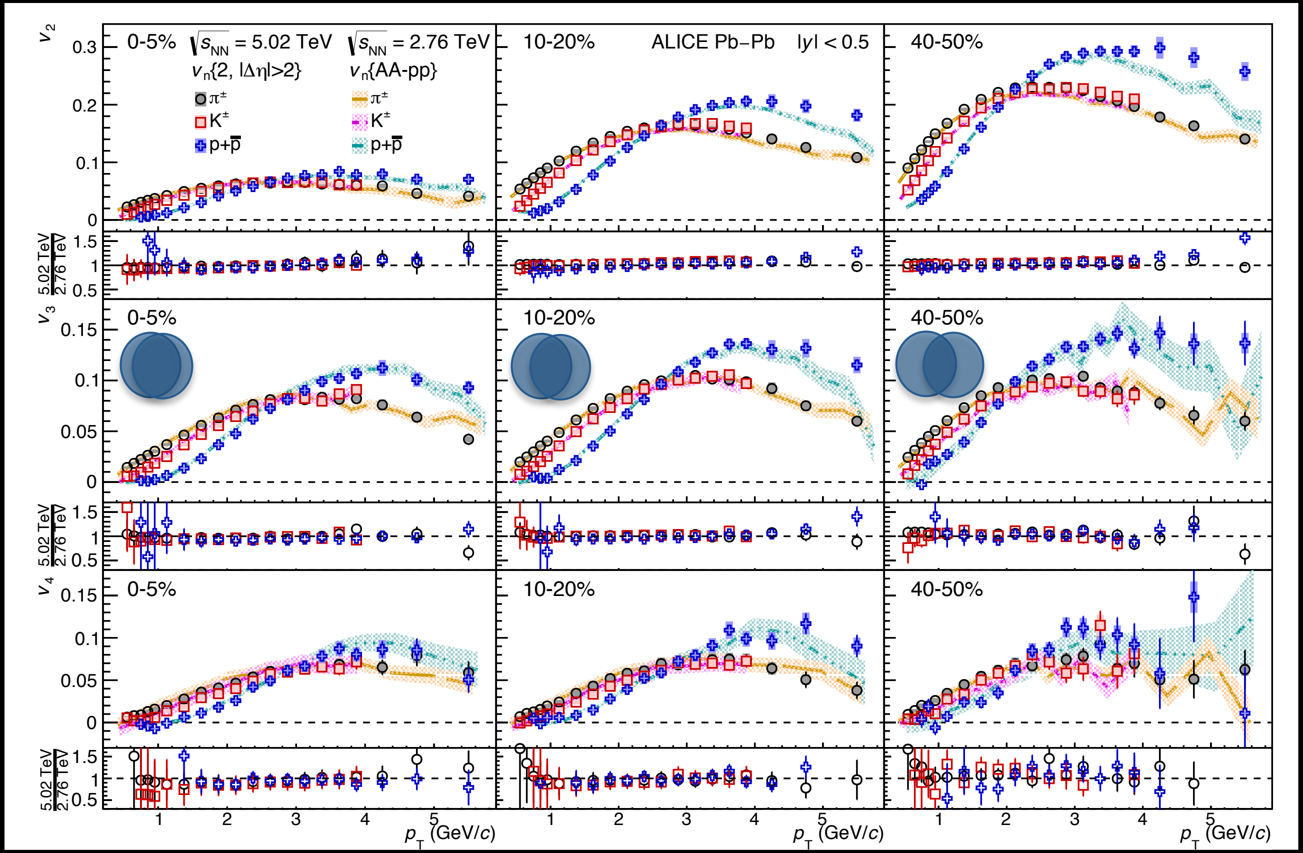
Historically a signature of the QGP
Rafelski & Mueller, PRL 48 (1982) 1066

- Smooth evolution from pp to Pb-Pb
- Enhancement observed in A-A which increases with strangeness content
- Enhancement also seen in the smaller systems pp and p-Pb
- No significant energy and system dependence is observed at similar multiplicity
- DIPSY model (rope hadronization) describes data best
    - But DIPSY overestimates p/π (not shown)

PYTHIA 8: Comput. Phys. Commun. 178 (2008) 852867
EPOS LHC: PRC92 (2015) 034906
DIPSY: PRD92 (2015) 094010

Identified particle v_2, v_3, v_4 in Pb-Pb

JHEP09 (2018) 006

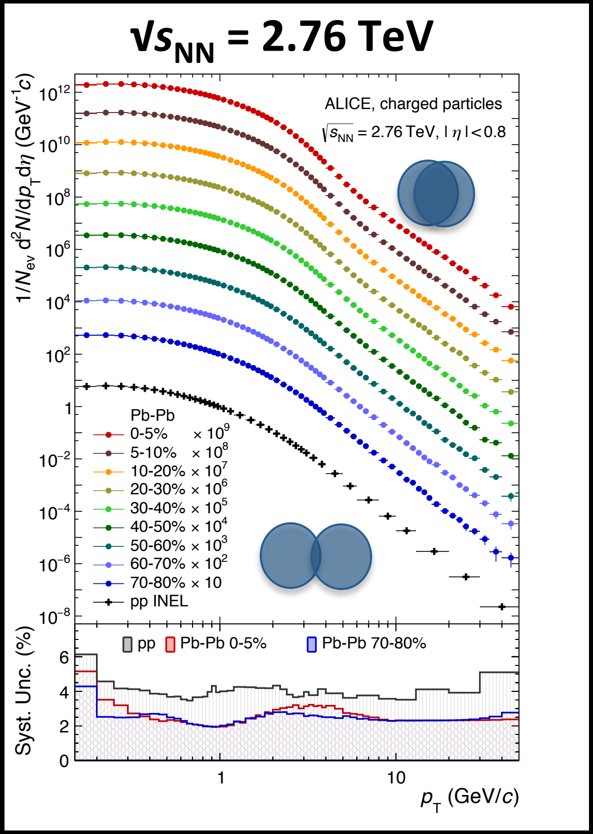


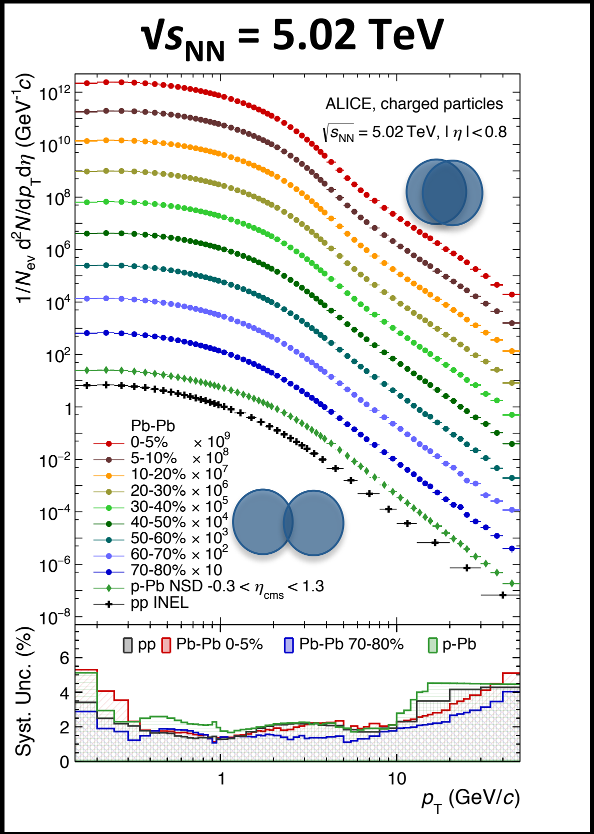
- Weak energy dependence of flow coefficients
- Hadron mass ordering at low p_T
- Strong centrality dependence of v_2
- v_3 is driven by initial state fluctuations

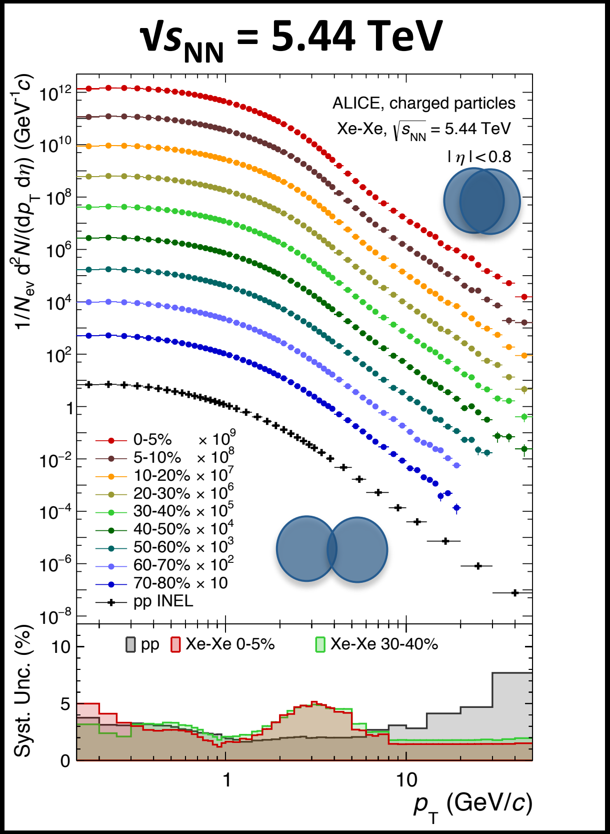
Charged-particle p_T spectra in pp, p-Pb, Pb-Pb and Xe-Xe

JHEP 1811 (2018) 013

Phys. Lett. B 788 (2019) 166



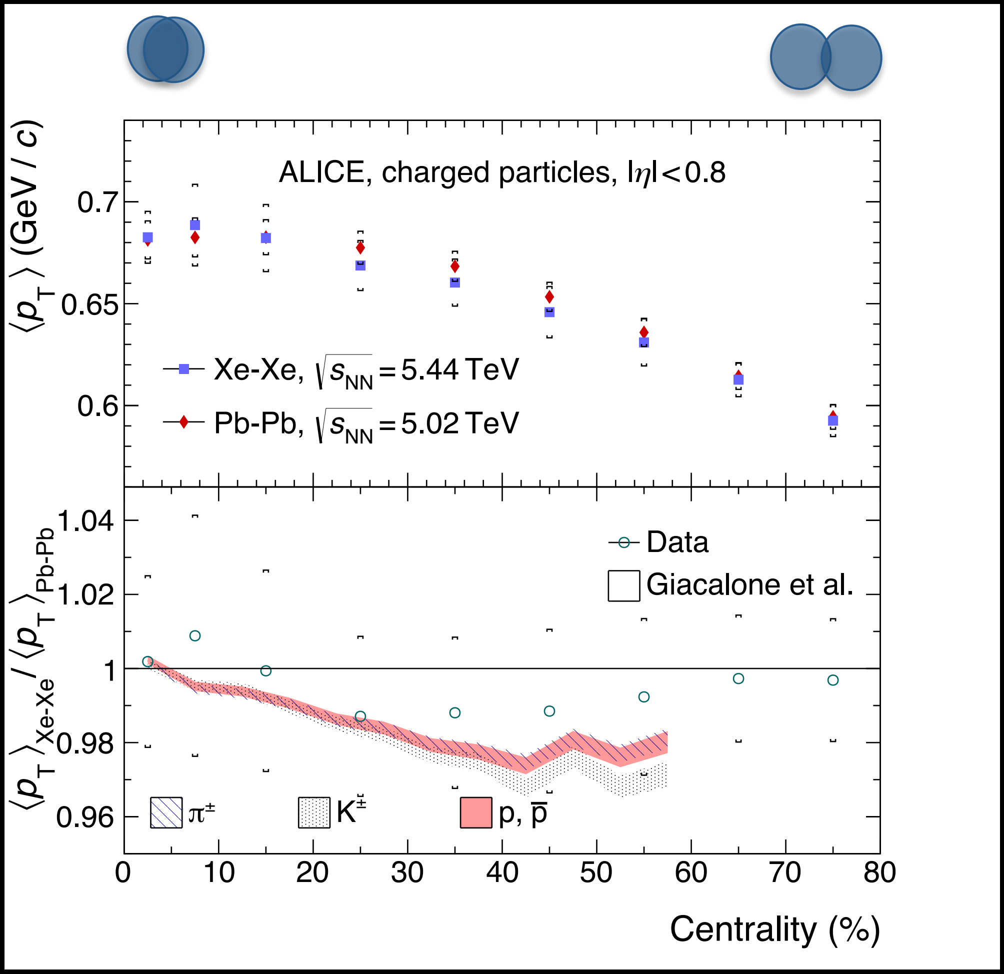




- p_T spectra in Pb-Pb and Xe-Xe measured in nine centrality intervals
- p_T reference spectra measured in pp and p-Pb collisions
- All spectra obtained using updated corrections (MC tuned on data)

Mean p_T spectra in Xe-Xe and Pb-Pb

Phys. Lett. B 788 (2019) 166



Testing system size (A) dependence

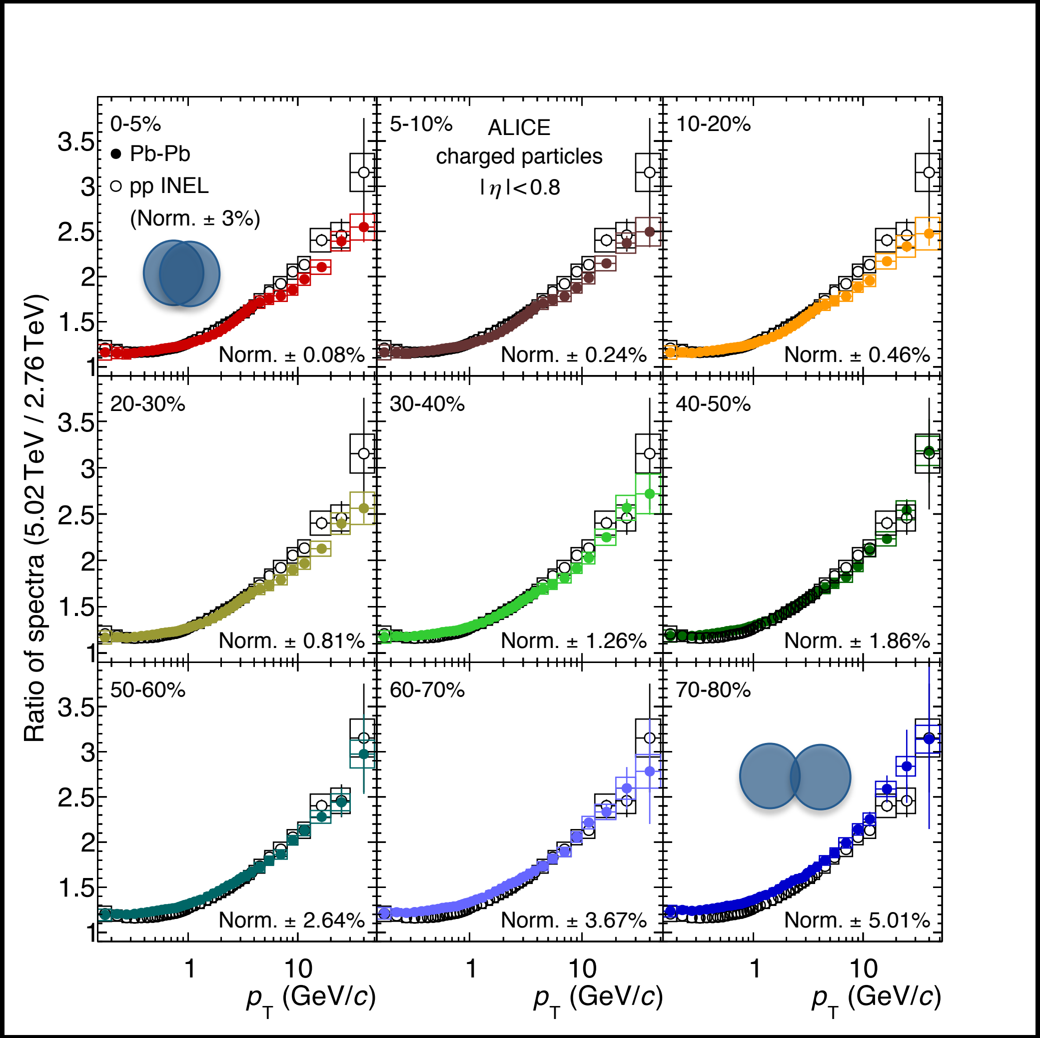
- Similar $<p_T>$ as function of centrality in Xe-Xe and Pb-Pb collisions
- $<p_T>$ increases with centrality due to radial flow

- Predictions by Giacalone et al. [Phys. Rev. C 97, 034904 (2018)] describes trend in the data
  - Event-by-event simulations: T_RENTo initial condition + viscous hydro

→ Strong constraints on the hydrodynamic evolution of the system

Ratios of spectra $\sqrt{s_{NN}}$ = 5.02 / 2.76 TeV

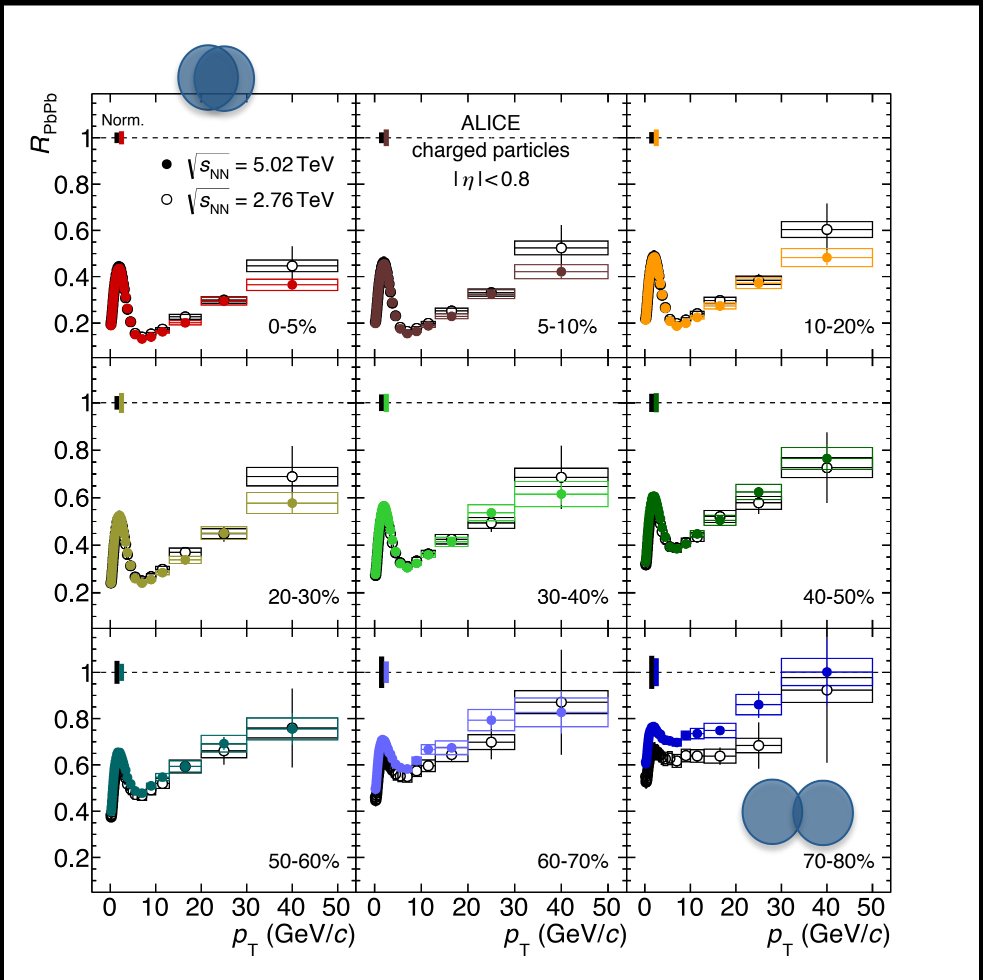
JHEP 1811 (2018) 013



- Spectra get significantly harder with collision energy
- Similar increase with energy in pp and peripheral Pb-Pb collisions
- Gradual reduction of the ratio towards central Pb-Pb collisions

Charged-particle R_{AA} at $\sqrt{s_{NN}}$ = 2.76 and 5.02 TeV

JHEP 1811 (2018) 013



$$R_{AA} = \frac{1}{\langle T_{AA} \rangle} \frac{dN_{AA}/dp_T}{d\sigma_{pp}/dp_T} \equiv \frac{[medium]}{[vacuum]}$$

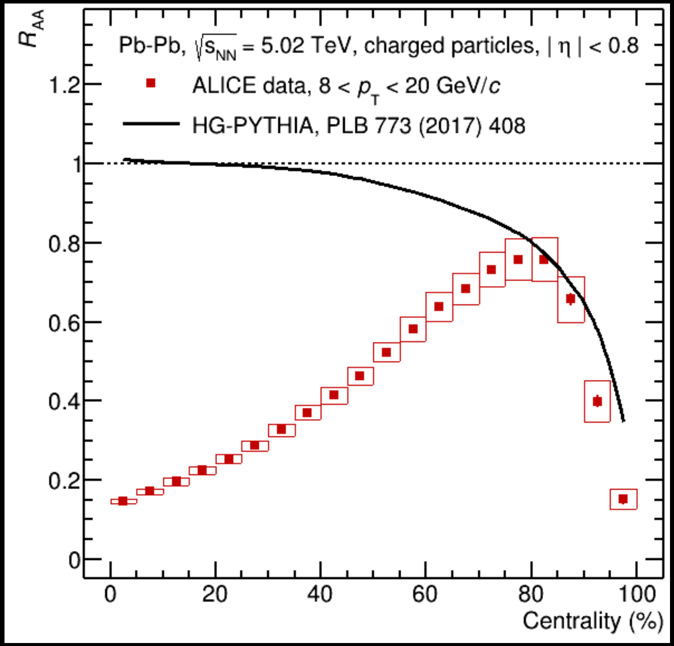
Nuclear overlap function $\langle T_{AA} \rangle$ from Glauber MC

- Different suppression pattern depending on Pb-Pb collision centrality
- Maximum suppression by a factor ~7 ($6 < p_T < 7$ GeV/c) in 0-5% collisions
- No significant evolution with collision energy

→ Indication of larger parton energy loss at $\sqrt{s_{NN}}$ = 5.02 TeV

Suppression in peripheral Pb-Pb collisions?

ALICE, arXiv:1805.05212



- R_{AA} average over 8 < p_T < 20 GeV/c
- R_{AA} never reach unity

- HG-Pythia contains no nuclear effects

→ no need for jet quenching

→ centrality selection is biased by fluctuations in particle production towards smaller #MPIs

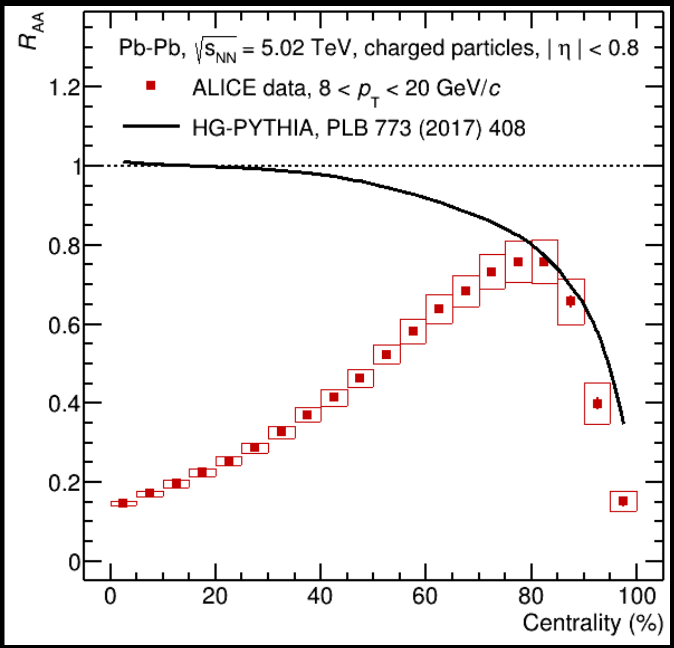
HG-Pythia model:

- incoherent superposition of Pythia pp collisions with #MPIs from HIJING-Glauber

A. Morsh & C. Loizides, PLB 773 (2017) 408

Suppression in peripheral Pb-Pb collisions?

ALICE, arXiv:1805.05212



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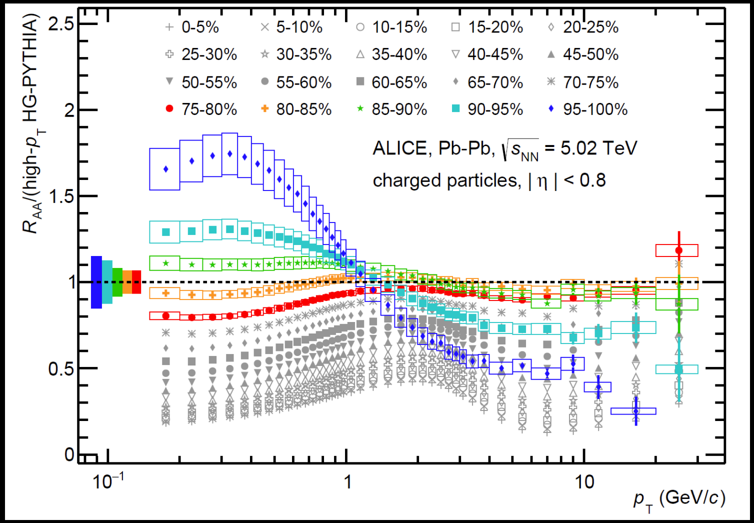

HG-Pythia model:

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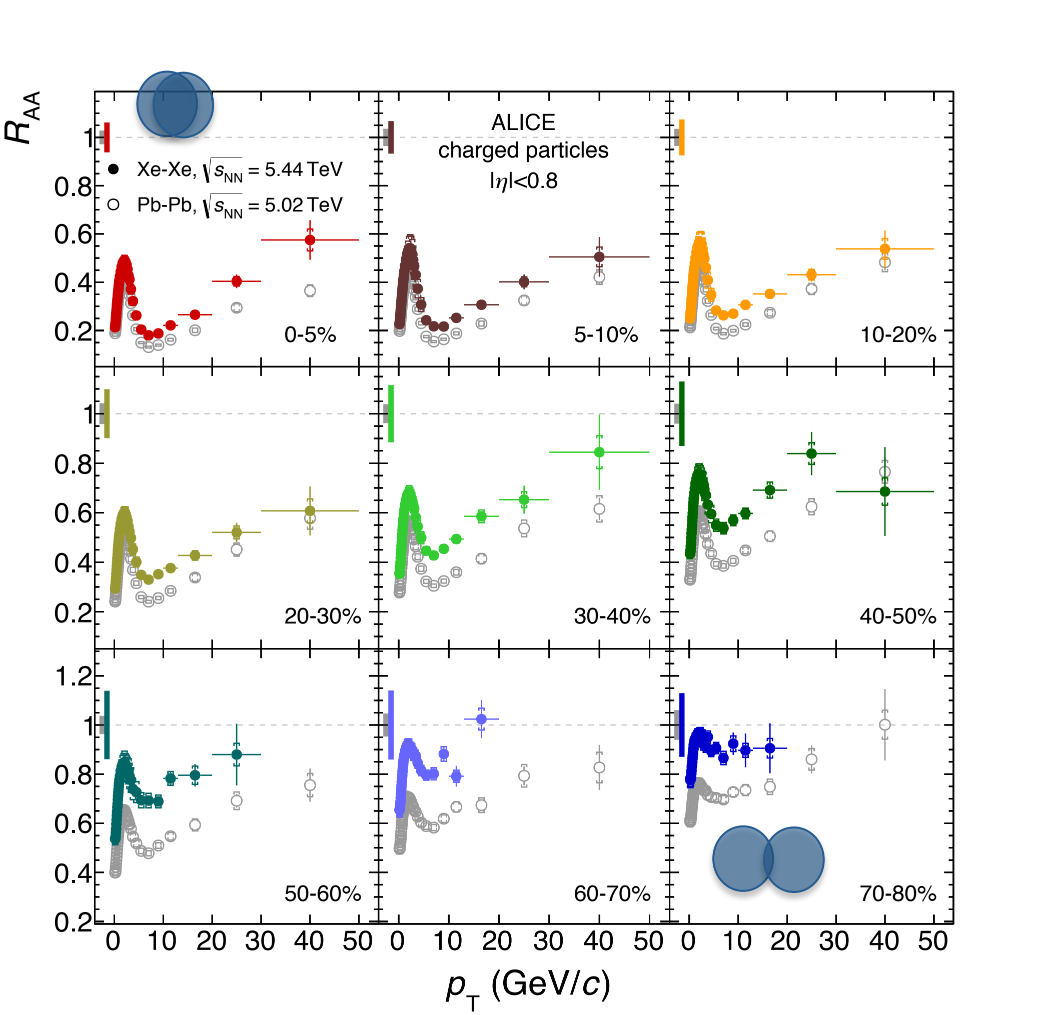
A. Morsh & C. Loizides, PLB 773 (2017) 408

R_{AA} scaled with high-p_T bias from HG-Pythia

→ Indication that R_{AA} ~ 1 for 75-90% central collisions

Charged-particle R_{AA} in Pb-Pb and Xe-Xe

Phys. Lett. B 788 (2019) 166



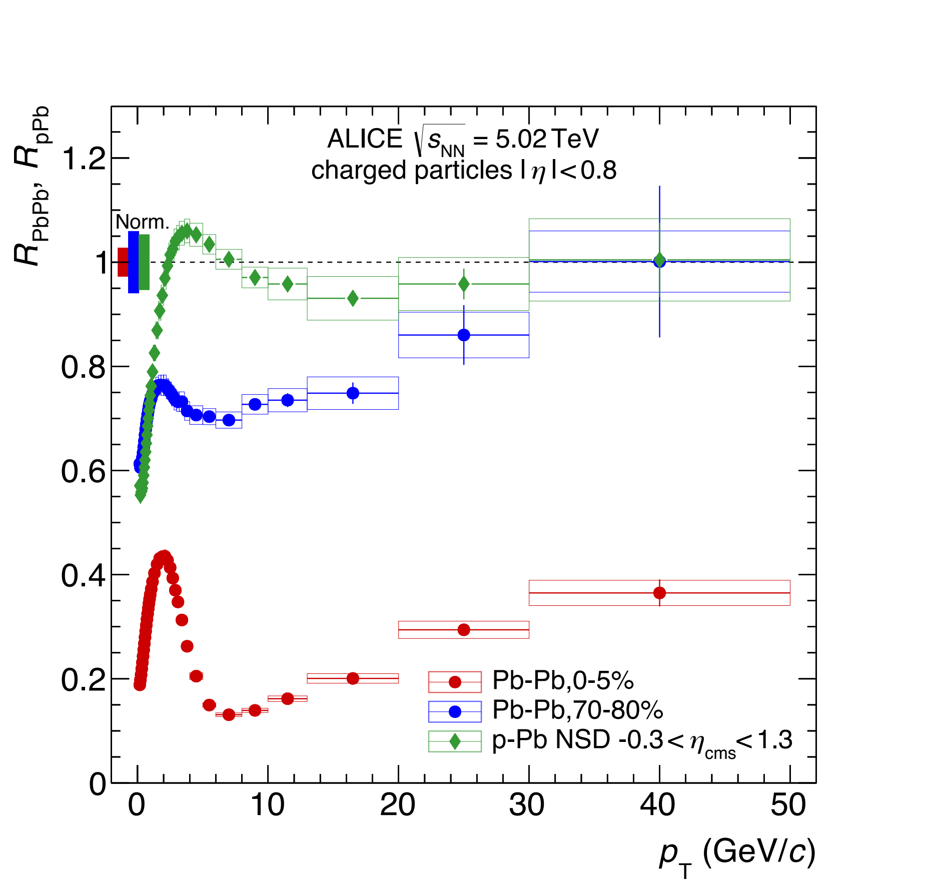
- Similar suppression pattern in Xe-Xe and Pb-Pb
- Larger suppression in Pb-Pb than in Xe-Xe collisions at high p_T at the same centrality
- Normalization uncertainty (T_{AA} and pp norm.) are much larger for Xe-Xe
  - less precisely known nuclear-charge-density distribution of deformed ^{129}Xe nucleus

→ Result of interplay between geometry and path length dependence of parton energy loss

Charged-particle R_{pPb} and R_{PbPb} at $\sqrt{s_{NN}}$ = 5.02 TeV

$$R_{AA} = \frac{1}{\langle T_{AA} \rangle} \frac{dN_{AA}/dp_T}{d\sigma_{pp}/dp_T} \equiv \frac{[medium]}{[vacuum]}$$

JHEP 1811 (2018) 013



For p_T > 7 GeV/c:

- Strong suppression in central Pb-Pb collisions
- Small suppression in peripheral Pb-Pb collisions
- No modification in p-Pb collisions (no centrality selection)

→ Suppression in central Pb-Pb collisions is due to final state effects!

Confirmed also by jet measurements
ALICE, Phys. Lett. B749 (2015) 68