Hadronic resonance production with ALICE at the LHC

Sergey Kiselev (ITEP Moscow) for the ALICE collaboration

- Motivation
- ALICE detector
- Signal extraction
- p_T spectra
- Mean transverse momentum
- Yields
- Ratios to stable hadrons
- Nuclear modification factors
- Summary

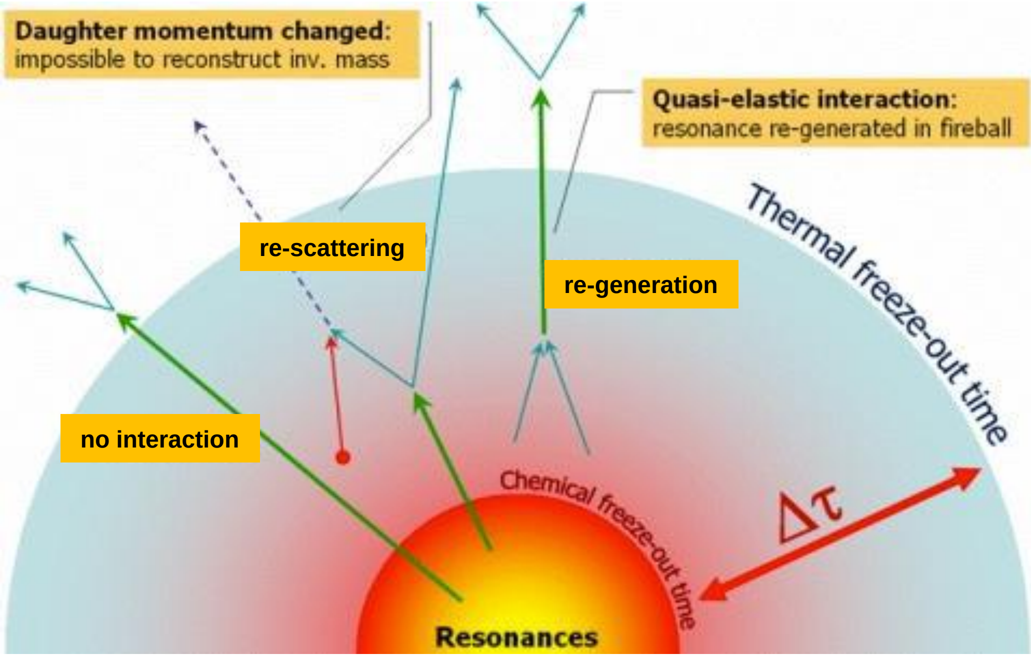
Motivation

- **pp and p-Pb collisions:**
  - ✓ the baseline for heavy-ion collisions
  - ✓ system size dependence
  - ✓ role of cold nuclear matter
  - ✓ study of collectivity in small systems

- **AA collisions**:
  - ✓ in-medium energy loss
    - → nuclear modification factor for resonances
  - ✓ restoration of chiral symmetry
    - → modification of width, mass and branching ratio
  - ✓ re-generation and rescattering effects
    - → modification of yield and ratios to stable hadrons
    - → timescale between chemical and kinetic freeze-out

recent results for resonances

Resonance	Γ (MeV)	cτ (fm)	Decay	System @energy (TeV)	Year of dataset
$K^*(892)^0$	50	4.2	**$\pi + K$**	pp@13 Pb-Pb@5.02 Xe-Xe@5.44	2015 2015 2017
$\phi(1020)$	4.3	46.2	**$K^+ + K^-$**	pp@13 Pb-Pb@5.02 Xe-Xe@5.44	2015 2015 2017
$\Lambda(1520)$	15.6	12.6	**$p + K$**	Pb-Pb@2.76	2010
$\Xi(1530)^0$	9	21.7	**$\Xi^- + \pi^+$**	Pb-Pb@2.76	2011

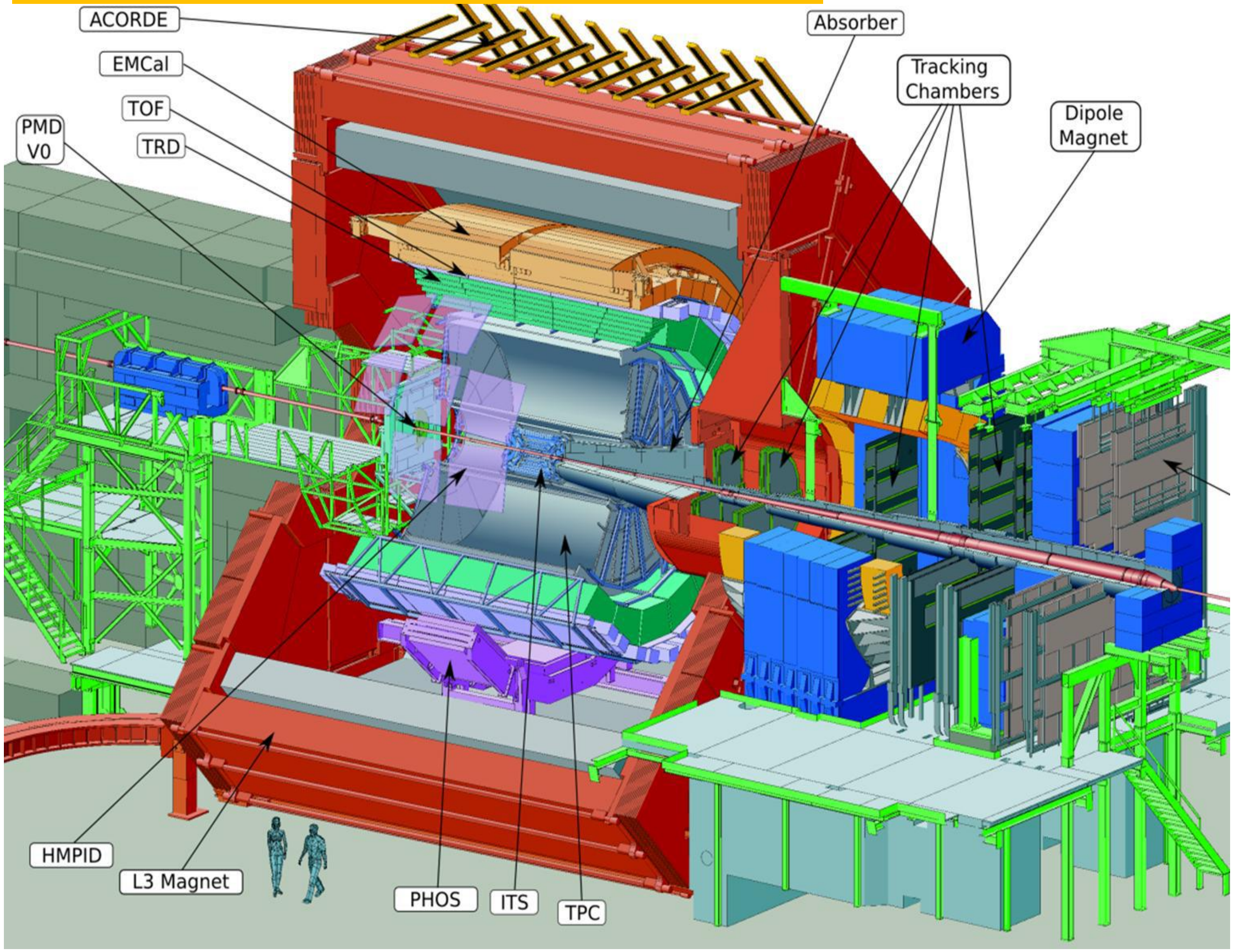


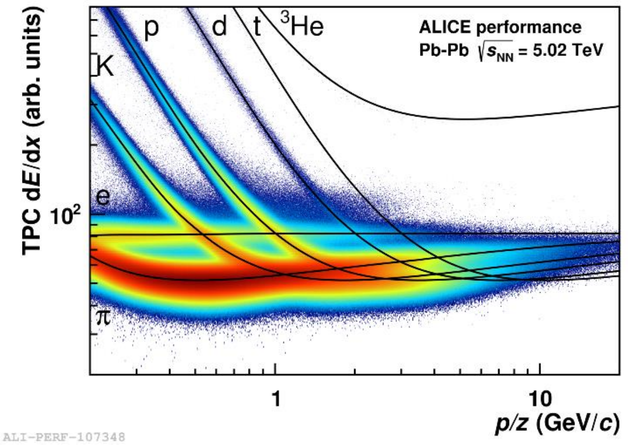
ALICE detector

V0 (scintillators):
→ triggering minimum bias collisions
→ centrality in Pb-Pb (V0A and V0C)
→ multiplicity classes in pp, p-Pb (V0A)

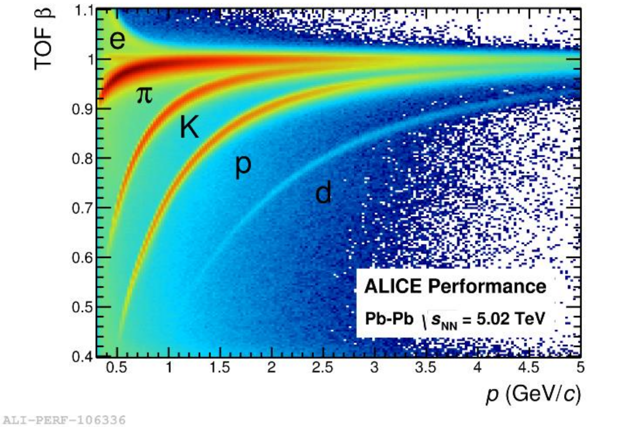
ITS: tracking and vertexing

TPC: tracking and PID through dE/dx





TOF: PID through particle time of flight

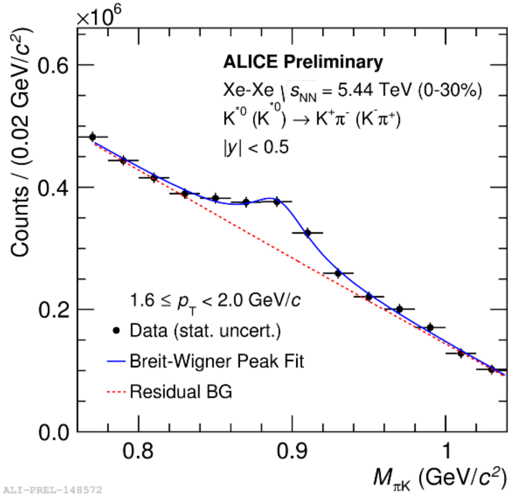


Signal extraction

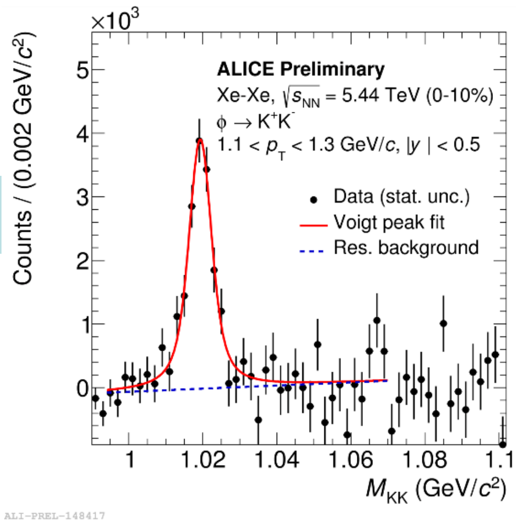
Xe-Xe@5.44 TeV

NEW

K*(892)^0



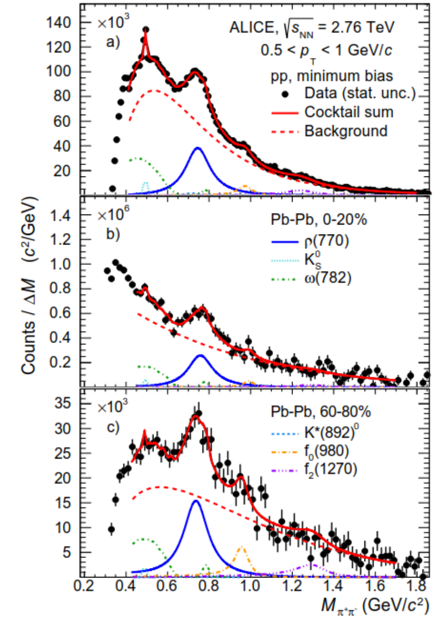
ϕ(1020)



Pb-Pb@2.76 ATeV

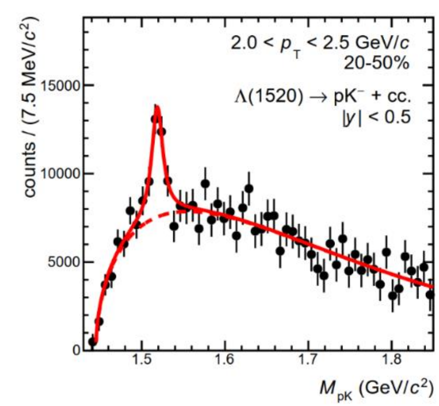
arXiv:1805.04365

ρ(770)^0



arXiv:1805.04361

Λ(1520)



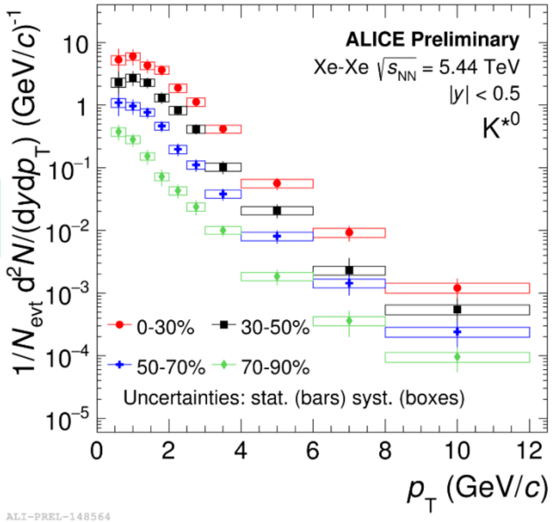
p_T spectra

Xe-Xe@5.44 TeV

NEW

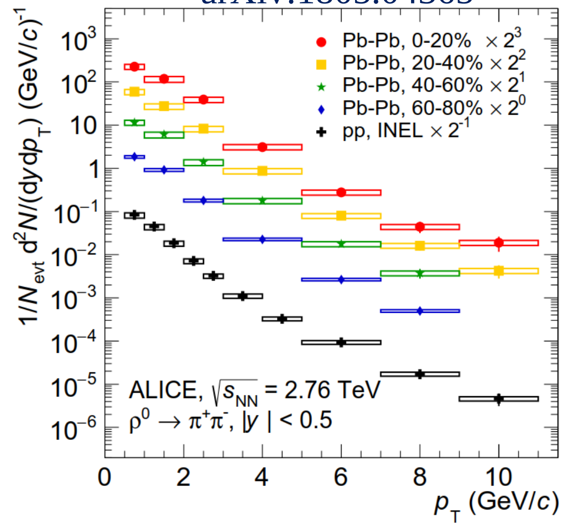
Pb-Pb@2.76 ATeV

K*(892)^0

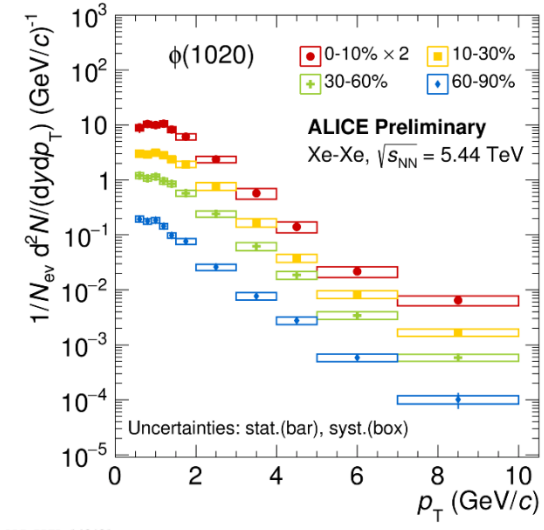


ρ(770)^0

arXiv:1805.04365

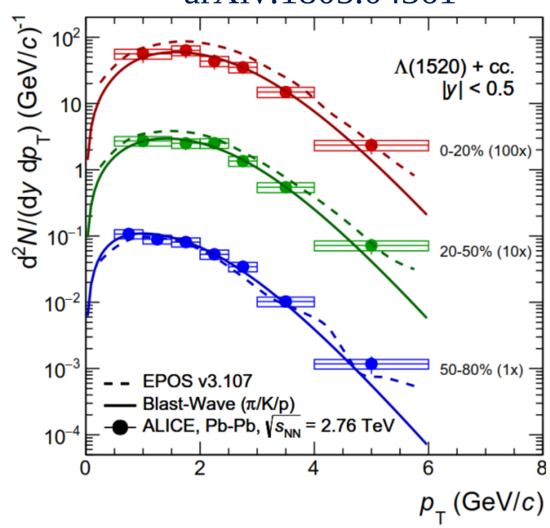


ϕ(1020)



Λ(1520)

arXiv:1805.04361

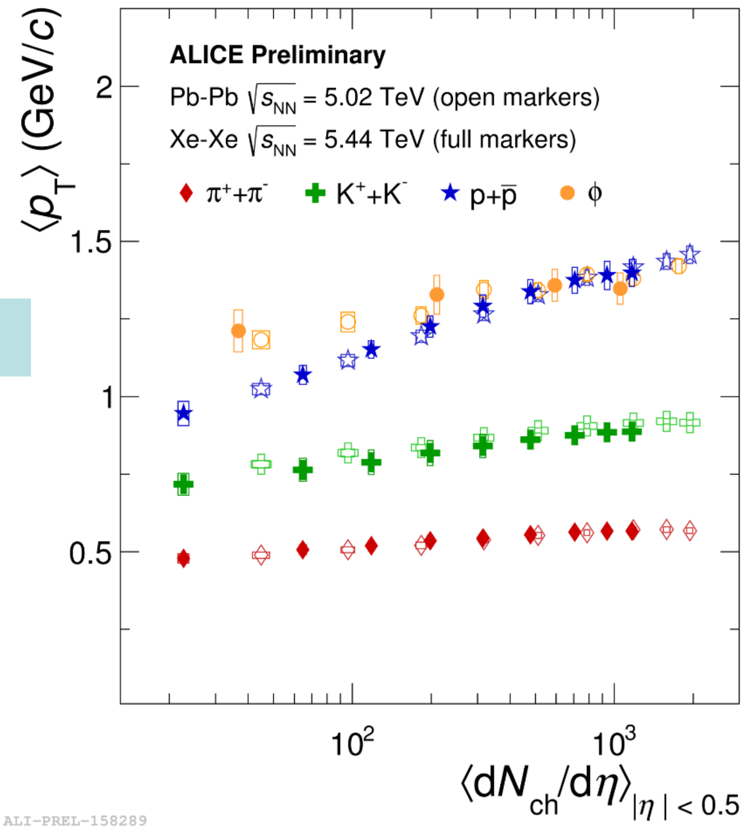


‹ p_T ›

Xe-Xe@5.44 ATeV

NEW

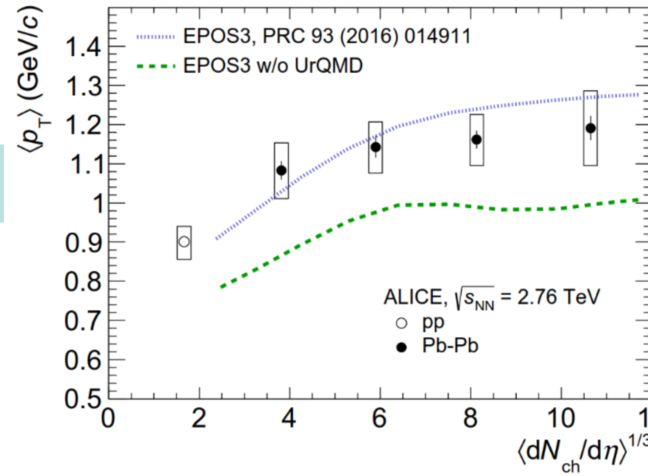
φ(1020)



Pb-Pb@2.76 ATeV

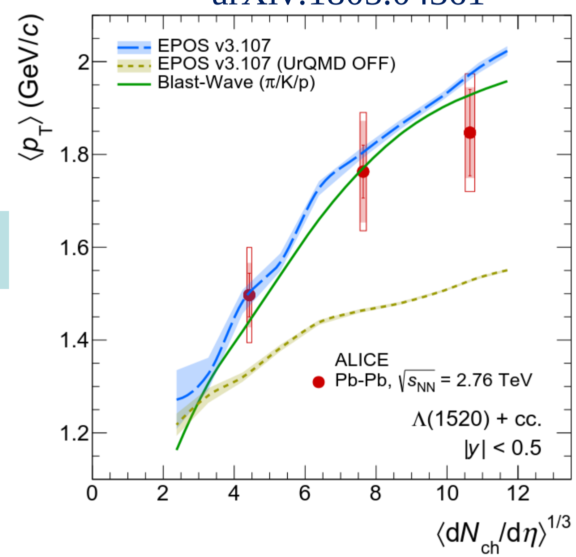
ρ(770)⁰

arXiv:1805.04365



Λ(1520)

arXiv:1805.04361

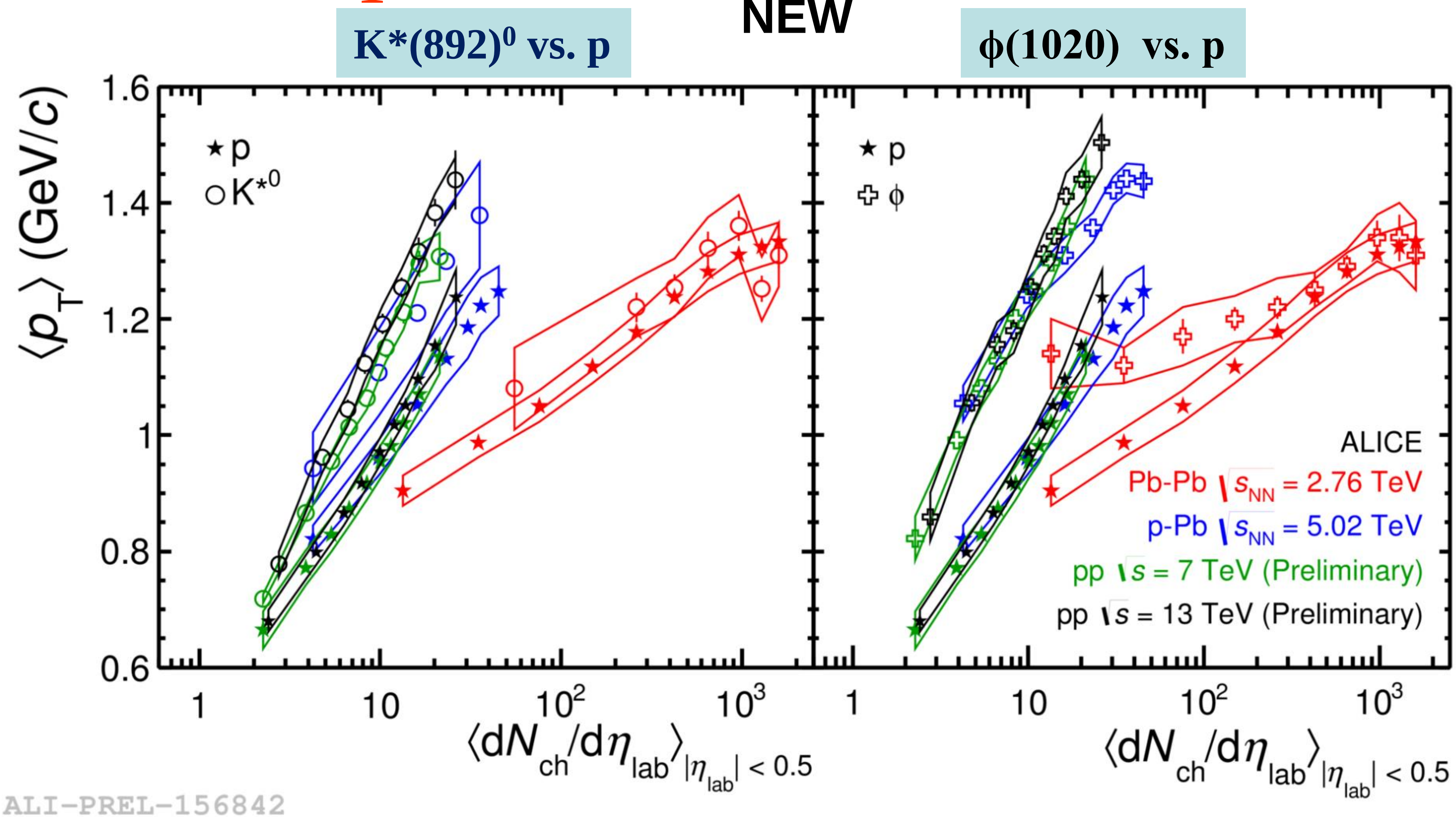


Results for Xe-Xe confirm the trends observed in Pb-Pb:

- central events: mass ordering, $\langle p_T \rangle_\phi \approx \langle p_T \rangle_p$, as expected from hydrodynamics
- peripheral events: $\langle p_T \rangle_\phi > \langle p_T \rangle_p$

agree with EPOS3 with UrQMD

$\langle p_T \rangle$ - system dependence



- pp: the increase with multiplicity at 13 TeV is similar to 7 TeV
- central Pb-Pb: mass ordering , $\langle p_T \rangle_{K^*} \approx \langle p_T \rangle_p$, $\langle p_T \rangle_\phi \approx \langle p_T \rangle_p$
- pp, p-Pb: mass ordering breaks down , $\langle p_T \rangle_{K^*} > \langle p_T \rangle_p$, $\langle p_T \rangle_\phi > \langle p_T \rangle_p$,
- pp, p-Pb: steeper increase with multiplicity (can be understood as the effect of color reconnection between strings produced in multi-parton interactions)

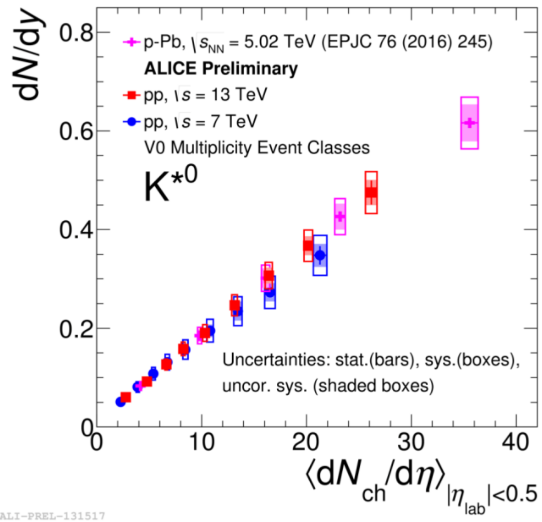
yields vs. multiplicity

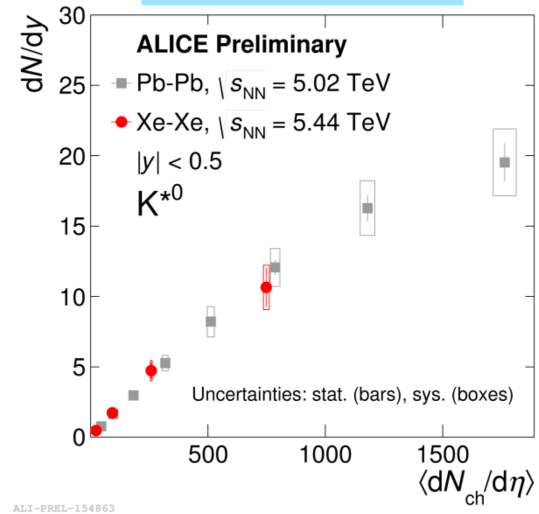
pp, p-Pb

NEW

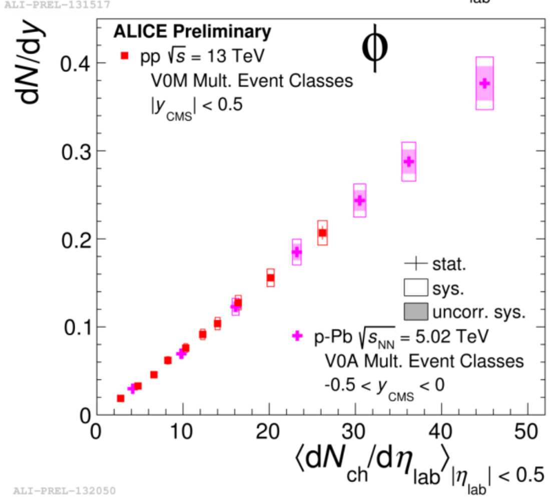
Xe-Xe, Pb-Pb

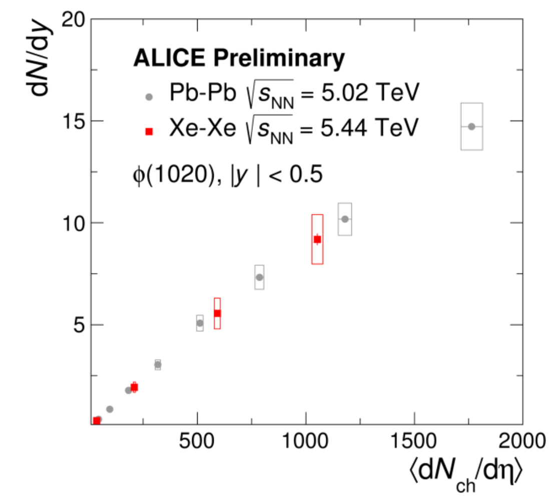
$K^*(892)^0$





$\phi(1020)$





yields independent of collision system and energy

yields appear to be driven by event multiplicity

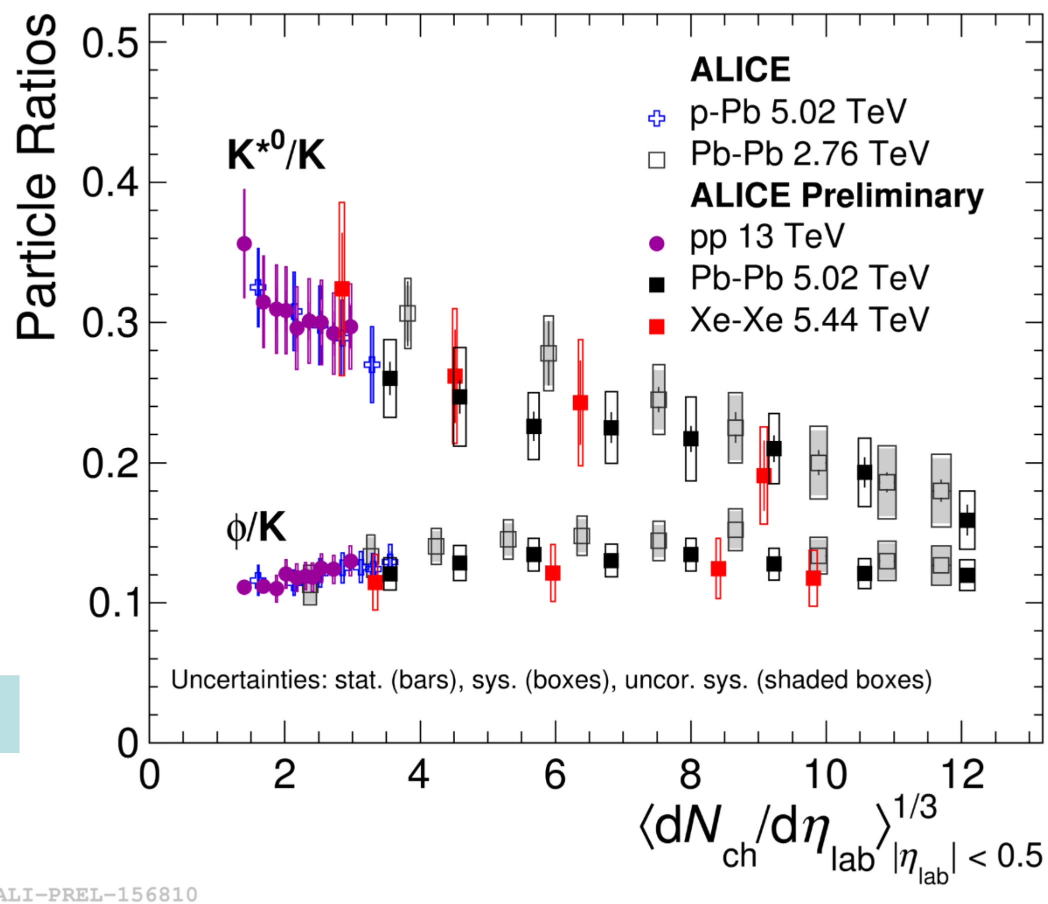
K*⁰/K, ϕ/K ratios

NEW

- **K*⁰/K** shows a significant suppression
  - going from pp, p-Pb and peripheral Pb-Pb collisions to most central Pb-Pb
  → consistent with the re-scattering of daughters as the dominant effect
  - results for Xe-Xe confirm the trend observed in Pb-Pb
  - pp, p-Pb: hint of decrease

- **ϕ/K** shows no suppression
  - almost constant behavior
  - re-scattering is not significant for ϕ:

τ(ϕ) = 46.2 fm/c >> **τ(K*⁰) = 4.2 fm/c**



ρ^0/π ratio

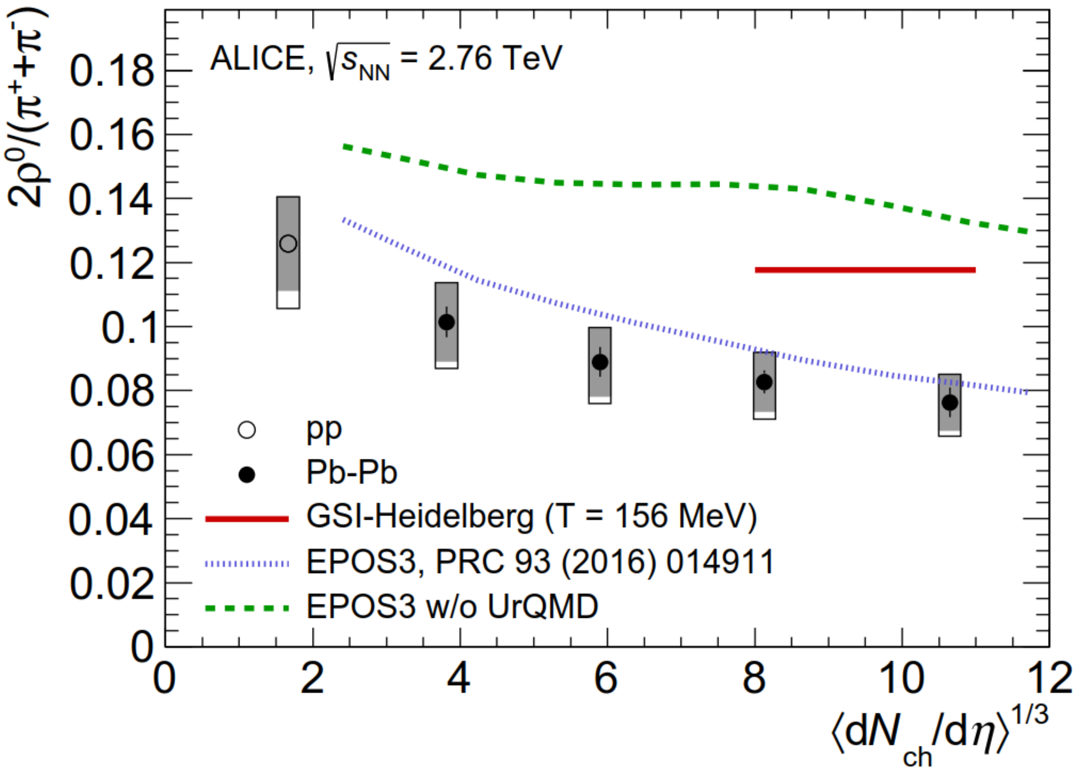
- **ρ^0/π** shows a significant suppression
  - going from pp and peripheral Pb-Pb collisions to most central Pb-Pb
  → consistent with the re-scattering of daughters as the dominant effect

- EPOS3 with UrQMD:
  - overestimates the data
  - qualitatively reproduces the trend of the suppression
  - fails to reproduce the trend without UrQMD

- thermal model
  - overestimates the data

$\tau(\rho^0)$ = 1.3 fm/c

arXiv:1805.04365



Λ^*/Λ ratio

$\tau(\Lambda^*)$ = 12.6 fm/c

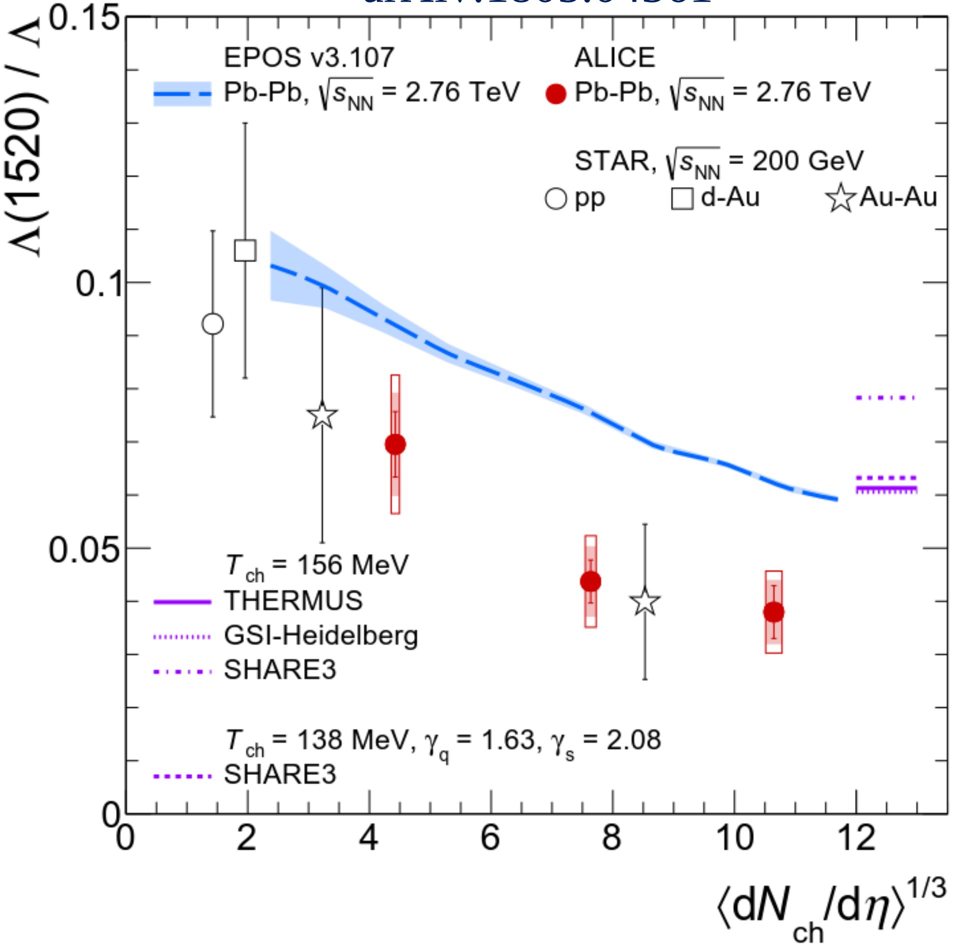
- Λ^*/Λ shows a significant suppression
  - going from pp, p-Pb and peripheral Pb-Pb collisions to most central Pb-Pb
  → consistent with the re-scattering of daughters as the dominant effect

- confirms trend seen by STAR at 200 GeV

- EPOS3 with UrQMD:
  - overestimates the data
  - qualitatively reproduces the trend of the suppression

- thermal models
  - all overestimate the ratio in central Pb-Pb collisions

arXiv:1805.04361

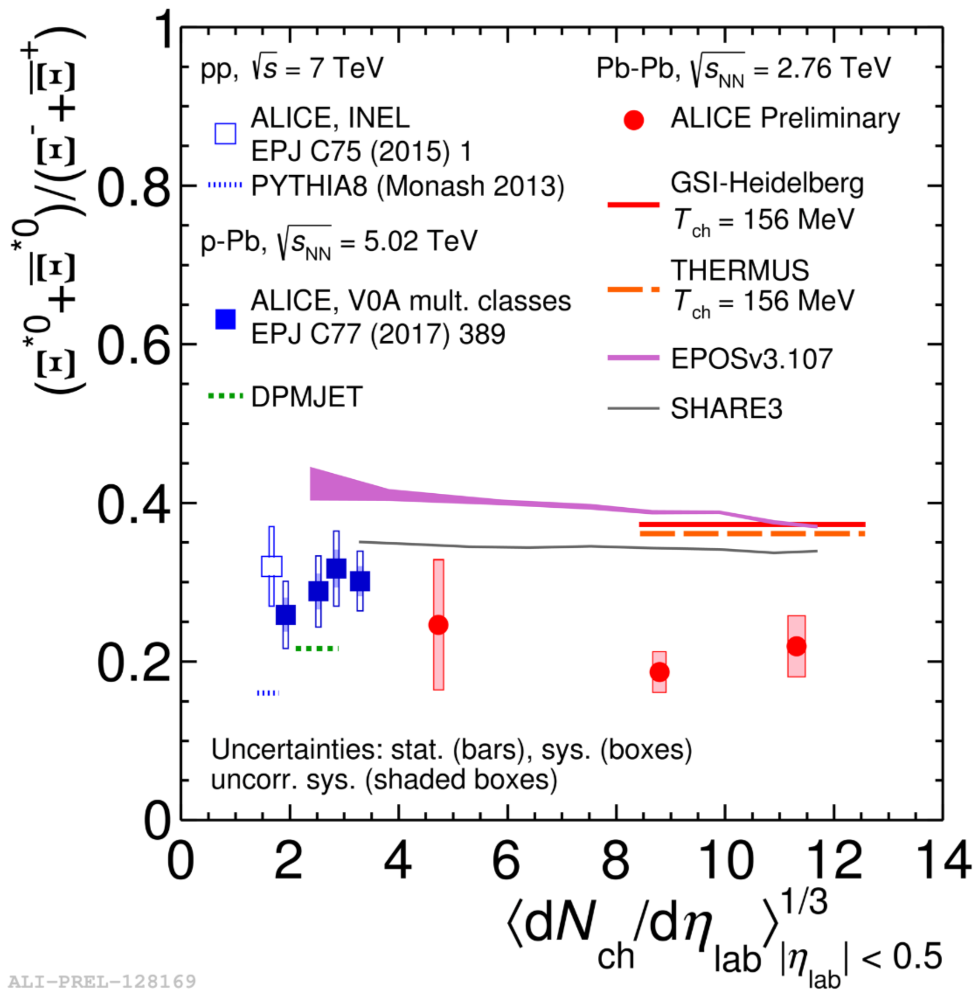


EPOS: PR **C93** (2016) 014911
THERMUS: Comput. Phys. Commun. **180** (2009) 84
GSI-Heidelberg: PL **B673** (2009) 142
SHARE3: Comput. Phys. Commun. **185** (20014) 2056
STAR data: PR **C78** (2008) 044906

Ξ*/Ξ ratio

$\tau(\Xi^{*0})$ = 21.7 fm/c

- Ξ*/Ξ
  - hint of suppression in central Pb-Pb w.r.t. pp and p-Pb, but systematics to be improved in peripheral Pb-Pb
- EPOS3 with UrQMD:
  - no suppression
  - overestimates the data
- thermal models
  - all overestimate the ratio in central Pb-Pb collisions



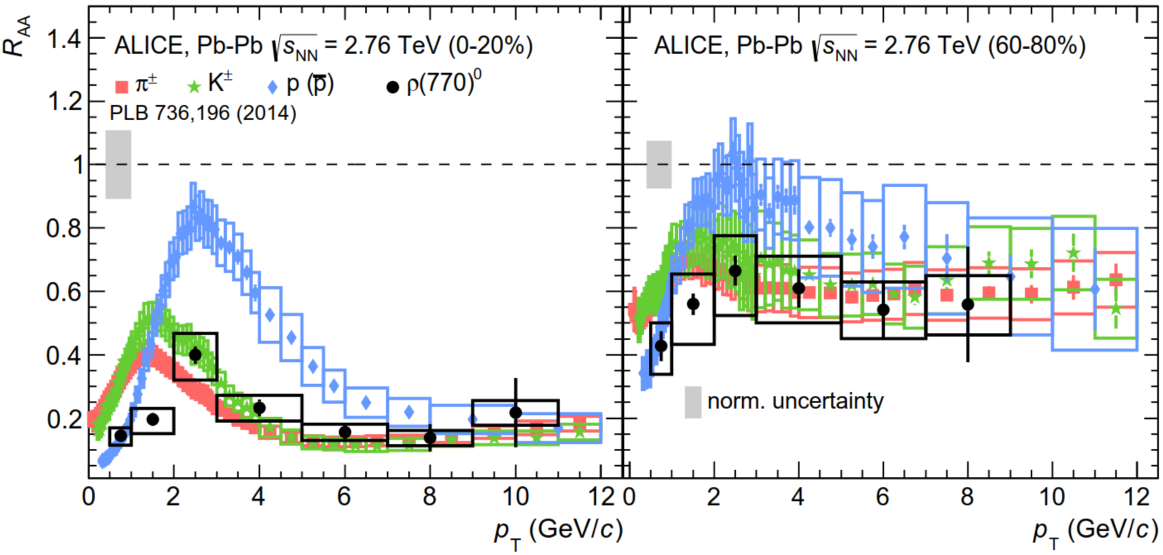
Nuclear modification factor R_{AA}

Pb-Pb@2.76 ATeV

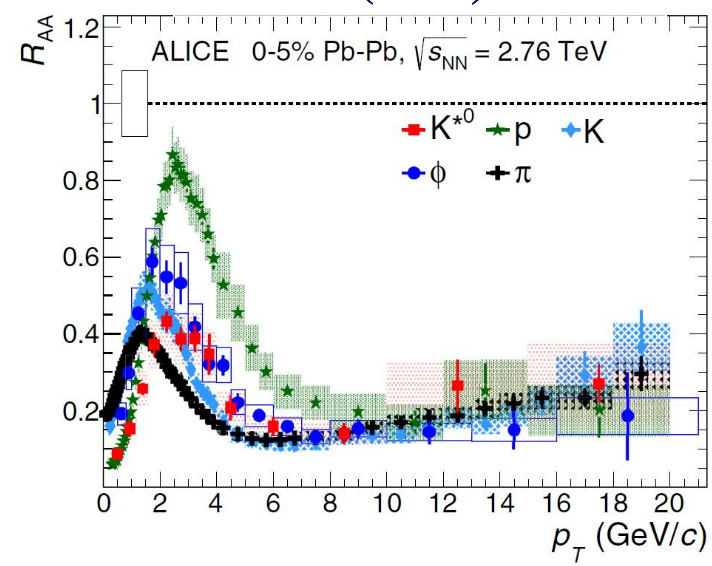
$\rho(770)^0$

K*(892)^0 **ϕ(1020)**

arXiv:1805.04365



PR **C95** (2017) 064606

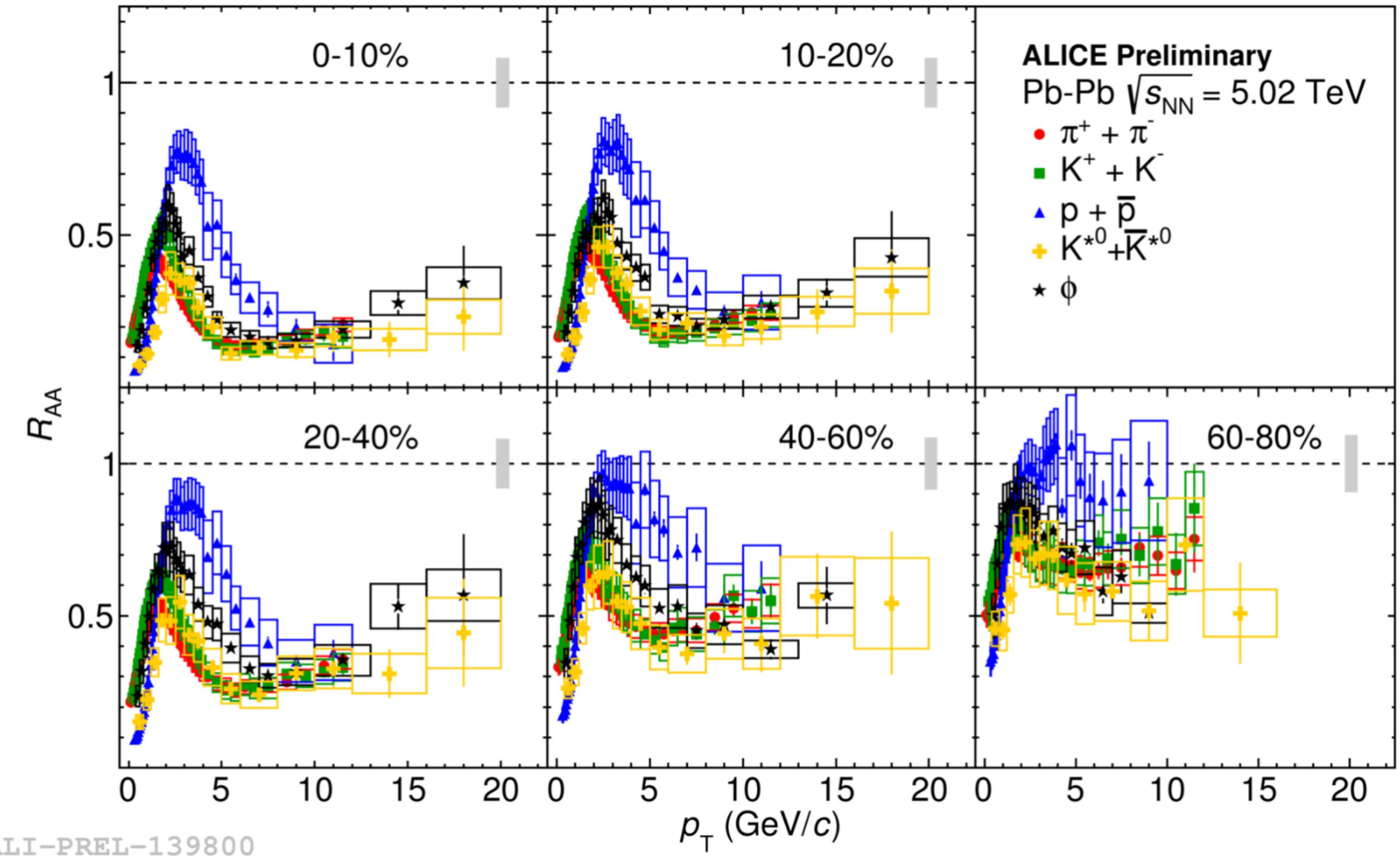


- consistent with light-flavoured hadrons at $p_T > 8$ GeV/c
  → suppression at high p_T is not dependent on hadron properties
- ρ^0 and K^{*0} affected by radial flow and suppression at lower p_T

R_{AA} – centrality dependence

NEW

Pb-Pb@5.02 ATeV **K*(892)^0** **ϕ(1020)**

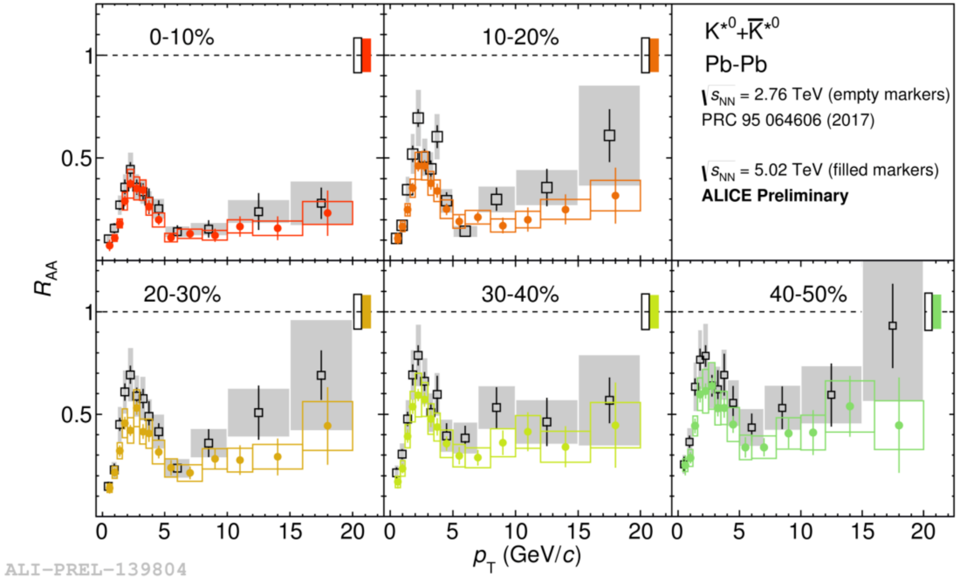


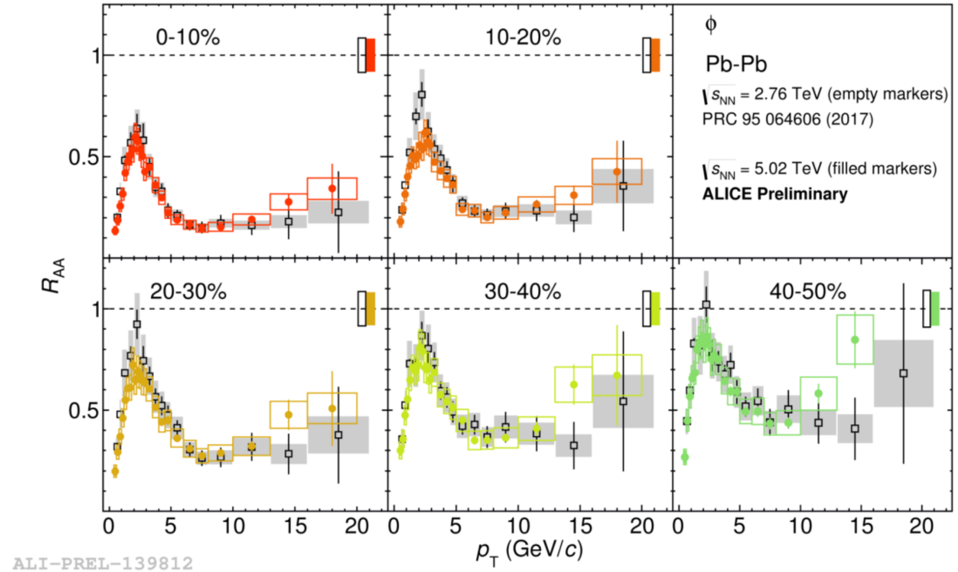
- strong suppression for the most central collisions
- behaviour similar to charged hadrons

R_{AA} – energy dependence

Pb-Pb

K*(892)^0 **NEW** **φ(1020)**





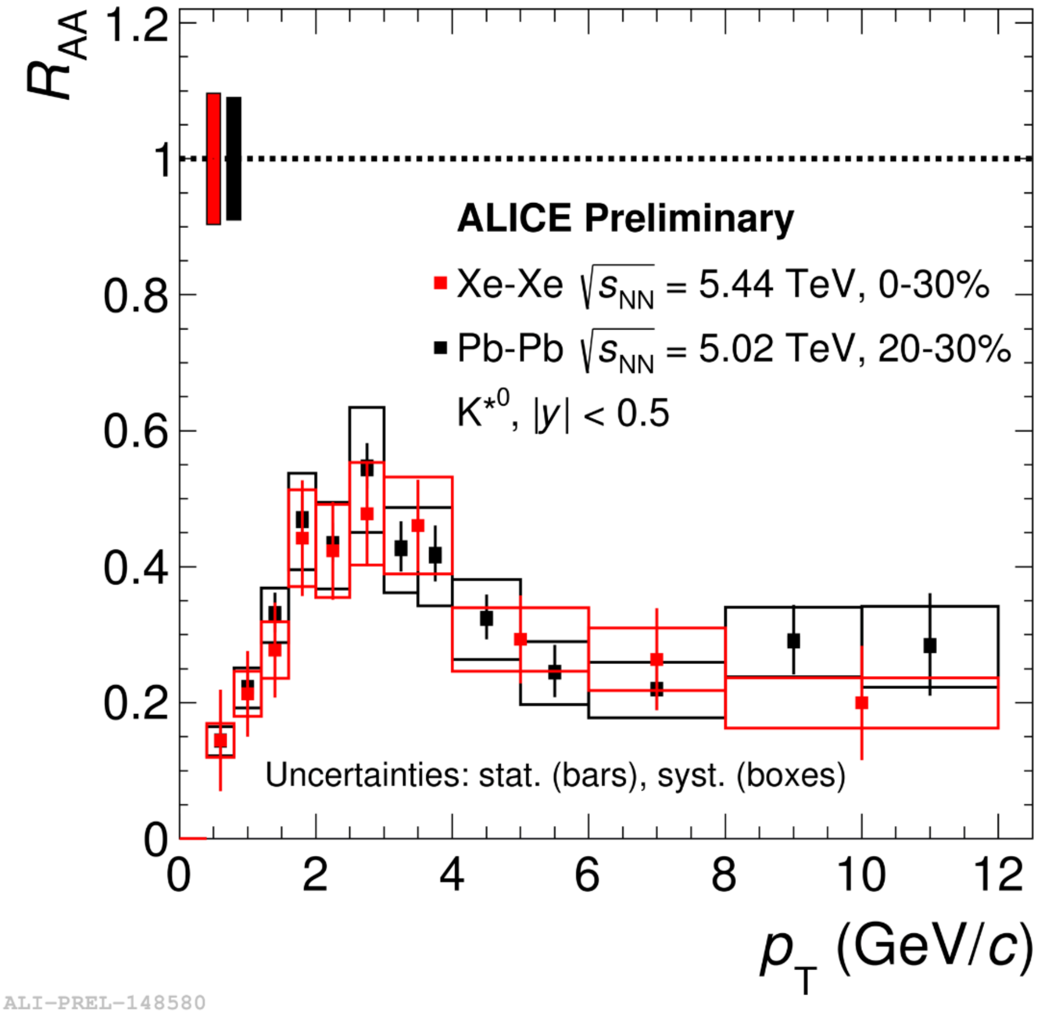
no significant energy dependence

R_{AA} – system size dependence

NEW

K*(892)^0

R_{AA} in Xe-Xe and Pb-Pb are consistent within uncertainties once compared at the same multiplicity (and not just centrality percentile)



Summary

Mean p_T:

- central **Pb-Pb**: mass ordering as expected from hydrodynamics
- **pp**, **p-Pb**: mass ordering violated
  steeper increase with multiplicity

Yields:

- **pp**, **p-Pb, Xe-Xe, Pb-Pb**: independent of collision system and energy
  appear to be driven by event multiplicity

Particle yield ratios:

- **Pb-Pb:**
  resonance suppression

resonance	ρ^0	K^{*0}	$\Sigma^{*\pm}$	Λ^*	Ξ^{*0}	ϕ
lifetime (fm/c)	1.3	4.2	5.5	12.6	21.7	46.2
suppression	**yes**	**yes**	**? in progress**	**yes**	**? weak**	**no**

  qualitatively described by EPOS3 with UrQMD
- **Xe-Xe:** confirm the trend observed in **Pb-Pb**

R_{AA} :

- **Pb-Pb:** consistent with light-flavoured hadrons at $p_T > 8$ GeV/c
  ρ^0 and K^{*0} affected by radial flow and re-scattering at lower p_T
  no significant energy dependence
- **Xe-Xe:** consistent with **Pb-Pb** once compared at the same multiplicity