Hadronic resonance production with ALICE at the LHC

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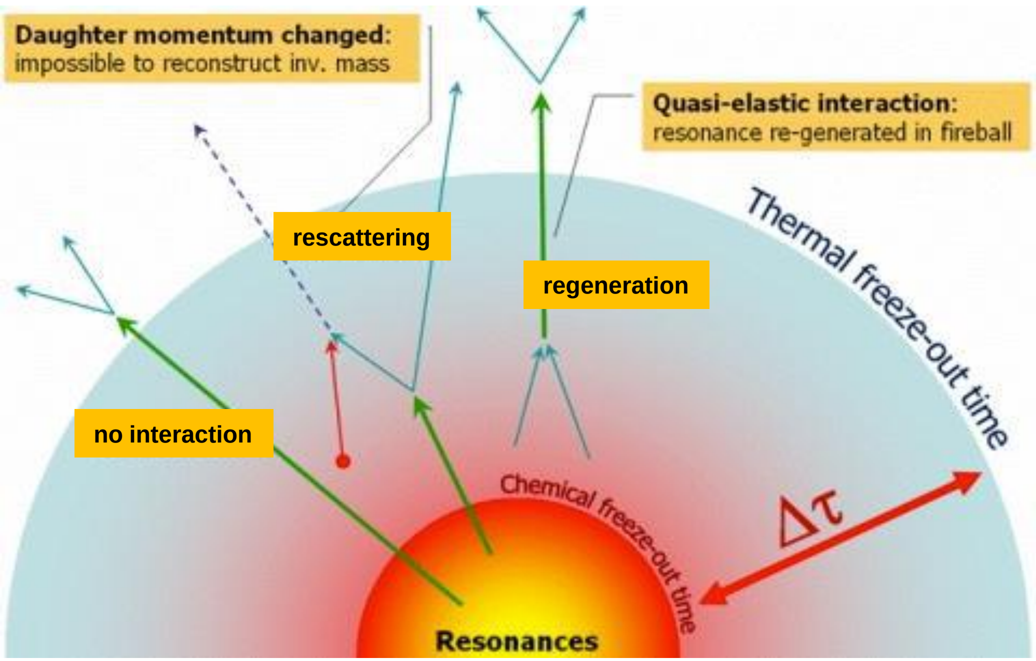
- Motivation
- ALICE detector
- Signal extraction
- p_T spectra
- Mean transverse momentum
- Yields
- Ratios to stable hadrons
- Nuclear modification factors
- Summary

Motivation

Resonance	cτ (fm)	Decay	System @energy (TeV)
$\rho(770)^0$	1.3	π π	pp/Pb–Pb@2.76
$K^*(892)^0$	4.2	K π	all
$K^*(892)^\pm$	4.2	K_S^0 π	pp @5.02/8/13 Pb–Pb@5.02
f_0 (980)	~ 5	π π	pp/p–Pb@5.02
$\Sigma(1385)^\pm$	5-5.5	Λ π	pp@7 p–Pb /Pb–Pb@5.02
$\Lambda(1520)$	12.6	p K	pp@7 p–Pb@5.02 Pb–Pb@2.76/5.02
$\Xi(1530)^0$	21.7	Ξ^- π	pp@7 p–Pb@5.02 Pb–Pb@2.76
$\phi(1020)$	46.4	K K	all

- **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

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

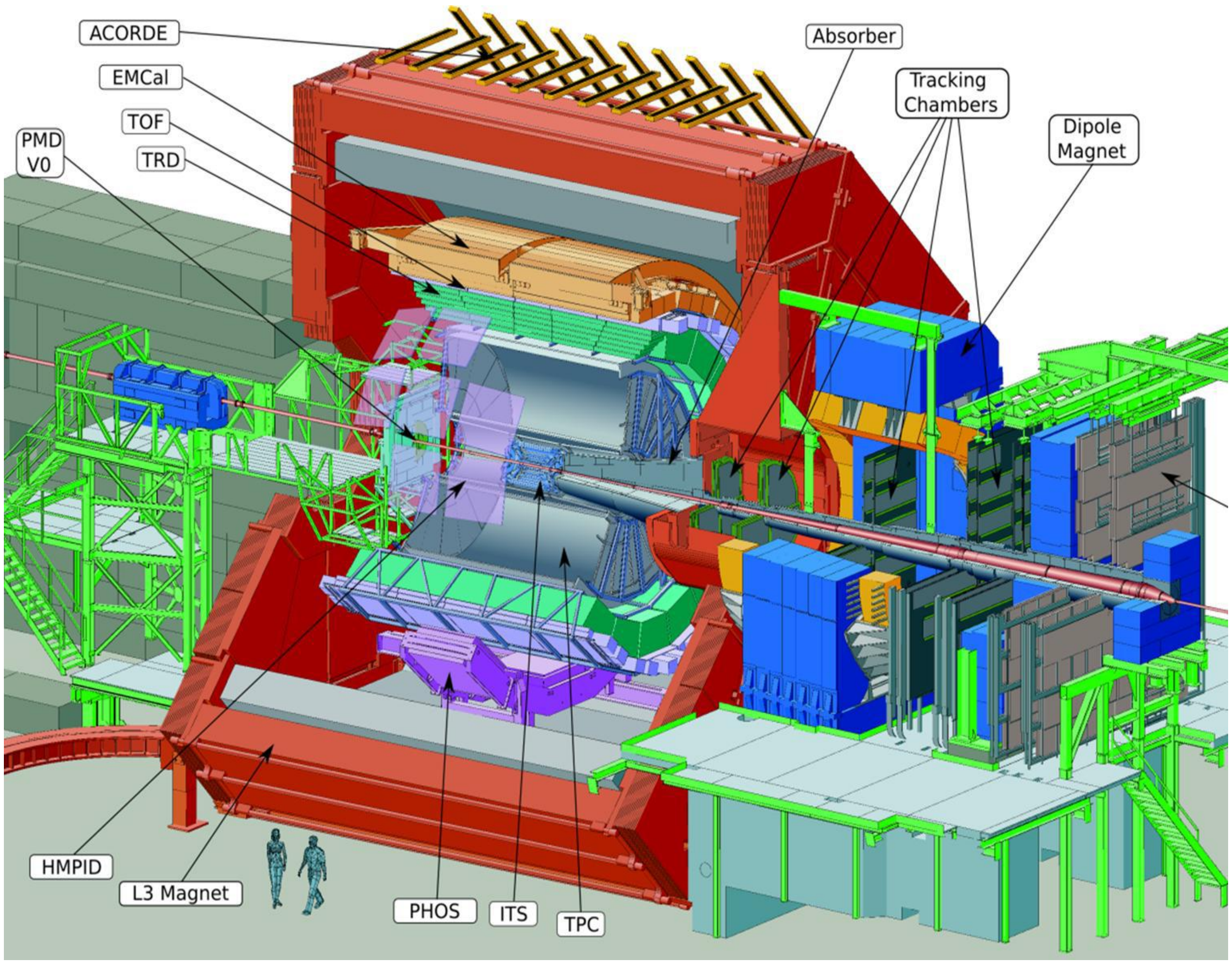


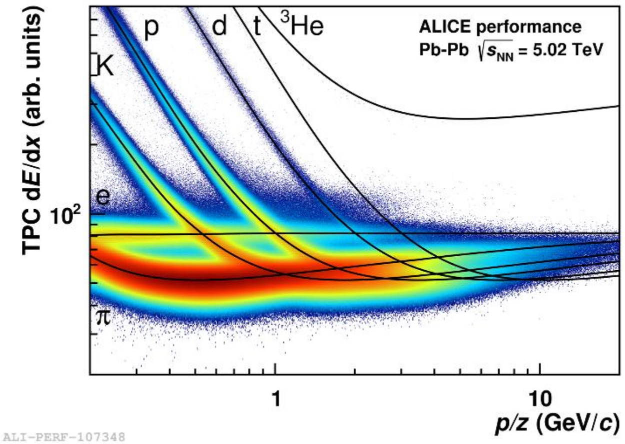
ALICE detector

V0 (scintillators):
→ triggering minimum bias collisions
→ centrality/multiplicity estimator

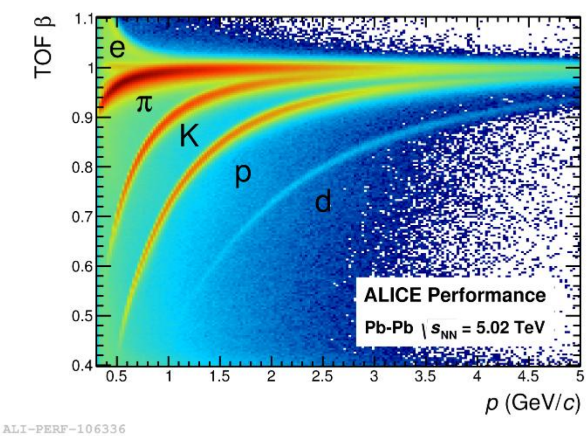
ITS: tracking and vertexing

TPC: tracking and PID through d*E*/d*x*





TOF: PID through particle time of flight



NEW

$f_0(980)$

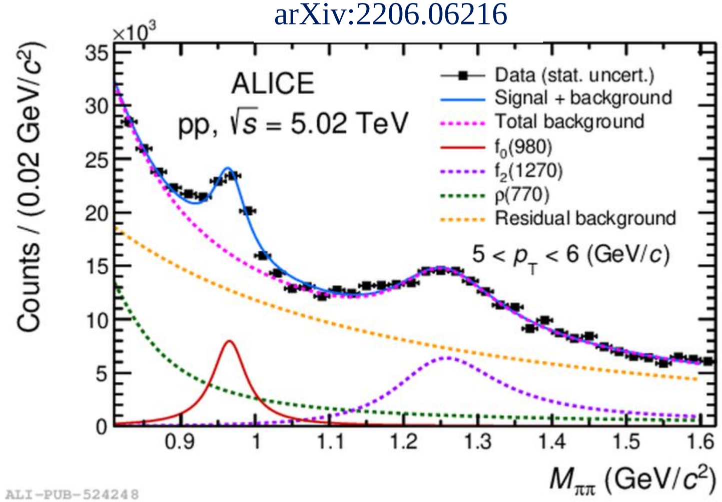
Signal extraction

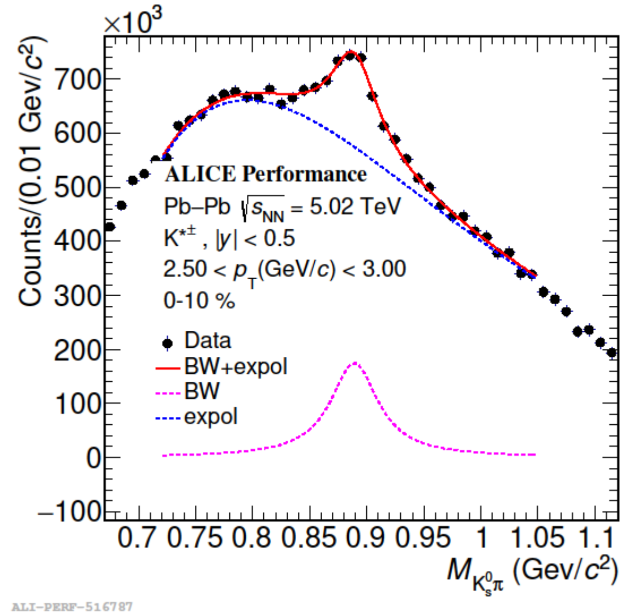
$K^*(892)^{\pm}$

pp@5.02 TeV

Pb–Pb@5.02 TeV

arXiv:2206.06216



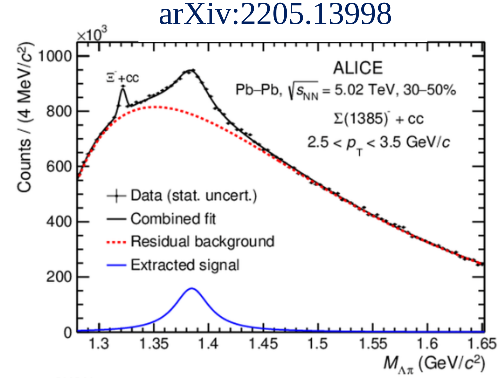


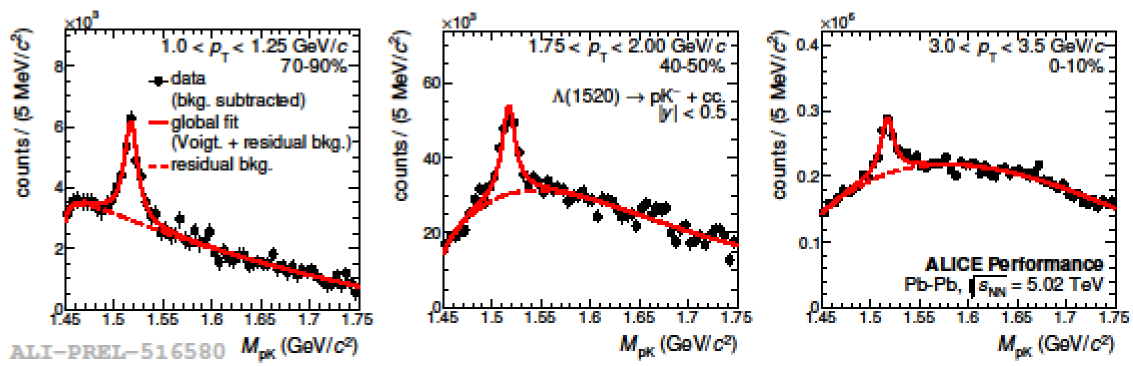
$\Sigma(1385)^-$

Pb–Pb@5.02 TeV

$\Lambda(1520)$

arXiv:2205.13998





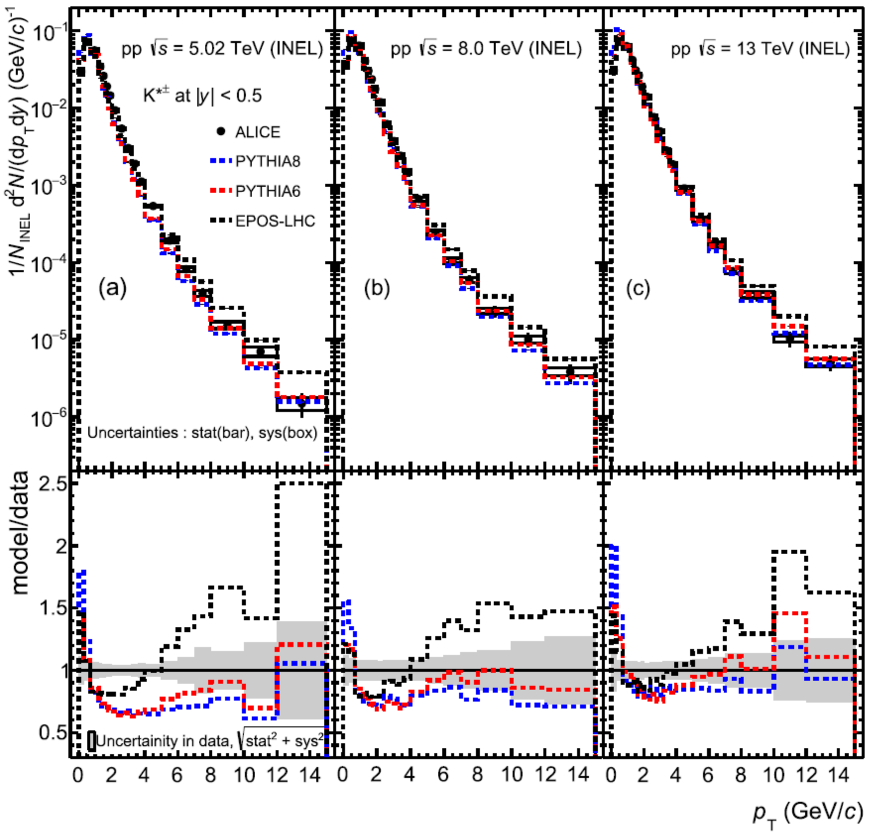
p_T spectra

NEW

pp @5.02, 8, 13 TeV

K*(892)$^{\pm}$

PL **B828** (2022) 137013

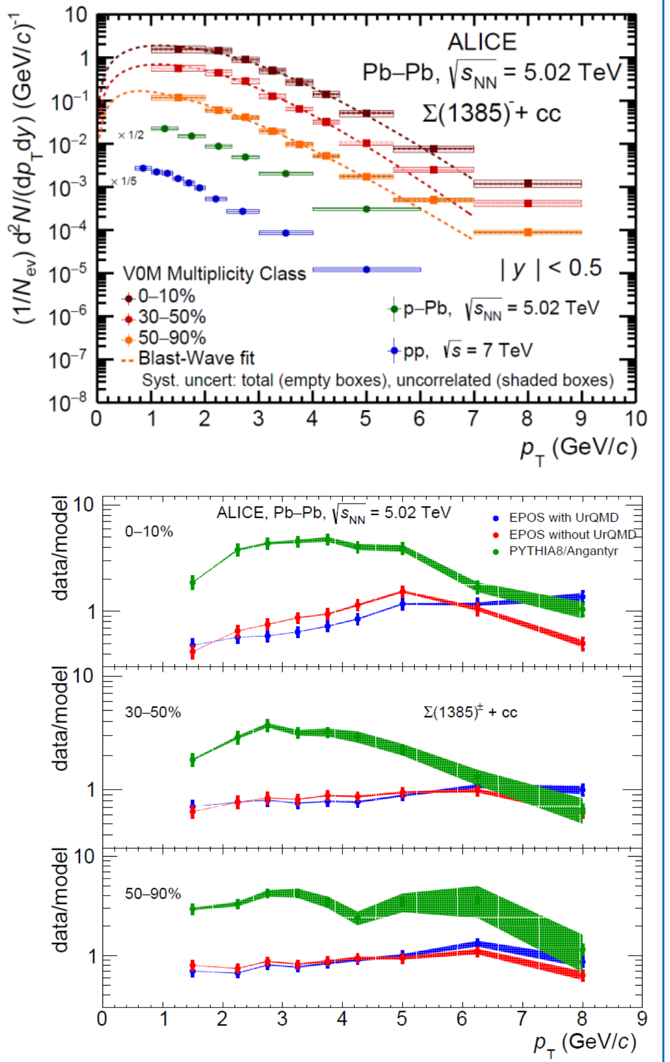


models do not fully describe data

Pb–Pb@5.02 TeV

Σ(1385)$^-$

arXiv:2205.13998



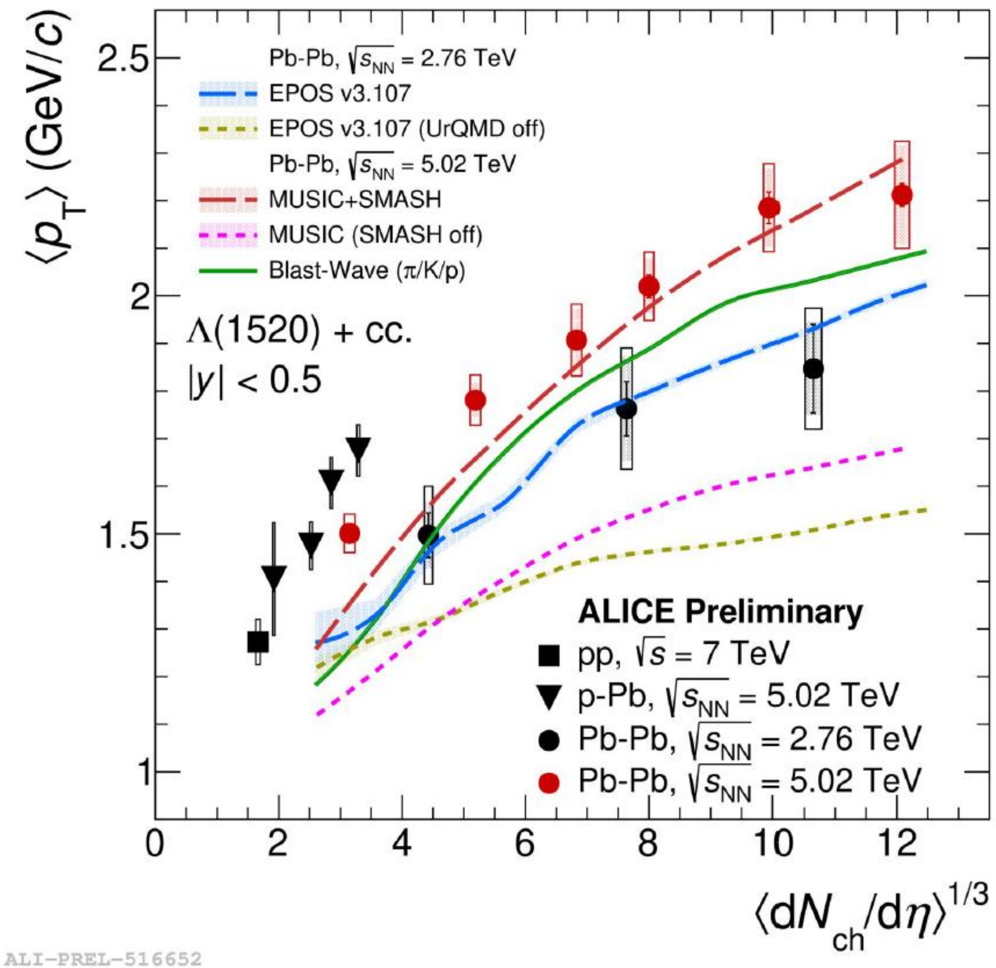
EPOS: PR **C93** (2016) 014911
PYTHIA8/Angantyr :
JHEP 10 (2018) 134,

NEW

$\langle p_T \rangle$ vs. $dN_{ch}/d\eta$

Λ(1520)

Pb–Pb@5.02 TeV



$\langle p_T \rangle$ rises with increasing multiplicity

models with rescattering effects (EPOS, MUSIC+SMASH) reproduce data

models without hadronic afterburner underestimate the measurements

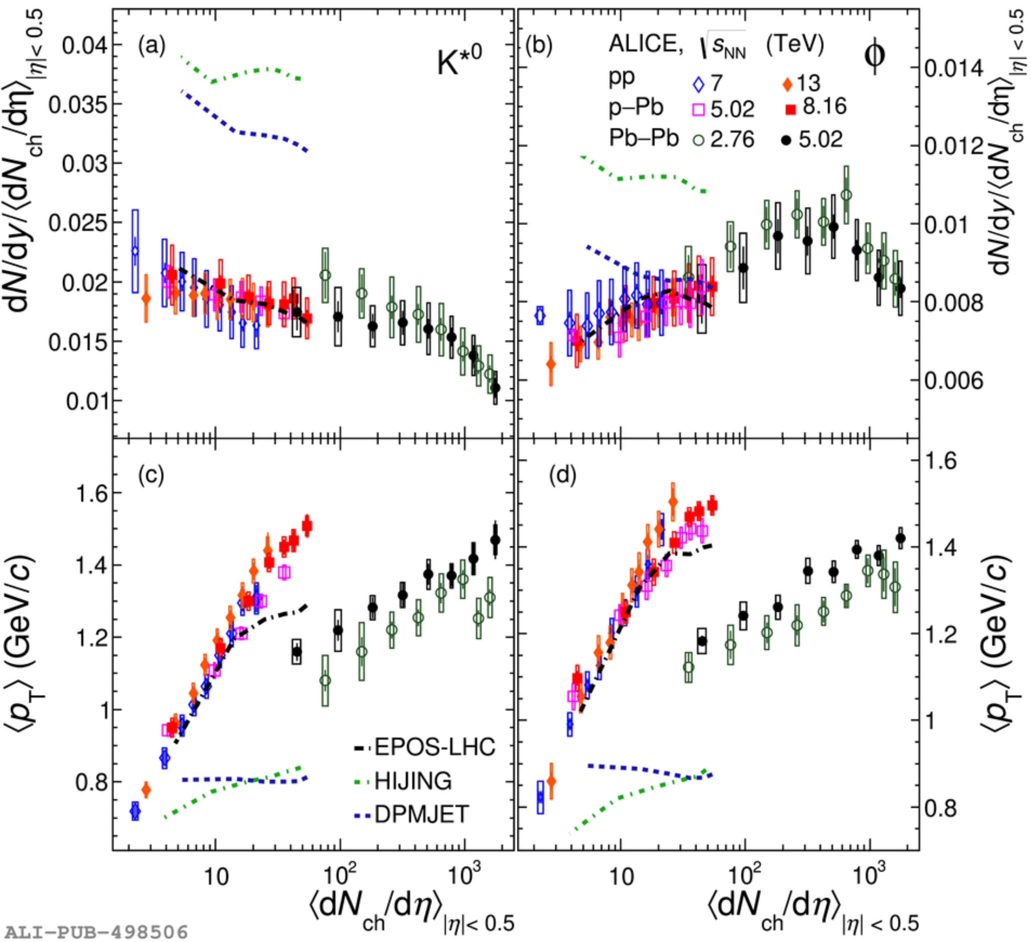
MUSIC:arXiv:2105.07539

NEW

yields, ‹ p_T › vs. $dN_{ch}/d\eta$

K*(892)^0 **ϕ(1020)**

arXiv:2110.10042



yields independent of collision system and energy
yields appear to be driven by event multiplicity

pp, p–Pb: steeper increase with multiplicity
(can be understood as the effect of color reconnection between strings produced in multi-parton interactions)

$K^{*\pm}/K$ vs. $dN_{ch}/d\eta$

NEW

$\tau(K^*)$ = 4.2 fm/c

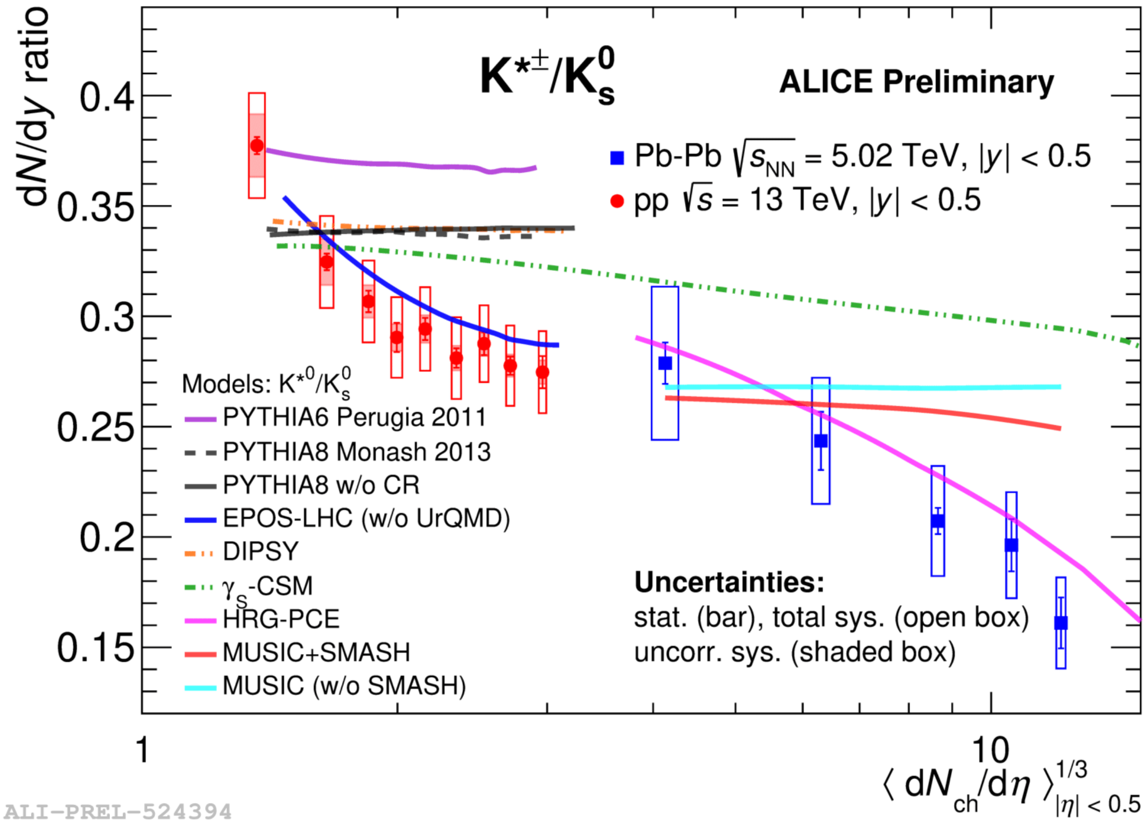
$K^{*\pm}/K$ shows a ~55% suppression
- going from peripheral Pb–Pb collisions to most central Pb–Pb

→ consistent with the rescattering of the daughters as the dominant effect

- models with rescaterring effect (MUSIC+SMASH and HRG-PCE) qualitatively describe the data

- pp: hint of decrease

- $K^{*\pm}$ measurement is consistent with previous results for K^{*0}



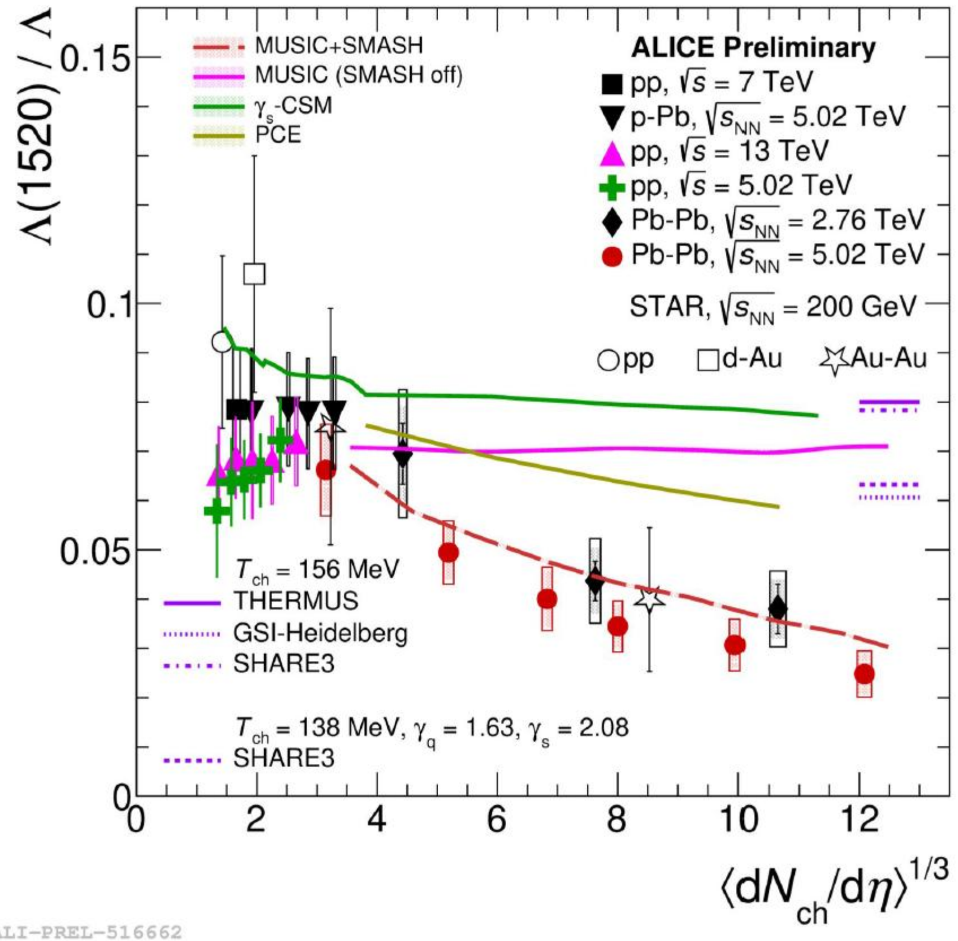
HRG-PCE: PRC102(2020)024909
γ_s-CSM: PRC100(2019)054906

Λ^*/Λ vs. $dN_{ch}/d\eta$

NEW(pp@5.02,13 Pb–Pb@5.02 TeV)

τ(Λ*) = 12.6 fm/c

- **Λ*/Λ** shows a ~ 70% suppression
  - going from peripheral Pb–Pb collisions to most central Pb–Pb
  - → consistent with the rescattering of the daughters as the dominant effect
  - it is larger than ~ 55% for K*± although τ(Λ*) = 3 τ(K*)
  - follows Pb–Pb@2.76 TeV (PR **C99** (2019) 02490) suppression trend
  - confirms the trend seen by STAR at 200 GeV



PCE: PRC102(2020)024909
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

- MUSIC-SMASH:
  - reproduce the multiplicity suppression trend
- thermal models
  - all overestimate the ratio in central Pb-Pb collisions
- pp: no suppression is observed

Σ^*/π vs. $dN_{ch}/d\eta$

NEW

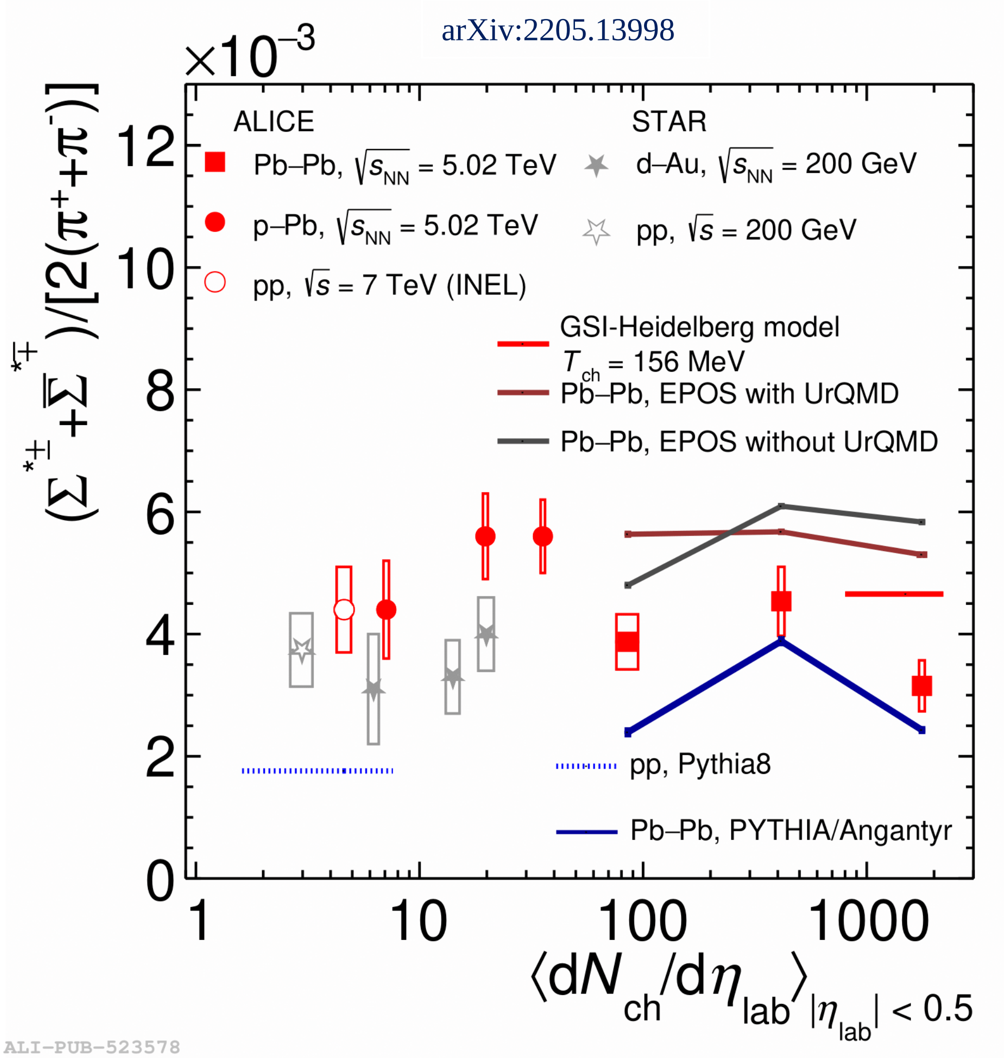
$\tau(\Sigma^*)$ = 5-5.5 fm/c

- **Σ^*/π:** no particular trend with multiplicity is observed given the uncertainties hint of some suppression at the highest multiplicity → future higher precision measurements

- EPOS with UrQMD:
  - reproduce qualitatively
  - overestimates the data

- thermal model
  - overestimates the ratio in central Pb–Pb collisions

- pp/p–Pb: close to the STAR pp/d–Au data

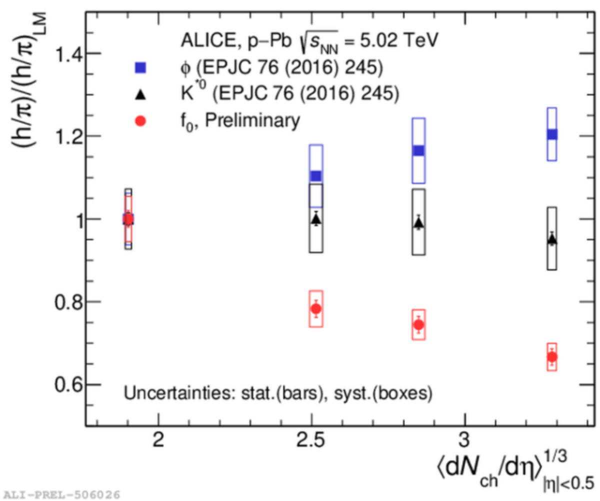


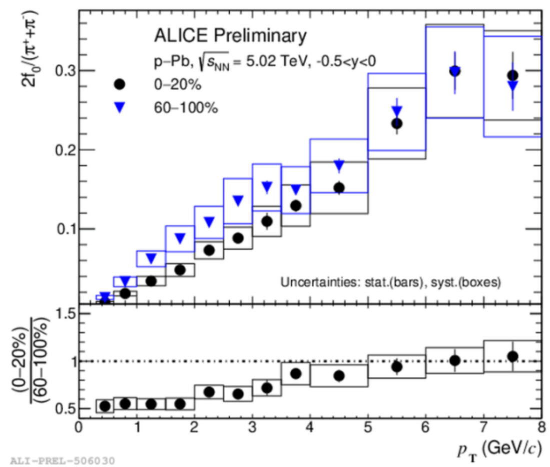
NEW

f_0/π vs. $dN_{ch}/d\eta$, vs. p_T

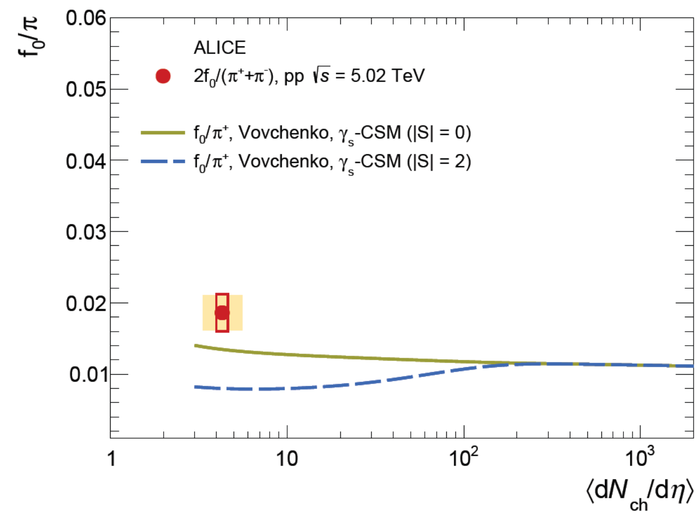
$\tau(f_0)$ = ~5 fm/c

quark structure of f_0 is still unknown.
possible configurations: qqbar, (qq)(qbar qbar), hadronic molecules, …





arXiv:2206.06216



ϕ/π: strangeness enhancement
K^{*0}/π: competition strangeness enhancement
and rescattering effect
f_0/π: rescattering is the dominant effect
exists at low p_T

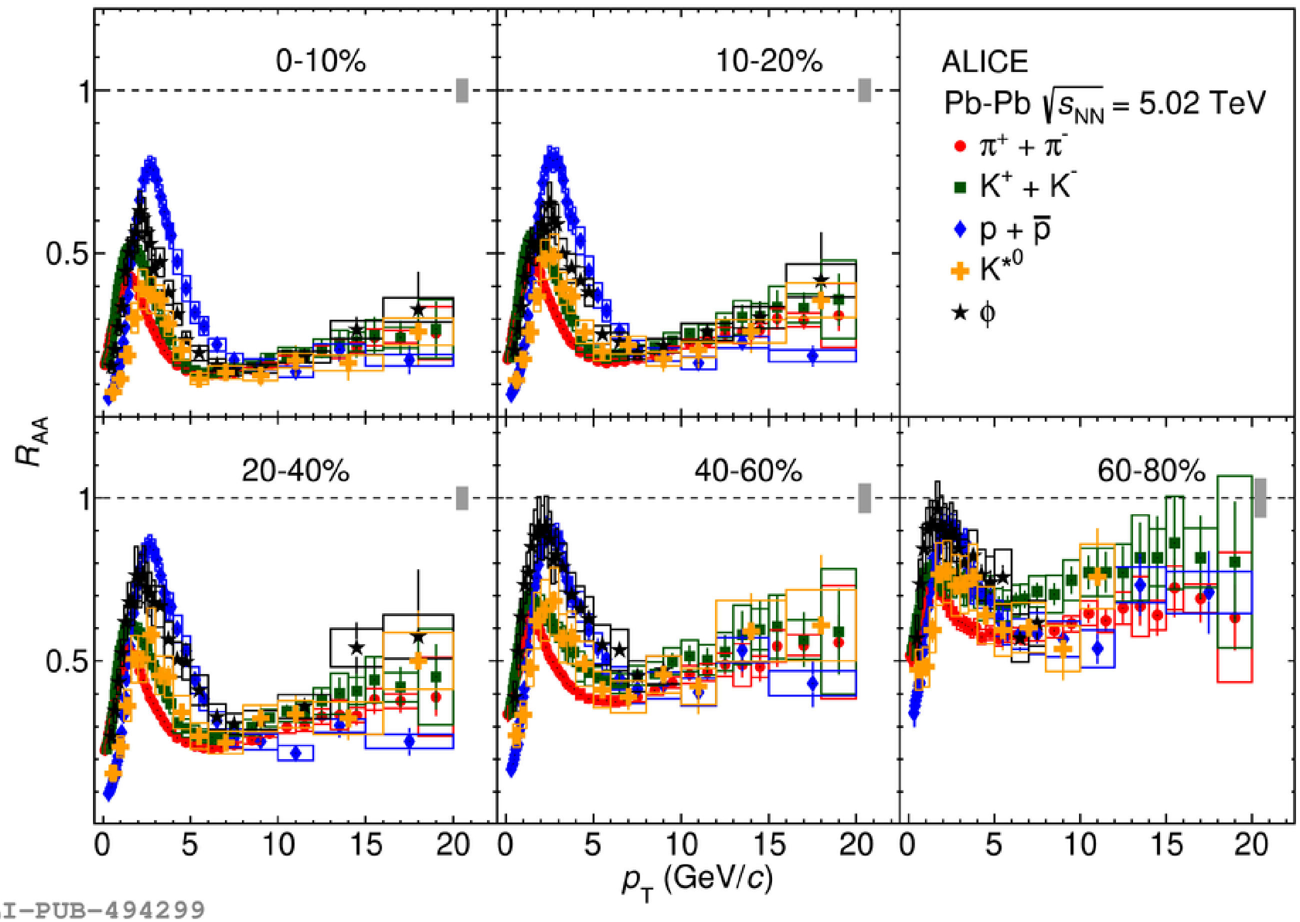
γ_s-CSM prediction for the f_0(980)
assuming net strangeness equal to zero
is consistent with the data within 1.9σ

Nuclear modification factor R_{AA} – centrality dependence

NEW

arXiv:2106.13113

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



strong suppression for the most central collisions

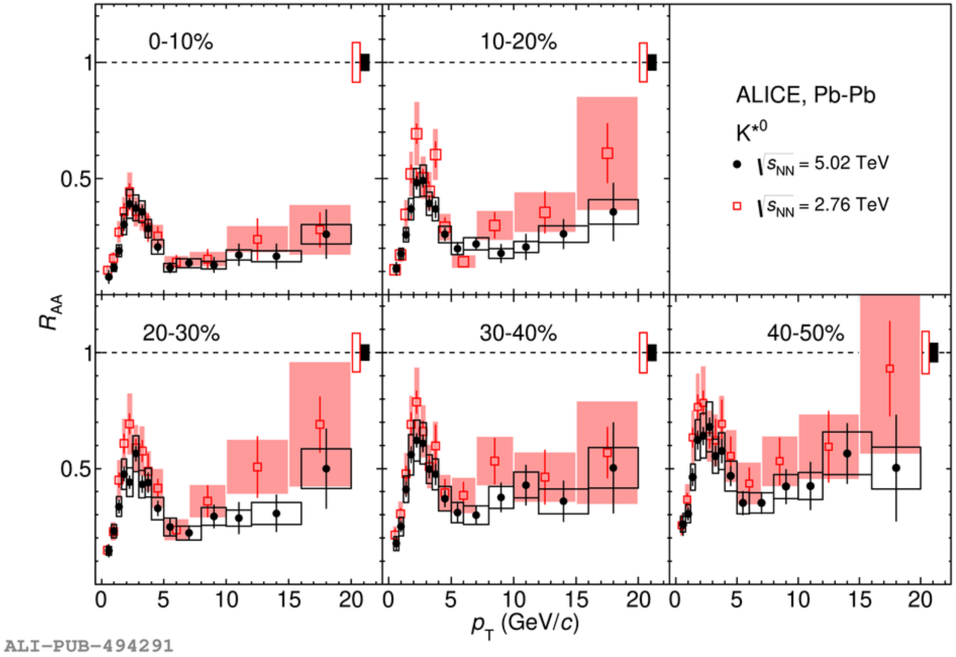
NEW

R_{AA} – energy dependence

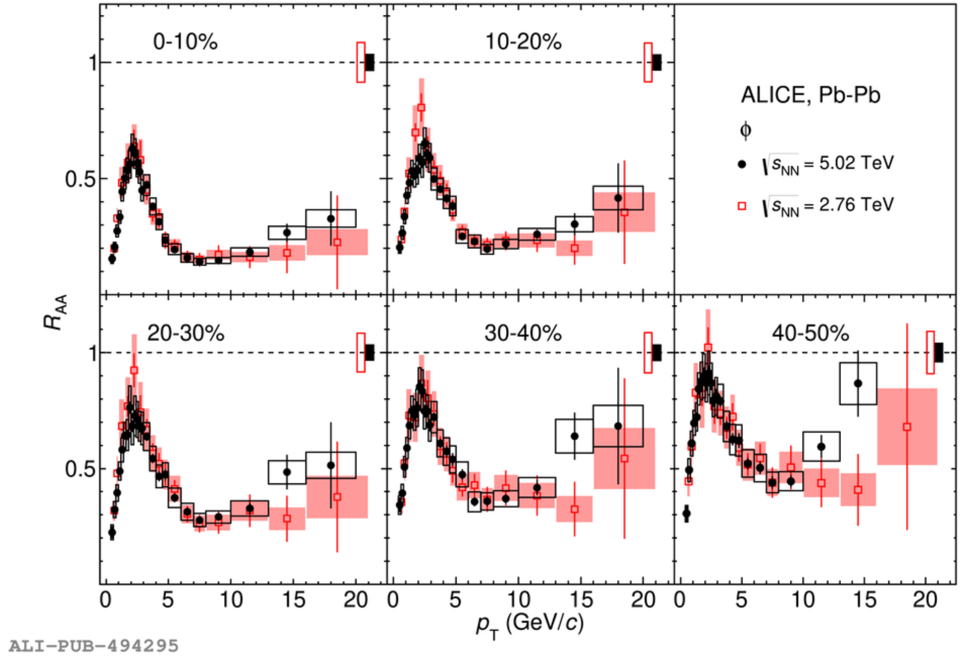
arXiv:2106.13113

Pb–Pb
2.76 TeV (empty markers)
5.02 TeV (filled markers)

K*(892)^0



ϕ(1020)



no significant energy dependence

Summary

Yields:

independent of collision system and energy

appear to be driven by event multiplicity

Particle yield ratios (with previous results):

Pb–Pb: resonance suppression

resonance	ρ^0	K*	$\Sigma^{*\pm}$	Λ^*	Ξ^{*0}	ϕ
lifetime (fm/c)	1.3	4.2	5-5.5	12.6	21.7	46.4
suppression	**yes**	**yes**	**?**	**yes**	**no**	**no**

qualitatively described by model with rescattering

pp, p–Pb: K*, f_0 – yes, Λ^* - no

R_{AA}**:**

Pb–Pb: no significant energy dependence