Hadronic resonance production with ALICE at the LHC

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- Motivation
- ALICE – particle identification
- Results on $K^*(892)^0$ and $\phi(1020)$ production
  - ✓ Signal extraction
  - ✓ Mass and width
  - ✓ p_T spectra
  - ✓ Mean transverse momentum
  - ✓ Ratios of resonances to stable hadrons
  - ✓ Resonances nuclear modification factors
- Summary

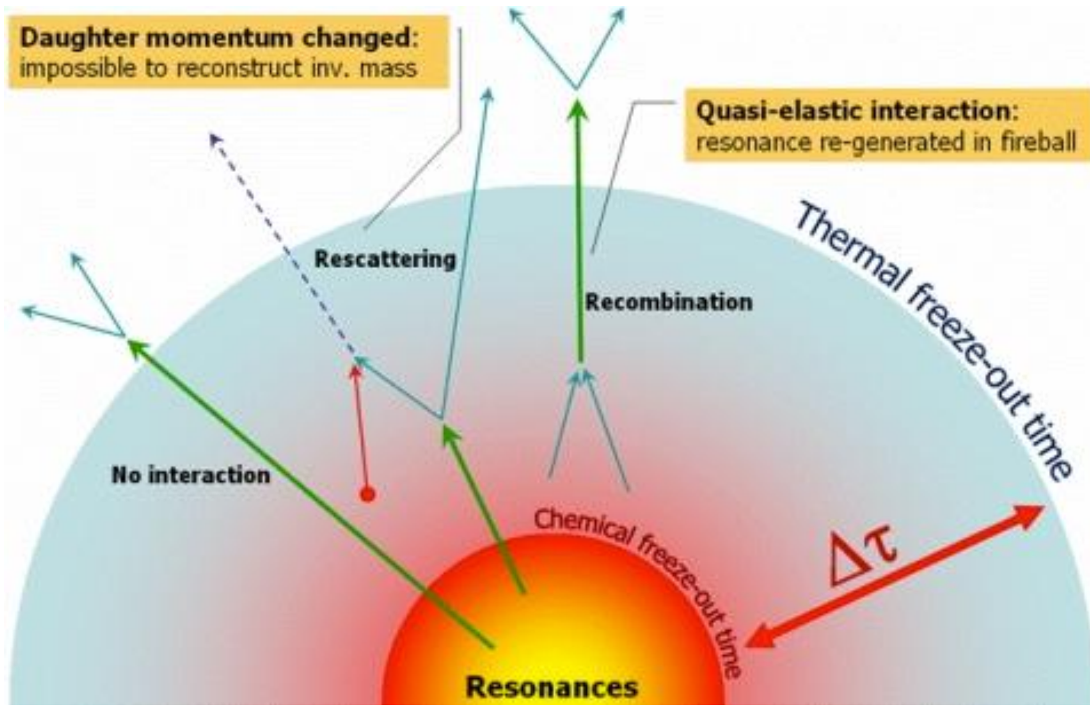
Motivation

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

Resonance	Γ (MeV)	cτ (fm)	Decay
K*(892)^0	50	4	**π + K**
ϕ(1020)	4.3	46	**$K^+ + K^-$**

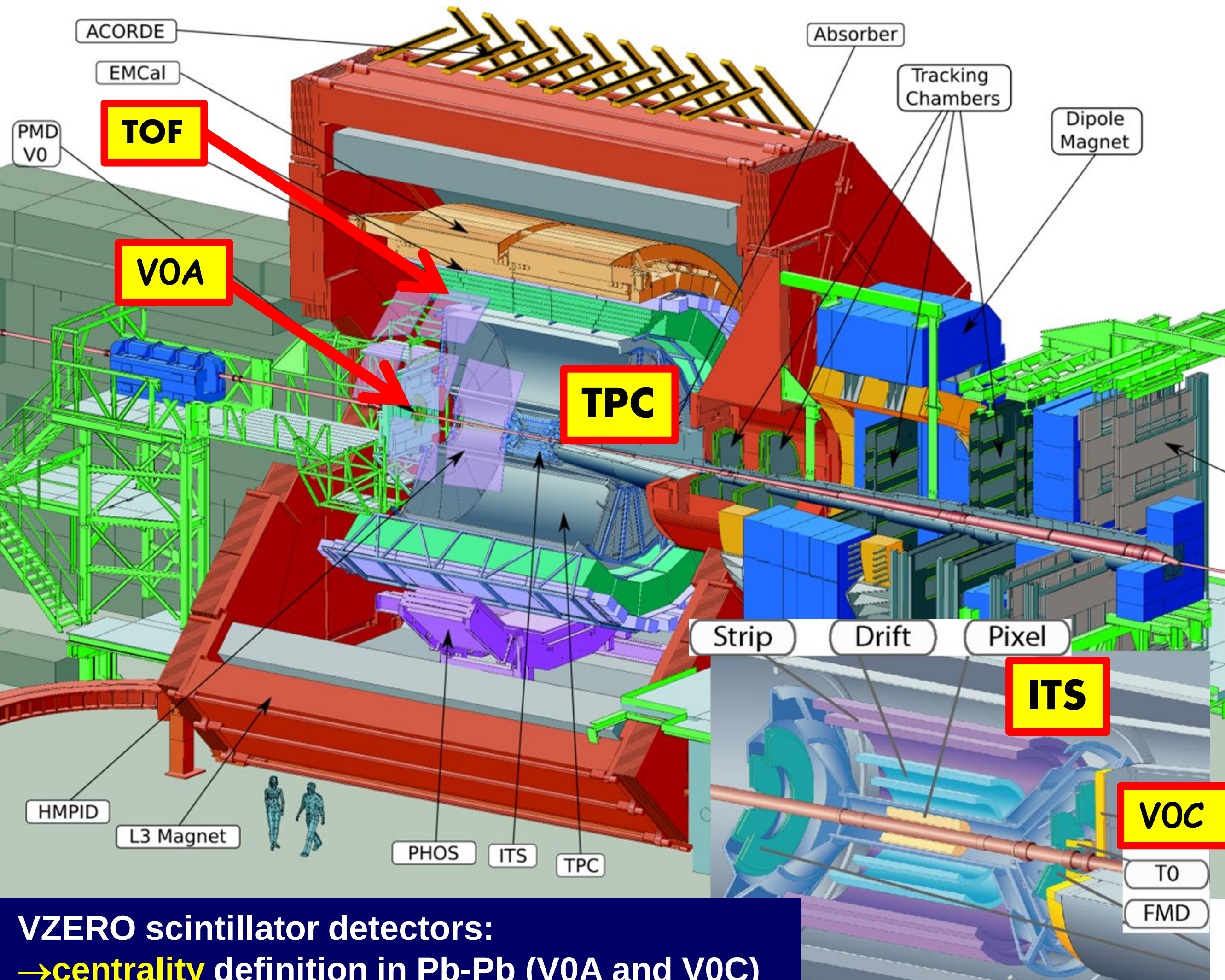
Dataset	**$\sqrt{s_{NN}}$ (TeV)**
2010 pp	**7**
2011 pp	**2.76**
2010 Pb-Pb	**2.76**
2011 Pb-Pb	**2.76**
2013 p-Pb	**5.02**

- **AA collisions:**
  - ✓ in-mediun energy loss
  - → resonance nuclear modification factor
  - ✓ restoration of chiral symmetry
  - → modification of width, mass and branching ratio
  - ✓ regeneration and rescattering effects
  - → modification of yield, ‹ p_T › and particle ratios
  - → timescale between chemical and kinetic freeze-out

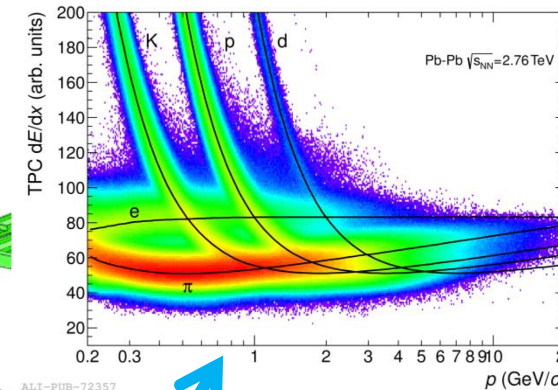


ALICE – particle identification

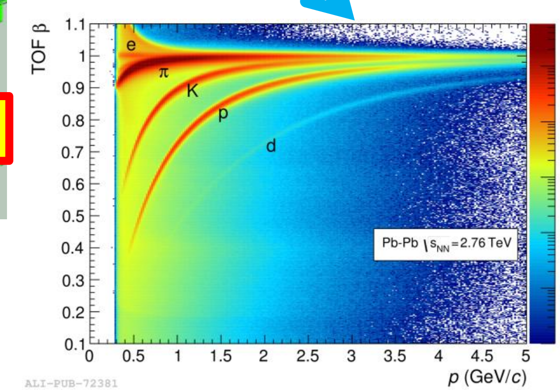
ALICE Coll. arXiv:1402.4476



Particle identification (π, K from resonance decay) by:



- **dE/dx in gas (TPC)**
- **Time-of-flight measurements (TOF)**

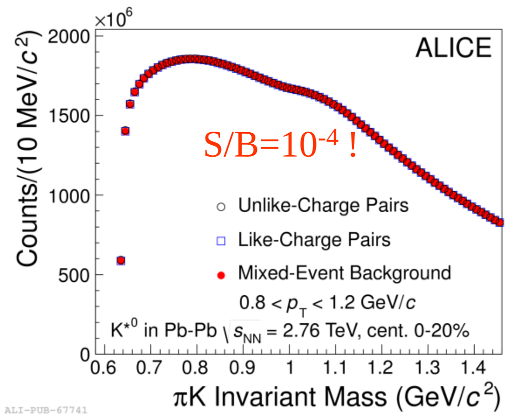


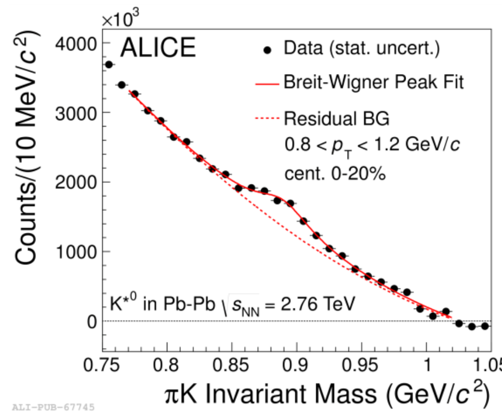
VZERO scintillator detectors:
→centrality definition in Pb-Pb (V0A and V0C)
→multiplicity event classes in p-Pb (V0A)

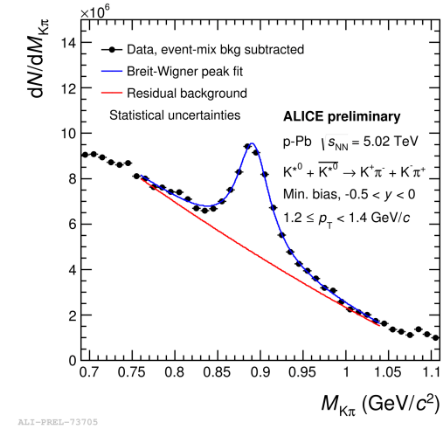
Signal extraction

Pb-Pb **p-Pb**

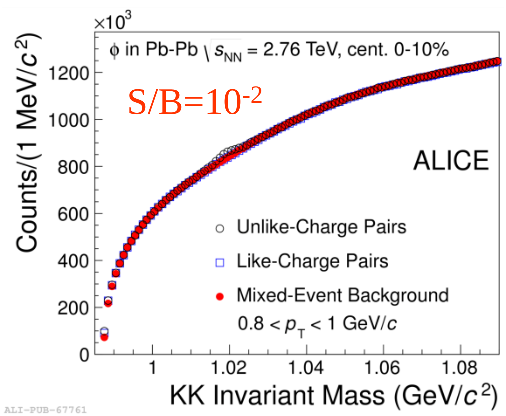
K^{*0}

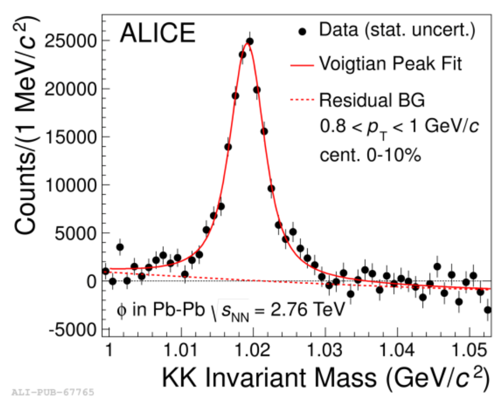


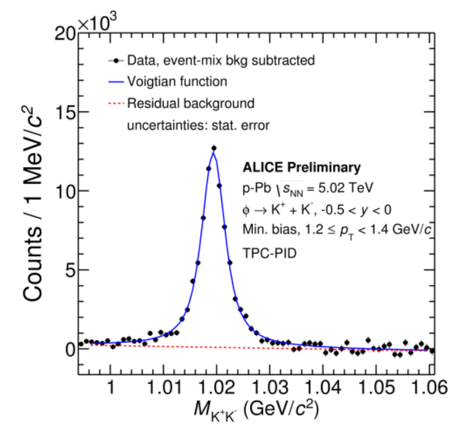




ϕ







ALICE Coll. arXiv:1404.0495

combinatorial background: mixed-event or like-sign techniques

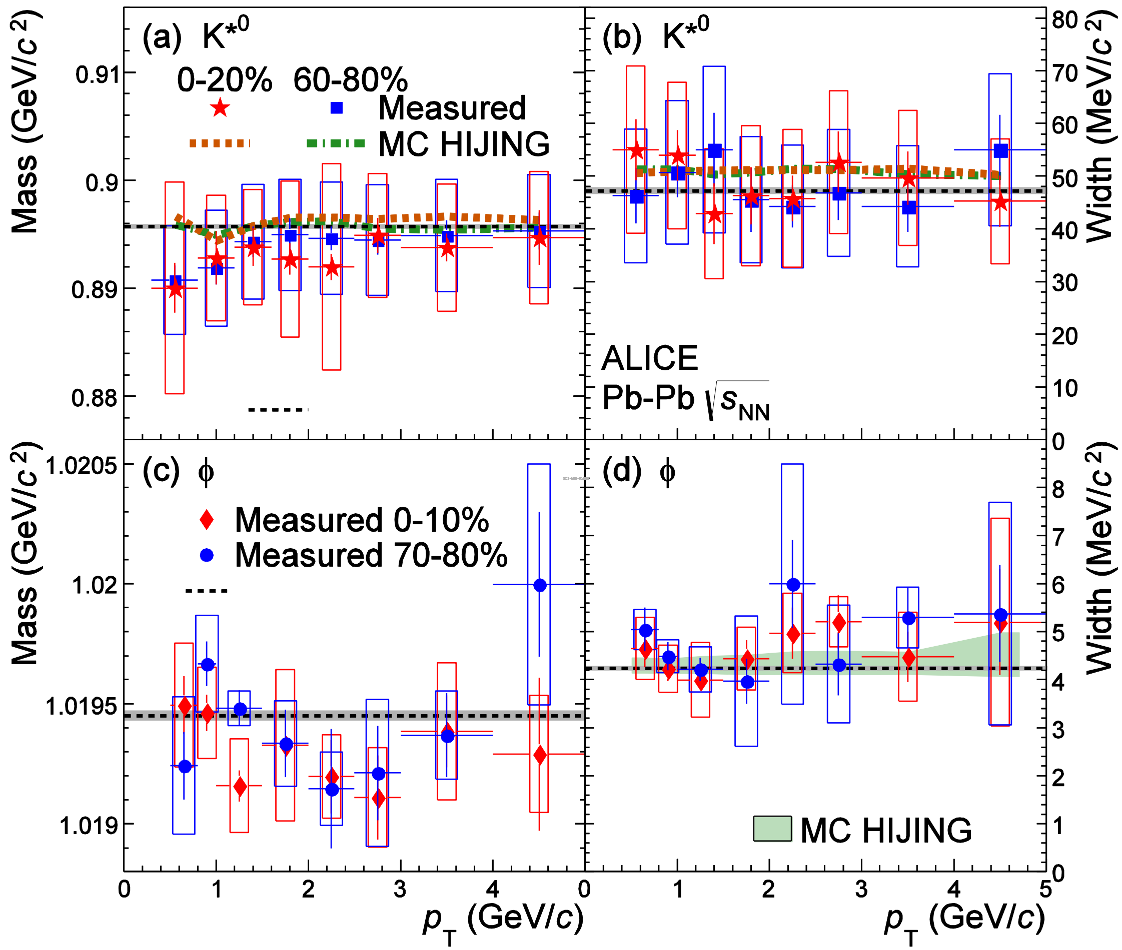
fit: Breit-Wigner (Voigtian for ϕ) + polynomial

Pb-Pb: mass and width

mass **width**

K*0

ϕ

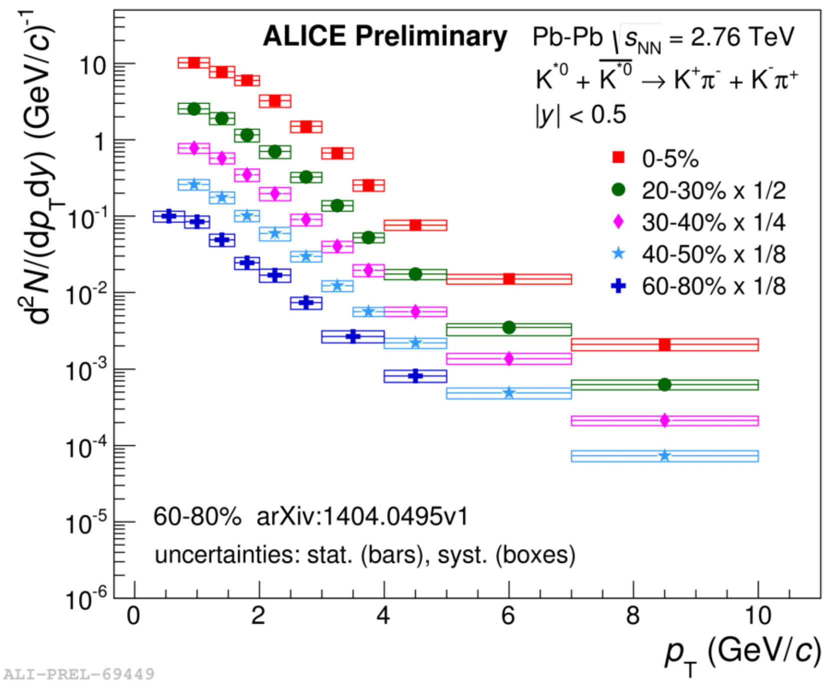


ALICE Coll. arXiv:1404.0495

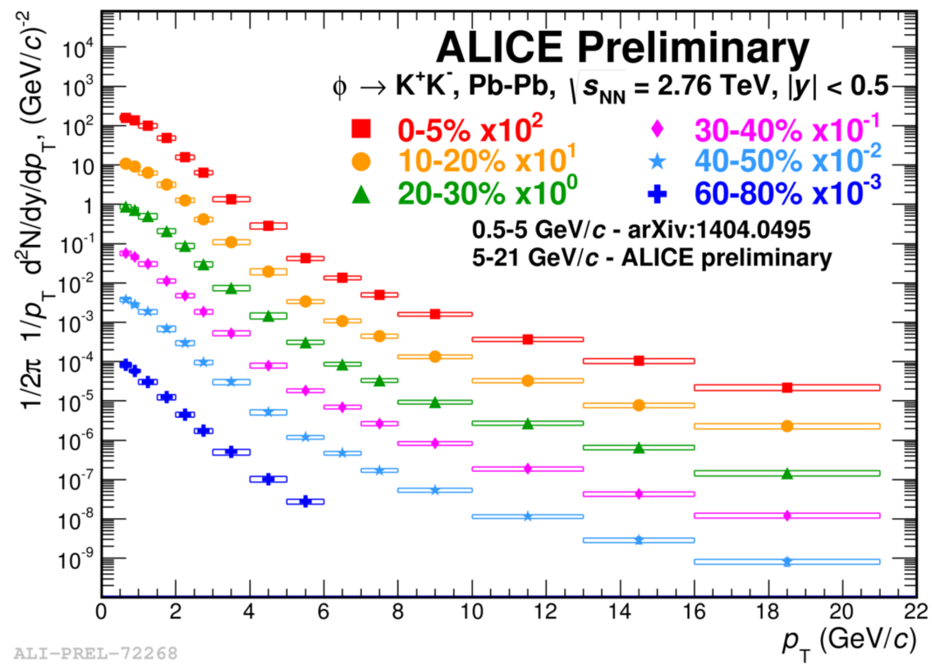
masses and widths consistent with PDG values

Pb-Pb: p_T spectra

K^{*0}



ϕ



2010 Pb-Pb data analysis : $p_T \leq 5$ GeV/c (ALICE Coll. arXiv:1404.0495)

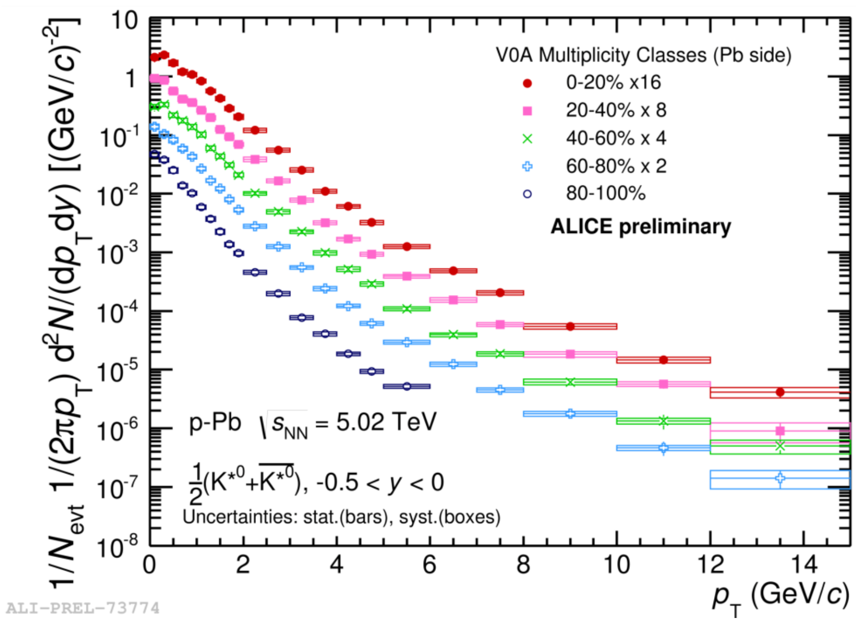
Analysis of Pb-Pb 2011 data extends measured p_T

K^{*0} : up to 10 GeV/c

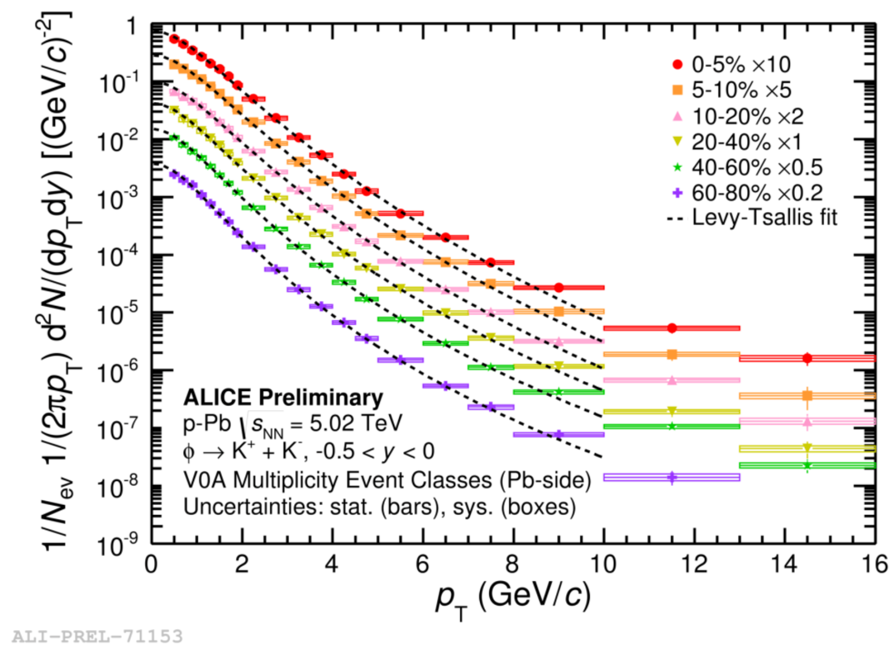
ϕ : up to 21 GeV/c

p-Pb: p_T spectra

K*0



ϕ

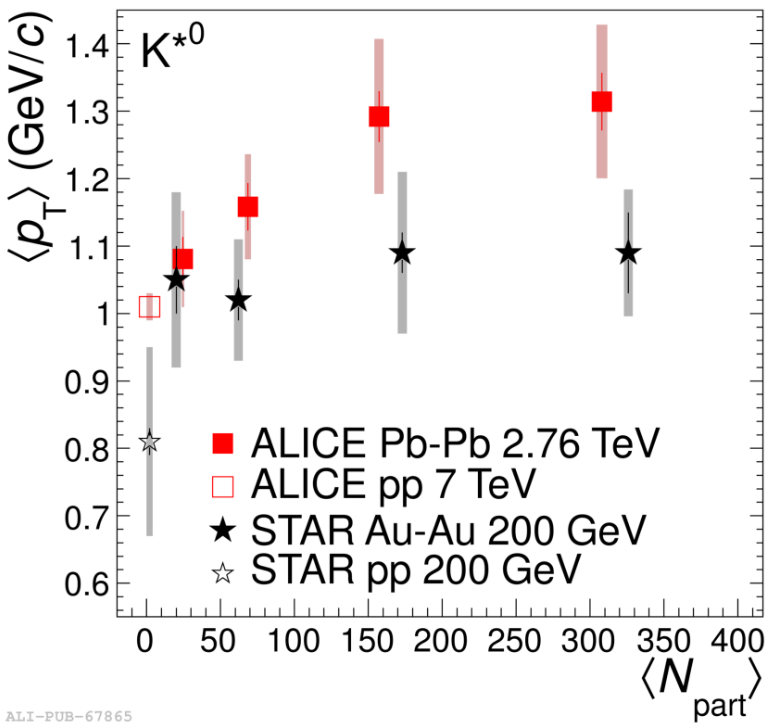


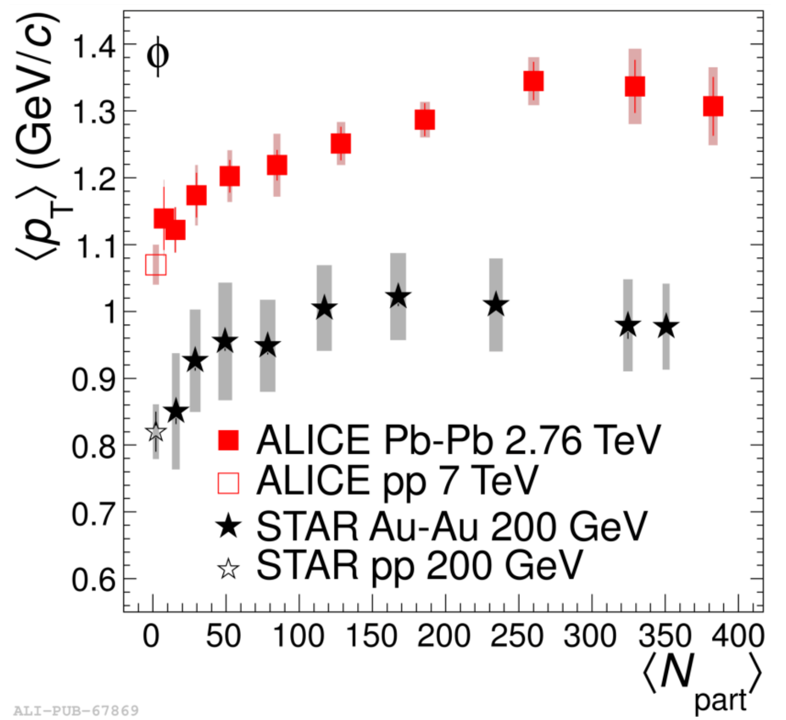
Analysis of p-Pb 2013 data
p_T spectra measured in various multiplicity bins

K^{*0} : $0 < p_T < 15$ GeV/c
ϕ : $0.2 < p_T < 16$ GeV/c

Pb-Pb: $\langle p_T \rangle$

K*0 ALICE Coll. arXiv:1404.0495 **ϕ**



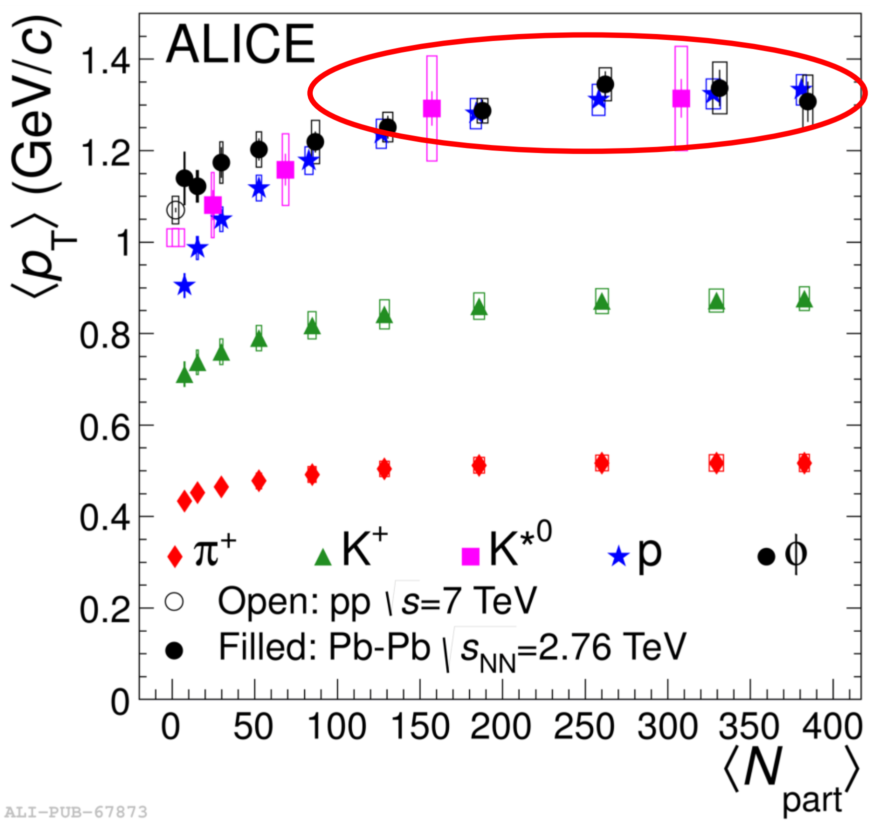


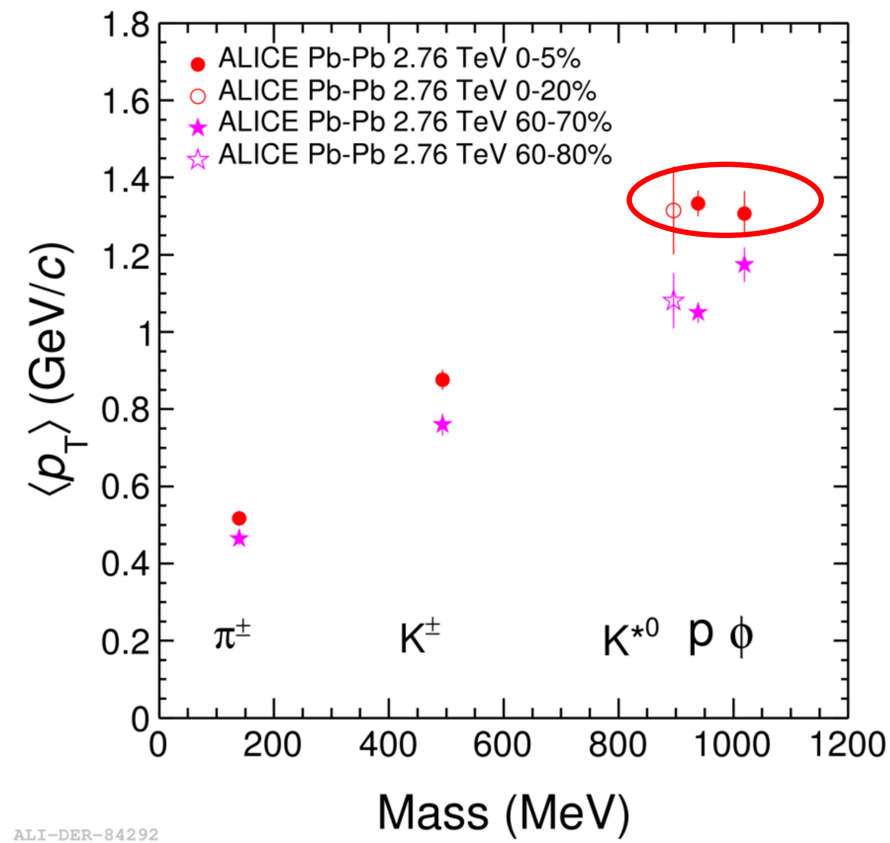
$\langle p_T \rangle_{LHC}$ higher than $\langle p_T \rangle_{RHIC}$, ~20% (30%) for K*(ϕ)

→ stronger radial flow

Pb-Pb: ‹ p_T ›, mass ordering

ALICE Coll. arXiv:1404.0495

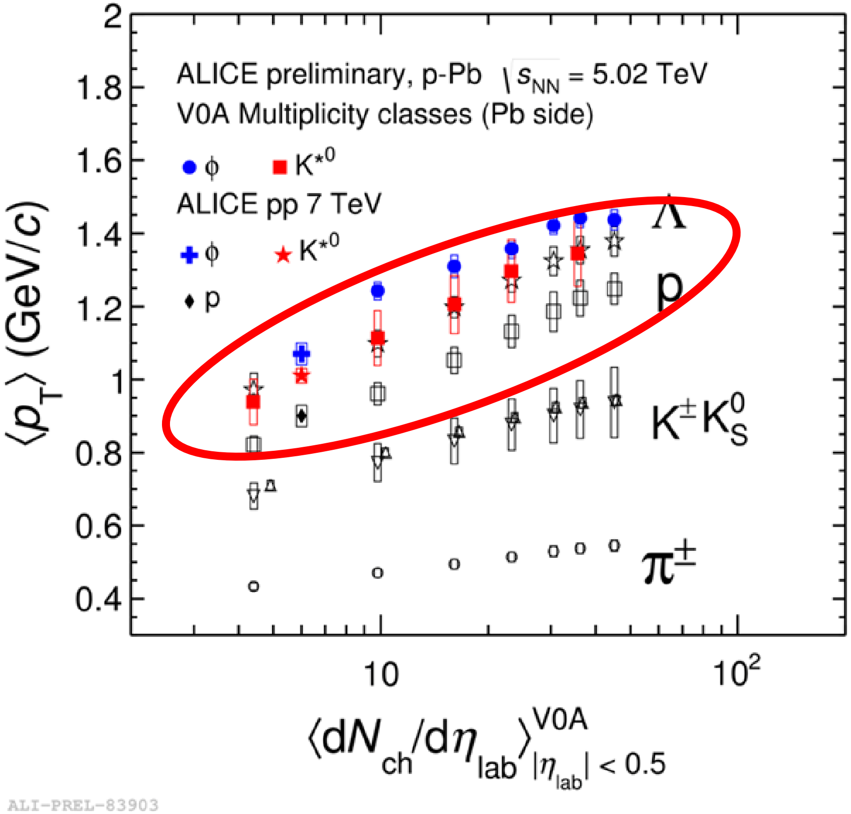


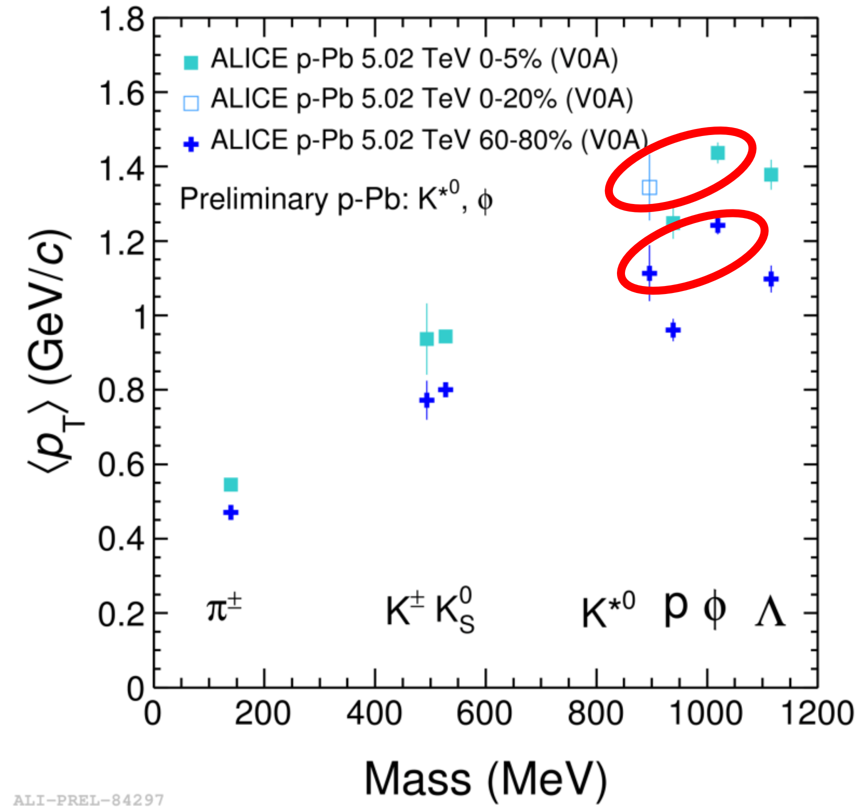


K*^{0} and ϕ: similar increasing trend with multiplicity as other hadrons

Central Pb-Pb collisions: particles with similar mass (K^{*0} , p and ϕ) have similar ‹ p_T›
→ p_T distribution determined by particle mass, i.e. consistent with hydrodynamical picture

pp, p-Pb: ‹ p_T ›, mass ordering ?



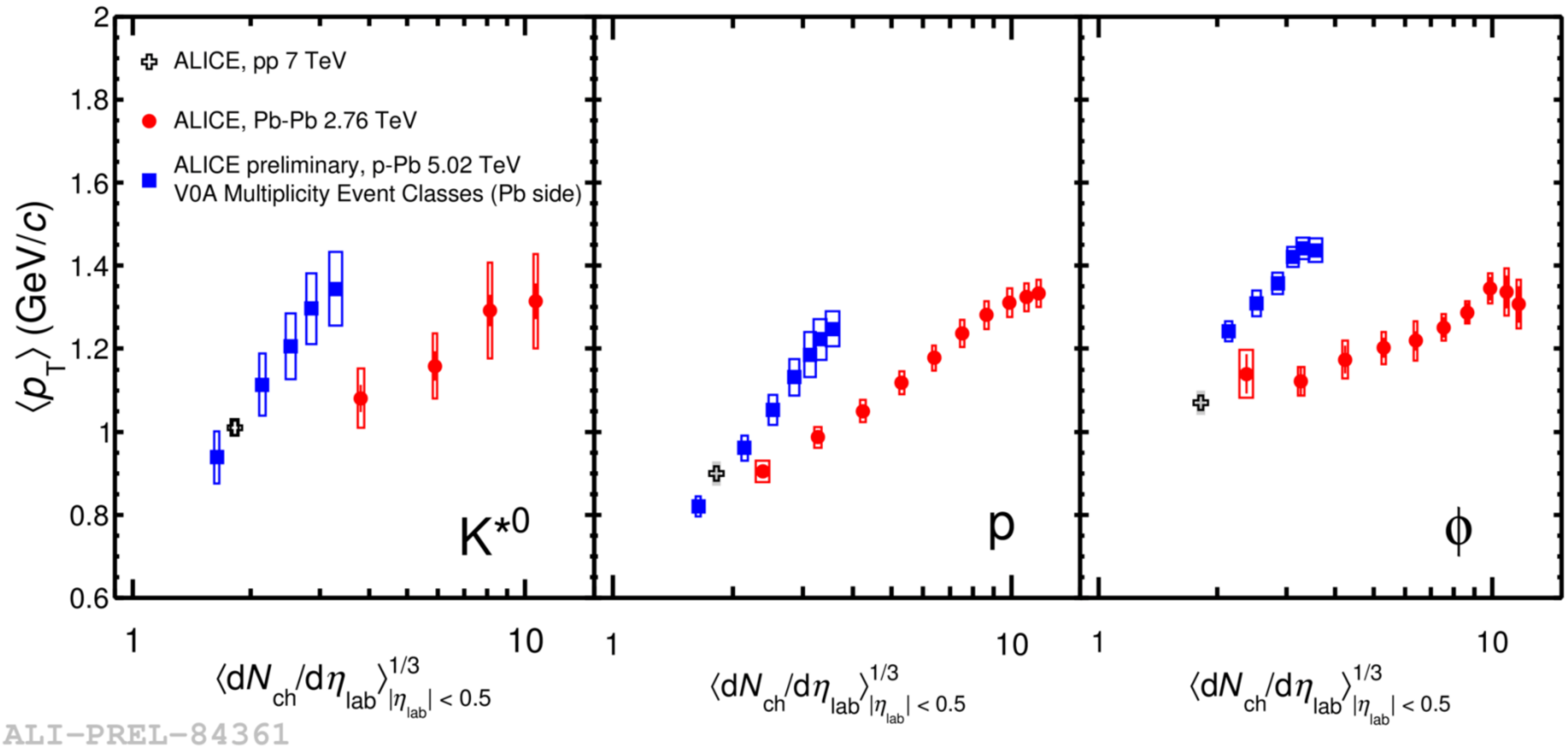


p-Pb: similar increasing trend for K^{*0} and ϕ with multiplicity as other hadrons

pp, p-Pb: $\langle p_T \rangle_\phi > \langle p_T \rangle_{K^{*0}} > \langle p_T \rangle_p$

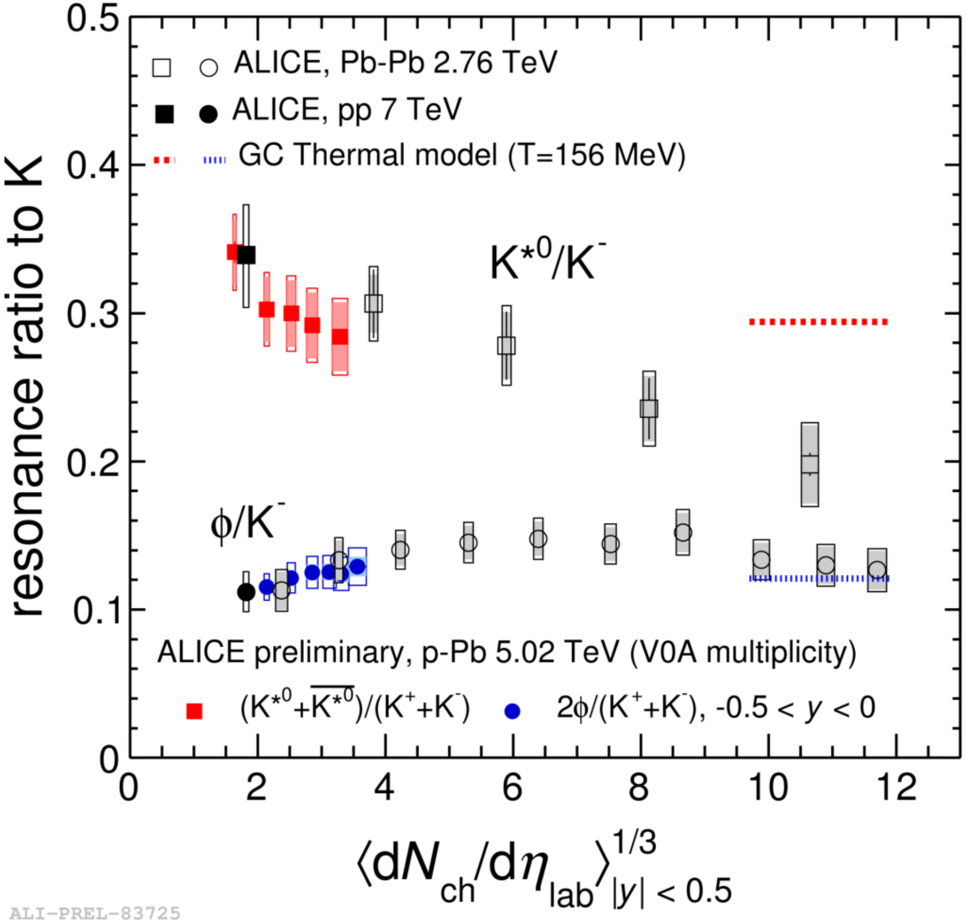
→ Do resonances not follow mass ordering or do protons deviate?

‹ p_T › - system dependence



steeper increase of ‹ p_T › for smaller systems
as also observed for charged particles in
ALICE Coll., Phys. Lett. B727(2013)371

K^{*0}/K and ϕ/K ratios



Pb-Pb:

- K^{*0}/K exhibits a strong suppression going from peripheral to most central Pb-Pb collisions (i.e. increasing system size)
  → consistent with the rescattering of K^{*0} daughters as the dominant effect

- ϕ/K in central Pb-Pb collisions consistent with the value measured in pp collisions and with thermal model prediction (Andronic et al., J. Phys. G38(2011)124081)

p-Pb:

- K^{*0}/K sits along the extrapolation from pp to peripheral Pb-Pb collisions

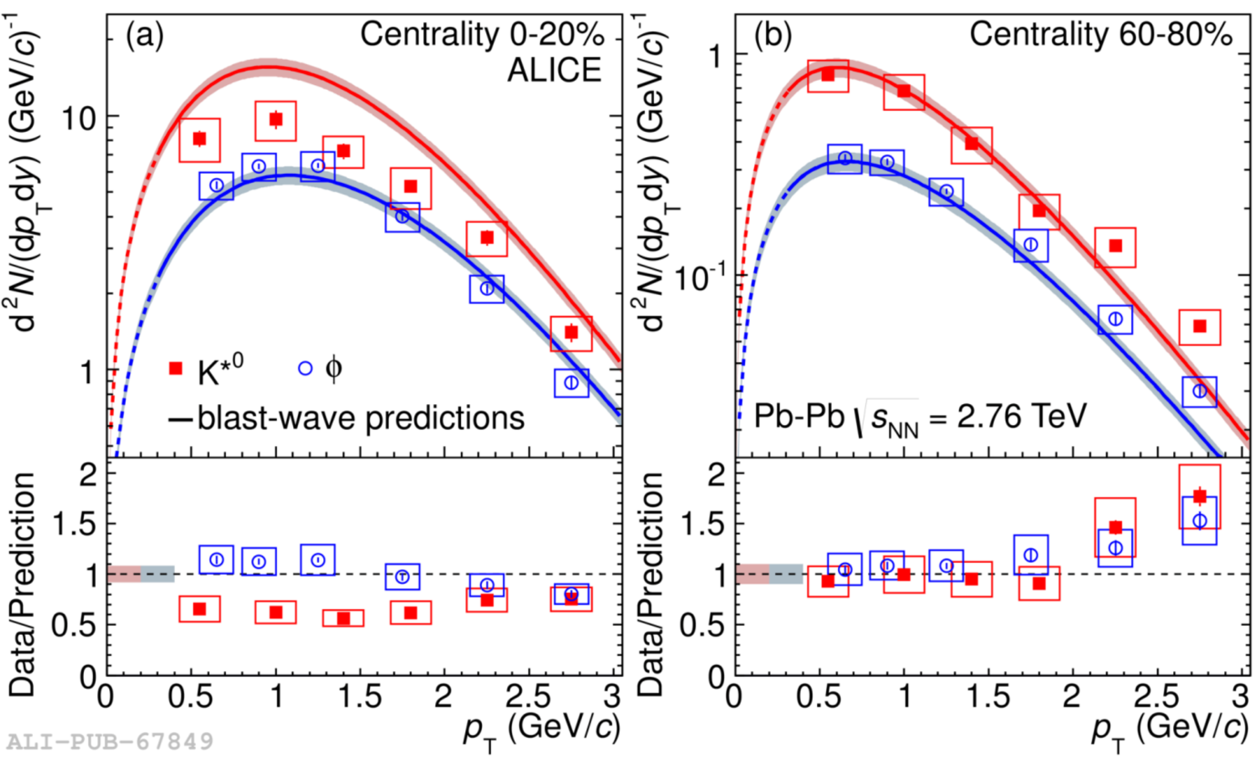
- ϕ/K rather independent from event multiplicity class

Central Pb-Pb: blast-wave predictions

Comparison of K^{*0} (ϕ) spectum with blast-wave model (BW) predictions.

- BW parameters (T_{kin},n,and β_s) from BW fit of π, K and p (ALICE Coll., Phys. Rev. C88(2013)044910) .
- Normalization: measured K yields times the K^{*0}/K (ϕ/K) ratio from the thermal model (J. Stachel et al., J. Phys. Conf. Ser. 509(2014)012019).

ALICE Coll. arXiv:1404.0495



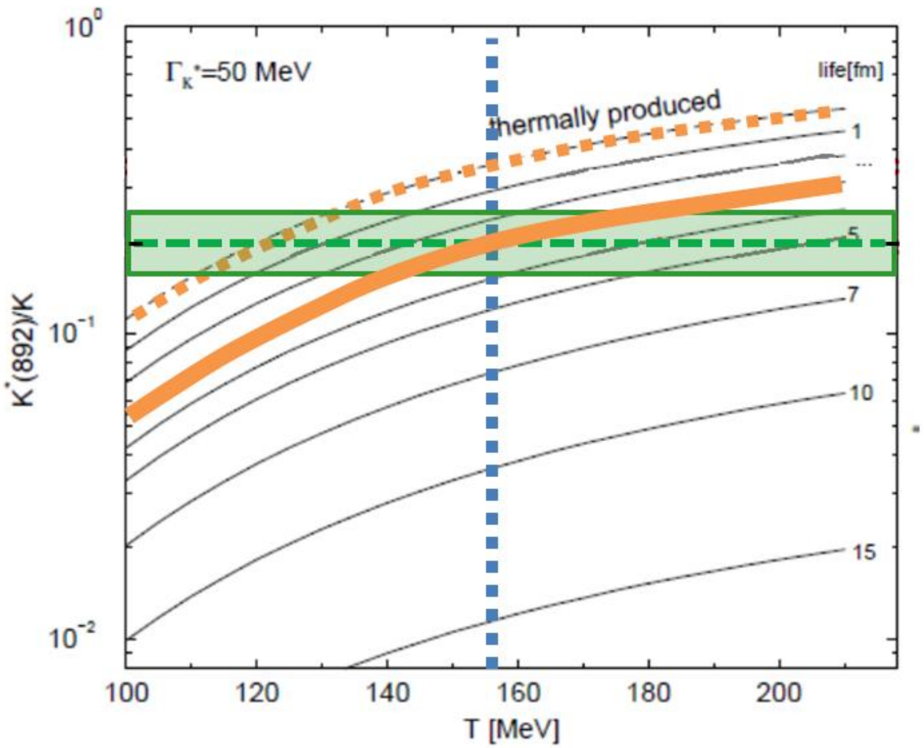
ϕ not suppressed in either central or peripheral collisions

K^{*0} suppressed for p_T< 2 GeV/c in central collisions. No suppression in peripheral collisions.
→ As expected from dominating rescattering effects

Central Pb-Pb: estimation τ_{kin}-τ_{chem}

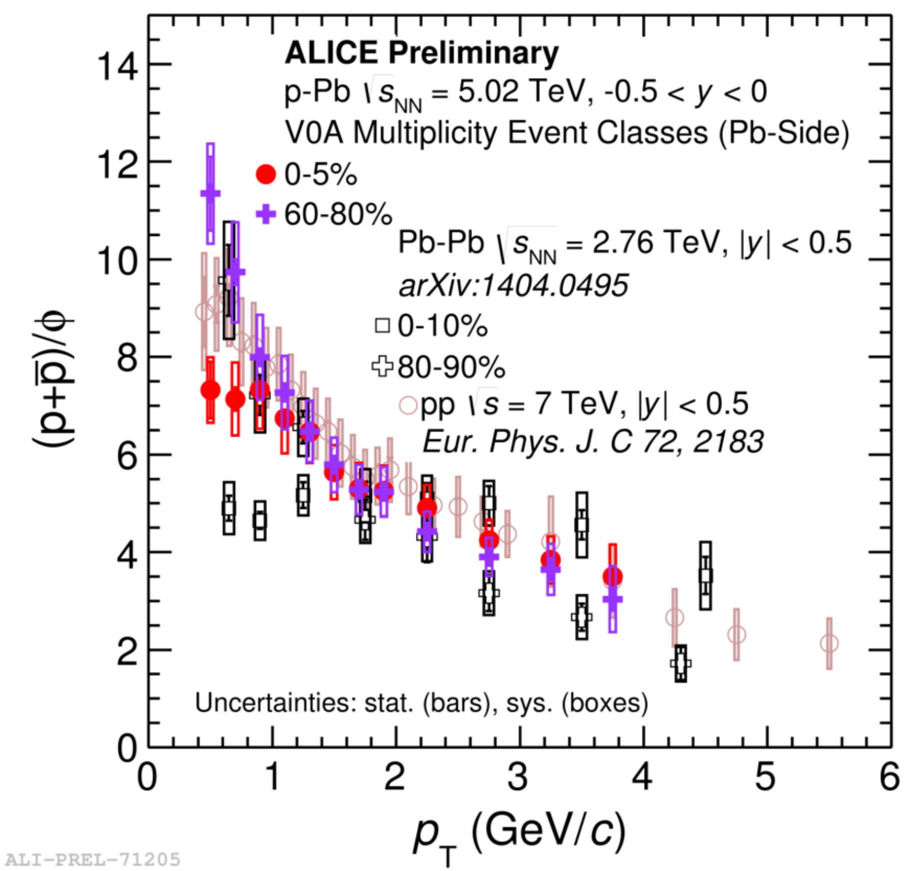
Thermal model with rescattering effect

- C. Markert, J. Rafelski and G. Torrieri, arXiv:0206260
- G. Torrieri and J. Rafelski, J. Phys. G28(2002)1911



the lower limit
τ_{kin}-τ_{chem} > 2 fm/c

p/ϕ ratio



central Pb-Pb:

- p/ϕ ratio is flat for p_T< 3-4 GeV/c, i.e. similar spectrum shapes of p and ϕ
  → low-p_T spectral shape determined by particle mass, i.e. consistent with hydrodynamic description

peripheral Pb-Pb:

- p/ϕ ratio similar to pp collisions

central p-Pb:

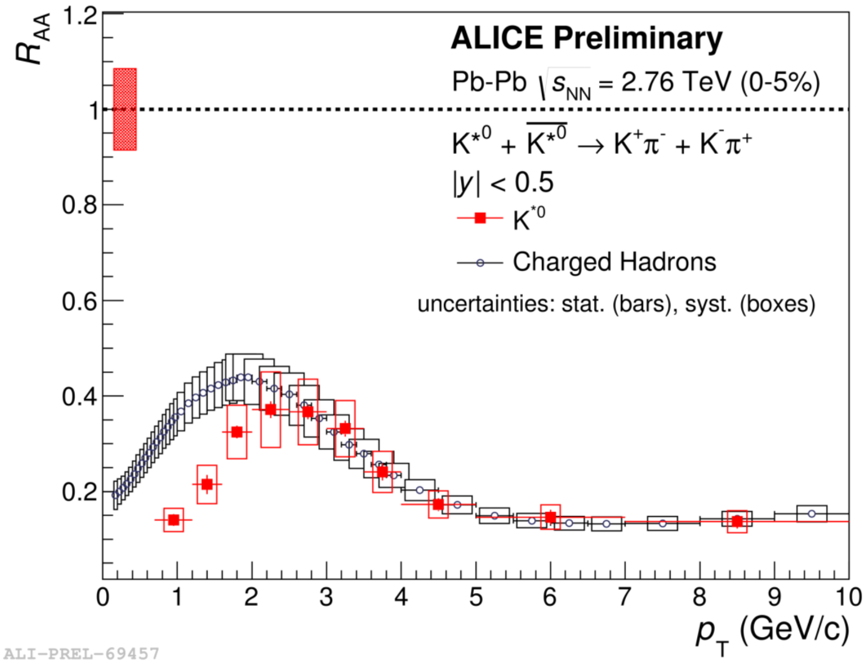
- Indication of flattening of the p/ϕ ratio below 1.5 GeV/c in most central collisions
  → hint of the onset of collective behaviour?

peripheral p-Pb:

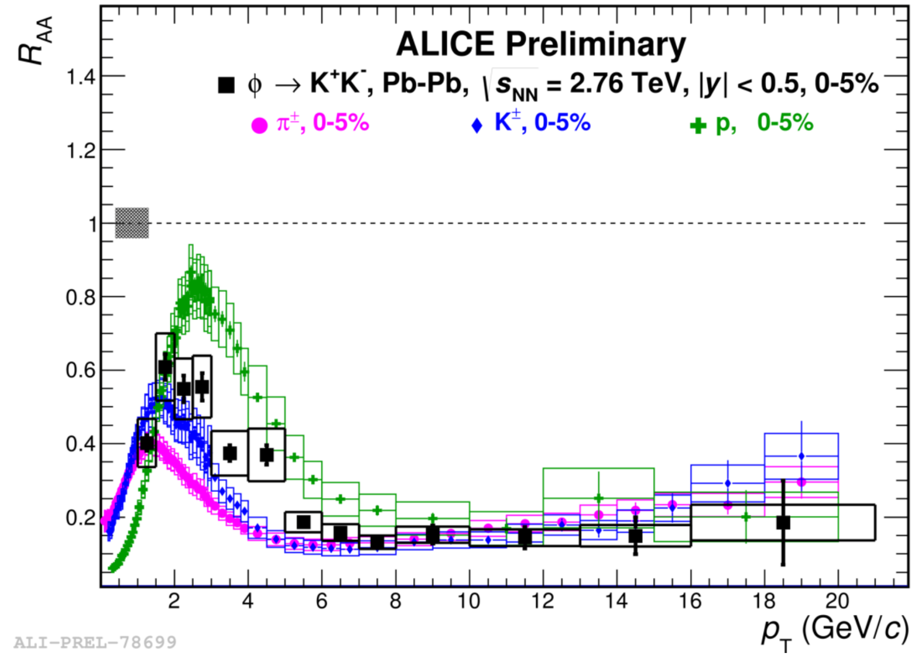
- p/ϕ ratio similar to peripheral Pb-Pb and pp collisions

Pb-Pb: R_{AA}

K^{*0}



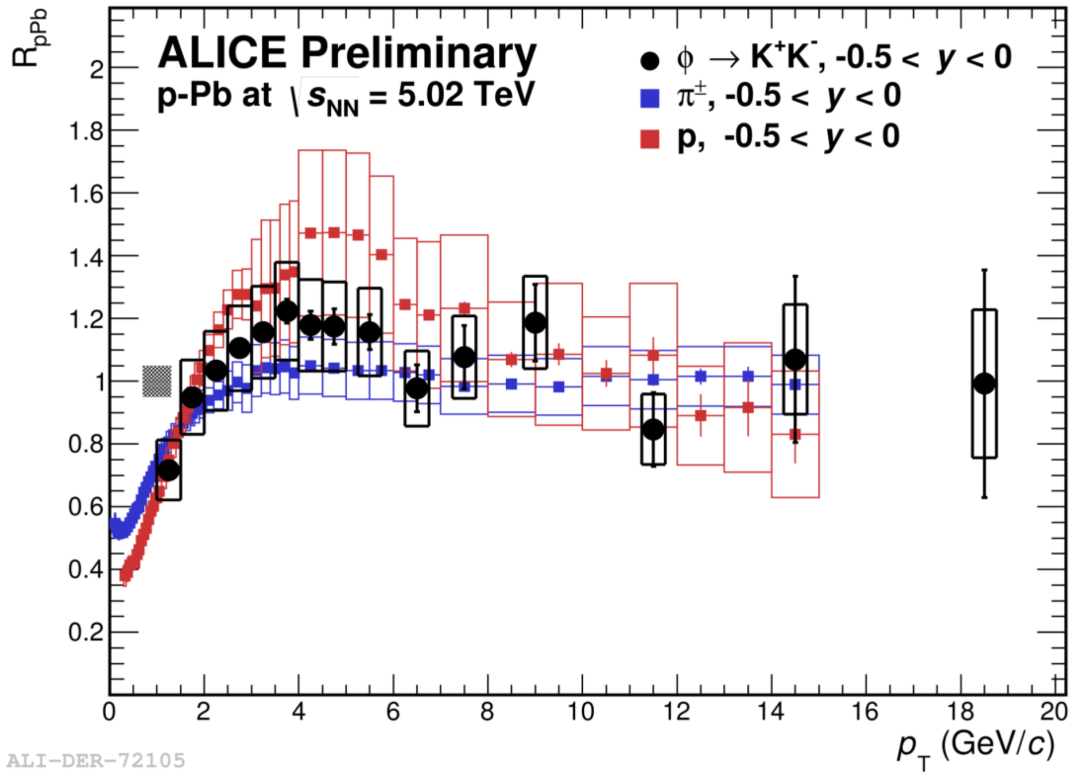
ϕ



- **High-p_T:** in most central collisions, a strong suppression is observed with respect to pp collisions, both for resonances as well as stable hadrons.
- **Intermediate p_T:** $R_{AA}(\phi) < R_{AA}(p)$. Since the p/ϕ ratio in Pb-Pb is flat $\to$ differences due to pp reference spectra.
- **Low p_T:** below 2 GeV/c larger suppression of K^{*0} production with respect to charged hadrons $\to$ can be explained in terms of rescattering effects

p-Pb: R_{pPb}

ϕ



no suppression with respect to pp

a moderate Cronin peak at intermediate momentum

Summary

$K^*(892)^0$ and $\phi(1020)$ resonance production has been measured in a wide momentum range in p-Pb and Pb-Pb collisions at the LHC, as a function of multiplicity (centrality)

- In pp and in p-Pb the resonance $\langle p_T \rangle$ does not follow the same mass ordering as in central Pb-Pb, where it is compatible to that of stable hadrons with similar mass

- K^{*0}/K exhibits a strong suppression going from peripheral to most central Pb-Pb collisions $\rightarrow$ K^{*0} yield affected by rescattering in the hadronic phase due to its short lifetime, while ϕ behaves as a long-lived particle

- In central p-Pb, ϕ/p at low p_T shows a hint of flattening $\rightarrow$ the onset of collective behaviour?

- In central Pb-Pb collisions, similarly to other hadrons, high-p_T resonances are strongly suppressed