Probing the hadronic phase with resonance production in pp, p-Pb and Pb-Pb collisions with ALICE at LHC

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PUSAN NATIONAL UNIV.
NPL
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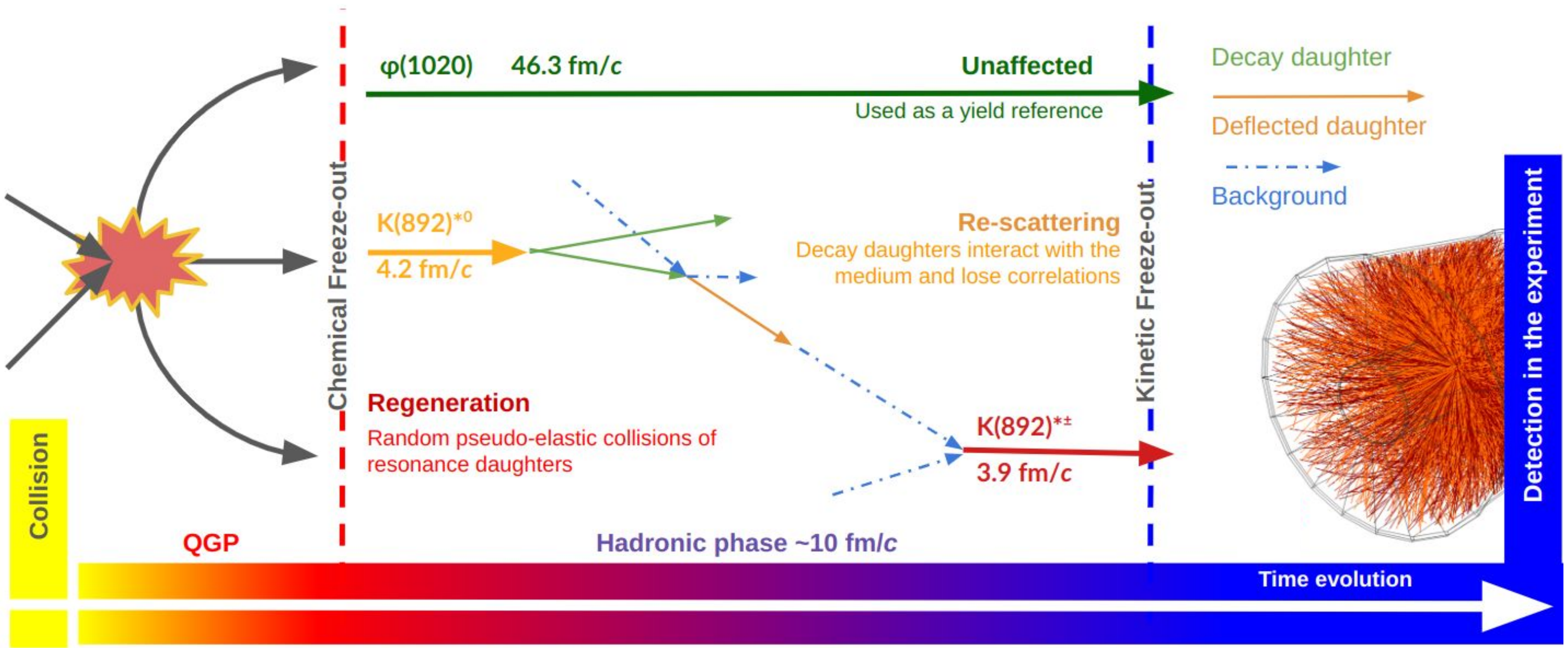
Motivation

Probing the properties of hadronic phase

- Resonances have **lifetimes** compare to that of the **Hadronic phase**
  - allow the study of properties of the hadronic phase in terms of **regeneration and re-scattering** effects
  - estimate the **duration between chemical and kinetic freeze-out**



Regeneration: pseudo-elastic scattering of decay products

→ ***Enhanced*** yield

Re-scattering: resonance decay products undergo elastic scattering or pseudo-elastic scattering through a different resonance state

→ Not reconstructed through invariant mass

→ ***Reduced*** yield

Resonances (particles & decay)

ALICE

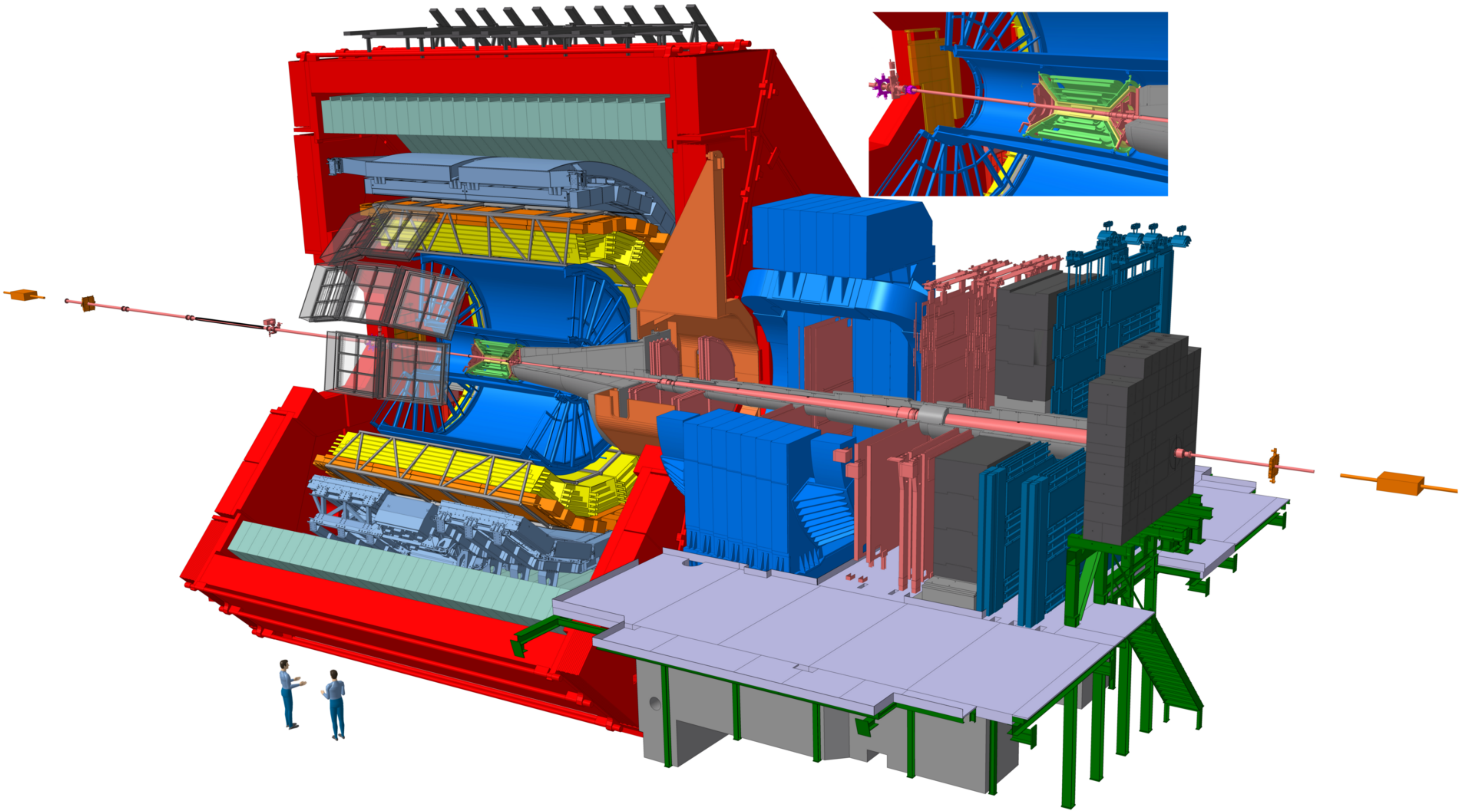
Meson	quark content	Decay modes	B.R.
$\rho(770)^0$	$(u\bar{u}+d\bar{d})/\sqrt{2}$	$\pi^+\pi^-$	100
$K^*(892)^0$	$d\bar{s}$	$K^+\pi^-$	66.6
$K^*(892)^\pm$	$u\bar{s}$	$K^0_S\pi^+$	33.3
$f_0(980)$, $f_2(1270)$	unknown	$\pi^+\pi^-$	46(84)
$K^*_{0,2}(1430)^0$	$d\bar{s}$	$K^+\pi^-$	93(49.4)
$\phi(1020)$	$s\bar{s}$	K^+K^-	48.9

Baryon	quark content	Decay modes	B.R.
$\Sigma(1385)^+$	uus	$\Lambda\pi^+$	87
$\Sigma(1385)^-$	dds	$\Lambda\pi^-$	87
$\Lambda(1520)$	uds	pK^-	22.5
$\Xi(1530)^0$	uss	$\Xi^-\pi^+$	66.7
$\Xi(1820)^{\mp,0}$	dss (uss)	$\Lambda K^\mp$ (ΛK^0_S)	unknown
$\Omega(2012)^\mp$	sss	$\Xi^\mp K^0_S$	unknown

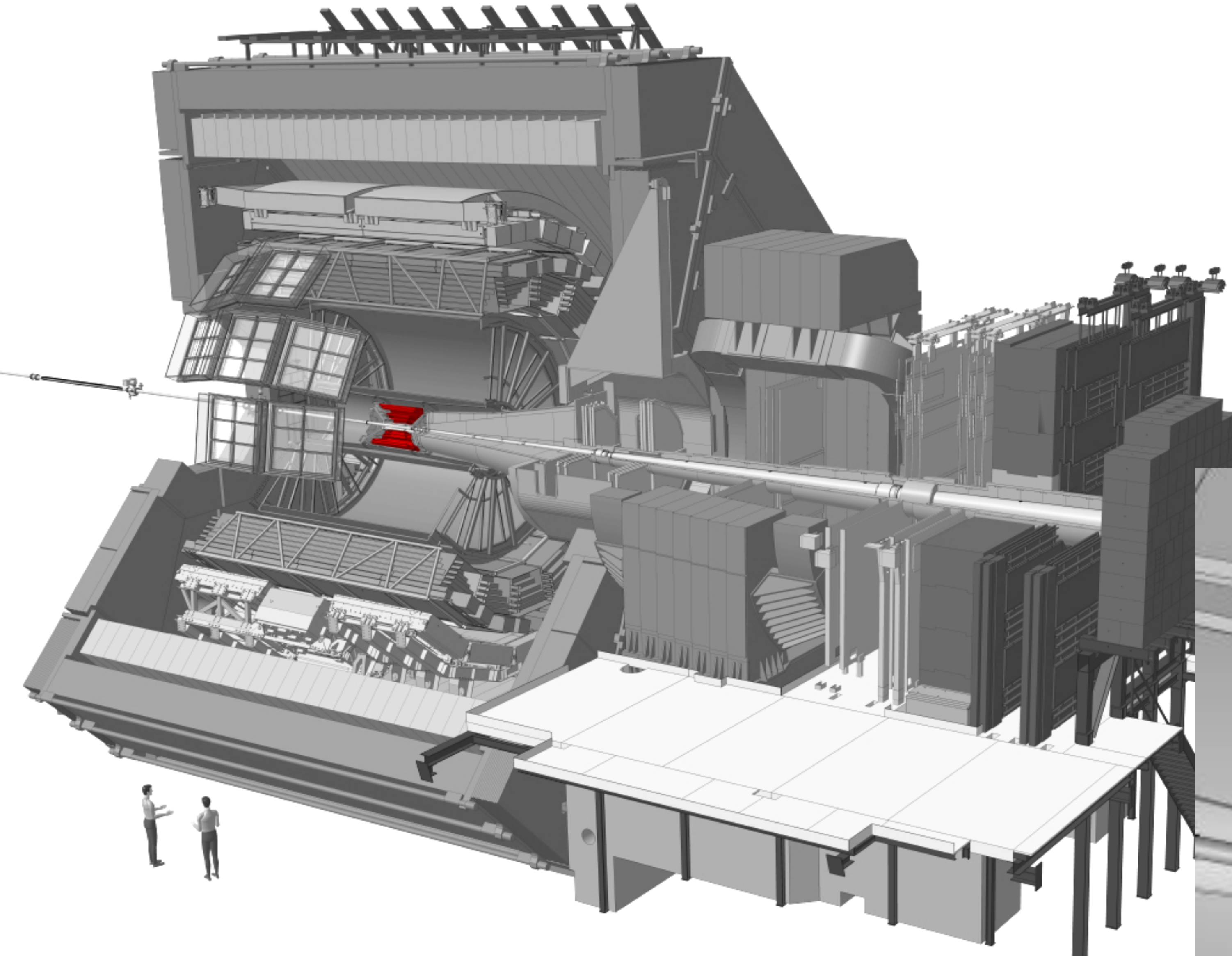
Lifetime(fm/c)

$$\rho(1.3) < K^{*\pm}(3.6) < K^{*0}(4.2) < \Sigma^{*\pm}(5.0\text{-}5.5) < \Lambda^*(12.6) < \Xi^*(21.7) < \phi(46.2)$$

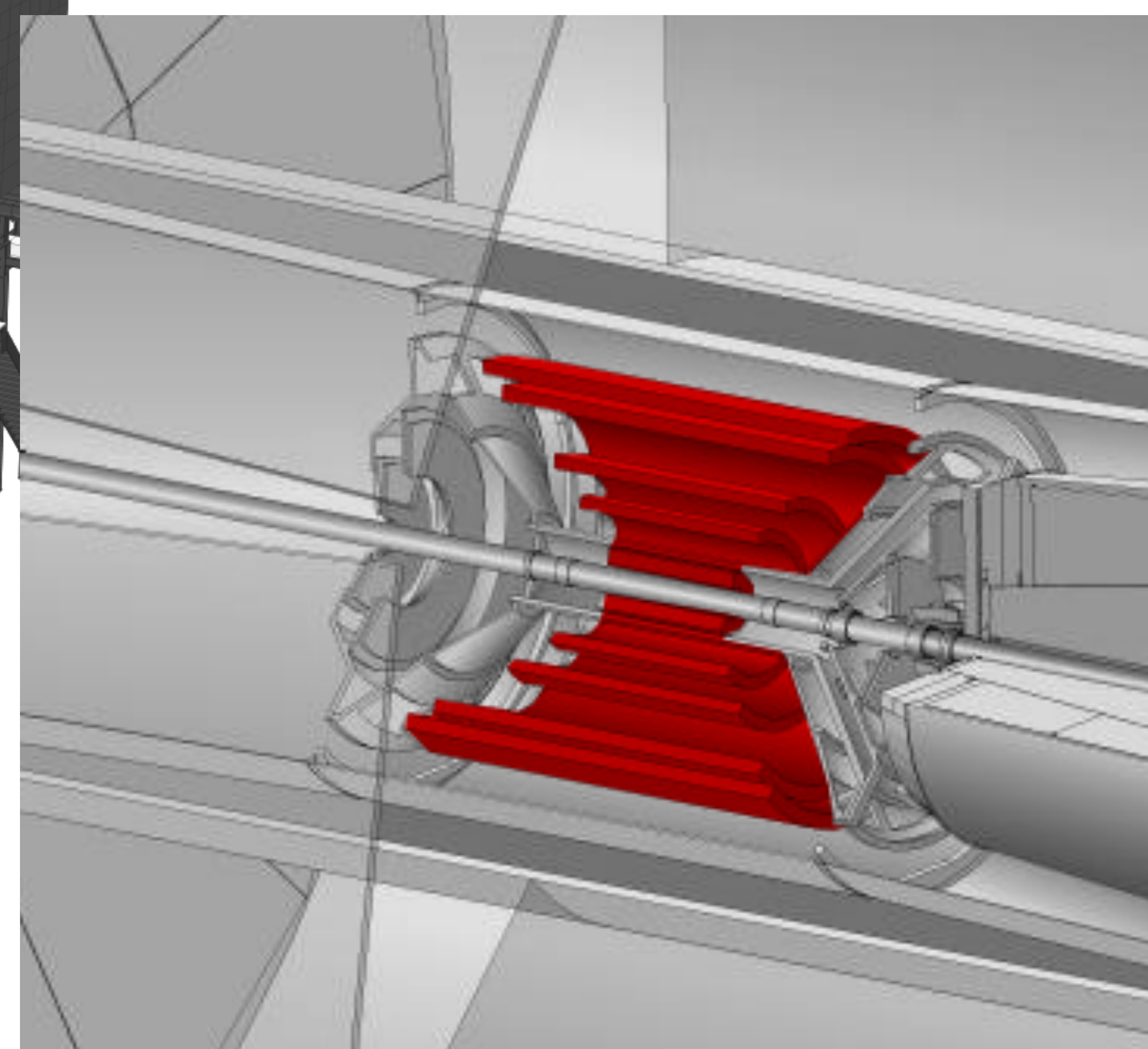
A Large Ion Collider Experiment: ALICE



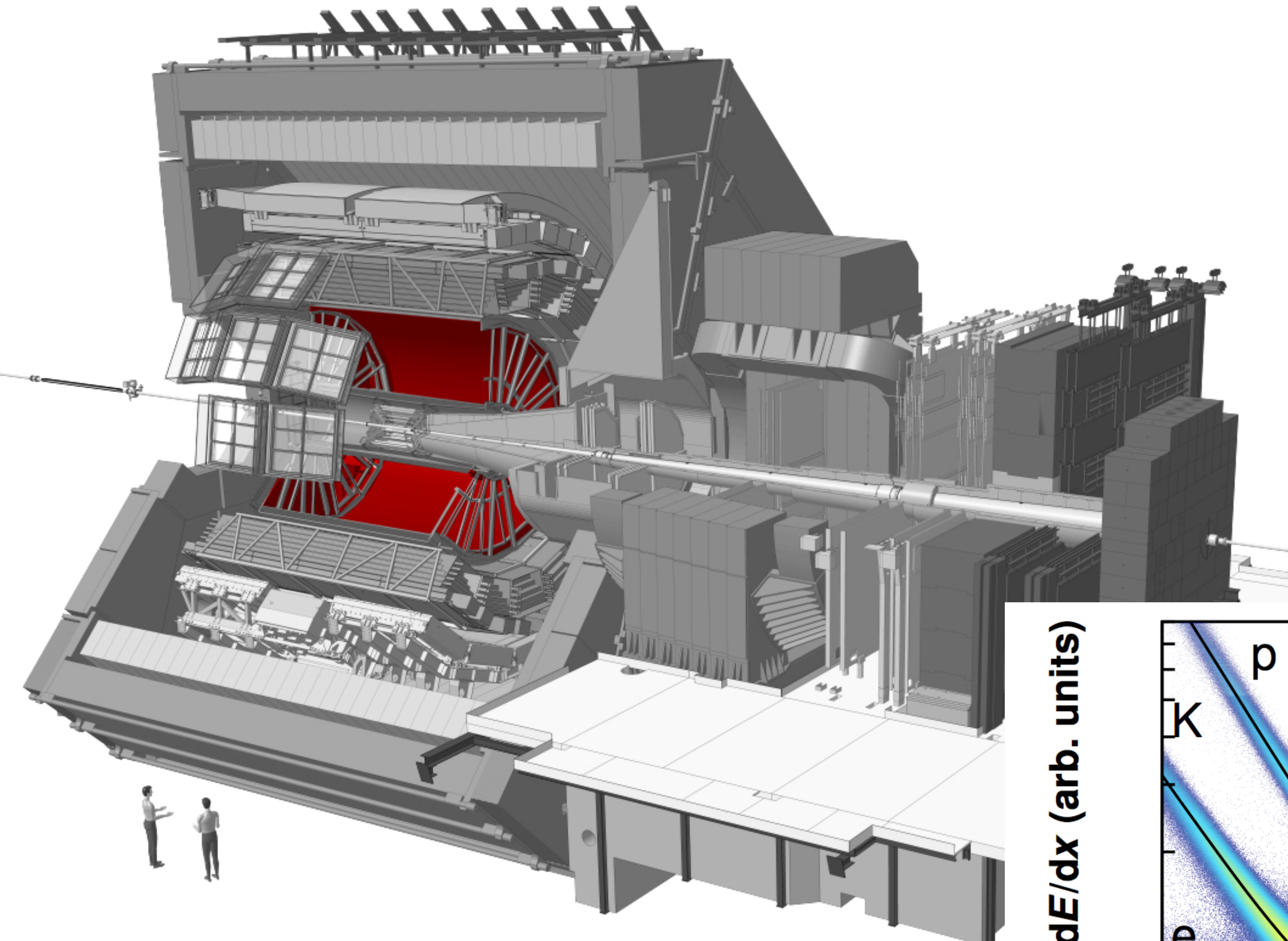
The ALICE detector



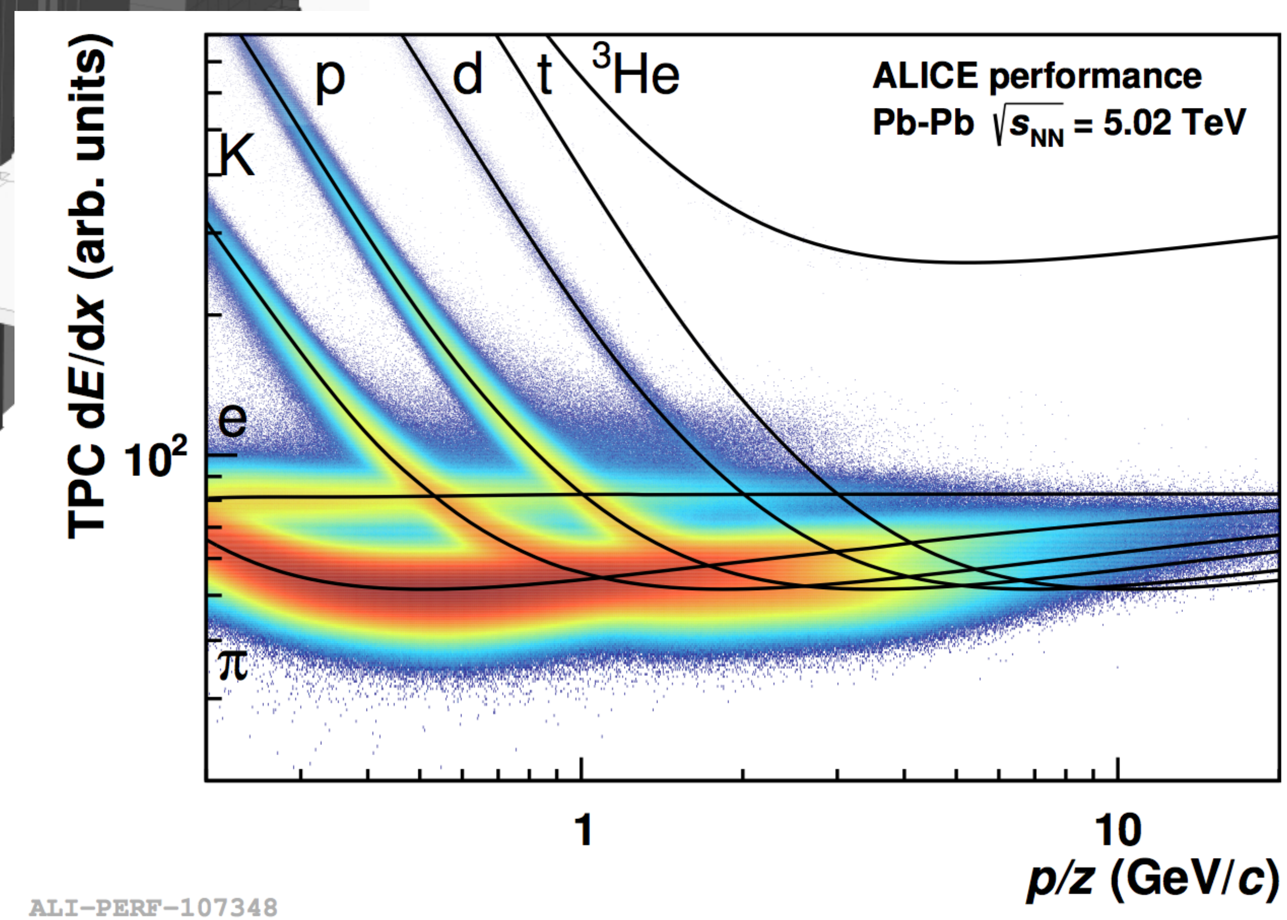
- **Inner Tracking System (ITS)**
  - Trigger, tracking, vertex, PID (dE/dx)



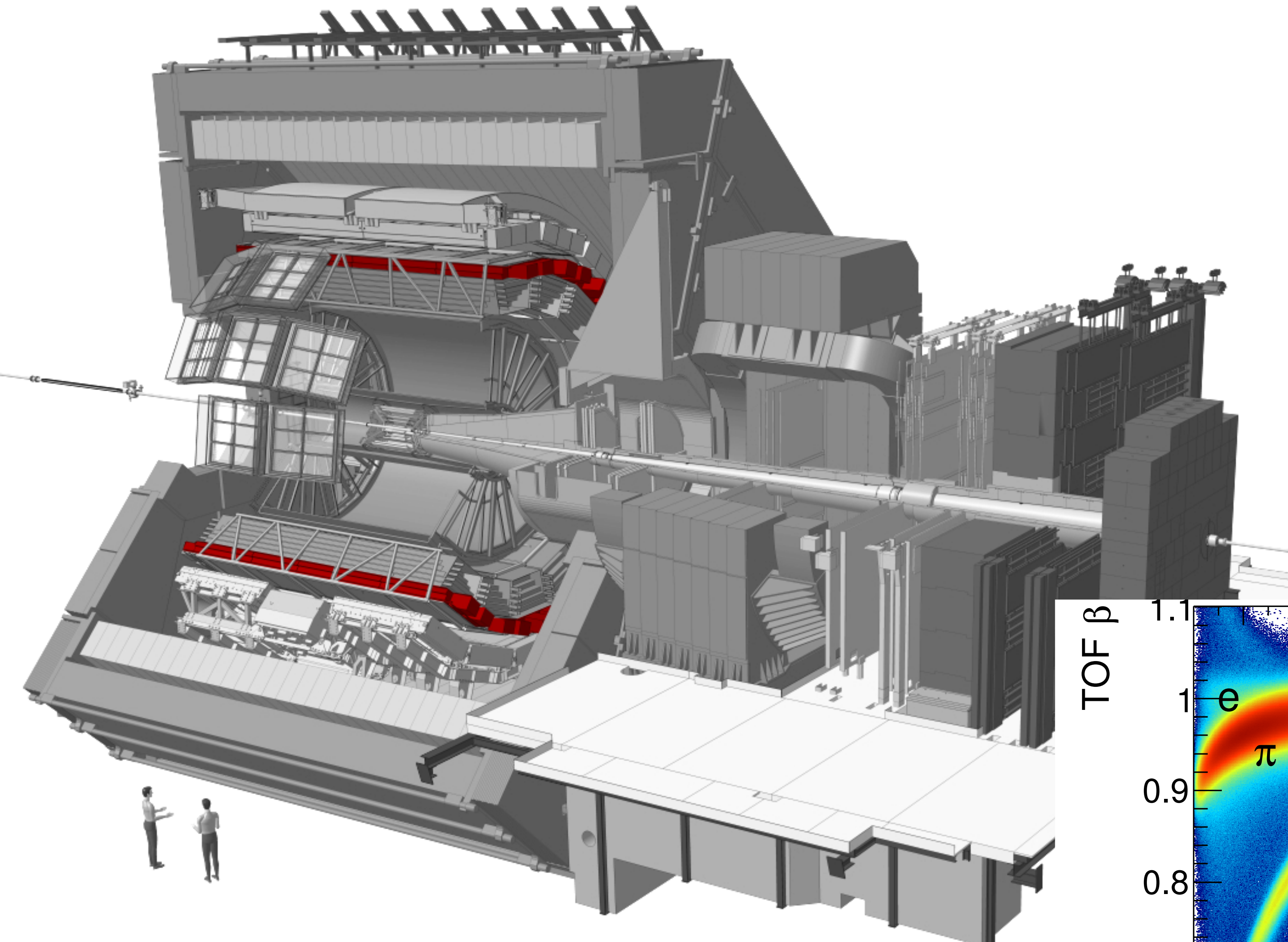
The ALICE detector



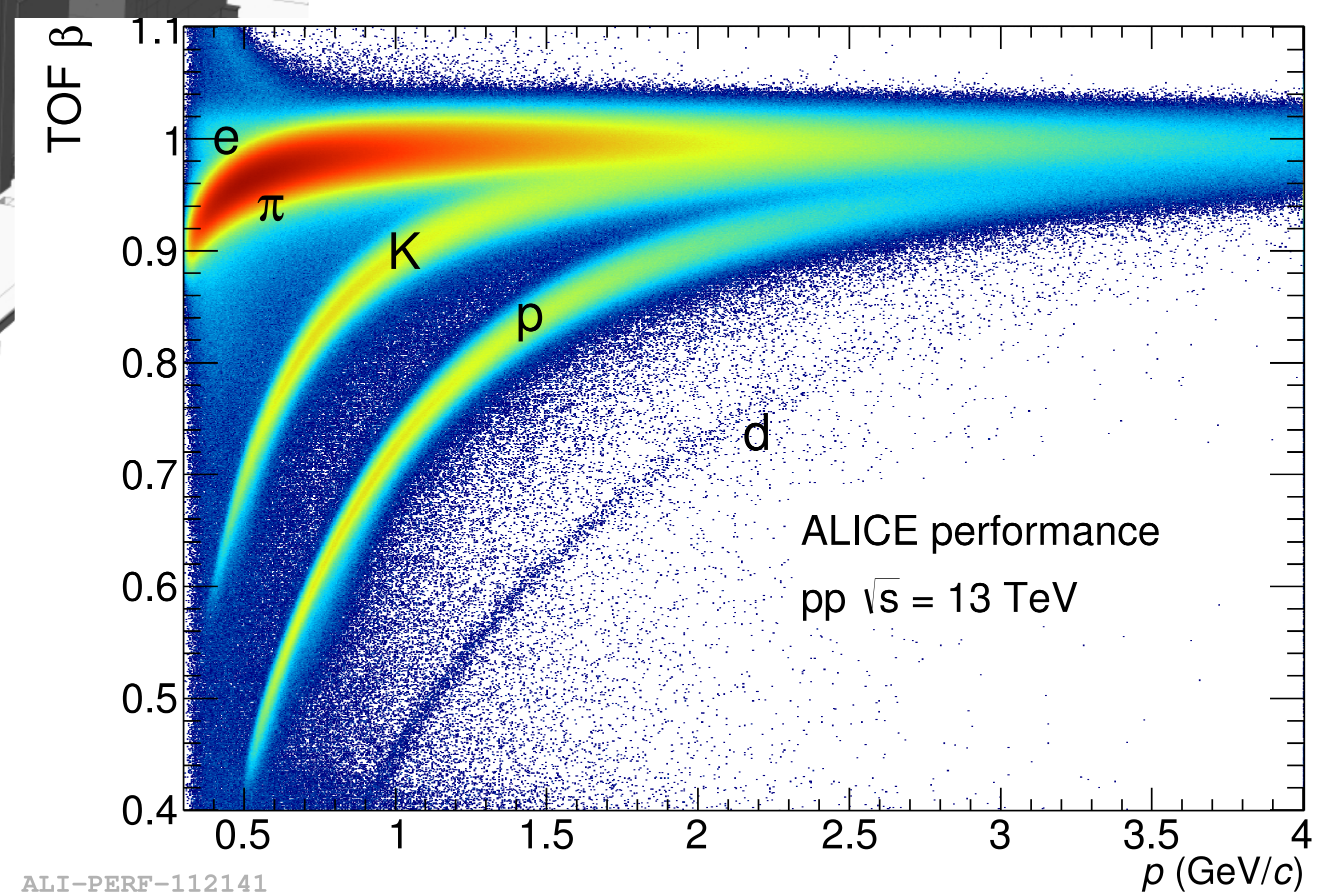
- **Time Projection Chamber (TPC)**
  - Gas-filled ionization detector
  - Tracking, vertex, PID, (dE/dx)



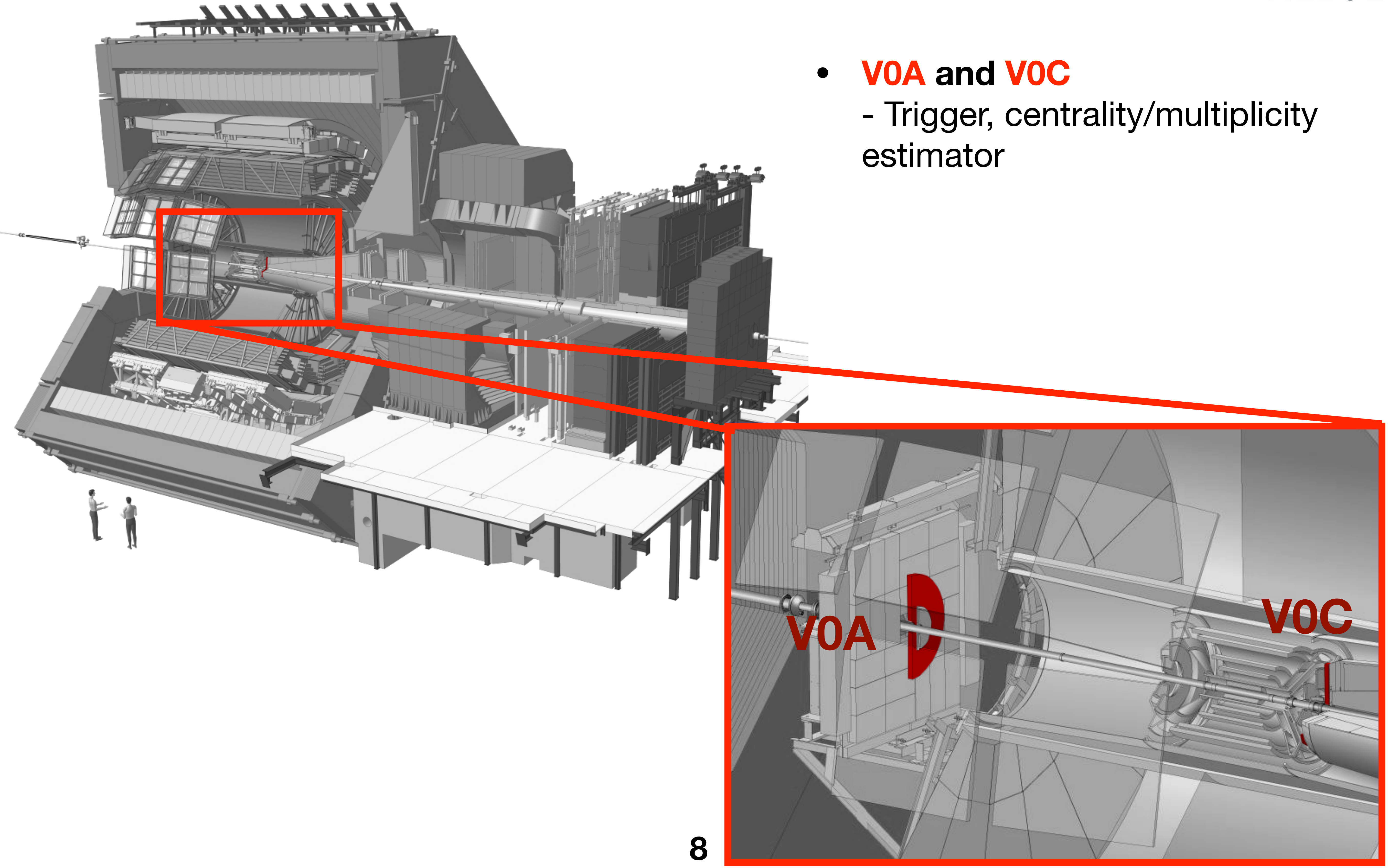
The ALICE detector



- **Time Of Flight (TOF)**
  - PID through particle time of flight

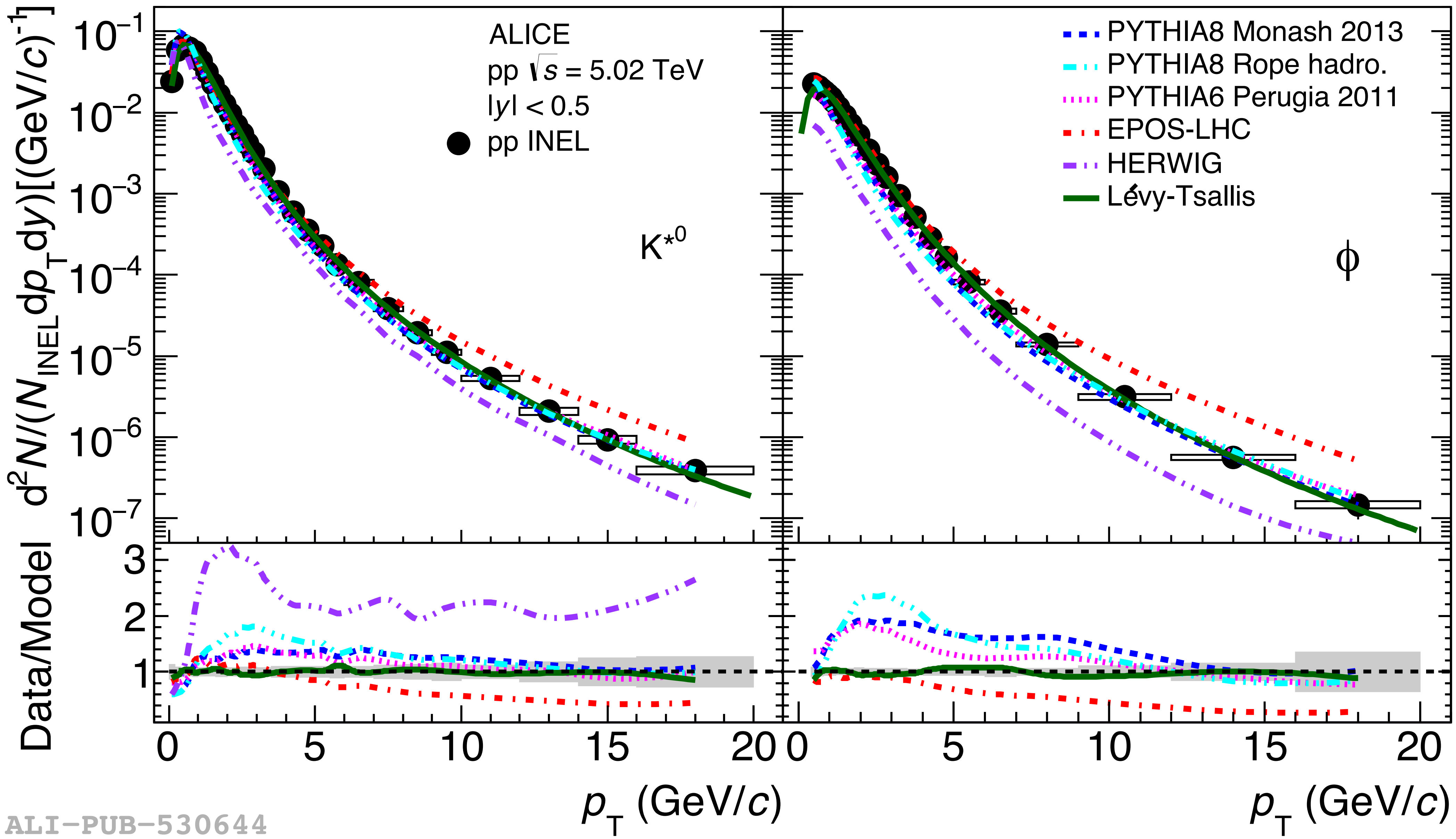


The ALICE detector



- **V0A and V0C**
  - Trigger, centrality/multiplicity estimator

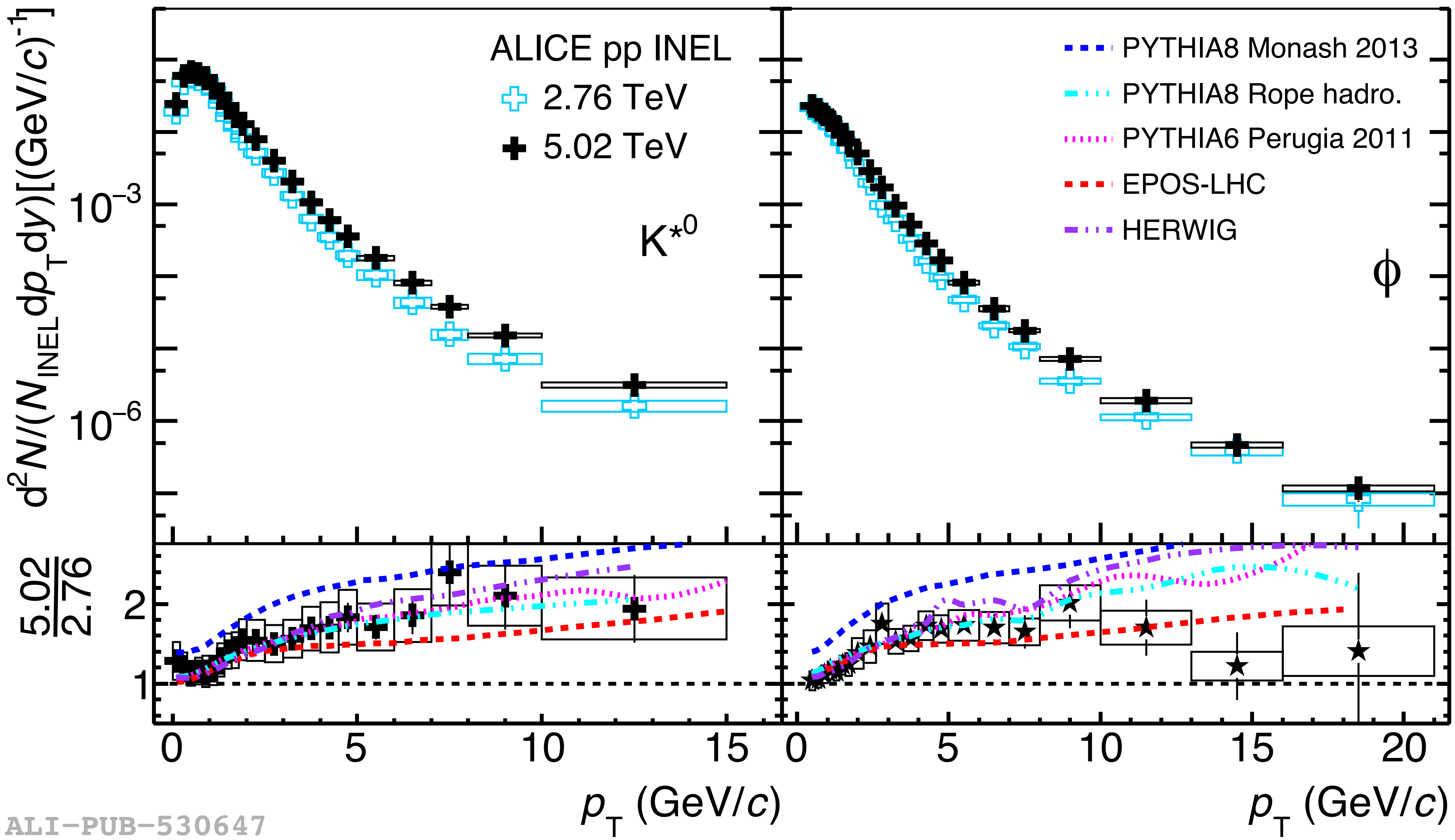
p_T spectra: pp



- Results are compared with several model calculations

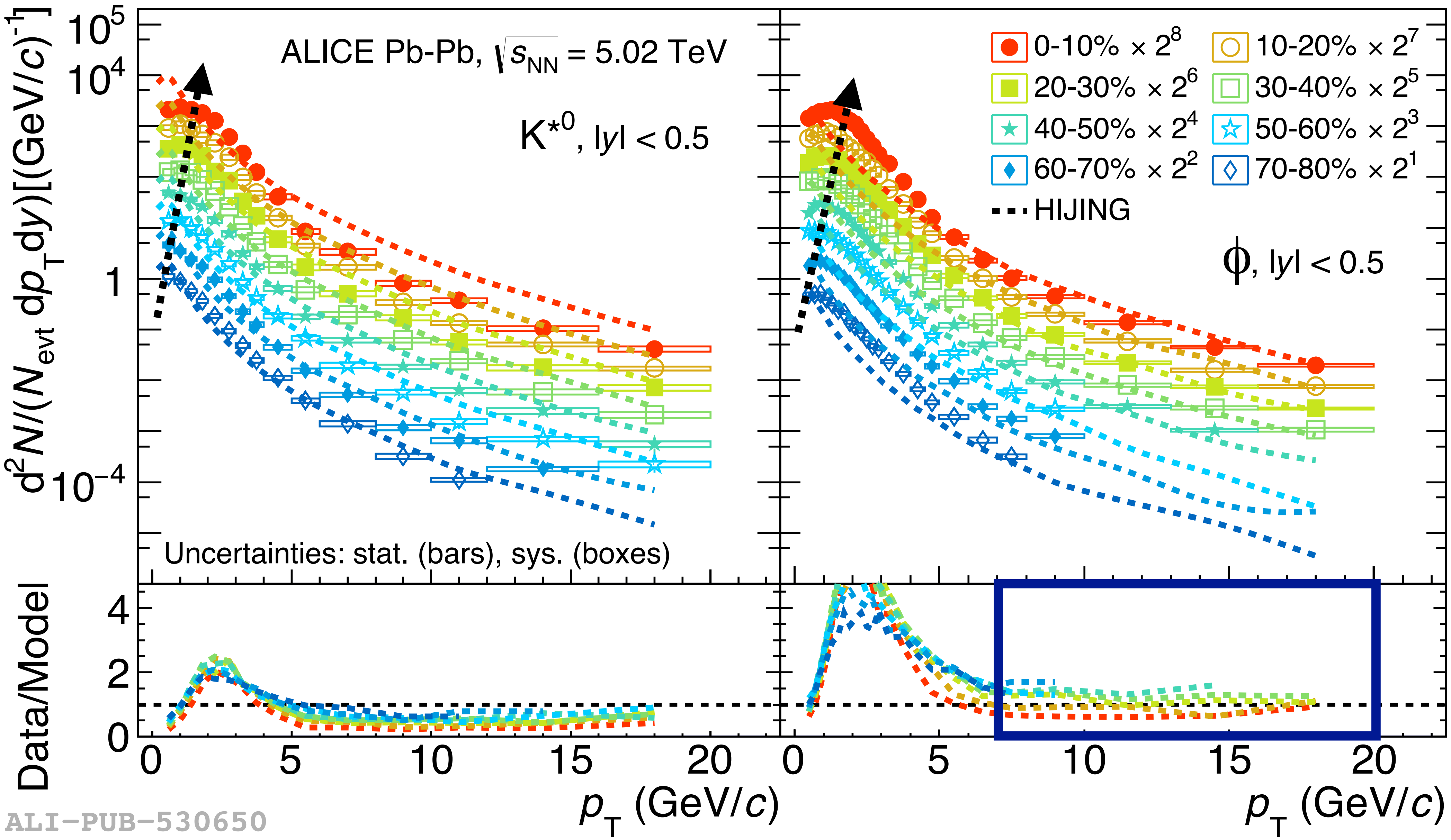
arXiv:2106.13113

p_T spectra: pp



- Yields of both K*0 and ϕ mesons are higher at $\sqrt{s}$ = 5.02 TeV compared to $\sqrt{s}$ = 2.76 TeV

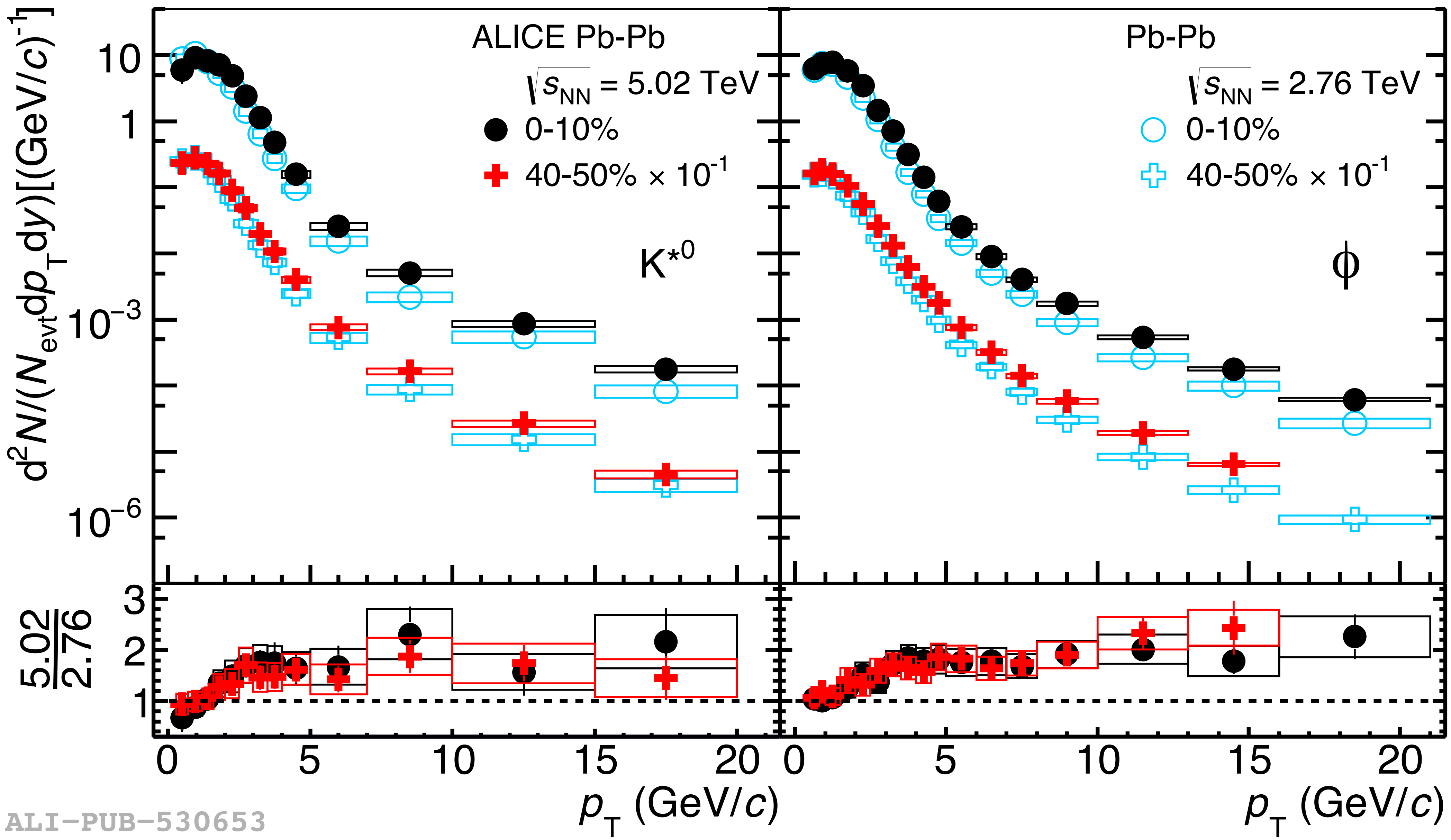
p_T spectra: Pb-Pb



- Hardening of particle spectra from peripheral to central collisions

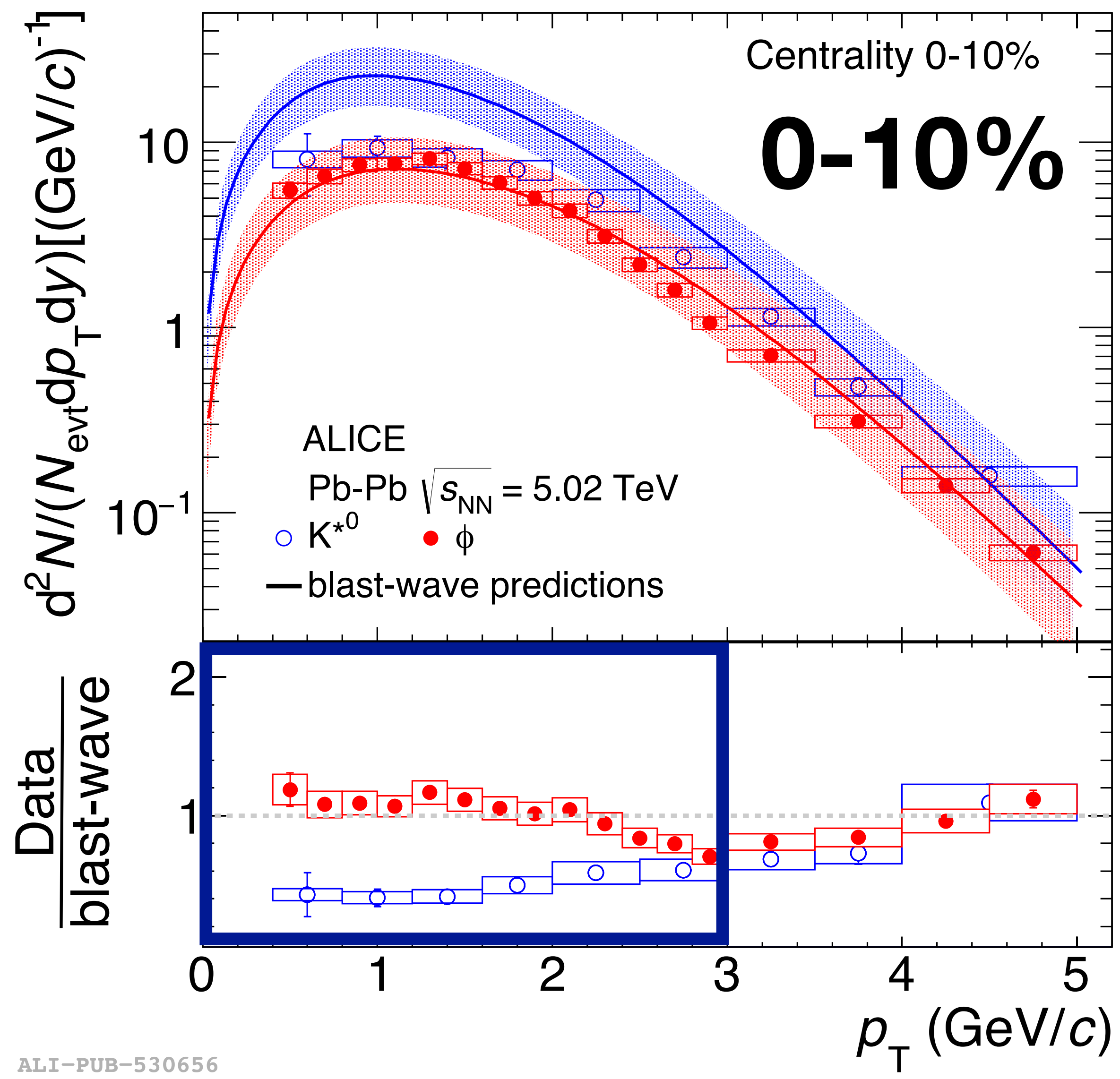
p_T spectra: Pb-Pb

ALICE



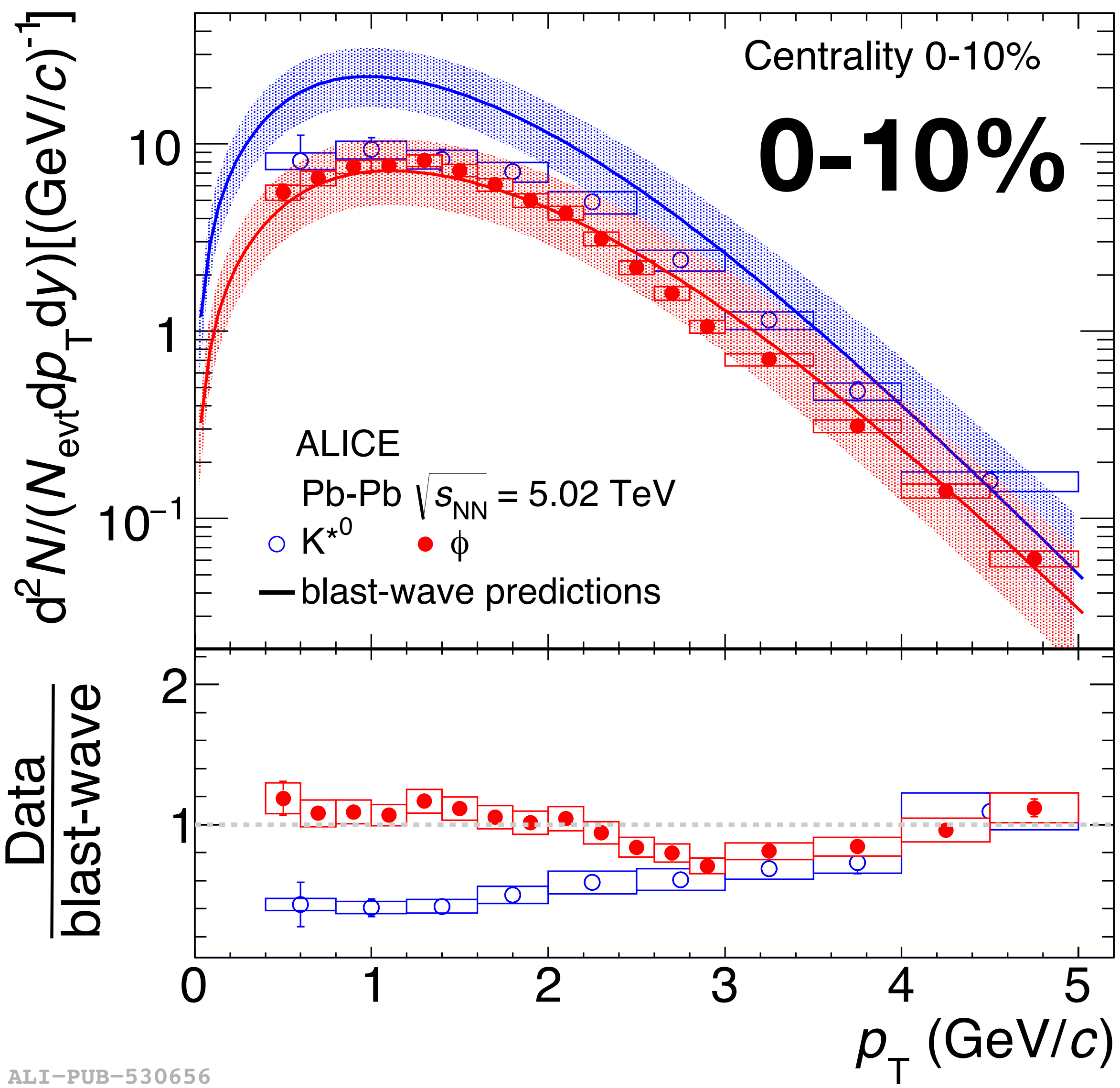
- Ratio of p_T spectra increase with p_T and tend to saturate at high p_T for both mesons in central and semi-central collisions

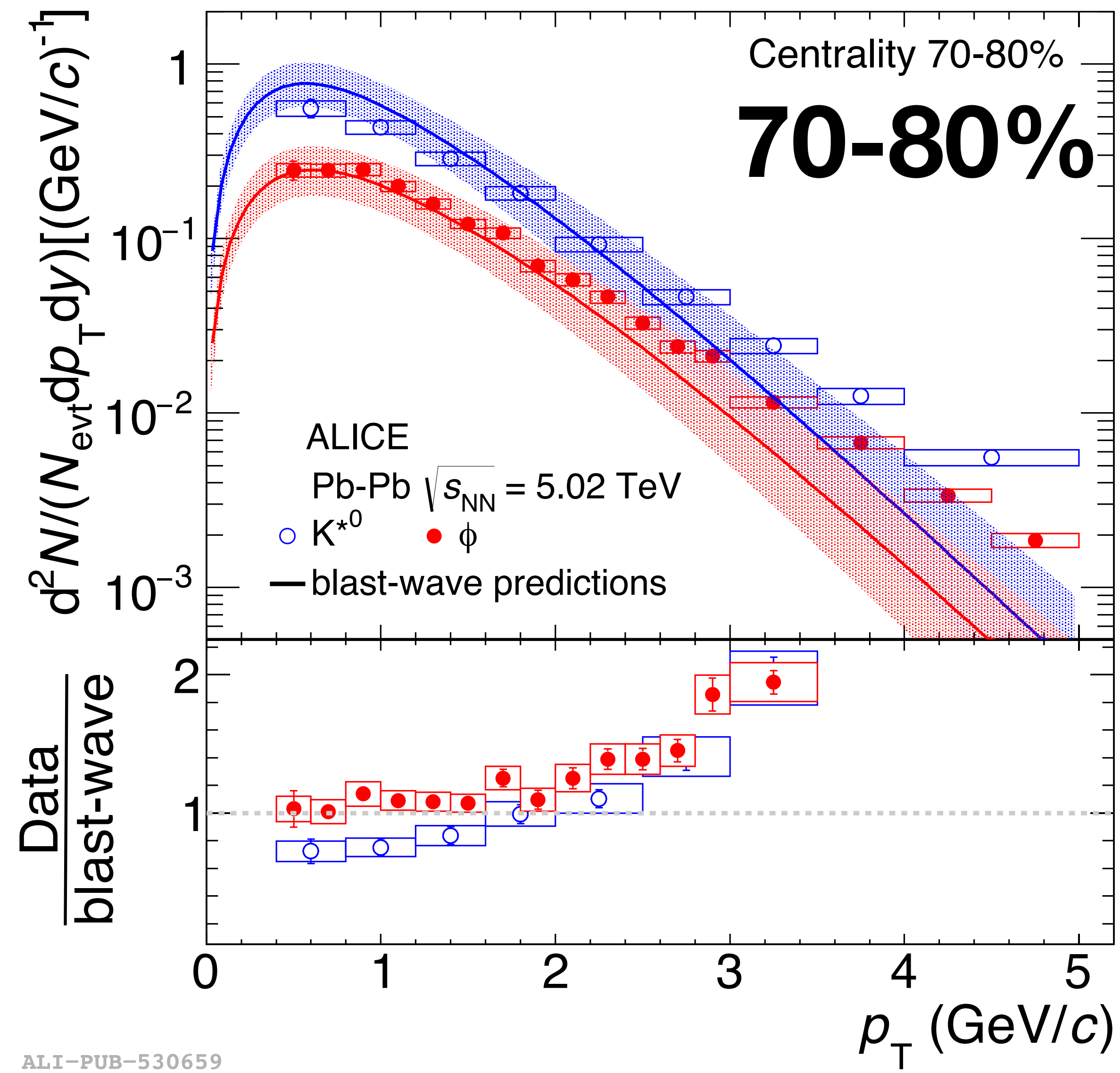
p_T spectra: model comparison



- K^{*0} yields is suppressed at low p_T with respect to that blast-wave model prediction

p_T spectra: model comparison





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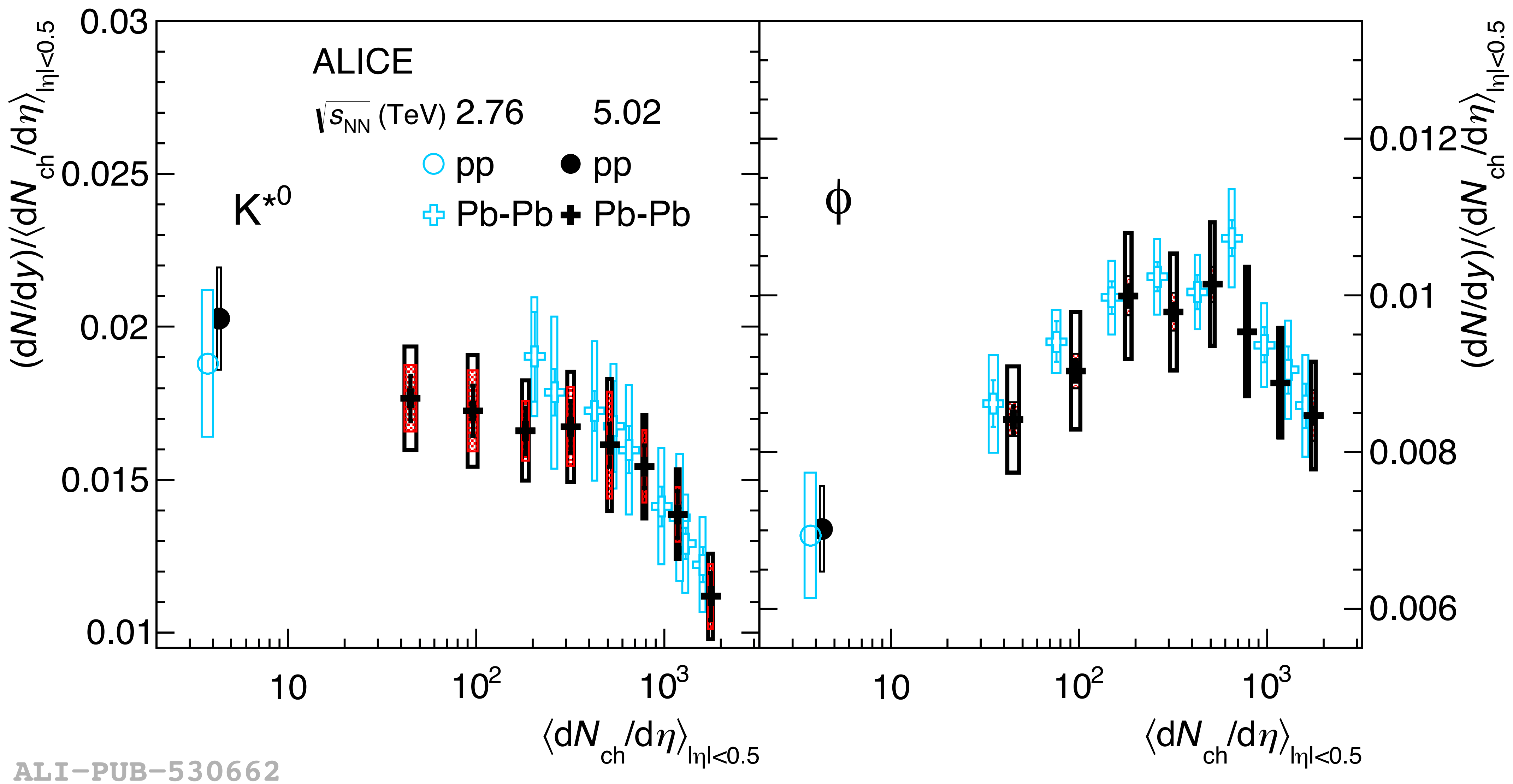
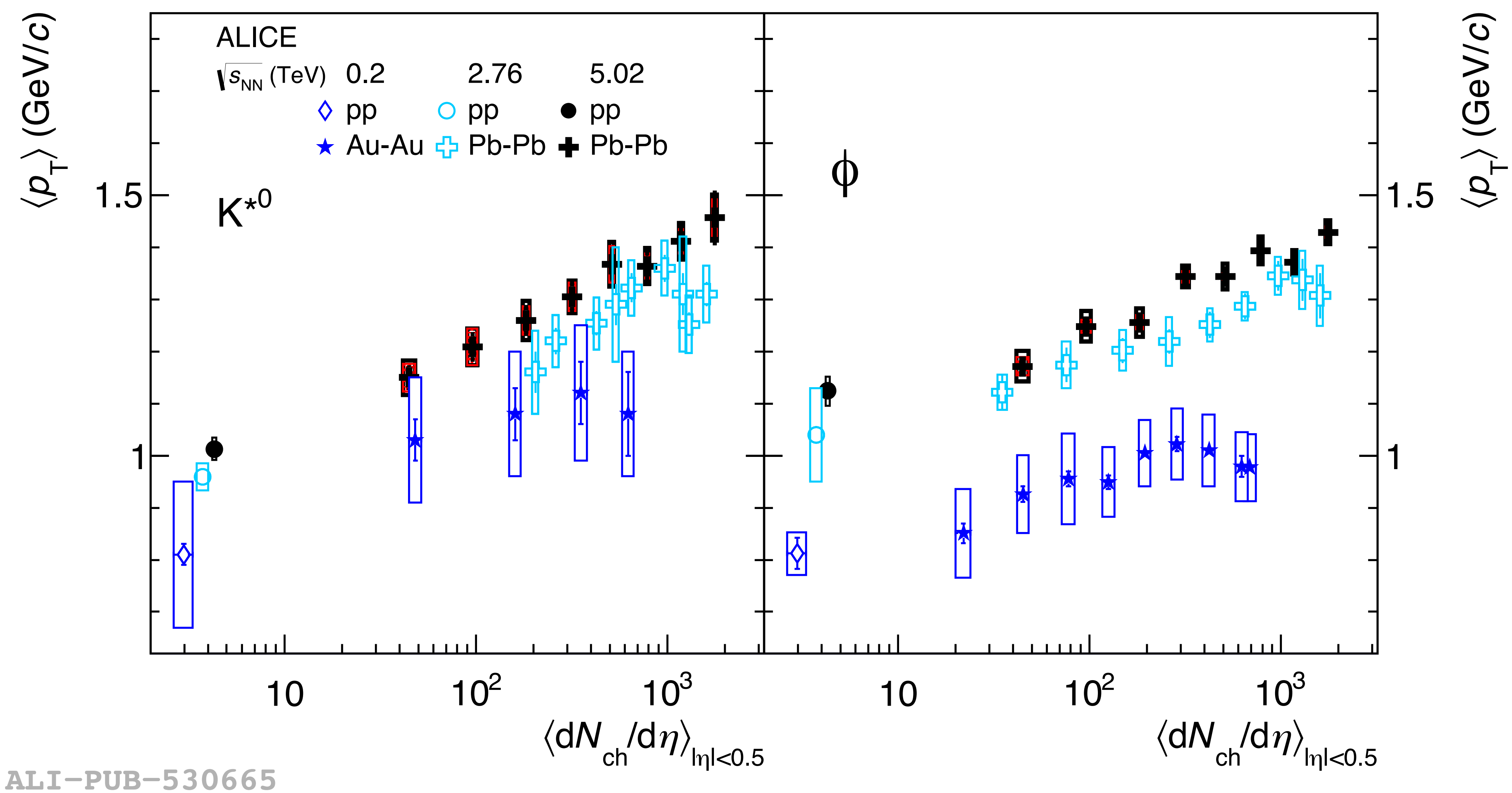
p_T integrated yields



- p_T-integrated yields of K*0 and ϕ scaled by average charged particle multiplicity measured at mid-rapidity as a function of multiplicity for pp and Pb-Pb collisions are presented

- Dependence of the normalized d*N*/d*y* is similar regardless of the beam energy

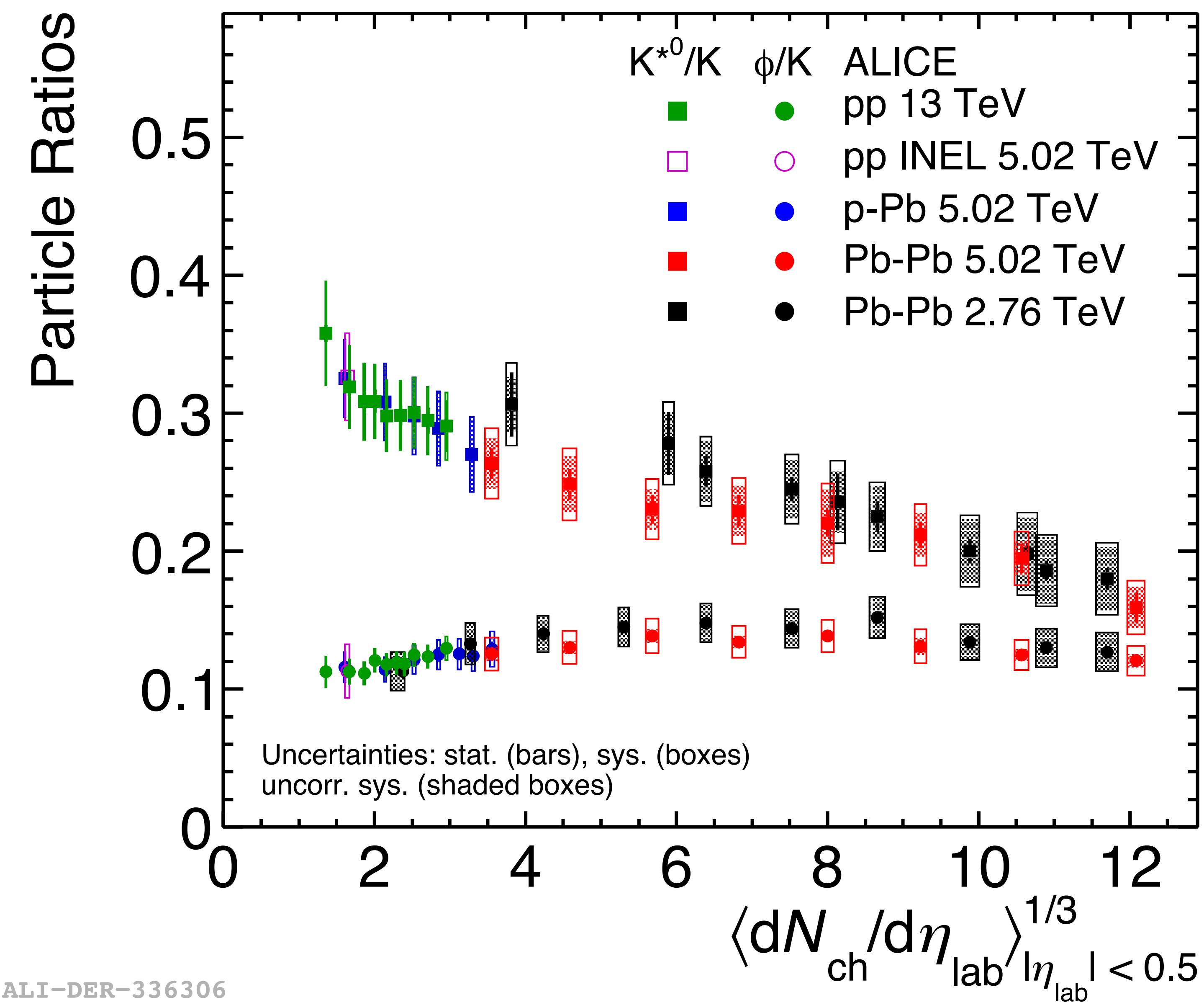
Mean transverse momentum



- $\langle p_T \rangle$ of K^{*0} and ϕ as a function of multiplicity for pp and Pb-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV, $\sqrt{s_{NN}}$ = 2.76 TeV and Au-Au and pp collisions at $\sqrt{s_{NN}}$ = 200 GeV are shown

- There is energy dependence between RHIC and LHC energies

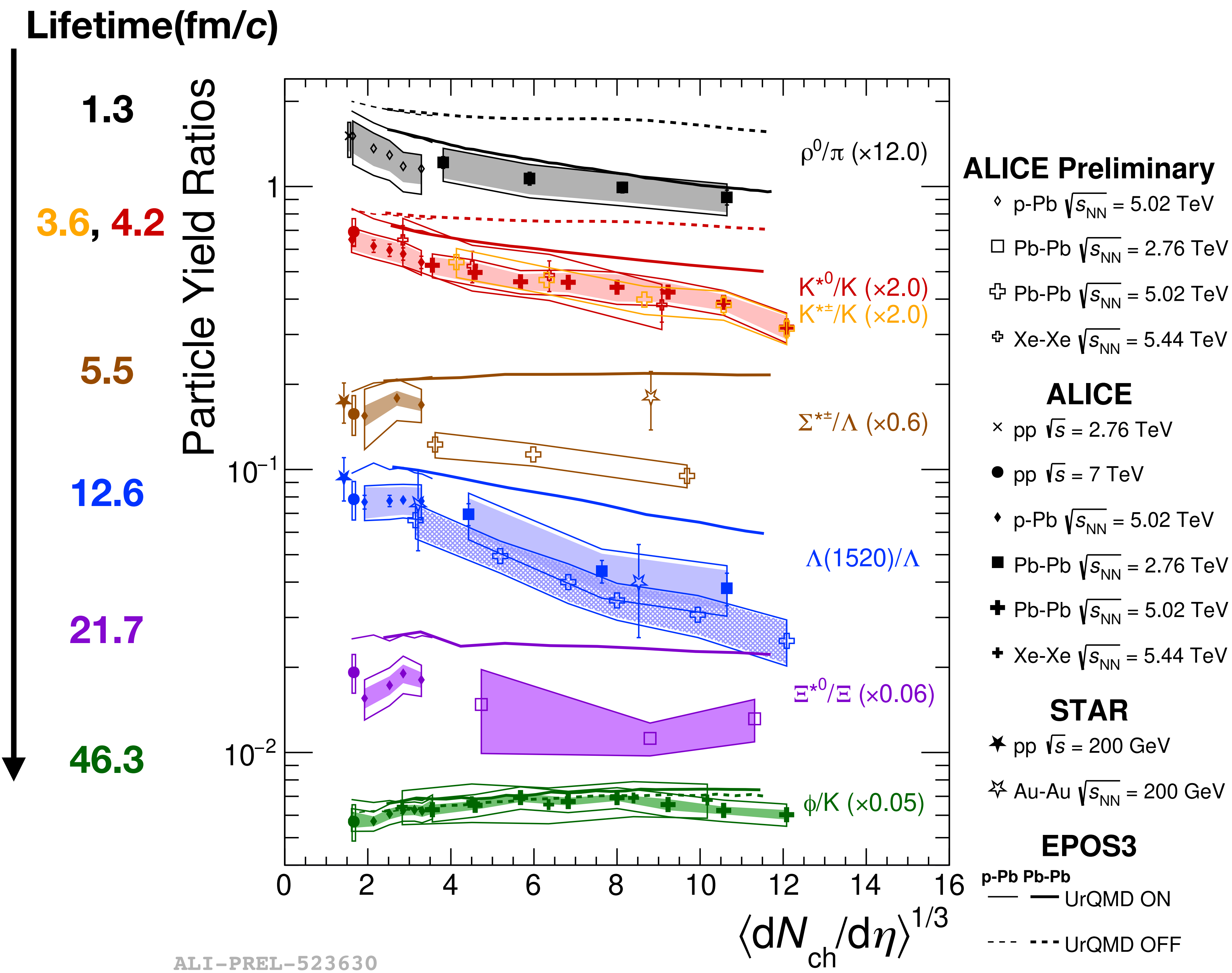
Particle yield ratios



- Suppression of K^{*0}/K in central heavy-ion collisions w.r.t. peripheral Pb—Pb, p—Pb and pp collisions
  - suggests K^{*0} **re-scattering** is dominant over **regeneration**
- Suppression in small systems at high multiplicity
  - hadronic phase also in small systems?
- No suppression of ϕ/K
  - due to larger ϕ lifetime

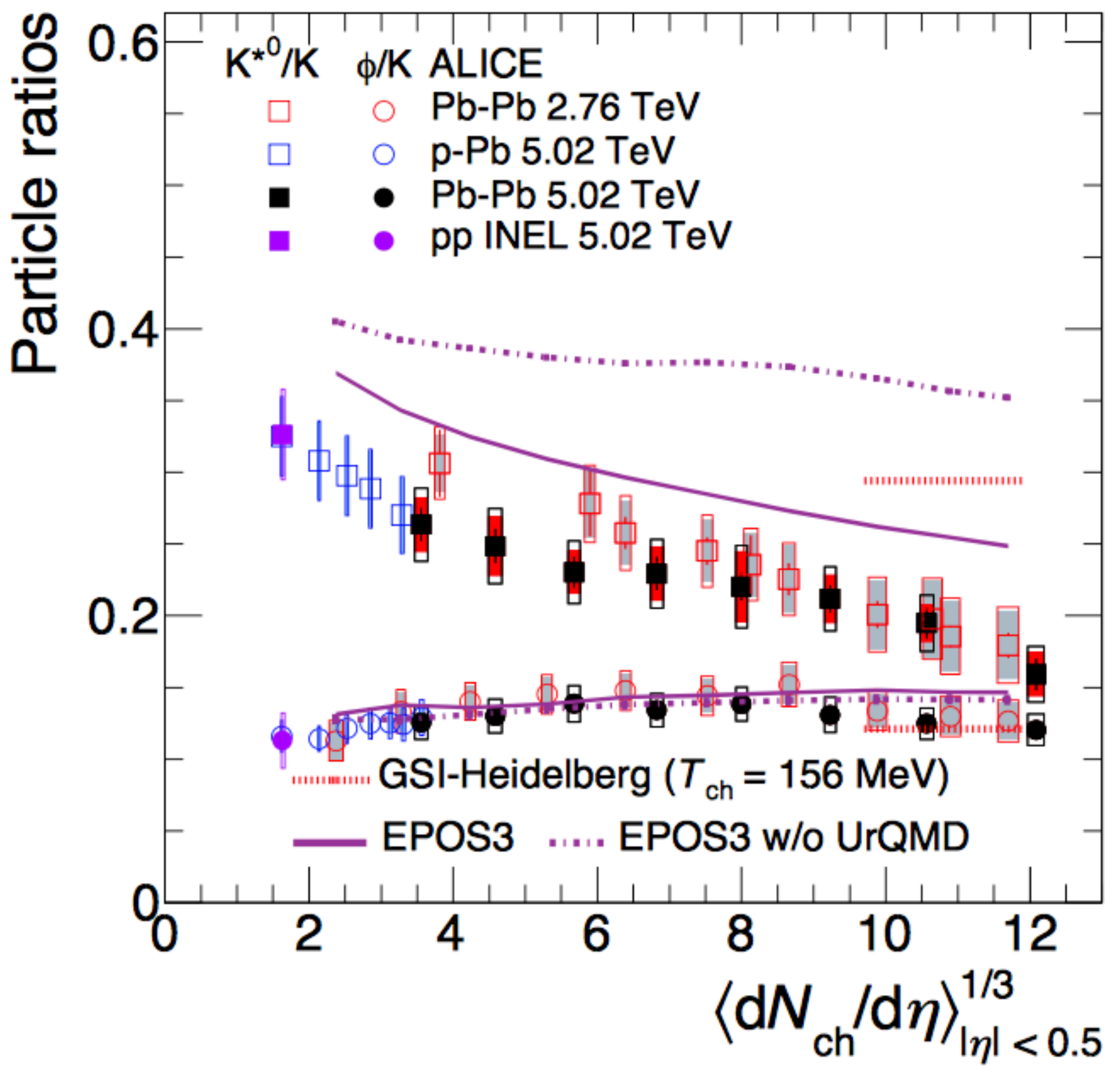
Lifetime(fm/c): ρ(1.3) < **K^{*0}(4.2)** < Σ*(5.5) < Λ*(12.6) < Ξ*(21.7) < **ϕ(46.2)**

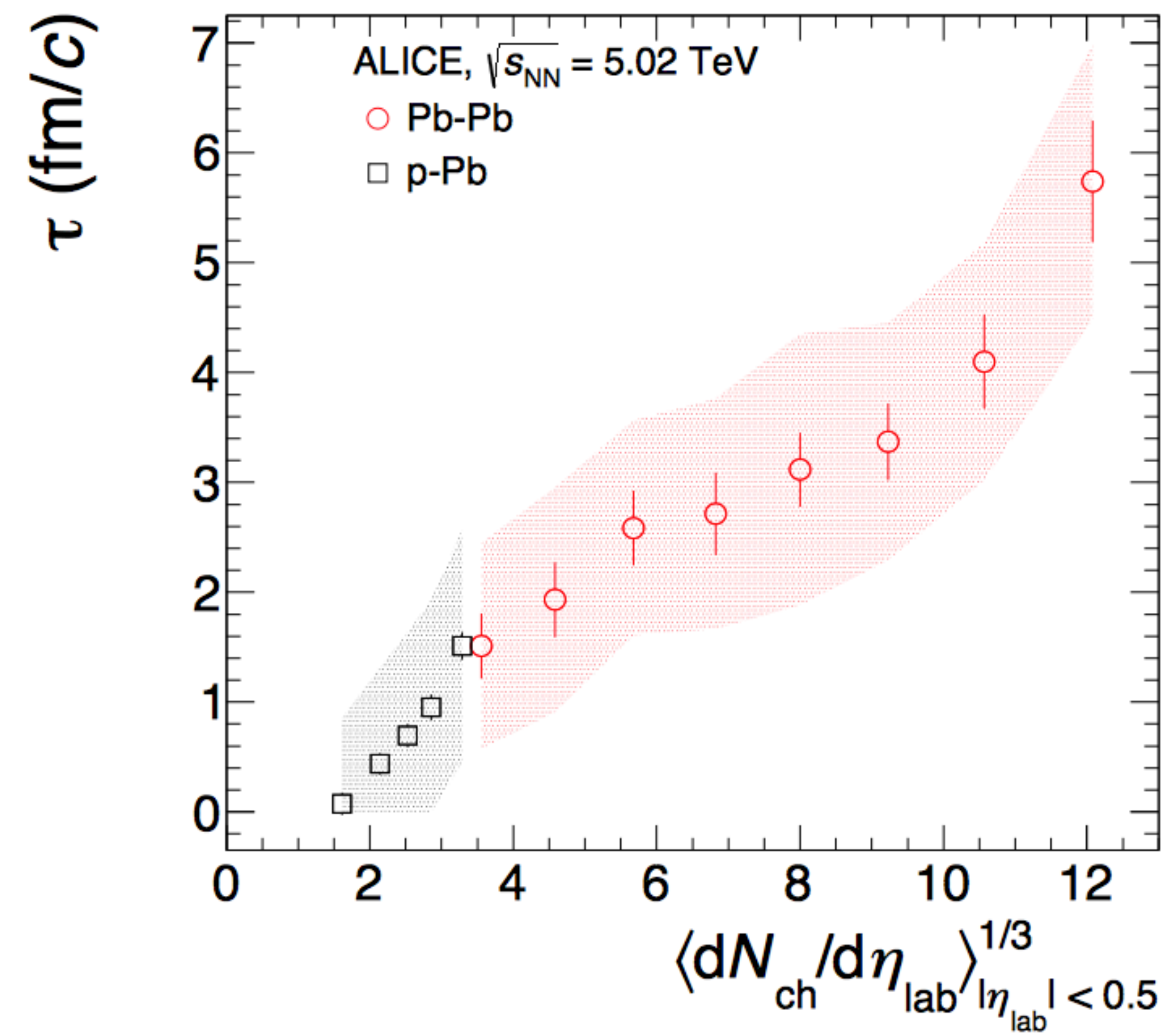
Resonance to long-lived particle ratios



- **suppression** of the ratios of **short-lived resonances** in central Pb-Pb collisions
  - indicates *dominance of re-scattering over regeneration*
- no significant centrality dependence for long-lived resonances e.g. Ξ^*,ϕ
- **no energy dependence** from RHIC to LHC
- smooth trend: pp→pA→AA

Probing the hadronic phase





$$[K^{*0}/K]_{kinetic(Pb\text{-}Pb)} = [K^{*0}/K]_{chemical(pp)} \times e^{-\tau/\tau_{K^{*0}}}$$

- Estimate the **time duration between chemical and kinetic freeze-out** from the measurement of K^{*0}/K ratios in Pb-Pb and pp collisions
  - lifetime of hadronic phase smoothly increases with multiplicity
  - found to be ~4-7 fm/c for central collisions

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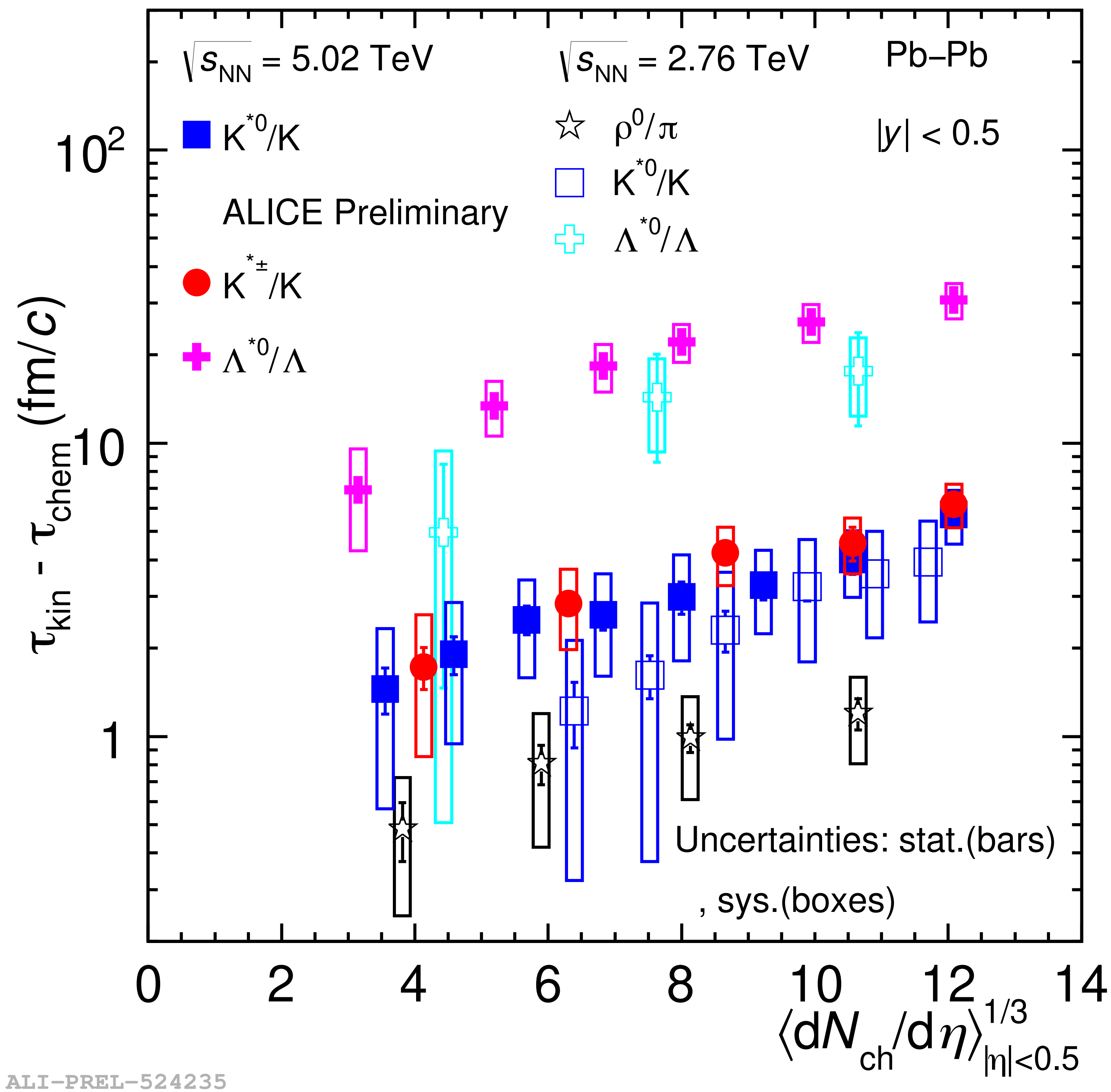
Probing the hadronic phase

Dukhishyam Mallic (SQM2022)



- Summary of estimation of the lower limit of hadronic phase for ρ^0/π, K^{*0}/K, $K^{*\pm}/K$, and Λ^*/Λ
- Estimated time duration measured in $\sqrt{s_{NN}}$=5.02 TeV energy seems larger than those from $\sqrt{s_{NN}}$=2.76 TeV
  - But within the systematic error
- Need theory input to have better understanding

Conclusion

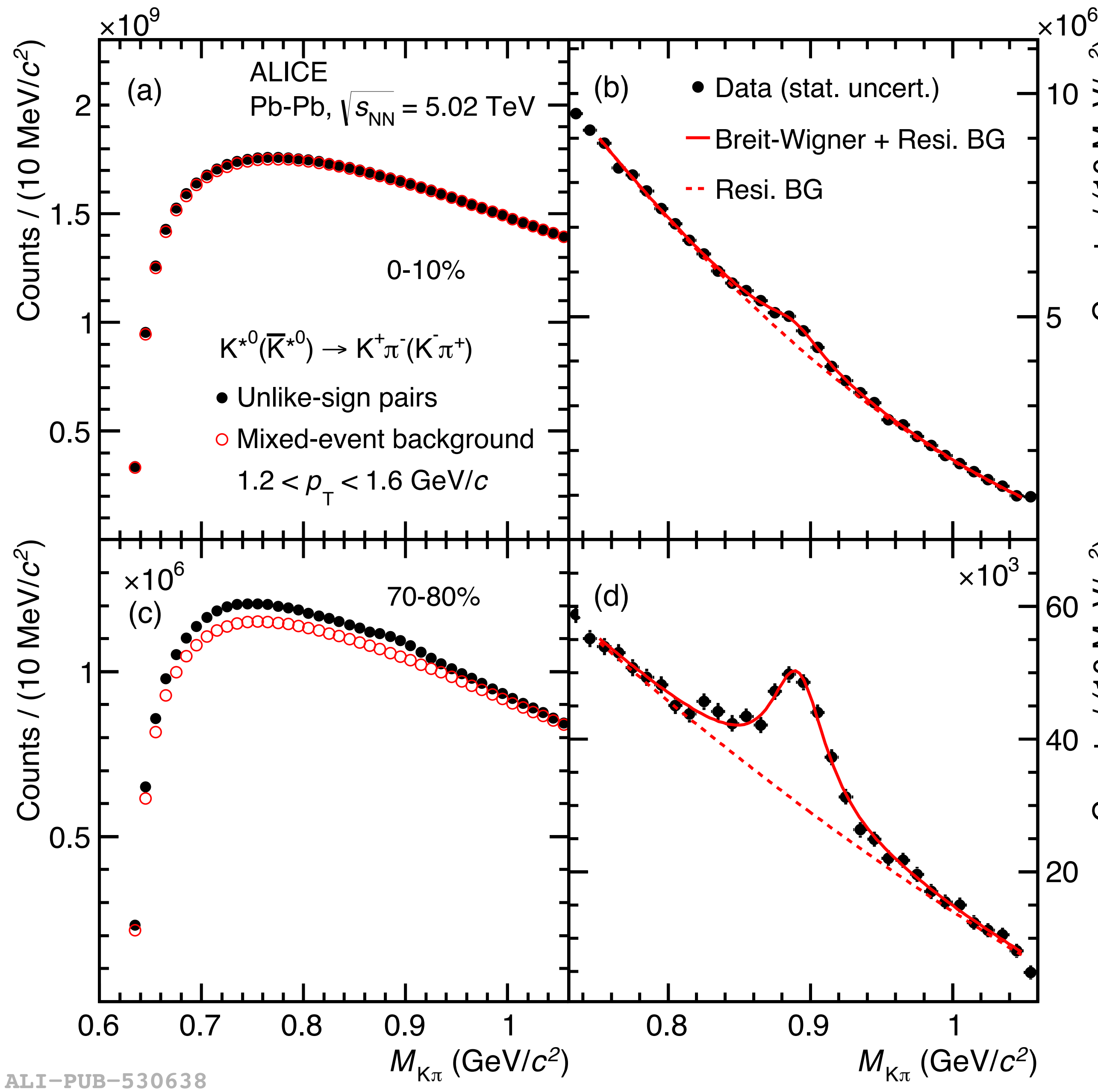
- Hadronic resonances are valuable probes to study the properties of hadronic phase
- **p_T-spectra of K^{*0} and ϕ are presented in pp and Pb-Pb collisions at 5.02 TeV** and compared with the spectra obtained at 2.76 TeV
- p_T spectra are compared with model
- p_T-integrated yields and $\langle p_T \rangle$ of the mesons are presented
- **Suppression of short-lived resonances** in large collision systems
  - dominance of re-scattering over regeneration
  - no suppression observed for the longer-lived resonances
- **time duration between chemical and kinetic freeze-out** is estimated with resonances

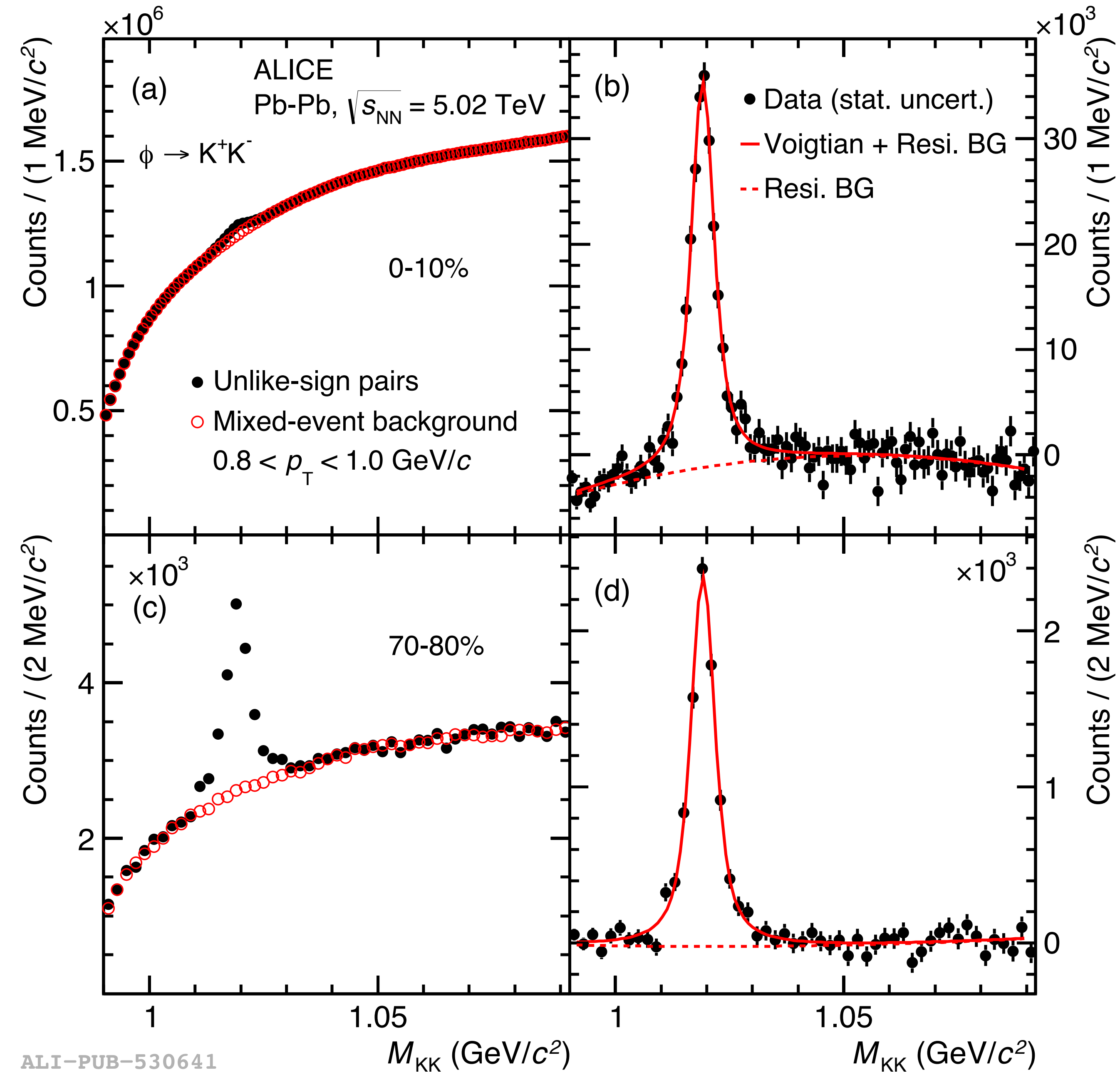
Backup

Invariant mass distribution: K*0 and ϕ

$K^{*0} \rightarrow K^{\mp}\pi^{\pm}$

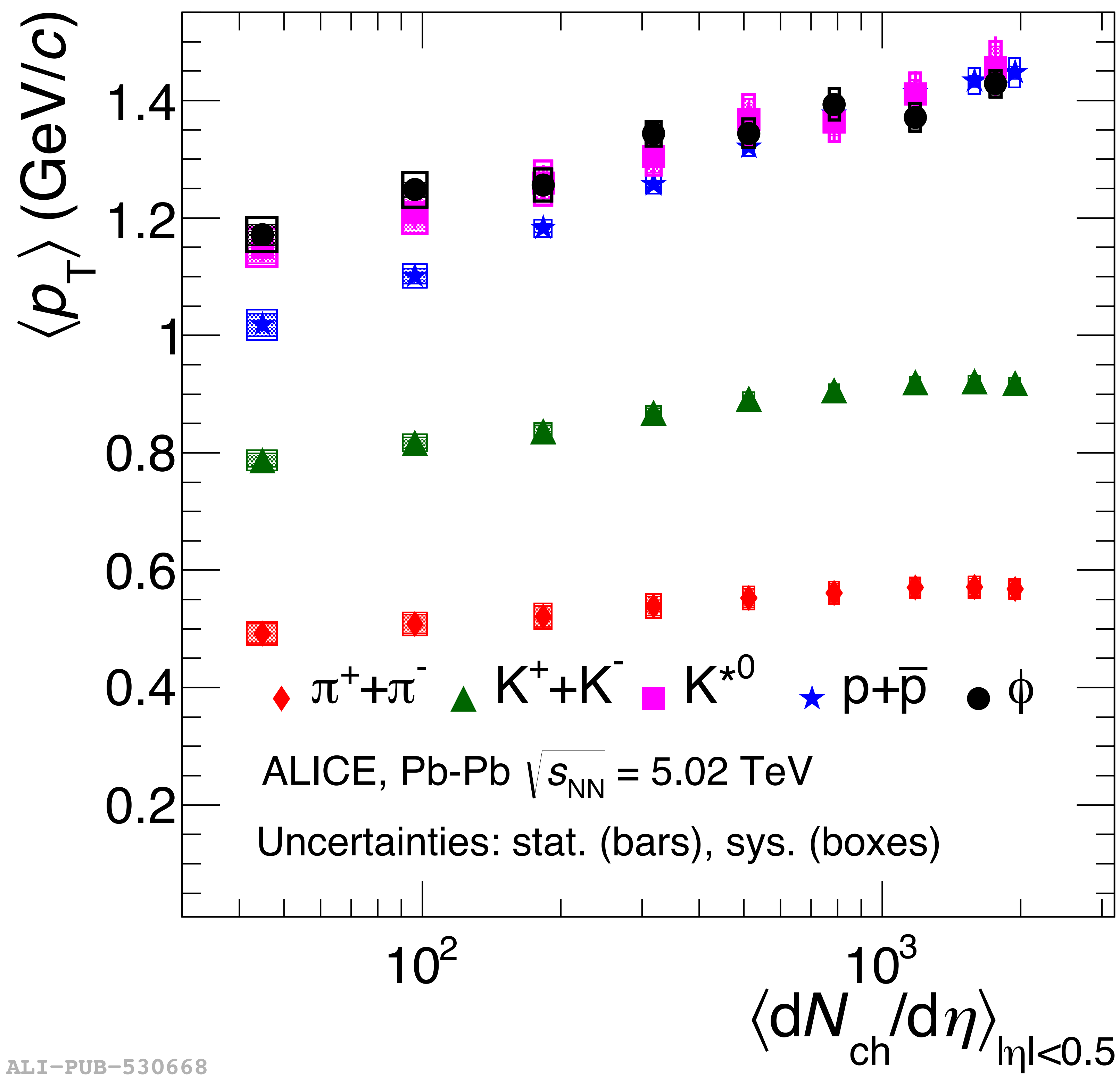
$\phi \rightarrow K^+K^-$



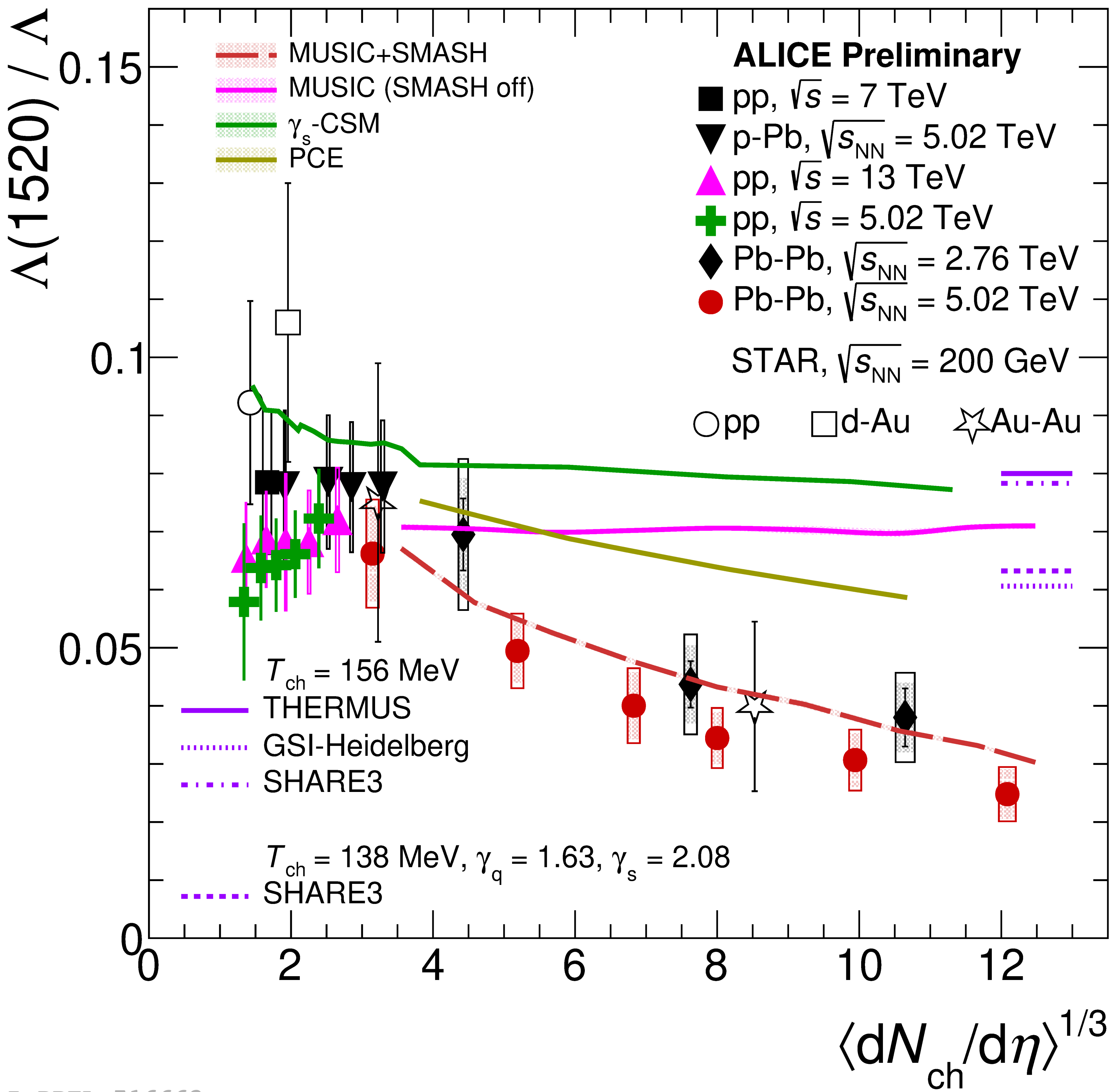


Phys. Rev. C 95 064606 (2017)

Mean transverse momentum



Particle yield ratios



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