

ALICE



# Production and modification of hadronic resonances measured with ALICE

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# Outline



- Hadronic phase
- Resonances in ALICE
- Mean  $p_T$  & integrated yield
- Particle yield ratios
- Reconstruction of  $\Xi(1820)$



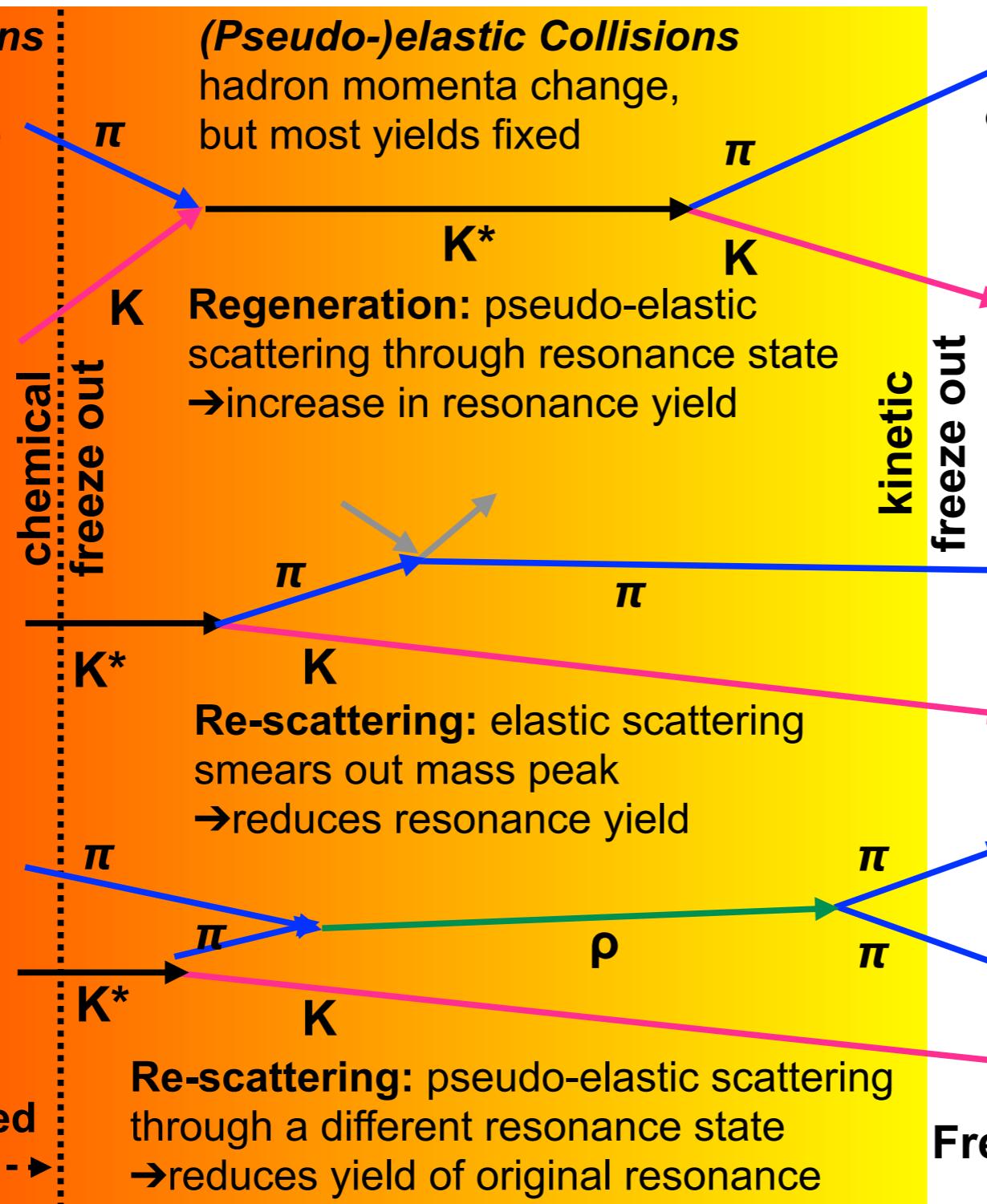
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# Hadronic Phase

**Inelastic Collisions**  
hadron momenta  
and yields change

**(Pseudo-)elastic Collisions**  
hadron momenta change,  
but most yields fixed

Yields of **long-lived**  
**hadrons** fixed ----->



- Resonances have different short lifetimes
  - allow to study properties of hadronic phase in terms of **re-scattering and regeneration effects**

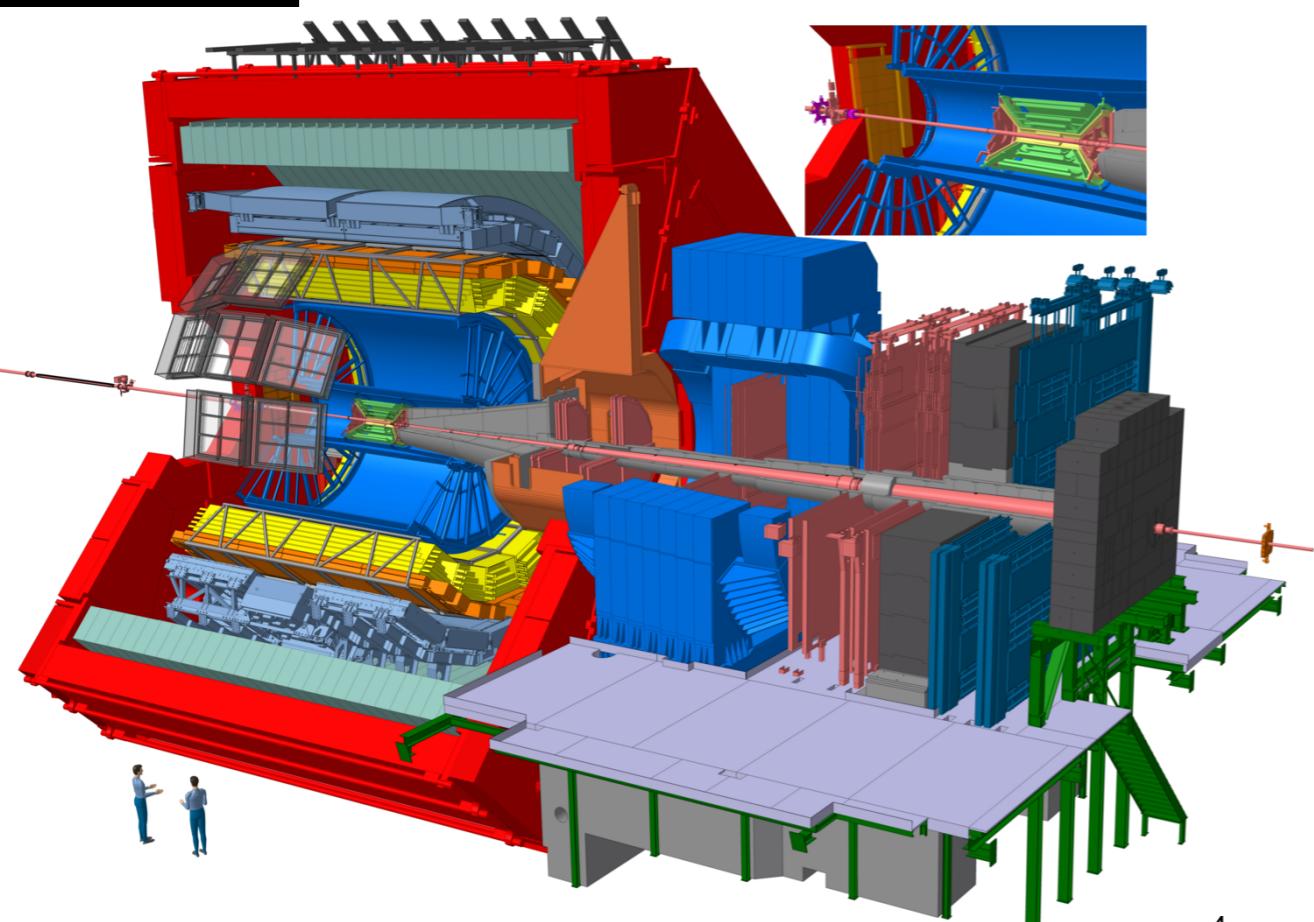
# Resonances in ALICE



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Resonance	$\tau(\text{fm}/c)$	Decay	BR
$\rho(770)^0$	1.3	$\pi\pi$	100
$K^*(892)^0$	4.2	$K\pi$	66.6
$\Sigma(1385)$	5.5	$\Lambda\pi$	87
$\Xi(1820)$	8.1	$\Lambda K$	unknown
$\Lambda(1520)$	12.6	$pK$	22.5
$\Xi(1530)^0$	21.7	$\Xi\pi$	66.7
$\phi(1020)$	46.4	$KK$	49.2

	Pb-Pb	Xe-Xe	p-Pb	pp
Year	2010-2011 2015,2018	2017	2013 2016	2009-2013 2015-2018
$\sqrt{s_{\text{NN}}}$ [TeV]	2.76 5.02	5.44	5.02 8.16	0.9, 2.76, 7, 8, 5.02, 13

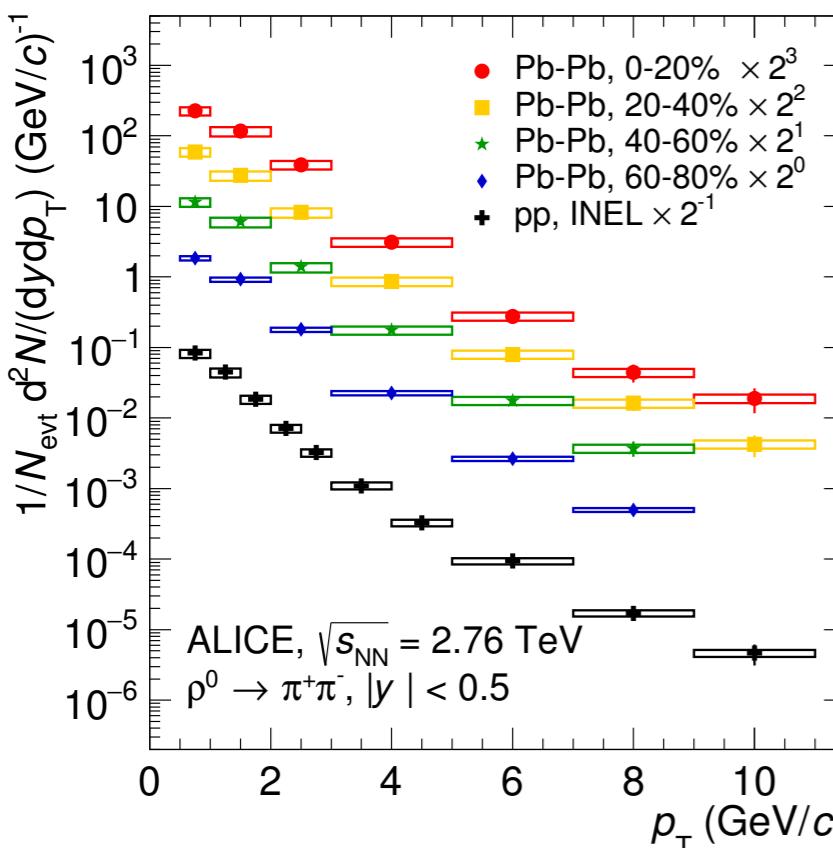


- Inner Tracking System (**ITS**)
  - Silicon detectors
  - Trigger, tracking, vertex, PID ( $dE/dx$ )
- Time Projection Chamber (**TPC**)
  - Gas-filled ionization detector
  - Tracking, vertex, PID ( $dE/dx$ )
- Time Of Flight (**TOF**)
  - PID through particle time of flight
- V0A and V0C
  - Trigger, centrality/multiplicity estimator

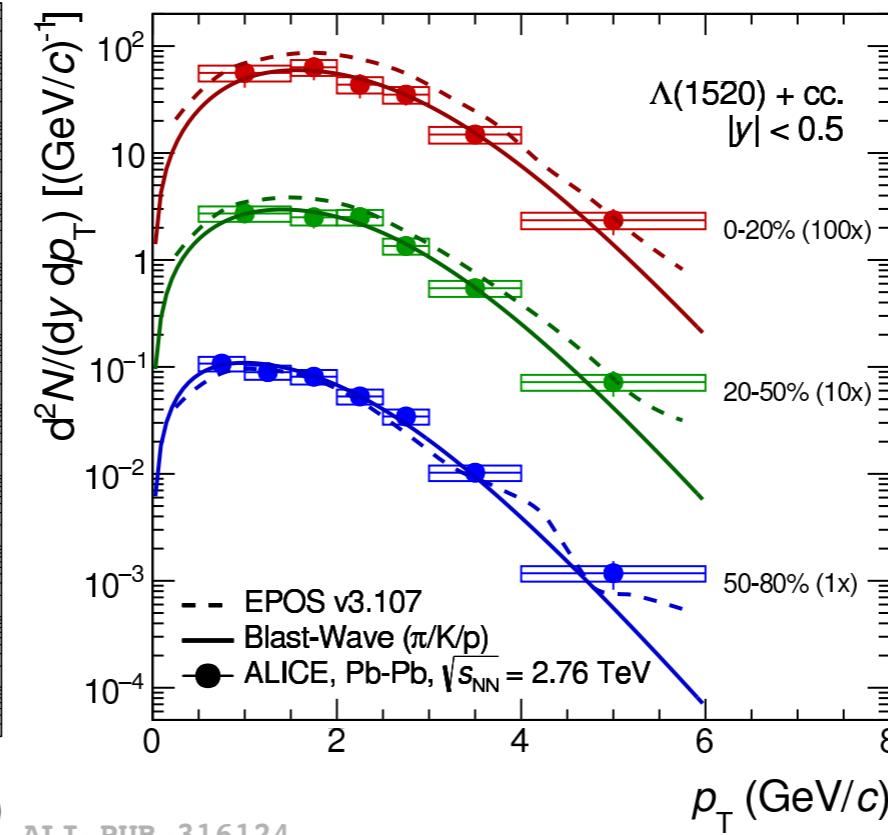
# $p_T$ -spectra in Pb-Pb collisions



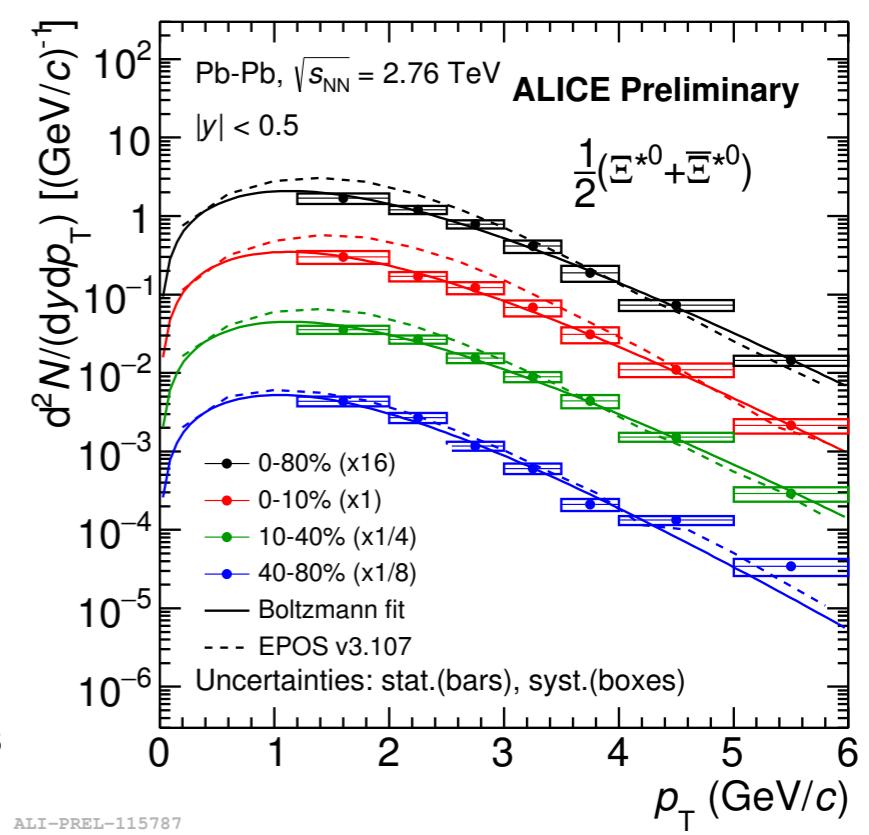
$\rho(770)^0$



$\Lambda(1520)$



$\Xi(1530)^0$



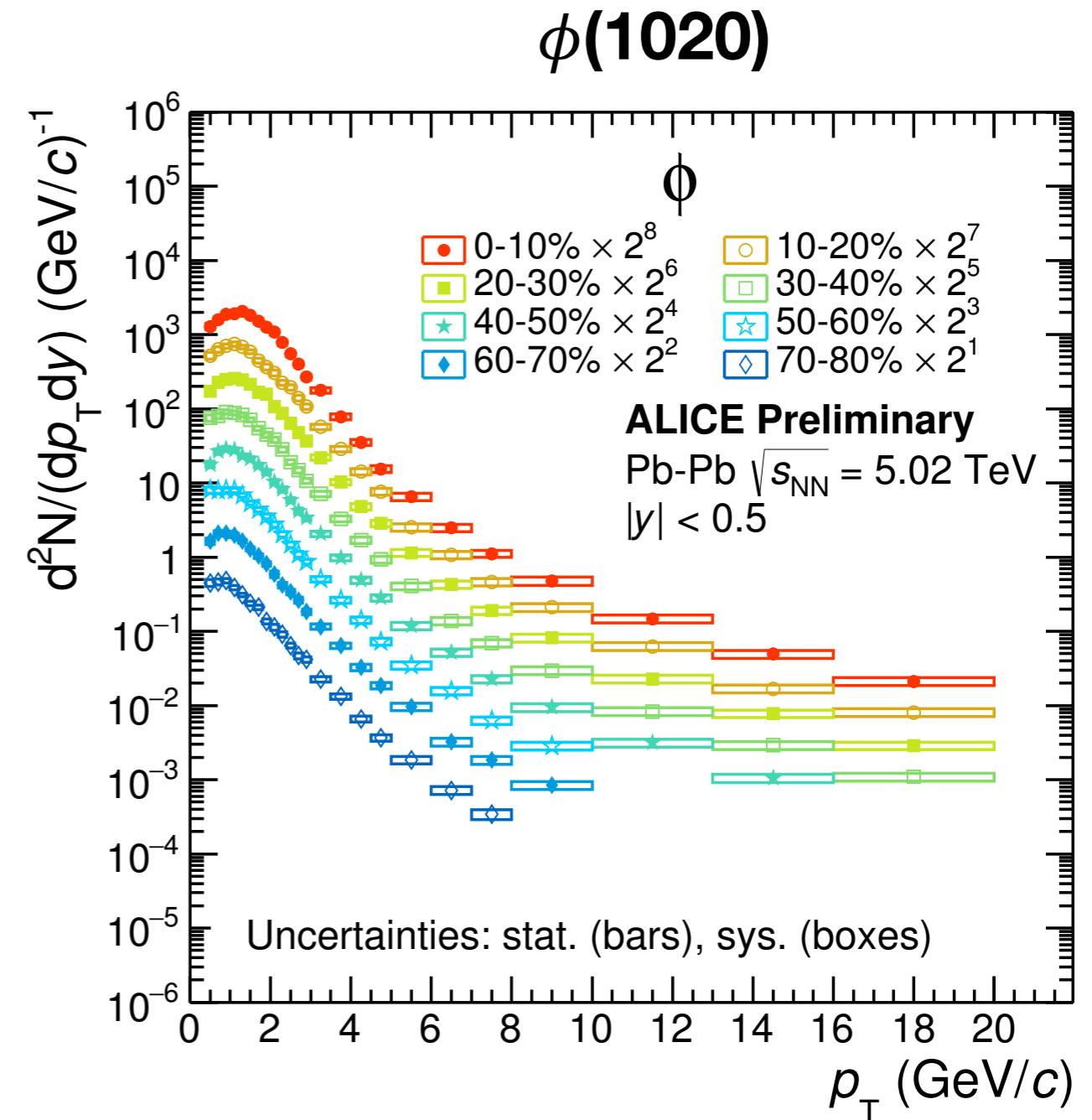
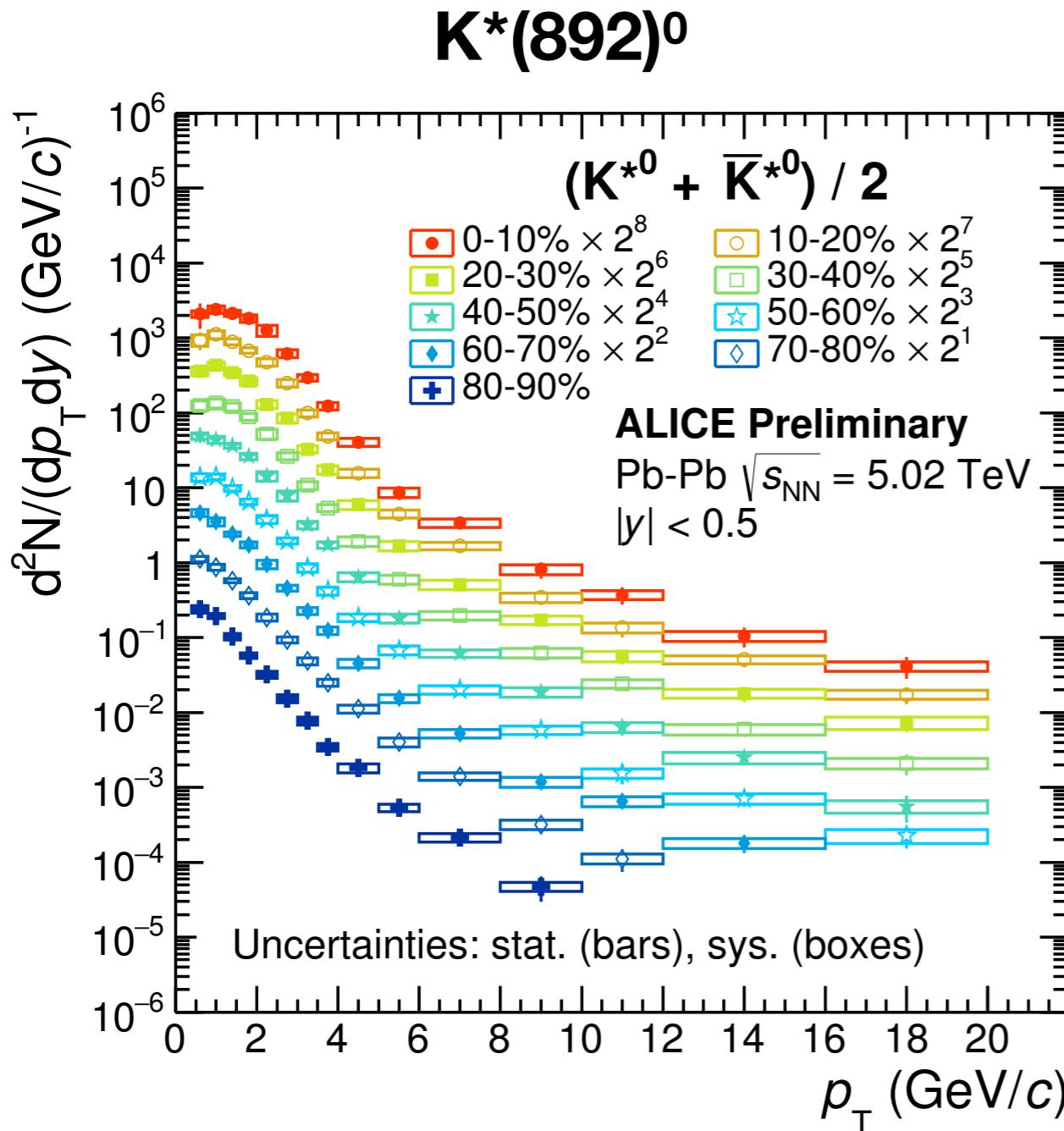
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Phys.Rev. C99 (2019) 064901

Phys.Rev. C99 (2019) 024905

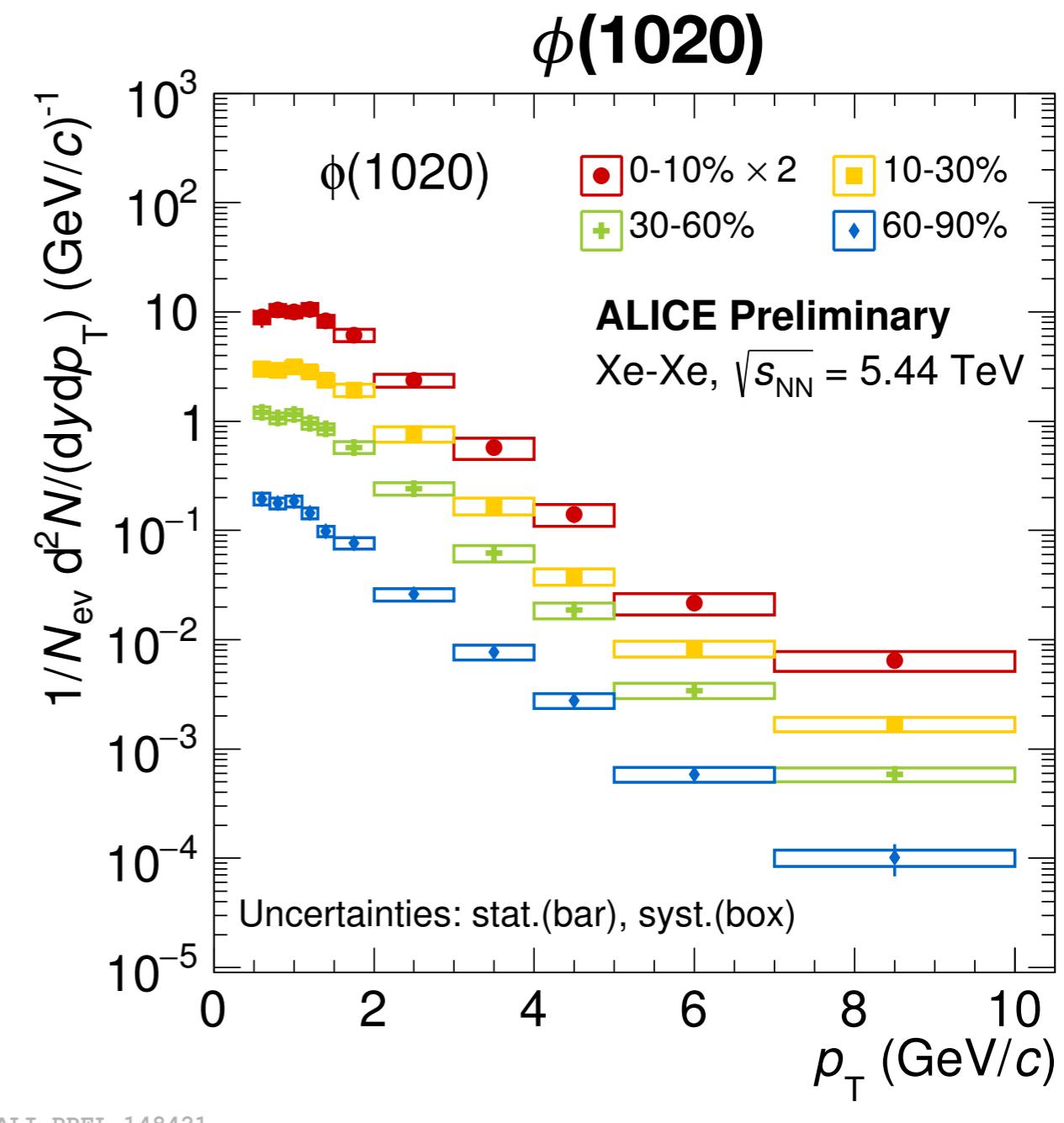
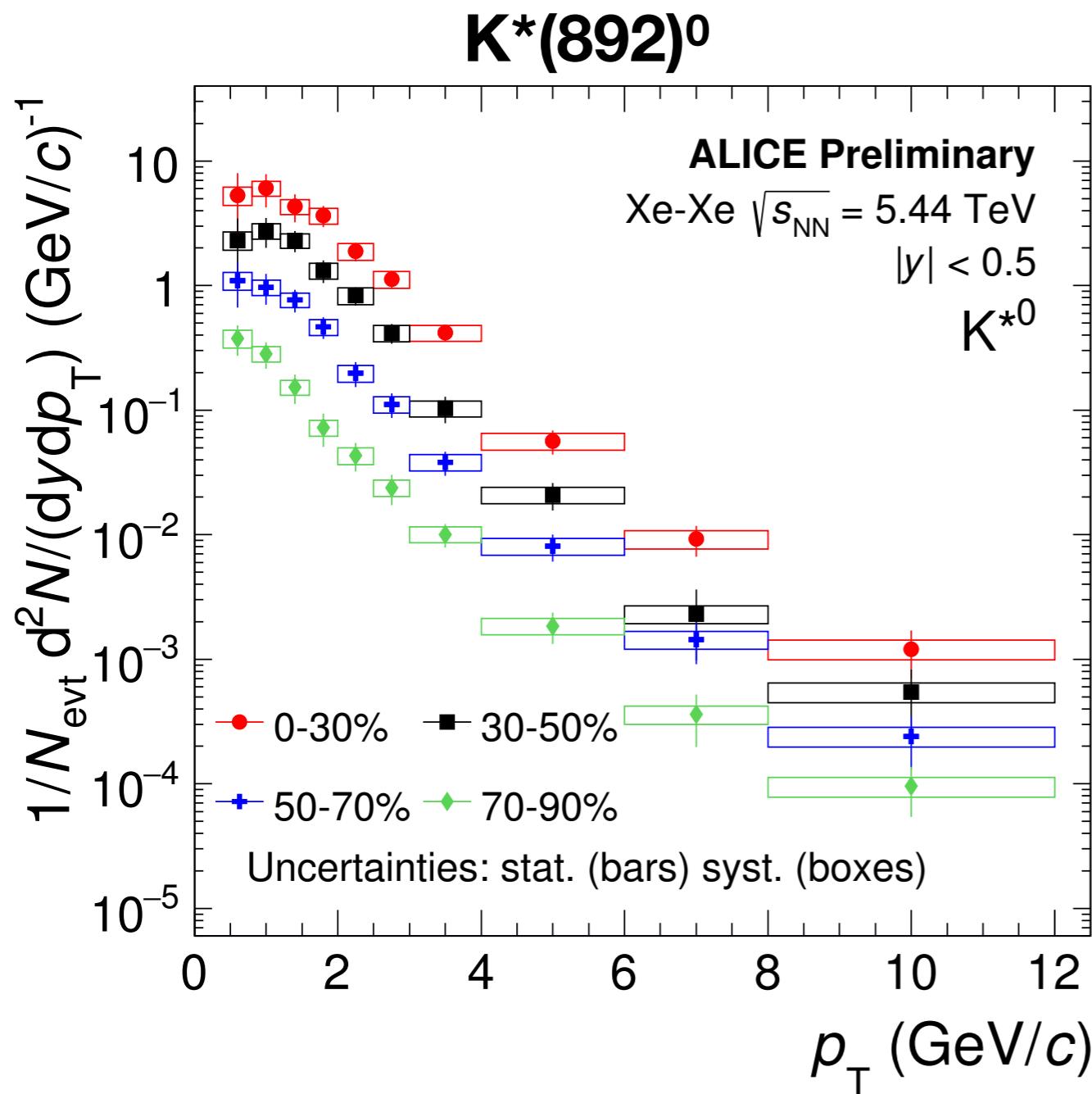
Lifetime(fm/c):  $\rho(1.3) < K^*(4.2) < \Sigma^*(5.5) < \Lambda^*(12.6) < \Xi^*(21.7) < \phi(46.2)$

# $p_T$ -spectra in Pb-Pb collisions



Lifetime(fm/c):  $\rho(1.3) < K^*(4.2) < \Sigma^*(5.5) < \Lambda^*(12.6) < \Xi^*(21.7) < \phi(46.2)$

# $p_T$ -spectra in Xe-Xe collisions

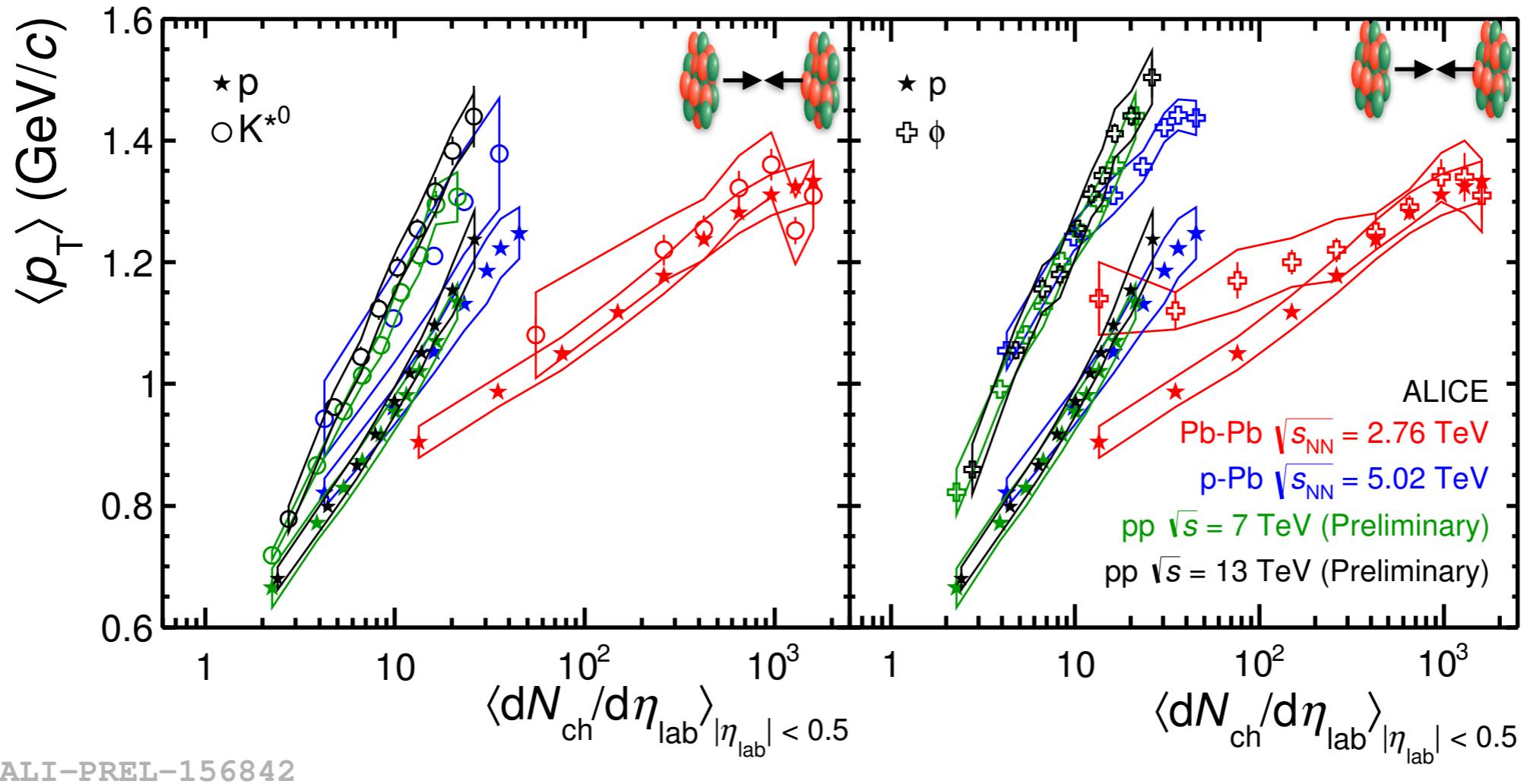


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ALI-PREL-148421

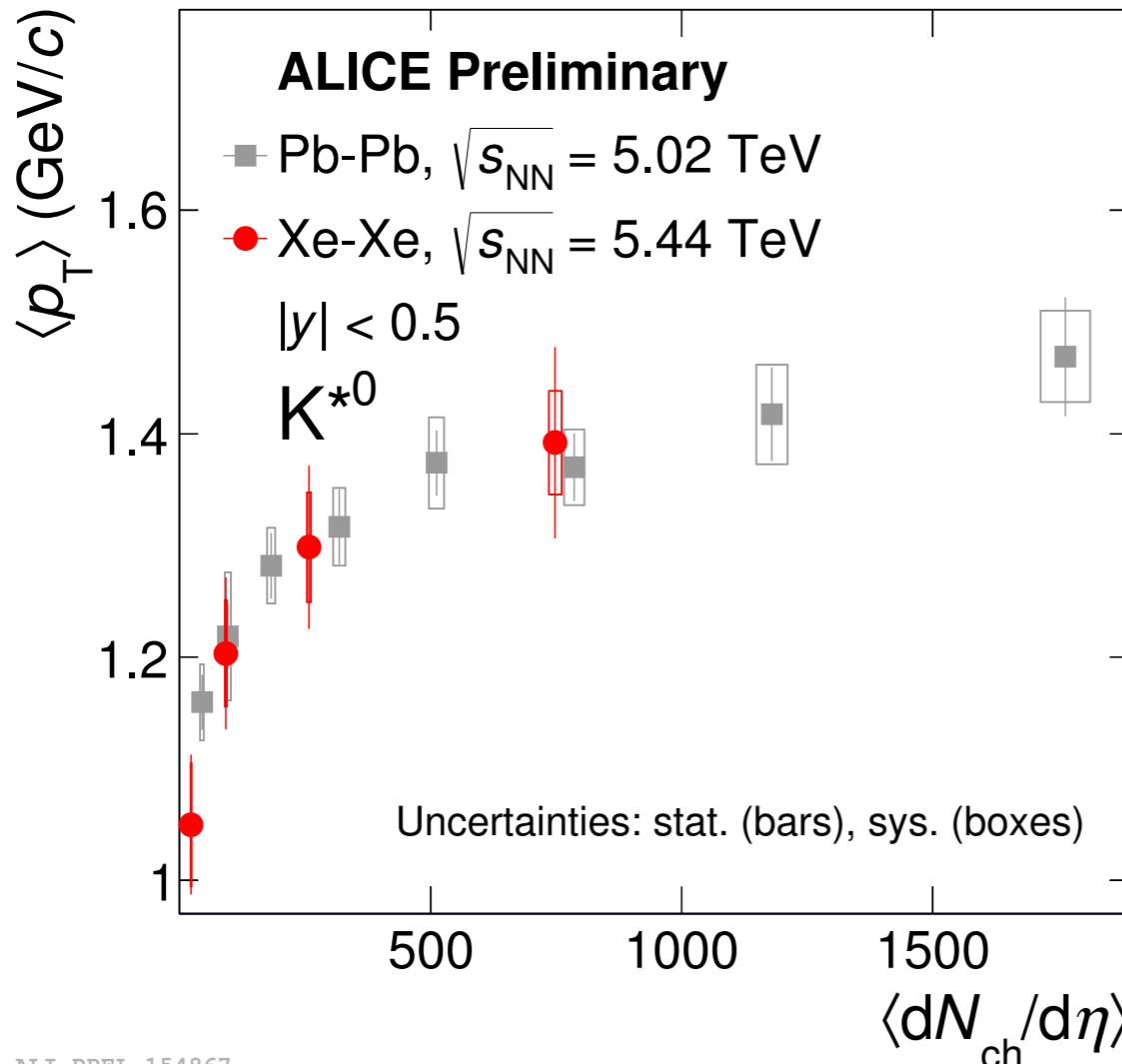
Lifetime(fm/c):  $\rho(1.3) < K^*(4.2) < \Sigma^*(5.5) < \Lambda^*(12.6) < \Xi^*(21.7) < \phi(46.2)$

# mean $p_T$

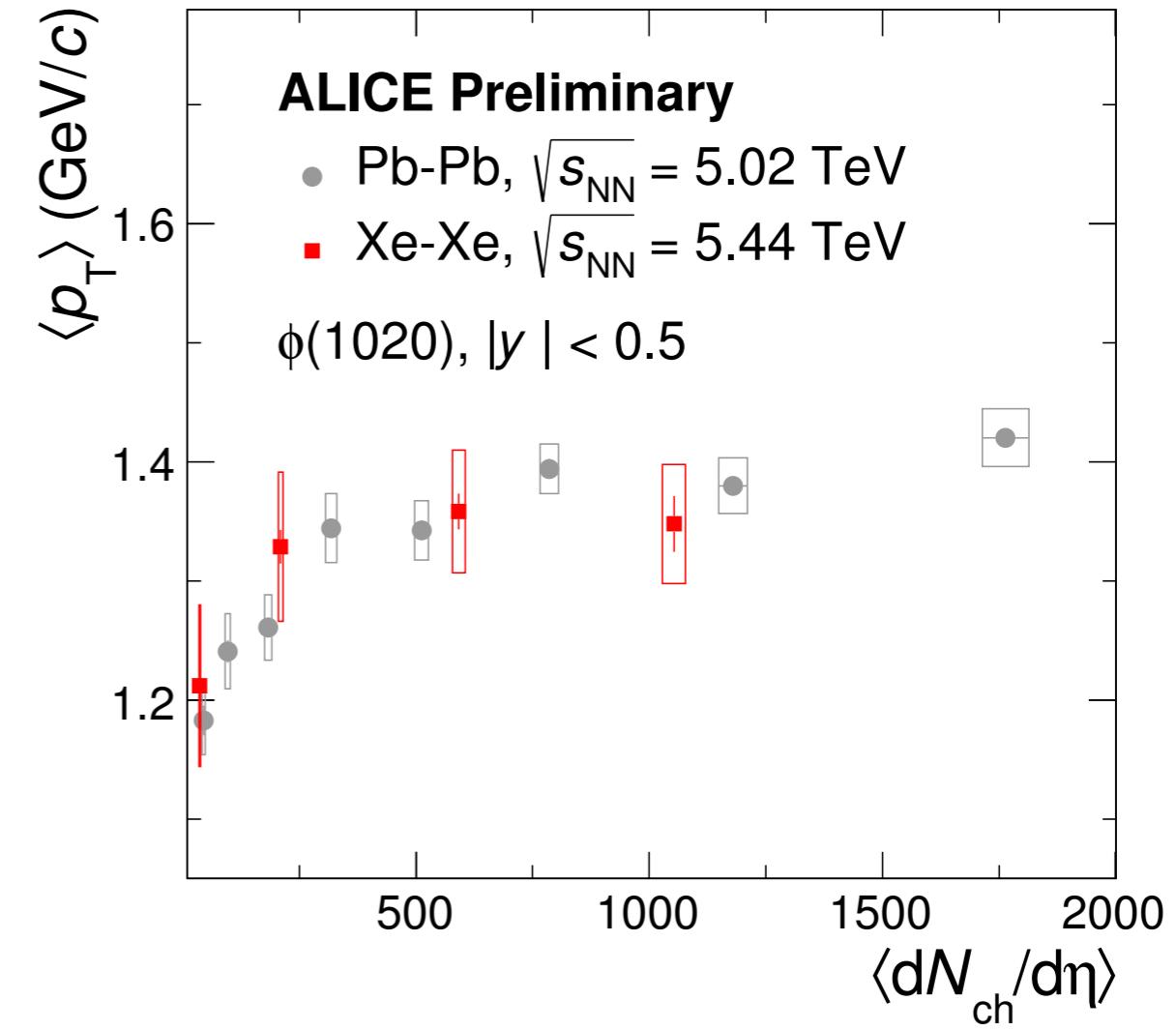


- In central Pb-Pb collisions
  - similar  $\langle p_T \rangle$  for  $p$ ,  $K^{*0}$  and  $\phi$  have been observed
  - expected from hydrodynamics as they have similar masses
- In small collision systems
  - $\langle p_T \rangle$  increases steeper and similarity of  $p$ ,  $K^{*0}$  and  $\phi$  is broken

# mean $p_T$



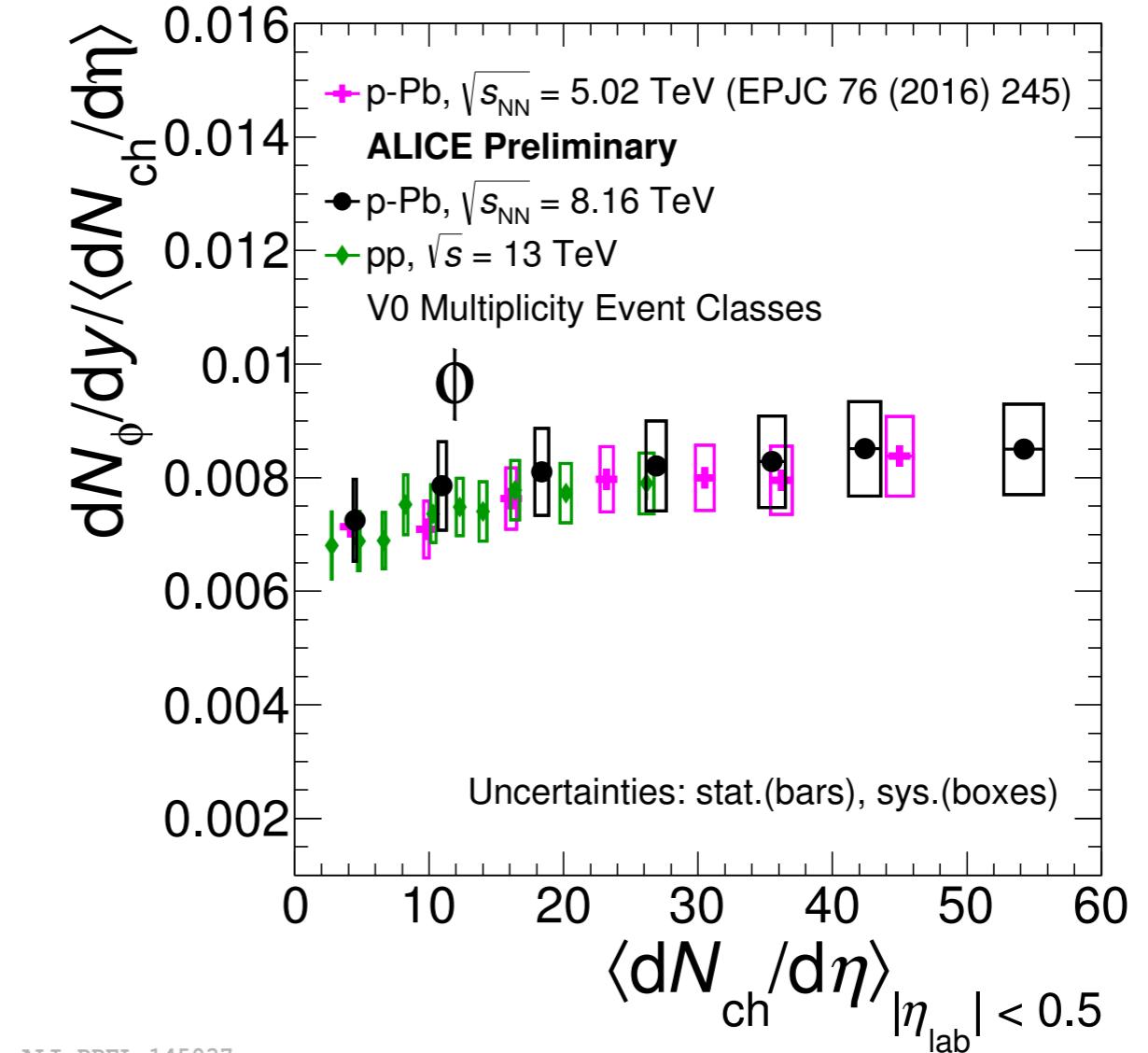
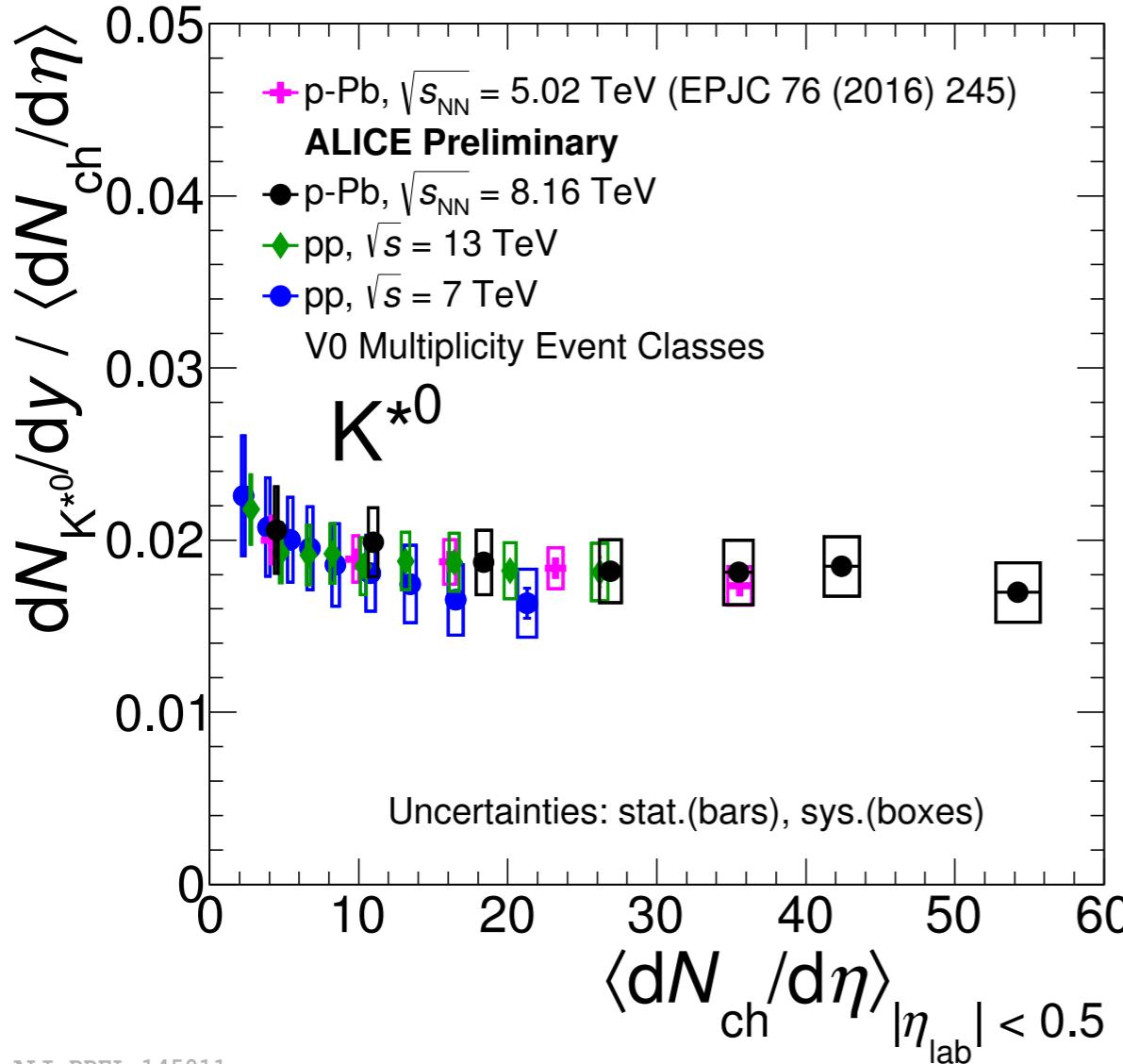
ALI-PREL-154867



ALI-PREL-155852

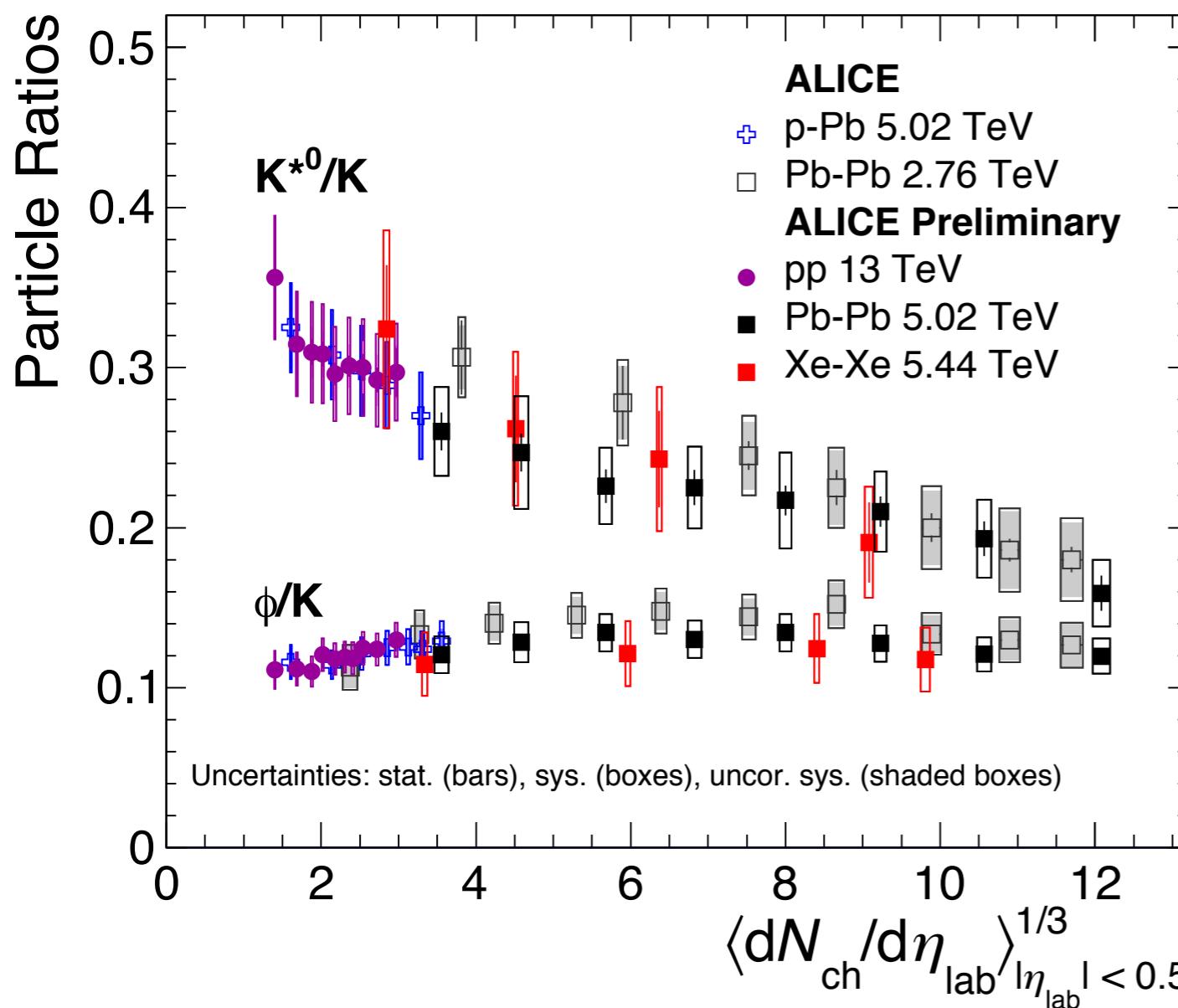
- $\langle p_T \rangle$  obtained from Pb-Pb and Xe-Xe collision are in agreement with each other

# Integrated yield



- Integrated yield normalized to  $\langle dN_{ch}/d\eta \rangle$  for  $K^{*0}$  and  $\phi$ 
  - independent of collision energy and systems for pp and p-Pb collisions

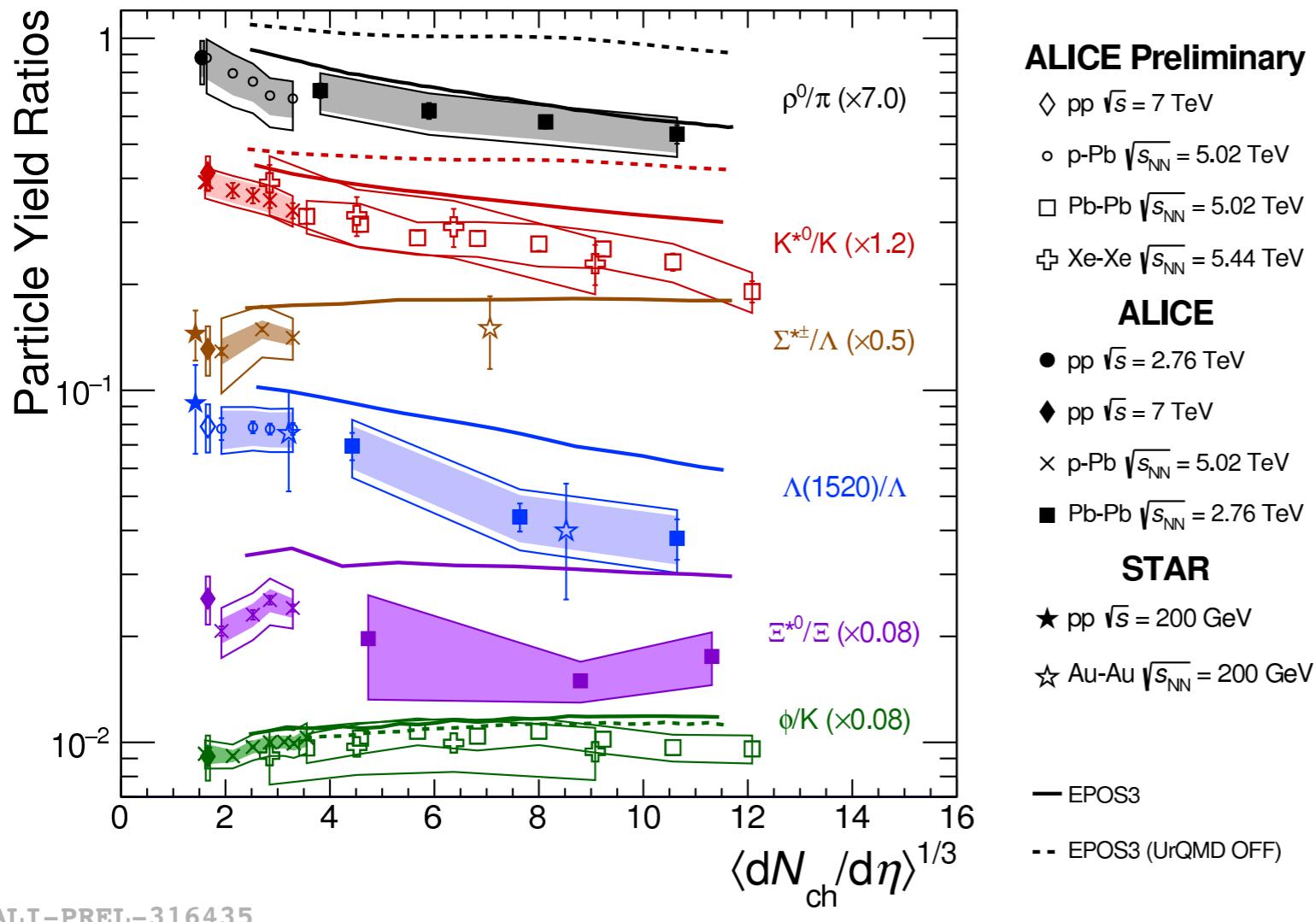
# Particle yield ratios



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

Lifetime(fm/c):  $\rho(1.3) < K^{\star 0}(4.2) < \Sigma^*(5.5) < \Lambda^*(12.6) < \Xi^*(21.7) < \phi(46.2)$

# Resonance to long-lived particle ratios



$\rho^0/\pi$ ,  $K^{*0}/K$  and  $\Lambda^*/\Lambda$  in Pb-Pb:  
suppression in central Pb-Pb  
collisions indicates dominance of  
re-scattering over regeneration for  
short lived resonances

$\Sigma^*/\Lambda$  and  $\Lambda^*/\Lambda$ : flat in small  
systems and no energy  
dependence from RHIC to LHC

$\Xi^*/\Xi$  and  $\phi/K$ : no significant  
centrality dependence across the  
different collision systems

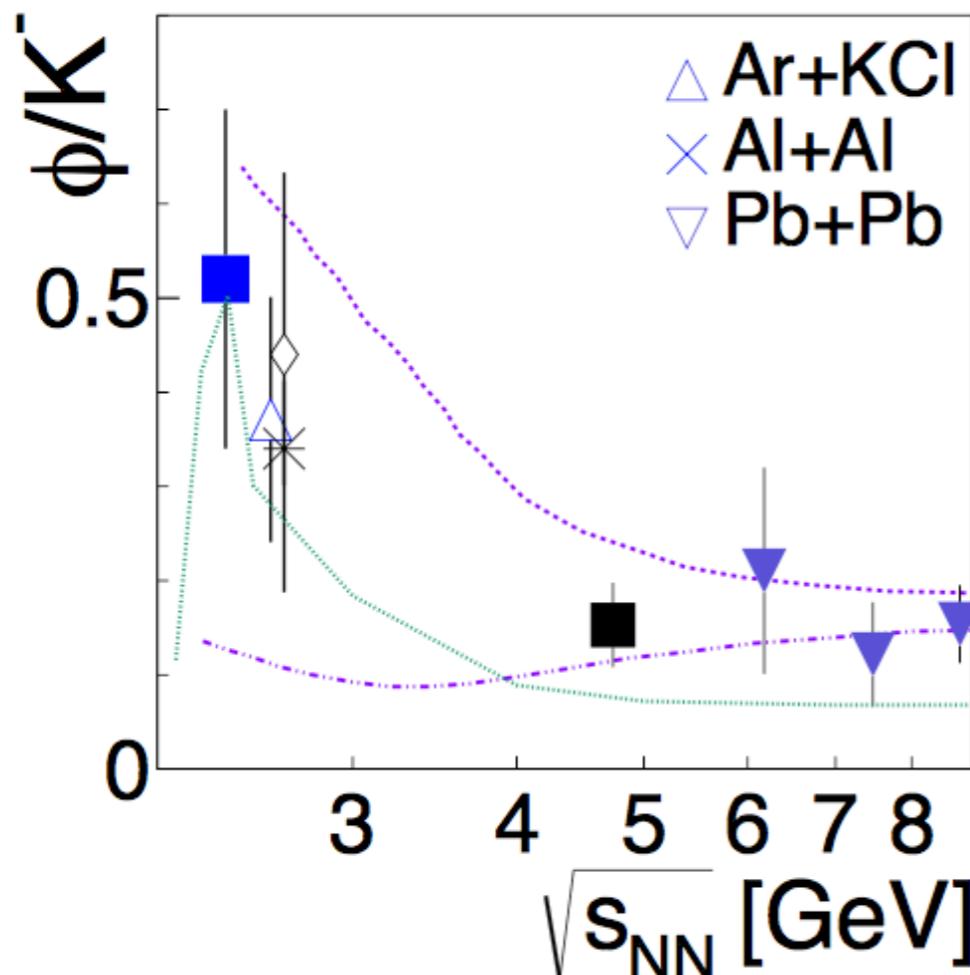
In most cases EPOS3 with UrQMD describes the trend qualitatively

Lifetime(fm/c):  $\rho(1.3) < K^{*0}(4.2) < \Sigma^*(5.5) < \Lambda^*(12.6) < \Xi^*(21.7) < \phi(46.2)$

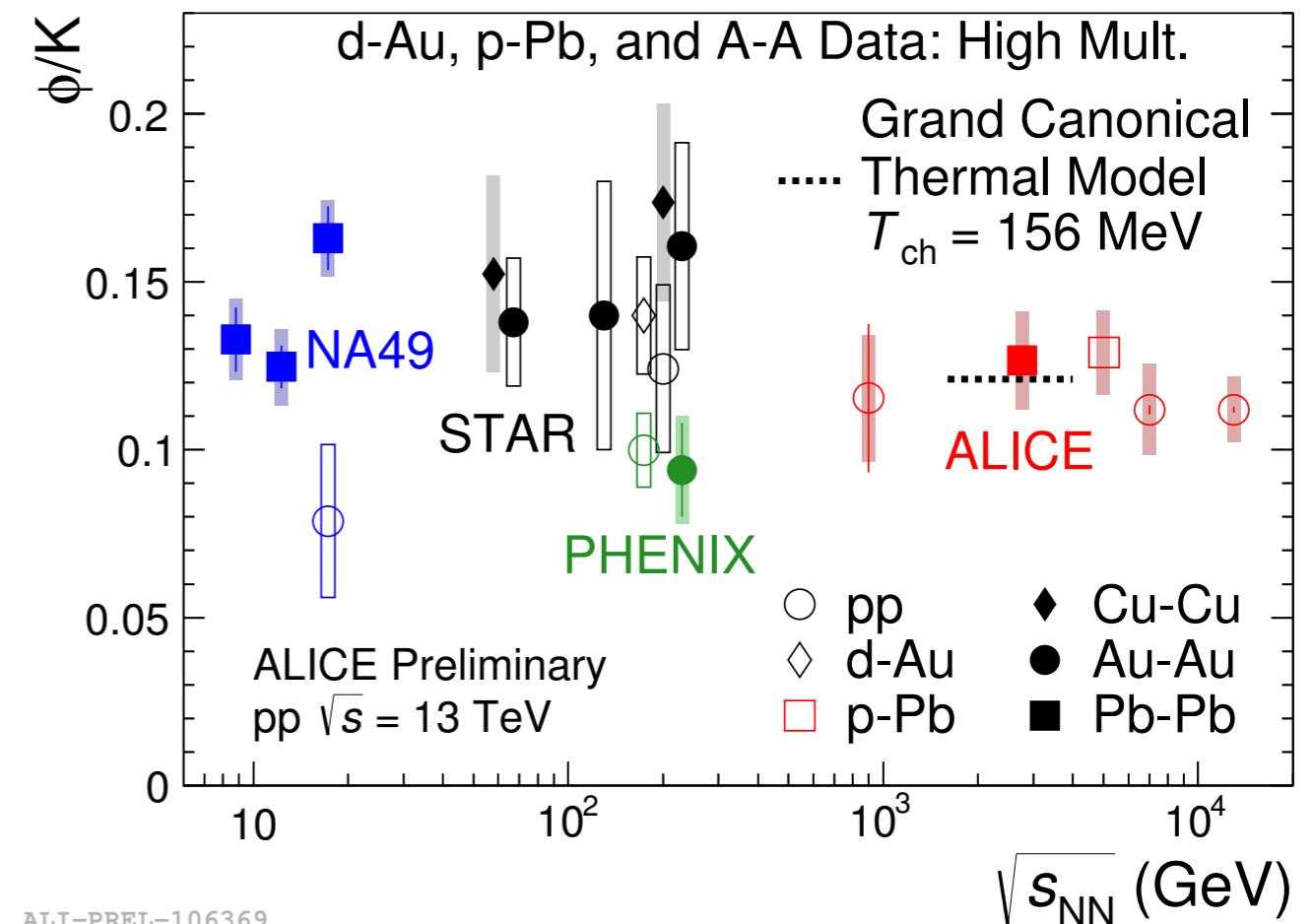
# Energy dependence: $\phi/K$



HADES, arXiv:1703.08418v1

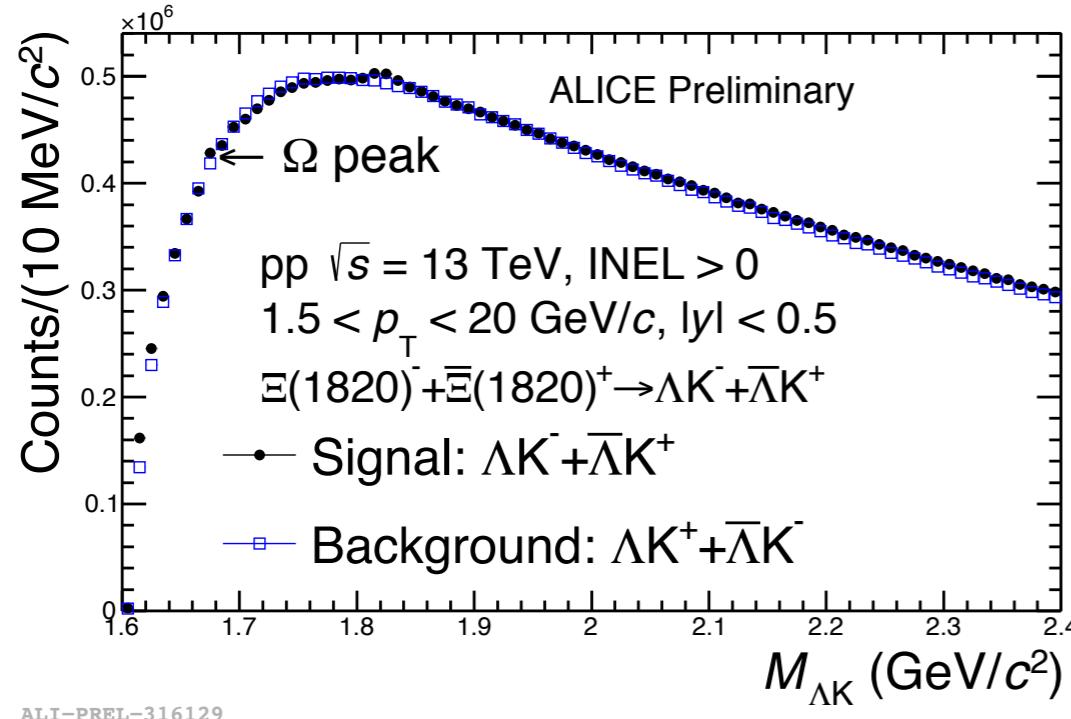


Phys. Rev. C 91 024609 (2015)

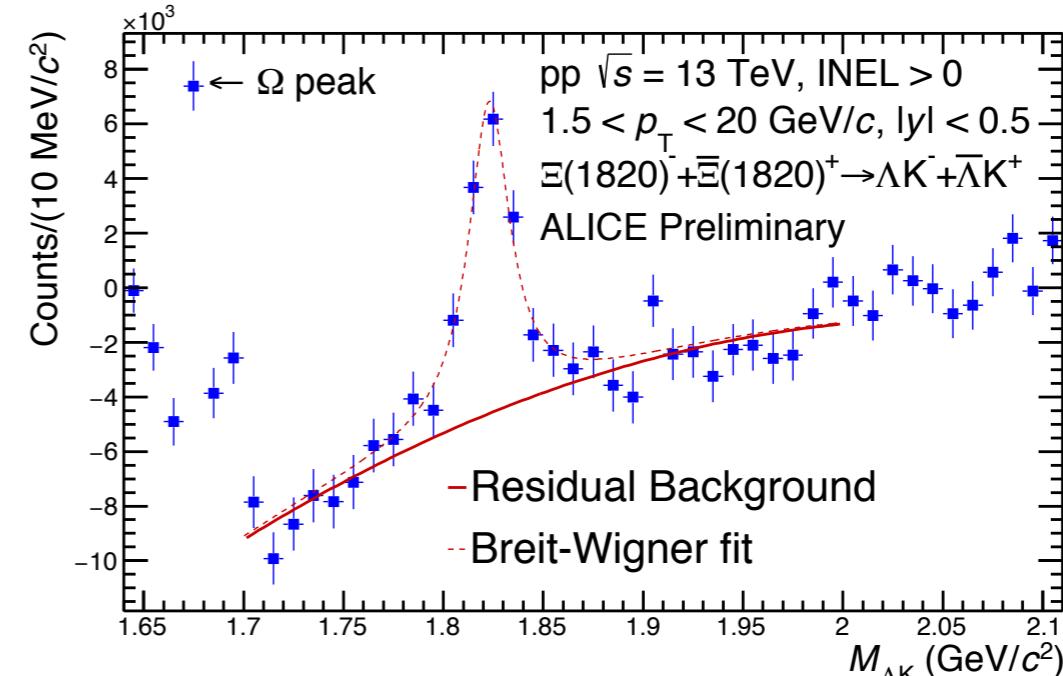


- Flat behavior in wide range of energy ( $\sim 10\text{-}10^4$  GeV)
- Increase for low energies due to canonical suppression
  - reproduced by statistical model calculation with strangeness correlation radius parameter  $R_c = 2.2$  fm

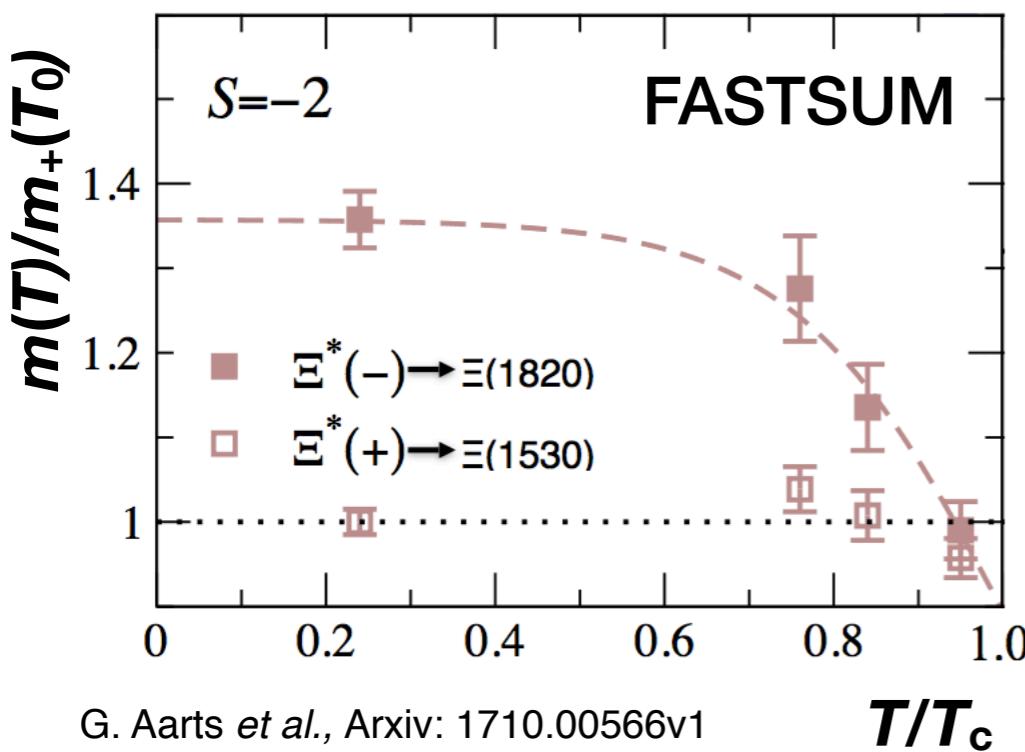
# Reconstruction of $\Xi(1820)$



ALI-PREL-316129



ALI-PREL-316134



G. Aarts *et al.*, Arxiv: 1710.00566v1

- First measurement of  $\Xi(1820)$  from collider experiment
- Calculation from FASTSUM Collaboration shows potential parity doubling
  - signature of chiral symmetry restoration in heavy-ion collisions
  - expected signal: mass shift, width broadening or change in yield ratio between  $\Xi(1820)$  and  $\Xi(1530)$

# Conclusion & outlook



- **ALICE** has measured comprehensive set of resonance particles
- **mean  $p_T$** 
  - steeper increase in small system and similar  $\langle p_T \rangle$  for  $p$ ,  $K^{*0}$  and  $\phi$  in central Pb-Pb collisions
- **Normalized integrated yield**
  - independent of collision energy and systems for pp and p-Pb collisions
- **particle yield ratios**
  - suppression of short-lived resonances,  $\rho^0$ ,  $K^{*0}$ ,  $\Lambda^*$ , has been observed in most central collisions w.r.t. small collision systems
  - no suppression observed for the longer-lived resonances,  $\phi$
- **Reconstruction of  $\Xi(1820)$** 
  - first measurement and clear signal
  - results will be compared to  $\Xi(1530)$