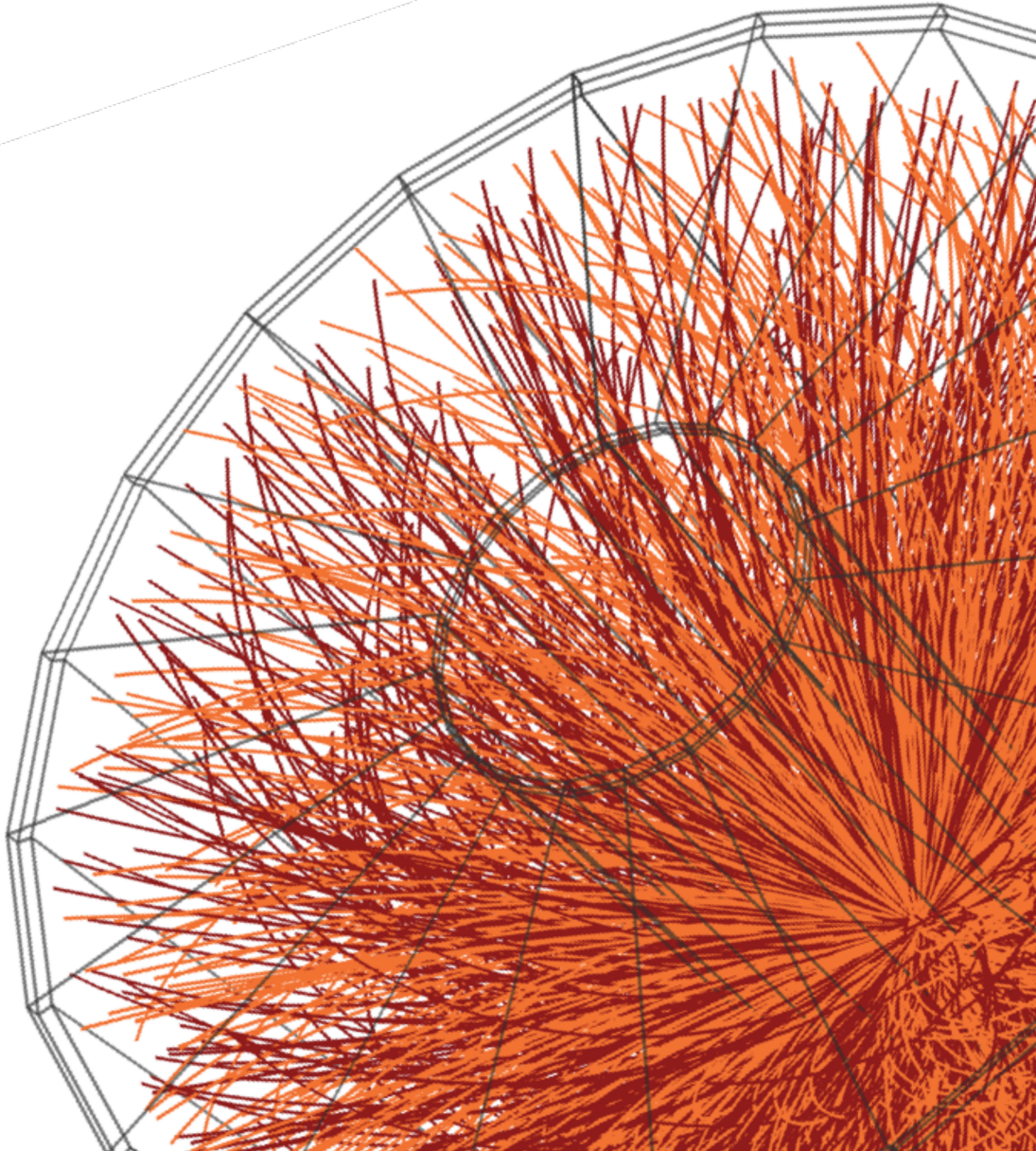
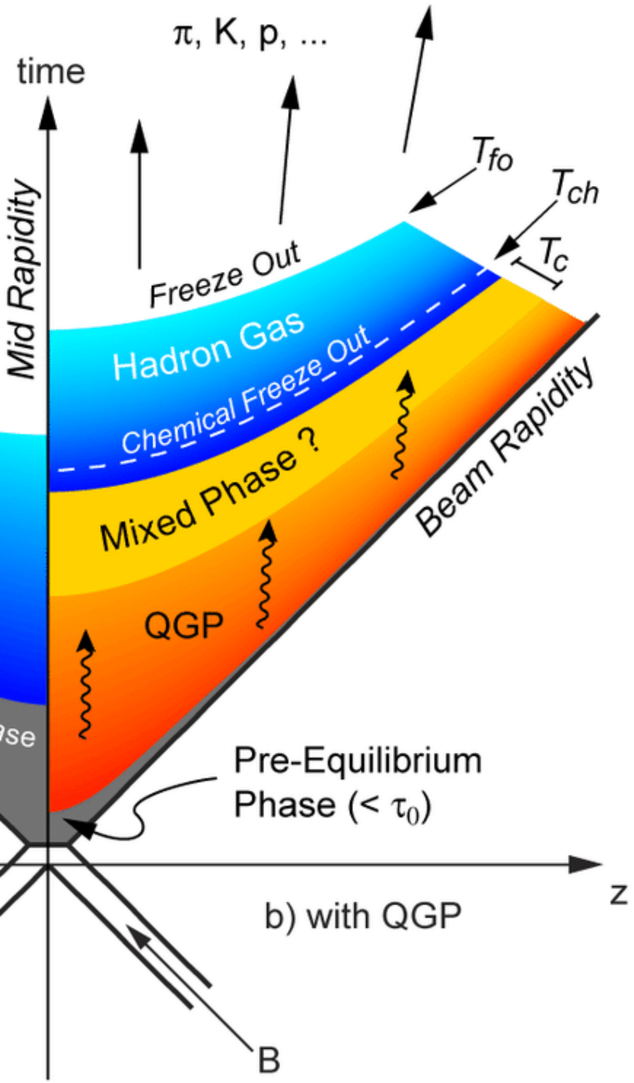
# Latest results on resonance production from small to large systems with ALICE



**Bong-Hwi Lim* for the ALICE Collaboration**
*Pusan National University, Inha University
07/04/2022

# Why resonances?




- **Short lifetimes**
  - Comparable to Hadronic phase
- **Excited states**
  - Can compare results to other particles with similar quark content

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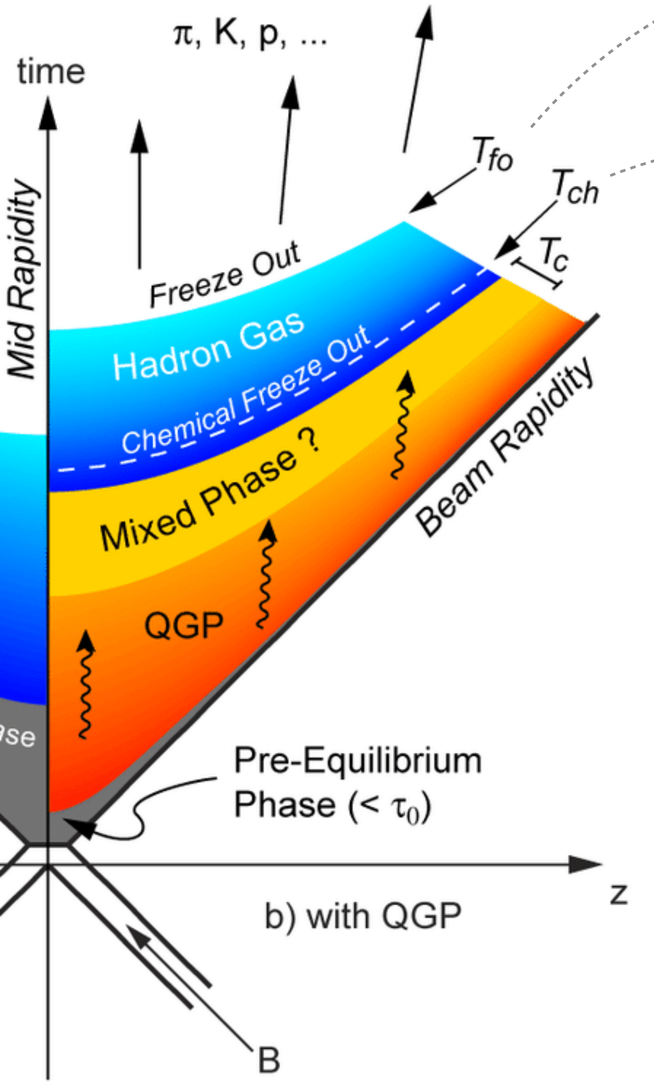


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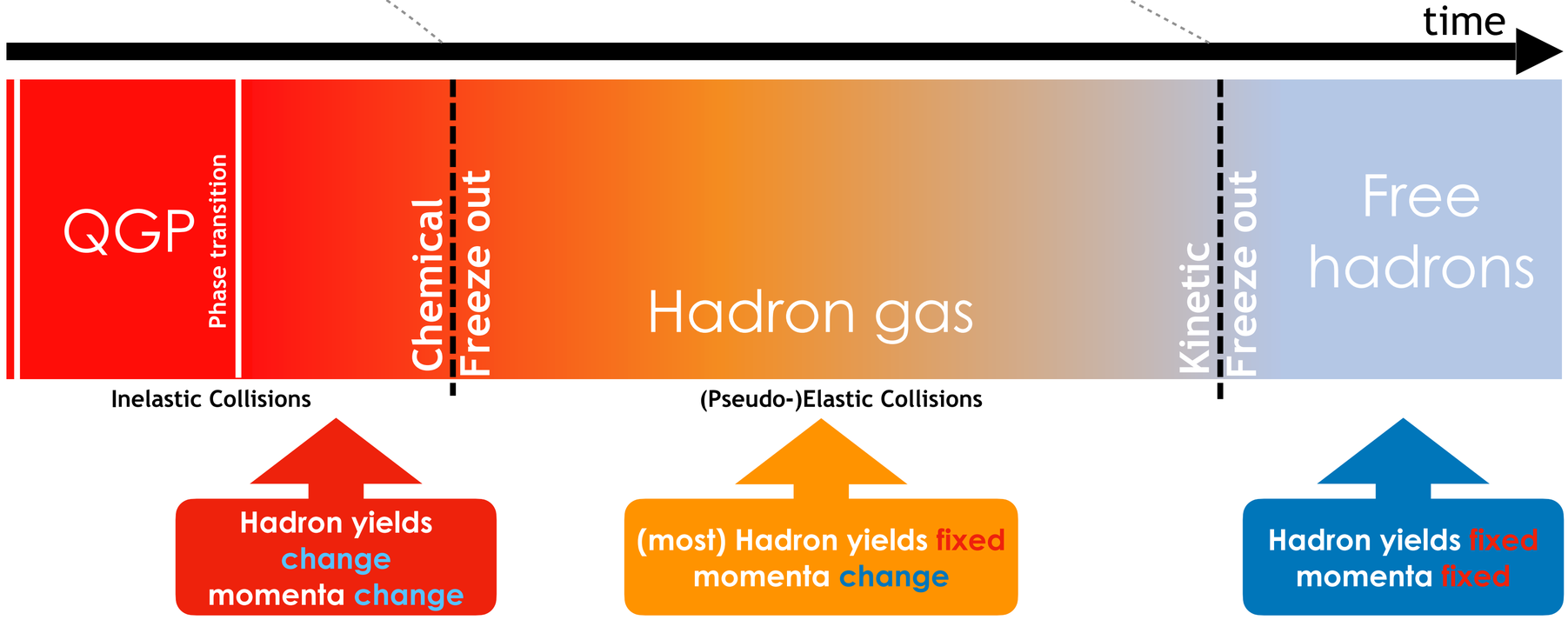

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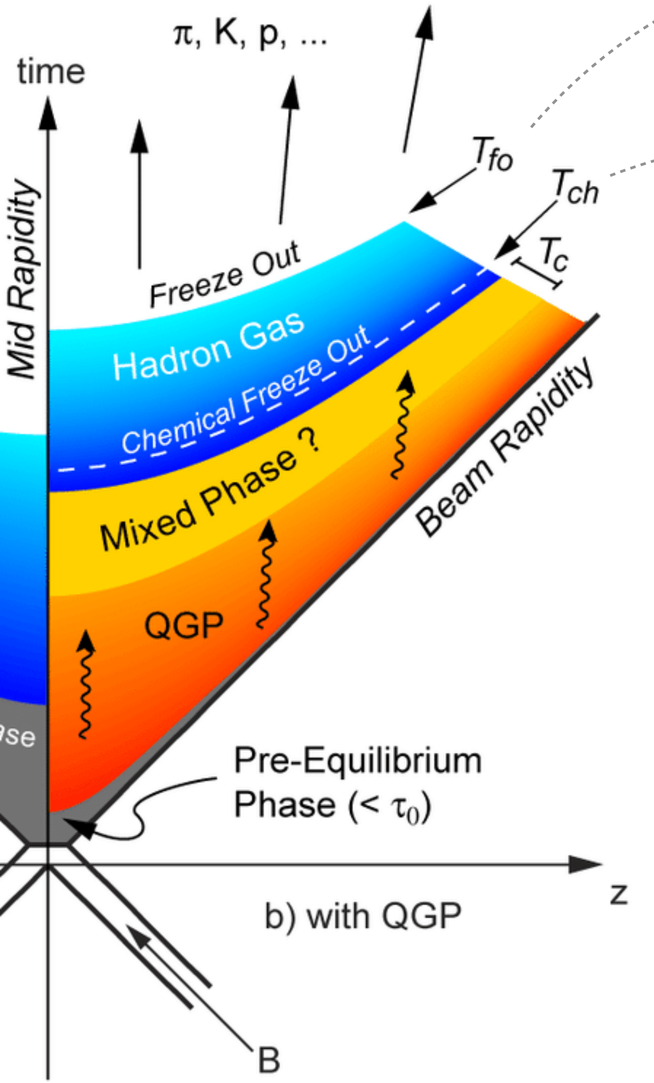


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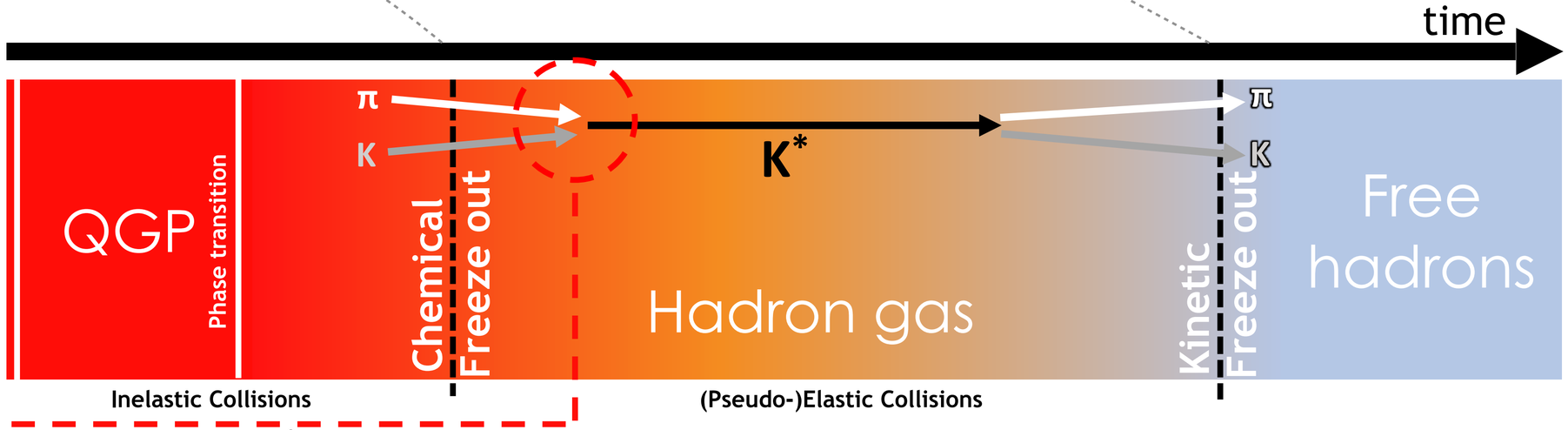


## Regeneration

pseudo-elastic scattering through resonance state

➡ **Enhanced yield**

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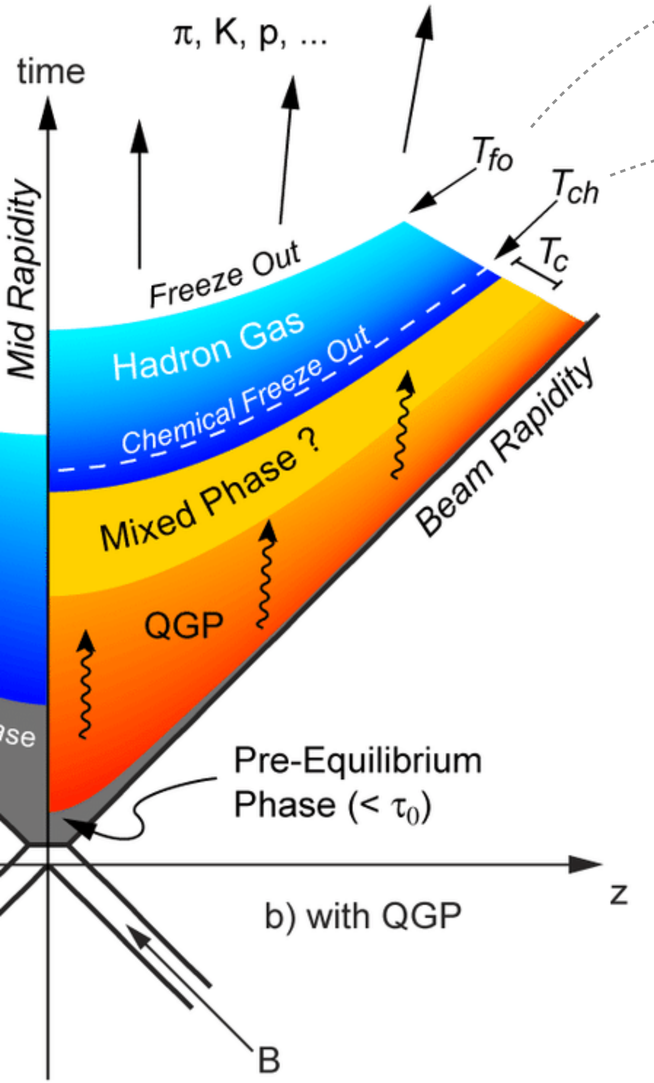


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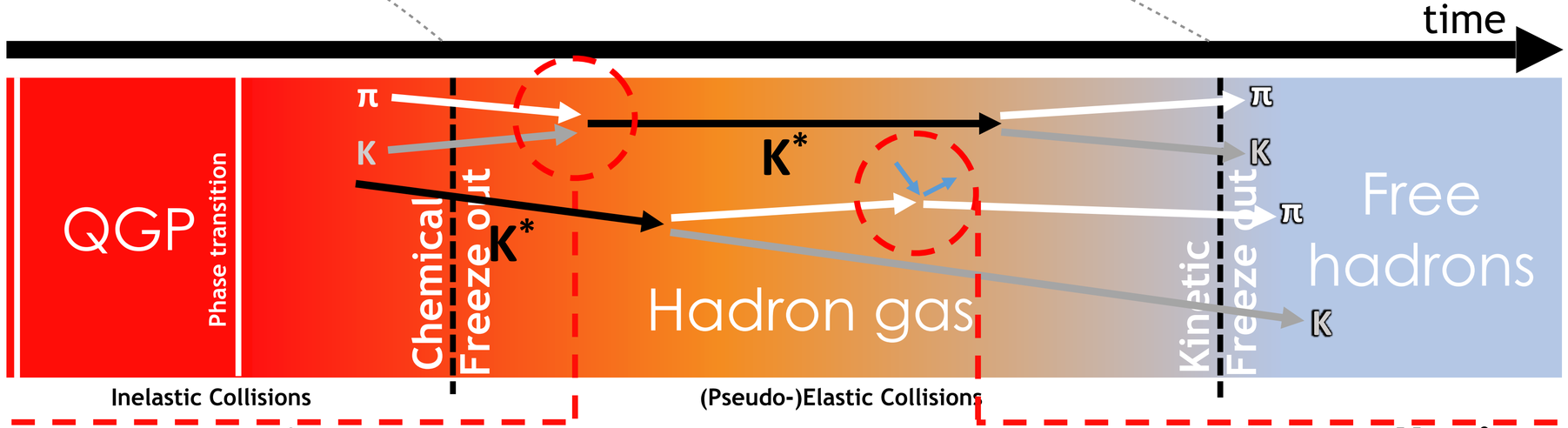


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➡ **Enhanced yield**

**Rescattering**

elastic scattering smears out mass peak

➡ **Reduced yield**

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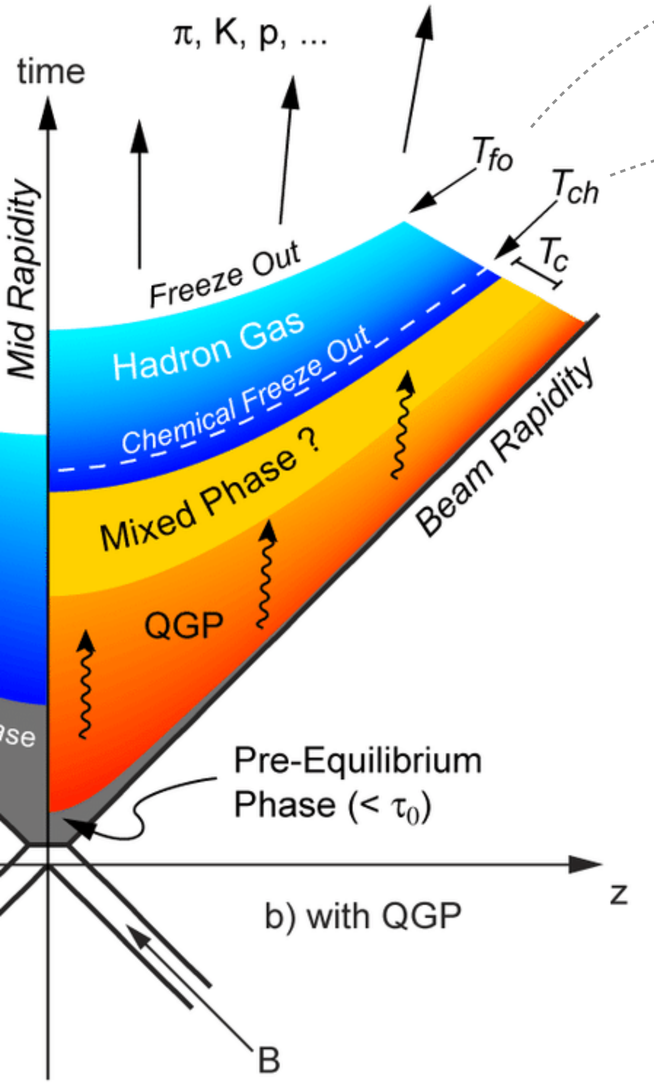


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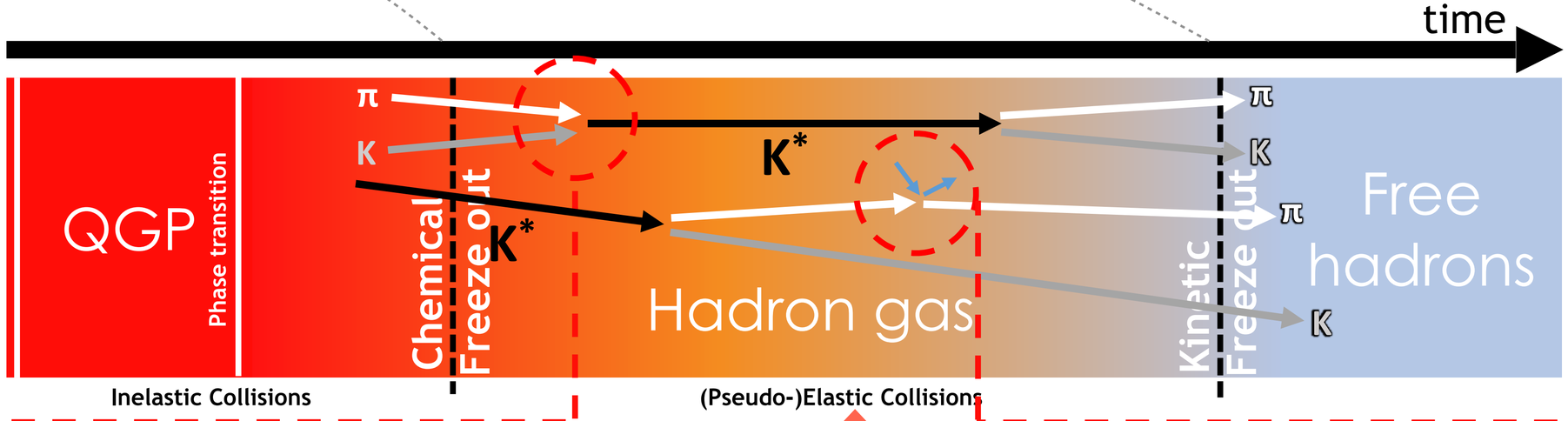



**Regeneration**
pseudo-elastic scattering through resonance state

➡ **Enhanced yield**

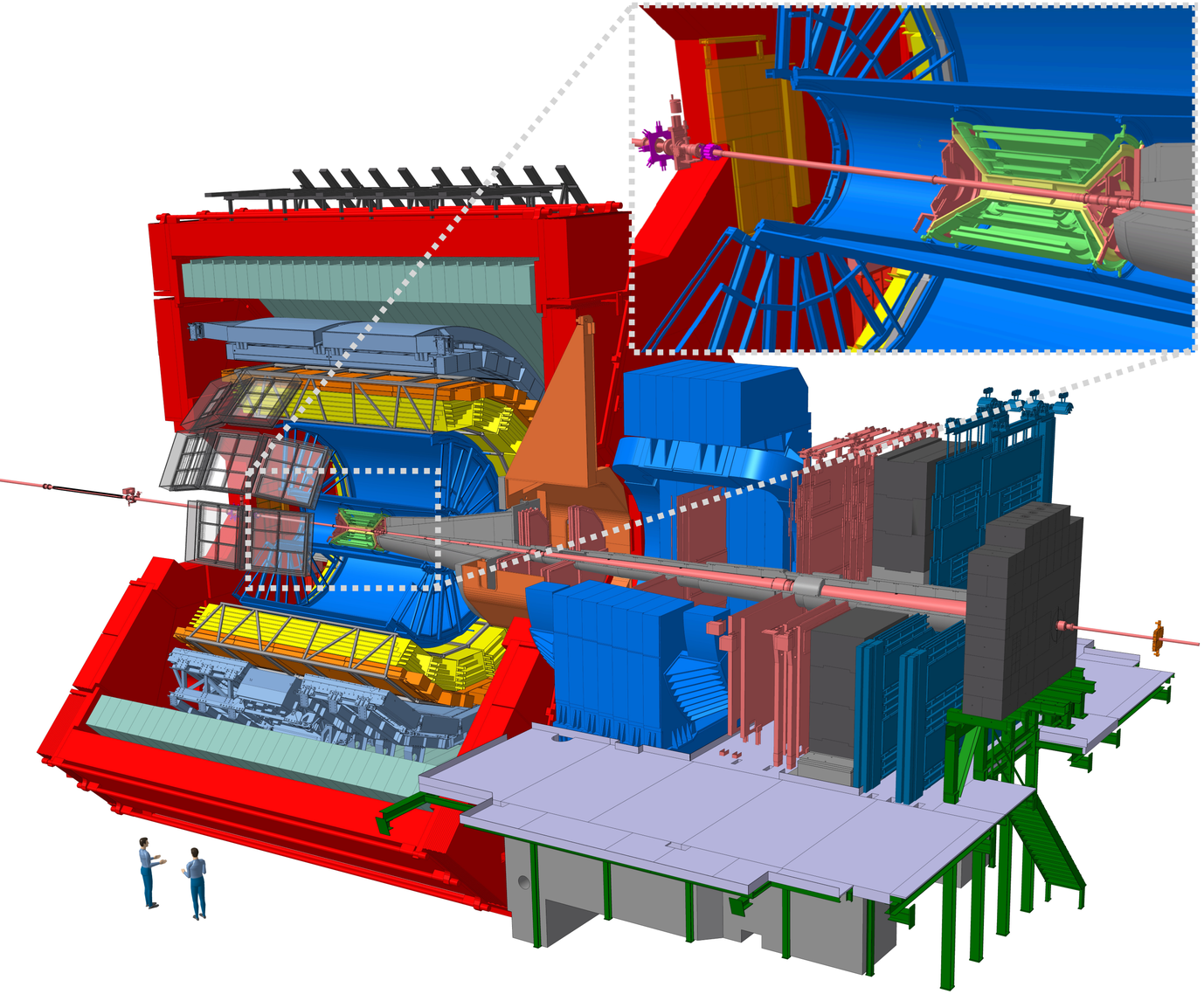
**Rescattering**
elastic scattering smears out mass peak

➡ **Reduced yield**

- **Chemical freeze out temperature ($T_{ch}$)**
- **Lifetime of hadronic phase**
- **Lifetime of resonance itself**
- **Scattering cross sections of decay products**

# The ALICE Detector

## Highlighted Sub-detectors Used for Resonance Study



- Multi-purpose detector at the LHC with unique **particle identification** capabilities and tracking down to **very low momenta**
- **Central barrel detectors ($|\eta| < 1$)**
  - ITS ($|\eta| < 0.9$)
    - 6 layers of silicon detectors
    - Trigger, tracking, vertex, PID ($\mathrm{d}E/dx$)
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    - PID ($\beta$, time of flight)
  - V0 [V0A ($2.8 < \eta < 5.1$) & V0C ($-3.7 < \eta < -1.7$)]
    - Arrays of scintillators
    - Trigger, beam gas rejection, **multiplicity estimator**

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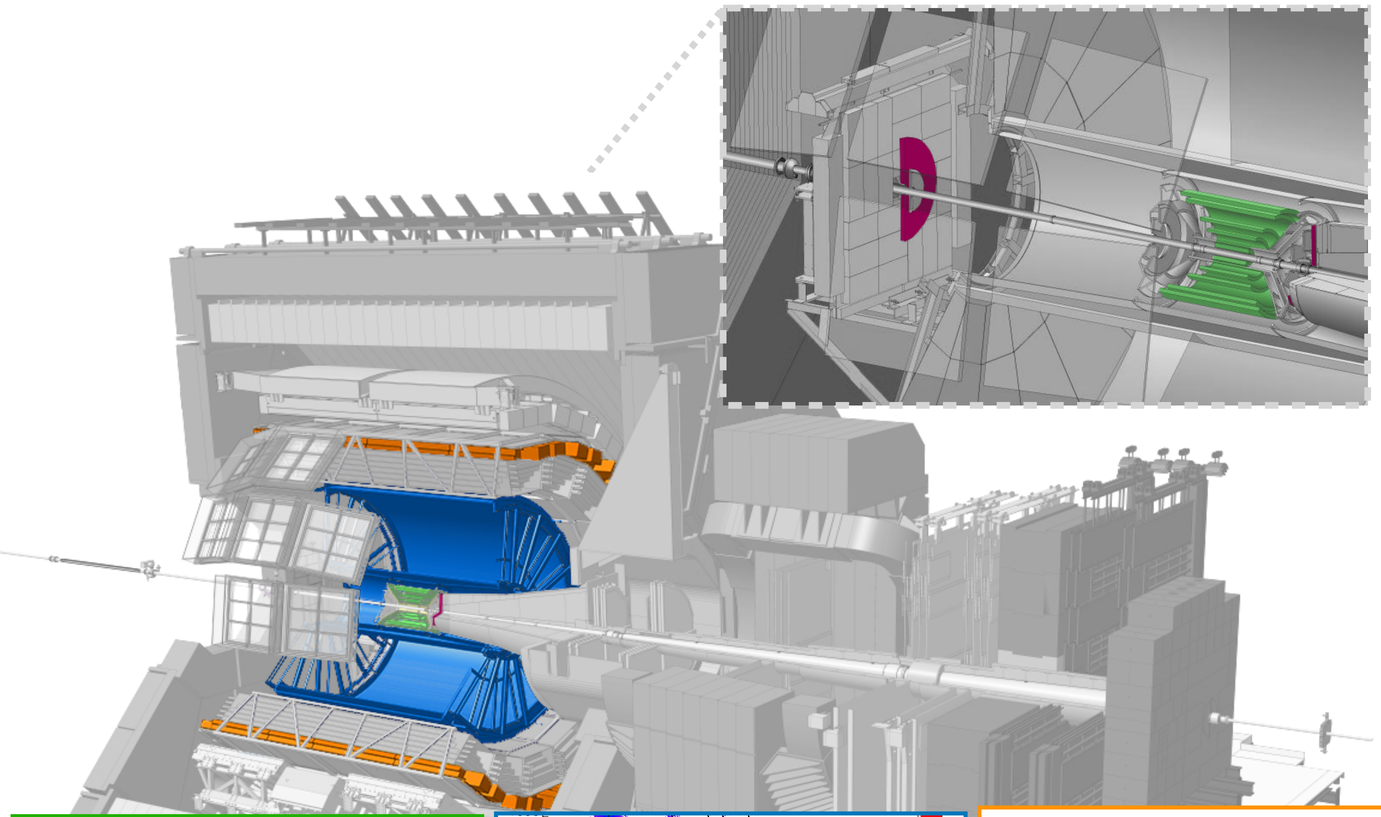

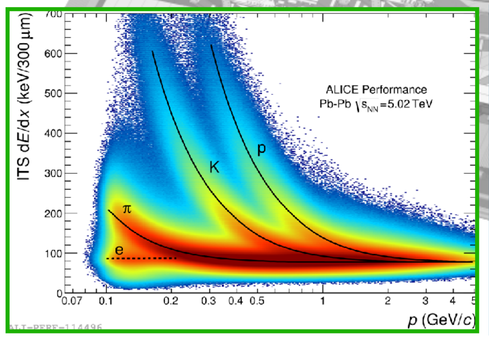


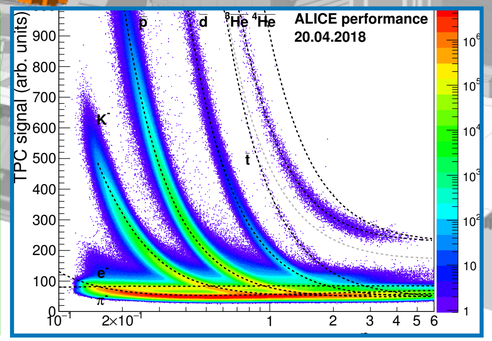


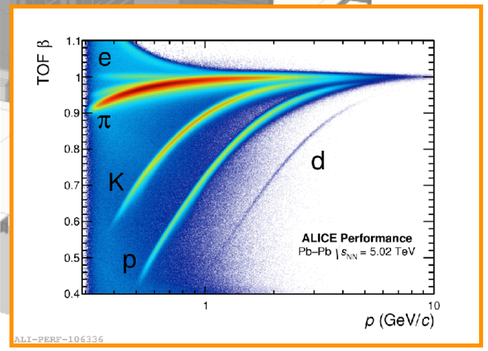


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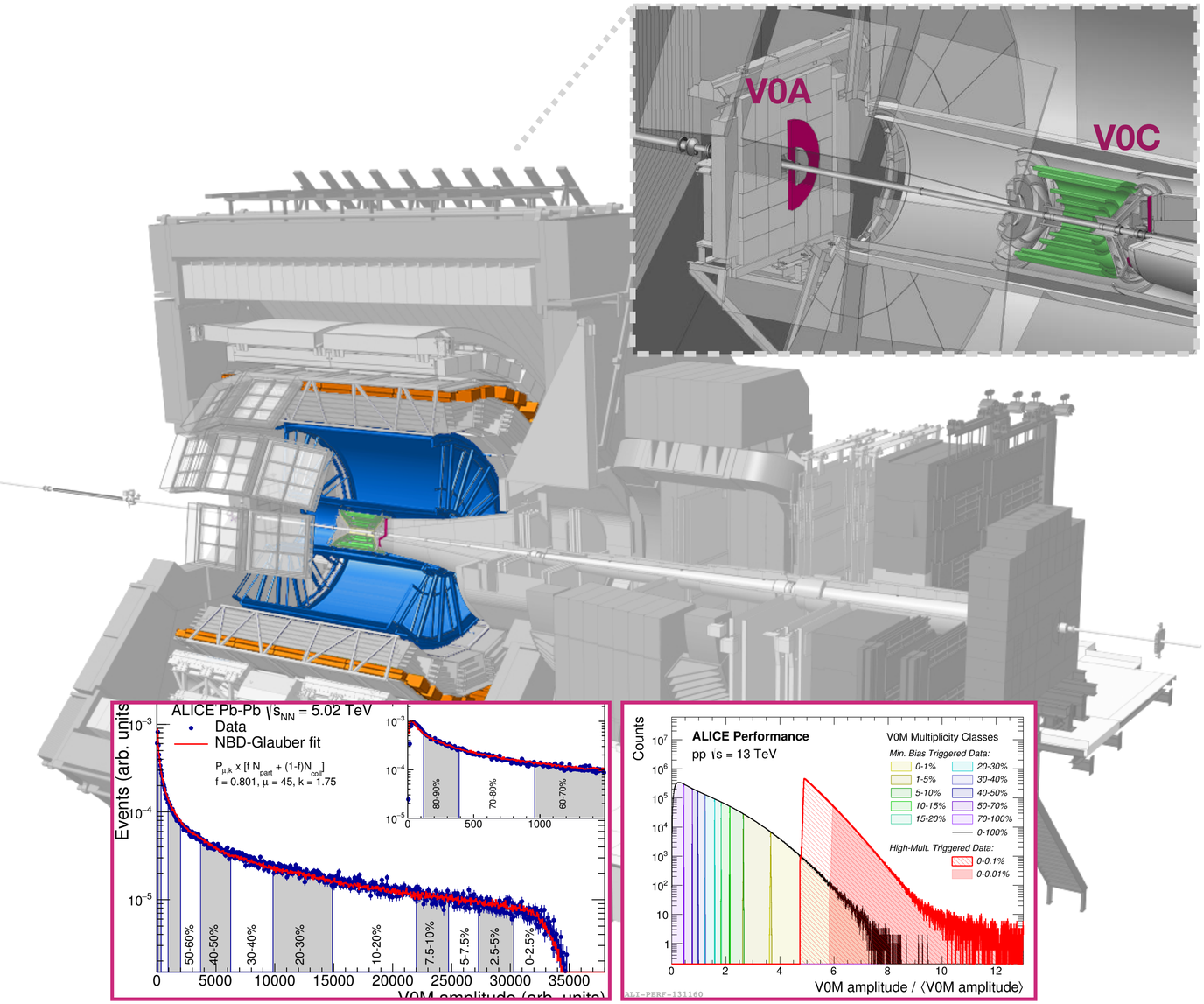








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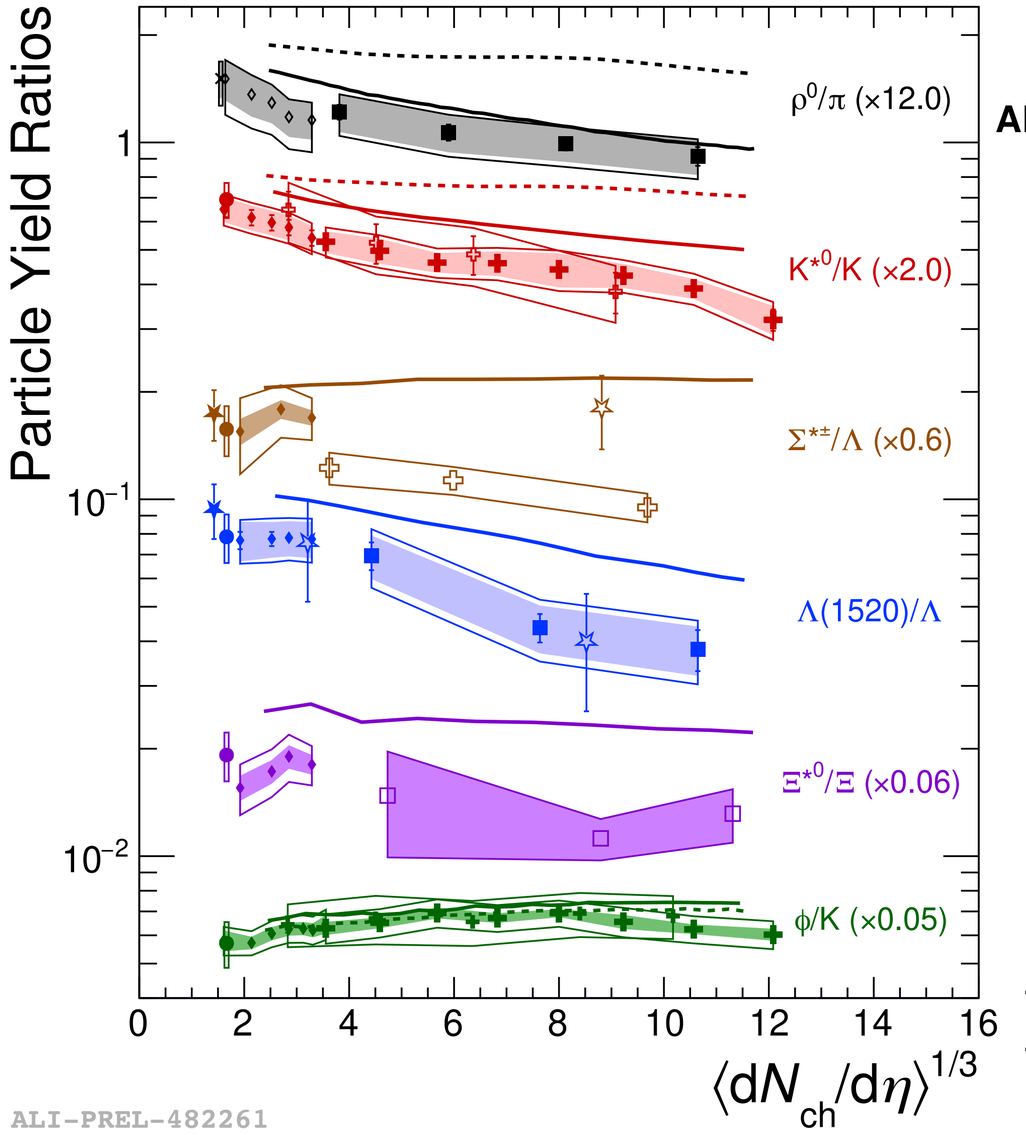
# Overview: the resonance production in ALICE




ALI-PREL-482261

**ALICE Preliminary**
- p-Pb $\sqrt{s_{NN}}$ = 5.02 TeV
- Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV
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- Xe-Xe $\sqrt{s_{NN}}$ = 5.44 TeV

**ALICE**
- pp $\sqrt{s}$ = 2.76 TeV
- pp $\sqrt{s}$ = 7 TeV
- p-Pb $\sqrt{s_{NN}}$ = 5.02 TeV
- Pb-Pb $\sqrt{s_{NN}}$ = 2.76 TeV
- Pb-Pb $\sqrt{s_{NN}}$ = 5.02 TeV
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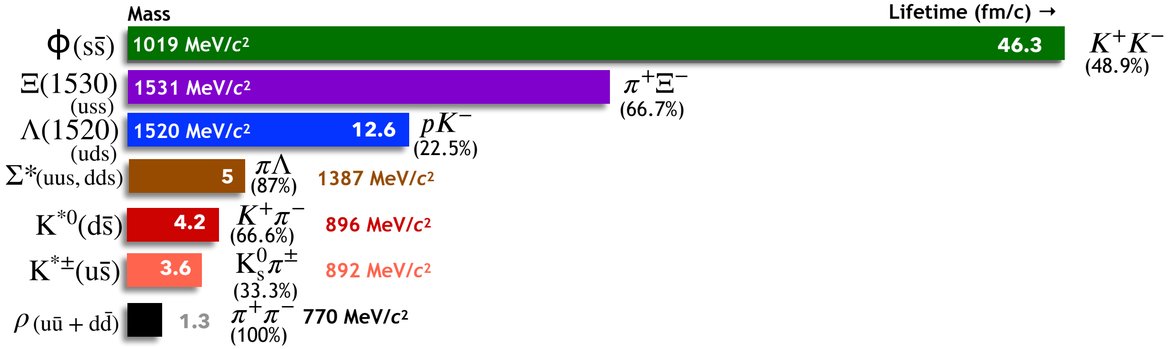
**STAR**
- pp $\sqrt{s}$ = 200 GeV
- Au-Au $\sqrt{s_{NN}}$ = 200 GeV

— EPOS3

-- EPOS3 (UrQMD OFF)

**Properties of the resonances**




- **Suppression** of the ratios of the **short-lived resonances**
- Huge role of a hadronic phase afterburner (UrQMD).

  → Suggests rescattering of decay products in hadronic phase.
- **No energy dependence** from RHIC to LHC
- **Smooth transition** from pp to A-A

  → System size **(multiplicity)** controls resonance yields

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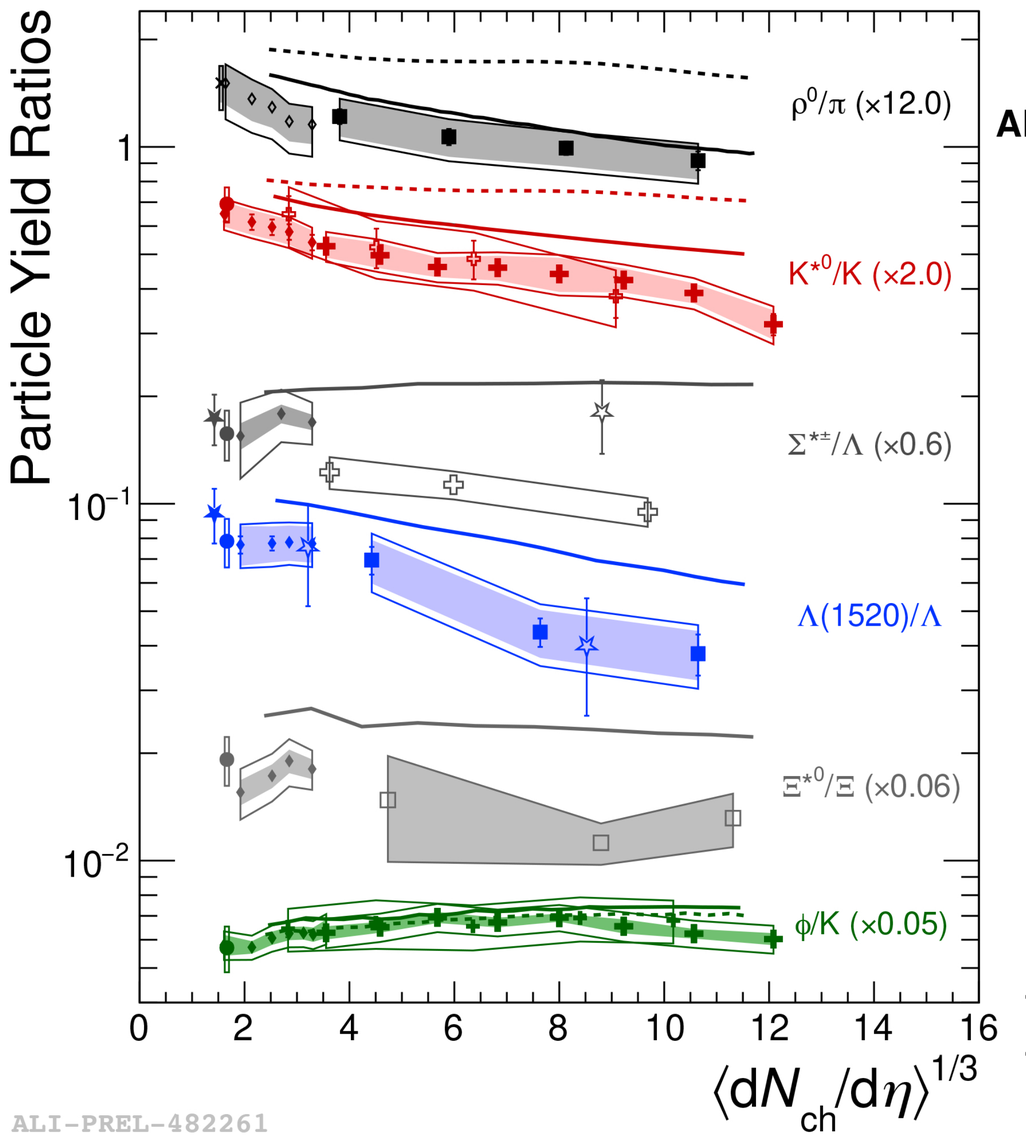


ALI-PREL-482261

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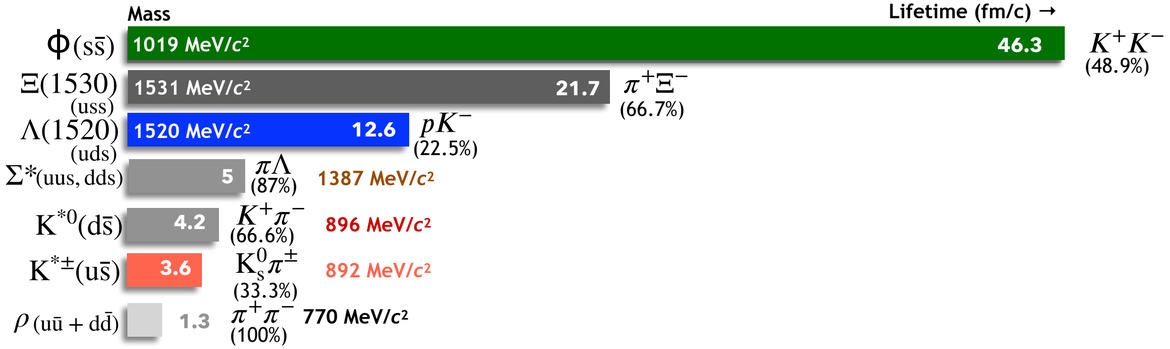


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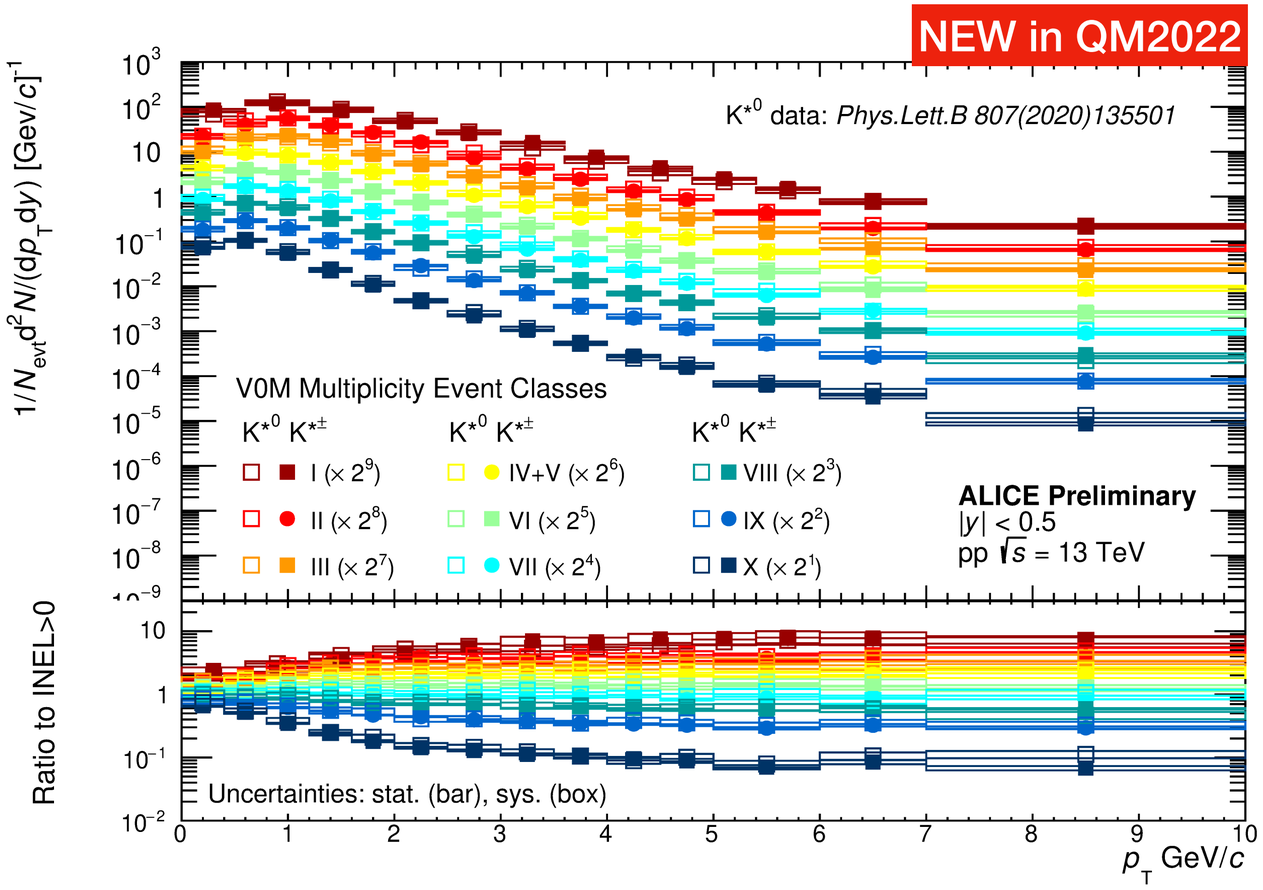
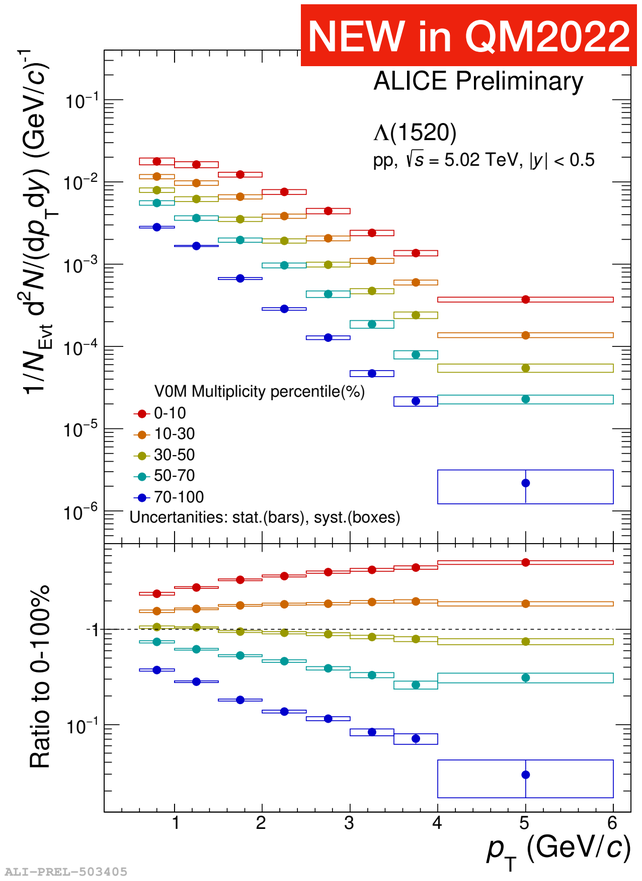
- $K^{*\pm}$, $\Lambda(1520)$, **ϕ will be updated in this talk.**

# New results: $K^*$ and $\Lambda(1520)$ in pp collisions

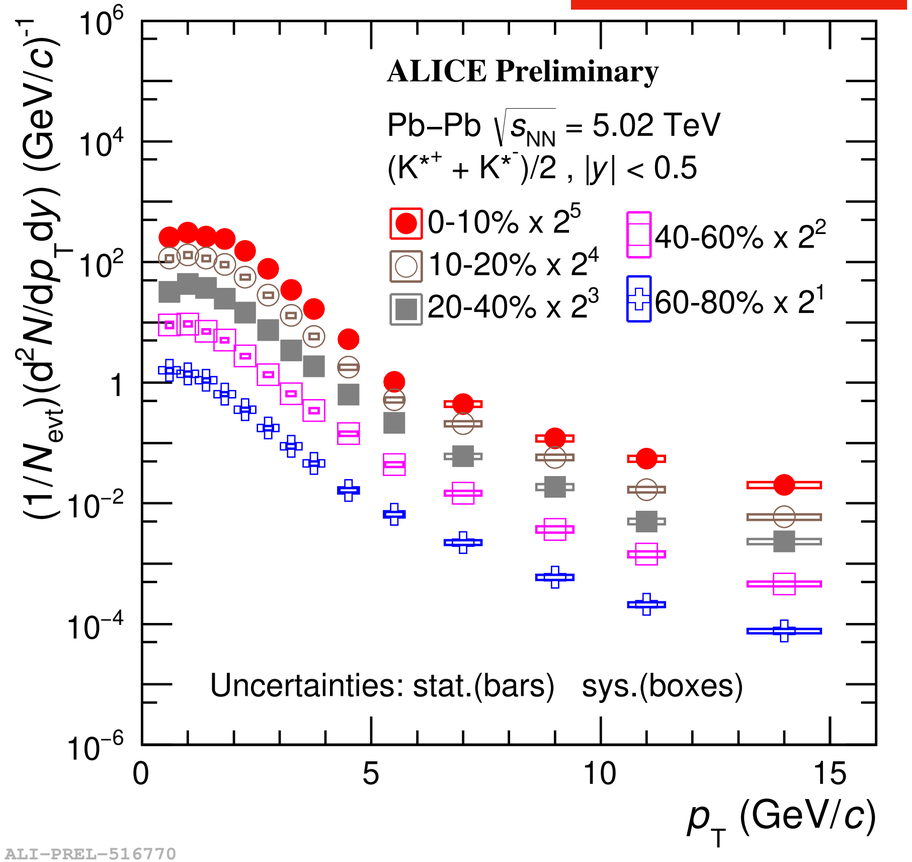



- New results of $K^{*\pm}$ and $\Lambda(1520)$ in pp collisions at $\sqrt{s}$ = 5.02 and 13 TeV in different multiplicity intervals and in Pb-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV in different centrality intervals.

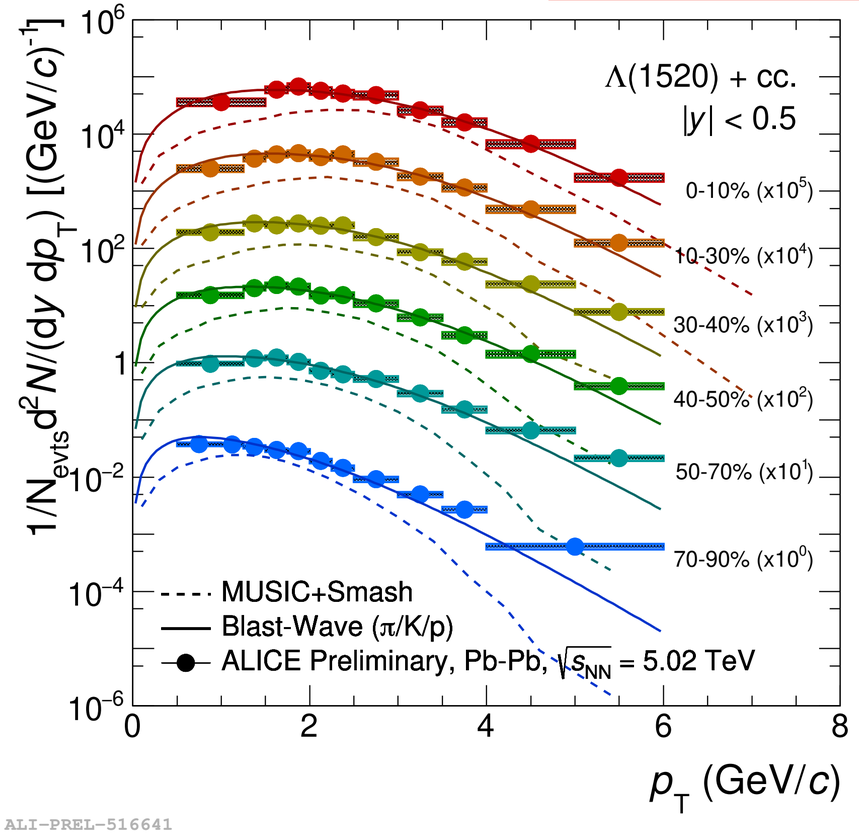
# New results: $K^*$ and $\Lambda(1520)$ in Pb-Pb collisions

NEW in QM2022




ALI-PREL-516770

NEW in QM2022



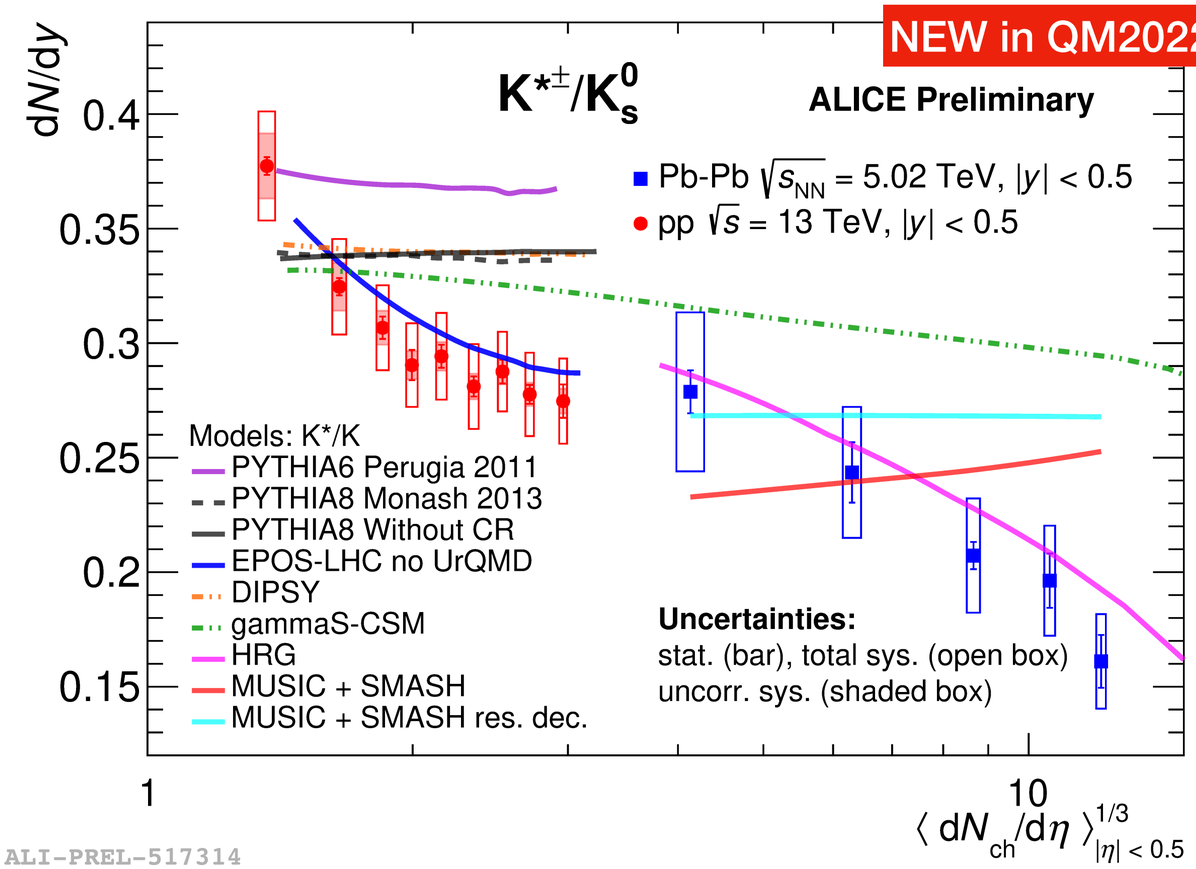

ALI-PREL-516641

- New results of $K^{*\pm}$ and $\Lambda(1520)$ in pp collisions at $\sqrt{s}$ = 5.02 and 13 TeV in different multiplicity intervals and in Pb-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV in different centrality intervals.

# New $K^{*\pm}$ results

Antonina Rosano, *Poster Session 1 T05_1*

Prottay Das, *Poster Session 1 T14_1*




- **Yields and particle ratios**: consistent with previous $K^{*0}$ results
  - Suppression of $K^{*\pm}/K$ yield ratio in high multiplicity events (A-A collisions)
  - **EPOS-LHC**: describes the measurements qualitatively at small systems.
  - **HRG**[1]: describes the measurements both qualitatively and quantitatively.
- $K^{*\pm}/K$ also shows hint of decreasing trend in high multiplicity pp collisions.

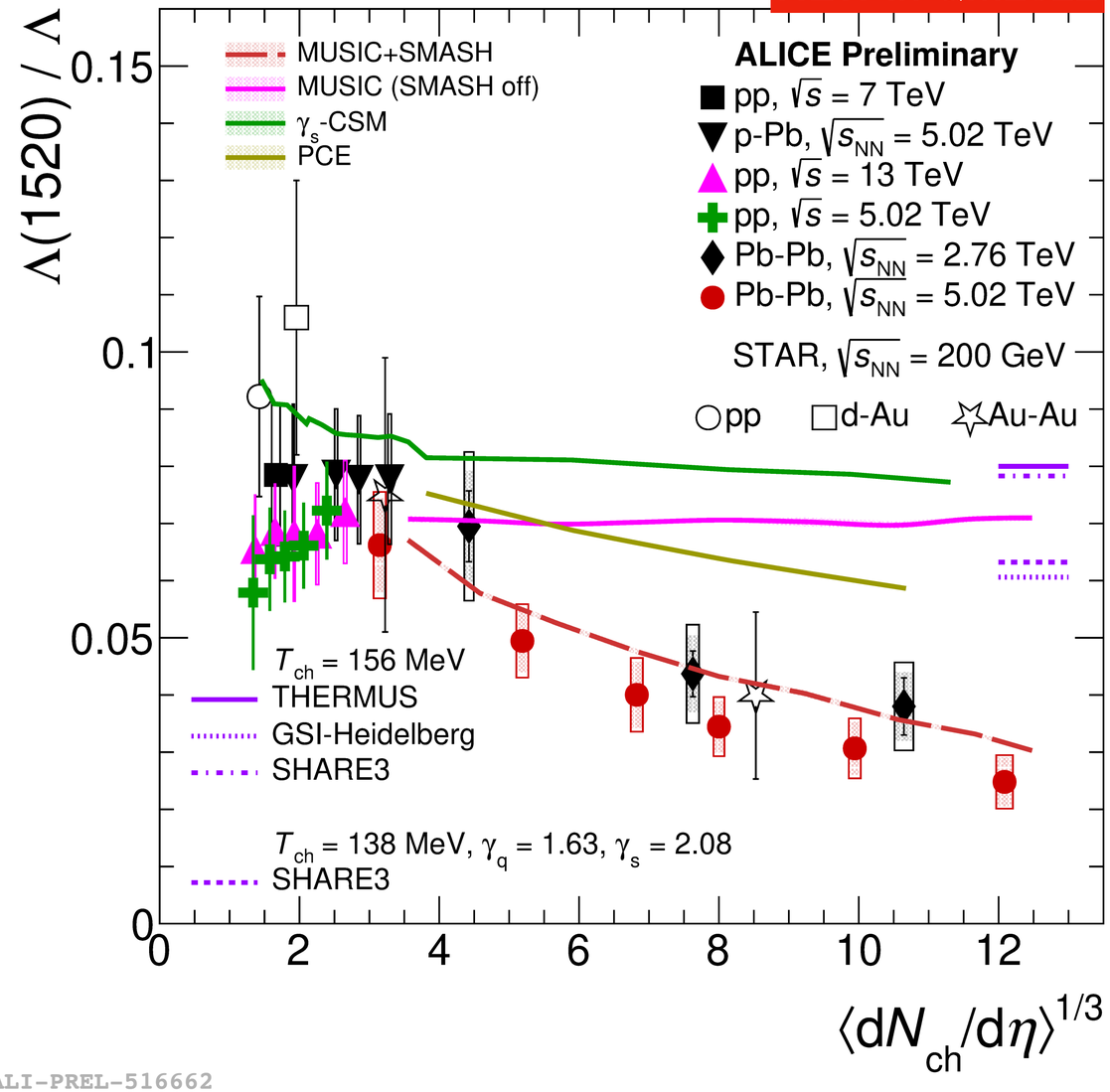
[1] *Phys.Rev.C* 102 (2020) 2, 024909

# Particle ratios: $\Lambda(1520)$

Sonali Padhan, *Poster Session 1 T05_1*

Neelima Agrawal, *Poster Session 2 T14_2*

NEW in QM2022

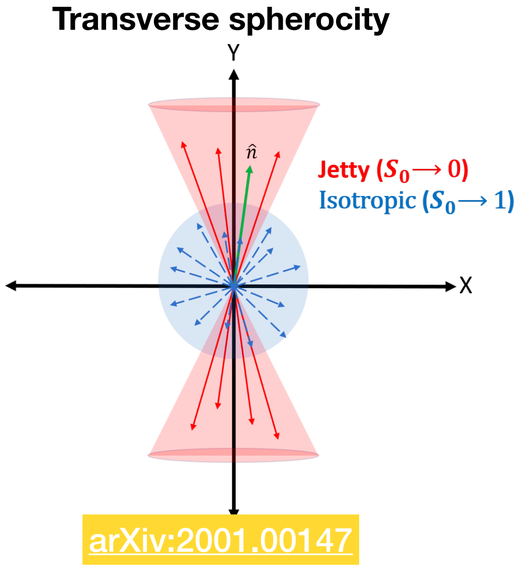



ALI-PREL-516662

- **<u>Suppression</u> of $\Lambda(1520)/\Lambda$ yield ratio in Pb-Pb events**
  - Yield ratio shows decreasing trend in the central A-A collisions
    - $\sim 7\sigma$ significance wrt most peripheral collision.
  - Similar to previous studies (2.76 TeV at ALICE and STAR)
  - Yields in central A-A collisions smaller than **<u>thermal model predictions</u>**.
  - **MUSIC+SMASH** vs MUSIC
    - Trend with centrality reproduced by hydro (MUSIC) with a hadronic phase afterburner (SMASH).
  - **Small systems**:
    - $\Lambda(1520)/\Lambda$ ratio: rather flat in the given multiplicity range.

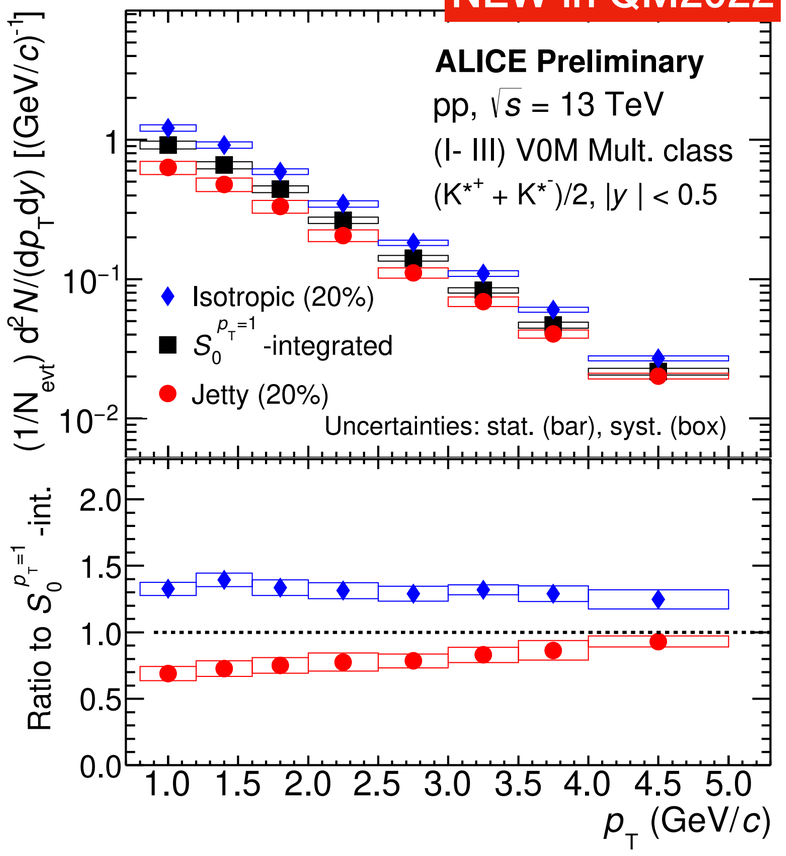
# $K^{*\pm}$ in pp $\sqrt{s}$ = 13 TeV in different spherocity interval

Suman Deb, *Poster Session 1 T05_1*



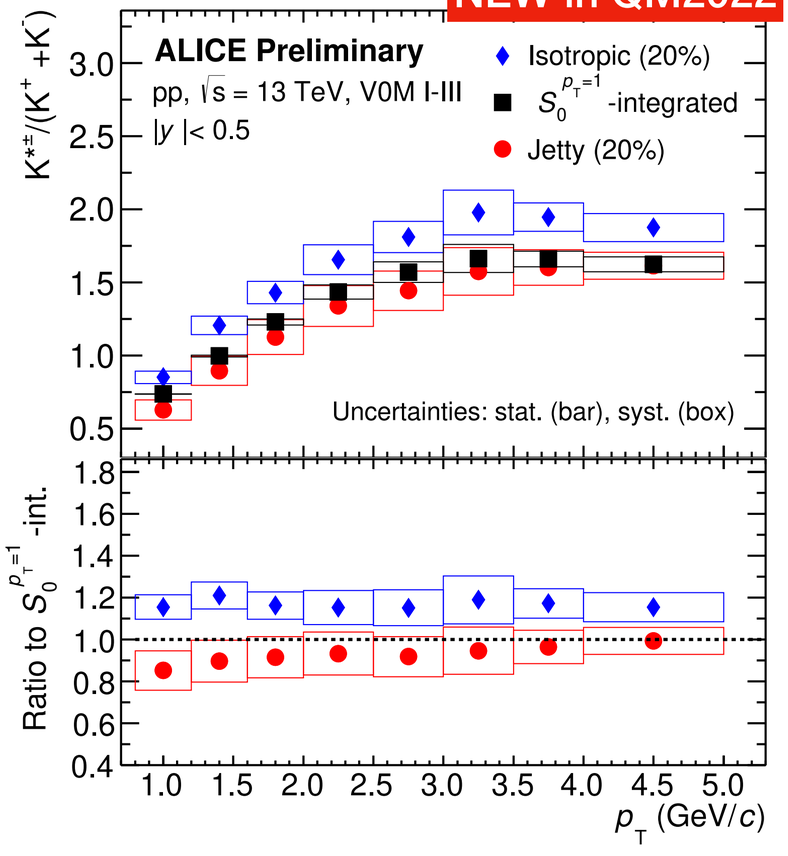

arXiv:2001.00147

NEW in QM2022




ALI-PREL-511092

NEW in QM2022

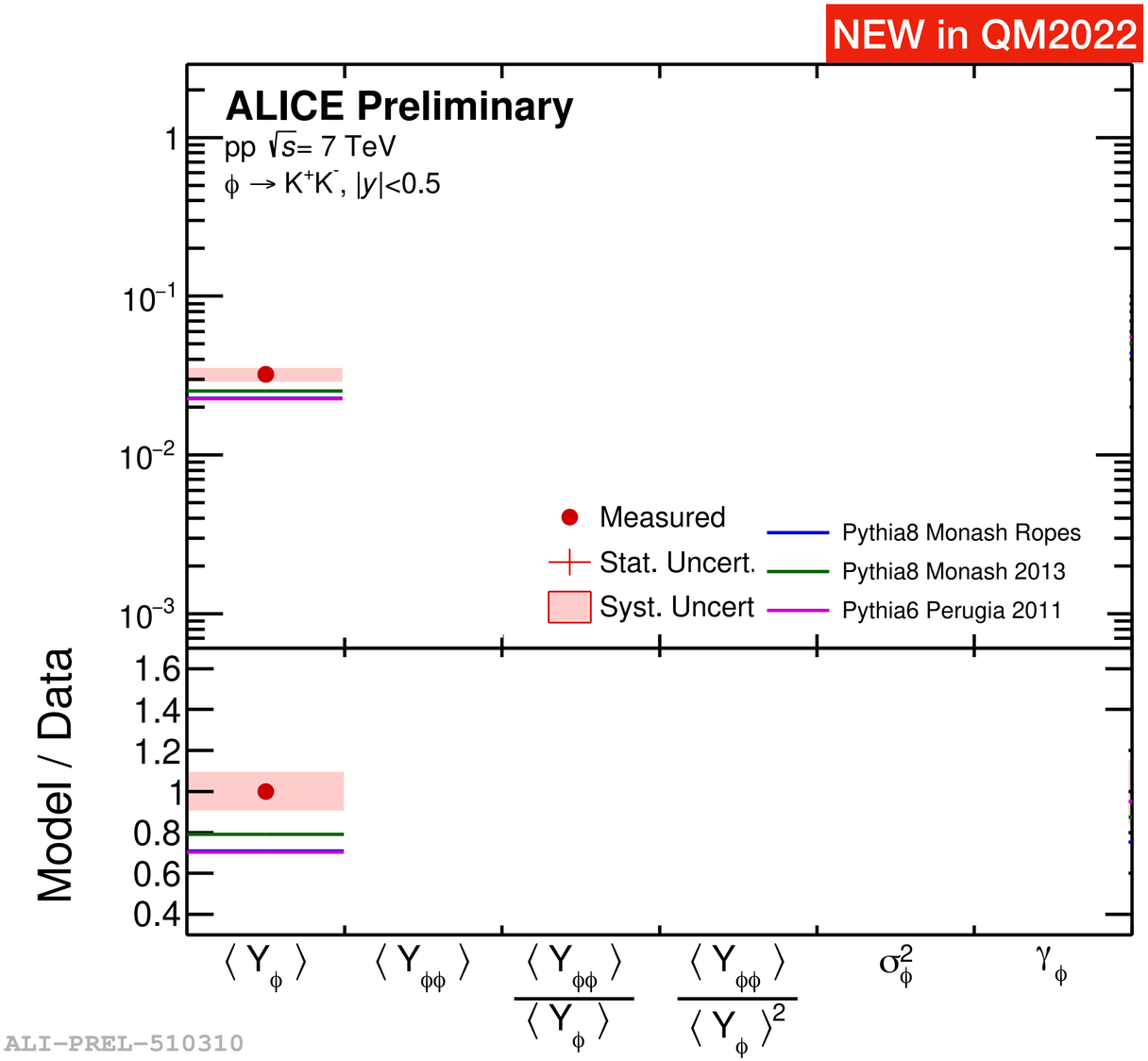



ALI-PREL-511172

- $p_T$ spectra with several spheoricity classes are measured in high multiplicity pp collisions at $\sqrt{s}$ = 13 TeV.
- Ratio of $p_T$ spectra $K^{*\pm}$/K : Hint of spherocity dependence.

# Measurement of ϕ meson pair

Nicola Rubini, *Poster Session 1 T14_2*




- **Strangeness enhancement in small systems**
  - Study of double ϕ production in pp collisions at $\sqrt{s}$ = 7 TeV
- ϕ meson pair production: $\langle Y_{\Phi\Phi} \rangle$
  - $\sigma^2_\Phi = 2\langle Y_{\Phi\Phi} \rangle + \langle Y_\Phi \rangle - \langle Y_\Phi \rangle^2$
  - $\gamma_\Phi = \frac{\sigma^2_\Phi}{\langle Y_\Phi \rangle} - 1 = 2\frac{\langle Y_{\Phi\Phi} \rangle}{\langle Y_\Phi \rangle} - \langle Y_\Phi \rangle$

    **Key observable**
  - If $\gamma_\Phi = 0$, double ϕ production is **purely statistical** with a poissonian distribution
  - If $\gamma_\Phi \neq 0$, the production **enhanced** or **suppressed**.
- Result:
  - $\gamma_\Phi > 0$: Not purely statistical but enhanced.
  - **Pythia models underestimate $\langle Y_\Phi \rangle$, $\langle Y_{\Phi\Phi} \rangle$ while $\gamma_\Phi$ is described quantitively.**

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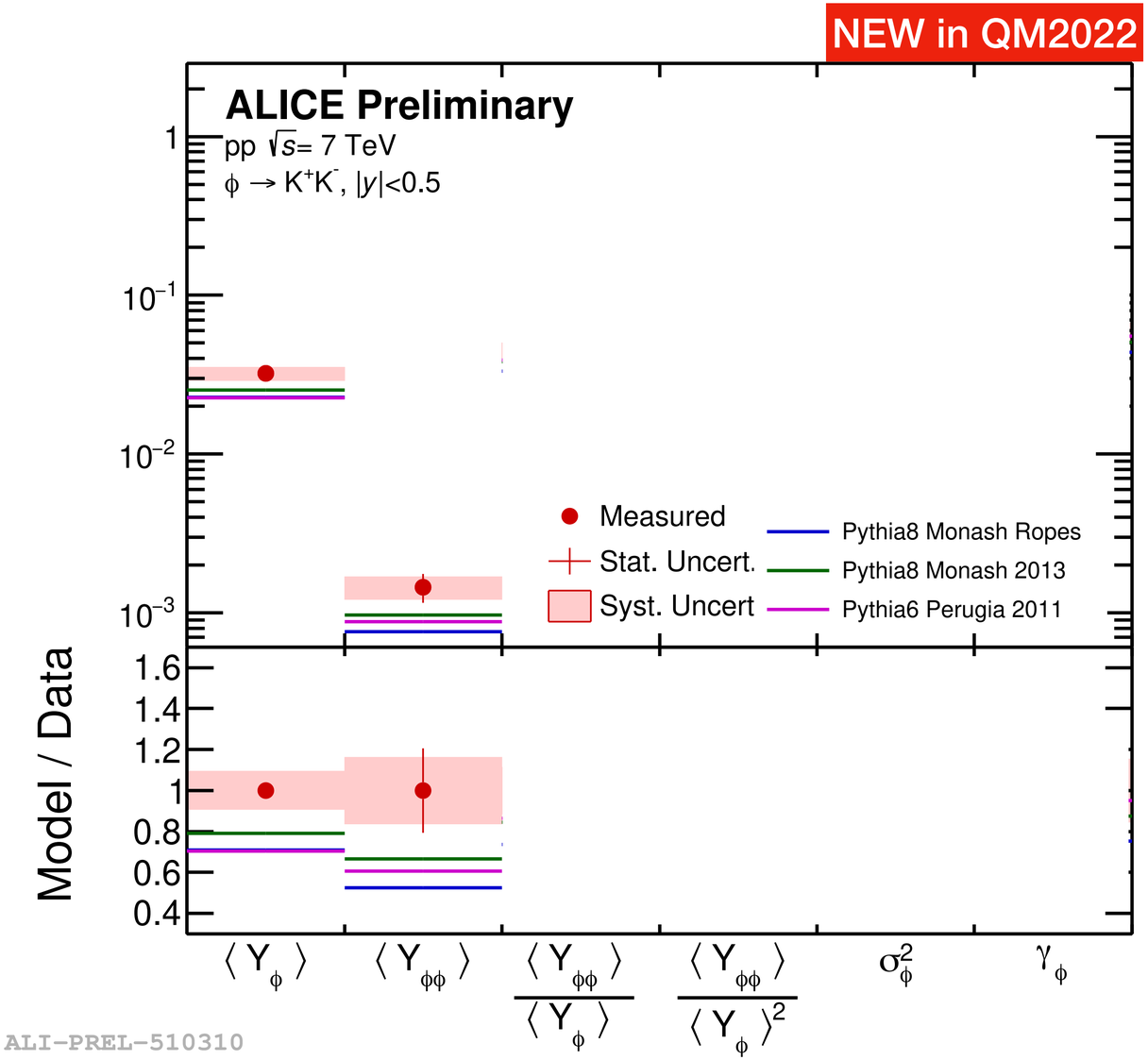


Nicola Rubini, *Poster Session 1 T14_2*

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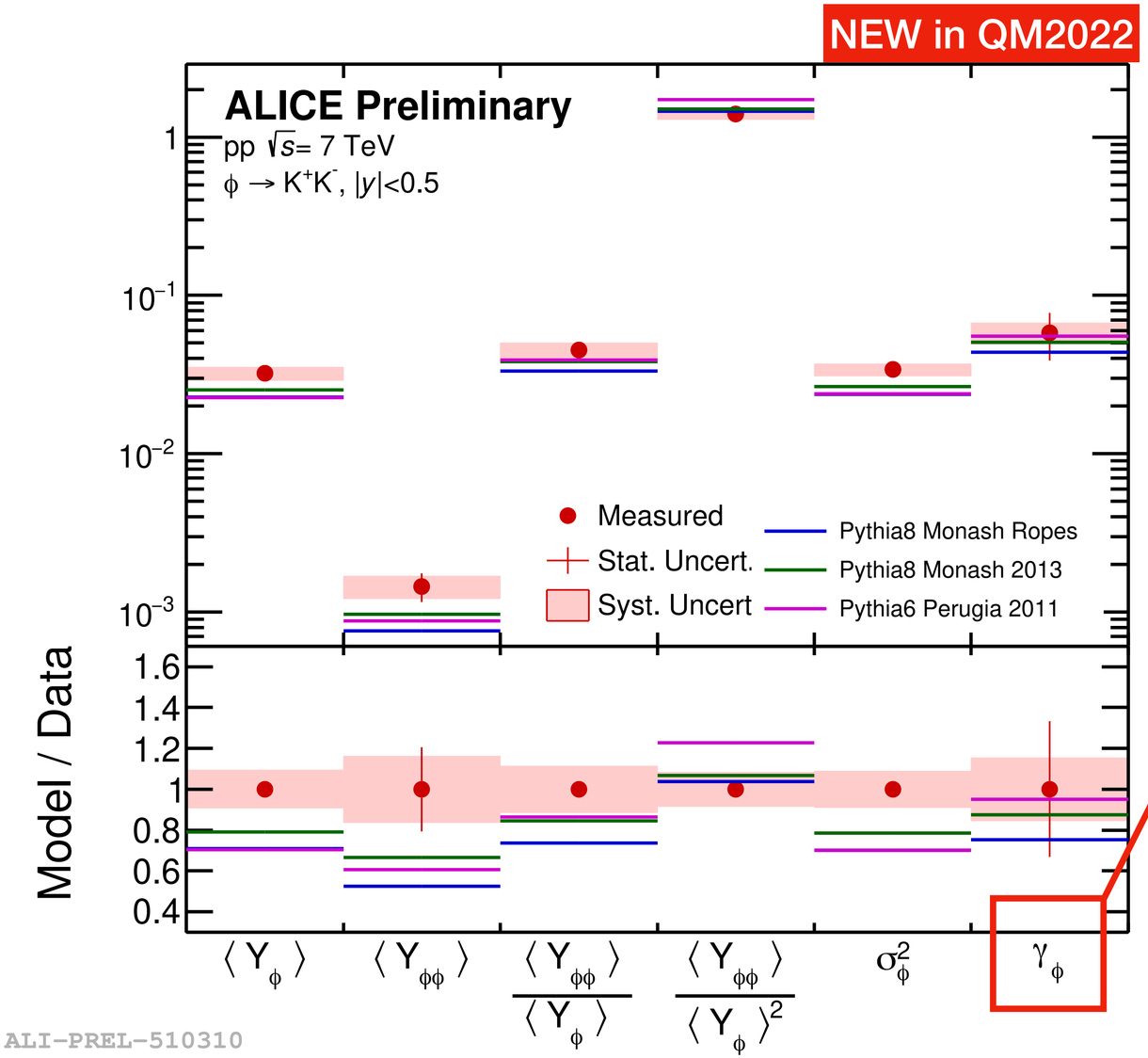


ALI-PREL-510310

Nicola Rubini, *Poster Session 1 T14_2*

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# Summary

- **Resonances** are useful tools to probe the characteristics of the hadronic phase.
- **ALICE** has measured a rich set of resonance particles in various systems.
  - **Rescattering** and **Regeneration** are the key mechanisms.
- New measurements of the $\mathrm{K}^{*\pm}$ in pp at $\sqrt{s}$ = 13 TeV and Pb-Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV
  - **Consistent** with the result obtained for $\mathrm{K}^{*0}$

  Antonina Rosano, *Poster Session 1 T05_1* Prottay Das, *Poster Session 1 T14_1*
- New measurements of $\Lambda(1520)$ in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV and pp collisions at $\sqrt{s}$ = 5 TeV and 13 TeV
  - The ratio $\Lambda(1520)/\Lambda$ in Central Pb-Pb collisions: **suppressed** w.r.t the peripheral with a significance of 7.1$\sigma$

  Neelima Agrawal, *Poster Session 2 T14_2* Sonali Padhan, *Poster Session 1 T05_1*
- **Spherocity** dependent $\mathrm{K}^{*\pm}$ in pp at $\sqrt{s}$ = 13 TeV.
  - The ratio of $p_{\mathrm{T}}$ spectra $\mathrm{K}^{*\pm}/\mathrm{K}$: Hint of spherocity dependence.

  Suman Deb, *Poster Session 1 T05_1*
- $\phi$ meson **pair** production
  - The enhanced yield of $\phi$ is not purely statistical.

  Nicola Rubini, *Poster Session 1 T14_2*

# Back up