Study of Resonance Production at ALICE

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Webinar on PINSTECH-CERN Collaboration
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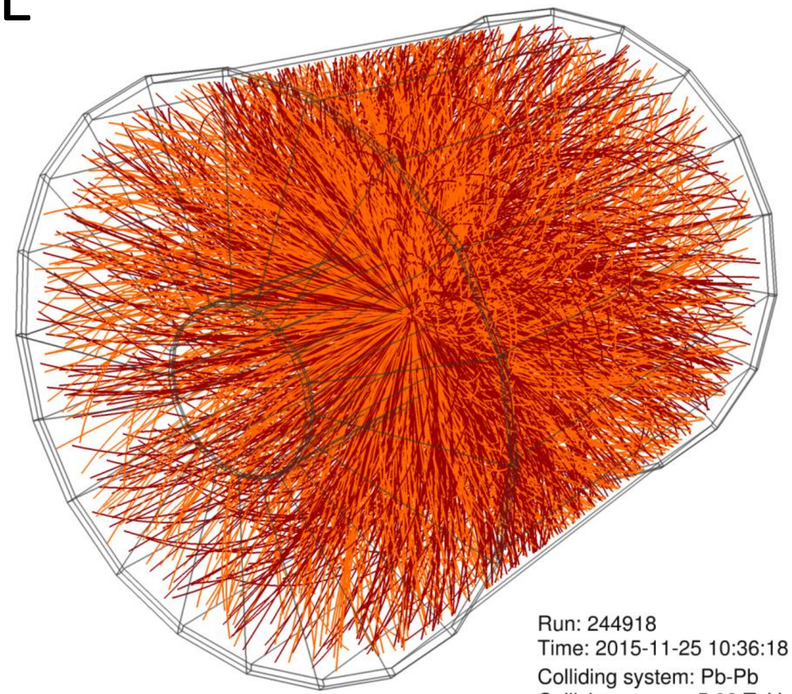
OUTLINE

- Introduction
  - Resonances
  - Motivation: What do we learn from resonances?
- ALICE: A Large Ion Collider Experiment
- Resonance Measurements in ALICE
  - Spectra
  - Integrated yields
  - Mean p_T
  - Particle Ratios
  - Nuclear Modification Factor
- Summary



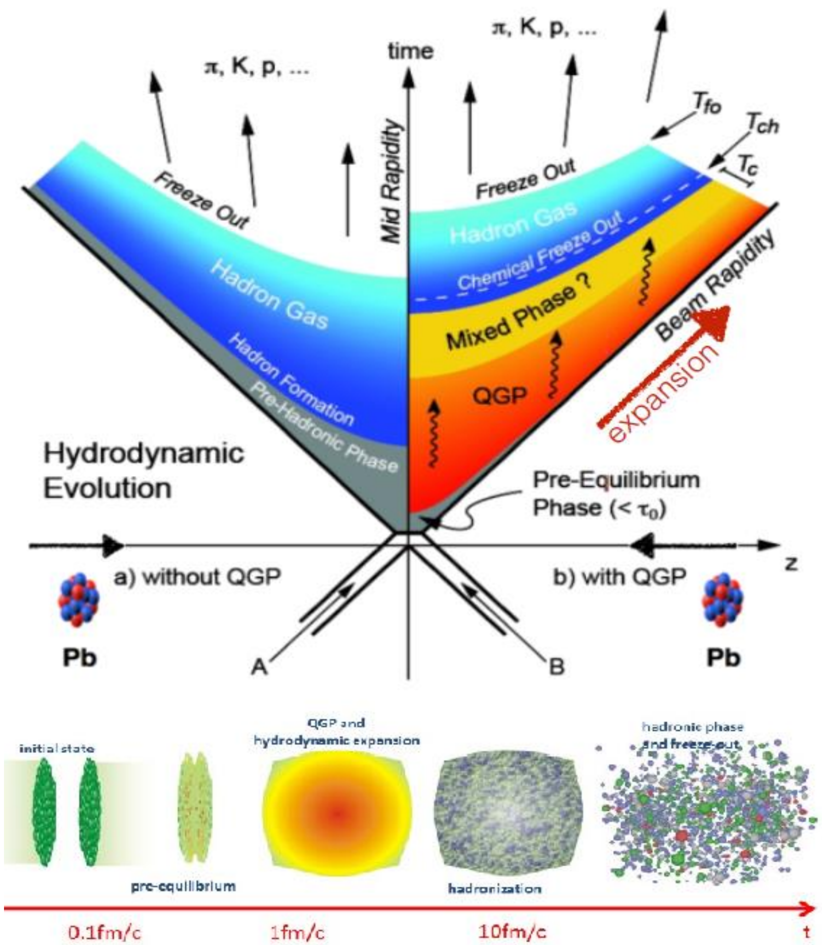
Introduction: Resonances

- Resonances are extremely short lived particles. ($\tau_{resonance} \sim \tau_{fireball}$)
- Due to this short lifetime they may decay between **chemical** and **kinetic freeze-outs**.

In heavy ion collisions:

→ the stage at which the particle species are fixed (no further inelastic interactions between hadrons) is called ***chemical freeze-out***.

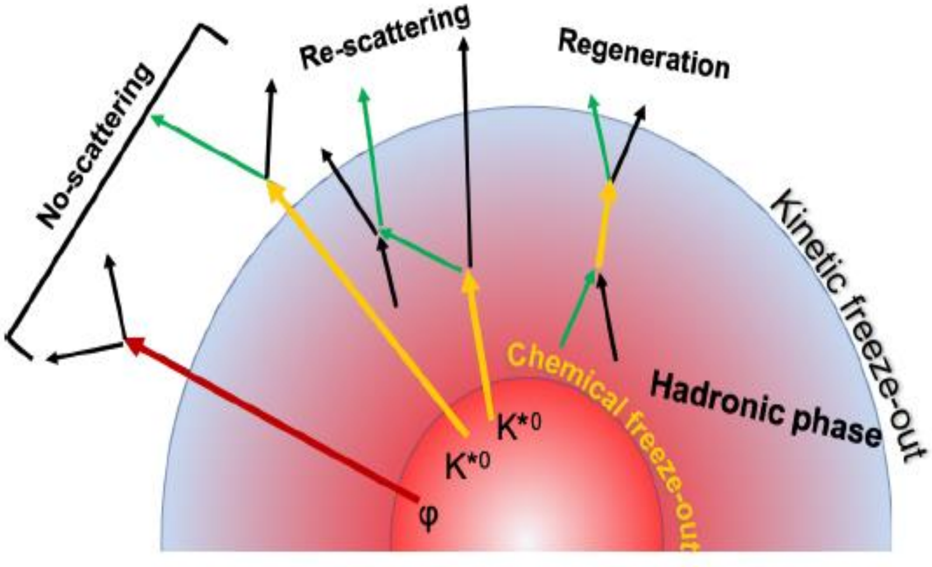
→ the stage at which the mean free path of hadrons beat the dynamical size of the system and stream freely (no further elastic interactions between hadrons) is called ***kinetic freeze-out***.



Introduction: Resonances

ALICE

- The medium may modify their properties as **mass**, **yield** and **width**.
- From partonic state to hadronic state resonances may
  - decay,
  - re-scatter,
  - regenerate.



Regeneration: resonance reproduction in hadronic phase by pseudo-inelastic interactions with hadrons in the medium.

→ Enhancement of the resonance yield

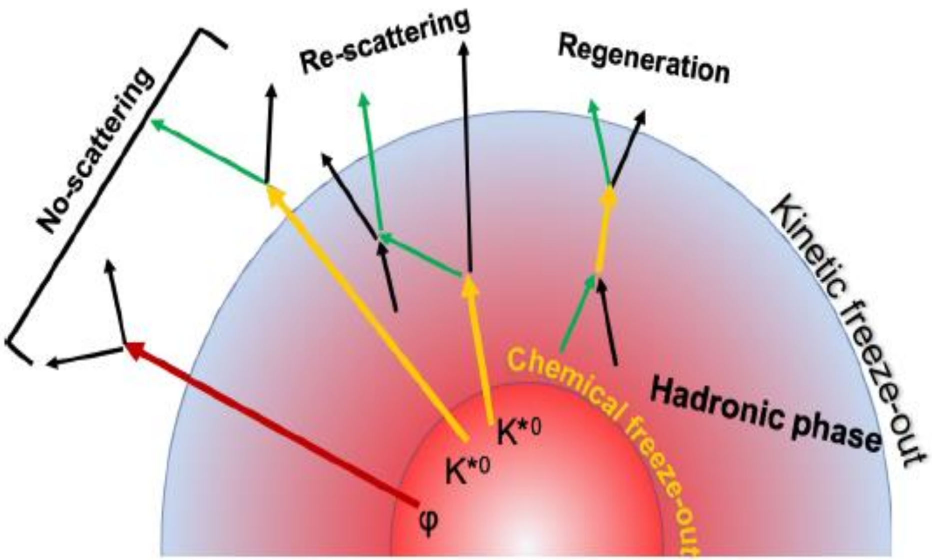
Re-scattering: Elastic scattering or pseudoelastic scattering of resonance decay products with hadrons in the medium.

→ Resonance can not be reconstructed (*lost resonance signal!*)

→ Reduction of the resonance yield

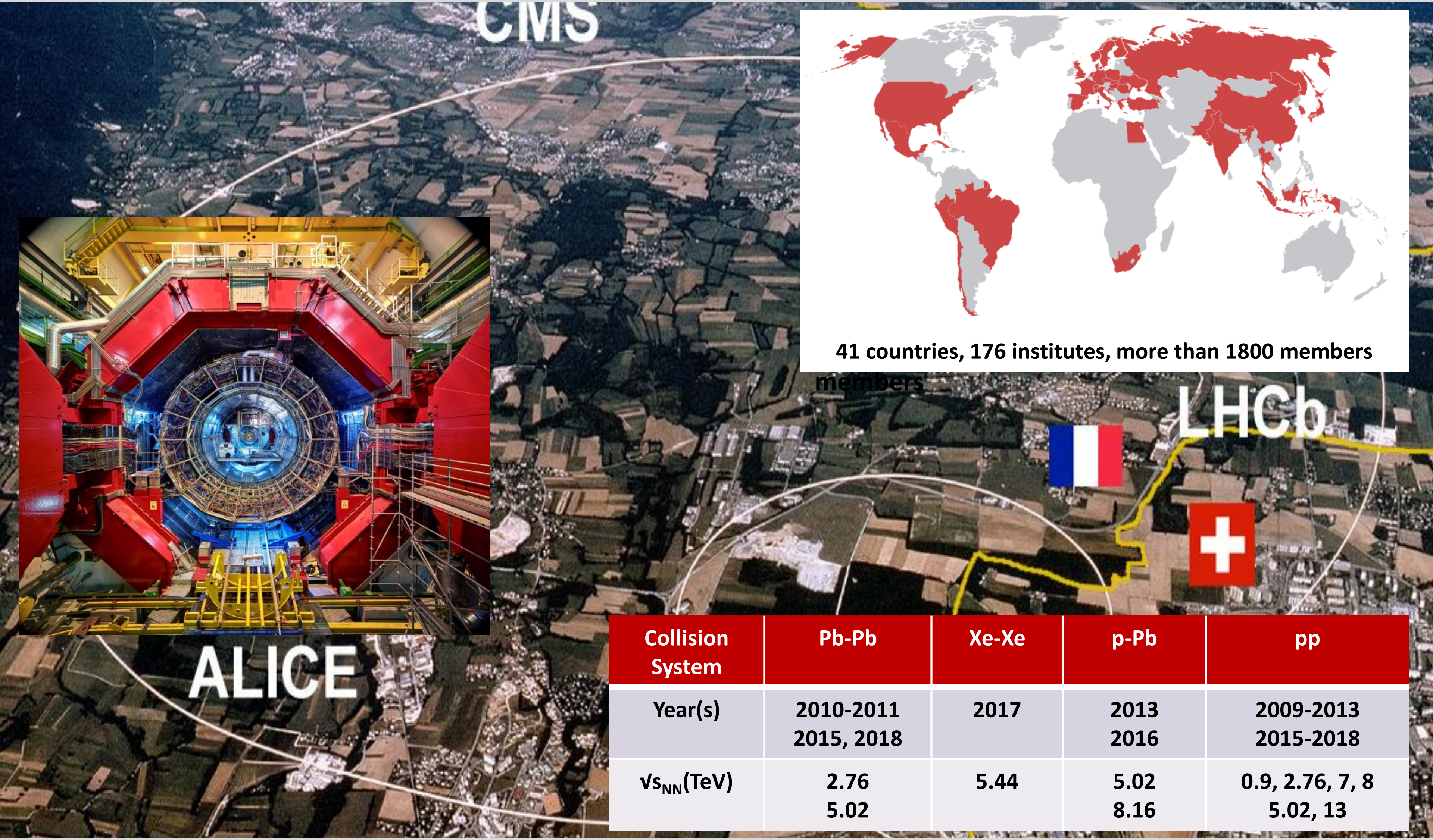
Motivation: Why resonances?

- Decay between chemical and kinetic freeze-outs
  - → information on hadronization.
- Particle ratios, yield and mean p_T
  - → hint of rescattering and regeneration effects in the hadronic phase.
- Nuclear modification factors
  - → information about energy loss mechanism in the medium.
- Study on the mass and width
  - → interactions of the resonances with the medium.
- Comparison of resonance production in different collision systems
  - → provide evidences for in-medium effects.



Resonances	τ(fm/c)	Decay	BR(%)
$\rho(770)^0$	1.3	ππ	100
$K^*(892)^0$	4.2	Kπ	66.6
$\Sigma(1385)^\pm$	5.5	Λπ	87
Λ(1520)	12.6	pK	22.5
$\Xi(1530)^0$	21.7	Ξπ	66.7
ϕ(1020)	46.4	KK	49.2

ALICE:A Large Ion Collider Experiment



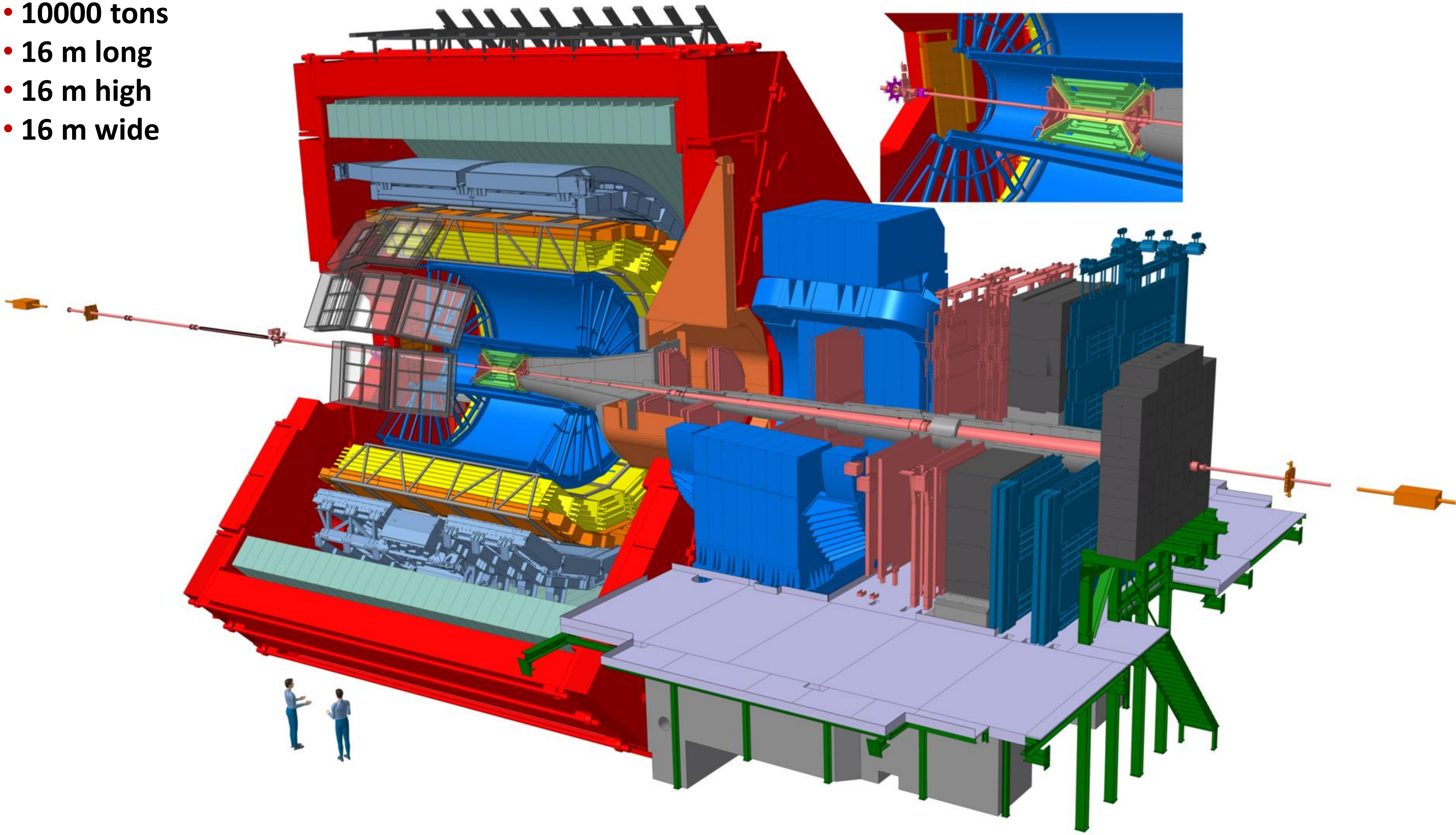
41 countries, 176 institutes, more than 1800 members

members

Collision System	Pb-Pb	Xe-Xe	p-Pb	pp
Year(s)	2010-2011 2015, 2018	2017	2013 2016	2009-2013 2015-2018
$\sqrt{s_{NN}}$(TeV)	2.76 5.02	5.44	5.02 8.16	0.9, 2.76, 7, 8 5.02, 13

ALICE:A Large Ion Collider Experiment

- 10000 tons
- 16 m long
- 16 m high
- 16 m wide



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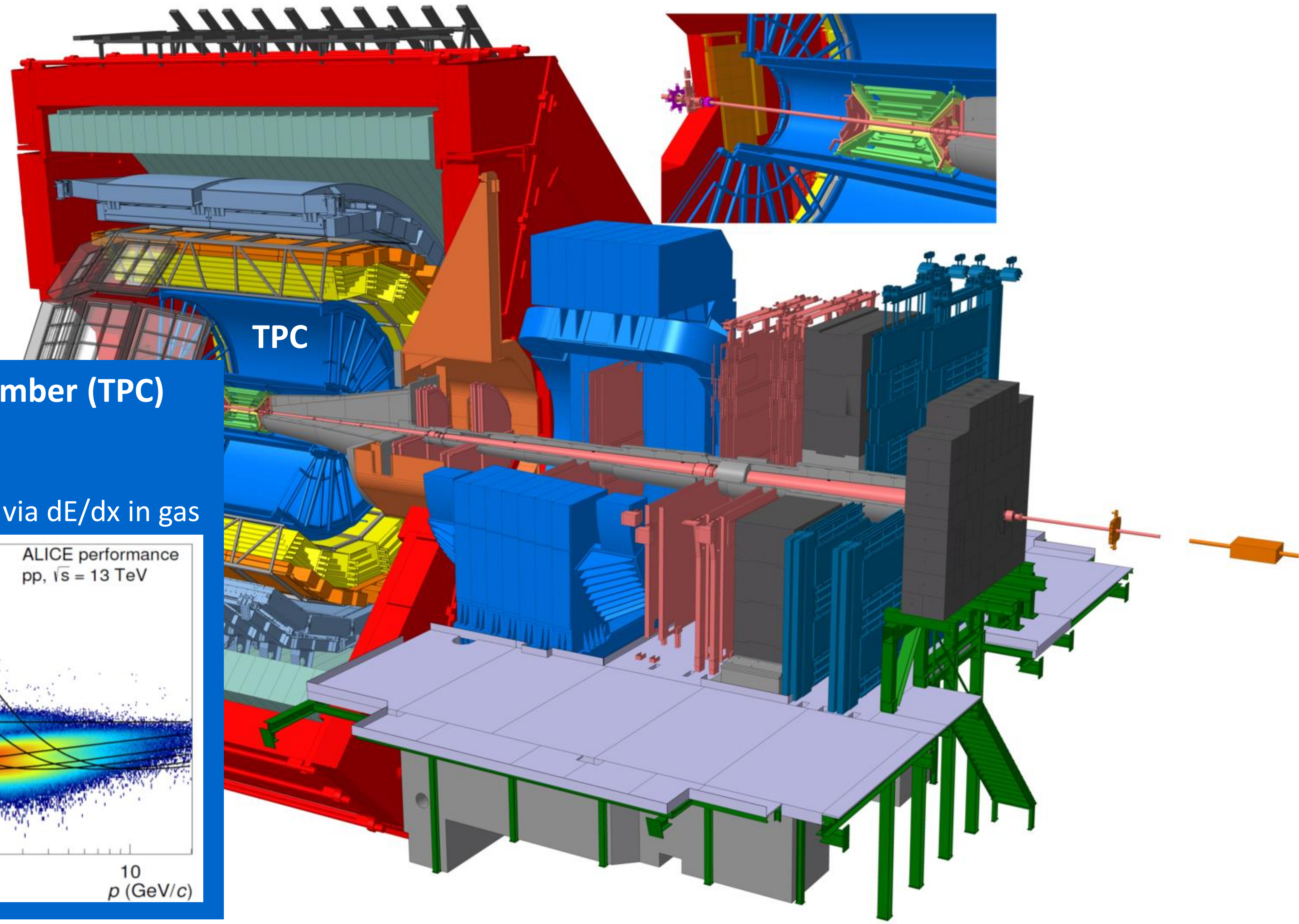
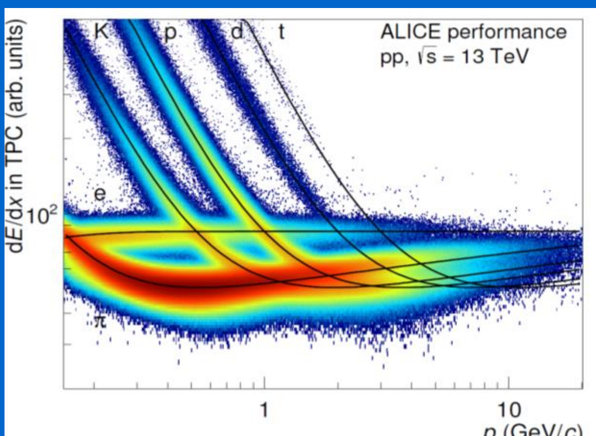


Time Projection Chamber (TPC)

- primary vertex
- global tracking
- Particle identification via dE/dx in gas



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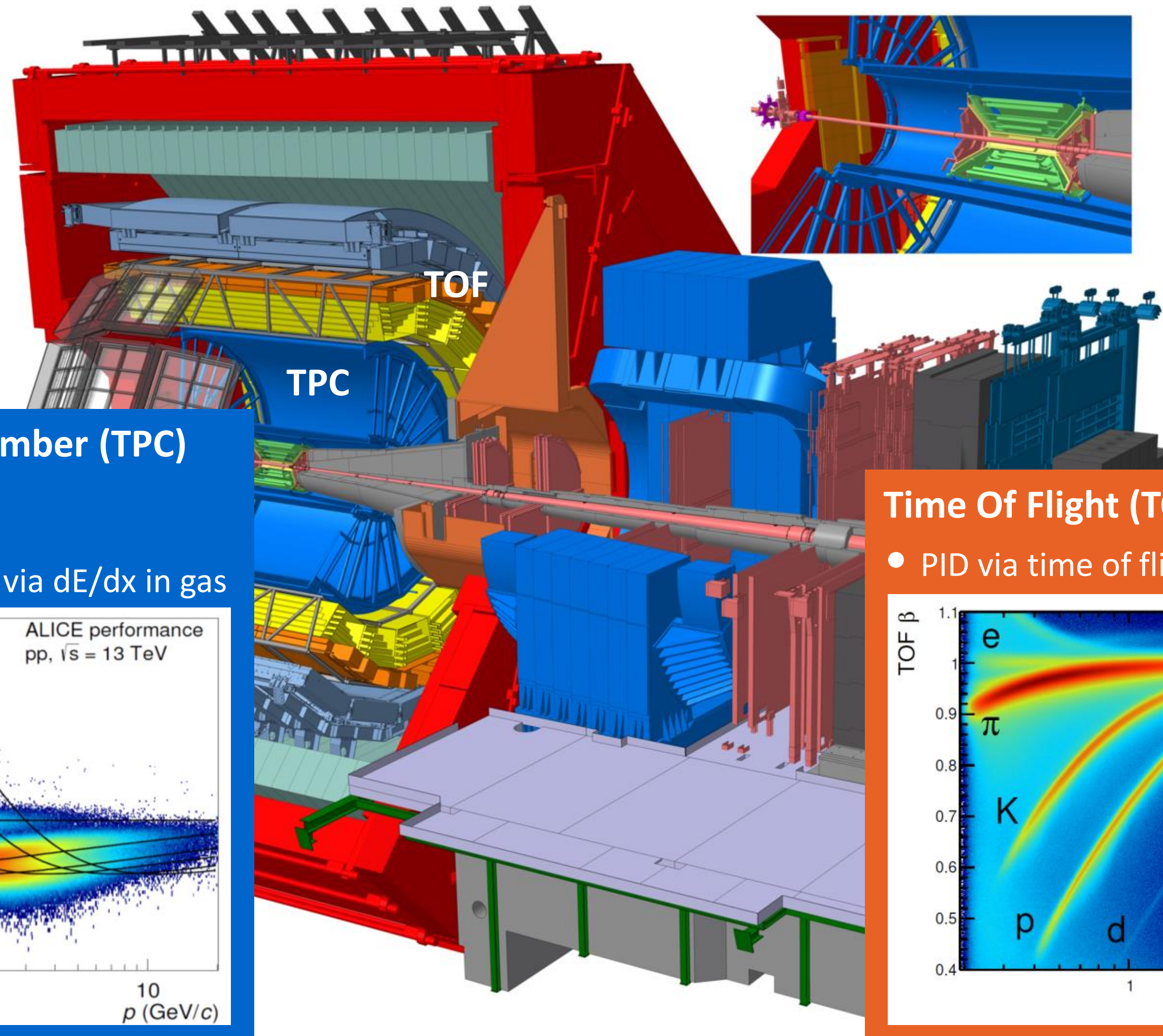

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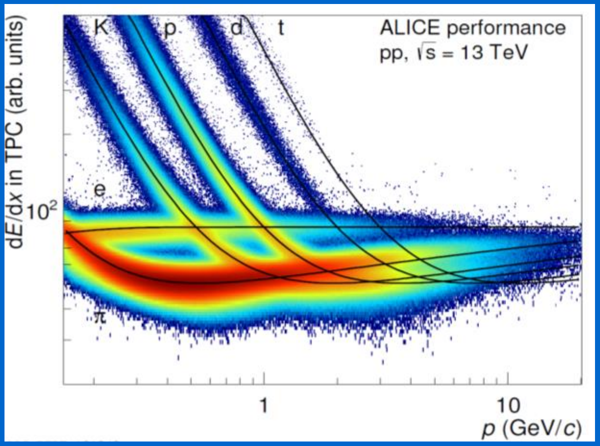
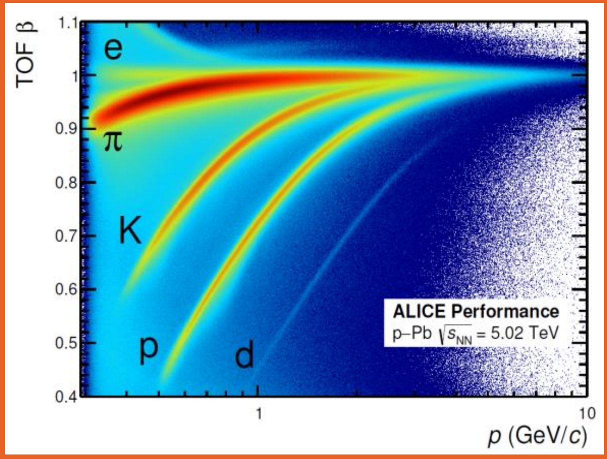


Time Of Flight (TOF)

- PID via time of flight measurement



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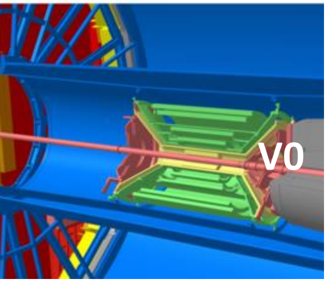

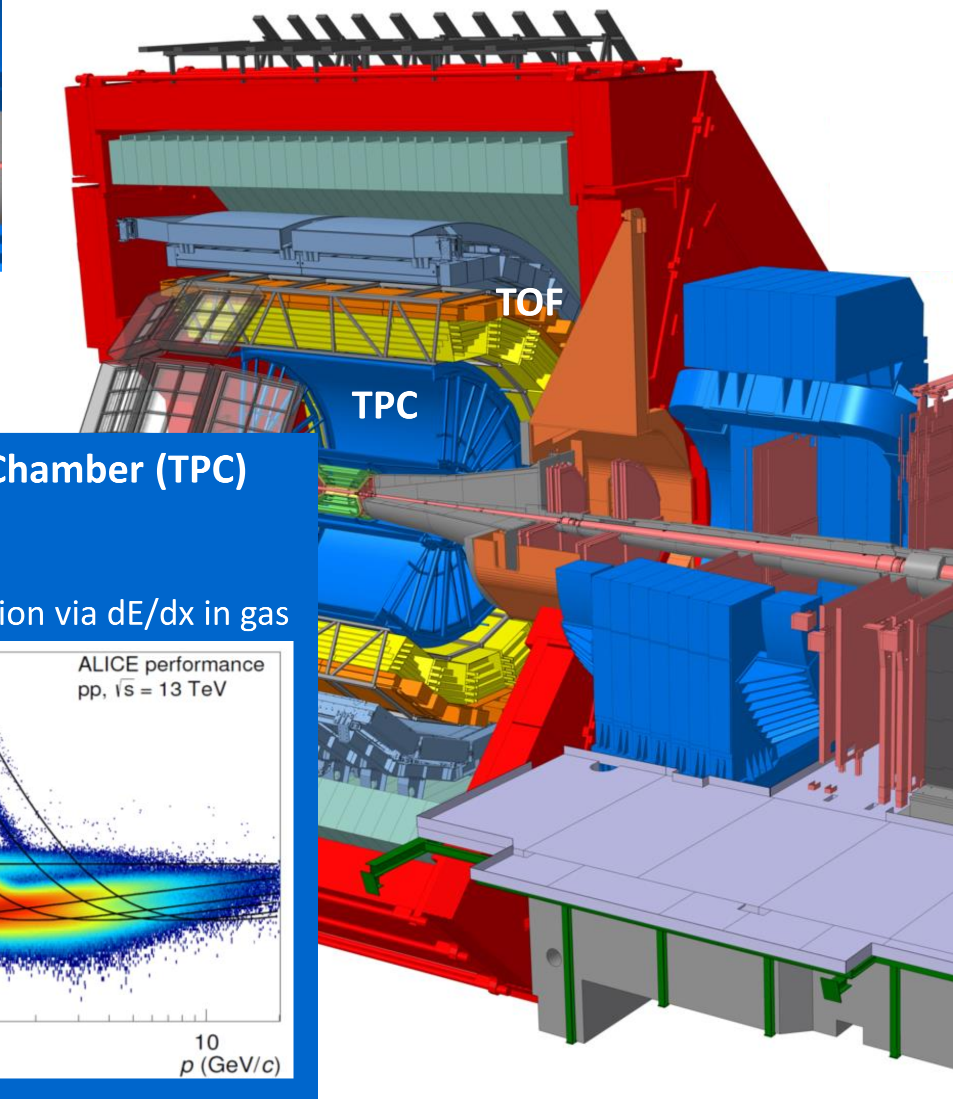

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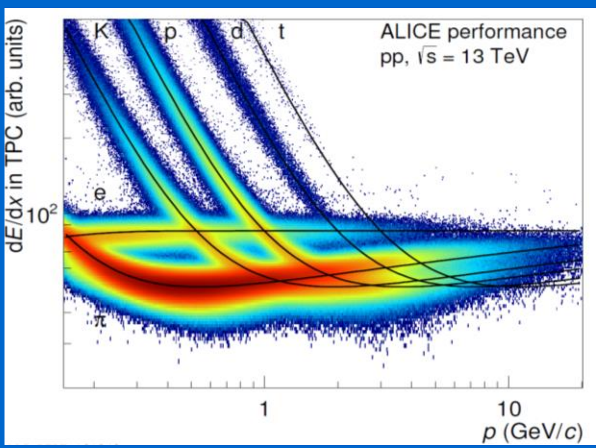
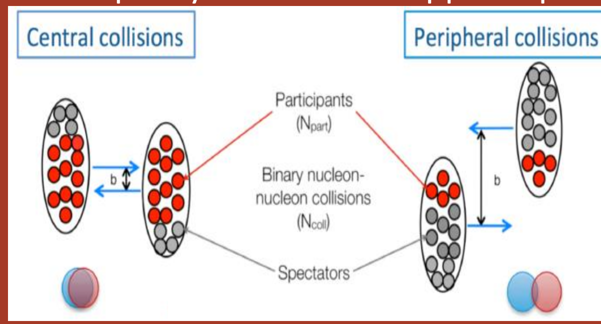


VZERO Scintillator Detectors(V0)

- Centrality definition in Pb-Pb, Xe-Xe
- Multiplicity event class in pp and p-Pb



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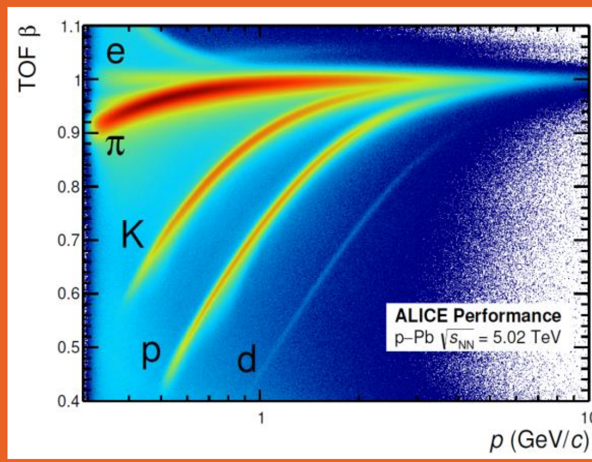
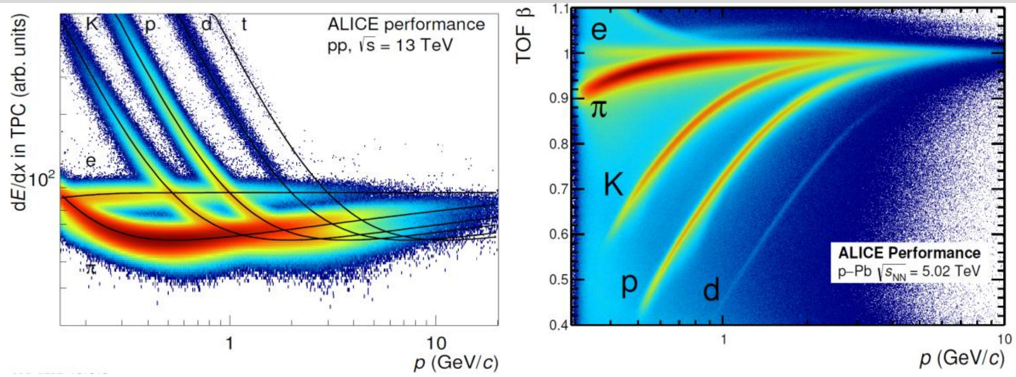


Resonance Measurements in ALICE

- Decay products as π, K, p identified via PID detectors (TOF, TPC).



Resonance Measurements in ALICE

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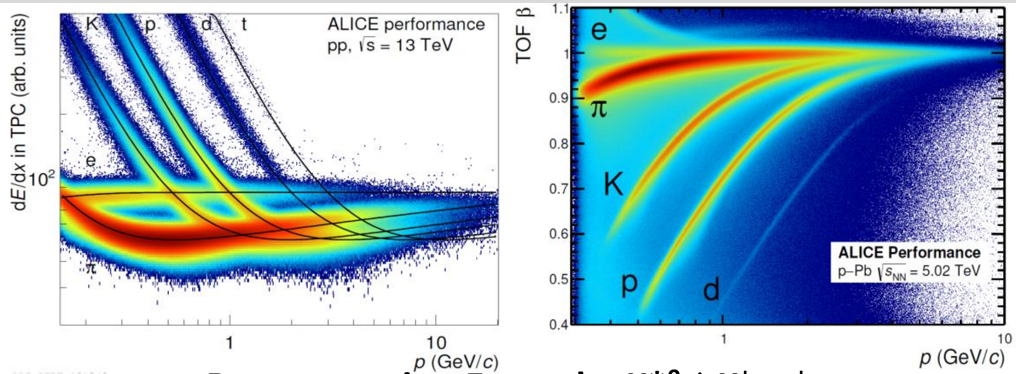
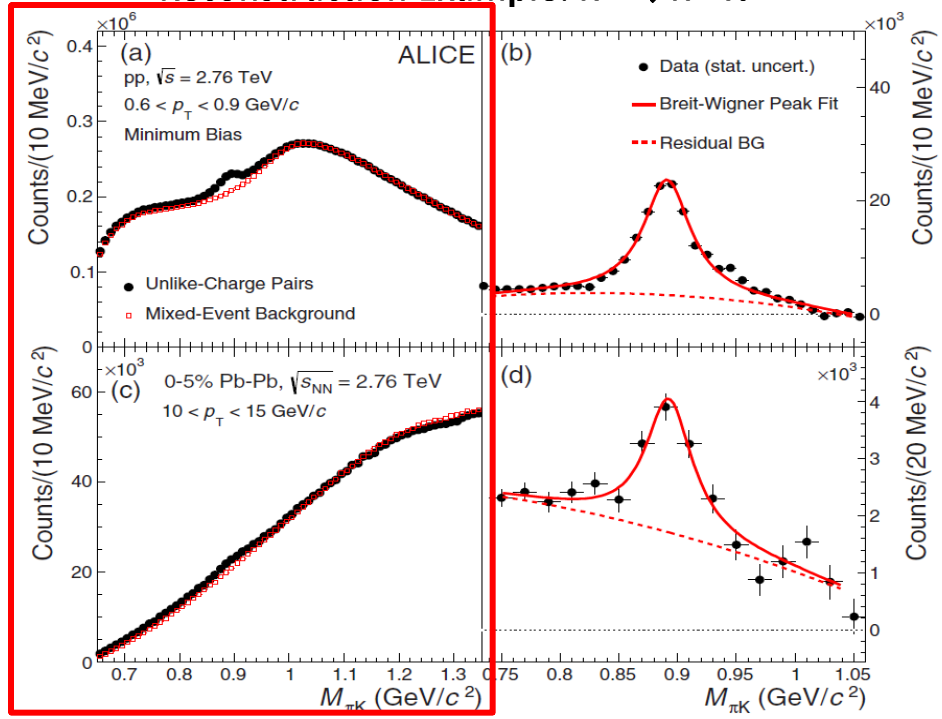
- Decay products as π, K, p identified via PID detectors (TOF, TPC).
- Resonances are reconstructed by calculation of **the invariant mass spectrum** via the identified decay products.

$$m_{inv} = \sqrt{(E_1 + E_2)^2 - (\vec{p}_1 + \vec{p}_2)^2}$$

- Combinatorial background is identified by various techniques:
  - Like sign technique,
  - Mixed event technique.



Reconstruction Example: $K^{*0} \rightarrow K^{\pm} + \pi^{\pm}$



PHYSICAL REVIEW C 95, 064606 (2017)

Resonance Measurements in ALICE

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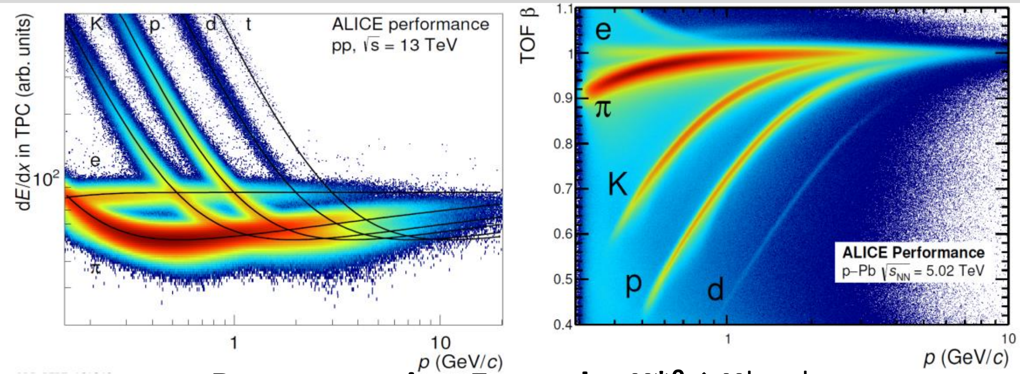
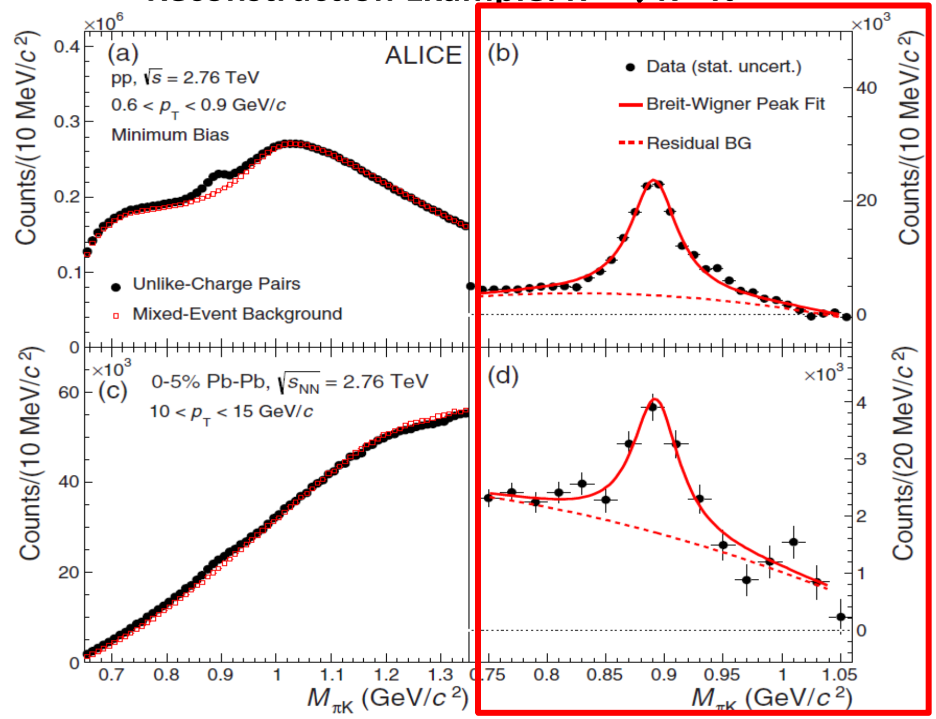


- Resonances are reconstructed by calculation of **the invariant mass spectrum** via the identified decay products.

$$m_{inv} = \sqrt{(E_1 + E_2)^2 - (\vec{p}_1 + \vec{p}_2)^2}$$

- Combinatorial background is identified by various techniques:
  - Like sign technique,
  - Mixed event technique.
- Mass, width and yield values are extracted from the background subtracted spectrum.

Reconstruction Example: $K^{*0} \rightarrow K^{\pm} + \pi^{\pm}$



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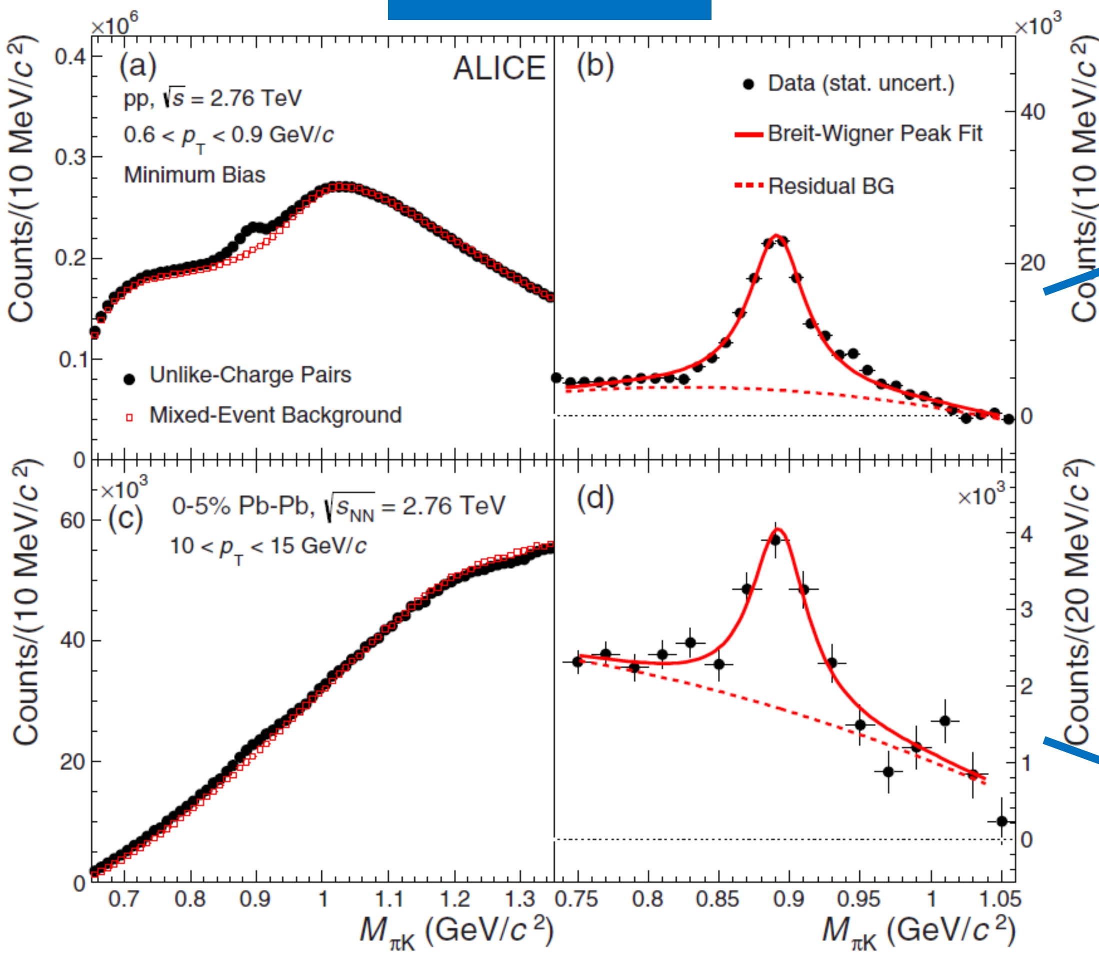
Spectra: $K^*(892)^0$

- Production of $K^*(892)^0$ in pp and Pb-Pb collisions.

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



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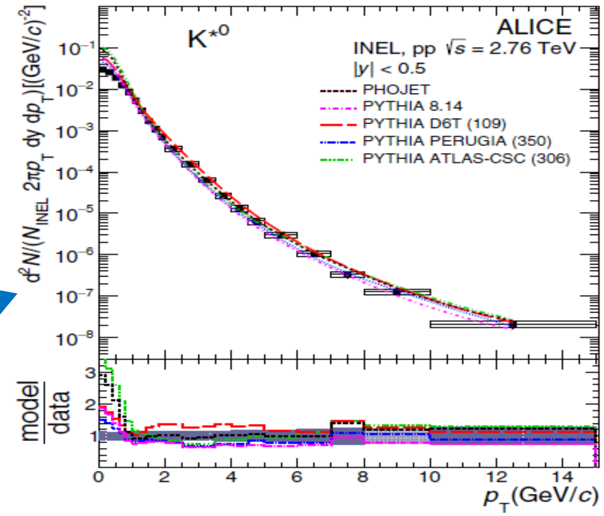
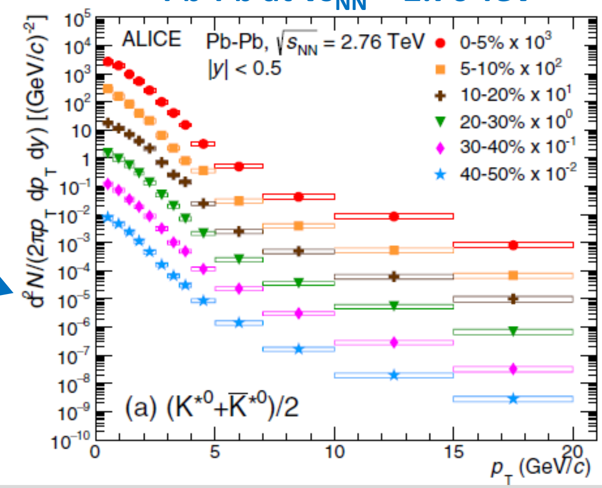
pp at √s = 2.76 TeV



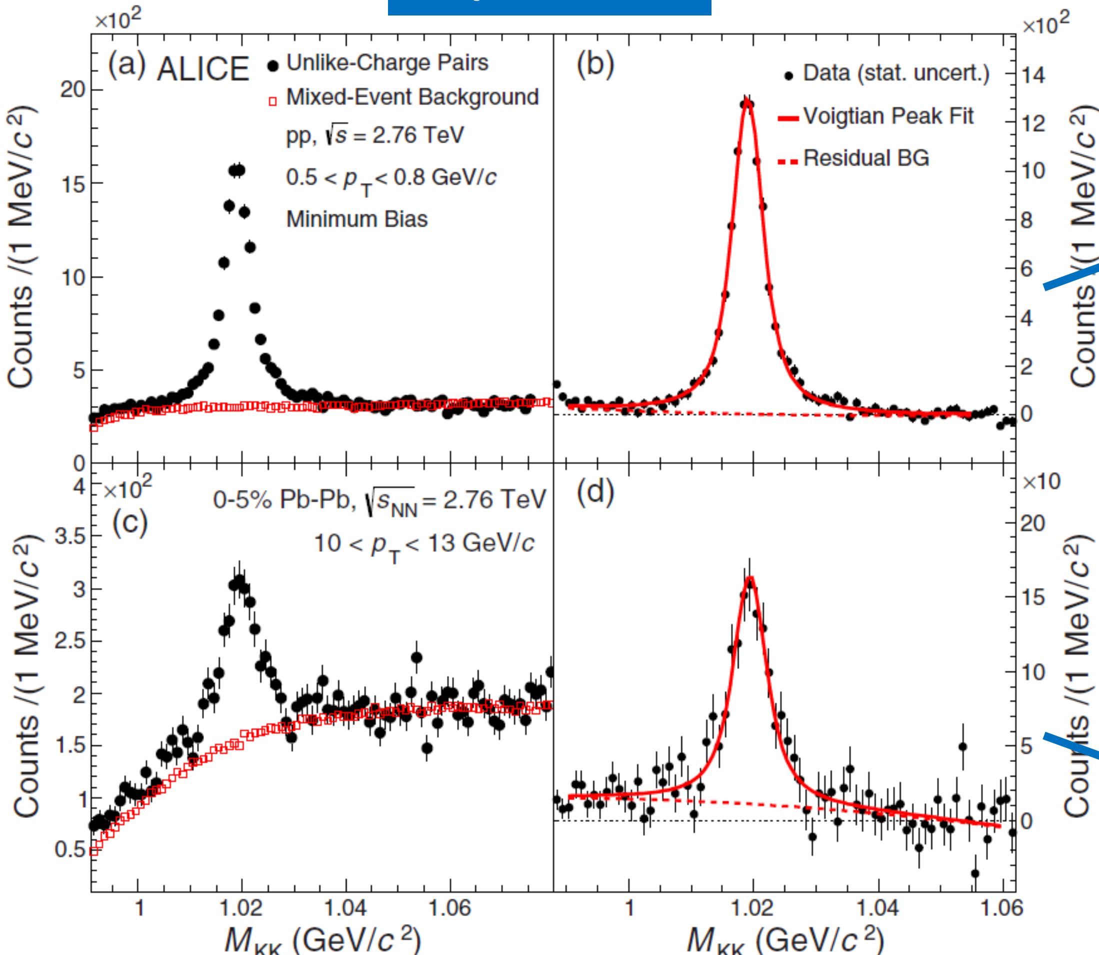
Pb-Pb at $\sqrt{s_{NN}}$ = 2.76 TeV



Spectra: ϕ(1020)

- Production of ϕ(1020) in pp and Pb-Pb collisions.

ϕ→K⁺+K⁻



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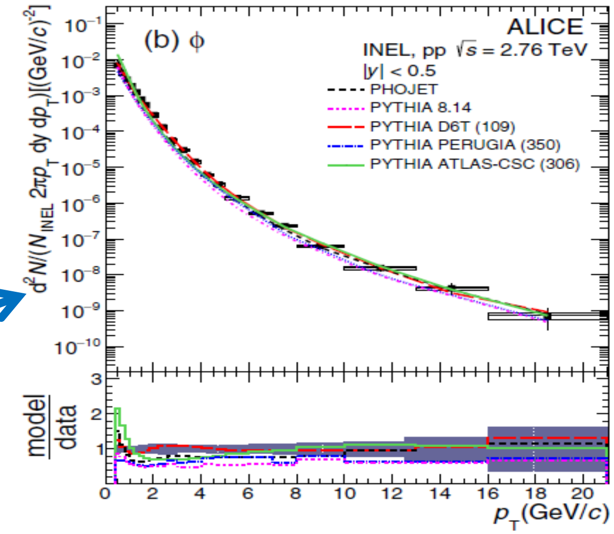

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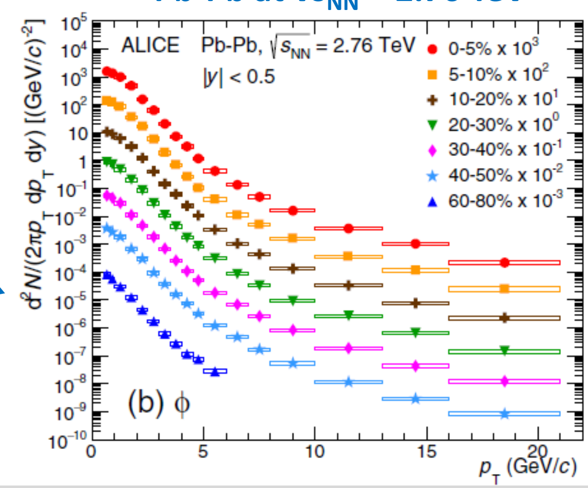
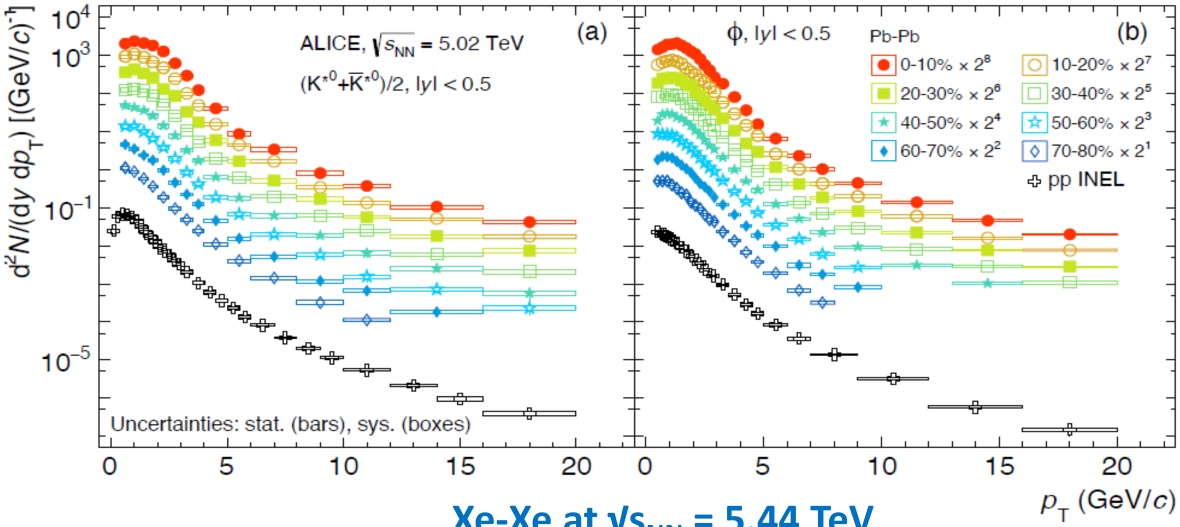


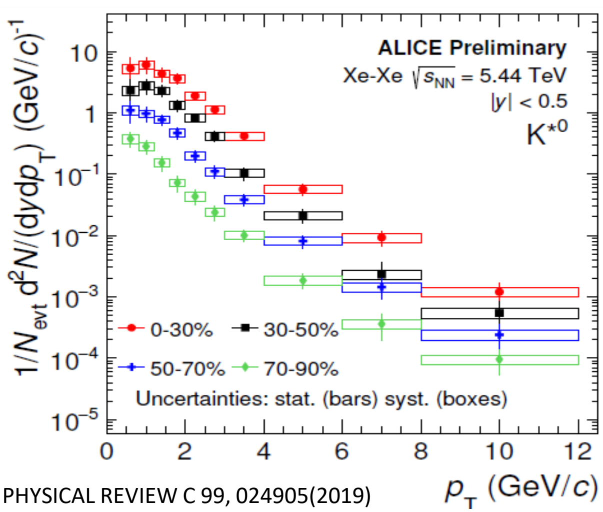
Spectra: More $K^*(892)^0$ and $\phi(1020)$

ALICE

Pb-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV



Xe-Xe at $\sqrt{s_{NN}}$ = 5.44 TeV



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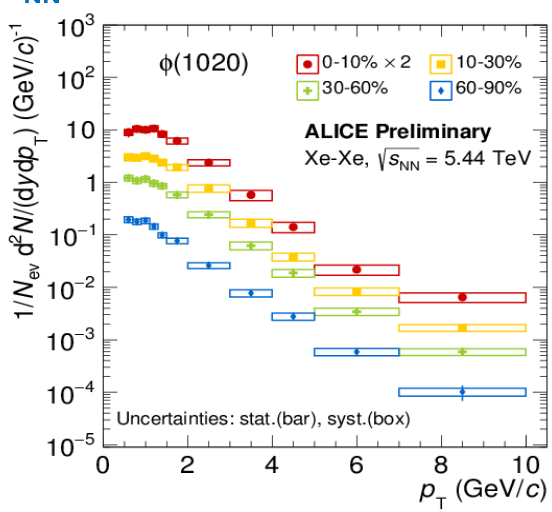
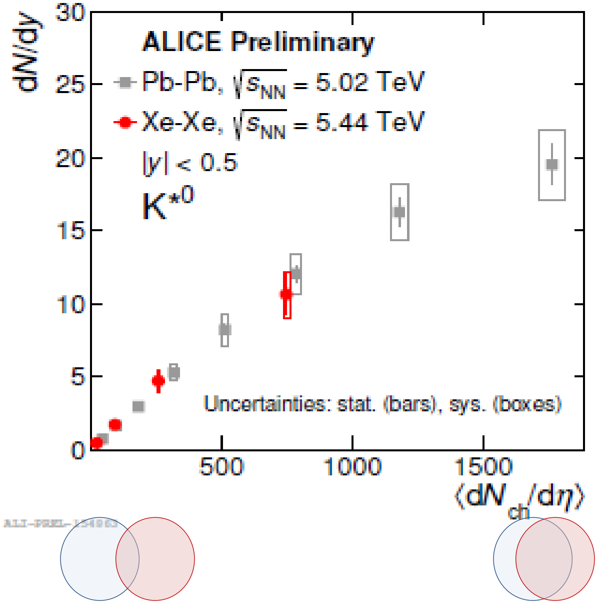
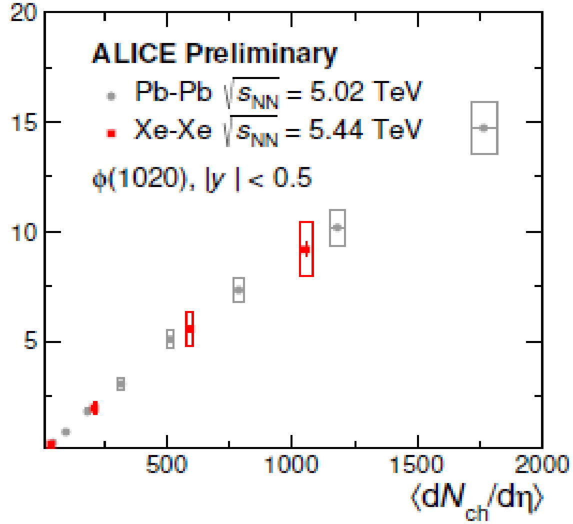


- Particle spectra is hardening from peripheral to central collisions for p_T< 5 GeV/c.
- Similar shape across multiplicity/collision centrality for p_T > 5 GeV/c.

Integrated Yields (dN/dy)

ALICE



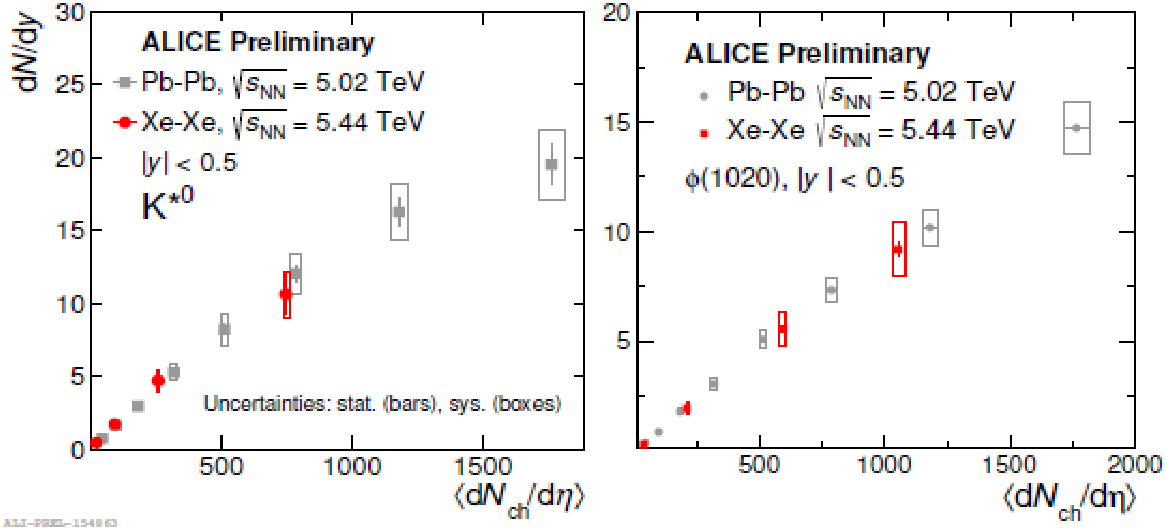


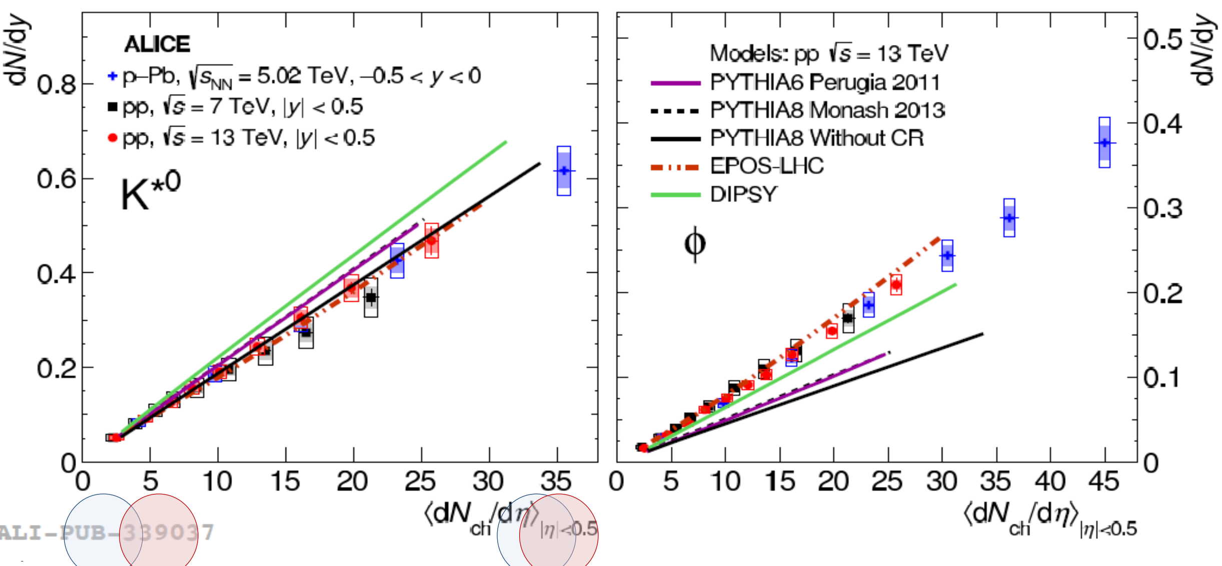
K^{*0} and ϕ:

- linear increase in dN/dy towards higher multiplicity.

Integrated Yields (dN/dy)

ALICE





K^{*0} and ϕ:

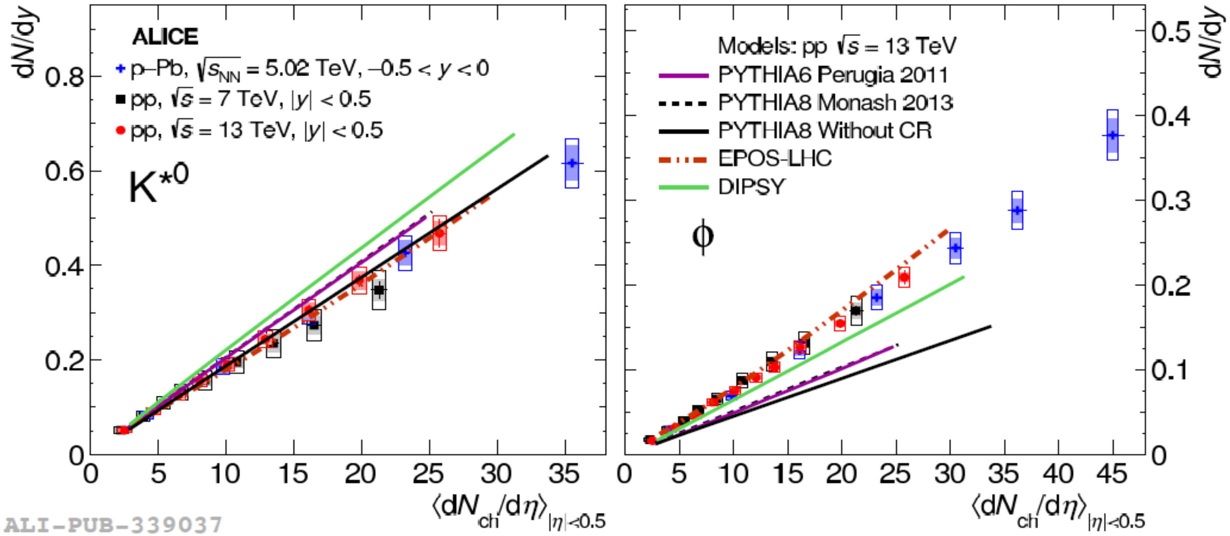
- linear increase in dN/dy towards higher multiplicity.

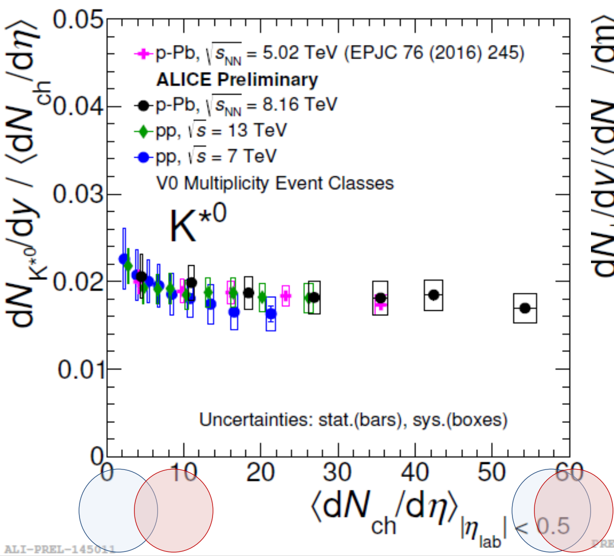
For pp results

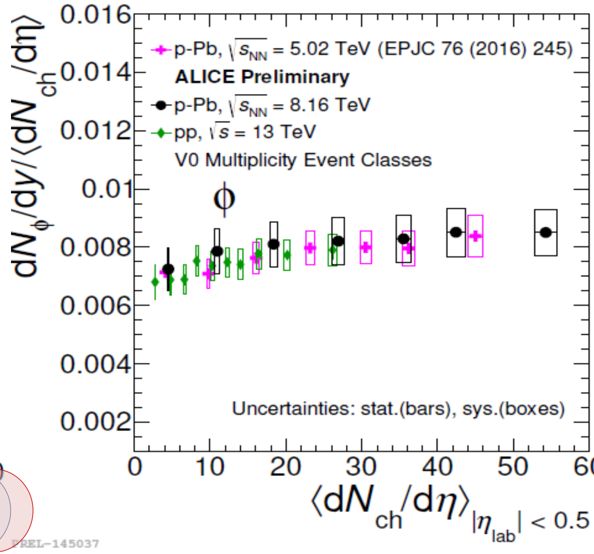
– K^{*0} described by EPOS-LHC and PYTHIA8 without CR (color reconnection) models.
– ϕ a little overestimated by EPOS-LHC and underestimated by PYTHIA models.

arXiv:1910.14397

Integrated Yields (dN/dy)







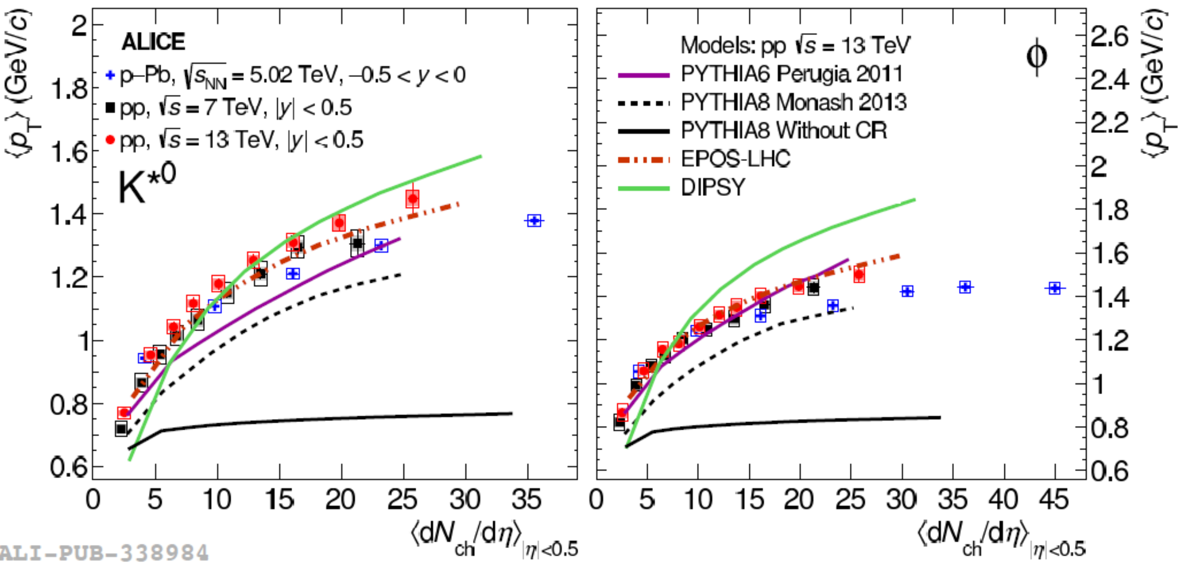
K^{*0} and ϕ:

- **linear increase** towards higher multiplicity.

- Normalized yields of K^{*0} and ϕ to $\langle dN_{ch}/d\eta \rangle$ are independent of the collision system and the energy.

arXiv:1910.14397

Mean p_T ($<p_T>$)



K^{*0} and ϕ:

- In pp collisions at √s = 7 TeV and 13 TeV $<p_T>$ values show similar behavior and rise faster than in p-Pb collisions.
- EPOS-LHC model predicts ϕ $<p_T>$ values well.

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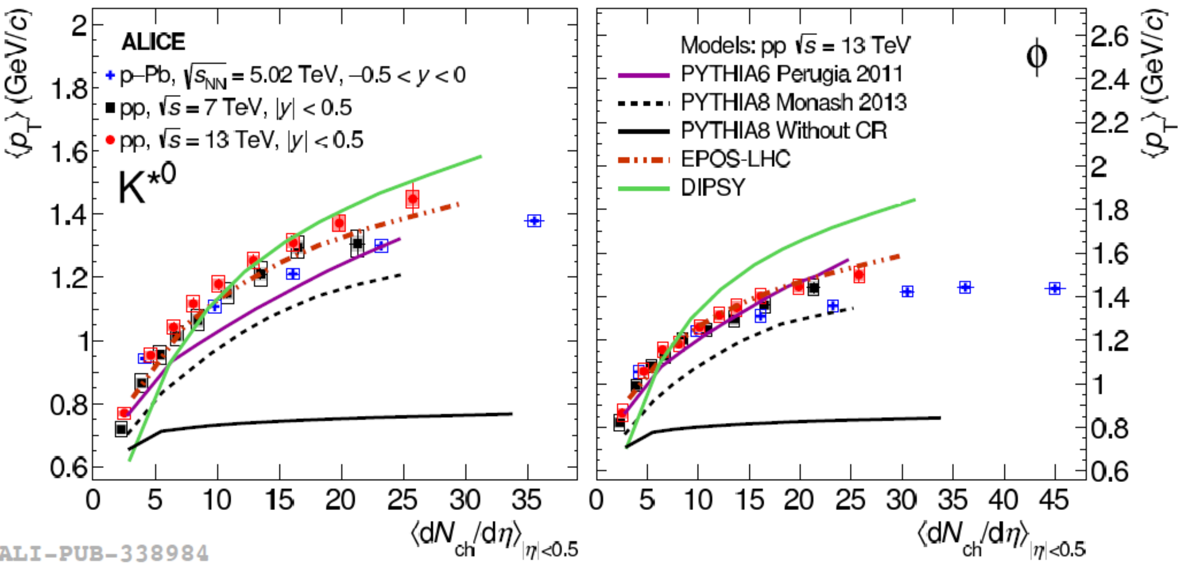

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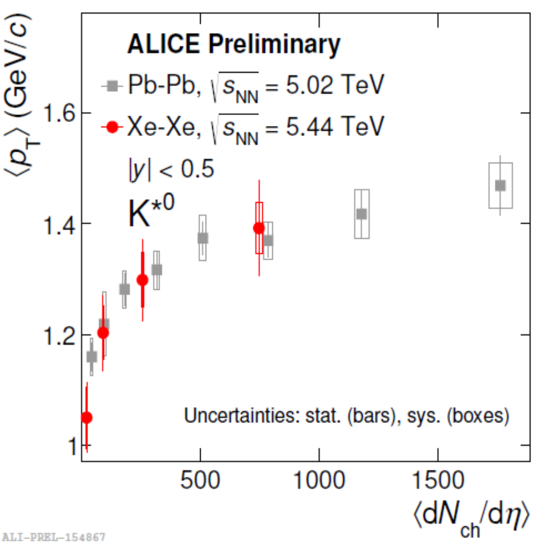

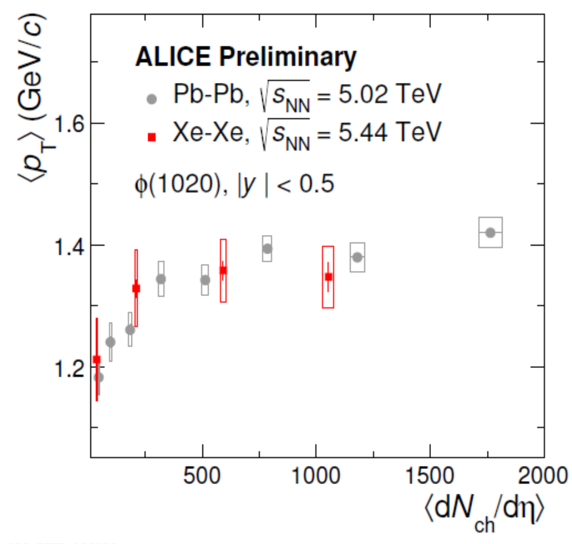

- $\langle p_T \rangle$ values from Pb-Pb and Xe-Xe collisions are in agreement.

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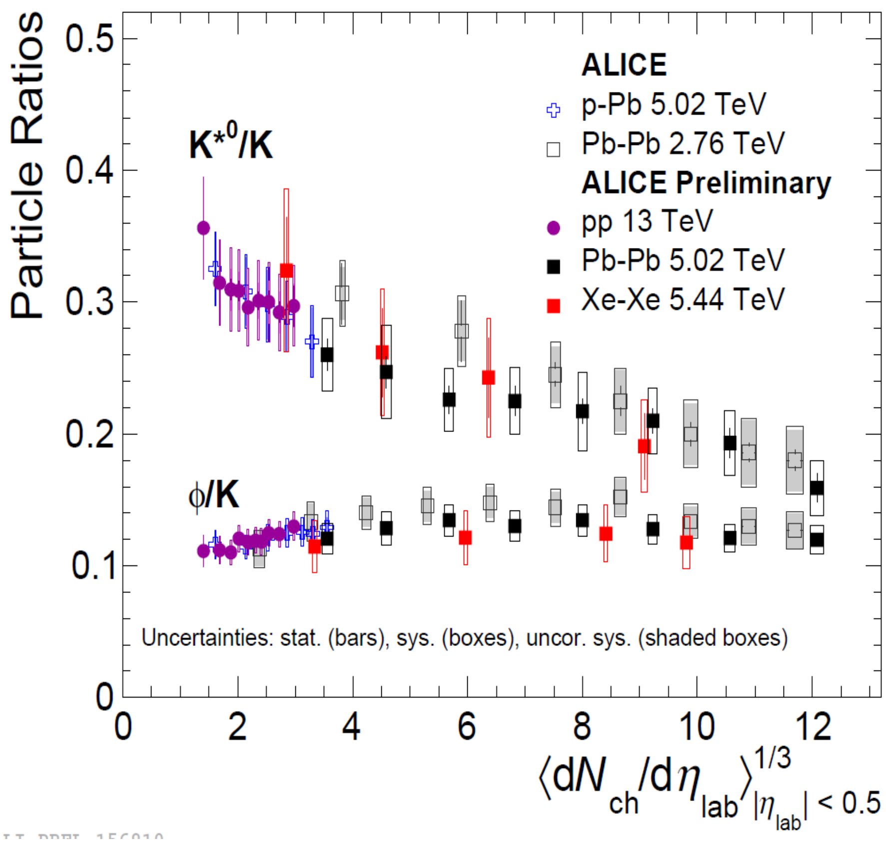
Particle Ratios



K^{*0}/K

- Significant suppression going from p-Pb and peripheral Xe–Xe/Pb–Pb collisions to most central Xe–Xe/Pb–Pb collisions.
- Suppression in central Xe–Xe/Pb–Pb collisions interpreted as re-scattering is dominant over regeneration.

ϕ/K

- No significant system-size dependence.
- Due to its long lifetime ϕ yield is not affected as K^{*0} .

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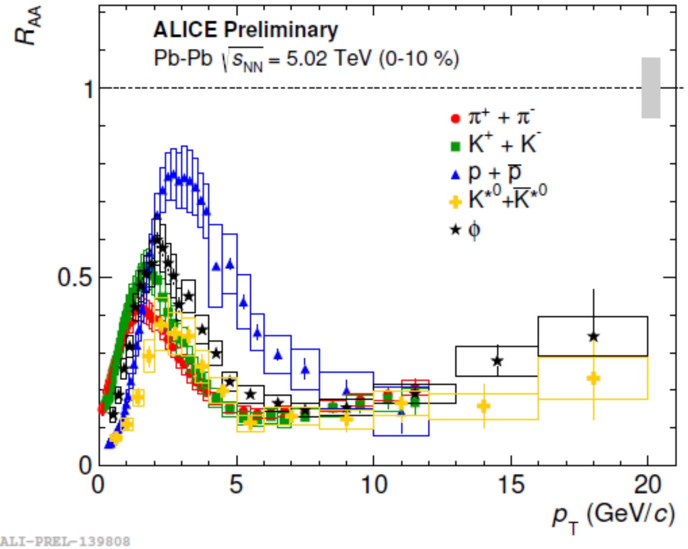
Nuclear Modification Factor (R_{AA})

ALICE



$$R_{AA}(p_T) = \frac{\text{Yield}_{AA}(p_T)}{\text{Yield}_{pp}(p_T) \times \langle N_{coll} \rangle}$$

- **p_T > 8 GeV/c :** a strong suppression in most central Pb-Pb collisions for resonances and stable hadrons:
  - not dependent on hadron species and properties like mass, quark content or baryon number
- **p_T < 8 GeV/c :** Baryon-meson splitting
  - K*, ϕ are closer to other mesons than to baryons

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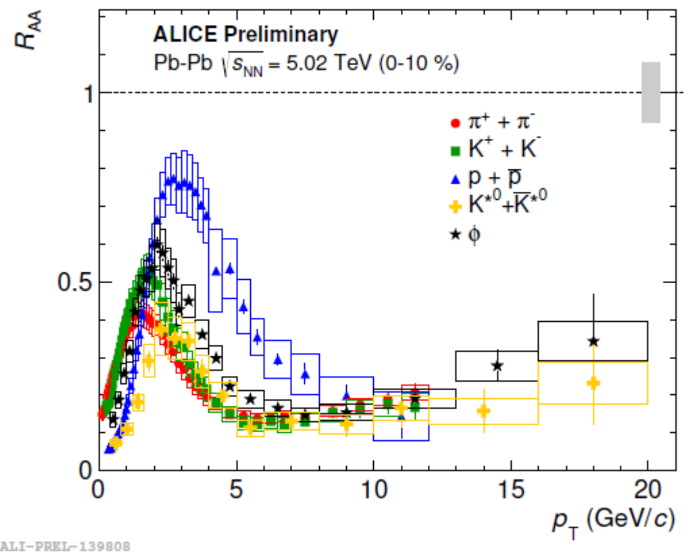

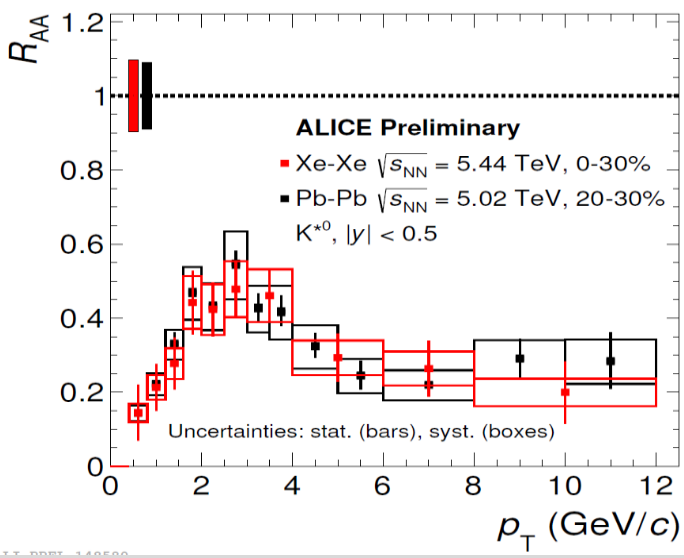

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- **p_T < 8 GeV/c :** Baryon-meson splitting
  - K*, ϕ are closer to other mesons than to baryons
- Comparison of R_{AA} of K^{*0} in Xe–Xe and in Pb–Pb collisions for centrality classes with similar multiplicities:
  - no significant system size dependence.

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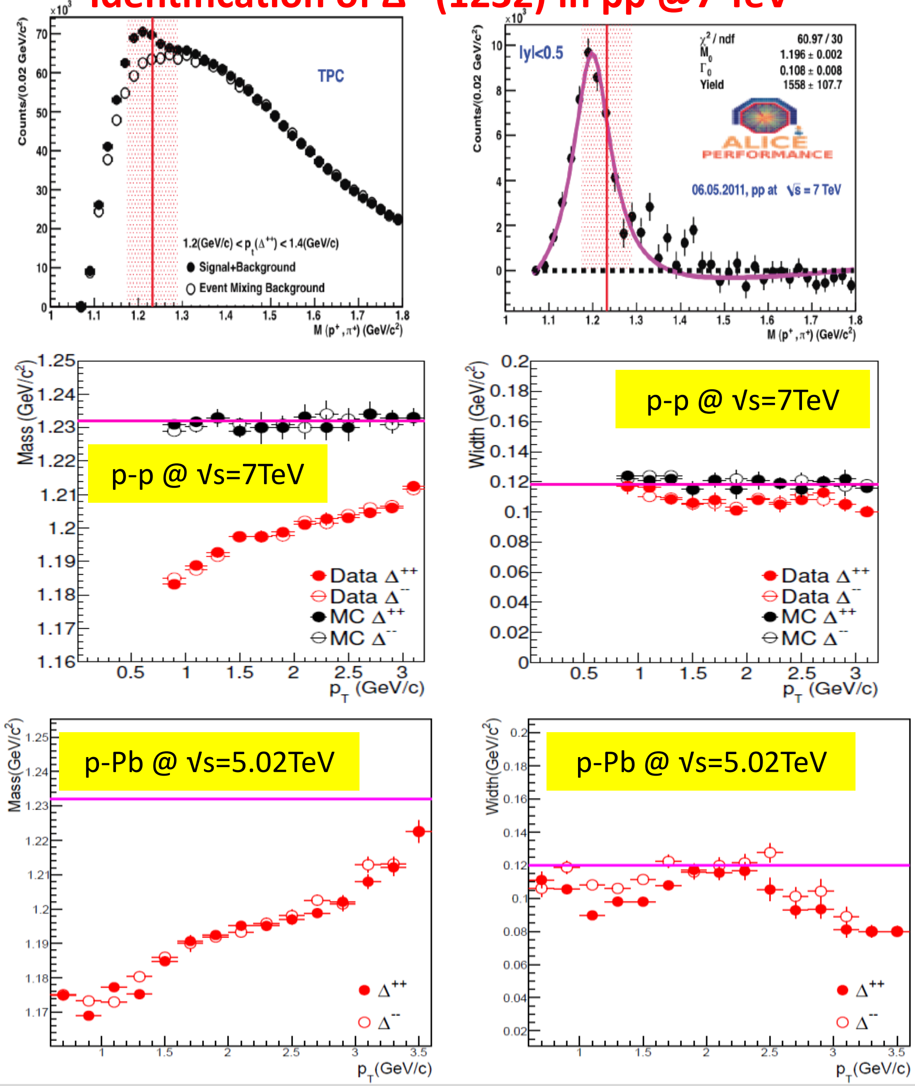
Mass and Width Study of Δ^{++} Resonance

Δ^{++}/Δ^{--}

- Mass and width values are extracted from the fit.
- Mass values from data are shifted from the PDG value.
- Mass values from MC simulation overlaps with the PDG value.
- Width values from the simulation and the data are around the PDG value.
- Similar behavior is observed in p-Pb collision at 5.02TeV.

Identification of Δ^{++}(1232) in pp @7 TeV



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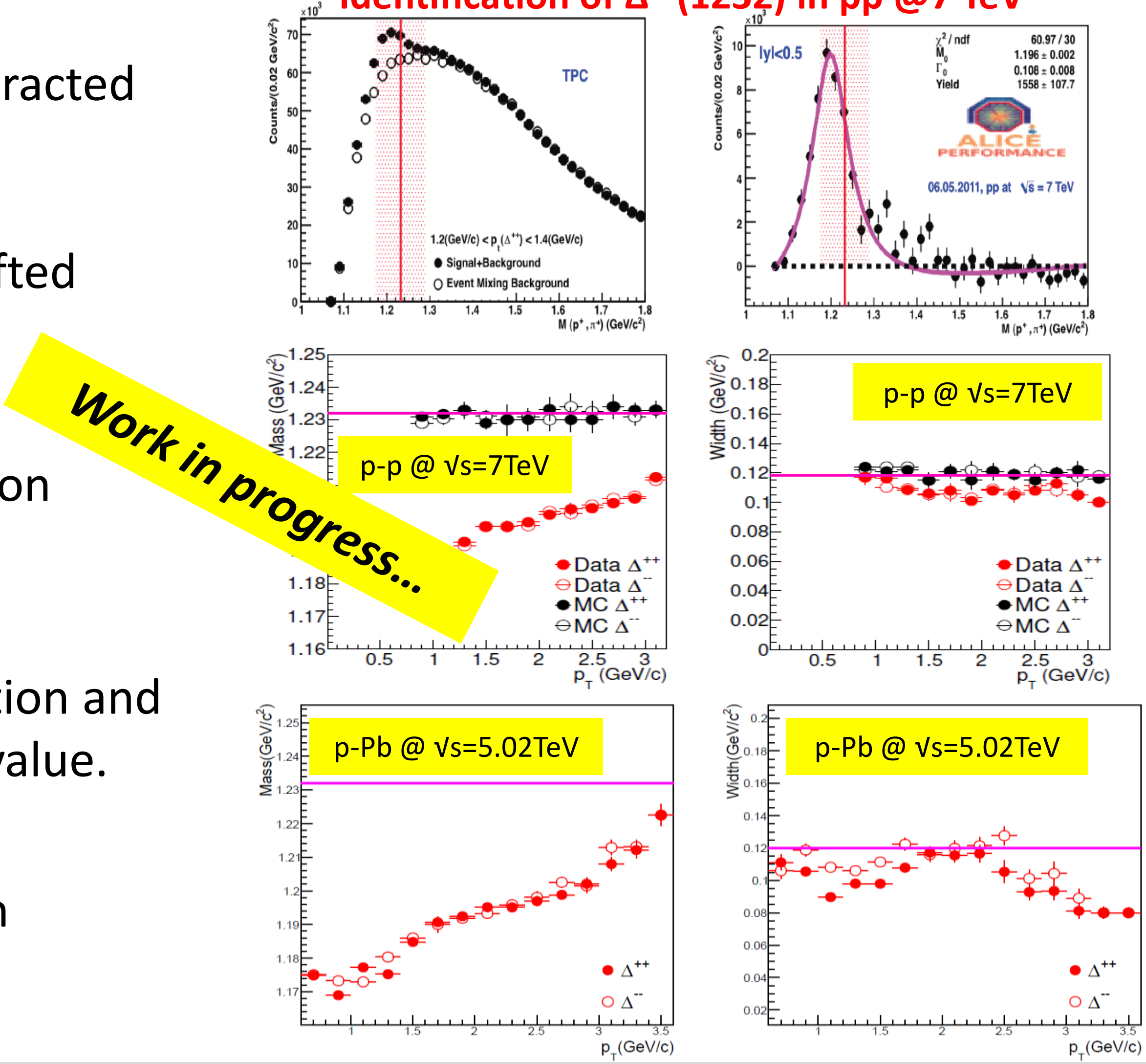

Summary

Resonances are measured for different collision systems with ALICE at the LHC :

K^{*0} and ϕ Spectra:

- Shapes of p_T spectra are different for different multiplicity classes ($p_T < 5.0$ GeV/c),
- spectra become harder with increasing multiplicity.

Integrated Yield of K^{*0} and ϕ (dN/dy):

- pp, p-Pb, Xe-Xe, Pb-Pb: Independent of colliding system, energy.

Mean p_T:

- In Pb-Pb and Xe- Xe : $\langle p_T \rangle$Values are in agreement.

Particle Ratios of K^{*0}/K and ϕ/K:

- Suppression of K^{*0}/K in central Xe–Xe/Pb–Pb collisions is due to re-scattering is dominant over regeneration.
- ϕ/K is independent from system size.

Nuclear Modification Factor:

- In central Pb-Pb collisions resonances are strongly suppressed at high p_T.
- R_{AA} of K^{*0} in Xe–Xe and in Pb–Pb collisions for centrality classes with similar multiplicities showed no significant system size dependence.

Results support the existence of a hadronic phase: lasting long enough to cause a significant reduction of the reconstructible yield of short lived resonances.

Thank you!

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