Hyperon and **resonance** production with ALICE at the LHC

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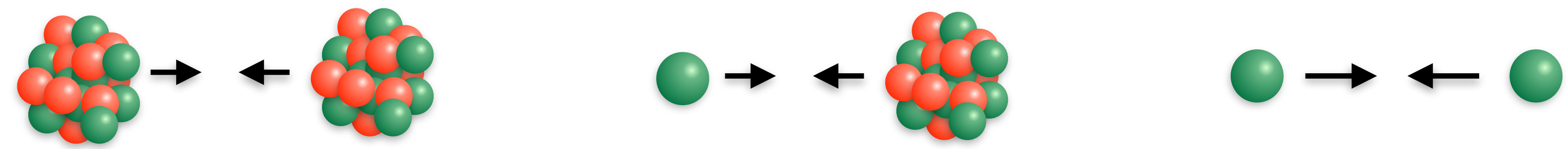
Heavy Ion Physics Experiment

Outline

- Motivation
- Hyperon and resonance reconstruction in ALICE
- Transverse momentum spectra
- Mean transverse momentum studies
  - in pp, p-Pb and Pb-Pb
  - versus particle type and mass
  - system size dependence
- p_T-dependent particle ratios
- Integrated particle ratios
  - strangeness production vs multiplicity
  - study of hadronic phase
- Conclusion and outlook

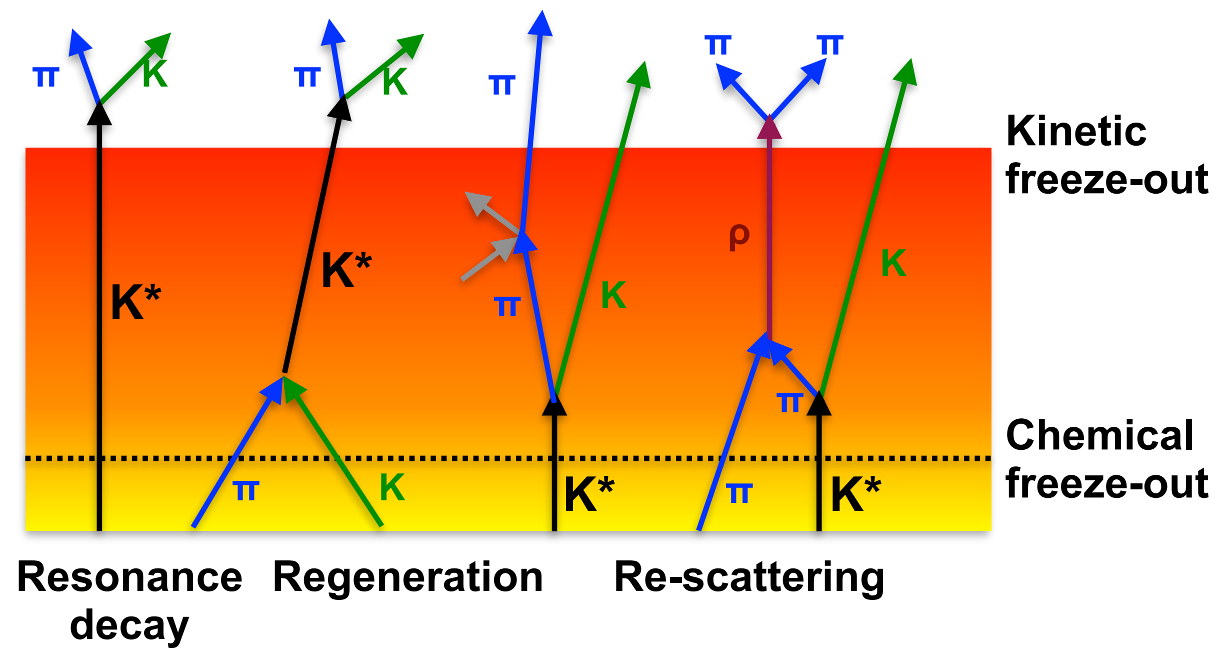
Motivation



The measurement of **hyperon** and **resonance** production in different systems allows one to study

★ Strangeness production and its evolution with the system size
→ measure Λ, Ξ, Ω production relative to π and to the pp system

★ Properties of the hadronic medium in the late stage of the collisions
→Particle re-scattering and regeneration in the hadronic phase
→ measure short-lived Σ^* and K^* production, in comparison to longer-lived resonances like Ξ^* and ϕ



Regeneration: pseudo-elastic scattering of decay products

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

→ Not reconstructed through invariant mass

Hyperons and resonances in ALICE

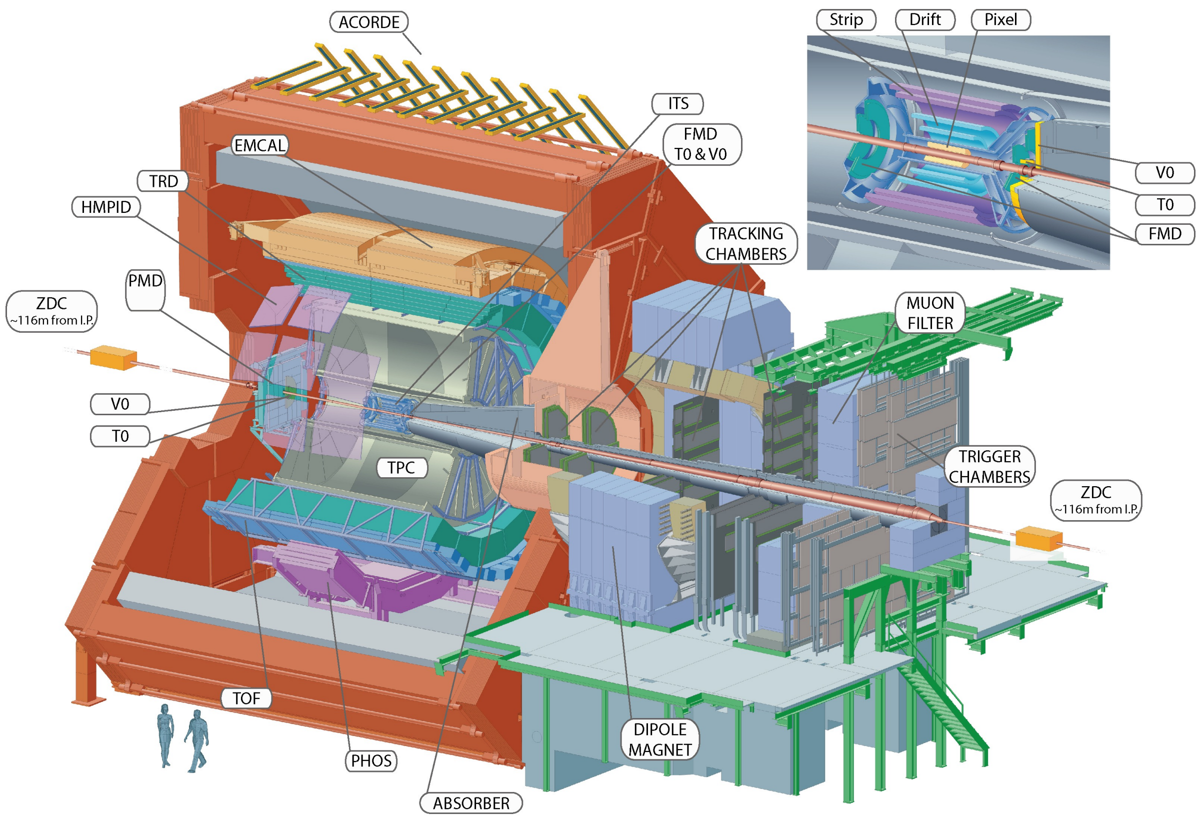
to be discussed today

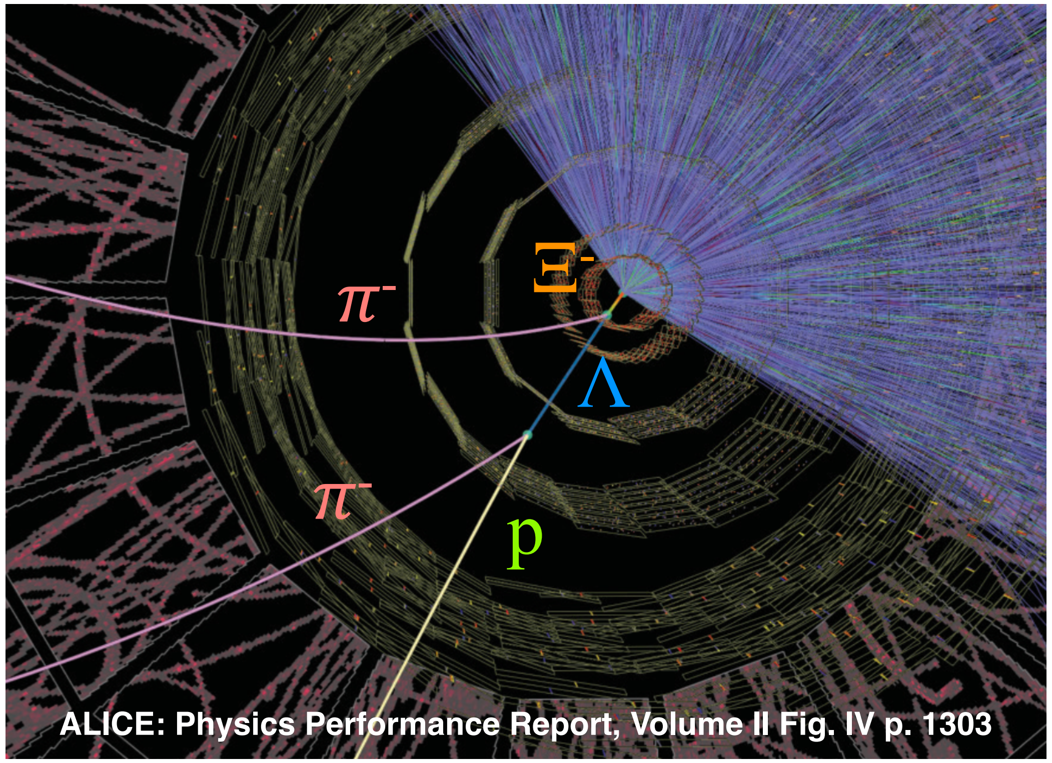
✓ : published or preliminary results
△ : work in progress

	Λ	Ξ	Ω	K^{*0}	ϕ	Σ^{*+}	Ξ^{*0}
pp @ 7 TeV	✓	✓	✓	✓	✓	✓	✓
p-Pb @ 5.02 TeV	✓	✓	✓	✓	✓	△	✓ (preliminary)
Pb-Pb @ 2.76 TeV	✓	✓	✓	✓	✓	△	△

$c\tau$	7.89 cm	4.91 cm	0.025cm	4.16 fm	46.3 fm	5.48 fm	22 fm
Mass[MeV]	1115.683 ± 0.006	1321.71 ± 0.07	1672.45 ±0.29	892.6 ±0.5	1019.462 ±0.019	1382.80 ± 0.35	1531.80 ± 0.32
Quark contents	uds	dss	sss	$d\bar{s}/s\bar{d}$	$s\bar{s}$	uus	uss

Hyperon and resonance reconstruction in ALICE





- **Charged hadron tracks** reconstructed in the central barrel tracking system (TPC and ITS)
  - $|\eta|<0.9$
  - $p_T \gtrsim 0.15$ GeV/c
- **V0** scintillator detectors
  - centrality/multiplicity definition
- **I**nner **T**racking **S**ystem (**ITS**)
  - tracking and vertex determination
  - $3.9 < r(\mathrm{cm}) < 43$

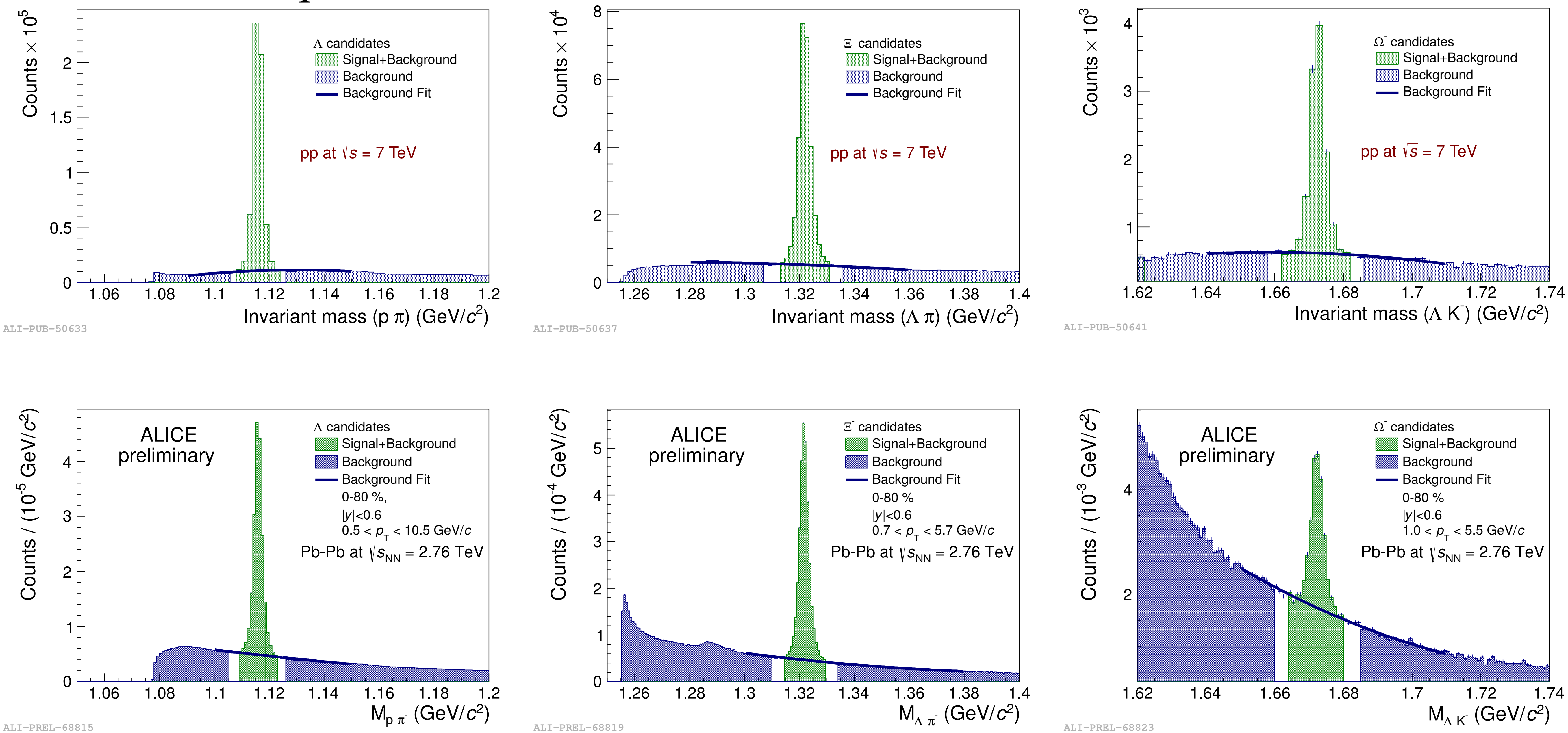
- **ITS**, **TPC** and **TOF** for particle identification of decay products

- **Topological reconstruction** of decays (geometrical selection criteria on reconstructed tracks)
  - V-shaped topology for K^0_s and Λ
  - cascade topology for Ξ and Ω

Signal extraction: hyperons

[1] Eur. Phys. J. C 73 (2013) 2496
[2] arXiv:1307.5530v2
[3] arXiv:1307.5543v3

$\Lambda \rightarrow p\pi^-$ $\Xi^- \rightarrow \Lambda\pi^-$ $\Omega^- \rightarrow \Lambda K^-$

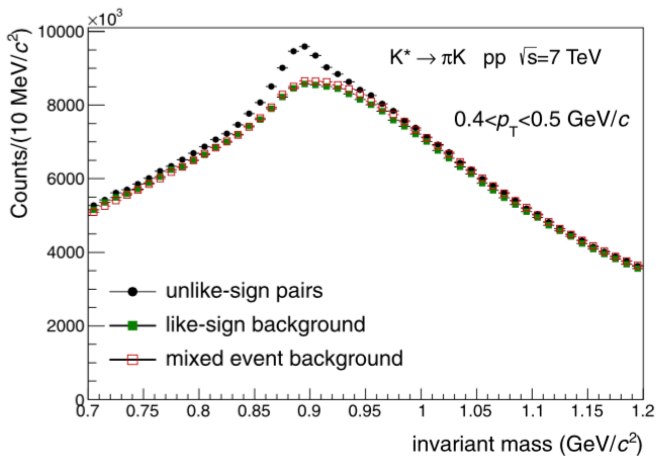


- Signal extraction of Λ, Ξ^- and Ω^- in pp (top) and Pb-Pb (bottom)
- Background in Pb-Pb collisions are significantly larger than in pp but can be described by fit function (polynomial)

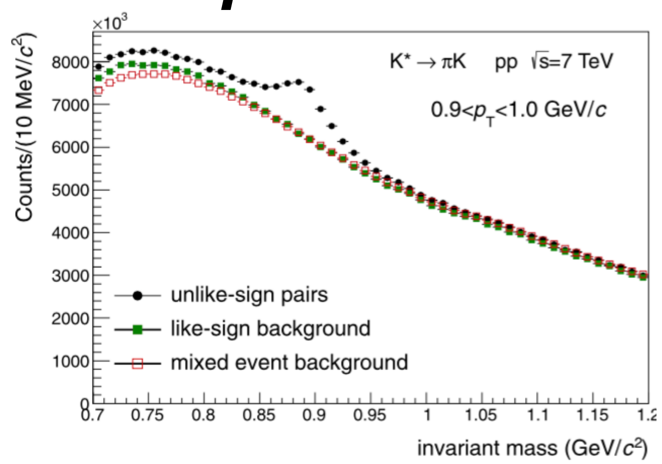
Signal extraction: resonances

[4] Eur. Phys. J. C (2012) 72:2183
[5] Eur. Phys. J. C (2015) 75:1
[6] Phys. Rev. C 91, 024609 (2015)

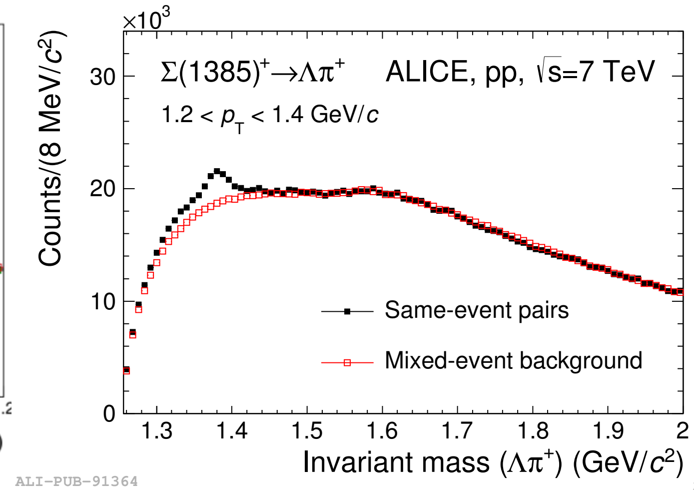
$K^{*0} \rightarrow K^{\mp}\pi^{\pm}$



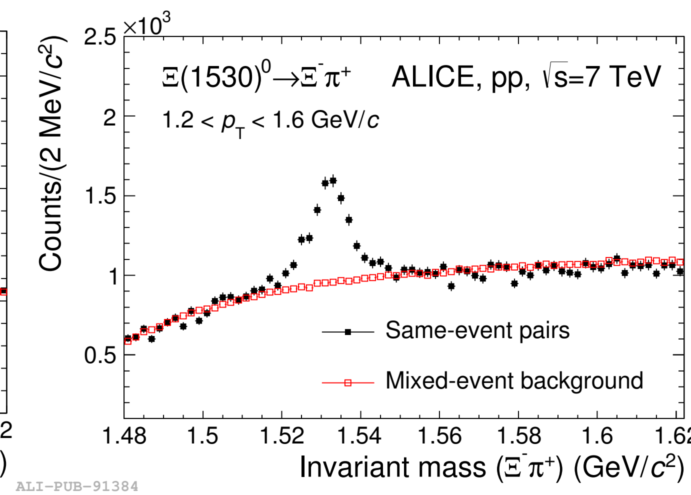
$\phi \rightarrow K^{+}K^{-}$

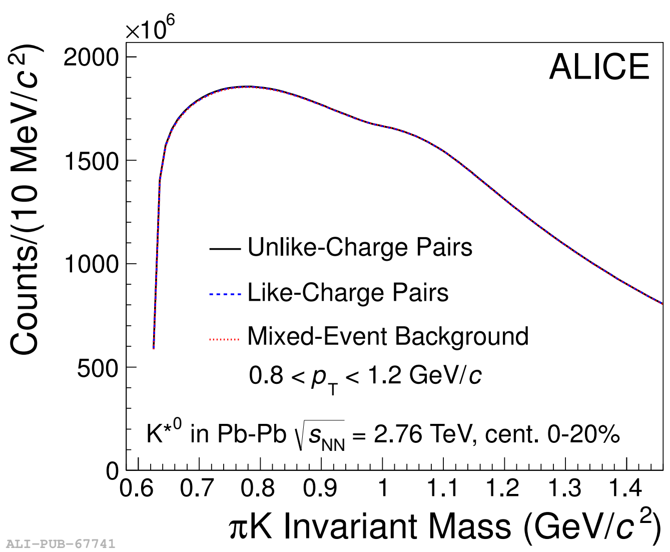


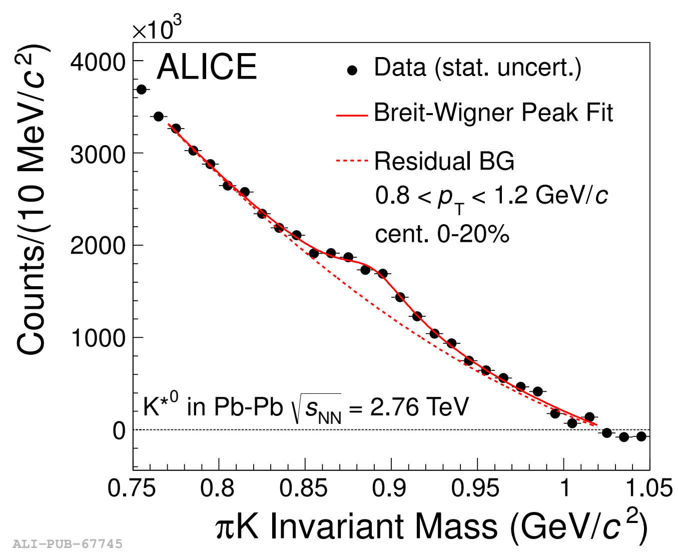
$\Sigma^{*+} \rightarrow \Lambda\pi^{+}$

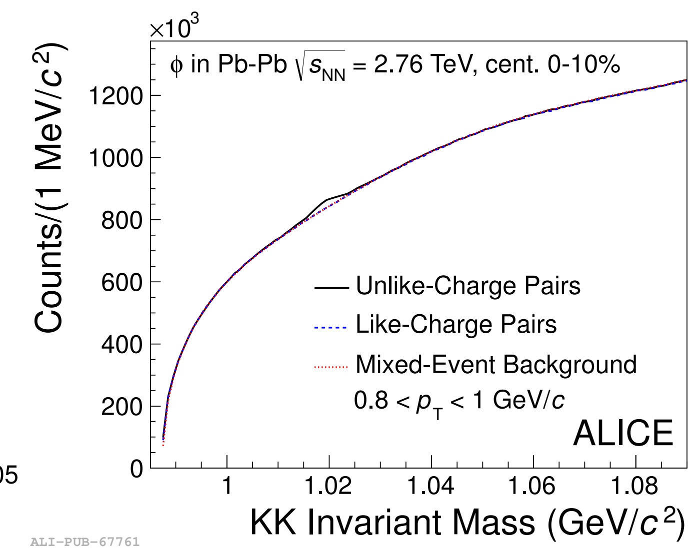


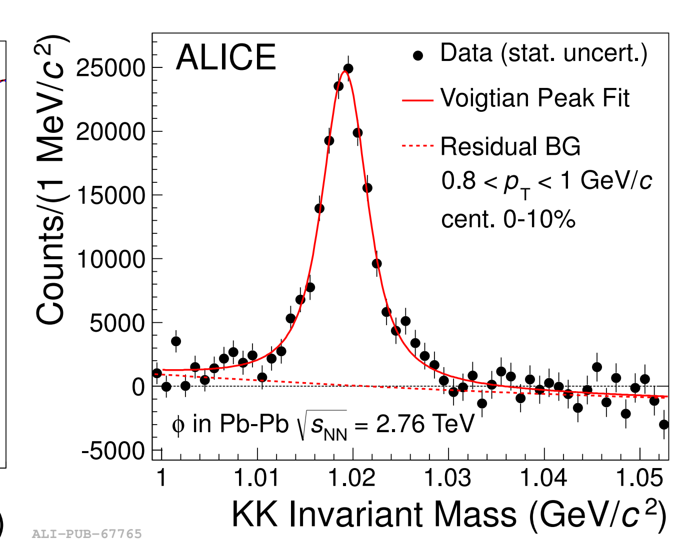
$\Xi^{*0} \rightarrow \Xi^{-}\pi^{+}$







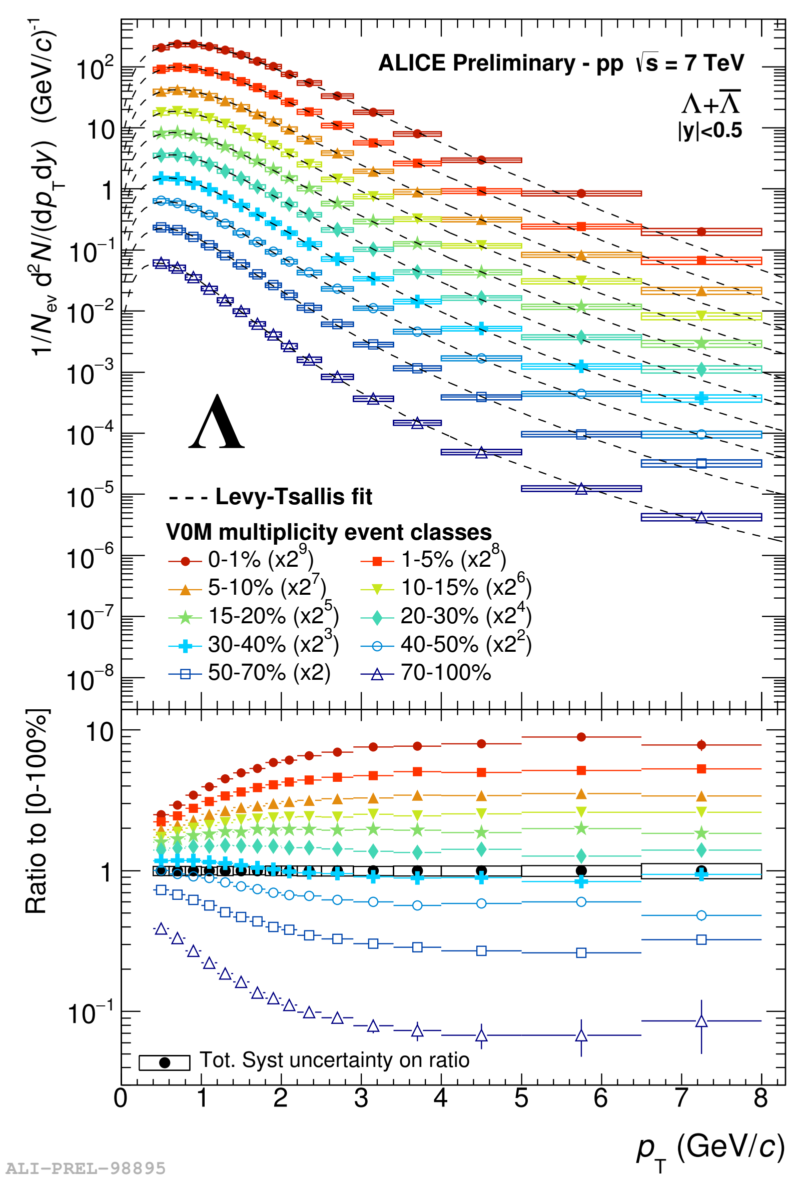


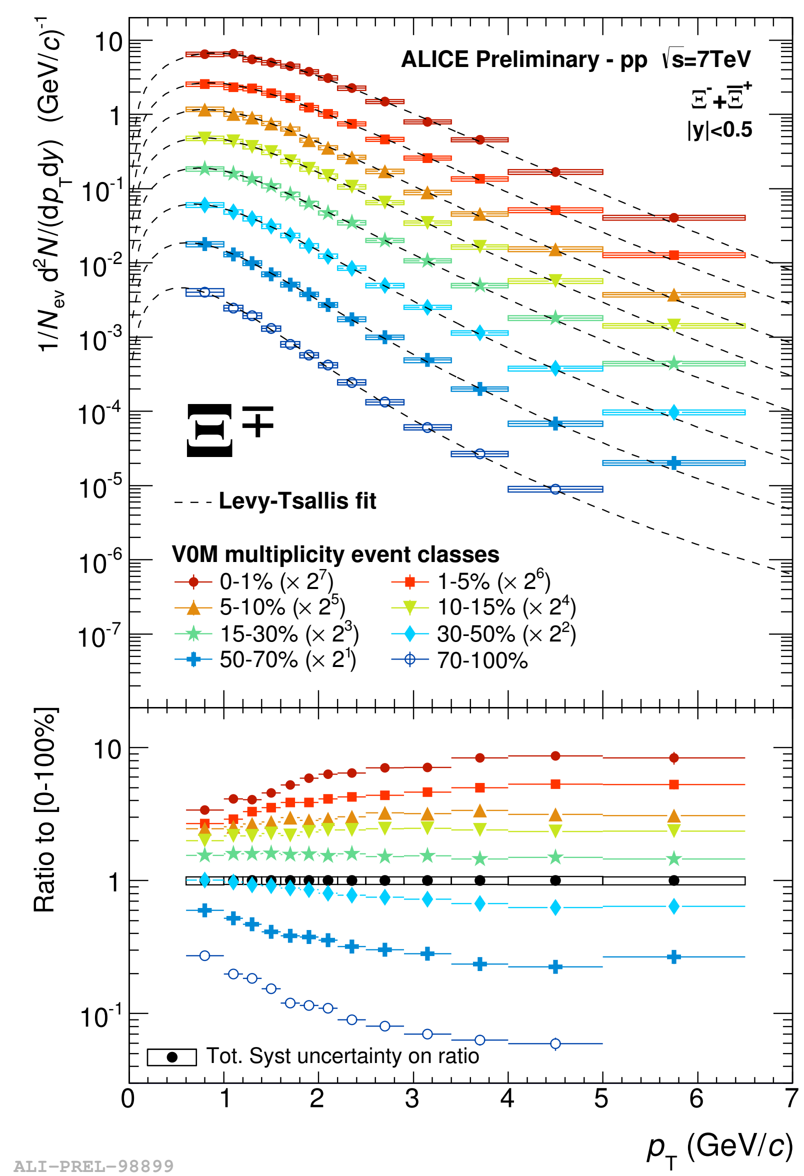


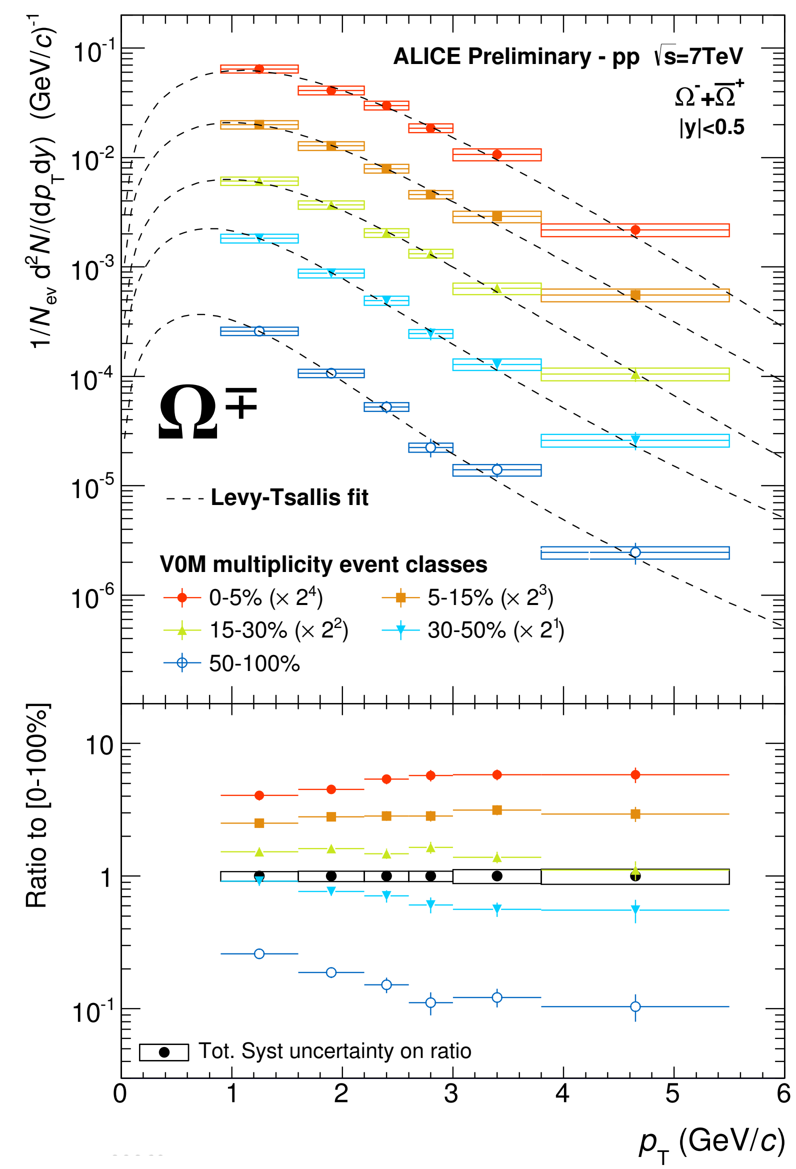
- Signal extraction of K^{*0} and ϕ in pp (top left) and Pb-Pb (bottom)
- Signal extraction of Σ^{*+} and Ξ^{*0} in pp (top right)
- For the resonances, event-mixing background/like-sign background methods are applied to estimate background

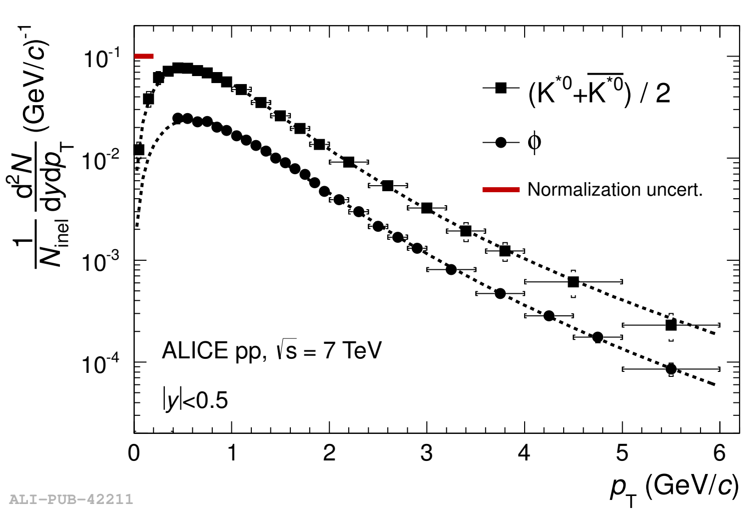
Spectra in pp collisions

[7] Physics Letters B 712 (2012) 309–318





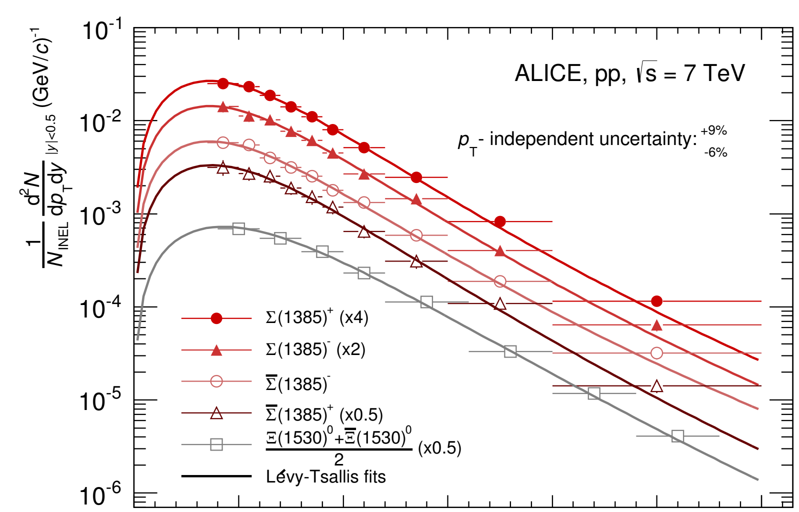




$K^{*0} \rightarrow K^{\mp}\pi^{\pm}$

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

(pp, INEL)



$\Sigma^{*\pm} \rightarrow \Lambda\pi^{\mp}$

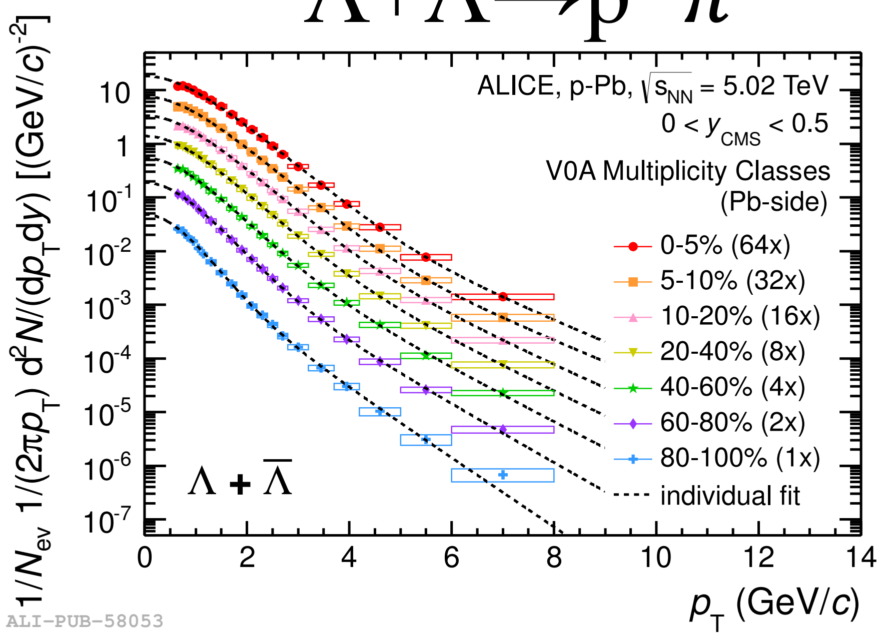
$\Xi^{*0} \rightarrow \Xi^{\mp}\pi^{\pm}$

(pp, INEL)

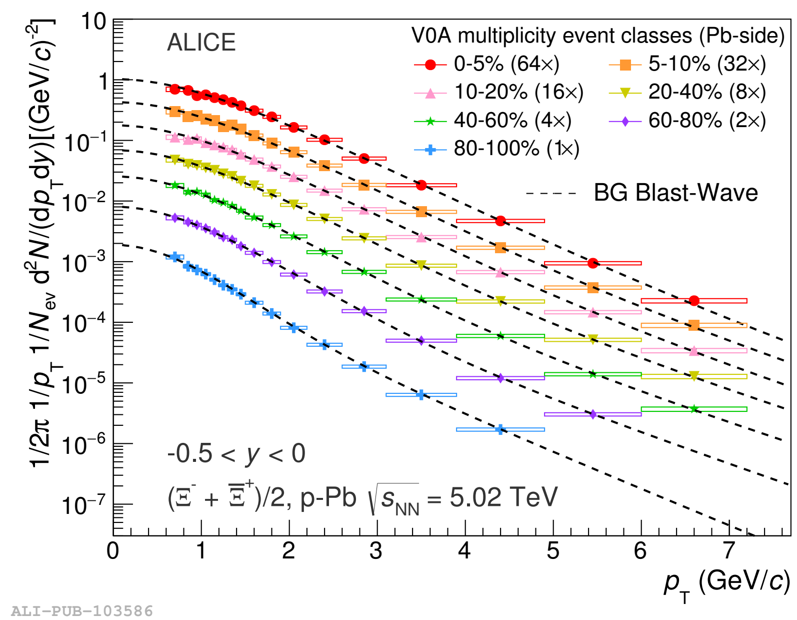
Spectra in p-Pb collisions

[8] arXiv:1512.07227
[9] arXiv:1601.07868
[10] Phys.Lett. B728 (2014) 25-38

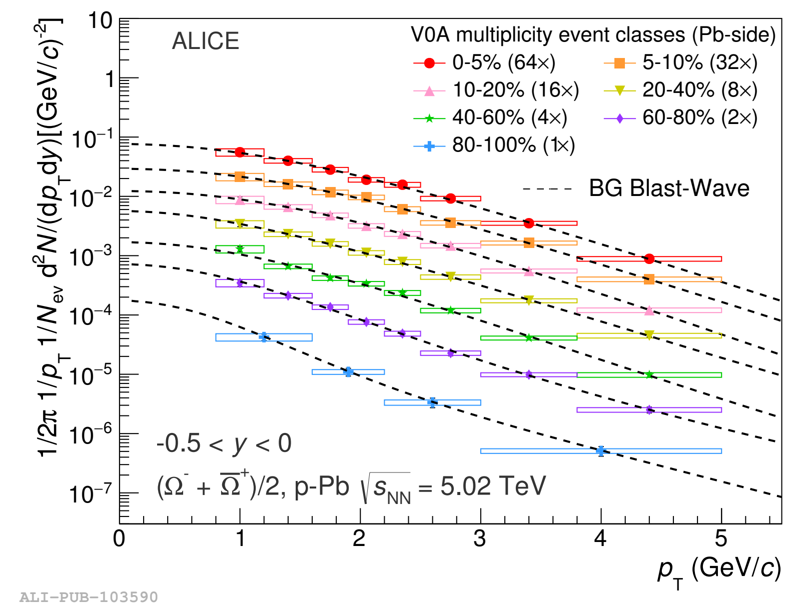
$\Lambda+\overline{\Lambda}\rightarrow p^{\mp}\pi^{\pm}$



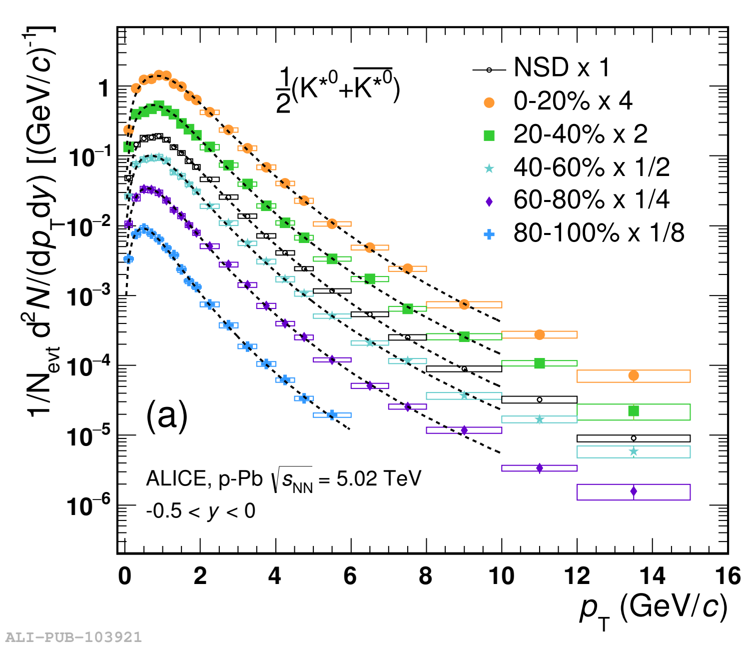
$\Xi^{\mp}\rightarrow\Lambda\pi^{\mp}$



$\Omega^{\mp}\rightarrow\Lambda K^{\mp}$



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



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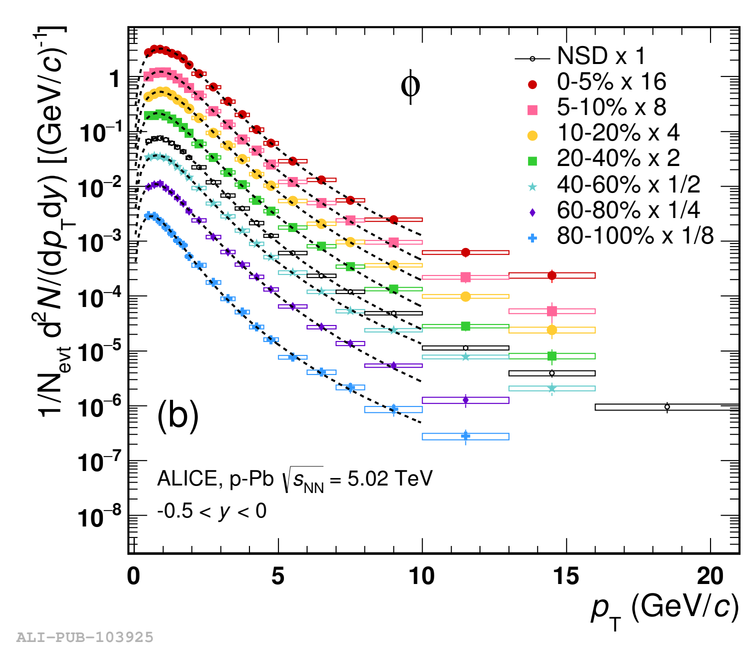
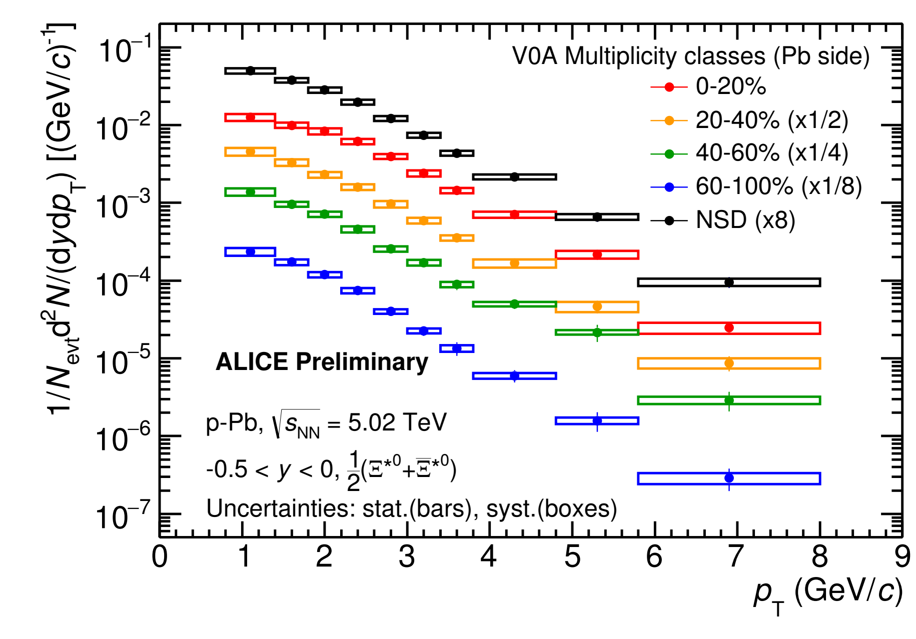
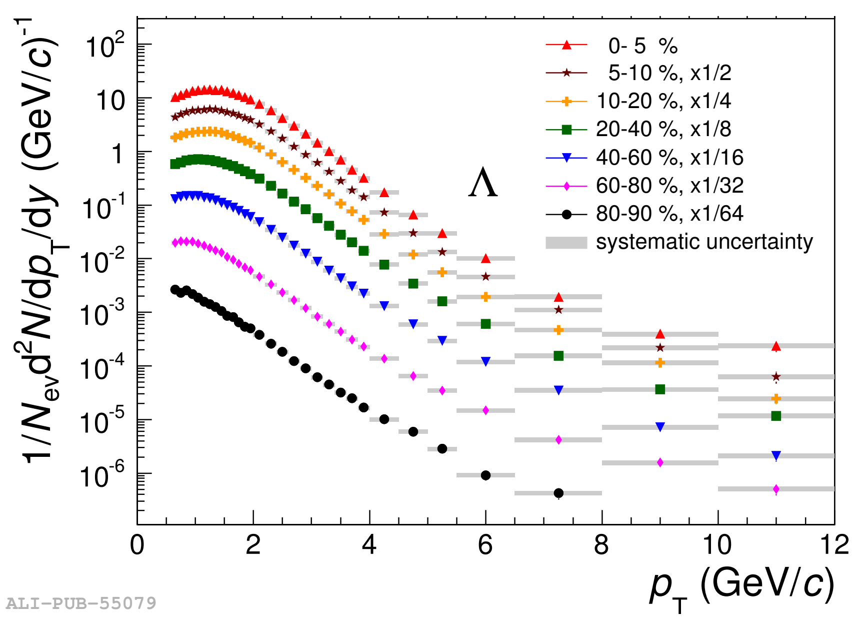


$\Xi^{*0}+\overline{\Xi^{*0}}\rightarrow\Xi^{\mp}\pi^{\pm}$

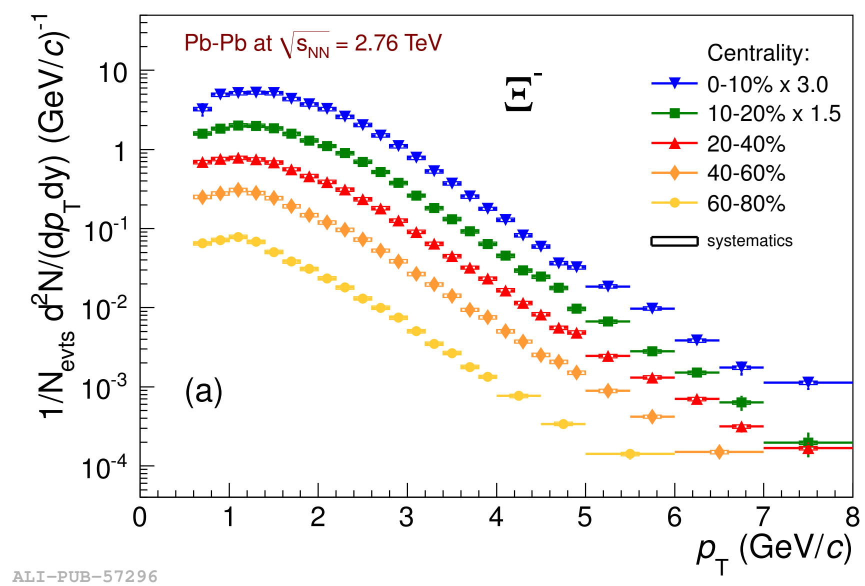


Spectra in Pb-Pb collisions

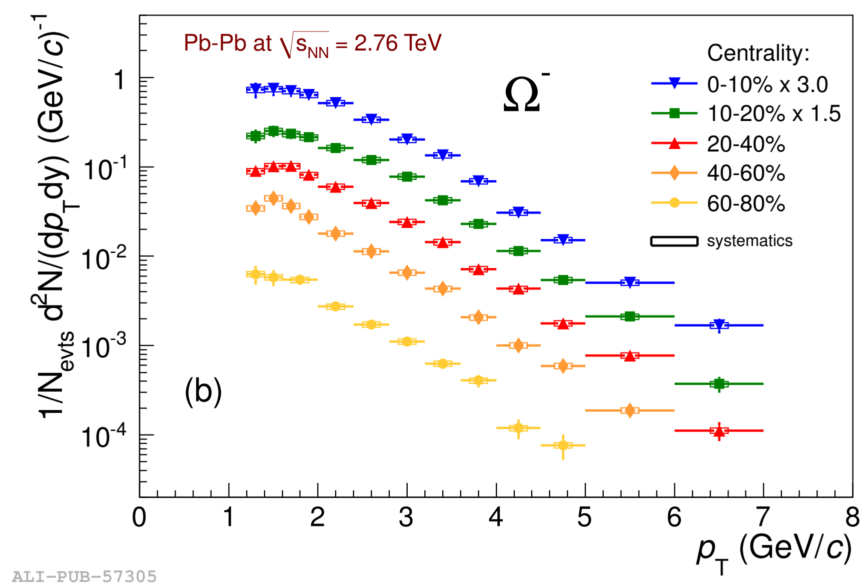
$\Lambda \rightarrow p\pi^-$



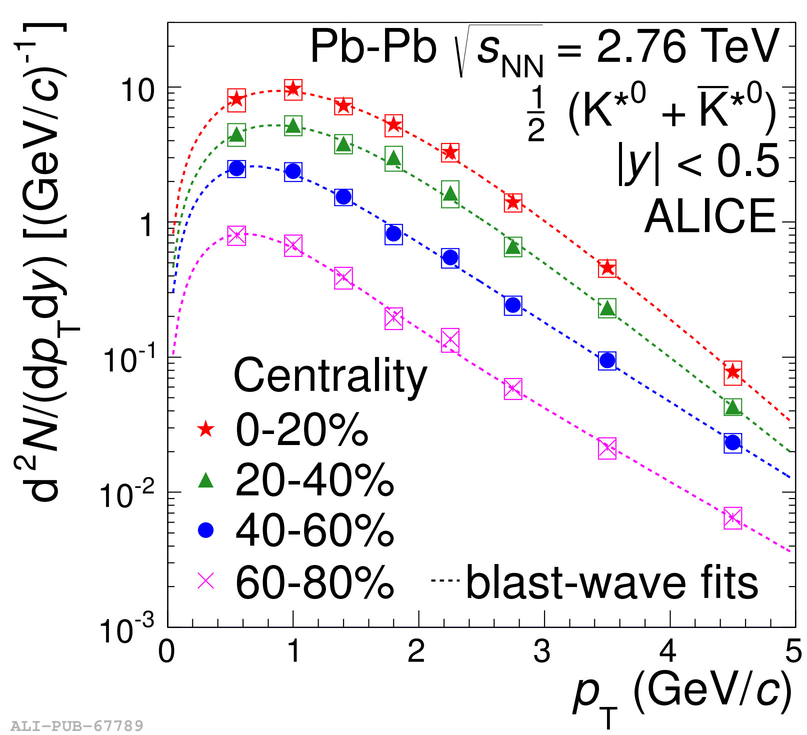
$\Xi^- \rightarrow \Lambda\pi^-$



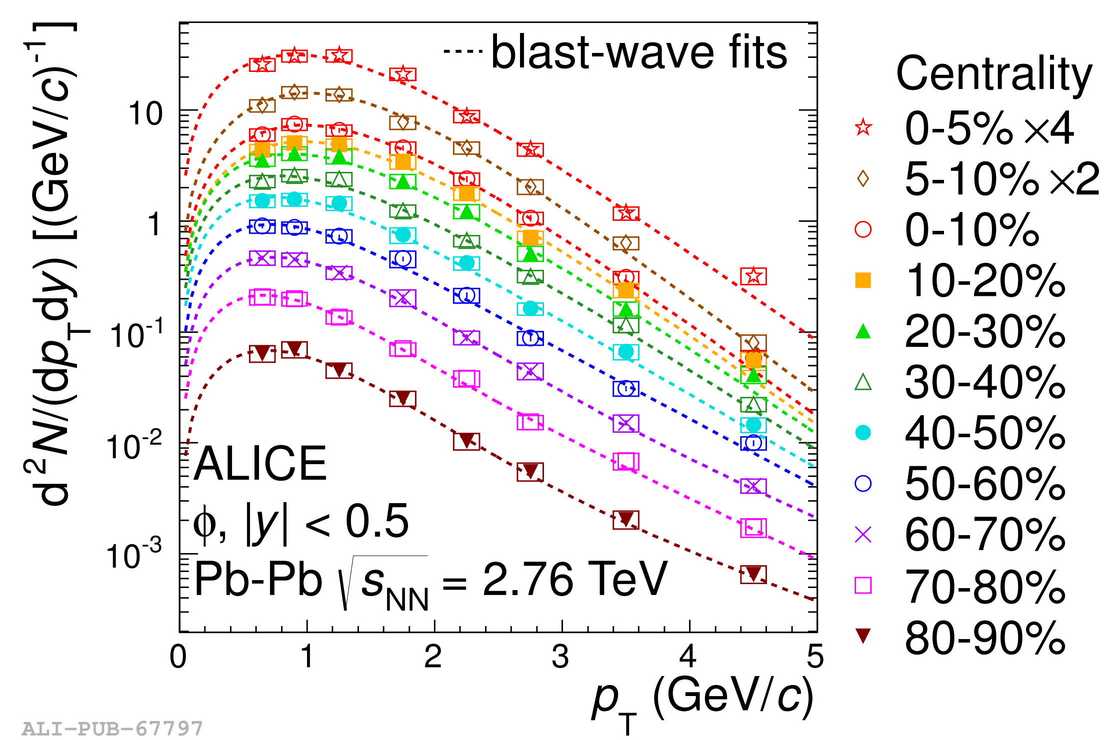
$\Omega^- \rightarrow \Lambda K^-$



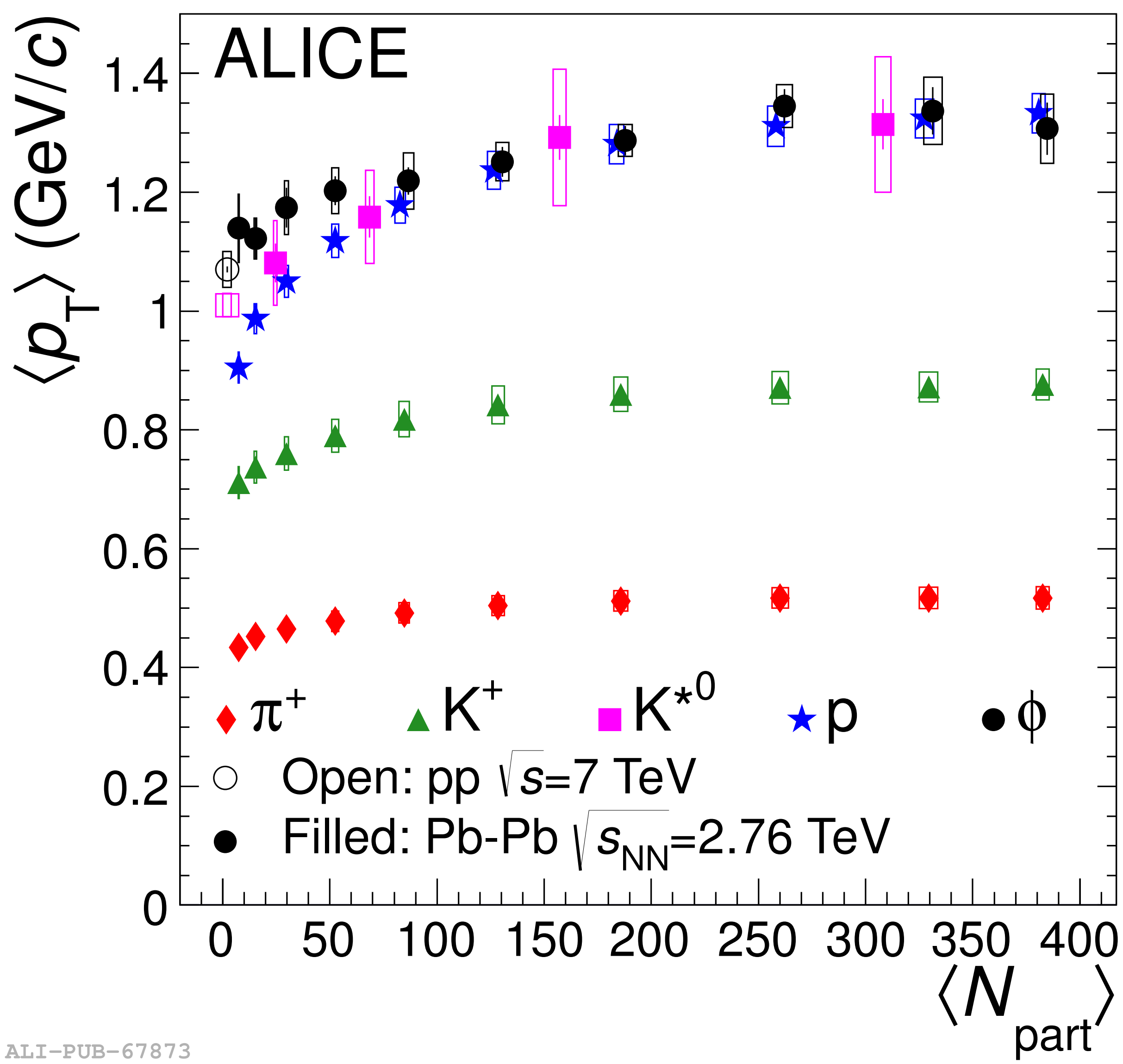
$K^{*0} \rightarrow K^{\mp}\pi^{\pm}$



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

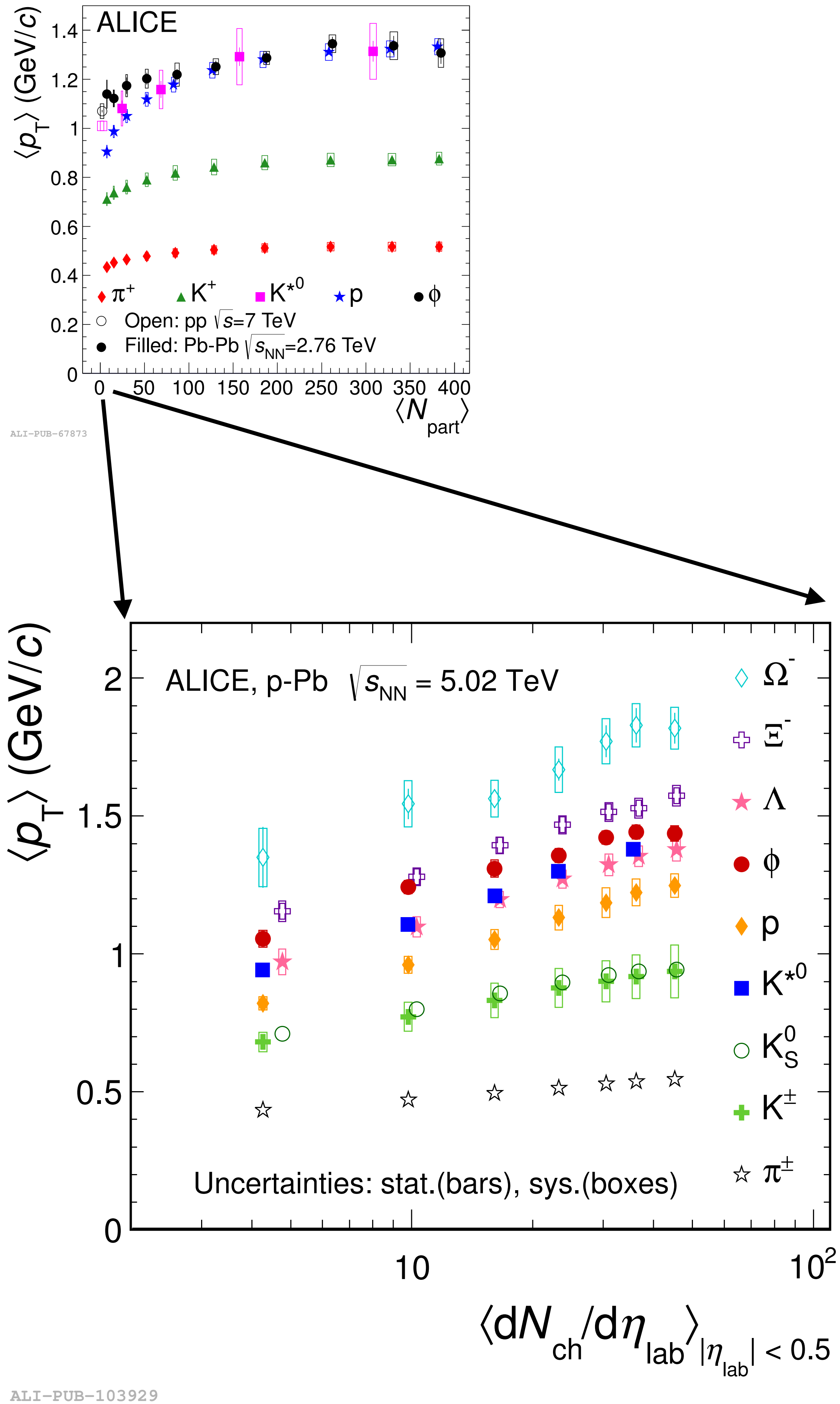


Mean p_T



★ **Pb-Pb** collisions

- **central**: K^{*0}, p and ϕ follow mass ordering
- **peripheral**: we observe a splitting of $\langle p_T \rangle$ for proton and ϕ
- **peripheral→central**: the $\langle p_T \rangle$ of p exhibits a larger increase than other particles



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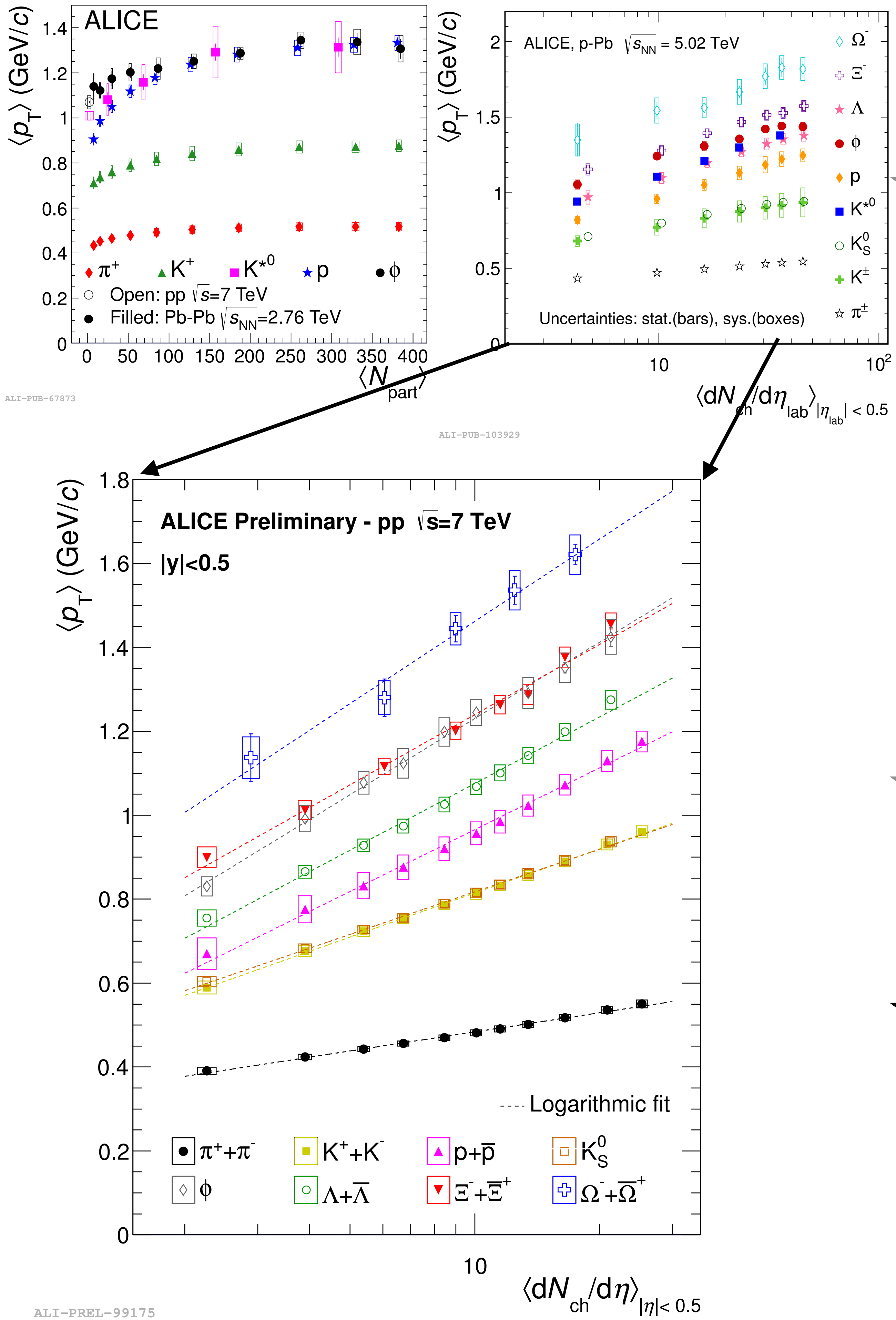
★ **p-Pb** collisions

- increase from lowest to highest multiplicity event class



Mean p_T

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- **central**: K^{*0}, p and ϕ follow mass ordering
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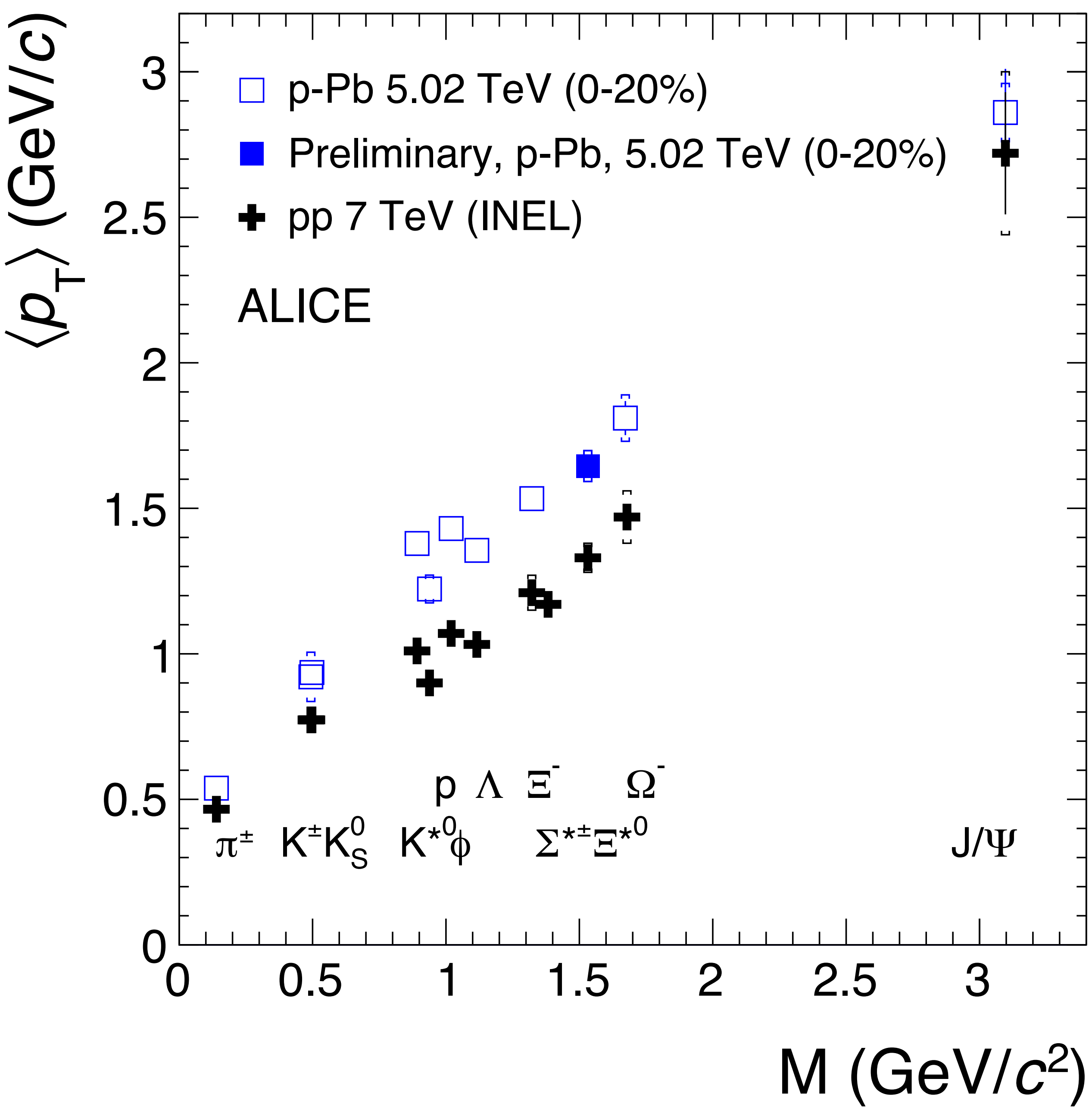
★ **p-Pb** collisions

- increase from lowest to highest multiplicity event class

★ **pp** collisions

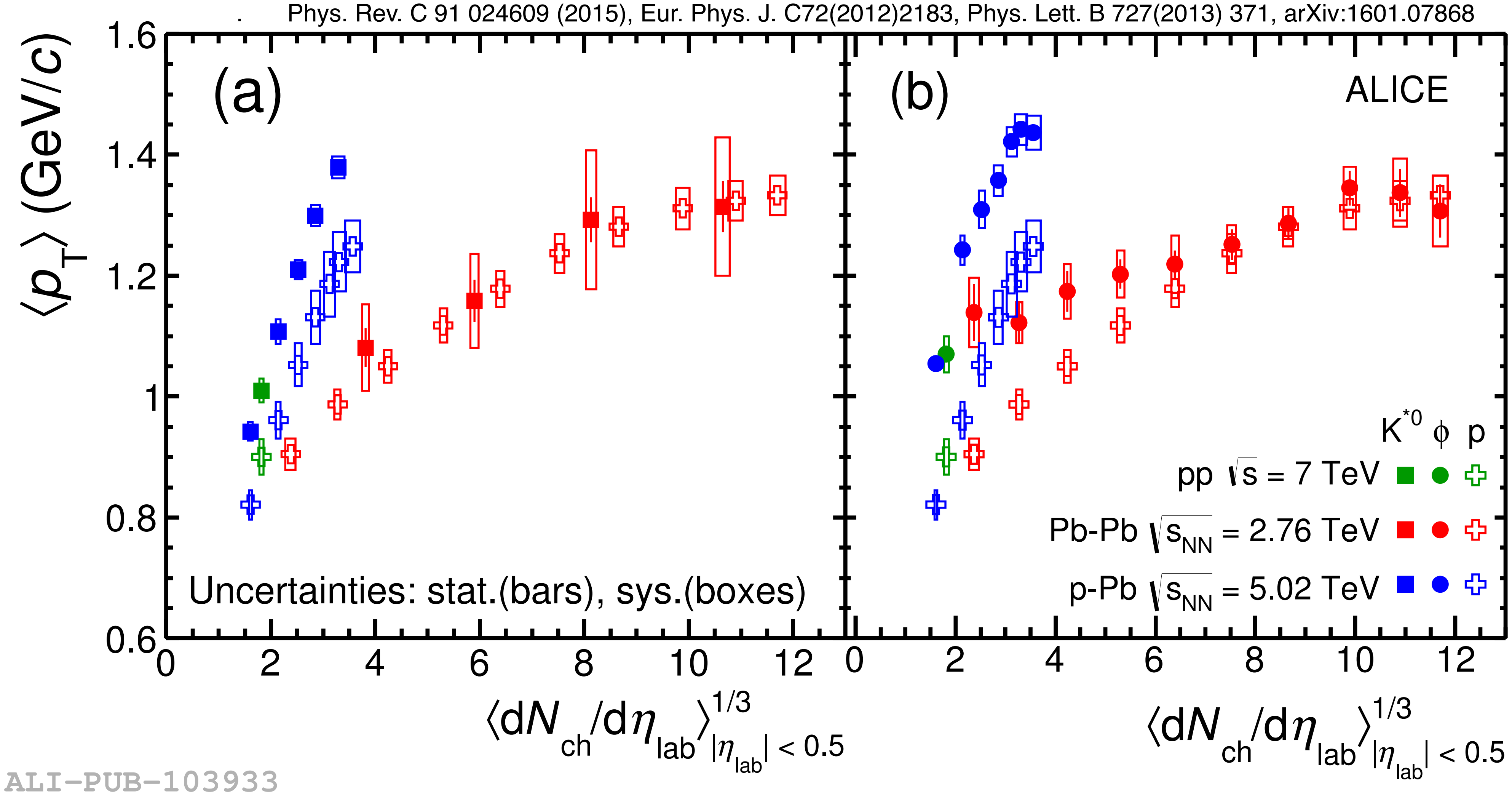
- follows same trend as p-Pb
- ϕ does not follow mass ordering

Mean p_T vs M



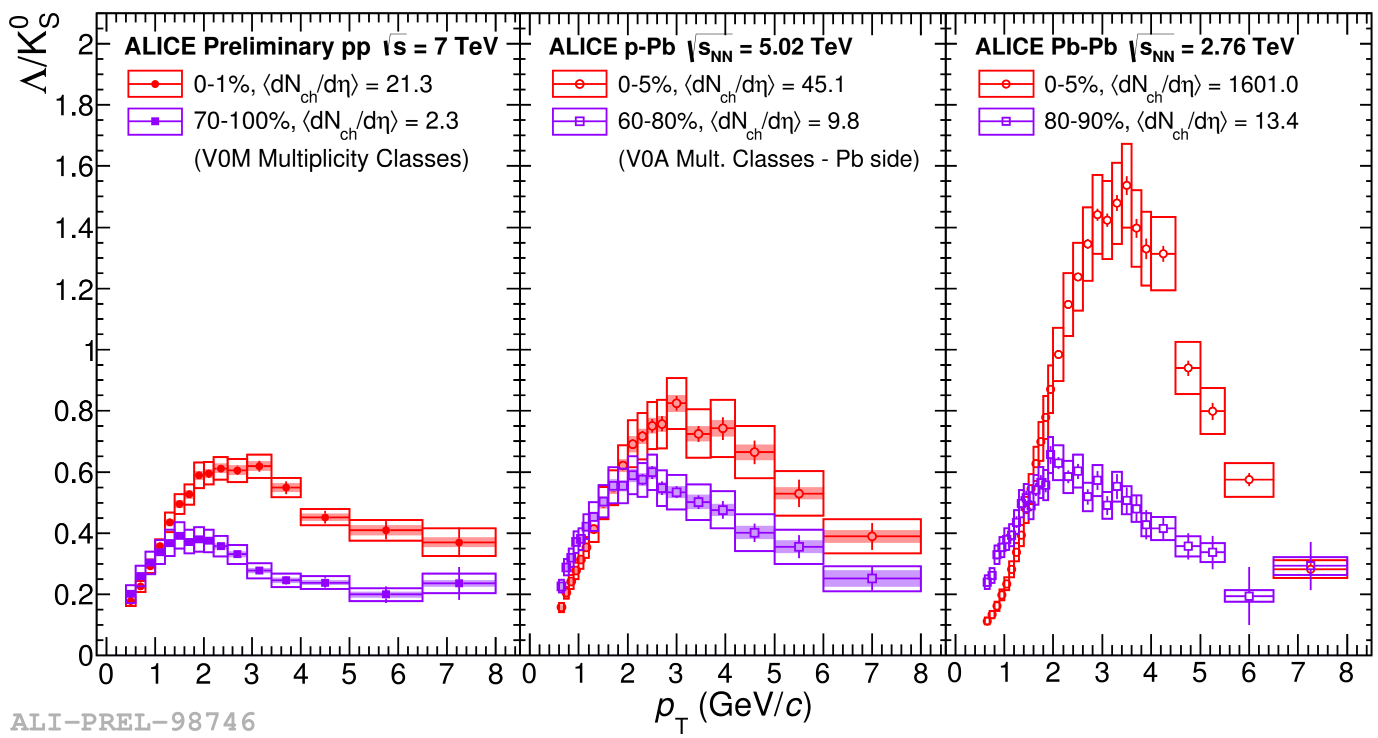
- ★ Mass ordering
- ★ $\langle p_T \rangle \propto M$
  - common βγ ?
- ★ no clear separation between meson and baryon trends
- ★ no mass-ordering of $\Delta\langle p_T \rangle$ between p-Pb and pp

Mean p_T: system size dependence

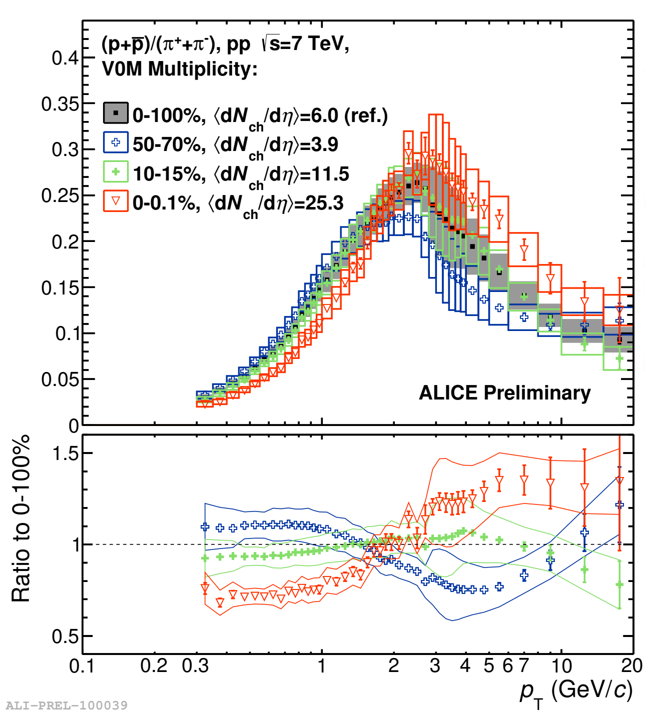


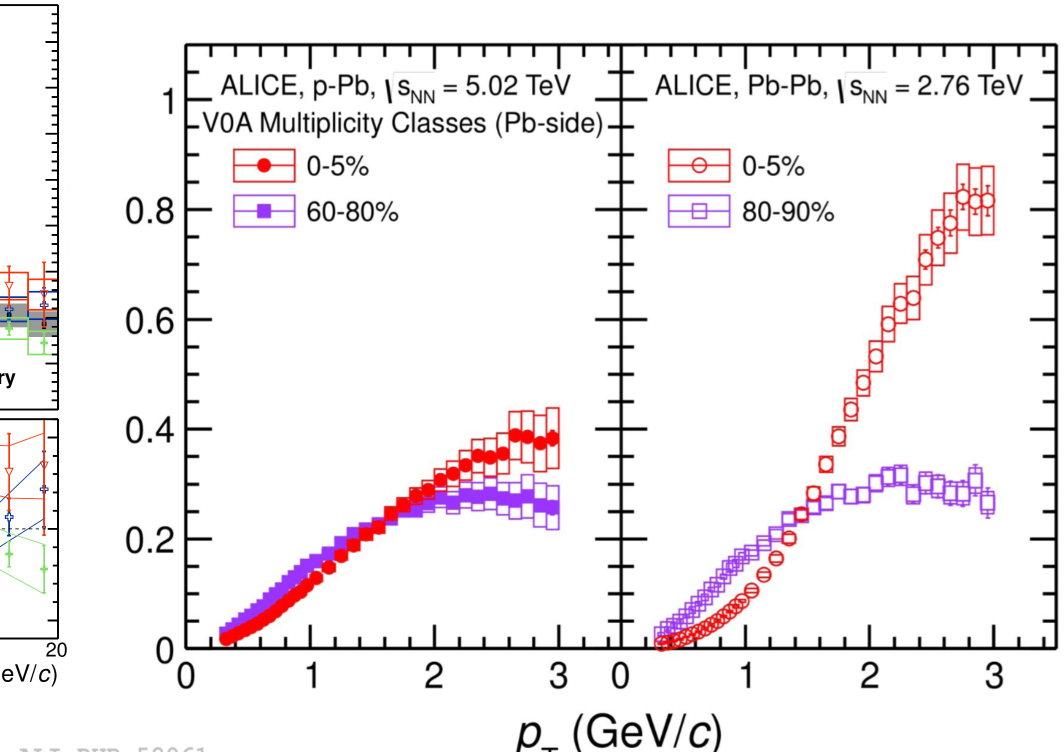
- ★ pp follows the trend observed in p-Pb
- ★ steeper increase of $\langle p_T \rangle$ for smaller systems
- ★ Pb-Pb values lower than p-Pb for similar multiplicities

p_T-dependent ratio : Λ/K^0_s and p/π



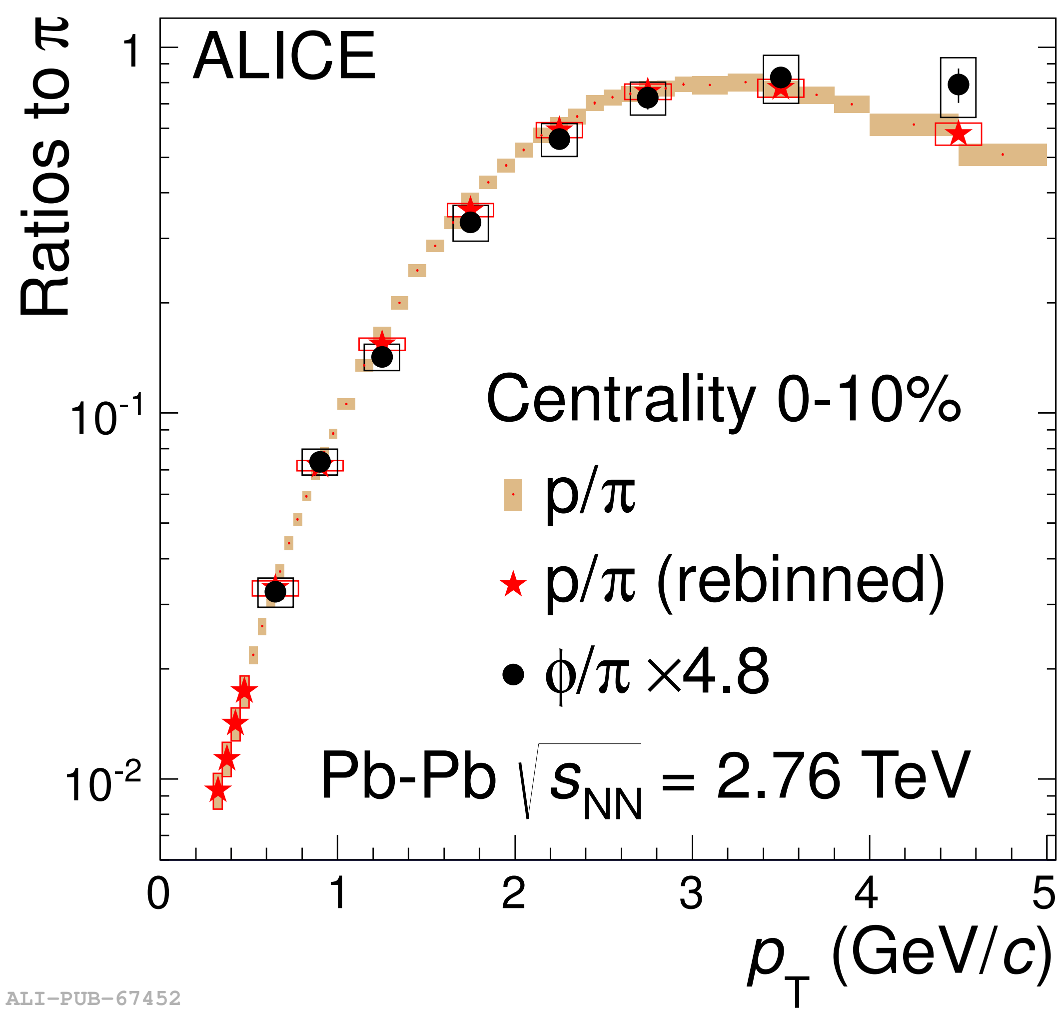
- ★ The ratios in pp and p-Pb are small compared to central Pb-Pb
- ★ What causes the shape of these ratios ?
  - particle mass / quark content / baryon vs. meson ?

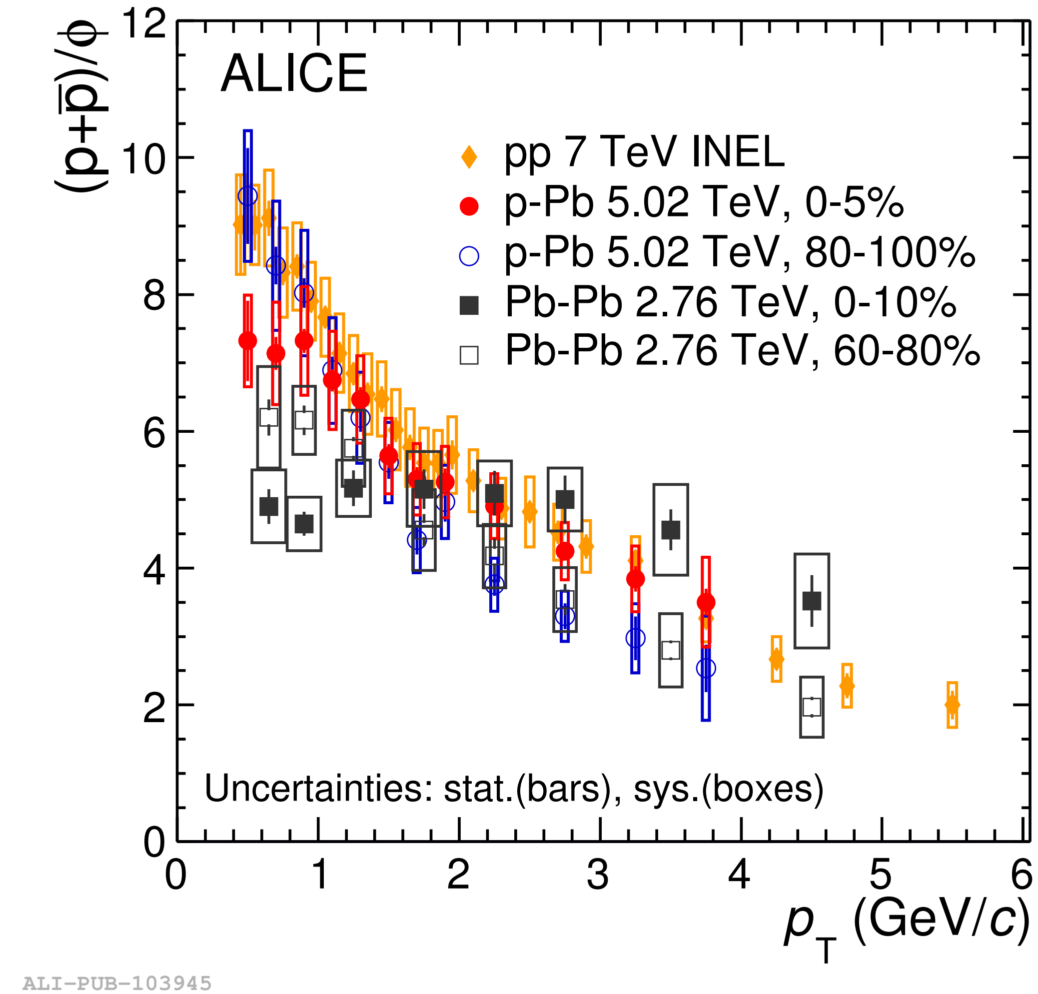




Check : meson with a mass similar to the proton (i.e. ϕ, $|m_\phi - m_p|$~80 MeV/c^2)

p_T-dependent ratio : p/π, ϕ/π and p/ϕ





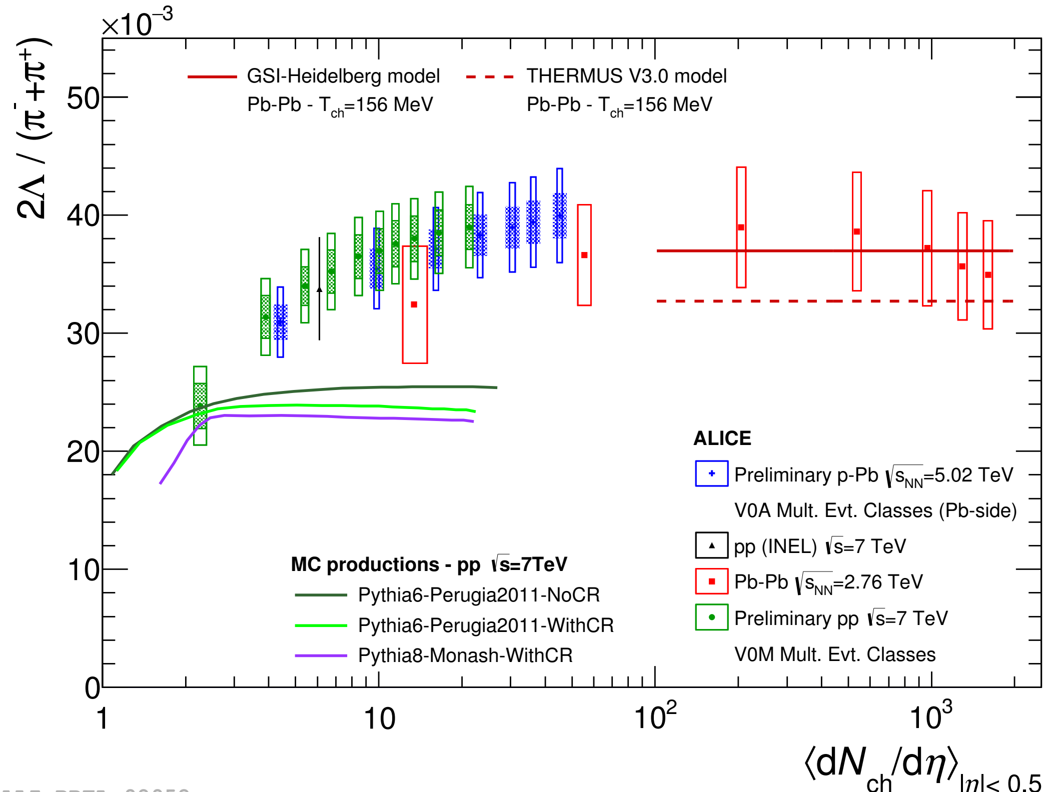
★ Baryon/meson and meson/meson ratios have similar shapes in central Pb-Pb

★ A flat p/ϕ ratio in central Pb-Pb for p_T<3-4 GeV/c

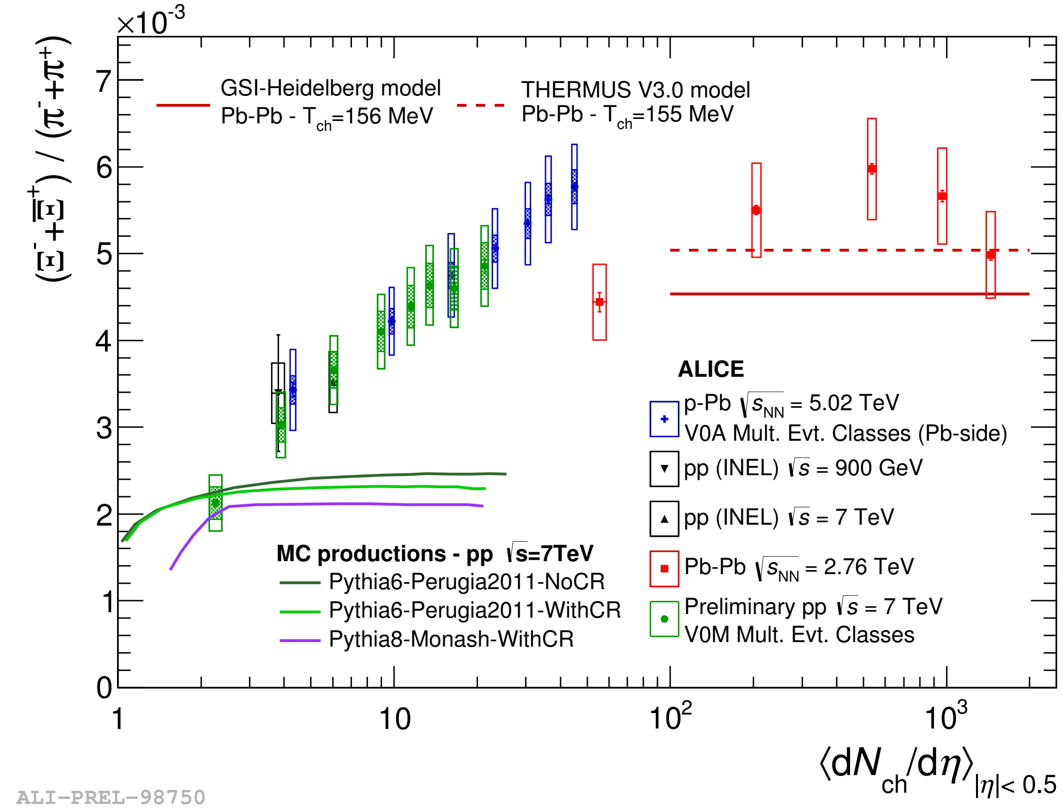
- p_T distribution determined by the mass (hydrodynamic picture)

★ Slope of the ratio changes from flat (central) to strong decrease (peripheral collisions, p-Pb and pp)

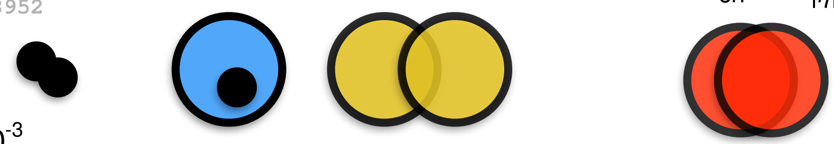
Strangeness production vs multiplicity

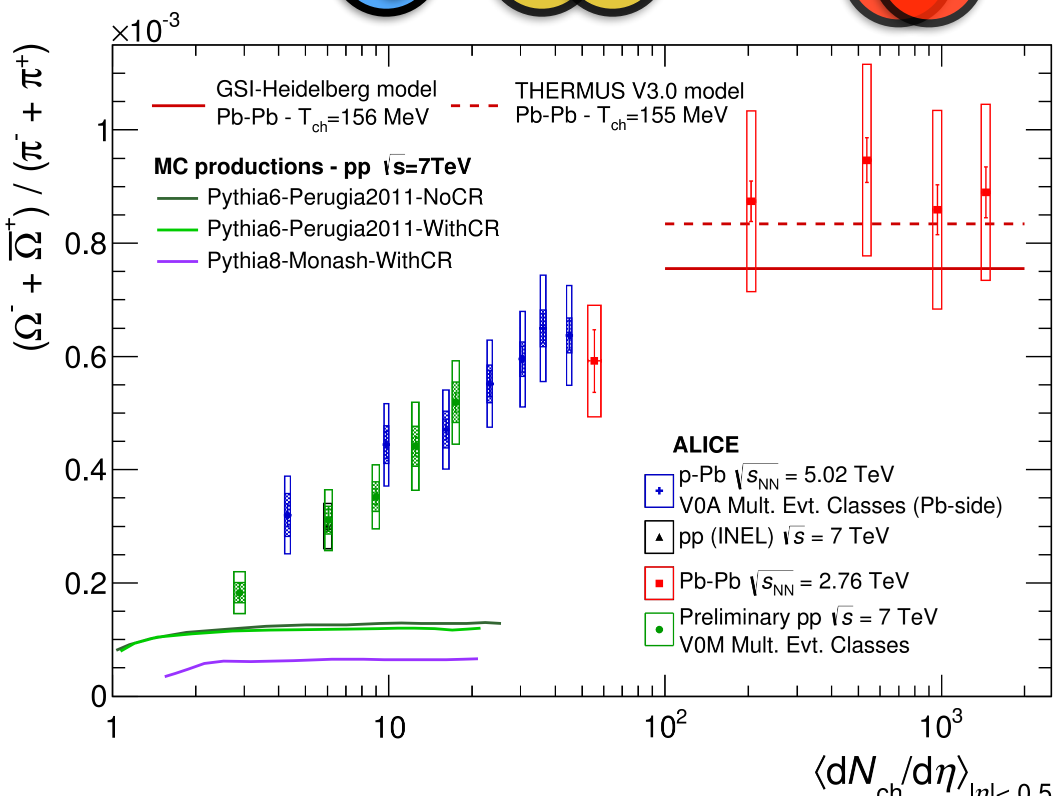


ALI-PREL-98952



ALI-PREL-98750



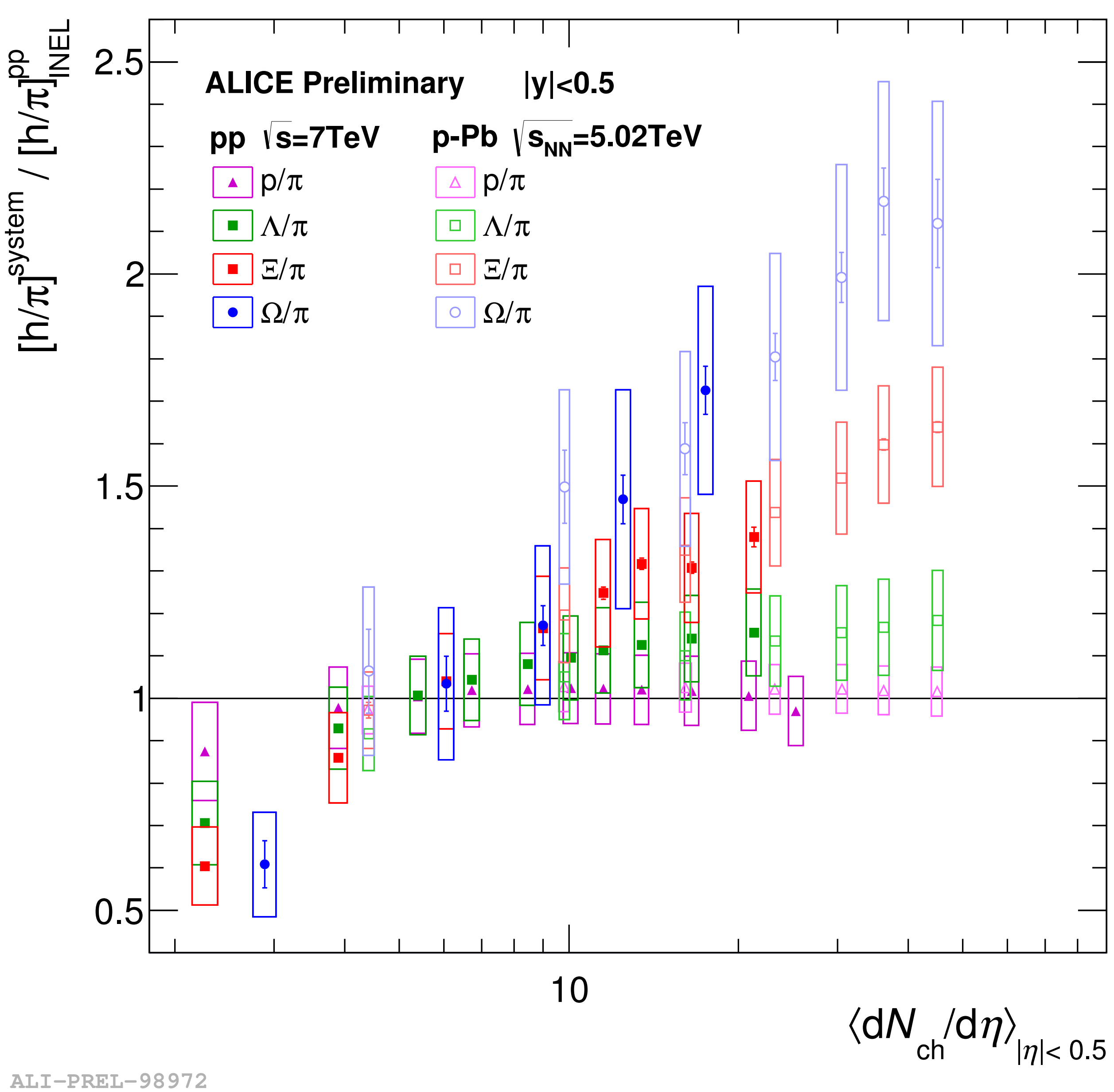


ALI-PREL-98754

- ★ Λ/π, Ξ/π and Ω/π ratios in pp, p-Pb increase with multiplicity
- ★ Same trend for pp and p-Pb
- ★ Canonical suppression describes observation
- ★ Grand canonical limit reached
- ★ PYTHIA 6, 8 and several tunes do not reproduce the data.

[11] Andronic et al., J. Phys. G38(2011)124081

Strangeness production vs multiplicity

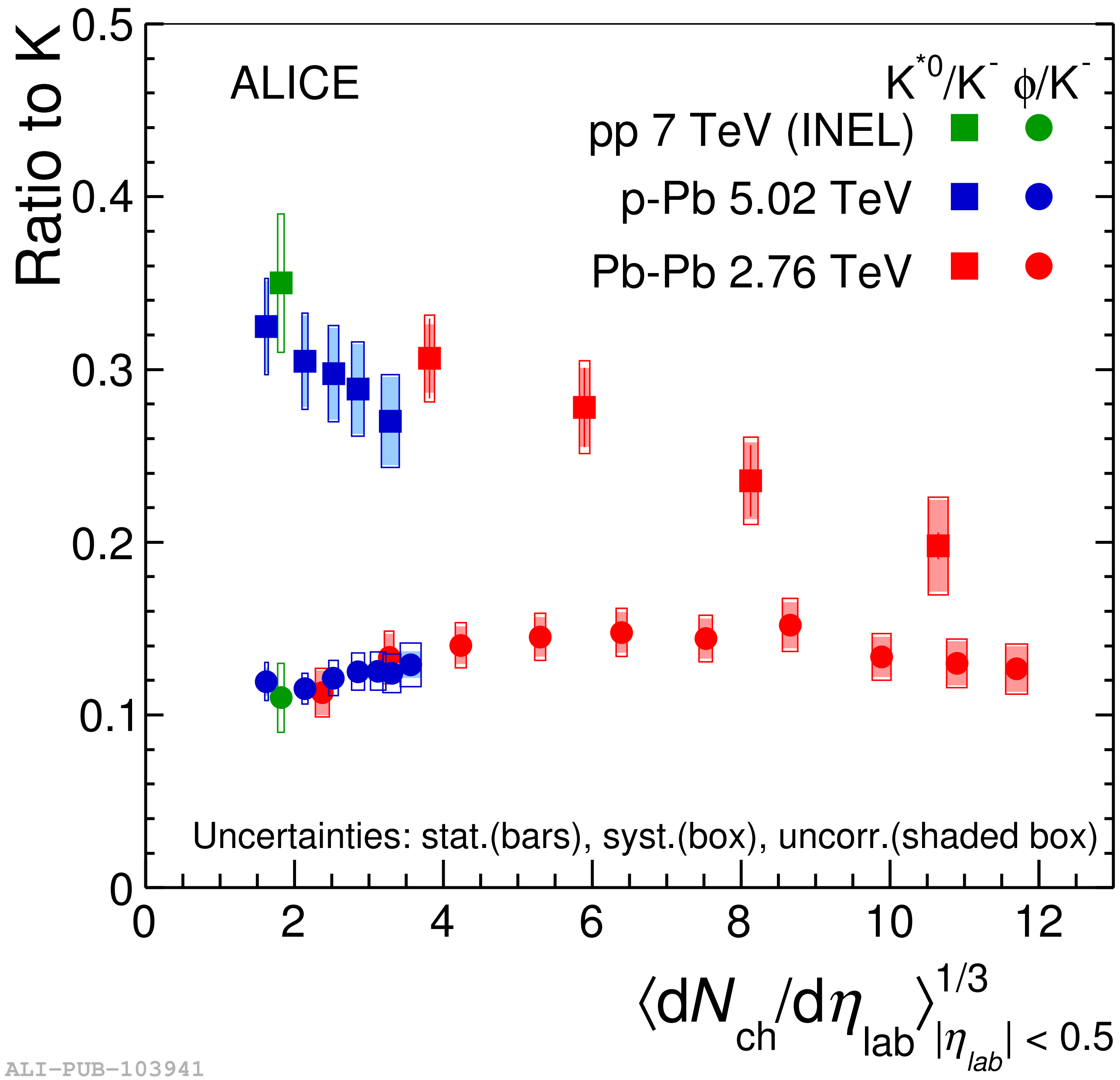


★ p/π is consistent with unity up to the highest multiplicity

★ The relative increases with multiplicity is more pronounced for hyperons with higher strangeness content

★ The increases is not baryon related, but strangeness related

Study of the hadronic phase



★ **K^{*0}/K^-**

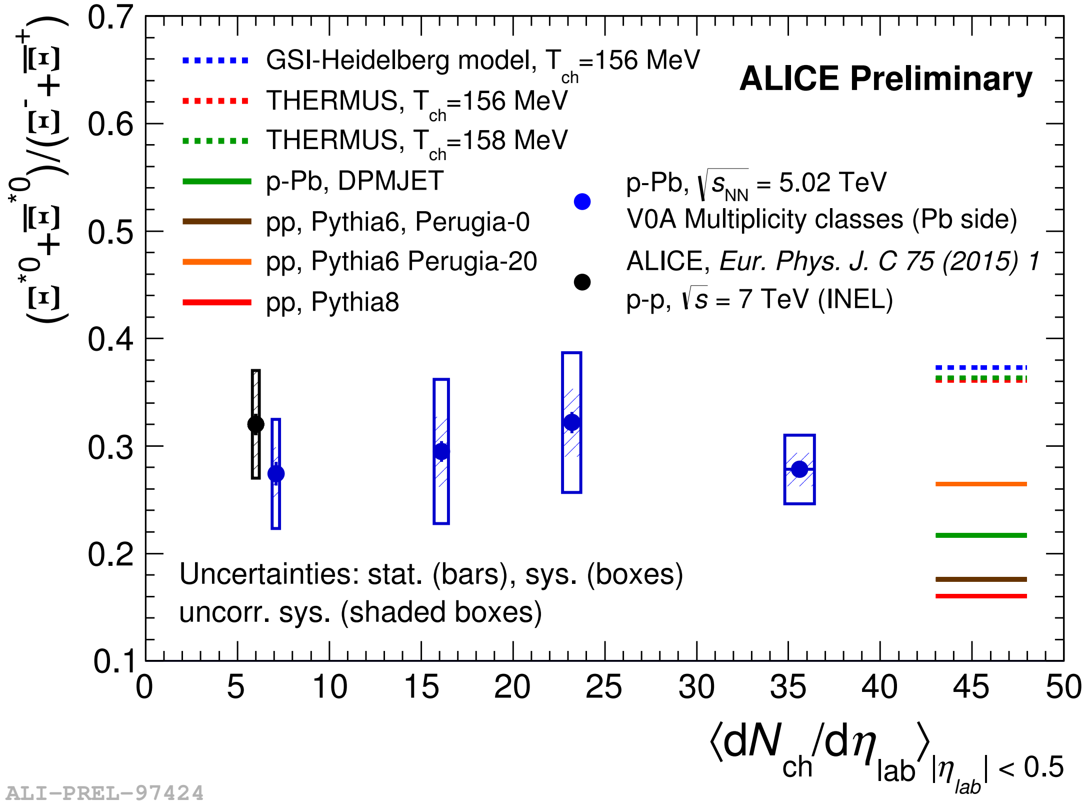
- progressively larger suppression when going from pp to p-Pb to central Pb-Pb
- suppression in central Pb-Pb collisions interpreted as due to dominant re-scattering

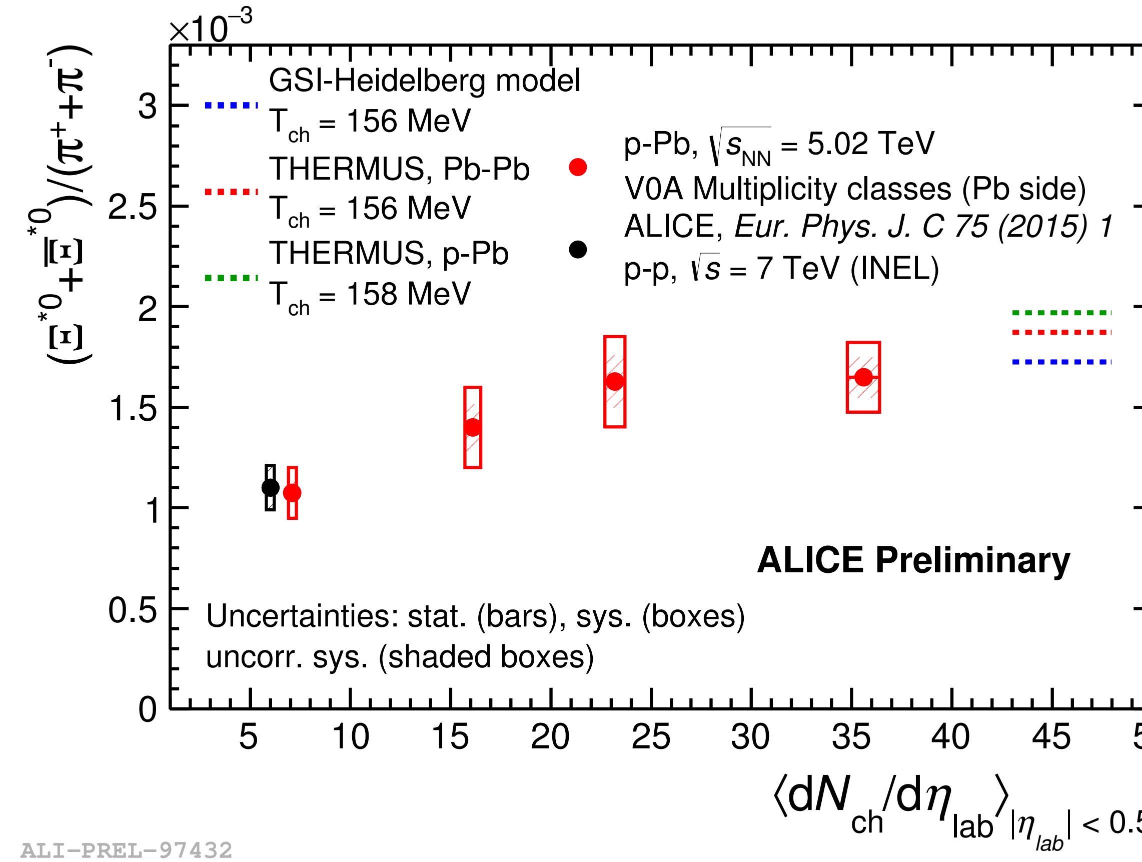
★ **ϕ/K^-**

- no significant system-size dependence

	Lifetime
$K^*(892)^0$	4.16 ± 0.05 fm/c
ϕ(1020)	46.3 ± 0.4 fm/c

Production of Ξ(1530)^0





★ **Ξ^{*0}/Ξ**

- multiplicity independent
- higher than pQCD-inspired models but slightly below statistical hadronization model
- measurement of more resonances ratios to longer lived hadrons (Σ^*/Λ, Ξ^*/Ξ, Λ^*/Λ) allow to probe further the hadronic phase with particles of different lifetime

★ **Ξ^{*0}/π**

- increases with multiplicity, approaching thermal model predictions in the highest multiplicity collisions
- related to the increase of strangeness with multiplicity

Summary and outlook

★ **Hyperons** and **resonances** have been measured in pp, p-Pb and Pb-Pb collisions at the LHC as a function of multiplicity/centrality

★ We observe a relative **increase of <p_T> with multiplicity** and **mass ordering**

★ From p_T-dependent ratio of p/ϕ, **$\mathbf{p_T}$ distribution determined by the mass** in central Pb-Pb collisions

★ We observe a strangeness-related increase with multiplicity of the ratio of hyperons to π in pp and p-Pb

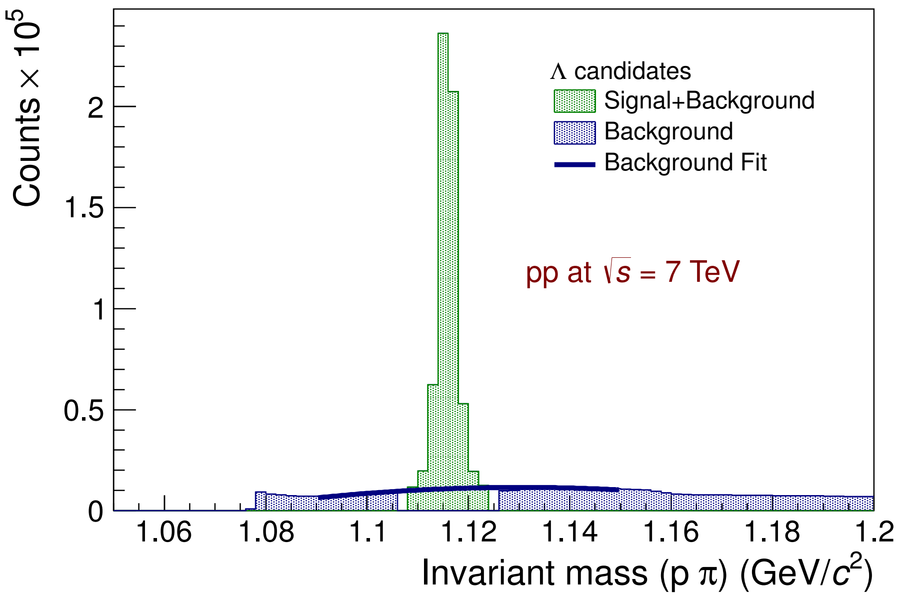
★ We see indications of **re-scattering effects for the short-lived $\mathbf{K^{*0}}$** in Pb-Pb

★ More resonances under study to further probe the properties of the hadronic phase

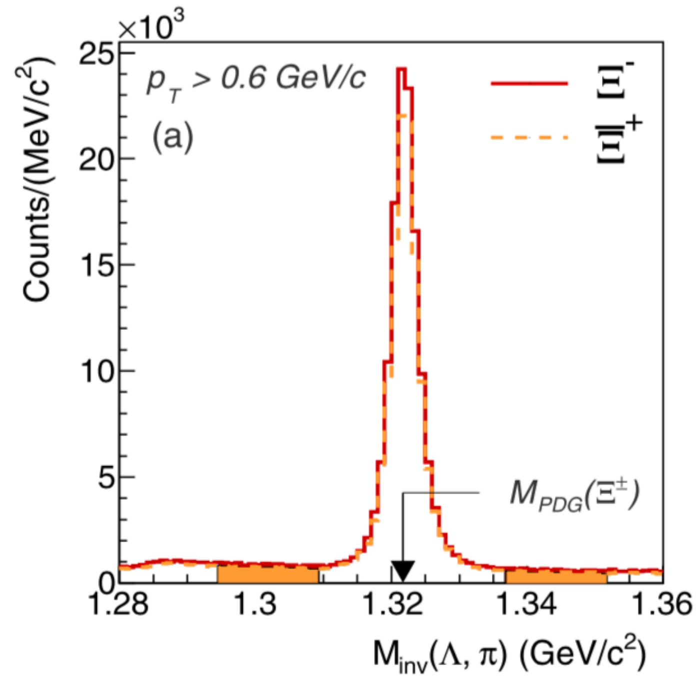
Backup

Reconstruction in pp collisions

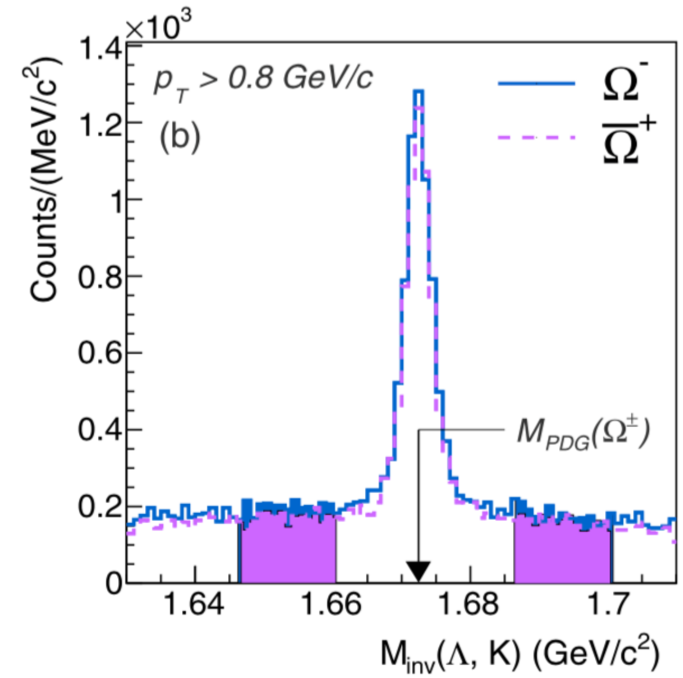
$\Lambda \rightarrow p\pi^-$



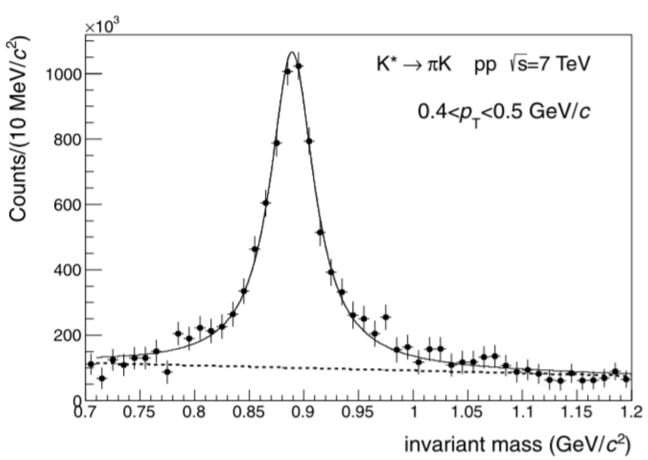
$\Xi^- \rightarrow \Lambda\pi^-$



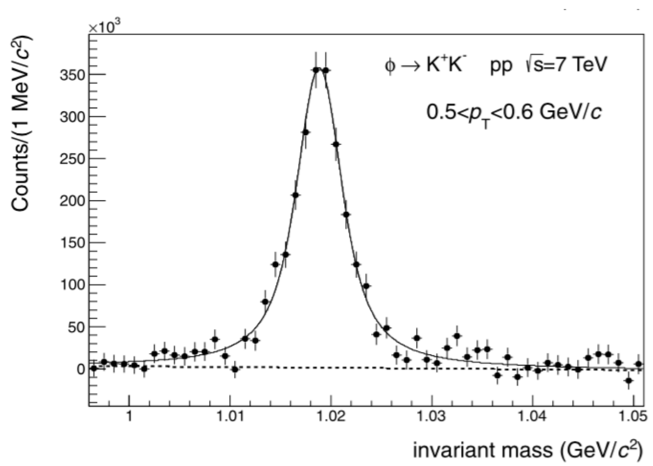
$\Omega^- \rightarrow \Lambda K^-$



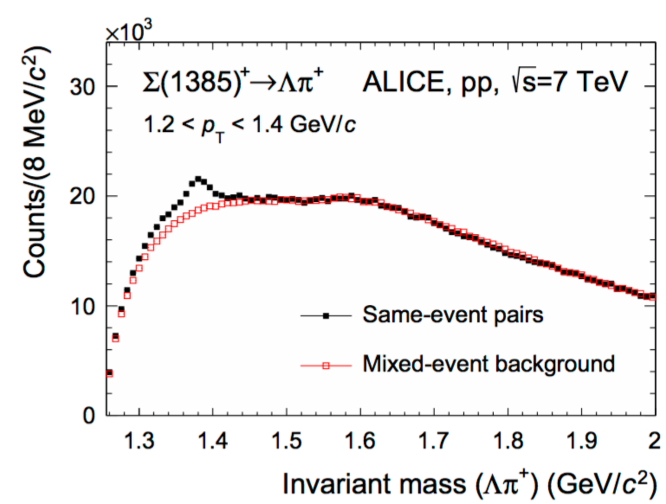
$K^{*0} \rightarrow K^{\mp}\pi^{\pm}$



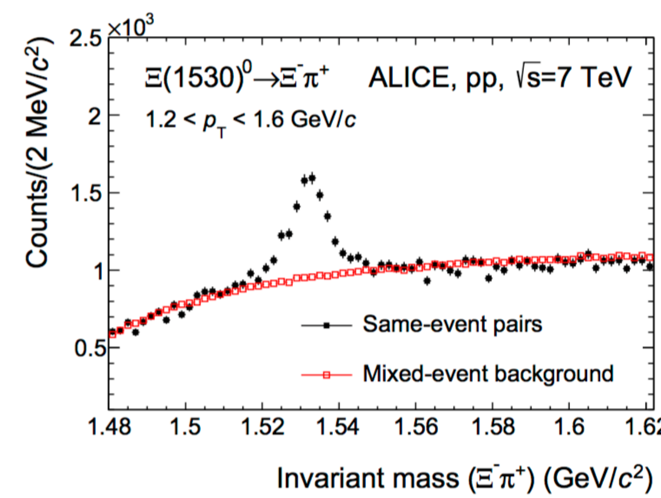
$\phi \rightarrow K^+K^-$



$\Sigma^{*+} \rightarrow \Lambda\pi^-$



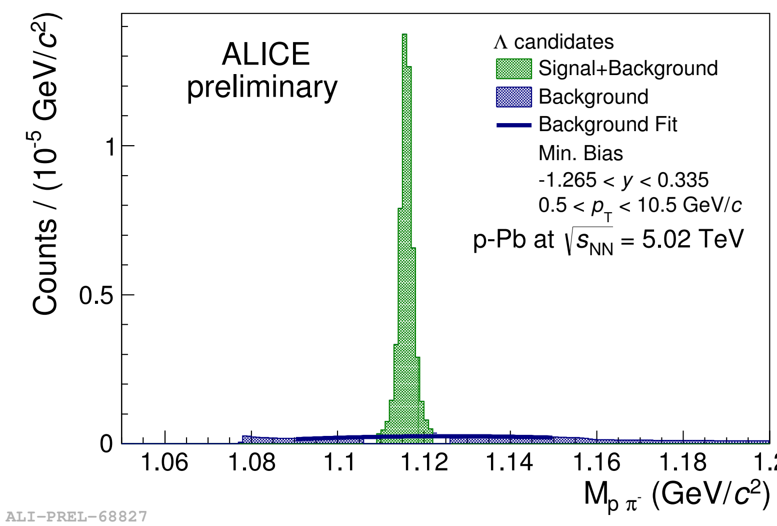
$\Xi^{*0} \rightarrow \Xi^-\pi^+$



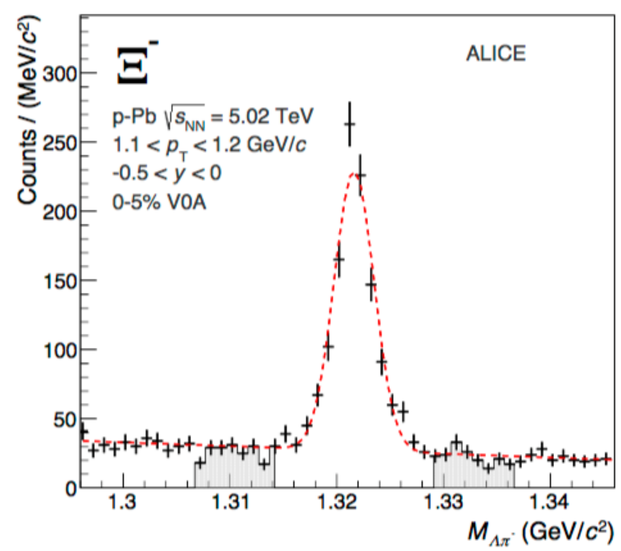
[1] Eur. Phys. J. C 73 (2013) 2496 [2]Physics Letters B 712 (2012) 309–318
[3] Eur. Phys. J. C (2012) 72:2183 [4] Eur. Phys. J. C (2015) 75:1

Reconstruction in p-Pb collisions

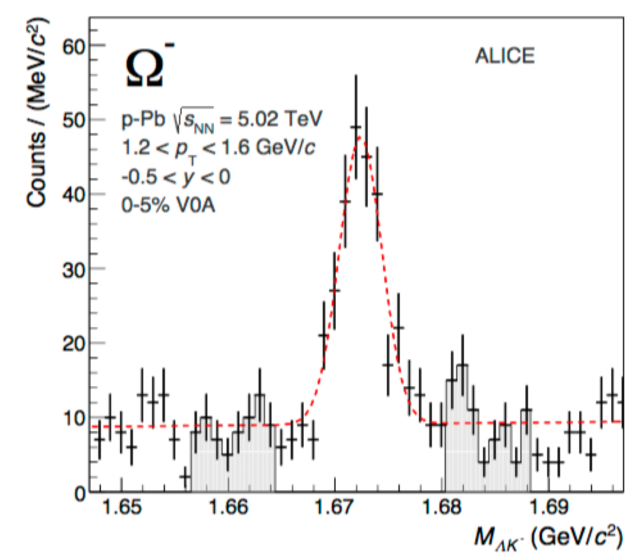
$\Lambda \rightarrow p\pi^-$



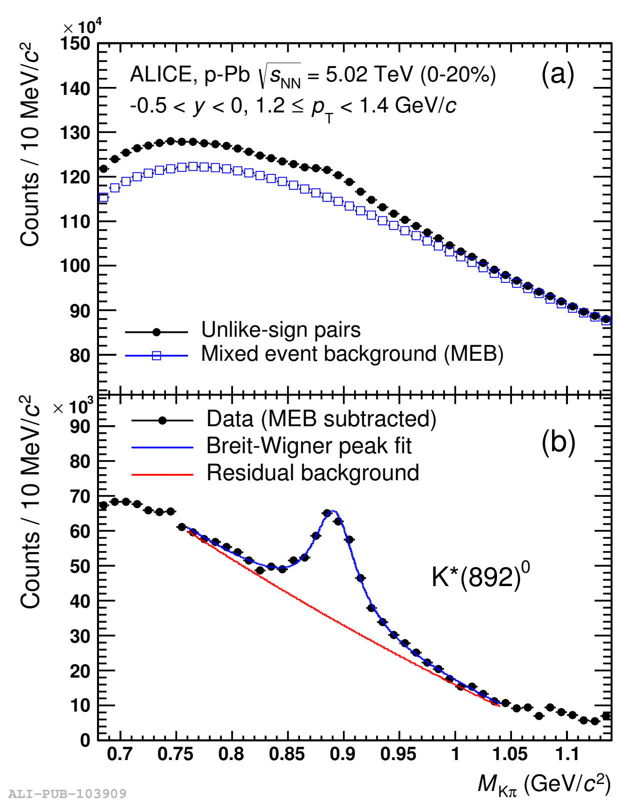
$\Xi^- \rightarrow \Lambda\pi^-$



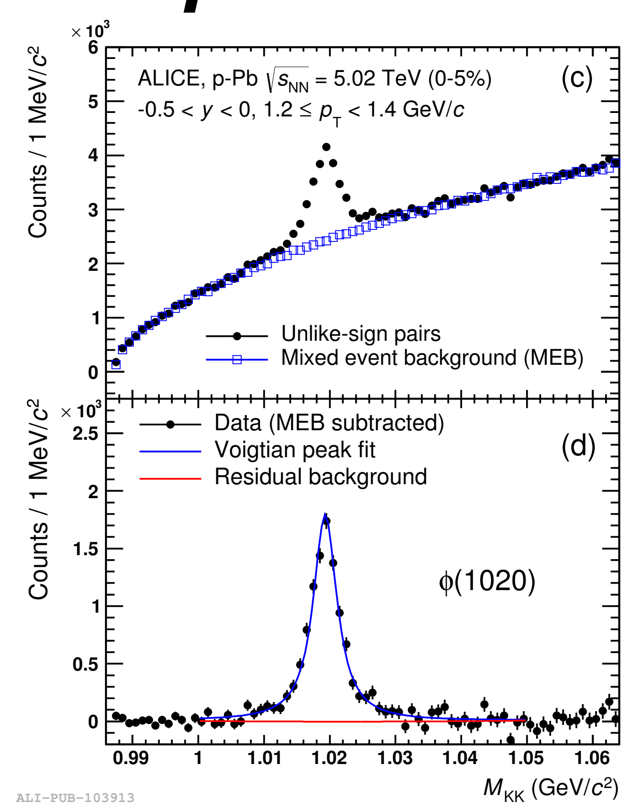
$\Omega^- \rightarrow \Lambda K^-$



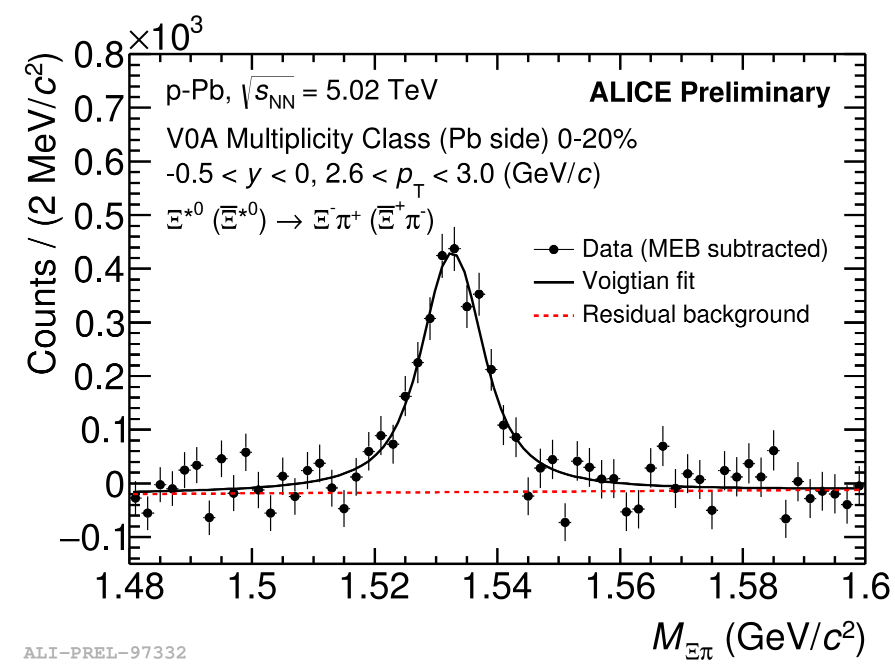
$K^{*0} \rightarrow K^{\mp}\pi^{\pm}$



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



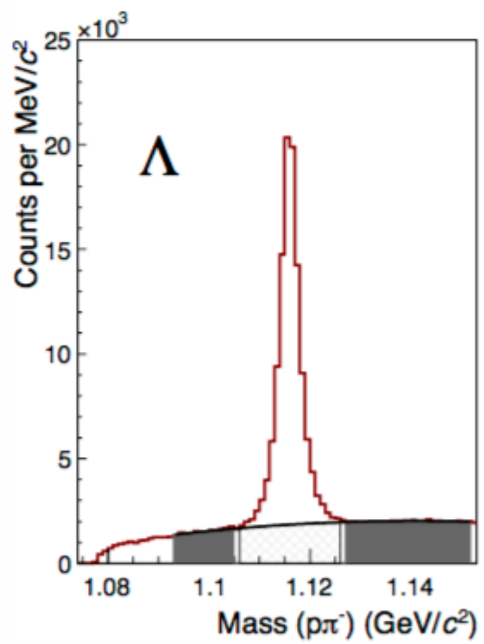
$\Xi^{*0} \rightarrow \Xi^{\mp}\pi^{\pm}$



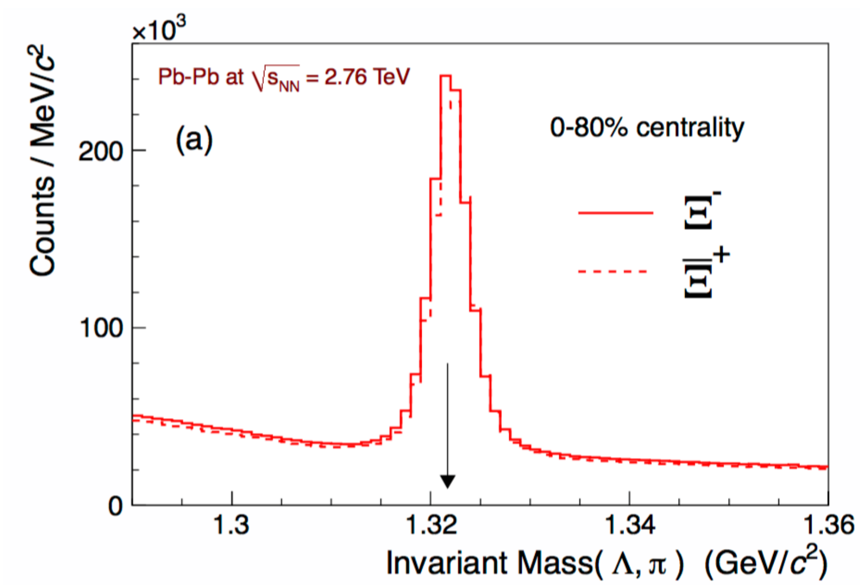
[4]arXiv:1512.07227 [5]arXiv:1601.07868 [6]Phys.Lett. B728 (2014) 25-38

Reconstruction in Pb-Pb collisions

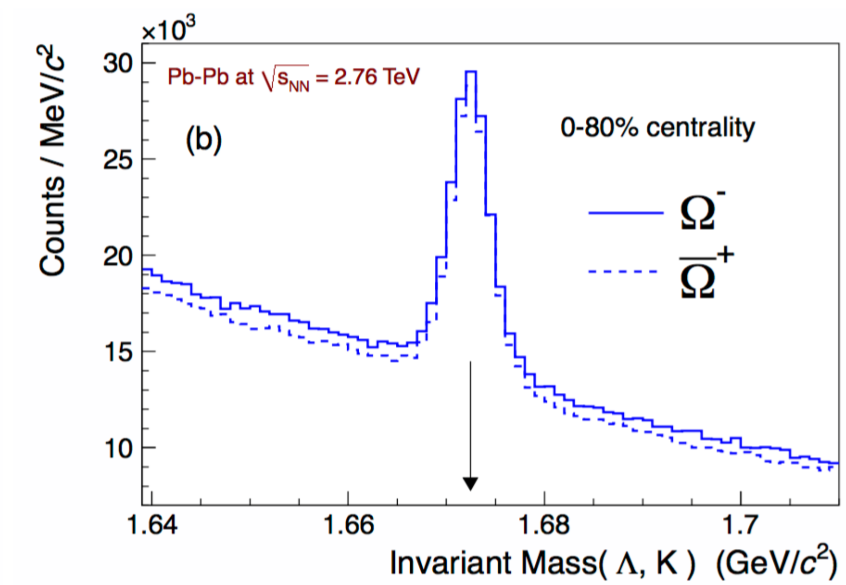
$\Lambda \rightarrow p\pi^-$



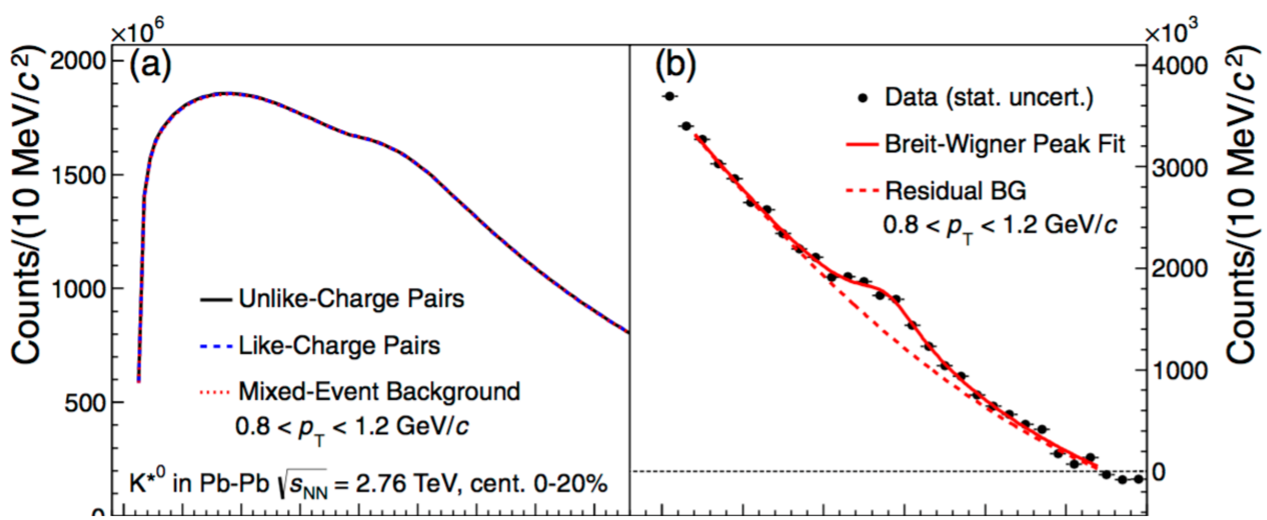
$\Xi^- \rightarrow \Lambda\pi^-$



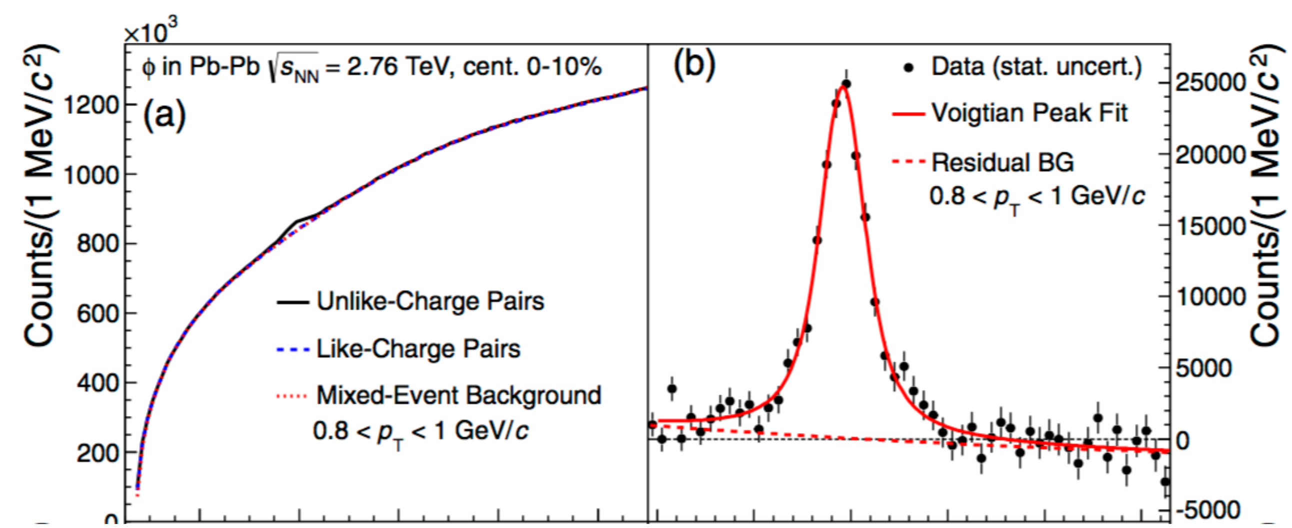
$\Omega^- \rightarrow \Lambda K^-$



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



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



[7]arXiv:1307.5530v2 [8]arXiv:1307.5543v3 [9]PHYSICAL REVIEW C 91, 024609 (2015)