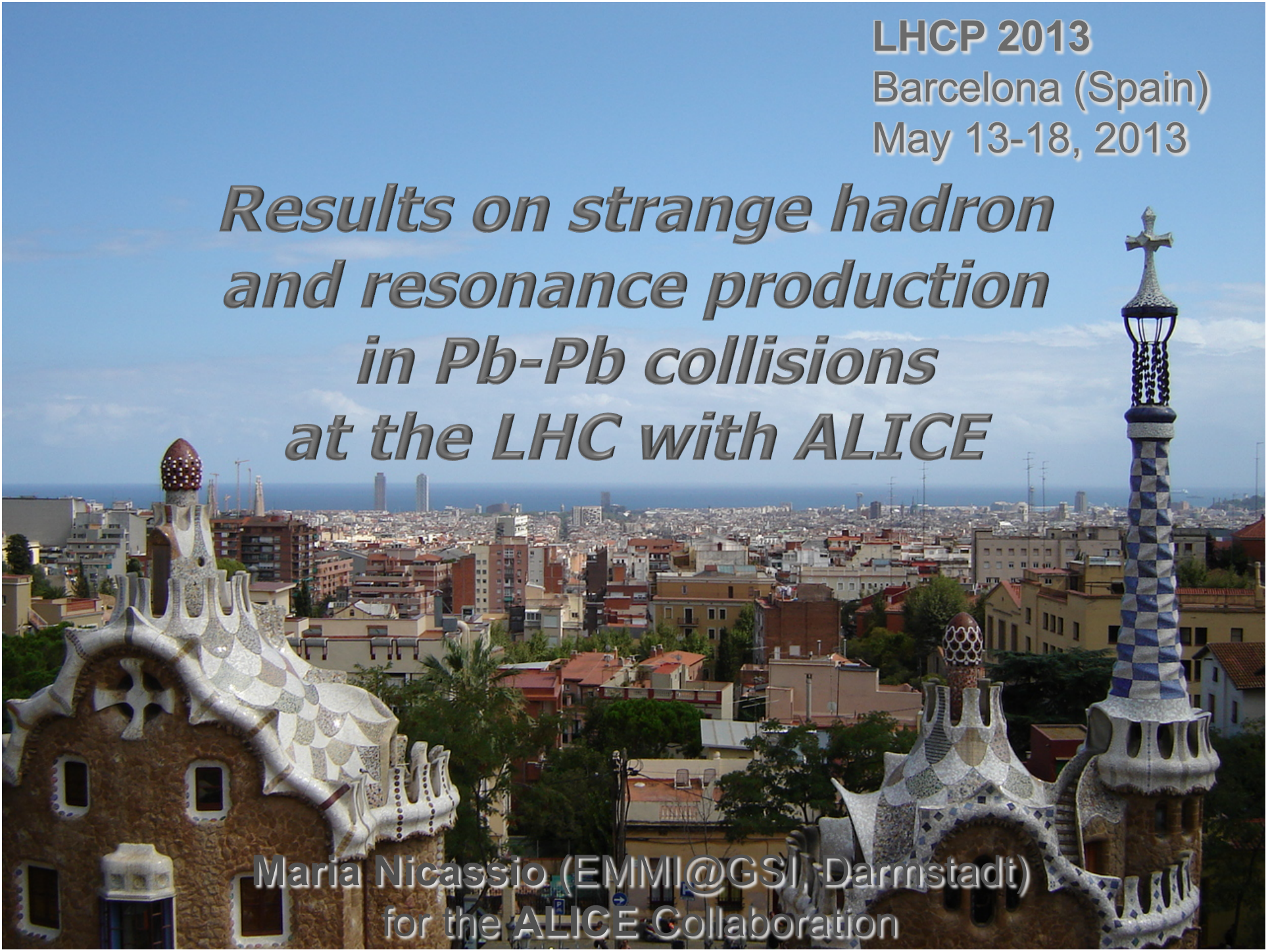

LHCP 2013
Barcelona (Spain)
May 13-18, 2013

# Results on strange hadron and resonance production in Pb-Pb collisions at the LHC with ALICE

Maria Nicassio (EMMI@GSI, Darmstadt)
for the ALICE Collaboration

# Outline

- Motivation to study strangeness production
- Strange hadron and resonance reconstruction in ALICE
  - $K^0_S$, $\Lambda$, $\Xi^-$ and $\Omega^-$ (+anti-particles), $\phi(1020)$, $K^*(892)^0$ (+anti-particle)
- Results and discussion
  - strangeness enhancement
  - thermal model fits of particle yields
  - resonance to non-resonance yield ratios
  - $\Lambda$ to $K^0_S$ ratio
- Conclusions and open issues

# Studying strangeness production in A-A collisions…

- …to retrieve information on the early partonic stages of the collision and its evolution
  - s-quarks are produced in the collision
  - strange hadrons have small hadronic cross section
  - resonances have lifetime≈fm/c

- …to understand some open issues
  - enhanced production of baryons compared to mesons at intermediate $p_T$ in central collisions ("baryon anomaly")
  - origin of observed strangeness enhacement compared to production in pp collisions
  - thermal model prediction and fits of measured yields: common freeze-out temperature?

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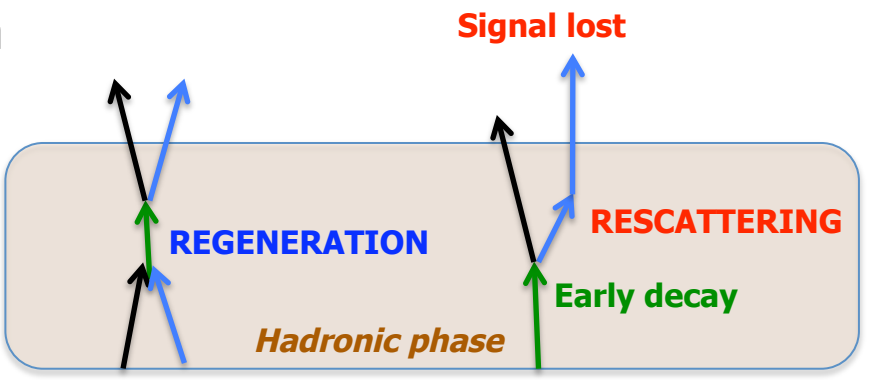


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# Reconstruction in ALICE

- Neutral and charged strange particles decaying into charged hadrons

**Hadrons**

| | Quark content | Branching ratio (%) | Decay length cτ (cm) |
|---|---|---|---|
| $K_S^0 \rightarrow \pi^+\pi^-$ | $(d\bar{s}+d\bar{s})/\sqrt{2}$ | 69.2 | 2.68 |
| $\Lambda \rightarrow p\pi^-$ + c.c. | uds | 63.9 | 7.89 |
| $\Xi^- \rightarrow \Lambda\pi^- \rightarrow p\pi^-\pi^-$ + c.c. | dss | 63.9 | 4.91 |
| $\Omega^- \rightarrow \Lambda K^- \rightarrow p\pi^- K^-$ + c.c. | sss | 43.3 | 2.46 |

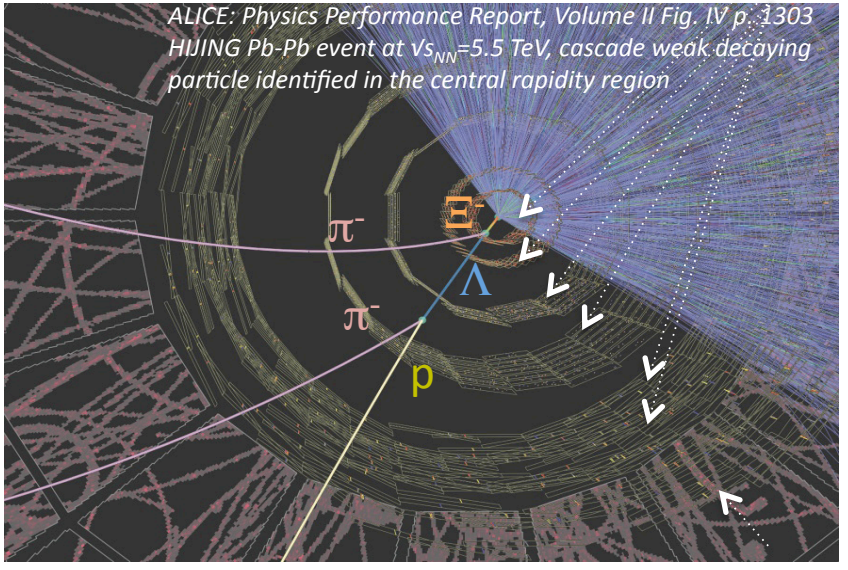
**Mesonic resonances**

| | Quark content | Branching ratio (%) | Lifetime (fm/c) | Width (MeV) |
|---|---|---|---|---|
| $\phi(1020) \rightarrow K^+K^-$ | $s\bar{s}$ | 48.9 | 45 | 4.26 |
| $K^*(892)^0 \rightarrow \pi^+K^-$+ c.c. | $d\bar{s}$ | ≈100 | 4 | 48.7 |

# Reconstruction in ALICE

- Neutral and charged strange particles decaying into charged hadrons
  - tracks reconstructed in the central barrel tracking system
  - V-shaped topology for $K^0_S$ and $\Lambda$
  - cascade topology for $\Xi$ and $\Omega$
  - TPC for particle identification of daughter tracks

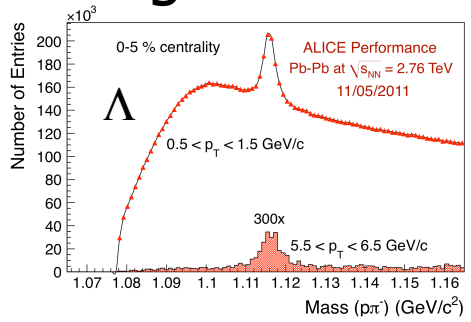
**Inner Tracking System:**
- **six silicon layers**
- **$|\eta|<0.9$**
- **$3.9 < r(cm) < 43$**

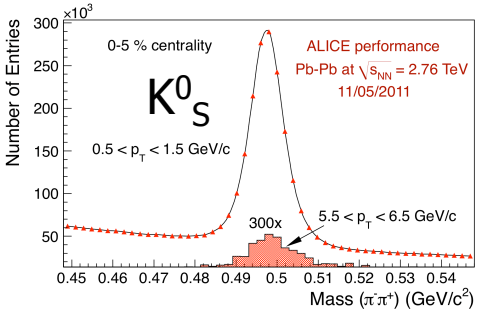



**Time Projection Chamber:**
- **$|\eta|<0.9$**
- **$85 < r(cm) < 247$**

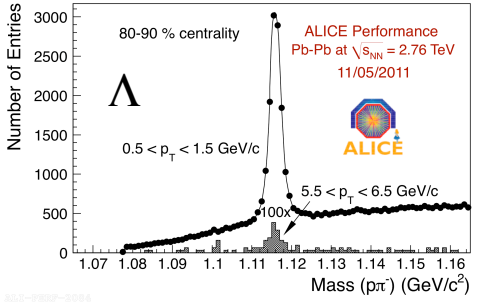
# Reconstruction in ALICE

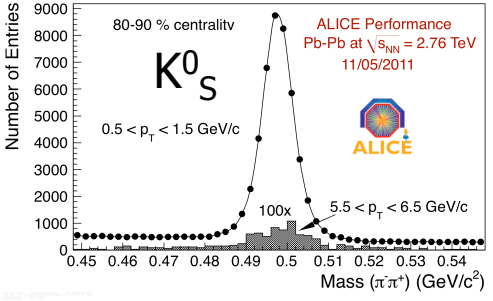
- Signal extracted from invariant mass analysis

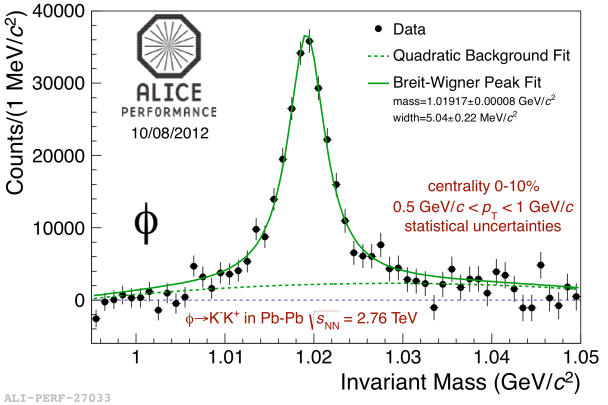


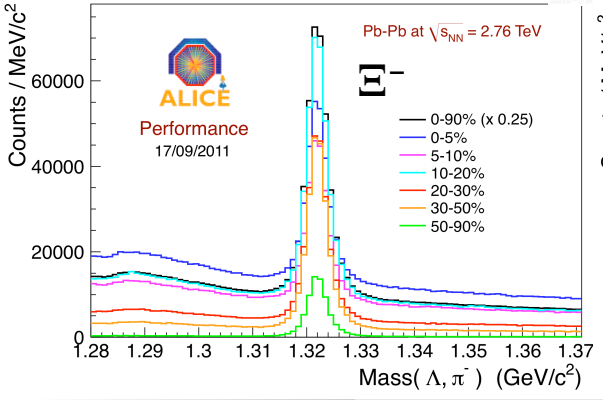



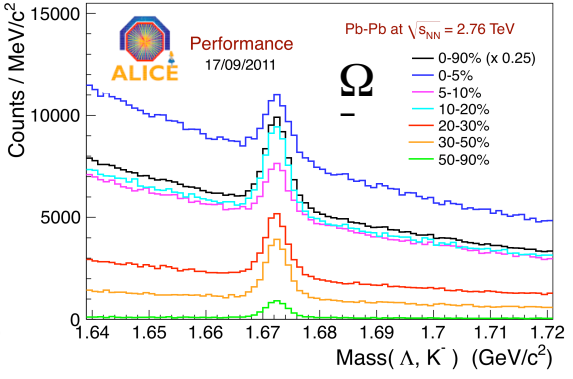

Resonances→combinatorial background subtracted (like-sign and event mixing techniques)

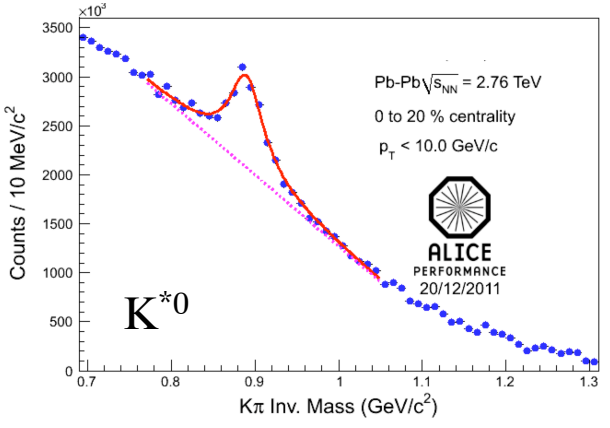


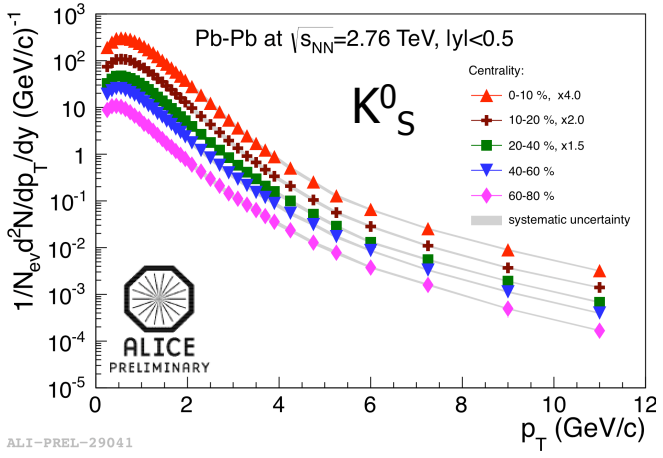



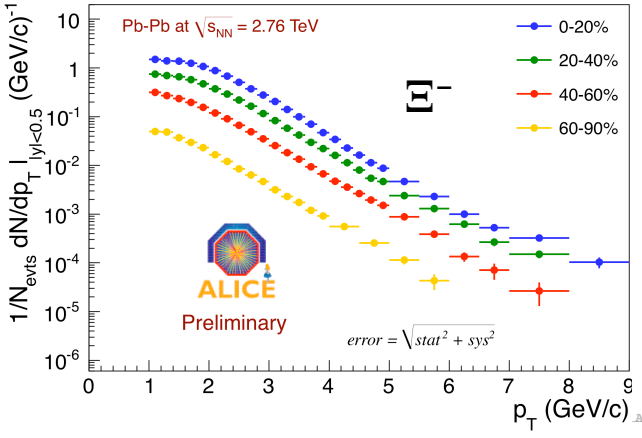



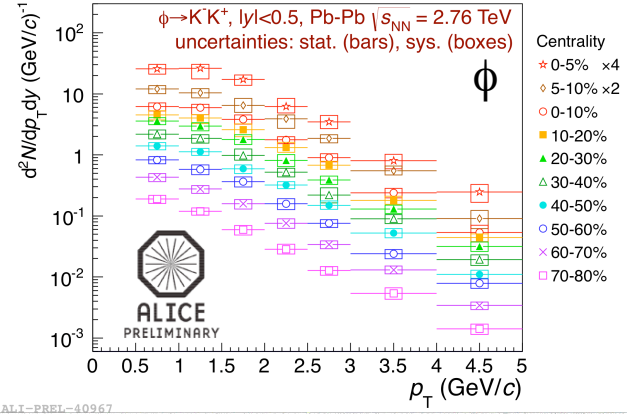



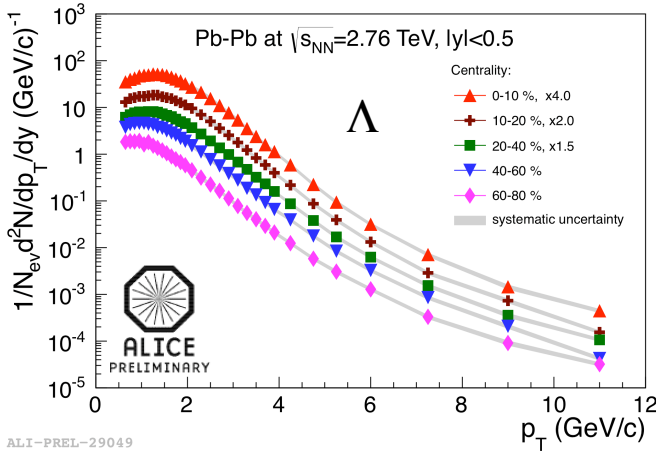



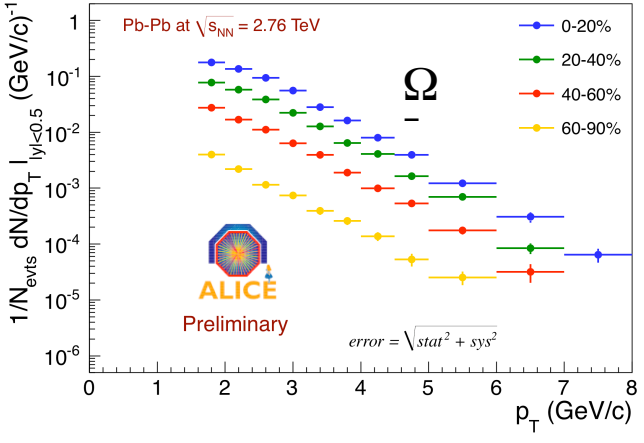
# Transverse momentum spectra

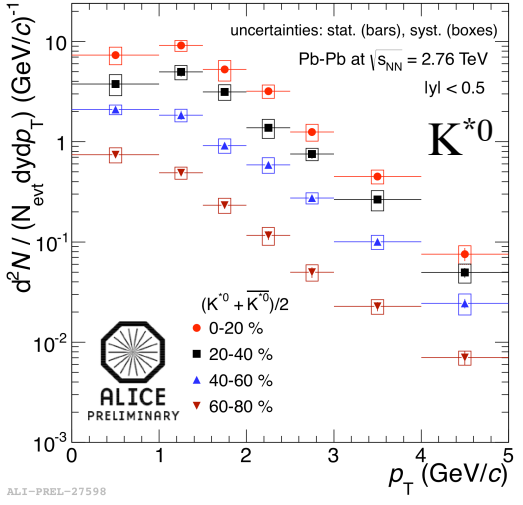


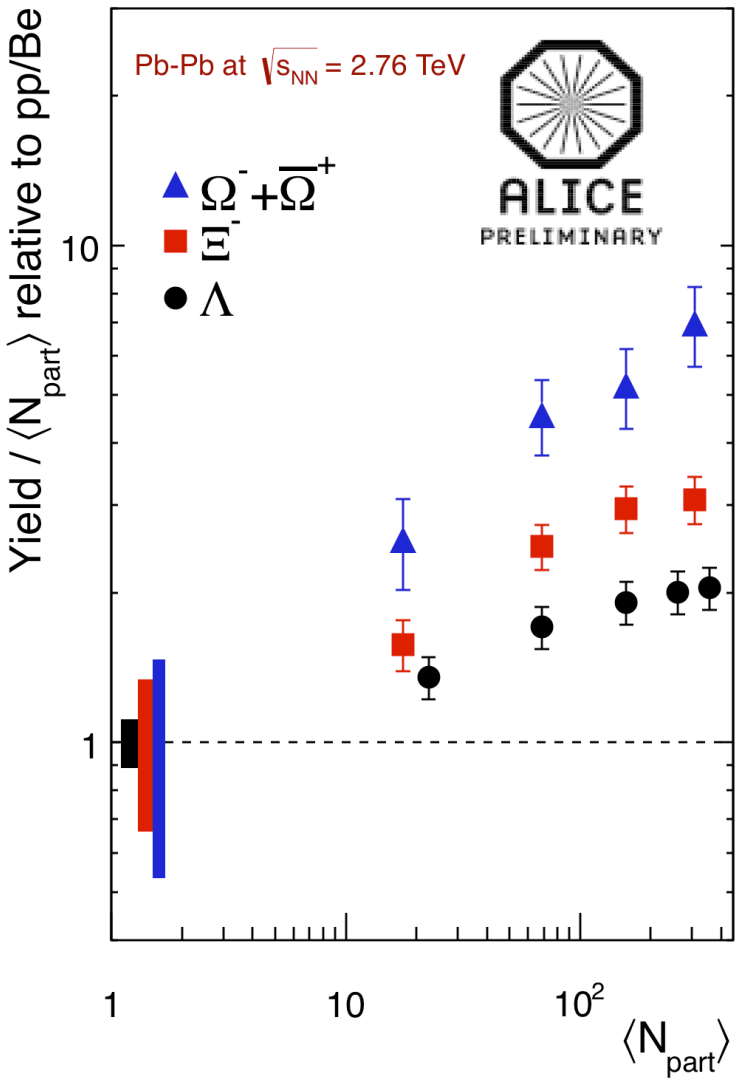



# Strangeness enhancement?




$$Enhancement\left(\langle N_{part}\rangle\right) = \frac{Yield_{PbPb}\left(\langle N_{part}\rangle\right) / < N_{part} >}{Yield_{pp}/2}$$

- Higher production yields with respect to pp collisions at the same energy when normalized to the number of participants:
  - hierarchy based on the strangeness content of the particle

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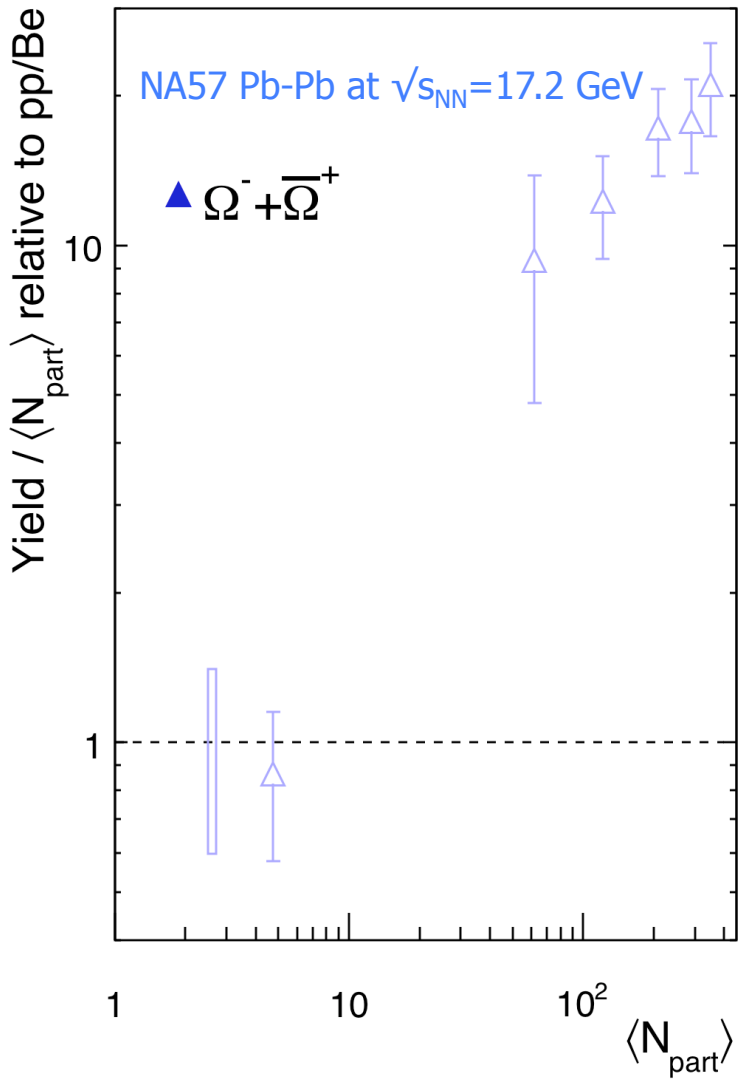


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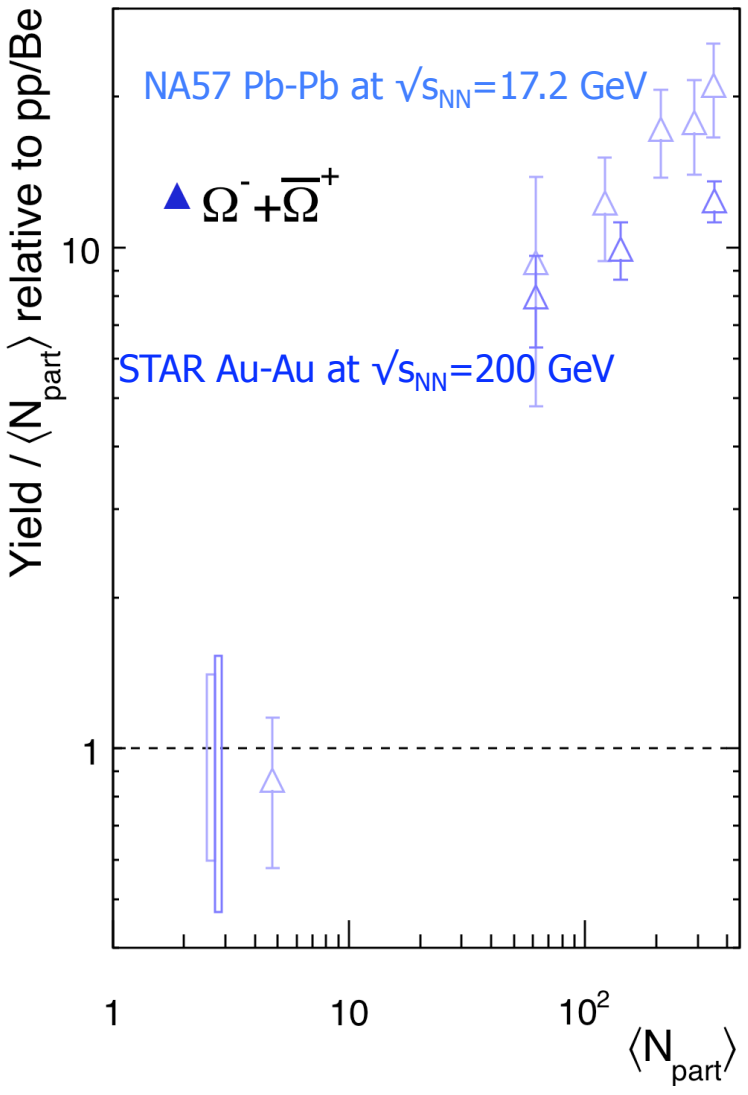


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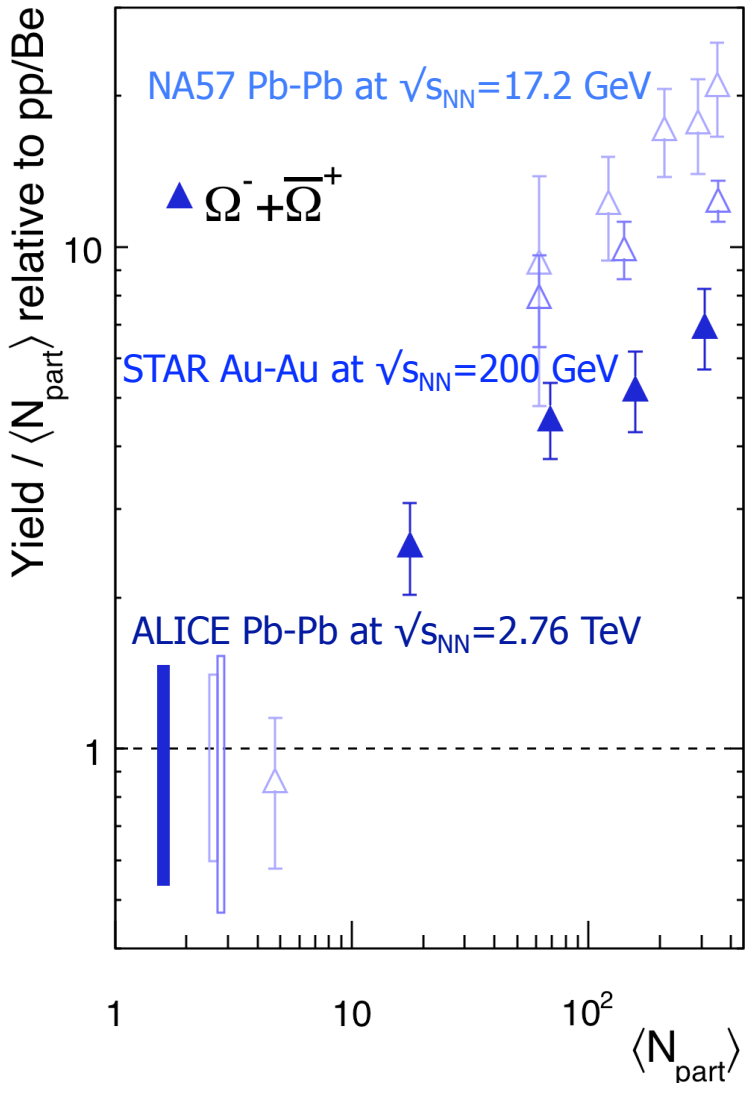


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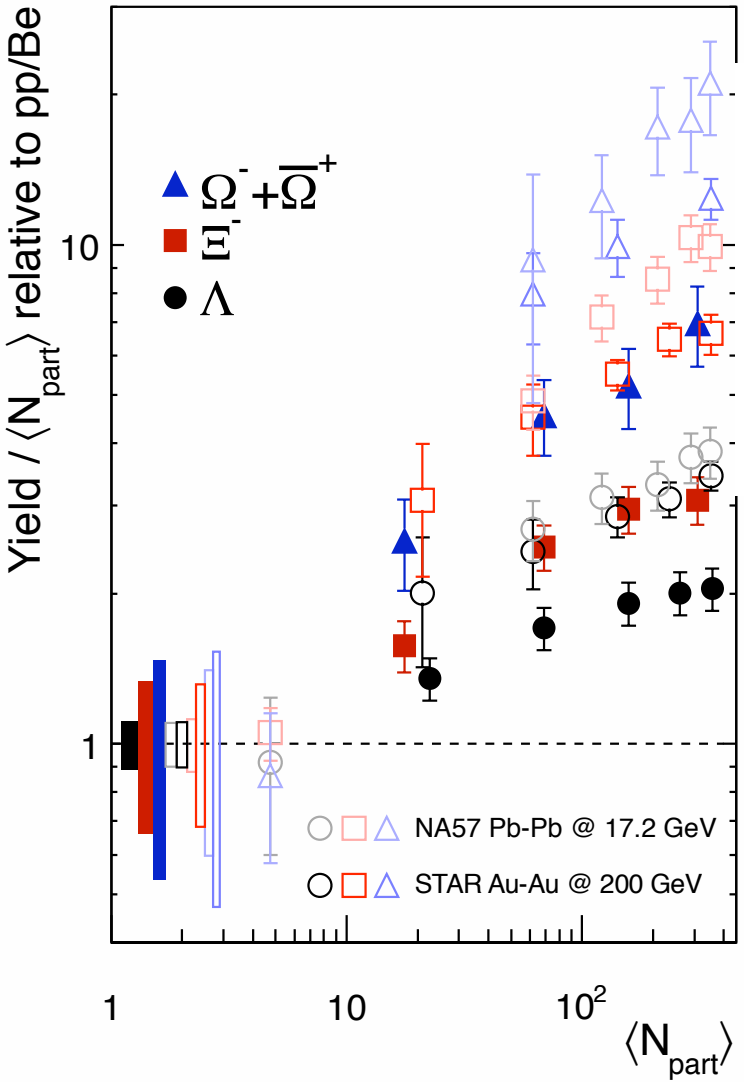
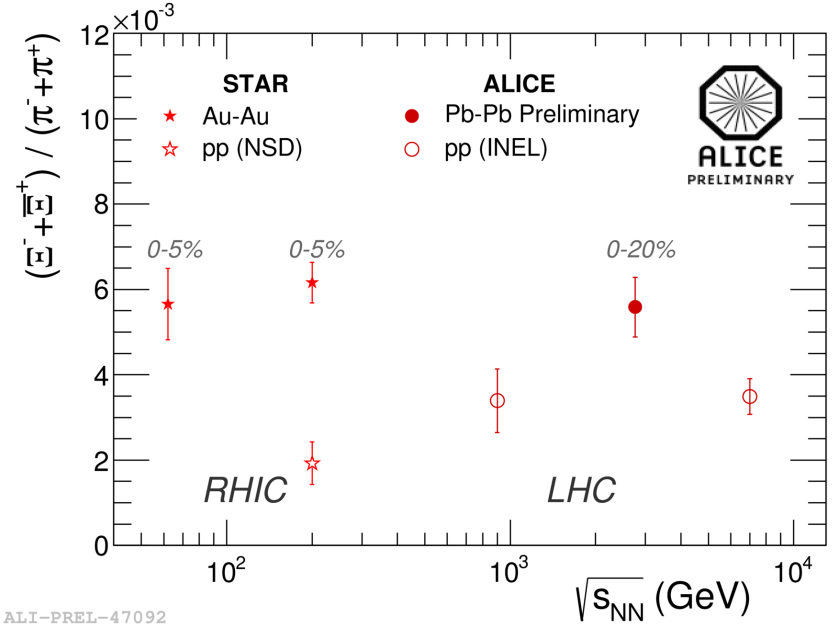


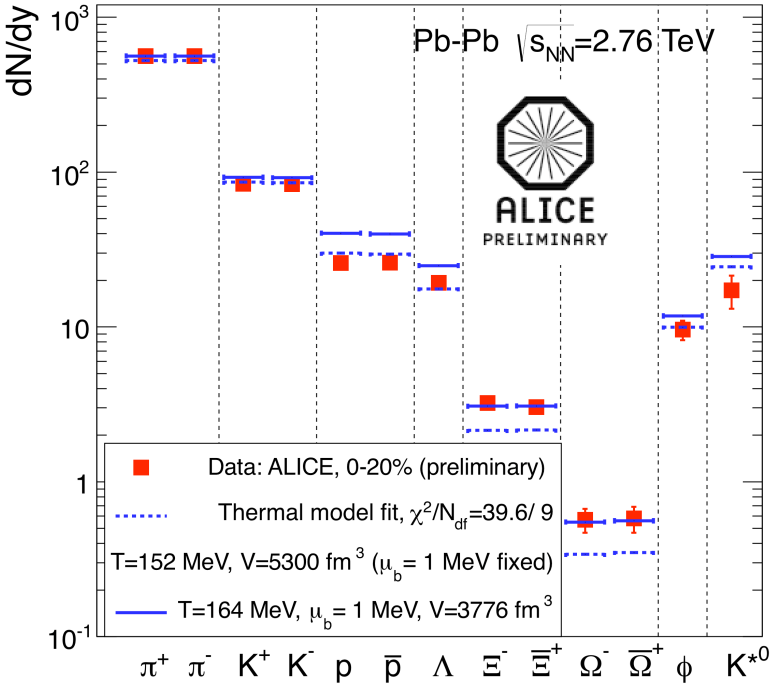




- decreasing as energy increases
- effect of lifting of canonical and strangeness suppression in heavy-ion collisions ($\gamma_S$=1)

# Chemical freeze-out: particle yields

- Extrapolation and fits with statistical hadronization model

A. Andronic *et al., PLB 673, 142 (2009)*




- statistical model ($\gamma_s$=1) fits data at lower energies
- extrapolation from RHIC → $T_{fo}$=164 MeV
  does not fit p and $\Lambda$
- fitting data → $T_{fo}$=152 MeV (resonances not included)
  but multi-strange deviate ***→ More on p and p/$\pi$ fit in F. Barile's talk tomorrow HI2***

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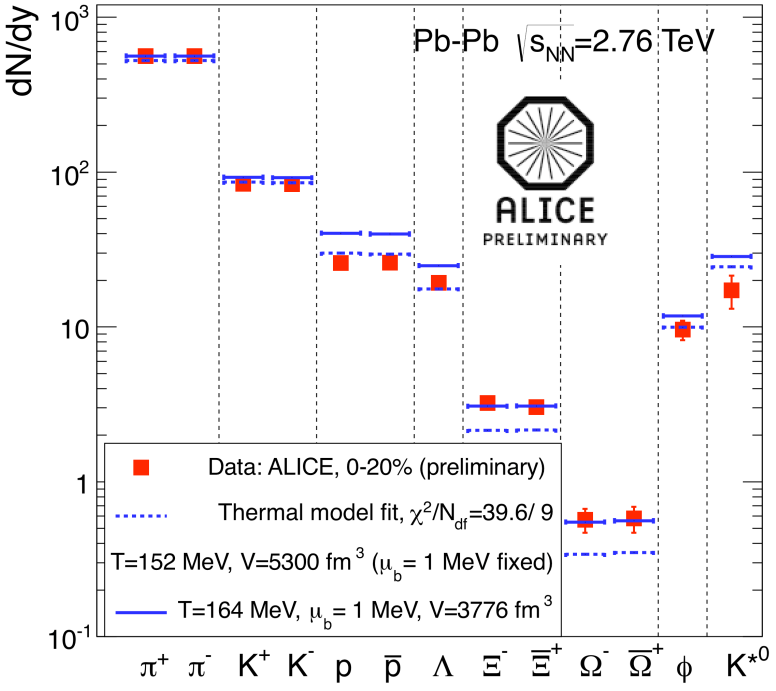
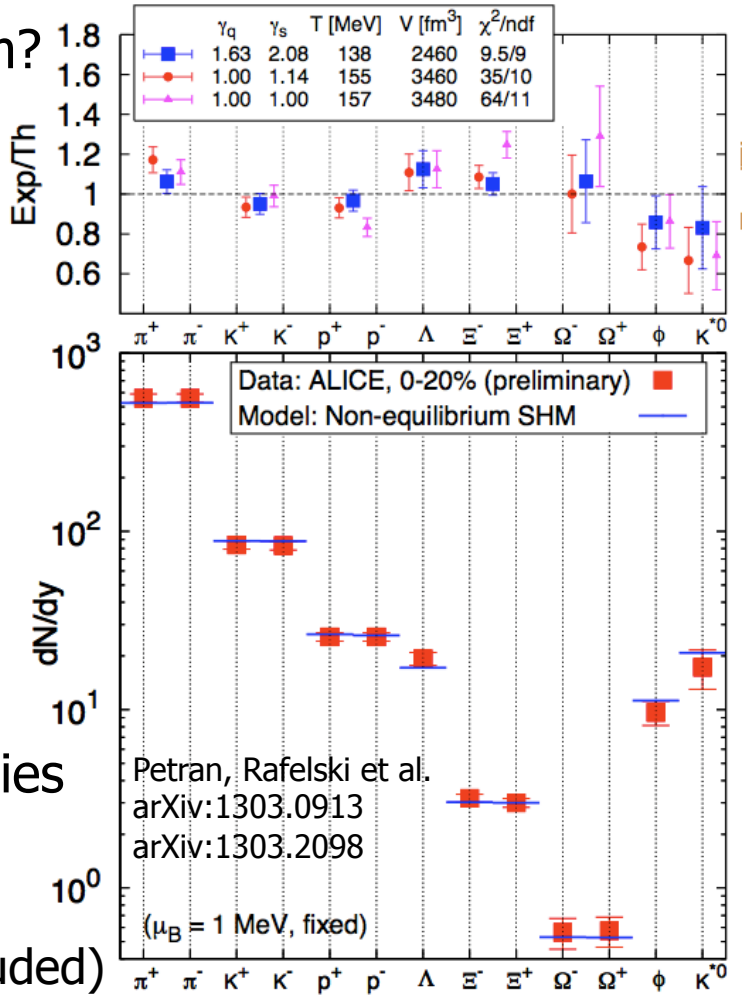



Non-equilibrium?

$\gamma_{s,q}$>1

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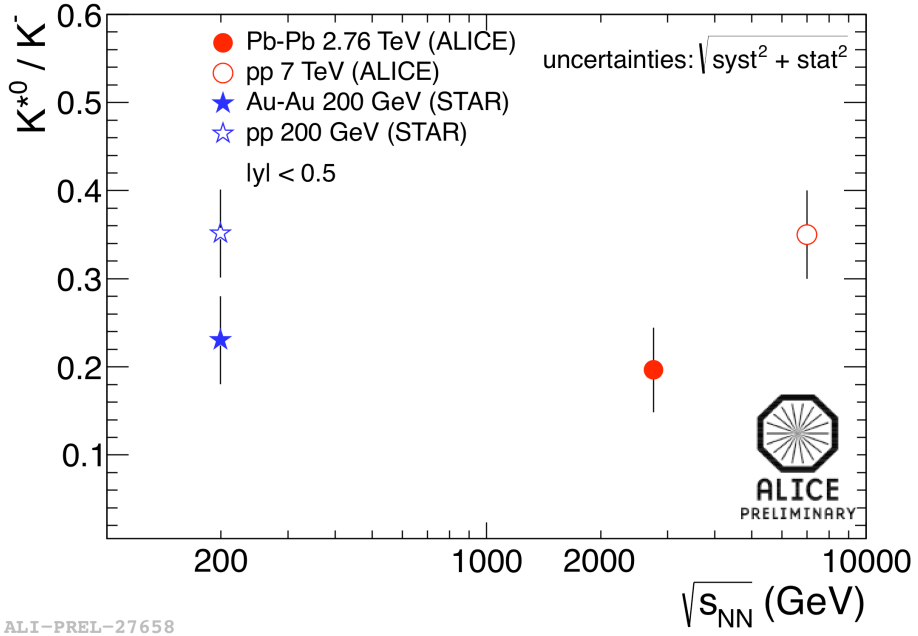
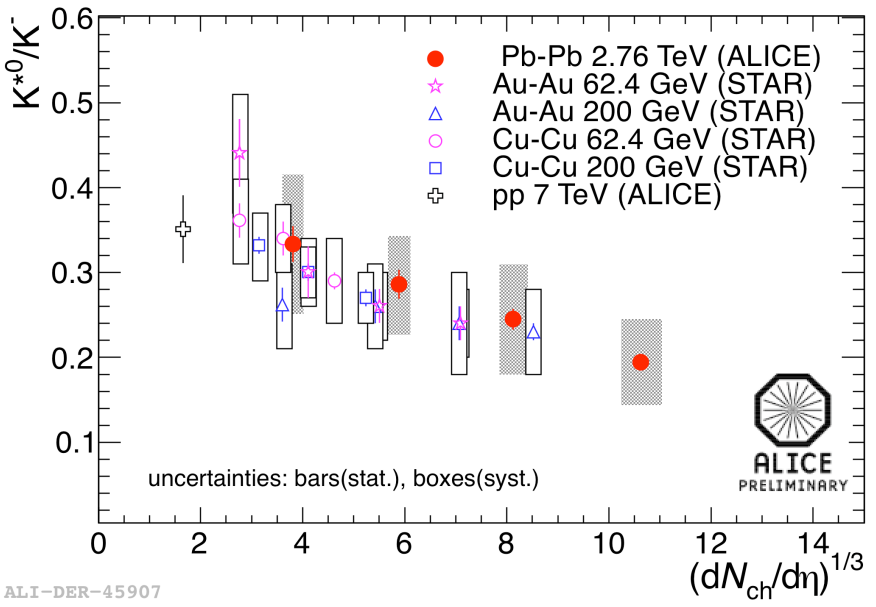
# Resonance/non-resonance yields

- Evolution during hadronic phase: regeneration/rescattering?



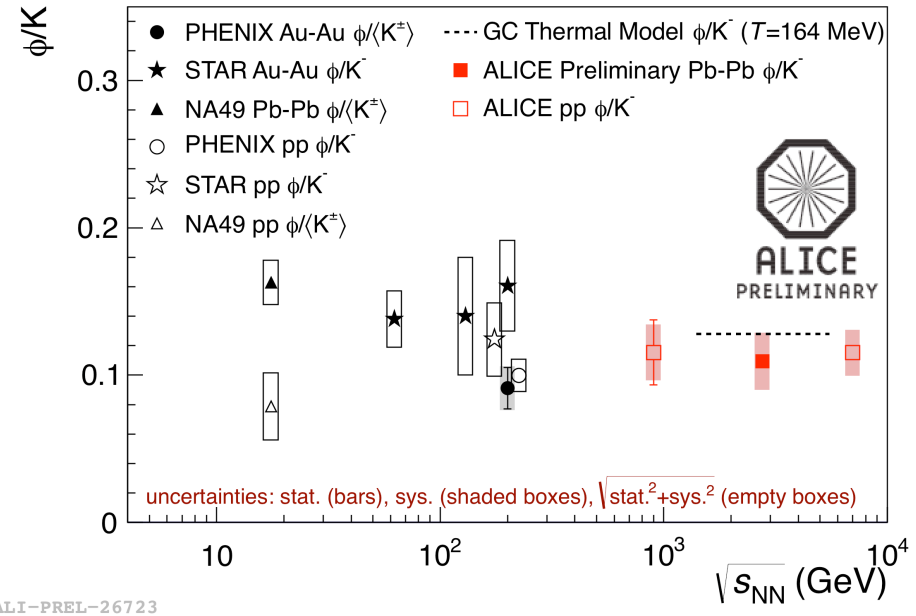



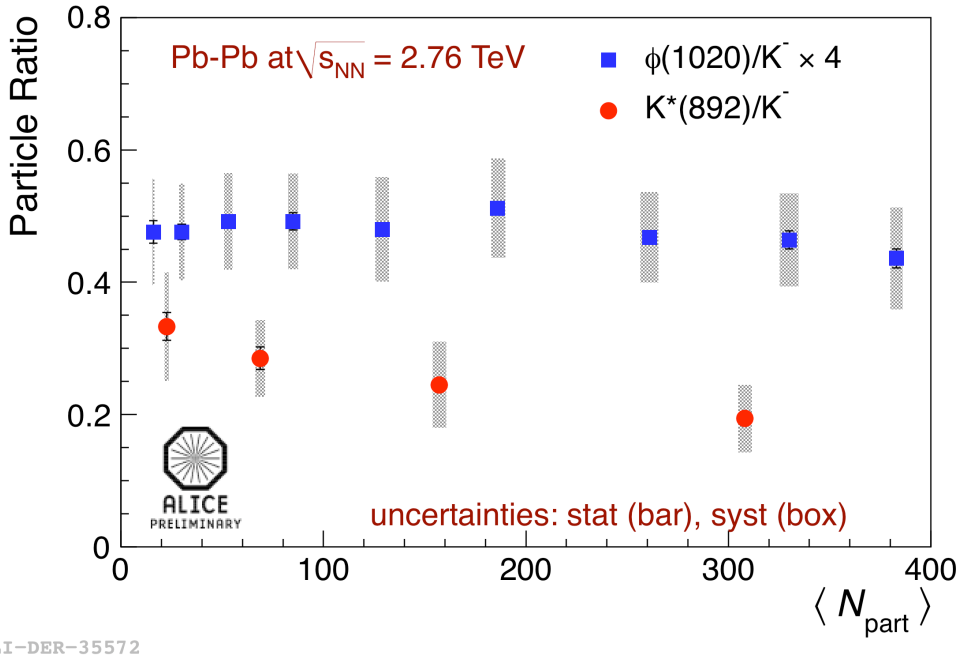

- $K^{*0}/K^-$
  - in Pb-Pb < in pp
  - in central collisions < in peripheral collisions

→ Rescattering?

# Resonance/non-resonance yields

- Evolution during hadronic phase: regeneration/rescattering?



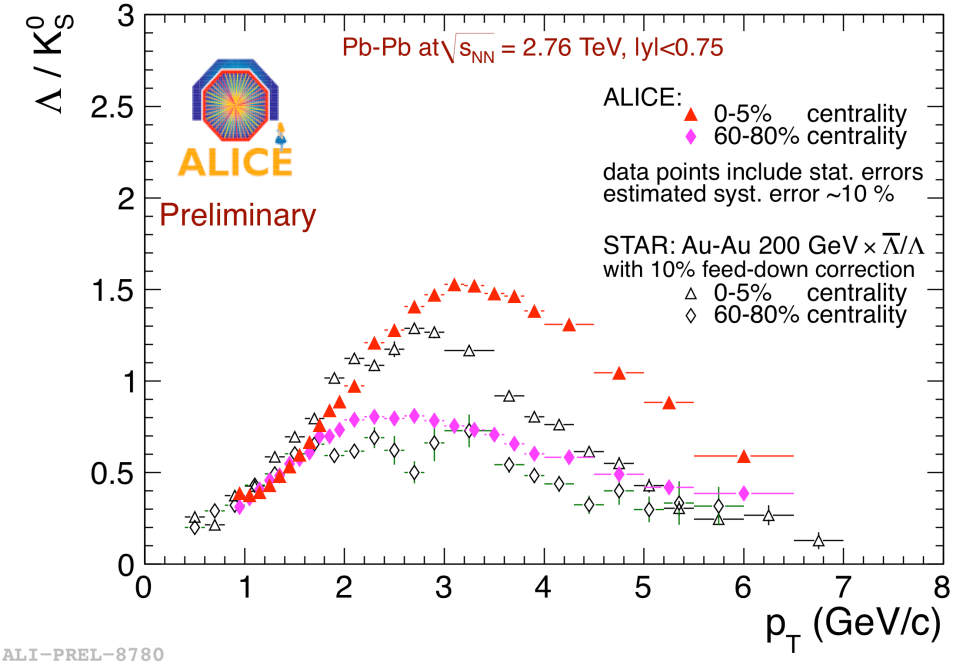




- $\phi/K^-$ ($\pi^-$)
  - in Pb-Pb ≈ in pp (+no energy dependence)
  - no centrality dependence*

→ Less affected by rescattering due to longer lifetime than $K^{*0}$?

*no φ production via kaon coalescence

# "Baryon anomaly"




- Favoured production of baryons with respect to mesons at intermediate $p_T$:
  - first observed at RHIC ($\sqrt{s_{NN}}$=200 GeV)
  - production yields become comparable in central collisions

→ ***p/π results in F. Barile's talk tomorrow HI2***

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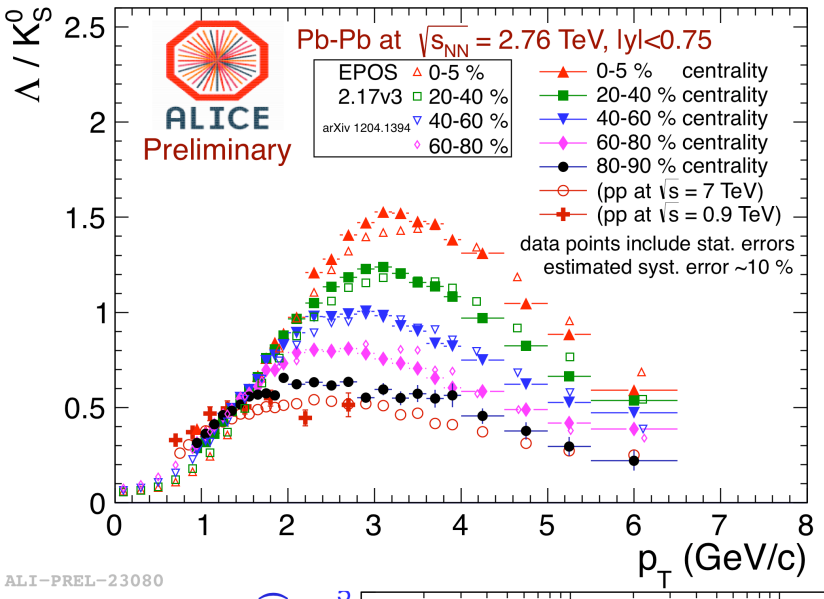
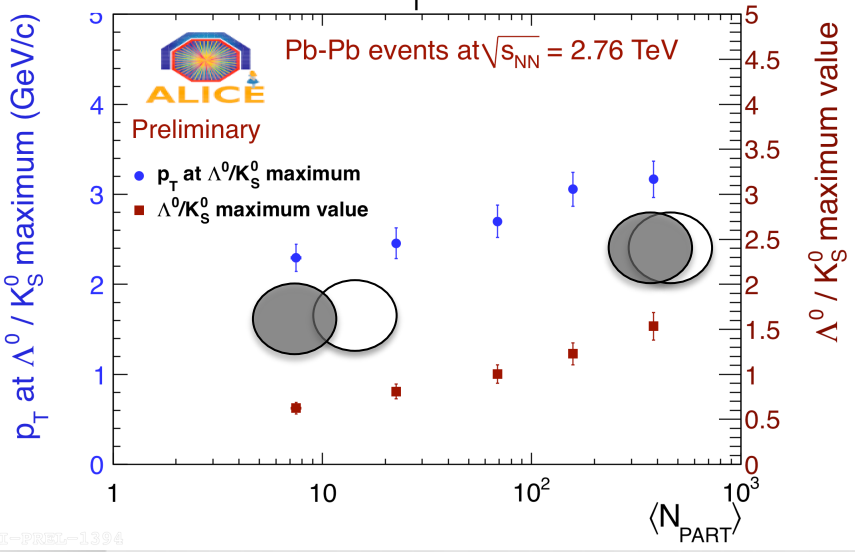



- Favoured production of baryons with respect to mesons at intermediate $p_T$:
  - first observed at RHIC ($\sqrt{s_{NN}}$=200 GeV)
  - production yields become comparable in central collisions
  - relative production similar in pp and peripheral Pb-Pb
  - behaviour well reproduced with EPOS
  - important test of models for the evolution of the medium (effects contributing flow, recombination, fragmentation)

# Conclusions and open issues

- Strangeness enhancement
  - patterns observed at lower energies still present at the LHC
    - enhancement increases as energy decreases
- Thermal model fits
  - one set of parameters seems not enough to fit all yields (p and hyperons at the same time)
  - equilibrium vs non-equilibrium models?
- Resonance to non-resonance ratios
  - relative weight of (re)generation/rescattering processes?
- Strange baryon to meson ratio
  - constrain coalescence and hydro models

# Backup slides

# Reconstruction in ALICE

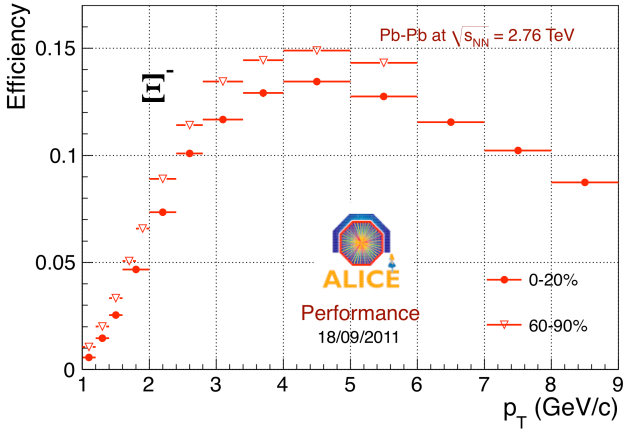
- Signal extracted from invariant mass analysis
- Background subtraction performed with
  - first or second degree polynomial fits for all particles
  - for resonances also like-sign from same event, unlike-sign mixing events and polynomial residual background
- Signal corrected for efficiency x acceptance x branching ratio usign Monte Carlo events (HIJING+GEANT3)
- Yield extraction
  - Blast-wave parametrization to extrapolate down to 0 $p_T$
  - Tsallis-Levy parameterization used for $K^{*0}$

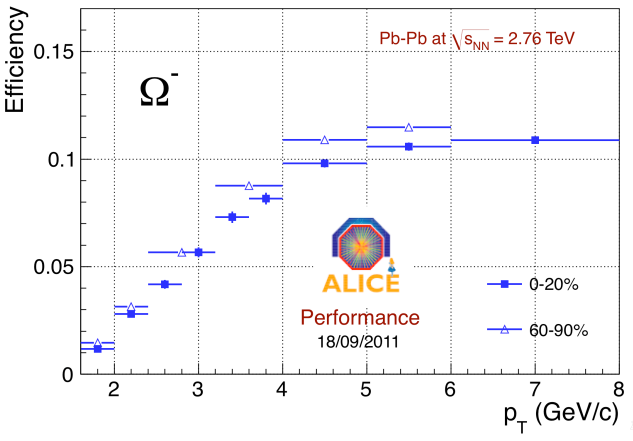
# Blast-wave parametrization

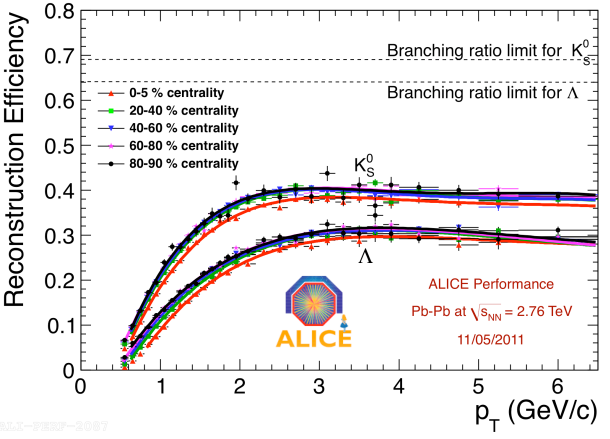
- Hydrodinamic inspired model which assumes thermalized, transversely expanding source
  - parameters from fit: kinetic freeze-out temperature and transverse velocity (T, $\beta_T$; n)
  - gives the best fit to individual particles
  - from PHOBOS evidence that this parametrization gives a good description to very low $p_T$

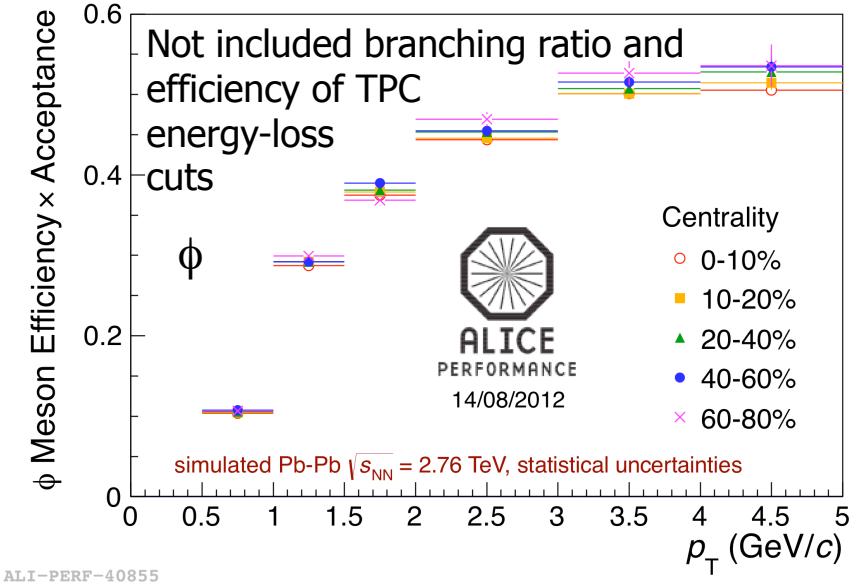
E. Schnedermann, J. Sollfrank and U. Heinz, Phys. Rev. C 48, 2462 (1993)

# Corrections




ALI-PERF-40855

# pp reference for enhancements

- Interpolation
  - assumed excitation functions
    - PYTHIA yields ($s^{0.13}$) for multi-strange
    - charged particle yields ($s^{0.11}$) for $\Lambda$
  - for the $\Xi$ and $\Lambda$: interpolating ALICE data at two energies ($\sqrt{s}$ = 0.9 and 7 TeV)
  - for the $\Omega$: interpolating STAR data at $\sqrt{s}$=200 GeV and ALICE data at 7 TeV