SQM 2015
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Production of strange hadrons at LHC energies measured with the ALICE detector

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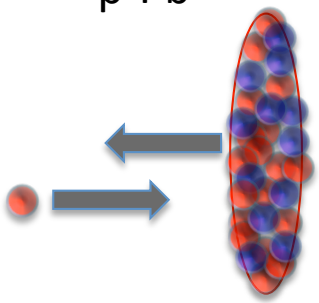
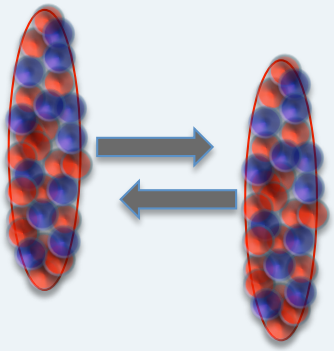
on behalf of the **ALICE** collaboration

Unterstützt von / Supported by
Alexander von Humboldt Stiftung/Foundation

Strangeness measurements in the three systems

Collision system	$\sqrt{s_{NN}}$ (TeV)
pp 	0.9 2.76 7
p-Pb 	5.02
Pb-Pb 	2.76

Results and discussion

- particle spectra
- particle ratios vs p_T
  - ✓ baryon-to-meson
  - ✓ nuclear modification factors
- elliptic flow
- ratios of yield to pions
  - ✓ vs event multiplicity
  - ✓ fit with statistical hadronization models

Reconstruction in ALICE

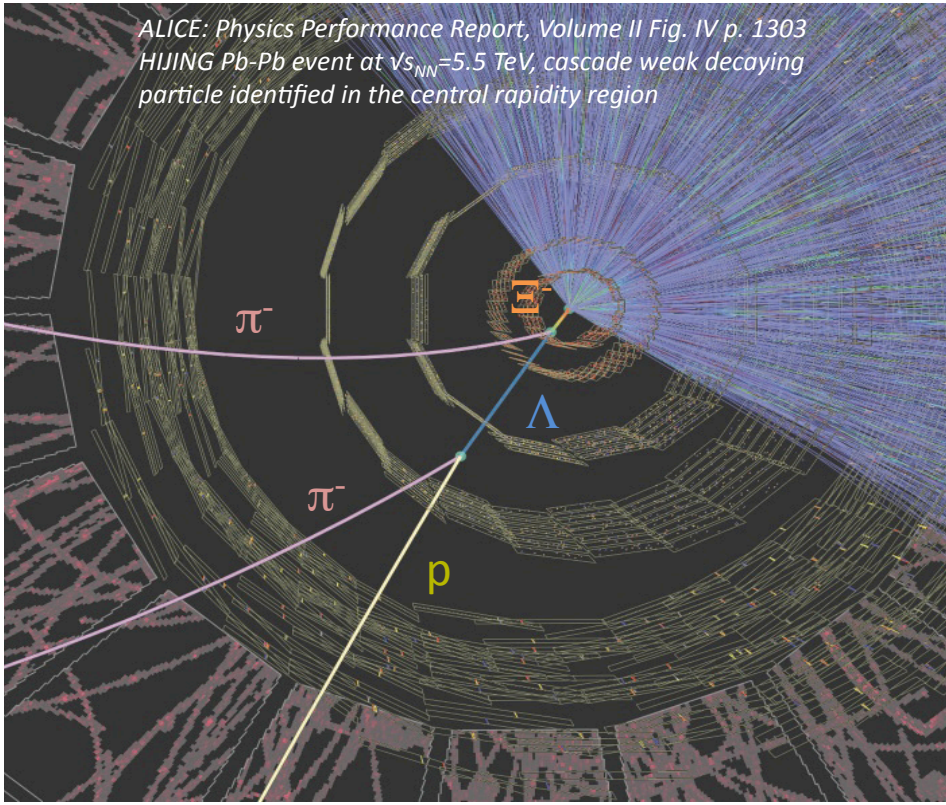
$K^0_S \rightarrow \pi^+\pi^-$ $\Lambda \rightarrow p\pi^-$ + c.c.

$\Xi^- \rightarrow \Lambda\pi^- \rightarrow p\pi^-\pi^-$ + c.c.

$\Omega^- \rightarrow \Lambda K^- \rightarrow p\pi^- K^-$ + c.c.

- Charged hadron tracks reconstructed in the central barrel tracking system
- Topological reconstruction of decays (geometrical and kinematical selection criteria on reconstructed tracks)
  - V-shaped topology for K^0_S and Λ
  - cascade topology for Ξ and Ω
- TPC for particle identification of candidate daughter tracks

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

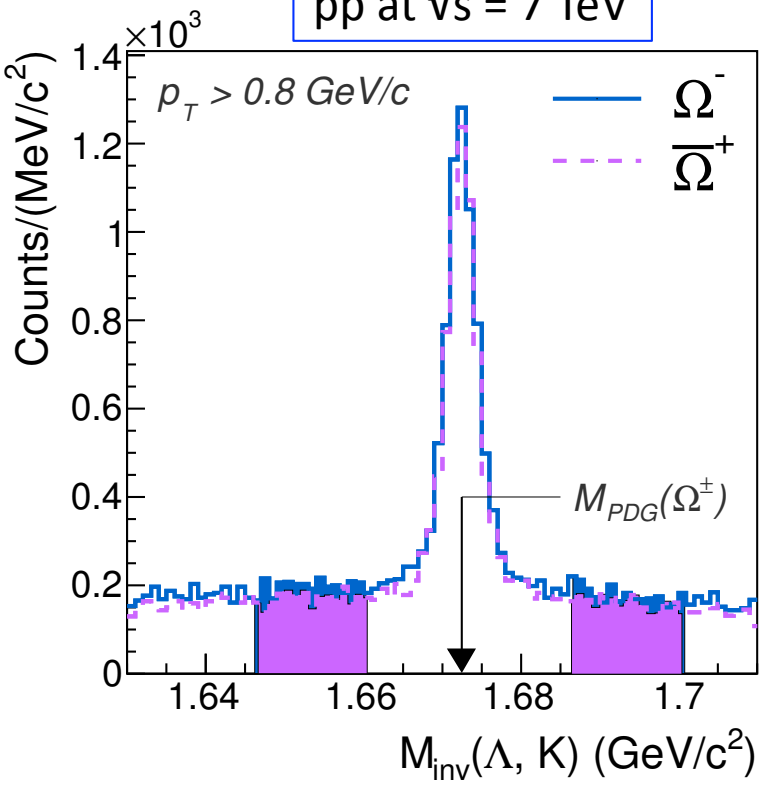


Time Projection Chamber:
- **$|\eta| < 0.9$**
- **$85 < r(cm) < 247$**

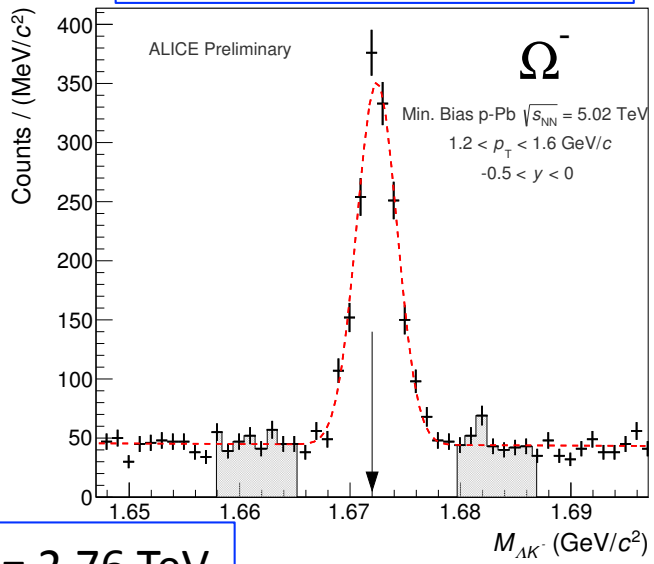
Reconstruction in ALICE

Signal extracted from invariant mass analysis

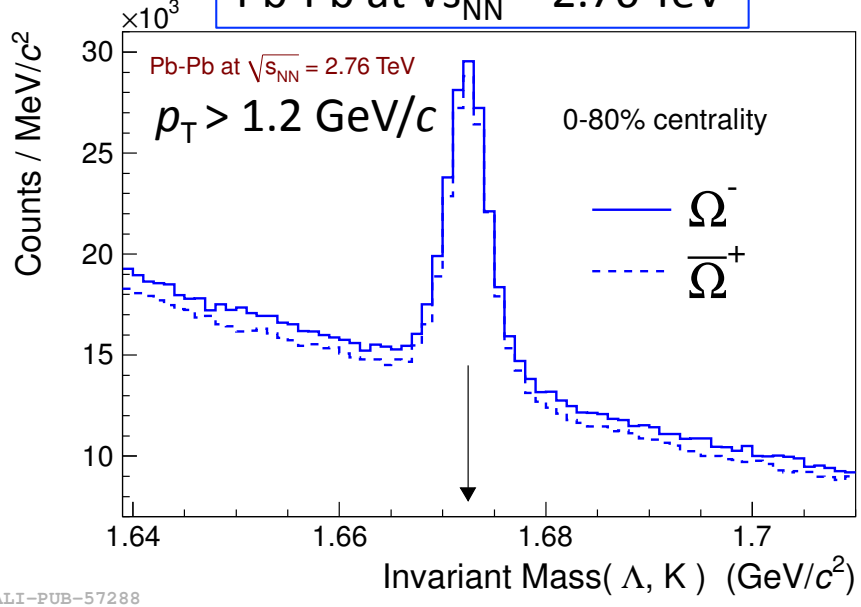
pp at √s = 7 TeV



p-Pb at √s_NN = 5.02 GeV



Pb-Pb at √s_NN = 2.76 TeV



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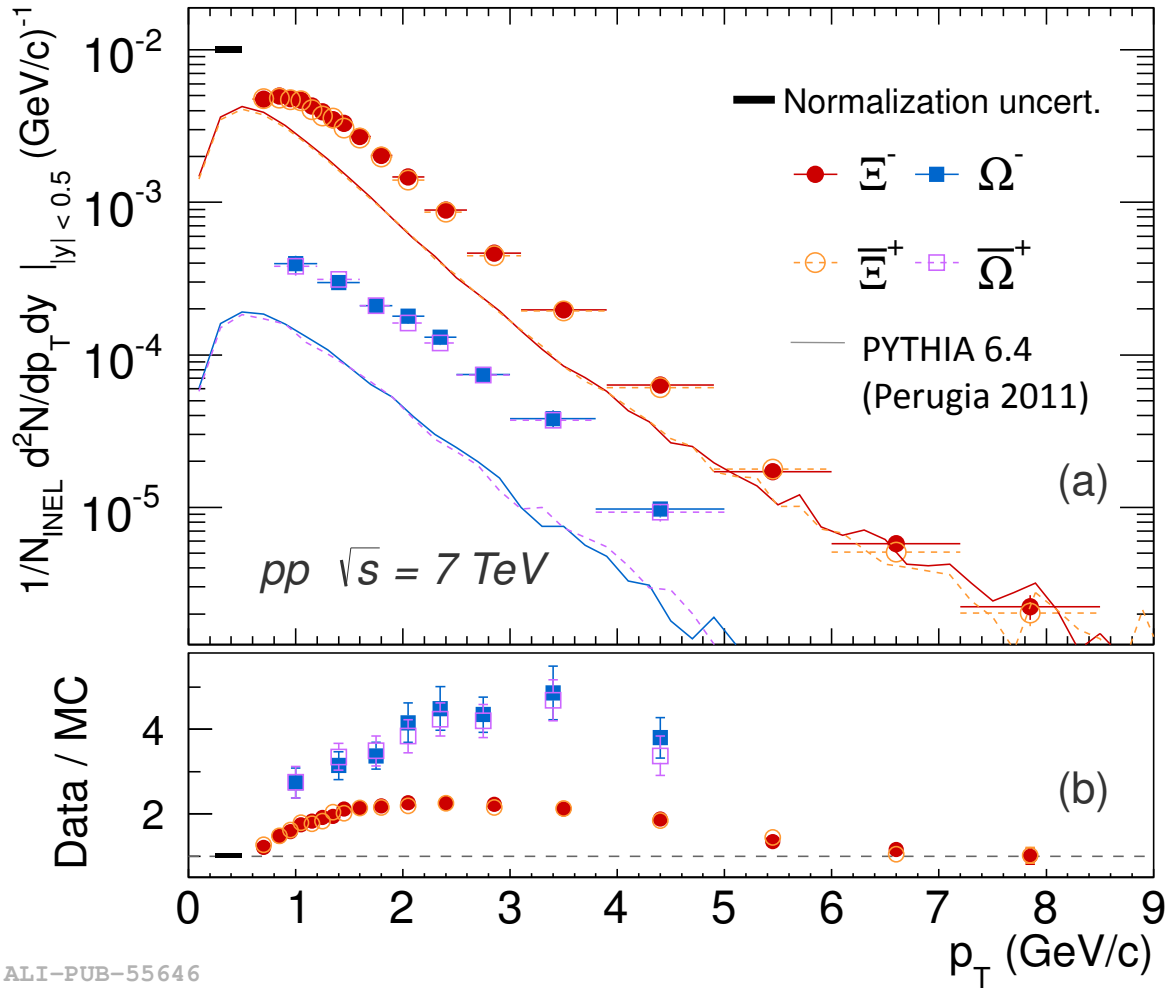
Transverse momentum spectra in pp collisions



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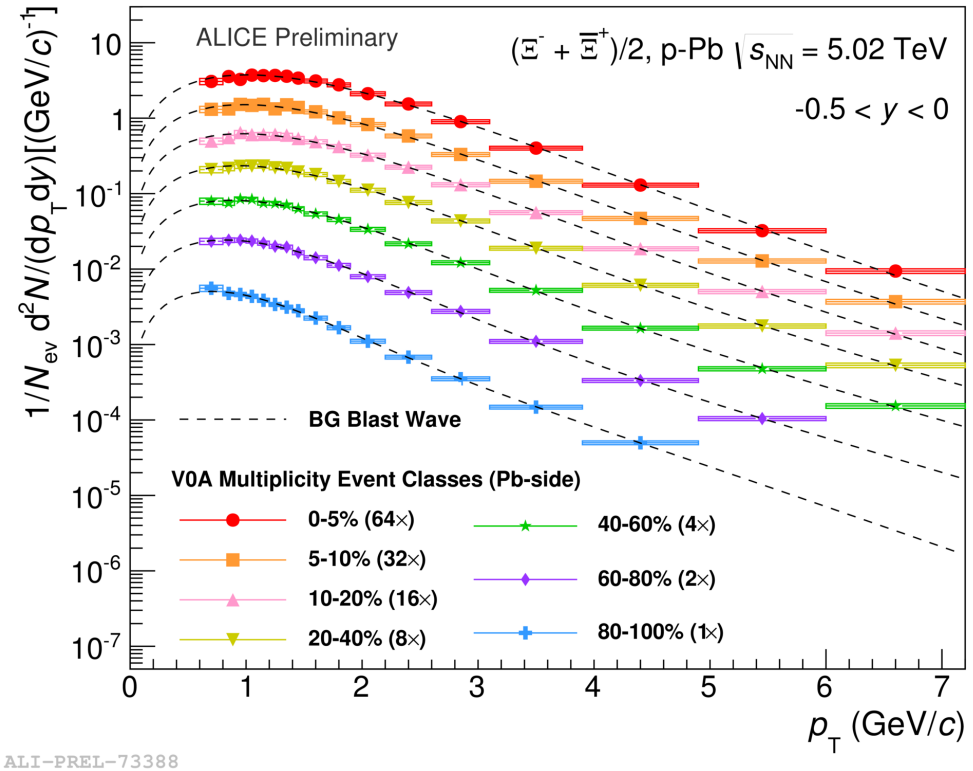
In general Monte Carlo underpredicts multi-strange yields at intermediate p_T

- deviation stronger for higher strangeness content
- PYTHIA tuned (Perugia 2011) describes data within a factor 2 to 4

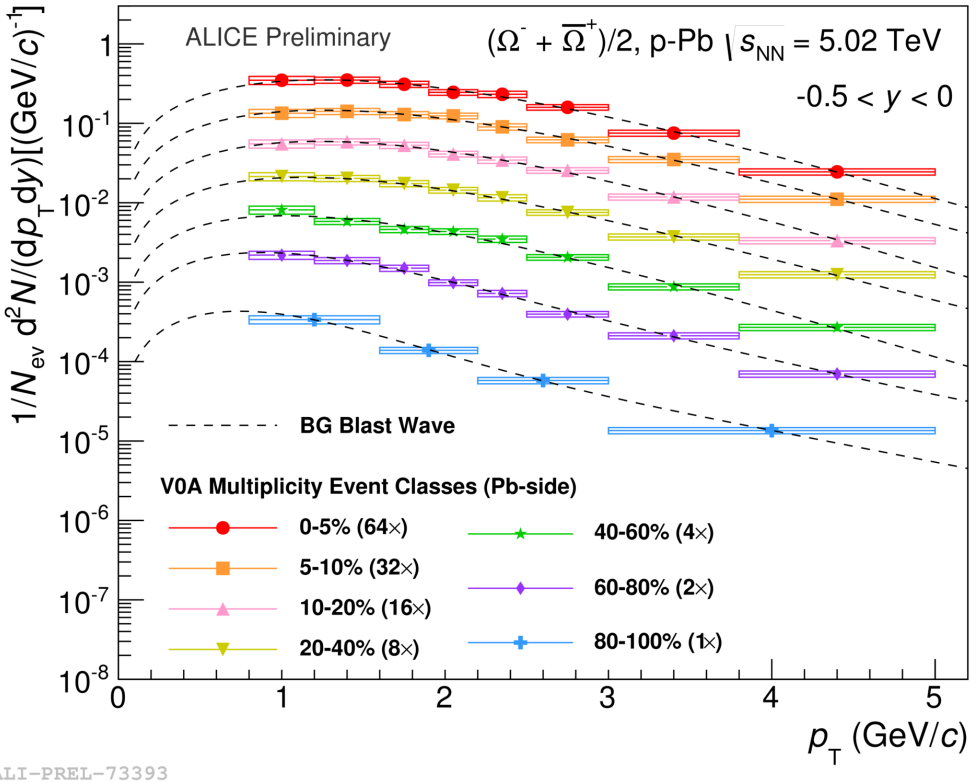
Transverse momentum spectra in p-Pb collisions

Ξ



ALI-PREL-73388

Ω



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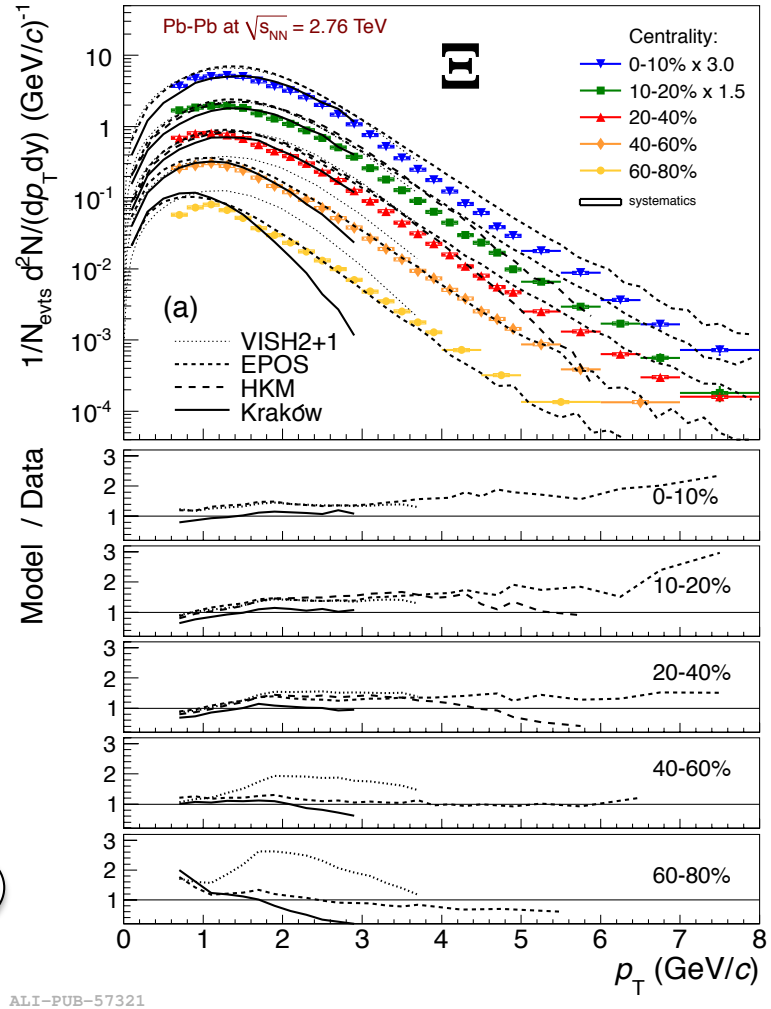
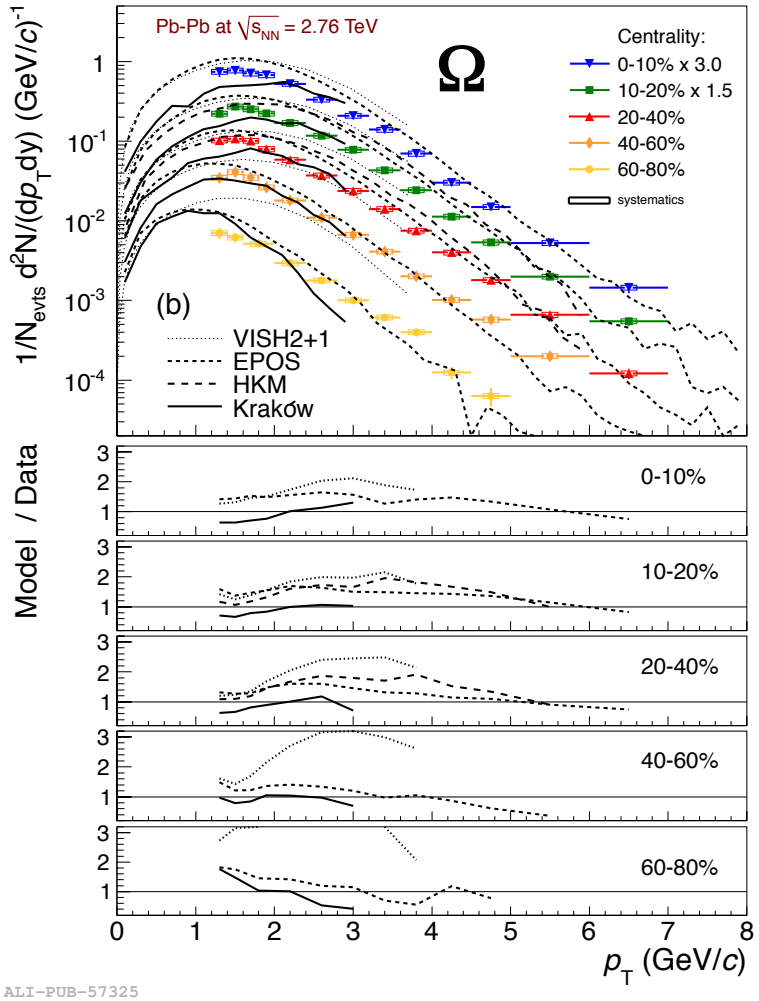
Individual BW fits to extract yields

Mean p_T increases with increasing event multiplicity

- similar behaviour in p-Pb and Pb-Pb collisions

Transverse momentum spectra in Pb-Pb collisions





Mean p_T increases with increasing event multiplicity

- similar behaviour in p-Pb and Pb-Pb collisions
- in Pb-Pb collisions described with hydrodynamic models: collective expansion

Phys. Lett. B 728 (2014) 216

More in B. Guerzoni's talk

Baryon-to-meson ratio

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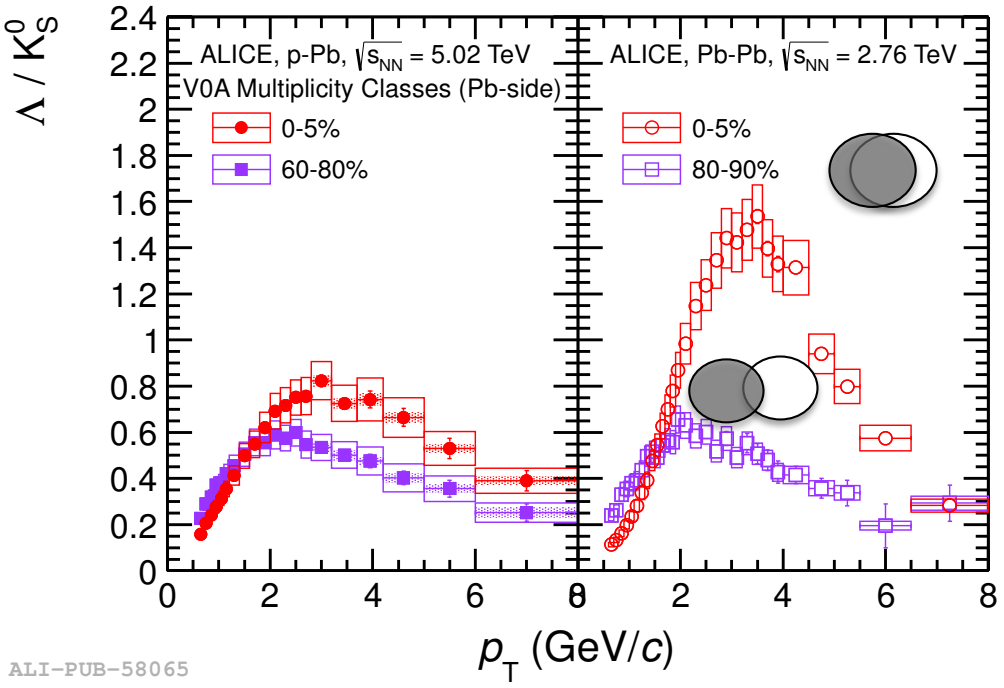
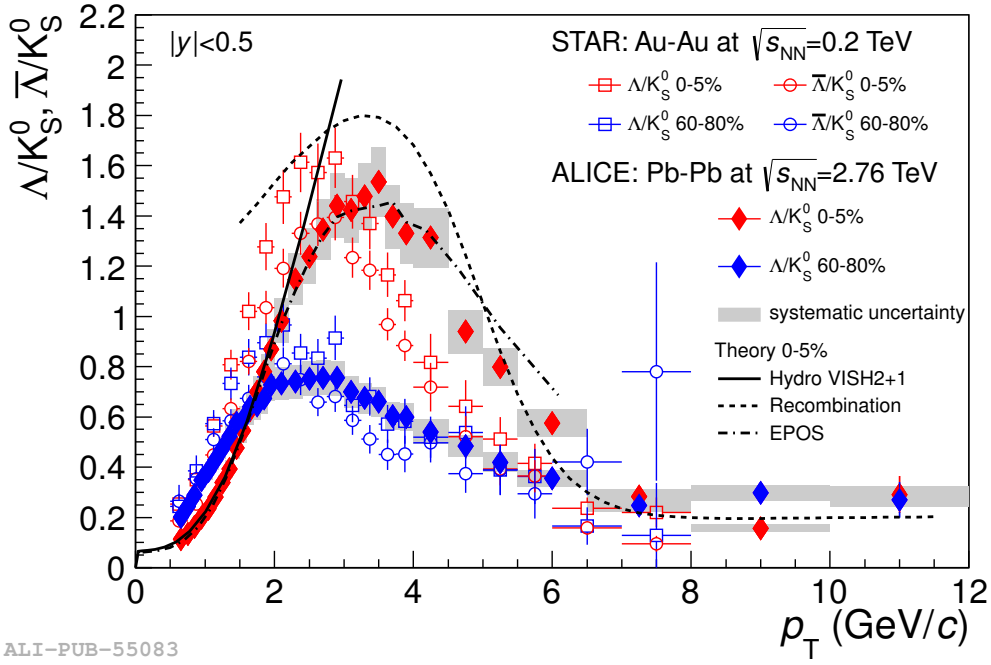


Phys. Rev. Lett. 111 (2013) 222301



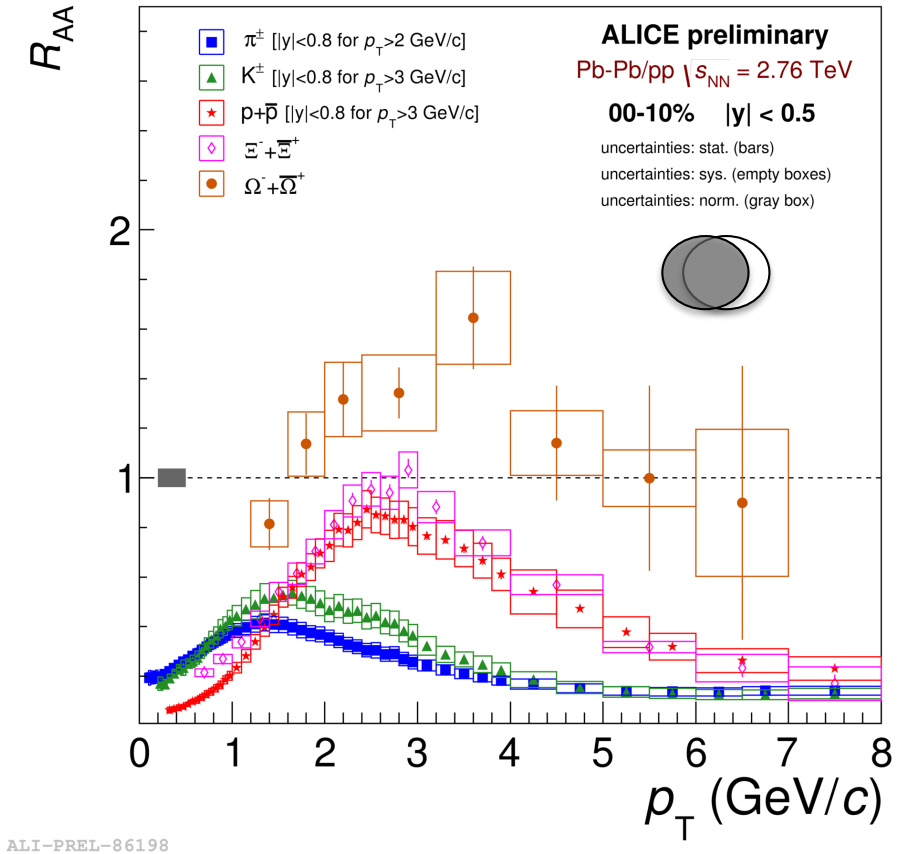
p/π results in G. Volpe's talk

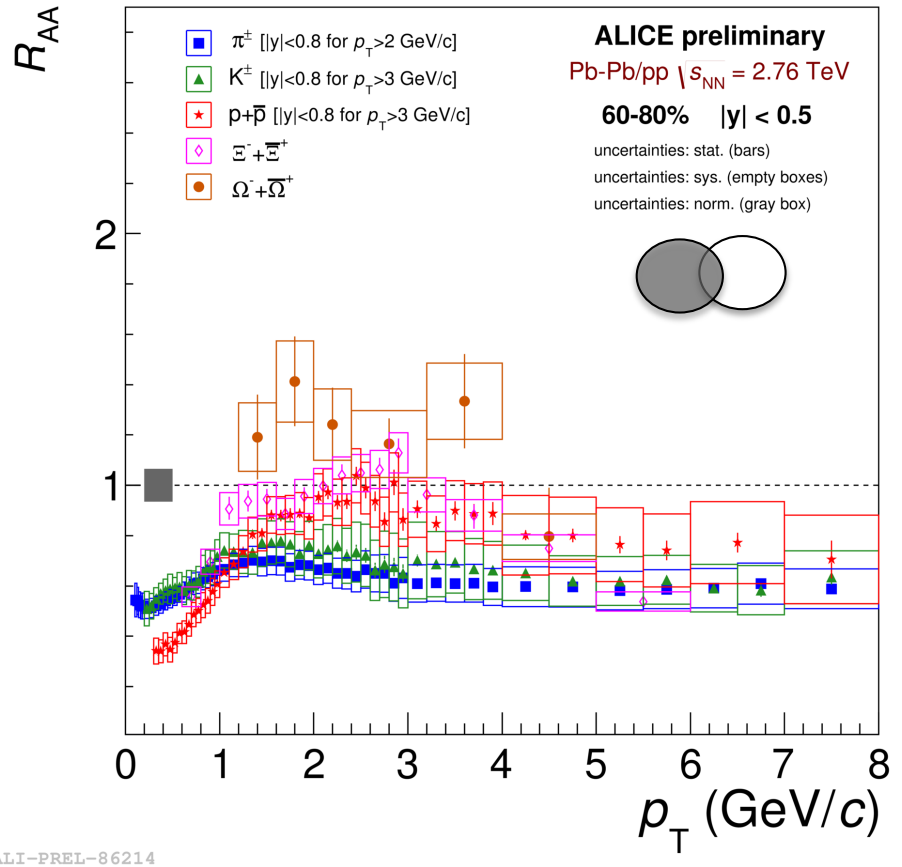
Maximum in the ratio of baryons to mesons at intermediate p_T also observed in p-Pb collisions

- same pattern with increasing multiplicity as in Pb-Pb, different magnitude
- in Pb-Pb collisions explained with radial flow (p_T<2 GeV/c), quark recombination (2<p_T<5 GeV/c), fragmentation (p_T>5 GeV/c)

Comparing spectra in different systems: R_{AA}

More in G. Volpe's talk





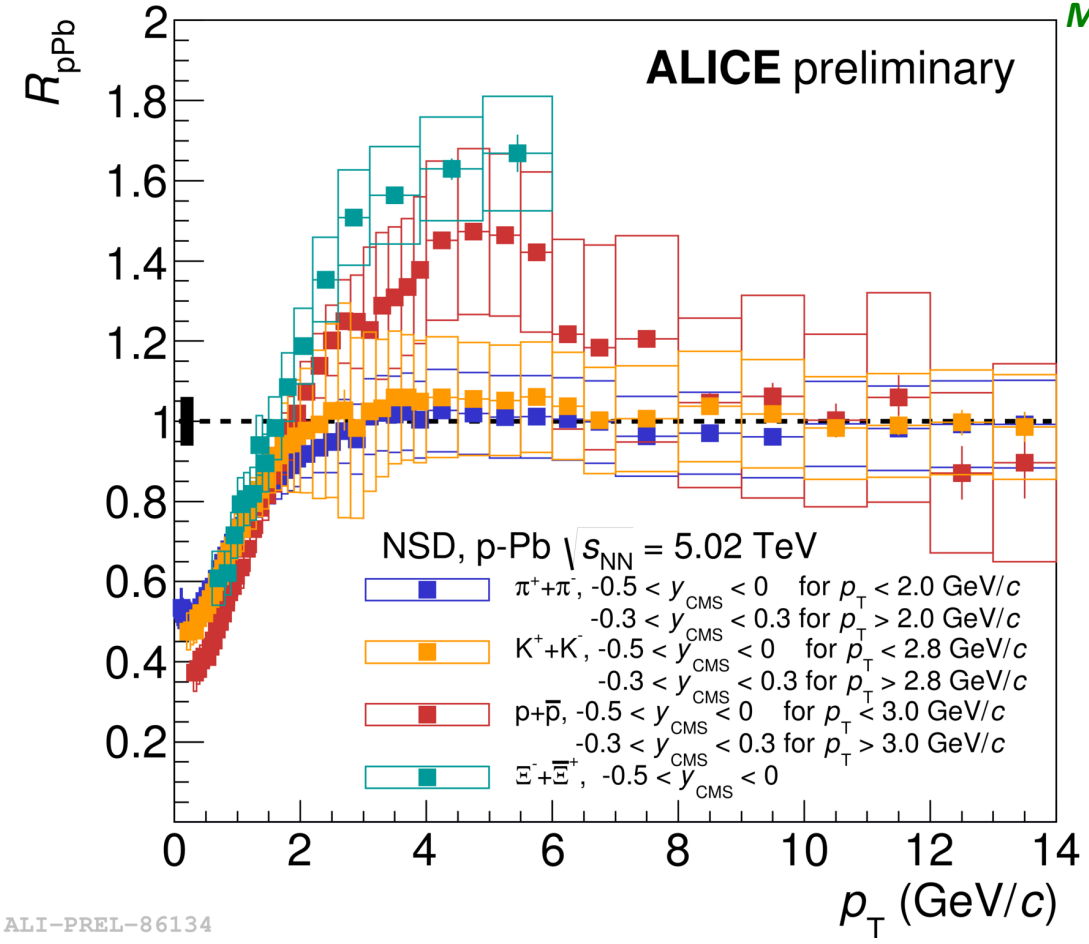
Intermediate p_T:

- maximum shifts with the mass of the particle: radial flow
- enhancement for Ω: strangeness enhancement in addition to flow

High p_T: suppression tends to be the same for all particles

Comparing spectra in different systems: R_{pPb}

More in G. Volpe's talk



Intermediate p_T:

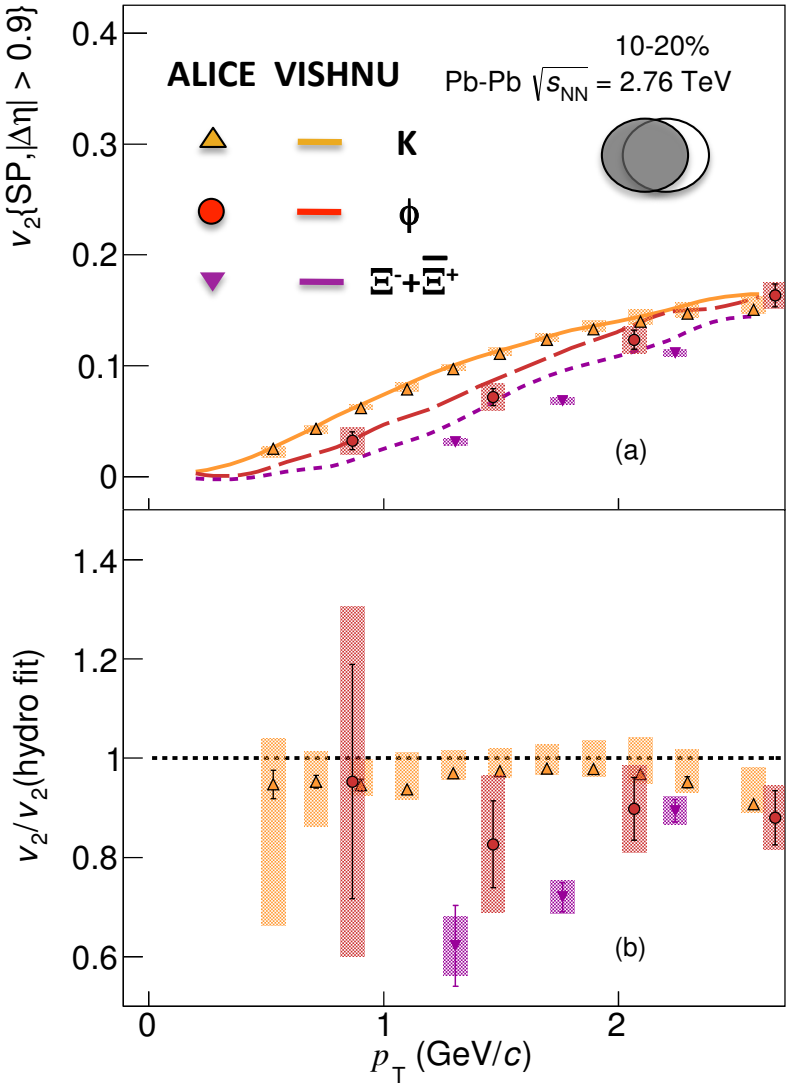
- mass ordering similar to Pb-Pb collisions
- enhancement for p and Ξ

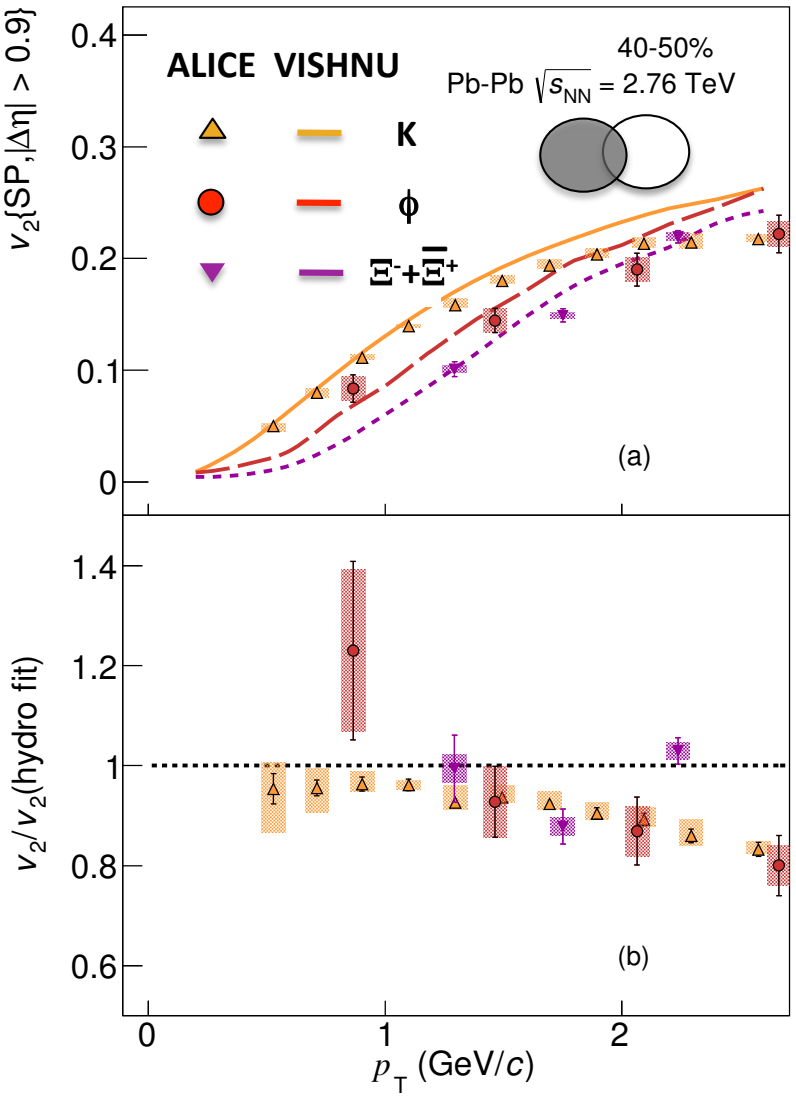
High p_T: binary N_{coll} scaling, no suppression

- suppression in Pb-Pb collisions is a hot nuclear matter effect

Elliptic flow in Pb-Pb collisions

arXiv:1405.4632, accepted for publication in JHEP

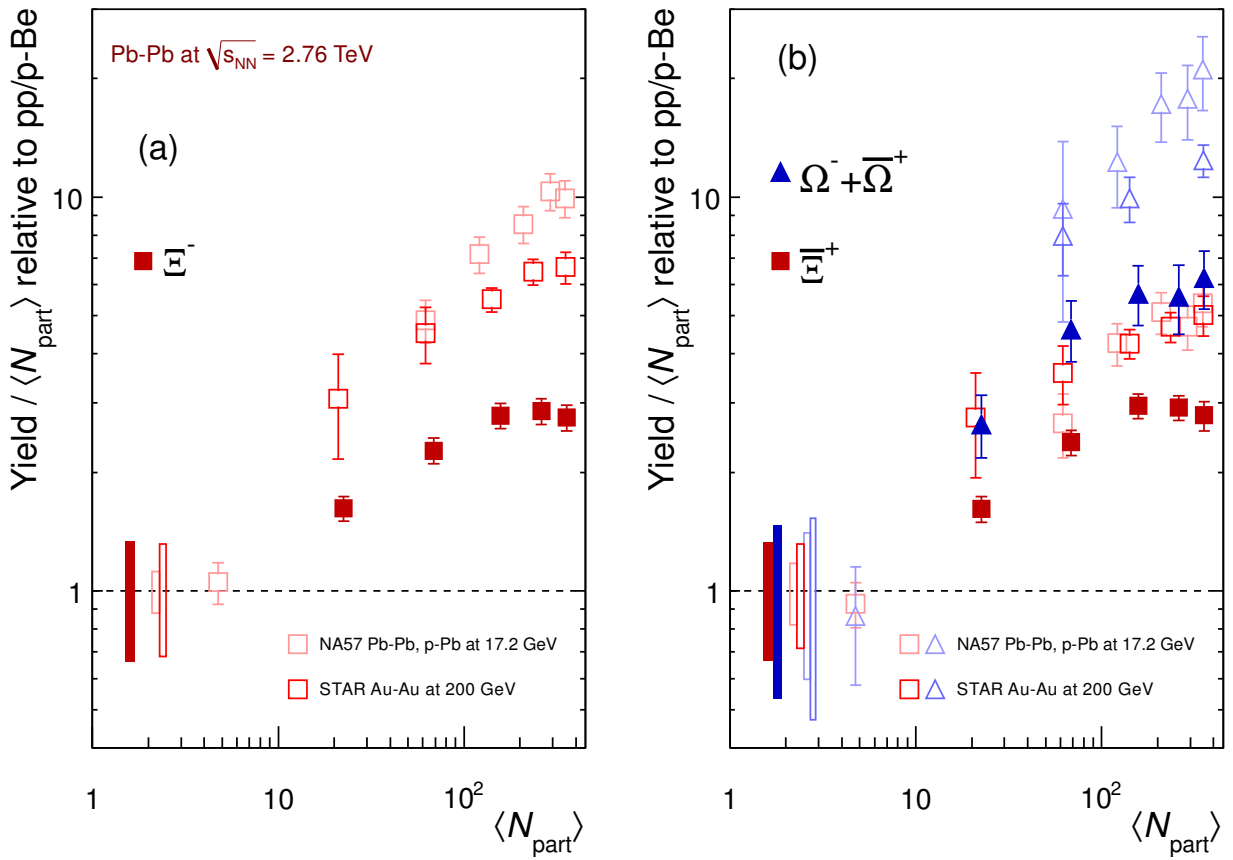




Mass ordering for p_T < 2-3 GeV/c

- reproduced by hydrodynamic models (v_2 overestimated for Λ and Ξ)

"Strangeness enhancement"



ALI-PUB-78347

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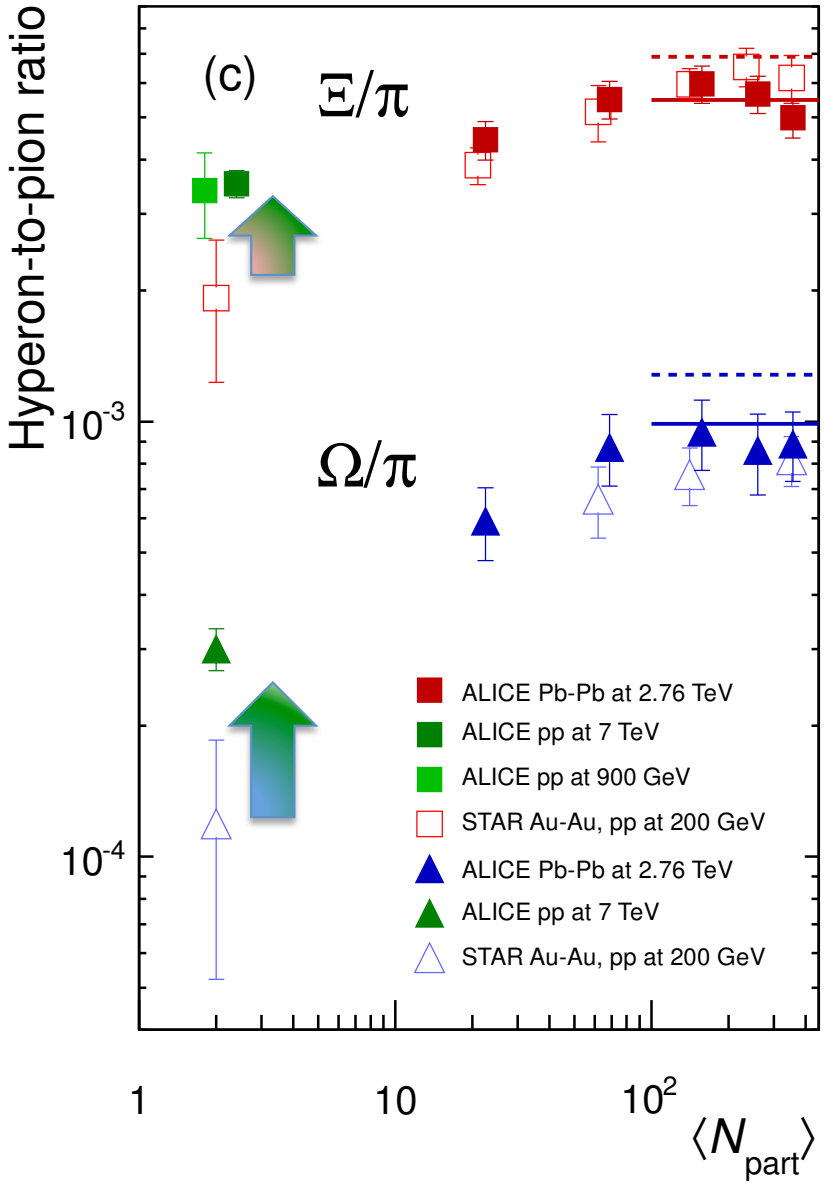
Higher production yields with respect to pp collisions at the same energy when normalized to the number of participants

- observed at lower energy (already at AGS)
- hierarchy based on the strangeness content of the particle
- decreasing as energy increases

"Strangeness enhancement"



Relative yields to pions disentagle effects contributing to the enhancement

- actual increase in AA vs pp
- trend with energy due to the increase of relative yields in pp collisions

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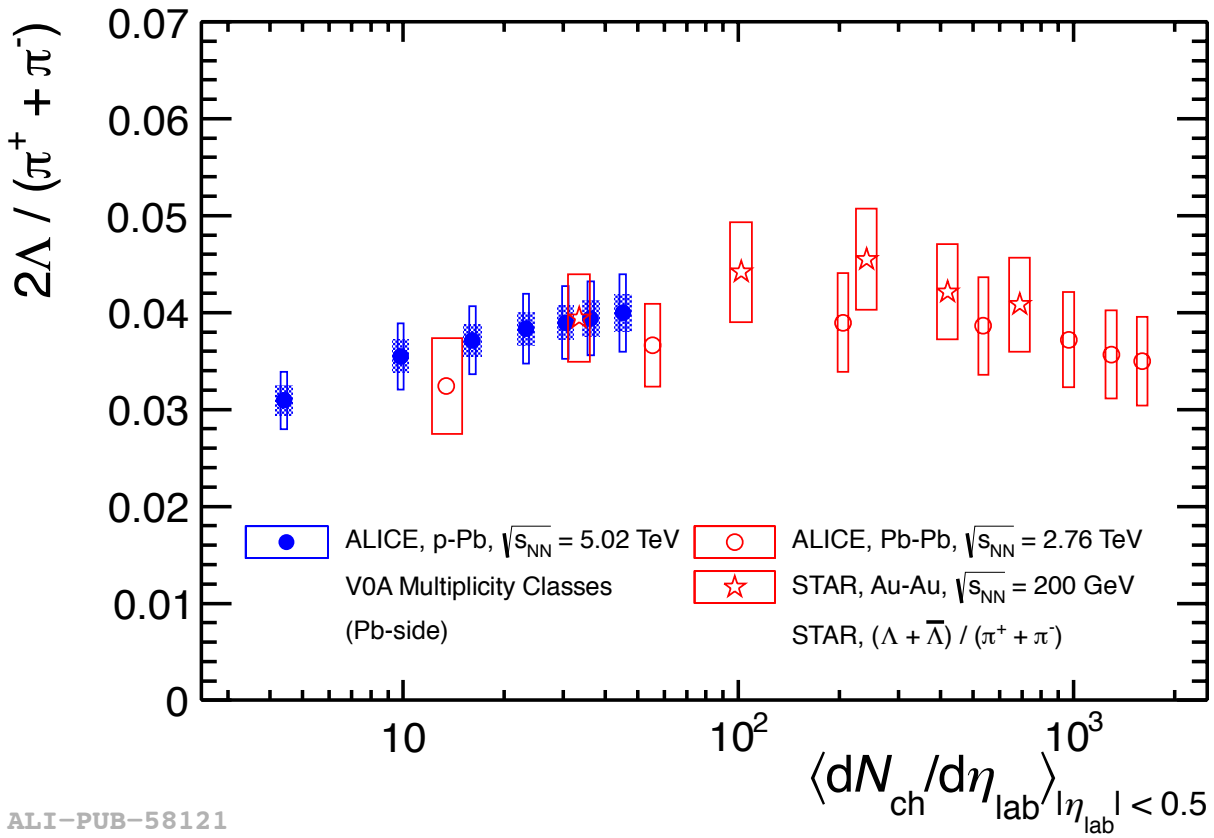
Yields: ratios to pions vs multiplicity



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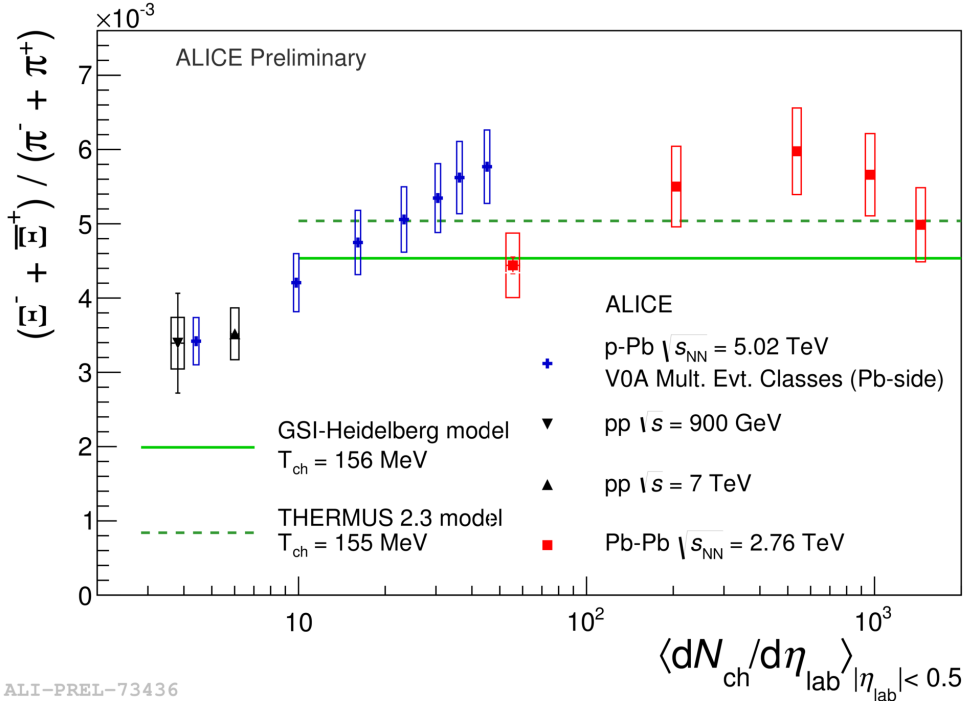
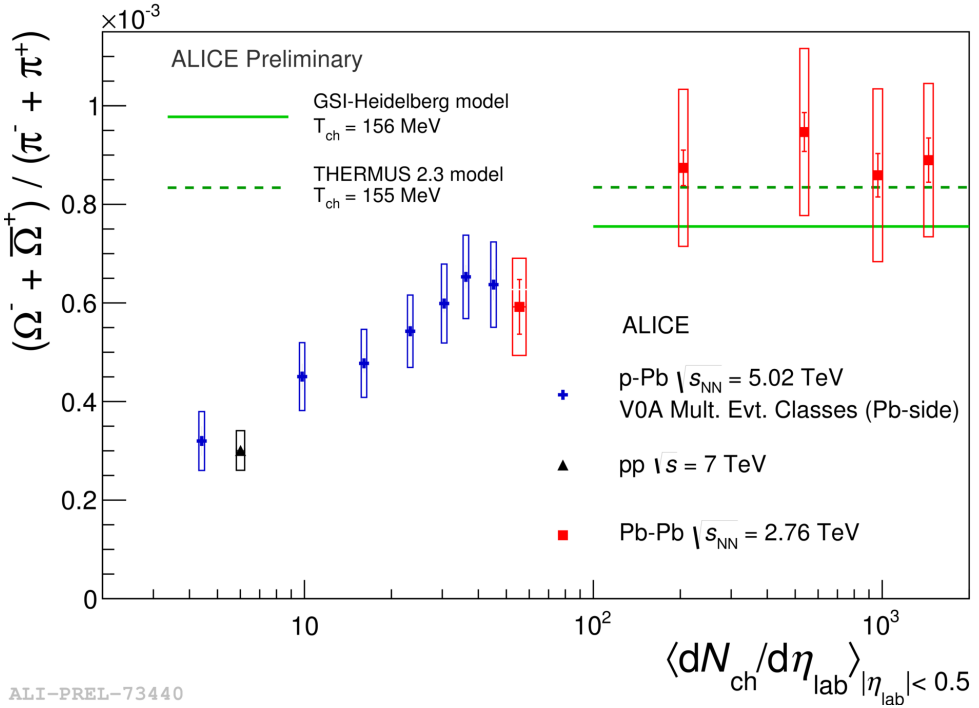
Increase of yields relative to pions with event multiplicity in p-Pb collisions

- similar increase in AA collisions at lower energy

Yields: ratios to pions vs multiplicity



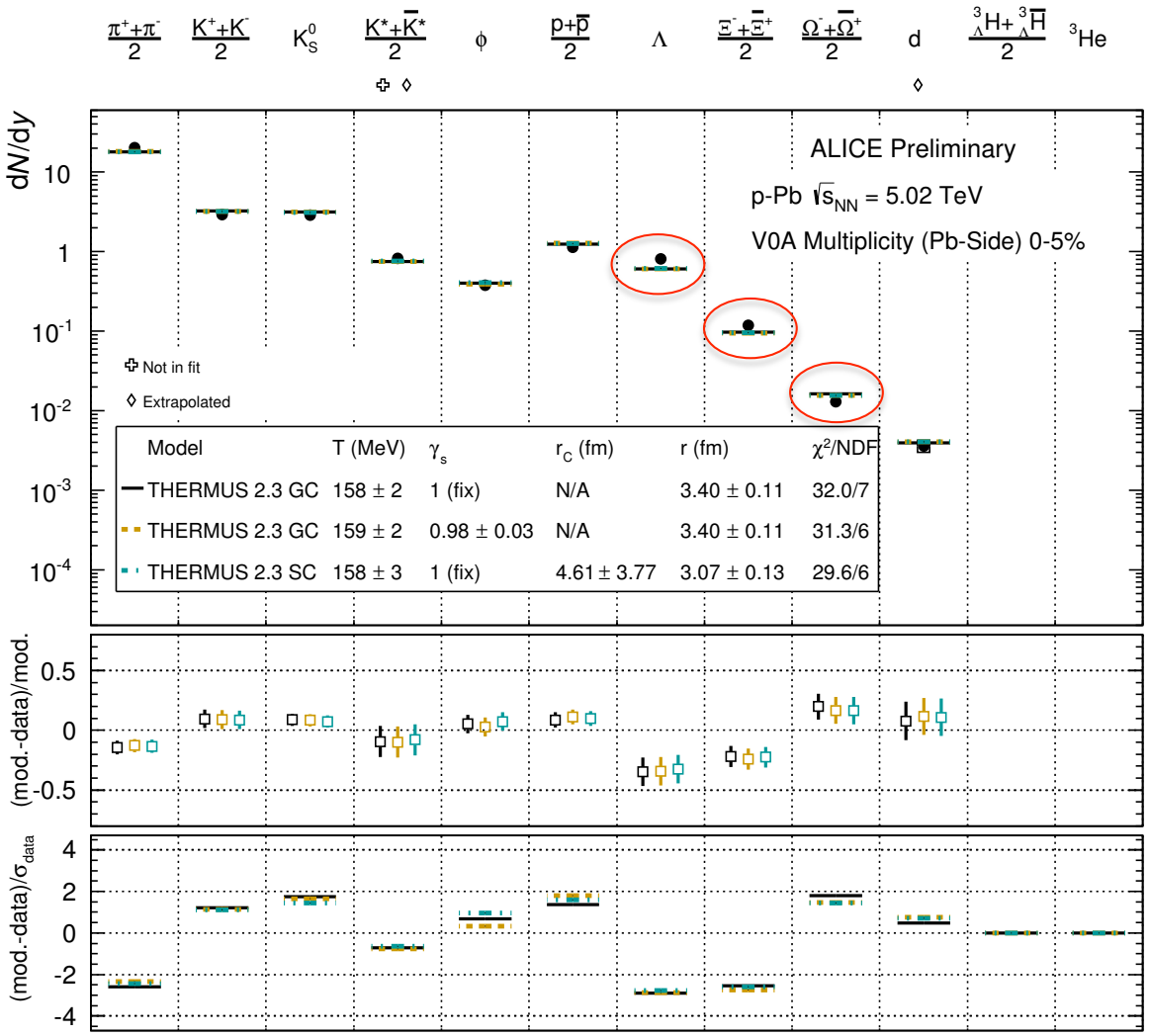


Increase of yields relative to pions with event multiplicity in p-Pb collisions

- values in between those of pp and Pb-Pb collisions
- highest multiplicity values in p-Pb collisions are compatible with central Pb-Pb values and GC limits
- relative increase scales with the power of strangeness quantum number

"Strangeness enhancement" consistent with lifting of canonical suppression

Yields and statistical hadronization models



ALI-PREL-74510

Fit of p-Pb data at high multiplicity with Grand Canonical (GC) and Strangeness Canonical (SC) treatment

- similar results
  - the extracted temperature is robust
  - γ_S is compatible with unity
  - r_C is compatible with r
- deviations of Λ, Ξ and Ω yields independent of the schema of the fit

More in B. Guerzoni's talk

Summary and conclusions

Strangeness production measured in three systems

- event multiplicity increasing over 3 orders of magnitude
- similar patterns observed in p-Pb and Pb-Pb collisions with increasing multiplicity
  - hardening of transverse momentum spectra
  - production of baryons compared to mesons
  - mass ordering
  - increase in ratio to pions

Conclusions and outlook

- suppression at high p_T in Pb-Pb collisions is a hot nuclear matter effect
- increase of relative strangeness production consistent with progressive lifting of canonical suppression
- is there radial flow expansion in p-Pb collisions?
- more statistics and higher energy in Run 2 to reach higher p_T and multiplicities

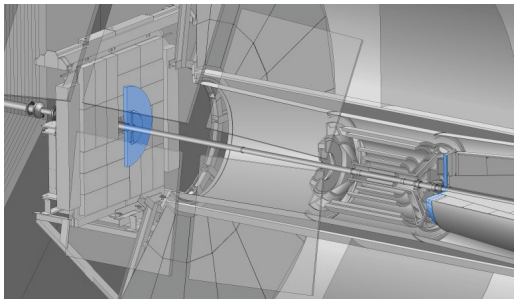
Backup slides

Strangeness measurements in the three systems

Differential studies in event multiplicity also in p-Pb collisions

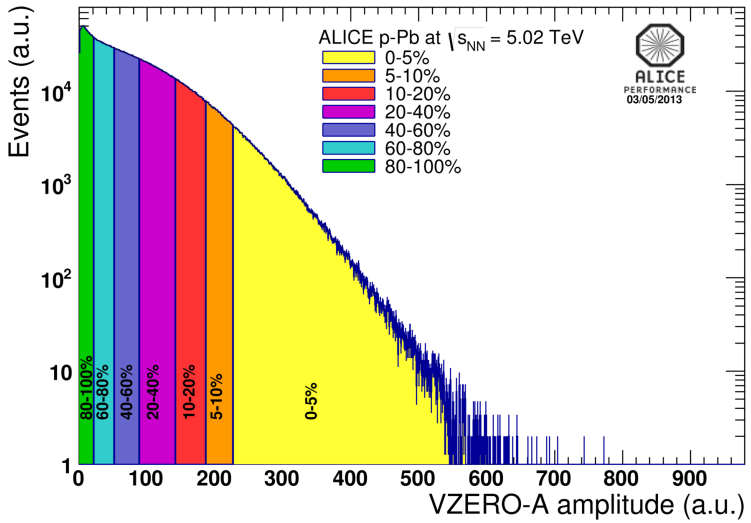
- clear evolution of observables
- systematic comparison of systems with different size and event activity
- main estimator: charge deposited in the VZERO detector, proportional to the number of particles produced in the event

VZERO counters:
- **two arrays of 32 scintillator tiles**
- **$2.8<\eta<5.1$ (VZERO-A)**
- **$-3.7<\eta<-1.7$ (VZERO-C)**

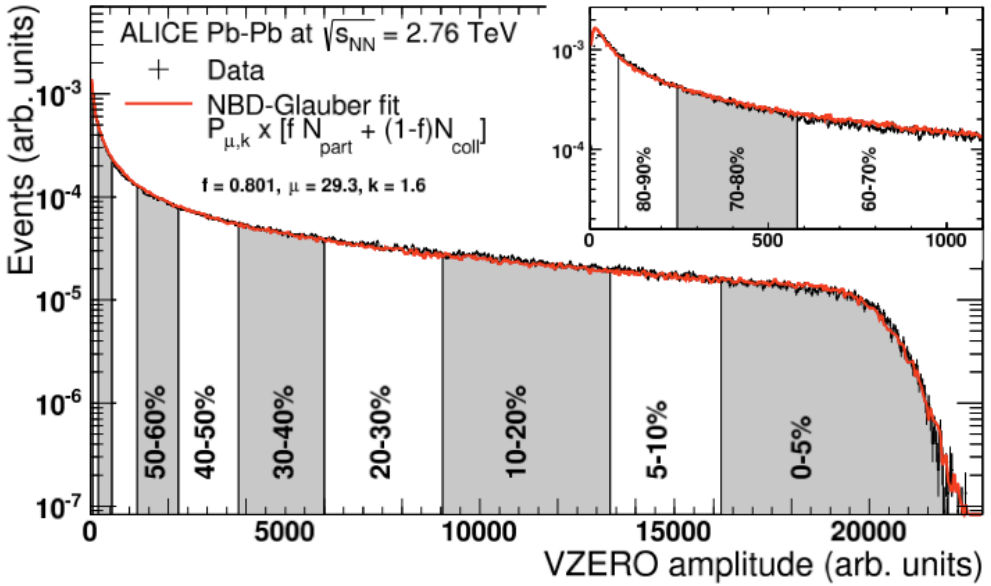


Phys. Rev. C 88 (2013) 044909

p-Pb



Pb-Pb



Reconstruction in ALICE

Strange and multi-strange hadrons decaying into charged hadrons only in the final state

	Quark content	Branching ratio (%)	Decay length cτ (cm)
$K^0_S \rightarrow \pi^+\pi^-$	$(\bar{d}s+d\bar{s})/\sqrt{2}$	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

Blast-wave parametrization

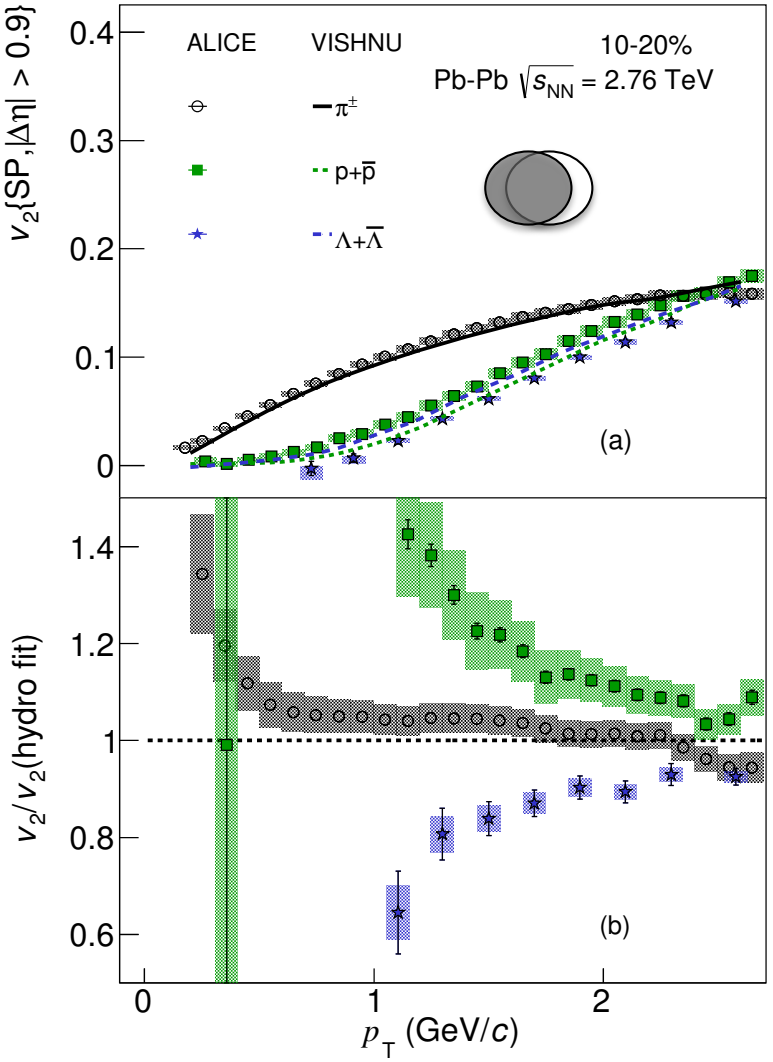
Hydrodinamic inspired model which assumes locally thermalized, collectively expanding source undergoing a common instantaneous freeze-out

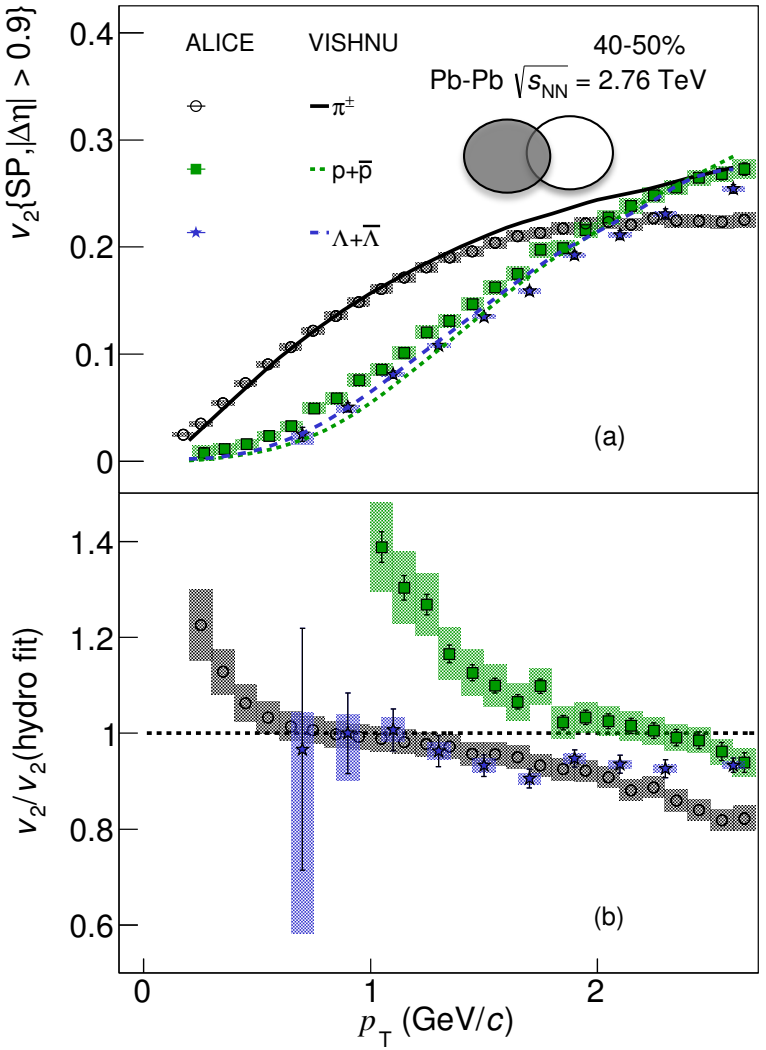
- free parameters in the fit: kinetic freeze-out temperature, transverse expansion velocity and exponent of the velocity profile (T, β_T; n) and a normalization parameter
- gives the best fit to individual particles over the full p_T range
- simultaneous fits to investigate common kinetic freeze-out of the system (but parameters depend heavily on fit ranges)
- 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)

Elliptic flow

arXiv:1405.4632, accepted for publication in JHEP





ALI-PUB-82695

ALI-PUB-82699

Yields and statistical hadronization models

Good description of yield ratios from SPS to LHC with the statistical hadronization model

Strangeness conservation implemented

- in large systems (central AA collisions) using grand canonical (GC) formalism
- in small systems (pp, pA) using canonical formalism + extra strangeness suppression with two alternative descriptions
  - γ_S: fugacity, deviations of strange hadrons yields from equilibrium values
  - R_C: radius of the strangeness correlation volume within which strangeness is conserved exactly ($R_C<R$)