Nuclotron-based
Ion Collider fAcility

Update on resonance measurements in the MPD at NICA

Victor Riabov for the MPD

Outline

- Resonances in heavy-ion collisions at LHC-RHIC-SPS-NICA
- Reconstruction of resonances in the MPD detector
- Prospects for the first years of running (Run-I)

Hadronic resonances

- A huge variety of resonances in the PDG with well-defined properties (M, Γ, decay channels & BRs)
- Most of resonances are experimentally measured in the dominant hadronic decay channels, accessible in pp/p-A/A-A collisions even at top multiplicities:

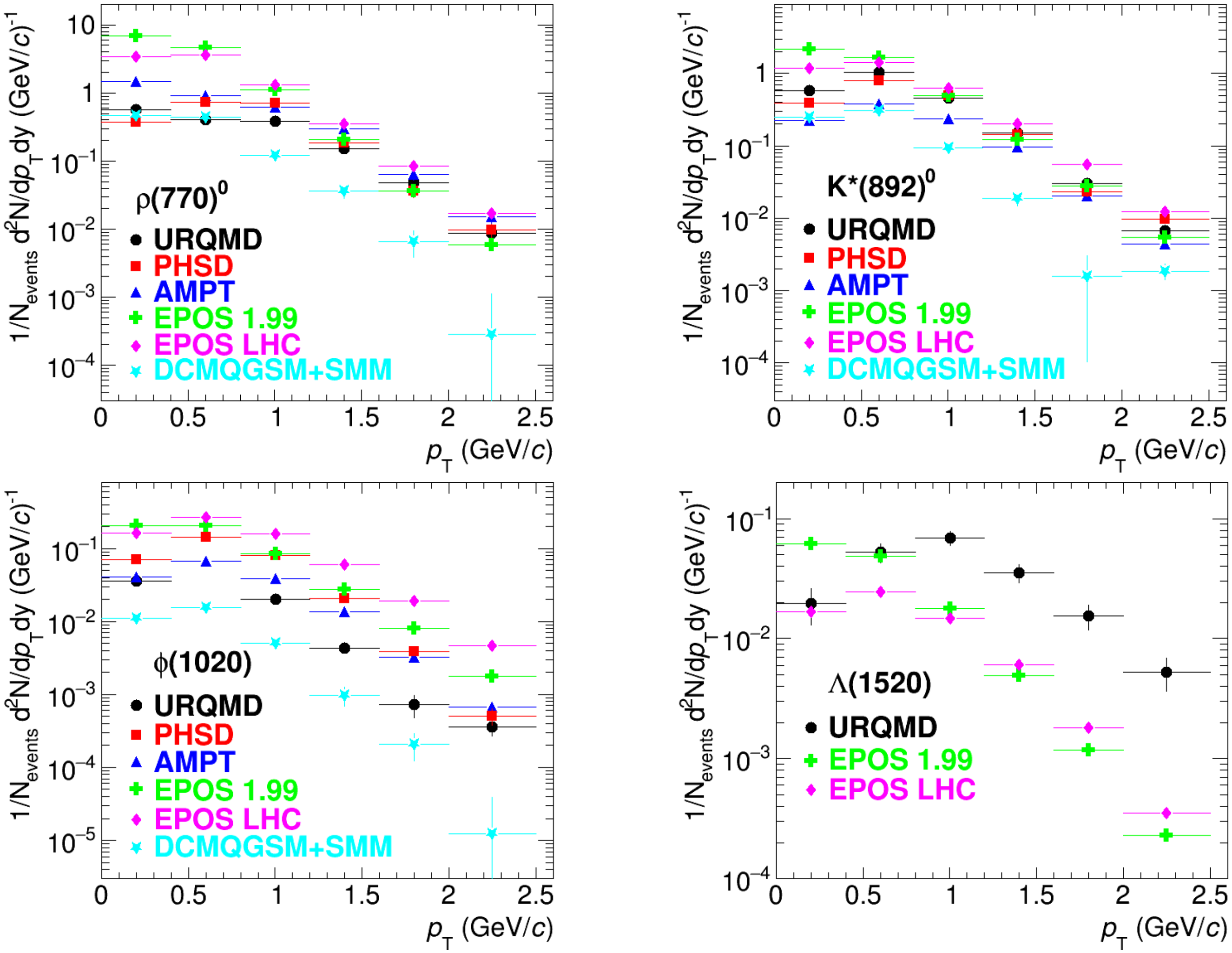
ρ(770)	$K^*(892)^0$	$K^*(892)^+$	ϕ(1020)	$\Sigma(1385)^\pm$	Λ(1520)	Ξ(1530)
$\frac{u\bar{u}+d\bar{d}}{\sqrt{2}}$	$d\bar{s}$	$u\bar{s}$	$s\bar{s}$	uus dds	uds	uss

Particle	Mass (MeV/c^2)	Width (MeV/c^2)	Decay	BR (%)
ρ^0	770	150	$\pi^+\pi^-$	100
$K^{*\pm}$	892	50.3	$\pi^\pm K_s$	33.3
K^{*0}	896	47.3	πK^+	66.7
ϕ	1019	4.27	K^+K^-	48.9
Σ^{*+}	1383	36	$\pi^+\Lambda$	87
Σ^{*-}	1387	39.4	$\pi\Lambda$	87
Λ(1520)	1520	15.7	K^-p	22.5
Ξ^{*0}	1532	9.1	$\pi^+\Xi^-$	66.7

- Resonances differ by lifetimes, mass and quark contents → probe reaction dynamics, properties of the hadronic phase, particle production mechanisms, spin-orbital interaction, etc.

Systematic study of resonances at NICA energies

- Resonance yields and properties can be estimated from different event generators
- Event generators decay the short-lived particles in the dominant hadronic decay channels
- Resonance final-state yields are estimated from the invariant mass distributions, BR corrected
- Example for **AuAu@7**: predictions for resonances differ quite substantially



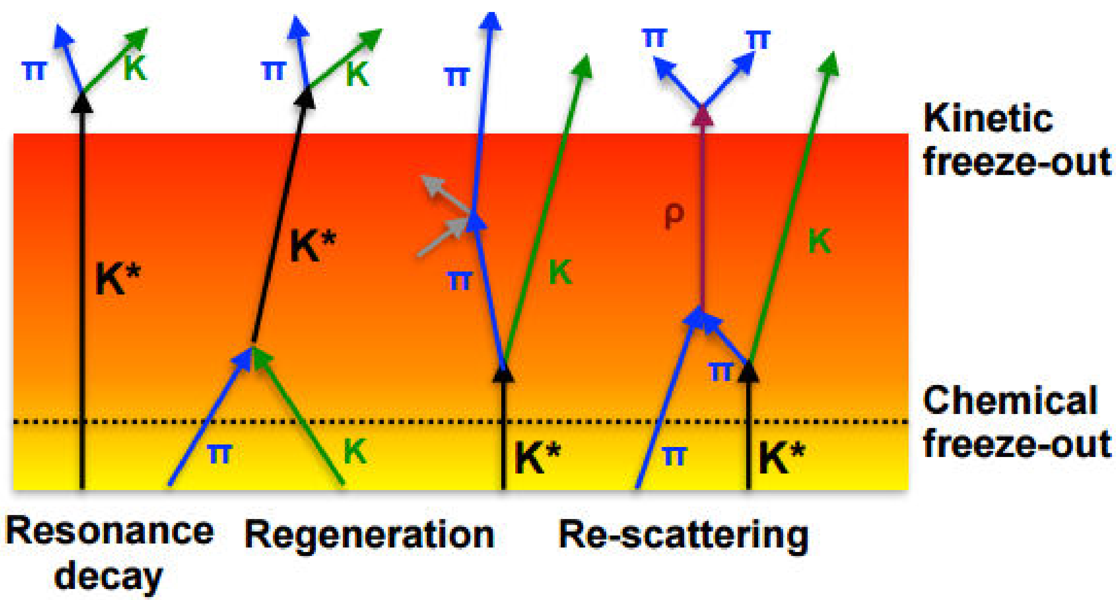
Motivation I: resonances probe the hadronic phase

- Short lifetimes: → chiral symmetry restoration: mass/width modifications
  → hadronic phase: lifetime, density

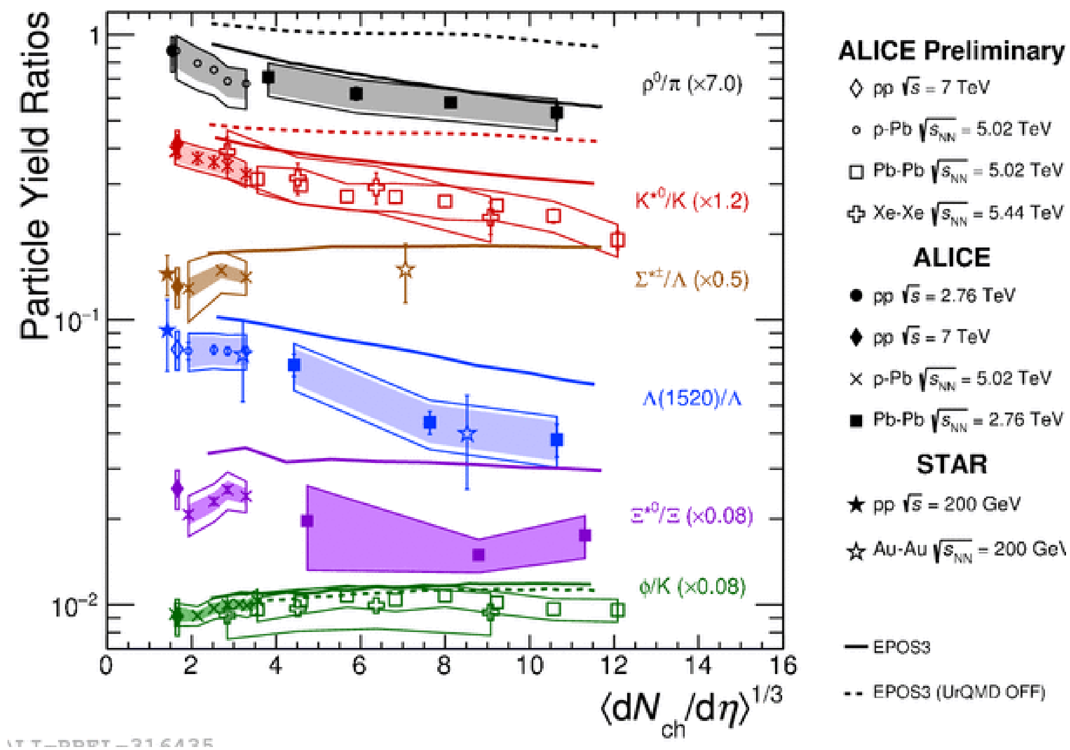
- Reconstructed resonance yields in heavy ion collisions are defined by:
  - ✓ resonance yields at chemical freeze-out
  - ✓ hadronic processes between chemical and kinetic freeze-outs:

    rescattering: daughter particles undergo elastic scattering or pseudo-elastic scattering through a different resonance → parent particle is not reconstructed → loss of signal

    regeneration: pseudo-elastic scattering of decay products ($\pi K \rightarrow K^{*0}$, $KK \rightarrow \phi$ etc.) → increased yields



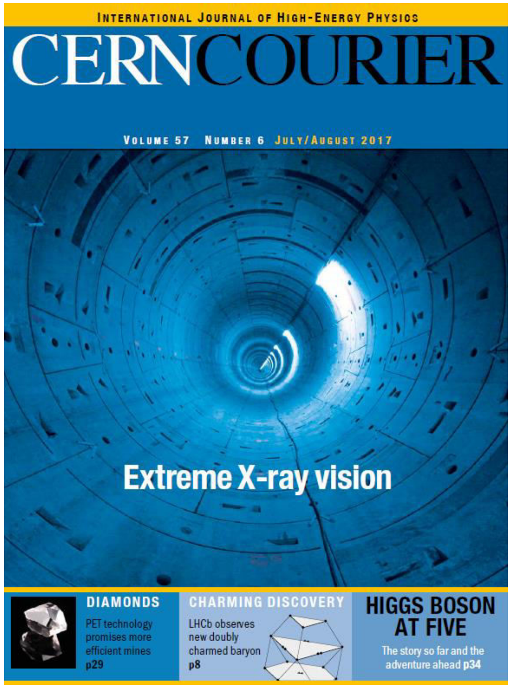
Measurements at RHIC & LHC



- RHIC & LHC observed multiplicity dependent suppression of ρ/π, K^*/K, Λ^*/Λ ratios, resonances with $c\tau \leq 20$ fm/c. Ratios of longer lived resonances are not affected
- Results support the existence of a hadronic phase that lives long enough to cause a significant reduction of the reconstructed yields of short lived resonances
- Hadronic phase lifetime, $\tau \sim 10$ fm/c*
- NICA: $\langle dN_{ch}/d\eta \rangle^{1/3} \sim 6$** → RHIC/LHC report modifications at such multiplicities

* ALICE, Phys.Lett.B 802 (2020) 135225, Phys.Rev.C 99 (2019) 024905
** PHENIX, Phys.Rev.C 93 (2016) 2, 024901

Highlights in the CERN Courier

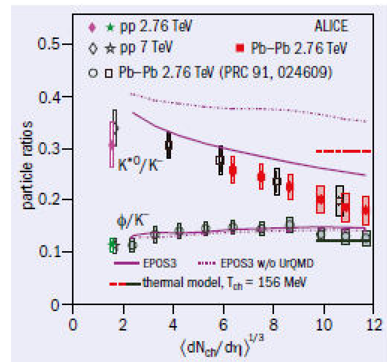


News

ALICE zooms in on evolution of the quark–gluon plasma

The precise particle-identification and momentum-measurement capabilities of the ALICE experiment allow researchers to reconstruct a variety of short-lived particles or resonances in heavy-ion collisions. These serve as a probe for in-medium effects during the last stages of evolution of the quark–gluon plasma (QGP). Recently, the ALICE collaboration has made a precise measurement of the yields (number of particles per event) of two such resonances: $K^*(892)^0$ and $\phi(1020)$. Both have similar masses and the same spin, and both are neutral strange mesons, yet their lifetimes differ by a factor of 10 (4.16 ± 0.05 fm/c for K^{*0}, and 46.3 ± 0.4 fm/c for ϕ).

The shorter lifetime of the K^{*0} means that it decays within the medium, enabling its decay products (π and K) to re-scatter with other hadrons. This would be expected to inhibit the reconstruction of the parent K^{*0}, but the π and K in the medium may also scatter into a K^{*0} resonance state, and the interplay of these two competing re-scattering and regeneration processes becomes relevant for determining the K^{*0} yield. The processes depend on the time interval between chemical freeze-out (vanishing inelastic collisions) and kinetic freeze-out (vanishing elastic collisions), in addition to the source size and the interaction cross-sections of the daughter hadrons. In contrast, due to the longer lifetime of the ϕ meson, both the re-scattering and regeneration effects are expected to be negligible.



Ratio of K^{*0} and ϕ yields to charged-kaon yields at midrapidity for Pb–Pb and pp collisions as a function of charged-particle pseudorapidity density at midrapidity $(dN_{ch}/d\eta)^{1/3}$, which is related to the final-state freeze-out geometry of the system. Also shown are corresponding results from models with and without re-scattering.

Using lead–lead collision data recorded at an energy of 2.76 TeV, ALICE observed that the ratio K^{*0}/K^- decreases as a function of system size (see figure). In small impact-parameter collisions, the ratio is significantly less than in proton–proton collisions and models without re-scattering effects. In contrast, no such suppression was observed in the ϕ/K^- ratio. This measurement thus suggests the existence of re-scattering effects on resonances in the last stages of heavy-ion collisions at LHC energies. Furthermore, the suppression of K^{*0} yields can be used to obtain the time difference between the chemical and the kinetic freeze-out of the system.

On the other hand, at higher momenta ($p_T > 8$ GeV/c), these resonances were suppressed with respect to proton–proton collisions by similar amounts. The magnitude of this suppression for K^{*0} and ϕ mesons was also found to be similar to the suppression for pions, kaons, protons and D mesons. The striking independence of this suppression on particle mass, baryon number and the quark-flavour content of the hadron puts a stringent constraint on models dealing with particle-production mechanisms, fragmentation processes and parton energy loss in the QGP medium.

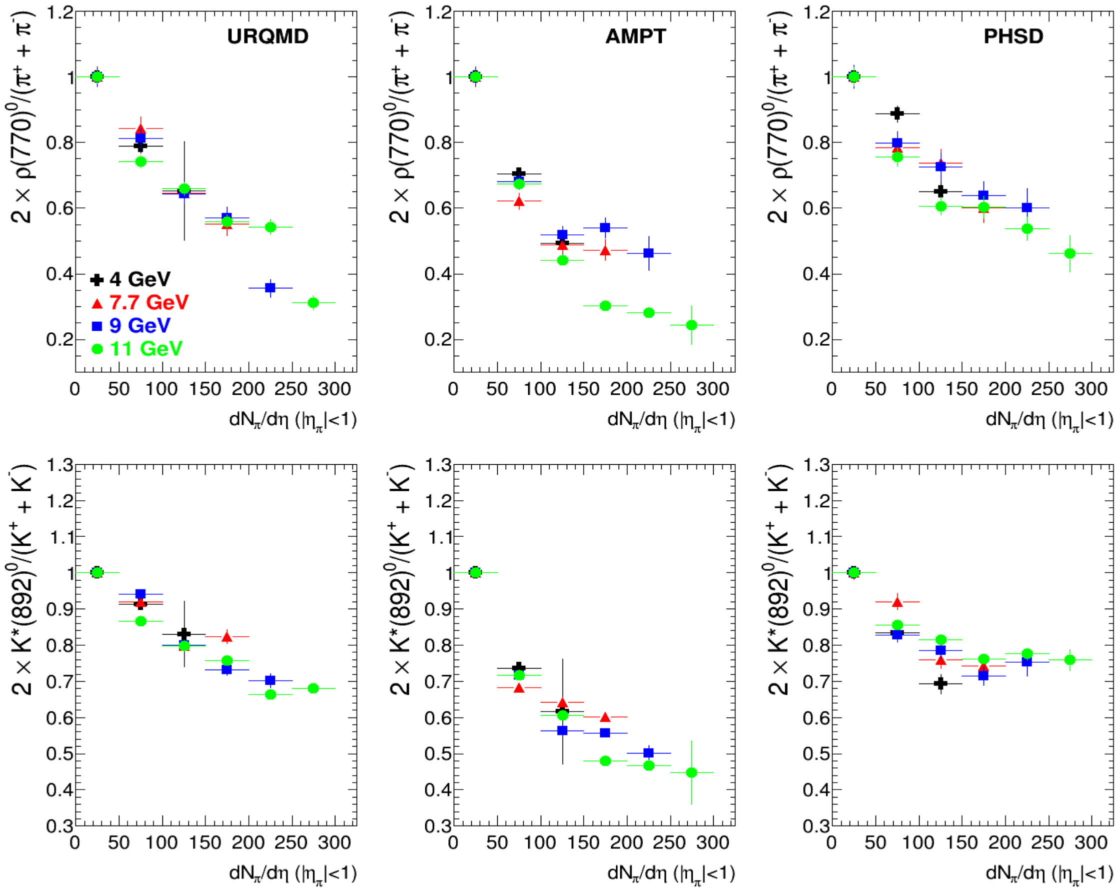
In future, it will be important to perform such measurements for high-multiplicity events in pp collisions at the LHC.

- **Further reading**

ALICE Collaboration 2017 *Phys. Rev. C.* **95** 064606.

ρ/π and K^*/π ratios in Au+Au collisions at $\sqrt{s_{NN}}$ = 4-11GeV

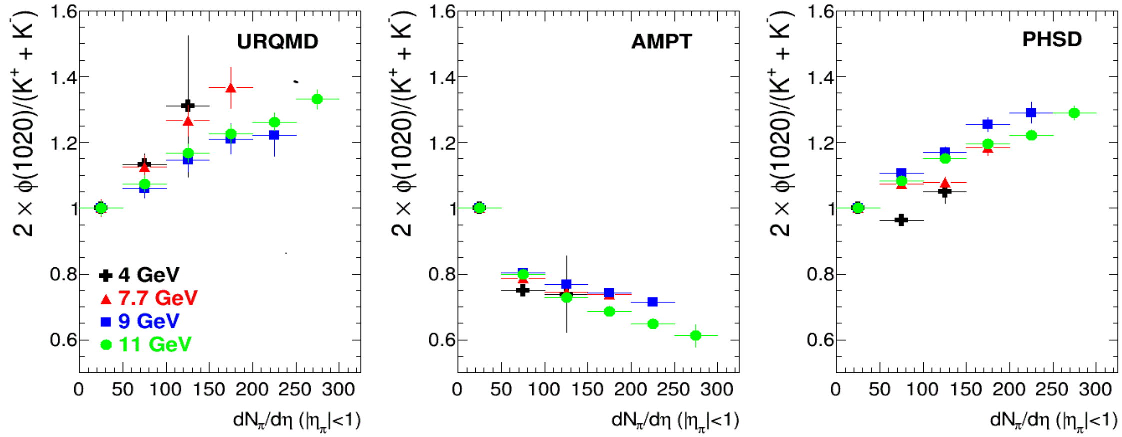
- ❖ Models with hadronic cascades (UrQMD, PHSD, AMPT) → properties of hadronic phase
- ❖ Ratios are shown normalized to most peripheral collisions → start at unity in peripheral collisions

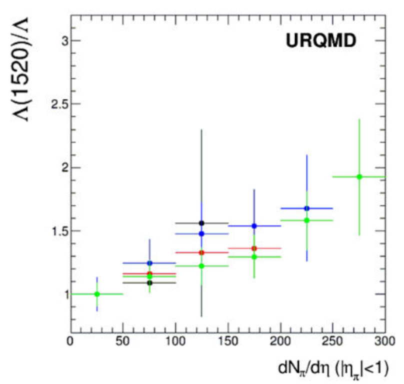


- ➢ models predict suppression of ρ/π and K^*/K ratios in Au+Au@4-11, resonances with small $c\tau$
- ➢ suppression depends on the final state multiplicity rather than on collision energy
- ➢ modifications occur at low momentum as expected for the hadronic phase effects, ratios converge to unity at high momentum

ϕ/K and Λ^*/Λ ratios in Au+Au collisions at $\sqrt{s_{NN}}$ = 4-11GeV

- ❖ Models with hadronic cascades (UrQMD, PHSD, AMPT) → properties of hadronic phase
- ❖ Ratios are shown normalized to most peripheral collisions → start at unity in peripheral collisions





- ➢ ϕ(1020)/K ratio is predicted to be enhanced by UrQMD and PHSD and suppressed by AMPT
- ➢ Λ(1520) is available in UrQMD only, Λ(1520)/Λ ratio gradually increases with multiplicity at all energies
- ➢ ϕ(1020)/K and Λ(1520)/Λ ratios are consistent for different collision energies at similar multiplicities

- ❖ Models predict yield modifications qualitatively similar to those obtained at SPS/RHIC/LHC:
  - ✓ lifetime and density of the hadronic phase are high enough
  - ✓ modification of particle properties in the hadronic phase should be taken into account when model predictions for different observables are compared to data
  - ✓ study of short-lived resonances is a unique tool to tune the hadronic phase simulations

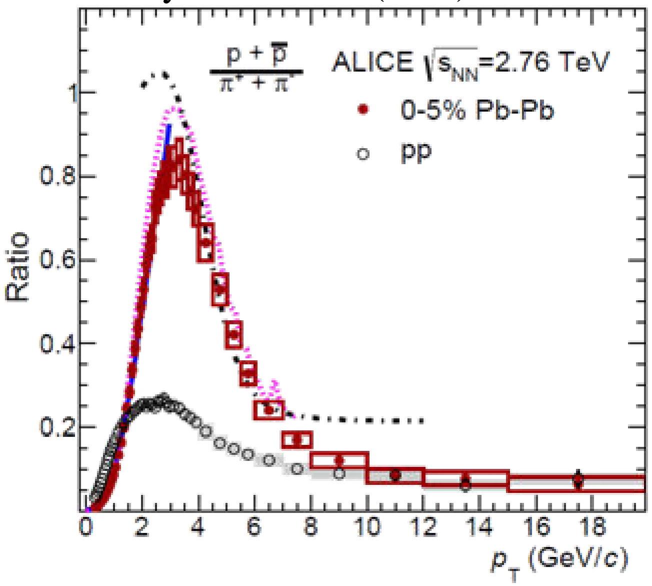
Motivation 2: hadronization at intermediate momenta

- Baryon puzzle - increased B/M (p/π, Λ/K_s^0, Λ_c^+/D etc.) ratios at RHIC and the LHC

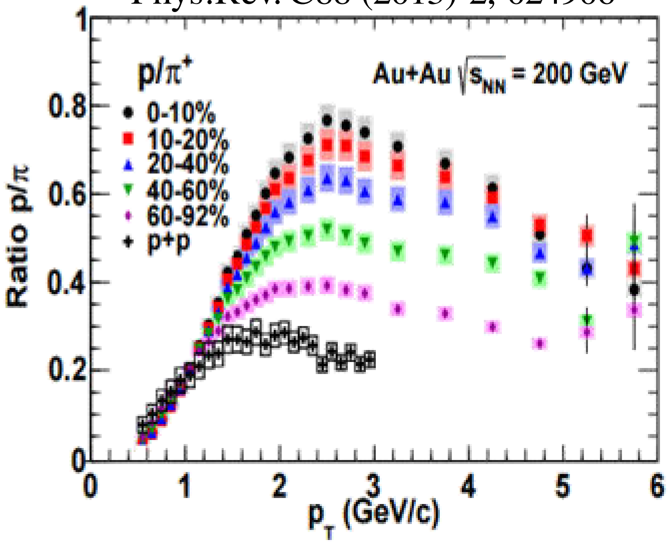
- Driving force of the enhancement is not yet fully understood:
  - ✓ particle mass (hydro)?
  - ✓ quark count (baryons vs. mesons)?

- ϕ and K^{*0} are well suited for tests as mesons with masses very close to that of a proton:
  - ✓ $\Delta m_{\phi} \sim$ 80 MeV/c^2, $\Delta m_{K^{*0}} \sim$ -45 MeV/c^2

Phys.Lett. B736 (2014) 196-207



Phys.Rev. C88 (2013) 2, 024906



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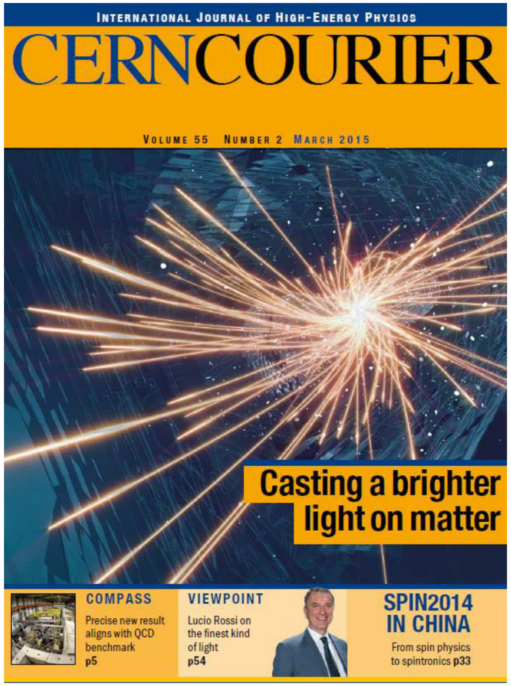


- p/ϕ(p_T) and p/K*(p_T) evolve with centrality and flatten in most **central Pb-Pb** collisions:
  - → similar spectral shapes of p, K* and ϕ
  - → spectral shapes are determined by particle masses, consistent with hydrodynamic evolution

News

ALICE sheds light on particle production in heavy-ion collisions

ALICE

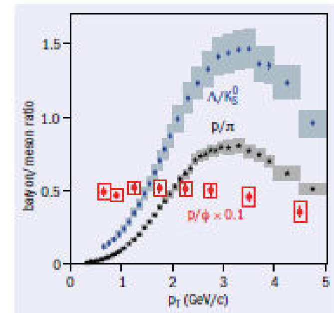
New results from the ALICE collaboration are providing additional data to test ideas about how particles are produced out of the quark–gluon plasma (QGP) created in heavy-ion collisions at the LHC.

Experiments at Brookhaven's Relativistic Heavy Ion Collider (RHIC) observed an enhancement in p_T-dependent baryon/meson ratios – specifically the p/π and Λ/K^0_S ratios – for central nucleus–nucleus (AA) collisions in comparison with proton–proton (pp) collisions, where particle production is assumed to be dominated by parton fragmentation. In addition, constituent-quark scaling was observed in the elliptic-flow parameter, v_2, measured in AA collisions. To interpret these observations, the coalescence of quarks was suggested as an additional particle-production mechanism. The coalescence (or recombination) model postulates that three quarks must come together to form a baryon, while a quark and an antiquark must coalesce to form a meson. The p_T and the v_2 of the particle created is the sum of the respective values of the constituent quarks. Therefore, coalescence models generally predict differences between the p_T spectra of baryons and mesons, predominantly in the range $2 < p_T < 5$ GeV/c, where the enhancement in the baryon/meson ratio has been measured.

While a similar enhancement in the p/π and Λ/K^0_S ratios is observed at the LHC, the mass scaling of v_2 is not, calling into question the importance of the coalescence mechanism. The observed-particle p_T spectra reflect the dynamics of the expanding QGP created in local thermal equilibrium, conferring to the final-state particles a common radial velocity independent of their mass, but a different momentum (hydrodynamic flow). The resulting blue shift in the p_T spectrum therefore scales with particle mass, and is observed as a rise in the p/π and Λ/K^0_S ratios at low p_T (see figure). In such a hydrodynamic description, particles with the same mass have p_T spectra with similar shapes, independent of their quark content. The particular shape of the baryon/meson ratio observed in AA collisions therefore reflects the relative importance of hydrodynamic flow, parton fragmentation and quark coalescence. However, for the p/π and Λ/K^0_S ratios, the particles in the numerator and denominator differ in both mass and (anti)quark content, so coalescence and hydrodynamic effects cannot be disentangled. To test the role of coalescence further, it is instructive to conduct this study using a baryon and a meson that have similar mass.

Fortunately, nature provides two such particles: the proton, a baryon with mass 938 MeV/c^2, and the ϕ meson, which has a mass of 1019 MeV/c^2. If protons and ϕ mesons are produced predominantly through coalescence, their p_T spectra will have different shapes. Hydrodynamic models alone would predict p_T spectra with similar shapes owing to the small mass-difference (less than 9%), implying a p/ϕ ratio that is constant with p_T.

For peripheral lead–lead collisions, where the small volume of the quark–gluon plasma reduces the influence of collective hydrodynamic motion on the p_T spectra, the p/ϕ ratio has a strong dependence on p_T, similar to that observed for pp collisions.



The flat dependence on p_T of the p/ϕ ratio measured by ALICE for central lead–lead collisions, compared with the p/π and Λ/K^0_S ratios, indicates hydrodynamics as the leading contribution to the p_T spectra.

In contrast, as the figure shows, in central lead–lead collisions – where the volume of the QGP produced is largest – the p/ϕ ratio has a very different p_T dependence, and is constant within its uncertainties for $p_T < 4$ GeV/c. The data therefore indicate that hydrodynamics is the leading contribution to particle p_T spectra in central lead–lead collisions at LHC energies, and it does not seem necessary to invoke coalescence models.

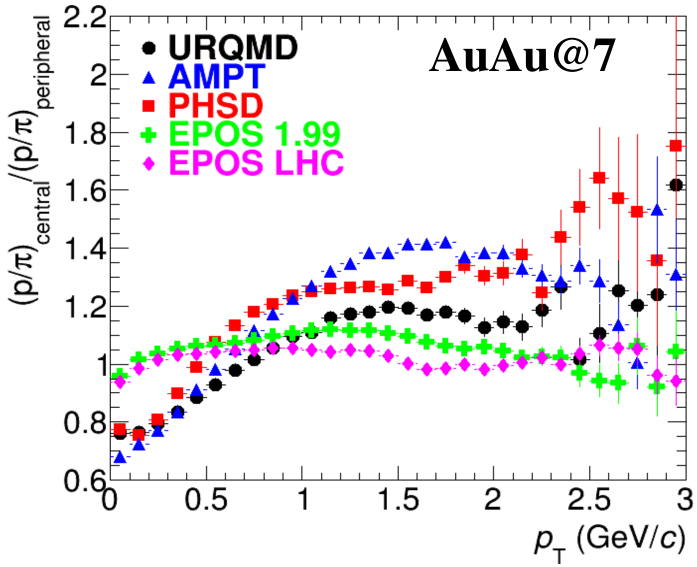
In the coming year, the ALICE collaboration will measure a larger number of collisions at a higher energy. This will allow a more precise study of both the p_T spectra and elliptic-flow parameters of the proton and ϕ meson, and will allow tighter constraints to be placed on theoretical models of particle production in heavy-ion collisions.

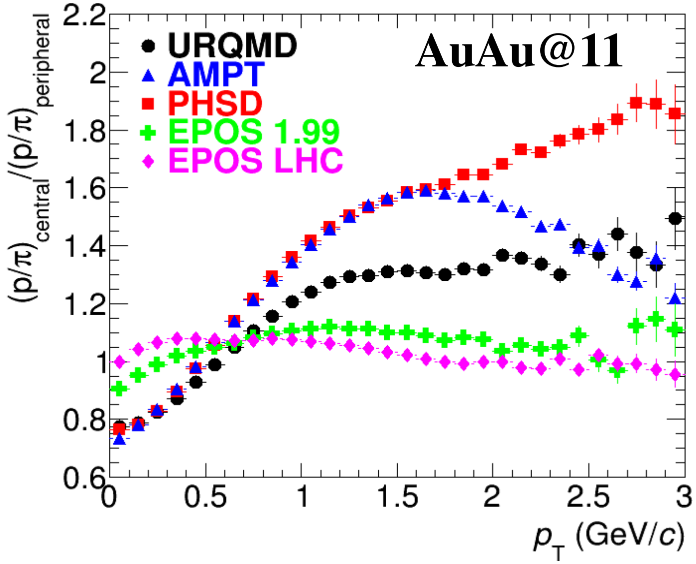
● Further reading

B Abelev *et al.* ALICE Collaboration 2014 arXiv:1404.0495 [nucl-ex], accepted for publication in *Phys. Rev. C*.

B/M ratios in Au+Au collisions at $\sqrt{s_{NN}}$ = 4-11GeV

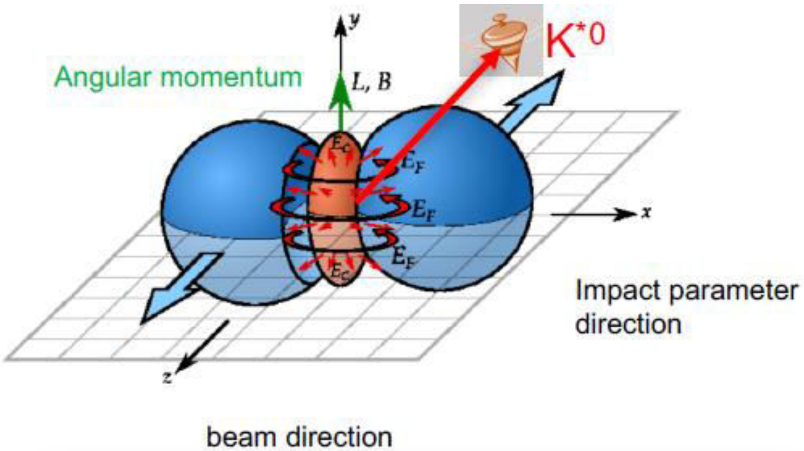
- UrQMD, PHSD, AMPT, EPOS …
- Baryon/meson ratios evolve with centrality/multiplicity





- strong model and collision energy dependence of B/M ratios
- predictions are qualitatively similar to experimental observations at RHIC and the LHC
- origin of the evolution of B/M ratios is not understood (radial flow, quark recombination, …)
- measurements of p/ϕ(1020) and p/K*(892) ratios will help to disentangle the mechanisms that shape the particle p_T spectra at low and intermediate momenta

Motivation 3: spin alignment of vector mesons in rotating QGP



$$\frac{dN}{dcos\theta} = N_0 \left[1 - \rho_{0,0} + cos^2\theta \, (3\rho_{0,0} - 1)\right]$$

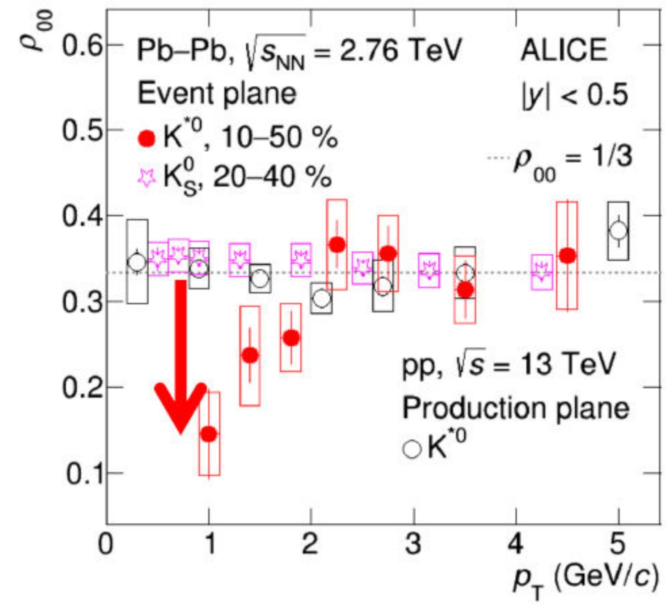
r_{00}: probability for vector meson to be in spin state = 0

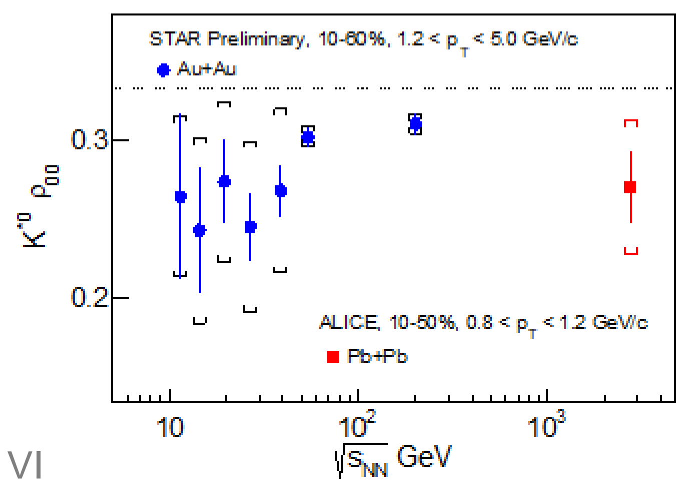
- Large angular momentum **L** in non-central collisions → **rotating QGP** (~ **10²¹** revolutions per second)
- spin-orbit interactions expected to polarize quarks
- If quarks recombine to produce vector mesons (spin=1), spin alignment could appear
- Measurement using K^{*0} → $K\pi$ decays shows a 3σ effect at low momentum (Run 1 data)
- STAR & ALICE measurements in a wide range of $\sqrt{s_{NN}}$ are consistent within rather large uncertainties

PRL 125 (2020) 012301

EDITORS' SUGGESTION

Evidence of Spin-Orbital Angular Momentum Interactions in Relativistic Heavy-Ion Collisions





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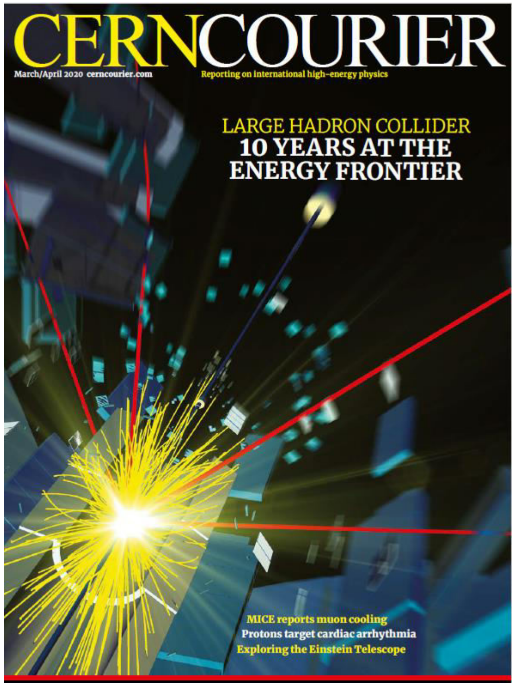


ALICE

Plasma polarised by spin-orbit effect

Spin–orbit coupling causes fine structure in atomic physics and shell structure in nuclear physics, and is a key ingredient in the field of spintronics in materials sciences. It is also expected to affect the development of the quickly rotating quark–gluon plasma (QGP) created in non-central collisions of lead nuclei at LHC energies. As such, plasmas are created by the collisions of lead nuclei that almost miss each other. They have very high angular momenta of the order of $10^7\hbar$ – equivalent to the order of 10^{21} revolutions per second. While the extreme magnetic fields generated by spectating nucleons (of the order of 10^{14} T, *CERN Courier* Jan/Feb 2020 p17) quickly decay as the spectator nucleons pass by, the plasma's angular momentum is sustained throughout the evolution of the system as it is a conserved quantity. These extreme angular momenta are expected to lead to spin–orbit interactions that polarise the quarks in the plasma along the direction of the angular momentum of the plasma's rotation. This should in turn cause the spins of vector (spin-1) mesons to align if hadronisation proceeds via the recombination of partons or by fragmentation. To study this effect, the ALICE collaboration recently measured the spin alignment of the decay products of neutral K^* and ϕ vector mesons produced in non-central Pb–Pb collisions.

Spin alignment can be studied by measuring the angular distribution of the decay products of the vector mesons. It is quantified by the probability ρ_{00} of finding a vector meson in a spin state 0 with respect to the direction of the angular momentum of the rotating QGP, which is approximately perpendicular to the plane of the beam direction and the impact parameter of the two colliding nuclei. In the absence of spin-alignment effects, the probability of finding a vector meson in any of the three spin states (–1, 0, 1) should be equal, with $\rho_{00} = 1/3$.

The ALICE collaboration measured the angular distributions of neutral K^* and ϕ vector mesons via their hadronic decays to $K\pi$ and KK pairs, respectively. ρ_{00} was found to deviate from 1/3 for low-p_T and mid-central collisions at a level of 3σ (figure 1). The corresponding results for ϕ mesons show a deviation of ρ_{00} values from 1/3 at a level of 2σ. The observed p_T dependence of ρ_{00} is expected if quark polarisation via spin–orbit coupling is subsequently transferred to the vector mesons by hadronisation, via the recombination of a quark and an anti-quark from the quark–gluon plasma. The data are also consistent with the initial angular momentum of the hot and dense matter being highest for mid-central collisions and decreasing towards zero for central and peripheral collisions.

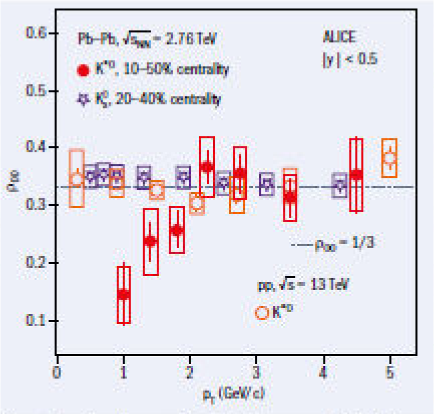


Fig. 1. *The spin alignment of (spin-1) K^{*0} mesons (red circles) can be characterised by deviations from $\rho_{00} = 1/3$, which is estimated here versus their transverse momenta, p_T. The same variable was estimated for (spin-0) K^0_S mesons (magenta stars), and K^{*0} mesons produced in proton–proton collisions with negligible angular momentum (hollow orange circles), as systematic tests.*

The results are surprising, however, as corresponding quark-polarisation values obtained from studies with Λ hyperons are compatible with zero. A number of systematic tests have been carried out to verify these surprising results. K^0_S mesons do indeed yield $\rho_{00} = 1/3$, indicating no spin alignment, as must be true for a spin-zero particle. For proton–proton collisions, the absence of initial angular momentum also leads to $\rho_{00} = 1/3$, consistent with the observed neutral K^* spin alignment being the result of spin–orbit coupling.

The present measurements are a step towards experimentally establishing possible spin–orbit interactions in the relativistic-QCD matter of the quark–gluon plasma. In the future, higher statistics measurements in Run 3 will significantly improve the precision, and studies with the charged K^*, which has a magnetic moment seven times larger than neutral K^*, may even allow a direct observation of the effect of the strong magnetic fields initially experienced by the quark–gluon plasma.

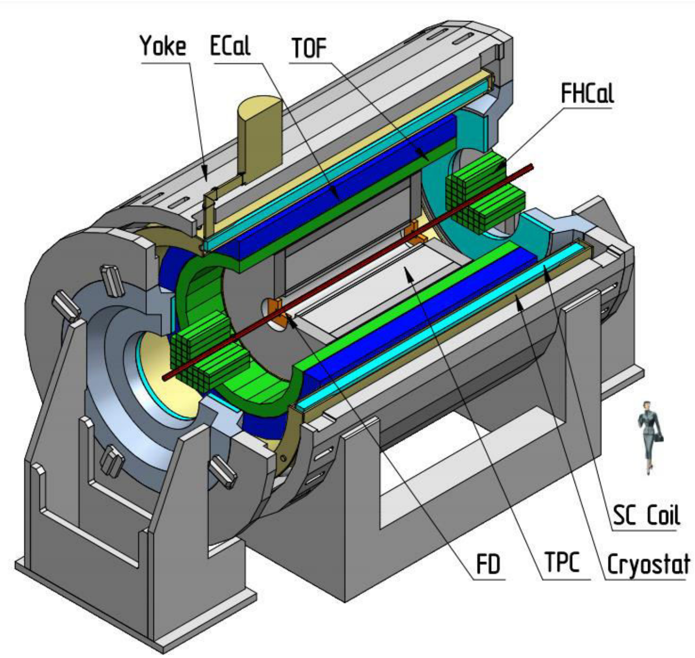
Further reading

ALICE Collab. 2019 arXiv:1910.14408.
ALICE Collab. 2019 arXiv:1909.01281.

MPD experiment, Stage-1

- Stage-1: **TPC, TOF, FFD, FHCAL и ECAL**
- Startup in 2022

- Simulate AuAu@4-11 collisions using different event generators
- Propagate particles through the MPD, 'mpdroot':
  - ✓ Geant (v.3 or v.4) for particle transport
  - ✓ realistic simulation of subsystem response (raw signals)
  - ✓ track/signal reconstruction and pattern recognition



- Basic event and track selections:
  - ✓ event selection: $|Z_{vrtx}| < 50$ cm
  - ✓ track selection:
    - number of TPC hits > 24
    - $|\eta| < 1.0$
    - |DCA to PV| < 3σ for primary tracks
    - V0 topology cuts for weakly decaying secondaries
    - $p_T > 50$ MeV/c
    - TPC-TOF combined π/K/p PID
  - ✓ combinatorial background:
    - event mixing ($|\Delta_{Zvrtx}| < 2$ cm, $|\Delta_{Mult}| < 20$, $N_{ev} = 10$)

TPC: $|\Delta\varphi| < 2\pi$, $|\eta| \leq 1.6$

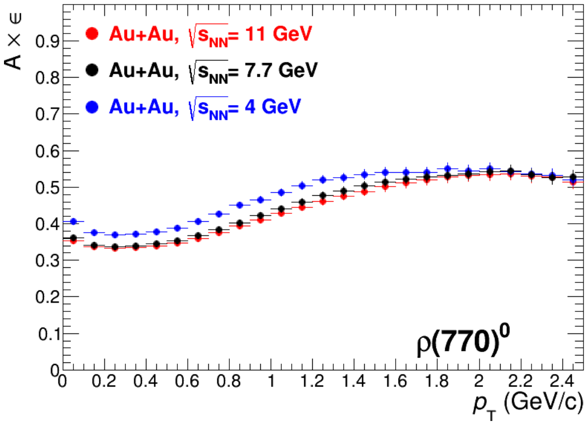
TOF, EMC: $|\Delta\varphi| < 2\pi$, $|\eta| \leq 1.4$

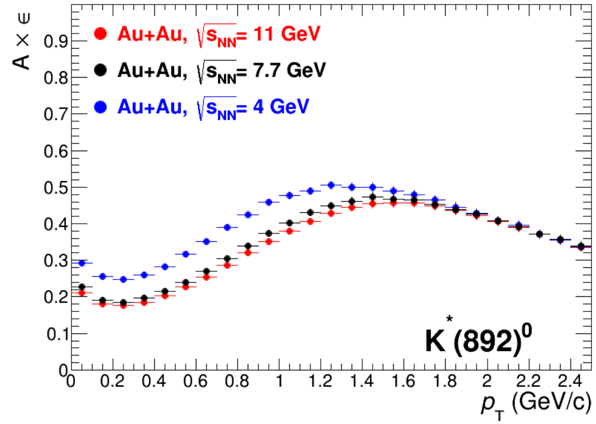
FFD: $|\Delta\varphi| < 2\pi$, $2.9 < |\eta| < 3.3$

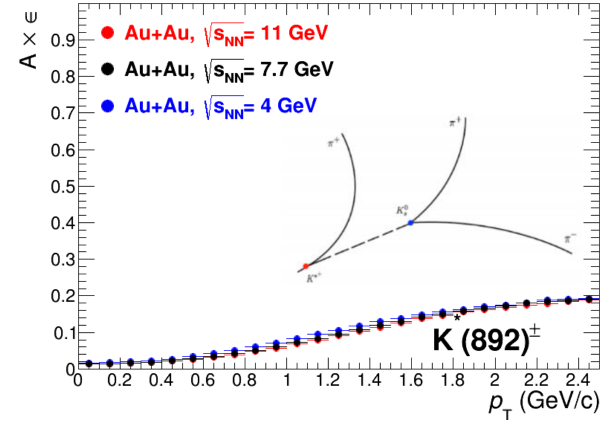
FHCAL: $|\Delta\varphi| < 2\pi$, $2 < |\eta| < 5$

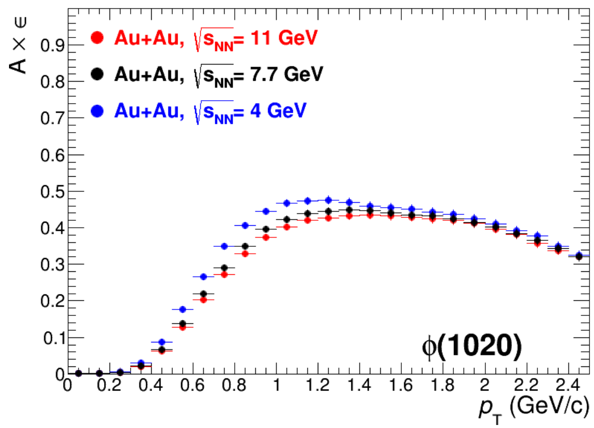
Reconstruction efficiency: ρ(770), K*(892), ϕ(1020), Λ(1520)

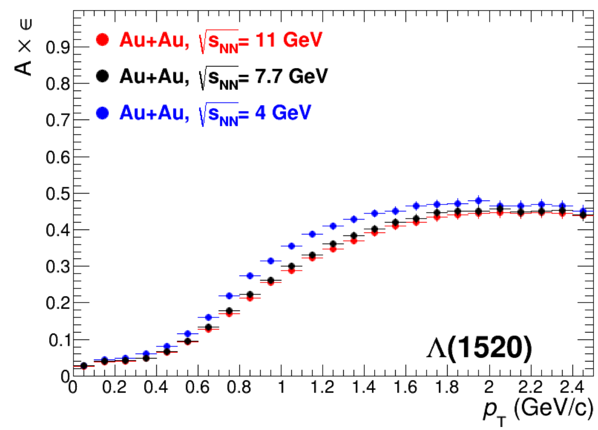
❖ Typical reconstruction efficiencies (A x ∈) in AuAu @ **4**, **7.7** and **11** GeV, |y| < 1









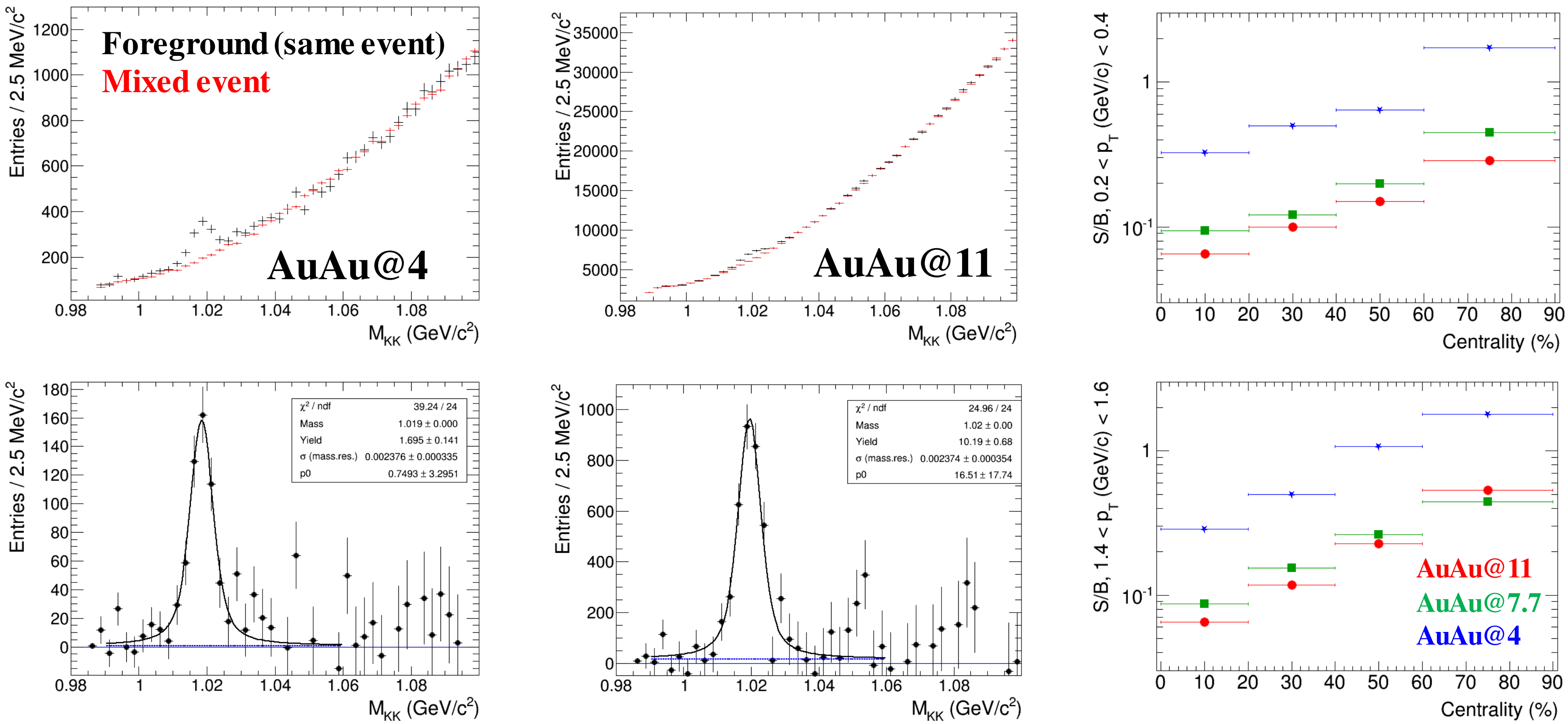


❖ Reasonable efficiencies in the wide p_T range, |y| < 1

❖ Modest multiplicity (and/or $\sqrt{s_{NN}}$) dependence

ϕ(1020), reconstructed peaks, AuAu@4-11

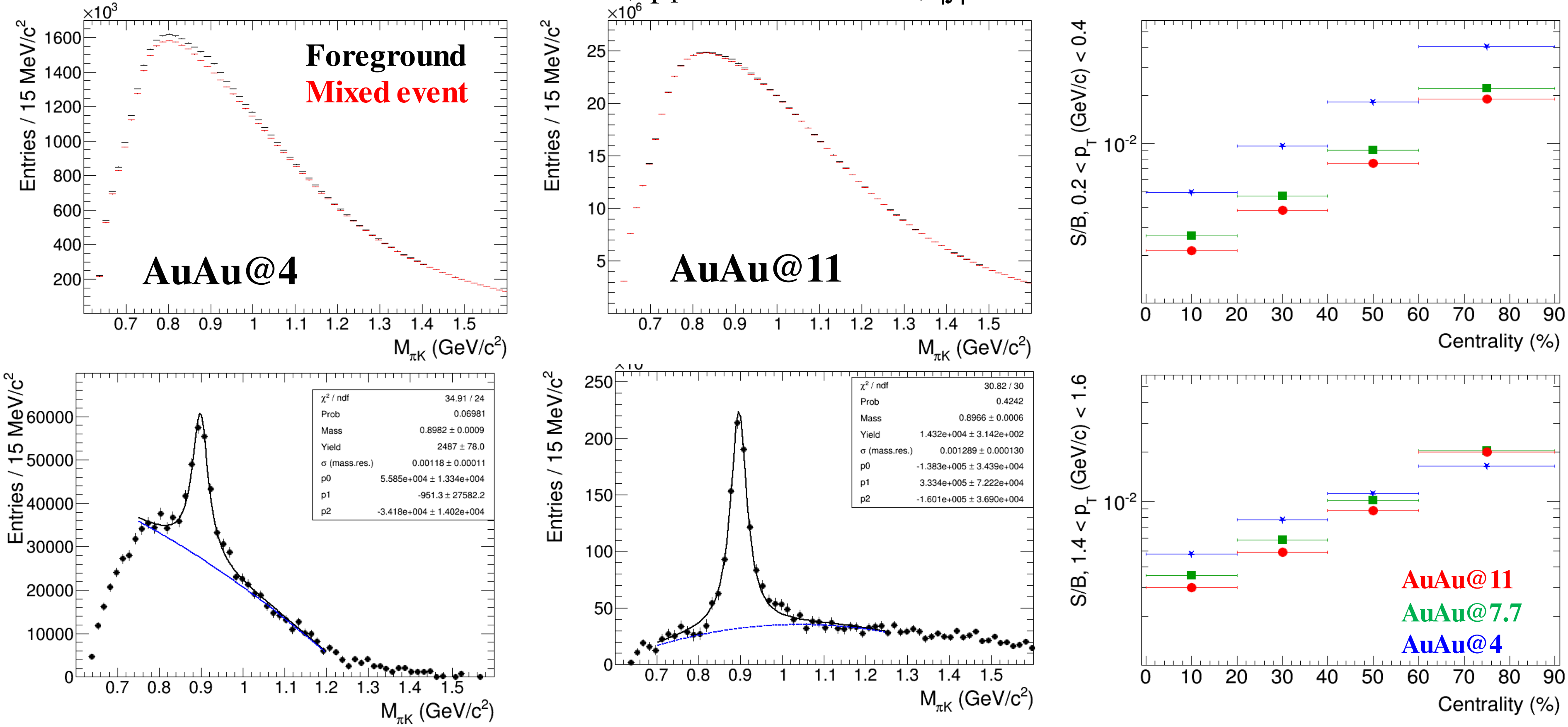
- ❖ UrQMD v.3.4: AuAu@11 (10M events), AuAu@7.7 (5M events), AuAu@4 (5M events)
- ❖ Full chain simulation and reconstruction, p_T = 0.2-0.4 GeV/c, $|y|$ < 1



- ❖ Mixed-event combinatorial background is scaled to foreground at high mass and subtracted
- ❖ Distributions are fit to Voigtian function + polynomial
- ❖ Signal can be reconstructed at p_T > 0.2 GeV/c, high-p_T reach is limited by available statistics
- ❖ S/B ratios deteriorates with increasing centrality and collision energy

$K^*(892)^0$, reconstructed peaks, AuAu@4-11

- ❖ UrQMD v.3.4: AuAu@11 (10M events), AuAu@7.7 (5M events), AuAu@4 (5M events)
- ❖ Full chain simulation and reconstruction, $p_T = 0.2\text{-}0.4$ GeV/c, $|y| < 1$

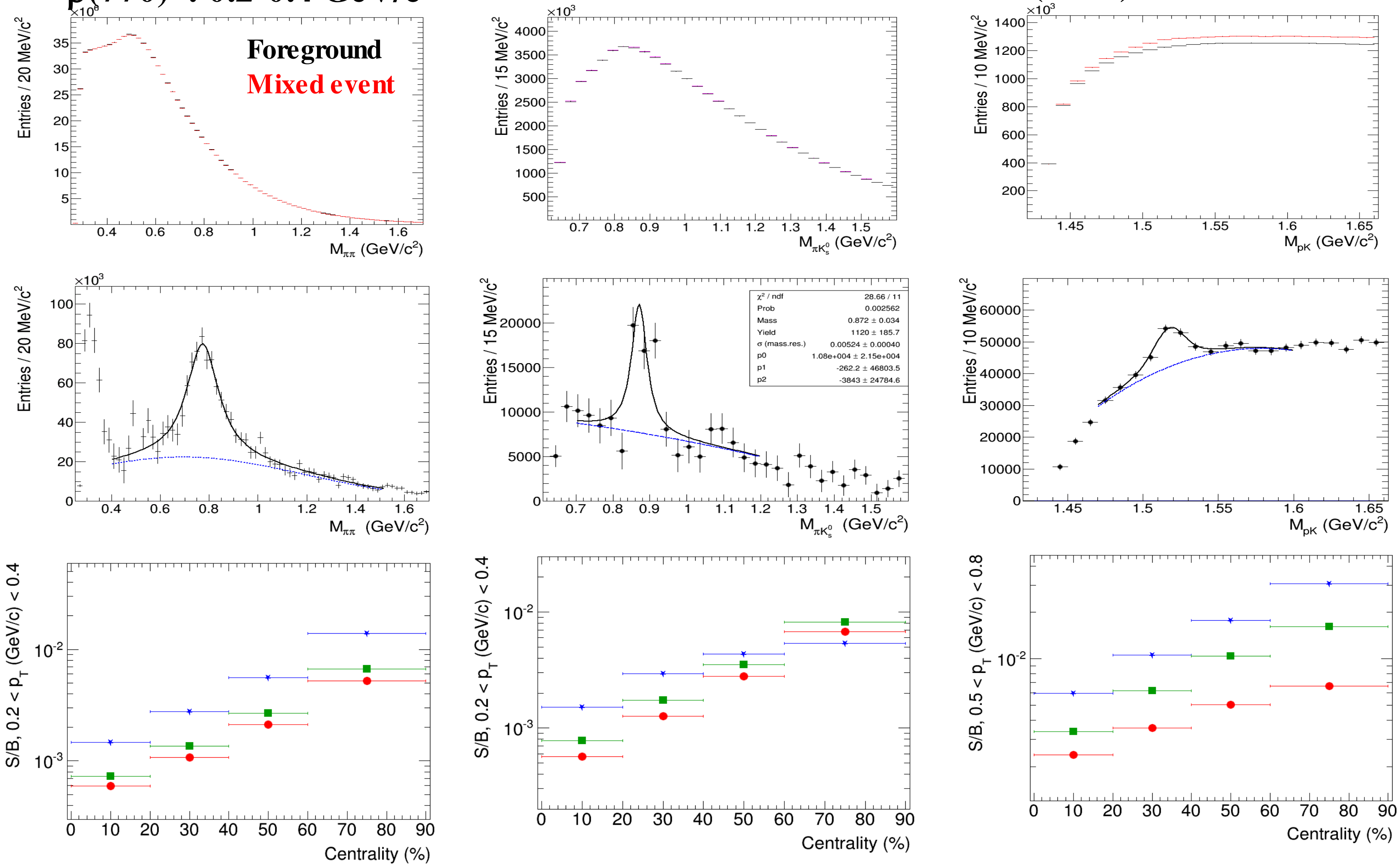


- ❖ Mixed-event combinatorial background is scaled to foreground at high mass and subtracted
- ❖ Distributions are fit to Voigtian function + polynomial
- ❖ Signal can be reconstructed at $p_T > 0.2$ GeV/c, high-p_T reach is limited by available statistics
- ❖ S/B ratios deteriorates with increasing centrality and collision energy

K^*(892) and Λ(1520), reconstructed peaks, AuAu@7

- UrQMD v.3.4: AuAu@11 (10M events), **AuAu@7.7** (5M events), AuAu@4 (5M events), |y| < 1

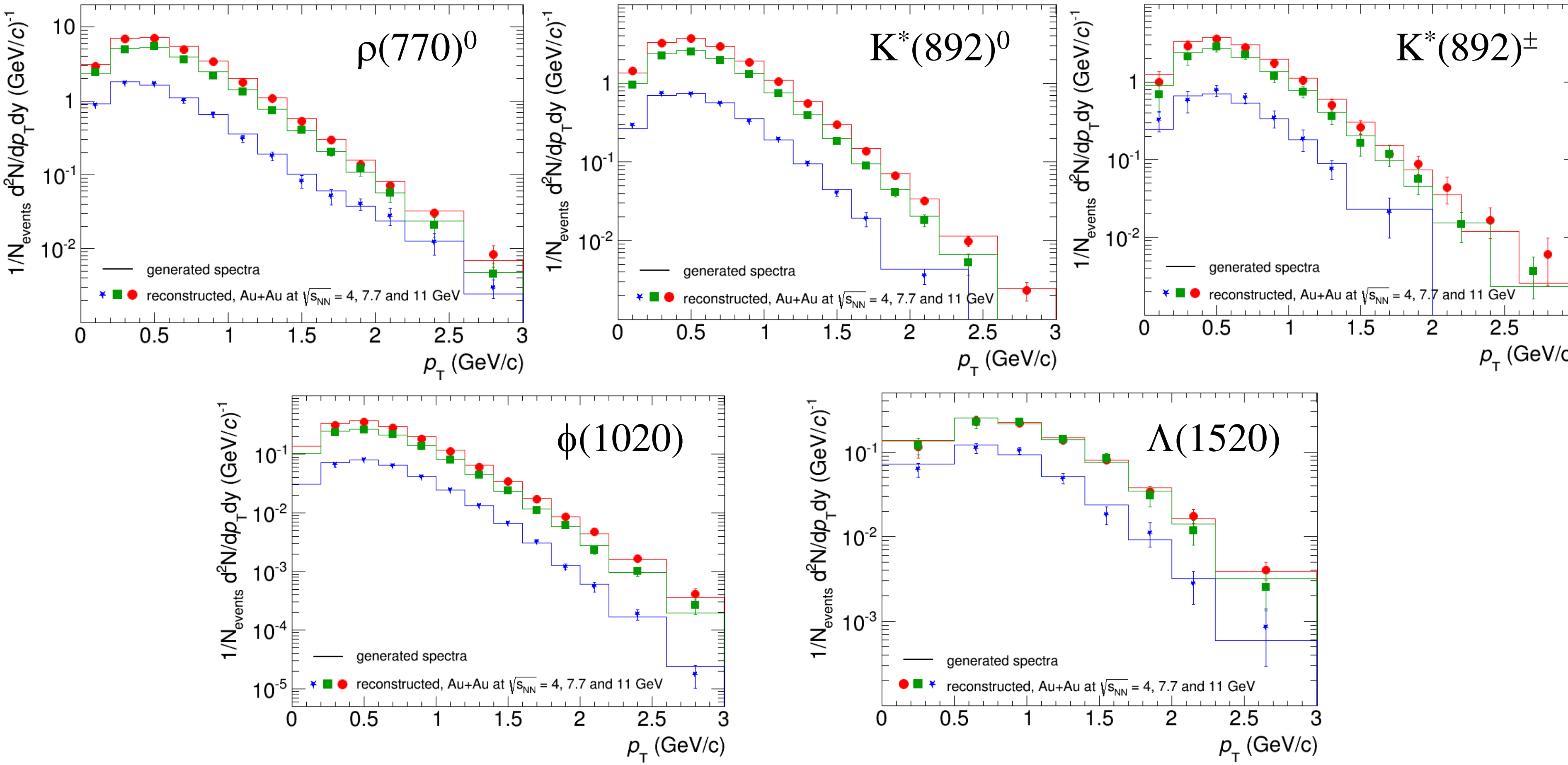
ρ(770)^0: 0.2-0.4 GeV/c **$K^{*\pm}$: 0.2-0.4 GeV/c** **Λ(1520) : 0.5-0.8 GeV/c**



- Signal can be reconstructed from zero momentum, high-p_T reach is limited by statistics
- S/B ratios deteriorates with increasing centrality and collision energy

MC closure tests: ρ, $K^{*0,\pm}$, ϕ, Λ^*

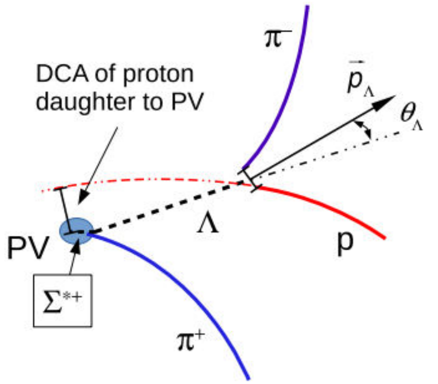
- UrQMD v.3.4: AuAu@11 (10M events), AuAu@7.7 (5M events), AuAu@4 (5M events)
- Full chain simulation and reconstruction, p_T ranges are limited by the possibility to extract signals, $|y| < 1$



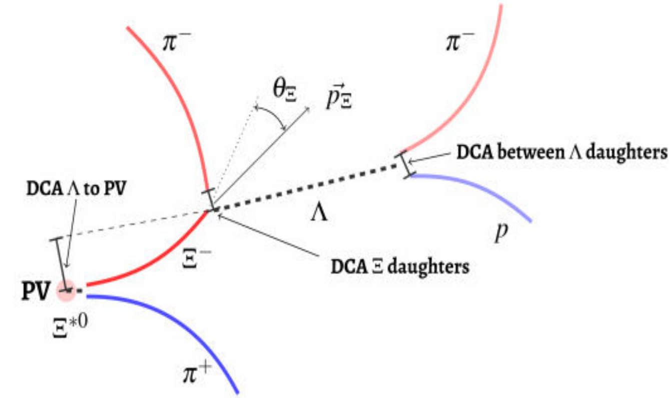
- Reconstructed spectra match the generated ones within uncertainties
- Measurements are possible starting from ~ zero momentum, sample p_T spectra in a wide range
- Maximum raw yields (smallest stat. uncertainties) are extracted at ~ 300 MeV/c

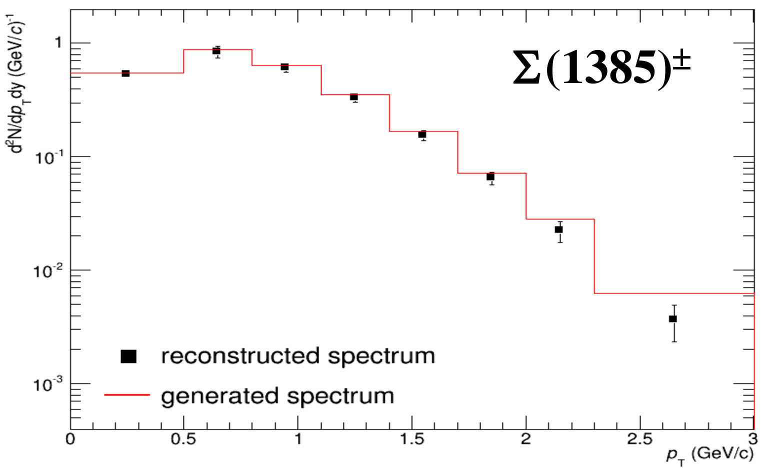
$\Sigma(1385)^{\pm}$ and $\Xi(1530)^{0}$ in AuAu@11

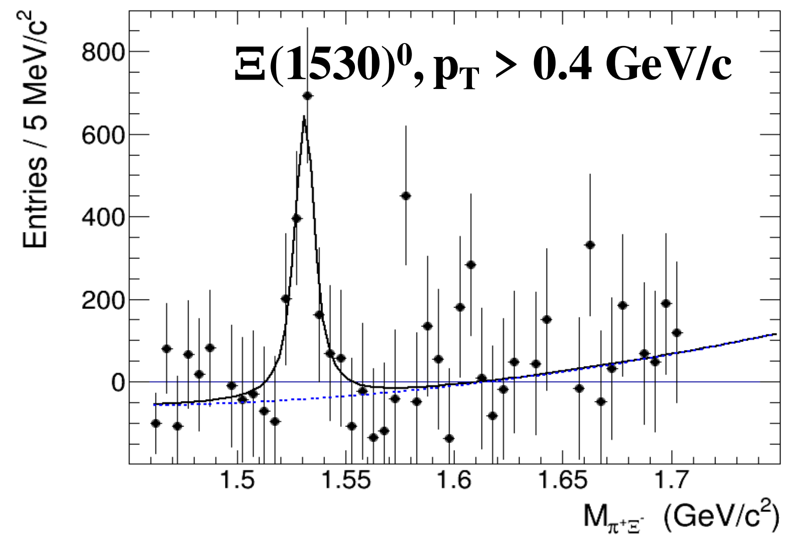
$\Sigma(1385)^{\pm} \rightarrow \pi^{\pm}\Lambda$ ($\Lambda \rightarrow p\pi$)



$\Xi(1530)^{0} \rightarrow \pi^{+}\Xi^{-}$ ($\Xi^{-} \rightarrow \Lambda\pi^{-}$, ($\Lambda \rightarrow p\ \pi^{-}$))







- $\Sigma(1385)^{\pm}$ signals can be reconstructed starting from zero momentum, Monte Carlo closure test is passed
- For $\Xi(1530)^{0}$ observe a hint of a signal at $p_T > 0.4$ GeV/c, statistics-hungry measurement → larger data samples and embedded simulations are required.

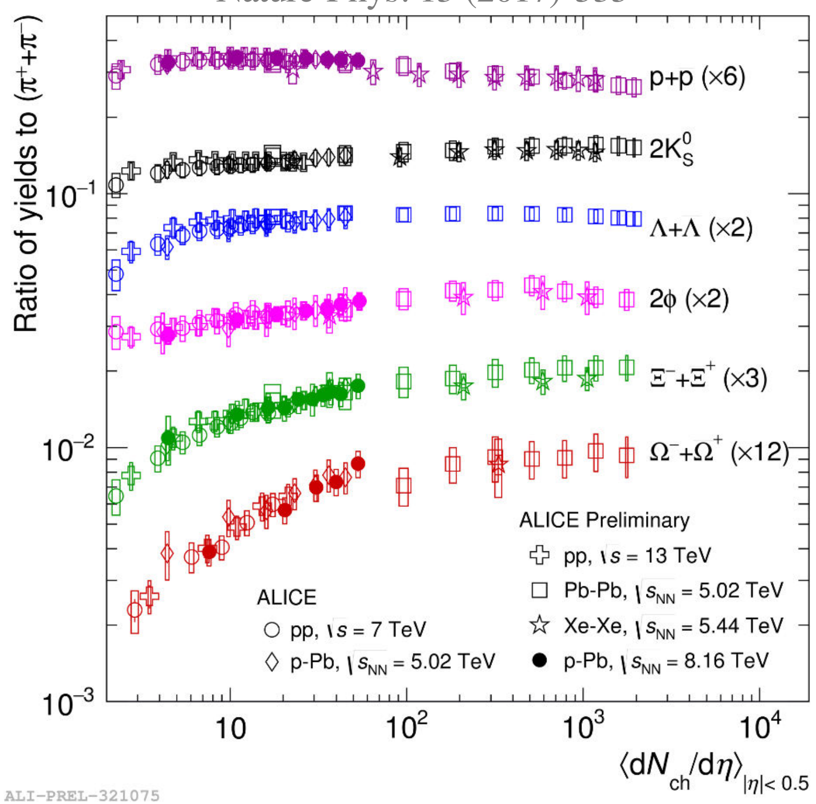
Summary

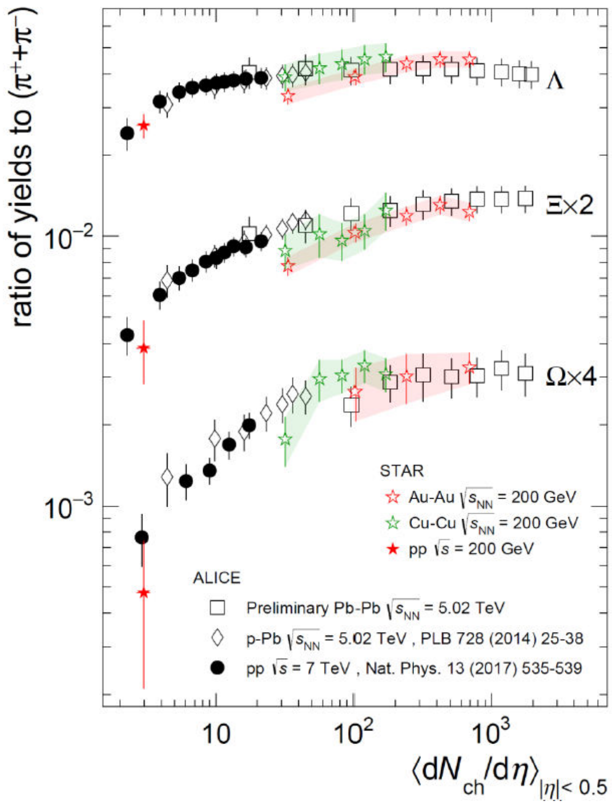
- ✓ Measurement of resonances contribute to the MPD physical program
- ✓ Resonances are expected to be very sensitive to the properties of the partonic/hadronic medium produced in heavy-ion collisions at NICA energies
- ✓ First-look measurements for resonances with the MPD detector are possible in a wide pT range from zero momentum up to ~ 3 GeV/c with ~10^7 sampled Au+Au collisions at $\sqrt{s_{NN}}$ = 4-11 GeV → plausible for year-1 operation
- ✓ More detailed and multiplicity-dependent studies would require x10-50 larger statistics, especially for multi-stage decays of $K^*(892)^{\pm}$, $\Sigma(1385)^{\pm}$ and $\Xi(1520)^0$

BACKUP

Enhanced strangeness production: RHIC & LHC

Nature Phys. 13 (2017) 535

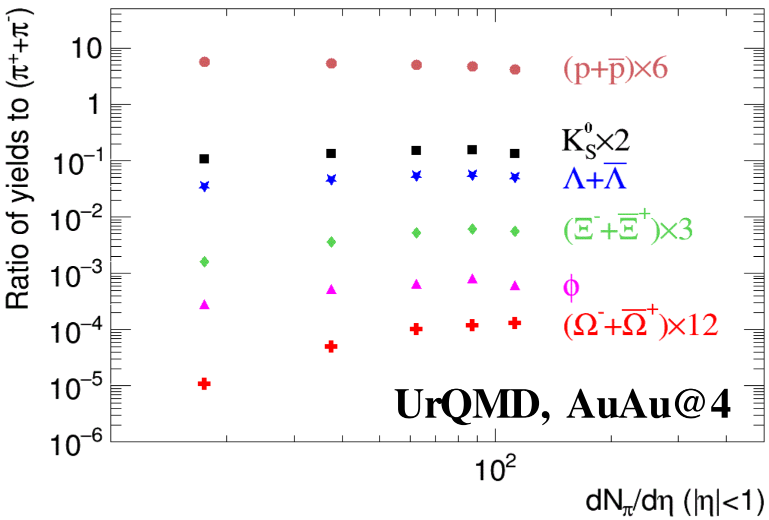


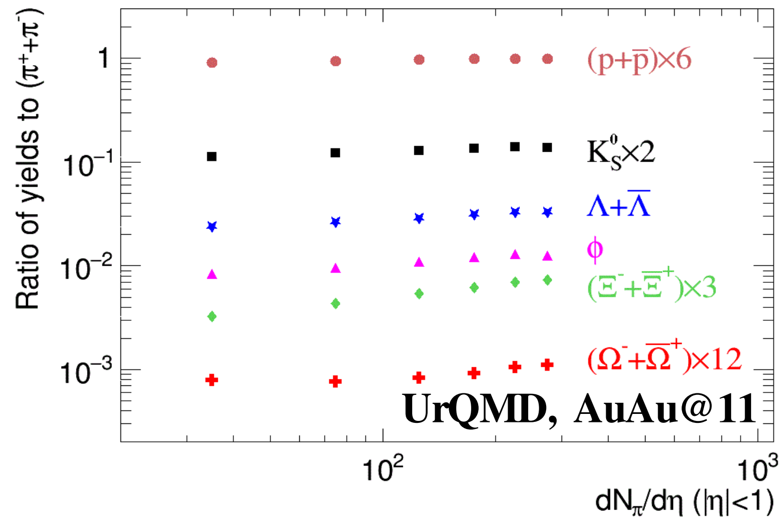


- Strangeness enhancement increases with strangeness content and charged particle multiplicity
- Smooth evolution vs. multiplicity in pp, p-Pb, Xe-Xe, Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$-13 TeV
  → hadrochemistry is driven by the multiplicity
- STAR measurements at $\sqrt{s_{NN}} = 200$ GeV are in agreement
- Origin of the strangeness enhancement in small/large systems is still debated
- φ/K is flat vs. multiplicity → behaves like a particle with open strangeness
  → inconsistent with canonical suppression models

Strangeness at NICA

- UrQMD, PHSD, AMPT, EPOS …
- Models predict enhanced production of particles with strangeness

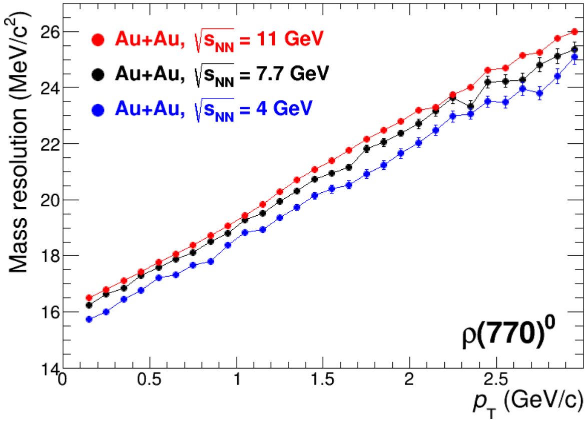


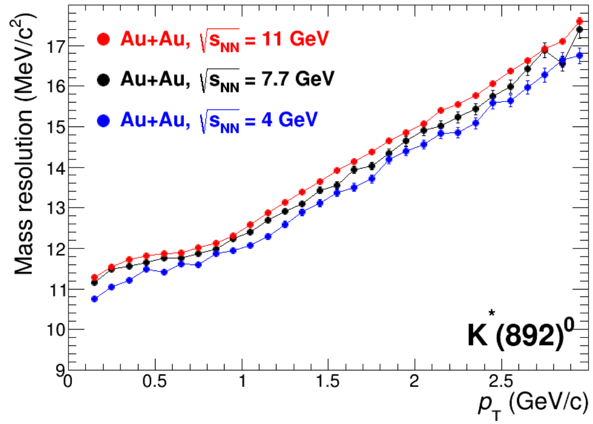


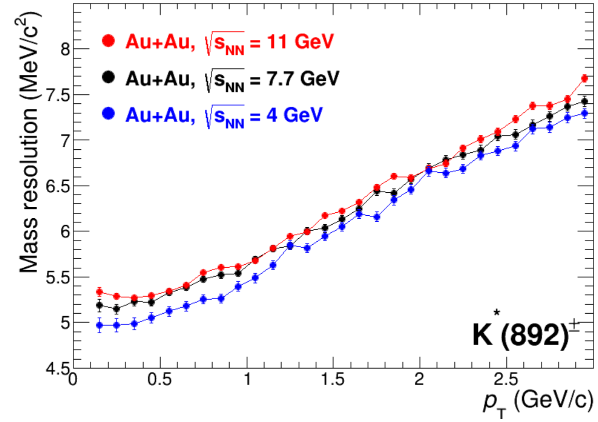
- predictions of event generators are qualitatively similar
- enhancement is more pronounced for particles containing a larger number of s-quarks
- relative enhancement is stronger at lower collision energies
- ϕ(1020) meson with hidden strangeness (a key observable) behaves like a hadron with open strangeness

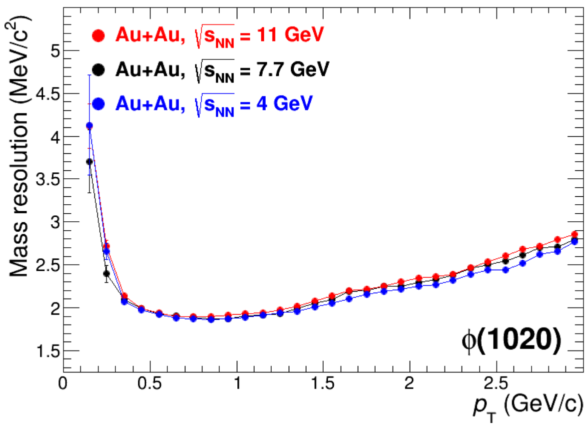
Mass resolution:
ρ(770), K*(892), φ(1020), Λ(1520)

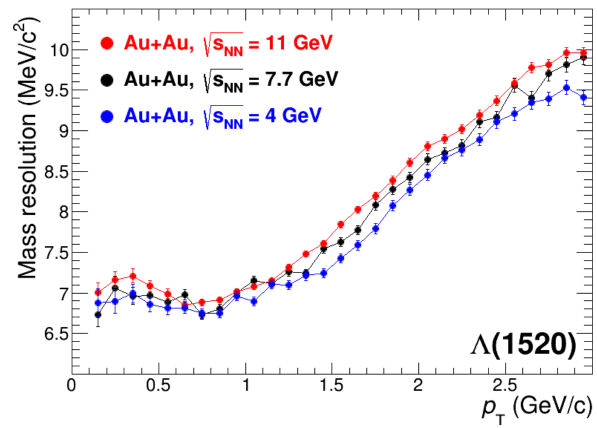
❖ Detector mass resolution ($m_{reconstructed} - m_{generated}$) in AuAu @ **4**, **7.7** and **11** GeV, $|y| < 1$











❖ Acceptable mass resolution

❖ Modest multiplicity (and/or $\sqrt{s_{NN}}$) dependence