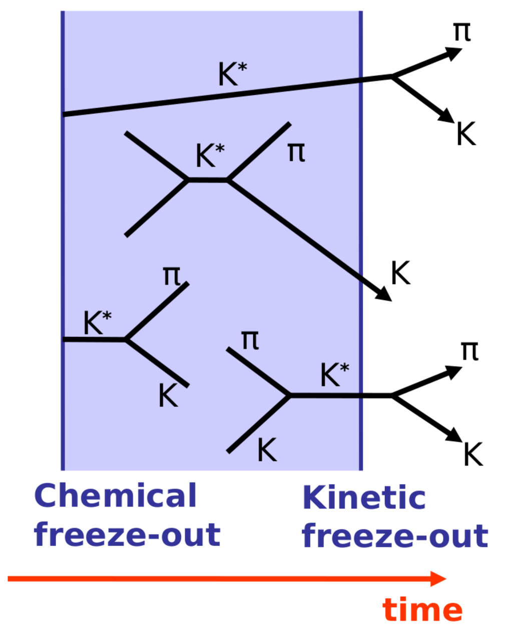
$K^*(892)^0$ production in p+p interactions at SPS energies from NA61/SHINE

Angelika Tefelska for the NA61/SHINE Collaboration
Warsaw University of Technology

Motivation

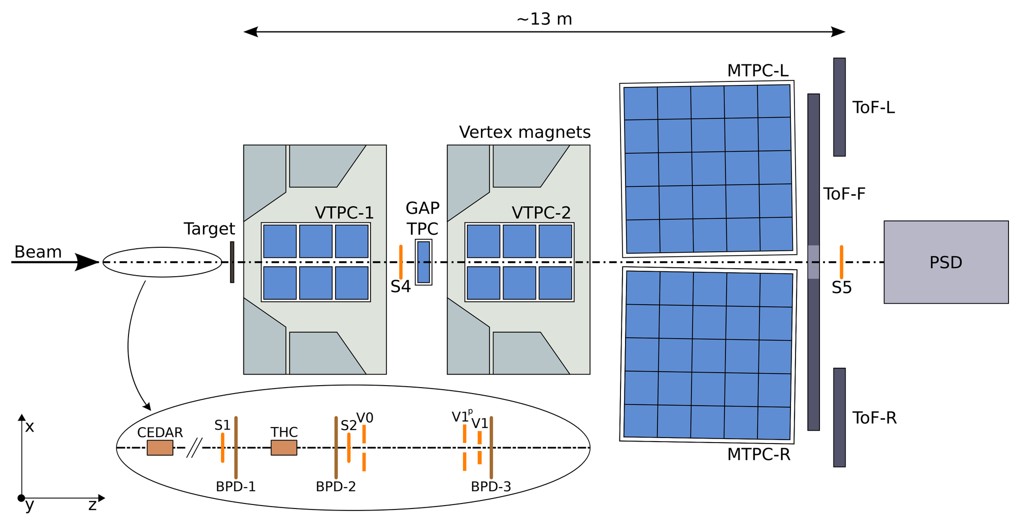
- the resonance yield is affected by regeneration and rescattering processes
- momenta of K^* decay products can be modified due to elastic scatterings during the rescattering process → **Suppression of observed K^* yield**
- K^*/K^- or K^*/K^+ → **time between chemical and kinetic freeze-outs**, properties of hadron gas phase (STAR, PR C71, 064902, 2005; C. Blume, APP B43, 577, 2012)
- mass and/or width changes for A+A interactions → **chiral symmetry restoration** (G.E. Brown, M. Rho, PRL 66, 2720, 1991)
- the reference data to Blast-Wave models and statistical Hadron Resonance Gas models
- resonance measurements in p+p interactions are useful as reference for larger systems



NA61/SHINE facility

The NA61/SHINE experiment uses a large acceptance hadron spectrometer located in the CERN North Area at the SPS accelerator. NA61/SHINE performs 2D scan with energy and system size (p+p, p+Pb, Be+Be, Ar+Sc, Xe+La, Pb+Pb at beam momenta 13A–150(8)A GeV/c). The experimental setup consists of:

- 8 Time Projection Chambers → p, q, dE/dx
- 3 Time of Flight walls → m^2
- Projectile Spectator Detector → centrality and event plain
- Vertex Detector → open charm
- beam monitoring system

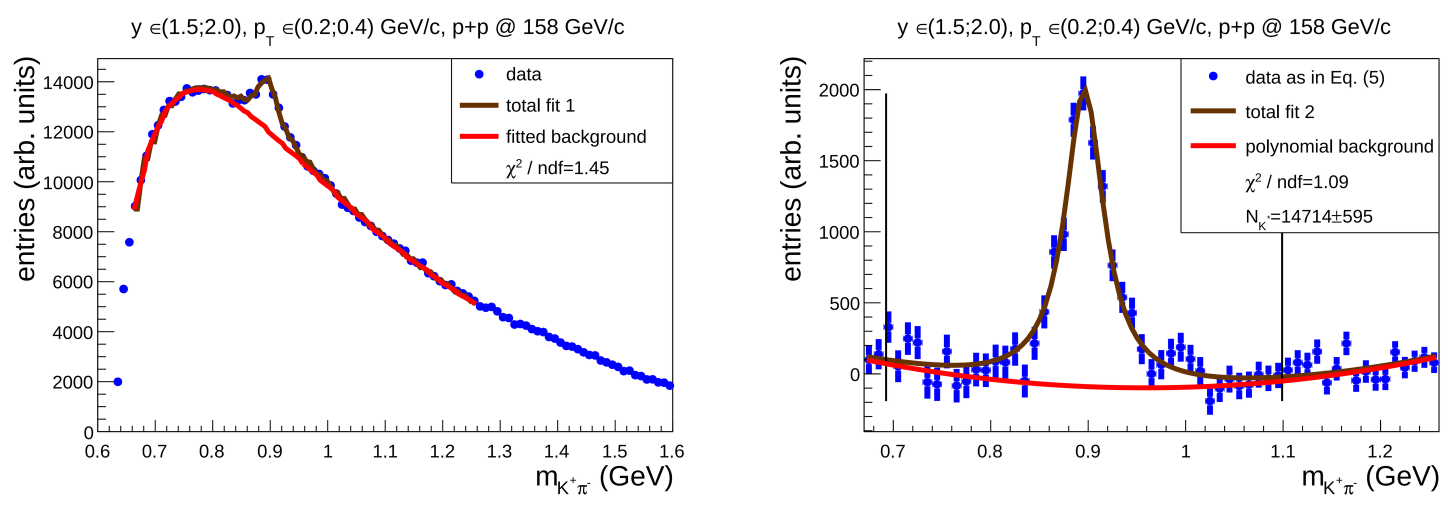


Method

The raw numbers of $K^*(892)^0$ are obtained by using ***the template method***, in which, the invariant mass spectra of data (blue points) are fitted with a function:

$$f(m_{K^+\pi^-}) = a \cdot T^{MC}_{res}(m_{K^+\pi^-}) + b \cdot T^{DATA}_{mix}(m_{K^+\pi^-}) + c \cdot BW(m_{K^+\pi^-}) \quad (1)$$

- T^{MC}_{res} – resonance background template from reconstructed Monte Carlo data ($K^+\pi^-$ pairs, which come from resonance decays with exception of $K^*(892)^0$)
- T^{DATA}_{mix} – the background estimated based on the mixing method
- BW – Breit-Wigner distribution
- a, b, c – normalisation constant (a+b+c=1)



In left figure, the fitted invariant mass spectra, using Eq. 1, is presented by brown curves (total fit 1). The red lines (fitted background) show the same fitted functions but without the signal description elements (BW). The spectra after background subtraction is shown in right figure. An additional background is described by the second order polynomial curve (the red line).

More details about methodology: A.Tefelska, PoS CORFU2018, 203, 2019.

Acknowledgements

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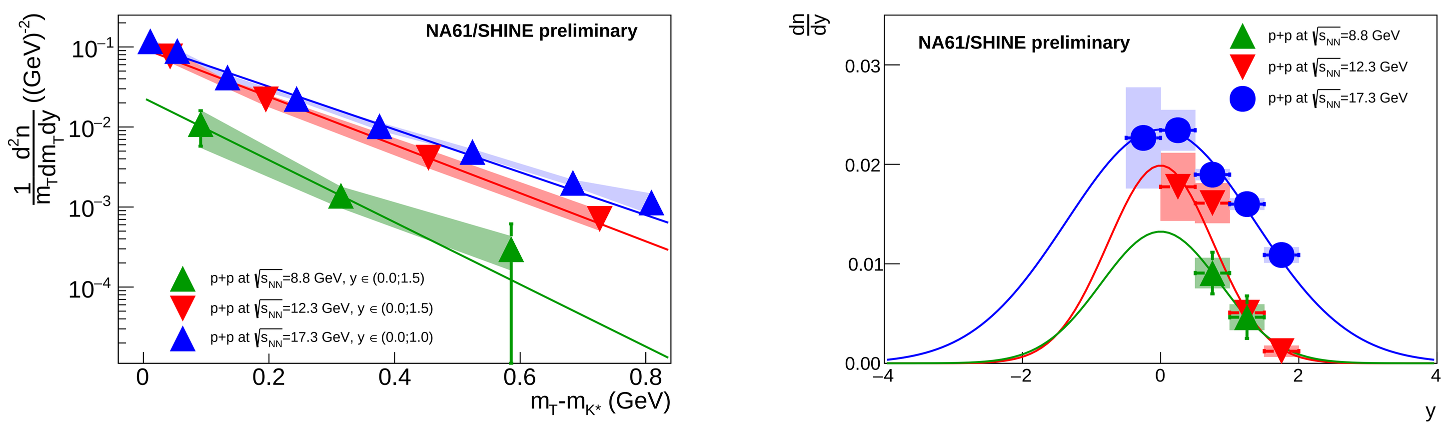
Contact: angelika.tefelska@cern.ch

Results

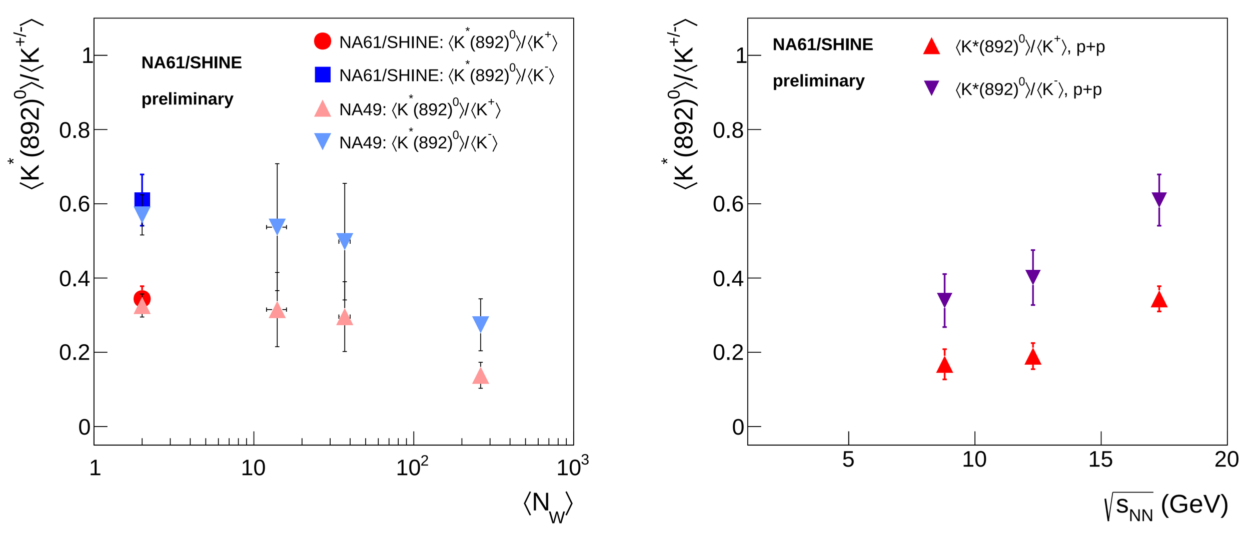
First results on $K^*(892)^0$ resonance production via its $K^+-\pi^-$ decay mode in inelastic p+p collisions at beam momenta 40–158 GeV/c ($\sqrt{s_{NN}}$ = 8.8–17.3 GeV). They are corrected for the losses of the $K^*(892)^0$ due to the dE/dx requirement, geometrical acceptance, reconstruction efficiency, losses due to the trigger bias, detector acceptance as well as the quality cuts applied in the analysis. The mean multiplicities of $K^*(892)^0$ are calculated by summing points (only for y>0) and adding integral of gaussian fit in non-measured area.



The NA61/SHINE $\langle K^*(892)^0\rangle/\langle K^+\rangle$ and $\langle K^*(892)^0\rangle/\langle K^-\rangle$ yield ratios for p+p collisions can be used to estimate the time between chemical and kinetic freeze-outs in Pb+Pb. Assuming no regeneration processes and following PR C71, 064902, 2005:

$$\left.\frac{K^*}{K}\right|_{kinetic} = \left.\frac{K^*}{K}\right|_{chemical} e^{-\frac{\Delta t}{\tau}} \quad (2)$$

- $\left.\frac{K^*}{K}\right|_{kinetic}$ can be taken as $\langle K^*(892)^0\rangle/\langle K^{+/-}\rangle$ ratio for central Pb+Pb (NA49),
- $\left.\frac{K^*}{K}\right|_{chemical}$ can be taken as $\langle K^*(892)^0\rangle/\langle K^{+/-}\rangle$ ratio in inelastic p+p interactions (NA61 preliminary result),
- τ is the $K^*(892)^0$ lifetime of 4.17 fm/c (PDG, CPC, 40, 100001, 2016),
- Δt is the time between chemical and kinetic freeze-outs.



The plots were prepared based on data: NA49 K^* (PR C84, 064909, 2011), NA49 $K^{+/-}$ (EPJC 68, 1, 2010; PRL 94, 052301, 2005; PR C66, 054902, 2002) and NA61/SHINE $K^{+/-}$ (EPJC 77, 671, 2017).

Left figure: For Pb+Pb at 158A GeV/c, the calculated times between chemical and kinetic freeze-outs assuming no regeneration processes are equal:

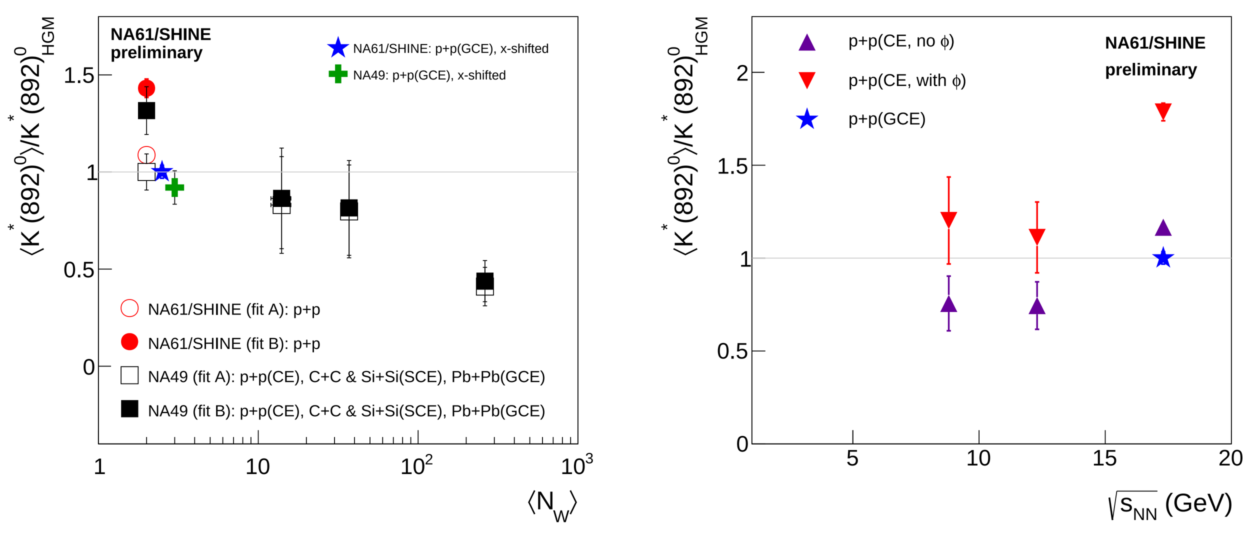
- 3.8 ± 1.1 fm/c for $K^*(892)^0/K^+$
- 3.3 ± 1.2 fm/c for $K^*(892)^0/K^-$

Right figure: Reference heavy ion data needed to estimate time between freeze-outs at lower energies (40 and 80 GeV/c).

The statistical Hadron Resonance Gas Models (HGM) are commonly used to predict particle multiplicities in elementary and nucleus-nucleus collisions, using as adjustable parameters the chemical freeze-out temperature T_{chem}, the baryochemical potential μ_B, strangeness saturation parameter γ_S, etc.

The $\langle K^*(892)^0\rangle$ values are compared with predictions of two HGM models described in: F. Becattini et al., PR C73, 044905, 2006 (left plot) and V.V. Begun et al., PR C98, 054909, 2018 (right and left plots). The two versions of fits (PR C73) where used to create left plot:

- Fit B: uses "standard" γ_s; for p+p Ξ and Ω baryons excluded from fit
- Fit A: γ_s replaced by $\langle s\bar{s}\rangle$; for p+p ϕ meson excluded from fit



The p+p data for 158 GeV/c can be described by GCE and CE only for fit without ϕ.
More results in: A.Tefelska, PoS CORFU2018, 203, 2019.