THERMAL ASPECTS OF AU+AU COLLISIONS AT 1.23A GEV

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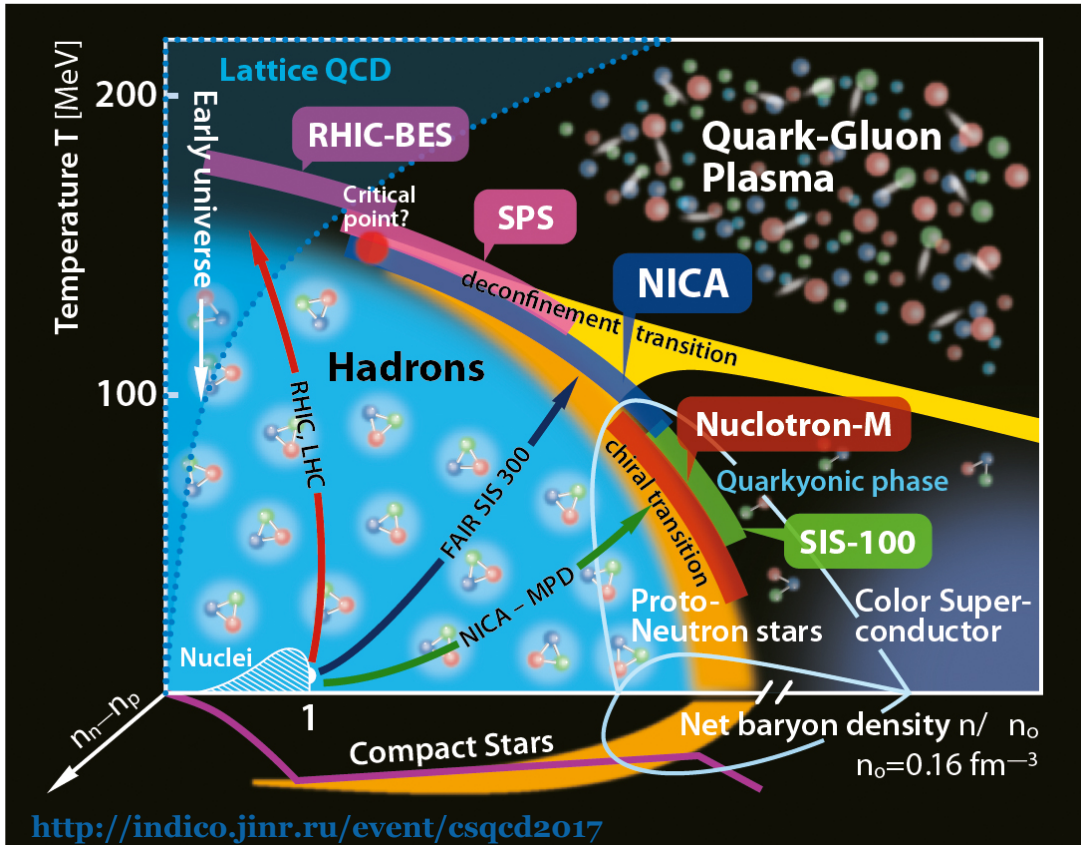
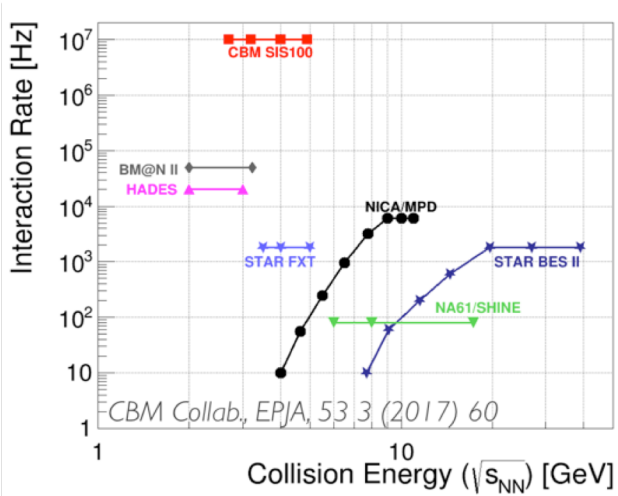
From QCD matter to hadrons

International Workshop XLVII on Gross Properties of Nuclei and Nuclear Excitations
Hirschegg, Kleinwalsertal, Austria, January 13-19, 2019

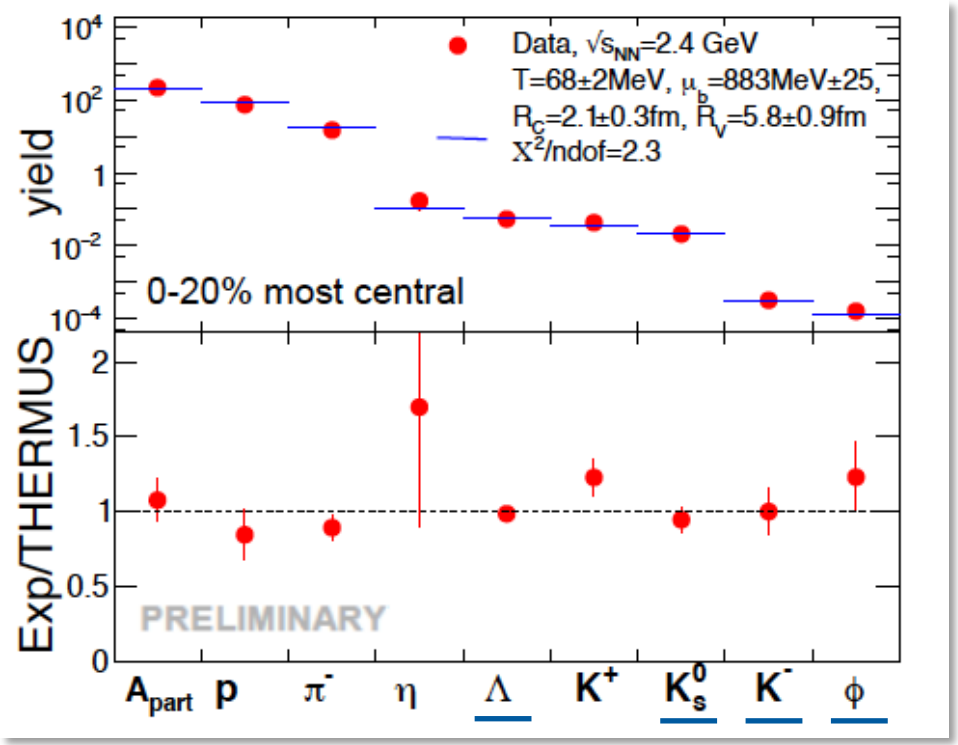
Can SIS18 contribute to the exploration of QCD phase diagram?



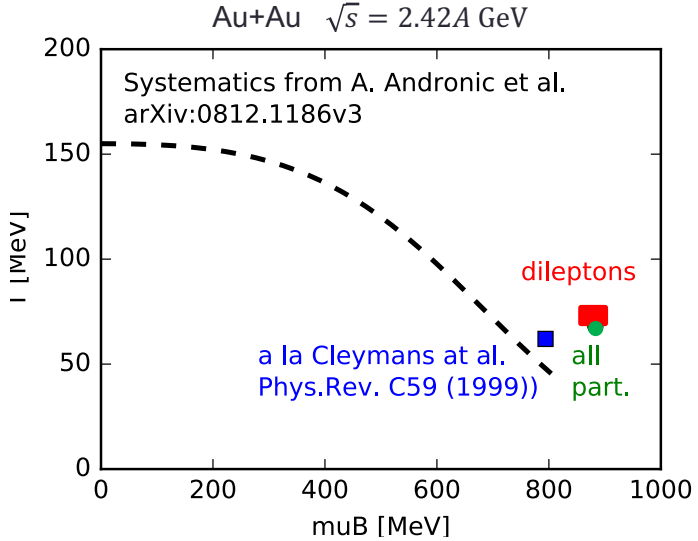
high-μ_B!



SHM fit to multiplicities from Au+Au



- Fit is obtained from THERMUS using a (R_c) canonical treatment of strangeness.
- Note the small freeze-out volume driven by the "large" temperature.
- All strangeness channels below NN threshold

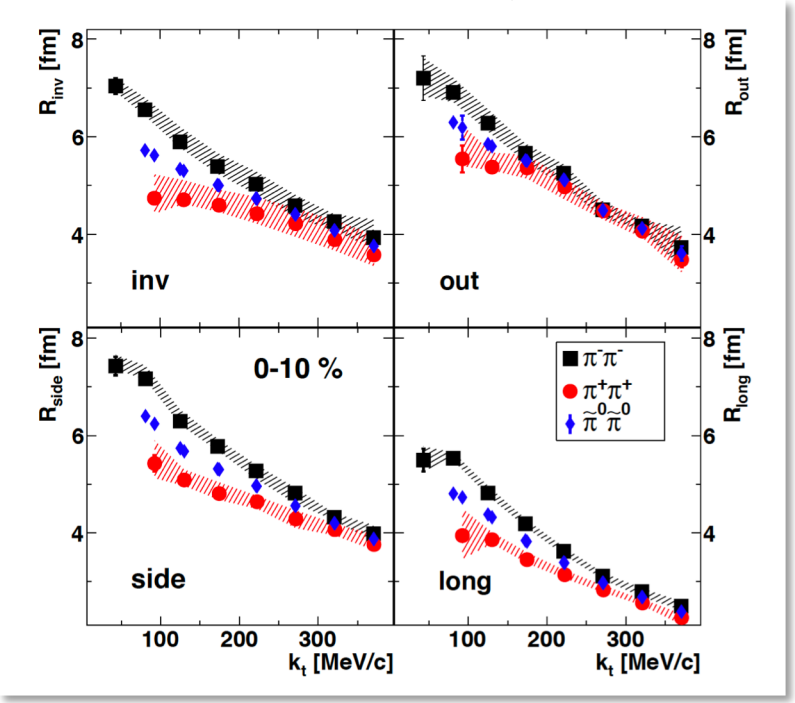


Two-pion correlations Au+Au 1.23*A* GeV

Coulomb effect treated according to GB, PBM (NPA 610, 286c (1996))

$\rightarrow \tilde{\pi}^0\tilde{\pi}^0$.

HADES, arXiv:1811.06213



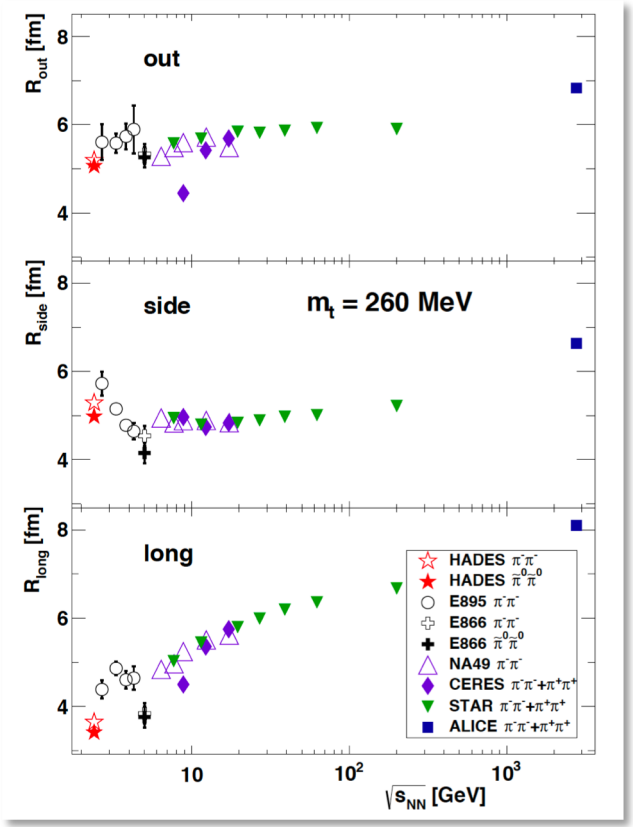
$V_{2\pi} = (2\pi)^{3/2} R_{\mathrm{side}}^2 R_{\mathrm{long}}$

$V_{2\pi}(@100) \simeq 2550\ \mathrm{fm}^3$

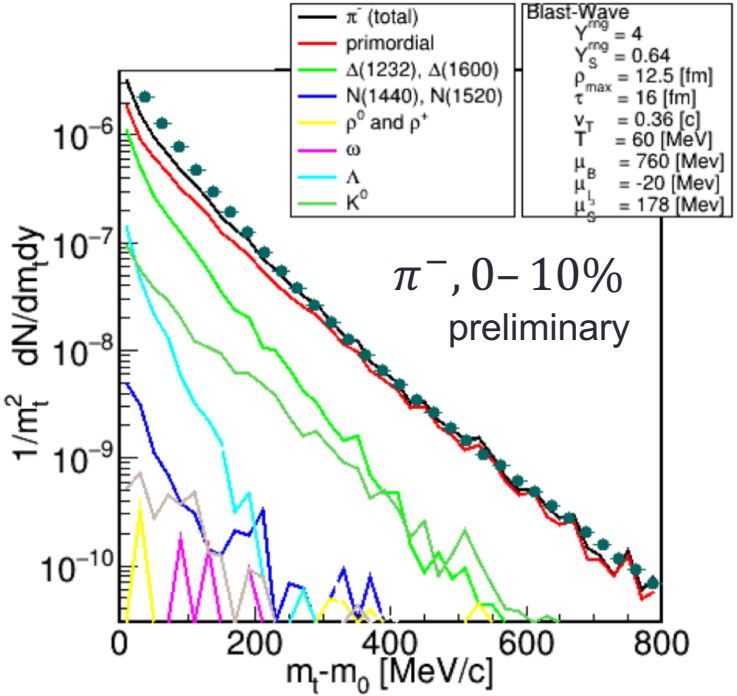
$V_{HRG}(\mathrm{full}) \simeq 817\ \mathrm{fm}^3$

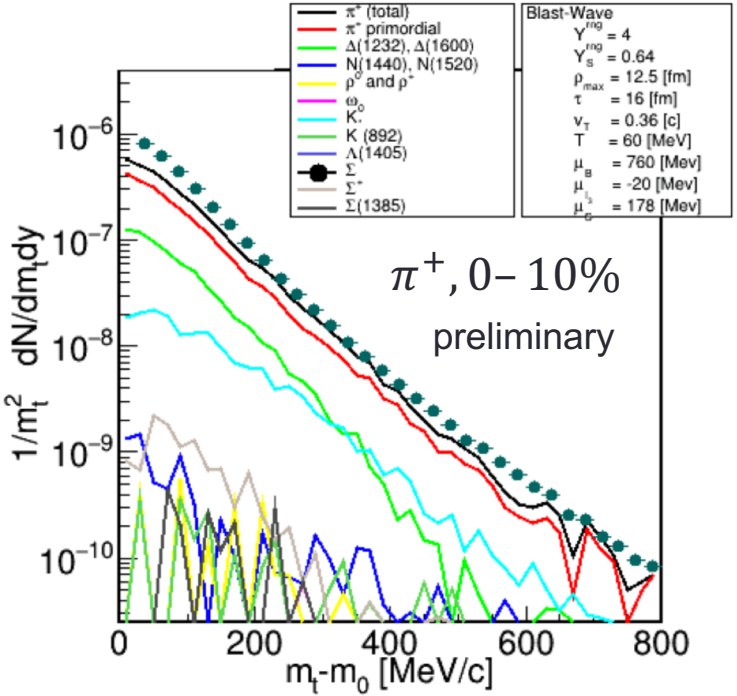
$V_{HRG}(\mathrm{red.}) \simeq 4570\ \mathrm{fm}^3$

$A_{part} = 303 \pm 11$



“Thermal cocktail” for pion production (THERMINATOR)



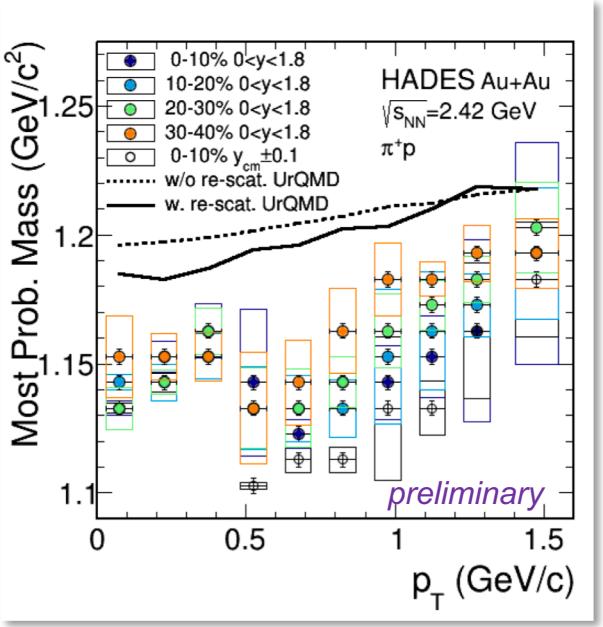


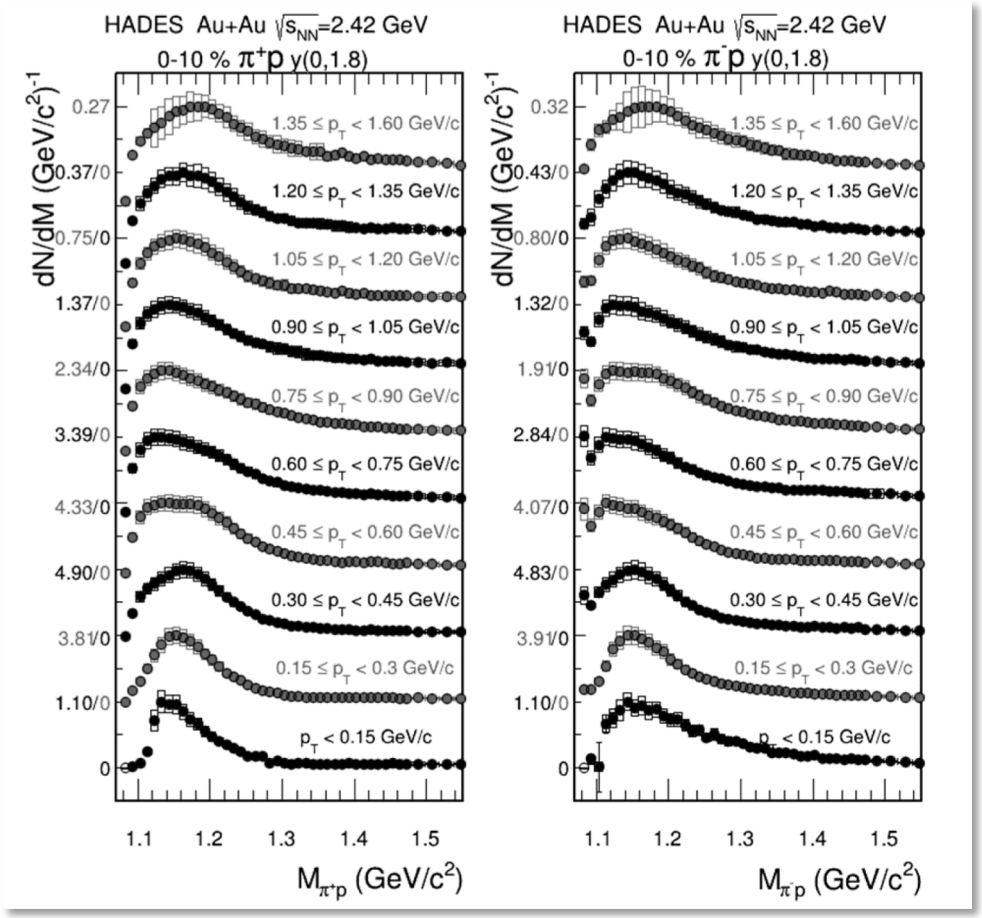
- Ongoing work, in collaboration with W. Florkowski and group: bell-shaped rapidity distribution, true Δ line shapes, flow profile.

More correlations: πp

Reconstructed Δ shows sifted maximum:

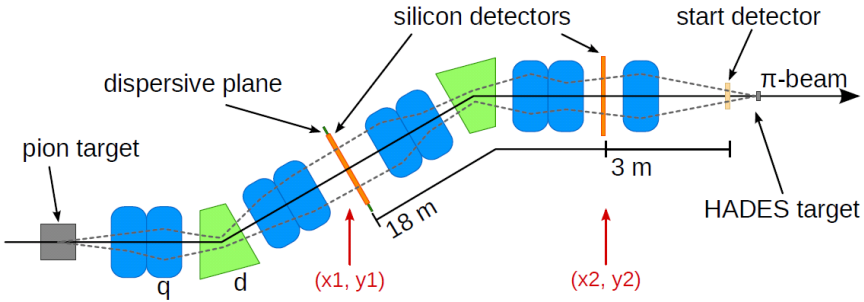
- Effect of the phase space
- an rescattering ?

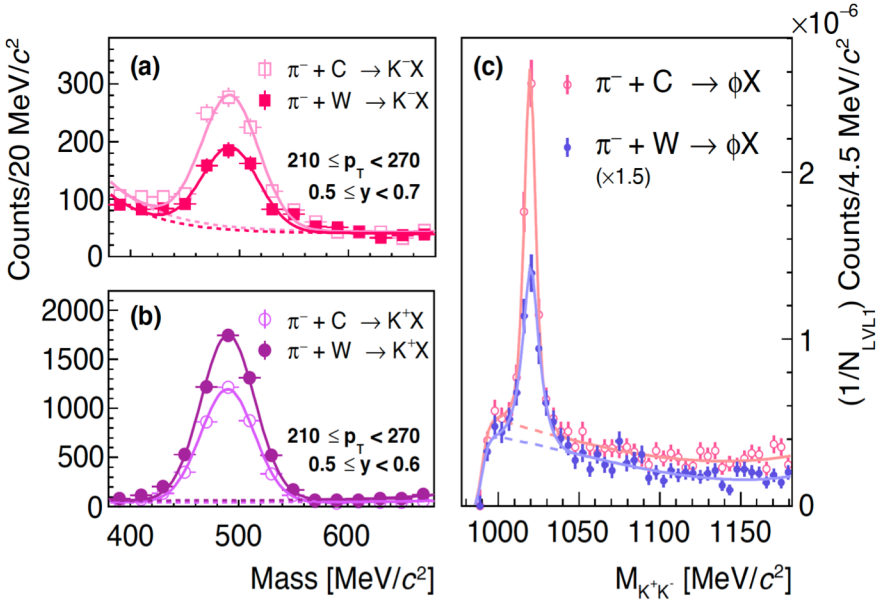




Meson production and propagation in cold matter

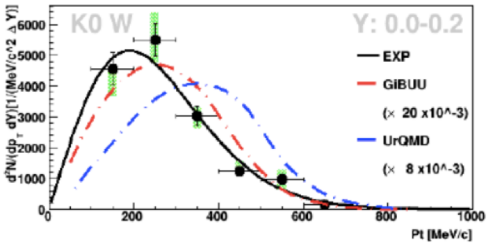
- $\pi^-(1.7\ \mathrm{GeV/c}) + C, W$
- $\sqrt{s(\pi N)} \simeq 2.07\ GeV$ ($\pm$Fermi momentum)
- Inclusive spectra for: $K^+, K^0, K^-, \Lambda, \phi$

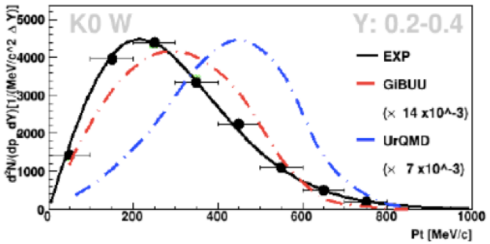


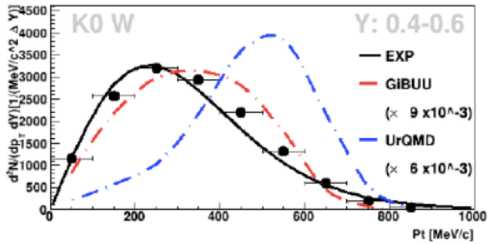


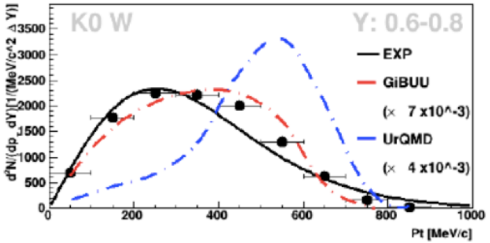
HADES: NIM-A 478-511 (2002), Eur. Phys. J. A53 (2017)

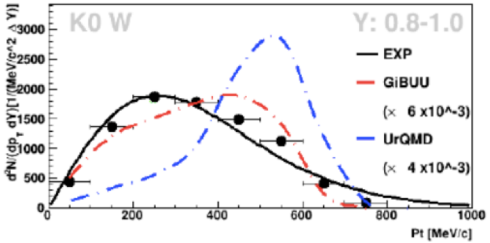
p_t spectra of K^0 for different rapidity bins (A=W, $Y_{CM} = 0.76$)

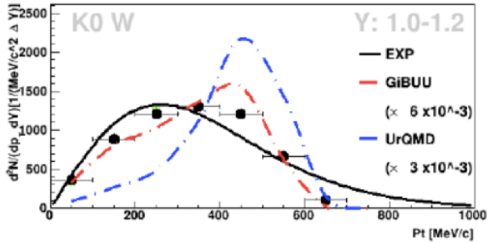


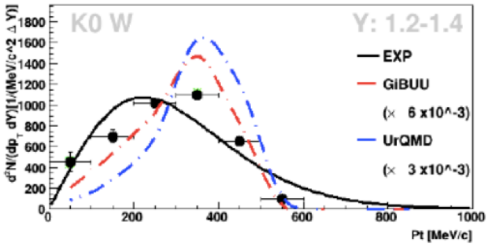


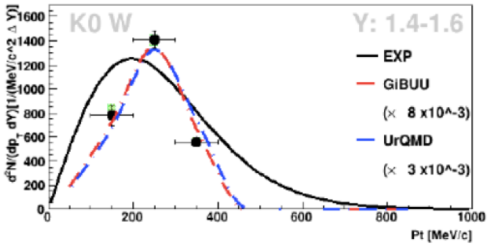








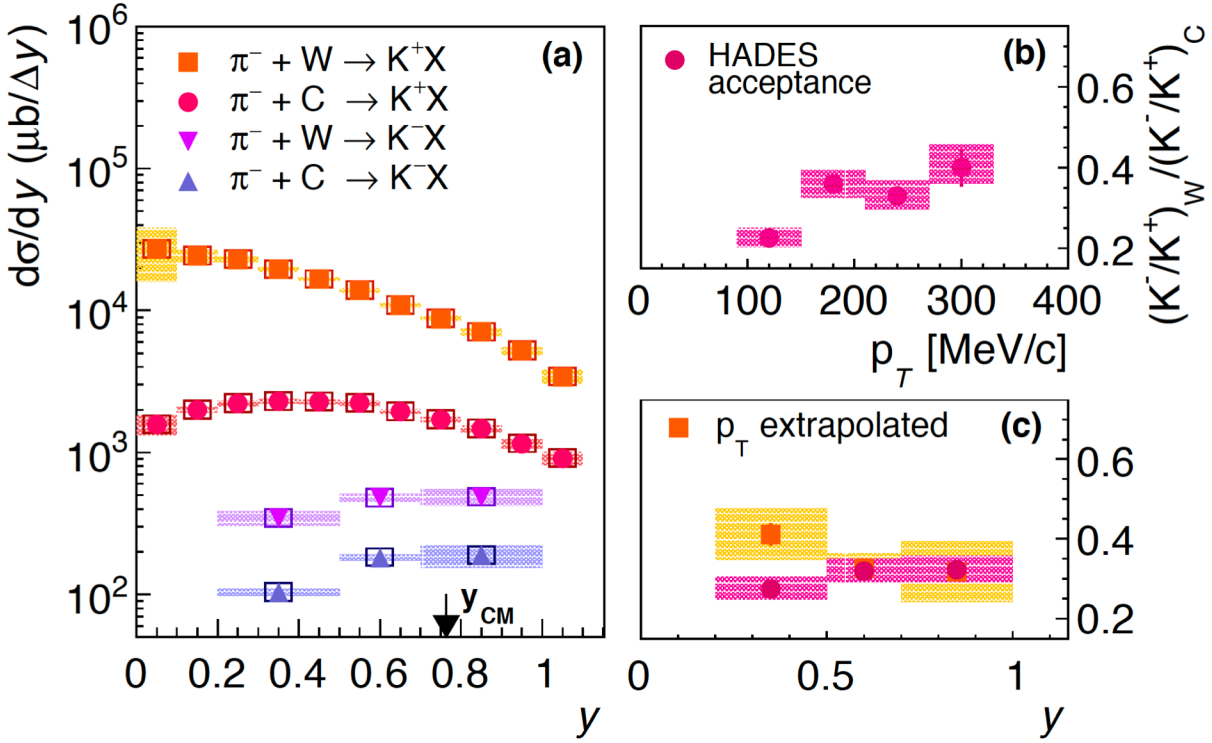




$dN_{K^0}/(dp_t dy)$ vs p_t

- Fit with Boltzmann distribution
- Compared to UrQMD and GiBUU

K^+ and K^- rapidity distributions ($\pi + C, W$)



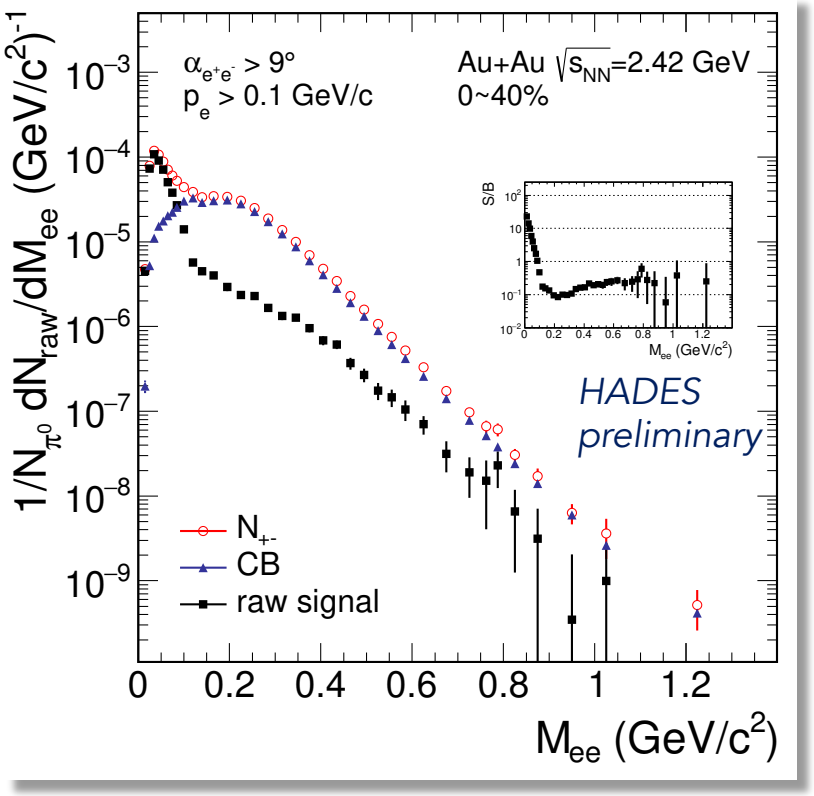
- Rescattering of K^+
- Absorption of K^- (ϕ)

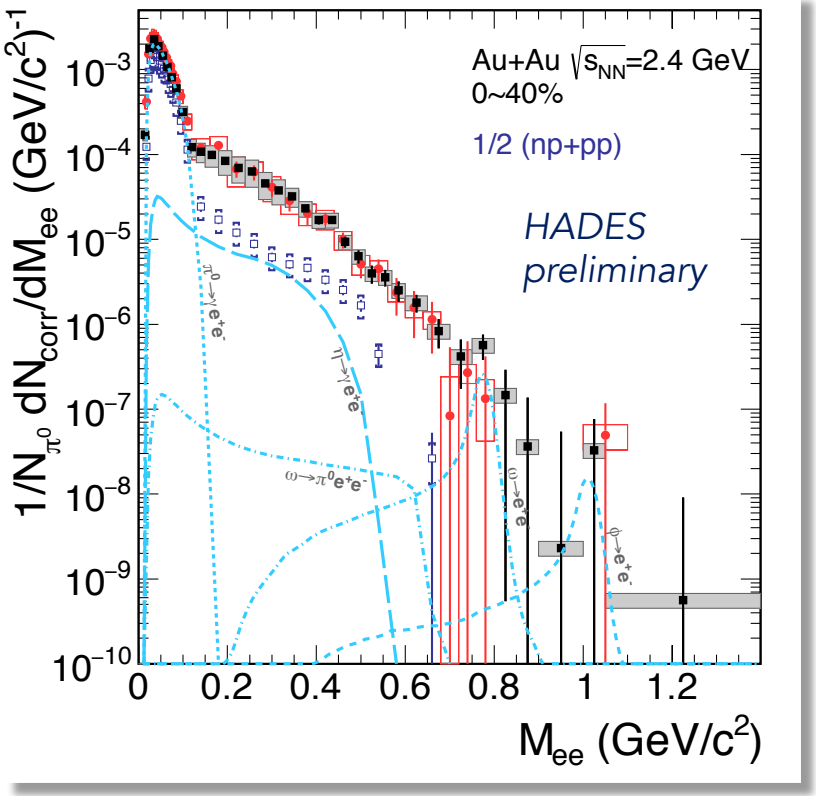
$$\frac{\left(\frac{K^-}{K^+}\right)_W}{\left(\frac{K^-}{K^+}\right)_C} = 0.319 \pm 0.016$$

$$\frac{\left(\frac{\phi}{K^-}\right)_C}{\left(\frac{\phi}{K^-}\right)_W} = \frac{0.55}{0.63}$$

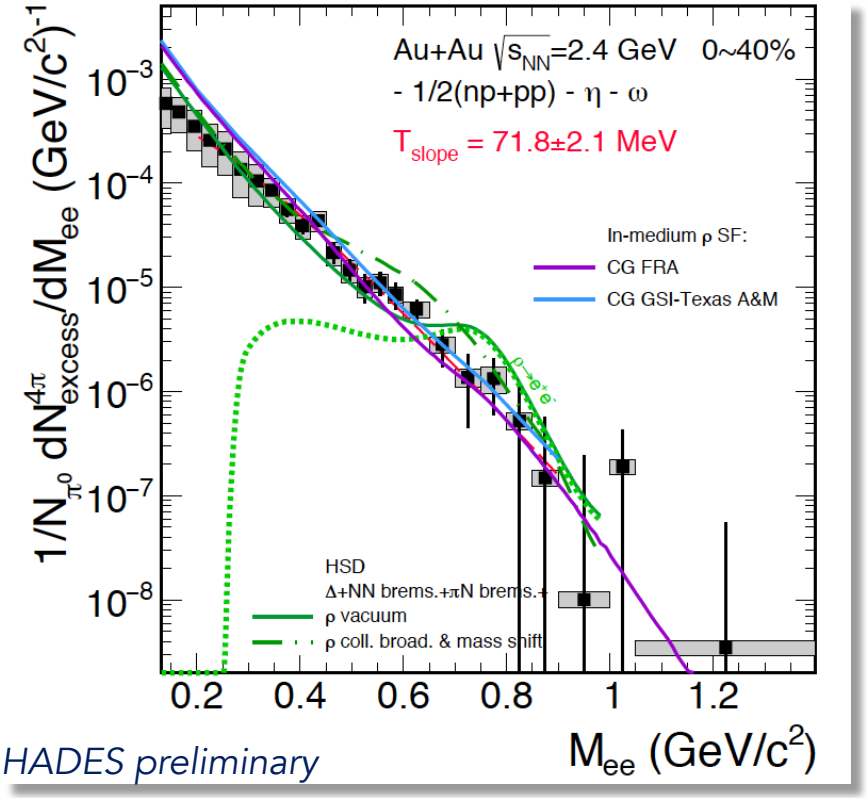
HADES collaboration arXiv:1812.03728

Inclusive Dielectron Yields from $Au + Au$ ($\sqrt{s} = 2.4\ AGeV$)





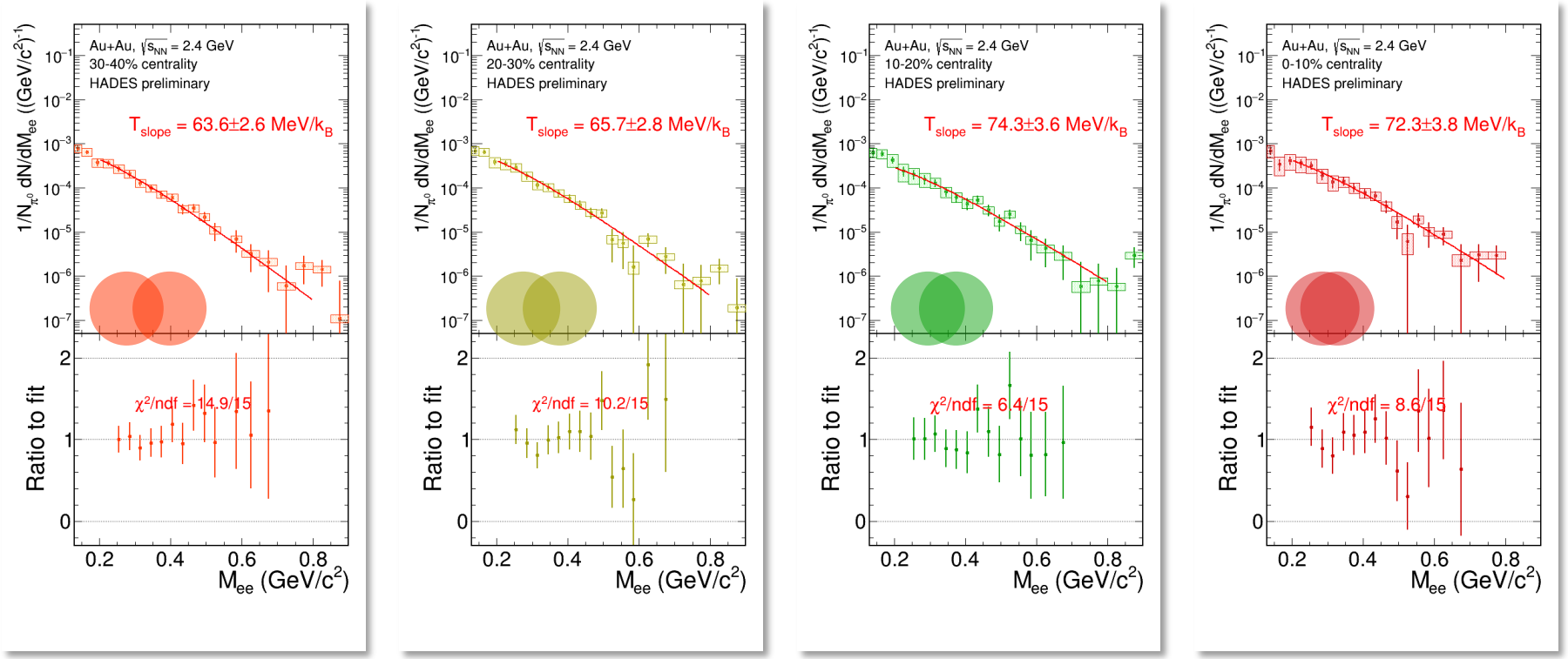
Thermal dileptons Au+Au 1.23*A* GeV



- Microscopic transport(2):
  - vacuum ρ spectral function and Δ regeneration
  - & explicit broadening and density dependent mass shift
- Coarse-grained UrQMD(3)
  - thermal emissivity with in-medium propagator (4)
  - $\rho - a_1$ chiral mixing(5) (not measured so far)

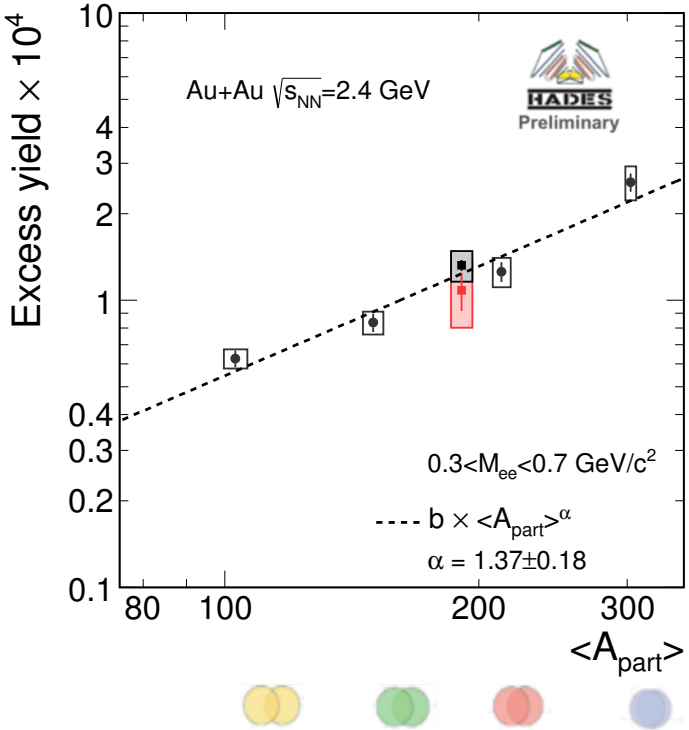
(4) Rapp, van Hees; arXiv:1411.4612v
(2) E. Bratkovskaya;
(3) CG FRA Endres, van Hees, Bleicher; arXiv:1505.06131
CG GSI-TAMU; Galatyuk, Seck, et al. arXiv:1512.08688
(4) Rapp, Wambach, van Hees; arXiv:0901.3289
(5) Rapp, Hohler; arXiv:1311.2921v

Dilepton excess radiation in centrality bins

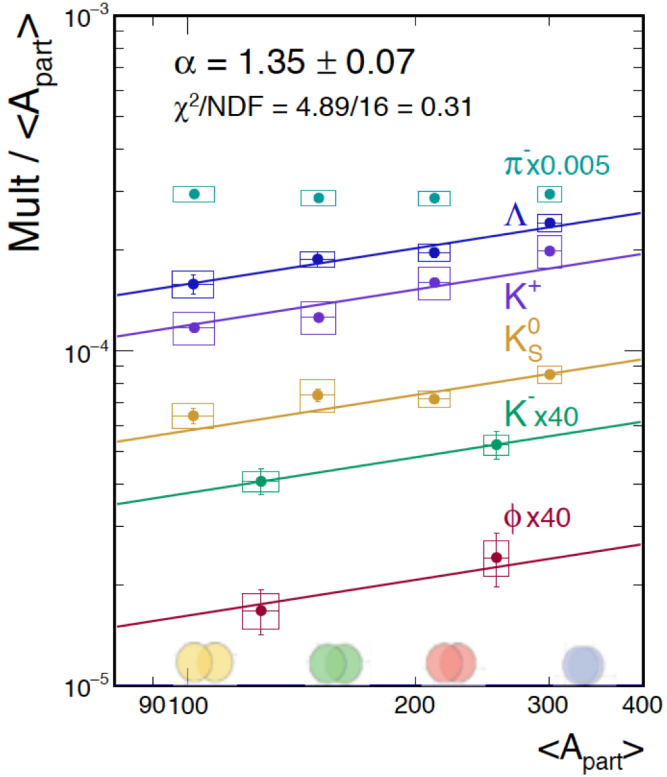


Indication for increasing average temperature as collisions go more central

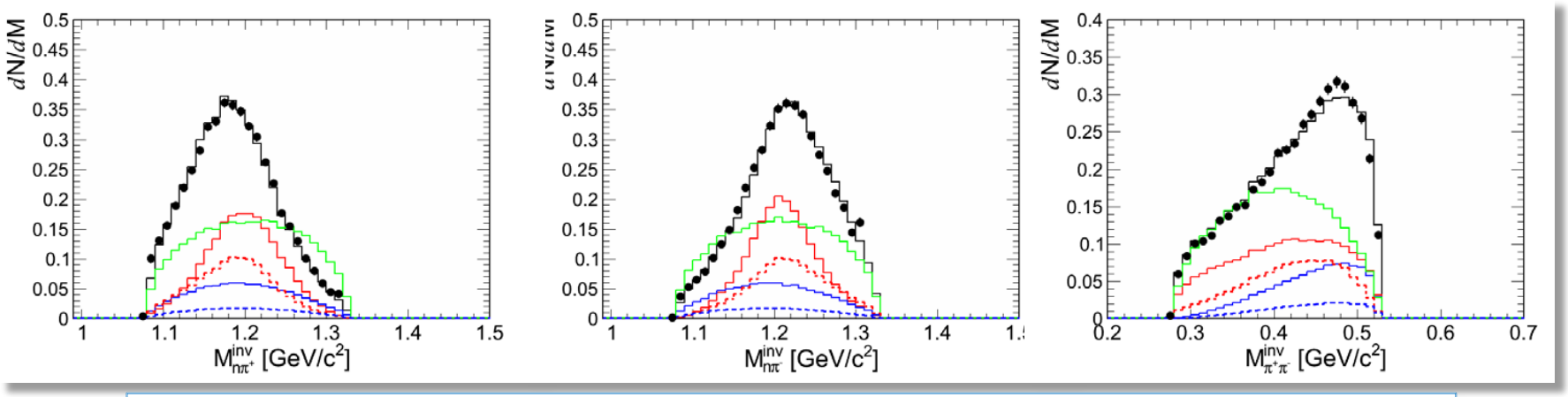
Common A_{part} scaling of Dileptons and Strangeness



x



$$\pi^- + p \rightarrow \pi^- + \pi^+ + n$$

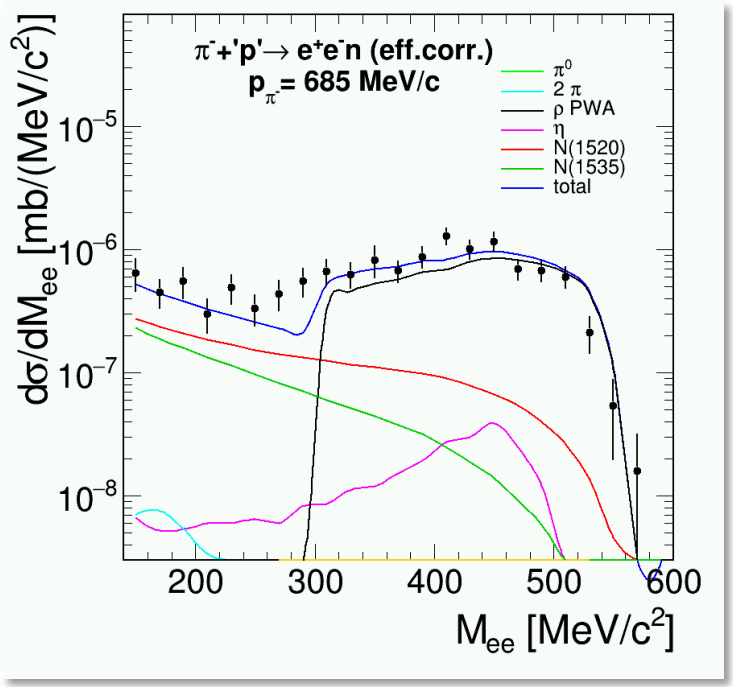


Hadronic final states used in PWA (A. Sarantsev; BONN/GATCHINA)

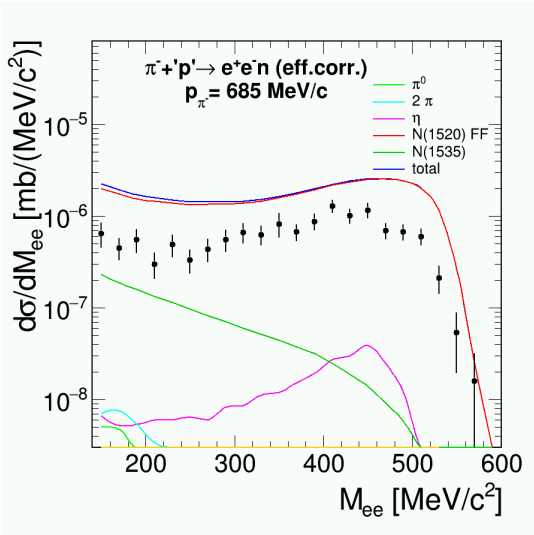
Beam energy scan: p_π = [656, 690, 748, 800] MeV (second resonance region)

Exclusive dilepton spectrum $\pi^- p \to e^+ e^- n$

- Cocktail constructed from cross sections extracted from PWA.



- Comparison to electromagnetic transition form factor calculated in a core+cloud model.
- Evidence for VMD in em decays of baryons.



G. Ramalho, T. Pena Phys. Rev. D95 (2017), 014003

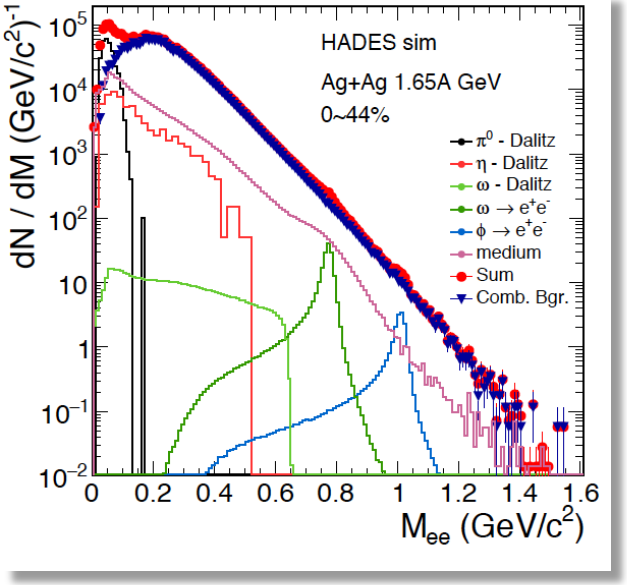
More results from Au+Au

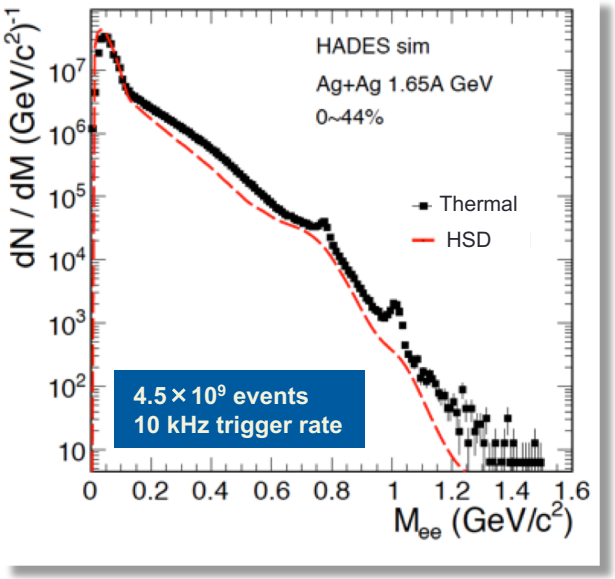
17:40 - 18:05 Behruz Kardan (Frankfurt)
Collective flow and correlation measurements with HADES in Au+Au collisions at 1.23 AGeV

18:30 - 18:55 Frederic Kornas (Darmstadt)
Lambda Polarization in Au+Au collisions at $\sqrt{s_{NN}}$ = 2.4 GeV measured with HADES

Dielectrons from Ag+Ag at 1.65*A* GeV

Expected dielectron invariant mass spectra after four weeks running (Full Monte-Carlo & reconstruction).





All Pairs
Combinatorial background
Signal contributions (colored)

- Quantify lifetime and baryon density dependence of the ρ spectral function
- Access for the first time at this collision energies the intermediate mass region:
  - Learn about $\rho - a_1$ chiral mixing
  - Extract fireball temperature

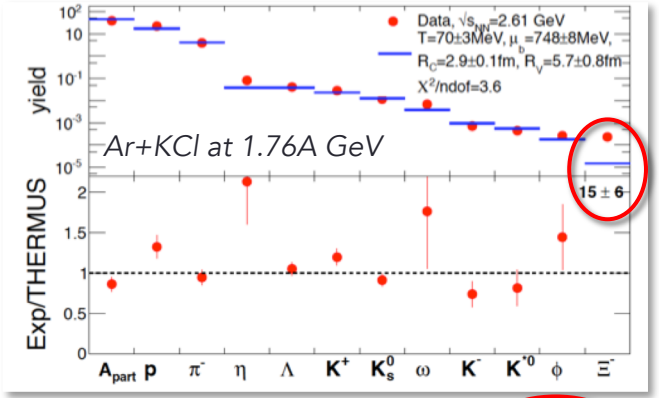
Discriminate between models

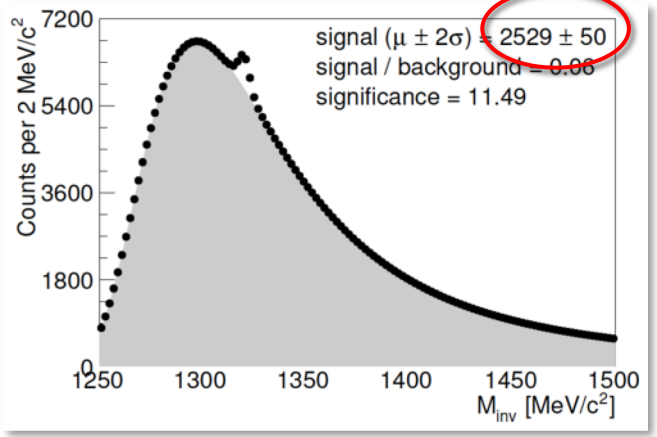
Signal: Coarse-grained transport with thermal electromagnetic rates & freeze-out contributions

Conventional transport model

M_{ee} range	<0.15 GeV/c^2	0.15-0.45 GeV/c^2	0.3-0.7 GeV/c^2	>1 GeV/c^2
Rate [84 shifts]	$2.89 \cdot 10^6$	$7.1 \cdot 10^5$	$2.1 \cdot 10^5$	107
Mesons	$\pi^0 \to \gamma e^+e^-$	$\eta \to \gamma e^+e^-$	$\omega \to e^+e^-$	$\phi \to e^+e^-$
Rate [84 shifts]	$1.5 \cdot 10^6$	$7.32 \cdot 10^5$	179	62

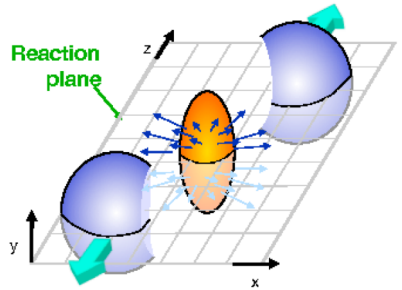
(Multi)-Strangeness in Ag+Ag at 1.65*A* GeV





Understanding of the Ξ^- excess:

- Additional information needed to increase the discrimination power with respect to models.
  - Measurement of the m_T-spectra
  - In addition factor 5 gain in statistics over Au+Au of other strange hadrons possible.
  - Allows for multi-differential analysis with respect to the event plane



Expected integral yields for after 4 weeks of running, selecting 44% of most central Ag+Ag collisions.

Mesons	K^+	K^-	K^0_s	Λ	ϕ	Ξ^-
Rate [84 shifts]	$7.6 \cdot 10^6$	$1.8 \cdot 10^5$	$6.36 \cdot 10^5$	$6.36 \cdot 10^5$	$2.4 \cdot 10^3$	$2.5 \cdot 10^3$

Summary

- HADES provides data at the lower end of the “Beam Energy Scan”
- Strong evidence that the fireball formed is equilibrated
- Common scaling behavior of strangeness production (below NN threshold)
- Substantial absorption of K^- and ϕ observed in cold matter
- Thermal dilepton radiation outshining the contributions from conventional sources found
- Can serve as thermometer, chronometer, barometer and polarimeter of the collision
- Spectral distribution sensitive to hadron properties in the medium
- emTTF of N* shows effect of VMD

Thank you