GSI

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

HADES

SPONSORED BY THE

HIC for FAIR Helmholtz International Center

EMMI

Federal Ministry of Education and Research

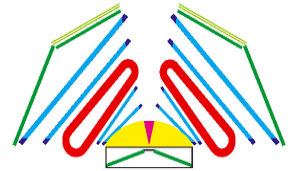
SYSTEMATICS OF STRANGENESS PRODUCTION AT $\sqrt{s_{NN}} = 2.4\ A$ GEV

Joachim Stroth

EMMI Workshop

Constraining the Phase Boundary with Data from HI Collision

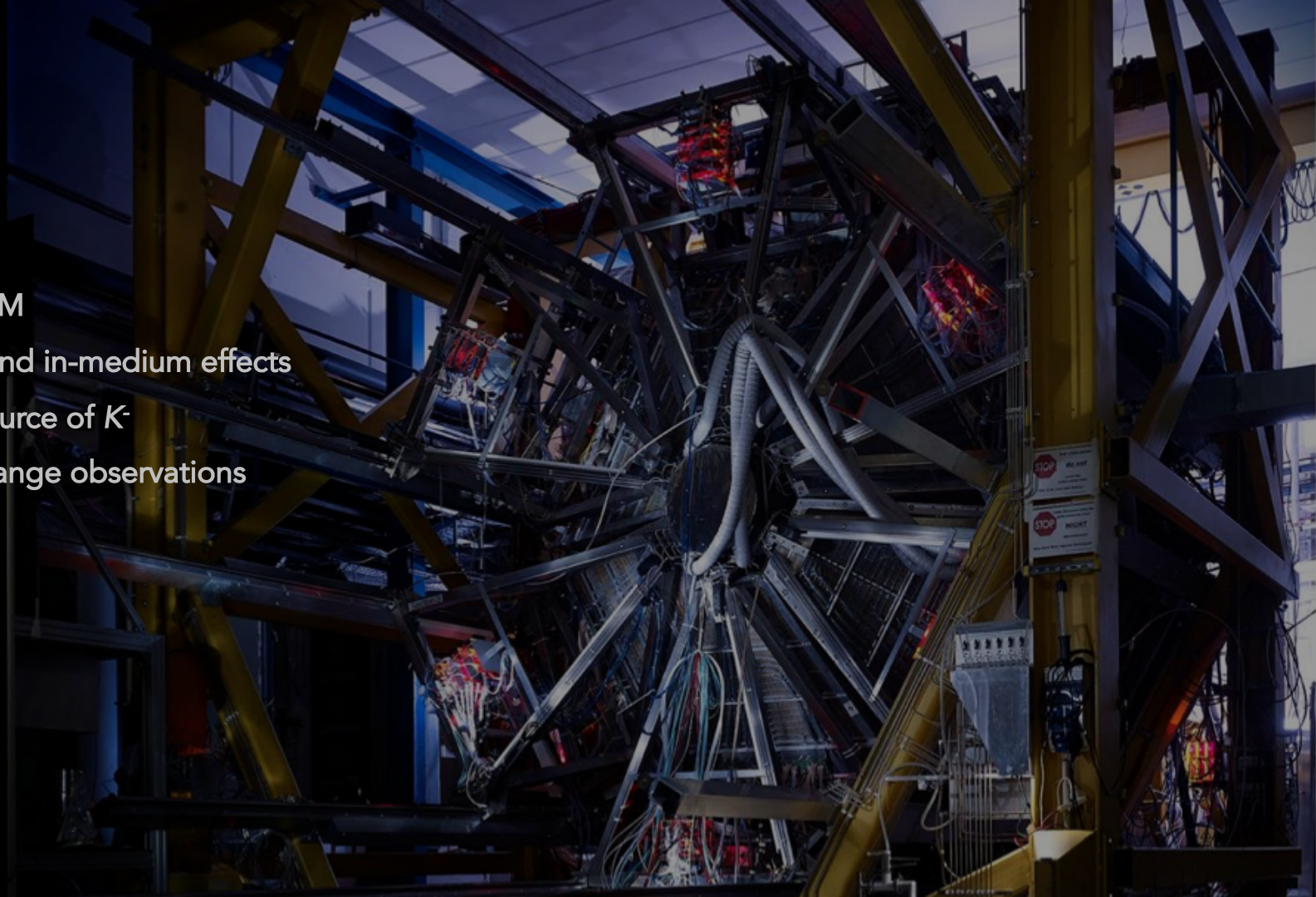
GSI, February 12-14, 2018



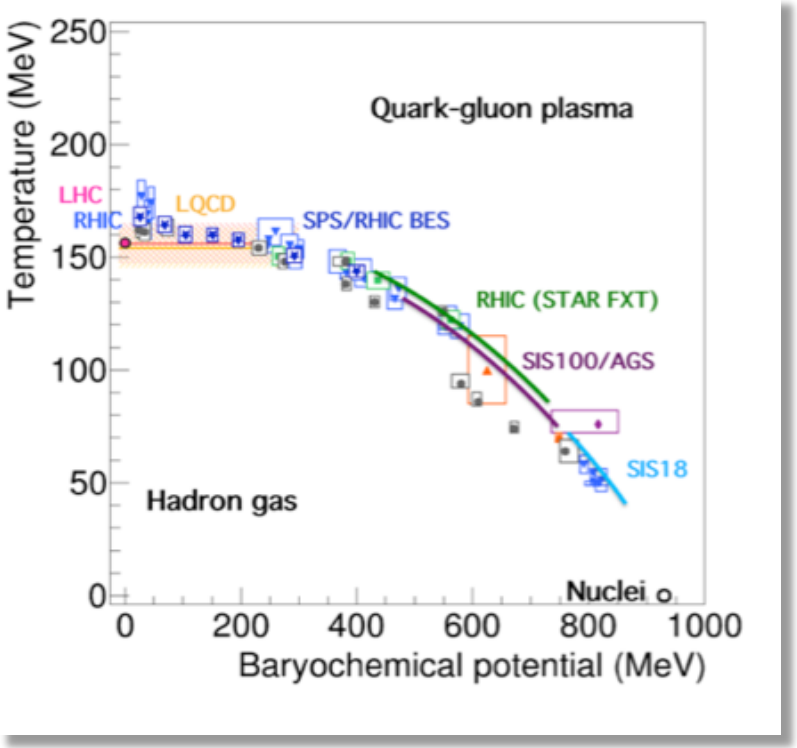
HADES

Program

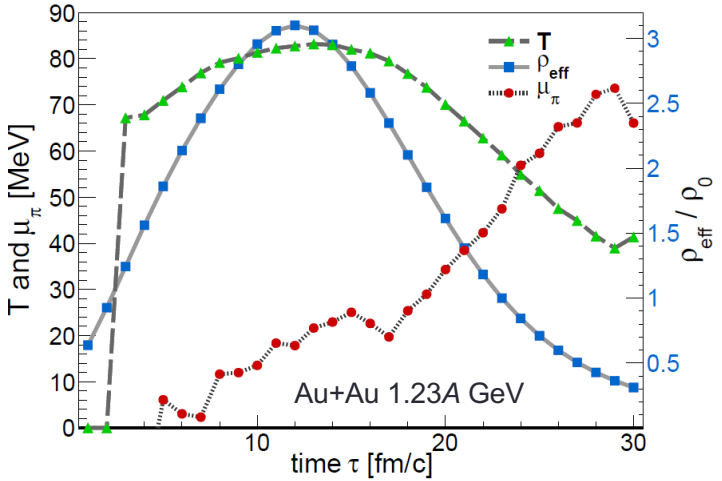
- Motivation
- Yields and SHM
- Strangeness and in-medium effects
- ϕ decay as source of K^-
- Other non-strange observations
- Outlook



HADES and the QCD Phase Diagram



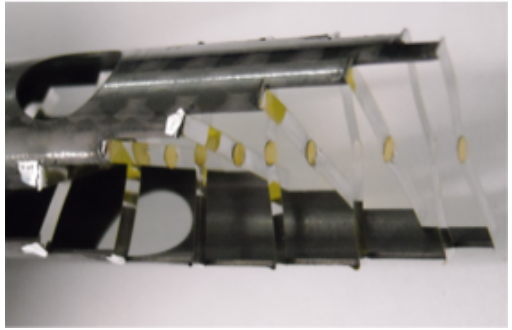
Central cell (3x3x3 fm^3) thermodynamic properties from coarse graining UrQMD.

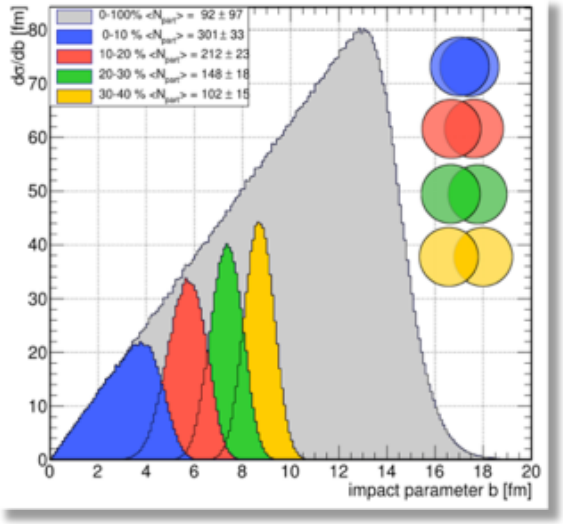


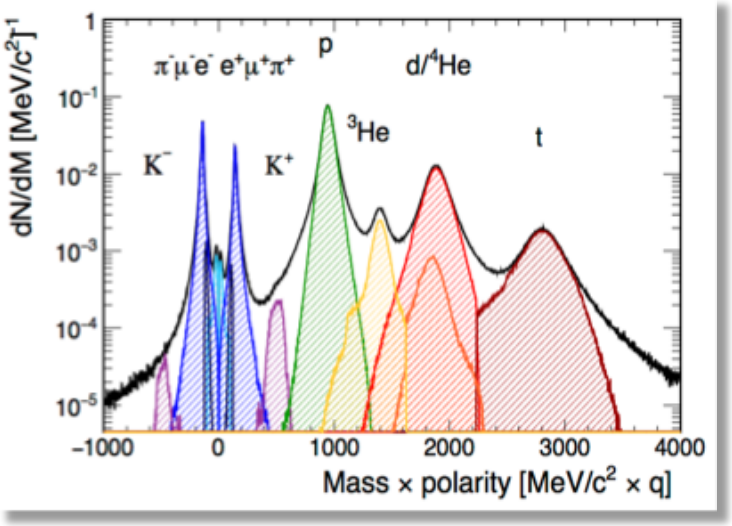
T. Galatyuk, F. Seck, et al.: arXiv-1512-08688

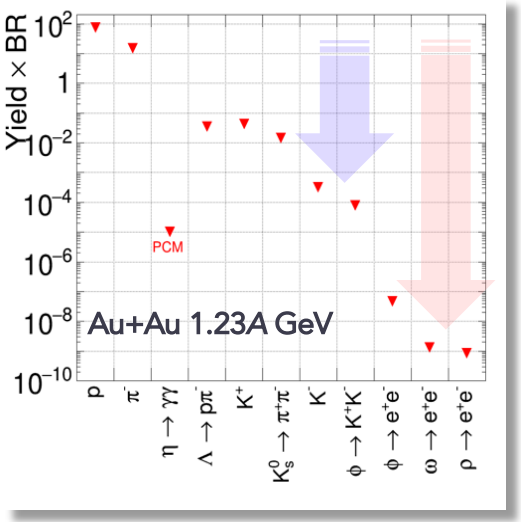
HADES Au+Au data

- 1.5 x 10^6 Au ions per second on 15-fold segmented Au target
- LVL1 trigger rates of up to 8 kHz, 7 10^9 events recorded
- Trigger on 40% most central coll.

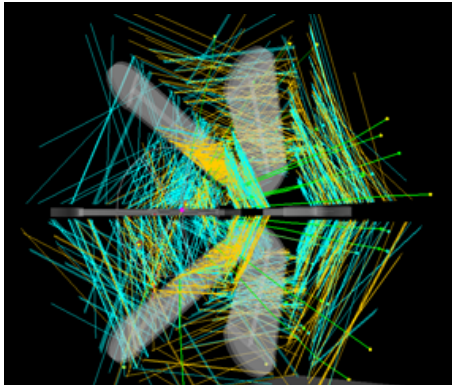




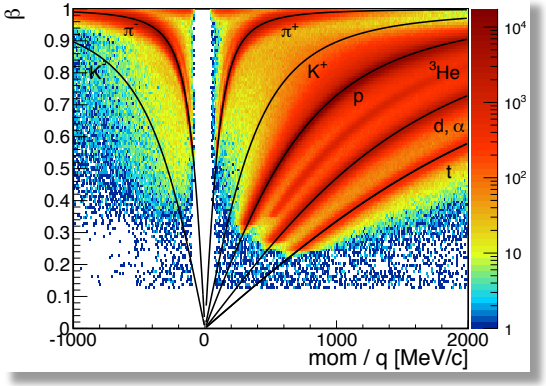


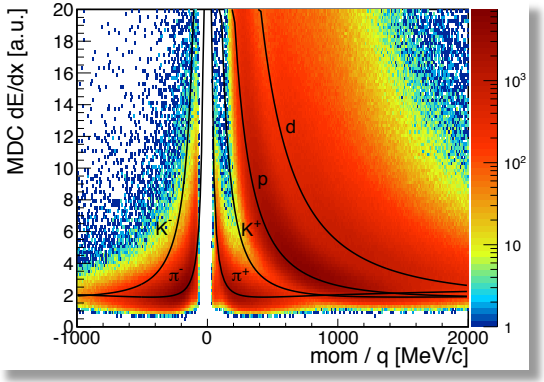


Performance (hadrons)

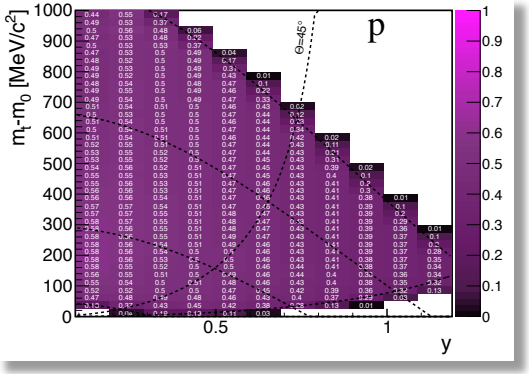


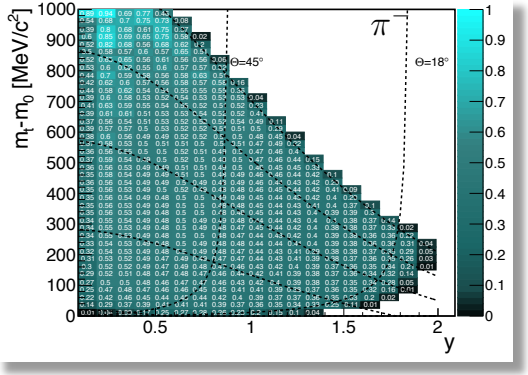
PID $(\mathrm{tof}, dE/dx)$





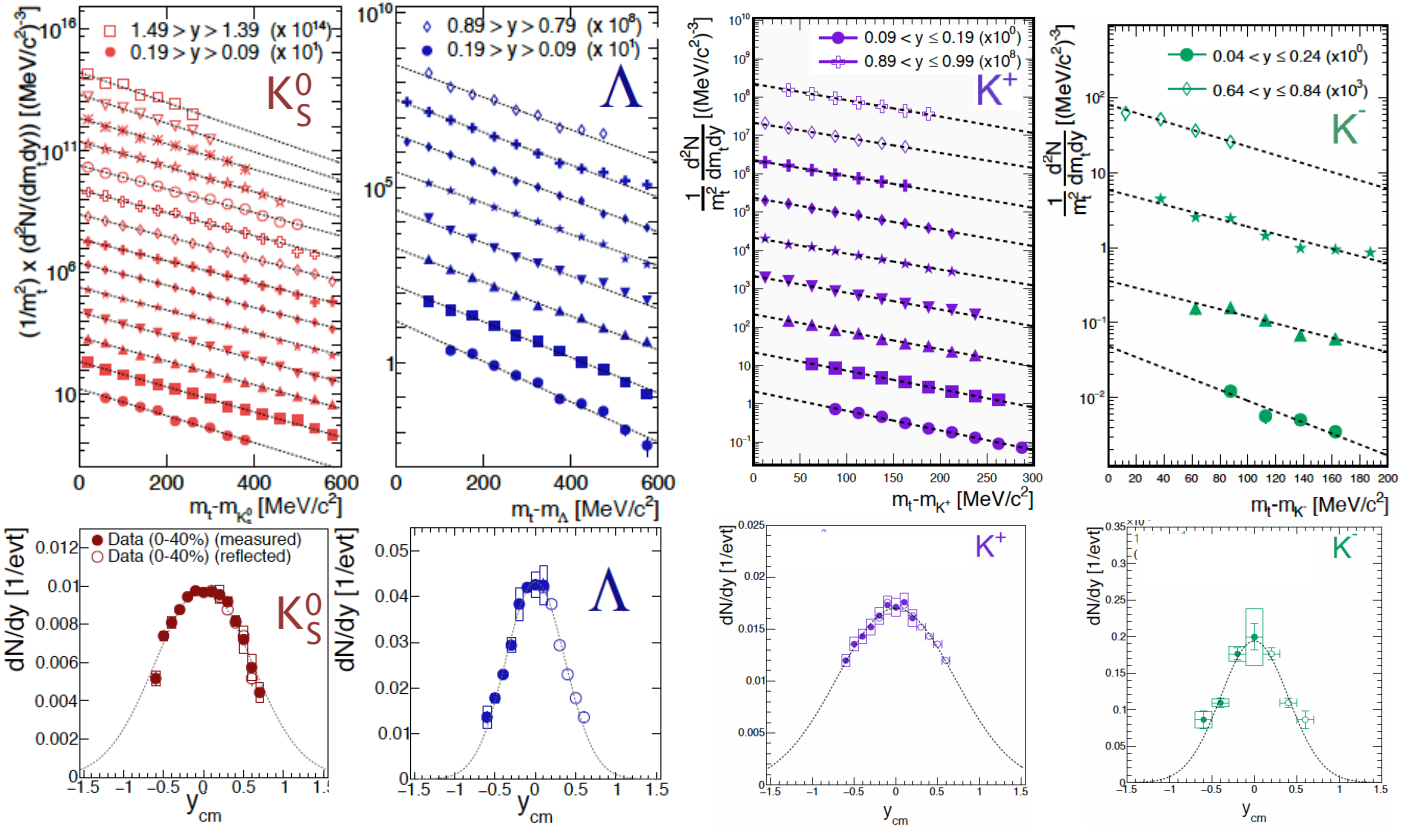
$\epsilon_{acc.} \times \epsilon_{det.} \times \epsilon_{reco.}$



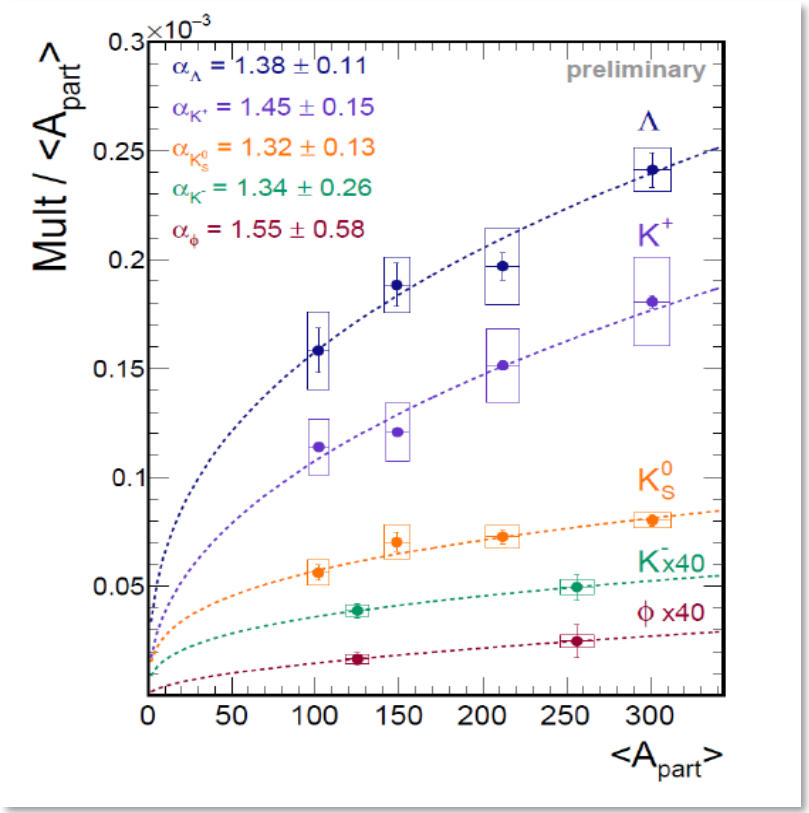


- Large acceptance around mid-rapidity.
- Centrality and event plane via forward hodoscope (FW)
- Reduced acceptance for elementary (exclusive channels)

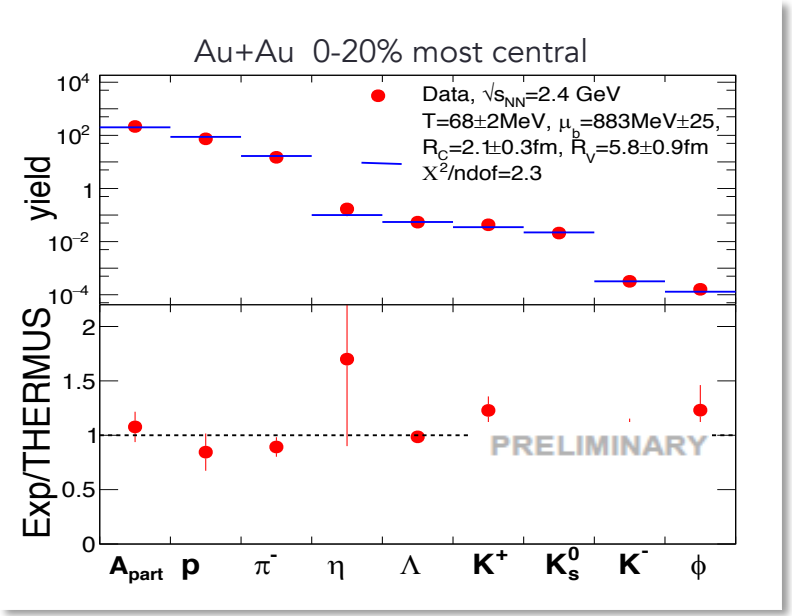
Reconstructed Open Strangeness



Yields



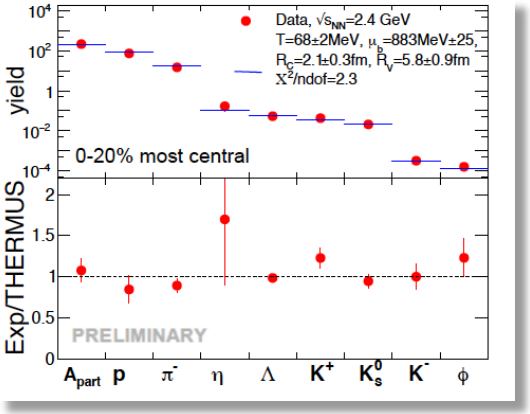
- All strange hadrons are produced below the free NN threshold: $K^+\Lambda\ (-160\ \mathrm{MeV}); K^+K^-\ (-470\ \mathrm{MeV})$
- Canonical suppression applied in THERMUS (R_c), ϕ not affected.



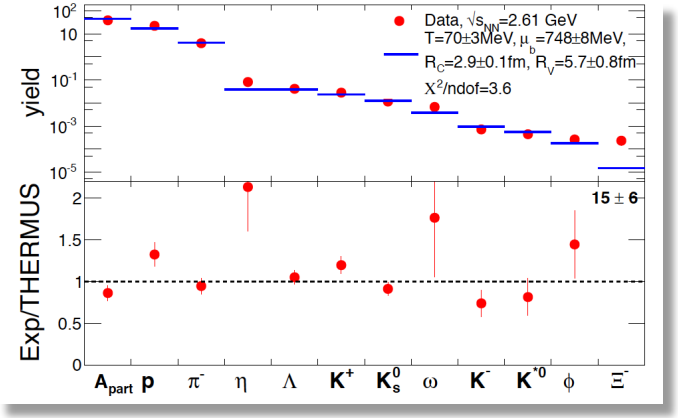
Statistical Interpretation of HADES Yields

- Measured (4π) yields can be interpreted by using canonical suppression for open strangeness (R_c)
- Also for p+A
- Inclusion of "non-strange" ϕ meson drives the fit to somewhat higher T/μ_B
- Double-strange hyperon not explained

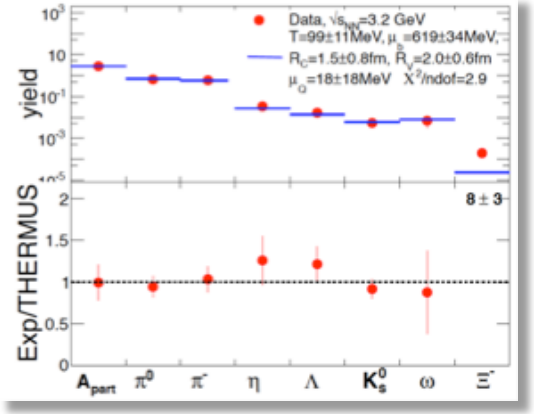
Au+Au $\sqrt{s_{NN}}$= 2.42 GeV



Ar+KCl $\sqrt{s_{NN}}$= 2.61 GeV

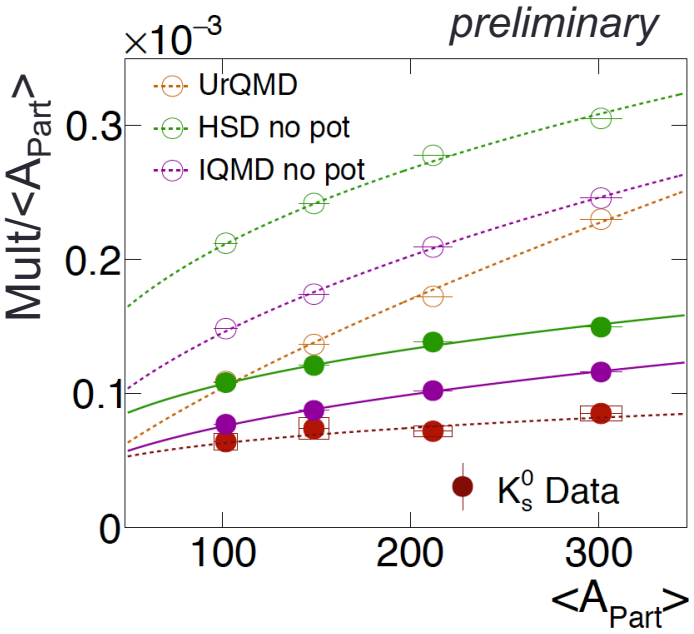


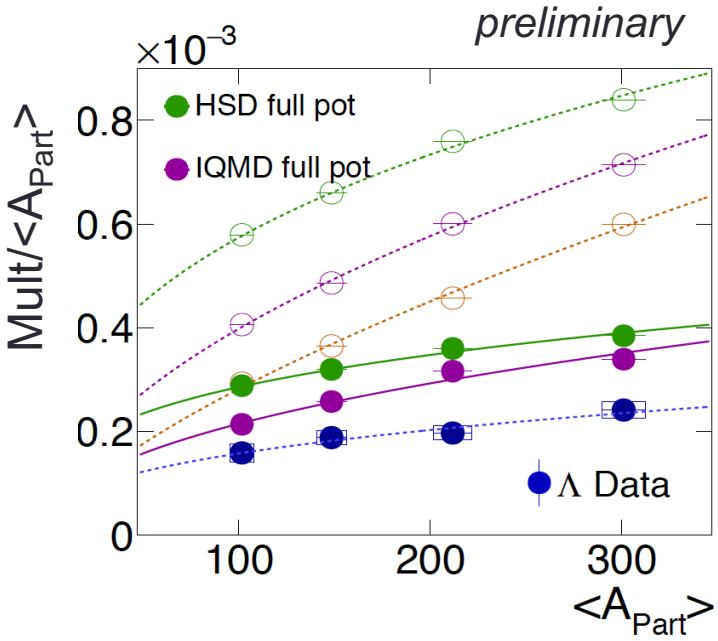
p+Nb $\sqrt{s_{NN}}$= 3. 2 GeV



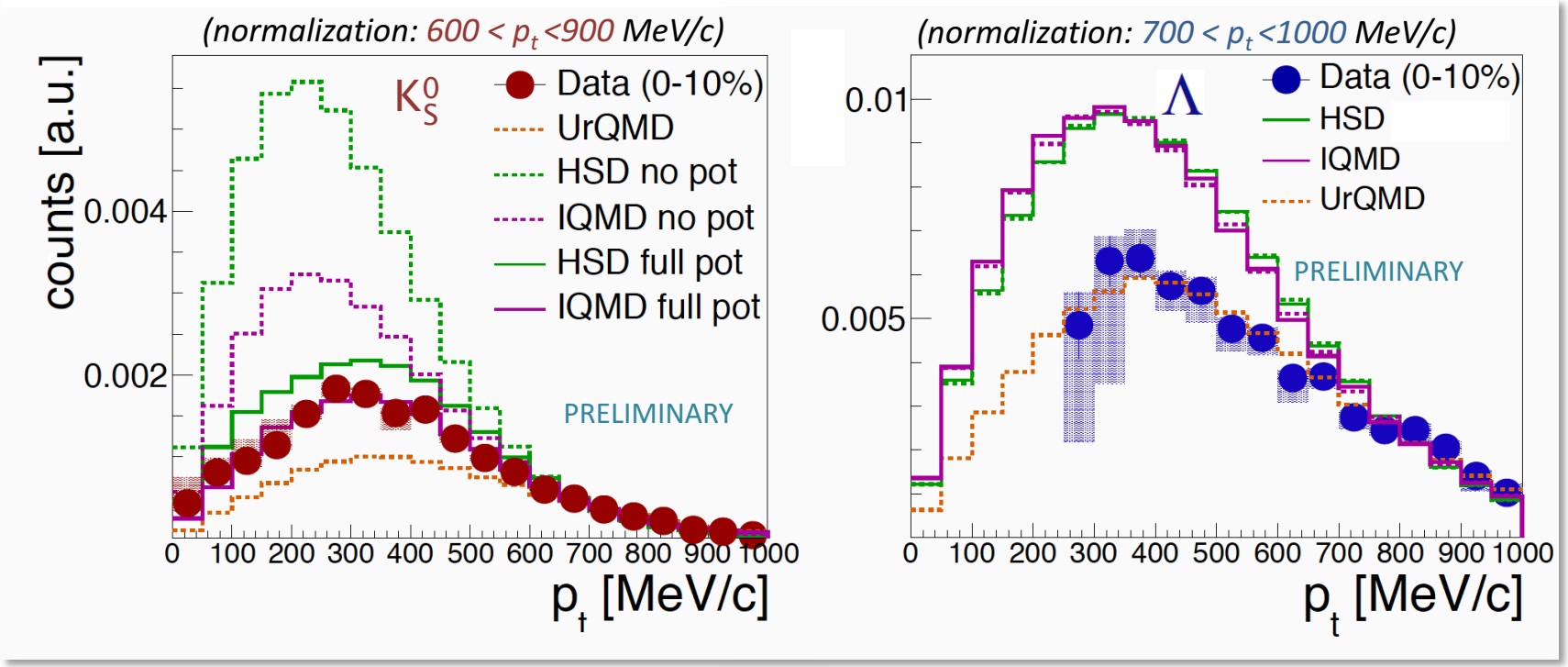
Centrality Dependence Compared to Transport

- Inclusion of repulsive Kaon in-medium potential lowers the multiplicities.



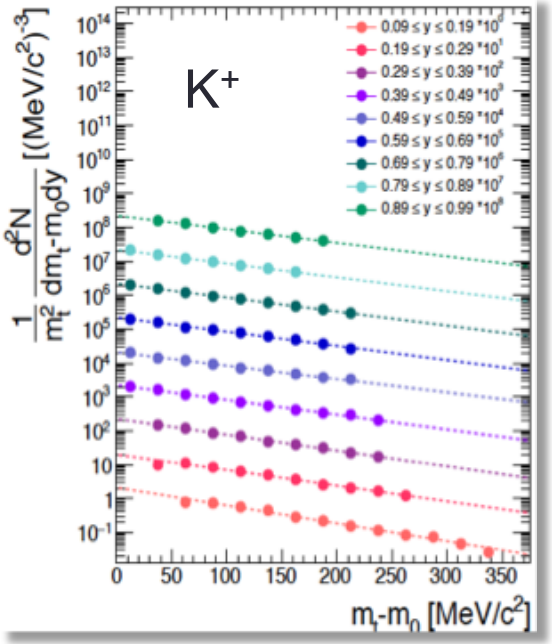


Transport and In-medium Potentials

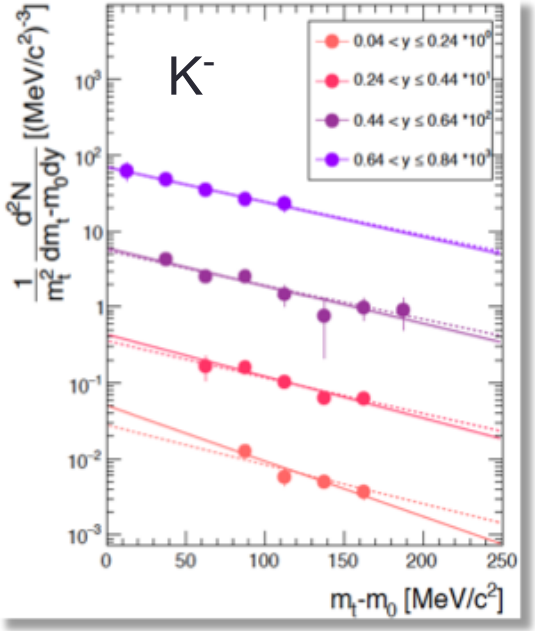


Transverse Momentum Spectra

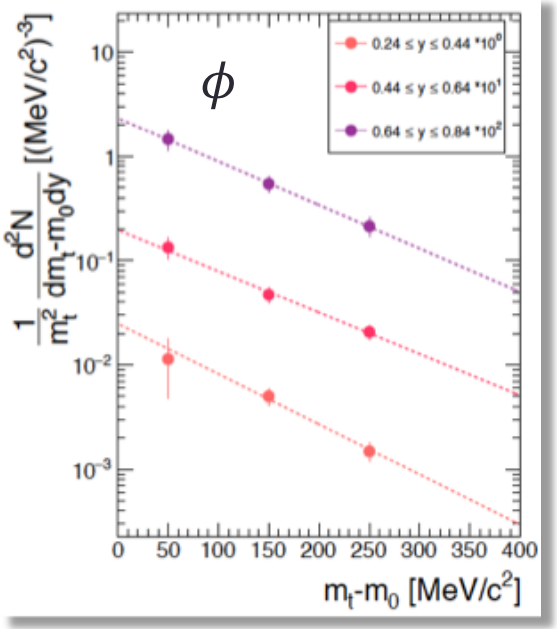
T_{eff} = 105 ± 4 MeV



T_{eff} = 82 ± 9 MeV



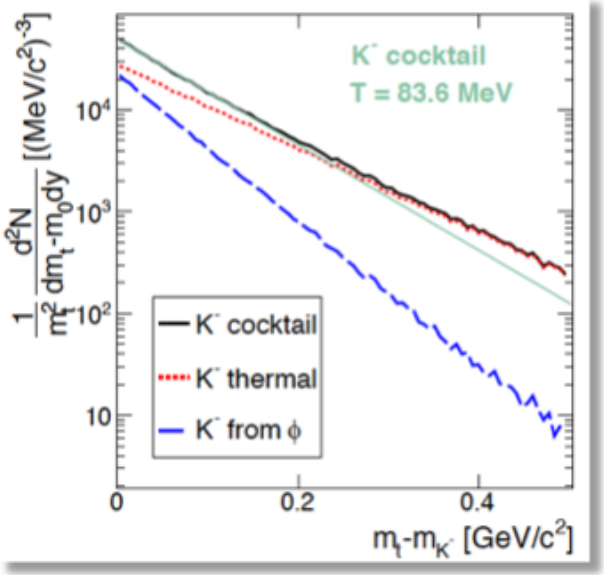
T_{eff} = 103±10 MeV



ϕ decay as source for K^- (feed-down correction)

26 % of K^- from ϕ decay

- *assume* T_{K-} (thermal) = T_{K+} (measured) = 105 MeV
- *derive* T_{K-} (cocktail) = 84 MeV ≈ T_{K-} (measured)

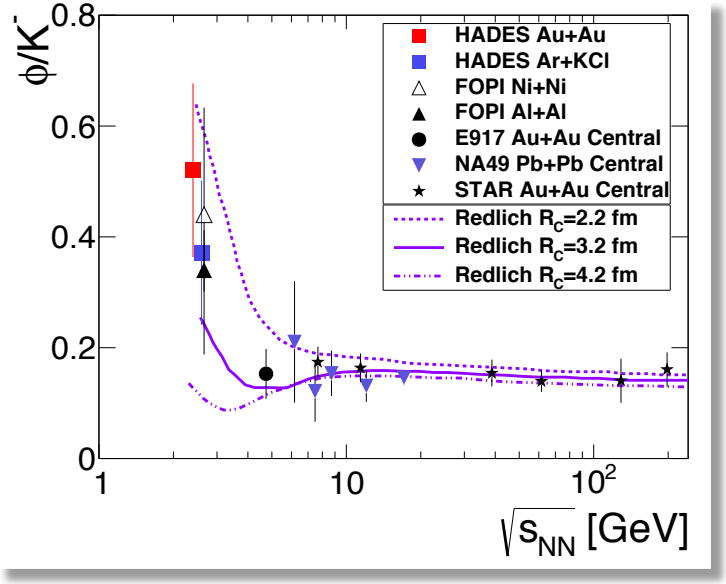


HADES; arXiv:1703.08418v2

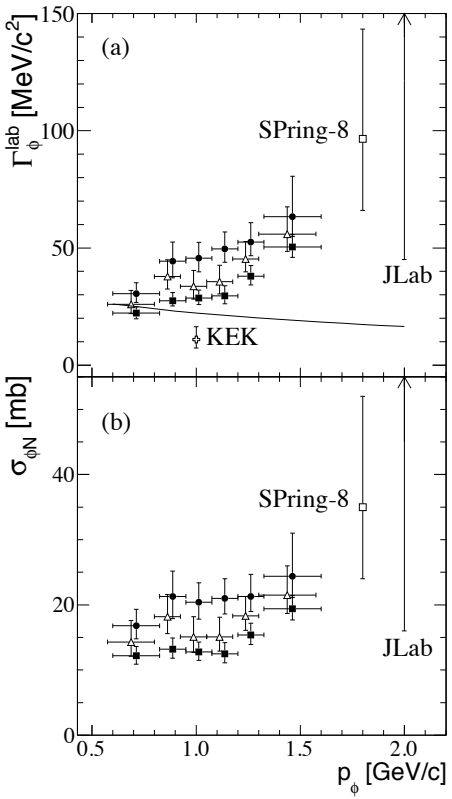
Excitation function of ϕ/K^-

- Trend explained assuming canonical suppression in a thermalized system

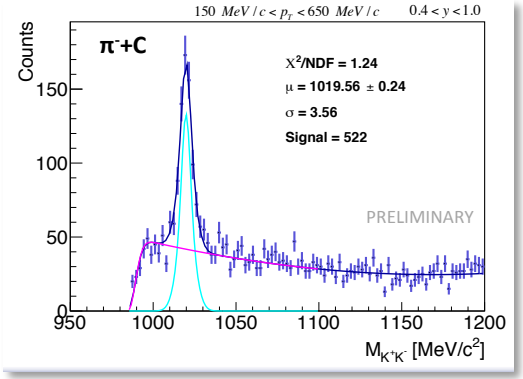
Cleymans, Redlich, Turko: arXiv:0412.262



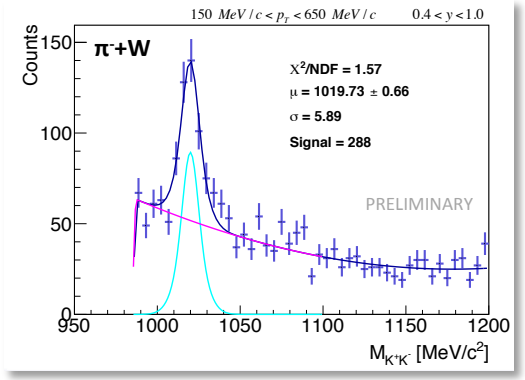
In-medium ϕ Propagation (Cold Matter)



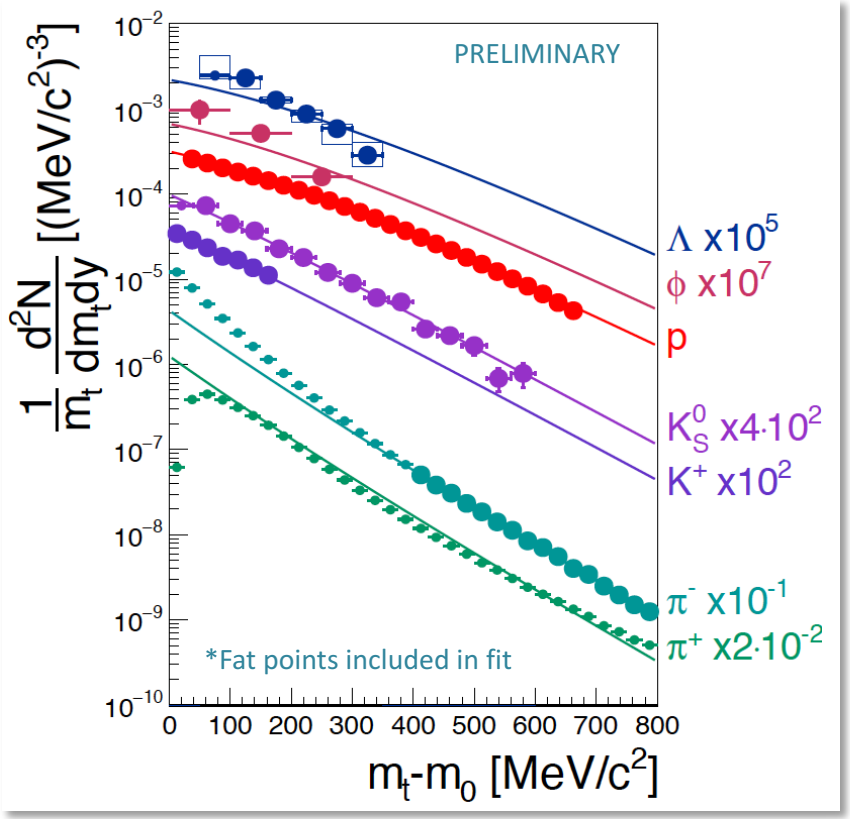
HADES pion induced production off nuclei. Results soon to come.



Anke "Data" from proton induced off nuclei (Au,Ag,Cu,C) using transport models for extraction of σ, Γ arXiv:1201.3517



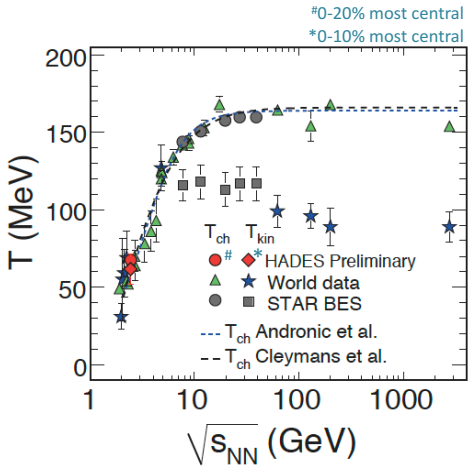
Blast Wave Fit

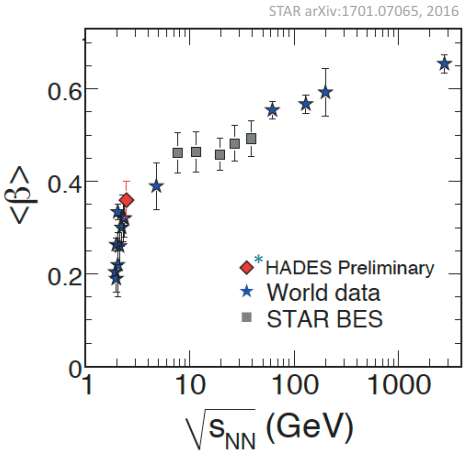


- „Blast wave“ fit with linear flow profile

$$\beta = \beta_S(r/R)$$

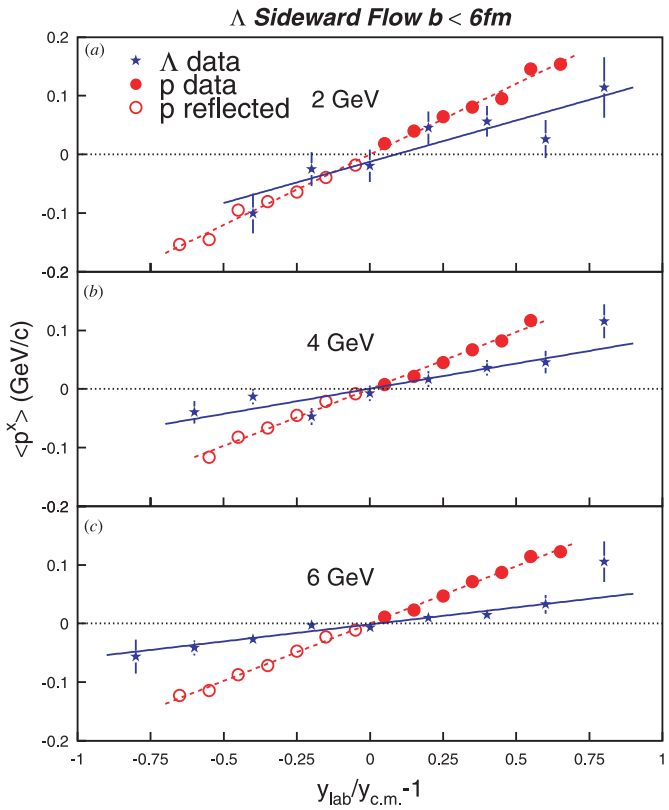
Schnedermann, Sollfrank, Heinz; Phys. Rev. C48 (1993) 2462-2475





Reduced Lambda Flow at AGS

However, they are in stark contrast to the antiflow pattern [8, 16] recently observed for K0s mesons at 6*A* GeV. It is suggested that this contrast results from differences in the kaon–nucleon and Lambda–nucleon potential; namely, for the densities of interest, the kaon–nucleon potential is repulsive, whereas that for K0s is attractive.

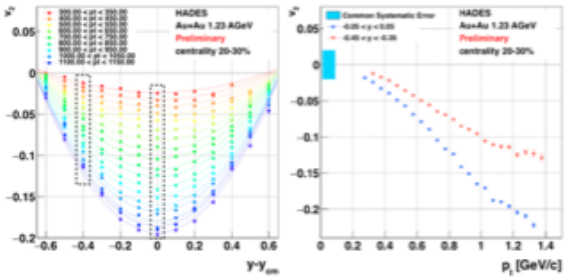


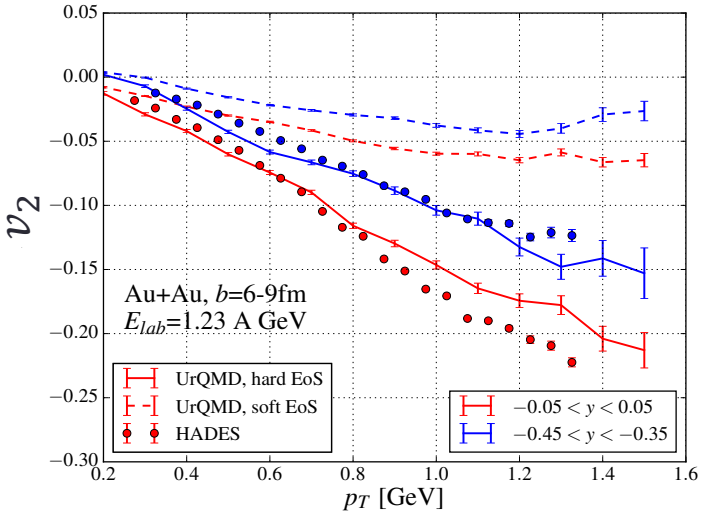
EOS Collaboration, JPhysG-27-2001

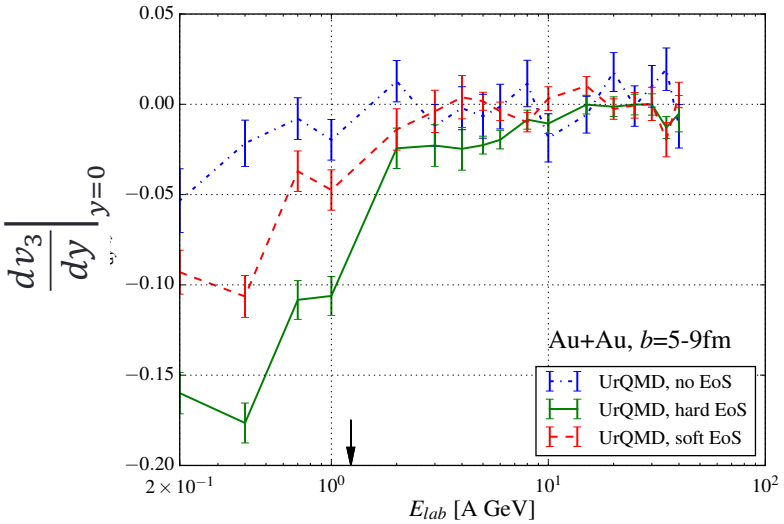
Proton Higher Flow Harmonics

- UrQMD transport plus potential
- HADES proton v_3 in preparation

HADES preliminary







Paula Hillmann, Jan Steinheimer, Marcus Bleicher; arXiv:1802.01951

NEXT TO COME

Studies of resonance matter with Ag+Ag collisions.

The HADES Collaboration

Spokespersons: J. Stroth (j.stroth@gsi.de), P. Tlusty (tlusty@ujf.cas.cz)
GSI contact: J. Pietraszko (j.pietraszko@gsi.de)

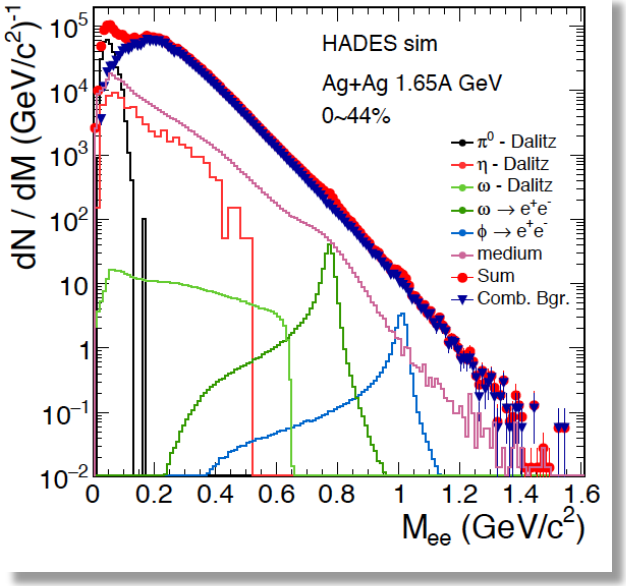
Infrastructure: SIS18 and HADES cave

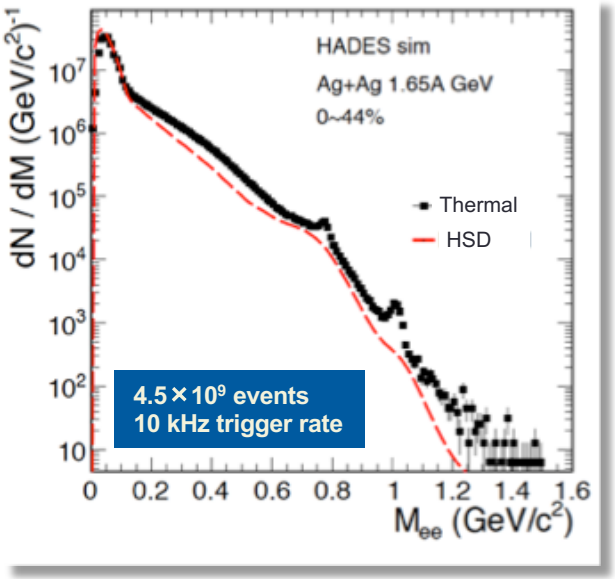
Beam: Ag at 1.65 A GeV, beam intensity 2×10^6 ions/s (flat top), slow extraction

88 shifts granted

Dielectrons from Ag+Ag at 1.65*A* GeV

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





- 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

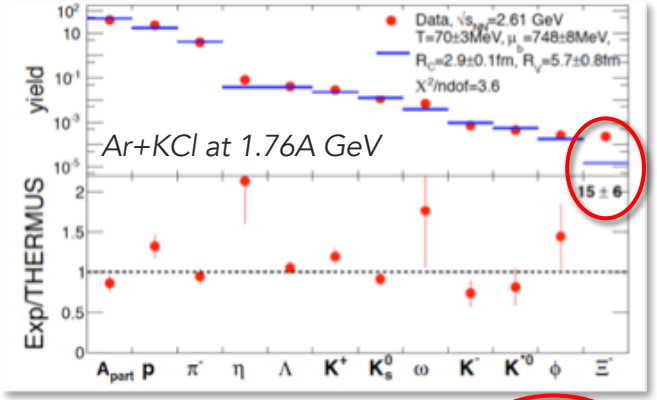
Conventional transport model

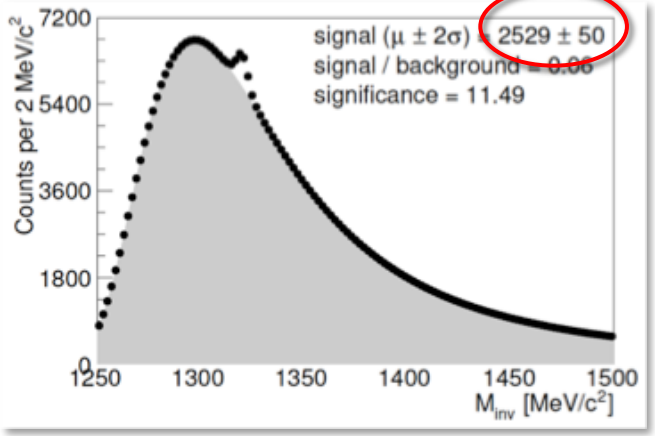
All Pairs
Combinatorial background
Signal contributions (colored)

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

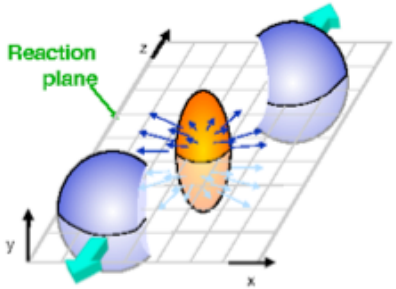
(Multi)-Strangeness in Ag+Ag at 1.65*A* GeV





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

- Universal centrality dependence of strangeness production with yields in accordance with SHM
- Comparison with transport demonstrates the importance of including potentials, yet a consistent description is missing
- No evidence for a (very) long mean-free path / earlier freeze-out of ϕ mesons
- Cascades (Ξ^-) not observed in Au+Au at $\sqrt{s}$ = 2.4*A*GeV
- Flow observables to come soon
- Ag+Ag run plan for August 2018. Higher energy and increased statistics.

Thank You for Your Attention