Overview HADES

The (Net)-Baryon rich Side of the Phase Diagram

Manuel Lorenz for the HADES Collaboration

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

GSI

HIC for FAIR Helmholtz International Center

Outline

HADES and the (Net)-Baryon rich Side of the Phase Diagram

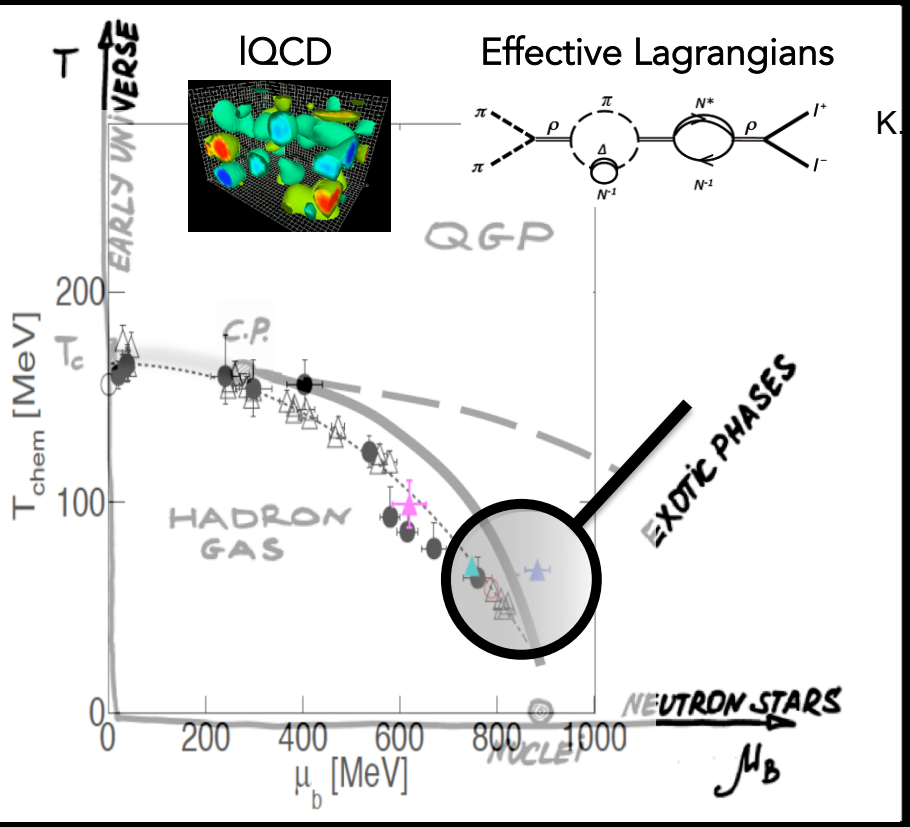
Au+Au @ $\sqrt{s_{NN}}$= 2.4 GeV

- (Sub-Threshold) Strangeness Production
- Virtual Photon Emission
- Freeze-out Parameters

π + p/A $\sqrt{s}$=1.7-2.0 GeV

Summary and Future

The (Net)-Baryon rich Side of the Phase Diagram



Au+Au $\sqrt{s_{NN}}$=2.4 GeV
Large stopping and interpenetration times
→ Baryon dominated system

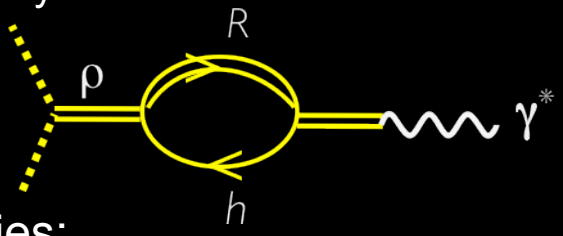
Clear hierarchy in hadron yields:
p ≈ 100, π ≈ 10, $K^+ \approx 10^{-2}$, $K^- \approx 10^{-4}$

- Sub-Threshold Strangeness Production:
Strong kinematical suppression of direct K^-

  $NN \rightarrow NYK^+$ $\sqrt{s_{NN}}$= 2.55 GeV
  $NN \rightarrow NNK^+K^-$ $\sqrt{s_{NN}}$= 2.86 GeV

Strong coupling of K^- to baryons
strangeness exchange reactions e.g. $\pi Y \rightarrow NK^-$

- Virtual Photon Emission:
  Vector meson spectral functions modified by coupling to baryons



- Flow Anisotropies:
  Preferred out-of-plane emission due to shadowing
  B.Kardan Wednesday 17:^{00}-17:^{30}

- Net-Proton Fluctuations:
  No Antiprotons, additional terms when correcting for volume fluctuations
  R. Holzman Thursday 11:^{00}-11:^{30}

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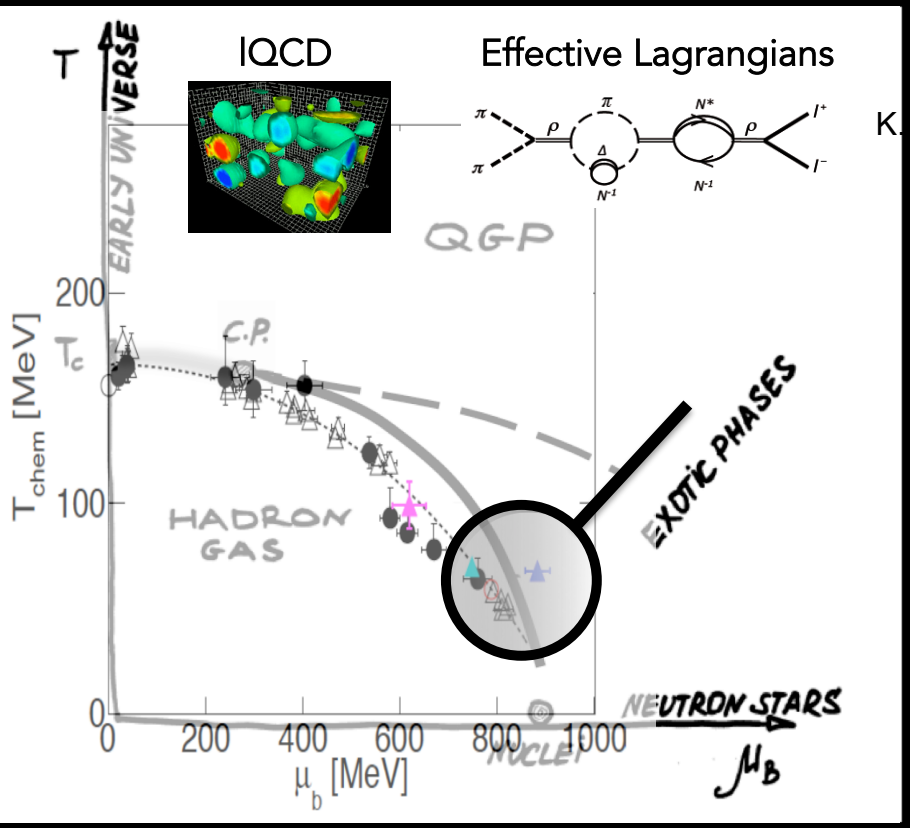

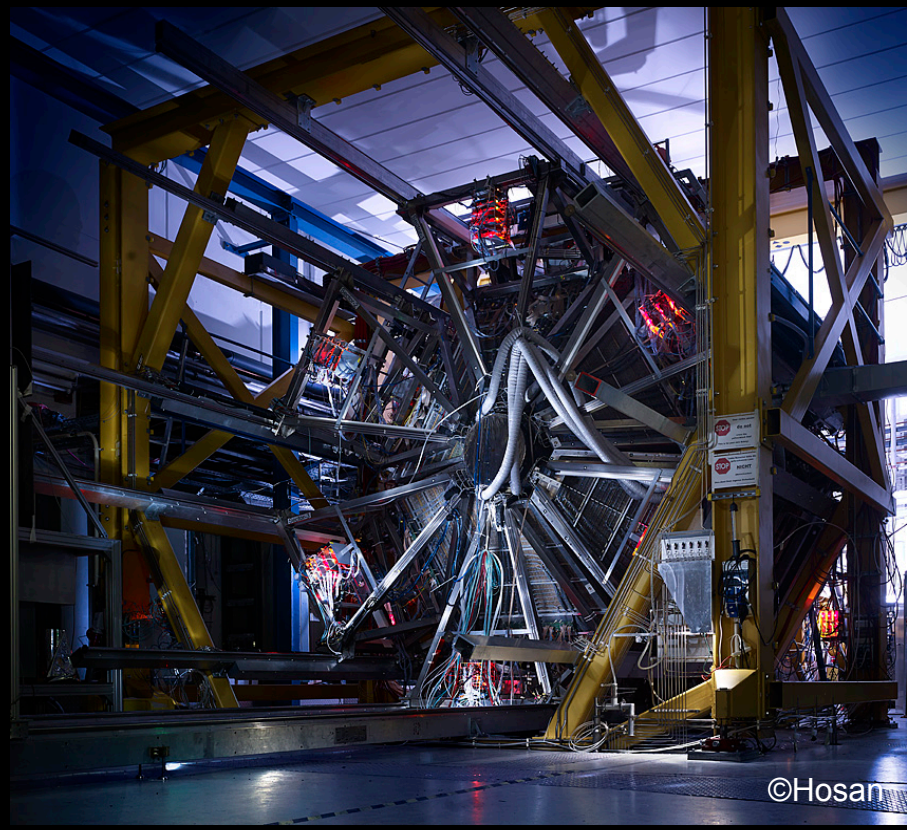

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Large acceptance: Full azimuthal and polar angle coverage of Θ = 18° – 85°

2.1×10^9 events analyzed

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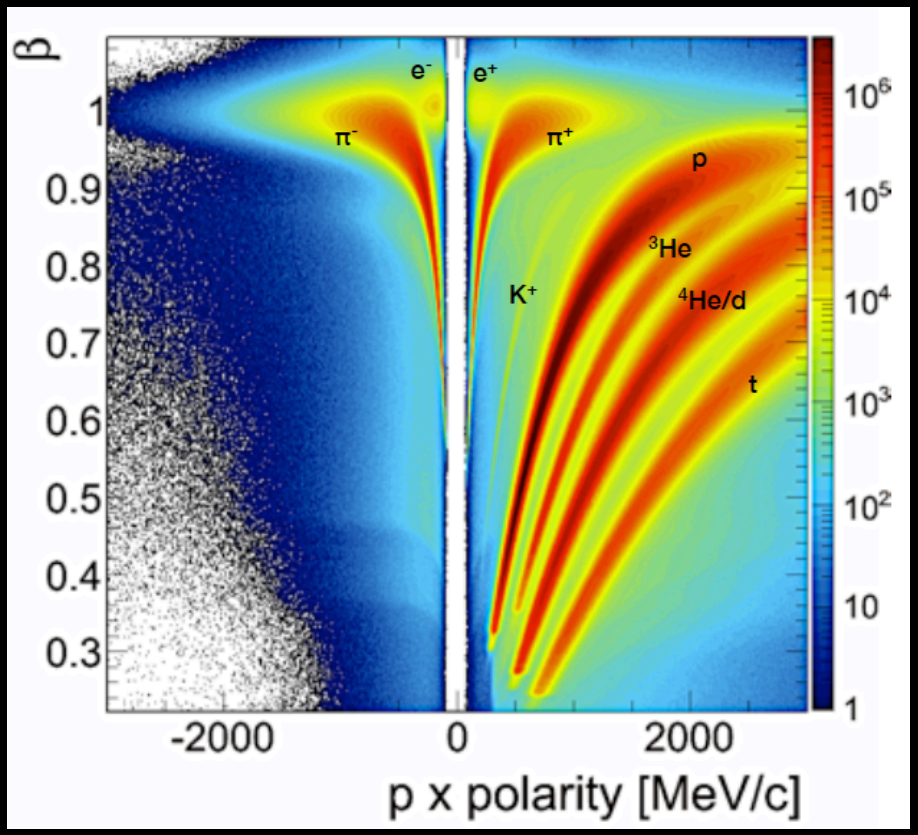

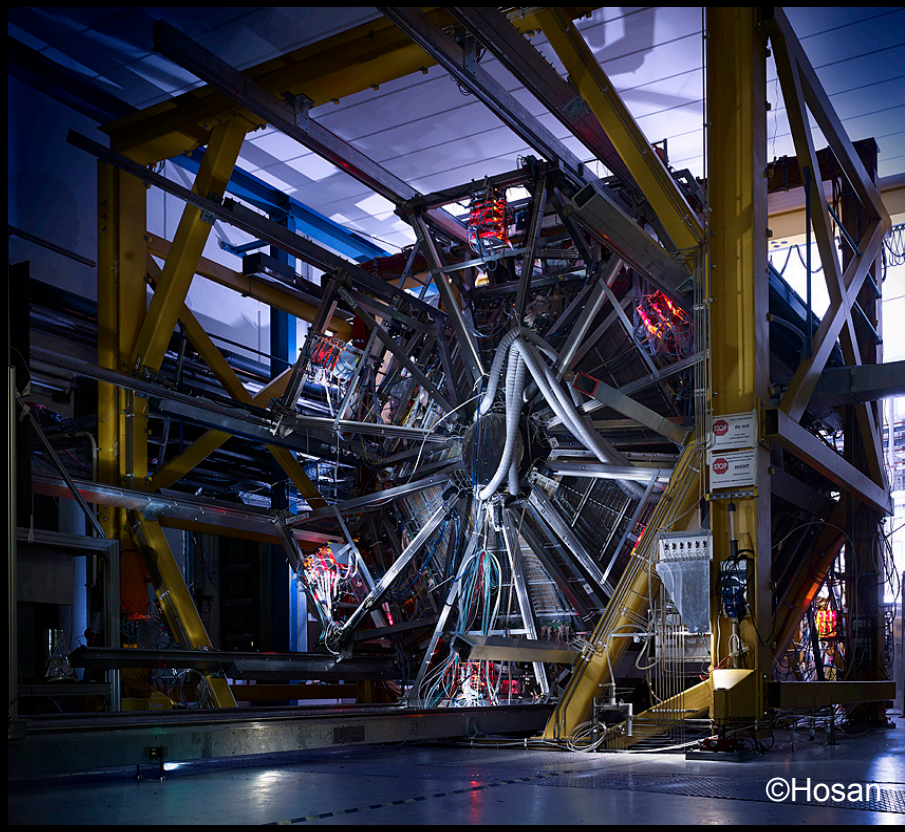

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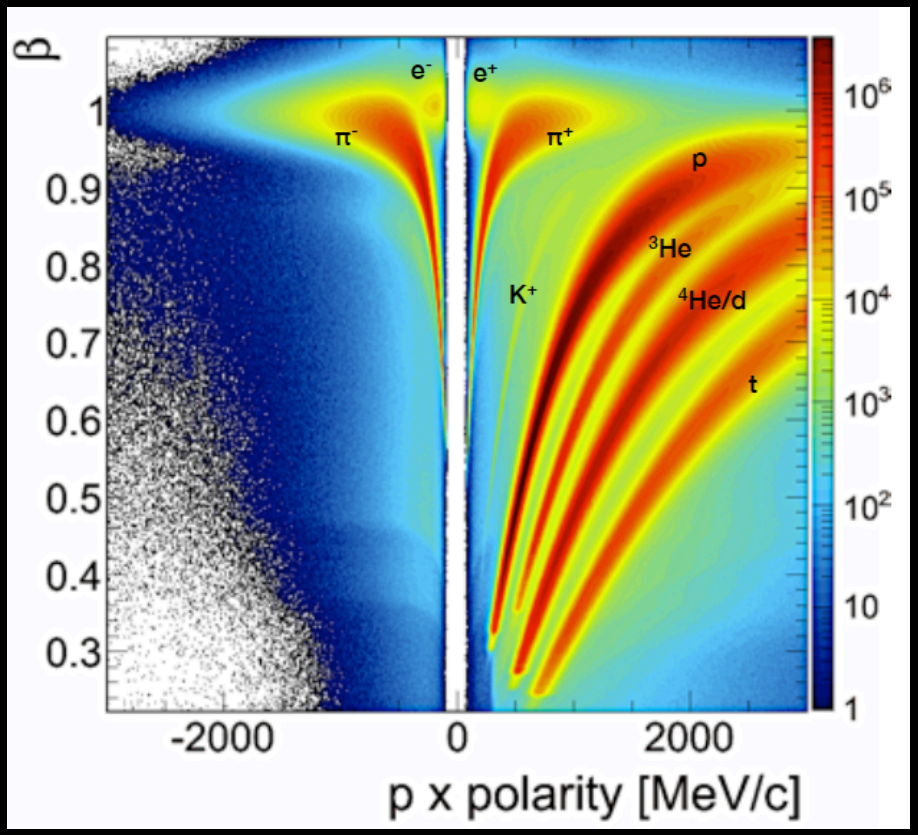

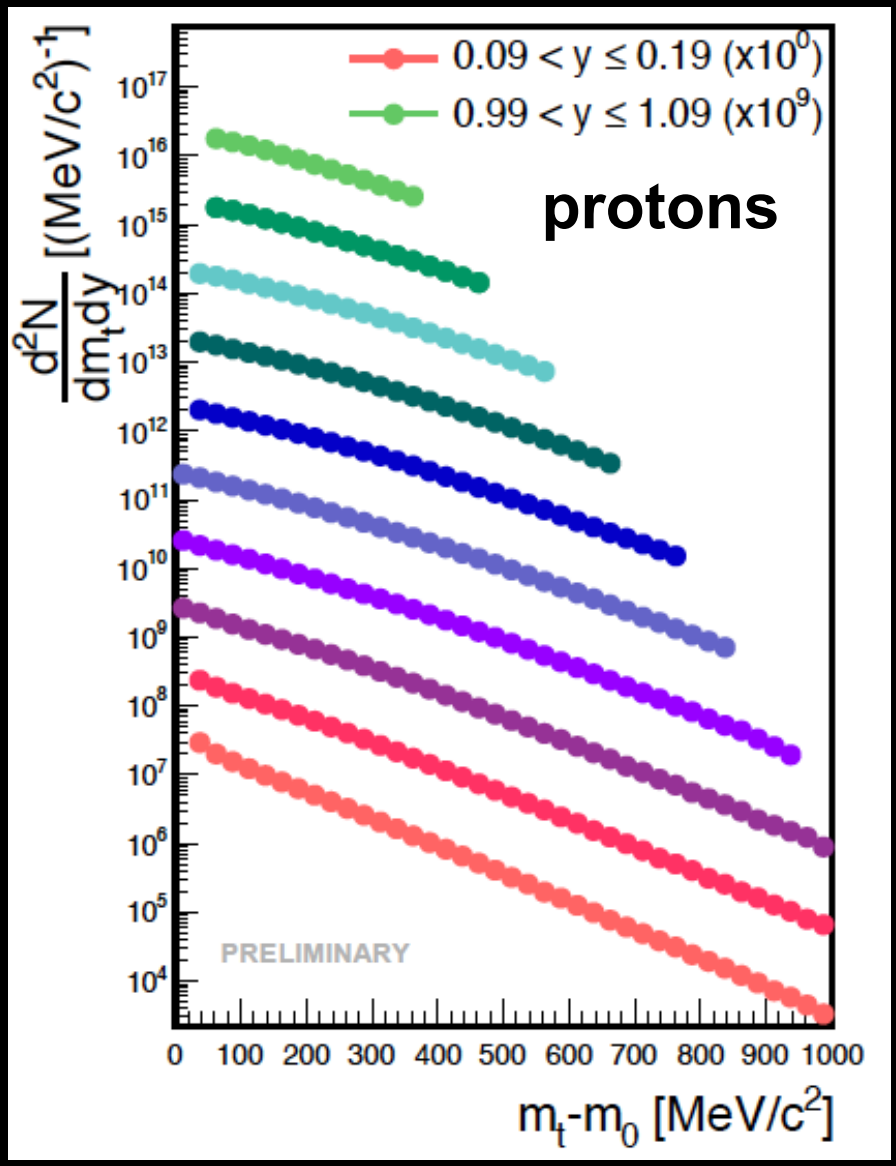

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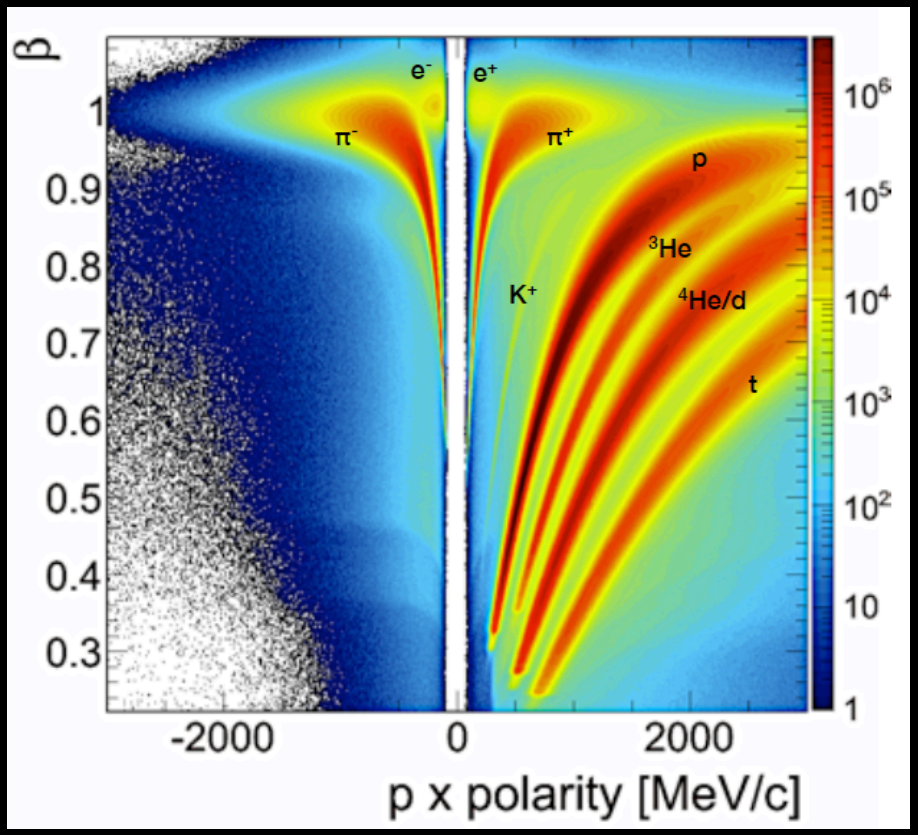

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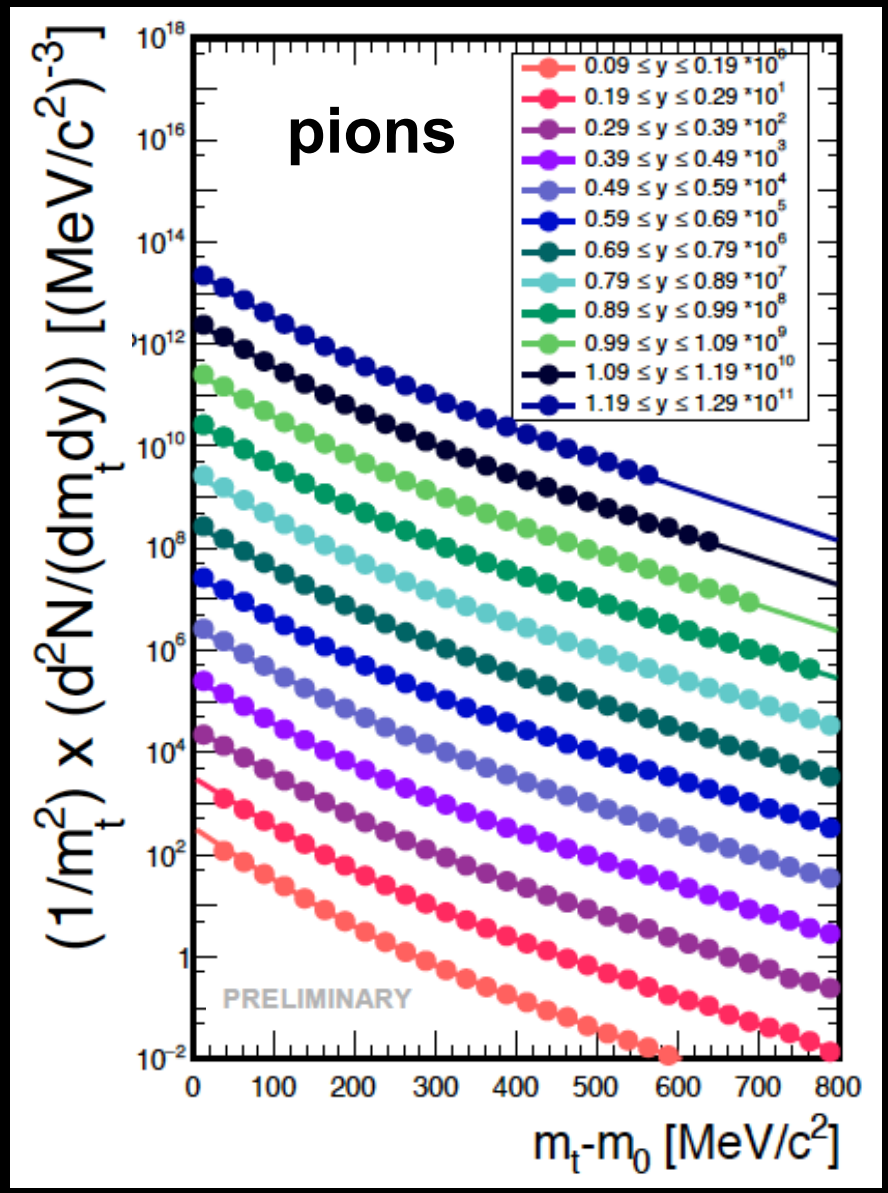

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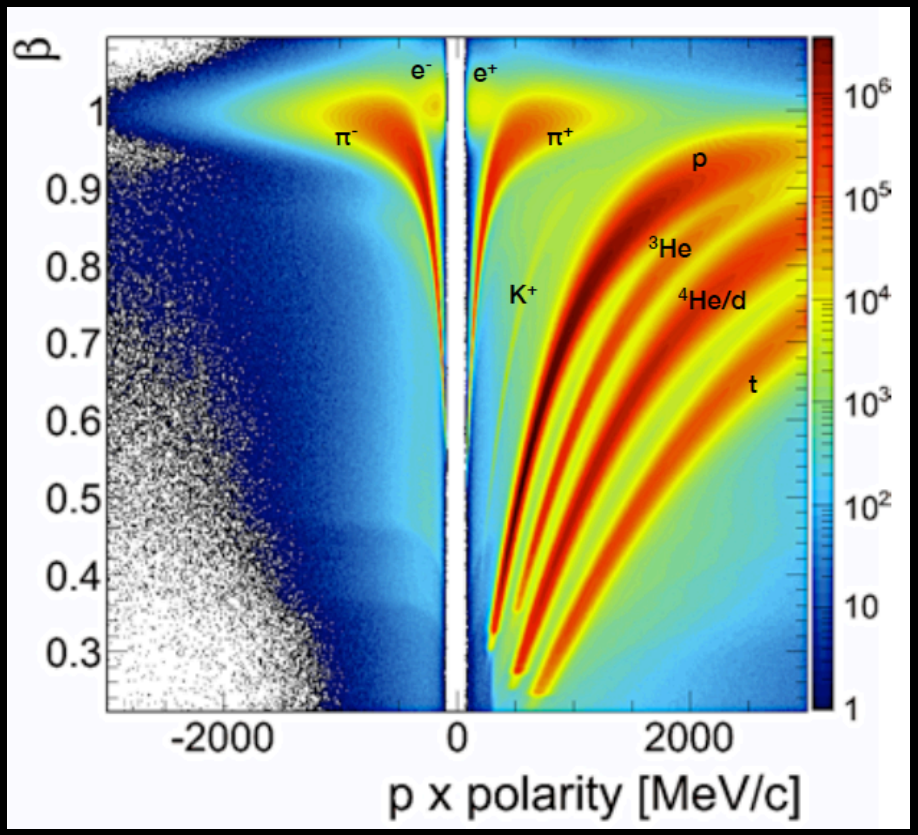

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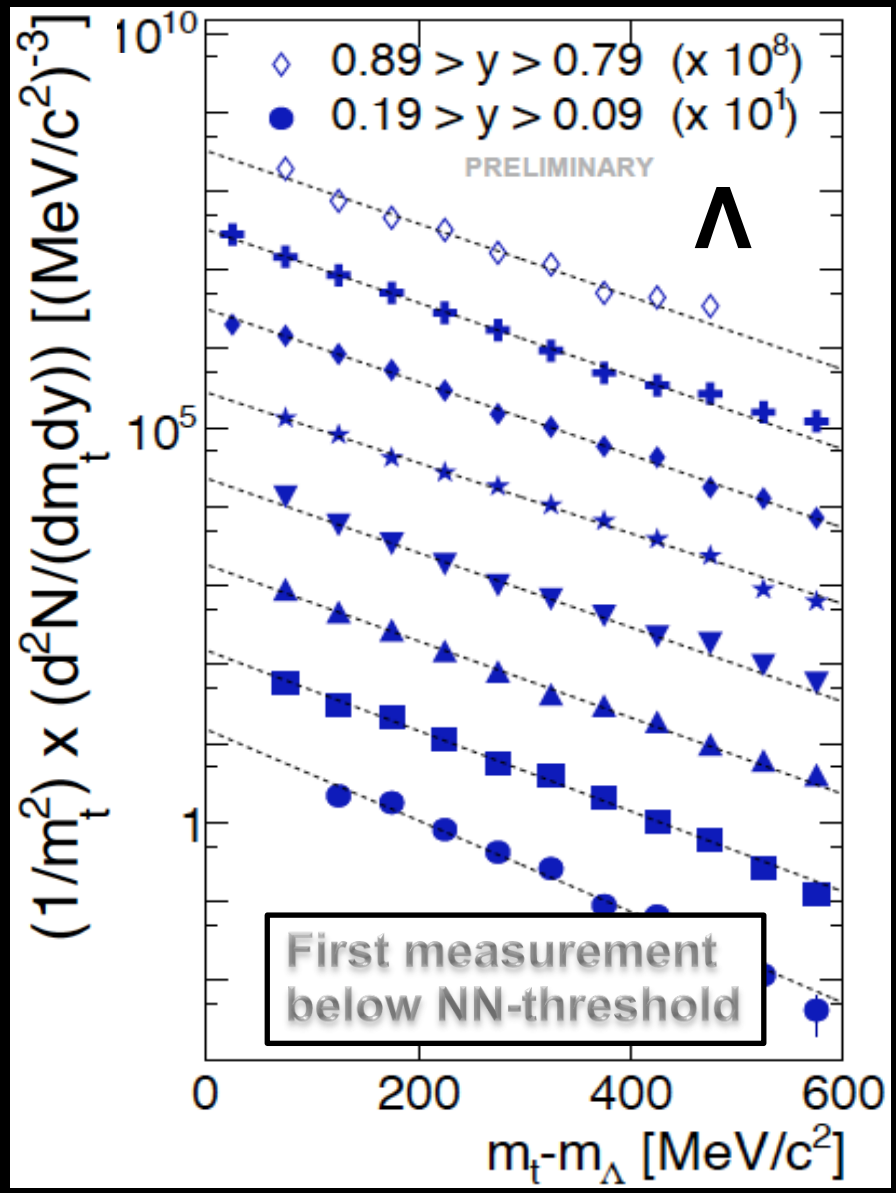

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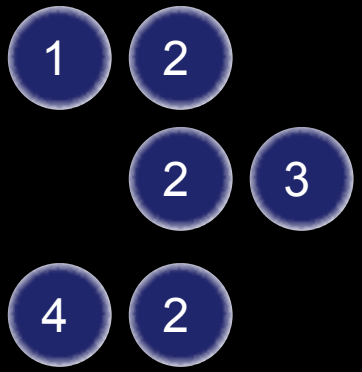

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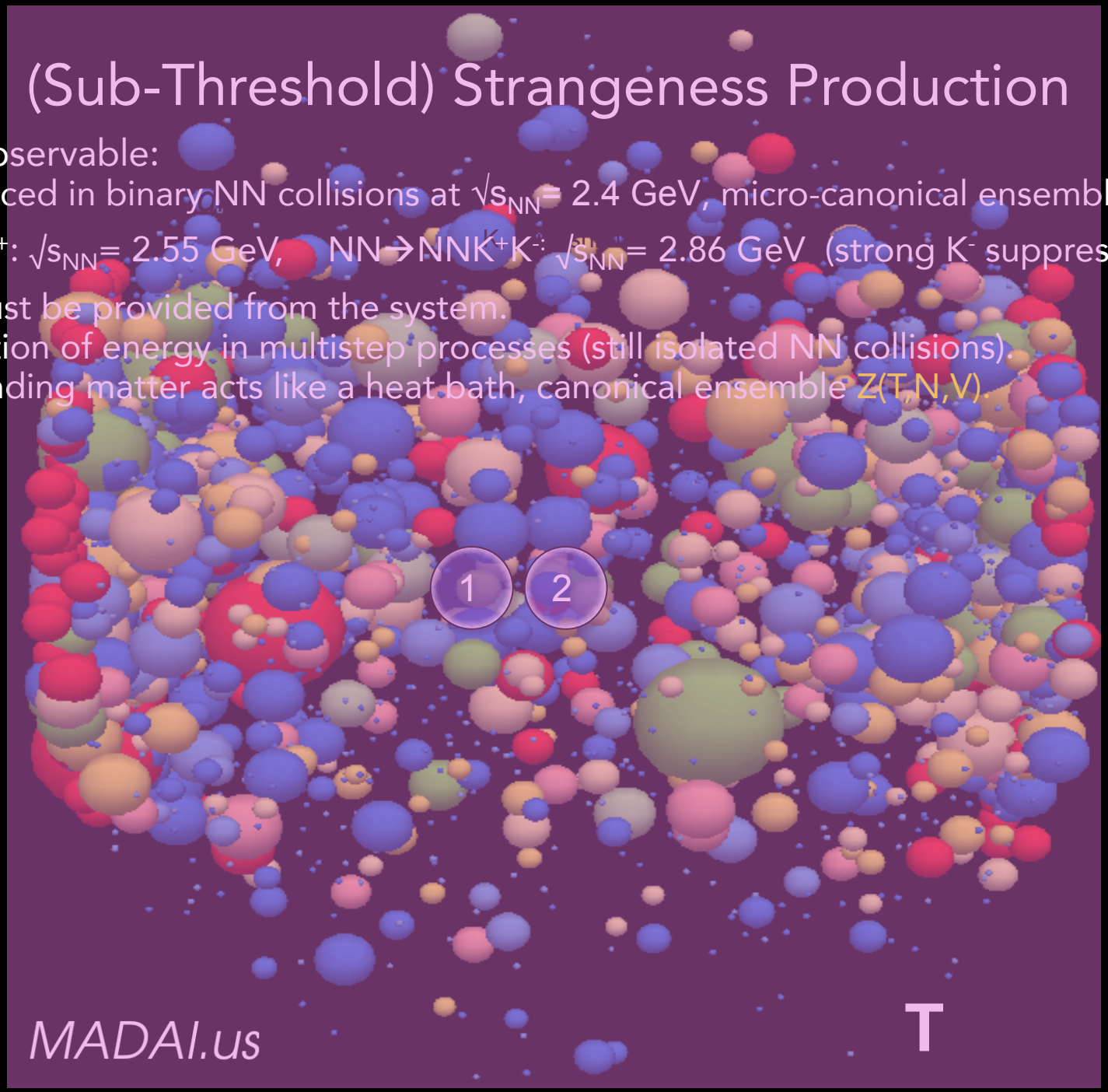

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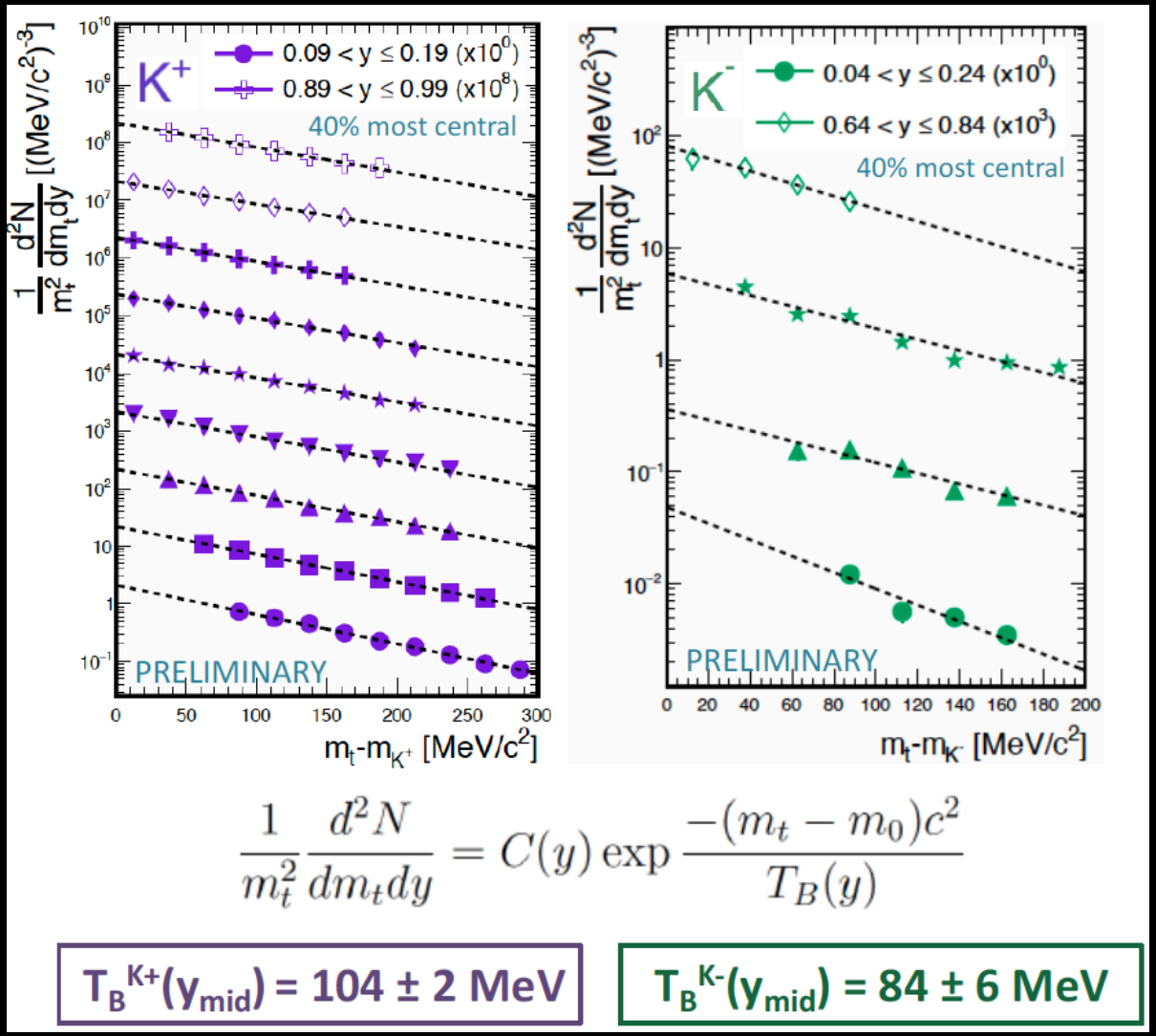


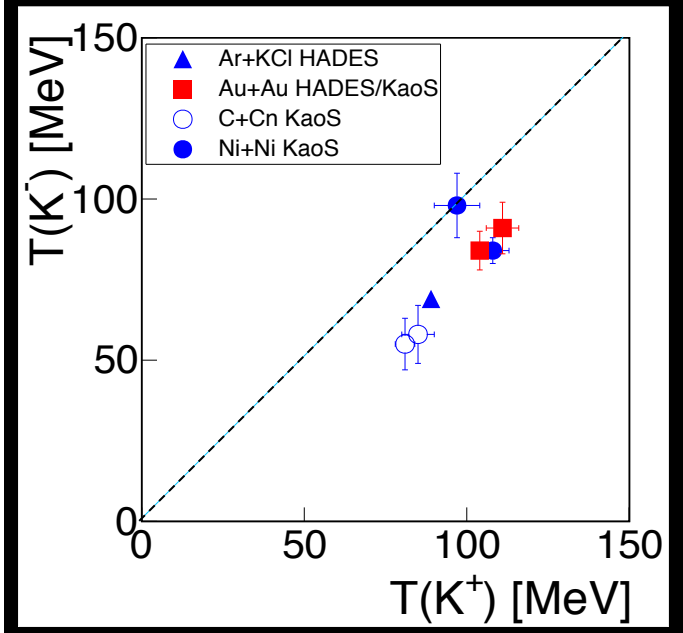
$$\frac{1}{m_t^2}\frac{d^2N}{dm_t dy} = C(y)\exp\frac{-(m_t - m_0)c^2}{T_B(y)}$$

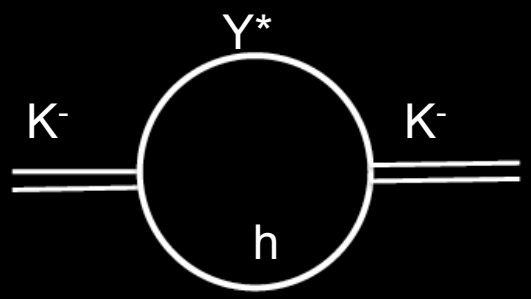
$T_B^{K+}(y_{mid}) = 104 \pm 2$ MeV

$T_B^{K-}(y_{mid}) = 84 \pm 6$ MeV

Kaons and antikaons show different slopes

KaoS: Phys.Rev. C75 (2007) 024906

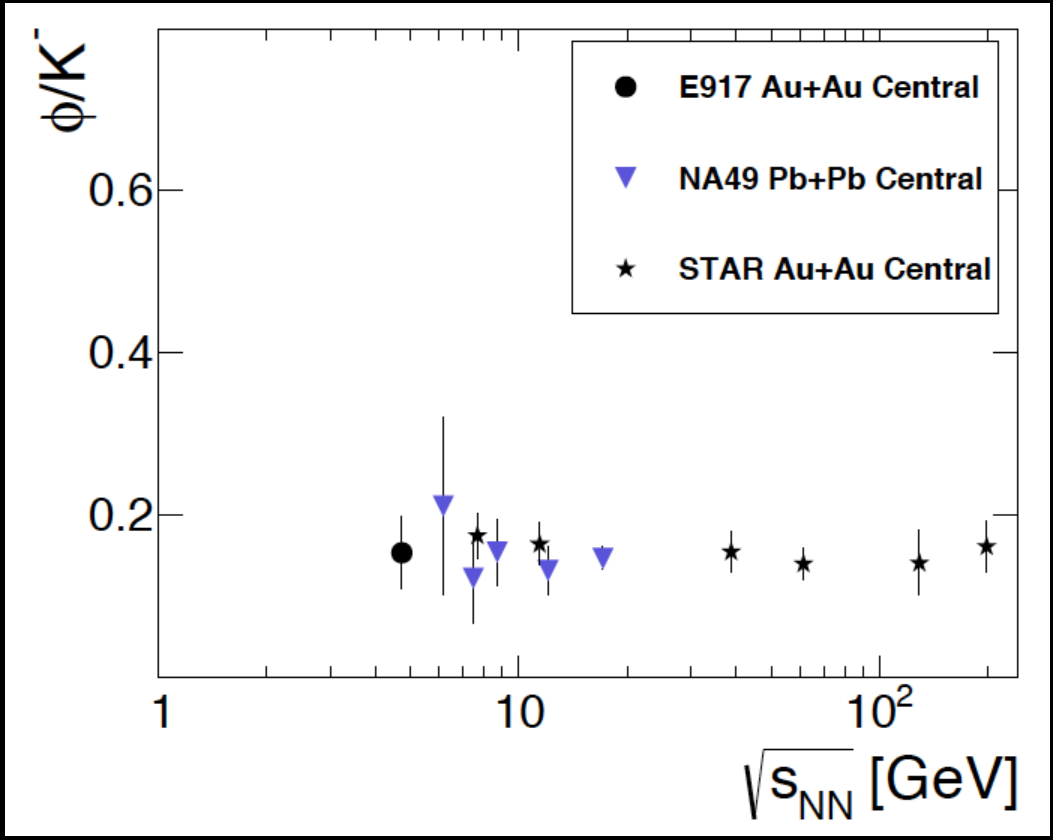




"Later freeze-out of K^- compared to K^+, due to coupling to baryons and strangeness exchange reactions ??"

https://arxiv.org/pdf/1703.08418.pdf

(Sub-threshold) Strangeness Production



Φ/K⁻ ratio constant at high energies

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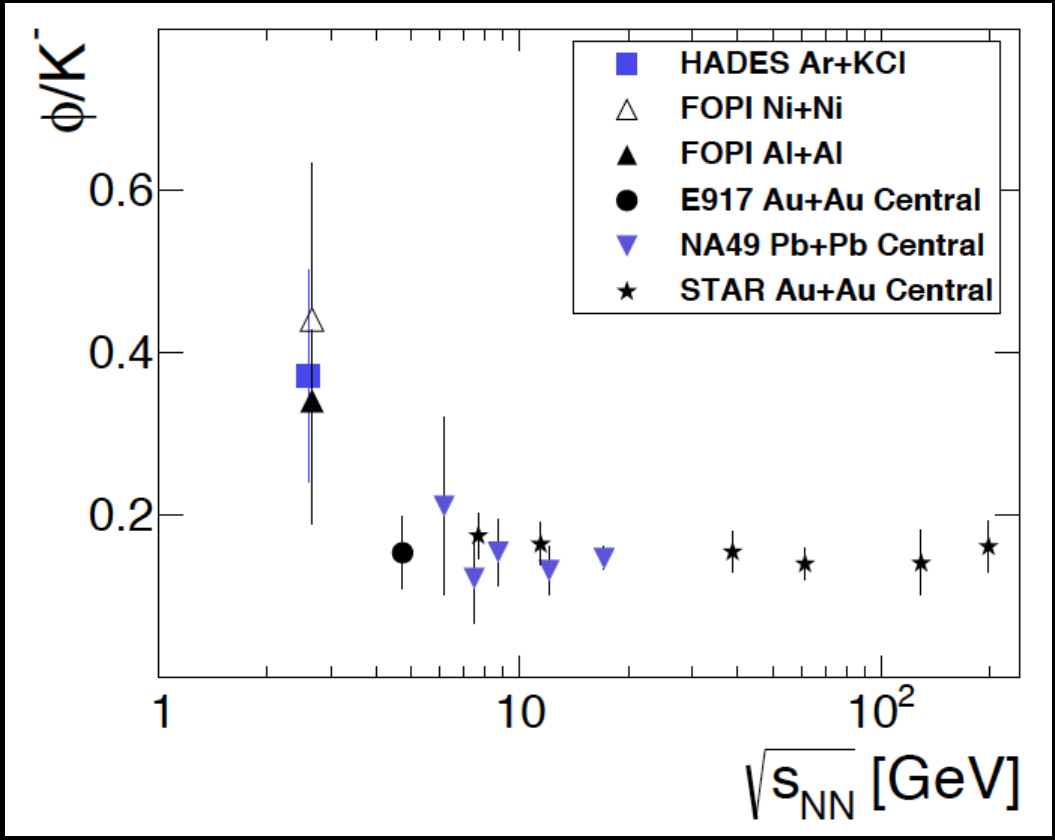

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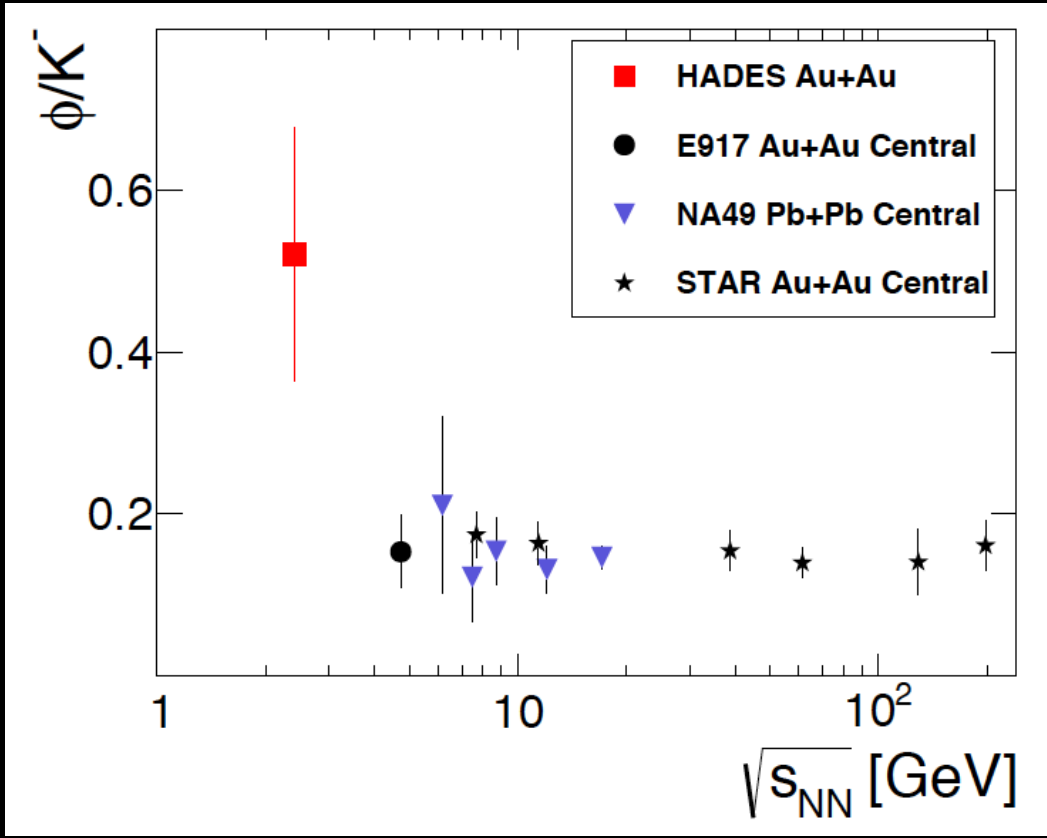

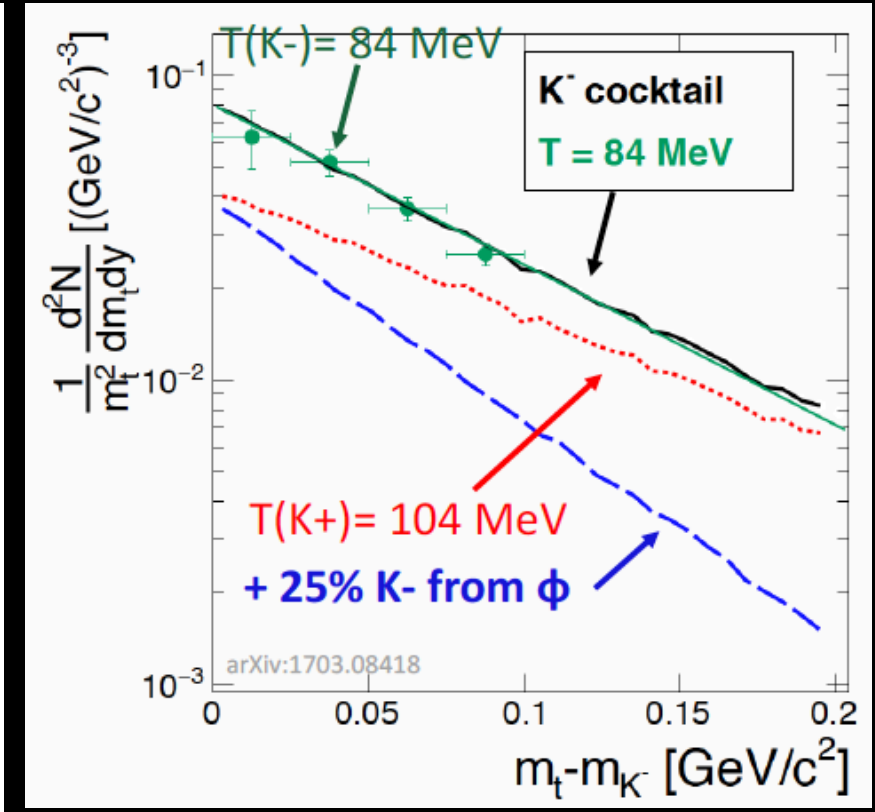

Increased in Au+Au collisions at low energies
➔ 25% of K^- result from Φ decays!

Φ feed-down can explain lower inverse slope parameter of K^- spectrum (T_{eff} = 84 ± 6 MeV) in comparison to the one of K^+ (T_{eff} = 104 ± 1 MeV)

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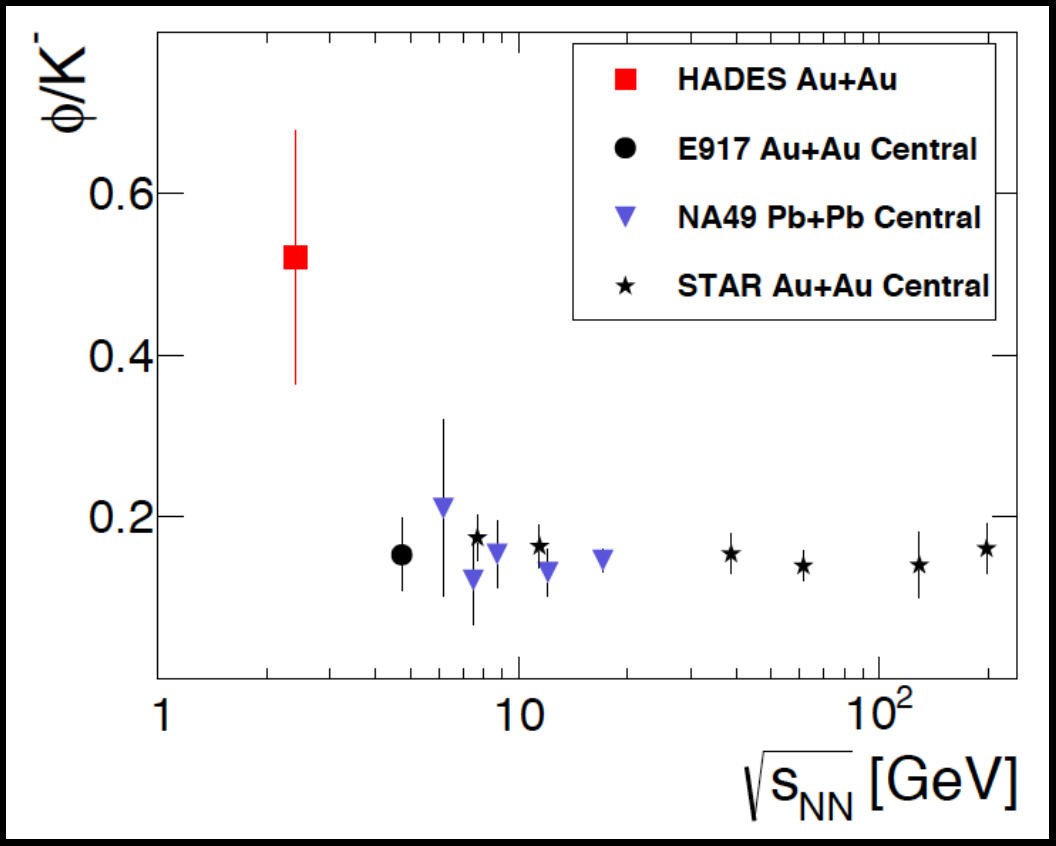

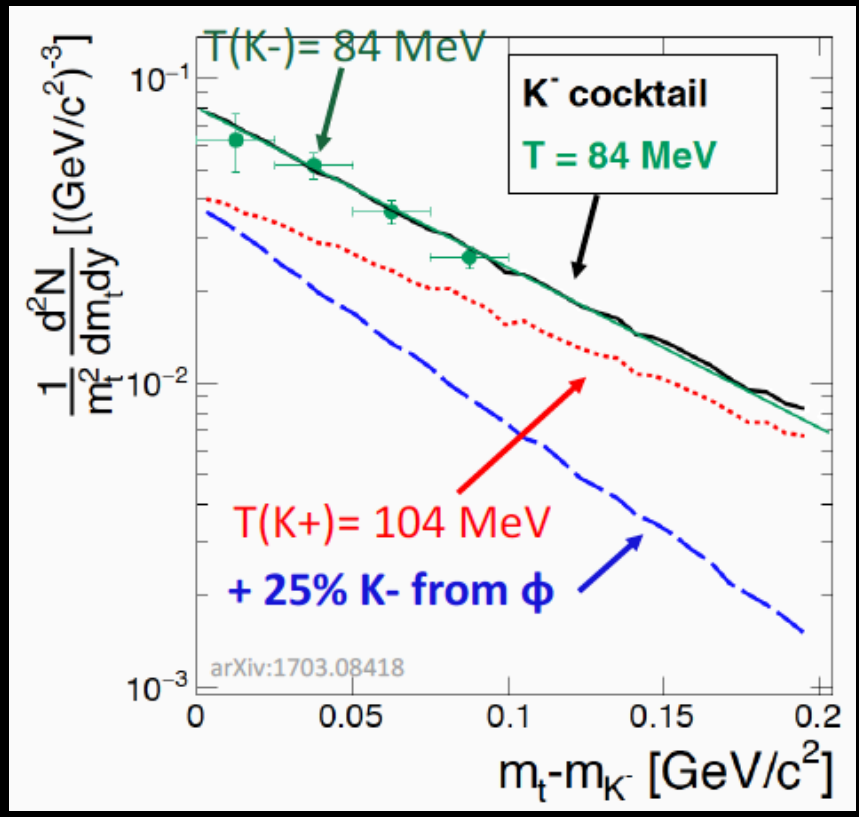

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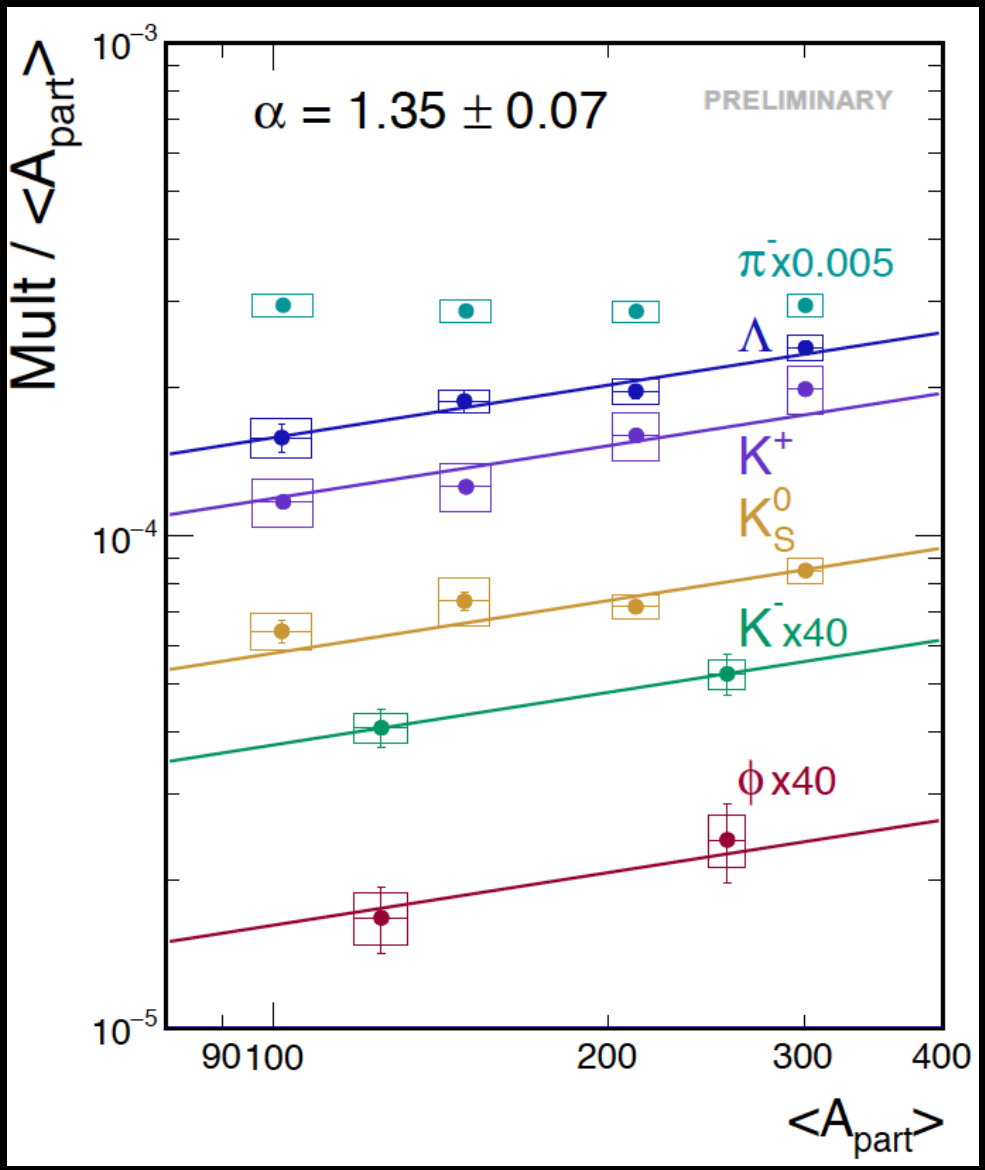
➔No indication for sequential K^+K^- freeze-out if K^- spectrum is corrected for feed-down.

(Sub-Threshold) Strangeness Production: the Complete Picture



- Strange particle yields rise stronger than linear with $\langle A_{part} \rangle$ ($M \sim \langle A_{part} \rangle^{\alpha}$)

- Universal $\langle A_{part} \rangle$ dependence of strangeness production

→ Hierarchy in production threshold not reflected

$N \rightarrow NYK^{+}$ $\sqrt{s_{NN}} = 2.55$ GeV
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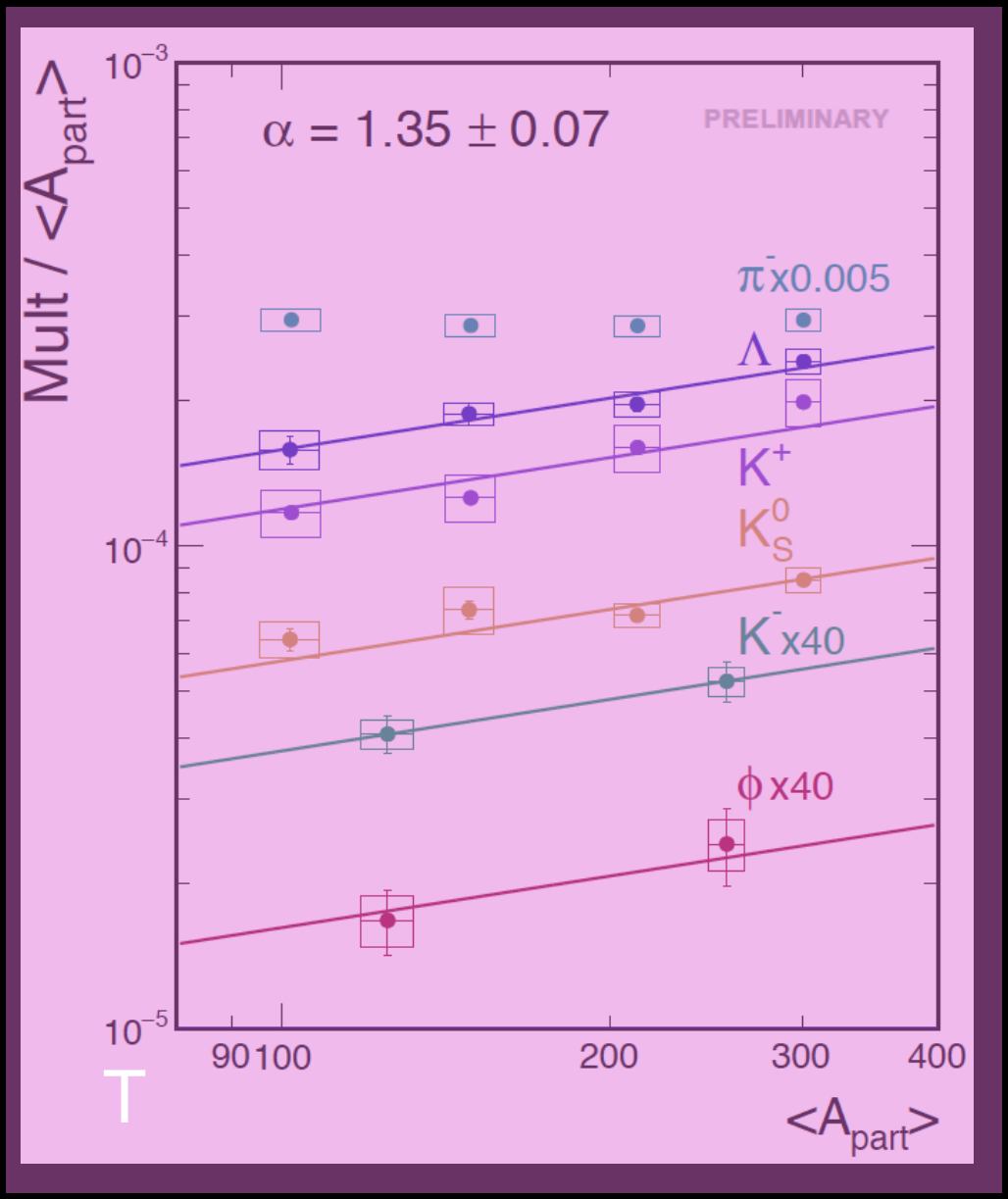

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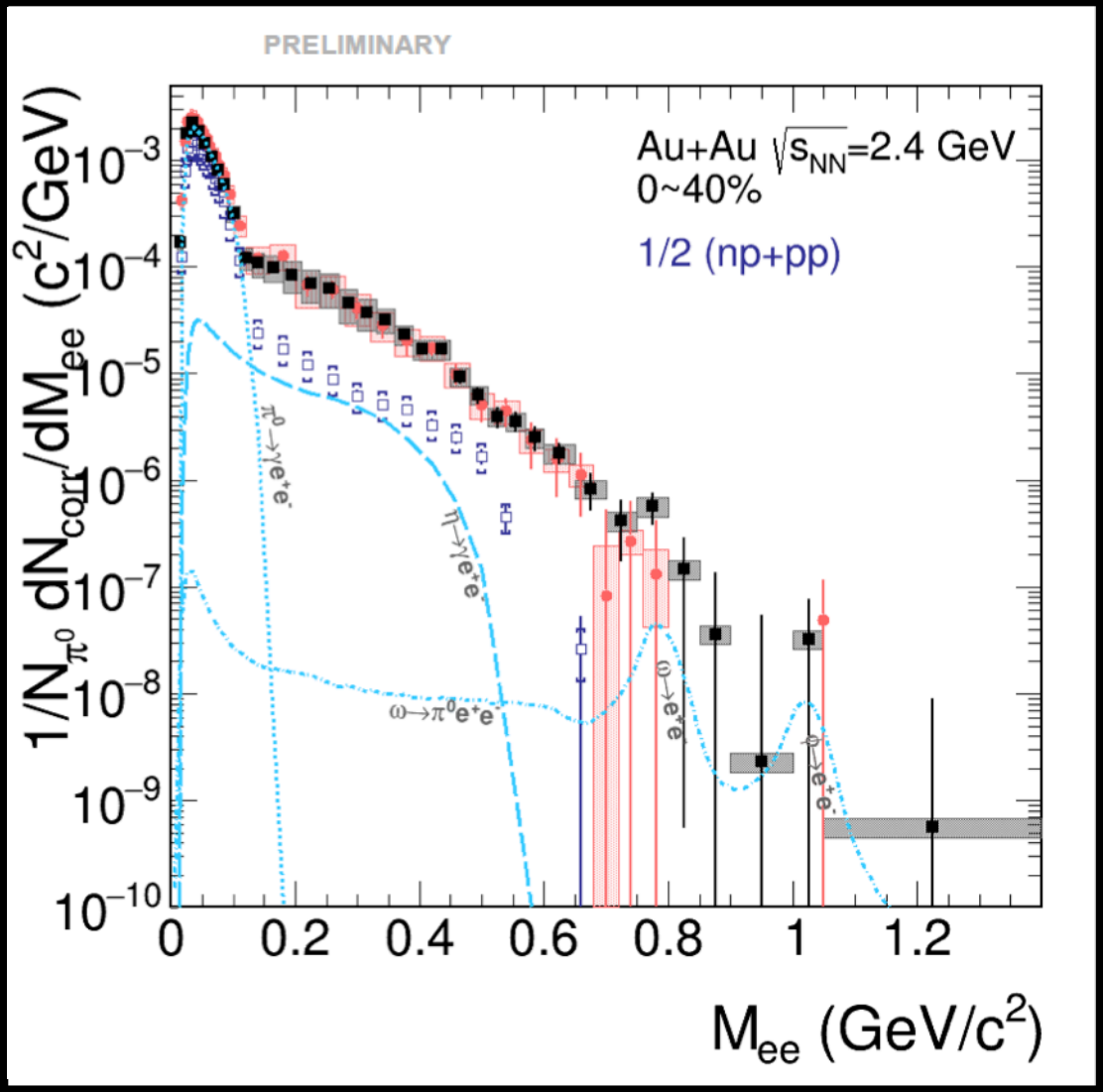

First measurement of e^+e^- for a heavy system in this energy regime.

Normalized to the number of π^0.

Strong excess yield ($0.15<M<0.7$ GeV/c^2) above e^+e^- cocktail components of meson decays at freeze-out and elementary baryonic reference observed.

→ Medium radiation

P. Sellheim, S. Harabasz

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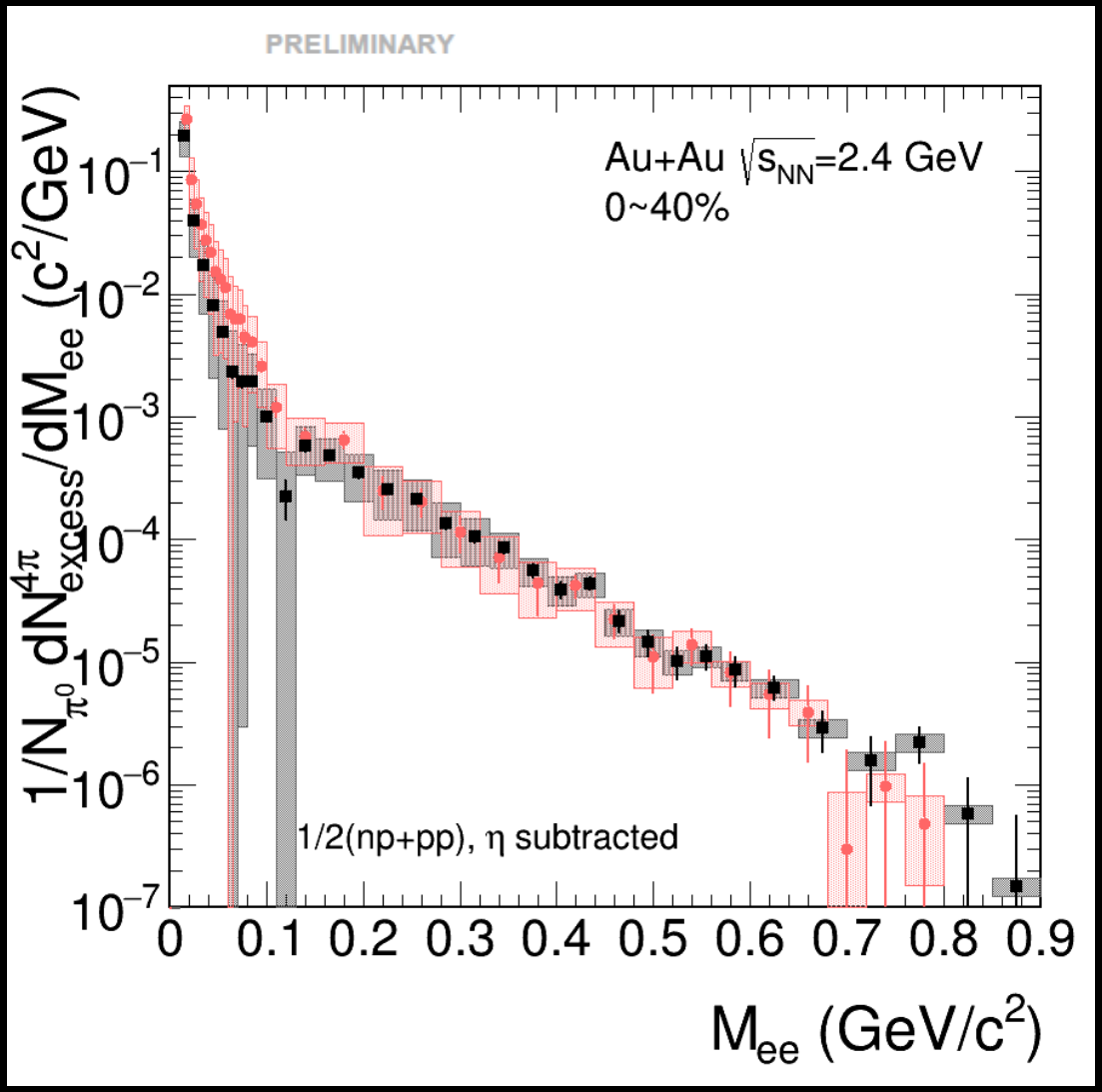

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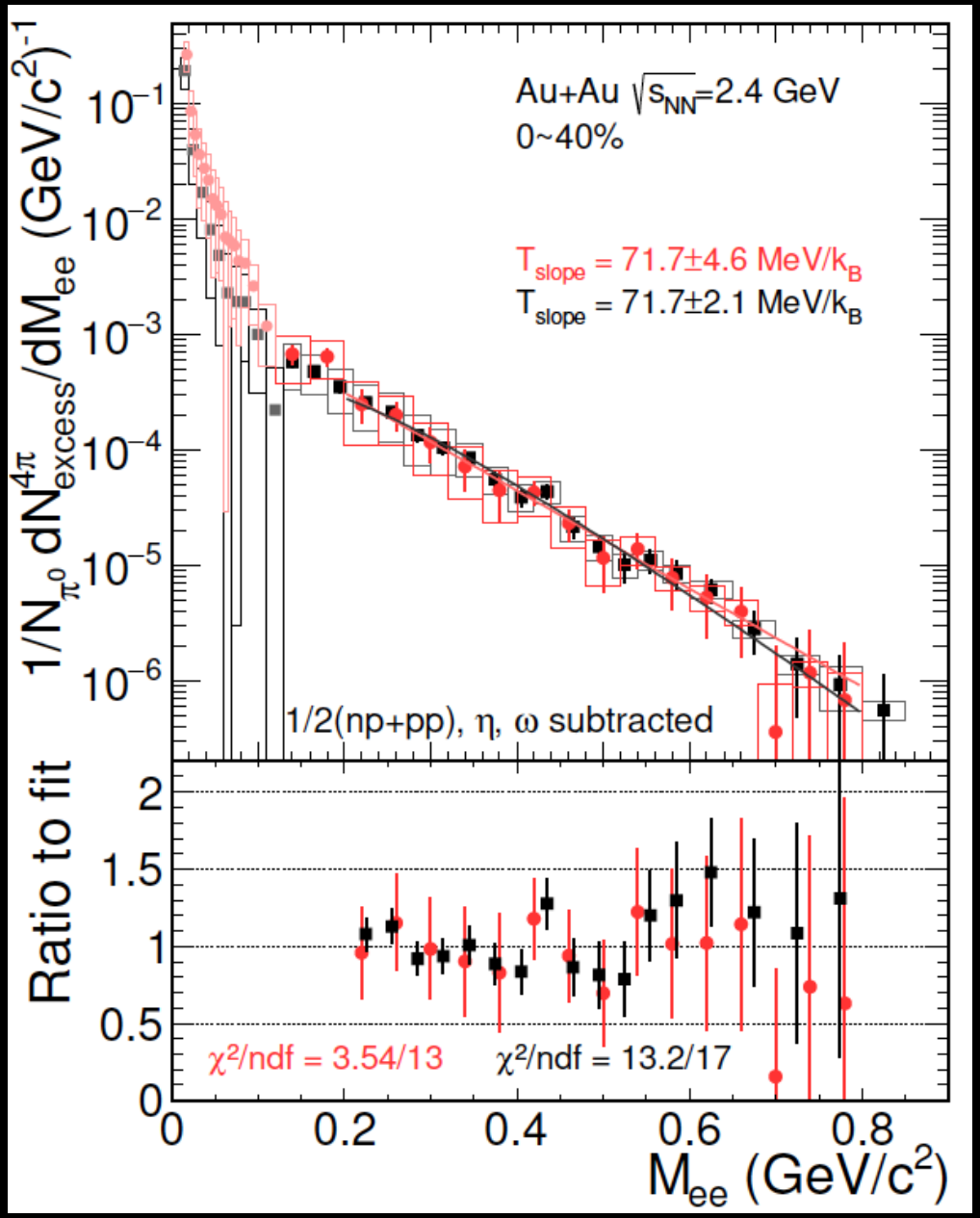

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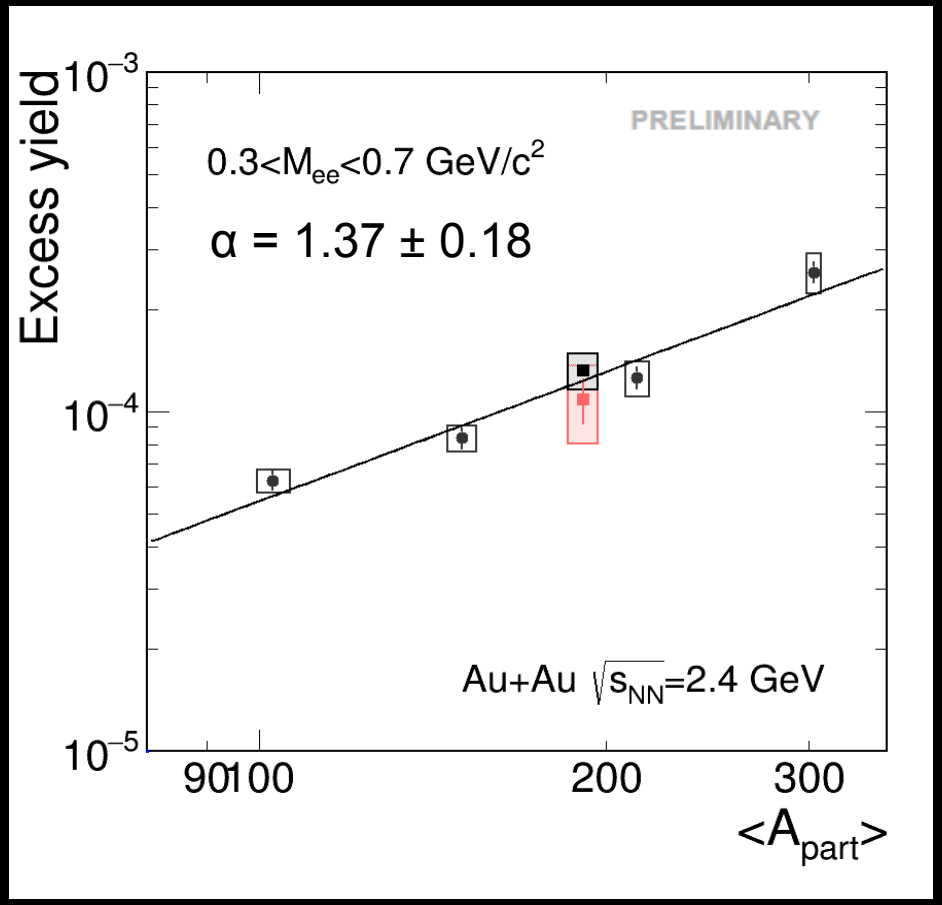
Exponentially falling spectrum,
→ extraction of source temperature

Centrality Dependence of Virtual Photon Emission

Dileptons: 0.3<M<0.7 GeV/c^2



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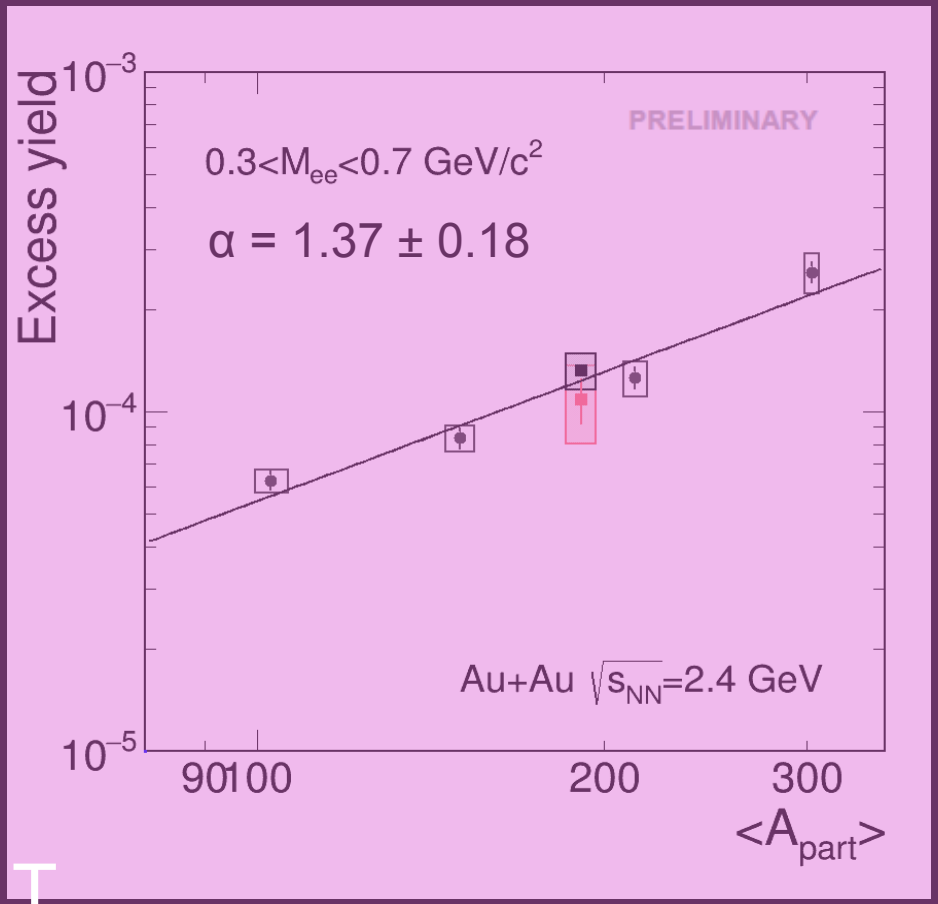
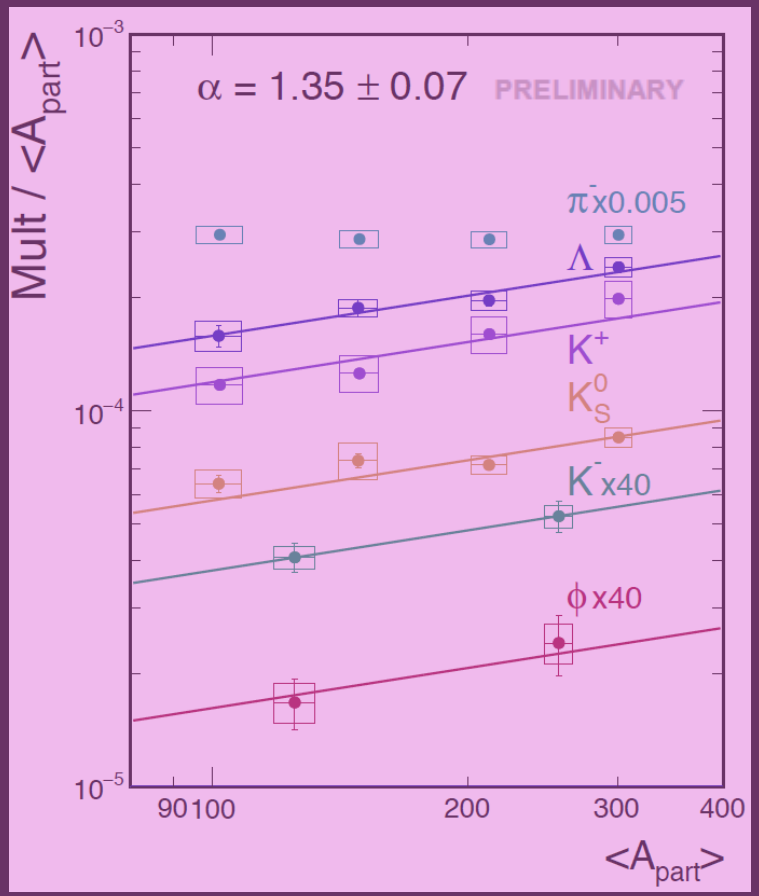


Strange Particles



Universal $<A_{part}>$ dependence

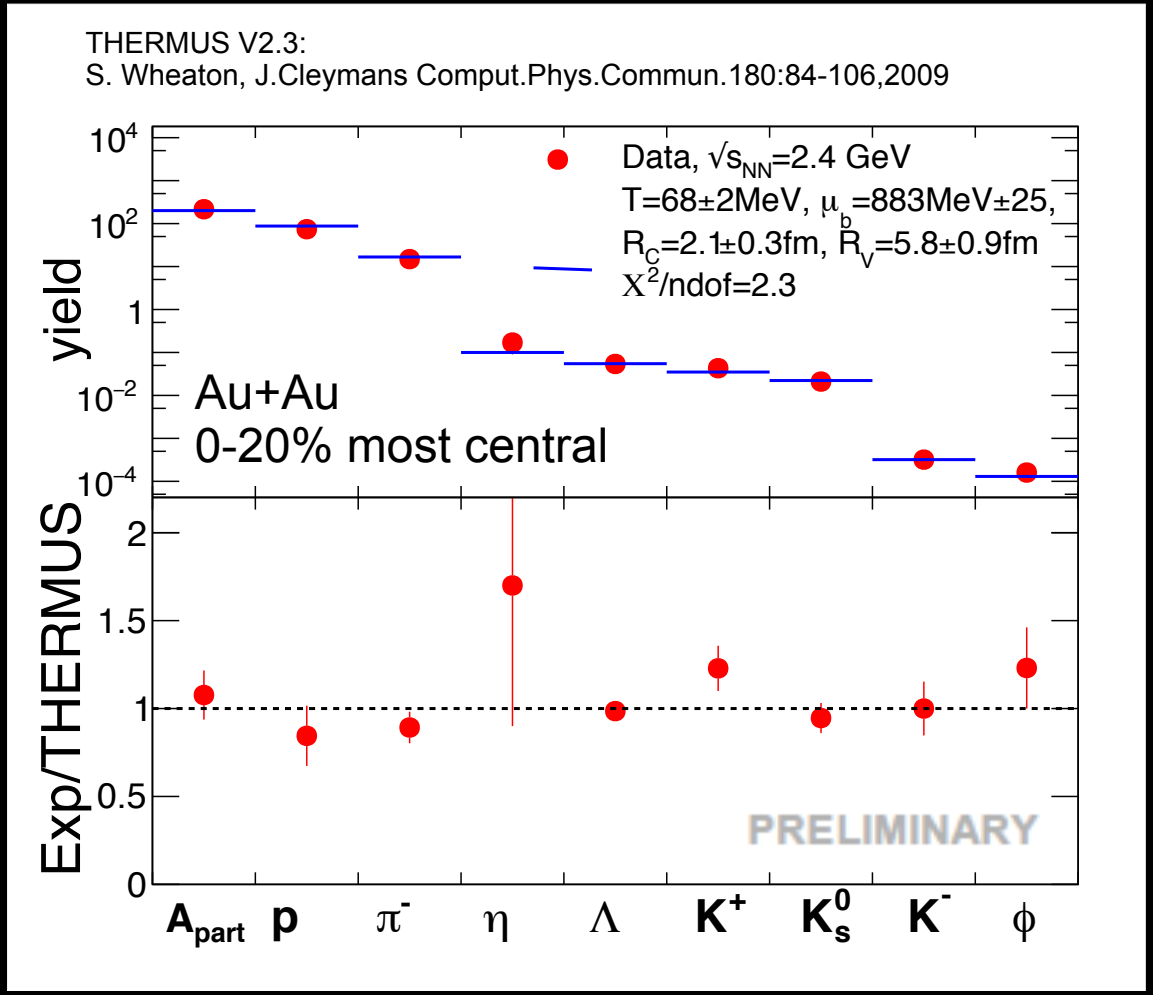
Macroscopic Description of Hadron Production

Particle production from a homogeneous source.

Strangeness canonical ensemble Parameter: T, μ_B, R_c, R.

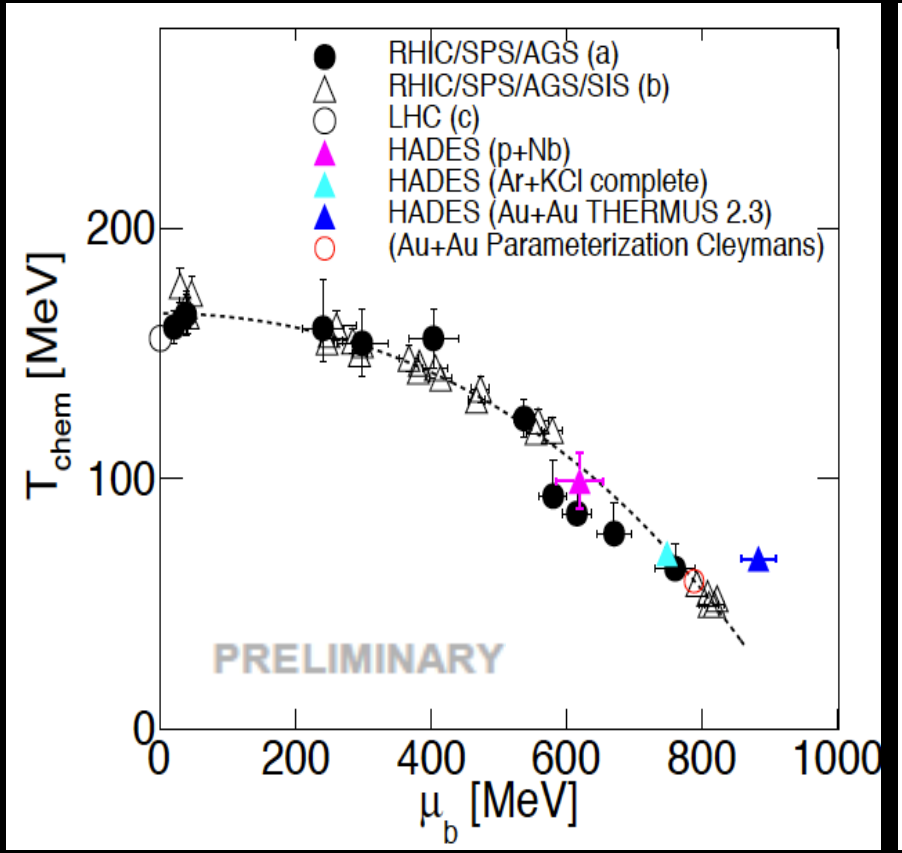
Additional parameter to suppress strangeness needed ($R_C < R_v$).

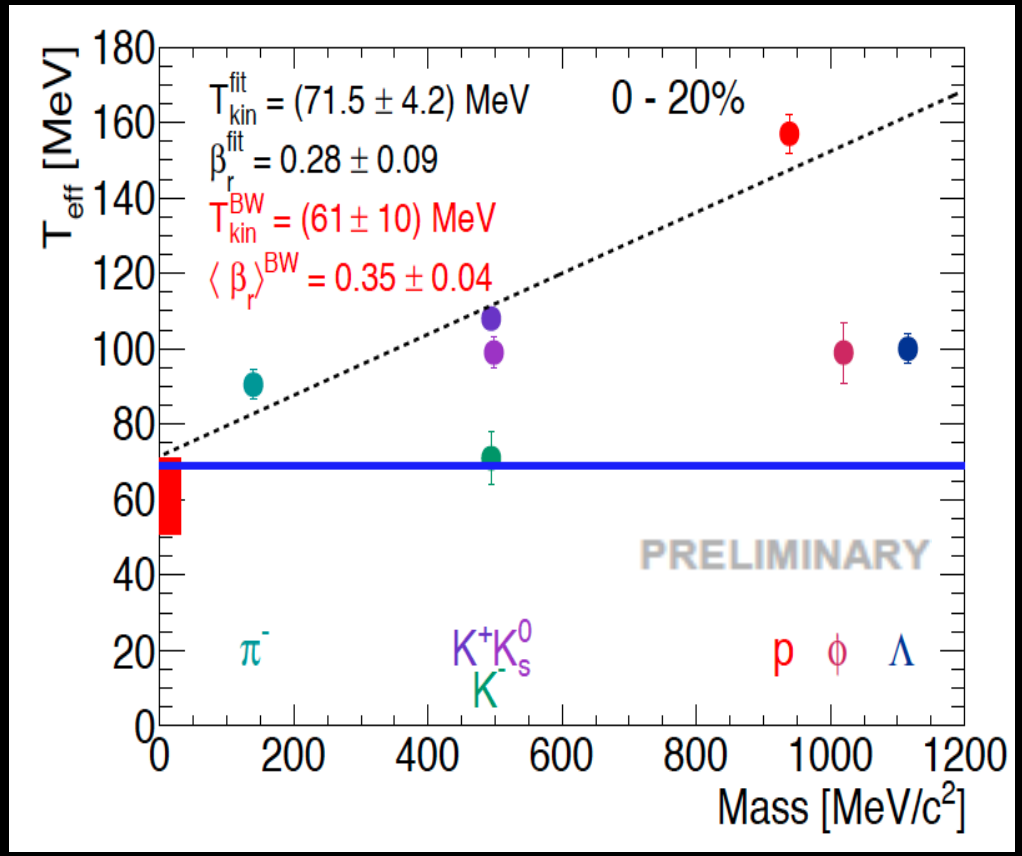
Fits at low beam energies based on limited number of particle species.



Hadron yields described by 4 parameters (T, μ_B, R, R_c)

Chemical vs. Kinetic Freeze-out



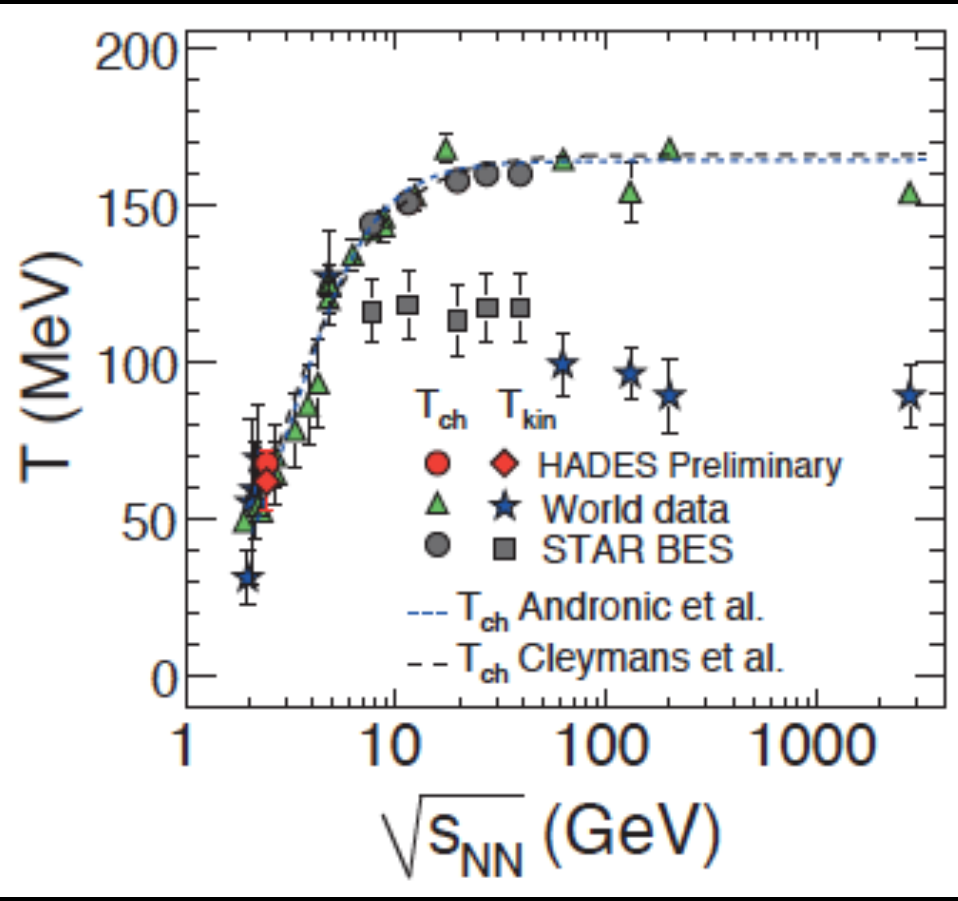


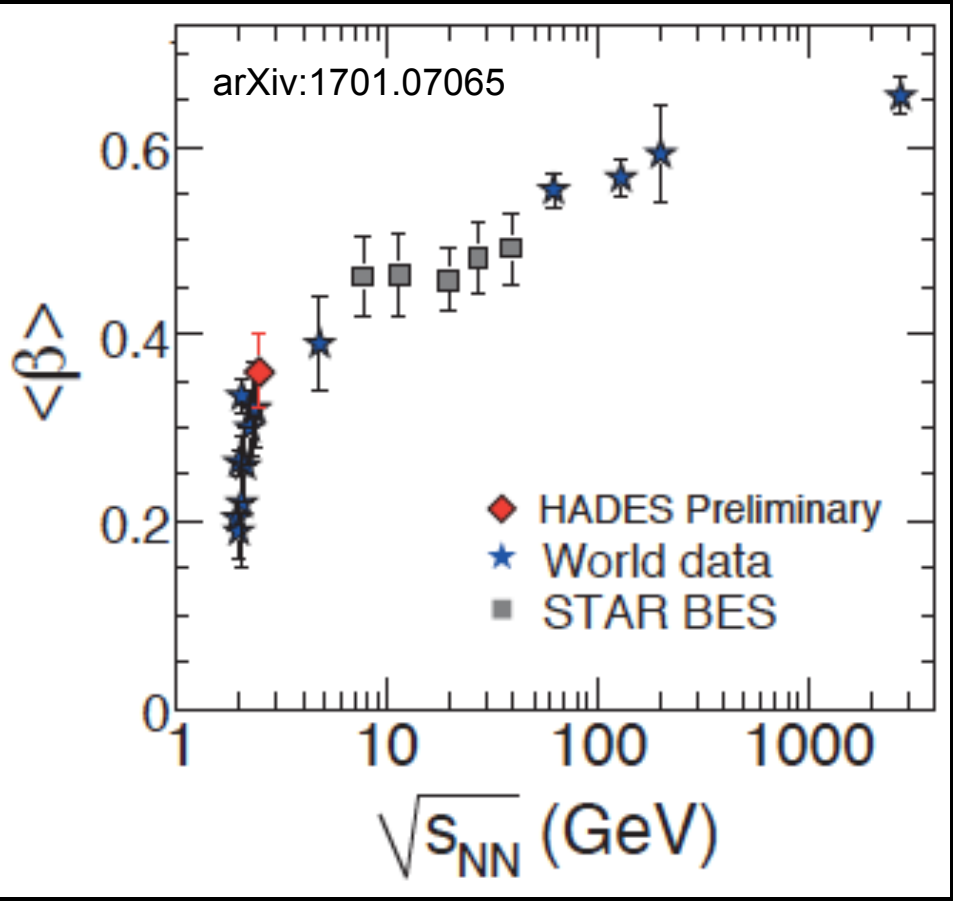
Freeze-out point at higher T and μ_B than expected from parameterization: under investigation

T_{chem} no longer in conflict with T_{kin}. What about Φ and Λ?

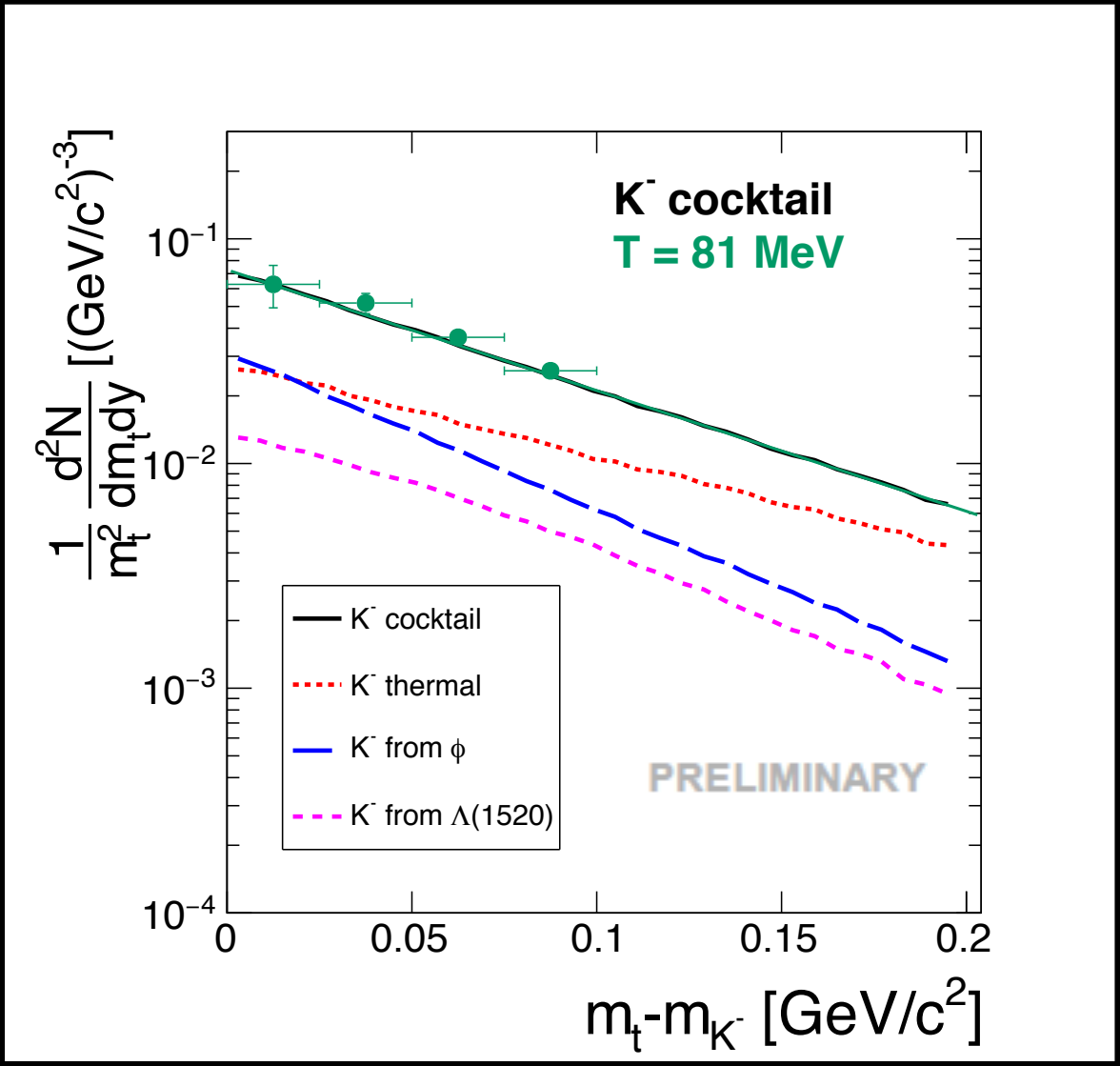
T_{chem}: 68±4 MeV
e^+e^- excess: T_{ee}=72±4 MeV

Freeze-out parameter systematics





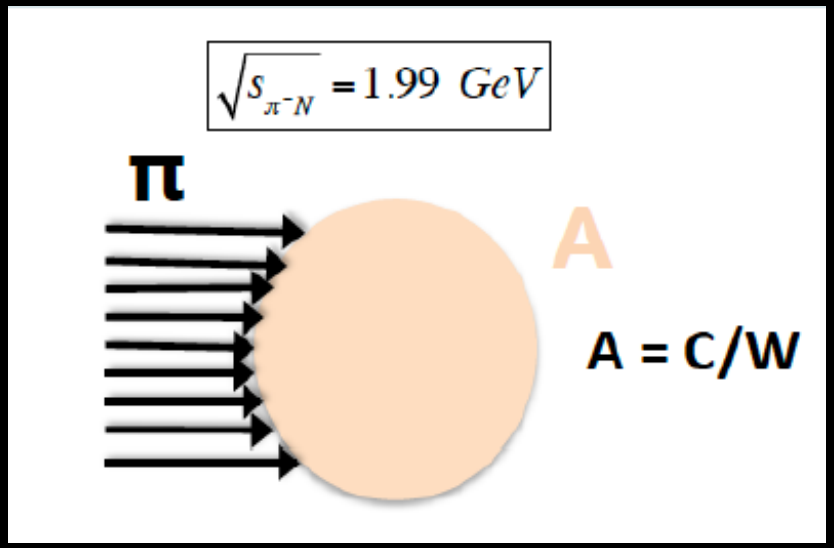
Cocktail components of hadron spectra from resonance decays: K^-

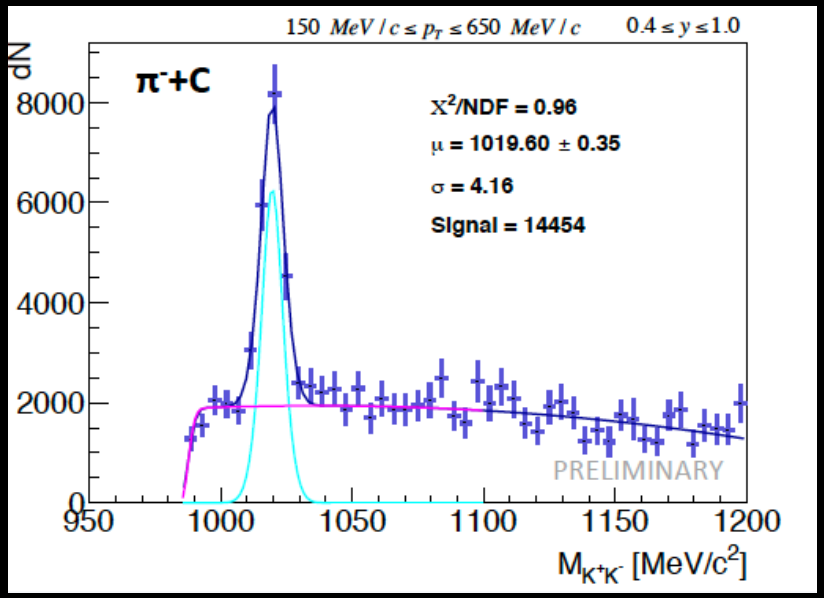


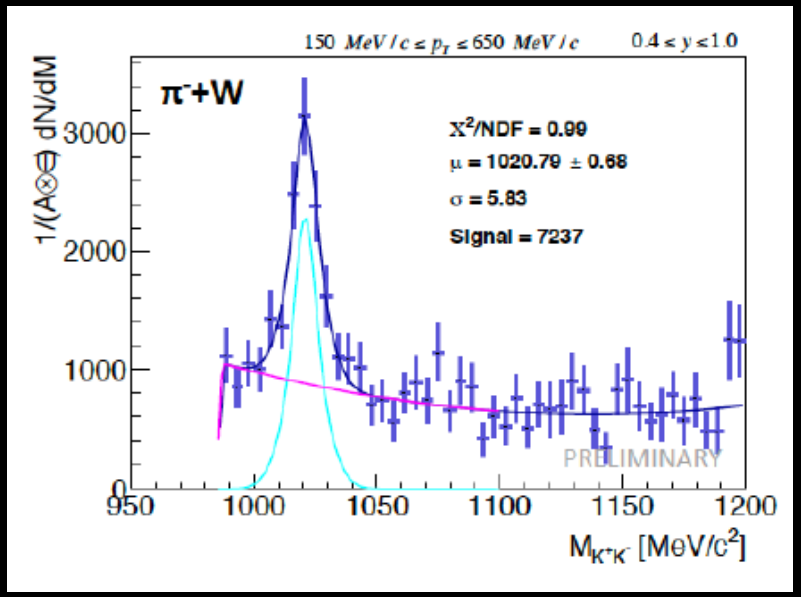
Λ(1520) yield based on Thermus fit

Thanks to Che-Ming Ko!

Pion induced reactions on nuclei: ϕ production

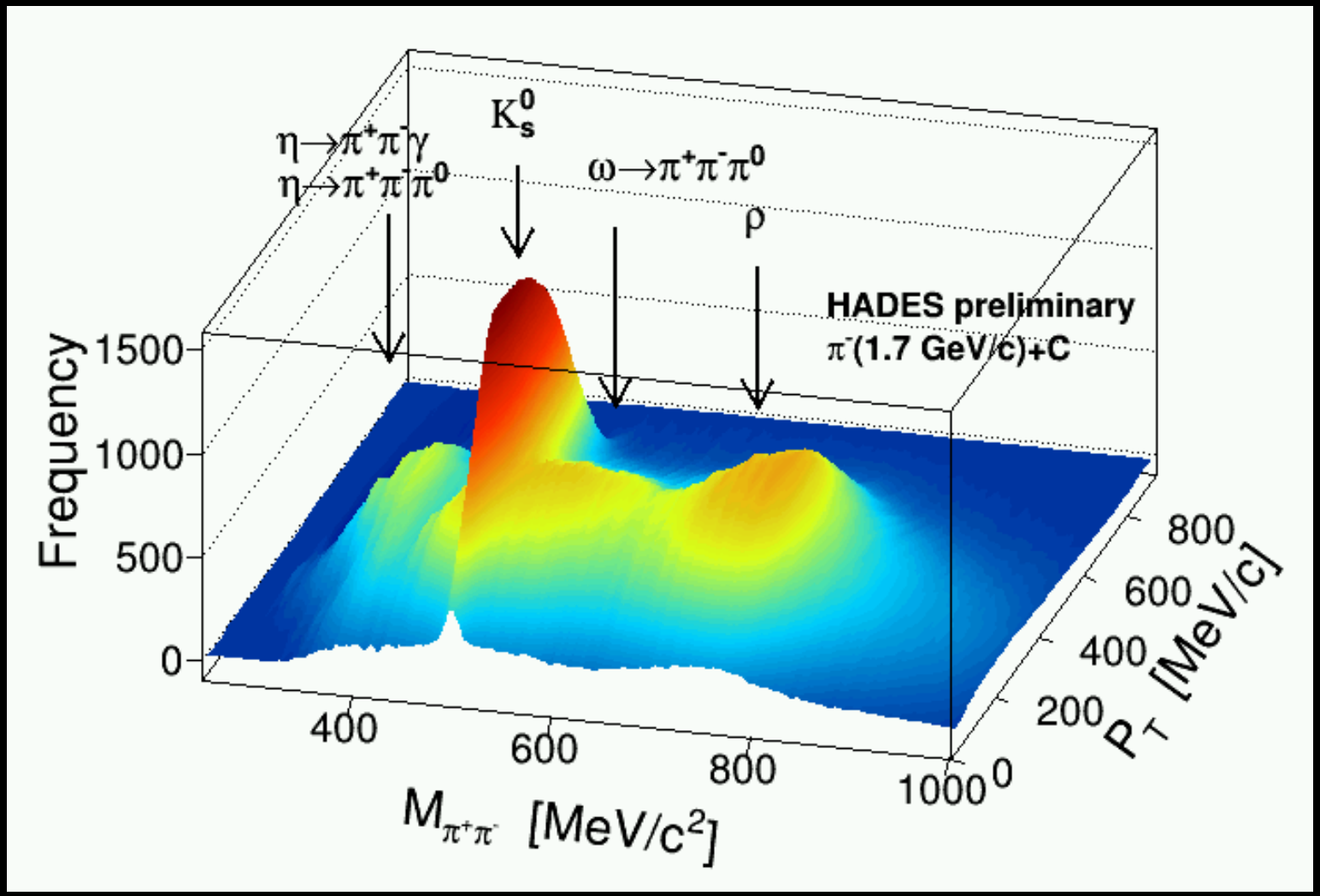






J. Wirth

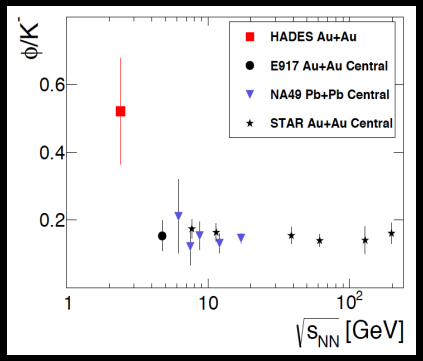
Pion induced reactions on nuclei: resonances



Summary

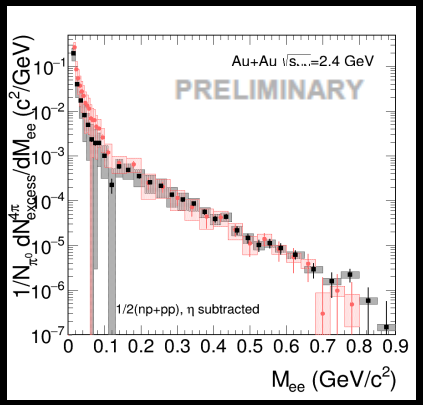
Sub-Threshold Strangeness Production

No indication for sequential K^+K^- freeze-out when correcting for ϕ feed-down.
Universal $<A_{part}>$ dependence of strange hadrons.



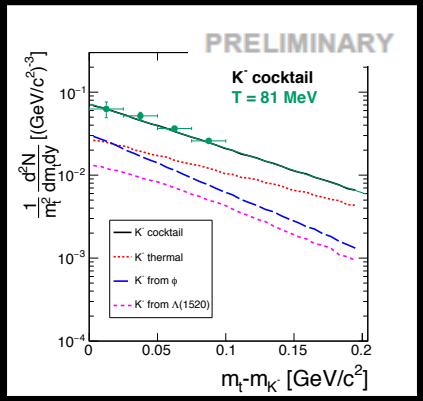
Virtual Photon Emission

Strong e^+e^- excess over reference.
Exponentially falling spectrum.
Similar rise with $<A_{part}>$ as observed for strange hadrons.



Freeze-out Parameter

T_{kin}=62±10 MeV and $<\beta_r>$=0.36±0.04 extracted from blast wave fit.
T_{chem}=68±2 MeV extracted from statistical model fit.
T_{ee}=71±4 MeV extracted from virtual photon spectrum.



Pion induced reactions

Clean tool to study ϕ in nuclear matter and to constrain resonance contributions to particle spectra.

The Future

Submitted to PAC on June 19, 2017

FAIR Phase-0:

π + p/A √s=1.7-1.9 GeV: resonance contributions and EM-structure

Ag+Ag@1.65 A GeV: Multi-strange hadrons & intermediate mass dileptons

SIS100:

Continue physics program at higher energies
(focus on elementary and light systems)

The HADES collaboration

Thank you for your attention!