Recent results from HADES

Manuel Lorenz for the Collaboration

Outline

Introduction:

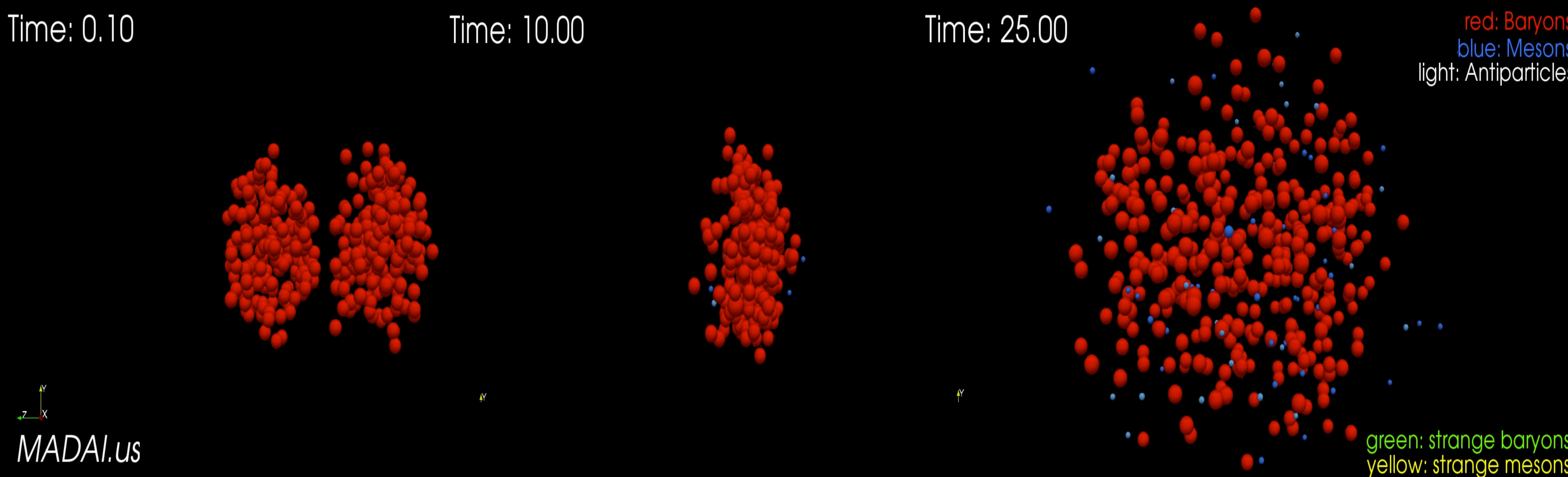
- Heavy-ion collisions @ $\sqrt{s_{NN}}$= 2.4 GeV
- Hadron production
- Hypernuclei

Sub-Threshold Strangeness Production:

- Microscopic description: the KN potential
- Details matter: the ϕ/K- ratio and the KbarN potential
- Macroscopic description and the complete picture

Summary and Future

Heavy-ion collisions a $\sqrt{s_{NN}}$=2.4 GeV



Long interpenetration times
Baryon stopping in the collision zone

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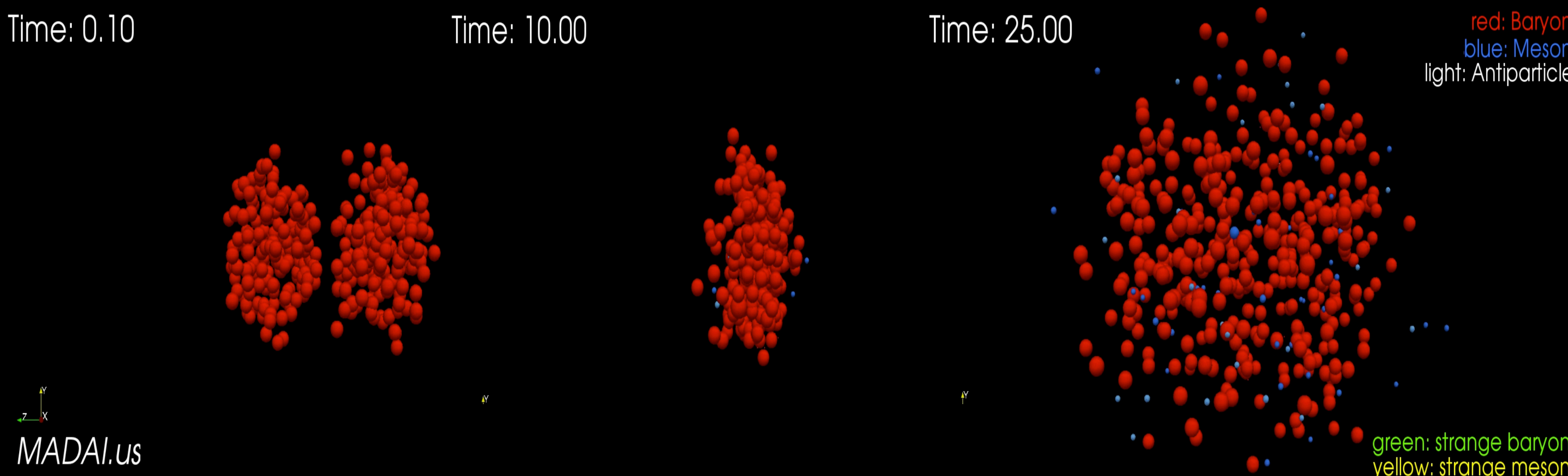

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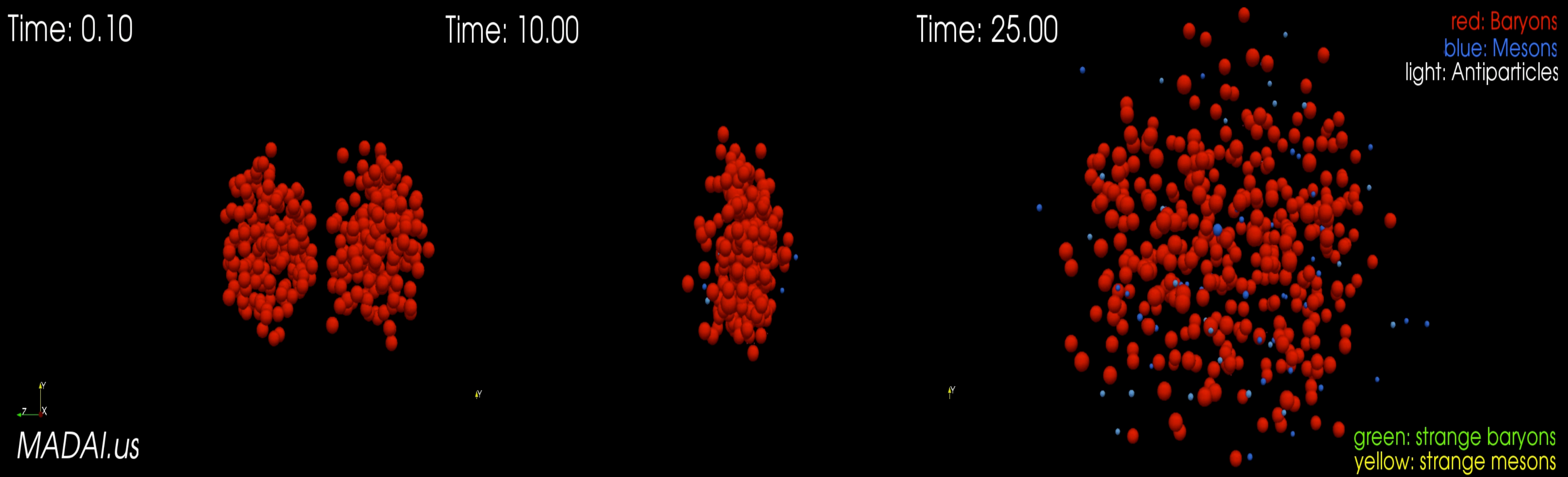

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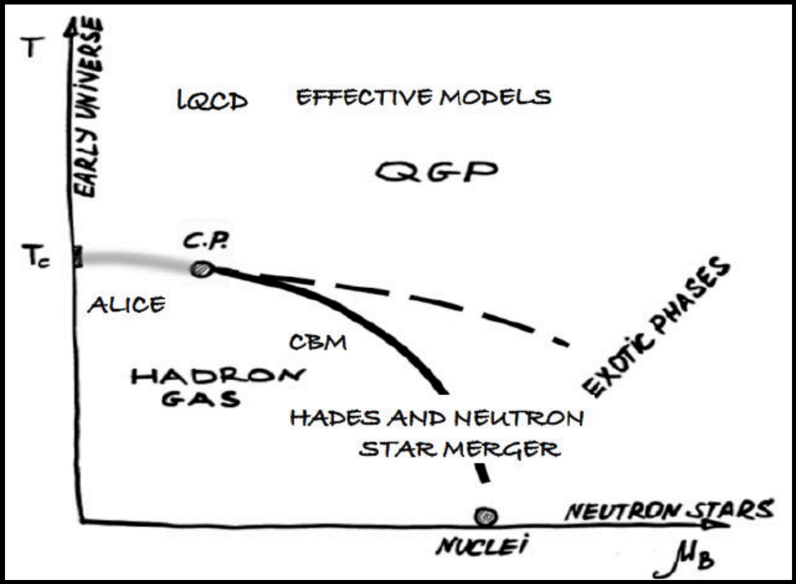

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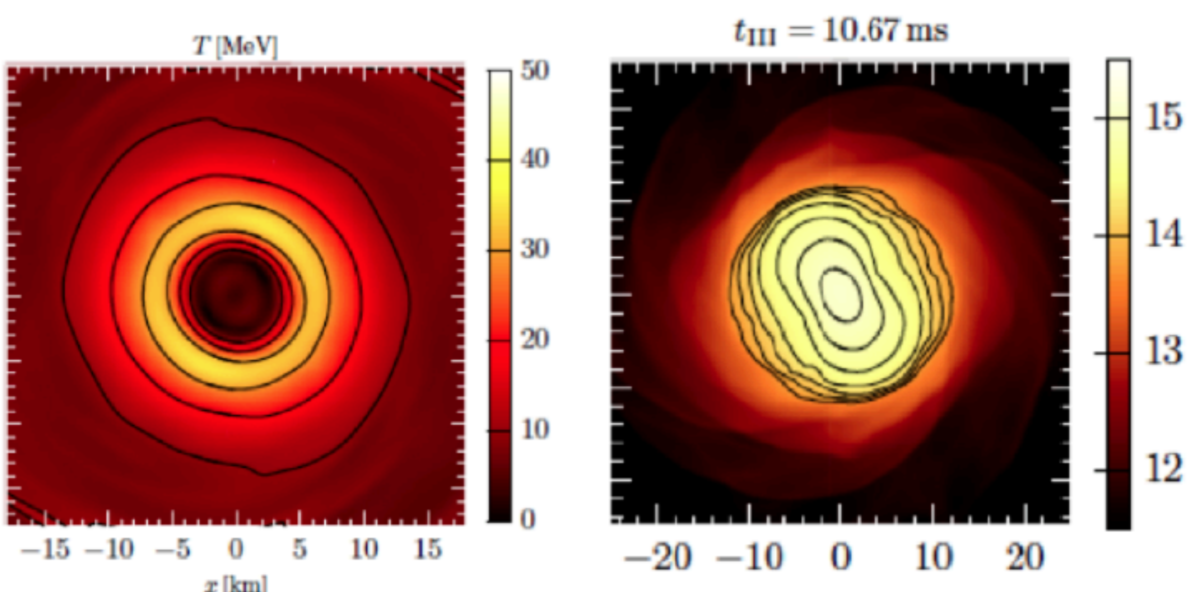
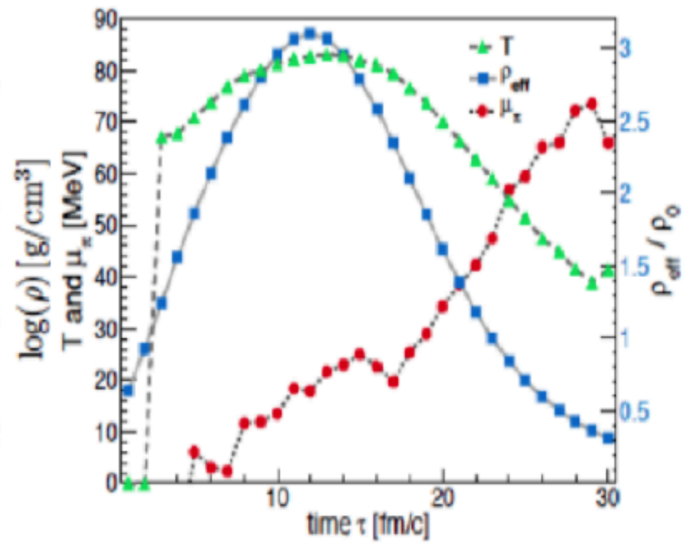


M. Hanauske et al. Phys.Rev. D 96 (2017) no.4, 043004.

T. Galatyuk et al. Eur. Phys. J. A 52 (2016) no.5, 131.



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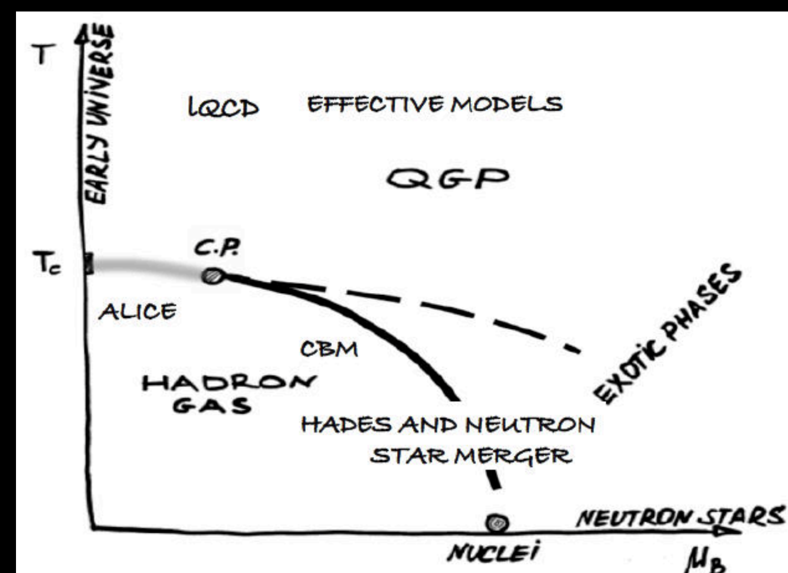
→ Similar region in the phase diagram as neutron star merger



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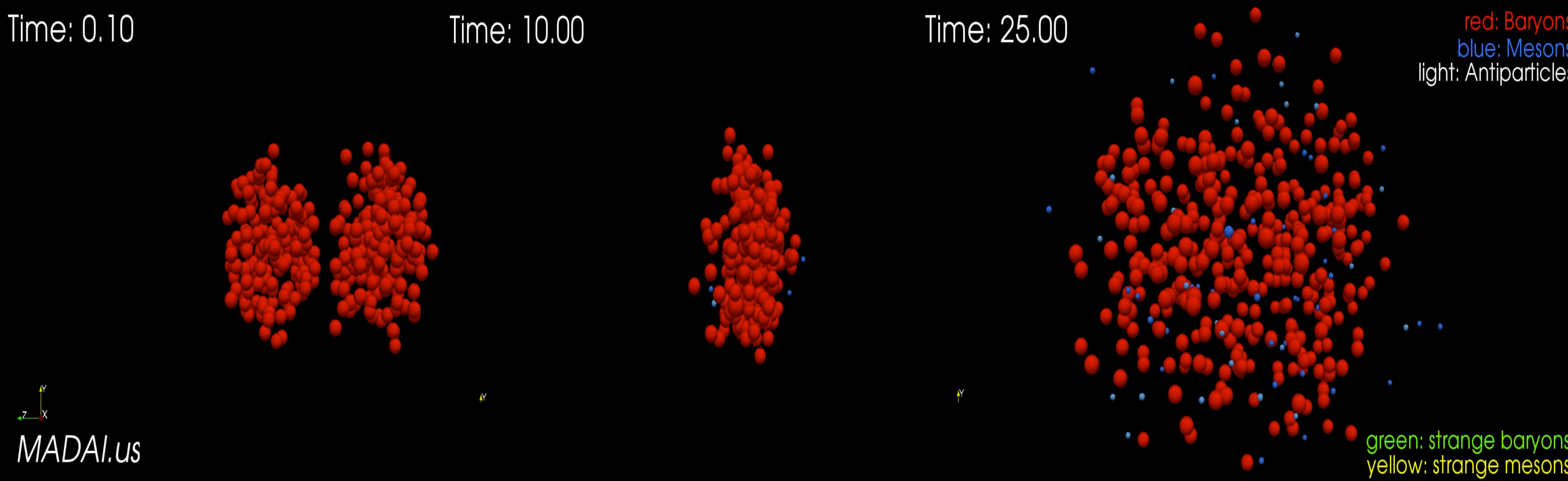

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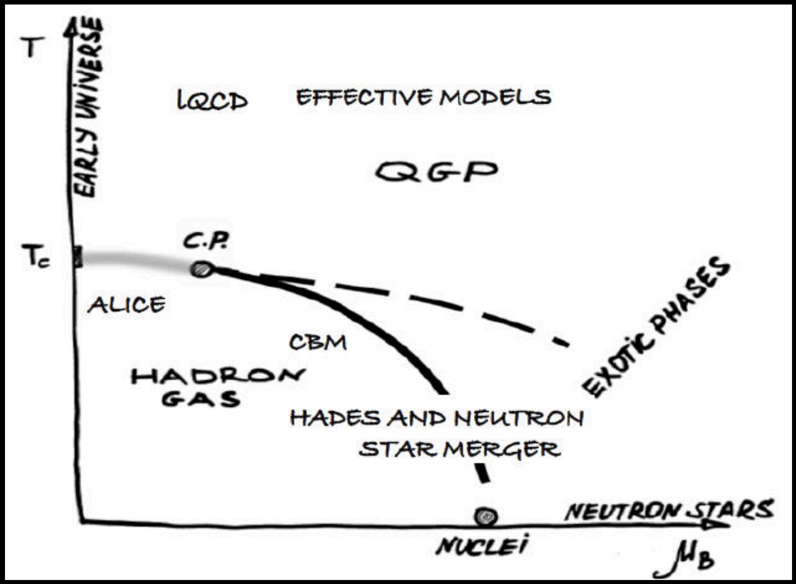

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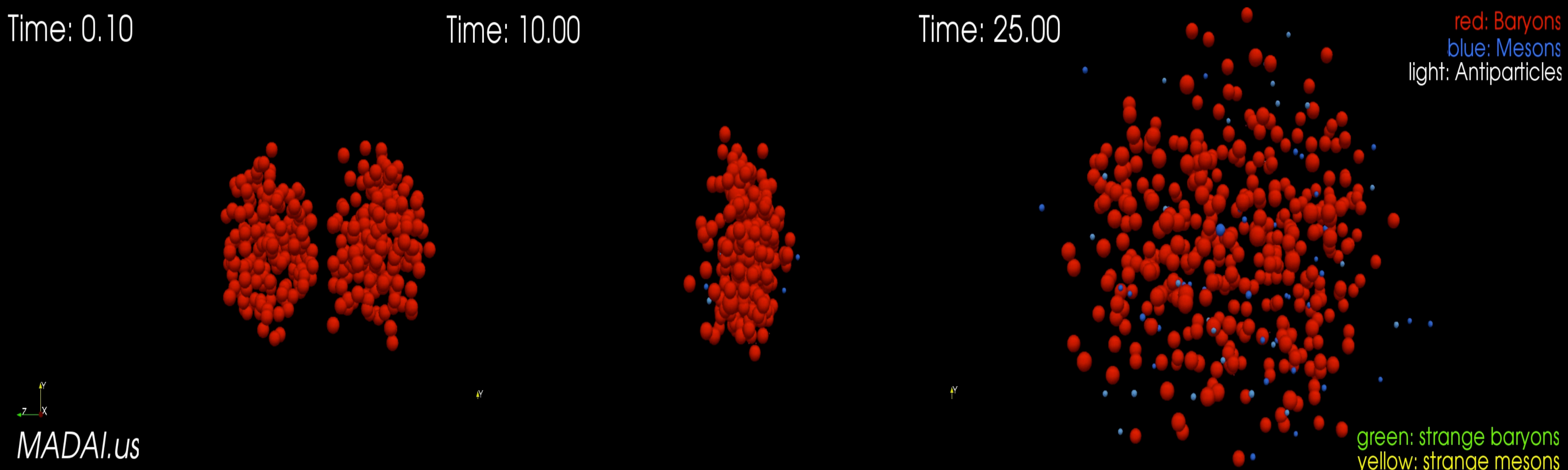

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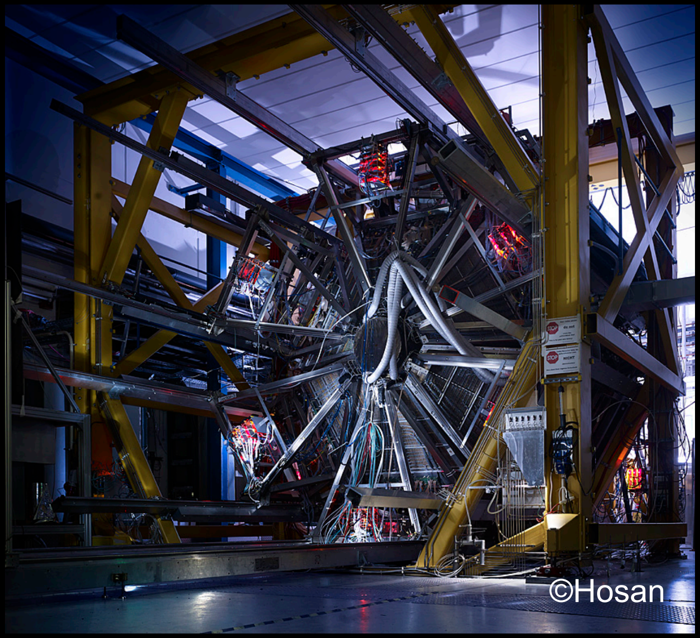
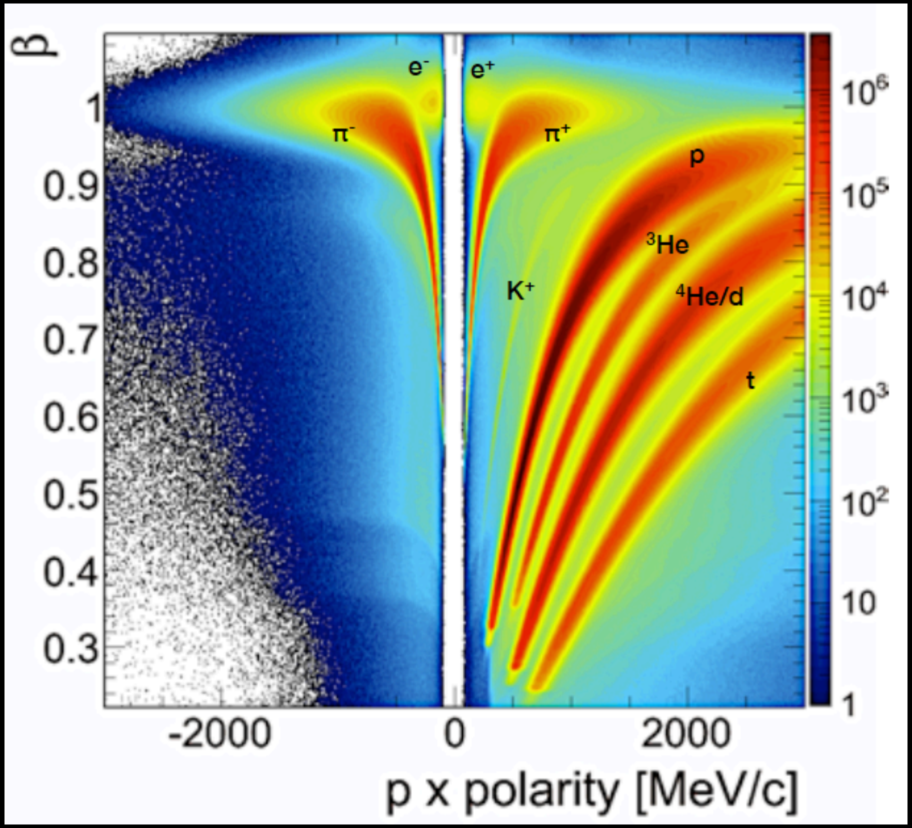


(Strange) Hadron production



Au+Au $\sqrt{s_{NN}}$=2.4 GeV
4.0x10^9 events collected in 4 weeks

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

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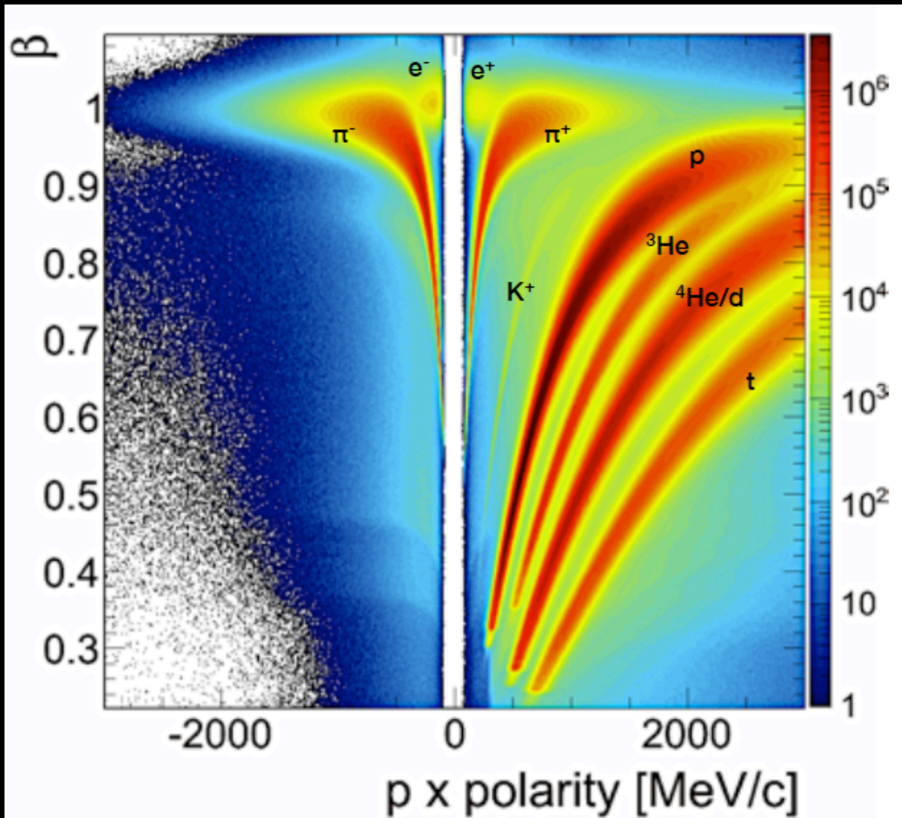

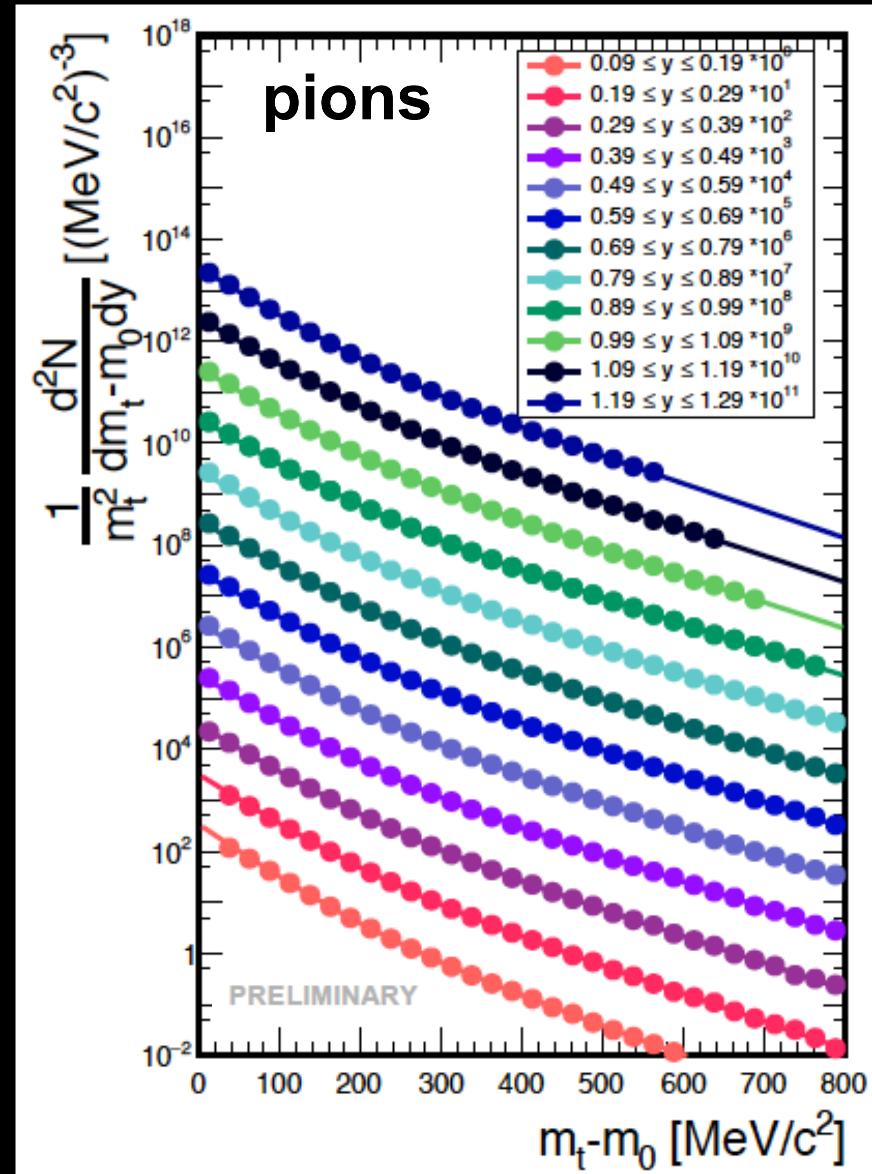

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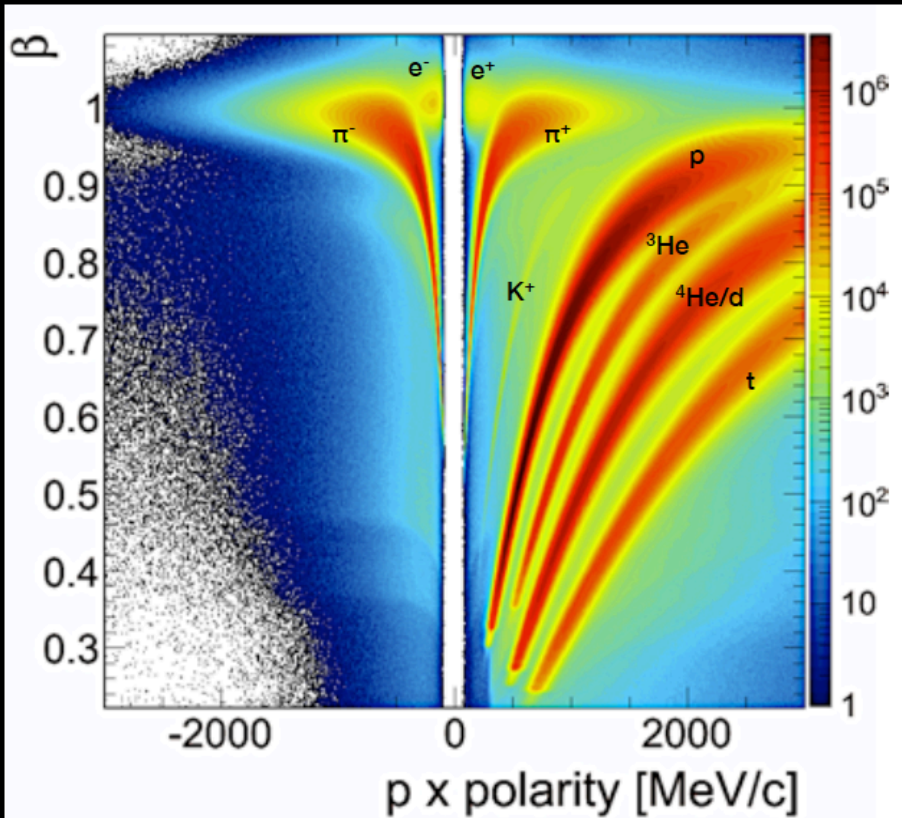

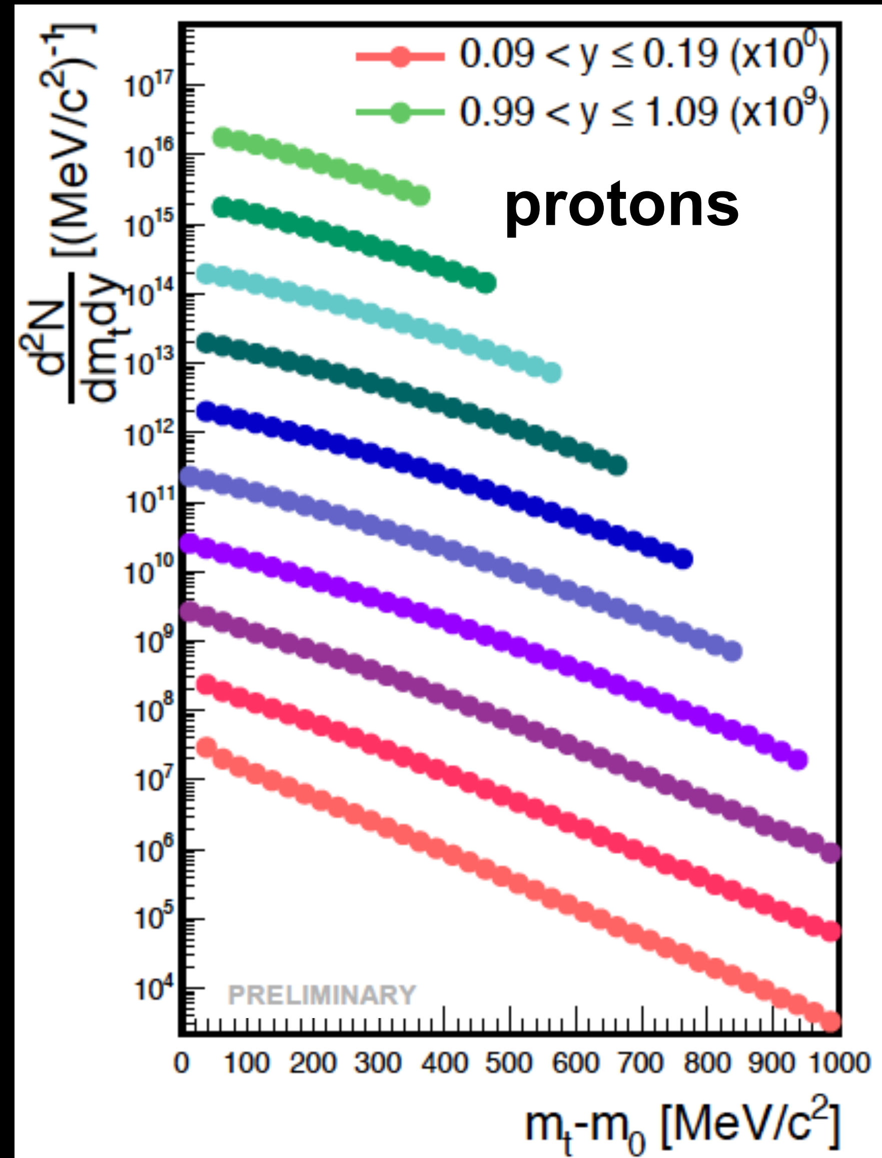

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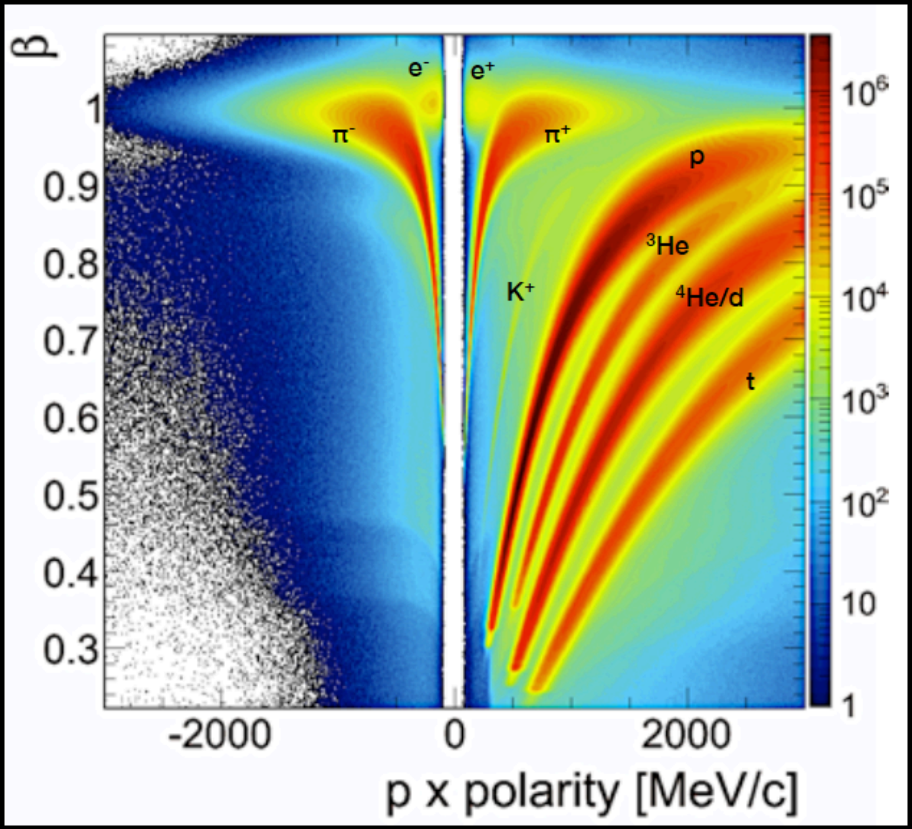

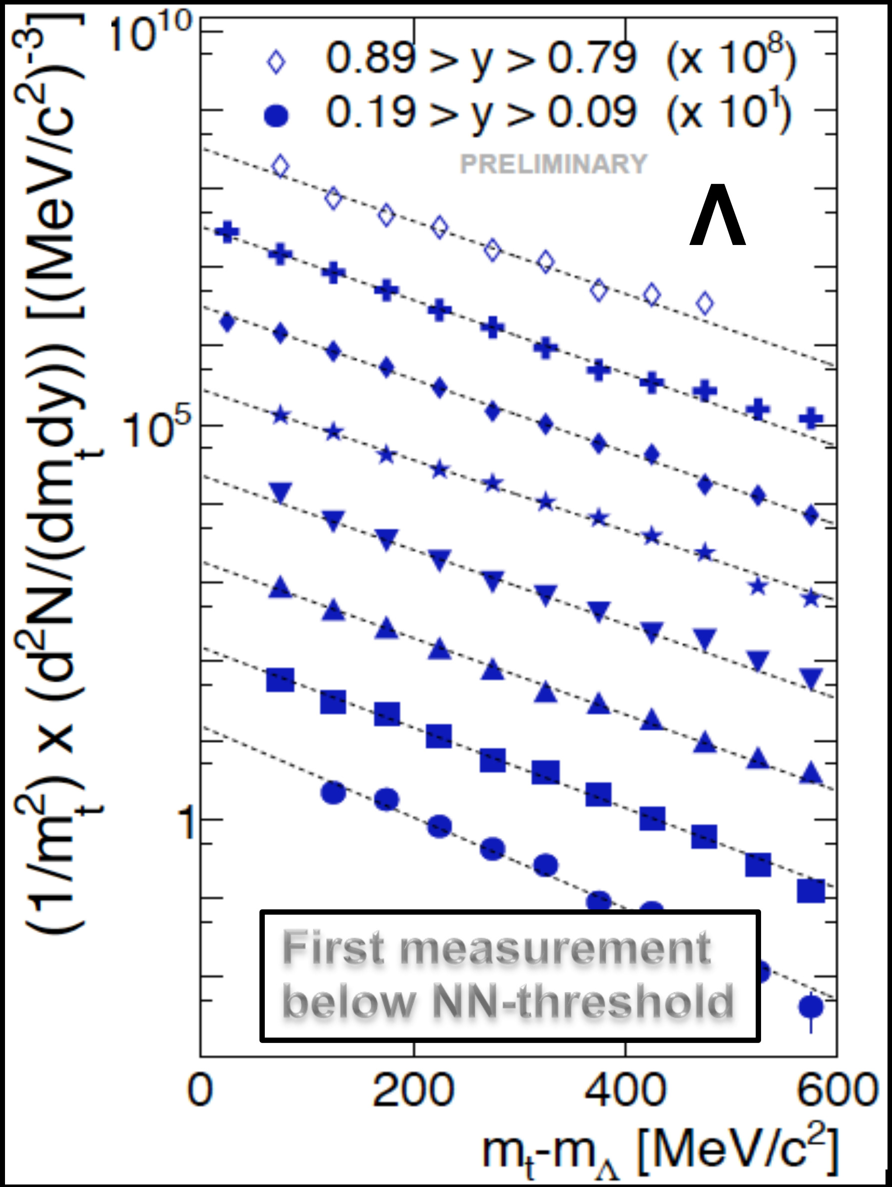

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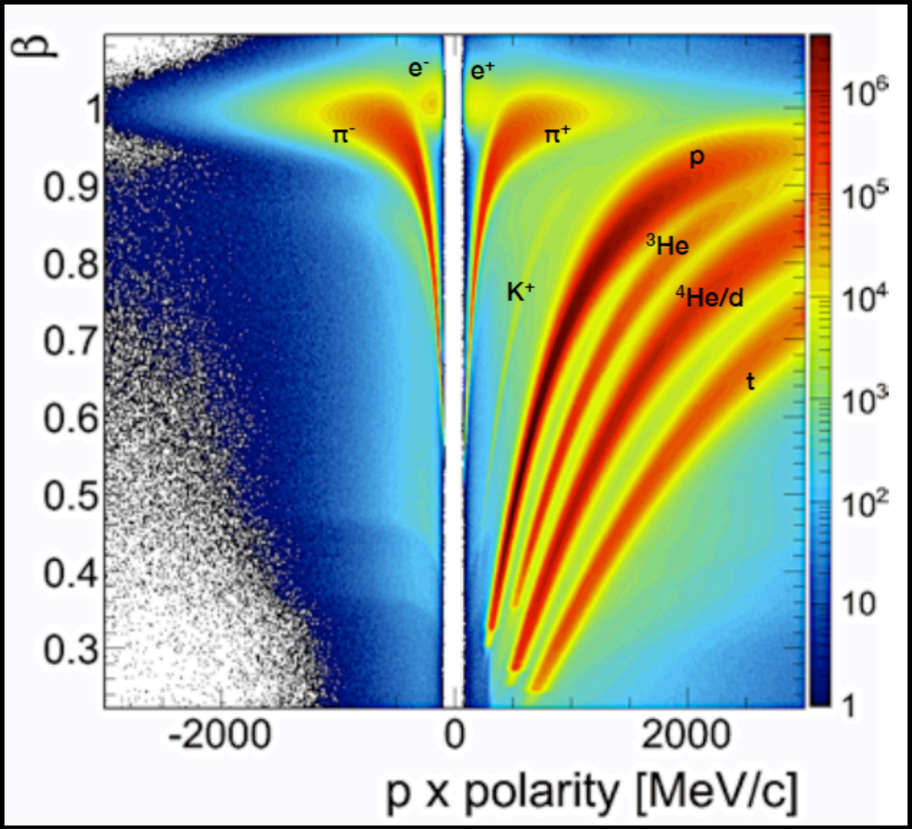

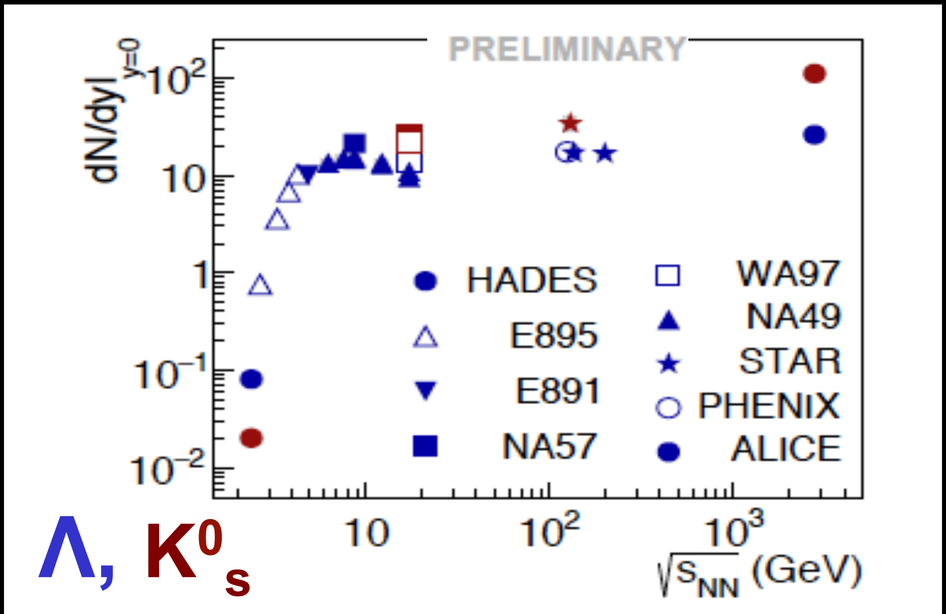

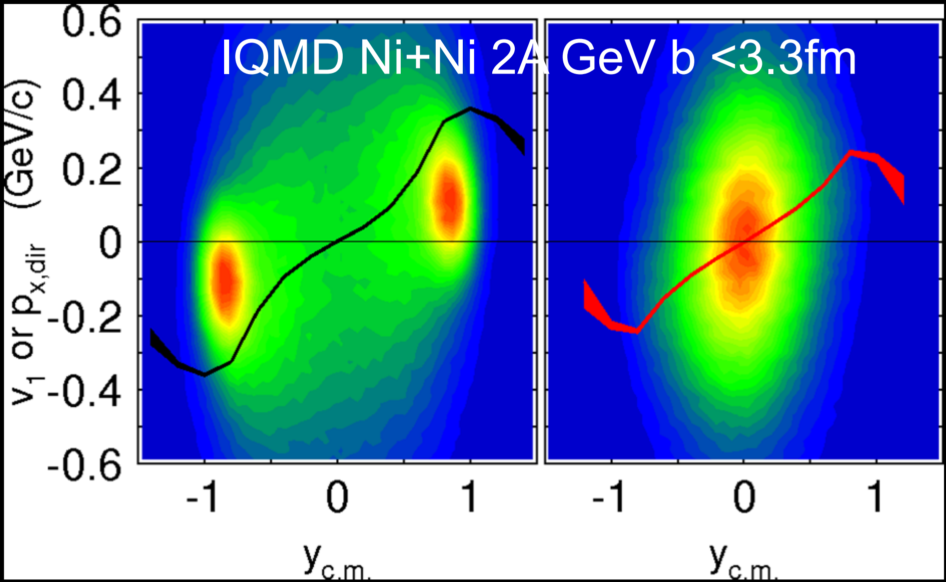

Courtesy Y. Leifels

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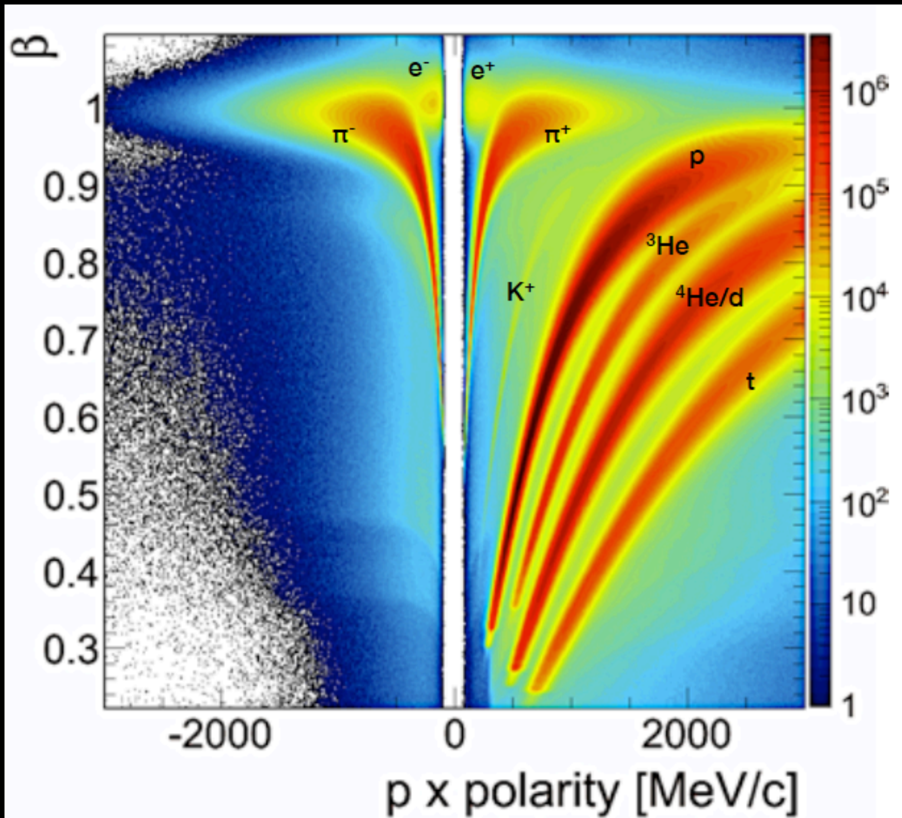

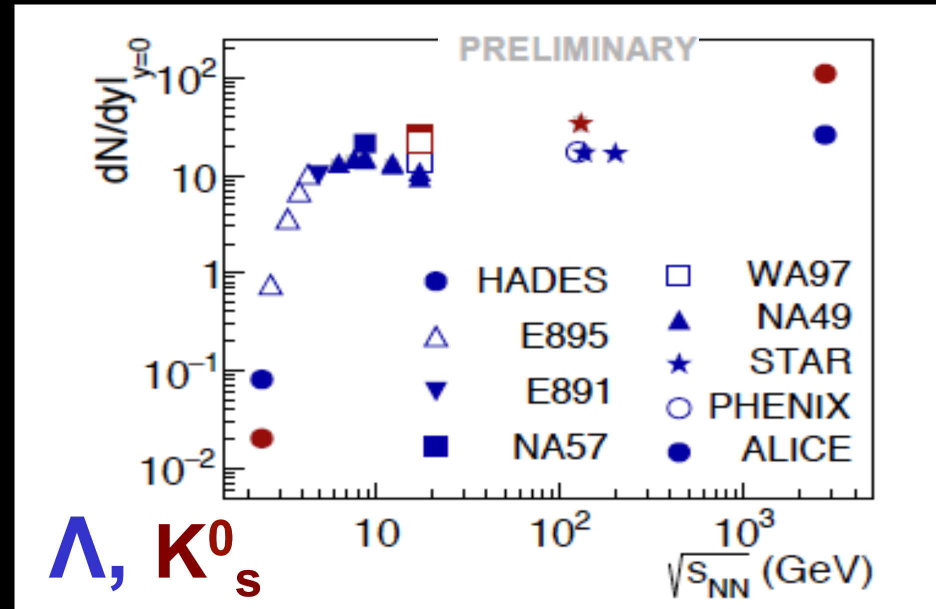

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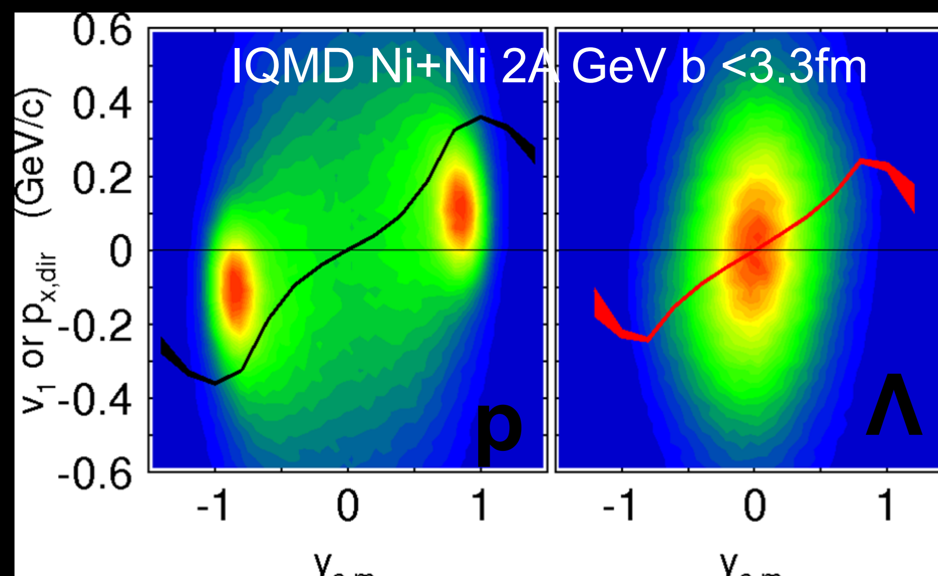
Strangeness is rare and separated from light nuclei in rapidity in peripheral collisions.



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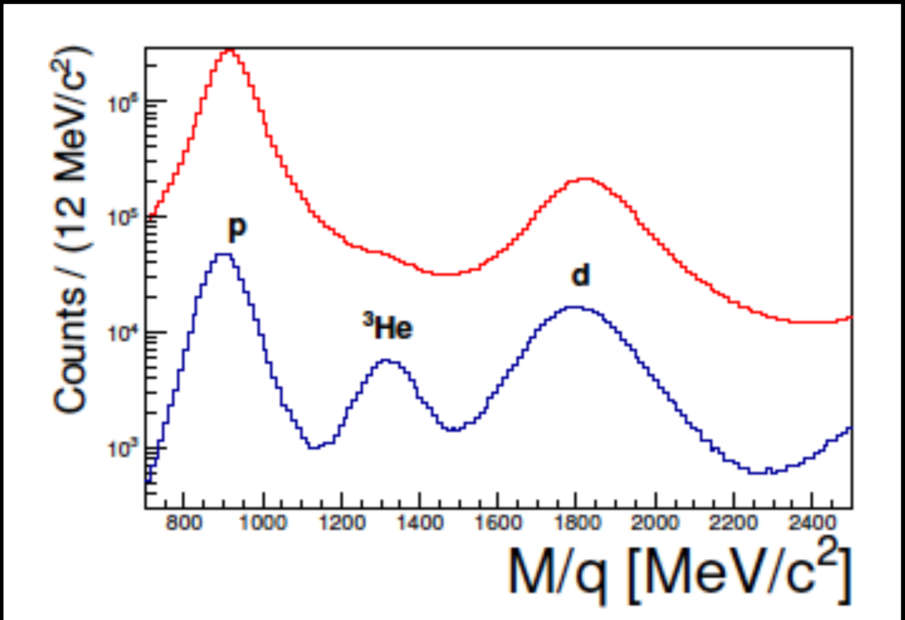
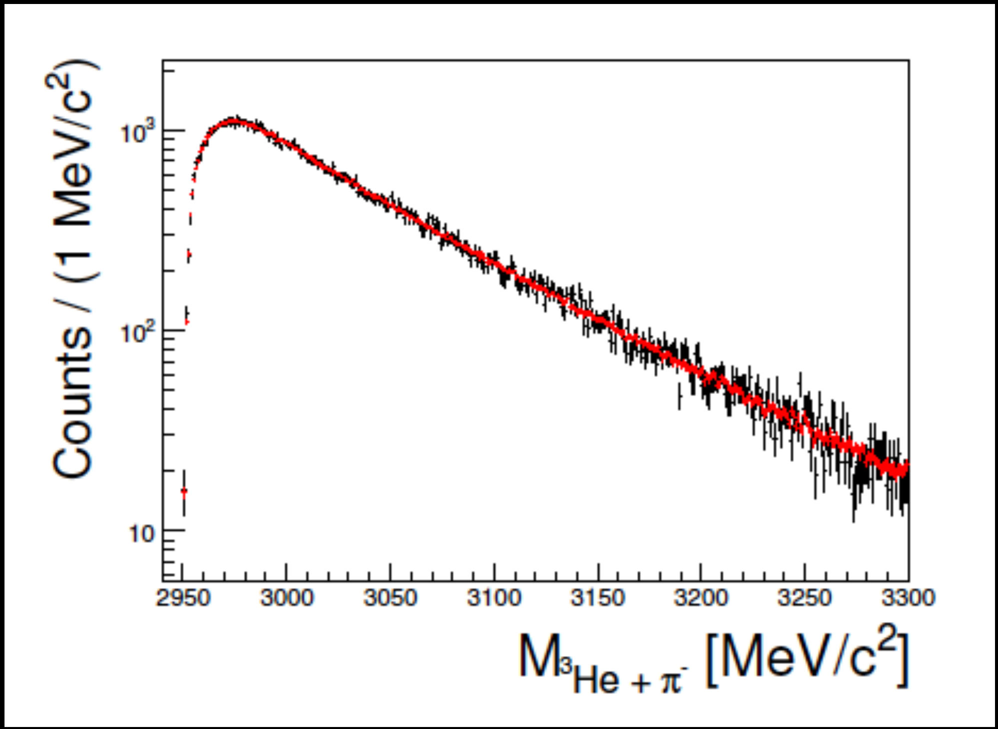
Hypertrition search in Ar+KCl 2.6 GeV





Upper limit:

$$M_{UL} = 1.04 \text{ x } 10^{-3}$$

$^{3}_{\Lambda}He/\Lambda$ $< (2.5 \pm 0.3) \text{ x } 10^{-2}$

Future plans:
Investigate Au+Au data at 2.4 GeV (lower energy but heavier system) and 3 body decay channel

Eur.Phys.J. A49 (2013) 146

(Sub-Threshold) Strangeness Production

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Unique observable:
Not produced in binary NN collisions at $\sqrt{s_{NN}}$= 2.4 GeV, micro-canonical ensemble Z(E,N,V).

NN→NYK$^+$: $\sqrt{s_{NN}}$= 2.55 GeV, NN→NNK$^+$K$^-$: $\sqrt{s_{NN}}$= 2.86 GeV (strong K$^-$ suppression).

Energy must be provided from the system.

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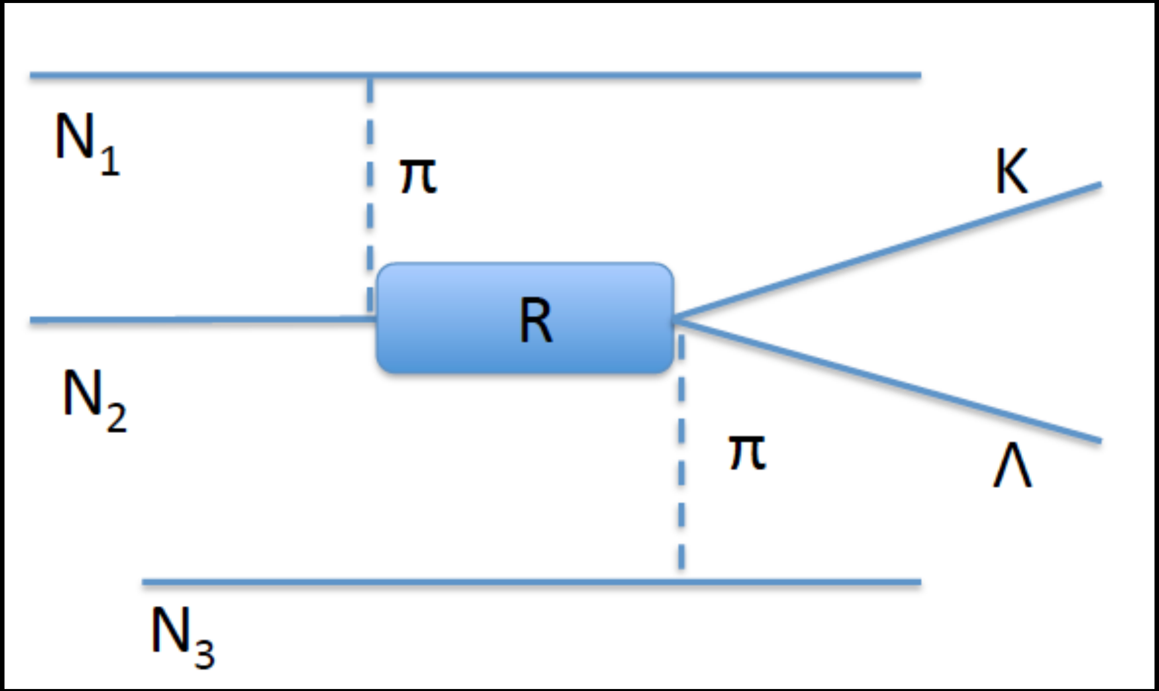
Isolated NN collisions o coherent process?
(Surrounding matter acts like a heat bath, canonical ensemble Z(T,N,V)).



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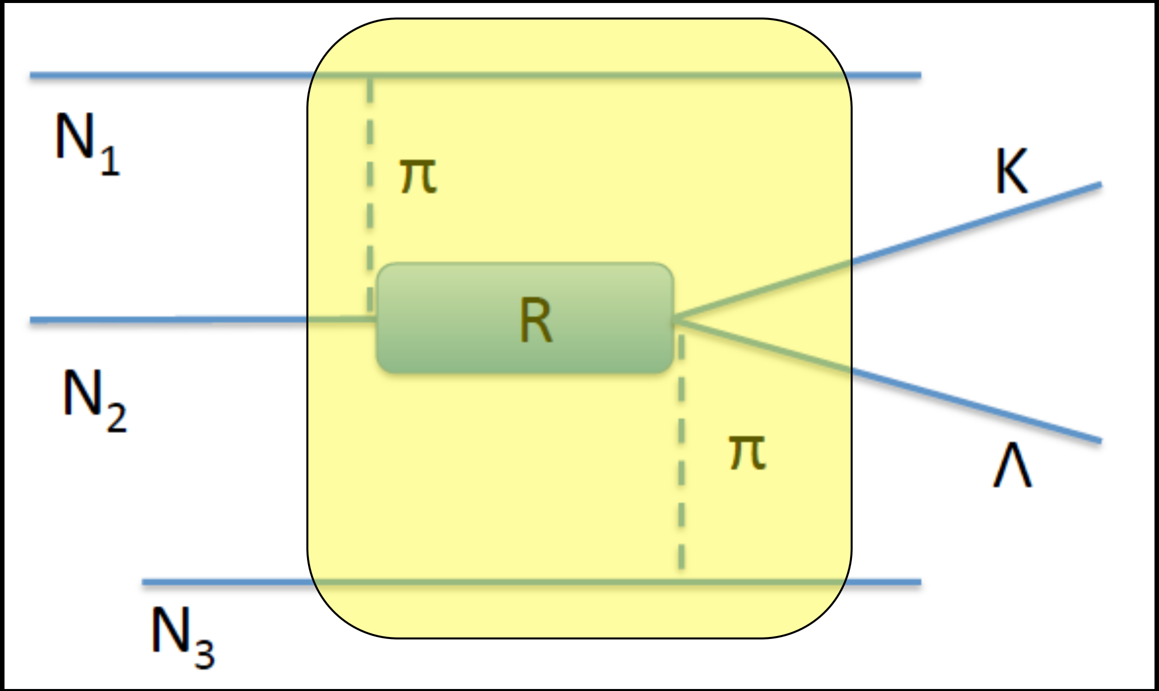
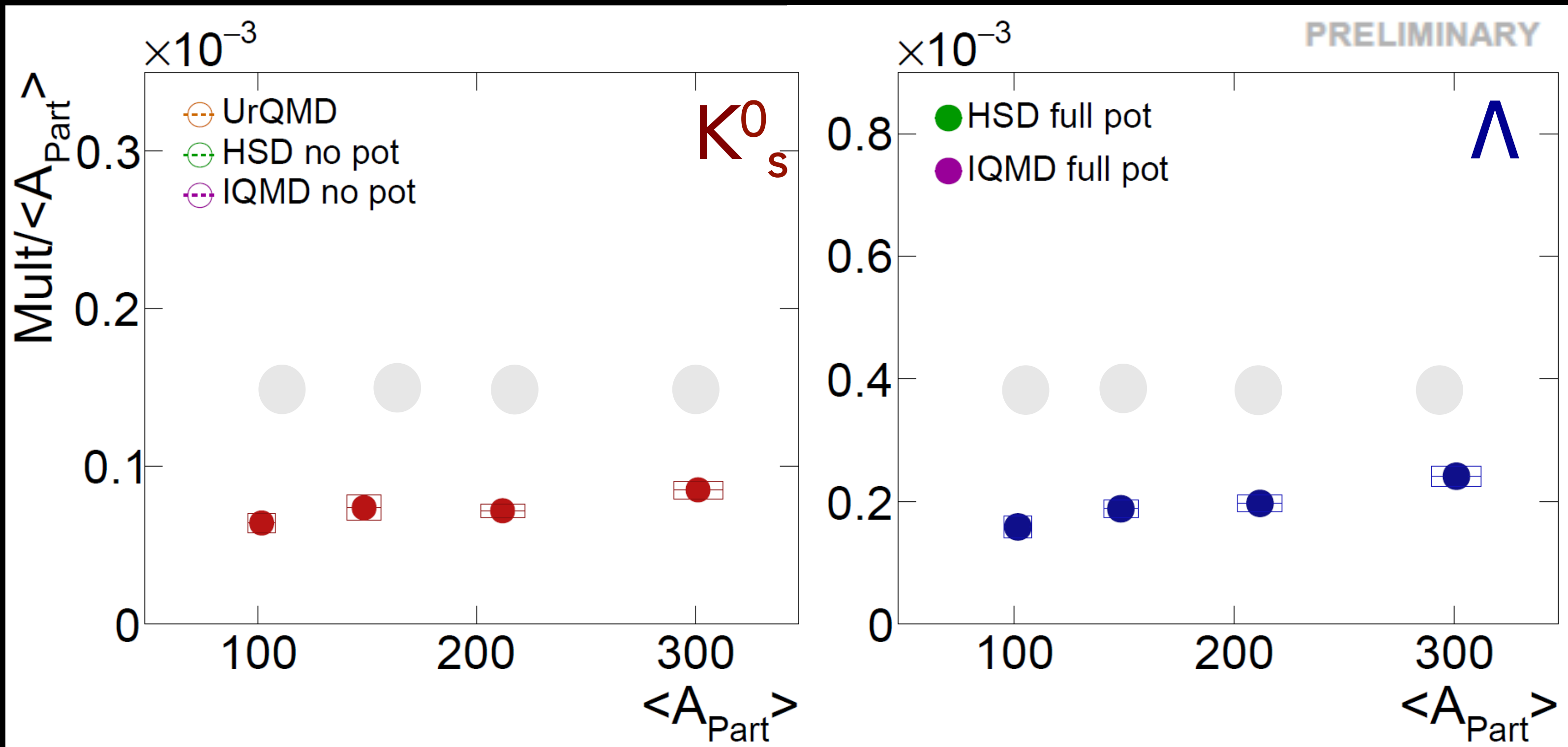


Microscopic description of strangeness production



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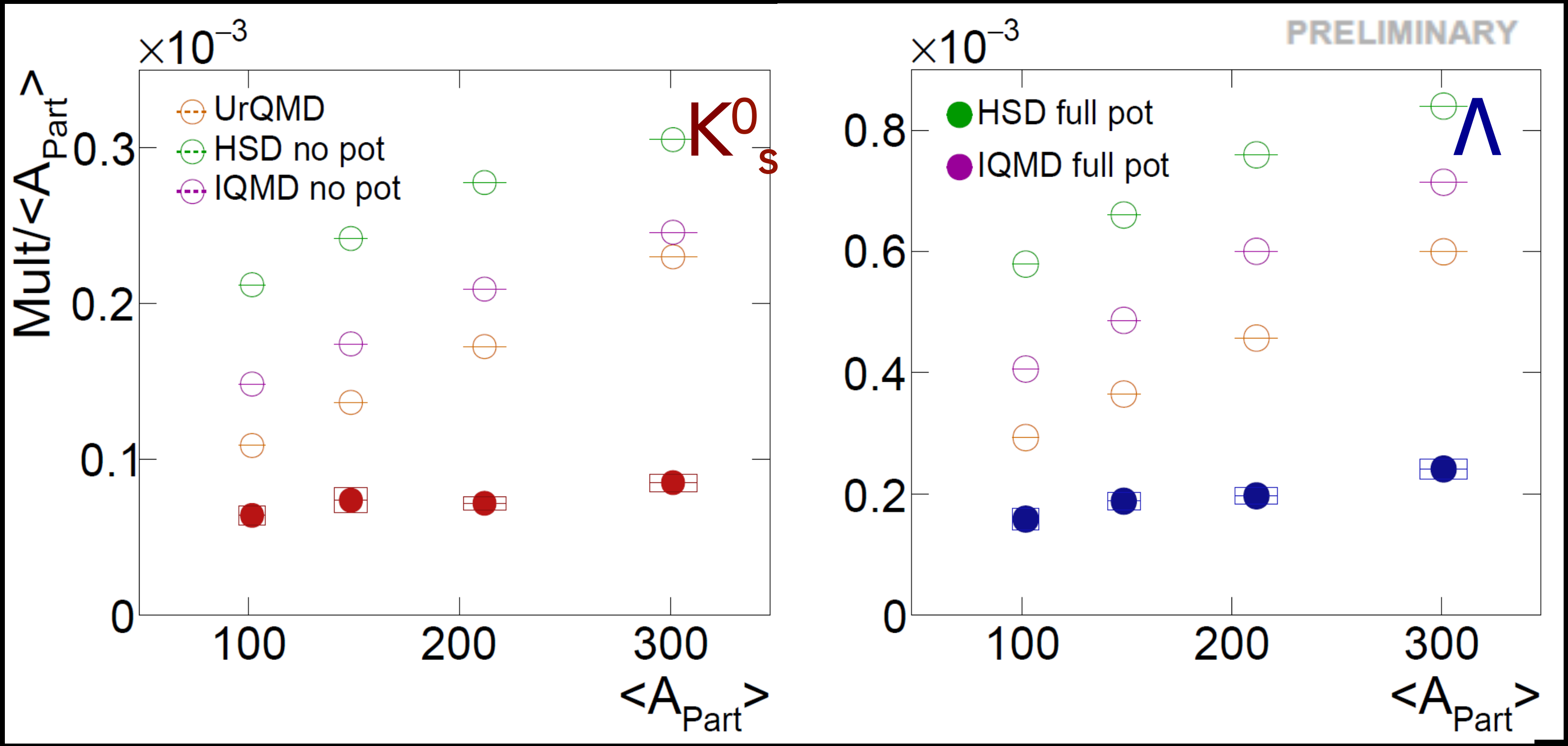

Model predictions: UrQMD 3.4, HSD 711n, IQMD c8, (full pot.= 40 MeV)

General trend to overshoot data → uncertainty in overall yield

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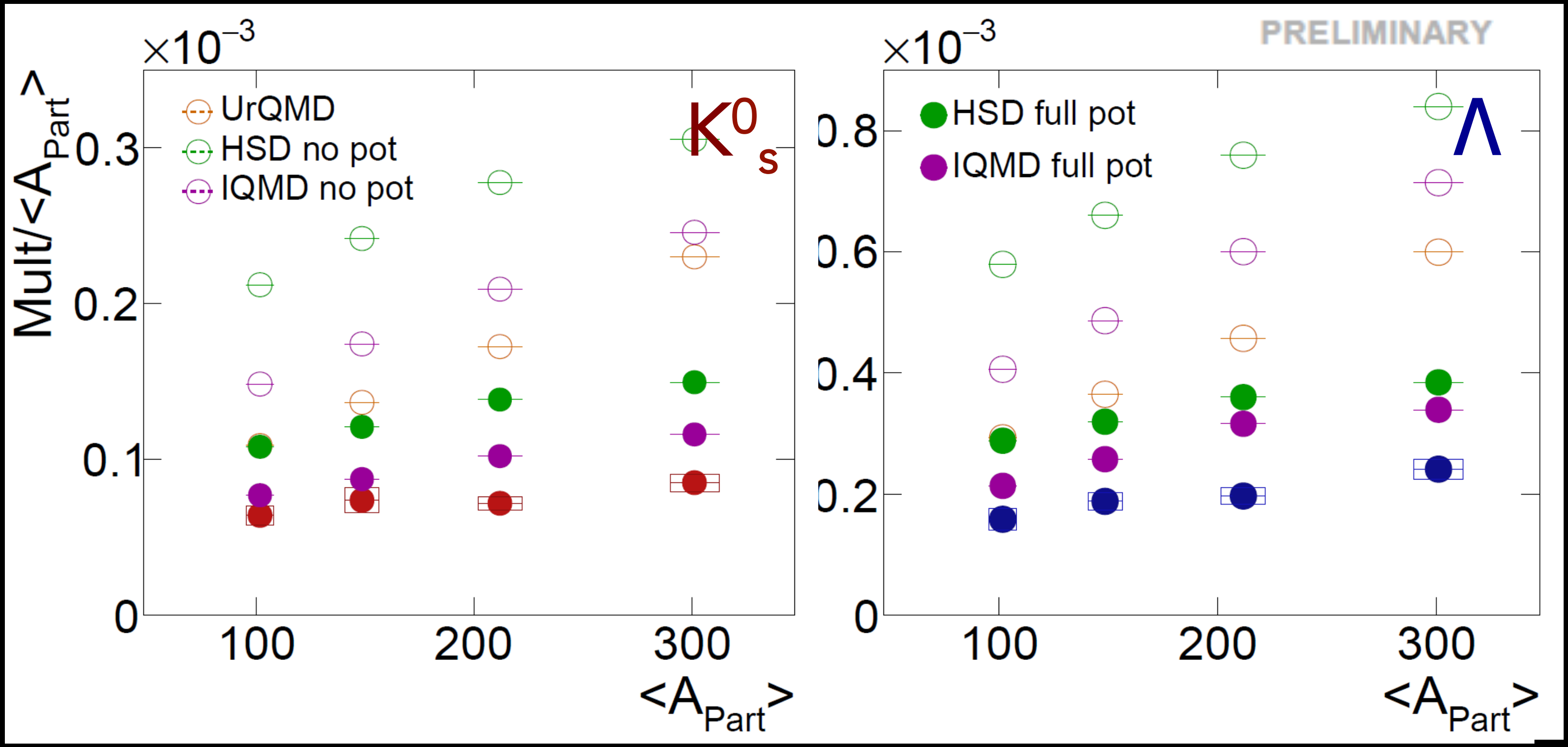

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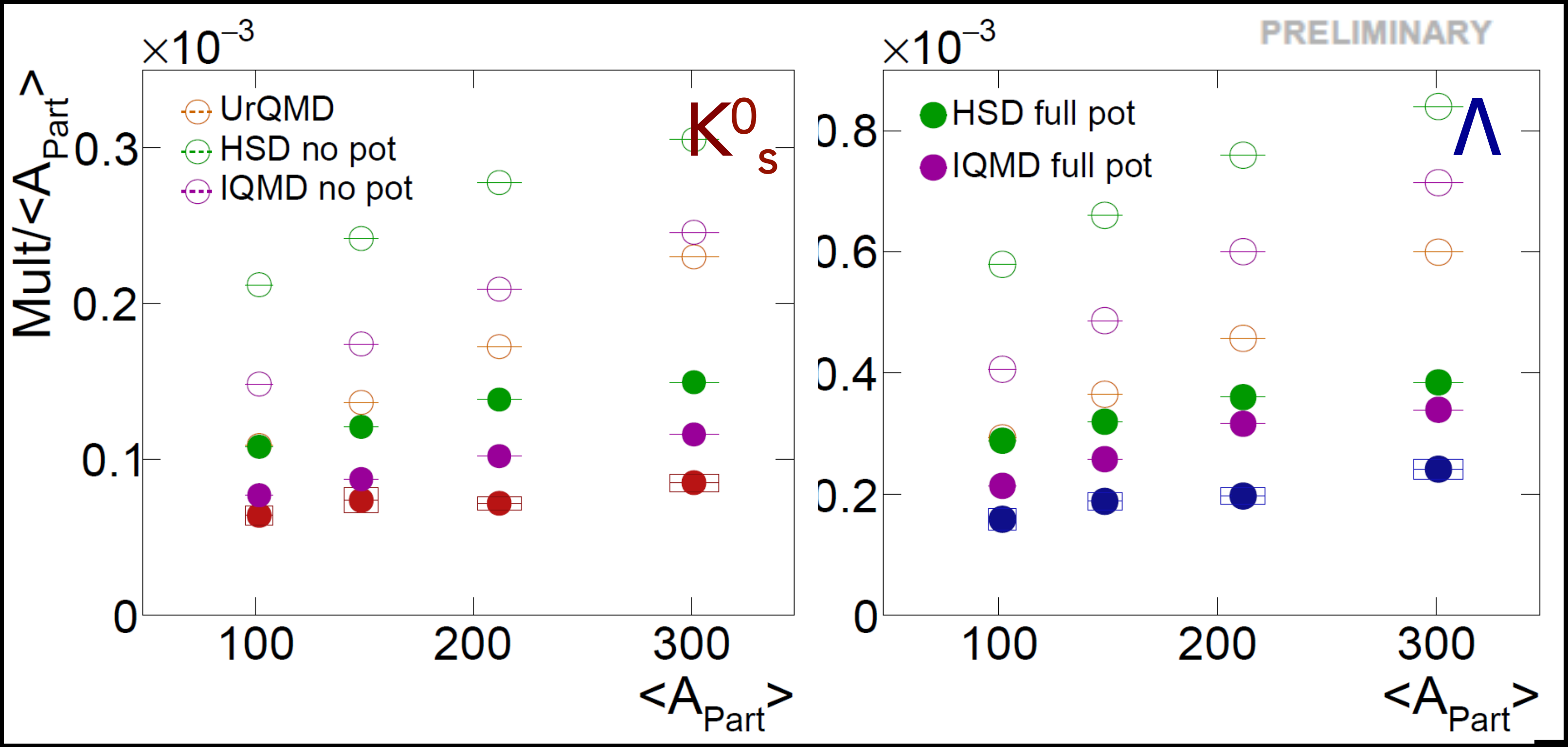

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Extraction of potential difficult, due to differences in yield between different models.

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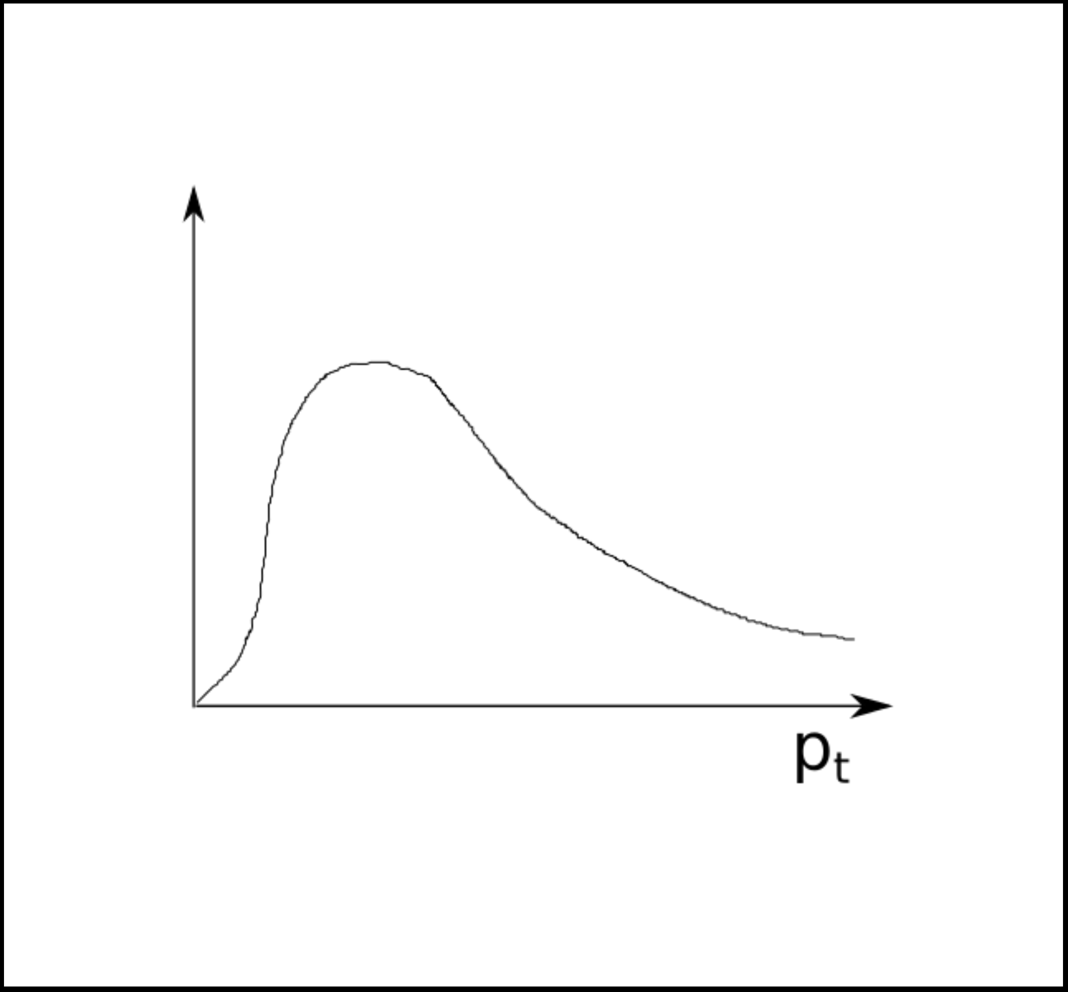
KN Potential revisited: comparison of the p_t shape



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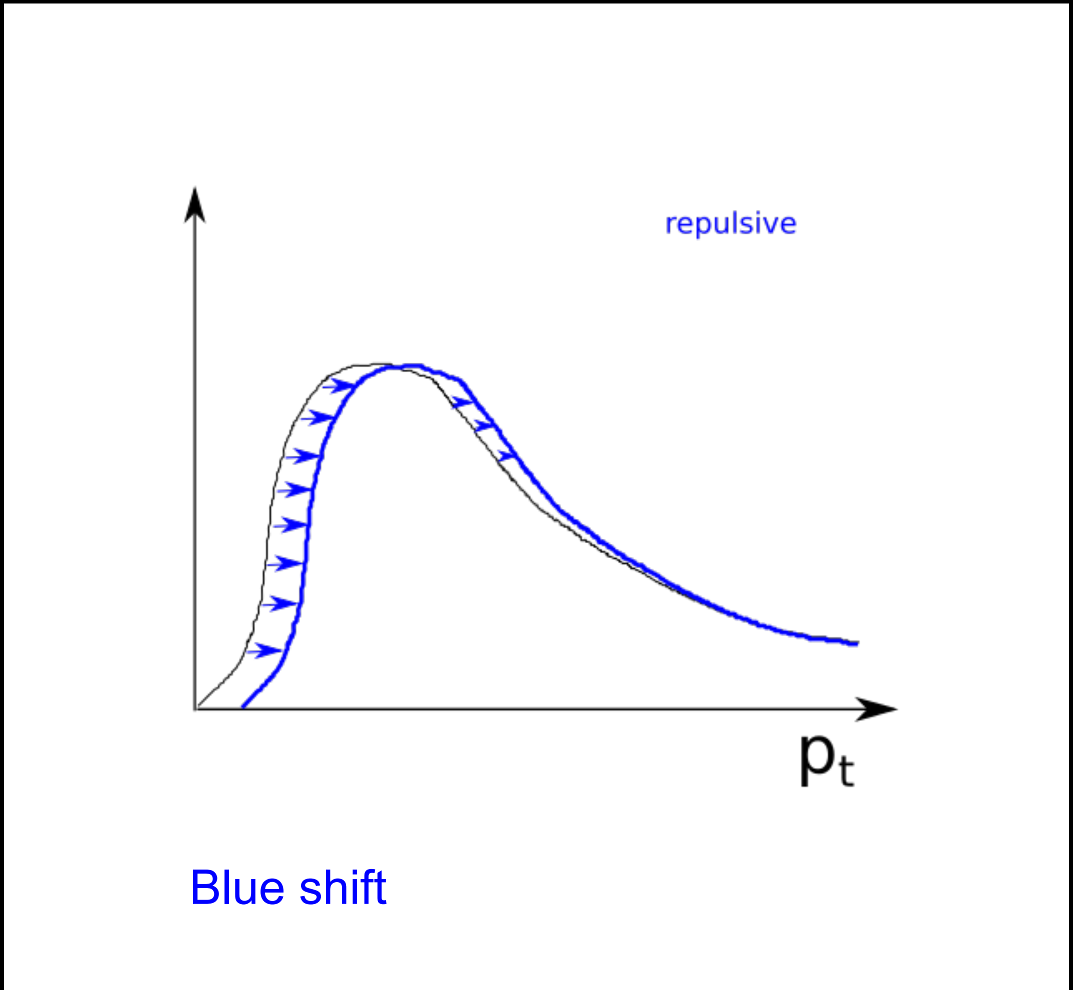

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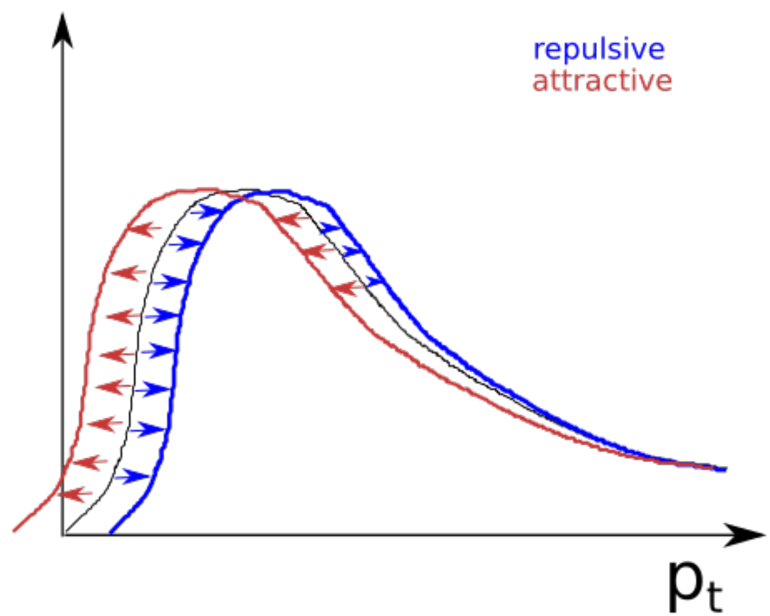

Blue shift, red shift

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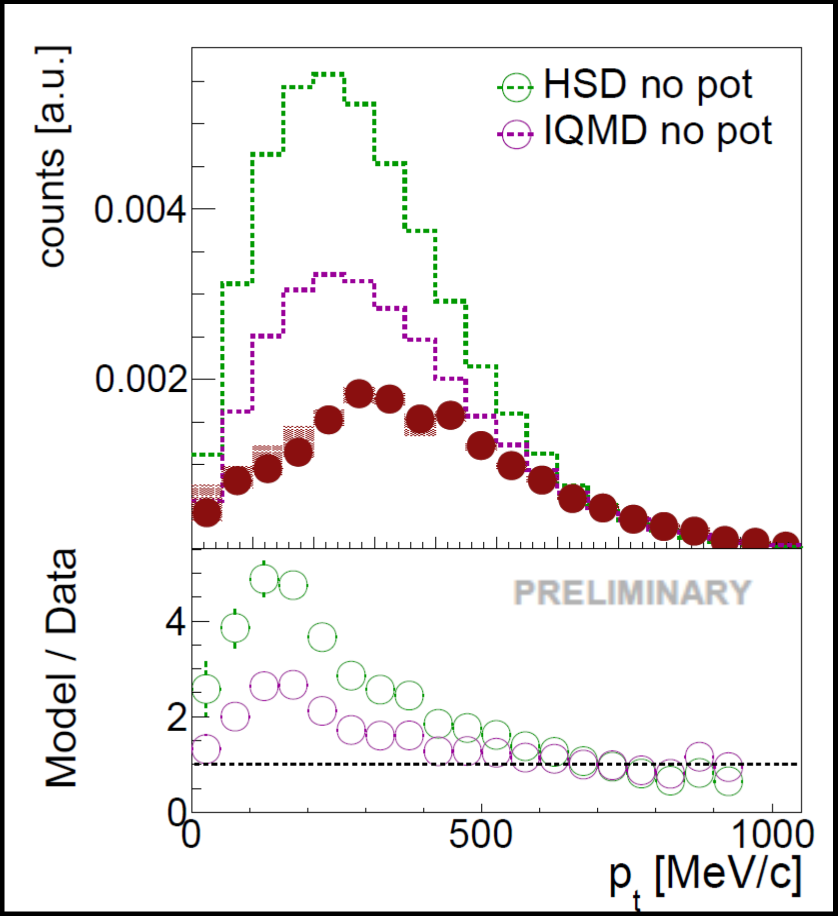

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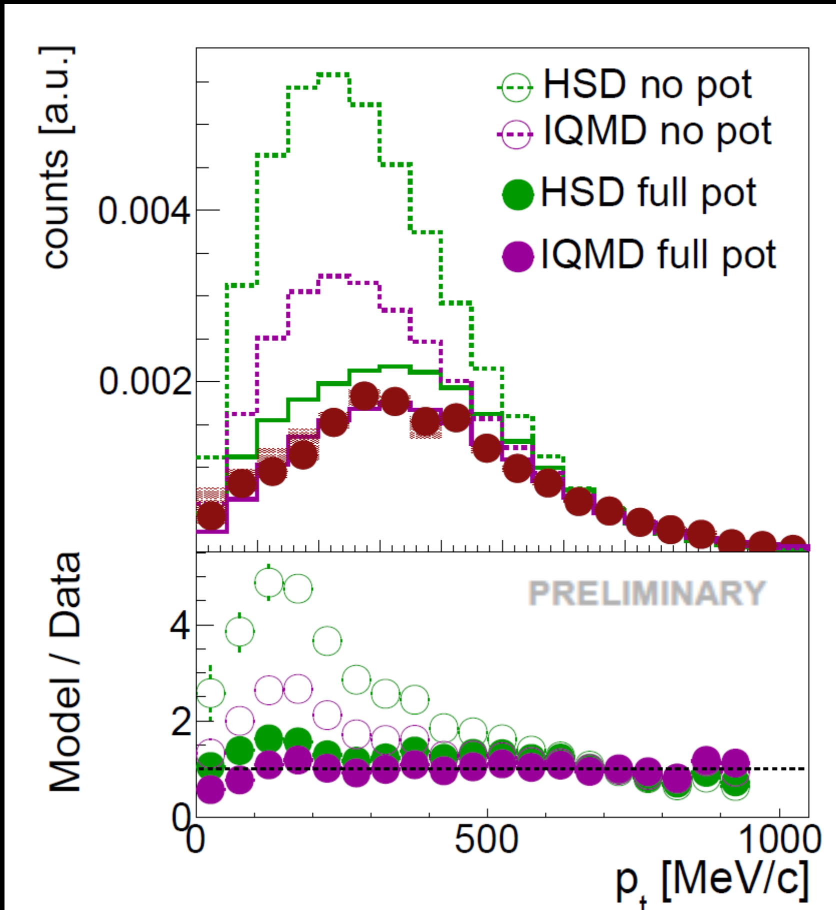

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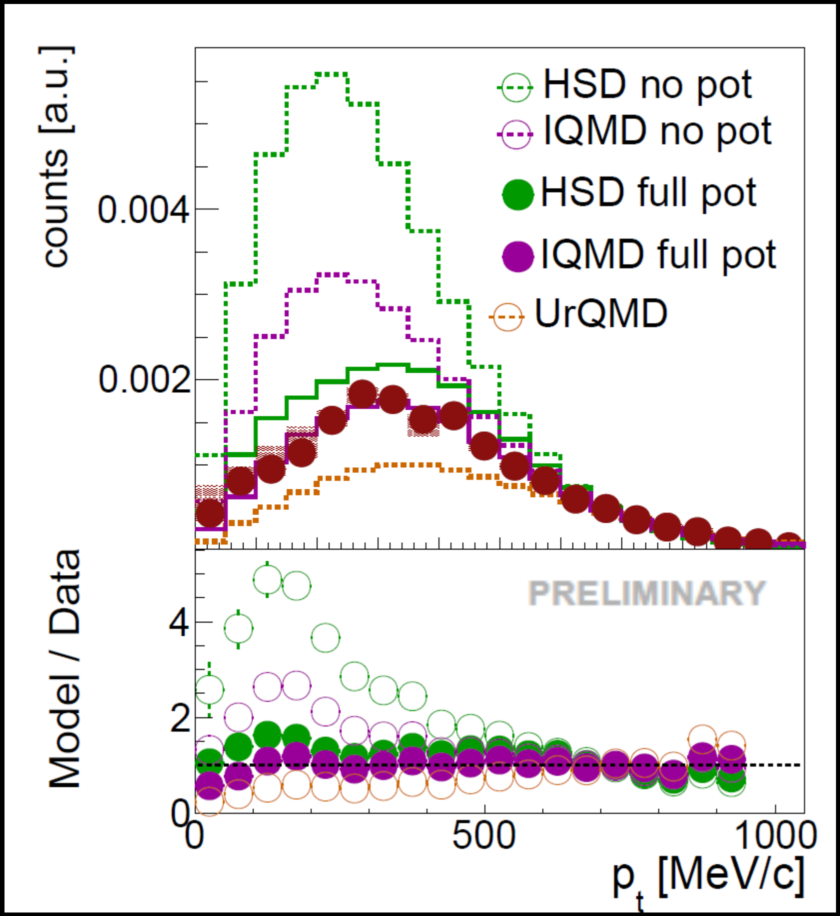

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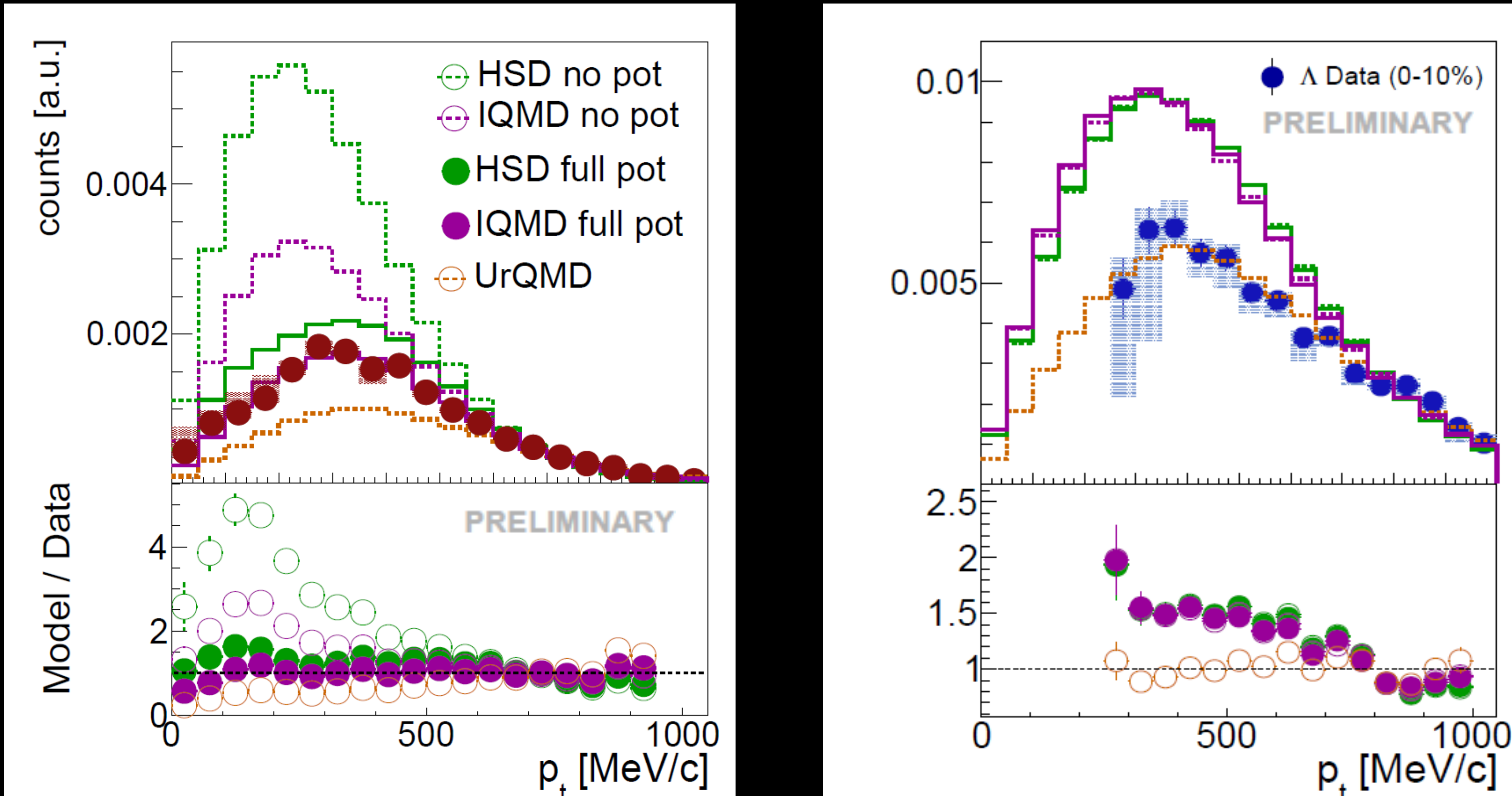

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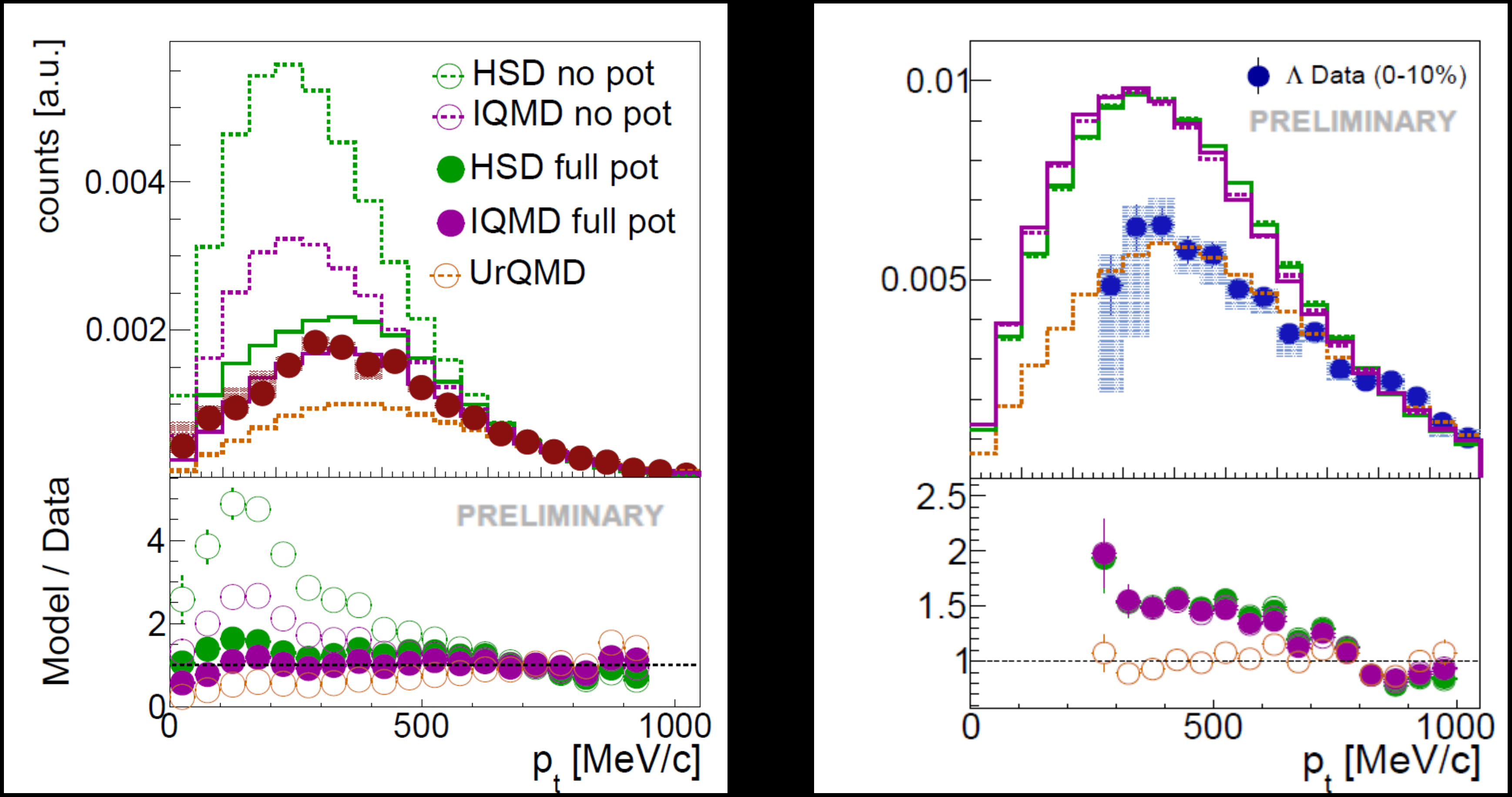

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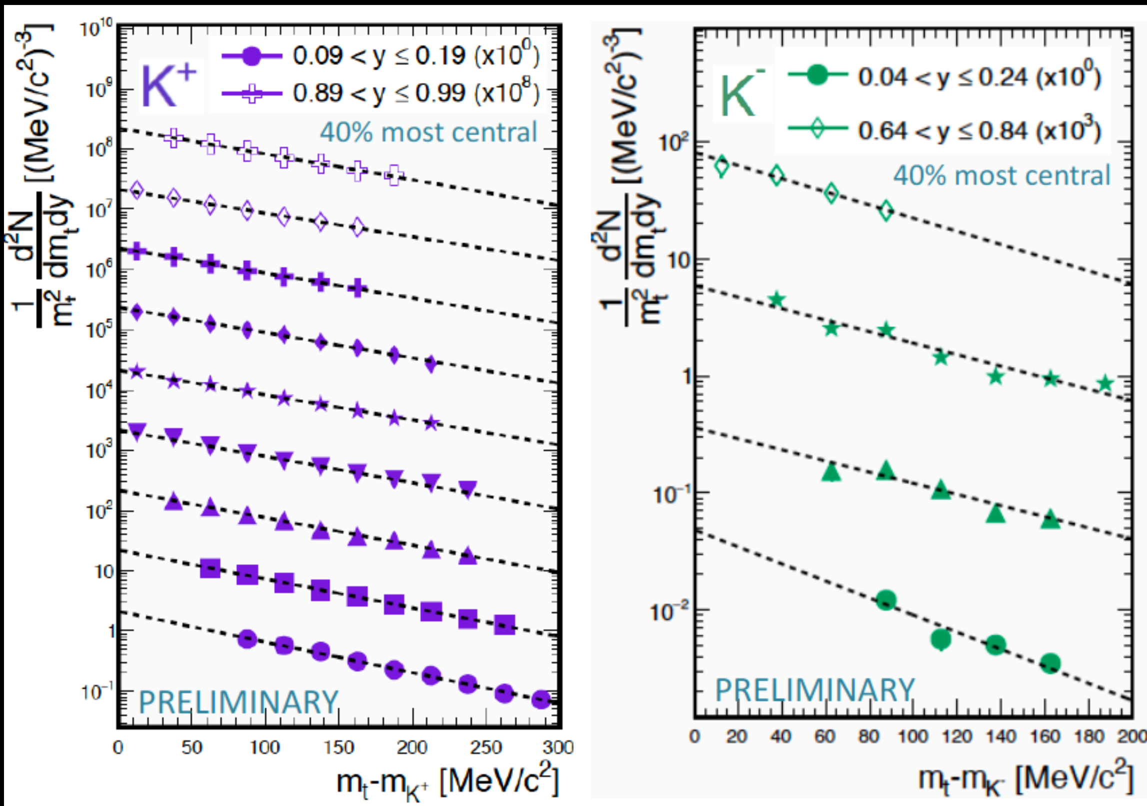
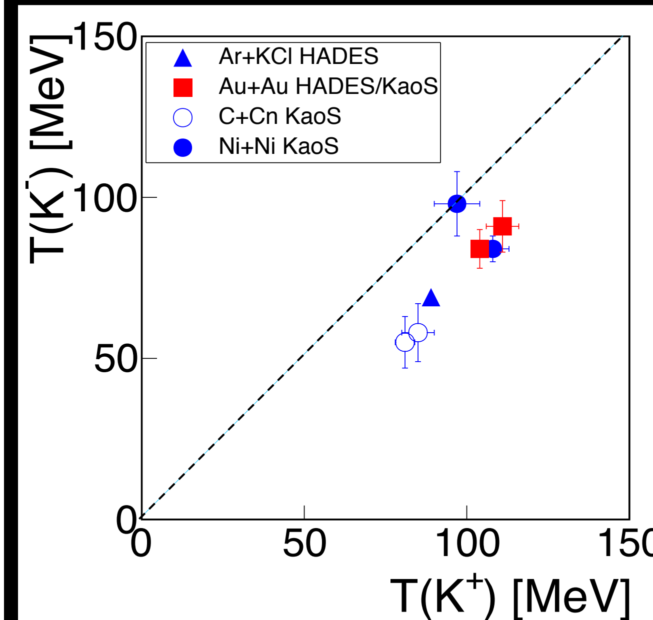
Ambiguities in description!!

(Sub-threshold) Strangeness Production



KaoS: Phys.Rev. C75 (2007) 024906



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

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

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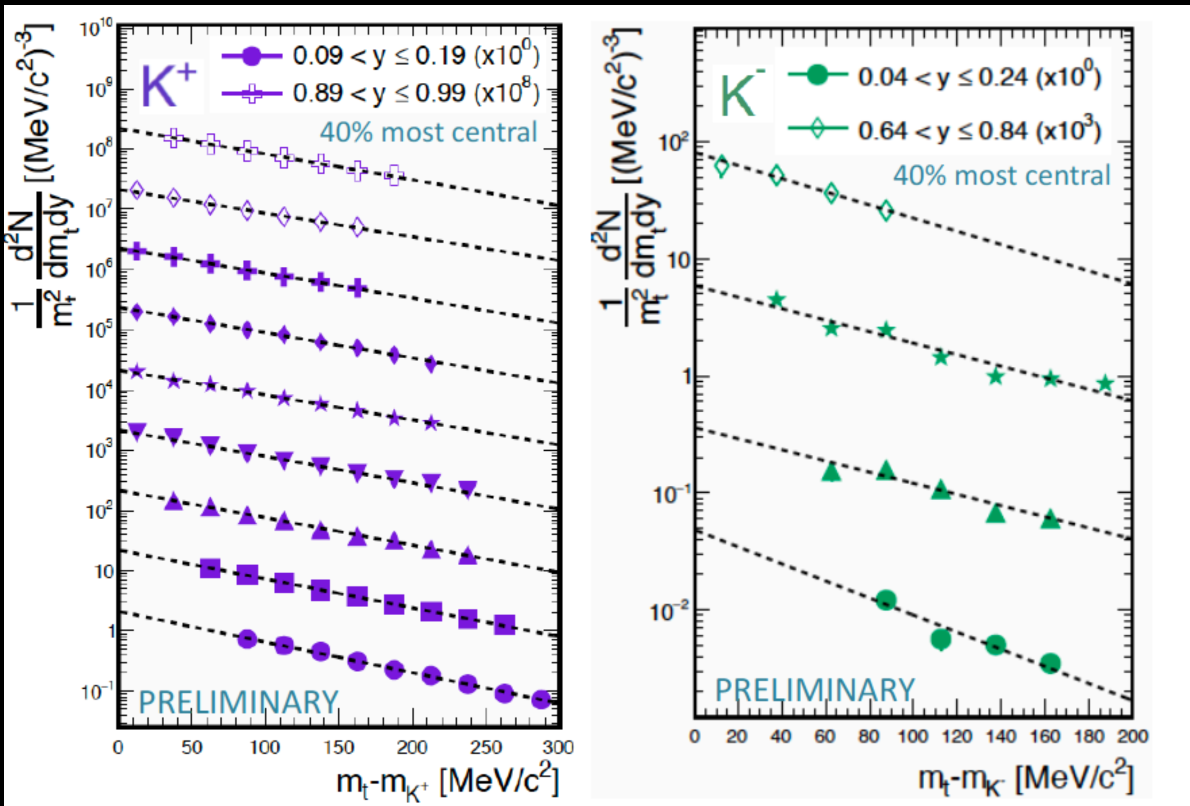

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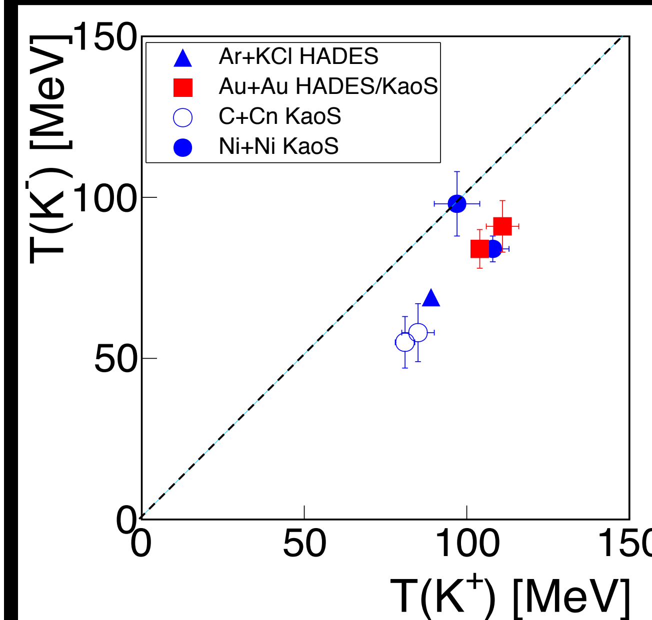
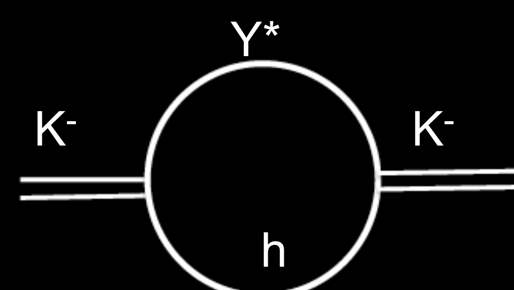
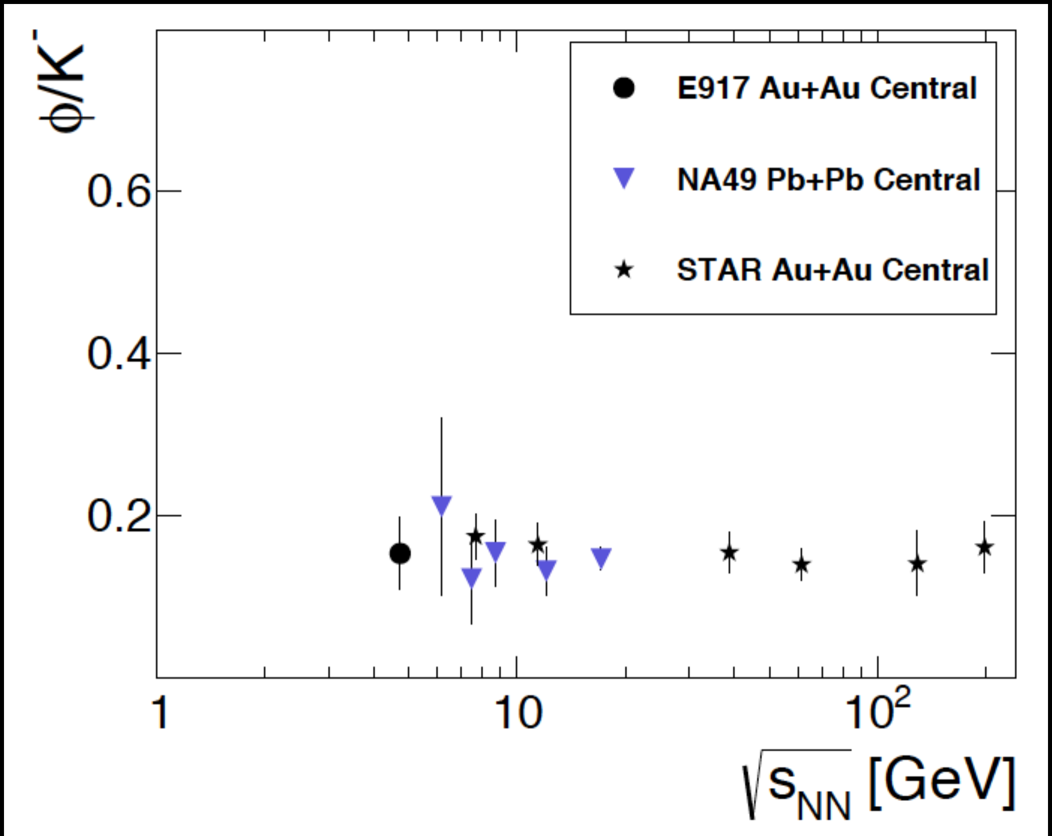




"Later freeze-out of K^- compared to K^+, due to coupling to baryons and strangeness exchange reactions ??"

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

(Sub-threshold) Strangeness Production



Φ/K^- ratio constant at high energies

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

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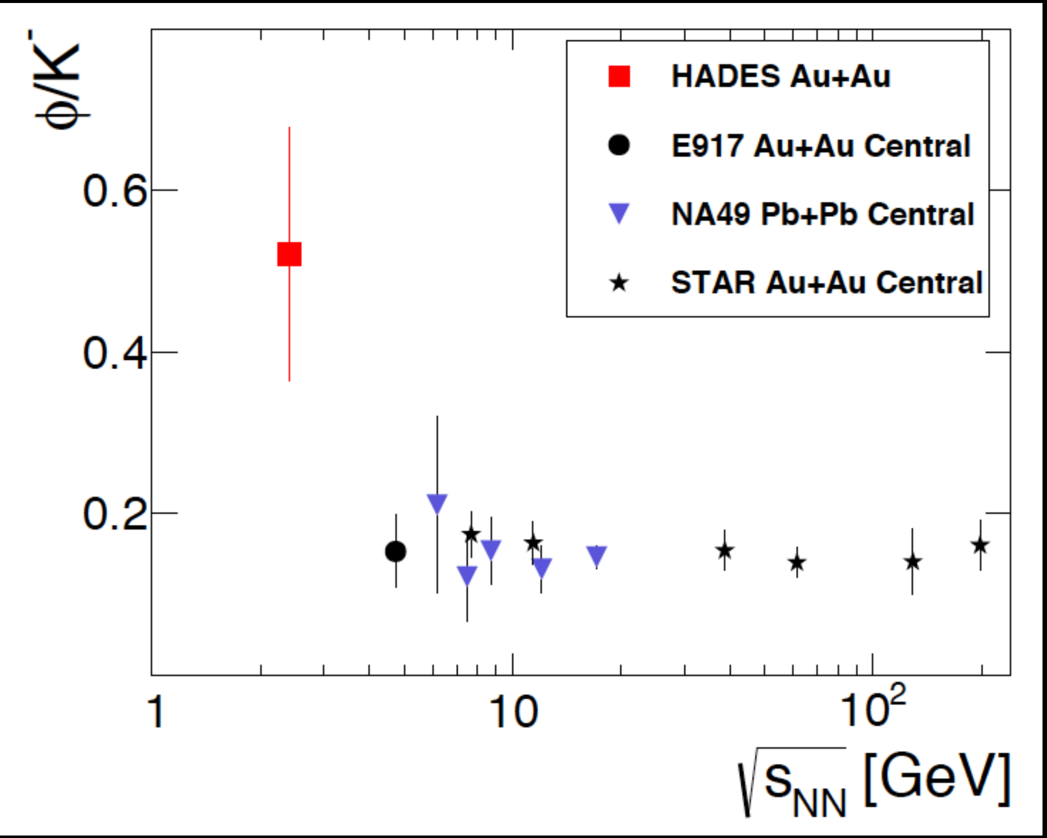

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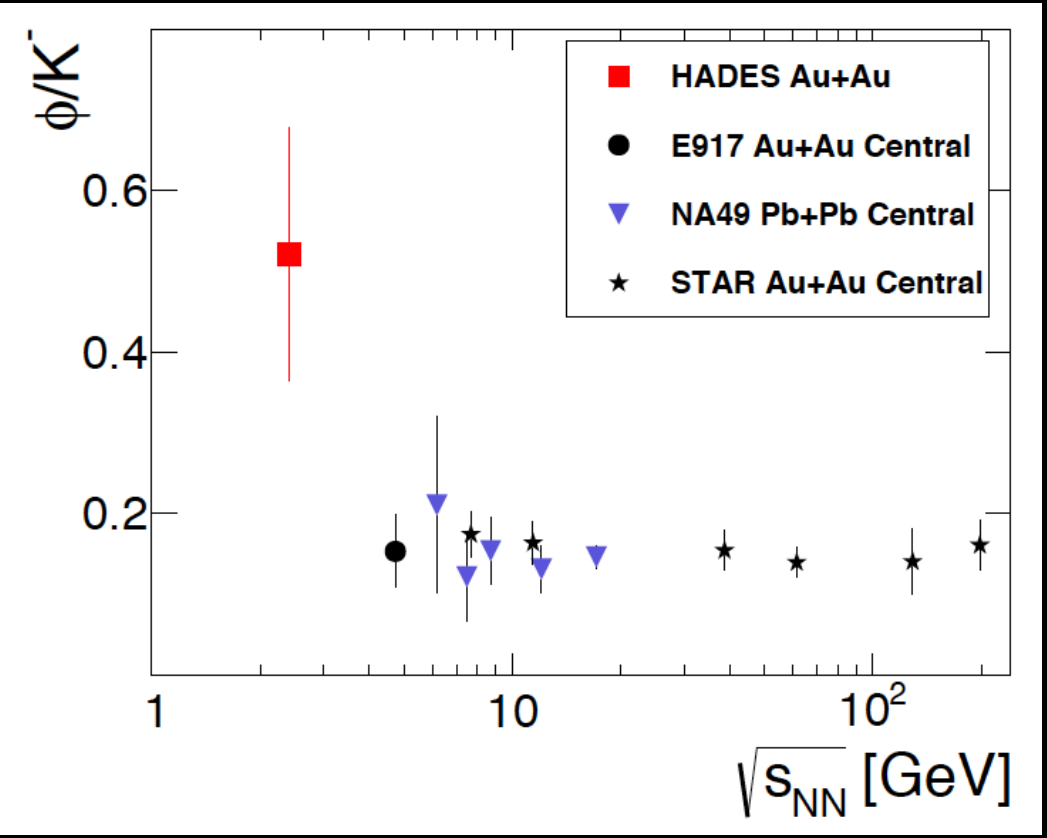

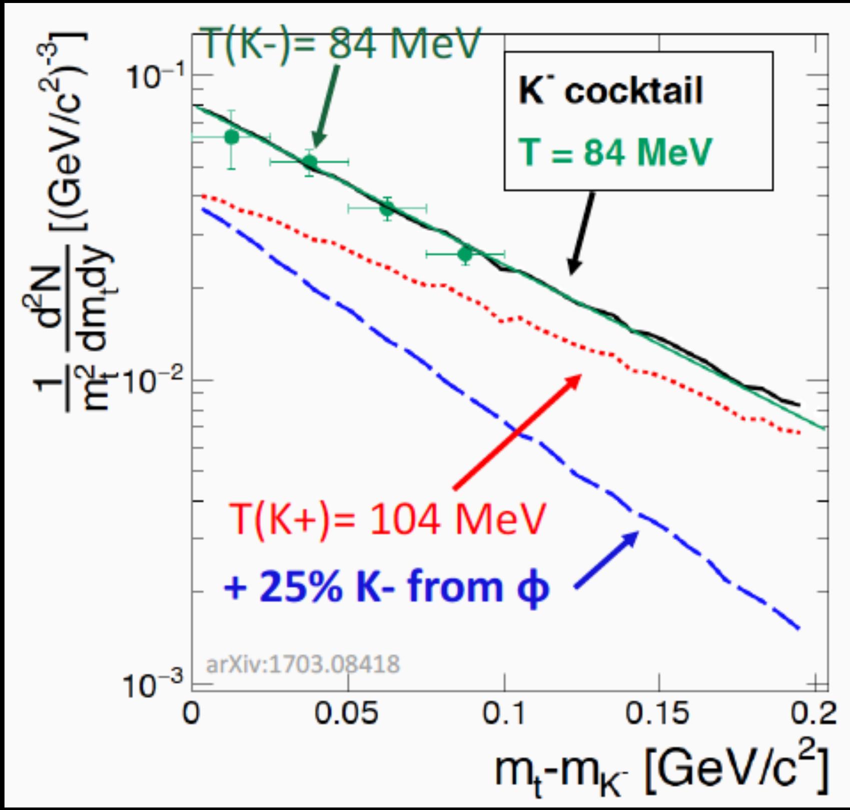

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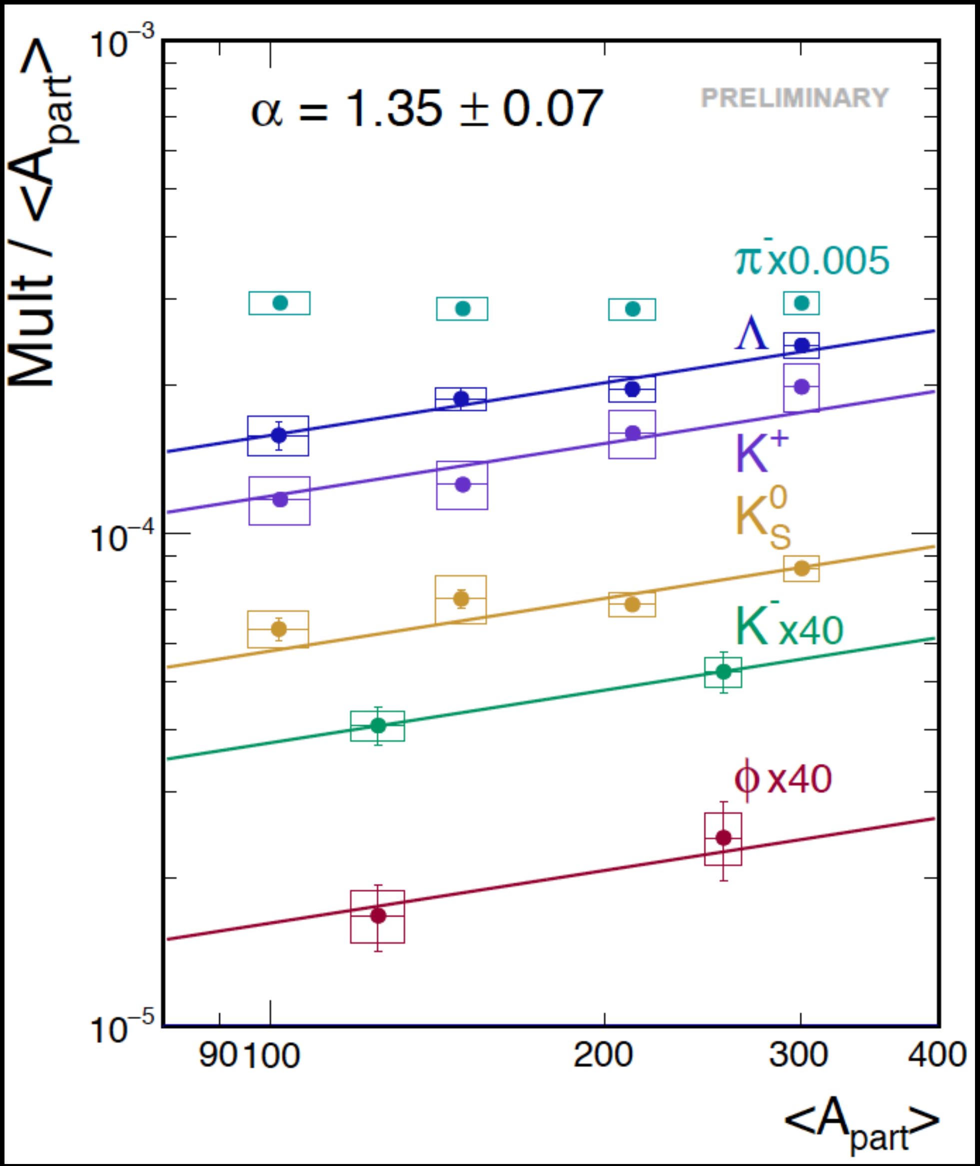
Φ feed-down can explain lower inverse slope parameter of K^- spectrum (T_{eff} = 84 ± 6 MeV) in comparison to the one of K^+ (T_{eff} = 104 ± 1 MeV)

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

H. Schuldes, T. Scheib

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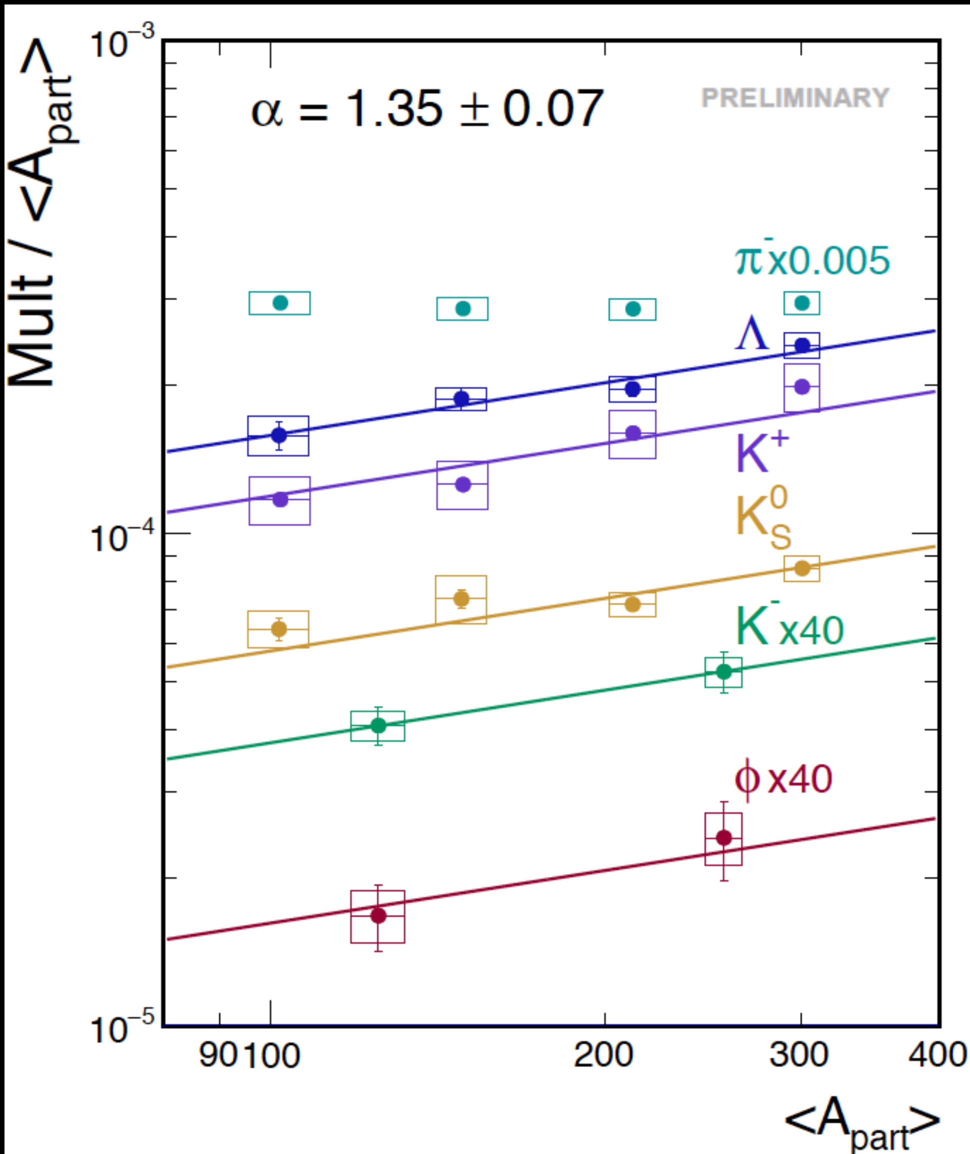

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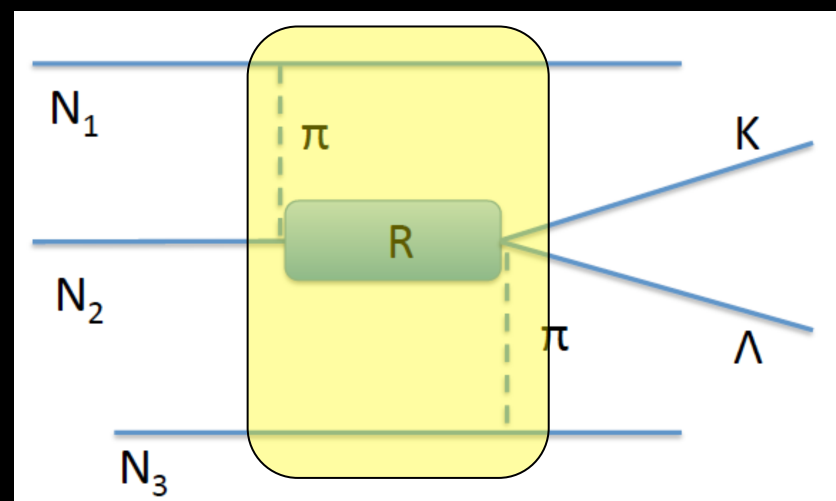


Heat bath

H. Schuldes, T. Scheib

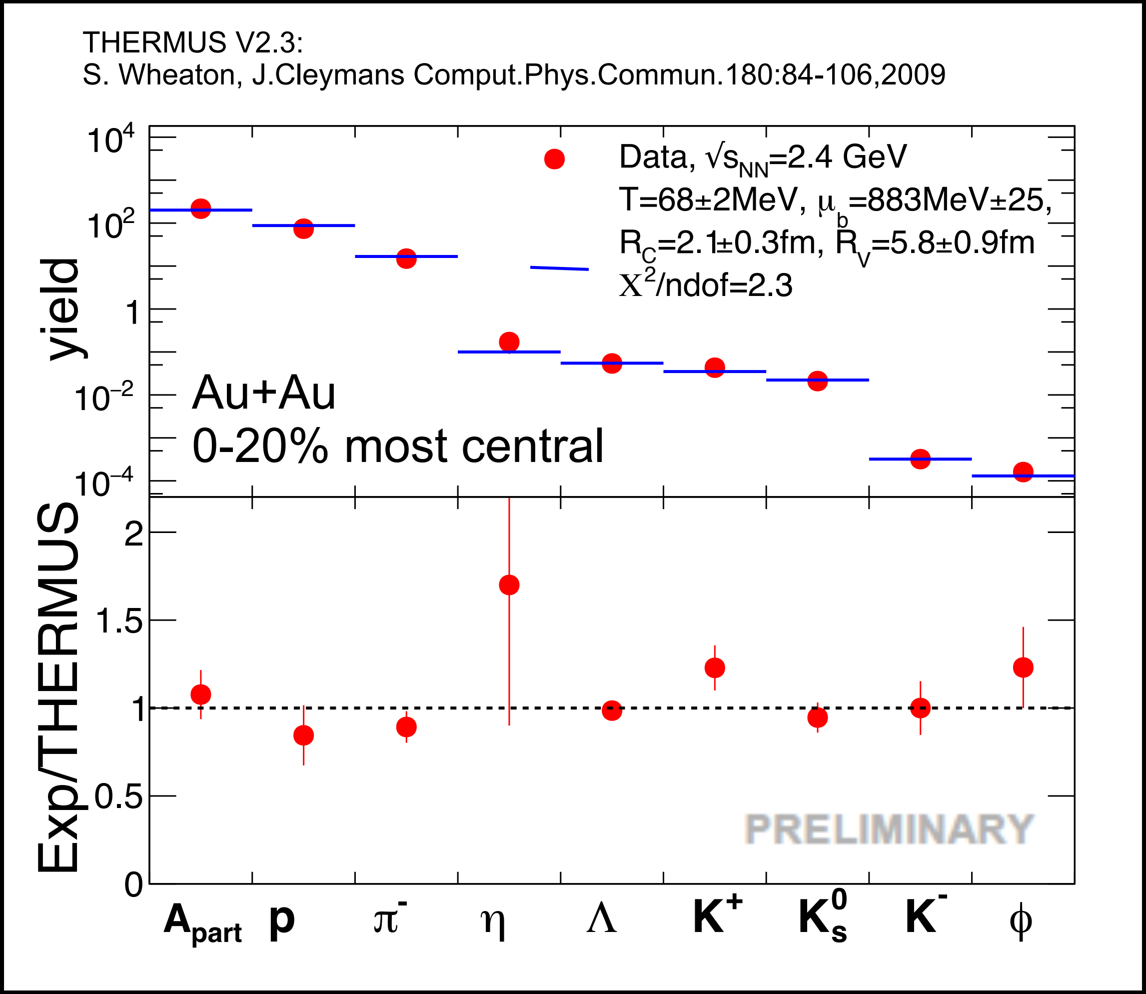
Macroscopic Description of Hadron Production

Particle production from a homogeneous source.

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

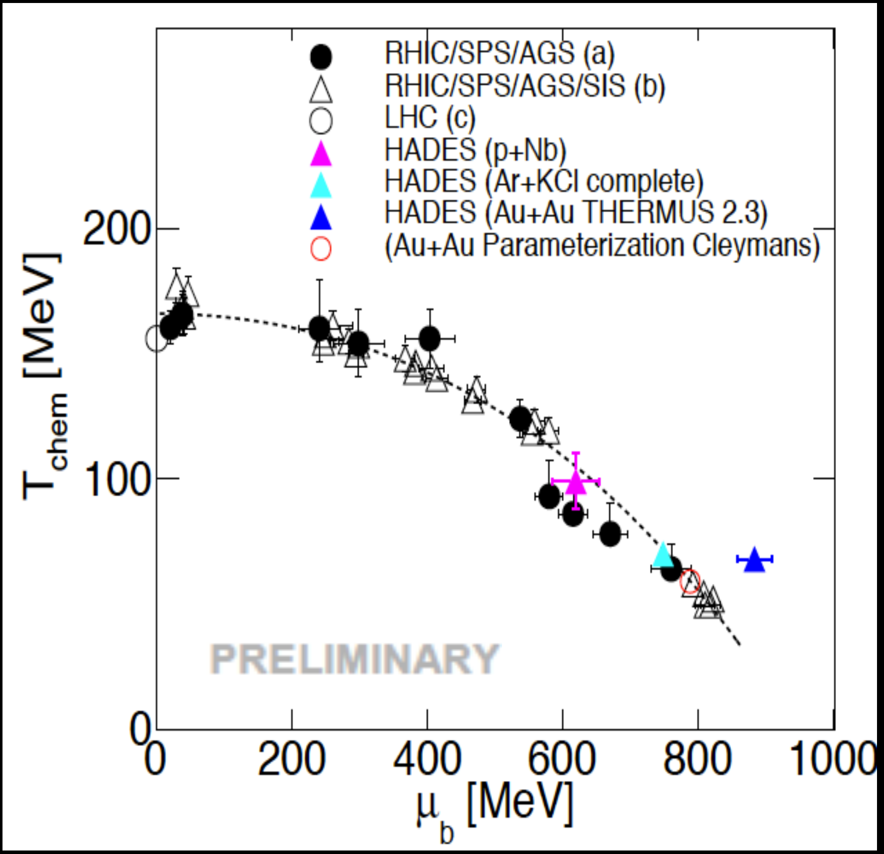
Additional parameter to suppress strangeness needed ($R_C < R_v$).

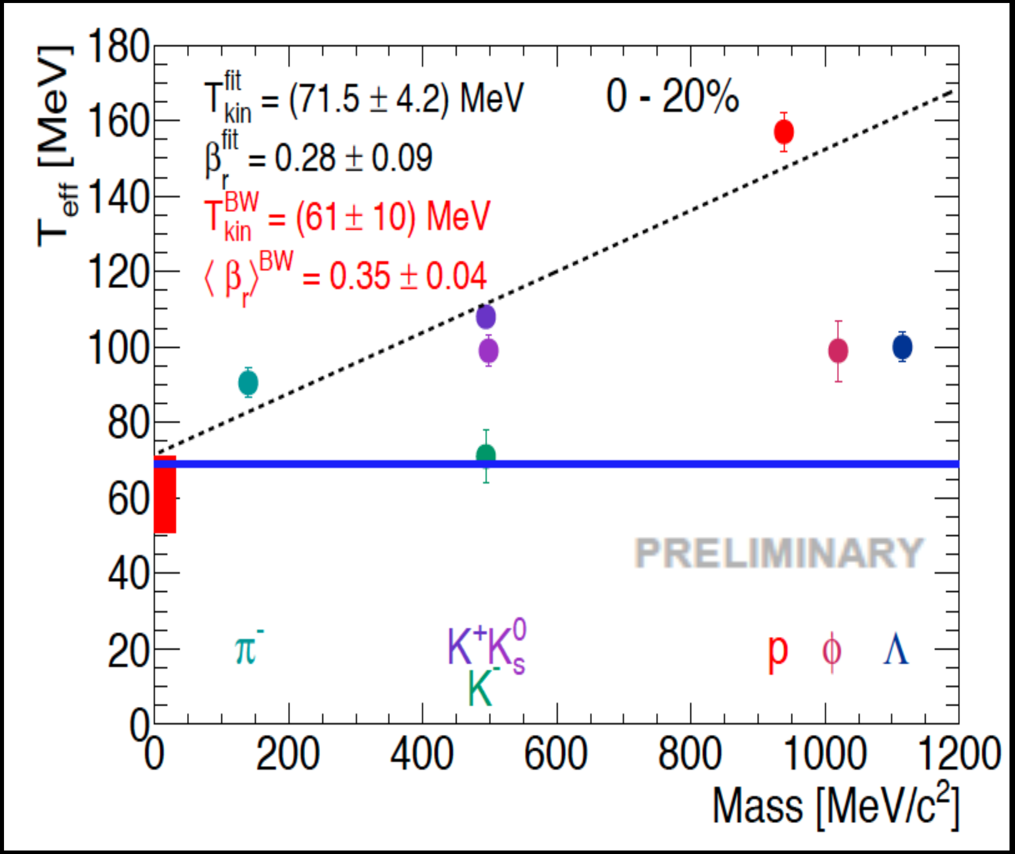
Fits at low beam energies based on limited number of particle species.



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

Chemical vs. Kinetic Freeze-out



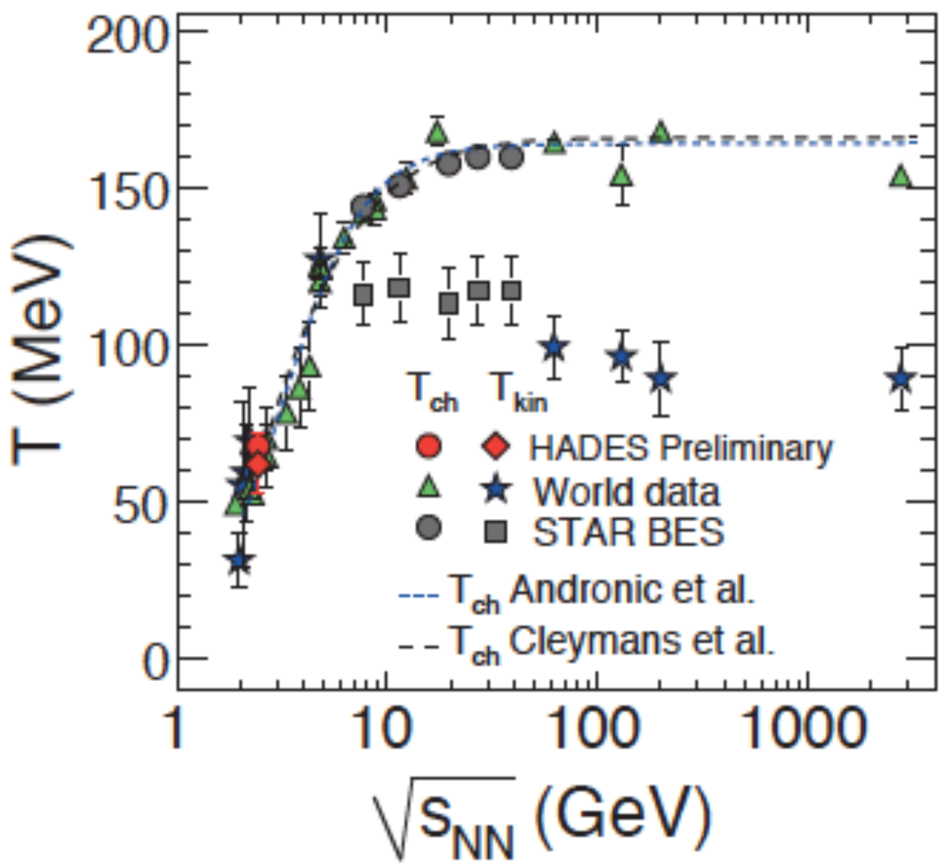


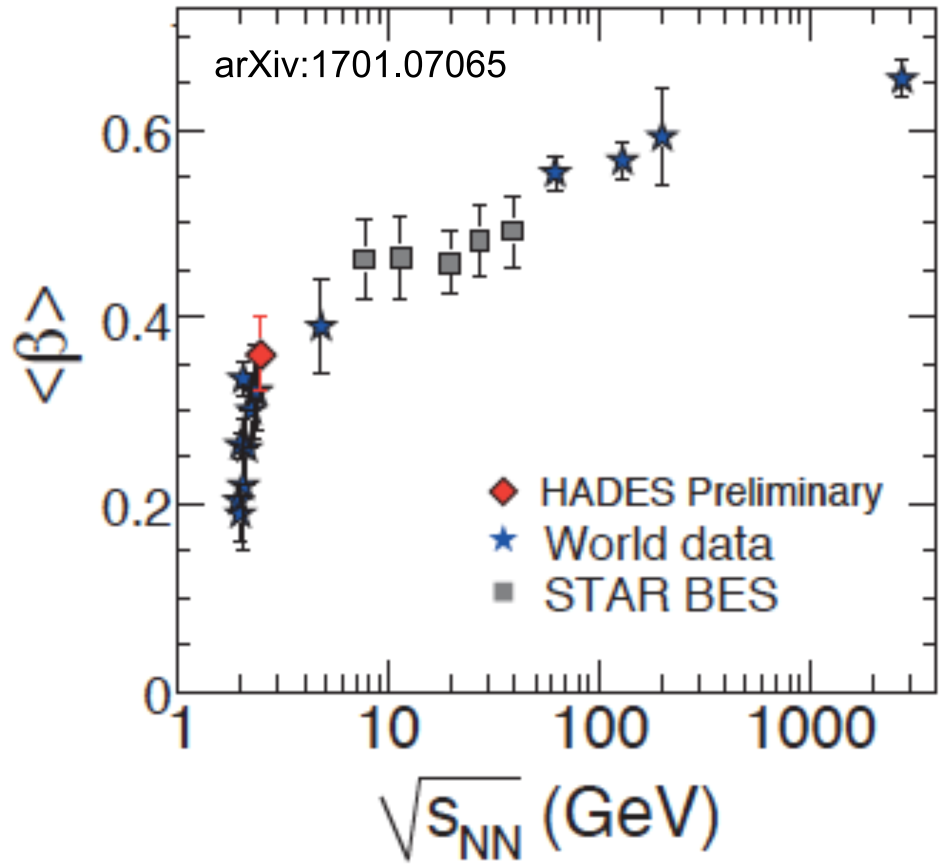
Freeze-out point at higher T and μ_B than expected from parameterization: under investigation

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





Summary

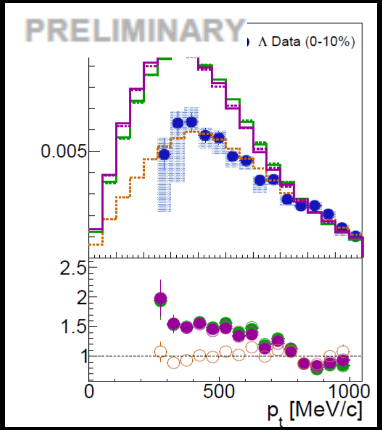
Ambiguities in description, potential extraction misleading at the moment.

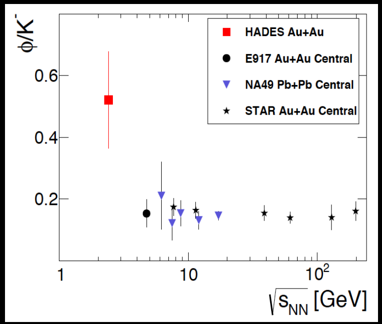
No indication for sequential K^+K^- freeze-out when correcting for φ feed-down.

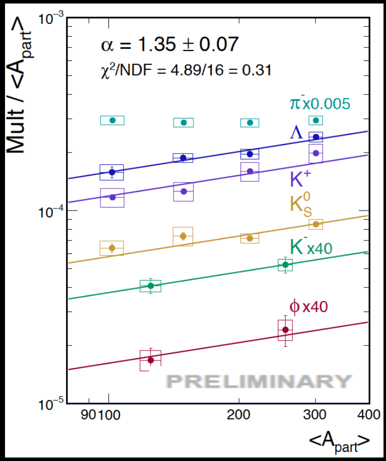
Universal $<A_{part}>$ dependence of strange hadrons.

Macroscopic description and 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.







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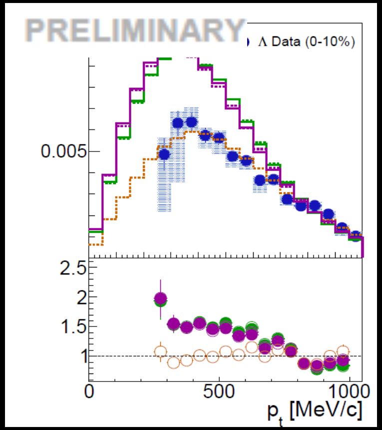
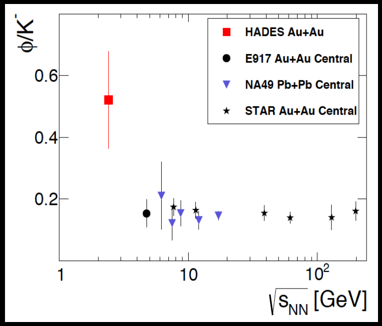
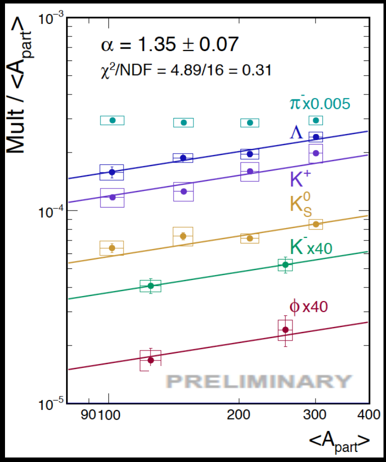
Pion induced reactions @ π + p/A $\sqrt{s}$=1.7-2.0 GeV

Clean tool to study φ and kaons in nuclear matter and understand microscopic interactions better.

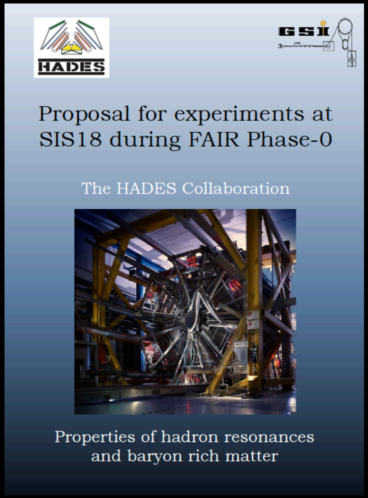






The Future

Submitted to PAC
on June 19, 2017



FAIR Phase-0:

π + p/A $\sqrt{s}$=1.7-1.9 GeV: resonance contributions and EM-structure

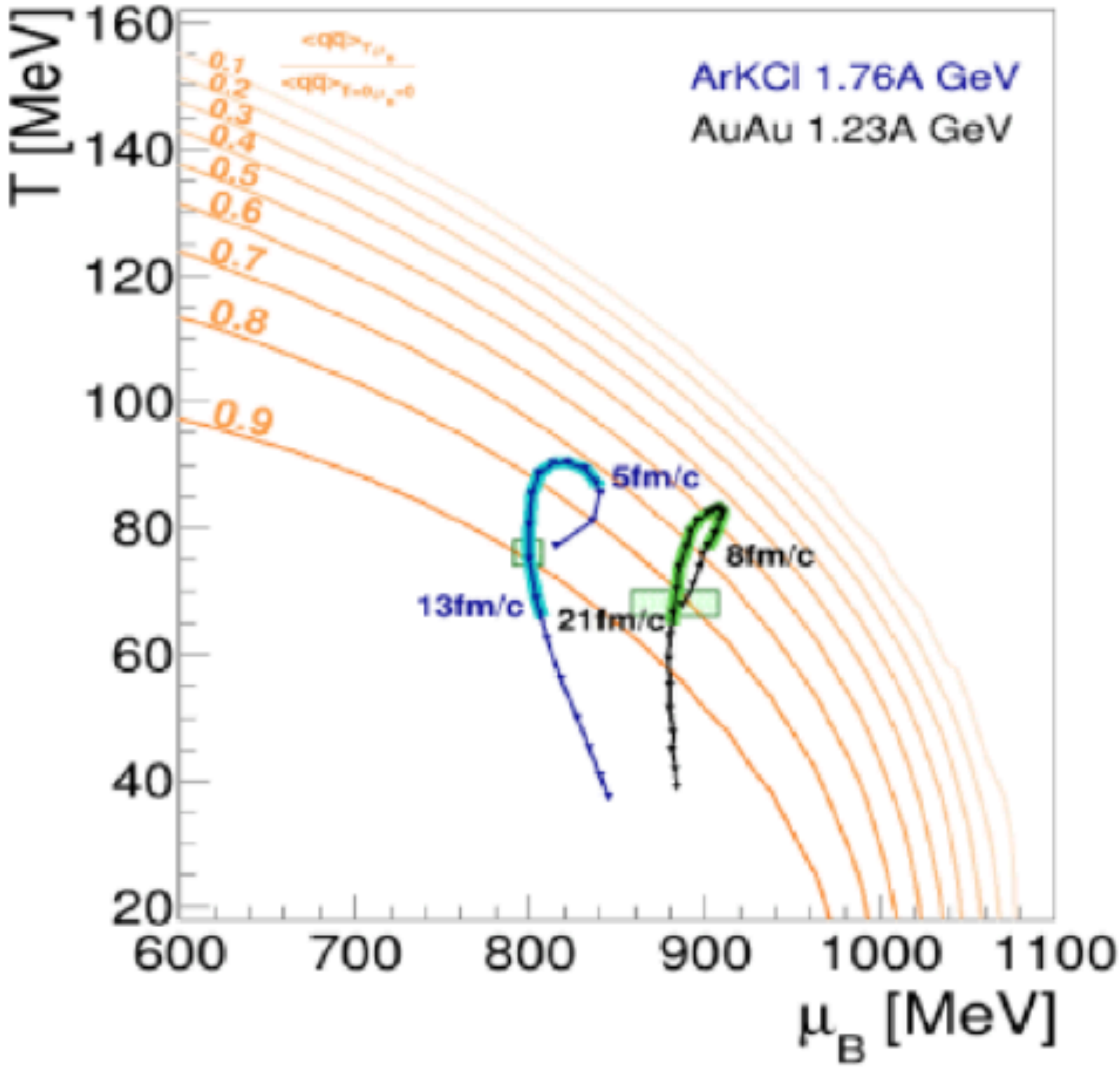
Ag+Ag@1.65 A GeV: Multi-strange hadrons & intermediate mass dileptons

SIS100:

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

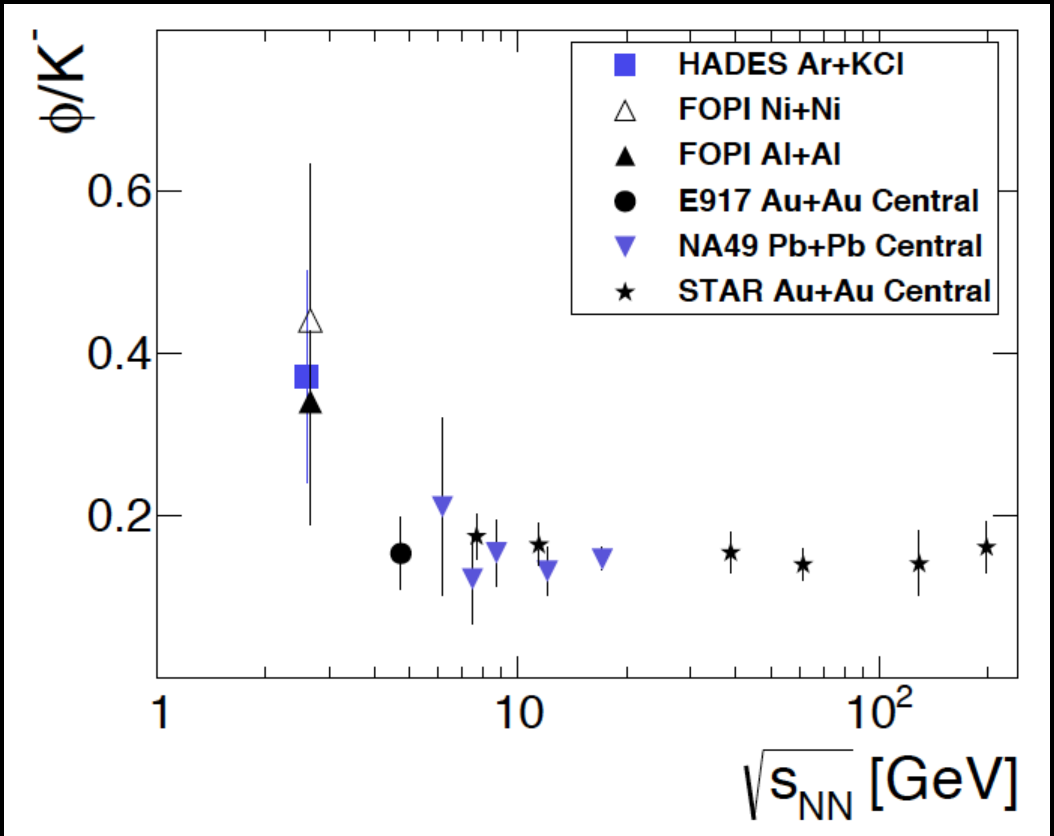
The HADES collaboration

Thank you for your attention!



T [MeV]
μ_B [MeV]
ArKCl 1.76A GeV
AuAu 1.23A GeV
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
5fm/c
8fm/c
13fm/c
21fm/c
160
140
120
100
80
60
40
20
600
700
800
900
1000
1100

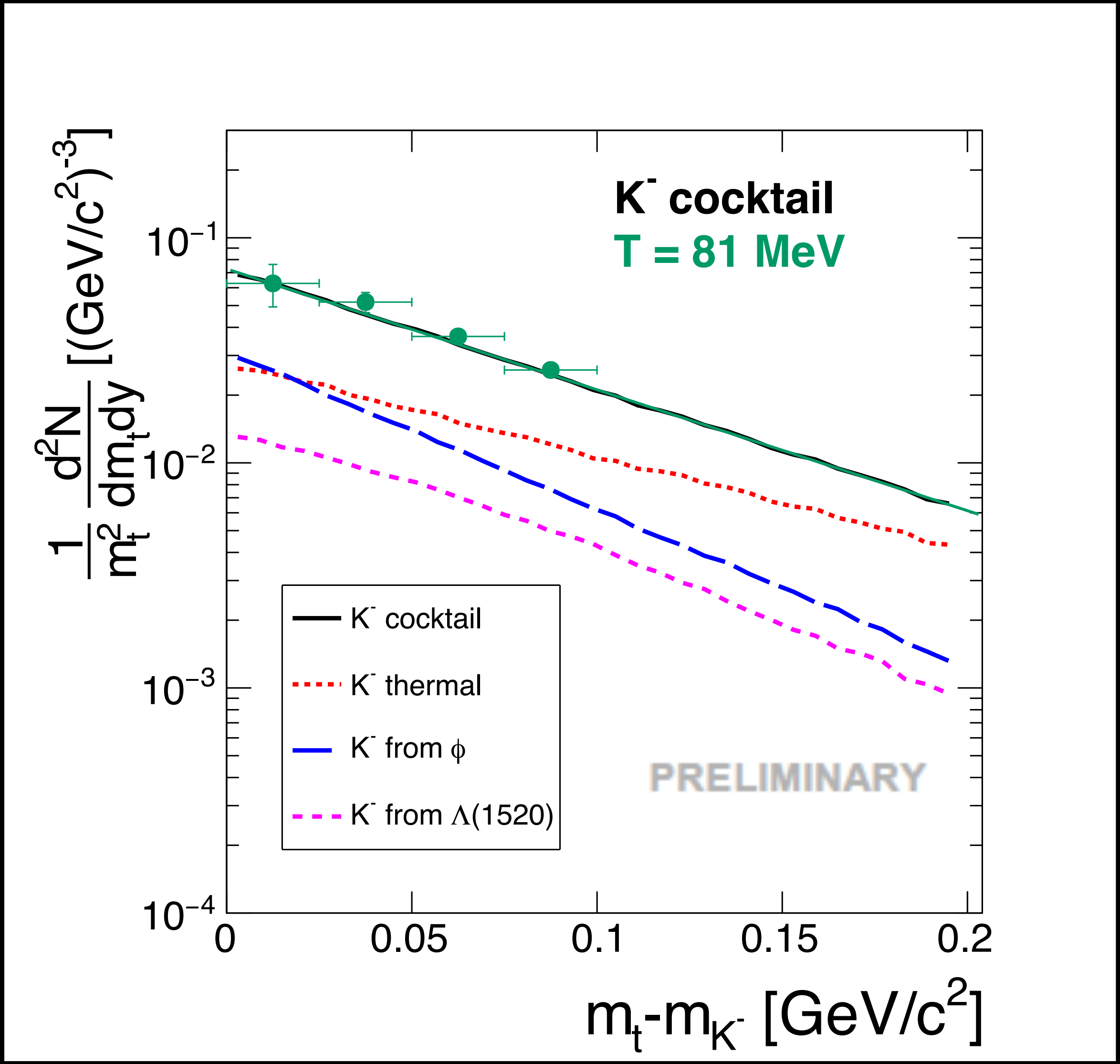
(Sub-threshold) Strangeness Production



Φ/K^- ratio constant at high energies

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

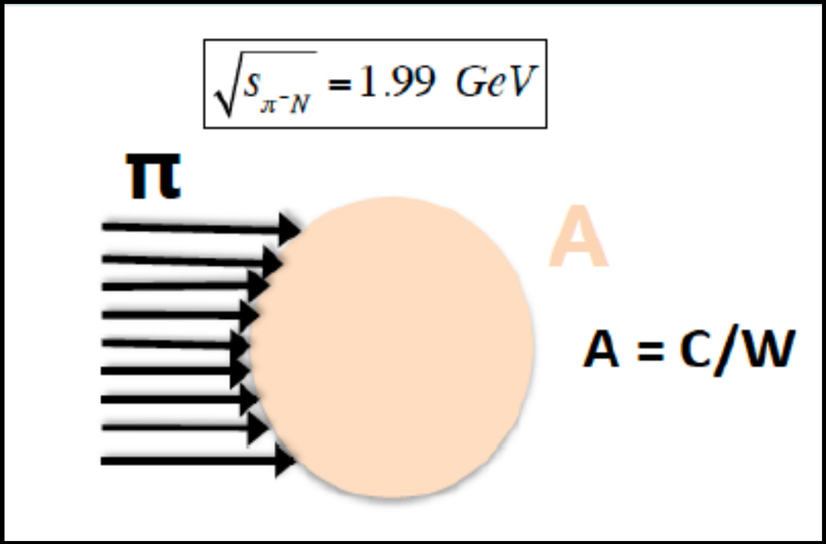
Cocktail components of hadron spectra from resonance decays: K^-

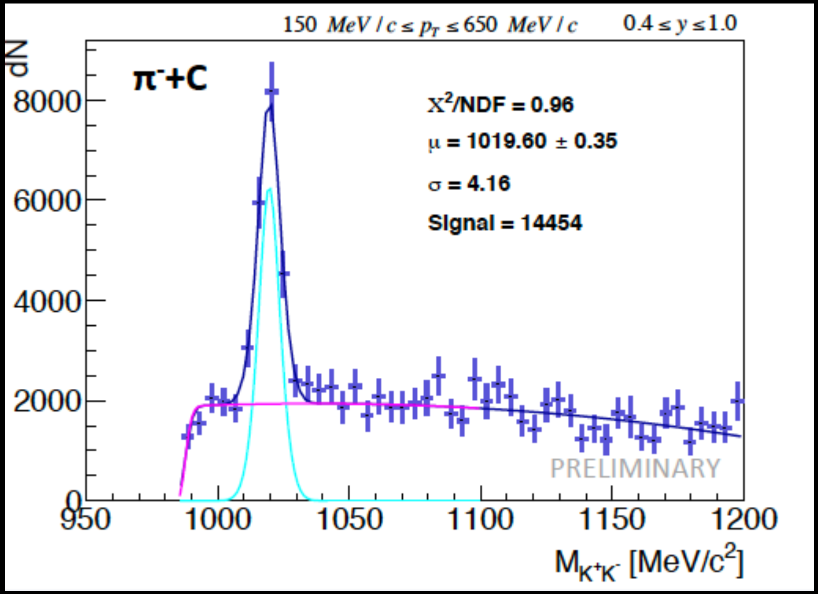


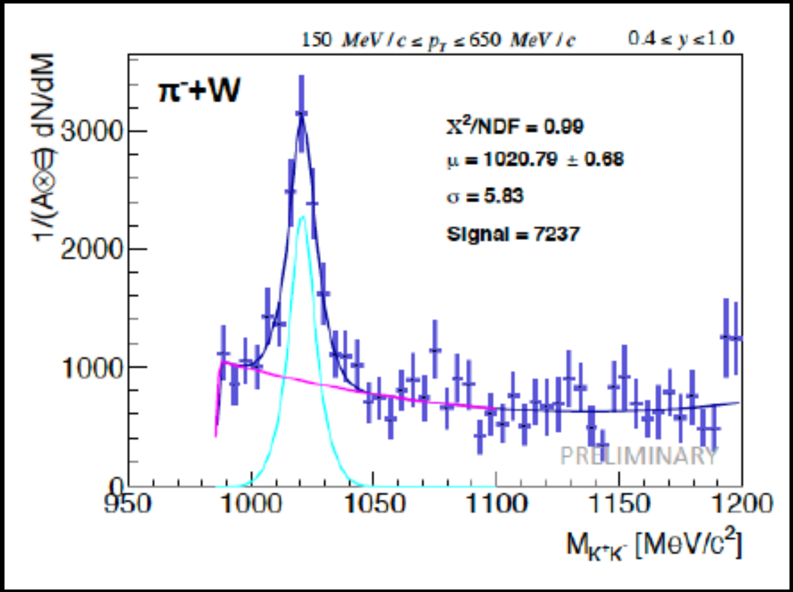
Λ(1520) yield based on Thermus fit

Thanks to Che-Ming Ko!

Pion induced reactions on nuclei: ϕ production

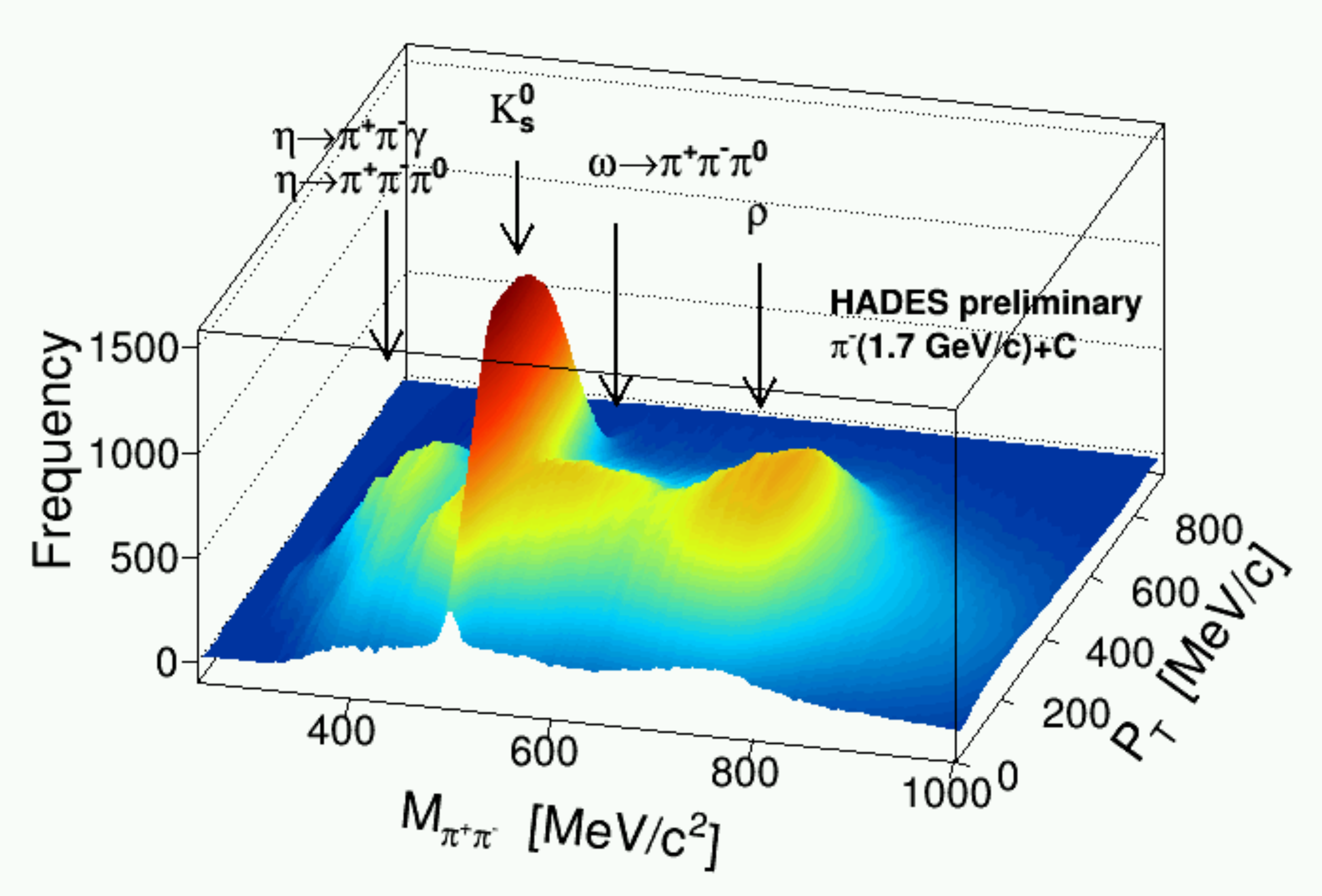






J. Wirth

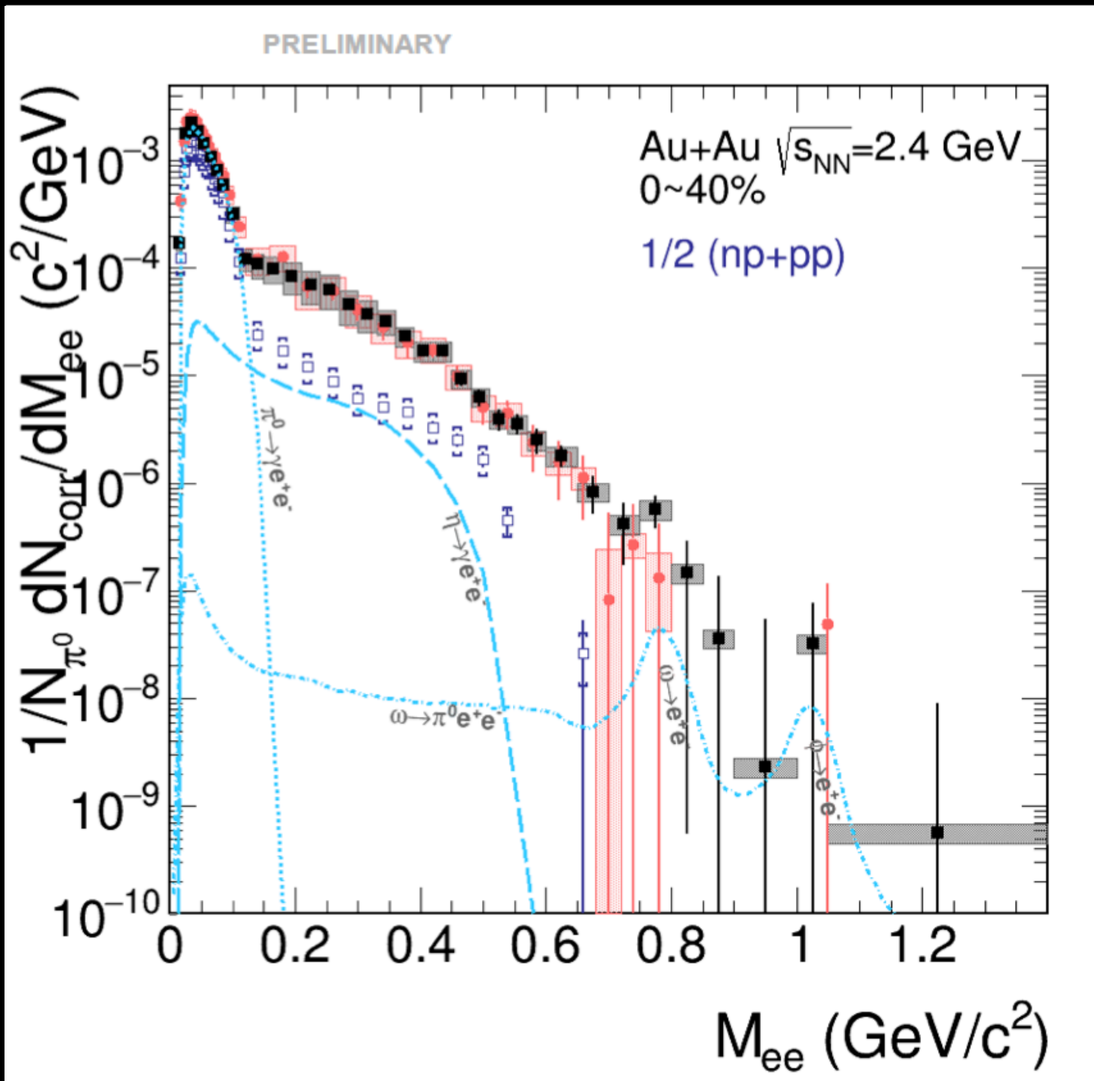
Pion induced reactions on nuclei: resonances



G. Kornakov

Virtual Photon Emission

Virtual Photon Emission



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

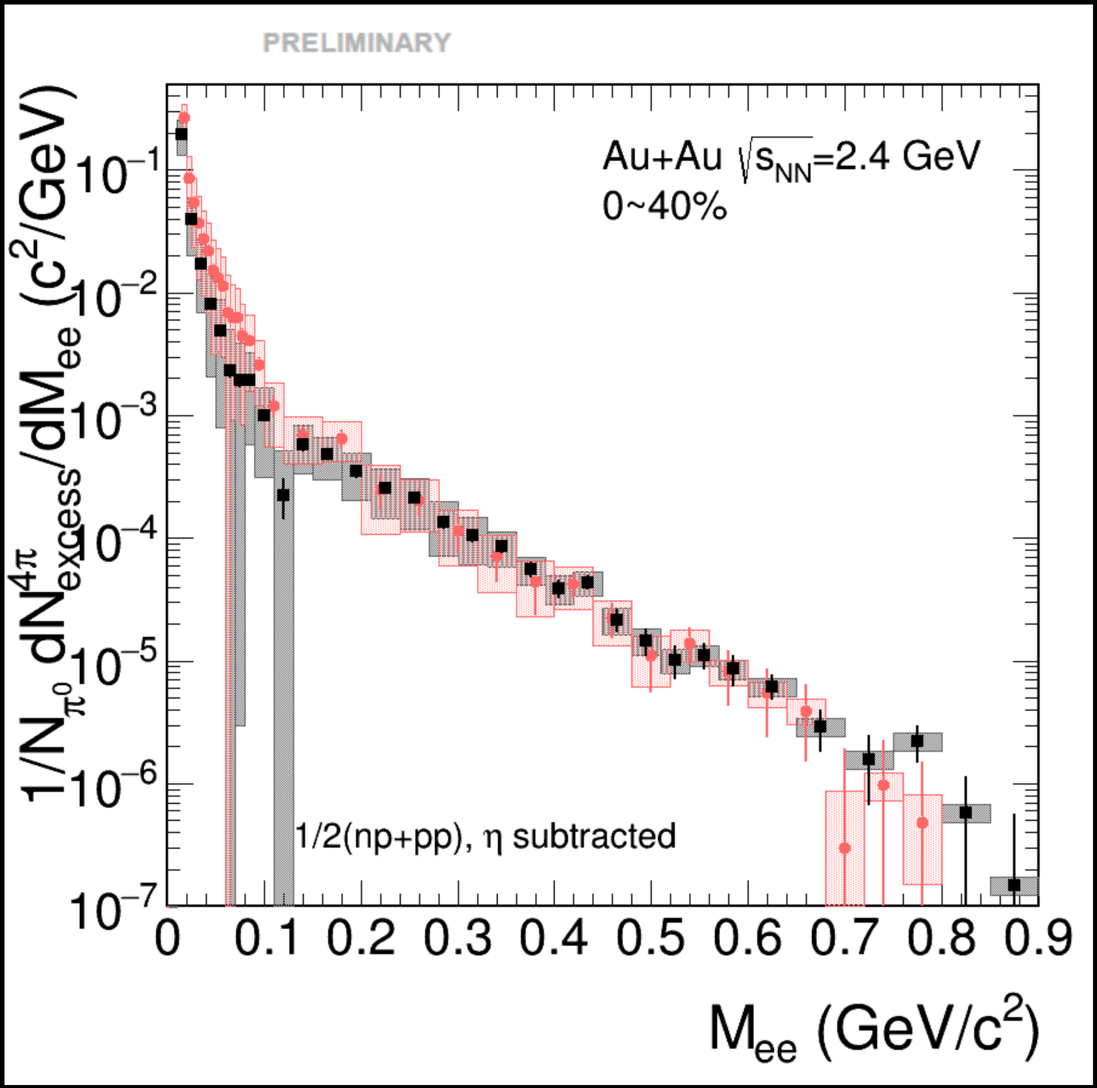
Normalized to the number of π^0.

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

Virtual Photon Emission



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Isolation of the excess by subtracting the elementary reference and the η-contribution.

Acceptance corrected excess yield.

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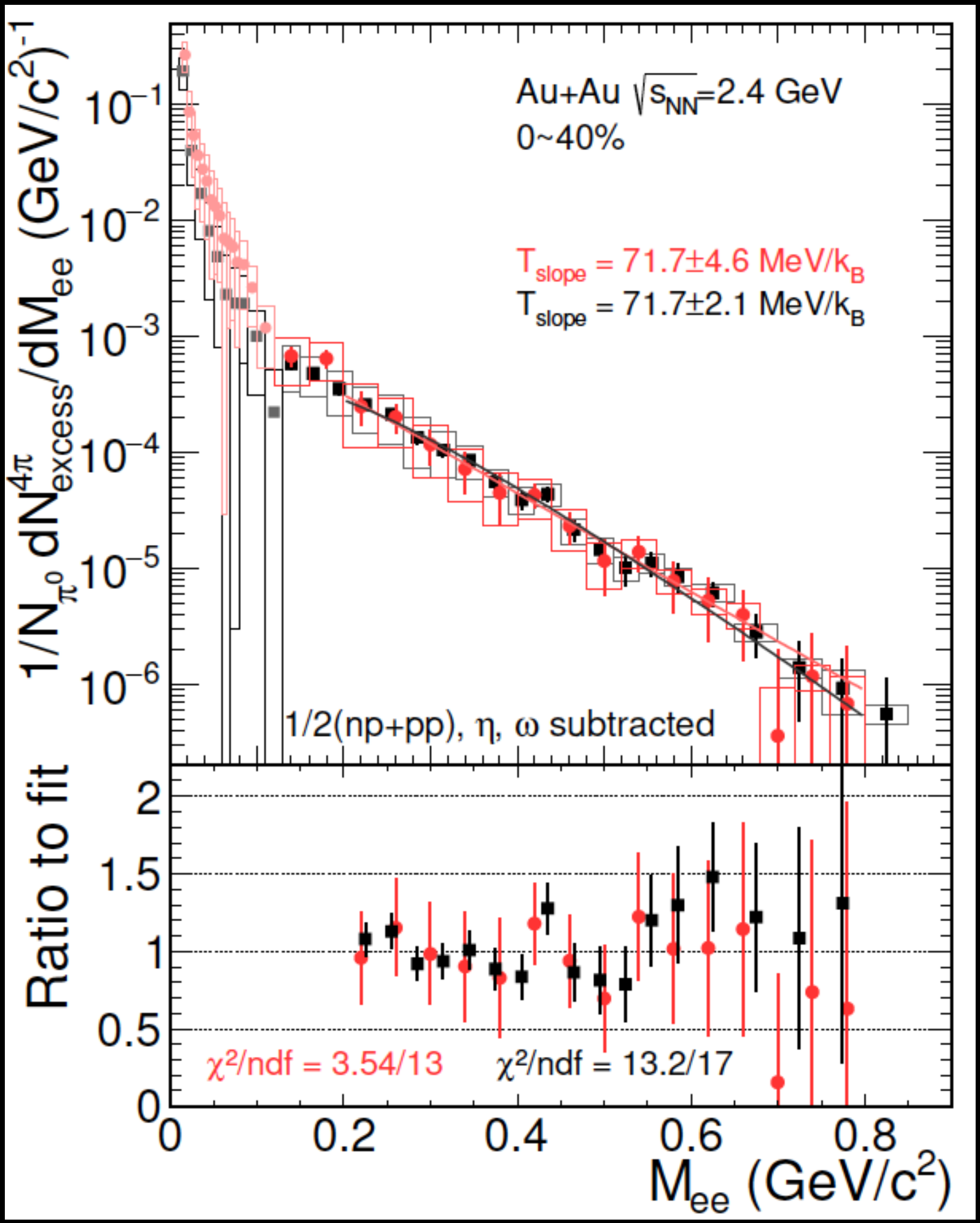

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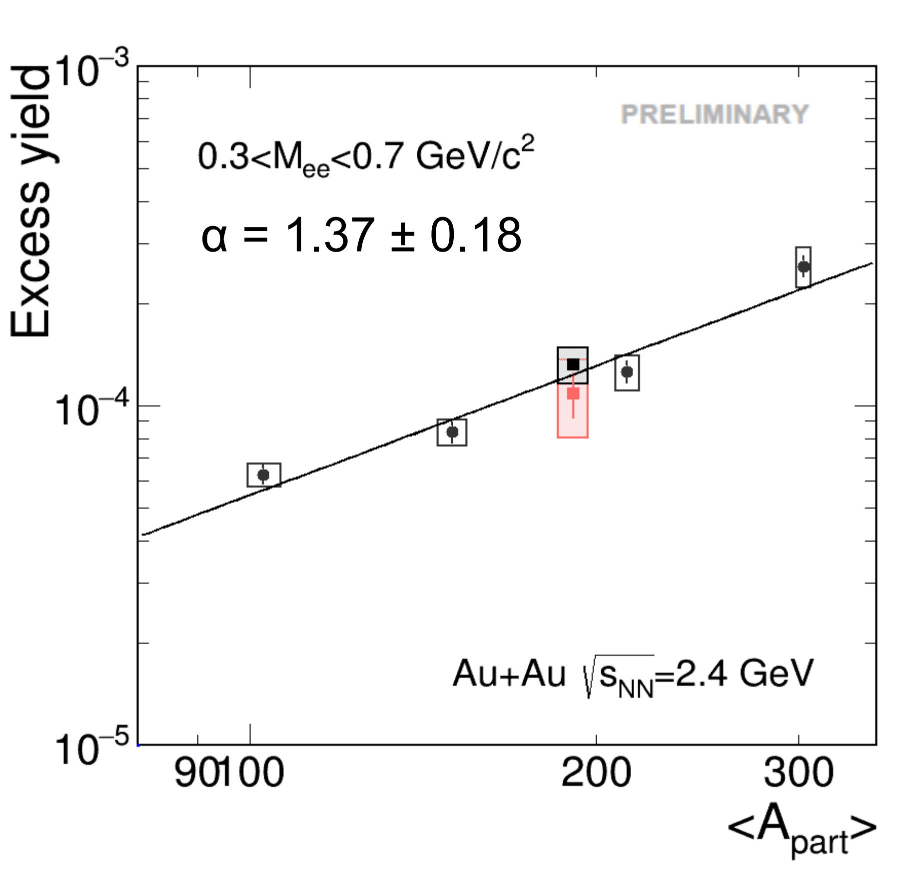
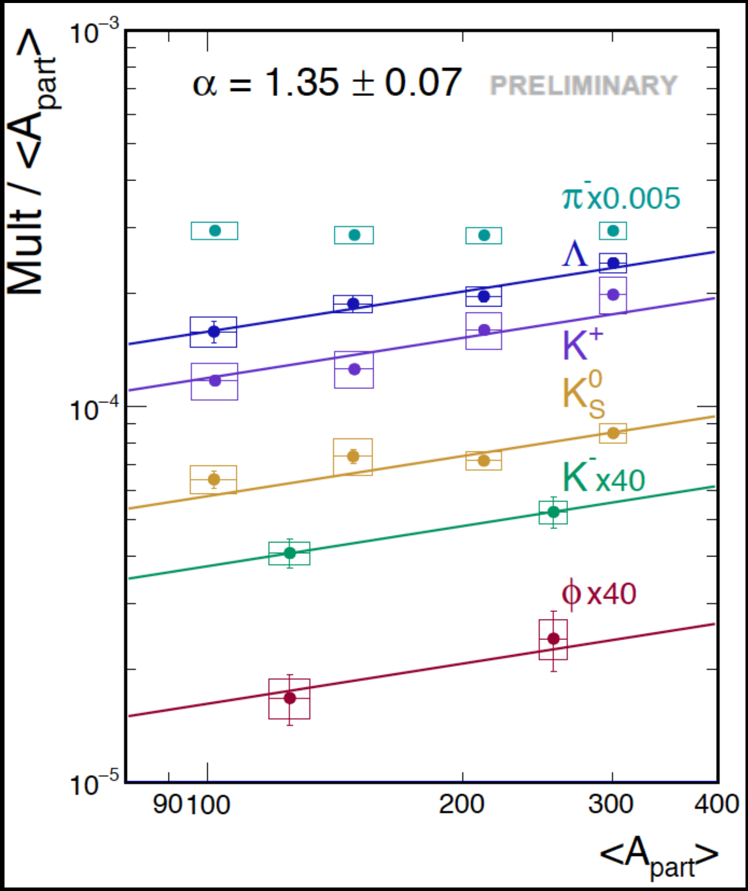
Exponentially falling spectrum,
→ extraction of source temperature

Centrality Dependence of Virtual Photon Emission

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



Strange Particles



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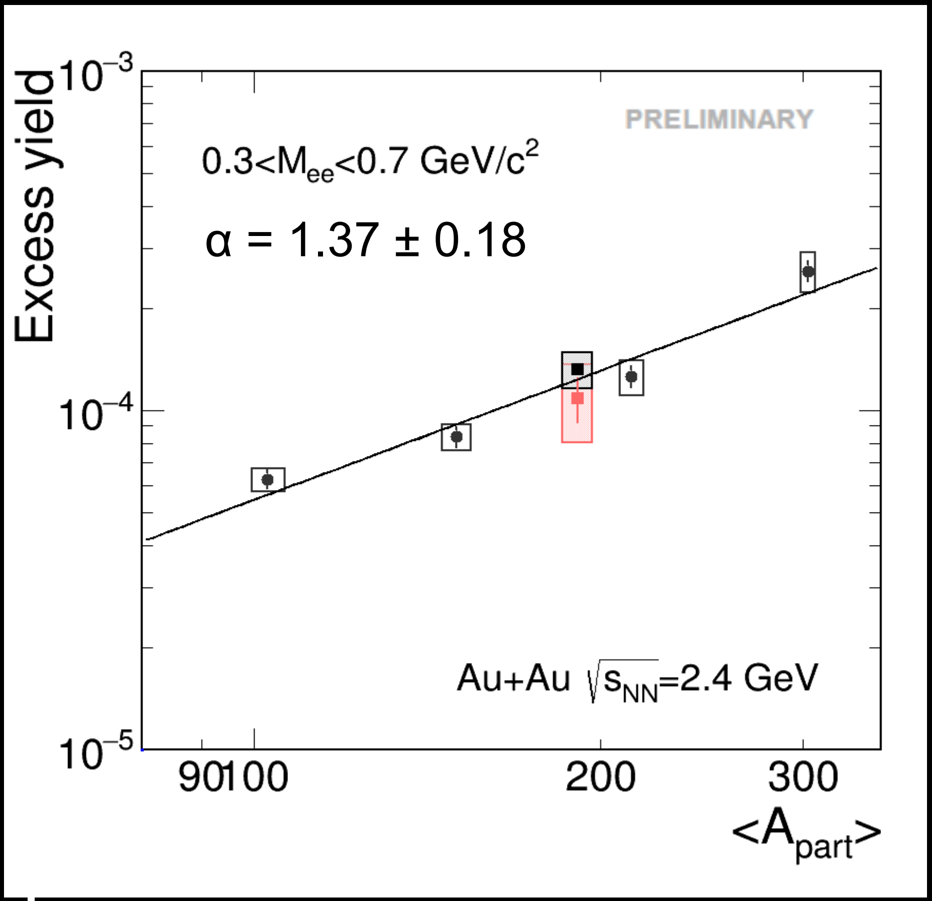

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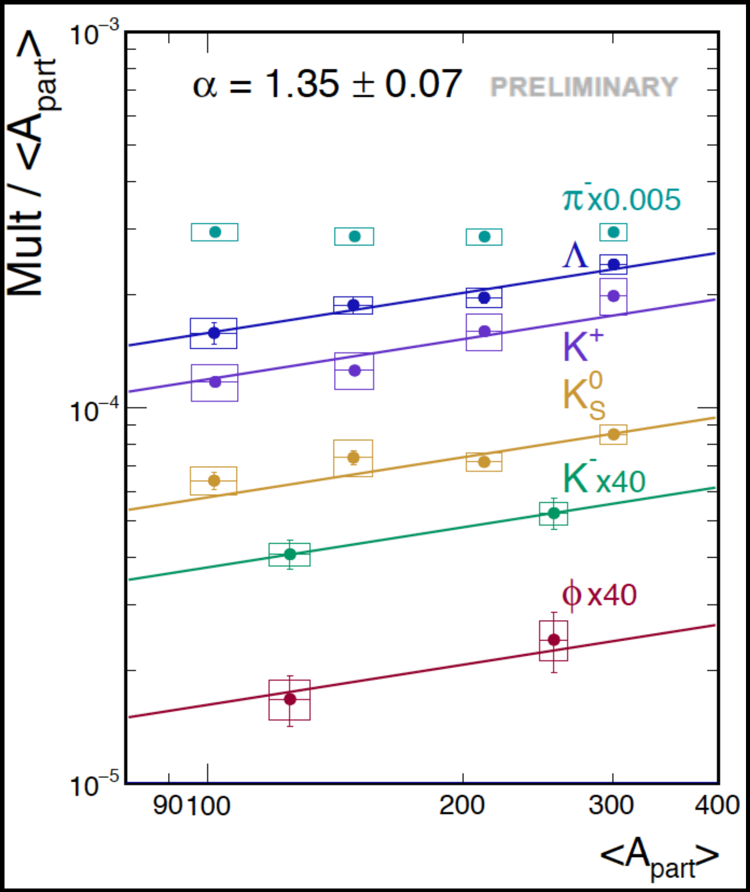

Universal $\langle A_{part} \rangle$ dependence