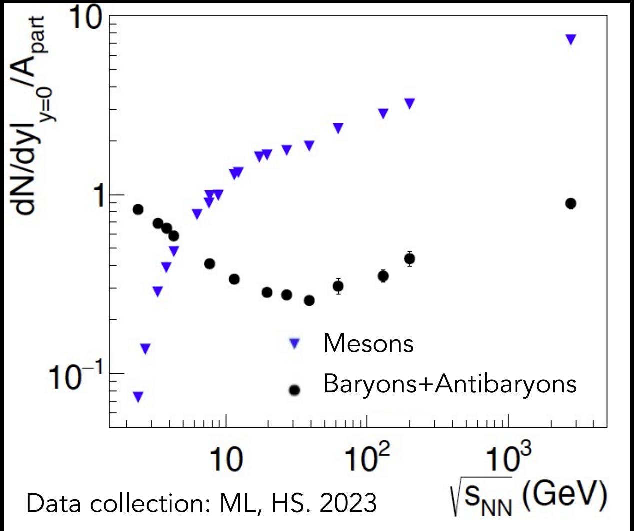
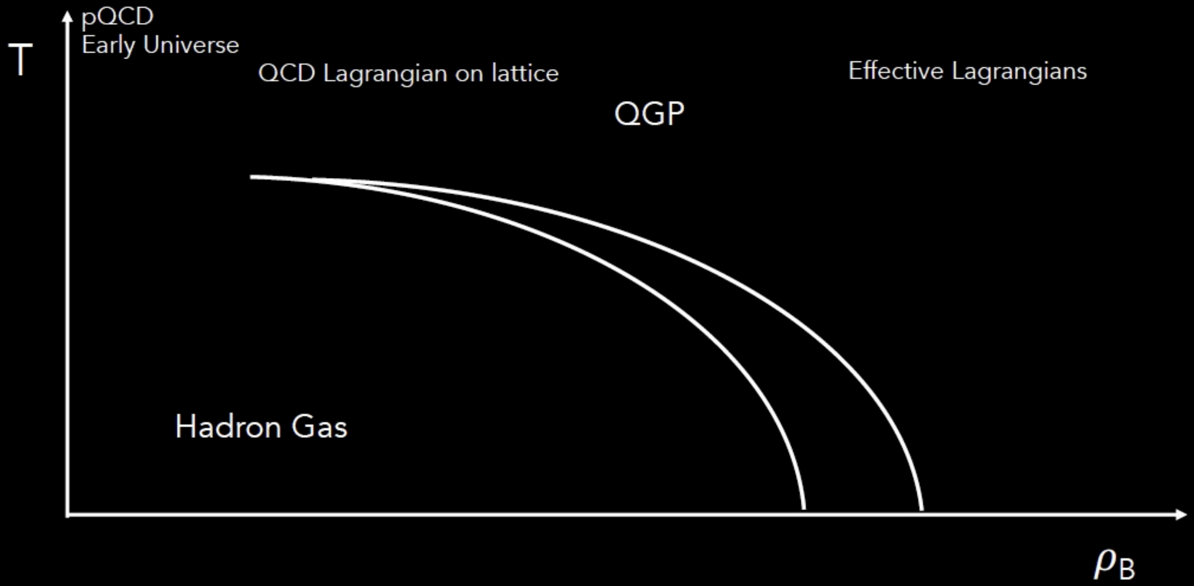
HADES HIGHLIGHTS: Recent results from HADES

Manuel Lorenz
for the collaboration
Goethe-University Frankfurt

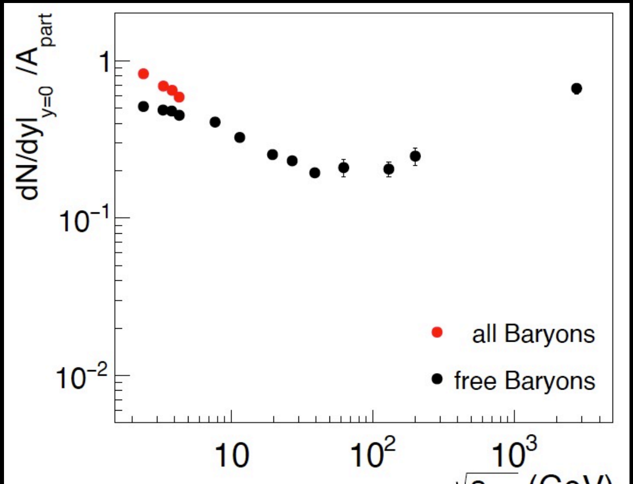
Baryon dominated matter at HADES



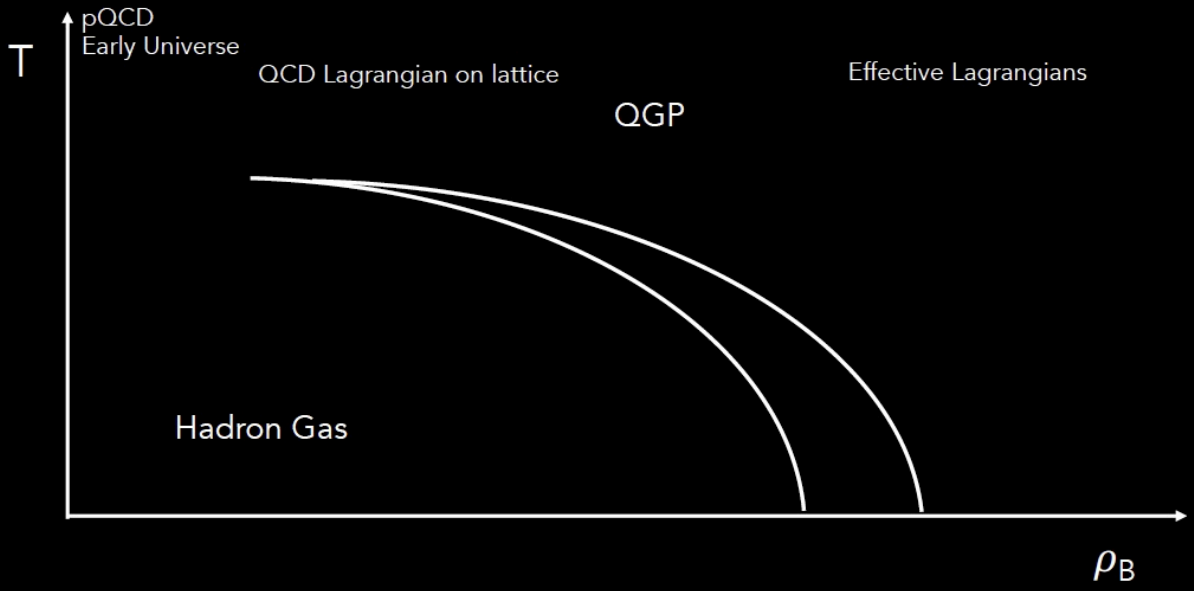


Baryon dominated system,

Baryon dominated matter at HADES

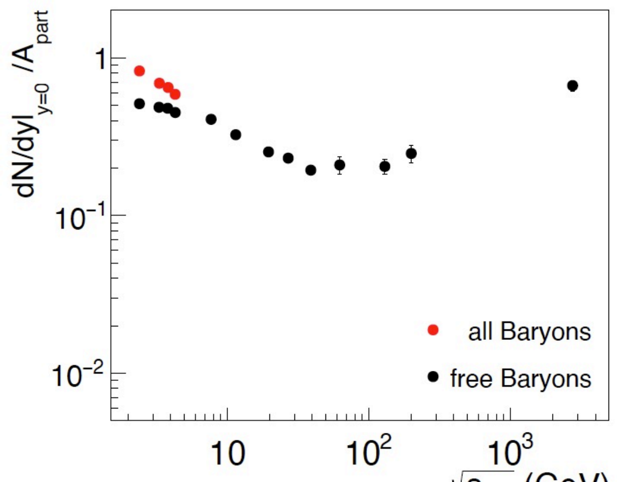


Data collection: ML, HS. 2023



Baryon dominated system,
large amount of bound nucleons.

Baryon dominated matter at HADES



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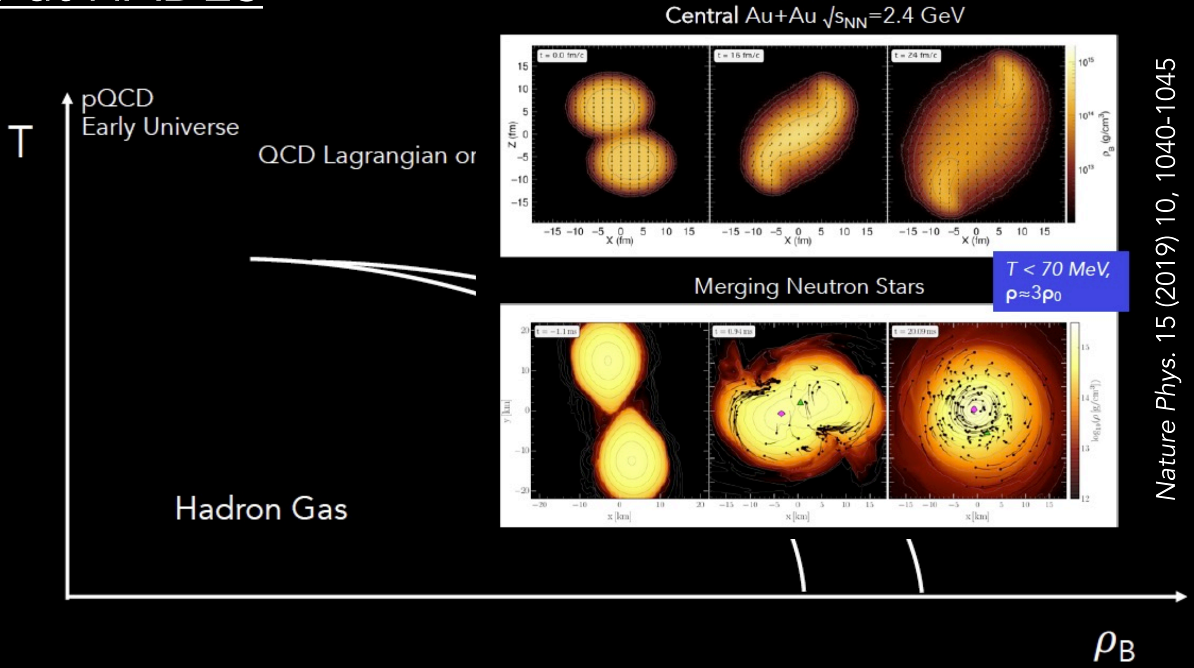


Nature Phys. 15 (2019) 10, 1040-1045

Baryon dominated system,
large amount of bound nucleons.

Created matter has similar properties in merging neutron stars.

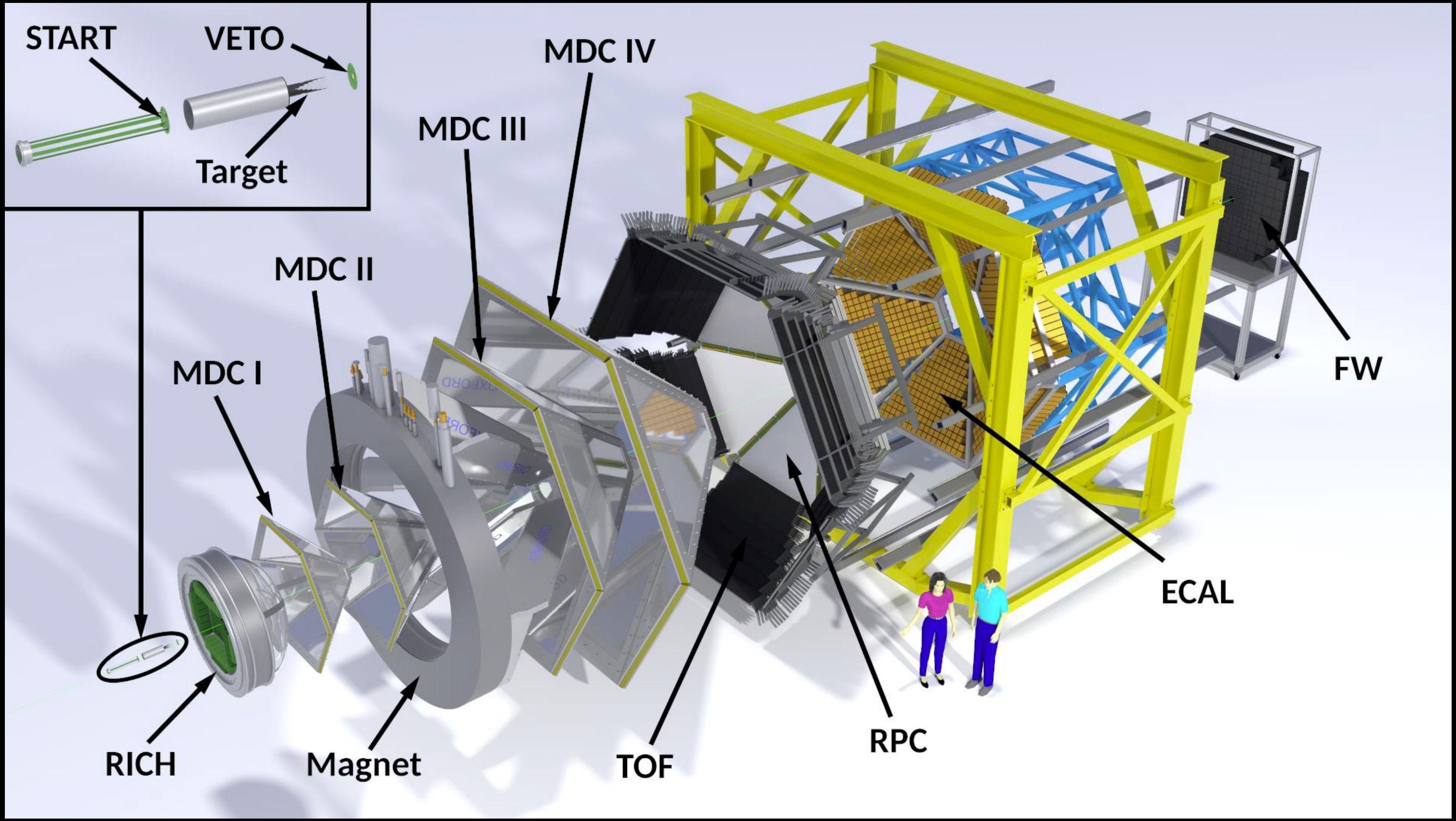
Clear hierarchy in hadron yields:

$p \approx 100$, $p_{bound} \approx 50$, $\pi \approx 10$,
$K^{+} \approx 10^{-2}$, $K^{-} \approx 10^{-4}$
} cent. Au+Au

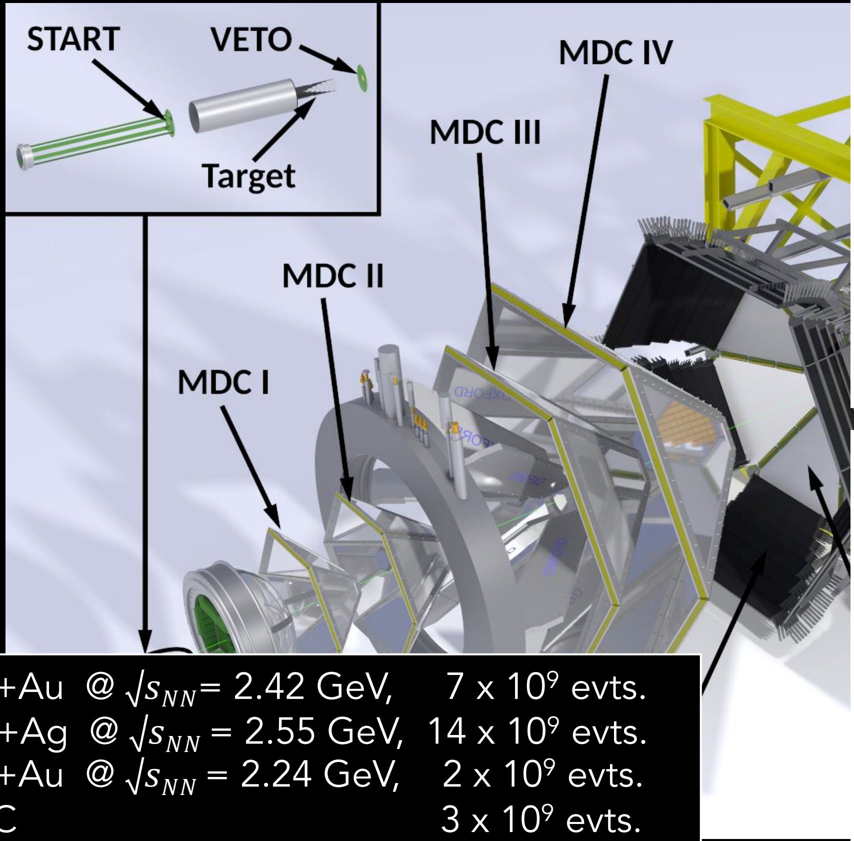
This talk, focuses on:

1. p, light nuclei and π to characterize bulk properties
2. strangeness as rare probe

HADES


START
VETO
Target
MDC IV
MDC III
MDC II
MDC I
FW
ECAL
RICH
Magnet
TOF
RPC

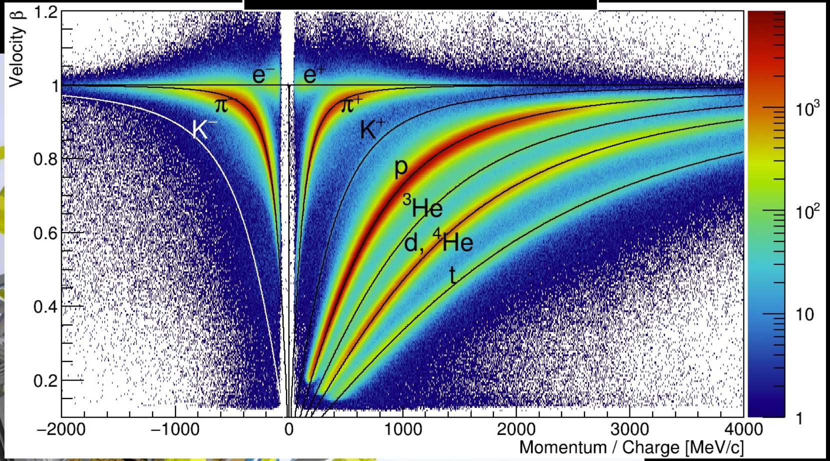
HADES

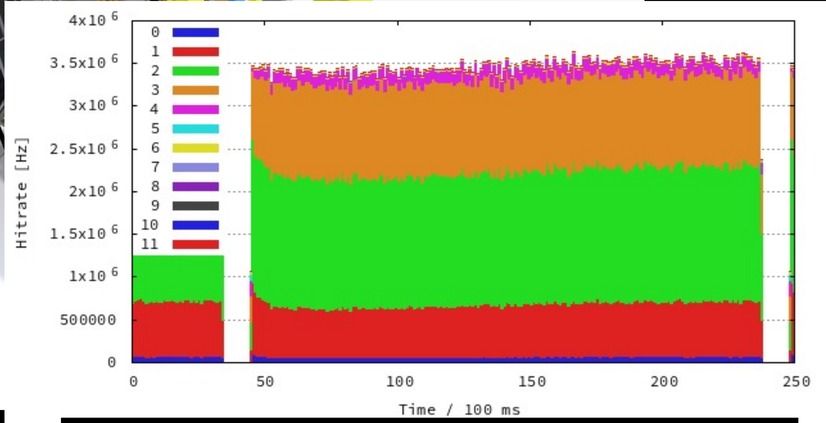


2012: Au+Au @ $\sqrt{s_{NN}}$= 2.42 GeV, 7 x 10^9 evts.
2019: Ag+Ag @ $\sqrt{s_{NN}}$ = 2.55 GeV, 14 x 10^9 evts.
2024: Au+Au @ $\sqrt{s_{NN}}$ = 2.24 GeV, 2 x 10^9 evts.
C+C 3 x 10^9 evts.

BES with 0.6, 0.4 and 0.2 A GeV beam planned for 2025.

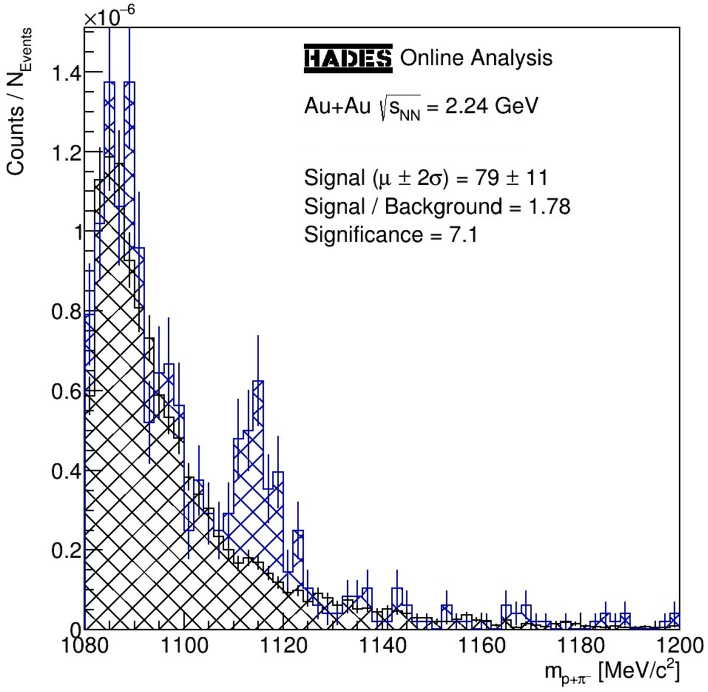
PID: Beta vs. Mom.



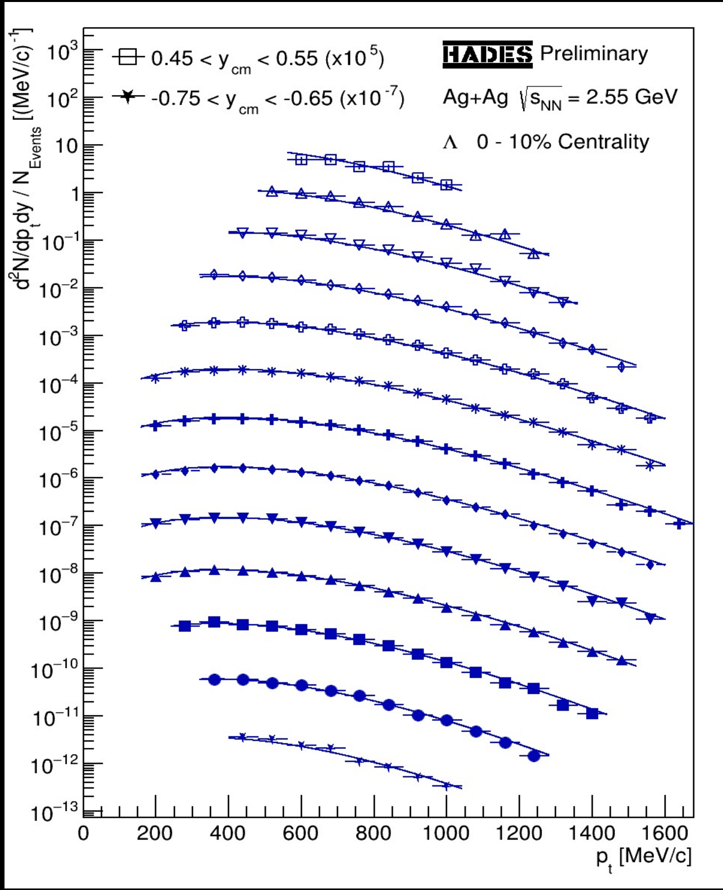


Improved spill shape due to active regulation of knock-out of SIS18.

Performance



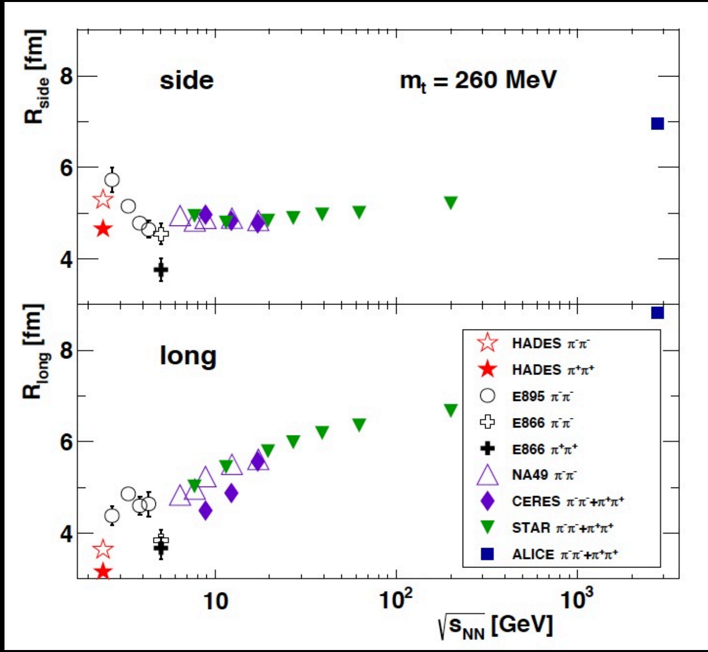
World record in subthreshold energy Λ reconstruction.

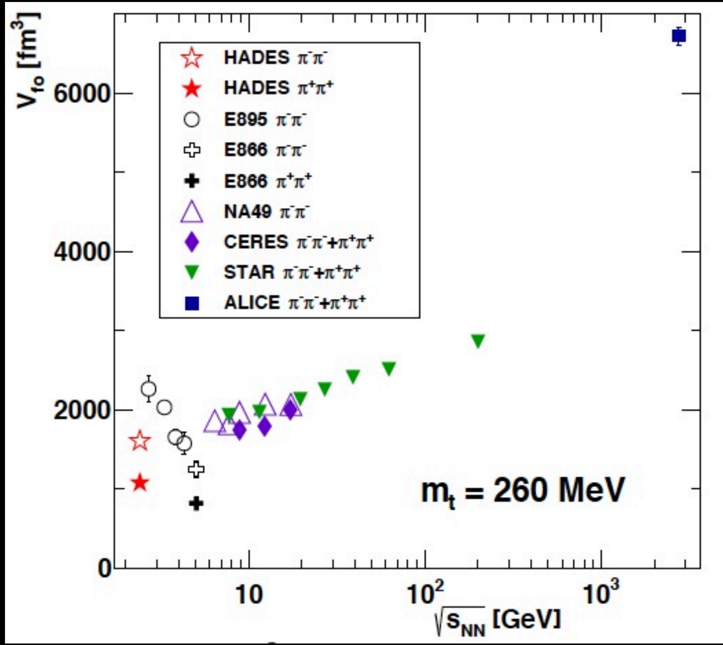


Bulk Properties

HBT Radii and B_A paramter

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



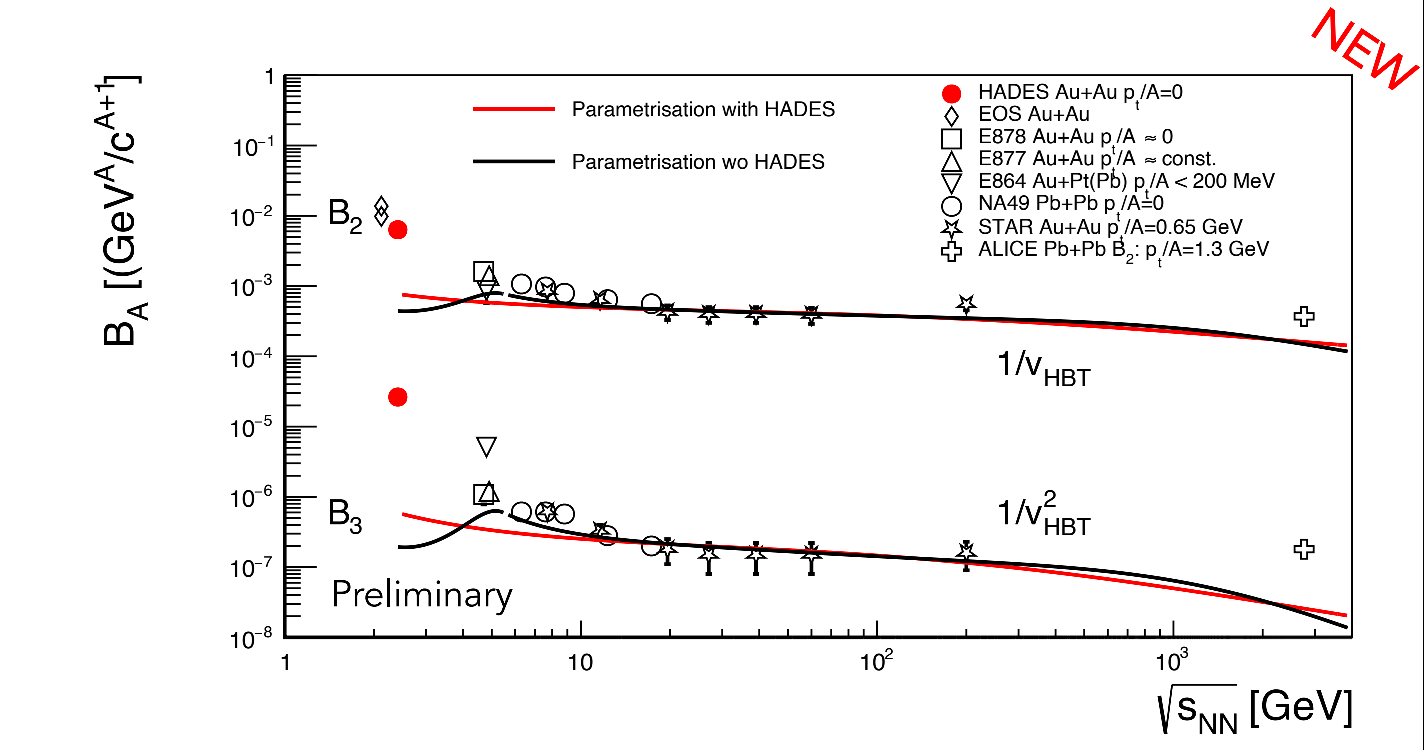


HADES HBT data suggest rather smooth trend from high to low energies.

Phys.Lett.B 795 (2019) 446-451, *Eur.Phys.J.A* 56 (2020) 5, 140

HBT Radii and B_A paramter

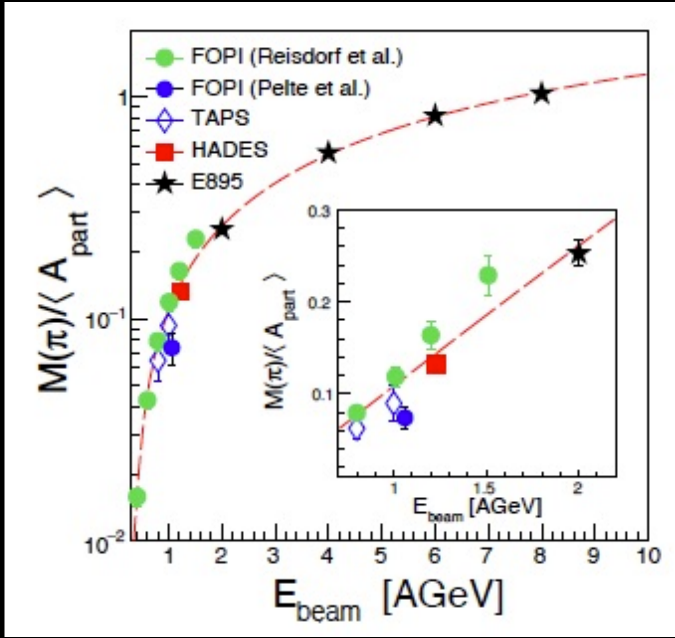
$$B_A \propto \left(\frac{1}{V}\right)^{(A-1)}$$



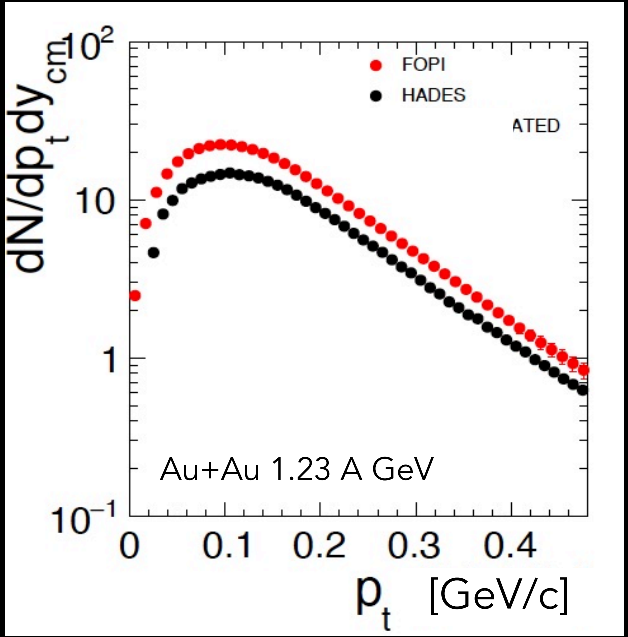
Smooth trend supported by extracted B_A parameter

Data collection: P. Braun-Munzinger, B. Dönigus, Nucl.Phys.A 987 (2019) 144-201

π yields in the few GeV regime



Discrepancy between HADES and FOPI data (factor ≈ 1.35).

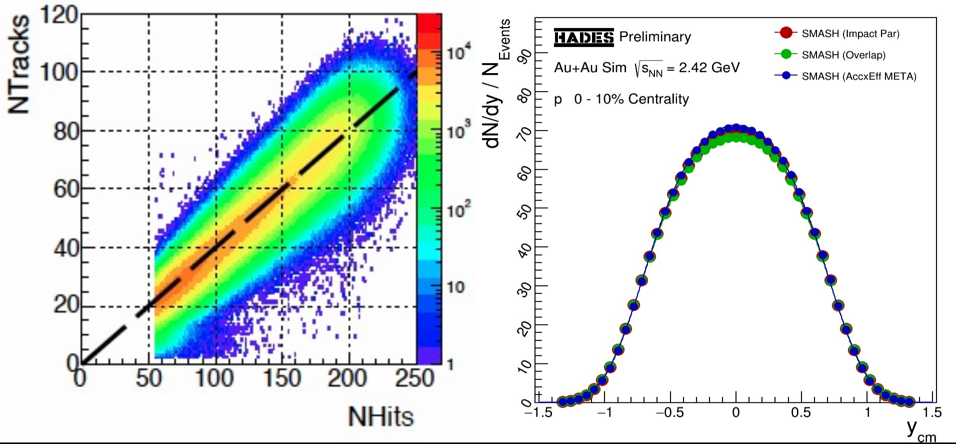


Very similar shape of spectra.

Eur.Phys.J.A 56 (2020) 259, private communication W.Reisdorf

π yields in the few GeV regime

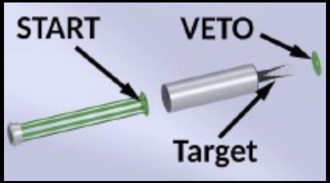
Centrality determination



- Investigation of correlation between Hits in ToF-detectors and reconstructed tracks
- Testing different variants of centrality selections for models: sharp impact parameter, various versions of sampling the amount of hits, tracks etc.
  - No significant change in selection of 0-10% most active events

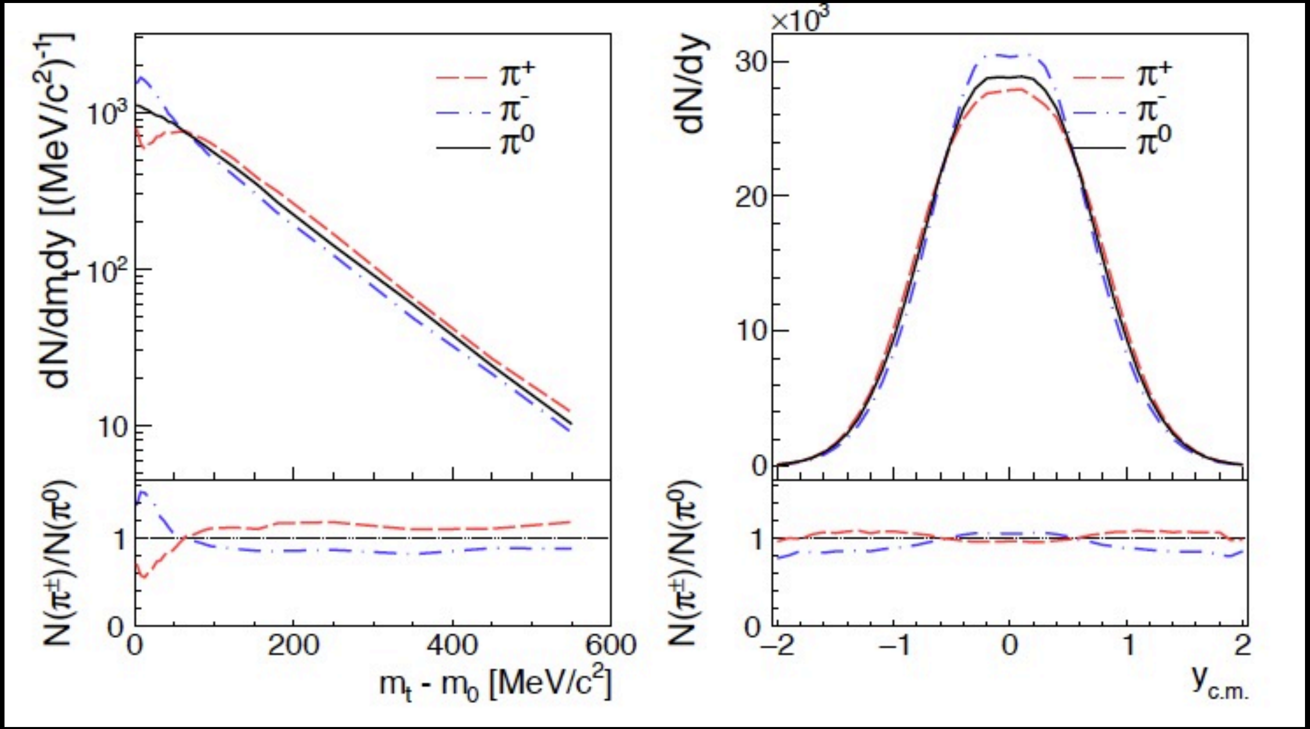
Higher order effects in eff. correction

- δ-electron emitted if beam ions traverse target
- SIS18 beam exhibited significant intensity jumps within milliseconds
- δ-electrons reduce the performance of the inner tracking by occupying detector cells
  - use measured intensity on start detector to calibrate beam intensity



  - adjust δ-electron event-by-event in simulation

Influence of Coulombpotential on extrapolation procedure in m_t

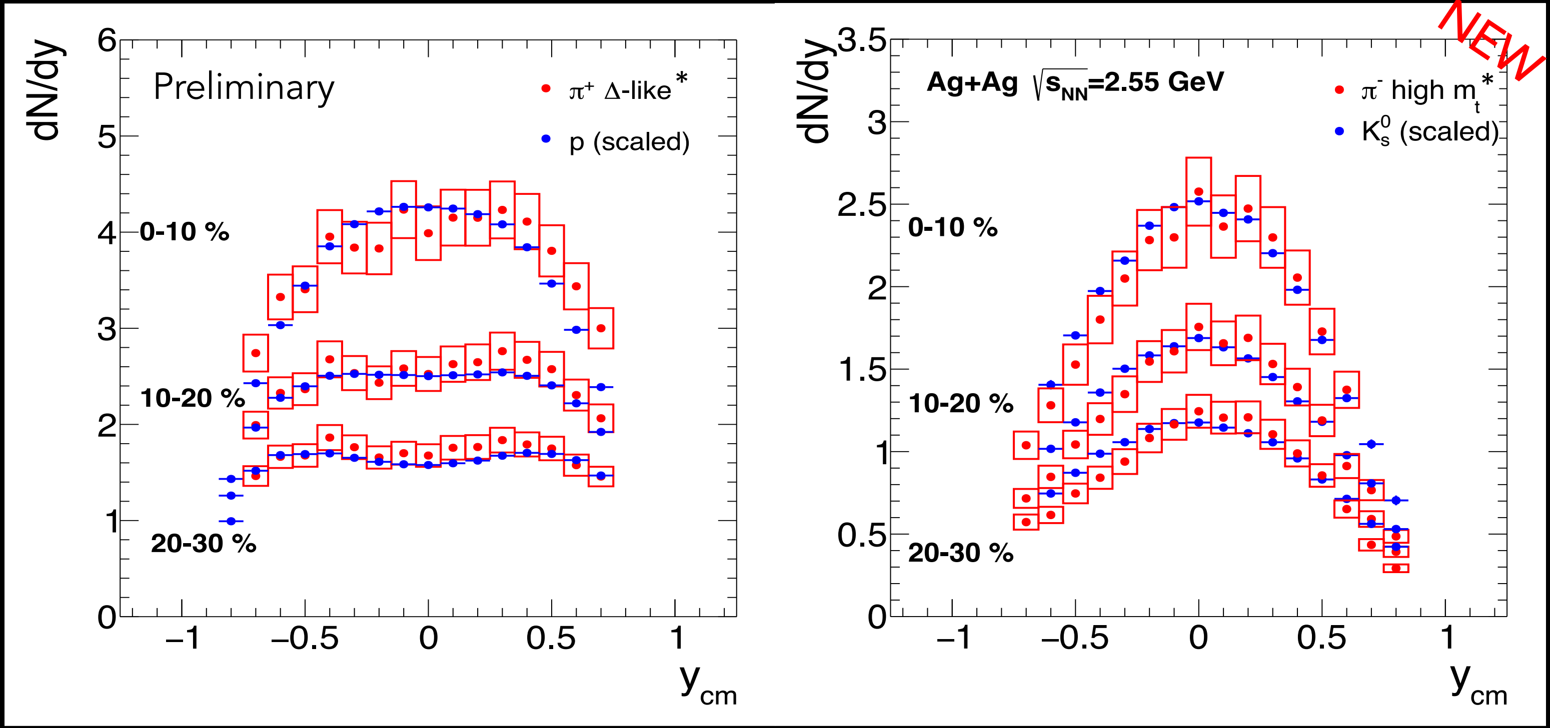


Eur.Phys.J.A 58 (2022) 9, 166

Take Coulomb interaction via potential into account.
Difference due to extrapolated in m_t: 3% for π^- and 8% for π^+ in case of HADES.

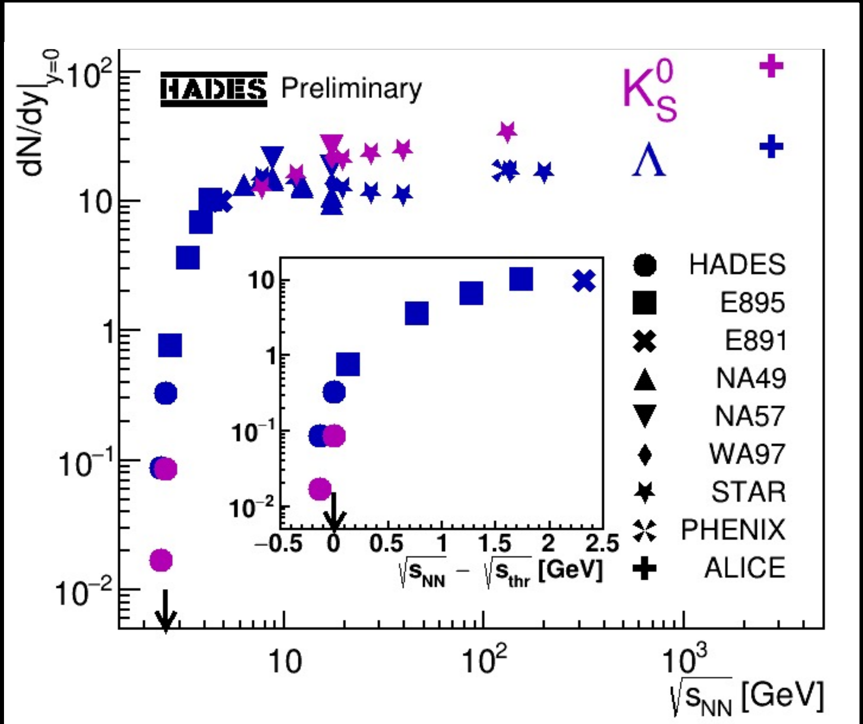
π y-distributions

* Defined by Boltzmann-slopes T_1 and T_2.



Low-p_t π show similar shape like protons, high p_t like K^0_s.

Strangeness

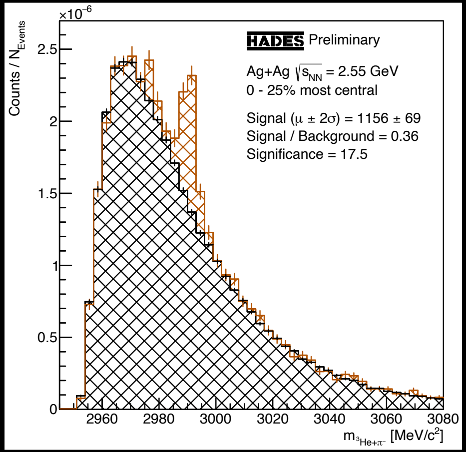


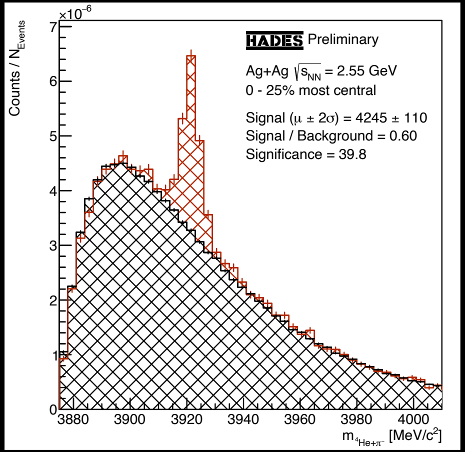
Phys.Lett.B 793 (2019) 457-463

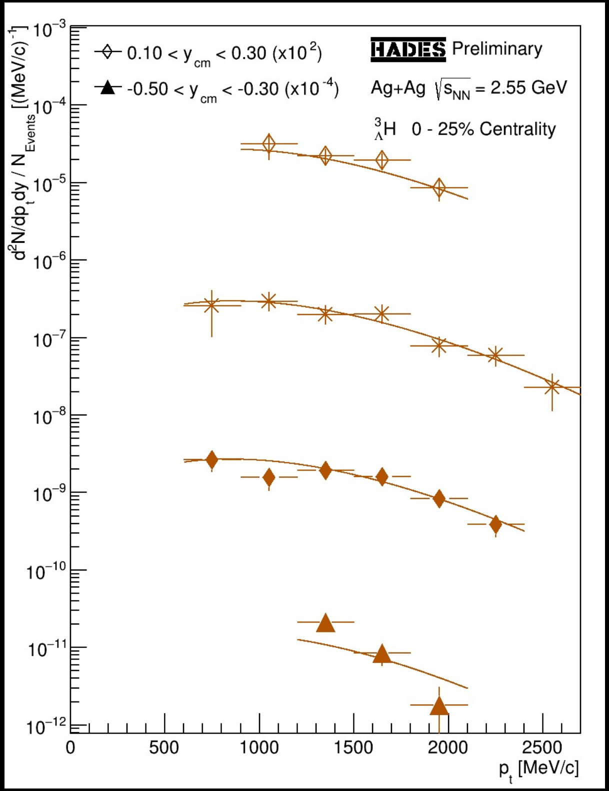
Kaon Flow: Jan Orliński, 05 Juni 2024, 10:40, Room Madrid

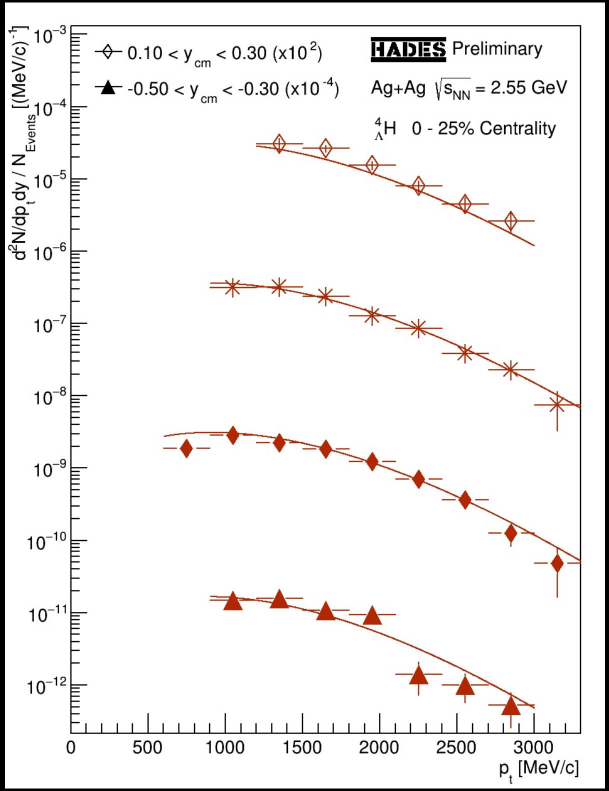
Hypernuclei Signals

Simon Spies 05 Juni 2024 11:20 Room Londres 1



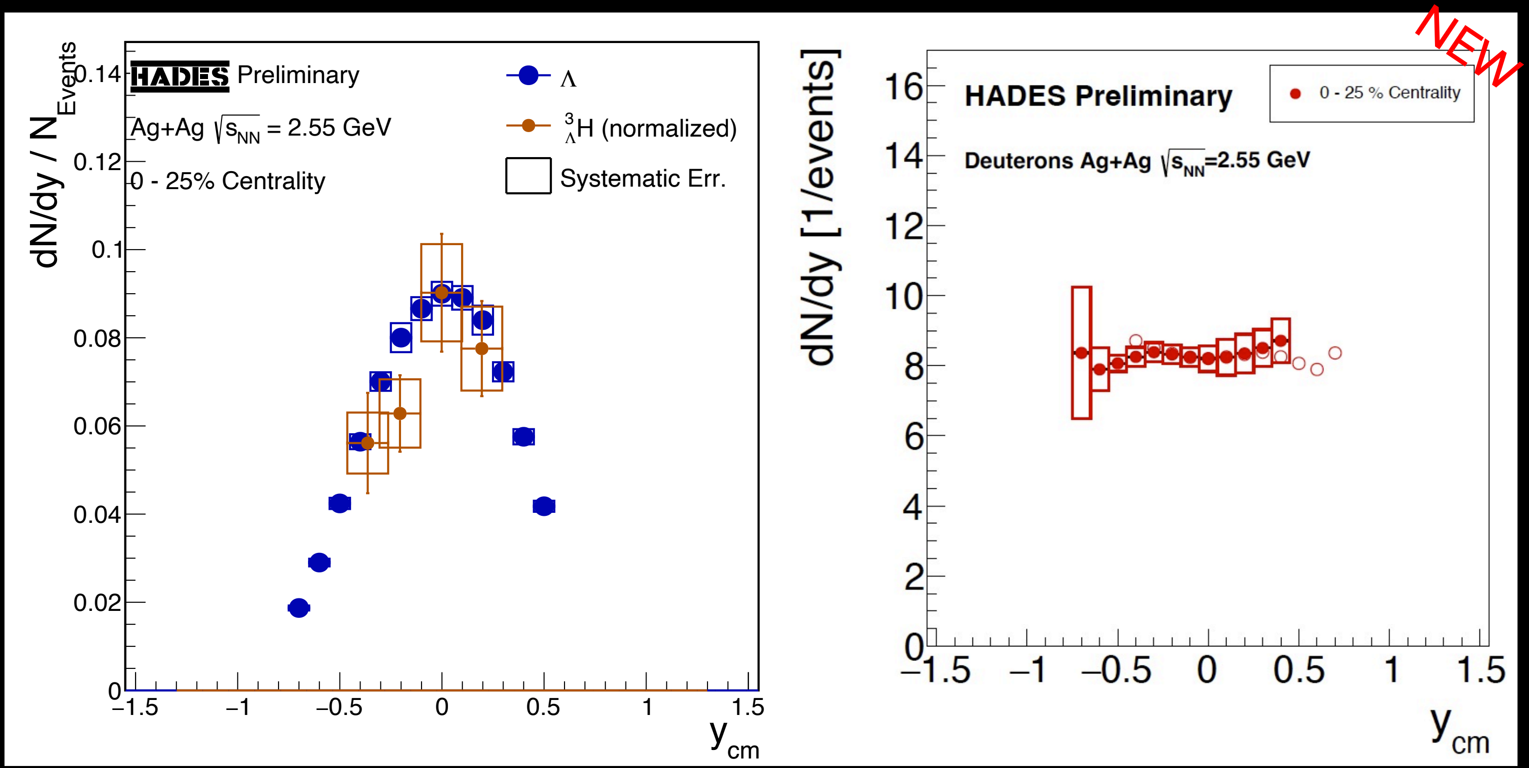






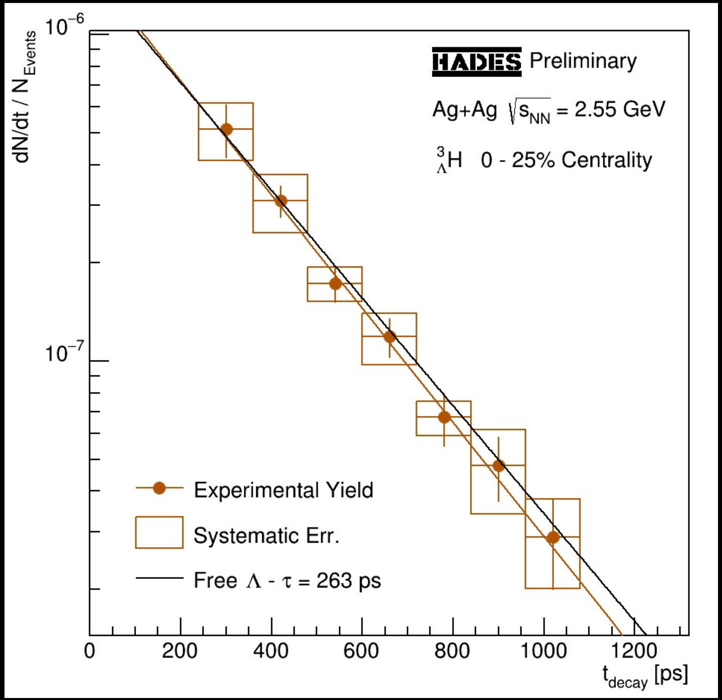
Multi-differential analysis of ${}^{3}_{\Lambda}H$ and ${}^{4}_{\Lambda}H$ production.
First measurement around mid-rapidity at SIS18 energies.

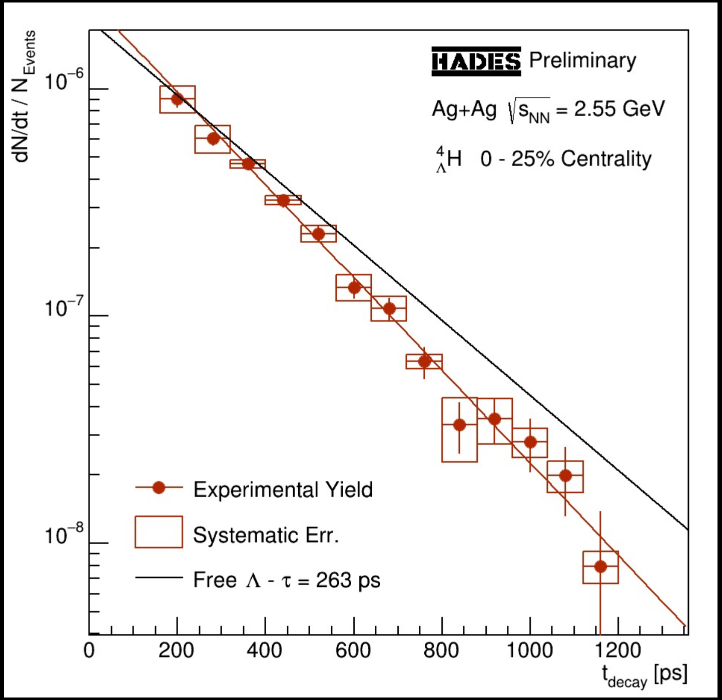
Rapidity Distributions Comparison to Λ and d



Shape of dN/dy distribution of $^{3}_{\Lambda}H$ similar to the one of the Λ, d show different shape.

Hypernuclei Decay Curves



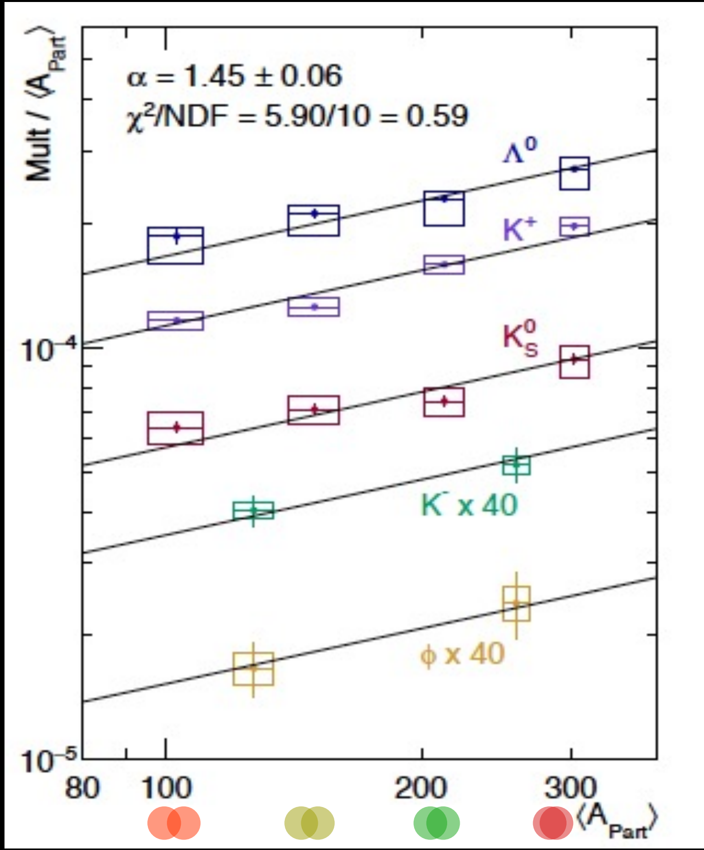


$^{3}_{\Lambda}H$ lifetime in agreement with free Λ, $^{4}_{\Lambda}H$ significantly lower.

Sub-threshold Strangeness Production in Au+Au @ $\sqrt{s_{NN}}$= 2.4 GeV

Complete set of strange hadrons produced below NN-threshold: NN→NYK+: $\sqrt{s_{NN}}$= 2.55 GeV
NN→NNK+K-: $\sqrt{s_{NN}}$= 2.86 GeV

Phys.Lett. B793 (2019) 457-463



→ unique observable:

Energy must be provided from the system.

Strange particle yields rise stronger than linear with

$<A_{part}>$ ($M \sim <A_{part}>^{\alpha}$)

Universal $<A_{part}>$ dependence of strangeness production

→ Hierarchy in production threshold not reflected.
Scaling with absolute amount of strangeness, not with individual hadron states.

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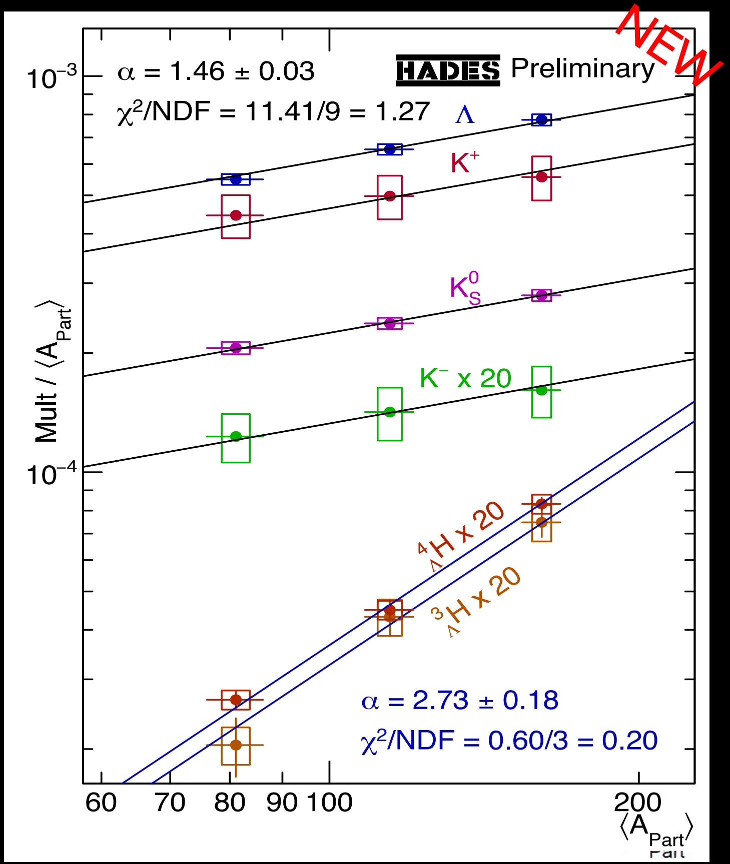

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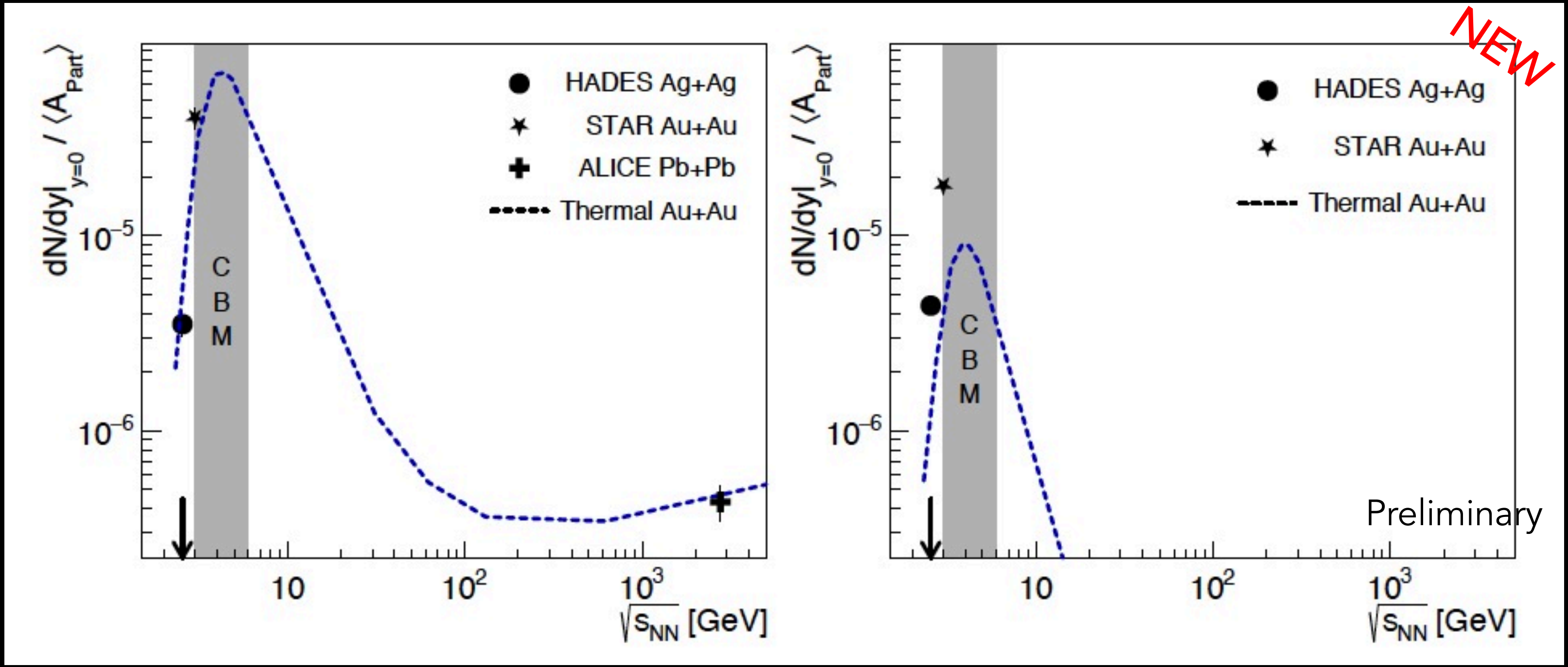
Hypernuclei yields scale stronger with centrality.

Excitation functions: Energy



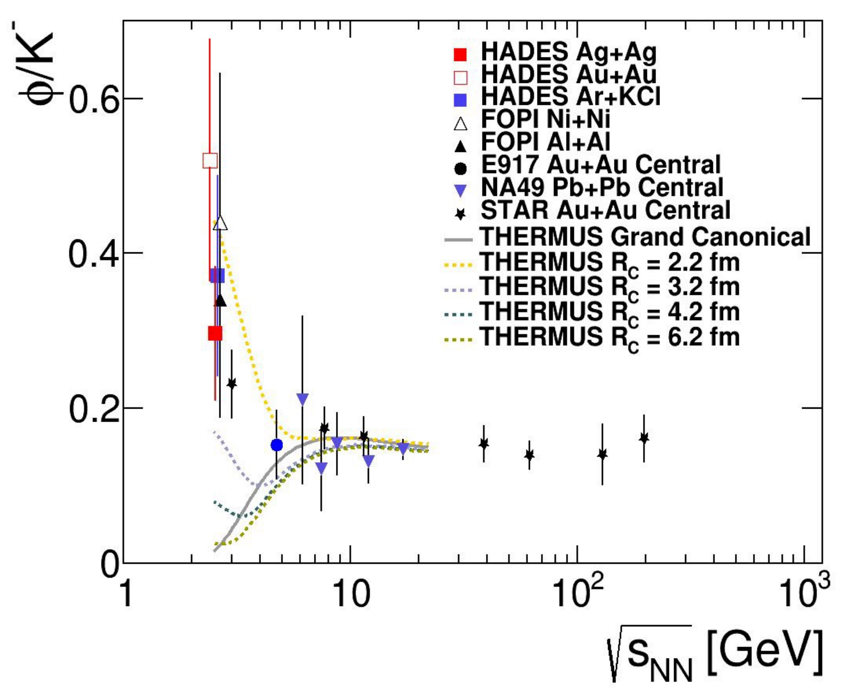
Shift of Hyperhydrogen maximum due to excited ${}^{4}_{\Lambda}H$ states, which are not yet included in the HRG.

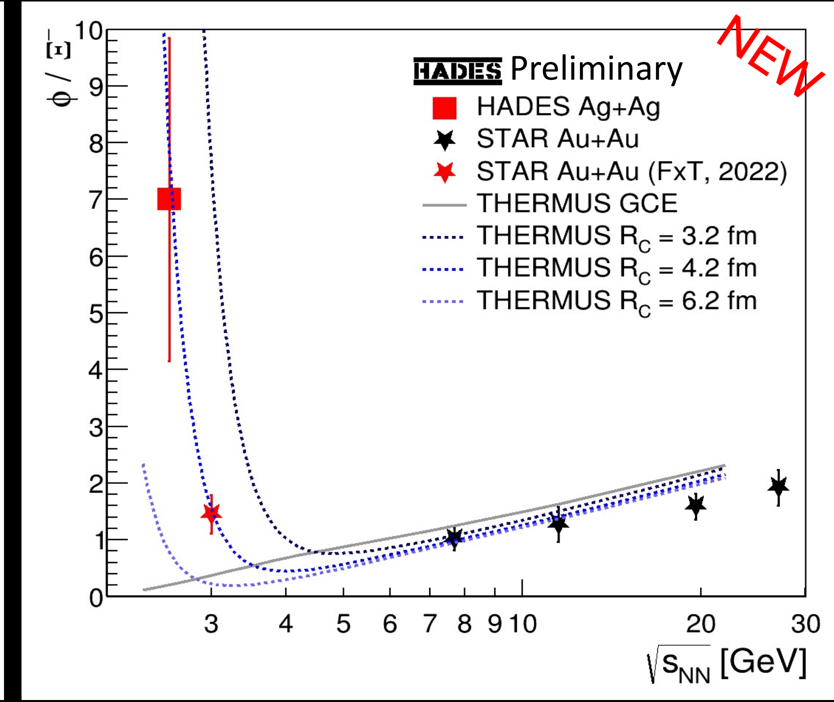
Phys. Lett. B, 754:360372, (2016)., Phys. Rev. Lett.,128(20):202301, (2022)., Phys. Lett. B, 697:203207, (2011).

Multistrangeness and the canonical HRG model

Poster by Marvin Kohls
Simon Spies 05 Juni 2024
11:20 Room Londres 1

Phys.Lett. B778 (2018) 403-407

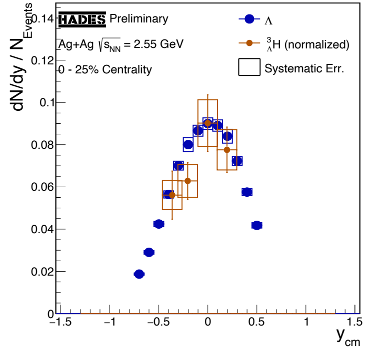


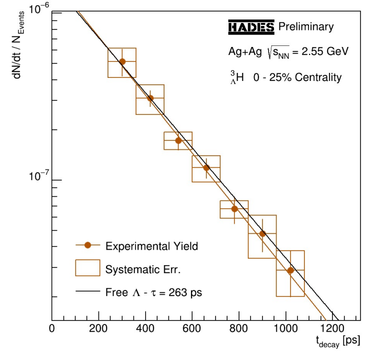


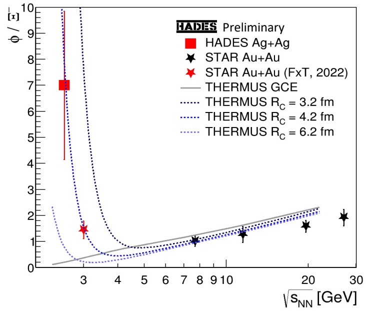
The ratios can not be described simultaneously with same value for R_c for the given T-μ_B parameterization.
Similar observation as STAR in *Phys.Lett.B* 831 (2022) 137152.

Summary

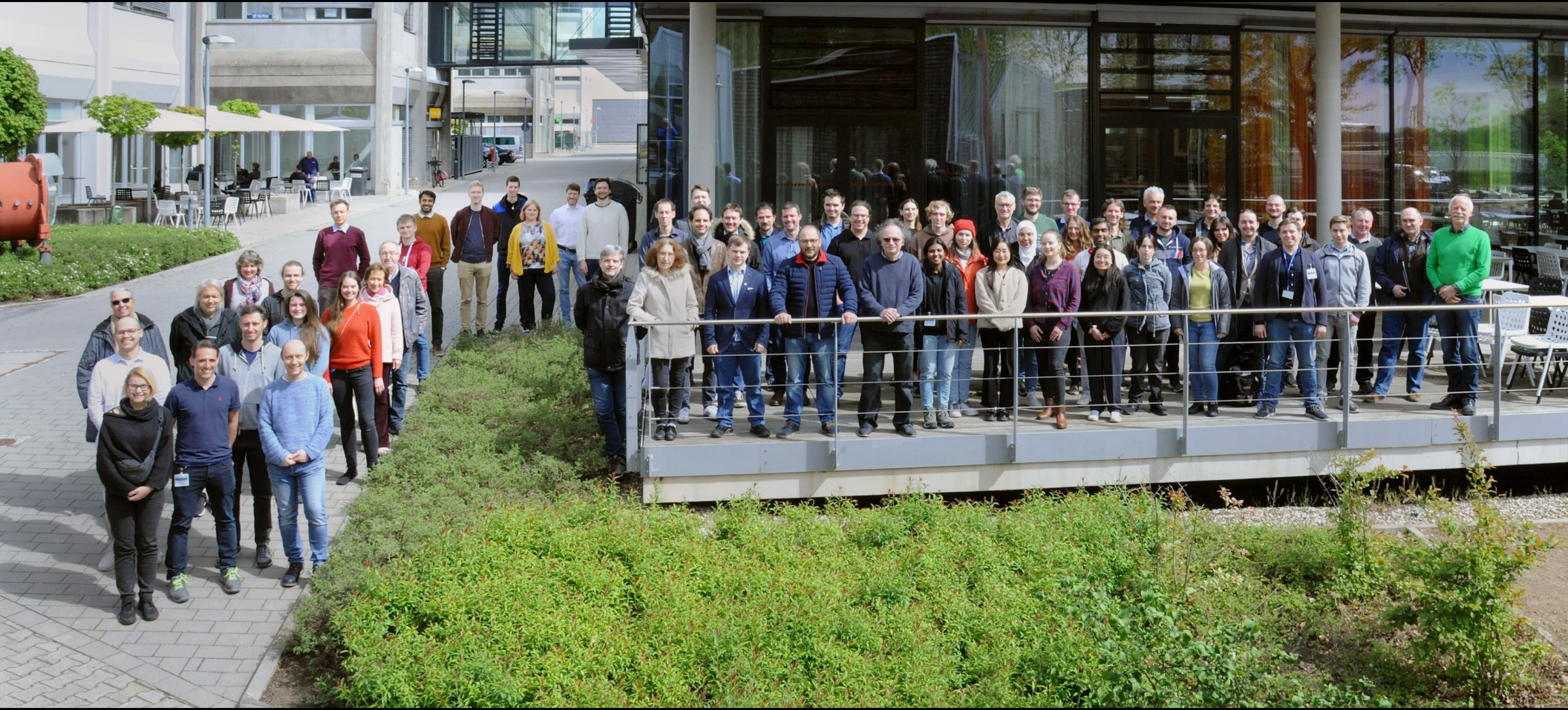
- Smooth trend suggest by HBT measurement supported by extracted B_A parameter
- Investigations on higher order eff. corrections and Coulomb potential on π yield
- Bell-like dN/dy distribution of Hypernuclei.
- ${}^{3}_{\Lambda}H$ lifetime in agreement with free Λ, ${}^{4}_{\Lambda}H$ significantly lower.
- Hints for importance of decays from short lived- ${}^{4}_{\Lambda}H$ states.
- Stronger A_{part} scaling compared to other strange hadrons.
- The $\boldsymbol{\phi}/K^-$ and $\boldsymbol{\phi}/\Xi^-$ ratios can not be described simultaneously with R_c value





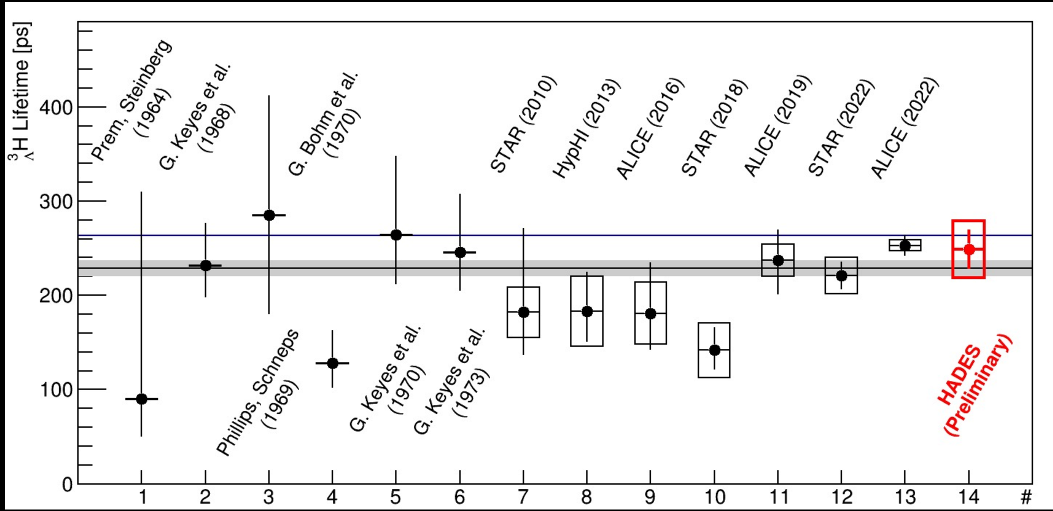


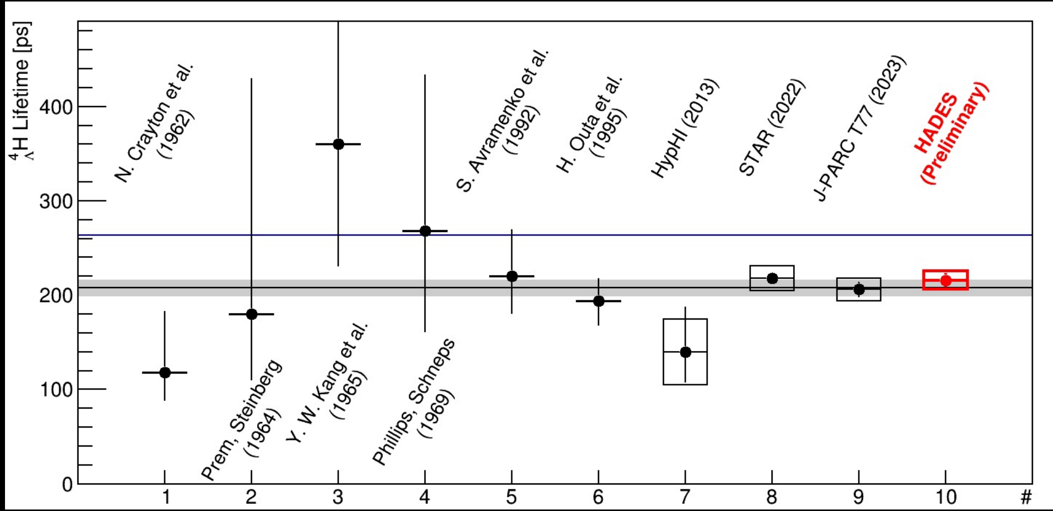
The Team



Back Up

World Data: Lifetimes





Sub-threshold Strangeness Production in Ag+Ag @ $\sqrt{s_{NN}}$= 2.55 GeV

Complete set of strange hadrons produced below (at) NN-threshold

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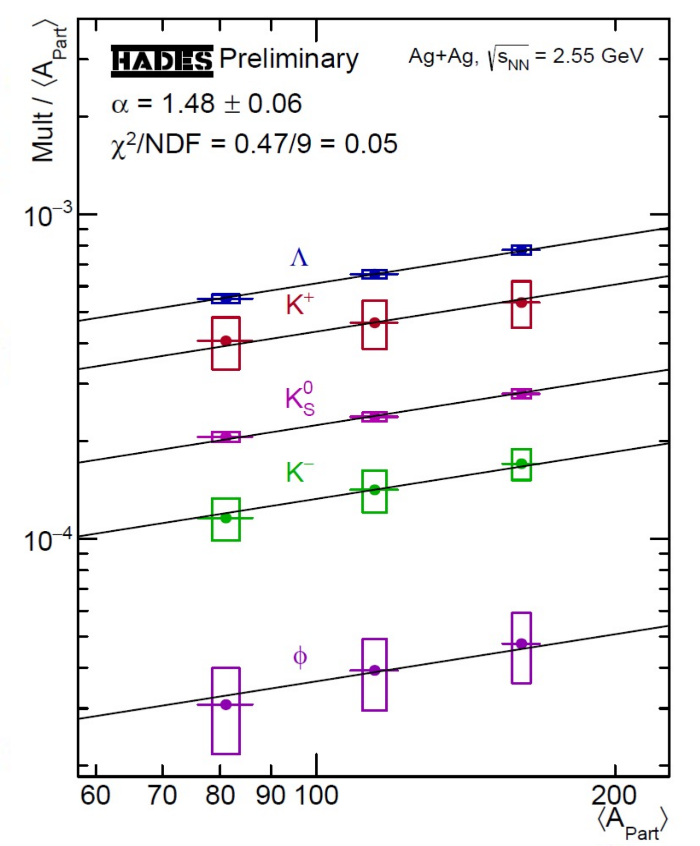
Phys.Lett. B793 (2019) 457-463



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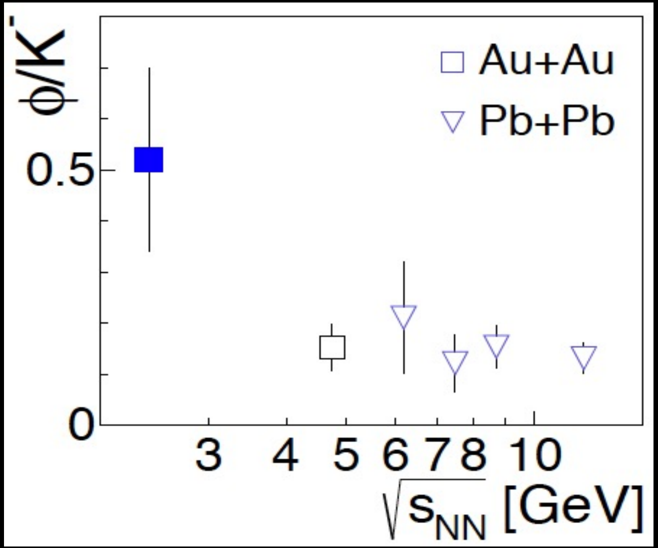
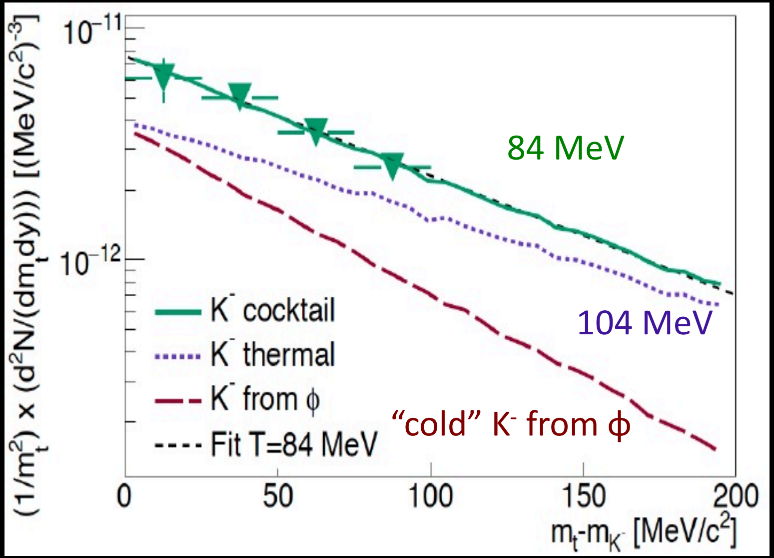
ϕ-AntiKaon Interplay in HIC

Reminder

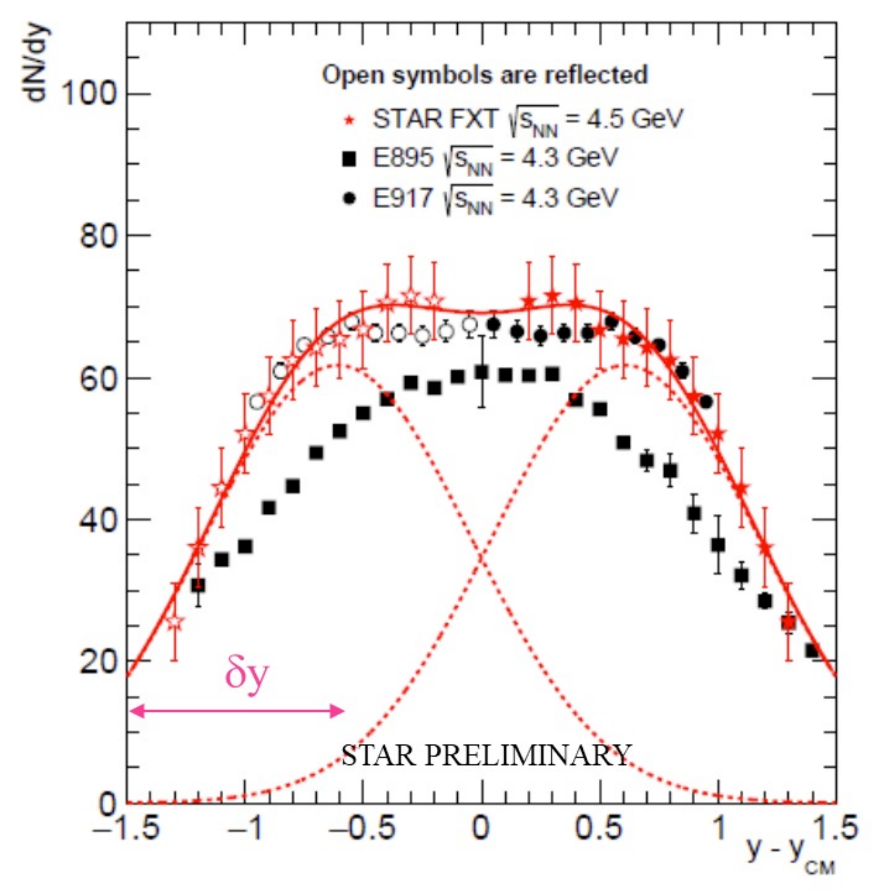




Increased in HIC at low $\sqrt{s_{NN}}$:
→ 25% of K^- result from Φ decays!

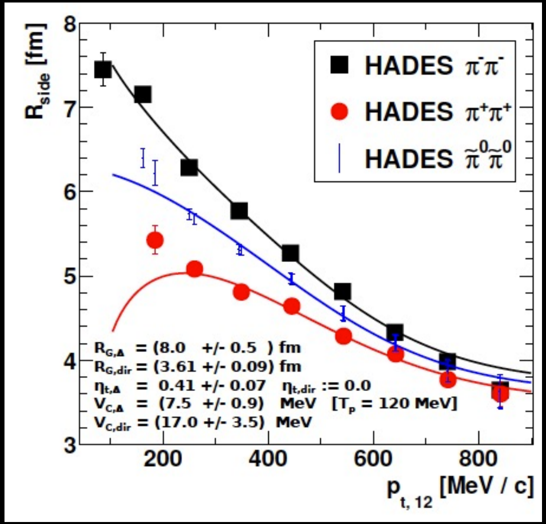
→ No indication from K^- spectrum for sequential K^+K^- freeze-out if corrected for feed-down.

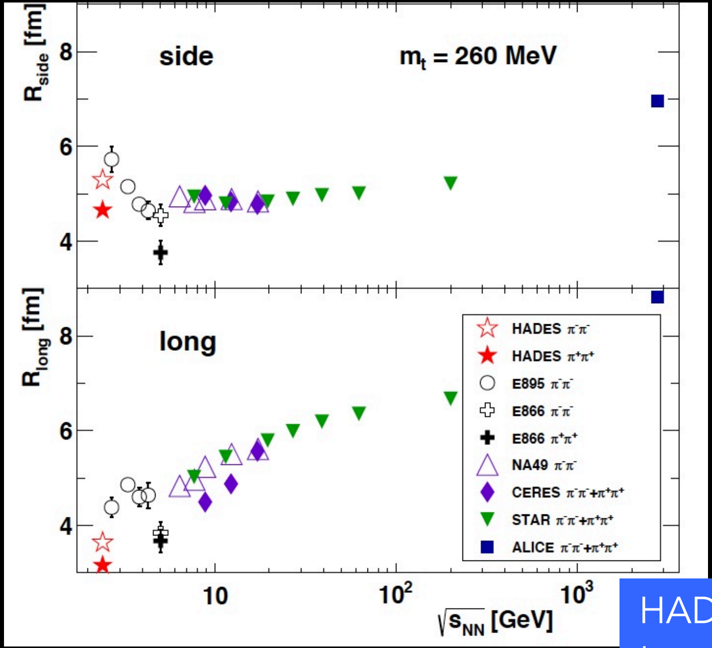
Phys.Lett. B778 (2018) 403-407

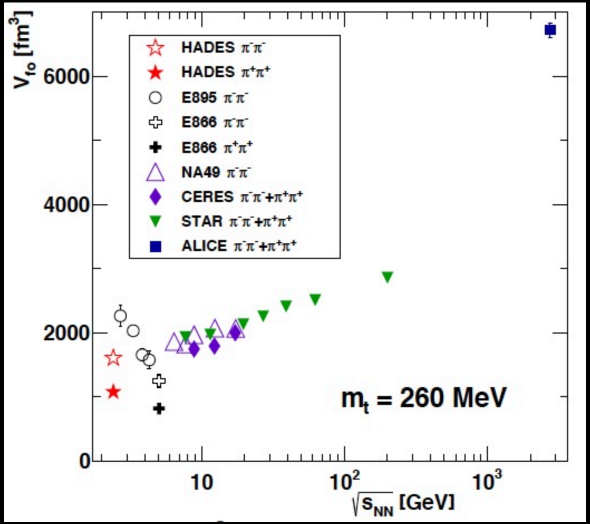


D. Cebra, INT Workshop 22-84W: Dense Nuclear Matter Equation of State 2022

Identical π Intensity Interferometry







Indications for charge-sign differences reported previously:

E866 R. A. Soltz, M. Baker, J. H. Lee, Nucl. Phys. A 661, 439c (1999)
E877 D. Miskowiec et al., Nucl. Phys. A590, 473c (1995)
NA44 I.G. Bearden et al., Nucl. Phys. A638, 103c (1998)

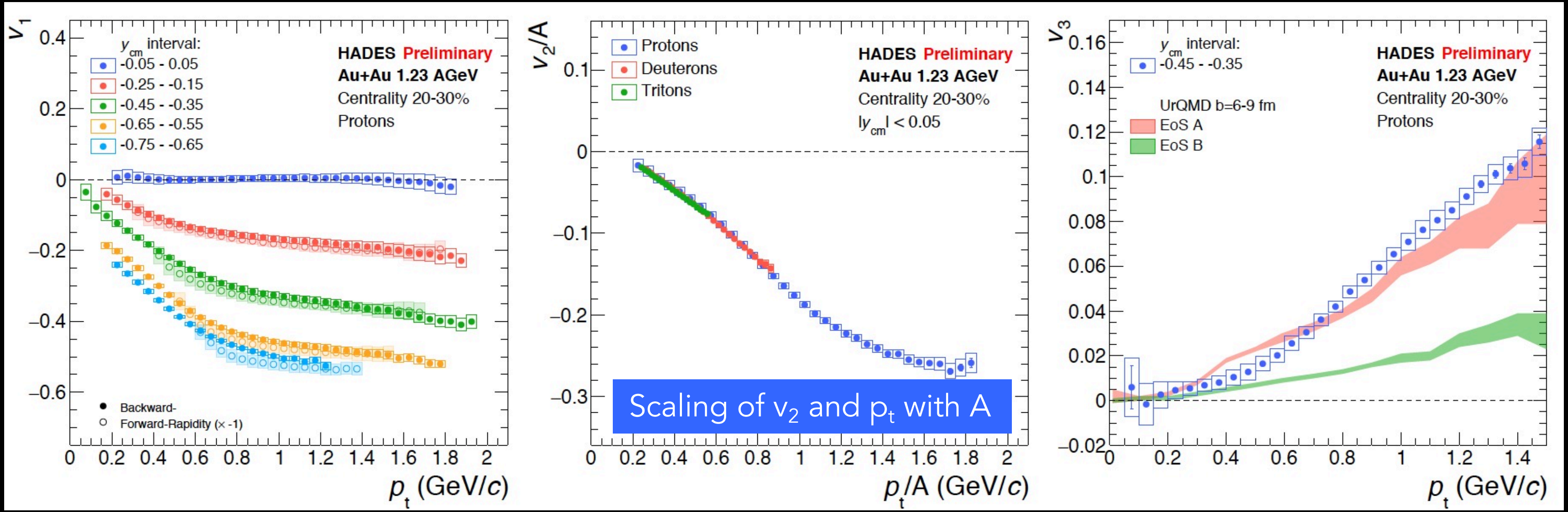
HADES data suggest rather smooth trend from high energies→ room for structures?

First time observation of substantial differences!

How does the trend continue at lower energy?

Phys.Lett.B 795 (2019) 446-451

p, d, t v_1, v_2, v_3, v_4



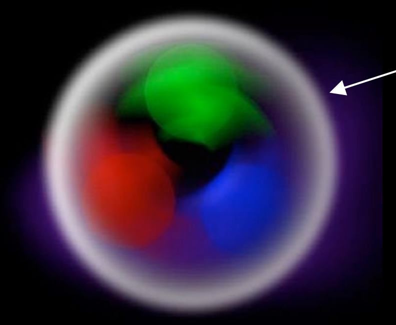
High statistic multi-differential data

Comparison p,d,t at mid-rapidity

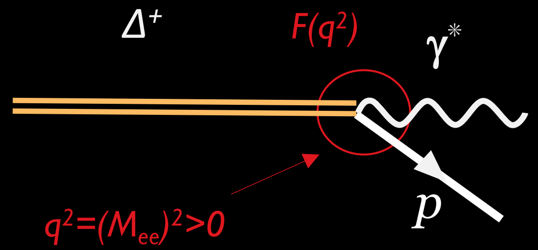
Sensitivity to EOS

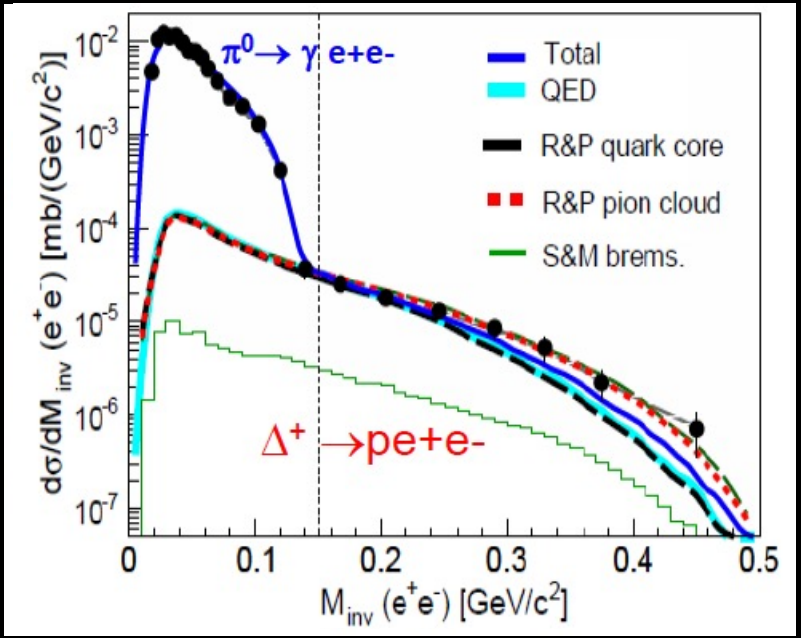
UrQMD prediction: P. Hillmann et al. J.Phys. G45 (2018) no.8, 085101

EM Formfactors of Baryonic Resonances



p+p(1.25 GeV) → p+p+e⁻+e⁺

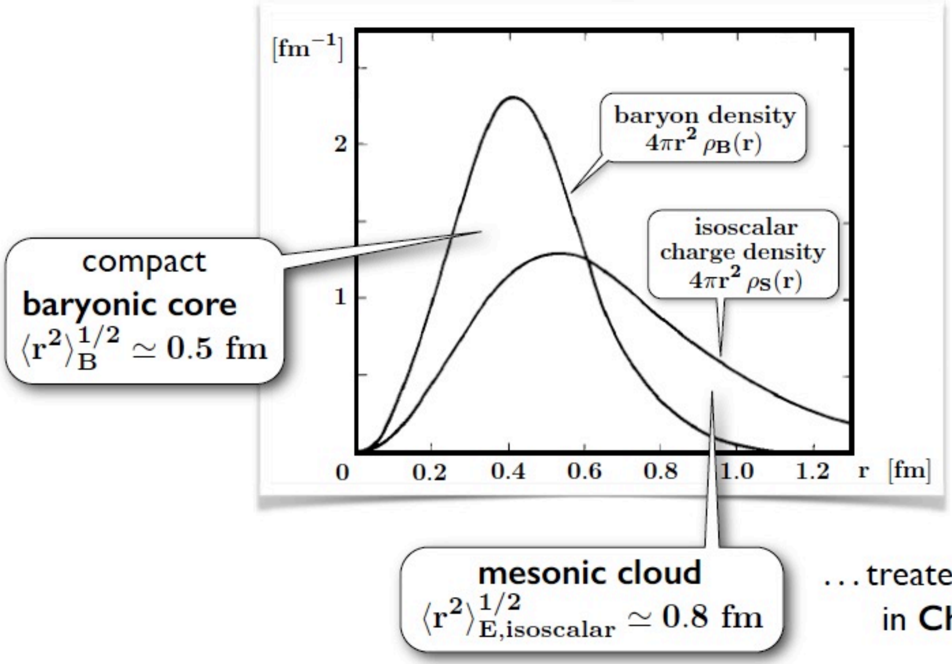




Phys. Rev. C95 (2017) no.6 065205

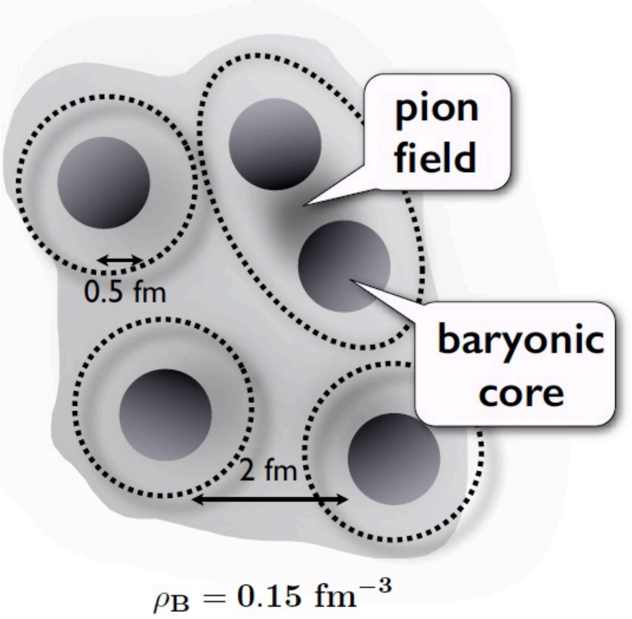
Good agreement with model of Ramahlo & Pena if pion cloud is taken into account

Consequences for the created system?



N. Kaiser,
U.-G. Meißner,
W.W.
Nucl. Phys.
A466 (1987) 685

. . . treated properly
in **Chiral EFT**



Can we connect this to an observable?

Figures from W. Weise