Reviewing hadron production in the SIS energy regime using new HADES Au+Au data

Manuel Lorenz
for the HADES collaboration

QM, Darmstadt 2014

0. strangeness production at sis 18 energies
1. hades and au+au data taking
2. preliminaries
3. hadron ratios vs. statistical model fit

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

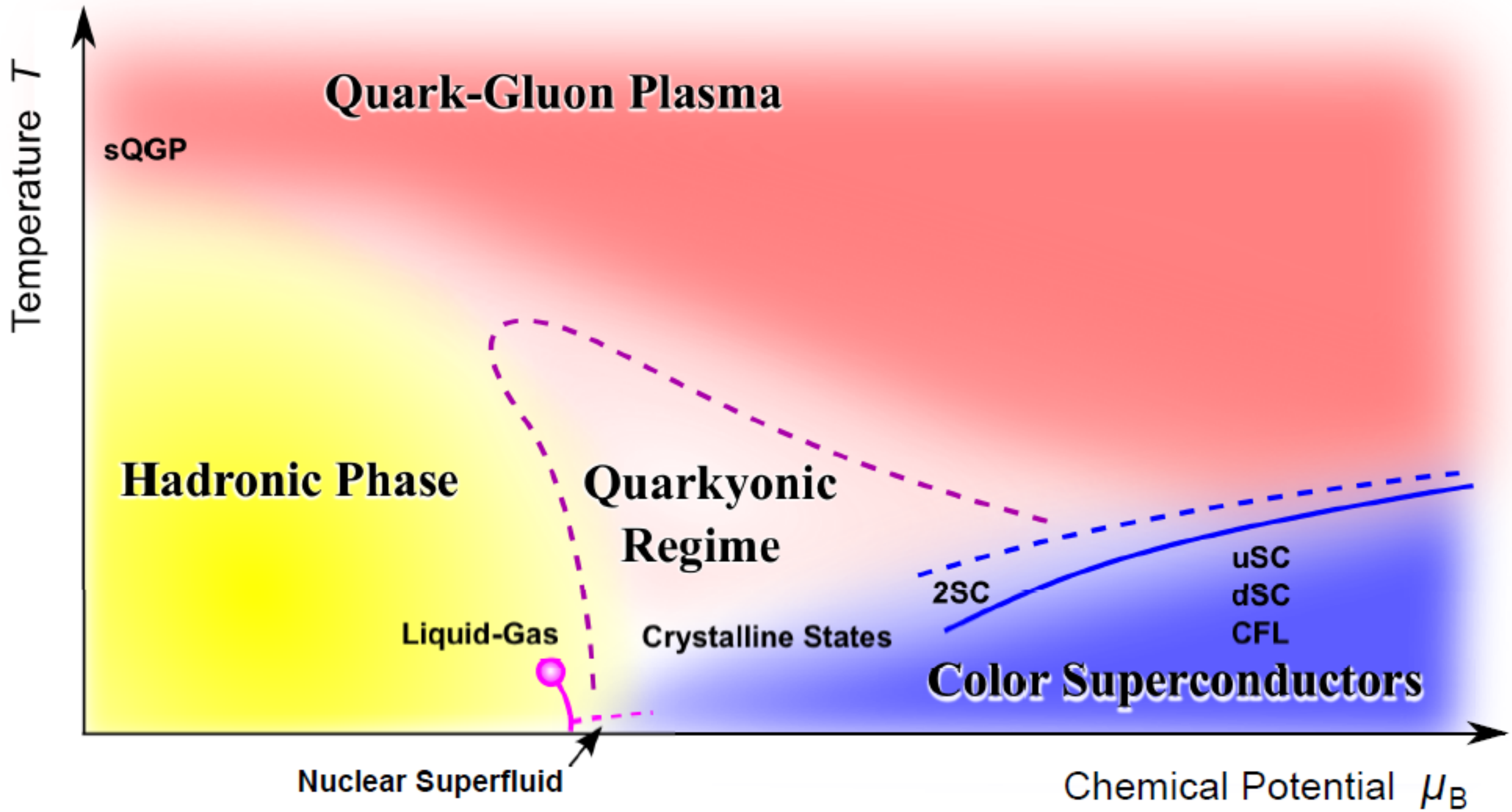
EMMI

HIC for FAIR Helmholtz International Center

GSI

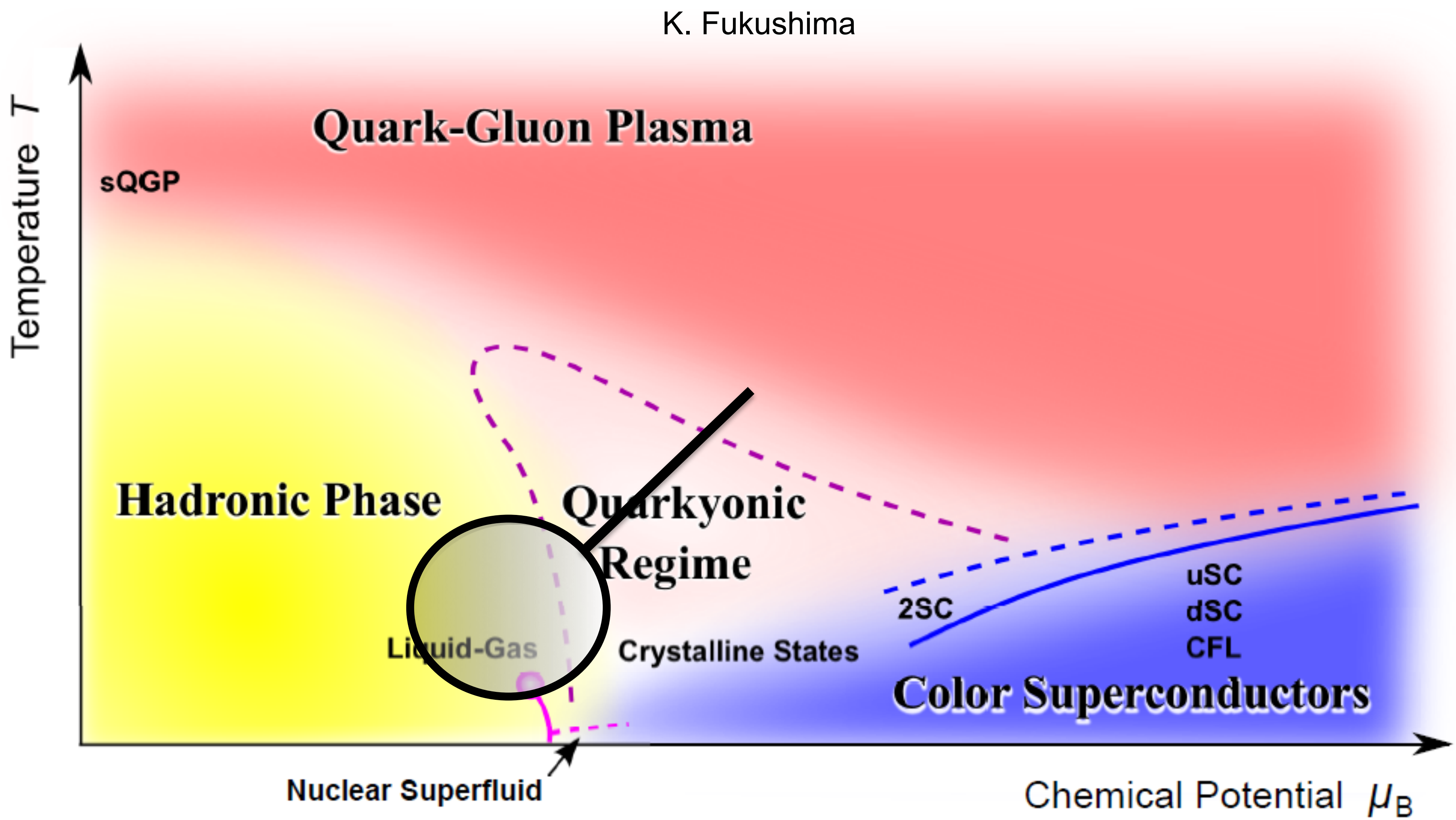
Heavy-ion collisions and QCD phase diagram

K. Fukushima



SIS 18 energy regime:
beam energies of 1-2 AGeV for ions, baryon dominated rather long living system

Heavy-ion collisions and QCD phase diagram



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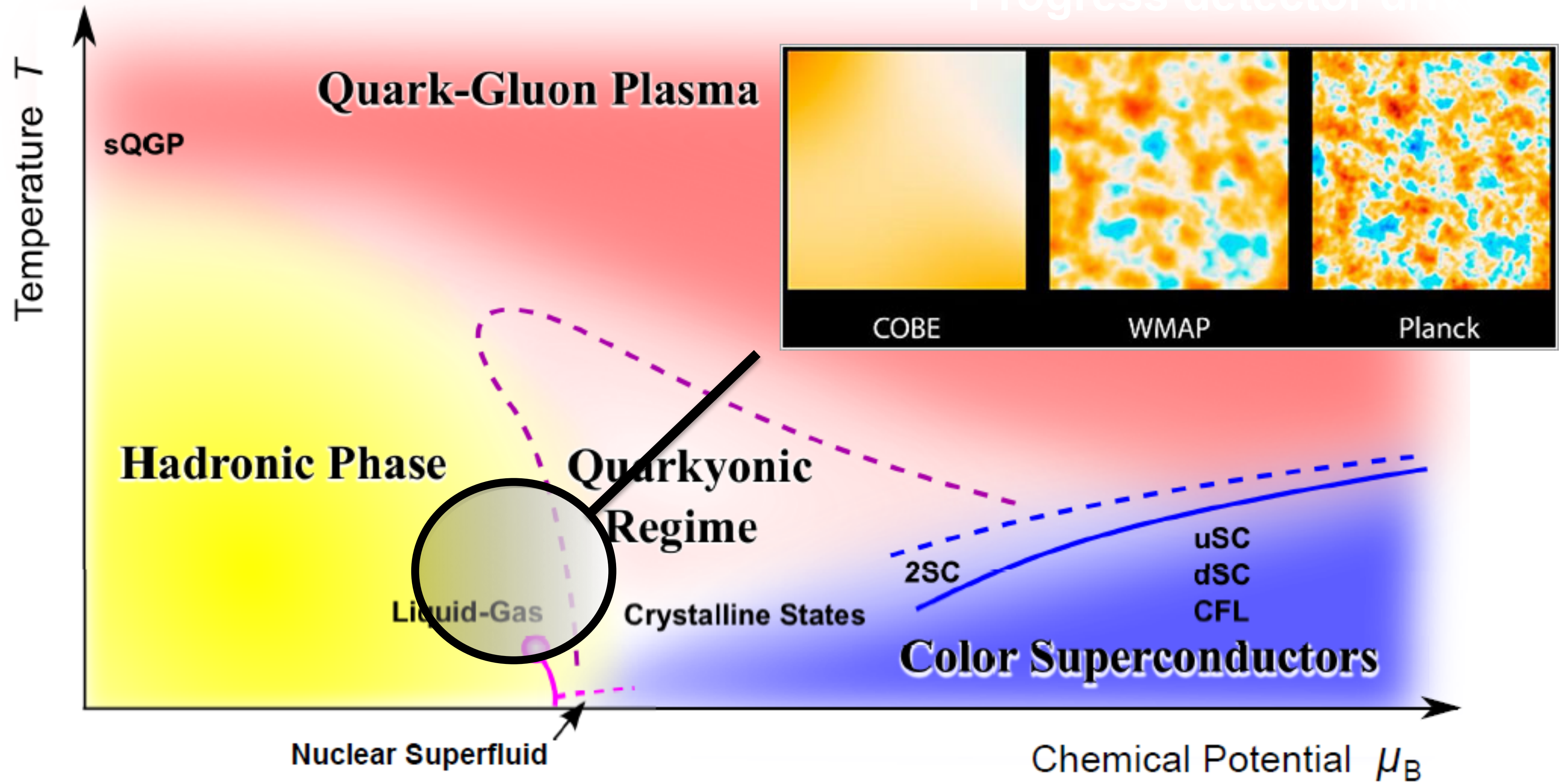


SIS 18 energy regime:
beam energies of 1-2 AGeV for ions, baryon dominated rather long living system

Strangeness production

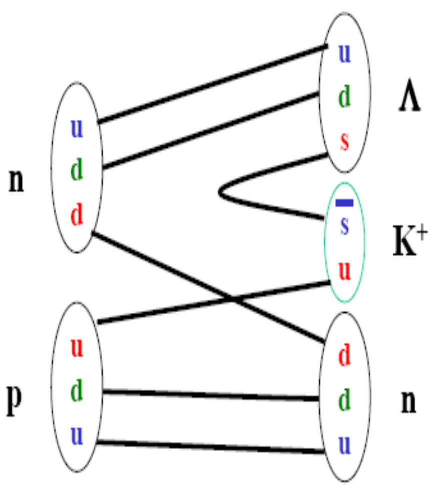
Elementary collisions

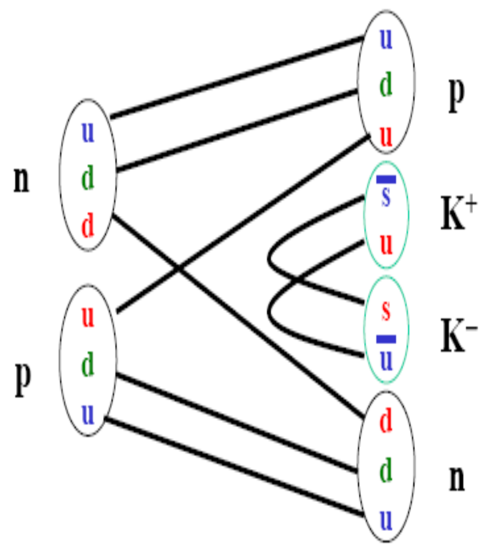
$$NN \rightarrow NK^{+}\Lambda \qquad (E_{thr} = 1.58\,GeV)$$

$$NN \rightarrow NNK^{+}K^{-} \qquad (E_{thr} = 2.49\,GeV)$$

$$NN \rightarrow NN\varphi \qquad (E_{thr} = 2.59\,GeV)$$

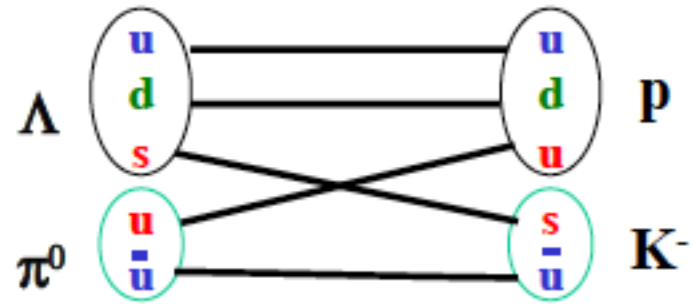
Meson and baryon production but quantum number conserved on the quark level!



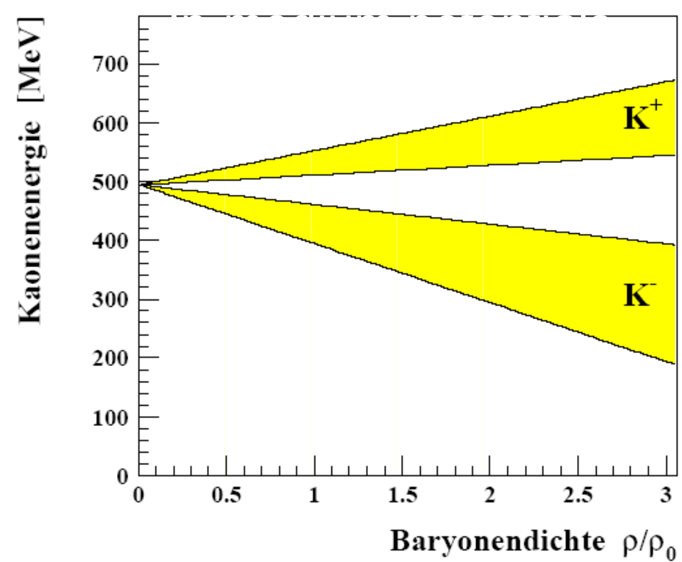


Heavy-ion collisions

- Accumulation of energy in multi–step processes
- Strangeness exchange reactions + potentials



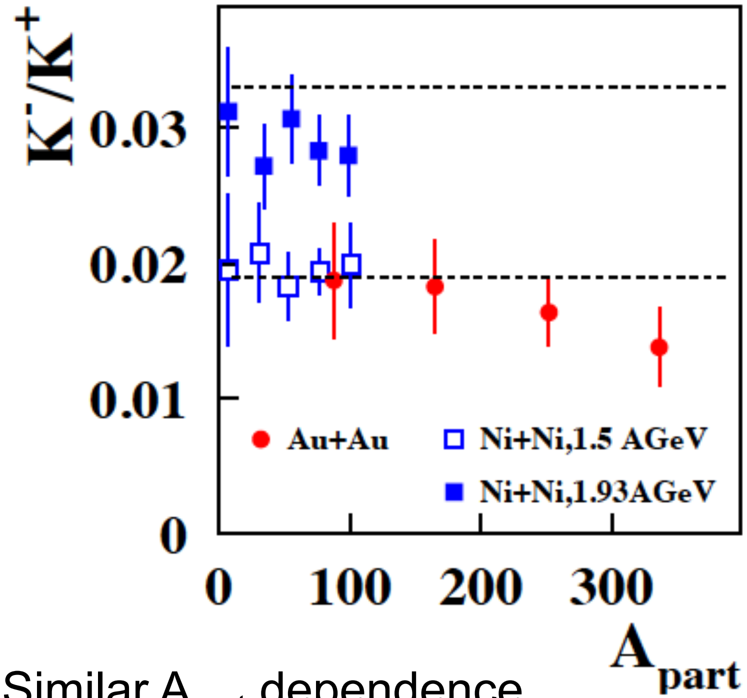
endothermal in vacuum!



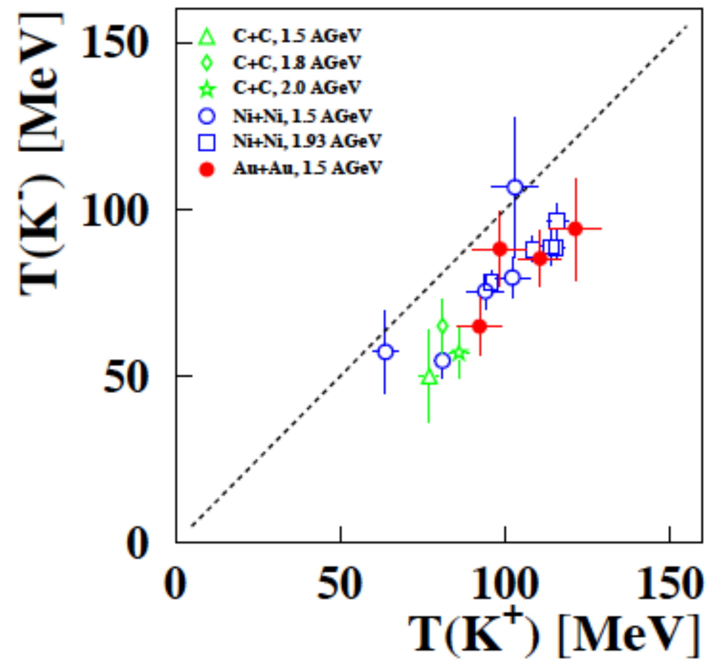
Schaffner-Bielich

Strangeness production

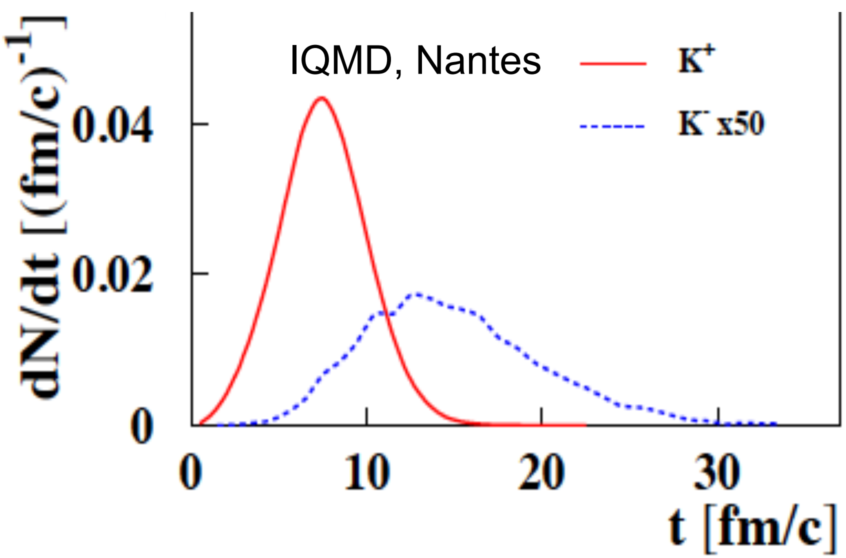
Förster et. al (KaoS)



Similar A_{part} dependence



Different inverse slope parameters

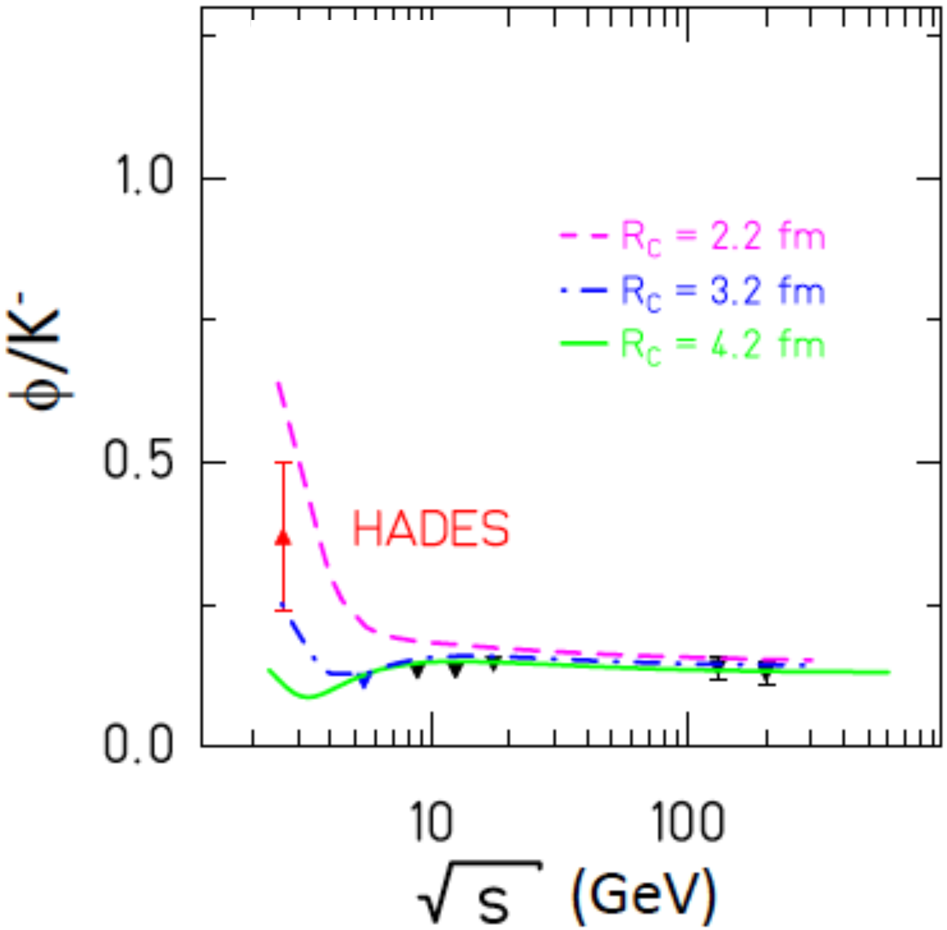


Transport:

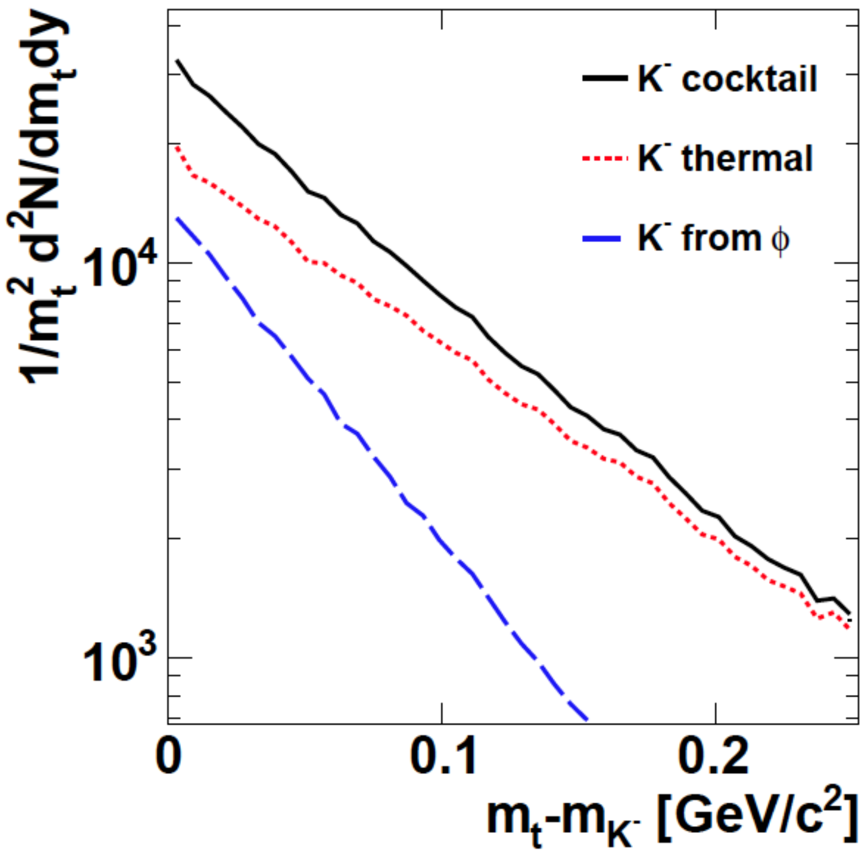
- Production of K^+/K^- coupled
- Strangeness exchange dominant for K^-
- Later freeze-out of K^- compared to K^+, due to coupling to baryons

Strangeness production

Enhanced Φ production at low beam energy



Feed-down of Φ can explain different slope parameters of K^+ and K^-



Not taken into account so far.
Can we understand the yields, with fewer assumptions? (Ockham's razor)

Hadrons in Ar+KCl@1.76A GeV

Particle production from a homogeneous source:

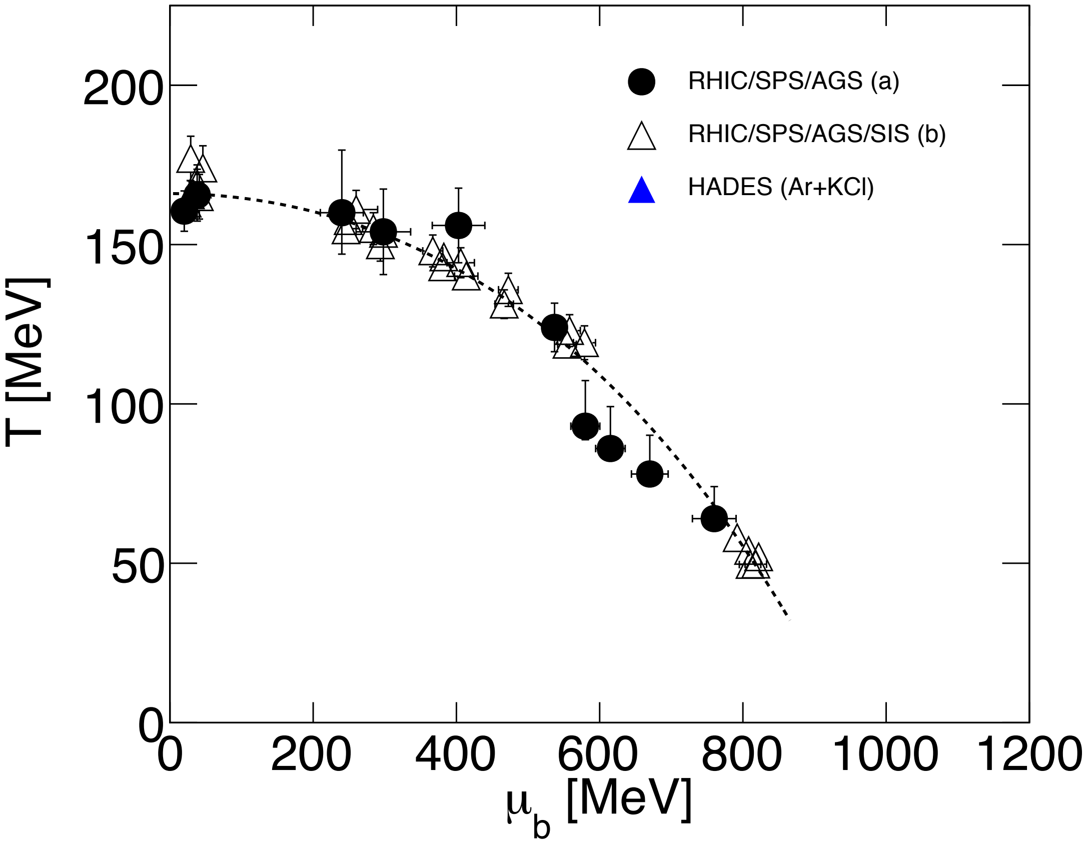
$$\rho_{i,q} \propto \int_0^\infty p^2 dp \; exp\left(\frac{-E_i + \vec{\mu}\vec{q_i}}{kT}\right)$$

- Grand canonical ensemble (T, μ= μ_B μ_s μ_Q, V and sometimes γ_s, usually μ_s and μ_Q are constrained)

- Strangeness canonical ensemble (T, μ= μ_B μ_Q, V_c, V) (Strangeness canonically suppressed at low temperatures)

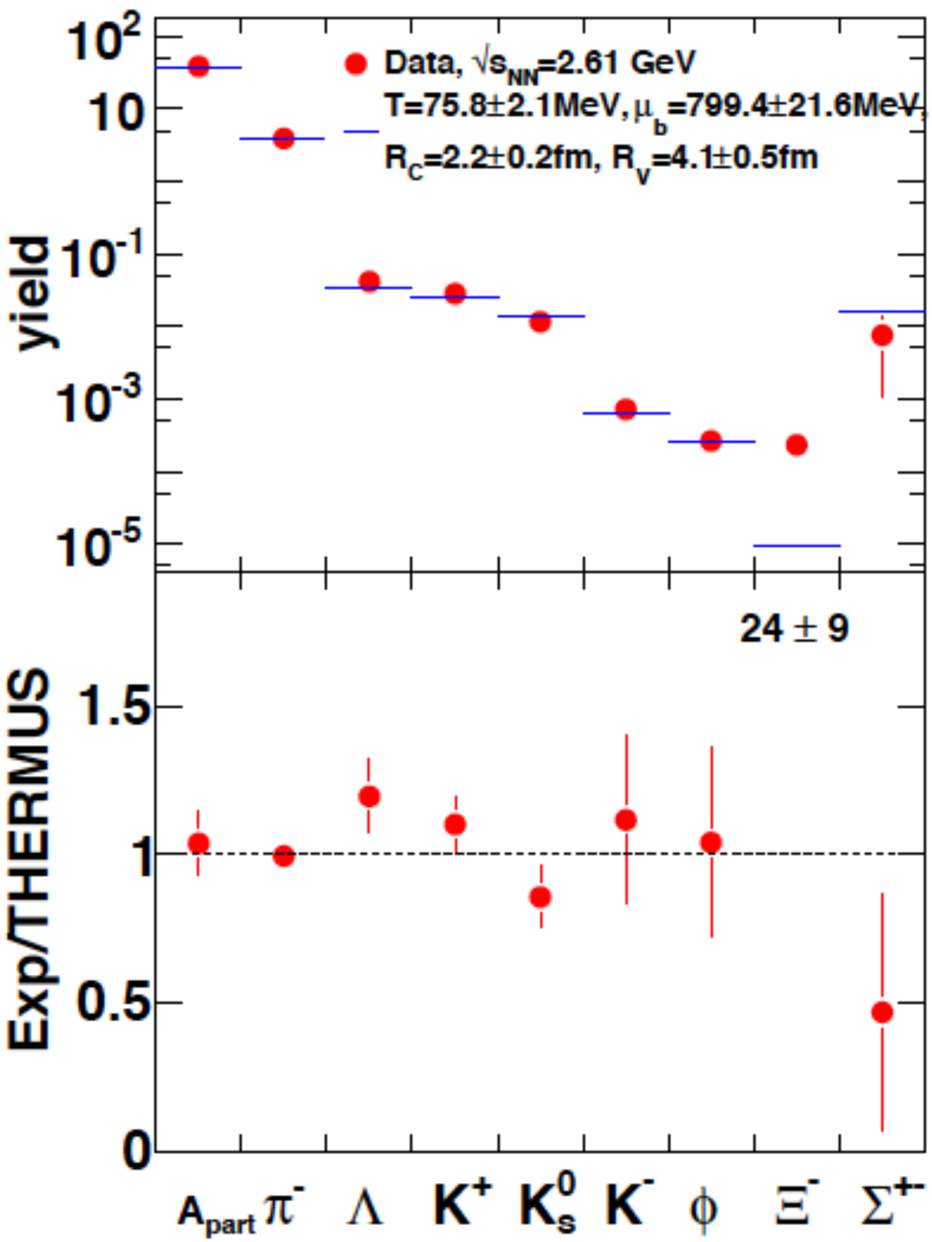
- Fits at low beam energies based on limited number of particle species

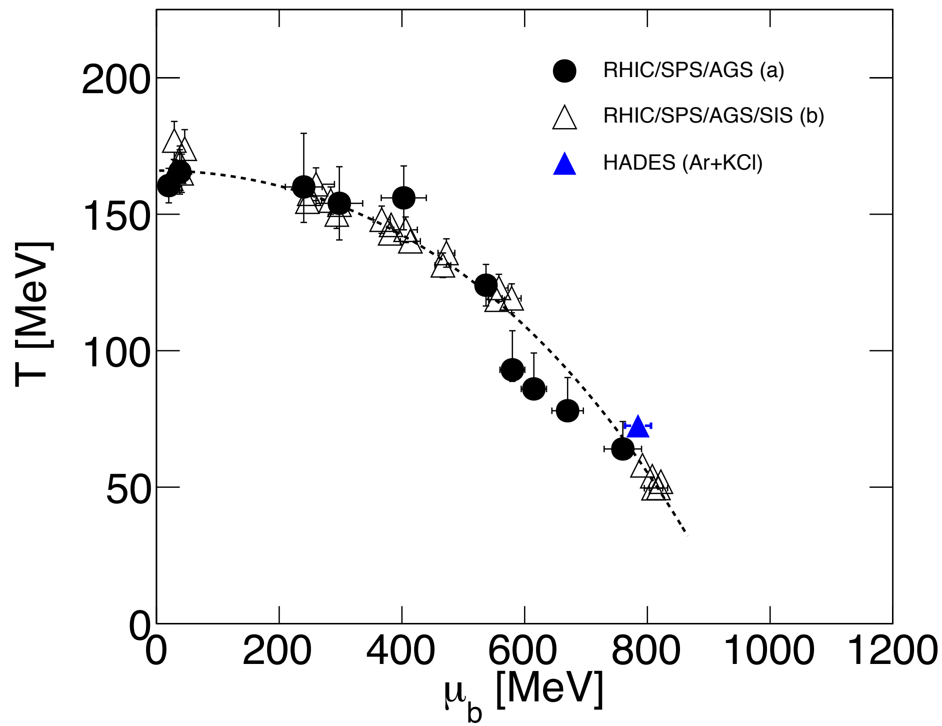
Eur. Phys. J., A 47(21)



How will it work for more particle species in Ar+KCl?

Hadrons in Ar+KCl@1.76A GeV





Statistical model works reasonably well at low energies for medium-sized system

THERMUS: S. Wheaton, J.Cleymans: Comput.Phys.Commun.180:84-106,2009

Au+Au @ 1.23 A GeV:
Lower energy and heavier system

Complete strangeness production below NN-threshold
(production and propagation)

$$NN \rightarrow NK^{+}\Lambda \qquad (E_{thr} = 1.58\,GeV)$$
$$NN \rightarrow NNK^{+}K^{-} \qquad (E_{thr} = 2.49\,GeV)$$
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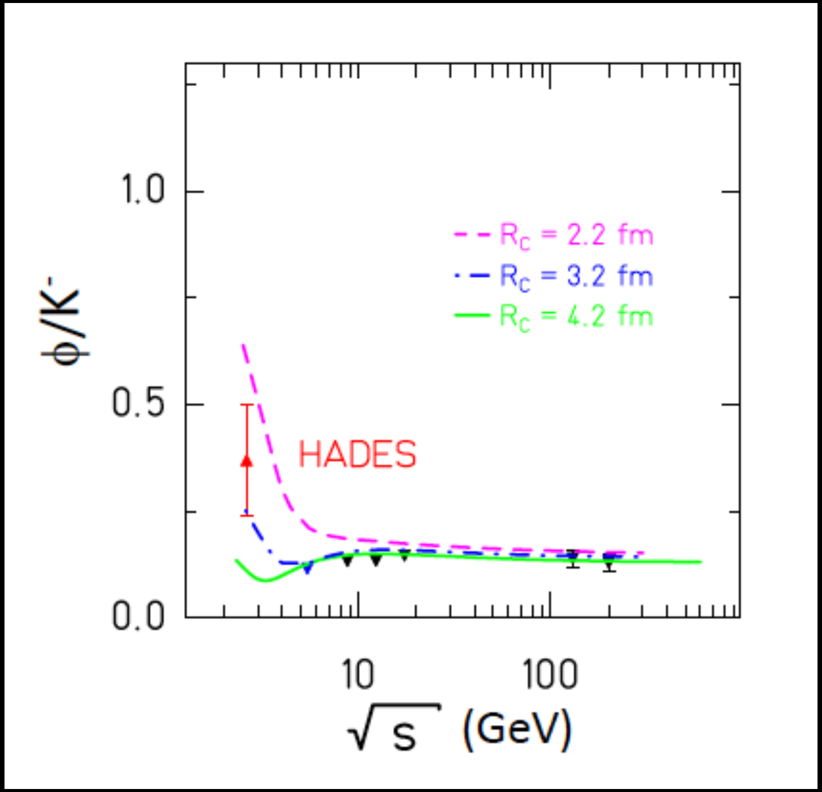


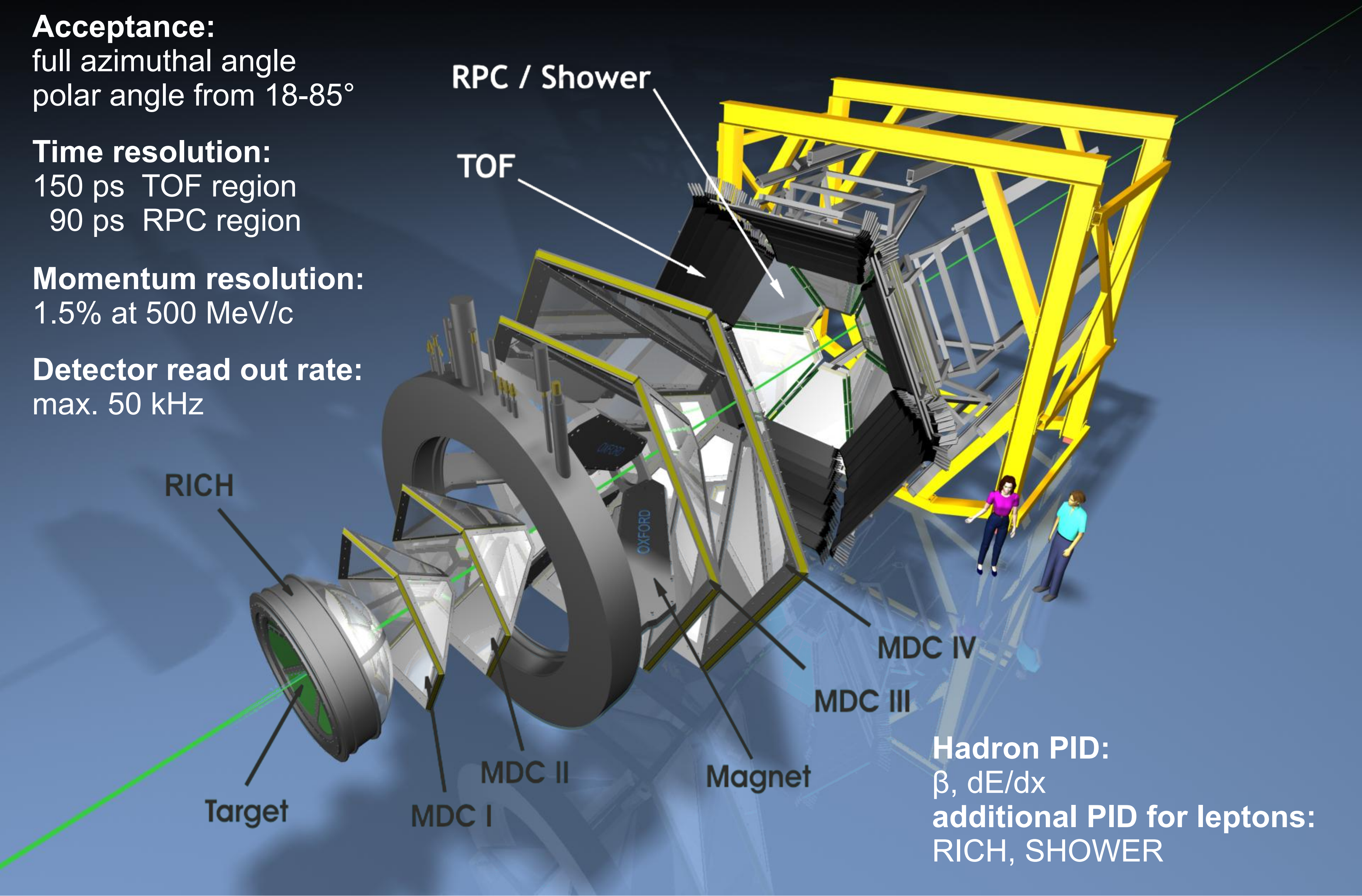
HADES

Acceptance:
full azimuthal angle
polar angle from 18-85°

Time resolution:
150 ps TOF region
  90 ps RPC region

Momentum resolution:
1.5% at 500 MeV/c

Detector read out rate:
max. 50 kHz

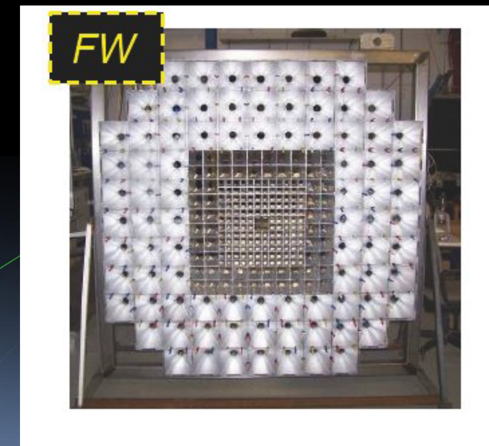


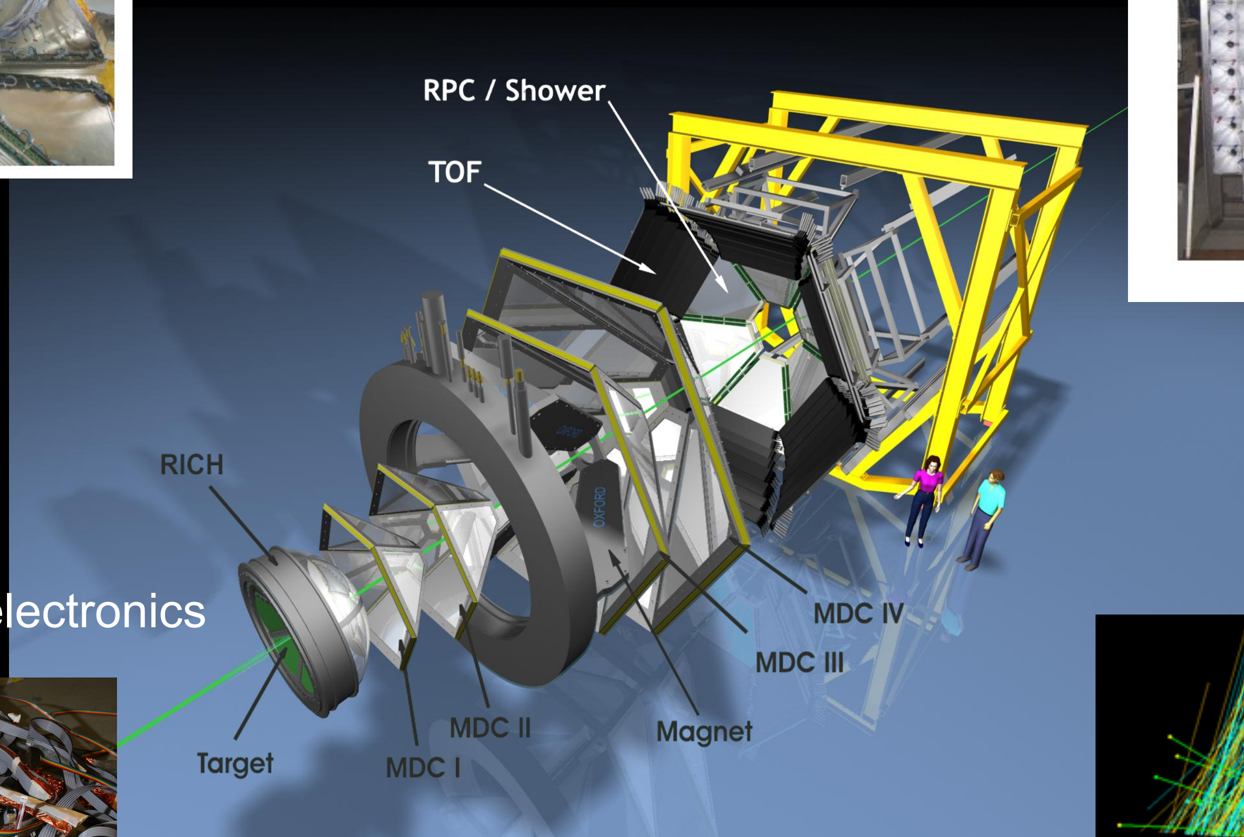
Hadron PID:
β, dE/dx
additional PID for leptons:
RICH, SHOWER

Upgrades for Au+Au

Time-of-flight wall (RPC)

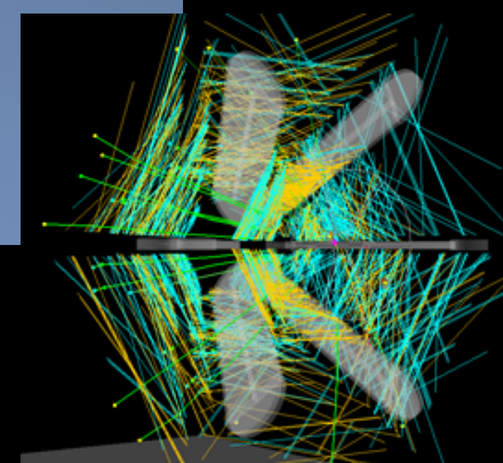
Forward wall





DAQ and readout electronics

Tracking



Performance: data taking and analysis

557 hours beam Au on Au target in April 2012

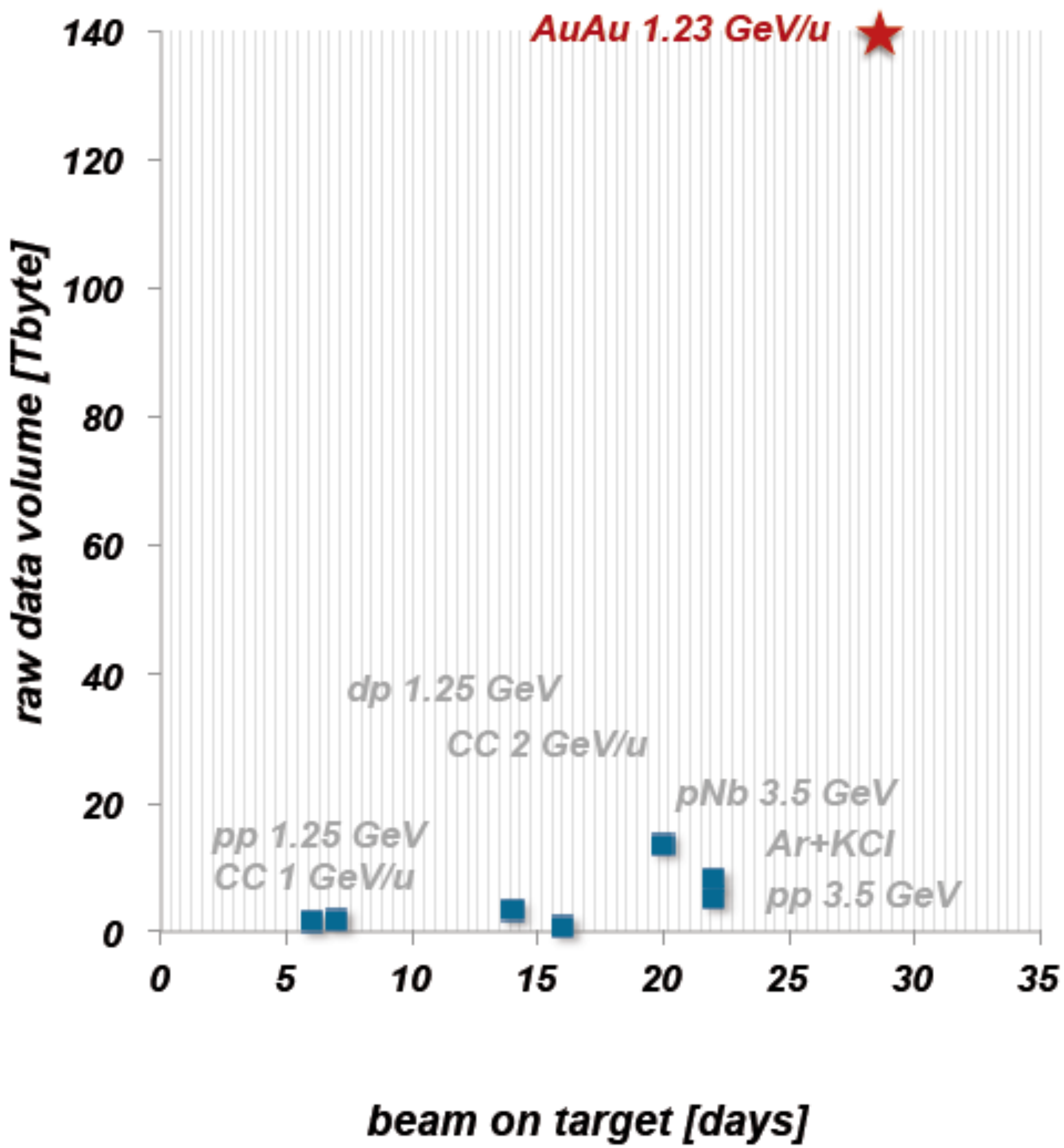
(1.2 - 1.5) x 10^6 ions per second

8 kHz trigger rate

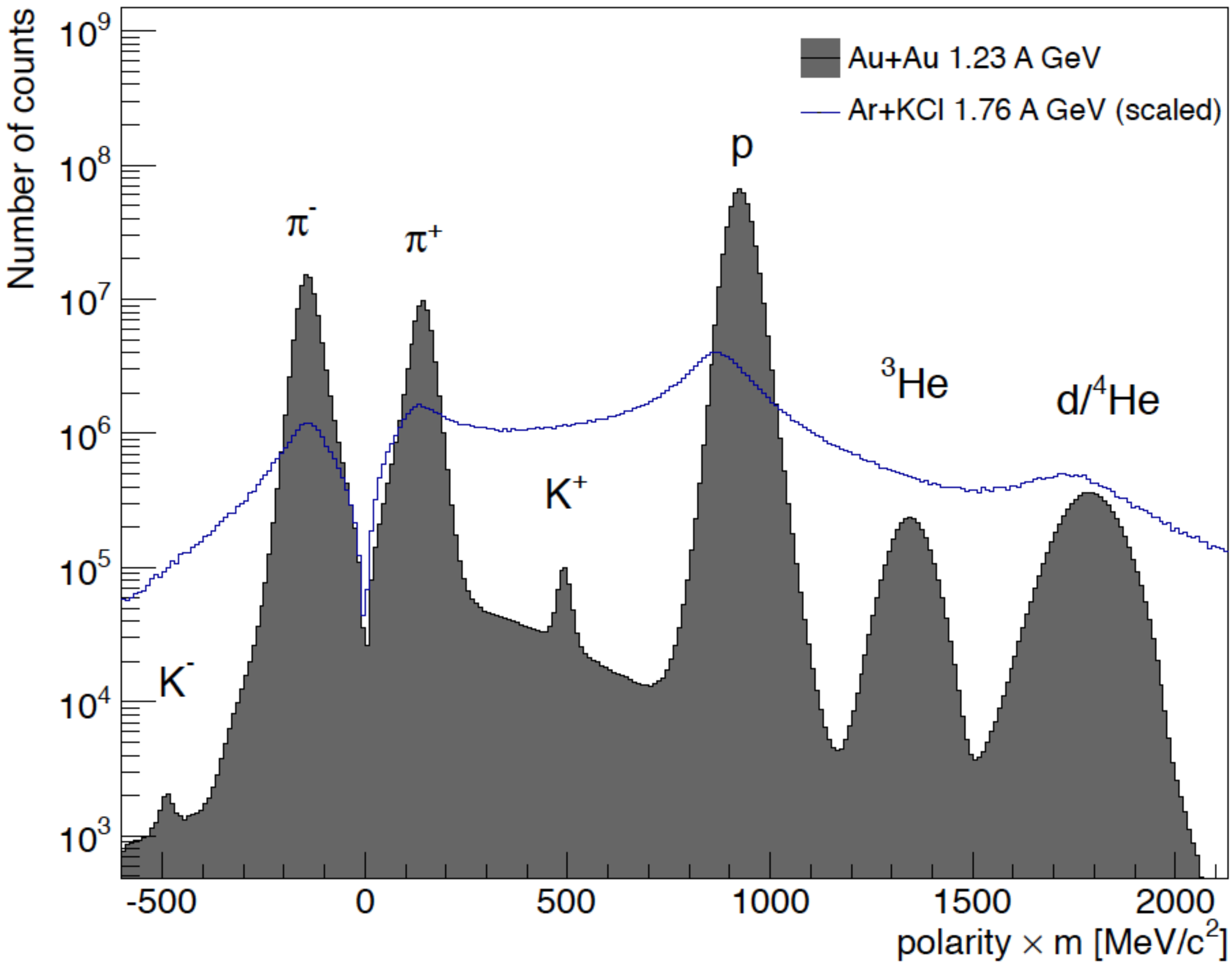
200 Mbyte/s data rate

7.3 x 10^9 events

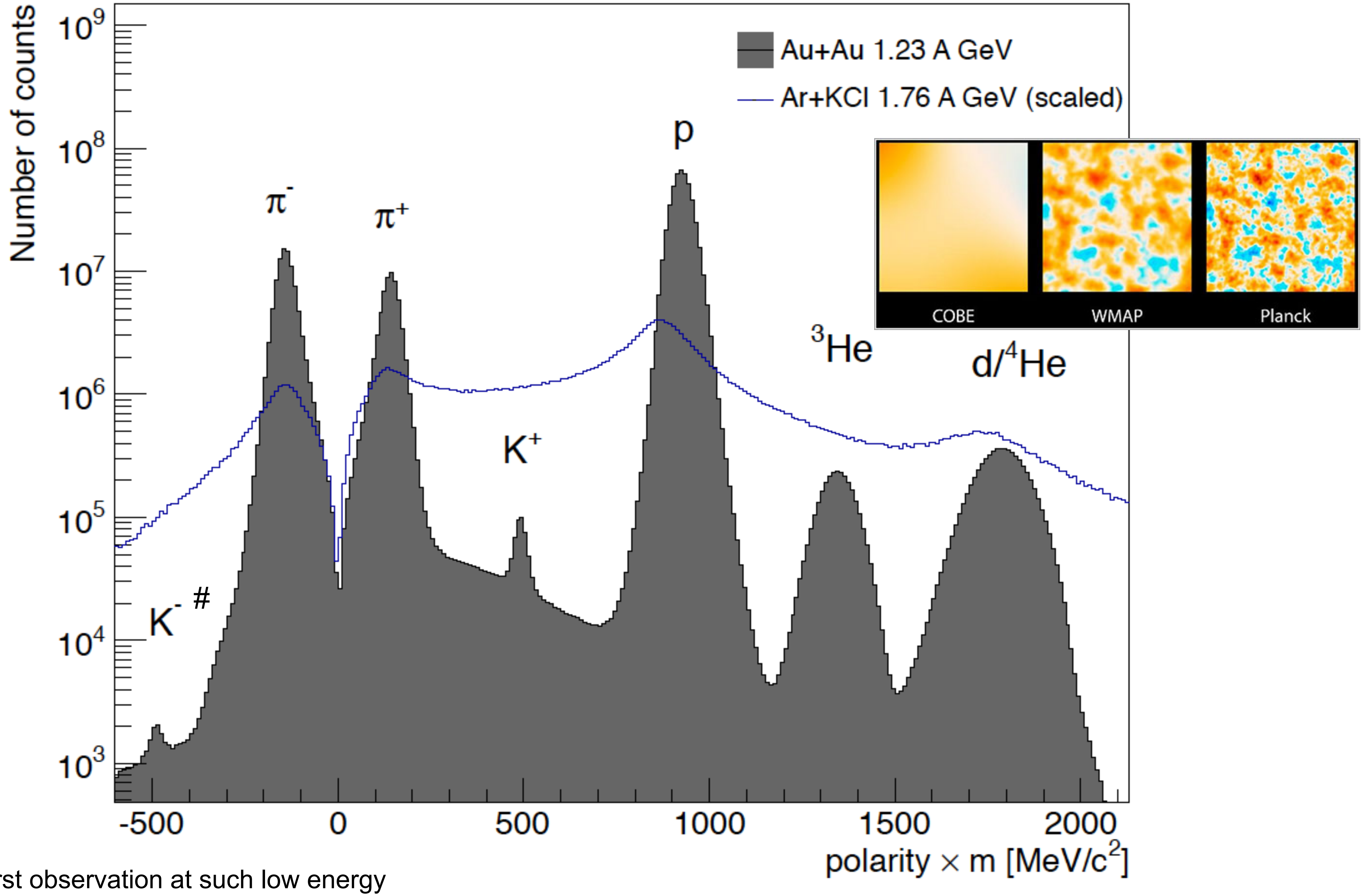
140 x 10^{12} Bytes of data



Performance: mass spectrum

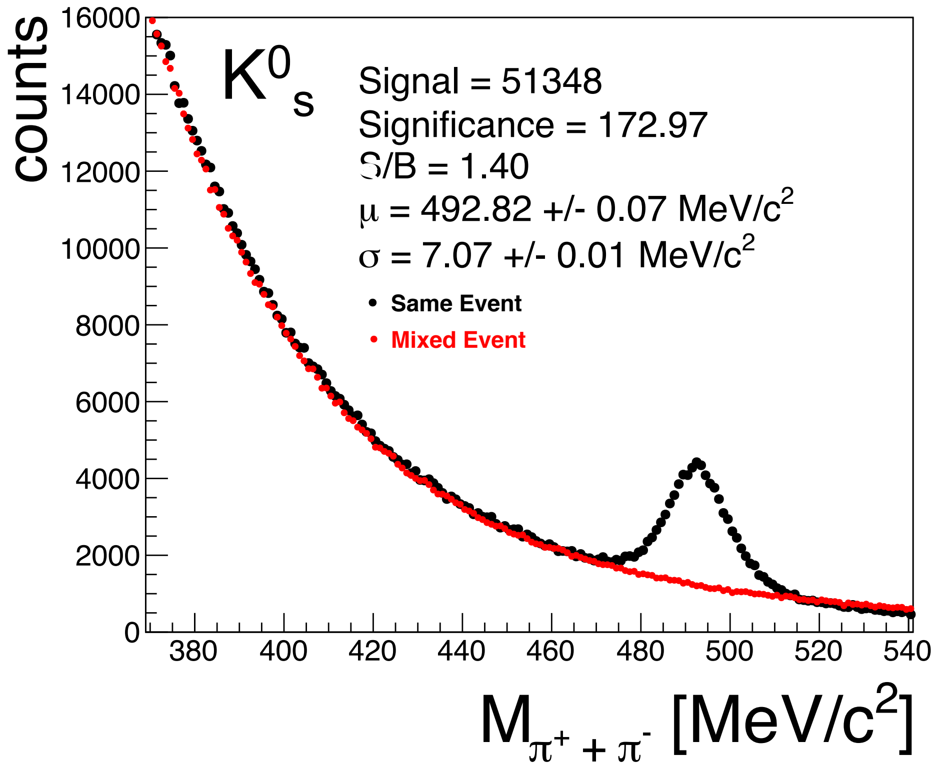


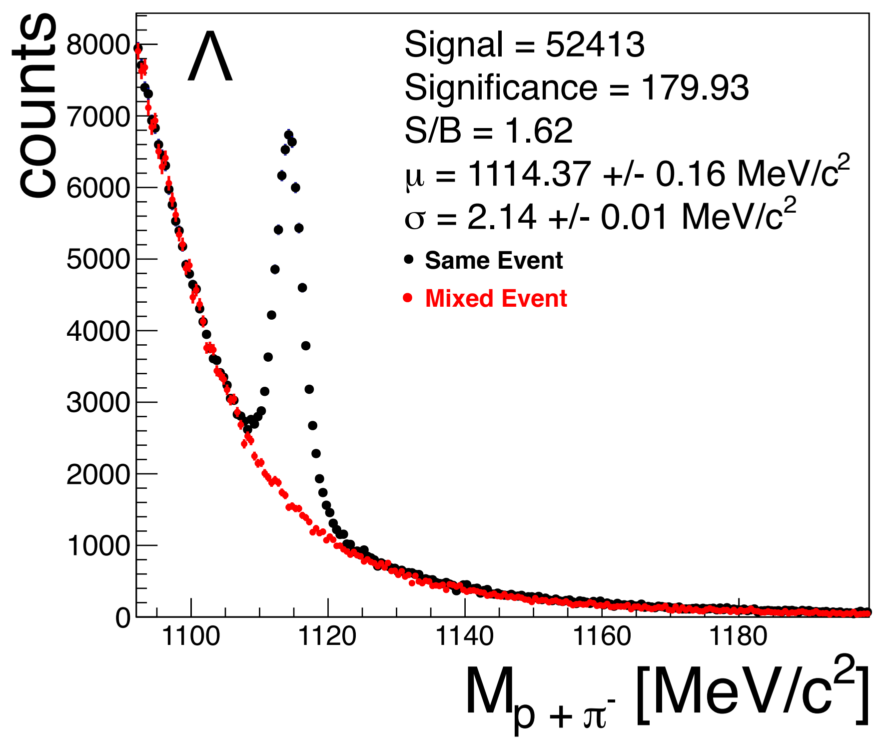
Performance: mass spectrum

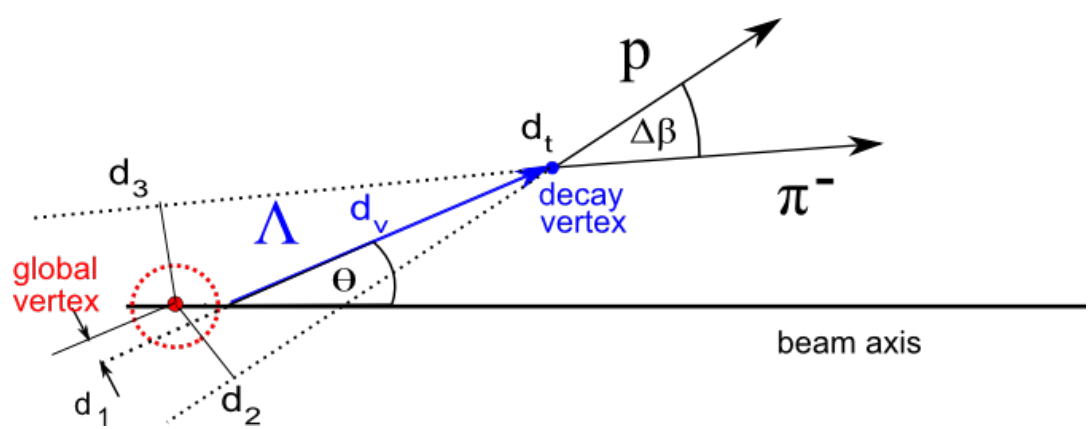


#First observation at such low energy

Performance: Secondary vertices

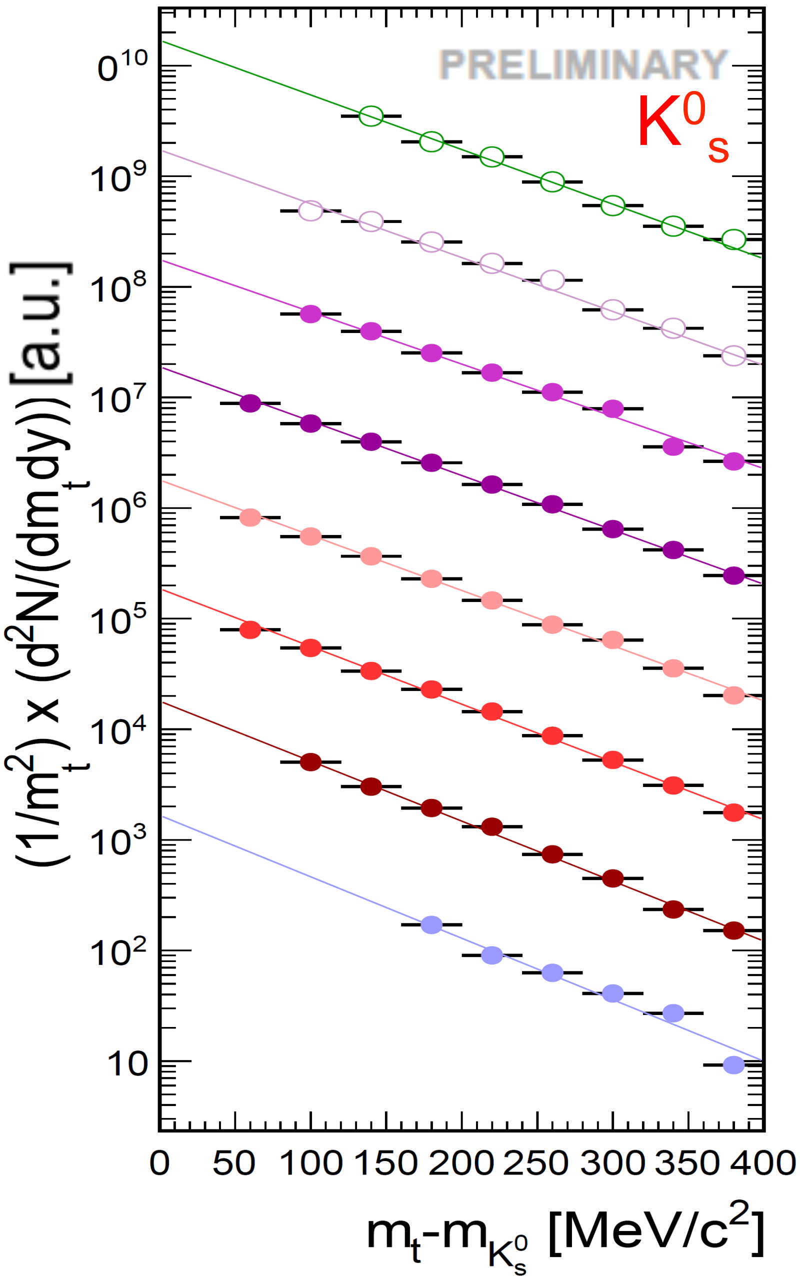


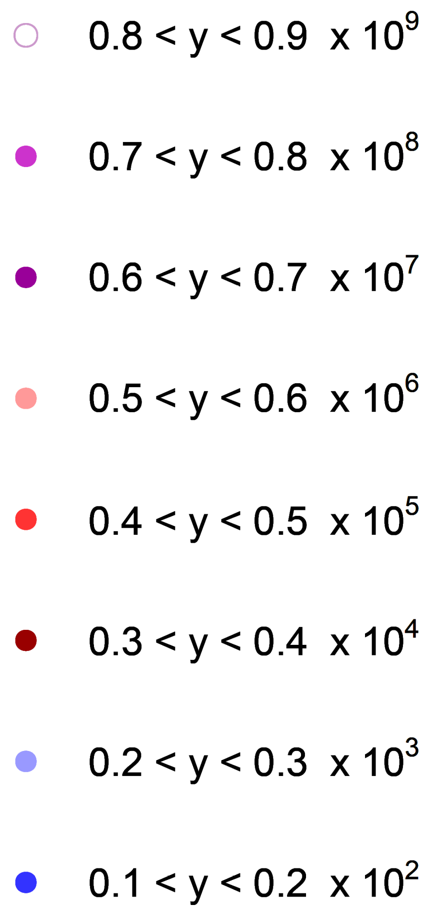


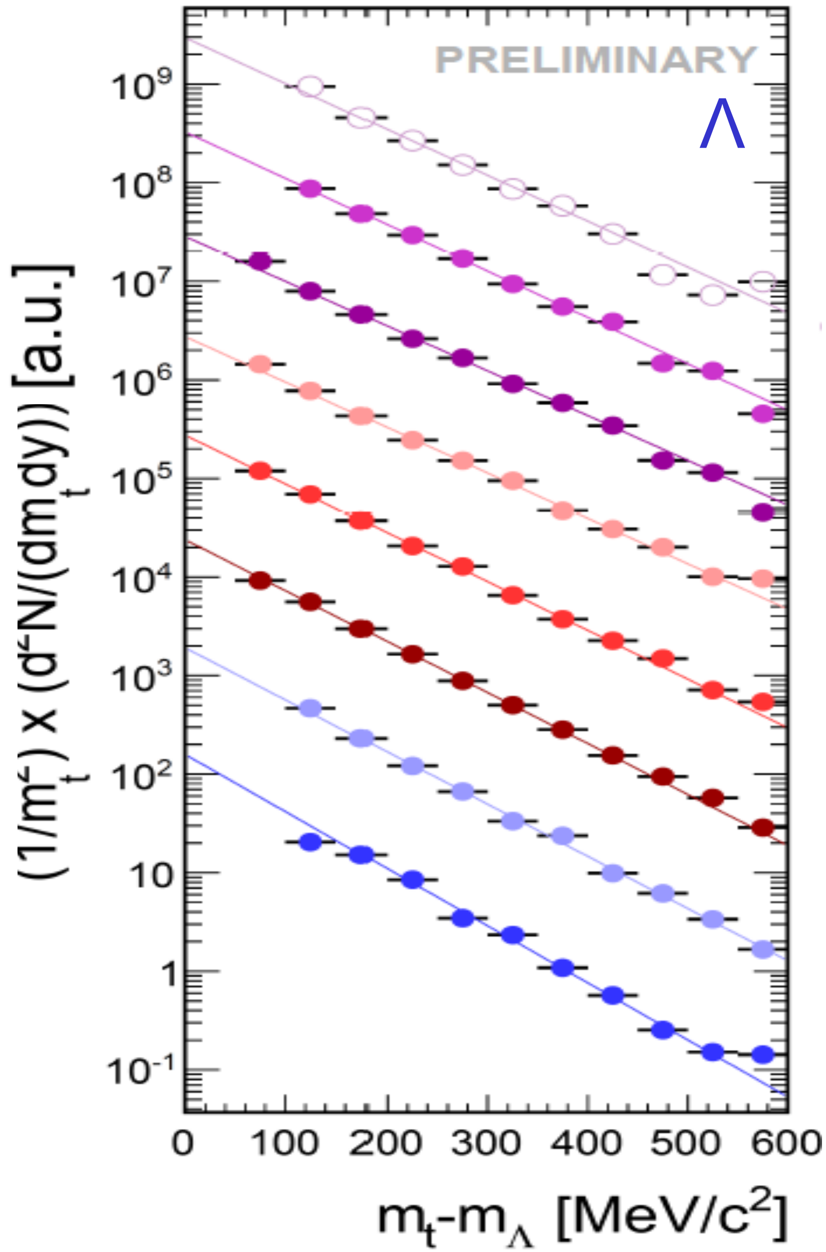


PhD T. Scheib

Transverse mass spectra

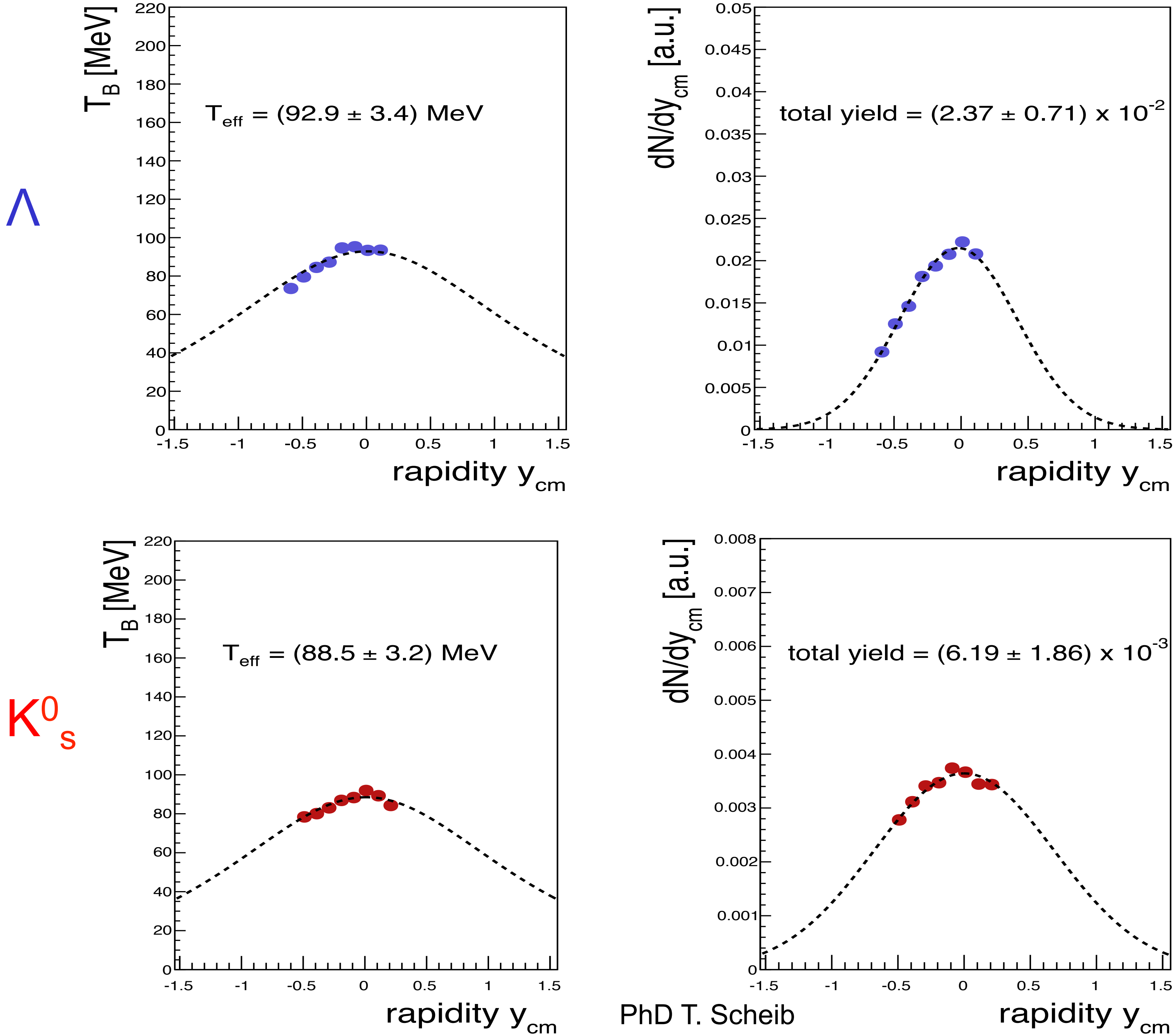






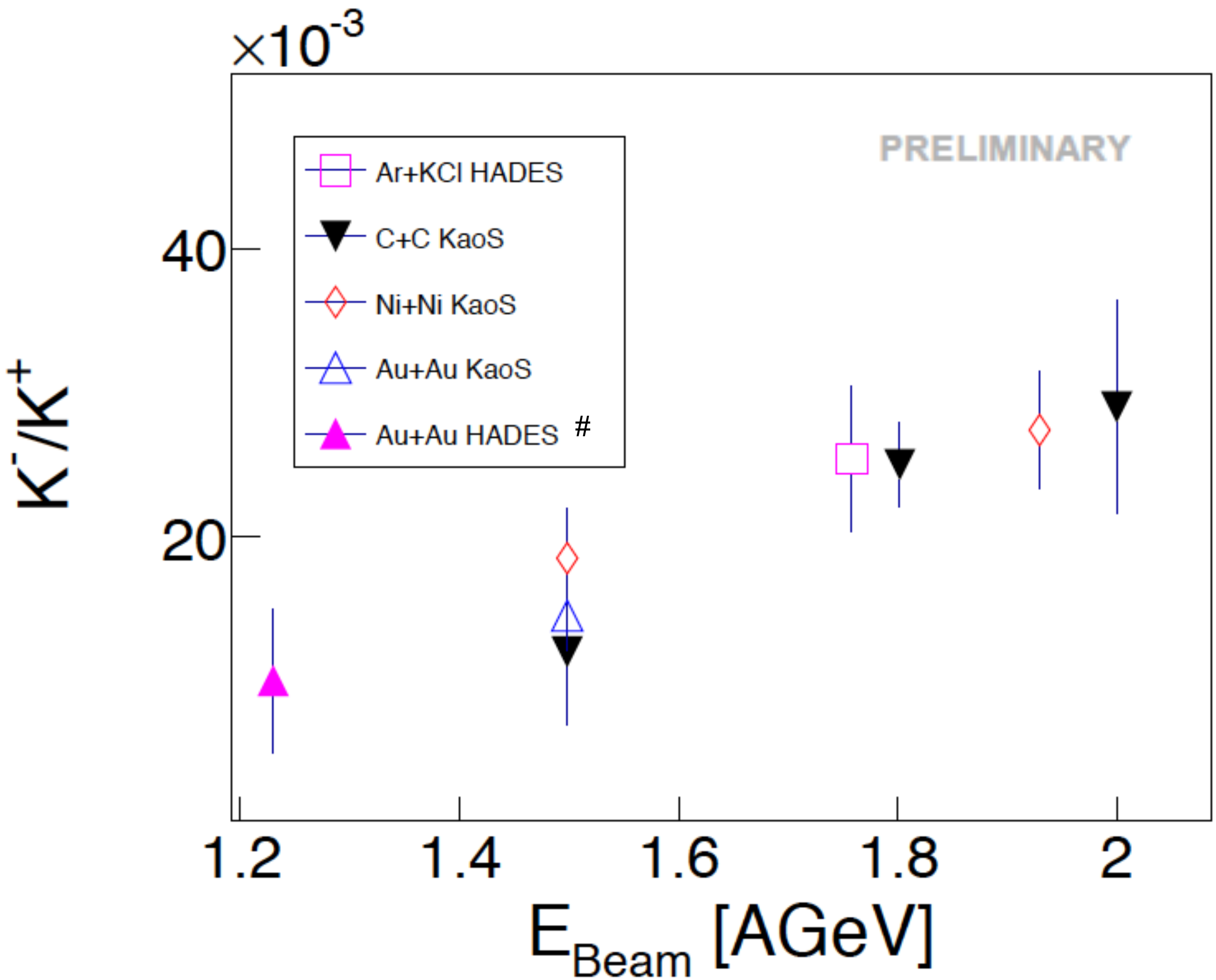
PhD T. Scheib

Rapidity distributions



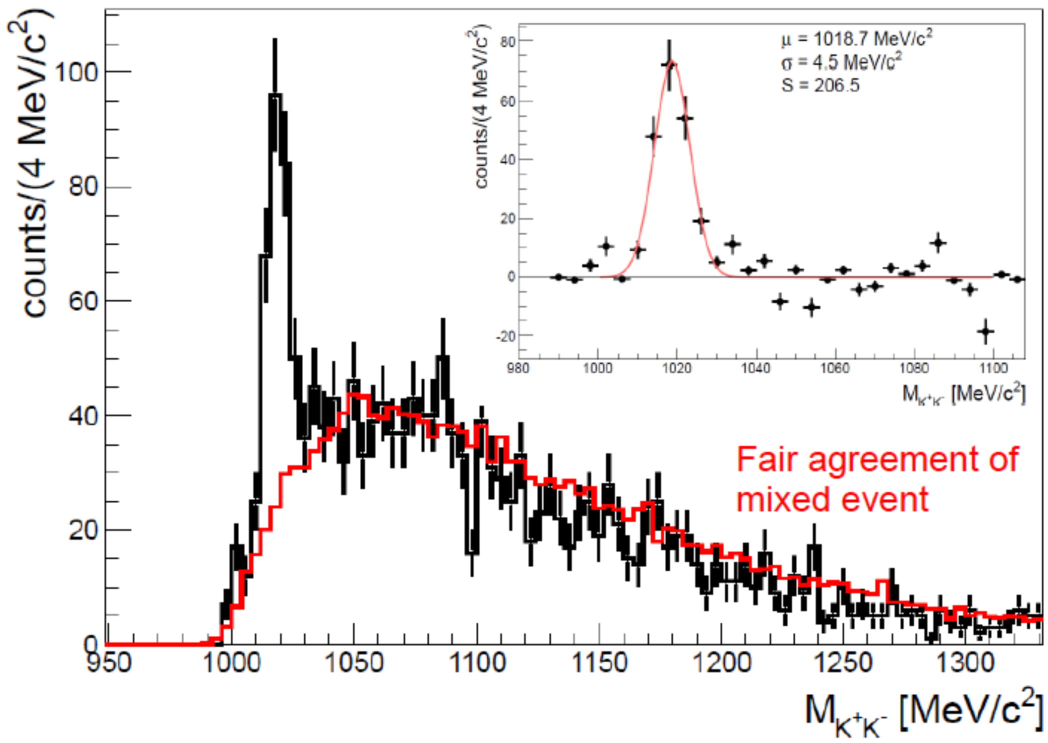
PhD T. Scheib

Charged kaons: comparison to other experiments



ratio at mid-rapidity

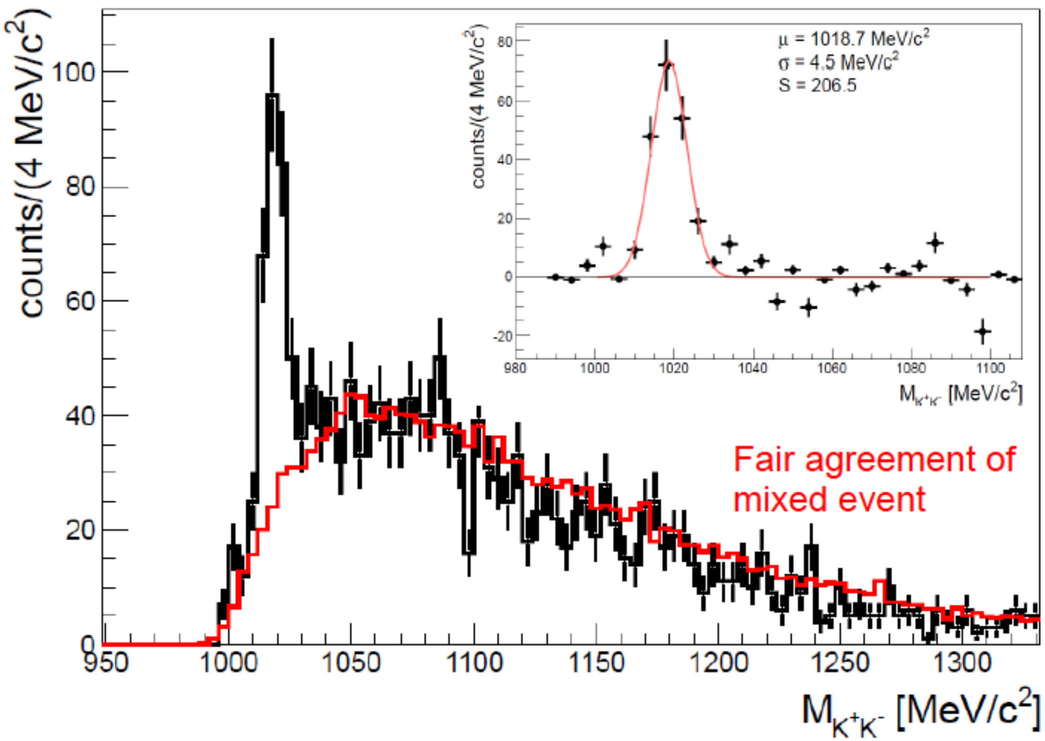
Φ and K⁻



Φ meson reconstructed via charged kaons

PhD H. Schuldes

Φ and K⁻



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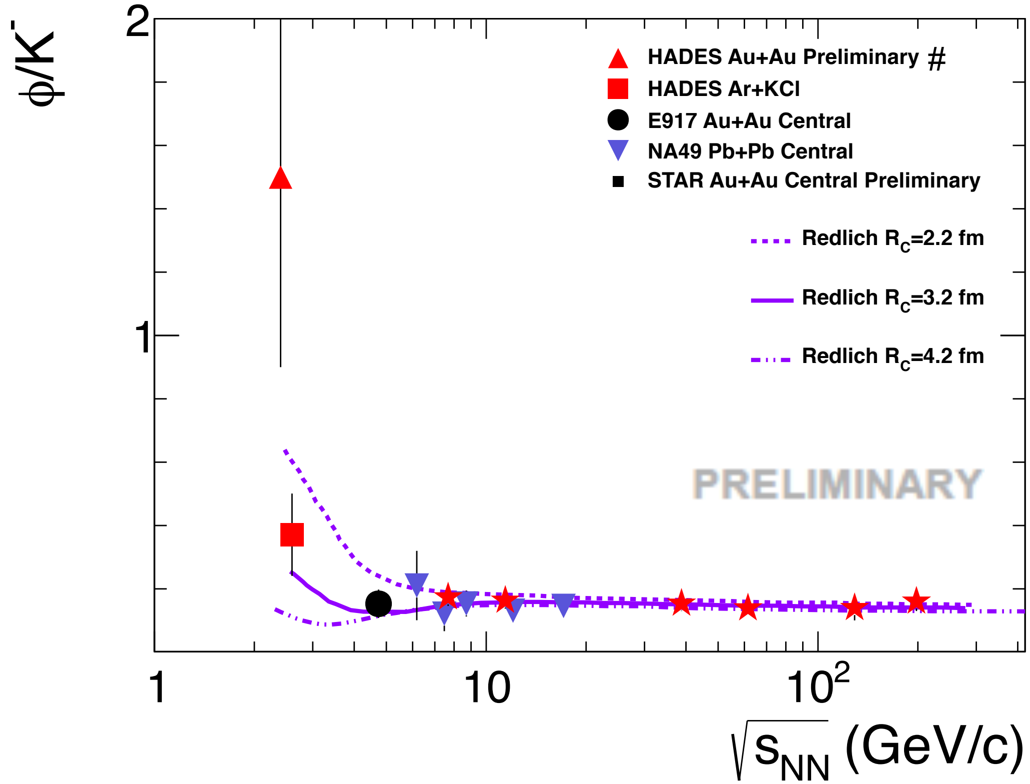
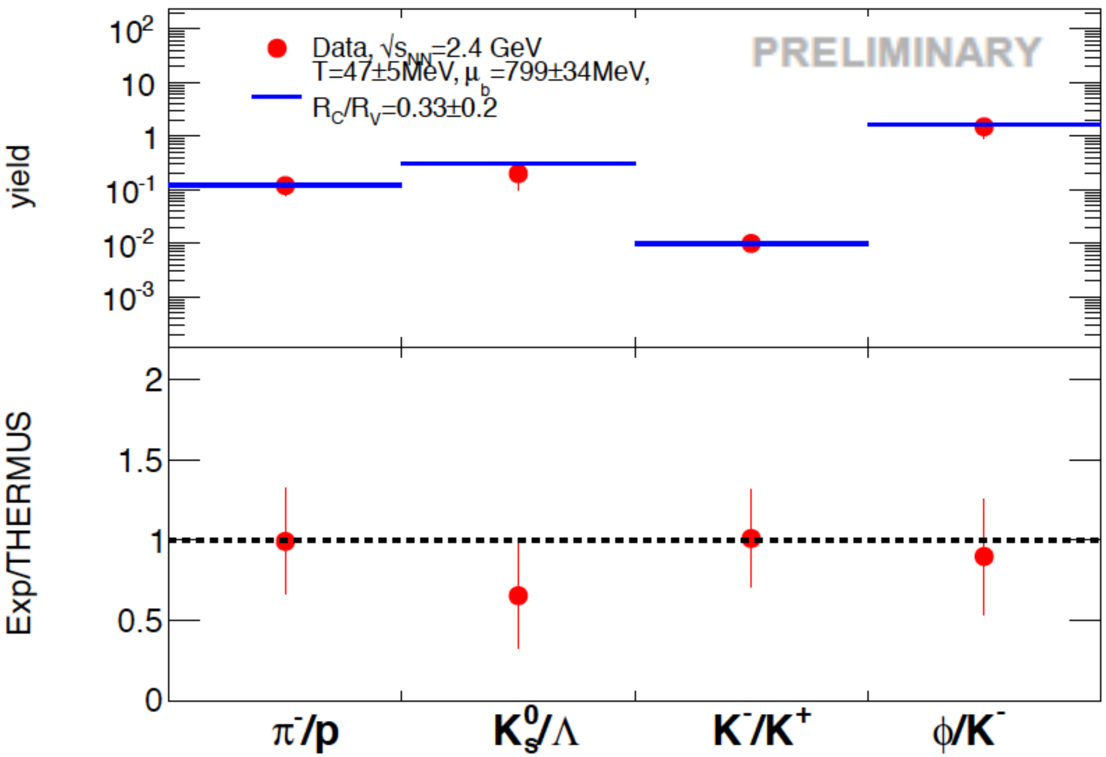


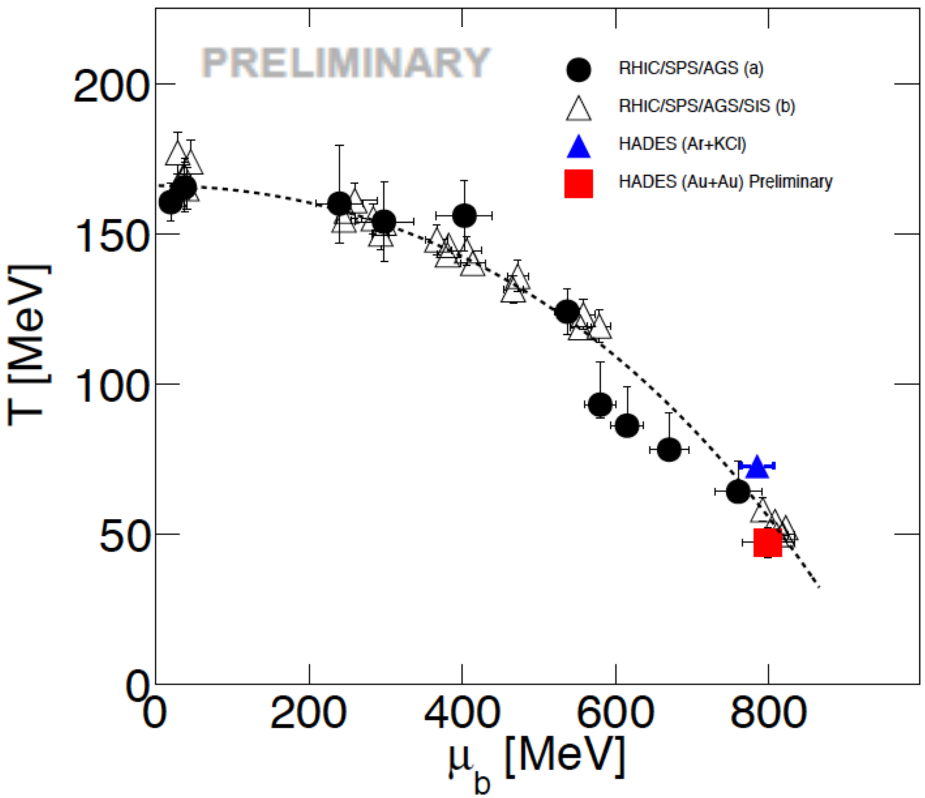
Strong rise of Φ/K⁻ ratio with decreasing beam energy as predicted by stat. model

PhD H. Schuldes

ratio at mid-rapidity

Statistical model fit: first attempt





First attempt of statistical model fit to ratios gives reasonable values:

T= 47±5 MeV

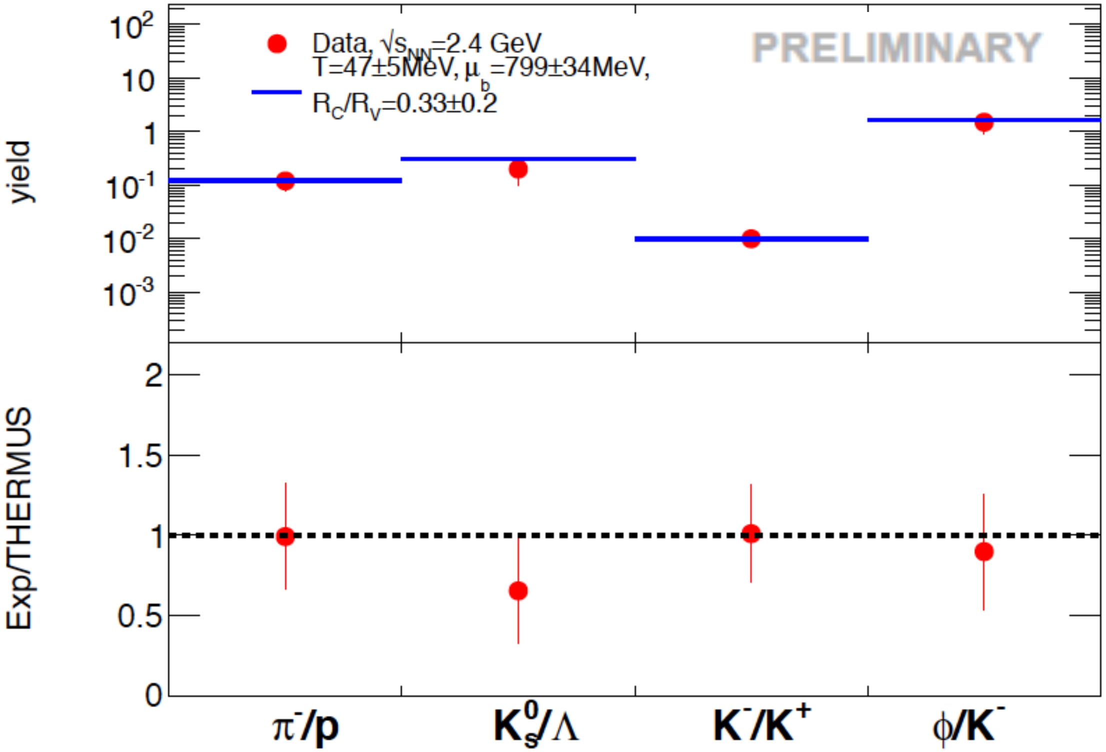
μ_B= 799±34 MeV

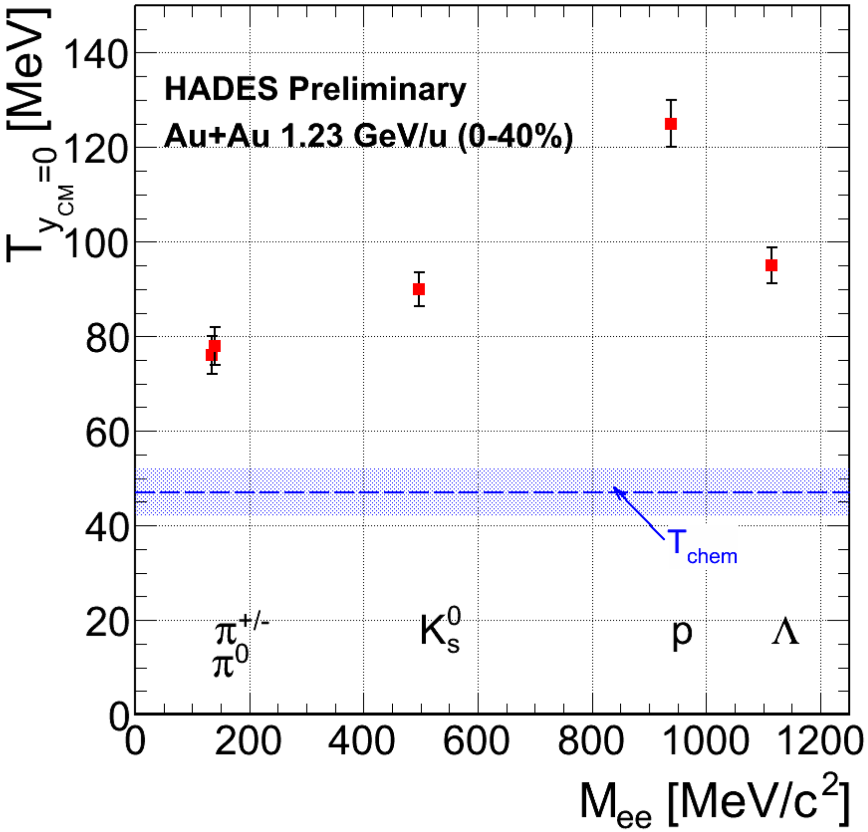
R_c/R_v= 0.3±0.2

(no systematical errors!!)

THERMUS: S. Wheaton, J.Cleymans: Comput.Phys.Commun.180:84-106,2009

Statistical model fit: first attempt





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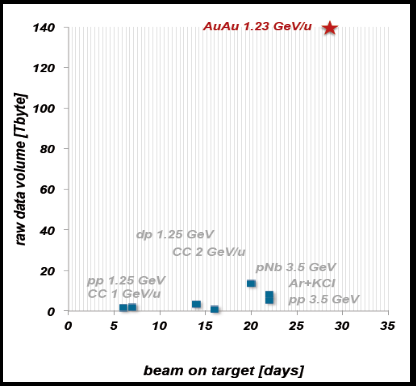
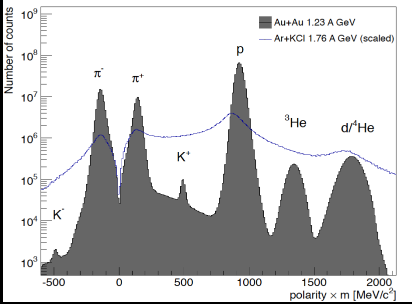
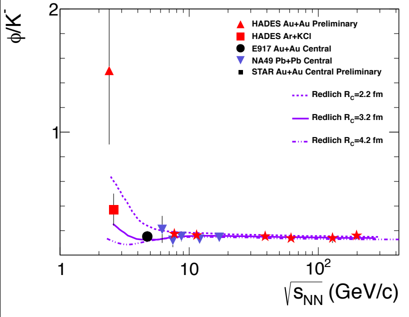
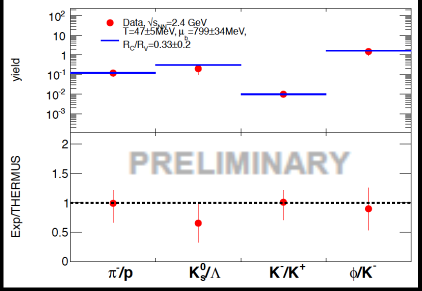
Summary

- Successful Au+Au data taking with upgraded HADES
  - Definitely a challenge
  - Mass spectra and reconstructed particles
- First physics results
  - K^0_s and Λ rapidity distributions, K^-/K^+, Φ/K^-
  - First preliminary ratios consistent with statistical model
  - Conflict between slopes of spectra and T extracted from statistical model
- Very long shopping list:
  - Fluctuations (up to 6th order harmonic)
  - Flow analysis (v1,v2,v3,v4)









The HADES collaboration

Thank you for your attention!

Back up

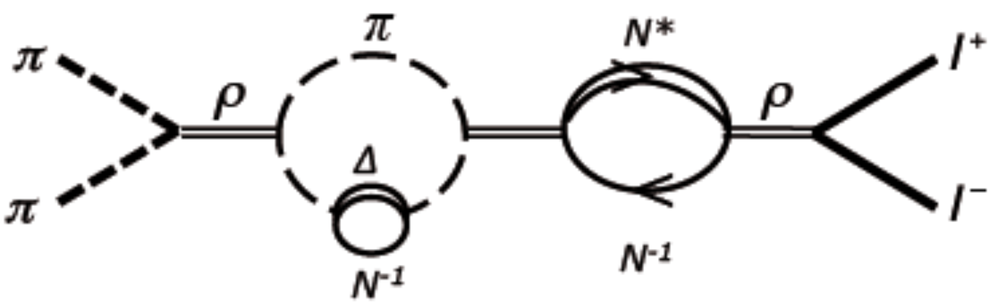
Hadronic models

Chiral condensates can only be related to the integral over hadronic spectral functions by QCD sum rules: → spectral function constrained but not determined

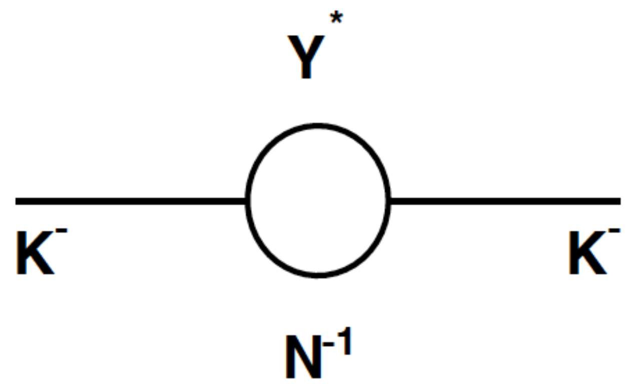
Hadronic models needed to predict hadron properties inside the medium

Additional contributions to particle self energy by coupling to resonances inside the medium:

Example: **ρ meson**



Example: **K^- meson**



Probe: dilepton decay

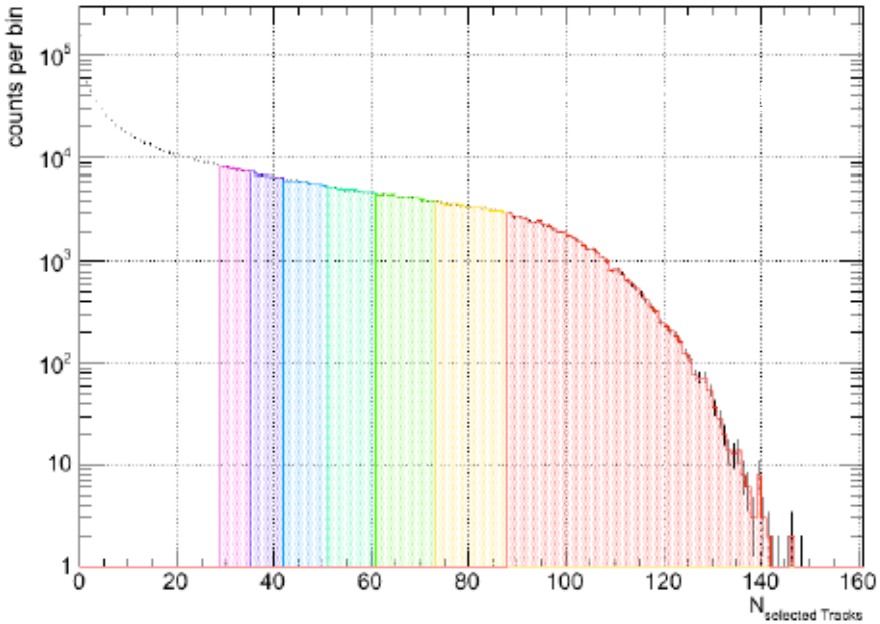
Observable: Lineshape modifications

Probe: direct reconstruction of hadron

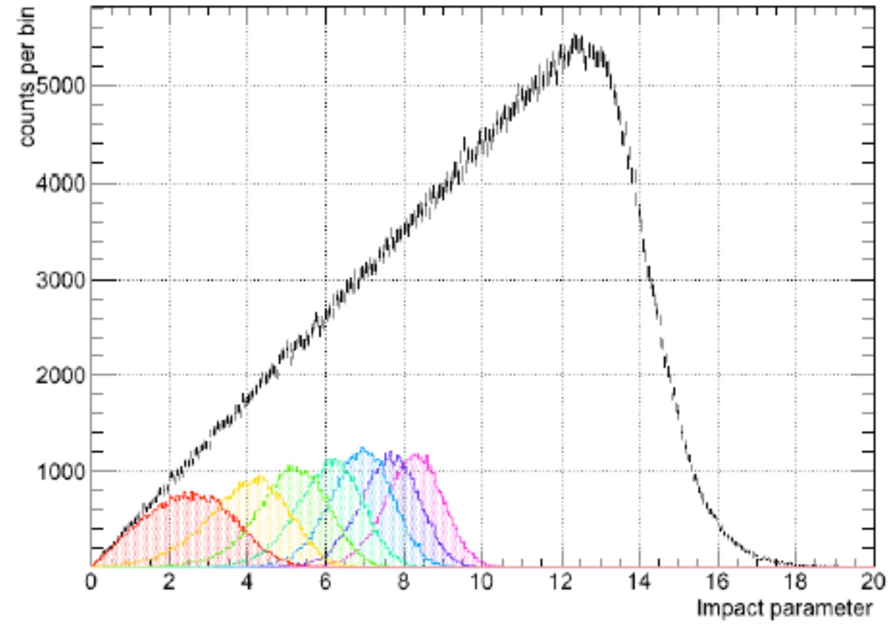
Observable: Production yields
(steep excitation functions)
and phase space distributions

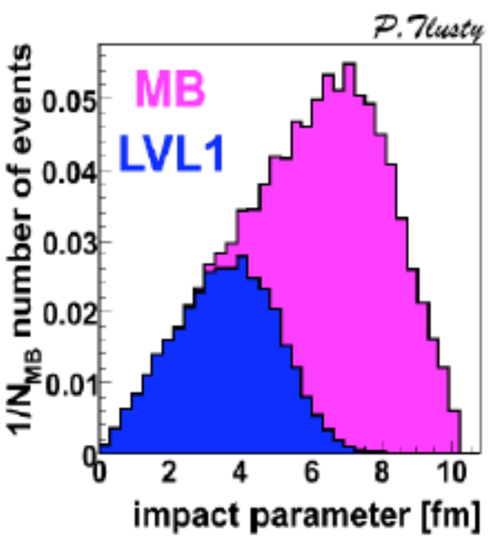
Centrality selection

N_{ch}



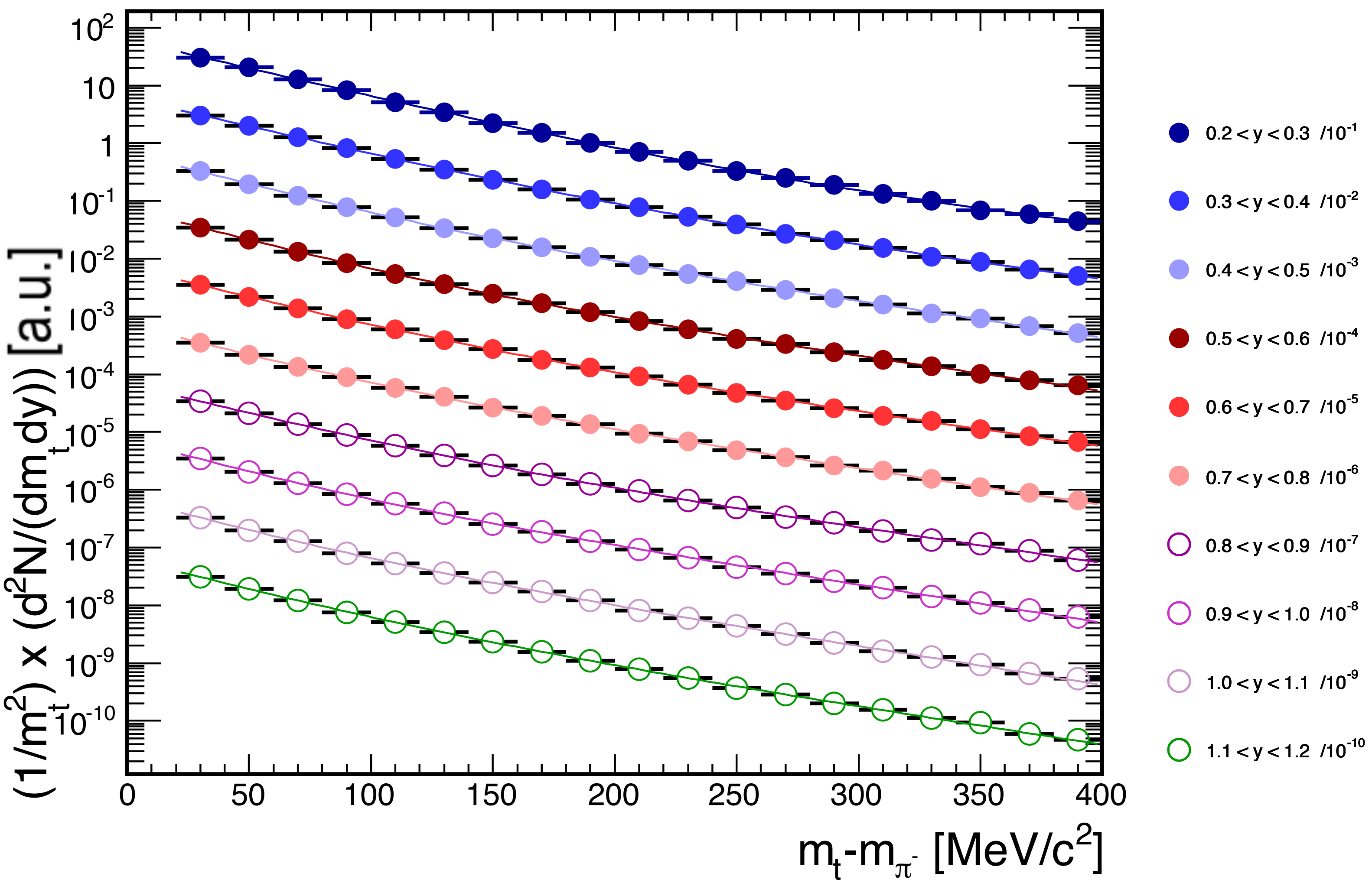
Impact parameter





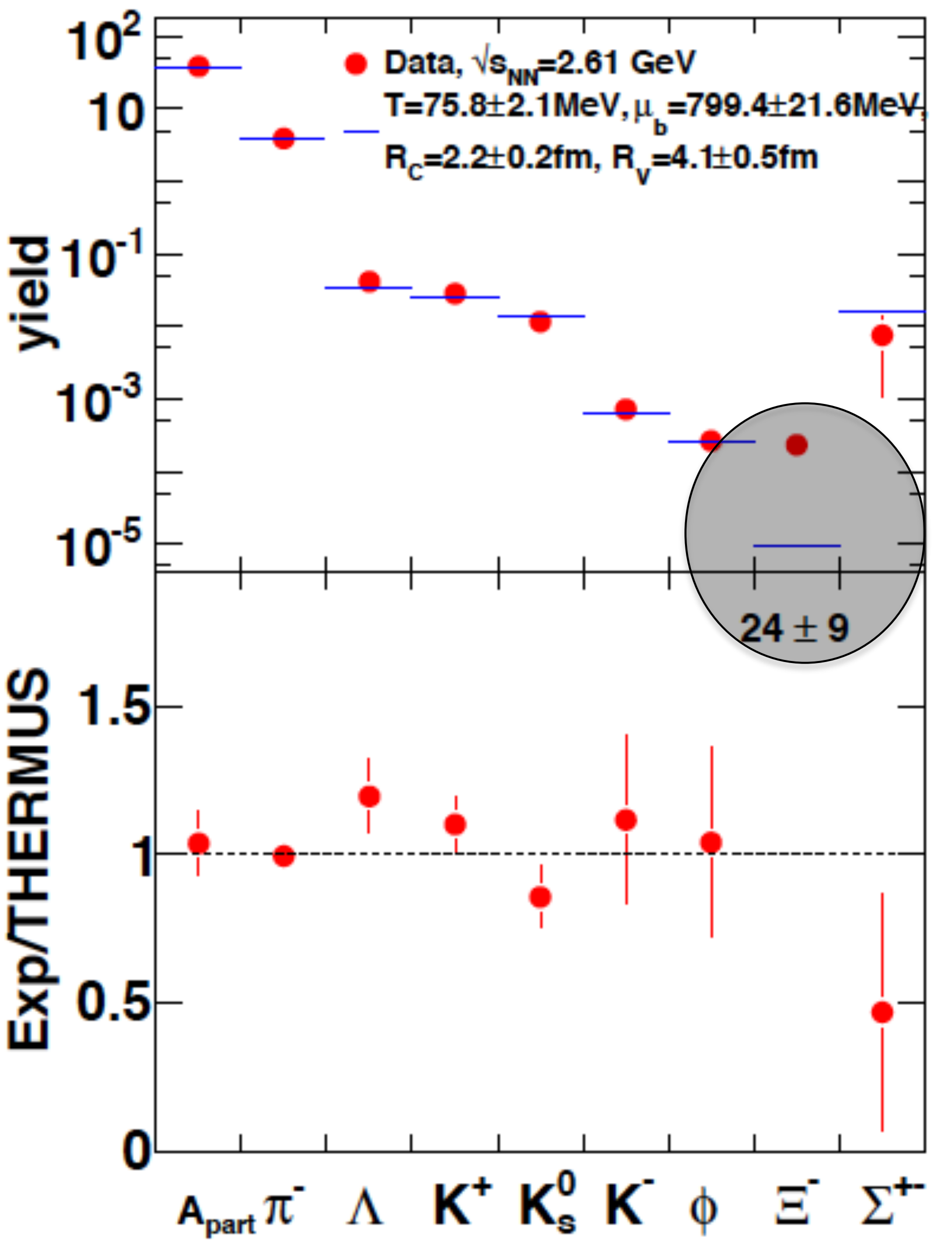
	<b> (fm)	<$N_{part.}$>
min. bias	5.83	19.25
LVL1	3.54	38.5

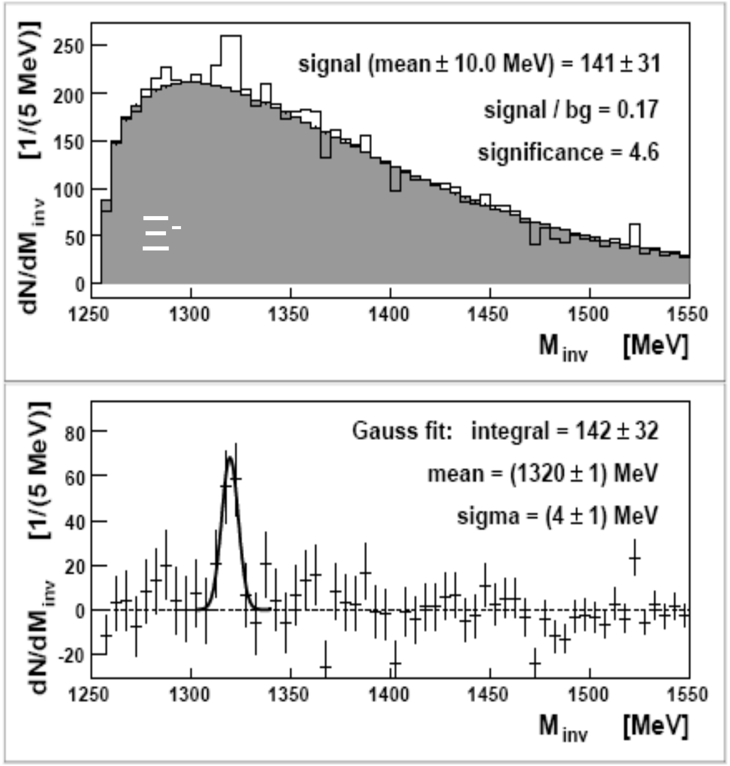
Pions



(1/m_t^2) x (d^2N/(dm_t dy)) [a.u.]
m_t-m_π- [MeV/c^2]
0.2 < y < 0.3 /10^-1
0.3 < y < 0.4 /10^-2
0.4 < y < 0.5 /10^-3
0.5 < y < 0.6 /10^-4
0.6 < y < 0.7 /10^-5
0.7 < y < 0.8 /10^-6
0.8 < y < 0.9 /10^-7
0.9 < y < 1.0 /10^-8
1.0 < y < 1.1 /10^-9
1.1 < y < 1.2 /10^-10

Hadrons in Ar+KCl@1.76A GeV



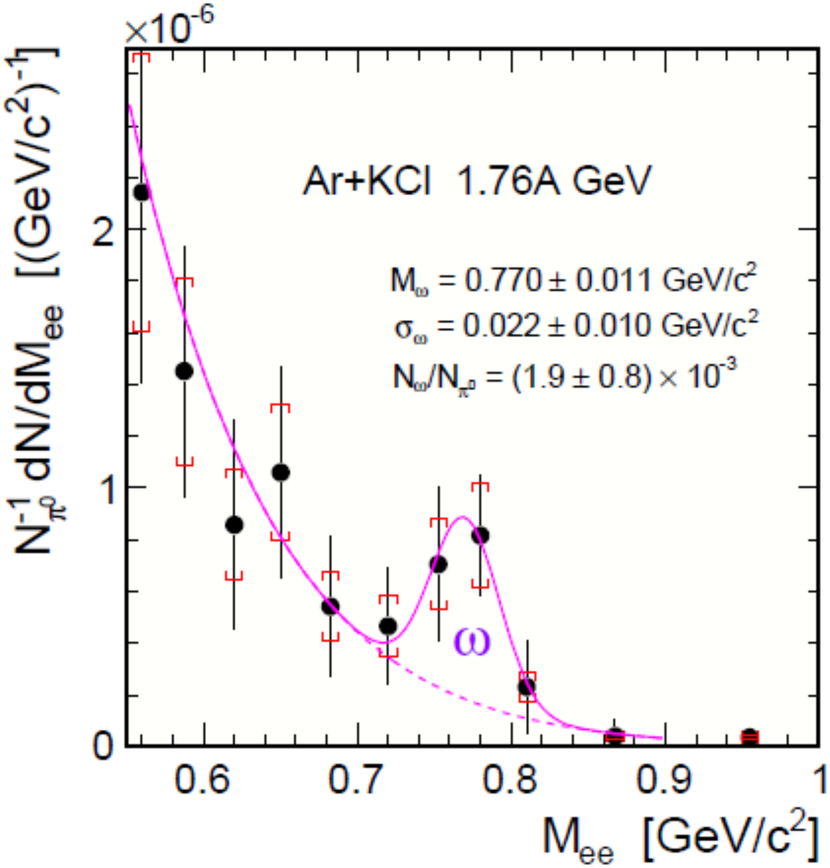


Probability P_{ss} to produce a strange quark pair ≈ 0.05 → $\mathbf{P_{\Xi^-} \approx 0.1\, P_{ss}^2}$

Strangeness production not independent?

Ar+KCl: vector mesons

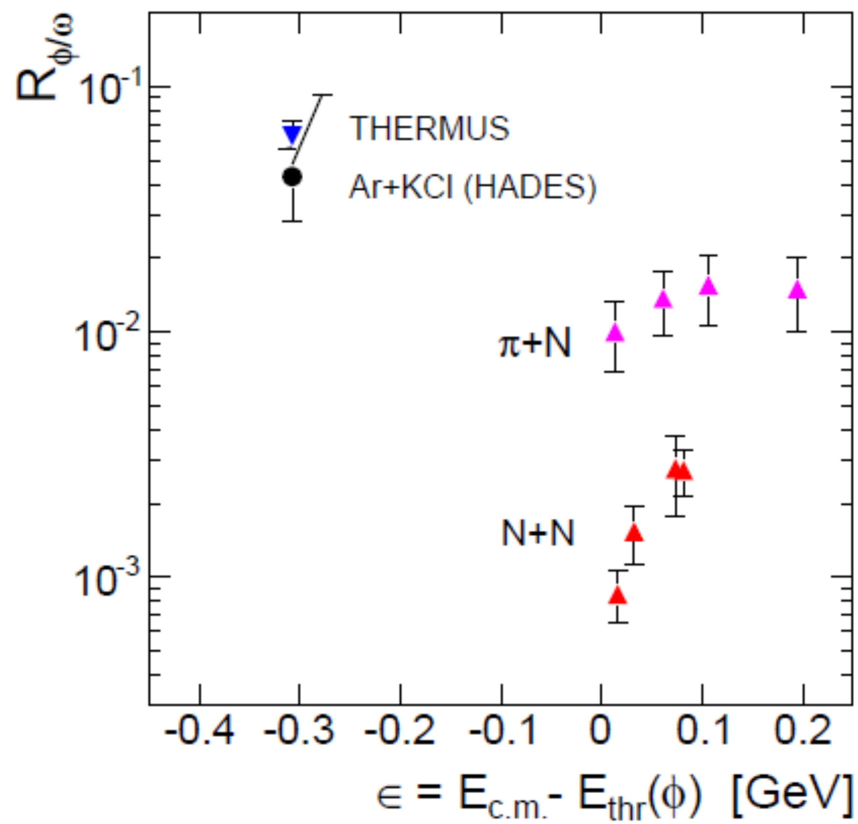
ω-meson:
subthreshold + electromagnetic decay channel: **50 million events for one ω!**



$\phi \rightarrow K^+K^-$, multiplicity: $(2.6 \pm 0.7) \cdot 10^{-4}$

$\omega \rightarrow e^+e^-$, multiplicity: $(6.7 \pm 2.8) \cdot 10^{-3}$

Φ/ω ratio:
suppressed in elementary reactions due to OZI rule



>> $R_{\phi/\omega}$ in NN and πN reactions !
Impact of other channels besides NN and πN ? (e.g. ρN, ρΔ, …) Effect of the medium?

G. Agakishiev et al. [HADES Collaboration]. Dielectron production in Ar+KCl collisions at 1.76A GeV. Phys. Rev., C84(014902), [arXiv:1103.0876 [nucl-ex]]. 2011