HADRON PRODUCTION WITH HADES

Pavel Tlustý, NPI Řež

for the HADES collaboration

- **motivation: study of hadron production at SIS energies**
- **status: pion & strangeness data from HADES**
- **experiments at SIS100 – basic considerations**

Motivation

- pions

charged pion multiplicities used for normalization of dilepton spectra
new data from the same experiment – same setup and trigger, wide acceptance

- K, Φ, Λ, …

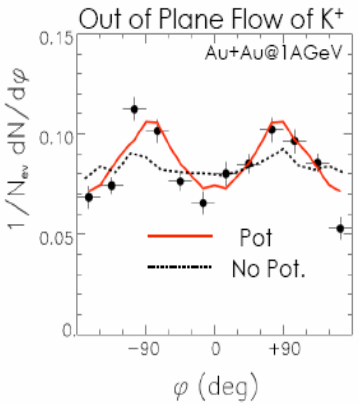
equation-of-state
in-medium modification of hadrons (mass/width)
kaon/lambda-nucleon potential

at 1-2 A GeV - strangeness production close to the NN-threshold → sensitive probes
at ~ 10 A GeV - higher baryon densities
- production higher by 2 orders of magnitude
- new particles and effects: antiprotons, multistrange baryons, strangeness enhancement …

HADES

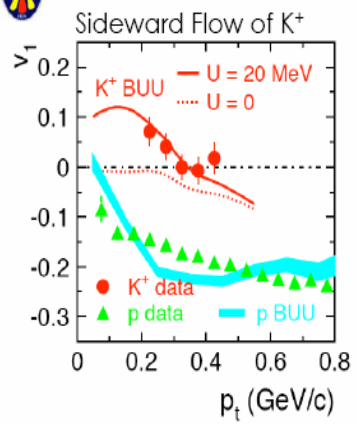
What is K-N potential ?

KAOS Y. Shin et al. Phys. Rev Lett. 81 (1998) 1576-1579.



RBUU:G.Q.Li et al. Phys. Lett. B 381 (1996) 17.

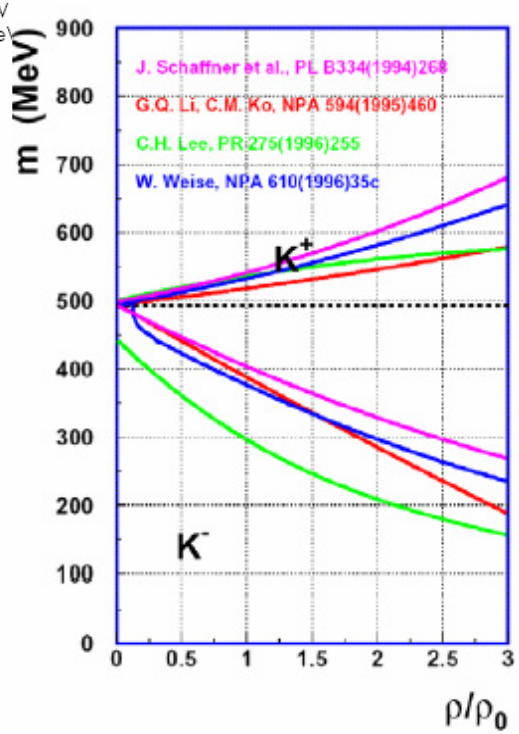
P.Crochet et al. Phys. Lett. B 486 (2000) 6.



Ni+Ni@1.93AGeV
Ru+Ru@1.69AGeV

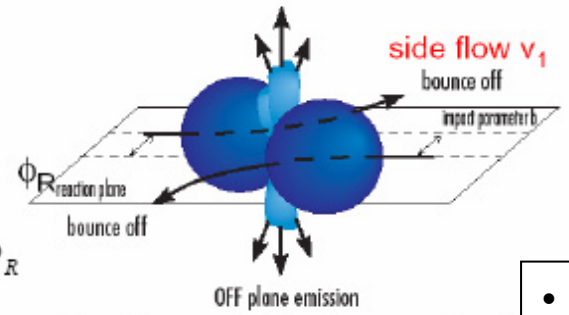
RBBU: E. Bratkovskaya et al. Nucl. Phys. A622 (1997) 593.

Medium effects



ρ/ρ_0

Flow phenomena



$$\varphi' := \varphi - \Phi_R$$

$$\frac{d^3N}{p_t dp_t dy d\varphi'} \propto (1 + 2v_1 \cos(\varphi') + 2v_2 \cos(2\varphi'))$$

- K^+ potential seems to be slightly repulsive

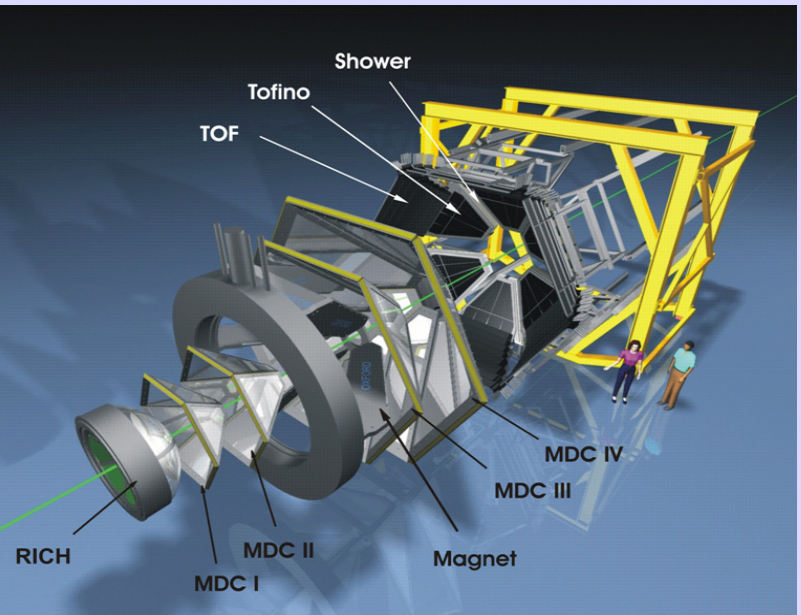
Precise data on K^- /K^0 flow can be provided by FOPI , HADES (2009,2010)

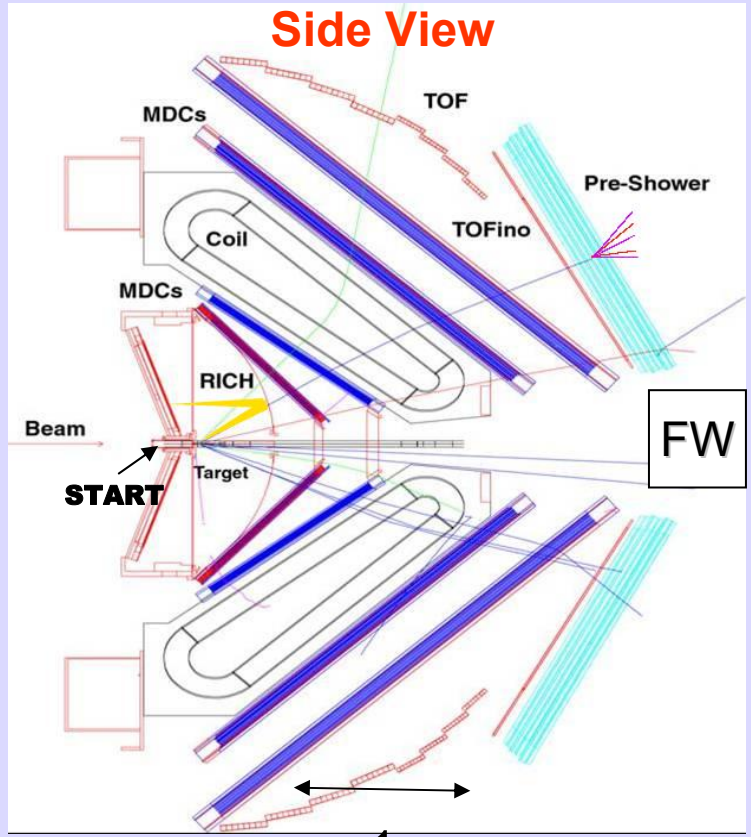
HADES

HADES

A High-Acceptance Di-Electron Spectrometer

- Beams from SIS18: pions, protons, nuclei
- Spectrometer with high invariant mass resolution (2% at ρ/ω mass) and powerful PID capabilities : $p/\pi/K/e^{\pm}$
- Versatile detector for rare particle decays :
  - dielectrons (e+,e-)
  - strangeness: Λ, $K^{\pm,0}$, φ





Geometry

Full azimuth, polar angles 18° - 85°

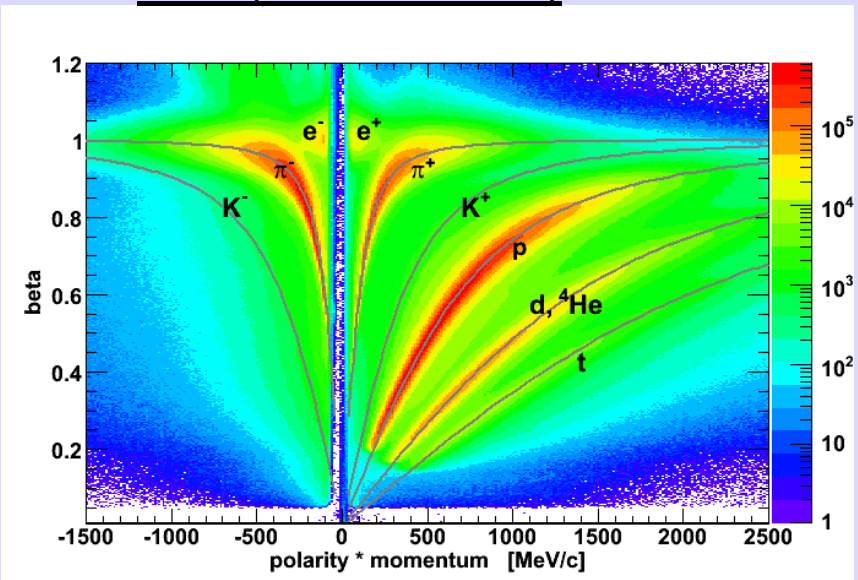
A+A systems measured:

C+C @ 1 and 2A GeV, Ar+KCl @ 1.76A GeV

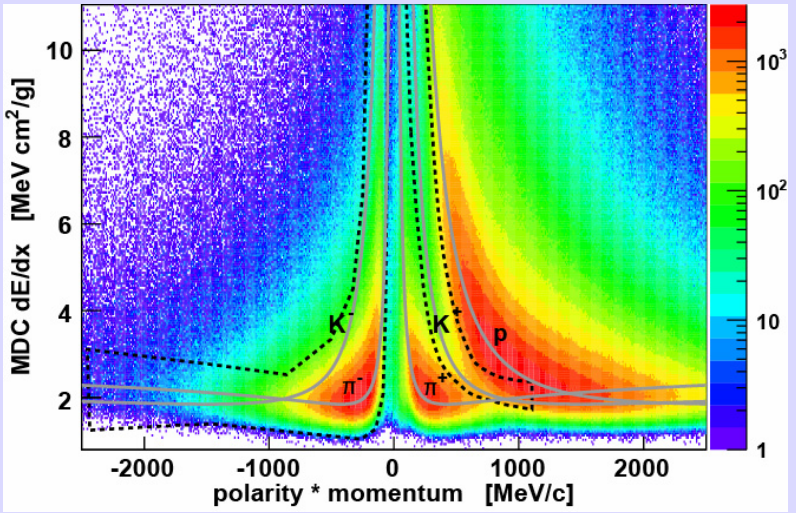
HADES

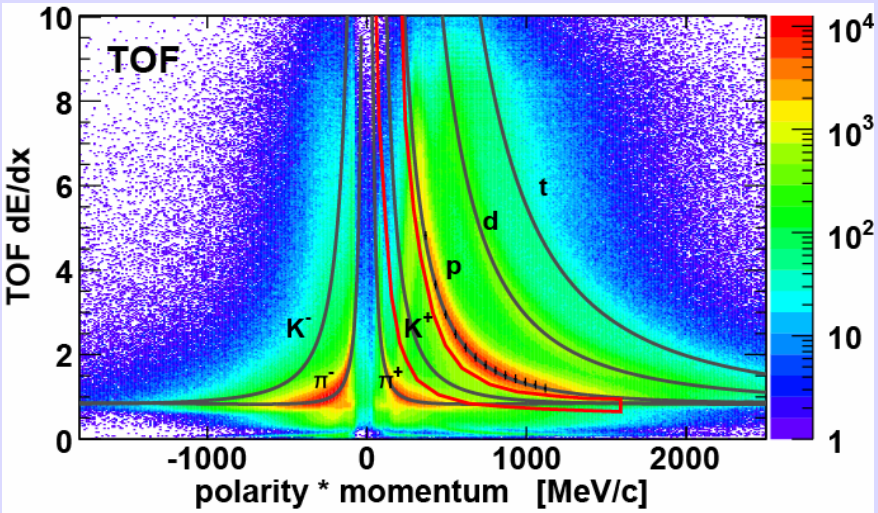
Charged Particle Identification

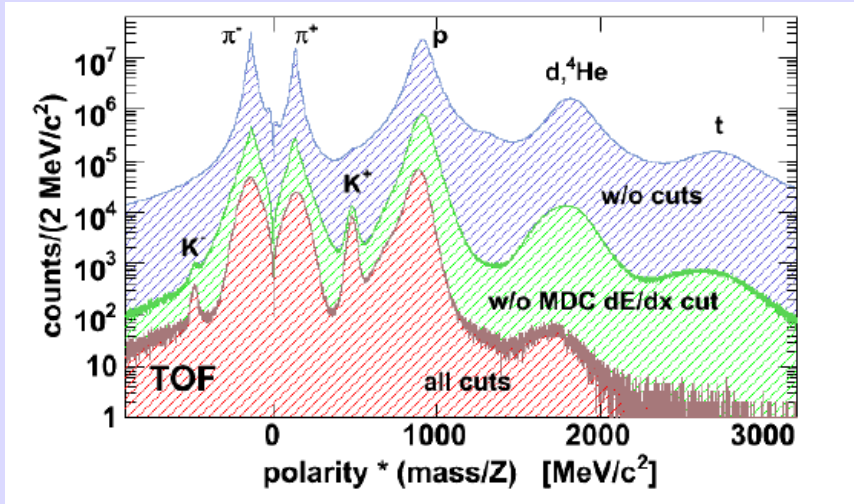
TOF (44° < ✈ < 88°)



MDC



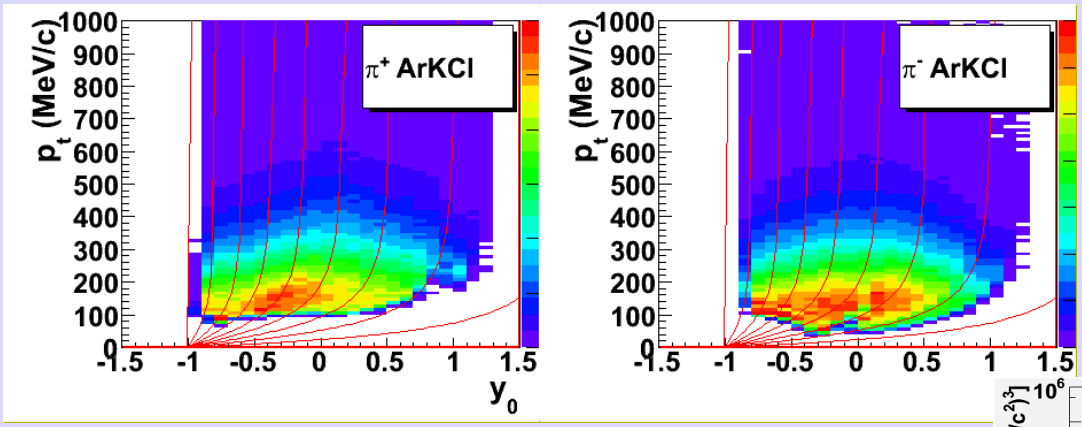




A. Schmah

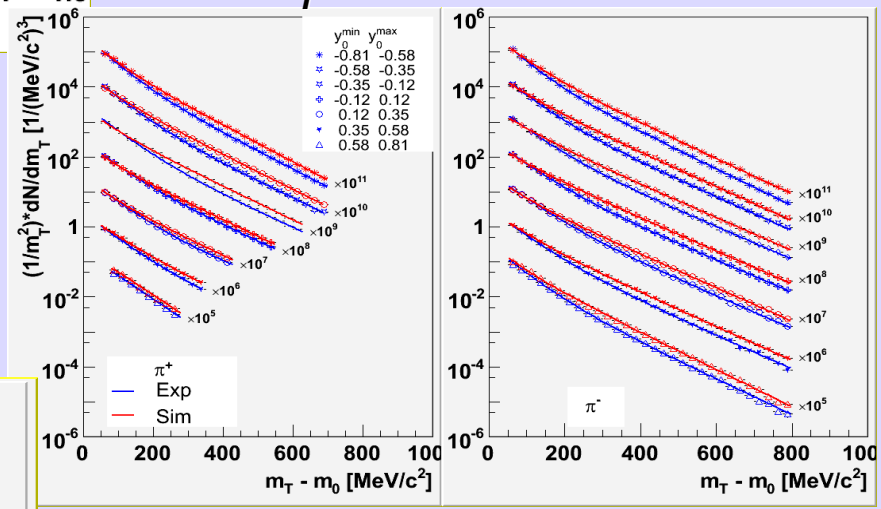
HADES

Pions – Ar+KCl 1.76 A GeV



$y_0 = (y_{lab} - y_{cm})/y_{cm}$

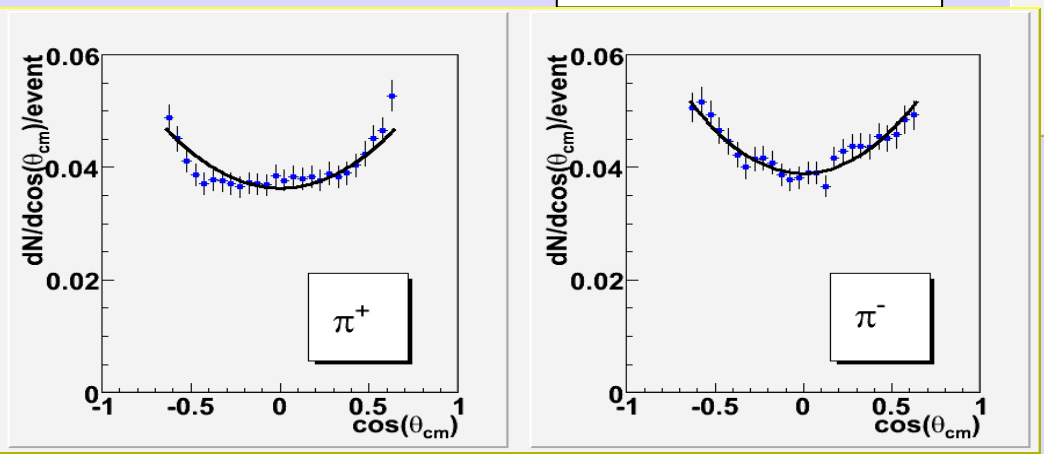
m_T distributions



$$\frac{1}{m_T^2}\frac{d\sigma}{dm_T} = C_1 \cdot e^{-m_T/T_1} + C_2 e^{-m_T/T_2}$$

angular distributions

$A_2 = 0.75 \pm 0.10$

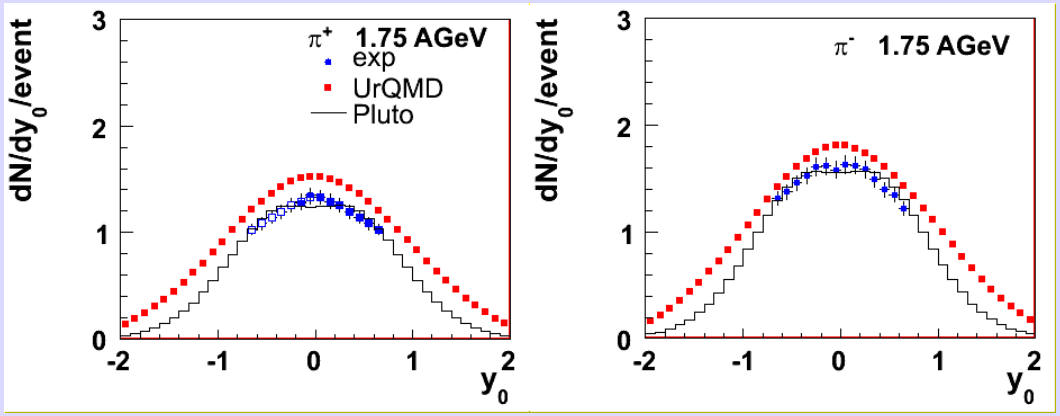


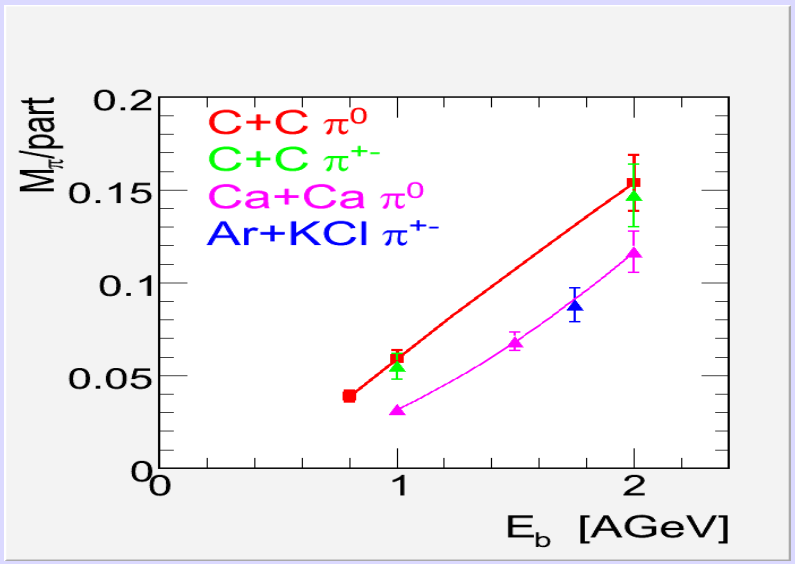
$$dN/d\cos(\theta_{cm}) \sim 1. + A_2 \cdot \cos^2(\theta_{cm})$$

HADES

π multiplicities

Ar+KCl 1.76A GeV

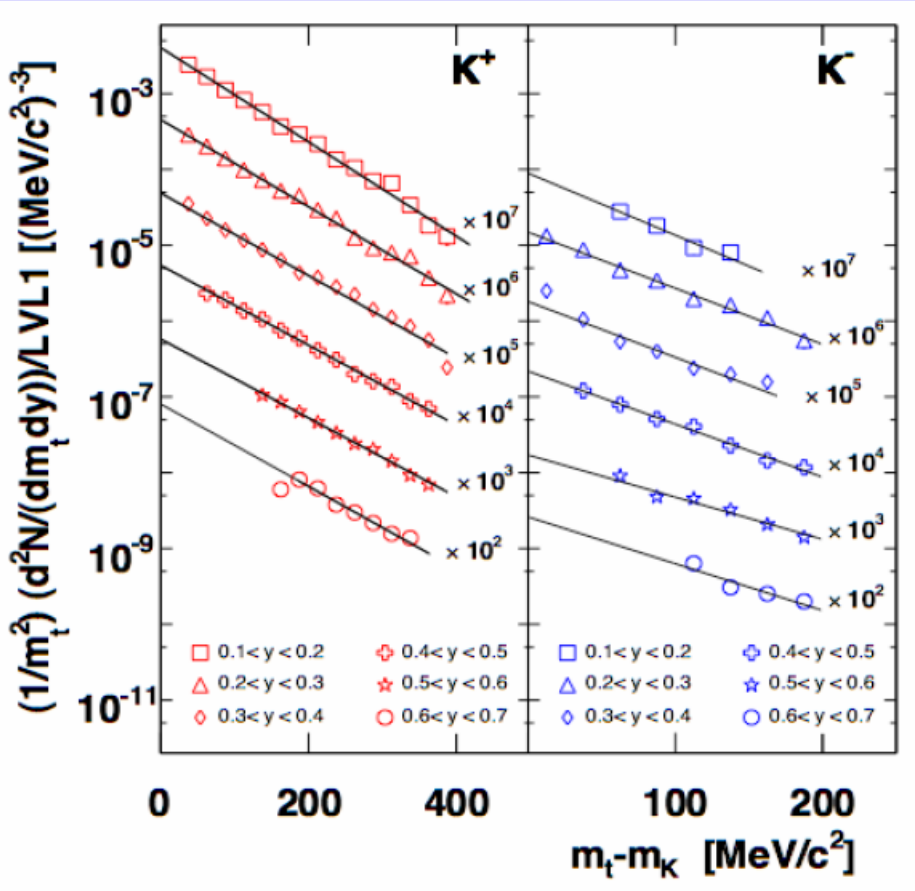


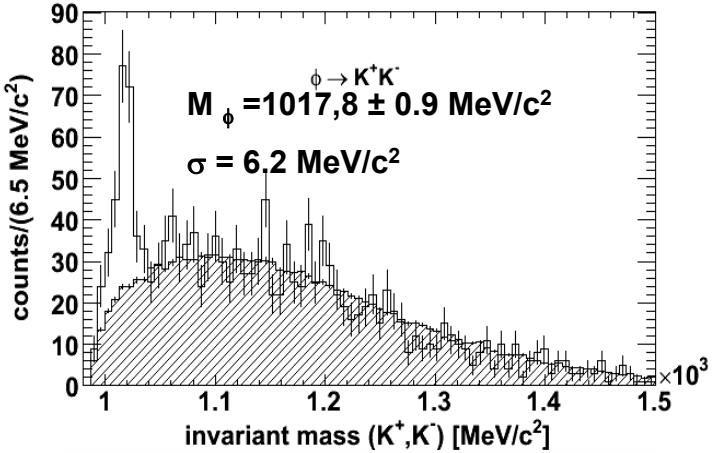


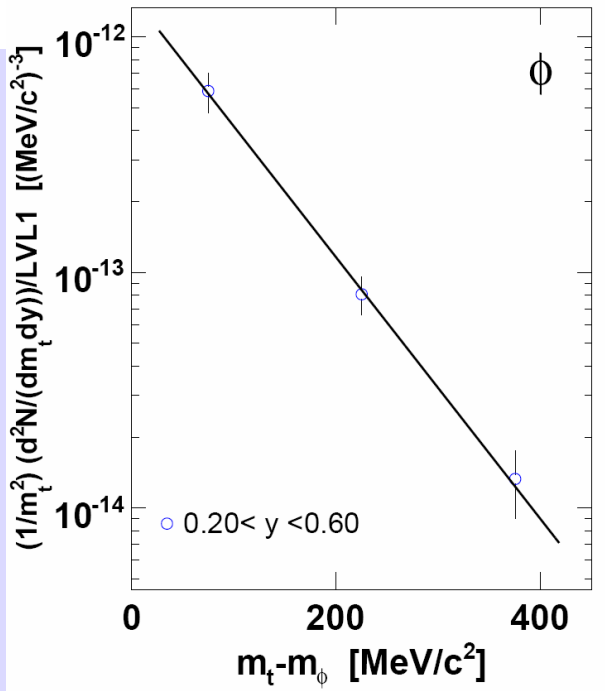
G. Agakishiev et al., EPJ A 40 (2009) 45-59

HADES

K^+, K^-, ϕ differential production rates





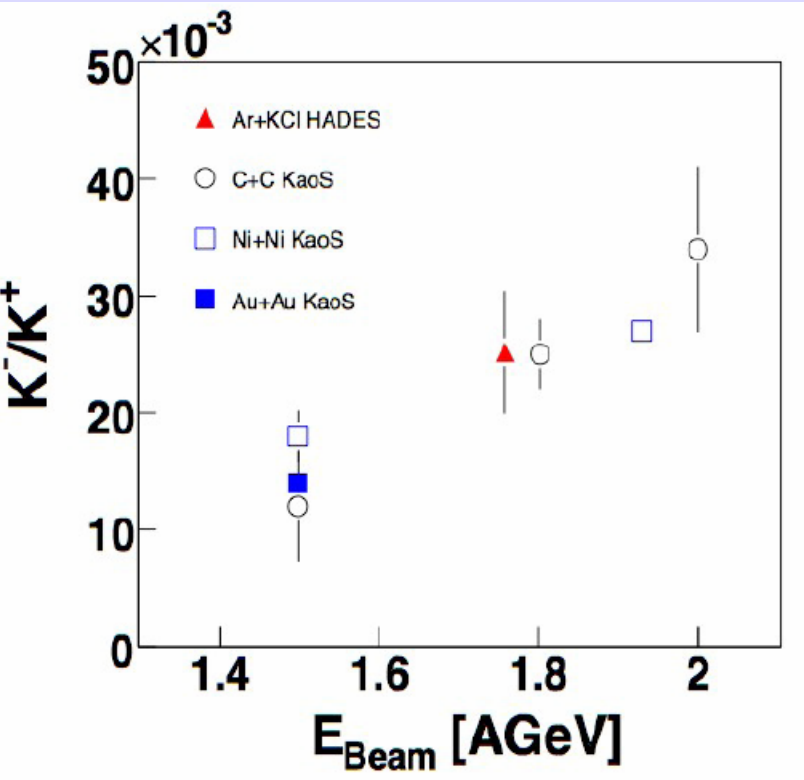


- for the first time measured in the same (large) acceptance
- ϕ/K^- =0.37±0.13 ~18% K^- comes from ϕ

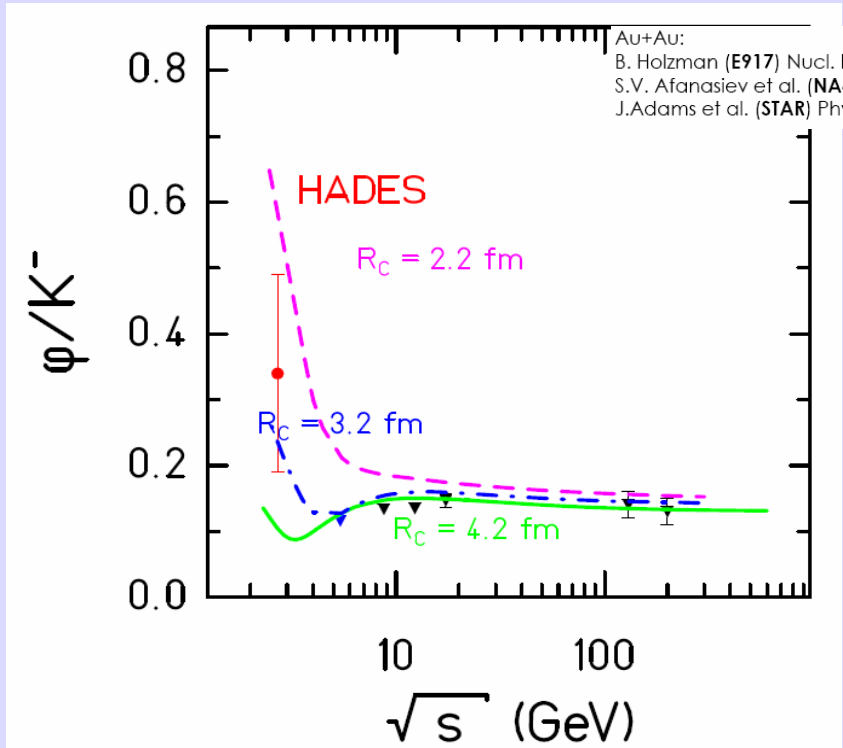
HADES

K-/ϕ ratio

- Agreement with Kaon systematics



Statistical model K. Redlich, H. Oeschler-priv.comm



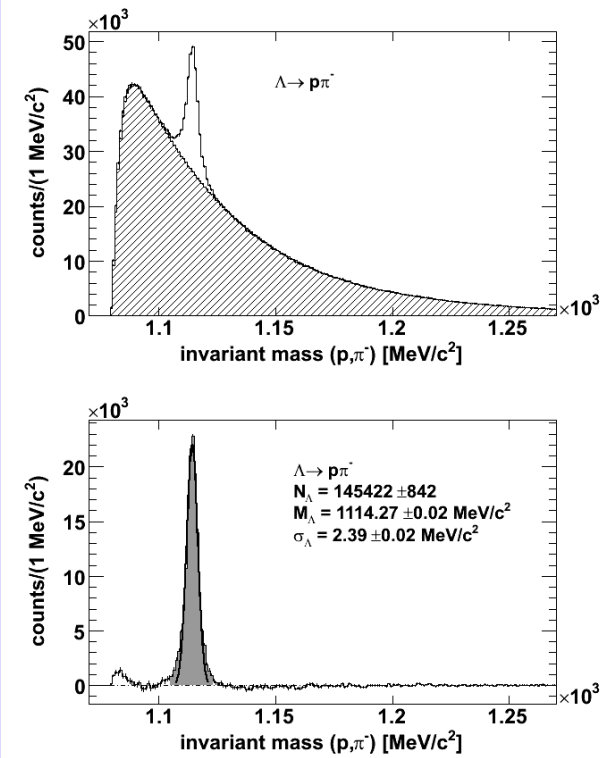
- For NN at threshold $\phi/K^- = 1.02 \pm 0.1$

ANKE coll. PHYS. REV. C **77, 015204 (2008)**

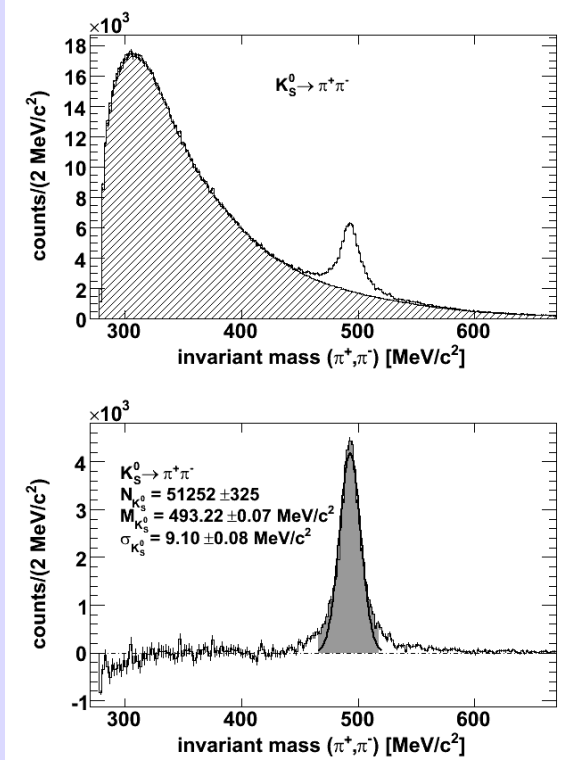
- ϕ/K^- in Ar+KCl is ~ 3 smaller -> more K^- thanks to medium (i.e strangeness exchange)
- **…**but reactions of the type NN->NNϕ and NN->NNK^+K^- (non-resonant) are important,too !

Invariant Mass Spectra of Λ and K^0

$\Lambda \to p\pi^-$



$K_S^0 \to \pi^+\pi^-$



- 145.000 Λ
- $\langle S/B \rangle \approx 0.3$
- $\sigma_\Lambda \approx 2.4\,\mathrm{MeV/c^2}$

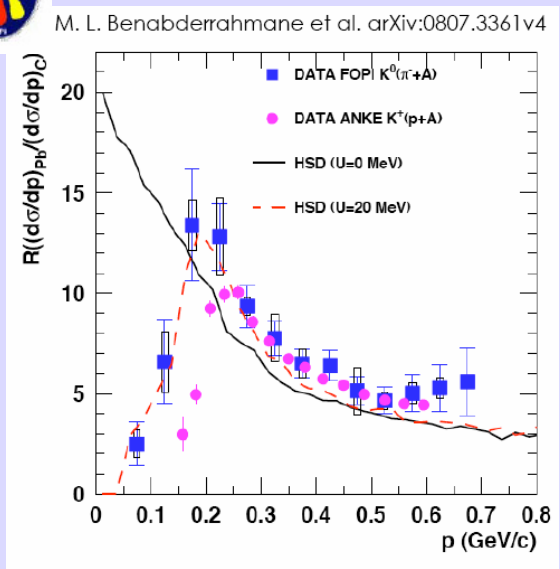
- 51.000 K_S^0
- $\langle S/B \rangle \approx 1.0$
- $\sigma_{K_S^0} \approx 9.1\,\mathrm{MeV/c^2}$

HADES

Kaon-Nucleon Potential

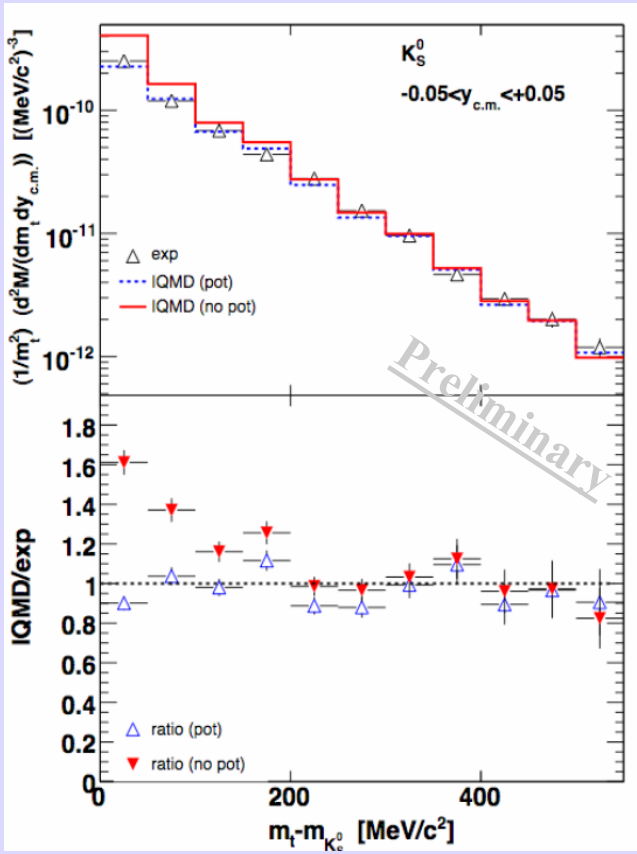
Results from FOPI↔ HSD

M. L. Benabderrahmane et al. arXiv:0807.3361v4



→KN-Potential is repulsive with a strength of U=20 MeV

Results from HADES↔ IQMD

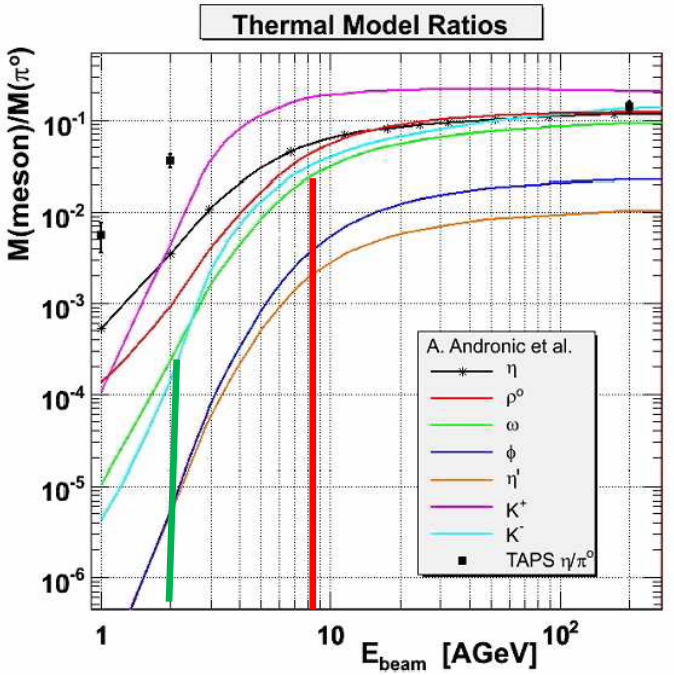


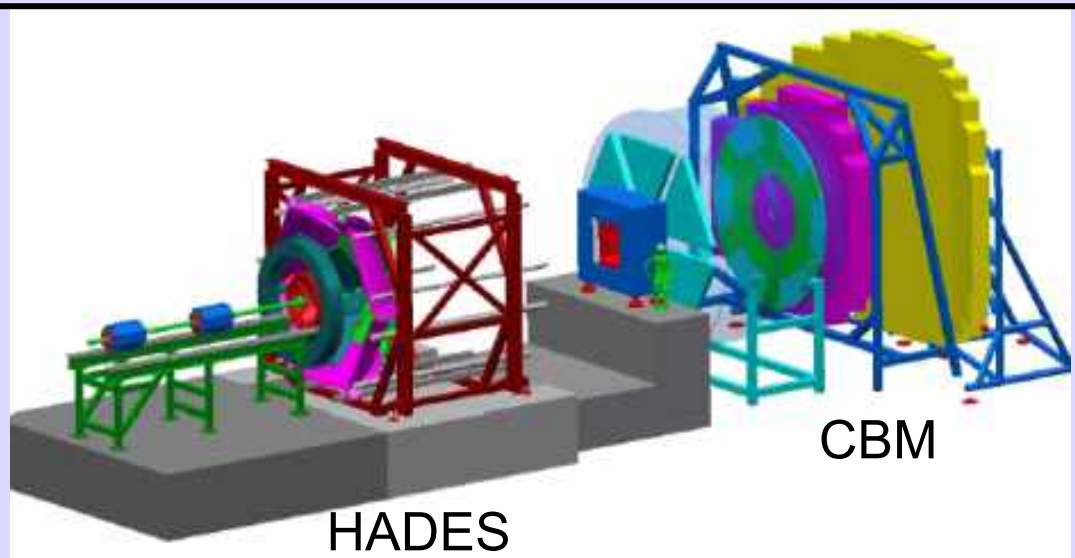
→KN-Potential is repulsive with a strength of U=30 MeV @ $\rho=\rho_0$

C. Hartnack, J. Aichelin, H. Oeschler

Future experiments

2009	**HADES upgrade: RPC TOF:** 50-80ps resolution, high granularity
2010-2012 SIS18	**Ni+Ni 1-1.93A GeV** **dielectrons, strangeness** **Ag+Ag 1.65A GeV** **Au+Au 1A GeV** **π+N, π+A** **resonances, radiative decays, strangeness**
2013- SIS100	**8A GeV**



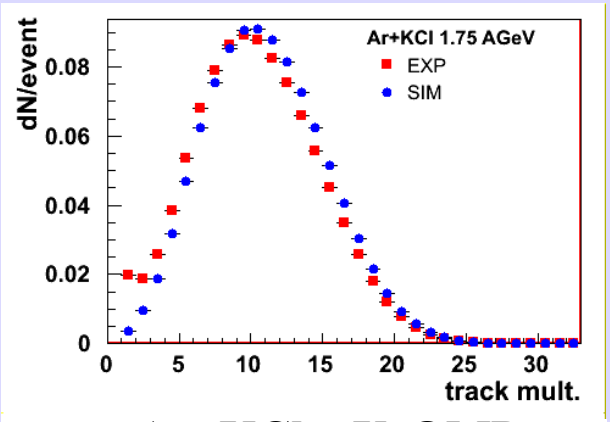


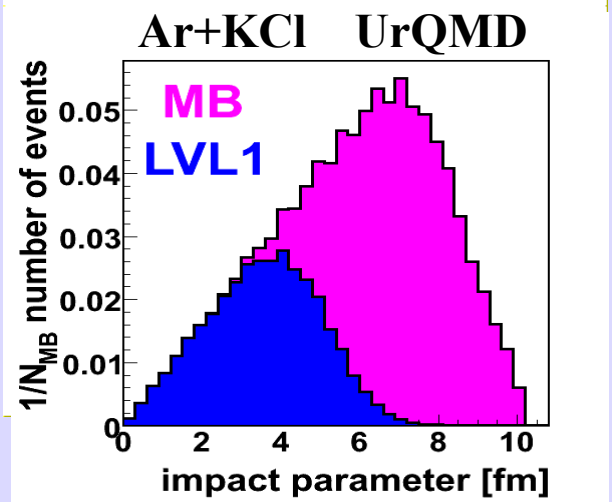
increase of M(K) by 2 orders of magnitude

Centrality selection by the LVL1 trigger

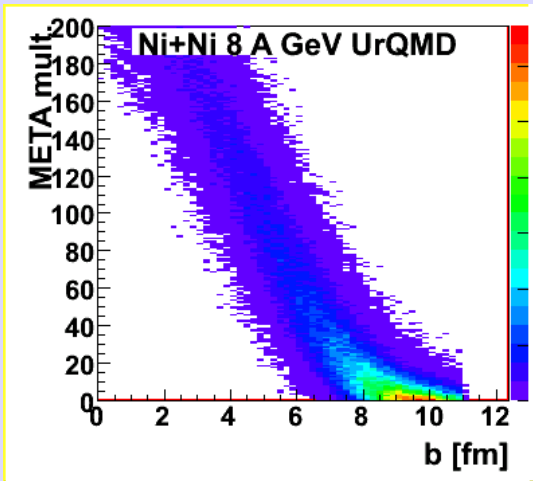
Ar+KCl 1.76 A GeV

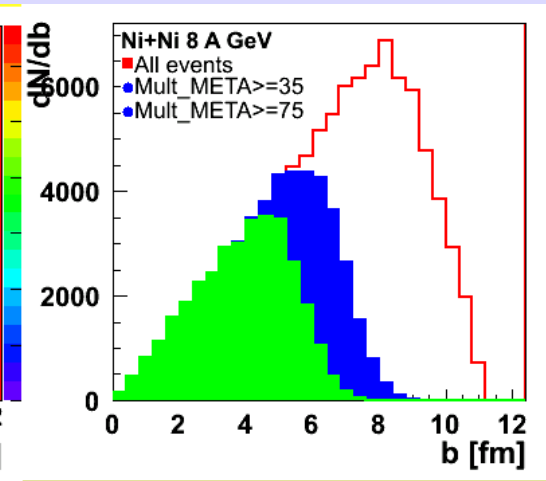
exp. and simulated multiplicities





Ni+Ni 8.0 A GeV





$M_{ch} \geq 35$	~ 50% of reactions	N_{part} increase by ~ 1.7
$M_{ch} \geq 75$	~ 33% of reactions	~ 2.0

$M_{ch} \geq 16$

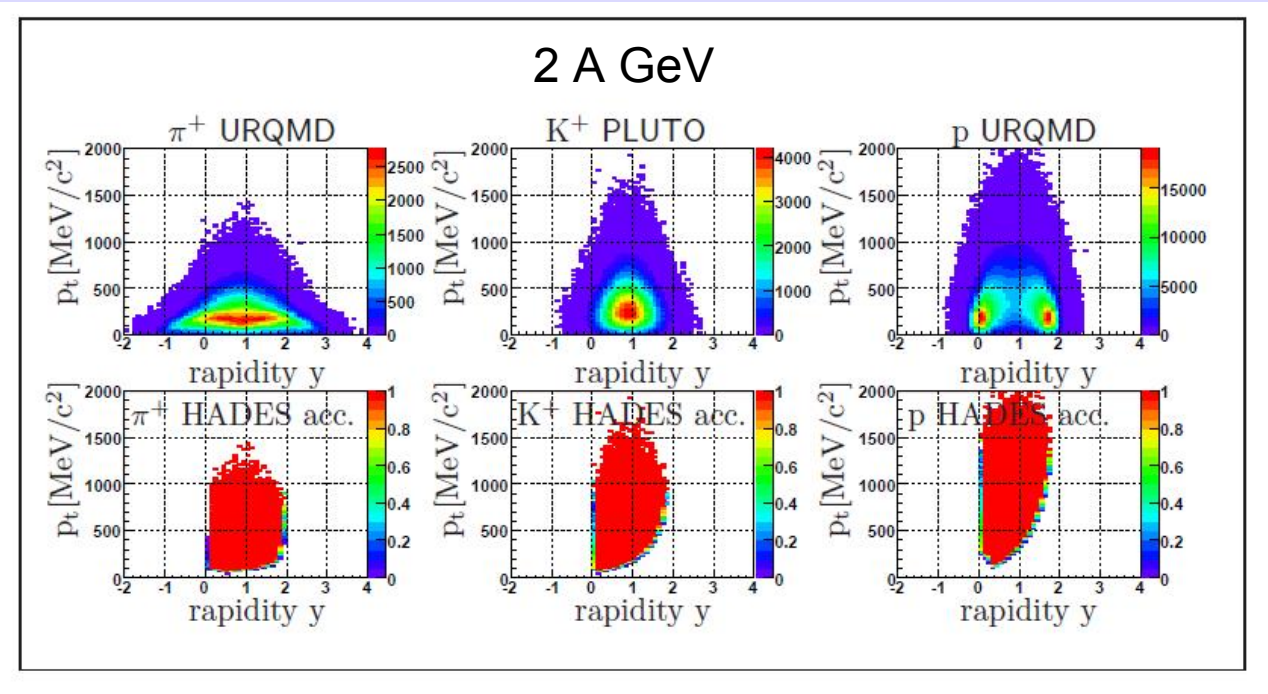
LVL1 trigger selects ~ 35% of reactions

N_{part} increase by ~ 2.0

HADES

Acceptance for hadrons

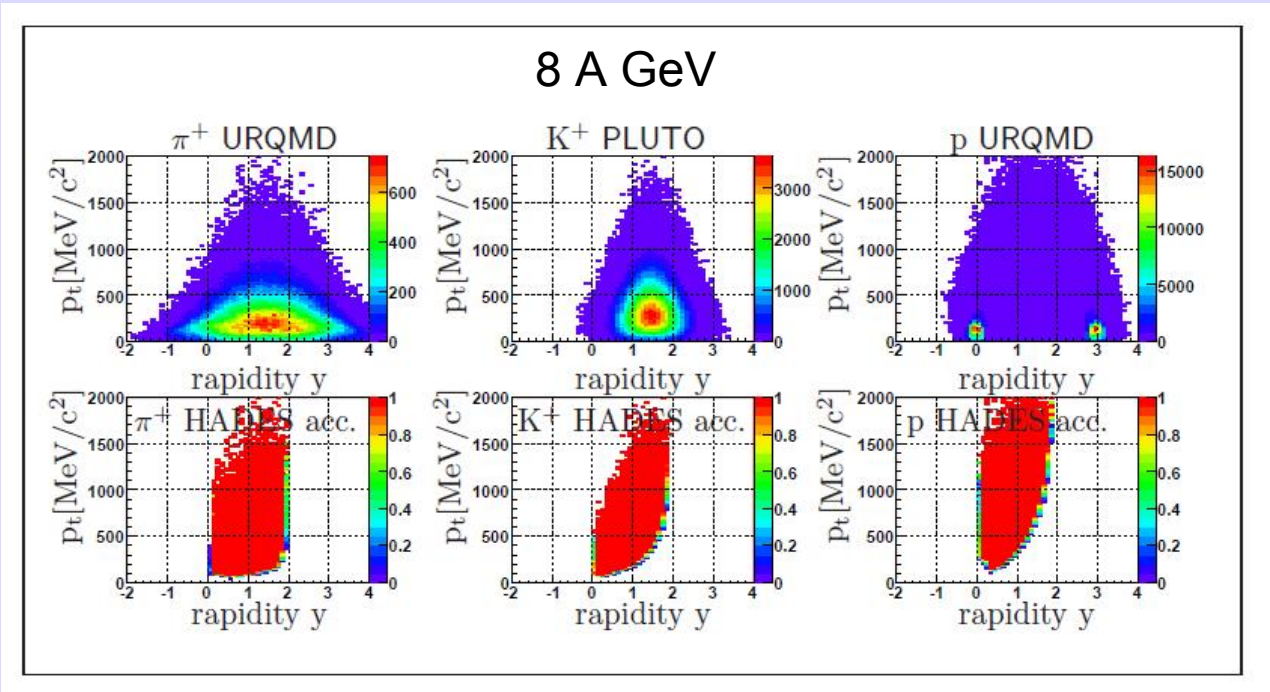
- **URQMD and PLUTO events filtered with HADES acceptance**



Acceptance for hadrons

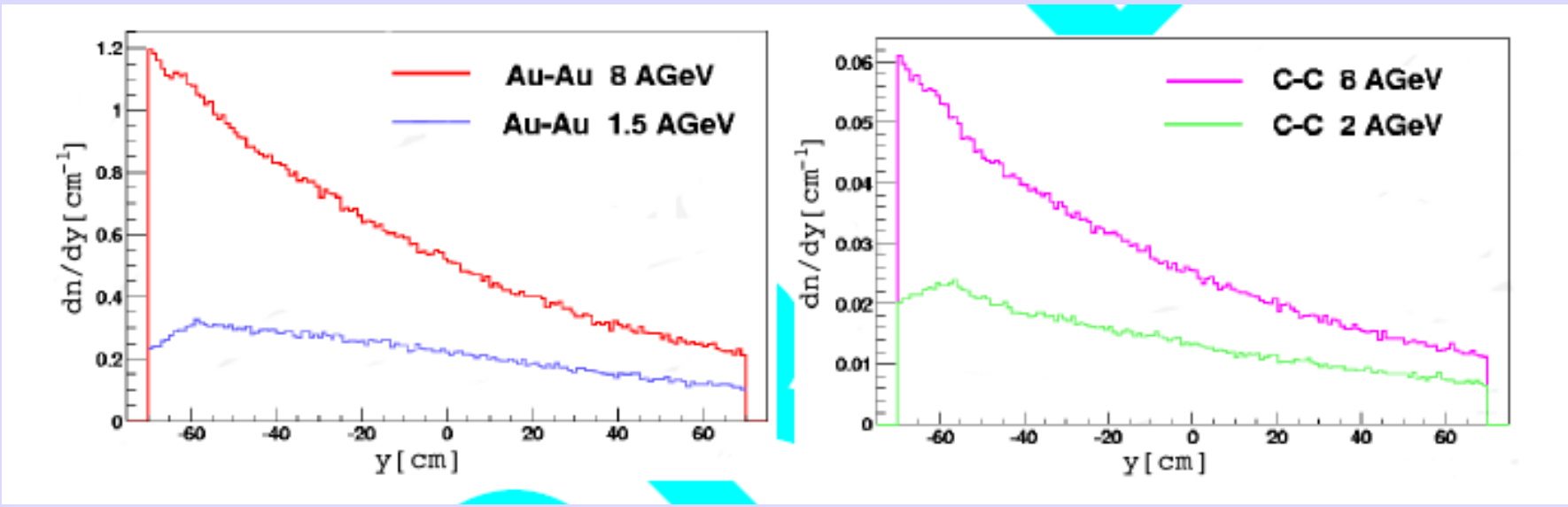
- **URQMD and PLUTO events filtered with HADES acceptance**
  - ✓ midrapidity covered at both 2.0 and 8.0 AGeV
  - ✓ 15 % reduction at 8 AGeV for π
  - ✓ 40 % reduction at 8 AGeV for K

particle	2 AGeV	8 AGeV
π^+	0.63	0.50
K^+	0.73	0.43
p	0.40	0.15



Occupancy estimation at 8 AGeV

- **Simulated events**
  - ✓ central Au+Au at 1.5 AGeV and 8 AGeV, C+C at 2.0 AGeV and 8 AGeV
  - ✓ HGeant used for a realistic detector modeling
- **Main outcome**
  - ✓ from C+C at 2.0 AGeV → Au+Au at 1.5 AGeV (SIS18) - factor of 14
  - ✓ at Au+Au at 1.5 AGeV expected 20% double hit probability !!!
    → corresponds to Ni+Ni at 8 AGeV - heaviest system at SIS 100

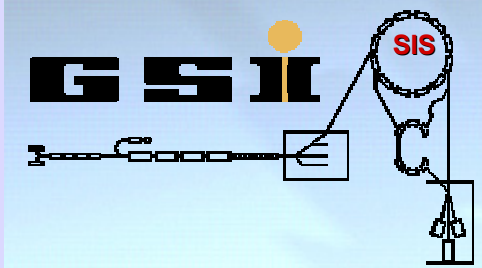


Summary

- **hadron spectroscopy by HADES**
  - ✓ high quality, wide acceptance and high statistic data taken for $\pi^{\pm}$, Λ, $K^{\pm}$, K^0, Φ from Ar+KCl @ 1.76A GeV
- **upgrade projects finished by 2009**
  - ✓ better time resolution (PID) and granularity
  - ✓ ready for ^{197}Au+ ^{197}Au@SIS18
  - ✓ realistic simulations are being performed
- **from SIS18 to SIS100**
  - ✓ looks feasible
  - ✓ Ni+Ni – the heaviest system planned at SIS100

HADES

The Collaboration

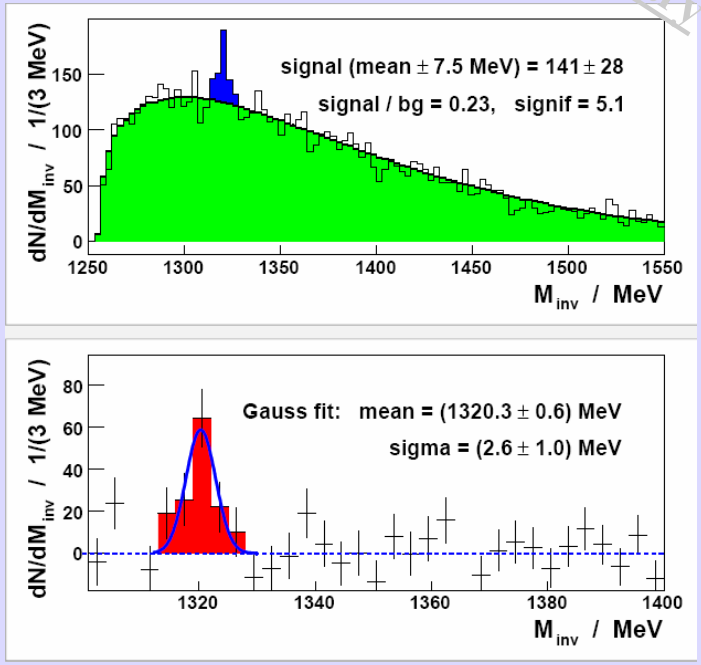


- Catania (INFN - LNS), Italy
- Cracow (Univ.), Poland
- Darmstadt (GSI), Germany
- Dresden (FZD), Germany
- Dubna (JINR), Russia
- Frankfurt (Univ.), Germany
- Giessen (Univ.), Germany
- Milano (INFN, Univ.), Italy
- München (TUM), Germany
- Moscow (ITEP,MEPhI,RAS), Russia
- Nicosia (Univ.), Cyprus
- Orsay (IPN), France
- Rez (CAS, NPI), Czech Rep.
- Sant. de Compostela (Univ.), Spain
- Valencia (Univ.), Spain
- Coimbra (Univ.), LIP, Portugal

HADES

$$\Xi^- \rightarrow \Lambda\pi^-$$

Preliminary



R. Kotte

Under investigation...!

HADES