CBM physics at SIS100

Motivation unchanged:
Strangeness not yet understood.

Goal:
Systematic high statistics measurements for

- **Particle yields**
- **Particle flow**
- **Search for (multi) strange baryons**

http://www.gsi.de/documents/DOC-2006-Oct-48-2.ppt

CBM @ SIS100

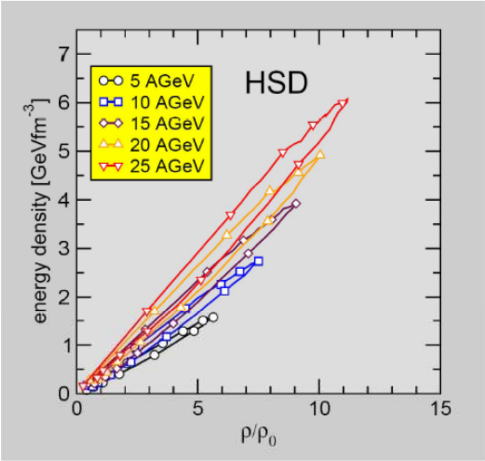
Motivation
global conditions
effective masses and in-medium potentials

Evidence for medium effects at SIS18
(anti)kaon yield
(anti)kaon flow

'Review' of AGS results
flow of strange particles

Exotic effects at 'low' energies
exited hyperon states
deeply bound kaonic states

E.Bratkovskaya et al.



Discussion: Hadronic probes program at SIS100 (2 – 10AGeV, $\sqrt{s_{NN}}$<4.5 GeV)
staging scenario, setup, acceptance
physics at SIS18* (FAIR phase 1a) ?

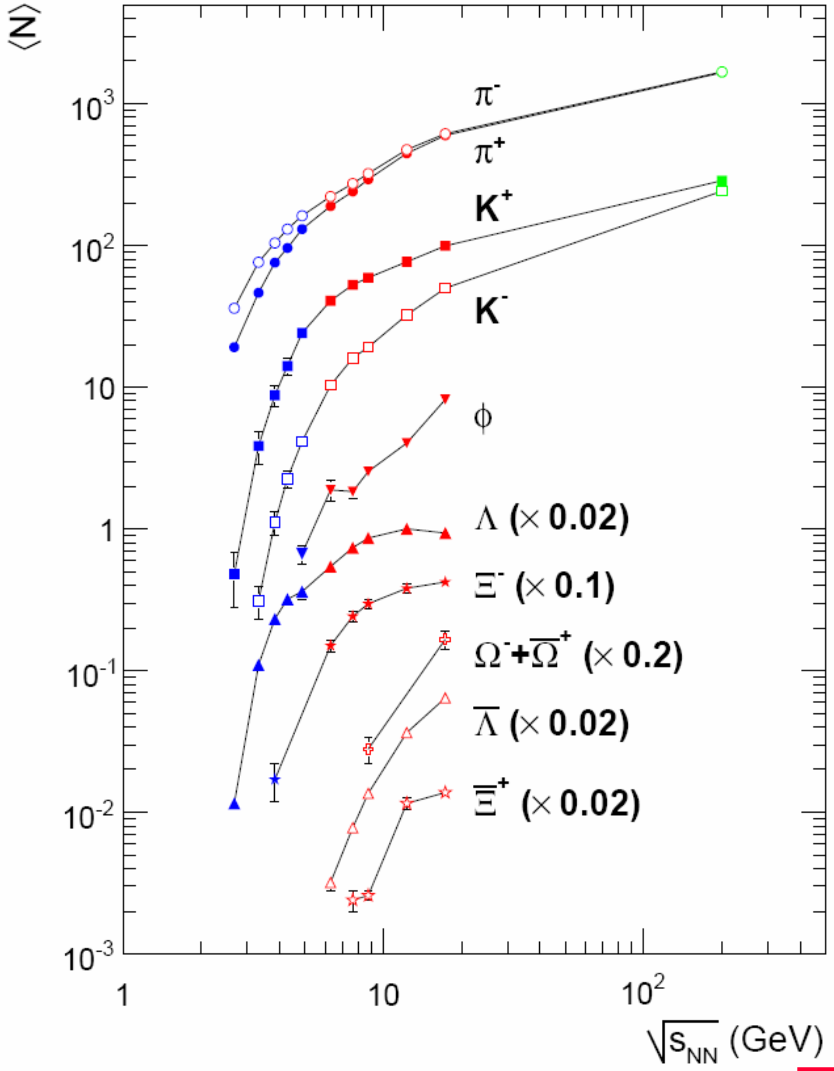
Conclusion

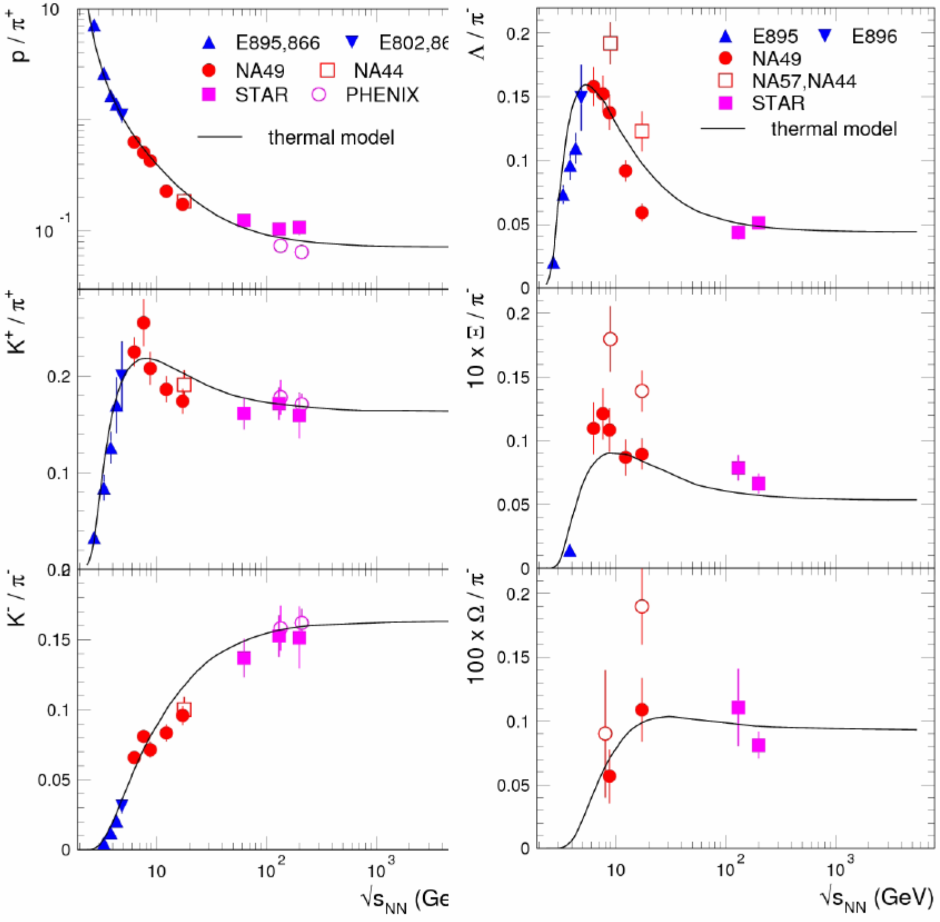
CBM Collaboration Meeting, Strasbourg, September 06 N.Herrmann, Uni-HD 1/22

Physics highlights:

Equilibration mechanism
In-medium effective masses / potentials / EOS
Bound strange baryonic states

Excitation function of particle production



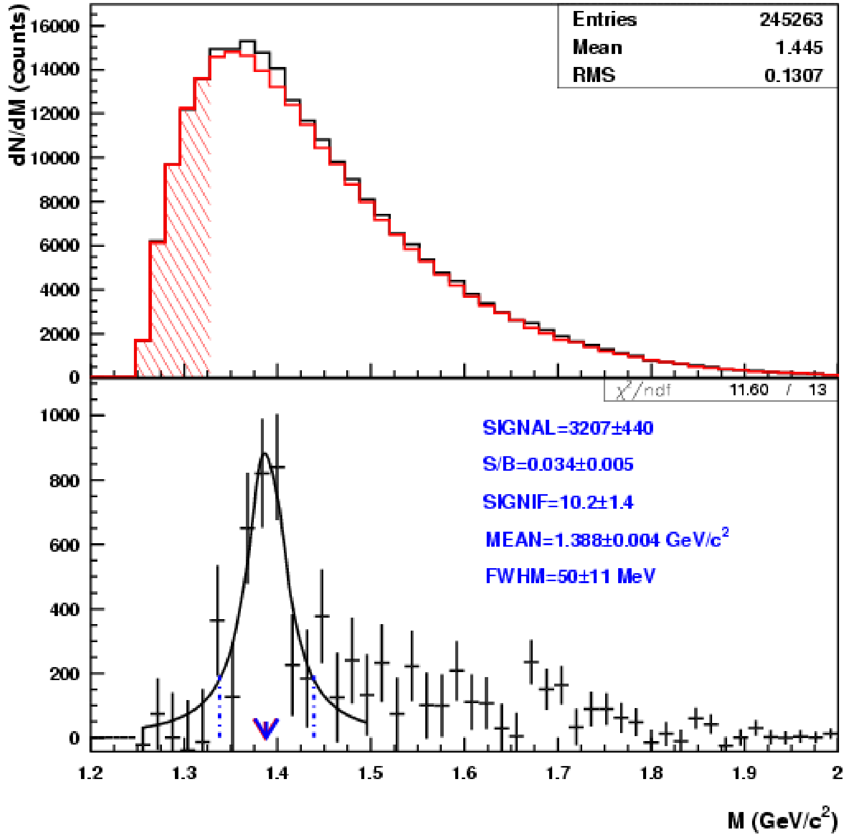


… not many particle species measured below 10 AGeV …
How about Φ, K^*, Σ^*, … ?

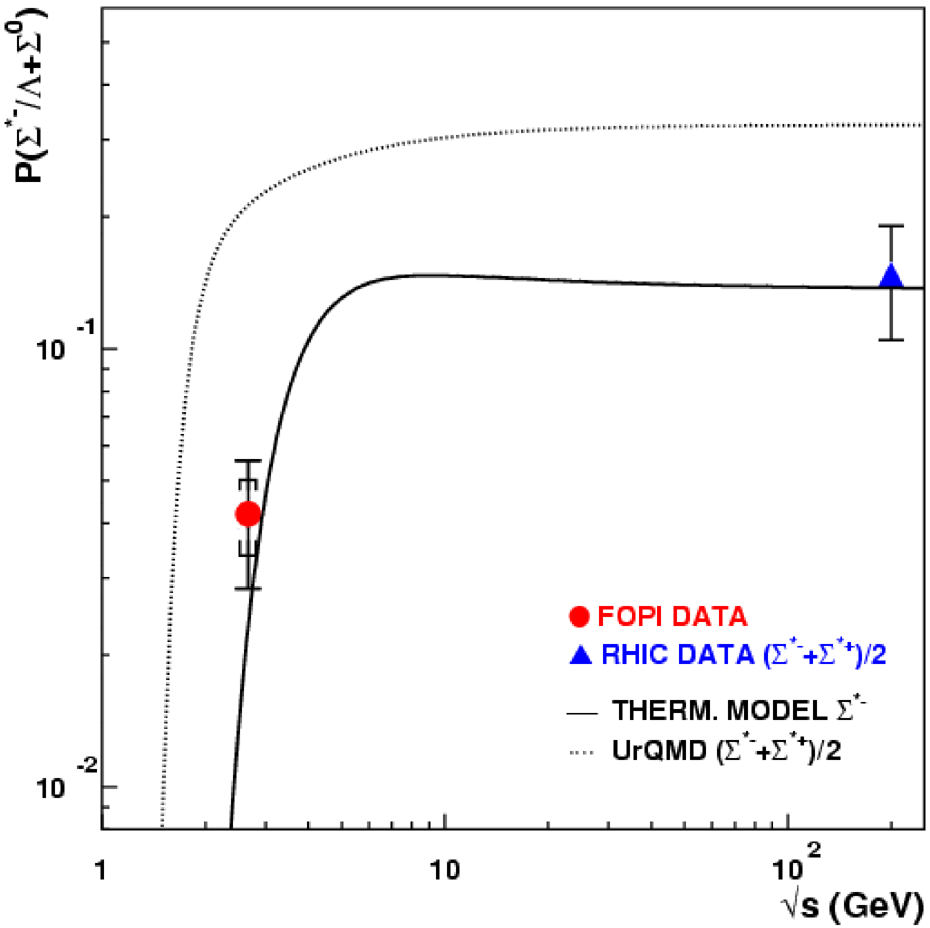
Production of strange baryon resonances

Invariant mass distribution of $\Lambda + \pi^{\pm}$

X. Lopez et al. (FOPI), PRC 76, 052203(R) (2007)



FOPI - data: Al+Al @ 1.92AGeV
($3 \cdot 10^8$ events,
14 days data taking)



RHIC DATA: S.Salur, nucl-ex/0410039

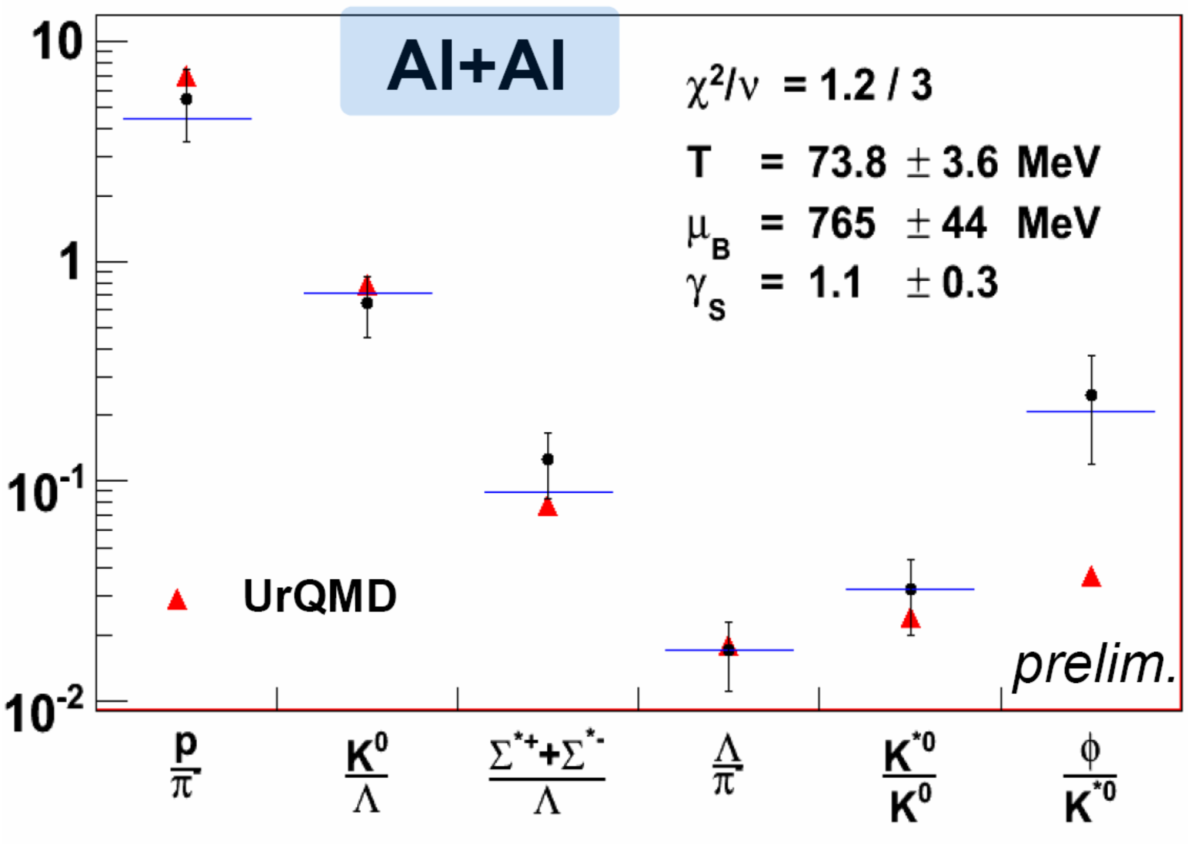
THERM. MOD.: .A. Andronic, private communication

URQMD MOD.: M. Bleicher, NPA 715 (2003) 85

Equilibration mechanism

FOPI data for Al+Al at 1.92 AGeV

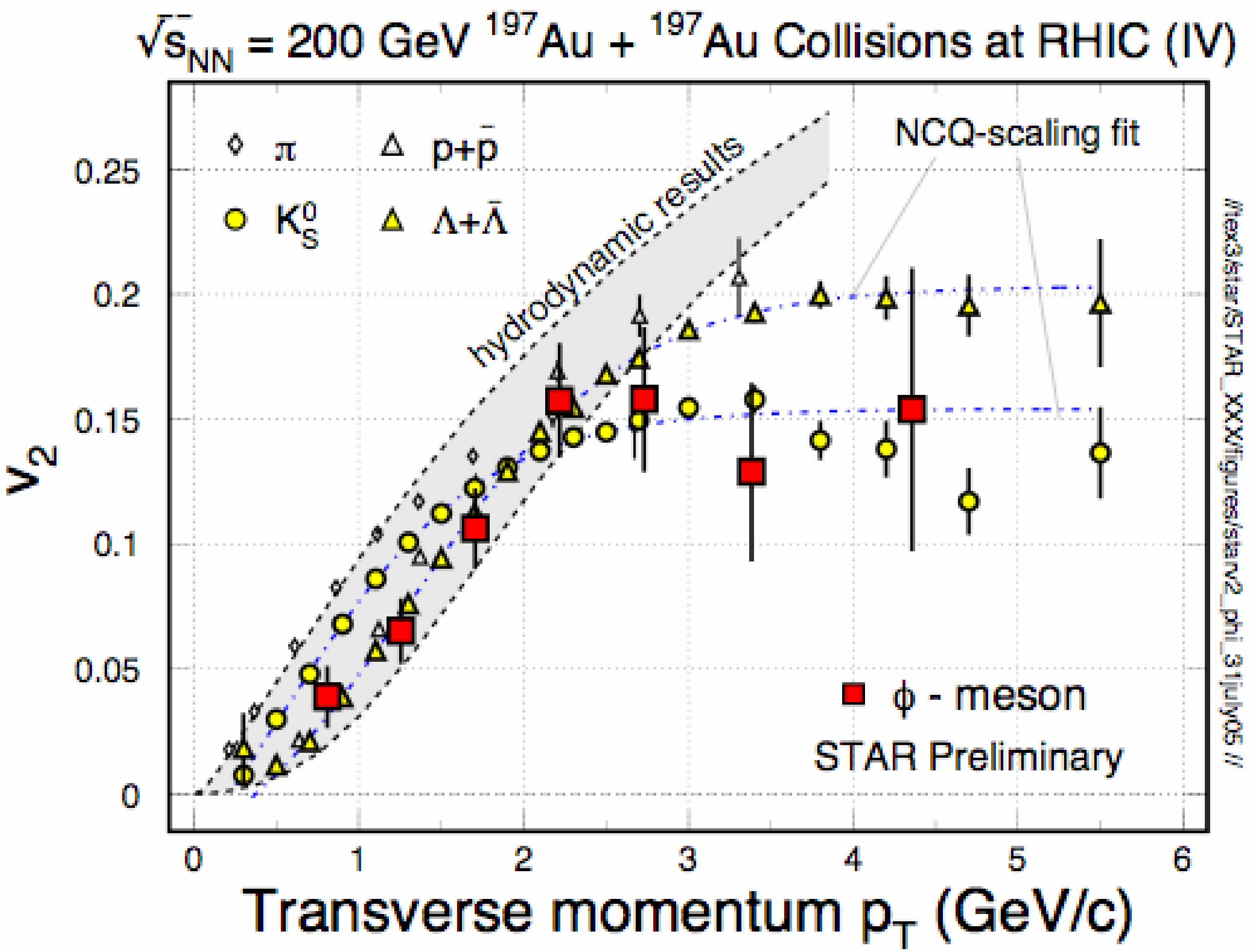
Statistical model analysis with THERMUS code (K. Piasecki)



How can the phase space be populated statictically?
Problem with data reconstruction?

⇒ **Measure full phase space with sufficient statistics**
System mass dependence

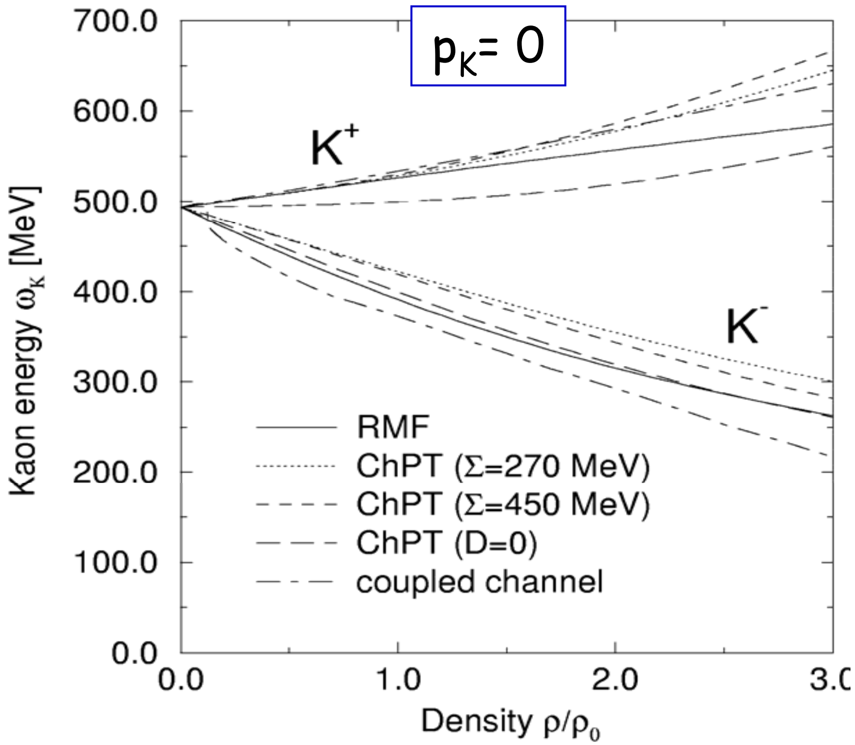
Φ – meson flow



Ultimate goal: triple differential cross section
consistent description of all particles species → theory

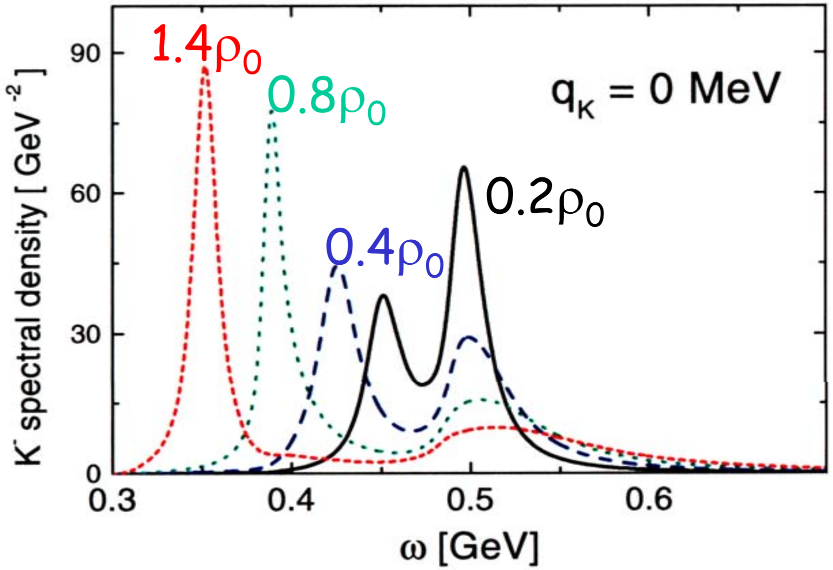
Kaons in hadronic matter

in-medium energy



spectral function of antikaons in dense matter

Coupled channel calculation
M. Lutz, Phys. Lett. B426 (1998) 12



$$\omega_{K^\pm}(p,\rho) = \left(m^{*2} + p^2\right)^{\frac{1}{2}} = U + \left(m_K^2 + p^2\right)^{\frac{1}{2}}$$

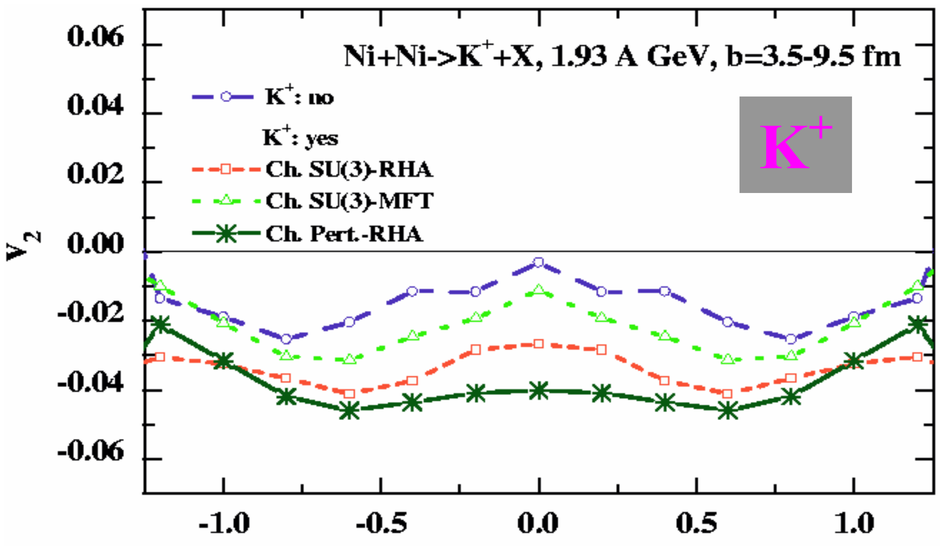
effective mass **Kaon potential**

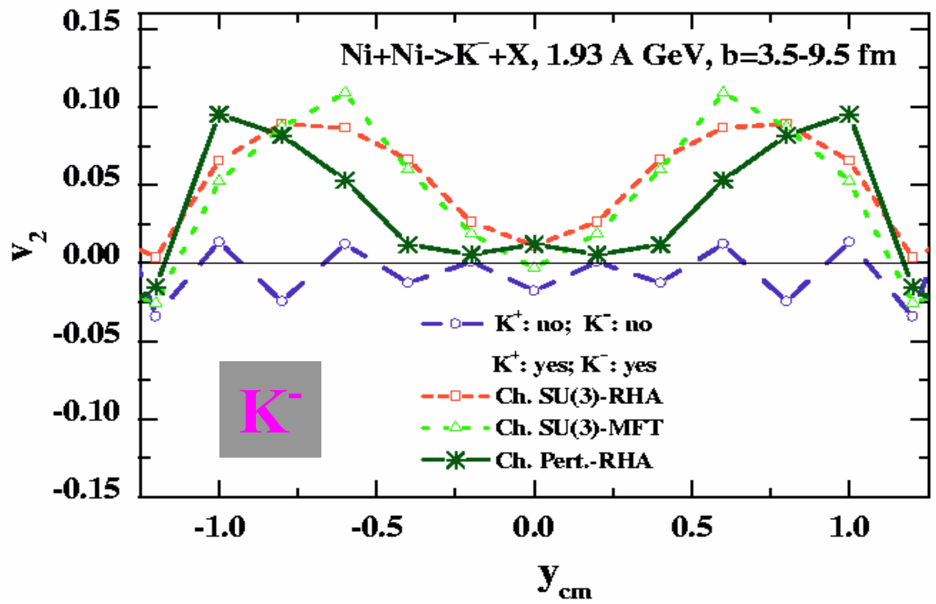
Production: P ~ exp (-m*/T) → K-yields

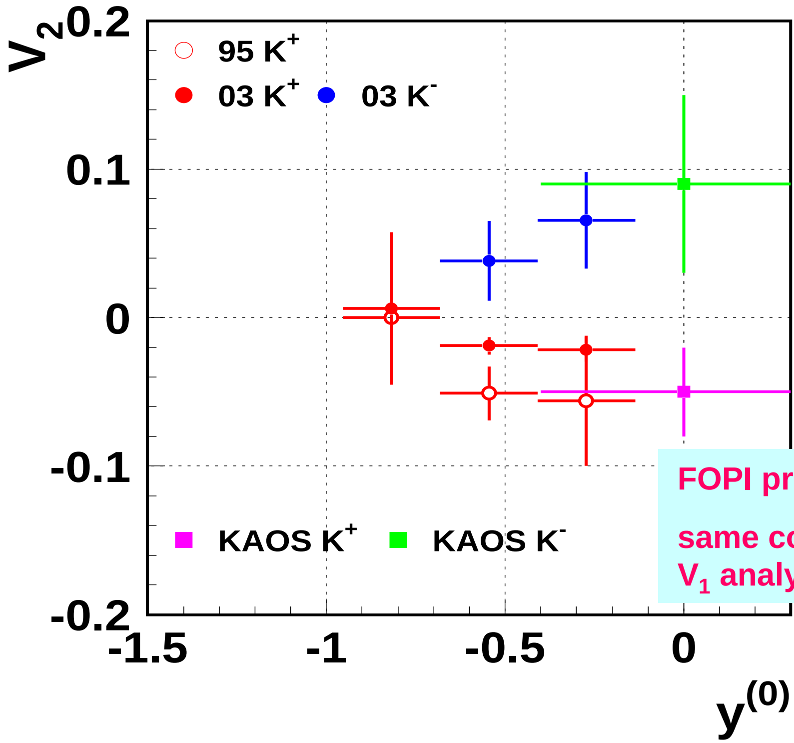
Propagation: F=-∇U → K-flow

Kaon and antikaon elliptic flow

A. Mishra *et al*. PRC 70(2004) 044904







KAOS data:

F. Uhlig *et al.* PRL 95(2005) 012301

FOPI preliminary

same condition as V_1 analysis

Kaon and antikaon have different sign.

Antikaon elliptic flow strongly in-plane.

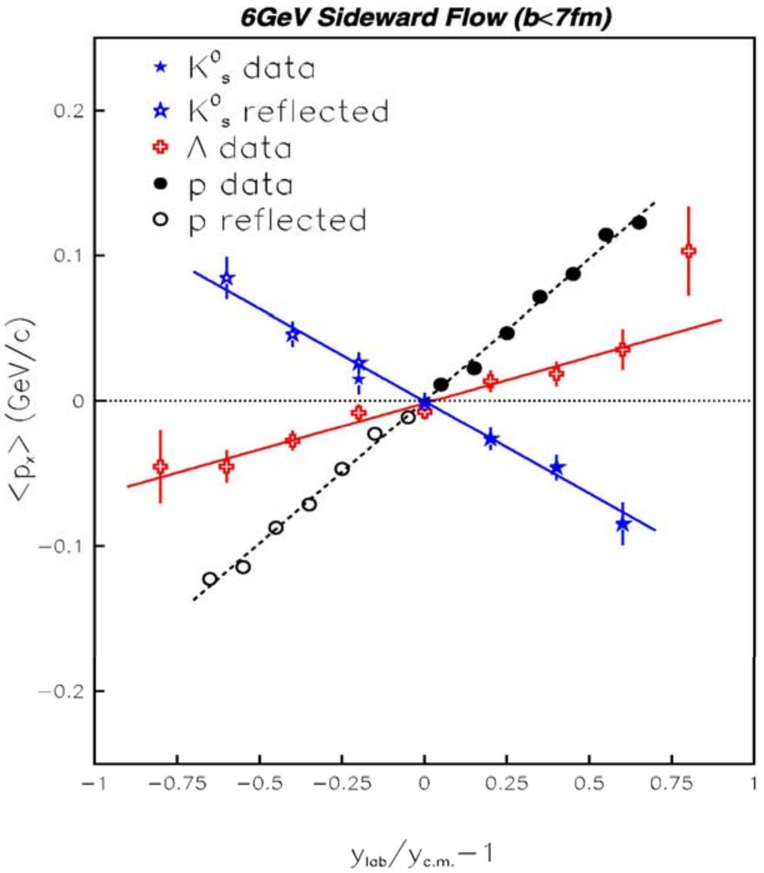
Available statistics in FOPI (2008):

$N_{ev} \sim 10^8$, $K^- \sim 5000$, $K^+ \sim 95000$

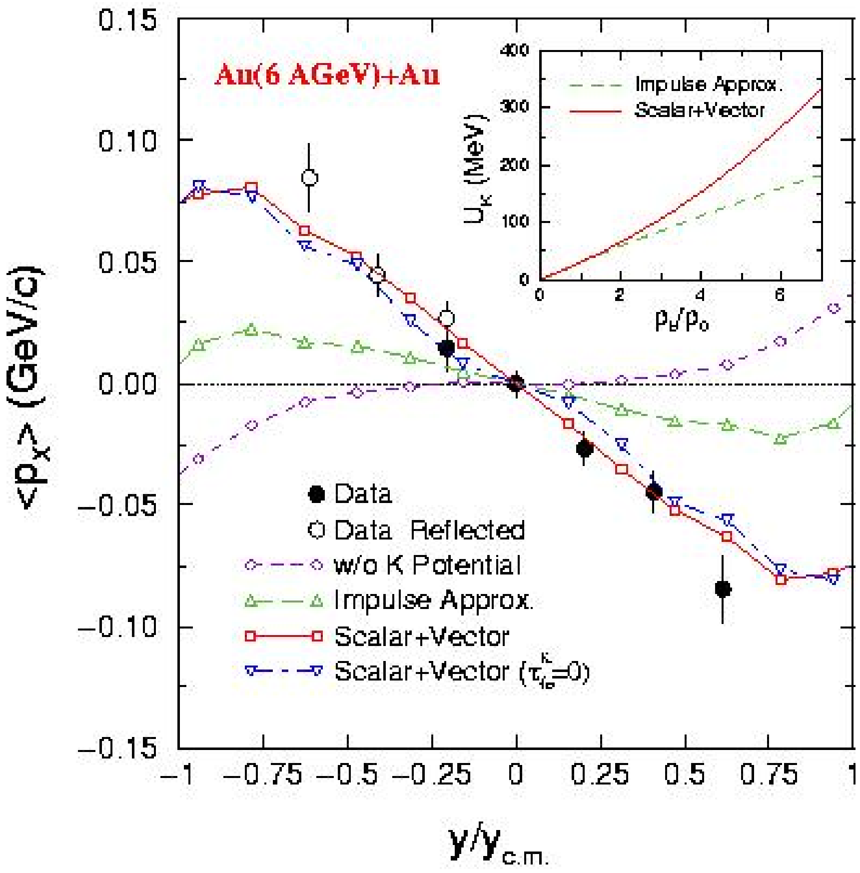
For relevant statistical errors: $N(K^-) > 50000$!

Kaon/Lambda sideflow at 6AGeV

Data: P. Chung et al. (E895), PRL85, 940 (2000)



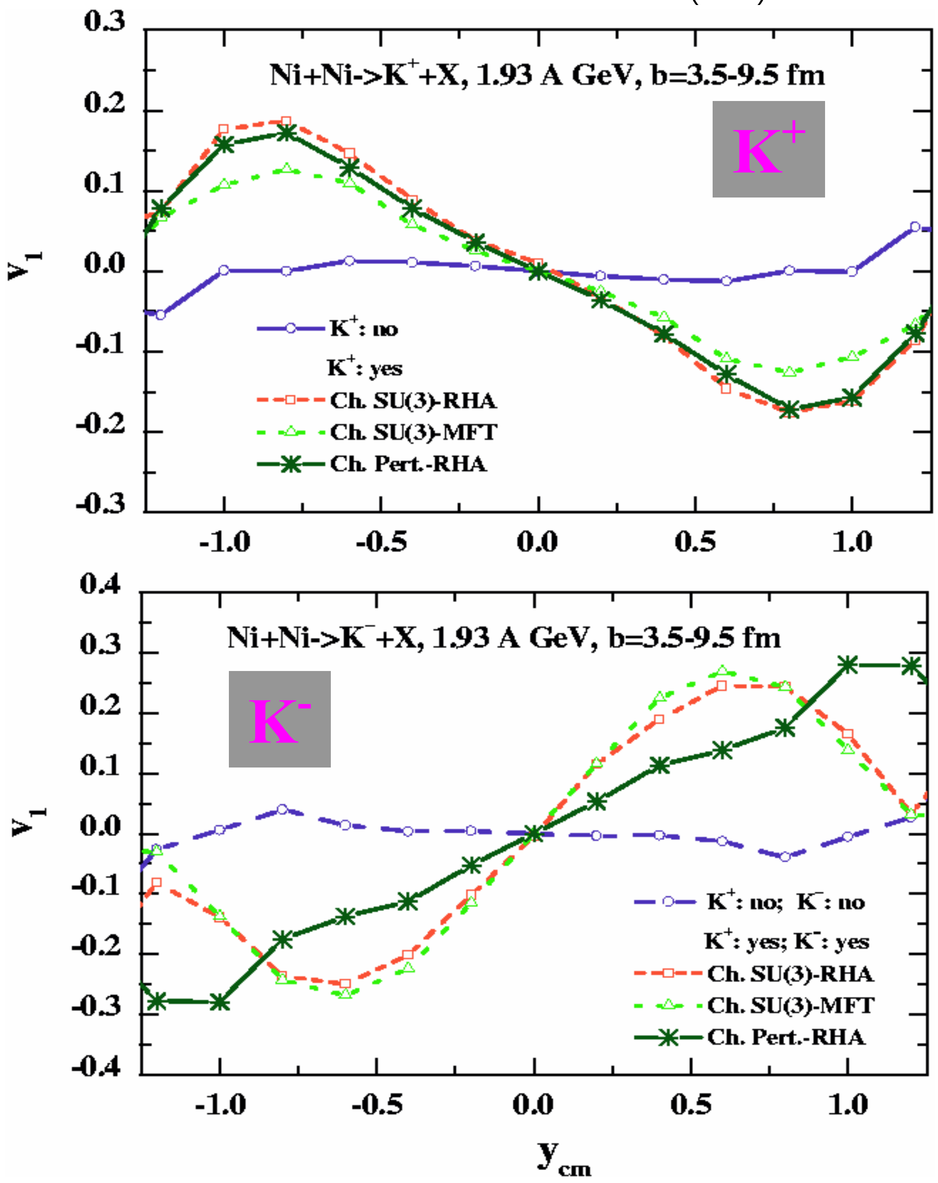
Theo: S. Pal et al., Phys.Rev.C62:061903, (2000)

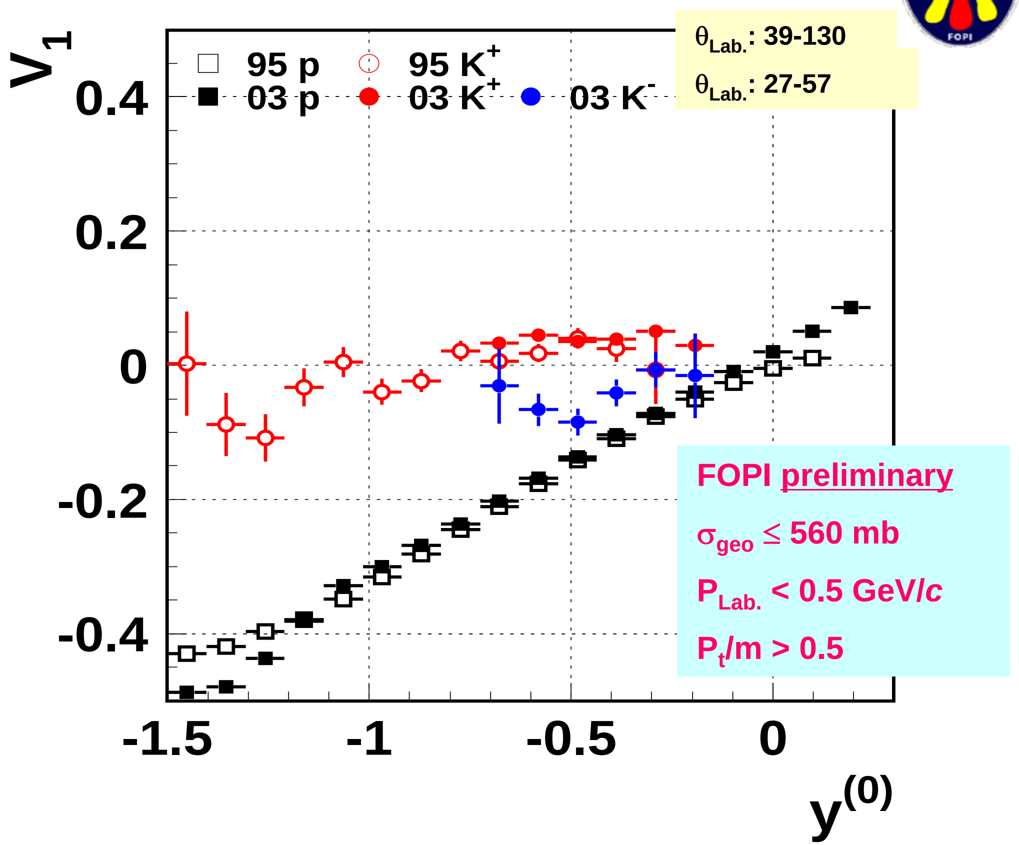


Very strong kaon antiflow signal, as big as proton flow (opposite sign)!

Kaon and Antikaon sideflow

A. Mishra *et al*. PRC 70(2004) 044904





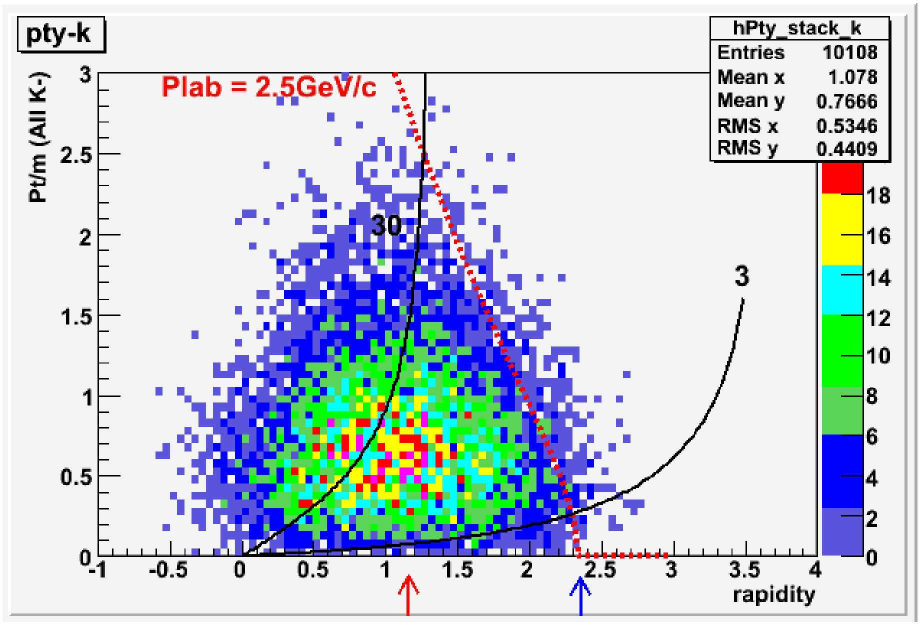
K^- - sideflow shows non monotoneous rapidity dependence.

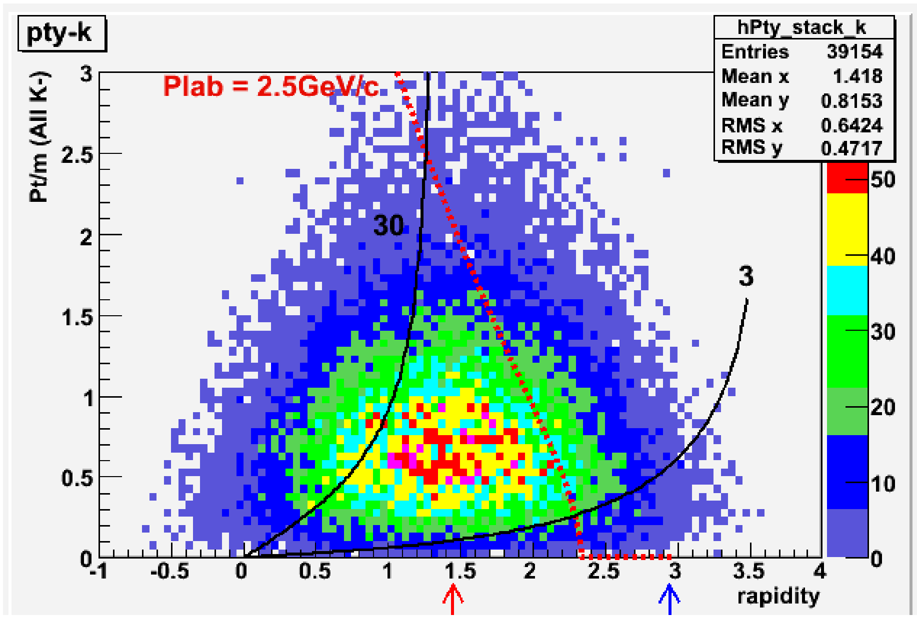
$K^{\pm}$, $\pi^{\pm}$, p measurement with large phase space coverage and with sufficient statistics needed.

Kaon acceptance for CBM @ SIS100

URQMD acceptance simulations:

4AGeV **8AGeV**





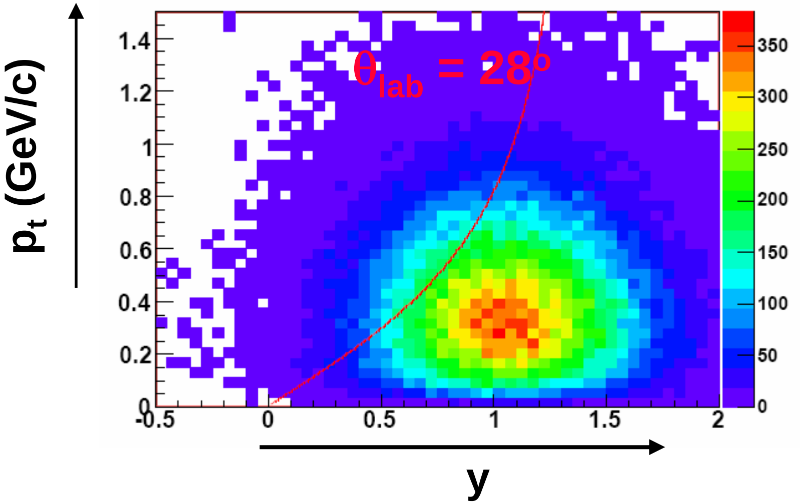
Charged Kaon acceptance with 3σ – TOF separation:

E_{lab} (AGeV)	4	6	8
ε	77%	64%	55%

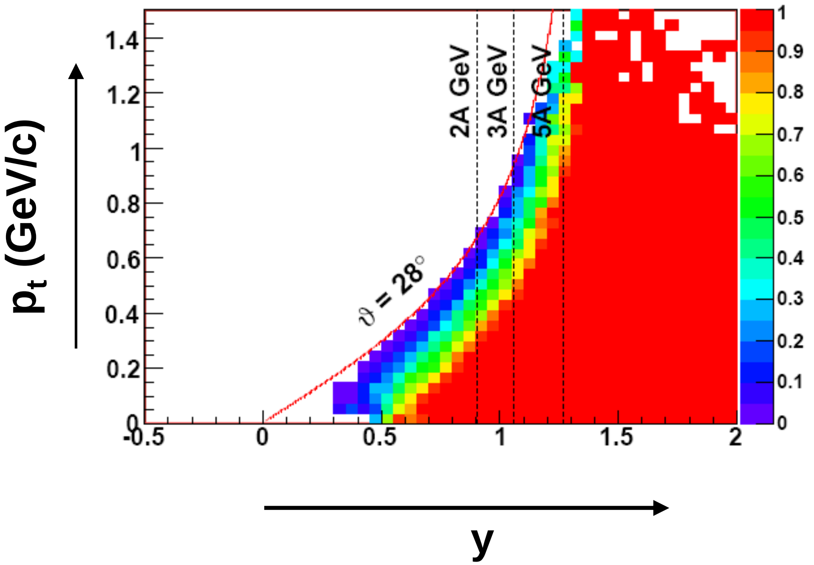
Coverage of low – p_t range of the spectrum !
However:
Limited p_t acceptance at midrapidity (e.g. for $v_2(p_t)$) for E_{beam} < 4 AGeV

CBM geometrical acceptance

Pluto simulations
(K. Piasecki, PI-HD)



Thermal Φ – source at 3 AGeV

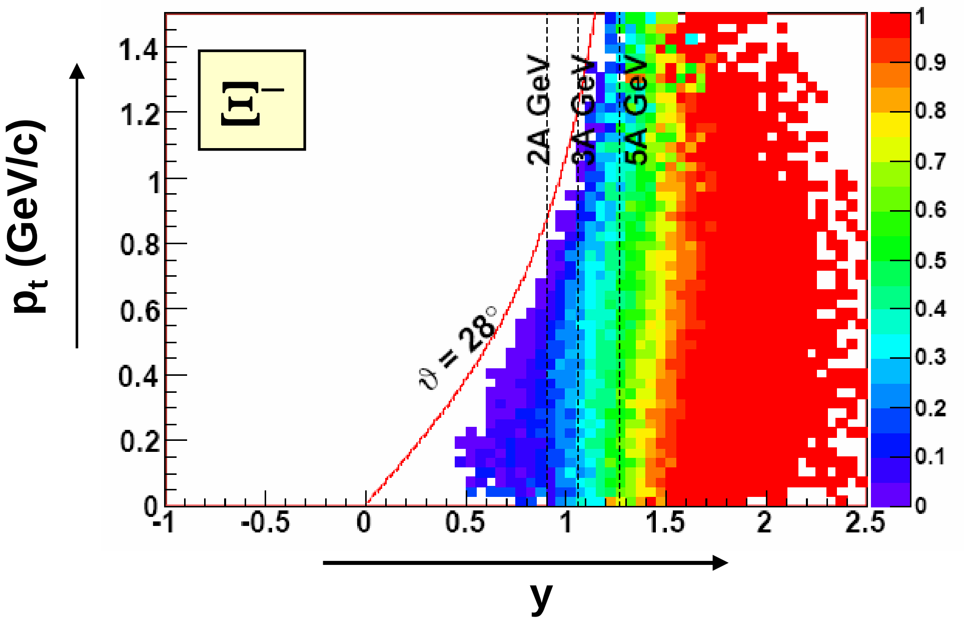


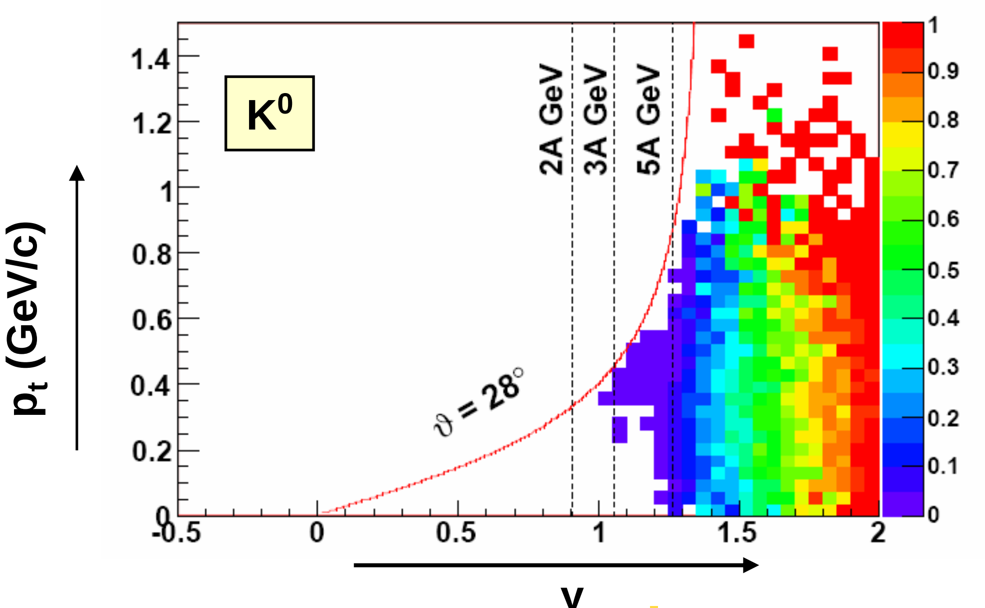
Geometrical acceptance efficiency

Only upper polar angle limitation for decay products is considered !

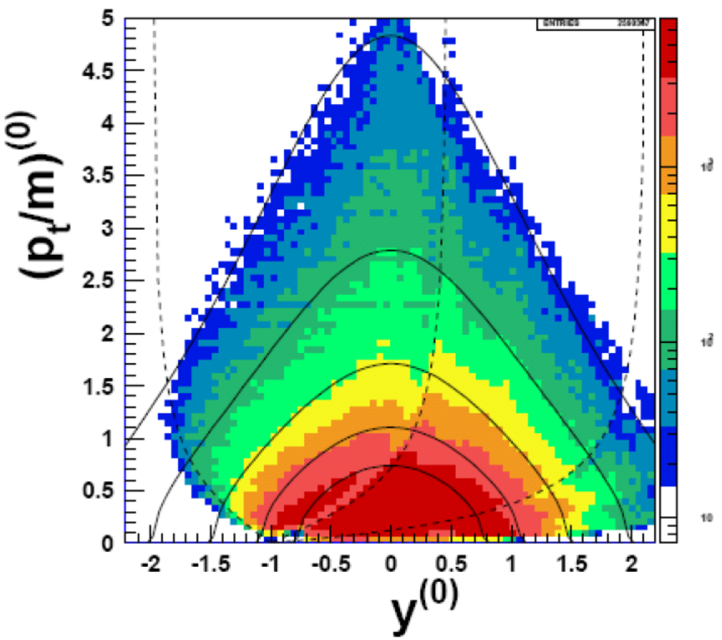
Geometrical acceptance (cont'd)

Efficiency





Relevant range from
Ni+Ni at 1.93 AGeV



Measure up to $p_t/m < 2$

Motivation of high density kaonic clusters

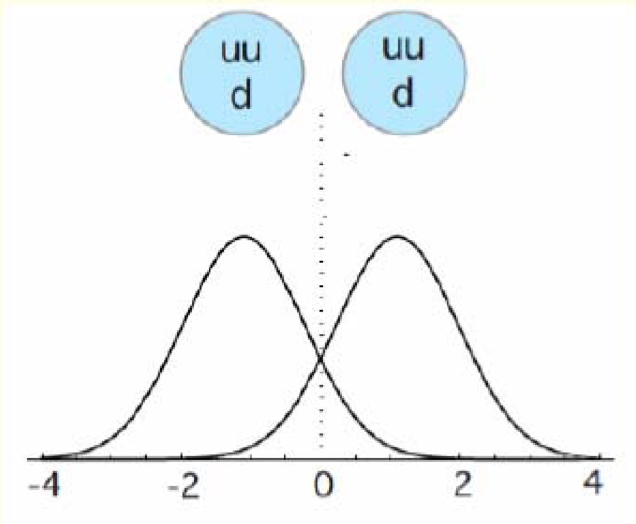
T.Yamazaki, HFD2006

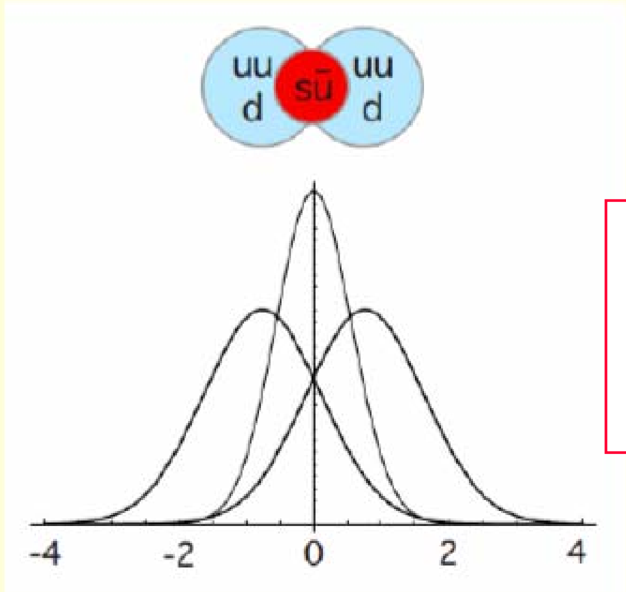
K^{bar} Nuclear Clusters $\rho_{av} \sim 3\,\rho_0$!!

Why high-density nuclei possible ?
Against the nuclear physics "law" of ρ = const.

Normally: N-N hard-core:
quark Pauli blocking
+ gluon entanglement

Exceptional:
K^- = s u^{bar}: no u,d quark:
no Pauli repulsion; strong attraction in u-u^{bar} and d-d^{bar}



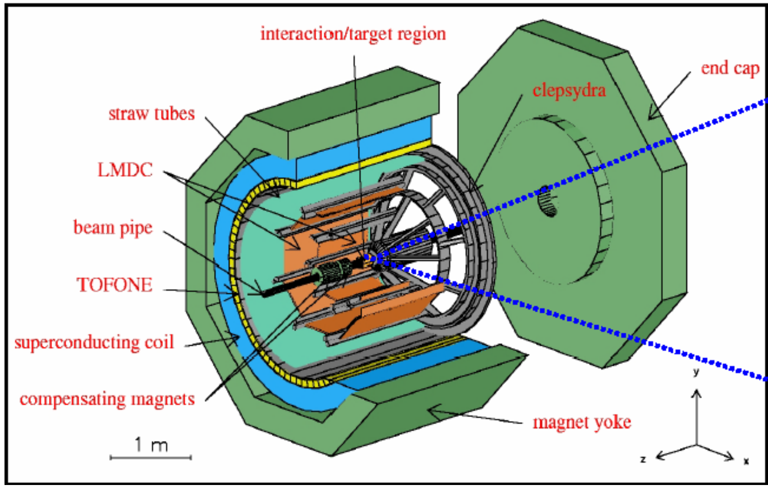


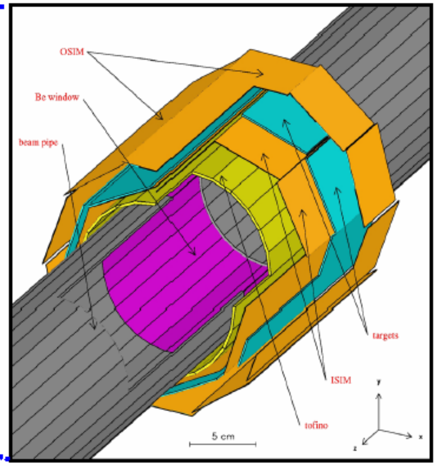
Prediction of bound states based on deep optical potential:
Y. Akaishi, T.Yamazaki, Phys.Rev.C65, 044005 (2002), Phys.Lett.B535, (2002)

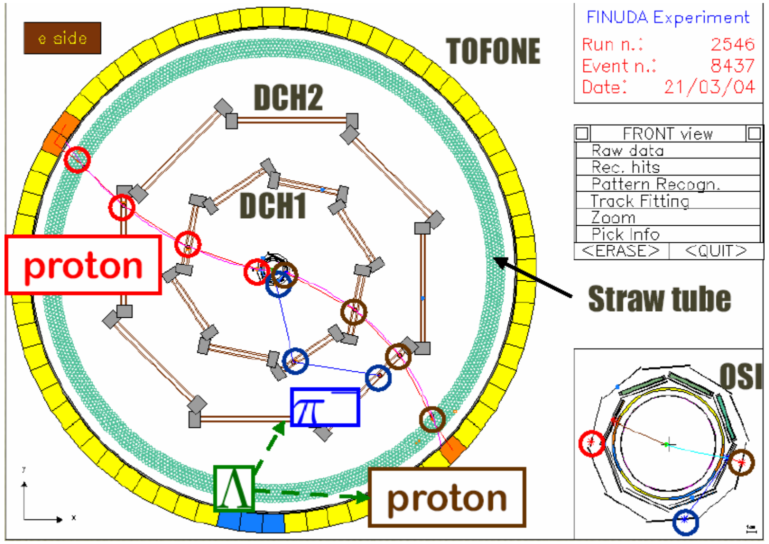
Evidence for $(ppK^-)_{bound}$ by FINUDA @ DaΦne

Invariant mass spectroscopy
$ppK^- \rightarrow \Lambda + p$

M. Agnello et al.,
PRL 94, 212303 (2005)







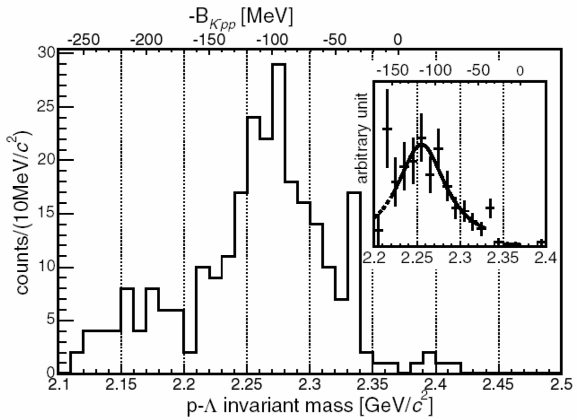


FIG. 3. Invariant mass of a Λ and a proton in back-to-back correlation ($\cos\theta^{\mathrm{Lab}} < -0.8$) from light targets before the acceptance correction. The inset shows the result after the acceptance correction for the events which have two protons with well-defined good tracks. Only the bins between 2.22 and 2.33 GeV/c^2 are used for the fitting.

Production probability:

P·BR = 0.1% per stopped K^-

Peak parameter:

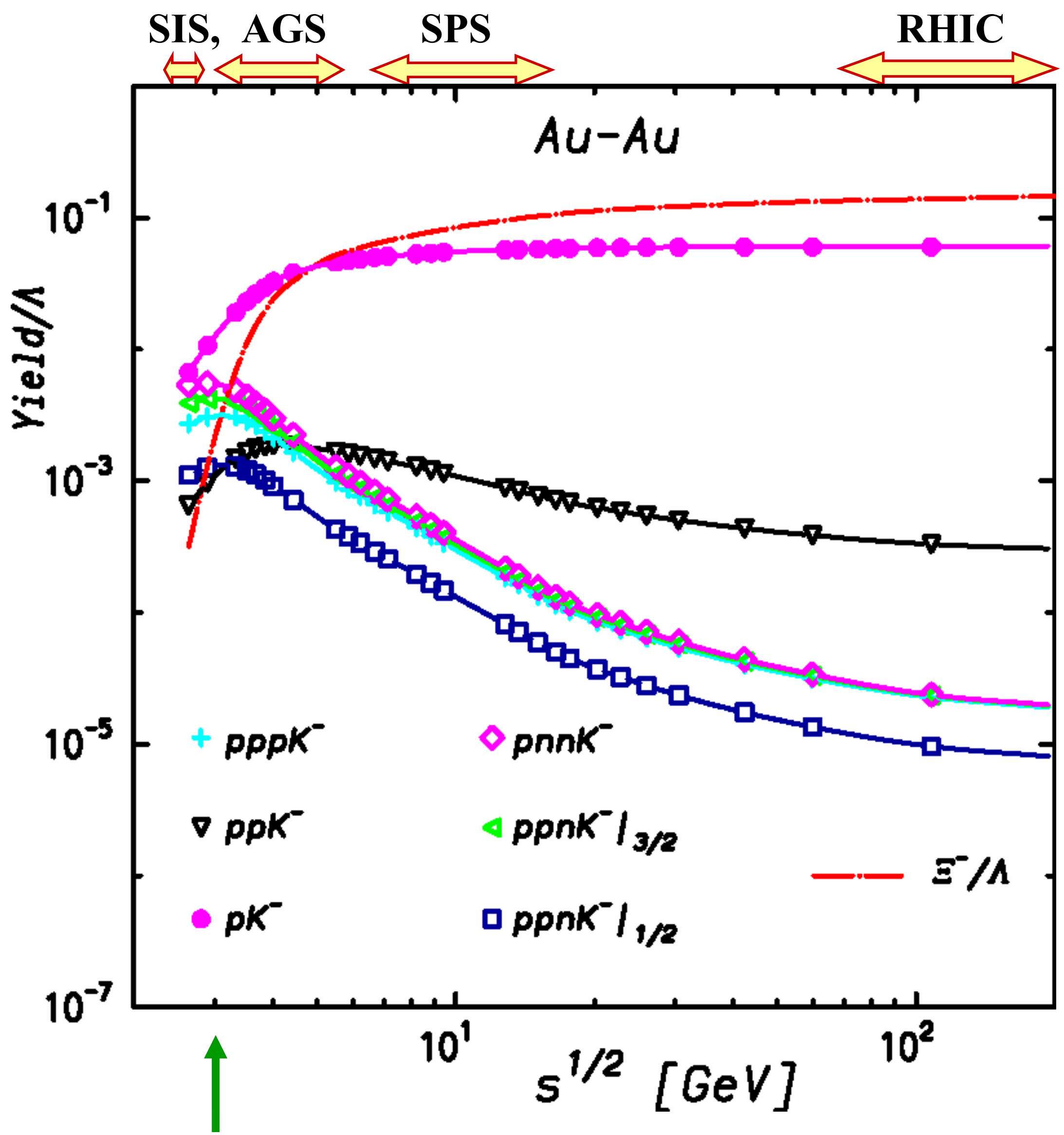
$$M = 2.255 \pm 0.009 \text{ GeV}$$

$$B = 115^{+6+3}_{-5-4} \text{ MeV}$$

$$\Gamma = 67^{+14+2}_{-11-3} \text{ MeV}$$

AY-theoretical prediction:
$M(ppK^-)$ = 2.322 GeV
Γ = 61 MeV

Thermal model predictions



E_{beam}=3.4 AGeV

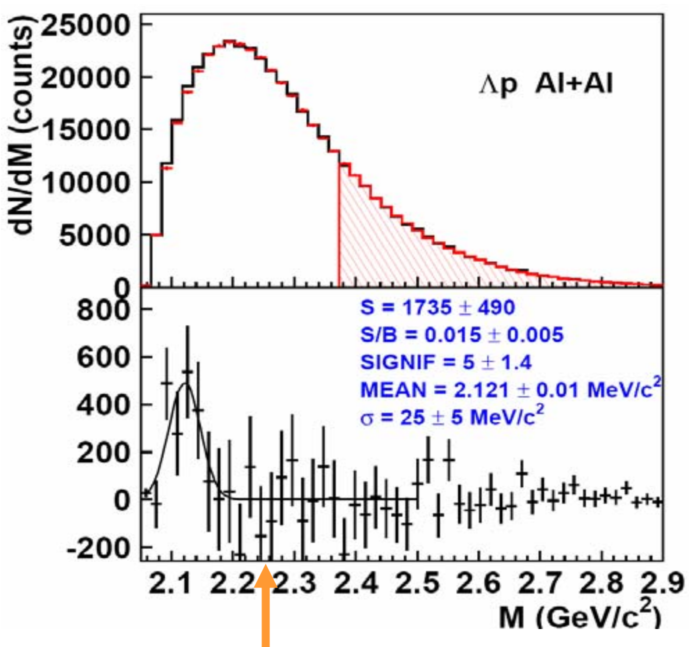
A.Andronic, P.Braun-Munzinger, K.Redlich (2005)
arXiv:nucl-th/0506083

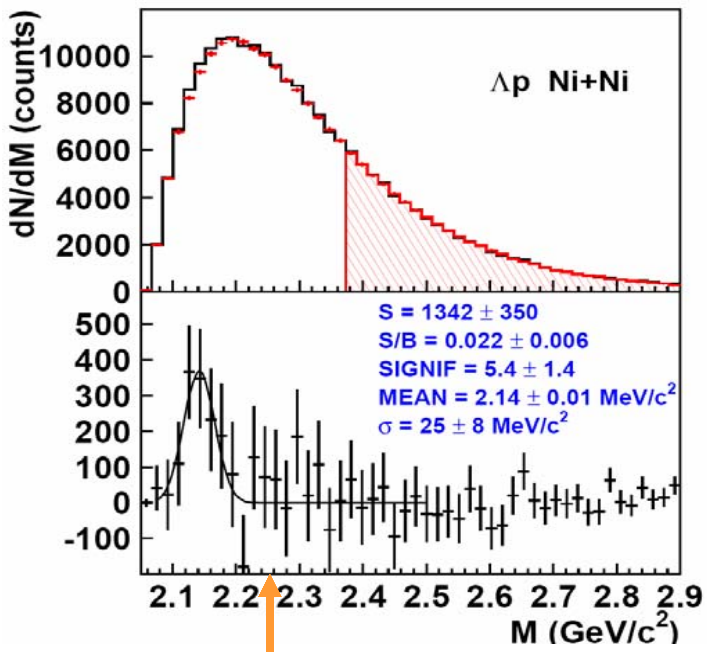
Yield of single strange clusters per Λ peaked at lowest beam energies

Abundance larger than Ξ^- - baryon below E_{beam} < 3.4 AGeV

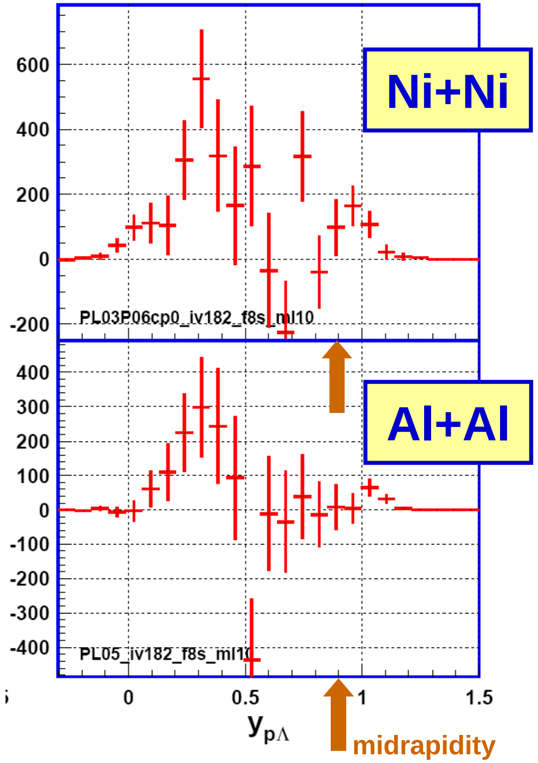
Search for ppK$^-$

Λp – invariant mass





Rapidity distribution



Excess observed in Ni+Ni (2003) and Al+Al (2005) with statistical significance of ~ 5.

Independently reconstructed with 2 different methods (by different people),

Yield located in spectator/fireball interface region (like non-strange clusters) – non thermal!

Peak position in variance with FINUDA result.

Possible interpretation: ΣN – bound state H(2129)

Object seen in K$^-$ + d → Λpπ$^-$ (O. Braun et al., NPB 124,45 (1977), width not constrained)

Hypernuclei and other strange composite systems

CBM physics book

Cluster	Mass [GeV]	Quark content	Cluster	Mass [GeV]	Quark content
H^0	2.020	$4q+2s$	$\{2\Xi^-, 2\Xi^0\}$	5.268	$4q+8s$
$\{\Xi^-, \Xi^0\}$	2.634	$2q+4s$	${}^{6}_{\Lambda\Lambda}He$	5.982	$16q+2s$
${}^4He$	3.750	$12q$	$\alpha_q\{6\Lambda\}$	6.060	$12q+6s$
${}^{4}_{\Lambda\Lambda}H$	4.206	$10q+2s$	${}^{6}_{\Lambda\Xi}He$	6.183	$15q+3s$
$\{4\Lambda\}$	4.464	$8q+4s$	$\{2n, 2\Lambda, 2\Xi^-\}$	6.742	$12q+6s$
$\{2\Lambda, 2\Sigma^-\}$	4.610	$8q+4s$	${}^{7}_{\Xi^0\Lambda\Lambda}He$	7.297	$16q+2s$
${}^{5}_{\Lambda}He$	4.866	$14q+1s$	$\{2\Lambda, 2\Xi^0, 2\Xi^-\}$	7.500	$8q+10s$
$\{2\Lambda, 2\Xi^-\}$	4.866	$6q+6s$			

Table 10.1 Properties of light multibaryonic states with strangeness.

Experimental strategy at lower beam energies:

reduce combinatorial background as much as possible

⇒ **tag events for strangeness content (by K^+, (K^0))**

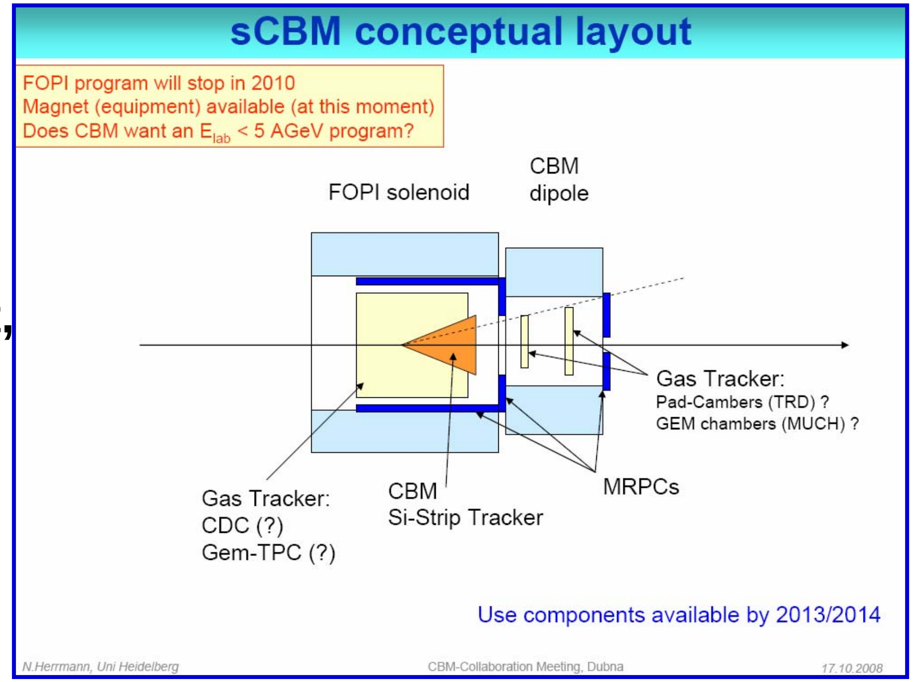
⇒ **detect K^+ as efficiently as possible**

⇒ **compact kaon PID over full solid angle (coverage of large polar angles?)**

Conclusions

Strange physics from 2 – 10 AGeV

Status
• Chemical equilibration not fully understood yet,
• K^0 antiflow at 6 AGeV surprisingly large,
• $K^{\pm}$, Φ – flow largely unknown.



Possible Program
Beam energy and system size scan
with N_{Φ}=50.000 each.

Potential
Clarify density dependence of K – interaction,
EOS
Establish in-medium effects in strangeness sector as reference for charm physics,
Discovery of strange baryonic resonances.

Questions
Whether and how to cover the large polar angles?