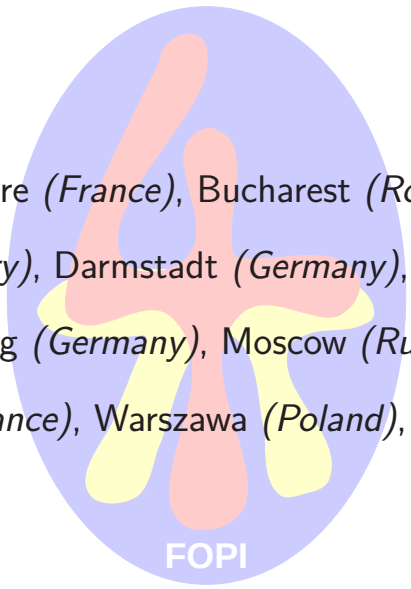
RESULTS FROM FOPI ON STRANGENESS PRODUCTION AND PROPAGATION AT SIS ENERGIES

Aubière *(France)*, Bucharest *(Romania)*

Budapest *(Hungary)*, Darmstadt *(Germany)*, Dresden *(Germany)*

Firenze *(Italy)*, Heidelberg *(Germany)*, Moscow *(Russia)*, Seoul *(South Korea)*

Strasbourg *(France)*, Warszawa *(Poland)*, Zagreb *(Croatia)*



introduction

1- particle identification

2- strangeness production

- K^+ and K^0 rapidity distributions
- K^+ production vs. system size
- K^-/K^+ ratio

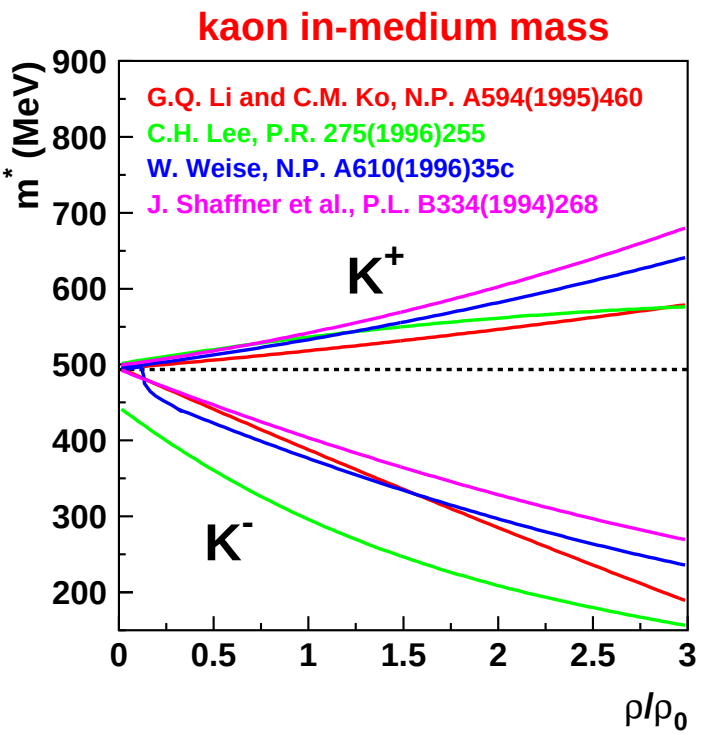
3- strangeness propagation

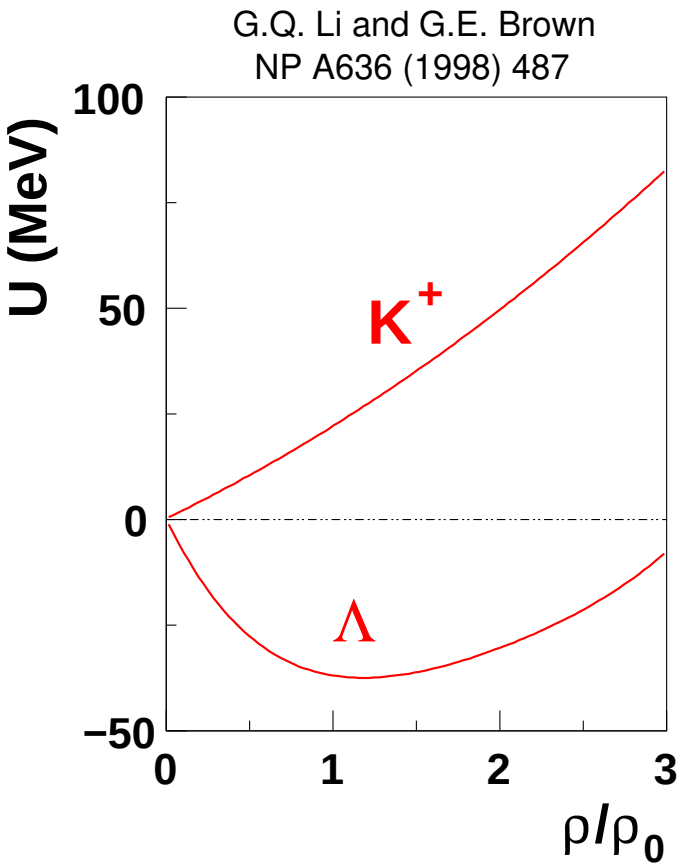
- sideward flow

4- FOPI future plans

summary and outlook

KAONS IN DENSE NUCLEAR MATTER





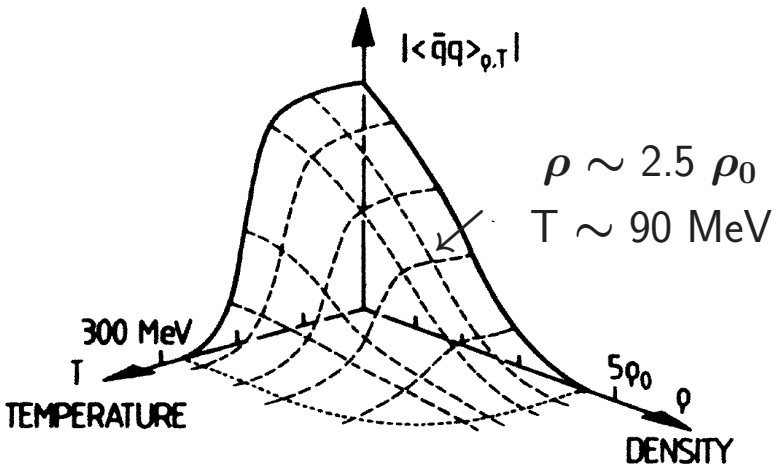
same trend predicted by different groups

in-medium potential: repulsive for K^+ and K^0
attractive for K^- and Λ

- observable for production: YIELD
- observable for propagation: FLOW
  (G.Q. Li et al, PRL 74 (1995) 235)

observable	production yield	propagation momentum
K^+	↘	↗
K^-	↗	↘

WHY AT SIS?



M. Lutz. S. Klimt and W. Weise. NP A542 (1992) 521

- decreasing part of the quark condensate

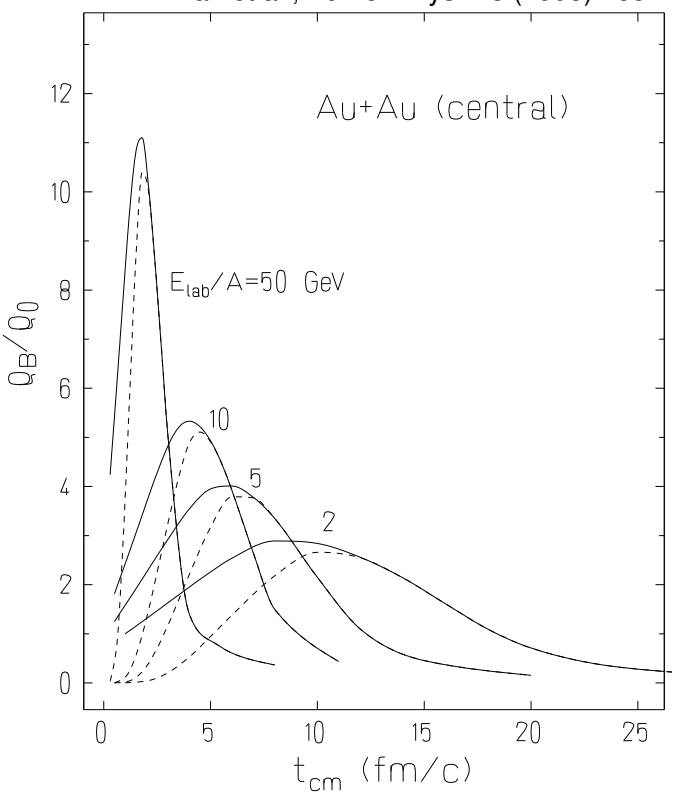
- production of kaons close to threshold

$K^+ : NN \rightarrow K^+\Lambda N$ $\quad E_{thres} = 1.6$ GeV

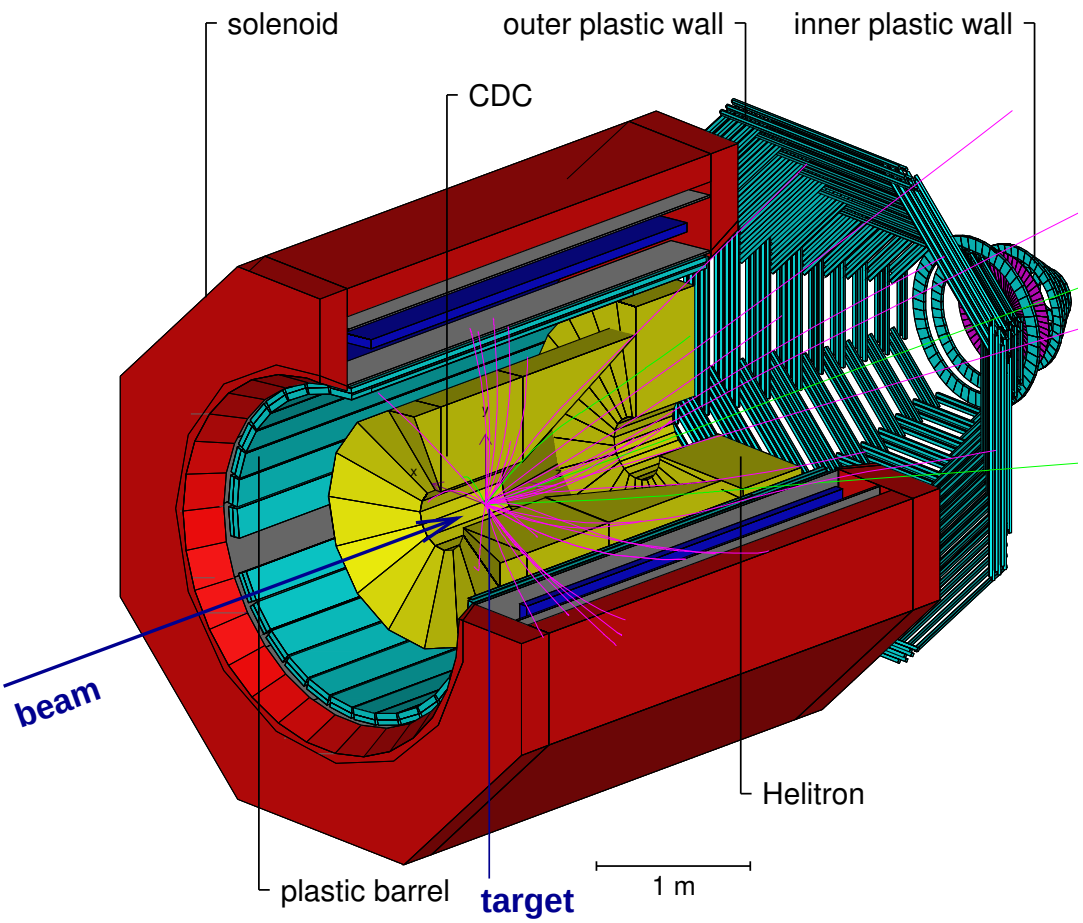
$K^- : NN \rightarrow K^+K^-NN$ $\quad E_{thres} = 2.5$ GeV

- relatively high ρ for a relatively long time

B. Friman et al., Eur. J. Phys. A3 (1998) 165



FOPI EXPERIMENT @ GSI



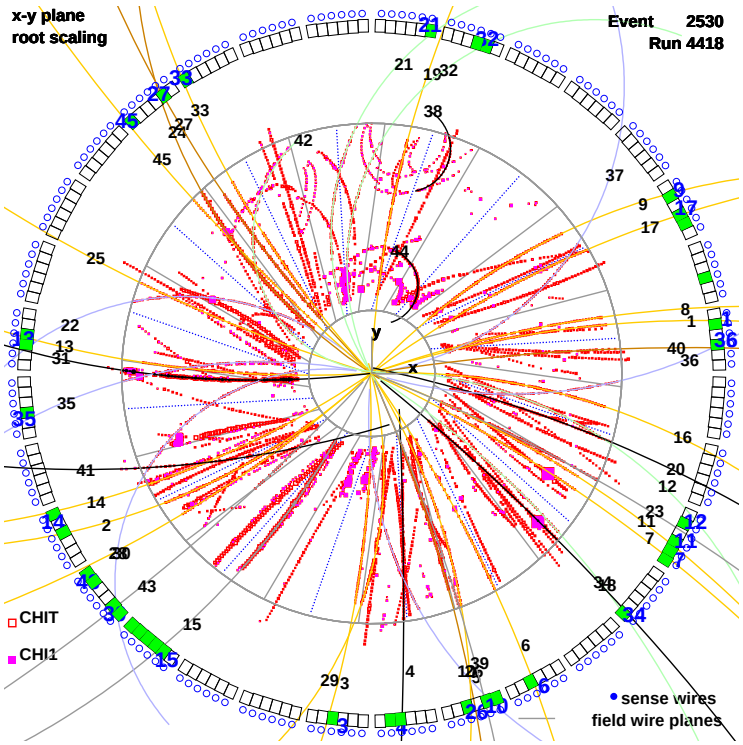
transverse projection of a

Ru+Ru @ 1.69 AGeV

collision

in the central part

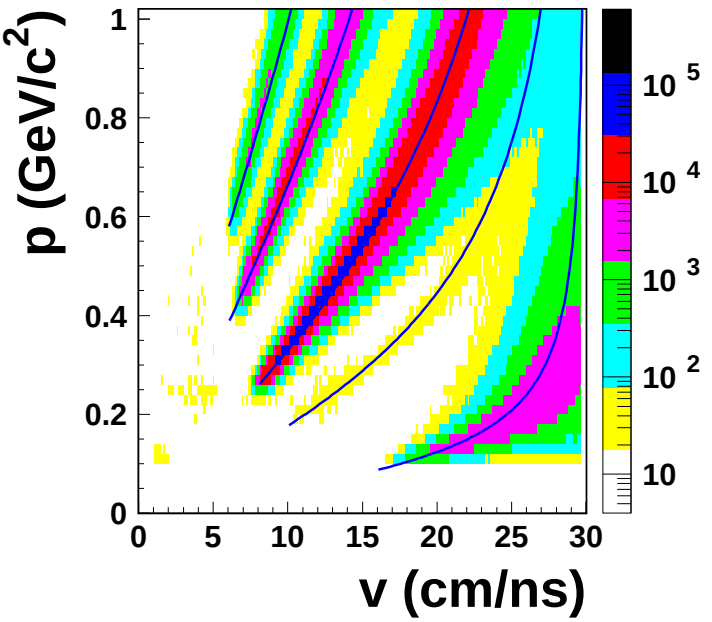
(CDC + BARREL)



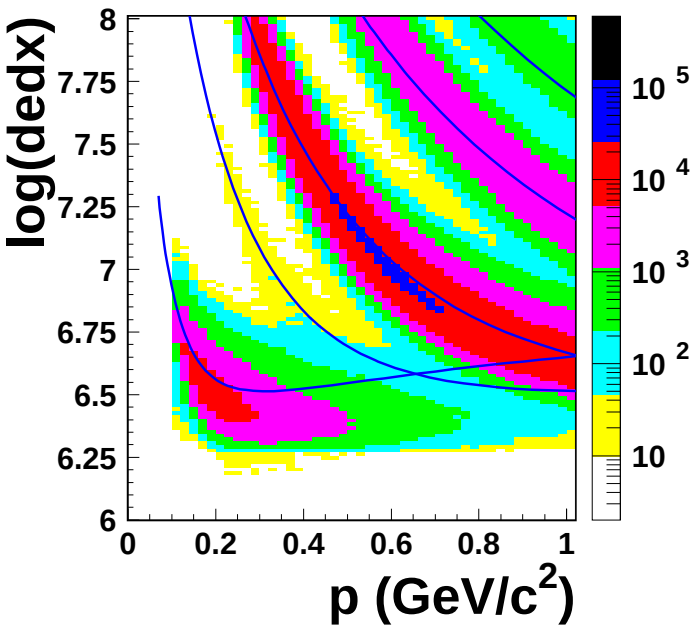
CHARGED KAON IDENTIFICATION

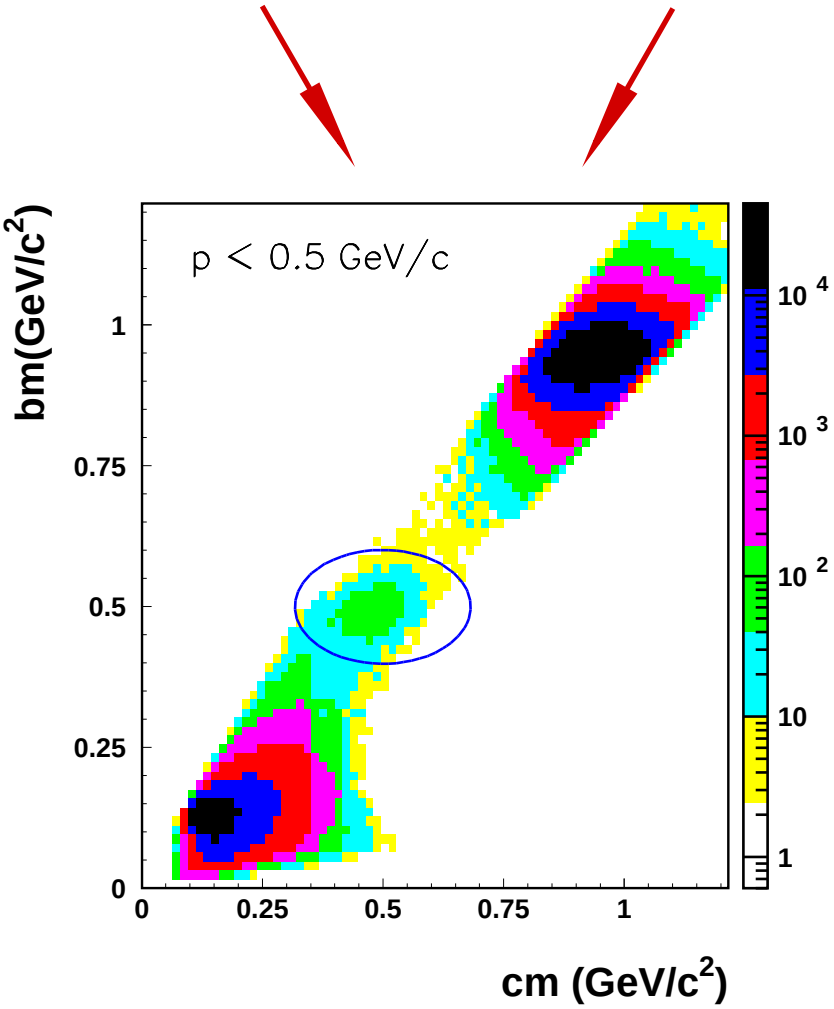
Ru+Ru @ 1.5 AGeV

$p = m\gamma\beta$ (CDC+TOF)

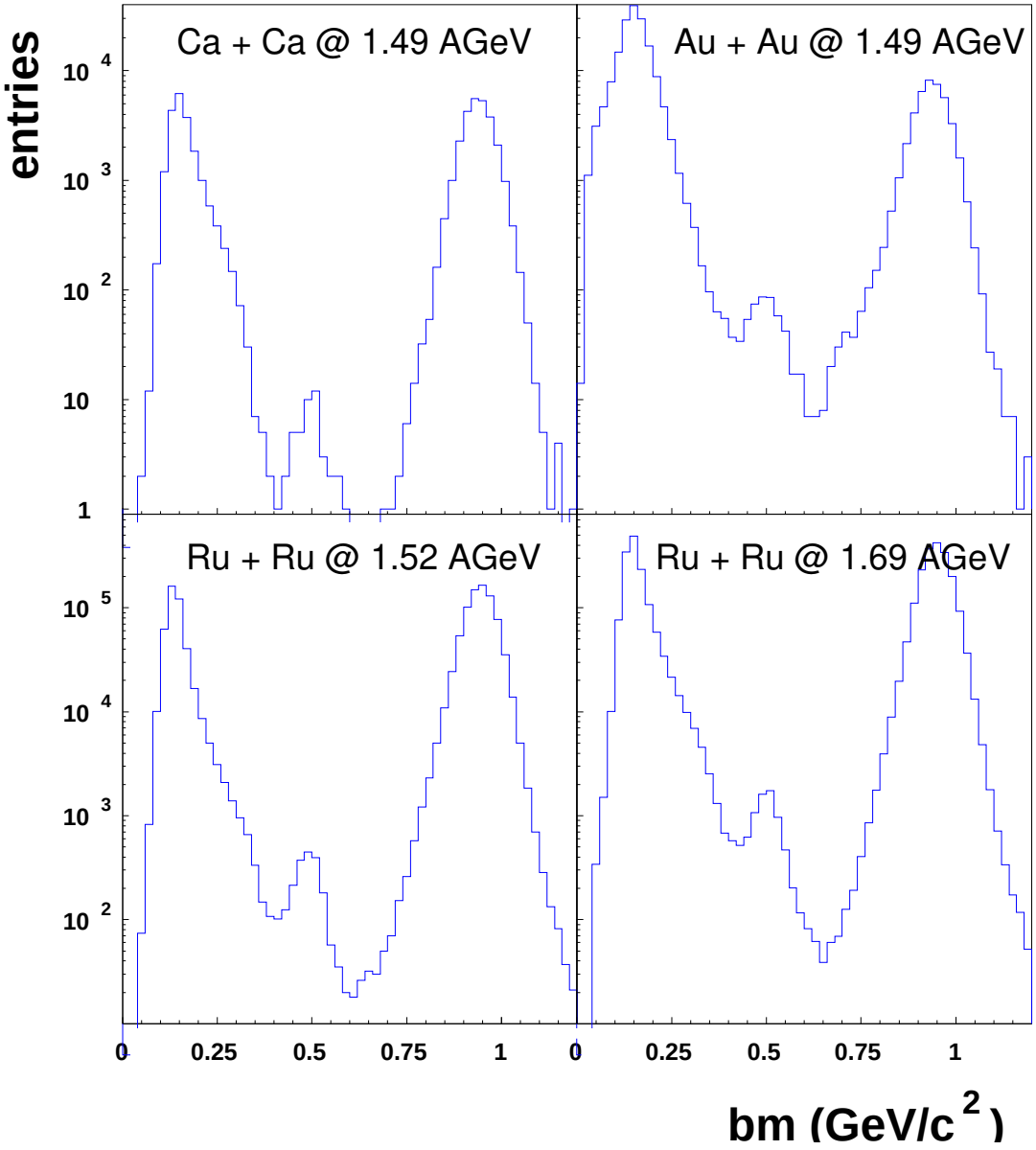


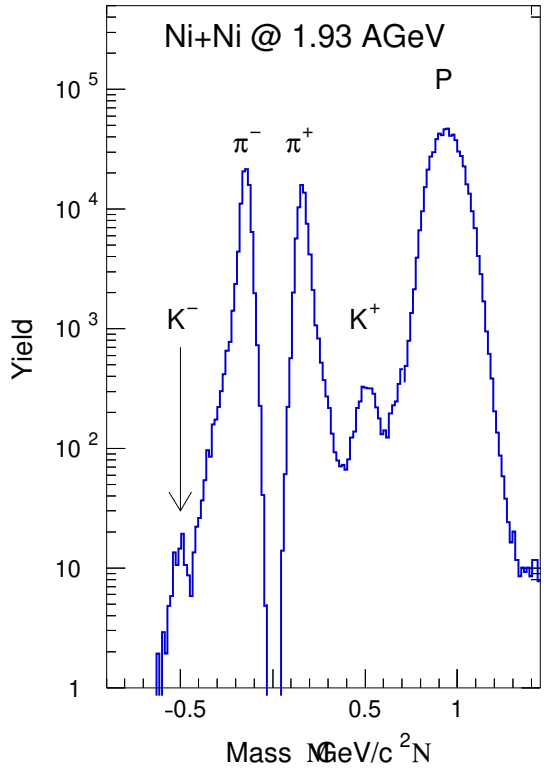
Bethe-Bloch (CDC)





MASS DISTRIBUTIONS



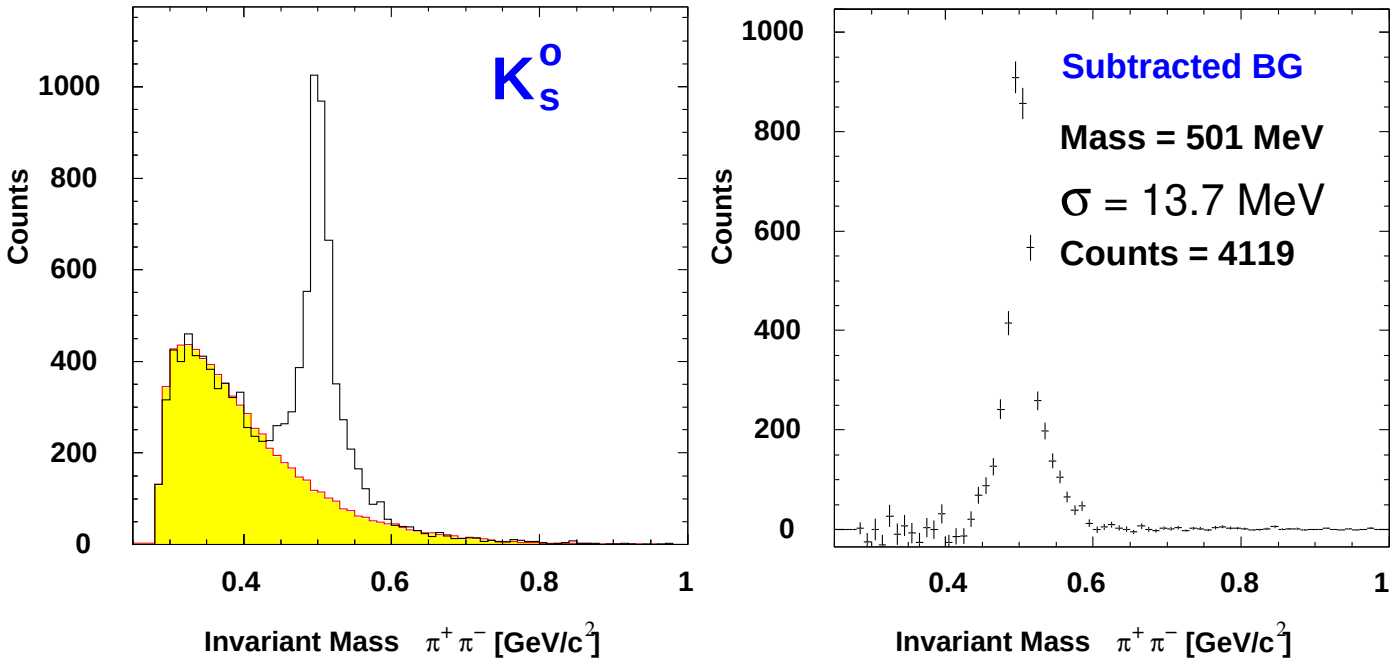


System	Beam Energy	N events	K^+
Ca+Ca	1.49 AGeV	$6.9 \cdot 10^3$	43
Ni+Ni	1.93 AGeV	$1.4 \cdot 10^6$	500
Ru+Ru	1.52 AGeV	$1.5 \cdot 10^6$	2200
Ru+Ru	1.69 AGeV	$7.7 \cdot 10^6$	26000
Au+Au	1.49 AGeV	$3.6 \cdot 10^5$	800

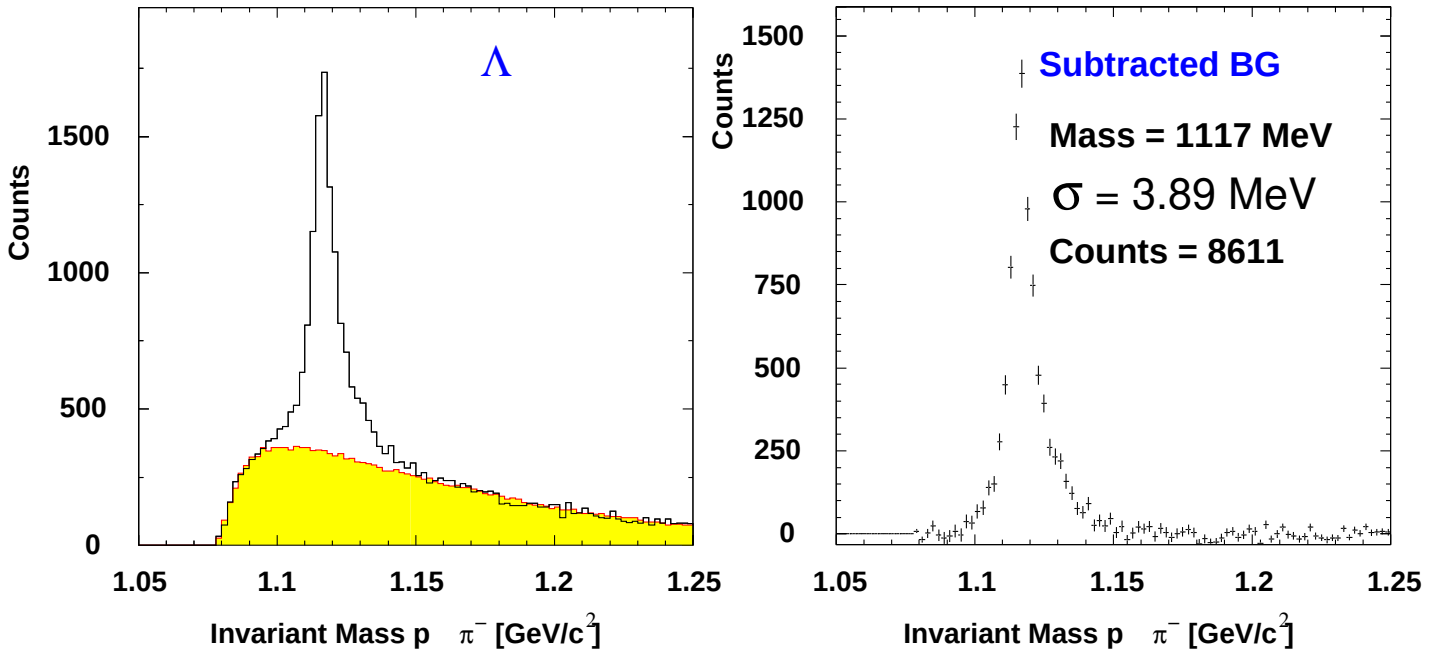
NEUTRAL STRANGE PARTICLE IDENTIFICATION

Ru+Ru @ 1.69 AGeV

- $K^0_s \rightarrow \pi^+\pi^-$ (BR = 68.6 %, $c\tau$ = 2.68 cm)



- $\Lambda \rightarrow p\pi^-$ (BR = 63.9 %, $c\tau$ = 7.9 cm)

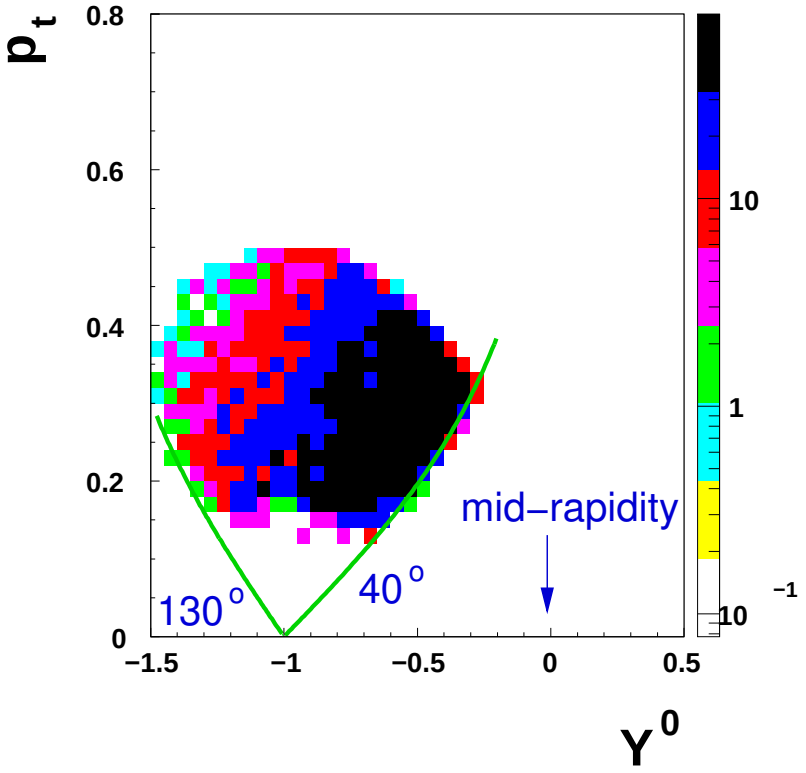


Ch. Finck for the FOPI collaboration

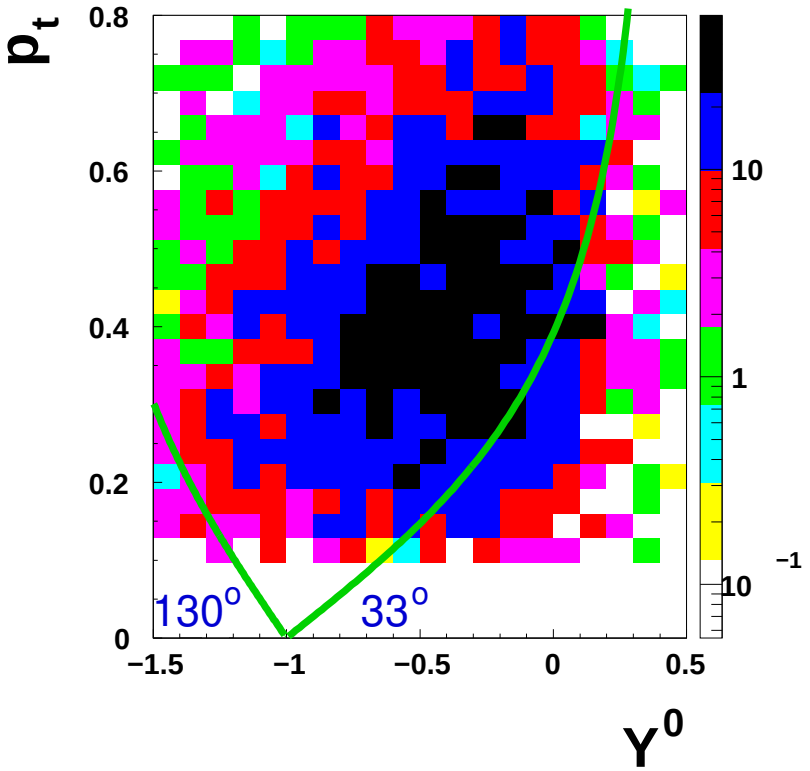
ACCEPTANCE

- charged kaons:

- $40° < \Theta_{lab} < 130°$
- $p < 0.5$ GeV/c
- $p_t > 0.1$ GeV/c



- neutral kaons (background subtracted):

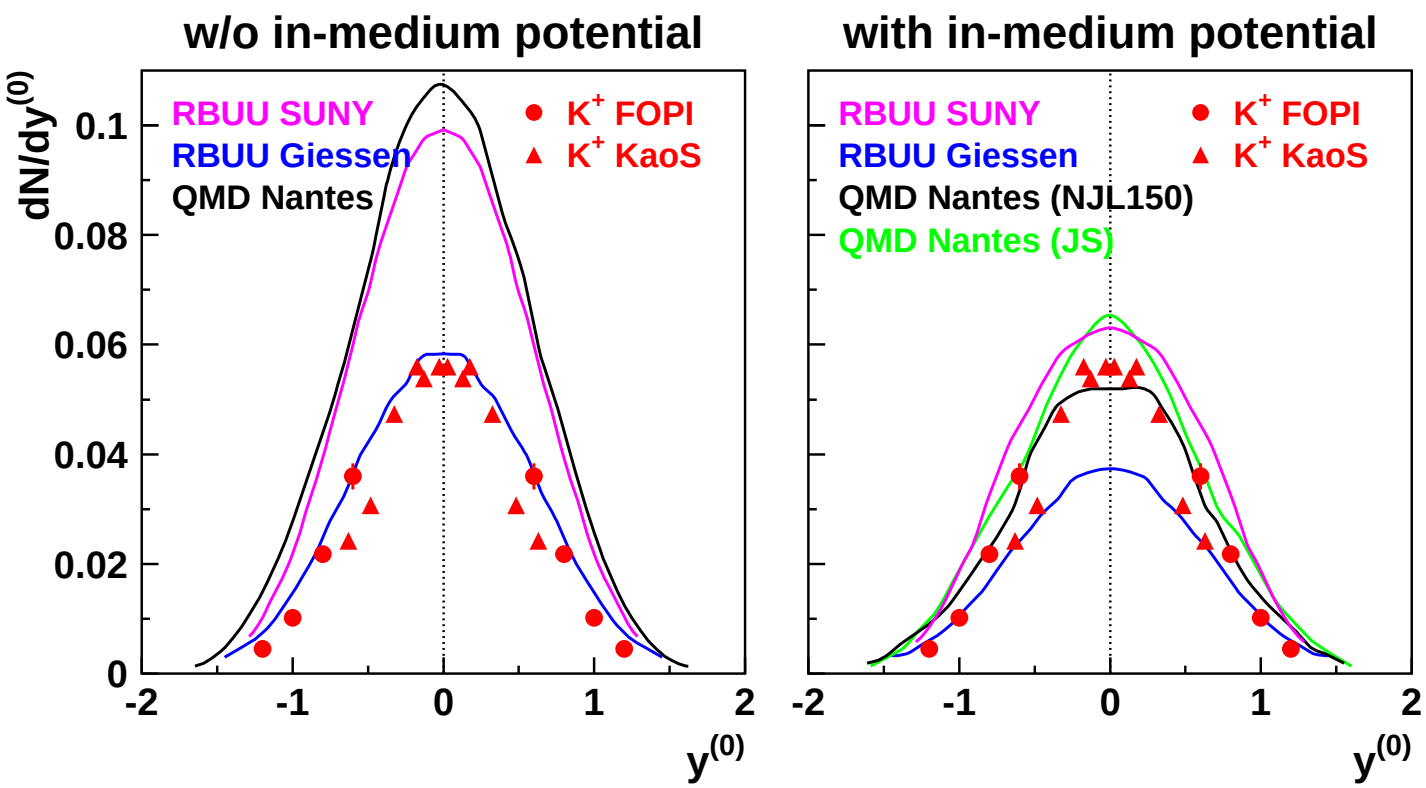


large acceptance due to:

- kinematics of the decay
- no need of BARREL for pion id.

K^+ YIELD

Ni+Ni @ 1.93 AGeV



- good agreement between FOPI and KaoS data
- cross sections depend on the model

FOPI data: D. Best et al., NP A625 (1997) 307

KaoS data: M. Menzel et al., GSI-report 2000-01, p47

RBUU SUNY: G.Q. Li et al., NP A625 (1997) 372

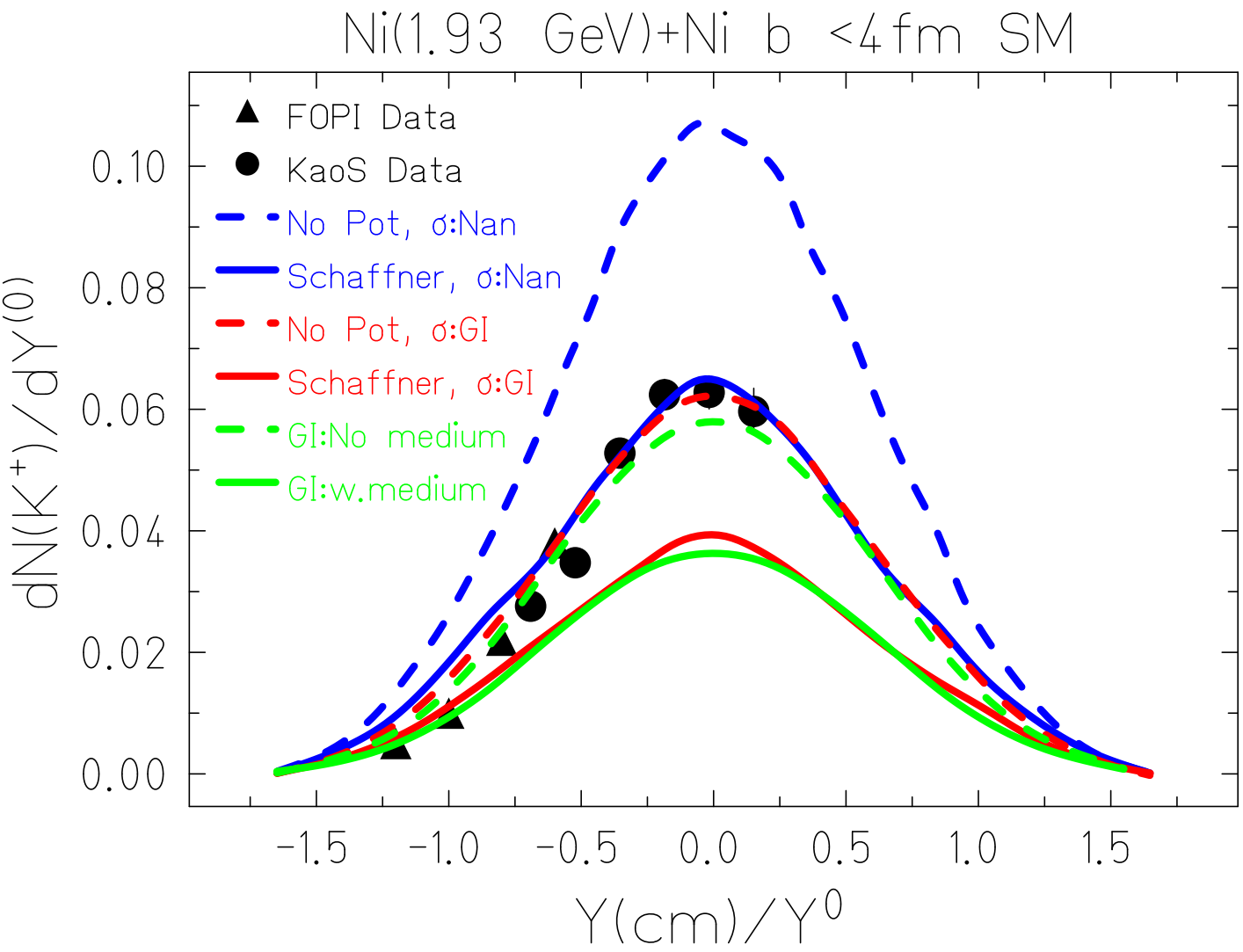
RBUU Giessen: W. Cassing and E.L. Bratkovskaya, Phys. Rep. 308 (1999) 65

QMD: Ch. Hartnack and J. Aichelin, Hirschegg 2000

MODEL COMPARISON

what happens when different groups

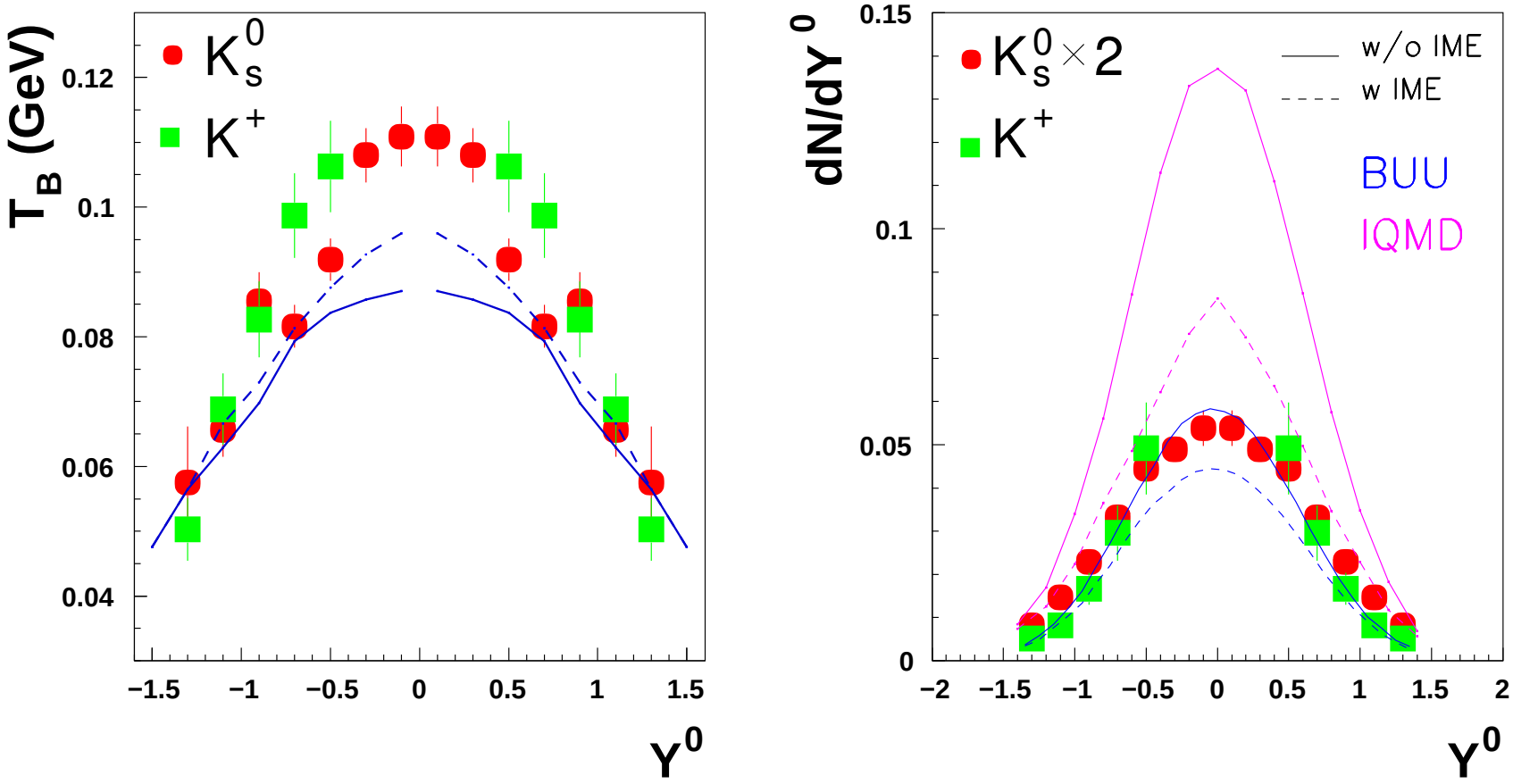
use the same cross sections?



GOOD AGREEMENT!!

K^+ AND K^0 PRODUCTION

Ru + Ru at 1.69 AGeV



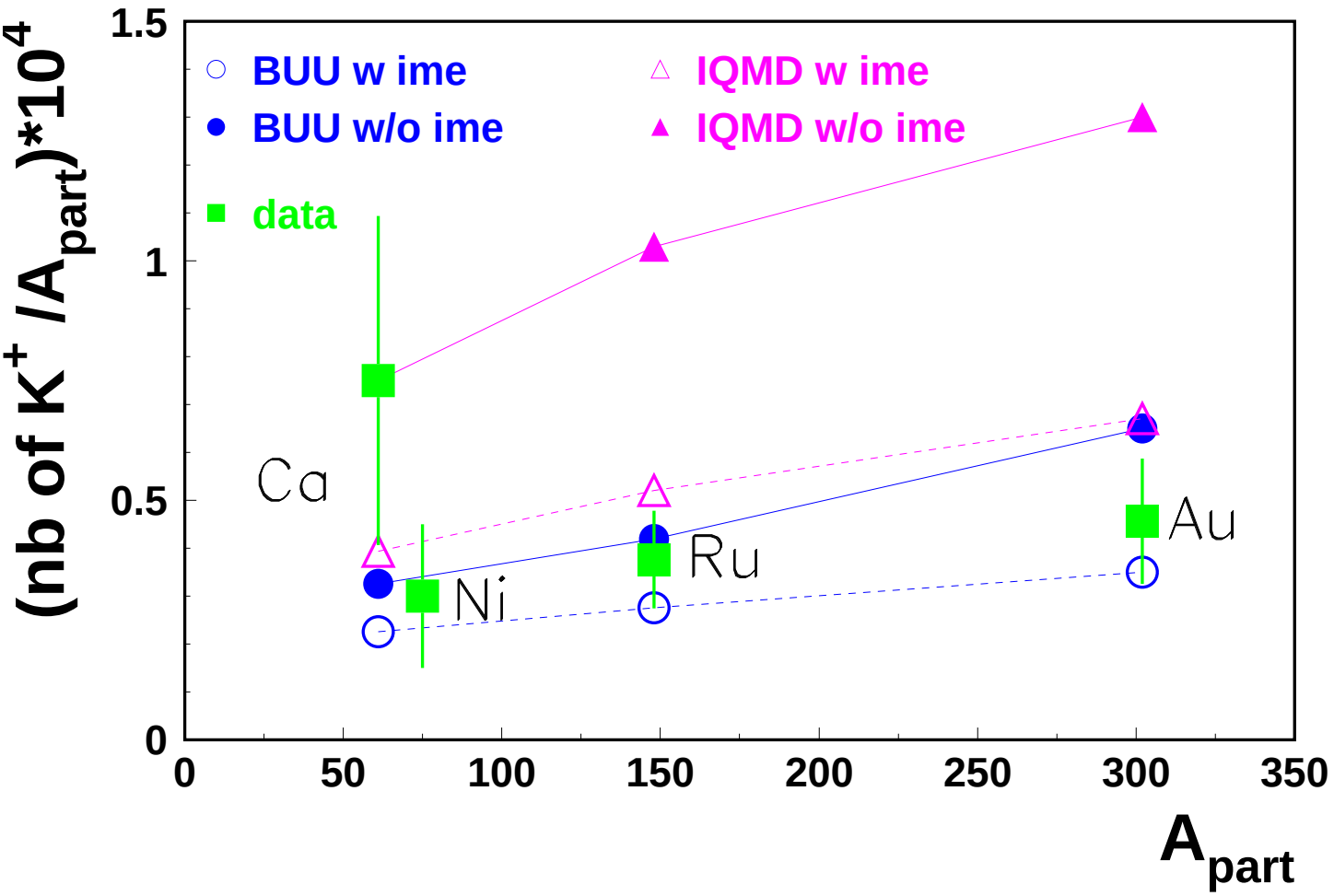
same temperature, same yield

data favor BUU without IME

BUU: E.L. Bratkovskaya and W. Cassing - IQMD: Ch. Hartnack and J. Aichelin

K^+ PRODUCTION vs. SYSTEM SIZE AT 1.5 AGeV

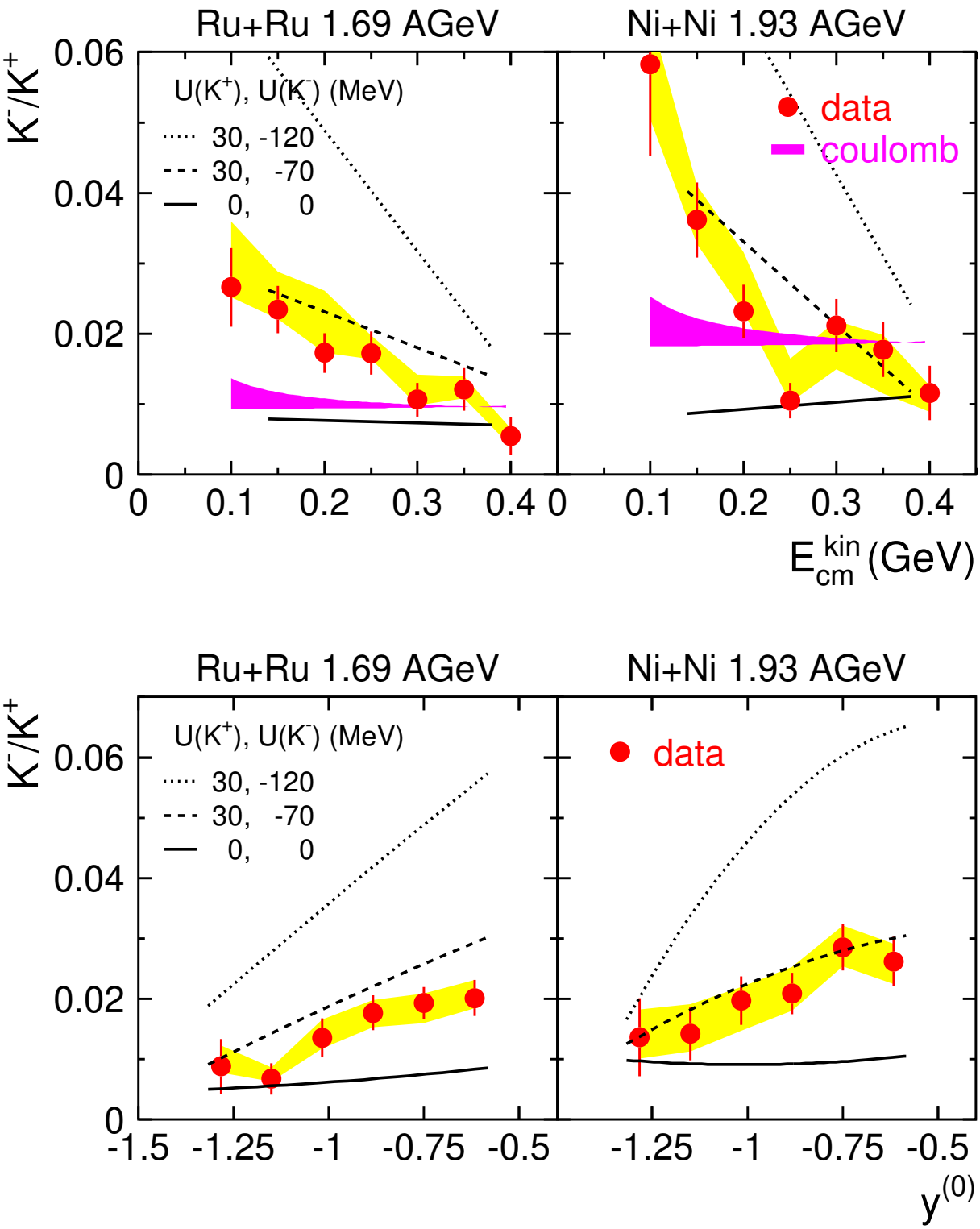
- direct comparison data/model in CDC/BAR acc.
- central collisions: Ca+Ca: b < 2.6 fm
  Ru+Ru: b < 3.4 fm
  Au+Au: b < 4.4 fm



- data favor calculations with IME for IQMD
- hard to say for BUU
- BUU gives same trend in 4π

BUU: E.L. Bratkovskaya, W. Cassing - IQMD: Ch. Hartnack, J. Aichelin

K^-/K^+ ratio



data favor IME

K. Wiśniewki et al., Eur. Phys. J. A9 (2000) 515

BUU: E.L. Bratkovskaya and W. Cassing

SIDEWARD FLOW

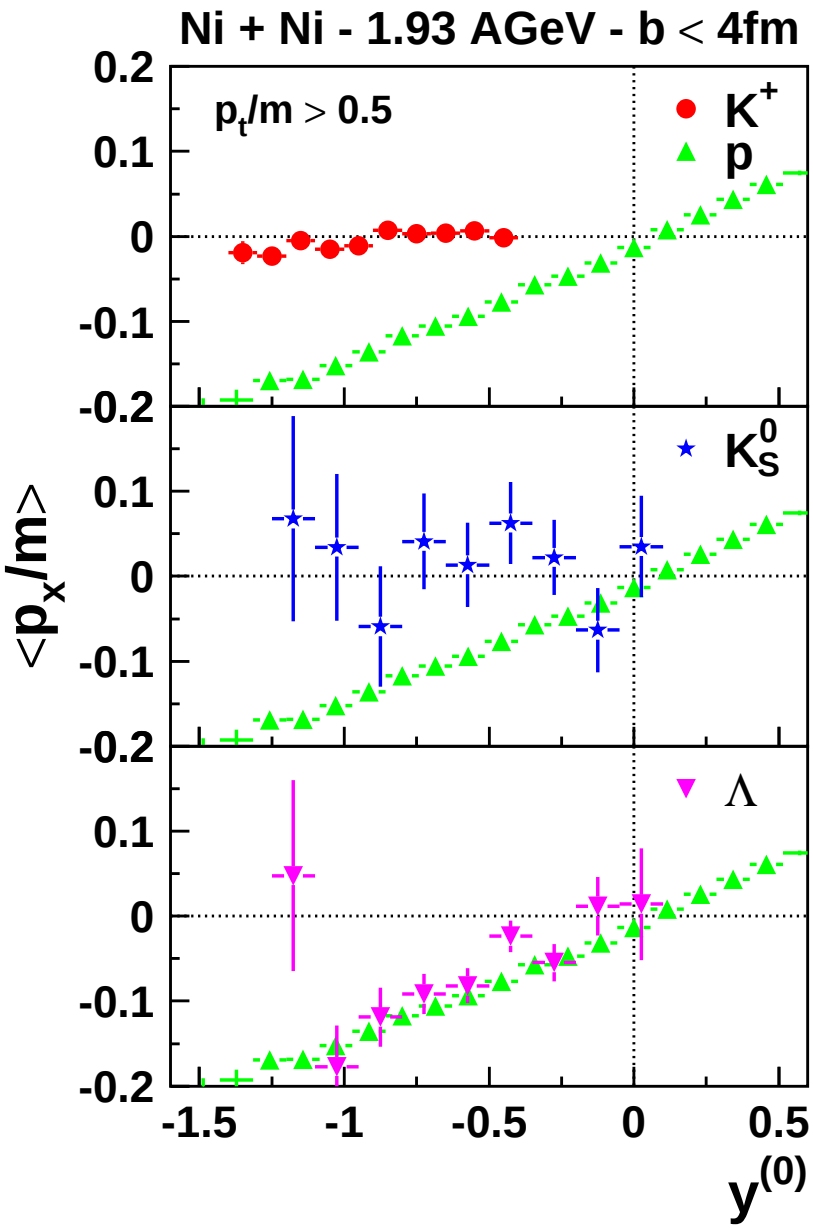
- K^+ pushed away from protons
  Coulomb potential?

but same flow pattern for K^+ and K^0

- K^+ and Λ co-produced
  but different propagation

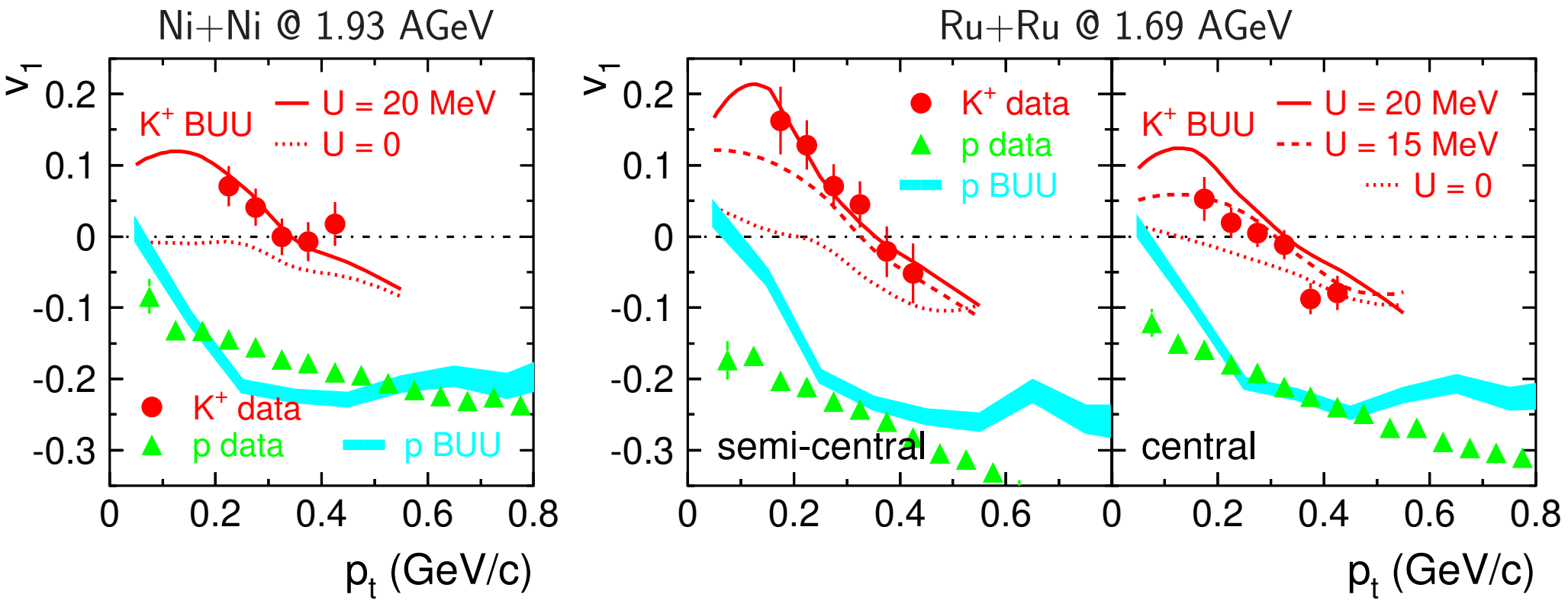
- signal averaged over p_t
  $\Rightarrow$ p_t dependence hidden

N. Herrmann et al., NP A610 (1996) 49c
Full statistics 95



K^+ DIFFERENTIAL SIDEWARD FLOW

$-1.2 < Y^{(0)} < -0.65$



- flow pattern changes with p_t
- K^+ data favor in-medium potential
- highest sensitivity at low p_t

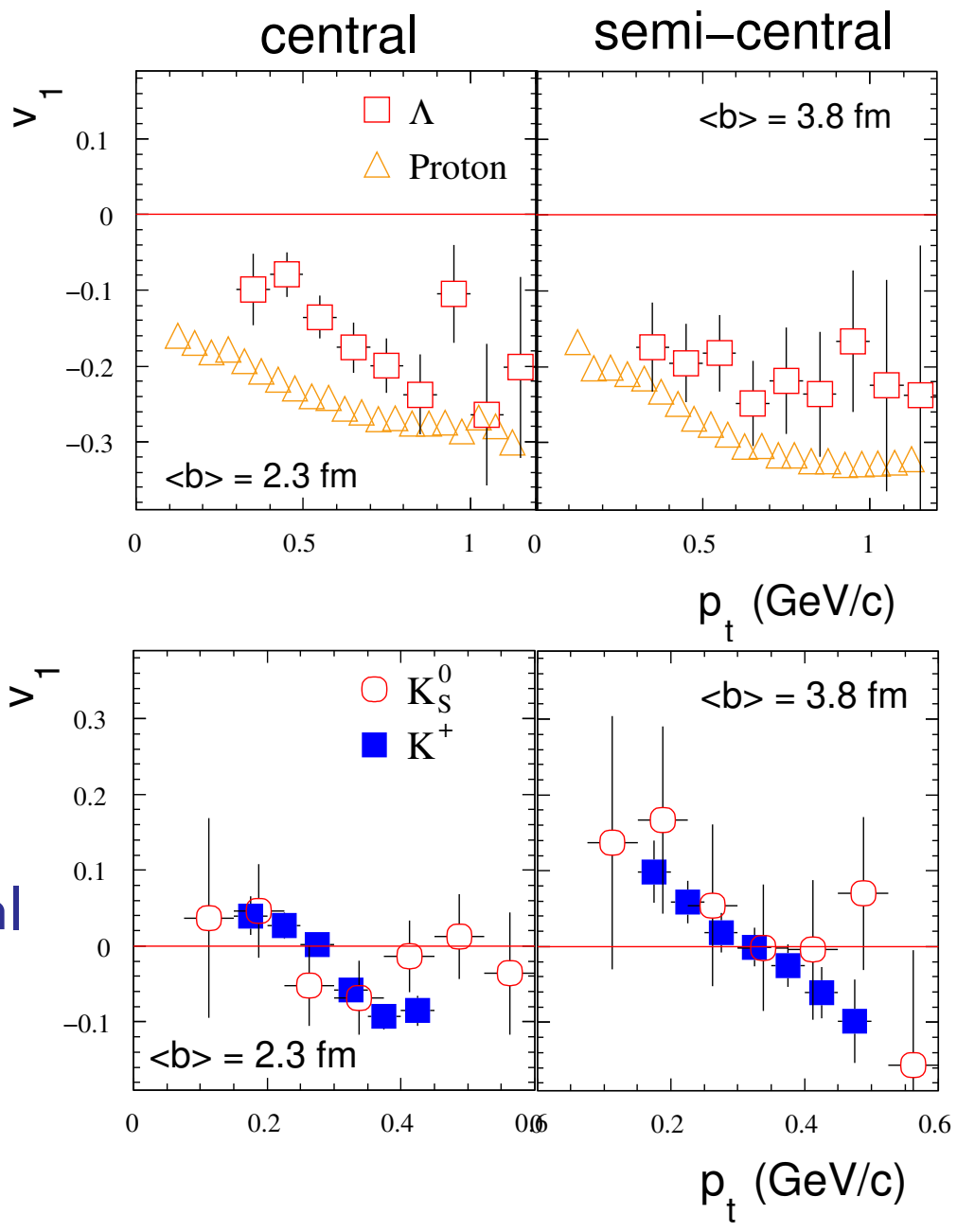
data: P. Crochet, PL 486 (2000) 6 - BUU: E.L. Bratkovskaya and W. Cassing

K^0 AND Λ DIFFERENTIAL SIDEWARD FLOW

- Λ flow compatible with Λ potential = 2/3 nucleon potential
- flow pattern changes from central to semi-central collisions
- K^0 flow compatible with K^+ flow

$\Rightarrow$ weak effect from Coulomb potential

R. Kutsche, PhD. thesis 2000



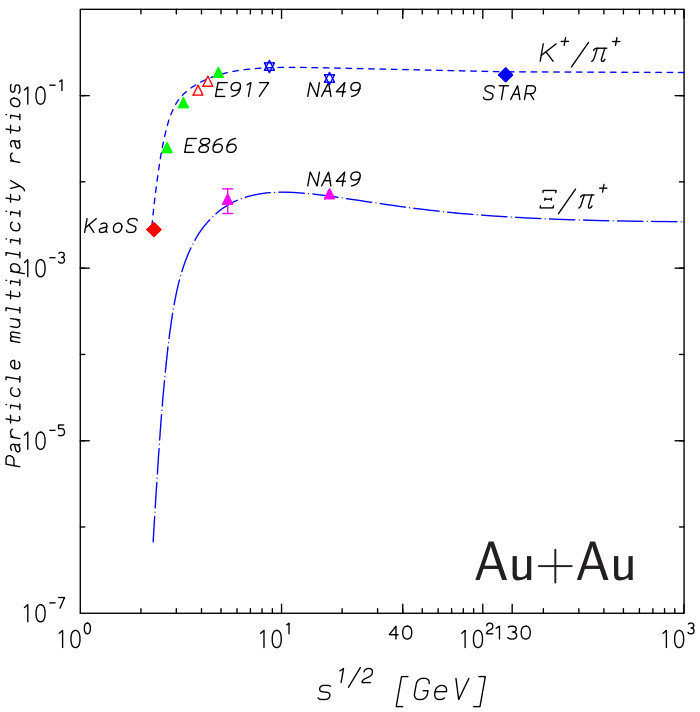
Ξ^- (dss) IN HEAVY ION REACTIONS

- what is known?
  - SPS, Pb + Pb @ 160 AGeV
    - WA97: at mid-rap.: enhancement ($\times$ 4.5) / pp
    - NA49: in 4π: enhancement ($\times$ 10) / pp

      UrQMD underpredicts those yields
  - AGS, Si + Pb @ 14.6 AGeV
    - E810: $\Xi^-/\Lambda \sim 0.12$

      RQMD predicts a factor of 5 lower

- what is predicted?



Thermal model by K. Redlich

$\Xi^- = 8.5 \cdot 10^{-5} \pm 2.0 \cdot 10^{-5}$

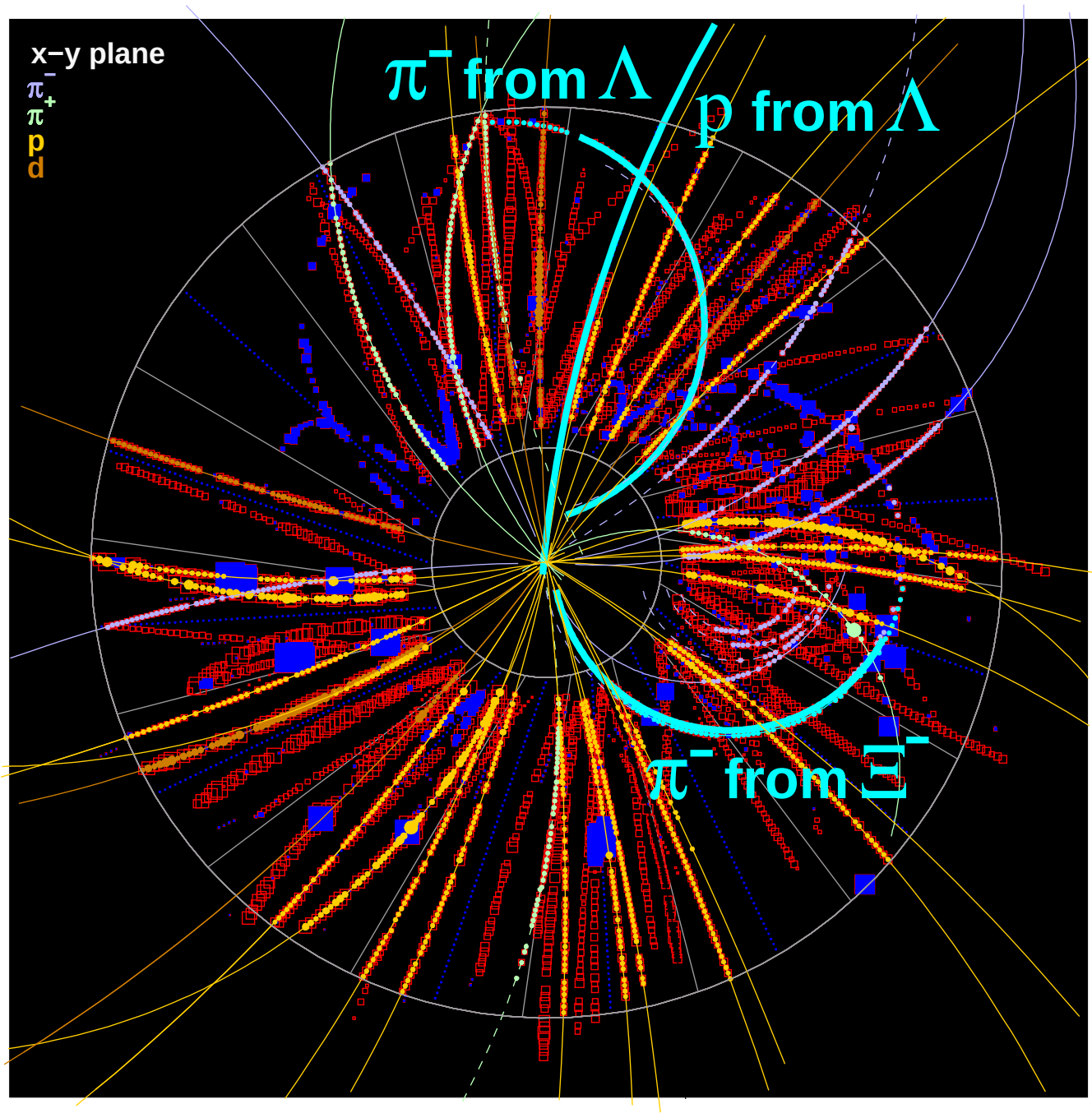
(central Ni+Ni @ 1.93 AGeV)

Is there an

enhancement at SIS?

Ξ^- SIMULATION FOR FOPI

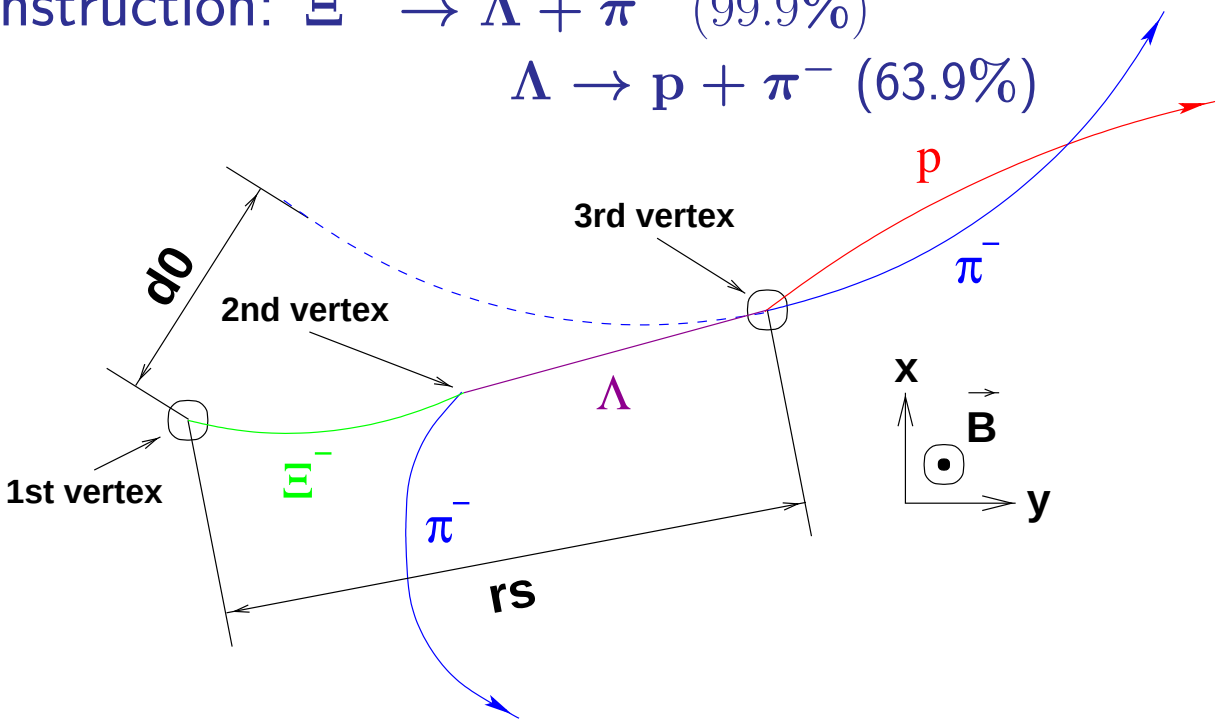
GEANT simulations for Ni+Ni @ 1.93 AgeV



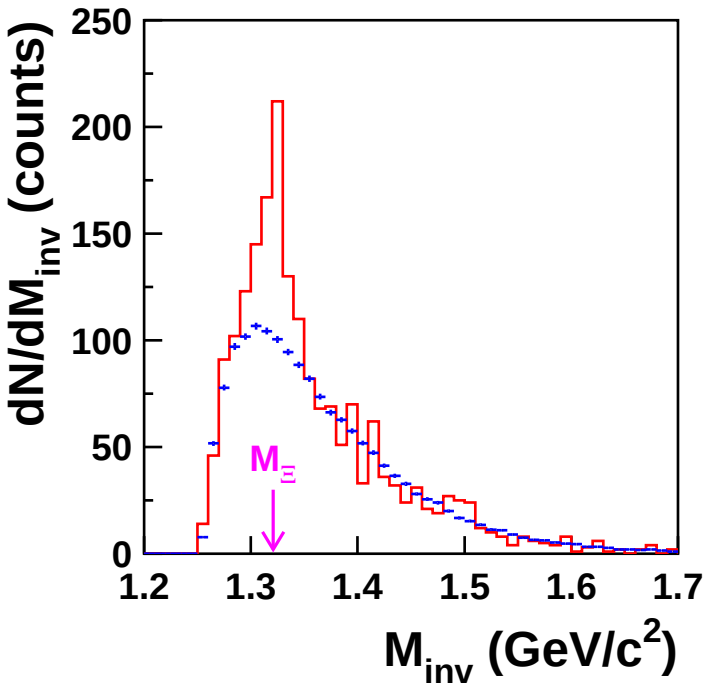
Ξ^- RECONSTRUCTION WITH FOPI

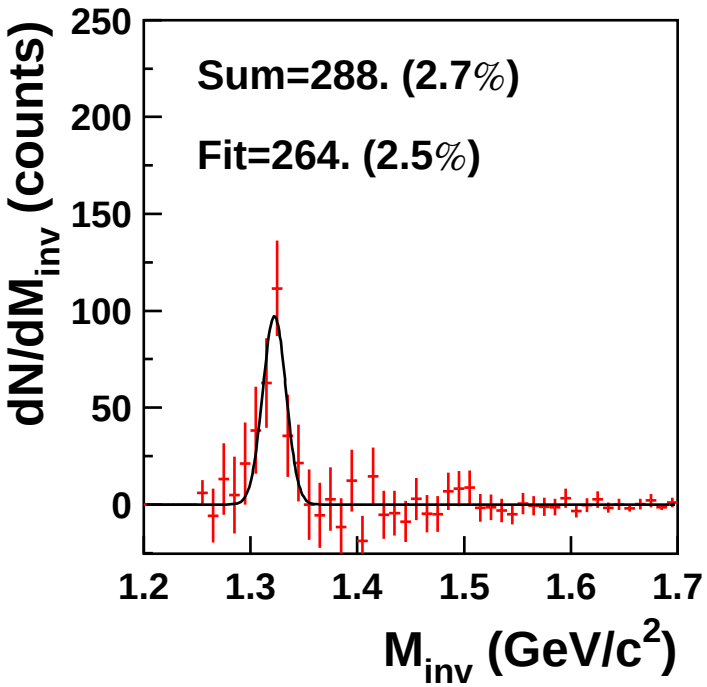
- production: $NN \rightarrow \Xi^- K^+ K^+ N$ $\quad m = 1.321\ GeV/c^2$
  $E_{thres} = 3.74\ GeV$ $\quad c\tau = 4.91\ cm$

- reconstruction: $\Xi^- \rightarrow \Lambda + \pi^-$ (99.9%)
  $\Lambda \rightarrow p + \pi^-$ (63.9%)



Ni + Ni @ 1.93 AGeV, b < 4 fm (IQMD)





expectations: 300 Ξ^- in 2 weeks

SUMMARY

first results on kaon in 1995 and since then:

- K^+ and K^0 rapidity distributions
- K^+ production vs. system size
- K^-/K^+ ratio
- K^+, K^0 and Λ sideward flow

comparison to model predictions:

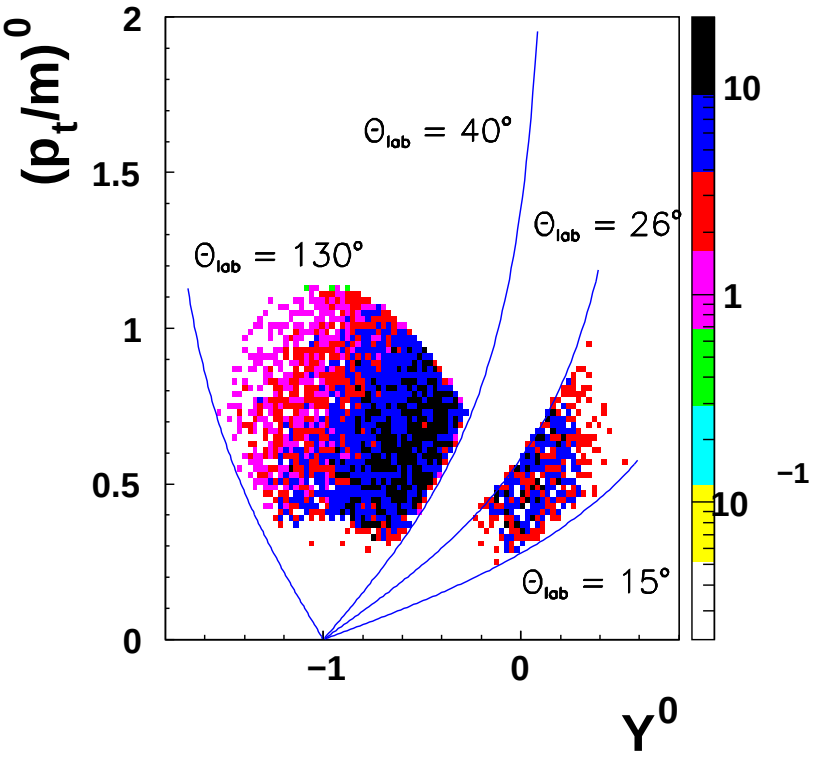
- sideward flow and ratio favor calculations with in-medium effects
- absolute yields favor calculations without in-medium effects
- discrepancy between different models

possible contributions from FOPI:

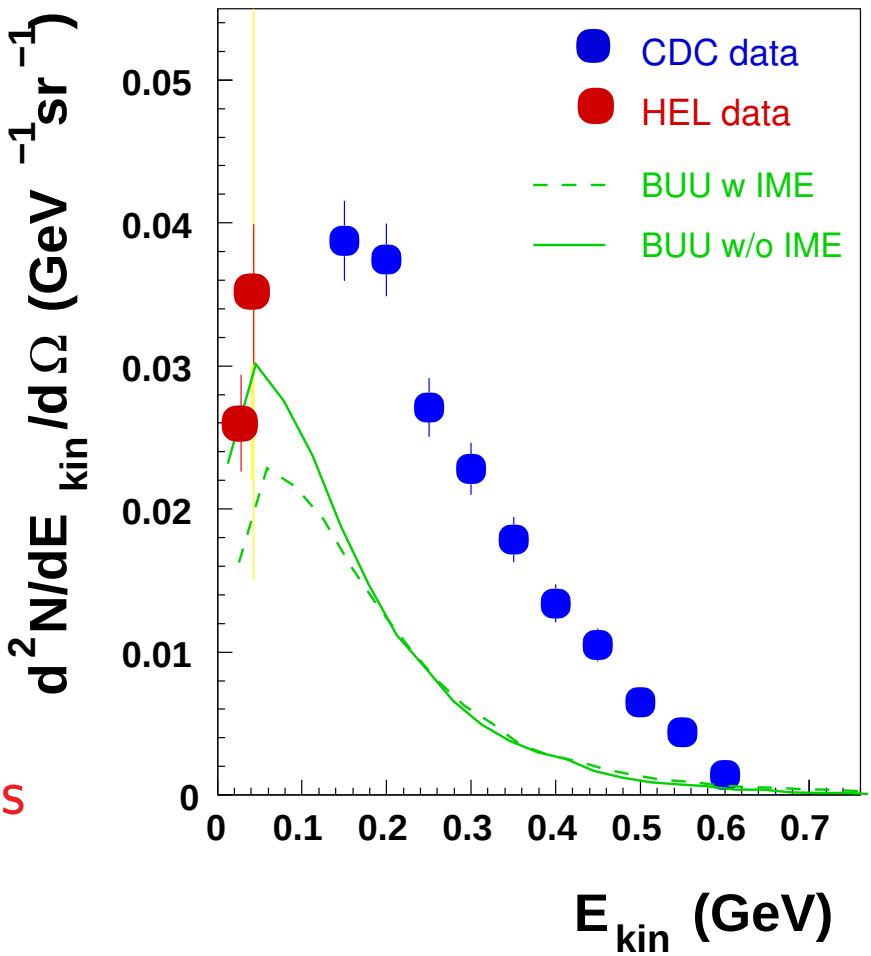
- measurement of Ξ^- (beginning 2002)
- measurement of Φ (work in progress)
- measurement of kaons at mid-rapidity (work in progress + FOPI upgrade)

MEASUREMENT OF KAONS AT MID-RAPIDITY

Ru+Ru @ 1.69 AGeV



low p_t and mid-rapidity kaons measured in the forward drif chamber

biggest effect at low p_t (E_{kin}) according to BUU

work under progress