Results from FOPI on Strangeness in Nuclear Matter at SIS Energies

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CRIP/KFKI Budapest, Hungary
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LPC Clermont-Ferrand, France
Korea University Seoul, Korea
GSI Darmstadt, Germany
IReS Strasbourg, France
FZ Rossendorf/Dresden, Germany
Univ. of Warsaw, Poland
Univ. of Heidelberg, Germany
RBI Zagreb, Croatia
FOPI

1 Kaons in dense nuclear matter

2 FOPI detector

3 $\mathbf{p}$, $\boldsymbol{\pi}$ & $\mathbf{K^+}$ yield

4 $\mathbf{K^-/K^+}$ ratio

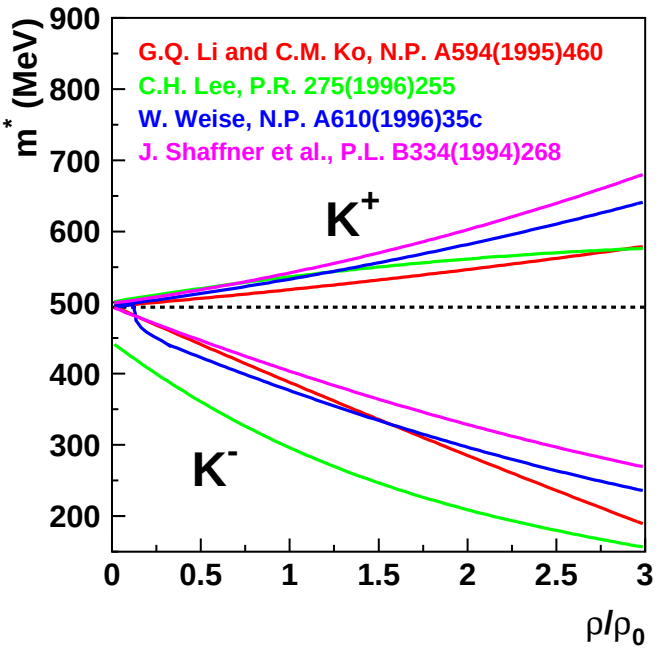
5 $\mathbf{K^+}$, $\mathbf{K^0_S}$ & $\boldsymbol{\Lambda}$ sideward flow

6 Summary & outlooks

Strangeness in Dense Nuclear Matter @ SIS Energies

Chasing the Kaon-Nucleon potential

kaon in-medium mass



kaon production channels

NN	→	NΛK	NΛπK	NΛππK
NN	→	NΣK	NΣπK	NΣππK
NΔ	→	NΛK	NΛπK	NΛππK
NΔ	→	NΣK	NΣπK	NΣππK
ΔΔ	→	NΛK	NΛπK	NΛππK
ΔΔ	→	NΣK	NΣπK	NΣππK
πN	→	ΛK	ΛπK	
πN	→	ΣK	ΣπK	**K+**
πΔ	→	ΛK	ΛπK	
πΔ	→	ΣK	ΣπK	

NN	→	NNKK	NNπKK	NNππKK
NΔ	→	NNKK	NNπKK	NNππKK
ΔΔ	→	NNKK	NNπKK	NNππKK
πN	→	NKK	NπKK	
πΔ	→	NKK	NπKK	
πΛ	→	NK		
πΣ	→	NK		
NΛ	→	NNK		**K-**
NΣ	→	NNK		
ππ	→	KK		

Challenges :

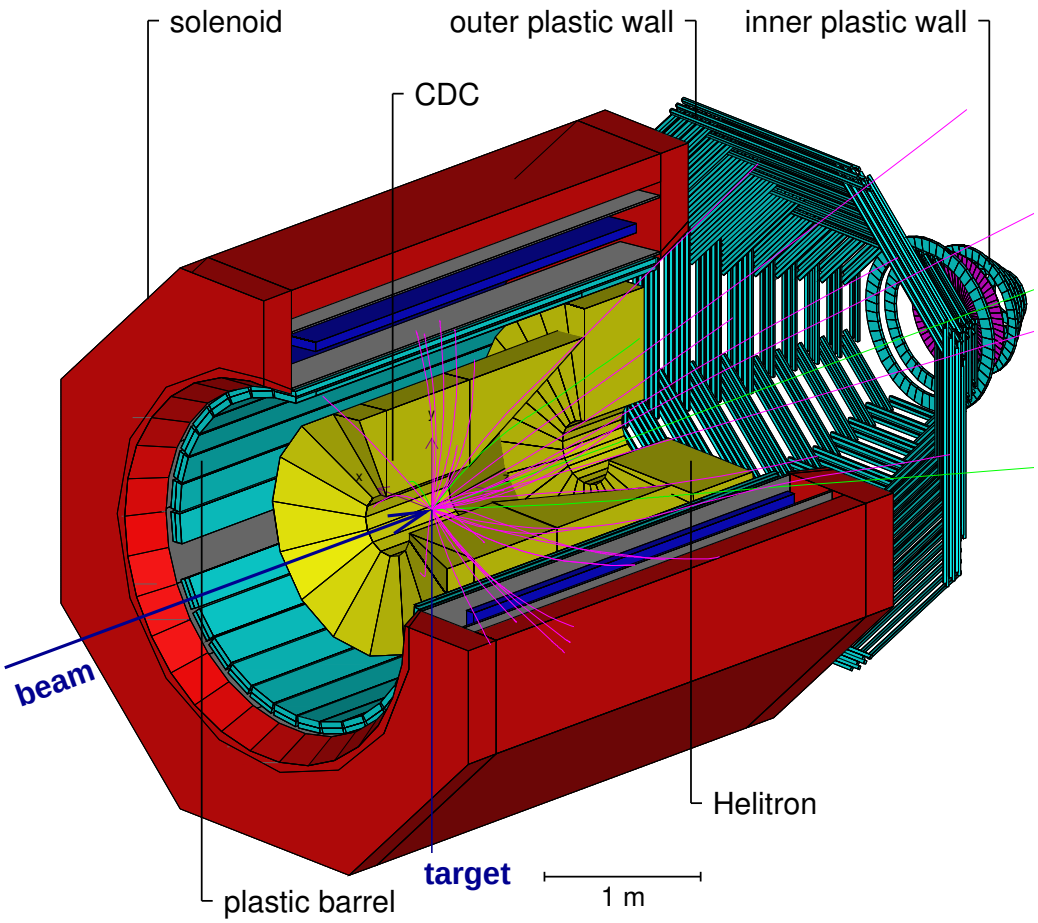
- understand baryon and pion phase space distributions
- disentangle in-medium effects : rescattering, absorption, mass shift, change of resonnance widthes and cross-sections
- measure kaons

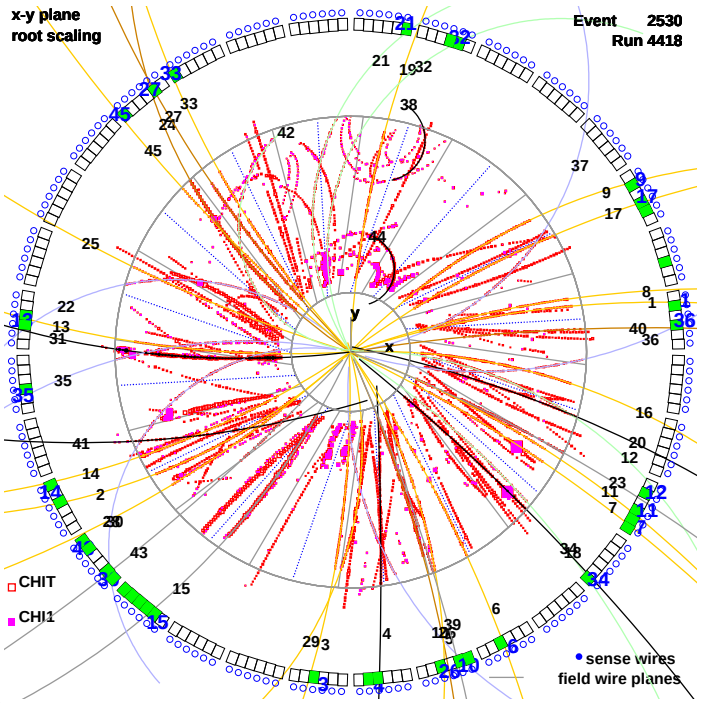
SIS : near-threshold kaon production

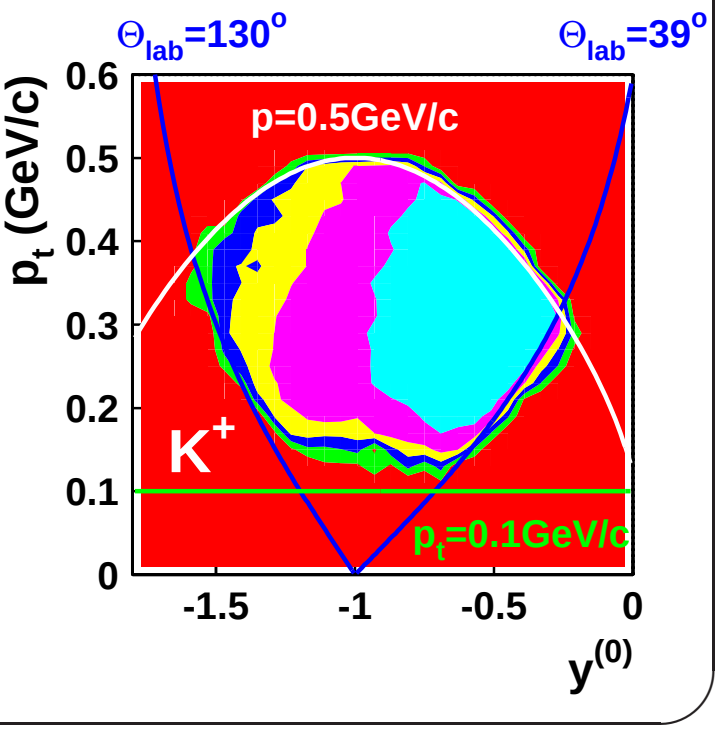
$\sim 1\mathrm{K}^{+}(\mathrm{K}^{-})$ per $1{\cdot}10^{2}(1{\cdot}10^{4})$ central event

- find observables sensitive to the potential

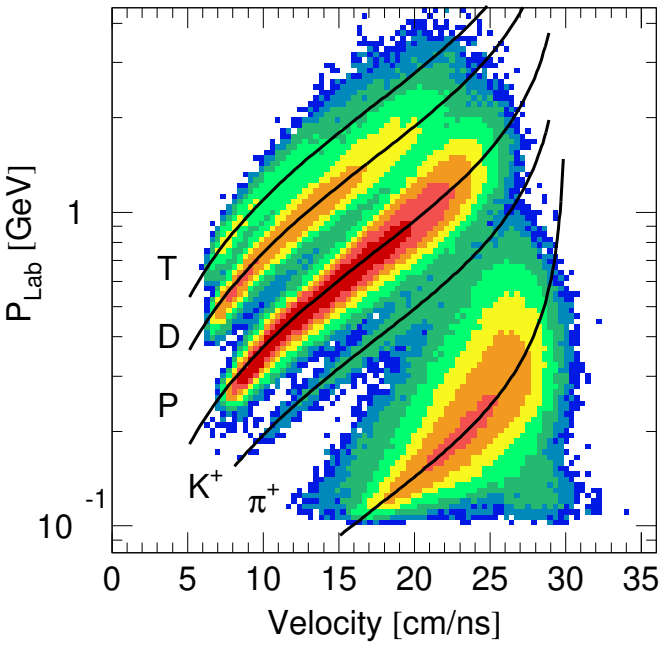
FOPI detector @ GSI

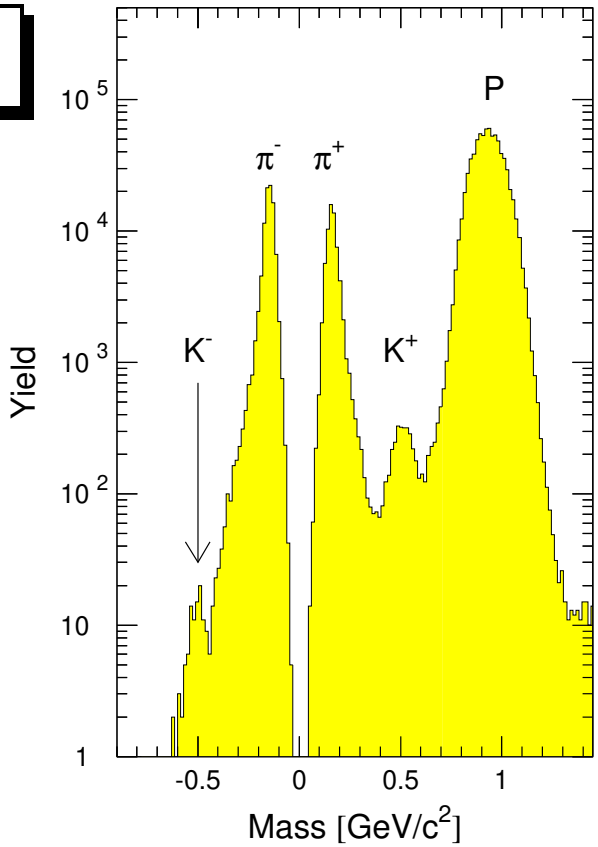


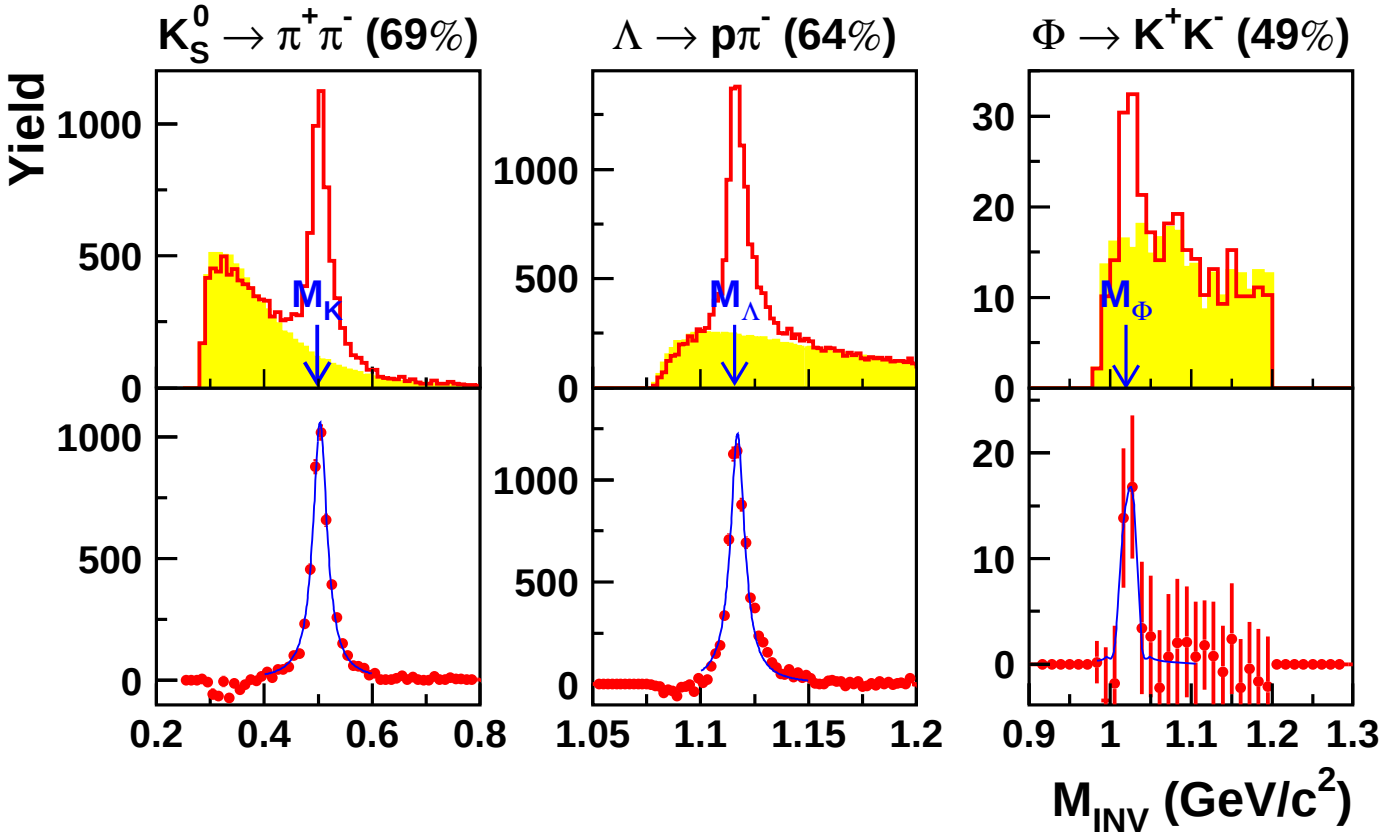




Particle Identification

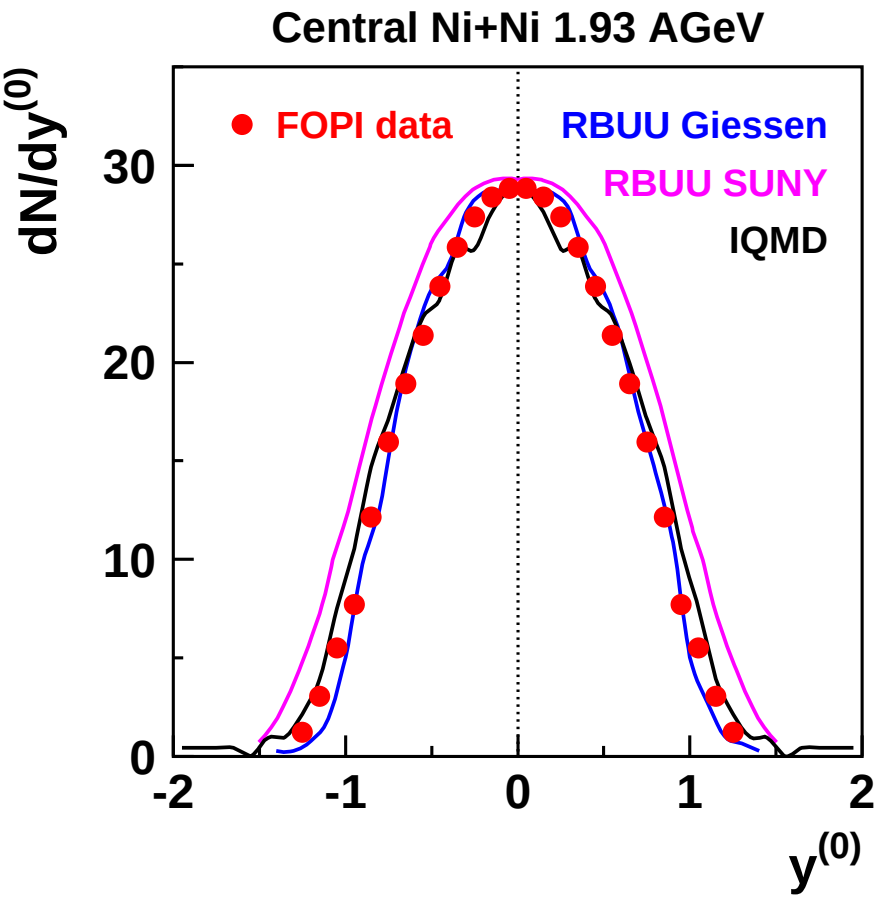






D. Best, A. Devismes, M. Kirejczyk, R. Kutsche,
A. Mangiarotti, C. Plettner, K. Wiśniewski, PhD Thesis

Proton Yield



proton dN/dy well reproduced by various transport codes

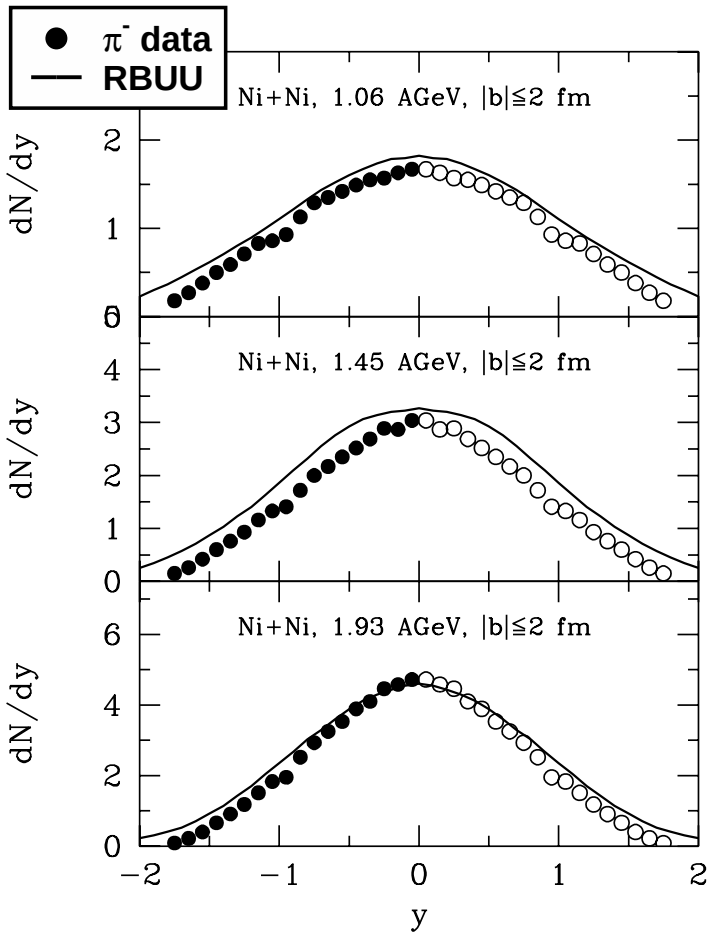
FOPI data : B. Hong et al., Phys. Rev. C 57(1998)244

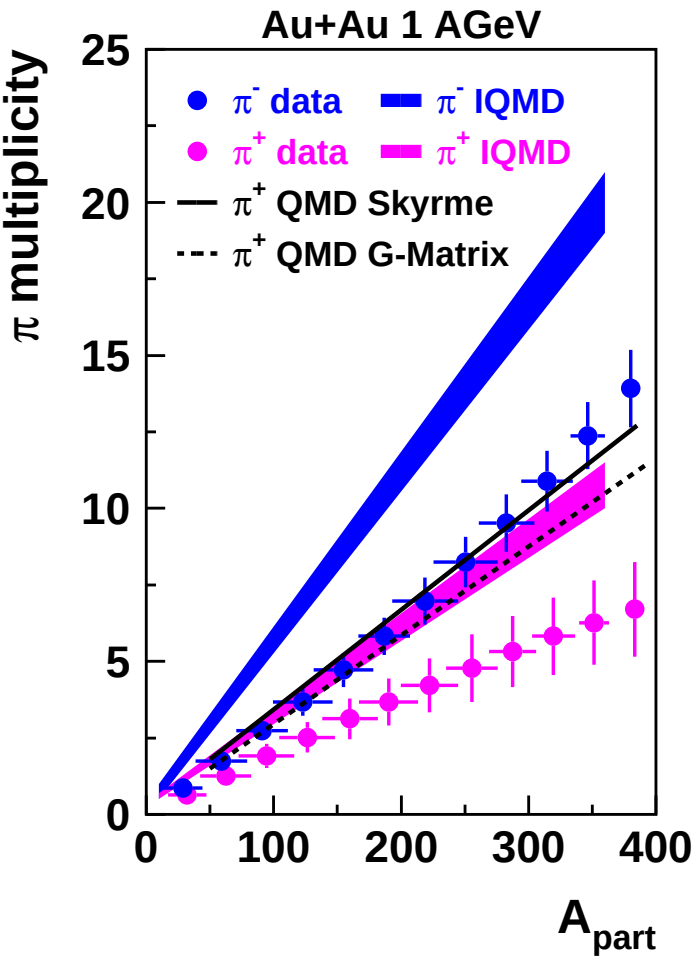
RBUU Giessen : W. Cassing, E.L. Bratkovskaya, Phys. Rep. 308(1999)65

RBUU SUNY : G.Q. Li et al., Nucl. Phys. A 625(1997)372

IQMD : C. hartnack et al., B. Hong et al., Phys. Rev. C 57(1998)244

Pion Yield





- π yield overestimated by transport models in large systems
- π production understood in small systems (?)

FOPI Ni-data : B. Hong et al., Phys. Rev. C 57(1998)244

FOPI Au-data : D. Pelte et al., Z. Phys. A 357(1997)215

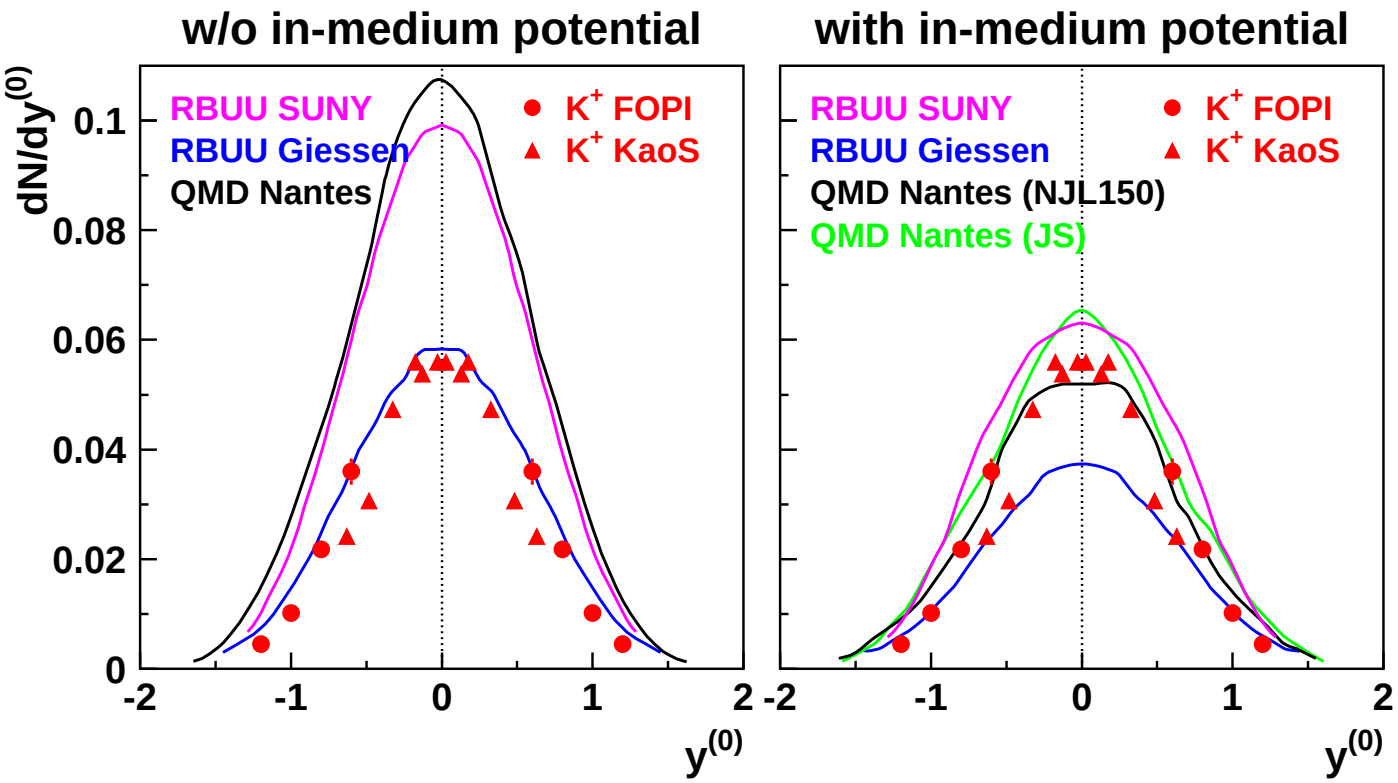
RBUU : G.Q. Li et al., Nucl. Phys. A 625(1997)372

IQMD : C. Hartnack et al., D. Pelte et al., Z. Phys. A 357(1997)215

QMD : V.S. Uma Maheswari et al., Nucl. Phys. A 628(1998)669

K^+ Yield

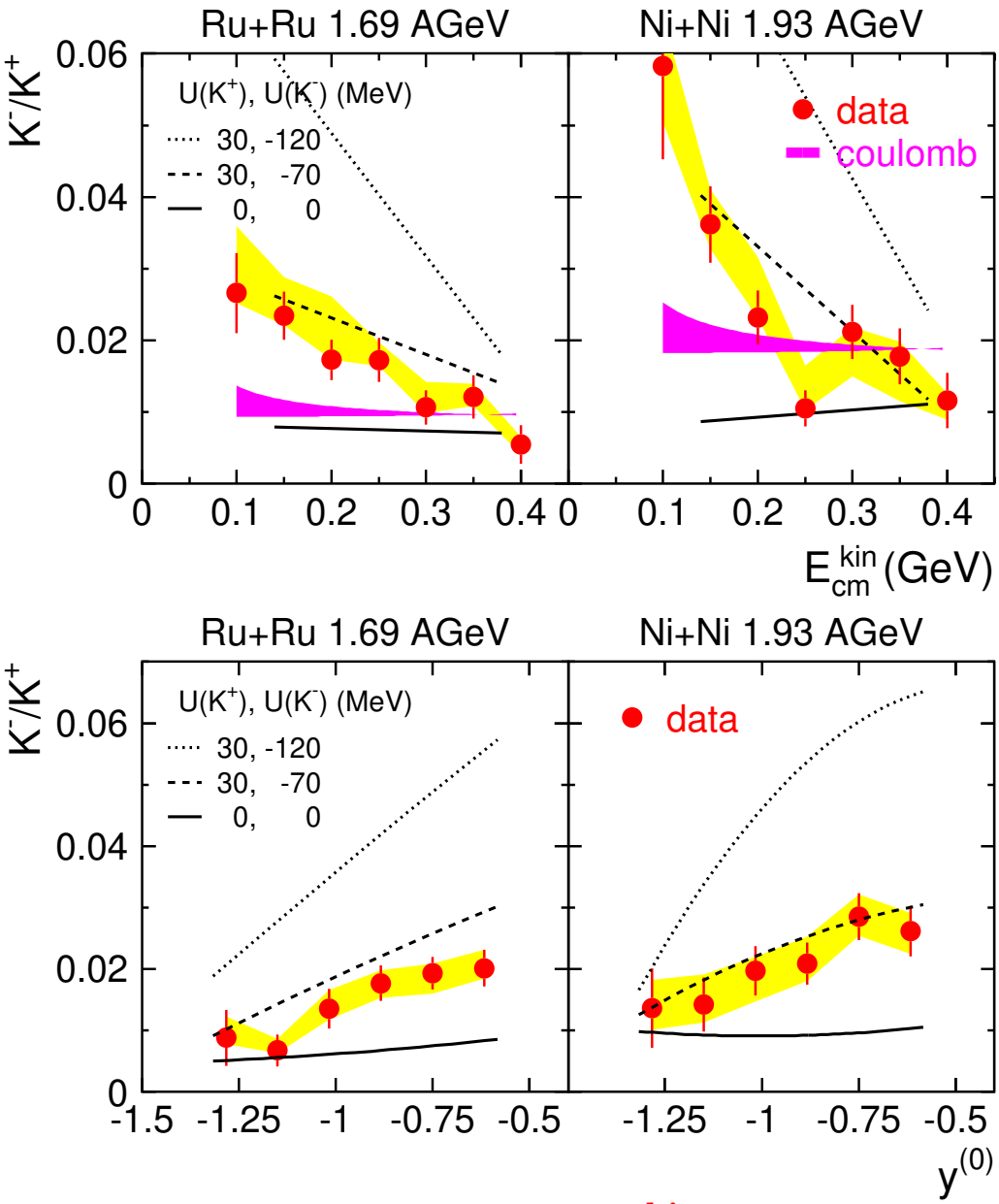
Central Ni+Ni @ 1.93 AGeV



- nice overlap between FOPI and KaoS data
- bare cross-sections are obviously model dependent
- best general agreement with data if in-medium potential
- is this still true with in-medium cross-sections ?

FOPI data : D. Best et al., Nucl. Phys. A 625 (1997) 307
KaoS data : M. Menzel et al., GSI-Report 2000-01, p47
RBUU SUNY : G.Q. Li et al., Nucl. Phys. A 625(1997)372
RBUU Giessen : W. Cassing, E.L. Bratkovskaya, Phys. Rep. 308(1999)65
QMD : C. Hartnack and J. Aichelin, Hirschegg 2000

The K^-/K^+ Ratio



- Enhancement at low $\mathbf{E^{kin}}$ and low p_t
- not explained by coulomb
- data favour in-medium potential

K. Wiśniewski et al., submitted to Eur. Jour. Phys. A

RBUU by W. Cassing and E.L. Bratkovskaya

The K^-/K^+ Ratio (cont.)

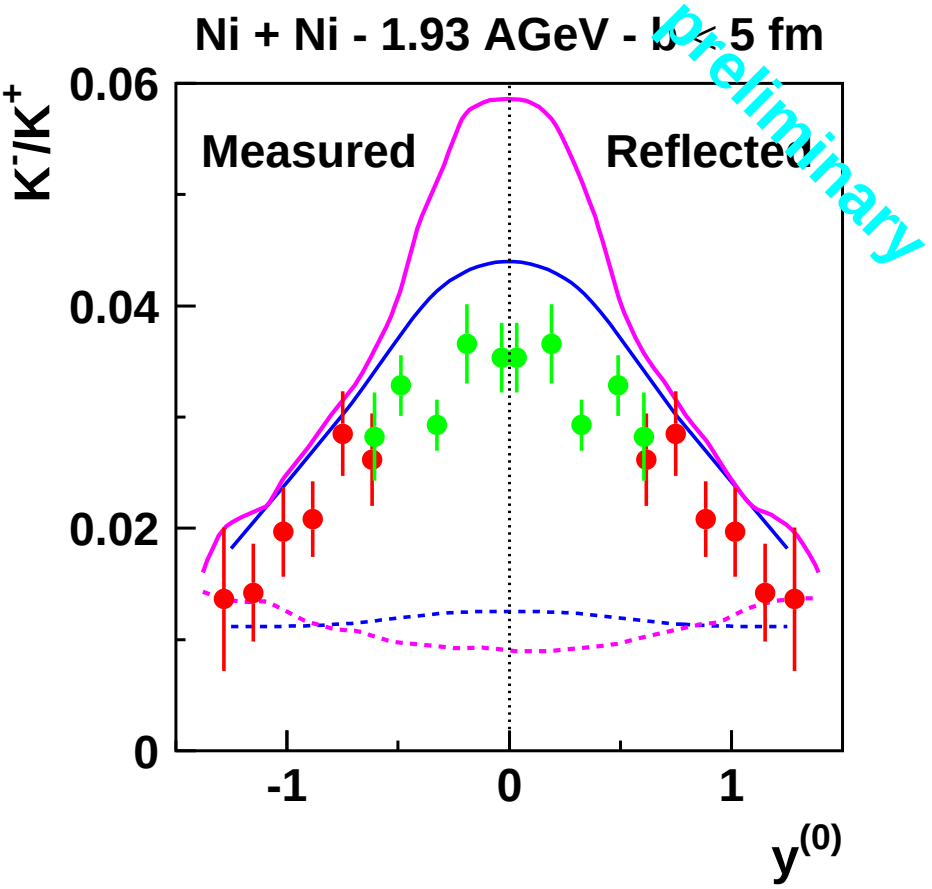
- FOPI data : K. Wisniewski et al., submitted to Eur. Jour. Phys. A
- KaoS data : M. Menzel et al., GSI-Report 2000-01, p47

— RBUU in-medium effects

- - RBUU no medium effects

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

G.Q. Li and G.E. Brown, Phys. Rev. C58(1998)1698



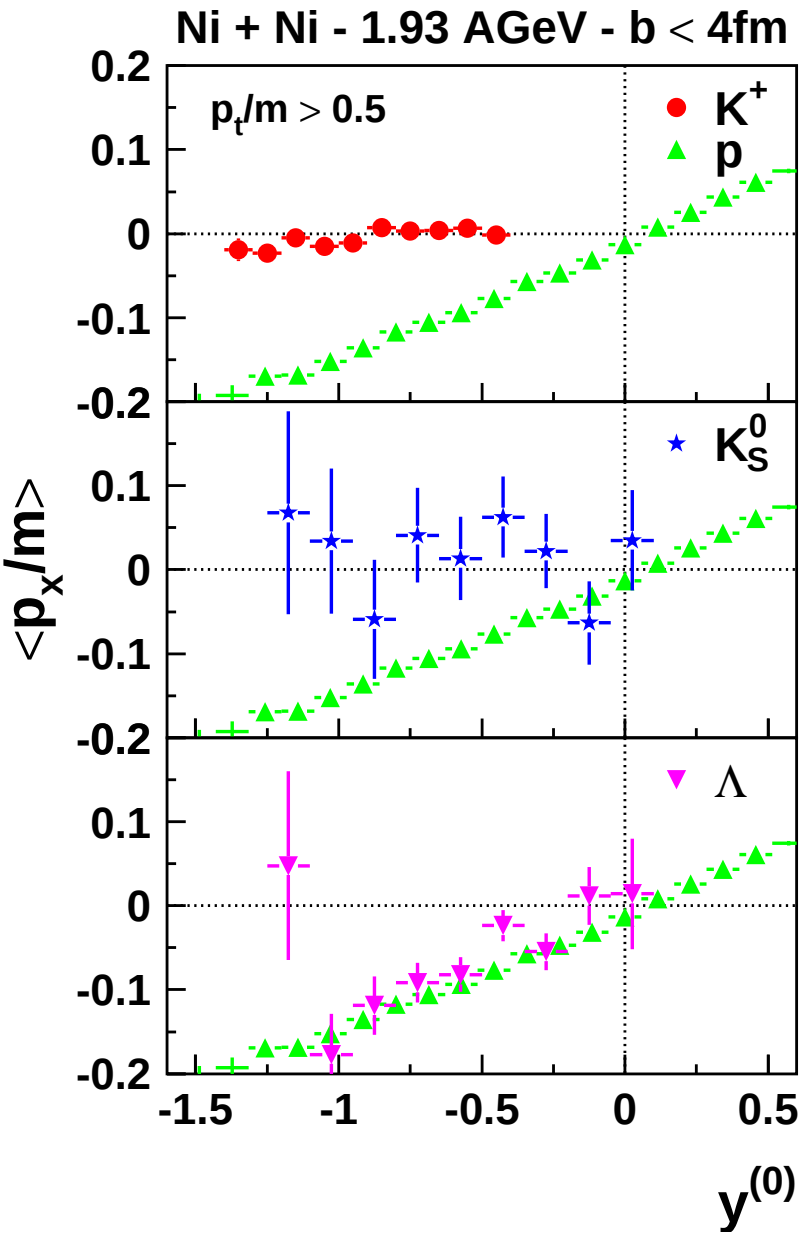
Data favour in-medium potential

None of the transport codes reproduces simultaneously and consistently K^+ dN/dy and K^-/K^+ ratio

Strangeness Sideward Flow

Not corrected for reaction plane fluctuations, $\sigma(\Delta\Phi) \simeq 40^\circ$

Errors = statistical uncertainties only

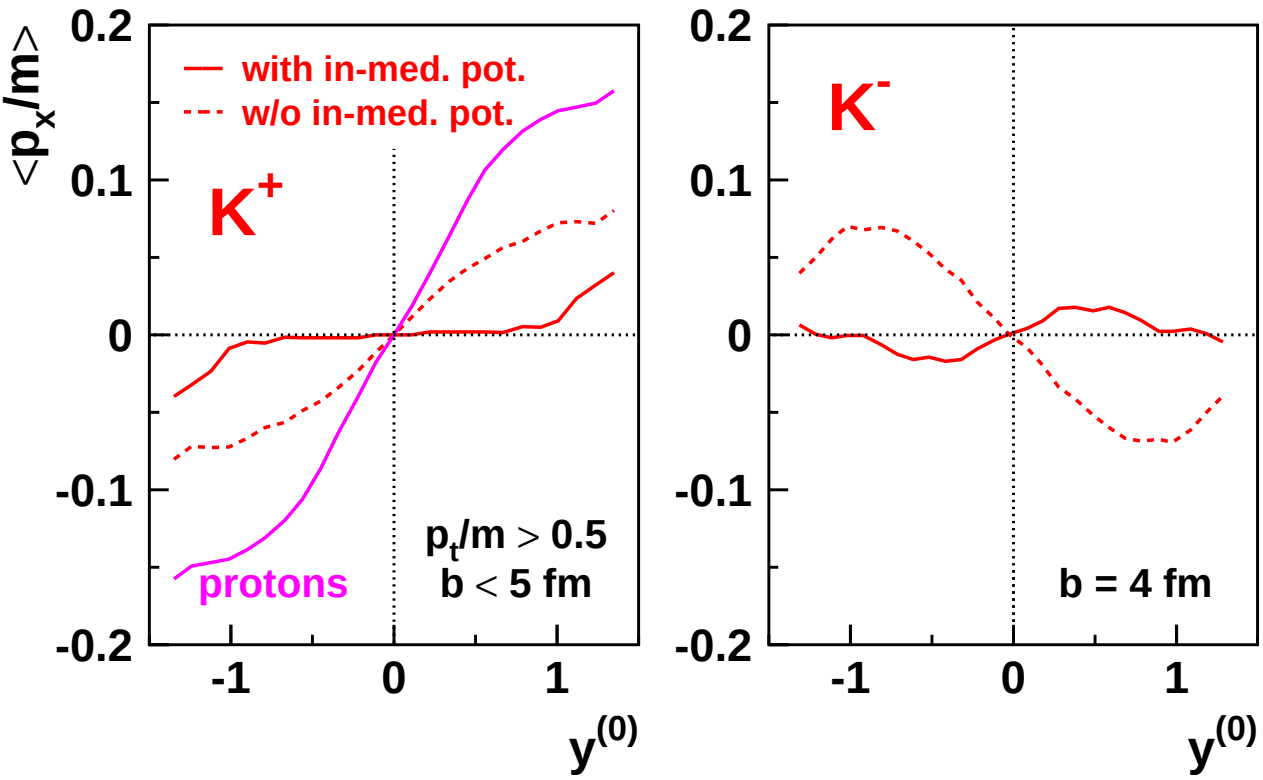


K & Λ co-produced but different propagation

J. Ritman et al., Z.Phys. A352 (1995) 156, GSI report (1996)

Kaon Sideflow : Model Predictions

Central Ni + Ni @ 1.93 AGeV - RBUU



With in-medium potential : $\begin{cases} \mathbf{K}^+ \text{ pushed away from nucleons} \\ \mathbf{K}^- \text{ pulled towards nucleons} \end{cases}$

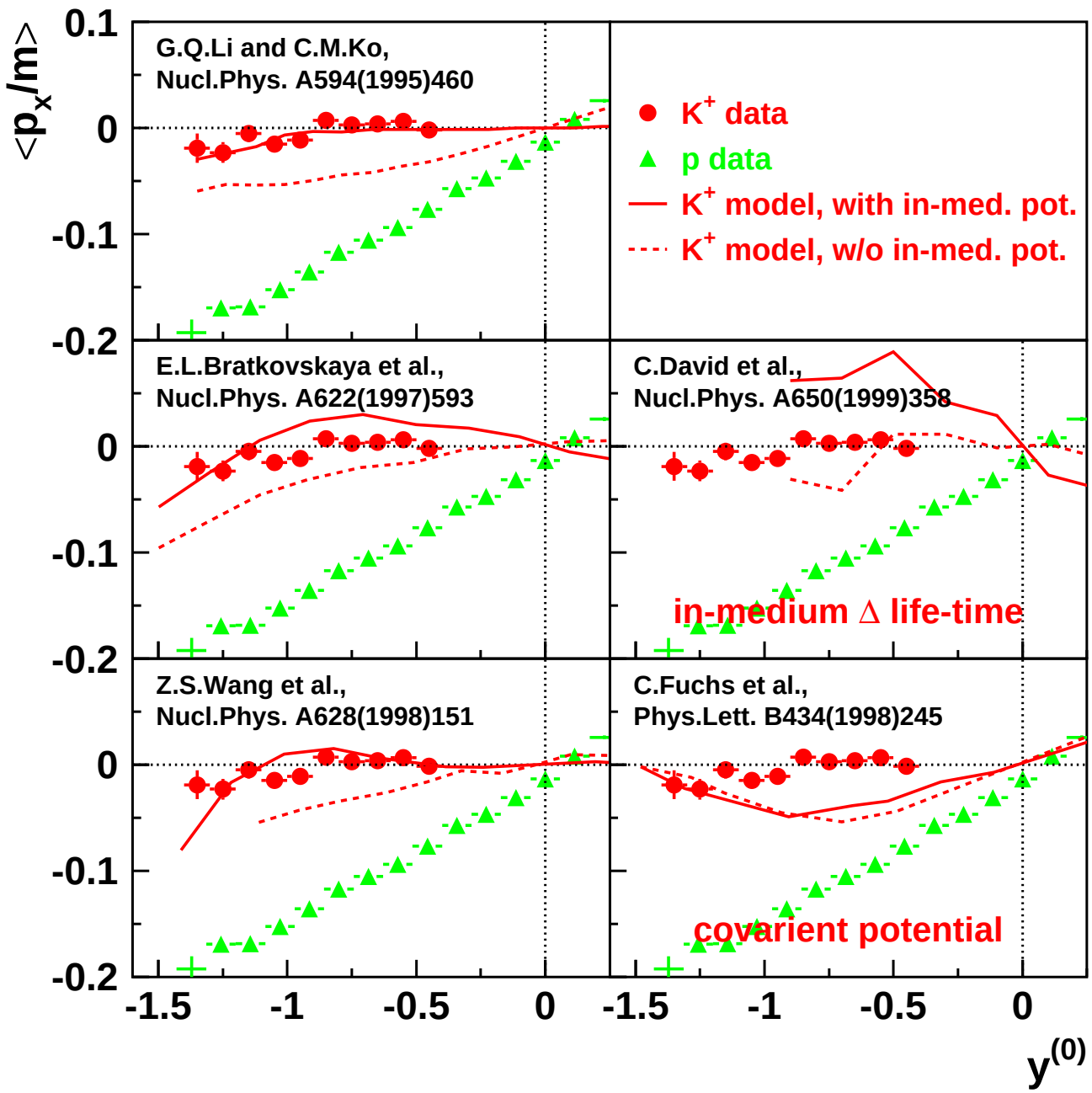
G.Q. Li et al., Phys.Rev.Lett 74 (1995) 235

G.Q. Li and C.M. Ko, Nucl.Phys. A594 (1995) 460

G.Q. Li and C.M. Ko, Phys.Rev. C54 (1996) R2159

G.Q. Li and G.E. Brown, Nucl.Phys. A636 (1998) 487

K^+ Flow in Central Ni+Ni @ 1.93AGeV

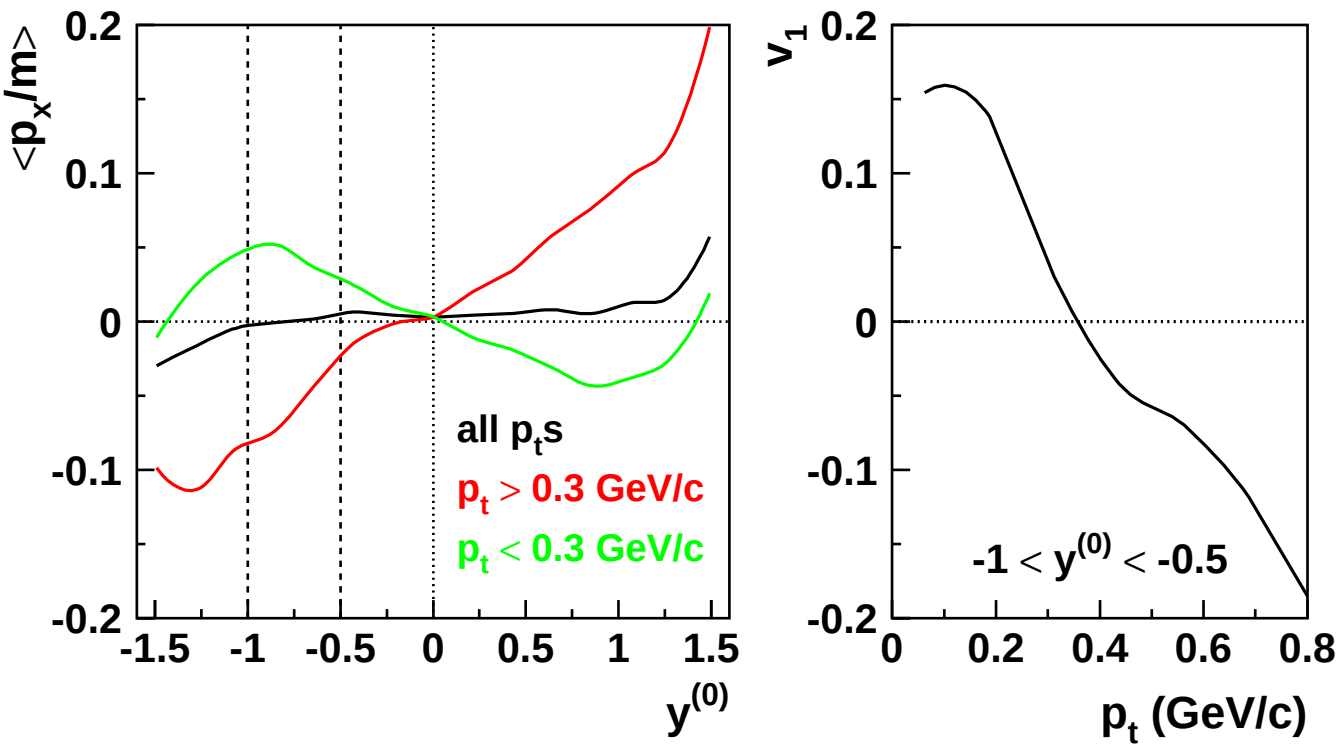


better agreement with data if in-medium potential except if in-medium Δ life-time and/or in-medium covarient potential

Why $< p_x >$-y is a "Problematic" Observable for Comparing Data and Model-Predictions

K^+ flow in Ru+Ru @ 1.69 AGeV

RBUU-Giessen : W. Cassing and E.L. Bratkovskaya

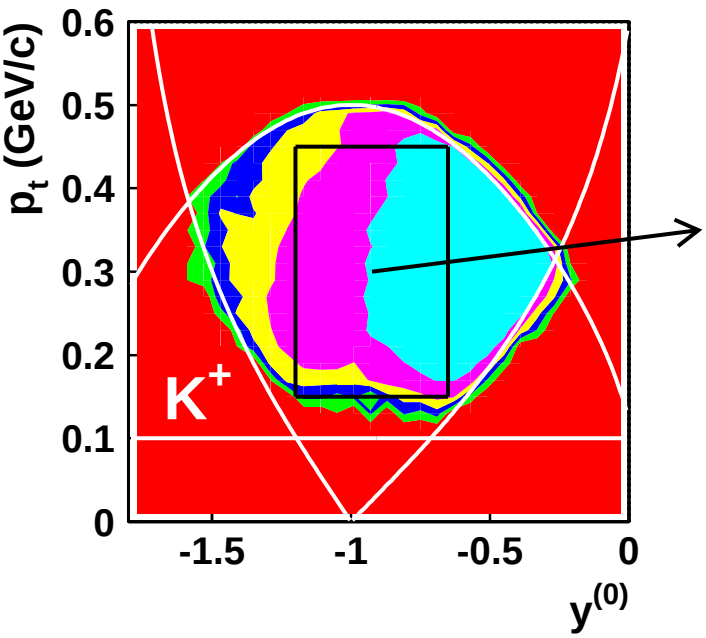


zero flow when p_t-integrated but { negative flow at low p_t / positive flow at high p_t

detector acceptance = complex convolution of y and p_t

The use of the $< p_x >$-y representation needs to filter the calculations in a realistic way

Extracting Acceptance-Free Differential-Flow

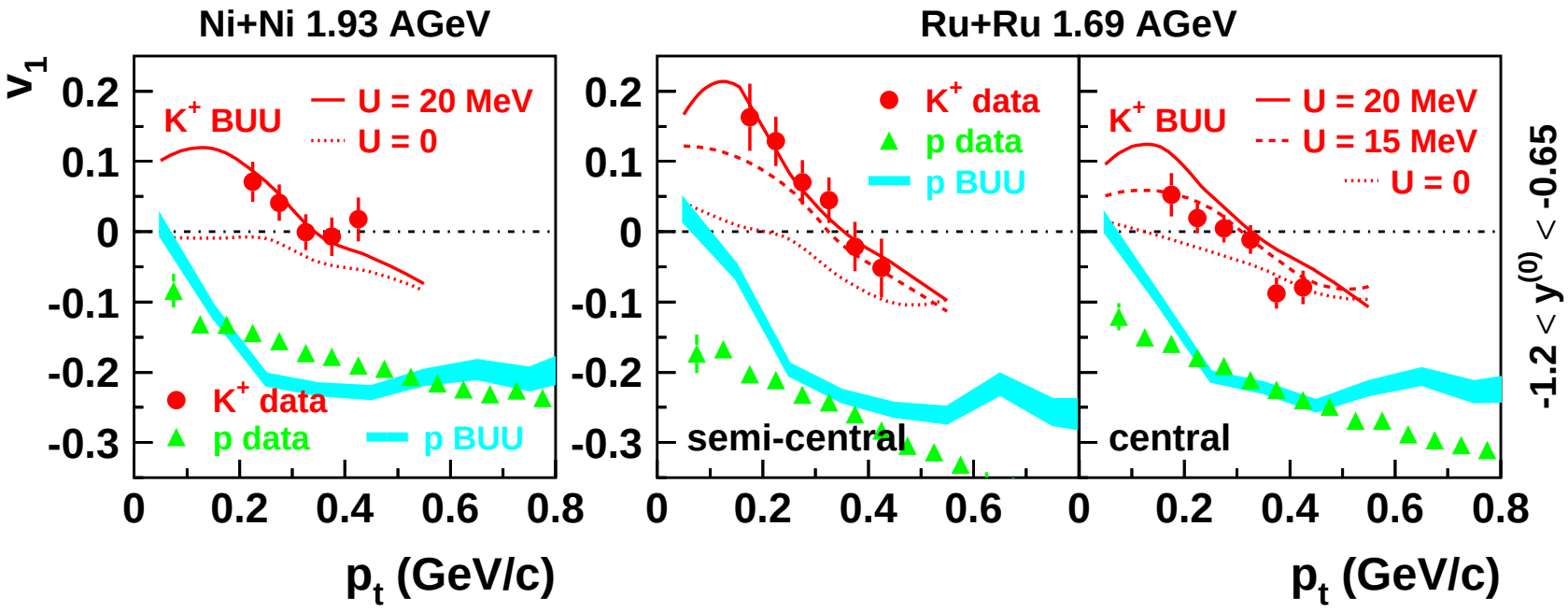


acceptance-free

Advantages :

- no need to apply any filter for model comparison
- more precise information (differential instead of integrated)

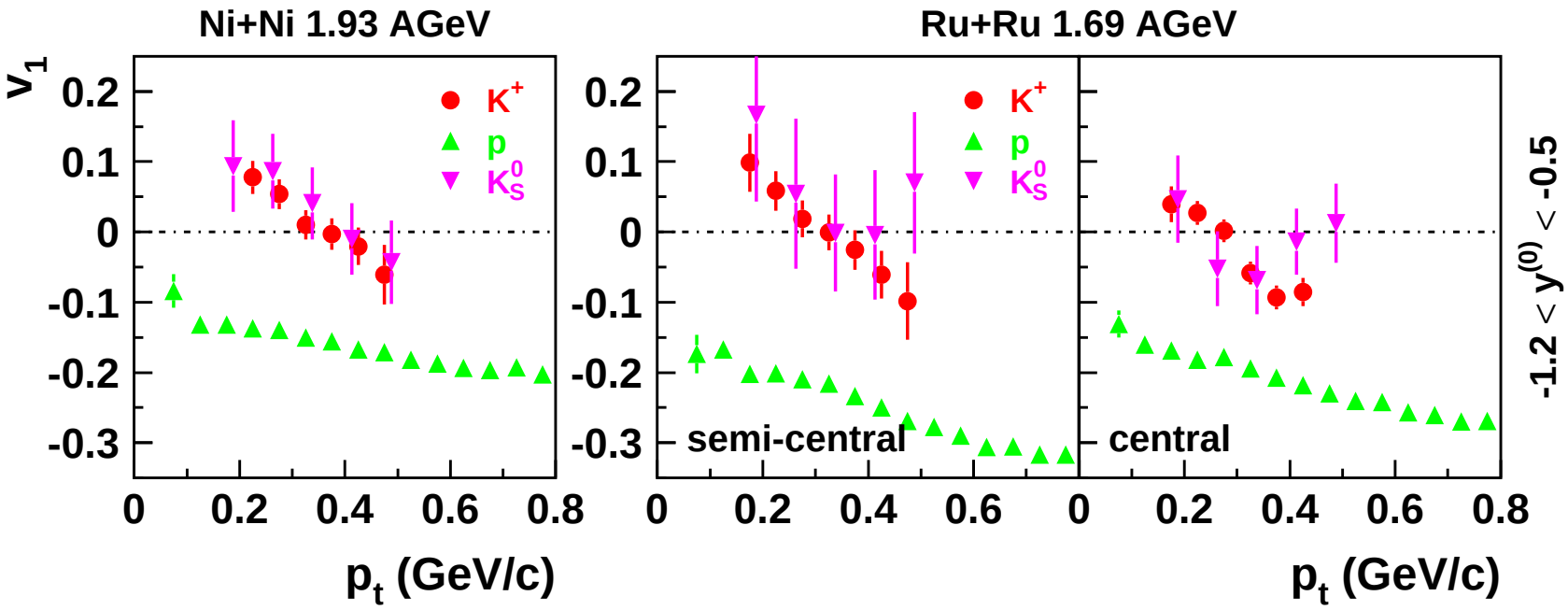
K^+ Differential Flow



- K^+ anti-flow at low p_t, most pronounced in non-central events
- K^+ flow data favour in-medium potential
- largest sensitivity to in-medium potential at low p_t
- proton flow not well reproduced by RBUU

nucl-ex/0006004, Phys. Lett. B in press, RBUU calculations by W. Cassing and E.L. Bratkovskaya

K^0_S Differential Flow

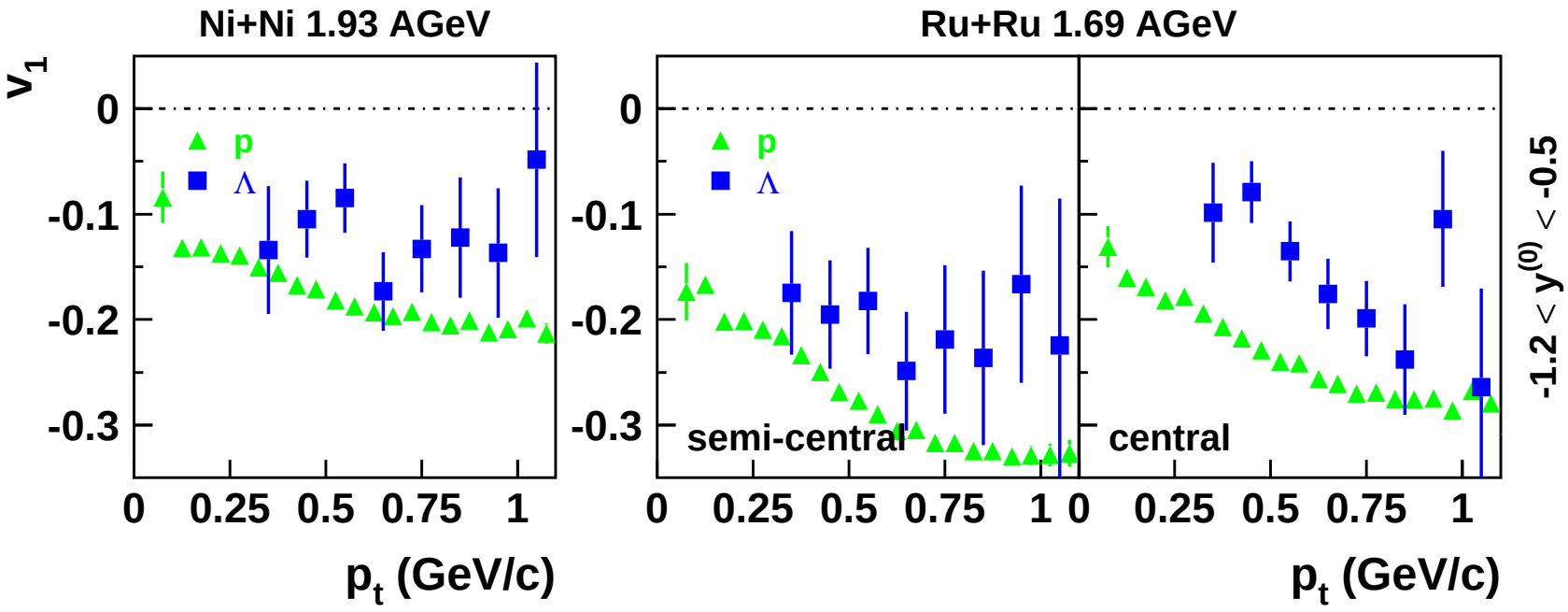


- K^0_S similar to K^+ flow
- qualitative agreement with E895 data P. Chung et al., J. Phys. G 25(1999)255
- diff. between K^0_S and K^+ flow (coulomb) is expected to be weak

Z.S. Wang et al., Nucl.Phys. A 628(1998)151, B. Zhang et al., nucl-th/9906067

R. Kutsche, PhD Thesis GSI-DISS/2000-05

Λ Differential Flow



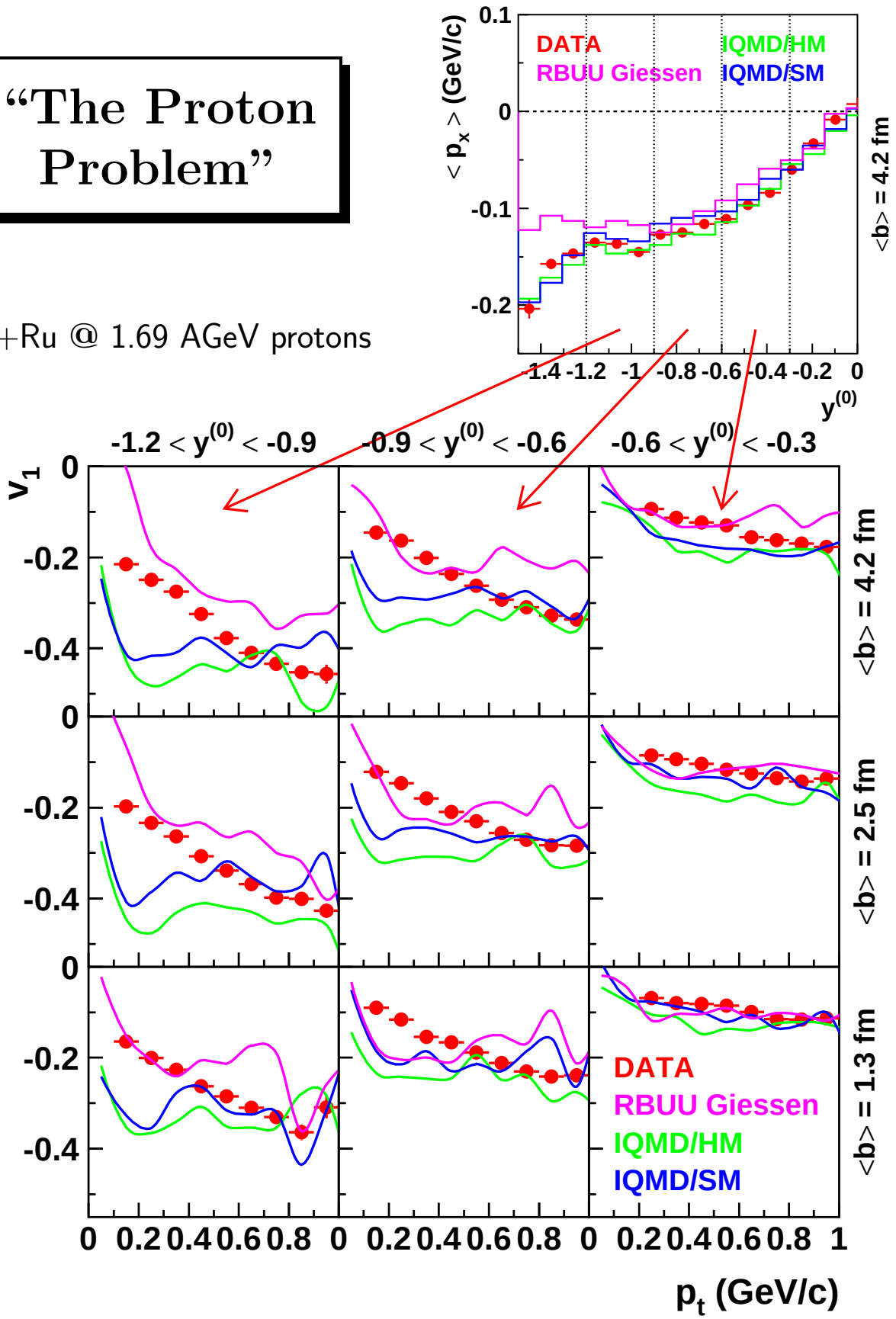
- Λ flow smaller than proton flow
- qualitative agreement with E895 data P. Chung et al., J. Phys. G25(1999)255
- supports a Λ potential of $2/3$ the nucleon potential

G.Q. Li and C.M. Ko, Phys.Rev. C54(1996)1897, G.Q. Li and G.E. Brown, Nucl.Phys. A636(1998)487, Z.S. Wang et al., Nucl.Phys. A645(1999)177

R. Kutsche, PhD Thesis GSI-DISS/2000-05

"The Proton Problem"

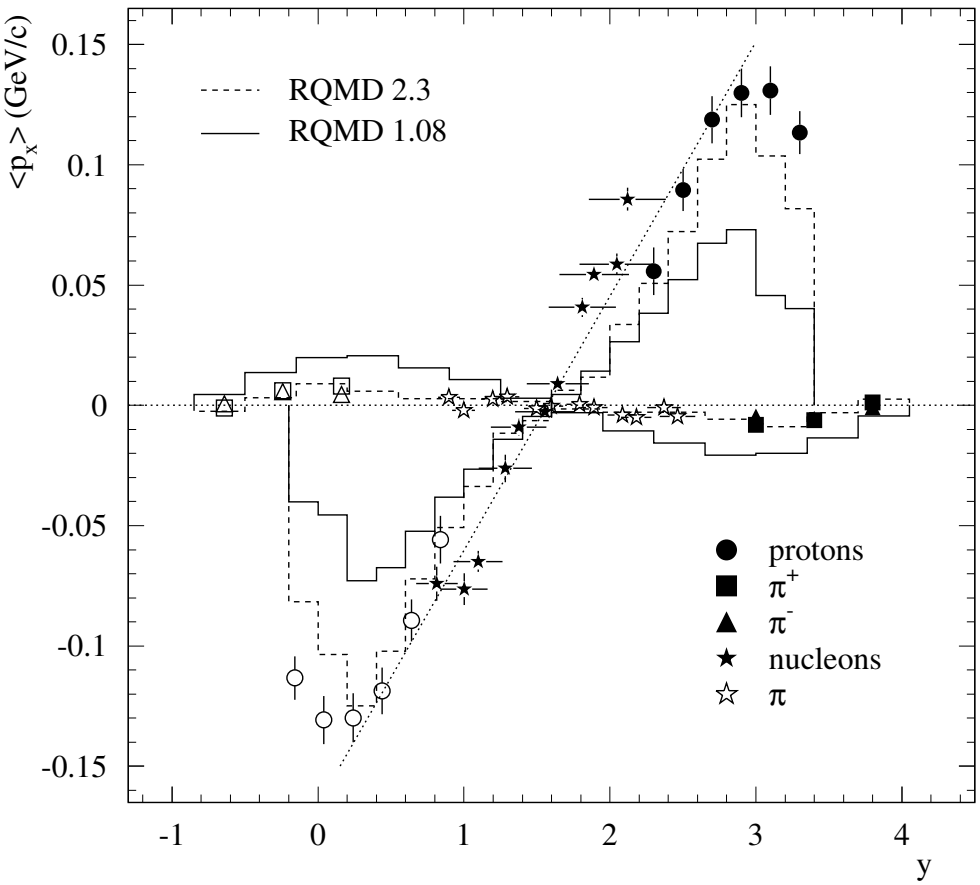
Ru+Ru @ 1.69 AGeV protons

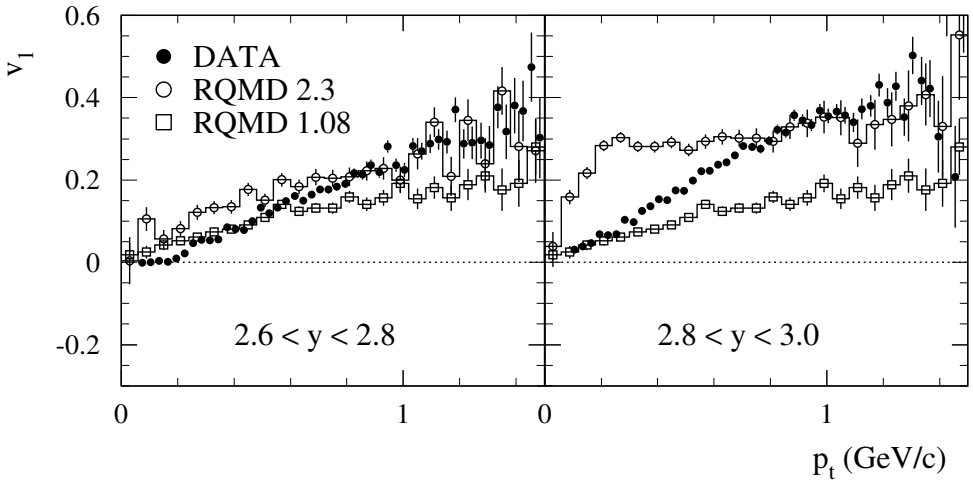


The p_t-integrated representation hides strong discrepancies

same feature with RQMD in Au+Au @ 11 AGeV : PRC 56(1997)3254

Au+Au @ 11 AGeV





J. Barrette and the E877 Collaboration, Phys. Rev. C 56 (1997) 3254