K^+ Flow in Heavy Ion Collisions at SIS Energies

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FOPI

FOPI Collaboration

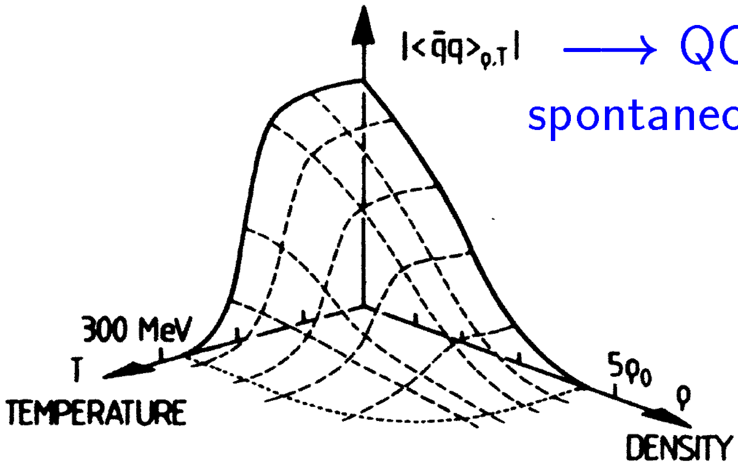
1 Kaons in dense nuclear matter

2 K^+ flow in $\left\{ \begin{array}{l} \mathbf{Ni + Ni\ @\ 1.93\ AGeV} \\ \mathbf{Ru + Ru\ @\ 1.69\ AGeV} \end{array} \right.$

3 p_t dependence of K^+ flow

4 Summary

Kaons in Dense Nuclear Matter



$\longrightarrow$ QCD vacuum : $<\bar{q}q>\neq 0$

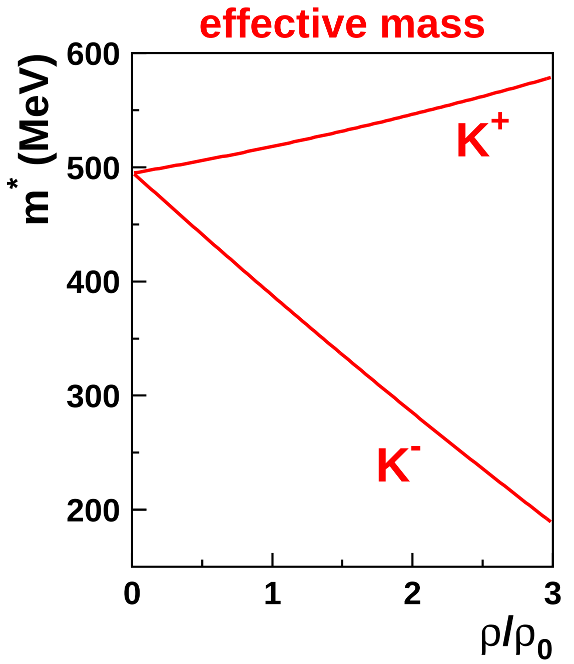
spontaneous chiral symmetry breaking

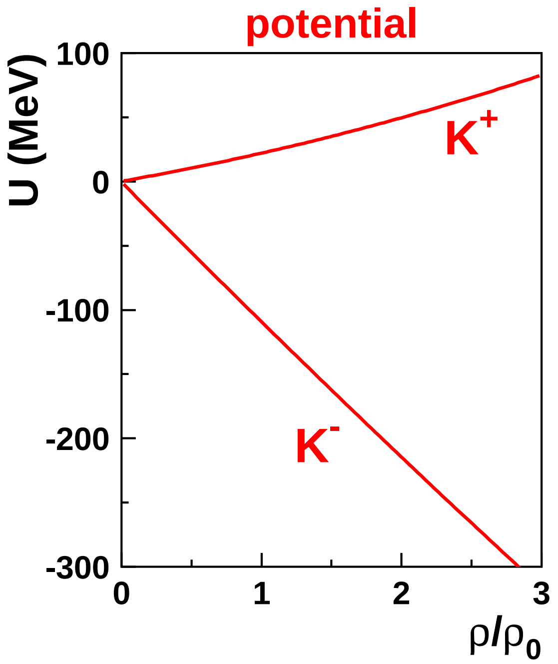
Tendency towards partial chiral symmetry restoration in dense & hot nuclear matter

$\Downarrow$

change of hadron properties

Kaon : Goldstone boson with strangeness



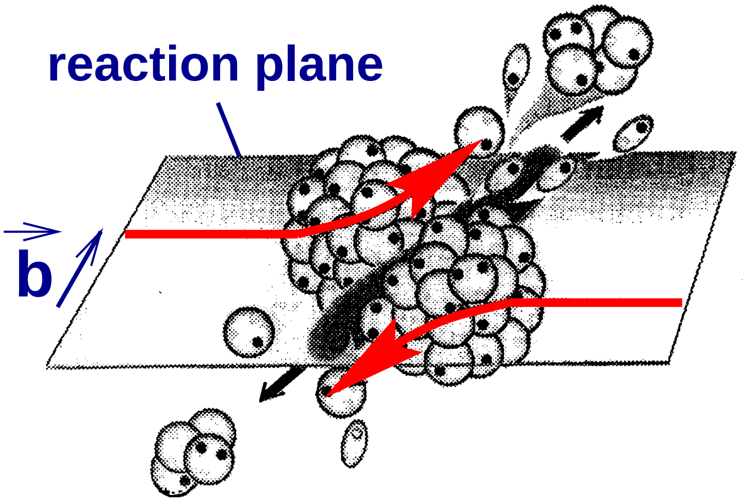


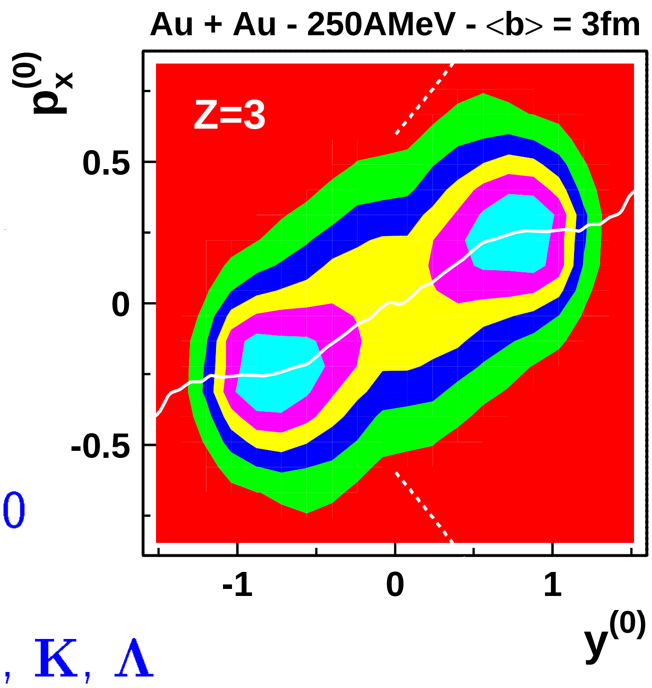
production $\longleftarrow$ characteristic $\longrightarrow$ propagation

yield $\longleftarrow$ observable $\longrightarrow$ flow

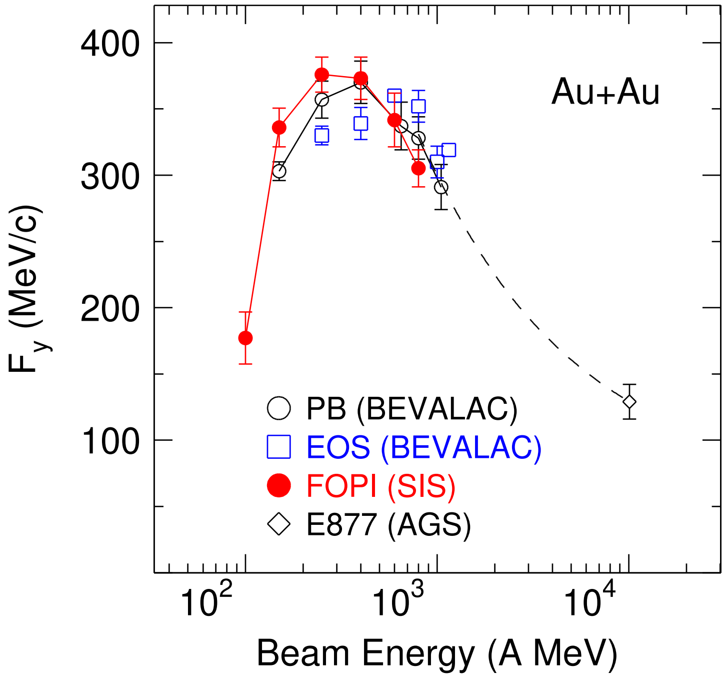
G.Q. Li and C.M. Ko, Nucl.Phys. A594(1995)460, C.H. Lee, Phys.Rep. 275(1996)255
W. Weise, Nucl.Phys. A610(1996)35c, W. Cassing et al., Nucl.Phys. A614(1997)415
C.M. Ko, V. Koch and G. Li, Ann.Rev.Nucl.Part.Sci. 47(1997)
J. Schaffner et al., Phys.Lett. B324(1994)268

Sideward Flow





- Predicted by hydrodynamic '70
- Evidenced by Plastic Ball '80
- Observed for LCP, IMF, n, π, K, Λ
- Studied from GANIL/MSU to SPS

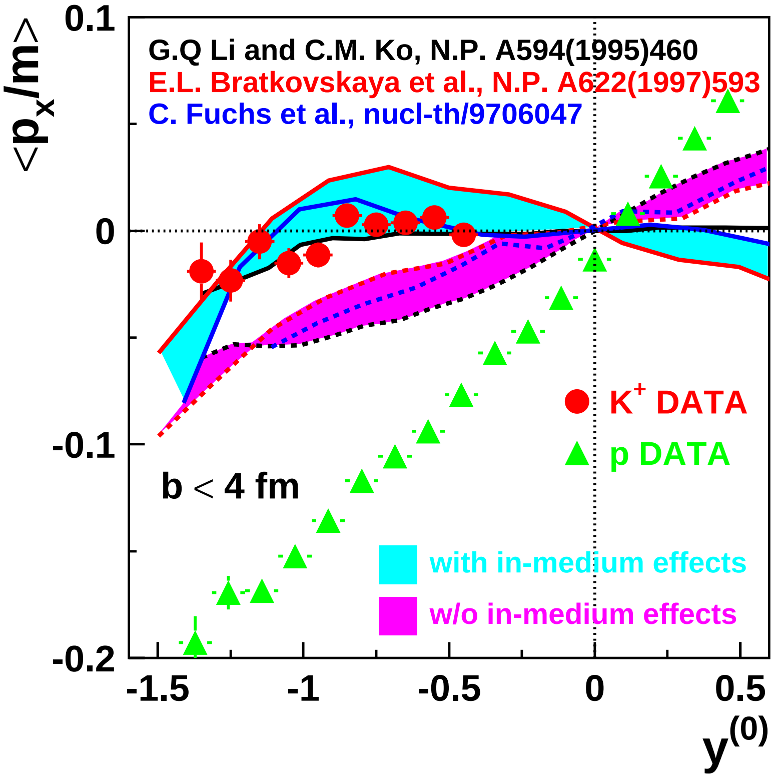


Excitation function :
maximum at SIS energies

$$F_y = \left. \frac{d < p_x >}{dy} \right|_{y=0}$$

W. Reisdorf and H.G. Ritter, Annu.Rev.Nucl.Part.Sci. 47 (1997)

K^+ Flow in Ni+Ni @ 1.93 AGeV



$3 \neq$ models favour
in-medium potential for K^+

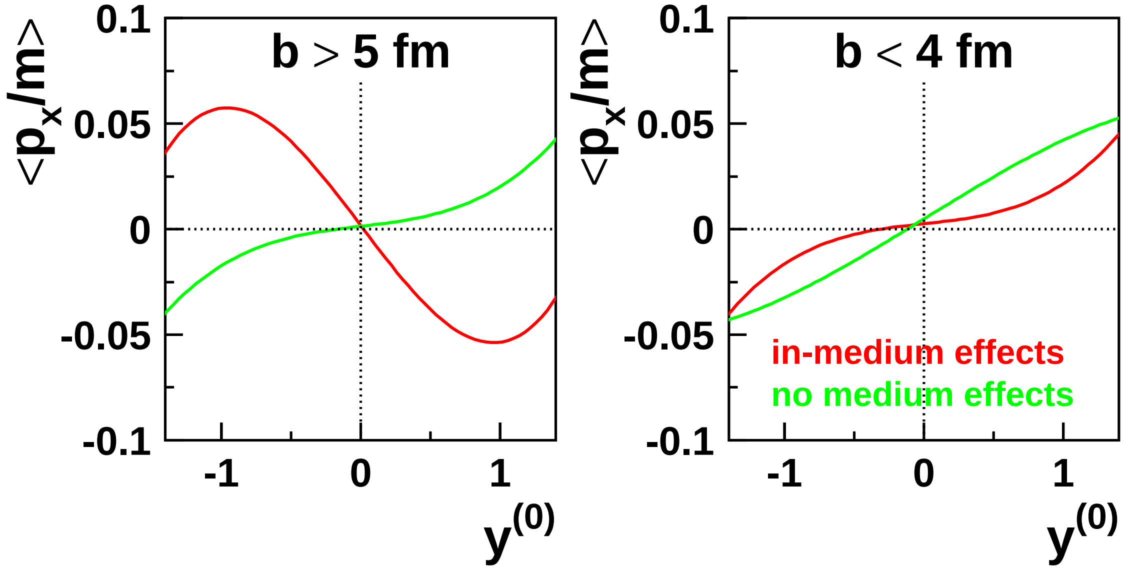
BUT influence of :

production channels :
C. David et al., nucl-th/9805017

momentum dependent potential :
C. Fuchs et al., nucl-th/9801048

K^+ Flow in Ru+Ru @ 1.69 AGeV

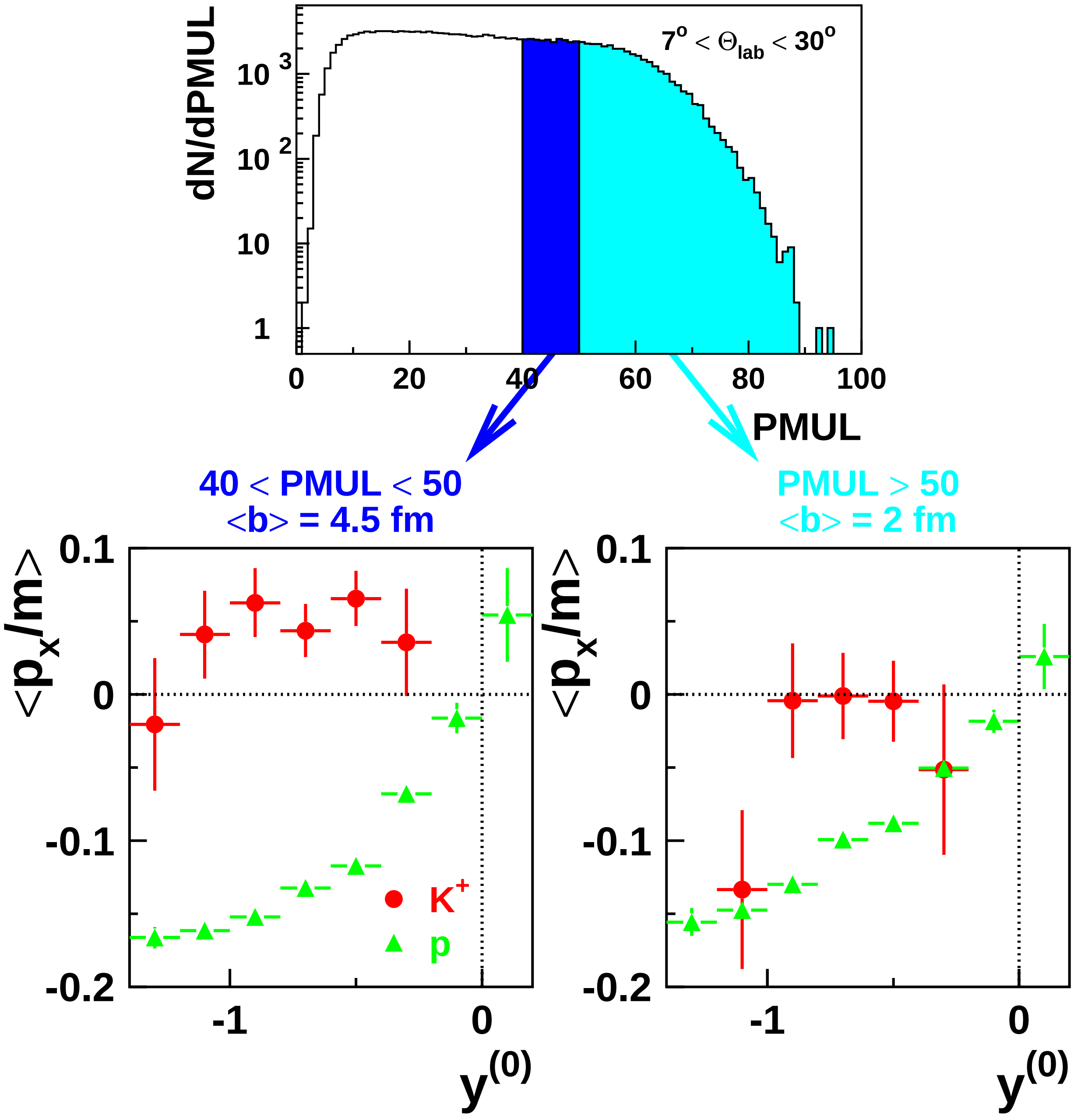
RBUU by W. Cassing and E.L. Bratkovskaya, to appear in Phys.Rep.



Large sensitivity expected in peripheral collisions
from NME to IME $\Rightarrow$ flow to antiflow

K^+ Flow in Ru+Ru @ 1.69 AGeV

Centrality selection : charged particle multiplicity PMUL



K^+ anti-flow in non-central reactions

in agreement with RBUU-in-medium

GSI-report (1997)

p_t Dependence of K^+ Flow

Fourier expansion of azimuthal distributions

$$\frac{d^3N}{dy\, p_t dp_t d\Phi} = \frac{d^2N}{dy\, p_t dp_t}\frac{1}{2\pi}\left(1 + 2v_1\cos(\Phi) + 2v_2\cos(2\Phi) + \ldots\right)$$

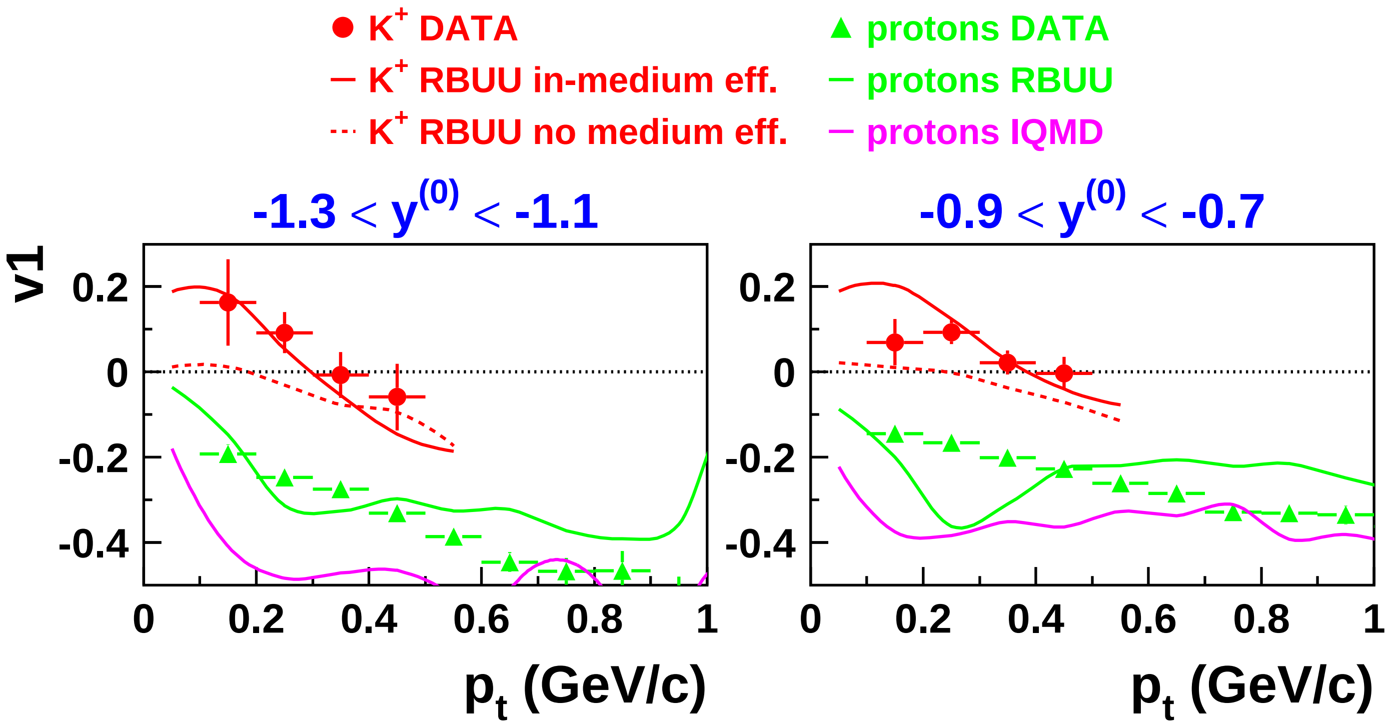
$$\Phi = \phi - \phi_{rp}$$

Fourier coefficients : $v_n = < \cos\left(n\left(\Phi\right)\right) >$

In-plane flow : $< p_x > = v_1 < p_t >$

S. Voloshin and Y. Zhang, Z.Phys. C70 (1996) 665
J.Y. Ollitrault, nucl-ex/9711003, Quark Matter'97

Ru+Ru - 1.69 AGeV - $< b > \sim 4$ fm



Sensitivity to in-medium effects at low p_t
BUU and IQMD don't reproduce proton flow

RBUU : E.L. Bratkovskaya and W. Cassing, IQMD/HM : C. Hartnack

SUMMARY

$\mathbf{K}^+$ Flow in Heavy Ion Collisions at SIS Energies

Experimental data in

$\mathbf{Ni + Ni}$ **@ 1.93 AGeV** and $\mathbf{Ru + Ru}$ **@ 1.69 AGeV**

need in-medium modification of kaon properties to be satisfactory reproduced by transport models

Open questions and problems :

Theory : $\left\{ \begin{array}{l} \text{alternative explanations for kaon data} \\ \text{description of baryon data} \end{array} \right.$

Experiment : $\left\{ \begin{array}{l} \text{systematical errors} \\ \text{limited statistic} \end{array} \right.$

Future : $\mathbf{K}^-$ flow

Larger sensitivity to in-medium effects

FOPI ToF upgrade : $\left\{ \begin{array}{l} \text{more precise measurements} \\ \text{better statistic} \end{array} \right.$