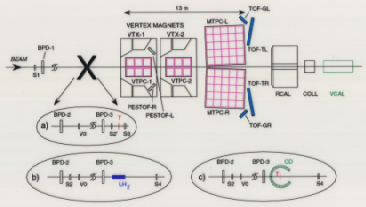
# ENERGY DEPENDENCE OF PION AND STRANGENESS AND QUARK GLUON PLASMA

M. GAŹDZICKI / FRANKFURT

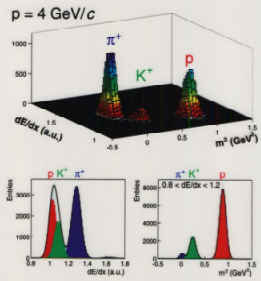
- NA49
- RESULTS
- MODELS
- SUMMARY

## NA49 experiment




Large acceptance hadron detector

CENTRAL PB+PB AT 40 AGEV




σ(dE/dx) ≈ 4% , σ(TOF) ≈ 60 ps

## NA49

LARGE ACCEPANCE HADRON DETECTOR AT SPS

CURRENT PHYSICS PROGRAMS:

- SEARCH FOR THE ONSET OF DECONFINEMENT BY STUDY OF ENERGY DEPENDENCE (20 – 160 A·GEV)
- UNDERSTANDING SYSTEM SIZE/CENTRALITY DEPENDENCE (p+p, p+A, C+C, Si+Si, Pb+Pb)
- STUDY OF LOW CROSS SECTION OBSERVABLES (D-MESONS, $\varphi \to e^+e^-$...) (Pb+Pb at 160 A·GEV)

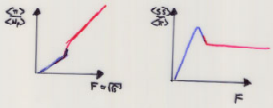
## LOW ENERGY PROGRAM AT SPS:

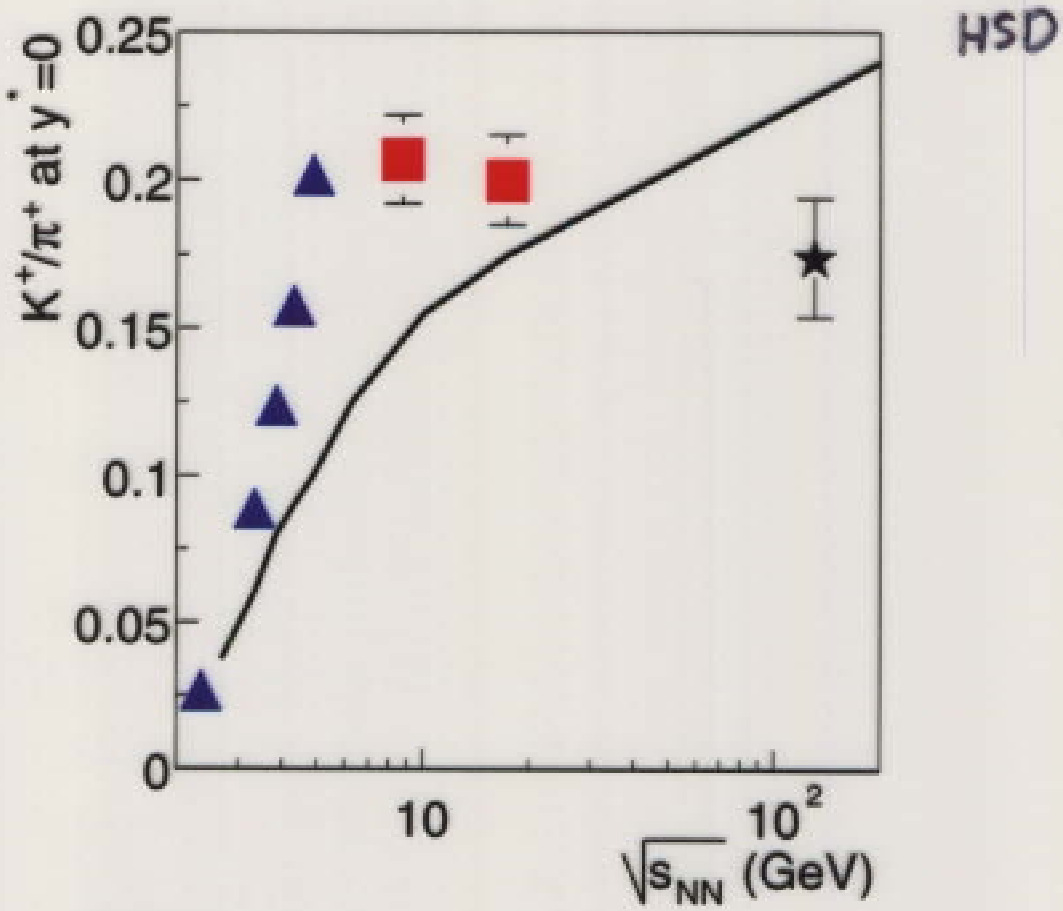
- TRIGGERD BY OBSERVATION OF ANOMALIES IN PION AND $s\bar{s}$ YIELDS LOCATED BETWEEN TOP AGS AND TOP SPS ENERGIES,

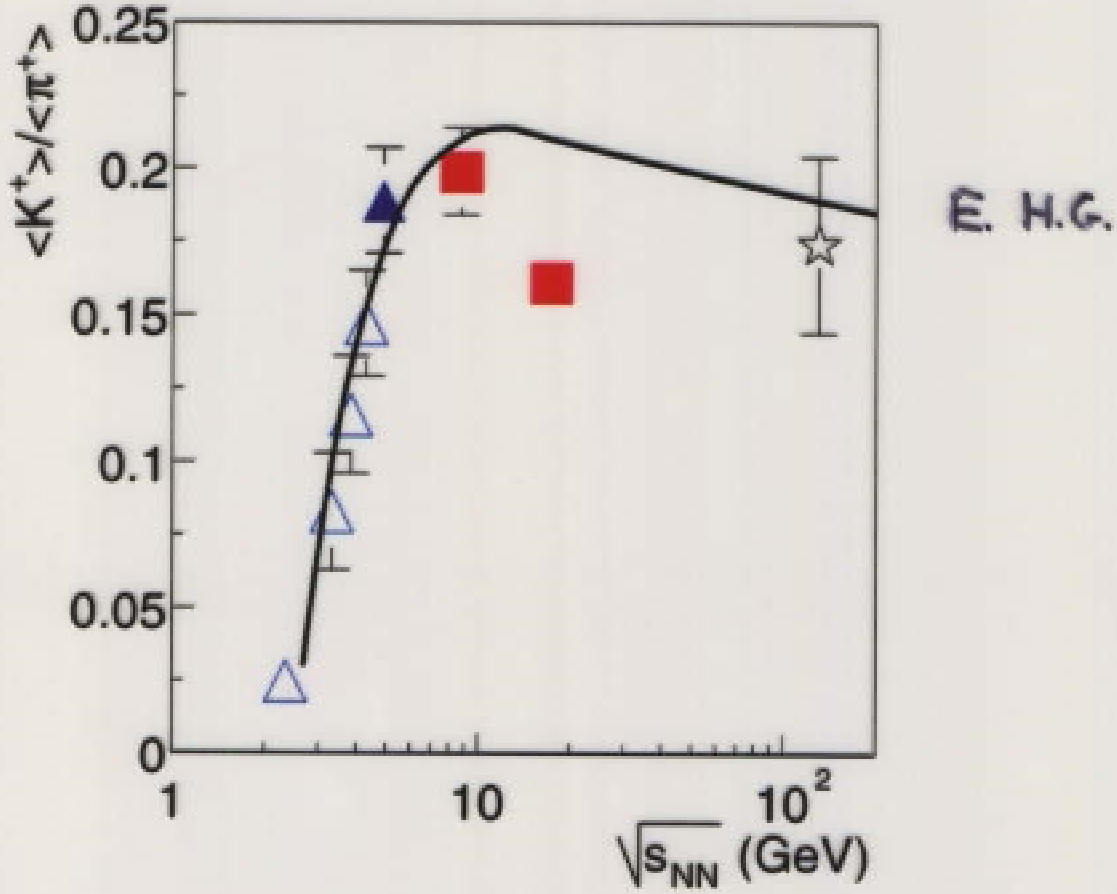
  M.G., D. RÖHRICH, Z. PHYS. C65 (95) 215, C71 (96) 55

WHICH ARE INTERPRETED AS AN EVIDENCE FOR TRANSITION TO QGP

M.G., Z. PHYS. C65 (95) 659
M.G., M. I. GORENSTEIN, ACTA PHYS. POLON. B30 (99) 2705




HSD
$K^+/\pi^+$ at $y^*=0$
0.25
0.2
0.15
0.1
0.05
0
10
$10^2$
$\sqrt{s_{NN}}$ (GeV)

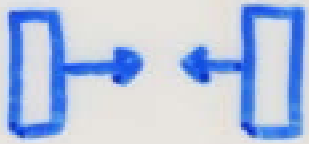

E. H.G.
$\langle K^+\rangle/\langle\pi^+\rangle$
0.25
0.2
0.15
0.1
0.05
0
1
10
$10^2$
$\sqrt{s_{NN}}$ (GeV)

# STATISTICAL MODEL OF THE EARLY STAGE

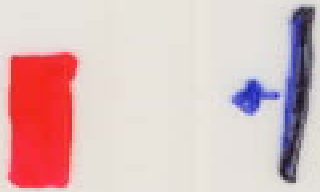
## ASSUMPTIONS:

A GENERAL PICTURE:

INITIAL STATE:



EARLY STAGE:



STATISTICAL PRODUCTION OF PARTICLES

TWO FORMS OF MATTER POSSIBLE:

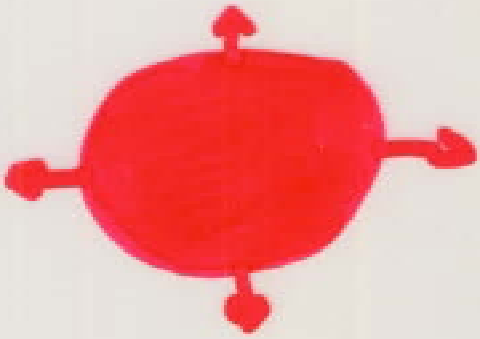
CONFINED MATTER

QGP

EXPANSION

HADRONIZATION

EXPANSION

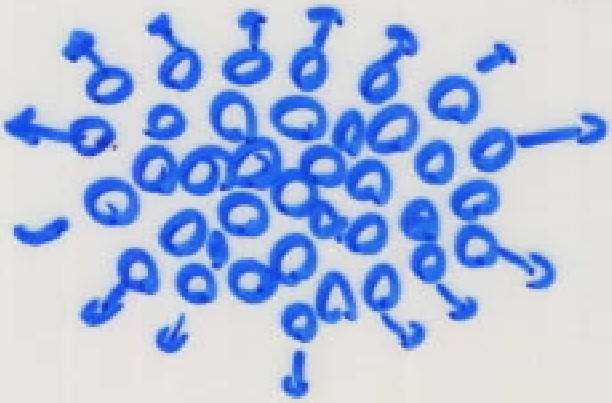


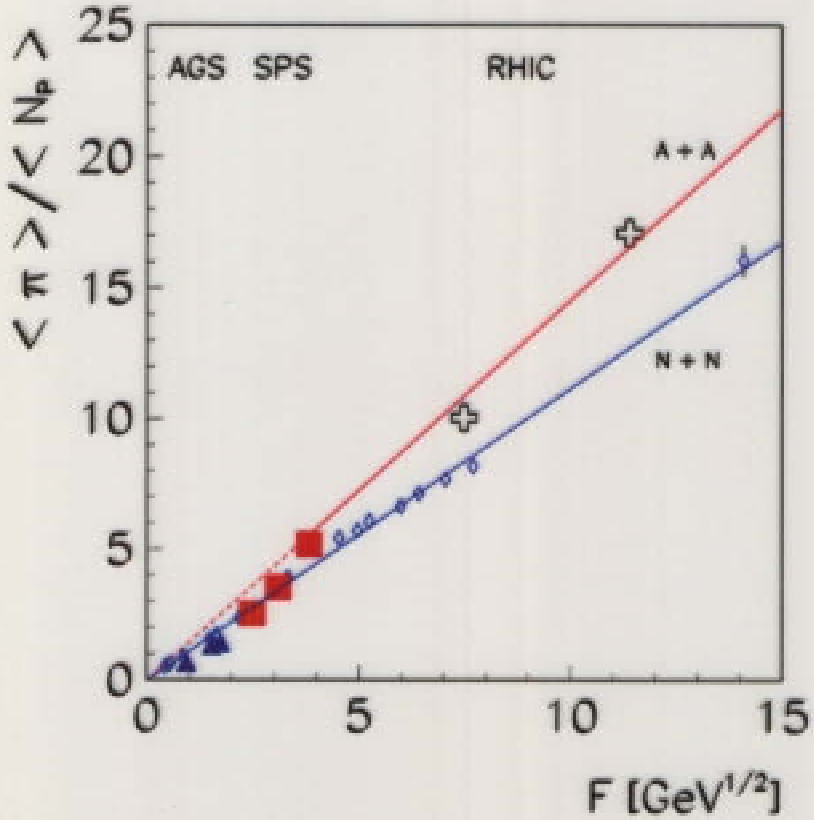
ENTROPY,

$S+\bar{S}$

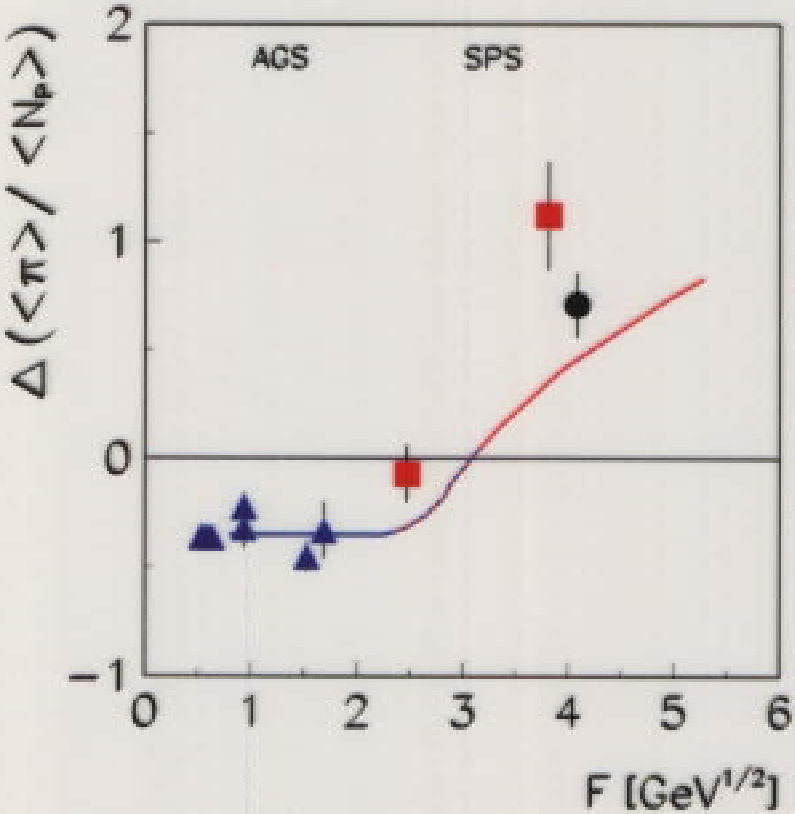
$C+\bar{C}$ ≈CONSERVED

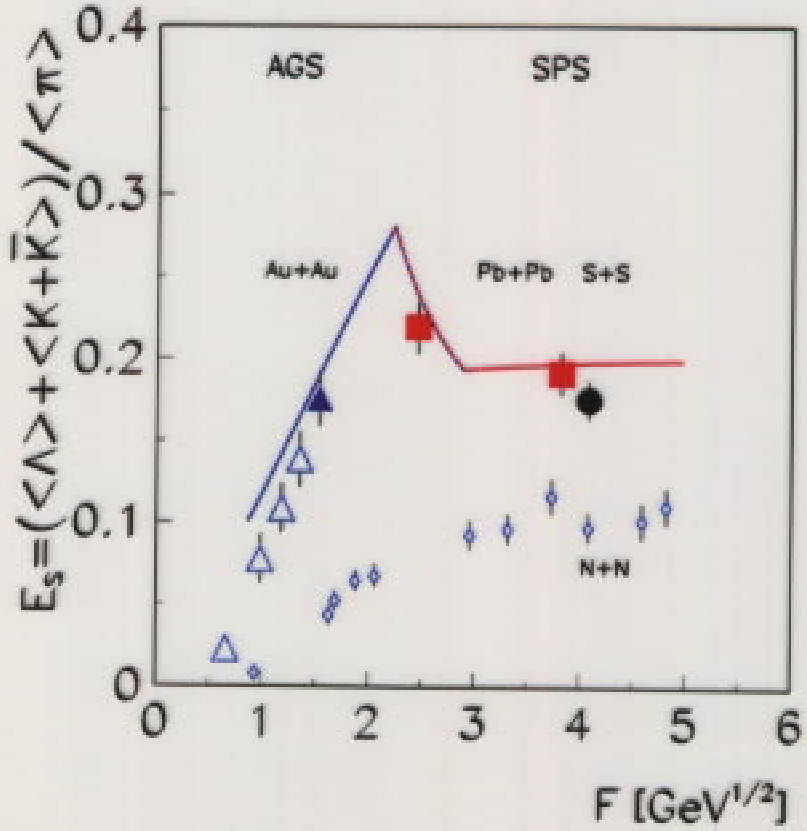
FREEZE-OUT

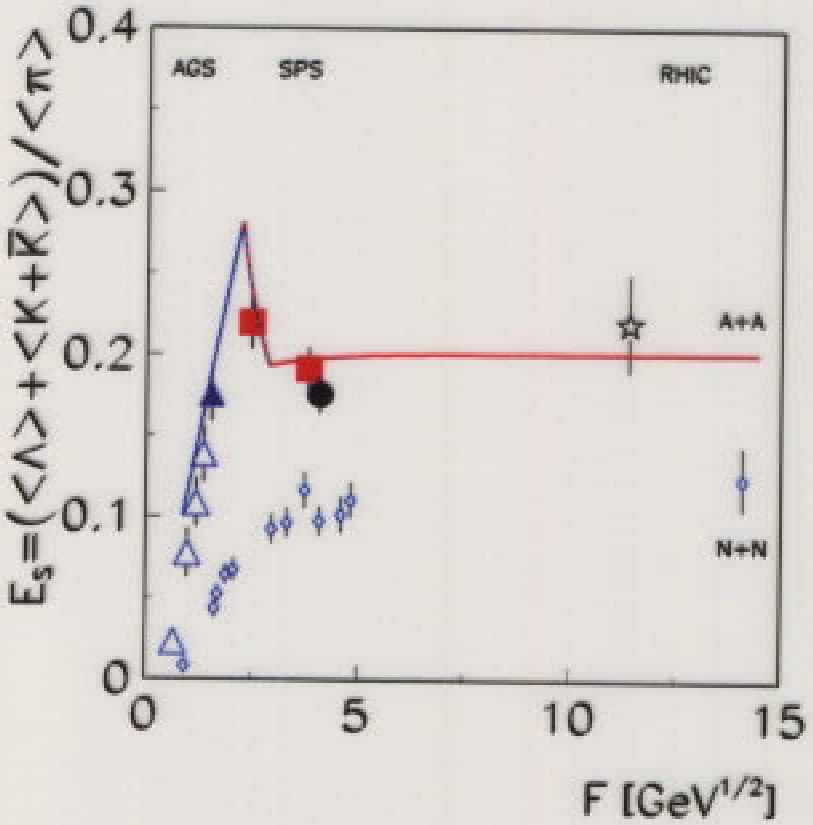





SLOPE $\sim g^{1/4}$




AGS
SPS
Au+Au
Pb+Pb
S+S
N+N
$E_s=(\langle\Lambda\rangle+\langle K+\bar{K}\rangle)/\langle\pi\rangle$
F [GeV$^{1/2}$]


AGS
SPS
RHIC
A+A
N+N
$E_s=(\langle\Lambda\rangle+\langle K+\bar{K}\rangle)/\langle\pi\rangle$
F [GeV$^{1/2}$]

# SUMMARY

- ANOMALIES IN PION AND $s\bar{s}$ YIELDS OBSERVED AT $\approx$ 40 A·GEV

  PIONS: SUPPRESSION → ENHANCEMENT

  $s\bar{s}$: MAXIMUM OF $\langle K^+ \rangle / \langle \pi^+ \rangle$

- THEY ARE CONSISTENT WITH HYPOTHESIS OF TRANSITION TO DECONFIMENT MATTER (AGS → SPS) (WITHIN STATISTICAL MODEL OF THE EARLY STAGE)

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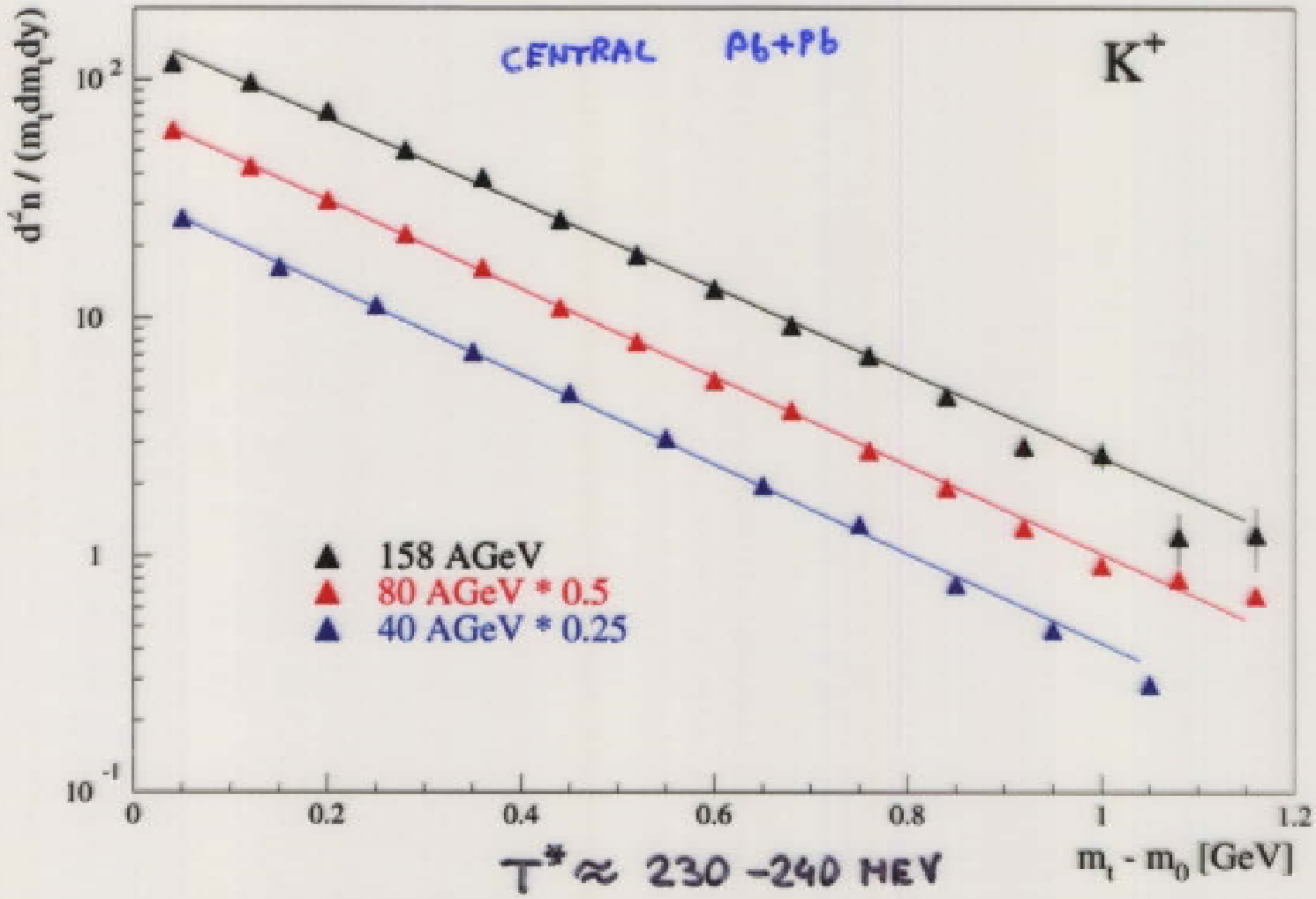
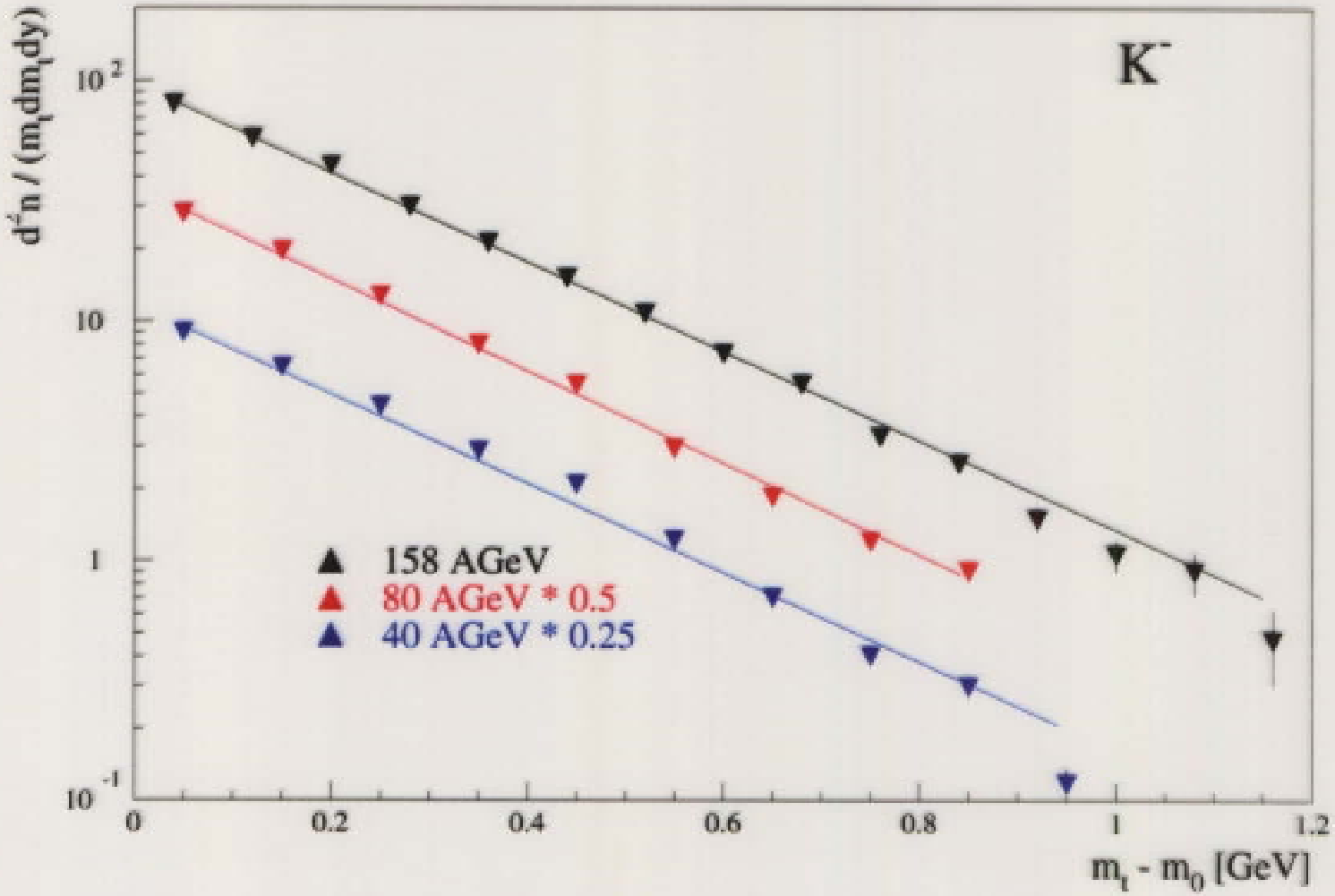
IN PROGRESS:

- ANALYSIS OF OTHER OBSERVABLES (E-by-E, FLOW ...)
- STUDY OTHER ENERGIES (20, 30 AGEV IN 2002)
- STUDY ALTERNATIVE MODELS

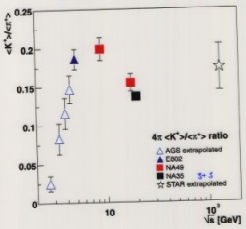



$T^* \approx 230 - 240$ MEV



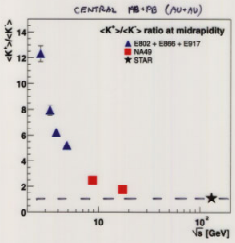
dN/dy
158 A GeV
80 A GeV
40 A GeV
AGS 10.7 A GeV
y
$\pi^+$
dN/dy
158 A GeV
80 A GeV
40 A GeV
AGS 10.7 A GeV
y
$\pi^-$

CENTRAL PB+PB (AU+AU)

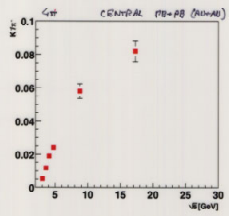



$\sim \frac{\text{STRANGENESS}}{\text{ENTROPY}}$

CENTRAL Pb+Pb (Au+Au)




$\frac{K^+}{K^-}$ ↘ 98 ↘



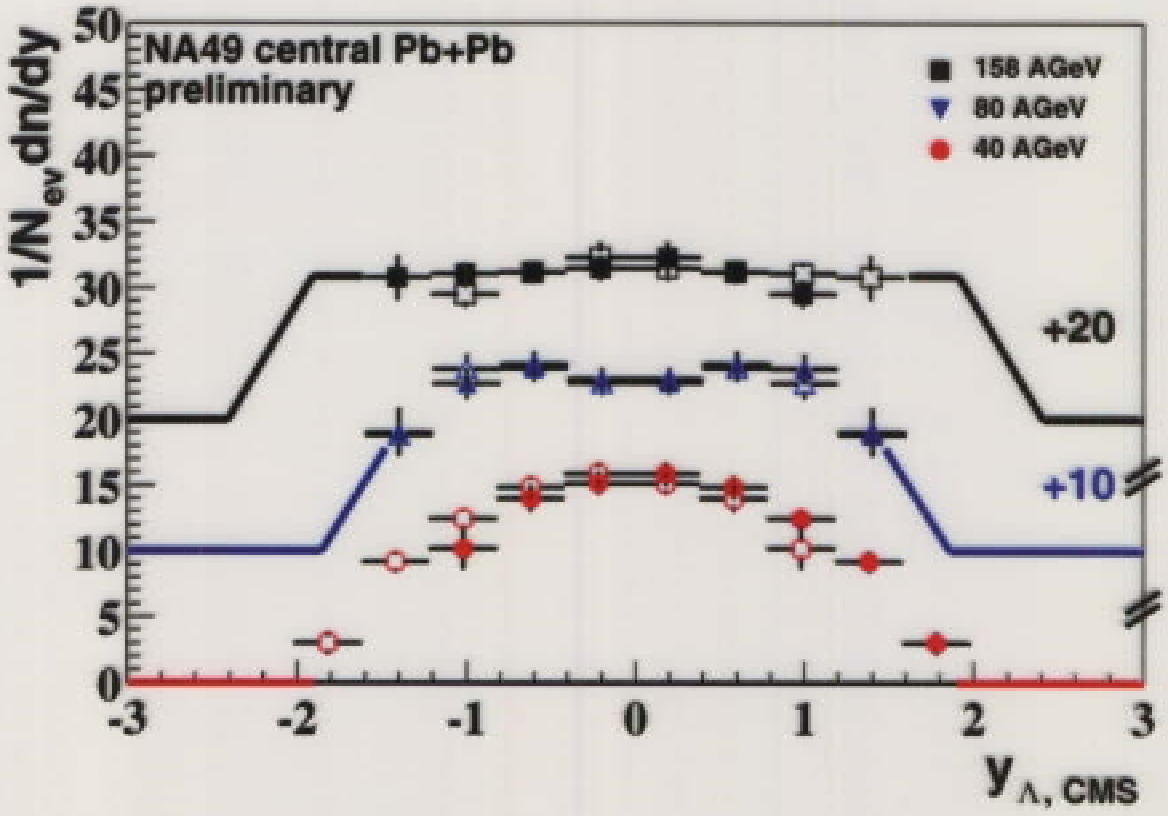

SENSITIVE TO BOTH:

STRANGENESS/ ENTROPY

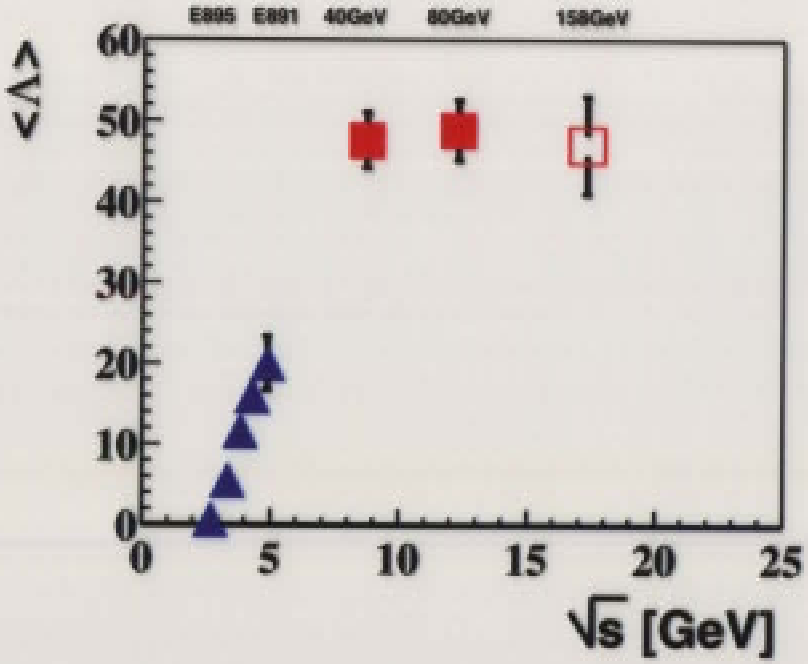
AND

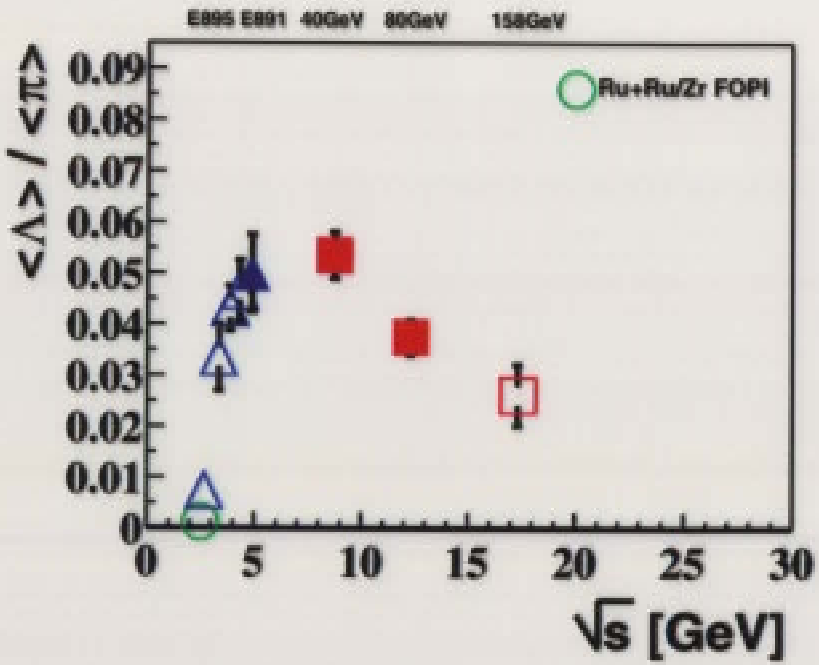
$\rho_B$

Λ




A. MISCHKE, GSI




AS $K^-$ SENSITIVE TO BOTH: STRANGENESS / ENTROPY
AND
$\rho_B$

# MODELS

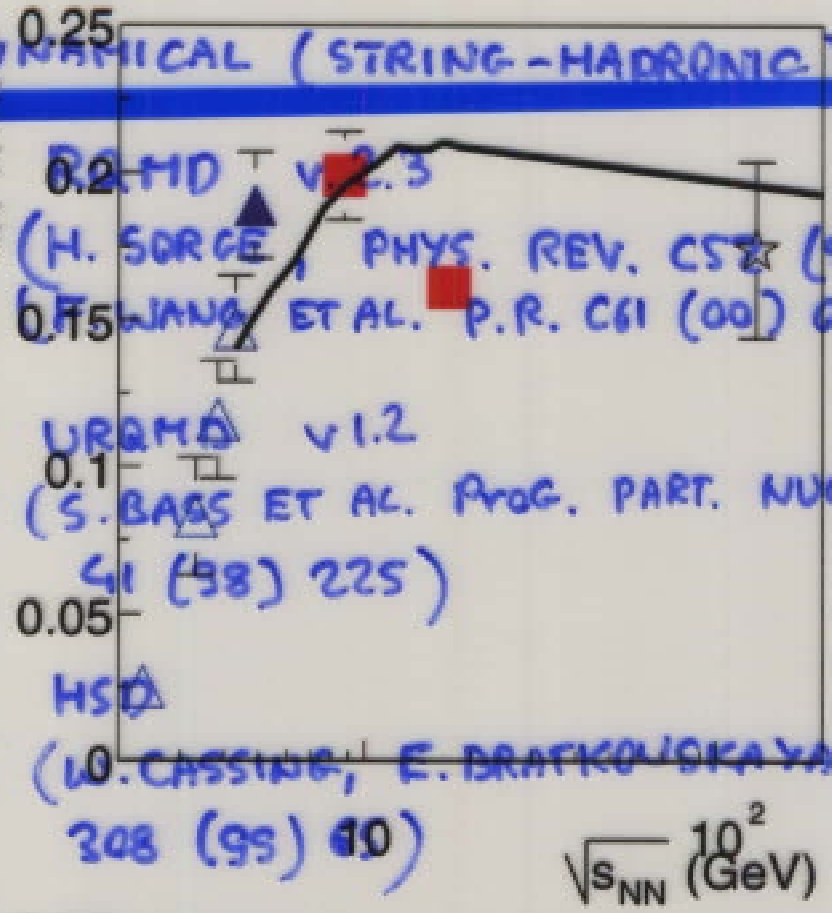
NO TRANSITION TO QGP

DYNAMICAL (STRING-HADRONIC)

RQMD v2.3
(H. SORGE, PHYS. REV. C52 (95) 3291)
(LIANG ET AL. P.R. C61 (00) 064904)

URQMD v1.2
(S. BASS ET AL. PROG. PART. NUCL. PHYS. 41 (98) 225)

HSD
(W. CASSING, E. BRATKOVSKAYA, PHYS. REP. 308 (99) 65)

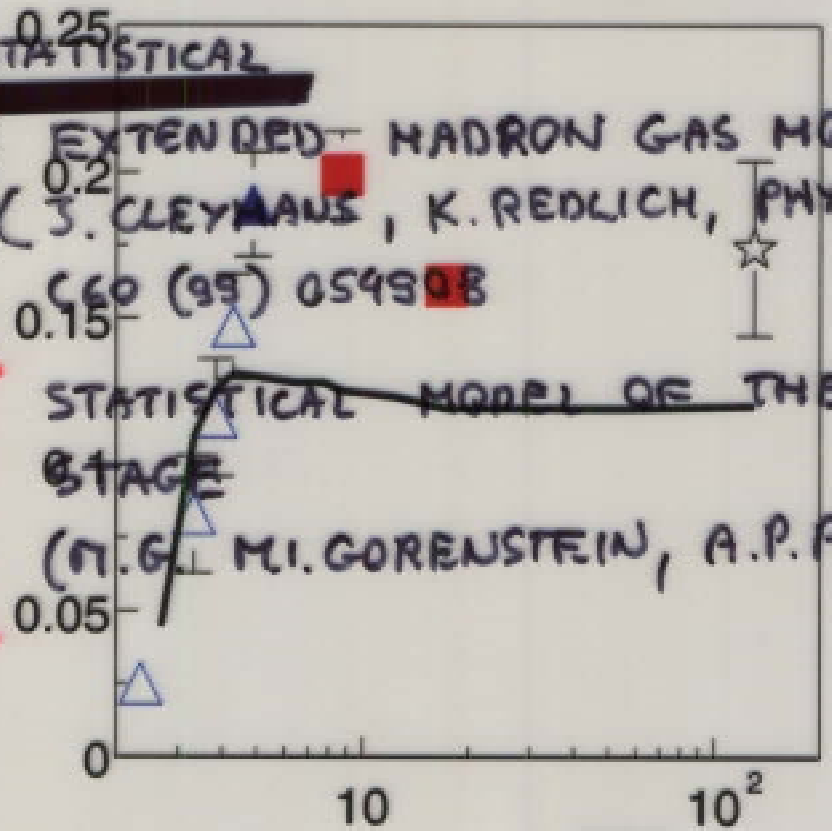


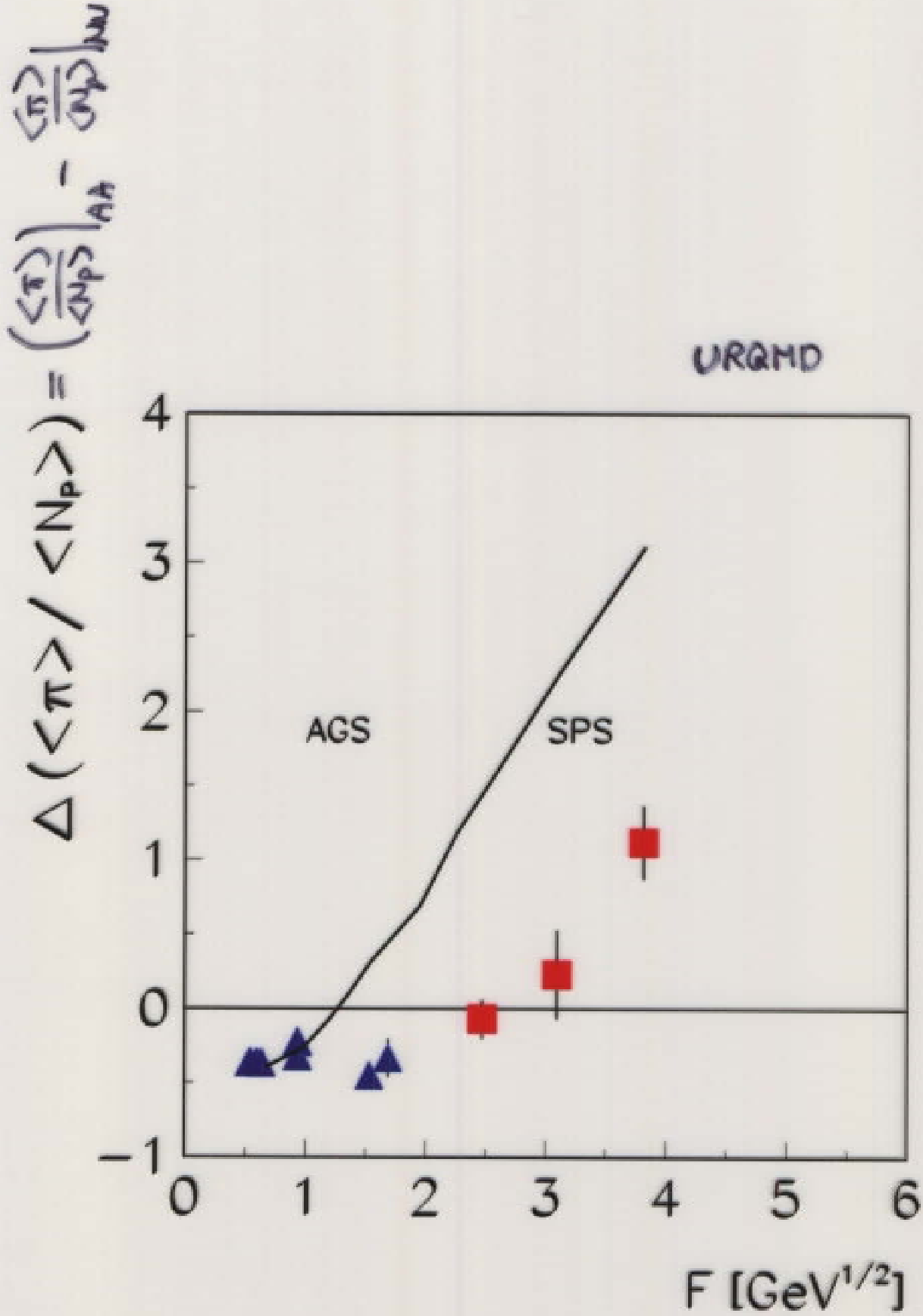

STATISTICAL

EXTENDED HADRON GAS MODEL
(J. CLEYMANS, K. REDLICH, PHYS. REV C60 (99) 054908)

TRANSITION TO QGP

STATISTICAL MODEL OF THE EARLY STAGE
(M.G. MI. GORENSTEIN, A.P.P. B30 (99) 2705)




URQMD
AGS
SPS
$\Delta(\langle\pi\rangle/\langle N_p\rangle) = \left(\frac{\langle\pi\rangle}{\langle N_p\rangle}\right)^{AA} - \left(\frac{\langle\pi\rangle}{\langle N_p\rangle}\right)^{pp}$
F [GeV$^{1/2}$]
4
3
2
1
0
−1
0
1
2
3
4
5
6

1997:

NA49 REQUESTED LOW ENERGY (30 AGEV) PB BEAM AT SPS

1998:

FIRST TEST 40 AGEV PB BEAM DELIVERED TO NA49

1999:

- FULL 40 AGEV PB RUN AT SPS

2000:

- FIRST RESULTS FROM 40 AGEV
- 80 AGEV RUN FOR NA49
- FIRST RESULTS FROM RHIC
- CERN RESEARCH BOARD GRANTS 20 AND 30 AGEV BEAM FOR 2002

2001:

RESULTS FROM 80 AGEV

2002:

- 20 AND 30 AGEV RUN

2003:

RESULTS FROM 20 AND 30 AGEV

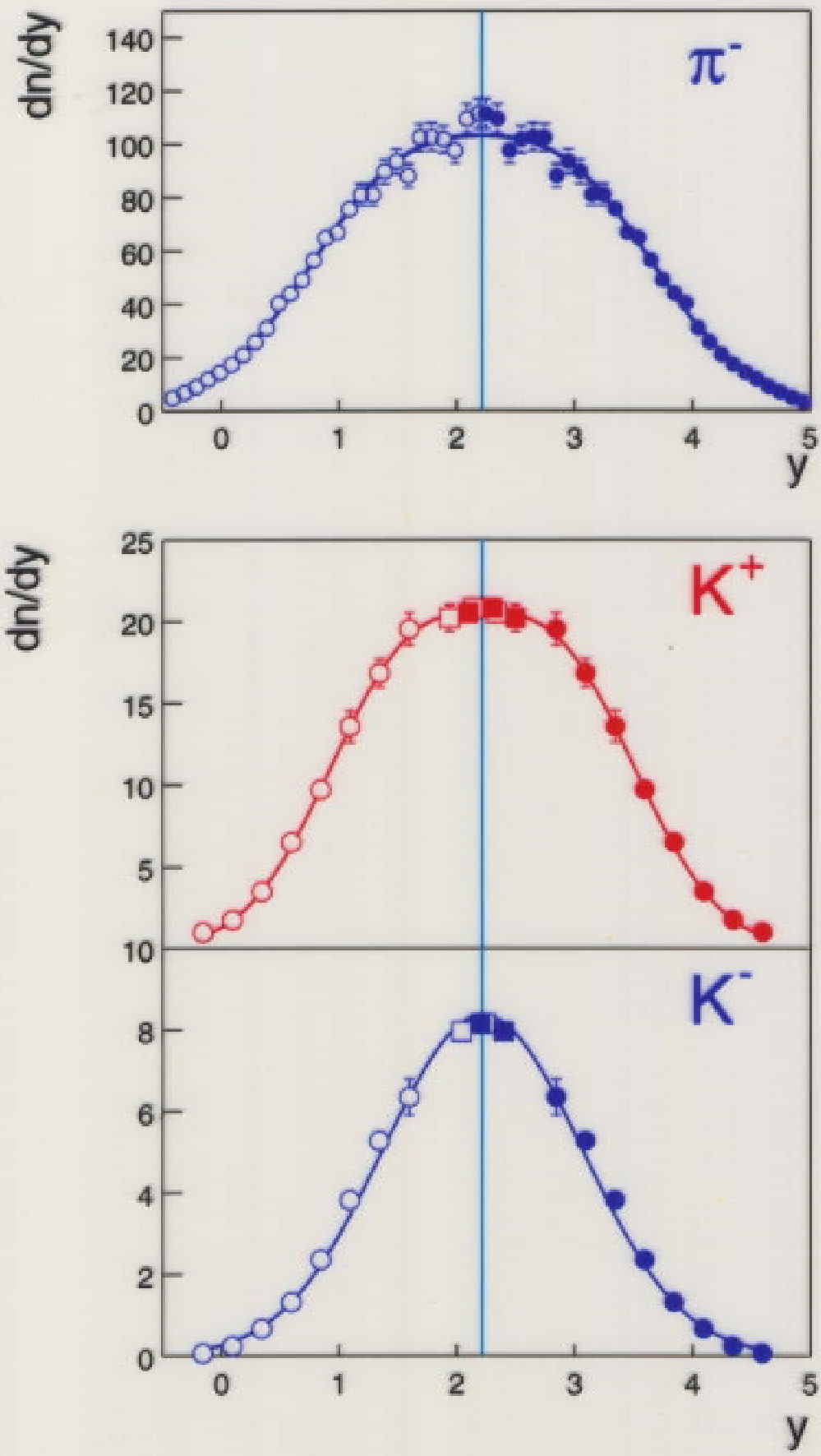
# RESULTS

PIONS

KAONS

LAMBDAS

Pb+Pb central @ 40 GeV/A → $\pi^-$, $K^+$, $K^-$ R. Bramm Th. Kollegger PRA

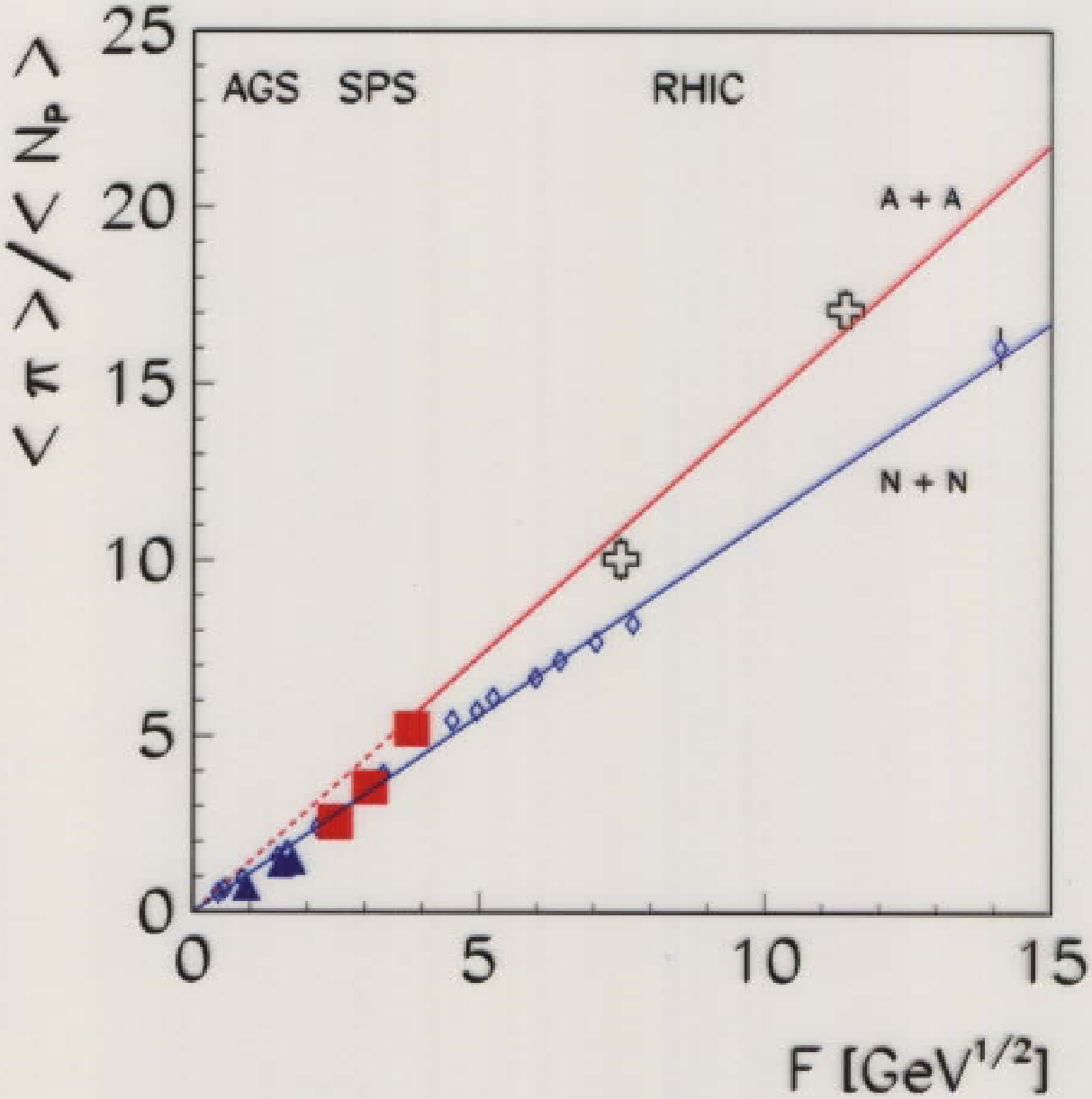



R. BRAMM

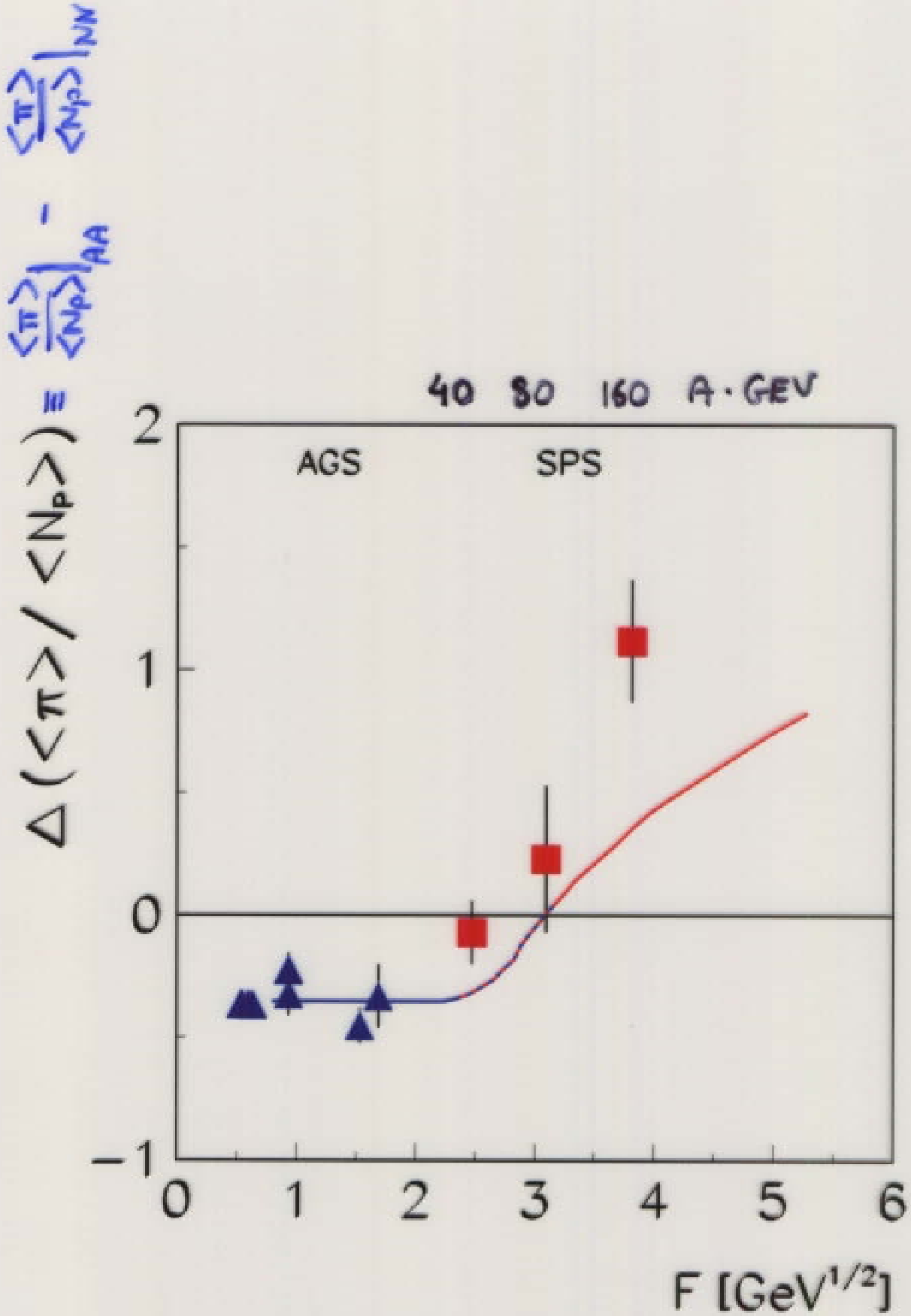
CENTRAL
Pb+Pb
AT 40 AGEV

● MEASURED
○ REFLECTED

T. KOLLEGER
V. KOLESHNIKOV
F. FRIESE




$$F = \frac{(\sqrt{s_{NN}} - m_p)^{3/4}}{\sqrt{s_{NN}}^{1/4}} \approx \sqrt{\sqrt{s_{NN}}}$$


$\Delta(\langle\pi\rangle/\langle N_p\rangle) \equiv \frac{\langle\pi\rangle}{\langle N_p\rangle}\Big|_{AA} - \frac{\langle\pi\rangle}{\langle N_p\rangle}\Big|_{NN}$
40 80 160 A·GEV
AGS
SPS
2
1
0
−1
0
1
2
3
4
5
6
F [GeV$^{1/2}$]