

DECONFINEMENT PHASE TRANSITION IN NUCLEUS-NUCLEUS COLLISIONS

M.G.
FRANKFURT/KIELCE

- LAST 10 YEARS
- ● SIGNALS OF DPT
- ● ● FUTURE

DOES QGP EXIST IN NATURE?

A POSSIBLE(?) TEST BY STUDY OF
HIGH ENERGY A+A COLLISIONS

BUT MANY UNCERTAINTIES:

- QGP PROPERTIES?
- PROPERTIES OF A+A COLLISIONS?
 - EQUILIBRATION?
 - ENERGY DENSITY?

...

THUS CLEAR EVIDENCE FOR THE QGP
POSSIBLE ONLY BY AN OBSERVATION
OF THE THRESHOLD PHENOMENA
CAUSED BY DECONFINEMENT
PHASE TRANSITION

● LAST 10 YEARS

SEARCH FOR THE THRESHOLD PHENOMENA
IN THE ENERGY DEPENDENCE OF
HADRON PRODUCTION IN CENTRAL
Pb+Pb COLLISIONS

INITIAL
STATE

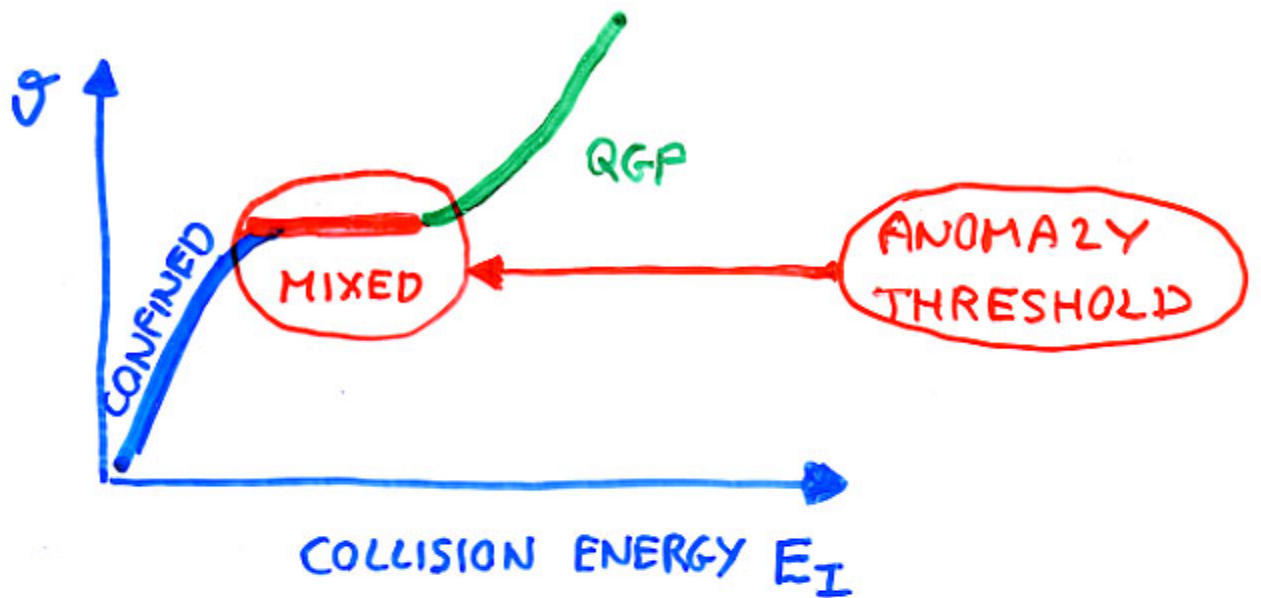


$$\sqrt{s} = 2 \cdot E_I$$

EARLY
STAGE



$$\varepsilon \equiv \frac{E}{V} \nearrow \quad E_I \nearrow$$



THE HISTORY:

1994-1996: FIRST INDICATIONS OF THE ANOMALIES BETWEEN THE TOP SPS AND AGS ENERGIES

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

1995-1999: THESE ANOMALIES ARE CONSISTENT WITH THE EXPECTATIONS FOR THE DPT

- FORMULATION OF THE STATISTICAL MODEL OF THE EARLY STAGE

- NEW PREDICTIONS

(M.G., M. GORENSTEIN, Z. PHYS. C66 (95) 659, ACTA PHYS. POLON. B30 (99) 2705)

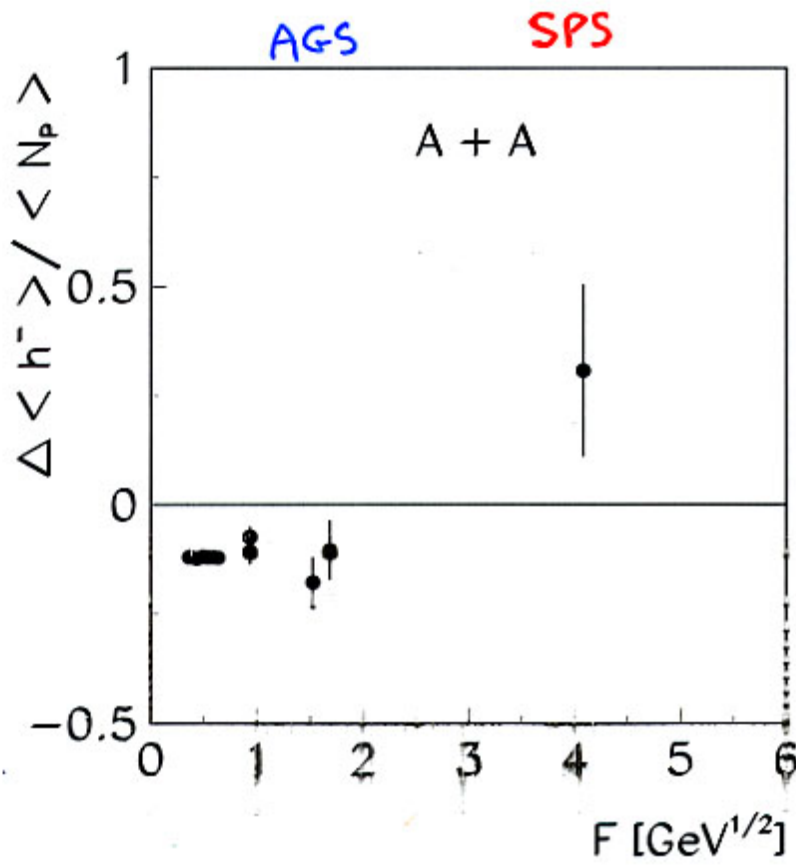
1997-2002: ENERGY SCAN PROGRAM AT CERN SPS (CENTRAL Pb+Pb COLLISIONS AT 20,30,40,80 AND 158 A·GEV)

- EXPERIMENTAL CONFIRMATION OF THE "STRANGE" PREDICTIONS,

- DISCOVERY OF THE NEW EFFECTS

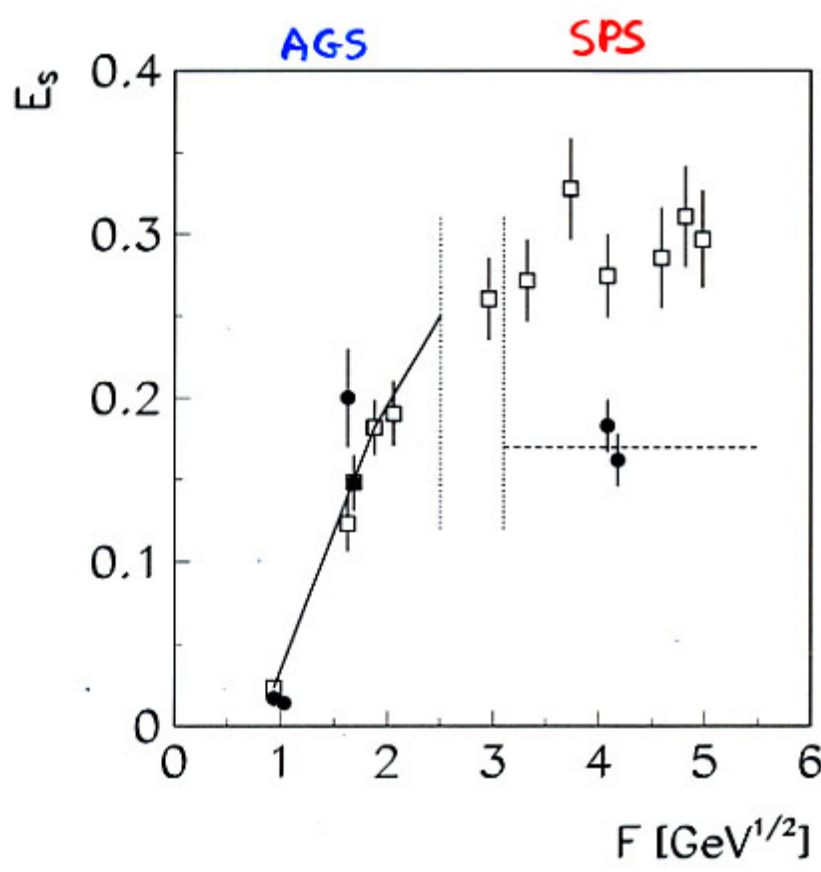
(M.G., P. SEYBOTH, NA49)

1994-1996: FIRST INDICATIONS OF THE ANOMALOUS ENERGY DEPENDENCE OF



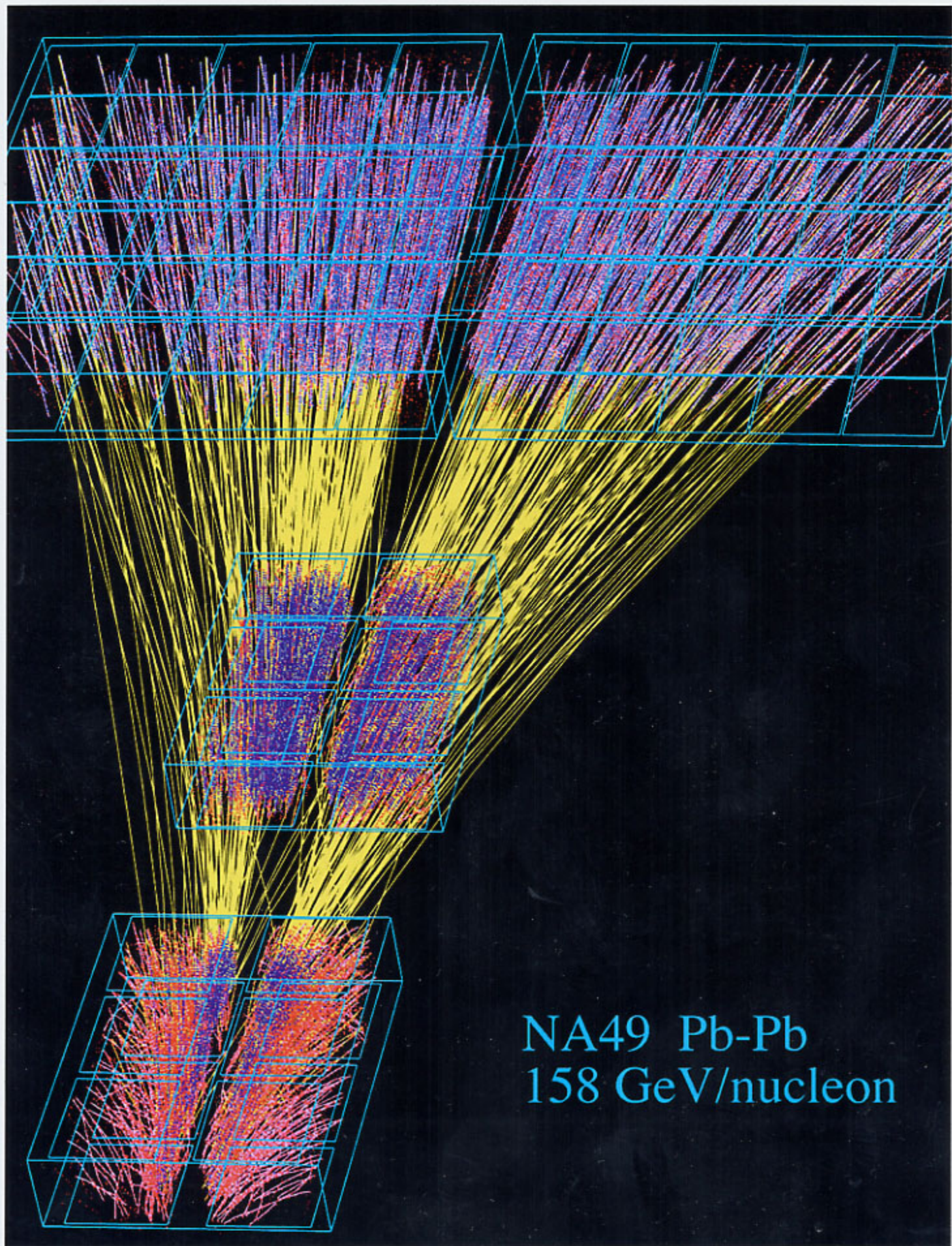
PIONS
(M.G. D.R. ZP C65 (95) 215)

$(\approx \sqrt{2E_T})$



STRANGENESS
(M.G. D.R. ZP C71 (96) 55)

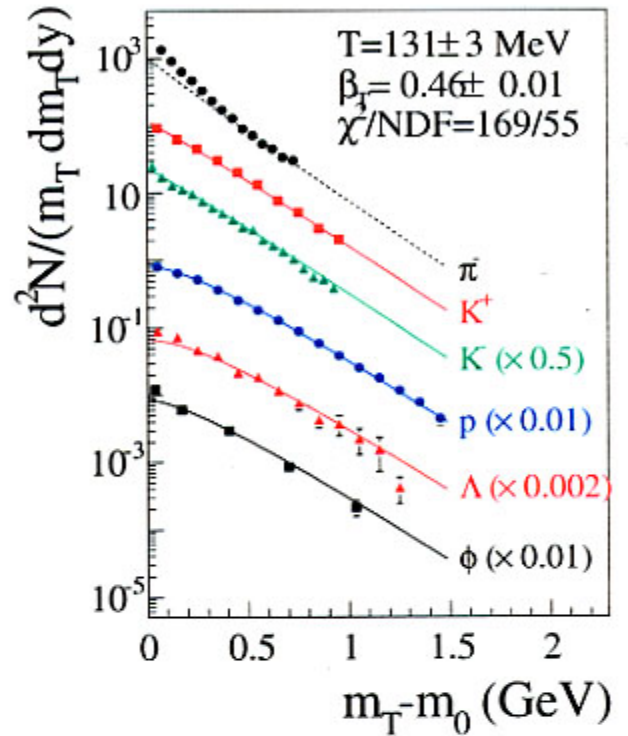
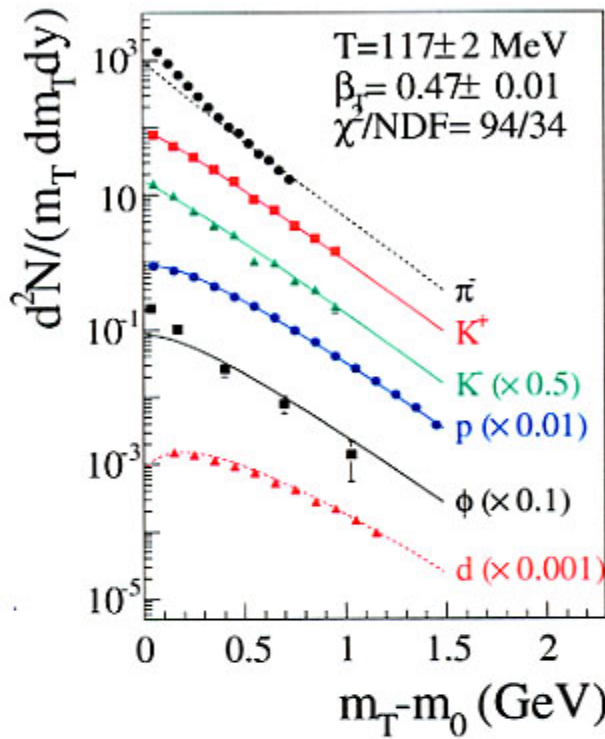
AT LOW SPS ENERGIES



CENTRAL PB+PB COLLISIONS AT

20 A-GEV

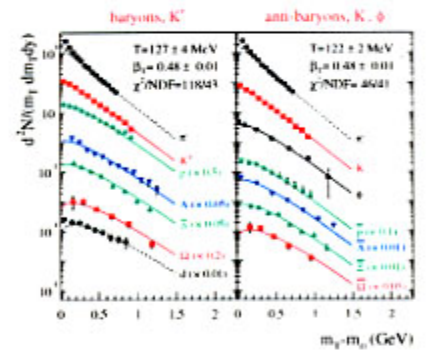
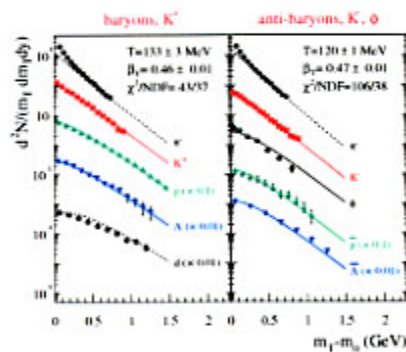
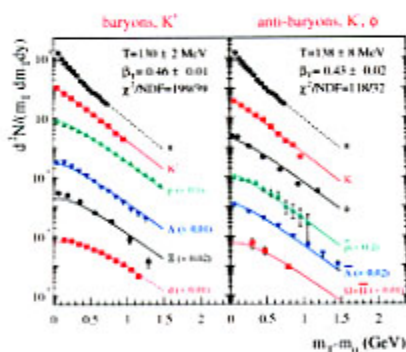
30 A-GEV



40 A-GEV

80 A-GEV

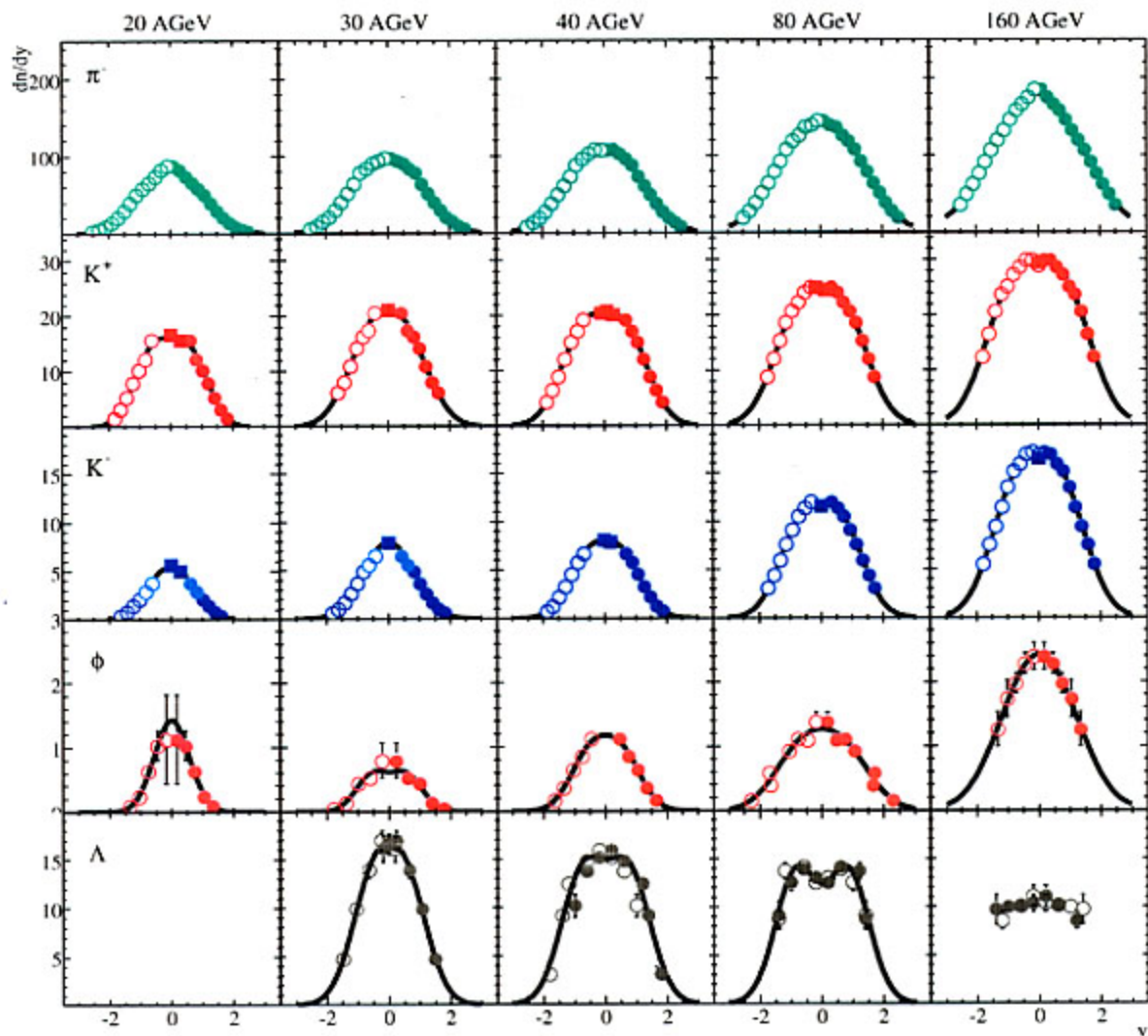
158 A-GEV



TRANSVERSE MASS SPECTRA

$$m_T = \sqrt{m_0^2 + p_T^2}$$

CENTRAL PB+PB COLLISIONS AT



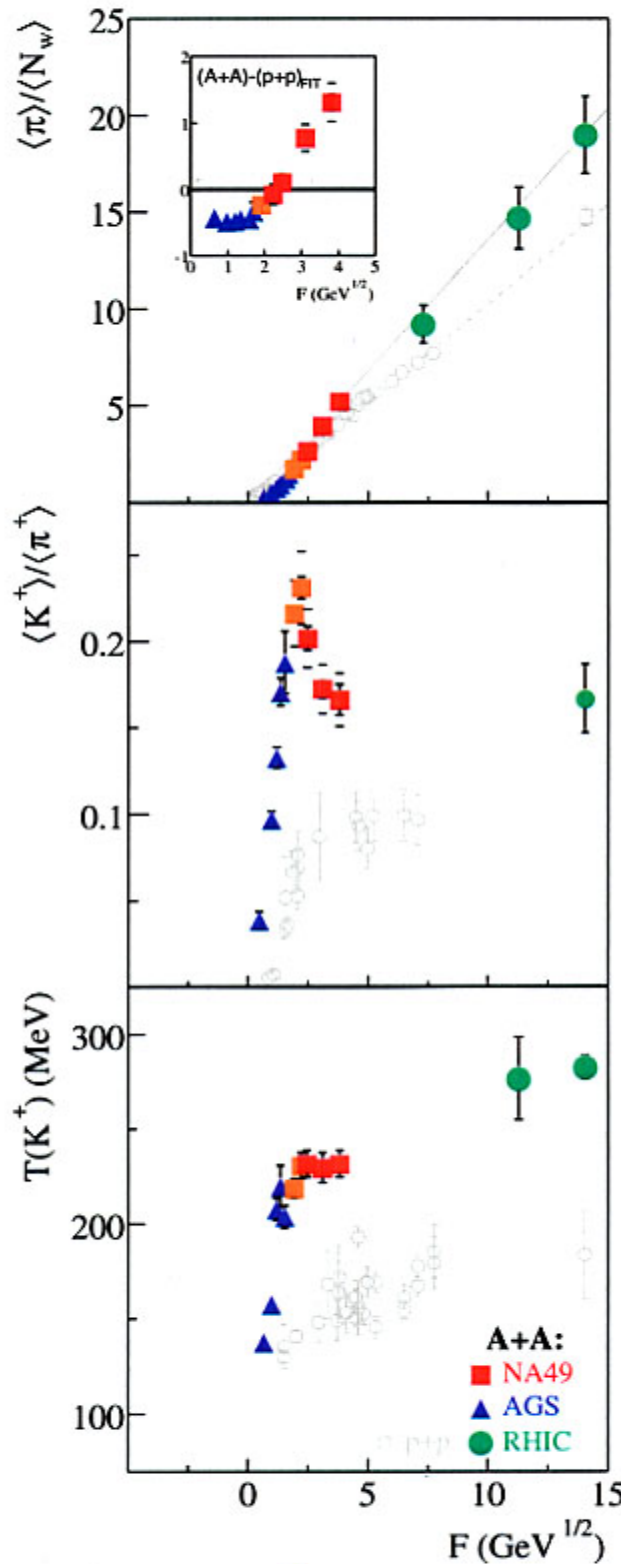
RAPIDITY SPECTRA

$$y \equiv \tanh^{-1} \beta_L$$

MEAN MULTIPLICITY FROM INTEGRATION OF
($\langle \dots \rangle$) THE RAPIDITY SPECTRA



SIGNALS OF DPT



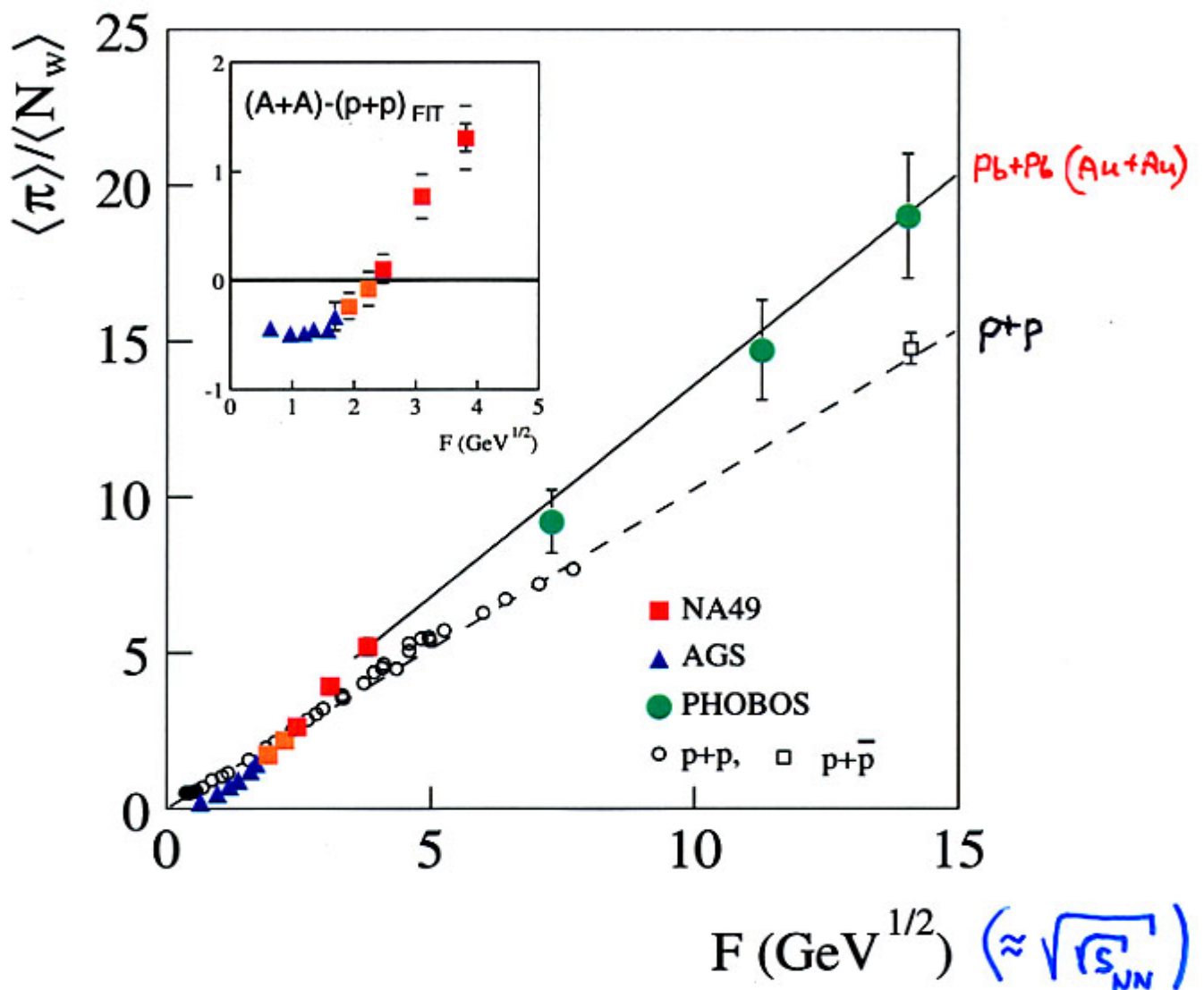
THE KINK

THE HORN

THE STEP



SEVERAL ANOMALIES LOCATED IN THE SAME ENERGY DOMAIN AND CONSISTENT WITH THE DPT EXPECTATIONS



$$\langle \pi \rangle \equiv 1.5 (\langle \pi^+ \rangle + \langle \pi^- \rangle)$$

$\langle N_w \rangle \equiv$ MEAN NUMBER OF WOUNDED NUCLEONS

FERMI-LANDAU (1950-53):

$$\langle \pi \rangle \sim F \approx S^{0.25}$$

SMES (M.G., GORENSTEIN, 95-99):

PURE PHASES:

$$\langle \pi \rangle \sim g^{1/4} \cdot F - \epsilon$$

DEGENERACY
FACTOR

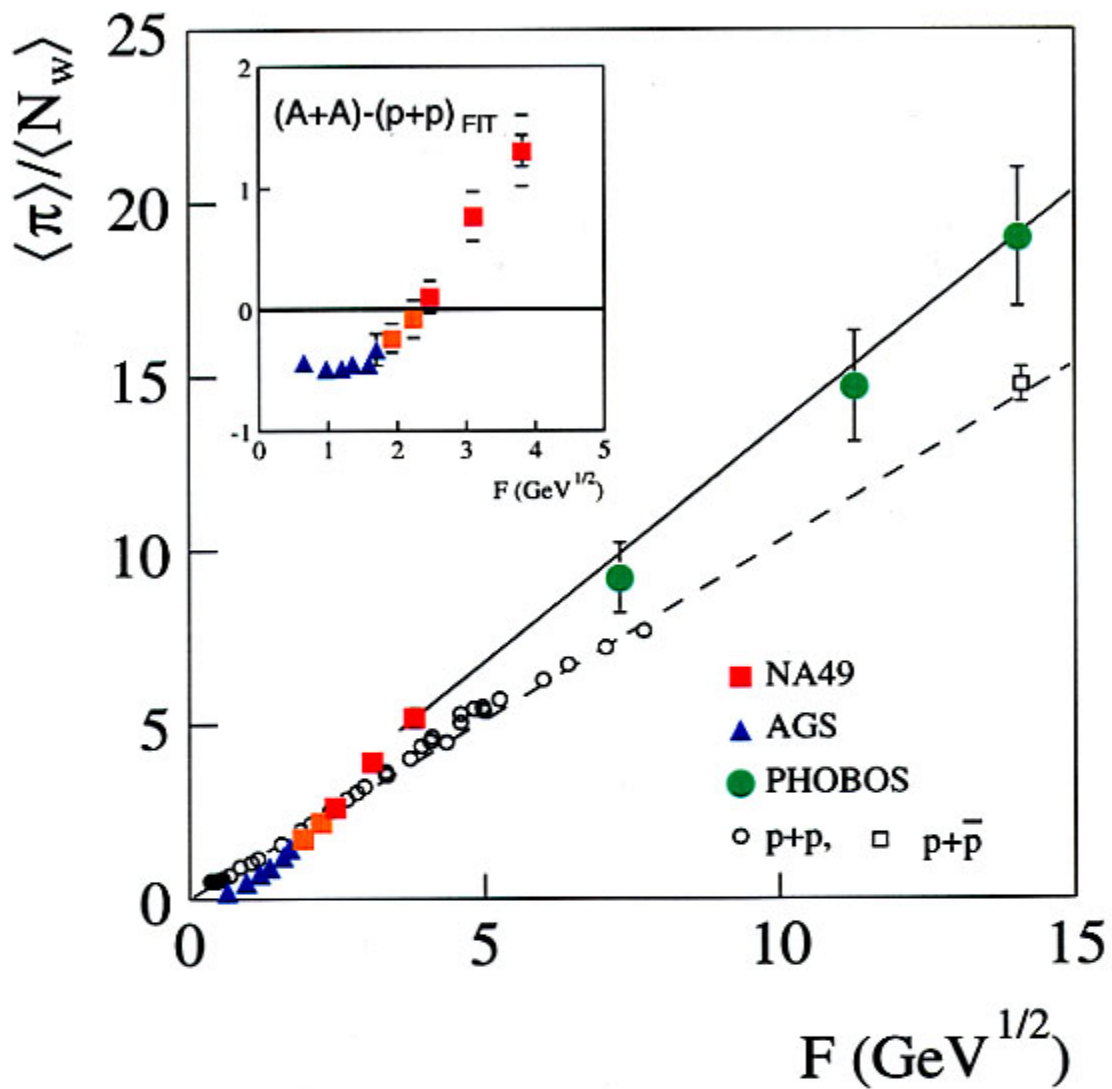
EFFECT OF NON-ZERO
BARYON DENSITY

MIXED PHASE:

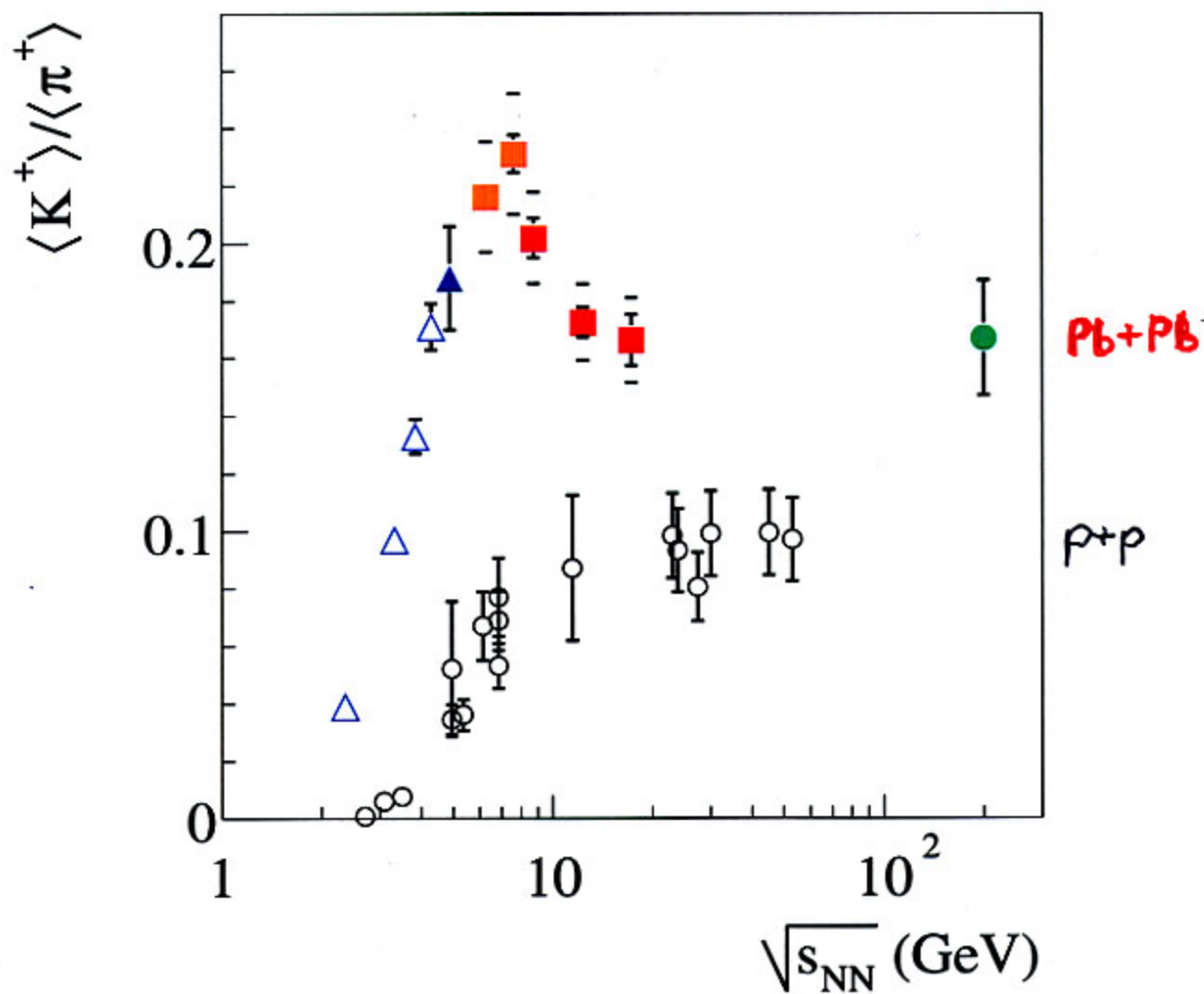
$$\langle \pi \rangle = \frac{C_1}{\sqrt{S}} + C_2 (\sqrt{S} - m_N) - C_3$$

↑ ≈ 1.3

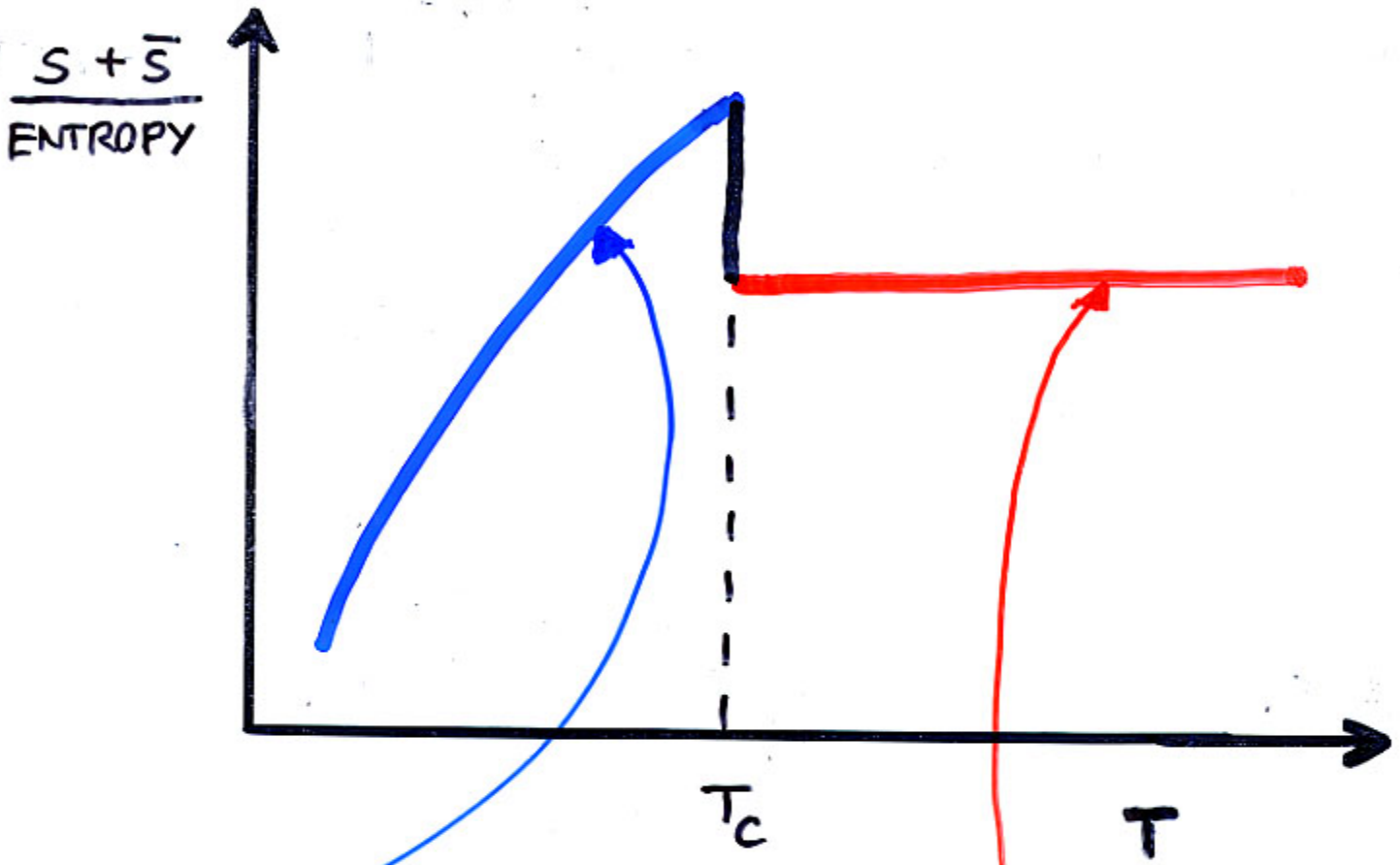
$$\frac{g_{QGP}}{g_{CONF}} \approx (1.3)^4 \approx 3 //$$



M.G., GORENSTEIN, 1994 →



SMES (M.G., GORENSTEIN):



HEAVY KAON
LIGHT PION

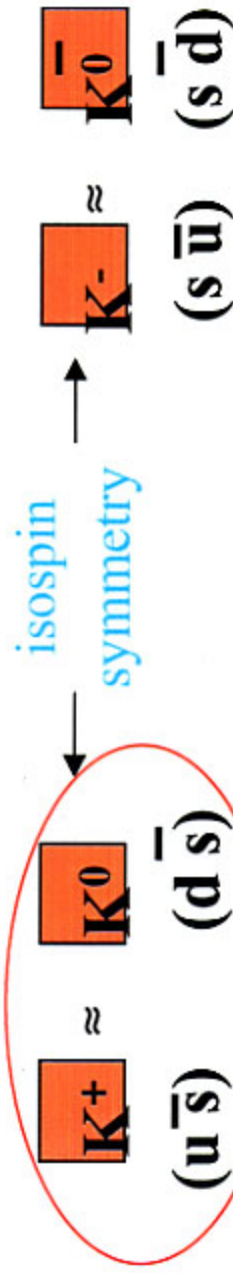
$$\frac{T^{3/2} e^{-m_K/T}}{T^3}$$

LIGHT s, u, d, q

$$\frac{T^3}{T^3} = \text{CONST}(T)$$

Main Strangeness Carriers in Pb+Pb Collisions at SPS :

strangeness conservation



\gg

sensitive to total strangeness



$(\bar{u} \bar{d} \bar{s})$

\ll

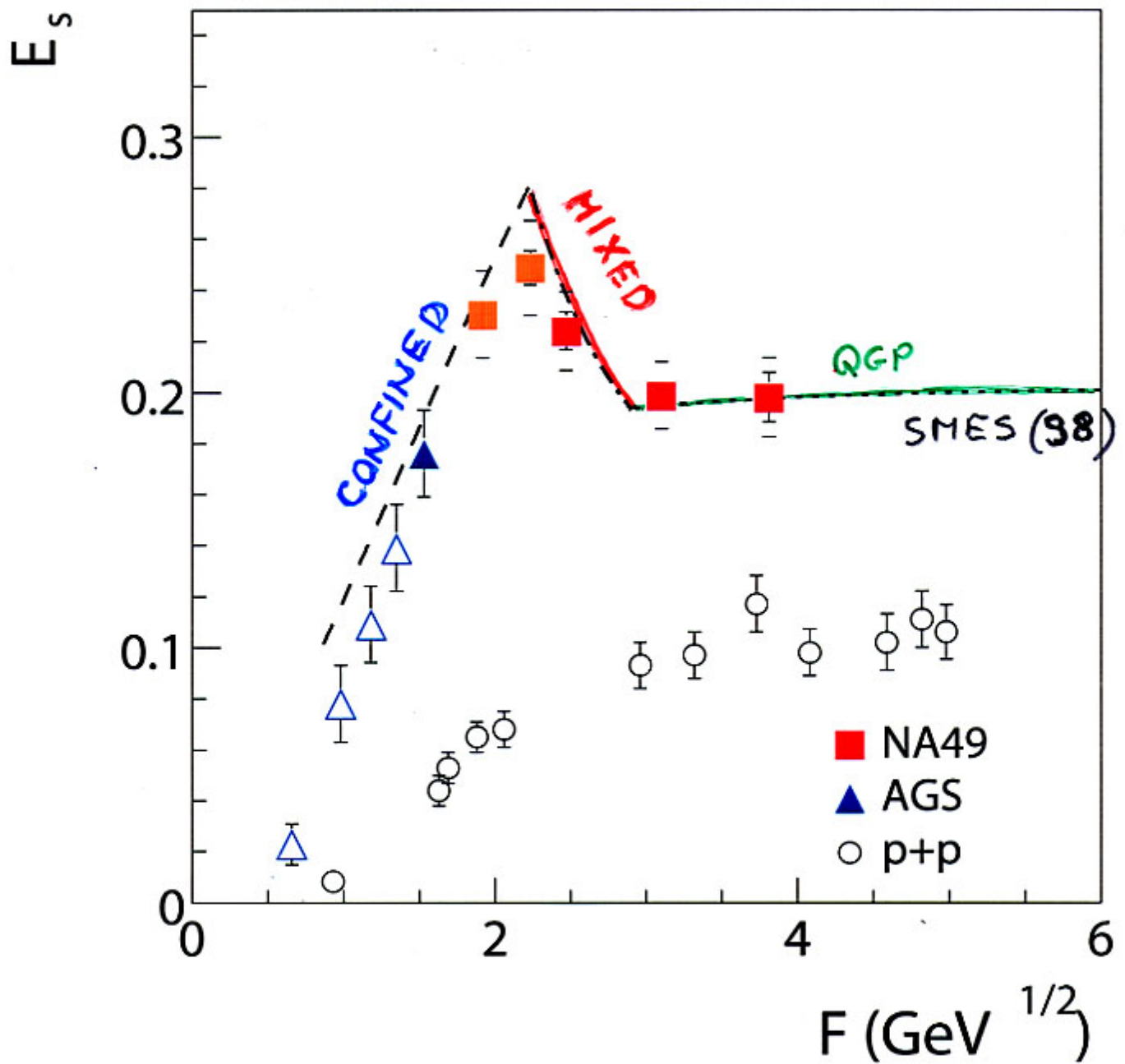
high baryon density

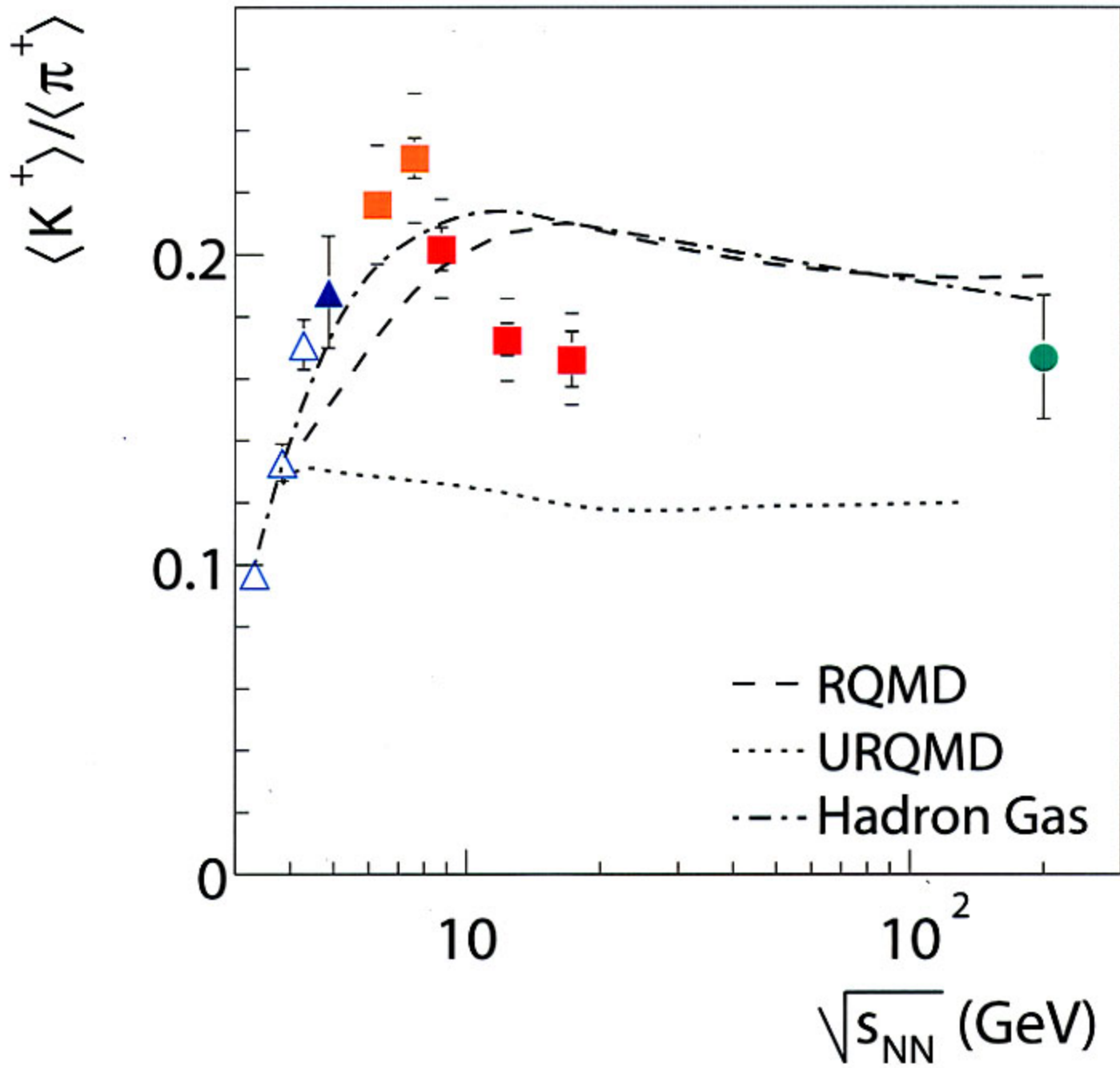


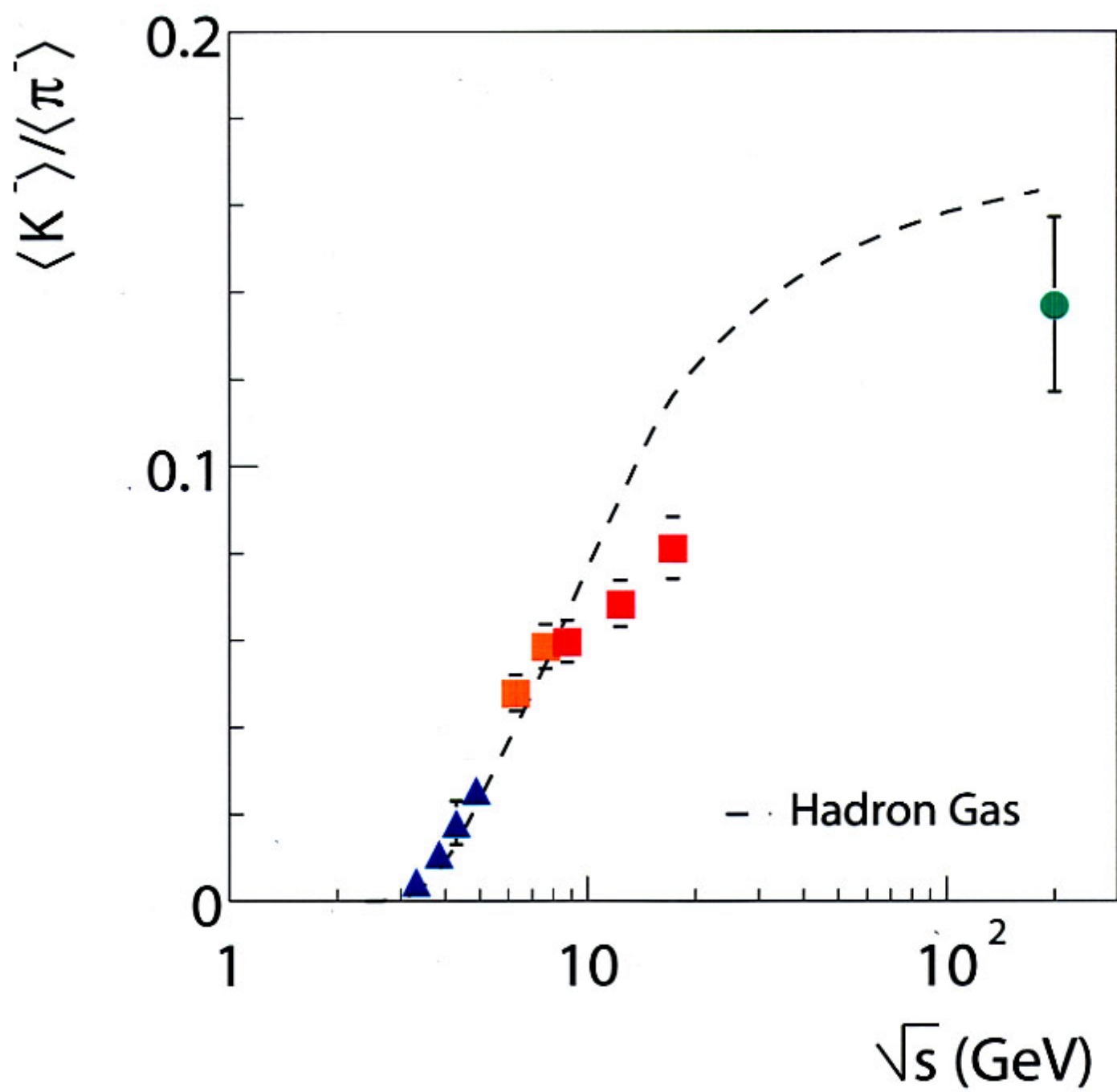
$(u d s)$

sensitive to total strangeness
AND baryon density

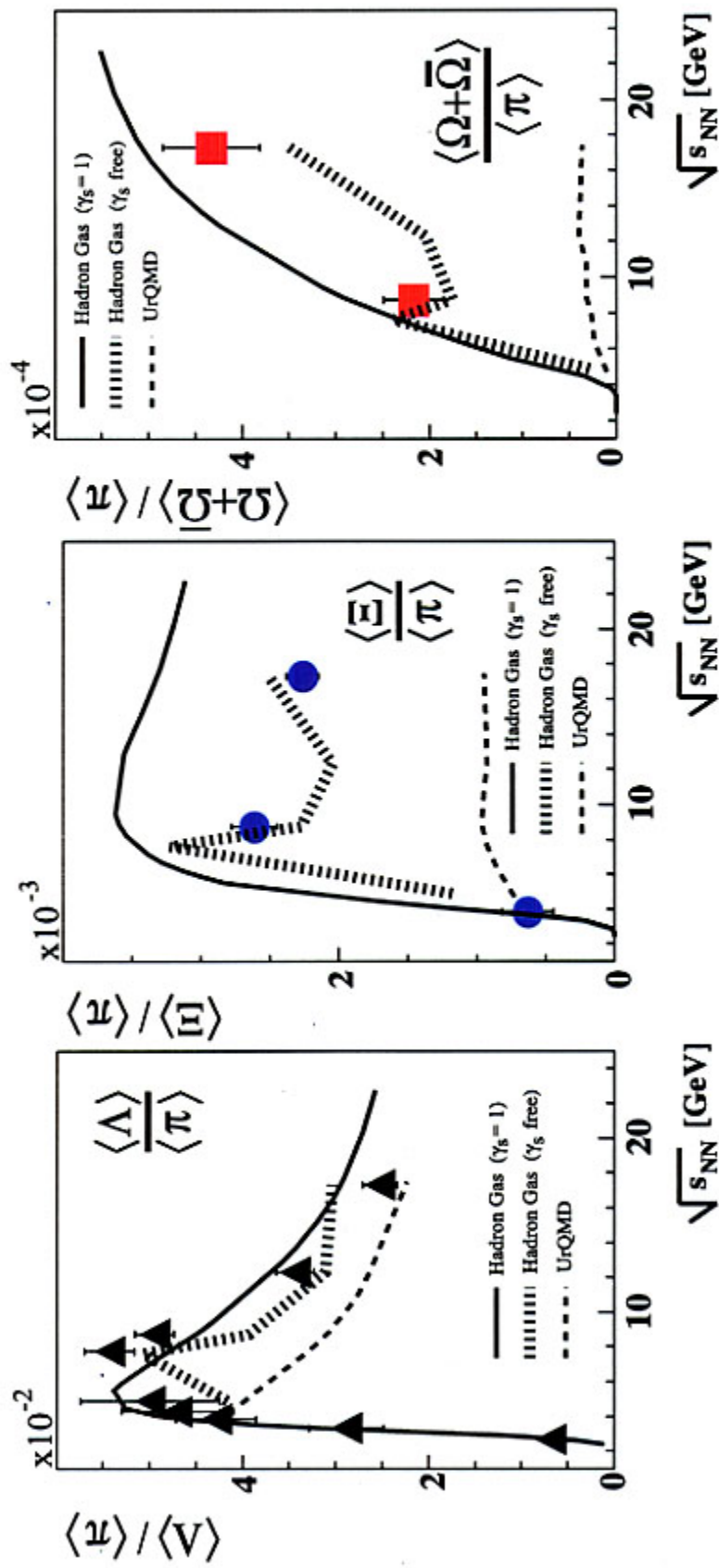
$$E_s \equiv \frac{\langle \Lambda \rangle + \langle K + \bar{K} \rangle}{\langle \pi \rangle}$$

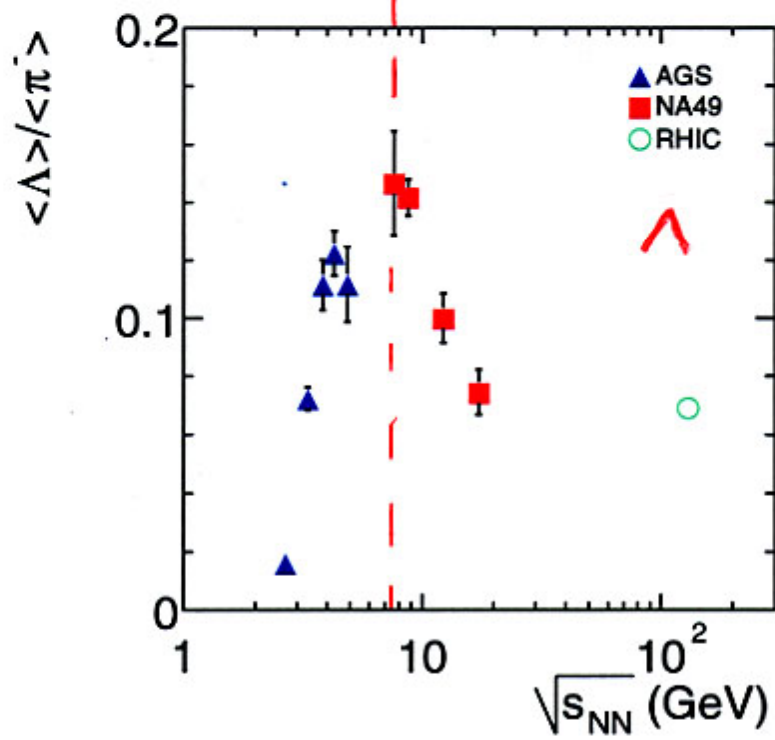
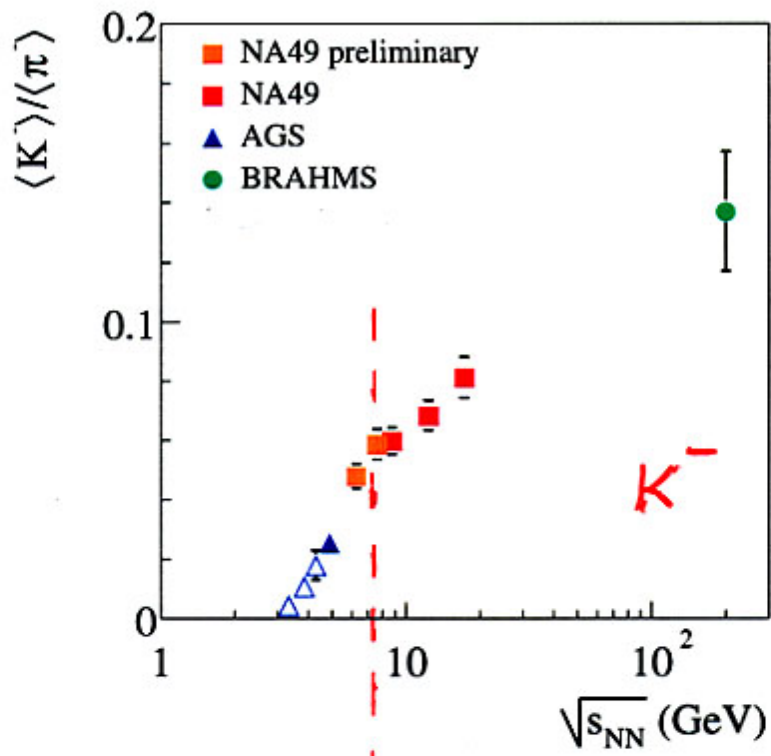




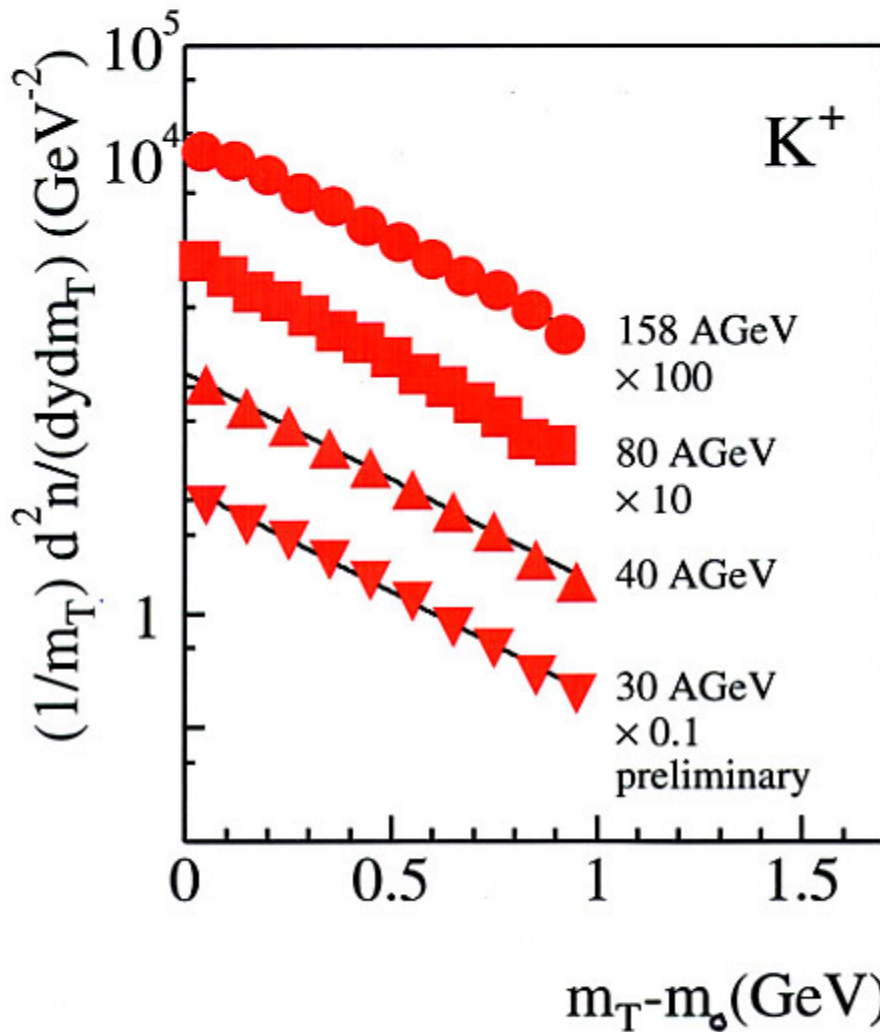


ENERGY DEPENDENCE OF HYPERON PRODUCTION (NA49)





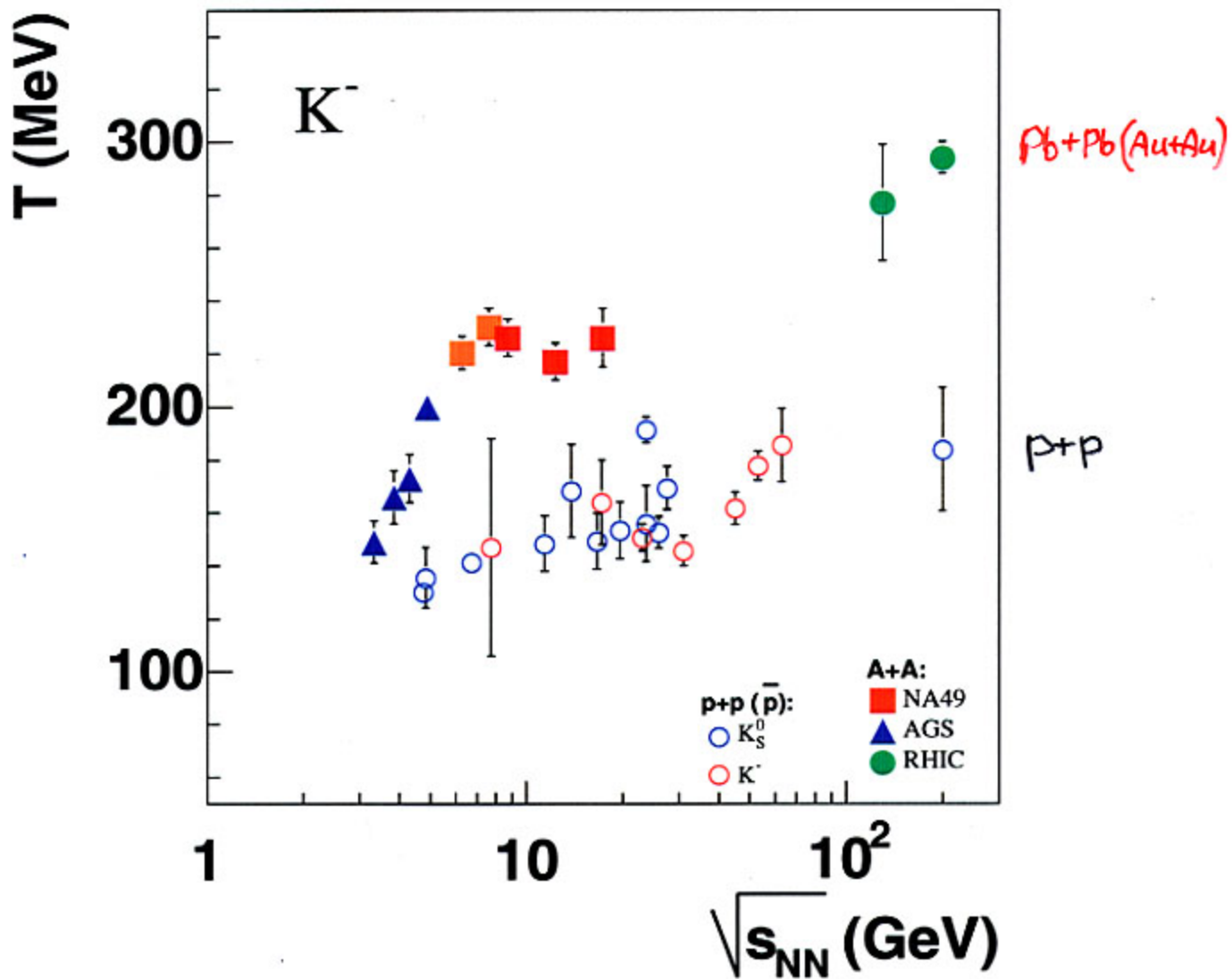
CENTRAL PB+PB AT SPS



$$\frac{1}{m_T} \frac{dn}{dm_T} \sim e^{-m_T/T}$$

$$m_T \equiv \sqrt{p_T^2 + m_0^2}$$

EXPONENTIAL SHAPE OF K_{0N} m_T SPECTRA
OBSERVED FROM AGS TO RHIC ENERGIES

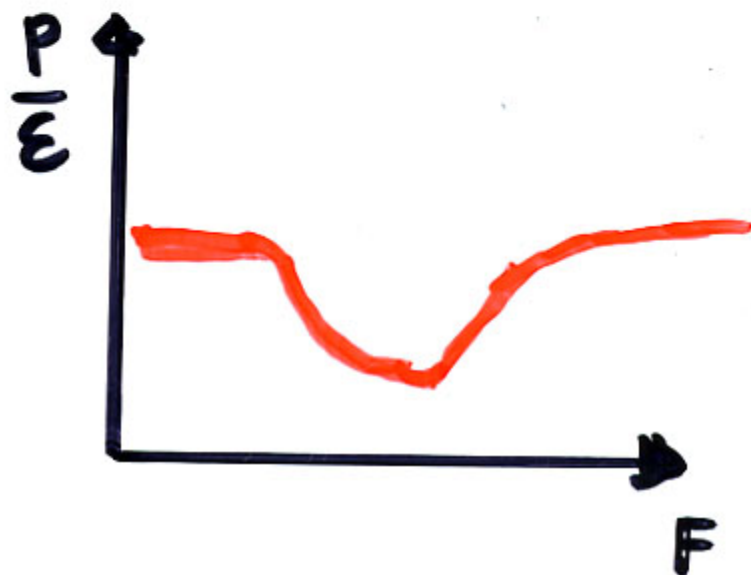
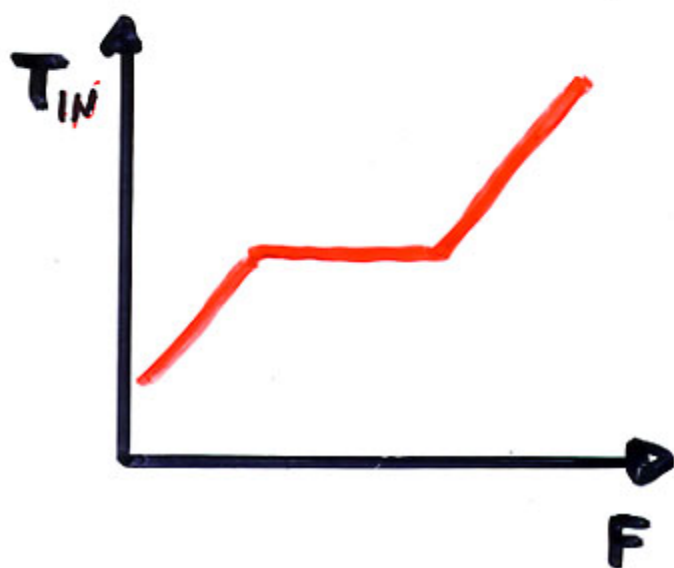


GORENSTEIN, M.G., BUGAEV,
PHYS. LETT. B567, 175 (2003)

THE STEP IN SLOPES

ONSET OF DECONFINEMENT

MODIFICATION OF EOS

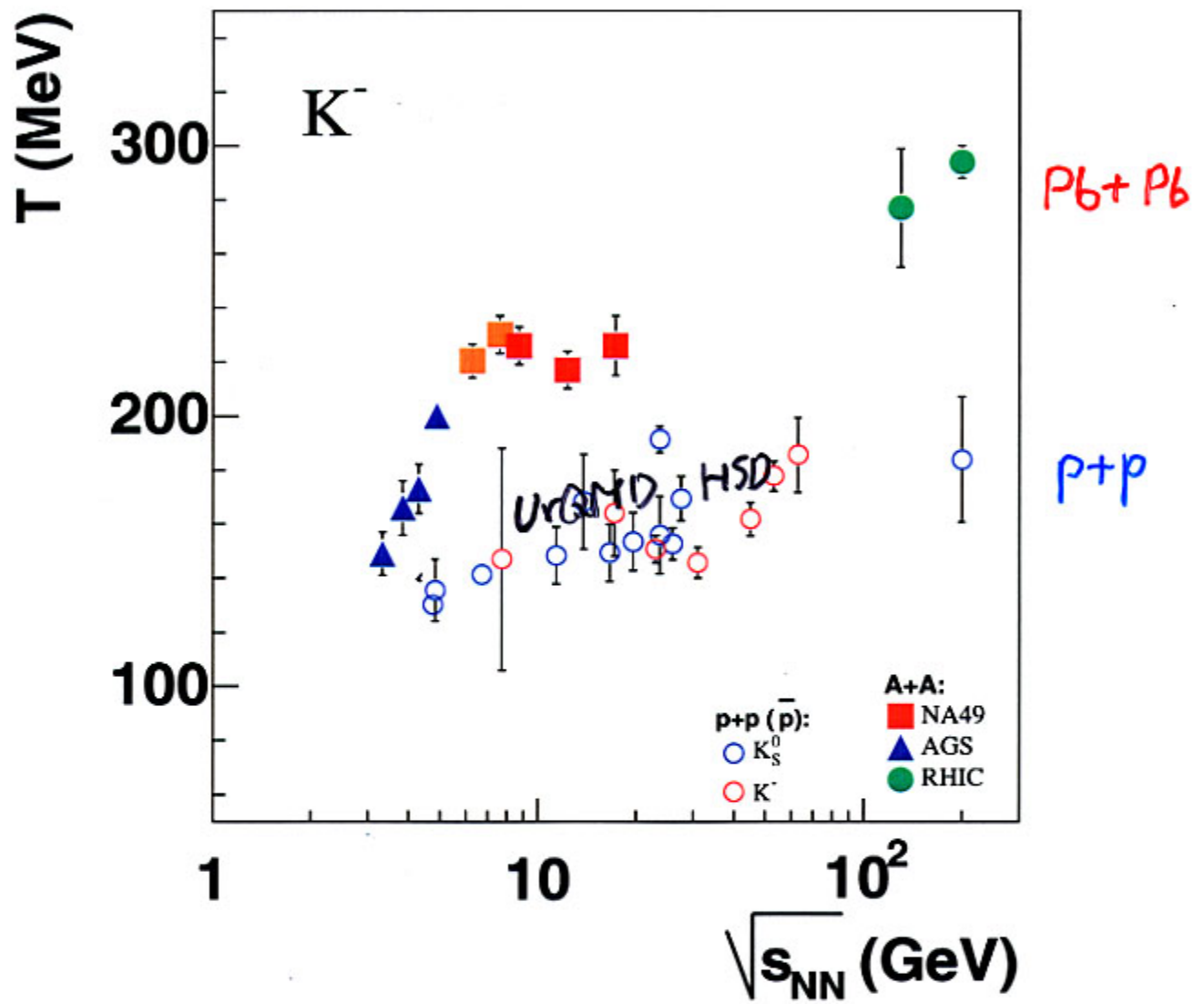


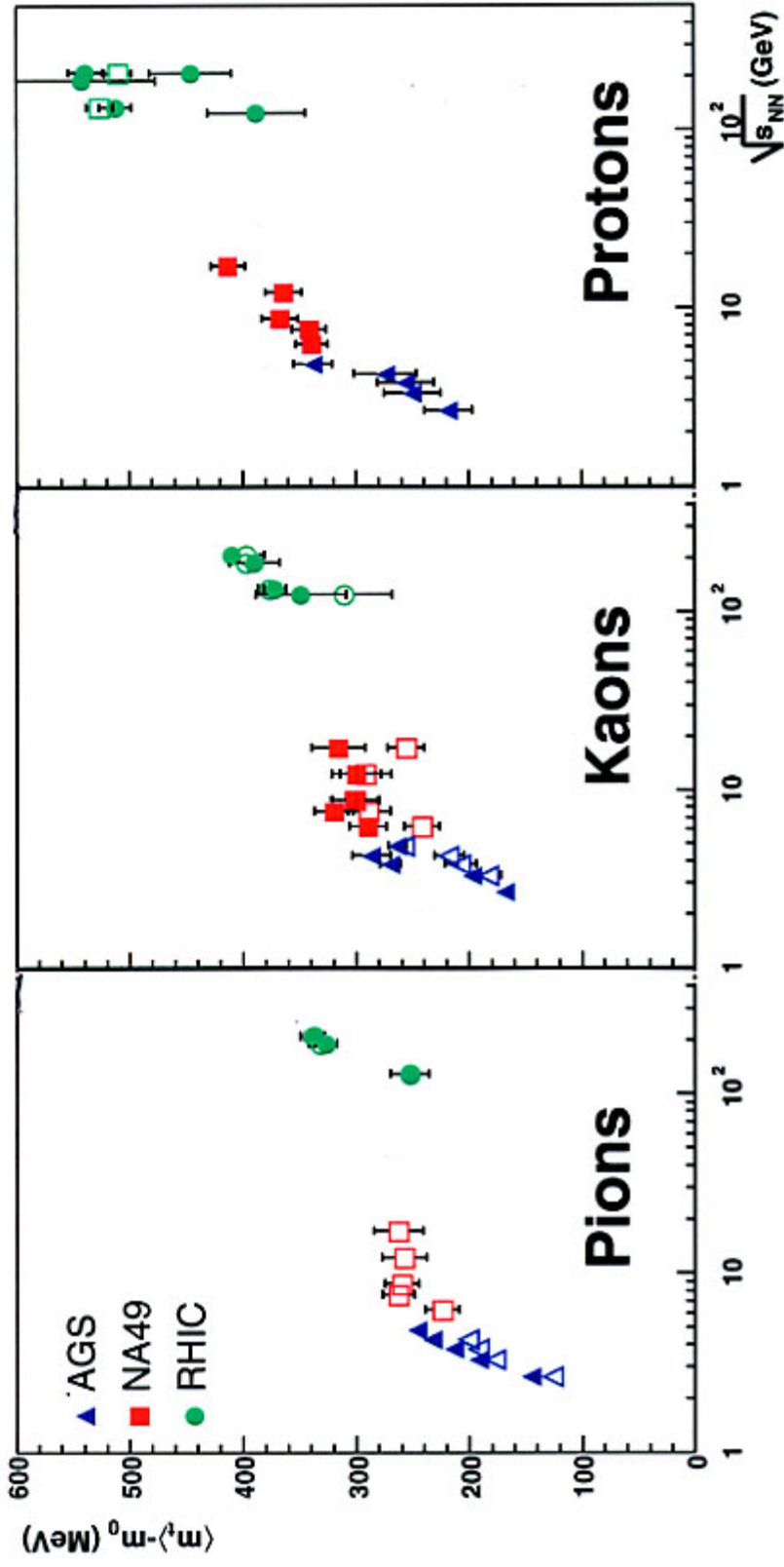
ANOMAZY IN TRANSVERSE EXPANSION

E. Shuryak, O. Zhivov, PHYS. LETT.
B89, 253 (79)

L. Van Hove, PHYS. LETT.

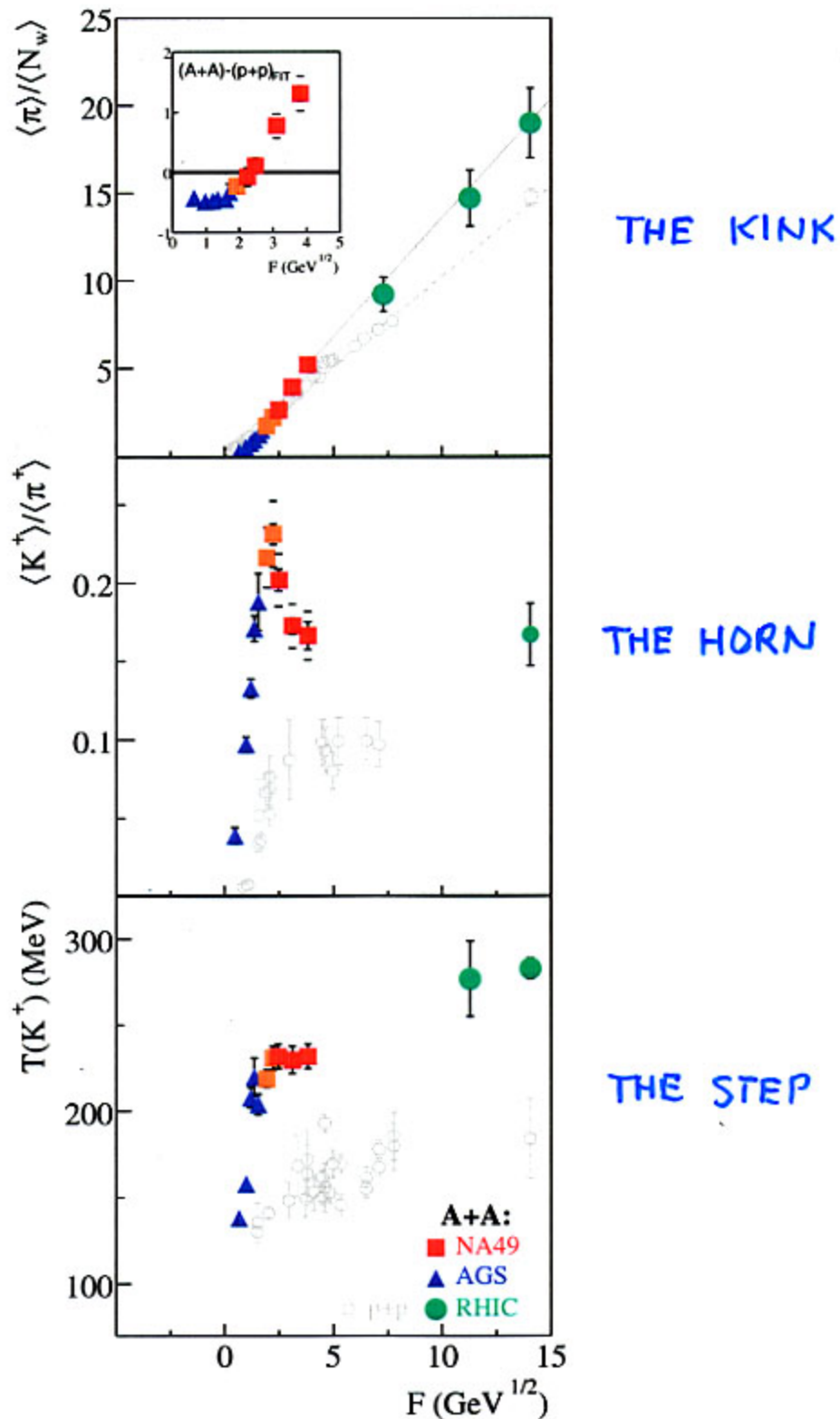
B118, 138 (82)





EVIDENCE FOR

DECONFINEMENT PHASE TRANSITION



THE KINK

THE HORN

THE STEP

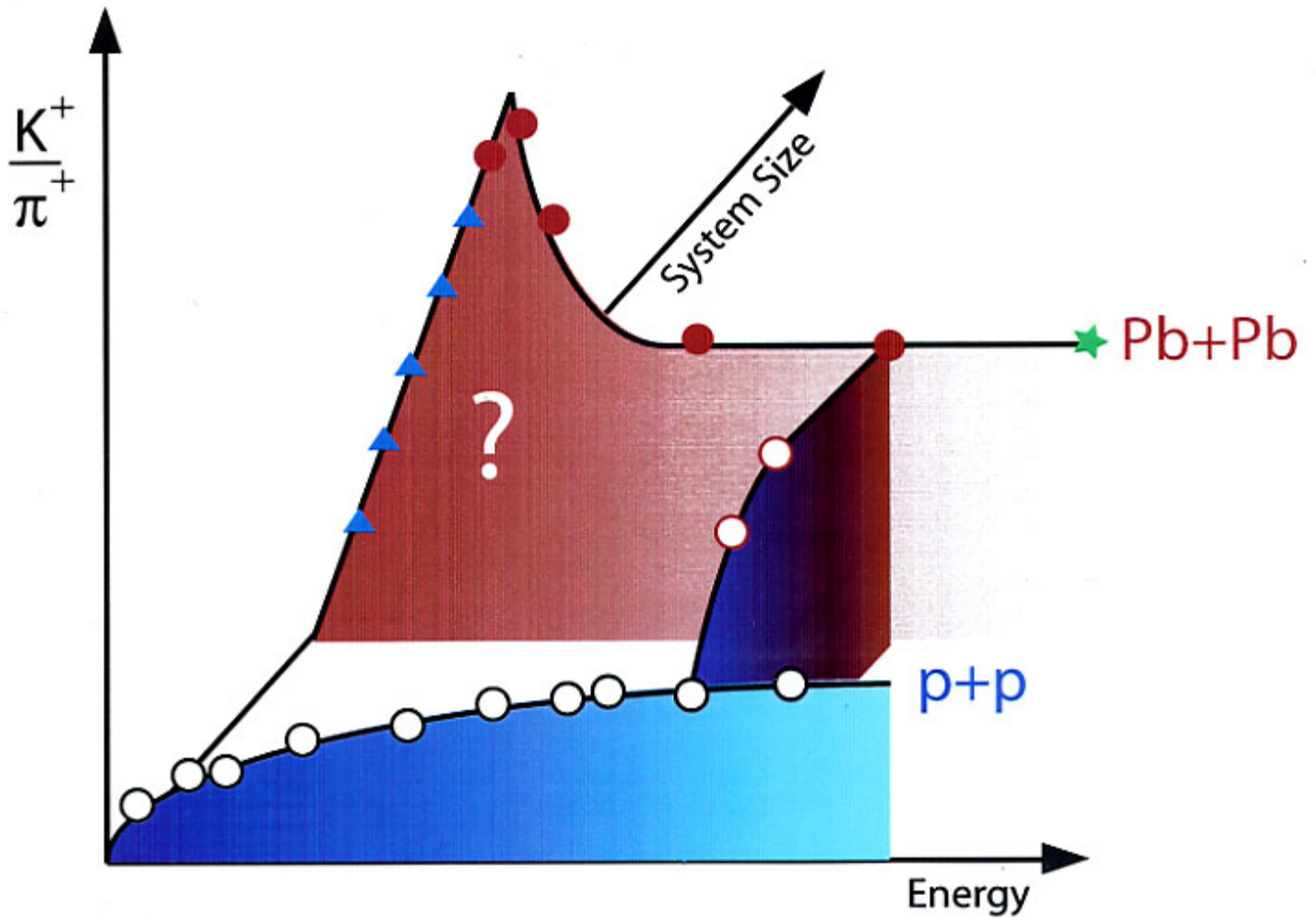
SEVERAL ANOMALIES:

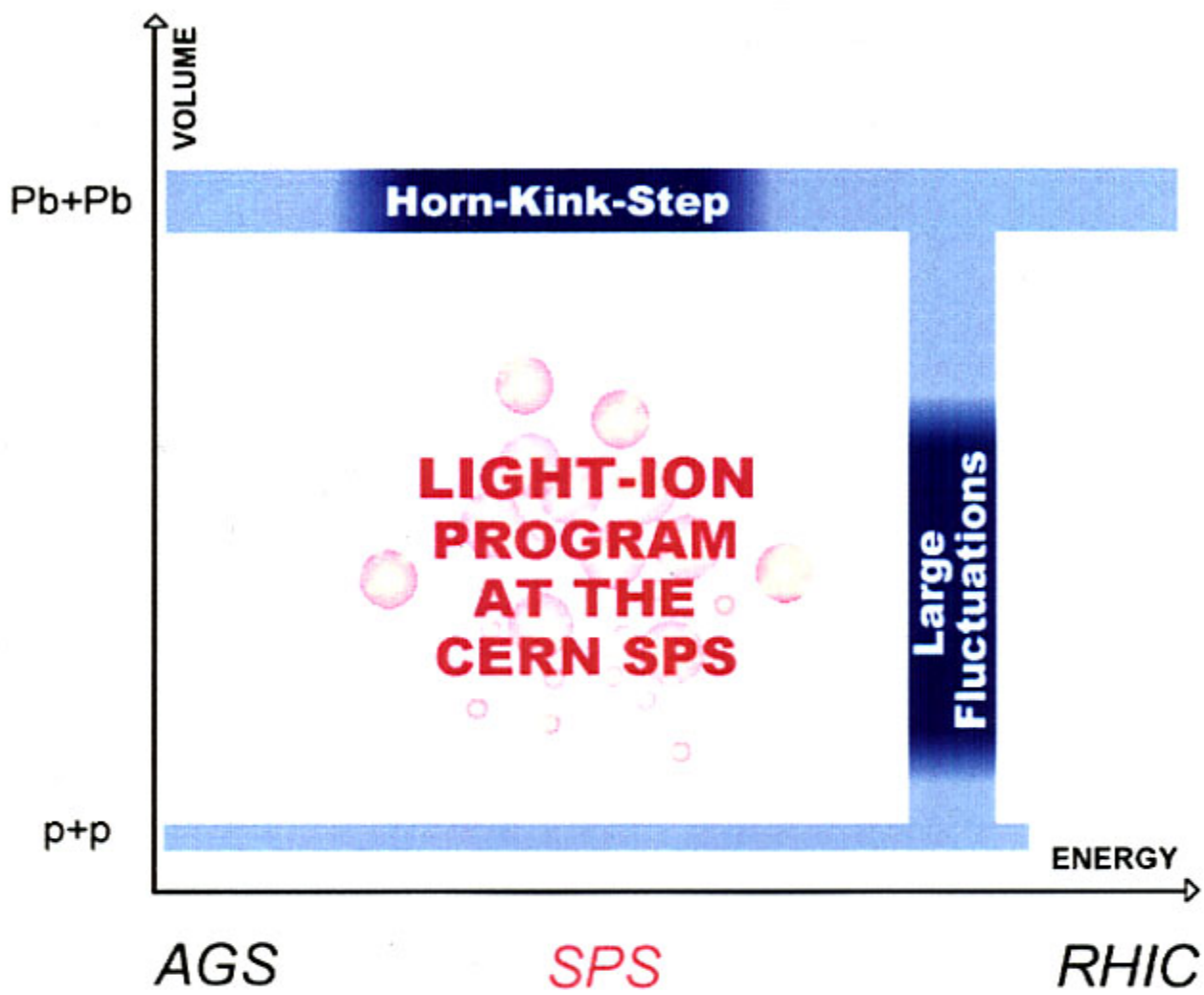
- LOCATED IN THE SAME ENERGY RANGE
- CONSISTENT WITH DPT
- DIFFICULT TO EXPLAIN BY HADRONIC MODELS

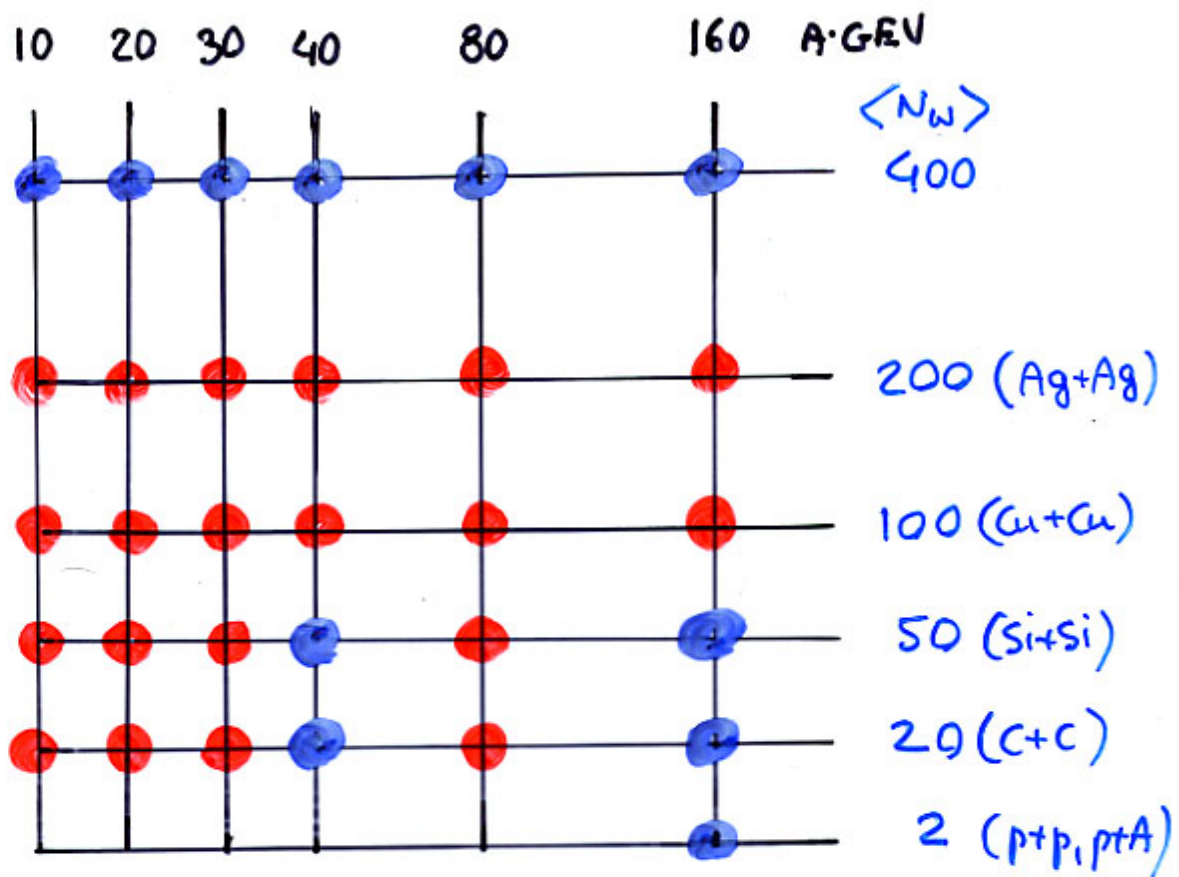
● ● ● FUTURE

LIGHT ION PROGRAM AT THE CERN SPS

- CBM AT FAIR (GSI) → V. FRIESE
- FIXED TARGET PROGRAM AT RHIC







● TAKEN DATA

● REQUESTED DATA

A New Experimental Programme with Nuclei and Proton Beams at the CERN SPS

Expression of Interest (CERN-SPSC-2003-038, SPSC-EOI-01)
submitted to the CERN SPSC on November 21, 2003.

Physics:

- Energy Scan with Light Nuclei
(volume and deconfinement)
- Energy Scan for p+p and p+A
(constrain models for A+A and astroparticle physics)
- Identified Hadrons at High p_T
(onset of jet quenching)
- High Statistics p+p Data
(pentaquarks)

Experiment:

- Upgraded NA49 Installation
- Low Cost (≈ 1 M EUR)
- First Data Taking Possible in 2007

New Collaborators are Welcome !!!