STRANGENESS AND DECONFINEMENT IN NUCLEAR COLLISIONS

M. G. FRANKFURT / KIELCE

- A BRIEF HISTORY OF IDEAS
- EXPERIMENTAL STATUS
- FURTHER SIGNALS OF DECONFINEMENT

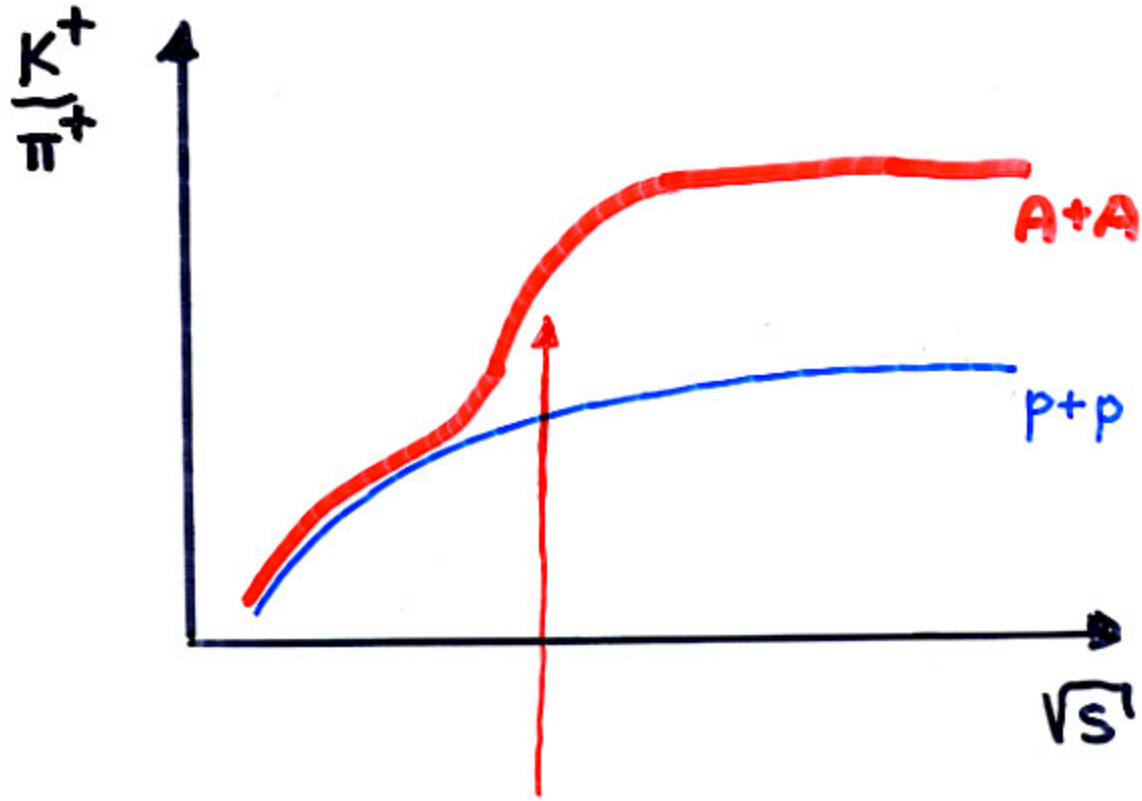
FUTURE

A BRIEF HISTORY OF IDEAS

- DYNAMICAL APPROACH
- STATISTICAL APPROACH

DYNAMICAL APPROACH (RAPELSKI, MÜLLER 82-)

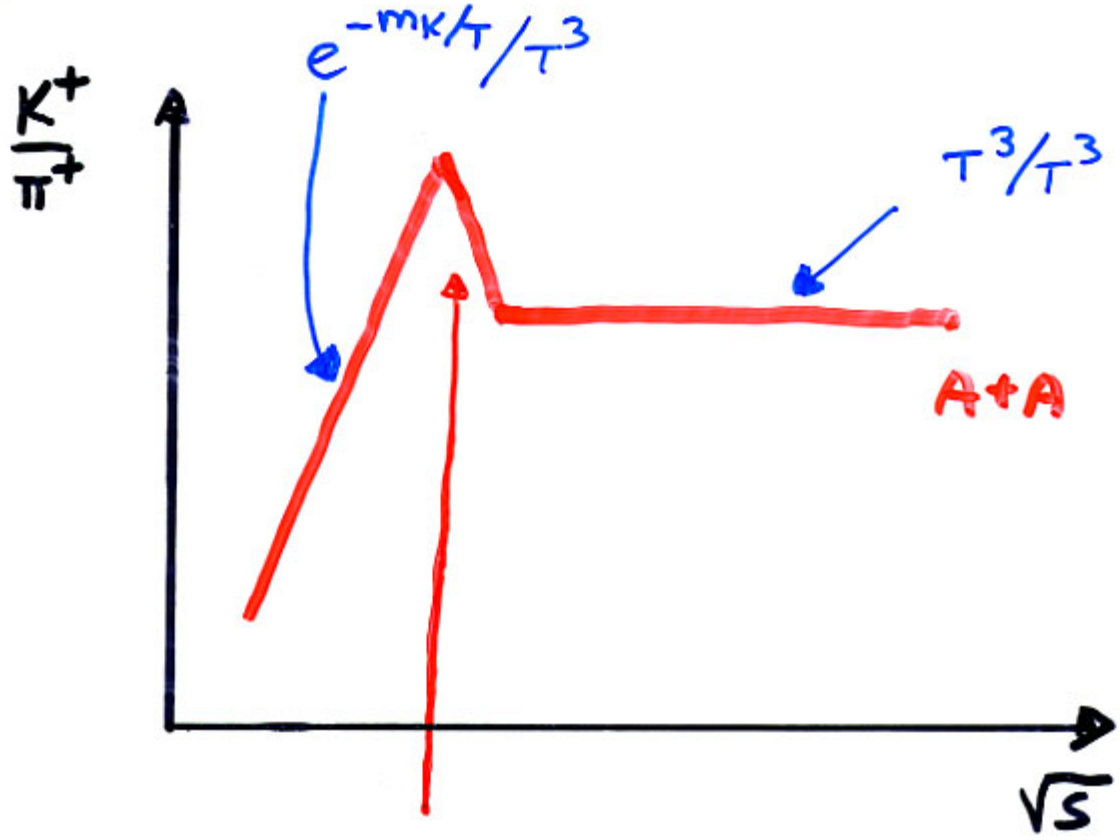
FAST STRAGENESS $(s + \bar{s})$ PRODUCTION IN QGP LEADS TO AN ENHANCEMENT OF RELATIVE STRANGENESS YIELD IN A+A COLLISIONS IN COMPARISON TO p+p INTERACTIONS WHEN THRESHOLD FOR QGP PRODUCTION IS CROSSED



→ STRANGENESS ENHANCEMENT SIGNALS ONSET OF DECONFINEMENT

STATISTICAL APPROACH (M.G., GORENSTEIN, 96-)

MAXIMUM ENTROPY STATE IS CREATED AT THE EARLY STAGE OF A+A COLLISIONS IN BOTH QGD AND CONFINED PHASES



→ A SUPPRESSION OF RELATIVE STRANGENESS YIELD IN A+A COLLISIONS IS EXPECTED AT THE THRESHOLD FOR QGP CREATION

→ "STRANGE HORN" SHOULD BE OBSERVED AT ABOUT 30 AGEV

⇒ 1997 : START ENERGY SCAN PROGRAM AT THE CERN SPS

EXPERIMENTAL STATUS

- A BRIEF HISTORY OF DATA TAKING
- ENERGY DEPENDENCE OF STRANGENESS PRODUCTION
- ENERGY DEPENDENCE OF HYPERON PRODUCTION

A BRIEF HISTORY OF THE ENERGY SCAN PROGRAM AT CERN SPS:

1994 - 1996: FIRST IDEAS

1997: FIRST NA49 REQUEST OF LOW ENERGY SPS RUN (30 A GEV)

1998: TEST 40 A GEV RUN (NA49)

1999: FULL 40 A GEV (NA49, NA50, NA45, NA57)

2000: 5 DAYS OF 80 A GEV (NA49, NA45)

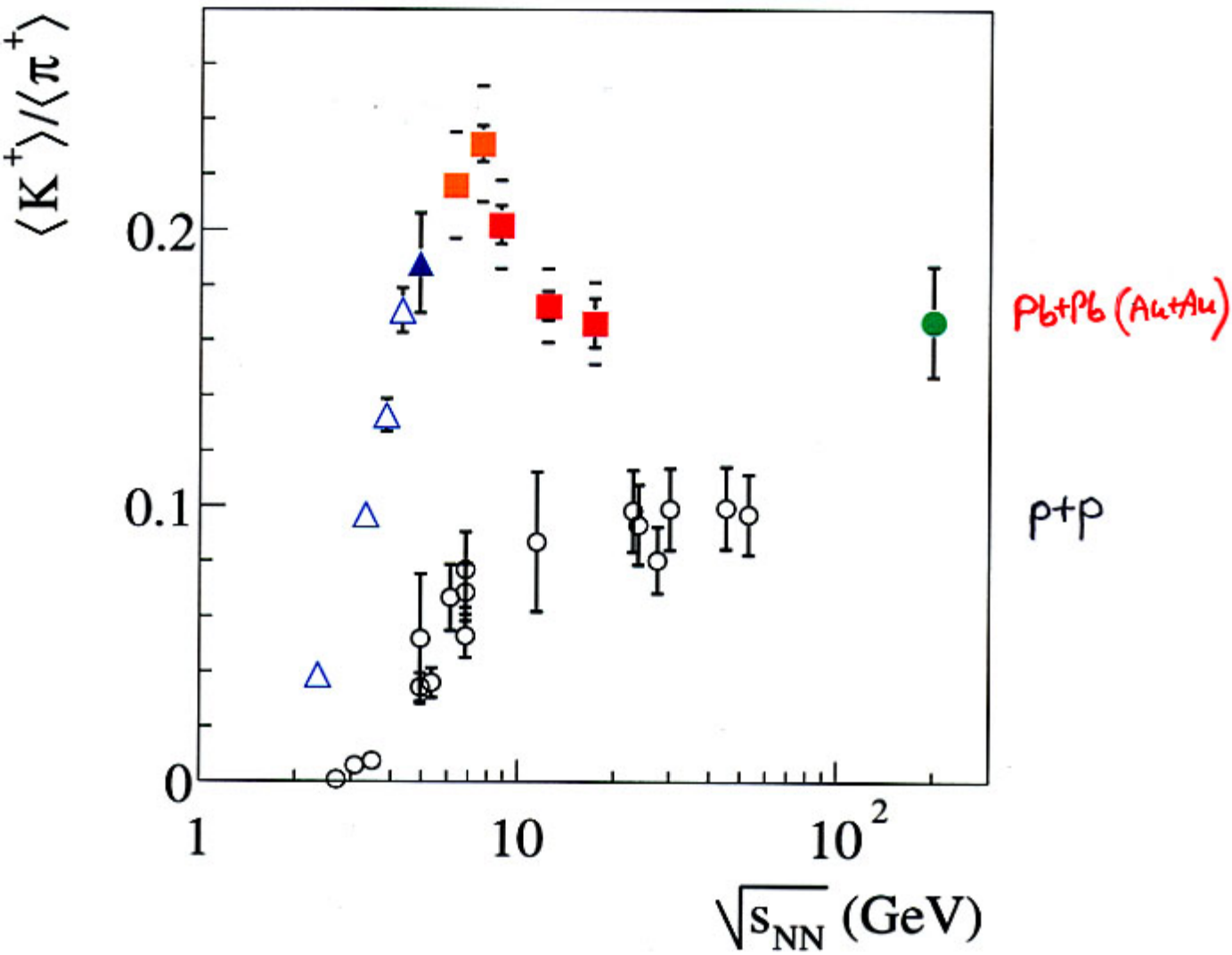
2002: 7 DAYS OF 30 A GEV (NA49, NA60)
7 DAYS AT 20 A GEV (NA49, NA60)

SPS: 160, 80, 40, 30, 20 A GEV

\+ NEW RHIC DATA

\+ AGS DATA

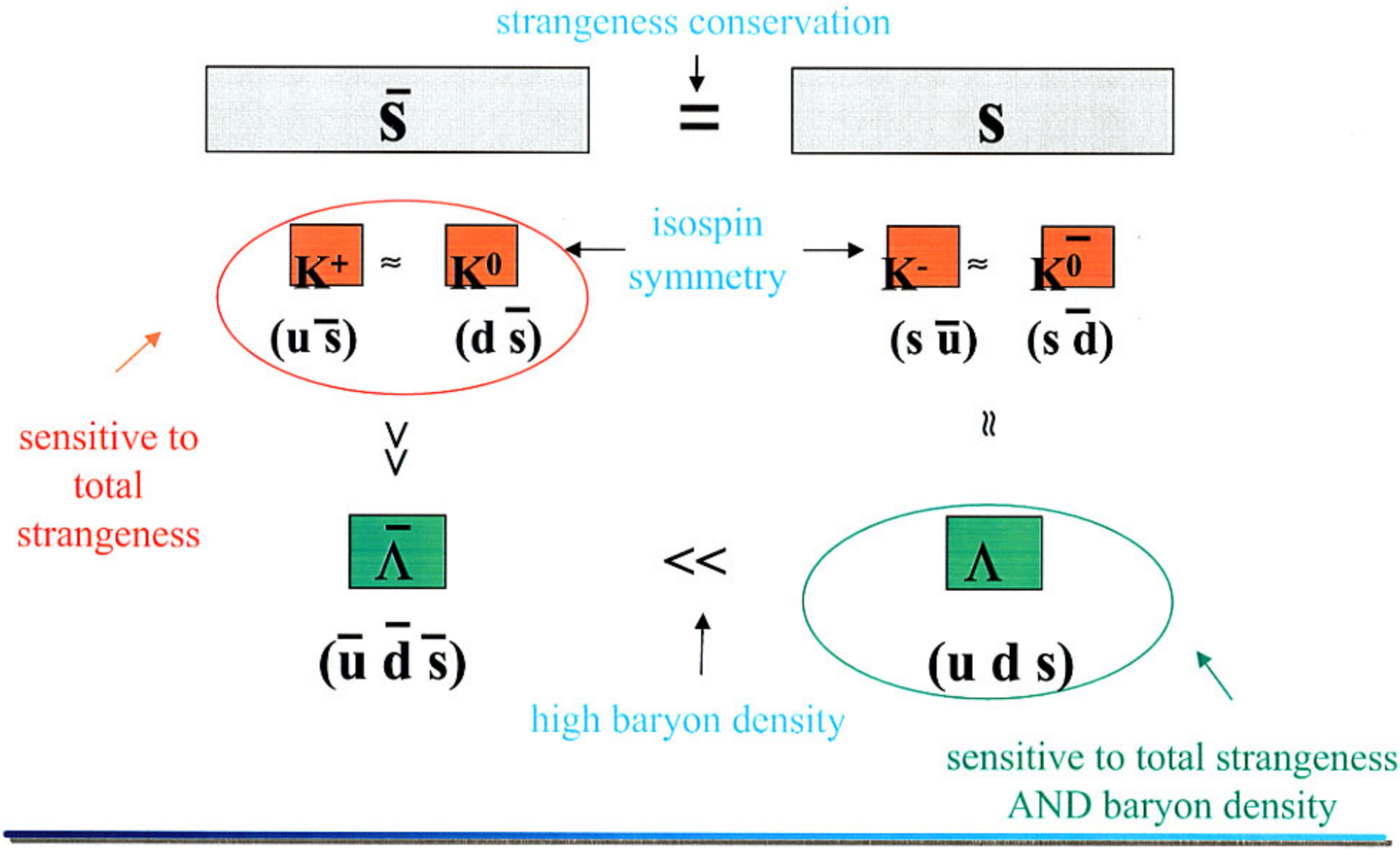
- ENERGY DEPENDENCE OF STRANGENESS PRODUCTION


$\langle K^+ \rangle / \langle \pi^+ \rangle$
0.2
0.1
0
1
10
10^2
$\sqrt{s_{NN}}$ (GeV)
Pb+Pb (AuAu)
p+p

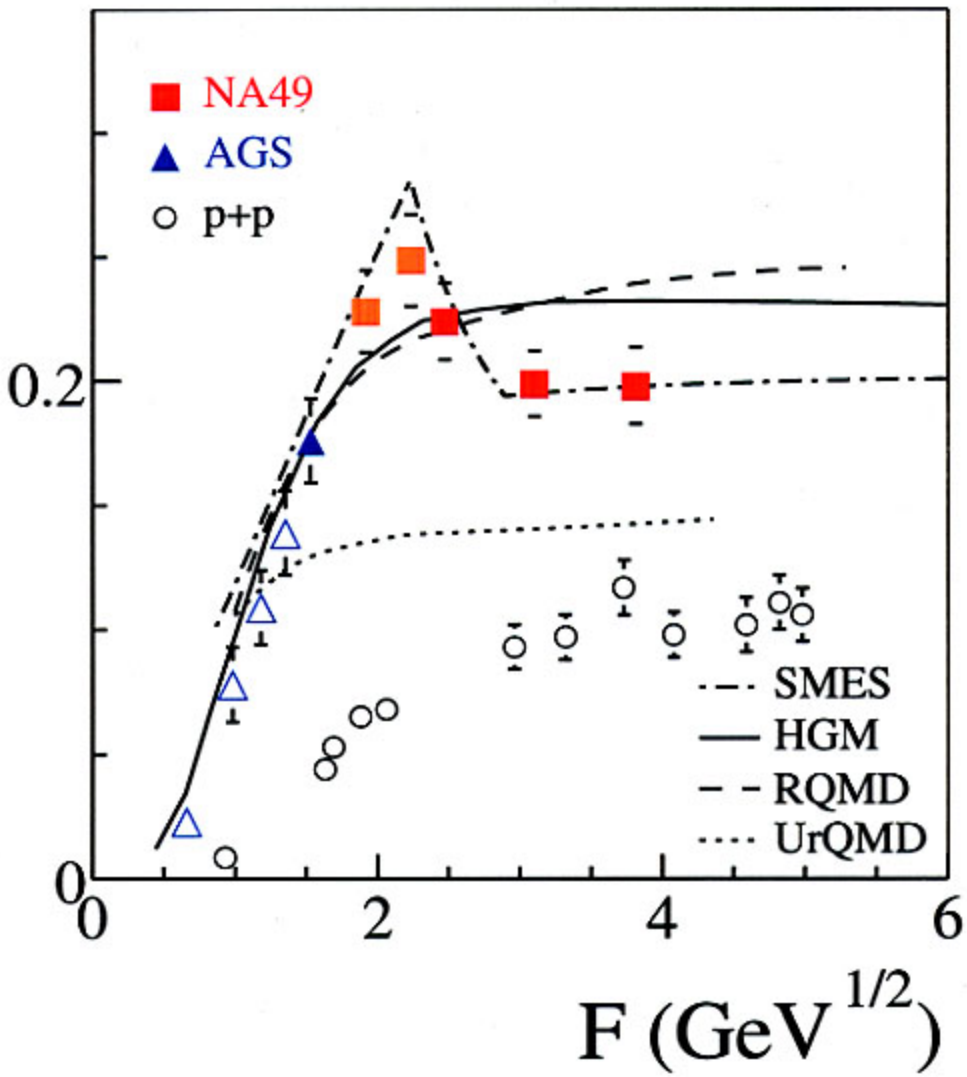
THE STRANGE HORN PREDICTED WITHIN STATISTICAL APPROACH AS SIGNAL OF THE ONSET OF DECONFINEMENT IS OBSERVED

(M.G., GORENSTEIN, ACTA PHYS. POLON. B30, 2705 (99))

Main Strangeness Carriers in Pb+Pb Collisions at SPS :



$$E_s = \frac{\langle \Lambda \rangle + \langle K^+ + K^- \rangle}{\langle \pi \rangle}$$

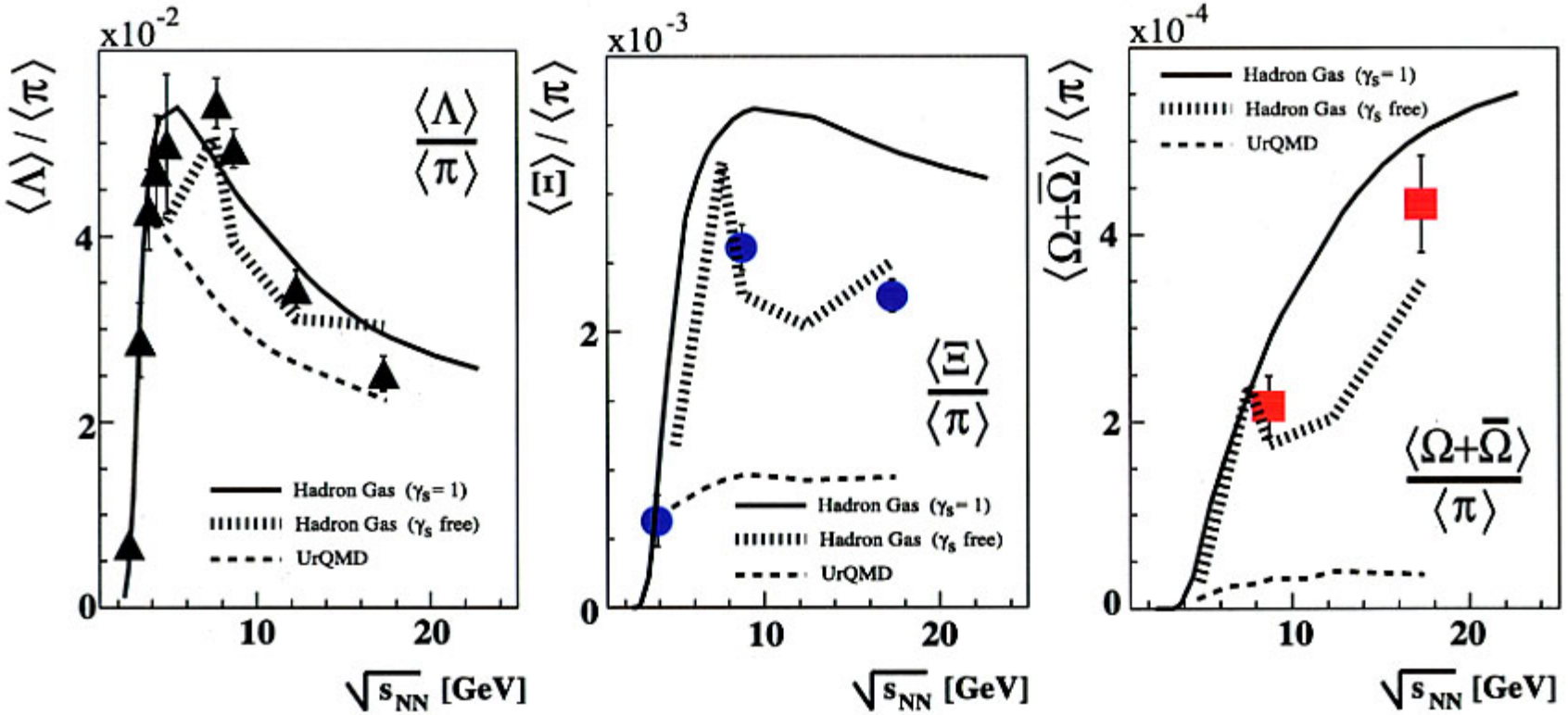


Pb+Pb

p+p

$F \approx \sqrt{\sqrt{s_{NN}}}$

ENERGY DEPENDENCE OF HYPERON PRODUCTION

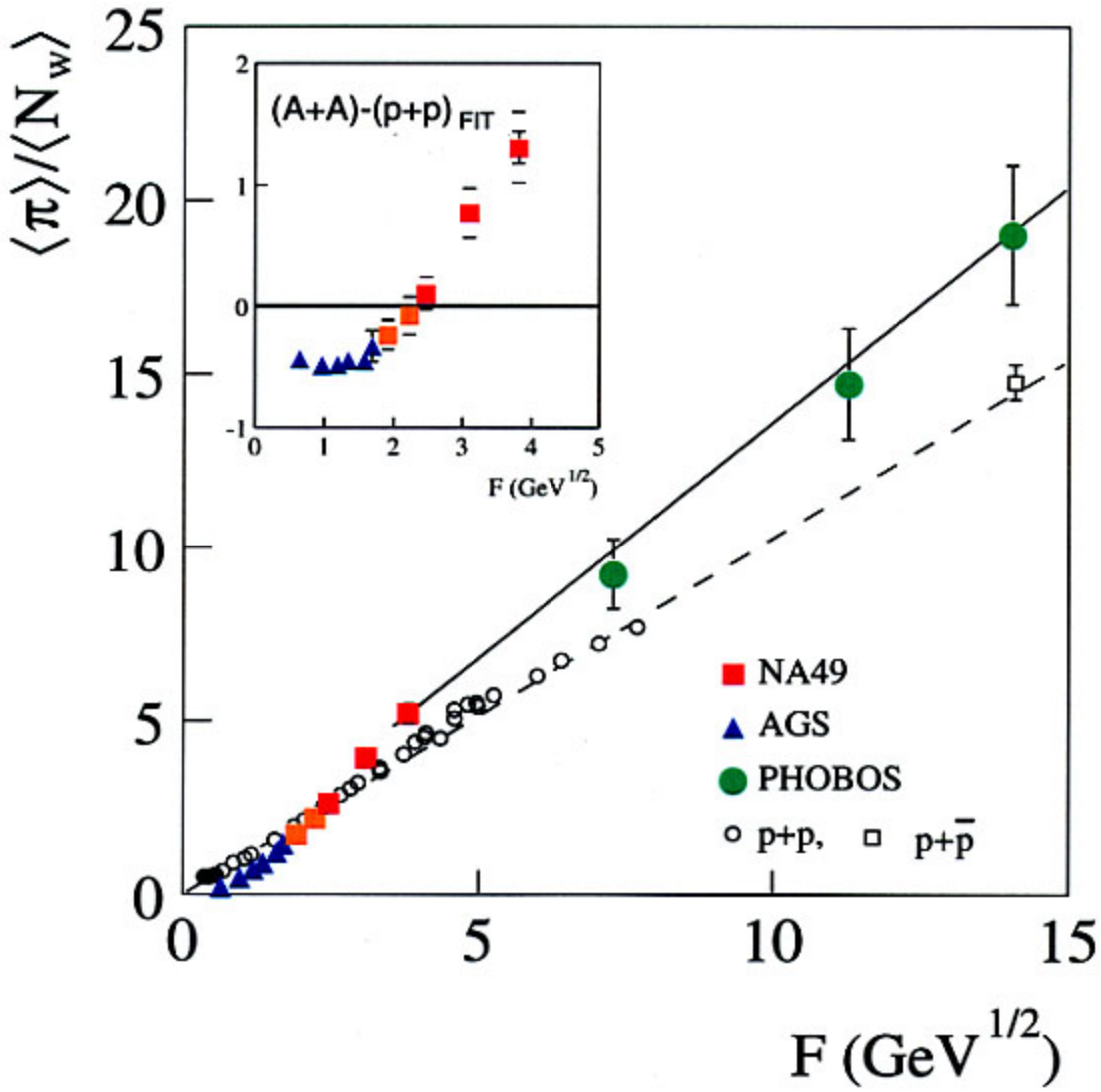


FURTHER SIGNALS OF DECONFINEMENT

- THE PION KINK

- THE STEP IN SLOPES

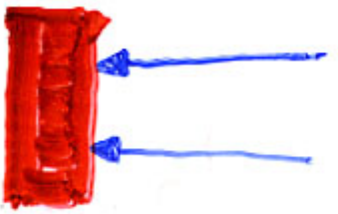
THE PION KINK



M.G., GORENSTEIN, 1994 →

FERMI 1950:

THE EARLY STAGE OF THE COLLISION



$$\varepsilon \equiv \frac{E}{V} \sim (\sqrt{s})^2 ; \quad \varepsilon \sim g \cdot T^4$$

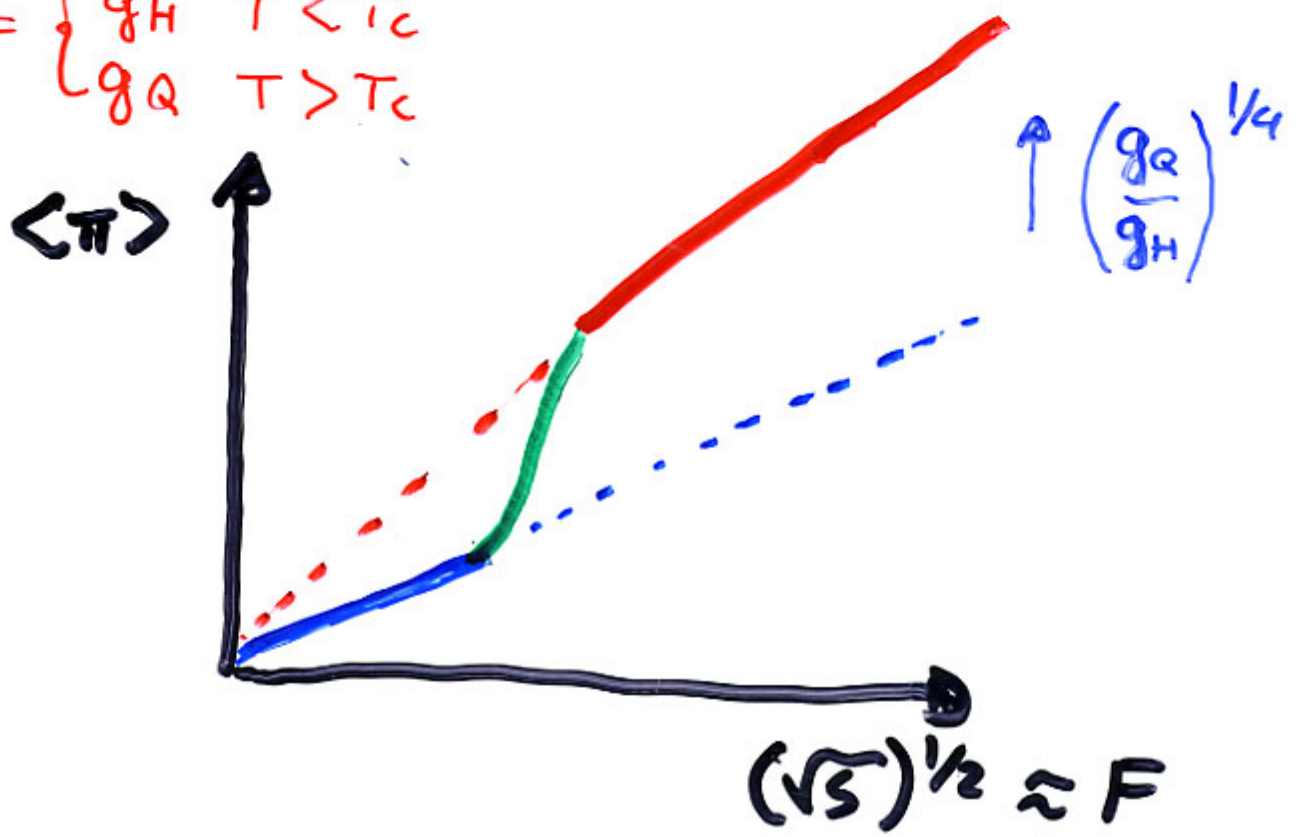
M.G. 1995

$$T \sim g^{-1/4} \cdot (\sqrt{s})^{1/2}$$

$$\langle \pi \rangle \sim S \sim g \cdot \bar{V} \cdot T^3 \sim g \cdot (\sqrt{s})^{-1} \cdot g^{-3/4} \cdot (\sqrt{s})^{3/2}$$

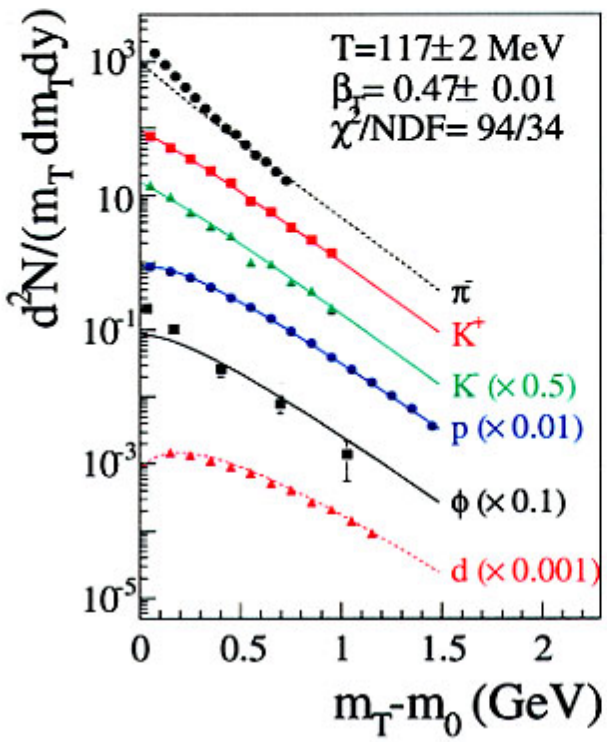
$$\langle \pi \rangle \sim g^{1/4} \cdot (\sqrt{s})^{1/2}$$

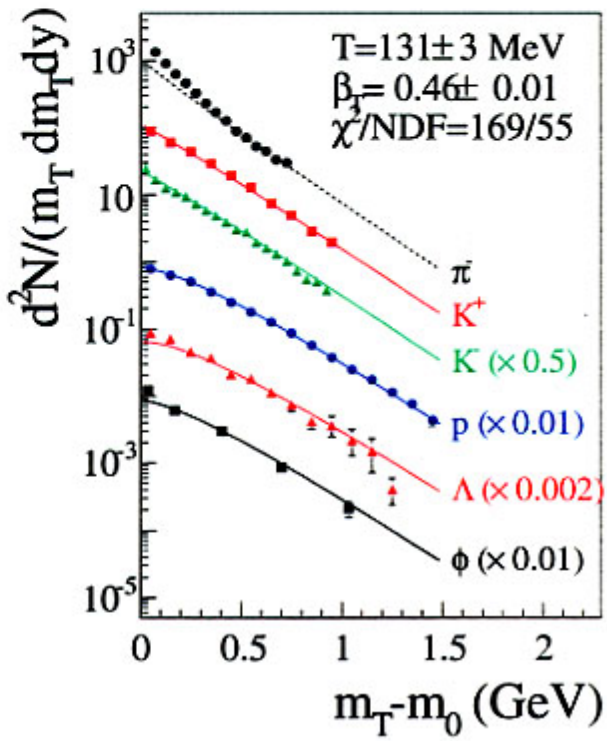
$$g = \begin{cases} g_H & T < T_c \\ g_Q & T > T_c \end{cases}$$

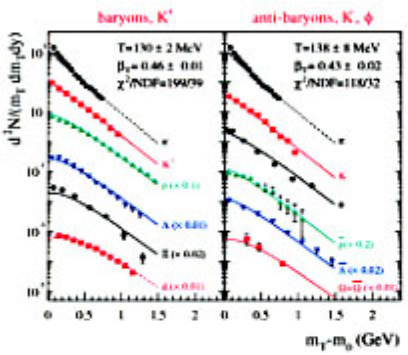


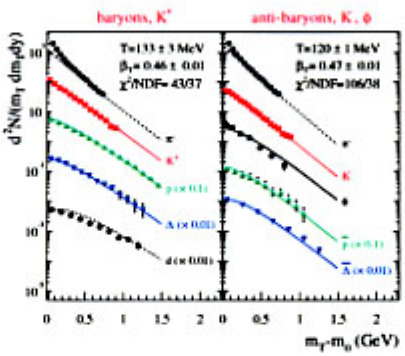
$$\frac{g_{QGP}}{g_{CONF}} \approx (1.3)^4 \approx 3$$

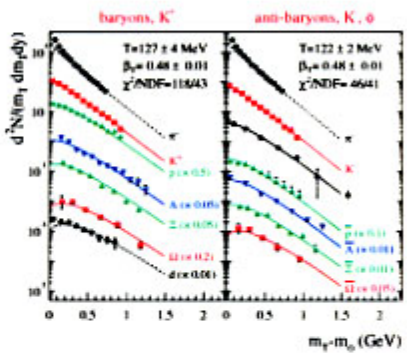
THE STEP IN SLOPES


T=117±2 MeV
β_T= 0.47± 0.01
χ²/NDF= 94/34
π⁻
K⁺
K⁻ (×0.5)
p (×0.01)
φ (×0.1)
d (×0.001)
d²N/(m_T dm_T dy)
m_T-m_0 (GeV)

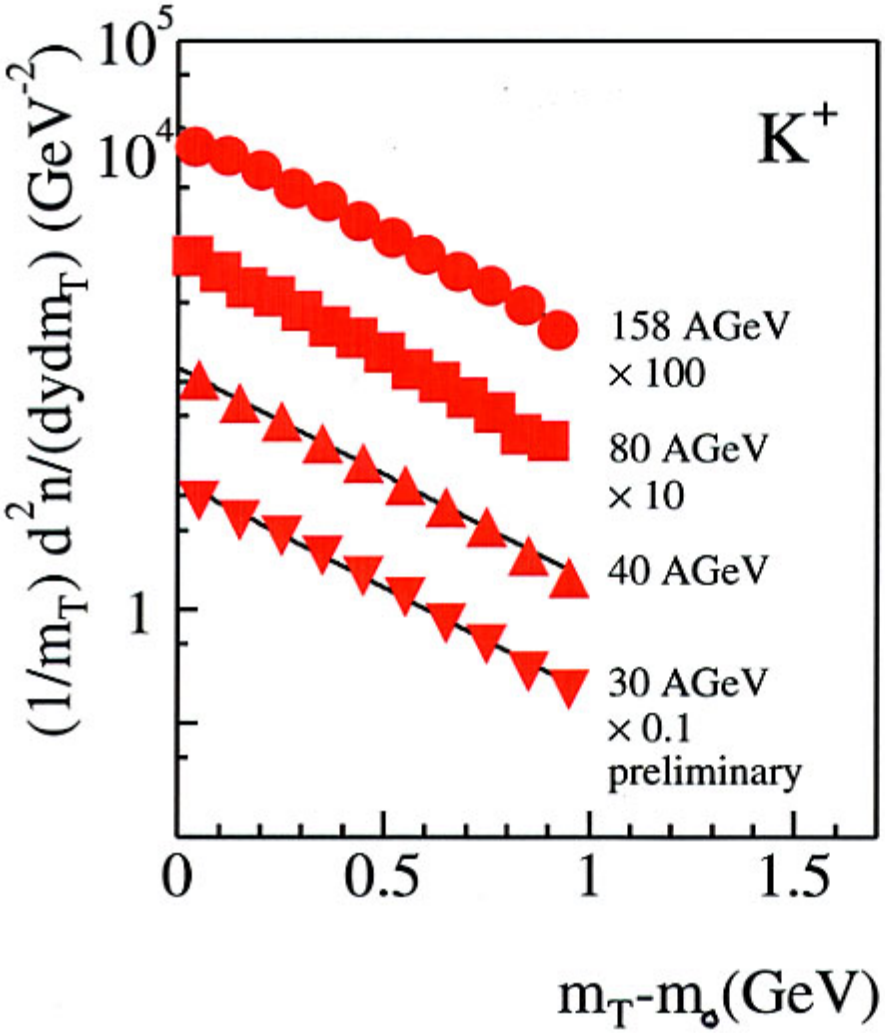

T=131±3 MeV
β_T= 0.46± 0.01
χ²/NDF=169/55
π⁻
K⁺
K⁻ (×0.5)
p (×0.01)
Λ (×0.002)
φ (×0.01)
d²N/(m_T dm_T dy)
m_T-m_0 (GeV)


baryons, K⁺
anti-baryons, K⁻, φ
m_T-m_0 (GeV)


baryons, K⁺
anti-baryons, K⁻, φ
m_T-m_0 (GeV)


baryons, K⁺
anti-baryons, K⁻, φ
m_T-m_0 (GeV)

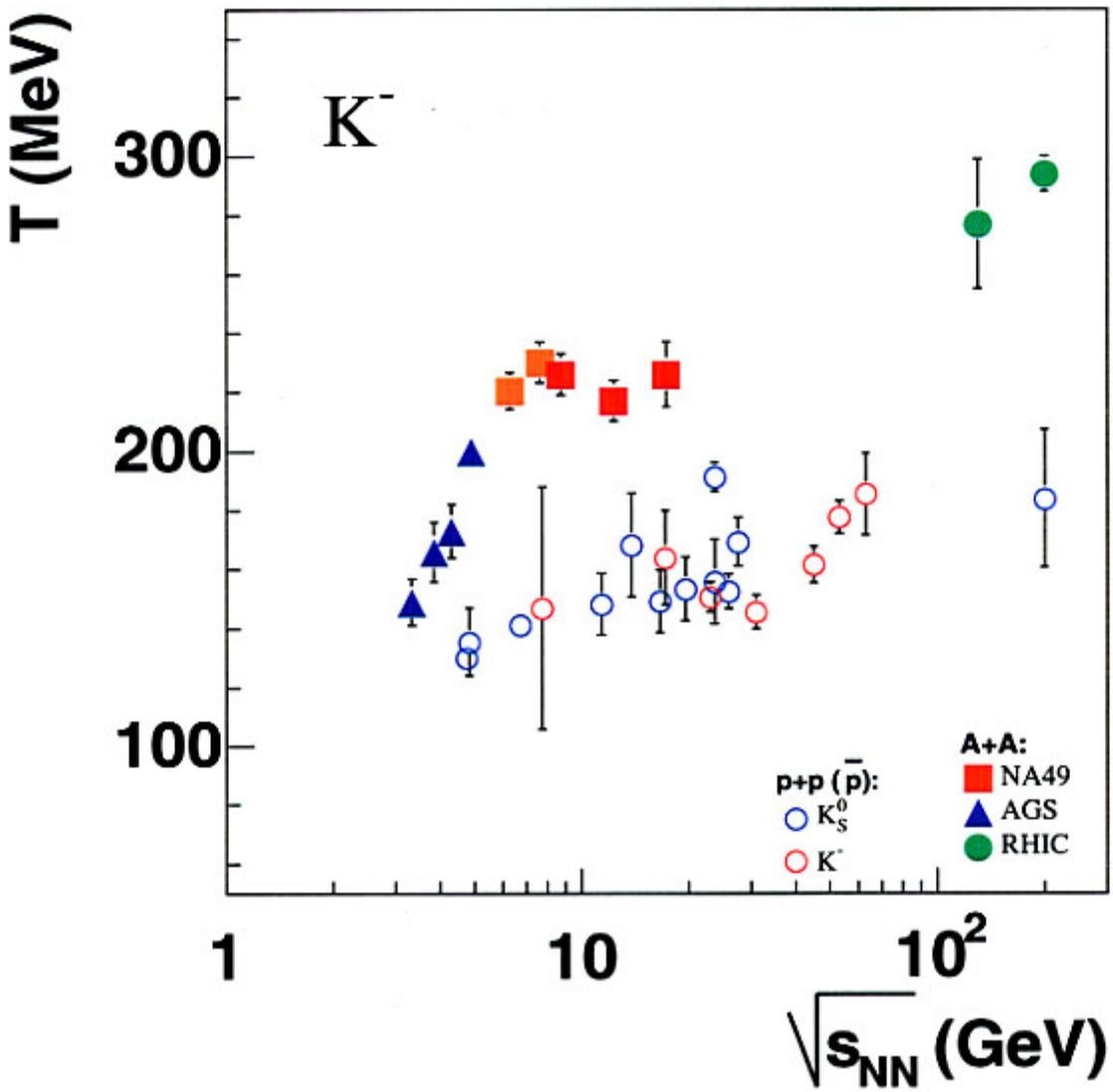
CENTRAL PB+PB AT SPS



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

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

EXPONENTIAL SHAPE OF KAON m_T SPECTRA OBSERVED FROM AGS TO RHIC ENERGIES



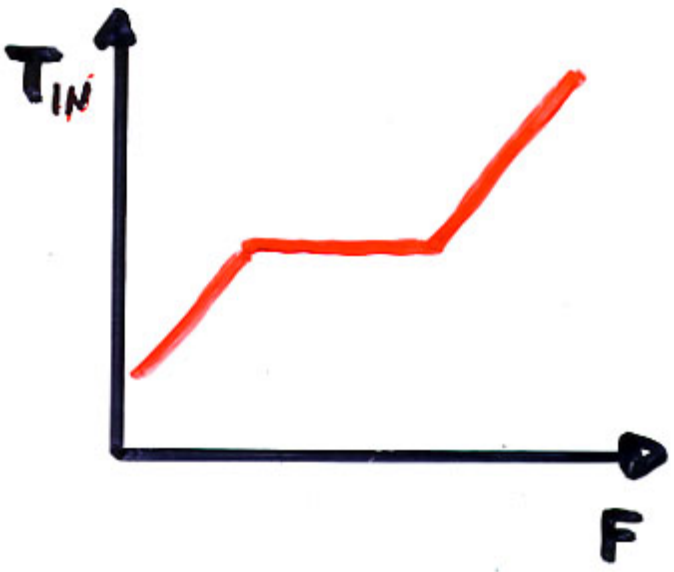
GORENSTEIN, M.G., BUGAEV,
PHYS. LETT. B567, 175 (2003)

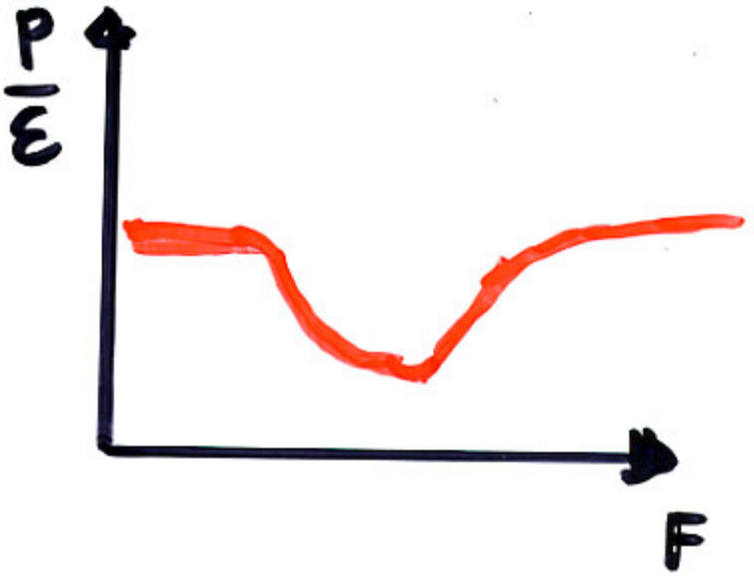
THE STEP IN SLOPES

ONSET OF DECONFINEMENT

↓

MODIFICATION OF EOS





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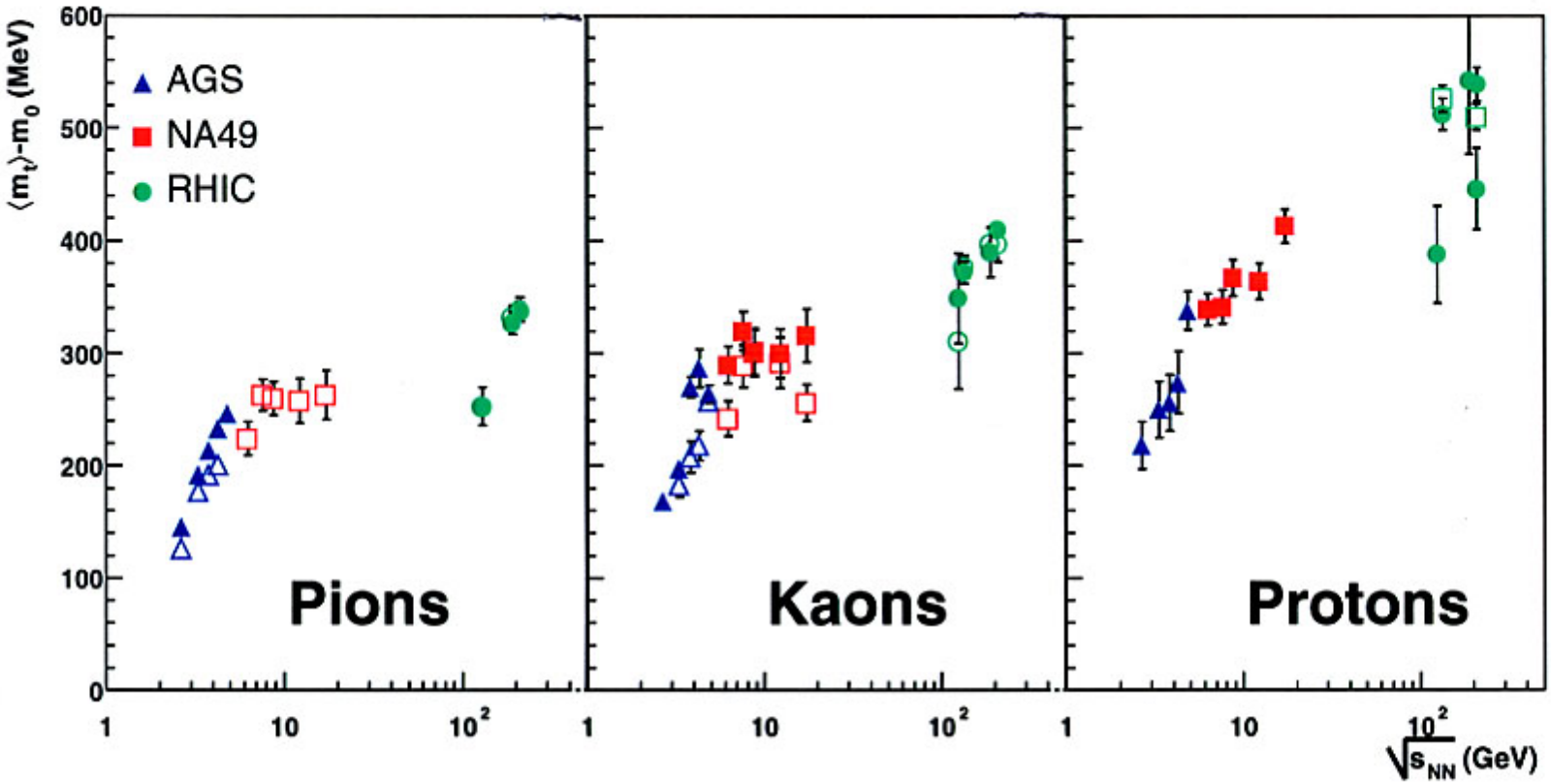
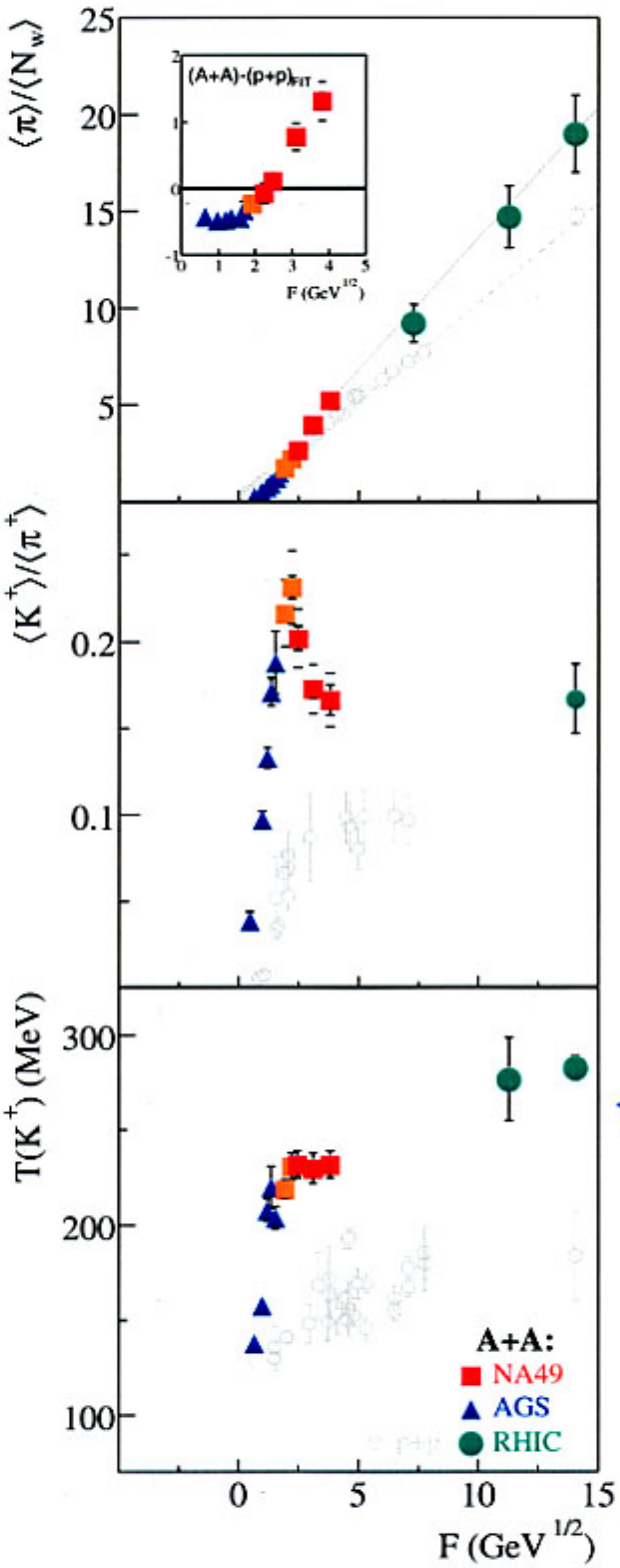
ANOMALY IN TRANSVERSE EXPANSION

L. Van Hove, PHYS. LETT. B118, 138 (82)


AGS
NA49
RHIC
Pions
Kaons
Protons
$\langle m_t \rangle - m_0$ (MeV)
$\sqrt{s_{NN}}$ (GeV)
0
100
200
300
400
500
600
1
10
10^2

SIGNALS OF DECONFINEMENT



THE PION KINK

THE STRANGE HORN

THE STEP IN SLOPES

COLLISION ENERGY $F \approx \sqrt{E}$

CONCLUSIONS:

EVIDENCE FOR DECONFINEMENT PHASE TRANSITION IN CENTRAL PB+PB COLLISIONS AT LOW SPS ENERGIES

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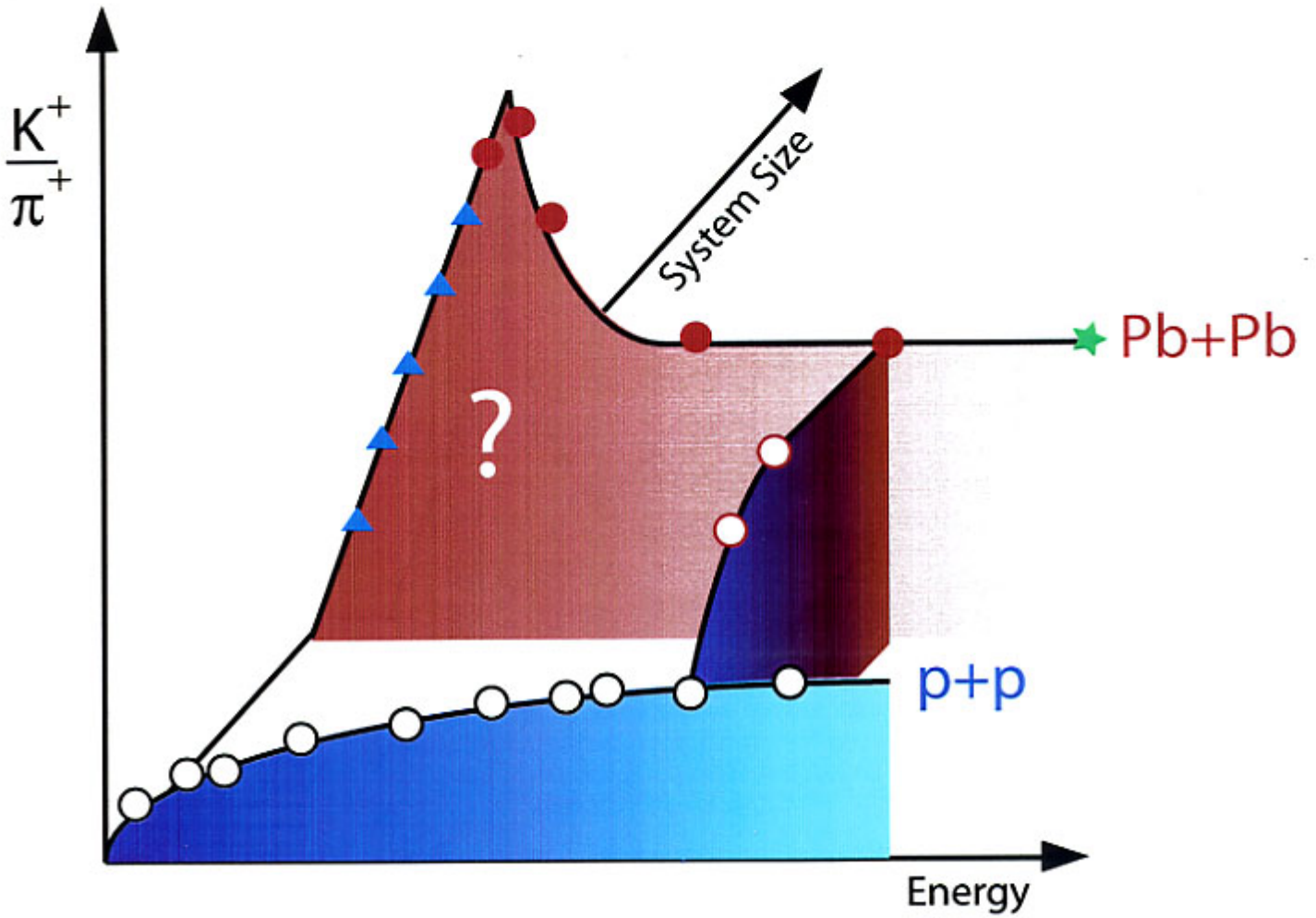
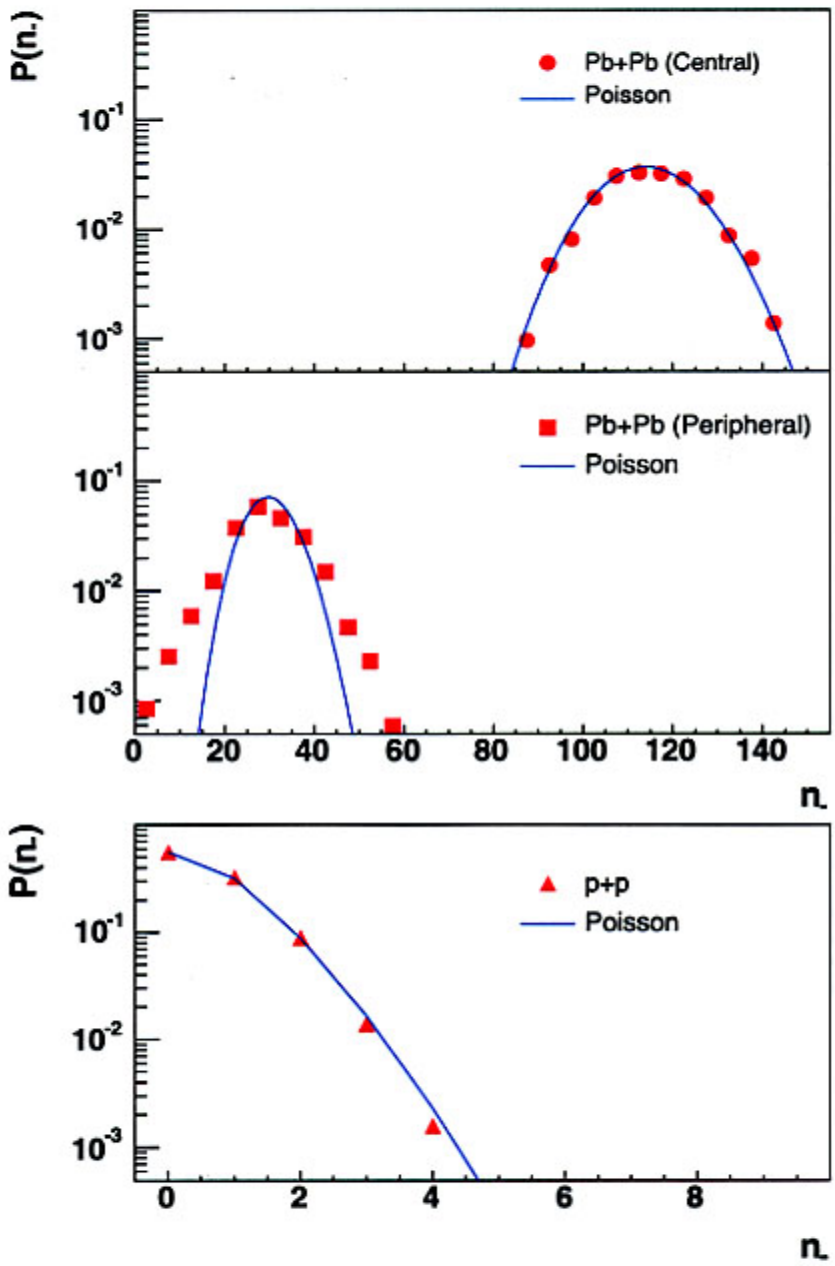
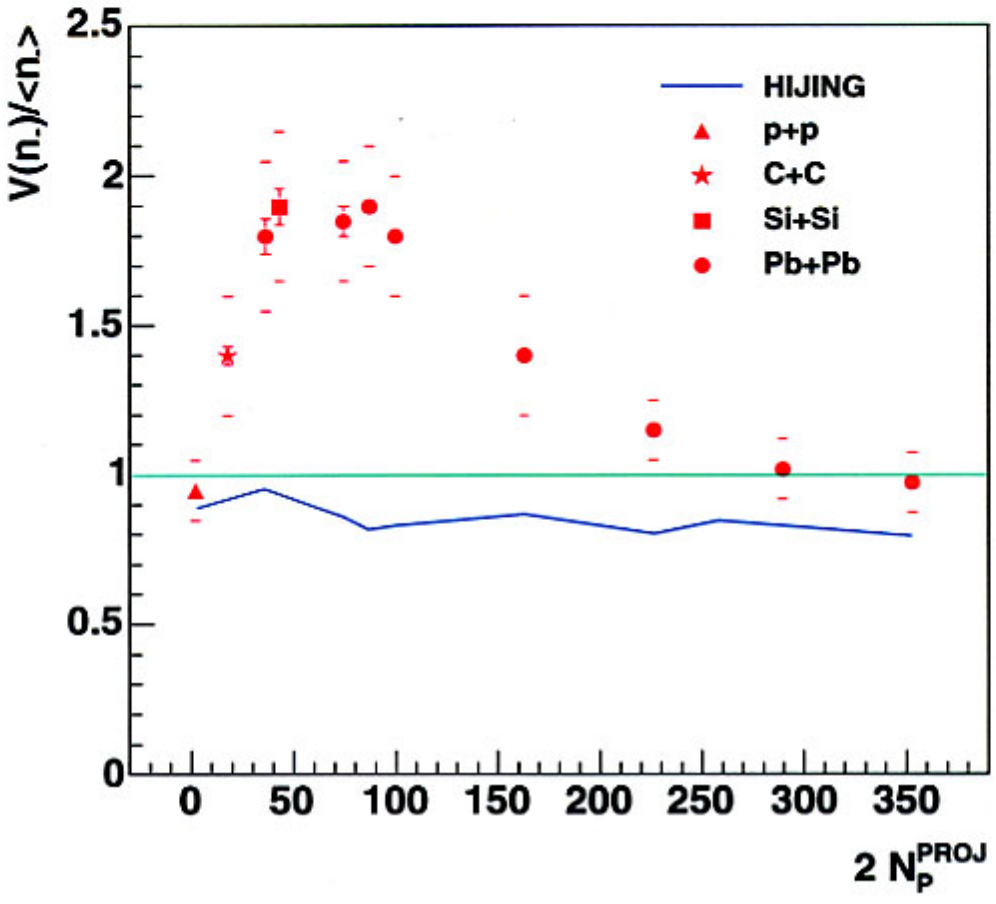
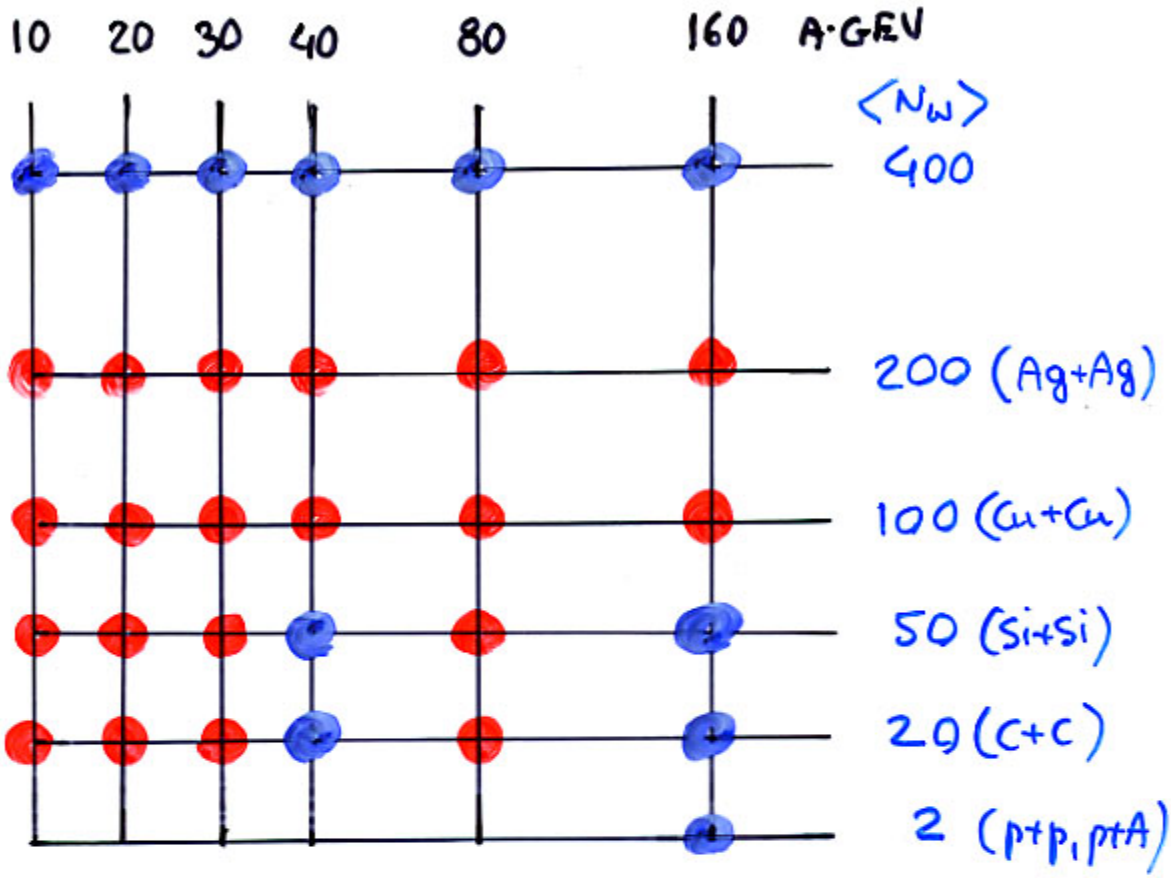
EVIDENCE FOR EXISTANCE OF QGP IN NATURE

FUTURE


K+/π+
System Size
Pb+Pb
?
p+p
Energy

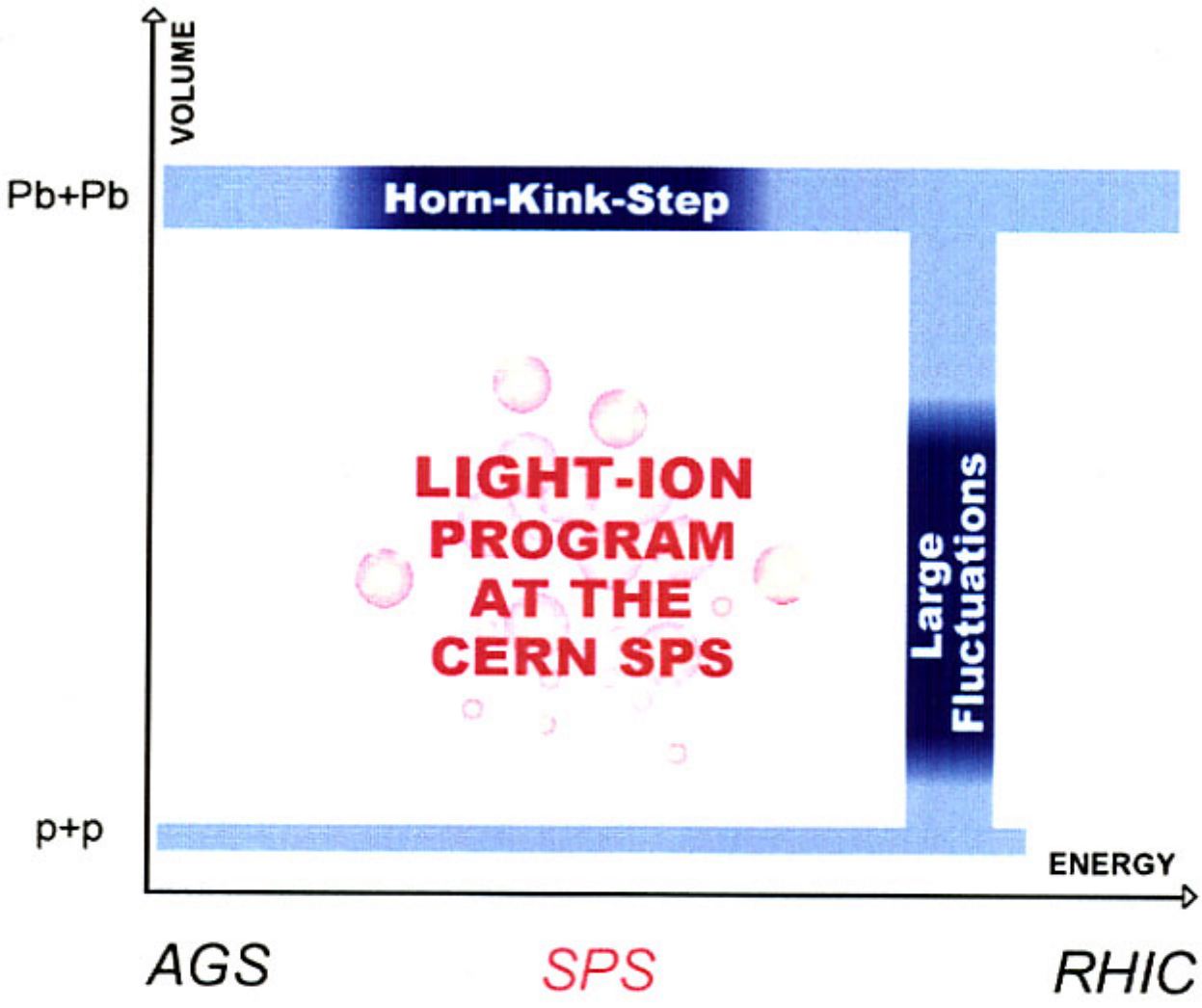

P(n_ch)
Pb+Pb (Central)
Poisson
Pb+Pb (Peripheral)
Poisson
p+p
Poisson
n_ch


V(n-)/<n->
2.5
2
1.5
1
0.5
0
0
50
100
150
200
250
300
350
2 N_P^PROJ
HIJING
p+p
C+C
Si+Si
Pb+Pb



TAKEN DATA

REQUESTED DATA


VOLUME
Pb+Pb
Horn-Kink-Step
LIGHT-ION
PROGRAM
AT THE
CERN SPS
Large
Fluctuations
p+p
ENERGY
AGS
SPS
RHIC

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 ($\approx$1 M EUR)
- First Data Taking Possible in 2007

New Collaborators are Welcome !!!