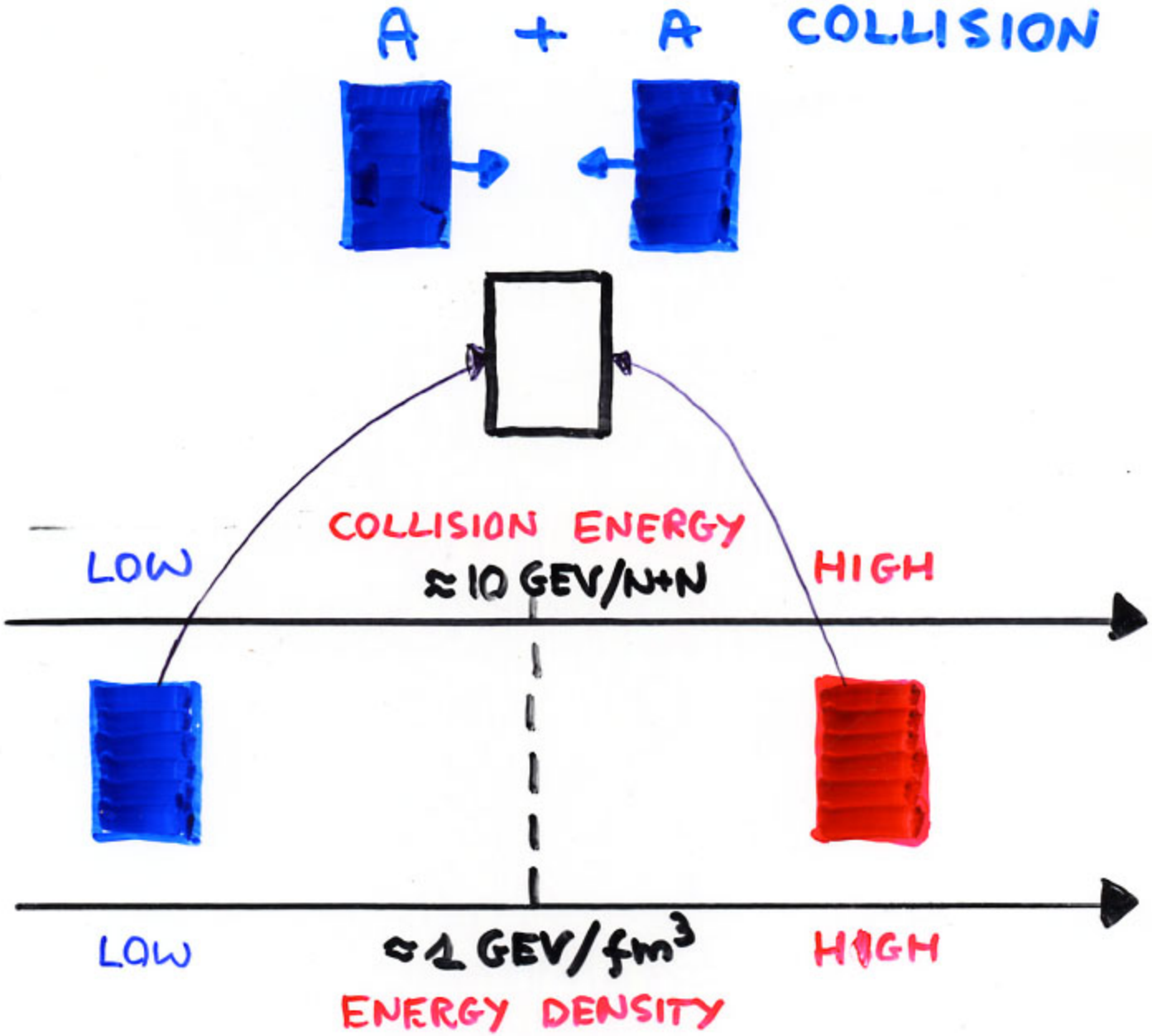
ENERGY SCAN PROGRAM AT CERN SPS

M. GAŹDZICKI FOR THE NA49 COLLABORATION

- A BRIEF HISTORY
- BASIC DATA
- SIGNALS OF DECONFINEMENT
- CONCLUSIONS AND FUTURE

A BRIEF HISTORY OF

- IDEAS
- EXPERIMENTS



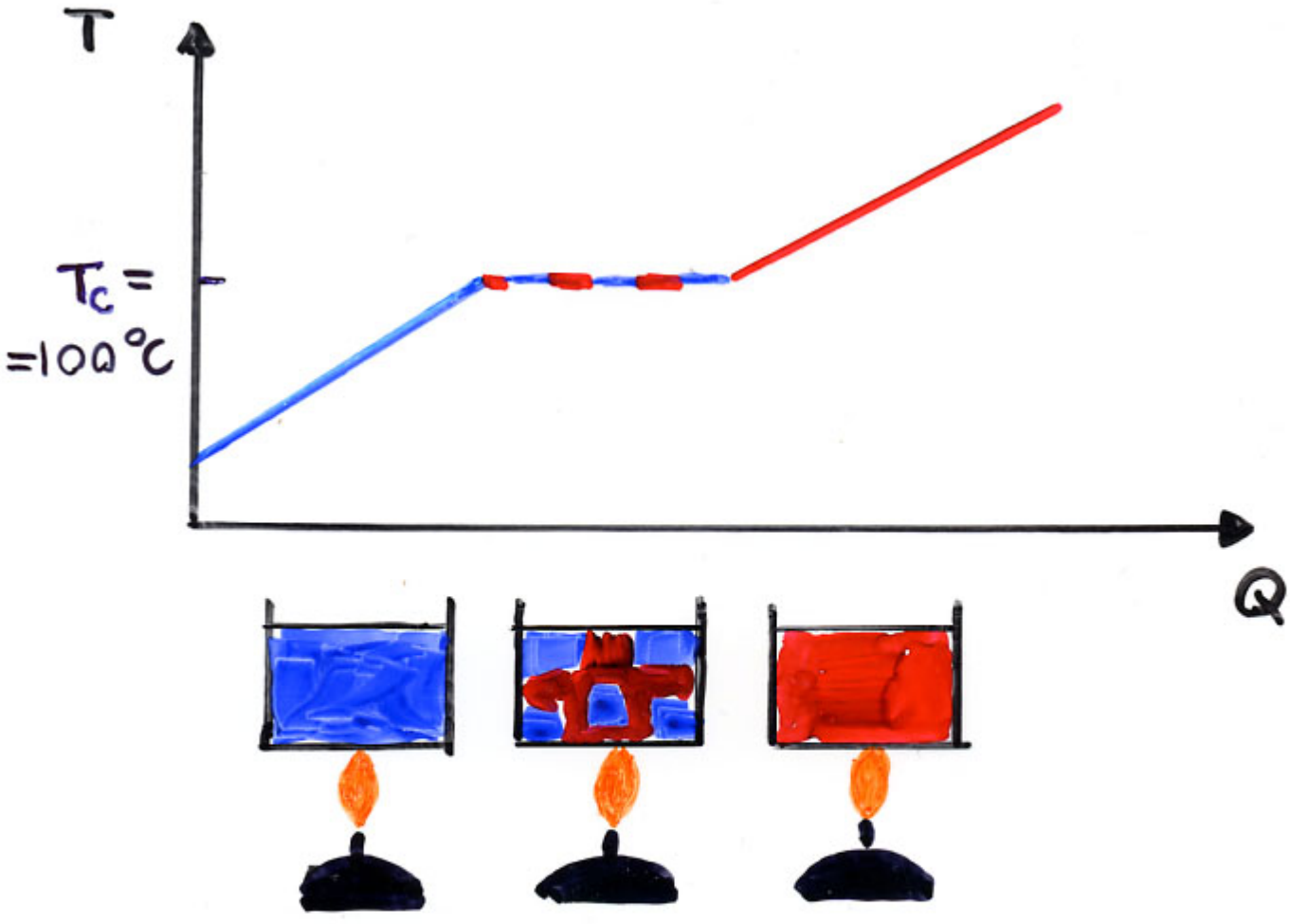
DEGREES OF FREEDOM

HADRONS

QUARKS AND GLUONS

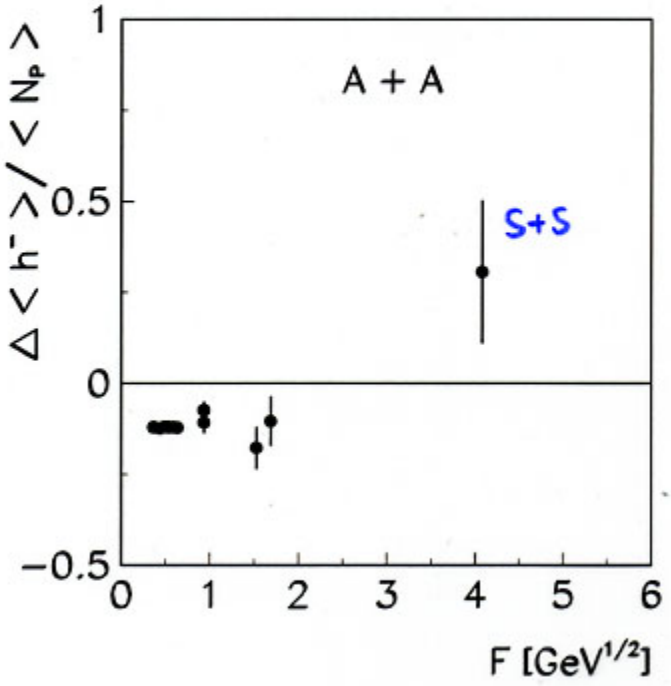
IN THE CASE OF TRANSITION ONE EXPECTS ANOMALIES IN THE ENERGY DEPENDENCE OF THE RELEVANT OBSERVABLES

A SIMPLE ANALOGY:



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

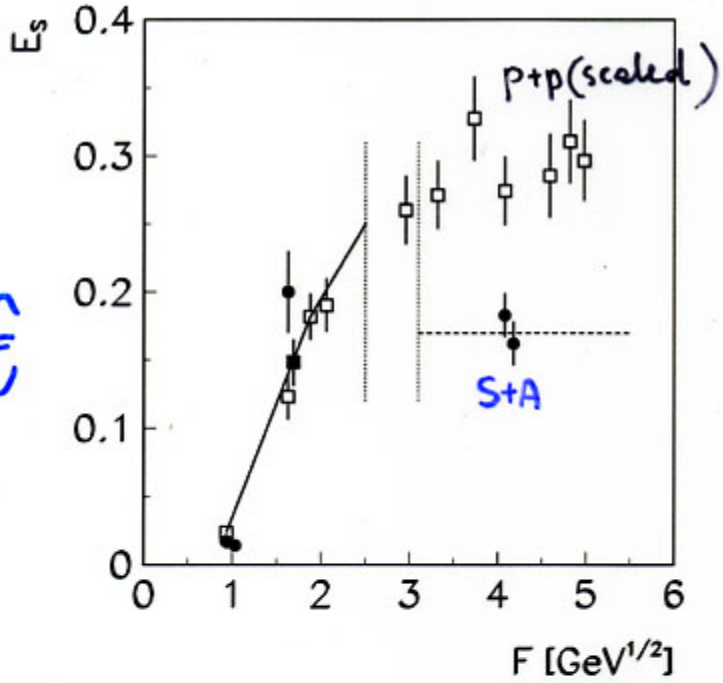
$\langle h^- \rangle_{(AA)} / \langle N_p \rangle - \langle h^- \rangle_{(NN)} / \langle N_p \rangle$



PIONS

(Z.P. C65 (95) 215)

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



STRANGENESS

(Z.P. C71 (96) 55)

$\approx \sqrt{s}$

1994 - 1999:

FORMULATION OF THE STATISTICAL MODEL OF THE EARLY STAGE

M. G. Workshop on Hot Hadronic Matter (1994) NATO ASI SERIES, p. 215

M.G. Z. PHYS C66 (1995) 659

M.G. J. PHYS. G23 (1997) 1881

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

OBSERVED ANOMALIES IN ENERGY DEPENDECE SIGNAL ONSET OF DECONFINEMENT AT LOW SPS ENERGIES

START ENERGY SCAN PROGRAM AT CERN SPS

AT THE SAME TIME ($\approx$ 1996):

AN OBSERVATION OF "OLD" SIGNALS OF DECONFINEMENT:

- STRANGENESS ENHANCEMENT
- J/ψ SUPPRESSION

IN SYSTEM SIZE DEPENDENCE AT 158 A·GEV.

THE SIGNIFICANCE OF THESE SIGNALS IS NOW, HOWEVER, UNDER CRITICAL DISCUSSION

A BRIEF HISTORY OF EXPERIMENTS

1997: ADDENDUM 1 TO NA49 PROPOSAL

Searching for QCD Phase Transition

Proposal of NA49 for a low energy Pb–run at the SPS

1 Introduction

An analysis of results of the experiments NA49 [1] and NA35 [2] on central Pb+Pb and S+S collisions at CERN SPS energies (158 A·GeV and 200 A·GeV) and AGS experiments ($\approx$ 15 A·GeV) show that the collision energy dependence of the relative pion and strangeness production in central nucleus–nucleus (A+A) interactions changes between these two energies [3]. The most exciting of the possible interpretations of these observation is that a transition to a new form of strongly interacting matter, the Quark Gluon Plasma, takes place somewhere in the above energy range. This interpretation is plausible because estimated initial energy density in A+A collisions at SPS is larger than the critical energy density obtained from lattice QCD calculations. Therefore, we suggest to confirm such an interpretation with a search for the transition energy. *For this purpose the NA49 Collaboration proposes to study central Pb+Pb collisions at the intermidate collision energy (around 30 A·GeV) as soon as possible.* Further studies (selection of different collisions energies and smaller colliding nuclei) will depend on the results from the intermidiate energy run.

This note presents the justification for this proposal. The experimental and theoretical motivations are reviewed in Section 2. The expected signals of the QCD transition are summarized in Section 3. The performance of the NA49 experiment and the required statistics and quality of data are discussed in Section 4.

30 A·GEV RUN IN 2002

March 9, 2003

THE NA49 SPOKESMEN :

R. STOCK (< 1997)

P. SEYBOTH (≥ 1997)

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)

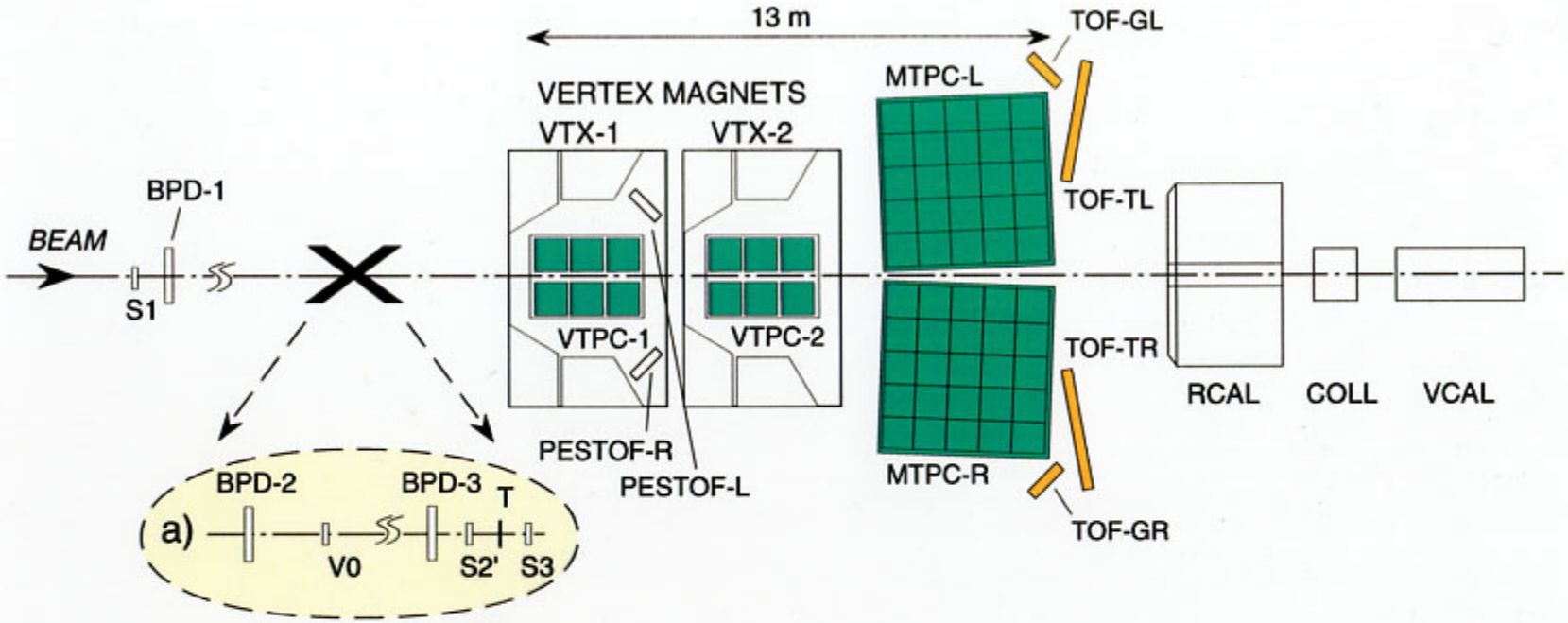
2002: 7 DAYS OF 30 A GEV (NA49, NA60)
7 DAYS AT 20 A GEV (NA49, NA60)

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

\+ NEW RHIC DATA

\+ AGS DATA

NA49 AT CERN SPS

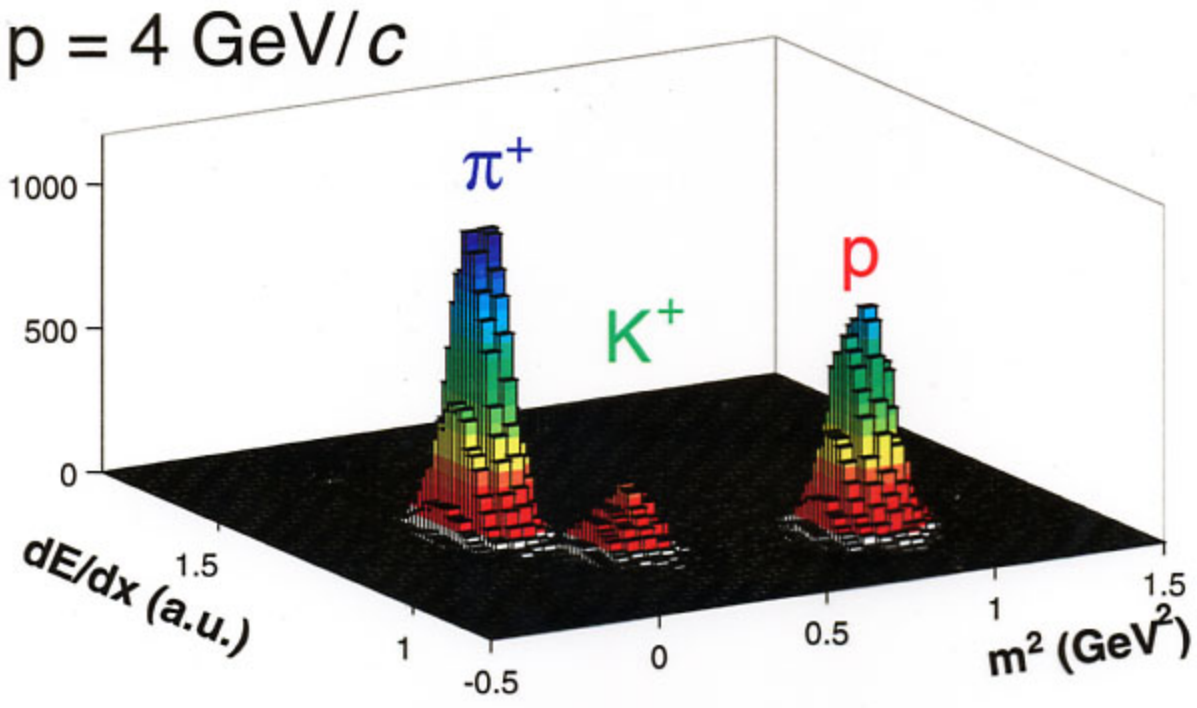


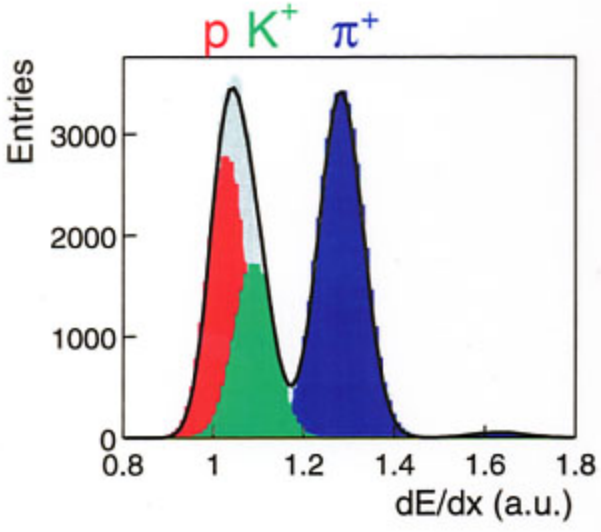
LARGE ACCEPTANCE HADRON SPECTROMETER

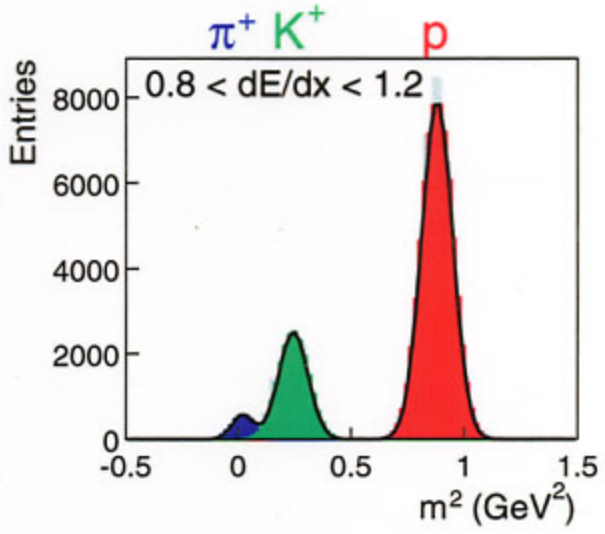
PARTICLE IDENTIFICATION:

- dE/dx
- TOF
- DECAY TOPOLOGY AND KINEMATICS

CHARGED PARTICLE IDENTIFICATION IN NA49







$\sigma(\text{TOF}) \approx 60$ ps $\sigma(dE/dx) \approx 4\%$

BASIC DATA

- m_T SPECTRA

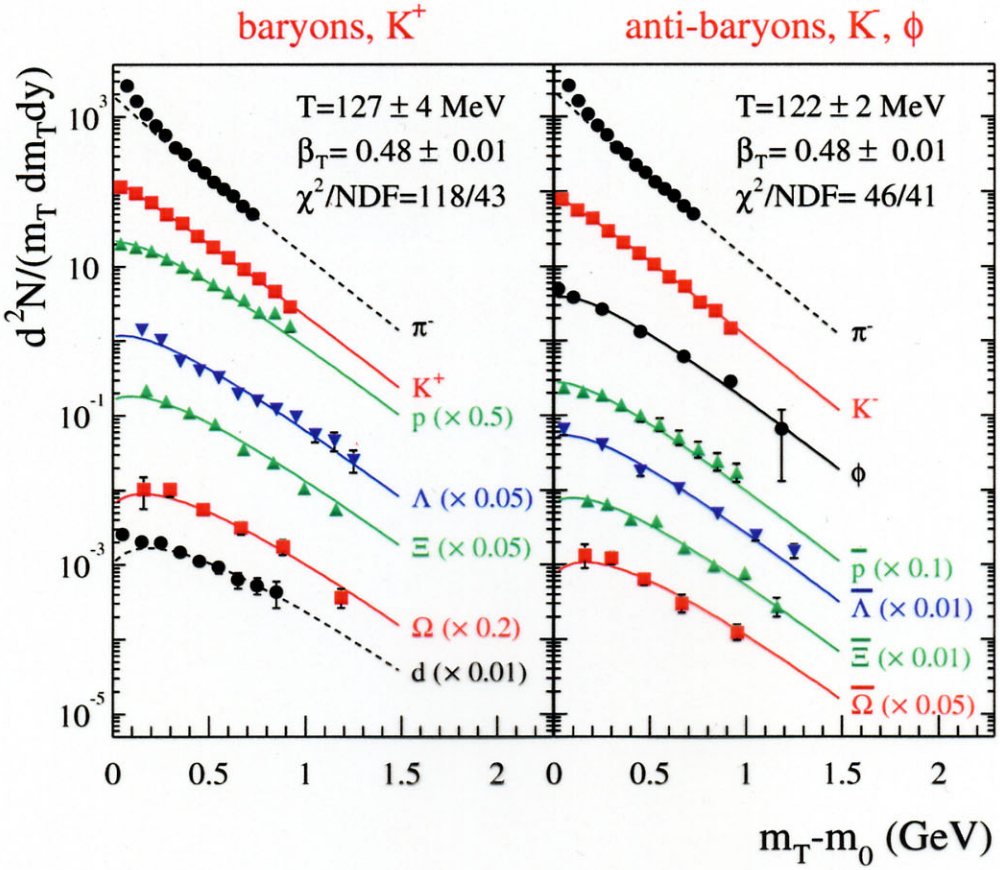
  (THERMAL FREEZE-OUT)

- RAPIDITY SPECTRA

  MULTIPLICITIES

  (CHEMICAL FREEZE-OUT)

CENTRAL PB+PB AT 158 A·GEV



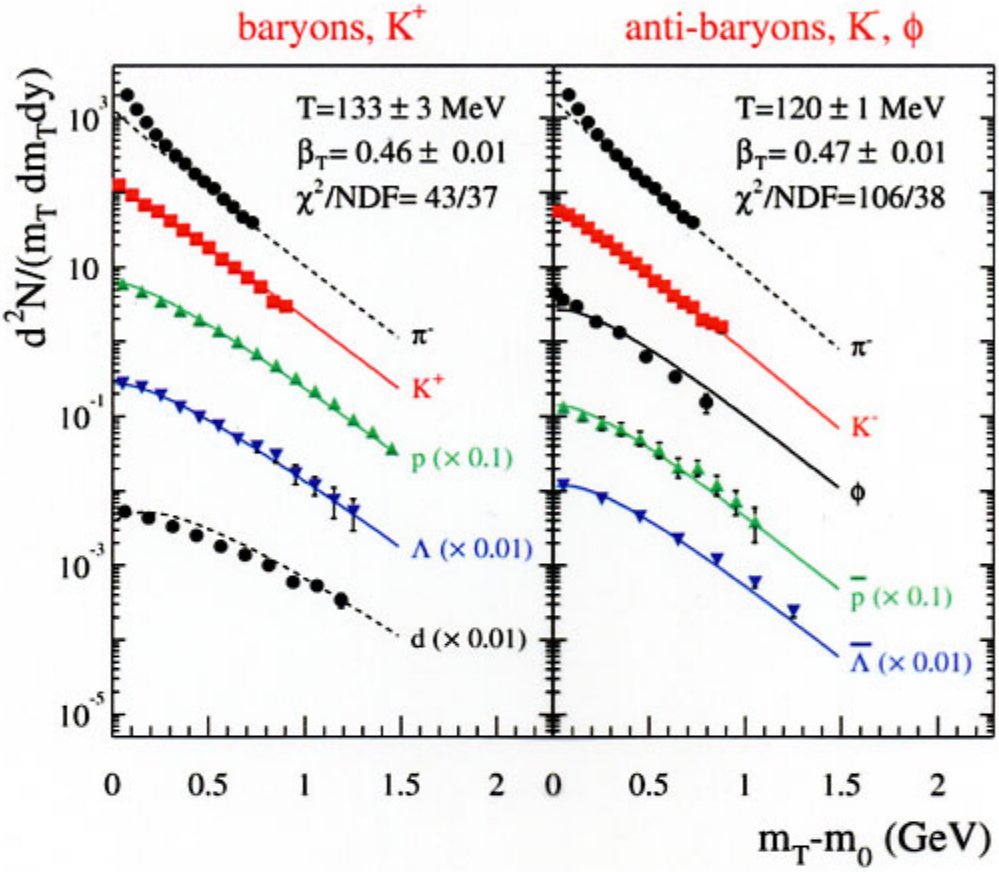
m_T SPECTRA CAN BE FITTED ASSUMING COLLECTIVE TRANSVERSE FLOW OF FREEZING-OUT MATTER

THERMAL FREEZE-OUT PARAMETERS

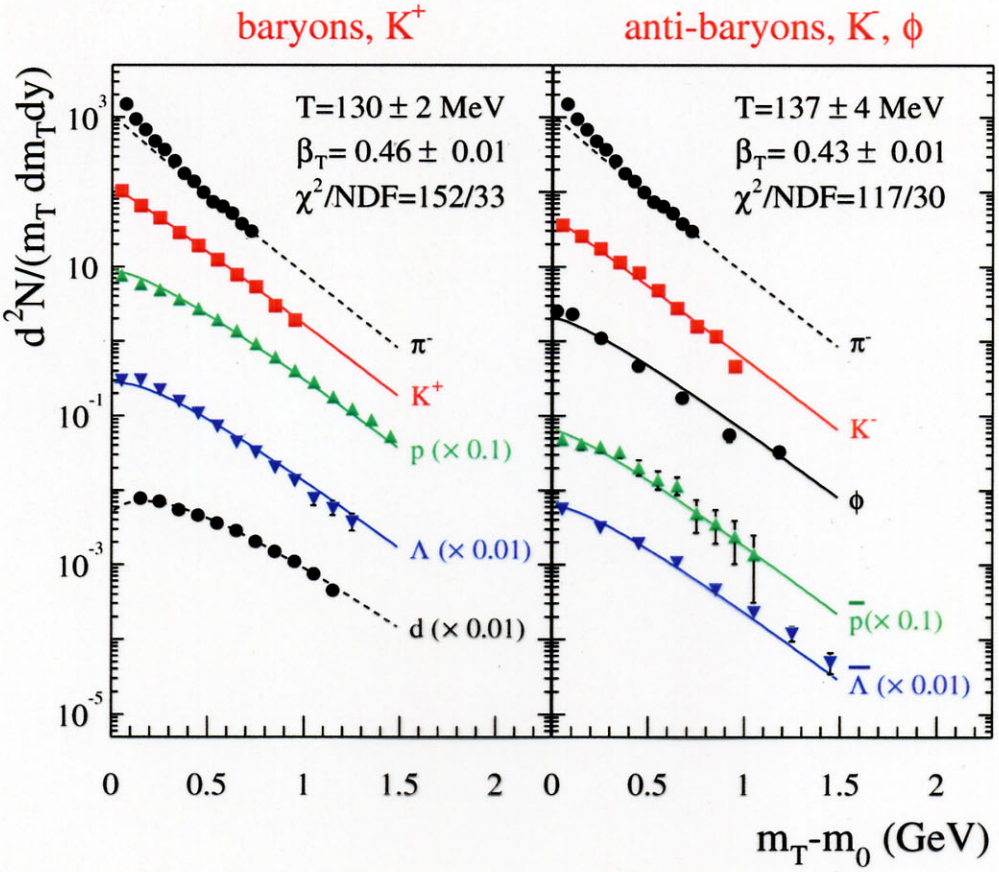
$\overline{T_F} \approx 120$ MEV (TEMPERATURE) $\overline{\beta_F} \approx 0.5$ (FLOW VELOCITY)

SCHNEDERMANN, SOLLFRANK, HEINZ
PRC 48 (93) 2462.

CENTRAL PB+PB AT 80 A·GEV



CENTRAL PB+PB AT 40 A·GEV



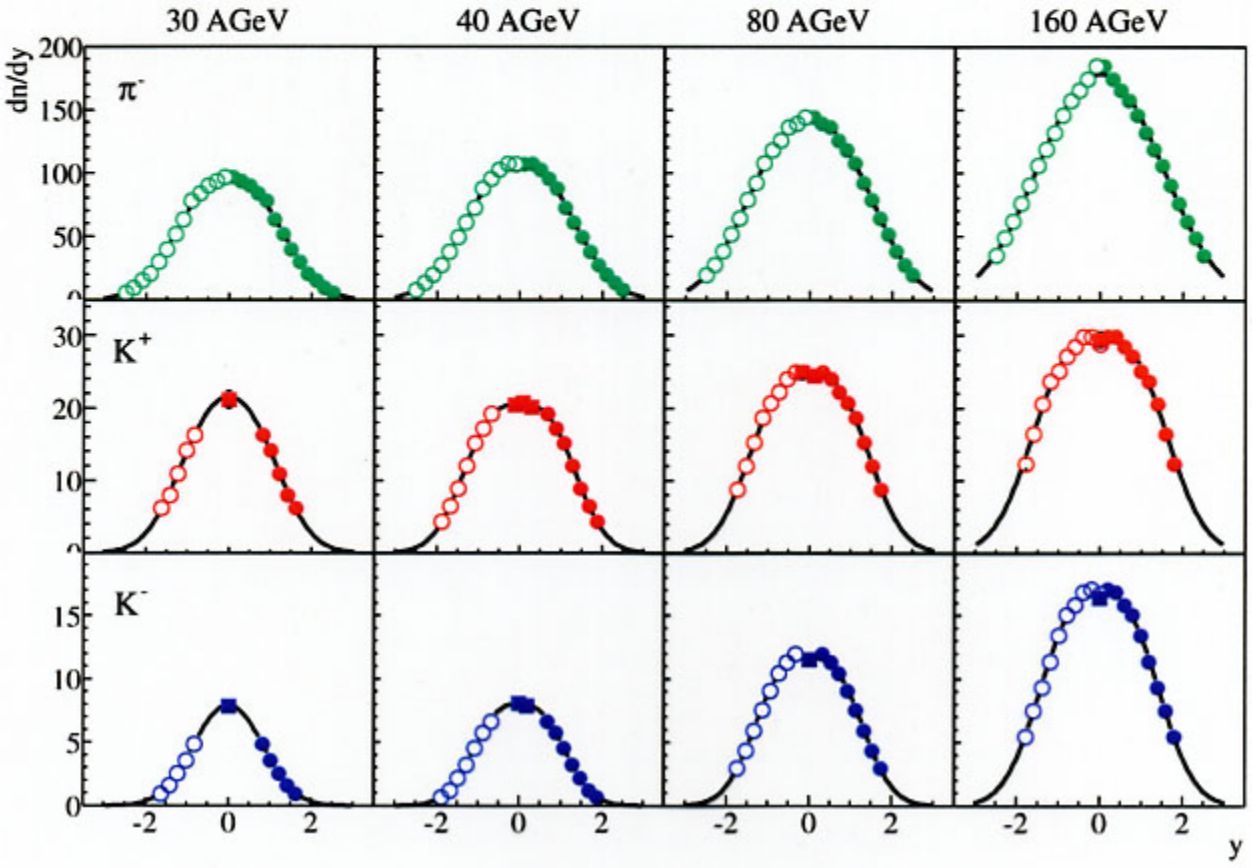
NO SIGNIFICANT VARIATION OF THERMAL FREEZE-OUT PARAMETERS AT SPS ENERGIES

RAPIDITY SPECTRA

MULTIPLICITIES

AND CHEMICAL FREEZE-OUT

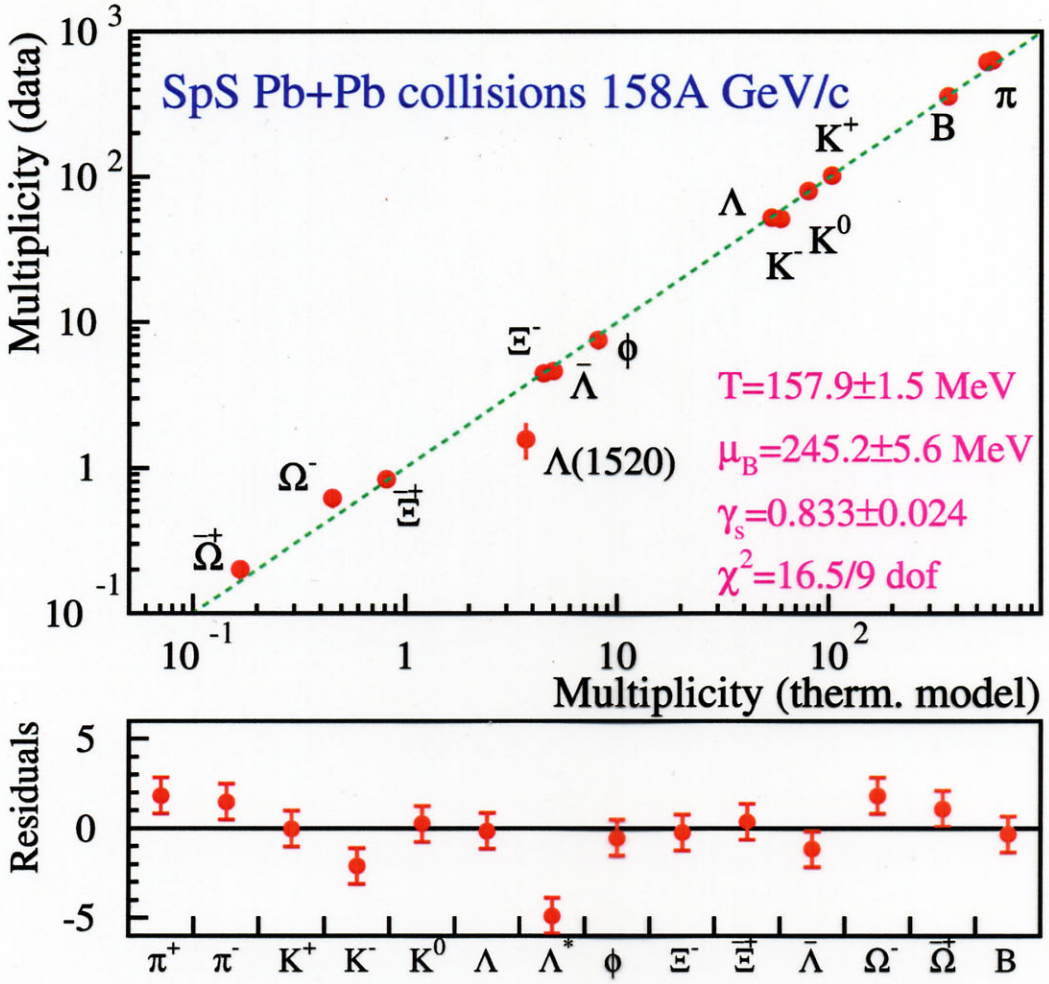
CENTRAL PB + PB AT:



FULL - MEASURED

OPEN - REFLECTED

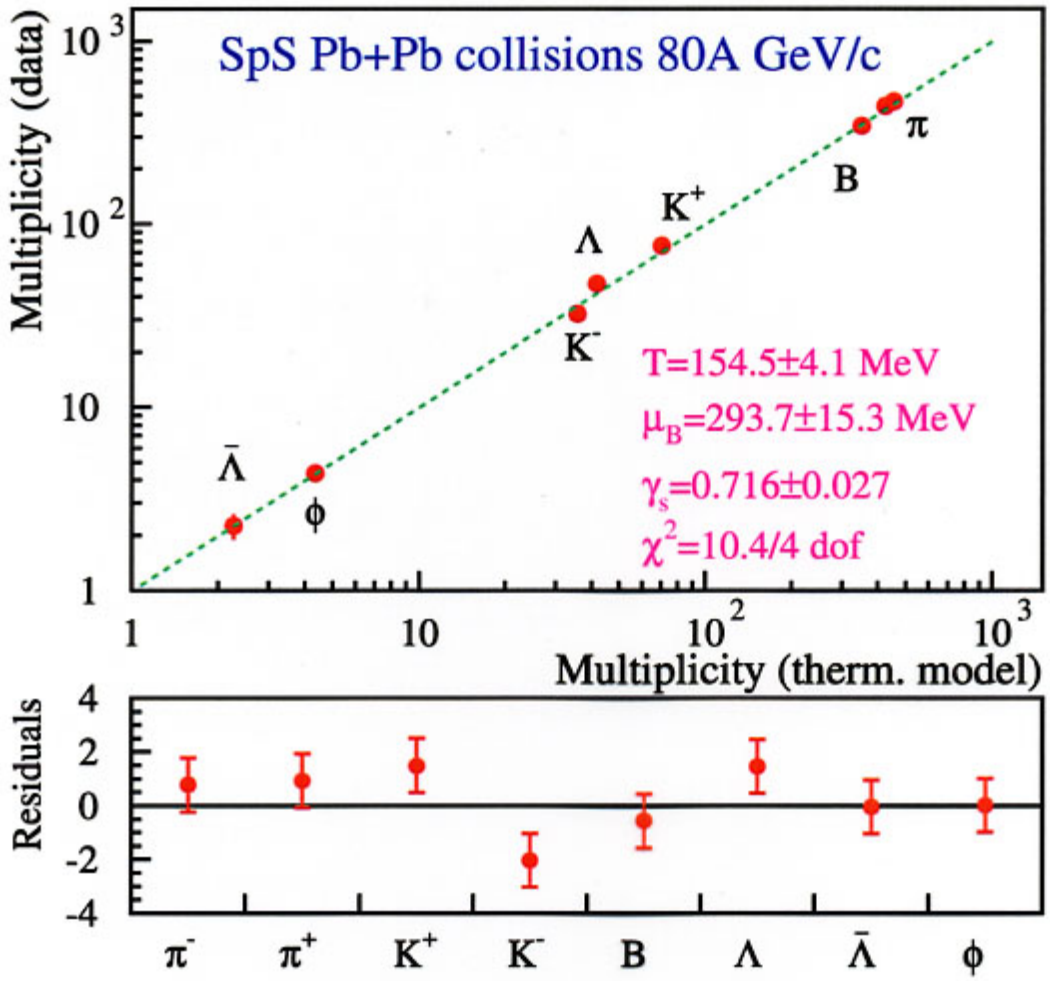
INSPIRED BY ROLF HAGEDORN IDEAS:

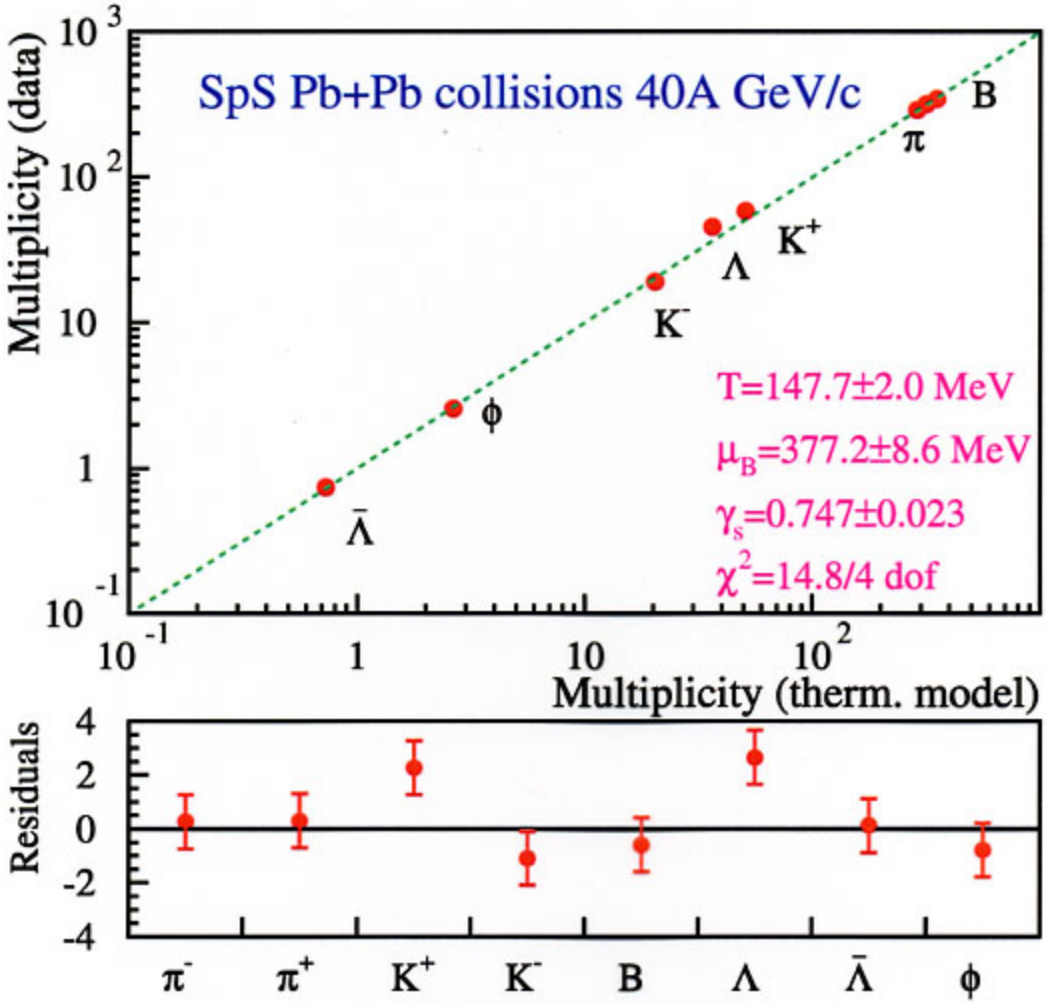


HADRON GAS MODEL WITH PARTIAL STRANGENESS SATURATION (γ_S)

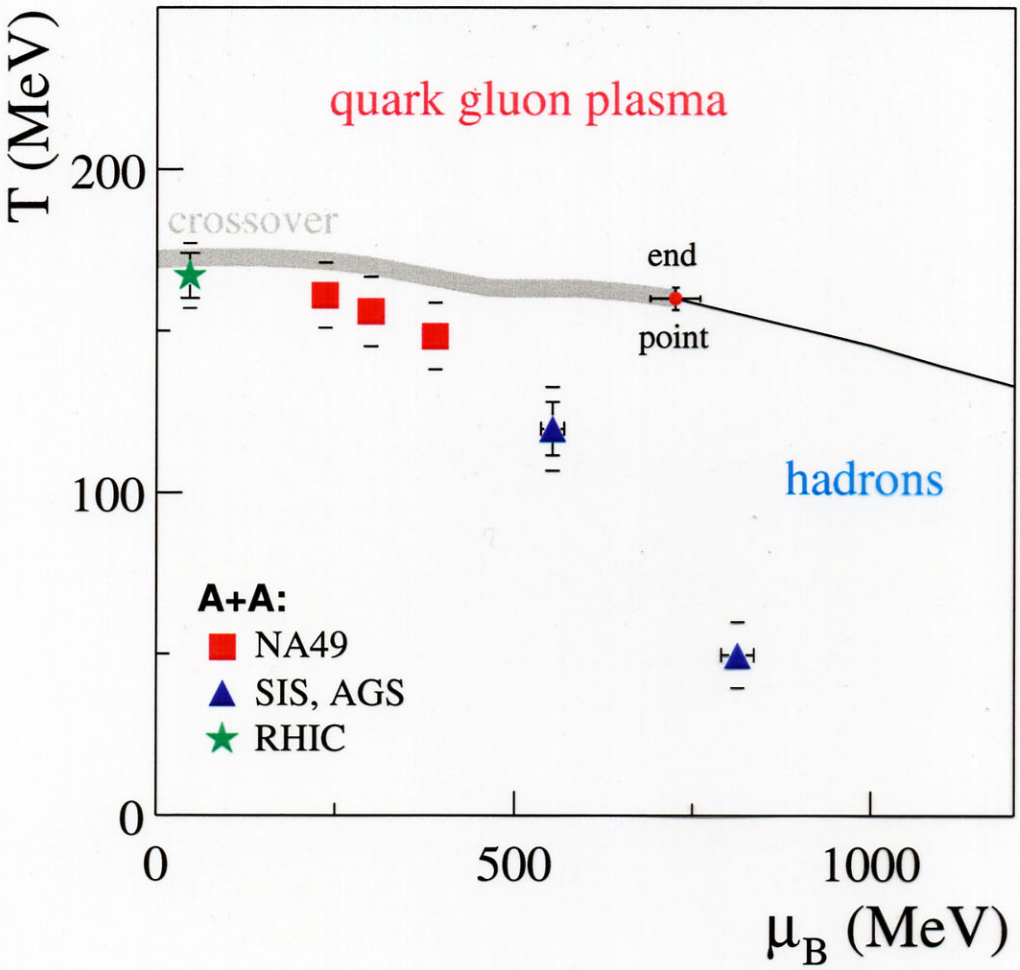
F. BECATTINI, M.G., J. SOLFFRANK, EPJ C5, 143 (98)

SIMILAR ANALYSIS BY BRAUN-MUNZINGER, STACHEL
CLEYMANS, REDLICH
YEN, GORENSTEIN


SpS Pb+Pb collisions 80A GeV/c
Multiplicity (data)
Multiplicity (therm. model)
Residuals
T=154.5±4.1 MeV
μB=293.7±15.3 MeV
γs=0.716±0.027
χ2=10.4/4 dof
π
B
K+
Λ
K-
Λ̄
φ
π-
π+
K+
K-
B
Λ
Λ̄
φ


SpS Pb+Pb collisions 40A GeV/c
Multiplicity (data)
Multiplicity (therm. model)
Residuals
T=147.7±2.0 MeV
μB=377.2±8.6 MeV
γs=0.747±0.023
χ2=14.8/4 dof
π
B
K+
Λ
K-
φ
Λ̄
π-
π+
K+
K-
B
Λ
Λ̄
φ

CHEMICAL FREEZE-OUT PARAMETERS:



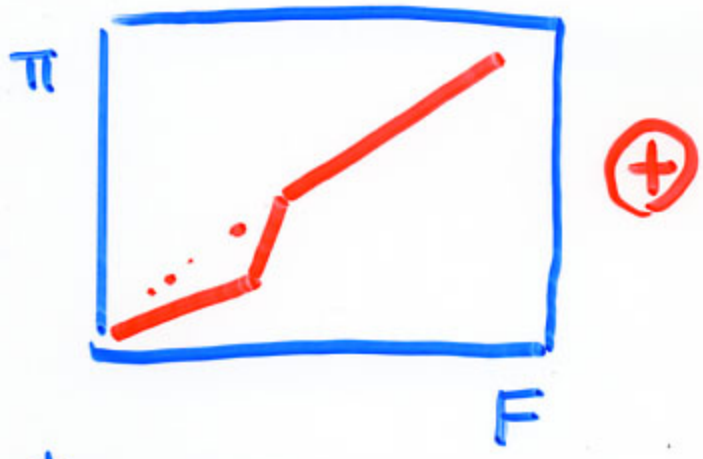
QCD CROSS-OVER CURVE:
FODOR, KATZ, hep-lat/0209029

BUT SIMILAR FITS AND CHEMICAL FREEZE-OUT PARAMETRS DESCRIBE ALSO p+p AND e^+e^- DATA (F. BECATTINI ET AL.)

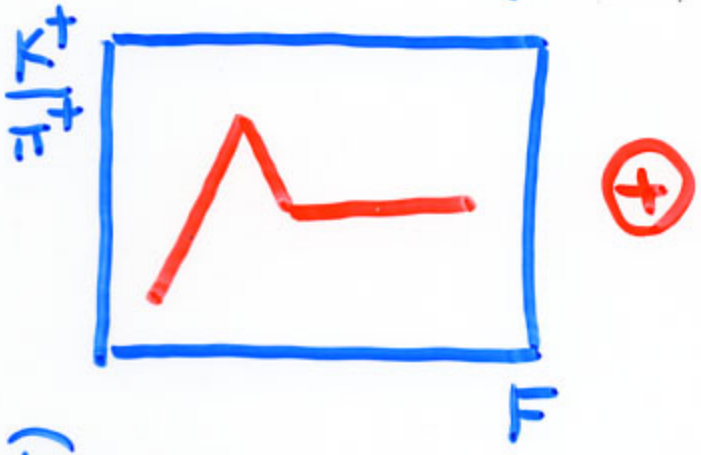
SIGNALS OF DECONFINEMENT

SIGNALS OF DECONFINEMENT

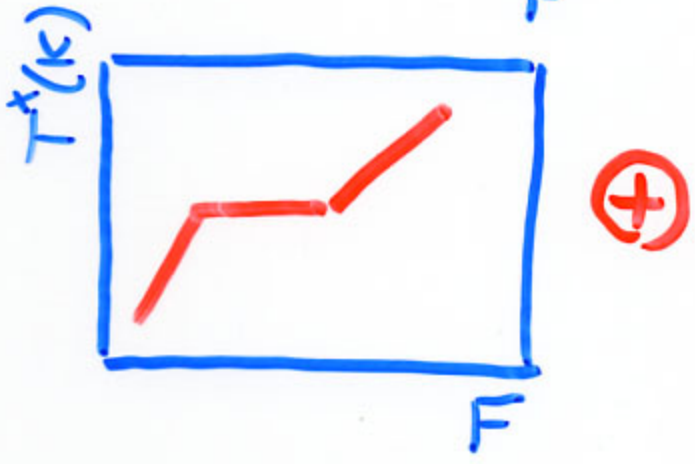
- PION ANOMALY ("THE KINK")



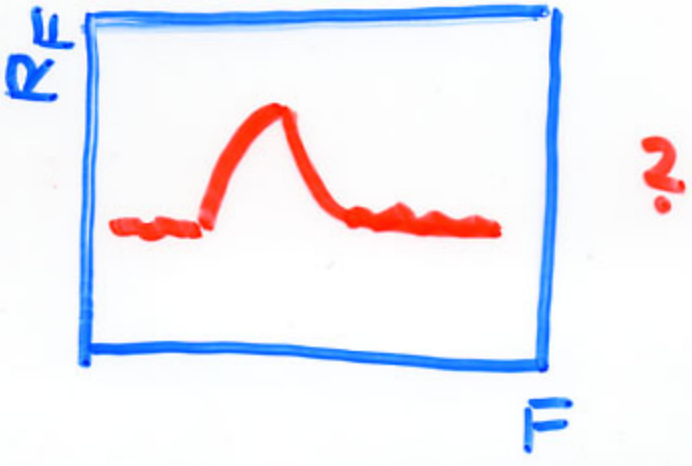
- STRANGENESS ANOMALY ("THE HORN")



- SLOPE ANOMALY ("THE STEP")



- FLUCTUATION ANOMALY ("THE SHARK FIN")



PION ANOMALY

DECONFINEMENT

↓

AN INCREASE OF ENTROPY PRODUCTION

DUE TO HIGH NUMBER OF EFFECTIVE DEGREES OF FREEDOM IN QGP, g

$\langle \pi \rangle \sim$ ENTROPY

AN INCREASE OF PION YIELD AT THE ONSET OF DECONFINEMENT

WITHIN SMES:

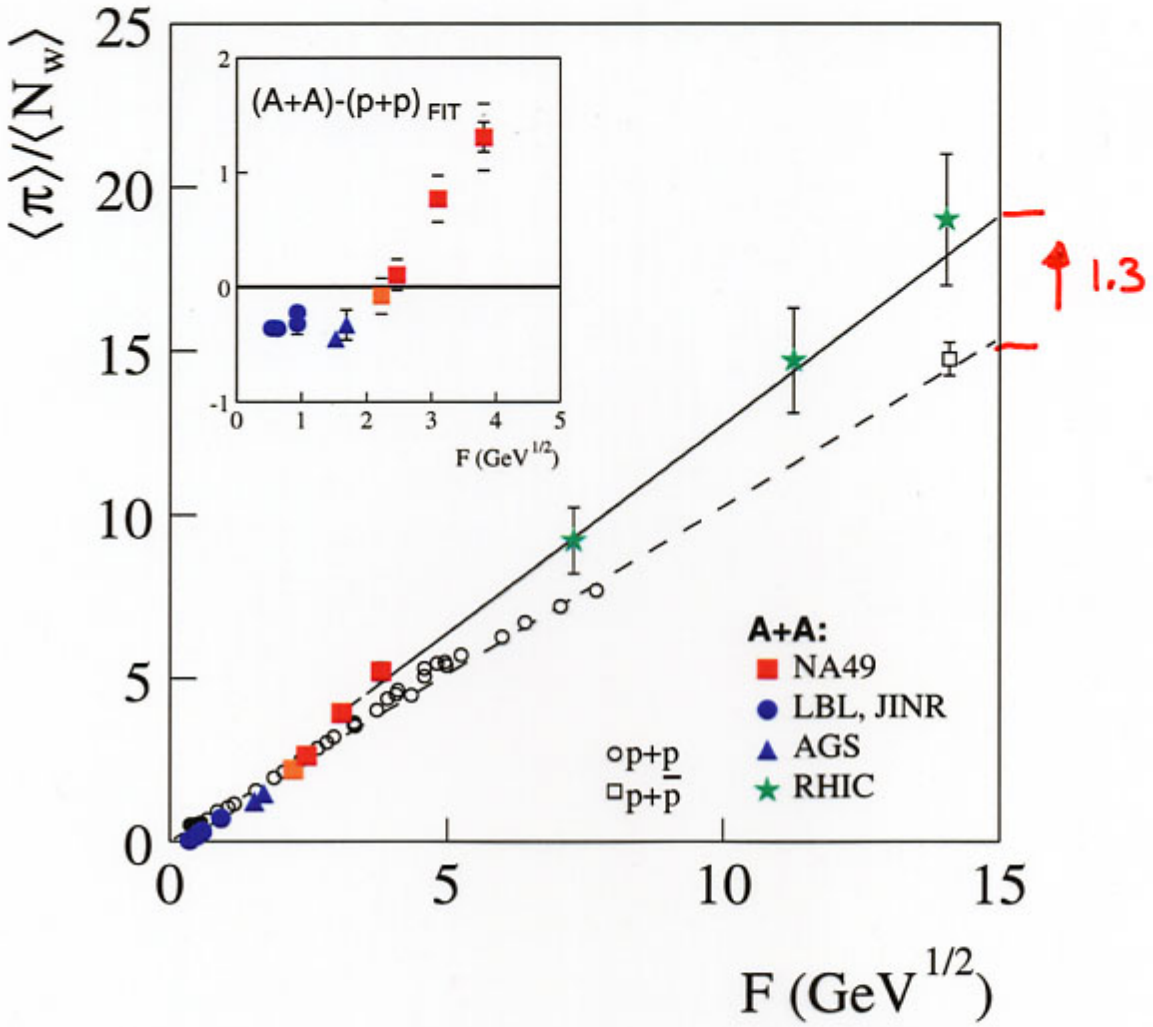
$$\langle \pi \rangle \sim g^{1/4} \cdot F + \varepsilon$$

$$F \approx \sqrt{s}$$

M. G. Z. PHYS. C66(95)659

WITHIN SMES

ONSET OF DECONFINEMENT AT ≈ 30 AGEV



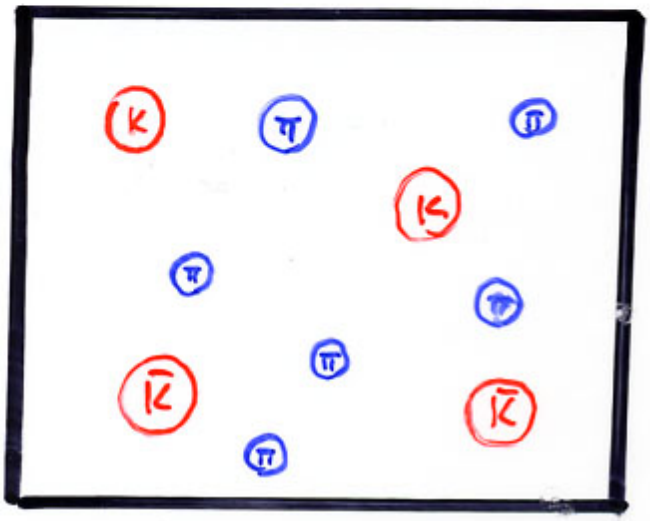
$$\frac{g_{QGP}}{g_{CONF}} \approx (1.3)^4 \approx 3$$

STRANGENESS ANOMALY

STRANGE / NON STRANGE RATIO

HADRON GAS: $(K+\bar{K})/(\pi)$

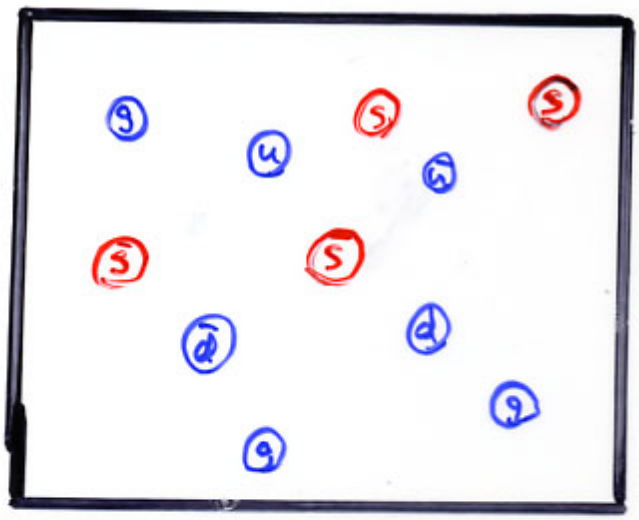
FOR $T \approx T_c$



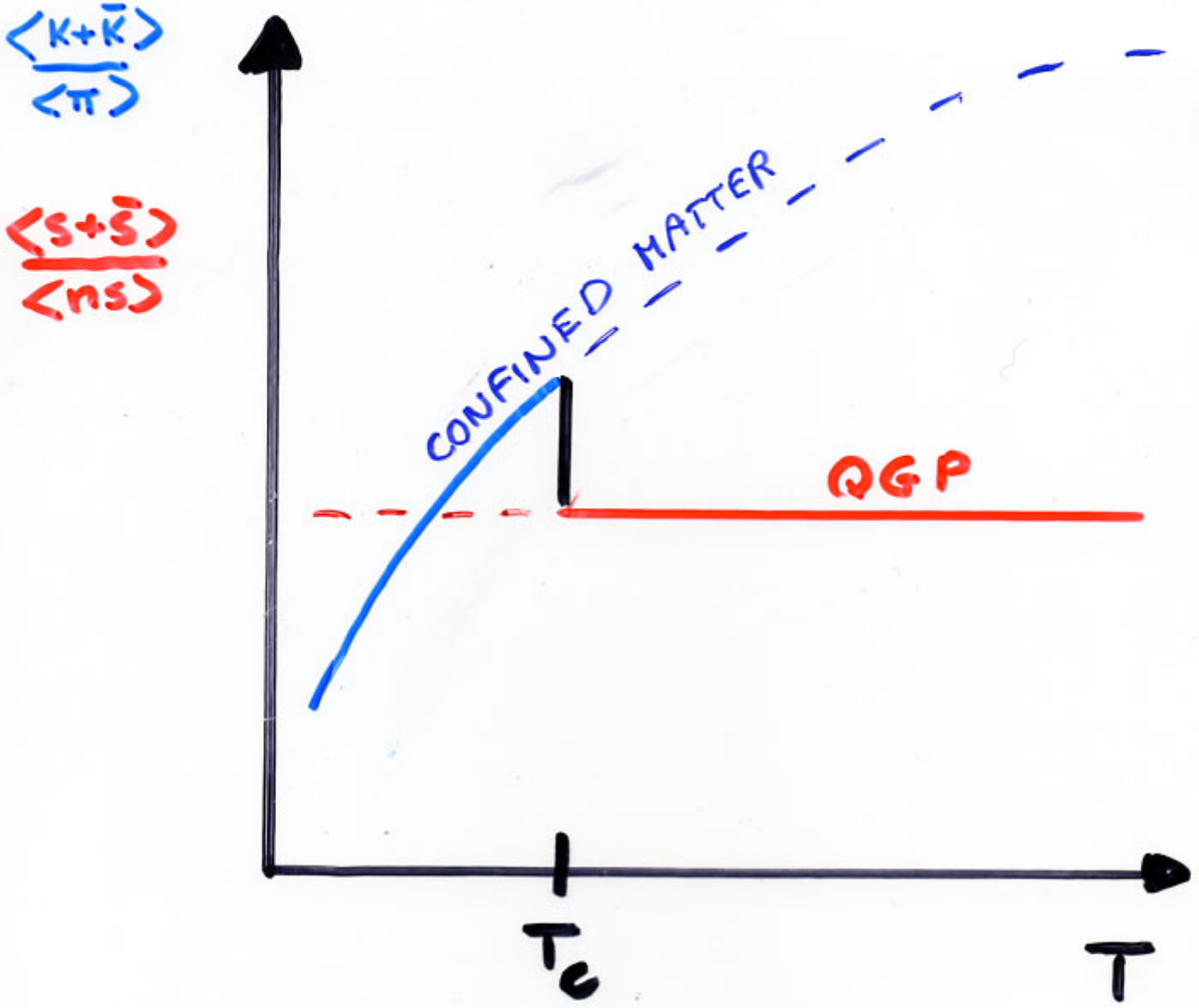
$$\frac{\langle K+\bar{K} \rangle}{\langle \pi \rangle} \sim \frac{g_K T^{3/2} e^{-m_K/T}}{g_\pi \cdot T^3}$$

QGP: $(s+\bar{s})/(g+u+\bar{u}+d+\bar{d})$

$T > T_c \quad (m_s < T)$

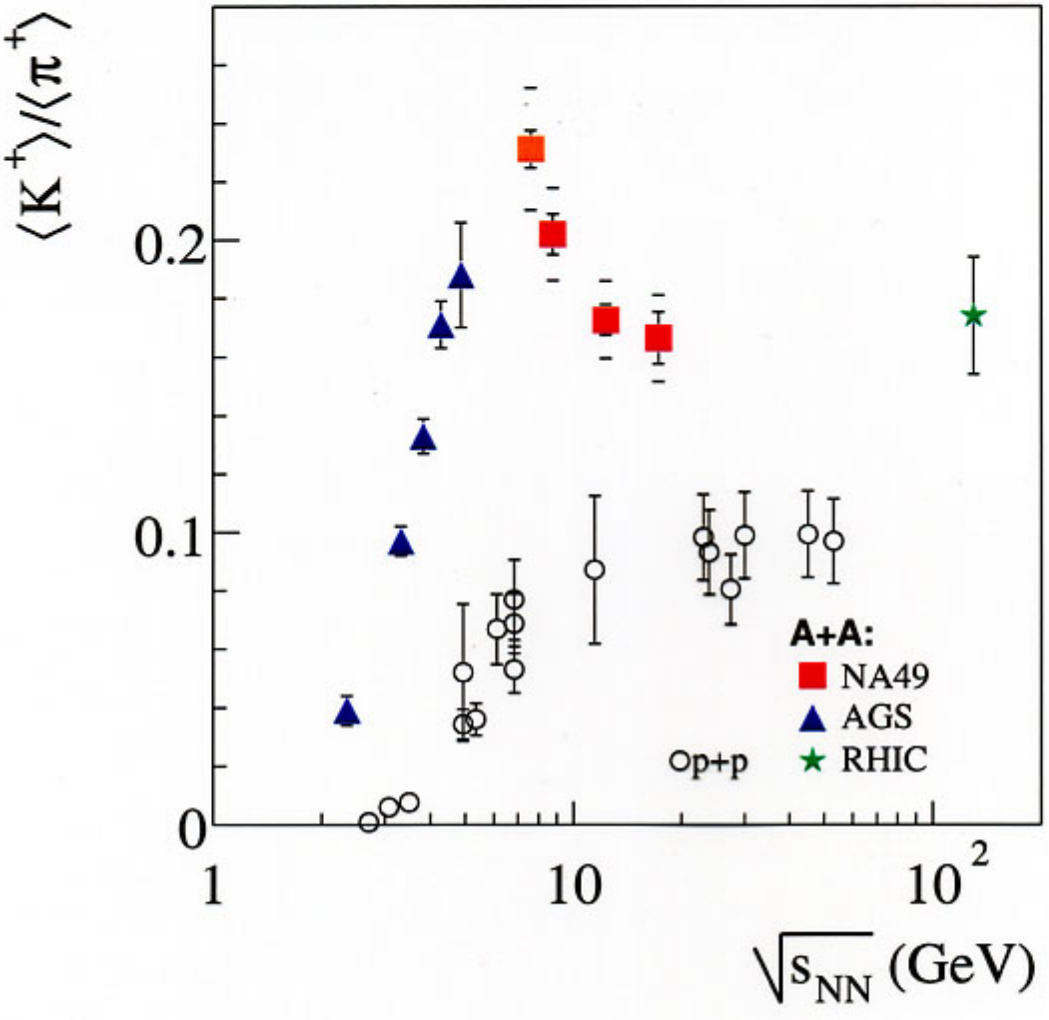


$$\frac{\langle s+\bar{s} \rangle}{\langle ns \rangle} \sim \frac{g_s T^3}{g_{ns} T^3}$$

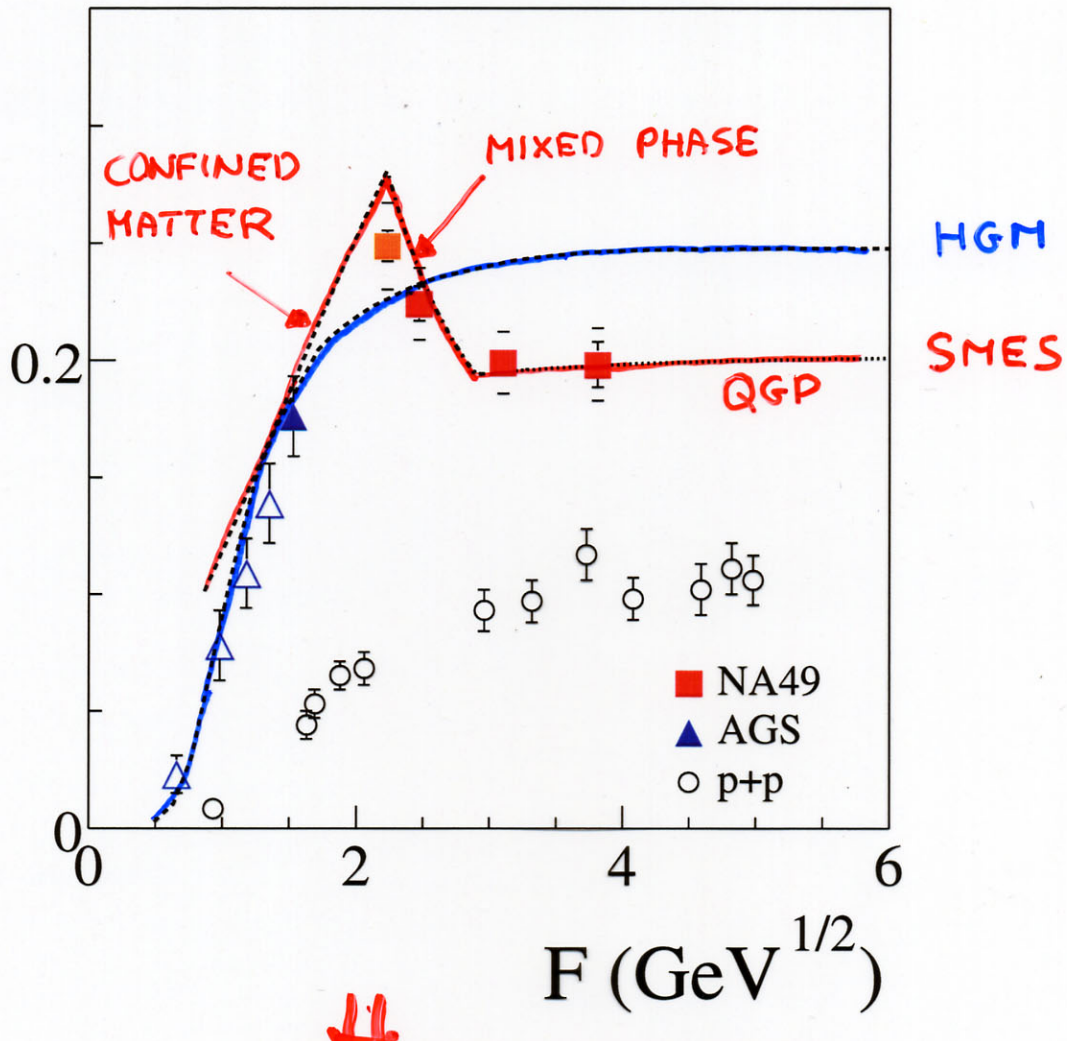


M.G., D. RÖHRICH, Z. PHYS. C71 (1996) 55

M.G., M.I. GORENSTEIN, APP B30 (1999) 2705


⟨K+⟩/⟨π+⟩
0.2
0.1
0
1
10
10 2
A+A:
NA49
AGS
p+p
RHIC
√sNN (GeV)

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



WITHIN SMES ONSET OF DECONFINEMENT AT ≈30 A·GEV

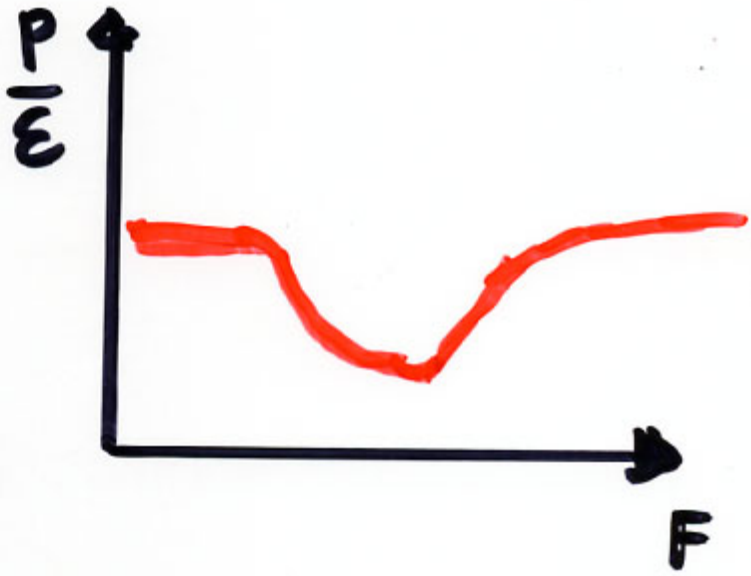
PROBLEMS OF MODELS WHICH DO NOT ASSUME PHASE TRANSITION E.G.: HADRON GAS MODEL BY CLEYMANS, REPLICH

SLOPE ANOMALY

ONSET OF DECONFINEMENT

↓

MODIFICATION OF EOS

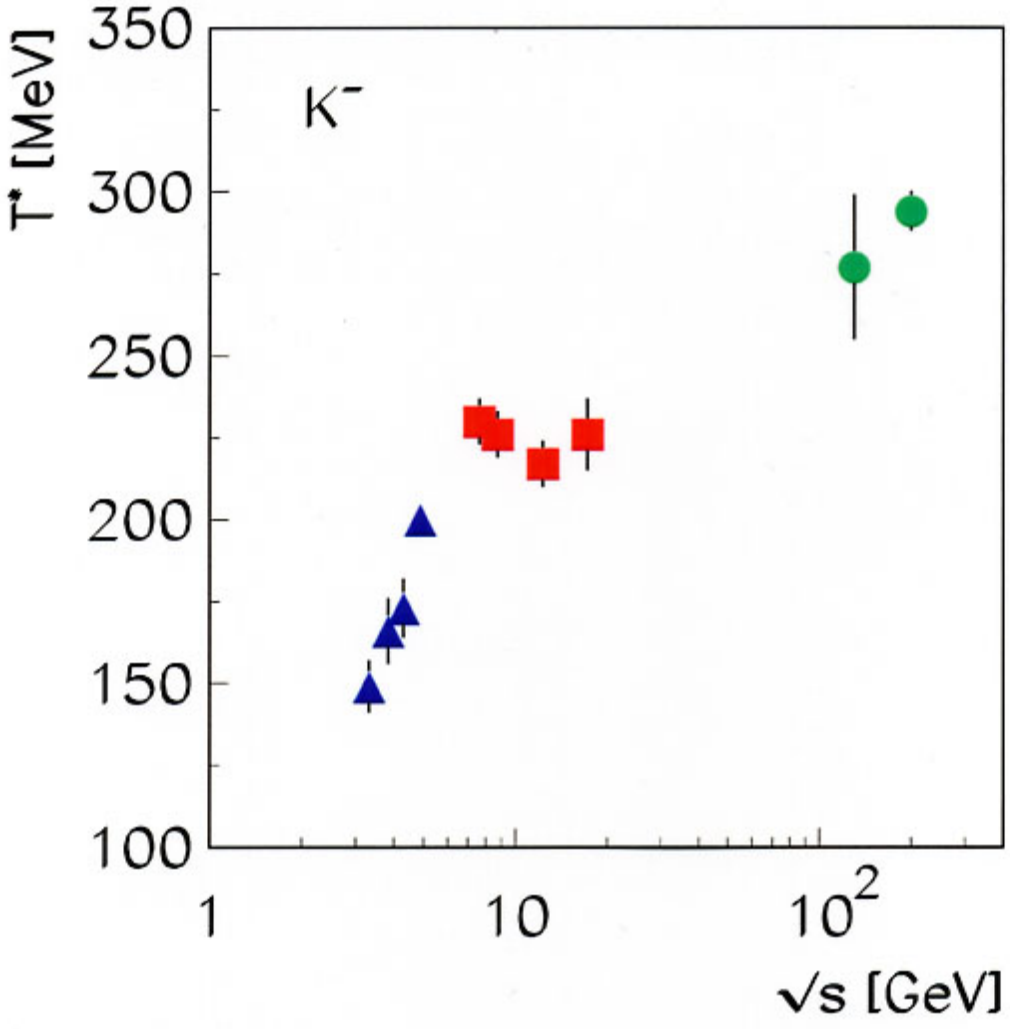


↓

ANOMALY IN TRANSVERSE EXPANSION

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

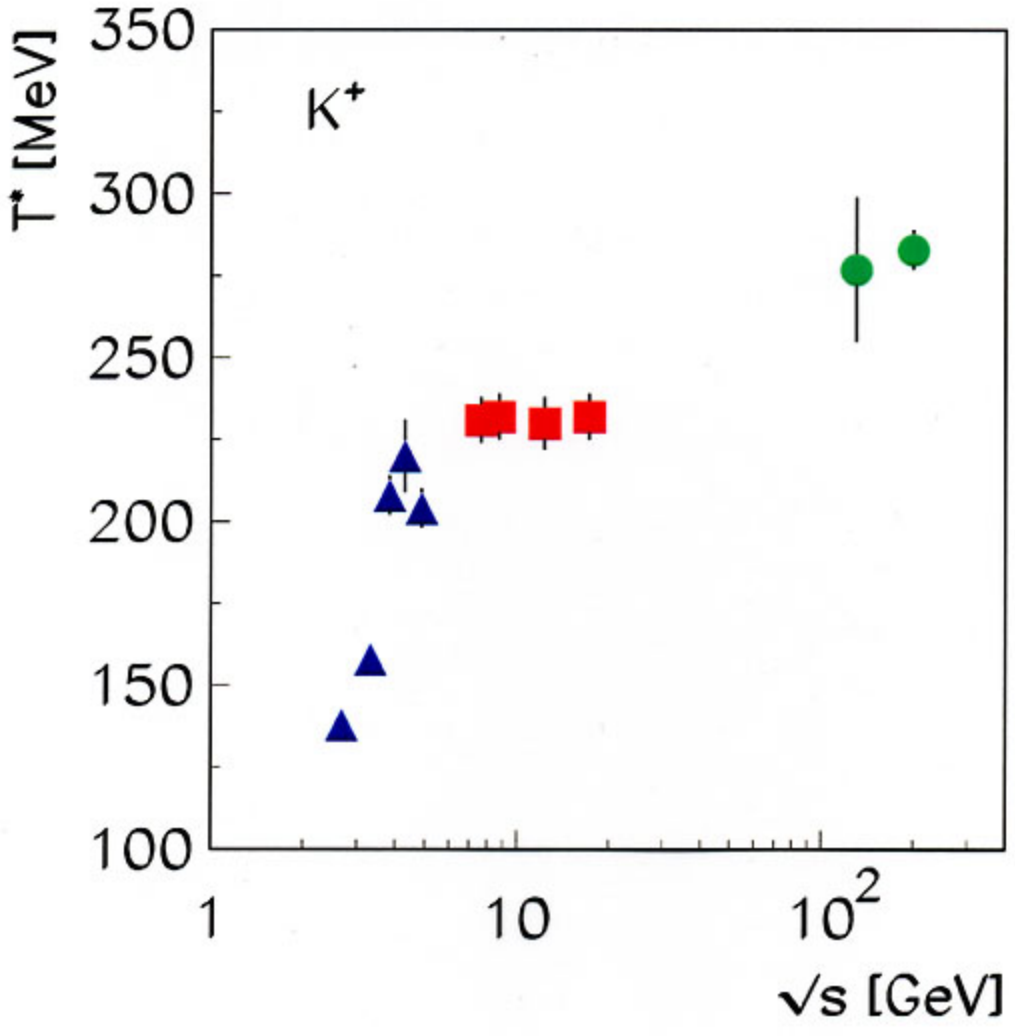
$$\frac{1}{m_T}\frac{dn}{dm_T}\Big|_{y\approx 0} \sim e^{-m_T/T^*}$$



WITHIN SMES

ONSET OF DECONFINEMENT AT ≈ 30 A GEV

GORENSTEIN, M.G., BUGAEV,
hep-ph/0303041


T* [MeV]
350
300
250
200
150
100
K+
1
10
10^2
√s [GeV]

CONCLUSIONS / FUTURE

ENERGY SCAN PROGRAM AT SPS

OBSERVATION OF ANOMALIES IN ENERGY DEPENDENCE OF HADRON PRODUCTION (PIONS, STRANGENESS, SLOPES, ... ?)

SUGGESTS DECONFINEMENT PHASE TRANSITION IN A+A COLLISIONS AT LOW SPS ENERGIES

FUTURE

- FINISH ANALYSIS OF ALREADY TAKEN DATA (NEXT SEVERAL YEARS)

- POSSIBLE A NEW PROGRAM AT CERN SPS

  ENERGY SCAN PROGRAM WITH LIGHT IONS AT CERN SPS

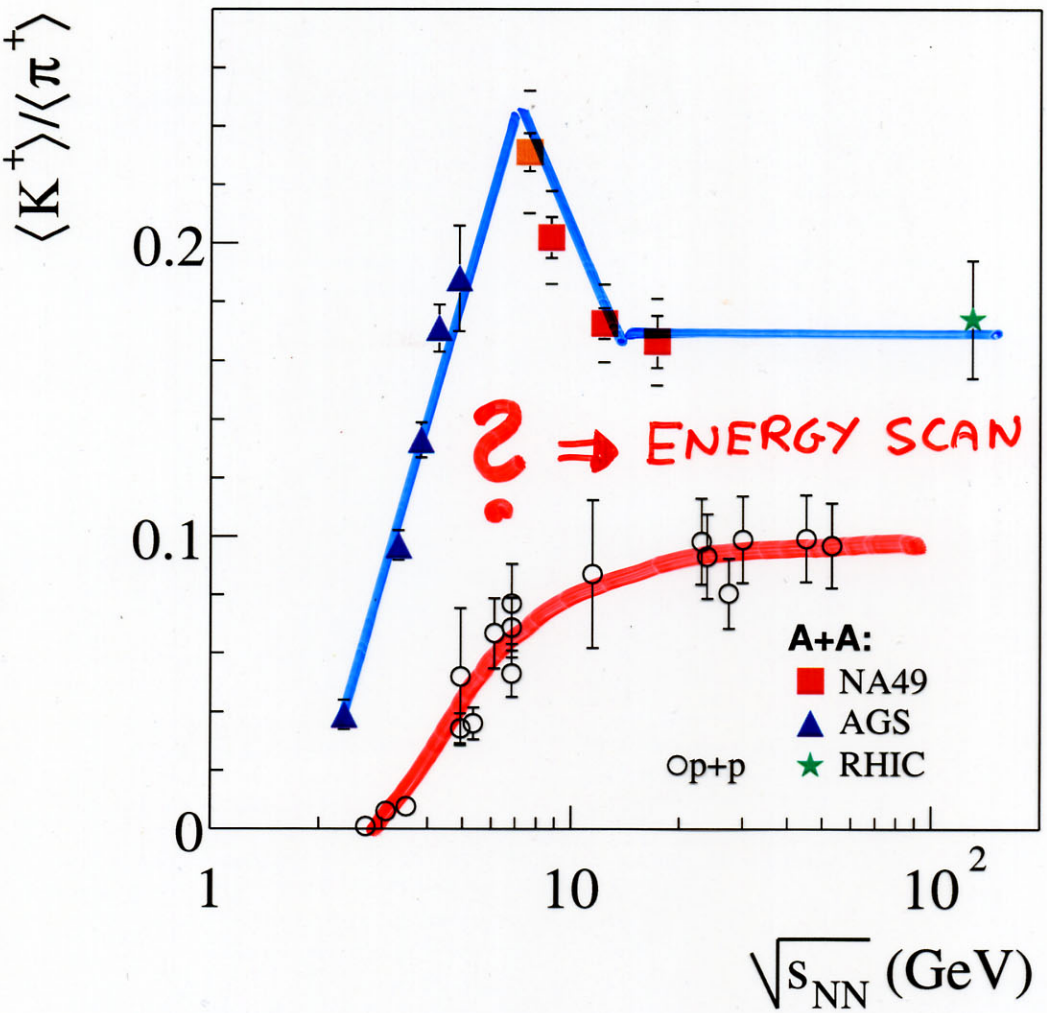
  $E \geq 10 - 200$ A·GEV

  A = p, C, Si, Ca, ...

  (2006 ↗)

- CONTINUE STUDY AT SIS200 (LOW CROSS SECTION OBSERVABLES)

- POSSIBLE HELP/COMPETITION AT RHIC



⇒ ENERGY SCAN PROGRAM WITH LIGHT IONS

⇓

STUDY ONSET OF DECONFINEMENT AS A FUNCTION OF SYSTEM SIZE