ENERGY SCAN PROGRAM AT CERN SPS

M. GAŹDZICKI IKF FRANKFURT
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- A BRIEF HISTORY
- SIGNALS OF DECONFINEMENT
- OTHER RESULTS
- A NEW IDEA
- CONCLUSIONS AND FUTURE

- **A BRIEF HISTORY OF**
  - IDEAS
  - EXPERIMENTS

– A BRIEF HISTORY OF IDEAS

THE BEGINING: 1994

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IKF-HENPG/3-94

Pion Multiplicity in Nuclear Collisions – A Compilation

Marek Gaździcki[1] and Dieter Röhrich[2]

Abstract

Data on the mean multiplicity of π^--mesons produced in minimum bias proton-proton, proton-neutron and proton-nucleus interactions as well as central nucleus-nucleus collisions at momenta of 1.4–400 GeV/c per nucleon have been compiled and studied. The results for neutron-neutron and nucleon-nucleon interactions were then constructed. The dependence of the mean pion multiplicity in proton-nucleus collisions on the target nucleus mass number A is weak at incident proton momenta below 10 GeV/c. The mean pion multiplicity increases approximately proportionaly to $A^{1/3}$ at incident proton momenta larger than ~100 GeV/c. The dependence of the normalized mean pion multiplicity on the incident proton momentum is shown for proton interactions with light and heavy nuclei. The multiplicity of pions produced in central collisions of identical nuclei with $A \gtrsim 10$ is studied as a function of the nucleus mass number and the collision energy. The number of produced pions per participant nucleon in central collisions of identical nuclei is found to be independent of the number of participants at a fixed incident momentum per nucleon. The mean multiplicity of negatively charged hadrons per participant nucleon for central nucleus-nucleus collisions is lower by about 0.12 than the corresponding multiplicity for nucleon-nucleon interactions at $p_{LAB} \lesssim 15$ A·GeV/c. The normalized mean multiplicity per participant nucleon increases rapidly with the incident momentum per nucleon at low momenta ($p_{LAB} \lesssim 15$ A·GeV/c). This increase is significantly weaker at high momenta.

Z. PHYS. C65, 215 (1995)

September 22, 1994

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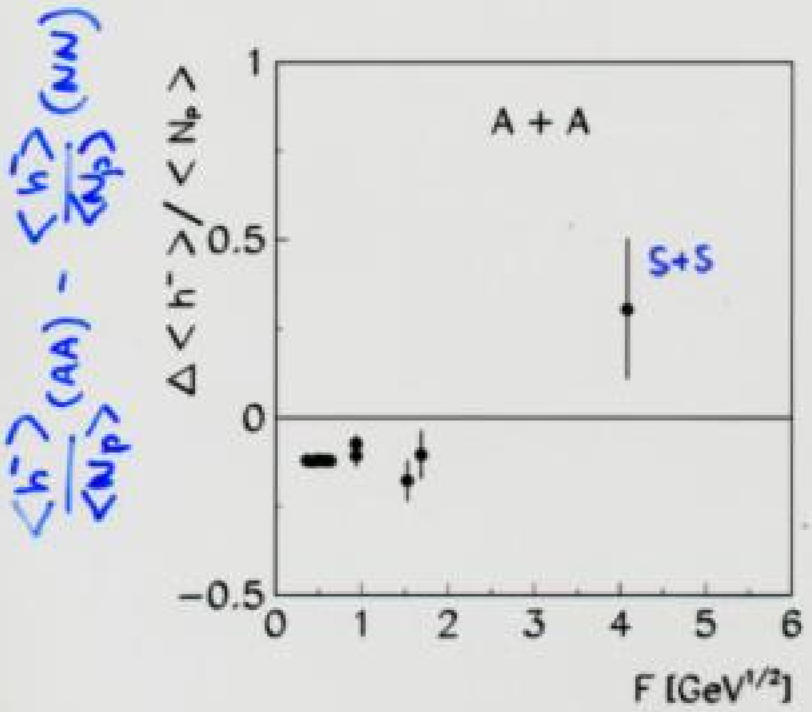
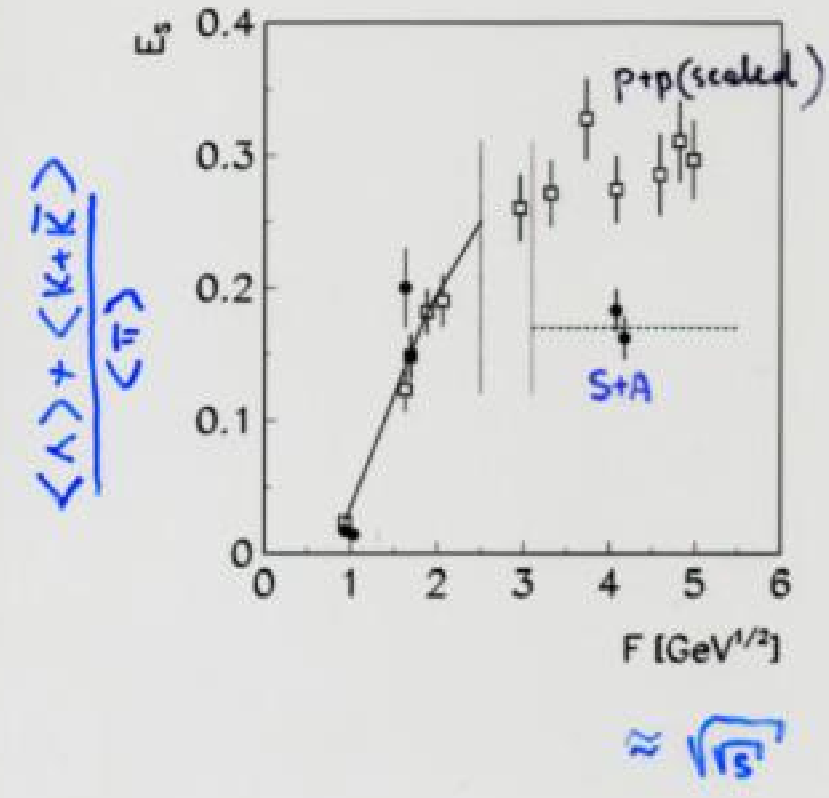
1994-1996: FIRST INDICATIONS OF THE ANOMALOUS ENERGY DEPENDENCE OF



PIONS

(Z.P. C65 (95) 215)



STRANGENESS

(Z.P. C71 (96) 55)

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

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

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> START ENERGY SCAN PROGRAM AT CERN SPS

– 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

SPOKESPERSON: PETER SEYBOTH

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 (≈ 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 GEV RUN IN 2002

[redacted]

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 OF 20 A GEV (NA49, NA60)

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

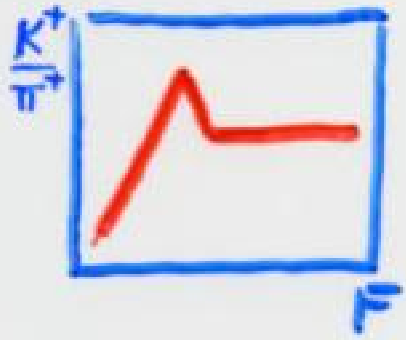
+ NEW RHIC DATA

+ AGS DATA

●● SIGNALS OF DECONFINEMENT

- PION ANOMALY ("THE KINK")

- STRANGENESS ANOMALY ("THE HORN")



- SLOPE ANOMALY ("THE STEP")

– PION ANOMALY

DECONFINEMENT

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AN INCREASE OF ENTROPY PRODUCTION

$\langle \pi \rangle \sim$ ENTROPY

AN INCREASE OF PION YIELD AT THE ONSET OF DECONFINEMENT

WITHIN SMES:

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

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

WITHIN SMES

ONSET OF DECONFINEMENT AT ≈ 30 A·GEV

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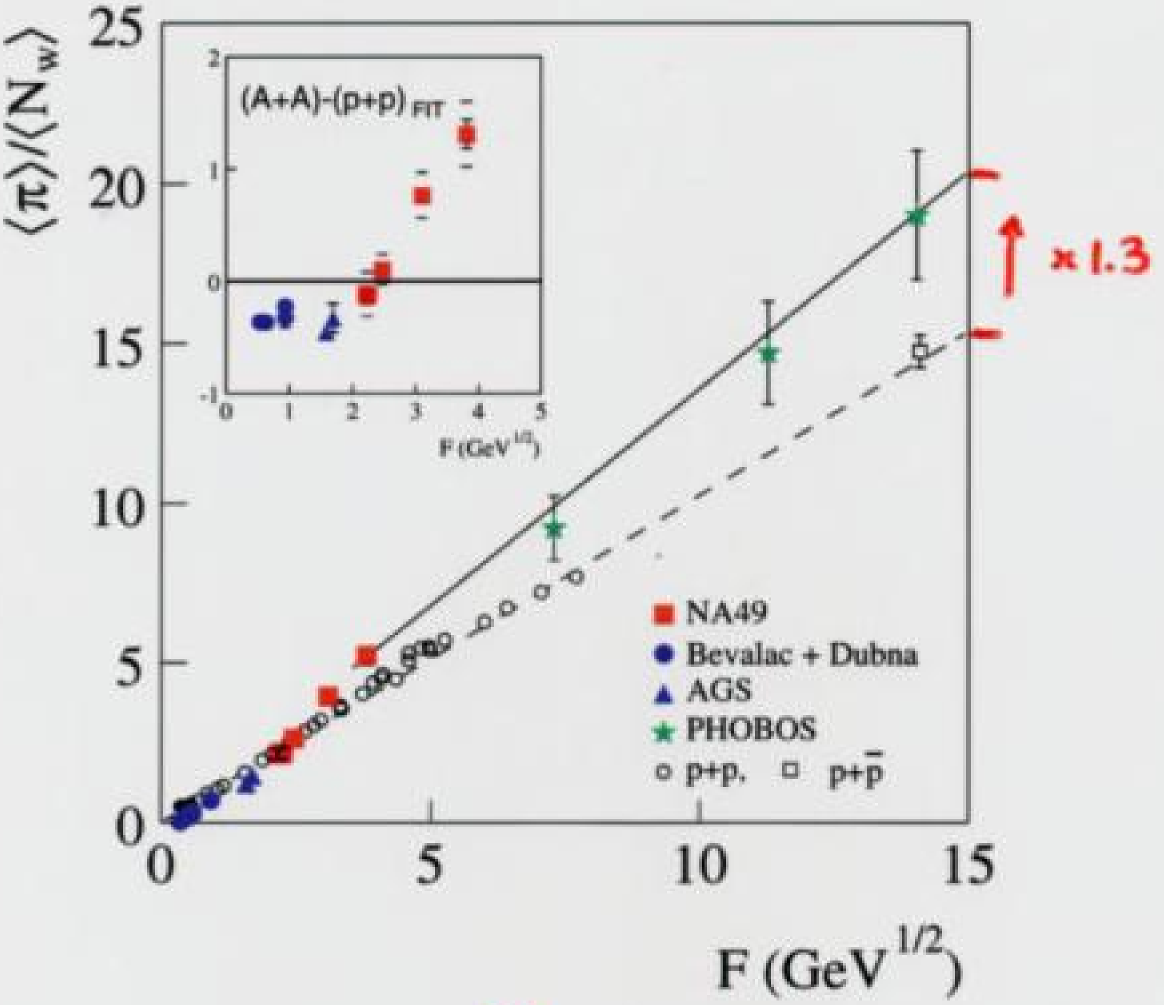

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$$\frac{g_{QGP}}{g_{CONF}} \approx (1.3)^4 \approx 3$$

STRANGE / NON STRANGE RATIO

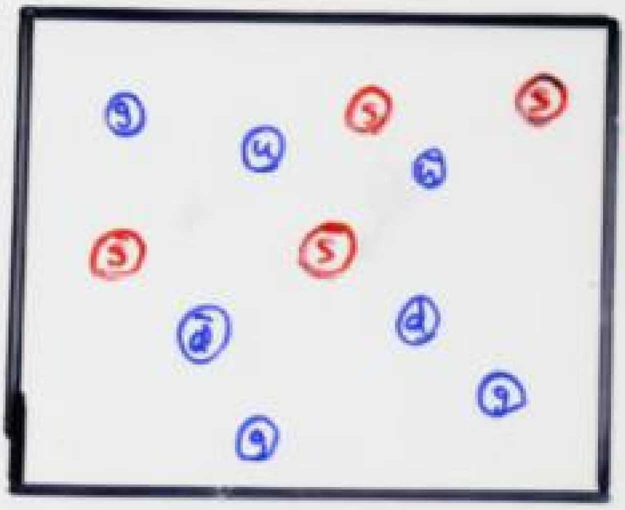
HADRON GAS: $(K+\bar{K})/(\pi)$

FOR $T \approx T_c$

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

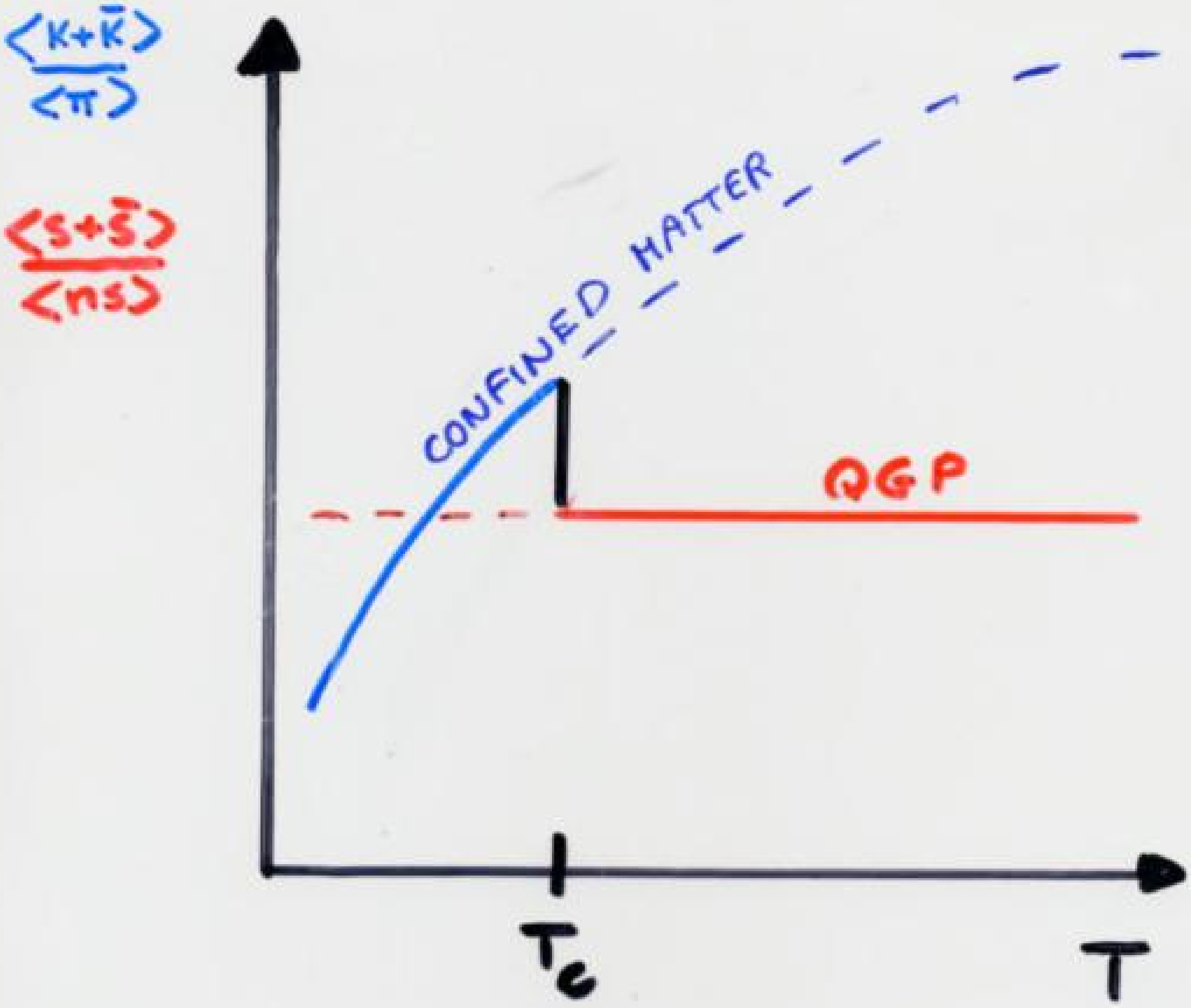
QGP: $(s+\bar{s})/(g+u+\bar{u}+d+\bar{d})$

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

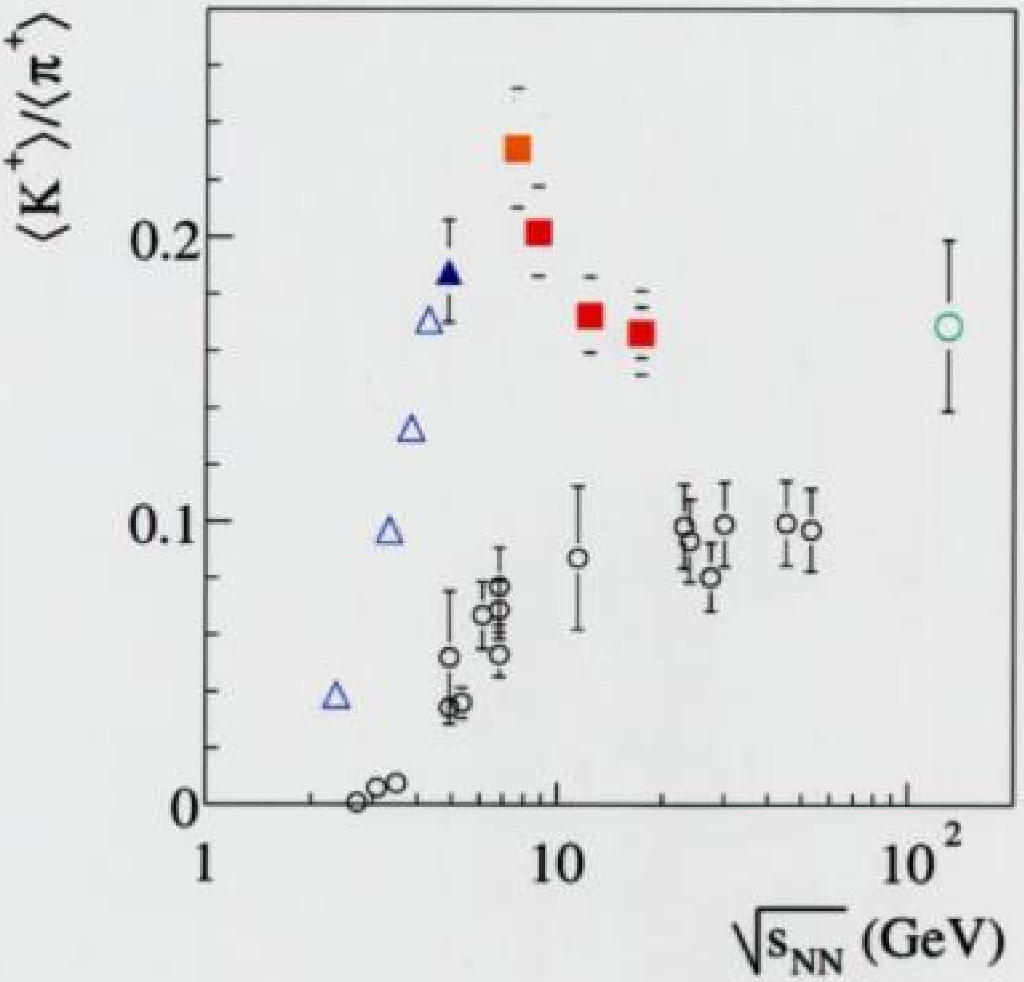


$$\frac{\langle s+\bar{s}\rangle}{\langle ns \rangle} \sim \frac{g_s\, T^3}{g_{ns}\, T^3}$$

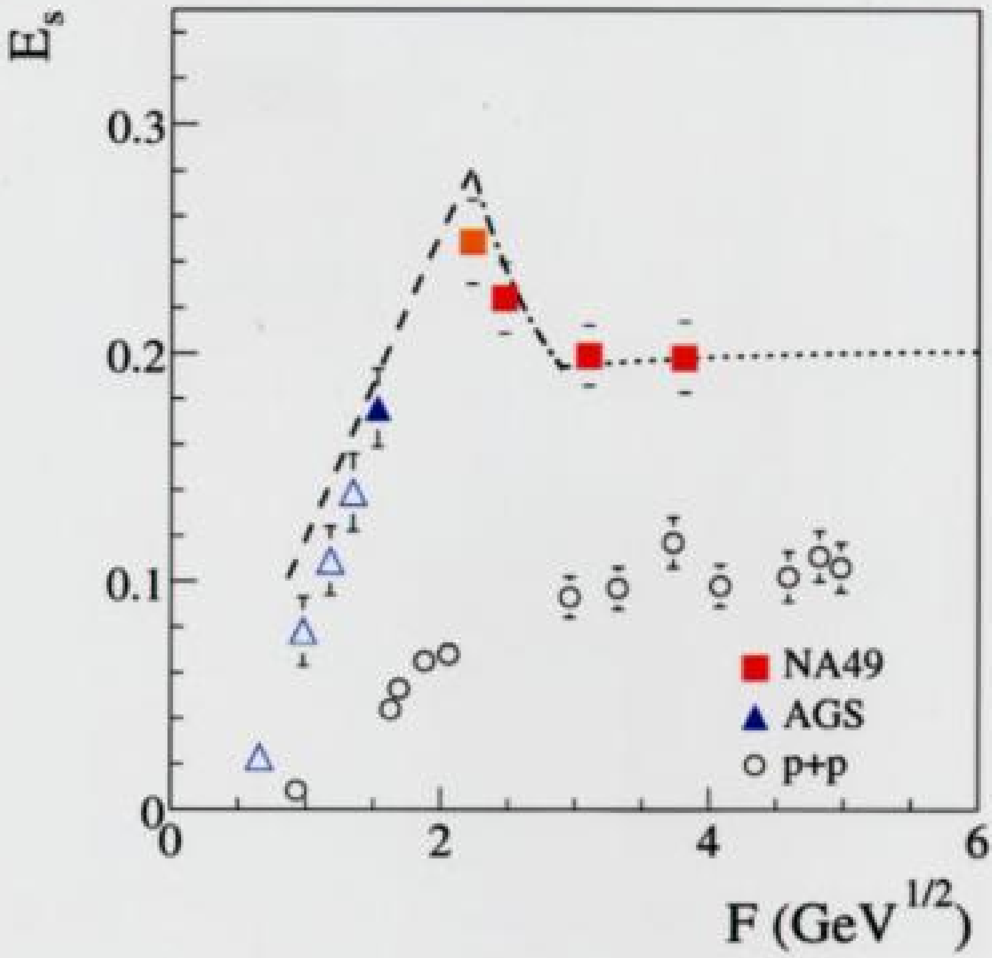
- STRANGENESS ANOMALY



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



⟨K+⟩/⟨π+⟩
0.2
0.1
0
1
10
10^2
√s_NN (GeV)



WITHIN SMES

ONSET OF DECONFINEMENT AT ≈ 30 A·GEV

– SLOPE ANOMALY

ONSET OF DECONFINEMENT

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MODIFICATION OF EOS

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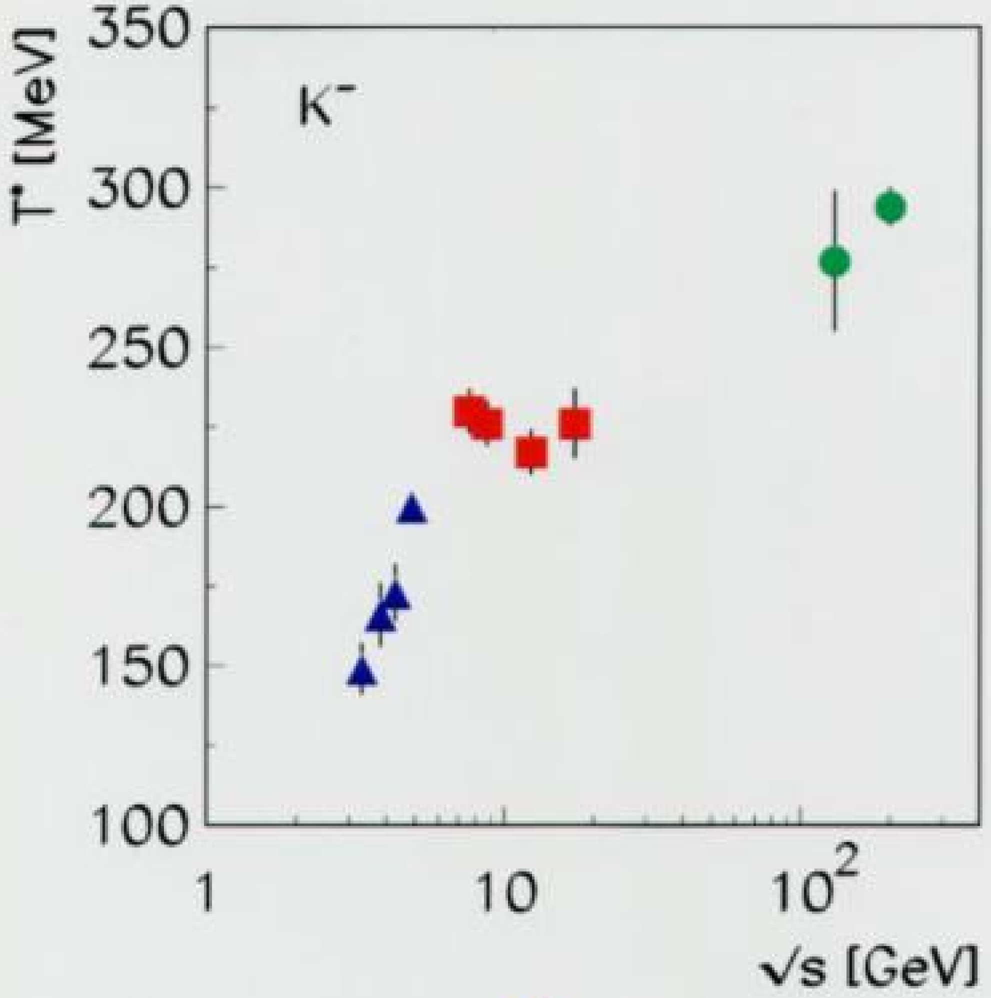
ANOMALY IN TRANSVERSE EXPANSION

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

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



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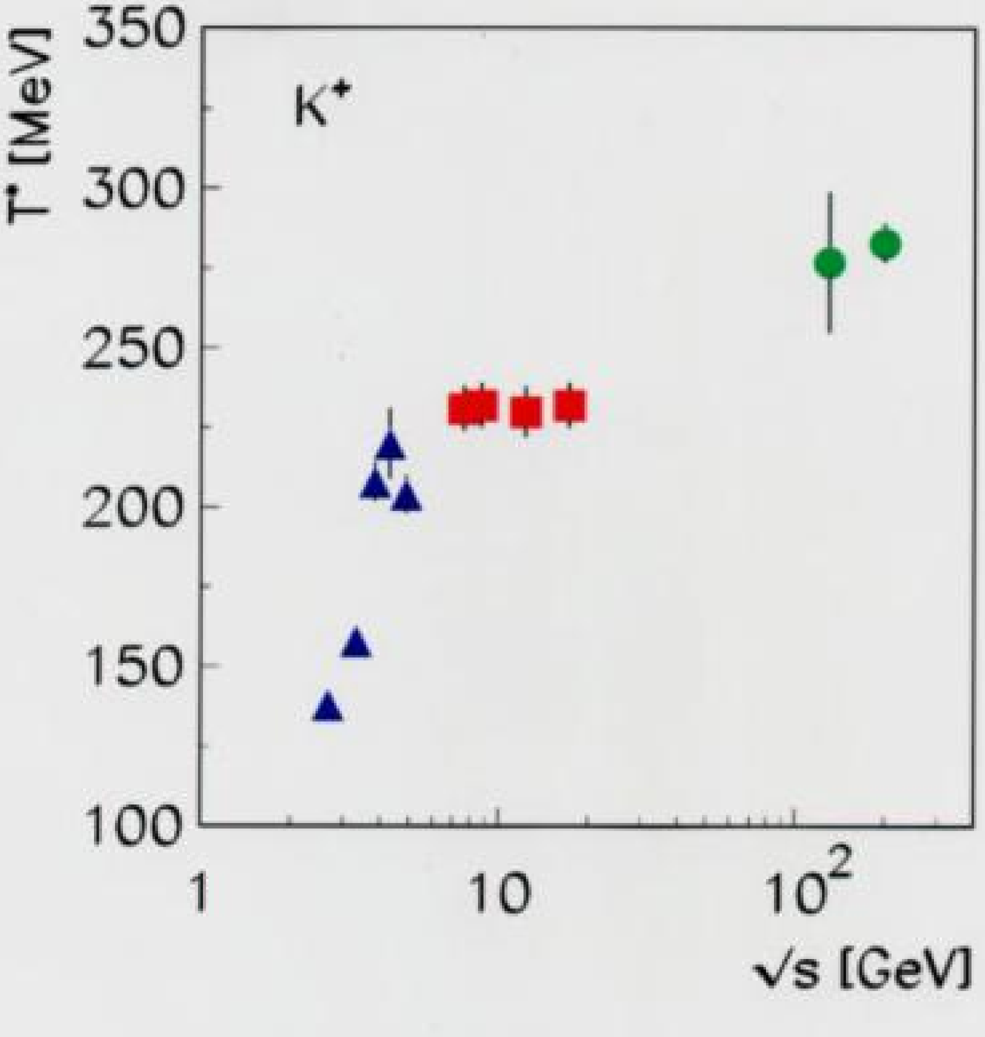
WITHIN SMES

ONSET OF DECONFINEMENT AT ≈ 30 A GEV

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



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

A NEW IDEA

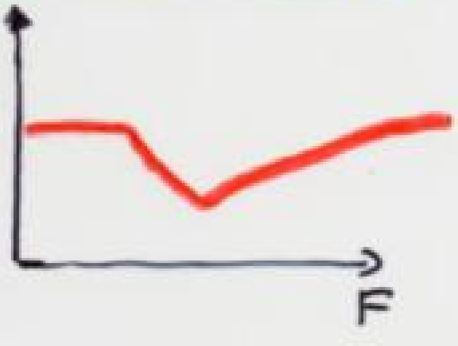
EVENT-BY-EVENT FLUCTUATIONS WITHIN SMES

BASIC THERMODYNAMICS:

$$\frac{\text{ENTROPY FLUCT.}}{\text{ENERGY FLUCT.}} = f(\text{EOS})$$

$$\frac{(\delta S)^2/S^2}{(\delta E)^2/E^2} = \left(1 + \frac{p}{\varepsilon}\right)^{-2}$$

BUT IN TRANSITION REGION:



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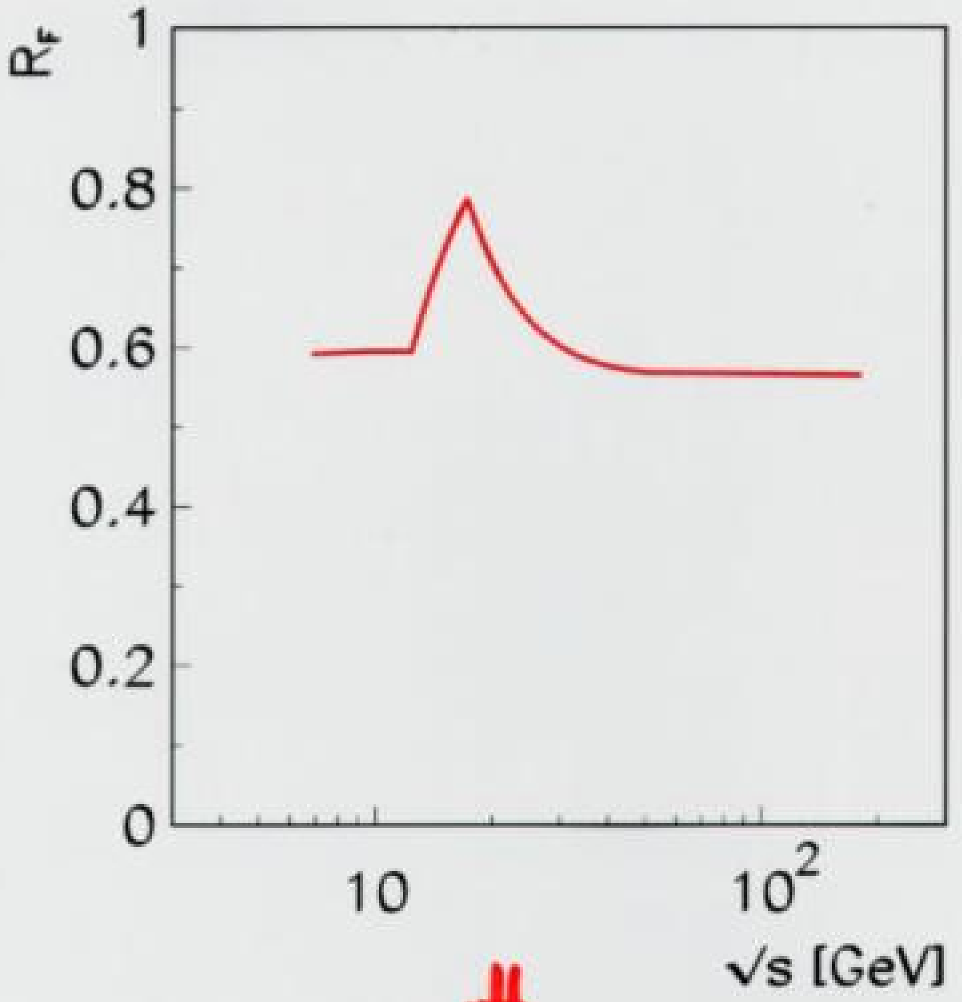
ANOMALY IN ENTROPY (MULTIPLICITY) FLUCTUATIONS

M.G., GORENSTEIN, MROWCZYNSKI
in preparation

$$R_F \equiv \frac{(\delta S)^2/S^2}{(\delta E)^2/E^2}$$



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WITIN SHES ONE EXPECTS A MAXIMUM IN PROPERLY FILTERED MULTIPLICITY FLUCTUATIONS WHEN CROSSING TRANSITION REGION

GGM in preparation

CONCLUSIONS / FUTURE

ENERGY SCAN PROGRAM AT SPS

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NUMEROUS STRIKING EVIDENCES
(PION, STRANGENESS, SLOPE ANOMALIES)
OF THE ONSET OF DECONFINEMENT
IN A+A COLLISIONS
AT ≈ 30 A·GEV

FUTURE

FIRST GET 2.0 A·GEV POINT