Фізика високих густин енергії.
Початок: 1970-1985

High Energy Density Physics = Elementary particles + Statistical Mechanics

1970-1974: Statistical Approach to Dual Resonance model

1974-1983: Proton-Nucleus collisions
Phase Transitions: Fireballs → Quark-Gluon Plasma

1983-1985: High Energy Density Physics

1970-1974

Statistical-theory view on the dual-resonance model,
M.I. Gorenstein, V.I. Makarov, V.A. Miransky, V.P. Shelest, and
G.M. Zinovjev, Lett. Nuovo Cim. **3**, 347 (1972);

Statistical Approach, to the Calculation of Resonant Width and
Multiplicity in Dual Models, M. I. Gorenshtein, G. M. Zinov'ev,
V. I. Makarov, V. A. Miranskii, V. P. Shelest, JETP Letters 15, 686 1972;

A fresh look at the **statistical** bootstrap model,
M.I. Gorenstein, V.A. Miransky, V.P. Shelest, and G.M. Zinovjev,
Phys. Lett. B 45, 475 (1973);

Dynamical **averages** in the dual-resonance model,
M.I. Gorenstein, V.A. Miransky, V.P. Shelest, B.V. Struminsky, and G.M. Zinovjev,
Lett. Nuovo Cim. **6,** 325 (1973);

Statistical Bootstrap and the Pomeranchuk Model for Multiple Hadron Production,
M. I. Gorenshtein, G. M. Zinov'ev, V. A. Miranskii, V. P. Shelest,
JETP Letters **17**, 673 (1973);

Statistical And Dynamical Features Of Dual Resonances,
M.I. Gorenstein, V.A. Miransky, B.V. Struminsky, V.P. Shelest, and G.M. Zinovev,
Sov. J. Nucl. Phys. **18**, 577 (1974);

The Physical Content of The **Statistical** Bootstrap,
M.I. Gorenstein, V.A. Miransky, V.P. Shelest, G.M. Zinovev and H. Satz,
Nucl. Phys. B **76**, 453 (1974).

1974

2-томная монография
«Модели сильновзаемодействующих элементарных частиц»,
Шелест В.П., Зиновьев Г.М., Миранский В.А.,
Москва, Атомиздат,
т.1 Структурные модели и динамика адронных взаимодействий, 1975 г.,
т.2 Дуальные модели, 1976 г.

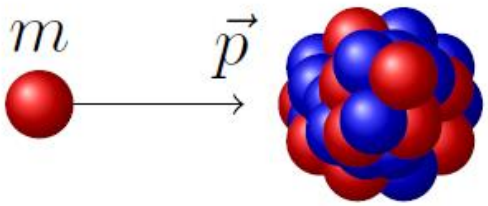
Г.М. Зиновьев «Статистический подход в теории множественного рождения и вопросы дуальности», докторская диссертация, 1975 г.

1974 – 1983:

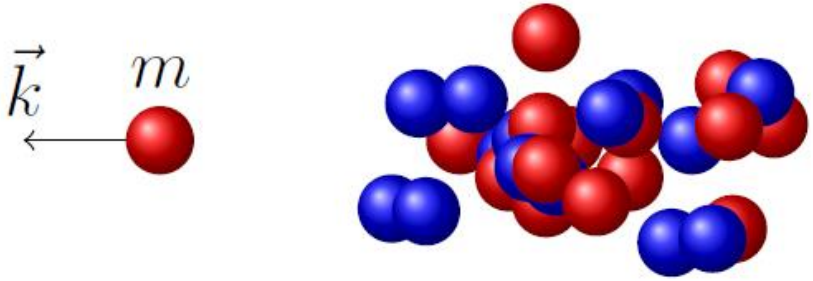
18 joint papers with Zinovjev

Physics Letters B, Ядерная Физика

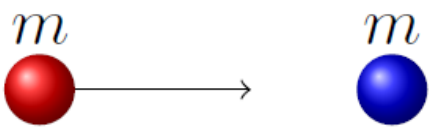
1977: Cumulative Effect



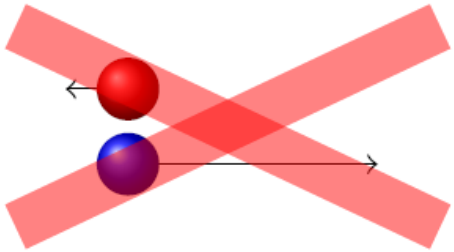
(a) Initial state.



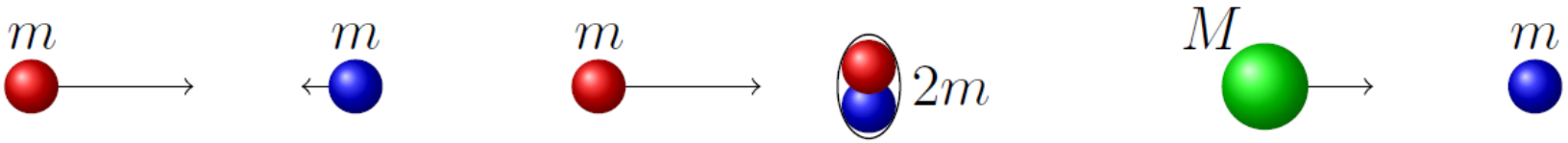
(b) Final state.



Initial state.



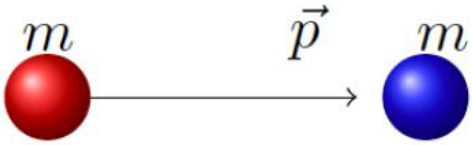
Final state.



Frankfurt, Strikman, Phys. Lett. B, (1977).

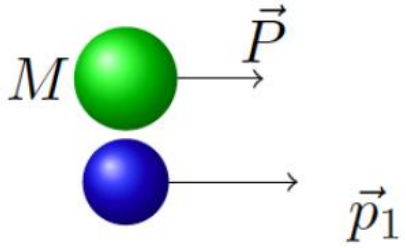
Burov *et al.*, Phys. Lett. B, (1977).

Gorenstein, Zinovjev, Phys. Lett. B, (1977).

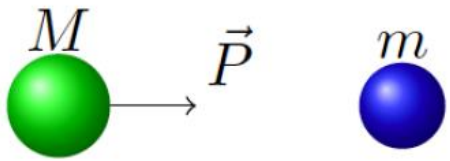


(a) Initial state.

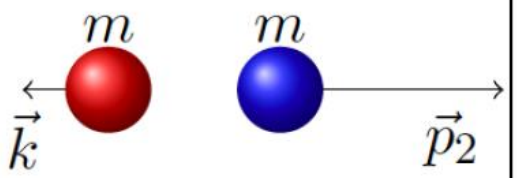
$\Delta, N^*, \ldots$



(b) Intermediate state.



(c) Intermediate state.



$$R + N \rightarrow N + N(180°)$$

(d) Final state.

1981: Phase Transition

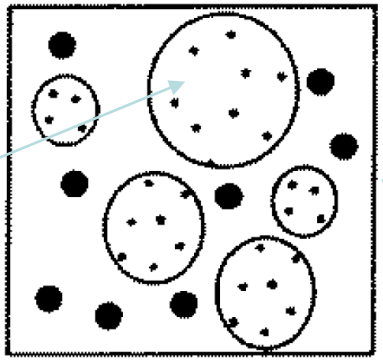
$$\rho(m) \approx C m^{-a} \exp(bm), \quad m \to \infty$$

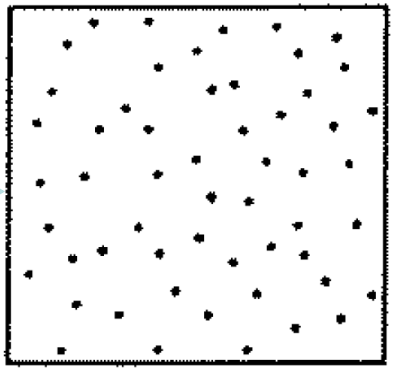
$$T < T_c = 1/b \simeq 160 \text{ MeV}$$

Limiting (Hagedorn) temperature in the hadron world (confinement)

Almost Ideal Gas of Quarks and Gluons at very high energy densities (asymptotic freedom)

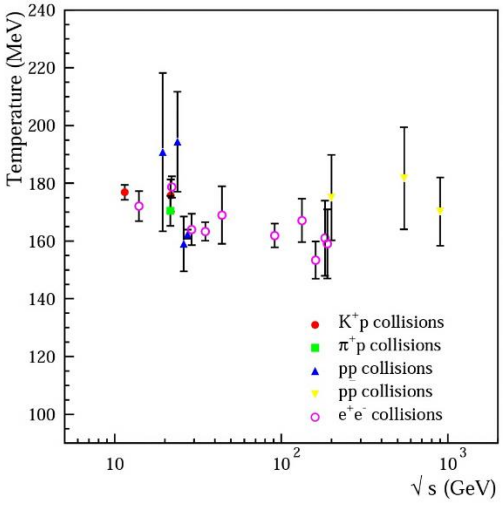
Quark-Gluon Bag





Hadron-Resonance-Gas

Quark Gluon Plasma



Hagedorn Temperature

Early 1970s: Gross, Politzer, Wilczek (NP, 2004)

Gorenstein, Petrov, Zinovjev,
Phase Transition In The Hadron Gas Model
Phys. Lett. B 106, 327 (1981),
cited **150** times

Fireball = Quark-Gluon Bag

Phase Transition in the Gas Bags

$$V \to \left(V - \sum_{i=1}^{N} v_i \right)$$

Gorenstein, Petrov, and Zinovjev, Phys. Lett. B (1981)

$$\rho(m) \to \rho(m,v) = \rho_0 + Cv^{\gamma}(m - Bv)^{\delta} \exp\left[\frac{4}{3}\sigma^{1/4} v^{1/4} (m - Bv)^{3/4} \right]$$

$$\hat{Z}(T,s) = \int_0^{\infty} dV \exp(-sV)\ Z(T,V) = \frac{1}{s - f(T,s)}$$

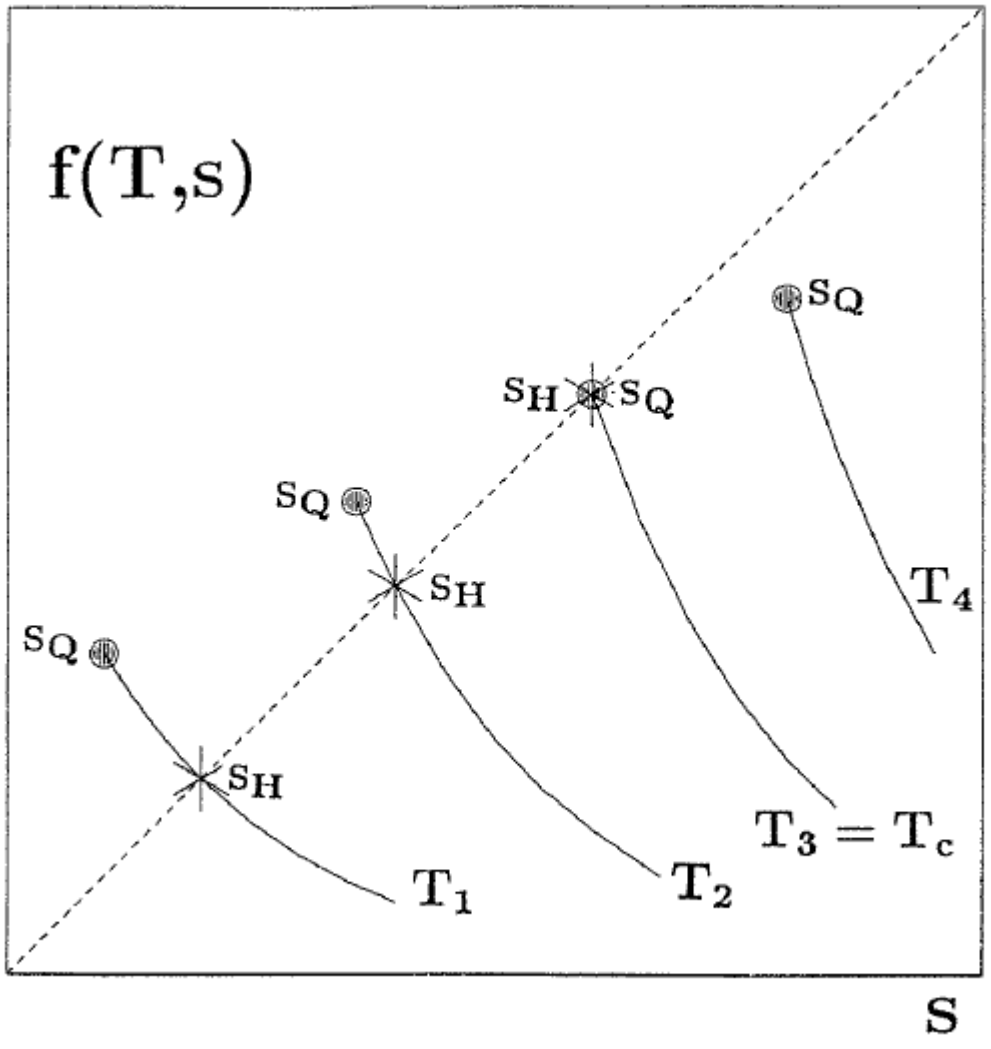
$$f(T,s) \equiv \int dm dv\ \rho(m,v)\ \varphi(T,m)\ \exp(-sv)$$

$$p(T) = Ts^*(T) = T \max\{s_H(T), s_Q(T)\}$$

s^* is the farthest-right singularity of $\hat{Z}(T,s)$: $p(T) = Ts^*(T)$

$\gamma + \delta < -3, \quad \delta < -7/4$ conditions for the PTs

$$p(T) = Ts_Q(T) = \frac{\sigma}{3}T^4 - B$$



HG $\rightarrow$ QGP

M.I.G., Zinovjev, Petrov, and Shelest, Teor. Mat. Fiz. (1982)
M.I.G. Yad. Fiz. (1984)
1st order PT

M.I.G., W. Greiner, and Shin Nan Yang, J. Phys. G (1998)
2nd order PT

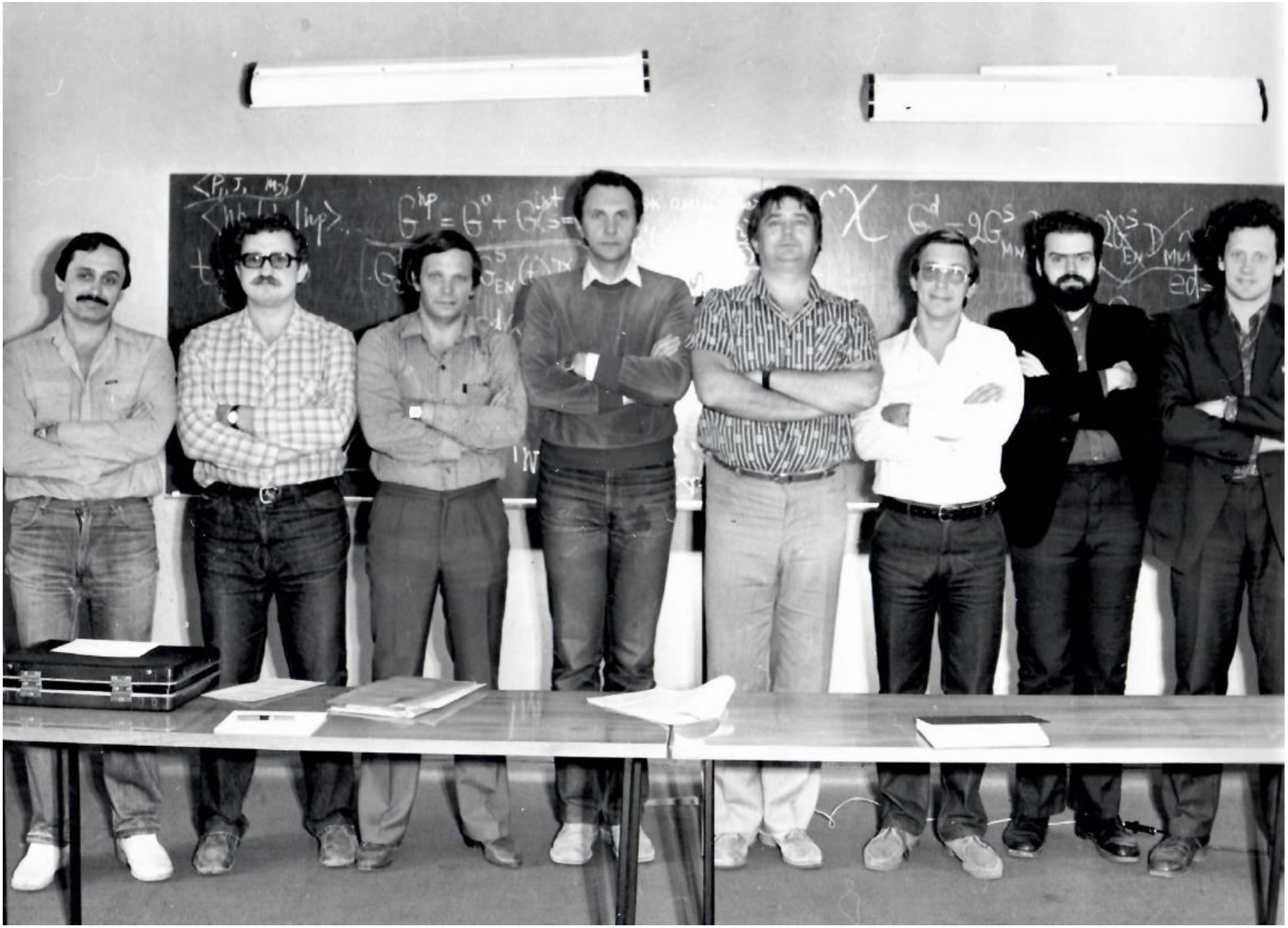
M.I.G., Gazdzicki, and W. Greiner, Phys. Rev. C (2005)
Higher order PTs

Vovchenko, Gorenstein, C. Greiner, Stoecker, Phys. Rev. C (2019)
Comparison to lattice QCD

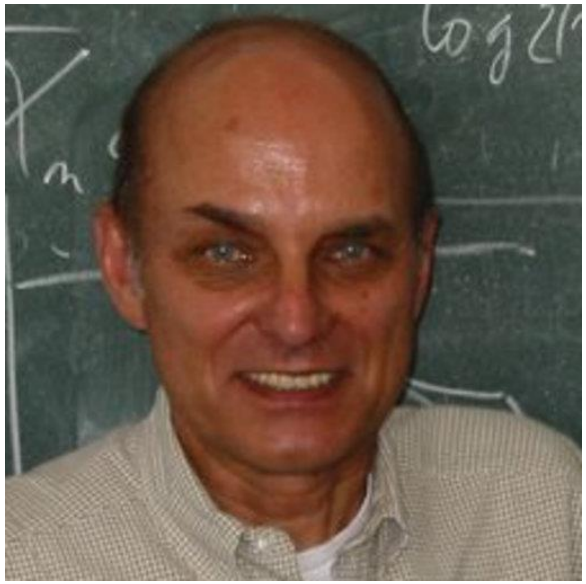
1983 - 1985:

Department of High Energy Density Physics,
G.M. Zinovjev

…

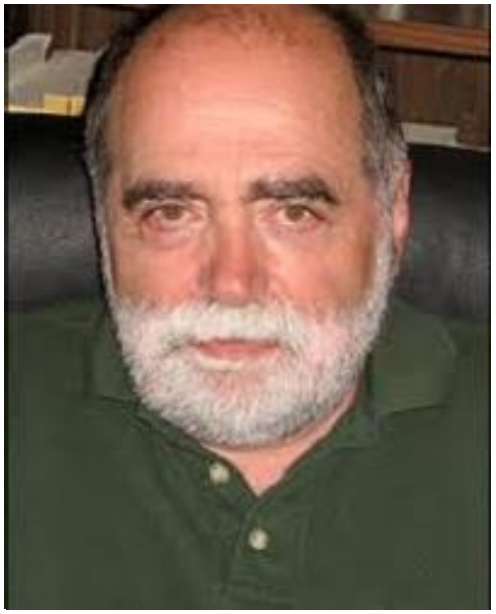


18:00 – 19:45



Helmut Satz

Peter Braun-Munzinger



Larry McLerran