Equation of State in the framework of percolation

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Percolation

T. Celik, F. Karsch, H. Satz Phys Lett B 97 128 1980(3d percolation)

N. Armesto et al PRL77 3736 1996(2d per)

M. Nardi, H. Satz Phys Lett B 442 14 1998

H. Satz Nuc Phys A642 130c 1998,
Rep Prog Phys 63 1511 2000

Thermal hadronization and Hawking-Unruh radiation in QCD

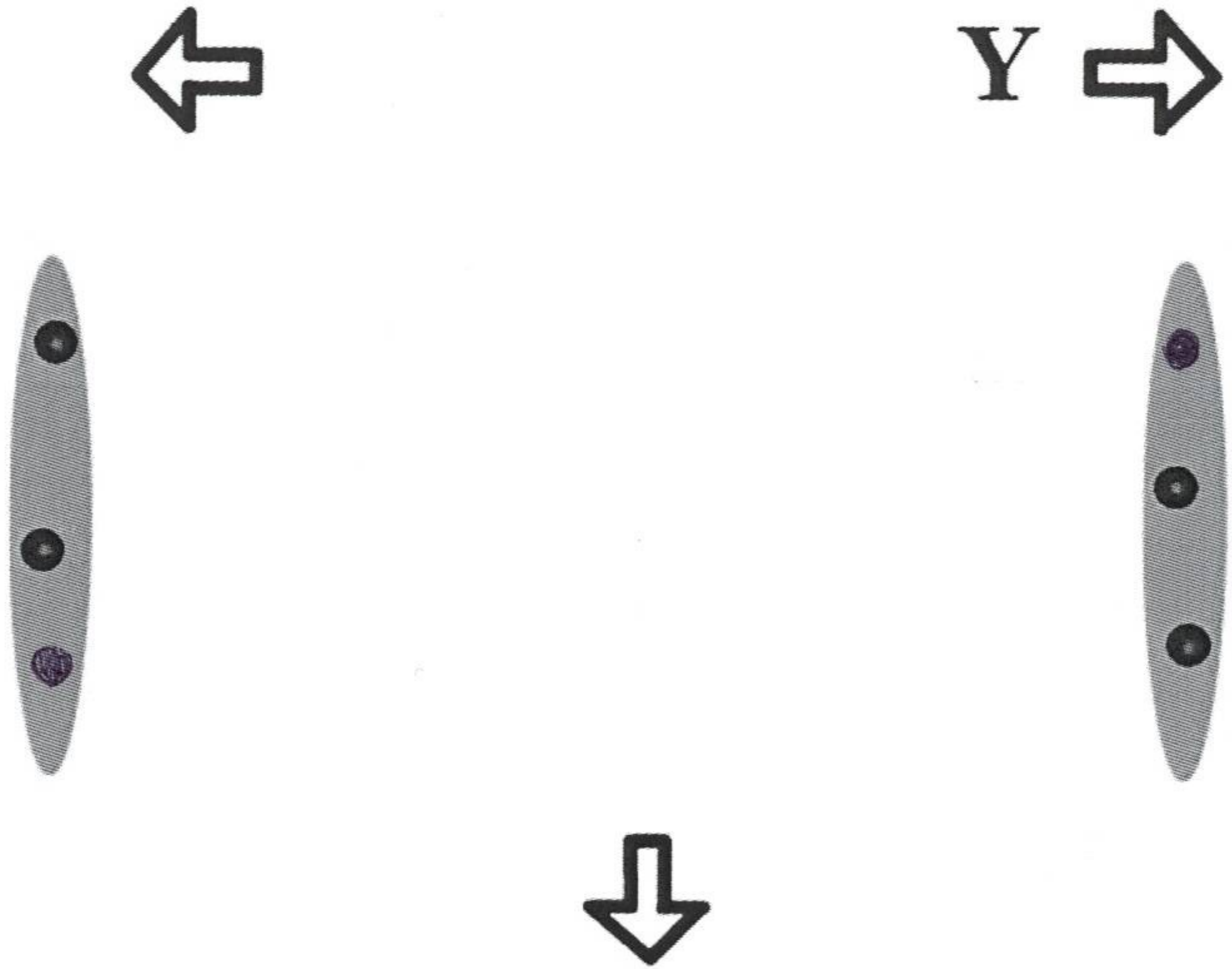
P. Castorina, D. Kharzeev, H. Satz Eur Phys J C 52 187 2007 D. Kharzeev Eur Phys J A 29 83 2006

J. Dias de Deus et al Phys LettB142 455 2006

P. Castorina, D. Miller, H. Satz arXiv:1101.1255

P. Castorina, R. V. Gavai; H. Satz Eur Phys J C66 207 2010

F.Becattini,P.Castorina,A.Milov,H.Satz Eur Phys J C66 377 2010



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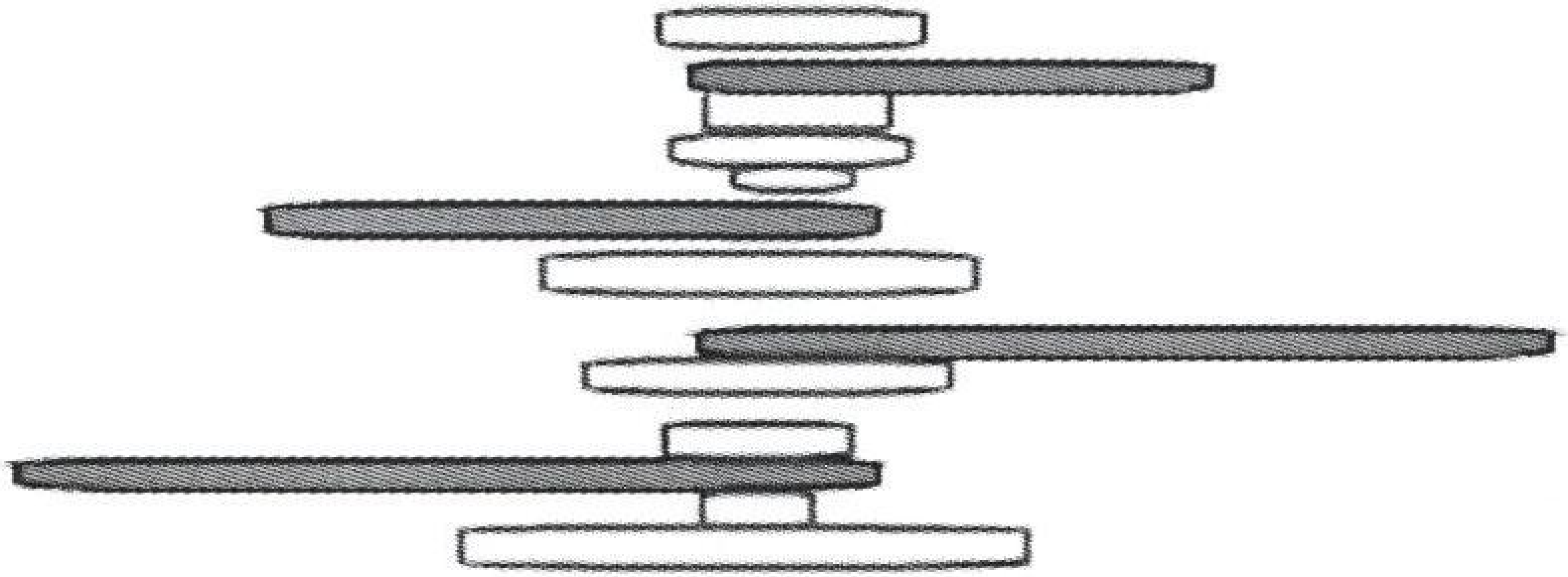
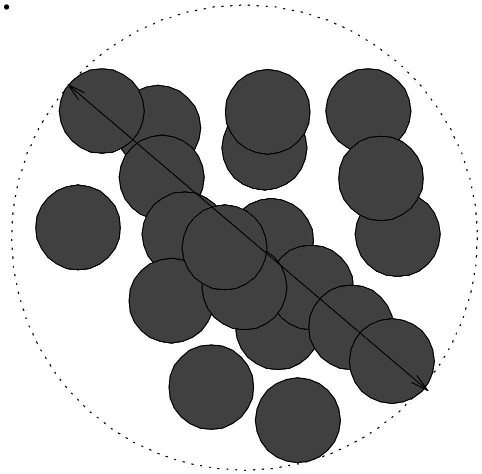


- Color strings are stretched between the projectile and target
- Strings = Particle sources: particles are created via sea qq production in
- the field of the string
- Color strings = Small sources areas in the transverse space filled with color field created by the colliding partons
- With growing energy and/or atomic number of colliding particles, the number of grows
- So the elementary color sources start to overlap, forming clusters, very much like disk in the 2-dimensional percolation theory
- In particular, at a certain critical density, a macroscopic cluster appears, which marks the percolation phase transition

(N. Armesto et al., PRL77 (96); J. Dias de Deus et al., PLB491 (00); M. Nardi and H. Satz (98).

- How?: Strings fuse forming clusters. At a certain critical density η_c (central PbPb at SPS, central AuAu at RHIC, central pp at LHC) a macroscopic cluster appears which marks the percolation phase transition (second order, non thermal).



$$\eta = N_{st}\frac{S_1}{S_A}, \quad S_1 = \pi r_0^2, \quad r_0 = 0.2 \text{ fm}, \quad \eta_c = 1.1 \div 1.2.$$

$$\mu_n = \sqrt{\frac{nS_n}{S_1}}\,\mu_1 \qquad Q_n^2 = \sqrt{\frac{nS_1}{S_n}}\,Q_1^2$$

Energy-momentum of the cluster is the sum of the energy-momemtum of each string.

As the individual color field of the individual string may be oriented in an arbitrary manner respective to one another, $Q_n^2 = nQ_1^2$

- At high densities
  - $< \mu >_n = nF(\eta) < \mu >_1 \;\; < p_T^2 >_n = \frac{<p_T^2>_1}{F(\eta)}$
  - $F(\eta) = \sqrt{\frac{1-e^{-\eta}}{\eta}}$, $\eta = N_S \frac{\pi r_0^2}{S_A}$
  - r_0 is the transverse size of a single string $\simeq$ 0.2 fm.

$$dn/dp_T^2 \sim e^{-p_T/\sqrt{2\pi/<x^2>}}$$

with $< x^2 >= \pi < p_T^2 >_1 /F(\eta)$.

The temperature is given by

$$T(\eta) = \sqrt{\frac{<p_T^2>_1}{2F(\eta)}}$$

$$\varepsilon_t = \frac{3}{2} \frac{\frac{dN_\sigma}{dy} < m_T >}{S_a \tau_{pro}}$$

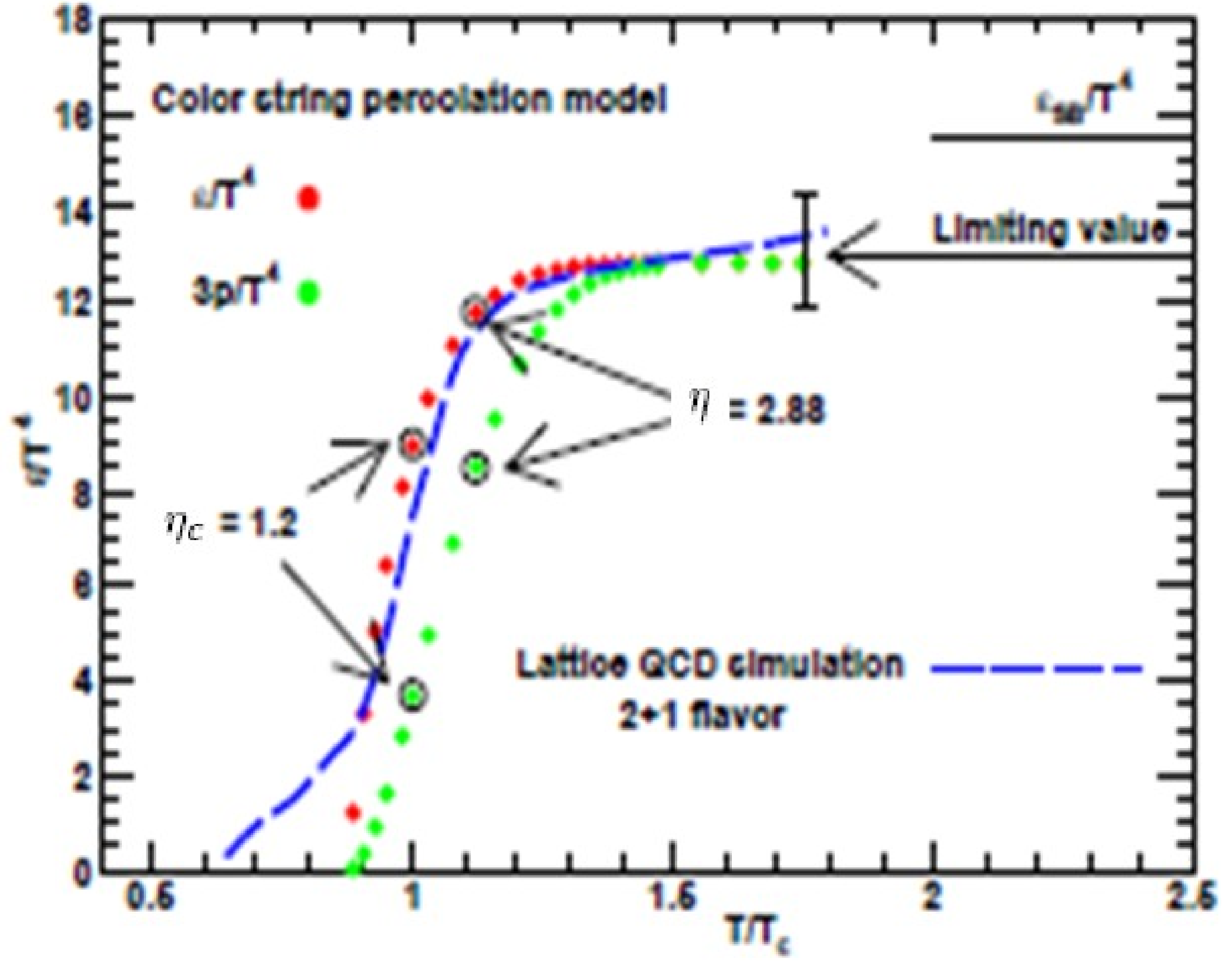
$$\frac{1}{T}\frac{dT}{d\tau} = -C_s^2/\tau$$

$$\frac{dT}{d\tau} = \frac{dT}{d\varepsilon}\frac{d\varepsilon}{d\tau}$$

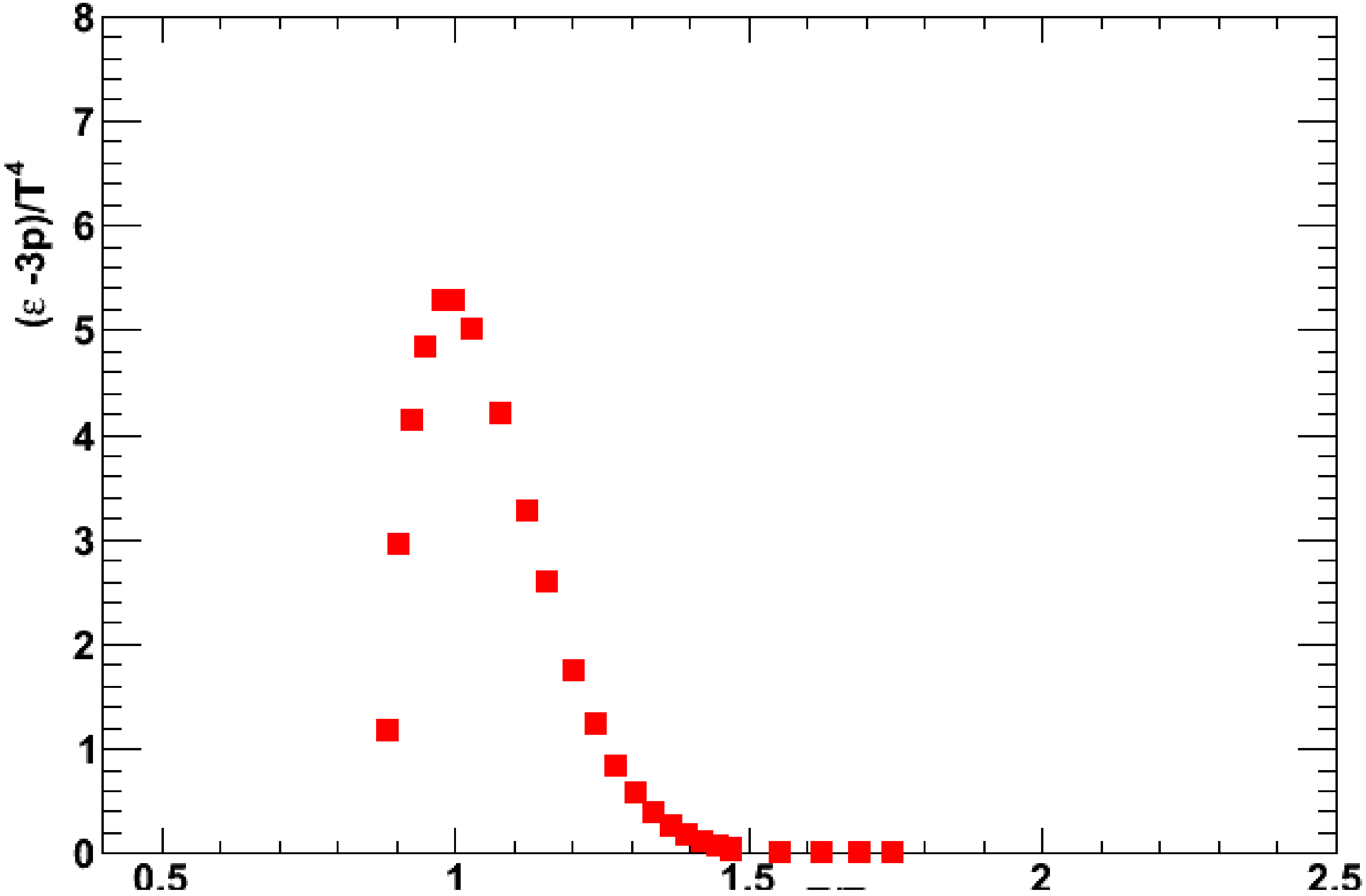
$$\frac{d\varepsilon}{d\tau} = -Ts/\tau$$

$$s = (1 + C_s^2)\frac{\varepsilon}{T}$$

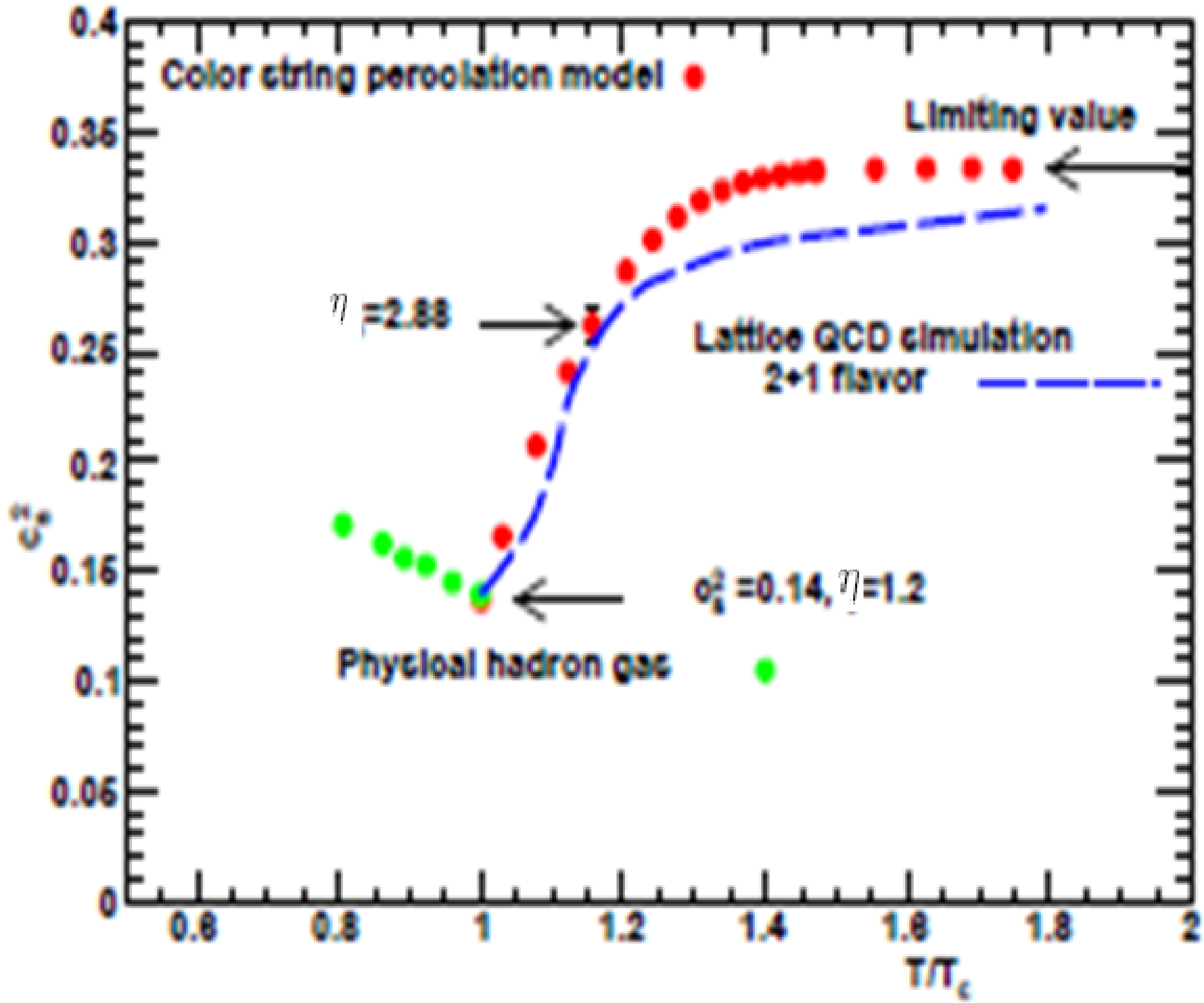
$$\frac{dT}{d\varepsilon}s = C_s^2$$



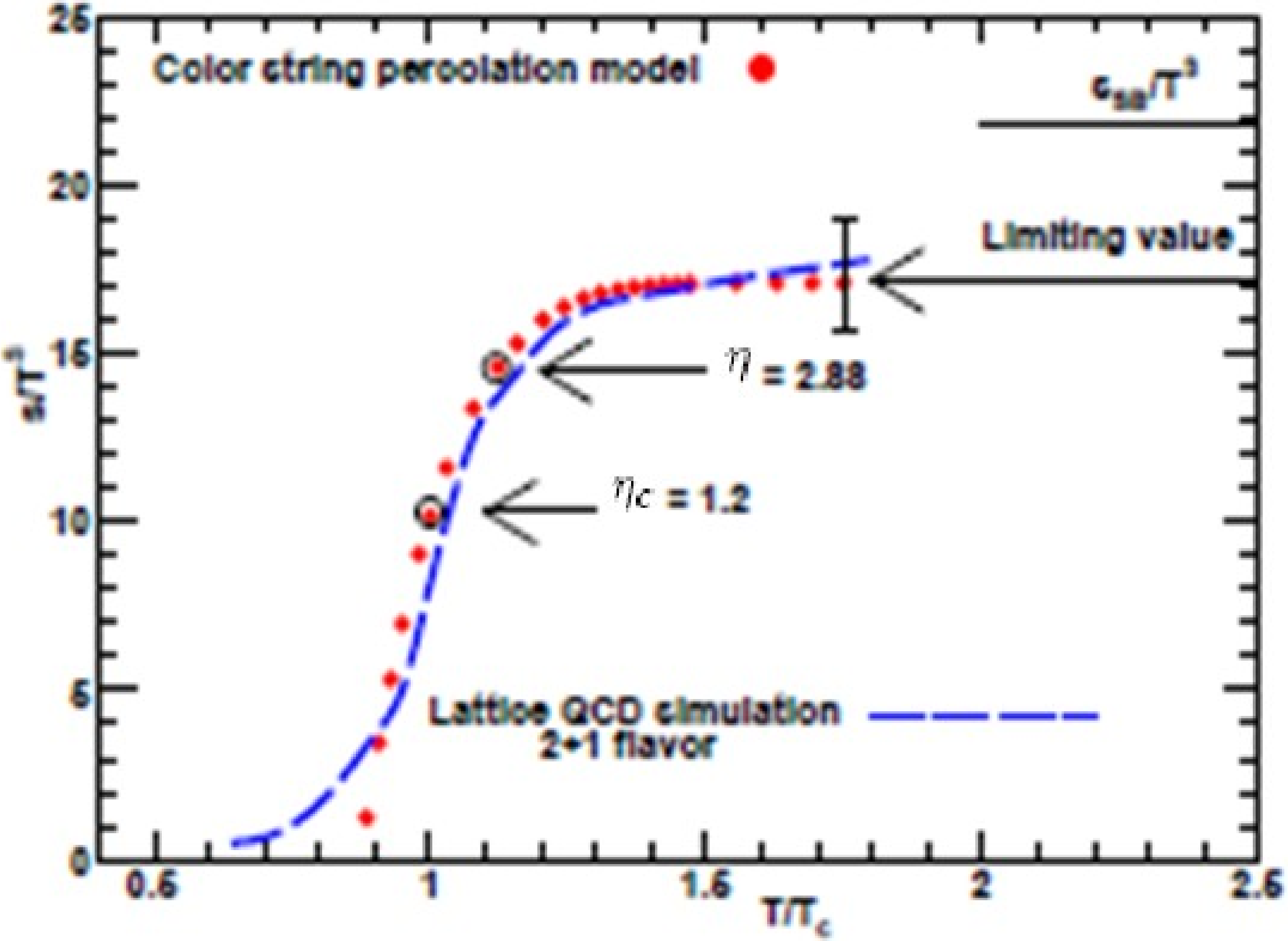
Color string percolation model
ε/T⁴
3p/T⁴
ε_SB/T⁴
Limiting value
η = 2.88
η_c = 1.2
Lattice QCD simulation
2+1 flavor
ε/T⁴
T/T_c



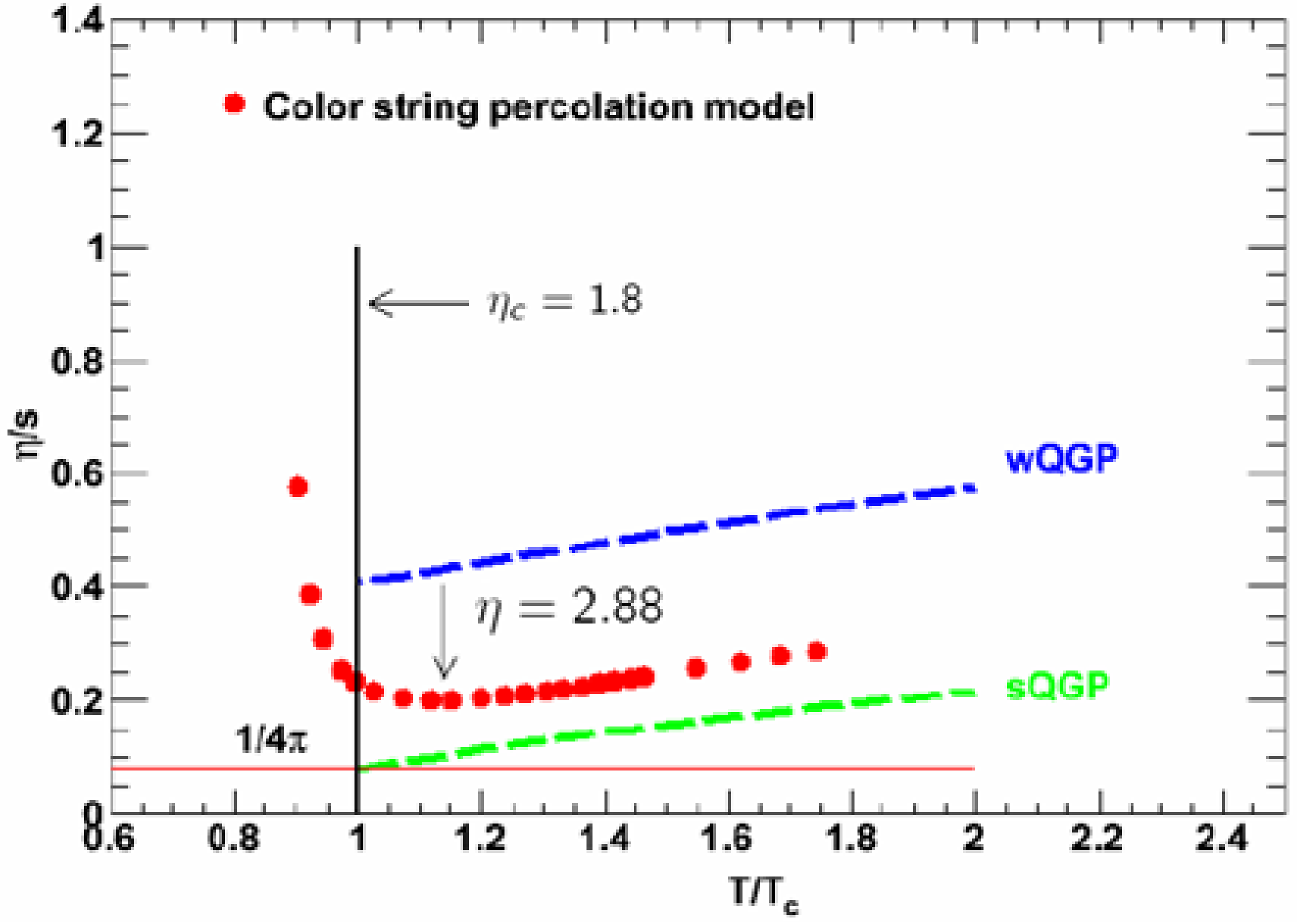
(ε -3p)/T^4
0
1
2
3
4
5
6
7
8
0.5
1
1.5
2
2.5



Color string percolation model
Limiting value
η =2.88
Lattice QCD simulation
2+1 flavor
c_s^2 =0.14, η=1.2
Physical hadron gas
c_s^2
T/T$_c$
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.6
0.8
1
1.2
1.4
1.6
1.8
2


Color string percolation model
ϵ_{SB}/T^3
Limiting value
η = 2.88
η_c = 1.2
Lattice QCD simulation
2+1 flavor
ϵ/T^3
T/T$_c$
0
5
10
15
20
25
0.6
1
1.5
2
2.5

$$\frac{\eta}{s} = \frac{1}{5\sqrt{2}} \frac{<p_T>_1 \eta^{1/4}}{(1-e^{-\eta})^{5/4}} L$$



Color string percolation model
$\eta_c = 1.8$
$\eta = 2.88$
wQGP
sQGP
1/4π
η/s
T/T$_c$
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4

Conclusions

- Percolation gives a good description of the main observables, including reasonable shear viscosity/entropy density ratio

- Helmut Satz is in a very good shape as it was

(at least)in the last four decades

CONGRATULATIONS