J/psi suppression, percolation model and the critical energy density in AA collisions at SPS and RHIC energies with the account of centrality

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Baldin ISHEPP XIX. Dubna, Oct 2, 2008

Outline

1. Introduction.

2. Estimates of local energy density for AA collisions at SPS CERN (sqrt(s)=**17,3 GeV**) as a function of centrality.

3. Estimates of local percolation parameter for AA collisions at SPS CERN (sqrt(s)=**17,3 GeV**) as a function of centrality.

4. Comparison of energy density and percolation parameter values for different impact-parameters.

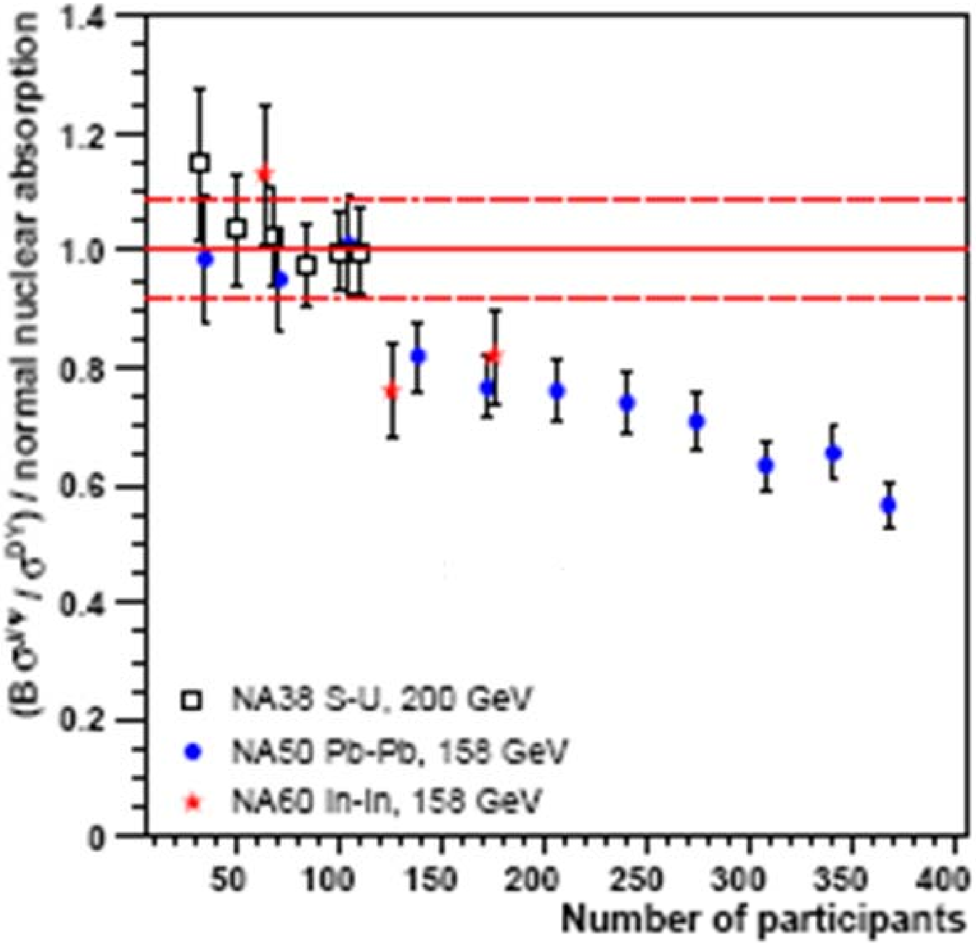
5. RHIC (sqrt(s)=**200 GeV**) data and critical value percolation parameter and energy density.

6. Conclusions.

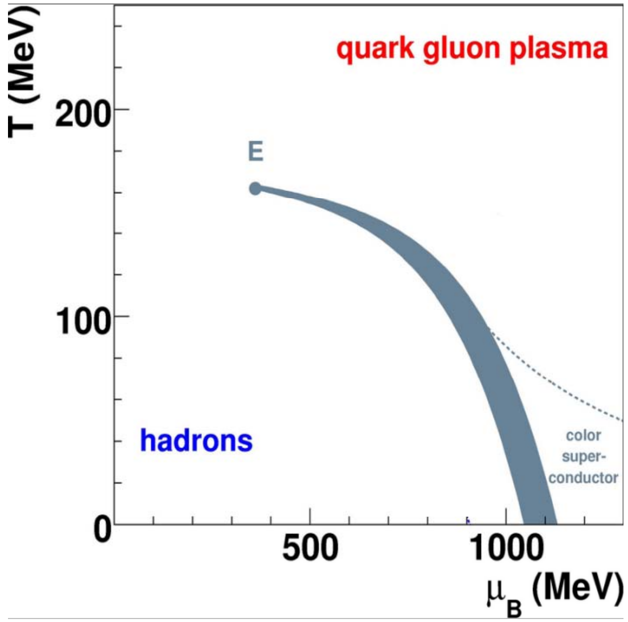
Onset of J/Psi suppression.

$$\sqrt{s} = 17,3 GeV$$

Experimental results: Na38, Na50, Na60 CERN SPS



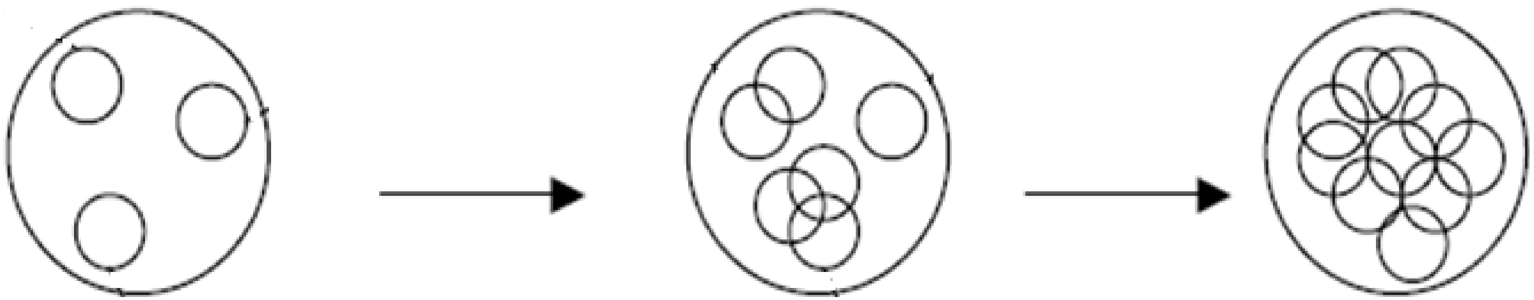
“Critical value” $N_{part} \approx 110$



[1] CERN–2005–005 arXiv:hep-ph/0412158v2 26 Jul 2005, p. 428

Hypothesis for SPS data:

Hadron gas - QGP phase transition corresponds to percolation phase transition (string model)



Peripheral collision

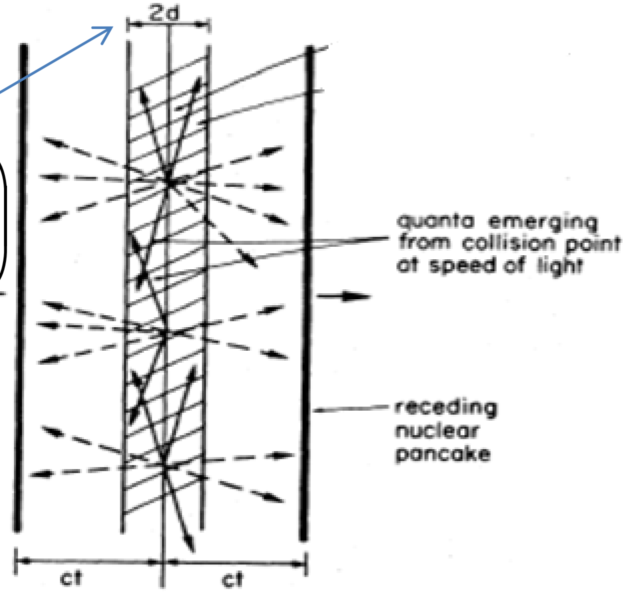
Central collision

Energy density according to Bjorken formula

Energy density according to classical Bjorken formula[2].

$$\varepsilon = E/V$$

$$E = N_{part}\frac{d\langle E\rangle}{dy}\Delta y \approx N_{part}\left(\frac{3}{2}\frac{dN_{ch}}{dy}\langle E\rangle\right)\frac{1}{2}\left(\frac{2d}{\tau}\right)$$



$$2\Delta y \approx 2\frac{d}{\tau}$$

Assumption:

1. central collisions
2. Nuclei have regular spherical shape.
3. <E> ≈400 MeV in the central rapidity region
4. *τ ≈ 1 fm/c*

$$\varepsilon = \frac{N_{part}}{S}\frac{d\langle E\rangle}{dy}\frac{1}{2\tau} = \frac{A^{1/3}}{4{,}5\,fm^2}\frac{d\langle E\rangle}{dy}\frac{1}{2\tau}$$

Area is calculated as $S = \pi R^2$
where $R = (1{,}2A^{1/3}\,fm)$ nuclear radius.

[2] J.D. Bjorken, Highly relativistic nucleus-nucleus collision: The central rapidity region// Phys.Rev.D27, 140(1983).

Impact-parameter dependence of energy density in AA collisions. Refined Bjorken formula.

$$\varepsilon(b) = \frac{N_{part}(b)}{S(b)} \frac{3}{2} \frac{dN_{ch}}{dy}(b) \langle E \rangle \frac{1}{2\tau}$$

$\frac{dN_{ch}}{dy}$ - Experimental data

where **<E> ≈400 MeV** in the central rapidity region,

τ ≈ 1 fm/c

Npart – number of nucleons- participant

S – overlap area

Idea: area **S** was selected, then number of nucleons- participant **Npart** is counted in defined geometrically region the instrumentality of computer system – simulation of the process by Monte-Carlo method.

$\frac{dN_{ch}}{dy}$ is found for this Npart.

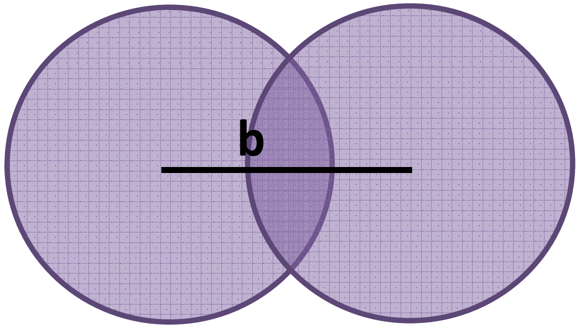
$$S -> N_{part} -> \frac{dN_{ch}}{dy}$$

S(b)

Let us select overlap area **S(b)**, then number of nucleons-participant **Npart** is the one in the overlap area.
We take nuclear density with sharp edge.

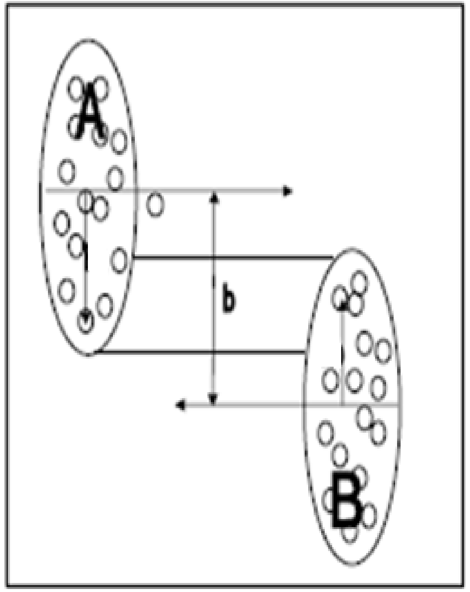
$$\sqrt{s} = 17{,}3 GeV, Pb + Pb$$

$$\varepsilon(b) = \frac{N_{part}(b)}{S(b)} \frac{3}{2} \frac{dN_{ch}}{dy}(b) \langle E \rangle \frac{1}{2\tau}$$



S – overlap area

Nucleus-nucleus collision process. Determination of impact parameter b and number of participants Npart.



$$\sqrt{s} = 17{,}3 GeV, Pb + Pb$$

$$\varepsilon(b) = \frac{N_{part}(b)}{S(b)} \frac{3}{2} \frac{dN_{ch}}{dy}(b) \langle E \rangle \frac{1}{2\tau}$$

b – impact-parameter,

Npart is found by Monte-Carlo calculation[5].

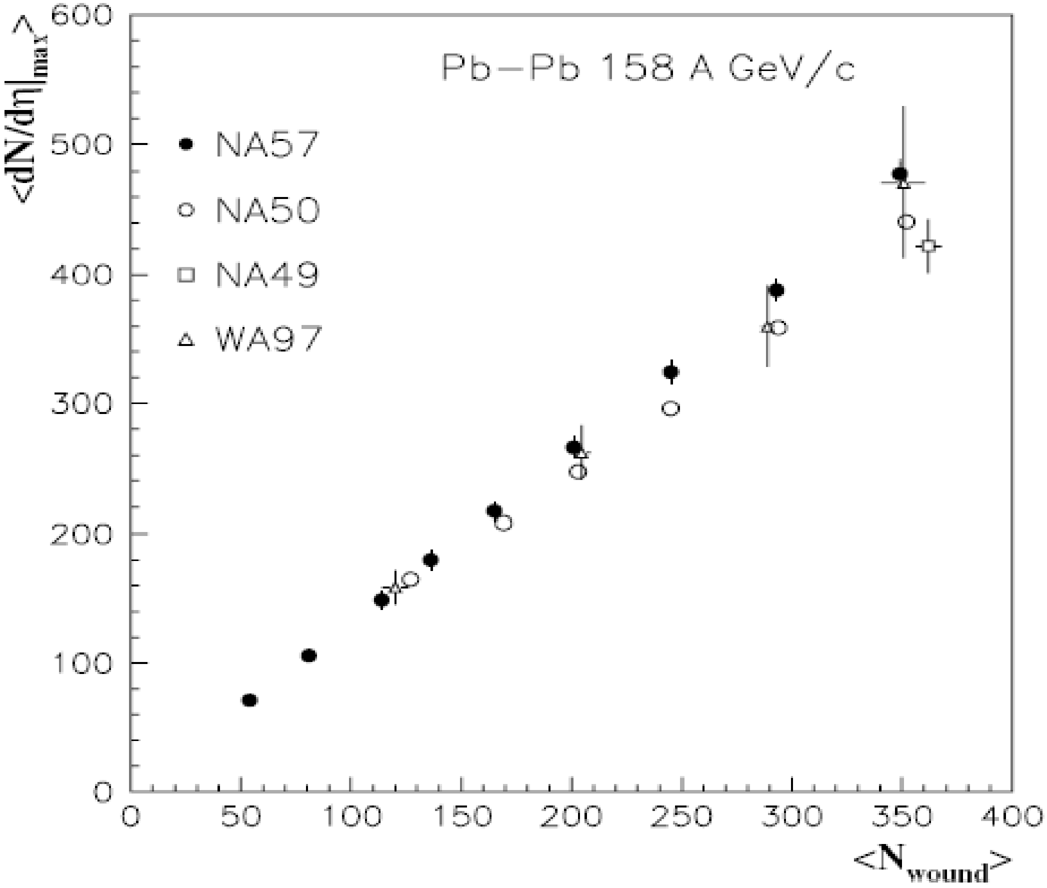
[4] A. Bialas et al., Nucl. Phys. B111, 461 (1976).

[5] G.Feofilov,A.Ivanov, “Number of nucleon-nucleon collisions vs. energy in modified Glauber calculations”, Journal of Physics: Conference Series 5 (2005) 230–237]

Determination of charged particle density per rapidity unit. *dNch/dy*– (Experimental data)

$$\sqrt{s} = 17{,}3GeV, Pb + Pb$$

$$\varepsilon(b) = \frac{N_{part}(b)}{S(b)} \frac{3}{2} \frac{dN_{ch}}{dy}(b) \langle E \rangle \frac{1}{2\tau}$$



$$\left\langle \frac{dN}{d\eta} \right\rangle = \left\langle \frac{3}{2} \frac{dN_{ch}}{dy} \right\rangle$$

$$\eta = y$$

$$\langle N_{wound} \rangle = \langle N_{part} \rangle$$

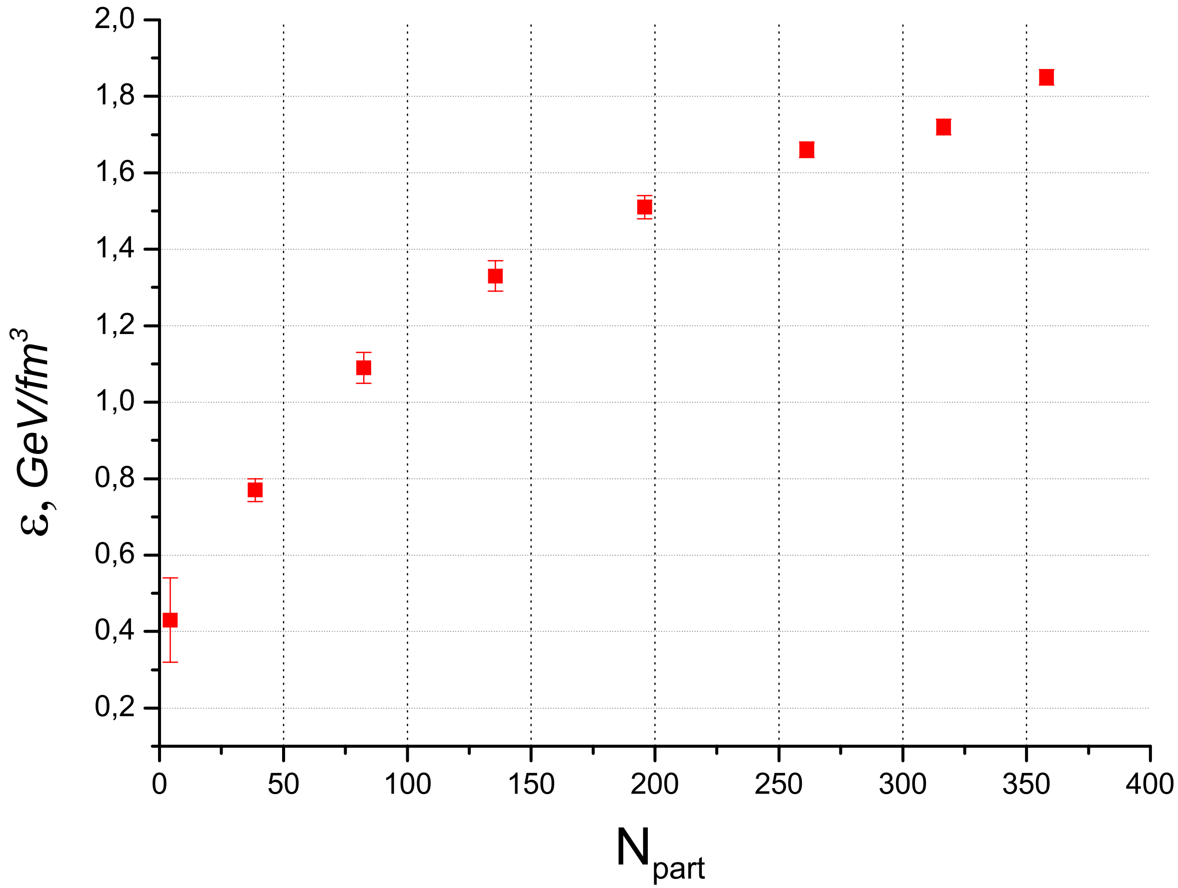
[3] F. Antinori, et al.// Journal of Physics: Conference Series **5** (2005) 64–73

Results

$$\varepsilon(b) = \frac{N_{part}(b)}{S(b)} \frac{3}{2} \frac{dN_{ch}}{dy}(b)\langle E \rangle \frac{1}{2t}$$

Energy density vs. number of participants

$$\sqrt{s} = 17{,}3 GeV, Pb + Pb$$

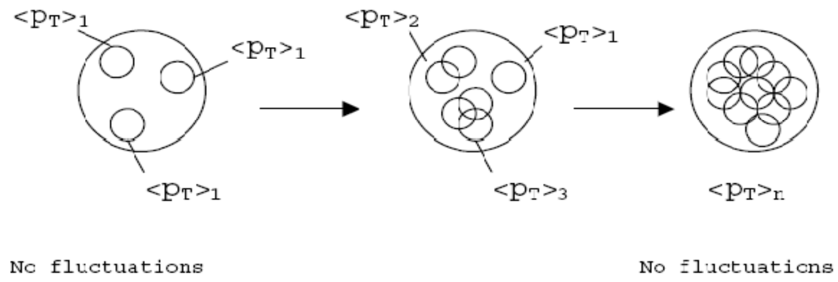


Hypothesis for SPS data:

Hadron gas - QGP phase transition
corresponds to
percolation phase transition in string
fusion model

String model. Estimate of string percolation parameter.

With growing energy and/or atomic number of colliding particles, the number of strings grows and they start to overlap, forming clusters.
At a critical density a macroscopic cluster appears that marks the percolation phase transition.[9]



$$\eta(b) = N_{str}(b)\pi r_0^2 / S(b)$$ - Percolation parameter

"Critical value" $N_{part} \approx 110$

N_{Str} - number of strings, πr_0^2 string transverse area, S overlap area.

r_0=0,2-0,25 fm – change of string radius value results in different percolation parameter

η_c= 1,15([4])

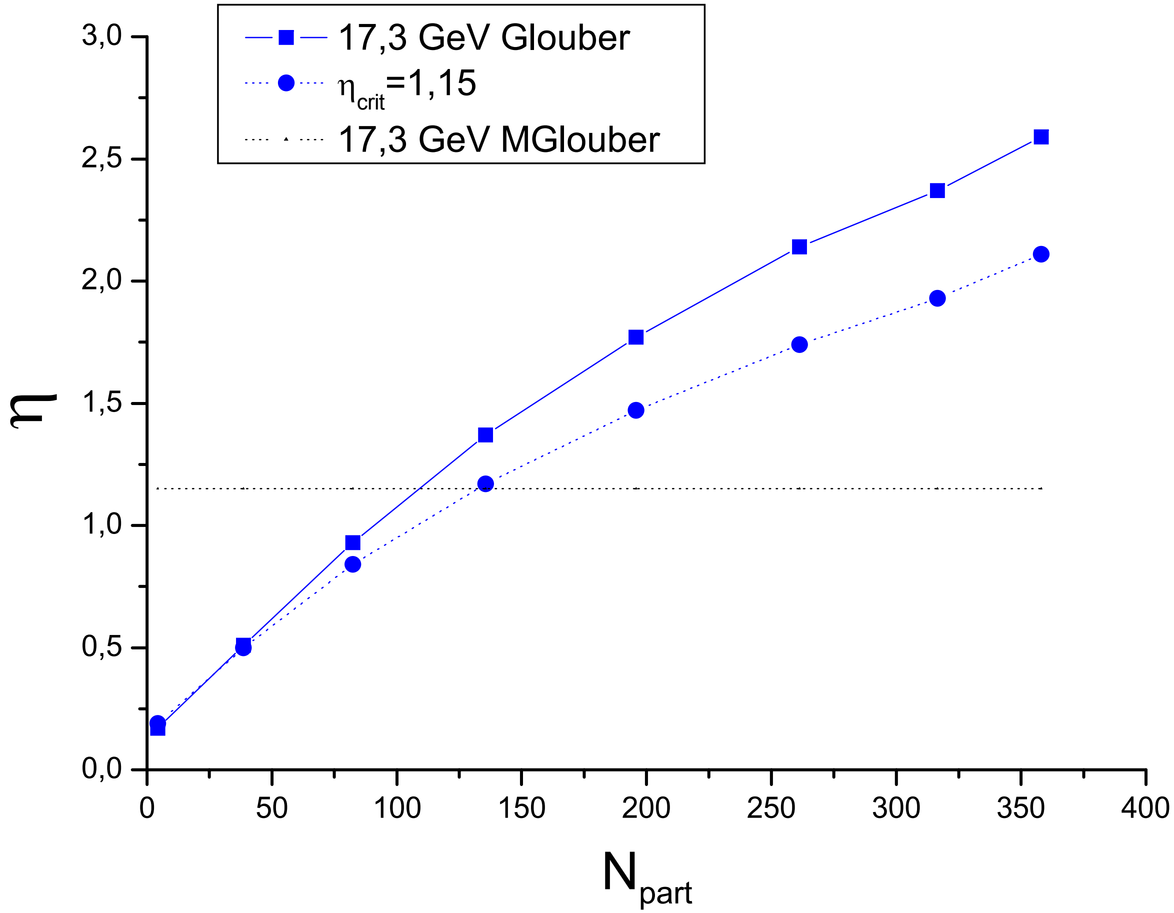
[4] J.Dias de Deus and A. Rodrigues// Phys. Rev. C 67, 064903 (2003)
[5] C. Pajares // arXiv:hep-ph/0501125v1 14 Jan 2005

Percolation parameter vs. number of participant.

$$\eta(b) = N_{str}(b)\pi r_0^2 / S(b)$$

$$\sqrt{s} = 17{,}3 GeV, Pb + Pb$$

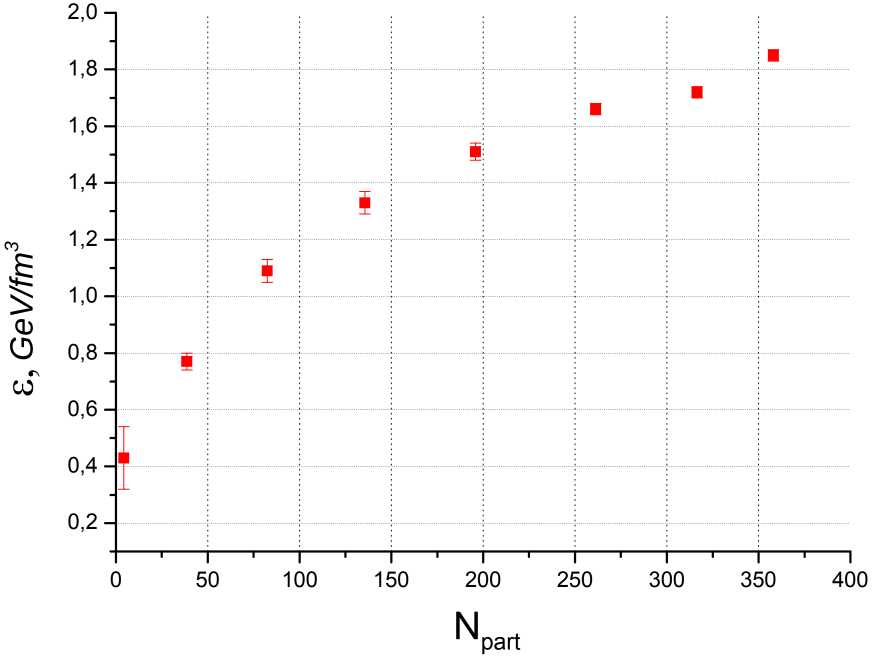
r_0=0,2 fm

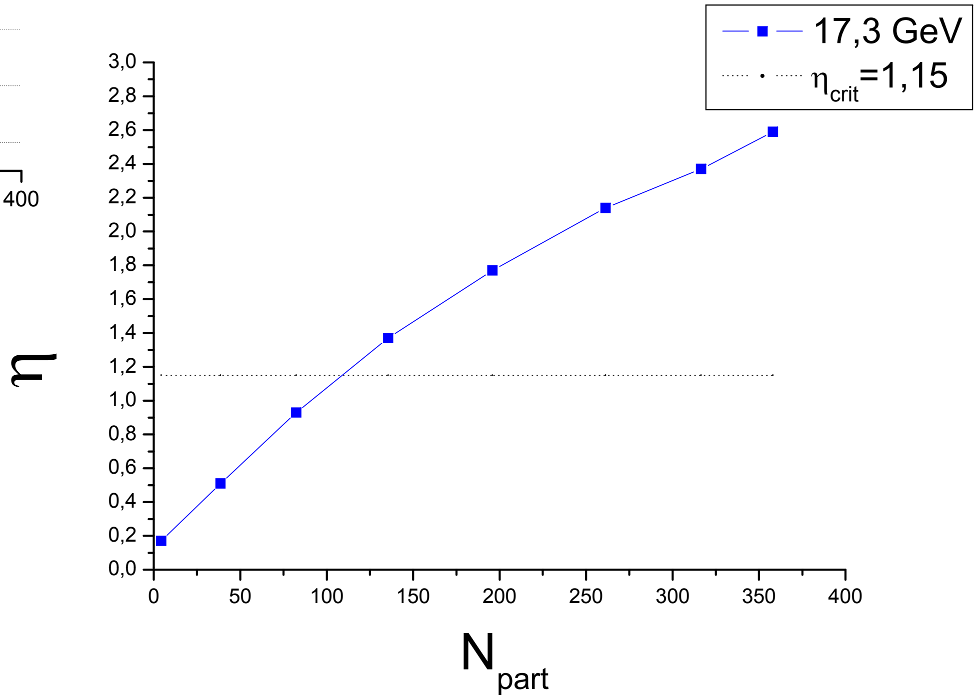


Critical percolation parameter *η is* reached at *Npart ≈ 110*

Comparison η and ε.

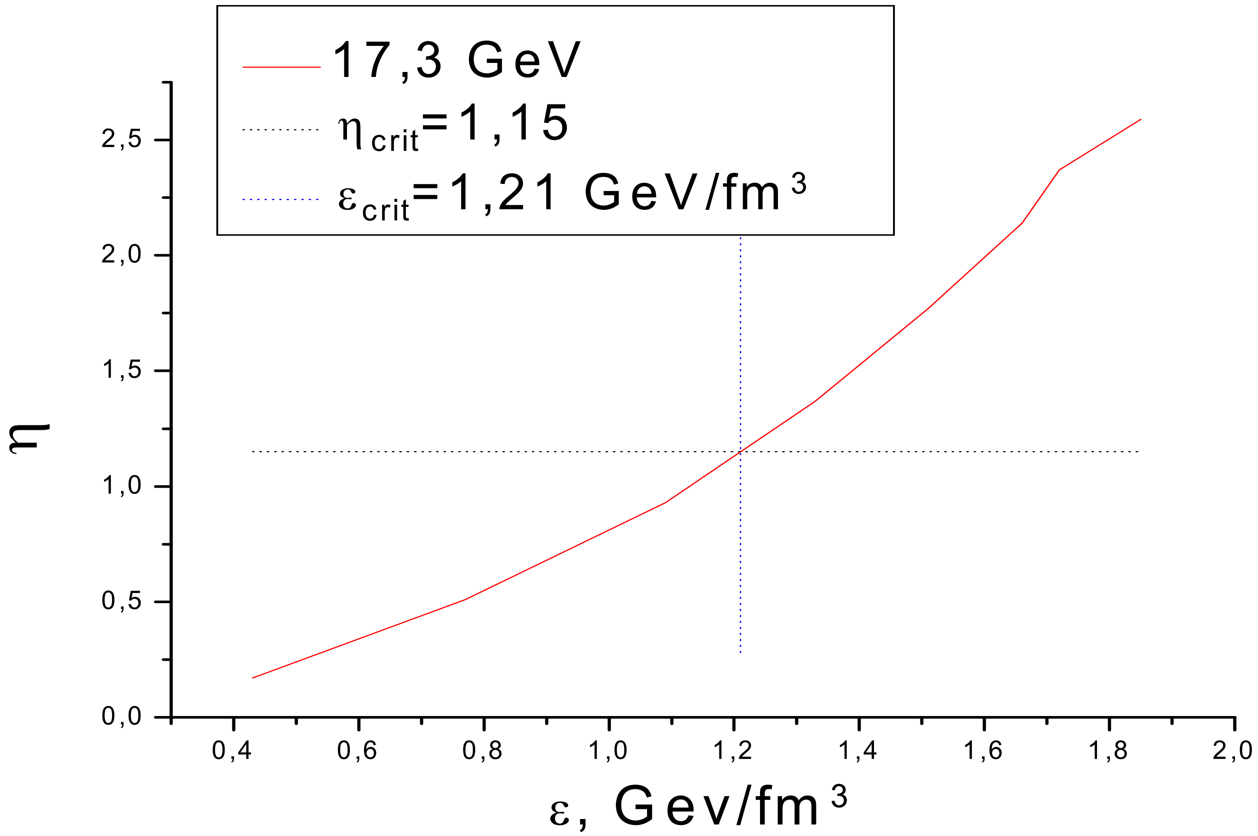
$$\sqrt{s} = 17{,}3 GeV, Pb + Pb$$





Comparison η and ε.(2)

$$\sqrt{s} = 17{,}3 GeV, Pb + Pb$$



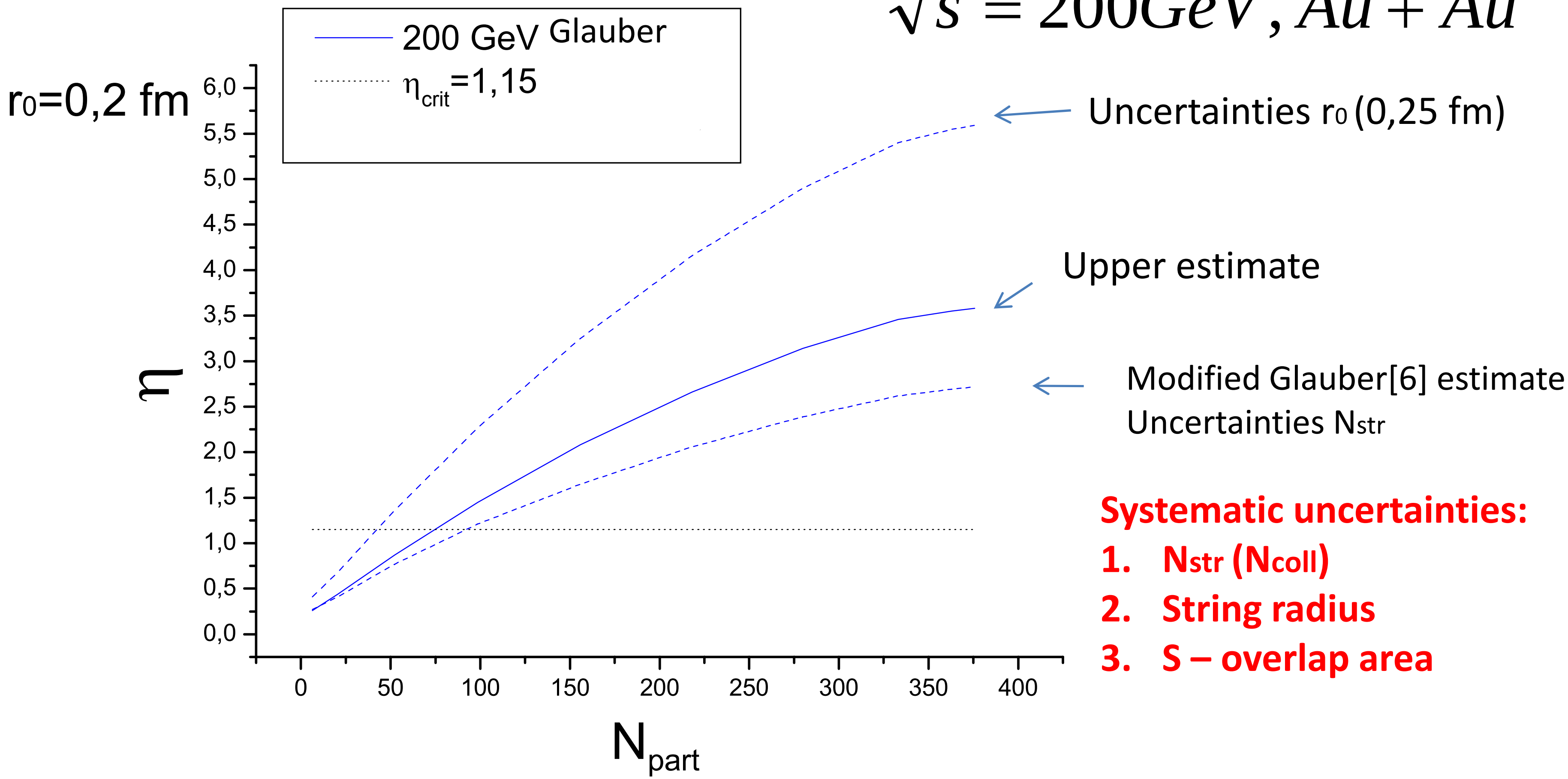
Percolation phase transition could be in line with hypothesis of phase transition between hadrons gas and quark - gluon plasma at center-of-mass system energy sqrt(s) = 17,3 GeV (Npart = 110). Energy density corresponding to transition should be equal approximately 1,21 GeV/fm^3.

Check the hypothesis on RHIC (sqrt(s)=200) data.

Percolation parameter vs. number of participant: Systematic uncertainties

$$\eta(b) = N_{str}(b)\pi r_0^2 / S(b)$$

$$\sqrt{s} = 200GeV, Au + Au$$



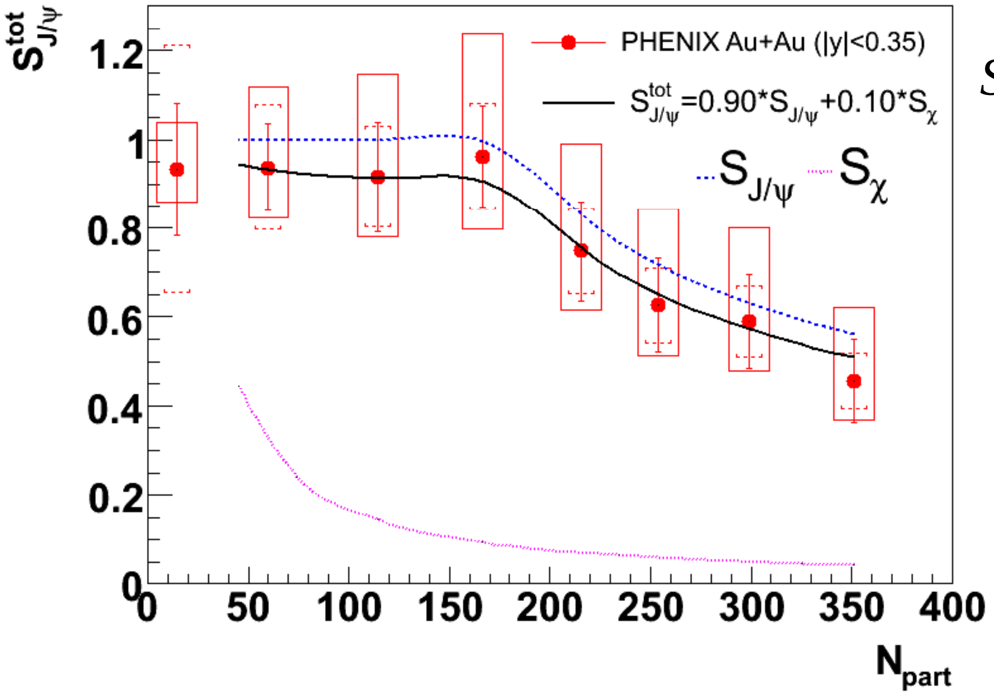
Systematic uncertainties:

1. **N_{str} (N_{coll})**
2. **String radius**
3. **S – overlap area**

Critical value of percolation parameter should be obtained at number of participant "Critical value" of N_{part} from 30 to 95.

[6] G.Feofilov,A.Ivanov, "Number of nucleon-nucleon collisions vs. energy in modified Glauber calculations", Journal of Physics: Conference Series 5 (2005) 230–237]

J/Psi suppression (sqrt(s) = 200 GeV RHIC) occurs at number of participant



$$S_{AA} = \frac{R_{AA}}{R_{AA}(CNM)}$$ survival probability

J/Psi suppression (sqrt(s) = 200 GeV RHIC) occurs at number of participant "Critical value" of N_{part} ~ 160

Percolation model predication is Npart ~70

Contradiction : With growing energy the number of strings grows , so number of participant , necessary for obtaining critical percolation parameter, should be less.

[6] T. Gunji and H. Hamagaki /arXiv:hep-ph/0703061v2 6 Jul 2007

Conclusions

1. There is an agreement between the hypothesis of percolation transition and onset value of critical energy density in PbPb at CERN SPS (17,3 GeV). Energy density conforming to transition should be equal approximately 1,21 GeV/fm^3.

2. Contradiction between experimental results for J/psi suppression at RHIC energy (200 GeV) and theoretical sting model requires subsequent investigation.

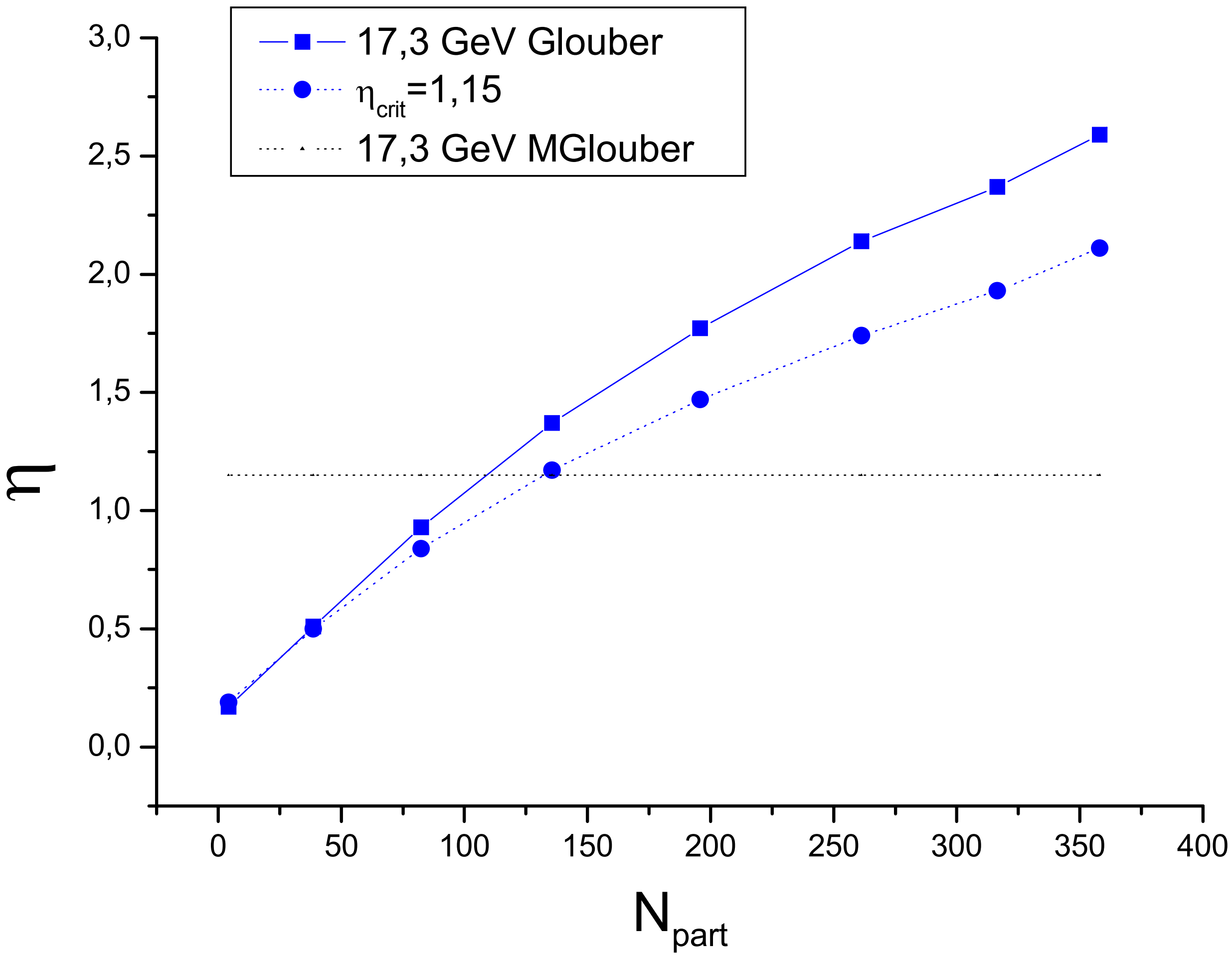
3. What process can give such result at sqrt(s)=200 GeV?

Thank you!

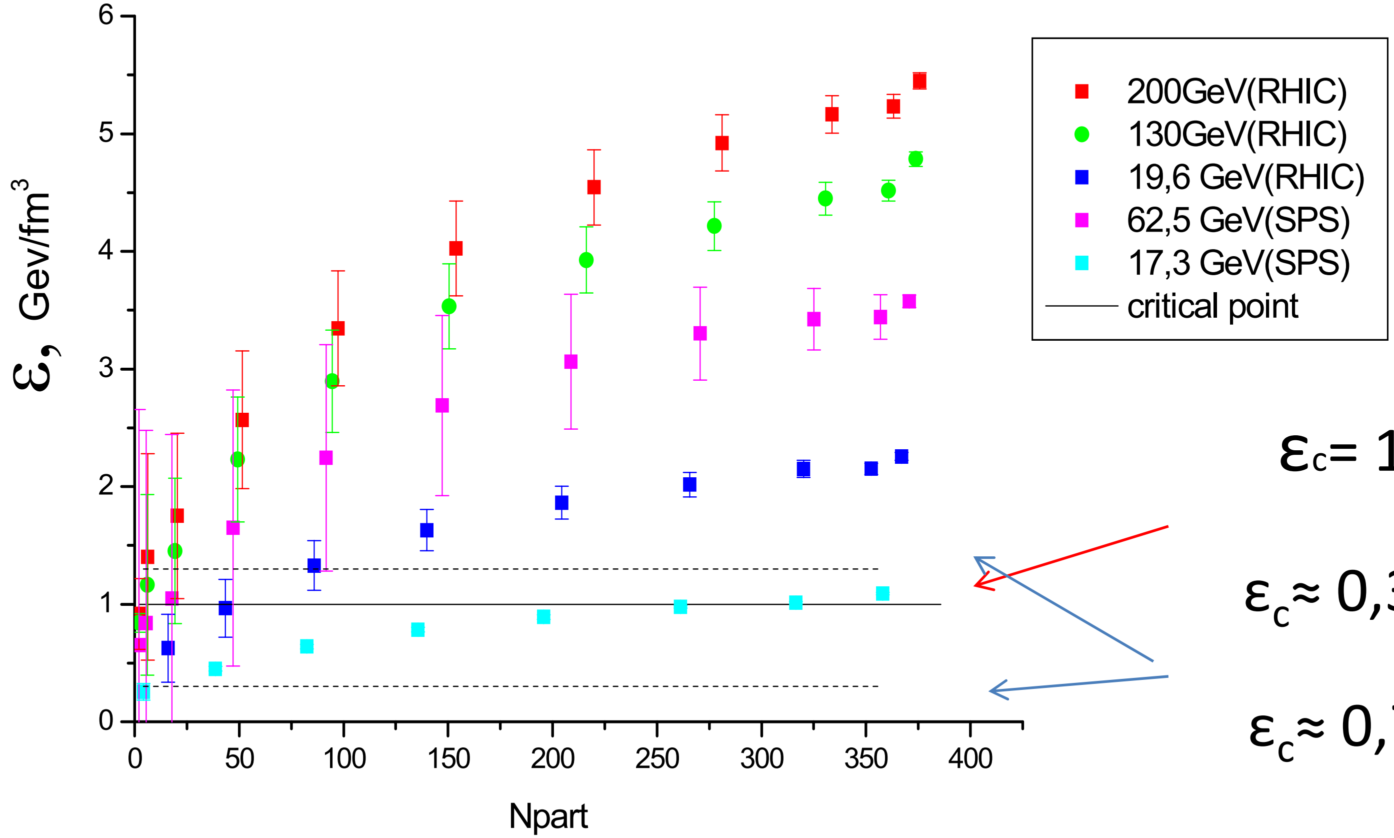
Backup slides

Percolation parameter vs. number of participant.

$$\sqrt{s} = 17{,}3 GeV, Pb + Pb$$



Estimates of energy density for energy *sqrt(s)* from 17,3GeV to 200 GeV. Energy density vs. *Npart*



Au+Au

Pb+Pb

$\varepsilon_c = 1$ GeV/fm^3

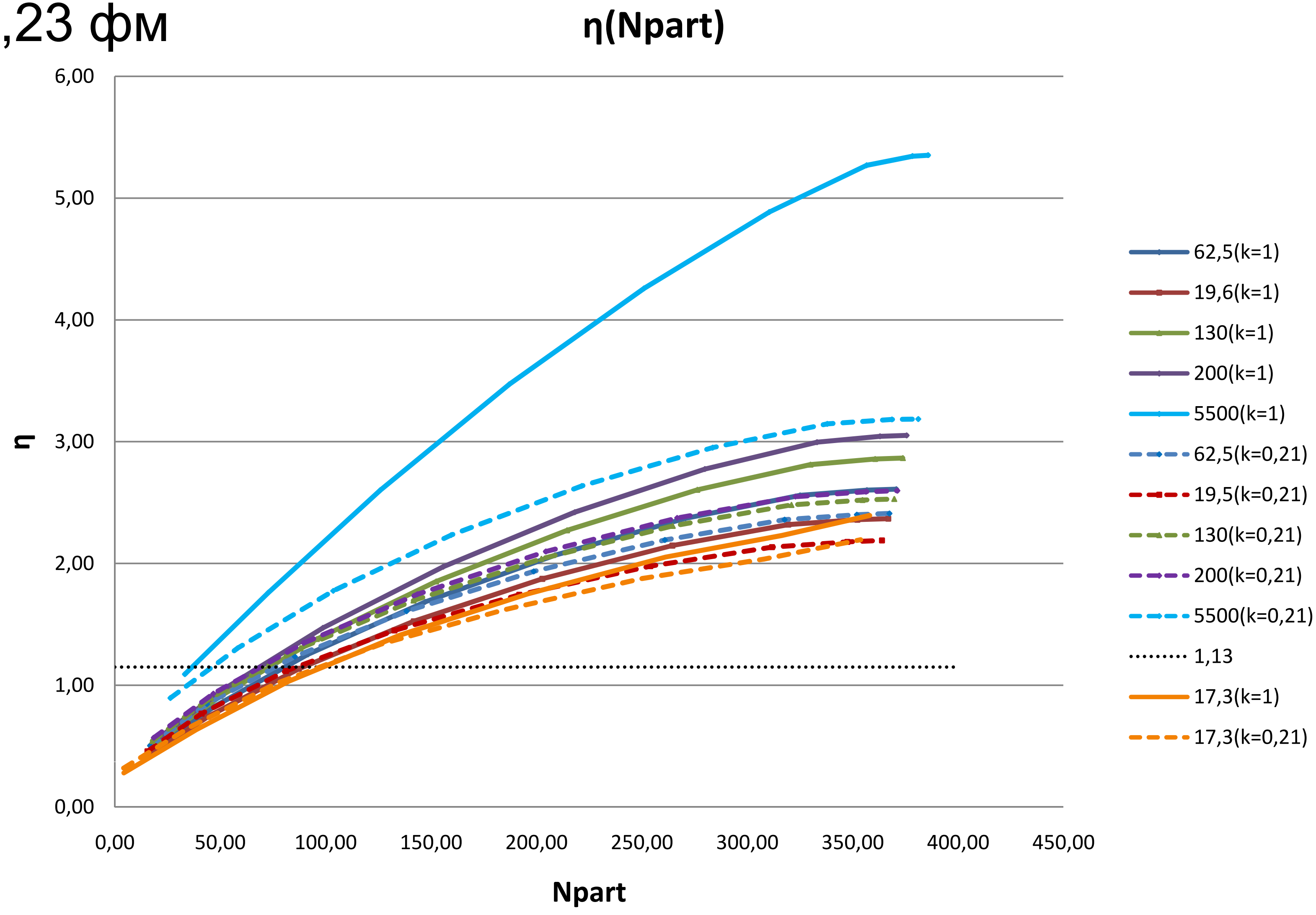
$\varepsilon_c \approx 0{,}3\text{-}1{,}3$ ГэВ/фм^3 [4]

$\varepsilon_c \approx 0{,}73$ ГэВ/фм^3 [2]

[4] CERN/LHCC 2003-049. ALICE PPR Volume I. 7 November 2003. P.4-6

Parameter percolation vs. Npart for energes from 17,3 GeV to 5500 GeV

r_0=0,23 фм



$$N_{str} = \eta_c \frac{S}{\pi r_0^2} \qquad N_{str} = N_S + N_V$$

$$N_{str} \sim N_{coll} \qquad N_v = N_{part}$$

Nv – number of valent strings
Ns – number of sea strings
Ncoll – number of collisions
(taken from the Monte-carlo calculation for Glauber model)

$$N_s = N_{str} - N_V$$

$$\sqrt{s} = 17{,}3 GeV, Pb + Pb$$

r_0=0,2 fm

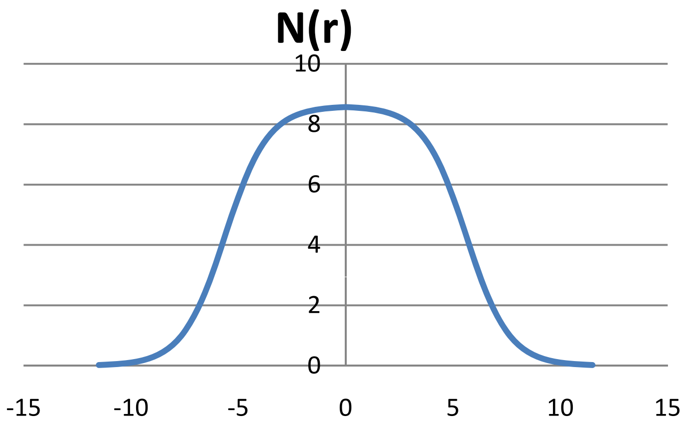
$N_v = N_{part}$	Nstr	Ns	Ncoll (s)	Ncoll (G)
110	503,6	393,6	251,8	180,6

$N_{str} = 2N_{coll}$

[10] J.Dias de Deus and A. Rodrigues// Phys. Rev. C 67, 064903 (2003).

Diffuse edge model

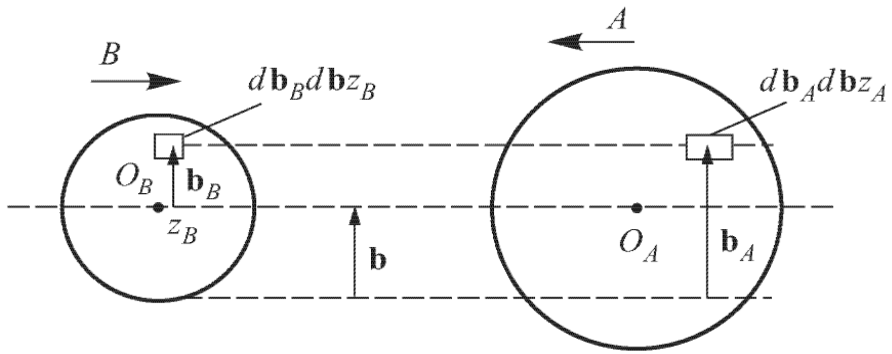
Pb+Pb

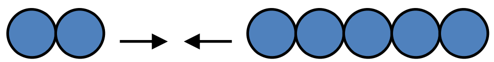


$$N(r) = 15{,}735 \frac{1}{1+\exp\left(\frac{r-R}{c}\right)}$$

R=1,07·A^(1/3) fm, c = 0,545 fm

Glauber model.





$N_{part} = 7$

$N_{coll.} = 10$

$$N_{pat}^{AB}(b) = A\int d^2t T_A(t)\{1-[1-\sigma_{in}T_B(b-t)]^B\} + B\int d^2t T_B(t)\{1-[1-\sigma_{in}T_A(b-t)]^A\}$$

Wit Busza RHIC Physics Through the Eyes of PHOBOS// Moriond, March 2003

Percolation parameter vs. number of participant.

$$\sqrt{s} = 200GeV, Au + Au$$