Shear & bulk viscosity for pp, pPb collisions in the string percolation model

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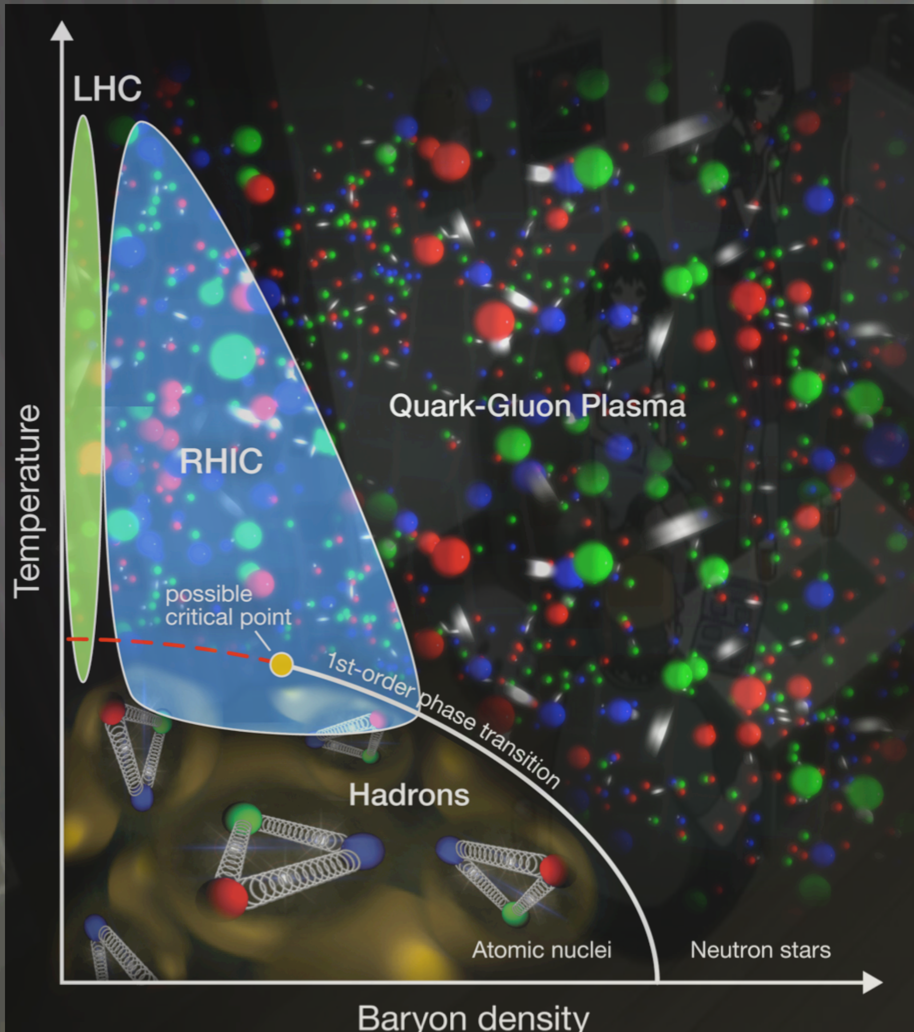
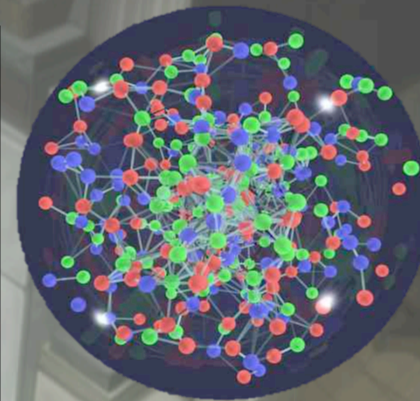
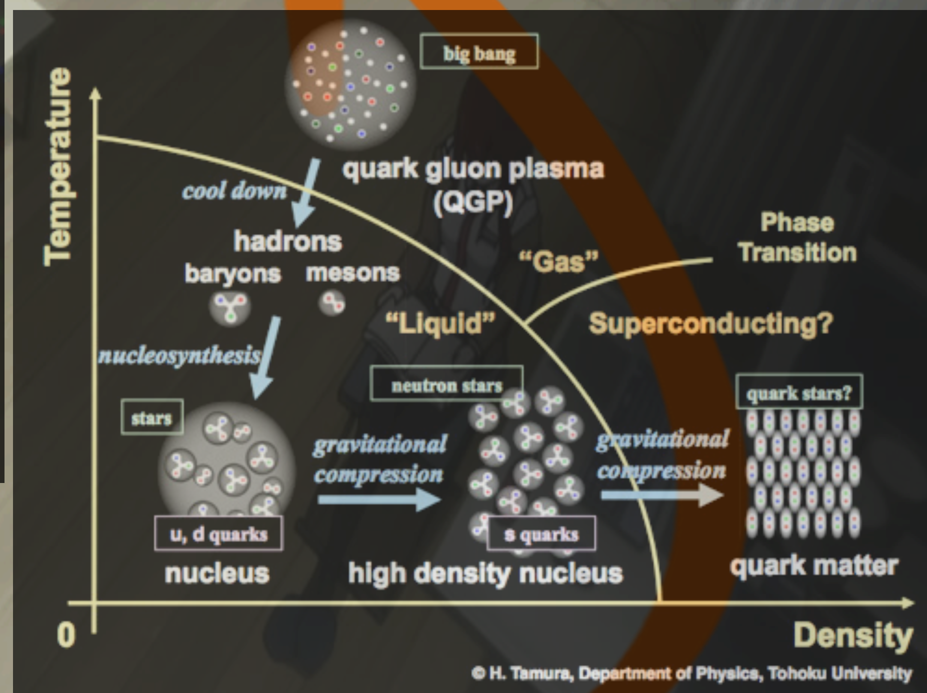
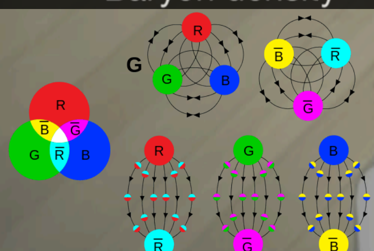
Abstract

Within the color String Percolation Model, the contribution of bulk viscosity in pp and pPb collisions is exposed for the first time. It is intended to exhibit a phase transition as a change on this variable in the critical temperature region.





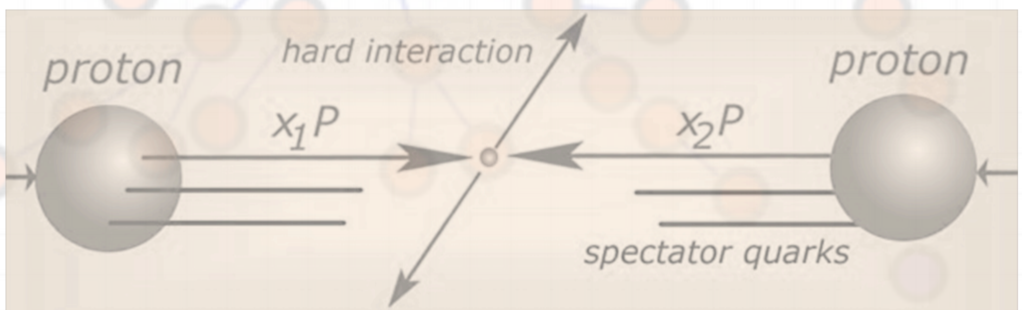




Images from…
http://www.emiliosilveravazquez.com/blog/2013/04/24/fisica-a-conocer-la-naturaleza/
http://www2.kek.jp/proffice/archives/feature/2010/StrangeHadronTheory.html …and Steins;Gate

String Percolation Model

The percolation theory uses scaling and power laws to make descriptions. From these we can obtain the critical points of thermodynamic quantities.



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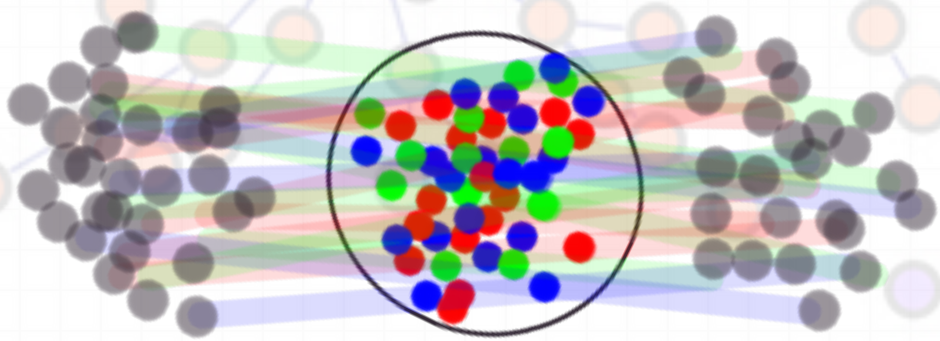

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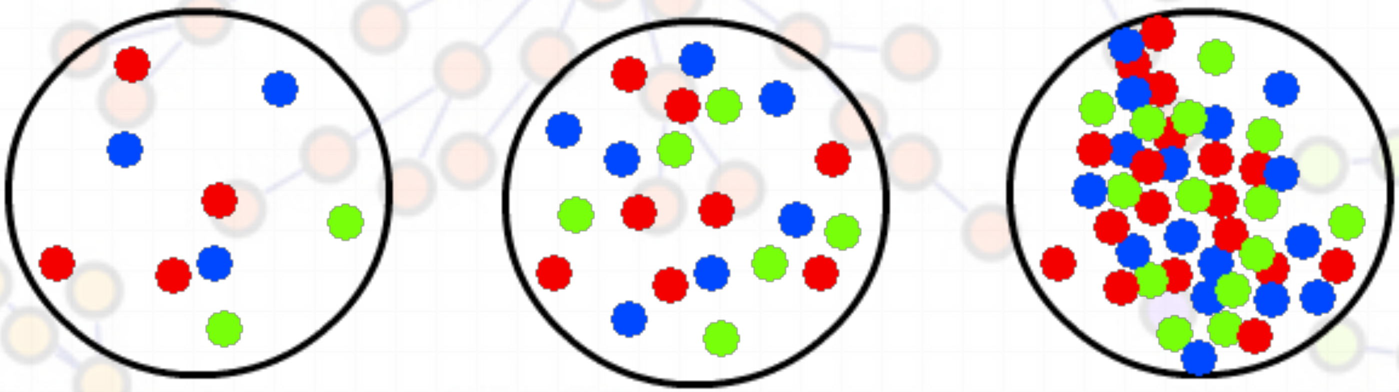


At a given critical temperature we will have a geometric phase transition or connected system

Model parameters

To study percolation, a density of elements is necessary:

$$\zeta^t = \frac{S_0}{S_p}\bar{N}^s$$

$$\frac{dN}{dy} = kF(\zeta^t)\bar{N}^s$$

The multiplicity of particles depends on the average number of strings and is scaled by a factor that is a function of the density parameter (in the central rapidity region).

The function that describes this color saturation is:

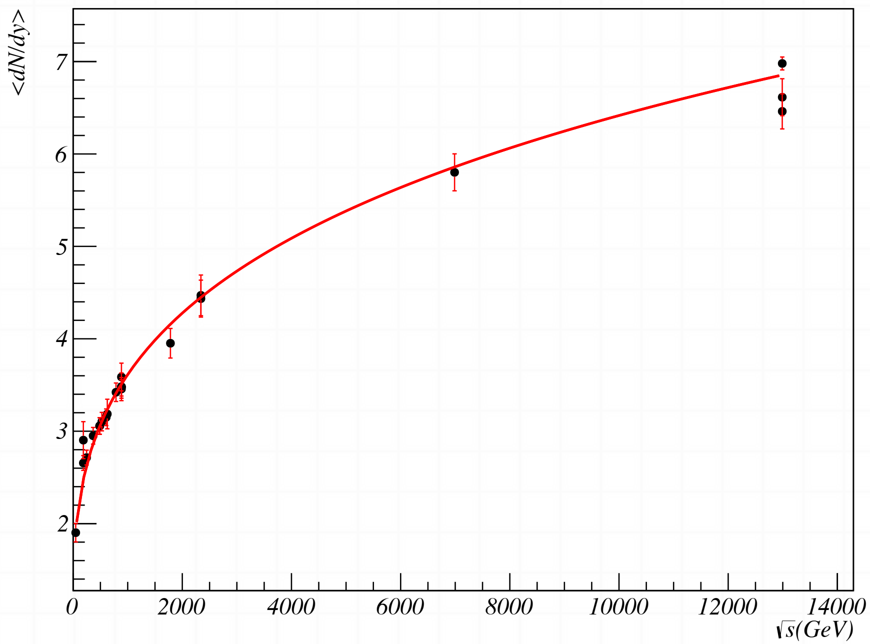
$$F(\zeta^t) = \sqrt{\frac{1-e^{-\zeta^t}}{\zeta^t}}$$

[1] Bautista, I. Milhano, J. G. Pajares, C. 2012. and Dias de Deus. J.Phys.Lett.,B715,2

The overall fit to all energies of this multiplicity in the region of central rapidity provides the values that will be used

$$\frac{dN}{dy} = kF(\zeta^t)\bar{N}^s$$

Multiplicity dependence of $\sqrt{s}$



	$\sqrt{s}$(TeV)	N^s	ζ^t	$F(\zeta^t)$
pPb	5.02	9.747293703	0.609205856	0.865374147
pp	7	10.85516256	0.678447660	0.852093488
	2.76	8.091336298	0.505708519	0.885936059
	0.9	5.882152711	0.367634544	0.914757690

$$\bar{N}^s = 2 + 4\left(\frac{S_0}{S_p}\right)\left(\frac{\sqrt{s}}{m_p}\right)^{2\lambda}$$

[1] Bautista, I. Milhano, J. G. Pajares, C. 2012. and Dias de Deus. J.Phys.Lett.,B715,230
[a1] J. Adam et al. [ALICE Collaboration], Phys. Lett. B 753 (2016) 319
[a2] V. Khachatryan et al. [CMS Collaboration], Phys. Lett. B 751, 143 (2015)
[a3] G. Aad et al. [ATLAS Collaboration], Phys. Lett. B 758 (2016) 67

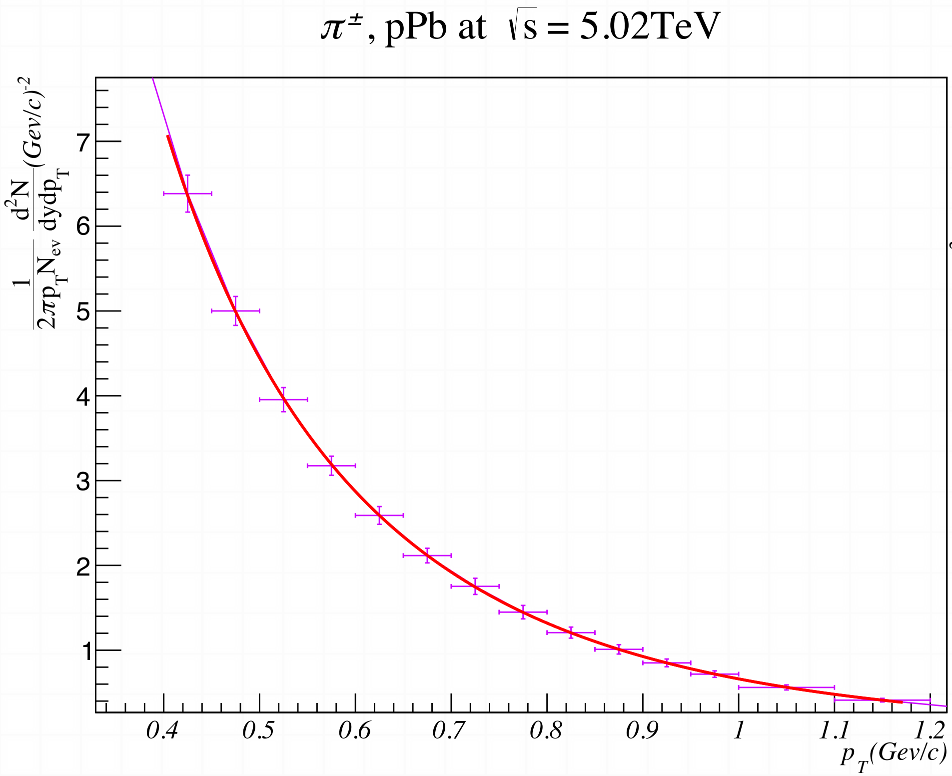
To determine the parameters we use a fit for the invariant transverse momentum spectra with the minimum bias for charged particles is used, with three energy dependent quantities from the following power law:

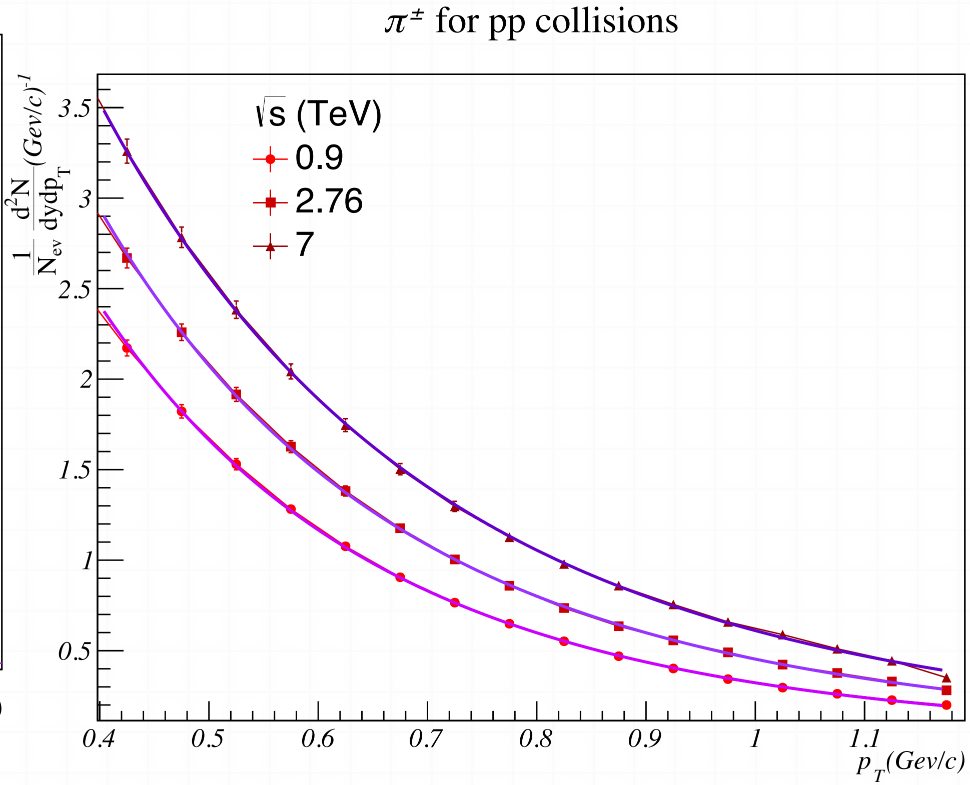
$$\frac{1}{N}\frac{d^2N}{dp_T^2} = \frac{(\alpha-1)(\alpha-2)}{2\pi p_0^\alpha}\frac{p_0^\alpha}{[p_0+p_T]^\alpha}$$

of which we have

$$\frac{d^2N}{dy dp_T} \sim \frac{p_0^{\alpha-2}}{[p_0+p_T]^{\alpha-1}}$$

[2]Braun, M. A. Dias de Deus, J. Hirsch, A. S. Pajares, C. Scharenberg, R. P. and Srivastava, B. K., arXiv 1501.01524 [nucl-th].





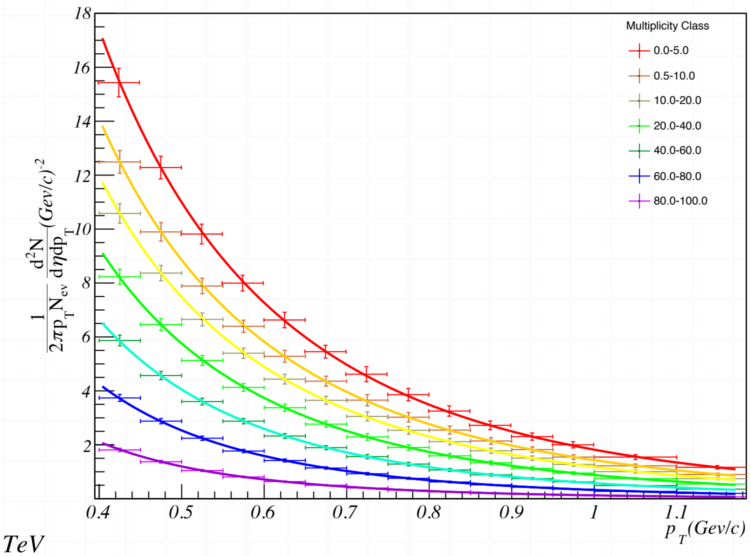
	$\sqrt{s}$(TeV)	a	p_0	α
pPb	5.02	29.79±6.76	3.373±0.91	10.98±2.22
pp	7	33.12±9.30	2.32±0.88	9.78±2.53
	2.76	22.48±4.20	1.54±0.46	7.94±1.41
	0.9	23.29±4.48	1.82±0.54	9.40±1.80

[3]ALICE Collaboration, Phys. Lett. B 728 (2014) 25–38. arXiv:1307.6796
[4]S. Chatrchyan et al. [CMS Collaboration], Eur. Phys. J. C 72 (2012) 2164.

The deviation is used for each type of multiplicity with respect to the minimum bias spectra.

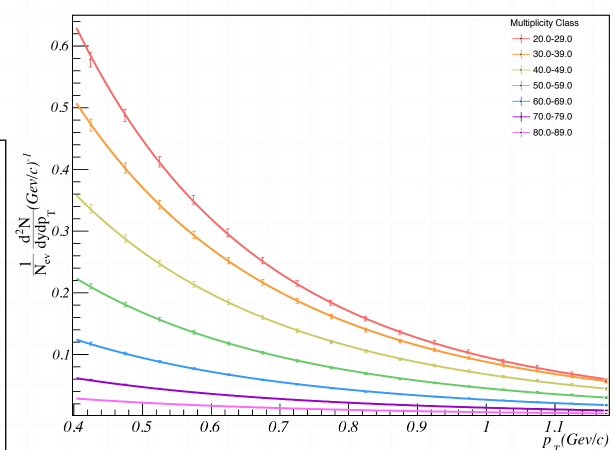
$$\frac{d^2N}{d\eta dp_T} = \frac{a\left(p_0\sqrt{\frac{F(\zeta_{pp})}{F(\zeta_{HM})}}\right)^{\alpha-2}}{\left[p_0\sqrt{\frac{F(\zeta_{pp})}{F(\zeta_{HM})}}+p_T\right]^{\alpha-1}}$$

pPb $\sqrt{s} = 5.02$ *TeV*

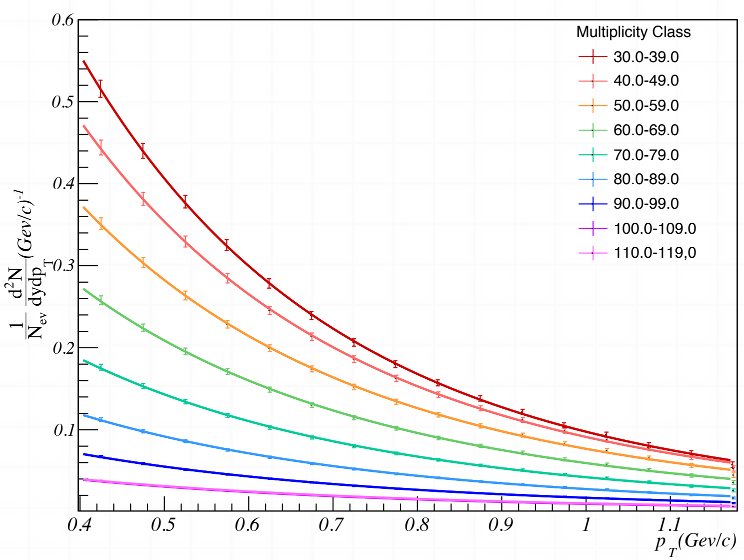


Lowest multiplicity in red

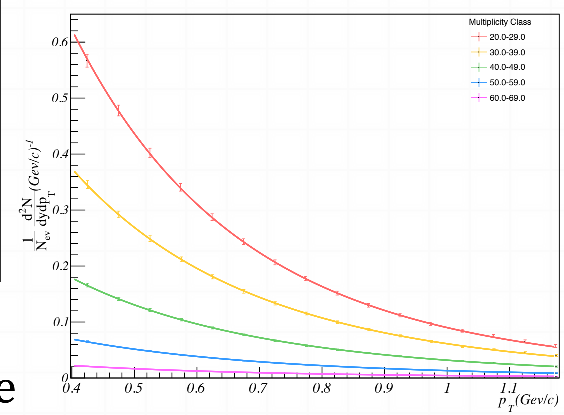
pp $\sqrt{s} = 2.76$ *TeV*



pp $\sqrt{s} = 7$ *TeV*



pp $\sqrt{s} = 0.9$ *TeV*



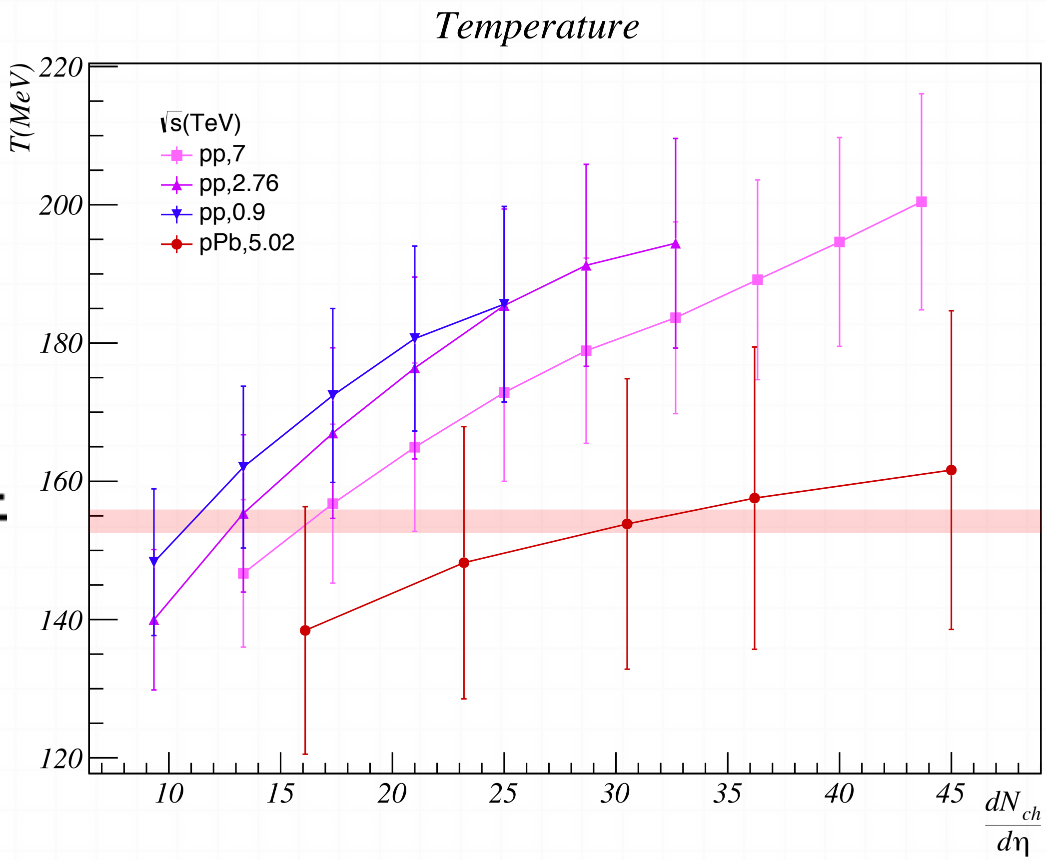
Highest multiplicity in purple

[3]ALICE Collaboration, Phys. Lett. B 728 (2014) 25–38. arXiv:1307.6796
[4]S. Chatrchyan et al. [CMS Collaboration], Eur. Phys. J. C 72 (2012) 2164

To obtain the temperature we used the distribution for the color field fluctuations modulated by the Schwinger mechanism. As they are related to the average tension of strings and thus with the color reduction factor is proposed to be proportional to the inverse square root of this factor.

$$\frac{dN}{dp_T} \sim e^{-\sqrt{2F(\zeta^t)}\frac{p_T}{\langle p_T \rangle_1}}$$

$$T(\zeta^t) = \frac{\langle p_T \rangle_1}{\sqrt{2F(\zeta^t)}}$$



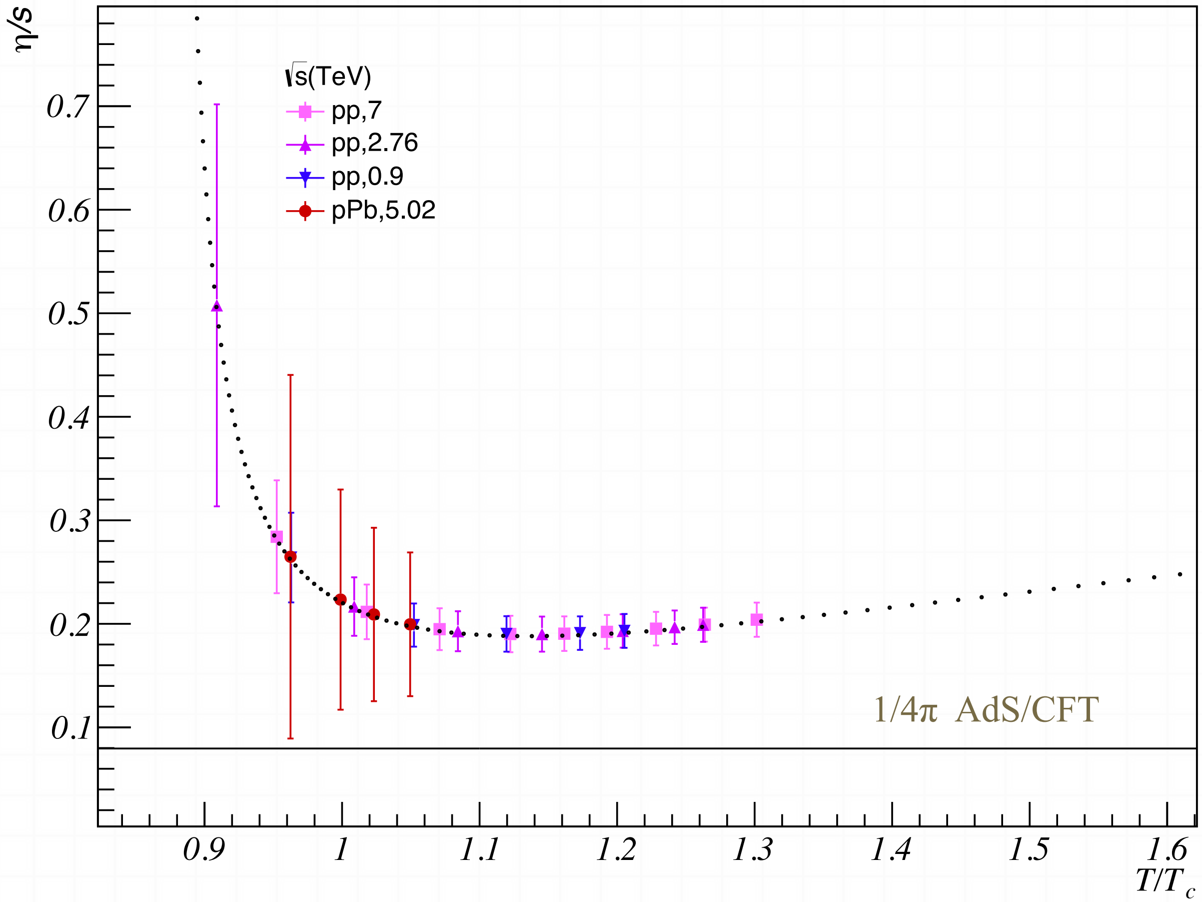
[5] J. S. Schwinger, Phys. Rev. 128 (1962) 2425. doi:10.1103/PhysRev.128.2425
[6] A. Bazavov et al. [HotQCD Collaboration], J. Phys. G 38 (2011)

Viscosity

Experimental results had showed that systems formed from collisions at LHC share characteristics with a near-perfect fluid.

In general, for any material there are two types of viscosity defined: the shear which has to do with surface tension and the bulk depending on the internal characteristics of the fluid also called volumetric viscosity.

Shear Viscosity



$$\frac{\eta}{s} = \frac{TL}{5(1 - e^{-\zeta^t})}$$

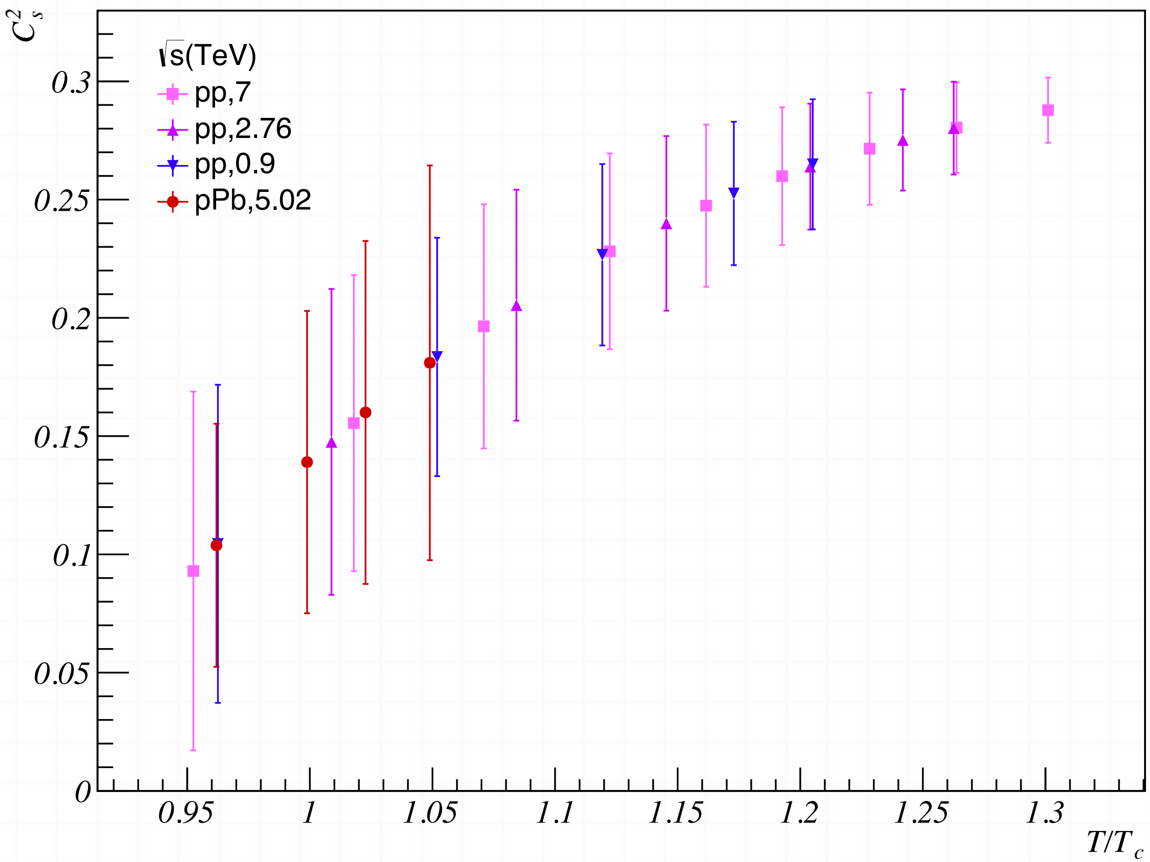
From the kinetic theory, a mean free path is assumed for the sources in a way that relates the viscosity to the string density parameter.

[7] P. K. Kovtun, D. T. Son, A. O. Starinets, Phys. Rev. Lett. 94 (2005) 111601.
[8] I. Bautista, A. F. Téllez and P. Ghosh, Phys. Rev. D 92 (2015) no.7

$$c_s^2 = \left(\frac{e^{-\zeta^t}}{F(\zeta^t)^2} - 1\right)\left(-0.33 + \frac{0.019\Delta}{3\zeta^t F(\zeta^t)^2}\right)$$

Speed of Sound

A property describing the internal behavior of a medium is the rate at which the sound is propagated. The model provides an expression for its determination.



[1]Braun, M. A. Dias de Deus, J. Hirsch, A. S. Pajares, C. Scharenberg, R. P. and Srivastava, B. K., arXiv 1501.01524 [nucl-th].

Conclusions

The speed of sound is according to the results of Lattice

Thank you !!!

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