



The Plasmonic Phase and Hydro-dynamical Modeling.

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Abstract: This paper converses about the brief appraisal for few accomplishments during the exploration and studies regarding the Quantum Chromo-dynamics plasmonic stuff appears into picture at elevated thermal conditions via the nuclear impinging at relativistic energies. Here the description is based on bulk properties uniquely not on the soft perspective. More precisely we are watching at hydrodynamic as well as thermo- dynamic bulk properties.

Keywords: Quantum Chromo-dynamics, plasmonic stuff, Glauber thermo- dynamic bulk properties.

I. Introduction

The plasmonic phase of quarks and gluons has a sturdily interacting nuclear stuff (as depicted in figure 1) anticipated by Quantum-Chromo-Dynamics (QCD) and is created whether at adequately elevated thermal conditions or rich baryon densities. This is the state where quarks and gluons have much larger degrees of freedom as compared to a classic hadron dimension. This atypical QCD pursue from the asymptotic freedom hypothesis describes that the interplays of elementary fields get feeble with amplified energy density.

As a result of that, a demand of critical thermal condition is there for such sturdily interplaying arrangement which isolates the state of deconfinement of plasmons with the hadron gas and currently it is well proved for chemical potential's zero value at least, the conversion of hadron gas to plasma state is a incessant one [1]. The investigational pursue for nuclear plasma is continuously revealing the hidden aspects of impinging of bulky nuclei at elevated energy spectra. Choosing the bulky nuclei for impacts is to attain a space province in which highly dense condition is expected to accomplish than the classic hadron dimension for appropriate deconfinement. Hence, at a given nucleon's beam energy, the creation of plasma appears more probable with bulky nuclei, in comparison to the impacts amidst proton and proton, though remarkable resemblance is perceived in the two arrangements.

The investigational agenda has been instigated for colliding the bulky ions with distinct centre-of-mass energy values, from few GeV at BNL in alternating gradient synchrotron amidst gold and gold nuclei a transitional energy spectra like 6-17 GeV with lead-lead nuclei at CERN in super proton synchrotron till hundred GeV at relativistic heavy ion collider (BNL) and RHIC, and lastly 2009 onwards the impacts amidst lead-lead using large hadron collider at energy in few TeV. Scientists are in search of dominating signatures and prods related to the end state evident particles generated through the nuclei impacts.

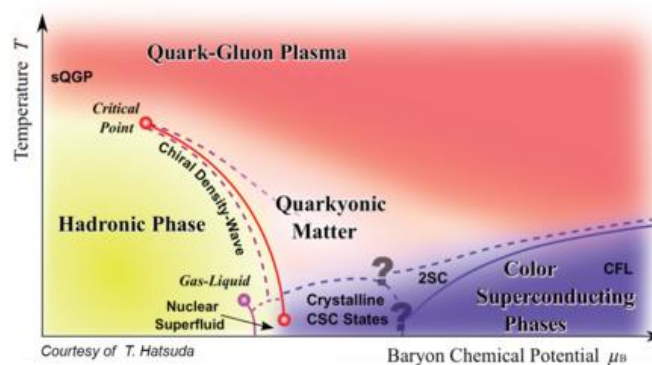


Figure 1: Quark-Gluon plasma phase diagram.

Here a depiction of soft probes of hadrons is presented without considering the other hard probes. Since the entire mechanism of two nuclei impinging with elevated energies is much intricate, majority of phenomenology are altered with variant approaches and modeling. The most thriving depiction out of amongst all of impact's consideration is the "hydrodynamic approach" as its foundation is a universal physical idea than that of the atypical suppositions. This hydrodynamic depiction is actually endowing great imminence perspective to the highly energetic nuclear impacts and result into the plasma creation.

1. Consideration of plasma almost like a perfect fluid

The hydro-dynamical depiction is acceptable prudently for the progression of plasma states two conditions are must: the first is to get the arrangement being close proximity to the local thermodynamic equilibrium for a satisfactorily extended duration, means it should be attainable in the preliminary state in plasma transition phases, secondly the usual micro interaction extent must be too diminutive in comparison to the length of alteration of temperature also the energy density, thus too diminutive than the system's dimension. The proceedings which are not perturbative i.e. going ahead toward local thermalization within fluid-like, are yet to be explored. Nevertheless if the first supposition embraces, mostly the fluid like phase of plasma be much of the life of the plasma can be drawn up via continuity equations of hydrodynamics, so long as the hadronized stage transpires and the later constraint usually gets satisfied for bulky ion impacts at relativistic energy zone because fireball is anticipated of possessing the radii dimension of the order of few Fermi whereas the microscopic extent must be lower to one Fermi.

The enumeration routed on hydrodynamics attempts for drawing up the continuum of particles gauged at small momenta values and for establishing the preliminary state of affairs like energy density lay out, regulate the corresponding parameters along with the factors; thermal magnitude and baryon chemical potential factors on which hydrodynamic establishment terminates. Getting the equation of state is an utterance of lattice QCD consequences for elevated thermal condition also the hadron-resonance gas down the critical precondition. Typically accepted preliminary prerequisite conditions comprise a density lay-out enumerated by the geometric overlapping caused by two approaching nuclei also the effluence lay-out in longitudinal dimension as per the Bjorken's scaling speculation with disappearance of transversal direction effluence. The majority of computations point to a premature equilibrium period $\approx$ one fermi/c at Super Proton Synchrotron as well as Relativistic Heavy Ion Collider's energy spectra, for the preliminary thermal condition quite beyond that of critical condition of the order of 160 Mega electronVolt.

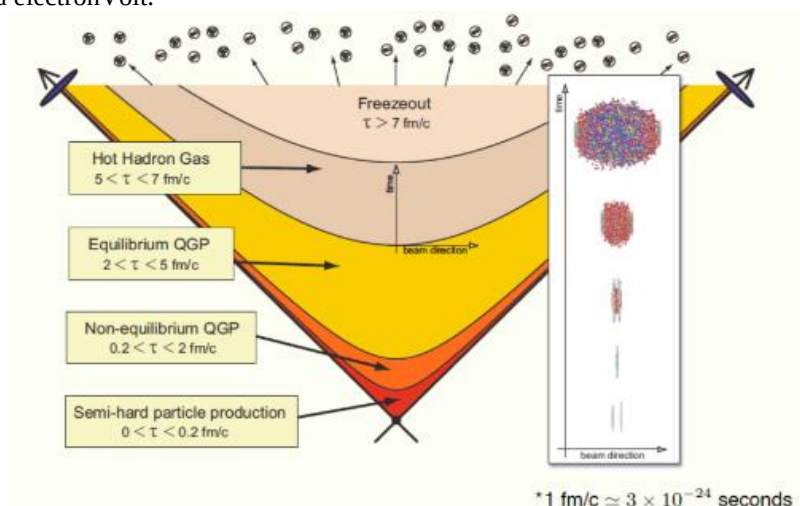


Figure 2. Outline depicted for nuclear impacts at relativistic elevate energy level, showing thermalization attainment subsequent to impact, later expansion of plasmonic phase and transit to hadronization as reaches to critical level of QCD thermal condition. Afterwards hadronized gas grows and reaches to freeze out.

One of the significant probe or feature is elliptic effluence reflects the anisotropy in the momenta continuum of particles in azimuthal dimension within the plane of reactance for sideways impacts. For the impact parameter above zero values, the geometrical overlapped zone depicted as almond shaped and not the sphere kind we expect in centric impinging. When the local thermal equilibristic condition situates earlier stage leads to considerably elevated pressure gradient within the plane of reactance than that of the normal direction. Thus augmented collective effluence and consequently enriched particle momenta along the plane of reactance.

Elliptic effluence i.e. flow is weighed via the second order expression of the Fourier series extension of term $dN/dp_T d\phi$ and varying with ϕ with constant transverse momenta values, symbolized as v_2 as a function of transverse momenta. For attaining the elevated v_2 values, essential conditions are like need to reach equilibrium soon along with feeble viscous field; means almost like a perfect fluid. Because of the feature of apparent behavior of QCD stuff more likely to be a perfect fluid, offered agreement with the myth about QGP being a fluid possessing

sturdy interactions within, having disparity to the anticipation of gaseous form of plasmons interplaying feebly. Undeniably, the lattice QCD enumeration designates the energy of interplay action being extremely considerable in the vicinity of the critical temperature magnitude; almost one third than that of the overall energy denseness. The computed low proportion of viscosity to entropy (η/s) as per hydro-dynamics fitting, strengthens this consequence and merely comprehended using the much proverbial expression for viscosity as per the kinetics:

$$\eta = \frac{1}{3} \rho v_T \lambda(1)$$

Here ρ signifies mass-denseness, v_T referring the average thermal velocity and λ ; mean free path. Let we alter the expression mentioned in eq. 1 by the use of averaged thermal momenta p_T also the particle's density n :

$$\eta = \frac{1}{3} n m v_T = \frac{1}{3} n p_T \lambda(2)$$

So making a skilled supposition for its approach towards the relativistic arena as reinstating particle's denseness term n to the entropy denseness term s (provides gauge about the degrees of freedom microscopically). Thus

$$\frac{\eta}{s} = \mathcal{O} p_T \lambda(3)$$

Means the proportion relation of viscosity to the entropy possesses the order of ratio of averaged free path to the particle's averaged wavelength. In the normal case of any liquid this ratio is too bigger than one. As the value is one or below that like the state of QGP [2], for this the above mentioned ratio in eq. 3 is approximately $1/2\pi$ i.e. the averaged free path value is below to thermal particle wavelength, entails a crash of the kinetic. Principally, we get, for temperature magnitude equal to 160 MeV:

$$\lambda = \mathcal{O} \left(\frac{\eta}{s p_T} \right) \approx \frac{1}{2\pi T} \cong 0.2 \text{ fermi} \quad (4)$$

Undeniably, plasma close to the critical thermal condition is an extraordinary illustration of a liquid phase which does not possess the essential kinetic basis (consequently it does not has aggravation of impinging particle or quasi particle), an attribute contributed with the well known Fermi gas [3]. So the case of such arrangement, a kinetically behaving explanation containing self-governing bumping particles is thus doubtful. Yet the hydro-dynamically explained depiction holds well, takes account of transport coefficients. Certainly, it's quite probable devising hydro-dynamical approach by employing averaged value of the elementary quantum stress-energy tensor operator: $T^{\mu\nu} = \text{tr}(\hat{p}\hat{T}^{\mu\nu})$ (5)

Thus for illustrating that overall coefficient referring transportation may be characterized in the way of two-point functions of this tensor at equilibrium condition utilizing the Kubo modulus operandi [4].

2. Freeze-out condition in a growing hadron gas

The plasma of nuclear stuff enlarges then chills down to the state of critical thermal environment at which it gets hadronized. The gaseous hadronic phase enlarges till particle's mutual interaction seizes means the freezing out situation. For an enlarging organism where the particles interact, the freezing-out of interacting particles freeze-out state arises for averaged scattering time τ_{scatt} goes beyond the averaged collision time τ_{exp}

$$\tau_{scatt} = \frac{1}{n\sigma(v)} > \tau_{exp} = \frac{1}{\partial.u} \quad (6)$$

Here u refers the velocity field of hydro-dynamics also the term $\langle v \rangle$ depicts averaged particle velocity. It all depends on the cross-section nature; if it is opted for inelastic case the freeze out referred as chemical freeze-out on the other hand if for elastically happened proceedings we see, it is the kinetic one. The freeze-out appears chemically definitely goes prior to the kinetical one because in magnitude terms inelastic cross-section is found lesser to the overall one.

3. Ahead of Hadronization: Modeling through statistics

Along with variant modeling anticipated for describing the hadronic creation's attribute quantitatively while studying the relativistic bulky ions impinging, the hadronization modeled statistically is a good approach. Moreover it is significantly doing well to reproduce particle's multiplicities by means of some parameterization, and the modeling is opted well practically for each and every one hydrodynamic enumerations analyse the hadronization from the fluid plasmons utilizing the Cooper-Frye's depiction, imposing local thermo-dynamic equilibria. Besides all this the modeling is proficiently useful for the reproduction of multiplicities with respect to the hadrons, in basic nuclei impacts, from positron-electron also from proton-proton lower up to higher energies spectra [5]. Consequently, it reflects that statistic based modeling grabs an atypical widespread attribute for the process of conversion to hadrons. Some anticipation says about the attainment of thermalization via manifold impacts on hadronic level [6, 7]. While few [8] supports the concept that it is because of conversion to hadronic phase, it tends to increase to equilibrated hadronic arrangement. As explained by Hagedorn's concept the hadronic creation occurs in equilibrated condition because it is must to utilize dispensation statistically seen in basic impinging which possess multiplicities in a way that freezing-out condition matches with hadron, & predominantly, the evident complete equilibration happened chemically of strange element profusion for appropriate clarification.

So if hadronic conversion helps in rising the hadronic populace in equilibrium, the afterward proceedings do influence it or not as it is too significant to know the mechanics of hadronic creation in basic as well as relativistic bulky ions impinging. To depict this in an extremely idyllic approach - the key proceedings in the progression to show the way to freezing-out condition in relativistic nuclei impinging, pointing by the side of a time-oriented alignment. In a real picture, freezing-out mechanisms are incessant, depends on type of particles, have geometrical dependence as well as overlapping.

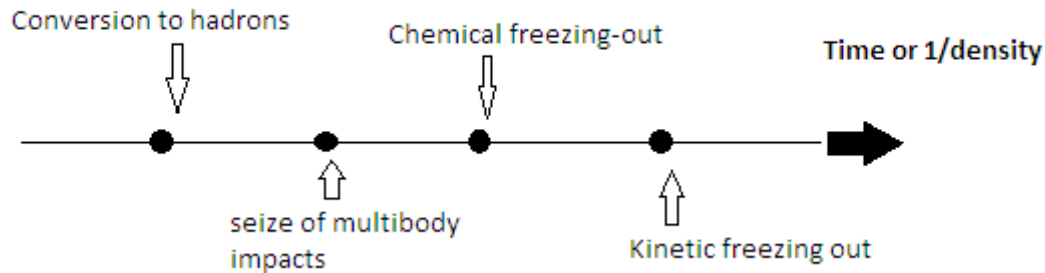


Figure 3. The time progression of all proceedings happens during the evolution inside the sturdy plasma phase of strongly interplaying hadron particles then proceed to multi-particle impacts. Later the most of binary impacts endure up to chemically freezing-out condition and then to freezing-out kinetically.

Following the hadronic state the arrangement commences to get bigger, yet it can reside slightly in the sturdy coupling organization and here its depiction as a kinetically behaving organism is not acceptable as per earlier conversation. On a position, chemically equilibrated organization dies away also the period of binary impinging places in, with the condition when number of particles is beyond $O(100)$. For some duration the impinging happen in-elastically i.e. the chemically freezing out later on up to kinetic freezing solely elastically happened impinging crop up, lastly the organism gets decoupled. Survival of a phase of where binary impinging succeeds is established via these chief facts:

(i) The repression of momentary resonances weighted against the prolonged particles using statistically performed modeling in shape [9, 10, 11], a consequence is not observed in basic impinging [12] and is explainable via the re-scattered outcomes of resonance decay within the escalating system, which is not probable with a diminutive organism.

(ii) The disparity amidst the thermal condition concluded during multiplicity fitting also the fitting in the transversal band [11]. Thus signifies the continuity of elastically happened interplays later to the chemically freezing-out condition. And the consequence is also not probable in basic impinging [12].

(iii) The thermal conditions dependence at kinetically appeared freezing-out varying with the impact parameter [11, 13]. The decouple feature of impinging trusts upon the particle multiplicity, like observed already also on geometrical specifications, and it takes place for upper denseness values in case of smaller multiplicity values.

It is well approved that the kinetic arena exists in which hadronic interplays take place elastically, On the other hand the verification for profusions means hadronic chemical de-coupling next to the phase of binary impacts is still dubious. Because if there survives a phase of this kind the profusion of hadrons must reflect a digression from the preliminary chemical equilibration circumstances [14]. The novel investigation on output of anti-particle of proton with Super-Proton Synchrotron energies [15] also with Large Hadron Collider [16] reflected in appreciably inferior values in contrast to statistically performed modeling sortileges [17]. These outcomes are has been soon inferred as the consequence of in-elastically happened re-scattering later to the hadronization, in the case when the annihilation of anti-baryons occurs prior to the chemically freezing-out condition tend to rise pion multiplicity [18, 19] and it is reflected that this annihilation must present in the phase of impinging amidst duo bodies and enent simulated via Monte-Carlo model like UrQMD [20] take account of binary impacts solely. Though, it is stated, that the partition from N numbered-ary to binary impinging phases are not pronounced enough [21] it is seen that the re-generation process as a result of aback-reaction of N pions collisions may go on lately too.

It has been observed in re-analyzing the data with supposition of equilibration at conversion to hadrons condition also the consequent elastically re-scattered phase next to hadronizing stage via UrQMD calculations as alteration features provides an improved fit to the figures and a hadronic segment found concurrent with Quantum Chromodynamics lattice line using extrapolation [22]. Still UrQMD modeling not takes account of N more than 2-nary impinging, it is a prominent sign that proceedings happen in-elastically subsequent to hadronic conversion affect a lot and the chemically freezing-out condition does not concur with conversion to hadrons process. Hence the inclusion of all proceedings appropriately, there is a probability of reconstructing the actual hadronic appearance situation.

II. Summary & Conclusions

The experimentation and investigations on relativistically impinging of bulky ions for elevated energies are going on from Super-Proton-Synchrotron till Large Hadron Collider spectra providing the confirmation for a variety of Quantum Chromo-dynamics speculations for the plasmonic state of sturdily inter-participating stuff. Still few characteristics regarding the phasor depiction are not explored completely; one of them is about the presence of critical point, which is in process to explore with the future experimentations at CERN and GSI. The plasmonic state of torrid nuclear stuff generated in earthly laboratories, provides an exceptional prospect for building up, investigating also widening the relativistic province with the theoretic ways employed for the typical stuff.

References

- [1] Aoki Y, Endrodi G, Fodor Z, Katz S D, and Szabo K K 2006 Nature **443** 675
- [2] Heinz U, talk given at the workshop Relativistic Aspects of Nuclear Physics 2013, Rio de Janeiro, September 2013
- [3] Casalderrey-Solana J, Liu H, Mateos D, Rajagopal K, and Wiedemann U A arXiv:1101.0618 [hep-th]; Adams A, Carr L D, Schaefer T, Steinberg P and Thomas J E 2012 New J. Phys. **14** 115009
- [4] Hosoya A, Sakagami M, and Takao M 1984 Annals Phys. **154** 229
- [5] Becattini F, An Introduction to the Statistical Hadronization Model arXiv:0901.3643 [hep-ph]; Becattini F and Fries R, in Relativistic heavy ion physics, Landolt-Börnstein 1-23 arXiv:0907.1031 [nucl-th] and references therein
- [6] Braun-Munzinger P, Stachel J, and Wetterich C 2004 Phys. Lett. B **596** 61
- [7] Noronha-Hostler J, Beitel M, Greiner C, and Shovkovy I 2010 Phys. Rev. C **81** 054909
- [8] Becattini F and Heinz U W 1997 Z. Phys. C **76** 269; Heinz U 1999 Nucl. Phys. A **661** 140; Stock R 1999 Phys. Lett. B **456** 277; Castorina P, Kharzeev D, and Satz H 2007 Eur. Phys. J. C **52** 187
- [9] Becattini F, Gazdzicki M, Keranen A, Manninen J, and Stock R 2004 Phys. Rev. C **69** 024905
- [10] Markert C 2005 J. Phys. G **31** S169
- [11] Blume C 2012 Acta Phys. Polon. B **43** 577
- [12] Becattini F and Passaleva G 2002 Eur. Phys. J. C **23** 551
- [13] Heinz U and Kestin G 2006 PoS CPOD **2006** 038
- [14] Bass S A and Dumitru A (2000) Phys. Rev. C **61** 064909
- [15] Anticic T et al. [NA49 Collaboration] 2011 Phys. Rev. C **83** 014901
- [16] Abelev B et al. [ALICE Collaboration] 2013 Phys. Rev. C **88** 044910
- [17] Becattini F, Manninen J, and Gazdzicki M 2006 Phys. Rev. C **73** 044905
- [18] Pan Y and Pratt S arXiv:1210.1577 [nucl-th]
- [19] Steinheimer J, Aichelin J, and Bleicher M 2013 Phys. Rev. Lett. **110** 042501
- [20] Petersen H et al. 2008 Phys. Rev. C **78** 044901 and references therein
- [21] Rapp R and Shuryak E V 2001 Phys. Rev. Lett. **86** 2980
- [22] Becattini F, Bleicher M, Kollegger T, Schuster T, Steinheimer J, and Stock R 2013 Phys. Rev. Lett. **111** 082302