Dissociation baryonic chemical potential of the QGP at momentum anisotropy with Quasi-Particle approach

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ABSTRACT : In the present work we have investigated the properties of the heavy quarkonia in the presence of finite baryonic chemical potential and momentum anisotropy by using the quasi-particle approach. The effect of the finite baryonic chemical potential has been incorporated through the quasi-particle Debye mass, and momentum anisotropy is used to examine the binding energies of the quarkonium states. We have also calculated the thermal width of the quarkonium states from the imaginary part of the potential and found that the thermal width is decreases with momentum anisotropy. The dissociation baryonic chemical potential of the states of quarkonia have been calculated with the help of thermal width in the presence of temperature and momentum anisotropy. The effect of the temperature and momentum anisotropy on the mass spectra with finite baryonic chemical potential of the quarkonium states has also been studied.

INTRODUCTION & MOTIVATION

- Matsui and Satz [1] was the first to study the dissociation of the quarkonia particularly that of charmonia (J/ψ) because of the color screening in the deconfined state.
- As we discuss the most of literature [2,3] calculate the dissociation temperature by several model under various impact parameter. Since in the QGP phase diagram (T-μ plane) two main condition for the existence of QGP are high temperature or high baryon density.
- Since the studies like [4,5], the authors have calculated the dissociation temperature by using the criteria that at the dissociation point thermal width equal to the twice of binding energy.
- We here in the present work, investigated the dissociation chemical potential in the presence of anisotropy by using effective fugacity quasi-particle model (EQPM).
- We calculated the dissociation baryonic chemical potential by the intersection point of the thermal width and twice of binding energy, the effect of the baryonic chemical potential has been introduced through the quasi-particle Debye mass.

RESULTS

- The variation of binding energy with baryonic chemical potential has been shown in the fig.1 for ground state of charmonium (left panel) and ground state of bottomonium (right panel). We clearly seen that, if we increases the value of anisotropy in the fig.1 the variation of binding energy is also increases. But if we increases the values of temperature the variation of binding energy is decreases.
- Same variation of anisotropy and temperature is also observed in the case of Mass spectra for the ground states of charmonium and bottomonium in the fig.2. The expression of mass spectra is equal to the sum of the twice of mass of quarkonia and binding energy.

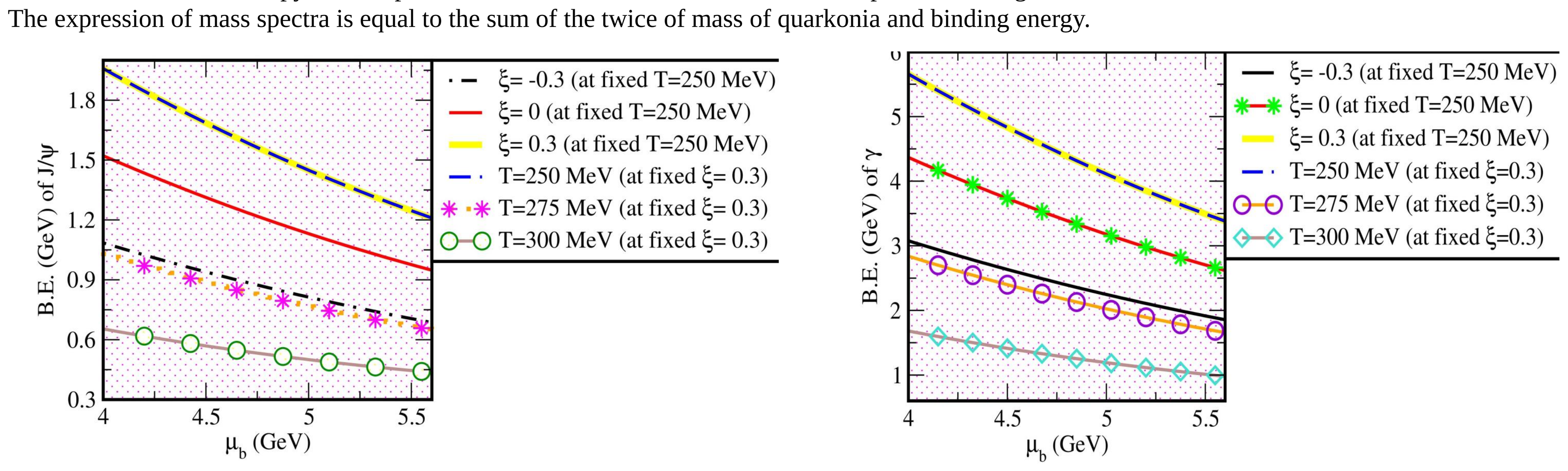


Fig 1: Variation of binding energy with baryonic chemical potential of J/ψ (left panel) and ϒ (right panel) at different values of anisotropy and temperature.

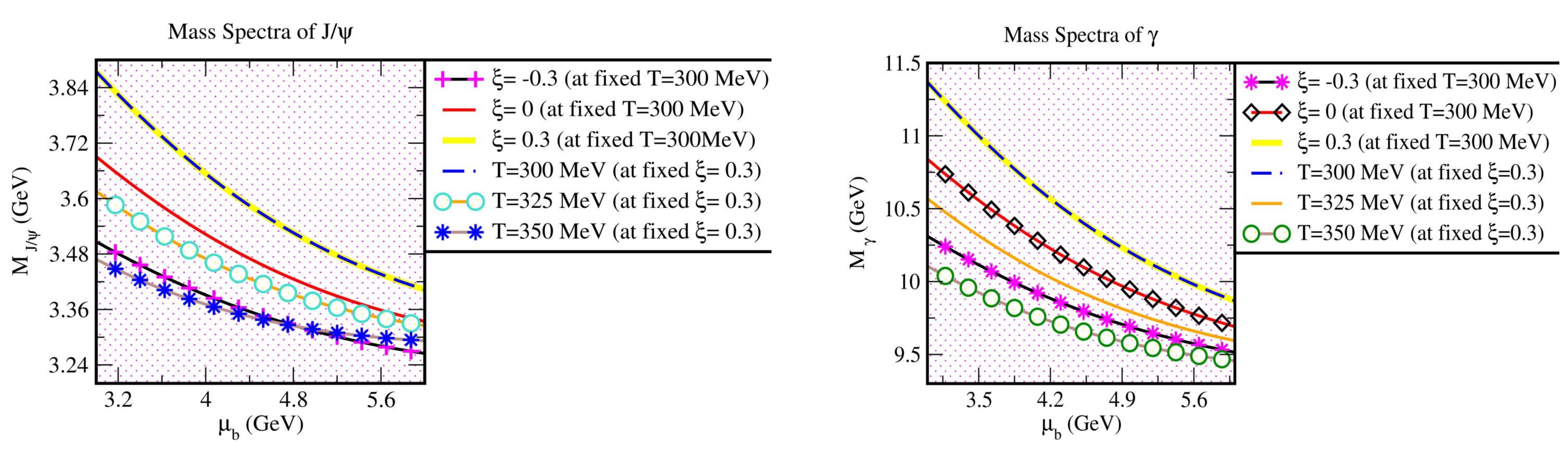


Fig 2: Variation of Mass Spectra with baryonic chemical potential of J/ψ (left panel) and ϒ (right panel) at different values of anisotropy and Temperature.

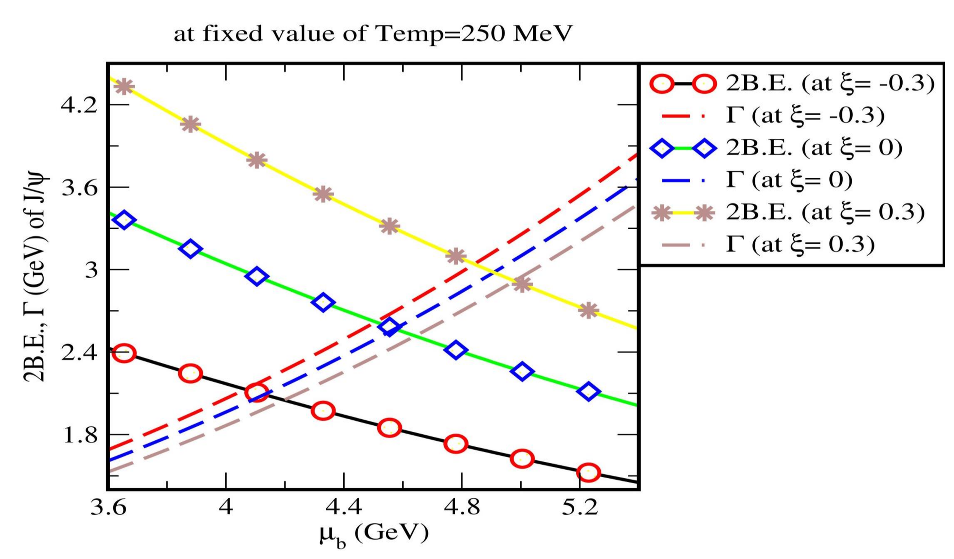


Fig 3: Variation of Thermal Width and 2B.E. with baryonic chemical potential of J/ψ at different values of anisotropy but the value of Temperature is fixed.

- In fig.3 we see the variation of thermal width and twice of binding energy with baryonic chemical potential at different values of anisotropy but the value of temperature is fixed. If we increases the value of anisotropy from -0.3 to 0.3, we see that the variation of binding energy is increases but the variation of thermal width is decreases.
- In fig.4 we see the variation of thermal width and twice of binding energy with baryonic chemical potential at different values of temperature but the value of anisotropy is fixed. If we increases the value of temperature from 220 MeV to 240 MeV, we see that the variation of binding energy is decreases but the variation of thermal width is increases
- The main reason of fig.3 and fig.4 is to calculate the dissociation baryonic chemical potential.
- The intersection point of the variation of twice of binding energy and thermal width is known as dissociation baryonic chemical potential.
- The values of dissociation baryonic chemical potential has been shown in the table-1 and table-2.

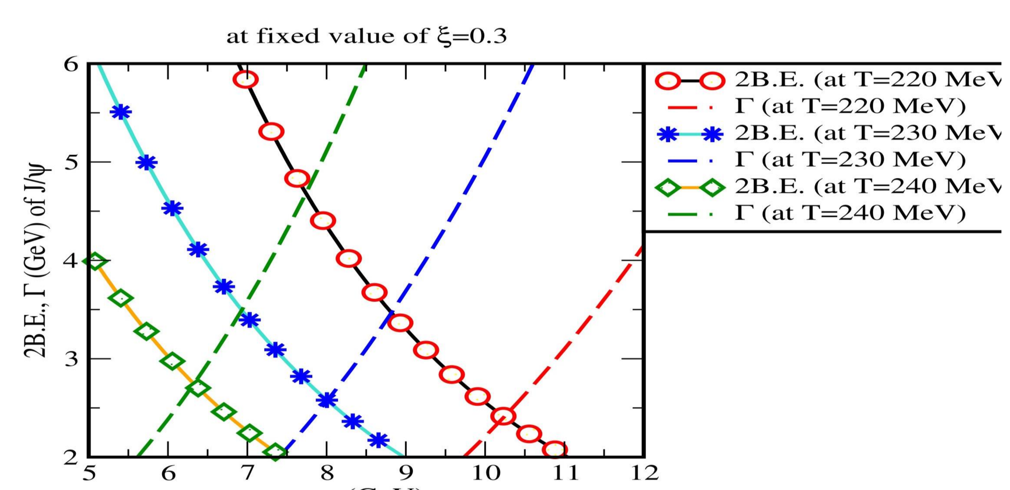


Fig 4: Variation of Thermal Width and 2B.E. with baryonic chemical potential of J/ψ at different values of Temperature but the value of anisotropy is fixed.

Methodology

- The Physics of the heavy quarkonia has been studied by several authors using either lattice QCD approaches/potential based phenomenology.
- Heavy quark potential has been modified by the authors [6] In the presence of dissipative medium where dielectric permittivity has been used in the Fourier space.
- The anisotropy parameter has been obtained as in [7,8].

$$f(p) = f_\xi(p) = C_\xi f\left(\sqrt{p^2 + \xi(p * \hat{n})^2}\right)$$

- Here f(p) is the distribution function for the isotropic medium [9].
- Since Equation of states are significantly affected by the Debye mass and the value of normalisation constant is,

$$C_\xi = \frac{\sqrt{|\xi|}}{tanh^{-1}\sqrt{|\xi|}} \quad \text{if } -1 \leq \xi < 0$$

And

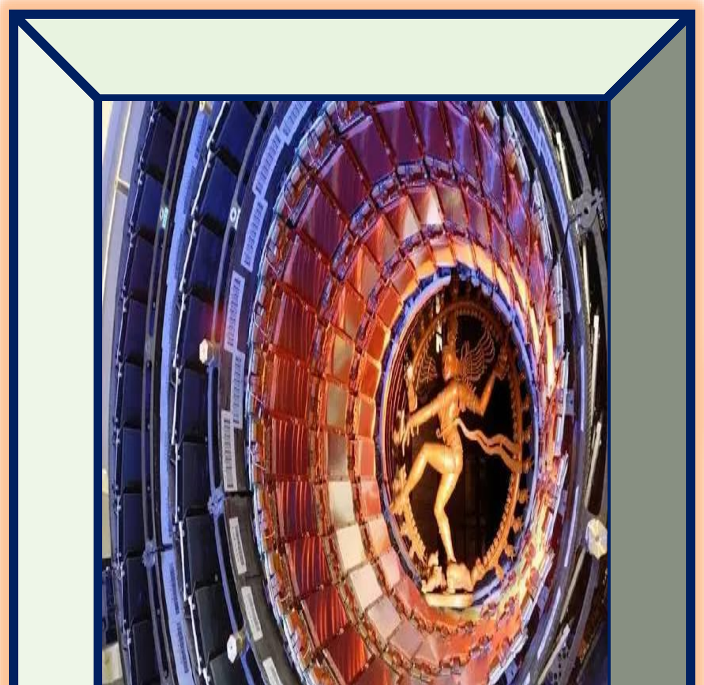
$$C_\xi = \frac{\sqrt{|\xi|}}{tan^{-1}\sqrt{|\xi|}} \quad \text{if } \xi \geq 0$$

- Energy eigen values of the heavy quarkonia can be obtained by using the Schrodinger equation with first order perturbation in anisotropy as one can found in [10].

$$Re[B.E.] = \left(\frac{m_Q\sigma^2}{m_D^4 n^2} + \alpha m_D + \frac{\xi}{3}\left\{\frac{m_Q\sigma^2}{m_D^4 n^2} + \alpha m_D + \frac{2m_Q\sigma^2}{m_D^4 n^2}\right\}\right)$$

- The thermal width of the heavy quarkonia can be estimated while considering the imaginary potential as perturbation to the vacuum potential in the small values of distance.
- Since the potential we have used, has the long range coulombic tail, so we choose the coulombic wave function for the ground states (1s) of quarkonia.

$$\Gamma_{1s} = T\left(\frac{4}{\alpha m_Q^2} + \frac{12\sigma}{\alpha^4 m_Q^2}\right)\left(1 - \frac{\xi}{6}\right) m_D^2 \log\left(\frac{m_D}{\alpha m_Q}\right)$$



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CONCLUSIONS

- In the present work, we calculate the dissociation baryonic chemical potential by using the criteria of thermal width. In this criteria we take the intersection point of the twice of the real part of binding energy curve and thermal width curve. The values of dissociation baryonic chemical potential is shown in the table-1 and table-2.
- In the table-1 if we increases the values of anisotropy, the values of dissociation baryonic chemical potential is also increases.
- But in the table-2 if we increases the values of temperature, the values of dissociation baryonic chemical potential is decreases.
- In conclusions, The present work might be helpful in exploring the studies of the compact objects like neutron stars. Since the Compressed Baryonic Matter (CBM) experiment at FAIR is exploring the quark gluon plasma at higher baryon densities, so such type of theoretical studies may contribute to the physics of compact bodies with high baryon densities.

DISSOCIATION BARYONIC CHEMICAL POTENTIAL

TABLE 1 : Values of dissociation baryonic chemical potential of ground state of charmonium at fixed values of temperature (250 MeV).

ξ= -0.3	ξ=0	ξ=0.3
4.061 GeV	4.577 GeV	4.9791 GeV

TABLE 2 : Values of dissociation baryonic chemical potential of ground state of charmonium at fixed values of anisotropy (0.3).

T=220 MeV	T=230 MeV	T=240 MeV
10.2777 GeV	8.012 GeV	6.348 GeV

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