X(3872) as a $D\overline{D}^*$ MOLECULE BOUND BY QUARK EXCHANGE FORCES

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Matter at highest baryon densities in the laboratory and in space
NICA/JINR-FAIR Bilateral Workshop, FIAS Frankfurt (Germany), April 2 - 4, 2012

Outline

- What is X(3872) resonance ?

  Experimental evidence of X(3872)

  Expected composition

  Lippmann-Schwinger equation (T=0)

- What could it be Its role if HIC ?

  Charmonium suppression in HIC RAA/RAA(CNM) [InIn]

  EoS and initial temperatures

  Self energy contribution to Jpsi potential (T≠0)

What is the X(3872) resonance?

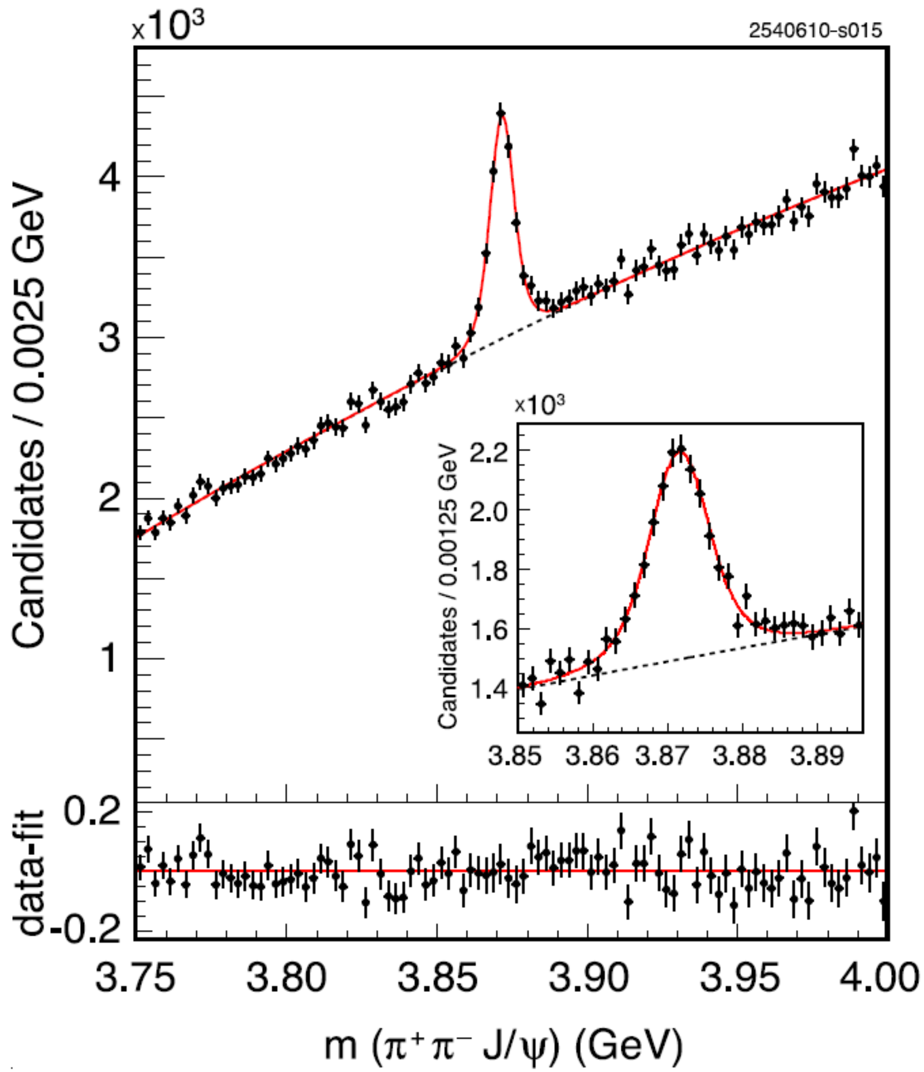
Experimental evidence of X(3872)

BaBar-SLAC
(U.S.A 2003+)

Belle-KEK
(Japan2003)

CDF-Fermilab
(U.S.A 2009)

Invariant mass distribution for X(3872) candidates



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What is the X(3872) resonance?

Experimental evidence of X(3872)

State	m (MeV)	Γ (MeV)	J^{PC}	Process (mode)	Experiment (#σ)	Year	Status
$X(3872)$	3871.52±0.20	1.3±0.6	$1^{++}/2^{-+}$	$B \to K(\pi^+\pi^- J/\psi)$	Belle [85, 86] (12.8), BABAR [87] (8.6)	2003	OK
		(<2.2)		$p\bar{p} \to (\pi^+\pi^- J/\psi) + ...$	CDF [88–90] (np), DØ [91] (5.2)		
				$B \to K(\omega J/\psi)$	Belle [92] (4.3), BABAR [93] (4.0)		
				$B \to K(D^{*0}\bar{D}^0)$	Belle [94, 95] (6.4), BABAR [96] (4.9)		
				$B \to K(\gamma J/\psi)$	Belle [92] (4.0), BABAR [97, 98] (3.6)		
				$B \to K(\gamma\psi(2S))$	BABAR [98] (3.5), Belle [99] (0.4)		
$X(3915)$	3915.6 ± 3.1	28±10	$0/2^{?+}$	$B \to K(\omega J/\psi)$	Belle [100] (8.1), BABAR [101] (19)	2004	OK
				$e^+e^- \to e^+e^-(\omega J/\psi)$	Belle [102] (7.7)		
$G(3900)$	3943 ± 21	52±11	1^{--}	$e^+e^- \to \gamma(D\bar{D})$	BABAR [27] (np), Belle [21] (np)	2007	OK
$Y(4260)$	4263 ± 5	108±14	1^{--}	$e^+e^- \to \gamma(\pi^+\pi^- J/\psi)$	BABAR [108, 109] (8.0)	2005	OK
					CLEO [110] (5.4)		
					Belle [104] (15)		
				$e^+e^- \to (\pi^+\pi^- J/\psi)$	CLEO [111] (11)		
				$e^+e^- \to (\pi^0\pi^0 J/\psi)$	CLEO [111] (5.1)		
$Y(4360)$	4353 ± 11	96±42	1^{--}	$e^+e^- \to \gamma(\pi^+\pi^- \psi(2S))$	BABAR [113] (np), Belle [114] (8.0)	2007	OK

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What is the X(3872) resonance?

Expected composition

PDG $\frac{m_{D^0} + m_{\bar{D}^{*0}}}{\text{MeV}} = (1864.5 \pm 0.4) + (2006.7 \pm 0.4) = 3871.2 \pm 0.8$

Mode	Mass (MeV)	Width (MeV)	Ref. (χ^2/d.o.f.)
$\pi^+\pi^- J/\psi$	$3871.46 \pm 0.37 \pm 0.07$	1.4 ± 0.7	Belle [86]
$(B^\pm)$	$3871.4 \pm 0.6 \pm 0.1$	$1.1 \pm 1.5 \pm 0.2$	*BABAR* [87]
(B^0)	$3868.7 \pm 1.5 \pm 0.4$	-	*BABAR* [87]
	$3871.8 \pm 3.1 \pm 3.0$	-	DØ [88]
	$3871.61 \pm 0.16 \pm 0.19$	-	CDF [90]
	3871.52 ± 0.20	1.3 ± 0.6	Avg[3] (2.1/4)
$D^{*0}\bar{D}^0$	$3875.1^{+0.7}_{-0.5} \pm 0.5$	$3.0^{+1.9}_{-1.4} \pm 0.9$	*BABAR* [96]
	$3872.9^{+0.6}_{-0.4}{}^{+0.4}_{-0.5}$	$3.9^{+2.8}_{-1.4}{}^{+0.2}_{-1.1}$	Belle [95]
	3874.0 ± 1.2	$3.5^{+1.6}_{-1.0}$	Avg[3] (4.7/1)

Is X(3872) composed by two D-mesons?

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What is the X(3872) resonance?

Expected composition

CLEO

$$m[X(3872)] - [m(D^{*0}) + m(D^0)] = -0.42 \pm 0.39 \ \text{MeV}$$

The DD*bar threshold remains ambiguous !!!

D-mesons binding energy   less than 1Mev

It is likely a narrow resonant structure with the most probably quantum numbers

$$J^{PC} = 1^{++} \quad \text{and} \quad I = 0 \ , \ I = 1$$

It may have comparable decay rates to $D^{*0} \ D^0$

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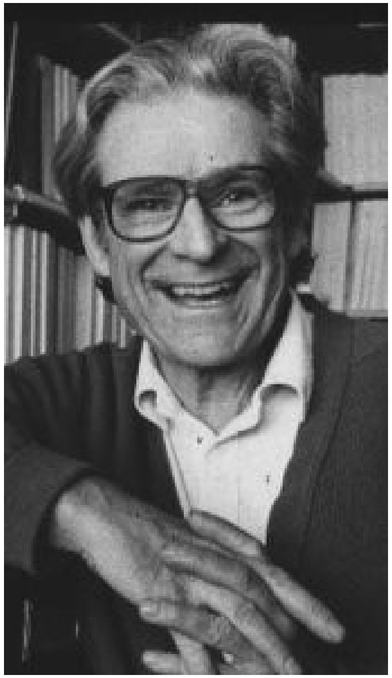
What is the X(3872) resonance?

Lippmann-Schwinger equation (T=0)

Relativistic equation for bound state problems
Phys. Rev. 82, 291–346 (1951)

$$T = U + U \frac{1}{E - H_0} T$$

Bound States in Quantum Field Theory
Phys. Rev. 84, 350–354 (1951)



Salpeter

Hans Albrecht Bethe

Nobel prize in 1967

Successfully applications in QED and semiconductors were published in 70's -80's

What is the X(3872) resonance?

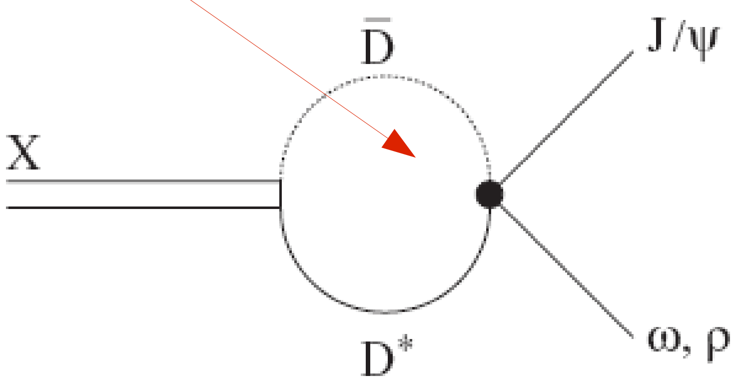
Lippmann-Schwinger equation (T=0)

It is a non-relativistic version of the Bethe-Salpeter equation

D. Gamermann et al. Phys. Rev D 81 (2010) 014029

$$T = U + U \frac{1}{E - H_0} T$$

Resonance is formed before D-mesons decay !!



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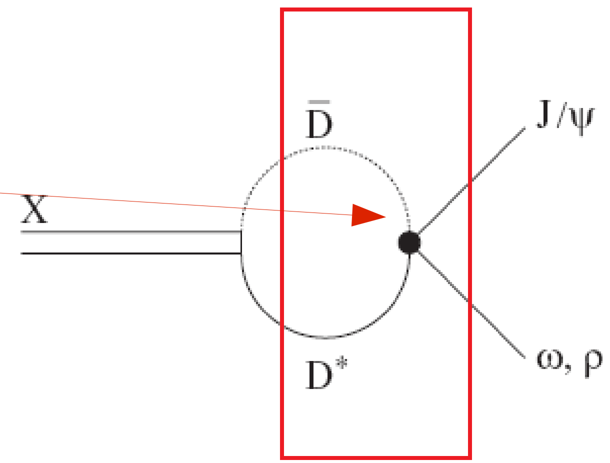
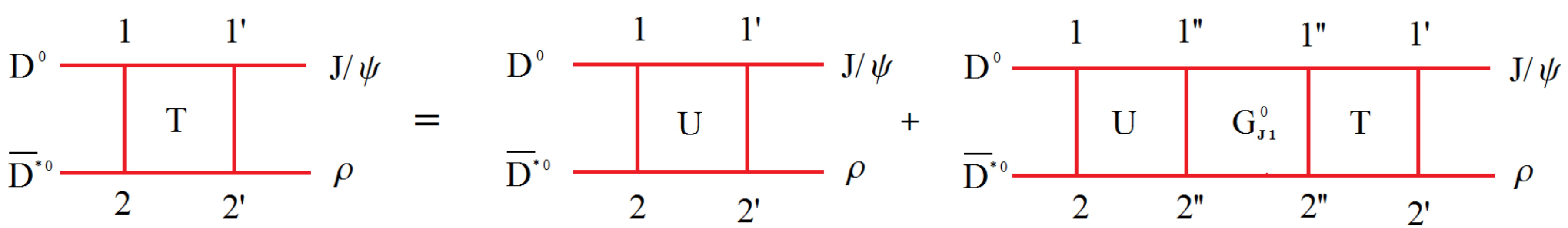




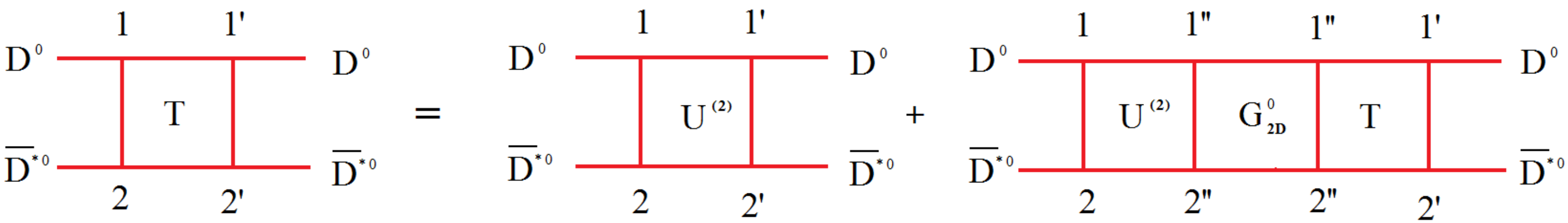
Can X(3872) be formed in a D-mesons symmetric T-matrix ?

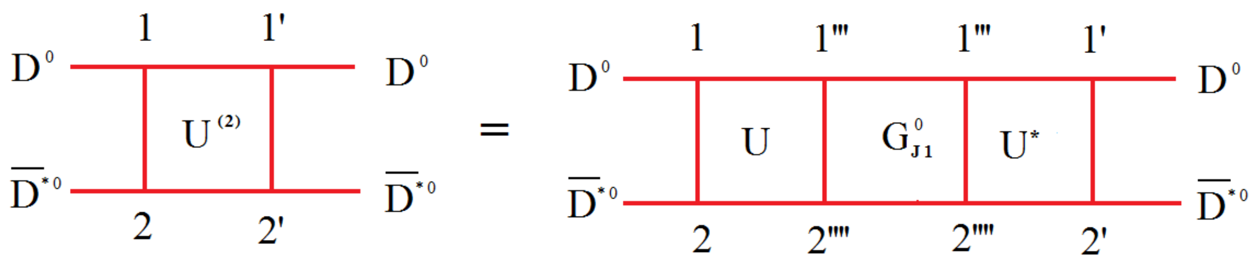
What is the X(3872) resonance?

Lippmann-Schwinger equation (T=0)

C. Peña, D. Blaschke. X(3872) as a D D* molecule bound by quark exchange forces.

ArXiv:1201.0309v1 To appear in Acta Polonica





$$T(a, a', z) = U^{(2)}(a, a') + \sum_{a''} U^{(2)}(a, a'')\, G^0_{2D}(a'', z)\, T(a'', a', z)$$

$$\mathbf{U}^{(2)}(a, a', z) = \sum_{a'''} \mathbf{U}(a, a''')\, G^0_{J_1}(a''', z)\, \mathbf{U}^*(a''', a')$$

What is the X(3872) resonance?

Lippmann-Schwinger equation (T=0)

C. Peña, D. Blaschke. X(3872) as a D D* molecule bound by quark exchange forces.

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$$\mathbf{U}(a,a') = -\lambda\, L(a)\, R(a')\ , \quad \mathbf{U}^*(a',a) = -\lambda\, R(a')\, L(a)$$

$$\mathbf{U}^{(2)}(a,a',z) = \mathbf{V}(z)\, L(a)\, L(a')$$

$$\mathbf{V}(z) = \lambda^2 \sum_{a'''} R^2(a''')\, G^0_{J_1}(a''',z) > 0$$

Positive for $z > m_{J/\psi} + m_\rho$

What is the X(3872) resonance?

Lippmann-Schwinger equation (T=0)

C. Peña, D. Blaschke. X(3872) as a D D* molecule bound by quark exchange forces.

ArXiv:1201.0309v1 To appear in Acta Polonica

$$T(a, a', z) = L(a)\, L(a')\ t(0, z)$$

In the C.M. P=0

$$t(0, z) = \frac{\mathbf{V}(z)}{1 - \mathbf{V}(z) \sum_{a''} L^2(a'')\, G^0_{2D}(a'', z)}$$

By integrating around the pole of the propagator of two D-mesons T(a,a',z) is complex !!

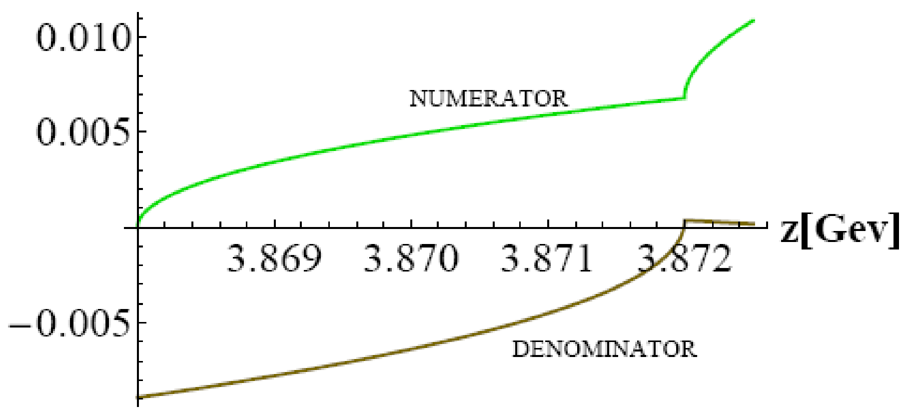
What is the X(3872) resonance?

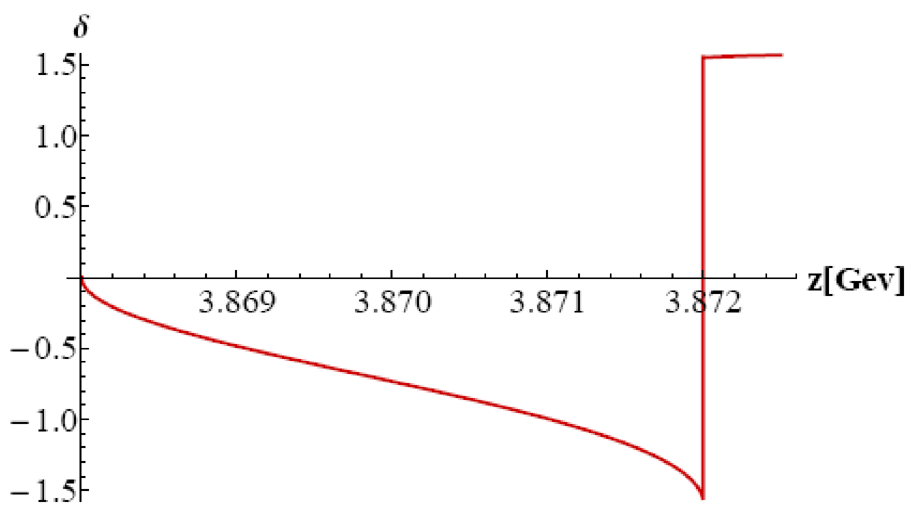
Lippmann-Schwinger equation (T=0)

C. Peña, D. Blaschke. X(3872) as a D D* molecule bound by quark exchange forces.

ArXiv:1201.0309v1 To appear in Acta Polonica

$$\delta = \text{arcTan}\left[\frac{\text{Im}[t(0,z)]}{\text{Re}[t(0,z)]}\right]$$



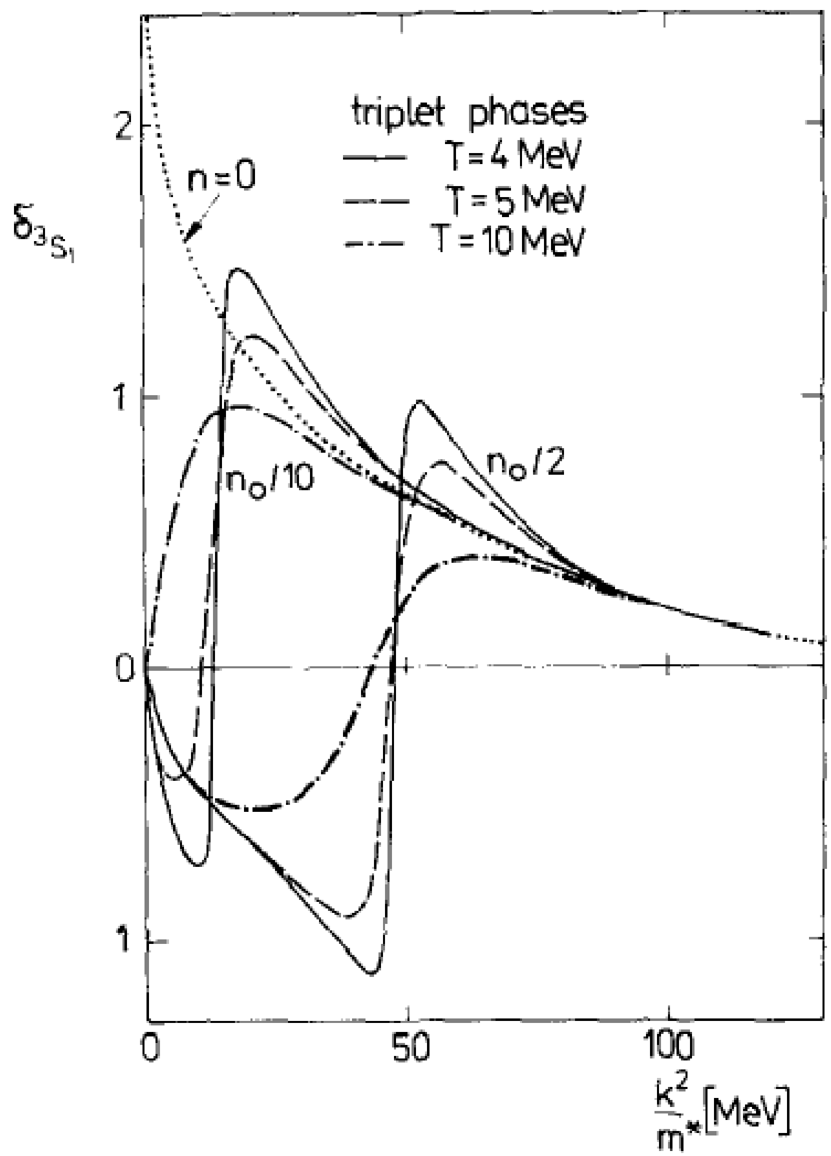


Re[t(0,z)] changes sign around 3.872 GeV creating a resonance.
Binding energy B=0 !! C. Peña, D. Blaschke. Binding D D* by quark exchange. prog.

What is the X(3872) resonance?

Lippmann-Schwinger equation (T=0)

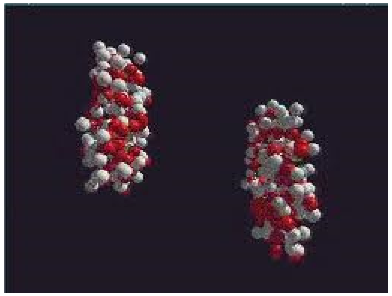
Annals of physics 202, 57 (1990). M. Schmidt, G. Ropke, H. Schulz



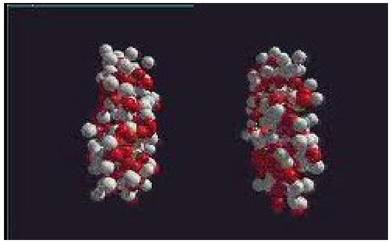
What could be its role in HIC?
Charmonium suppression in HIC RAA/RAA(CNM)

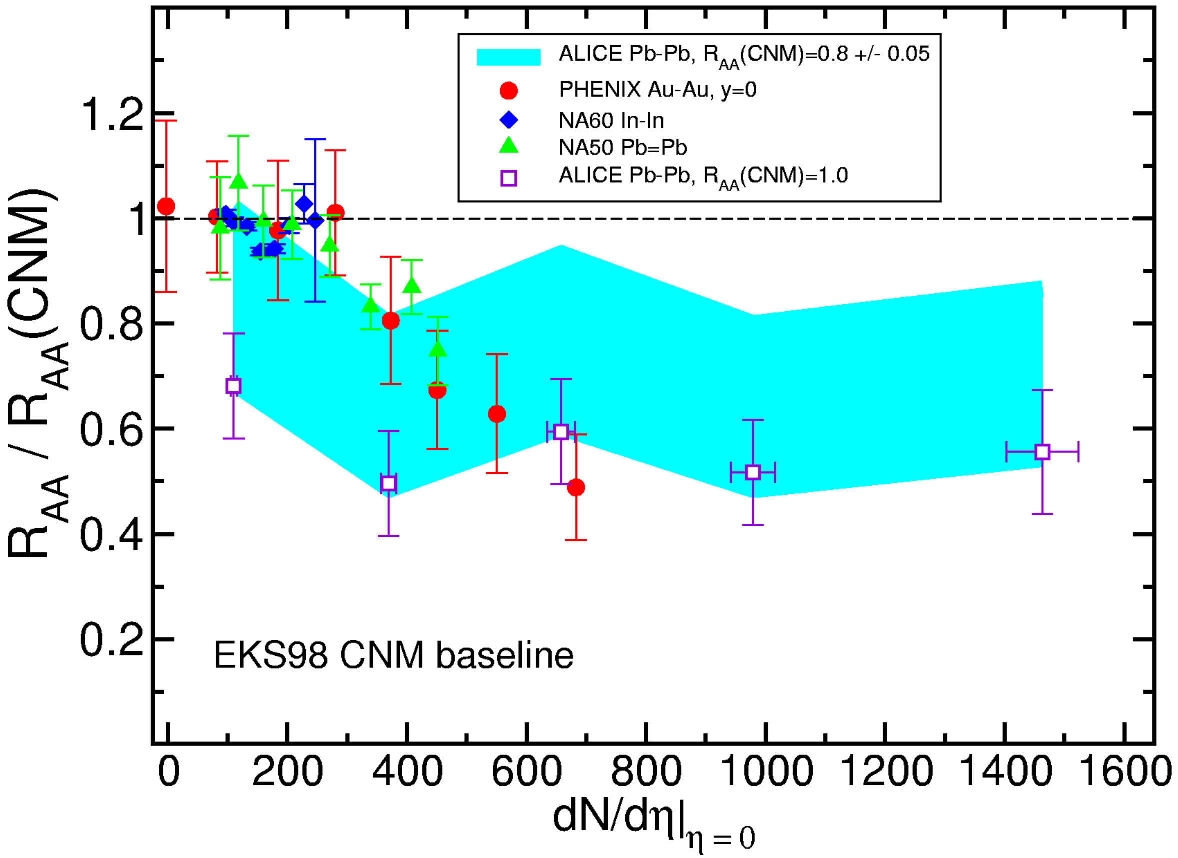
$S_\psi = a\, S_{J/\psi} + b\, S_\chi + c\, S_{\psi'} \quad + \quad S_{X(3872)}$?

Peripheral



Central

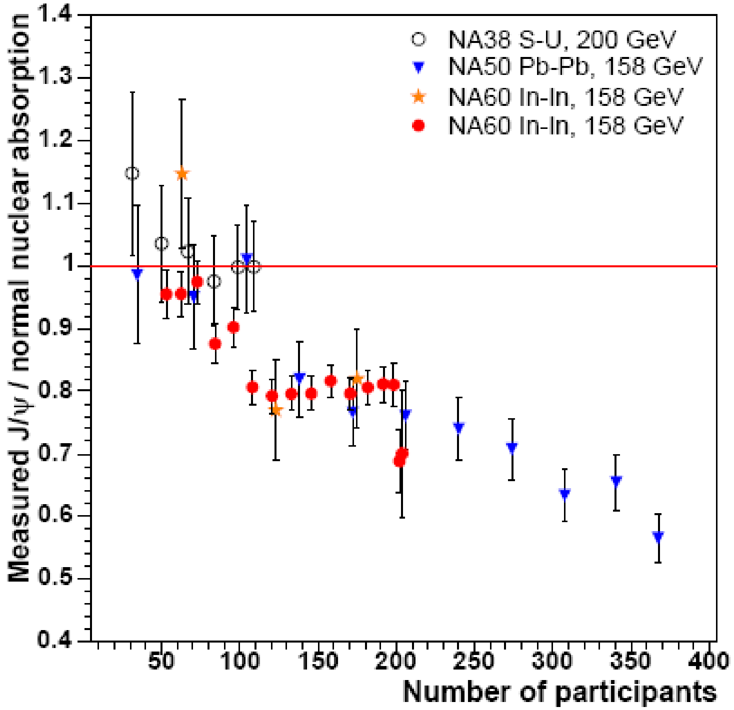


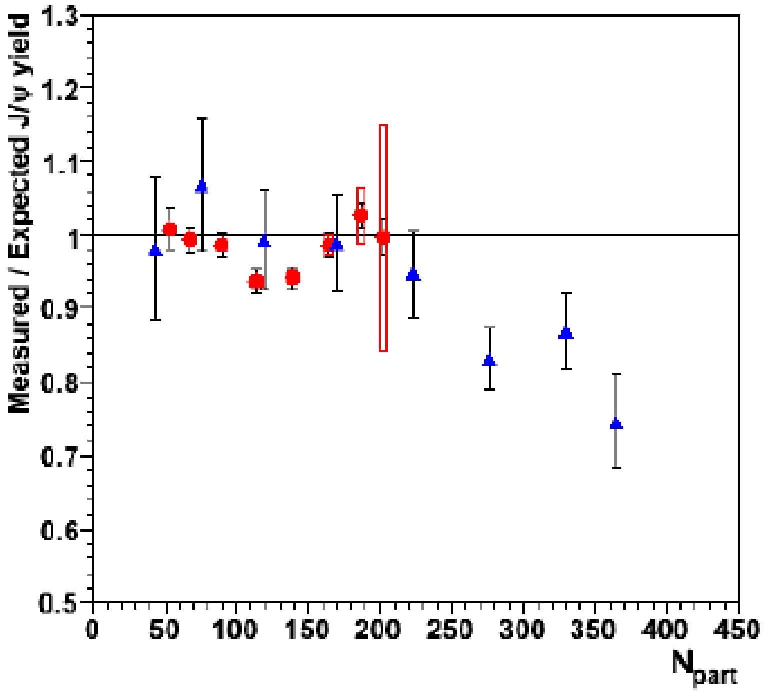


$$s(T_0) = \frac{\xi}{V_0}\left(\frac{dN}{dy}\right)_{y=0}$$

What could be its role in HIC?

Charmonium suppression in HIC RAA/RAA(CNM)





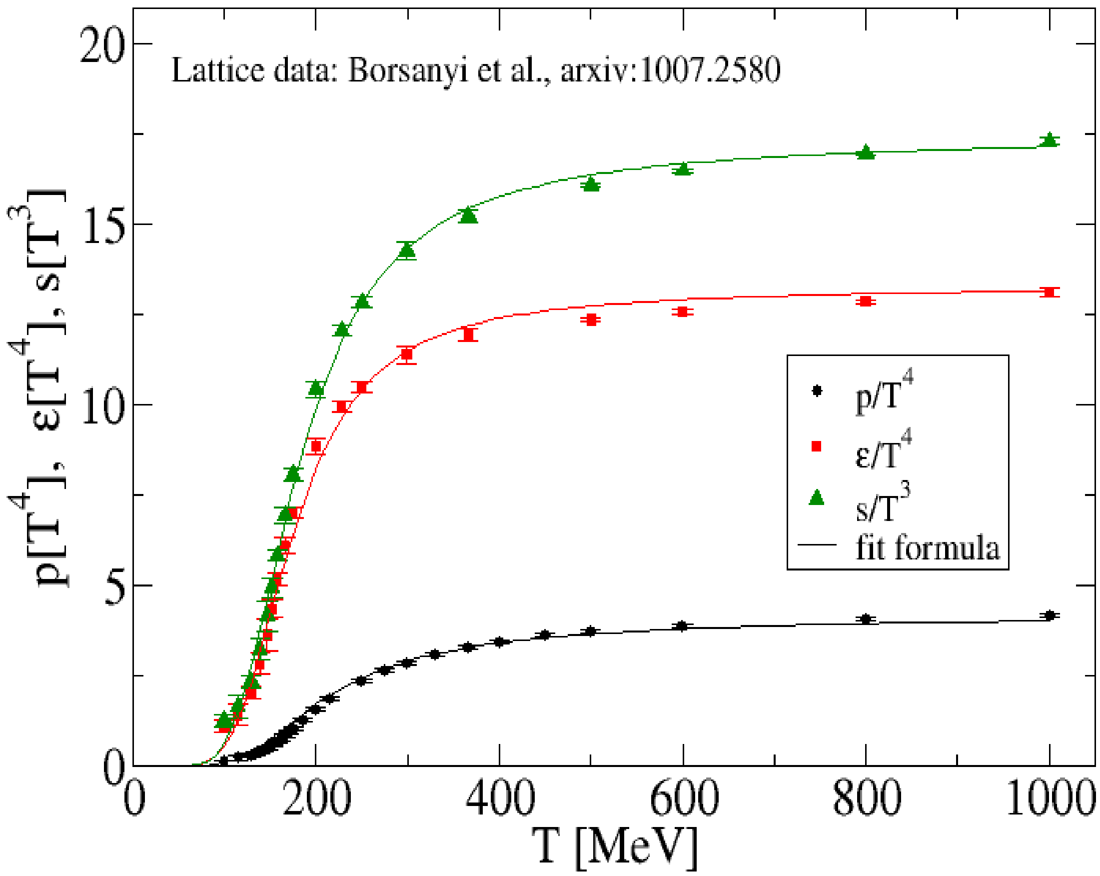
Can hot medium effects creates a wiggle for Npart~100 ?

$$s(T_0) = \frac{\xi}{V_0}\left(\frac{dN}{dy}\right)_{y=0}$$

What could be its role in HIC?

Charmonium suppression at InIn

$$s(T_0) = \frac{\xi}{V_0}\left(\frac{dN}{dy}\right)_{y=0}$$



D. Blaschke, C. Peña. Nuclear Physics B (Proc. Suppl.) 214 (2011) 137

What could be its role in HIC?

Charmonium suppression at InIn

$$s(T_0) = \frac{\xi}{V_0}\left(\frac{dN}{dy}\right)_{y=0}$$

1.3 Tc - 1.4 Tc

Onset of Charmonium Suppression

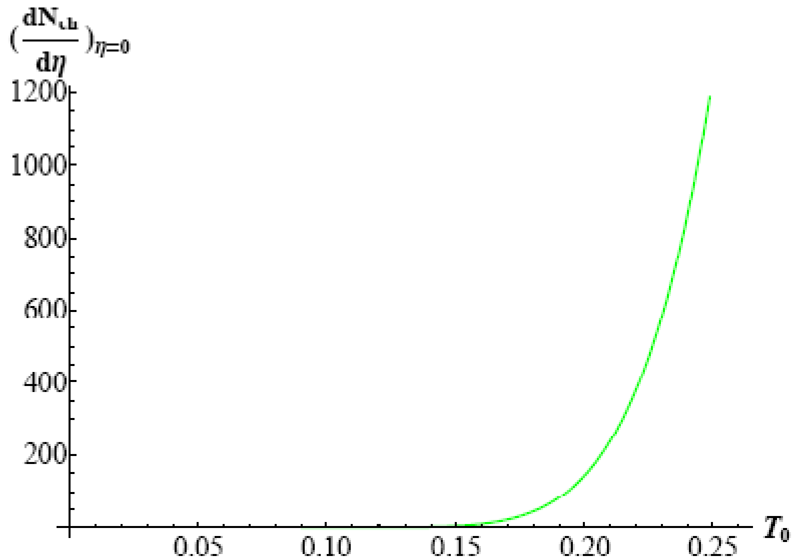


FIG. 3: Variable $\left(\frac{dN_{ch}}{d\eta}\right)_{\eta=0}$ as a function of initial temperature.

NA60-InIn

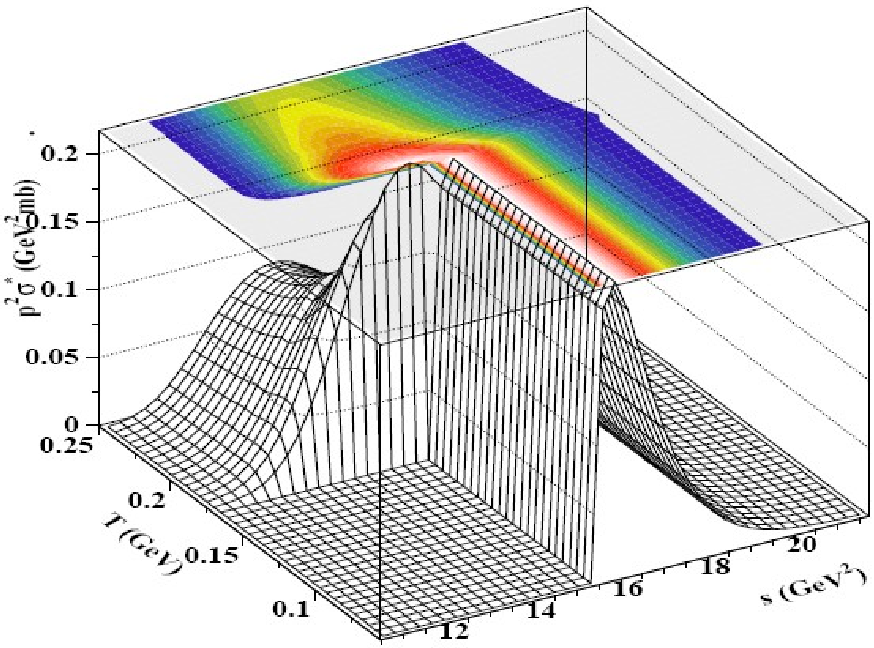
$\left(\frac{dN_{ch}}{d\eta}\right)_{\eta=0}$	V_0/fm^3	T_0/Gev
246.332	110.7	0.210
228.062	106.0	0.209
202.409	99.0	0.207
178.545	92.2	0.204
154.682	84.9	0.201
131.773	77.5	0.198
109.818	69.9	0.195
96.4545	64.9	0.193

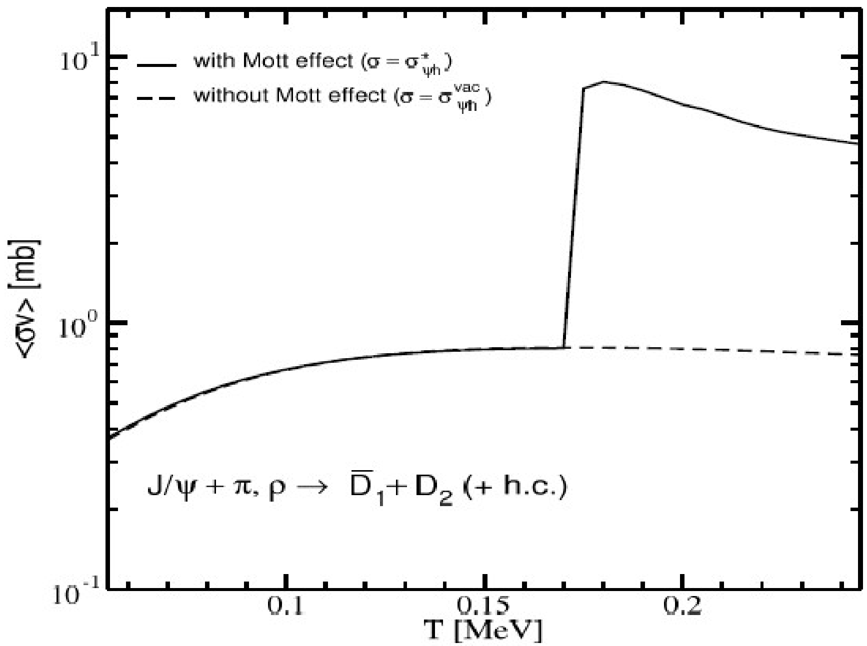
EoS shows that are some mesons in medium !!

What could be its role in HIC?

Charmonium suppression at InIn

energy (s) and temperature (T) dependence of the effective cross section (σ^*) for J/ψ breakup by ρ-meson impact.





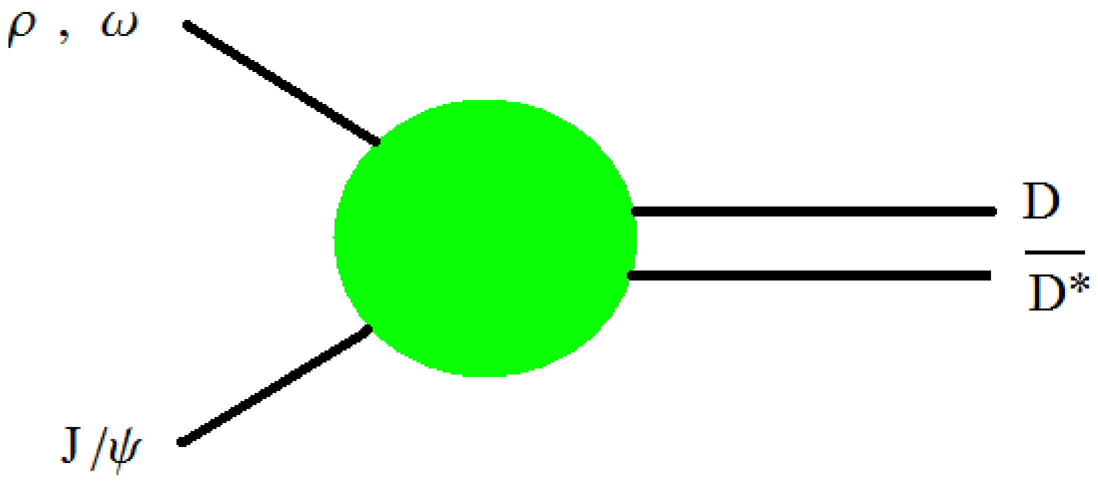
D. Blaschke,
DESY-PROC-2009-07. arXiv:0912.4479v1

How does Charmonium interact with light mesons?

What could be its role in HIC?

Self energy contribution to Jpsi potential (T≠0)

The width of this decay is calculated from the self energy



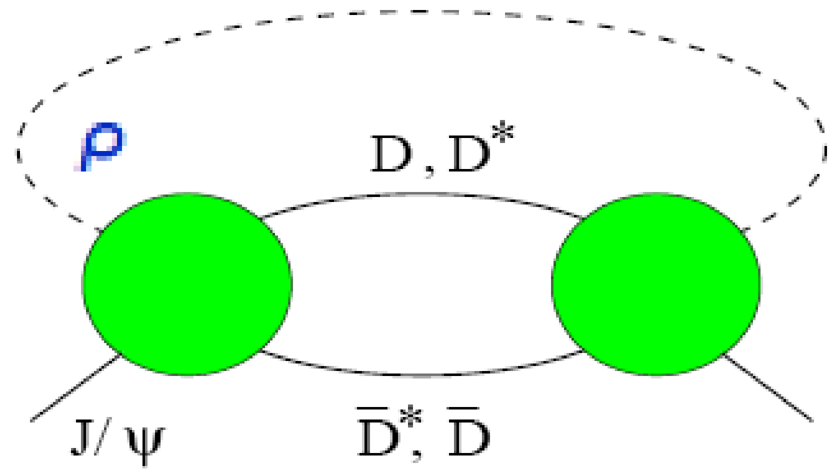
$$\Gamma(p,\omega) = \Sigma^{>}(p,\omega) - \Sigma^{<}(p,\omega)$$

Leo P. Kadanof, Gordon Baym. Quantum Statistical Mechanics. Green's Function Methods in Equilibrium and Nonequilibrium Problems. Addison-Wesley Publishing Co.,Inc, New York, 1962. 97

What could be its role in HIC?

Self energy contribution to Jpsi potential $(T \neq 0)$

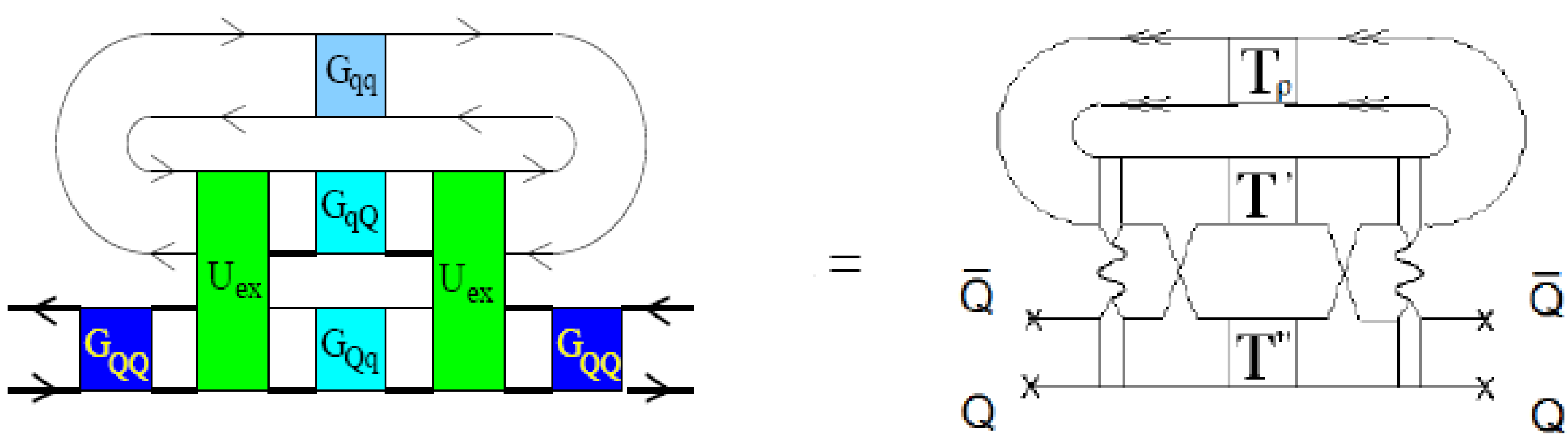
At meson level



**Rapp, Blaschke, Crochet
Prog.Part.Nucl.Phys.
65 (2010) 209-266**

**D. Blaschke,
DESY-PROC-2009-07.
arXiv:0912.4479v1**

At Quark level is the 4-particle T -matrix T4



What could be its role in HIC?

Self energy contribution to Jpsi potential (T≠0)

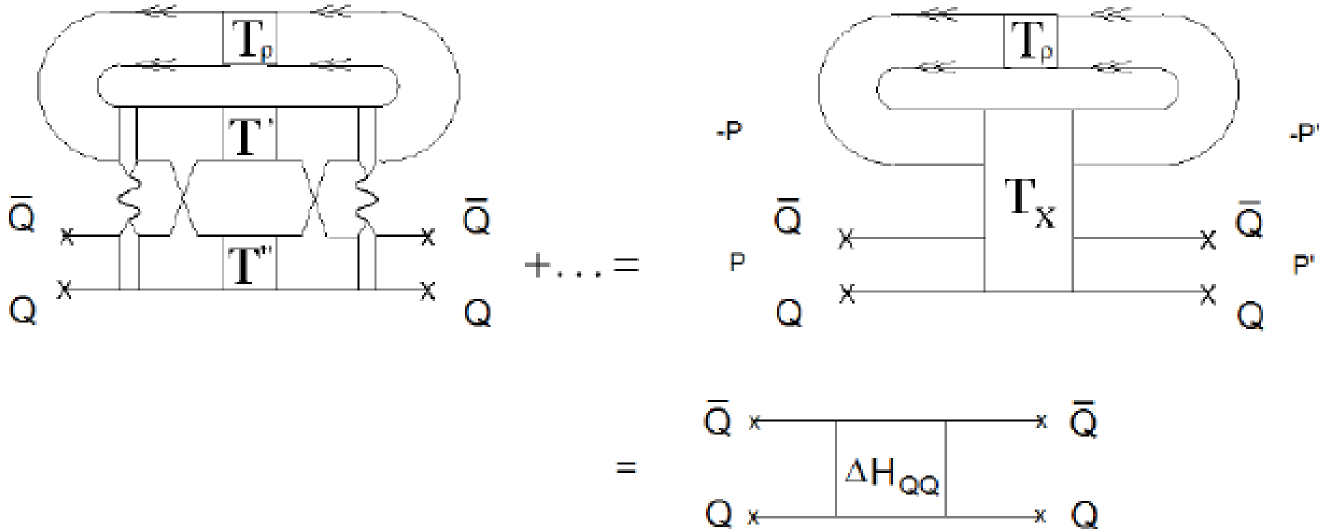


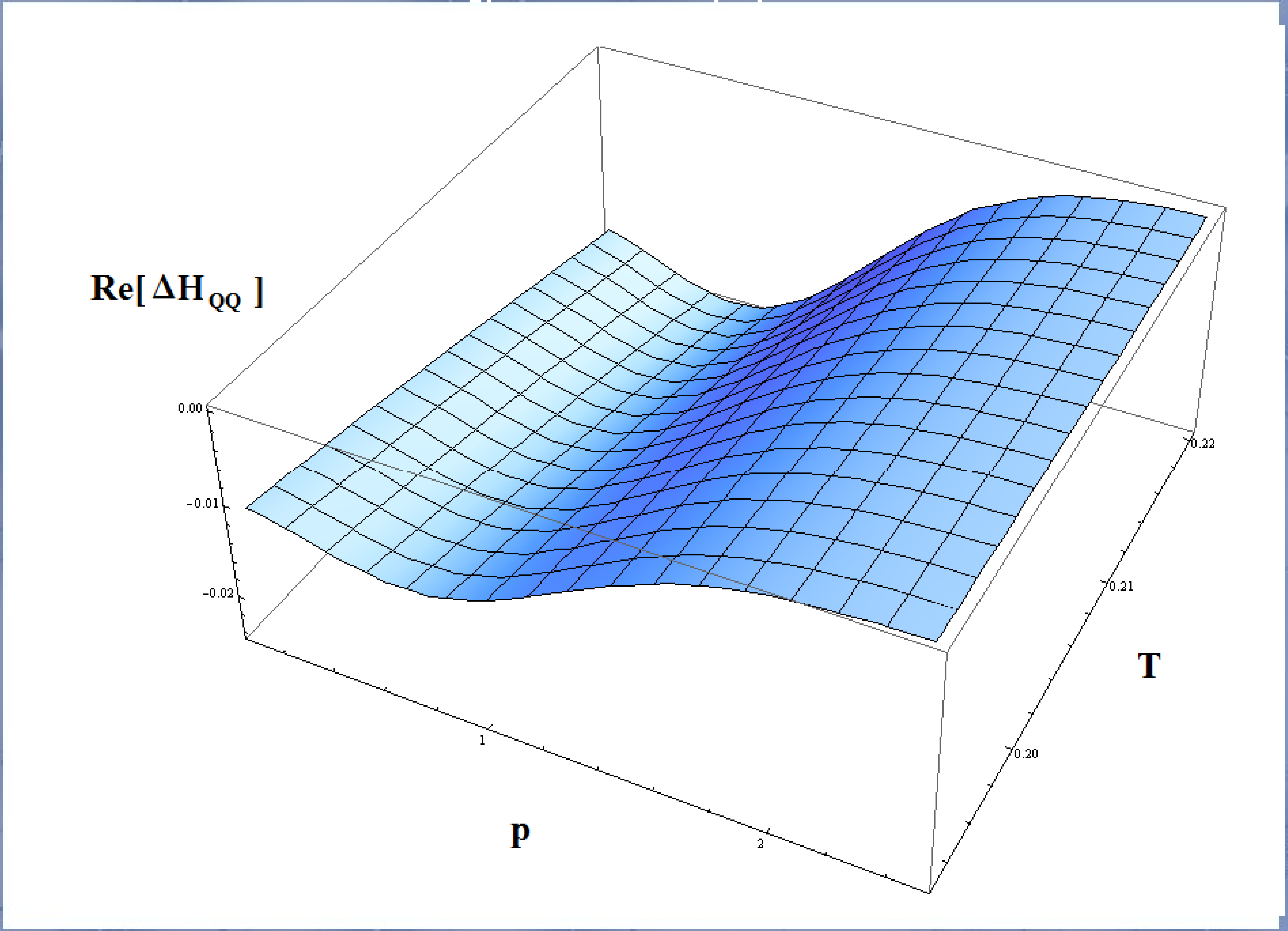
Figure F.5: $Q\bar{Q}$ Hamiltonian contribution due to production of the exotic resonance $X(3872)$ inside the T-matrix interaction of $D\bar{D}^*$.

$$\Delta H_{Q\bar{Q}} = \sum_{34} (E_x - E_1 - E_2 - E_3 - E_4)^2 \, \psi_\psi(12)\psi^*_\psi(1'2') \, |\psi_\rho(34)|^2 \, \frac{f(E_x) - f(E_\rho)}{E_x - iz_\mu - E_\rho}$$

$$+ \sum_{34} (E_x - E_1 - E_2 - E_3 - E_4) \, \psi_\psi(12)\psi^*_\psi(1'2') \, |\psi_\rho(34)|^2 \, f(E_p)$$

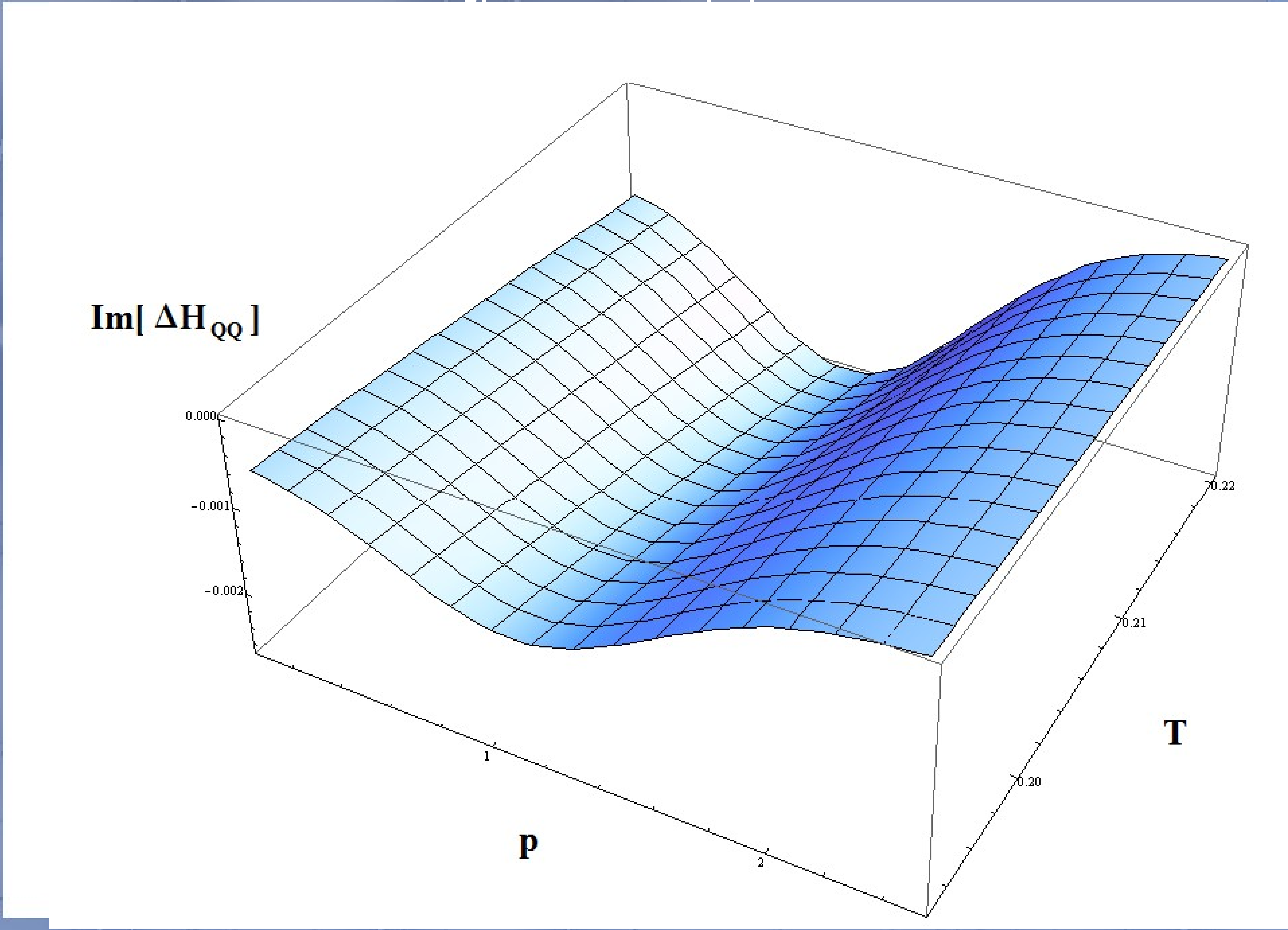
What could be its role in HIC?

Self energy contribution to Jpsi potential (T≠0)



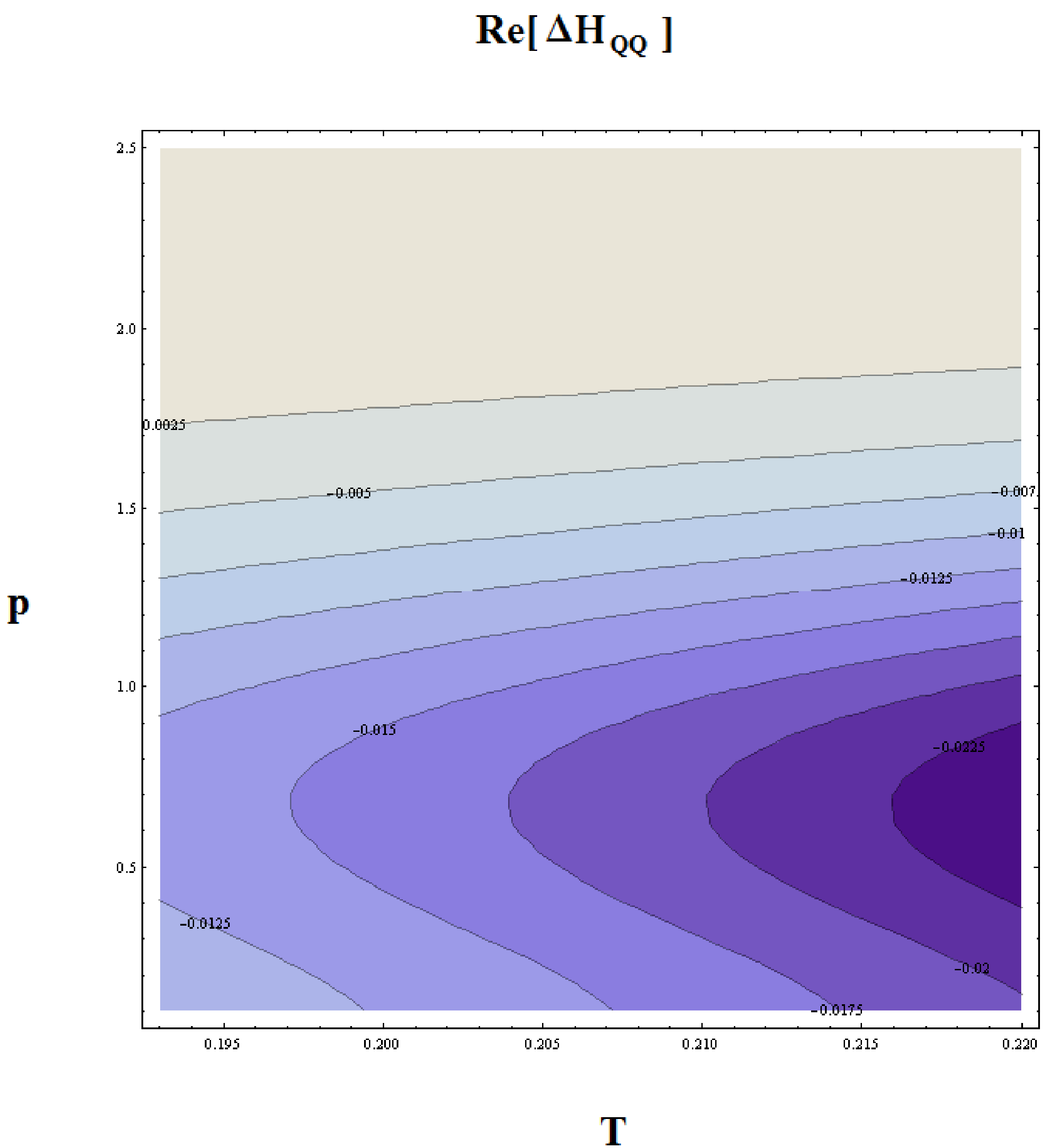
What could be its role in HIC?

Self energy contribution to Jpsi potential ($T \neq 0$)



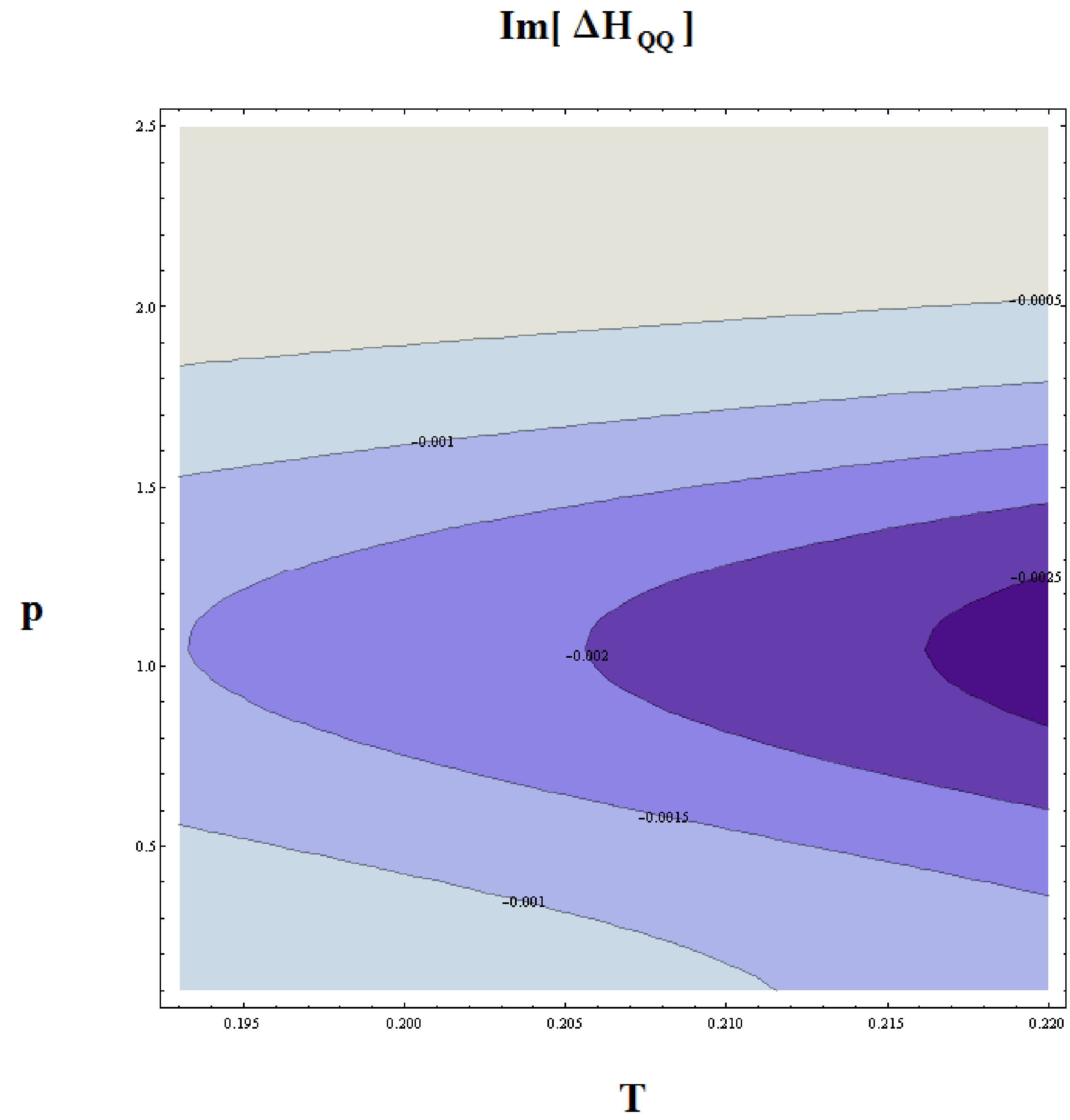
What could be its role in HIC?

Self energy contribution to Jpsi potential (T≠0)



What could be its role in HIC?

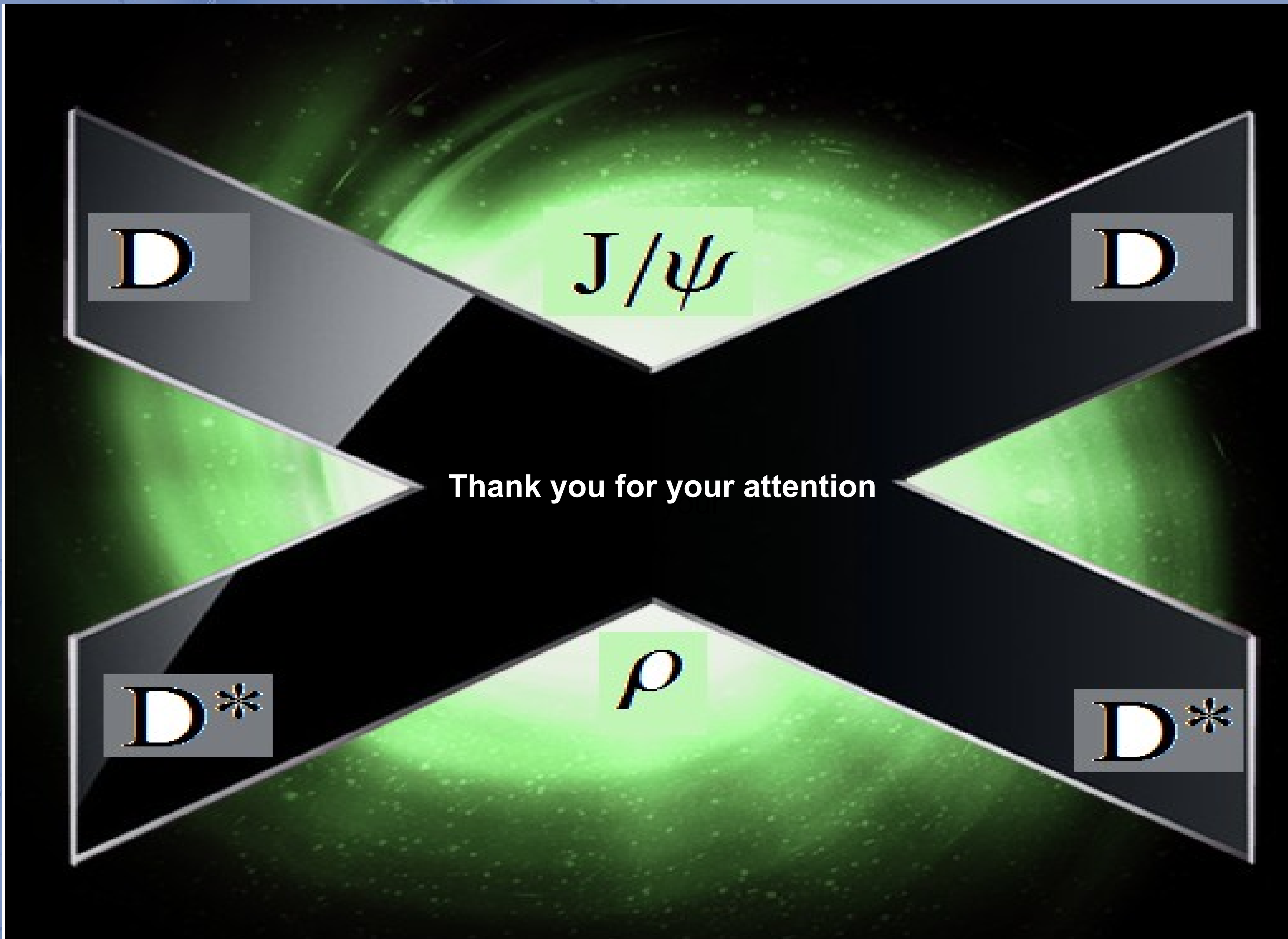
Self energy contribution to Jpsi potential ($T \neq 0$)



Summary

1. Would be it possible that X(3872) be produced in HIC ?

2. If so, the X(3872) may give us information about the onset of Charmonium suppression.


D
J/ψ
D
Thank you for your attention
D*
ρ
D*