

# CONFXIII

XIIIth Quark Confinement and the Hadron Spectrum

Maynooth University, August 2018



# A QUARK MODEL DESCRIPTION OF $\psi(4260)$

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## MOTIVATION

$\psi(4260)$  is a well established  $1--$  neutral state challenging the standard quark model since its mass and decay properties are in conflict with conventional expectations.

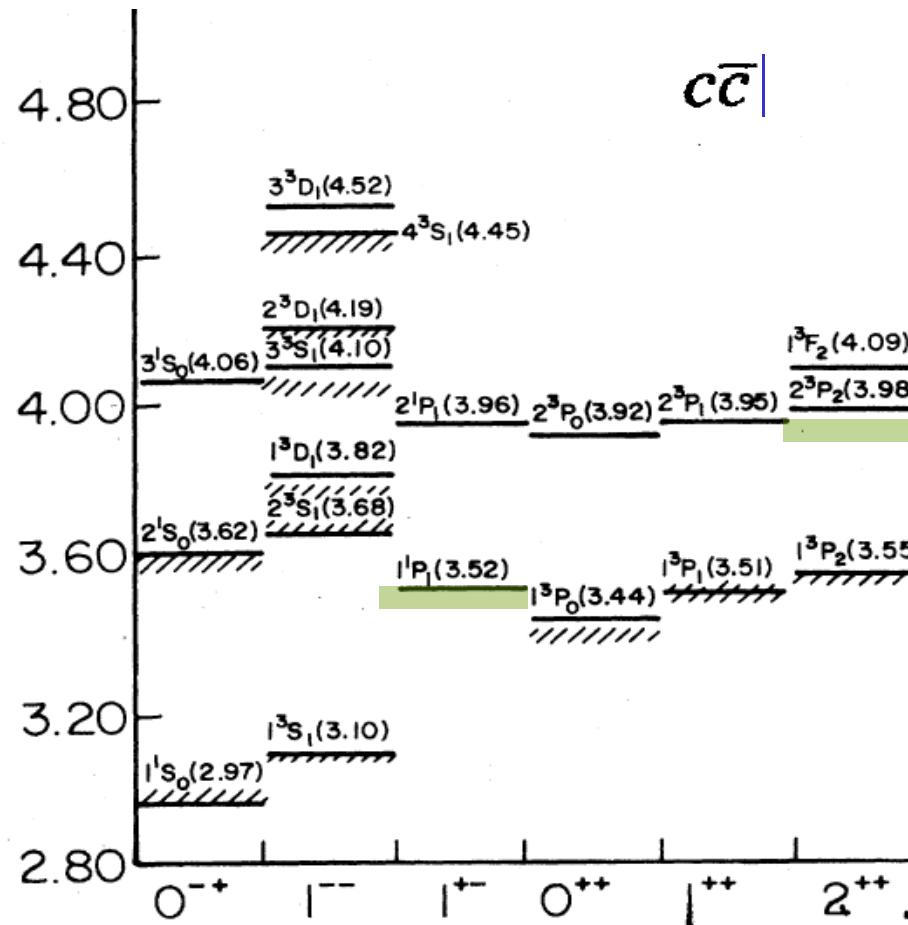
A “universal” non conventional quark model description based on effective quark and antiquark degrees of freedom can be done and tested.

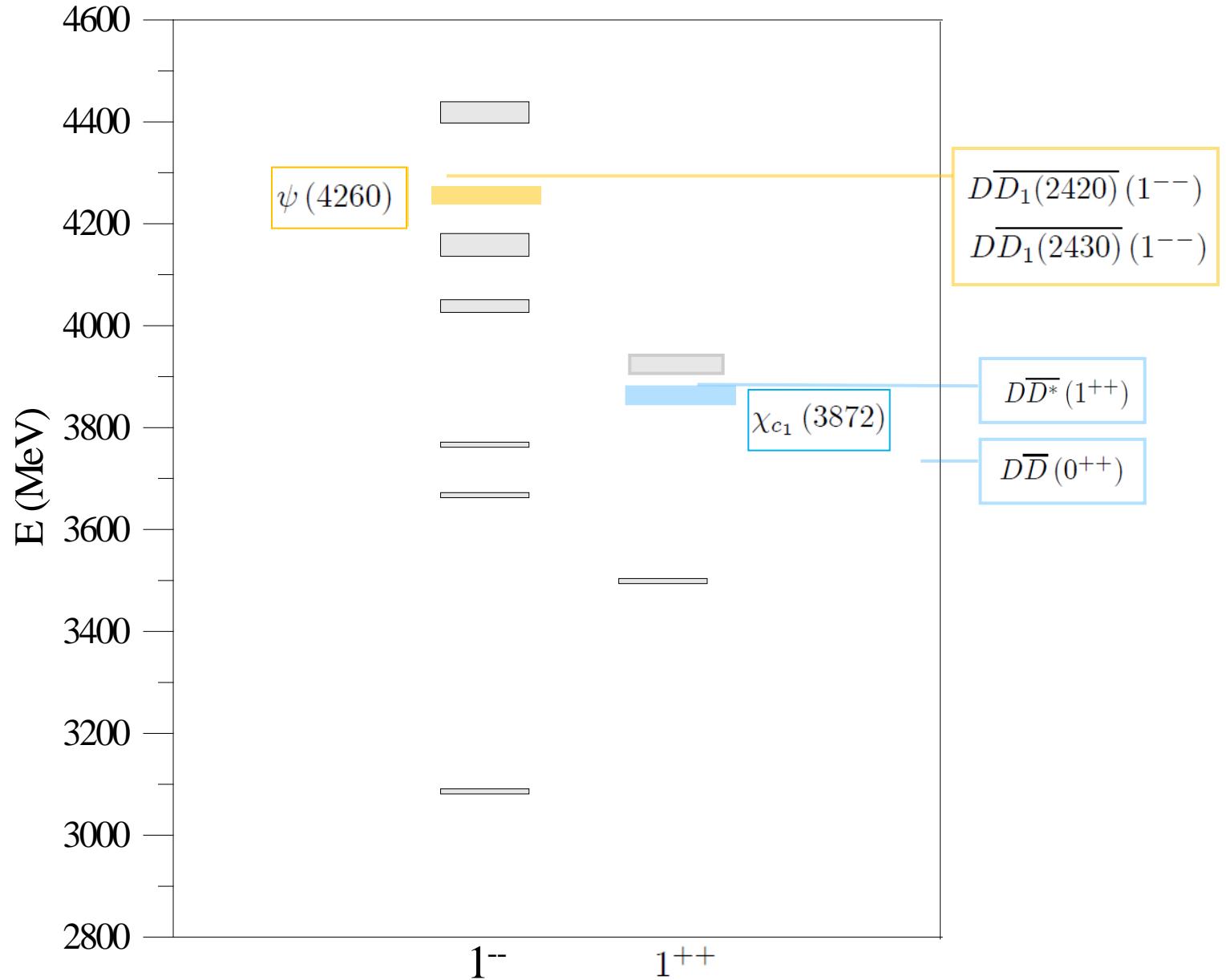
# Conventional States

$$H = T(Q) + T(\overline{Q}) + V_{conf} + V_{Coul} + V_{Sd}$$

$$V_{conf} = \sigma r \quad V_{Coul} = -\frac{\chi}{r} \quad \chi = \frac{4}{3}\alpha_s \hbar$$

S. Godfrey, N. Isgur  
PRD 32, 189 (1985)





$\psi(4260)$ ,  $\chi_{c1}(3872)$  : Close-below their First S-wave M-M Threshold

Decay properties of  
conventionally expected

$\psi(4260) : 0^-(1^{--})$

very different from

M. Tanabashi et al (PDG), PRD 98, 030001 (2018)

Conventional description:

$\psi(4S)$

$\psi(3D)$

However  $\psi(4260) \rightarrow J/\psi\pi\pi$  higher than expected.

$J/\psi\pi^+\pi^-$  discovery channel

$\psi(4260) \rightarrow D\bar{D}$  not seen

Opposite behaviour to bottomonium

# What is it ?

Chen, Chen, Liu, Zhu, Phys. Rep. 639, 1 (2016); Lebed, Mitchell, Swanson, Prog. Part. Nuc. Phys. 93, 143 (2017); Esposito, Pilloni, Polosa, Phys. Rep. 668, 1 (2017); Guo, Hanhart, Meissner, Wang, Zhao, Zou, Rev. Mod. Phys. 90 (2018), 015004

Hybrid (Quark-Antiquark + Gluon) State ?

Molecular Sate ?

Tetraquarks (compact state) ?

Quark-Antiquark + Molecular State ?

What is the effect of Meson-Meson Thresholds ?

Can we implement threshold effects within a **quark-antiquark model framework?**

Quark-Antiquark effective potential description implicitly incorporating meson-meson components.

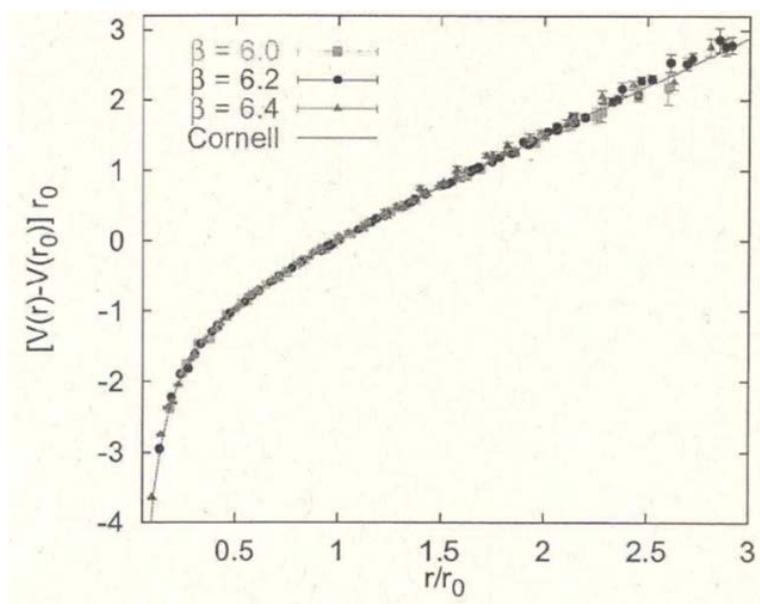
## INDEX

- i) Quenched versus Threshold-Unquenched Quark-Antiquark Energy from Lattice.
- ii) Energy dependent potential. Static Potential in the first energy region.
- iii) Heavy quarkonia description:  $\chi_{c1}(3872)$  ,  $\psi(4260)$
- iv) Summary.

# Quenched vs Threshold-Unquenched Quark-Antiquark Energy

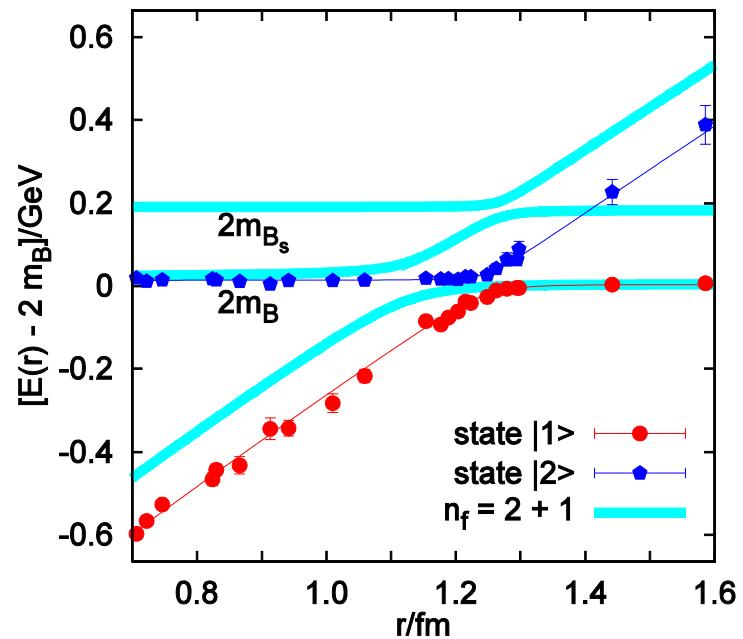
$$E(r) = V(r) + m_Q + m_{\bar{Q}}$$

G. S. Bali, Phis. Rep. 343,1 (2001)



$$V_{Q_0\bar{Q}_0}(r) \equiv V_{Cor}(r) = \sigma r - \frac{\chi}{r} + C$$

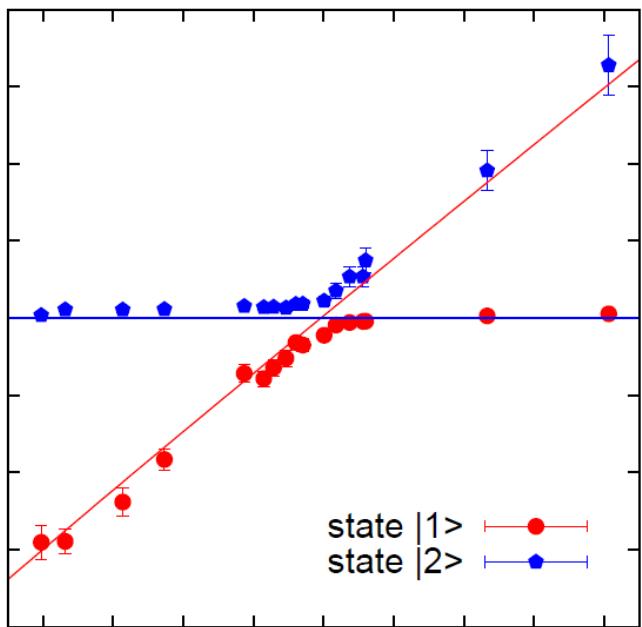
G. S. Bali *et al.*, PRD 71, 114513 (2005)



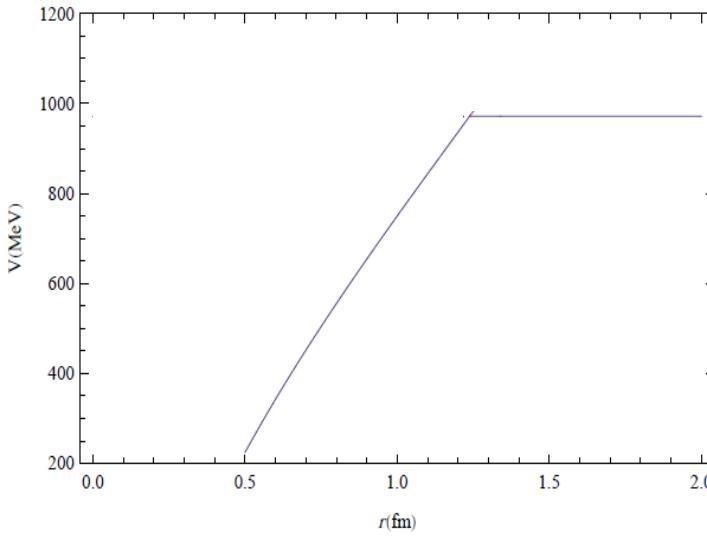
$$V_{Q\bar{Q}}(r) \equiv V_{E_{Q\bar{Q}}}(r)$$

# Static Potential in the first energy region : J++ states

## Single thresholds with no significant widths



$$V_{[M_{T_0}, M_{T_1}]}(r) = \begin{cases} \sigma r - \frac{\chi}{r} & r \leq r_{T_1} \\ M_{T_1} - m_Q - m_{\bar{Q}} & r \geq r_{T_1} \end{cases}$$



Cornell potential modulated by the threshold

# Heavy Quarkonia Description

The lowest lying spectrum is described by the Cornell potential

$$V_{Cor}(r) \equiv \sigma r - \frac{\chi}{r}$$

$$\sigma = 850 \text{ MeV/fm} (0.17 \text{ GeV}^2)$$

$$\chi = 100 \text{ MeV.fm}$$

$$m_b = 4793 \text{ MeV}$$

$$m_c = 1348.5 \text{ MeV}$$

$$\alpha_s = \frac{3\chi}{4\hbar} \simeq 0.38$$

Calculated masses for the lowest lying spin triplet states differing at most 30 MeV (60 MeV) for bottomonium (charmonium).

# J++ States (single thresholds with no significant widths)

$b\bar{b}$

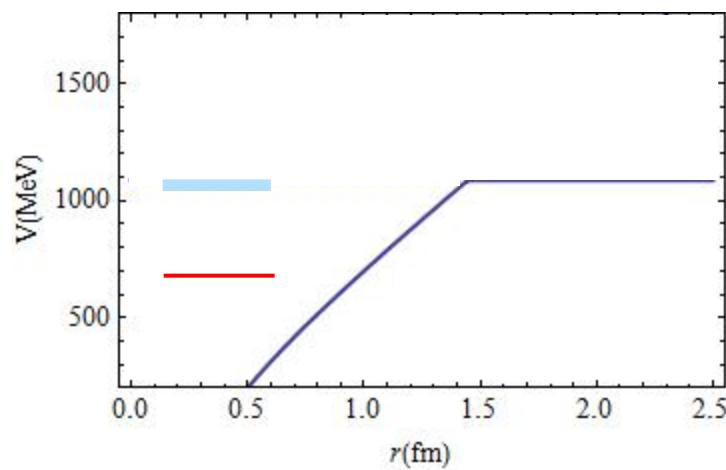
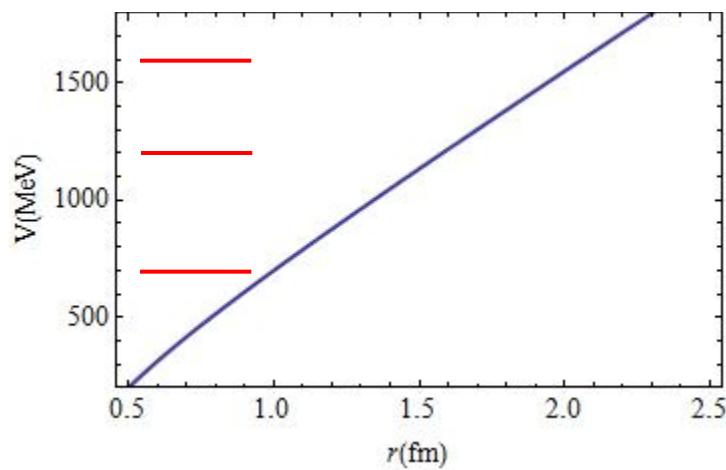
$c\bar{c}$

$J^{PC}$	GSPM States $k_{[T_{i-1}, T_i]}$	$M_{GSPM}$ MeV	$M_{PDG}$ MeV	$M_{Cor}$ MeV
0 <sup>++</sup>	$1p_{[T_0, T_1]}$	9920	$9859.44 \pm 0.42 \pm 0.31$	9920
1 <sup>++</sup>	$1p_{[T_0, T_1]}$	9920	$9892.78 \pm 0.26 \pm 0.31$	9920
2 <sup>++</sup>	$1p_{[T_0, T_1]}$	9920	$9912.21 \pm 0.26 \pm 0.31$	9920
0 <sup>++</sup>	$2p_{[T_0, T_1]}$	10259	$10232.5 \pm 0.4 \pm 0.5$	10259
1 <sup>++</sup>	$2p_{[T_0, T_1]}$	10259	$10255.46 \pm 0.22 \pm 0.50$	10259
2 <sup>++</sup>	$2p_{[T_0, T_1]}$	10259	$10268.65 \pm 0.22 \pm 0.50$	10259
0 <sup>++</sup>	$3p_{[T_0, T_1]}$	10521		10531
1 <sup>++</sup>	$3p_{[T_0, T_1]}$	10526		10531
2 <sup>++</sup>	$3p_{[T_0, T_1]}$	10528	$10530 \pm 5 \pm 9$	10531

$J^{PC}$	GSPM States $k_{[T_{i-1}, T_i]}$	$M_{GSPM}$ MeV	$M_{PDG}$ MeV	$M_{Cor}$ MeV
0 <sup>++</sup>	$1p_{[T_0, T_1]}$	3456.1	$3414.75 \pm 0.31$	3456.2
1 <sup>++</sup>	$1p_{[T_0, T_1]}$	3456.1	$3510.66 \pm 0.07$	3456.2
2 <sup>++</sup>	$1p_{[T_0, T_1]}$	3456.1	$3556.20 \pm 0.09$	3456.2
1 <sup>++</sup>	$2p_{[T_0, T_1]}$	3871.7	$3871.69 \pm 0.17$	3910.9
2 <sup>++</sup>	$2p_{[T_0, T_1]}$	3903.0	$3927.2 \pm 2.6$	3910.9

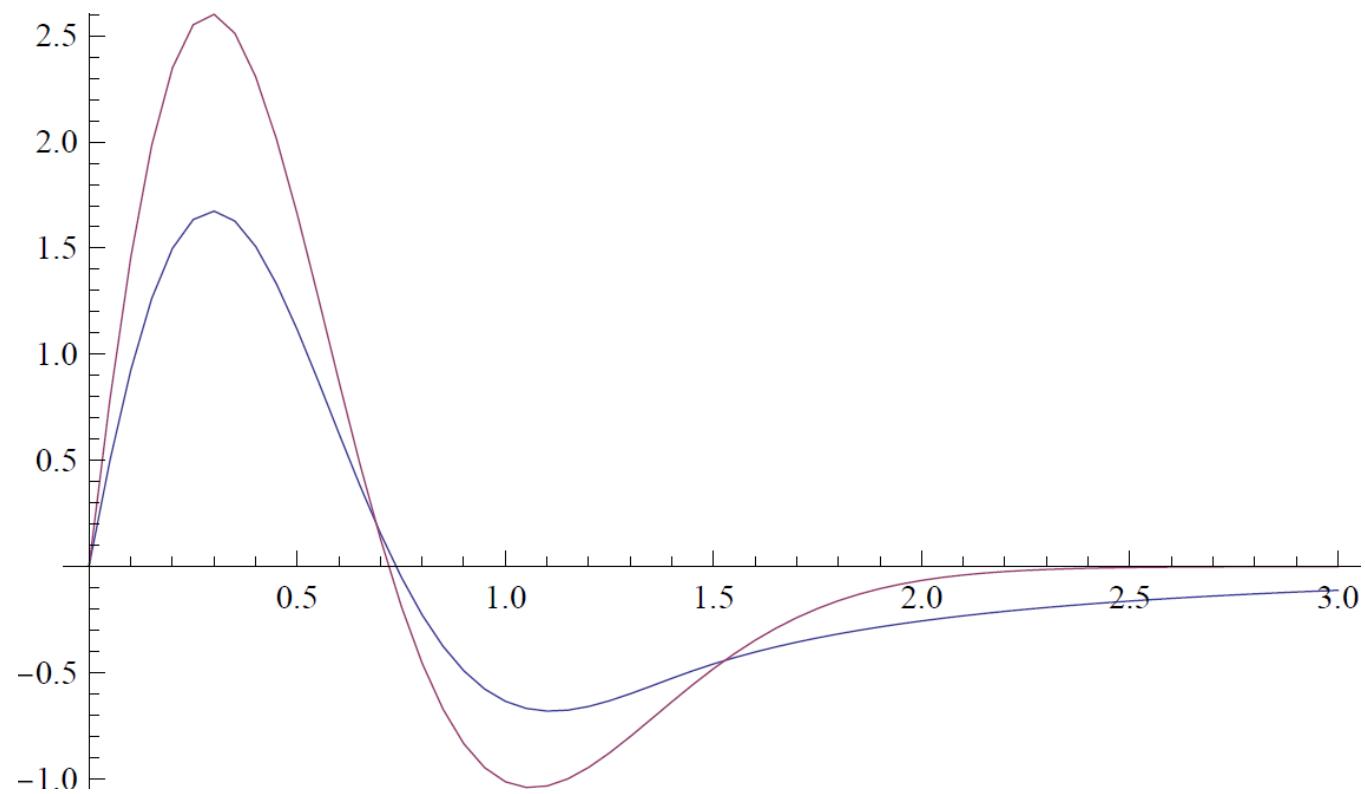
$\chi_{c_1}(3872)$

## Threshold Effect



$\chi_{c_1}(3872)(2p_{[T_0, T_1]})$ 

versus

 $\chi_{c_1}(2p)$ 

# Charmonium

## J++ S-wave Thresholds

$J^{PC}$	$T_i$	$Meson1 - Meson2$	$(J_1^P, J_2^P)$	$M_{T_i}$
0 <sup>++</sup>	$T_1$	$D^0 \overline{D}^0$	$(0^-, 0^-)$	3730
1 <sup>++</sup>	$T_1$	$D^0 \overline{D^*(2007)}^0$	$(0^-, 1^-)$	3872
2 <sup>++</sup>	$T_1$	$D^*(2007)^0 \overline{D^*(2007)}^0$	$(1^-, 1^-)$	4014

No significant threshold widths

## 1-- S-wave Threshold

$J^{PC}$	$T_i$	$Meson1 - Meson2$	$(J_1^P, J_2^P)$	$M_{T_i}$
1 <sup>--</sup>	$T_1$	$D^0 \overline{D_1(2420)}^0$ $D^0 \overline{D_1(2430)}^0$	$(0^-, 1^+)$	4287

Double threshold  
+  
Significant threshold widths

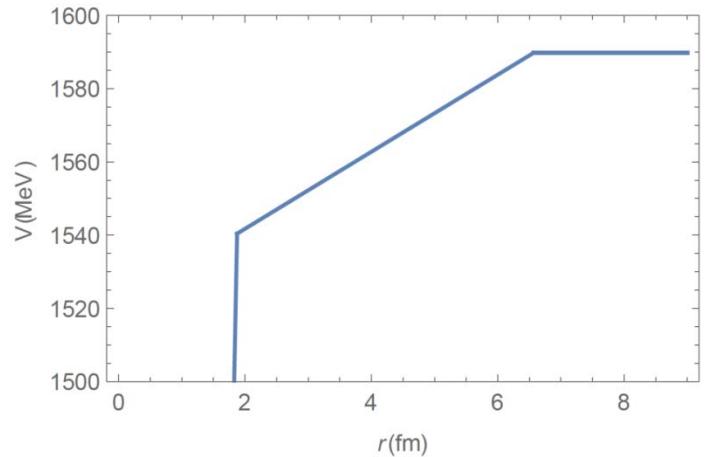
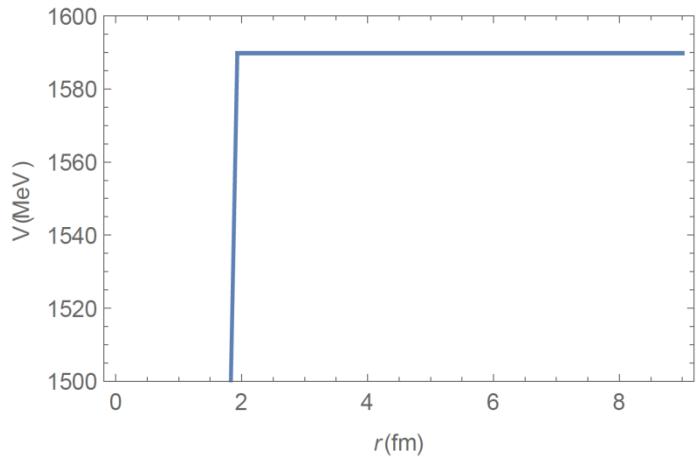
$$D_1(2420) : {}^1 P_1 \quad D_1(2430) : {}^3 P_1$$

$$\Gamma(D_1(2420)) : 27.4 \pm 2.5 \text{ MeV}$$

$$\Gamma(D_1(2430)) : 384^{+107}_{-75} \pm 74 \text{ MeV}$$

# Static Potential in the first energy region: 1– states

## Double threshold with significant width

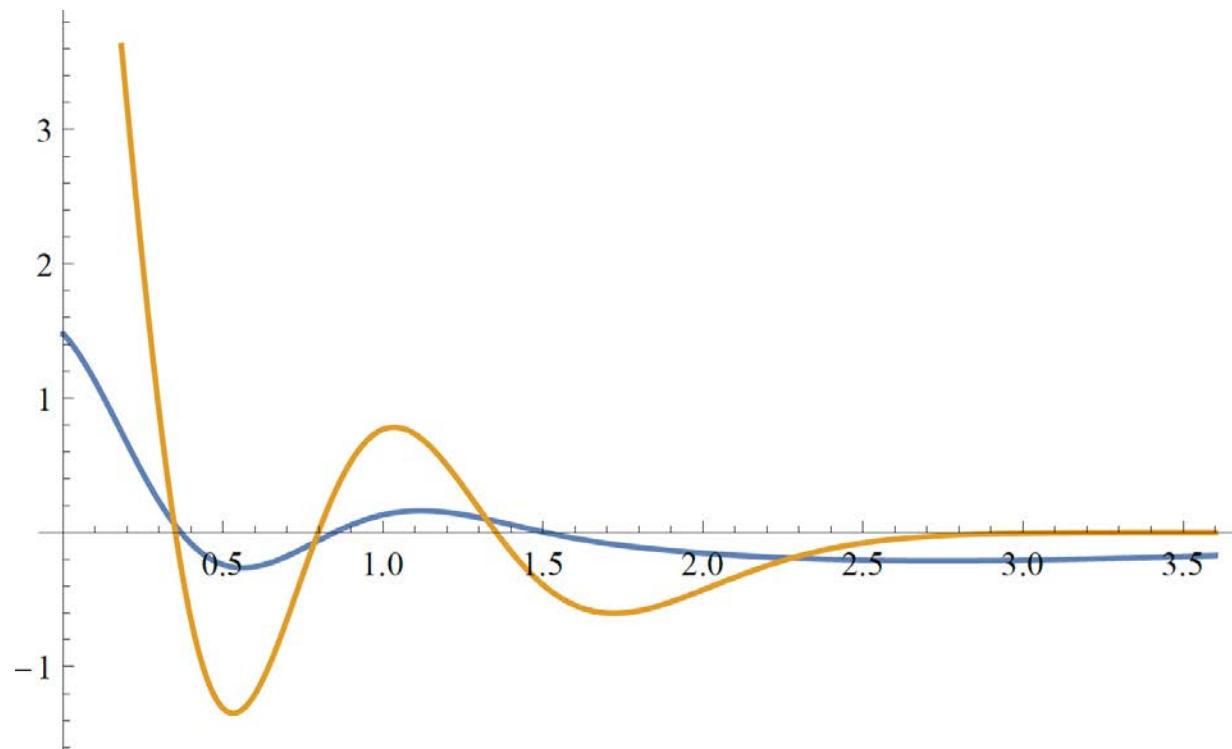


$$V_{[M_{T_0}, M_{T_1}]}(r) = \begin{cases} \sigma r - \frac{\zeta}{r} & r \leq (r_-)_{T_1} \\ (E_{T_1} - (\Delta_-)_{T_1}) + s_{T_1} (r - (r_-)_{T_1}) & (r_-)_{T_1} \leq r \leq (r_\times)_{T_1} \\ E_{T_1} & r \geq (r_\times)_{T_1} \end{cases}$$

# Spectrum

$J^{PC}$	IGSPM States $k_{[T_{i-1}, T_i]}$	$M_{IGSPM}$ MeV	$M_{PDG}$ MeV	$M_{Cor}$ MeV	Cornell States $k$
1 <sup>--</sup>	$1s_{[T_0, T_1]}$	3046.0	$3096.916 \pm 0.011$	3046.0	$1s$
	$2s_{[T_0, T_1]}$	3632.1	$3686.09 \pm 0.04$	3632.2	$2s$
	$1d_{[T_0, T_1]}$	3743.4	$3773.15 \pm 0.33$	3743.5	$1d$
	$3s_{[T_0, T_1]}$	4061.4	$4039 \pm 1$	4065.8	$3s$
	$2d_{[T_0, T_1]}$	4137.0	$4191 \pm 5$	4142.8	$2d$
	$4s_{[T_0, T_1]}$	4267.6	$4230 \pm 8$		

$\psi(4260)(4s_{[T_0, T_1]})$  versus  $\psi(4s)$



# Data (M. Tanabashi et al (PDG), PRD 98, 030001 (2018))

Mass :  $4230 \pm 8$  MeV  
 $(4220 - 4280)$

Width :  $55 \pm 19$  MeV  
 $(40 - 150)$

$J/\psi\pi^+\pi^-$  : discovery channel

$\psi(4260) \rightarrow D\bar{D}$  not seen

$$\left( \frac{\Gamma_{\psi(4260) \rightarrow J/\psi\pi^+\pi^-} - \Gamma_{\psi(4260) \rightarrow e^+e^-}}{\Gamma_{\psi(4260)}} \right)_{\text{exp}} = 9.2 \pm 1.0 \text{ eV}$$

$\psi(4260) \rightarrow \chi_{c1}(3872)\gamma$  seen versus  $\psi(4260) \rightarrow \chi_{c1}(1p)\gamma$  not seen

# E1 Decays

$$\Gamma_{E1}(i \rightarrow f + \gamma) = \frac{4\alpha e_c^2 w_{if}^3 (2J_f + 1)}{27} |D_{if}|^2$$

$$w_{if} = \frac{1}{2M_i} \left( M_i^2 - M_f^2 \right) \quad D_{if} = \int_0^\infty R_f(r) r^2 \frac{3}{w_{if}} \left( \frac{w_{if}r}{2} j_0 \left( \frac{w_{if}r}{2} \right) - j_1 \left( \frac{w_{if}r}{2} \right) \right) R_i(r) dr$$

$$\frac{\Gamma_{E1}(i \rightarrow f_1 + \gamma)}{\Gamma_{E1}(i \rightarrow f_2 + \gamma)} = \frac{(2J_{f_1} + 1)}{(2J_{f_2} + 1)} \frac{w_{if_1}^3}{w_{if_2}^3} \frac{|D_{if_1}|^2}{|D_{if_2}|^2}$$

$$\frac{\Gamma_{E1}(i_1 \rightarrow f + \gamma)}{\Gamma_{E1}(i_2 \rightarrow f + \gamma)} = \frac{w_{i_1 f}^3}{w_{i_2 f}^3} \frac{|D_{i_1 f}|^2}{|D_{i_2 f}|^2}$$

# E1 Decays

$\psi(4260) \rightarrow \chi_{c1}(3872)\gamma$  seen      VS       $\psi(4260) \rightarrow \chi_{c1}(1p)\gamma$  not seen

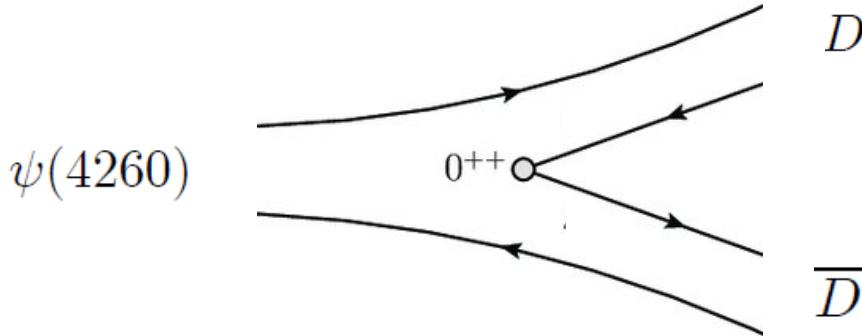
$$\frac{\Gamma(\psi(4260) \rightarrow \chi_{c1}(3872)\gamma)}{\Gamma(\psi(4260) \rightarrow \chi_{c1}(1p)\gamma)} = 80 \pm 24$$

$$\frac{\Gamma(\psi(4260) \rightarrow \chi_{c1}(1p)\gamma)}{\Gamma(\psi(2s) \rightarrow \chi_{c1}(1p)\gamma)} = 0.028 \pm 0.009$$

$$(\Gamma(\psi(2s) \rightarrow \chi_{c1}(1p)\gamma))_{\text{exp}} = 29 \pm 1 \text{ keV}$$

$$\Gamma(\psi(4260) \rightarrow \chi_{c1}(3872)\gamma) = 64 \pm 50 \text{ keV}$$

# Open Flavor Meson-Meson Decays



$$\Gamma = 2\pi \frac{E_D E_{\overline{D}}}{M_{\psi(4260)}} k_D |A|^2$$

$$|A|_{^3P_0}^2 \equiv \gamma^2 |M|^2 \quad \left(|M|^2\right)_{\psi(4260) \rightarrow D\overline{D}} = \tfrac{1}{96} I (+)^2$$

$$I (+)^2 = \left| \left[ p j_1 \left( \frac{pr_X}{\hbar} \right) j_1 \left( \frac{\frac{1}{\hbar} \int_0^\infty r_X^2 dr_X \psi_X (r_X) \int p^2 dp \tilde{u}_D (p) \tilde{u}_{\overline{D}} (p)}{(m_c + m_q) \frac{kr_X}{\hbar}} \right) + \frac{m_q}{(m_c + m_q)} k j_0 \left( \frac{pr_X}{\hbar} \right) j_0 \left( \frac{m_c}{(m_c + m_q)} \frac{kr_X}{\hbar} \right) \right] \right|^2$$

$$\tilde{u}_D (p) \equiv \sqrt{\frac{2}{\pi}} \int_0^\infty r_D^2 dr_D \psi_D (r_D) j_0 \left( \frac{pr_D}{\hbar} \right) \quad \psi_D (r_D) = \frac{2}{\pi^{\frac{1}{4}} R_D^{\frac{3}{2}}} e^{-\frac{r_D^2}{2R_D^2}}$$

$$\psi(4260) \rightarrow D\overline{D} \quad \text{not seen}$$

$$\psi(3770)\equiv\psi\left({}^3D_1\right)$$

$$\frac{\Gamma_{\psi(4260)\rightarrow D\overline{D}}}{\Gamma_{\psi(3770)\rightarrow D\overline{D}}} = 7\times 10^{-3}$$

$$\left(\Gamma_{\psi(3770)\rightarrow D\overline{D}}\right)_\text{exp} = 25.3~\,\text{MeV}$$

$$BR\left(\psi(4260)\rightarrow D\overline{D}\right)=3\times 10^{-3}$$

# Leptonic Width

$$\frac{\Gamma_{2s \rightarrow e^+ e^-}}{\Gamma_{1s \rightarrow e^+ e^-}} = 0.5 \quad \text{vs} \quad \left( \frac{\Gamma_{\psi(2s) \rightarrow e^+ e^-}}{\Gamma_{\psi(1s) \rightarrow e^+ e^-}} \right)_{\text{exp}} = 0.42 \pm 0.02$$

$$\frac{\Gamma_{\psi(4260) \rightarrow e^+ e^-}}{\Gamma_{\psi(2s) \rightarrow e^+ e^-}} = \frac{|R_{\psi(4260)}(0)|^2}{|R_{\psi(2s)}(0)|^2} \frac{M_{\psi(2s)}^2}{M_{\psi(4260)}^2}$$

$$(\Gamma_{\psi(2s) \rightarrow e^+ e^-})_{\text{exp}} = 2.30 \pm 0.06 \text{ keV} \longrightarrow$$

$$\boxed{\Gamma_{\psi(4260) \rightarrow e^+ e^-} \simeq 68 \pm 14 \text{ eV}}$$



Compatible with  $J/\psi \pi^+ \pi^-$   
being the discovery channel

$$\Gamma_{\psi(4260) \rightarrow e^+ e^-} \simeq 68 \pm 14 \text{ eV} \quad \left( \frac{\Gamma_{\psi(4260) \rightarrow J/\psi \pi^+ \pi^-} - \Gamma_{\psi(4260) \rightarrow e^+ e^-}}{\Gamma_{\psi(4260)}} \right)_{\text{exp}} = 9.2 \pm 1.0 \text{ eV}$$

$$\boxed{\frac{\Gamma_{\psi(4260) \rightarrow J/\psi \pi^+ \pi^-}}{\Gamma_{\psi(4260)}} \simeq (13 \pm 3)\%}$$

However for a 4s Cornell type state:

$$\left| \frac{R_{\psi(4s)}(0)}{R_{\psi(4260)}(0)} \right|^2 \simeq 24$$

$$\frac{\Gamma_{\psi(4s) \rightarrow J/\psi \pi^+ \pi^-}}{\Gamma_{\psi(4260)}} \simeq (0.54 \pm 0.17)\%$$

# Summary

- i)  $\psi(4260)$  is an unconventional charmonium state.
- ii) There is a plausible explanation for it based on an Effective Quark-antiQuark Potential incorporating threshold effects.
- iii) Decay properties can be understood by the change in the wave function (with respect to the Cornell one) due to the presence of thresholds.

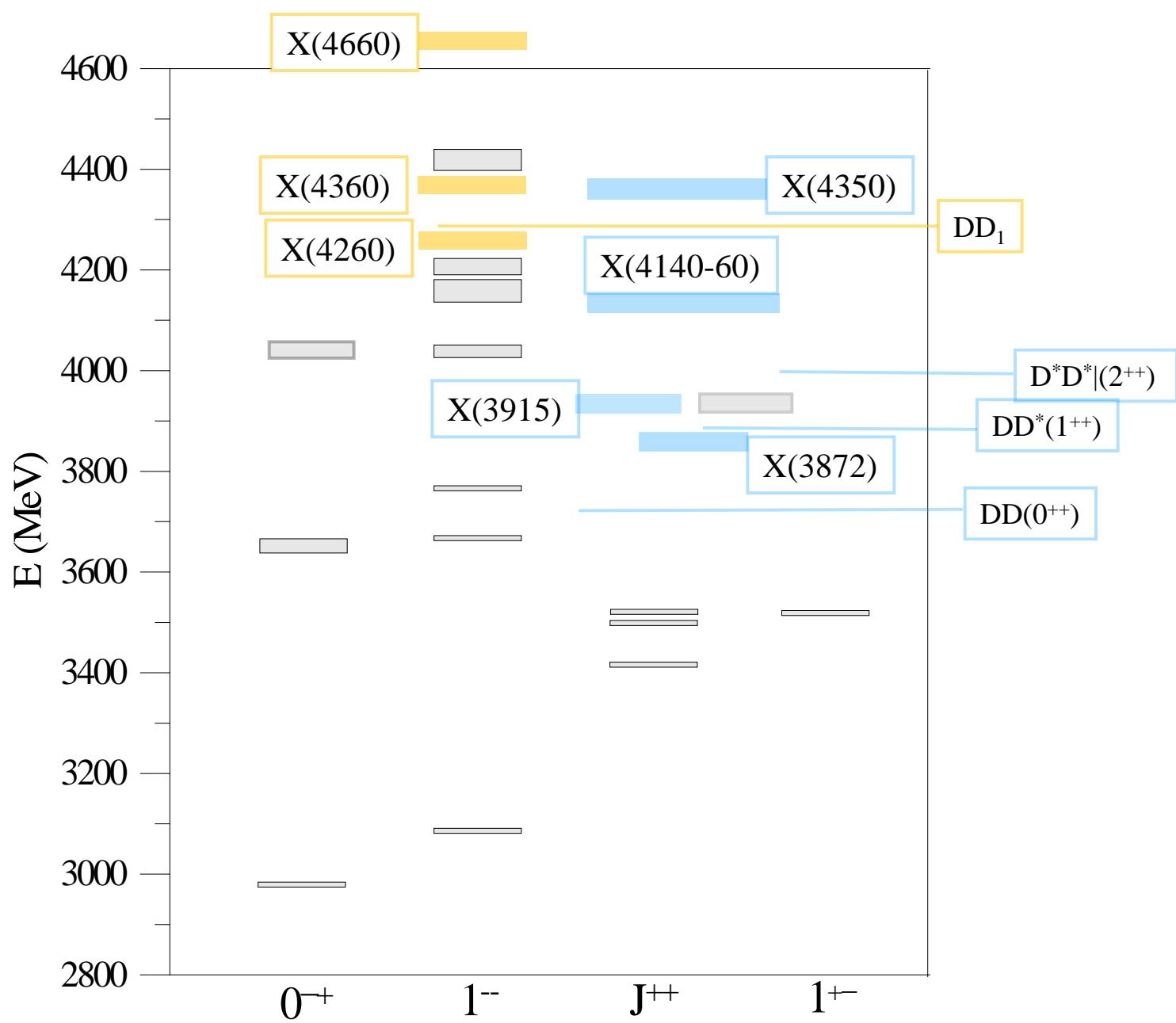
THE END



# Charmonium

## J++ Thresholds

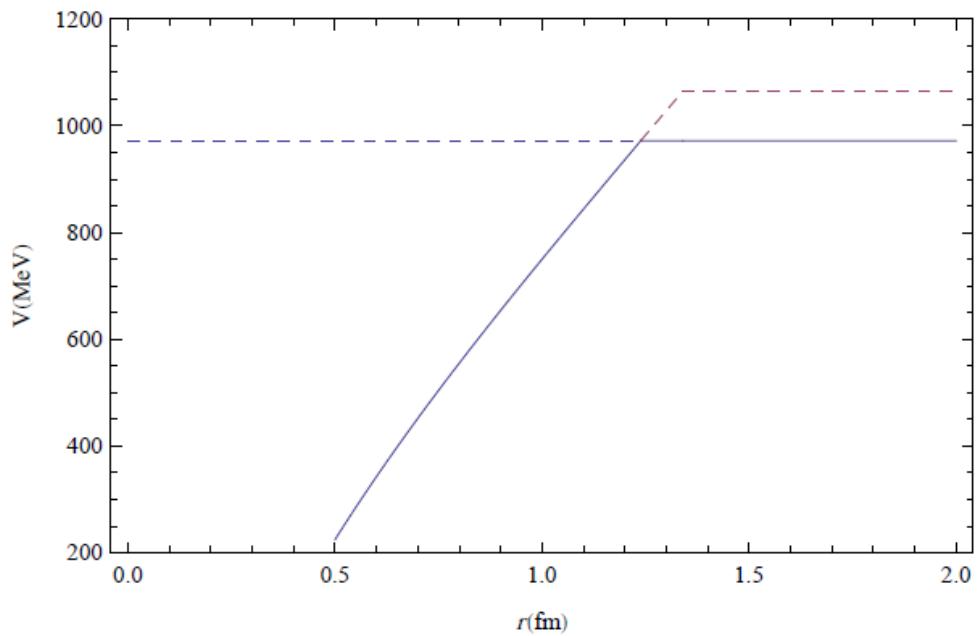
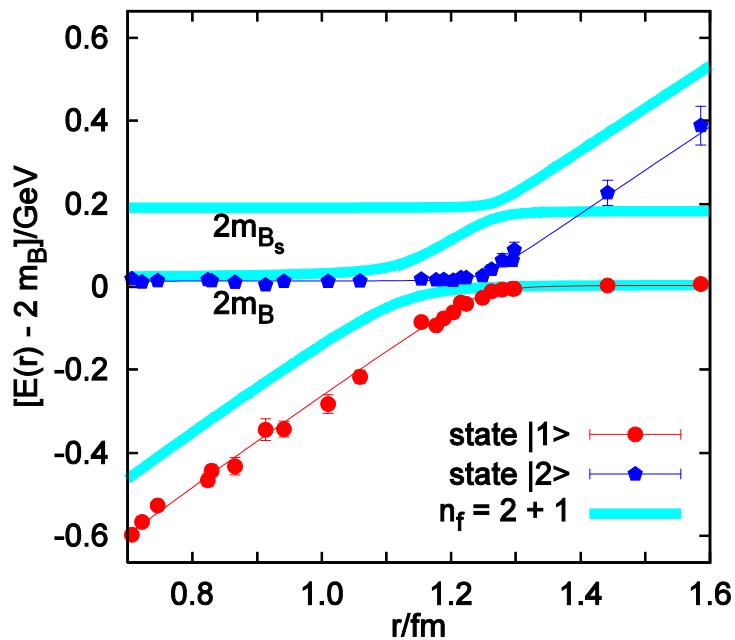
$J^{PC}$	$T_i$	$Meson1 - Meson2$	$(J_1^P, J_2^P)$	$M_{T_i}$
<hr/> <hr/>				
0 <sup>++</sup>				
	$T_1$	$D^0 \overline{D}^0$	$(0^-, 0^-)$	3730
	$T_2$	$D_s^+ D_s^-$	$(0^-, 0^-)$	3937
	$T_3$	$D^*(2007)^0 \overline{D^*(2007)}^0$	$(1^-, 1^-)$	4014
	$T_4$	$D_s^{*+} D_s^{*-}$	$(1^-, 1^-)$	4224
	$T_5$	$D^0 \overline{D(2550)}^0$	$(0^-, 0^-)$	4405
 1 <sup>++</sup>				
	$T_1$	$D^0 \overline{D^*(2007)}^0$	$(0^-, 1^-)$	3872
	$T_2$	$D_s^+ D_s^{*-}$	$(0^-, 1^-)$	4080
 2 <sup>++</sup>				
	$T_1$	$D^*(2007)^0 \overline{D^*(2007)}^0$	$(1^-, 1^-)$	4014
	$T_2$	$D_s^{*+} D_s^{*-}$	$(1^-, 1^-)$	4224



$X$  states : Close-below or Above their First S-wave M-M Threshold

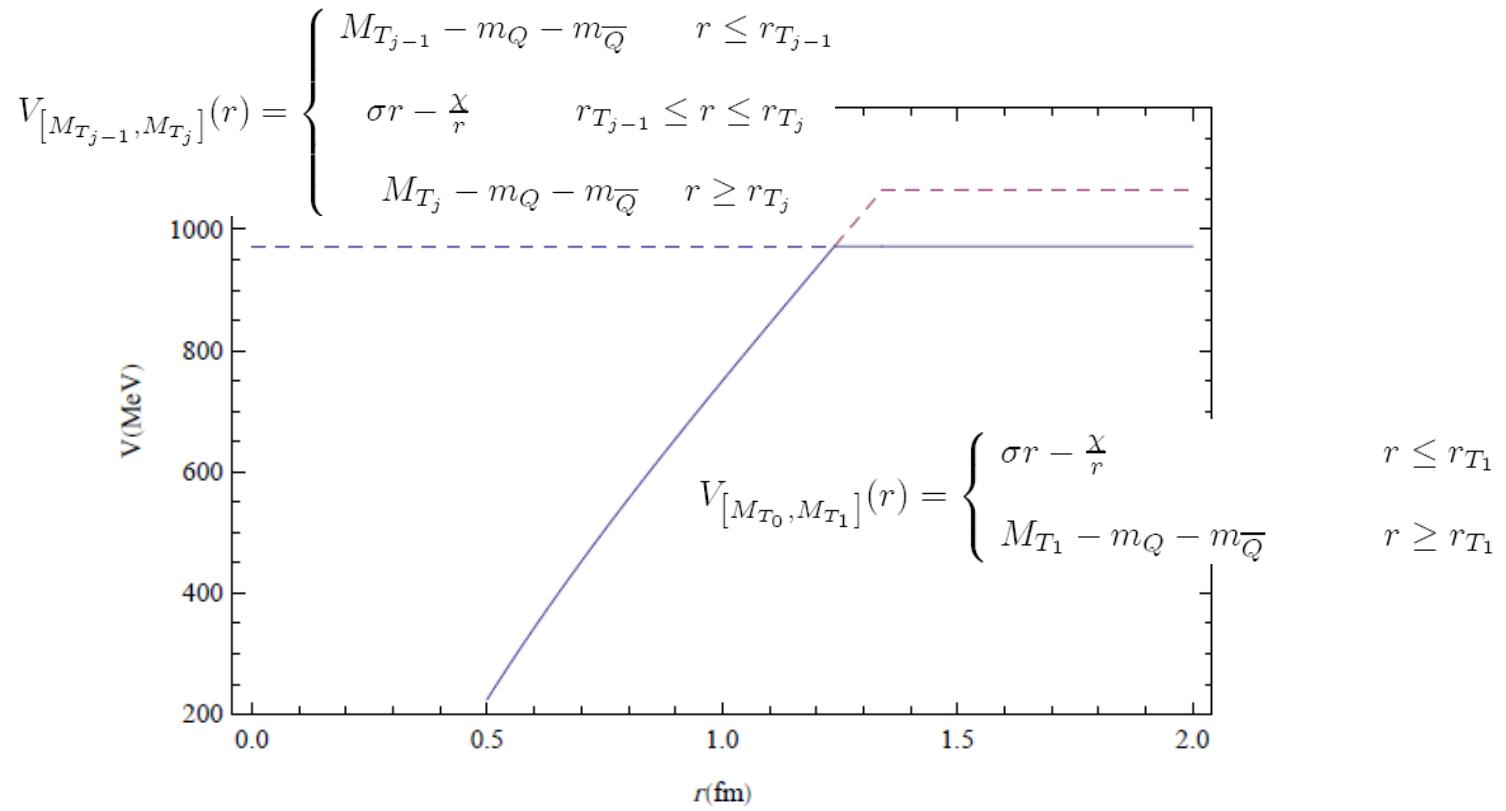
# Generalized Screened Potential Model (GSPM)

$$V_{E_{Q\bar{Q}}}(r) = V_{[M_{T_{i-1}}, M_{T_i}]}(r) \quad \text{if } M_{T_{i-1}} < E_{Q\bar{Q}} \leq M_{T_i} \quad M_{T_0} \equiv 0$$



$$\sigma r_{T_{j-1}} - \frac{\chi}{r_{T_{j-1}}} = M_{T_{j-1}} - m_Q - m_{\bar{Q}}$$

$$V_{E_{Q\bar{Q}}}(r) = V_{[M_{T_{i-1}}, M_{T_i}]}(r) \quad \text{if } M_{T_{i-1}} < E_{Q\bar{Q}} \leq M_{T_i}$$



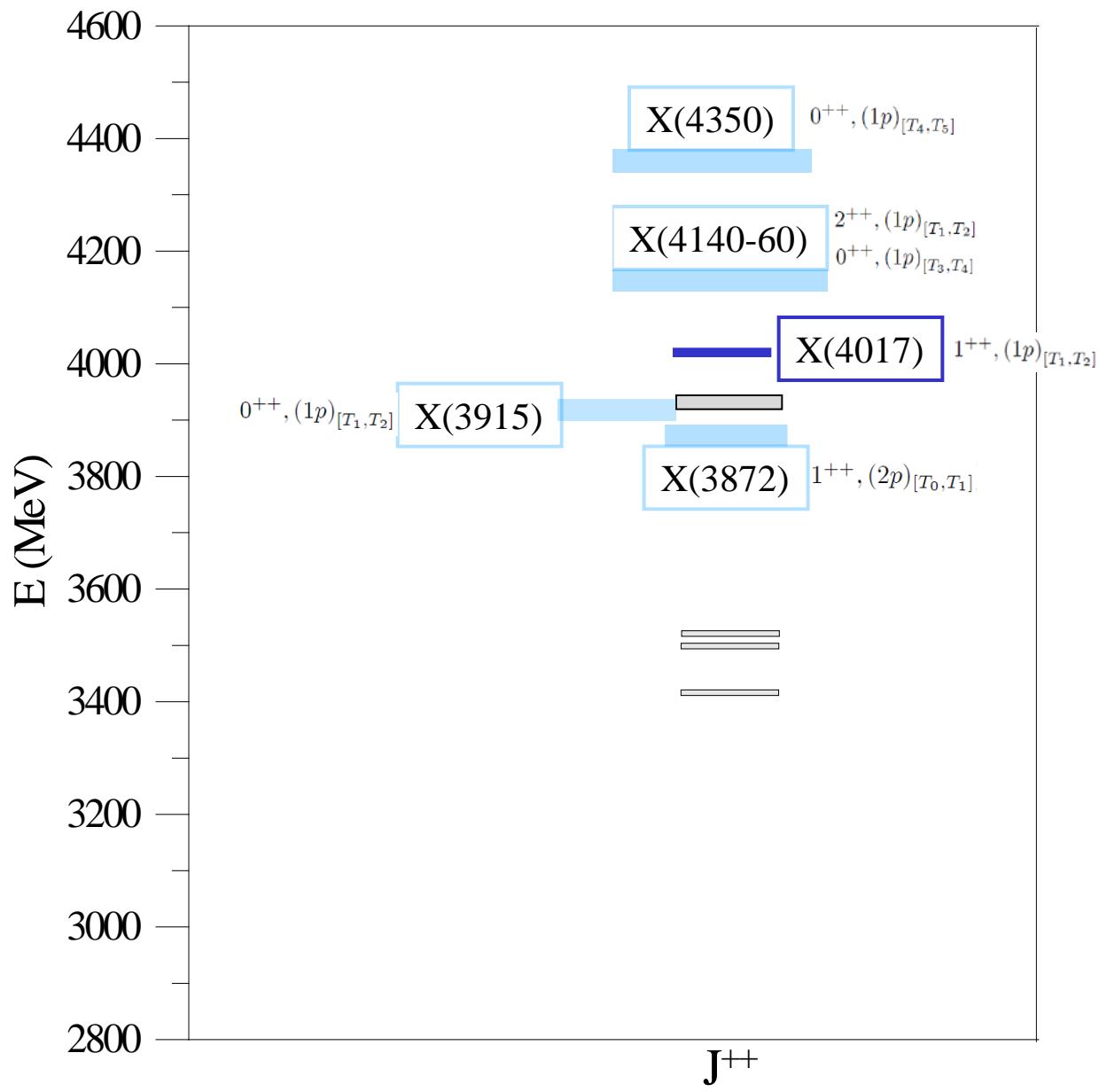
Cornell potential modulated by thresholds

## Possible Shortcomings

- Non relativistic potential (effective).
- No spin dependent terms in the Cornell potential.
- Only screening from meson-meson channels.
- No thresholds widths.

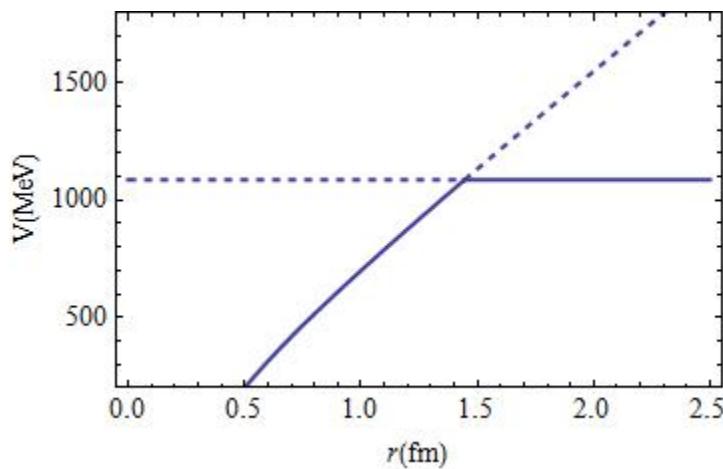
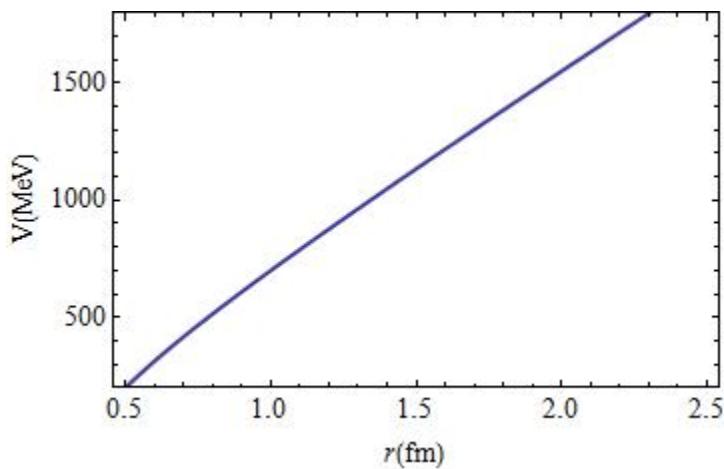
# GSPM J++ Spectrum

$J^{PC}$	GSPM States $k_{[T_{i-1}, T_i]}$	$M_{GSPM}$ MeV	$M_{PDG}$ MeV	$M_{Cor}$ MeV
$0^{++}$	$1p_{[T_0, T_1]}$	3456	$3414.75 \pm 0.31$	3456
$1^{++}$	$1p_{[T_0, T_1]}$	3456	$3510.66 \pm 0.07$	3456
$2^{++}$	$1p_{[T_0, T_1]}$	3456	$3556.20 \pm 0.09$	3456
$1^{++}$	$2p_{[T_0, T_1]}$	3871.7	$3871.68 \pm 0.17$	3911
$0^{++}$	$1p_{[T_1, T_2]}$	3898	$3918.4 \pm 1.9$	3911
$2^{++}$	$2p_{[T_0, T_1]}$	3903	$3927.2 \pm 2.6$	3911
$1^{++}$	$1p_{[T_1, T_2]}$	4017		
$0^{++}$	$1p_{[T_3, T_4]}$	4140	$4143.0 \pm 2.9 \pm 1.2$	
$2^{++}$	$1p_{[T_1, T_2]}$	4140	$4156^{+25}_{-20} \pm 15$	
$0^{++}$	$1p_{[T_4, T_5]}$	4325	$4350.6^{+4.6}_{-5.1} \pm 0.7$	4295



# Threshold Effect

$1^{++}$



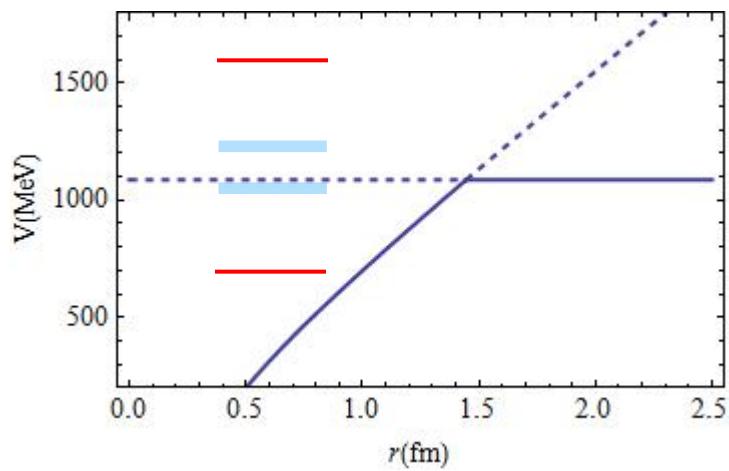
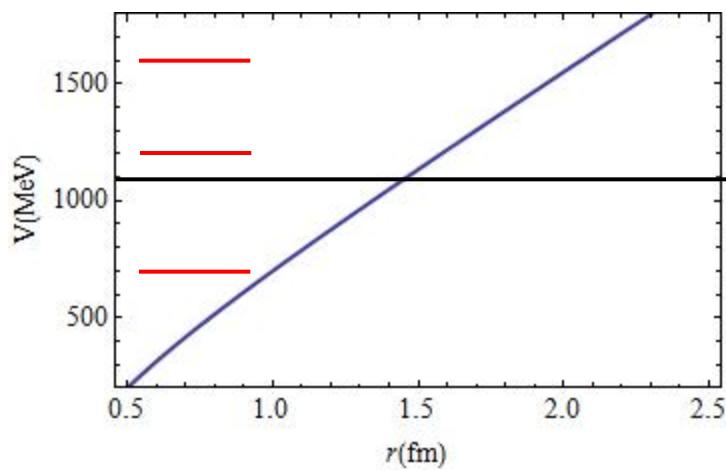
## Attraction + Additional States

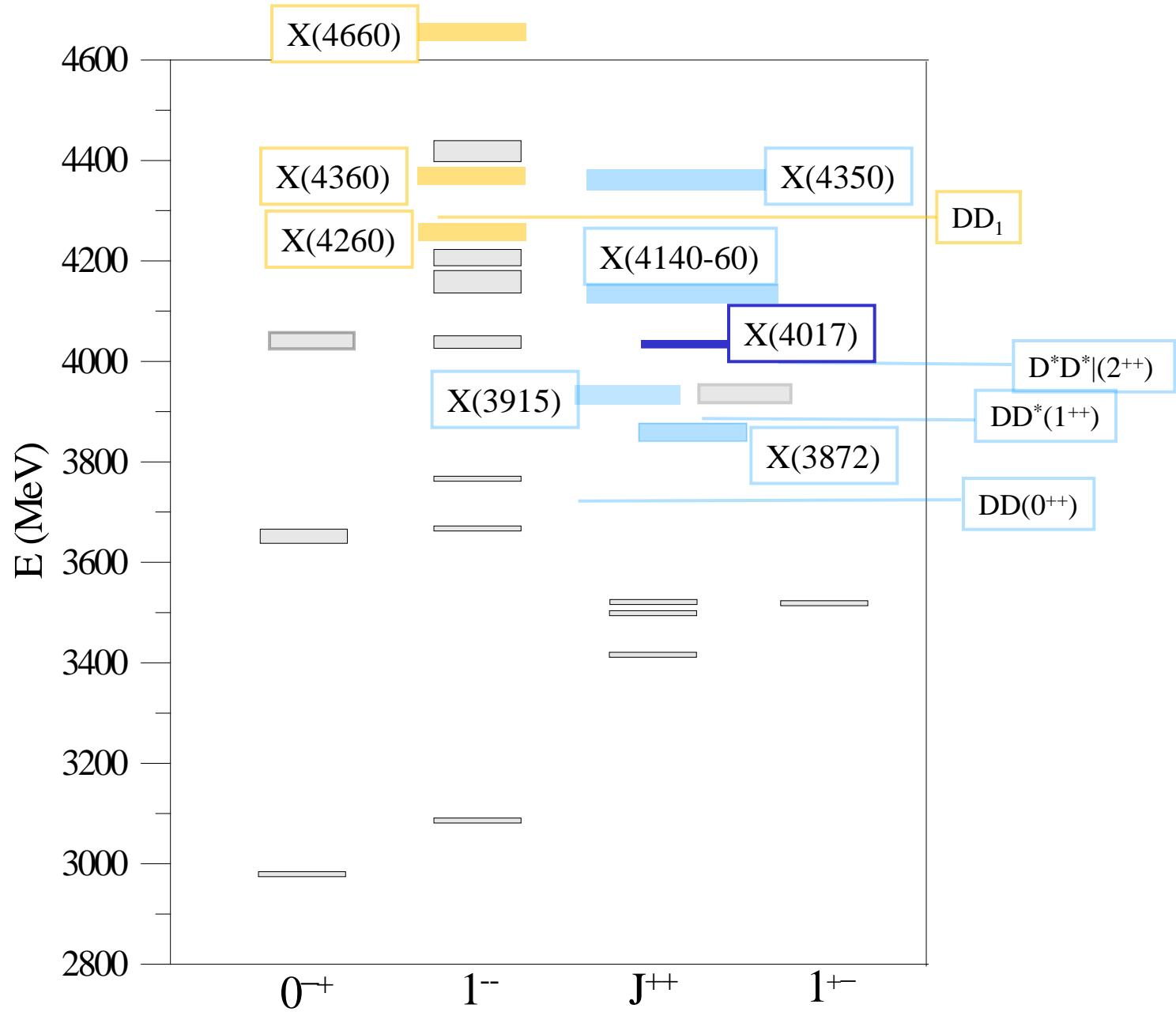
$c\bar{c} (1^{++})$				GSPM States	$M_{GSPM}$ MeV	$M_{Cor}$ MeV	Cornell States
				$k_{[T_{i-1}, T_i]}$			
$T_1$	$D^0 \overline{D^*(2007)}^0$	$(0^-, 1^-)$	3872				
$T_2$	$D_s^+ D_s^{*-}$	$(0^-, 1^-)$	4080	$1p_{[T_0, T_1]}$	3456	3456	$1p$
				$2p_{[T_0, T_1]}$	3871.7	3911	$2p$
				$1p_{[T_1, \infty]}$	4029		
				$2p_{[T_1, \infty]}$	4303	4295	$3p$

$X(3872)$  results from the interaction between  $T_1$  and the Cornell state

Additionally a new state  $X(4029)$  appears.

# Additional States



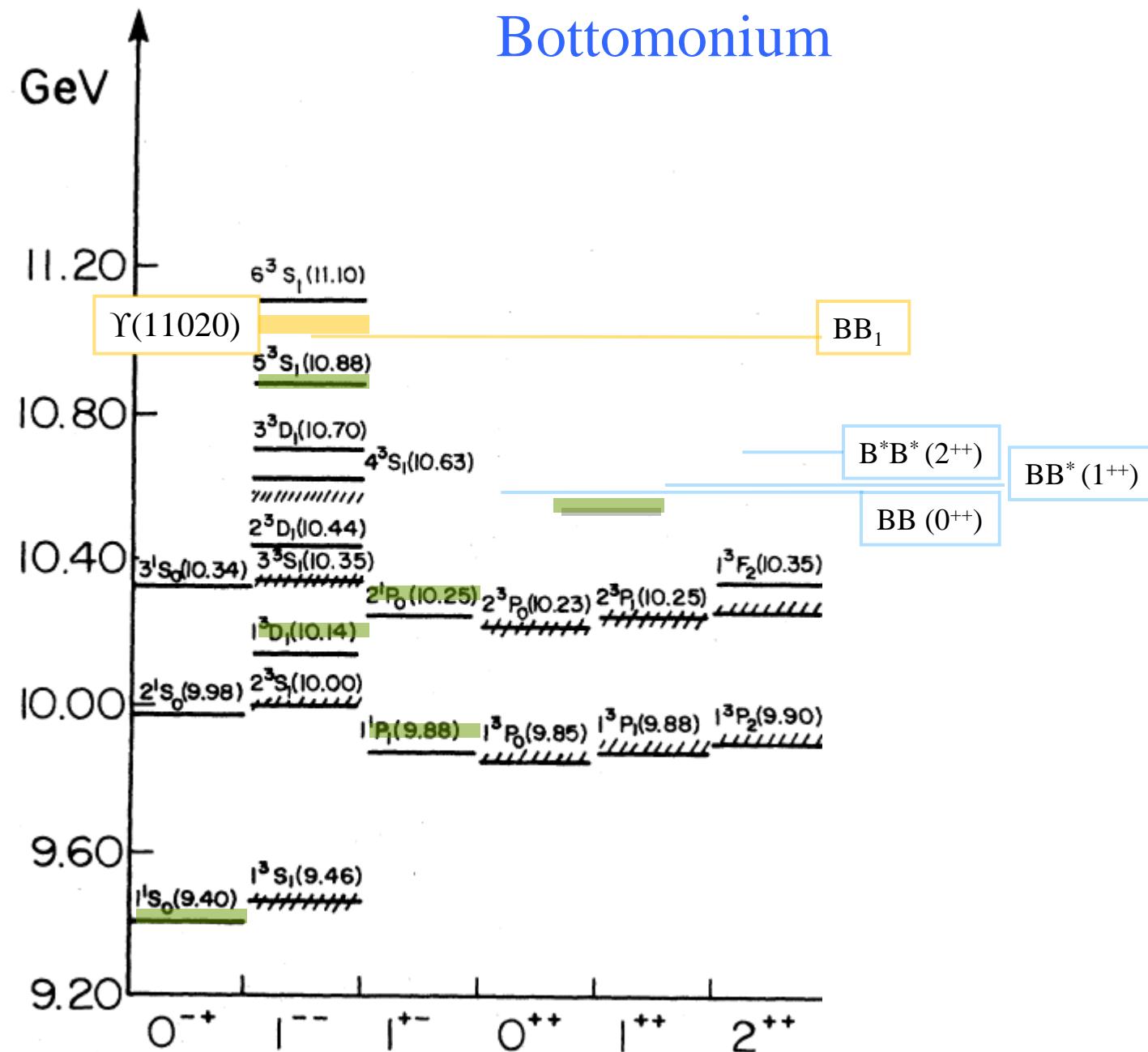


# 1-- Thresholds

$J^{PC}$	$T_i$	$Meson1 - Meson2$	$(J_1^P, J_2^P)$	$M_{T_i}$
$1^{--}$				
	$T_1$	$D^0 \overline{D_1(2420)}^0$ $D^0 \overline{D_1(2430)}^0$	$(0^-, 1^+)$	4287
	$T_2$	$D^*(2007)^0 \overline{D_0^*(2400)}^0$	$(1^-, 0^+)$	4325
	$T_3$	$D^*(2007)^0 \overline{D_1(2420)}^0$ $D^*(2007)^0 \overline{D_1(2430)}^0$ $D_s^+ D_{s1}(2460)^-$ $D_s^{*+} D_{s0}^*(2317)^-$	$(1^-, 1^+)$ $(1^-, 1^+)$ $(0^-, 1^+)$ $(1^-, 0^+)$	4429
	$T_4$	$D^*(2007)^0 \overline{D_2^*(2460)}^0$	$(1^-, 2^+)$	4470
	$T_5$	$D_s^+ D_{s1}(2536)^-$	$(0^-, 1^+)$	4504
	$T_6$	$D_s^{*+} D_{s1}(2460)^-$	$(1^-, 1^+)$	4572
	$T_7$	$D_s^{*+} D_{s1}(2536)^-$	$(1^-, 1^+)$	4648
	$T_8$	$D_s^{*+} D_{s2}^*(2573)^-$	$(1^-, 2^+)$	4685

Overlapping Thresholds

## Bottomonium



# J++ States

$b\bar{b}$

$J^{PC}$	$T_i$	$Meson1 - Meson2$	$(J_1^P, J_2^P)$	$M_{T_i}$	$J^{PC}$	GSPM States $k_{[T_{i-1}, T_i]}$	$M_{GSPM}$ MeV	$M_{PDG}$ MeV	$M_{Cor}$ MeV
$0^{++}$					$0^{++}$	$1p_{[T_0, T_1]}$	9920	$9859.44 \pm 0.42 \pm 0.31$	9920
	$T_1$	$B^0 \overline{B}^0$	$(0^-, 0^-)$	10558	$1^{++}$	$1p_{[T_0, T_1]}$	9920	$9892.78 \pm 0.26 \pm 0.31$	9920
	$T_2$	$B^{*0} \overline{B}^{*0}$	$(1^-, 1^-)$	10650	$2^{++}$	$1p_{[T_0, T_1]}$	9920	$9912.21 \pm 0.26 \pm 0.31$	9920
	$T_3$	$B_s^0 \overline{B}_s^0$	$(0^-, 0^-)$	10734	$0^{++}$	$2p_{[T_0, T_1]}$	10259	$10232.5 \pm 0.4 \pm 0.5$	10259
	$T_4$	$B_s^* \overline{B}_s^*$	$(1^-, 1^-)$	10830	$1^{++}$	$2p_{[T_0, T_1]}$	10259	$10255.46 \pm 0.22 \pm 0.50$	10259
					$2^{++}$	$2p_{[T_0, T_1]}$	10259	$10268.65 \pm 0.22 \pm 0.50$	10259
					$0^{++}$	$3p_{[T_0, T_1]}$	10521		10531
					$1^{++}$	$3p_{[T_0, T_1]}$	10526		10531
								$10530 \pm 5 \pm 9$	
$1^{++}$					$2^{++}$	$3p_{[T_0, T_1]}$	10528		10531
	$T_1$	$B^0 \overline{B}^*$	$(0^-, 1^-)$	10604					
	$T_2$	$B_s^0 \overline{B}_s^*$	$(0^-, 1^-)$	10782	$0^{++}$	$1p_{[T_1, T_2]}$	10620		
$2^{++}$					$1^{++}$	$1p_{[T_1, T_2]}$	10668		
	$T_1$	$B^{*0} \overline{B}^{*0}$	$(1^-, 1^-)$	10650	$0^{++}$	$1p_{[T_2, T_3]}$	10704		
	$T_2$	$B_s^* \overline{B}_s^*$	$(1^-, 1^-)$	10830	$2^{++}$	$1p_{[T_1, T_2]}$	10710		10768
					$1^{++}$	$2p_{[T_1, T_2]}$	10776		
					$0^{++}$	$1p_{[T_3, T_4]}$	10784		
					$2^{++}$	$2p_{[T_1, T_2]}$	10815		

