Overview Task 1.2: Hadron decays

Theoretical Aspects of Hadron Spectroscopy and Phenomenology

15-17 December 2020

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Task 1.2: Hadron decays

General description

We will investigate decays of heavy hadrons, looking for particular interacting hadron pairs in the final state that might produce resonant states. Using Dalitz-plot based methods, EFT and dispersive techniques, we shall also explore issues such as the exotic nature of resonances, isospin or CP violations.

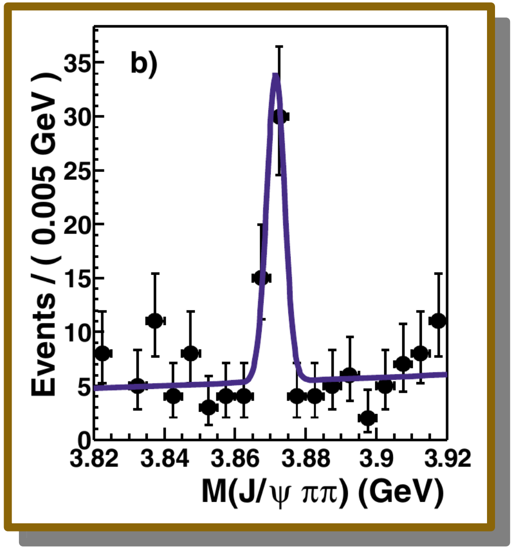
Hadron decays are essential properties of hadrons

The decays can discriminate between different pictures to understand the nature of the states

Deviations from expectations due to well known symmetries can give signatures of new physics

The X(3872) now $\chi_{c1}(3872)$

Belle 2003



Mass very close to the $D^{*0}\bar{D}^0$

$$B \equiv m_{X(3872)} - m_{D^{*0}} - m_{\bar{D}^0} = 1.1^{+0.6+0.1}_{-0.4-0.3}\ \text{MeV}$$
$$= (0.00 \pm 0.18)\ \text{MeV}$$

From a ω Belle arXiv: hep-ex/0505037

$$\frac{\mathcal{B}(X(3872) \to \pi^+\pi^-\pi^0 J/\psi)}{\mathcal{B}(X(3872) \to \pi^+\pi^- J/\psi)} = 1.0 \pm 0.4(\text{stat}) \pm 0.3(\text{syst})$$

From a ρ^0 CDF Phys. Rev. Lett. 96, 102002

Isospin breaking scale

$$\frac{m_{D^+} - m_{D^0}}{m_{D^+} + m_{D^0}} \sim 0.13\%$$
$$\frac{m_{D^{*+}} - m_{D^{*0}}}{m_{D^{*+}} + m_{D^{*0}}} \sim 0.08\%$$

$$m_{D^{*+}} + m_{D^-} - m_{D^{*0}} - m_{\bar{D}^0} = 8.2 \pm 0.1\ \text{MeV} \gg B$$

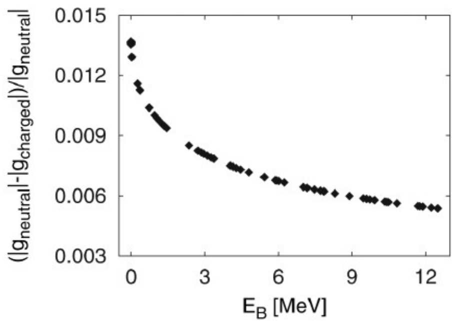
Isospin violation

D. Gamermann and E. Oset, Phys. Rev. D 80, 014003 (2009). QFT treatment

Less than 1% isospin violation

$$g_{D^+D^{*-}} = 2982$$
$$g_{D^0\bar{D}^{*0}} = 3005$$

Interpreted as probabilities



Small isospin breaking effect $\mathcal{R}_{\rho/\omega} \sim 3.2\%$

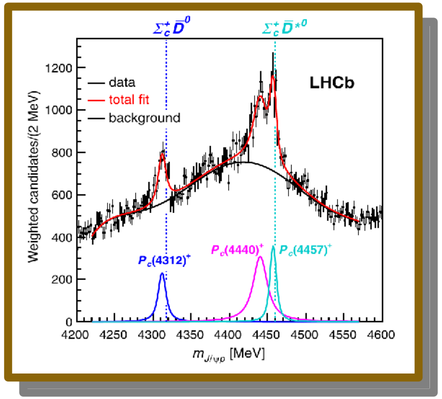
$$\frac{\mathcal{B}(X(3872) \to \pi\pi J/\psi)}{\mathcal{B}(X(3872) \to \pi\pi\pi J/\psi)} = \mathcal{R}_{\rho/\omega} \frac{\int_0^\infty q\mathcal{S}(s, m_\rho, \Gamma_\rho)\theta(m_X - m_{J/\psi} - \sqrt{s})ds}{\int_0^\infty q\mathcal{S}(s, m_\omega, \Gamma_\omega)\theta(m_X - m_{J/\psi} - \sqrt{s})ds} \times \frac{\mathcal{B}_\rho}{\mathcal{B}_\omega}$$

Final result compatible with experimental data

Phase space effect due to large differences on the widths

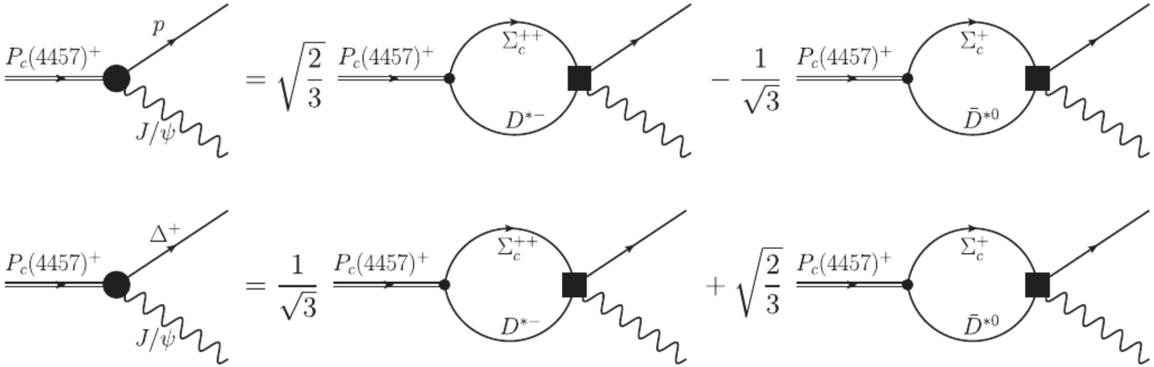
Pentaquarks

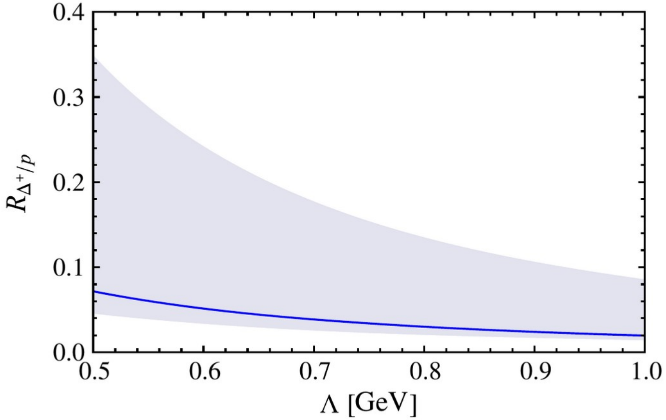
$$
\begin{aligned}
M_{P_c(4457)^+} &= 4457.3 \pm 0.6^{+4.1}_{-1.7} \\
\Gamma_{P_c(4457)^+} &= 6.4 \pm 2.0^{+5.7}_{-1.9} \\
M_{\Sigma_c^+} + M_{\bar{D}^{*0}} &= 4459.8 \pm 0.4\,\mathrm{MeV} \Rightarrow B_1 = 2.5^{+1.8}_{-4.2}\,\mathrm{MeV} \\
M_{\Sigma_c^{++}} + M_{D^{*-}} &= 4464.23 \pm 0.15\,\mathrm{MeV} \Rightarrow B_2 = 6.9^{+1.8}_{-4.1}\,\mathrm{MeV}
\end{aligned}
$$



In analogy to the X(3872)

$$
R_{\Delta^+/p} = \frac{|\mathcal{B}(P_c(4457)^+ \to J/\psi \Delta^+)|}{|\mathcal{B}(P_c(4457)^+ \to J/\psi p)|}
$$





F.-K. Guo et al., Phys. Rev. D 99, 091501 (2019).

Uncertainties coming from pentaquark mass

The X(3872) binding energy

F.-K. Guo, Phys. Rev. Lett. 122, 202002 (2019)

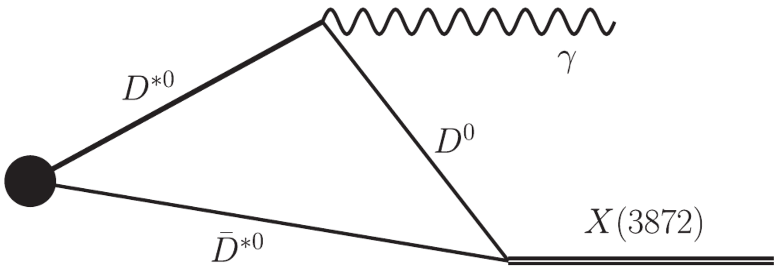
Proposal to measured the X(3872) binding energy with the triangle singularity

Prove the long range properties of the X(3872)

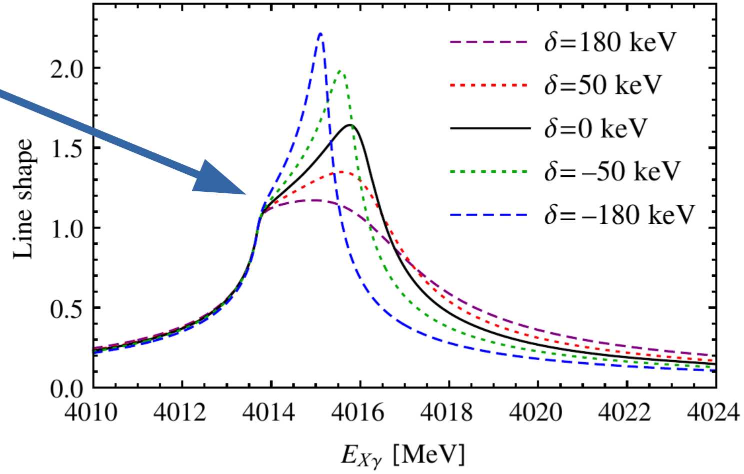
$$I(E_{X\gamma}) = \frac{1}{E_\gamma}\left[\arctan\left(\frac{c_2 - c_1}{2b\sqrt{c_1}}\right) + \arctan\left(\frac{c_1 - c_2 + 2b^2}{2b\sqrt{c_2 - b^2}}\right)\right]$$

$$E_{X\gamma}^{TS} = 2m_{D^{*0}} + \frac{x^2}{2m_{D^0}} + \mathcal{O}\left(\frac{x^3}{m_{D^0}^2}\right)$$

$$x = m_{D^{*0}} - m_{D^0} - 2\sqrt{-m_{D^0}\delta} + \delta$$



Cusp fixed



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Eur. Phys. J. C (2020) 80:510
https://doi.org/10.1140/epjc/s10052-020-8058-8

THE EUROPEAN PHYSICAL JOURNAL C

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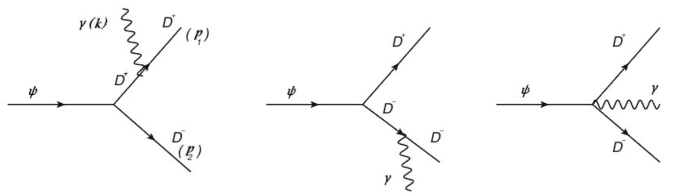
Regular Article - Theoretical Physics

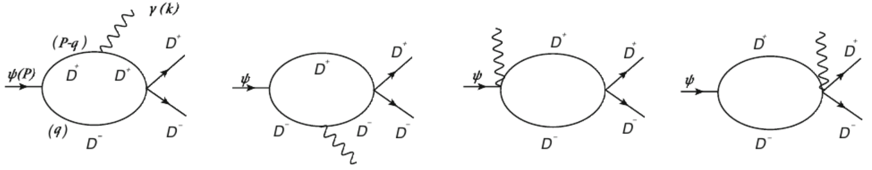
Searching for a $D\bar{D}$ bound state with the $\psi(3770) \to \gamma D^0 \bar{D}^0$ decay

Lianrong Dai[1,2,a], Genaro Toledo[3,4,b], Eulogio Oset[4,c]

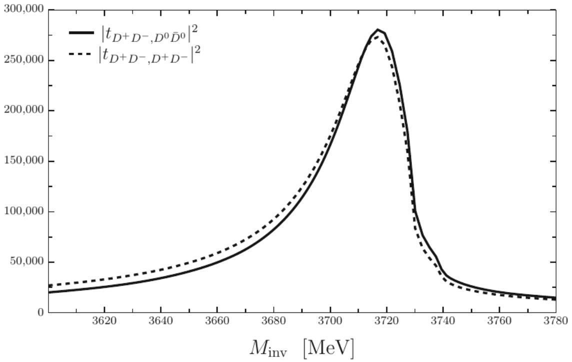
$$\Gamma = 27.2\, MeV \begin{cases} 52\%\, D^0 \bar{D}^0 \\ 41\%\, D^+ D^- \end{cases}$$



(a) (b) (c)

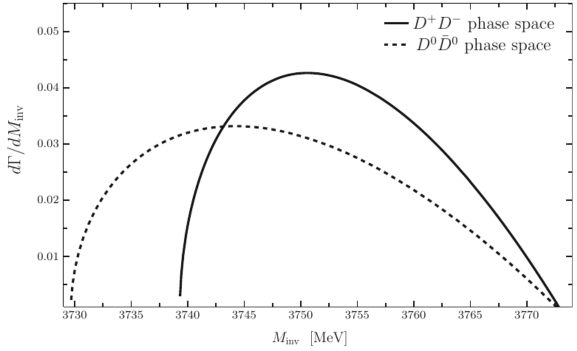


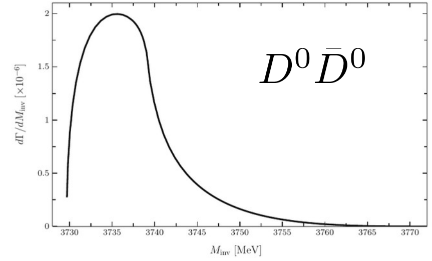
(a) (b) (c) (d)

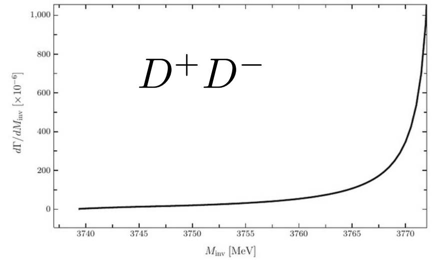


Bound state

Phase space







Decay and Electromagnetic production of strongly coupled quarkonia in pNRQCD

Nora Brambilla, Hee Sok Chung, Daniel Müller, Antonio Vairo,
JHEP04(2020)095

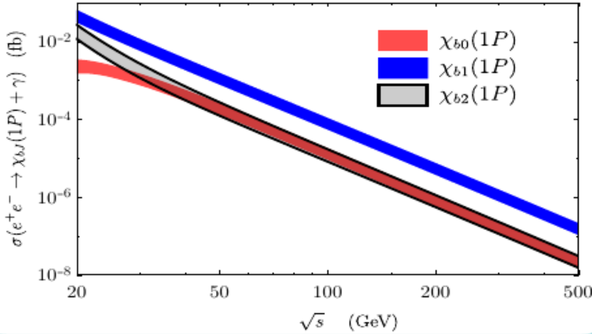
- Potential NRQCD provides expressions for NRQCD matrix elements in terms of quarkonium wavefunctions and universal gluonic correlators.
- This brings in a ***reduction of nonperturbative unknowns***, owing to the *universality* of gluonic correlators.
- We compute decay and production rates of *S*-wave and *P*-wave quarkonia by fitting the gluonic correlators to measured *P*-wave charmonium data.

pNRQCD results for electromagnetic production rates

P-wave charmonium cross sections at $\sqrt{s} = 10.6$ GeV

$$\sigma(e^+e^- \to \chi_{c0}(1P) + \gamma) = 1.84^{+0.25}_{-0.26} \pm 0.76\,\text{fb}\,,$$
$$\sigma(e^+e^- \to \chi_{c1}(1P) + \gamma) = 16.4^{+0.2}_{-0.2} \pm 6.4\,\text{fb}\,,$$
$$\sigma(e^+e^- \to \chi_{c2}(1P) + \gamma) = 3.75^{+0.67}_{-0.56} \pm 2.16\,\text{fb}\,,$$

P-wave bottomonium cross sections at future lepton colliders



A model to explain the angular distribution of J/ψ and $\psi(2S)$ decay into $\Lambda\overline{\Lambda}$ and $\Sigma^0\overline{\Sigma}^0$

Istituto Nazionale di Fisica Nucleare

Chin. Phys. C 43 023103

Rinaldo Baldini Ferroli, Monica Bertani,
Alessio Mangoni, Simone Pacetti, et al.

Effective strong Lagrangian

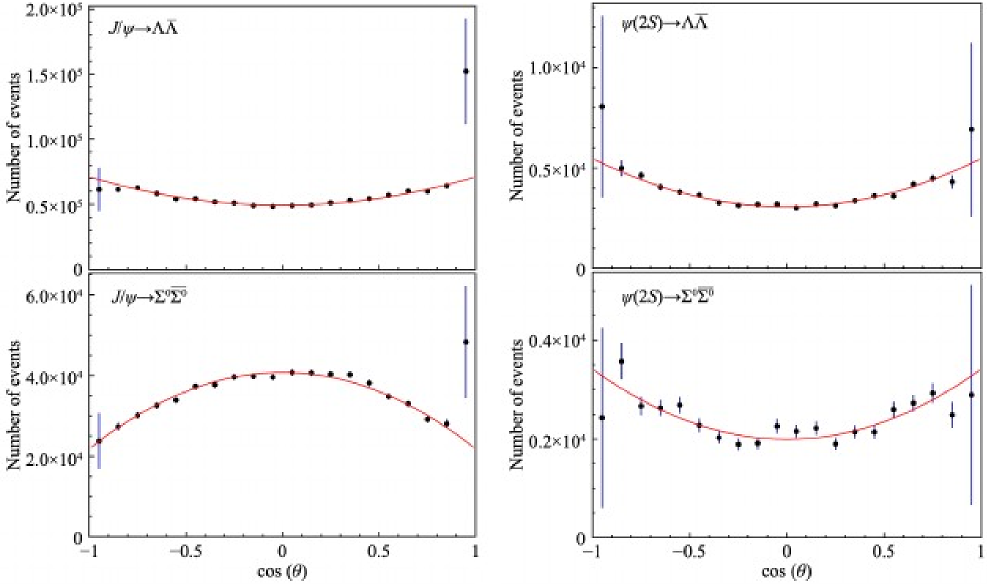
$$\mathscr{L} = (G_0 + G_1)\Sigma^0\overline{\Sigma}^0 + (G_0 - G_1)\Lambda\overline{\Lambda}$$

The interplay between the leading G_0 and sub-leading G_1 contributions to the decay amplitude determines the sign and value of the polarization parameter α_B

$$\frac{d\sigma}{d\cos\theta} = \frac{\pi\alpha^2\beta}{2M_\psi^2}\left(\left|g_M^B\right|^2 + \frac{4M_B^2}{M_\psi^2}\left|g_E^B\right|^2\right)\left(1+\alpha_B\cos^2\theta\right),$$

$$\beta = \sqrt{1-\frac{4M_B^2}{M_\psi^2}} \qquad \alpha_B = \frac{M_\psi^2\left|g_M^B\right|^2 - 4M_B^2\left|g_E^B\right|^2}{M_\psi^2\left|g_M^B\right|^2 + 4M_B^2\left|g_E^B\right|^2}$$

Particular angular distribution of J/ψ and $\psi(2S)$ mesons into $\Lambda\overline{\Lambda}$ and $\Sigma^0\overline{\Sigma}^0$ (BESIII data)



Strong and electromagnetic amplitudes of the J/ψ decays into baryons and their relative phase

Phys. Lett. B 799 135041

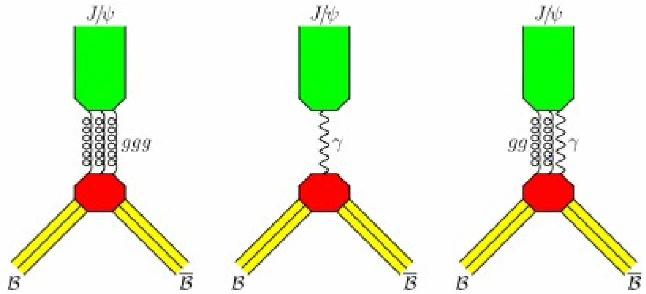
Rinaldo Baldini Ferroli, Alessio Mangoni,
Simone Pacetti, Kai Zhu

$$\mathscr{A}_{J/\psi} = \mathscr{A}^{ggg}(1+R)e^{i\varphi} + \mathscr{A}^{\gamma}$$

Decay process	$\mathcal{A}^{ggg} + \mathcal{A}^{gg\gamma} + \mathcal{A}^{\gamma}$
$J/\psi \to \Sigma^0\overline{\Sigma}^0$	$(G_0 + 2D_m)e^{i\varphi} + D_e$
$J/\psi \to \Lambda\overline{\Lambda}$	$(G_0 - 2D_m)e^{i\varphi} - D_e$
$J/\psi \to (\Lambda\overline{\Sigma}^0 + \mathrm{cc})$	$\sqrt{3}\,D_e$
$J/\psi \to p\overline{p}$	$(G_0 - D_m + F_m)(1+R)e^{i\varphi} + D_e + F_e$
$J/\psi \to n\overline{n}$	$(G_0 - D_m + F_m)e^{i\varphi} - 2\,D_e$
$J/\psi \to \Sigma^+\overline{\Sigma}^-$	$(G_0 + 2D_m)(1+R)e^{i\varphi} + D_e + F_e$
$J/\psi \to \Sigma^-\overline{\Sigma}^+$	$(G_0 + 2D_m)(1+R)e^{i\varphi} + D_e - F_e$
$J/\psi \to \Xi^0\overline{\Xi}^0$	$(G_0 - D_m - F_m)e^{i\varphi} - 2\,D_e$
$J/\psi \to \Xi^-\overline{\Xi}^+$	$(G_0 - D_m - F_m)(1+R)e^{i\varphi} + D_e - F_e$

$R_{\mathrm{pQCD}} \sim -\frac{4}{5}\frac{\alpha}{\alpha_S}$

$J/\psi \to B\overline{B}$



$$B = \begin{pmatrix} \frac{\Lambda}{\sqrt{6}} + \frac{\Sigma^0}{\sqrt{2}} & \Sigma^+ & p \\ \Sigma^- & \frac{\Lambda}{\sqrt{6}} - \frac{\Sigma^0}{\sqrt{2}} & n \\ \Xi^- & \Xi^0 & -\frac{2\Lambda}{\sqrt{6}} \end{pmatrix}$$

$$\mathscr{L} = \mathscr{L}_{\Sigma^0\Lambda} + \mathscr{L}_p + \mathscr{L}_n + \mathscr{L}_{\Sigma^+} + \mathscr{L}_{\Sigma^-} + \mathscr{L}_{\Xi^0} + \mathscr{L}_{\Xi^-}$$

After a χ^2 minimization procedure

G_0	$(5.73511 \pm 0.0059) \times 10^{-3}$ GeV
D_e	$(4.52 \pm 0.19) \times 10^{-4}$ GeV
D_m	$(-3.74 \pm 0.34) \times 10^{-4}$ GeV
F_e	$(7.91 \pm 0.62) \times 10^{-4}$ GeV
F_m	$(2.42 \pm 0.12) \times 10^{-4}$ GeV
φ	$1.27 \pm 0.14 = (73 \pm 8)^\circ$
R	$(-9.7 \pm 2.1) \times 10^{-2}$

Strong-EM relative phase

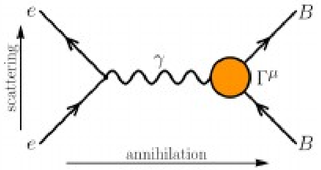
$$\varphi = 73^\circ \pm 8^\circ$$

$R \sim -0.097 \neq R_{\mathrm{pQCD}} \sim -\frac{4}{5}\frac{\alpha}{\alpha_S} \sim -0.025$

The cross section of $e^+e^- \to \Lambda\overline{\Sigma}^0 + \mathrm{c.c.}$ as a litmus test of isospin violation in the decays of vector charmonia into $\Lambda\overline{\Sigma}^0 + \mathrm{c.c.}$

Eur. Phys. J. C 80 903

Rinaldo Baldini Ferroli, Alessio Mangoni, Simone Pacetti



$B\bar{B}$	$g^\psi_\gamma \mathcal{A}^\gamma_{B\bar{B}}(M^2_\psi)$
$\Sigma^0\overline{\Sigma}^0$	D_e
$\Lambda\overline{\Lambda}$	$-D_e$
$\Lambda\overline{\Sigma}^0 + \mathrm{c.c.}$	$\sqrt{3}\,D_e$
$p\overline{p}$	$D_e + F_e$
$n\overline{n}$	$-2\,D_e$
$\Sigma^+\overline{\Sigma}^-$	$D_e + F_e$
$\Sigma^-\overline{\Sigma}^+$	$D_e - F_e$
$\Xi^-\overline{\Xi}^+$	$D_e - F_e$
$\Xi^0\overline{\Xi}^0$	$-2\,D_e$

$$\mathrm{BR}^\gamma_{B\bar{B}} = \frac{\left|g^\psi_\gamma\right|^2 \beta_{M_B}(M^2_\psi)}{16\pi M_\psi \Gamma_\psi} |\mathcal{A}^\gamma_{B\bar{B}}(M^2_\psi)|^2$$

$$\sigma^0_{\mu^+\mu^-}(q^2) = \frac{4\pi\alpha^2}{3q^2}$$

$$\sigma_{B\bar{B}}(M^2_\psi) = \frac{\sigma^0_{\mu^+\mu^-}(M^2_\psi)}{\mathrm{BR}^\gamma_{\mu^+\mu^+}} \mathrm{BR}^\gamma_{B\bar{B}},$$

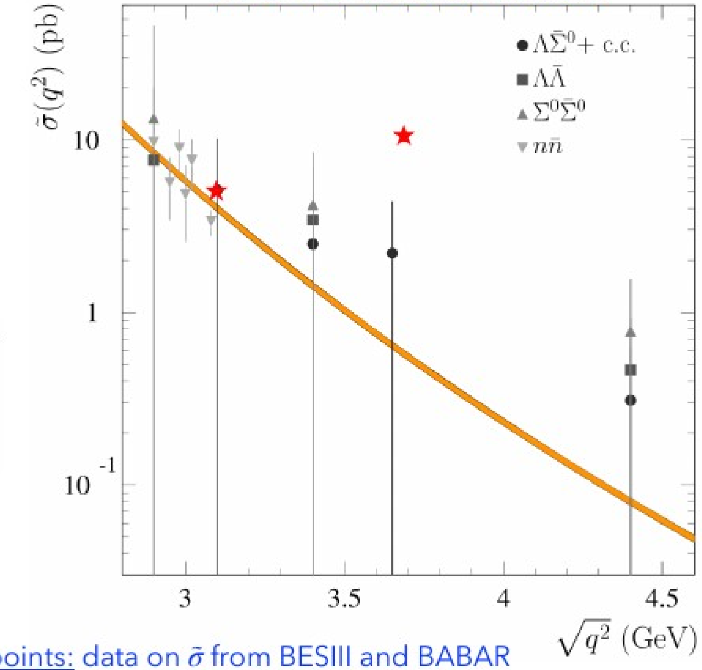
$$N_{B^0\bar{B}^0} \equiv \begin{cases} 1 & B^0\bar{B}^0 = \Lambda\overline{\Sigma}^0 + \mathrm{c.c.} \\ -2/\sqrt{3} & B^0 = n \\ -1/\sqrt{3} & B^0 = \Lambda \\ 1/\sqrt{3} & B^0 = \Sigma^0 \\ -2/\sqrt{3} & B^0 = \Xi^0 \end{cases}$$

Scaled cross section $\tilde{\sigma}$

$$\tilde{\sigma}(q^2) \equiv \frac{\sigma_{B^0\bar{B}^0}(q^2)}{N^2_{B^0\bar{B}^0}\,\beta_{M_{B^0}}(q^2)} = \frac{4\pi\alpha^2}{3q^2}|\mathcal{A}^\gamma_{\Lambda\overline{\Sigma}^0}(q^2)|^2$$

Assuming isospin conservation the amplitudes for $\Lambda\overline{\Sigma}^0 + \mathrm{c.c.}$ final states are purely EM

BESIII and BABAR data

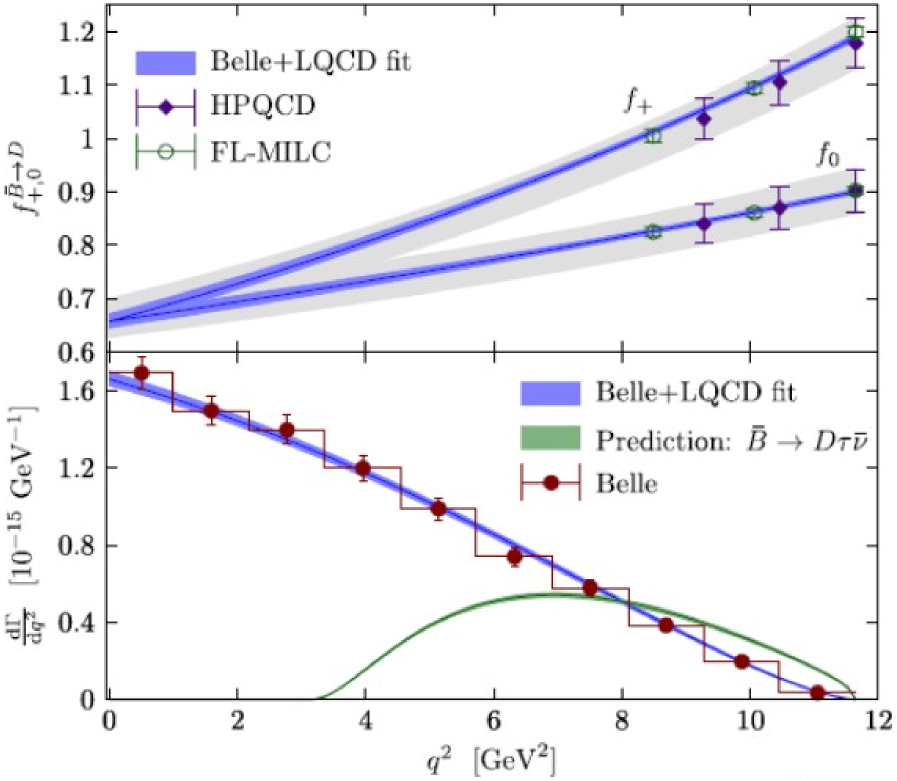


Solid points: data on $\tilde{\sigma}$ from BESIII and BABAR

Orange band: fit results including the errors

Red stars: values of $\tilde{\sigma}$ derived by the decays BRs from PDG

New parametrization of the form factors in $\bar{B} \longrightarrow D\ell\bar{\nu}_\ell$ decays
(D.L.Yao, P.Fernandez-Soler, F.K.Guo and J. Nieves, Phys. Rev. D101 (2020) 034014



$$f_i(q^2) = f_i(s_0) \prod_{n=0}^{\infty} \exp\left[\frac{q^2 - s_0}{s_{\rm th}} \mathcal{A}_n^i \frac{q^{2n}}{s_{\rm th}^n}\right]$$

f_+ and f_0 FF's are parametrized using a Omnés form, where the parameters (phase moments) are related to phase shifts by sum-rule like dispersion relations and encode important scattering information of the $\bar{B}\bar{D}$ interactions which are poorly known so far. Thus, we give strong hints about the **existence of at least one bound and one virtual $\bar{B}\bar{D}$ S-wave 0^+ states**, subject to uncertainties produced by potentially sizable inelastic effects.

We also get $|V_{cb}| = (41.01 \pm 0.75) \times 10^{-3}$ and $\mathcal{R}_D = \frac{\mathcal{BR}(\bar{B} \to D\tau\bar{\nu}_\tau)}{\mathcal{BR}(\bar{B} \to D\ell\bar{\nu}_\ell)} = 0.301(5)$

Physics Letters B 803 (2020) 135340

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Physics Letters B

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$\Upsilon(nl)$ decay into $B^{(*)}\bar{B}^{(*)}$

Wei-Hong Liang [a,b,*], Natsumi Ikeno [c,d], Eulogio Oset [a,d]

Fit A and R

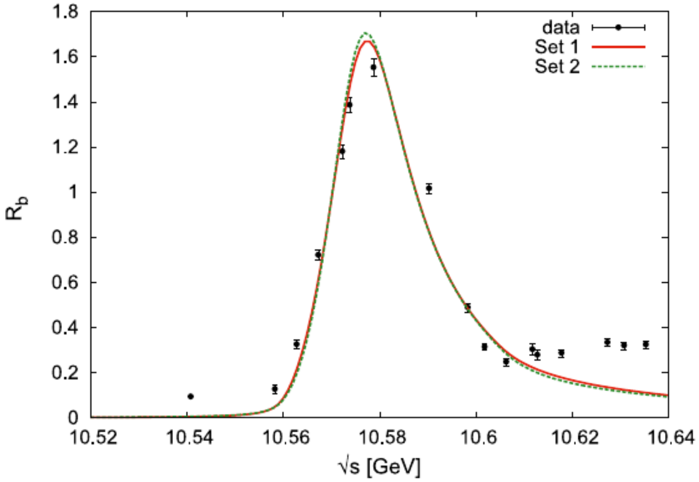
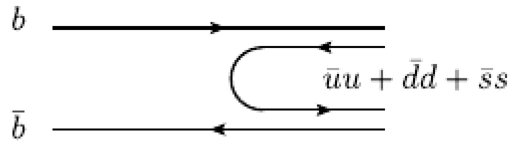


Fig. 3. The $e^+e^- \to \Upsilon(4s) \to B\bar{B}$ cross section and our fits to the data from BaBar [28]. $R_b = 3s\sigma/4\pi\alpha^2$.

3P0 model



Branching ratios for $\Upsilon(4s)$ decay.

Channel	$BR\|_{Theo.}$	$BR\|_{Exp.}$
$B^0\bar{B}^0$	48.8%	$(48.6 \pm 0.6)\%$
B^+B^-	51.2%	$(51.4 \pm 0.6)\%$

Values of $-\frac{\partial \Pi_i}{\partial p^2}\Big|_{p^2=M_R^2}$ for the different channels and the value of Z for $\Upsilon(4s)$ state.

	Set 1	Set 2
$B^0\bar{B}^0$	$-0.021 + 0.232i$	$0.008 + 0.386i$
B^+B^-	$-0.024 + 0.234i$	$0.004 + 0.389i$
$B^0\bar{B}^{*0} + c.c.$	$0.080 + 0.002i$	$0.208 + 0.005i$
$B^+B^{*-} + c.c.$	$0.080 + 0.002i$	$0.209 + 0.005i$
$B^{*0}\bar{B}^{*0}$	$0.069 + 0.001i$	$0.185 + 0.002i$
$B^{*+}B^{*-}$	$0.069 + 0.001i$	$0.185 + 0.002i$
$B_s^0\bar{B}_s^0$	0.005	0.014
$B_s^0\bar{B}_s^{*0} + c.c.$	0.015	0.041
$B_s^*\bar{B}_s^*$	0.021	0.057
Total	$0.295 + 0.472i$	$0.912 + 0.788i$
Z	0.772	0.523

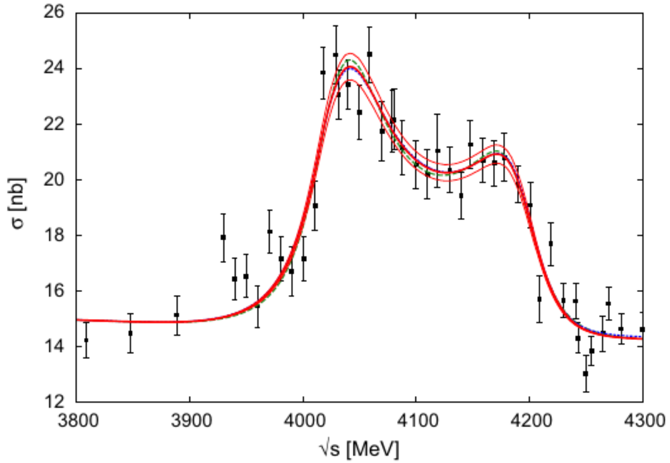
Eur. Phys. J. C (2020) 80:222
https://doi.org/10.1140/epjc/s10052-020-7785-1

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Theoretical Physics

Analysis of the $\psi(4040)$ and $\psi(4160)$ decay into $D^{(*)}\bar{D}^{(*)}$, $D_s^{(*)}\bar{D}_s^{(*)}$

M. Bayar[1,2,a], N. Ikeno[2,3,b], E. Oset[2,4,c]



Parameters	Set I	Set II	Set III
M_{R_1} [MeV]	4036.34 ± 3.04	4035.95 ± 2.97	4036.73 ± 3.21
f_{R_1}	37.38 ± 1.37	35.75 ± 1.97	36.92 ± 1.49
A_1^2	149.99 ± 5.71	139.9 ± 3.15	153.9 ± 6.48
R_1[MeV^{-1}]	$(8.71 \pm 4.36) \times 10^{-3}$	$(1.19 \pm 0.59) \times 10^{-2}$	$(7.41 \pm 3.71) \times 10^{-3}$
M_{R_2} [MeV]	4197.5 ± 7.95	4195.63 ± 4.56	4199.17 ± 11.21
f_{R_2}	30.92 ± 3.31	27.94 ± 11.76	25.47 ± 8.19
A_2^2	53.91 ± 7.35	56.12 ± 7.85	53.91 ± 14.56
R_2[MeV^{-1}]	$(2.68 \pm 1.34) \times 10^{-3}$	$(2.23 \pm 1.12) \times 10^{-3}$	$(1.71 \pm 0.86) \times 10^{-3}$
ϕ [radian]	3.408 ± 0.283	3.207 ± 0.683	3.133 ± 0.474

Table 4 Meson–meson probabilities in the $\psi(4040)$ wave function for Set I

Channels	$-\frac{\partial \Pi}{\partial p^2}\big\vert_{p^2=M^2_{\psi(4040)}}$	$P_{(MM)}$	Z
$D^0\bar{D}^0$	$(-1.499 + 1.065i) \times 10^{-2}$	-1.499×10^{-2}	
D^+D^-	$(-1.434 + 1.054i) \times 10^{-2}$	-1.434×10^{-2}	
$D^0\bar{D}^{*0} + c.c$	$(-2.816 + 3.499i) \times 10^{-2}$	-2.816×10^{-2}	
$D^+\bar{D}^{*-} + c.c$	$(-2.654 + 3.437i) \times 10^{-2}$	-2.654×10^{-2}	
$D^{*0}\bar{D}^{*0}$	$(-1.572 \times 10^{-3} + 3.267i \times 10^{-2})$	-1.572×10^{-3}	
$D^{*+}D^{*-}$	$(2.108 \times 10^{-3} + 2.968i \times 10^{-2})$	2.108×10^{-3}	
$D_s^+D_s^-$	$(-4.026 + 7.377i) \times 10^{-3}$	-4.026×10^{-3}	
$D_s^+D_s^{*-} + c.c$	$(1.591 \times 10^{-3} + 2.366i \times 10^{-5})$	1.591×10^{-3}	
$D_s^{*+}D_s^{*-}$	$(8.467 \times 10^{-4} + 4.427i \times 10^{-6})$	8.467×10^{-4}	
Total	$(-0.0851 - 0.0160i)$	-0.0851	0.91

Table 5 Meson–meson probabilities in the $\psi(4160)$ wave function for Set I

Channels	$-\frac{\partial \Pi}{\partial p^2}\big\vert_{p^2=M^2_{\psi(4160)}}$	$P_{(MM)}$	Z
$D^0\bar{D}^0$	$(-1.155 \times 10^{-2} + 5.296i \times 10^{-3})$	-1.155×10^{-2}	
D^+D^-	$(-1.107 \times 10^{-2} + 5.339i \times 10^{-2})$	-1.107×10^{-2}	
$D^0\bar{D}^{*0} + c.c$	$(-6.171 + 5.157i) \times 10^{-2}$	-6.171×10^{-2}	
$D^+\bar{D}^{*-} + c.c$	$(-5.934 + 5.141i) \times 10^{-3}$	-5.934×10^{-3}	
$D^{*0}\bar{D}^{*0}$	$(-2.057 + 3.648i) \times 10^{-2}$	-2.057×10^{-2}	
$D^{*+}D^{*-}$	$(-1.939 + 3.624i) \times 10^{-2}$	-1.939×10^{-2}	
$D_s^+D_s^-$	$(-4.471 + 5.007i) \times 10^{-3}$	-4.471×10^{-3}	
$D_s^+D_s^{*-} + c.c$	$(-1.127 + 4.361i) \times 10^{-3}$	-1.127×10^{-3}	
$D_s^{*+}D_s^{*-}$	$(8.845 \times 10^{-3} + 1.423i \times 10^{-4})$	8.845×10^{-3}	
Total	$(-7.145 \times 10^{-2} + 0.103i)$	-7.145×10^{-2}	0.93

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Regular Article - Theoretical Physics

Spectroscopy of B_c mesons and the possibility of finding exotic B_c-like structures

Pablo G. Ortega[1,a], Jorge Segovia[2,b], David R. Entem[1,c], Francisco Fernández[1,d]

chiral quark model

A.M. Sirunyan et al. (CMS), Phys. Rev. Lett. **122**, 132001 (2019)

$$6871 \pm 1.2(stat) \pm 0.8(syst) \pm 0.8(B_c)$$

State	J^P	n	The.
B_c	0^-	1	6277
		2	6868
		3	7248
		4	7534
		5	7761
B_{c0}	0^+	1	6689
		2	7109
		3	7421
		4	7668
		5	7868
B_{c1}	1^+	1	6723
		2	6731
		3	7135
		4	7142
		5	7442
		6	7449
B_c^*	1^-	1	6328
		2	6898
		3	6999
		4	7270
		5	7333
B_{c2}	2^+	1	6742
		2	7151
		3	7226
		4	7456
		5	7508

Unquenched chiral quark model

Channel	DB	DB^*	D^*B	D^*B^*
Mass	7146.57	7192.33	7287.96	7333.72

J^{PC}	Mass [MeV]	Width [MeV]	$\mathcal{P}_{mol}$ [%]	$b\bar{c}^{max}$	$\mathcal{P}_{b\bar{c}}^{max}$ [%]
0^+	7198 ± 6	64 ± 5	35 ± 6	2^3P_0	65 ± 6
	7420.96 ± 0.05	0.5 ± 0.1	57 ± 1	3^3P_0	43 ± 1
1^+	7109 ± 4	0	$14.2^{+1.5}_{-1.6}$	3^3P_1	$85.8^{+1.6}_{-1.5}$
	7117^{+4}_{-5}	0	7.8 ± 1.1	4^1P_1	92.1 ± 1.1
	7436 ± 1	40.86^{+14}_{-10}	40^{+2}_{-3}	5^3P_1	52^{+3}_{-2}
	7360^{+7}_{-5}	40^{+11}_{-7}	67^{+5}_{-6}	6^1P_1	19^{+5}_{-4}
2^+	$7222.6^{+0.7}_{-0.8}$	0	1.2 ± 0.2	3^3F_2	98.8 ± 0.2
	$7333.68^{+0.04}_{-0.2}$	0	$99.5^{+0.5}_{-1.0}$	4^3P_2	$0.5^{+1.0}_{-0.5}$
	7401^{+8}_{-7}	42 ± 5	52.7 ± 5	4^3P_2	47.0 ± 5

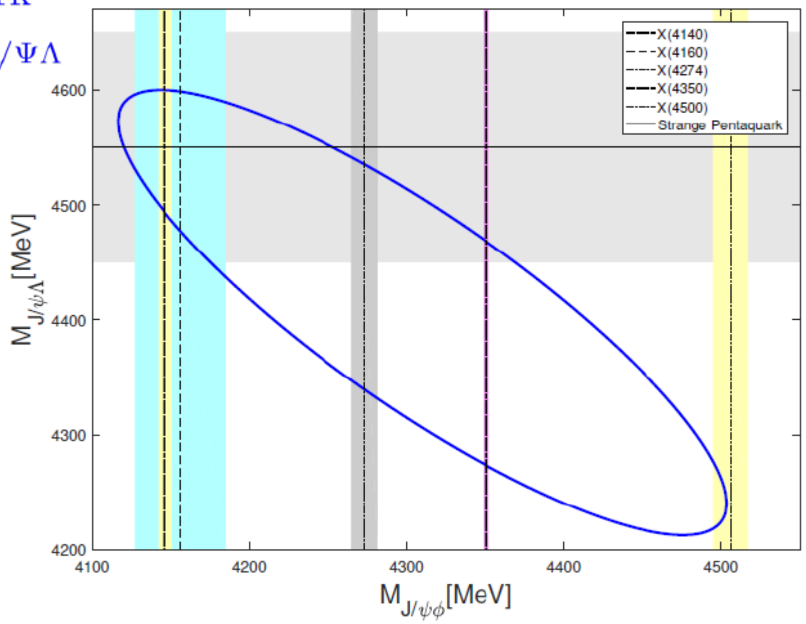
Exotic hadrons in $\Lambda_b \to J/\psi\ \phi\ \Lambda$ decay

Volodymyr Magas

In collaboration with
Rahul Somasundaram, Angels Ramos, Julia Tena Vidal

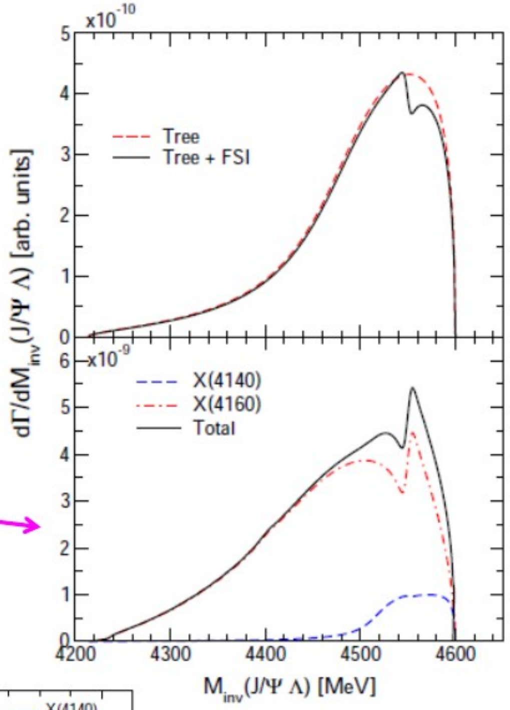
Potentially, three or four X resonances and a strange partner to the pentaquark can be seen in the $M_{J/\Psi\phi}$ and $M_{J/\Psi\Lambda}$ mass spectra respectively.

Dalitz plot



Phys. Rev. D 102 (2020) 054027

Two Reaction Mechanisms



Broad X(4140) (Γ=83 MeV)

LHCb [PRL118(2017)022003]

Narrow X(4140) (Γ=19MeV) + X(4160)