Review of exotic meson spectroscopy

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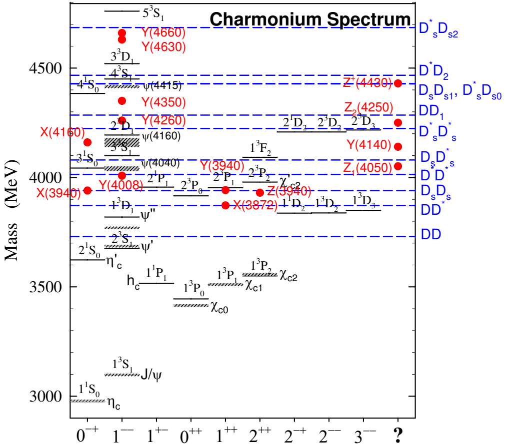
Outline

- General features of theoretical alternatives
    - molecular states
    - hadrocharmonium
    - hybrids
    - tetraquark states (diquark - antidiquark)
- Issue of production cross sections for exotica at hadronic colliders
    - $X(3872)$ at Tevatron
    - $X(3872)$ at LHC
    - recent estimates for production cross sections of charged exotic states
    - $Y(4260)$ at LHC

charmonium spectrum few years ago: 14 new states



- all $c\bar{c}$ states below open charm threshold have been identified
- good agreement between data and theory
- new entries above open charm threshold

S. Godfrey, arXiv:0910.3409[hep-ph]

Today more than than 20 new states (3 at the beauty thresholds)

see previous talks of P. Gianotti and C. Patrignani

Summary of the available information on XYZ (I)

from T. Bodwin et al, arXiv:1307.7435[hep-ph] plus recent updates

State	M (MeV)	Γ (MeV)	J^{PC}	Process (decay mode)	Experiment (#σ)	1$^{\rm st}$ observation
$X(3823)$	3823.1±1.9	< 24	$?^{?-}$	$B \to K + (\chi_{c1}\gamma)$	Belle (3.8)	Belle 2013
$X(3872)$	3871.68±0.17	< 1.2	1^{++}	$B \to K + (J/\psi\,\pi^+\pi^-)$	Belle (12.8), BaBar (8.6)	Belle 2003
				$p\bar{p} \to (J/\psi\,\pi^+\pi^-) + \ldots$	CDF (np), D0 (5.2)	
				$B \to K + (J/\psi\,\pi^+\pi^-\pi^0)$	Belle (4.3), BaBar (4.0)	
				$B \to K + (D^0\bar{D}^0\pi^0)$	Belle (6.4), BaBar (4.9)	
				$B \to K + (J/\psi\,\gamma)$	Belle (4.0), BaBar (3.6)	
				$B \to K + (\psi(2S)\,\gamma)$	BaBar (3.5), Belle (0.4)	
				$pp \to (J/\psi\,\pi^+\pi^-) + \ldots$	LHCb (np), CMS	
$X(3915)$	3917.5 ± 1.9	20±5	0^{++}	$B \to K + (J/\psi\,\omega)$	Belle (8.1), BaBar (19)	Belle 2004
				$e^+e^- \to e^+e^- + (J/\psi\,\omega)$	Belle (7.7), BaBar (7.6)	
$\chi_{c2}(2P)$	3927.2 ± 2.6	24±6	2^{++}	$e^+e^- \to e^+e^- + (D\bar{D})$	Belle (5.3), BaBar (5.8)	Belle 2005
$X(3940)$	3942^{+9}_{-8}	37^{+27}_{-17}	$?^{?+}$	$e^+e^- \to J/\psi + (D^*\bar{D})$	Belle (6.0)	Belle 2007
				$e^+e^- \to J/\psi + (\ldots)$	Belle (5.0)	
$G(3900)$	3943 ± 21	52±11	1^{--}	$e^+e^- \to \gamma + (D\bar{D})$	BaBar (np), Belle (np)	BaBar 2007
$Y(4008)$	$4008^{+121}_{-\ 49}$	226±97	1^{--}	$e^+e^- \to \gamma + (J/\psi\,\pi^+\pi^-)$	Belle (7.4)	Belle 2007
$Y(4140)$	4144.5 ± 2.6	$15^{+11}_{-\ 7}$	$?^{?+}$	$B \to K + (J/\psi\,\phi)$	CDF (5.0), D0 (3.1) CMS (>5)	CDF 2009
$X(4160)$	4156^{+29}_{-25}	139^{+113}_{-65}	$?^{?+}$	$e^+e^- \to J/\psi + (D^*\bar{D}^*)$	Belle (5.5)	Belle 2007

State	M (MeV)	Γ (MeV)	J^{PC}	Process (decay mode)	Experiment (#σ)	1$^{\rm st}$ observ
$Y(4260)$	4263^{+8}_{-9}	95±14	1^{--}	$e^+e^- \to \gamma + (J/\psi\,\pi^+\pi^-)$	BaBar (8.0), CLEO (5.4) Belle (15)	BaBar 200
				$e^+e^- \to (J/\psi\,\pi^+\pi^-)$	CLEO (11)	
				$e^+e^- \to (J/\psi\,\pi^0\pi^0)$	CLEO (5.1)	
$Y(4274)$	$4274.4^{+8.4}_{-6.7}$	32^{+22}_{-15}	$?^{?+}$	$B \to K + (J/\psi\,\phi)$	CDF (3.1)	CDF 2010
$X(4350)$	$4350.6^{+4.6}_{-5.1}$	$13.3^{+18.4}_{-10.0}$	0/2^{++}	$e^+e^- \to e^+e^-\,(J/\psi\,\phi)$	Belle (3.2)	Belle 2009
$Y(4360)$	4361 ± 13	74±18	1^{--}	$e^+e^- \to \gamma + (\psi(2S)\,\pi^+\pi^-)$	BaBar (np), Belle (8.0)	BaBar 200
$X(4630)$	$4634^{+\ 9}_{-11}$	92^{+41}_{-32}	1^{--}	$e^+e^- \to \gamma\,(\Lambda_c^+\Lambda_c^-)$	Belle (8.2)	Belle 2007
$Y(4660)$	4664±12	48±15	1^{--}	$e^+e^- \to \gamma + (\psi(2S)\,\pi^+\pi^-)$	Belle (5.8)	Belle 2007
$Z_c^+(3900)$	3898 ± 5	51 ± 19	$1^{?-}$	$Y(4260) \to \pi^- + (J/\psi\,\pi^+)$	BESIII (np), Belle (5.2)	BESIII 201
				$e^+e^- \to \pi^- + (J/\psi\,\pi^+)$	Xiao *et al.* (6.1)	
$Z_c'(3900)$	3883.9 ± 6.3	24.8 ± 11.5	1^+	$Y(4260) \to Z_c'\pi^+ \to D\bar{D}^*\pi^+$	BESIII (np)	BESIII 201
$Z_c'(4020)$	4022.9 ± 2.8	7.9 ± 3.8	?	$Y(4260) \to Z_c'\pi^+ \to h_c\pi^-\pi^+$	BESIII (np)	BESIII 201
$Z_c'(4025)$	4026.3 ± 4.5	24.8 ± 9.5	?	$Y(4260) \to Z_c'\pi^+ \to D^*\bar{D}^*\pi^+$	BESIII (np)	BESIII 201
$Z_1^+(4050)$	4051^{+24}_{-43}	82^{+51}_{-55}	?	$B \to K + (\chi_{c1}(1P)\,\pi^+)$	Belle (5.0), BaBar (1.1)	Belle 2008
$Z_2^+(4250)$	$4248^{+185}_{-\ 45}$	$177^{+321}_{-\ 72}$	?	$B \to K + (\chi_{c1}(1P)\,\pi^+)$	Belle (5.0), BaBar (1.1)	Belle 2008
$Z^+(4430)$	4443^{+24}_{-18}	$107^{+113}_{-\ 71}$	?	$B \to K + (\psi(2S)\,\pi^+)$	Belle (6.4), BaBar (2.4)	Belle 2007
$Y_b(10888)$	10888.4±3.0	$30.7^{+8.9}_{-7.7}$	1^{--}	$e^+e^- \to (\Upsilon(nS)\,\pi^+\pi^-)$	Belle (2.0)	Belle 2010
$Z_b^+(10610)$	10607.2±2.0	18.4±2.4	1^{+-}	$\Upsilon(5S) \to \pi^- + (\Upsilon(nS)\,\pi^+)$	Belle (16)	Belle 2011
				$\Upsilon(5S) \to \pi^- + (h_b(nP)\,\pi^+)$	Belle (16)	
$Z_b^+(10650)$	10652.2±1.5	11.5±2.2	1^{+-}	$\Upsilon(5S) \to \pi^- + (\Upsilon(nS)\,\pi^+)$	Belle (16)	Belle 2011
				$\Upsilon(5S) \to \pi^- + (h_b(nP)\,\pi^+)$	Belle (16)	

features of most popular th-models of exotic mesons

- hadronic molecules
  - $Q\bar{q}$ tightly bound in heavy mesons which move at distances longer than typical size of mesons
  - masses close to thresholds
  - typically loosely bound systems which can decay easily through the independent decay of their constituents
  - isospin breaking easily accomodated

  - difficult to make predictions (in principle any pair of mesons at threshold can rescatter and form a molecule)
- hybrids ($c\bar{c}+$ excited gluons)
  - different quantum numbers from charmonium
  - natural preference to decay to $J/\psi+$ pions

  - lowest lying state predicted around 4200 MeV by LQCD $\Longrightarrow Y(4260)$
- diquark-antidiquarks (tetraquarks)
  - Qq tightly bound in diquarks, which interact by QCD colour force
  - masses not necessarily close to threshold
  - many new states (charged and neutral) foreseen (a nonet for each spin-parity)
  - neutral states expected to appear in doublets

  - decays include both open and hidden charm channels and (if kinematically allowed) baryonium
- hadro-quarkonium
  - $Q\bar{Q}$ tightly bound as in quarkonium
  - $Q\bar{Q}$ embedded in a spatially large excited state of light mesonic matter
  - interactions through QCD analog of Van der Waals force

  - natural suppression of decay to open chearm/beauty

$X(3872)$, the oldest one and still debated one

Information available for different production and decay channels

- $M(X3872) = 3871.68 \pm 0.17$ MeV $\Gamma_X \lesssim 1.2$ MeV
- $M(D_0) + M(\bar{D_0}^*) = 3871.82 \pm 0.19$ MeV
- binding energy: -0.14 ± 26 MeV $\Longrightarrow$ crucial an an increase of precision also in D meson
- $M(X3872)$ in the region of $\chi_{c_1}(2P)$ and $\eta_{c_2}(1D)$
- $J^{PC} = 1^{++}$ (LHCb recently excluded the 2^{-+} option)
- production
  - production through B decays at e^+e^- and $p\bar{p}/pp$ colliders
  - dominant prompt production at Tevatron/LHC ($p\bar{p} \to X+$ all)
- decay
  - $J/\psi\rho \to J/\psi\pi^+\pi^-$
  - $J/\psi\omega \to J/\psi\pi^+\pi^-\pi^0$
  - $D^0\bar{D^0}{}^* \to D^0\bar{D}^0\pi^0$
  - $D^0\bar{D^0}{}^* \to \bar{D}^0\gamma$
  - $J/\psi\gamma$, $\psi(2S)\gamma$

(large isospin violation)

Theoretical interpretations

- first models:
    - molecule (most popular by now)

e.g. Close and Page (2005), Braaten and Kusunoki (2004), Swanson (2006)

    - tetraquark

Maiani, F.P., Polosa, Riquer, Phys.Rev. D71 (2005) 014028

- other models:
    - χ'_{c1}, first radial excitation of χ_{c1}

F. de Fazio, Phys. Rev. D79, 054015 (2009)

    - $c\bar{c}$ dynamically coupled to open charm channels

Ferretti, Galatà, Santopinto, Phys. Rev. C88, 015207 (2013)

    - . . .

see talk of A. Pilloni for very recent ideas

Prompt production at CDF

CDF measured the fraction of *prompt* $X(3872)_{\to J/\psi\pi^+\pi^-}$: 83.9 ± 5.2%

CDF Coll. PRL **98** 132002 (2007)

Assuming the same detection efficiency for $\psi(2S)$ and $X(3872)$ and using the well measured $\mathcal{B}(\psi(2S) \to \mu^+\mu^-)$

$$\frac{\sigma(p\bar{p} \to X(3872) + \mathrm{All})_{\mathrm{prompt}} \times \mathcal{B}(X(3872) \to J/\psi\pi^+\pi^-))}{\sigma(p\bar{p} \to \psi(2S) + \mathrm{All})} = 4.7 \pm 0.8\%$$

Lower experimental bound

$$\begin{aligned} \sigma(p\bar{p} \to X(3872) + \mathrm{All})^{\mathrm{min}}_{\mathrm{prompt}} &> \sigma(p\bar{p} \to X + \mathrm{All}) \times \mathcal{B}(X \to J/\psi\pi^+\pi^-) \\ &= 3.1 \pm 0.7 \text{ nb} \end{aligned}$$

for $p_\perp(X) > 5 \text{ GeV}, |y(X)| < 0.6$

Assuming conservatively $\mathcal{BR}(X \to J/\psi\pi\pi) \sim 10\%$

$\sigma(p\bar{p} \to X(3872) + \mathrm{All})_{\mathrm{prompt}} \sim$ 30 nb

Upper theoretical bound

Bignamini, Grinstein, F.P., Polosa, Sabelli: Phys. Rev. Lett. 103, 162001, 2009

Hypothesis: $X(3872)$ is an S-wave bound state of two D mesons

E.S. Swanson, E. Braaten et al.

$$\begin{aligned}
\sigma(p\bar{p} \to X(3872)) &\sim \left| \int d^3\mathbf{k} \langle X | D\bar{D}^*(\mathbf{k}) \rangle \langle D\bar{D}^*(\mathbf{k}) | p\bar{p} \rangle \right|^2 \\
&\simeq \left| \int_{\mathcal{R}} d^3\mathbf{k} \langle X | D\bar{D}^*(\mathbf{k}) \rangle \langle D\bar{D}^*(\mathbf{k}) | p\bar{p} \rangle \right|^2 \\
&\leq \int_{\mathcal{R}} d^3\mathbf{k} |\psi(\mathbf{k})|^2 \int_{\mathcal{R}} d^3\mathbf{k} |\langle D\bar{D}^*(\mathbf{k}) | p\bar{p} \rangle|^2 \\
&\leq \int_{\mathcal{R}} d^3\mathbf{k} |\langle D\bar{D}^*(\mathbf{k}) | p\bar{p} \rangle|^2 \sim \sigma(p\bar{p} \to X(3872))^{\text{max}}_{\text{prompt}}
\end{aligned}$$

- $\mathbf{k}$ is the rest-frame relative 3-momentum between the D and D^*
- $|\langle D\bar{D}^*(\mathbf{k}) | p\bar{p} \rangle|^2$ can be computed with MC simulations
- $\mathcal{R}$ has to be given with a reasonable conservative Ansatz for the bound state wave function (we use a simple gaussian form)

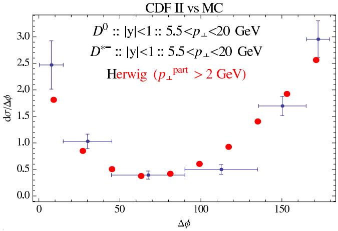
$|\langle D\bar{D}^*(\mathbf{k})|p\bar{p}\rangle|^2$

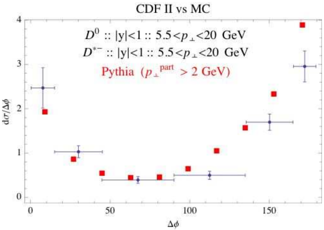
- we expect the bulk of the contribution from events with a gluon recoiling against an almost collinear $c\bar{c}$ pair
- the standard Parton Shwower MC Event Generators (like Herwig and Pythia) describe well the events with gluons radiated at small p_{T}, which are enhanced by collinear logarithms
- contributions from large p_{T} gluons are expected to be suppressed. We checked this numerically with ALPGEN finding a totally negligible contribution

We used both Herwig and Pythia for the simulations, since they include two completely different hadronization schemes, to have an estimate of the uncertainty introduced by the hadronization model

Herwig and Pythia tuning on CDF data for $D^0 D^{*-}$ pairs

We generated two samples of 2 $\rightarrow$ 2 QCD processes with parton showering and hadronization (with loose partonic cuts)





The $\Delta\phi$ shape is well reproduced once an overall k-factor is applied to the MC predictions, $\simeq 1.8$ for Herwig and $\simeq 0.7$ for Pythia

Estimate of $\mathcal{R}$

We need an estimate of the momentum and its spread in the gaussian. Assuming a Yukawa potential between the D mesons

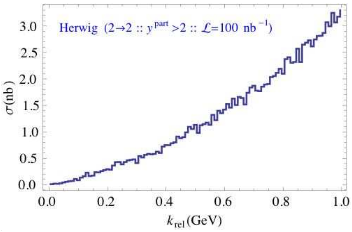
$$\frac{\hbar^2}{\mu r_0^2} - \frac{g^2}{4\pi}\frac{e^{-\frac{m_\pi c}{\hbar} r_0}}{r_0} = \mathcal{E}_0 \sim M_X - M_D - M_{D^*}$$

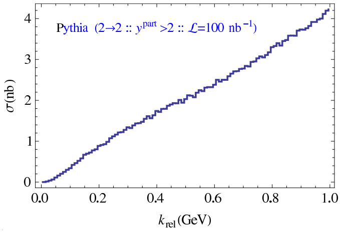
Solving for r_0 we find $r_0 \sim 10$ fm

- minimal uncertainty relation gives $\Delta k \simeq 12$ MeV
- $k \simeq \sqrt{\lambda(m_X^2, m_D^2, m_D^{*2})}/2m_X \simeq 27$ MeV

We consider the region within a sphere of radius $\mathcal{R} = 35$ MeV

$D^0\bar{D}^{0*}k_{\rm rel}$ distributions



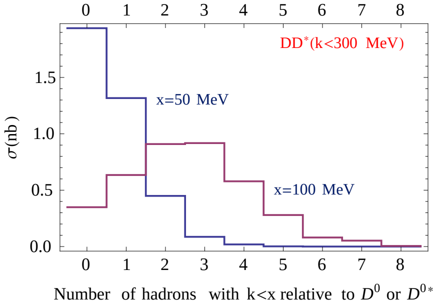


- To integrate 30 nb we need $k_{\rm rel}$ up to sevreal hundreds MeV
- in the region of relative momentum R Herwig and Pythia integrate 0.071 nb and 0.11 nb respectively, too low by more than two order of magnitude!
- According to Artoisenet and Braaten (PRD81 (2010) 114018) we didn't consider final state interactions, which can enhance the cross section by orders of magnitude
  - because of rescattering effects the effective maximum $k_{\rm rel}$ can reach ~ 400 MeV

hadronic activity close to $D^0\bar{D}^{0*}$ pairs

Bignamini, Grinstein, F.P., Polosa, Riquer, Sabelli, PLB684 (2010) 228

- FSI relies on the Migdal-Watson theorem, which assumes no additional adronic activity between the two particles which undergo FSI
- we estimated this activity by means of MC event generators



- this hadronic activity (mainly pions) could give an handle for an alternative mechanism of molecule formation

possible mechanism alternative to FSI

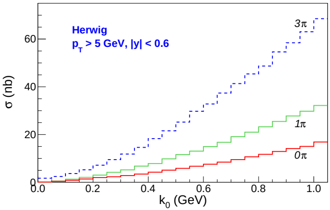
A. Esposito, F.P., A. Pilloni and A.D. Polosa, J.Mod.Phys. 4 (2013) 1569

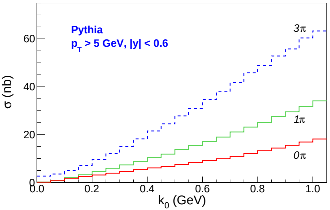
- additional pions close to $D^{0(*)}$ in momentum space can interact elastically and change the relative momentum between D^0 and D^{0*}
- the interactions are regulated by the matrix elements

$$\langle \pi(p) D(q) | D^*(P,\eta) \rangle = g_{\pi D D^*}\, \eta \cdot p$$
$$\langle \pi(p) D^*(q,\lambda) | D^*(P,\eta) \rangle = \frac{g_{\pi D^* D^*}}{M_{D^*}}\, \epsilon_{\alpha\beta\gamma\delta} \lambda^\alpha \eta^\beta p^\gamma q^\delta$$

- given the initial asymmetric distribution in $k_{\rm rel}$ there could be a feed-down process from larger relative momenta to lower ones
- assuming D^0 and D^{0*} are under an attractive potential (modelled by a square well), the above interaction can bring D pairs from positive to negative energies (bound state)

preliminary results @ Tevatron





- from a simulation of $p\bar{p} \to c\bar{c}$ the gain in the first bin $k_{\rm rel} < 50$ MeV ranges from a factor of 2 (Herwig) to 7 (Pythia)
- the simulation should be completed with all possible QCD processes, where $c\bar{c}$ pairs can originate from the last splitting $g \to c\bar{c}$
- including the above simulation, very small differences between Herwig and Pythia
- even if the mechanism enhances the cross section, the inclusion of one pion scattering is not enough to explain the data

predictions from Tevatron to LHC

- Artoisenet and Braaten (PRD81 (2010) 114018), relying on CDF data, give predictions for the $X(3872)$ inclusive cross section at the LHC using the NRQCD factorization formula

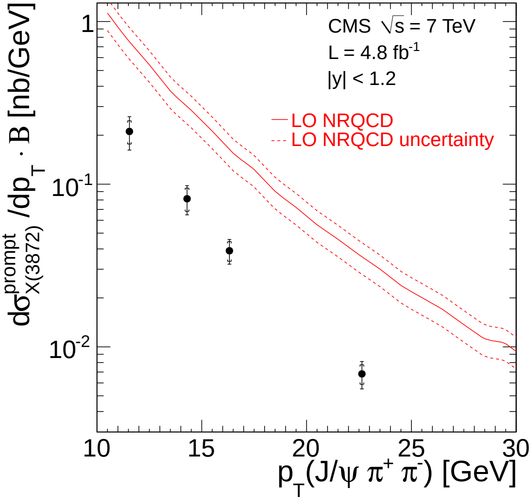
$$\sigma(X(3872)) = \sum_n \hat{\sigma}[c\bar{c}_n] < \mathcal{O}_n^X >$$

  n runs over color and angular-momentum channels of $c\bar{c}$

- four independent universal matrix elements:
  - $< \mathcal{O}_1^X(^3S_1) >$
  - $< \mathcal{O}_1^X(^1S_0) >$
  - $< \mathcal{O}_8^X(^3S_1) >$
  - $< \mathcal{O}_8^X(^1S_0) >$
- simplifying assumptions can be adopted to reduce the number of independent matrix elements, e.g. $S-$wave dominance, spin-triplet dominance, color-octet dominance

comparison with LHC production data

CMS Collaboration, JHEP 1304 (2013) 154



from $X(3872)$ to predictions for charged $Z_{c/b}$

F.-K. Guo, U.-G. Meissner and W. Wang arXiv:1308.0193[hep-ph]

- following the original idea of Bignamini et al, 2009, very recent application to production cross section prediction for charged exotic states
- since these states are above threshold

$$\sigma(Z_Q) \approx K_{H\bar{H}} \int_0^\Lambda dk \, \frac{d\sigma^{\mathrm{MC}}_{H\bar{H}}(k)}{dk} \, \frac{|f(E)|^2}{|f(E = E_\Lambda)|^2} ,$$

Table: Integrated normalized cross sections (in units of nb) for the reactions $pp/\bar{p} \to Z_b(10610), Z_b(10650), Z_c(3900)$, and $Z_c(4020)$ at the LHC and the Tevatron. Results are obtained using Herwig (Pythia). The rapidity range $|y| < 2.5$ has been assumed for the LHC experiments (ATLAS and CMS) at 7, 8 and 14 TeV, respectively, for the Tevatron experiments (CDF and D0) at 1.96 TeV, we use $|y| < 0.6$; the rapidity range $2.0 < y < 4.5$ is used for LHCb.

	$Z_b(10610)$	$Z_b(10650)$	$Z_c(3900)$	$Z_c(4020)$
Tevatron	0.26(0.47)	0.06(0.17)	11(13)	1.7(2.0)
LHC 7	4.8(8.0)	1.2(3.0)	187(211)	29(31)
LHCb 7	0.76(1.3)	0.18(0.47)	33(39)	5.5(5.8)
LHC 8	5.9(9.5)	1.4(3.5)	220(240)	34(36)
LHCb 8	0.9(1.4)	0.22(0.56)	40(48)	6.3(6.9)
LHC 14	11(17)	2.6(6.5)	382(423)	61(63)
LHCb 14	1.9(3.0)	0.52(1.2)	84(88)	14(14)

$Y(4260)$ production at LHC

A. Ali and W. Wang, Phys. Rev. Lett. 106 (2011) 192001

Model indipendent estimates for production at LHC

- $Y(4260)$ has been measured at BaBar, Belle and CLEO in e^+e^- production through ISR: $J^{PC} = 1^{--}$
- hadroproduction can be calculated as in the case of SM Drell-Yan

$$\sigma(pp/p\bar{p} \to V+X) = \int dx_1 dx_2 \sum_{a,b} f_a(x_1) f_b(x_2) \sigma(a+b \to V(p)+X),$$

$$\sigma_0 = (\delta_{aq}\delta_{b\bar{q}} + \delta_{a\bar{q}}\delta_{bq}) \frac{\pi |g_{q\bar{q}V}|^2}{N_c} \delta(p^2 - m_V^2), \;\; g_{q\bar{q}V} = e_q g_{e^+e^-V}$$

- The coupling e^+e^-V can be obtained from ISR production of $Y(4260)$ at

$$\sigma_{e+e-} = \frac{12\pi\Gamma_{ee}\mathcal{B}(Y \to J/\psi\pi^+\pi^-)}{m_Y^2\Gamma_Y}$$

- Also higher order IS QCD corrections accounted for easily

Predictions

Table: Cross sections (in units of pb) for the processes $p\bar{p}(p) \to \phi(2170)(\to \phi(1020) f_0(980) \to K^+K^-\pi^+\pi^-)$, $p\bar{p}(p) \to Y(4260)(\to J/\psi\pi^+\pi^- \to \mu^+\mu^-\pi^+\pi^-)$, and $p\bar{p}(p) \to Y_b(10890)(\to \Upsilon(1S, 2S, 3S)\pi^+\pi^- \to \mu^+\mu^-\pi^+\pi^-)$, at the Tevatron ($\sqrt{s} =$ 1.96 TeV) and the LHC ($\sqrt{s} =$ 7 TeV and 14 TeV), using the MSTW PDFs. A rapidity range ($|y| < 2.5$) is assumed for the Tevatron experiments (CDF and D0) and for the LHC experiments (ATLAS and CMS); a rapidity range $1.9 < y < 4.9$ is used for the LHCb.

	$\phi(2170)$	$Y(4260)$	$Y_b(10890)$
Tevatron($\|y\| < 2.5$)	$2.3^{+0.9}_{-0.9}$	$0.23^{+0.19}_{-0.05}$	$0.0020^{+0.0006}_{-0.0005}$
LHC 7TeV ($\|y\| < 2.5$)	$3.6^{+1.4}_{-1.4}$	$0.40^{+0.32}_{-0.09}$	$0.0040^{+0.0013}_{-0.0011}$
LHCb 7TeV ($1.9 < y < 4.9$)	$2.2^{+1.2}_{-1.1}$	$0.24^{+0.20}_{-0.07}$	$0.0023^{+0.0007}_{-0.0006}$
LHC 14TeV ($\|y\| < 2.5$)	$4.5^{+1.9}_{-1.9}$	$0.54^{+0.44}_{-0.12}$	$0.0060^{+0.0019}_{-0.0016}$
LHCb 14TeV ($1.9 < y < 4.9$)	$2.7^{+1.9}_{-1.6}$	$0.31^{+0.27}_{-0.11}$	$0.0033^{+0.0011}_{-0.0010}$

- Cross section for $Y(4260)$ of the order of hundreds of fb, challenging signature at LHC
- $Y_b(10890)$ even more challenging!

Summary

- many exotic new states, in particular in the charm sector
- in the near future we have three machines producing new data: BEPC, SUPERKEK and LHC
- the sinergy of these machines will allow to clarify many of the (up to now discovered) new states in the coming years with possible new entries