Drell-Yan production of $\phi(2170)$,X(4260) and $Y_b(10890)$ at LHC and Tevatron

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DESY Hamburg

DESY Theory Workshop

Sept. 27 - 30, 2011

On the basis of

A.Ali, WW, Phy. Rev. Lett. 106(2011)192001 [1103:4587]

Outline

- Exotic spectroscopy - An overview
- Tetraquarks (four-quark states):

$$\phi(2170) : s\bar{s}s\bar{s} \qquad X(4260) : c\bar{c}q\bar{q} \qquad Y_b(10890) : b\bar{b}q\bar{q}$$

- Drell-Yan-like production at LHC and Tevatron
- Summary

Exotic spectroscopy

A.Zupanc [Belle], 0910.3404

State	M (MeV)	Γ (MeV)	J^{PC}	Decay Modes	Production Modes	Also observed by
$Y_s(2175)$	2175 ± 8	58 ± 26	1^{--}	$\phi f_0(980)$	e^+e^- (ISR) $J/\psi \to \eta Y_s(2175)$	BaBar, BESII
$X(3872)$	3871.4 ± 0.6	< 2.3	1^{++}	$\pi^+\pi^- J/\psi$, $\gamma J/\psi$,$D\bar{D}^*$	$B \to KX(3872)$, $p\bar{p}$	BaBar CDF, D0,
$X(3915)$	3914 ± 4	28^{+12}_{-14}	$0/2^{++}$	$\omega J/\psi$	$\gamma\gamma \to X(3915)$	
$Z(3930)$	3929 ± 5	29 ± 10	2^{++}	$D\bar{D}$	$\gamma\gamma \to Z(3940)$	
$X(3940)$	3942 ± 9	37 ± 17	$0^{?+}$	$D\bar{D}^*$ (not $D\bar{D}$ or $\omega J/\psi$)	$e^+e^- \to J/\psi X(3940)$	
$Y(3940)$	3943 ± 17	87 ± 34	$?^{?+}$	$\omega J/\psi$ (not $D\bar{D}^*$)	$B \to KY(3940)$	BaBar
$Y(4008)$	4008^{+82}_{-49}	226^{+97}_{-80}	1^{--}	$\pi^+\pi^- J/\psi$	e^+e^-(ISR)	
$X(4160)$	4156 ± 29	139^{+113}_{-65}	$0^{?+}$	$D^*\bar{D}^*$ (not $D\bar{D}$)	$e^+e^- \to J/\psi X(4160)$	
$Y(4260)$	4264 ± 12	83 ± 22	1^{--}	$\pi^+\pi^- J/\psi$	e^+e^-(ISR)	BaBar, CLEO
$Y(4350)$	4361 ± 13	74 ± 18	1^{--}	$\pi^+\pi^- \psi'$	e^+e^-(ISR)	BaBar
$X(4630)$	4634^{+9}_{-11}	92^{+41}_{-32}	1^{--}	$\Lambda_c^+\Lambda_c^-$	e^+e^-(ISR)	
$Y(4660)$	4664 ± 12	48 ± 15	1^{--}	$\pi^+\pi^- \psi'$	e^+e^-(ISR)	
$Z(4050)$	4051^{+24}_{-23}	82^{+51}_{-29}	?	$\pi^\pm \chi_{c1}$	$B \to KZ^\pm(4050)$	
$Z(4250)$	4248^{+185}_{-45}	177^{+320}_{-72}	?	$\pi^\pm \chi_{c1}$	$B \to KZ^\pm(4250)$	
$Z(4430)$	4433 ± 5	45^{+35}_{-18}	?	$\pi^\pm \psi'$	$B \to KZ^\pm(4430)$	
$Y_b(10890)$	$10,890 \pm 3$	55 ± 9	1^{--}	$\pi^+\pi^- \Upsilon(1,2,3S)$	$e^+e^- \to Y_b$	

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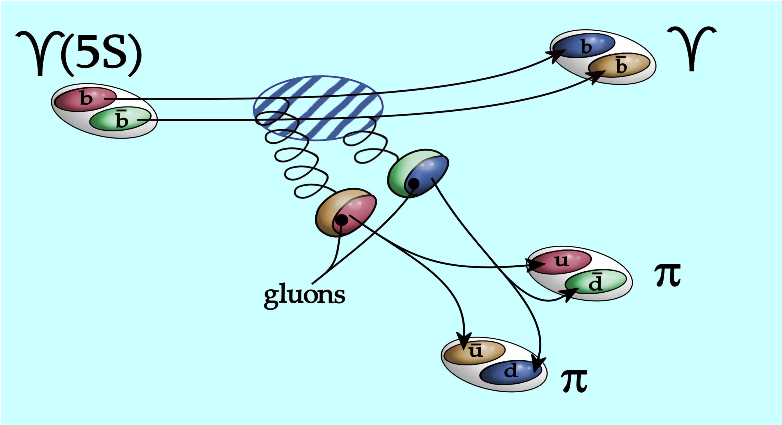
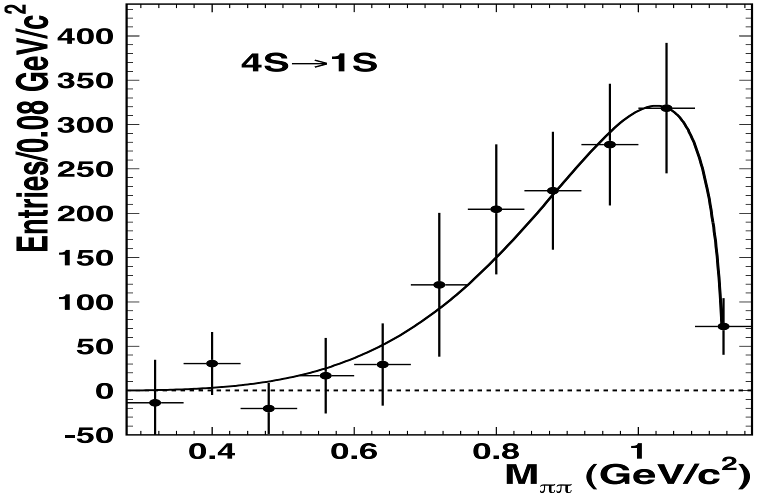
$Y_b(10890)$ as $\Upsilon(5S)$?





A.Sokolov et al 2009

forbids → **small partial widths**

$$\Gamma(\Upsilon(2S) \to \Upsilon(1S)\pi\pi) \approx 0.0060\mathrm{MeV}$$
$$\Gamma(\Upsilon(3S) \to \Upsilon(1S)\pi\pi) \approx 0.0009\mathrm{MeV}$$
$$\Gamma(\Upsilon(4S) \to \Upsilon(1S)\pi\pi) \approx 0.0019\mathrm{MeV}$$

Zweig

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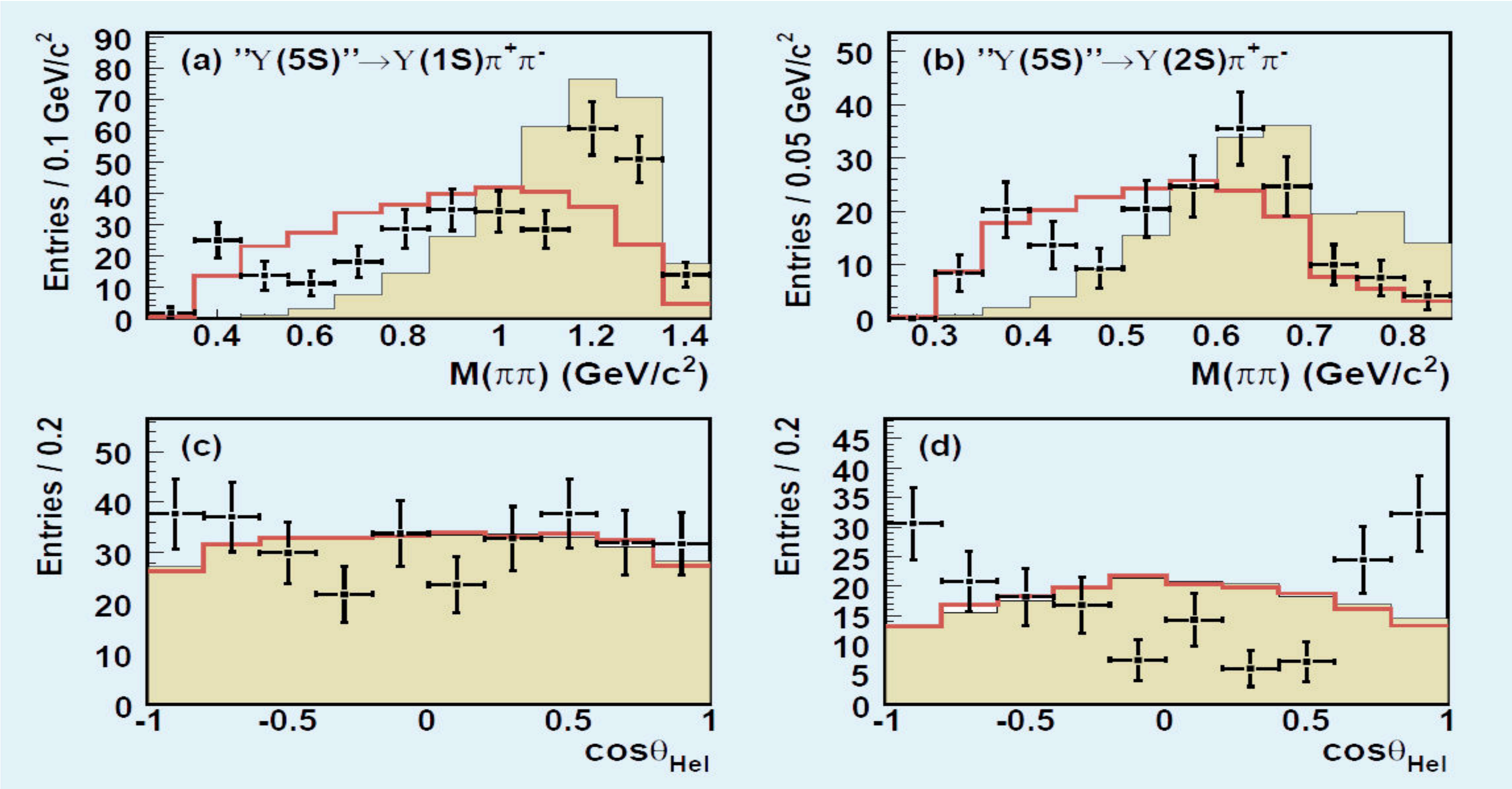
$$\Gamma(\text{“}\Upsilon(5S)\text{”} \to \Upsilon(1S)\pi^+\pi^-) \approx 0.59\text{MeV}$$

K..Chen et al[Belle] 2008F



It seems that $Y_b(10890)$ is unlikely to be $\Upsilon(5S)$.

$\Upsilon(5S)$ vs Tetraquarks

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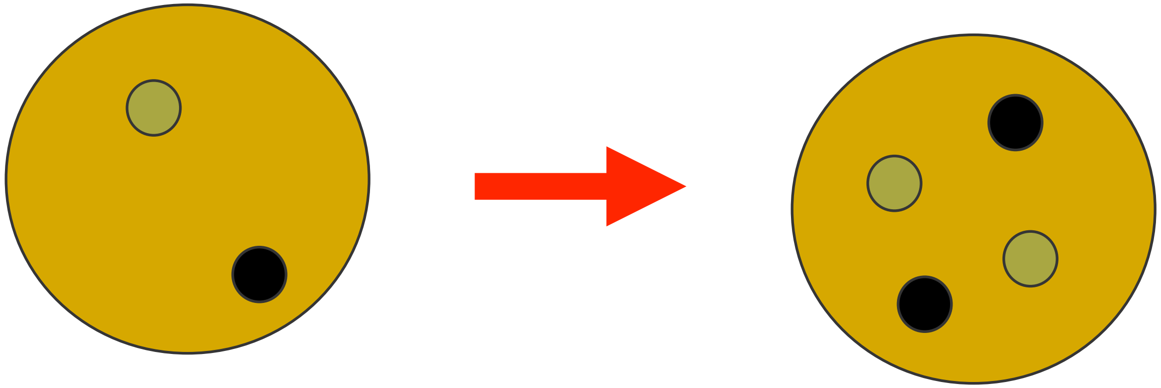
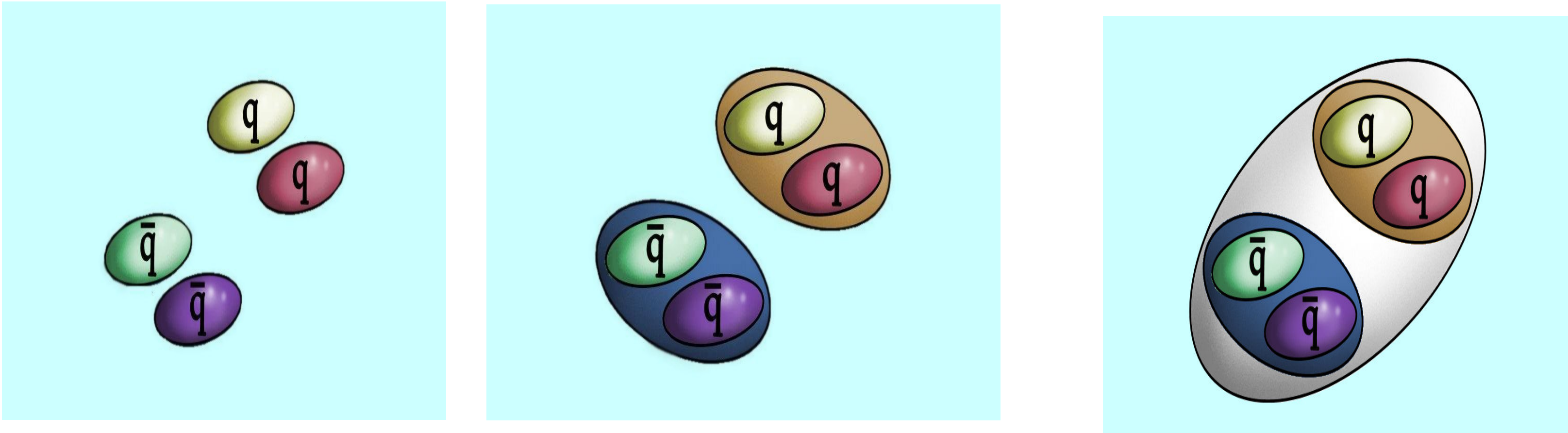


$$Y_b = \bar{b}b\bar{q}q$$

$Y_b(10890)$ as Tetraquarks



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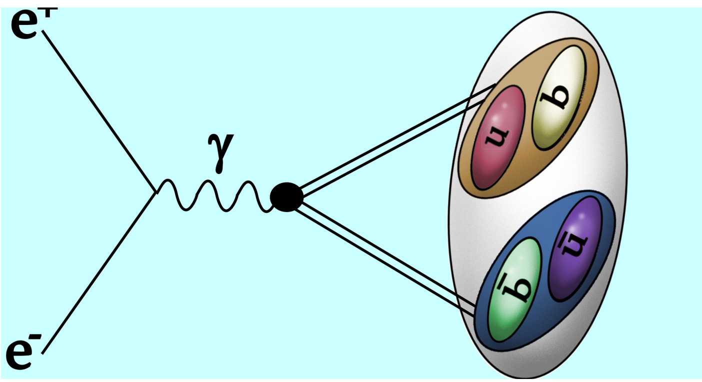
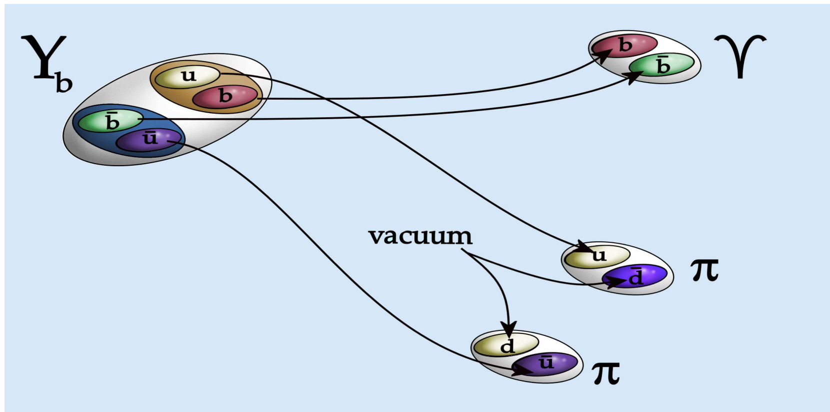
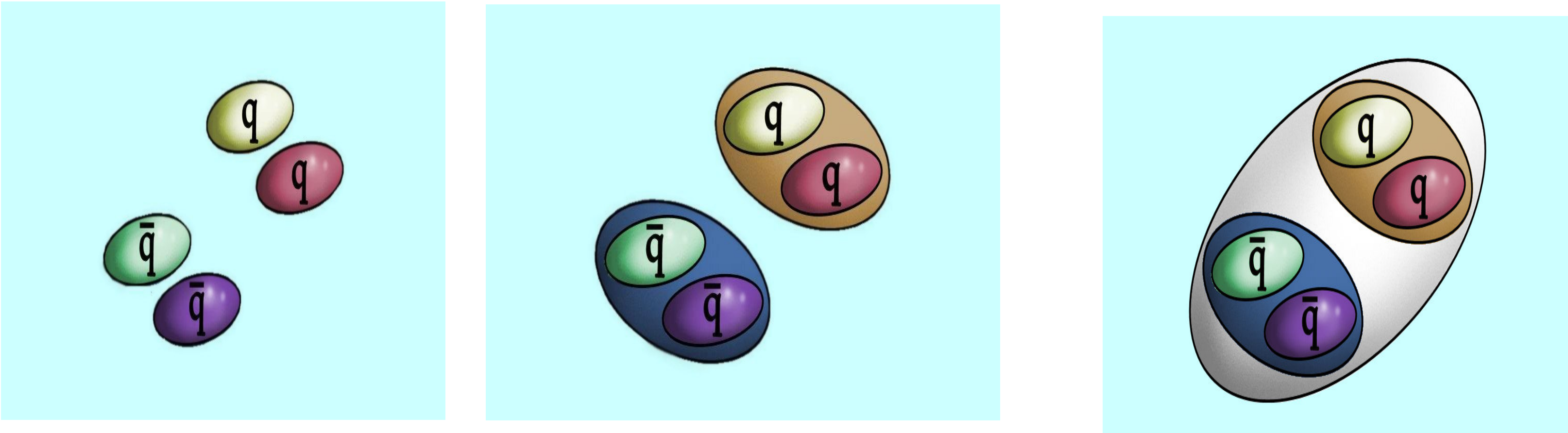




Van Royen-Weisskopf formula

Y_b(10890) as Tetraquarks



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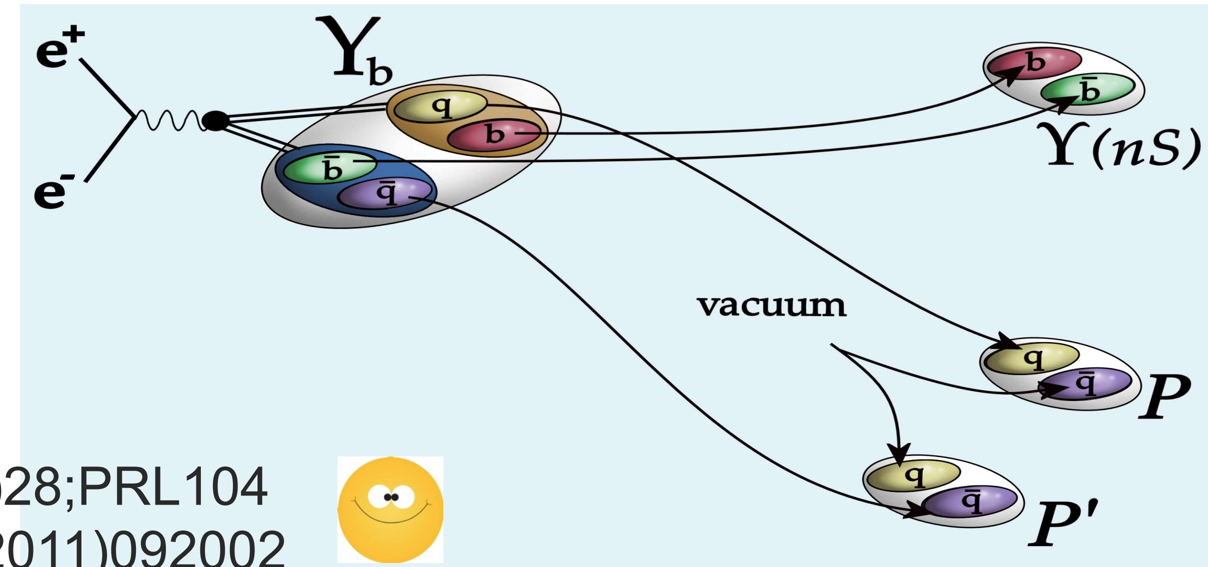

A.Ali et al, PLB684(2010)28;PRL104 (2010)062001; PRL106(2011)092002

ϕ(2170) and X(4260) as Tetraquarks

$\phi(2170) = \bar{s}s\bar{q}q$

$X(4260) = \bar{c}c\bar{q}q$

Drenska et al PLB669(2008) 160
Maiani et al PRD72(2005) 031502(updated)

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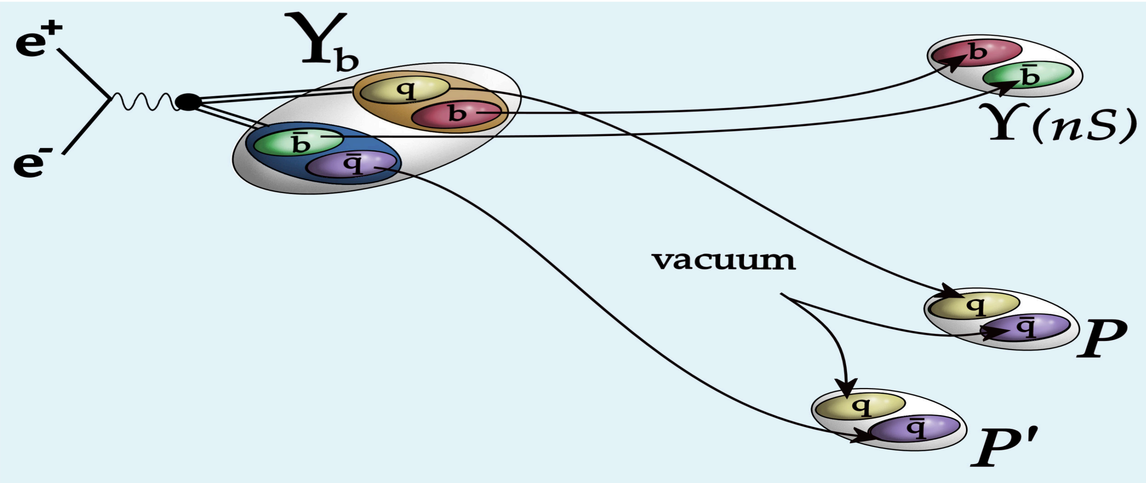
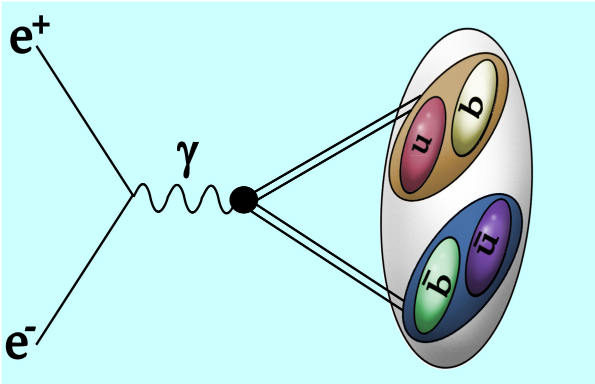
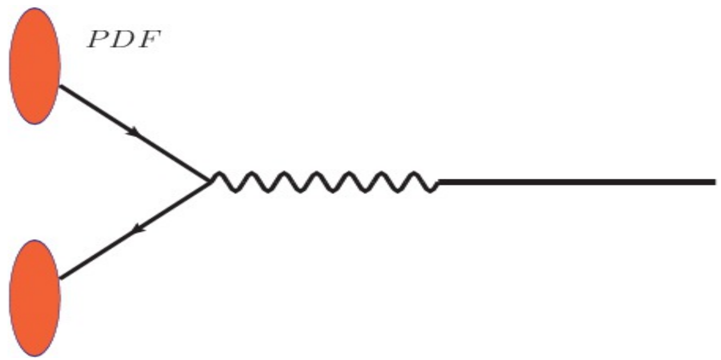
b➔c
b➔s



Drell-Yan production on hadron collider





- Based on factorization formula:

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

  - $f_a(x_1)$and $f_b(x_2)$are parton distribution functions (MSTW, CTEQ10)
  - Include $O(\alpha_s)$corrections to generate large-p_T
  - Resum the large logarithms in the small-p_T region (Collins-Soper-Sterman)
  - Matching function: $f(p_T) = \frac{1}{1+(p_T/Q_{\mathrm{match}})^4}$; $Q_{\mathrm{match}} = (2 \pm 1) m_V$

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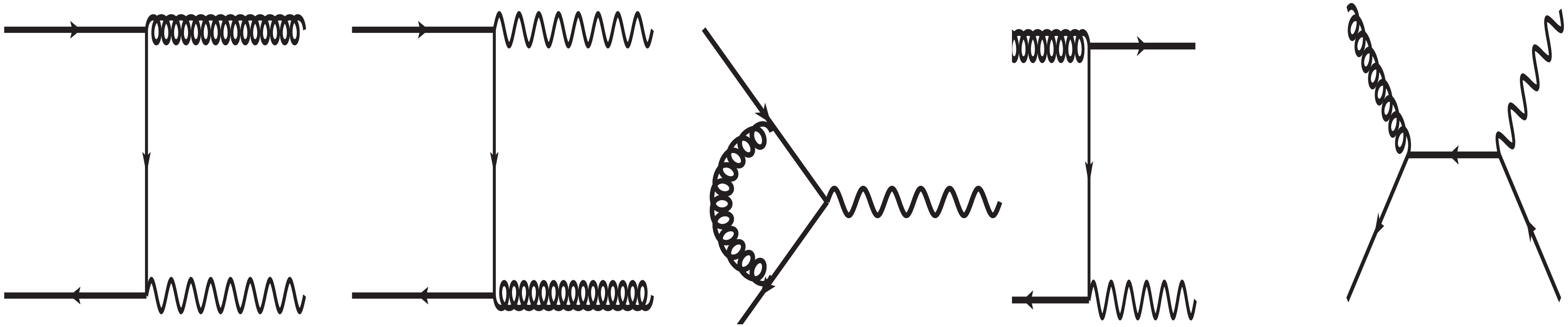

(a) (b)

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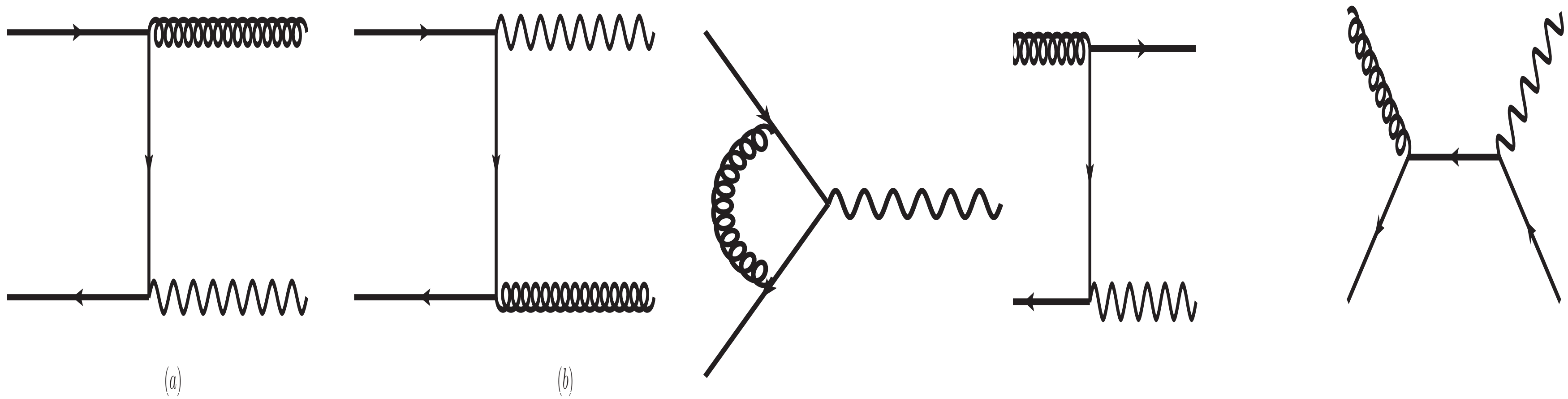

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$$\frac{d\sigma}{dy dp_T^2} = \frac{d\sigma^{per}}{dy dp_T^2} + f(p_T)\left(\frac{d\sigma^{res}}{dy dp_T^2} - \frac{d\sigma^{asy}}{dy dp_T^2}\right)$$

- Resum the large logarithms in the small-p_T region

  (Collins-Soper-Sterman)

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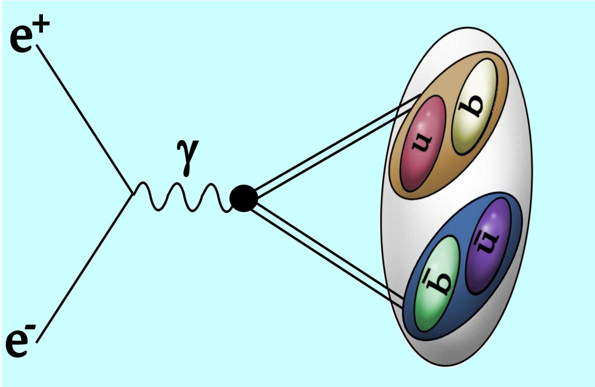
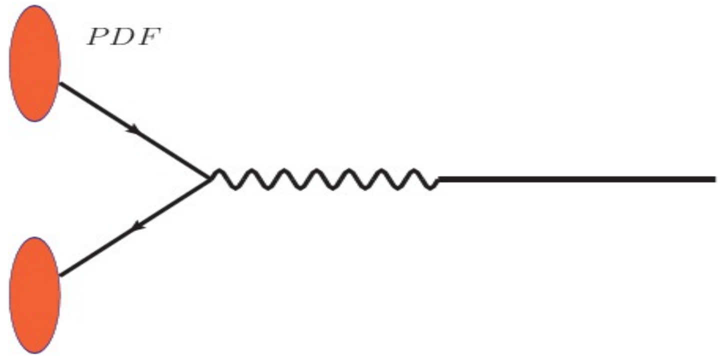
Drell-Yan production on hadron collider





Couplings from e⁺e⁻ data,
model independent!

TABLE I. Masses, total and partial decay widths of the $\phi(2170)$, $X(4260)$ and $Y_b(10890)$.

	m_V (MeV)	Γ (MeV)	$\Gamma_{ee}\mathcal{B}$ (eV)
$\phi(2170)$	(2175 ± 15)	(61 ± 18)	(2.5 ± 0.9) [a]
$X(4260)$	4263^{+8}_{-9}	108 ± 21	$(6.0^{+4.9}_{-1.3})$ [b]
$Y_b(10890)$	$10888.4^{+3.0}_{-2.9}$	$30.7^{+8.9}_{-7.7}$	$(0.69^{+0.23}_{-0.20})$ [c]
$\mathcal{B}_{\phi\to K^+K^-}$	$(48.9 \pm 0.5)\%$	$\mathcal{B}_{f_0(980)\to\pi^+\pi^-}$	$(50^{+7}_{-9})\%$
$\mathcal{B}_{J/\psi\to\mu^+\mu^-}$	$(5.93 \pm 0.06)\%$	$\mathcal{B}_{\Upsilon(1S)\to\mu^+\mu^-}$	$(2.48 \pm 0.05)\%$
$\mathcal{B}_{\Upsilon(2S)\to\mu^+\mu^-}$	$(1.93 \pm 0.17)\%$	$\mathcal{B}_{\Upsilon(3S)\to\mu^+\mu^-}$	$(2.18 \pm 0.21)\%$

[a] $\Gamma_{ee} \times \mathcal{B}(\phi(2170) \to \phi(1020)f_0(980))$.
[b] $\Gamma_{ee} \times \mathcal{B}(X(4260) \to J/\psi\pi^+\pi^-)$.
[c] $\Gamma_{ee} \times \mathcal{B}(Y_b(10890) \to \Upsilon(1S)\pi^+\pi^-)$ obtained from $\sigma = (2.78^{+0.48}_{-0.41})$ pb. For $Y_b \to \Upsilon(2S)\pi^+\pi^-$, the cross section $(4.82^{+1.01}_{-0.91})$ pb gives $\Gamma_{ee}\mathcal{B} = (1.20^{+0.43}_{-0.37})$ eV, while for $Y_b \to \Upsilon(3S)\pi^+\pi^-$, the cross section $(1.71^{+0.42}_{-0.39})$ pb corresponds to $\Gamma_{ee}\mathcal{B} = (0.42^{+0.16}_{-0.14})$ eV.

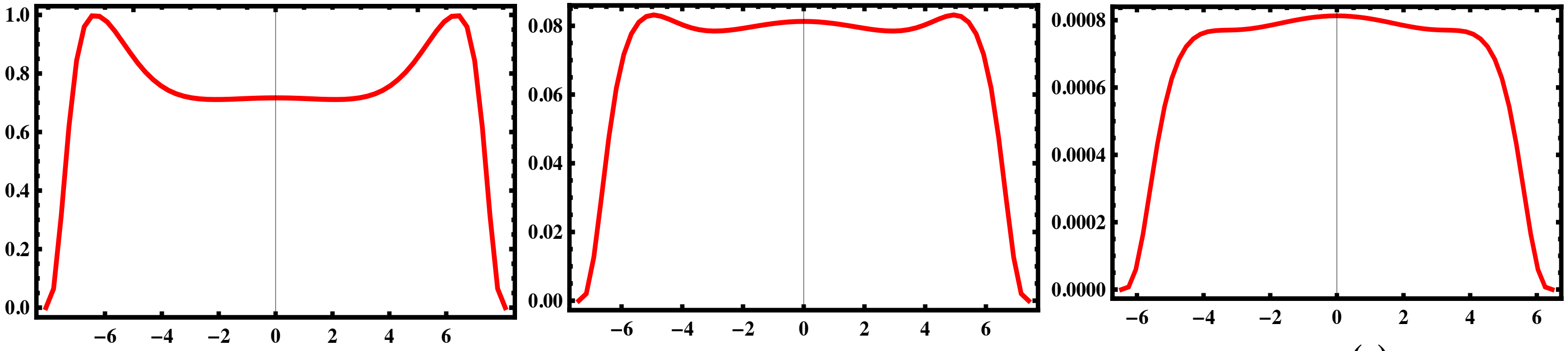
Rapidity Distributions and pT Distributions

Rapidity (y) and p_T-distributions at $\sqrt{s} = 7$ TeV for

(a) $pp \longrightarrow (\phi(2170) \longrightarrow \phi(1020) f_0(980) \longrightarrow K^+K^-\pi^+\pi^-) + \ldots$;

(b) $pp \longrightarrow (X(4260) \longrightarrow J/\psi\pi^+\pi^- \longrightarrow \mu^+\mu^-\pi^+\pi^-) + \ldots$;

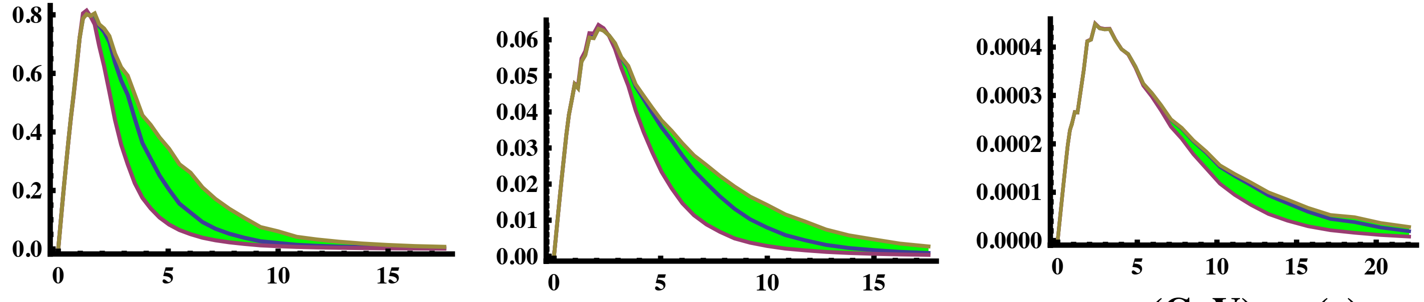
(c) $pp \longrightarrow (Y_b(10890) \longrightarrow (\Upsilon(nS)\pi^+\pi^- \longrightarrow \mu^+\mu^-\pi^+\pi^-) + \ldots$



y (a) y (b) y (c)

$$y \equiv \frac{1}{2} \ln \frac{p^0 + p^3}{p^0 - p^3}$$

$$|y| < 2.5$$



p_T(GeV) (a) p_T(GeV) (b) p_T(GeV) (c)

Integrated Cross sections

Cross sections (in units of pb) for the processes $p\bar{p}(p) \to \phi(2170)(\to \phi(1020) f_0(980) \to K^+K^-\pi^+\pi^-)$, $p\bar{p}(p) \to X(4260)(\to J/\psi\pi^+\pi^- \to \mu^+\mu^-\pi^+\pi^-)$, 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.

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

For CTEQ10 PDFs, most changes amount to less than 30%

Integrated Cross sections

Events numbers. The integrated luminosity at Tevatron: $10\,fb^{-1}$, while for LHC: $5\,fb^{-1}$

	$\phi(2170)$	$X(4260)$	$Y_b(10890)$
Tevatron($\lvert y\rvert < 2.5$)	23000	2300	20
LHC 7TeV ($\lvert y\rvert < 2.5$)	18000	2000	20
LHCb 7TeV ($1.9 < y < 4.9$)	11000	1200	11
LHC 14TeV ($\lvert y\rvert < 2.5$)	22000	2700	30
LHCb 14TeV ($1.9 < y < 4.9$)	13000	1500	16

ϕ(2170) and X(4260) **have measurable rates!**

Y_b(10890) **may have to wait for higher luminosities.**

Summary

•Exotic Spectroscopy: not all of the observed states can be accommodated with qqbar interpretation

•Vector tetraquark candidates

$$\phi(2170) : s\bar{s}s\bar{s} \qquad X(4260) : c\bar{c}q\bar{q} \qquad Y_b(10890) : b\bar{b}q\bar{q}$$

•Production at LHC and Tevatron via Drell-Yan is studied

•ϕ(2170) and X(4260) have measurable rates;
Y_b(10890) may have to wait for higher luminosities.

Many thanks for your attention!

Cosmology did not meet particle physics in this talk unless