Heavy Quarks and Leptons 2010: Spectroscopy Session Summary

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Centro Brasileiro de Pesquisas Físicas – CBPF

Xth International Conference on Heavy Quarks and Leptons – Frascati, October , 2010

After 46 years of the CQM, light and heavy quark spectroscopy can still surprise, providing new experimental and theoretical challenges.

In the past decade there was a tremendous improvement on the EFT of $Q\bar{Q}$ systems: spectra, decays, doubly charm baryons, production, standard model parameters, nonperturbative potentials for LQCD...

"pNRQCD is today the theory used to address quarkonium bound states properties" (N. Brambilla)

Exes_and_why_Z

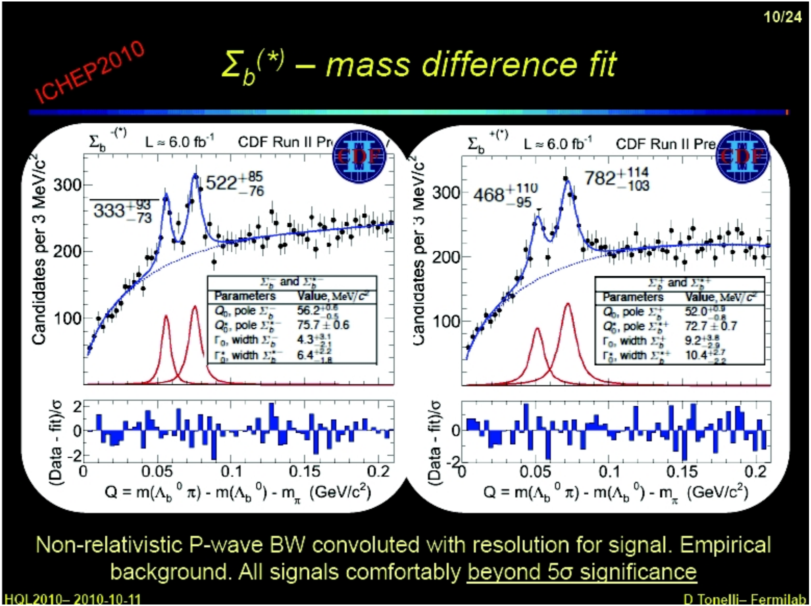
The $c\bar{c}$ spectrum bellow $D\bar{D}$ threshold is now very well understood (all expected states were found). The unexpected observation of the *XYZ* states renewed the interest on heavy quark spectroscopy.

These states don't quite fit into the $c\bar{c}$ scheme. They are likely to be the first evidence of new forms of quark aggregation. They may be just the "visible edge of the iceberg".

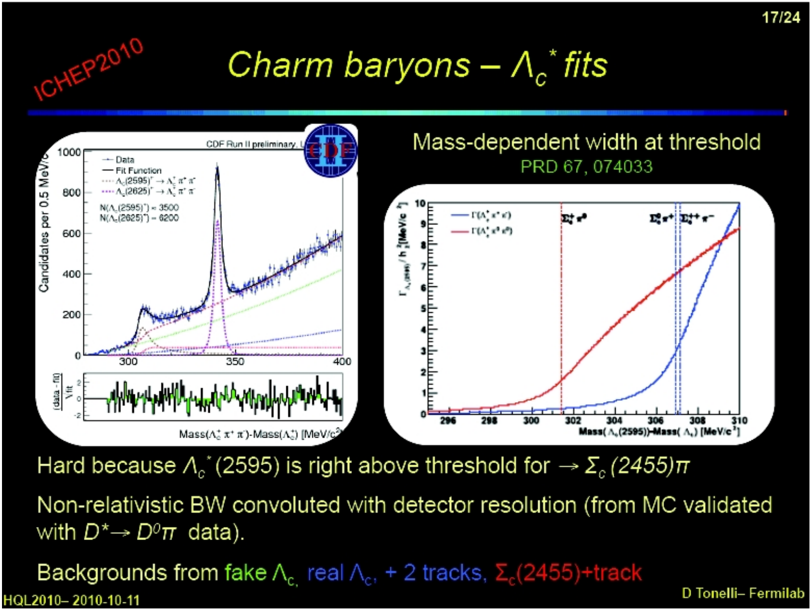
The central problem of heavy quark spectroscopy: what is the internal structure of these states? Molecules? Tetraquarks? Hybrids? Or what?

E. van Beveren offered a very interesting picture for the *XYZ* states, showing how the crossing of different $D\bar{D}$ thresholds can cause enhancements and depletions in the cross-section.

Charm and beauty baryons from CDF



Charm and beauty baryons from CDF



BaBar – What are the $X(3872)$ quantum numbers?

E. Prencipe - Spectroscopy results from BaBar - HQL2010 (Frascati)

PRD-RC 82, 011101 (2010)

Evidence of $X(3872) \to J/\psi\,\omega$

- Belle reported an excess of events in m(3π) above 750 MeV/c^2 in the decay $B \to J/\psi 3\pi K$

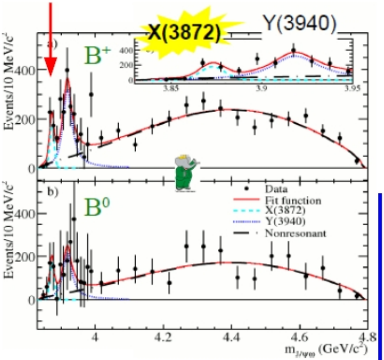
  $|m_{J/\psi 3\pi} - 3872| < 16.5$ MeV/c^2

  ⇒ interpreted as $X \to J/\psi\omega$

- *BABAR* confirmed the existence of the Y(3940) in $B \to Y(J/\psi\omega)K$ but could not see the $X(3872) \to J/\psi\omega K$ signal when requiring PRL 101, 082001 (2008)

  0.7695< m3π<0.7965 *(B+)*

New analysis: 4.0σ ($X \to J/\psi\omega$)



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E. Prencipe - Spectroscopy results from BaBar - HQL2010 (Frascati)

PRD-RC 82, 011101 (2010)

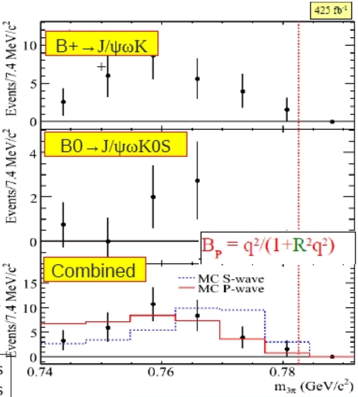
Angular distribution study in $J/\psi\ \omega$

- The *P-wave* hypothesis for the X(3872) describes data better than S-wave
  - X(3872) is more likely J^P=2- than J^P=1+ state, consistent with charmonium η_{c2}(1D) interpretation.

S-wave: χ2/NDF=10.17/5
P(χ2/NDF)=7%
P-wave: χ2/NDF=3.53/5
P(χ2/NDF)=62%
JP=1+ is still not excluded!

- From the decay modes: $X \to J/\psi\gamma$, $X \to \psi(2S)\gamma \Rightarrow C=+1$

Dalitz weighting technique: each event is given weight of $(5/2)(1-3\cos^2\theta_h)$, where θ_h is the angle between the $\pi+$ and $\pi 0$ in the $\pi+\pi-$ rest frame → See SLIDES 40,41,42, 46 for details



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BaBar – new excited D states

E. Prencipe - Spectroscopy results *from BaBar* - HQL2010 (Frascati)

Observation of new D states (I)

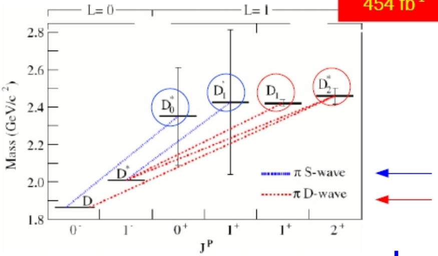
arXiv:1009.2076

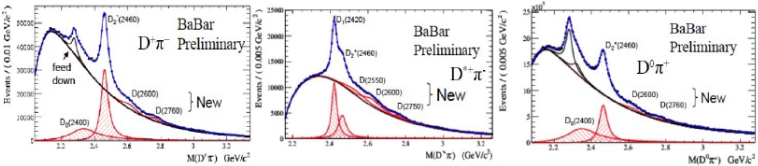
454 fb^{-1}

- 4 new states observed: L=1
  2 in D-waves, Γ ~40 MeV
  2 in S-waves, Γ~300 MeV

- Channel under study:

  $e^+e^- \to c\bar{c} \to D^{**}X \to D^{(*)}\pi X$





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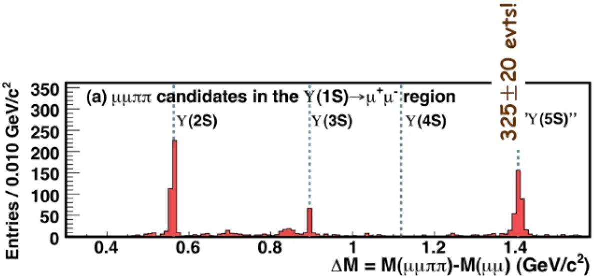
Belle: $\Gamma(\Upsilon_{5S} \to \pi^+\pi^-\Upsilon_{1S})$



1/20th the data: 477 fb^{-1} → 23.6 fb^{-1}

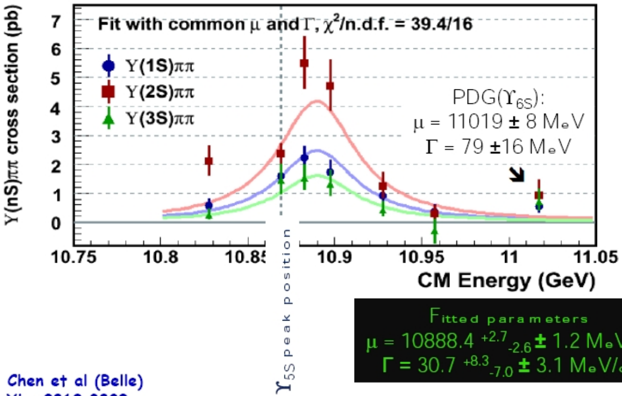
1/5th the cross-section

But >6 times as many events

K.F. Chen et al (Belle)
PRL 100, 112001 (2008)

Are these events from the Υ_{5S}?

$\sigma(e^+e^- \to \pi^+\pi^-\Upsilon_{nS})$ from a cm energy scan



Fitted parameters

$\mu = 10888.4\ ^{+2.7}_{-2.6} \pm 1.2\ \mathrm{MeV}/c^2$

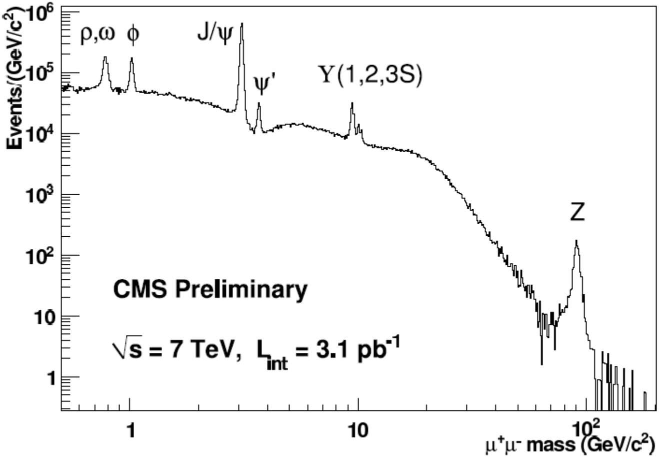
$\Gamma = 30.7\ ^{+8.3}_{-7.0} \pm 3.1\ \mathrm{MeV}/c^2$

K.F. Chen et al (Belle)
arXiv: 0810.3829

PDG(Υ_{5S}): $\mu = 10865 \pm 8$ MeV
$\Gamma = 110 \pm 13$ MeV

The LHC gets into the game: $\mu^+\mu^-$ from CMS

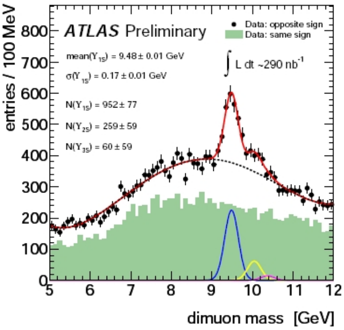
Welcome to diμdorado !

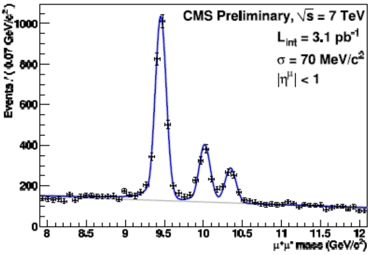


similar spectrum observed also by ATLAS

Bottomonium from ATLAS and CMS

$\Upsilon(1S)(b\bar{b})$ (PDG: 9460.30 ± 0.26 MeV/c^2)



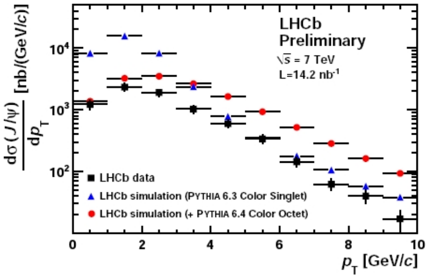


- ATLAS
  - Trigger: L1 muon trigger(no pT cut), or a LHT muon: $p_{T\mu} > 4$ GeV
  - $p_{T\mu 1} > 2.5$ GeV; $p_{T\mu 2} > 4$ GeV

- CMS
  - $p_{T\mu} > 3.5$ GeV; $|\eta_\mu| < 1.0$; $|y_\Upsilon| < 2$
  - $P(\mu^+\mu^-_{S.V.}) > 0.1\%$
  - $|z_{\mu^+} - z_{\mu^-}| < 0.2$ cm:
    - $N(\Upsilon(1S)) = 2440 \pm 61$
    - $N(\Upsilon(2S)) = 757 \pm 40$
    - $N(\Upsilon(3S)) = 464 \pm 34$

LHCb – J/ψ cross section

$J/\psi(1S)$



- The cross-section is presented on the range $0 \to 10$ GeV/c
  - There is an efficiency dependence on the polarisation, to which we presently assign a conservative systematic error
  - This will be measured with a larger dataset
- $\sigma(pp \to J/\psi(1S)X) = \left(7.65 \pm 0.19 \pm 1.10^{+0.87}_{-1.27}\right)$ μb ($p_T < 10$ GeV/c, $2.5 < y < 4$)
- $J/\psi(1S)$ measurement seems to favour neither color singlet or octet models

C. Fitzpatrick

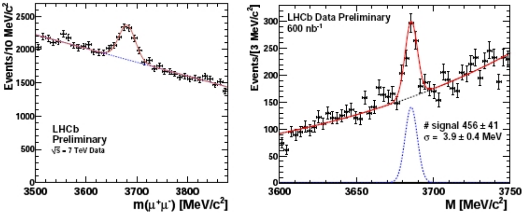
October 11, 2010

THE UNIVERSITY OF EDINBURGH

$\psi(2S)$

600 nb^{-1}

$\psi(2S) \to \mu^-\mu^+$ $\psi(2S) \to J/\psi(1S)\pi^+\pi^-$



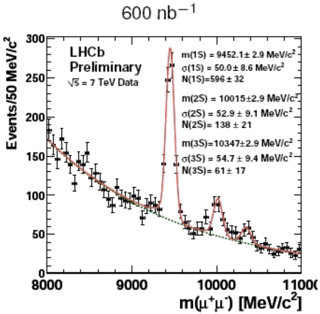
- Two modes under investigation at LHCb: $\psi(2S) \to \mu^-\mu^+$ and $\psi(2S) \to J/\psi(1S)\pi^+\pi^-$
- $\psi(2S)$ has essentially no feed-down from higher quarkonia states, so the production cross-section is easier to interpret than $J/\psi(1S)$
- When we have enough statistics production cross-sections in p_T will be presented for both prompt and $\psi(2S)$ from b quarks

C. Fitzpatrick

October 11, 2010

LHCb – $\Upsilon(1S)$ cross section by next winter

Υ



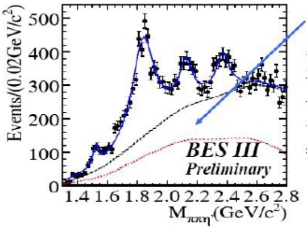
- ≈ 50 MeV/c^2 mass resolution!
- $\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$ well separated
- Expect a $\Upsilon(1S)$ cross-section in p_T and a few y bins by the winter conferences

Light quarks - still lots of interesting problems

Fitting the mass spectrum:

- Three background components:
  1. Contribution from non-η′ events estimated by η′ mass sideband
  2. Contribution from $J/\psi \to \pi^0\pi^+\pi^-\eta'(\eta' \to \gamma\rho)$ with re-weighting method
  3. Contribution from "PS background"

$$f_{bkg}(x) = (x-m_0)^{1/2} + a_0(x-m_0)^{3/2} + a_1(x-m_0)^{5/2},\ m_0 = 2m_\pi + m_{\eta'}$$



Red line: estimated contribution of ①+ ②

Black line: total background

resonance	M(MeV$/c^2$)	Γ(MeV$/c^2$)	Stat. sig.
X(1835)	1838.1 ± 2.8	179.5 ± 9.1	$> 25\sigma$
X(2120)	2124.8 ± 5.6	101 ± 14	$> 7.2\sigma$
X(2370)	2371.0 ± 6.4	108 ± 15	$> 6.7\sigma$

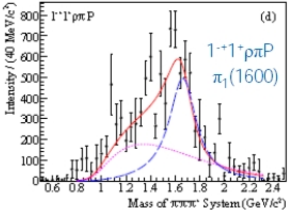
Stat. sig. is conservatively estimated:
fit range, background shape,
contribution of extra resonances

- X(1835) resonance is confirmed at BESIII, but the width is significantly larger than that measured at BESII with one resonance in the fit.
- Two new resonances, X(2120) and X(2370), are observed.
- PWA is needed

Light quarks - still lots of interesting problems

Exotic wave $1^{-+}1^{+}\rho\pi P$: $\pi_1(1600)$

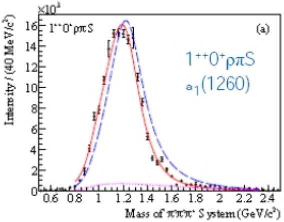
PRL 104, 241803 (2010)

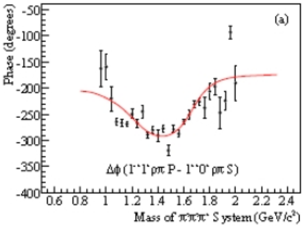


- Significant 1^{-+} amplitude consistent with resonance at ~ 1.6 GeV
- No leakage observed
- BW for $\pi_1(1600)$ + background:

  $M = (1.660 \pm 0.010\ ^{+0.000}_{-0.064})$ GeV

  $\Gamma = (0.269 \pm 0.021\ ^{+0.042}_{-0.064})$ GeV





10/11/2010 HQL 2010 – Reiner Geyer

The one-sentence summary

Heavy quark spectroscopy is more than ever a very active field, full of opportunities for theoreticians and experimentalists.

Many thanks to the Organizers for the perfect organization, for the extreme kindness and for the great time we had here!