Broad resonances in dilepton spectra

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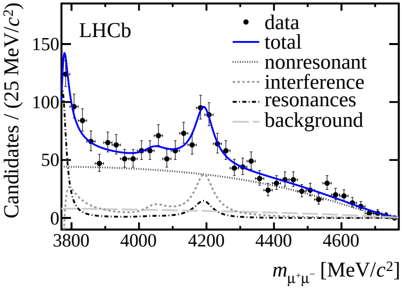
Experimental Situation

- in 2012 LHCb announced observation of a resonance beyond $\psi(3770)$ in dilepton spectrum of $B^+ \to K^+\mu^+\mu^-$
- to paraphrase Douglas Adams:

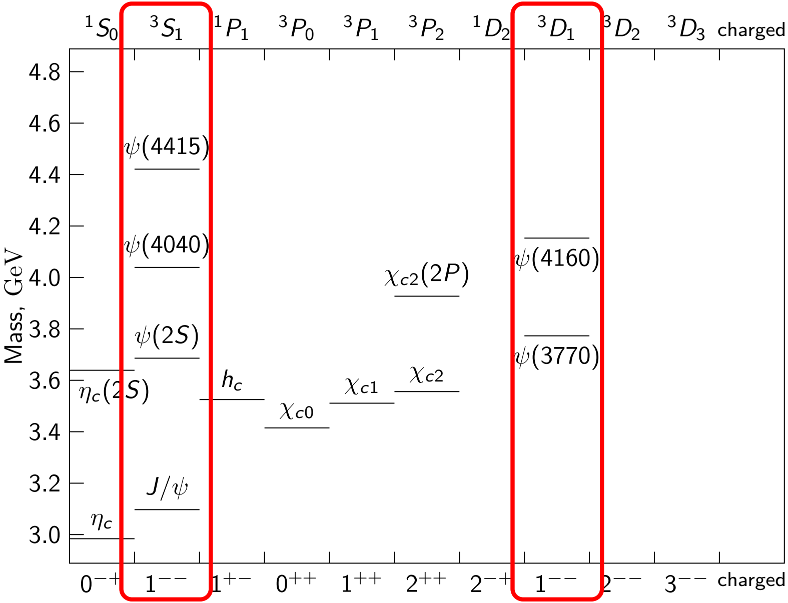
"this made a lot of people very irritated and has been widely regarded as a bad move"

experiment performed **model-dependent** decomposition



- theory side did never claim absence of resonances in low recoil region $\hookrightarrow$ non-resonant curve $\neq$ OPE prediction $\leftarrow$ see Sebastian Jäger's contribution
- same resonances as in $e^+e^- \to$ *hadrons* expected in $B \to K^{(*)}\ell^+\ell^-$

Known Charmonia with $J^P = 1^-$



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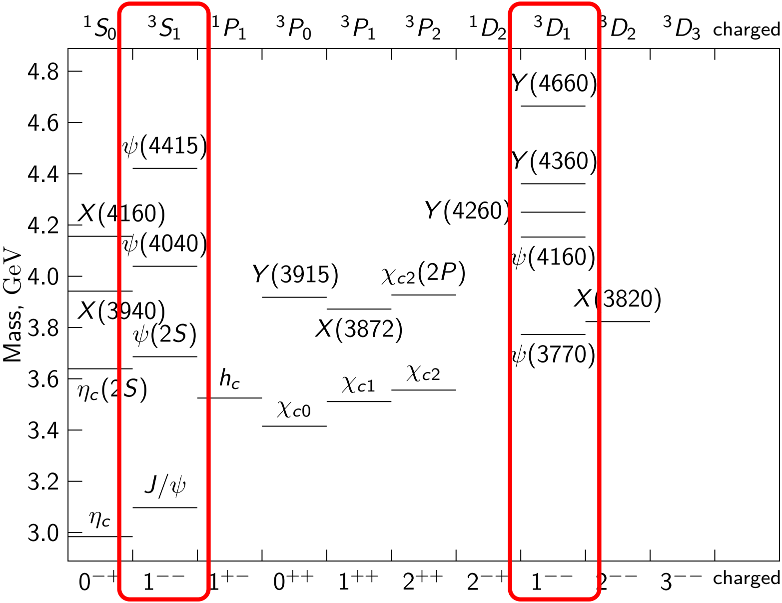

Open Questions

- where are the other resonances beside $\psi(4160)$?
- to what extent is quark-hadron duality violated?
  - what is the value of $H_T^{(1)}$?
  - what is the value of S_7?
- can we learn more about the q^2 spectrum when combining exclusive $b \to s\ell^+\ell^-$ data?

Low Recoil - OPE and Resonances

Sebastian Jäger's slides

Low Recoil - Resonances and Experimental Interpretation

Tom Blake's slides

An experimentalists confusion

- We are all used to seeing predictions for observables that are continuous in q^2 even at high q^2. Are these continuous curves misleading (at best)?
- OPE predictions are only expected to be reliable after integration and the integration range in q^2 must also play an important role. Can we make a bad choice of q^2 range?
- For comparison with OPE should we be using a single wide?
  $\hookrightarrow$ what is a suitable lower bound for the bin, $15\mathrm{GeV}^2/c^4$?

An experimentalists perspective

- We know that experimentally we can see these resonances and are sensitive to their interference with the non-resonant contribution.
- Forgetting OPE for a minute, is this something worth measuring and would the theory community have a use for it?
- What model should we use? We currently use a sum of Breit-Wigner's

$$\frac{\mathrm{d}\Gamma}{\mathrm{d}q^2} \propto |A_{\mathrm{NR}}^{\mathrm{V}} + \sum_k e^{i\delta_k} A_{\mathrm{R}}^{k}|^2 + A_{\mathrm{NR}}^{\mathrm{AV}}|^2$$

- Is there a more appropriate model to use? e.g. hadronic model from Beylich, Buchalla and Feldmann, arXiv:1101.5118.

An experimentalists perspective

- We also see evidence for light resonances at large-recoil.
  $\hookrightarrow$ clear evidence for the $B \to K^{*0}\phi$.

  (Unfortunately we can't show you anything here)

NB We already have information on helicity structure of the $B \to K^{*0}\phi$ decay (from $\phi \to K^+K^-$).

Low Recoil - Resonance Model

Stefan Meinel's slides

Low Recoil

Summary(ish) slides

Low Recoil OPE

Quark-Hadron Duality

from M. Shifman, hep-ph/0009131

“[QCD] is a very strange theory [. . .] in terms of quarks and gluons [which are] never detected experimentally. What is actually produced and detected [. . .] are hadrons [. . .]. **The quark-hadron duality** *allows one,* **under certain circumstances** *to bridge the gap between the theoretical predictions and experimentally observable quantities.”*

emphasis added

Low Recoil OPE

OPE vs Reality

- OPE predictions only expected to be reliable after integration
  - start sufficiently beyond onset of open-charm threshold (that is, avoid inclusion of $\psi(3770)$)
  - ideally, start integration $\sim 15\text{GeV}^2$
- from quark-hadron duality: expect $\int X^{\text{OPE}}(q^2) \simeq \int X^{\text{exp}}(q^2)$
- however, $X^{\text{OPE}}(q^2)$ **will** differ substantially from $X^{\text{exp}}(q^2)$
- duality violation only(?) from hadronic models $\leftarrow$ fit to data?

Large Recoil - ρ, ϕ

Sebastian's slides