Heavy Hadrons at LHC

available at *http://lpsc.in2p3.fr/theorie/Richard/SemConf/Talks.html*

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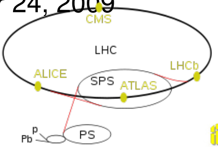

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Introduction

Encouraging recent results

- new states seen in high-energy experiments,
- for instance, $D_{s,J}$, $X(3872)$, $\eta_c(2S)$
- many new single-charm or single-beauty baryons
- while low-energy experiments sometimes gave misleading results (pentaquarks)
- even complex and fragile structures, such as antideuterium produced at high energy

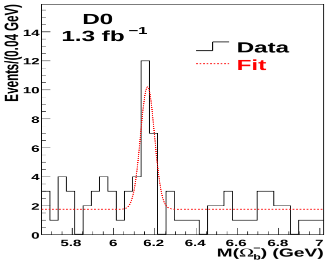
Less encouraging

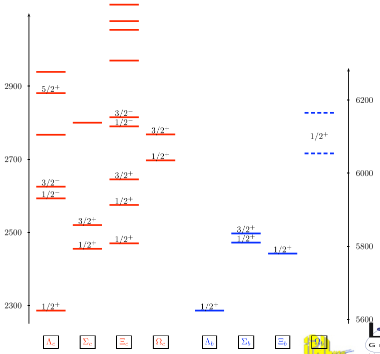
- spectroscopy and flavour program also foreseen at heavy-ion facilities (RHIC)
- see, e.g., BNL Workshop, May 2002
- but never given enough priority in detector tuning and in analysis

New baryons

Single-flavour baryons

Many new states, in particular at CLEO. At present, 34 charmed baryons and 7 beauty baryons are known.
Hope: Understanding light-quark dynamics from charmed baryons, before light baryon resonances?
Problems





New baryons

Double-charm baryons

- (ccq) and b analogues (bcq) and (bbq)
- Tentatively seen by SELEX
- Not seen elsewhere, in particular at BaBar,
- Combine the charmonium-like dynamics (non-relativistic limit of QCD)
- With the D-like dynamics (ultra-relativistic regime)
- In a single hadron, with also interesting weak-decay properties

New baryons

Triple-charm baryons

- (ccc) and b analogues (bcc), (bbc) and (bbb)
- *The ultimate goal of baryon spectroscopy* (Bjorken)
- To probe the real three-quark interaction of QCD, independently of light-quark complications
- The baryon analogue of heavy quarkonium
- Large binding effects in weak decay

New baryons

Exotic baryons

- $QQQg$, on the same footing as the more advertised hybrid mesons ($Q\overline{Q}g$)
- but with the same quantum numbers as (QQQ)
- Heavy pentaquarks (1987 vintage, Lipkin, Gignoux et al.) ($\bar{Q}qqqq$)
- Predicted on the same (fragile) chromomagnetic mechanism as Jaffe's H dibaryon

Mesons
Heavy quarkonia

- Missing $(b\bar{b})$ states, e.g., the $\eta_b(nS)$ ($n = 1$ seen reported recently)
- $(b\bar{c})$ spectroscopy, probing flavour independence
- $(b\bar{c})$ decays, in particular binding effect, role of c vs. b, etc.
- Production mechanisms

Mesons
Hybrid mesons

- Predicted since the late 70's, on the basis of models (Gilles and Tye (1978), Mandula and Horn (1978), and Hasenfratz, Horgan, Kuti and R. (1980), etc.
- Confirmed in more elaborated approaches, e.g., Lattice QCD
- Better seen in heavy quarkonia? (cleaner background of "ordinary states")
- Possibility of exotic J^{PC}
- Already some speculations for $X(3872)$, $X(3940)$ or $Y(4260)$

Mesons

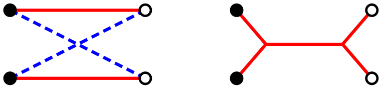
Multiquark mesons

- Very old problem. In particular for light scalar mesons. Some of them often described as S-wave $(qq\bar{q}\bar{q})$ rather than P-wave $(q\bar{q})$
- For light quarks and antiquarks, chromomagnetism is a possible source of stability (or metastability) against dissociation into two mesons,
- Heavy quarks more sensitive to chromoelectric forces, hence new type of configurations become favoured
- An example, on which all theorists agree is $(QQ\bar{q}\bar{q})$ (double-flavour mesons), which should be *below* the threshold $(Q\bar{q} + (Q\bar{q})$ if the mass ratio Q/q is large enough
- Same mechanism by which in atomic physics (ppe^-e^-) is more stable than $(e^+e^+e^-e^-)$: the 4-body compound benefits of the heavy-heavy binding, and this effect is not active in the threshold.

$(QQ\bar{q}\bar{q})$ Mesons

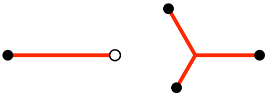
Recent developments

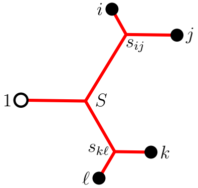
- Favourable heavy–light asymmetry confirmed by QCD sum rules
- A better treatment of confinement, as suggested by lattice QCD, gives a more realistic (and much more difficult to handle) potential



gives more attraction than the additive ansatz used previously.

- Similarly $(\bar{q}\, q_1 q_2 q_3 q_4)$ found to be stable if q_i different





Further exotics

- Four-quark mesons sometimes described as meson–meson molecules
- Bound by nuclear forces (Törnqvist, Swanson, Ericson & Karl, Manohar, etc
- Other states predicted in this approach, in particular bound states of charm baryons
- For instance $(ccq) - (ccq)$ (Riska & Julia-Diaz)

Conclusion

- LHC can contribute to confinement and flavour physics
- Many states await discovery
- Some predictions are fragile and controversial
- Other predictions are more solid, e.g. $(QQ\bar{q}\bar{q})$
- LHC offers a good opportunity
- If a reasonable fraction of efforts devoted to this physics