Observation of the doubly charmed baryon Ξ_{cc}^{++}

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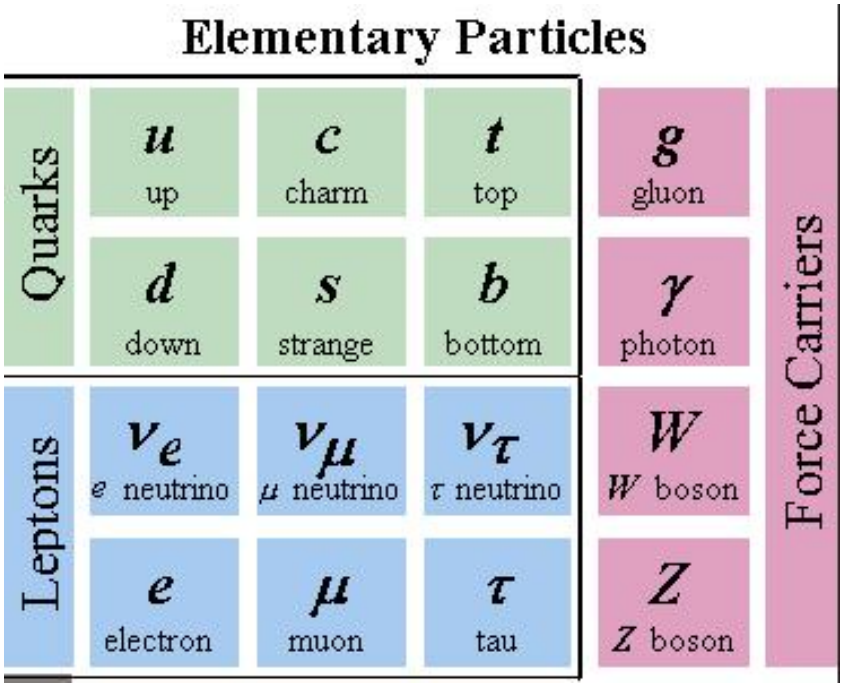
JC 24 report

Introduction

--standard model of particle physics



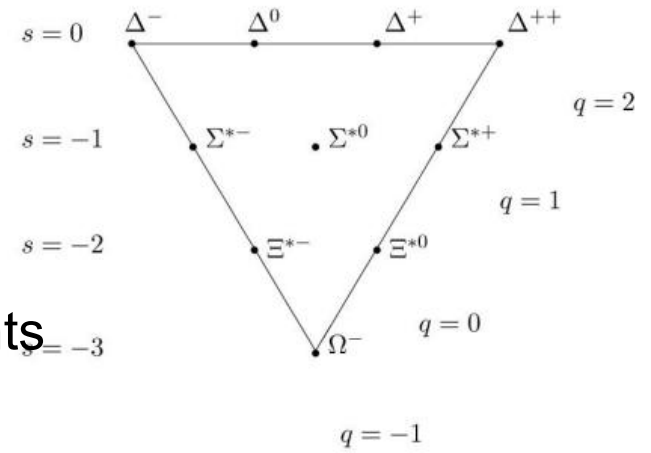
- fermions: quarks and leptons
- bosons: force carriers

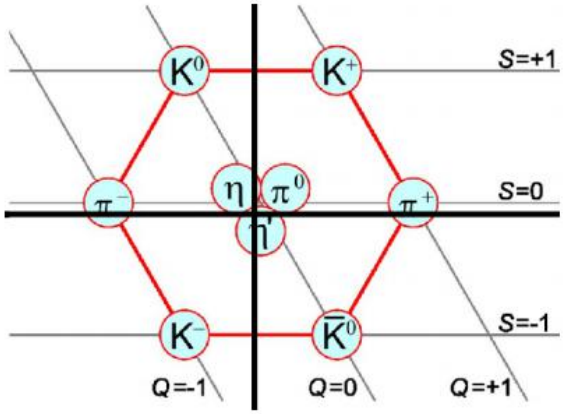
Quark Model for hadrons

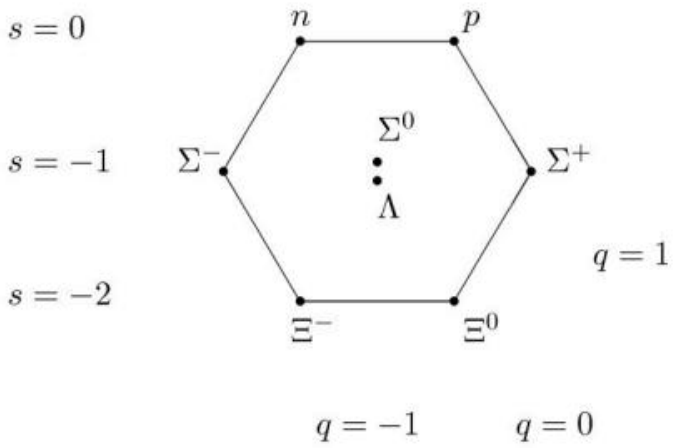
- The quark model was independently proposed by physicists Murray Gell-Mann,and George Zweig in 1964.
- **Classification of hadrons**
  - meson: qqbar
  - baryon: qqq
  - tetraquark states/ pentaquark states/molecule states ....

SU(3) quark model

- the three flavored quarks : u, d, s
- classified the baryons and mesons well
- theoritical predictions confirmed in experiments

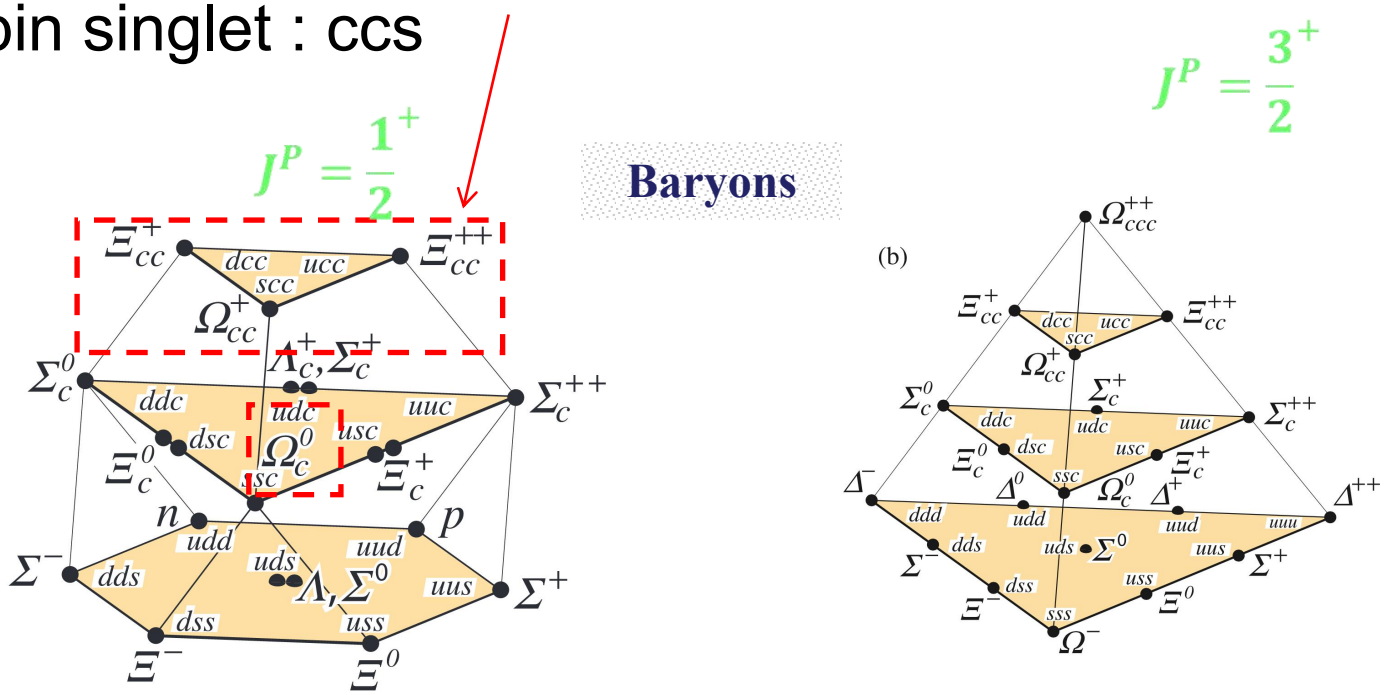






SU(4) Quark Model

- for u, d, s, c , hadrons form SU(4) multiplets
- C=0,1 ground states all observed yet
- for C=2: three ground states not firmly discovered
  - isospin doublet(Xicc): ccd , ccu
  - isospin singlet : ccs



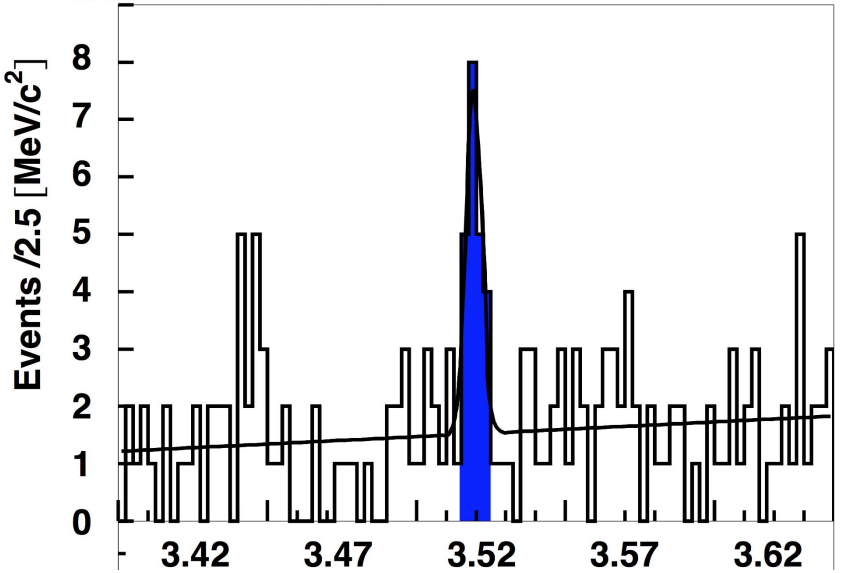
Study of doubly heavy baryon

- Nearly all the matter that we see around us is made of baryons, which are baryons, the best-known being protons and neutrons. But there are six flavor quarks, then many different combinations could form many other kinds of baryons.
- have a better understanding of the strong interaction between quarks, and three body systems
- hadrons contains heavy quark(s) are better enviroment for the study: many techniques could be performed: example, heavy quark limit.

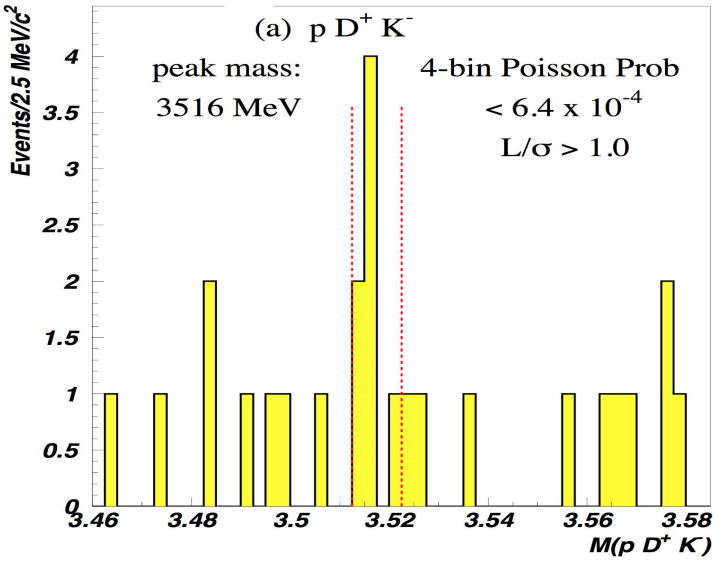
Some history of Xicc+

- SELEX experiment report the result of Xicc+ in two modes: $\Lambda_c^+ K^- \pi^+$ $pD^+ K^-$

$\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$ PRL 89 (2002) 112001



$\Xi_{cc}^+ \to pD^+\pi^-$ PLB 628 (2005) 18



NOT observed by FOCUS, BaBar, Belle, and LHCb

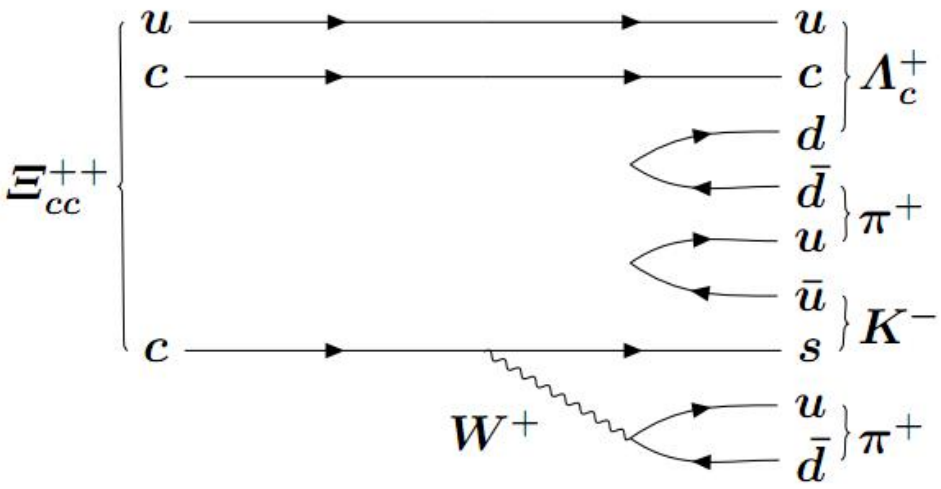
Searching for Xcc++

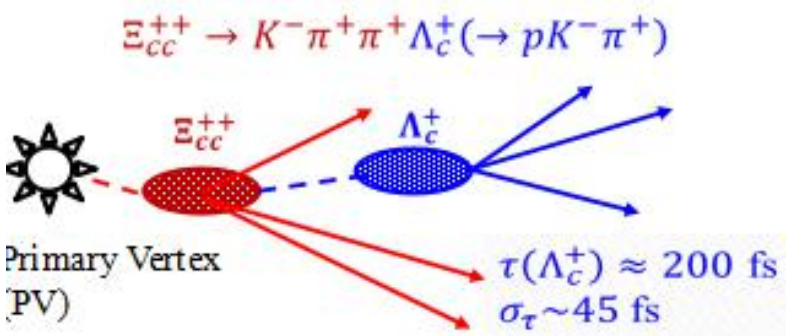
https://aps.arxiv.org/abs/1703.09086

- Yu F.-S. suggested:
  - Xicc++ --> Lc+ K- pi+ pi+ is the most promising channel
  - longer lifetime and maybe larger branching fraction

The existence of doubly heavy flavor baryons has not been well established experimentally so far. In this Letter we systematically investigate the weak decays of the doubly charmed baryons, Ξ_{cc}^{++} and Ξ_{cc}^{+}, which would be helpful for experimental searches for these particles. The branching fractions are studied under the factorization hypothesis for the short-distance contributions and considering the rescattering effect for the long-distance contributions which are significantly enhanced. Comparing all the decay modes, we recommend the processes of $\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$ and $\Xi_c^+ \pi^+$ as the first priority for experiments to search for the doubly heavy baryons.

Searching for Xcc++ in LHCb



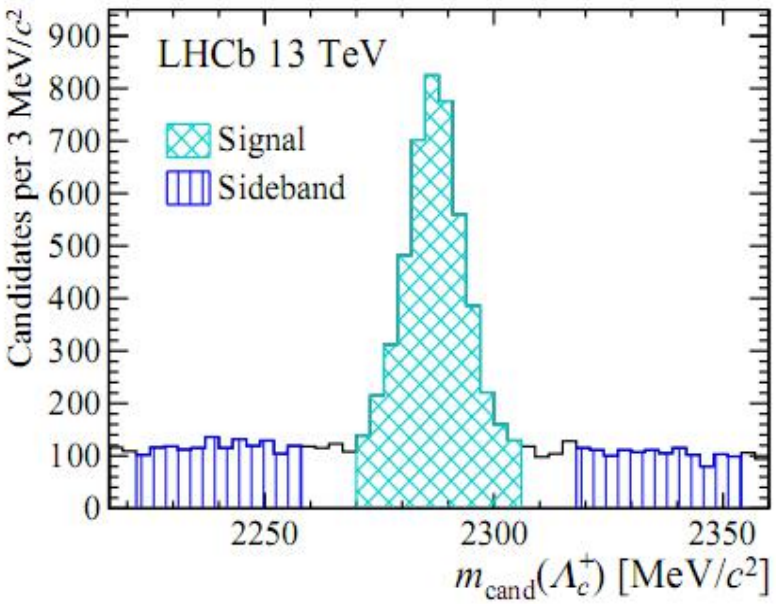


some key points of the Basic selections:

- tracks with good track quality, good PID, and enough distance from PV
- Good Vertices, large decay length significance, large Pt

Multi-variable technique introduced to further suppress the background

Mass spectrum after selections



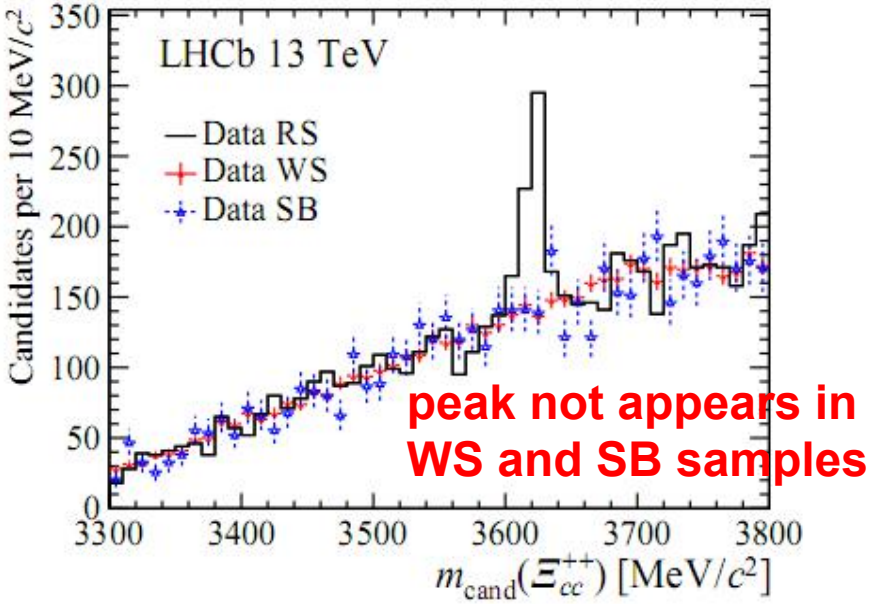
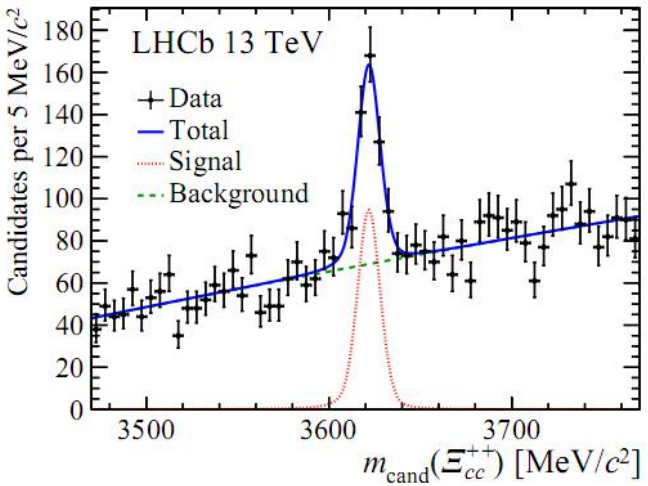
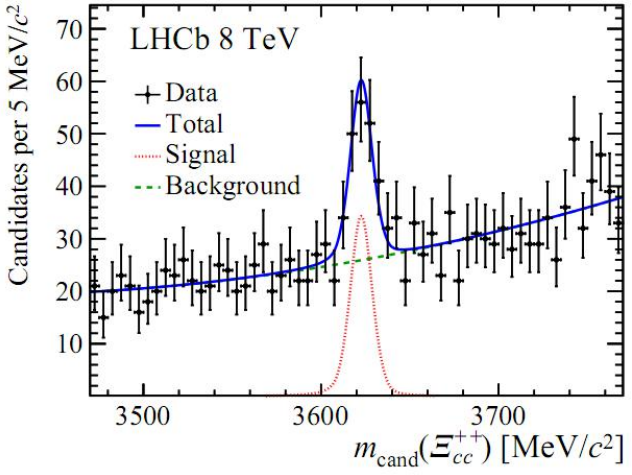


Figure 2: Mass spectra of (left) Λ_c^+ and (right) Ξ_{cc}^{++} candidates. The full selection is applied, except for the Λ_c^+ mass requirement in the case of the left plot. For the Λ_c^+ mass distribution the (cross-hatched) signal and (vertical lines) sideband regions are indicated; to avoid duplication, the histogram is filled only once in events that contain more than one Ξ_{cc}^{++} candidate. In the right plot the right-sign (RS) signal sample $\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$ is shown, along with the control samples: Λ_c^+ sideband (SB) $\Lambda_c^+ K^- \pi^+ \pi^+$ candidates and wrong-sign (WS) $\Lambda_c^+ K^- \pi^+ \pi^-$ candidates, normalized to have the same area as the RS sample in the $m_{\rm cand}(\Xi_{cc}^{++})$ sidebands.

Fit to data and some discussions





- consistent with the cross-check(8 TeV) data sample.

- The peak still significant after requiring minimum decay time, t > 5sigma_{t}. Therefore it decays via weak interaction.

- the measured mass is larger than SELEX Xcc+ value about 100 MeV.

The SELEX result is disfavored!

  - larger than any other known isospin splitting effect
  - larger than the theoritical expectation ~ a few MeV.

Summary

- A ground doubly charmed baryon state is firstly observed by LHCb.
- The result disfavors the previous SELEX result.

Thanks