

# Charmed Baryon Spectroscopy with LHCb

## The LHCb Detector

- ▶ LHCb is a forward arm spectrometer on the LHC ring at CERN, designed for studying heavy flavour physics.
- ▶ Key to physics analyses are the Vertex Locator (VELO) and Ring Imaging Cherenkov detectors (RICH), Glasgow closely involved with both.
- ▶ These provide up to 4μm vertex resolution and high performance PID, with a 95% Kaon ID rate.

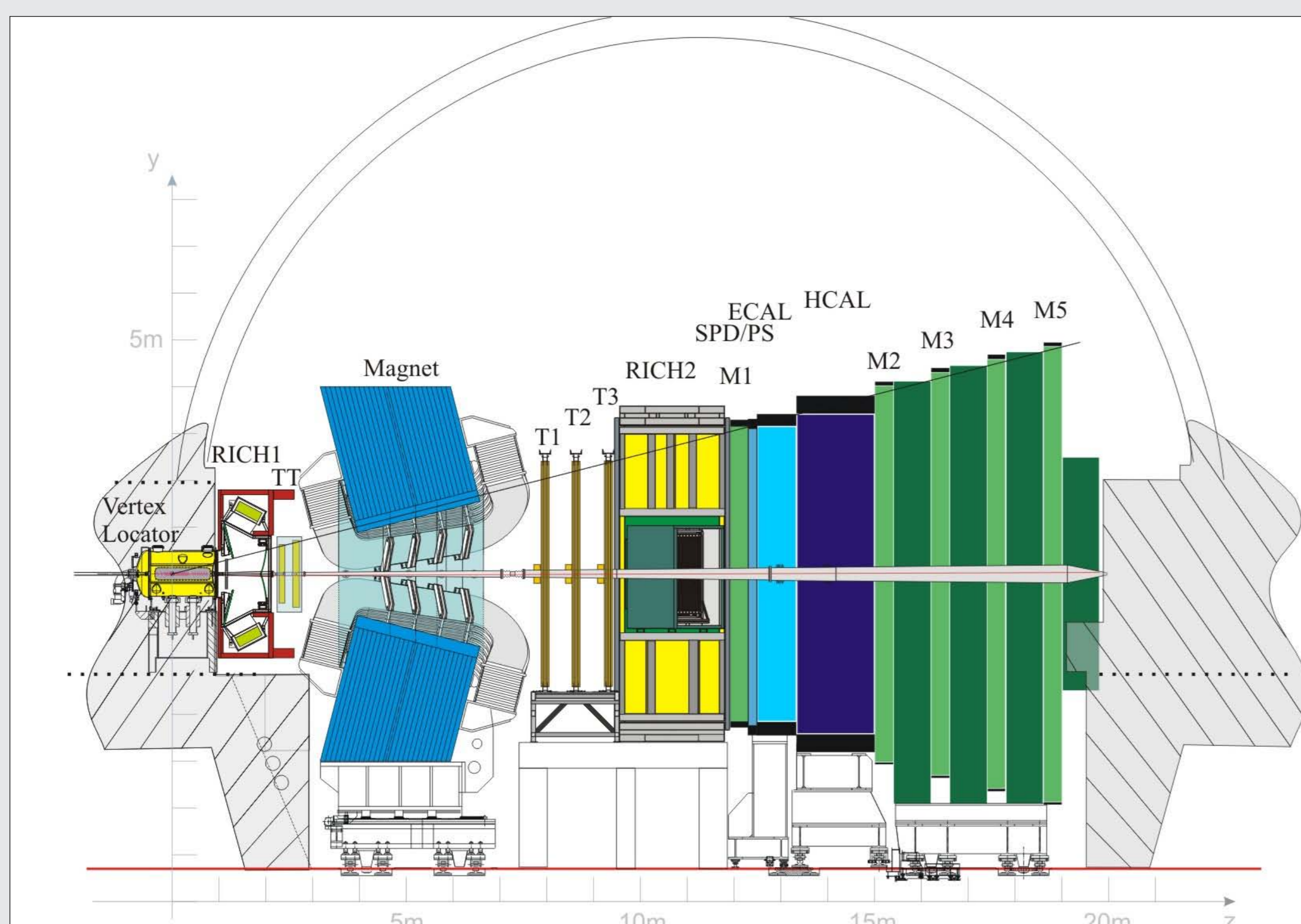


Figure 1: The LHCb detector.

- ▶ The experiment recorded 1.04fb<sup>-1</sup> of data in 2011. On target for a further 1.5fb<sup>-1</sup> by the end of 2012.

## State of the Field

- ▶ Baryons containing u,d,c,s form an SU(4) group, Figure 2.

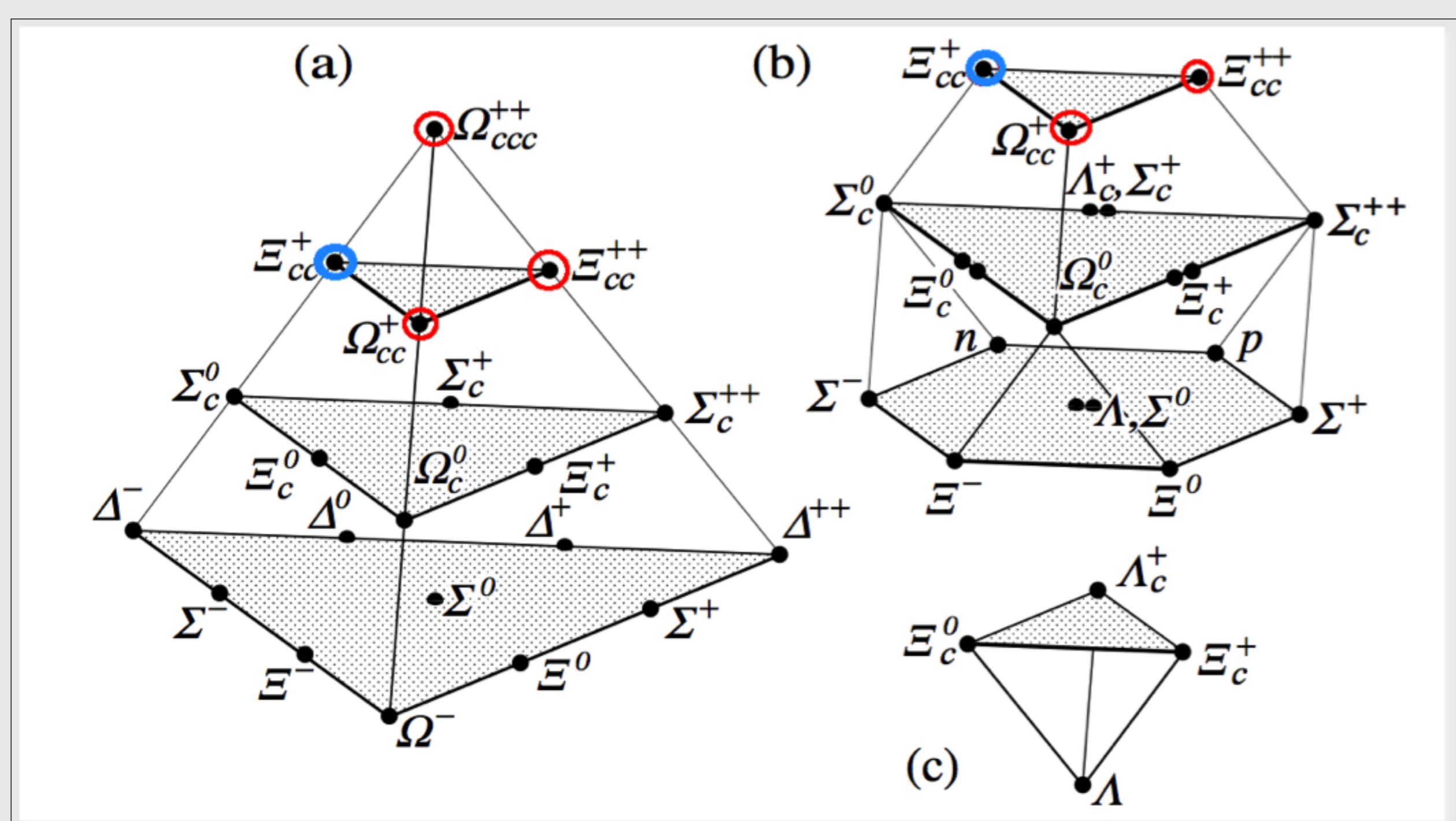


Figure 2: The SU(4) generated multiplets of charm baryons. From PDG [1].

- ▶ Circled in blue = observed only by SELEX, red = not observed. B factories have searched for but have not observed doubly charmed production.
- ▶ SELEX observation of the  $\Xi_{cc}^+ \tau$  disagrees strongly with theory.
- ▶  $\Lambda_c^+ \rightarrow p h h$  modes still poorly understood in terms of BFs, decay amplitudes and resonance structure.
- ▶ Current PDG BFs shown below, the doubly-Cabibbo Suppressed decay  $\Lambda_c^+ \rightarrow p K^+ \pi^+$  has not been observed.

Decay Mode	PDG Branching Fraction
$\Lambda_c^+ \rightarrow p^+ K^- \pi^+$	$0.05 \pm 0.013$
$\Lambda_c^+ \rightarrow p^+ K^- K^+$	$(7.7 \pm 3.5) \times 10^{-4}$
$\Lambda_c^+ \rightarrow p^+ \pi^- \pi^+$	$(3.5 \pm 2.0) \times 10^{-3}$
$\Lambda_c^+ \rightarrow p^+ K^+ \pi^-$ (DCS)	$< 2.3 \times 10^{-4}$ @ 90% CL

Table 1: The  $\Lambda_c^+ \rightarrow p h h$  decay modes and their branching fractions.

## References

- 1) J. Beringer et al. (Particle Data Group), Phys. Rev. D86, 010001 (2012).
- 2) Muriel Pivk, "sPlot: A Quick Introduction", 2006, arXiv:physics/0602023v1 [physics.data-an].
- 3) Chao-Hsi Chang et al. GENXICC2.0: An Upgraded Version of the Generator for Hadronic Production of Double Heavy Baryons  $\Xi_{cc}$ ,  $\Xi_{bc}$  and  $\Xi_{bb}$ , 2009, arXiv:0910.4462v2 [hep-ph].

## $\Lambda_c^+ \rightarrow p h h$ BF Measurement

- ▶ LHCb has gathered the largest ever dataset of  $\Lambda_c^+$  decays, both prompt and from semileptonic  $\Lambda_b^0$  secondary decays.
- ▶ The 2011 dataset is being used for a BF measurement of the  $\Lambda_c^+ \rightarrow p h h$  modes. This incorporates a search for the DCS mode, which is currently blinded.
- ▶ MVA selections for the DCS search are being trained on sweigted [2] Cabibbo Favoured data to maximise sensitivity.
- ▶ Raw data yield for prompt CF decays shown below.

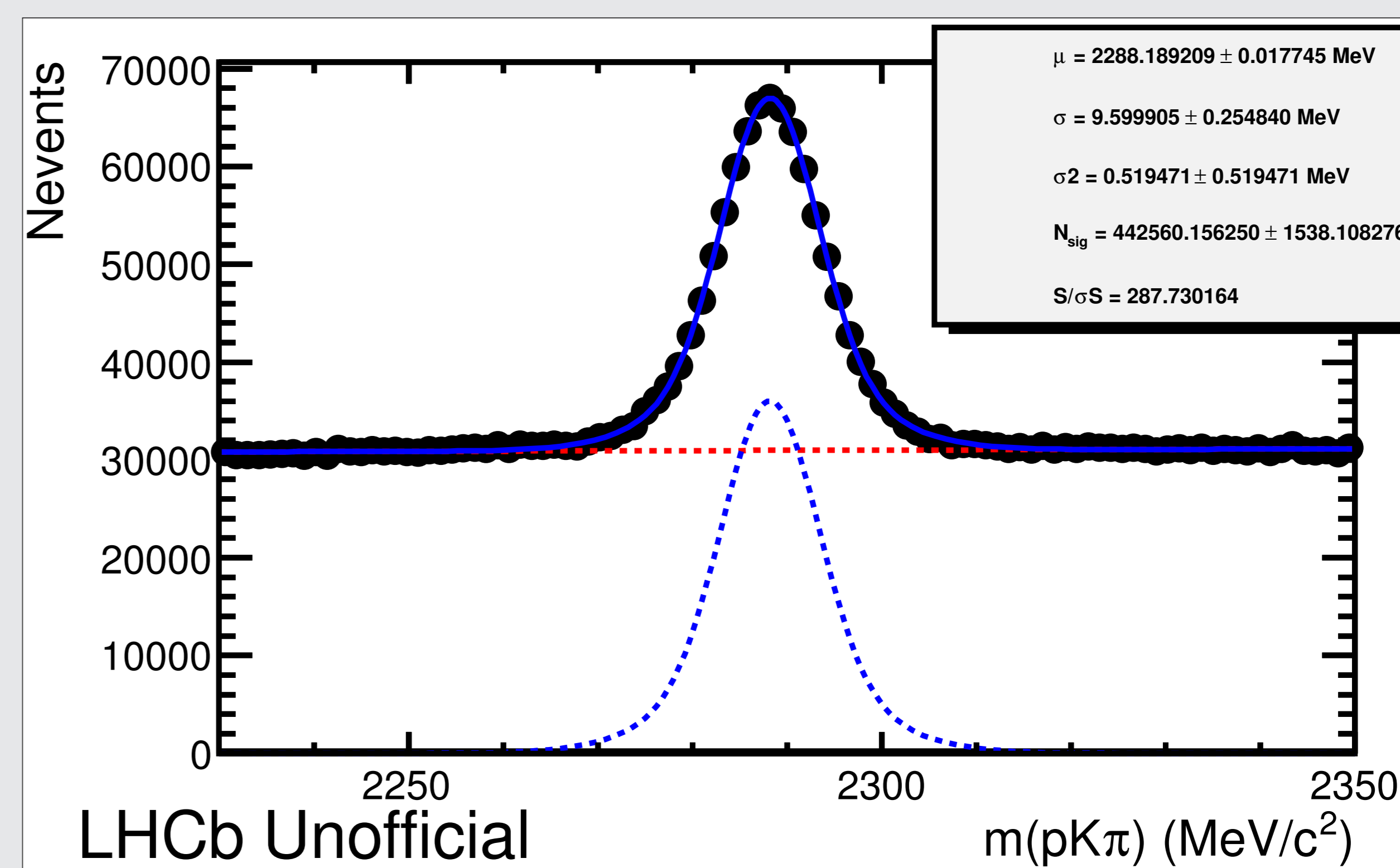


Figure 3: Massfit for the full 2012 CF prompt data.

- ▶ A large fraction of  $\Lambda_c^+ \rightarrow p h h$  decays proceed through intermediate resonances. The structure of these resonances is still very poorly understood.
- ▶ Understanding the decay amplitudes/resonance structure is key to a BF measurement, as effects of the trigger and offline selections may favour certain regions of the decay phase space.
- ▶ Shown below is a 2-dimensional phase space showing the invariant masses of daughter pairs for the CF mode. The  $K^*(892)$  and  $\Lambda(1520)$  resonances can be clearly seen.

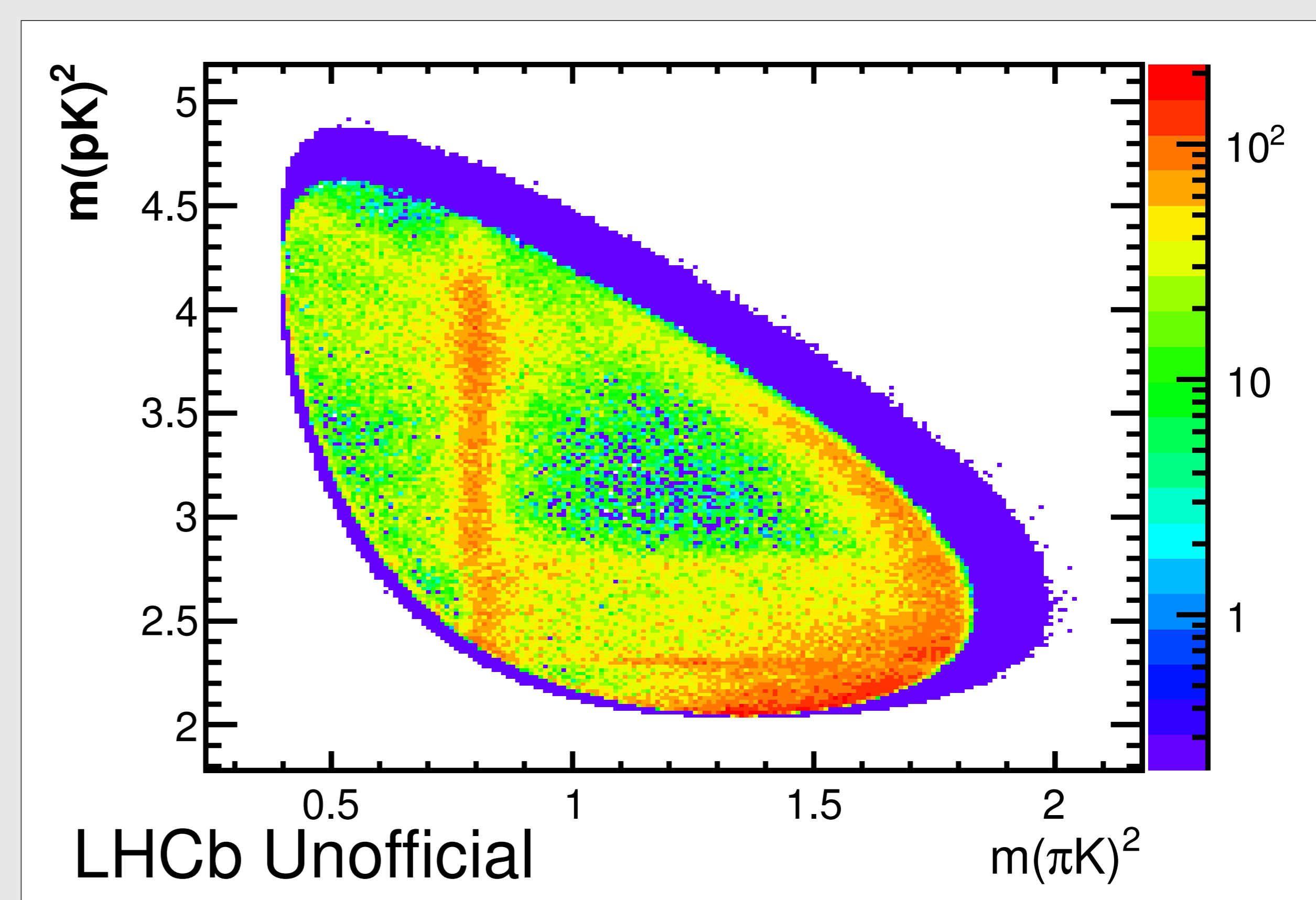


Figure 4: Invariant mass of charge-opposite daughter pairs for the CF mode, log scale. The plot has been sWeighted for sideband subtraction

## Search for the Doubly Charmed Baryon $\Xi_{cc}^+$

- ▶ Searches are underway for the particle through the decay modes:
  - ▶  $\Xi_{cc}^+ \rightarrow \Lambda_c^+ \pi^+ K^-$
  - ▶  $\Xi_{cc}^+ \rightarrow (D^+ \rightarrow K^- \pi^+ \pi^+) p^+ K^-$
  - ▶  $\Xi_{cc}^+ \rightarrow (D^0 \rightarrow K^- \pi^+) p^+ K^- \pi^+$
- ▶ The double-heavy flavour baryon generator genxicc2.0 [3] has been interfaced to LHCb's MC generation to provide MC for studies on these modes.
- ▶ Trigger and stripping lines have been in place for the 2011 run. Data gathering continues in 2012. The channels are currently being kept blind.
- ▶ MVA selection and physics background studies underway.
- ▶ If the baryon can be found its spectroscopy will be key to understanding the internal structure of double heavy baryons. This will offer tests for internal baryon structure modelling beyond Heavy Quark Effective Theory, which approximates single heavy flavour baryon internal structure as one heavy quark interacting with a light quark dipole.

## For Further Information...

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