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$\Lambda_b^0 \to \Lambda_c^+ \overline{\Lambda}_c^- n$: First Neutron Studies With LHCb

Liverpool Annual HEP Meeting

Ned Howarth

Supervisors: Eduardo Rodrigues, David Hutchcroft, Juan Leite, Tara Shears

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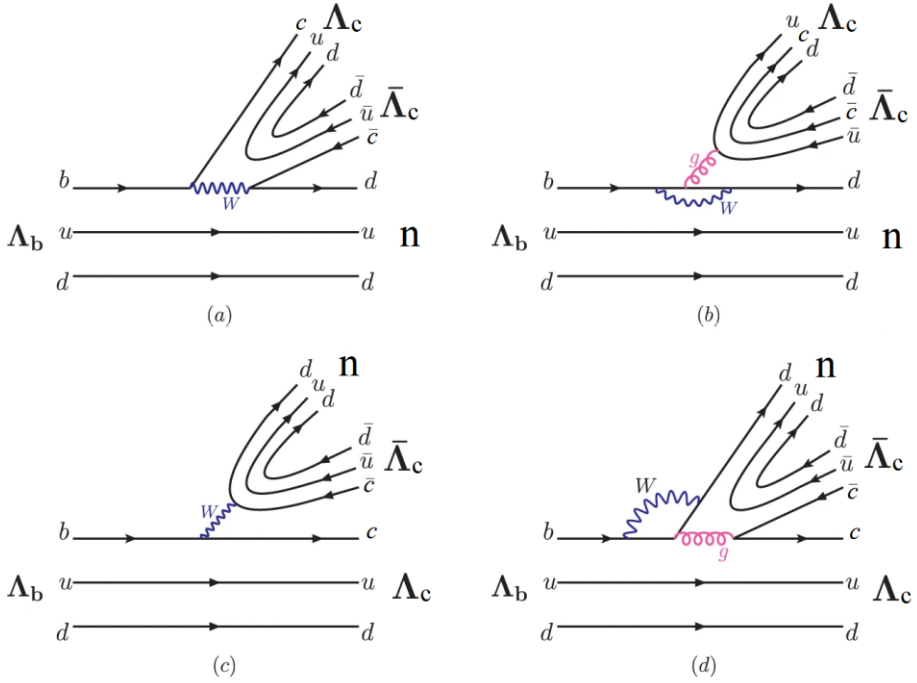
Purely Baryonic Decays and Neutrons

- Purely Baryonic Decays are currently an unstudied and unexplored family of decay modes.
- Some baryonic final sate B decays are known but only one Purely Baryonic Decay has currently been observed.
- We operate under the constraint of baryon number conservation and so a generic purely baryonic decay must have a tri-baryonic final state.

- Why $\Lambda_b^0 \to \Lambda_c^+ \overline{\Lambda}_c^- n$?
  - High predicted branching fraction $\sim 10^{-5}$.
  - Low Q value.
    $m(\Lambda_b^0) - 2m(\Lambda_c) - m(n) \approx 100\text{MeV}$
  - Excellent momentum resolution for Λ_c pair when reconstructed from $\Lambda_c^+ \to p^+ K^- \pi^+$. charged system is well optimised
  - Opportunity to observe decay with neutron in final state for first time at LHC.



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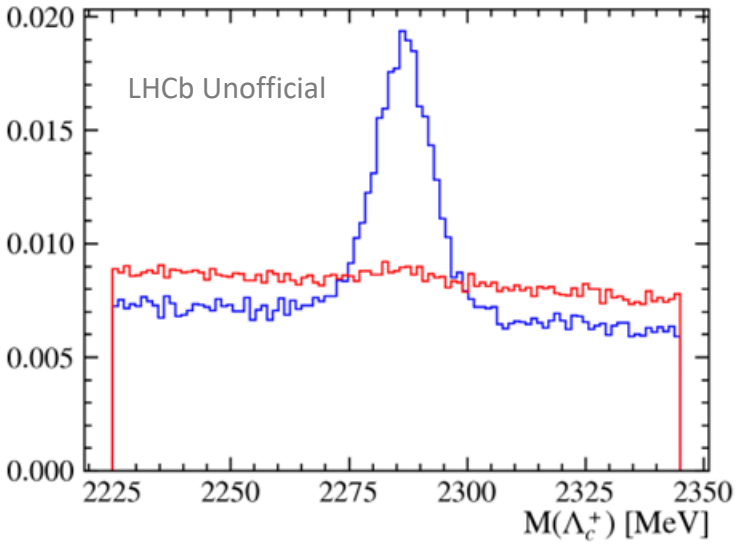
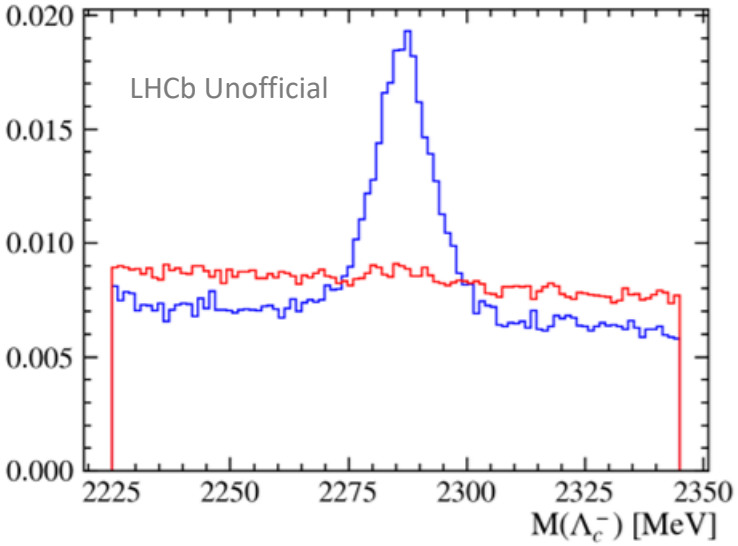
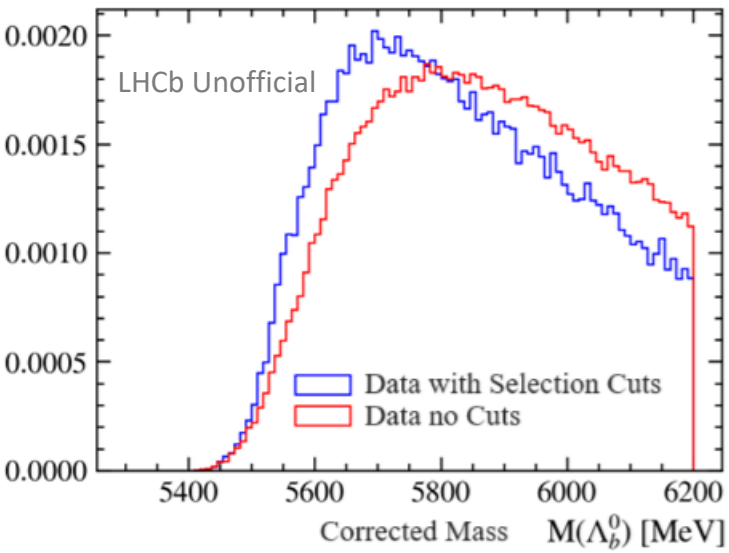
Run 2: Neutrons as Missing Momentum

- My work involves the Analysis of $\Lambda_b^0 \to \Lambda_c^+ \overline{\Lambda}_c^- n$ using the 2016-2018 dataset.
- Normalise Signal channel against $B^+ \to \Lambda_c^+ \, \overline{\Lambda}_c^- \, K^+$. A recently studied decay at LHCb.
- This is an unblinded analysis.
- Our selection and reconstruction algorithms were applied to data in a process starting from the end of last year and ending in Feb 2024.
- A mass correction is applied to account for the missing neutron using momentum transverse to B mother flight.
- $M_{CORR} = \sqrt{{P_{vis}^T}^2 + m_{vis}^2} + \sqrt{{P_{vis}^T}^2 + m_{invis}^2}$







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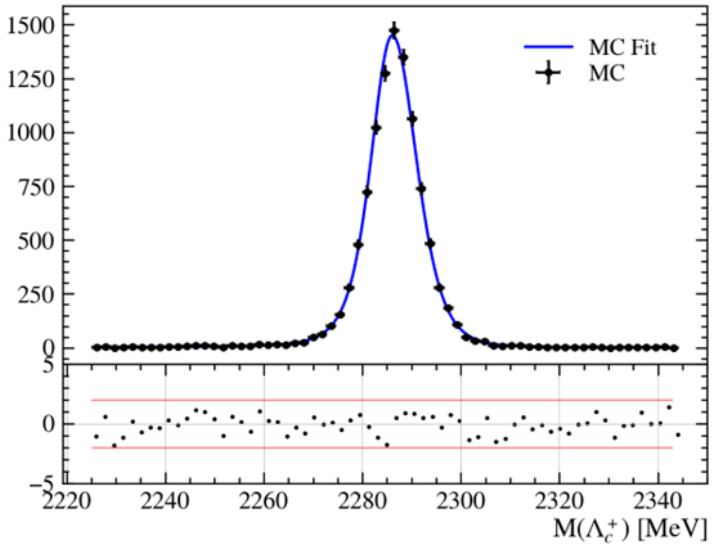
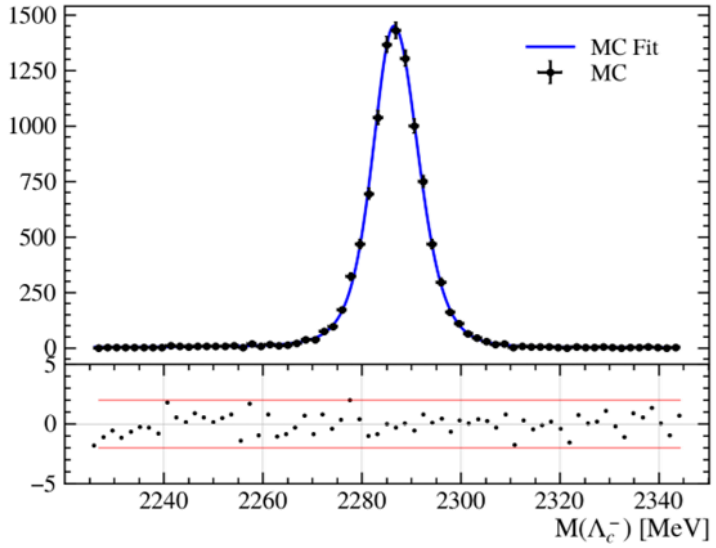
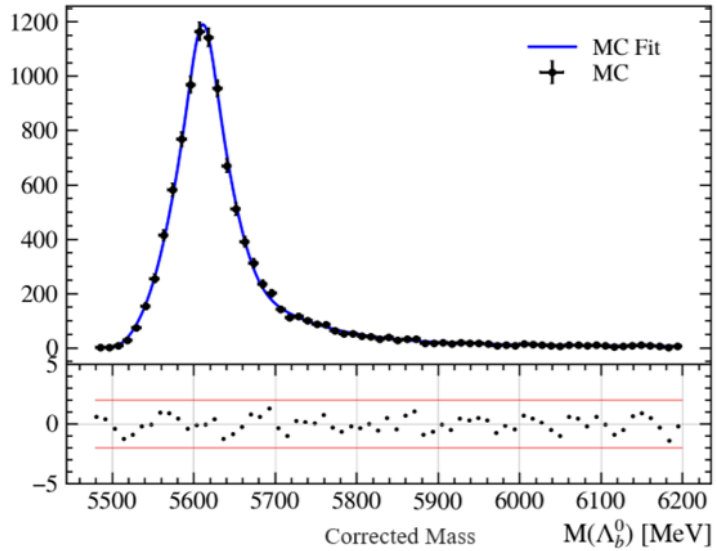
LHCb

Signal Fit

- Signal Fit is 3 dimensional Unbinned NLL fit to the two Λ_c^+ & $\overline{\Lambda}_c^-$ masses and the Corrected Λ_b^0 mass.
- Both Λ_c are fitted with a Cruijff distribution with shared parameters.
- The Λ_b^0 Corrected Mass fitted with a Cruijff distribution and 2 additional Gaussians.
- Total 13 Floating Fit Parameters.
- Λ_c mass peak is fixed but Λ_b^0 mass peak parameter is left floating.







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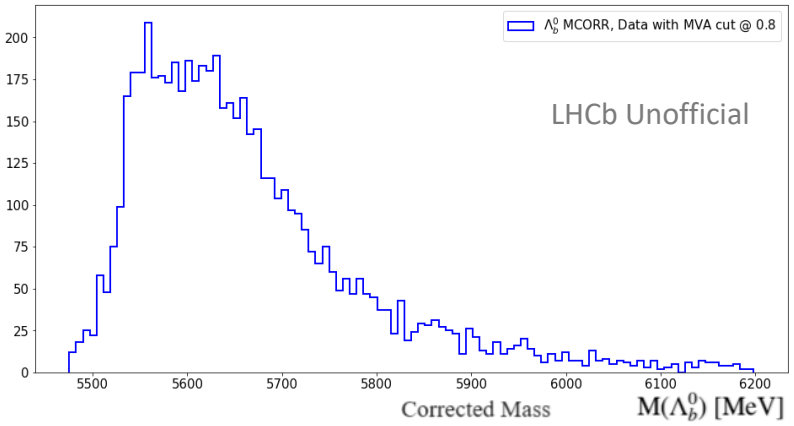
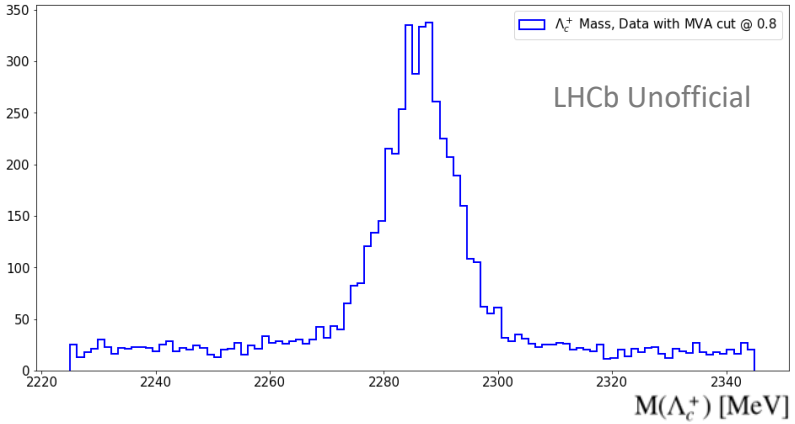
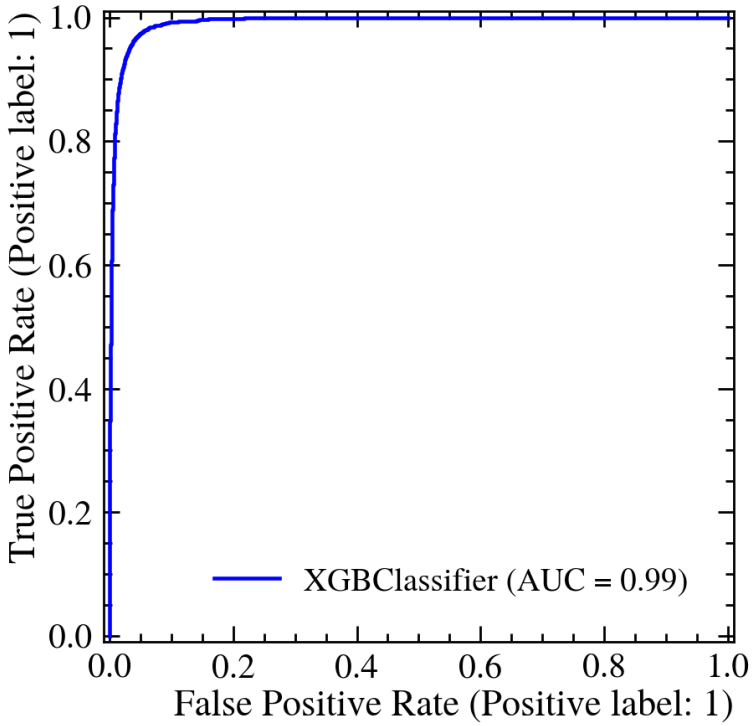
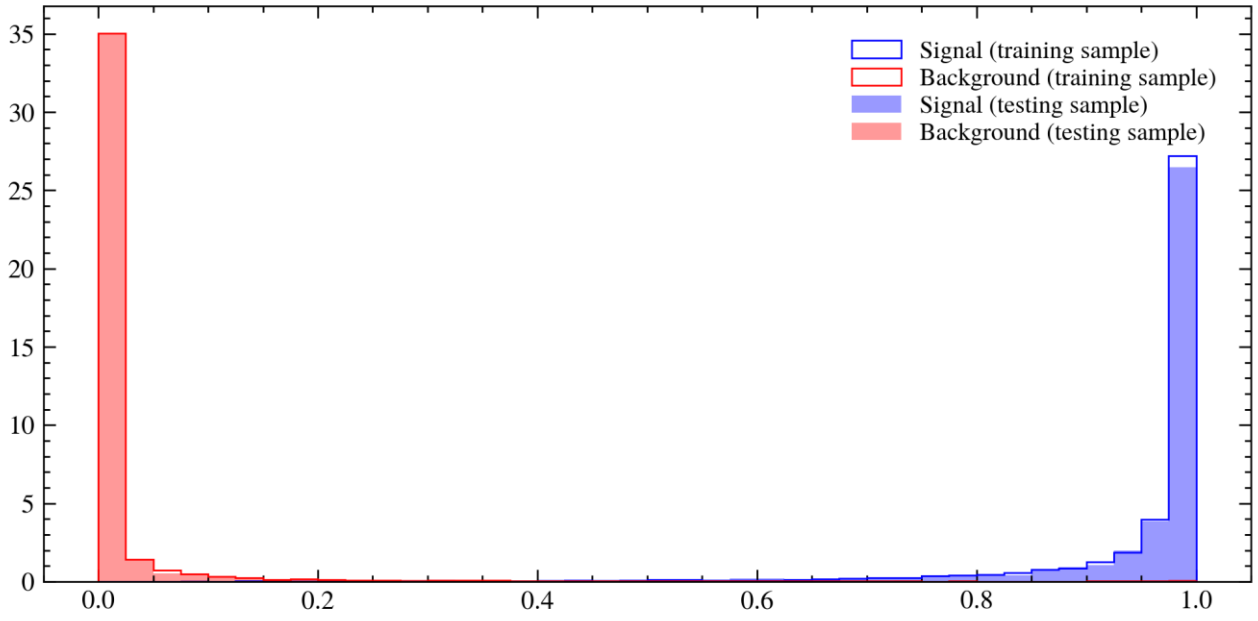
MVA: Combinatorial

- To help veto a large amount of Combinatorial Background we are using a multi-variate analysis.
- MVA model used is XGBoost.
- Truth Data is Signal MC.
- Background is data appearing in sidebands of both Λ_c^+ & $\overline{\Lambda}_c^-$ and the Λ_b^0 Mass.
- Trained Model shows good separation and cleans up both Λ_c^+ & $\overline{\Lambda}_c^-$ spectrums very nicely.









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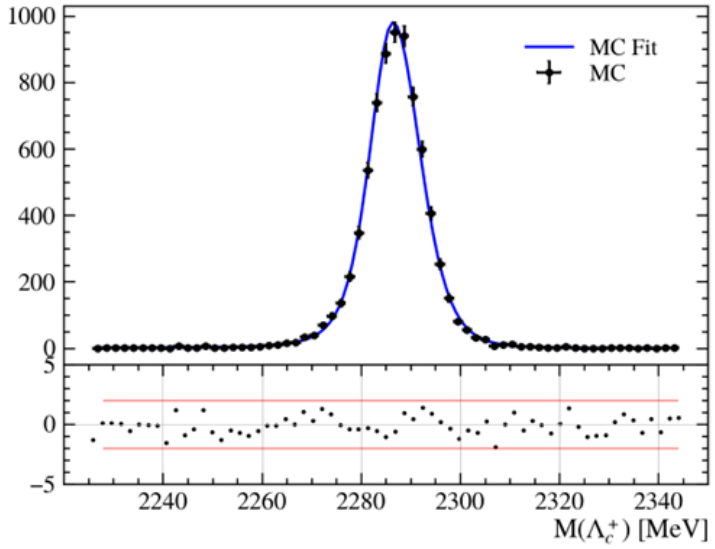
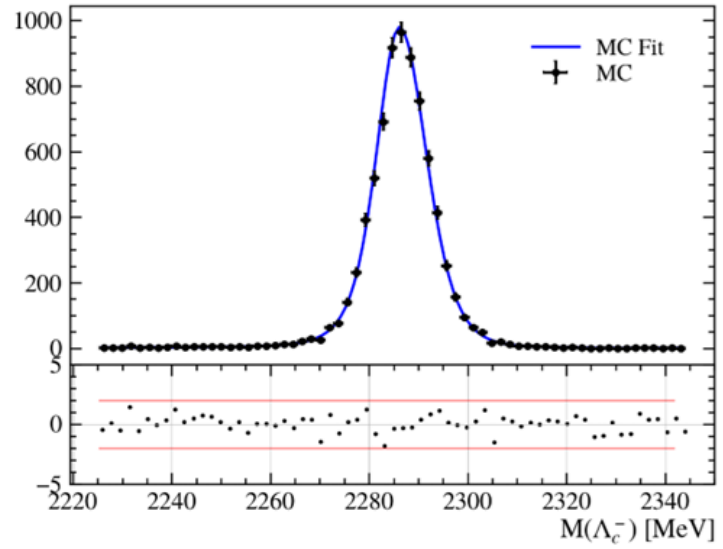
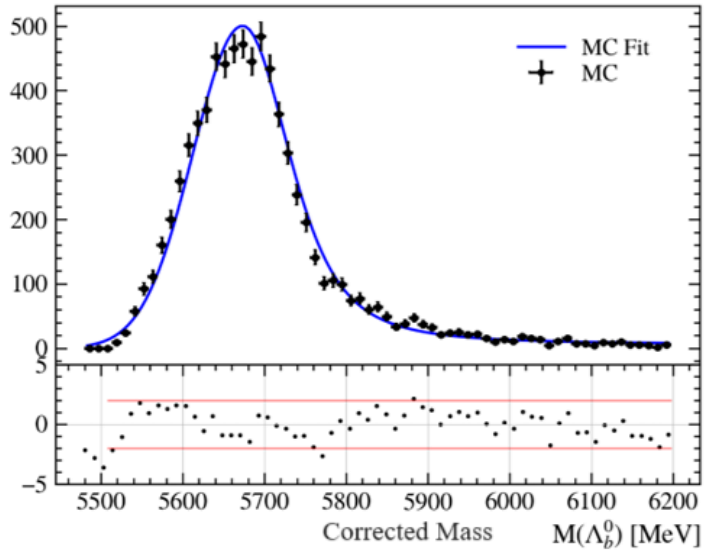
LHCb

Remaining Background

- Whilst The two Λ_c^+ & $\overline{\Lambda}_c^-$ masses are reasonably clean the Λ_b^0 corrected mass spectrum contains additional background that must be understood.
- There remains 2 Categories of backgrounds that need to be accounted for
  1. Remaining Combinatorial: Events that are flat in either of the Λ_c^+ / $\overline{\Lambda}_c^-$. A Subdominant background that can be fit with MC samples or using sideband projections.
  2. Physics Decays: Decays that are peaking in both Λ_c^+ & $\overline{\Lambda}_c^-$ mass spectrums.
- These Physics Backgrounds must be simulated and then fit for templates.
- Two Such backgrounds are $B^+ \to \Lambda_c^+ \overline{\Lambda}_c^- K^+$ and $B^0 \to \Lambda_c^+ \overline{\Lambda}_c^- K_s^0$ which can be fit together (Plot Bellow):

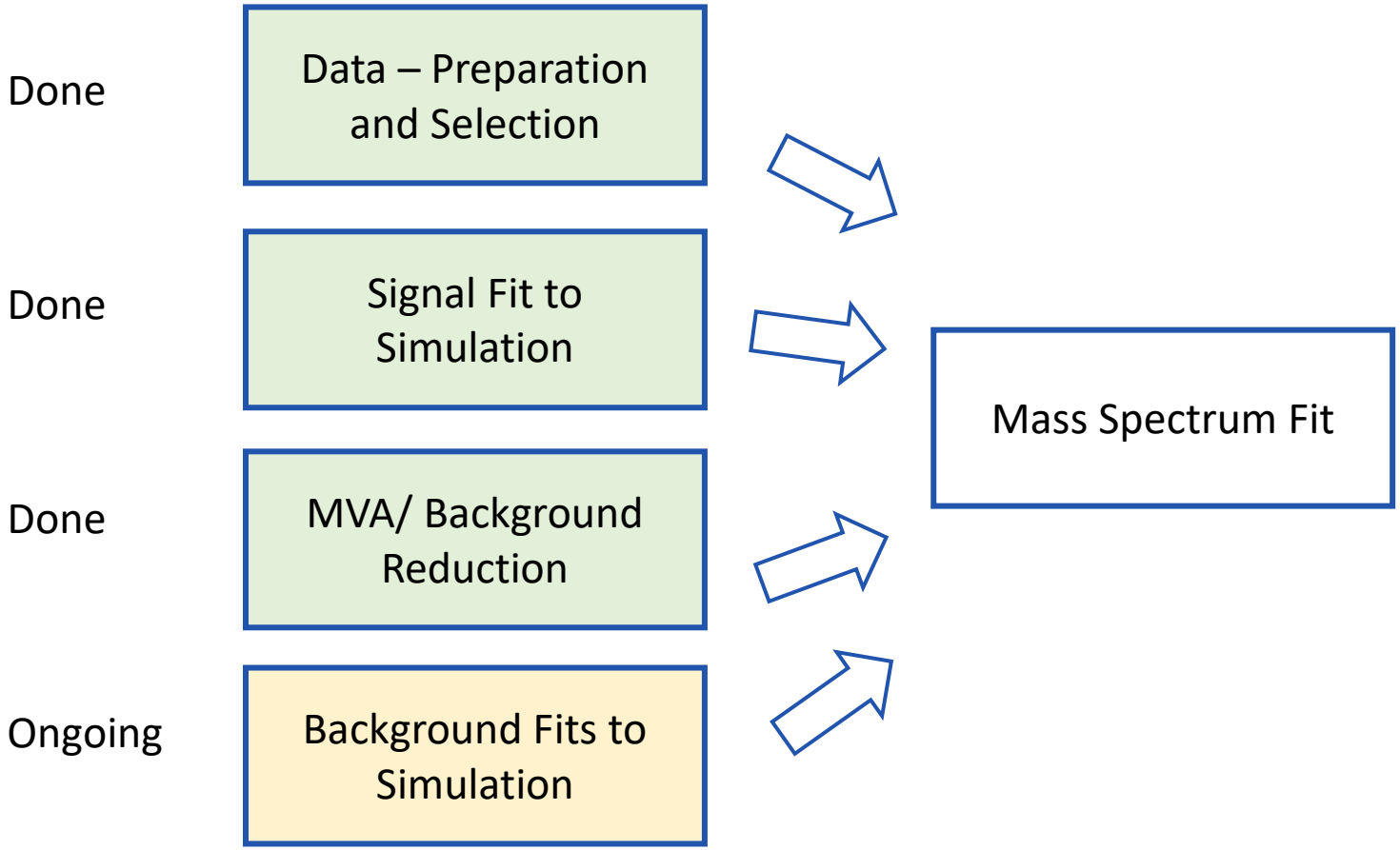






Analysis Strategy Status

- End goal for branching Fraction Measurements involves extracting a signal yield from an overall mass fit.



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Summary

- This analysis stands to be the first observation of a decay mode with neutrons at LHCb (and the LHC).
- It is also the first comprehensive study of a purely baryonic decay mode.
- My work is the analysis of the run 2 dataset (2016 -2018).
- We have selection, Signal Fits and a combinatorial MVA XGBoost applied to data.
- Yet to come - finalising background templates.
- Any Questions?