

# Supplementary material for LHCb-PAPER-2023-018

This appendix contains supplementary material that will be posted on the public CDS record but will not appear in the paper.

## Signal region mass spectra

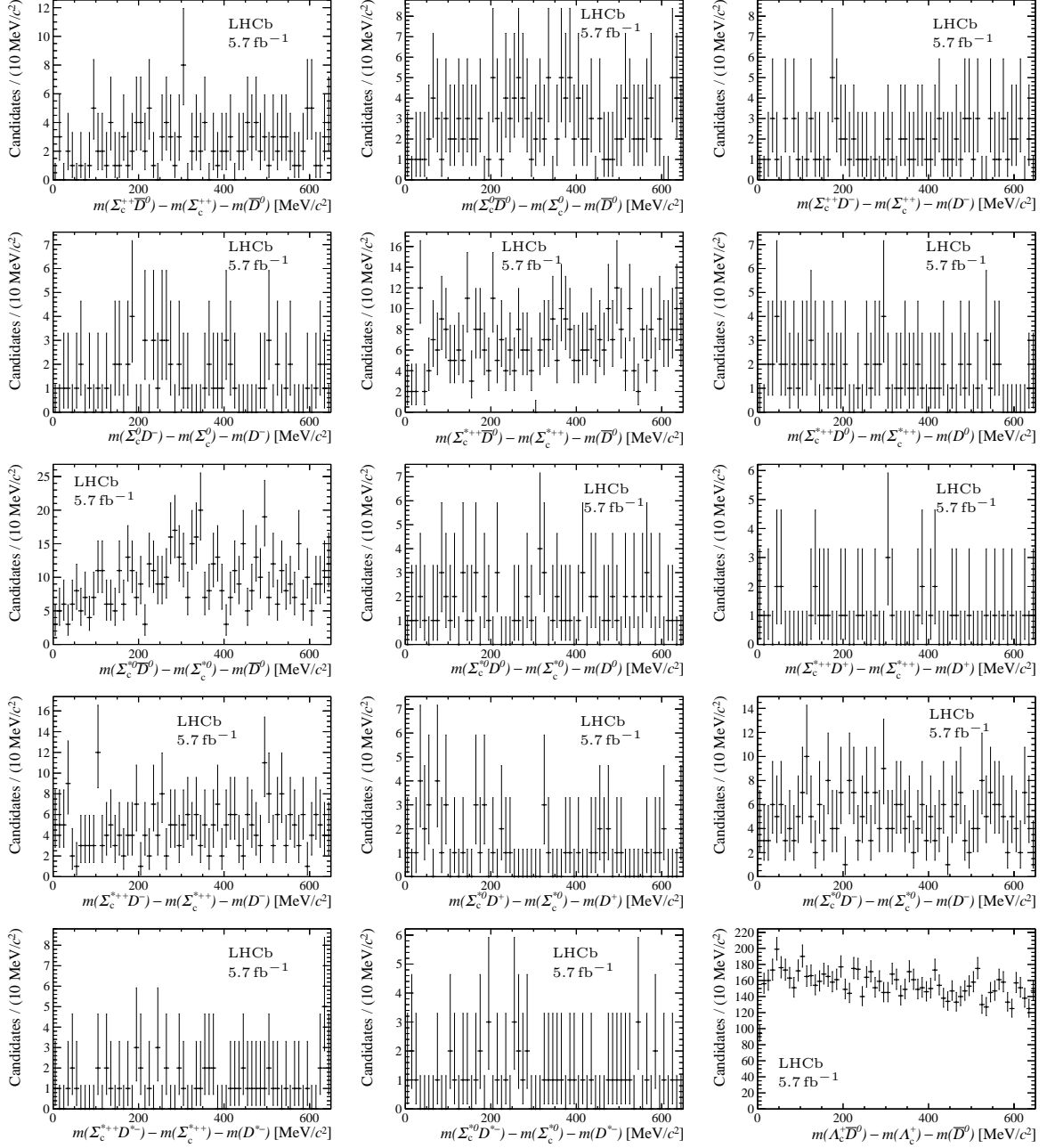


Figure 1: Distributions of  $Q$ -value for each signal region is shown from threshold to  $650 \text{ MeV}/c^2$  for each signal mode.

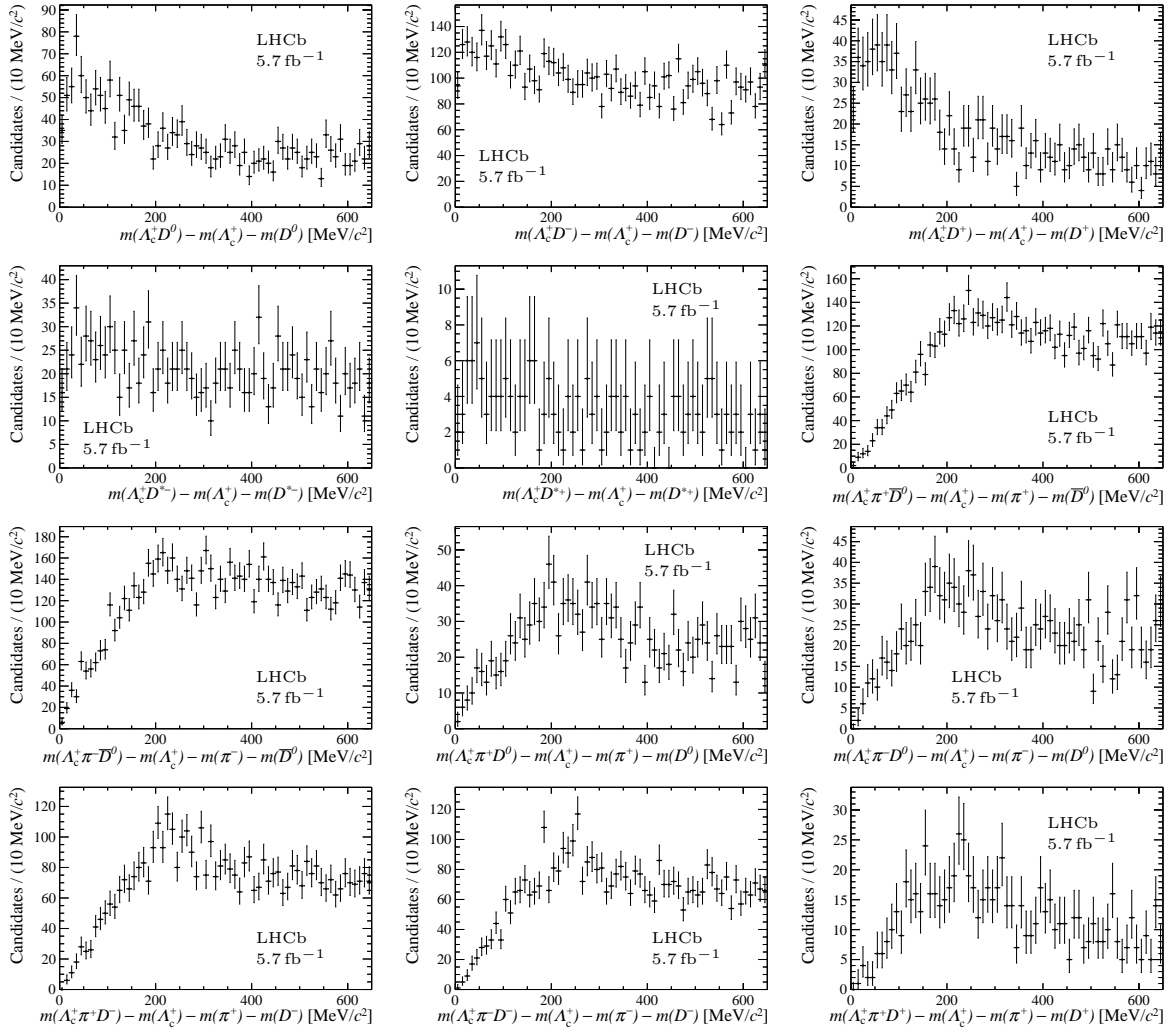


Figure 1 (cont.): Distributions of  $Q$ -value for each signal region is shown from threshold to  $650 \text{ MeV}/c^2$  for each signal mode.

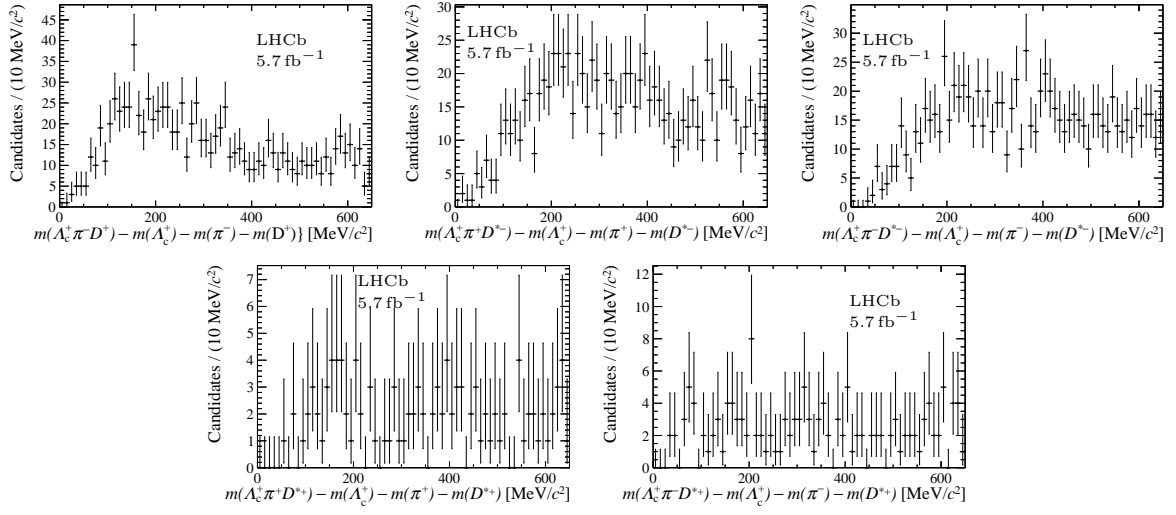


Figure 1 (cont.): Distributions of  $Q$ -value for each signal region is shown from threshold to  $650 \text{ MeV}/c^2$  for each signal mode.

## Results of $p$ -value plots from Gaussian scans

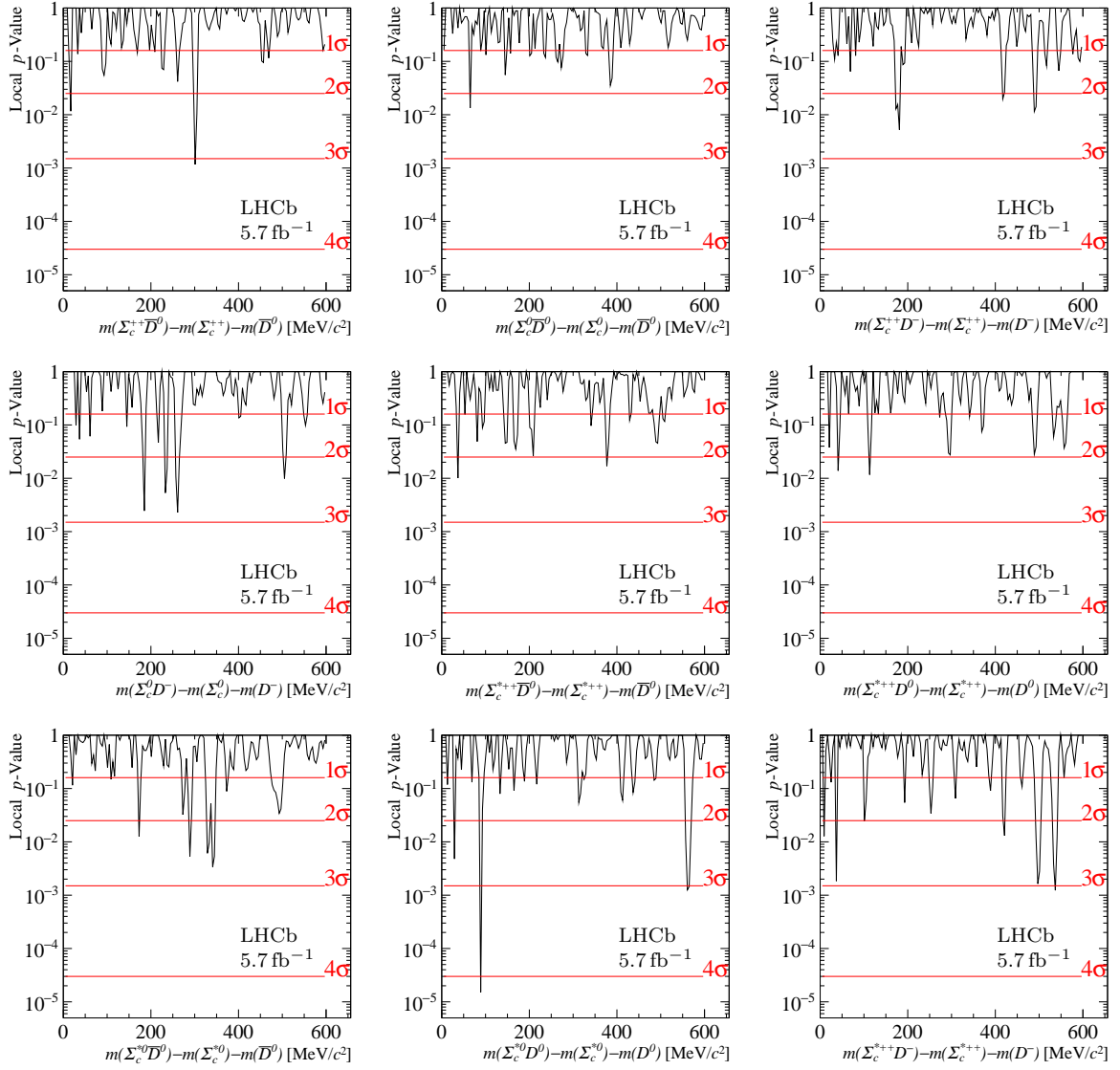


Figure 2: Scan of  $p$ -value across the  $Q$ -value for all modes where the signal model uses a Gaussian function.

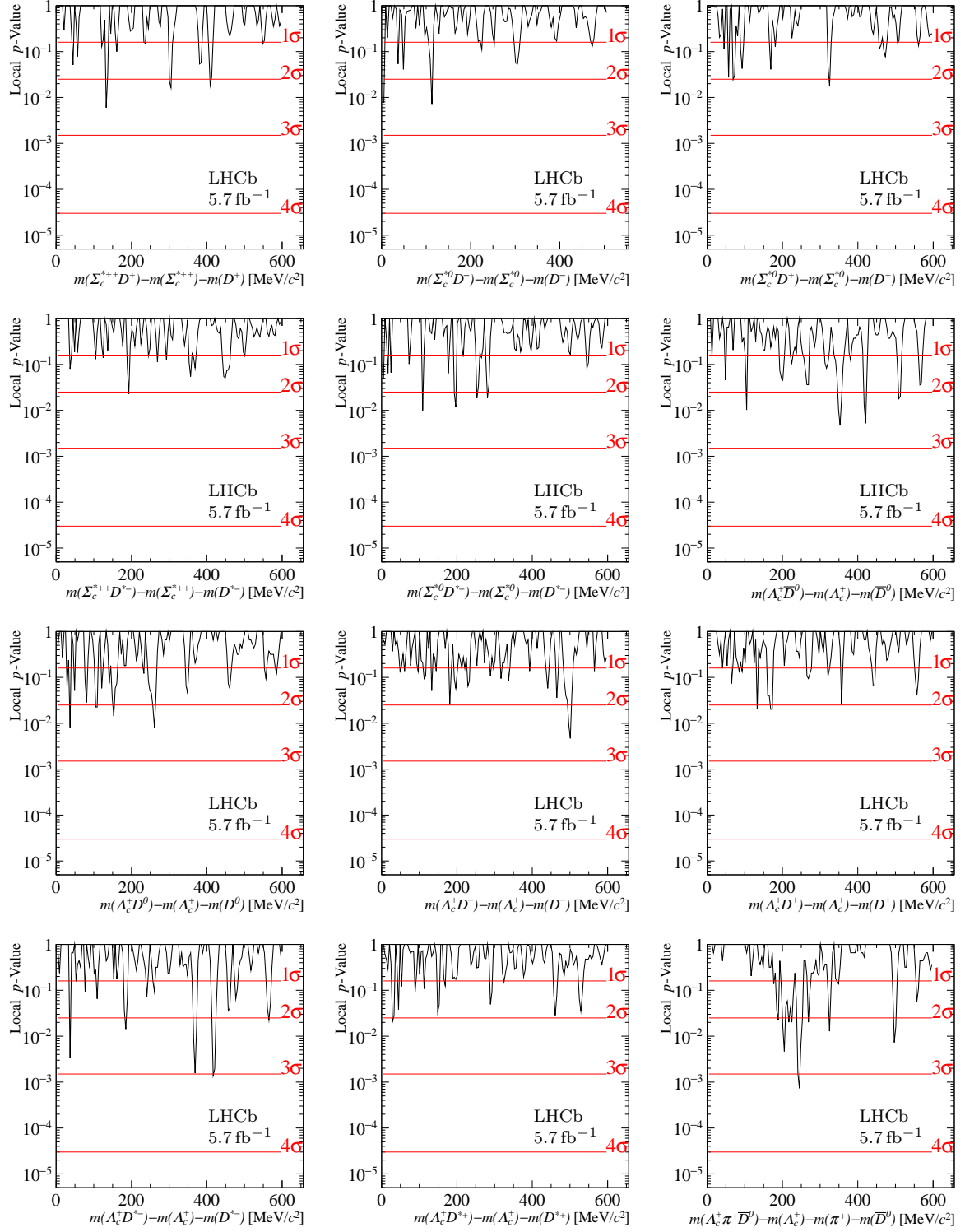


Figure 2 (cont.): Scan of  $p$ -value across the  $Q$ -value for all modes where the signal model uses a Gaussian function.

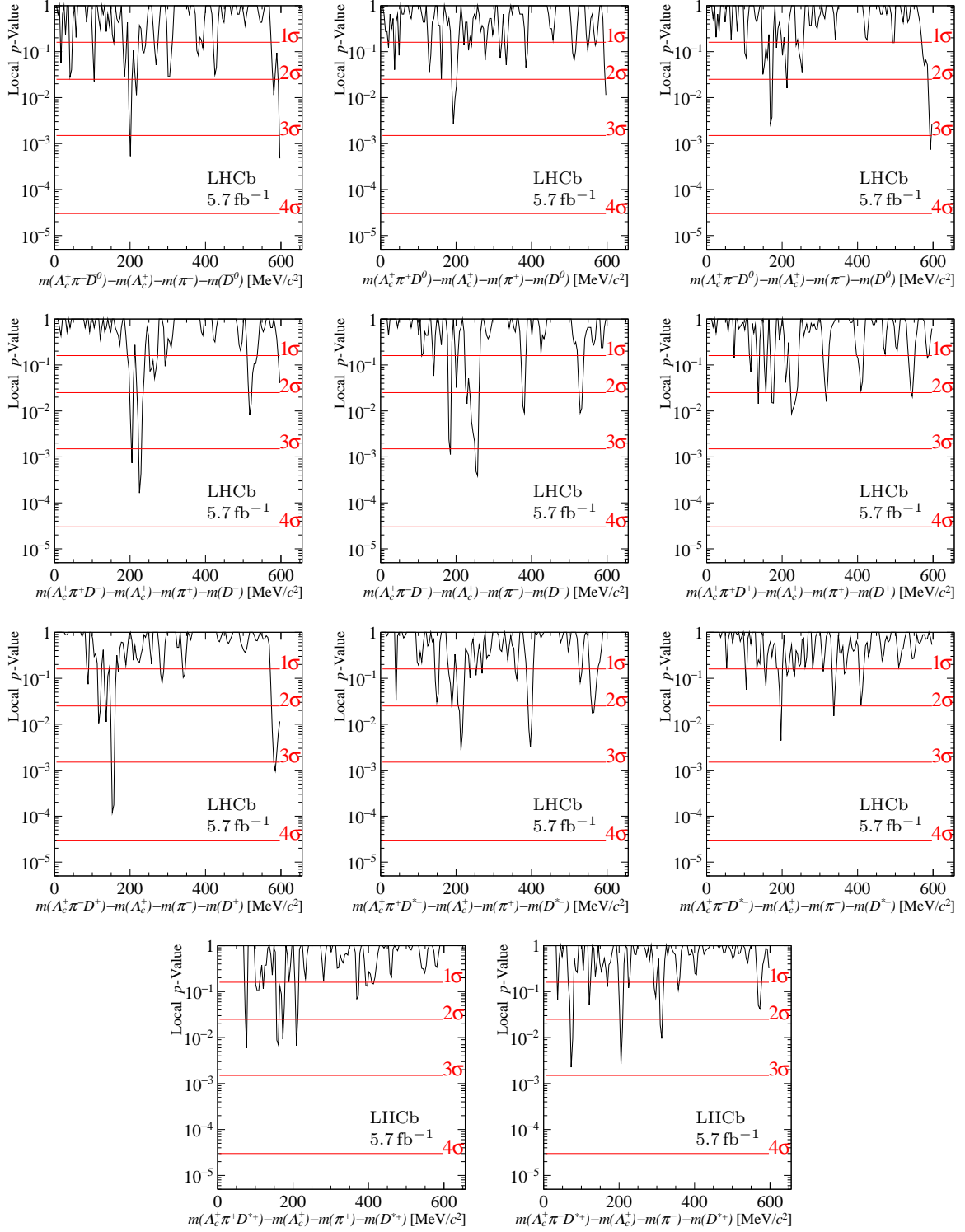


Figure 2 (cont.): Scan of  $p$ -value across the  $Q$ -value for all modes where the signal model uses a Gaussian function.

# Results of $p$ -value plots from Voigtian scans with width set to $5 \text{ MeV}/c^2$

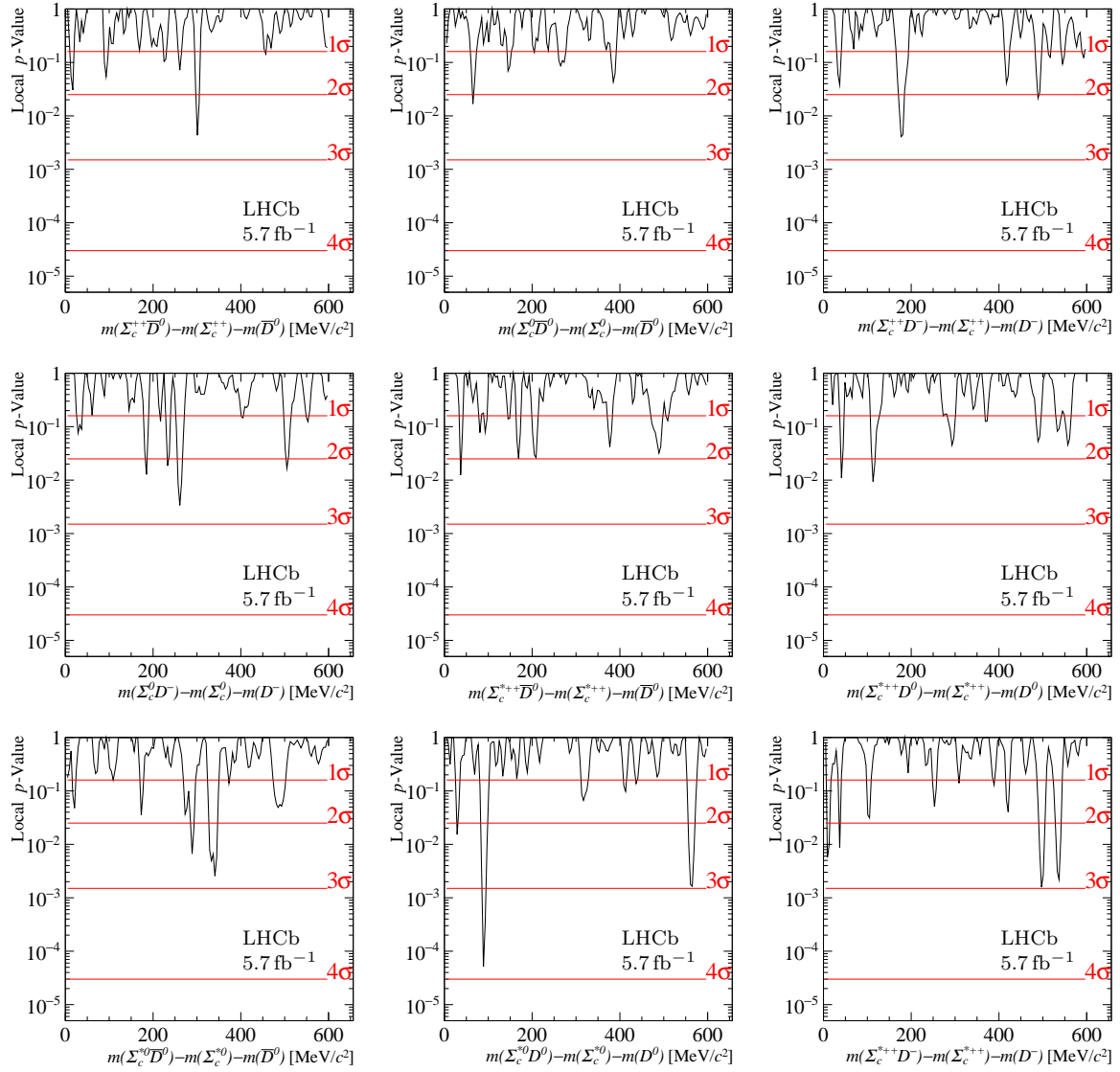


Figure 3: Scan of  $p$ -value across the  $Q$ -value for all modes where the signal model uses a Voigtian function with the width set to  $5 \text{ MeV}/c^2$ .

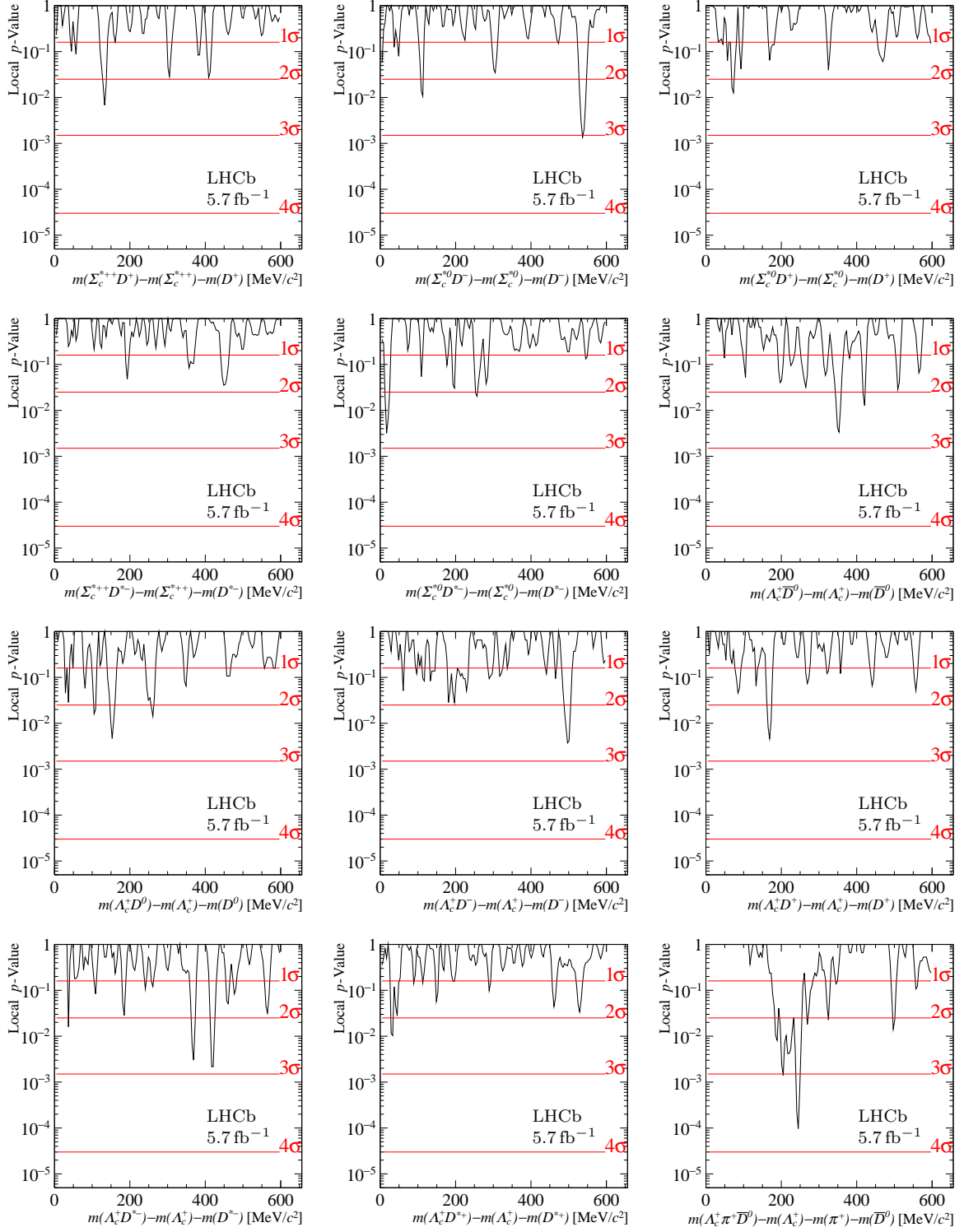


Figure 3 (cont.): Scan of  $p$ -value across the  $Q$ -value for all modes where the signal model uses a Voigtian function with the width set to  $5 \text{ MeV}/c^2$ .



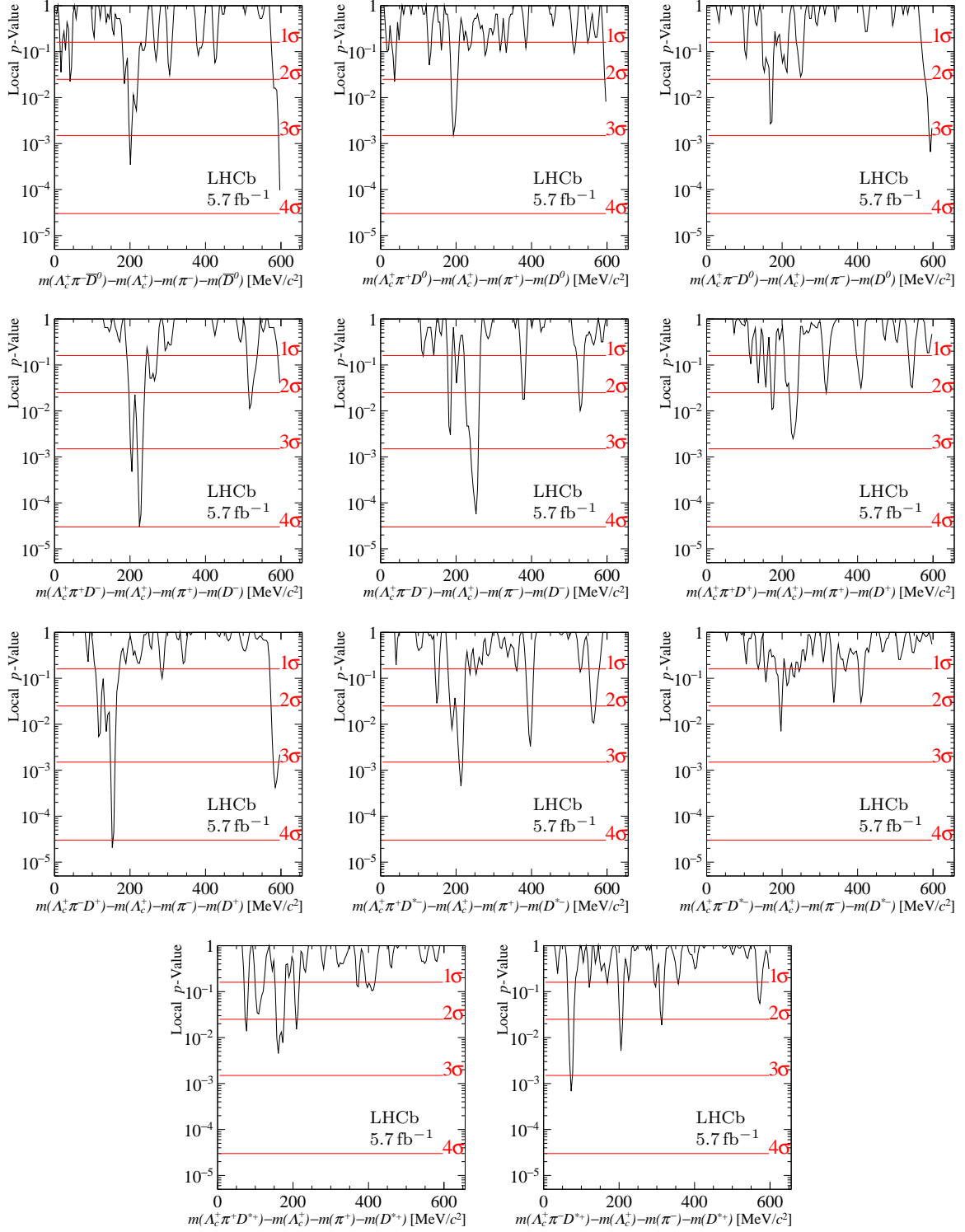


Figure 3 (cont.): Scan of  $p$ -value across the  $Q$ -value for all modes where the signal model uses a Voigtian function with the width set to  $5 \text{ MeV}/c^2$ .

# Results of $p$ -value plots from Voigtian scans with width set to $10 \text{ MeV}/c^2$

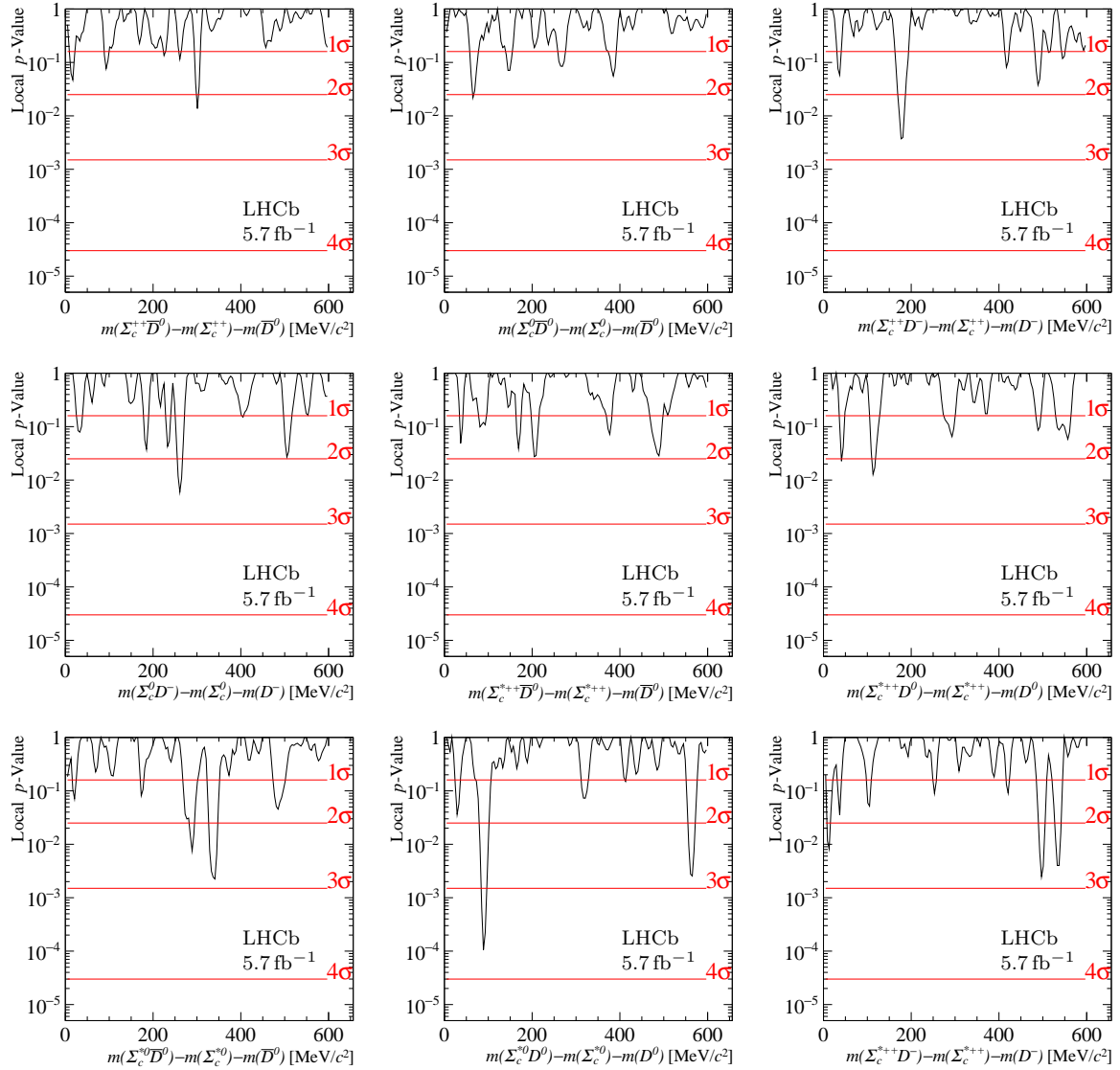


Figure 4: Scan of  $p$ -value across the  $Q$ -value for all modes where the signal model uses a Voigtian function with the width set to  $10 \text{ MeV}/c^2$ .

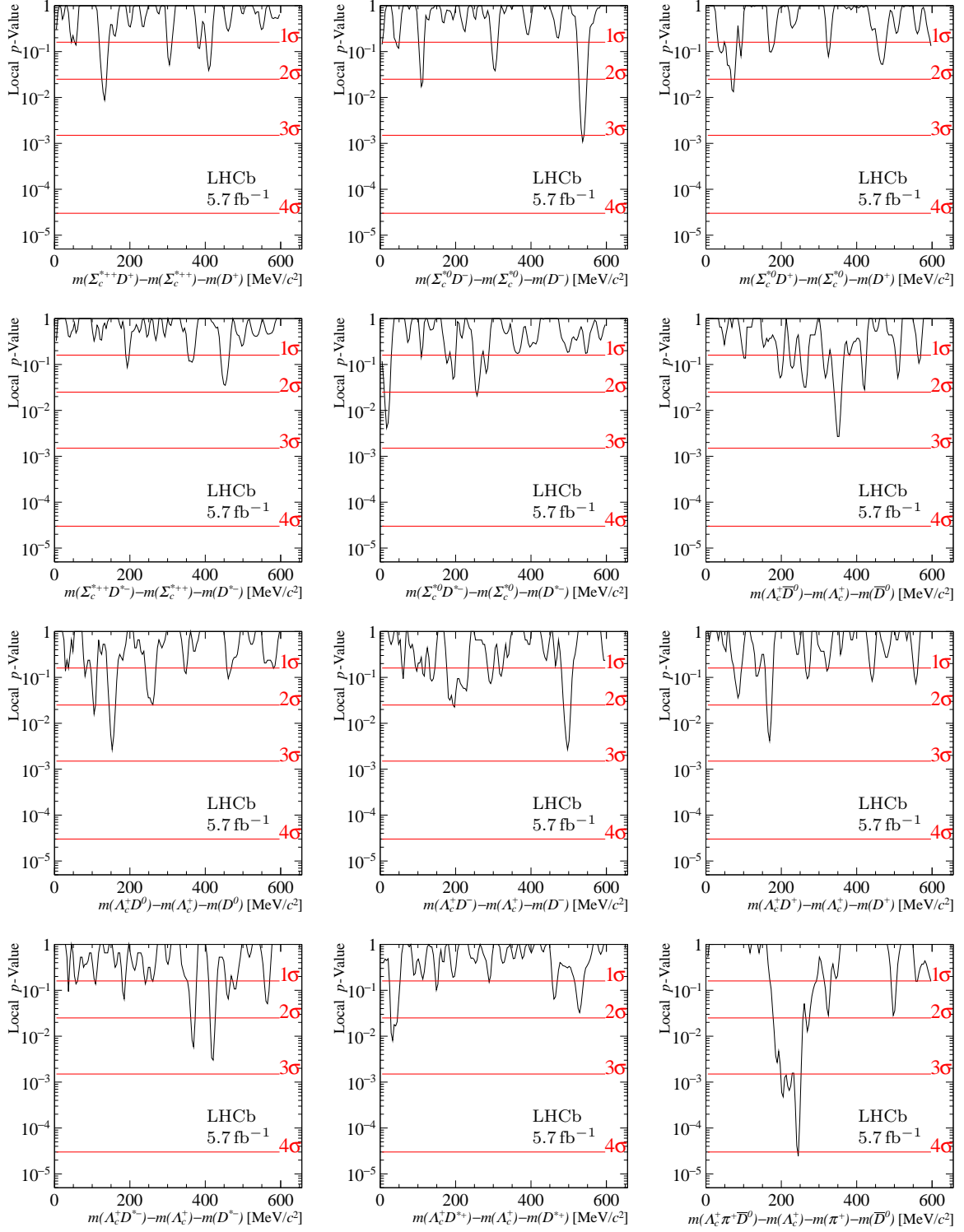


Figure 4 (cont.): Scan of  $p$ -value across the  $Q$ -value for all modes where the signal model uses a Voigtian function with the width set to  $10 \text{ MeV}/c^2$ .

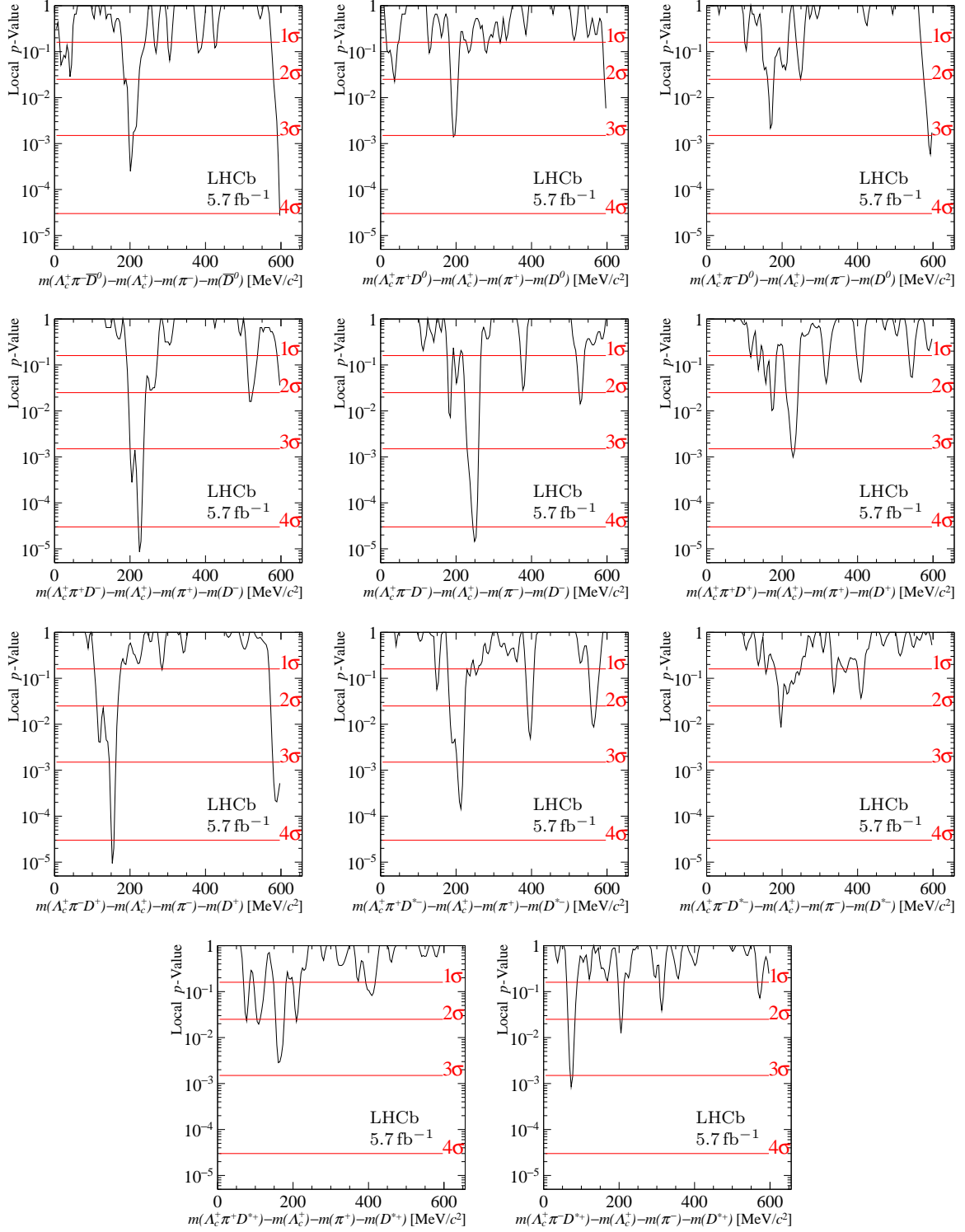


Figure 4 (cont.): Scan of  $p$ -value across the  $Q$ -value for all modes where the signal model uses a Voigtian function with the width set to  $10 \text{ MeV}/c^2$ .

# Results of $p$ -value plots from Voigtian scans with width set to $15 \text{ MeV}/c^2$

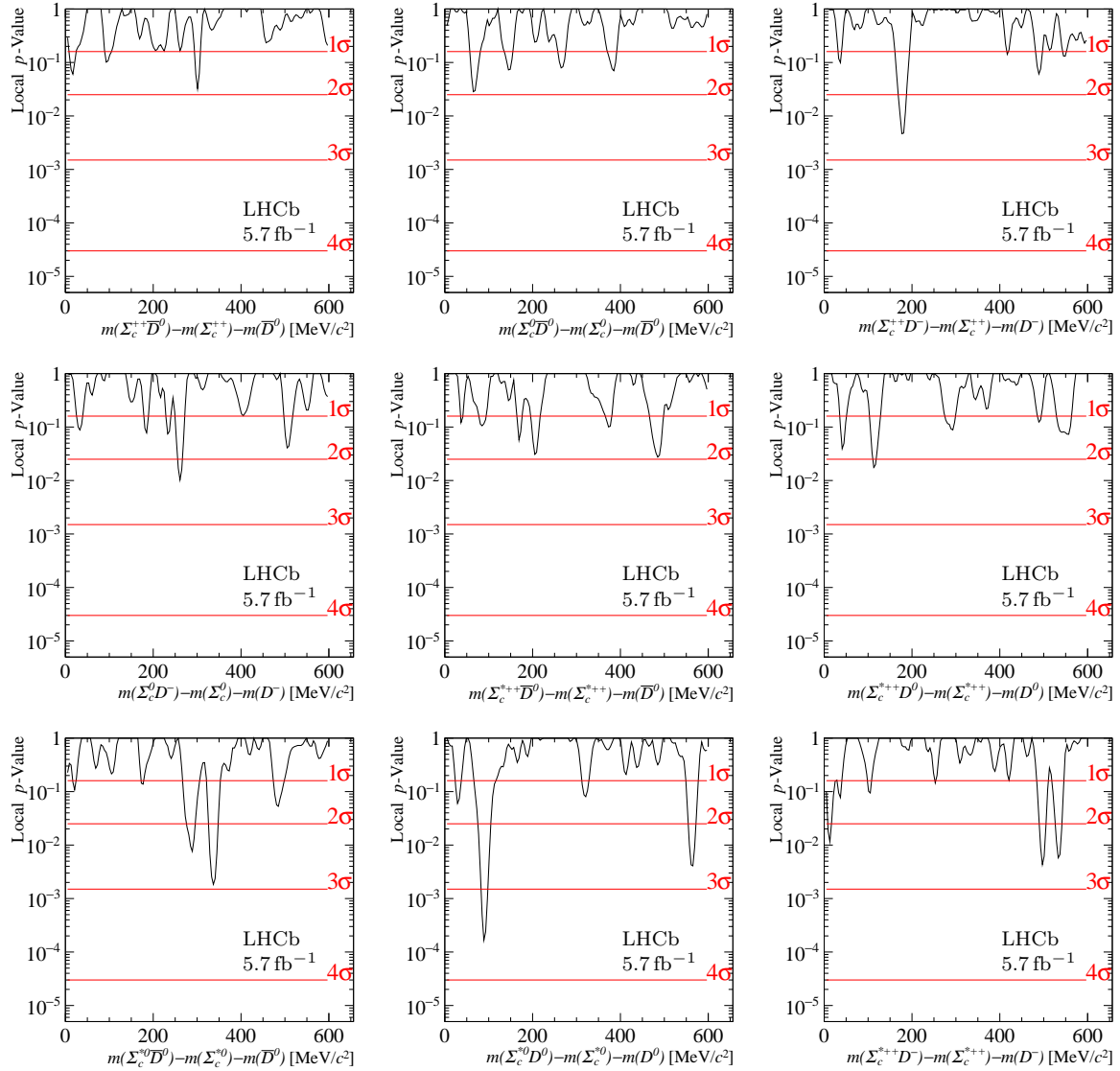


Figure 5: Scan of  $p$ -value across the  $Q$ -value for all modes where the signal model uses a Voigtian function with the width set to  $15 \text{ MeV}/c^2$ .

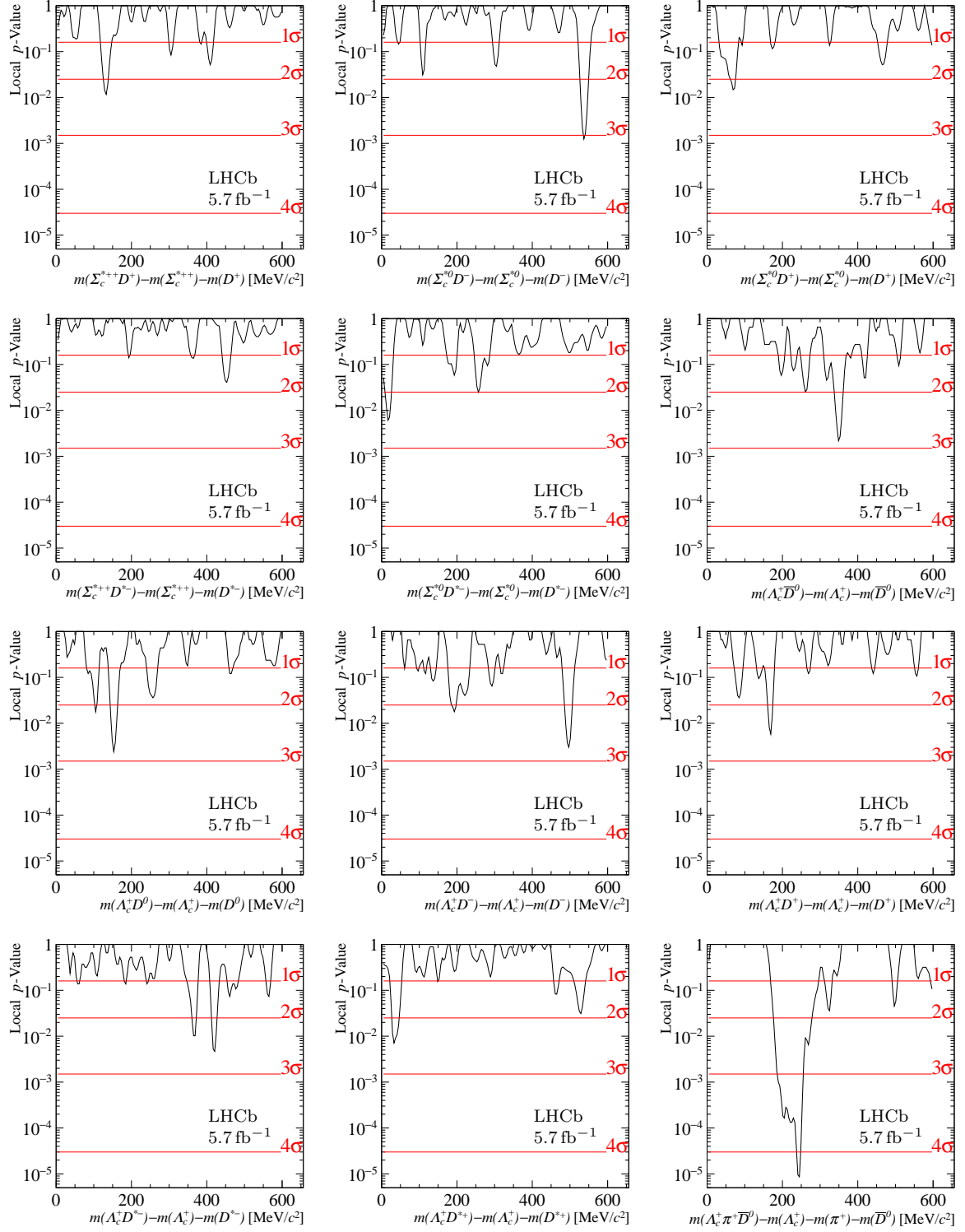


Figure 5 (cont.): Scan of  $p$ -value across the  $Q$ -value for all modes where the signal model uses a Voigtian function with the width set to  $15 \text{ MeV}/c^2$ .

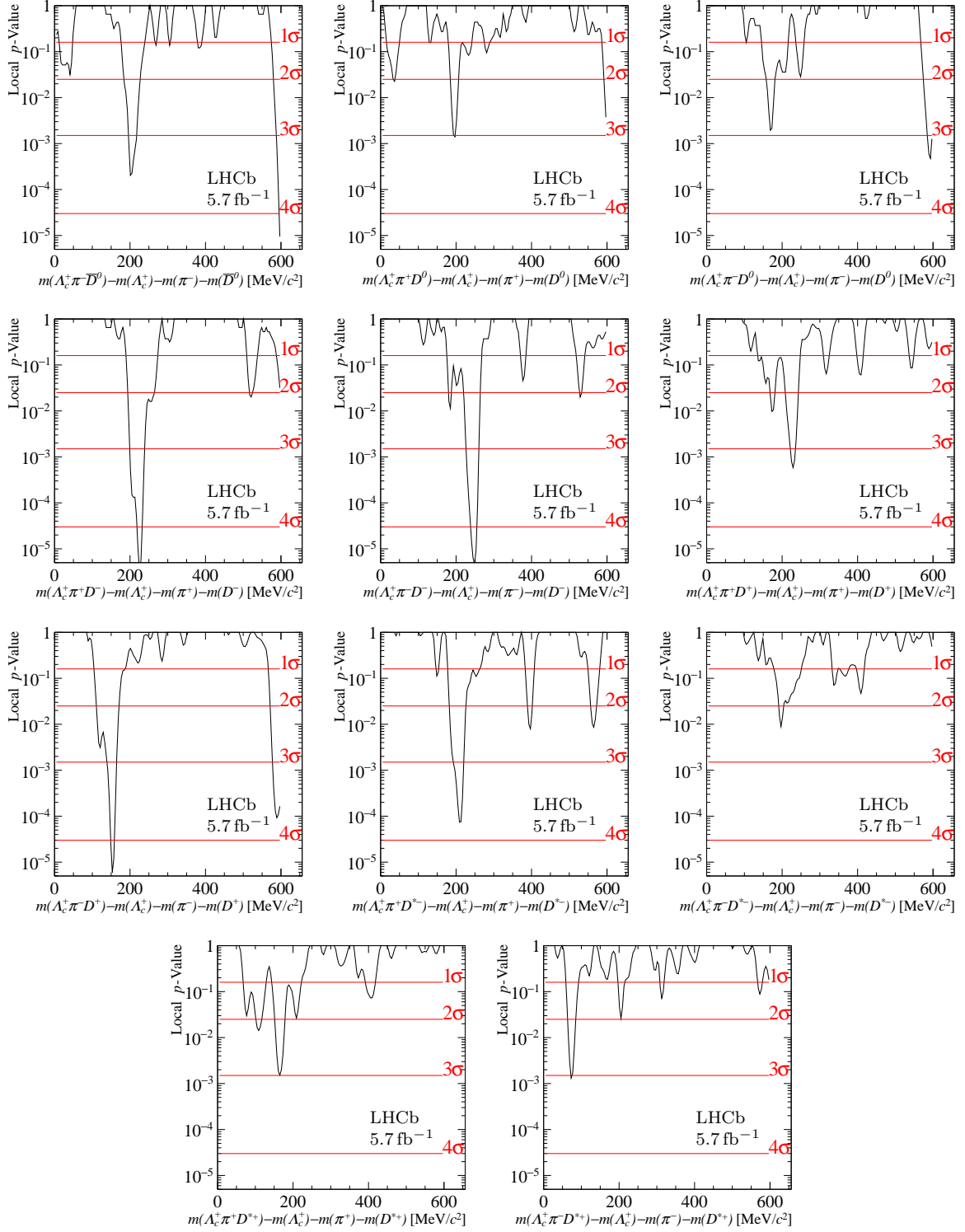


Figure 5 (cont.): Scan of  $p$ -value across the  $Q$ -value for all modes where the signal model uses a Voigtian function with the width set to  $15 \text{ MeV}/c^2$ .

## UL plots from Gaussian scans

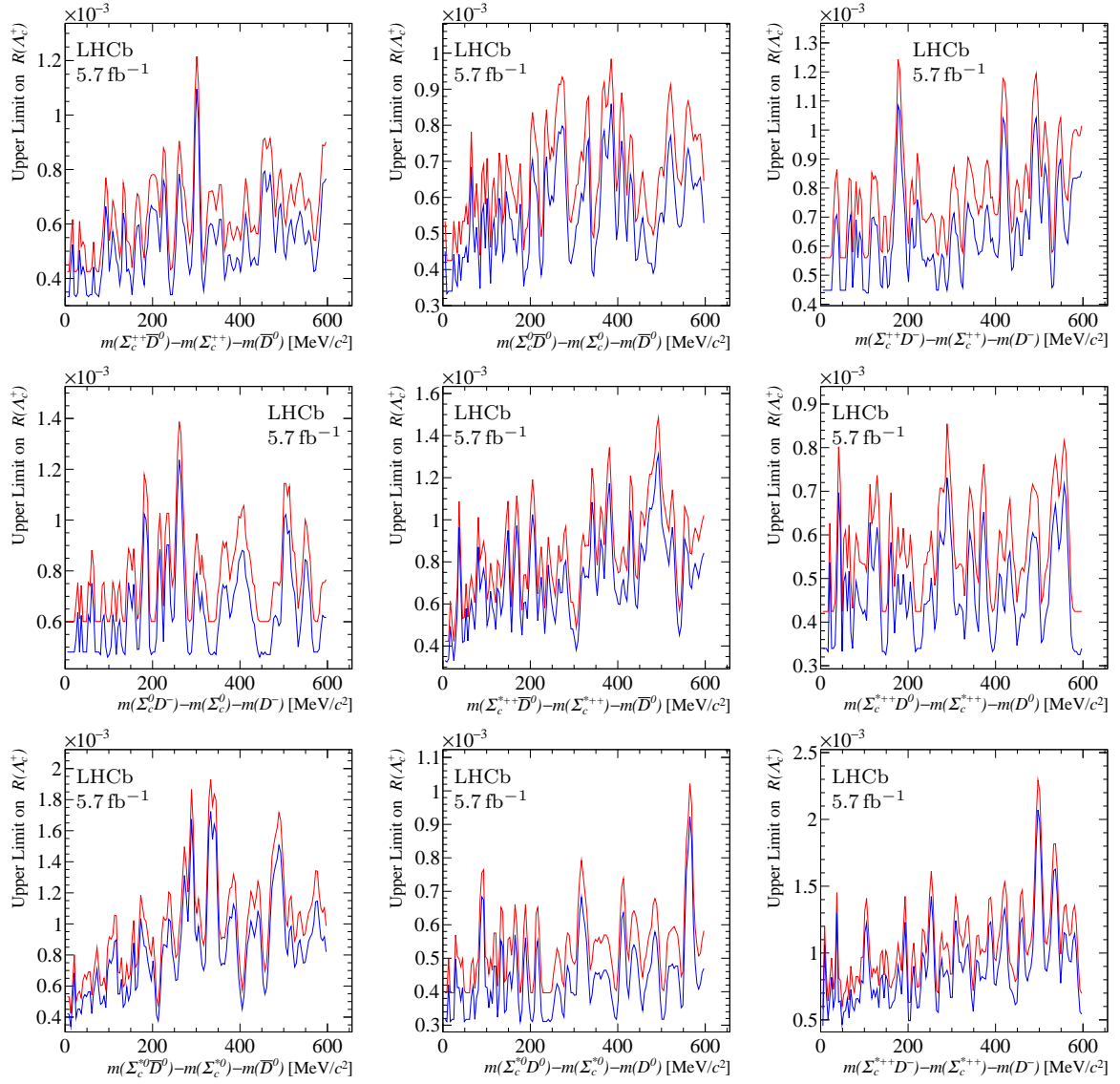


Figure 6: UL scans across the  $Q$ -value for all modes where the UL at 90% and 95% CL are shown in blue and red respectively, and the signal model uses a Gaussian function.



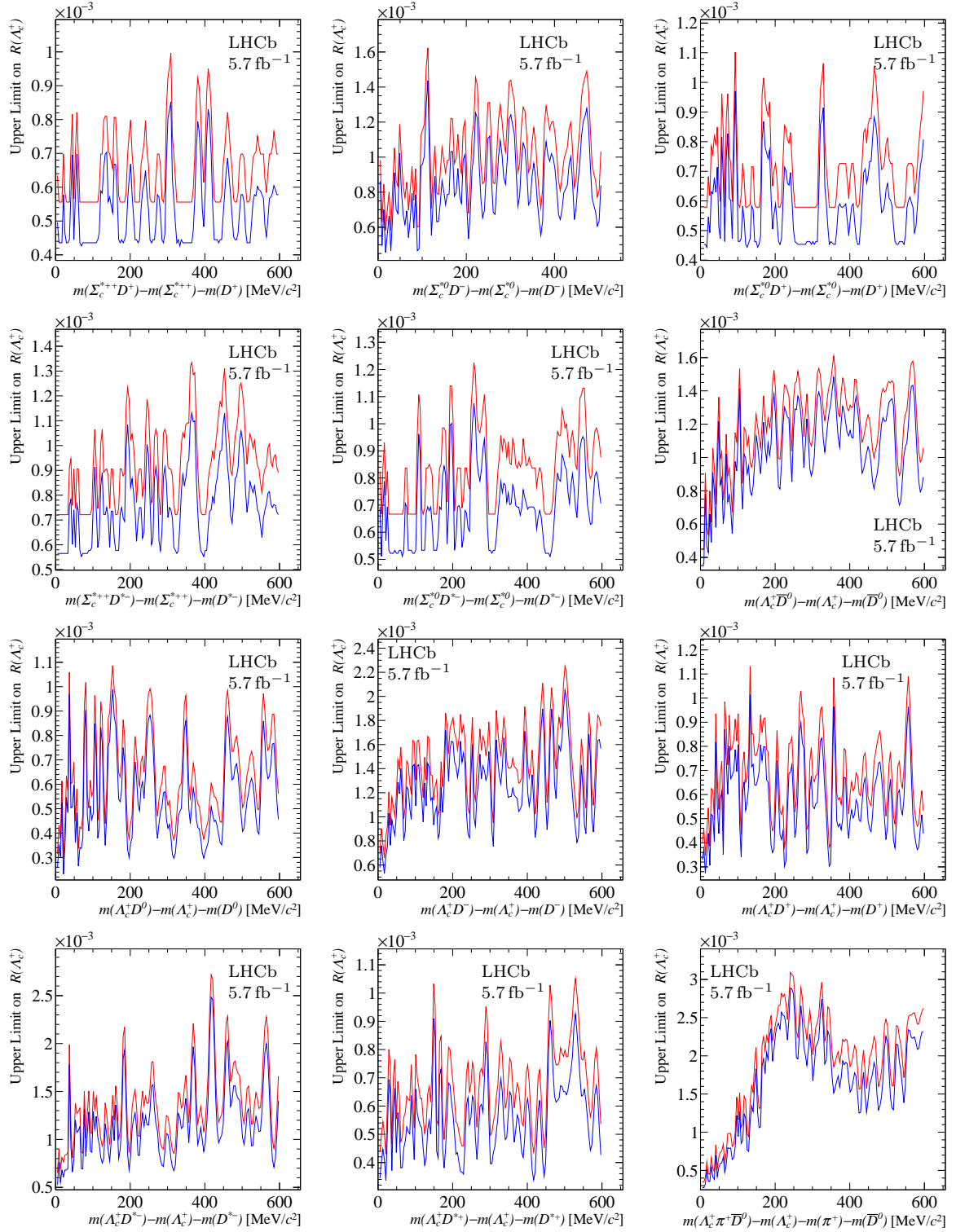


Figure 6 (cont.): UL scans across the  $Q$ -value for all modes where the UL at 90% and 95% CL are shown in blue and red respectively, and the signal model uses a Gaussian function.

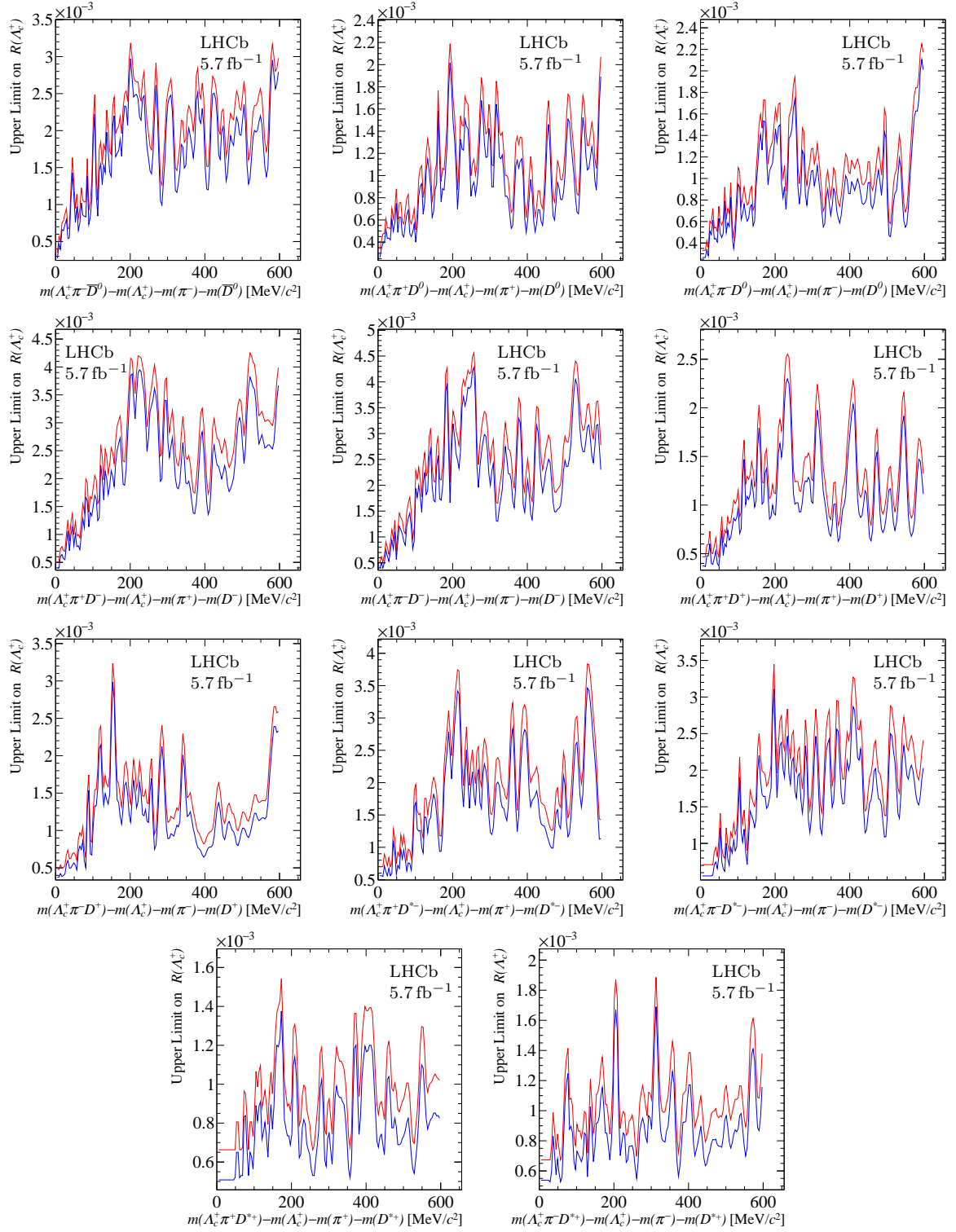


Figure 6 (cont.): UL scans across the  $Q$ -value for all modes where the UL at 90% and 95% CL are shown in blue and red respectively, and the signal model uses a Gaussian function.

## UL plots from Voigtian scans with width set to $5 \text{ MeV}/c^2$

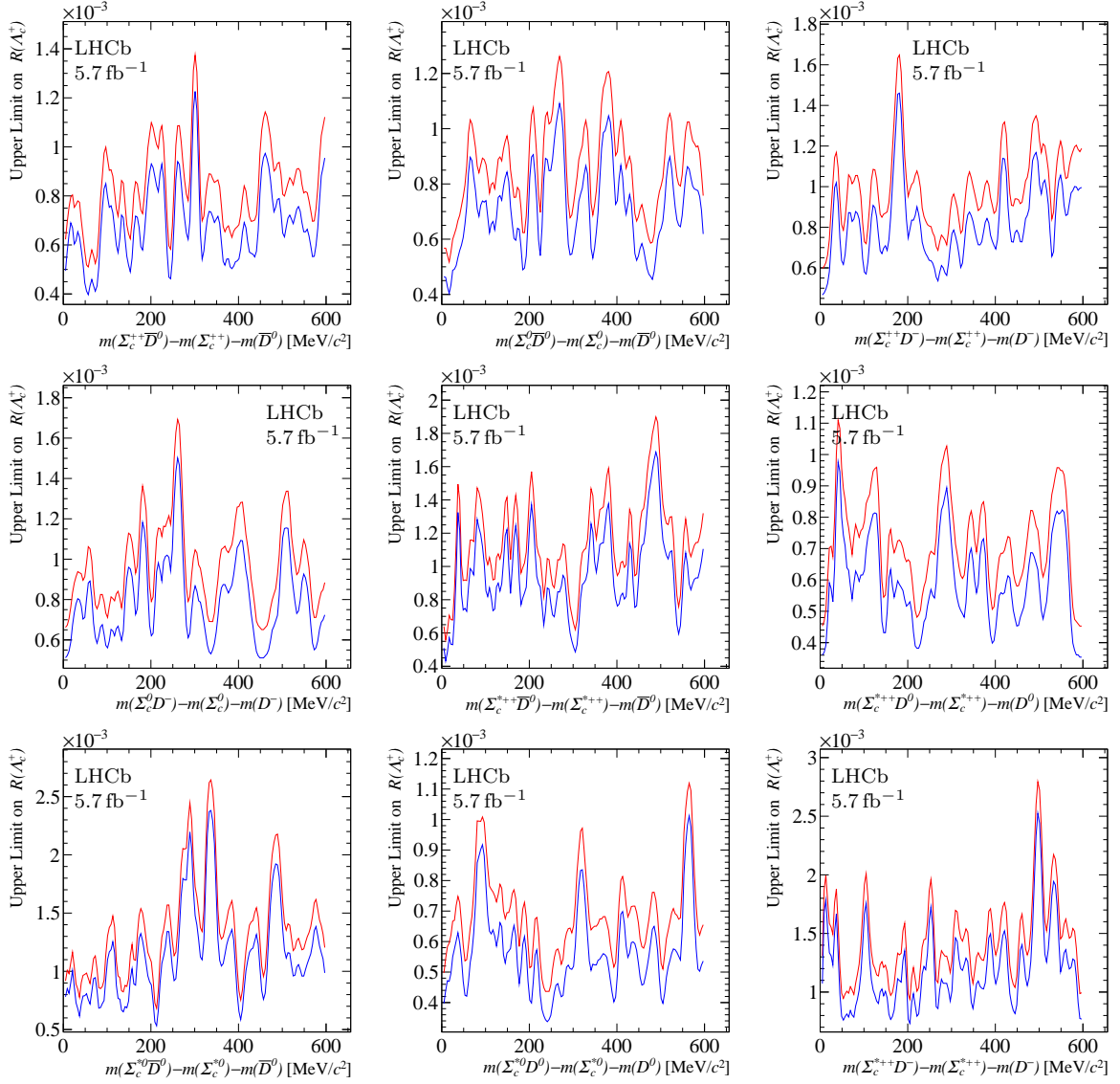


Figure 7: UL scans across the  $Q$ -value for all modes where the UL at 90% and 95% CL are shown in blue and red respectively, and the signal model uses a Voigtian function with the width set to  $5 \text{ MeV}/c^2$ .

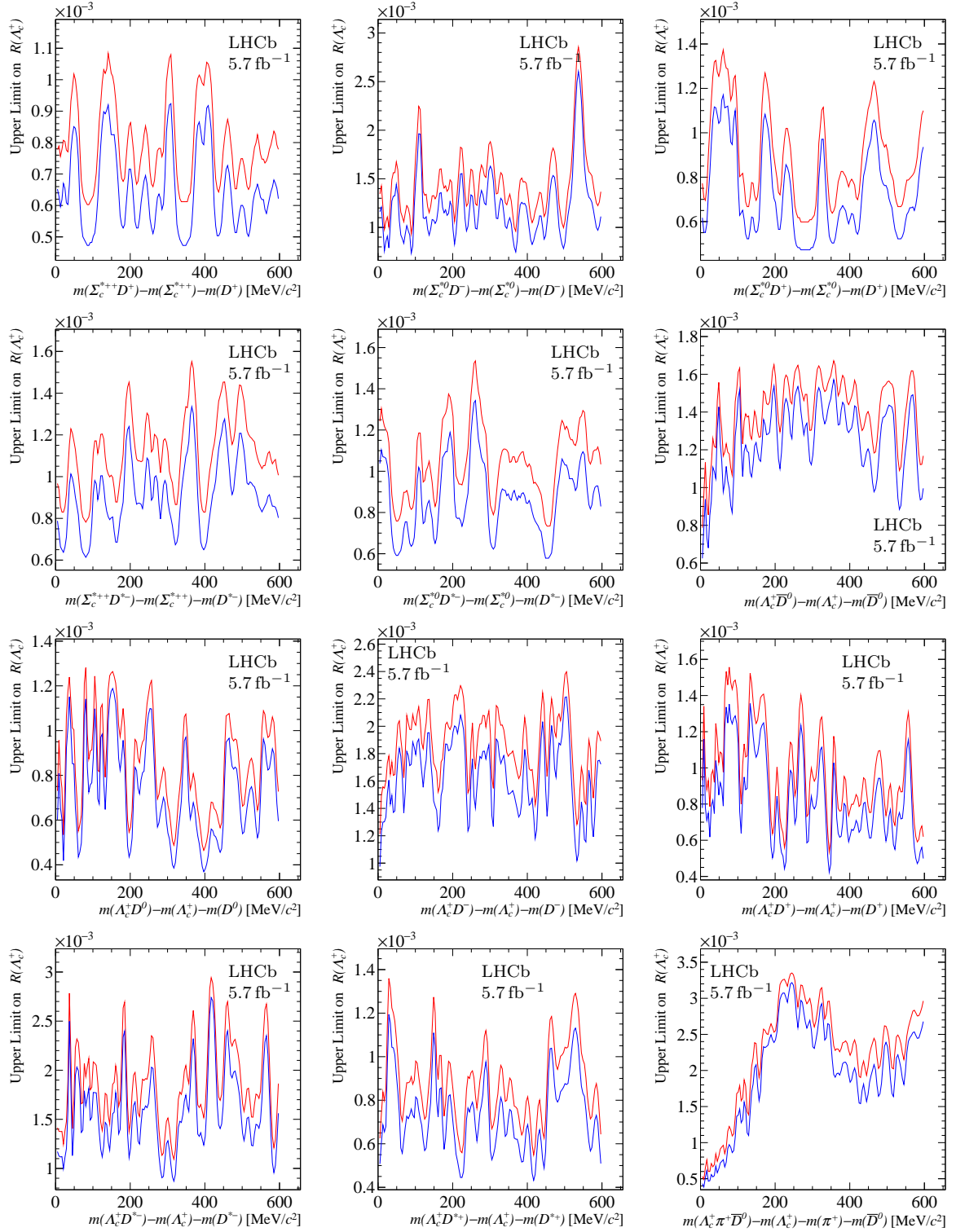


Figure 7 (cont.): UL scans across the  $Q$ -value for all modes where the UL at 90% and 95% CL are shown in blue and red respectively, and the signal model uses a Voigtian function with the width set to  $5 \text{ MeV}/c^2$ .

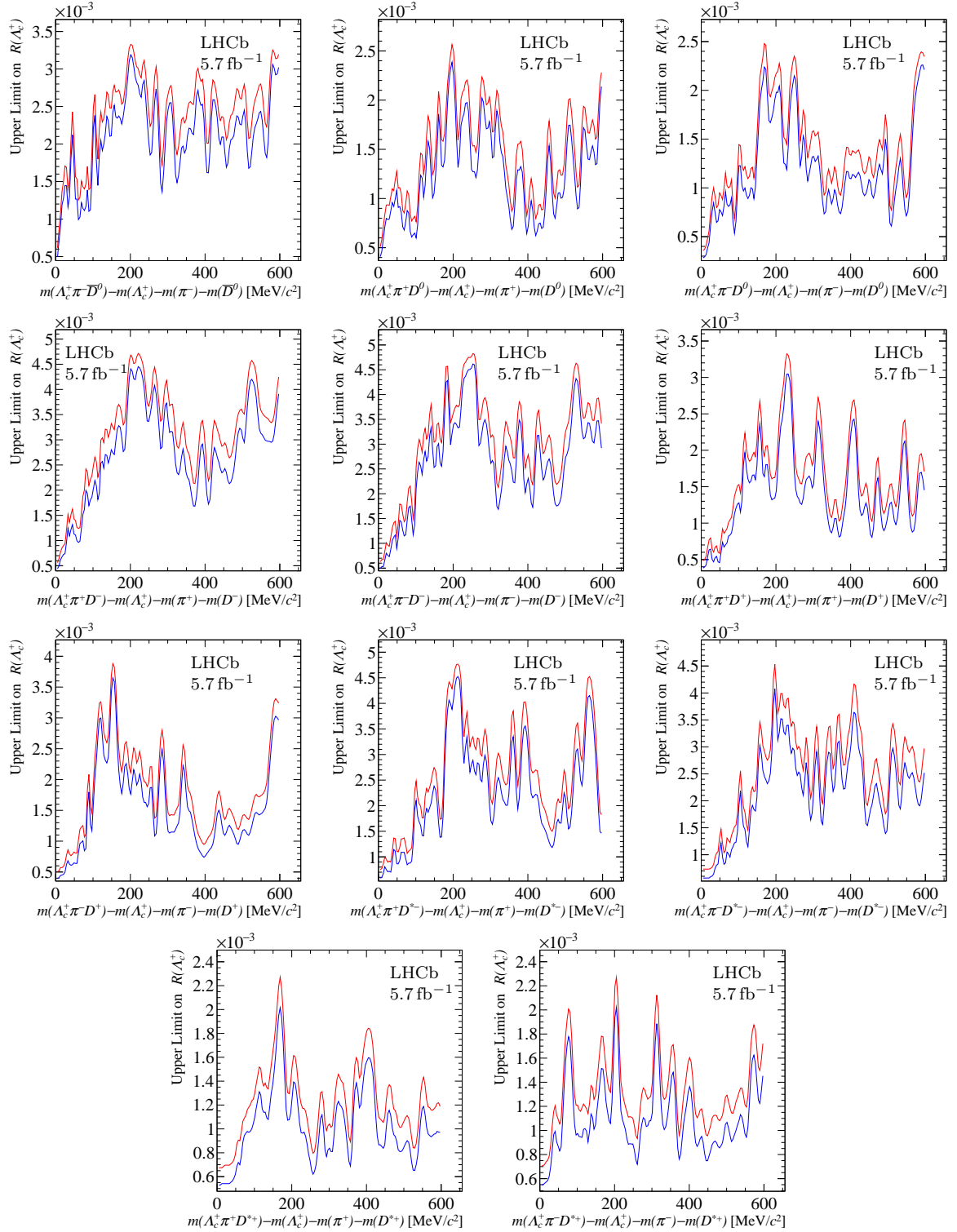


Figure 7 (cont.): UL scans across the  $Q$ -value for all modes where the UL at 90% and 95% CL are shown in blue and red respectively, and the signal model uses a Voigtian function with the width set to  $5 \text{ MeV}/c^2$ .

## UL plots from Voigtian scans with width set to $10 \text{ MeV}/c^2$

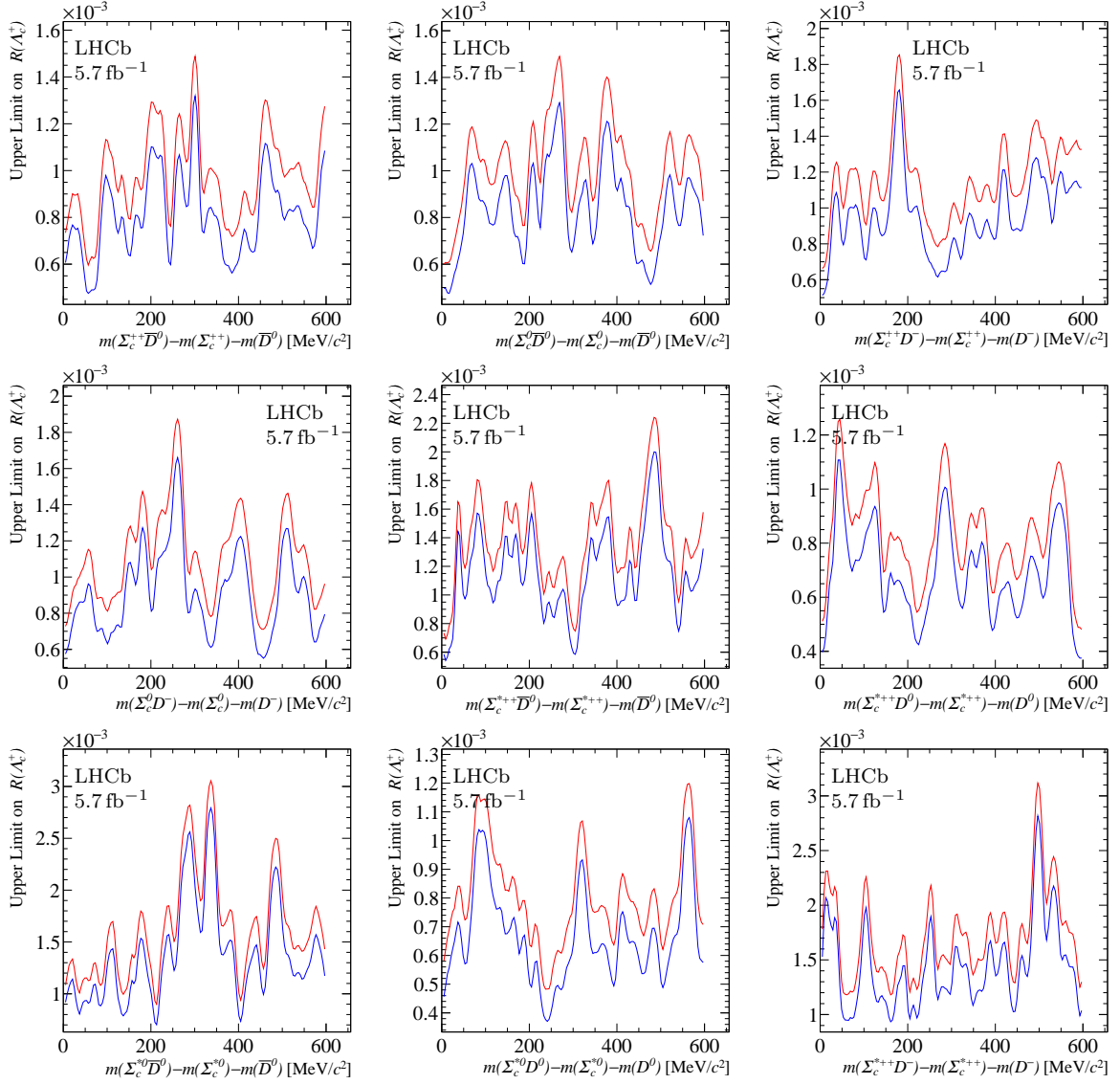


Figure 8: UL scans across the  $Q$ -value for all modes where the UL at 90% and 95% CL are shown in blue and red respectively, and the signal model uses a Voigtian function with the width set to  $10 \text{ MeV}/c^2$ .

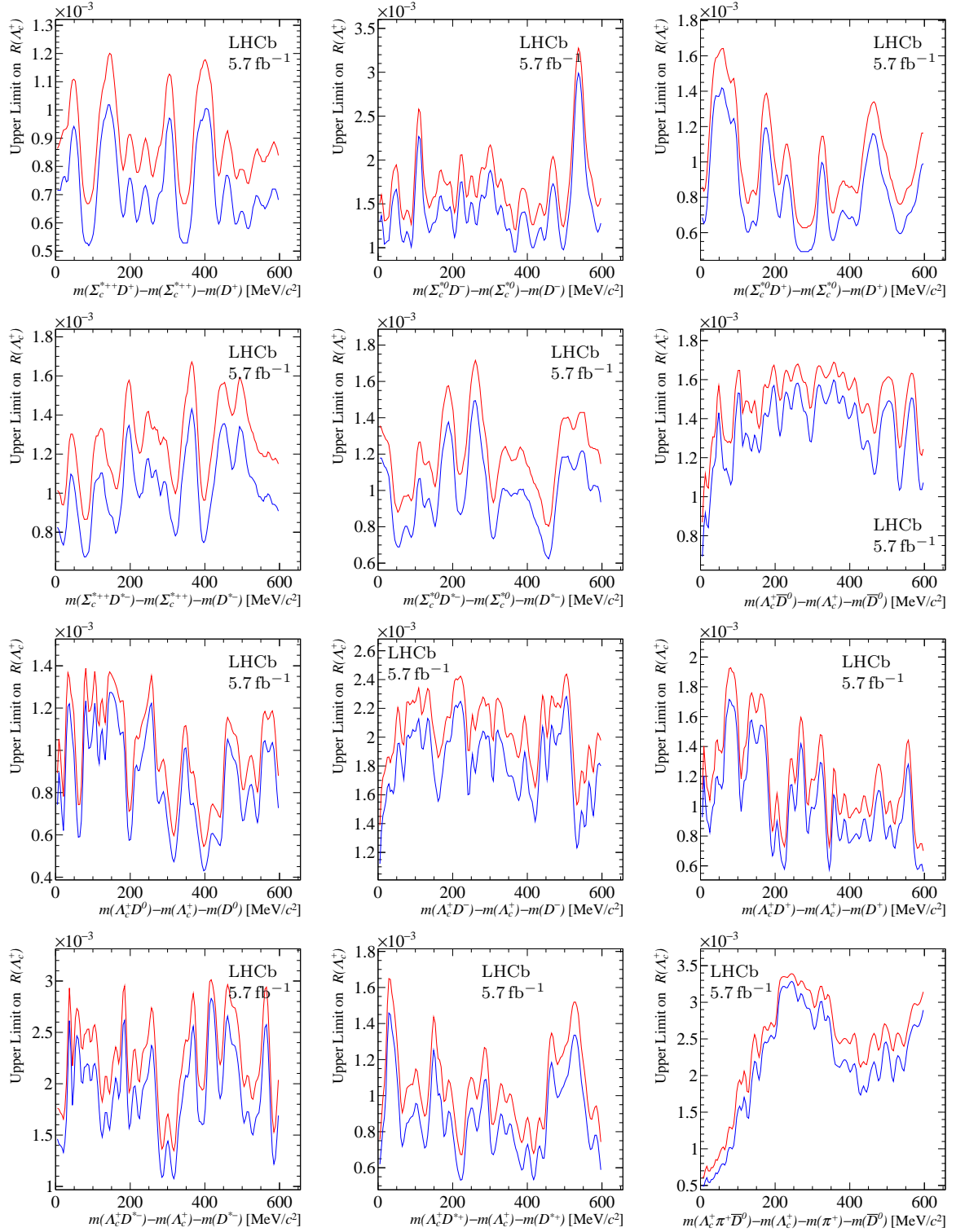


Figure 8 (cont.): UL scans across the  $Q$ -value for all modes where the UL at 90% and 95% CL are shown in blue and red respectively, and the signal model uses a Voigtian function with the width set to  $10 \text{ MeV}/c^2$ .

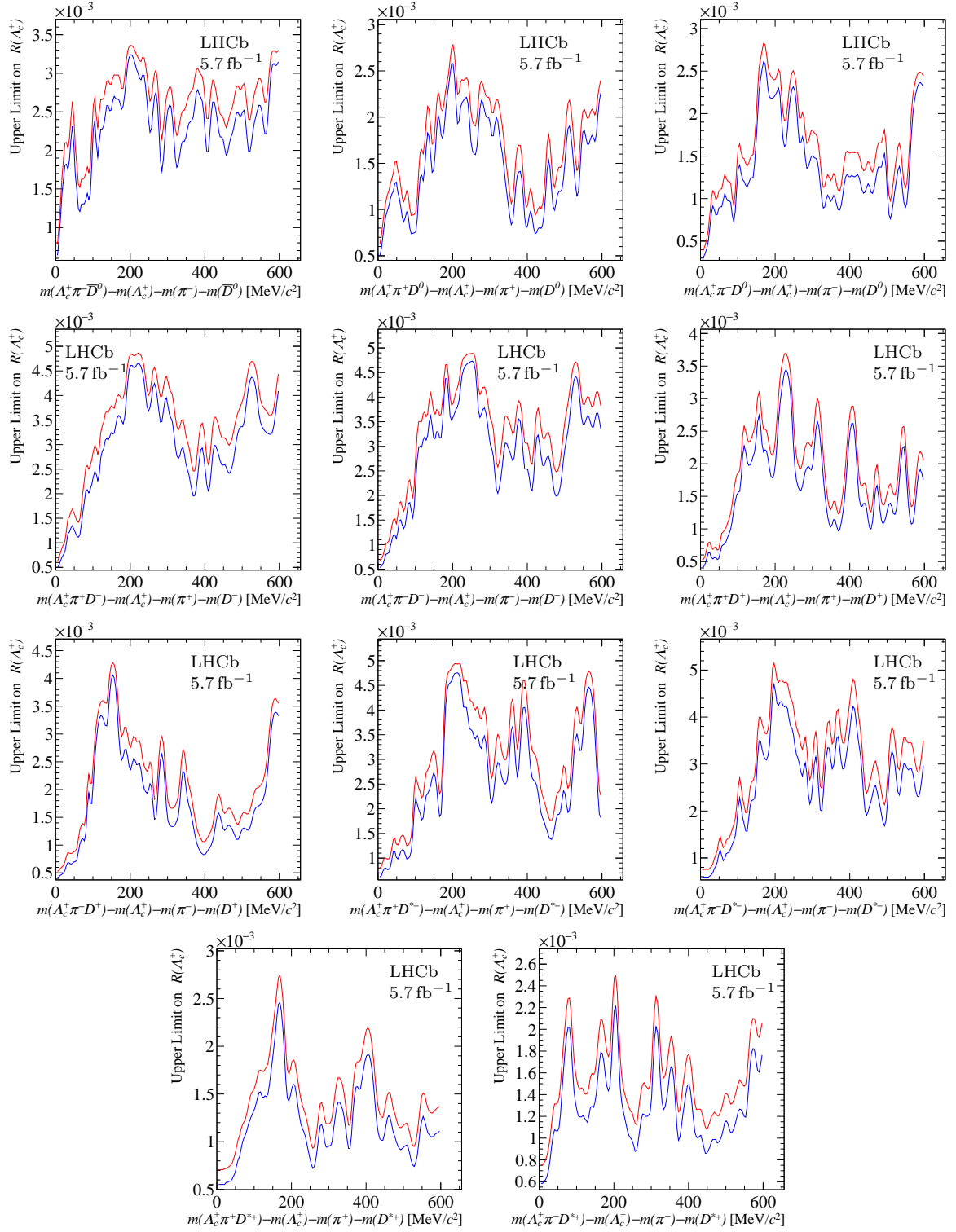


Figure 8 (cont.): UL scans across the  $Q$ -value for all modes where the UL at 90% and 95% CL are shown in blue and red respectively, and the signal model uses a Voigtian function with the width set to  $10 \text{ MeV}/c^2$ .



## UL plots from Voigtian scans with width set to $15 \text{ MeV}/c^2$

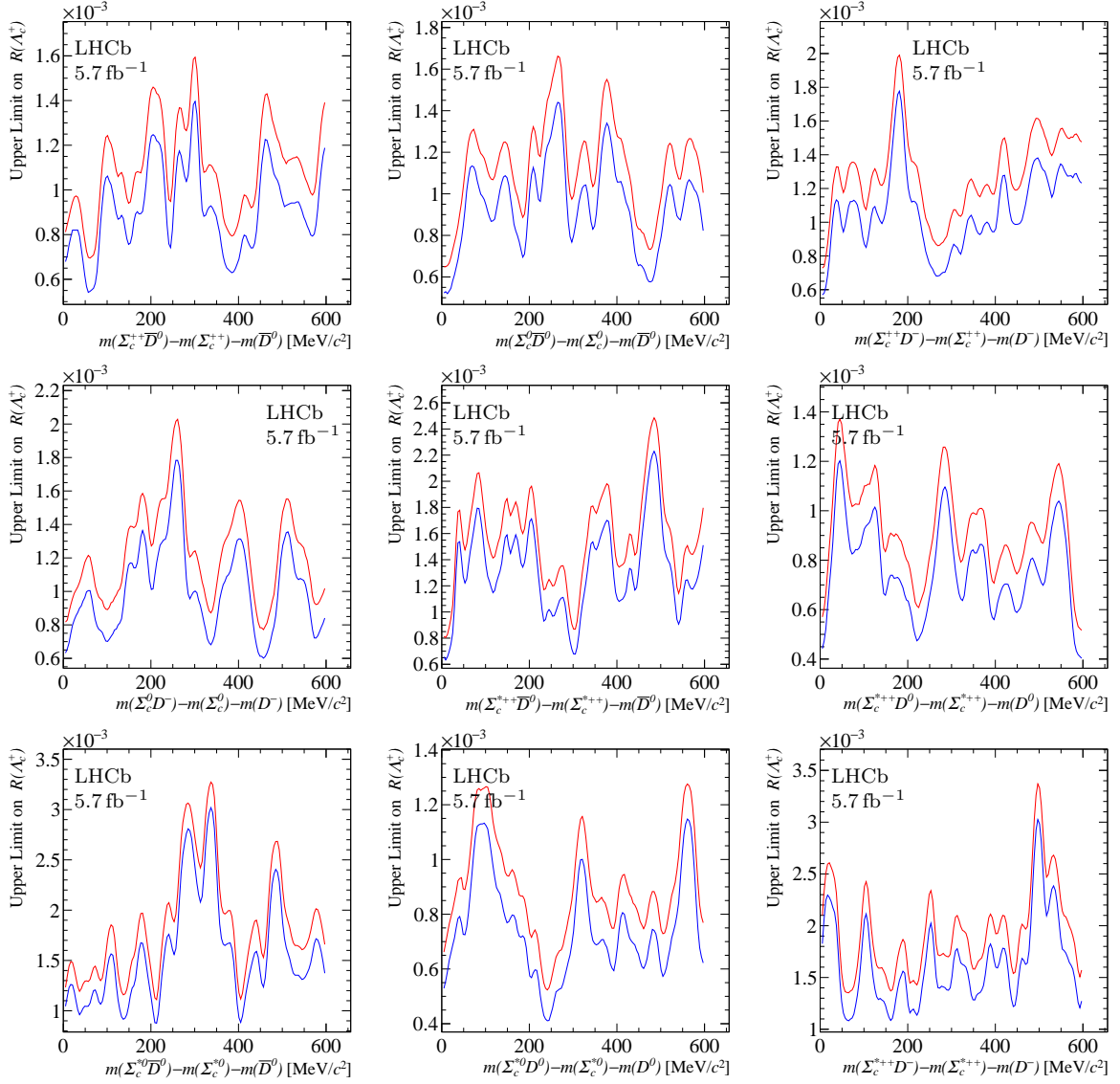


Figure 9: UL scans across the  $Q$ -value for all modes where the UL at 90% and 95% CL are shown in blue and red respectively, and the signal model uses a Voigtian function with the width set to  $15 \text{ MeV}/c^2$ .

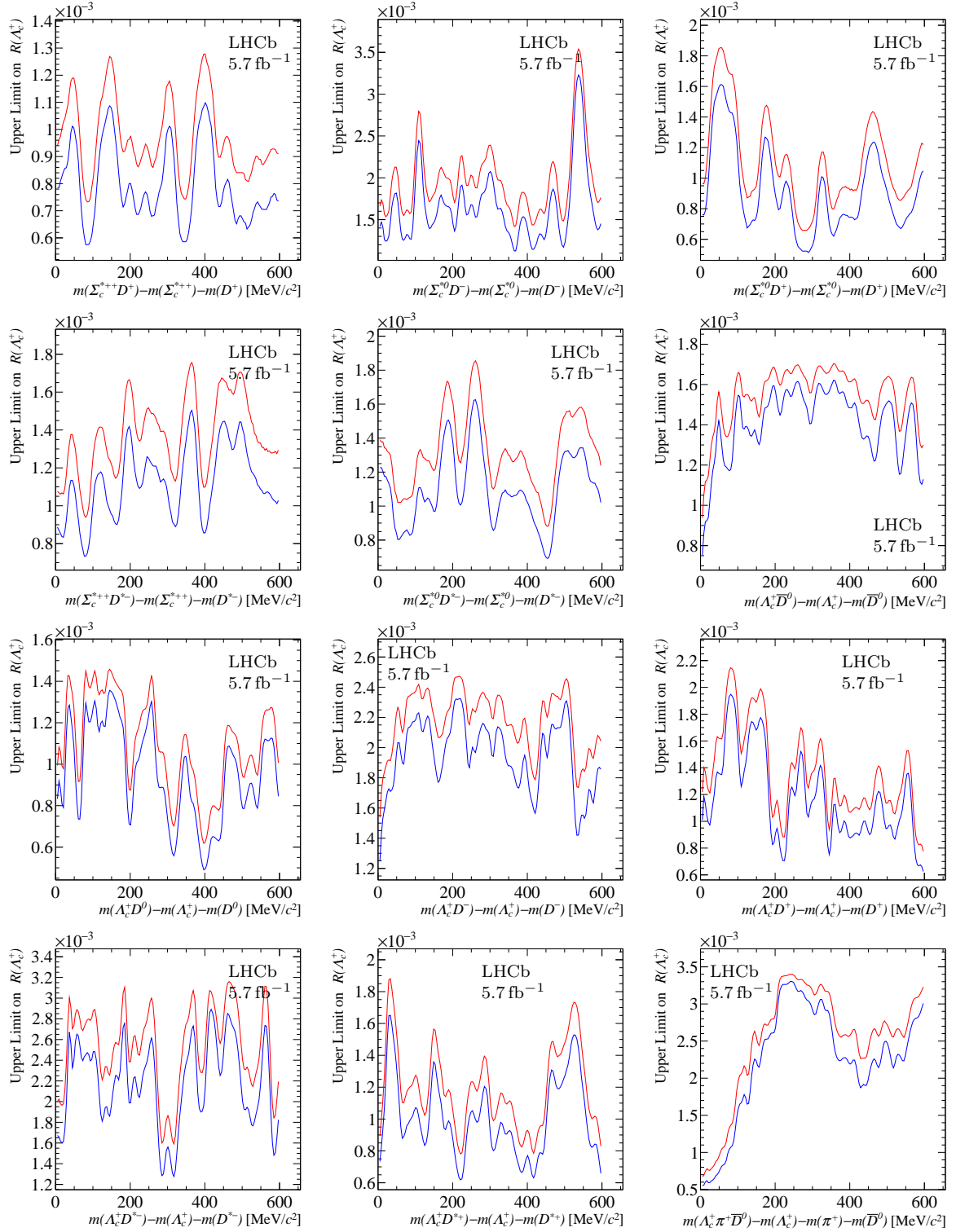


Figure 9 (cont.): UL scans across the  $Q$ -value for all modes where the UL at 90% and 95% CL are shown in blue and red respectively, and the signal model uses a Voigtian function with the width set to  $15 \text{ MeV}/c^2$ .

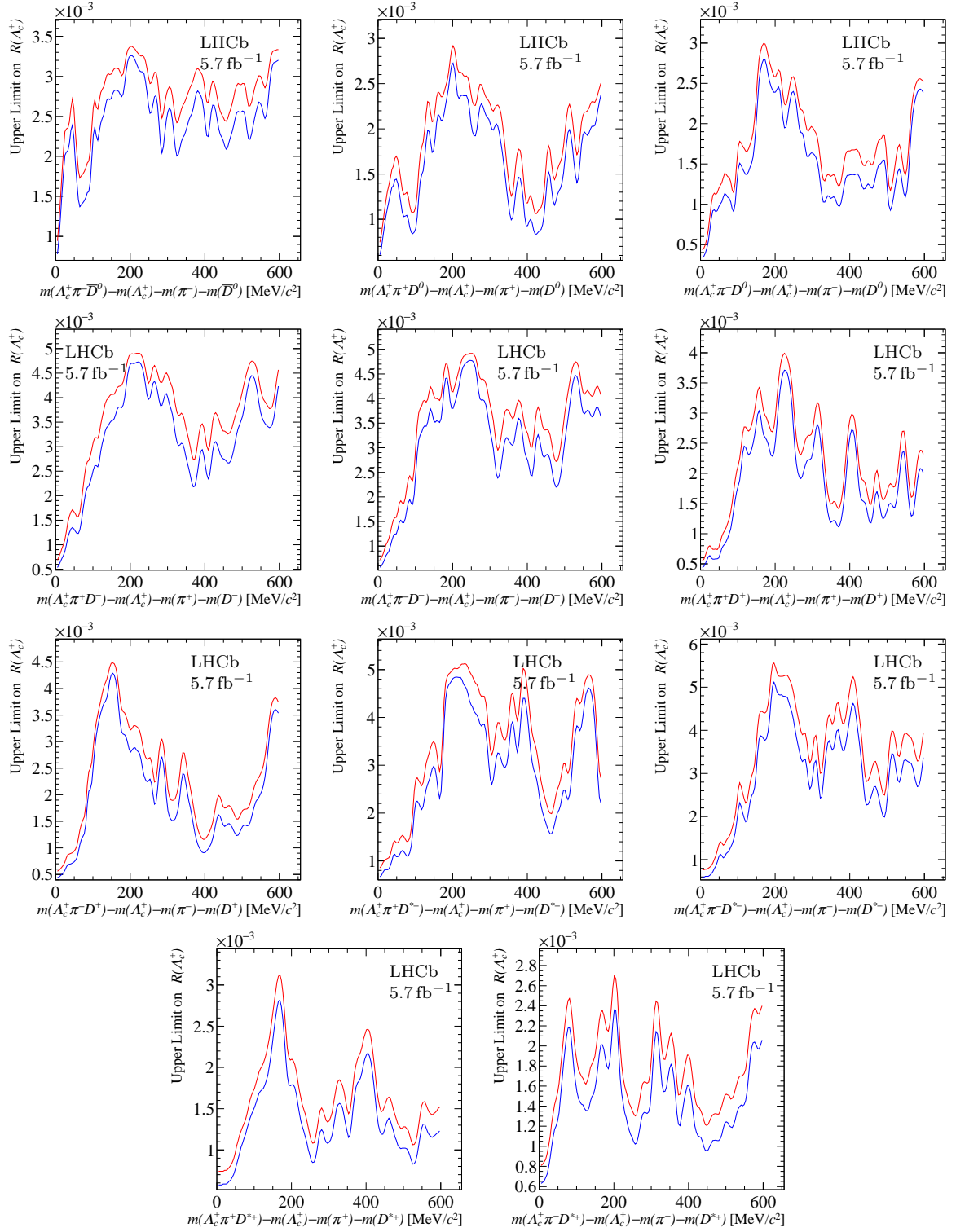


Figure 9 (cont.): UL scans across the  $Q$ -value for all modes where the UL at 90% and 95% CL are shown in blue and red respectively, and the signal model uses a Voigtian function with the width set to  $15 \text{ MeV}/c^2$ .

## Mass spectrum of the $\Lambda_c^+ \pi^+ D^-$ decay with extra axis

The plot shown in the paper is reproduced in Fig. 10 with an extra axis which indicates the invariant mass value of the combination of hadrons in the  $\Lambda_c^+ \pi^+ D^-$  channel, such that easier comparisons can be drawn with existing spectra.

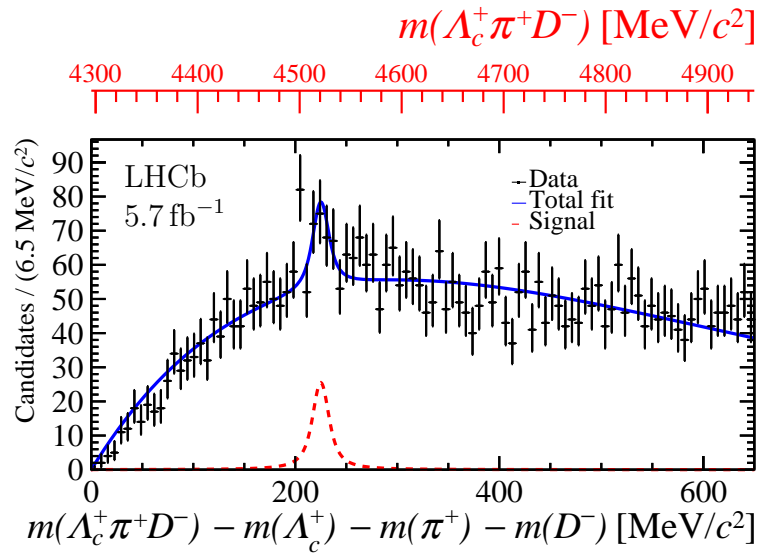


Figure 10: Distribution of the Q-value in the  $\Lambda_c^+ \pi^+ D^-$  channel, where the most significant signal is seen. The fit result is overlaid. An axis corresponding to the sum of invariant masses for each particle in the combination is also drawn in red. The red axis is available to be produced for other signal channels ([code repository](#)).