Correction reply format.

All significant changes to the thesis after the viva are listed here in two sections.
The list of formal corrections responds to the corrections that were listed in the email
The list of annotated corrections responds to comments written in the thesis copies that I received at the end of the thesis.

Each correction is listed with a page and paragraph or figure reference.
Corrections are listed in blue if they are significant.

Corrections that were simple textual suggestions/fixing typos are not included here. In addition, to maintain a logical positioning of the text and figures on the page, some text and figures are now in different positions. These changes are also not included here.

Wednesday, 20 June 2018

List of formal corrections:

1. **P37: Last Para**:
   Are these branching ratios mass dependent? Specify any mass assumptions.

   Additional text added to clarify

   For the mass range considered the branching ratios are not mass dependant**.** Evidence for this statement is found in [42]

2. **P46: Para 2**:
   "Large density of charged particles (high Z)" : note how large-Z is even more important than density (they are related of course) due to the scaling behaviour of the cross-sections.

   Additional text added

3. **P53, Eq. 4.1** :
   Specify the momentum or curvature resolution for tracks.

   Equation added

4. **P58, Para 2 and 3Wednesday, 20 June 2018**
   Does the pile-up correction also depend on the jet area "A" ? You should make sure you fully understand the different steps in the jet energy correction algorithm.

   A description of ρ has been added

   A is not used in residual correction. Additional text added to clarify.

   The residual pile-up correction does not depend on *A*. I think that *A* is effectively taken account for in alpha and beta, which are fitted parameters.

5. **P64, Last Para and P65, Table 4.1**
   What sample have the numbers in Table 4.1 been calculated for ?

   Additional text added

6. **P67**
   It feels like a plot would be useful to illustrate the b-tagging efficiency extrapolation. Check if such a plot exists.

   No such public plot exists. No change made to thesis.

   I confirmed the absence of a good plot with the b-tagging community in ATLAS.

7. **P75:**
   Why can't the online b-tagging algorithms be run offline ?

   They can, but using a b-perf trigger is preferred.
   As this is a very specific technical point I have not made a change to the thesis text, as I believe it would not add overall clarity for a reader.

   There are two reasons why using the online algorithms (i.e. using a b-perf trigger) is preferred.

   Firstly, using a b-perf trigger calibrate the *actual* output of the online algorithms and therefore is calibrating the true performance of the b-jet trigger. For example if the

real online hardware was not performing the expected algorithm (for example if there was some faulty hardware) then we would be able to detect and adjust for this effect.

Secondly, it is important to note that the b-perf trigger are used to provide in-time monitoring of the b-jet trigger, which cannot be done by running online b-tagging offline due to the additional time taken. Therefore, given than the online algorithms are already run online, it is simplest to record the weights for calibration as well.

8. **P88; Table 5.2** :
   Explain (or remove ?) 0.0% normalisation entries in Table 5.2.

   Changed to '< 0.01%'

9. **P99 Para**: 4
   Theoretical motivation for setting the Z' width to be 3% of the mass ?

   No specific motivation. Text added to clarify.

   This is reality the default value from Pythia. As long as the resonance is relatively narrow (width is not >> dijet resolution) then this a reasonable model to choose for our given search.

10. **P99, Para 4**:
    Does the Z' cross-section normalisation (at NLO) affect the setting of limits on sigma-times-BR ? Perhaps all of the signal physics discussion should come earlier, rather being in this chapter.

    Yes it does. Text rearranged for clarity

    Signal discussion moved to new outline chapter. In addition it is specifically mentioned that these signal models are used in all three parts of the di-b-jet analysis.

11. **P170 Para 5:**
    It is stated that the LowMass data-set upper bound is 1533 GeV to avoid a gap, but this isn't what I see on page 160. Somewhere, there needs to be a clear discussion on this point.

    Text added to discuss this point.

12. **P114 Para 2:**
    Can you explain the trend in inclusive (acceptance*efficiency) in Figure 6.8(a) ?

    Text added

    This is due to a large low mass tail for the high mass Z' boson signal dijet mass spectrum, due low mass enhancement of the BW shape.

    This is known to be the cause by comparing two DM Z' boson models, which are identical before PDFs and b-tagging were considered except that in one model the tail of the BW resonance shape considered is truncated.

    In the model with no truncation, a large low mass tail was observed in dijet mass spectrum, similar to that the caused the trend in the inclusive (acceptance*efficiency). In the model with no truncation, no such low mass tail was observed.

    This shows that the large low mass tail (and hence the trend line of acc*eff) is caused by the events in the BW tail.

    There is no effect of the large low mass tail on the analysis, as the wide tail is indistinguishable from background.

13. **P121-127 Section 8.4**:
Why is figure 7.3 for the 4-parameter fit function while it was concluded earlier than 3-parameters is better ? Overall, it is rather easy for the reader to become confused about the choice of number of parameters.

Rearranged order of (8.4.1-8.44)

The orders are changed to reflect the true time order they were performed in.

Section 8.4.2 uses the 4 parameter function and, in P123 para 1, justifies this choice.
Section 8.4.3 then shows how the 3 parameter is selected
Section 8.4.4 and onwards then use the 3 parameter fit function.
The introductory paragraph to this section is changed to represent the new structure.

14. **P136 Para 4** : Discrepancy between p-values in text and on plot.

Corrected

15. **P139 Para 1 and 2**
Clarify some aspects of the binning and window definition (for example the window is not symmetric in mass due to non-constant bin width).

Additional text added

16. **P147-148**
Clarify certain aspects of the “exclusion region procedure” (make sure all steps are precisely written).

Additional text added to the numerated list.

17. **P151, Last Para to P153 Para 1 :**
How do I draw the stated conclusions from the contents of Table 8.4 ?

Additional text added with explicit reference to table.

18. **P158, Para 4** :
Explain Gaussian modelling which later (page 163) seems to be also applied to broad resonances. Why not use a Breit-Wigner lineshape for broad resonances (i.e. not resolution dominated) ?

Additional text added

In addition a reference is added that specifically describes how a theorist should interpret Gaussian limits.

19. **P165, Fig 9.4, accompanying text P164 Para 3-5**
How well do the morphed and explicitly generated distributions compare ?

They are consistent within statistical uncertainties of the generated models.

Figure 9.4 changed to show a comparison, additional text added

20. **P170 Final Para**:
Why the different Gaussian limit setting treatment for HighMass and LowMass ? Explain that this kind of inconsistency will be resolved in the final joint analysis/publication

Additional text added

List of annotated corrections

- **Chapter 1: Introduction**

1. P18, Para 2: Line now reads “when the invariant mass of the *colliding partons* is equal to the mass of the BSM particle”
2. P18, Para 2: Remove line “Dijet searches are particularly interesting at hadron colliders as BSM particles that decay to quarks will be strongly produced.” as this is misleading in the use of strong, and does not add to the argument
3. P19: Correctly list chapter structure for addition of new analysis chapter
4. P20-21: In personal contributions: explicitly state if work was not presented in thesis.
5. P19 Para 1, P21 Para 3 and 4: The *Full16_LowMass* and *Full16_HighMass* data-sets have now been submitted to a journal and have a public reference [11]

- **Chapter 2: Theory**

6. Section 2.2.1: Renormalisation explanation expanded.

- **Chapter 3: Detector**

7. P39; Para 3: Added definition ‘bunch spacing’ in the sentence.
8. P40; Para 3: Added description in-time and out-of-time pile-up.
9. P46; Para 1: “The ATLAS calorimeter is designed such that *as much as possible of* the full particle shower of the initial particle will occur within its volume, …”
10. P47; Final Para: I had misread the units of granularity on the forward calorimeter. Now reads: “*The finest granularity of the LAr calorimeter in the x–y plane is 3.0 cm x 2.6 cm.”*
11. P49; Table 3.2: Add a noise term. In text in previous paragraph, *The noise term depends strongly on η and pile-up conditions, so an approximate order of magnitude is given*.

- **Chapter 4: Object**

12. P52, Para 3: This paragraph is slightly rewritten to be clearer.
13. P56 Para 1: Slight rewrite of this section for clarity.
14. P62, Fig. 4.5 : Remove proton beams from diagram
15. P62, Final sentence : Explanation of why IP2D is more robust to pile-up
16. P64-65 and Table 4.1: Increased explanation of what an operating point is.
17. P65 Final 2 paras: Paragraph arrangement to keep figure on same page as reference.
18. P67: Section 4.3.5 (bJES) rewritten to described the 2.6% uncertainty actually used in the analyses.

- **Chapter 5: Trigger**

19. P69: Removed Figure of ATLAS trigger. It was noted that this figure was not described fully in the caption. As the details of the figure went beyond the scope of the work, I decided to remove the item. The text provides a verbal description at the level of detailed I want.
20. P74 Para 2: This paragraph describing b-perf triggers has been described before the event selection list.
21. P75 Para 5: Description of GRL moved here to reduce forward referencing.
22. P77 Table 5.1: Range of run numbers included

- **Chapter 6: Analysis Outline**

23. A new chapter formed from the parts of the old event selection chapter that were too general to be part of the event selection
24. P95, Para 2 and 3. As a new chapter there is a different introduction to the chapter.
25. P96 para 2: Here I note the interplay between the validation studies for the search phase and the event selection making the structure of those two chapters easier for a reader to follow.
26. P97-99: Data-sets and signals described here as these affect all three parts of the analysis.
27. P98 Para 2-3 Both analyses are now submitted "to Phys. Rev. D. [11]."
28. P98 Para 2; Explicitly state reason for mentioning the Full16_HighMass analysis.

- **Chapter 7: Event Selection**

29. P101, Para 1-4. Chapter now only focuses on event selection; introduction and outline hence changed.
30. P113. Fig 7.8a. Inclusive added to legend text.

- **Chapter 8: Search Phase**

31. P116, final para: Added text to explain form in Eq. 8.1
32. P136 Para 3: ‘chi^2/n.d.f. = 3.65’ in place of ‘chi^2/n.d.f. >> 1’
33. Figure 8.16(b), Figure 8.23(b), Figure 8.24(b) : Title of y-axis changed.

- **Chapter 9: Limit Setting**

34. P159, Para 4 : Correct statement of bJES uncertainty used in dibjet analyses.
35. P160 Final Para: Fuller description of how the function parameter uncertainty is implemented.
36. P161, Figure 9.1 and P166 Figure 9.5(b).
    Figures changed from around 1 to around 0. y-axis title changed.

Title and style based on a previous public plot:
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2016-21/figaux_08.png.
Text in paragraph above figures changed to add clarity.

37. P162, Para 1 and P163, Final Para and P170, Para 4 and P173 Final Para.
As the results are now formally approved by ATLAS I removed the statements that were adding caution that these are preliminary results.
E.g. 'The results have not yet been published so should be considered as preliminary.' is removed and 'it is anticipated that an upper limit will be placed' is changed.
38. P172, Para 1 and 2: These are rewritten to be more explicit in the motivations for using a new gaussian limit setting in the Full16_LowMass data-set.

- **Chapter 10: Future Prospects**

39. P174, Para 2: '13 or 14 TeV' instead of '13 TeV'.
40. P175, Table 10.1 updated to reflect that the End of 2016 results are public.

- **Chapter 11: Conclusions**

41. P178, Para 3: Paper now stated as submitted to journal

- **Appendix C**

42. All plots made larger. To fit on page all figures split into two parts, one containing plots showing the 4 parameter fits and the other has the 5 parameter fits.