**LiH Referees meeting**

15:00 BST 3rd September 2021

Present:
Mariyan Bogomilov
Paul Soler
John Cobb
John Nugent
Chris Rogers

We tried to avoid going into the details of wording.

We discussed the level of detail in the introduction. JHC commented that there may have been a bit too much detail. Comment on first line of the introduction. that should be scattering off *nuclei and electrons* not *atoms*.

On line 24 **Please mention that G4 has been updated since MuScat (v4.7.0)**. We also thought it would be valuable to **describe in detail the ingredients/options/version numbers that went into the G4 and Moliere calculation**, perhaps in the section where the simulation is described, S3.4.

On line 28 it is probably worth **give a few words to help non-accelerator physicists get a grasp on emittance**. This would probably be more valuable than the equation where it is defined. Also worth **highlight why low-Z materials are important** (that they have lower equilibrium emittance).

Please f**lip the sentence on line 26** to "reduced due to energy loss and increase by scattering" i.e. matches the term ordering in equation 4.

We discussed **moving equation 6 to the appendix** as it is trivial. We also discussed defining the momentum unit vector, but decided it would introduce another definition (which is then only used once).

We discussed Table 1, noting that the scattering from both trackers combined is a more significant (by factor sqrt(2)). **please use the total including two trackers.**

Line 74: **please remove the word *significantly***. The scattering from the detectors is notable when you include two trackers.

Line 93: the diffuser messes up the TOF01 mapping to momentum, so they are removed due to energy loss (not scattering as indicated in the text). **Please fix the text.**

Line 99/table 2: the cut is made on chi2 per degree of freedom *on the track fit*. **It is not clear from the text, please clarify**.

We discussed what is the meaning of "overflow bin"/"normalisation" mean. In fact, the assumption is that tracks that are not detected are scattered out of the experiment. I don't think we had a specific action here.

Line 118 and figure 3: **please use "acceptance" consistently.**

Line 122: what does "compatible" mean. Is it really "compatible"? Do we need this sentence? **Please remove the sentence.**

Plots show MAUS v3.1.2 but that is inconsistent with the text. **Please make sure the MAUS version number is listed consistently.**

We spent some time discussing the momentum reconstruction. There was confusion as to how the momentum reconstruction, as listed in equation (7), related to the track fit as listed in the plot fig. 4. It turned out the fit function was used when calculating derivatives for error propagation (but not used elsewhere). Also, the correction terms and energy loss terms were not included in eq (7). **Please add an extra term in eq. (7) to indicate that there is a correction for energy loss and clarify that it is energy loss *at the centre of the absorber* that is reconstructed**. **Give an explicit rough estimate of the resolution and explanation of the correction term e.g. Bethe Bloch or systematic correction.**

Fig. 4: We thought that fig. 4 would be more valuable if the fit was the same as the one used in equation 7. **Please update the plot so that at least it doesn't show a fit that contradicts the text.** Also would be valuable to **show the same plot but with TOF12 time vs Pz**.

Table 3: **Please add in true momentum spread (estimated from MC)** and comment that it is estimated from the MC.

Fig. 5: **please use finer bins.**

Fig. 6: The subcaptions were confusing. Selected muons pz distribution … for the <p> sample – should be "pz distribution … for muons in the <p> sample". **Please fix the subcaptions.**

We had some discussion as to the meaning of column 6 table 3 and fig. 5. **JN needs to clarify what the different things mean.** Fig. 5 is the "detector resolution" but it is not consistent with table 3 "detector resolution".

Fig. 7: we discussed whether these plots were really desirable. The MC vs data agreement is okay but not great. Also, there is obviously missing plots of x' and y'. JN doesn't want to show those because the misalignment is exposed. We thought the best solution was to **remove fig. 7 and the corresponding sentence on line 138.** Better still if you can show the raw x' and y' distributions (but would need to fix the misalignment).

Fig.8,9,10: and last para of Section 3.4 – we thought this would be more appropriate **moved to the results**. We also discussed including empty data, and noted that the theta_scatt plots are more-or-less a duplicate of theta^2_scatt, which everyone thought looked very nice. In the end we agreed:

- fig. 8 9 10 will be theta x LiH, theta y LiH, theta x empty, theta y empty
- add in a new fig. 11 which is theta^2 scatt LiH for 170 200 240

We noted that the vertical axis was rather squashed which made it challenging to see the data. **The text boxes and vertical axis should be adjusted to make the data more visible. The "integral" text box should be removed.** We had some discussion about the "integral"; this is the integral not including the overflow bin. When the overflow bin is included the integral becomes 1. We discussed whether the integral should be included in the text, and felt it was worth while to put it in as a line of text somewhere. **Please include the integral in the text.**

**We noted the units of fig. 8/9/10d should be radians^2.**

We started discussing chi2 and skipped forwards to table 5. Noted that table 5 is now missing columns compared to the caption. Also questioned the number of bins vs number of DOF listed in table 5. **Fix the NDF in table 5. Fix the caption in table 5.**

We discussed the ordering in Section 4. We wanted to put the chi2 closer to the raw data to make a statement "the raw data agrees well". Unfortunately we found that the chi2 has to follow systematics, and this needs to follow deconvolution. JN proposed moving the raw data towards Table 5. **We weren't sure and decided to have a look.**

We discussed equation 8. There was some question about where the equation came form. No one seemed to know. sigma_{sys,i} is not defined. **Check and justify equation 8. Define sigma_{sys,i}**

PS asked if the errors in fig. 8/9/10 are statistical. JN said no, they are statistical and systematic. JHC: what are the largest errors? JN: TOF systematics. CR: probably the stats errors on each bin are large compared to the sys error; whereas the sys error on the width is large compared to the stats error. JHC: I want to compare g4 with data without worrying about sys errors. I think sys errors are not significant. Please show me I am wrong. JN: I will make a plot of stats errors and sys errors bin-to-bin. JHC: Just doing chi2 with/without systematic errors; does it change significantly?

Fig. 11: why are the errors so large for 240? JN: I'm not sure, I will check. We probed the systematics. JN has applied the systematic error on the LiH data and the empty data (then convolved with the model). We asked should we apply systematic on full data and empty data. JN suggested that the systematic shift on the empty data might be different to systematic shift on full because they were taken under quite different conditions; so they should be treated independently. There was a long discussion.

Mariyan asked about the normalisation on fig. 11. John explained the normalisation.

Equation (9). JC asked about acceptance effects on eq 9. JN said that in the explanation he has not included the acceptance correction but he has included it in the actual calculation. **Explicitly mention that the acceptance correction is not included in eq 9. Add an expression analogous to Eq 9 to the forwards convolution discussion.**

Line 170. JC asked what ||something|| means. JN was not sure. **Explain what || means.** We questioned whether there is much value in some of the maths. **Proposed removing line 175 to 180.**

Line 185: the bin-by-bin systematics seem to have gotten lost. It makes things a bit confusing. **Add in a description of the bin-by-bin error**. Propose describing the bin-by-bin error first and then the width error.

Line 189: The resolution is not correct for systematic. **We should say systematic uncertainty or some such.** May be worth checking with Maurizio that he agrees.

PS asked for comments on wording to be scanned and sent through if possible.

Table 4: The TOF label and relation to line 203 was not clear. Please clarify.

Table 4: Some entries are 0. Try labelling as "< 0.01" where systematic is insignificant.

Table 4: Total systematic for 171.55 theta_x is not consistent with the other entries. Please fix.

Eq. 15: **Should have square root in denominator**. There was a question as to whether statistical error should appear in the denominator.

Eq. 16: **Remove n_data from the denominator.** This makes it consistent with equation 8. **Remove equation 8.**

JC asked what is being done in the code. JN says n_data is not in the code.

There was a discussion of how correlated chi2 were treated. Currently JN assumes uncorrelated because the calculation of deconvoluted errors did not converge properly. We decided to **remove chi2 from the deconvolution table**.

John was asked to include another results table; **add in convolved empty data compared to full data.**

We noted that Moliere was wider than data. G4 narrower. All more or less consistent within errors (1 sigma).

We agreed on another meeting aiming for **1 pm BST Friday October 1st**