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IWCD PMTs Calibration

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Plan

I/ Introduction

II/ Using the WCSim simulated true and digitised datasets to make sure the reconstructed datasets made sense

III/ Smearing and then calibrating the detectors

I/A) The calibration procedure

- Aim: calibrate IWCD 7,200 PMTs using only their response to the well-known light output.

- Method:
  - Simulate, in WCSim, the light source with the gps laser gun emitting isotropically.
  - Compare the Digitised PMTs response to the ‘true’ response.
  - Smear the PMTs’ reconstructed hit times randomly, to simulate potential experimental issues.
  - Calibrate out this smearing using only the experimentally accessible informations.

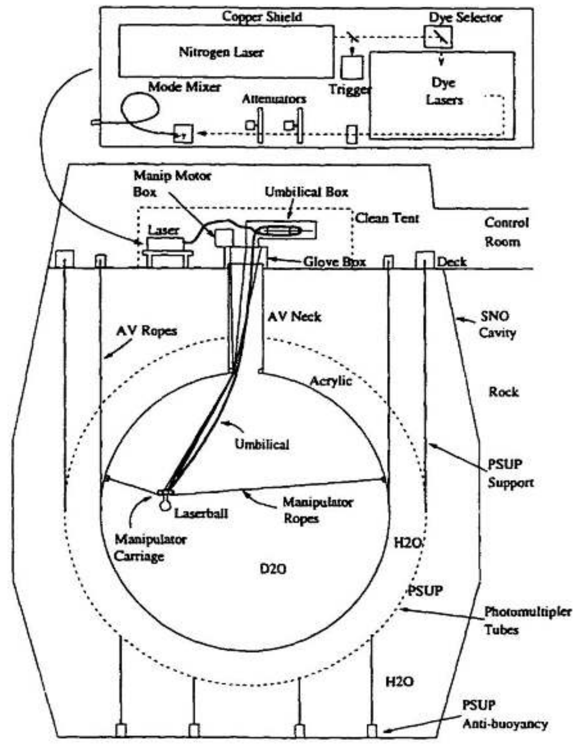


Figure 2.6: SNO calibration source manipulator system.

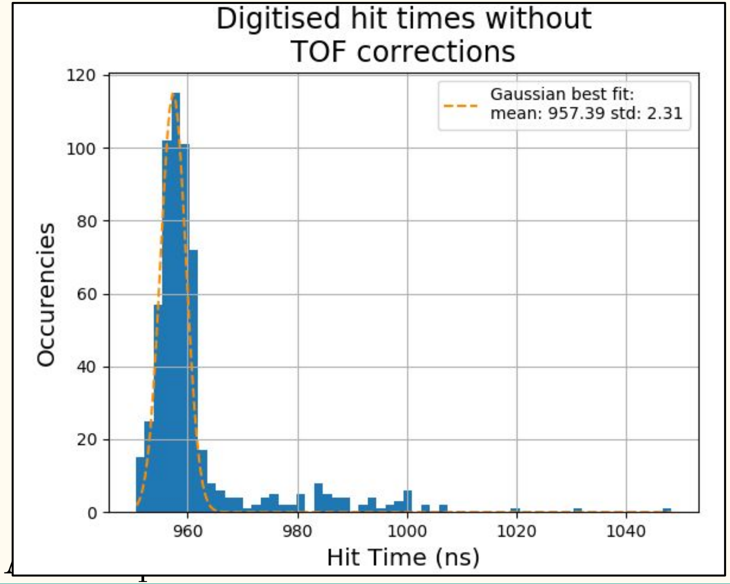
A similar design - R. Ford, Calibration of SNO for the detection of ^{8}B Neutrinos

I/B) The PMTs response to the light output

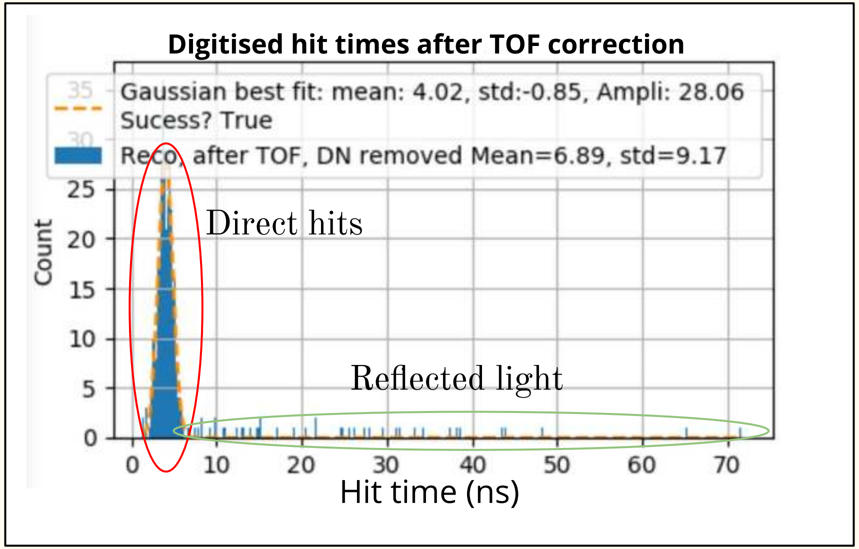
We want to compare the digitised data to the true data.

We have to correct for the digitised data :

1) Remove the 950ns offset in the digitised data.
2) For each PMT remove the Time Of Flight from the source to the PMT (assuming straight path) to have hit times centred at zero.
3) Add the Time Of Flight of the earliest hit (this first detection is t_0 in the digitised data but in the true data it is the light burst).

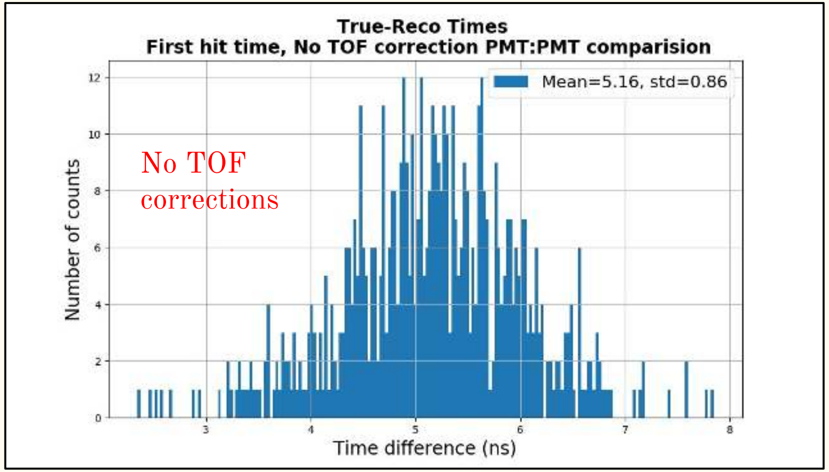


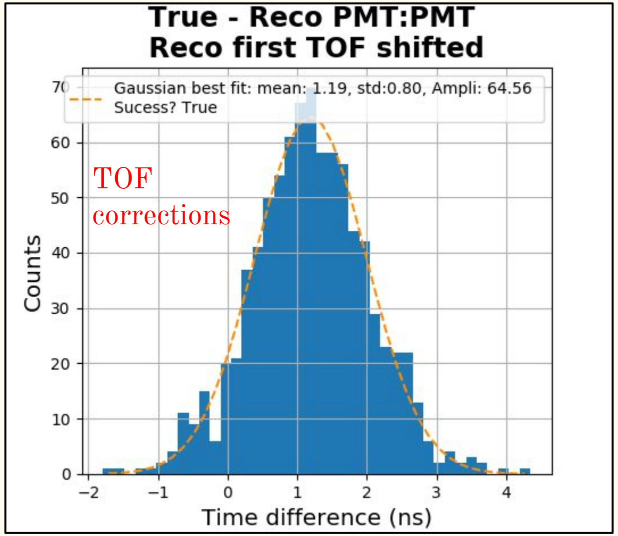
Offsets and TOF corrections



I/B) Comparing the true and digitised datasets

The TOF correction increases the precision: the mean difference between true and reco data is brought from 5.2ns to 1.2





Additional requirements for the comparison:

1) When a PMT records more than one hit time, select the earliest for analysis.
2) No Dark Noise.
3) Compare the true and reco datasets PMT by PMT

Conclusion: the digitised datasets can be corrected to agree with the true datasets to within 0.8ns with an offset of +1.2ns

II/A) Smearing the PMTs' hit times

Random PMT-dependant smearing

Choose randomly which pmt to smear (a user-controlled fraction of the PMTs are smeared).

For each PMT chosen: draw a random smearing value out of a gaussian of mean m and standard deviation std.

Repetitions over multiple Events

Add to that PMTs hit time the same smearing value across all Events (i.e. iterations of the simulation).

Gaussian Fittings for analysis

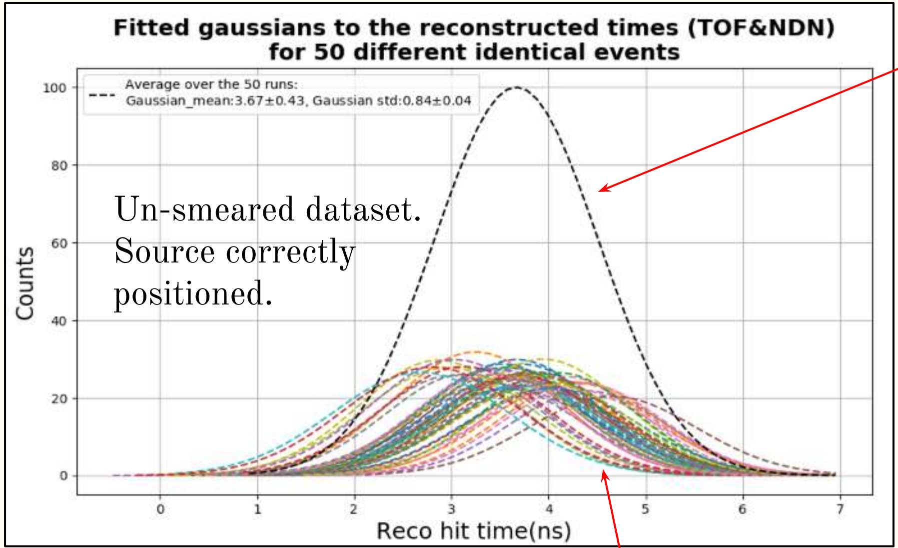
For each PMTs perform a Gaussian fit to the global hit time distribution (including all events), ignoring the reflected hits.

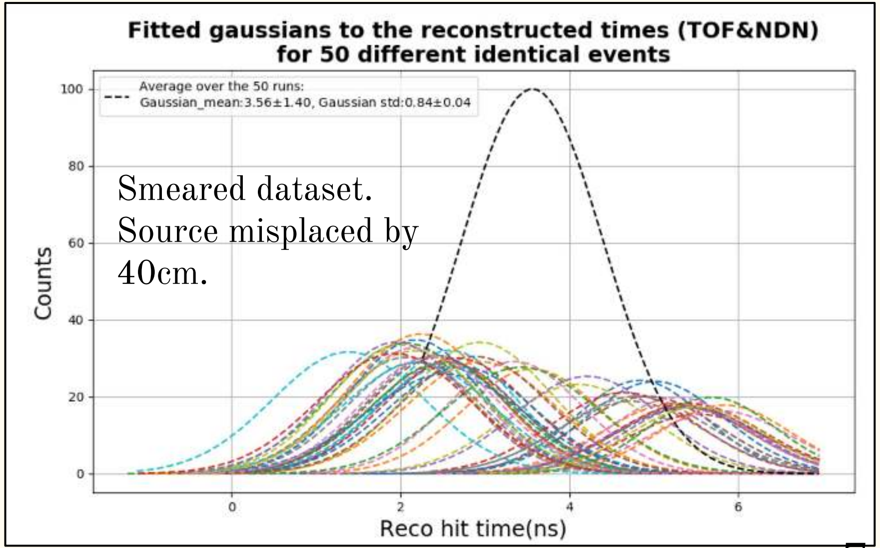
Finally, perform a Gaussian fit over all pmts and all events called total mean.

This provides the average hit time, which is the calibration reference.

II/B) Example of a ‘physical smearing’: misplacing the light source

Gaussian fit to all PMTs over the 50 events

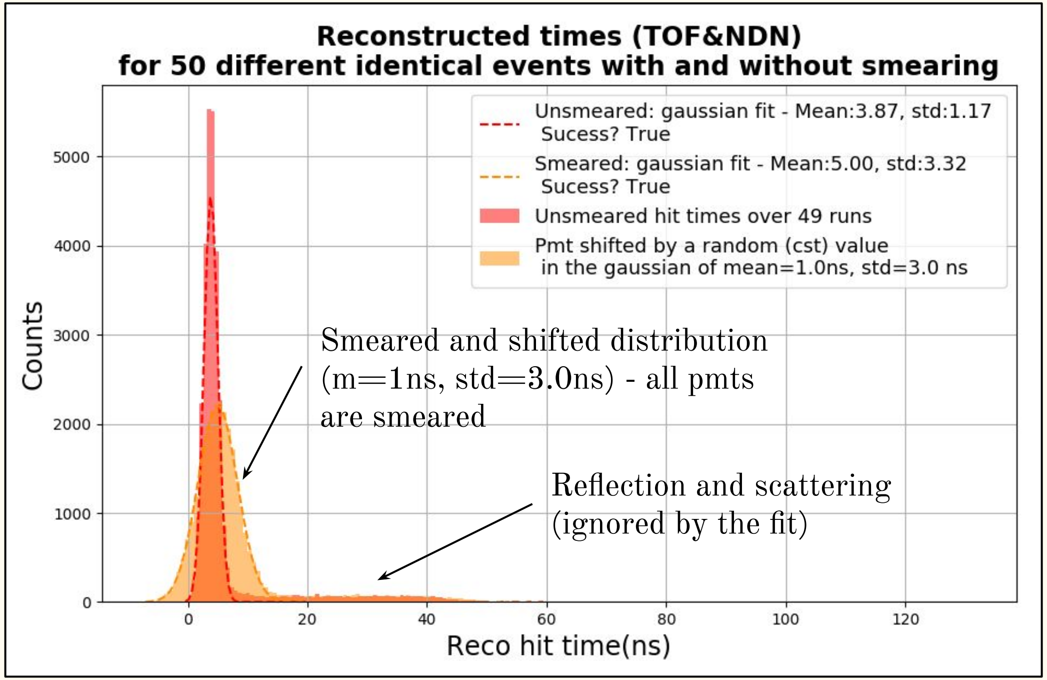




Gaussian fit to each PMT over the 50 events

II/C) Example of hit time distribution after smearing

All pmts are smeared by a different value drawn randomly out of a Gaussian distribution of mean 1ns and std 3ns

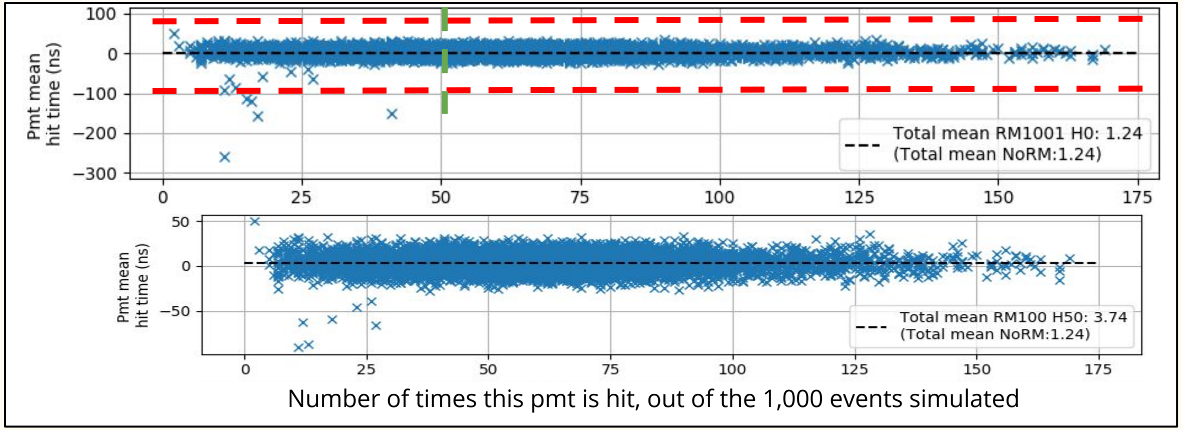


III/A) Determine which PMTs can be calibrated

Requirements for a good calibration:

- PMT did record data other than scattered/reflected photons.
- PMT was hit enough times (out of the 1,000 or so Events) for the fit to be meaningful.
- The Gaussian fit to the digitalised hit times was successful (and meaningful).
- The Total Mean only includes the data from PMTs that fulfill all above requirements.

Smearing of mean 0ns and std 9ns

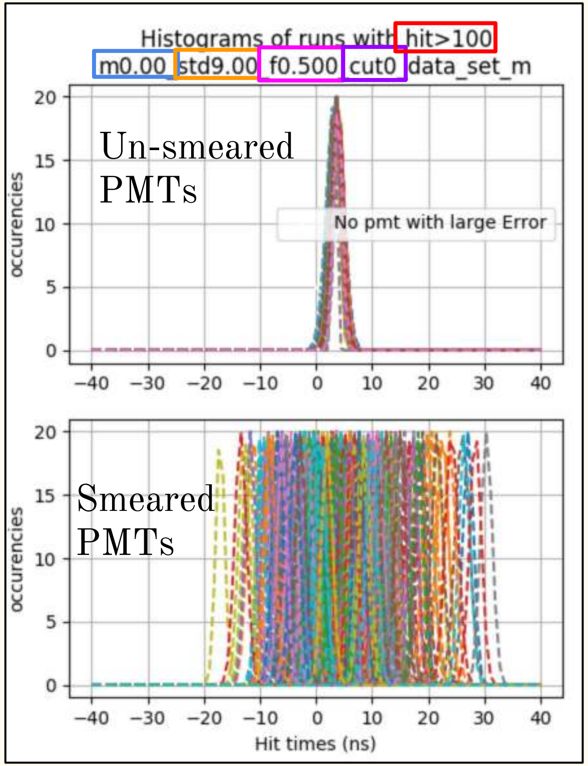


Mean Before requirements

Mean After requirements

III/ B) Calibrate the PMTs

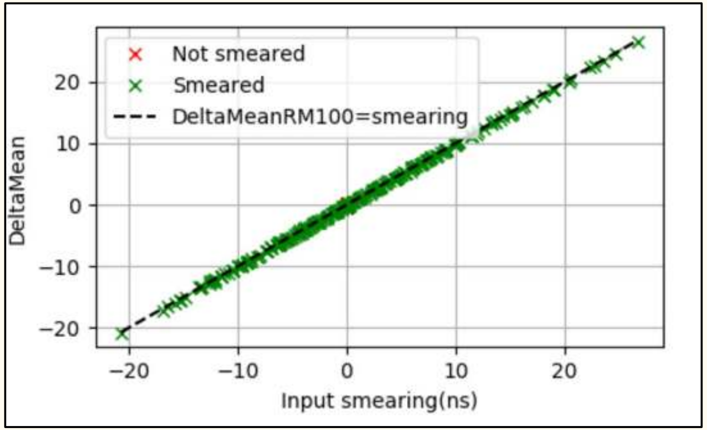
For each PMT fulfilling the requirements, plot the gaussian fit to its hit times.



Information about the run:

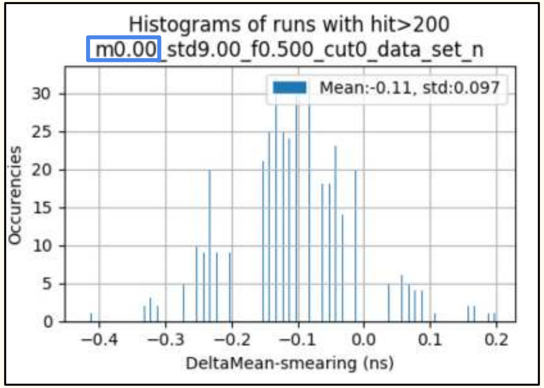
- Mean of smearing gaussian
- Std of the smearing gaussian
- Fraction of pmts hit (100=100%, 0.5~50%)
- Cut: minimal number of hits required to be smeared
- Hit: minimal number of hits required to be calibrated

Then subtract the PMT mean hit time to the Total Mean Hit Time (difference is called DeltaMeans) and compare this to the smearing value.

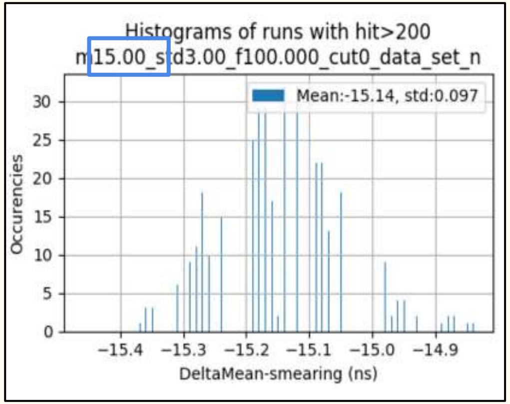


III/B) Calibrate the PMTs

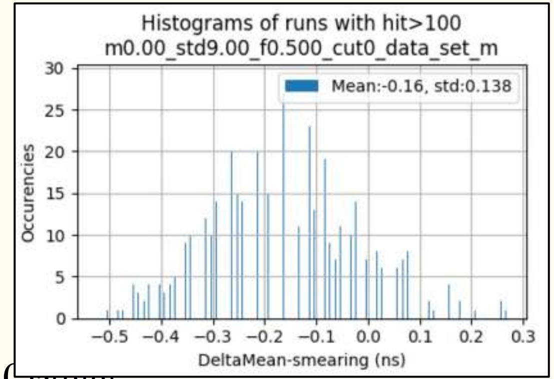
Example of histograms of the difference between DeltaMeans and the input SmearingValue (or 0 if there were no smearing).



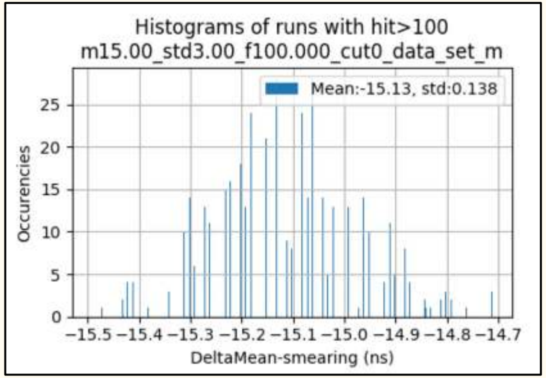
Cut at 200 hits.



When all the PMTs are smeared by a non-zero mean gaussian, we retrive the offsetting factor in calibration (since the Total mean moves as well).

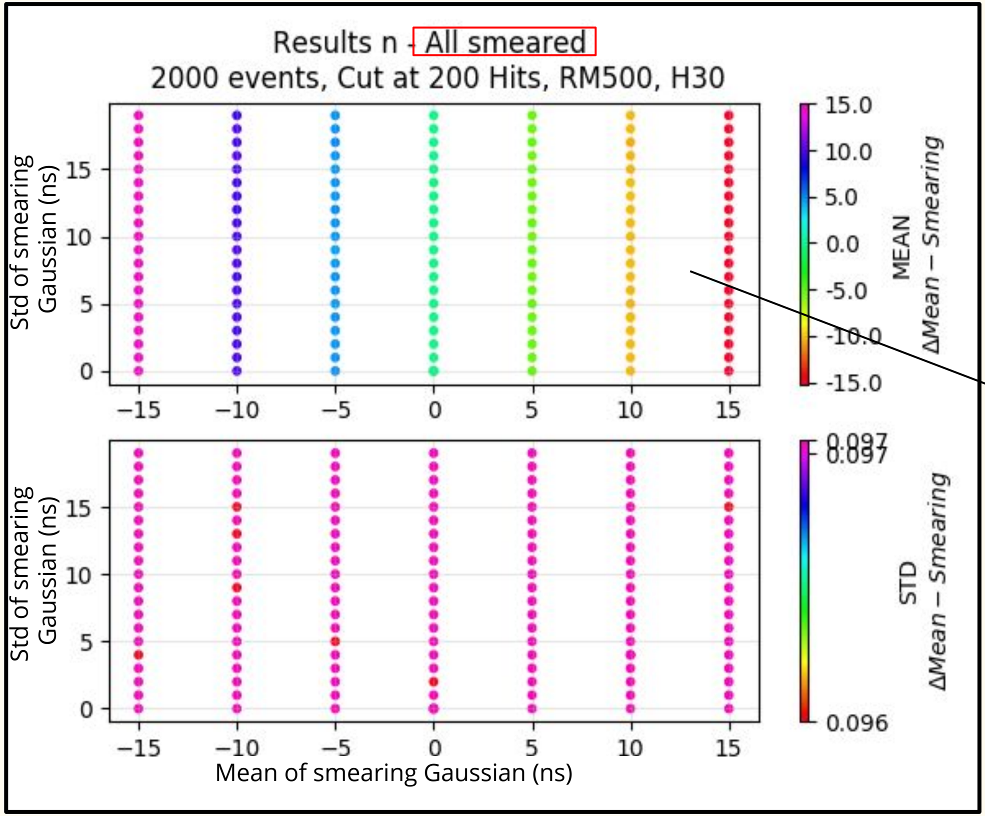


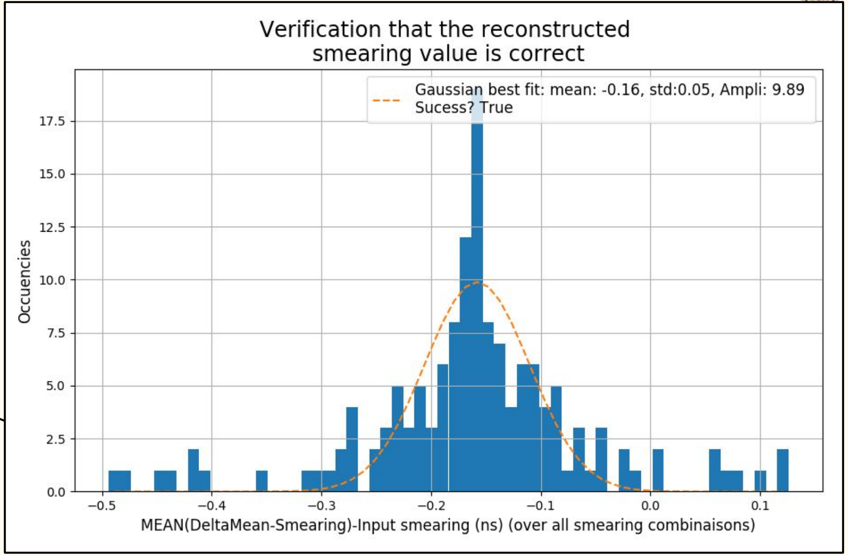
Same dataset with cut at 100 hits.



Doubling the statistics (by doubling the number of event Increases the accuracy from 0.13ns to 0.09ns)

III/C) An estimation of the quality of the smearing



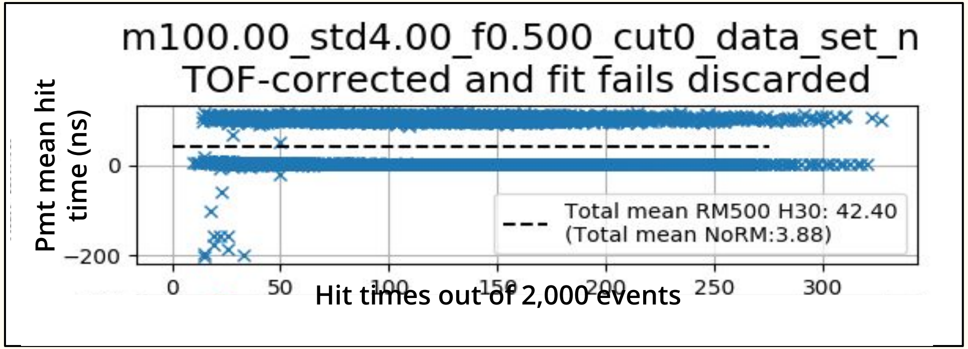


When all pmts are smeared, the mean of the DeltaMean-SmearingValue is almost exactly the input mean smearing.

The Standard deviation is constant with a value of 0.097 ns.

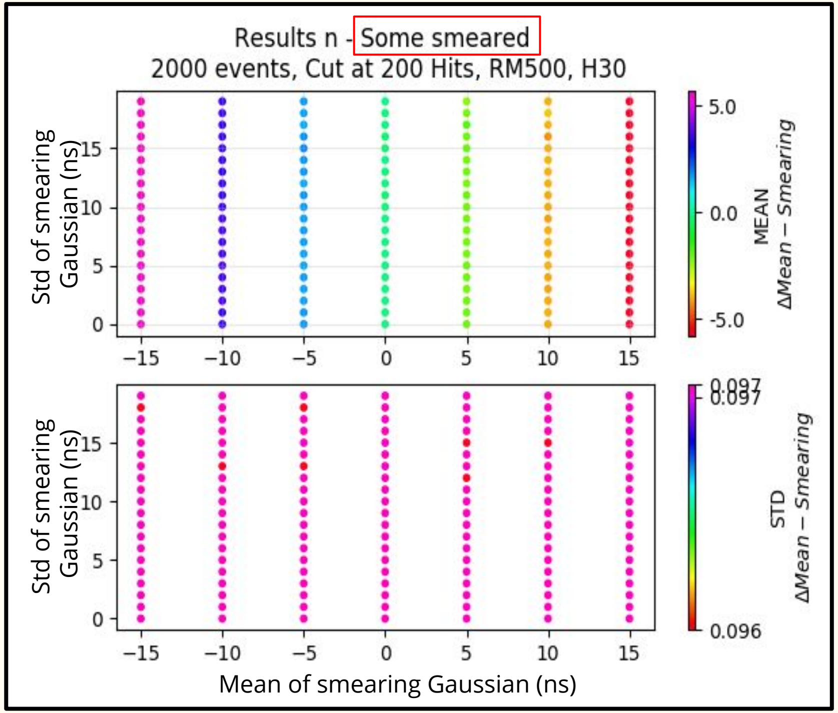
III/C) An estimation of the quality of the smearing

When some pmts are smeared by gaussian of different mean two populations with different offsets arise and the calculated mean isn't accurate anymore.



Because of this issue (here only half of the pmts are smeared) the mean of the DeltaMean-SmearingValue is not exactly the input mean of the smearing Gaussian anymore.

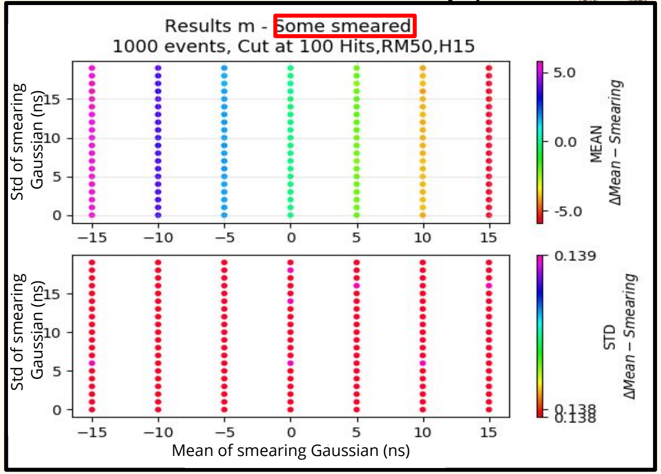
The Standard deviation is still almost constant with a value of 0.097 ns.

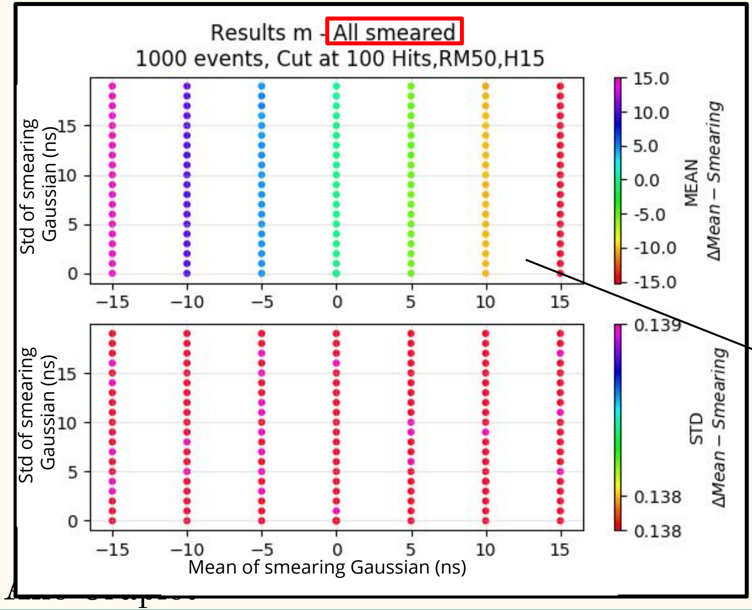


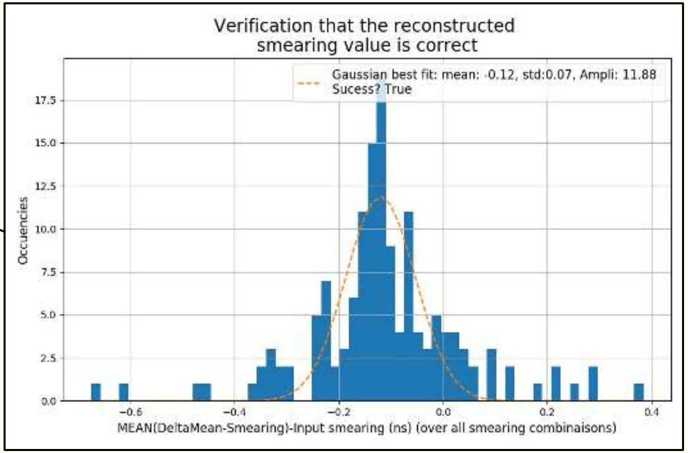
III/C) An estimation of the quality of the smearing

For comparison - having the same dataset but with only 1,000 events. The cuts have to be slightly modified, as presented in legend.

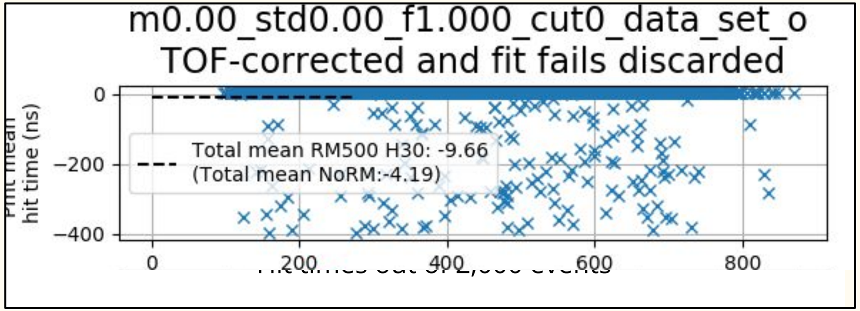
Similar quality with a higher constant standard deviation at 0.138 ns.



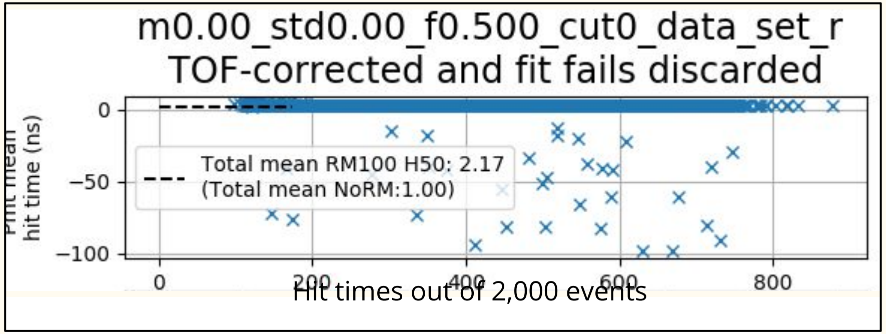




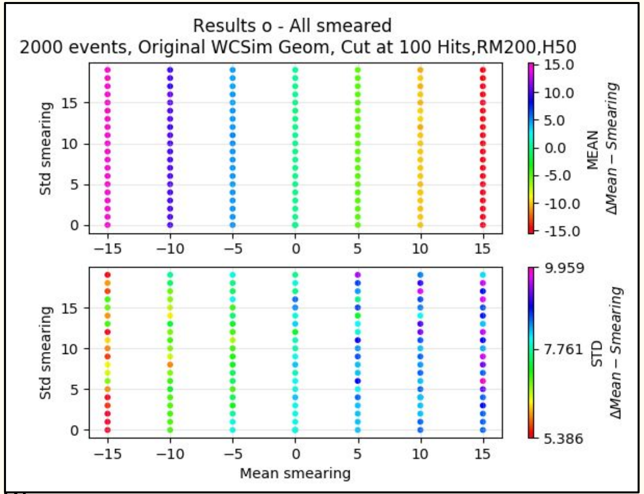
IV/A) Using this analysis on the WCTE geometry



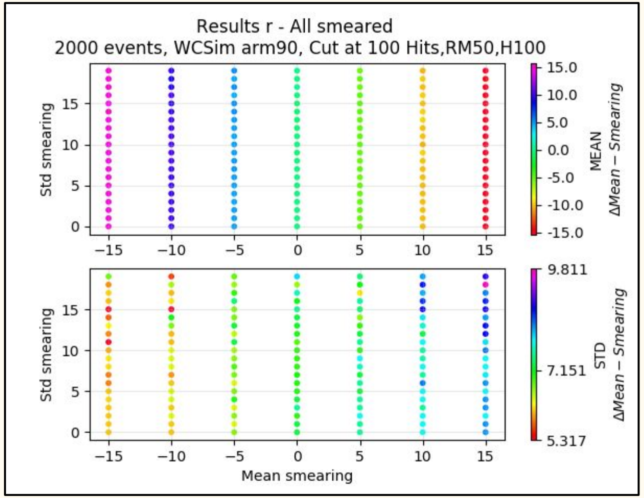
No Smearing and initial geometry: Still some unexplained very early hits...



Similarly with the arm at 90 degrees...



The mean of the DeltaMeans-Smearing is correct however the standard deviation is very large....



Conclusion

Efficient method to calibrate the tank's photomultiplier tubes using thousands of repetitions of the same calibration process whereby an isotropic source is located inside of the tank.

Inputs required on top of the information already available: Position and characteristics of the light source and velocity of photons in the tank.

All the calibrations have a spread of 0.097ns (with 2,000 events) or 0.138ns (with only 1,000 events) when working with the IWCD simulations. When all the PMTs are smeared, the calibration is accurate to $<$0.2ns.

Testing this method with the WCTE geometry without changing any parameter showed that this analysis could in principle be used for this detector, but that it needs some modifications.

IV/B) Potential solutions/leads to investigate

- Modify the fitting program to have a requirement on the amplitude of the fitted gaussian.
- Trace the photons’ paths within the tank (inside WCSim).
- Could be a binning issue

Questions for practise

- Time spent on each slide ok ?
- Not too much text ?
- Slide 8 - is it an issue (will it raise questions?)
- Issuer with the way we define accuracy
- Being a bit confused with the labeling of the different experiments...
- Which additional figures could I potentially need after the last slide ?
- Not include slide 16 for the actual presentation (only for our discussion on Thursday ?)