Analysis Note for 60H Dataset Relative Unblinding

University of ABC

Warning: This template might be highly biased towards how Recon West + UW team operates and documents analysis procedures. Templates specific for Recon East + analysis teams and Recon Q + analysis teams will require certain level of tweaking. Lawrence and Kim will work with the team leaders to come up with appropriate versions.

High-level Summary

- Lead Analyst(s): AAA, Support Analyst(s): BBB, CCC, DDD
- Positron Reconstruction Method: Recon East, Recon West or Recon Q
- Software Release and Dataset: V9_11_0, gm2pro_daq_full_run1_60h_5033A_withfullDQC
- Histogramming Method(s): Threshold, Asymmetry-weighted, Energy-binned or Ratio
- Gain and Pileup Correction Methods: Default in recon, Shadow window
- Lost Muon Spectrum Extraction: Triple coincidence, confirmation with tracking analysis
- Models for CBO and VW: Exponential envelopes and frequencies from tracking analysis
- Final Fit Function: N(t) = N*exp(-t/tau)*[1+Acos(w_at+phi)]*bla*bla*bla
- w_a = ABC +- XYZ (blinded with common string), for each method
- Reduced Chi2 = 1.01 {NDF=4000, acceptable range = 1 +- √(2/NDF)}, for each method

1. Analysis Procedures

1.1 Key parameters in Reconstruction Method

Reconstruction method: Recon North

Pulse Fitting ADT: 5 ns

Fitter Threshold: 50 ADC over baseline

Energy Calibration: Lost muons

Timing Alignment: Adjacent shower method

Clustering ADT: 7 ns

Customized Reconstruction Tip: Did you re-calibrate the timing or energy by yourself to get an optimal result from the fit? Please mention it here.

1.2 Analysis Data Preparation Procedure

1. Submit jobs to Fermigrid to produce bare ROOT files using an art analyzer (available at gm2analyses/analysis/MyAnalysis_module.cc in feature/ABCAnalysis branch)
2. Produce 3D histograms from produced bare ROOT files using a ROOT macro (available at gm2analyses/analysis/MyAnalysis_module.cc in feature/ABCAnalysis branch)
3. Histograms for fitting, pileup correction, lost muons all produced from produced 3D histograms using several ROOT macros (available at gm2analyses/analysis/MyAnalysis_module.cc in feature/ABCAnalysis branch)

1.3 Histogramming Procedure

Method: Threshold, Energy-binned

Histogramming Procedure

1. Loop through all clusters and fill in a time histogram for each calorimeter for clusters with energy > 1.7 GeV and time > 25 us
2. Histograms are constructed using ROOT's TH1D class with 4020 bins from 0 to 600 us

Histogramming Tip: If you use cluster time randomization method to reduce the fast rotation effect, please mention it here and include the name/version of the random number library.

1.4 Gain correction procedure

Gain correction method: Default by the Italian Calibration Team

Gain Correction Procedure

1. Long term gain is corrected using out-of-fill lasers including normalization with Source Monitor
2. In-fill gain is corrected using in-fill lasers including normalization with Source Monitor
3. Short-term double pulse (STDP) effect is not included

1.5 Pileup correction procedure

Pileup correction method: Shadow window

Pileup Correction Procedure

1. For each fill and for each cluster in a fill, search for a second cluster within 5-10 ns
2. Construct a (E,t) spectrum, D for the combined cluster ($E=E_1+E_2$, $t=t_1$) for each calorimeter
3. Subtract D from the original T-method histogram

1.6 Lost muon spectrum extraction procedure

Method: Triple coincidence of clusters

1. Triple coincidence of clusters in 3 consecutive calorimeters are made with an energy cut of 120 MeV < E < 220 MeV and 5 ns < dt < 7.5 ns
2. A time histogram is made with the muon cluster in the first calorimeter
3. Fit function as the following is used for the final fit:

1.7 Beam dynamics: CBO model

1. CBO frequency as a function of time is taken from the tracking analysis (docdb 12345)
2. An exponential function is assumed for the CBO decoherence
3. 2CBO term is also included
4. Final CBO, 2CBO terms are: N, A and Phase with the following function:

1.8 Beam dynamics: Vertical Waist model

1. VW frequency as a function of time is taken from the tracking analysis (docdb 24680)
2. An exponential function is assumed for the VW decoherence
3. Final VW term is:

1.9 Final Fit Function for histograms

The following function is used for the final fit for each calorimeter and for calorimeter sum. Please specify also which parameters are floating and which parameters are fixed from other analysis such as the changing CBO frequency from tracking analyses.

Recommended fit start time and end time are 30.2 us and 650 us (from Aaron), respectively. It is very important to use this range for the T-method result comparison among T-method analysts.

(to be discussed)

2. Analysis results

2.1 Pre-corrected and corrected energy and time spectrum

Energy and time spectra for 4 representative calorimeters: Calo 1, 7, 13 and 23 **(To be finalized)**

Pre-corrected = directly from production dataset

2.2 "14"-parameter fit to pre-corrected and corrected T-hist

As a cross check among all T-method analysts. Show both calo sum result and (N, A, tau, R, phase, A_{CBO}, A_{VW}, K_{loss}) vs calo. Show also the correlation matrix for comparison.

(assuming tau_{CBO}, $omega_{CBO}$, tau_{VW} and $omega_{VW}$ are fixed)

2.3 Residual and FFT of pre-corrected and corrected T-hist

As a cross check among all T-method analysts and a demonstration that all detector and beam effects are being taken care of for the final fit.

2.4 Start time scans for all floating parameters in the fit

Parameters of interests versus start times:

N, A, tau, R, phase, A_{CBO}, tau_{CBO}, $phase_{CBO}$, A_{VW}, tau_{VW}, $phase_{VW}$, K_{loss}

(assuming $omega_{CBO}$ and $omega_{VW}$ coming from tracking analyses)

2.5 Stop time scans for all floating parameters in the fit

Parameters of interests versus stop times:

N, A, tau, R, phase, A_{CBO}, tau_{CBO}, $phase_{CBO}$, A_{VW}, tau_{VW}, $phase_{VW}$, K_{loss}

(assuming $omega_{CBO}$ and $omega_{VW}$ coming from tracking analyses)

2.6 Consistency among calorimeters

Plot parameters of interests versus calorimeter number:

N, A, tau, R, phase, A_{CBO}, tau_{CBO}, $phase_{CBO}$, A_{VW}, tau_{VW}, $phase_{VW}$, K_{loss}

(assuming $omega_{CBO}$ and $omega_{VW}$ coming from tracking analyses)

2.7 Correlation and covariance matrix for the fit parameters

Can be extracted easily using the “S” option in your ROOT fit (in case you are using ROOT to Fit).

For every fit that involves R, please store your histograms into a ROOT file with URL/path information given, so that the reviewers can examine them in the review process.

3. Systematic Uncertainty Estimations

3.1 Sensitivity of w_a to gain corrections

- Extract sensitivity from R versus in-fill gain multiplication
- Extract sensitivity from R versus short term double pulse multiplication
- Estimates correction uncertainty from a technique(s) of your choice (e.g. early-to-late E spectrum)
- Estimates systematic uncertainties from gain corrections

- Reasoning behind choice of technique and methodology (why this range of parameter variation, why comparing these shape, etc)

3.2 Sensitivity of w_a to pileup

- Extract sensitivity from R versus pileup multiplication
- Estimates correction uncertainty from a technique(s) of your choice (e.g. high energy tail in E spectrum)
- Estimates systematic uncertainties from pileup correction
- Reasoning behind choice of technique and methodology (why this range of parameter variation, why comparing these shape, etc)

Pileup Tip: If the triplets are not being handled, please estimate the systematic uncertainty due to the omission.

3.3 Sensitivity of w_a to lost muon function shape

(A possible method)

- Obtain lost muon coefficient K_{loss} from the final fit
- Extract sensitivity from R versus K_{loss} multiplication
- Estimates correction uncertainty from a technique(s) of your choice (e.g. compare with tracking analysis)
- Estimates systematic uncertainties from lost muon function extraction
- Reasoning behind choice of technique and methodology (why this range of parameter variation, why comparing these shape, etc)

Lost Muon Tip: Based on BNL experience, the largest systematic of lost muon is coming from the phase population (80 ppb). We need to get an accurate shape of the lost muon function, a simulated muon spin distribution at the end of M5 (G4beamline), an accurate model of the g-2 storage ring (gm2ringsim, BMAD, On Kim model, etc) to precisely estimate this effect.

3.4 Sensitivity of w_a to CBO function

- Obtain A_{CBO}, tau_{CBO}, $phase_{CBO}$ from the final fit (assuming $omega_{CBO}$ is from tracking analysis)
- Extract sensitivity from R versus each parameter (e.g. vary each parameter by +- 25%)

- Estimates correction uncertainty from a technique(s) of your choice
- Estimates systematic uncertainties from CBO function
- Reasoning behind choice of technique and methodology (why this range of parameter variation, why comparing these shape, etc)

3.5 Sensitivity of w_a to VW function

- Obtain A_{VW}, tau_{VW}, $phase_{VW}$ from the final fit (assuming $omega_{VW}$ is from tracking analysis)
- Extract sensitivity from R versus each parameter (e.g. vary each parameter by +- 25%)
- Estimates correction uncertainty from a technique(s) of your choice
- Estimates systematic uncertainties from VW function
- Reasoning behind choice of technique and methodology (why this range of parameter variation, why comparing these shape, etc)

3.6 Sensitivity of w_a to various effects

- Bin size of histogram (60 ppb! from BNL, better check here)
- Reliability of fitter (e.g. estimate using toyMC + 5-parameter fit, BNL ~ 30 ppb)
- Beam relaxation term (beam scrapping effect, BNL ~ 50 ppb)
- Higher order beam effect (double CBO, VHF, BNL < 30 ppb)
- Vertical Centroid (acceptance effect, estimated with FSD and tracker for BNL, ~ 30 ppb)
- Vertical Width (acceptance effect, estimated with FSD and tracker for BNL, ~ 20 ppb)
- Bad resistor? (changing CBO/VW frequency, changing vertical beam position)
- Reasoning behind choice of techniques and methodologies (why this range of parameter variation, why comparing these shape, etc)

3.7 Final systematic uncertainty table

Put your favorite systematic table here!

3.8 Final results

w_a = ABC +- XYZ (blinded with common string), for each method

Reduced Chi2 = 1.01 {NDF=4000, acceptable range = 1 +- √(2/NDF)}, for each method = FGH