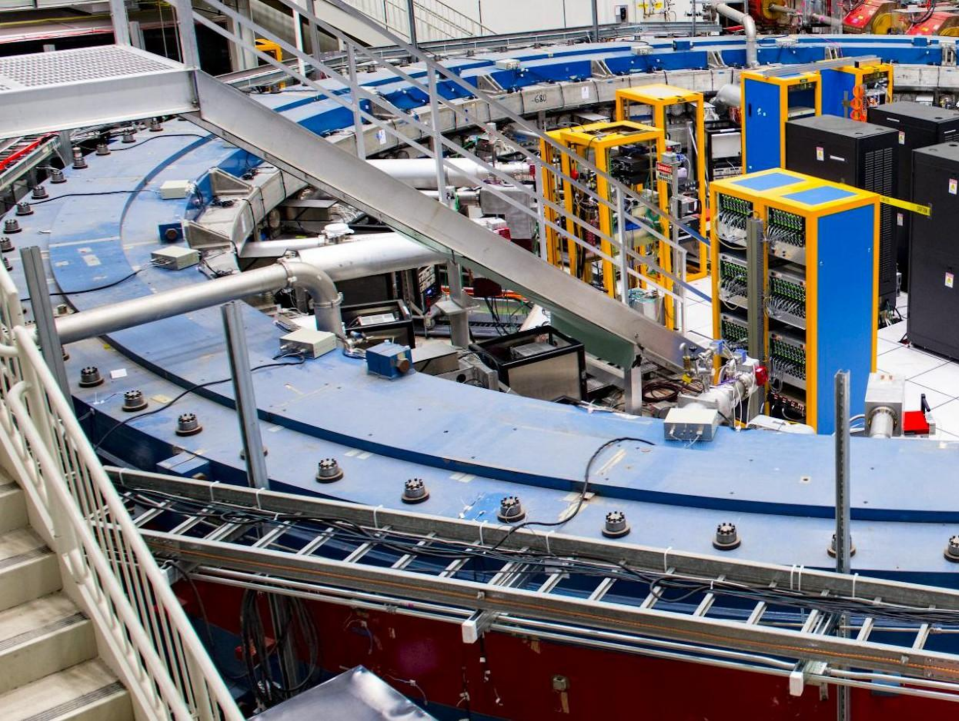
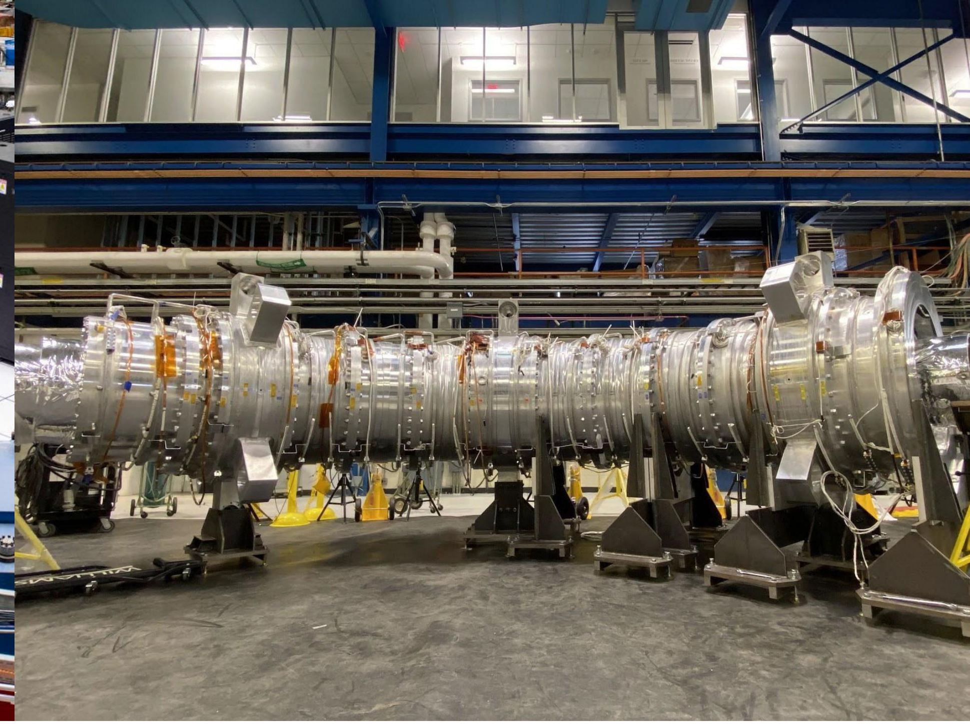
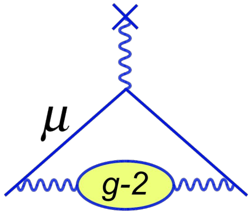




Measuring the anomalous precession frequency of the muon with the Muon g-2 tracking detectors

George Sweetmore

06/04/2022



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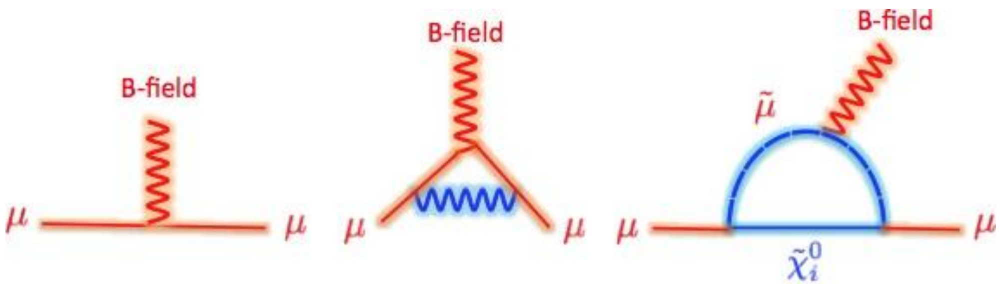
What are we searching for?

- The muon MDM (a_μ) is measured to a sub part-per-million precision and can be used as a probe for new physics from virtual loops.
- The BNL E821 Muon g-2 experiment found a ~3.7σ discrepancy from the Standard Model (SM) prediction
- The Fermilab Muon g-2 Experiment (E989) result, using the Run-1 calorimeter data, has a ~4.2σ discrepancy from the SM prediction.



"Dirac Interaction"
g=2

QED "Schwinger Interaction"
(g-2)=α/π

BSM SUSY interaction

$$a_\mu = \frac{g-2}{2}$$

$$\vec{\omega}_a = \vec{\omega}_s - \vec{\omega}_c = -\frac{(g-2)}{2}\frac{q}{m}\vec{B} = -a_\mu \frac{q}{m}\vec{B}$$

Spin frequency

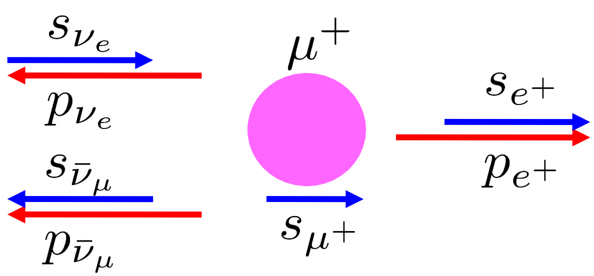
$$\vec{\omega}_s = -g\frac{q}{2m}\vec{B} - (1-\gamma)\frac{q}{\gamma m}\vec{B}$$

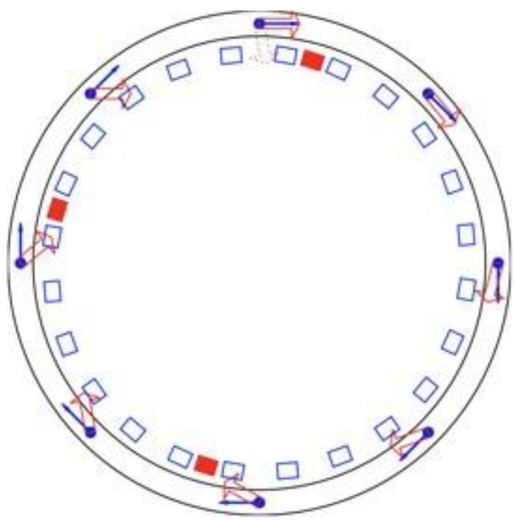
$$\vec{\omega}_c = -\frac{q}{\gamma m}\vec{B}$$

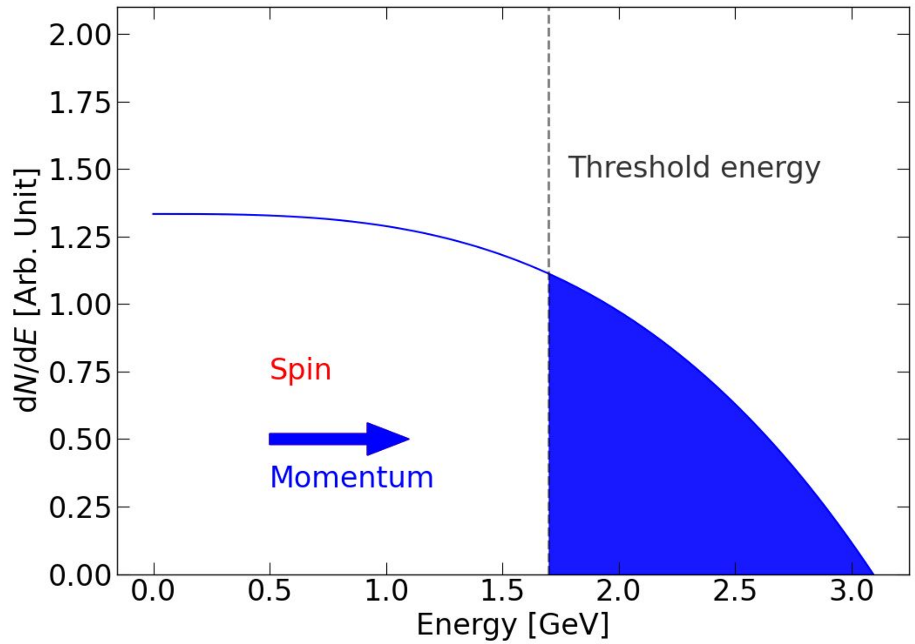
Cyclotron frequency

How can we extract ω_a ?

- e^+ preferentially emitted in direction of muon spin





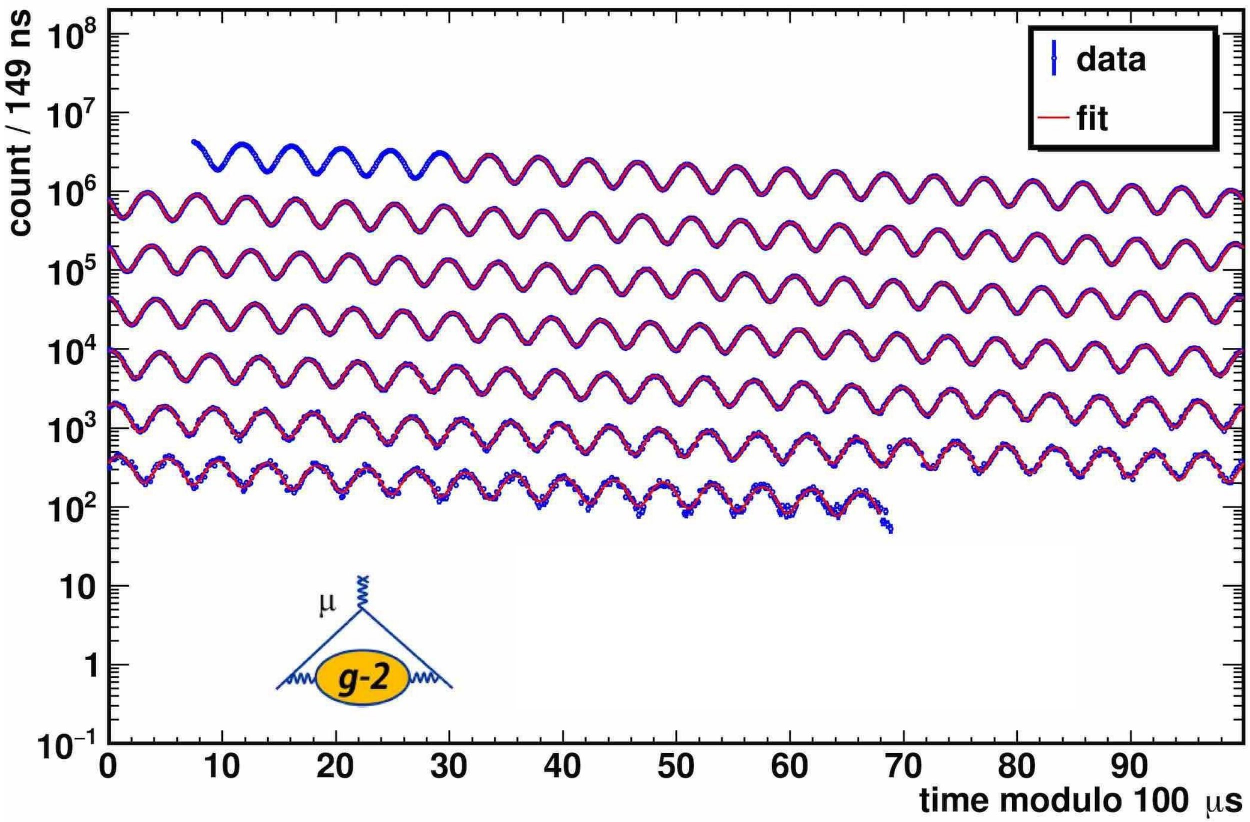


The number of high momentum positrons above a fixed energy threshold oscillates at precession frequency (ω_a)

Simply count the number above an energy threshold vs time

How can we extract ω_a ?

- The procedure to extract ω_a is to bin the data into time bins equal to the cyclotron period (149.2 ns).



$$N_e(t) \simeq N_0 e^{-\frac{t}{\gamma\tau}} [1 - A\cos(\omega_a t + \phi_a)]$$

How can we extract ω_a ?

- Full fit needs a 22 parameter function
- Data needs to be corrected for detector pileup before fitting
- Pileup and lost muon systematic contributions are detector dependent

$$f(t) \equiv N_0 \times e^{-t/\tau} \left[1 + A \times A_{CBO}(t) \cos\left(\omega_a t - \varphi - \varphi_{CBO}(t)\right)\right] \times$$
$$\times N_{CBO}(t) \times LM(t) \times VW(t) \times varY(t)$$

$$A_{CBO}(t) = 1 + A_{CBOA} e^{-t/\tau_{CBO}} \cos\left(\omega_{CBO} t - \varphi_{CBOA}\right)$$
$$\varphi_{CBO}(t) = A_{CBOP} e^{-t/\tau_{CBO}} \cos\left(\omega_{CBO} t - \varphi_{CBOP}\right)$$
$$N_{CBO}(t) = 1 + A_{CBON} e^{-t/\tau_{CBO}} \cos\left(\omega_{CBO} t - \varphi_{CBON}\right) +$$
$$+ A_{CBO2N} e^{-2t/\tau_{CBO}} \cos\left(2\omega_{CBO} t - \varphi_{CBO2N}\right)$$
$$VW(t) = 1 + A_{VW} e^{-t/\tau_{VW}} \cos\left(\omega_{VW} t - \varphi_{VW}\right)$$
$$LM(t) = 1 - k_{LM} \times J(t), \quad J(t) \equiv \int L_{3+4+5}(t') \exp\left(t'/\tau\right) dt'$$

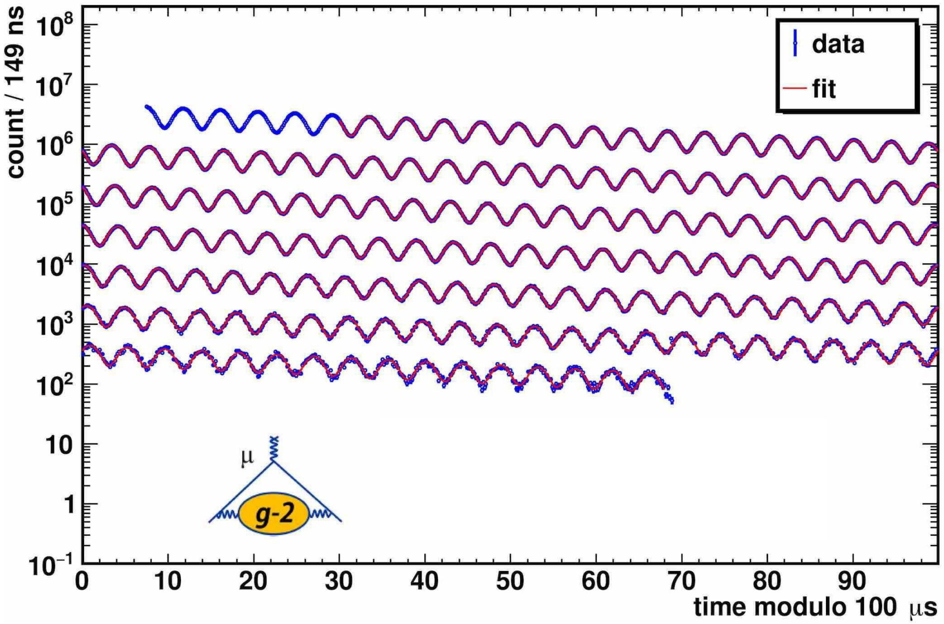
Beam dynamics corrections

Lost muon correction

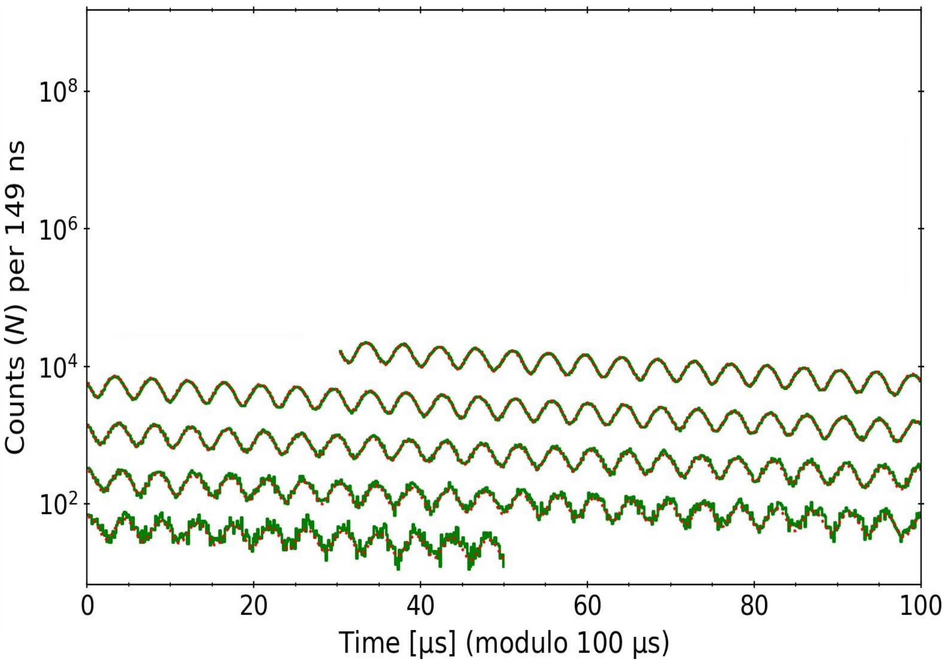
Why perform a tracker independent ω_a measurement?

- The experiment currently measures ω_a using positron information from the calorimeters.
- Tracker measurement allows a cross-check with a different set of systematics

Calorimeter (60hr data)

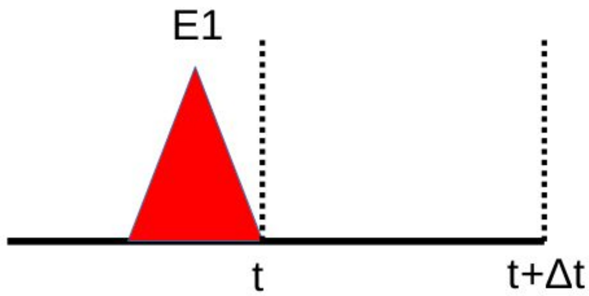


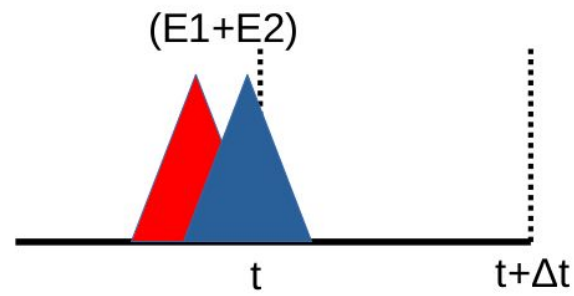
Tracker (60hr data)



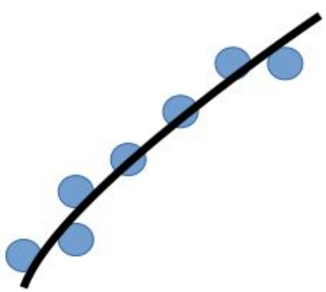
What is Pileup?

- Pileup in the calorimeter occurs when two (or more) decay positrons enter the calorimeter crystal within a very small window of time. The resolution of the detector isn't enough to distinguish them so it identifies this as a single pulse with the sum energy of the positrons.

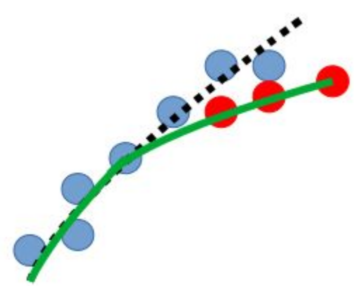




- Pileup in the tracker occurs when two (or more) decay positrons enter the tracker within a very small window of time. If this occurs, then the track reconstruction algorithms can misidentify the trajectories as single tracks and bias the momentum determination.

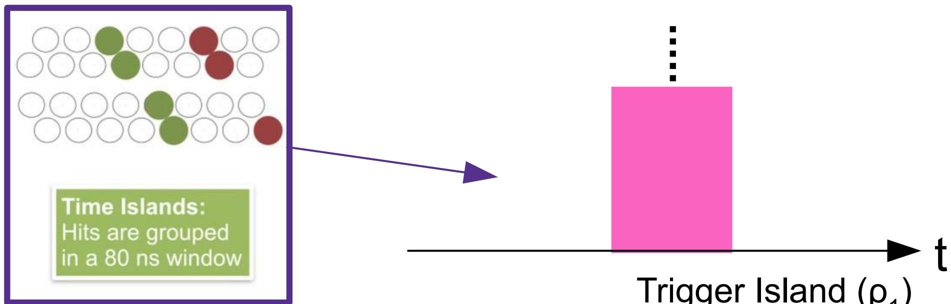


Normal track



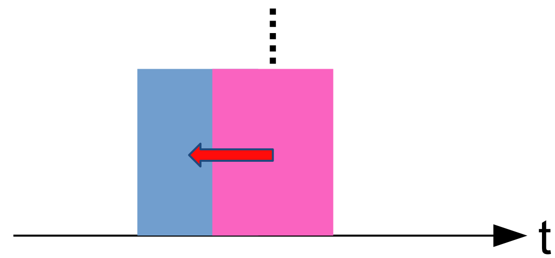
Misidentified pileup track

'Shifted Window' Pileup approach from data



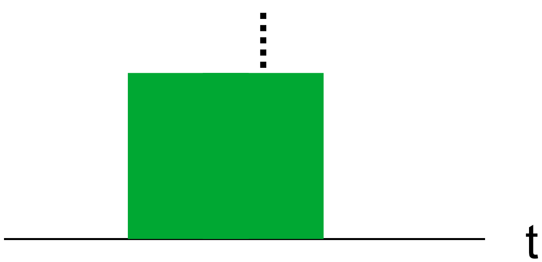
Trigger Island (ρ_1)

1: Take each island as a 'trigger'



Shifted Island (ρ_2)

2: Duplicate the hits and shift them back



Combined Island (ρ_{1+2})

3: End with an island with combined hits

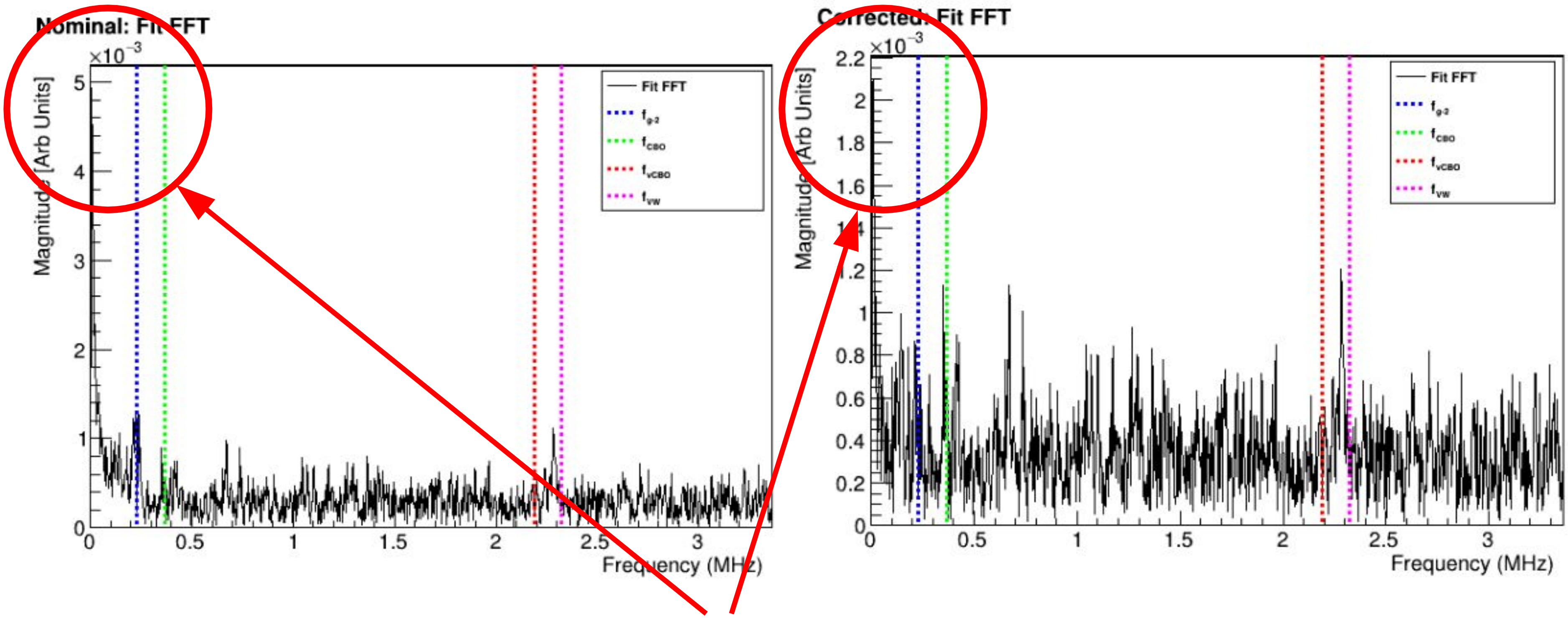
Generate 3 sets of tracks ($\rho_1, \rho_1, \rho_{1+2}$)

4: Form a spectrum based on equation and subtract from the nominal track spectrum

$$\delta\rho_{pu}(t) = \frac{\rho_{1+2}(t) - \rho_2(t) - \rho_1(t)}{2}$$

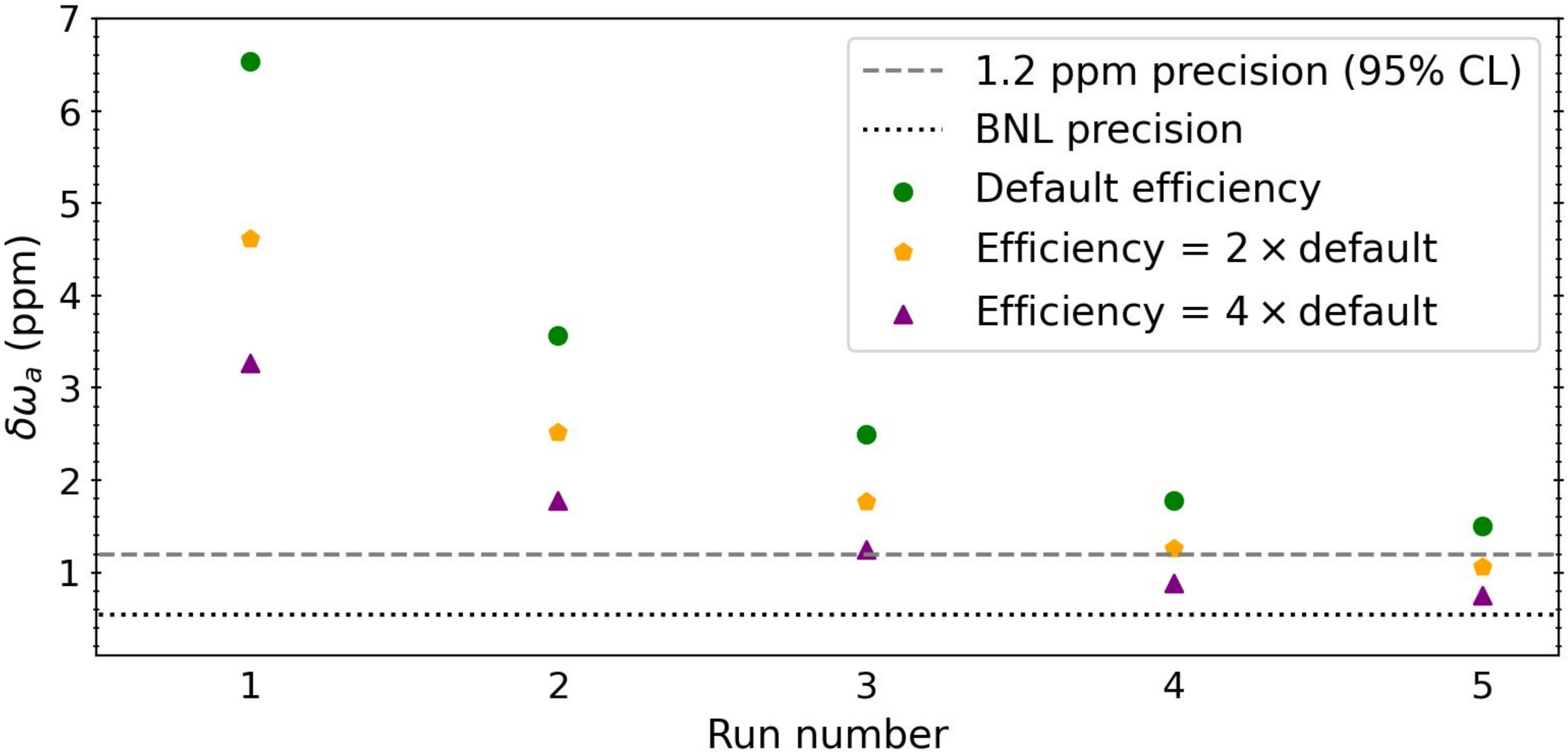
‘Shifted Window’ Pileup approach from data

Using a fast Fourier transform (FFT) of our fit we can see the residual frequencies we have missed



Reduction of a factor of 2 in the ‘slow term’ peak at zero shows promise in the pileup method. However, the algorithm still needs to be refined

Outlook



- With the Run 1 tracking efficiency alone we can achieve a ω_a measurement at the 95% confidence level by Run 5
- With new improvements to the tracking algorithm it is expected that we can achieve a precision equivalent to the BNL measurement