EDM tracking analysis at FNAL

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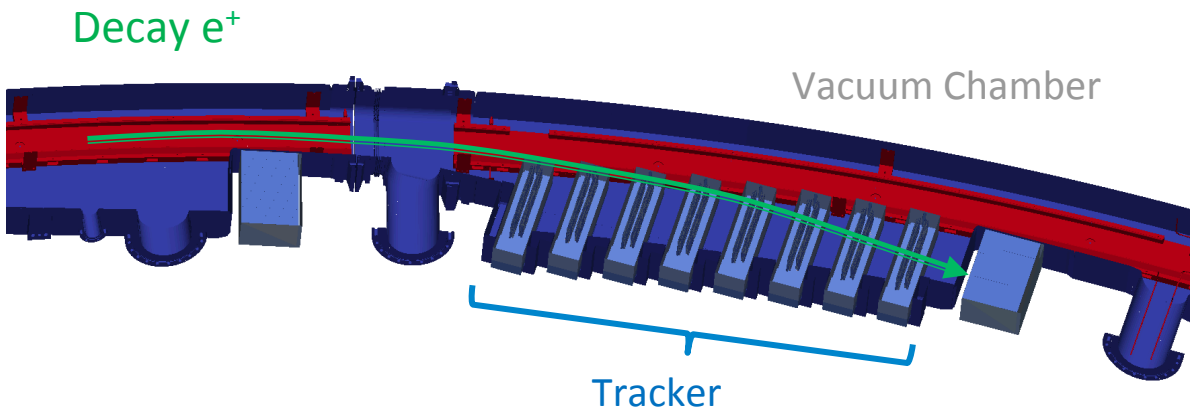
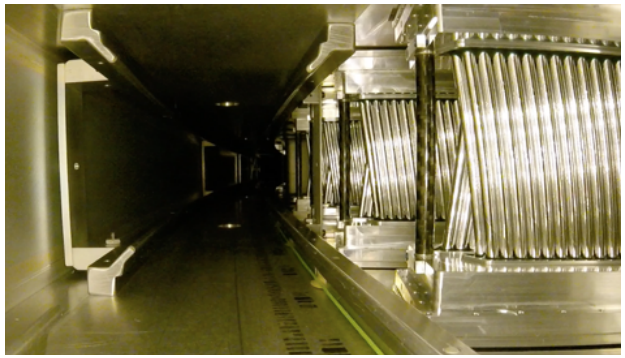
Oct 4th 2019

Introduction

- Tracking analysis at BNL (which sets best limit on muon EDM) equally sensitive to other BNL analyses but statistically limited
- Greatly improved tracking at FNAL compared to BNL:
  - Trackers present for more runs -> higher statistics
  - Turn on time ~2μs compared to 150μs
  - Acceptance increase - 2 tracking stations with >3m azimuthal coverage
  - Track and calorimeter matching -> particle ID
- In this talk:
  - Outline strategy for blinding
  - Show latest vertical oscillation studies
  - MC studies into sensitivity

Tracking detectors





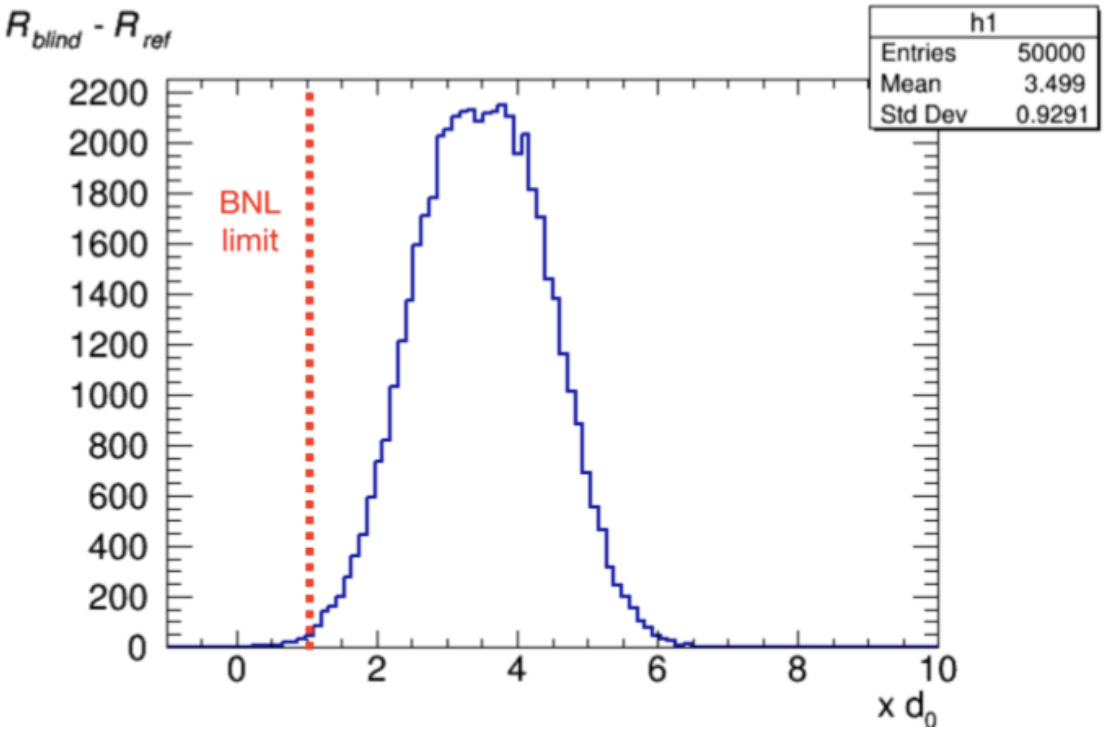
- Tracking detectors placed in 2 positions around the ring
- We study the muon beam by extrapolating the decay positrons back to the point of radial tangency (see previous talk)
- Measure the momentum, time, decay position and vertical decay angle
- Vertical angle vs time contains the key information for EDM

Note on blinding

- The plot that will be analysed is the vertical decay angle (at the extrapolated point of radial tangency) as a function of time
- Need to avoid looking at this plot directly, especially with a known g-2 phase
- Blind this plot by introducing an EDM signal of unknown size, greater than the current limit

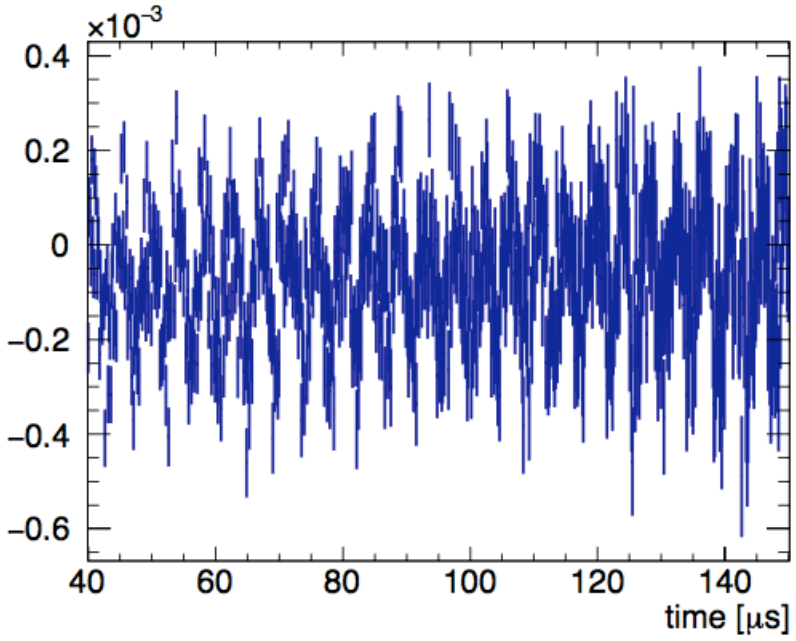
Blinding - strategy

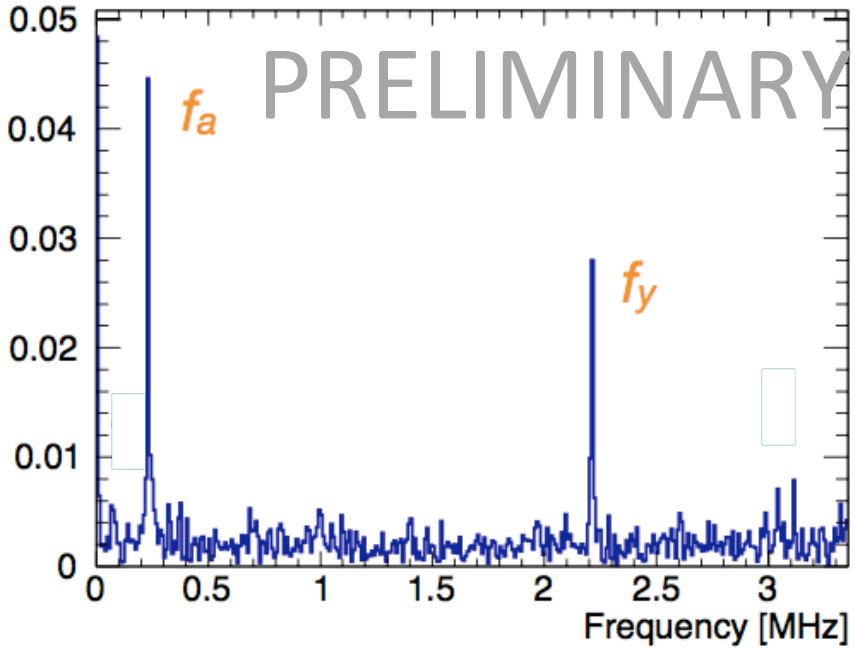
- Recast the current g-2 software to generate an EDM centered around 3.5 times the excluded value from BNL, with tails
- Put in a vertical oscillation π/2 out of phase with ω_a
- Fit the frequencies from this plot, and extract EDM. Once analysis is fixed unblind



Blinded pseudo-data

- Blinded vertical angle vs time is shown below
- FFT shows the introduced EDM signal, and the betatron osc.





- We are free to look at the FFT of other sensitive plots (vertical pos and width vs time) as long as we don't check the phase relative to ω_a

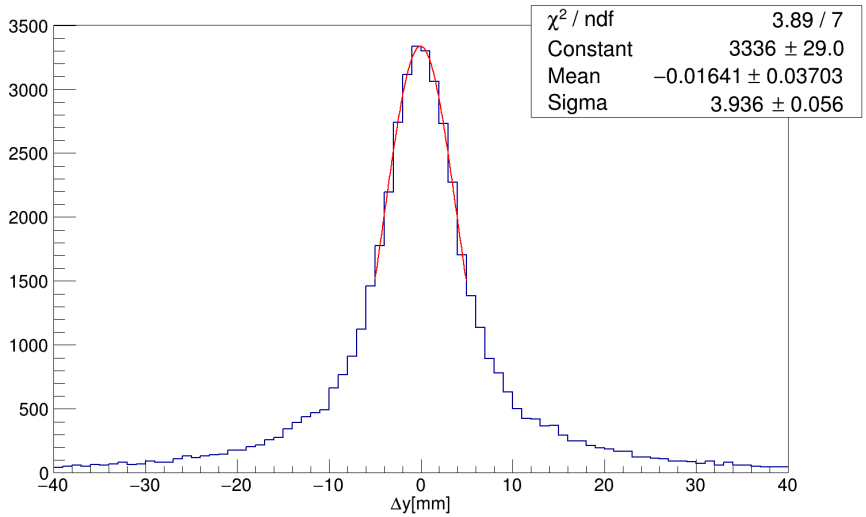
MC studies

- Using the simulation Saskia introduced we can check how well the vertical position, momentum and angle are measured
- Mainly look at the difference between truth and reconstruction to get an idea of accuracy
- Track fitting is improving all the time so these are upper limits

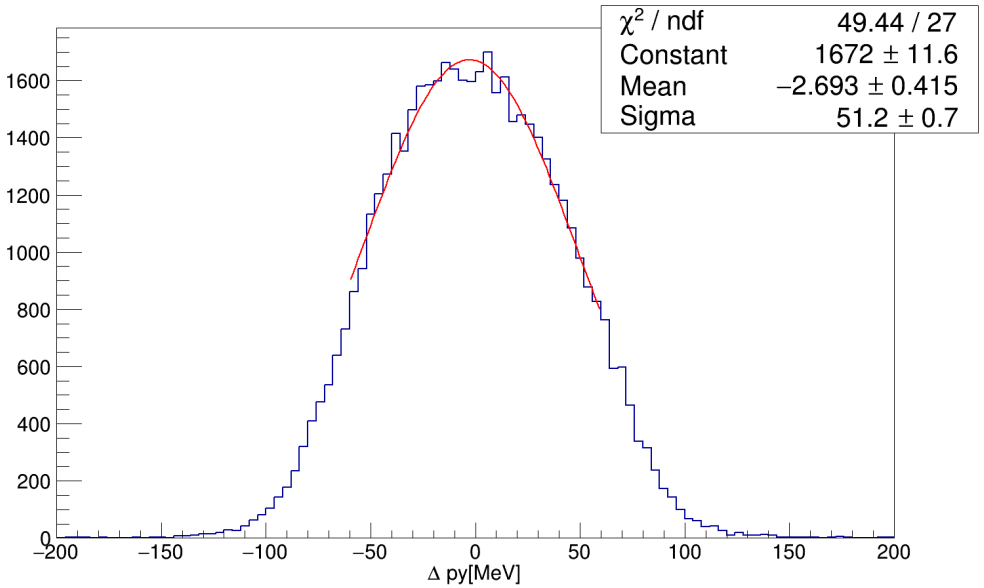
Vertical position and momentum

- Comparison of reconstructed position and momentum in the vertical direction - shown here is the difference
- Distributions centered around 0 - no bias from using radial tangency point as proxy for decay position

truth - reco vertical position



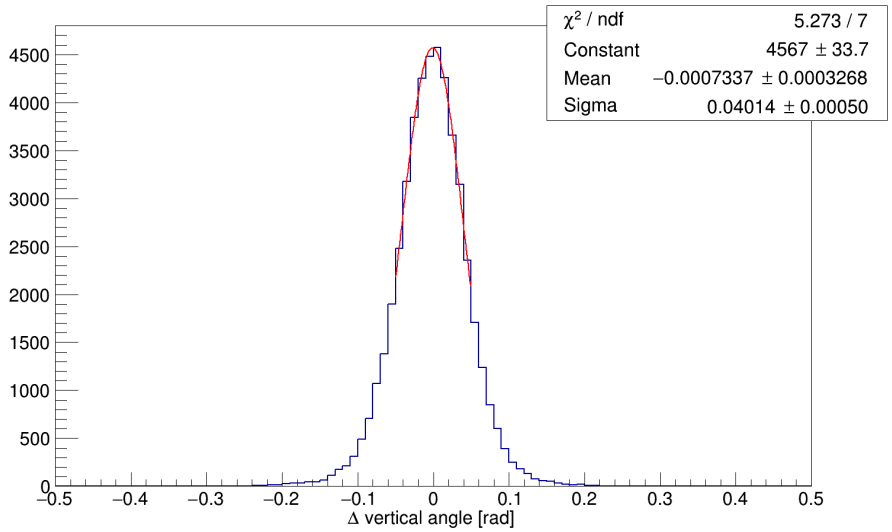
truth - reco vertical momentum



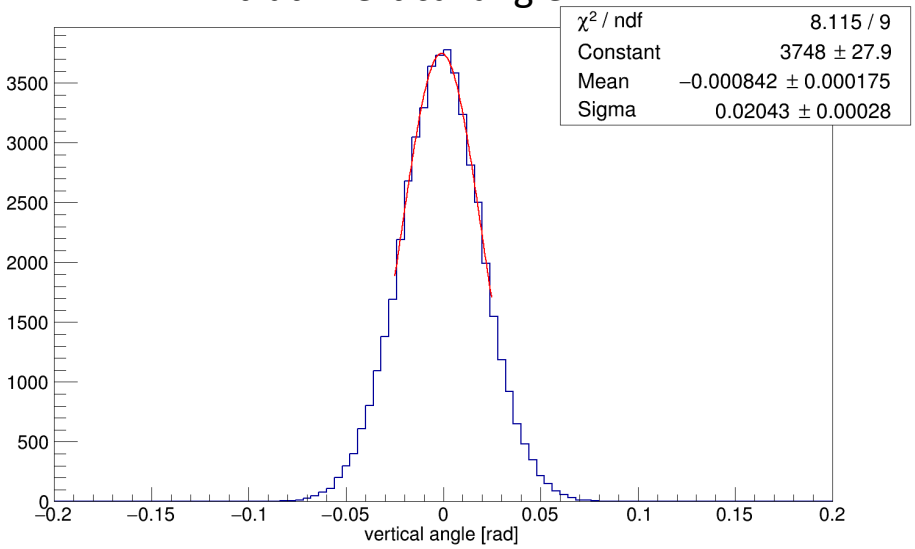
Vertical angle

- Similarly for vertical decay angle - uncertainty of about 0.04 rad
- The crucial number is the error on the mean, which of course is statistics dependent

truth - reco vertical angle



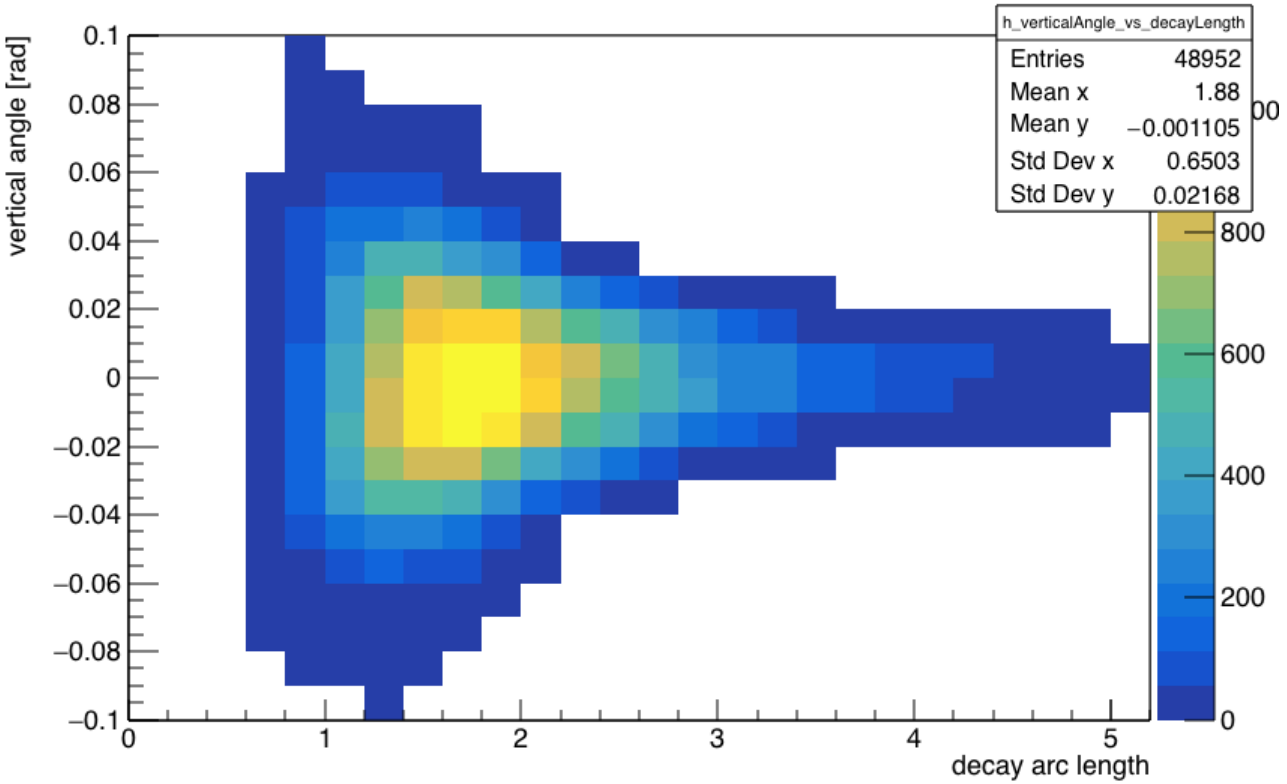
truth vertical angle



- Range of vertical angles seen due to acceptance varies with extrapolation distance…

Average vertical angle

- Acceptance means that we are more likely to see high angle from tracks closer to the trackers - lower momentum

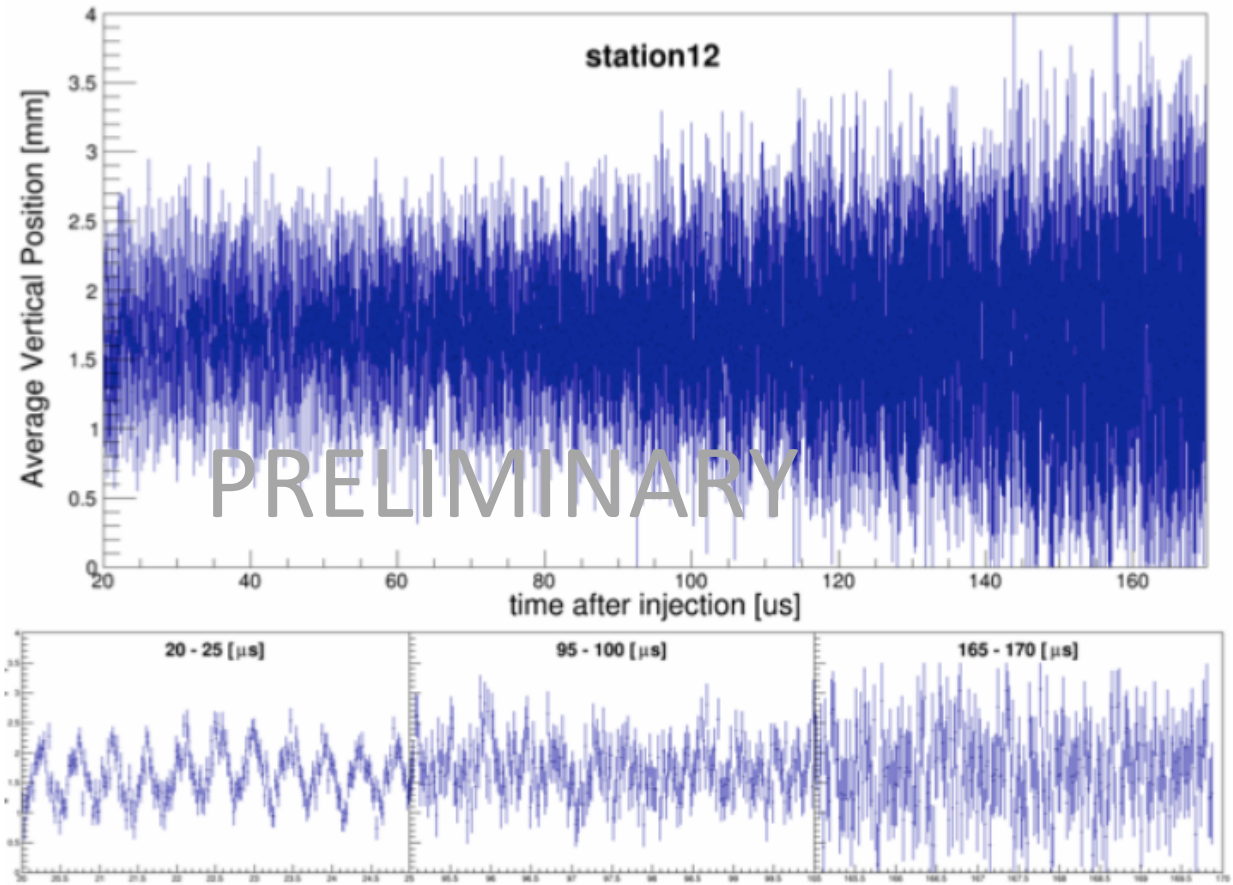


Vertical oscillations

- There are betatron oscillations in the stored muon beam that cause vertical oscillations at a range of frequencies
- These are potentially present in the fit for the EDM and must be understood to successfully fit EDM frequency
- Also allows us to exercise the framework for fitting vertical oscillations

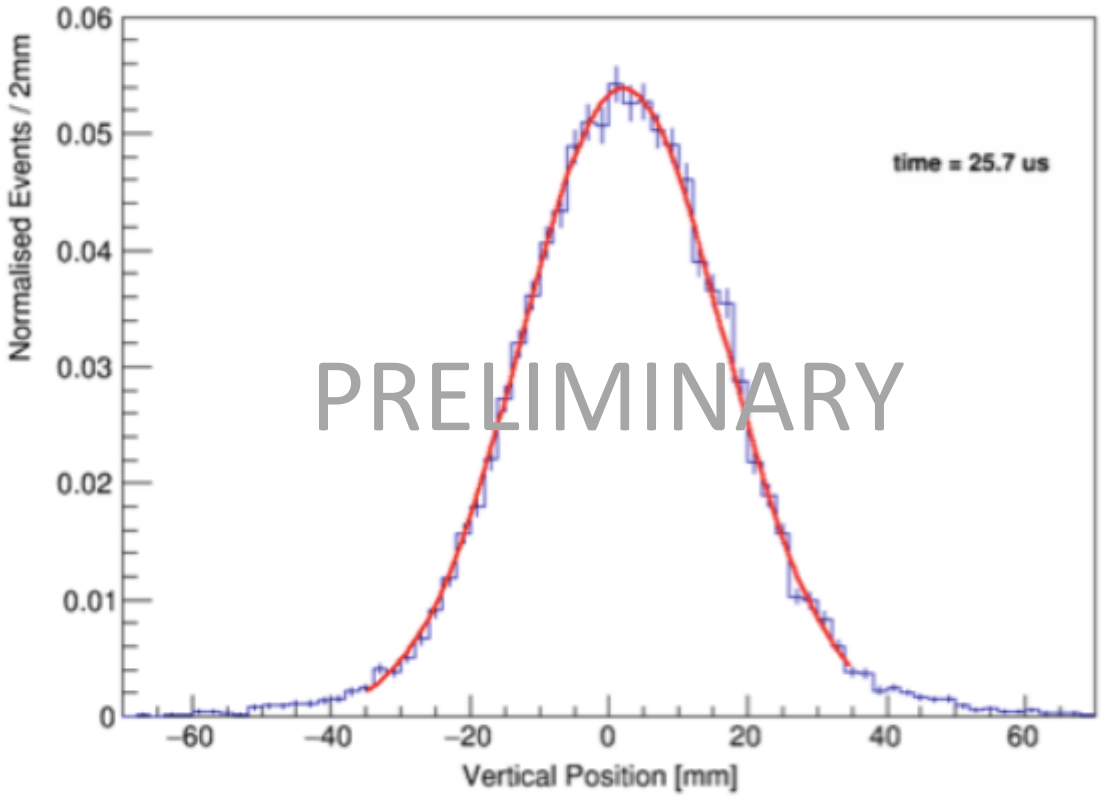
Average vertical position

- Average vertical position of beam varies with time
- Oscillations have small lifetime ~100μs, but tracker turn on early enough to observe them



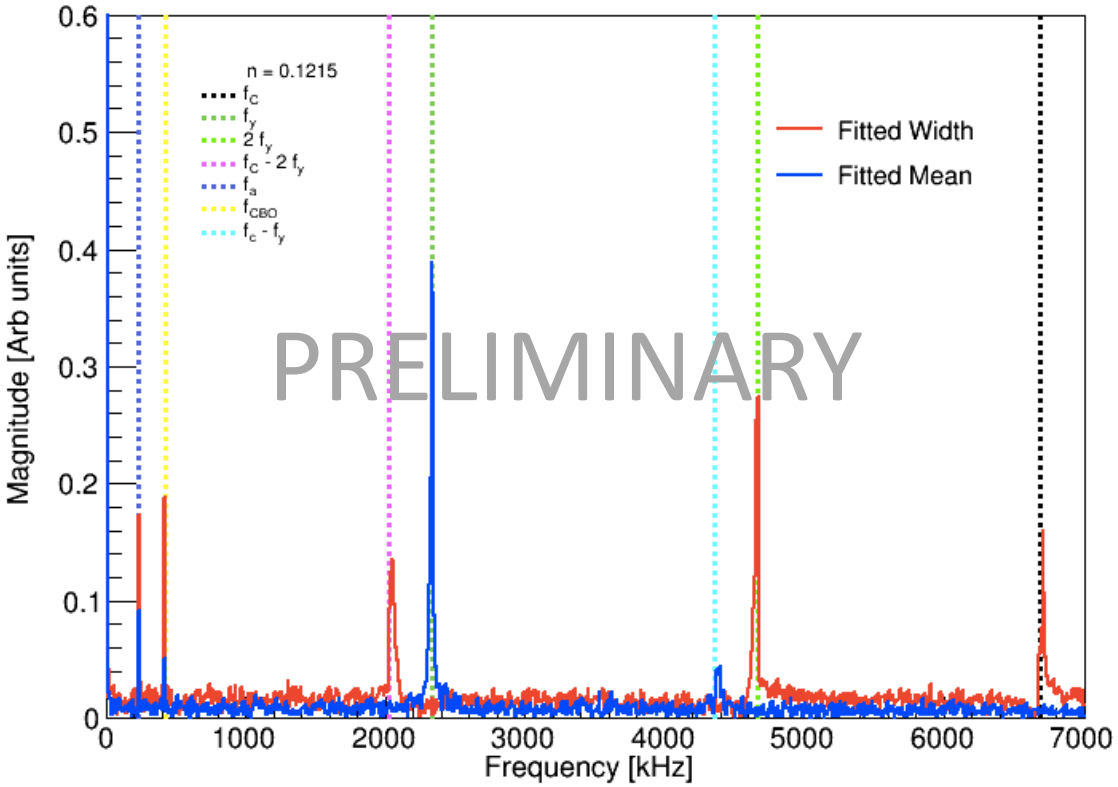
Vertical position fits

- We are rich in statistics, so to clean up these oscillations we can fit each time slice with a gaussian
- Extract the mean and the width from the fits



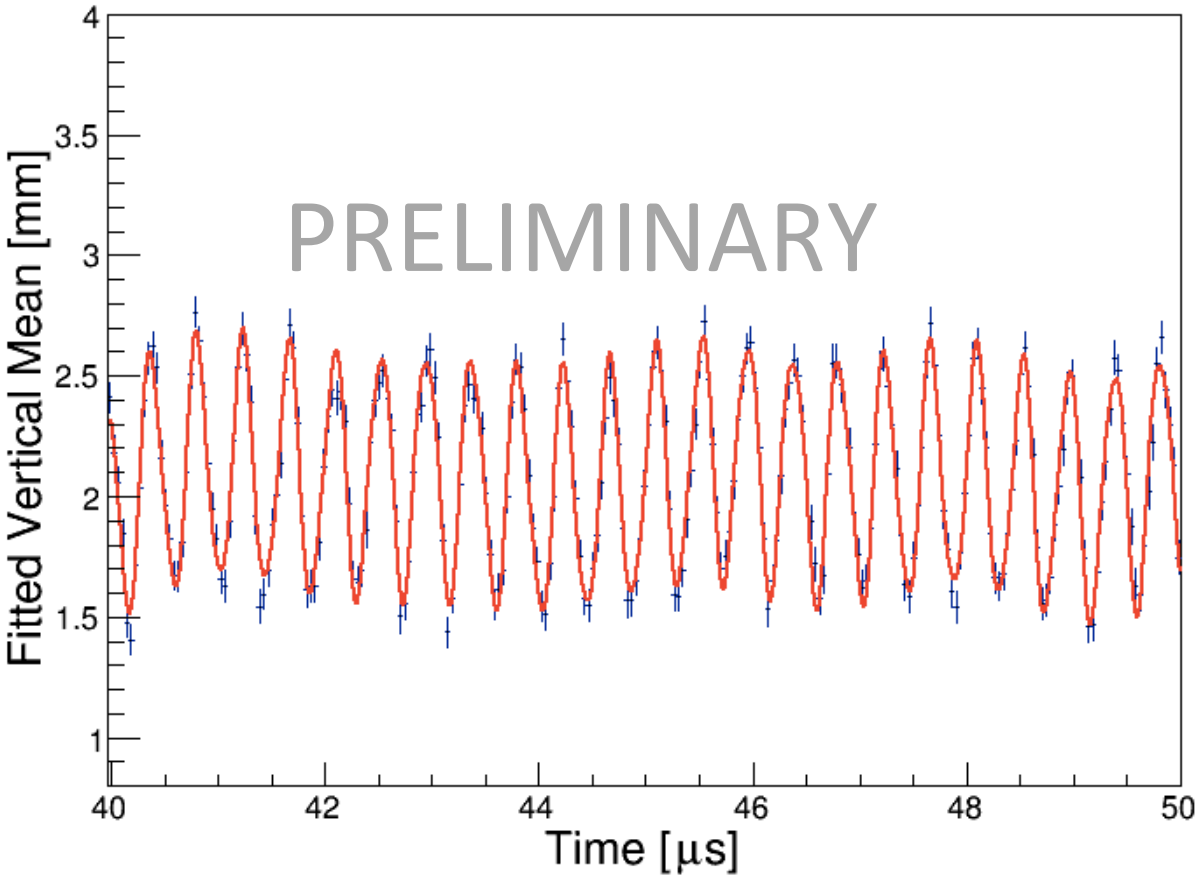
FFT of mean and width

- We the fourier transform the fits as a function of time for the mean and width to obtain the frequencies
- These are matched to known oscillations from acceptance effects and betatron oscillations



Extracting the amplitude and phase

- Now we can fit the main frequencies, allowing us to examine each individual frequencies amplitude, lifetime (some decay away) and phase



Conclusions

- Tracking detectors offer the best way to improve on BNL muon EDM limit
- Already enough statistics to go beyond BNL sensitivity!
- Blinding software in place for average vertical angle plot
- Simulations suggest tracking to point of radial tangency is sufficiently accurate for vertical angle
- Fitting software being exercised on the betatron oscillations and looks very promising
- Waiting for full alignment of tracking stations, and accurate fringe field measurement