Searching for a muon EDM with the FNAL g-2 experiment

Liverpool Particle Physics annual meeting

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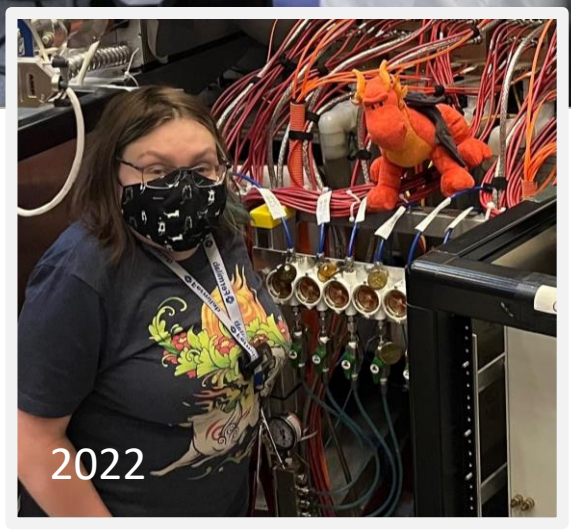
Introduction

- PhD at UCL on trackers/muon EDM at g-2
  - But, actually spent ~ 6 months on g-2 here at Liverpool in 2014/15…
- A new PDRA here at Liverpool as of 3 days ago!
- Now: continuing work on g-2 EDM, but also working on future muon EDM measurements (muEDM at PSI).



Muon EDM – why do we care?

- Analogous to the magnetic dipole moment (MDM), charged particles might also have an intrinsic electric dipole moment (EDM):

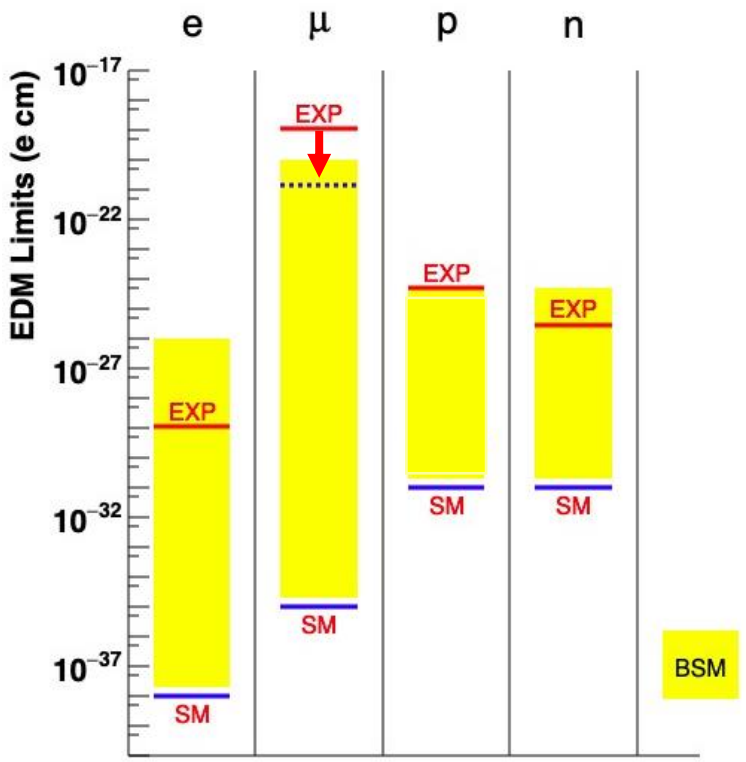
$$H = -\vec{\mu} \cdot \vec{B} + \vec{d} \cdot \vec{E}$$

MDM:

$$\vec{\mu} = g\frac{e}{2m}\vec{S}$$

EDM:

$$\vec{d} = \eta\frac{Qe}{2mc}\vec{S}$$



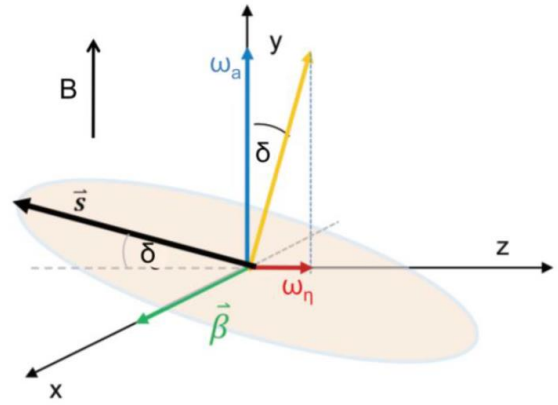
- Why muon EDM?
  - SM muon EDM well below the range of current experiments.
  - **d**.**E** is CP-odd, so observation gives a **new source of CP violation** in the lepton sector.

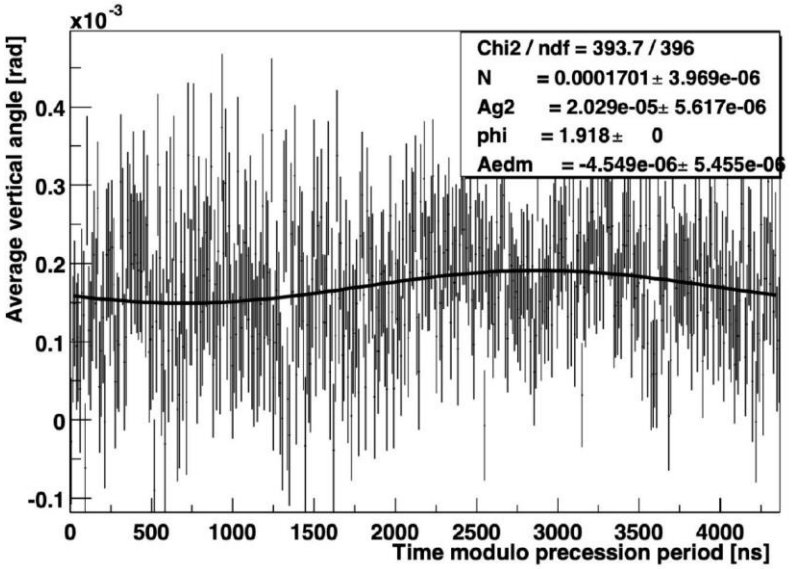
- Previous best limit was set at Brookhaven National Laboratory (BNL): **1.9 × 10^{-19}** $\boldsymbol{e \cdot cm}$**.**

Measuring the EDM at FNAL

- Non-zero EDM introduces a tilt to the precession plane of the muons.

- Two main methods possible to search for a tilt:
  - **Phase difference:** using calorimeters to look for a phase shift between ingoing and outgoing positrons.
    - Systematically limited at BNL/FNAL.
  - **Direct measurement:** either trackers or calorimeters.
    - Trackers better for this as statistically limited (calorimeter measurement systematically limited).

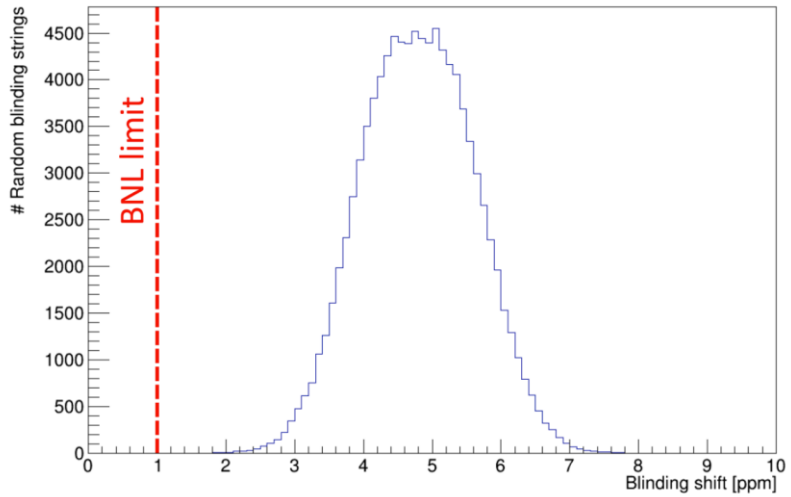


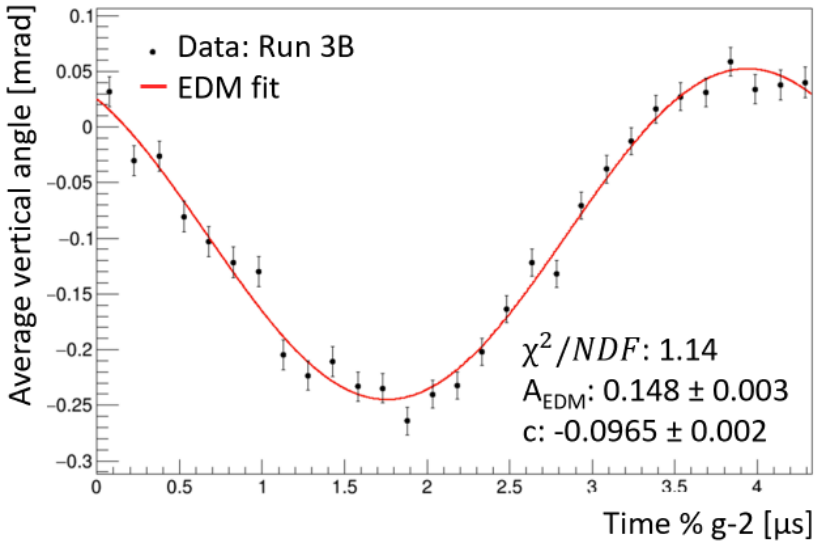


BNL 2000 data

Extracting the tilt from tracker data

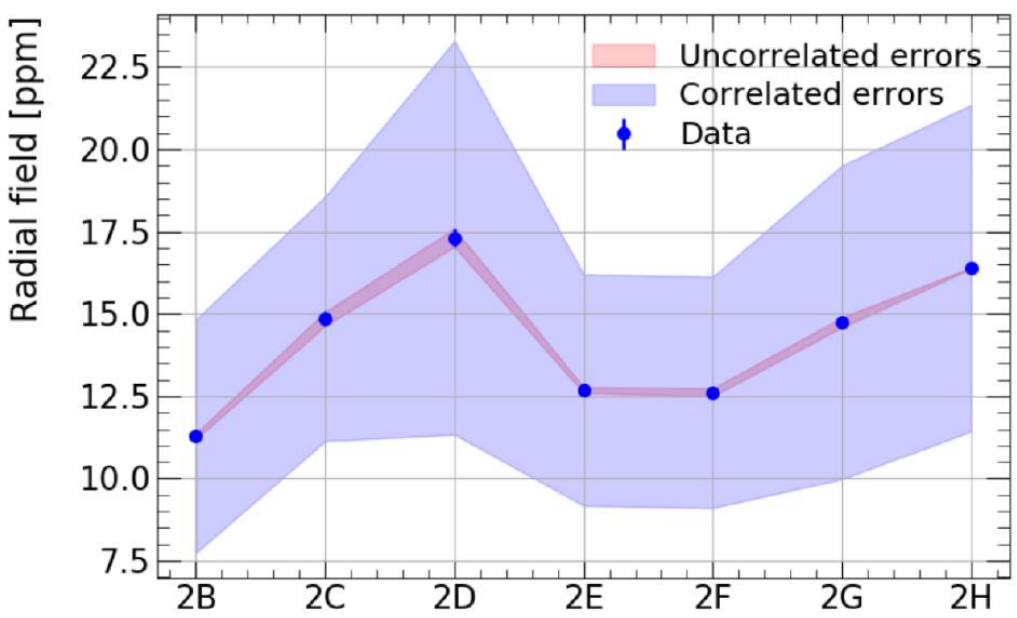
- Blind the data by injecting a large fake EDM signal.
  - Chosen to be >> BNL limit.
- Plot average vertical angle vs time, modulo the g-2 period, fit to extract the amplitude.
- Amplitude reduced by decay physics and detector acceptance: compute and apply corrections for both.
- Evaluate systematic uncertainties on the amplitude + combine for final result.

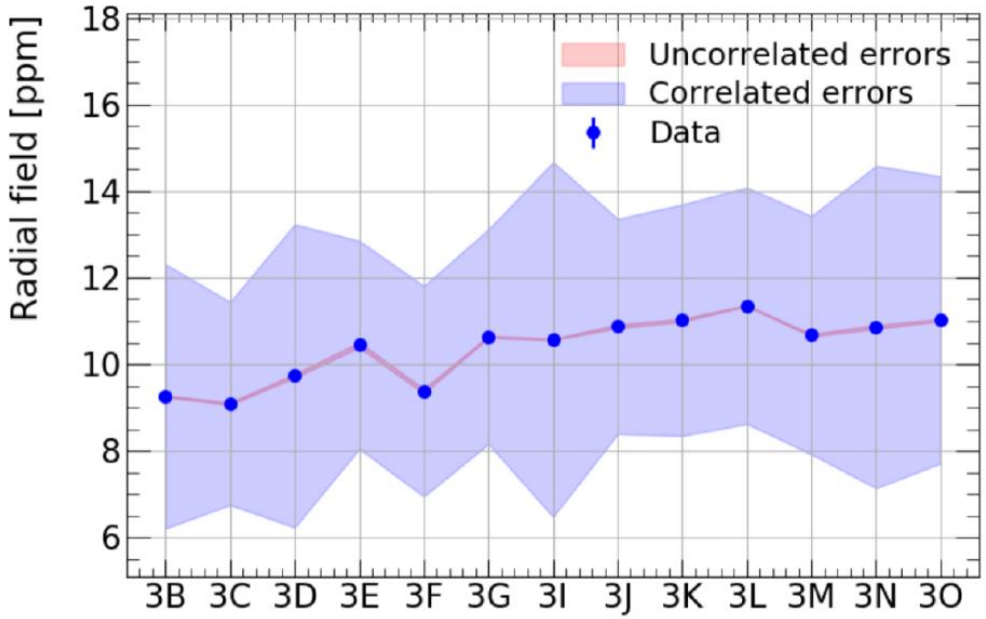




Analysis challenges: Radial field

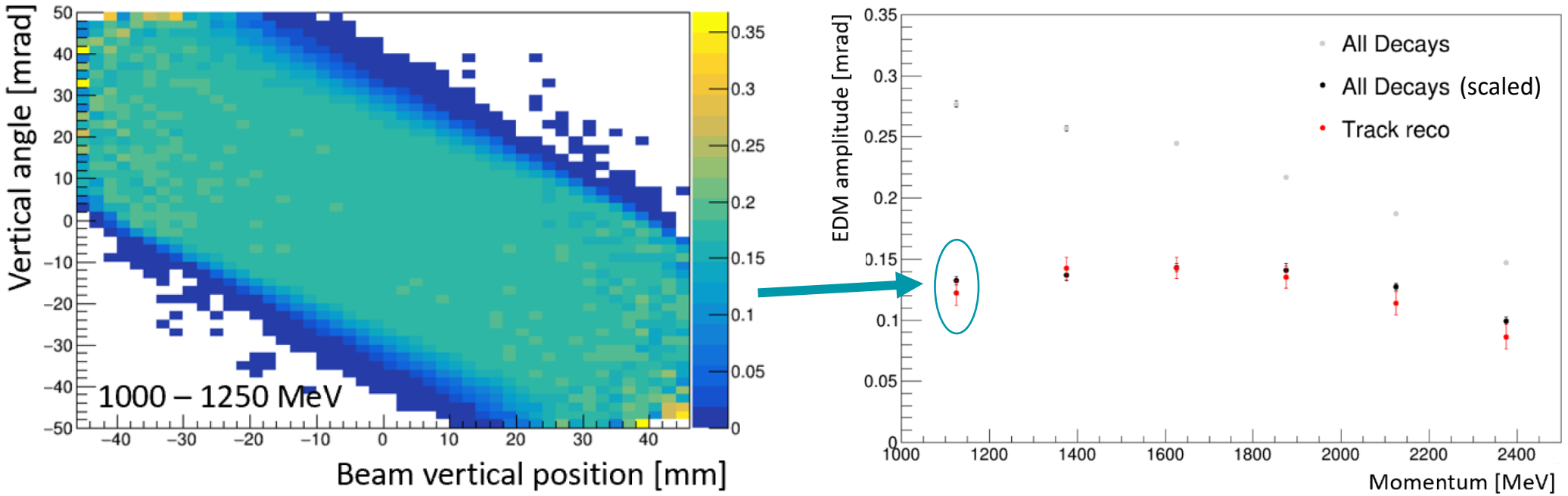
- Non-zero radial field introduces ‘fake’ EDM signal, would limit the result if not controlled.
  - Dedicated scans to measure the field in Run 4/5/6 – extrapolate these to Run 1/2/3.
  - Result: not radial field limited!





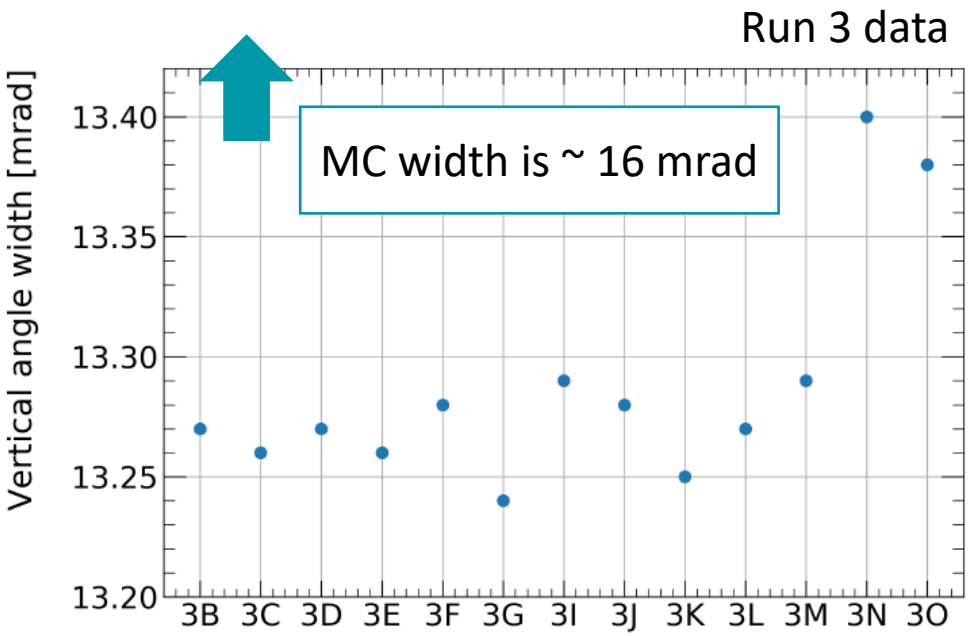
Analysis challenges: Acceptance

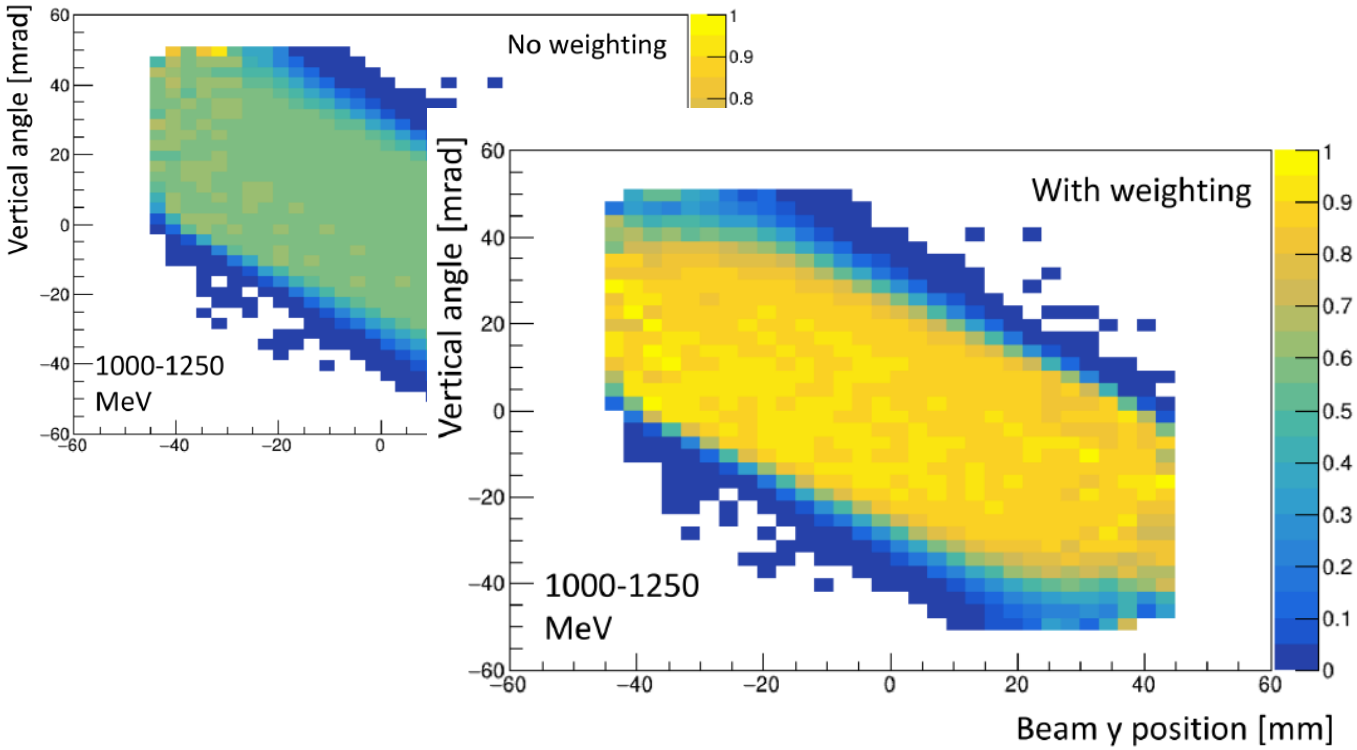
- Tracker acceptance corrections are the next largest systematic due to low stats in MC.
  - In Run 1, statistical error dominant over this, so not a concern.
  - In Run 2/3, improved acceptance map method to reduce impact – improves the uncertainty by a factor of 4.
  - Result: not acceptance limited! (in Run 1/2/3 at least…)



Analysis challenges: Data/MC differences

- Some corrections only possible to calculate using MC, but MC is not perfect.
  - Lots of work done to adjust MC output to better match data (beam distributions etc).
  - Not an issue for Run 1, work ongoing to better understand this for Run 2/3.

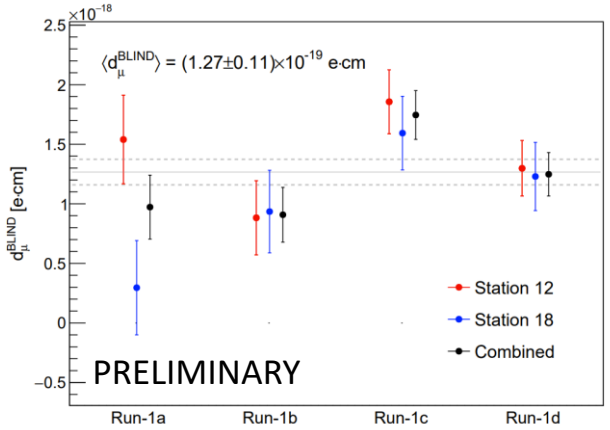




Status of the analyses

- Run 1: nearing unblinding (work mainly by S. Grant and M. Sakurai, UCL).
  - Expected to set a limit comparable to BNL:

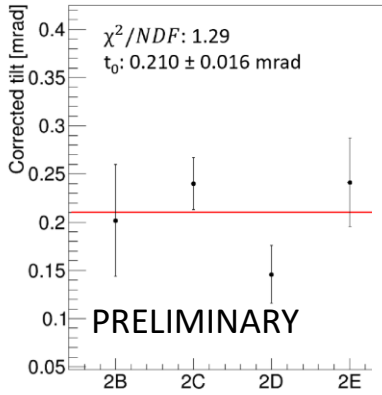
Run 1 (if $A_{EDM} = 0$): $|d_\mu| < 2.0 \times 10^{-19}$ e · cm



Run 1 (blinded)

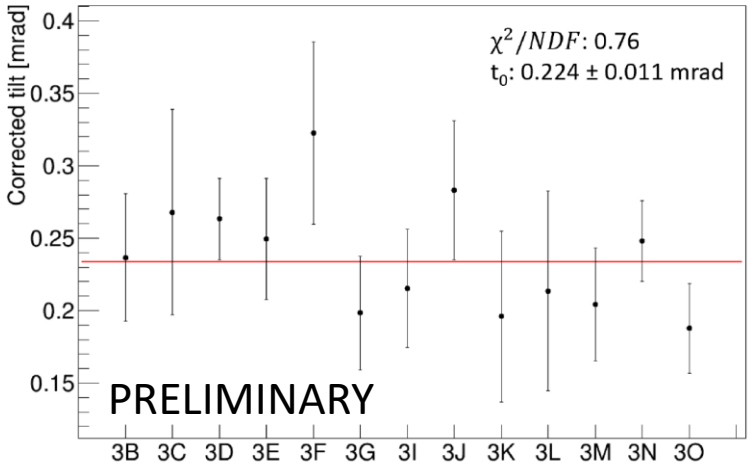
- Run 2/3: first set of blinded results complete, some more work to do!
  - **If central values consistent with zero**, will improve on the BNL limit by a factor of 3 – new world's best limit on the muon EDM:

Run 2 (if $A_{EDM} = 0$): $|d_\mu| < 8.4 \times 10^{-20}$ e · cm
Run 3 (if $A_{EDM} = 0$): $|d_\mu| < 5.9 \times 10^{-20}$ e · cm



Run 2 (blinded)

Run 3 (blinded)



Conclusions and outlook

- The FNAL g-2 experiment can be used to search for a muon EDM.
- Run 1 and Run 2/3 analyses are both nearing completion – will set a new world limit.
- Still have Runs 4/5/6 to analyse - are the most sensitive runs to an EDM.
  - Highest statistics, but also direct radial field measurements in these runs (uncertainty is ~ 5x better).
- Combined, expect to improve on BNL limit by an order of magnitude.