UNIVERSITY OF LIVERPOOL

MuEDM experiment

Joe Price

MuEDM @ PSI – frozen spin

- Permanent EDMs give an additional source of CP violation
- Can search for them directly in a storage ring:

$$\vec{\Omega} = -\frac{q}{m}\left[a\vec{B} - \frac{a\gamma}{(\gamma+1)}\left(\vec{\beta}\cdot\vec{B}\right)\vec{\beta} - \left(a+\frac{1}{1-\gamma^2}\right)\frac{\vec{\beta}\times\vec{E}}{c}\right] \quad \text{AMM term}$$

$$-\frac{\eta q}{2mc}\left[c\vec{\beta}\times\vec{B} + \vec{E} - \frac{\gamma\left(\vec{\beta}\cdot\vec{E}\right)\vec{\beta}}{(\gamma+1)}\right], \quad \text{EDM term}$$

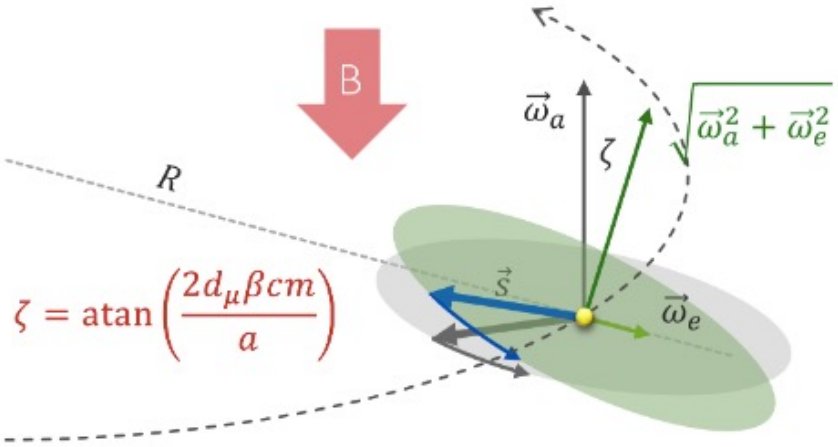
Relativistic spin precession of a charged particle (Thomas-BMT equation)

- Muon momentum, E-field and B-field form an orthogonal basis: $\vec{\beta}\cdot\vec{B} = \vec{\beta}\cdot\vec{E} = 0$
- By applying an appropriate radial E-field to the muon we remove the AMM term.

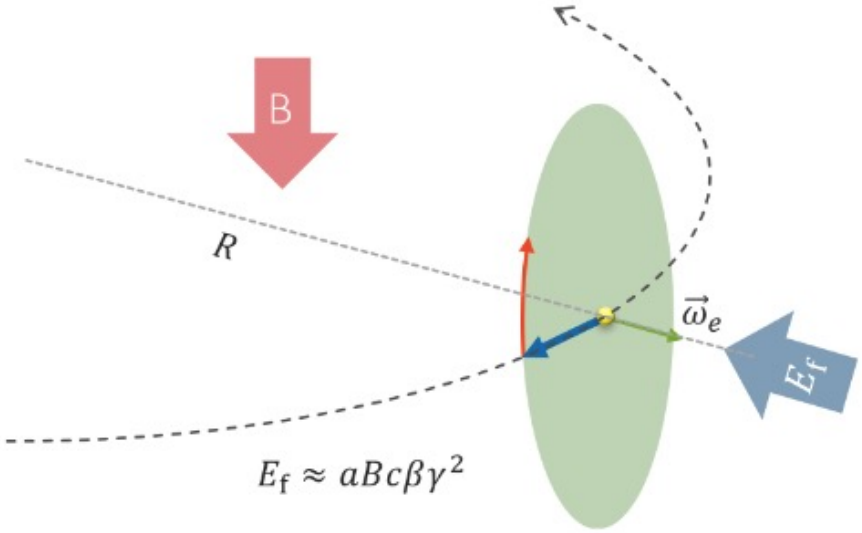
$$a\vec{B} = \left(a - \frac{1}{\gamma^2-1}\right)\frac{\vec{\beta}\times\vec{E}}{c}$$

- Any observed spin precession would be due to a non-zero EDM.

Frozen spin - visual

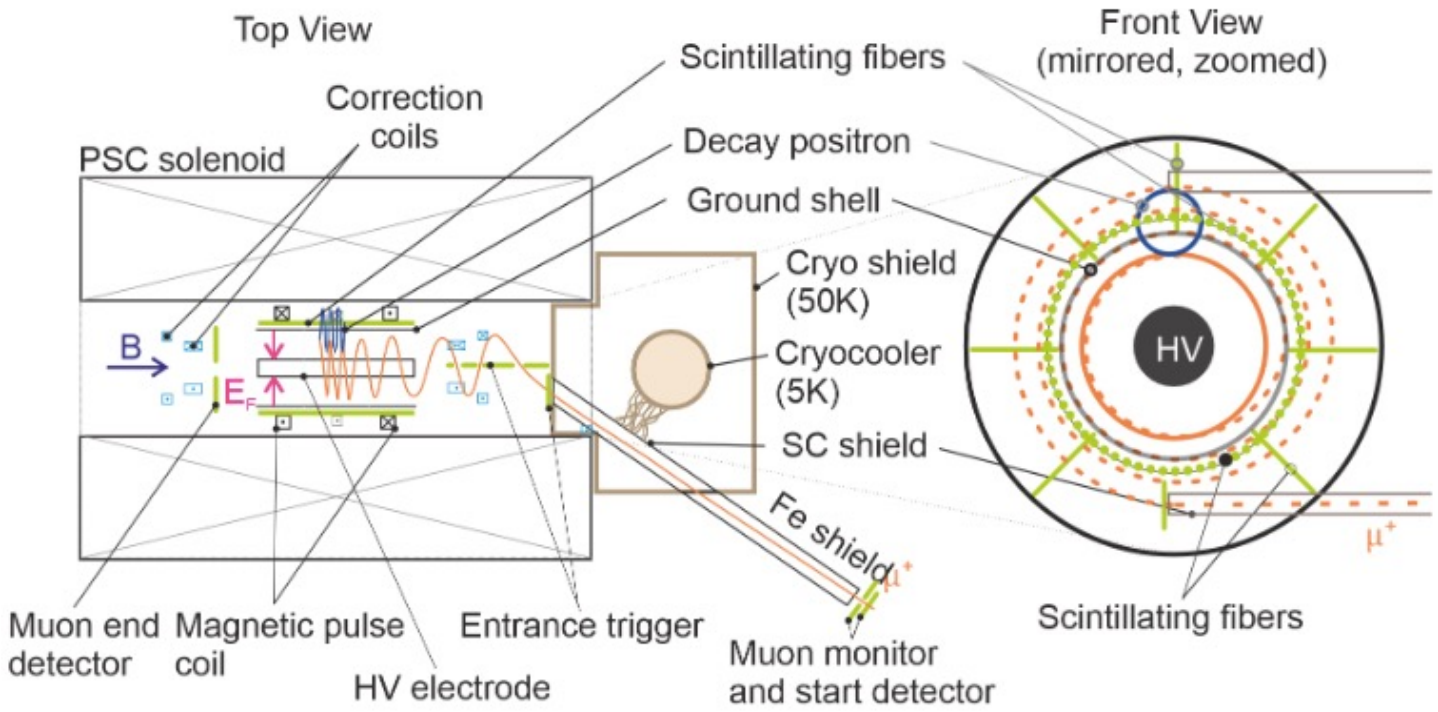


- Without frozen spin condition an EDM tilts the precession plane
- This is **Fermilab-style** EDM search



- With frozen spin condition an EDM is the only cause of the precession
- This is **PSI-style** EDM search
- **Advantage of frozen spin:** Every positron is useful!

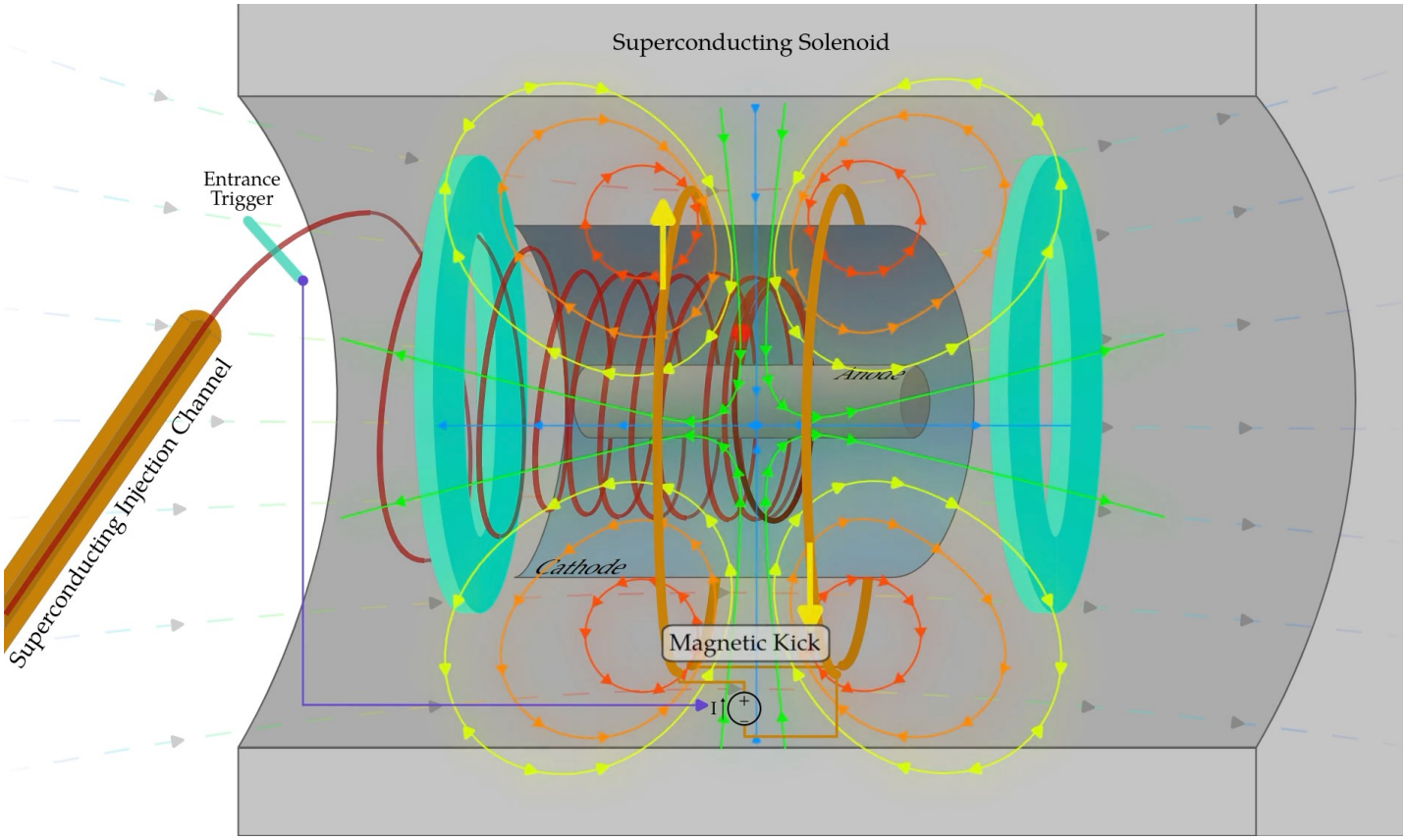
MuEDM@PSI - overview



- Store muons one at a time, freeze spin, observe change in polarisation vector due to muon EDM by measuring positrons
- Plan to run in 2 different phases with different muon momenta
  - **Phase I** ($|p_\mu| \approx 28$MeV) and **Phase II** ($|p_\mu| \approx 125$MeV)
- Projected sensitivity
  - Phase I: $\sigma(d_\mu) \leq 3 \times 10^{-21}$e.cm
  - Phase II: $\sigma(d_\mu) \leq 6 \times 10^{-23}$e.cm

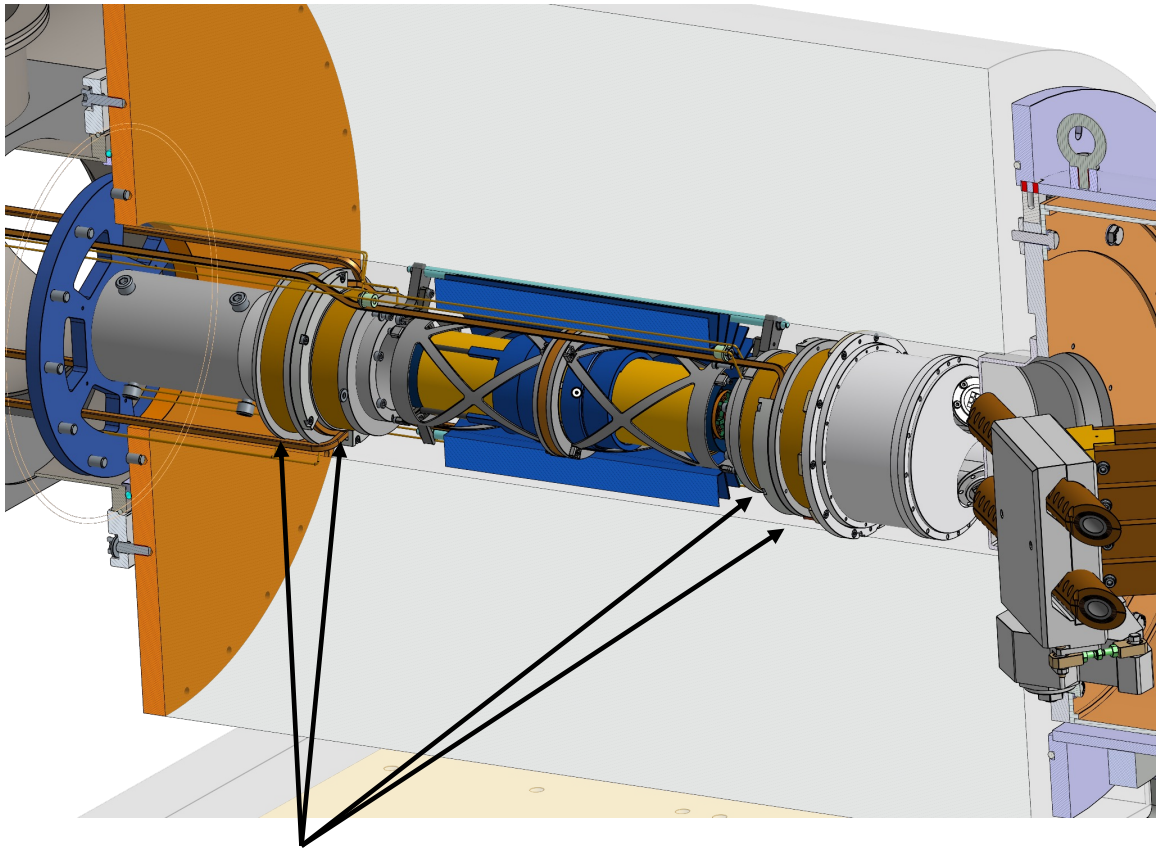
arxiv 2501.18979 (EPJC to follow)

Magnetic kicker



- Magnetic longitudinal ‘kick’ to keep injected muons in central orbit
- Trigger configured in 2024 test beam – storage tests in 2025

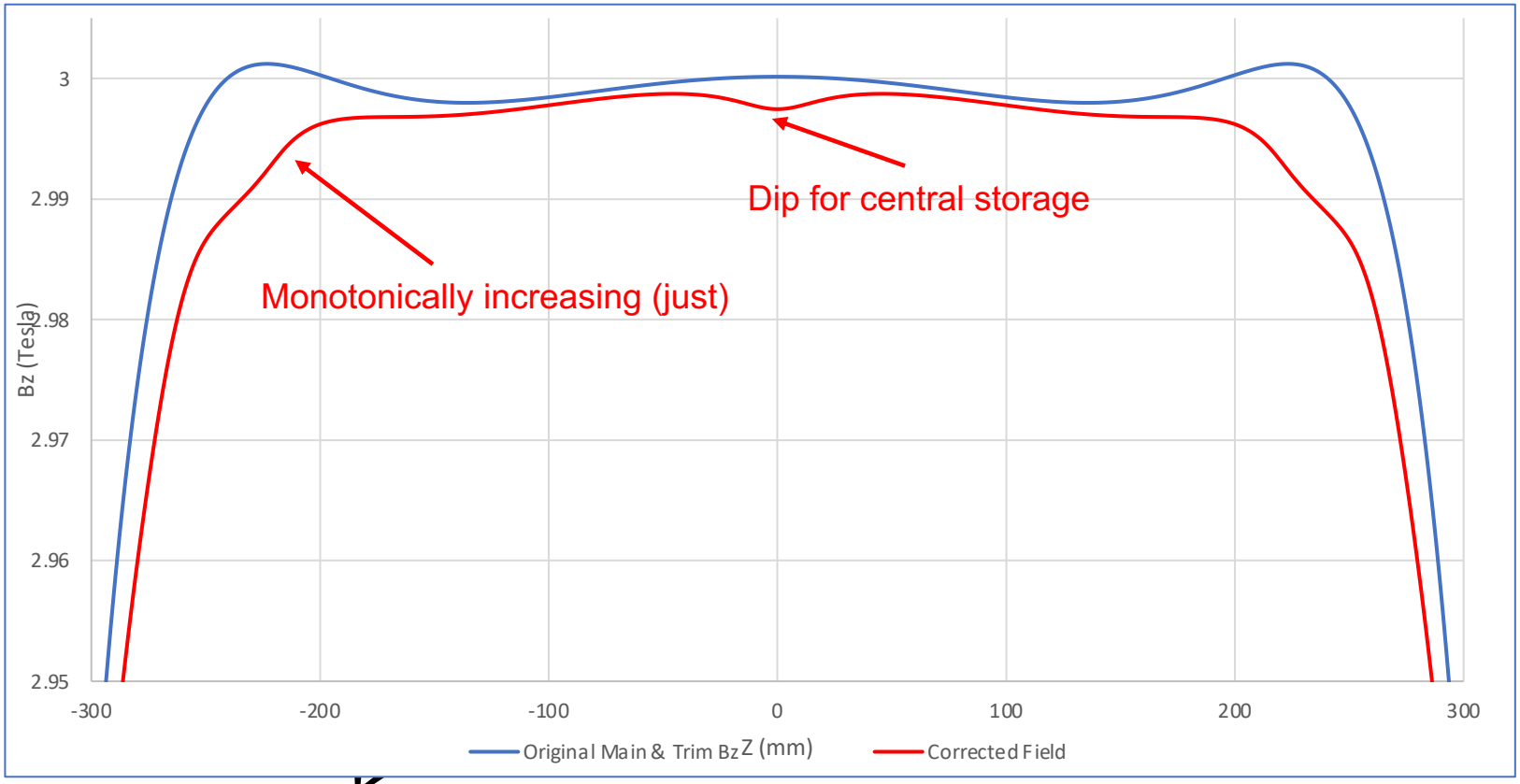
Magnetic field - storage



Design of correction coils finalised in 2024/5

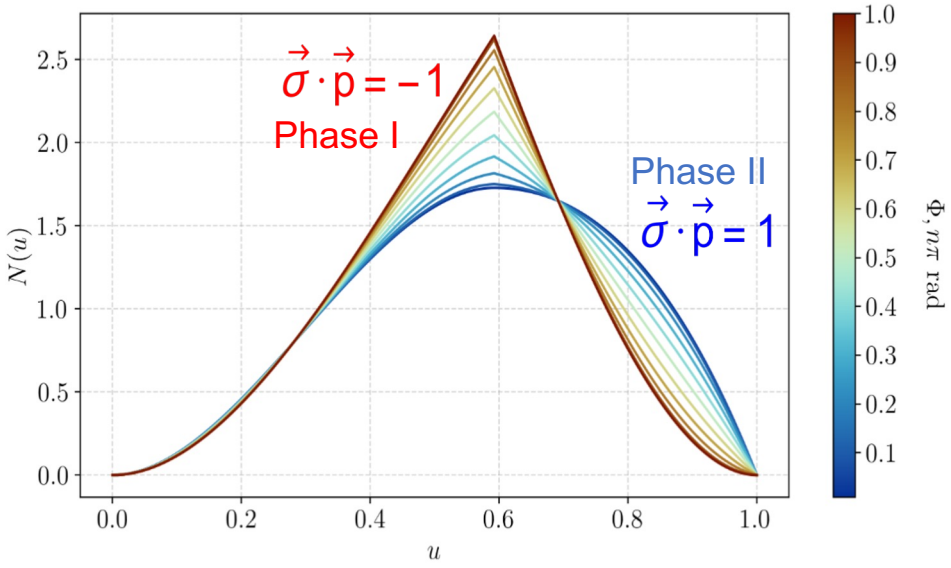
- Modified '**correction coils**' to ensure storage in central B-field
- Challenging windings for coils due to heat transfer and vacuum requirements
- UK deliverable – Daresbury Laboratory

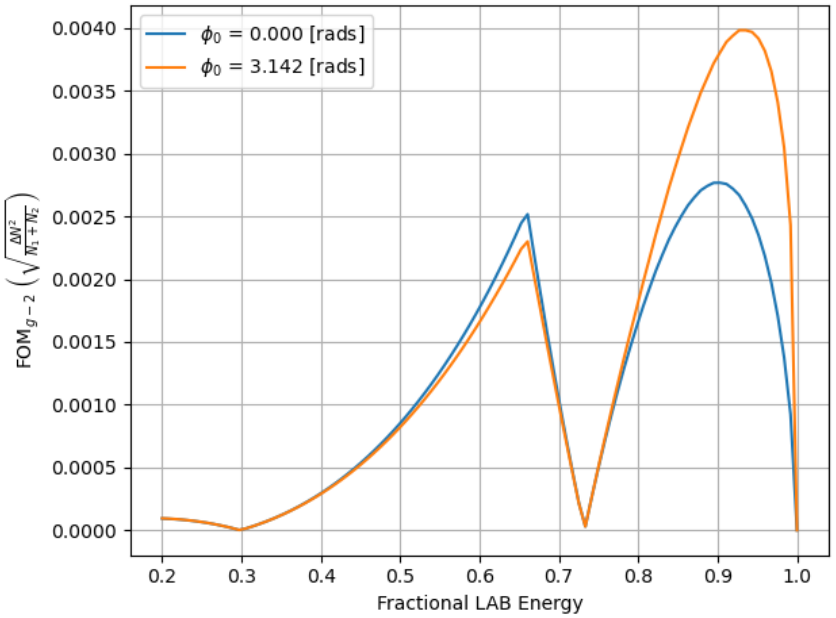
Magnetic field - storage



- Modified '**correction coils**' to ensure storage in central B-field
- Challenging windings for coils due to heat transfer and vacuum requirements
- UK deliverable – Daresbury Laboratory

Demonstrating frozen spin method

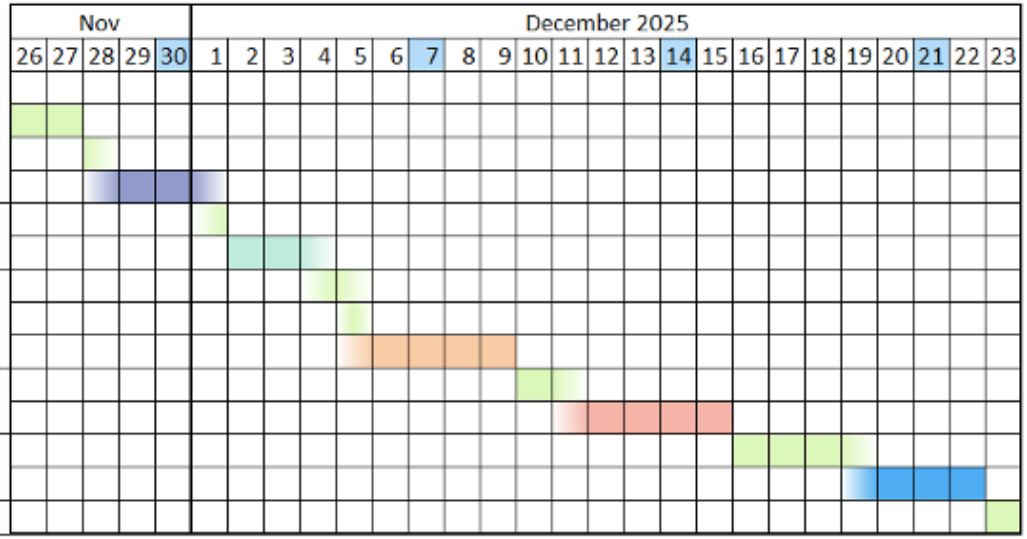




- Stored anti-muons will decay to positrons
- **Phase-I goal**: demonstrate frozen spin method by ensuring no g-2 style oscillation
- Need to know which positrons which are most sensitive to g-2
- Momentum of most sensitive positrons shown above, also optimised for longitudinal angle – Work done here at **Liverpool**

Timeline 2025

Beamtime programm 2025 in piE1	hours	days
Initial mounting and alignement	48	
Beam tuning	12	
Measure spiral injection with TPC	72	5.5
remove TPC	12	
Measure sprial transmission	60	3
Modification to muSR stopping target	24	
Beam tuning	6	
Measure muSR spin orientation	108	5.8
Modification to magnetic pulse	36	
Measure stopping efficiency	108	6
modify to SciFi tests	120	
Measrue SciFi performance	72	8
Unmounting	6	
total days		**29**



- Test beam in November/December 2025
- Prepare for data taking 2026!
- Sci-Fi tracker to give sensitivity to AMM and EDM…

Conclusions


Collaboration meeting at Liverpool in April 2025

Liverpool members

- Joe Price (Simulation coordinator)
- Fedor Ignatov
- Dominka Vasilikova
- Themis Bowcock
- Joost Vossebeld

- MuEDM will measure the muon EDM in two stages, improving on the current sensitivity by 2, then 4 orders of magnitude
- UK responsible for the correction coils (Lancaster)
- Liverpool's major input has been to simulation, optimising the placement of the sci-fi trackers.
- Fedor joined in April, working on tracking
- Applying for funding for the tracker build for phase II…