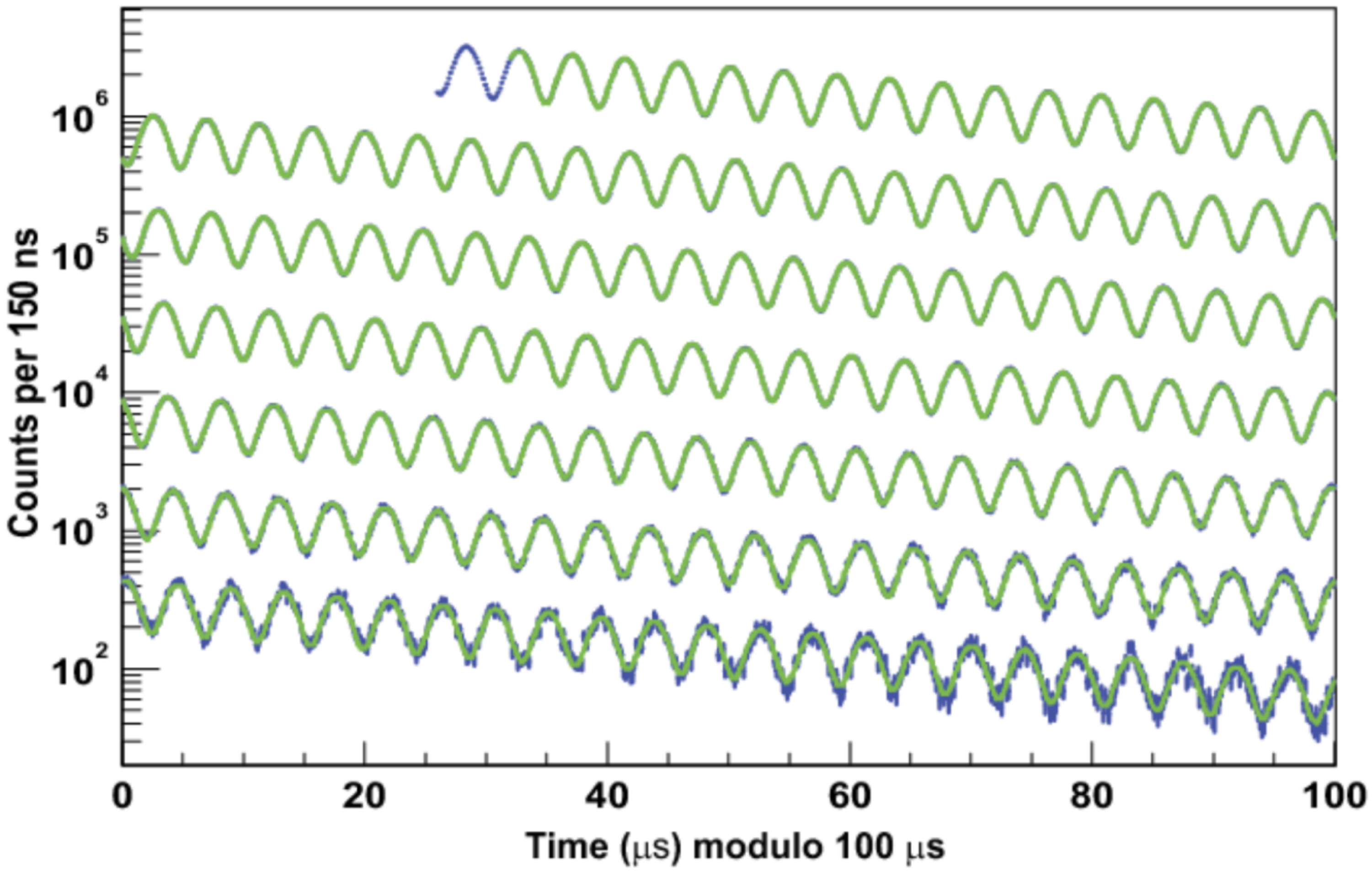
HOW DOES SUCH A MEASUREMENT LOOK?

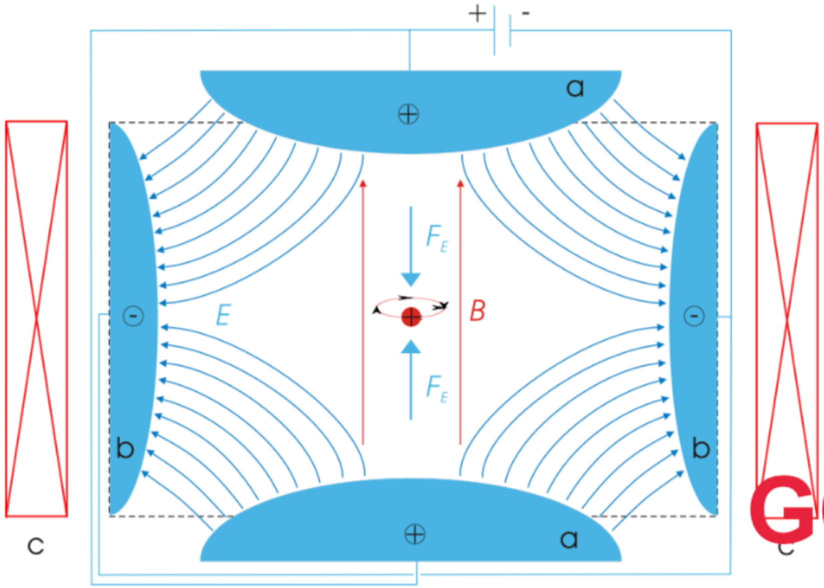


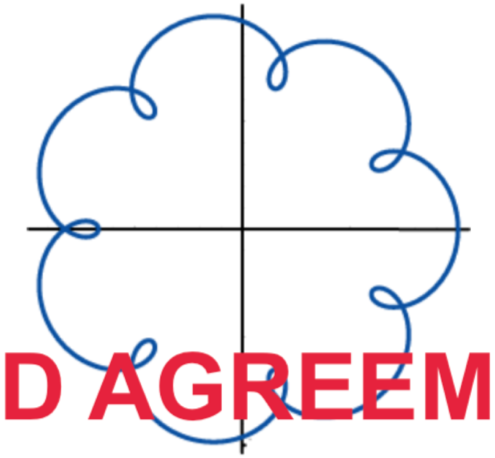
$$\vec{\omega}_a = a_\mu \left[\frac{e}{m}\vec{B}\right] \approx 229\,\mathrm{kHz}$$

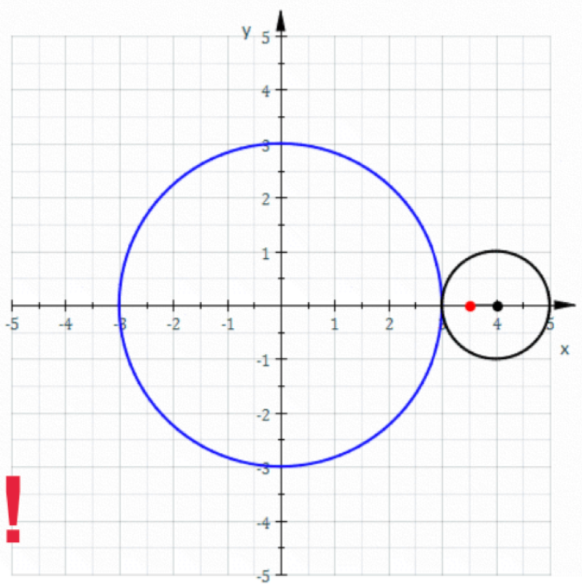
ELECTRONS - PENNING TRAP

Electrons are stable → study in a cold trap

The movement the electron makes in the trap tells us about its magnetic moment







GOOD AGREEMENT!

The muon is 207 times heavier than the electron, particularly sensitive to new types of virtual particles

- …implies higher sensitivity than for Δa_e since:

$$\frac{m_\mu^2}{m_e^2} \approx 42000$$

Can we do a trap with a muon? → No, it decays, we need longer lifetime

MUONS - G-2 EXPERIMENT

Already used in the 90's in Brookhaven BNL: $a_\mu^{\exp} = 116592023(151)\times 10^{-11}$

Theory prediction: $a_\mu^{SM} = a_\mu^{QED} + a_\mu^{Weak} + a_\mu^{Hadronic} = 116591802\,(42)\,(26)\,(2) \rightarrow (49_{total})\times 10^{-11}$

$$\Delta a_\mu^{SM} = a_\mu^{Exp} - a_\mu^{SM} = 2.90\ (90) \times 10^{-9} \rightarrow 3.5\ \sigma$$

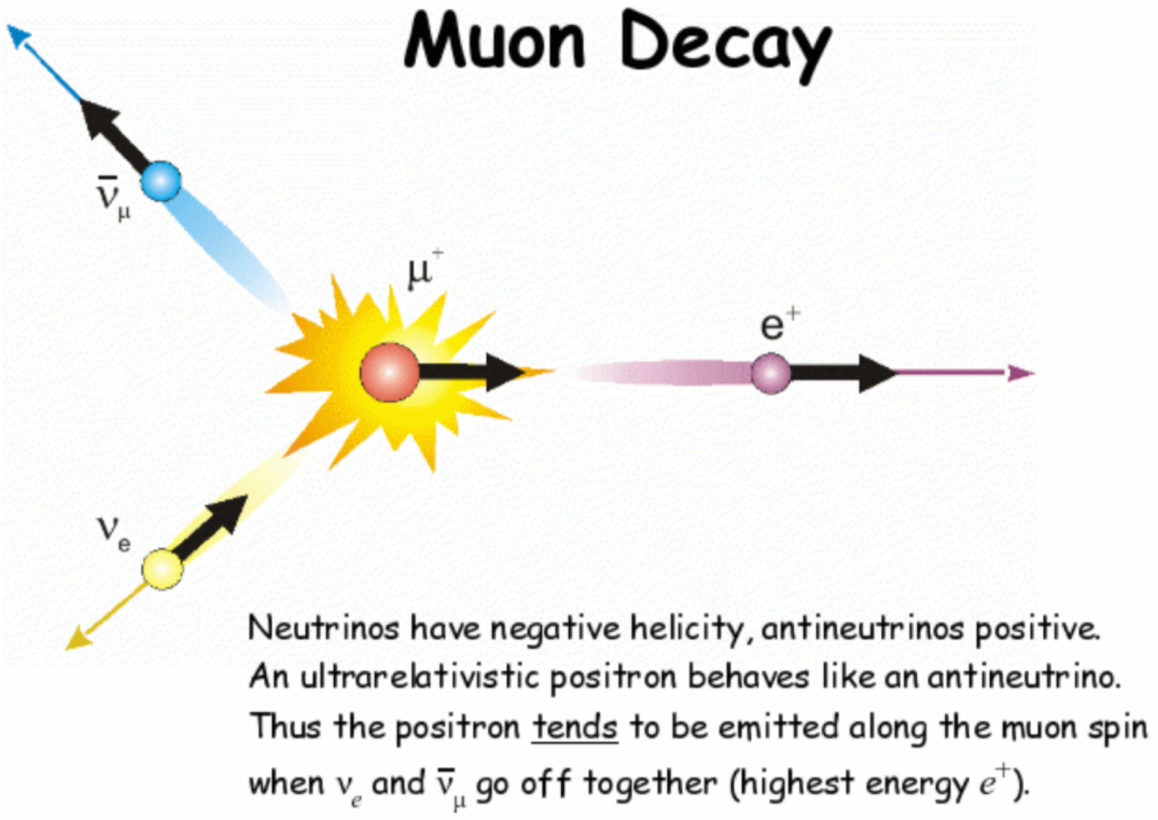
We all know you need 5 sigma is a magical number, so how do you make this better?

Increase the intensity of muons to reach a higher precision!

MUON DECAY

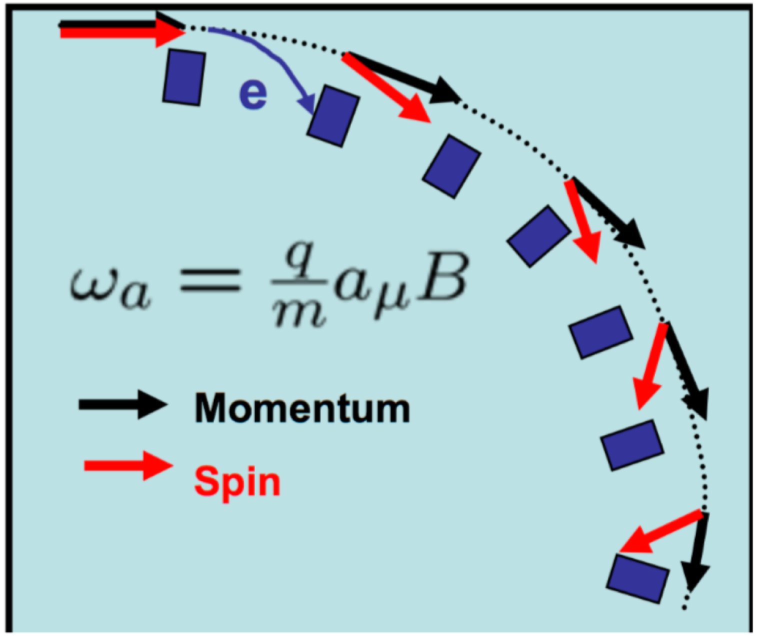
Muons travel around the ring

And then…

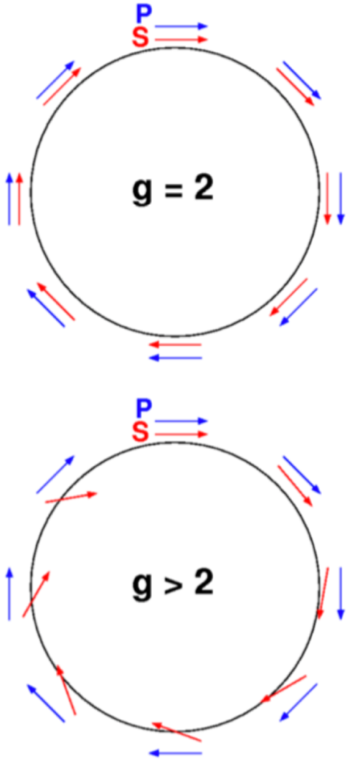


The number of high-energy positrons are detected as a function of time
High-energy positrons are selected → they are aligned with spin

THE ANALYSIS



Overview of the *Idealized* Measurement Technique



- Inject polarized muons into **magnetic** storage ring 1.45 T

$$\vec{\omega}_{\text{cyclotron}} = \frac{e}{\gamma m}\vec{B} \approx 2\pi \times 6.7\,\text{MHz}$$

$$\vec{\omega}_{\text{spin}} = g\frac{e}{2m}\vec{B} - (1-\gamma)\frac{e}{\gamma m}\vec{B} \approx 2\pi \times 6.9\,\text{MHz}$$

$$\vec{\omega}_a \equiv \vec{\omega}_s - \vec{\omega}_c = \left(\frac{g-2}{2}\right)\left[\frac{e}{m}\vec{B}\right]$$

$$\Rightarrow \quad \vec{\omega}_a = a_\mu \left[\frac{e}{m}\vec{B}\right] \approx 229\,\text{kHz}$$

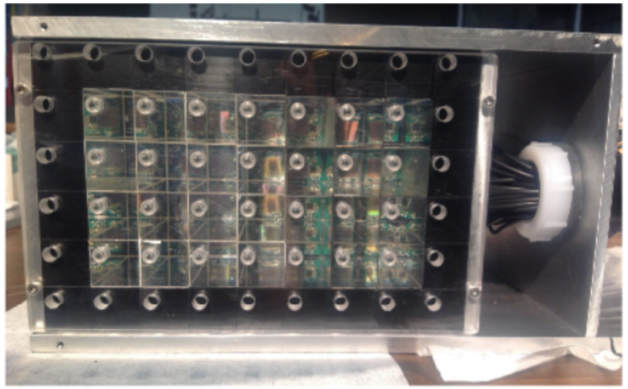
- Difference between spin and cyclotron frequencies: ω_a proportional to a_μ
- Difference sensitive to $a_\mu \approx 0.00116...$, not $g_\mu \approx 2.00232...$

$\Rightarrow$ Experiment measures two quantities:

(1) Muon anomalous precession frequency ω_a to ± 100 ppb (stat) ± 70 ppb (syst)

(2) Magnetic field $\vec{B}$ in terms of proton NMR frequency ω_p to ± 70 ppb (syst)

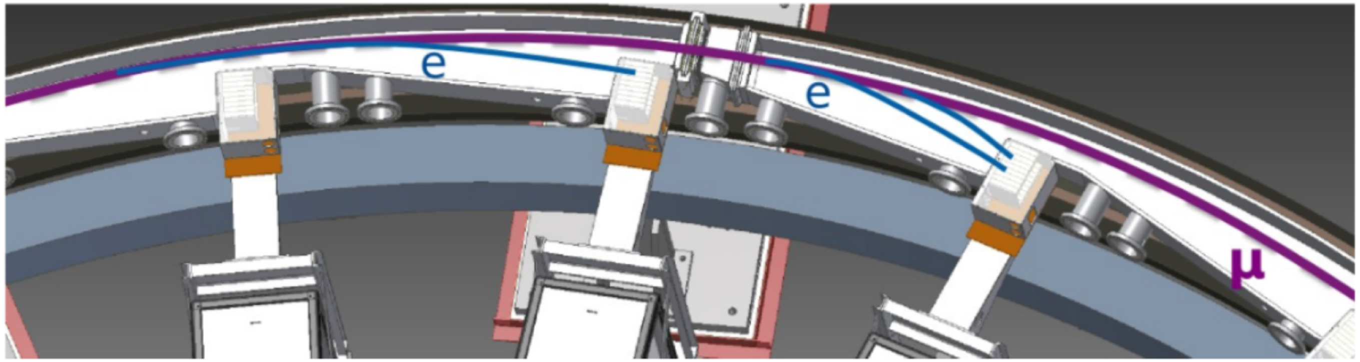
HOW ARE THE MUONS MEASURED?

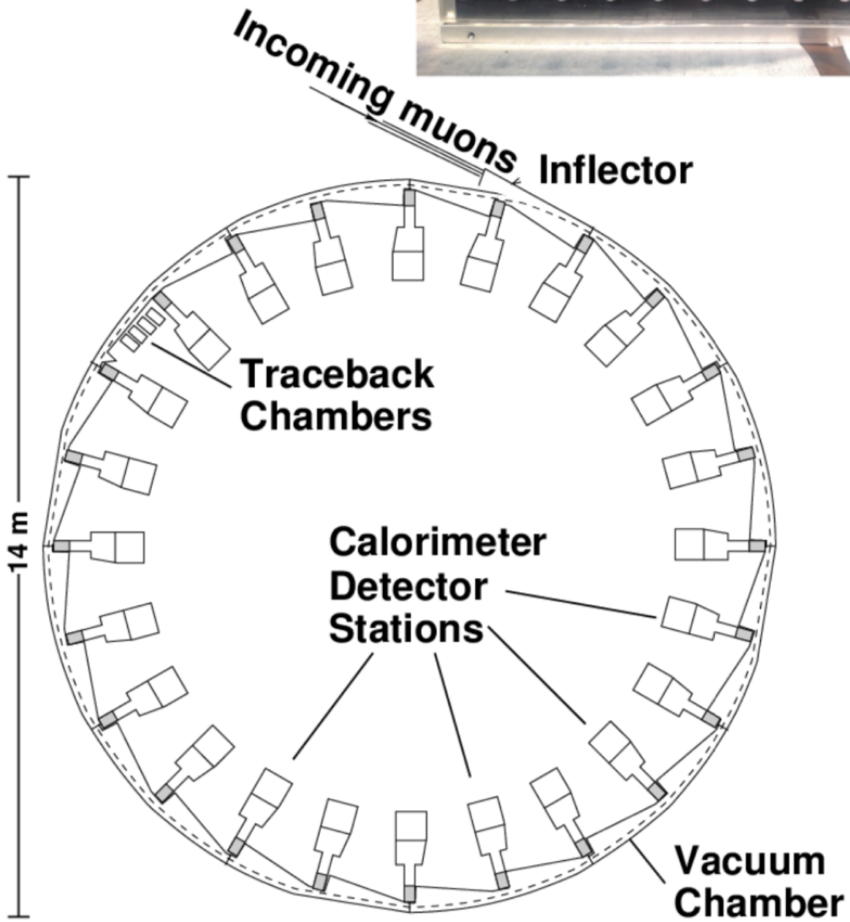


Calorimeters:

54 (6x9 array) lead fluoride (PbF_2) crystals

Crystals read-out by Silicon Photomultiplier

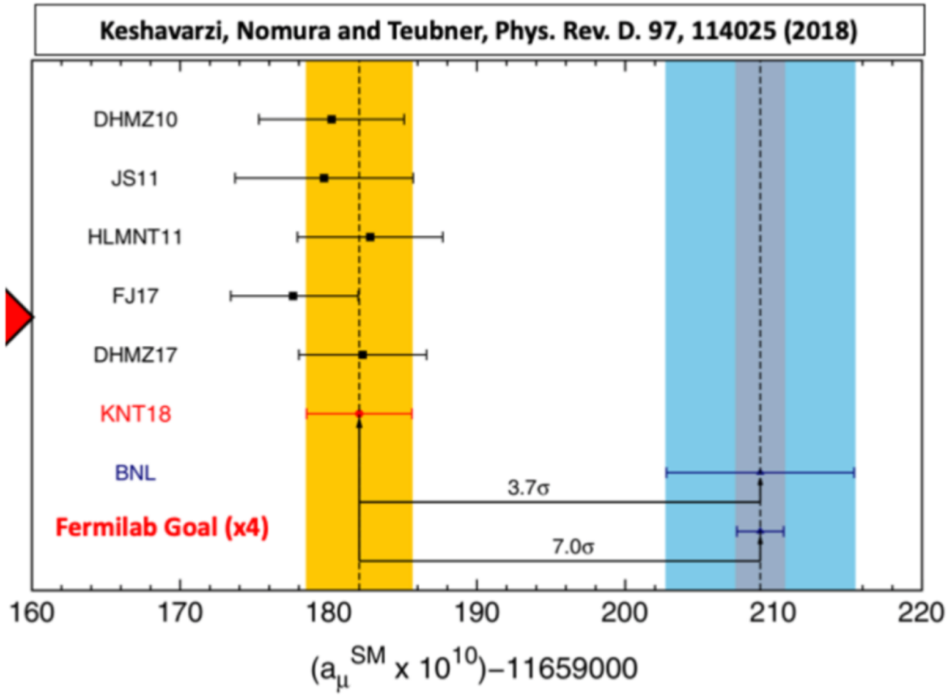




BUT FIRST.. MOVING THE EXPERIMENT

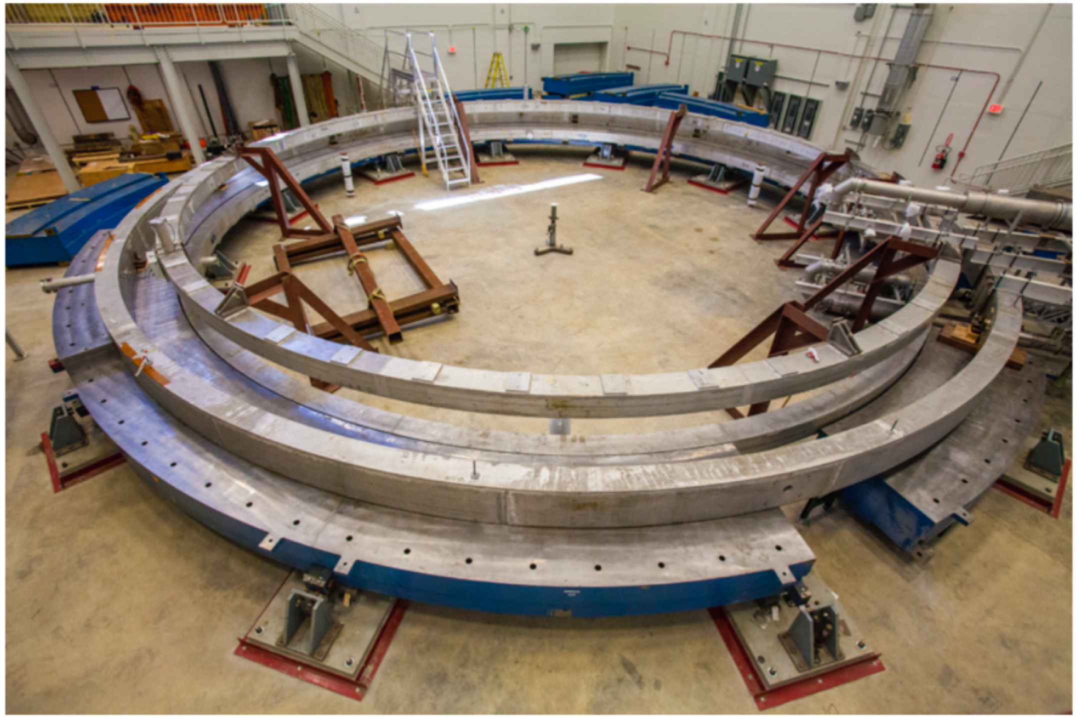
In the summer of 2013:

From Brookhaven to Fermilab for **more intense muons** beams



THE SUPERCONDUCTING MAGNET

The 1.45T superconducting magnet is the actual thing that got transported



Backup (I). The LHCb Upgrade

Collect ~50fb^{-1}, 5x luminosity in Run 1 and Run2 combined (9fb^{-1})!