Charged Lepton Flavour Violation

Becky Chislett

Workshop on muon precision physics

University of Liverpool

9th November 2022

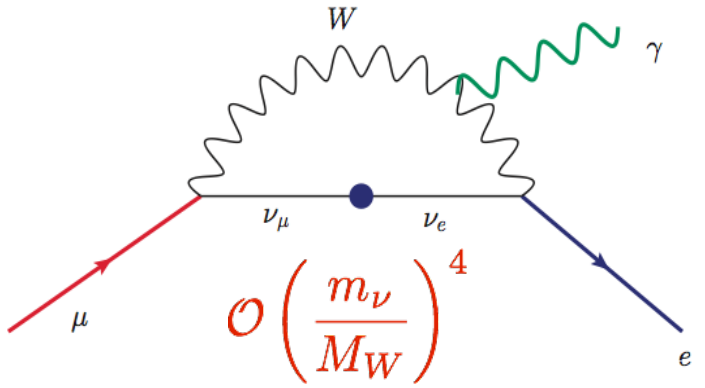
Charged Lepton Flavour Violation

Mu2e, COMET, Mu3e and MEG-II look for the neutrinoless conversion of a muon to an electron

Observed in the neutral sector through neutrino oscillations

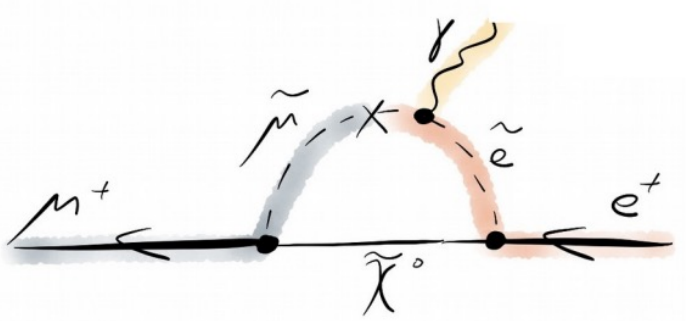
In the SM rate is O(10^{-50})

→ **Any observation is a sign of new physics**

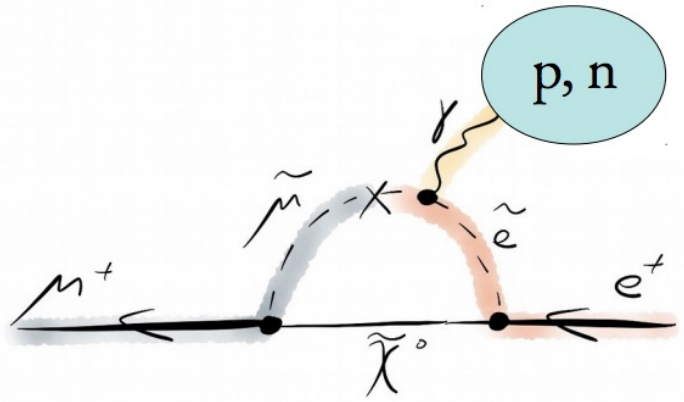


Probes a wide range of different physics models

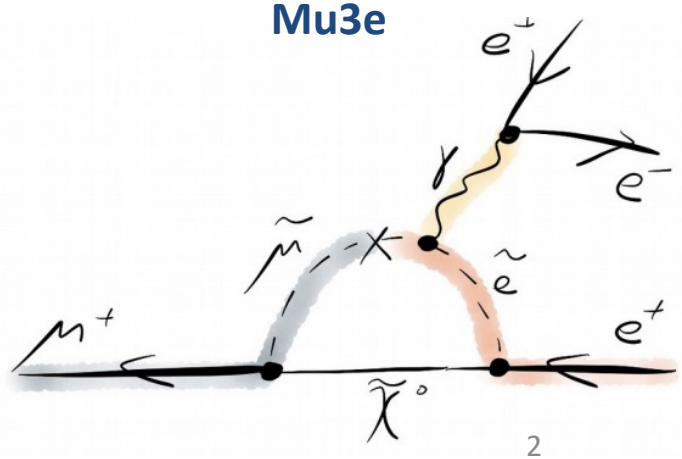
MEG-II



Mu2e/COMET



Mu3e



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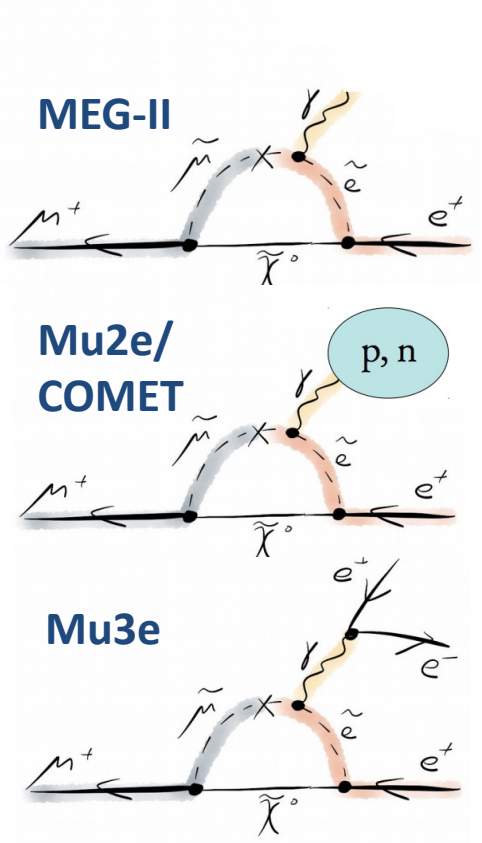
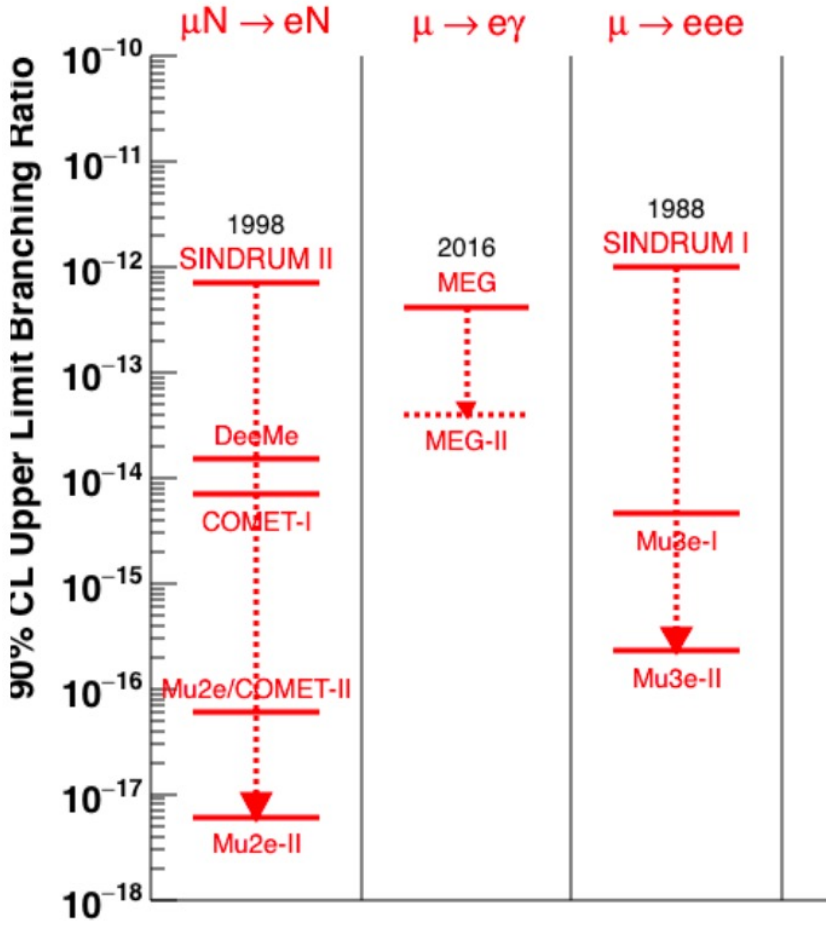
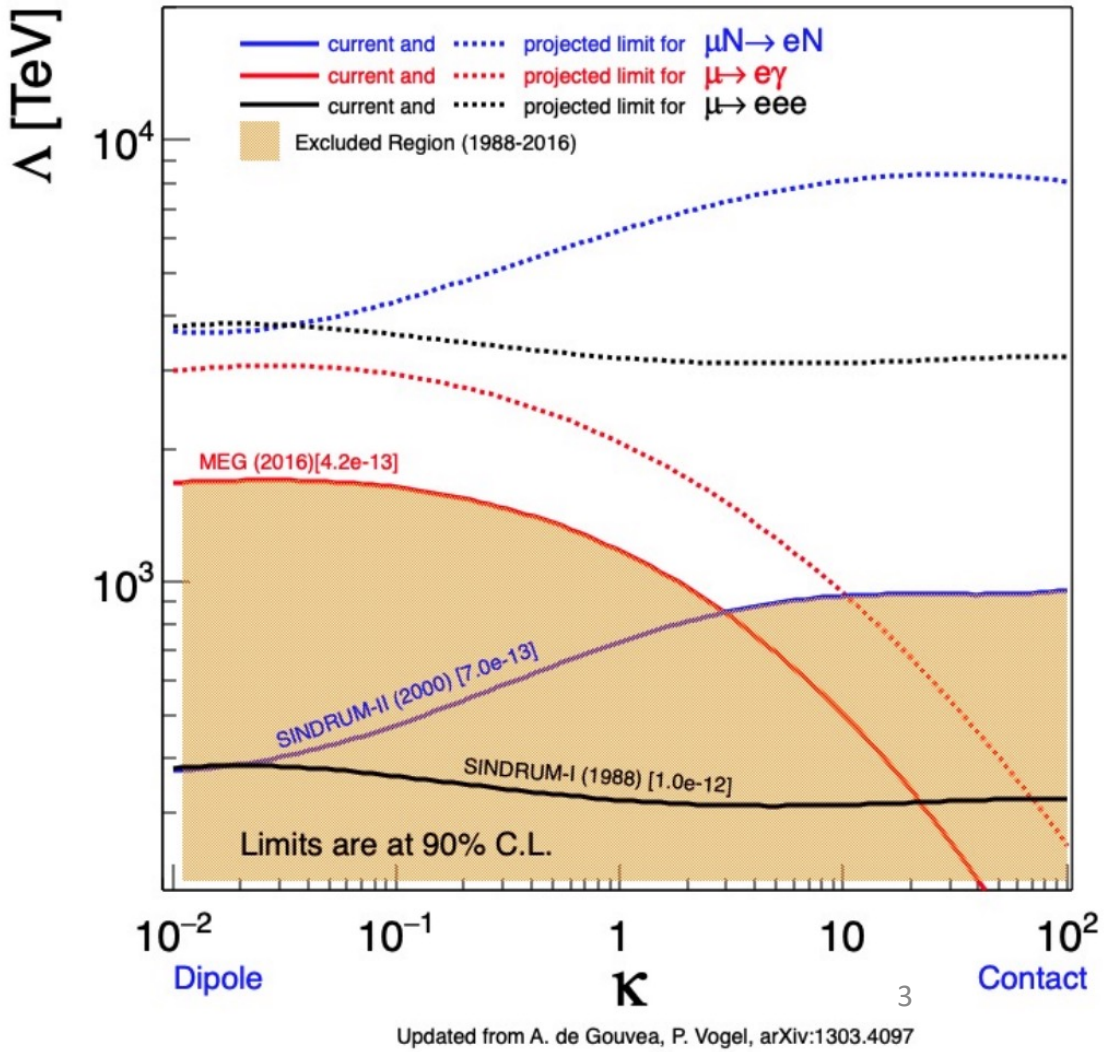
Mu2e, COMET, Mu3e and MEG-II look for the neutrinoless conversion of a muon to an electron



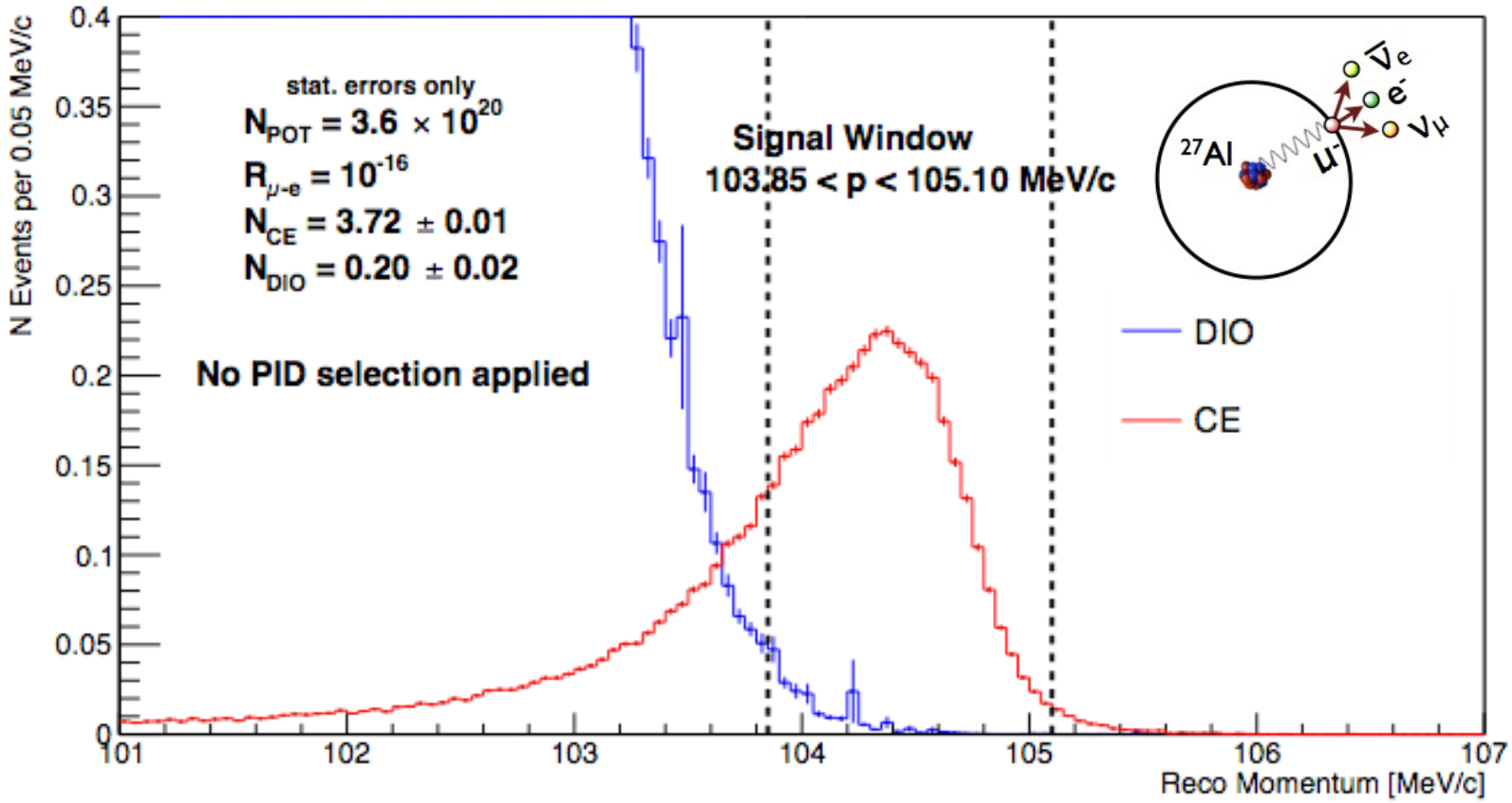




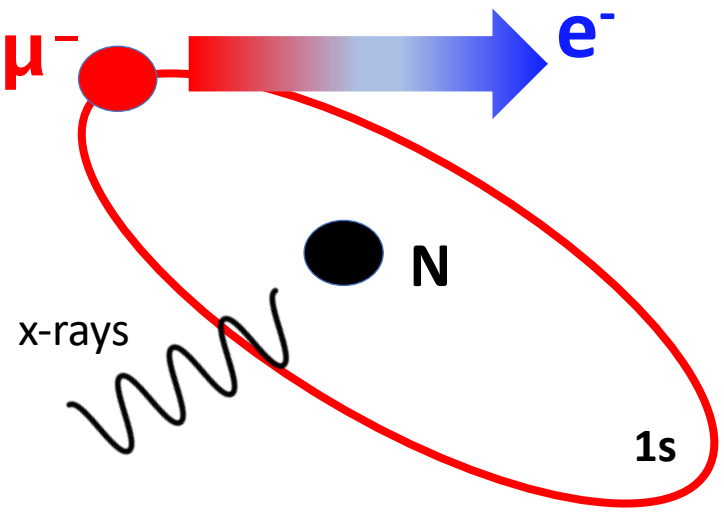
CLFV in the presence of a nucleus

The neutrinoless conversion of a stopped muon to an electron produces a mono-energetic electron signal

Measure the ratio : $\frac{\text{Muon to electron conversion}}{\text{Muon capture on the nucleus}}$



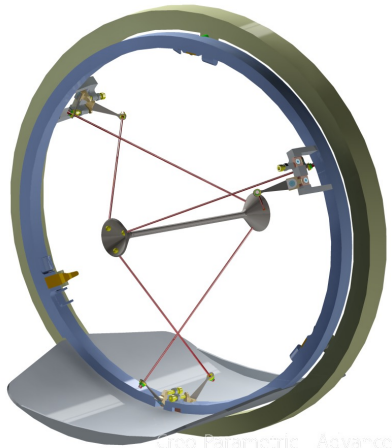
Signal



$$E_e = m_\mu - E_{bind} - E_{recoil}$$
$$= 105.67 - 0.47 - 0.22\ MeV$$
$$= \mathbf{104.98\ MeV}$$

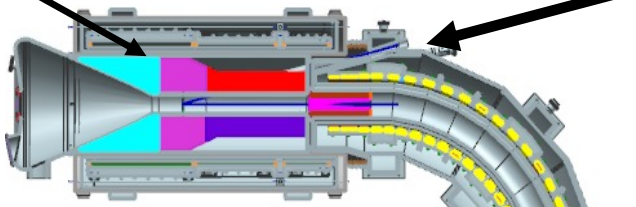
The Mu2e experiment

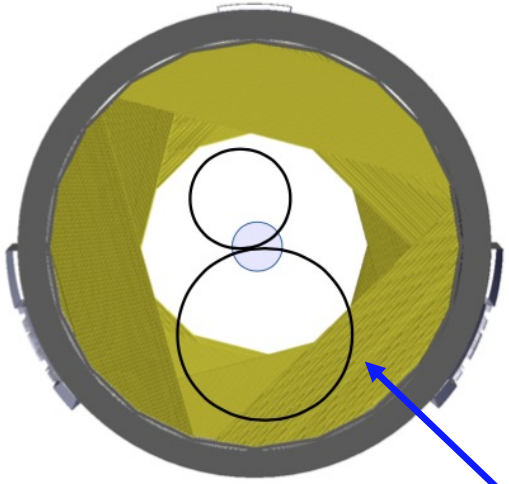
The experiment is designed to produce a low energy beam of muons which are captured on a stopping target



Production Solenoid

8 GeV protons

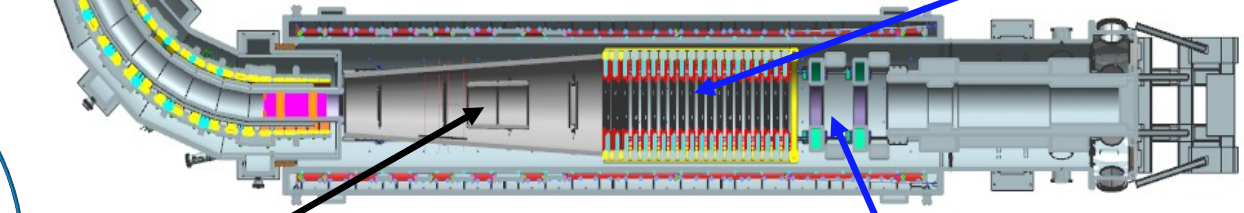


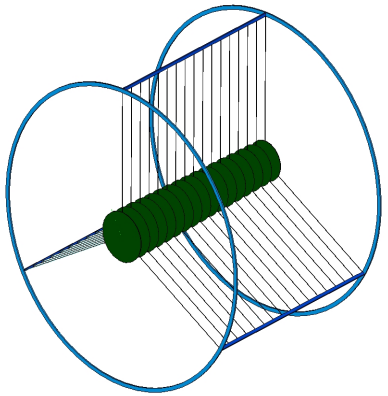


Transport Solenoid

Detector Solenoid & CRV

Tracker





Al-Stopping Target

6m

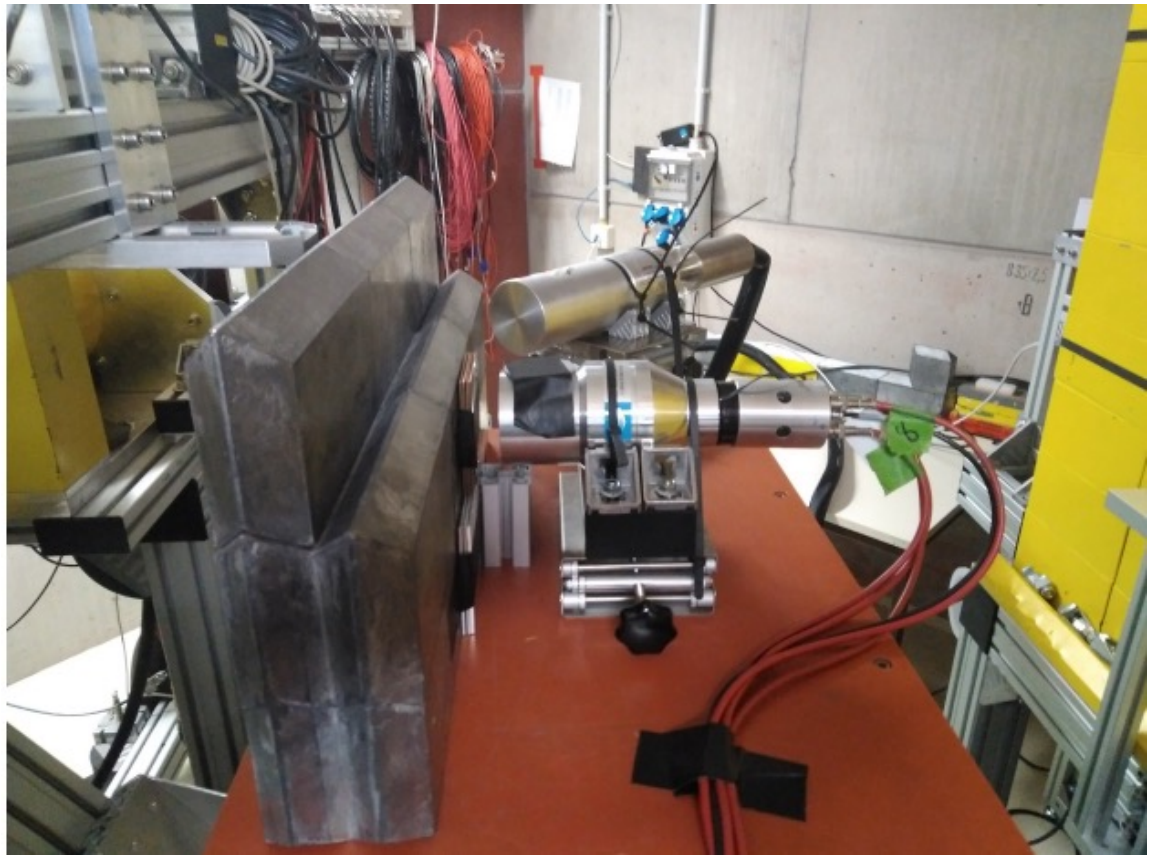
Calorimeter

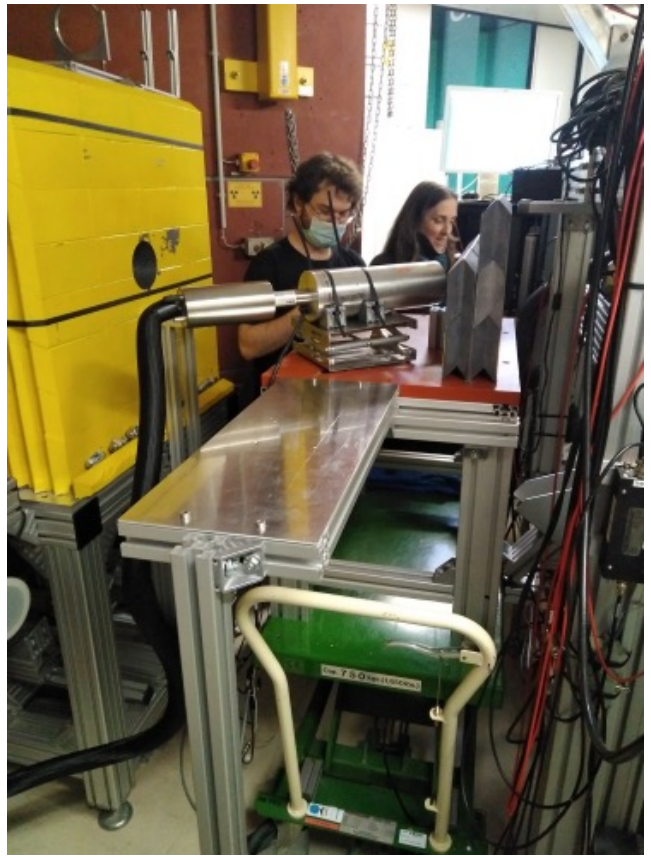
20 m downstream STM

UK contributions to Mu2e - STM

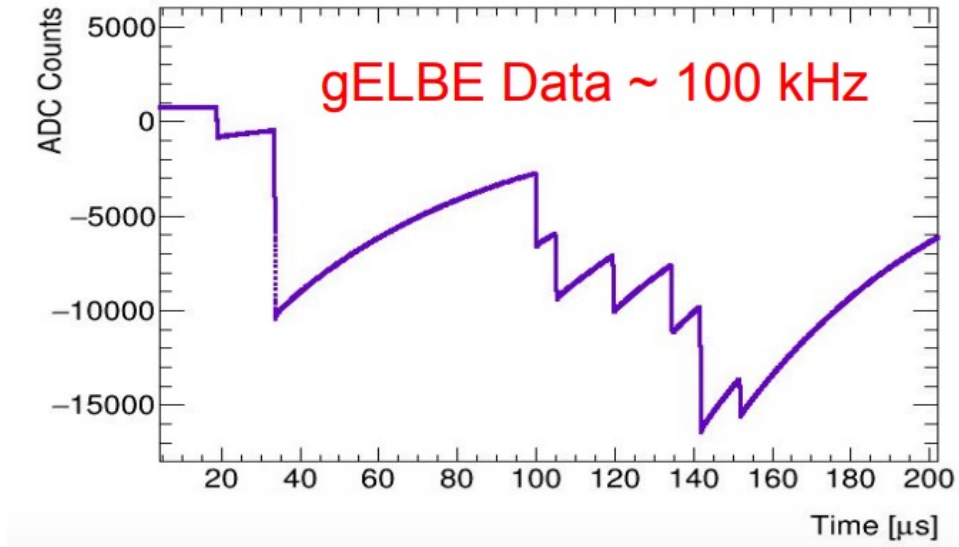
Need excellent energy resolution at high rate to detect the x-rays from muon capture on the nucleus

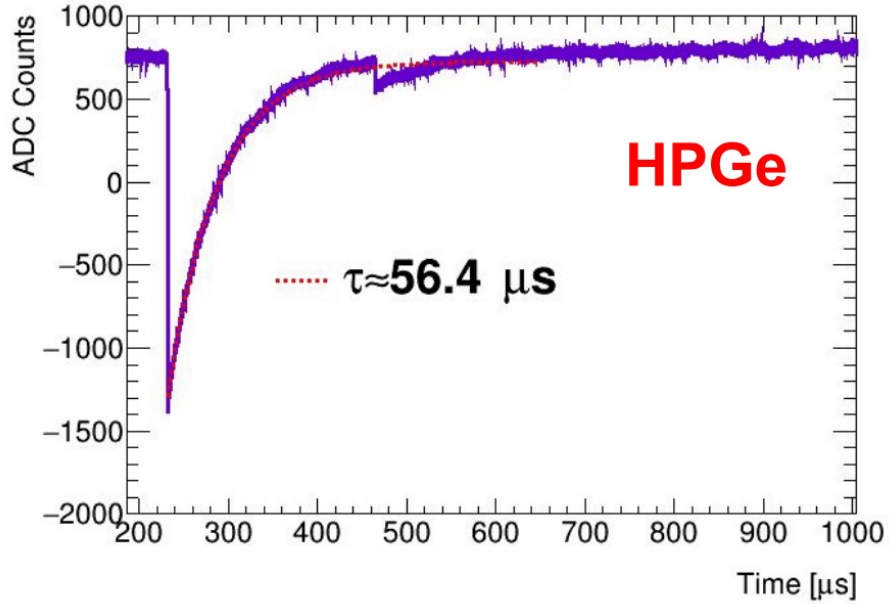
Determines the overall rate for normalization of the experiment





UK contributions to Mu2e - STM





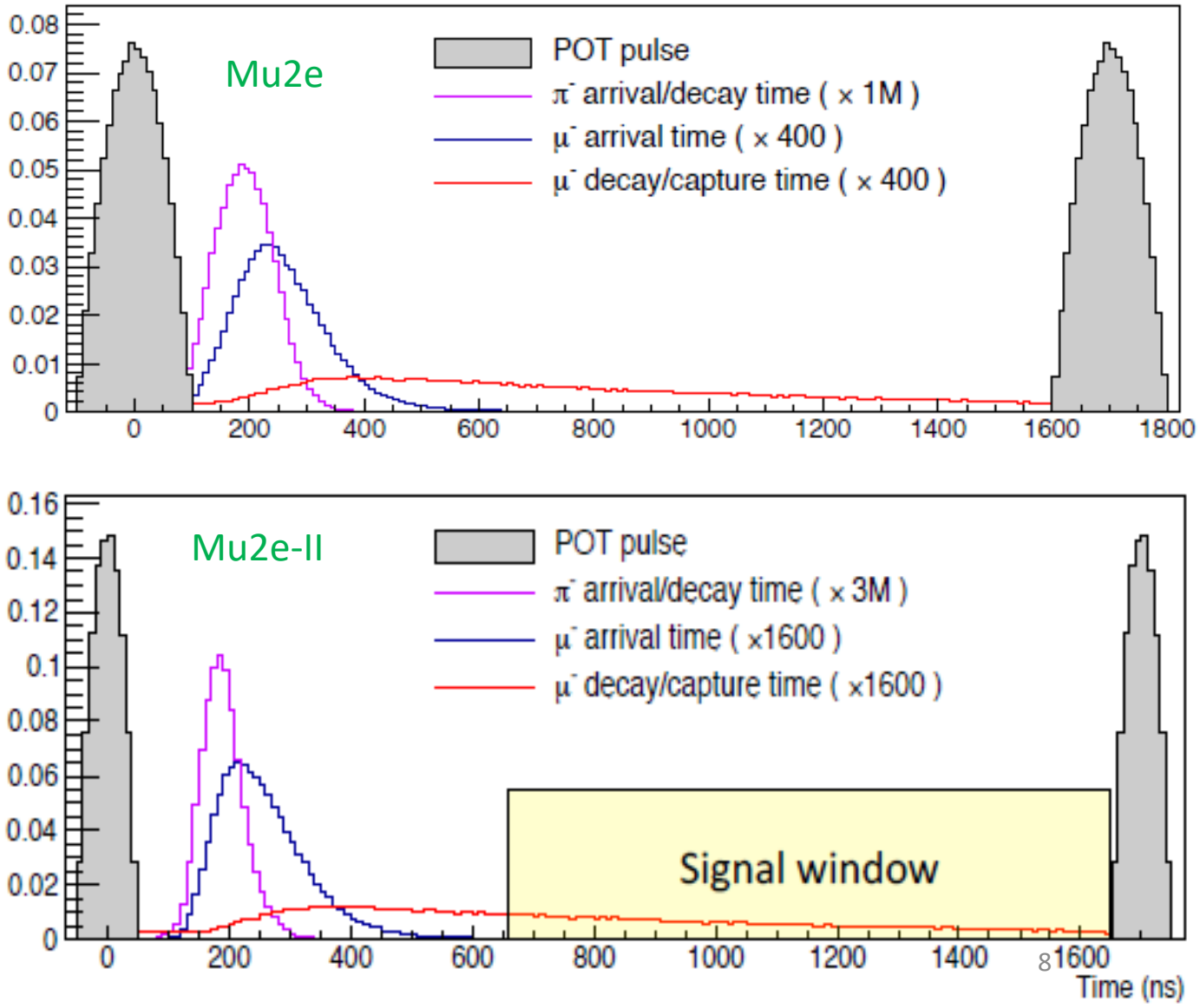
Mu2e-II

Mu2e-II proposes to improve by a further order of magnitude using the PIP-II beam:

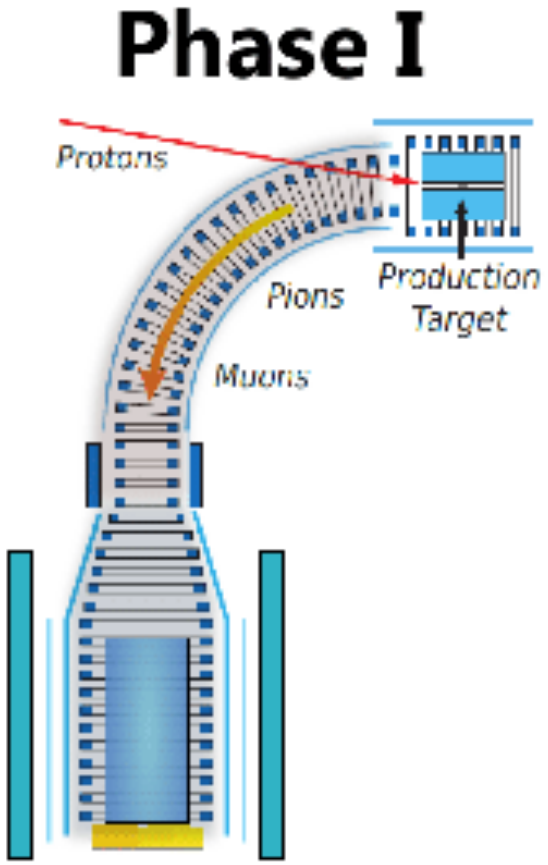
- Narrower pulses
- Less pulse to pulse variation
- Higher intensity
- Higher duty factor

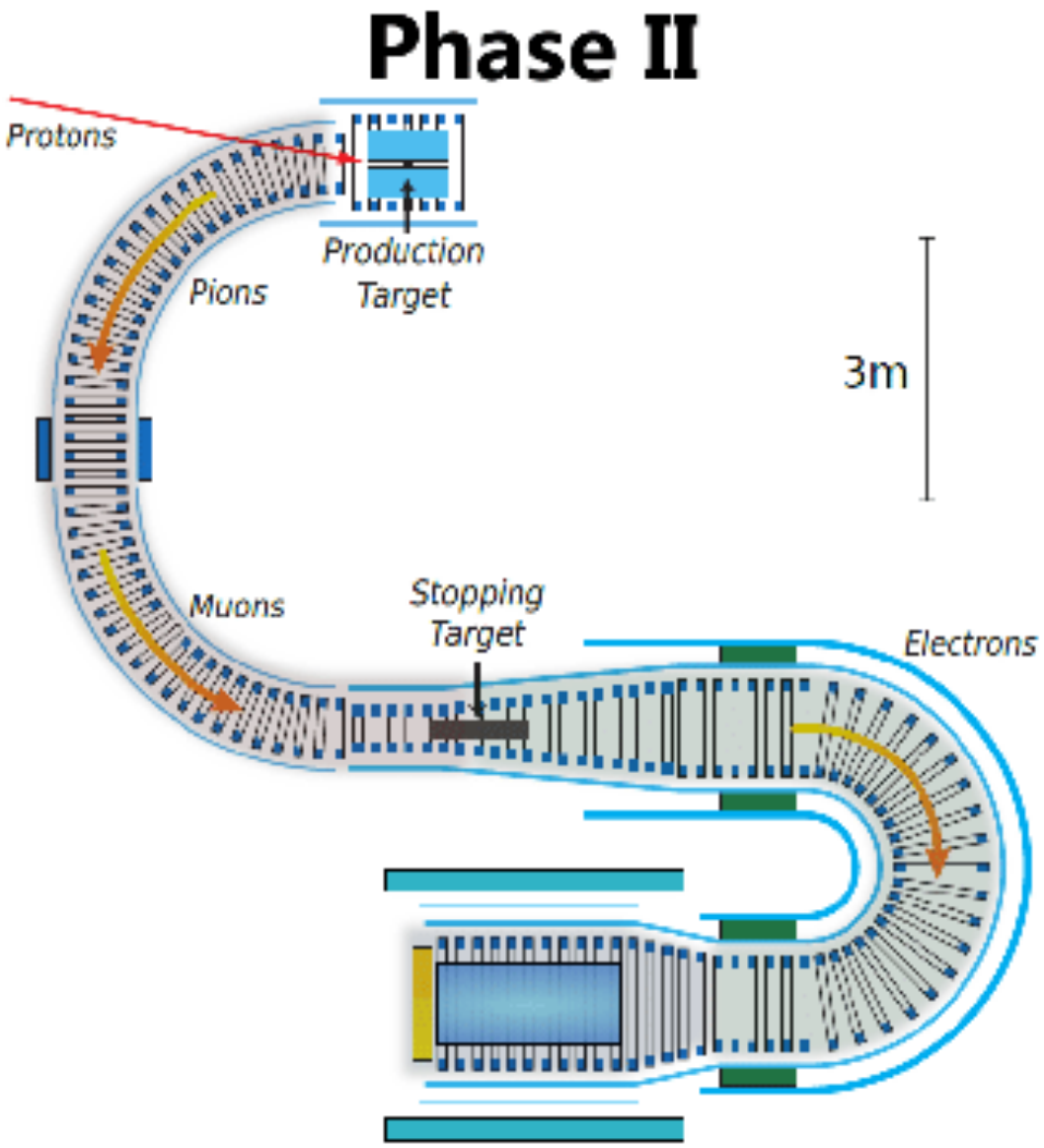
Also involves improvements to most other parts of the experiment

Simulations of different geometries and prototypes of different technologies are ongoing



COMET





COMET phase-I:

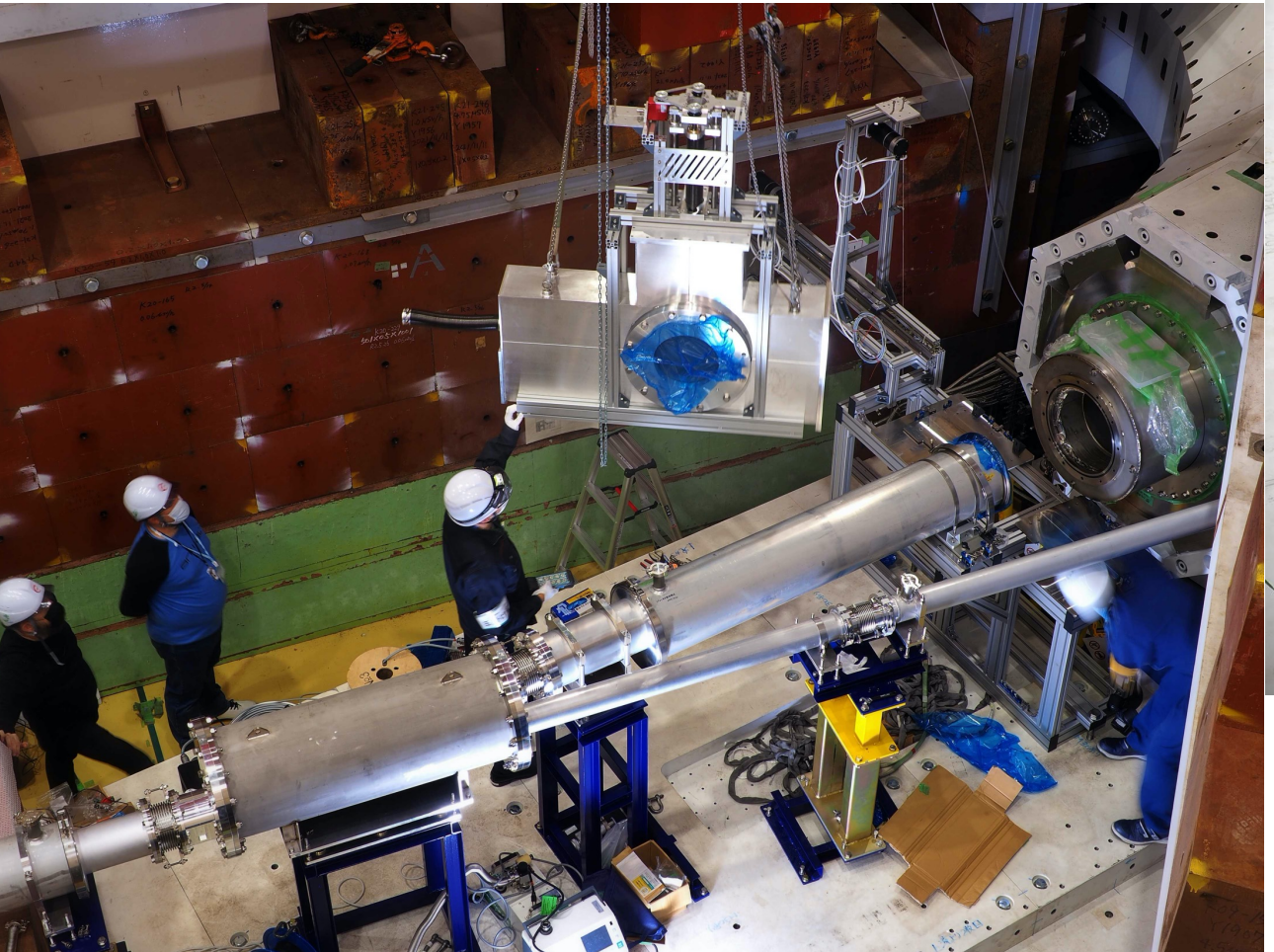
- Factor of 100 improvement on current limit

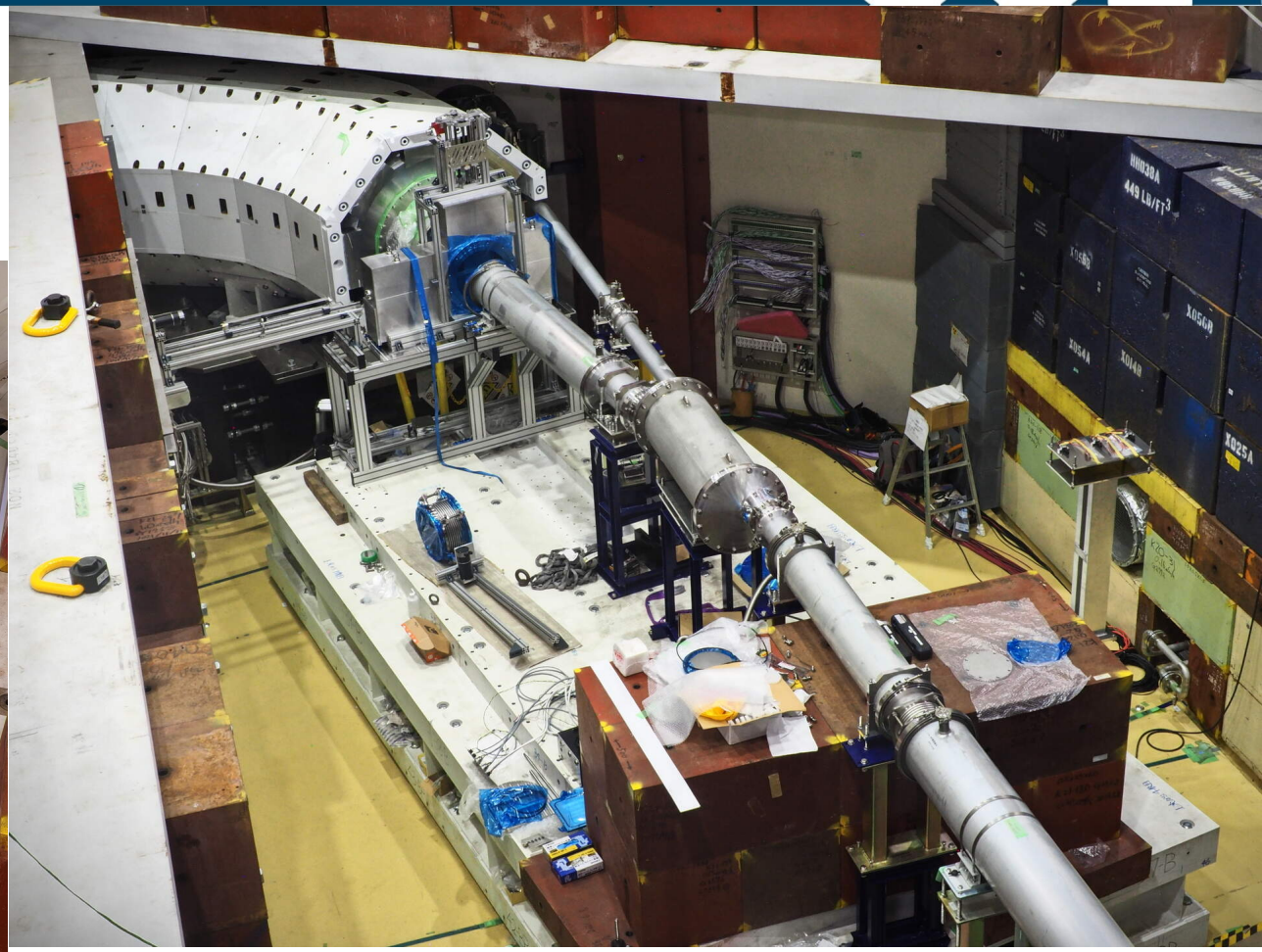
COMET phase-II:

- Improvement of a further factor of 100 (same as Mu2e)

UK contributions to COMET

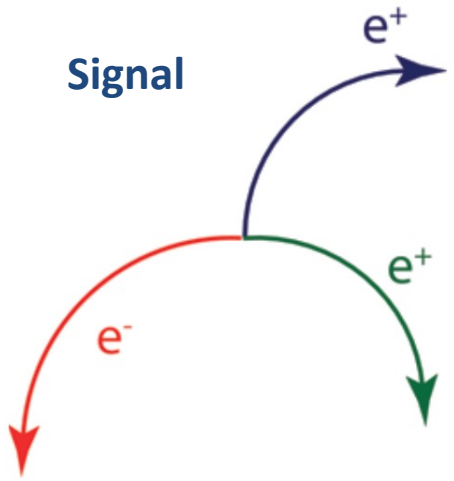
Installation of the variable beam mask system built in the UK to study the optics of the superconducting solenoid





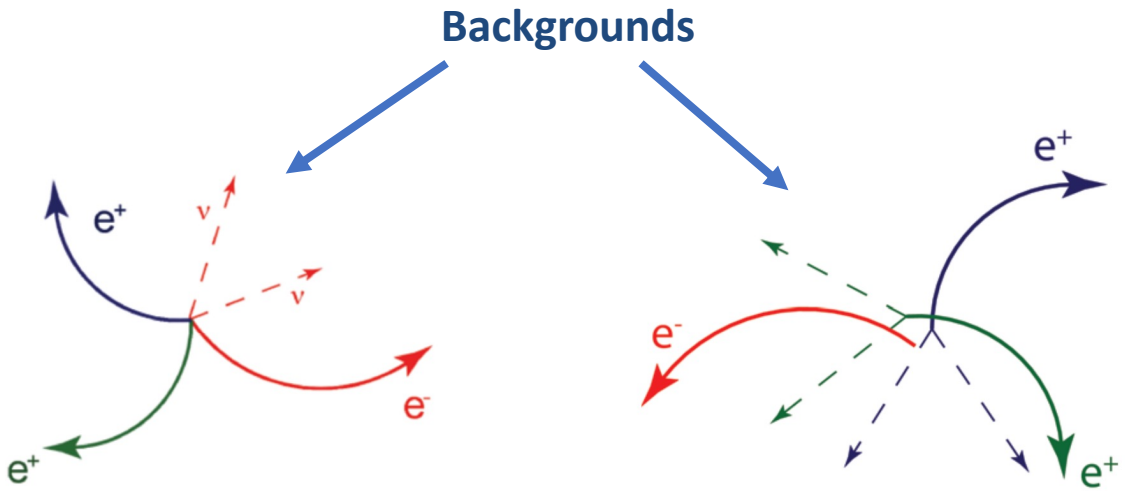
Runs starting in a few months time

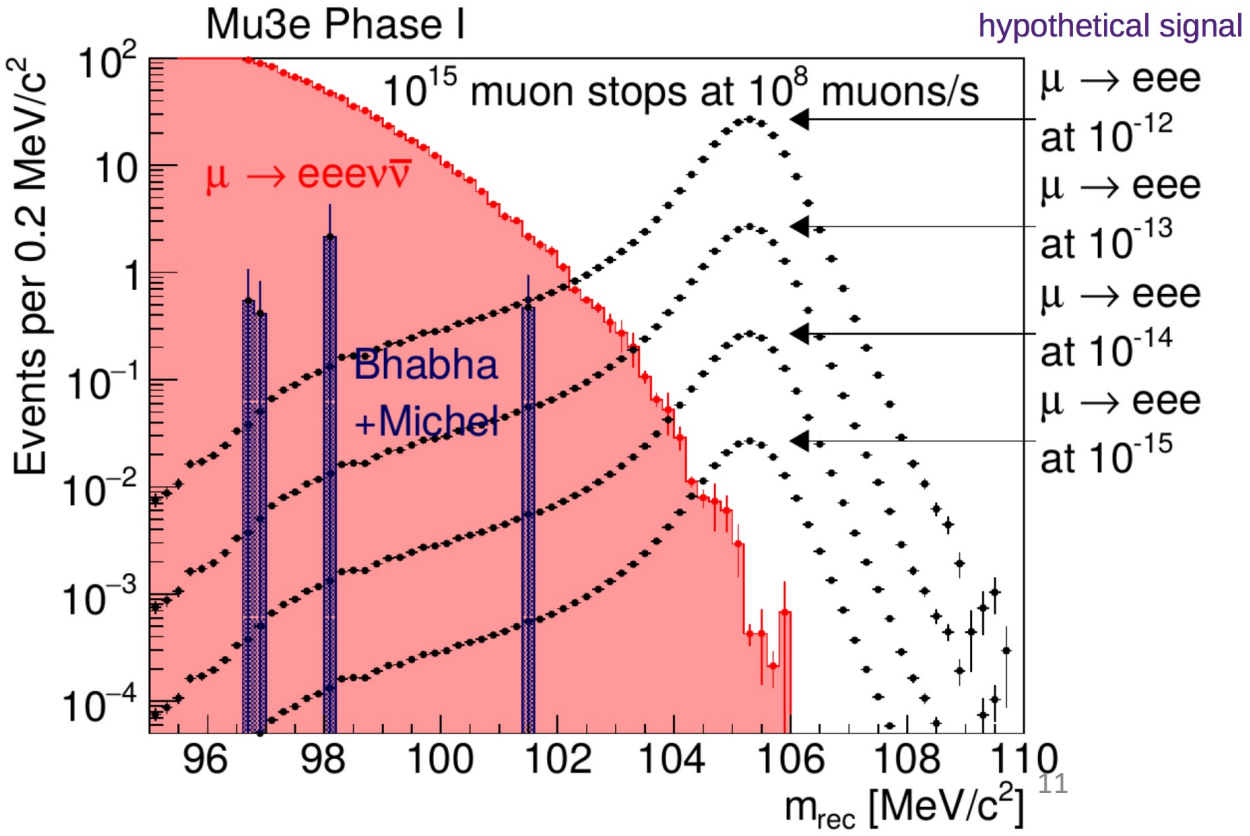
The Mu3e experiment



Requirements :

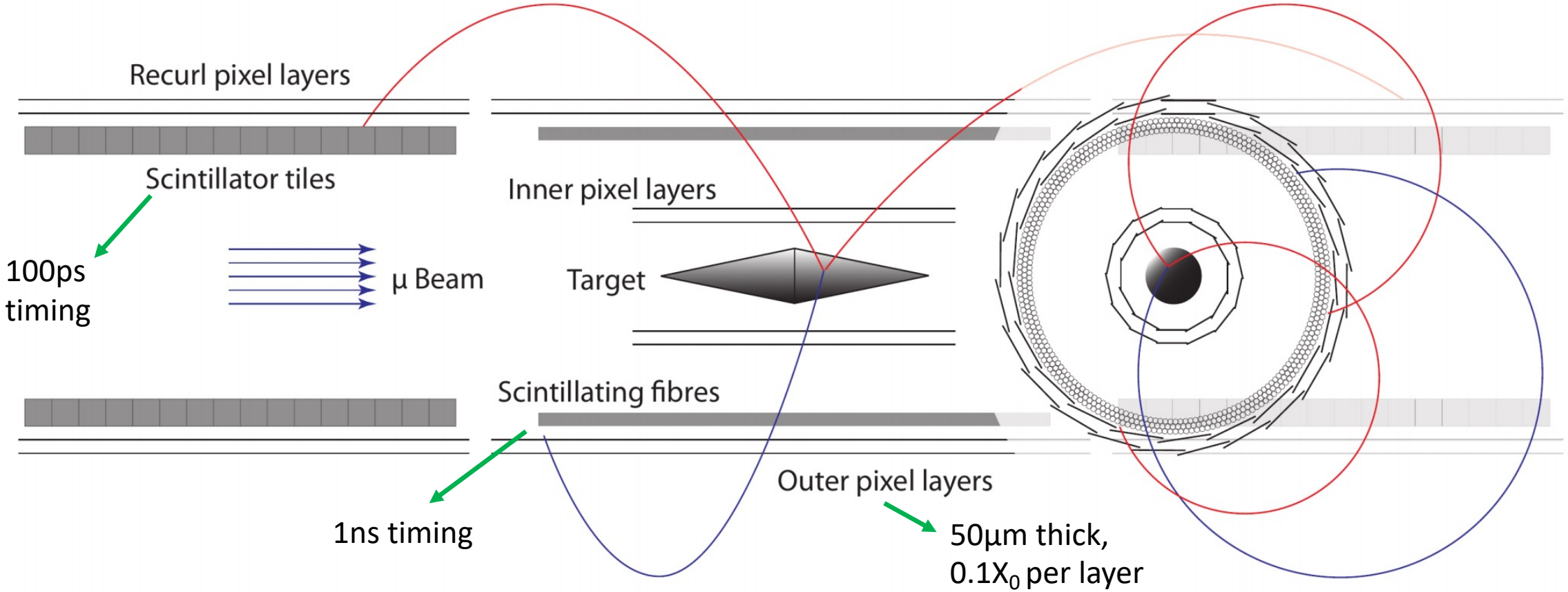
- Excellent timing information (1 ns)
- Good momentum resolution (0.5 MeV at ~53 MeV)
- Well reconstructed vertex (200 µm)
- Minimal material





The Mu3e experiment

PSI provides a constant low momentum (29 MeV) continuous muon beam with 10^8 muons per second on target

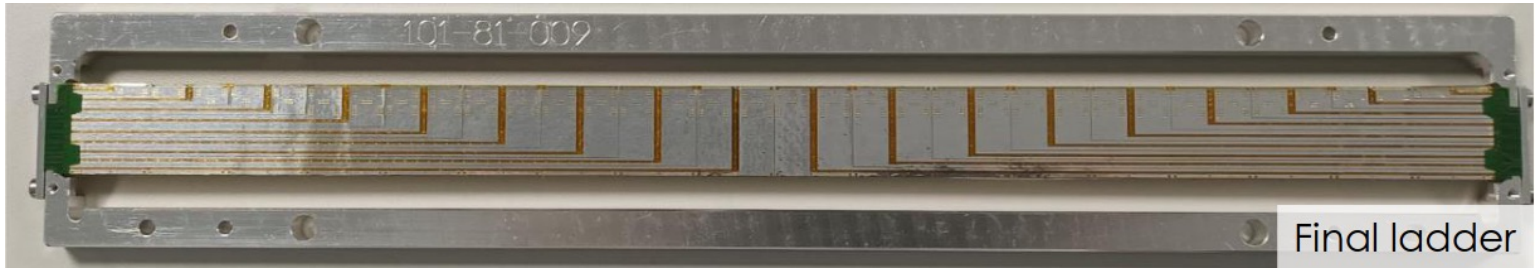


Integration run in 2021, construction of scintillating fibres, tiles and pixel next year with completion in 2024, physics data taking from 2025

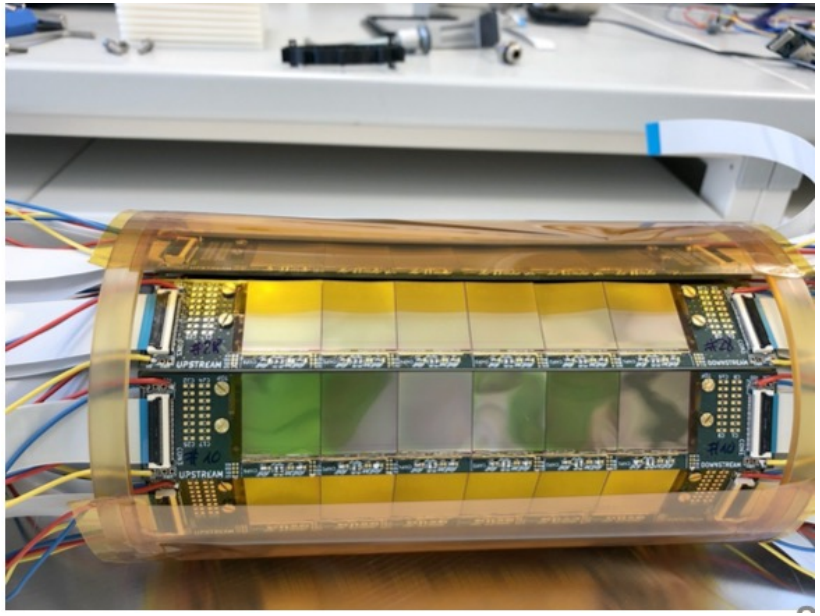
- Phase I : 1000x improvement on current limit
- Phase II : use HIMB to achieve a further factor of 10

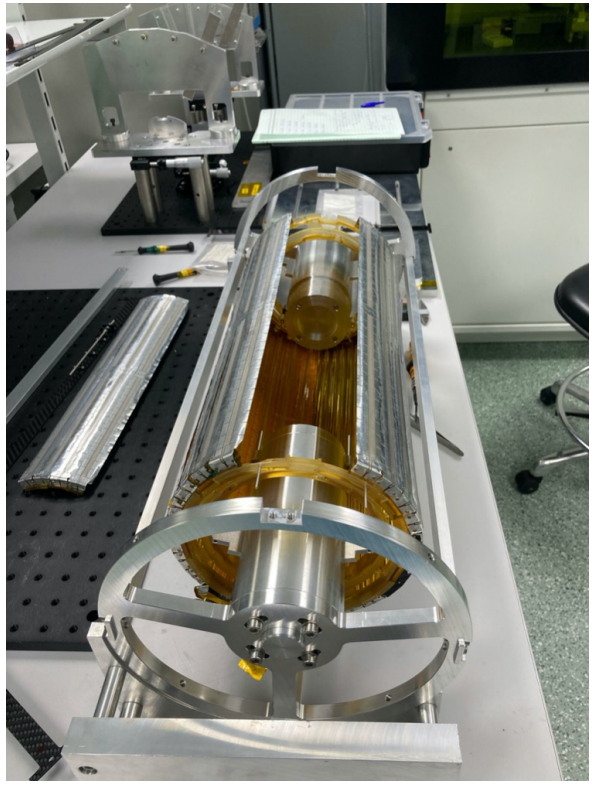
UK contributions to Mu3e

Outer pixel layers being built in the UK



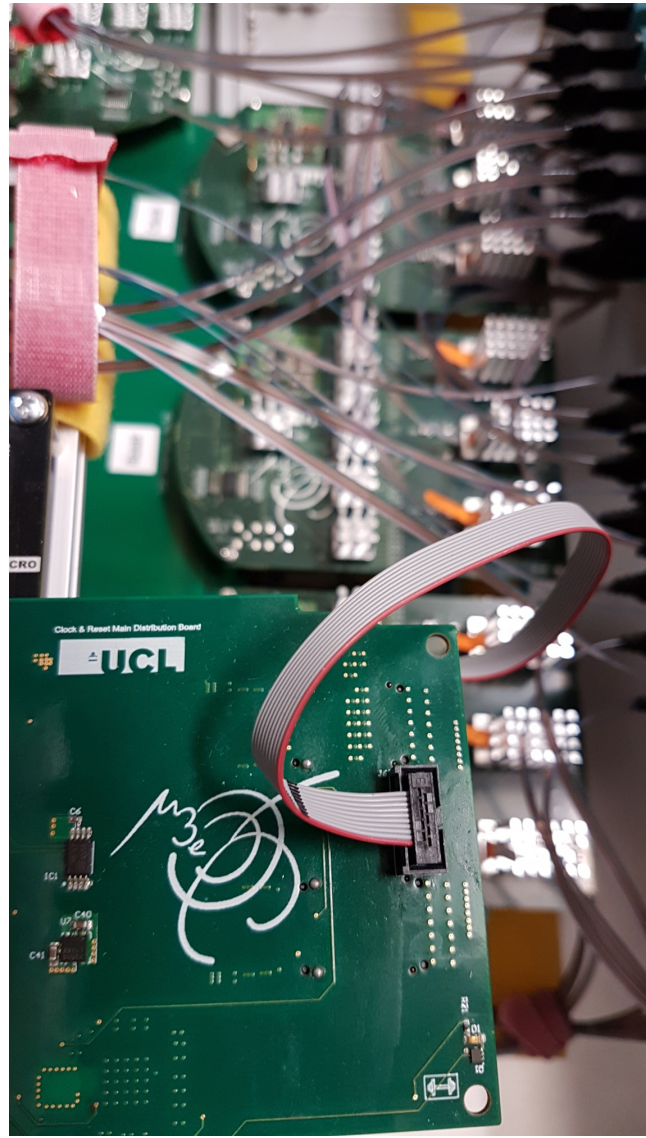
Inner pixel layer prototype for beam test at PSI in 2021.





Also: Physics Coordinator (Gavin Hesketh), pixel project leader (Joost Vossebeld), MC coordinator (Carlos Chavez) and extensive contributions to computing and analyses preparation

Clock and reset system



Conclusions

The UK is involved in a variety of different CLFV searches:

- Mu2e at FNAL (Liverpool, Manchester, UCL)
- COMET at J-PARC (Imperial)
- Mu3e at PSI (Bristol, Liverpool, Oxford, UCL)

Expect exciting results with large increases in sensitivity over the coming years