Detector studies and software analysis with The Mu3e Experiment
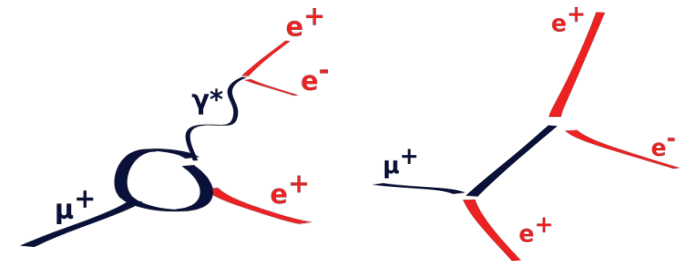
Spring annual HEP meeting

Sean Hughes

Supervisors: Dr Nikolaos Rompotis, Prof Joost Vossebeld

The Mu3e Experiment

- Search for Lepton Flavour Violating (LFV) decay $\mu^+ \rightarrow e^+e^-e^+$

- Heavily suppressed in the SM
  - Mediated by neutrino oscillations
  - Enhanced by various beyond-SM theories

- Current limit (90% CL):
  - $BR_{\mu \rightarrow eee} < 10^{-12}$ SINDRUM 1988

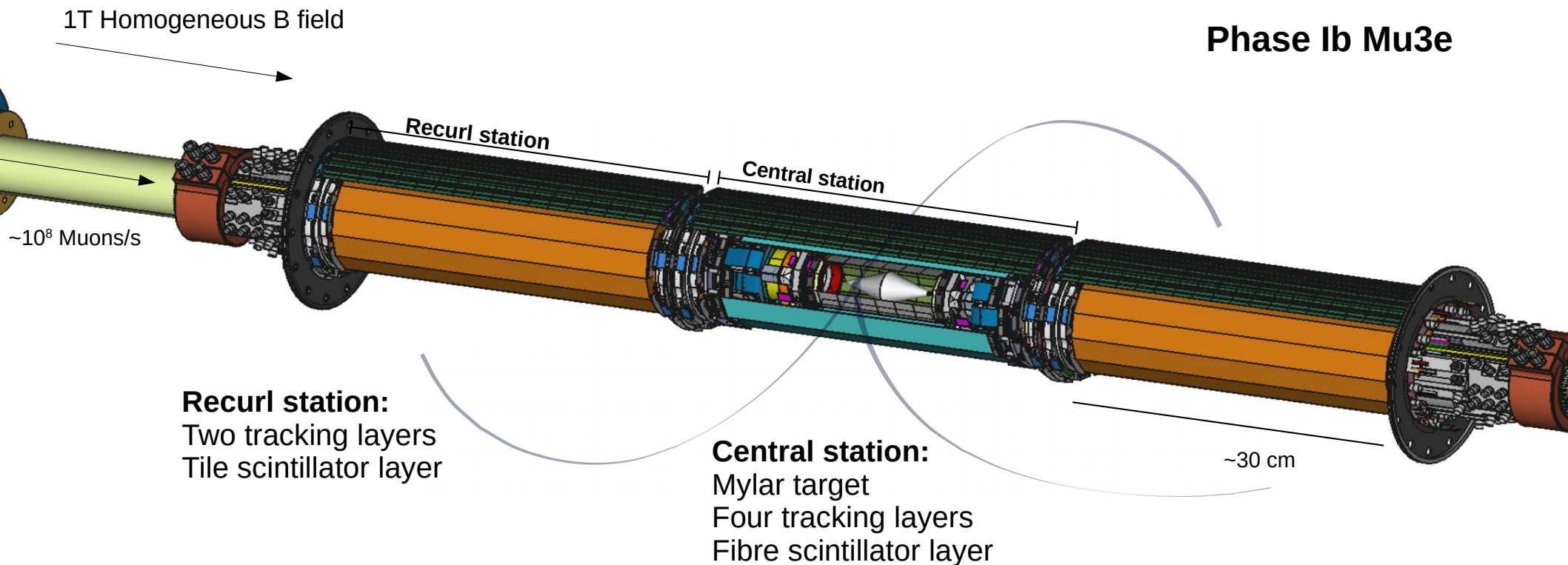- Mu3e aiming for a sensitivity of one in 10^{16} Muon decays
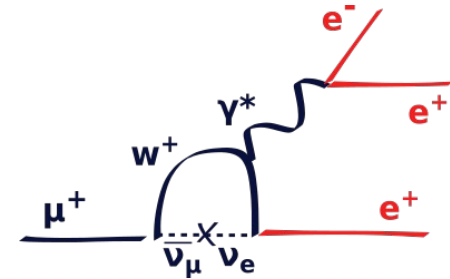
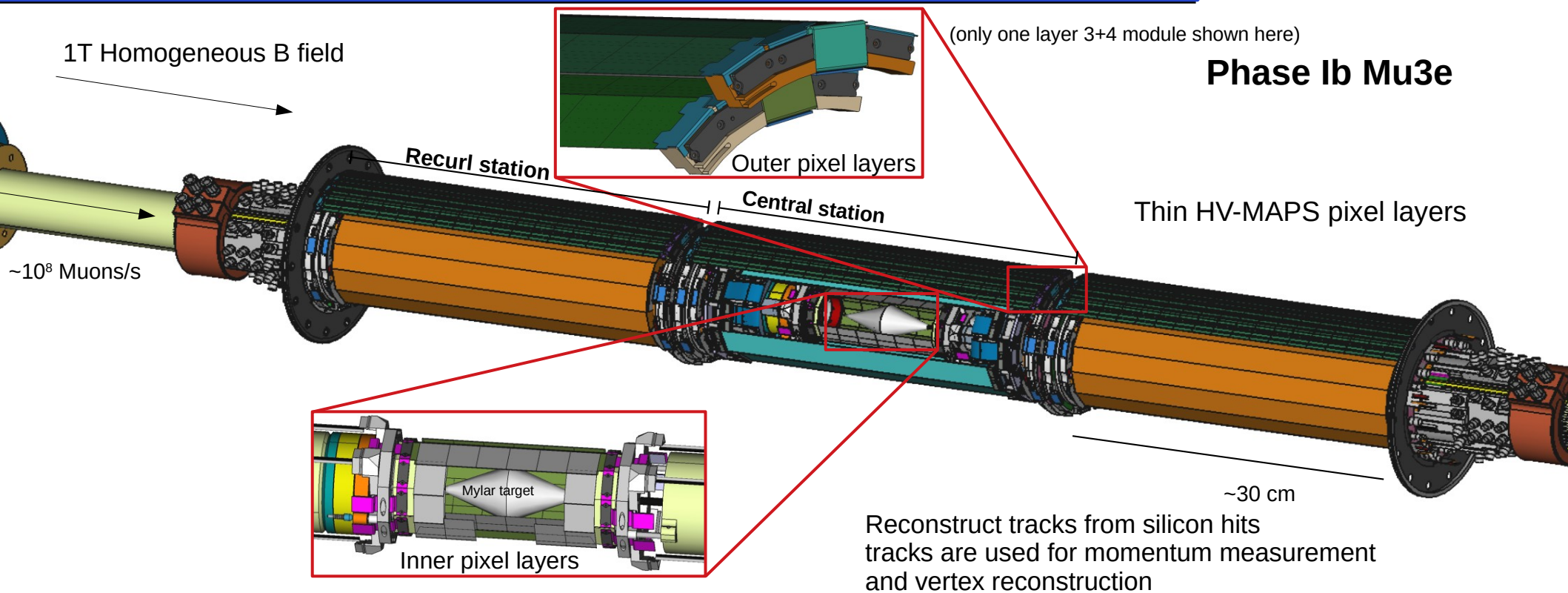$BR_{\mu \rightarrow eee} \sim (\Delta m_\nu^2/m_w^2)^2 < 10^{-54}$
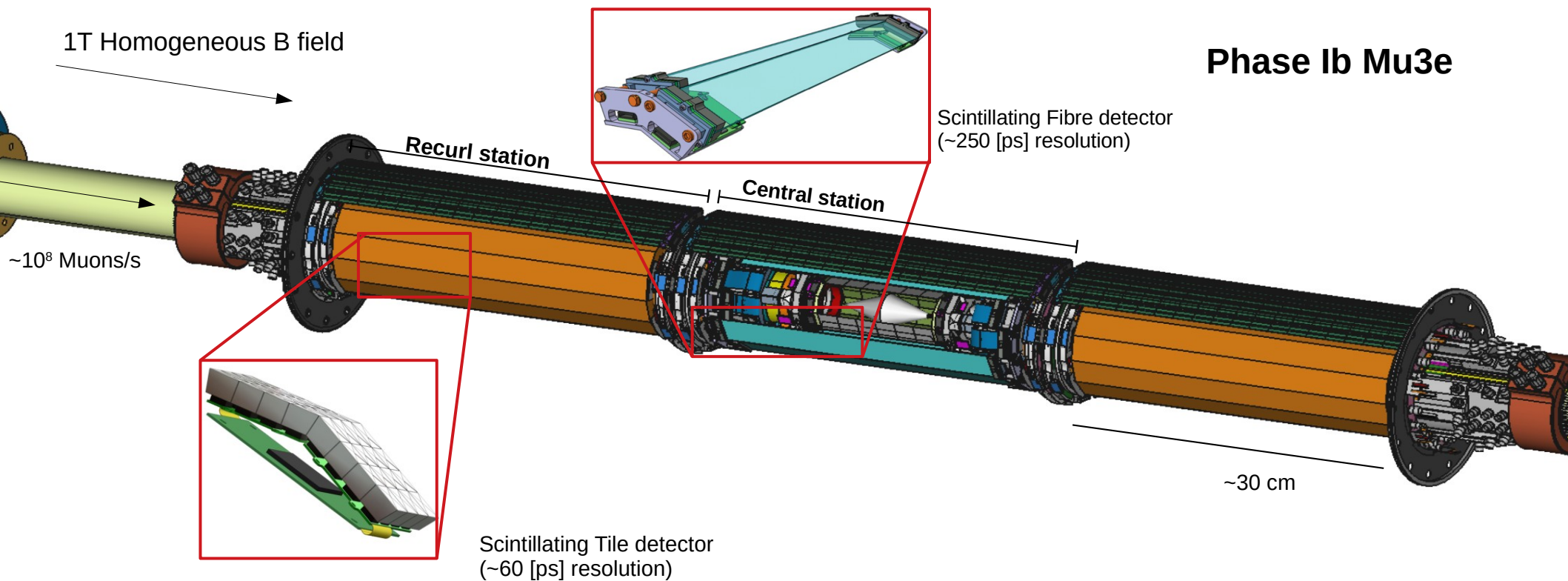
BSM Feynman Diagrams

The Mu3e Detector (1/3)

Phase Ib Mu3e

1T Homogeneous B field

~10^8 Muons/s

Recurl station

Central station

Recurl station:
Two tracking layers
Tile scintillator layer

Central station:
Mylar target
Four tracking layers
Fibre scintillator layer

~30 cm

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1T Homogeneous B field

(only one layer 3+4 module shown here)

Phase Ib Mu3e

Recurl station

Central station

Outer pixel layers

Thin HV-MAPS pixel layers

~10^8 Muons/s

Mylar target

Inner pixel layers

~30 cm

Reconstruct tracks from silicon hits
tracks are used for momentum measurement
and vertex reconstruction

Sean Hughes   28th April 2021   4

The Mu3e Detector (3/3)

1T Homogeneous B field

Phase Ib Mu3e

Recurl station

Central station

Scintillating Fibre detector (~250 [ps] resolution)

~10⁸ Muons/s

~30 cm

Scintillating Tile detector (~60 [ps] resolution)

Mu3e Software Performance + updates

- Undertaken several studies on the performance of the simulated (Geant4) Phase Ib Mu3e detector

- Investigated timing efficiencies of scintillator layers for different track types, observed distributions of tracks

- Assisted in updates to detector geometry of outer pixel layers in Mu3e software

  – Take into account 1° tilt in outer pixel layers
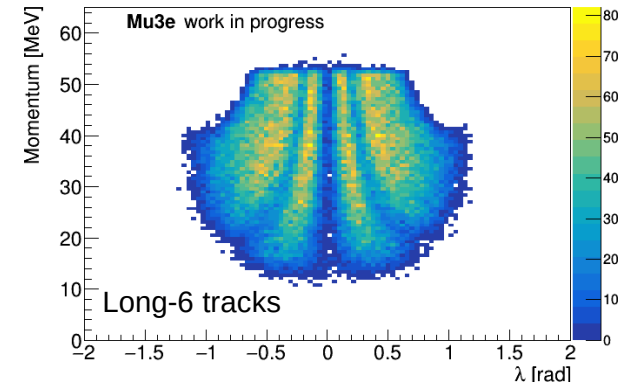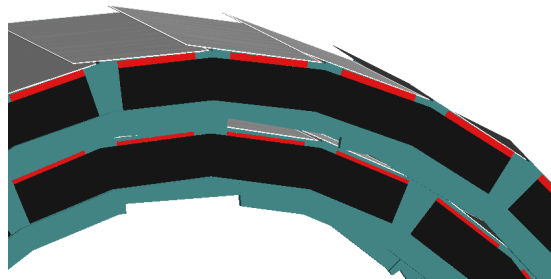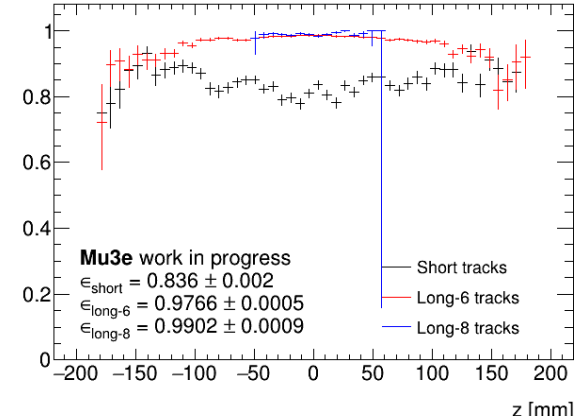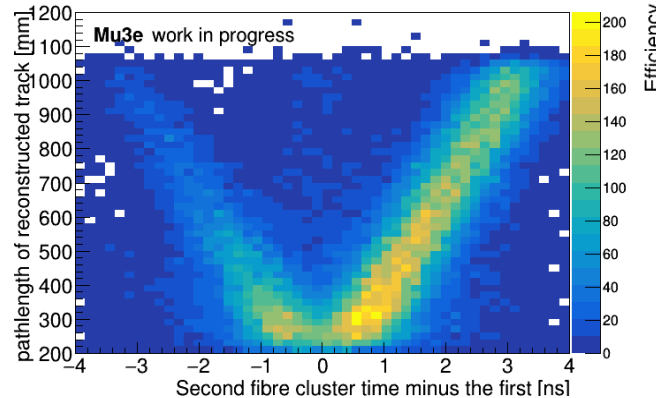
Mu3e Software
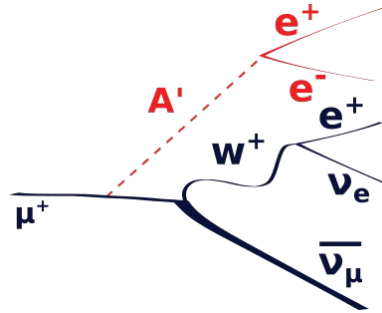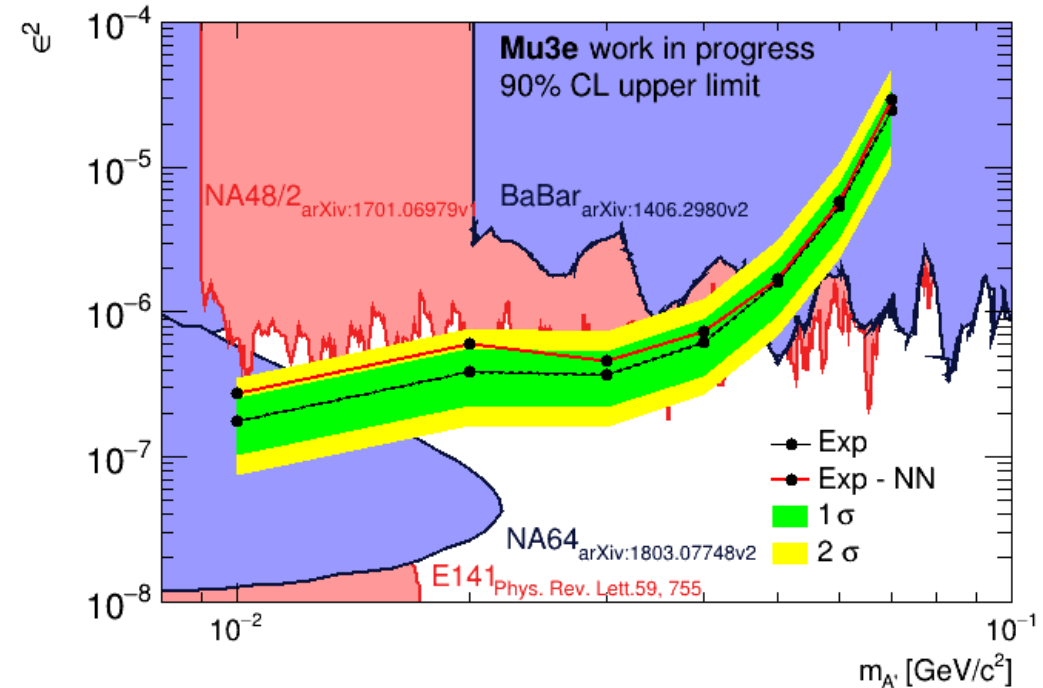# Dark Photon sensitivity study

- **Signature**:

  A' is Dark Photon

- Redo study with latest version of software

- A shallow neural network (NN) is also trained in attempt to improve current limit estimation

  – Difficult to train – results so far only worsened the upper limit

28th April 2021
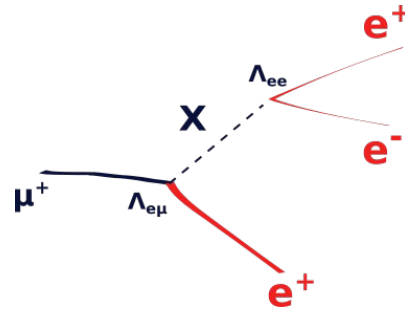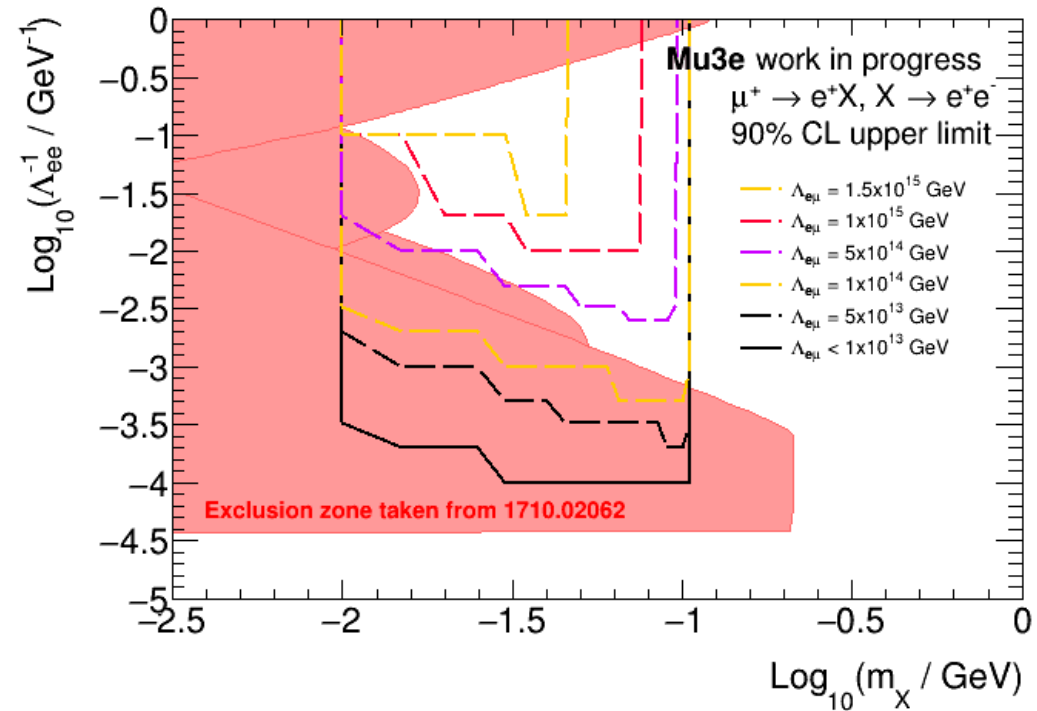
Mu3e Software
# Search for Axion-Like Particles

- **Signature**:

  X is ALP

- **X** has lifetime – displaced vertex

- Have estimated BR upper limits on Λ_{ee} for particular $\Lambda_{e\mu}$ and m_x

- Full simulation, including reconstruction of displaced X, using Phase Ib detector forthcoming
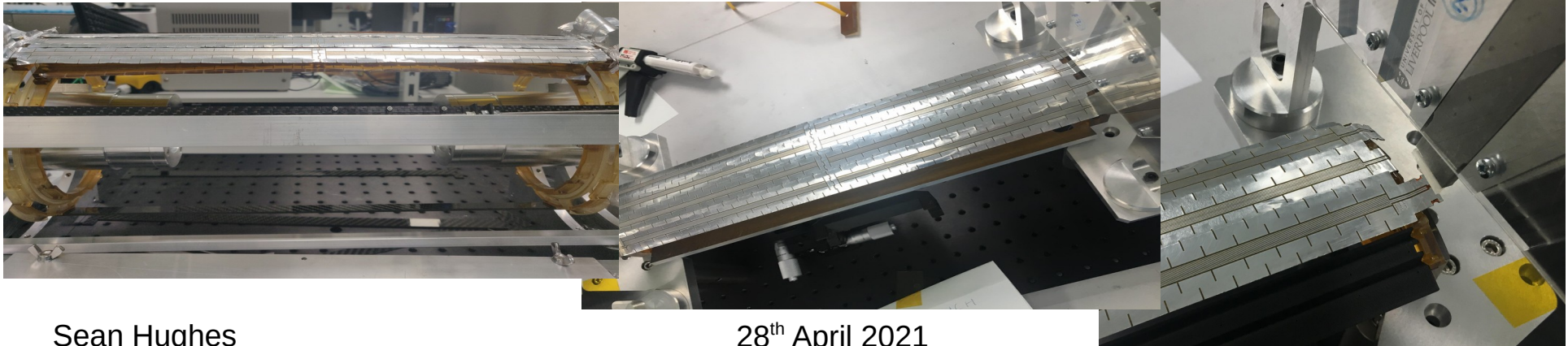
Mu3e Hardware Laboratory work

- Liverpool responsible for construction of Mu3e detector's outer pixel layers

- Assisted in:
  - Metrology
  - Construction of mock layer 3 and 4 modules
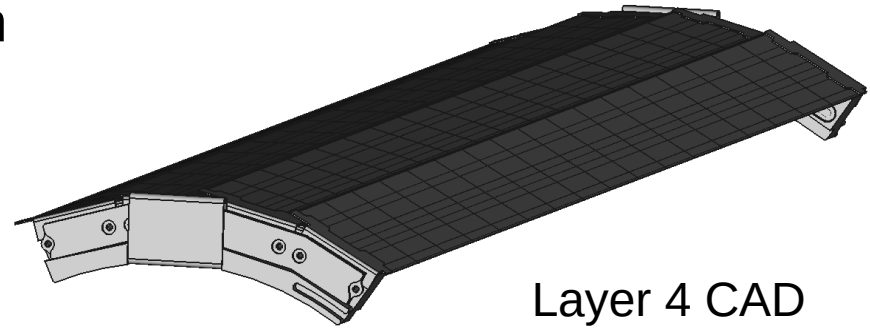
Layer 4 CAD

Summary

- Software studies:
  - Undertaken studies on performance of the simulated Phase Ib Mu3e detector
    - Helped update Mu3e detector geometry
  - Worked on sensitivity studies regarding other physics with Mu3e
    - Dark Photon sensitivity study
    - Study into Mu3e's sensitivity to ALP's ongoing
- Hardware studies:
  - Metrology
  - Construction of tape heater mock up modules