Detector studies and software analysis with The Mu3e Experiment

Spring annual HEP meeting

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The Mu3e Experiment

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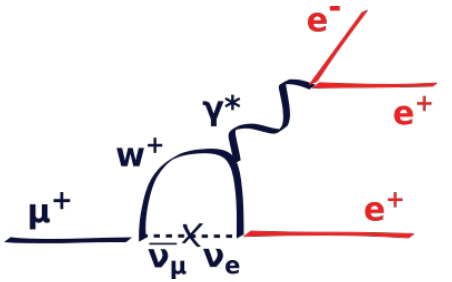
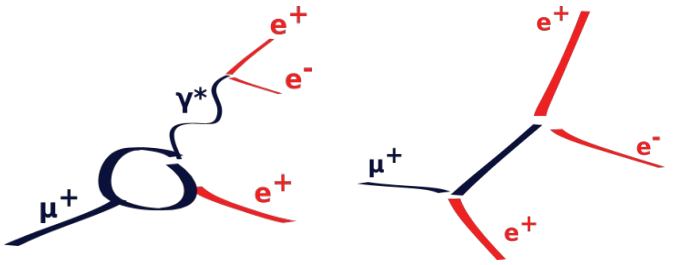
- Search for Lepton Flavour Violating (LFV) decay $\mu^+ \rightarrow e^+e^-e^+$
- Heavily suppressed in the SM
  - Mediated by neutrino mixing
  - Enhanced by various beyond-SM theories
- Current limit (90% CL):
  - $BR_{\mu \rightarrow eee} < 10^{-12}$ SINDRUM 1988
- Mu3e targets up to BR ~ 10^{-16}, 4 orders of magnitude better than the current results



$BR_{\mu \rightarrow eee} \sim (\Delta m_\nu^2/m_w^2)^2 < 10^{-54}$



BSM Feynman Diagrams

The Mu3e Detector (1/4)

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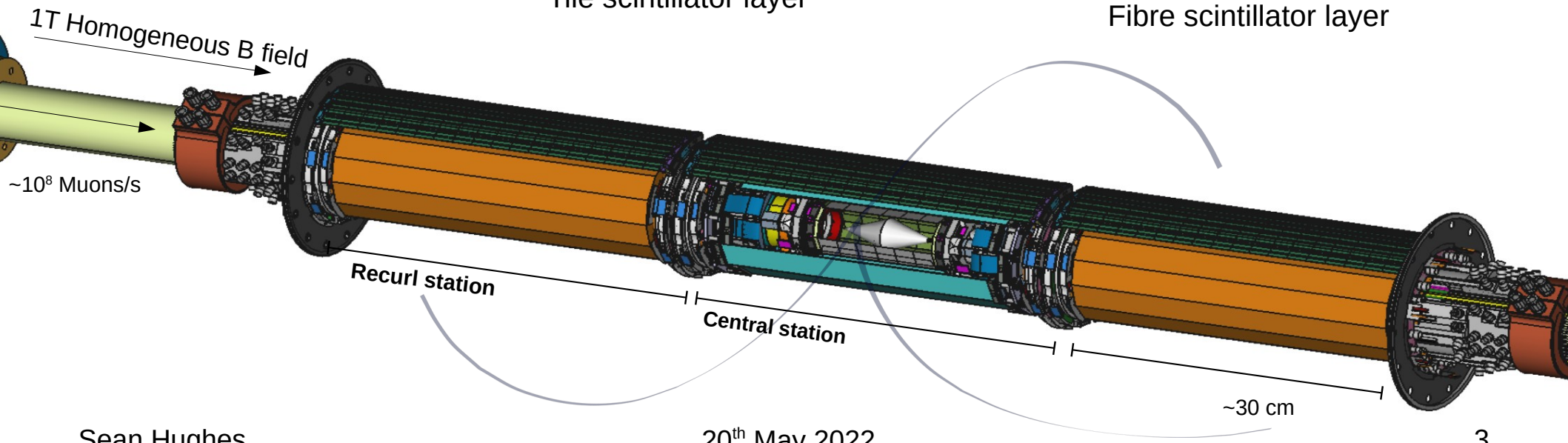
Recurl station:
Two tracking layers
Tile scintillator layer

Central station:
Mylar target
Four tracking layers
Fibre scintillator layer



The Mu3e Detector (2/4)

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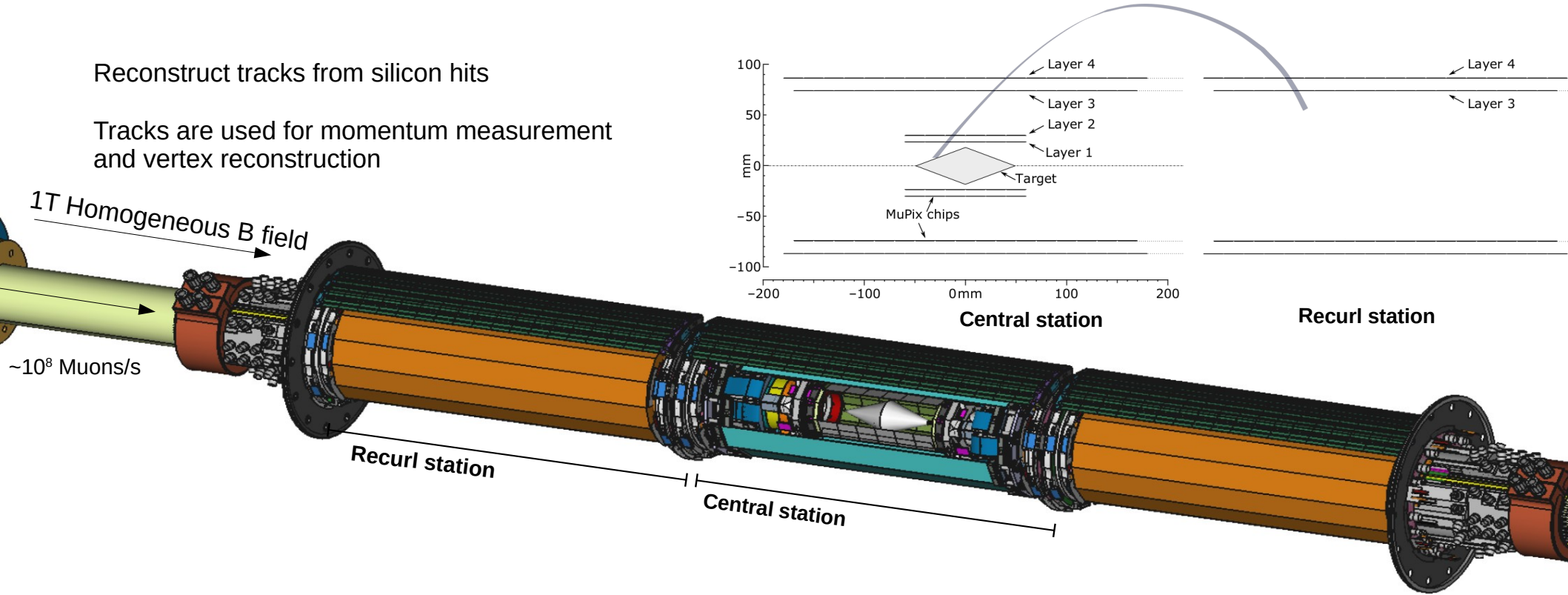
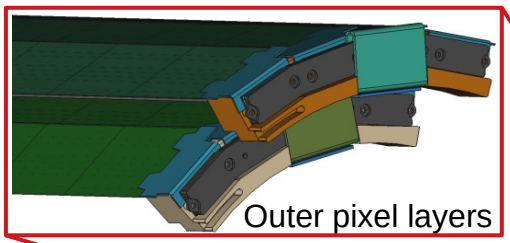
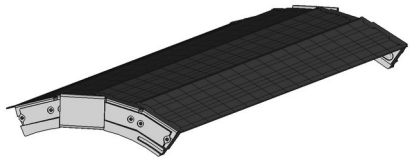
Reconstruct tracks from silicon hits

Tracks are used for momentum measurement and vertex reconstruction

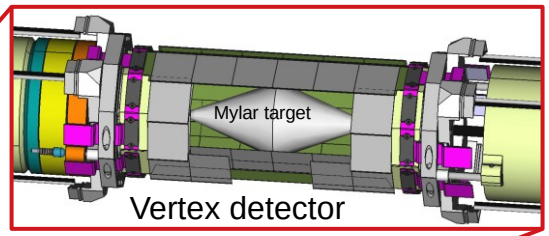


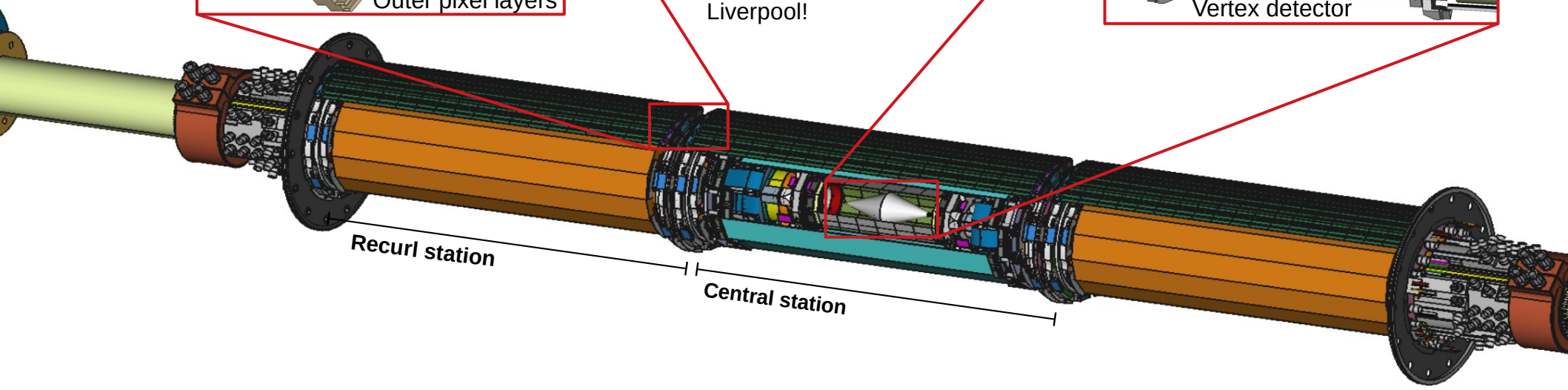
The Mu3e Detector (3/4)



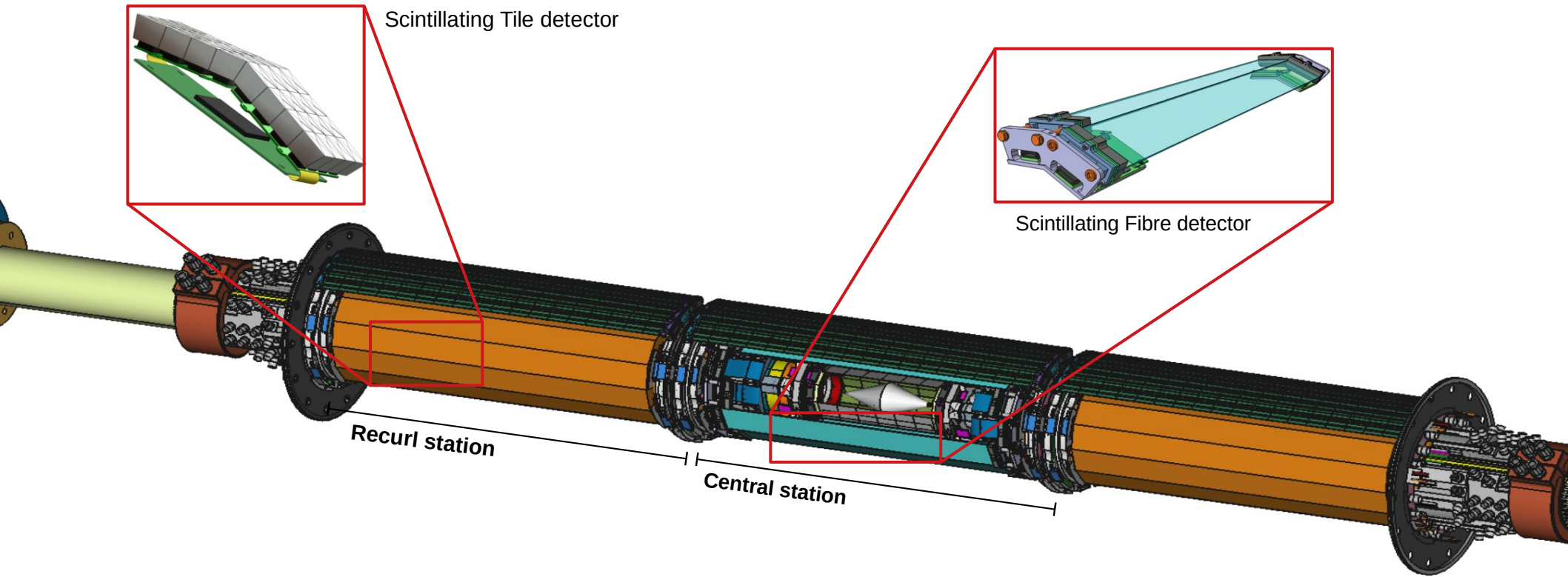


Outer pixel modules to be constructed in Liverpool!





The Mu3e Detector (4/4)



Mu3e Software
Two-layer tracking

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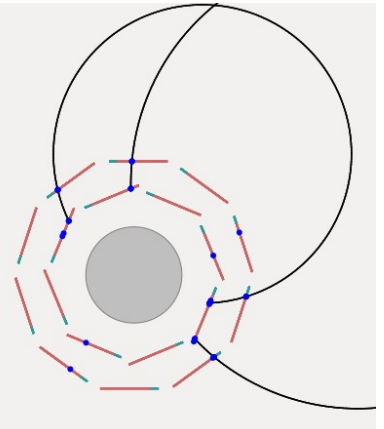
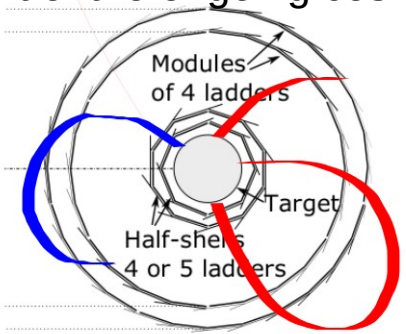
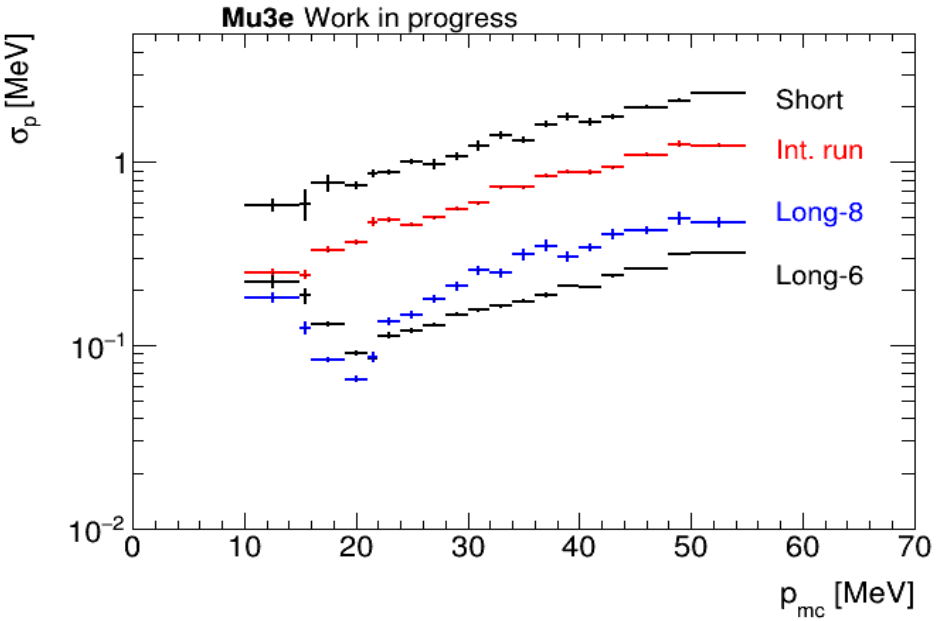
- Mu3e two-layer tracking performance studied (Integration run)
- Fake-rate, reconstruction efficiencies and momentum resolutions were estimated
- Simulation also used in the context of the ongoing cosmic run



Integration run



Phase I geometry



Mu3e Software
Search for Dark Photons

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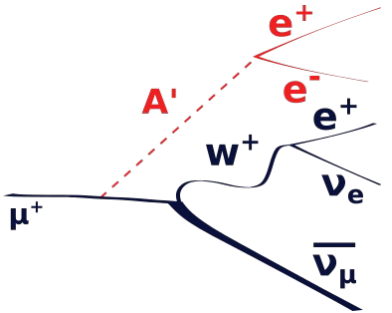
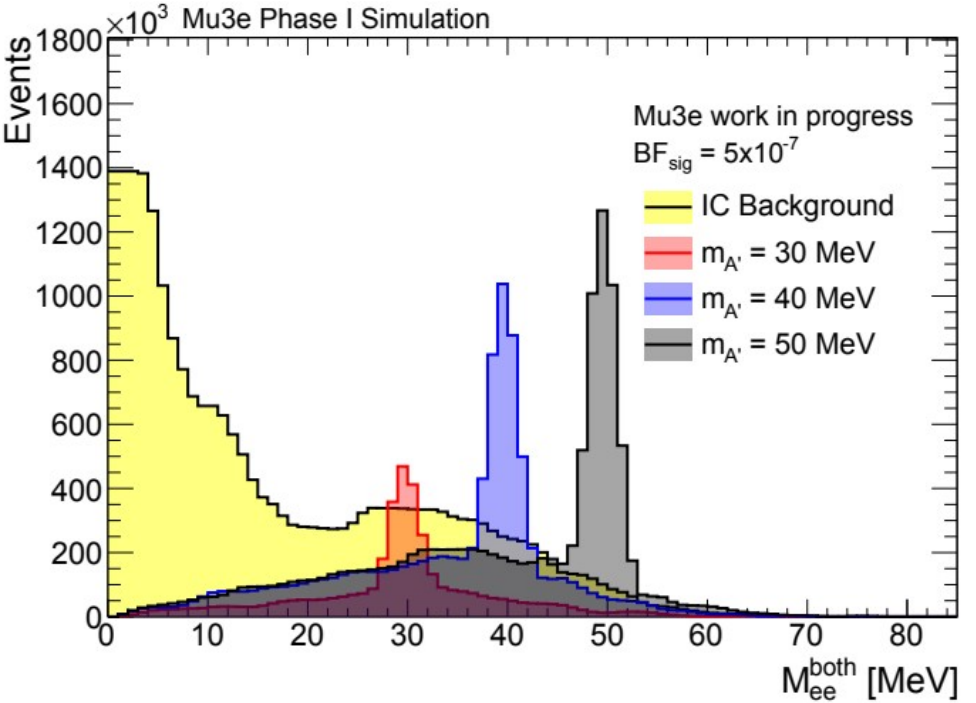
- **Signature**:

  A' is Dark Photon



- Redo an old study with latest version of software & an updated statistics treatment
- Multivariate techniques were also investigated
- Limit calculated using dielectron invariant mass distritbution



Mu3e Software
Search for Dark Photons

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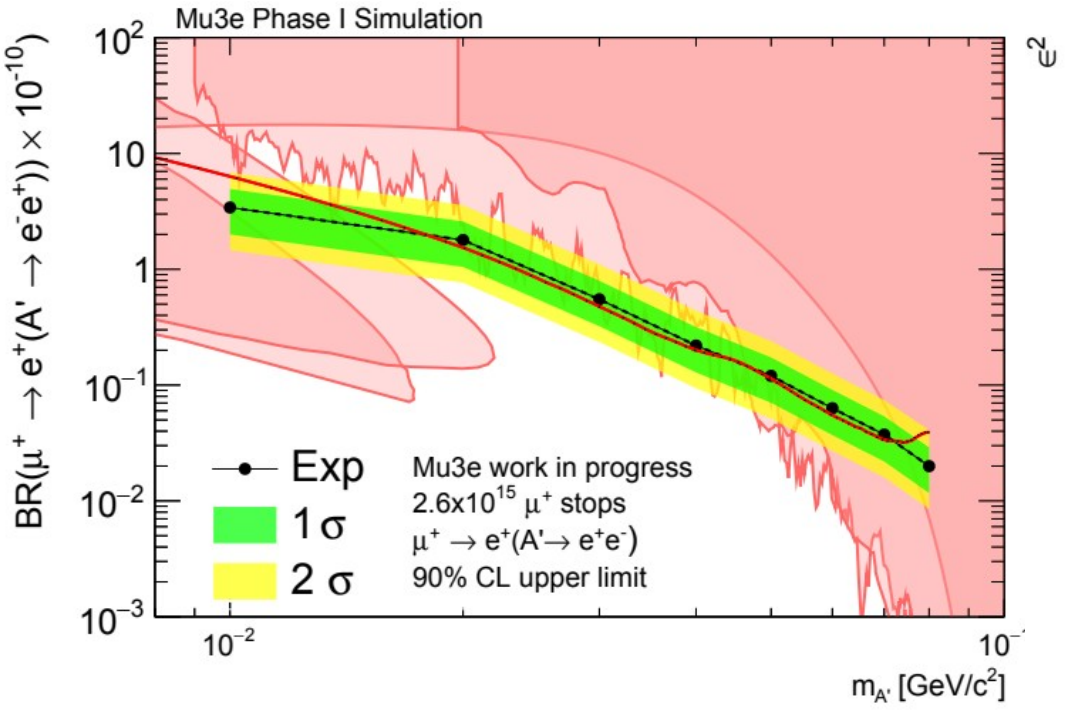

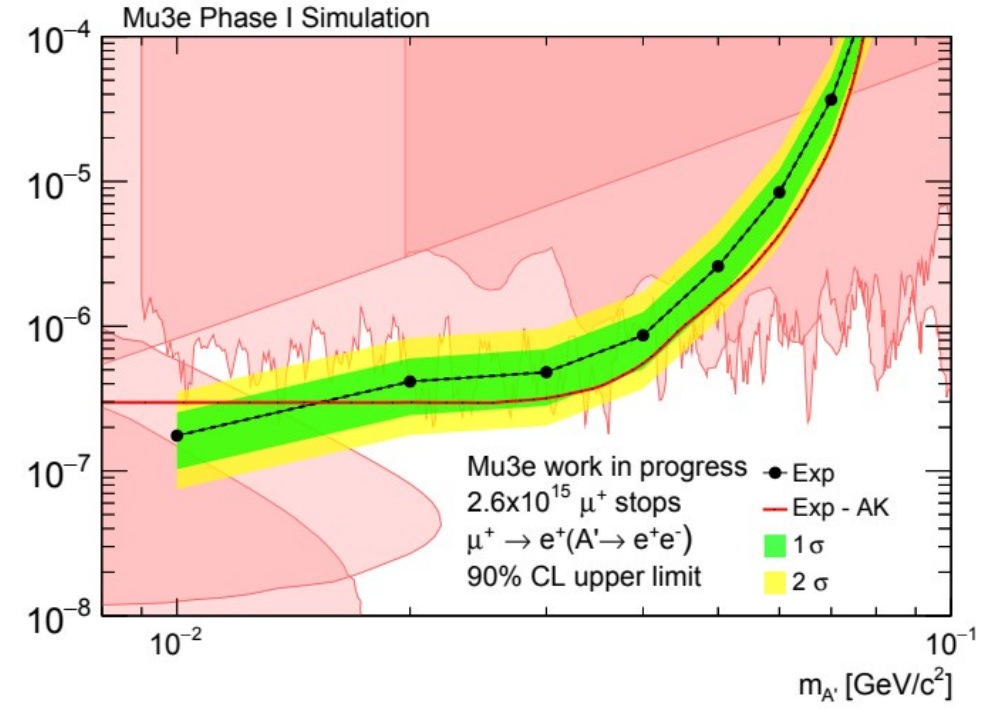

Mu3e Software
Search for Axion-Like Particles

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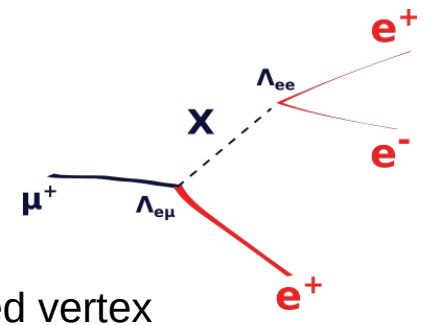
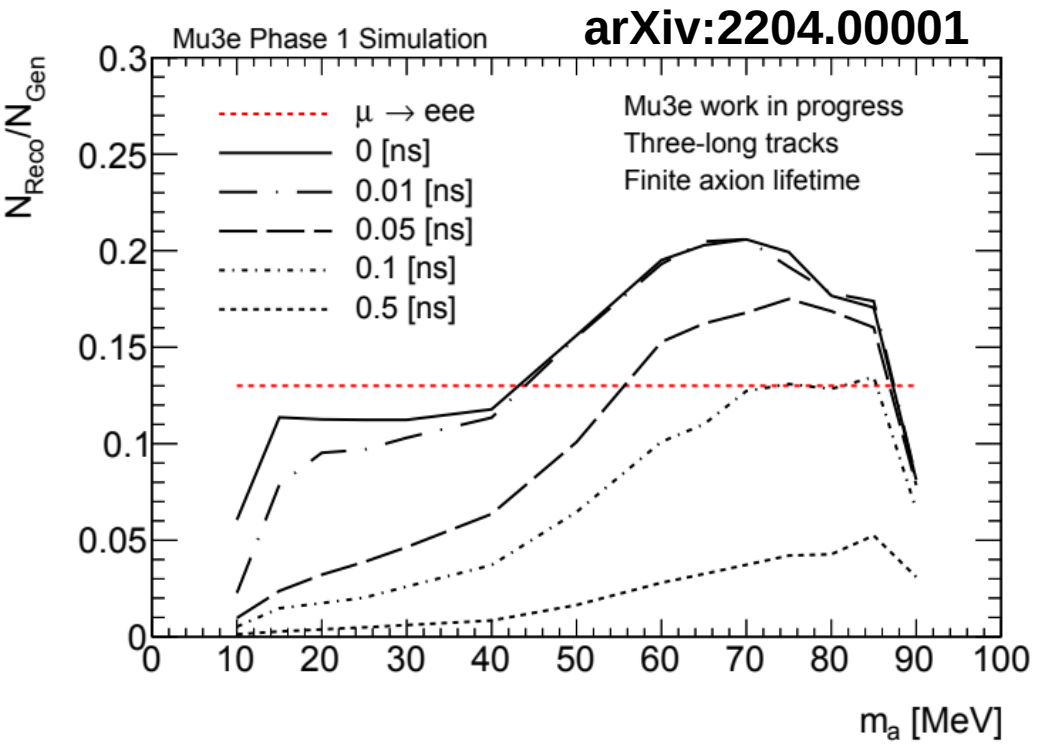
- **Signature**:

  X is ALP



- **X** has lifetime – displaced vertex
- Have estimated BR upper limits on Λ_{ee} for particular $\Lambda_{e\mu}$ and m_x
- Featured in public Mu3e Snowmass contribution
  - **arXiv:2204.00001**



Mu3e Software
Search for Axion-Like Particles

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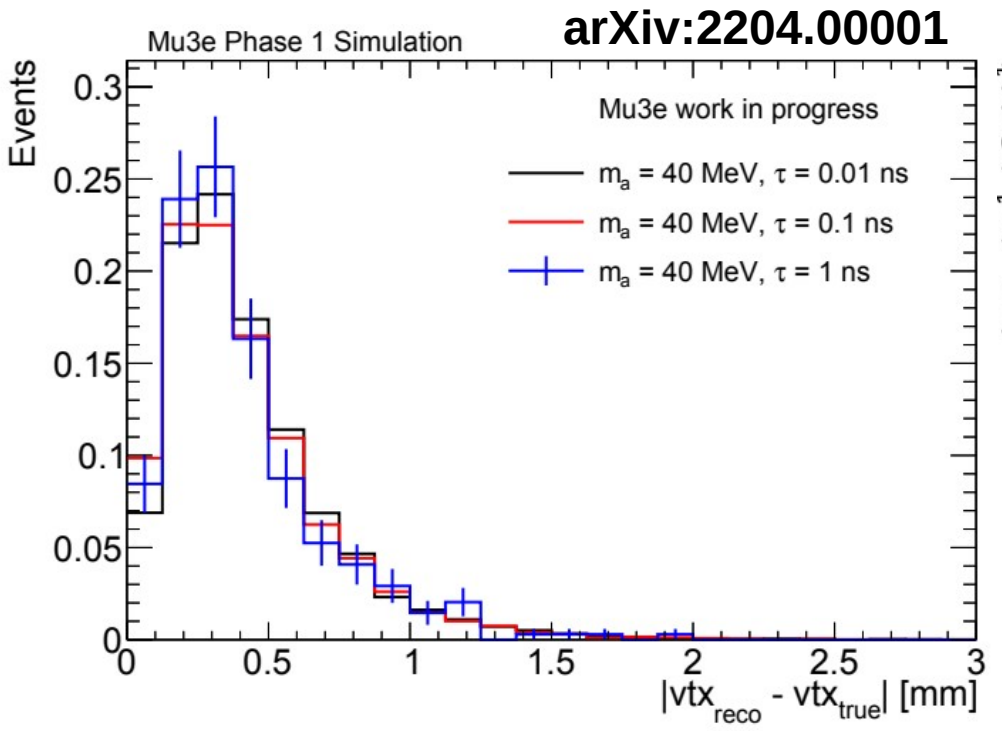

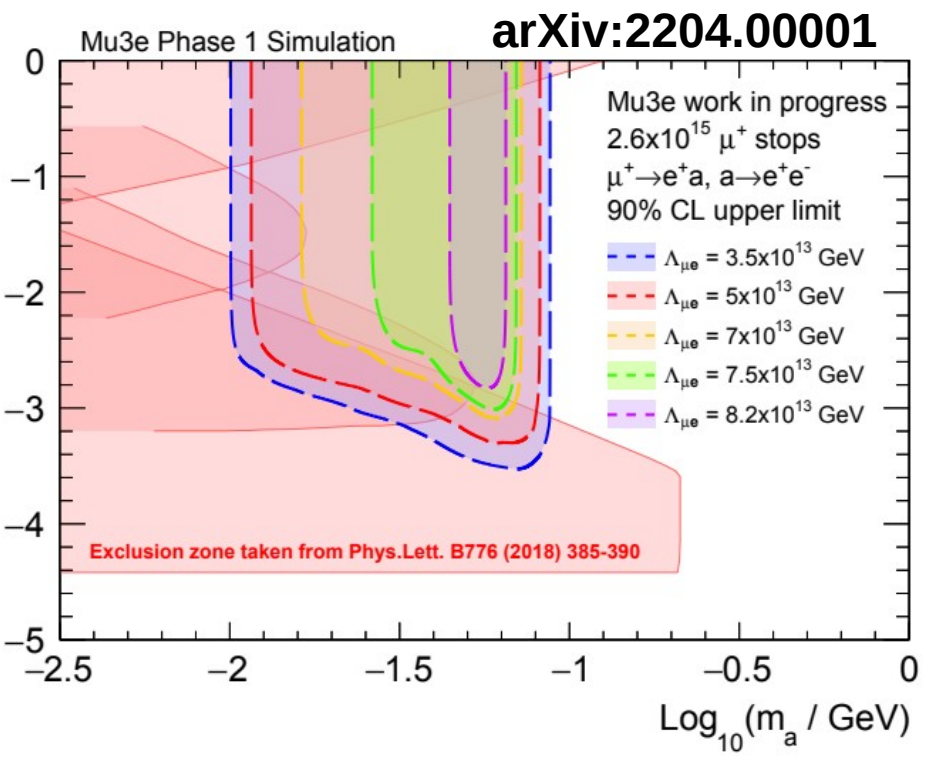

Mu3e Hardware Laboratory work

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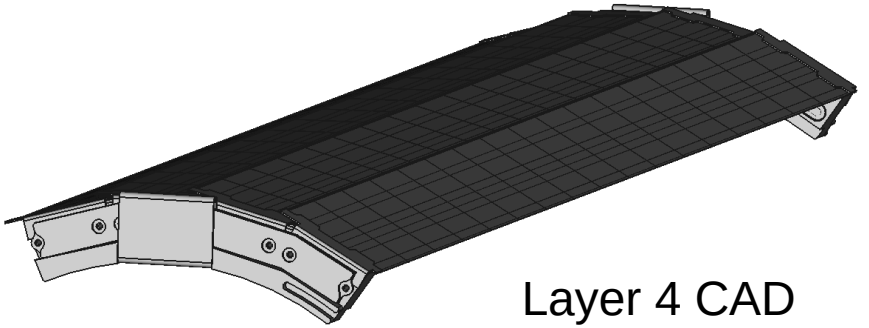
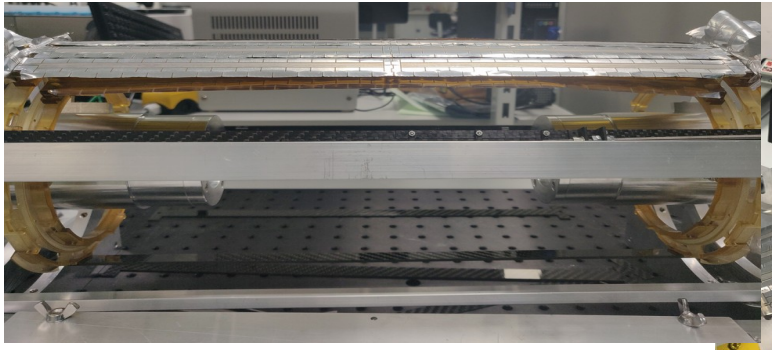
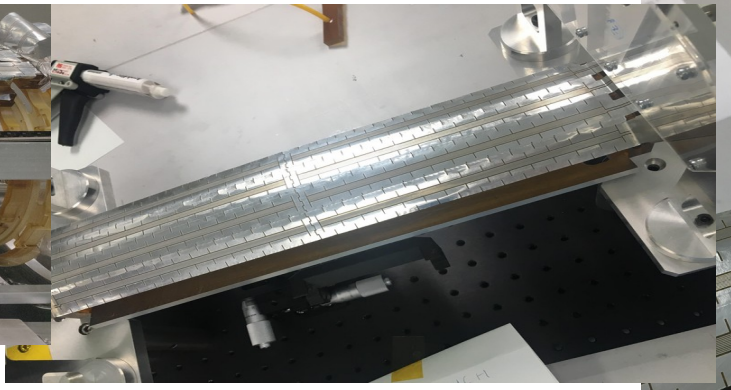
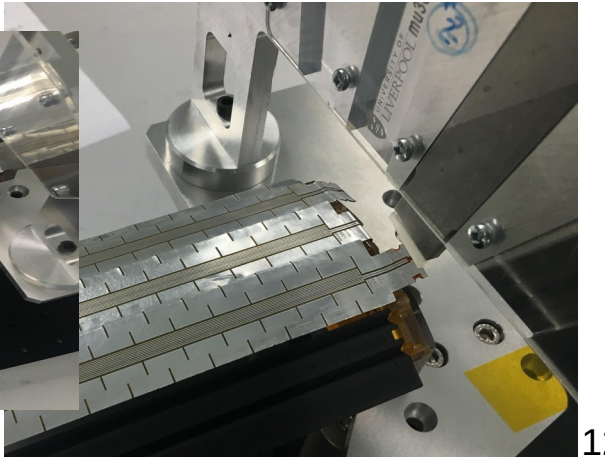
- Liverpool responsible for construction of Mu3e detector's outer pixel layers
- Work on metrology, preparation for module construction and cooling studies are ongoing



Layer 4 CAD

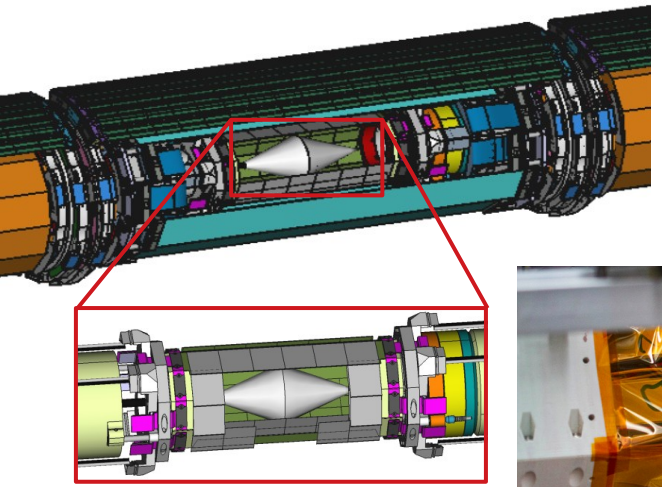


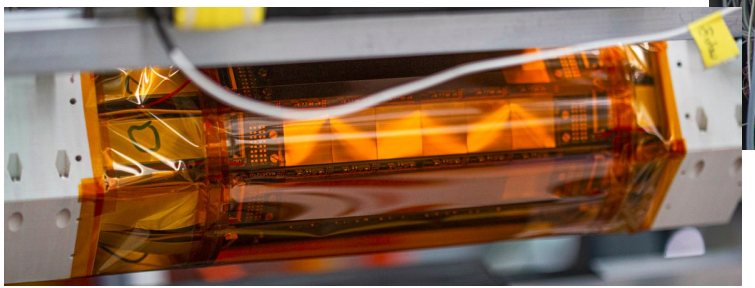




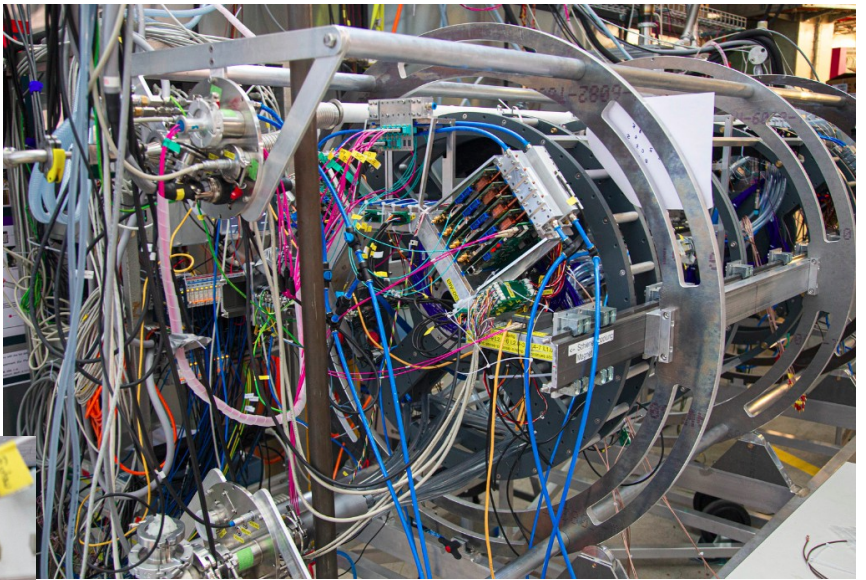
Mu3e Hardware
Cosmic run

- Had the privilege of working at PSI
- Assisted in detector setup of Cosmic run, silicon chip ladder quality control… cosmic data taking to begin soon
- Now can we see cosmics?





Vertex detector prototype



Summary

- Physics and performance:
  - 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
    - ALP sensitivity study
- Hardware:
  - Construction of tape heater modules
  - Cooling studies of outer pixel layers