The Mu3e experiment

- Search for Lepton Flavor Violation
  - Decay $\mu^+ \rightarrow e^+ e^- e^-$
  - Standard Model: $Br < 10^{-34}$
  - Can be enhanced in New Physics (SUSY, BSM, etc.)
- Current status: $Br < 10^{-12}$ (SINDRUM)
- Mu3e:
  - Location: Paul Scherrer Institute
  - Phase I: $Br < 10^{-15}$, Phase II: $Br < 10^{-16}$

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<th>Mu3e detector</th>
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**Pixel layers:**
- High Voltage Monolithic Active Pixel Sensor - HVMAPS
  - NIM A582 (2007) 876-885
  - $2 \times 2$ cm², $80 \times 80$ mm² pixels
- Thin: $50 \mu m \approx 10^{-2}X_0$
- Efficiency > 99%

**Triplet fit**
- Basic block for track reconstruction
- 3 hits (combination of 2 helices)
- Neglect energy loss and hit position uncertainty

**Triplet fit (arXiv:1606.04990):**
- Minimizes scattering angle in middle hit
- Linear approximation around circle solution (small Multiple Scattering angles)

**Track fit:**
- Track is a sequence of triplets
- Fit + weighted average of triplets

**Efficiency and resolution**

- Short tracks (4 hits):
  - Acceptance: 80%
  - Reconstruction efficiency: 95%
  - Geometrical and $\chi^2$ selections
  - $\sigma_{p} \approx 1.4 \mathrm{MeV/c}$

- Long tracks (6 and 8 hits):
  - 80% of short tracks are reconstructed as long
  - Gaps between stations
  - $\sigma_{p} \approx 0.1 - 0.5 \mathrm{MeV/c}$
  - $\approx 10$ better than for short tracks

**GPU filter farm**
- Need factor 100 data rate reduction
- Full online reconstruction
  - Track and vertex reconstruction
- Implemented on GPU
- Currently $O(10^9)$ track fits/s

**$\mu^+ \rightarrow e^+ e^- e^-$ signal and background**

- **Signal:**
  - Three tracks
  - Decay at rest
    - $p_{\mu} < 53 \mathrm{MeV/c}$
  - Common vertex
  - Same time
  - $\sum p = 0$
  - $\sum E = m_{\mu}$

- **Background:**
  - Internal conversion
    - $\mu^+ \rightarrow e^+ e^- e^- e^-$
  - Random combinations
  - Michel: $\mu^+ \rightarrow e^+ \nu
  - $e^- e^+$
  - Fake tracks
  - Not same vertex, time, etc.

**Track reconstruction**

- Make triplets:
  - Hits in first 3 layers
  - $O(n_{hit})$ combinations
  - Fake rate $\approx 4 \times$ true rate
  - Seeds for long tracks

- Short (4 hits) tracks:
  - Add 4th hit to triplet
  - Fake rate $\approx 0.25$
  - Seeds for long tracks

- Long (recur) tracks:
  - Combine 2 short tracks or
  - Combine short track with 2 hits in outer layers

**Fibre and tile timing**

- Fibre clusters and tile hits are linked to:
  - Seeds for long tracks
  - Two fibre clusters
  - Combine short track with 2 hits in outer layers

- Time difference between 2 fibre clusters

**Signal sensitivity**

- Signal sensitivity of $10^{-14}$
  - at $10^8$ stopped muons

**Selections:**
- Long tracks
- Vertex $\chi^2 < 14$
- Track/vertex $DCA < 1 \mathrm{mm}$
- $|\sum p| < 4 \mathrm{MeV/c}$
- Efficiency 14%