The Mu3e experiment searches for the lepton flavor violating decay $\mu^+ \rightarrow e^+ e^+ e^-$, aiming at a sensitivity of 1 in $10^{16}$ decays. Any observation of a signal would indicate new physics beyond the Standard Model.

A high precision silicon tracking detector combined with excellent timing resolution from scintillating fibers and tiles will measure the momenta, vertices and timing of the decay products of muons stopped in a target to suppress background.

The trigger-less readout system will deliver ~100 GB/s of data. A network of optical links and FPGAs sends the full detector information for a time slice to one node of the filter farm. Tracks are fitted by the GPU of the PC using a 3D tracking algorithm for multiple scattering dominated environment. Then, three-track vertices are reconstructed, allowing for a reduction of the output data rate to below 100 MB/s by removing combinatorial background.

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**Momentum Resolution**

- $\Omega$: bending angle
- $\sigma_p/p \sim \theta_{MS}/\Omega$
- $A \Omega = \pi$, scattering cancels to first order

- Apply magnetic field
- Use recurling tracks
- Minimize material

**GPU Workload**

- Number of possible triplet candidates: ~ (number of hits per layer)$^3$
- Loop over all combinations for:
  - Geometrical selection cuts
  - Triplet Fit
  - Propagation to 4th layer
  - Vertex estimate (work in progress)
- Compute in parallel on 2048 cores of GPU

- Process $10^{10}$ triplets/s
- 98% of true tracks found
- Reduce combinatorics by factor 300
- Reduce further with vertex constraint

**Results**

- Signal event:
  - 3 tracks
  - Common vertex
  - No missing energy

- Up to 100 tracks per reconstruction frame of 50 ns
- Triggerless → fully reconstructed on filter farm level

**Signal & Background**

- Combinatorial Background
  - Not coincident in time or place

**Target**

- Hollow double cone
- Large area → spread out vertices

**Beam**

- Paul-Scherrer Institute, Switzerland
- *Up to* $2 \times 10^9$ low energy $\mu$/$s$

**Pixel Sensors**

- High Voltage Monolithic Active Pixel Sensors
- Thickness of 1 layer < 1‰ of a radiation length
- Maximum readout frequency ~ 20 MHz
- Digital readout
  - Spatial resolution ~ 20 μm

**Timing**

- ~ 1 cm thick scintillating tiles
  - $\sigma_t \sim 70$ ps
- 250 μm scintillating fibers
  - $\sigma_t \sim 1$ ns

**Target**

- Inner pixel layers
- Scintillating
- Outer pixel layers
- Recurl pixel layers
- Scintillator tiles

**Magnet & Cooling**

- 1 T solenoidal magnetic field
- Gaseous helium for cooling

**Readout**

- Triggerless
- ~ 100 GB/s to online farm
- Track finding & reconstruction on GPUs

**Abstract**

- Electron energy: 10 - 50 MeV
- Momentum resolution $\sigma_p$ dominated by multiple Coulomb scattering

- Triplet Track Reconstruction on GPUs for the Mu3e Experiment

- The Mu3e experiment searches for the lepton flavor violating decay $\mu^+ \rightarrow e^+ e^+ e^-$, aiming at a sensitivity of 1 in $10^{16}$ decays. Any observation of a signal would indicate new physics beyond the Standard Model.

- A high precision silicon tracking detector combined with excellent timing resolution from scintillating fibers and tiles will measure the momenta, vertices and timing of the decay products of muons stopped in a target to suppress background.

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**Reconstruction**

- $\Omega$: bending angle
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- $A \Omega = \pi$, scattering cancels to first order

- Apply magnetic field
- Use recurling tracks
- Minimize material

**Multiple Scattering Fit**

- Ignore spatial uncertainty
- Multiple scattering at middle hit of three hits (triplet)
- Minimize multiple scattering:
  \[
  \chi^2 = \frac{\phi_M^2}{\sigma_{MS}^2} + \frac{\phi_S^2}{\sigma_{MS}^2} + \frac{\phi_{MS}^2}{\sigma_{MS}^2}
  \]

- Process $10^{10}$ triplets/s
- 98% of true tracks found
- Reduce combinatorics by factor 300
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* : on Nvidia GTX 980