

Mu3e γ upgrade simulations for the Mu3e Experiment

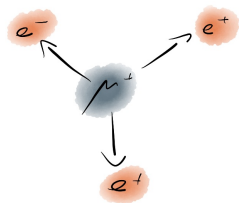
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On behalf of the Mu3e Collaboration

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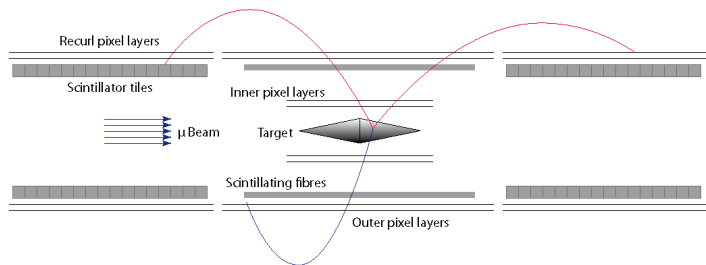


Mu3e motivation

- Search for the charged lepton flavour violating decay
 $\mu^+ \rightarrow e^+ e^- e^+$
- Forbidden in SM, $BR < e^{-52} \rightarrow$
sign for new physics
- Single event sensitivity of
 2×10^{-15} in phase I



Detector geometry



B-Field: 1 T

Outer radius: 9 cm

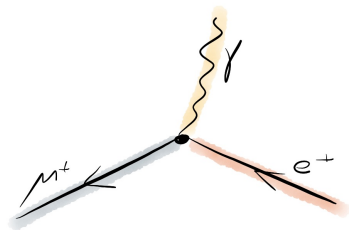
Length: 110 cm

- Thin Si pixel sensors (HV-MAPS) for tracking
- Scintillating fibers for timing

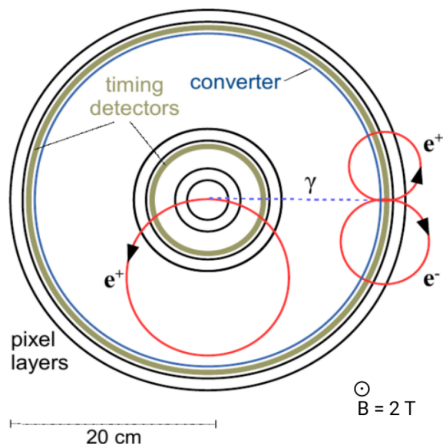
Decay electrons with $p < 53$ MeV \rightarrow **Multiple scattering** in detector layers

Mu3e γ motivation

- Search for the charged lepton flavour violating decay
 $\mu^+ \rightarrow e^+ \gamma$
- Current upper limit BR < $4.2e^{-13}$ (MEG)
- Energy signature of $\frac{m_\mu}{2}$ for e^+ and γ
- Potential to probe
 $BR(\mu \rightarrow e^+ \gamma) \approx O(e^{-15})$

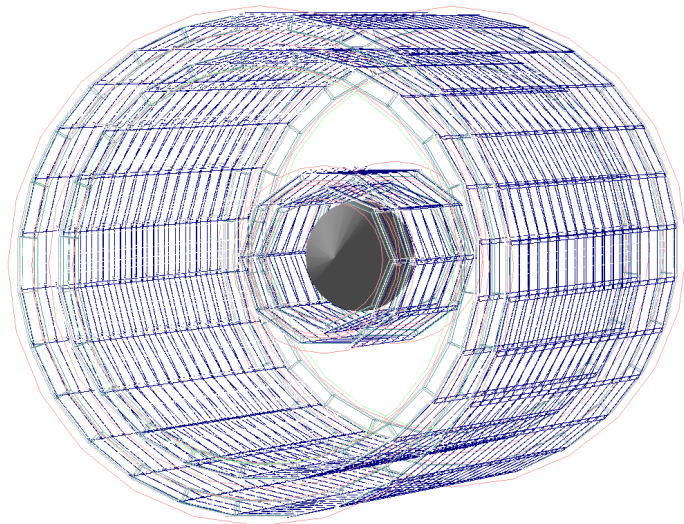


Changes to detector geometry

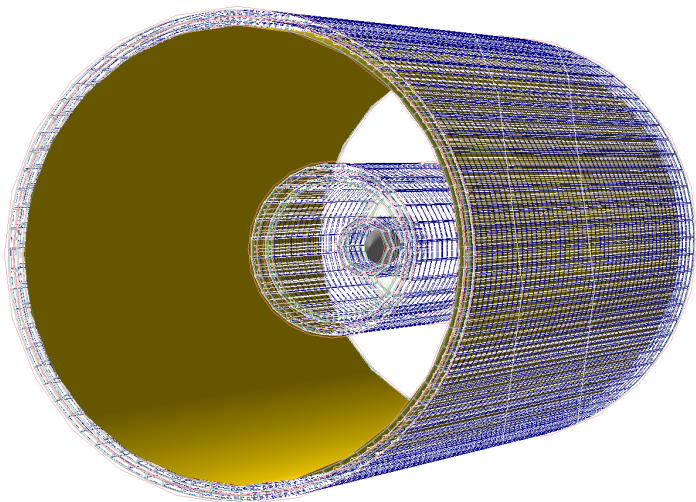


B-Field: 2 T Outer radius: 22 cm Length: 500 cm \rightarrow primary electrons of 52 MeV can not reach the new layers

Mu3e detector geometry

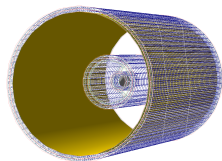


Mu3e γ geometry

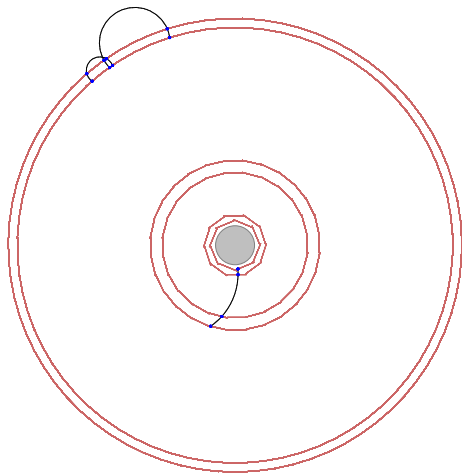


Converter layer properties

- Au cylindrical converter
- Minimum transversal electron momentum $pt_{\min} = 3.9 \text{ MeV}$
- Energy resolution highly dependent on converter layer thickness \rightarrow P in range 5% to 15% with reasonable energy resolution \rightarrow further studies



Track reconstruction

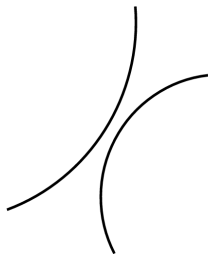


- **Triplet based** reconstruction \rightarrow two triplets per trajectory
- Reconstruct wrt. multiple scattering

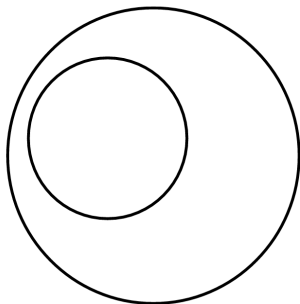
Vertex fit of e^+e^-



Find intersection
with closest z
distance



Find point of
closest approach



Find point of
closest approach

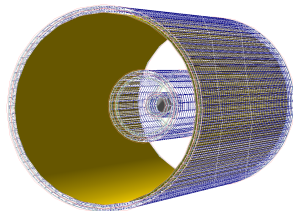
Distance in z is chosen as mean of both tracks at point of closest approach
→ Find vertex and linearly extrapolate to primary $e^+\gamma$ vertex

Summary

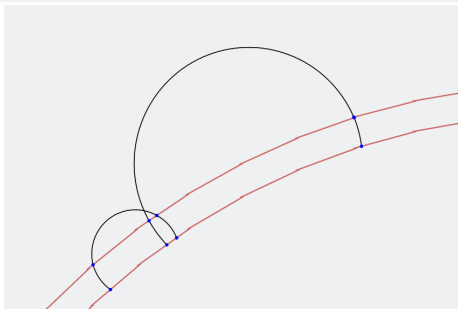
- Mu3e search for LFV decay
 $\mu^+ \rightarrow e^+ e^- e^+$
- Simulation studies for LFV decay
 $\mu^+ \rightarrow e^+ \gamma$
- Conversion layer and two detector layers added
- Trade-off between energy resolution and conversion probability



- $\mu \rightarrow e^+ \gamma$ vertex fit
- Optimizations of reconstruction, fit parameters and converter properties
- Sensitivity studies
- Search for dark photon decay
 $\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu A' \quad A' \rightarrow e^- e^+$



Challenges track reconstruction



- Two hits in each layer per trajectory \rightarrow need additional information for direction
- e^+ and e^- can share pixel hit
- Close hits of e^+ and e^- can lead to additional wrong reconstruction
- **Energy deposit in converter layer \rightarrow energy resolution**

Energy deposit in conversion layer

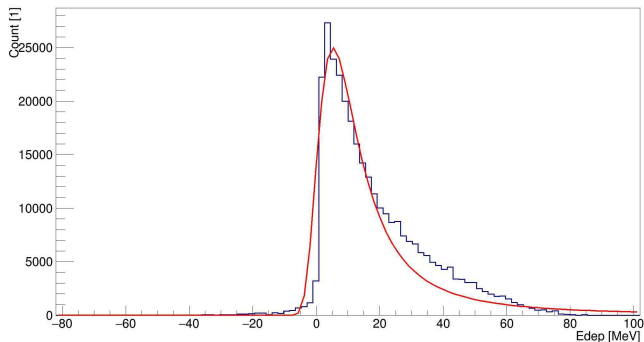


Figure: Energy deposit of e^+e^- up to $E = m_\mu$; $d = .3\text{mm}$

Uncertainties from conversion depth and e^+ , e^- trajectory angles \rightarrow depend on conversion layer thickness $d \rightarrow$ **minimize d**

Conversion probability linear in d in first approx. \rightarrow find optimal **trade-off wrt. conversion count and energy resolution**