The Mu3e Experiment

Searching for Lepton Flavour Violation

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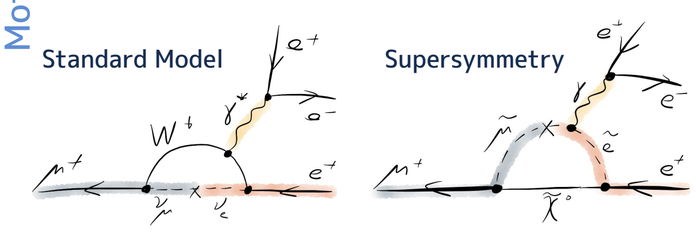
Abstract

The upcoming Mu3e experiment aims to search for the lepton-flavour violating decay $\mu^+ \to e^+e^-e^+$ at an unprecedented sensitivity of better than one in 10^{15} in a first and one in 10^{16} muon decays in the final phase. Any observation of this decay would be a clear sign for new physics.
The detector is based on novel ultra-thin pixel sensors for precise tracking and scintillating fibres and tiles for timing. Simulations of background processes and various physics models are performed for sensitivity studies.

Decay μ→eee

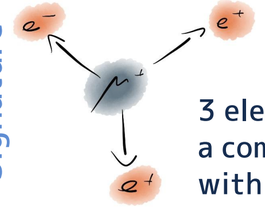
Motivation

Lepton-flavour violating (LFV) decay μ→eee in the Standard Model (SM) via neutrino mixing is suppressed to a branching ratio BR < 10^{-54}



Observation of μ→eee ⇒ New Physics
e.g. SUSY, GUT, extended Higgs sector

Signature



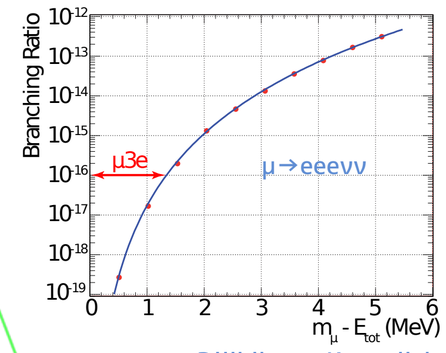
3 electrons from a common vertex with $\Sigma P_e = (m_\mu, 0)$

Test μ→eee with a sensitivity of BR < 10^{-16}

Background

Combinations of Michel decays with Bhabha scattering, photon conversion, ...
→ suppress by good vertex and timing resolution

SM background μ→eeevv (BR = $3.4 \cdot 10^{-5}$)
→ suppress by good momentum resolution

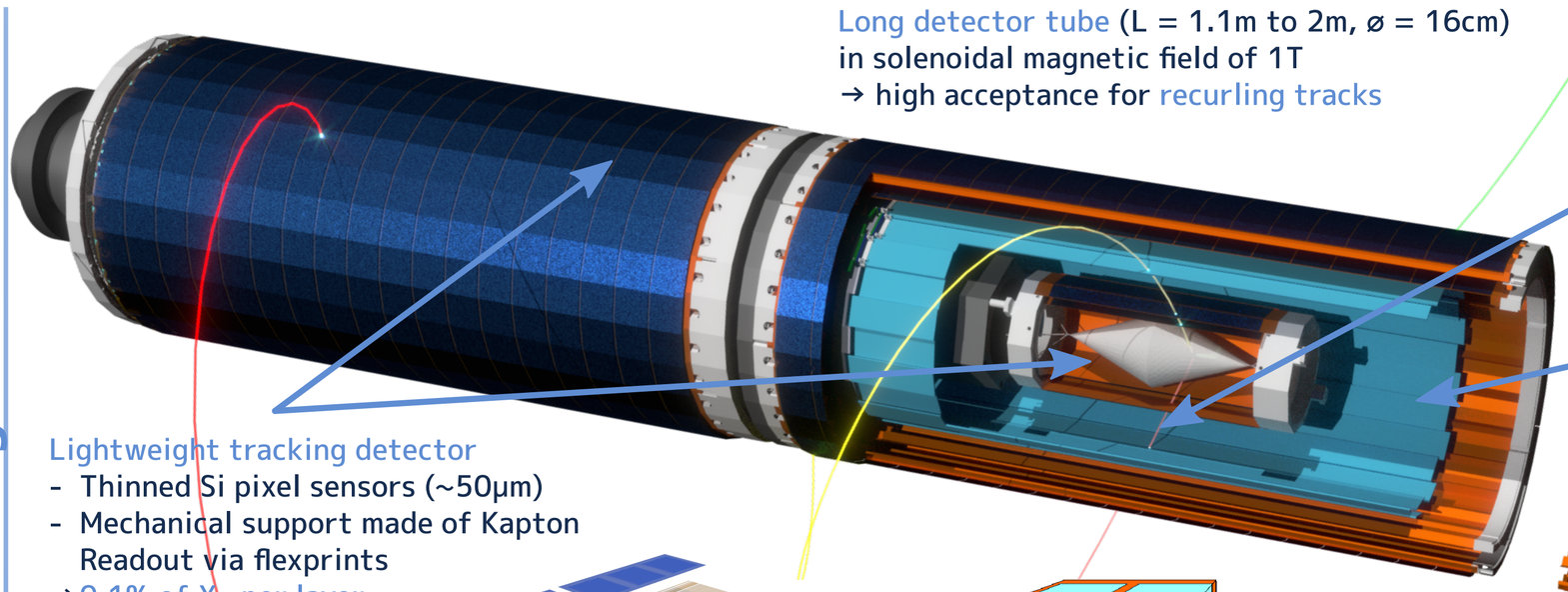


Djilkibaev, Konoplich
Phys.Rev.D79:073004 (2009)

Challenges

- High muon rates > 10^8μ/s to 10^9μ/s
- Excellent momentum resolution despite low momentum of electrons
→ Extremely low material budget (low multiple scattering)

Detector Design



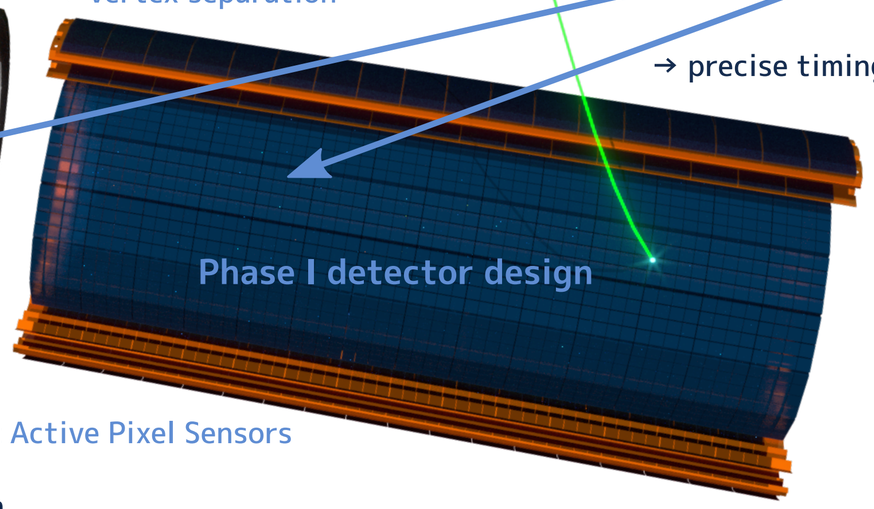
Long detector tube (L = 1.1m to 2m, ⌀ = 16cm) in solenoidal magnetic field of 1T
→ high acceptance for recurling tracks

28 MeV/c μ beam at PSI
Phase I: 10^8μ/s
Phase II: 10^9μ/s

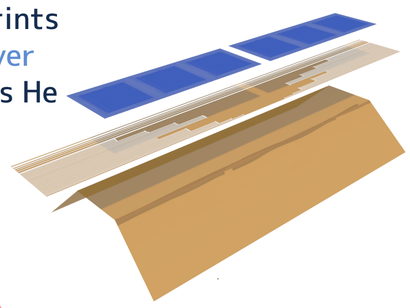
μ stop on extended hollow double cone target
→ vertex separation

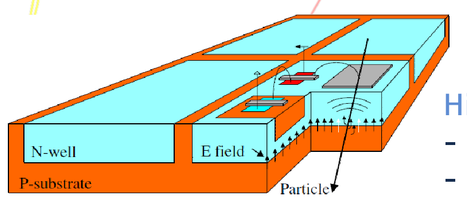
Triggerless DAQ system & online reconstruction on GPU based filter farm
→ reduce data rate

Scintillating fibres and tiles
→ precise timing



Lightweight tracking detector
- Thinned Si pixel sensors (~50μm)
- Mechanical support made of Kapton
  Readout via flexprints
→ 0.1% of X_0 per layer
+ Cooling by gaseous He

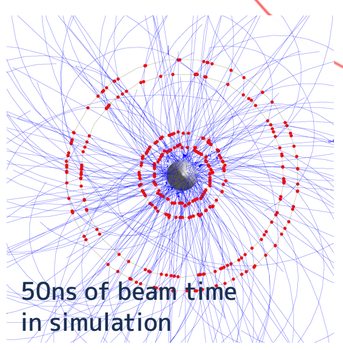




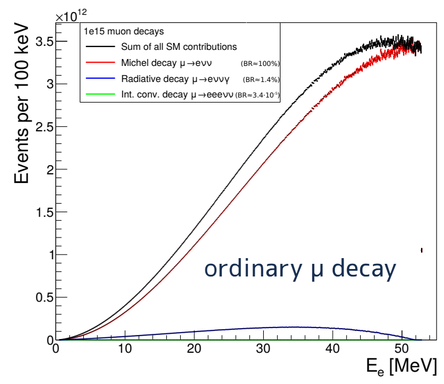
developed by Ivan Perić (KIT)
NIM A582 (2007) 876-885

High Voltage Monolithic Active Pixel Sensors
- Reverse bias of ~85V
- Fast charge collection
- Integrated readout electronics
- Zero-suppressed hit data

Detector & Physics Processes



Full Geant4-based simulation
- including all possible SM background processes
→ study influence of detector geometry
→ evaluate reconstruction
→ estimate sensitivity to various new physics models



Search for LFV at high intensities with Mu3e

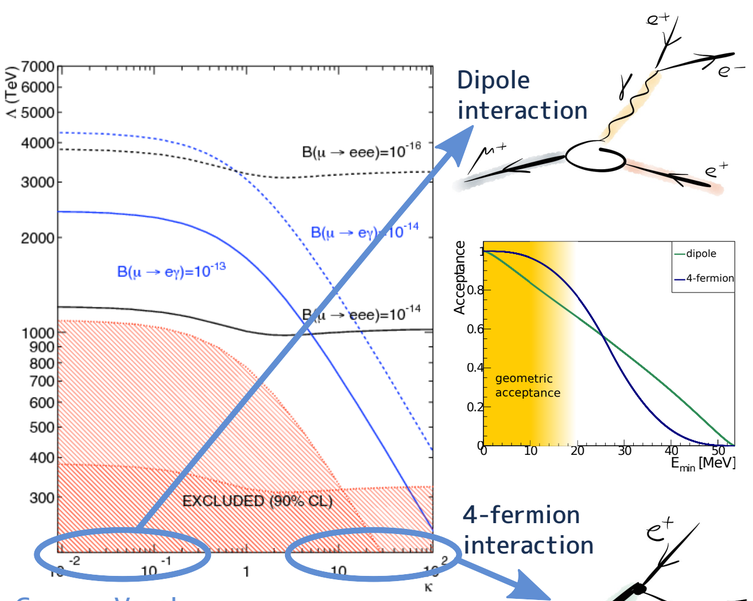
R&D ongoing
- Large scale pixel prototype in submission
- Mechanical mock-up
- ...

Detector construction and data taking in 2 phases

Phase I	Phase II
- Core detector	- Full detector
- 10^8μ/s	- 10^9μ/s
	- Final sensitivity BR ≈ 10^{-16}

Simulation

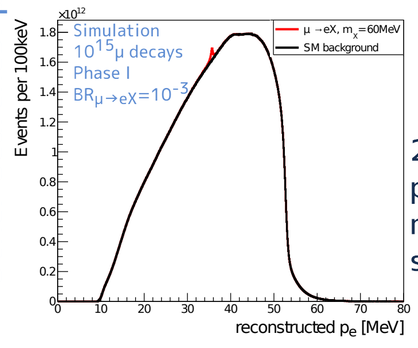
Effective Field Theory Approach for μ→eee

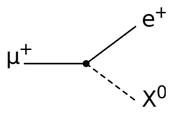


Gouvea, Vogel
Prog.Part.Nucl.Phys. 71 (2013) 75-92

Other Searches: μ→eX

X: neutral light or massless boson
e.g. familon (Wilczek, PRL 49 (1982) 1549)

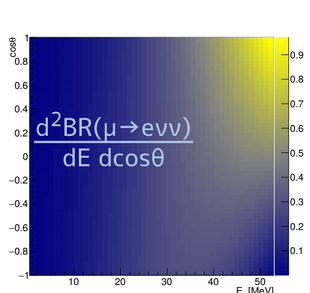




2-body decay: peak in momentum spectrum

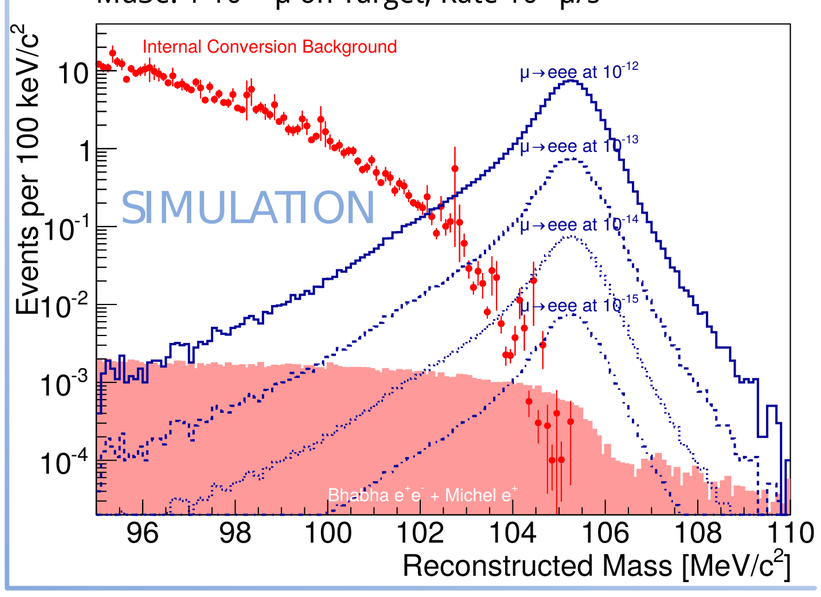
Mu3e has polarized muon beam

Sensitivity might improve for chiral bosons



Summary & Outlook

Mu3e: $1 \cdot 10^{15}$ μ on Target; Rate 10^8 μ/s



http://www.psi.ch/mu3e

AEPSHEP 2016 — 12 - 25 OCTOBER 2016, BEIJING, CHINA

BEYOND STANDARD MODEL

HGSFP

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