Searching for New Physics with
The Mu3e Experiment

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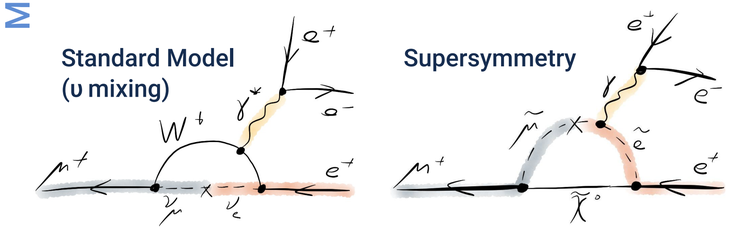
Summary

The Mu3e Experiment at PSI is designed to search for the lepton-flavour violating decay of a positive muon to two positrons and an electron with a branching ratio sensitivity of order 10^{-15} (phase I) and order 10^{-16} (phase II). The detector is based on ultra-thin high-voltage monolithic active pixel sensors combined with scintillating fibres and tiles for precise timing measurement. We present sensitivity studies performed for the Mu3e detector, both for the main signal decay in different models of new physics, as well as for electron-positron resonances, motivated by dark photon models, and two-body decays of the muon, motivated by Familon models.

Decay μ→eee

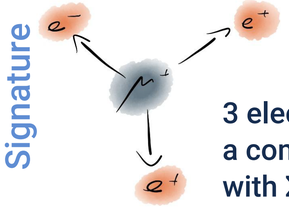
Motivation

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



Observation of μ→eee ⇒ Physics beyond SM
e.g. SUSY, GUT, extended electro-weak sector

Signature



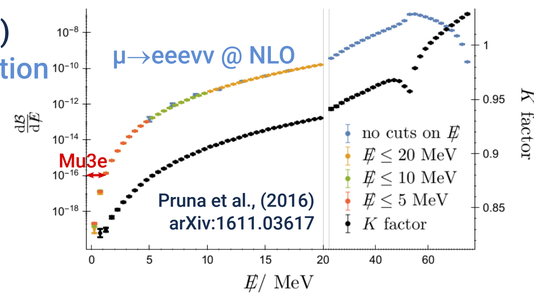
3 electrons from a common vertex with $\Sigma P_e = (m_\mu, 0)$

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

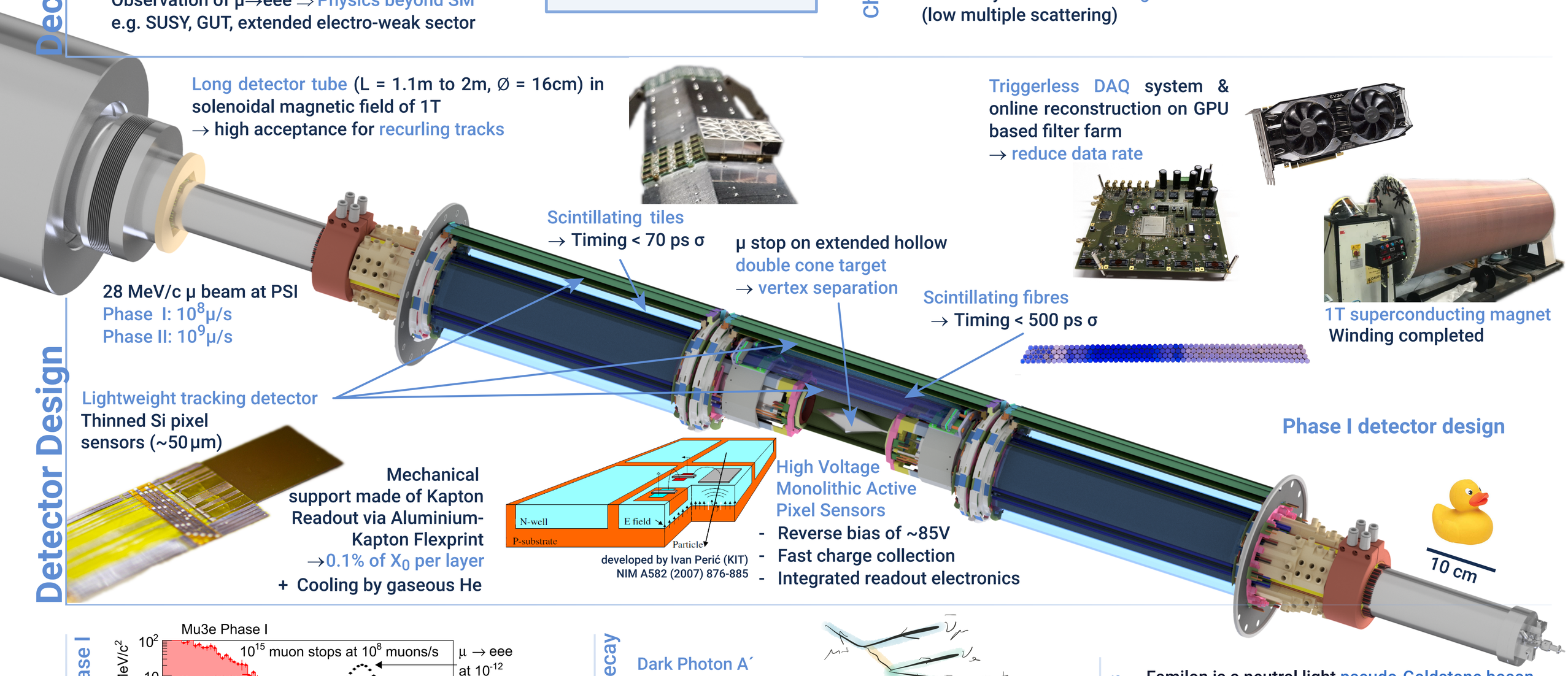


Challenges

- 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



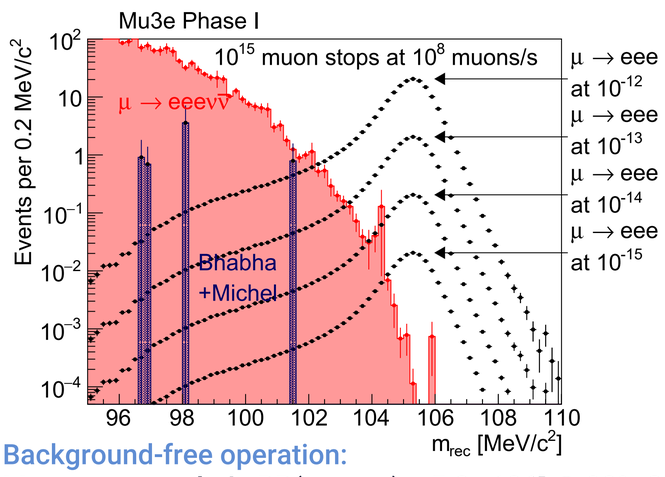
Triggerless DAQ system & online reconstruction on GPU based filter farm
→ reduce data rate

1T superconducting magnet
Winding completed

Phase I detector design

Sensitivity to μ→eee

Sensitivity in Phase I

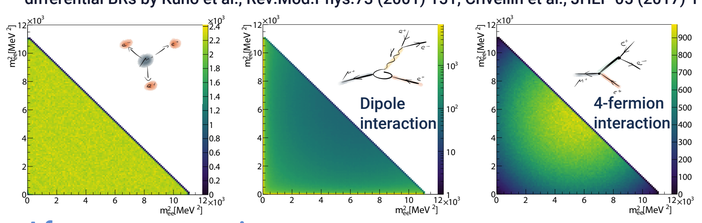


Background-free operation:
Measure or exclude BR(μ→eee) ≥ $5.2 \cdot 10^{-15}$ @ 90% C.L.

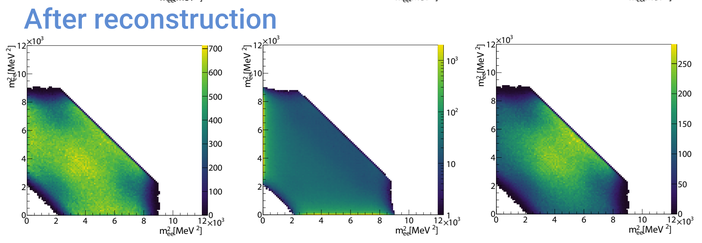
Effective Field Theory Approach

Type of interaction determines kinematics and affects signal reconstruction efficiency

Decay distributions
differential BRs by Kuno et al., Rev.Mod.Phys.73 (2001) 151; Crivellin et al., JHEP 05 (2017) 117

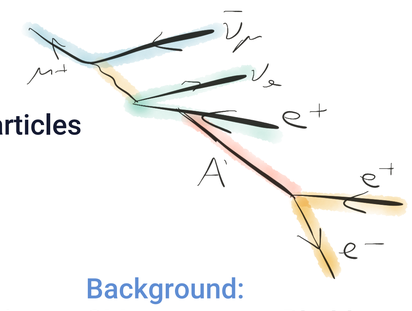


After reconstruction



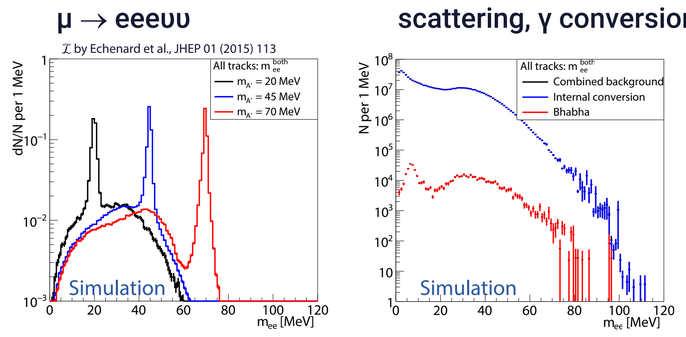
Dark Photons in Muon Decay

Dark Photon A´
interacting with SM particles via kinetic mixing

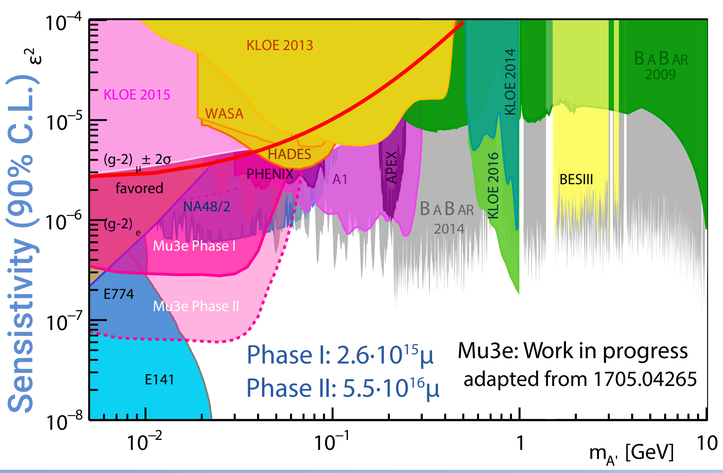


Signal:
A´ → e^+e^- resonance in μ → eeeυυ

Background:
SM μ → eeeυυ, Bhabha scattering, γ conversion



Resonances in e^+e^-

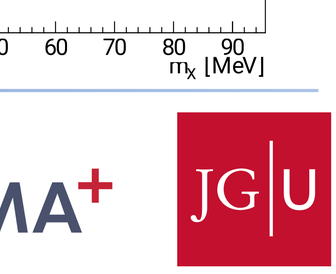


LFV Two-Body Decays μ→eX

Familons

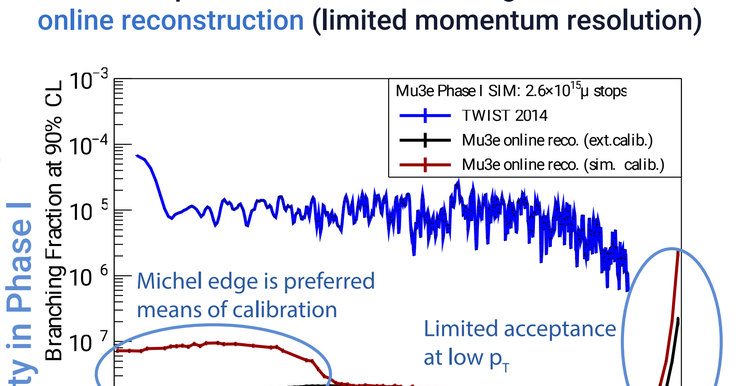
Familon is a neutral light pseudo-Goldstone boson from an additional broken flavour symmetry emitted in flavour-changing processes, e.g. μ→eX
Wilczek, PRL 49 (1982) 1549

Signature:
Narrow peak on smooth p_e spectrum from SM μ decays



Full track information cannot be stored:
Search for peaks in momentum histograms of the online reconstruction (limited momentum resolution)

Sensitivity in Phase I



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