

Mu3e Experiment

<https://www.psi.ch/mu3e/>

Search for $\mu^+ \rightarrow e^+ e^+ e^-$



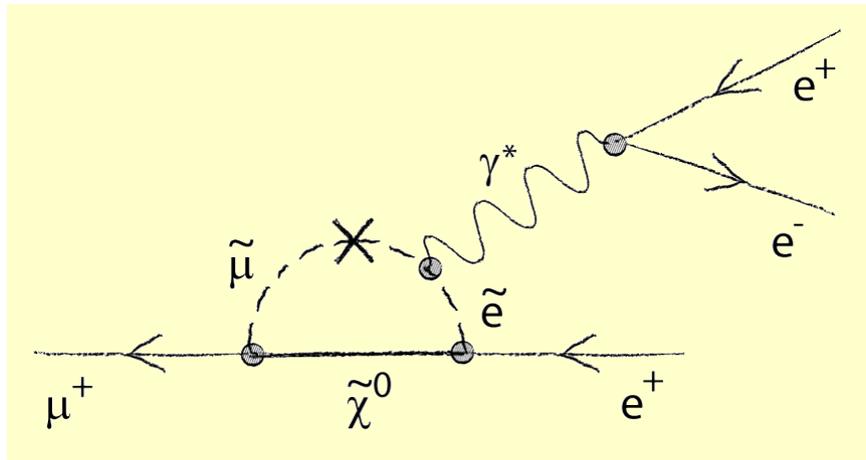
PhiPsi 2019 Workshop

Budker Institute

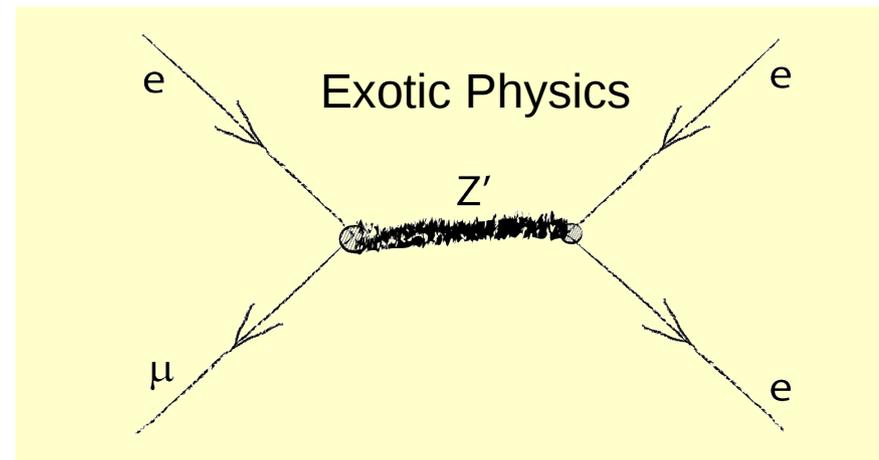
25.2-1.3. 2019, Novosibirsk



LFV Decay $\mu^+ \rightarrow e^+e^+e^-$



loop diagrams (similar to $\mu \rightarrow e \gamma$)



tree diagram (Mu3e specific)

- Supersymmetry
- Little Higgs Models
- Seesaw Models
- GUT models (Leptoquarks)
- many other models

- Higgs Triplet Model
- New Heavy Vector bosons (Z')
- Extra Dimensions (KK towers)

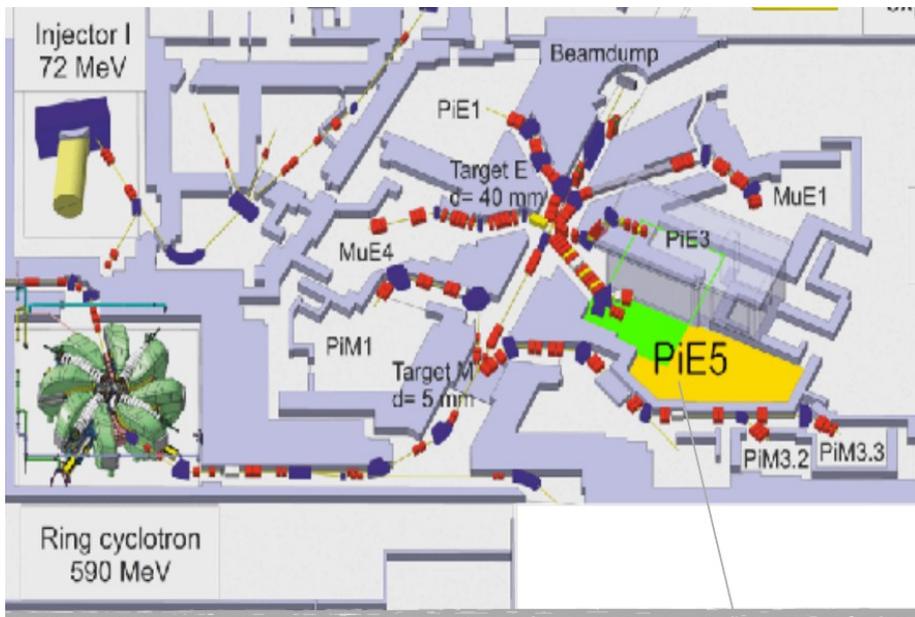
Most models “naturally” induce lepton flavor violation!



HiPA @ PSI & PiE5 Area



HiPA and Experimental Hall:



Compact Muon Beamline for Mu3e:



- Low momentum muons 29 MeV/c
- PiE5 beamline will be shared between **MEGII** and **Mu3e**



Mu3e Experiment

Aiming for a sensitivity (SES)

$$\text{BR}(\mu \rightarrow e e e) < 2 \cdot 10^{-15} \quad (\text{phase I})$$

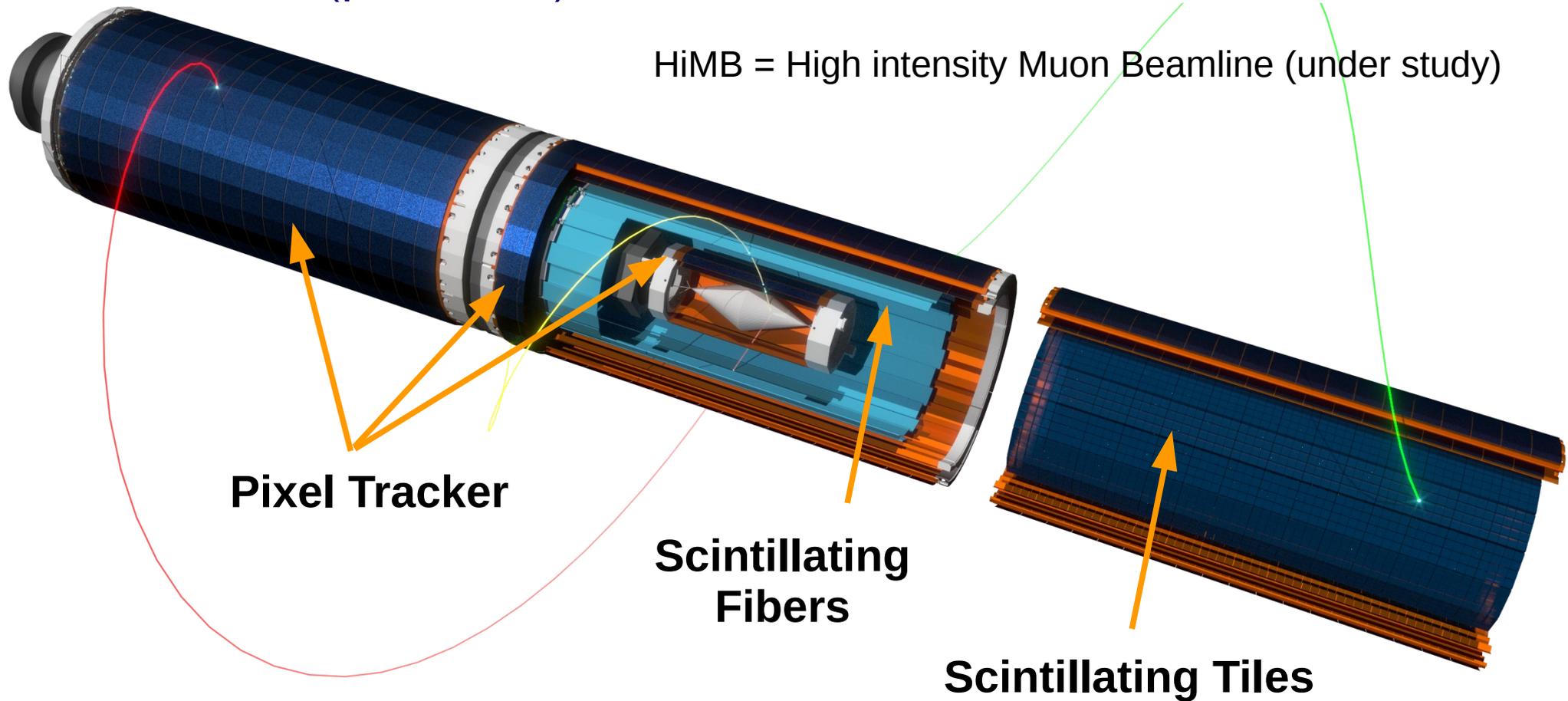
$$\text{BR}(\mu \rightarrow e e e) < 10^{-16} \quad (\text{phase II})$$

requires:

→ **10^8 muons/s (PiE5)**

→ **$>10^9$ muons/s (HiMB)**

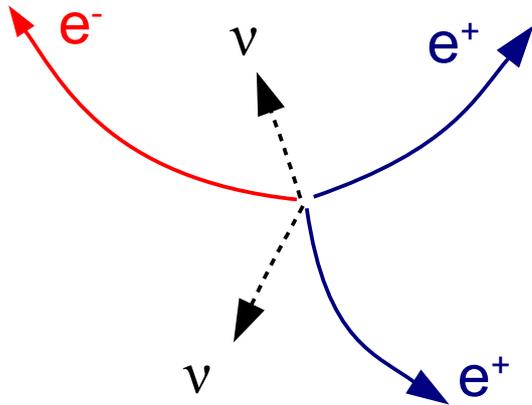
HiMB = High intensity Muon Beamline (under study)



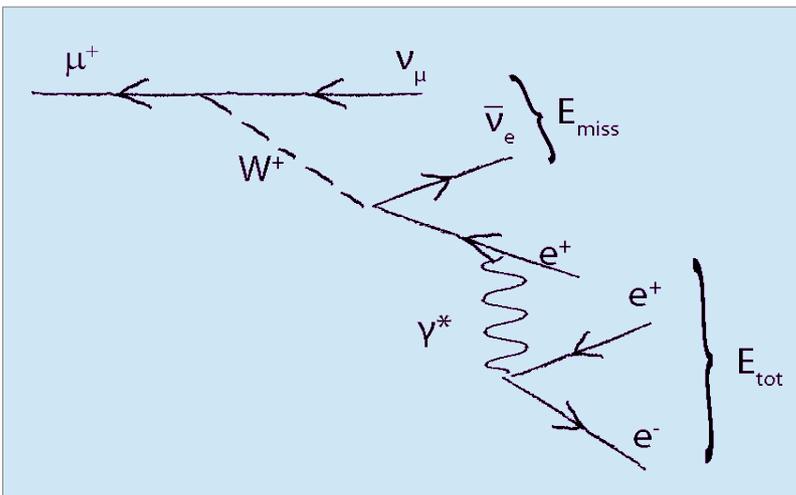


Irreducible Background

radiative decay with internal conversion



$$B(\mu^+ \rightarrow e^+e^+e^- \nu\nu) = 3.4 \cdot 10^{-5}$$



Mu3e signal

$\mu^+ \rightarrow e^+e^+e^-$

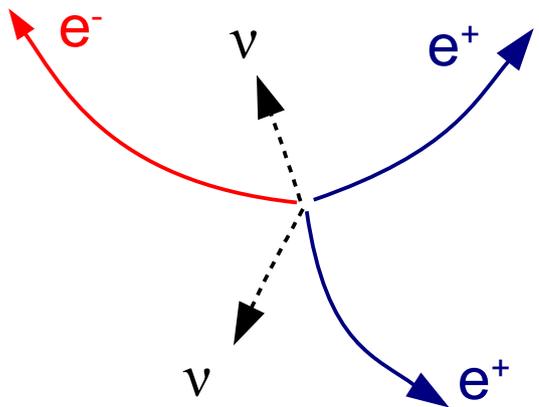
$$\sum_i E_i = m_\mu$$

$$\sum_i \vec{p}_i = 0$$

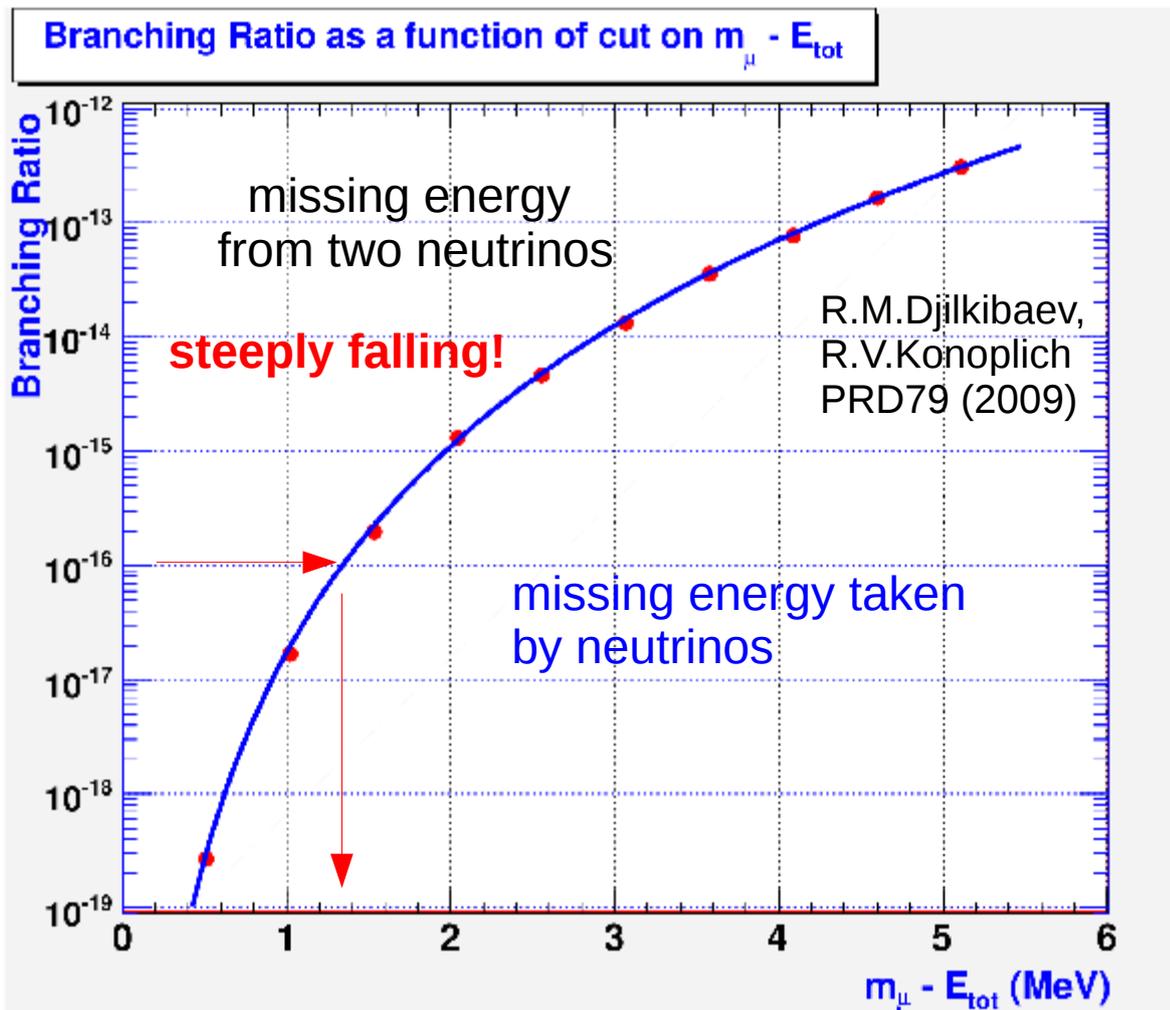
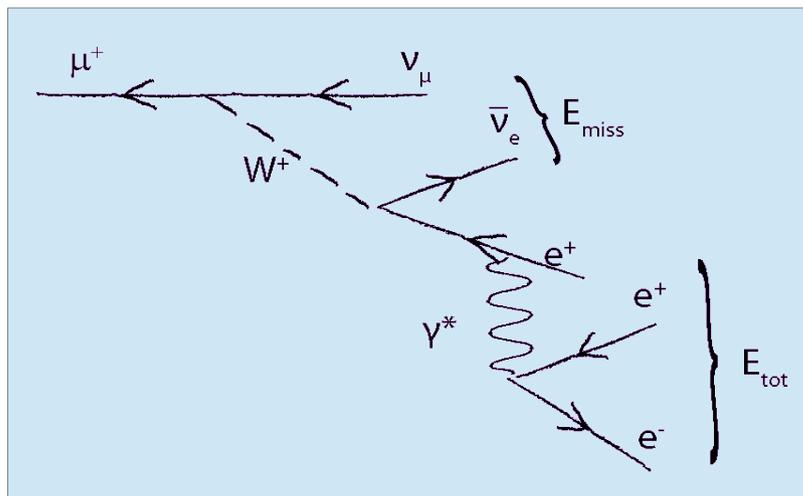


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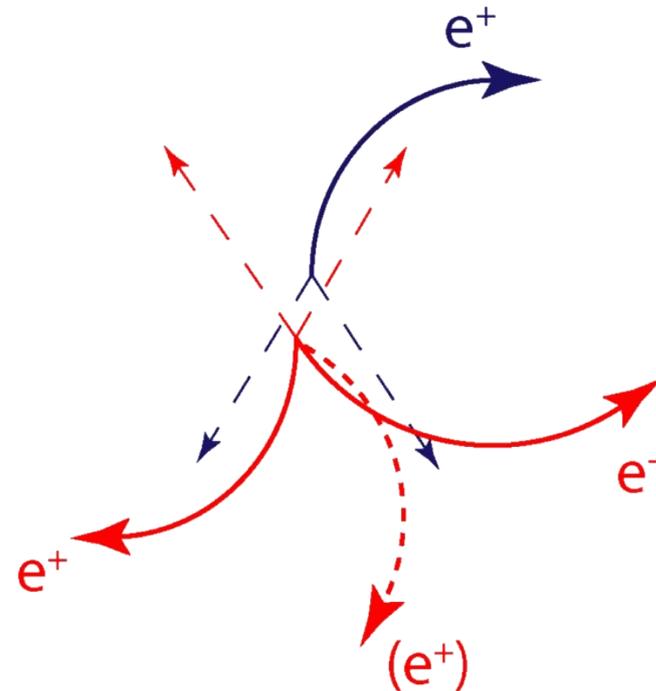
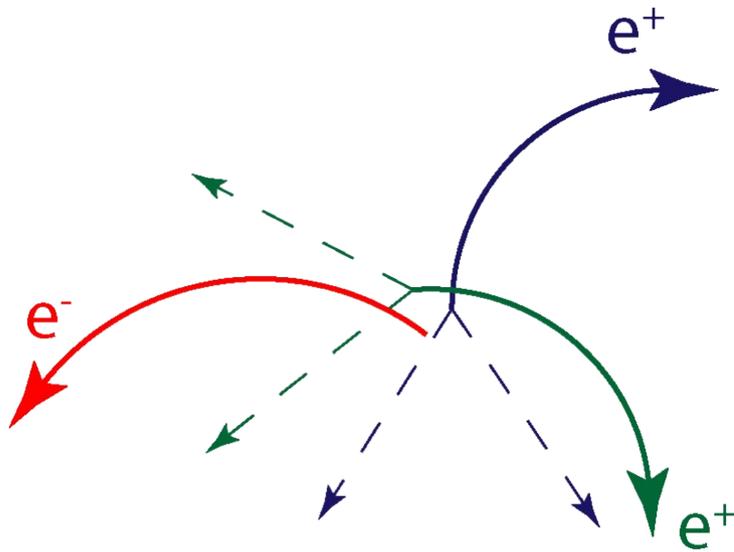


very good momentum + total energy resolution required!



Accidental Backgrounds

- **Overlays** of two ordinary μ^+ decays with a (fake) **electron (e^-)**
- Electrons from: **Bhabha** scattering, photon conversion, mis-reconstruction



Need excellent:

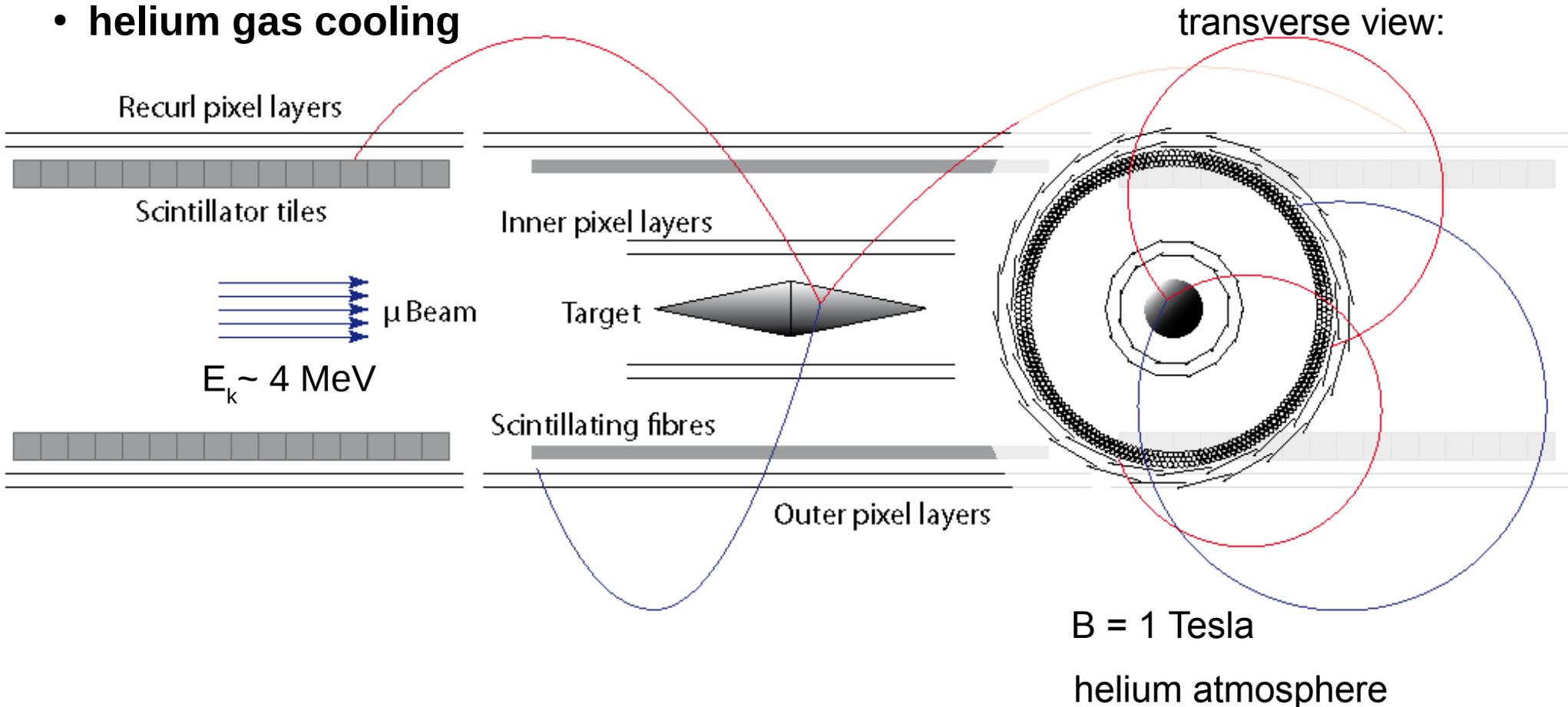
- **Vertex resolution**
- **Timing resolution**
- **Kinematic reconstruction**



Mu3e Design

Features:

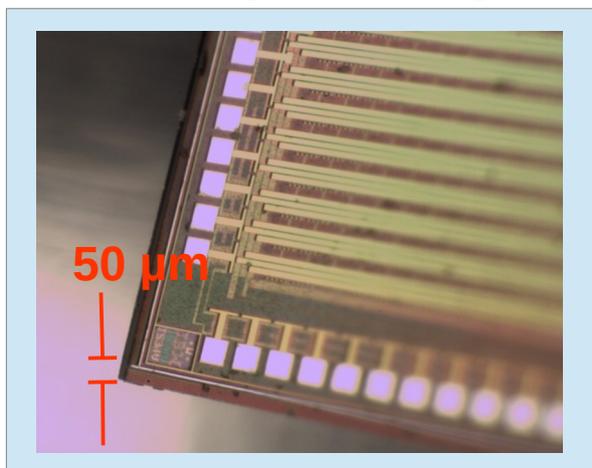
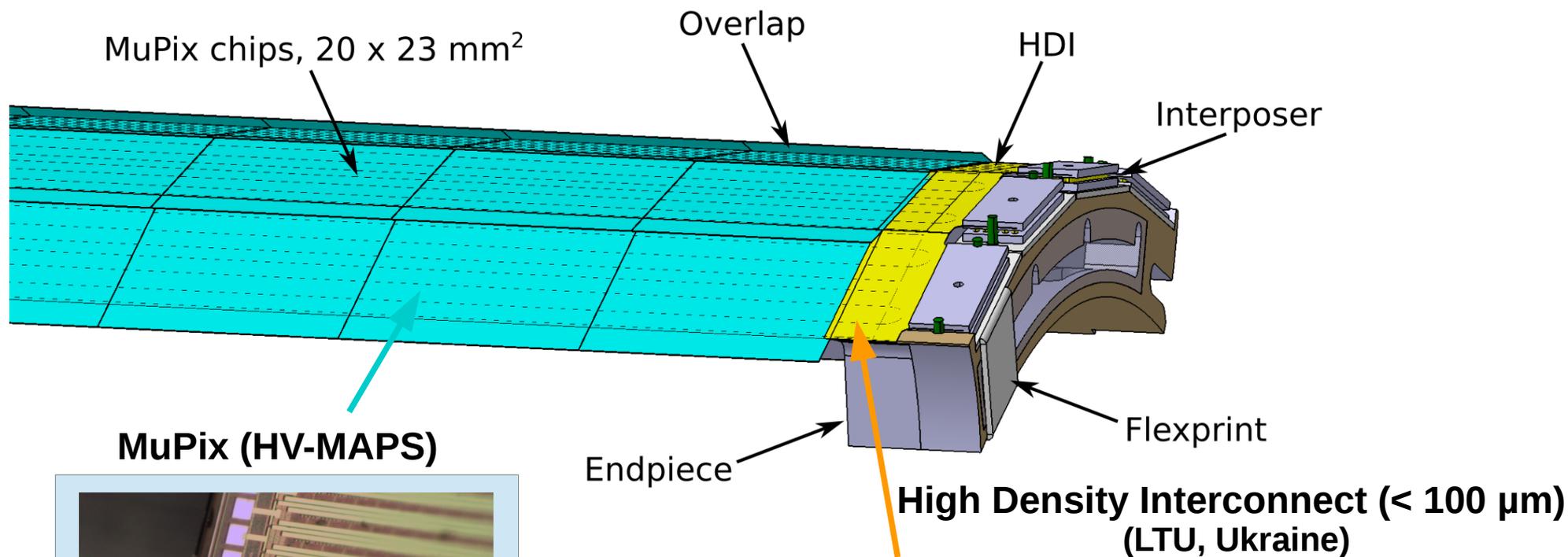
- surface muons ($p=29$ MeV/c, DC) stopped on target at high rate: $10^8 - 10^9$ /s
- ultra thin **silicon pixel detector** (HV-MAPS) with **1 per mill radiation length** / layer
- high precision tracking using **recurling tracks** in strong magnetic field
- **fast timing** detectors (**scintillating fibers & tiles**)
- **helium gas cooling**



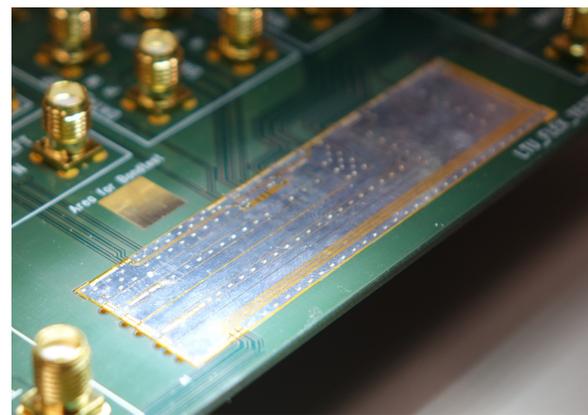


(Outer) Pixel Tracker Module

Ultra-thin pixel sensor modules with a radiation length of $X/X_0 = 1.15$ per mil



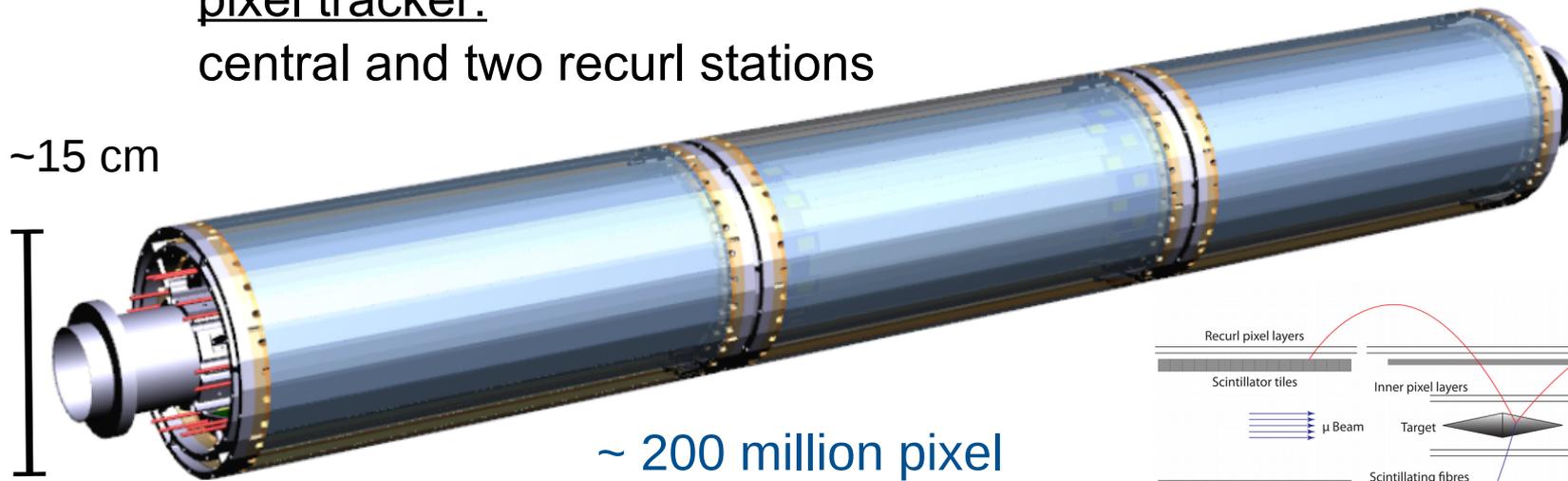
Monolithic pixel sensor in 180 nm HV-CMOS



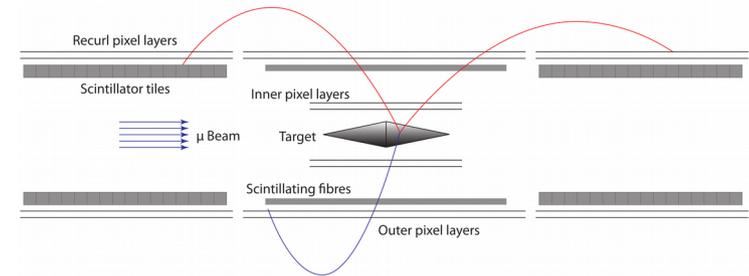
Pixel Detector + Helium Gas Cooling

pixel tracker:
central and two recurl stations

~15 cm



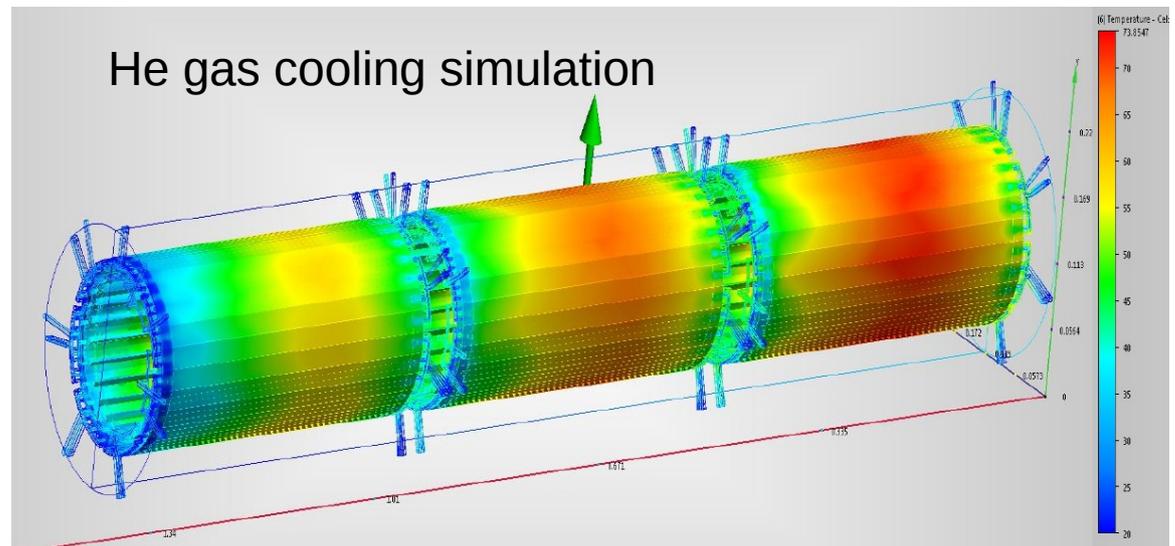
~ 200 million pixel



He gas cooling concept

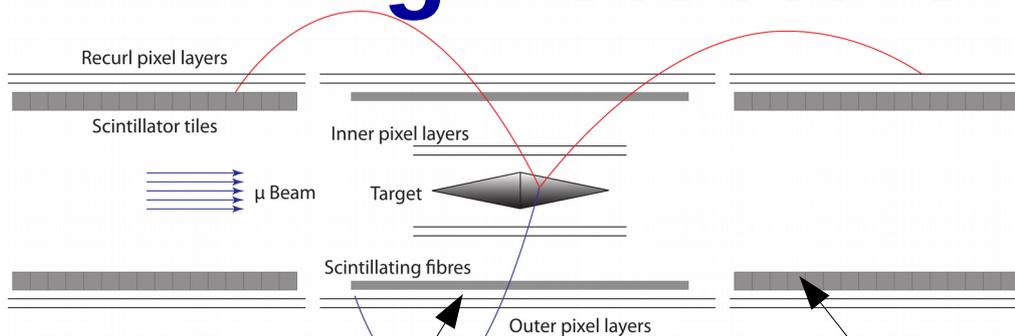
→ temperatures 20-50 °C

→ no extra material in active volume!

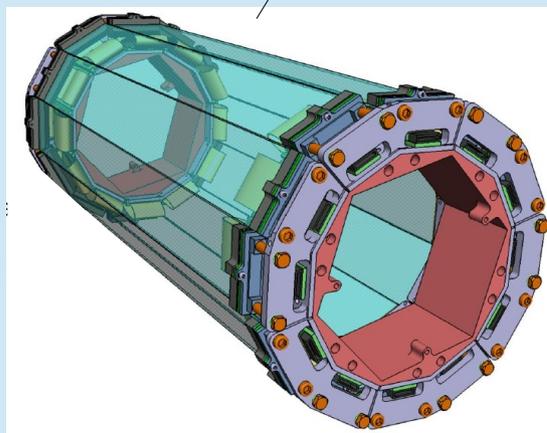
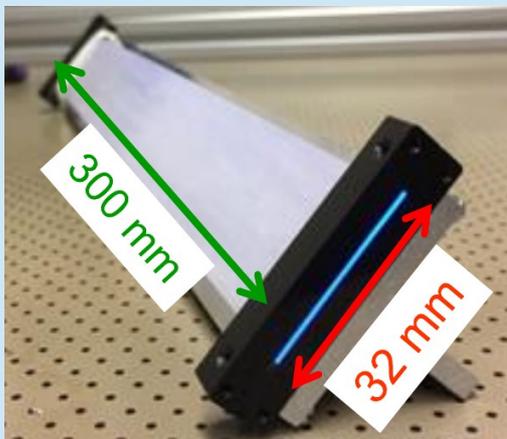




Timing Detectors



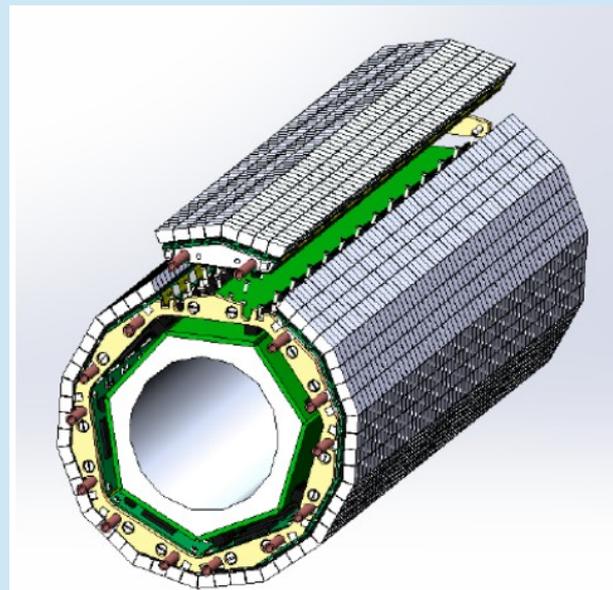
Scintillating Fibres



- 3 staggered layers of 250 μm scintillating fibres (SCSF-78MJ)
- very thin $\sim 0.2\% X_0$
- 128 channel SiPM array from Hamamatsu
- Readout with MuTrig ASIC
- time resolution $< 500\text{ps}$

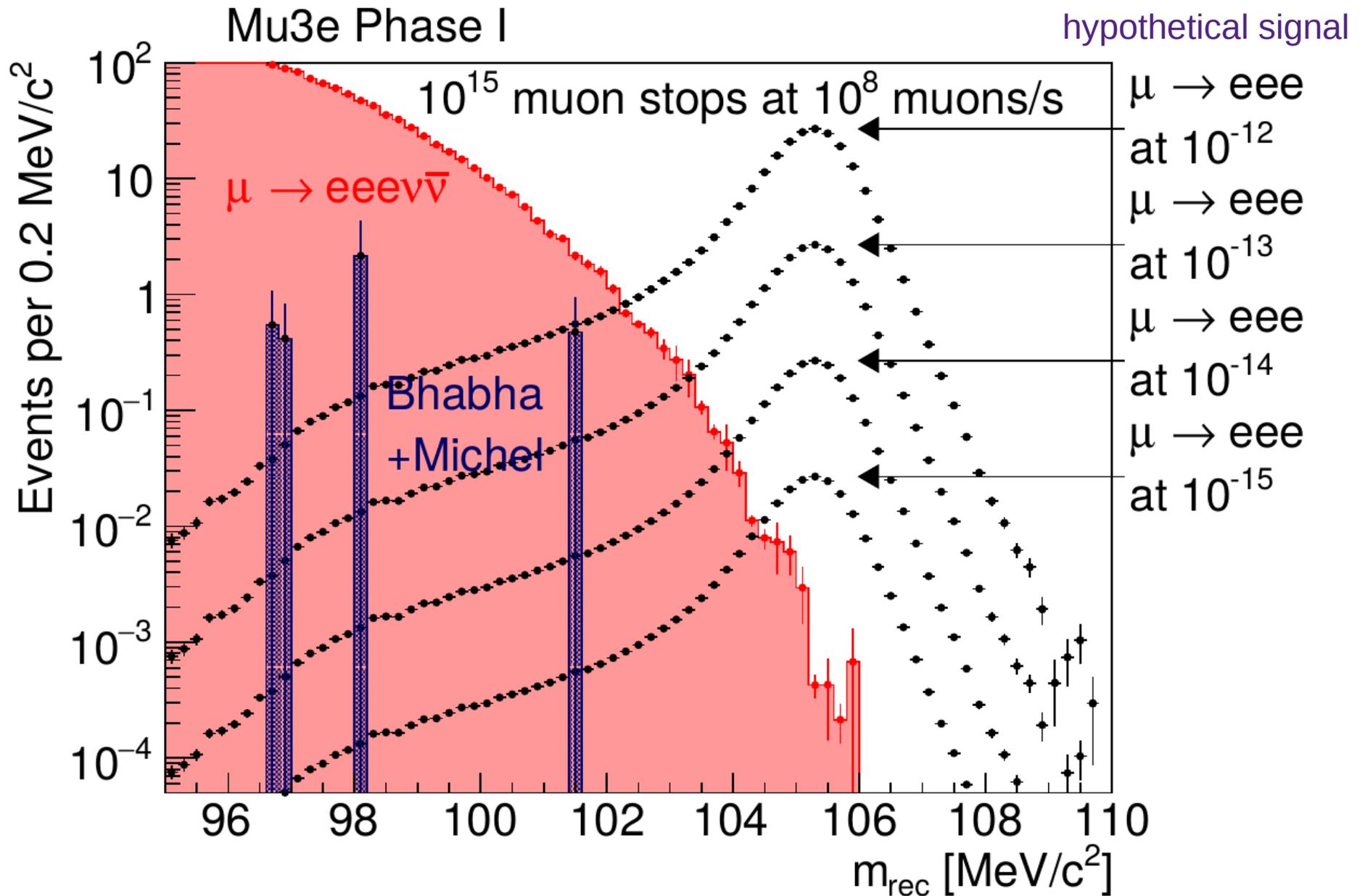
Scintillating Tiles

- tiles $\sim 6.5 \times 6.5 \times 5\text{mm}^3$
- SiPM $3 \times 3\text{mm}^2$
- Readout with MuTrig ASIC
- time resolution $< 100\text{ps}$



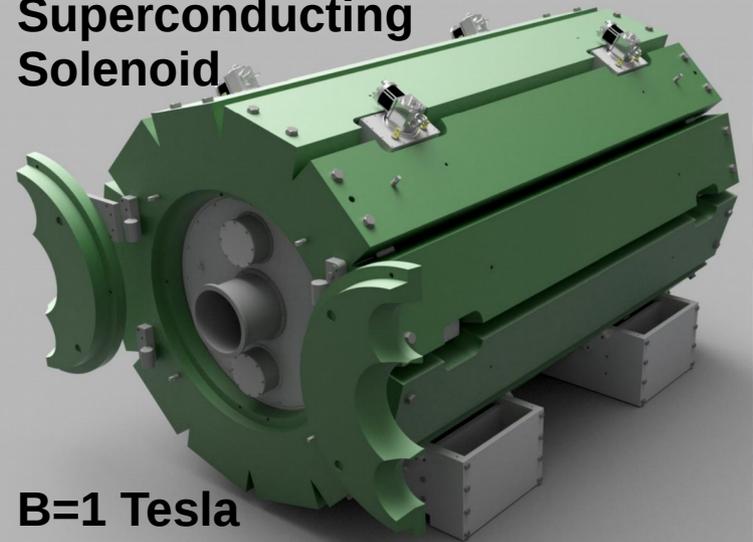


Mu3e Mass Plot (Phase I)



Mu3e Status and Plans

Superconducting Solenoid



B=1 Tesla

New "Skywalk"



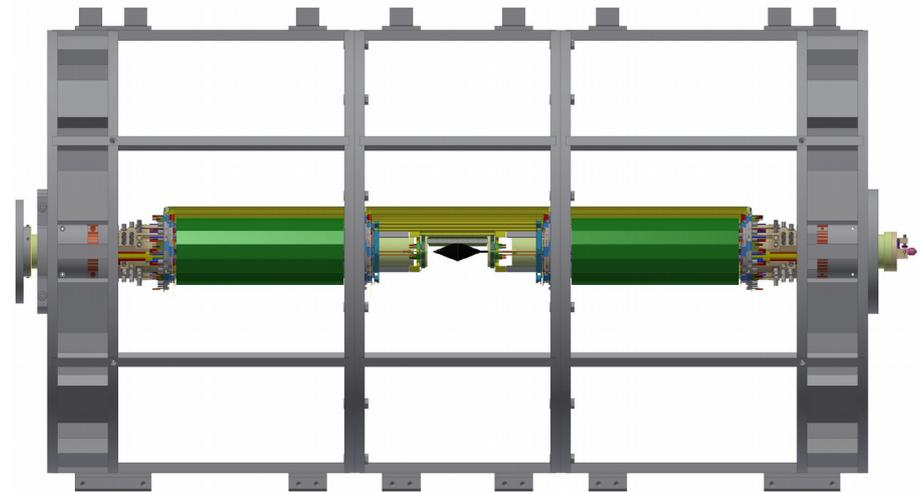
- Superconduction solenoid produced by Cryogenic (London)
- Delivery expected in summer 2019



Mu3e Status and Plans

Phase I

- Comprehensive R&D program for pixel & timing detectors completed
- Prototypes for essentially all sub-detectors exist
- Production readiness in 2019
- Detector construction in 2020
- Commissioning start in 2021



Mu3e Phase I detector w/o solenoid

Phase II

- requires design and approval of **High Intensity Muon Beam Line (HiMB)**
- not before 2025, physics program up to ~2030



Mu3e Collaboration

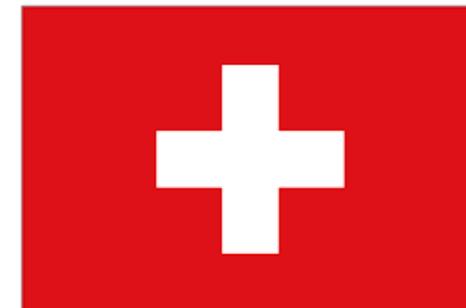
Germany

- University Heidelberg
- Karlsruhe Institute of Technology
- University Mainz



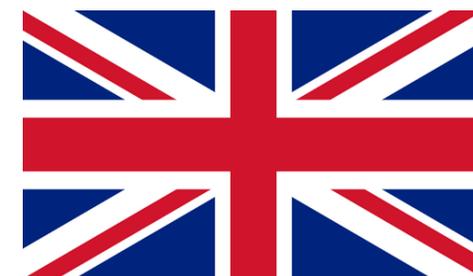
Switzerland

- University of Geneva
- Paul Scherrer Institute
- ETH Zurich
- University Zurich



United Kingdom

- Bristol
- Liverpool
- Oxford
- UC London



about 60 members; ~15 PhD students