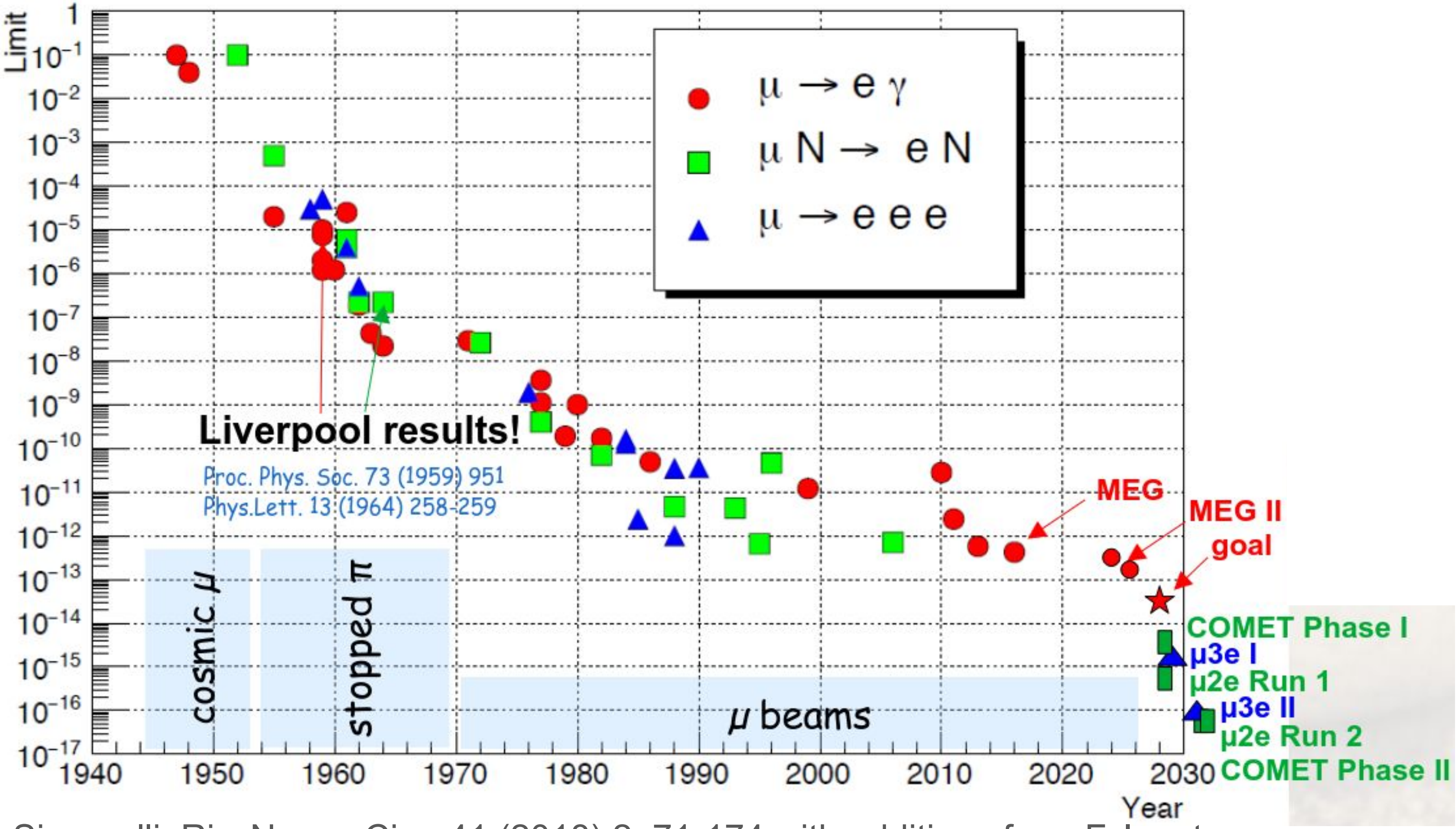
Mu3e, MEG II, MEG III

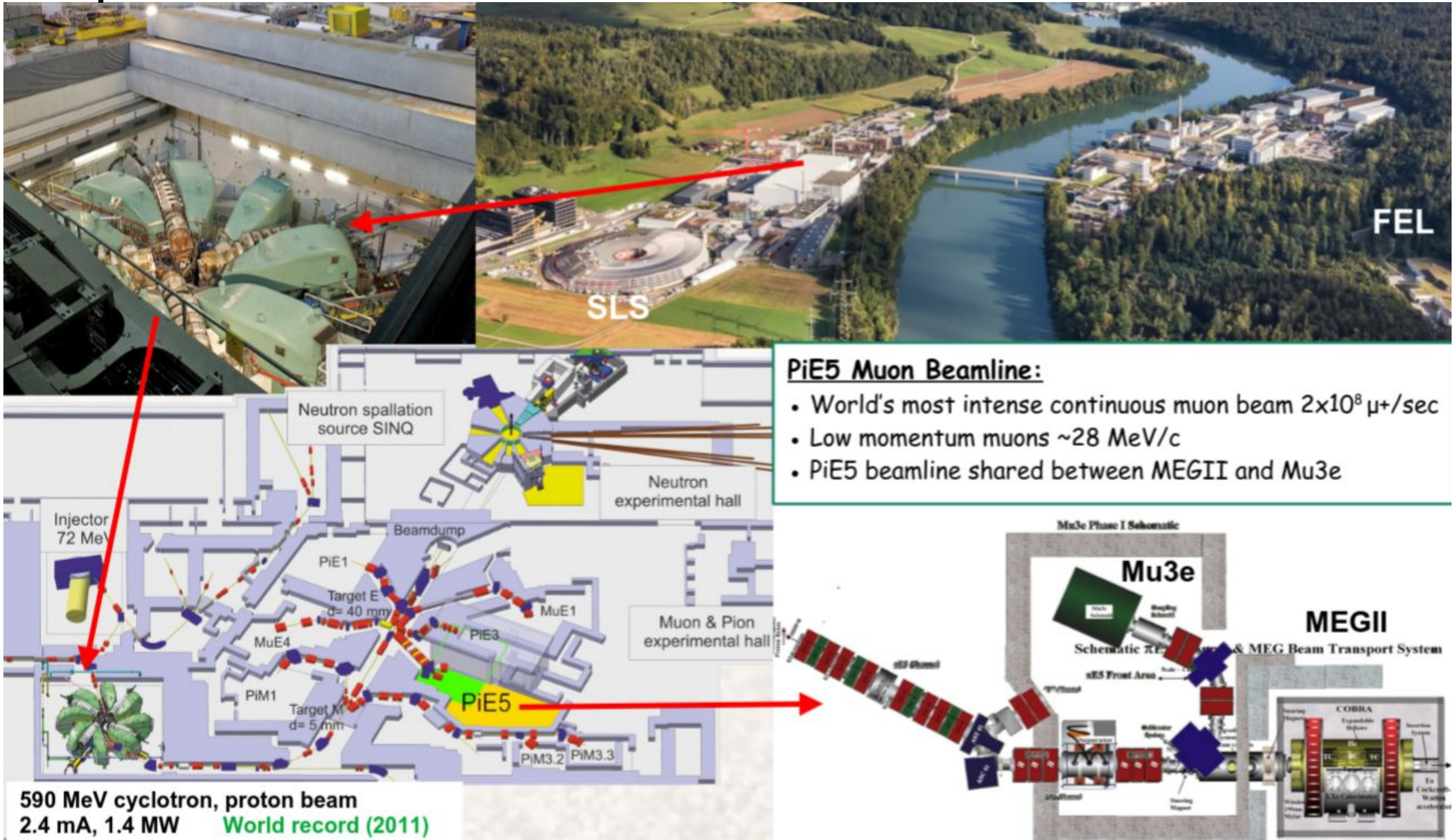
Mark Wong

History



L. Calibbi, G.Signorelli, Riv. Nuovo Cim. 41 (2018) 2, 71-174 with additions from F. Ignatov

PSI experiments



Motivation

Charged lepton flavour violation (cLFV) not yet observed and not forbidden.

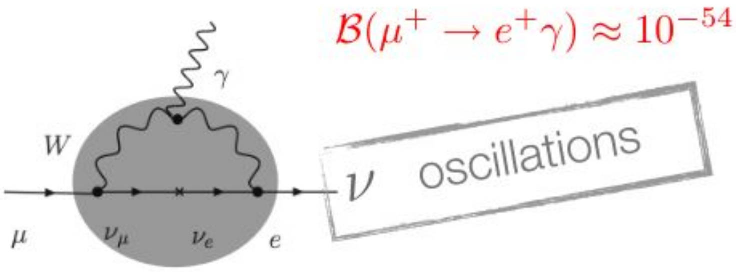
Heavily suppressed in the Standard Model with neutrino mixing O(10^{-54}).

Indirect detection of cLFV (New Physics) at current sensitivities is a clear signal for New Physics.

Use muons to probe because of:

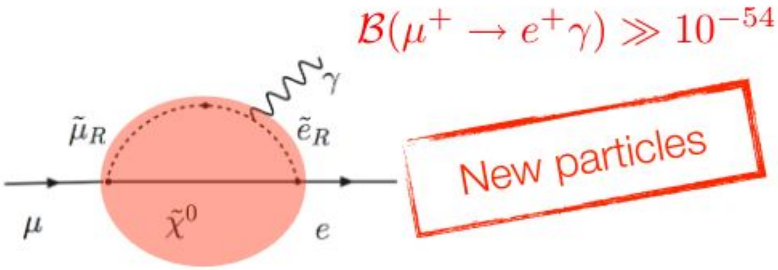
a. Availability of intense muon beams (10^8 μ/s)
b. Comparatively clean signal: long lifetime (2.2 μs), simple decay channels.

SM with massive neutrinos (Dirac)



too small to access experimentally

BSM

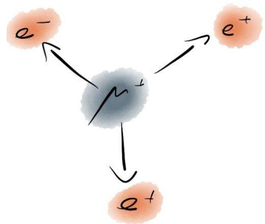


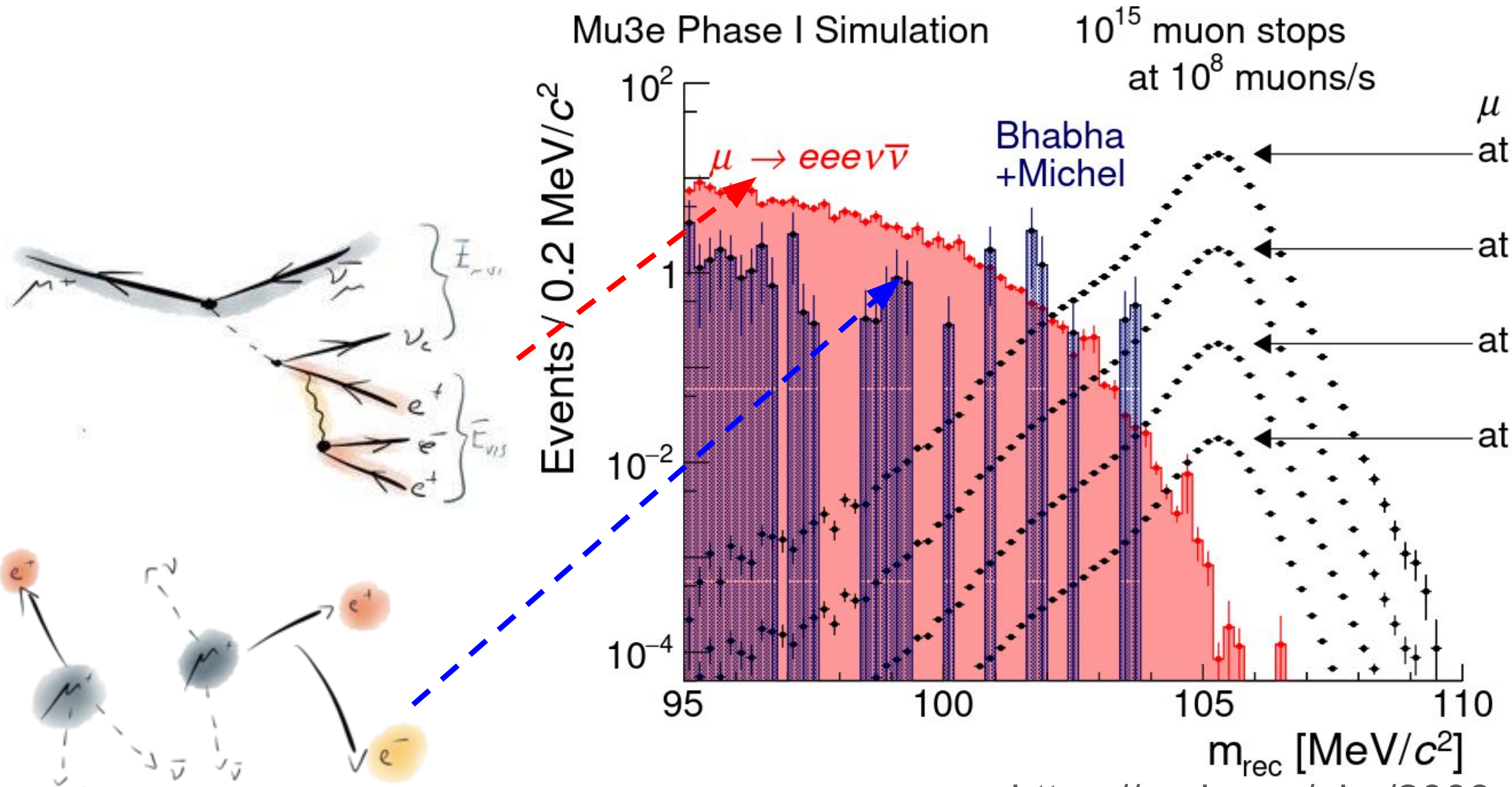
an experimental evidence:
a clear signature of New Physics NP
(SM background FREE)

Liverpool Mu3e team

Joost Vossebeld (head of Mu3e group)
Helen Hayward
Nikos Rompotis
Paolo Beltrame (Data & MC manager)
Mark Wong
Alan Taylor
Ashley Greenall
Matthew Brown
Charles Kinsman (student, writing)
Jak Woodford (student, Yr 2)

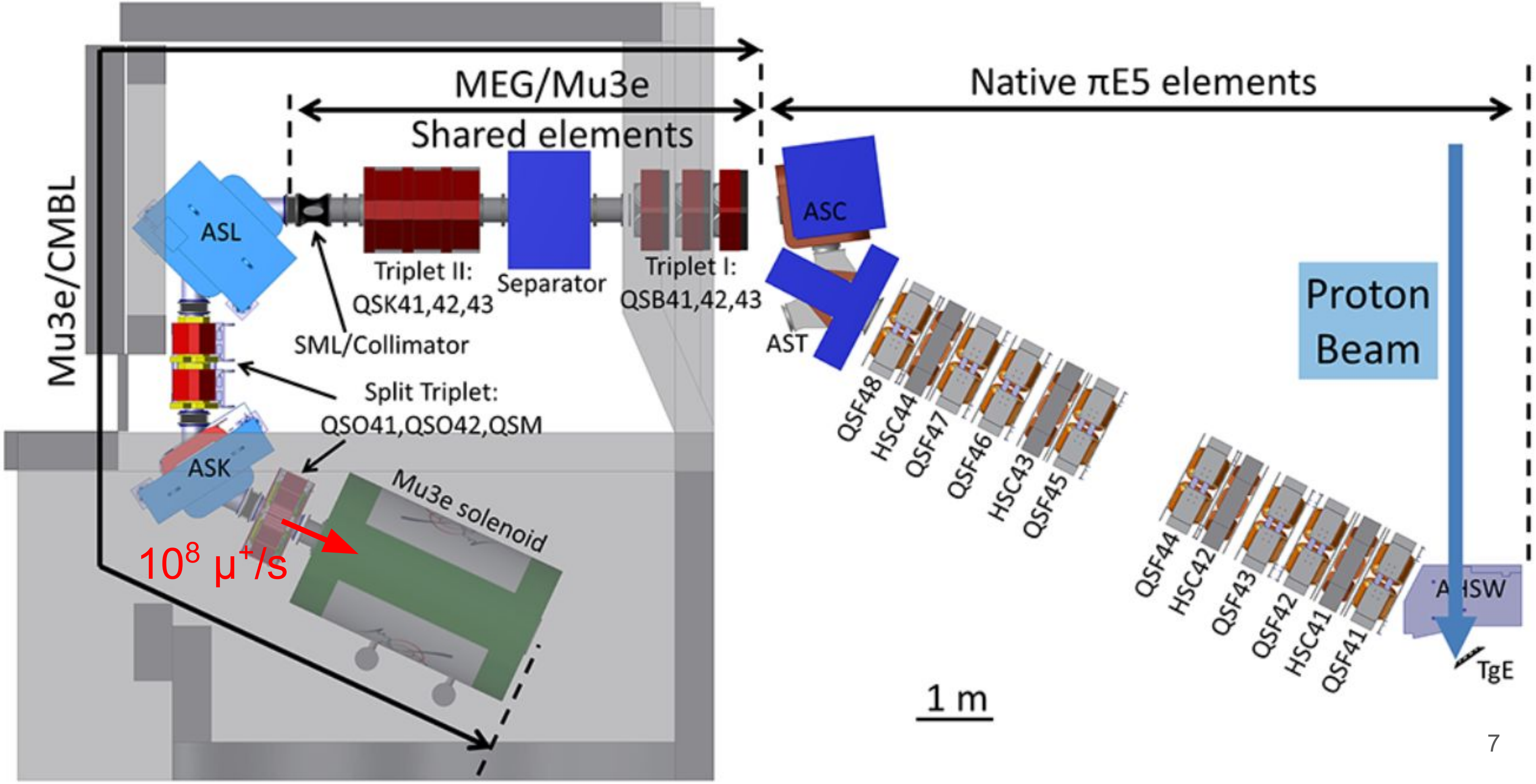
Backgrounds



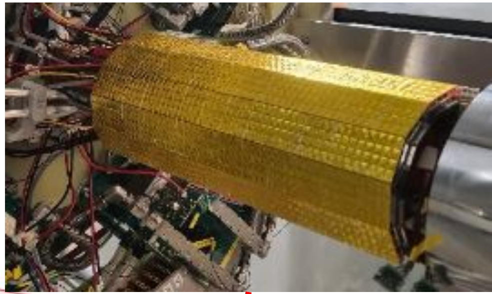


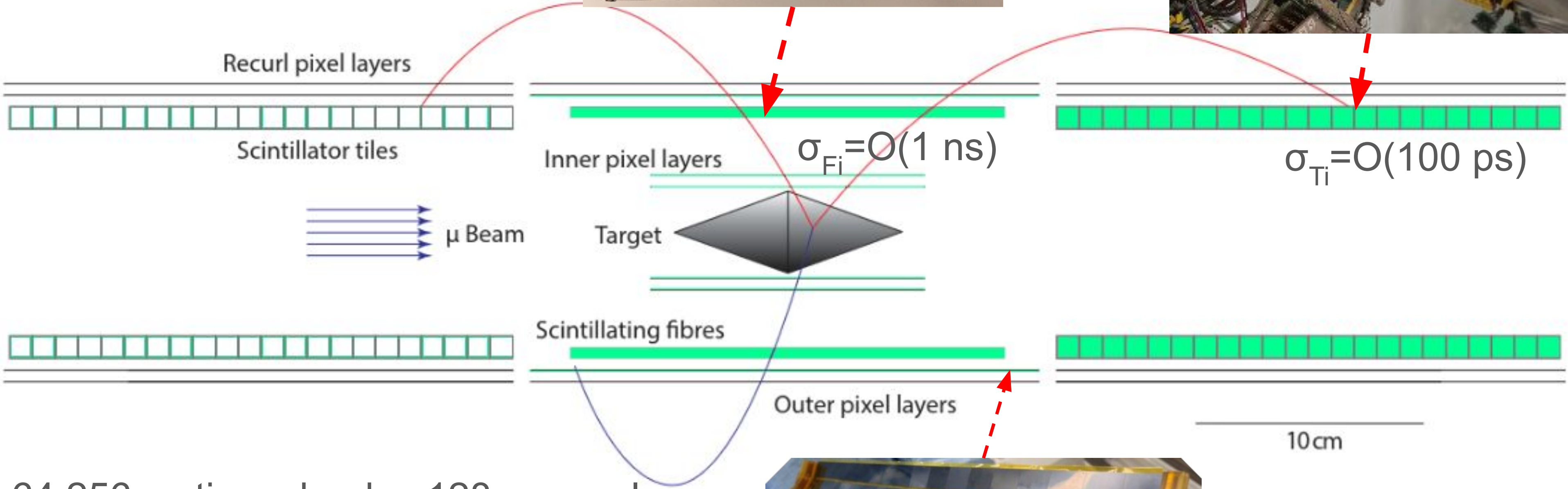
https://arxiv.org/abs/2009.11690

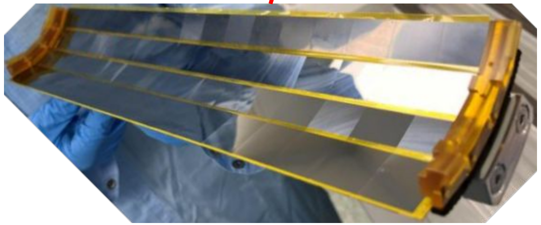
Mu3e/MEG shared beamline



Detector for commissioning 2026



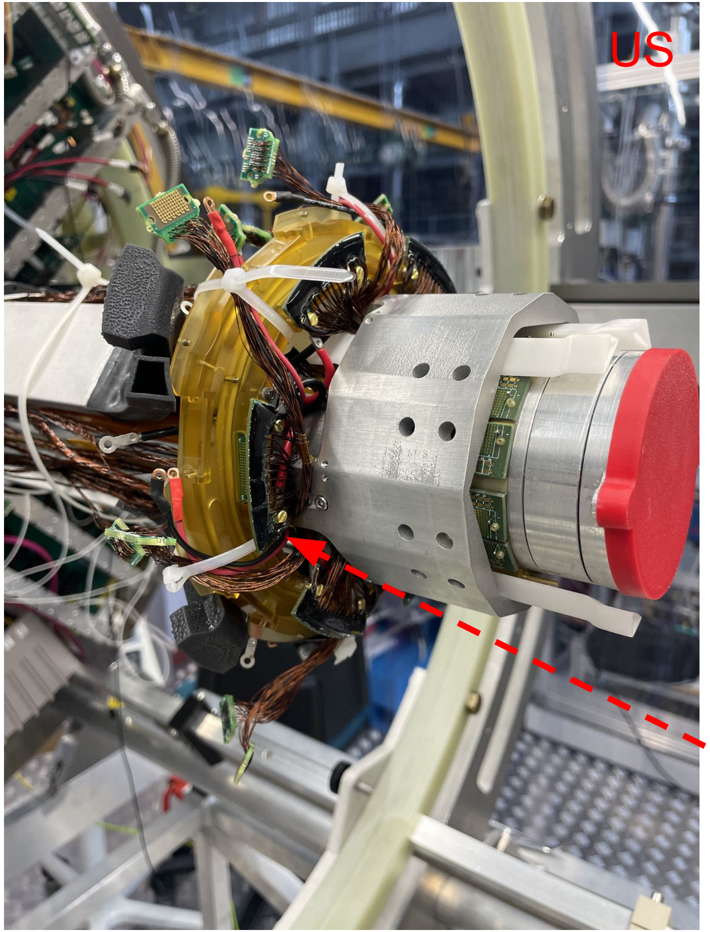


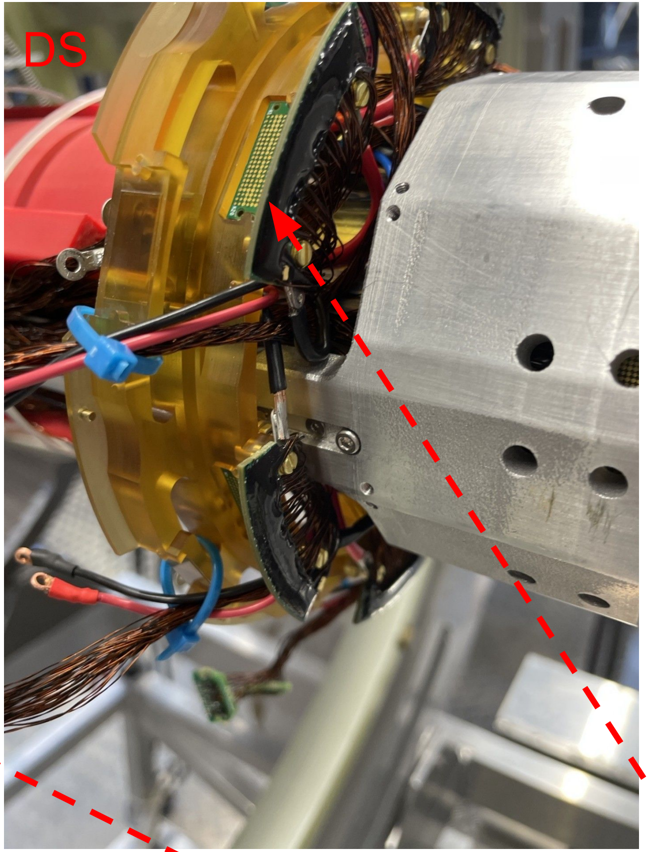


~~64~~ 256 ns time chunks, 128 ns overlap
8 million chunks/sec in GPU farm
Tracking eff = 0.86
Vertex selection eff = 0.92

B = 1 T

Outer pixel services



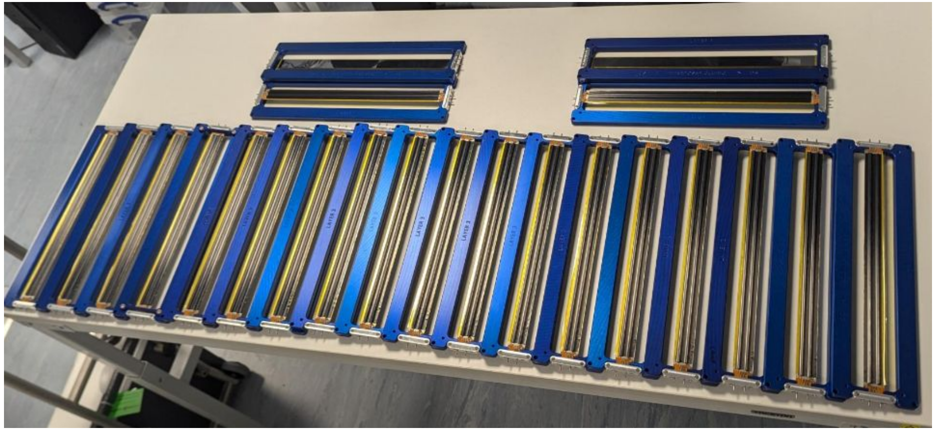


Support structure with power/data cables and cooling ducts for connecting the Layer 3 tracker in May, everything set for module installation this summer.

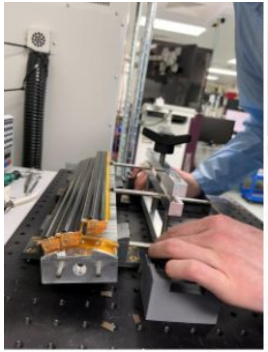
Data cable tooling by Matt B.

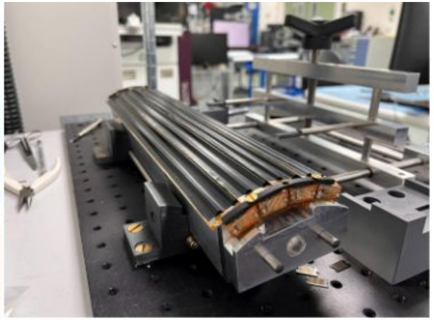
Connections to outer pixel layer 3

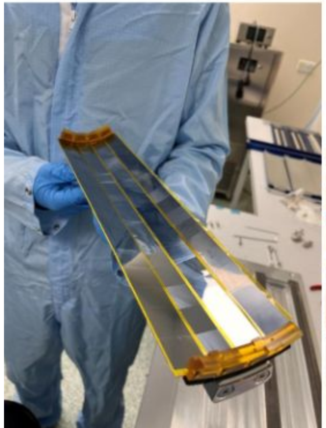
Module production

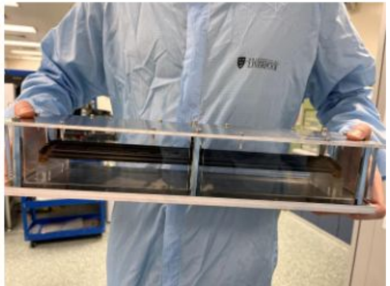


MuPix ladders for Layer 3 produced in Oxford, some of them in Liverpool now.







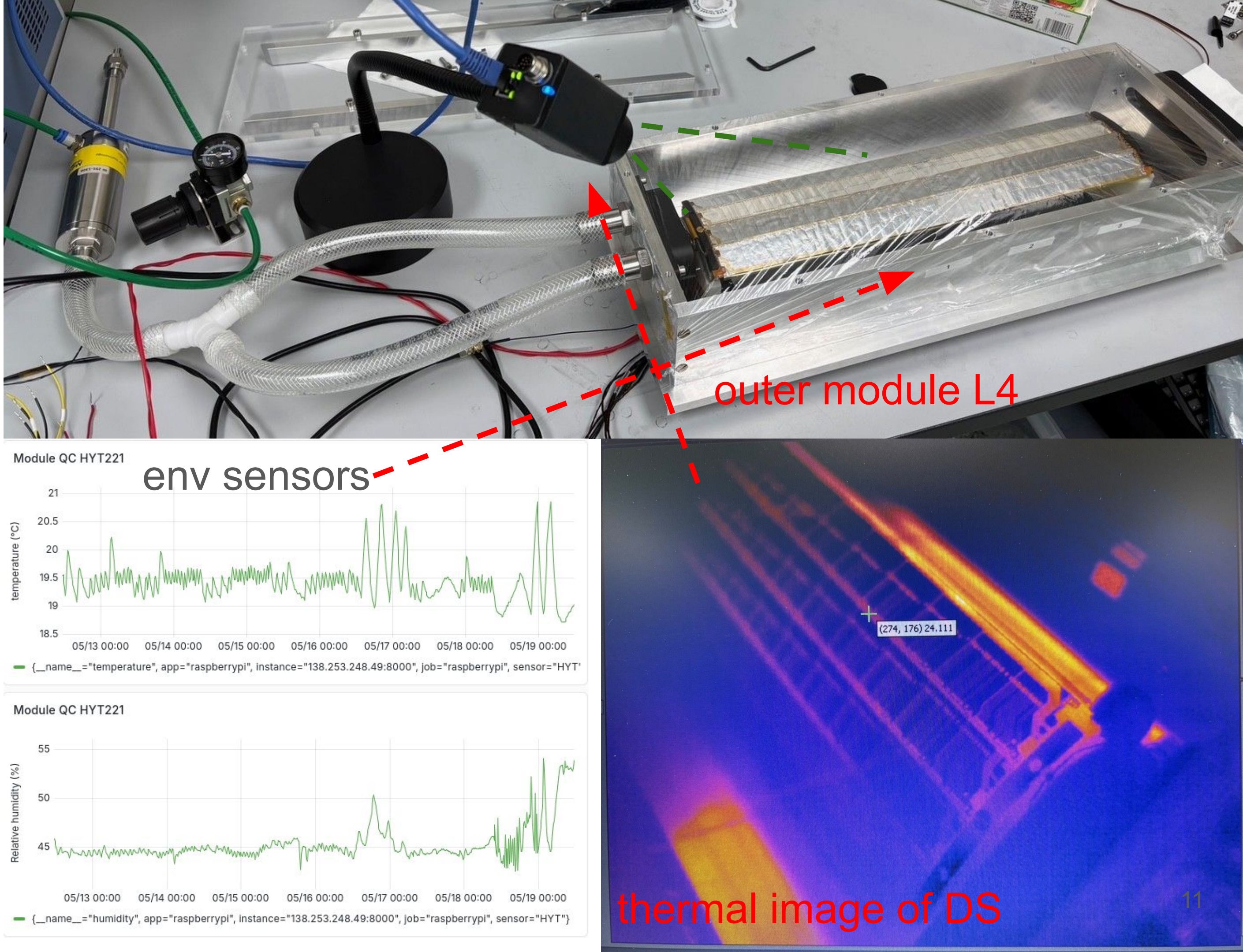


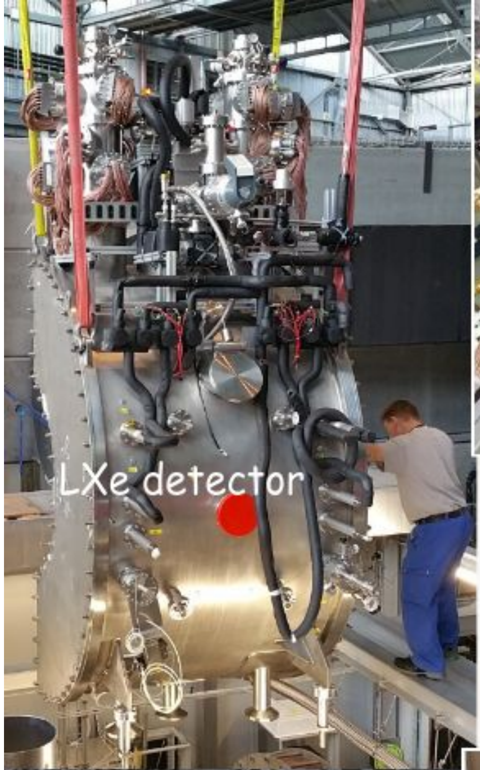
MuPix modules assembled by Matt B.
Many unforeseen challenges to connect the module to the frontend board.

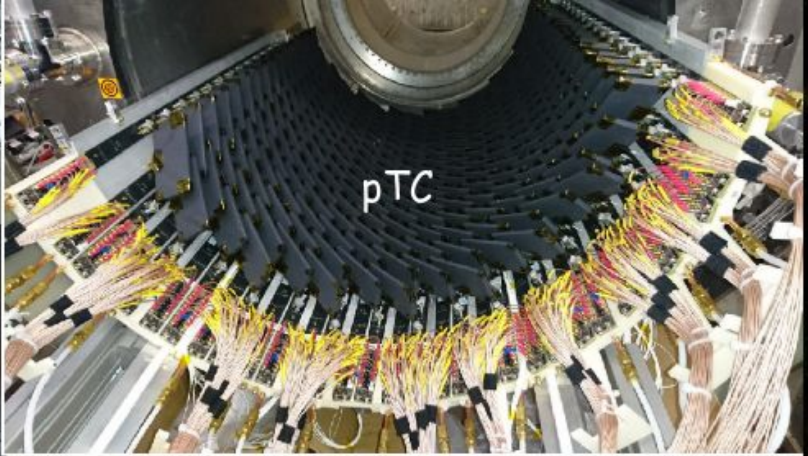
Module QC

MuPix11 module quality checks.

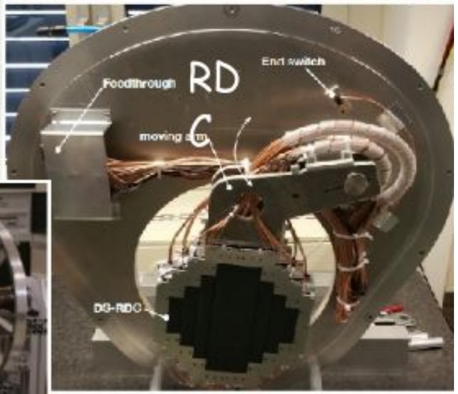
First installation of L3 outer modules by end of June 2026 in PSI

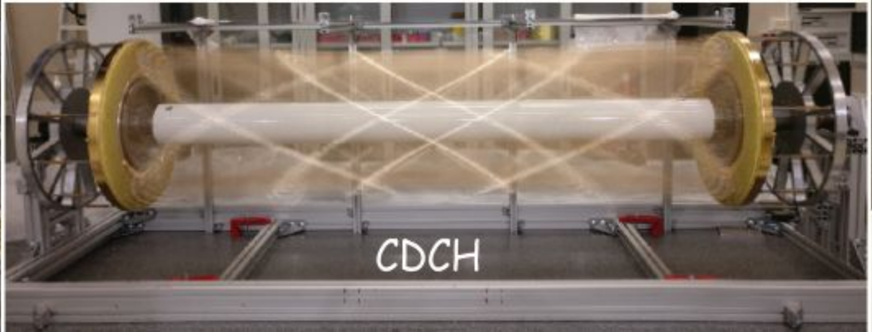






MEG II proposal 2013
Detector R&D 2012-2015
Construction in 2015-2020
Commissioning and physics run 2021-



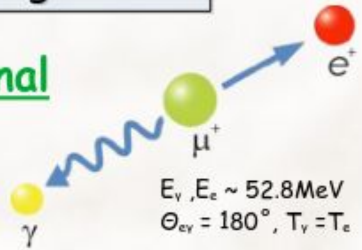


UK MEGII team

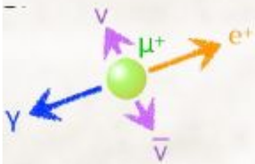
Liverpool staff:
Fedor Ignatov

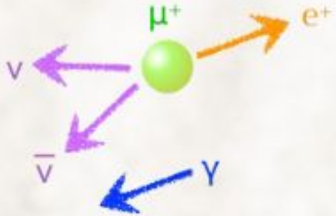
$\mu^+ \to e^+\gamma$

Signal

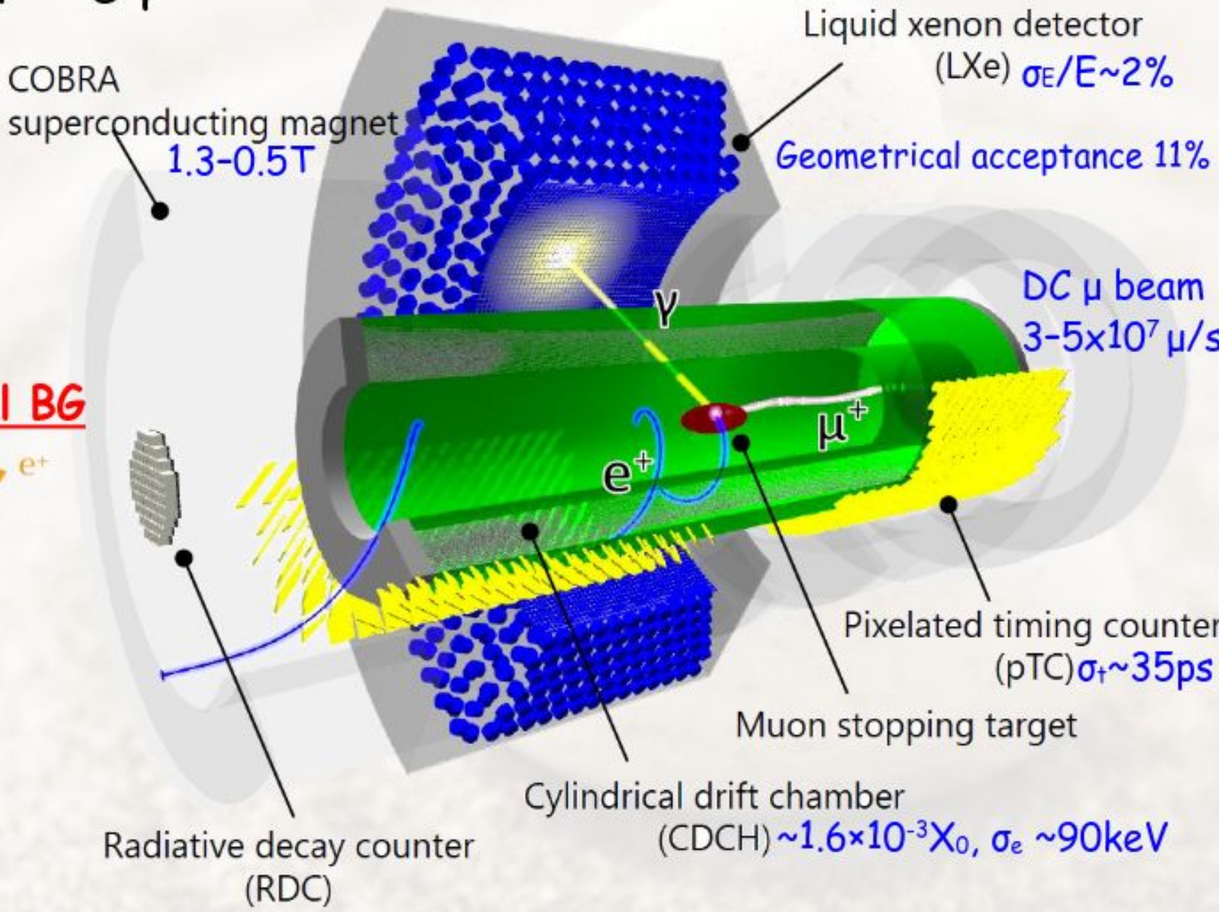


RMD BG **Dominant Accidental BG**





- Search for e+ and γ correlated by time, direction, energy
- Best resolutions are required to narrow signal region
- Continuous μ beam is mandatory



EPJC 84(2024)2, 190

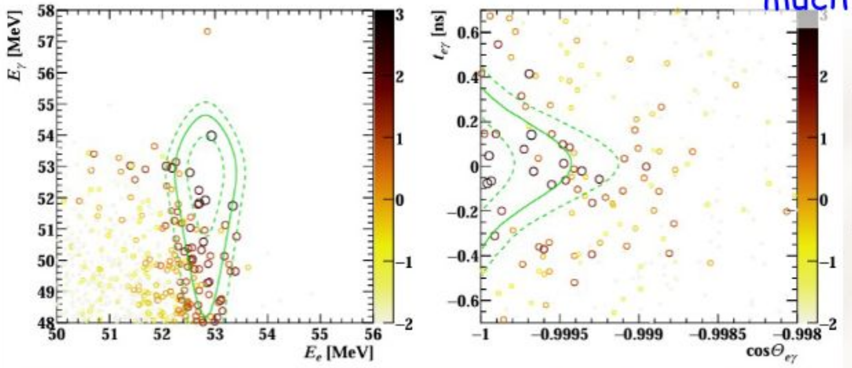
MEG II result 2021+2022 runs

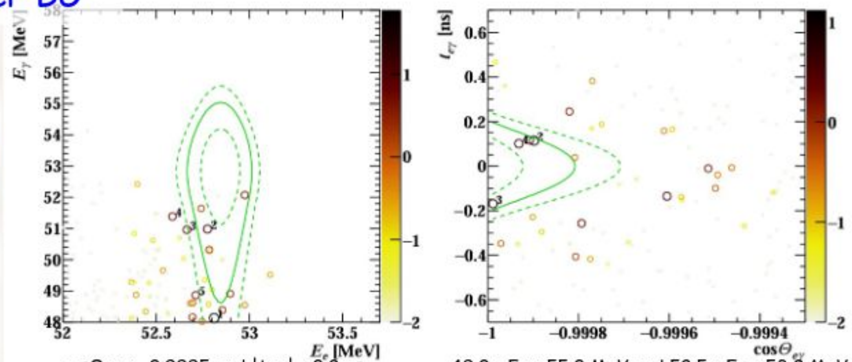
Eur.Phys.J.C 85 (2025) 10, 1177

MEG I 2009-2013

x2 more statistics
much cleaner BG

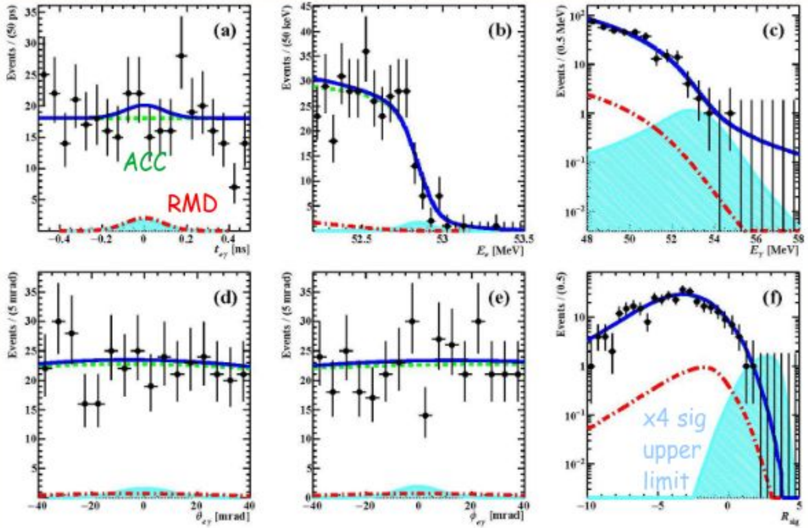
MEG II 2021+2022





cosΘeγ < -0.9995 and |teγ| < 0.2 ns

49.0 < Eγ < 55.0 MeV and 52.5 < Ee < 53.2 MeV



MEG I final Br($\mu^+ \to e^+\gamma$) < 4.2 × 10^{-13}

MEG II 2021+2022 Br($\mu^+ \to e^+\gamma$) < 1.5 × 10^{-13}

2021 data: Eur.Phys.J.C 84 (2024) 3, 216

2021+2022: Eur.Phys.J.C 85 (2025) 10, 1177

2023+2024 statistics x2.5 in total unpublished

MEG II goal Br($\mu^+ \to e^+\gamma$) < 0.5 × 10^{-13}

2021-2026 <u>2026</u> last data-taking season for MEG II

Future $\mu \to e\gamma$ experiment
MEG III

LETTER OF INTENT
for a future $\mu^+ \to e^+\gamma$ experiment at the High Intensity Muon Beam facility at PSI

THE STUDY GROUP FOR FUTURE $\mu^+ \to e^+\gamma$ EXPERIMENTS

Paolo Walter Cattaneo,[1*] Wataru Ootani,[2*] Francesco Renga,[3a*] André Schöning,[4*] Heiko Augustin,[4] Haris Avudaiyappan,[5] Sei Ban,[2] Paolo Beltrame,[6] Hicham Benmansour,[7ab] Daniela Bortoletto,[8] Alessandro Bravar,[9] Gianluca Cavoto,[3ab] Marco Chiappini,[7a] Alessandro Corvaglia,[18a] Giovanni Dal Maso,[10] Sacha Davidson,[11] Matteo De Gerone,[12] Lorenzo Ferrari Barusso,[12] Marco Francesconi,[13] Luca Galli,[7a] Giovanni Gallucci,[7] Helen Hayward,[6] Gavin Hesketh,[14] Malte Hildebrandt,[15] Fumihito Ikeda,[2] Fedor Ignatov,[6] Toshiyuki Iwamoto,[2] Tamasi Kar,[4] Marius Köppel,[15] Francesco Leonetti,[7ab] Weiyuan Li,[2] Satoshi Mihara,[17] Toshinori Mori,[2] Ljiljana Morvaj,[15] Donato Nicolò,[7ab] Hajime Nishiguchi,[17] Hiroyasu Ogawa,[2] Atsushi Oya,[2] Angela Papa,[7ab,15] Marco Panareo,[18ab] Daniele Pasciuto,[3a] Davide Pinci,[3a] Richard Plackett,[8] Nikolaos Rompotis,[6] Massimo Rossella,[1] Thomas Rudzki,[4] Rei Sakakibara,[2] Susanna Scarpellini,[3ab] Taikan Suehara,[2] Hiromu Suzuki,[19] Masato Takahashi,[19] Michele Tammaro,[20] Gianfranco Tassielli,[18ac] Yusuke Uchiyama,[17] Ryusei Umakoshi,[2] Antoine Venturini,[7ab] Luigi Vigani,[4] Cecilia Voena,[3ab] Joost Vossebeld,[6] Rainer Wallny,[16] Kensuke Yamamoto,[2] Yuji Yamazaki[19]

[1] INFN Sezione di Pavia, Via Bassi 6, 27100 Pavia, Italy
[2] ICEPP, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
[3] a) INFN Sezione di Roma, Piazzale A. Moro, 00185 Rome, Italy
b) Dipartimento di Fisica dell'Università "Sapienza", Piazzale A. Moro, 00185 Rome, Italy
[4] Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany
[5] Institut für Kernphysik und Exzellenzcluster PRISMA+, Johannes Gutenberg-Universität Mainz, Johann-Joachim-Becher-Weg 45, 55128 Mainz, Germany
[6] Oliver Lodge Laboratory, University of Liverpool, Oxford St., Liverpool L69 7TE, UK
[7] a) INFN Sezione di Pisa, Largo B. Pontecorvo 3, 56127 Pisa, Italy
b) Dipartimento di Fisica dell'Università, Largo B. Pontecorvo 3, 56127 Pisa, Italy
[8] Department of Physics, University of Oxford, Denys Wilkinson Building, Keble Road, Oxford OX1 3RH, United Kingdom
[9] Département de physique nucléaire et corpusculaire, Université de Genève, 24, quai Ernest-Ansermet, 1211 Genève 4, Switzerland

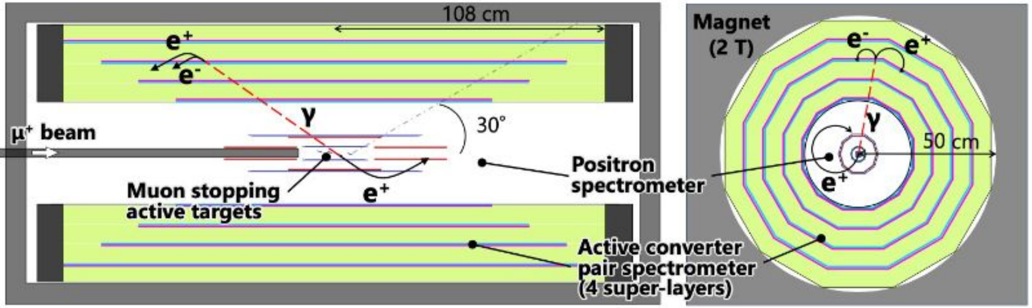
INFN
UTokyo
UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386
JG|U
UNIVERSITY OF LIVERPOOL
UNIVERSITÀ DI PISA
UNIVERSITY OF OXFORD
UNIVERSITÉ DE GENÈVE
SAPIENZA UNIVERSITÀ DI ROMA
CERN
iP2i
UNIVERSITÀ DEGLI STUDI DI GENOVA
UCL
PSI
ETH zürich
KEK
UNIVERSITÀ DEL SALENTO
KOBE UNIVERSITY
GGI

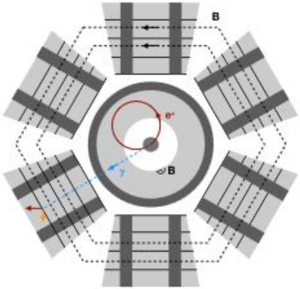
Core : MEG + Mu3e groups

Not a continuation of MEG II,
but a new effort in strong synergy with Mu3e
and open to external contributions

Detector concept

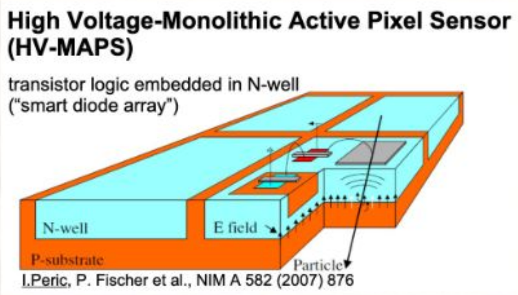
HIMB μ beam
$5\times10^{7} \rightarrow 10^{10}$ μ/s





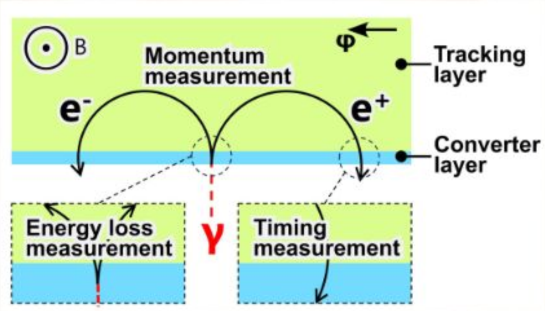
Tracker: from Mu3e

Monolithic silicon pixels (HV-MAPS)
high-rate tolerance,
low material budget,
high granularity



Momentum resolution ~ 100 keV

New technology
Calorimeter

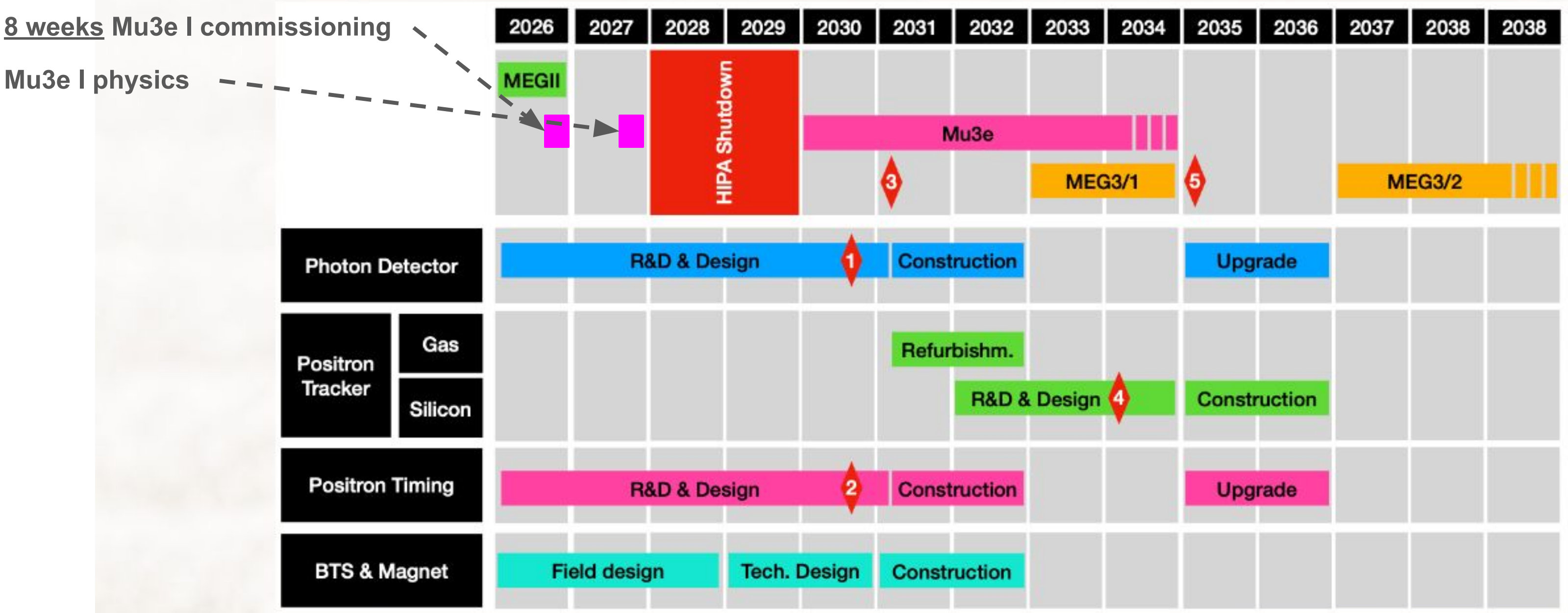


Energy resolution: 1 MeV → 0.2 MeV
On price of efficiency 60% → 10%
Time resolution ~ 30ps

Positron timing

MEGII baseline:
Scintillating tiles + SiPM
with reduced size
Time resolution ~ 30ps

Schedule



Phase-0 (proof-of-concept): a beam test with small photon conversion detector prototype

Phase-1 : at 2×10^{8} μ/s, reusing some MEG II hardware: COBRA magnet, drift chamber
1 or 2 photon conversion layers

Phase-2: at > 10^{9} μ/s, Silicon positron tracker, multiple conversion layers

Sensitivity: 6×10^{-14} (MEG2) → $(2 - 3)\times10^{-15}$