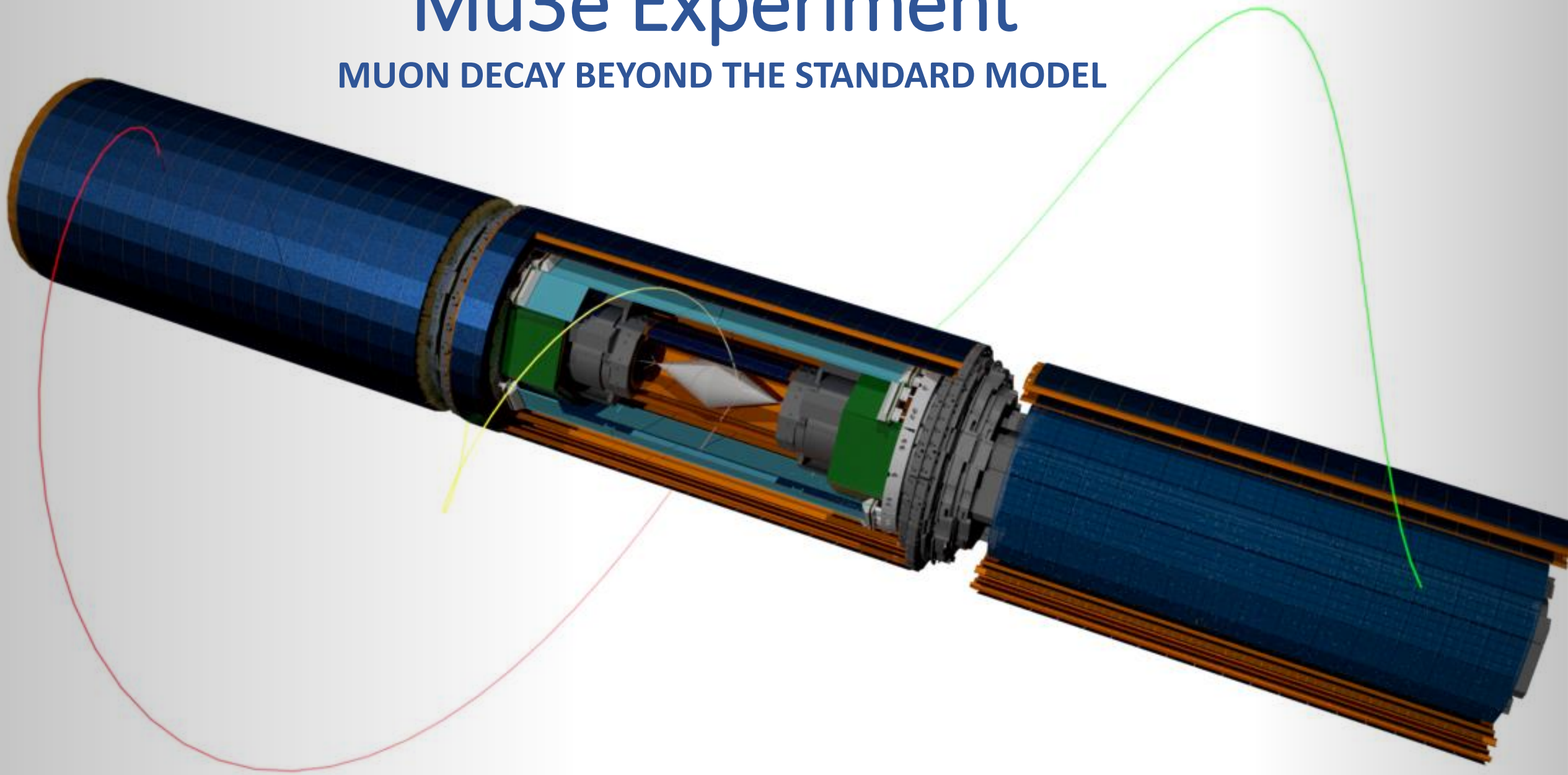
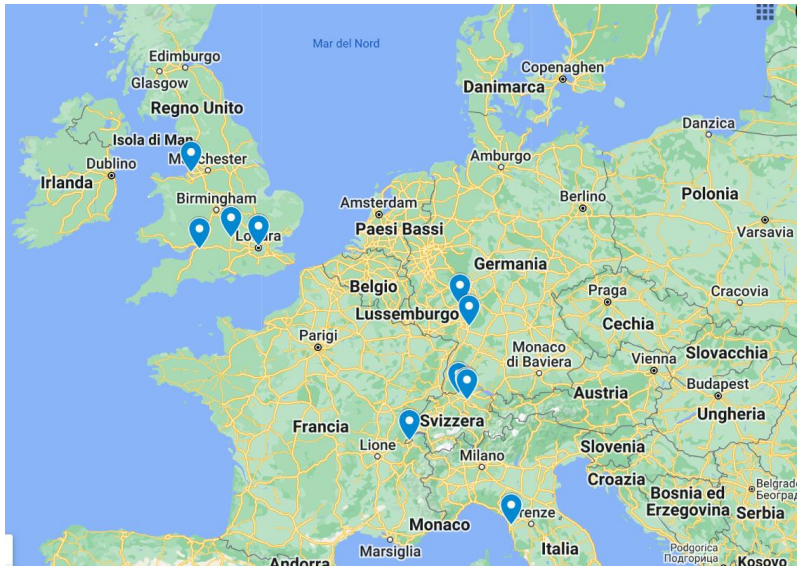
Mu3e Experiment

MUON DECAY BEYOND THE STANDARD MODEL



A. Loreti on behalf of mu3e @Liverpool

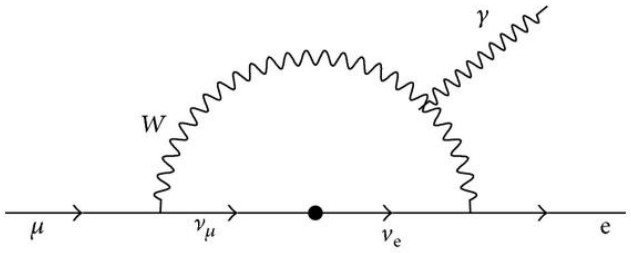
Mu3e Collaboration Overview



K. Arndt [a,1], H. Augustin [b], P. Baesso [c], N. Berger [d], F. Berg [e], C. Betancourt [f], D. Bortoletto [a], A. Bravar [g], K. Briggl [g,2], D. vom Bruch [d,3], A. Buonaura [e], F. Cadoux [g], C. Chavez Barajas [h], H. Chen [i], K. Clark [c], P. Cooke [h], S. Corrodi [e,4], A. Damyanova [g], Y. Demets [g], S. Dittmeier [b], P. Eckert [i], F. Ehrler [j], D. Fahrni [k], S. Gagneur [d], L. Gerritzen [e], J. Goldstein [c], D. Gottschalk [b], C. Grab [e], R. Gredig [f], A. Groves [h], J. Hammerich [b,5], U. Hartenstein [d], U. Hartmann [k], H. Hayward [h], A. Herkert [b,6], G. Hesketh [l], S. Hetzel [b], M. Hildebrandt [k], Z. Hodge [k,7], A. Hofer [k], Q.H. Huang [d,8], S. Hughes [h], L. Huth [b,6], D.M. Immig [b], T. Jones [h], M. Jones [a], H.-C. Kästli [k], M. Köppel [d], P.-R. Kettle [k], M. Kiehn [b,9], S. Kilani [l], H. Klingenmeyer [i], A. Knecht [k], A. Knight [a], B. Kotlinski [k], A. Kozlinskiy [d], R. Leys [j], G. Lockwood [a], A. Loreti [a,10], D. La Marra [g], M. Müller [d], B. Meier [k], F. Meier Aeschbacher [k,*,11], A. Meneses [b], K. Metodiev [a], A. Mtchedlishvili [k], S. Muley [b], Y. Munwes [i], L.O.S. Noehte [b,12], P. Owen [f], A. Papa [k,13], I. Paraskevas [l], I. Perić [j], A.-K. Perrevoort [b,14], R. Plackett [a], M. Pohl [g], S. Ritt [k,*], P. Robmann [f], N. Rompotis [h], T. Rudzki [b], G. Rutar [k], A. Schöning [b,*], R. Schimassek [j], H.-C. Schultz-Coulon [i], N. Serra [f], W. Shen [i], I. Shipsey [a], S. Shrestha [b,15], O. Steinkamp [f], A. Stoykov [k], U. Straumann [f], S. Streuli [k], K. Stumpf [b], N. Tata [a,16], J. Velthuis [c], L. Vigani [b], E. Vilella-Figueras [h], J. Vossebeld [h], R. Wallny [e], A. Wasili [h], F. Wauters [d], A. Weber [b,j], D. Wiedner [b,17], B. Windelband [b], T. Zhong [i]

- The most intense continuous muon beam in the word 10E8 muon/sec.
- Upgrade of the beamline will increase beam to 10E10 (2028).
- Rich muon physics research program.

CHARGED LEPTON FLAVOUR VIOLATION



Example of CLFV process involving muons and neutrino oscillations.

BR$(\mu^+ \to e^+ + \gamma) \sim O(m_\nu/m_W)^4 \sim 10^{-54}$

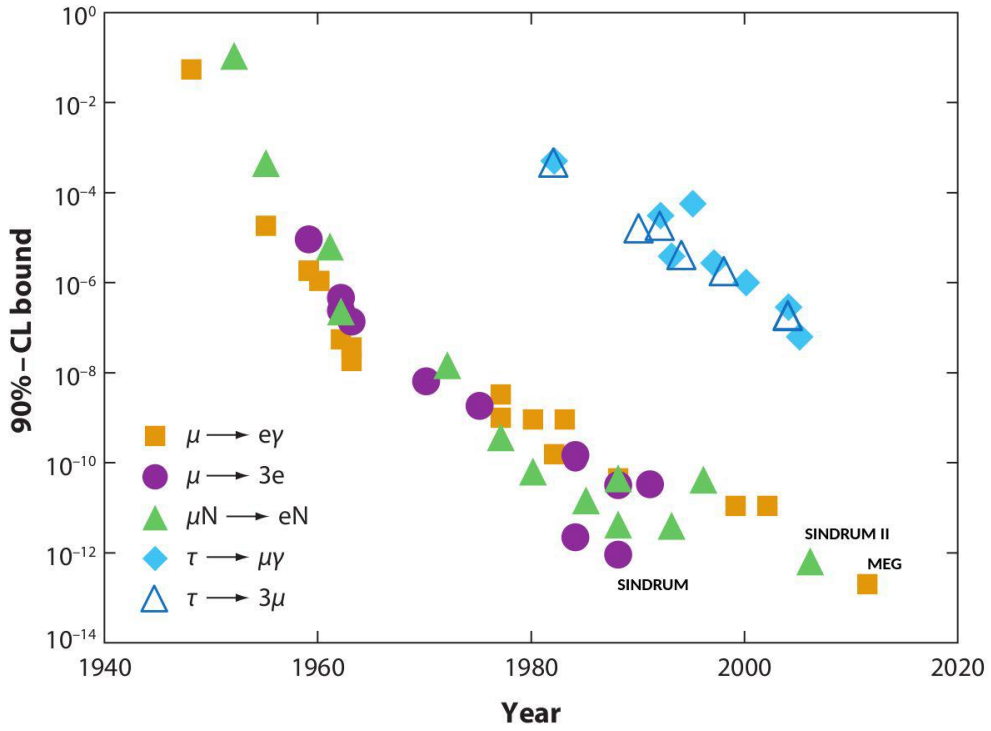
Neutrino oscillations have been measured by long-beam line experiments, e.g., solar neutrinos or KEK. However, oscillations at weak interaction scales (10^{-15}m) are practically zero.

BR$(\mu^+ \to e^+ + \gamma) \sim O(m_\nu/m_W)^4 \sim 10^{-54}$ **This is beyond the reach of current experiments!!**

There are theories Beyond the Standard Model (BSM) that predict lower values for CLFV processes like Mu3e. Any observation of CLFV would mean new physics BSM.

Mu3e EXPERIMENT

Muons** experiments have proved to be the **most sensitive** among all the experiments on CLFV conducted so far. Also, they have **long lifetime, few SM background decays, easily available.



Current limits set by muon experiments:

C.L. 90% - BR($\mu^+ \rightarrow e^+\gamma$) < 4.2x10^{-13} **MEG II**

C.L. 90% - BR($\mu^+ \rightarrow e^+e^+e^-$) < 1X10^{-12} **SINDRUM**

C.L. 90% - BR($\mu^- Au \rightarrow e^- Au$) < 7X10^{-13} **SINDRUM**

Mu3e goals:

BR($\mu^+ \rightarrow e^+e^+e^-$)<**2x10^{-15}** ($10^8 \mu/s$ phase I)

BR($\mu^+ \rightarrow e^+e^+e^-$)<**x10^{-16}** ($10^9 \mu/s$ phase II)

Mu3e design

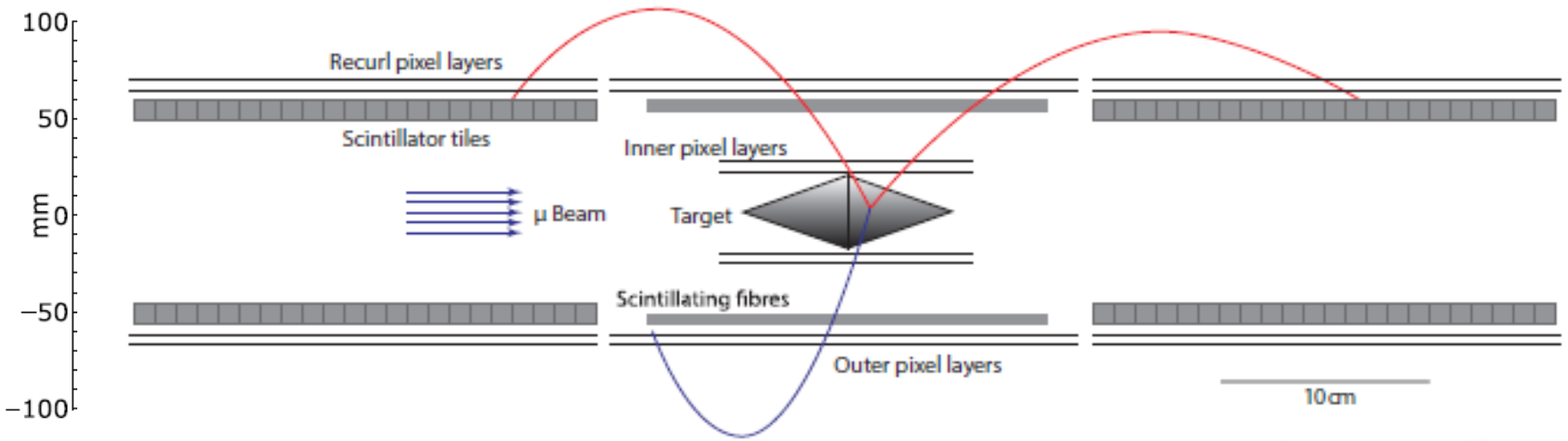
Mu3e signal is tiny and the SM background huge. In its quest Mu3e needs:

- High muon rate provided by the continuous muon source at PSI 10^8 muon /sec.
- Excellent momentum resolution, 1MeV.
- Excellent vertex and timing resolution to suppress combinatorial background.

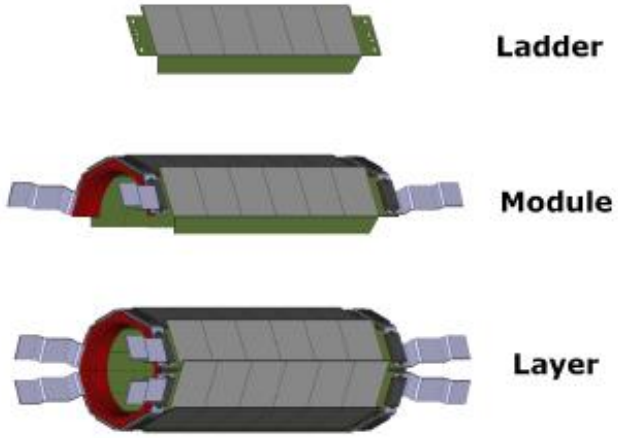
Mu3e detection system:

- **Ultra-light silicon pixel tracker** for vertexing.
- **Two timing detectors**: scintillating fibres (250ps) and scintillating tiles (100ps) for charge reconstruction and background discrimination for asynchronous decays.

Mu3e detector design

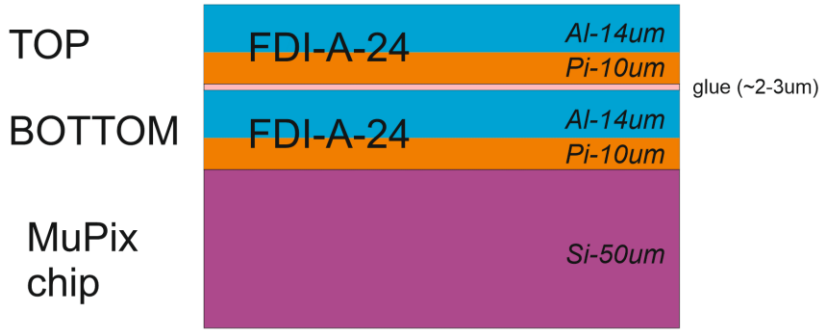


Layer	1	2	3	4
number of modules	2	2	6	7
number of ladders	8	10	24	28
number of MuPix sensors per ladder	6	6	17	18
instrumented length [mm]	124.7	124.7	351.9	372.6
minimum radius [mm]	23.3	29.8	73.9	86.3



Mu3e pixel detector design

Mu3e low-material budget detector i.e., thickness X/Xo $\sim 0.115\%$per layer.

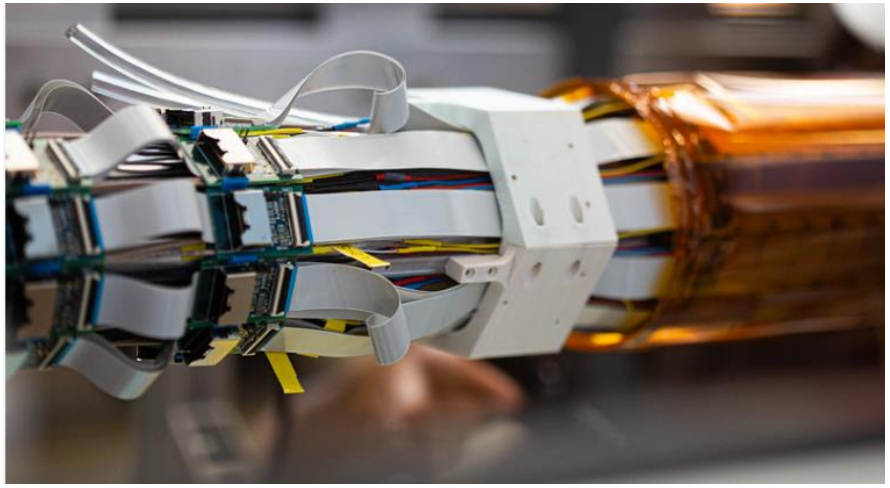


High-Voltage Monolithic Active Pixel Sensors MuPix
$50\mu m$ thickness (or $0.054\% X_o$).

The High-Density Interconnect
Flex tape made of 2X14 μm Al layers.

- **Mechanics**: the support of our detector ladder is a HDI flex thinner than a human hair.
- **Electronics**: high-density of traces in the HDI flex circuit (data lines, power, bias, for 18 chips).
- **HDI-production**: long fragile HDI flex, shrinking of the material, layers misalignment.
- **Tooling**: proper tooling for handling flex tapes and chips.

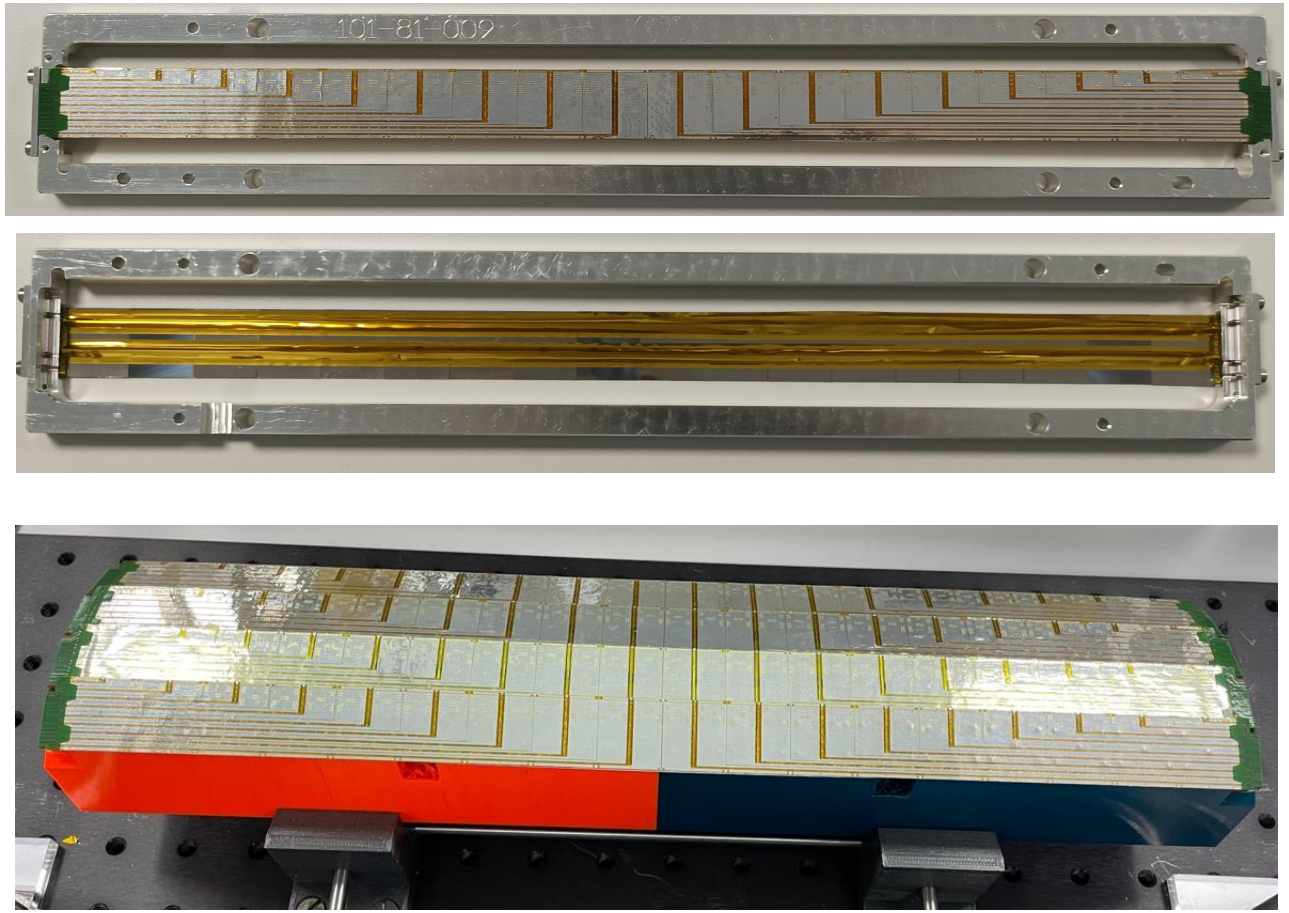
Mu3e pixel detector inner layers

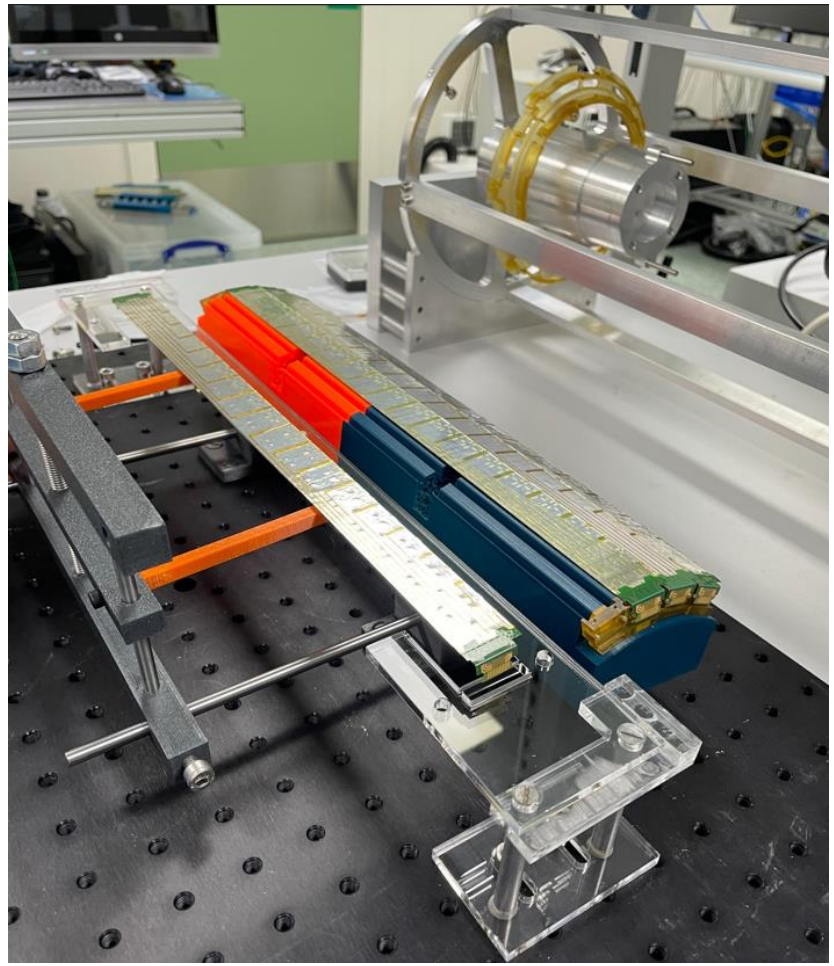


This is the **inner tracker** detector in Mu3e. There are two layers made of 18 (8+10) ladders containing 6 chips each.

In this early prototype, the layers were not built on HDI flexes. Instead, PCBs were designed together with bus lines (white cables) and connectors.

Mu3e pixel detector outer layers





Mu3e at Liverpool

- We are responsible for the construction of the outer layers of the pixel detector, together with Oxford
  - We are going to assemble the outer modules of the pixel detector.
  - We are going to perform the quality control tests of the detector modules

- We are also working on software and analysis studies to characterise the track and vertex reconstruction efficiency.

People in Liverpool: Prof. Vossebeld Joost, Dr Hayward Helen, Dr Rompotis, Nikolaos, Dr Chavez Barajas Carlos, Dr Loreti Andrea, Dr Beltrame Paolo, PhD students Hughes Sean and Kinsman, Charles, engineer Brown Matthew.

FOR MORE INFO:
https://www.physi.uni-heidelberg.de/Forschung/he/mu3e/
https://www.psi.ch/en/mu3e/

THANK YOU

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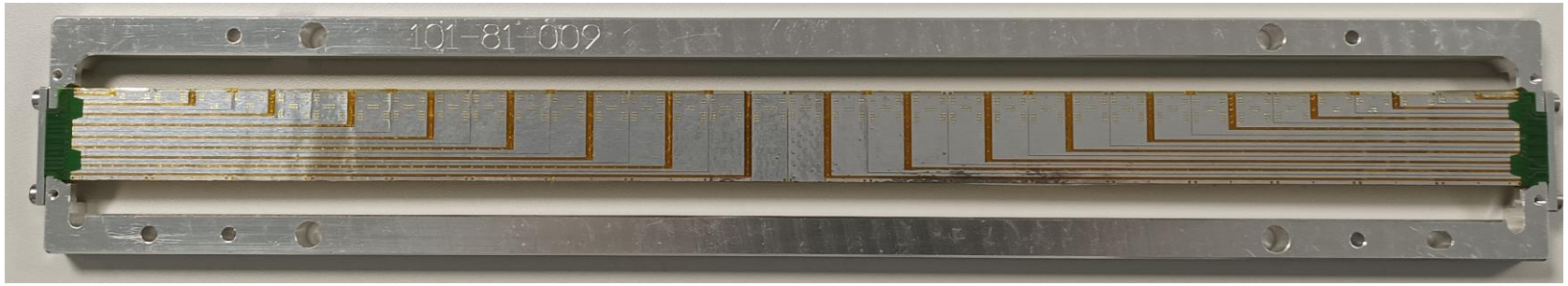
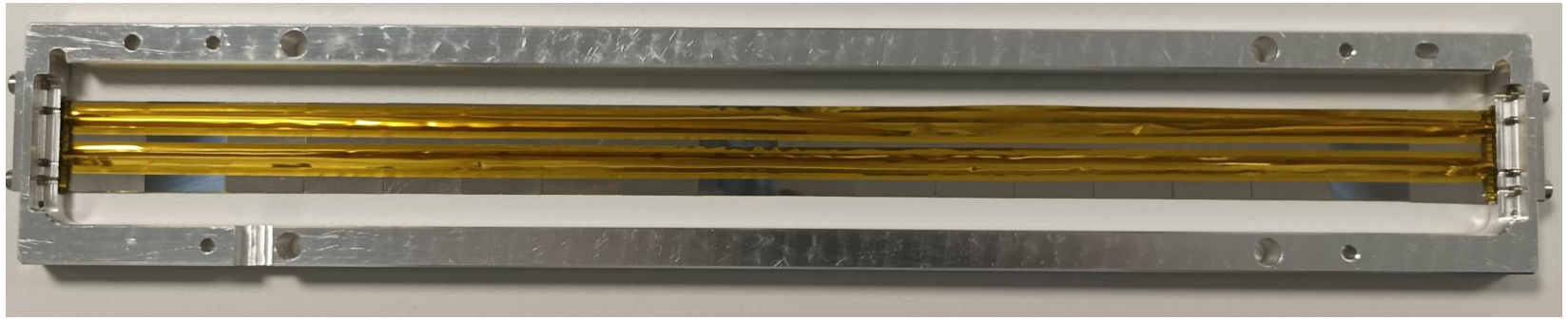
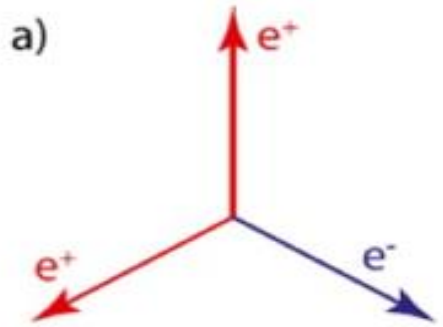
Спасибо

Mu3e pixel detector construction L3,4

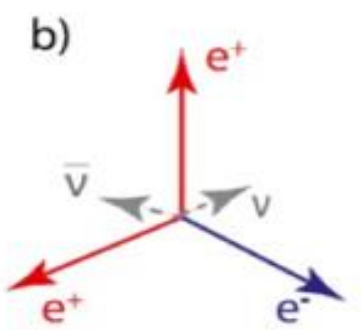




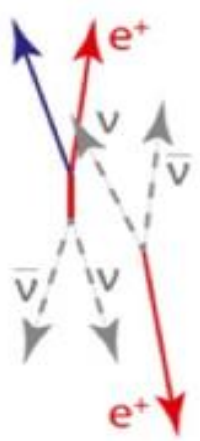
Mu3e Background



BR ~ $<10^{-13}$ (10^{-55})



BR ~ 10^{-5}



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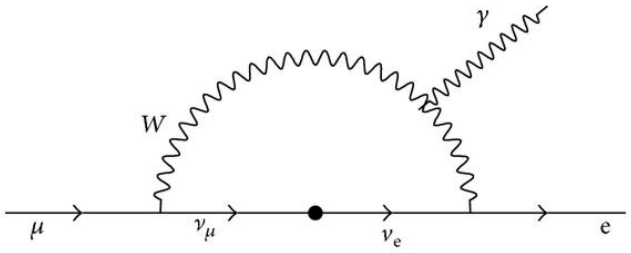

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