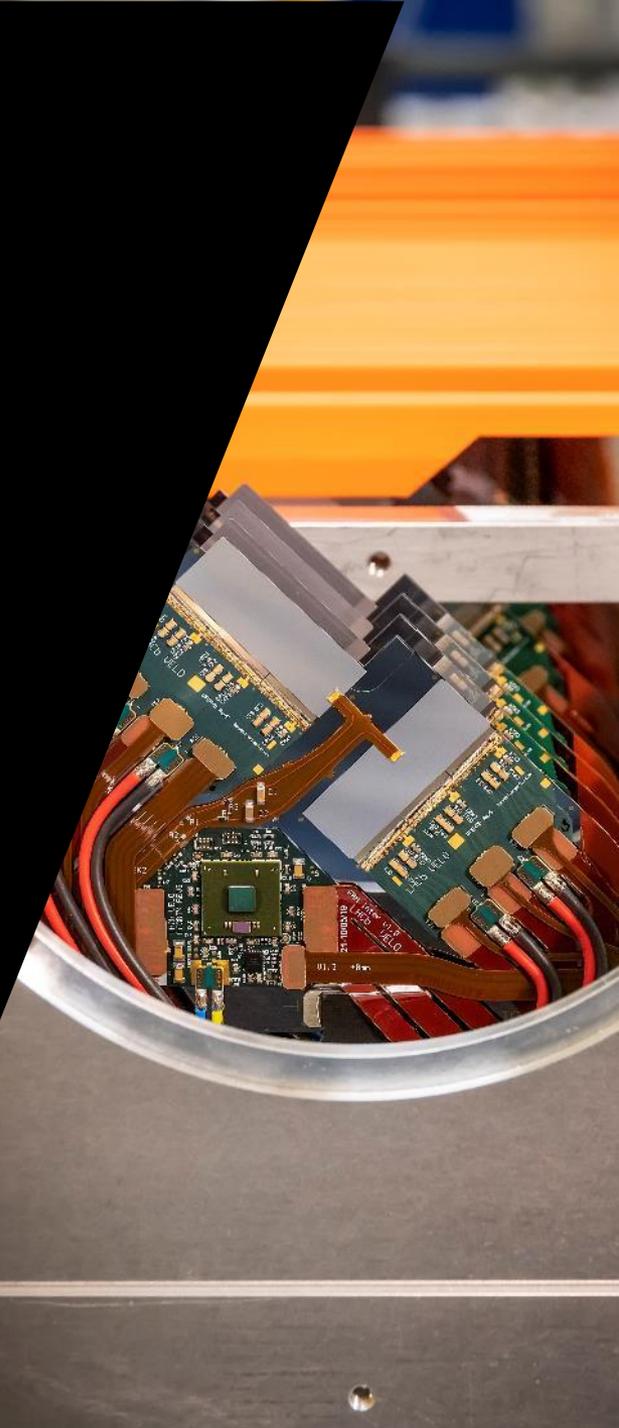


**Liverpool Particle Physics**  
*Short intro to the research cluster:  
overview, strategy, programme,  
facilities*

**Joost Vossebeld**





UNIVERSITY OF  
LIVERPOOL



## 2 Particle Physics Liverpool

### *Composition of the research cluster*

- 26 academics / fellows
- 27 staff physicists / postdocs
- 22 Engineers, cleanroom technicians, workshop machinists
- 2 computing staff
- 1 admin support staff;
- ~50 PGR students

*Size of the group and research income has grown substantially thanks to strong focus on creating a broader programme.*

*Research income across the entire PP cluster currently stands at ~£8.5M p.a.*

PARTICLE  
PHYSICS  
FUNDAMENTAL  
SCIENCE



<https://www.youtube.com/watch?v=rAWbi5YU9rl>

## 3 **Research Programme**

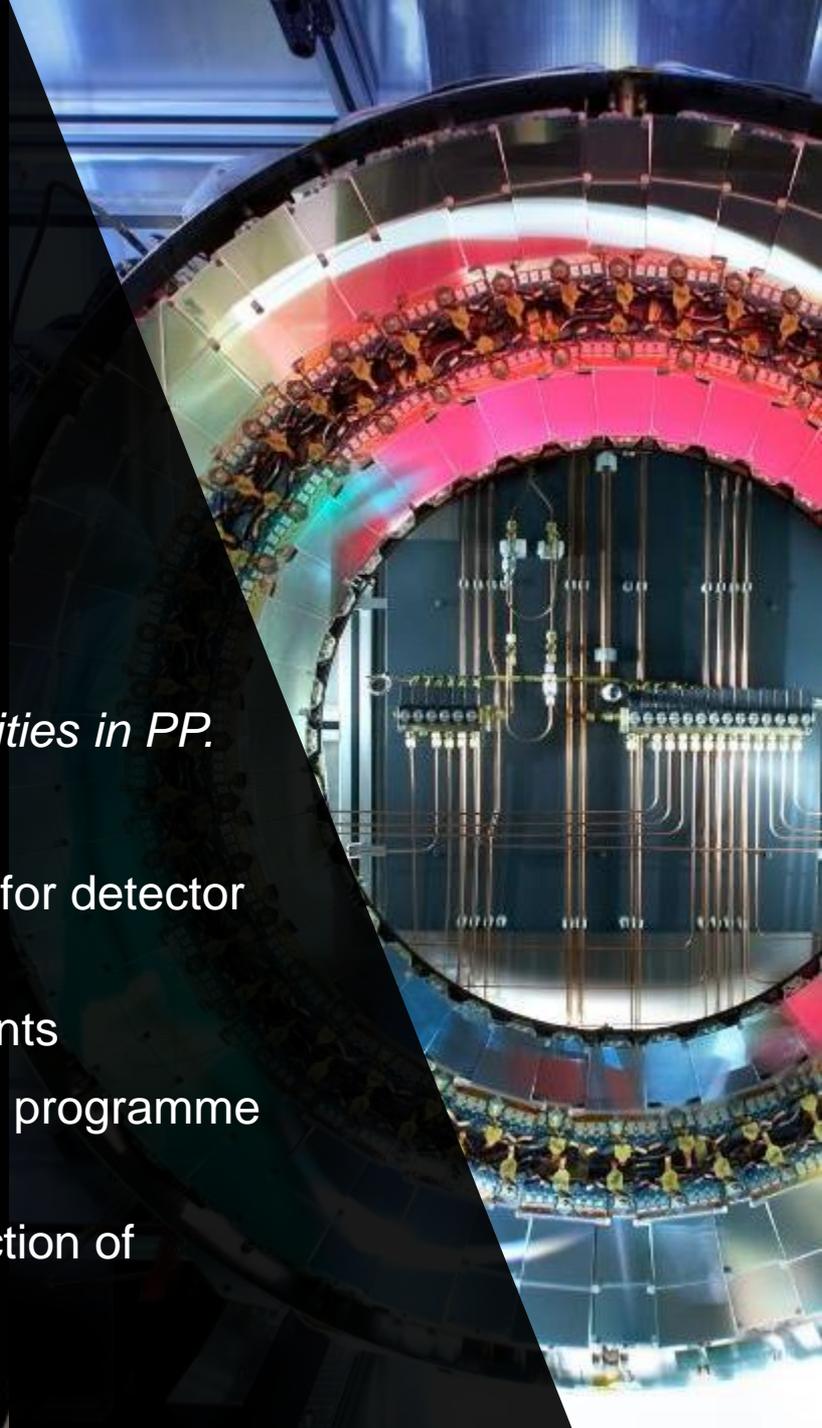
### **Four pillars (of similar size)**

- High energy collisions (LHC)
- Neutrino properties
- Precision experiments (muons, protons)
- Dark Matter searches

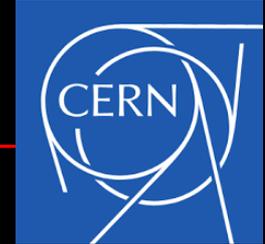
*These are closely aligned with international priorities in PP.*

### **What sets Liverpool PP apart?**

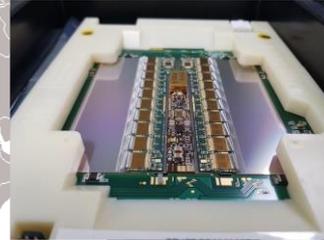
- Strong leadership in and superb infrastructure for detector development and construction.
- Technology R&D for next-generation experiments
- Particularly broad, diverse and forward looking programme with strong focus on discovery physics.
- Early involvement in the planning and construction of next-generation experiments.



**Higgs, Standard Model and Beyond, Quark Flavour, CP Violation, Dark Matter, Primordial Matter**



**ATLAS** - general purpose experiment  
**LHCb** - Heavy Flavour experiment  
**ALICE** - Heavy Ion experiment  
**FASER** - Dark Sector experiment

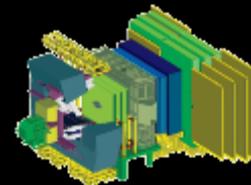
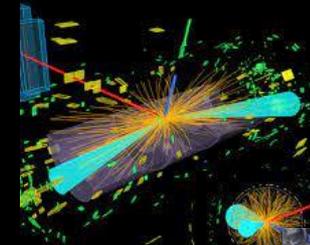


### LSDC (Semiconductor Centre)

- Silicon sensor technology R&D
- Silicon Detector design and construction

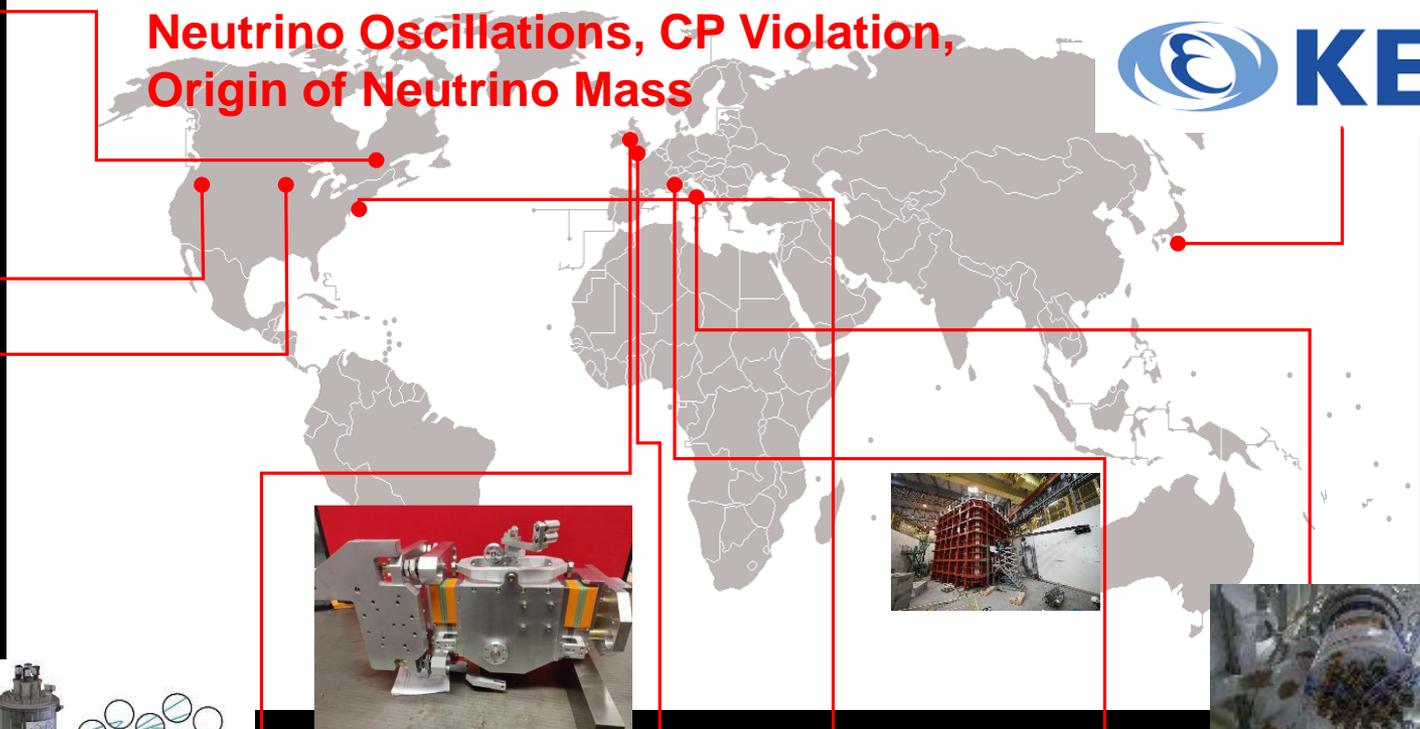
### Liverpool DFF (workshop) & AML (carbon-fibre lab)

- Assembly tooling
- Detector support structures





**Neutrino Oscillations, CP Violation,  
Origin of Neutrino Mass**



SNO+ neutrinoless  
double beta decay



US long baseline  
neutrino programme

- SBND at FNAL
- DUNE far-detector at Sanford Underground Research facility (SURF)



**LSDC**

- T2K ECAL assembly

**Liquid Argon Lab**

- Liquid Argon Readout technology (ARIADNE)

**Optics Lab in Robertson building**

- Optical lab for Hyper-K calibration development

**STFC Daresbury**  
DUNE anode plane array

**STFC Boulby Underground Facility**  
BUTTON water based anti-neutrino detection



**ProtoDUNE**  
test facility  
ARIADNE+  
technology demonstrator



**LEGEND200**  
neutrinoless  
double beta  
decays

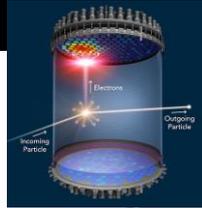
# Worldwide frontier research

## The Search for Dark Matter

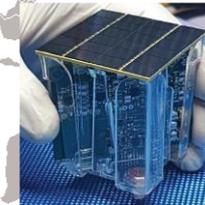
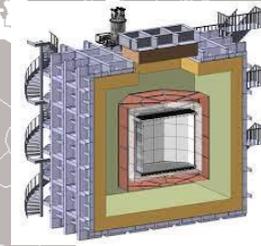
**Direct Search for WIMP dark matter, Search for low Mass DM, Gravitational Waves**



**Lux-Zeplin:**  
Liquid Xenon dark matter search experiment



**MAGIS:** 100m Atom-interferometer dark matter and gravitational waves experiment



### LSDC (Semiconductor Centre)

- SiPM detector assembly DarkSide-20k

### Liquid Argon Lab

- SiPM cryo test facility DarkSide20k

### New lab in Robertson building

- Optical lab for Hyper-k calibration development

### DFF (workshop)

- Camera Optics MAGIS experiment
- LZ optical calibration supports



**CTA Cherenkov Telescope Array**  
Paranal Chile



**BOULBY**  
UNDERGROUND LABORATORY

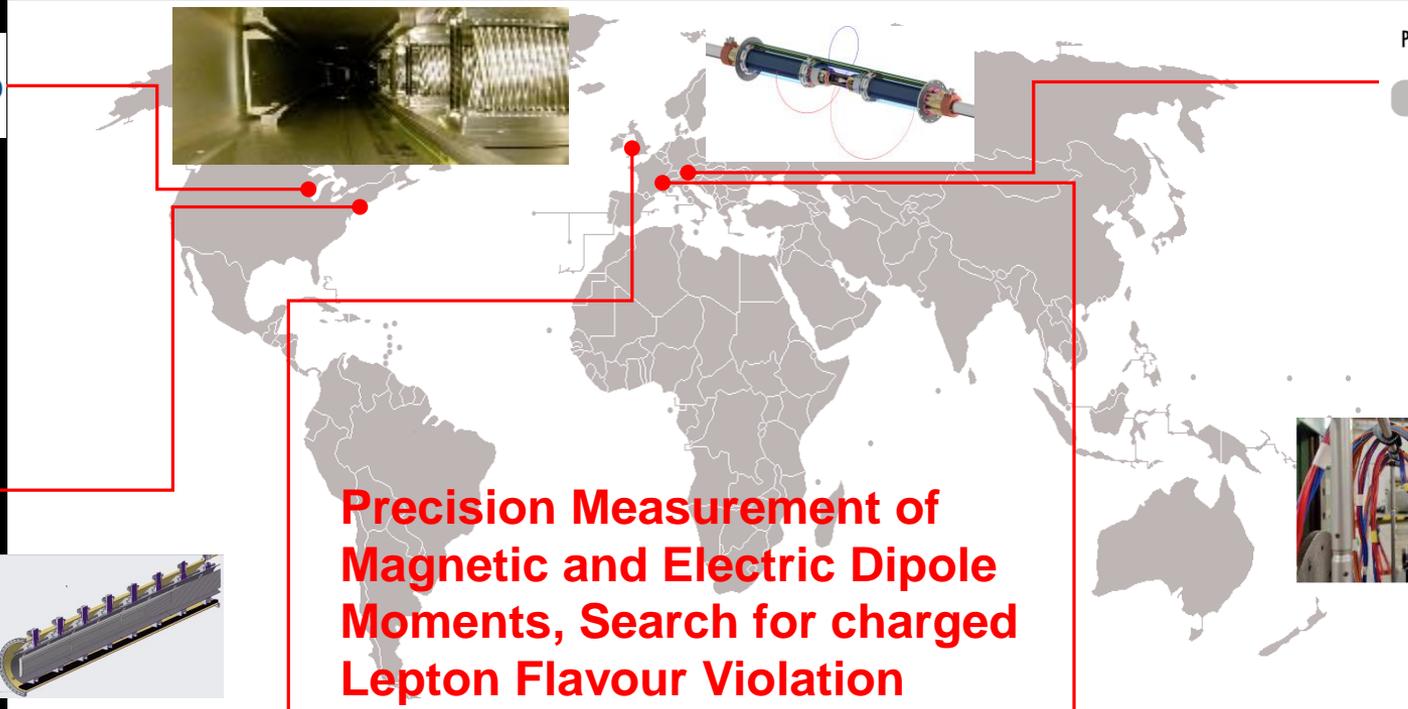
**STFC Boulby Underground Facility**  
XLZD: Proposed next-generation Xenon dark matter experiment



**INFN Gran Sasso DarkSide-20k:**  
Liquid Argon dark matter search

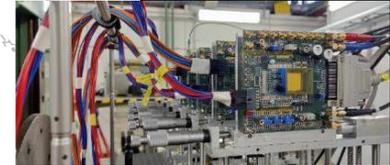


# Worldwide frontier research Muon and Precision Physics



**Mu3e  
experiment**

**Muon EDM  
proposed  
experiment**



**MUonE  
proposed  
experiment**

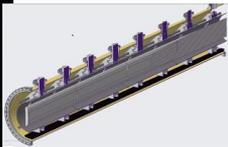
**Fermilab**

**g-2  
experiment**

**Mu2e  
experiment**

**Brookhaven  
National Laboratory**

**Proton EDM  
proposed  
experiment**



**LSDC (Semiconductor Centre)**

- Pixel detector construction Mu3e
- Straw tracker assembly g-2

**PP/NS collaboration on**

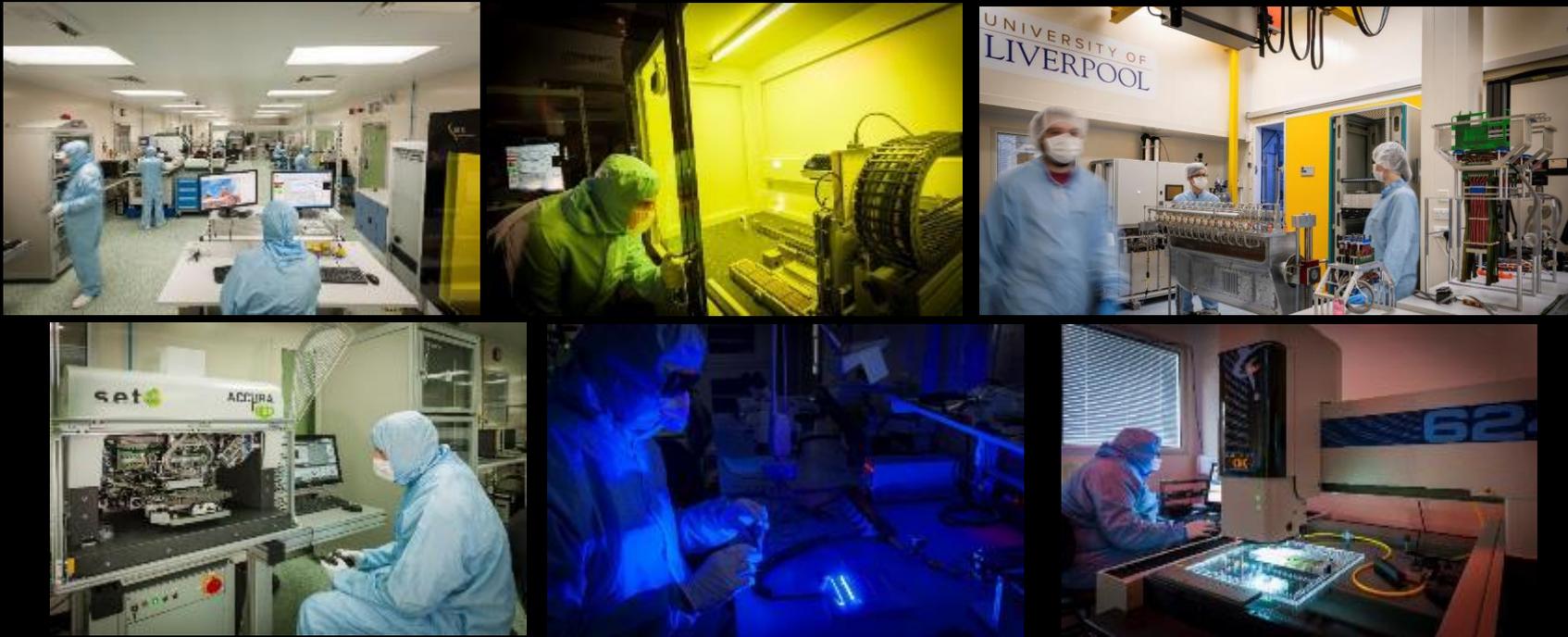
- High Purity Germanium for Mu2e

**DFF (workshop)**

- g-2 tracking stations
- Mu3e tracker mechanics and tooling
- MUonE tracking supports
- Proton EDM electro-static deflectors

## 8 **LSDC (Liverpool Semiconductor Detector Centre)**

450 m<sup>2</sup> ISO certified cleanroom facility, initially built for the assembly of the large silicon detectors for the LHC. In operation since 2002. Unique and state-of-the-art equipment, infrastructure and expertise on Silicon detector development and construction.



Several major construction project were (are) hosted in the LSDC:  
*Silicon tracking detectors and upgrades for three LHC experiments, T2K ECAL assembly, g-2 tracker, SBND cathode planes, Mu3e pixel tracker, Darkside-20k SiPM arrays, g-2 trackers, Also several Nuclear Physics projects: Alpha, R3B, ISOL, ALICE, ..*

## 9 **Detector Fabrication Facility (Workshop)**

Equipment and skills build through a long stream of projects and sustained investment by STFC. Advanced equipment and high level of expertise provide a facility for precision manufacture that is unique in the field.

Major recent investment by STFC and University (new equipment and facility refurb)



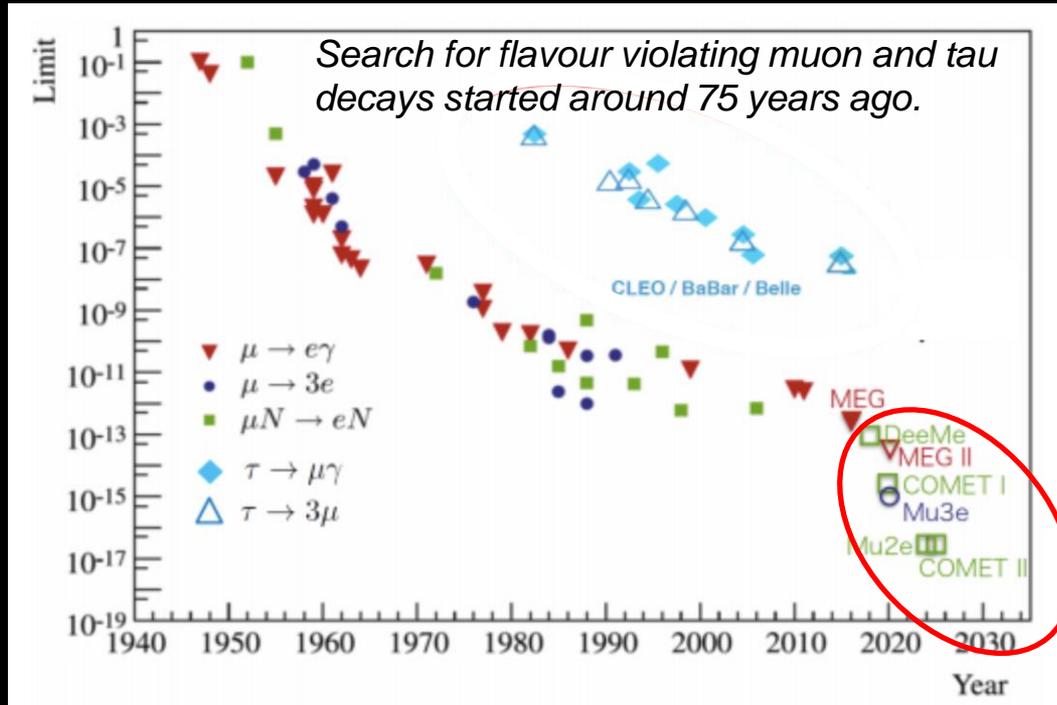
Manufacture of components for many experiments: *LHC experiments, ARIADNE, DEAI, T2K ECAL, LZ, g-2, Mu3e, NA62, MAGIS, DUNE, ...*  
Also several NP projects: *R3B, Alpha, Agata, Isol, ...*

# 10 Precision Muon Physics

*Some of the most precise measurements in physics can be made with leptons. In particular muons allow us to test for extremely small effects caused by new physics that is out of reach at the largest colliders.*

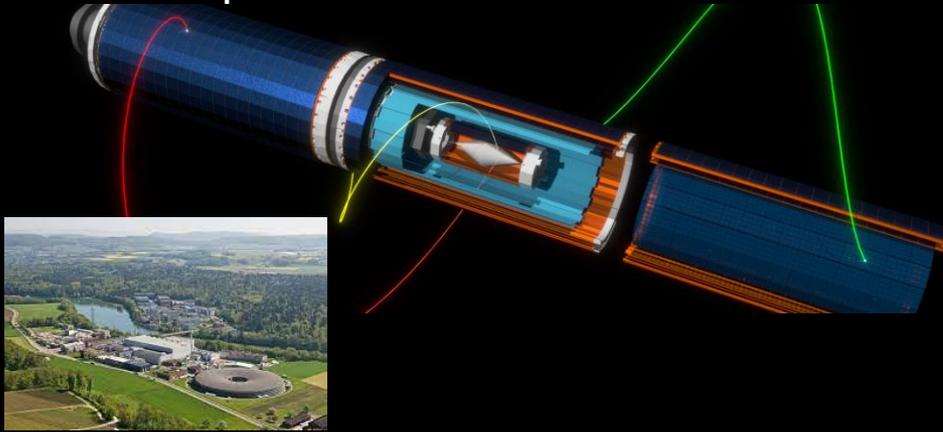
## Charged Lepton Flavour Violation

We see flavour violations for quarks and neutral leptons, but not for electrons, muons or tau leptons. The latter are not part of the Standard Model, however any new physics, would quite naturally introduce CLFV.



# 11 Charged Lepton Flavour Violation

## Mu3e experiment at PSI



Mu3e aim for a factor 10,000 improvement on the search for the CLFV  $\mu \rightarrow 3e$  decay

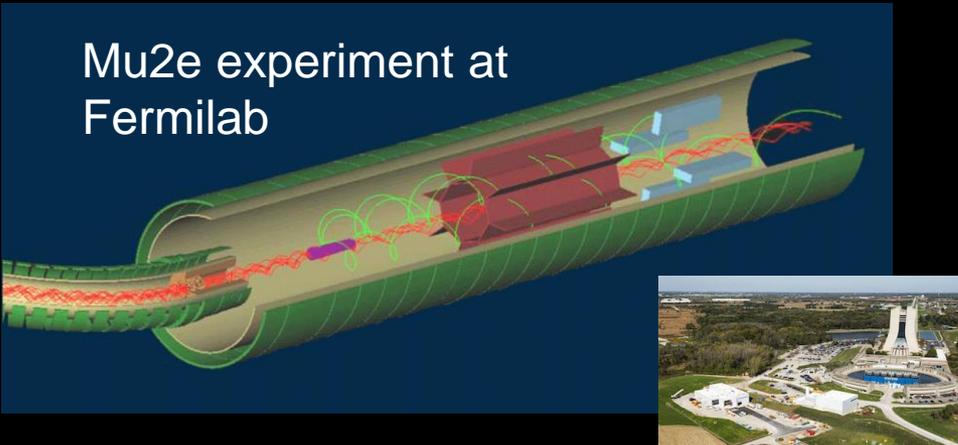
We were invited to join Mu3e because of our:

- track record and infrastructure for building complex silicon detectors
- R&D on high-voltage CMOS pixel sensors.

Led UK bid to join (UoL, Oxford, Bristol, UCL)

Today Liverpool lead the construction of the first ultra-low mass HVCMOS tracker.

## Mu2e experiment at Fermilab



Mu2e aim for a factor 10,000 improvement on the search for the CLFV  $N\mu \rightarrow Ne$  transition

UK participation initially Liverpool and UCL, Manchester.

Important aspect of UK bid to join, was Liverpool expertise (NS cluster) on High Purity Germanium detectors.

Liverpool responsible for measuring total muon decay rate, using downstream Germanium detector.

*Both scheduled to start physics operation in 2026.*

*After start expect a ~ 10 year programme off initial experiment and upgrades*