

Liverpool Particle Physics

*Research programme and
technology work*

Joost Vossebeld





- ~90 staff: academics, fellows, staff physicists, postdocs, engineers, cleanroom technicians, workshop machinists, computing staff, finance support staff
- ~45 PhD students

One of five University Research Frontiers

".. globally-significant and innovative research fields that take a holistic approach to modern day challenges, in order to help us understand the world we live in, and enhance it for the benefit of future generations."

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



Particle physics

Leading scientific breakthroughs to uncover the deepest secrets of the universe.



Therapeutics innovation

Combining world-class expertise to transform global health and medicine.



AI for life

Bringing different fields together to advance AI technologies and their applications.



Infection resilience

Breaking down barriers between fundamental science and frontline medicine.



Materials discovery

Redefining the future of materials through cutting-edge AI and digital innovation.

Research Areas

Understanding the smallest particles and their interactions.

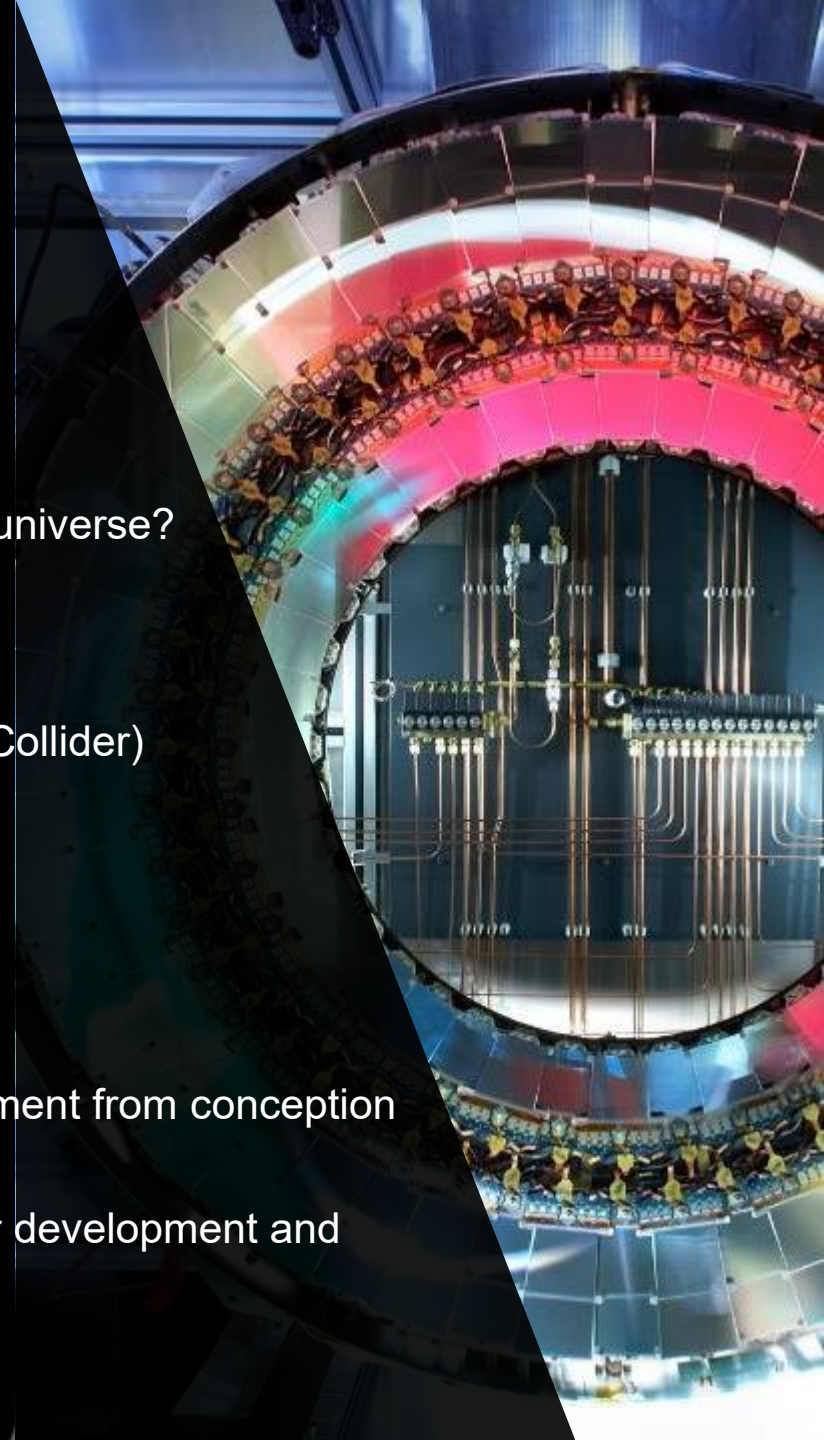
- What is the nature of dark matter?
- What cause matter anti-matter asymmetry in the universe?
- What lies beyond the standard model?

Main research areas

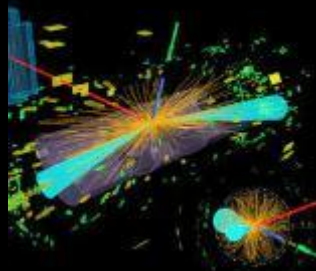
- High energy collider experiments (Large Hadron Collider)
- Extreme precision experiments (muons/protons)
- Neutrino experiments
- Dark Matter searches

What sets Liverpool apart?

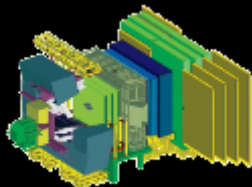
- Involvement in all aspects of experiment development from conception to exploitation
- Strong track record and infrastructure for detector development and extensive technology R&D.



The Large Hadron Collider at CERN



ATLAS



LHCb



FASER



ALICE

We study: Higgs Boson, Quarks and Leptons,
.. and look for evidence of CP Violation, Dark Matter or any other new physics

Liverpool-built silicon detector systems operate in ATLAS, LHCb and ALICE.

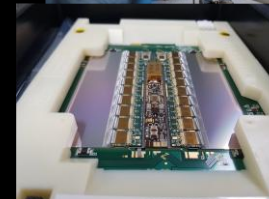
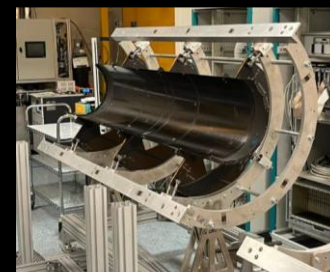
We are now building improved detectors for High Luminosity LHC Upgrade

LSDC (Semiconductor Centre)

- Silicon sensor technology R&D
- Silicon detector design, production and integration

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

- Precision detector components and assembly tooling
- Low-mass detector support structures



Extreme Precision Physics Muons and protons

Ultra precise measurements and searches for extremely rare processes to uncover evidence of new physics

The muon magnetic moment puzzle g-2 Puzzle:

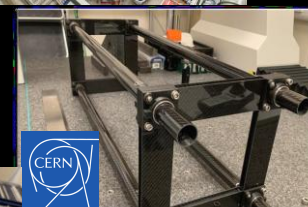
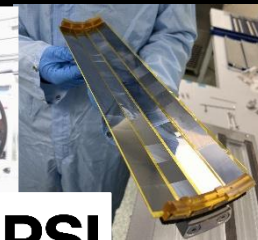
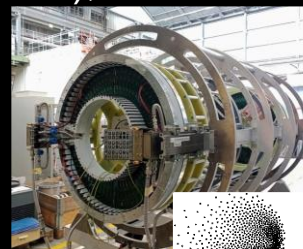
g-2 (US), KLOE (Italy), MUonE (CERN), future g-2 (Japan)



Electric Dipole Moments: Muon EDM (Switzerland), Proton EDM (US)

Charged Lepton Flavour Violation:

Mu2e (US), Mu3e & MEG-II (Switzerland)



LSDC (Semiconductor Centre):

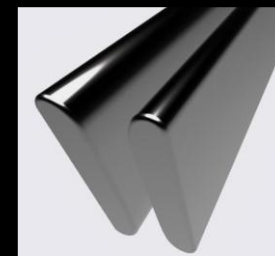
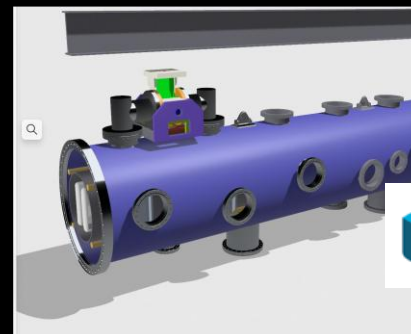
- Mu3ePixel detector
- g-2 straw tracker

Collab. with Nuclear Physics:

- HPGe detectors for Mu2e

DFE (workshop)

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



Studying neutrinos requires enormous Detector, mostly located deep underground

DUNE (US) and Super-K/Hyper-K (Japan):

- Neutrino Oscillations, CP Violation

SBN/SBND(US):

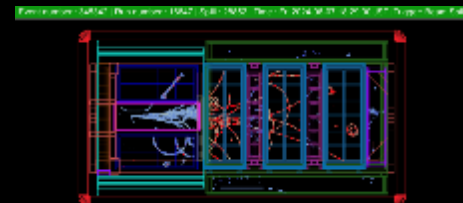
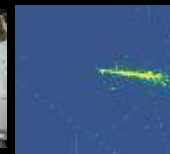
- TPC operation
- Sterile neutrinos

JUNO(CHINA):

- Neutrino Oscillations, Mass hierarchy

SNO+ (Canada) & LEGEND (Italy):

- Neutrinoless double beta decay



LSDC: T2K ECAL assembly & SBND CPAs

Workshop: DUNE APA wire-winding heads & BUTTON PMT frame

Liquid Argon Lab: ARIADNE Argon TPC Readout

Optics Lab: Hyper-K Optical Calibration System

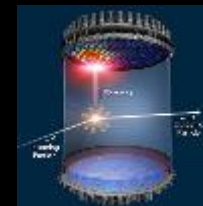
Collab. with Nuclear Physics: LEGEND HPGe detectors



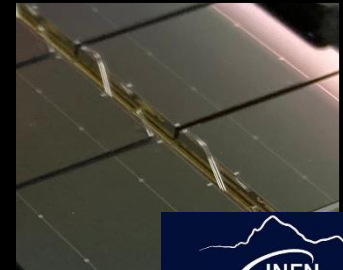
The Search for Dark Matter



SANFORD
UNDERGROUND
RESEARCH
FACILITY



BOULBY
UNDERGROUND LABORATORY



A wide range of experiments to try to establish the nature of Dark Matter

Large underground detectors:
LZ (US) XLZD(UK?..) & DarkSide20k (Italy)



Quantum Technologies: MAGIS100 (US), QuestDMC (UK)

Telescope experiments: CTA

Other Approaches: DarkSphere, future axion experiments, ..



Fermilab

LSDC

- DarkSide-20kSiPM VETO tile assembly

Liquid Argon Lab

- SiPM cryo test facility DarkSide20k

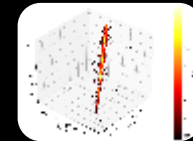
Optics lab: LZ OD Optical calibration

DFF (workshop)

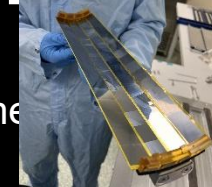
- MAGIS/AION: Camera Optics MAGIS experiment
- LZ low background PTFE mechanics
- CTA small camera protective doors



- **BUTTON-30:** 30-tonne WBLs detector
 - UK/US collaboration
 - Water shield for DARKSphere experiment if approved
 - development platform for kiloton WBLs detector
- **ARIADNE:** Optical readout Argon TPCs (ICFA EC instrumentation prize)
 - Liverpool developed low cost high performance TPC readout
 - Development/Manufacture of Thick Glass GEMs
 - Next deployment in ProtoDUNE III (technology qualification DUNE FD)



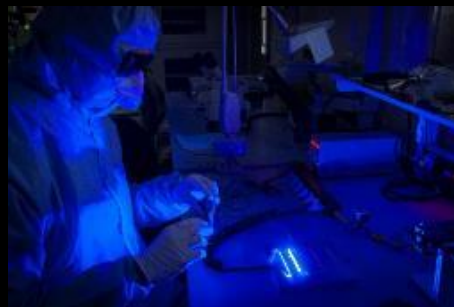
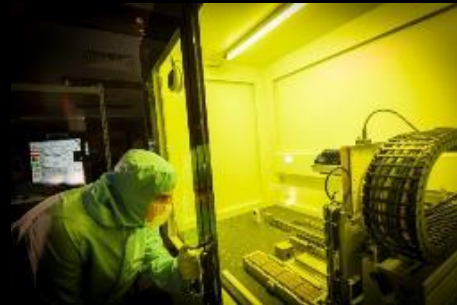
- **HV-MAPS:** fast and radiation hard monolithic pixel sensors
 - Integrated in CERN DRD 3 programme
 - RADPIX chip development LHCb Mighty Tracker
- **Particam:** sub-micron digital pixel sensors (with FBK, Trento)
 - develop sensor for surface neutron emission (with PSI)
- **Hadron therapy instrumentation:**
 - beam characterisation and dose delivery monitoring
- **Low mass detector integration: for precision experiments**
- **SiPM sensor integration:** for low background cryogenic experiments



- **Liverpool Atom Interferometer lab**
 - R&D platform for MAGIS / AION
- **R&D lab for SQUID and quantum amplifiers:** (in development)



450 m² 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, ..
Nuclear Physics projects: Alpha, R3B, ISOL, ALICE, ..

Silicon detector projects LSDC

ATLAS SCT Endcap



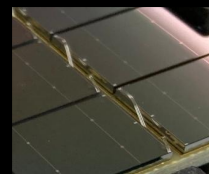
ATLAS Upgrade
Strip Barrel



ATLAS Upgrade
Pixel endcap



Darkside-20k
Veto Tiles



LHC / HL-LHC Plan



Future
Circular
Collider



LHC-b Vertex
Locator (+ spare)



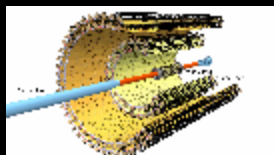
LHC-b Pixel VeLo



LHC-b Mighty
Tracker Upgrade



LHC-b VeLo4



ALICE ITS upgrade



Mu3e@PSI:
MuPix tracker

EIC CMOS
tracker

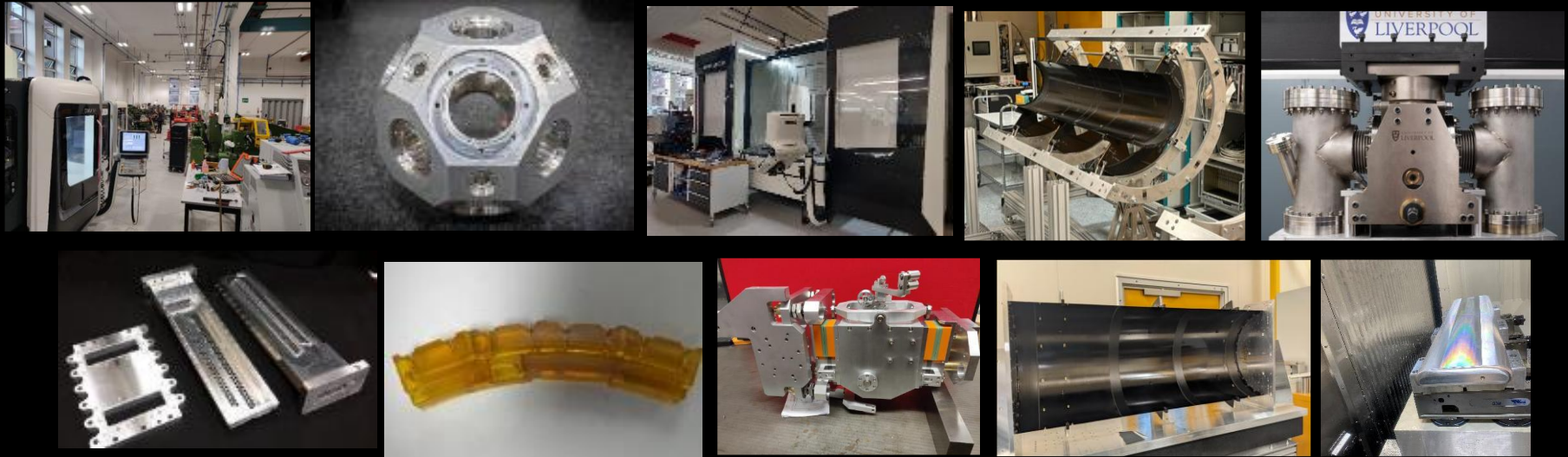
Mu3e-II
upgrade

MuEDM-II
positron
tracker

Detector Fabrication Facility (Workshop) and Advanced Materials Lab

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 in refurbishment and upgrade investment by University and research funding



Manufacture of components for many experiments: *ATLAS, LHCb, ARIADNE, DEAI, T2K ECAL, LZ, g-2, Mu3e, NA62, MAGIS100, DUNE, pEDM,...*

Also several Nuclear Physics projects: ALICE, R3B, ALPHA, AGATA, ISOL, ...