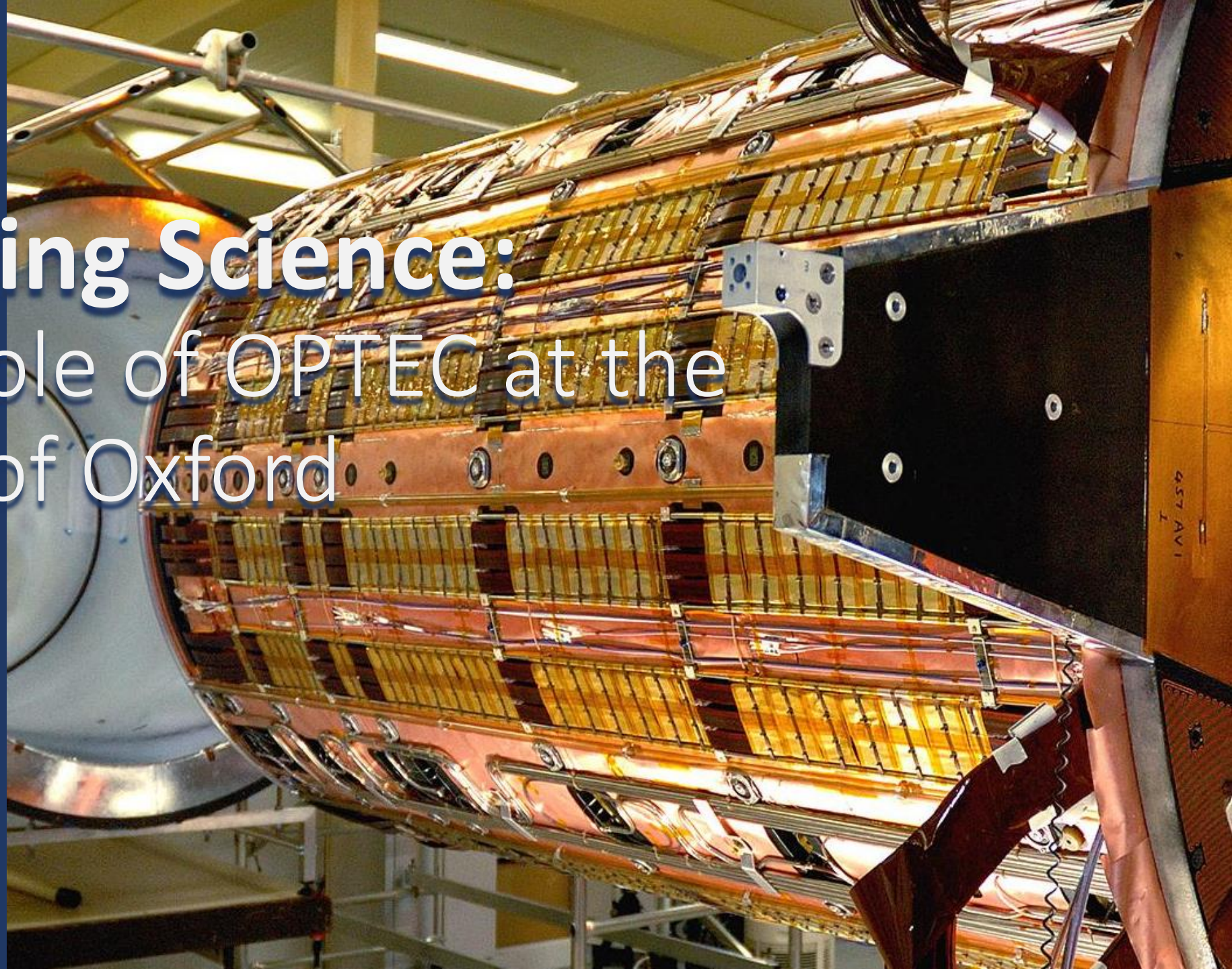
Empowering Science:
The Vital Role of OPTEC at the University of Oxford



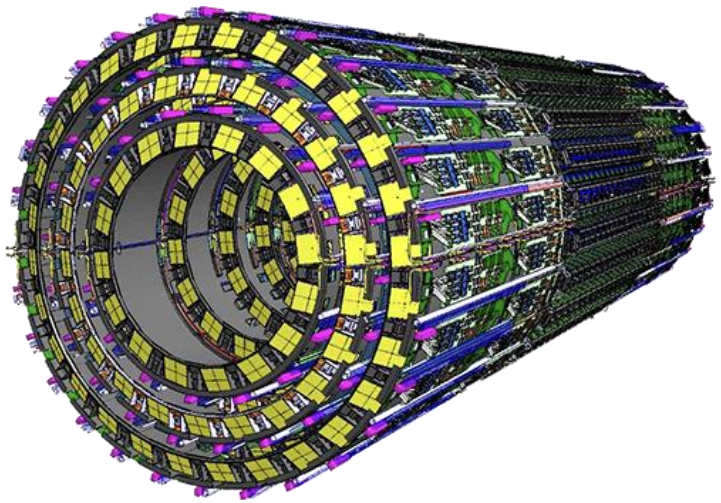
Rui Gao on behalf of OPTEC

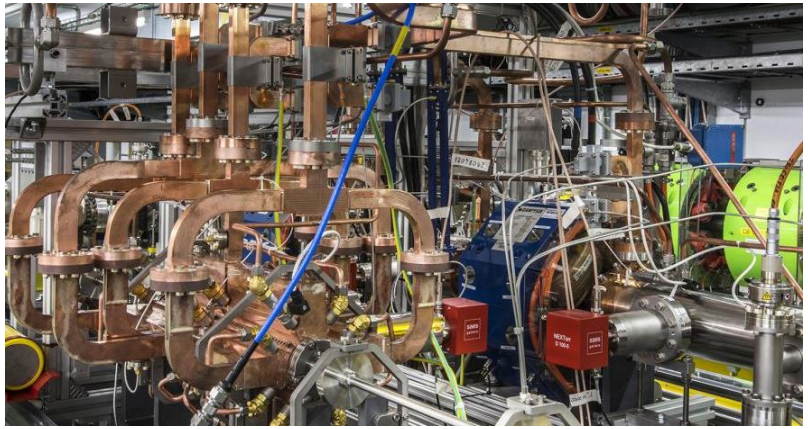
Department of Physics

University of Oxford

DEPARTMENT OF PHYSICS

Our mission:
Empowering big science





Our mission:
Enhancing campus activities

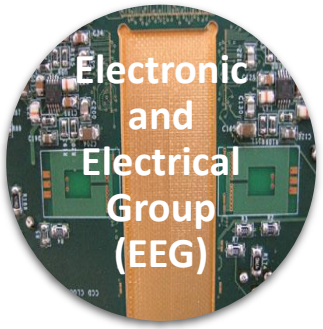
Outline of the talk

- Introduction of OPTEC
- Expertise repository
- Introduction of the groups
- Showcase of project involvement
- Funding and operation model
- Summary

What makes OPTEC

- OPTEC consists of 8 Groups
- 61 Highly skilled team members
  - Senior leaders
    - Strategic aspects and planning
  - Administrator
    - Paper works
    - Running of the group
  - Engineers
    - Design, testing and commissioning
    - Project management
  - Technicians
    - Build, testing installations
  - Apprentices/ Trainees
    - Learning and supporting

Expertise Repository



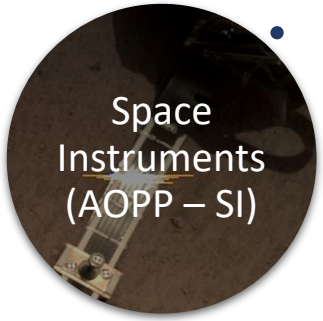
- Electronics & Electrical Group – 17 staff
  - Electronics system design and manufacturing
  - RF design, IC and FPGAs
  - Electrical safety testing and advice
  - Mange electronics components store
  - Licensing support
  - Manage loan equipment
  - Manage and support self-service workshop

- Mechanical Design and Manufacturing Group – 19 staff
  - Mechanical design and manufacturing
  - FEA analysis
  - System installation and commissioning
  - Mange mechanical components store
  - Manage and support self-service workshop
  - Training

- Thin Film Facility - 1.5 Staff
  - Thin metal coating 3nm – 500nm
  - Dielectric coating

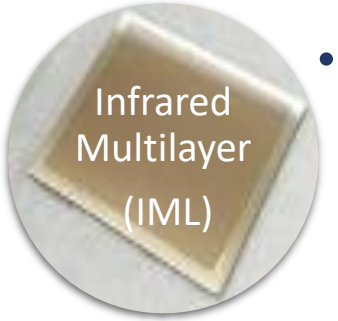
- Photo Fabrication - 1.5 Staff
  - Flexible Printed Circuit Board manufacturing
  - Chemical etching
  - Wire-bonding

Expertise Repository



- Space Instrumentation- 8 Staff
  - Specialised in space instrumentation design
  - Mechanical, electronics, thermal
  - Vibration testing
  - Product assurance and qualification

- Nano Fabrication
  - Clean room operations
  - Scanning electron microscopy expertise

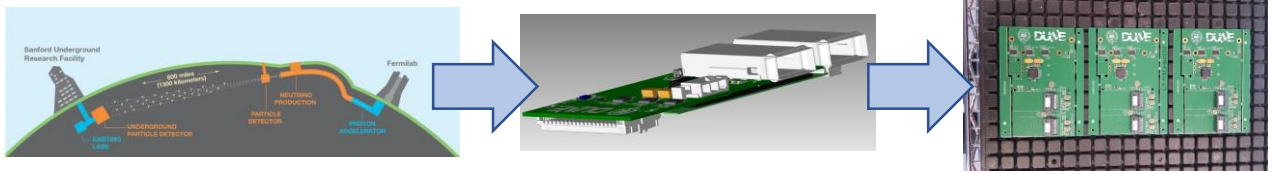


- Infrared Multilayer Lab - 5 Staff
  - Experts in thin-film optical filter design and manufacturing

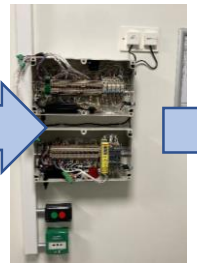
- CryoMagnetics
  - Low temperature experts
  - Coil winding Vacuums impregnation

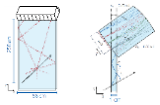
Electronics and Electrical Group

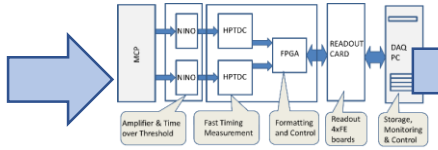
Concept *Design* *Manufacture*



Department of Physics developed Laser room access systems







Left: TORCH Module
Right: Focusing Block

Design

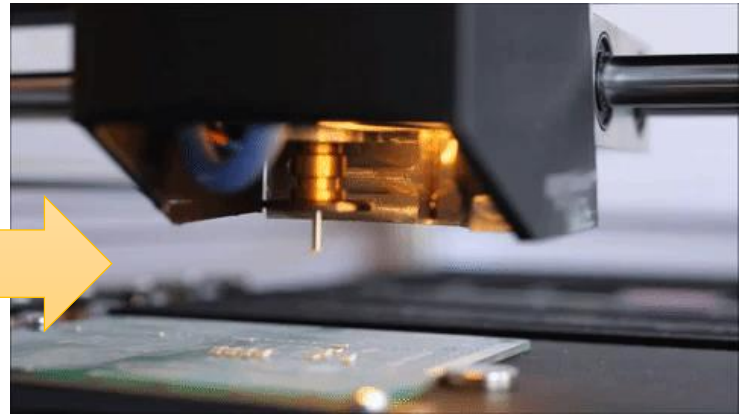
- Electronics design engineers are available to help with experiment and project components
- Design software suite support
- Centralised design / documentation server

Testing

- A major activity before system commissioning
- Automated of manual

Advising academics and researchers

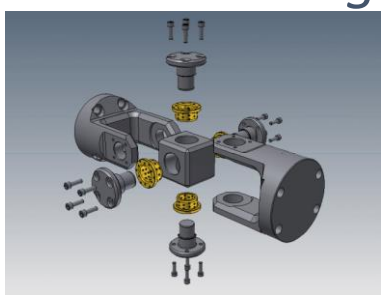
Electronics Workshop

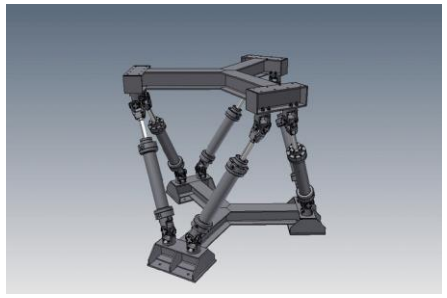


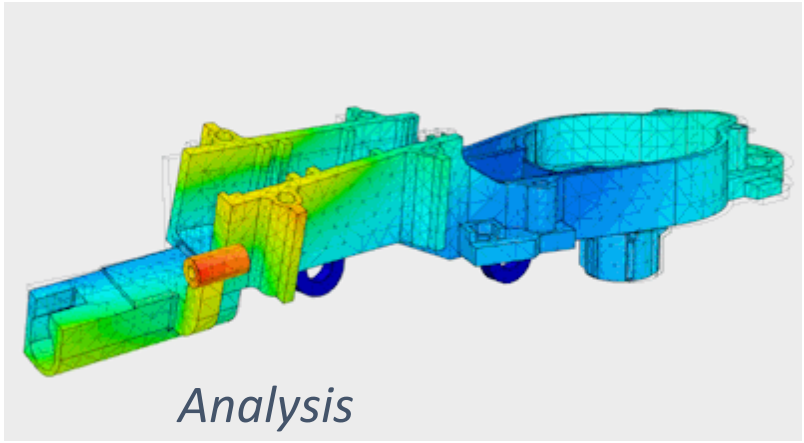
- Workshop provides a comprehensive construction & repair service
- Simple mechanics design and build, e.g. enclosure
- Run an electronic test equipment loan pool
- Carry out the regulation electrical appliance safety testing
- Electronics Research Workshop to build electronics yourself with the right equipment
- Training
- Manage electronics component store

Mechanical Design and Manufacturing group

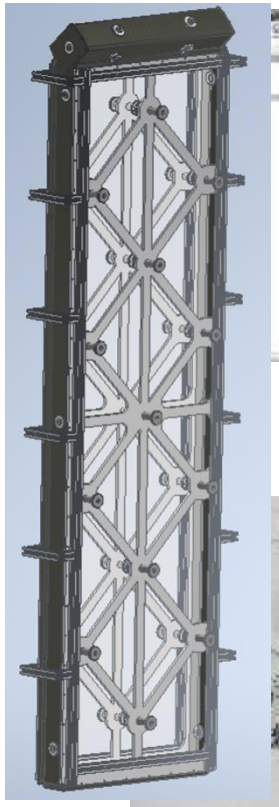
Design

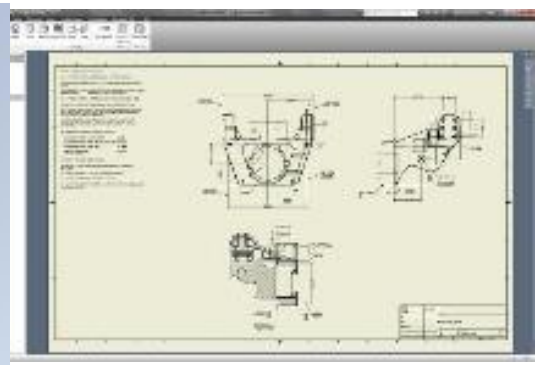


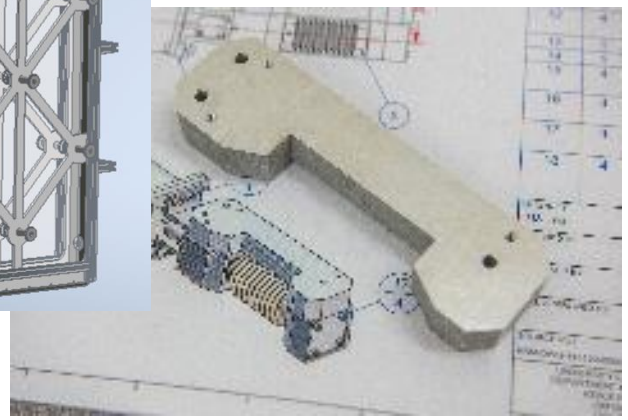




Analysis





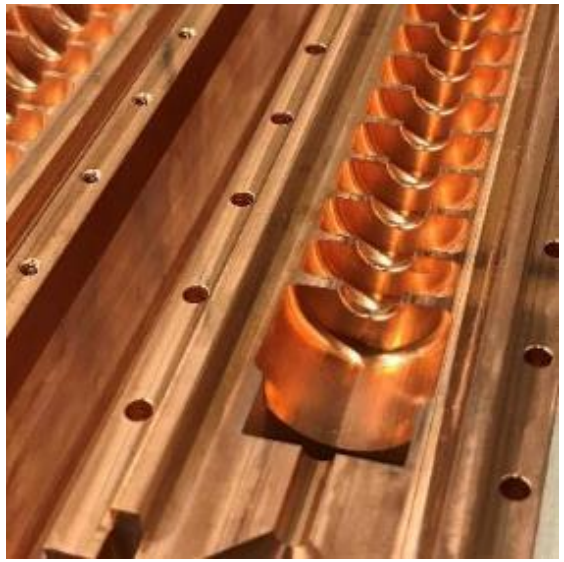


Drawings for Manufacture

Validate

- Design and manufacturing for research prototyping or production
- Finite Element Analysis (FEA) and Computation Fluid Dynamics (CFD)
- Conventional design to light-weight low material budget designs
- Design – Analysis – Manufacturing - Validation

Mechanical workshop

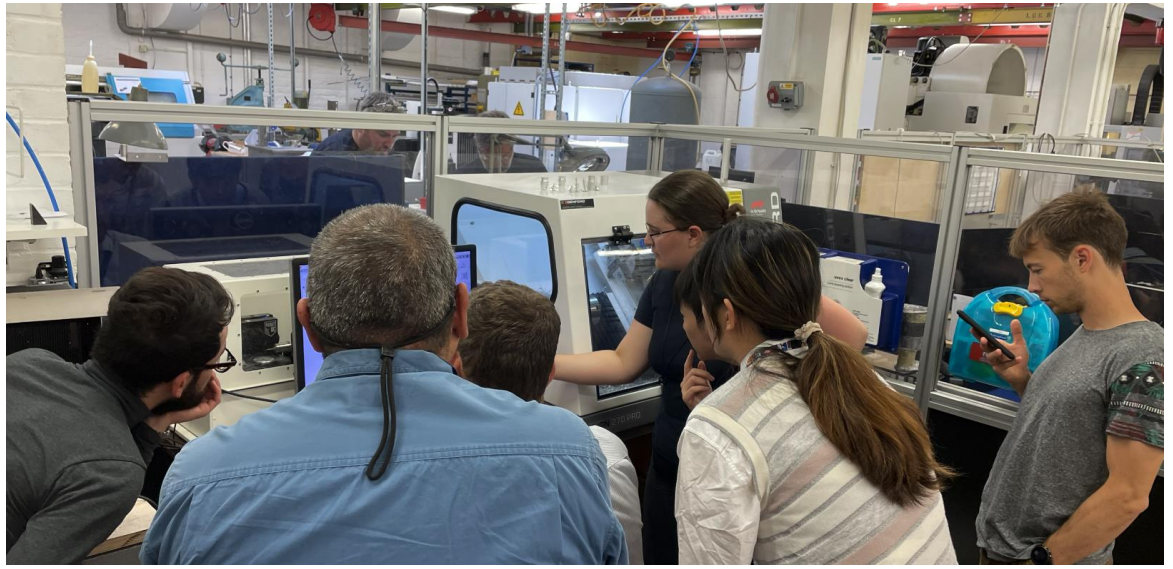


List of Services

- CNC milling
- CNC turning
- CNC wire and spark erosion
- Rapid prototyping - 3D printing
- Plastic injection moulding
- Manual machining
- Vacuum testing
- Welding & Assembly
- CMM measurement and metrology
- Mechanical engineering design
- Laser table equipment

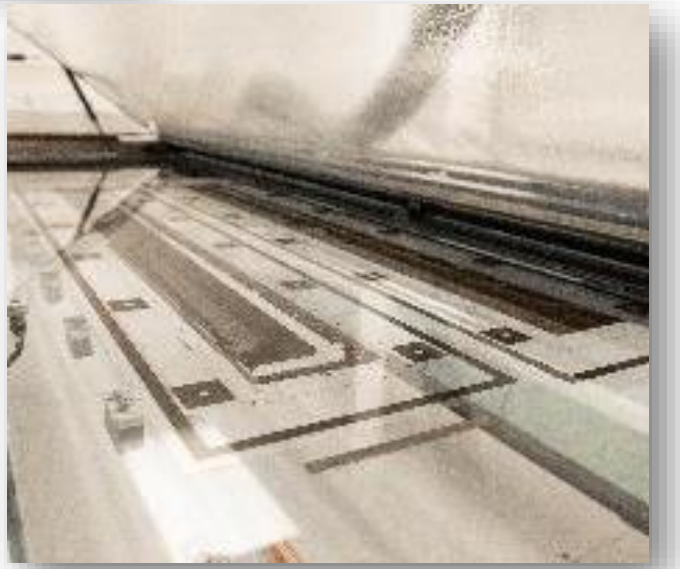
Self-Service Mechanical Workshop

- 5 Axis CNC Mill / CNC Lathe
- Drill + other tools
- Regular training sessions available



Components produced after one day training course

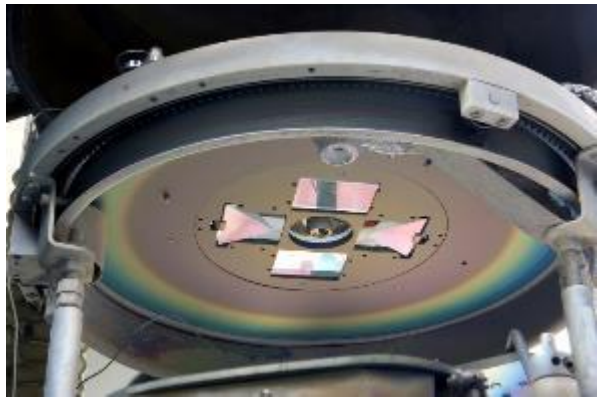
Photo Fabrication Unit

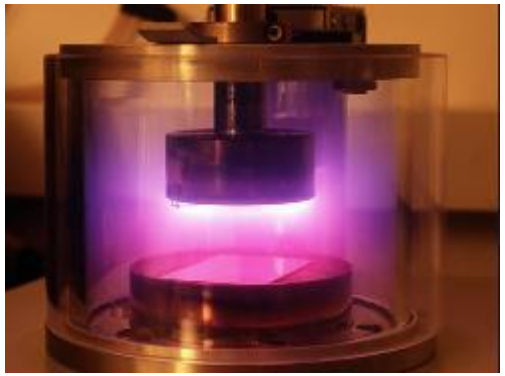


- Produce printed circuitry, ribbon cables, springs and other complex items from photographic or computer graphic masks using chemical etching techniques.
- Capable of very high resolution 25 micron track with 50 micron gap
- Items can be millimetric up to several metres in size
- Capable of medium production run

Thin Films Facility

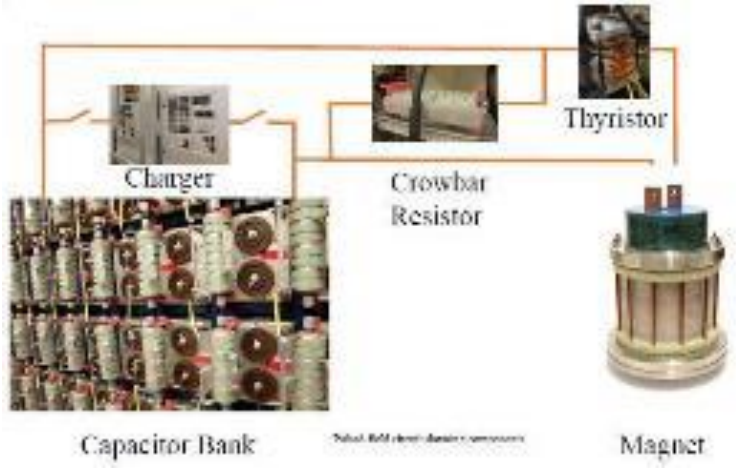
- Provides a comprehensive coating design, manufacture and measurement service
- Custom coatings are provided for the optical, electronic, semiconductor and aerospace fields using a range of thermal and electron beam evaporation techniques
- Metallic coating 3nm – 500nm
- Dielectric coating up to 30 layers





Cryomagnetics

- Operate and maintain the helium generation plant
  - Provide support for cryogentic safety
  - Deliver LN2 LHe
  - Maintain the recovery system



- Mobile superconducting magnet systems up to 21 T
- Custom-built superconductive magnets dedicated to individual experiments
- A pulsed field facility, the Nicholas Kurti Magnetic Field Laboratory
- Transport critical current measurements on superconductors at currents up to 500 A in a continuous field of up to 21 T
- Coil winding and vacuum impregnation expertise
- High field support
- Extensive expertise in adhesives and non-metallic composites at low temperatures
- *Delivery of Cryogenic safety training, equipment and PPE*

Space Instrumentation

Space instrument development, manufacture and test

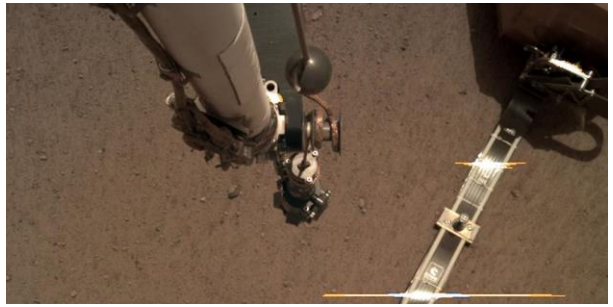
Our sub-Department of Atmospheric, Oceanic and Planetary Physics has been developing space instruments since the 1970s and is experienced in various areas of design and manufacturing for space use including:

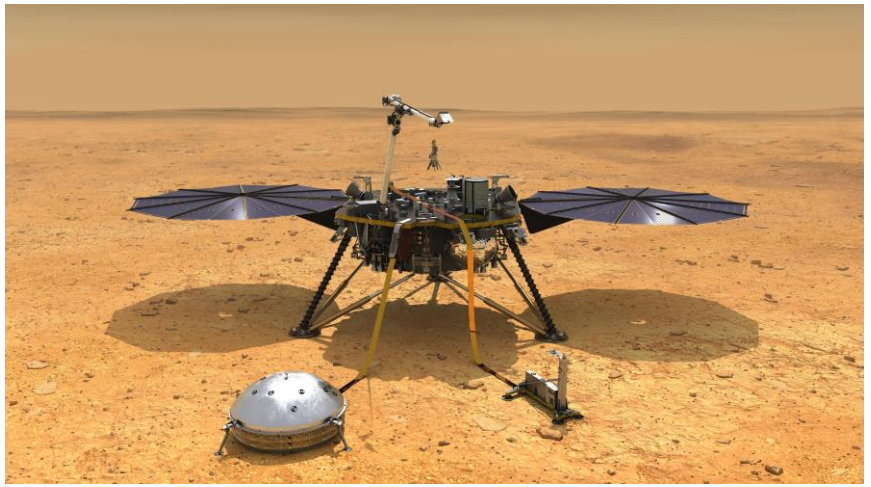
- Mechanical design
- Thermal design
- Focal plane design and manufacture
- Calibration target design and manufacture
- Facilities for CAD (Mechanical, and Optical)
- Product assurance
- Planetary protection requirements for planetary missions
- Flight electronics manufacture including flight flexible cabling based on etched circuits produced in the Department's Photofabrication Unit

1m diameter chambers in clean assembly area

2.2m Chamber with vibration isolated optical bench

The pre-flight calibration of multiple remote sensing instruments has been carried out in chambers in our clean areas and we have facilities for thermal vacuum, vibration and shock testing as well as characterisation on infrared sensors and seismometers.





InSight

Seismometer co-designed in Oxford

Lunar Traiblazer

Lunar Thermal Mapper

Designed and built in Oxford integrated on the Lunar Trailblazer spacecraft

Launch Q1 2024

Infrared Multilayer Lab

- The Infrared Multilayer Laboratory is engaged in the research, development and supply of specialist high-quality infrared optics

- Ranging from coatings for single optical components to the complete spectral design and manufacture of complex atmospheric sensing and ground based astronomical instruments.

- The laboratory has a spaceflight heritage of contributions of infrared optics to many of the most progressive scientific instrument programs in the study of atmospheric and planetary science.

We are available to manufacture custom made coatings to your specification on a wide variety of substrate materials and sizes to suit. Some of the fully-blocked filter types that we routinely manufacture in the 2-45µm range are:

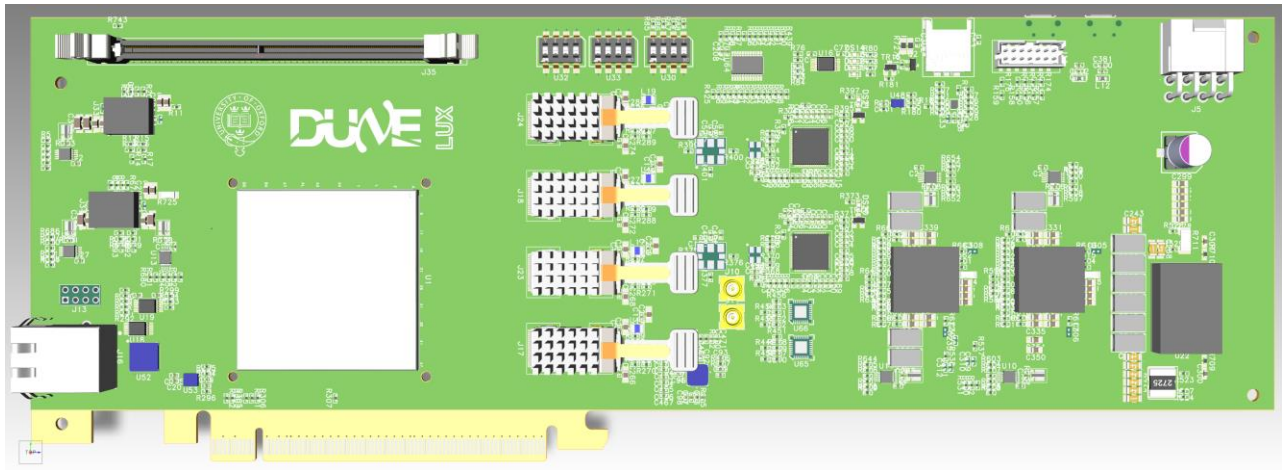
- Narrow bandpass filters
- Wide bandpass filters
- Longwave-pass edge filters
- Shortwave-pass edge filters
- Dielectric broadband mirror
- Broadband antireflection coatings
- Single wavelength antireflection coatings

Nano-Fabrication Facility

- Provides researchers with access to state-of-the-art capabilities for micro- and nano-fabrication and scanning electron microscopy.
- The foundation of the facility is a Class 100 and Class 1000 cleanroom suite used for sample preparation and lithography, including equipment for resist processing, metal and insulator deposition, and dry etching.

Showcase

High-speed PCB and firmware design

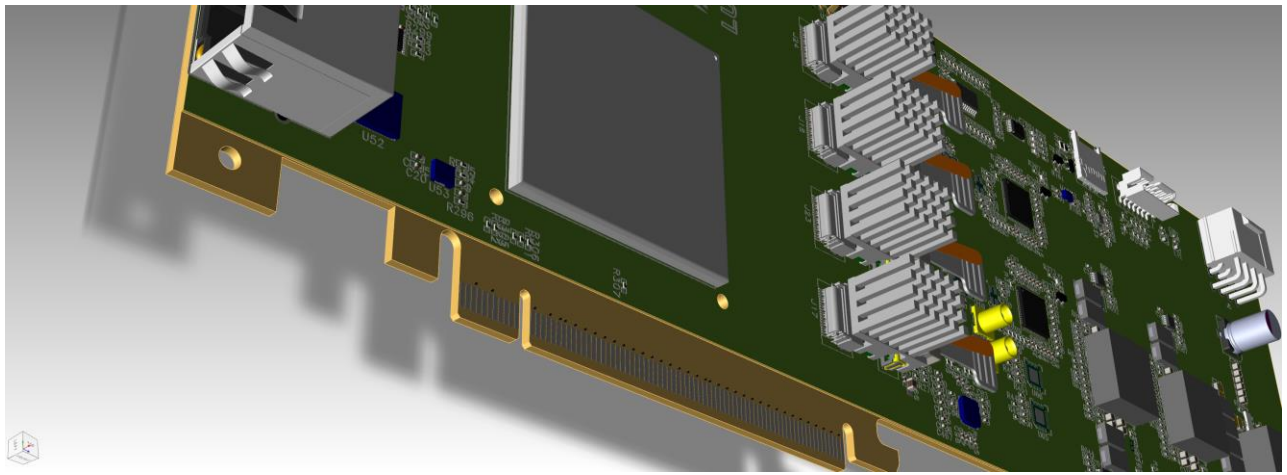


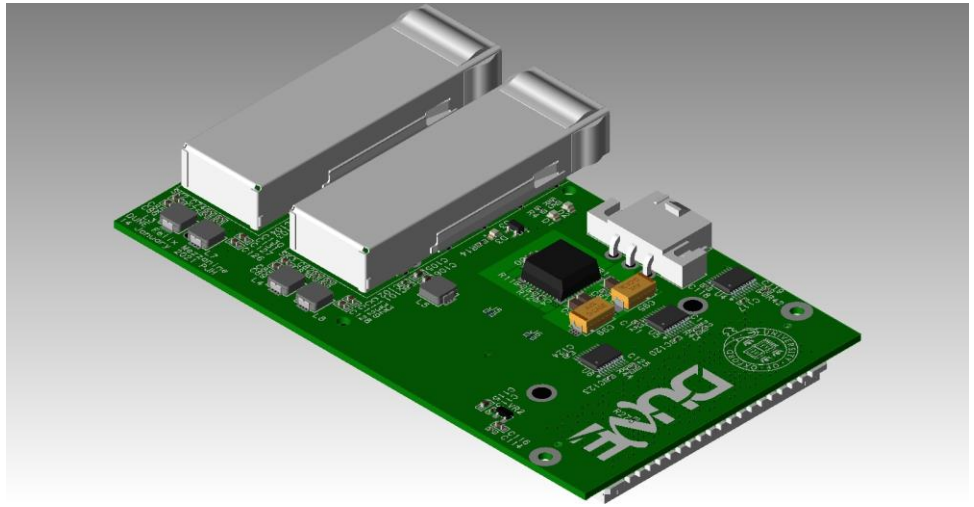
Project: DUNE (particle) Neutrino Detector

Left: Lux Board Xilinx Versal device, PCI-E

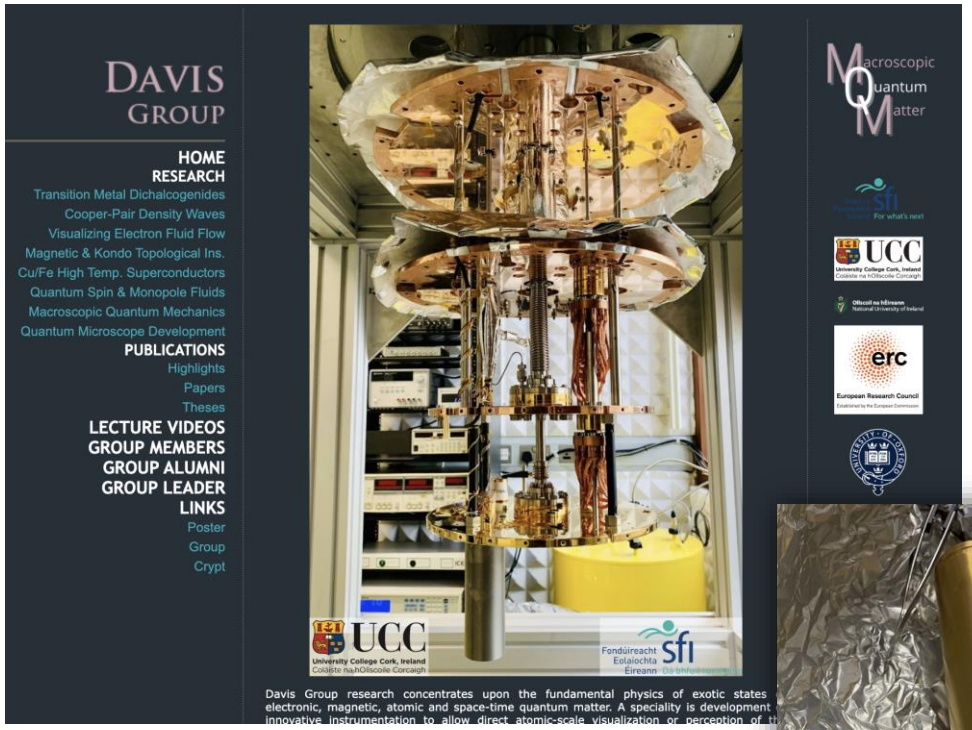
Bottom: Mezzanine: Test PCB capabilities using HDI for Lux card

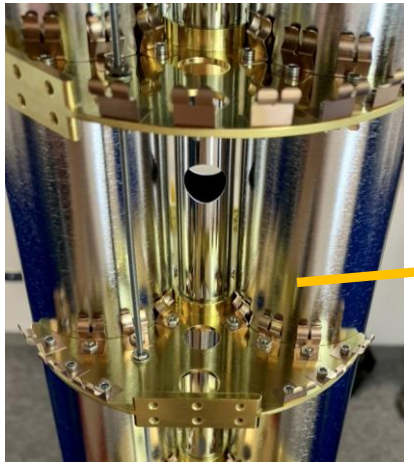
Multi gigabit transceivers from a Xilinx development board to two SSD drives

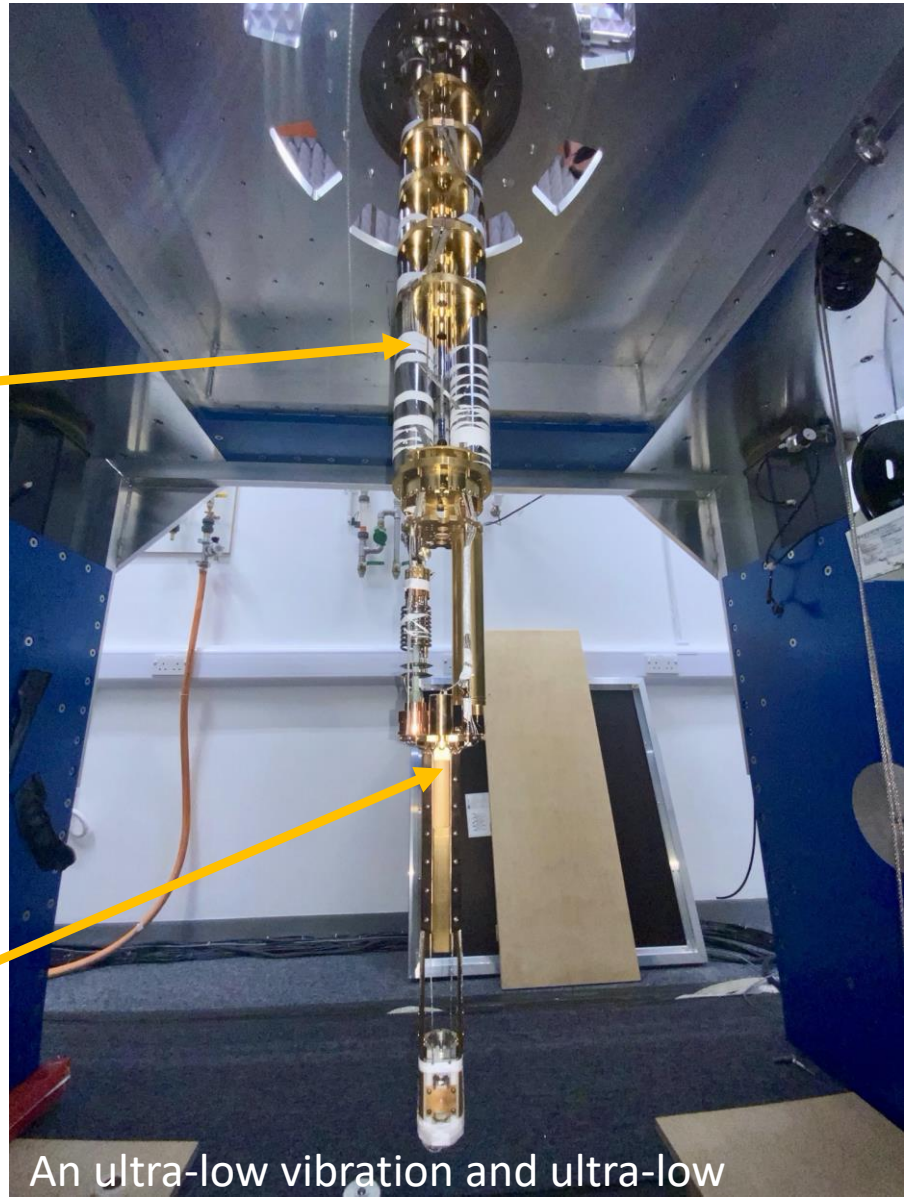




DAVIS GROUP







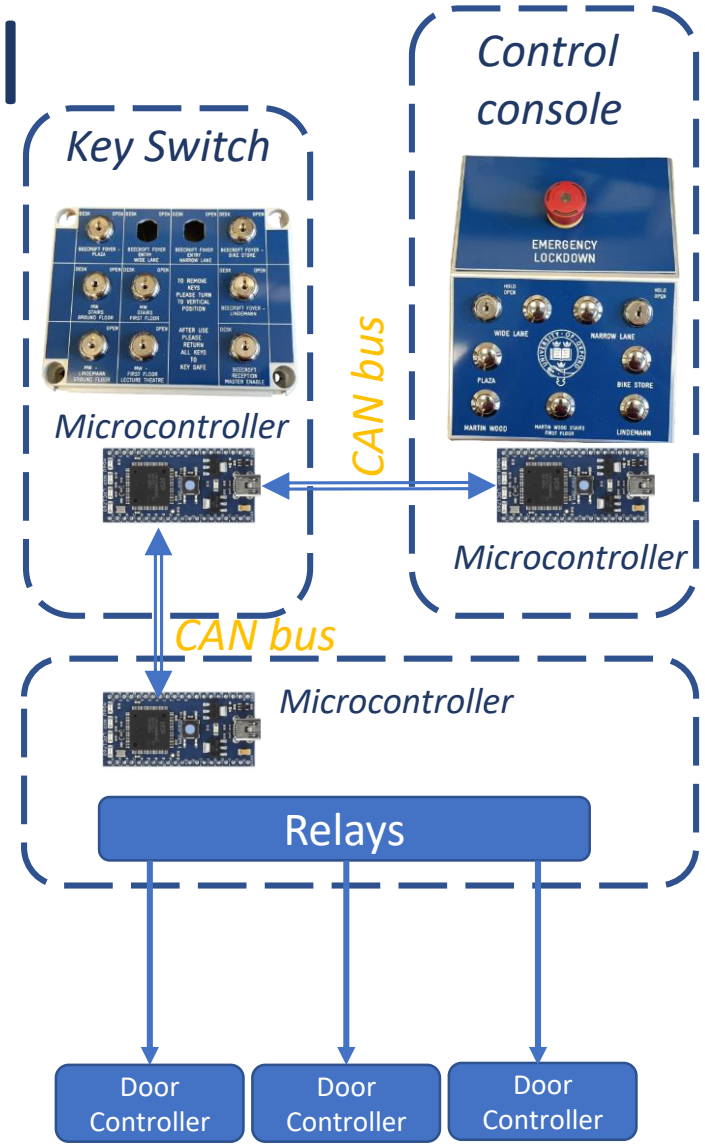
An ultra-low vibration and ultra-low temperature STM , which can provide morphology visualization and spectroscopic imaging with atomic precision.

The “1K plate” (right) manufactured in workshop, prepared and installed into a Scanning Tunneling Microscope (STM) in Oxford Physics

Nicholas Kurti Magnetic Field Laboratory – Pulsed Magnetic Fields

- **Capacitor bank**: upgraded to **15 kV** (from 7.5 kV) and energy storage upgraded to **3 MJ** (from 0.8 MJ); switched by **high voltage thyristors**
- provides fields of up to **65 tesla** for a few milliseconds for condensed matter physics experiments

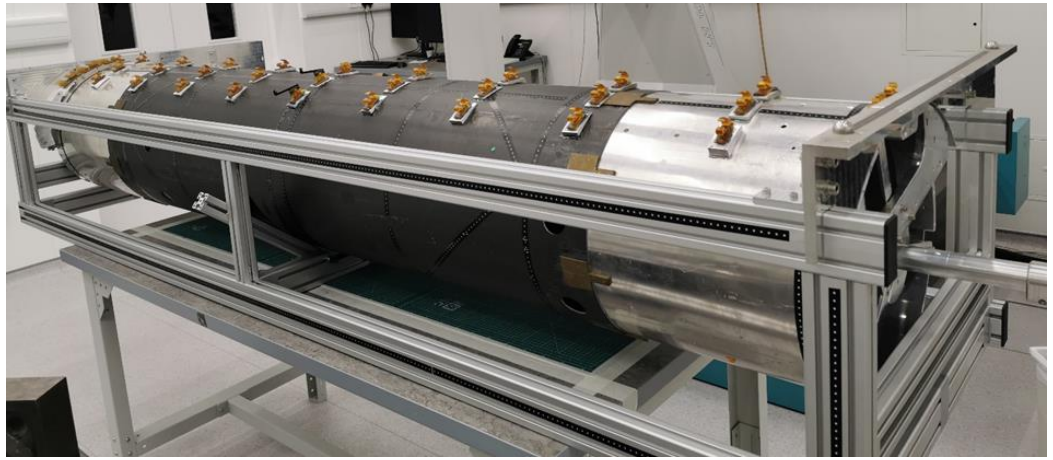
Beecroft Building Access Control



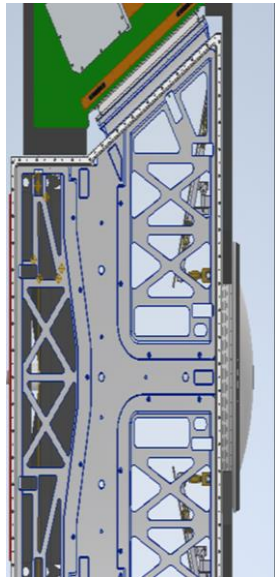
- New building joint to the existing Clarendon lab in 2019
- Two separate system to operate the doors
- New CAN bus and microcontroller based system was developed and commissioned.
- Joint effort of Electronics, mechanical Workshop and building services

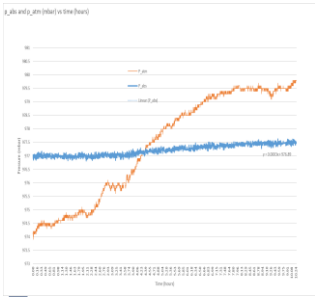
LHC experiments upgrade work

ATLAS cylinder dressing and bond joint testing



- Barrel brackets designed, manufactured and fitted by MEG.
- Tooling for complex bonding operation also produced



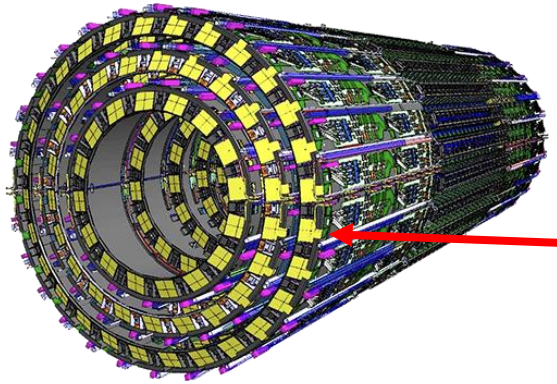


LHCb RICH Upgrade

- The LHCb RICH1 detector. A 5 year project for the MEG group,
- Upper quartz window installation
- Optics (mirror) installation.
- Multi Anode Photomultiplier Tubes enclosure installation.
- Site Acceptance Testing
- EEG carried out the testing of RICH digital boards

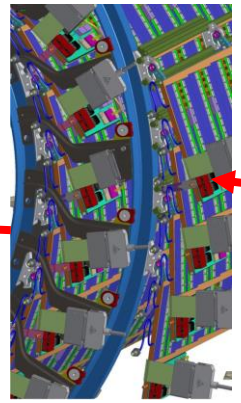
ALTAS ITK bus tape and testing

ATLAS ITK: Current ATLAS Inner Detector will be replaced with new all-silicon Inner Tracker (ITk) to accommodate tracking and radiation conditions at HL-LHC

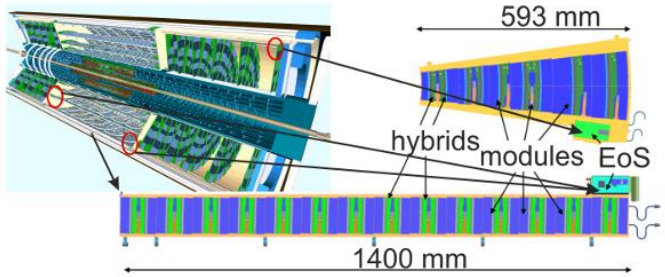


ITK barrel

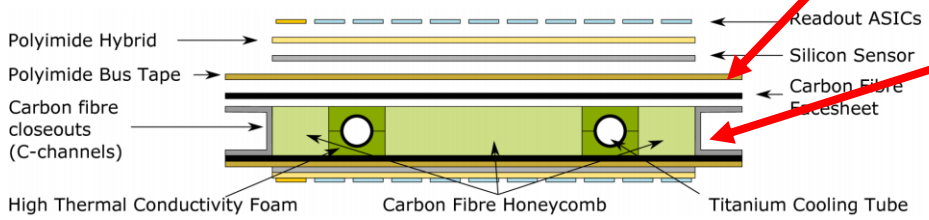
OPTEC is involved in many aspects in ATLAS here we focus in ITK bus tape design and testing



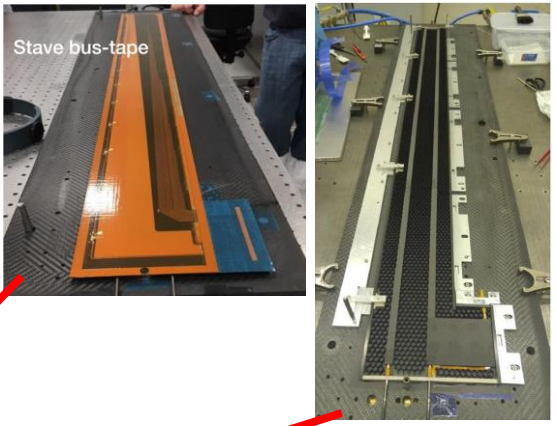
Barrel end assembly design by MEG



End of Structure (EoS) Card

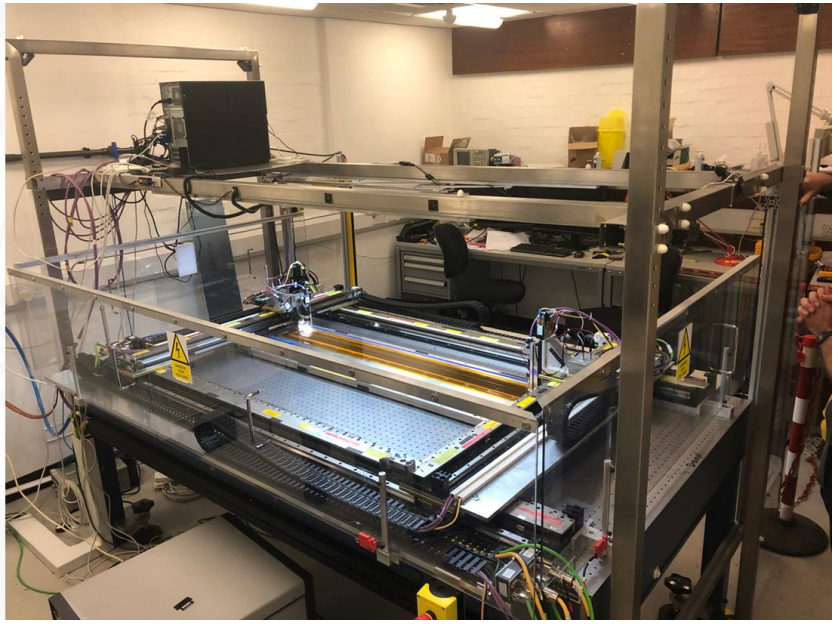


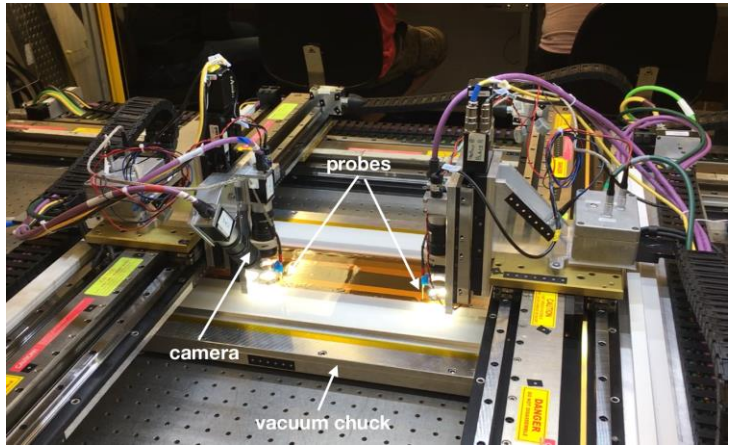
EoS cross-section

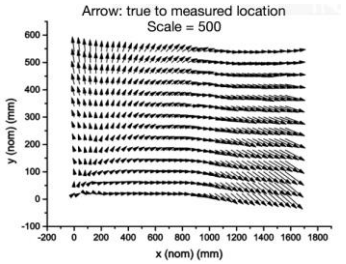


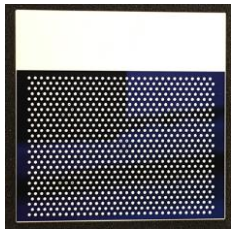
Bus Tape(left) and core assembly (right)
Bus Tapes designed in EEG
Manufactures in Photo fabrication

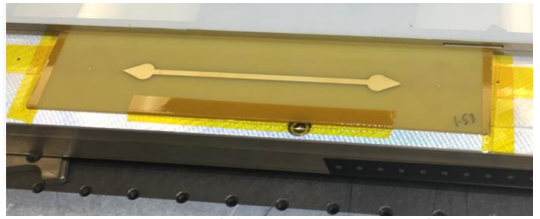
ALTAS ITK bus tape testing



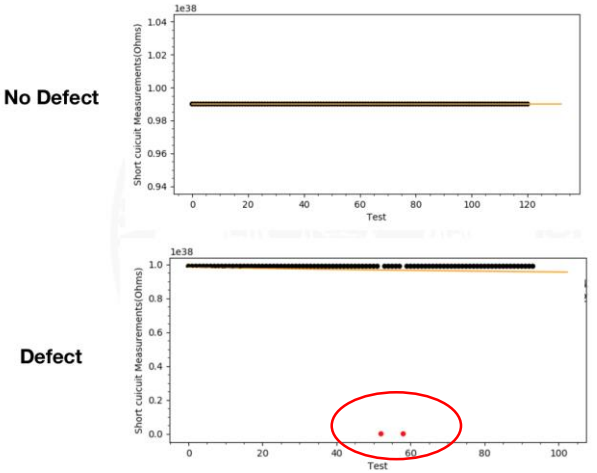








Camera calibration graph and tools

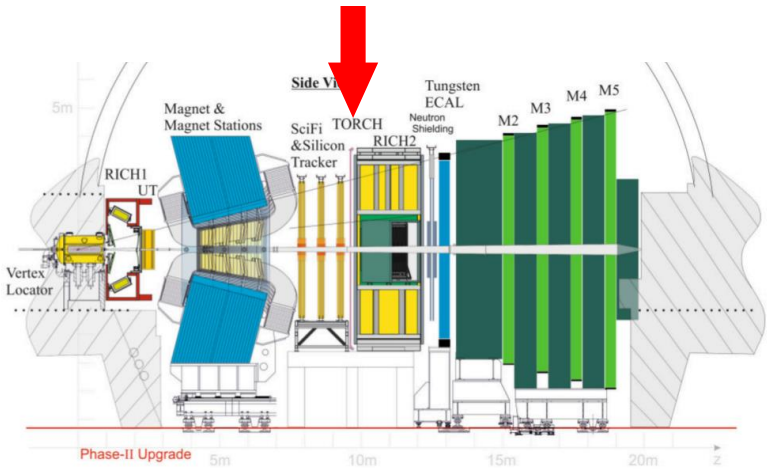


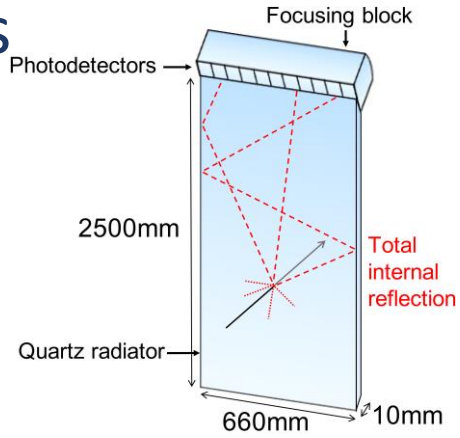
Example of detected shorts on tape

- A fully automated in EEG for QC testing of all bus-tapes
  - 2 independent probe heads on a gantry system with cameras for alignment
  - XY position control by linear stages, 5 µm resolution
  - Z position controlled by stepper motor, 1 µm resolution
  - Tape held down by vacuum chuck
  - System duplicated in other institutes

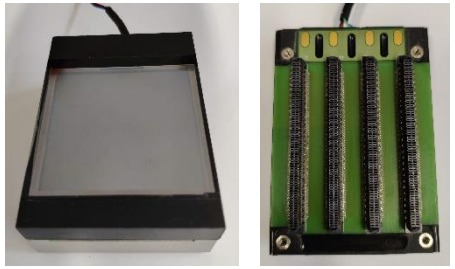
TORCH project introduction

- Large-area time-of-flight detector, PID for time-of-flight, momentum range 2–15 GeV/*c*, over 10m
- Micro-Channel Plate Photomultiplier Tubes (MCP-PMTs) and fast electronics are developed to meet the requirement of timing resolution 70ps per Cherenkov photon
- The job: to design and built and test electronics to instrument one quartz module



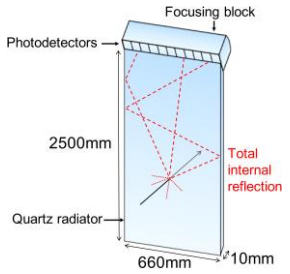


TORCH Quartz module



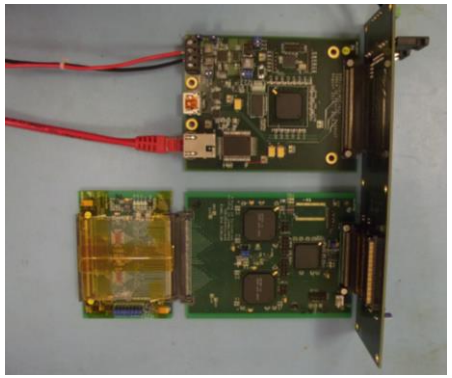
TORCH MCP

OPTEC contribution in TORCH timeline



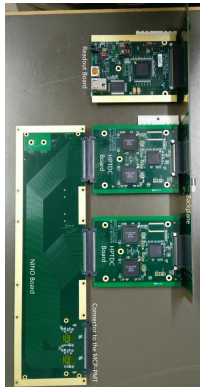
Detector concept

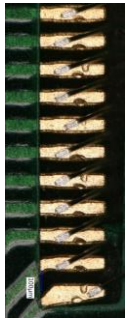
2013



V2 64-CH Electronics. Firmware development DAQ

2015

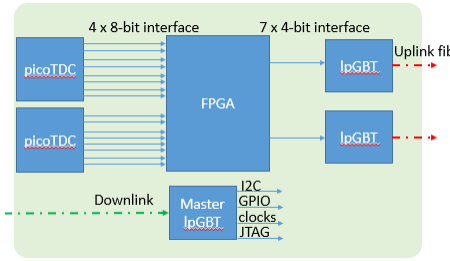




V3 Electronics production and testing

2017

Issue with NINO wire-bonding

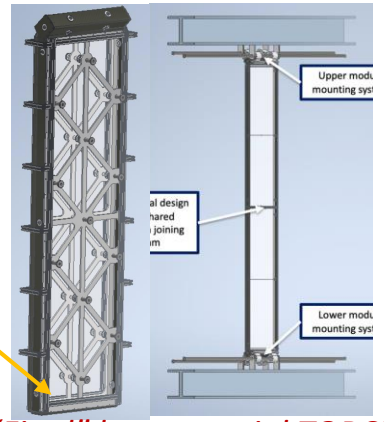


Design TORCH electronics with new generation of ASICs toward LHCb

2019

LHCb Upg II FTDR Preparing for test-beam 2022

2021



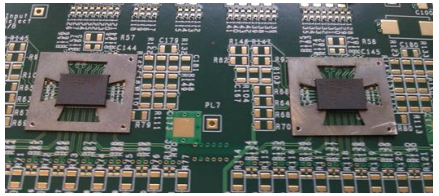
"Final" low material TORCH demo module with a 2.5m x 0.66m quartz plate

Synergy: RICH readout electronics

2023

2014

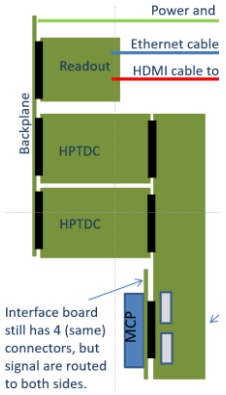
V1 16-CH Electronics Dev. Board readout



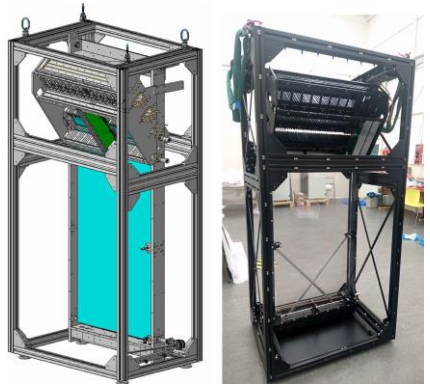
challenging chips assembly

2016

Planning new V3 geometry for the prototype – proto-TORCH



2018



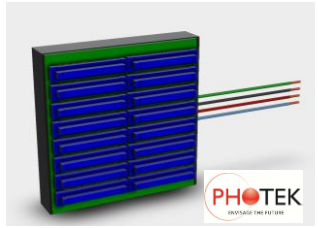
First test-beam with half-length quartz model in proto-TORCH with 2 MCPs

2020

Electronics production and testing
V3 Electronics firmware updating
DAQ work

2022

Test-beam - proto-TORCH with 7 MCPs



New 96 X 16 ch MCP development

Relations with other departments, institutes, and industry

- Customers from other department of Oxford University and other institutes such as RAL, CERN
- Use services from other department and institutes such as engineering and RAL
- Closely work the industries, such as CEAN and Photek
- Use outsourcing services from industry, e.g. 3D printing, PCB manufacturing and assembly

Funding and operation model

- OPTEC staff cost typically includes space, generic software cost, tool cost, some (insignificant) material cost.
- Project grant basis
  - Long term - (typically 3 – 5 years or aligning with the duration of the project)
  - Requires PI to incorporate engineer's cost in a grant proposal
  - A fraction of the full-time staff can be allocated
  - An engineers have more involvement on the projects
- Small Research Facility (SRF) basis
  - Short term – staff can be hired at hourly rate
  - All technical staff are on SRF basis
  - Short term jobs
  - Staff availability on short-notice is a challenge
- Flexibility: Projects can adapt with engineers assigned to various tasks as they progress or have multiple engineers to meet deadlines, effective planning is crucial.

Summary

- OPTEC is a support group that provide technical services to Physics department and the wider community
- 61 staff in 8 groups, a number of workshops, fabrication, assembly and testing facilities
- Significant contributions to big science projects and compass activities

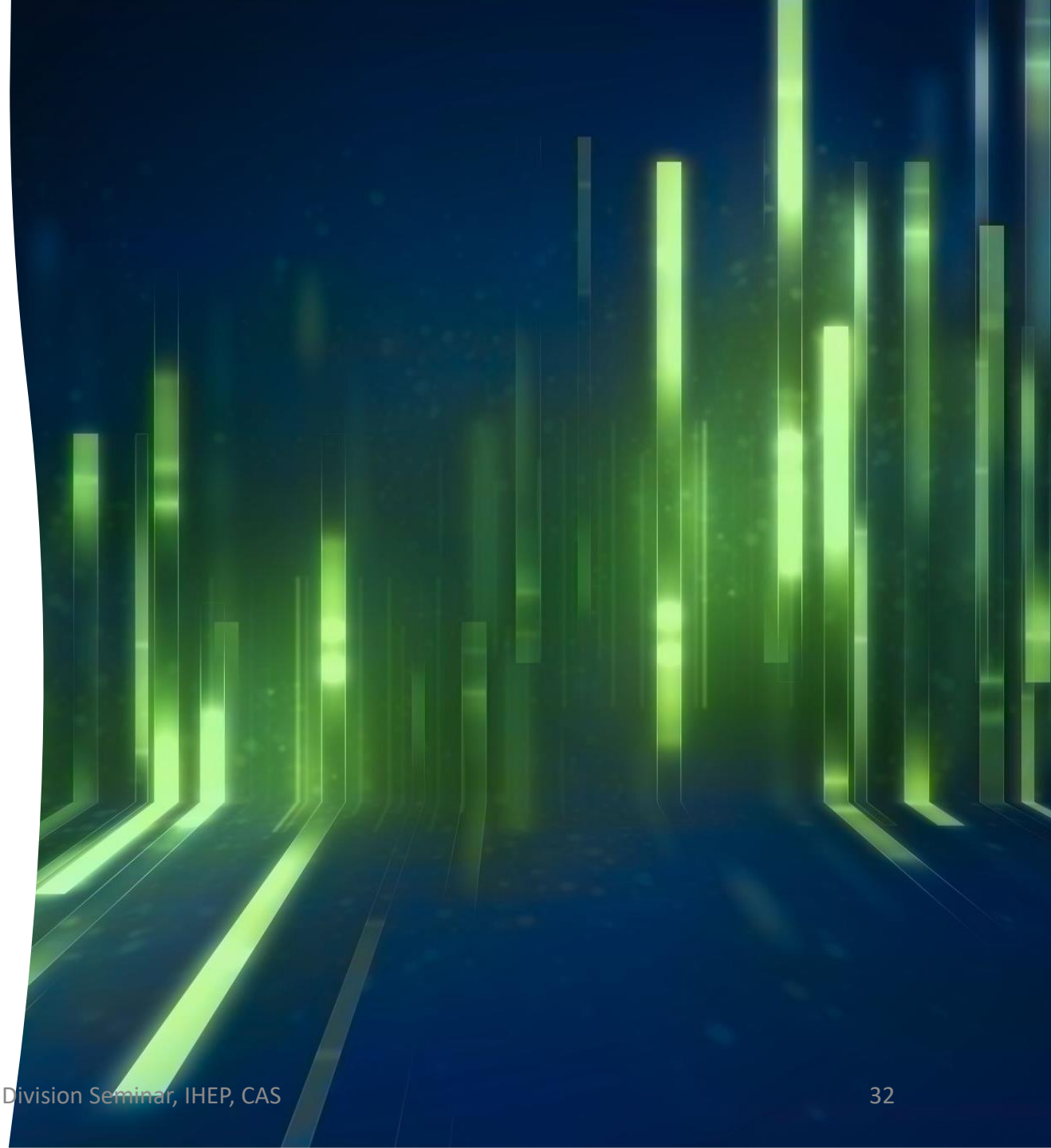
For further information on the Physics home web page at:

http://www2.physics.ox.ac.uk/enterprise

Or any enquiries to

OPTEC_Enquires@physics.ox.ac.uk

ANY QUESTIONS?

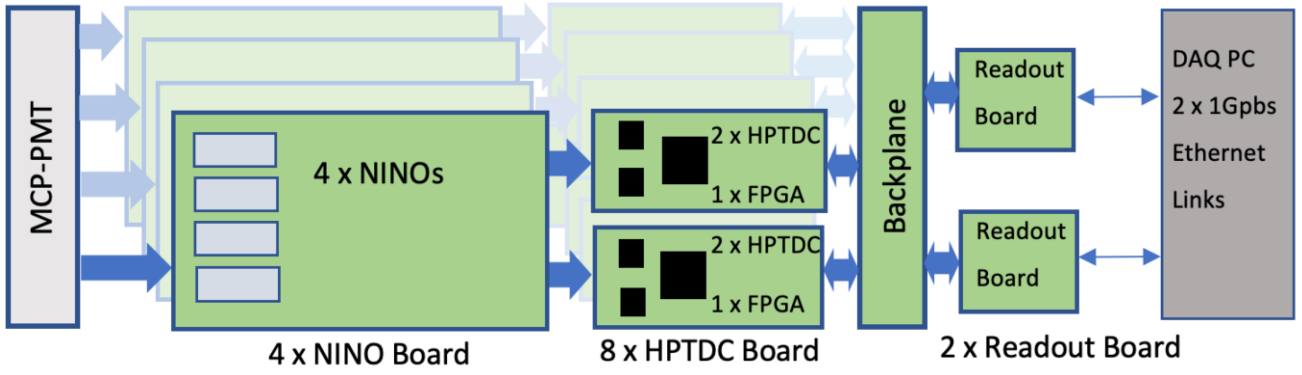


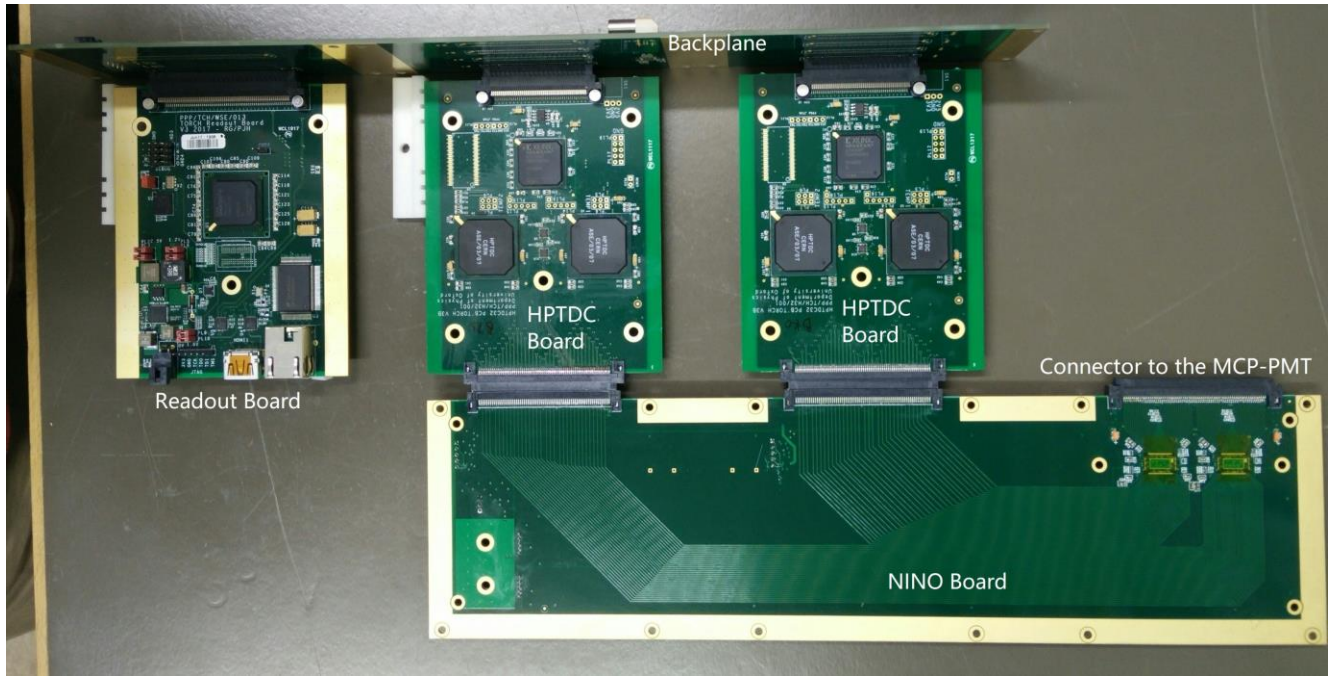
Backup slides

- The following slides are examples of deliveries from TORCH project.

TORCH Readout electronics

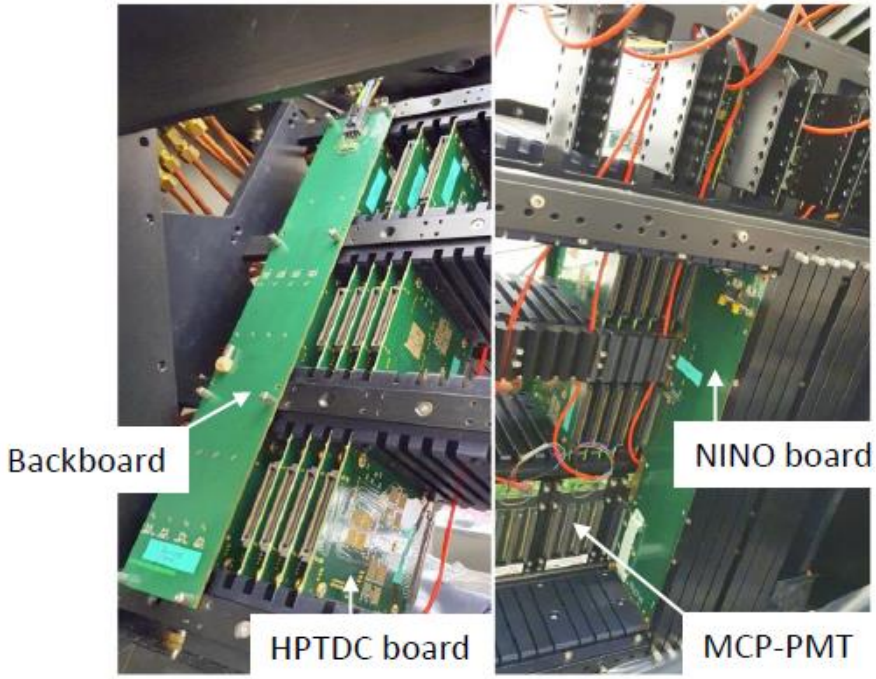
- Readout based on NINO and HPTDC chips
  - NINO – Amplifier and discriminator *10.1109/TNS.2010.2100409*
  - HPTDC – Time to digit convertor *10.1109/NSSMIC.2000.949889*
  - Instrument a MCP with 4 X 128 channel NINO boards and 8 HPTDC boards
- The measurement
  - Triggered measurement
  - Time of arrival
  - Time-over-Threshold (TOT)
  - 100 ps bin time
  - Extended timestamp for up to 8 hours
  - Intrinsic time resolution is 26.8ps *JINST(2014) 9 C02025*
- Custom Gigabit Ethernet Readout board
  - Raw MAC protocol for maximum efficiency
  - Use commercial router with 10Gigabit uplink to minimum links in DAQ
- DAQ based on EUDAQ framework

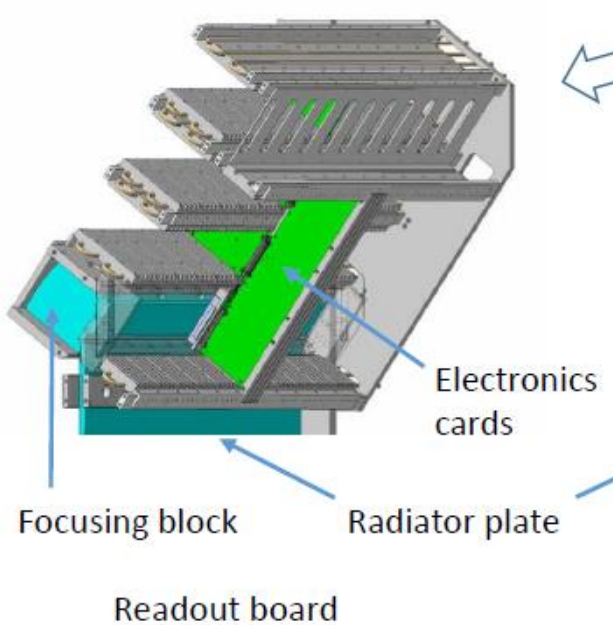




Module prototype

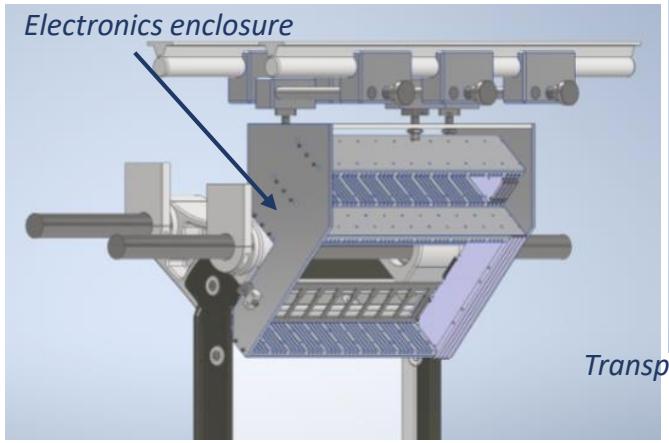
- The large scale TORCH prototype was constructed and initially tested in beam with two MCP-PMT tubes in 2018
- Last year the instrumentation was extended to 6 MCP-PMTs with a total of 3072 channels, and returned to the (renovated) T9 test beam area at the CERN PS

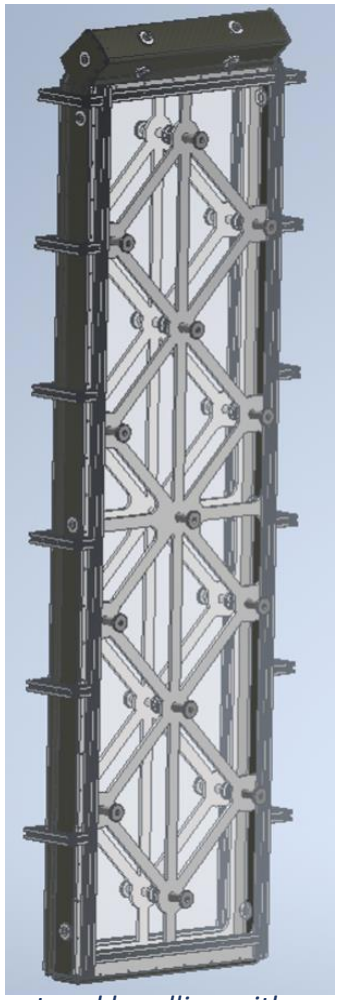




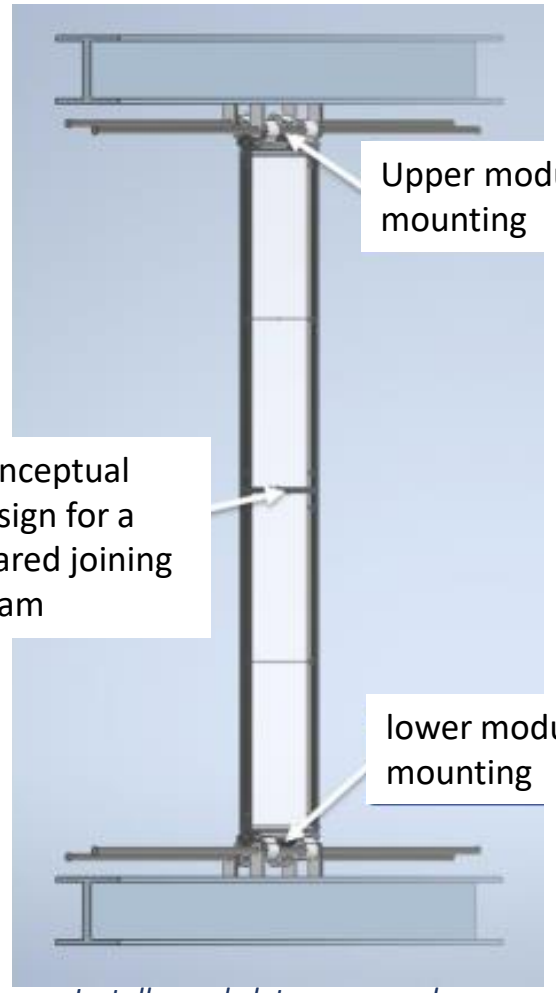
TORCH mechanics in LHCb

- Conceptual design is in progress for a light-weight carbon-fibre housing and support for TORCH modules
- The design aims to minimize material in the detector acceptance to keep total material budget as low as possible
- Robust exoskeleton will be used for quartz handling and jigging, and removed once module is in place
- Separate support of the (heavy) readout electronics enclosure under study
- Finite-element analysis and prototyping underway





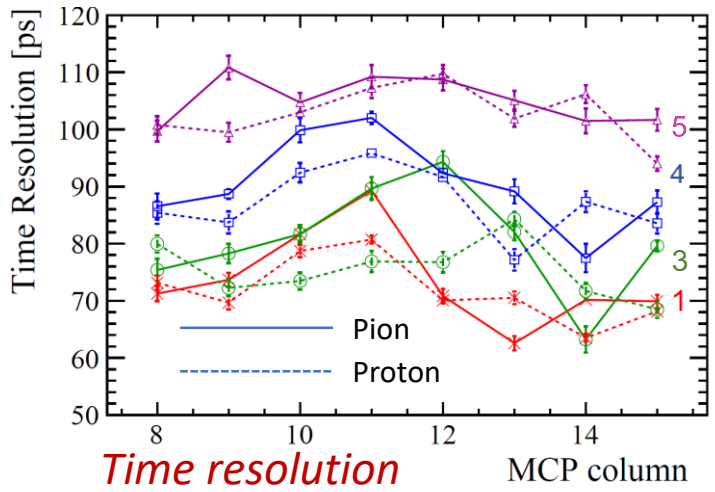
Transport and handling with exoskeleton



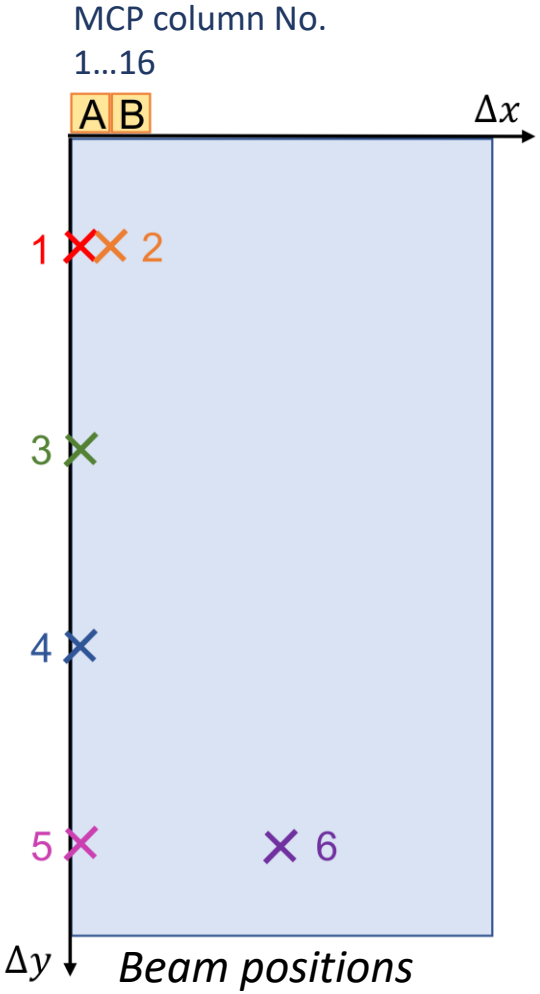
Install, exoskeleton removed

TORCH Test beam results from 2018

- For beam position close to MCP-PMT, 70ps time resolution is reached
- Further studies time resolution - propagation time-cluster size



Time resolution



- Time resolution expression

$$\sigma^2_{\mathrm{TORCH}} = \sigma^2_{\mathrm{const}} + \sigma_{\mathrm{prop}}(t_P)^2 + \sigma_{\mathrm{RO}}(N_{\mathrm{Hits}})^2,$$

Contribution	Fitted values (ps)		Target values (ps)
	Pion	Proton	
$\sigma_{\mathrm{prop}}(t_p)$	$(8.3 \pm 0.7) \times 10^{-3} \times t_p$	$(7.6 \pm 0.5) \times 10^{-3} \times t_p$	$(3.75 \pm 0.8) \times 10^{-3} \times t_p$
σ_{MCP}	34.5 ± 8.6	31.0 ± 7.6	33
$\sigma_{\mathrm{RO}}(N_{\mathrm{Hits}})$	$(96.2 \pm 6.7)/\sqrt{N_{\mathrm{Hits}}}$	$(95.0 \pm 6.0)/\sqrt{N_{\mathrm{Hits}}}$	$60/\sqrt{N_{\mathrm{Hits}}}$

- Further calibrations in Readout Electronics are expected to improve timing resolution

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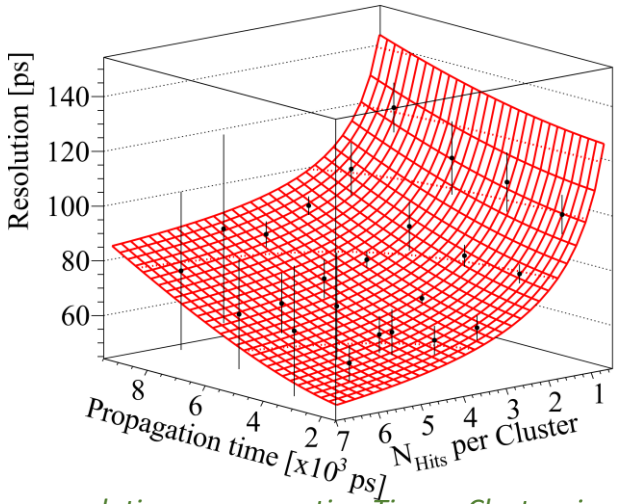

Time resolution – propagation Time – Cluster size