MANCHESTER 1824
The University of Manchester

European Strategy Update | ECFA European Committee for Future Accelerators

Detector Research & Development

DRD-UK Activity

- UK Organisation
- Funding Status

Supported by UK universities & national laboratories

University of Birmingham, University of Bristol, Brunel University London, University of Cambridge, University of Edinburgh, University of Glasgow, Imperial College London, King's College London, University of Lancaster, University of Leicester, University of Liverpool, University of Manchester, University of Oxford, Queen Mary University of London, Royal Holloway University of London, STFC Daresbury, STFC Particle Physics Department, STFC Technology Department, STFC ISIS, University of Sheffield, University of Sussex, University College London, University of York, University of Warwick.

DRD: 1-Gas; 2-Liquid; 3-Solid State; 4-PID; 5- Quantum; 6-Calo; 7-Electronics/DAQ; 8- Integration + Training, Industry

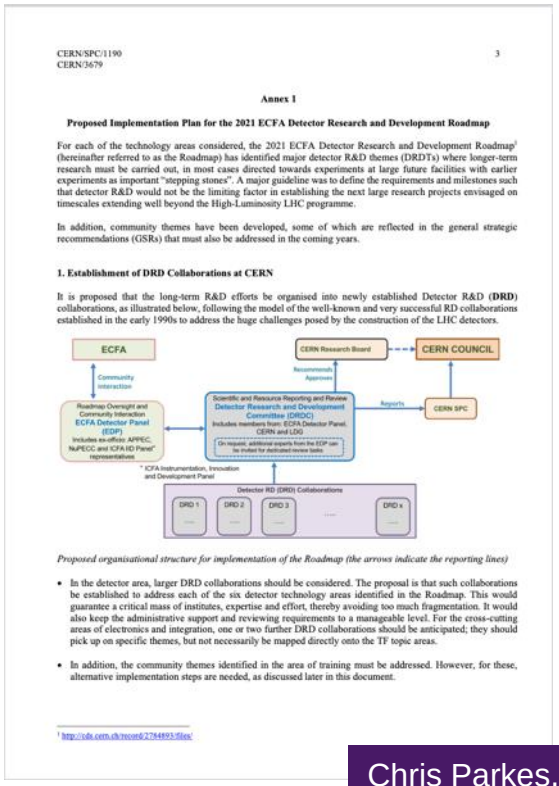
Concept

"The success of particle physics experiments relies on innovative instrumentation and state-of-the-art infrastructures. To prepare and realise future experimental research programmes, the community must maintain a strong focus on instrumentation...The community should define a global detector R&D roadmap."

European Particle Physics Strategy 2020 Update

Roadmap

Implementation



CERN/SPC/1190
CERN/3679

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Annex 1

Proposed Implementation Plan for the 2021 ECFA Detector Research and Development Roadmap

For each of the technology areas considered, the 2021 ECFA Detector Research and Development Roadmap[1] (hereinafter referred to as the Roadmap) has identified major detector R&D themes (DRDTs) where longer-term research must be carried out, in most cases directed towards experiments at large future facilities with earlier experiments as important "stepping stones". A major guideline was to define the requirements and milestones such that detector R&D would not be the limiting factor in establishing the next large research projects envisaged on timescales extending well beyond the High-Luminosity LHC programme.

In addition, community themes have been developed, some of which are reflected in the general strategic recommendations (GSRs) that must also be addressed in the coming years.

1. Establishment of DRD Collaborations at CERN

It is proposed that the long-term R&D efforts be organised into newly established Detector R&D (**DRD**) collaborations, as illustrated below, following the model of the well-known and very successful RD collaborations established in the early 1990s to address the huge challenges posed by the construction of the LHC detectors.

Proposed organisational structure for implementation of the Roadmap (the arrows indicate the reporting lines)

- In the detector area, larger DRD collaborations should be considered. The proposal is that such collaborations be established to address each of the six detector technology areas identified in the Roadmap. This would guarantee a critical mass of institutes, expertise and effort, thereby avoiding too much fragmentation. It would also keep the administrative support and reviewing requirements to a manageable level. For the cross-cutting areas of electronics and integration, one or two further DRD collaborations should be anticipated; they should pick up on specific themes, but not necessarily be mapped directly onto the TF topic areas.
- In addition, the community themes identified in the area of training must be addressed. However, for these, alternative implementation steps are needed, as discussed later in this document.

[1] http://cds.cern.ch/record/2744893/files/

- Strategic R&D in detector systems for **particle physics**, **particle astrophysics**, and related **nuclear physics** activities.
- Setup under the auspices of ECFA, with CERN as host.
- Expand upon and replace existing CERN RD collaborations
- First collabs started Jan. 2024

Why ? And why not ?

Entering new Era –post-ATLAS/CMS U2 construction

Medium/small scale projects and, potentially, FCC on 20+ yr horizon

Needs:

- **Costs**: technology costs are rising rapidly while the field remains – by commercial standards – a low-volume, niche market with complex requirements.
- **Complexity**: pooling of resources needed, and negotiation with vendors as larger-scale organisations.
- **Long-term strategic** funding programmes to sustain research and development in order for the technology to mature for FCC and other large-scale longer term projects
- **DRD structures will have the necessary critical mass**

Risks:

- Must ensure that **creativity** is maintained
- Must benefit the **medium-term** experiments
  - keep thriving community, learn through deploying technology

DRD-UK Aims

R&D programme will:

- Provide **international coordination** to identify and target common technological goals that will underpin the next generation of experiments facilitating long-term developments
- Provide and coordinate instrumentation **training and skill development** for the next generation of experimental particle physicists, engineers and technical staff
- Provide methods of establishing meaningful longer-term relationships with **industrial partners**

- DRD primarily aimed at mid-TRL levels
- Development of technology to a level where it can then be applied by specific experiments
- UK **strong** in recent / current construction
- **Falling behind** international competitors in instrumentation development
- DRD is opportunity to catch-up
  - Lack of longterm R&D funding at this TRL level

UK R&D Prior funding landscape

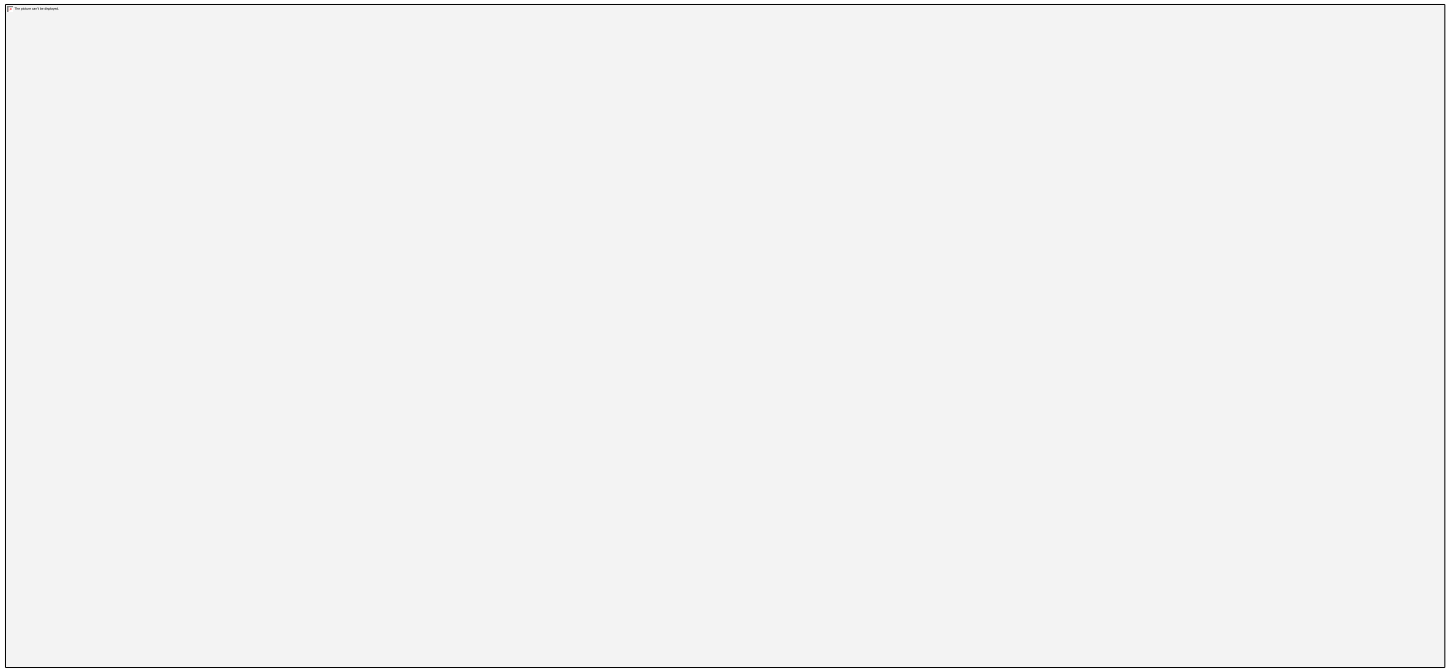
- Consolidated grant – fractions of staff with no formal UK wide coordination
- Project R&D call – annual 2/3 year R&D call. was terminated in 2016. Early-stage R&D call started in 2022.
- Much of longterm R&D was done under auspices of large construction programmes, particularly ATLAS.

Collider community clearly recognizes that detector R&D has declined in past decade.

Balance with successful delivery of major detector construction projects in past years & financial challenges.

Organisation - International

- DRD Collaborations – with coordinators
  - Major UK roles
- DRDC Review committee



Replaces collaborations such as:
RD50: underpinned most silicon developments that enabled LHC detectors and beyond
RD53: where a common ATLAS/CMS Upgrade II pixel chip basis was developed
RD42: Diamond detectors, RD51: gaseous detectors…

Major Roles in International Projects

- ECFA Detector Panel: Phil Allport,Ian Shipsey (ex-officio)
- DRDC: Mark Pesaresi
- DRD1:
- DRD2:
- DRD3: coord: Eva Vilella, Alex Oh
- DRD4: CB chair: Guy Wikinson, coord: Jon Lapington, Sajan Easo
- DRD5:
- DRD6:
- DRD7: Steer committee: Marcus French, coord: Iain Sedgwick, Mark Willoughby
- DRD8: Dep. Spokes: Georg Viehhauser, coord: Adam Lowe, Oscar Augusto De Aguiar Francisco

Awaiting input

Long-term Leadership of RD50: Gianluigi Casse
ECFA Detector Panel Leadership in DRD process: Phil Allport
Deputy spokes AIDAinnova: Daniela Bortoletto

DRD Collaborations (1-8)

1. Gaseous

e.g.
time/spatial resolution;

environment friendly gases

2. Liquid

e.g.
Light/charge readout;

low background materials

3. Semiconductor

e.g.
CMOS pixel sensors;

High time resolution
(10s ps)

4. PID & Photon

e.g.
spectral range of photon sensors;

Time resolution

5. Quantum

quantum sensors
- R&D, incl. beyond QFTP in conventional detectors

6. Calorimetry

e.g.
Sandwich;
noble liquid;
optical

7. Electronics

e.g.
ASICs;
FPGAs;
DAQ

8. Integration

tracking detector mechanics

DRD-UK Organisation

24 UK universities & National Laboratories,
Particle, Astro-Particle & (some) Nuclear physics

Steering Board

Institution	Representative
Birmingham	ALLPORT, Philip Patrick
Bristol	GOLDSTEIN, Joel
Brunel	KHAN, Akram
Cambridge	WILLIAMS, Sarah
Edinburgh	GAO, Yanyan
Glasgow	BATES, Richard
Imperial	TAPPER, Alex
King's	DI LODOVICO, Francesca
Lancaster	O'KEEFFE, Helen
Liverpool	VOSSEBELD, Joost
Manchester	PARKES, Chris (UK PI)
Oxford	BORTOLETTO, Daniela (UK Steering board Chair)
QMUL	HOBSON, Peter
RAL – PPD & DL	WILSON, Fergus
RAL - TD	FRENCH, Marcus Julian
RHUL	BOISVERT, Veronique
Sheffield	VICKEY, Trevor
Sussex	HARTNELL, Jeffrey John
UCL	KORN, Andreas
Warwick	RAMACHERS, Yorck

Coordinators

Institution	Representative
DRD-1 [Gas]	BRANDT, Oleg; MAJEWSKI, Pawel;
DRD-2 [Liquid]	GUENETTE, Roxanne; MONROE, Jocelyn; SAAKYAN, Ruben; SCOVELL, Paul;
DRD-3 [Si]	DOPKE, Jens; GONELLA, Laura; HYNDS, Daniel; VILELLA FIGUERAS, Eva
DRD-4 [PID]	BLAKE, Thomas; ROMANO, Angela
DRD-5 [Quantum]	BUCHMULLER, Oliver; DAW, Ed
DRD-6 [Calo]	SALVATORE, Fabrizio; WATSON, Nigel
DRD-7 [Electronics]	FITZPATRICK, Conor; FRENCH, Marcus; POTAMIANOS, Karolos; PRYDDERCH, Mark; ROSE, Andrew
DRD-8 [Systems]	GOLDSTEIN Joel; VIEHHAUSER, Georg
Training	LAZZERONI, Cristina; BATES, Richard
Industry Engagement	FARROW, Richard; CASSE, Gianluigi

Contributions to all DRDs, though at different levels

Email list: uk-detector-rd@cern.ch

Web site (with all submitted documents): https://drd.hep.ac.uk/

Meetings indico https://indico.cern.ch/category/17626/

Role of UK National Laboratories in R&D

- RAL particle physics division (PPD)
- RAL technical division (TD)
- Daresbury laboratory
- Boulby underground laboratory

Play an important role in detector development alongside the larger university groups – equal partners

major infrastructure outside (e.g. Liverpool semiconductor centre, Birmingham Cyclotron)

Expertise and facilities of TD available on contract basis

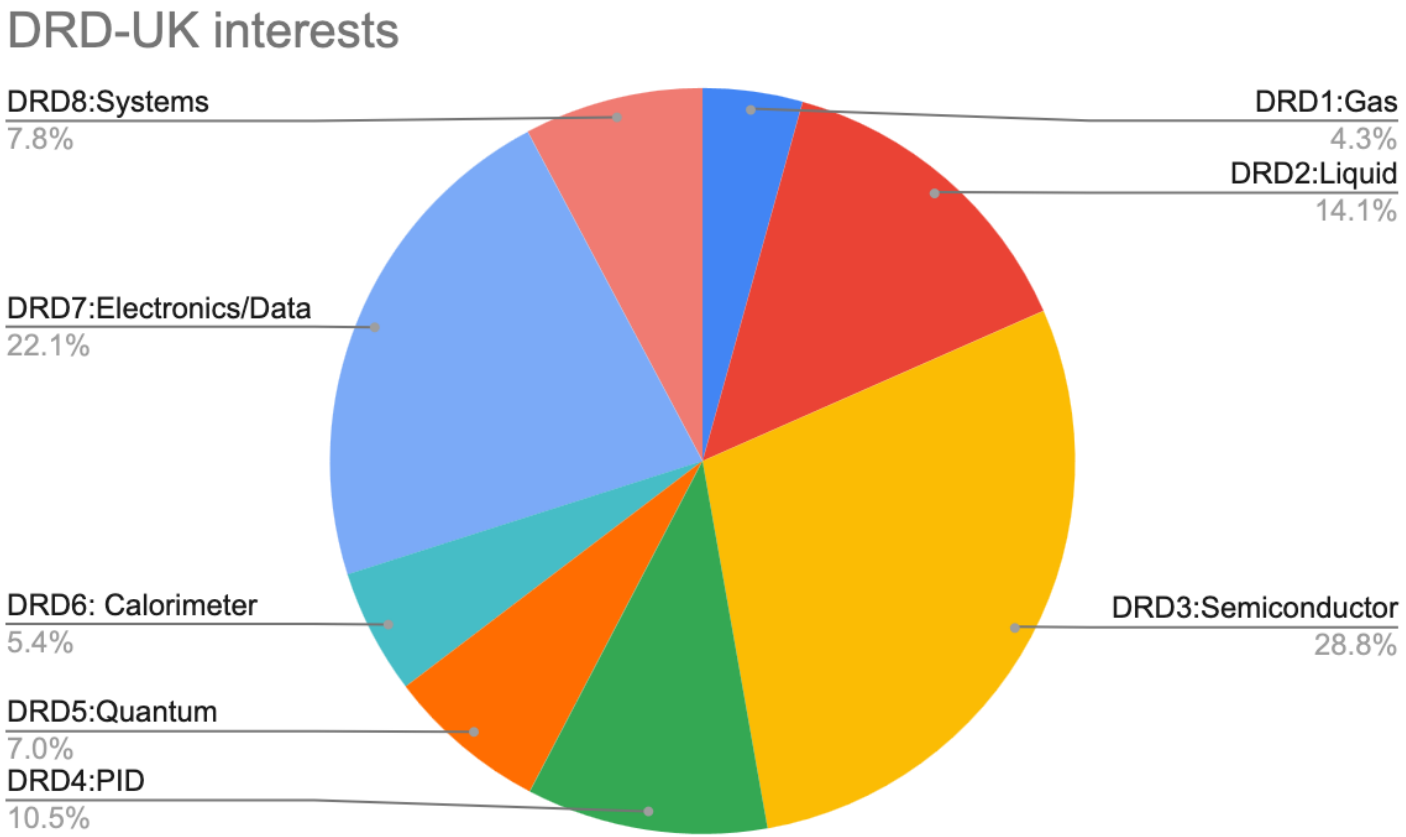
RAL PPD/TD impression more integrated with geographically closer region than the northern universities

Opportunity to level-up with Daresbury development?

Important initiatives to build-up world-class science in low-background science (DRD2) at Boulby

UK Interests

Survey of UK particle physics groups through steering board



Caveats: DRD5&8 were at earlier stage, numbers may not be representative
Opportunity to develop new areas
Presentations from most major UK projects on technology needs

Workplans & Task Lists

- All DRD-UK groups have identified their task lists
- Clearly too many / too wide for the available funding
- Awaiting feedback from STFC on funding envelope that will then facilitate devising a tailored programme

Examples:

DRD-UK 2: Liquid Detectors (neutrinos and dark matter)

Contributing institutes: Edinburgh, Imperial, King's, Liverpool, Manchester, Oxford, Sheffield, STFC PPD, Sussex, University College London, Warwick

1. Light sensors; 2. Light collection and detection efficiency over a broad wave-length; 3. Development of charge-to-light and charge+light readouts; 4. Material screening and low-background materials.

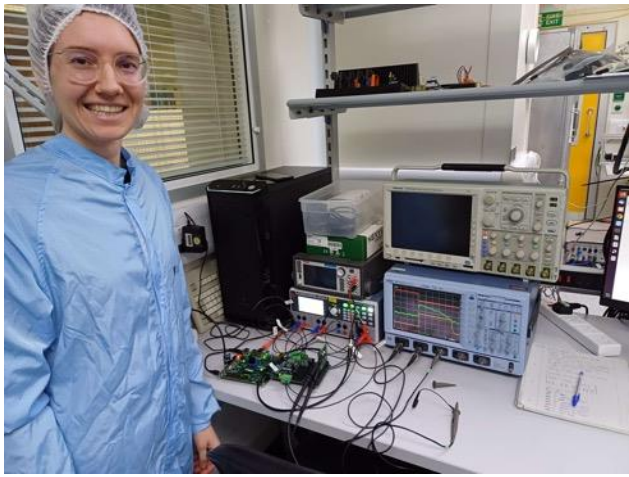
DRD-UK 3: Semiconductor detectors

Contributing institutes: Birmingham, Bristol, Brunel, Cambridge, Edinburgh, Glasgow, Lancaster, Liverpool, Manchester, Oxford, Queen Mary, Sheffield, STFC PPD, STFC TD, Warwick

1. Monolithic CMOS devices;
2. 4D tracking systems.
3. 3D stacked detectors.
4. Extreme radiation tolerance.

Recent DRD-UK Documents

- **Briefing Document** for STFC, Oct. 2023
  - Case for DRD-UK funding, positive feedback led to
- DRD-UK Particle Physics **Consolidated Grant,** Feb. 2024
  - Experiment like proposal to foster community
  - Request for fractions of (largely) existing core posts
  - Travel funds, industry engagement fund, training
- DRD-UK Statement of Interest, submitted to STFC PPAN **Science Board** May 2024
  - Request for DRD-UK project funding (level 5% of PP funds)
  - Request for Doctoral training school
- Five submissions to **early stage R&D** research call, July 2024
  - Photon detector for vacuum ultraviolet frontier; 4D tracking detectors; Radiation Tolerant monolithic pixels; novel vacuum photon detectors for PID; common interface ASIC
  - No mid stage R&D call – fit to existing call



Industry / Infrastructure / Training

- Training
  - UK system often generating physicists with limited instrumentation experience
    - Academic hires from tenure track fellowships – largely data analysis based
  - Need for **Doctorate Training**
  - **graduate training programme** – summer school bid planned

UK HEP Instrumentation Summer School Silicon

Welcome to the first UK HEP Instrumentation Summer School! The school will be held over the first two weeks of July 2024 (1st - 12th) at Jesus College, the University of Oxford.

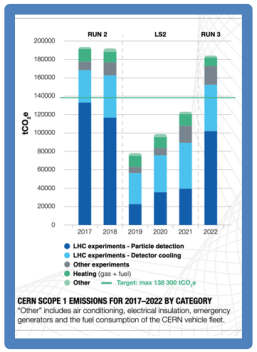
The school serves as a follow-on to the Advanced UK Instrumentation Training programme, and will feature two weeks of tutorials and hands-on exercises covering:

Photo from summer school – have asked Daniel

- Industrial engagement
  - CERN to UK industry return not well balanced
  - CG submission recommends UK **industry programme board**, **database** UK 'trusted' **suppliers**, proof of concept **technology fund**
- Major Infrastructure identified
  - e.g. Diamond, ISIS, B'ham Cyclotron, Boulby

Sustainability

- STFC considering sustainability policy, SOI options
- DRD-UK:
  - low-GWP gases for detectors
  - Low-GWP and non-PFAS liquid coolants
  - (Computing farm power consumption)



Detector aspects discussed in DRD PPAN Science Board SOI
Broad sustainability submission also made by community members (not DRD specific)
UK-HEP sustainability forum in November

Selected Take home messages

- UK organisation of DRD activities in place
- Lack of longterm funding for mid-TRL R&D in UK
- Funding schemes disfavour academic hires in instrumentation
- Awaiting feedback from STFC on proposals
  - facilitate progress with planning, MoU commitments

Strategic Review Particle Physics, December 2022

UKRI Science and Technology Facilities Council

77. There should be an increase in resources available for generic R&D for detectors and accelerators. An indicative goal would be to approach a minimum of 5% of the core programme.

Aware that with major construction projects ongoing, and schedule slippage, funds will need to ramp-up over time

- Encourage early establishing of DRD RRB for cross-country funding agency discusions

Backup

Group dimensions: Number of members (doctoral students, senior members, technicians, engineers, etc.)

- **Group financing:** Details of funding over the last 7 years
- **Group responsibilities:** Key roles in collaborations and significant results from recent years
- **Scientific output:** Number and relevance of publications, coordination positions in collaborations, theses, etc.
- **Difficulties and limitations:** This is crucial as RECFA will make recommendations to the STFC, so it is important to present our challenges.

Consolidated Grant – DRD-UK

- Following briefing document, asked to submit to CG in an “experiment-like” proposal

Part C: PPGP guidelines for bids to support the coordination of large-scale research and development (R&D) activities

8 R&D Submissions

8.1 **Scope**

8.1.1 This is a new opportunity to request funding to support the coordination of large-scale research and development activities. The purpose of this funding is to encourage strategic planning and to foster a sense of community among those involved in the R&D activity, beyond what can be reasonably expected through the CG funding provided to individual institutes.

Consolidated Grant – DRD-UK

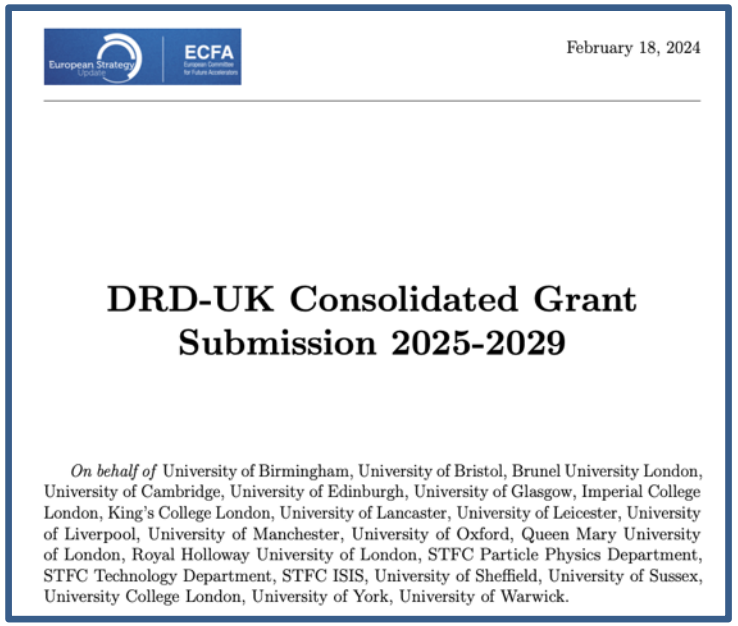
- CG submission
  - Fractions of posts to support detector R&D

Institute	DRD Collaboration 1	2	3	4	5	6	7	8	Other
Total	9.2	17.3	55.1	15.3	19.7	2.1	23.3	15.3	9.6

FTE yrs

Need dedicated project funds to effectively leverage

  - List of UK project activities for all DRDs
  - Travel
    - DRD workshops
    - Coordinators
    - Testbeam & irradiation
  - Training
  - Industry links


European Strategy Update | ECFA

February 18, 2024

DRD-UK Consolidated Grant Submission 2025-2029

On behalf of University of Birmingham, University of Bristol, Brunel University London, University of Cambridge, University of Edinburgh, University of Glasgow, Imperial College London, King's College London, University of Lancaster, University of Leicester, University of Liverpool, University of Manchester, University of Oxford, Queen Mary University of London, Royal Holloway University of London, STFC Particle Physics Department, STFC Technology Department, STFC ISIS, University of Sheffield, University of Sussex, University College London, University of York, University of Warwick.

PPAN Science Board SOI

Science and Technology Facilities Council

Strategic Review Particle Physics, December 2022

73. The UK should have an R&D portfolio that contains elements that are generic, i.e. not specialised to a specific project proposal while aligning with the European technology roadmaps. It should also include targeted involvement in feasibility studies for new projects at modest cost. The UK should invest in research projects in sustainable energy usage, e.g. in accelerator R&D. The portfolio should have both low- and high-risk elements.

77. There should be an increase in resources available for generic R&D for detectors and accelerators. An indicative goal would be to approach a minimum of 5% of the core programme. [core ~£55m per annum thus 5% is £2.75m]

PPAN Science Board, May 2024

Project title:	Uncommon Sense: Detector Research & Development for particle, astro-particle and nuclear physics
Project lead and contact email:	Chris Parkes, chris.parkes@manchester.ac.uk
STFC contact:	Sarah Verth
Institutes and groups involved in project • List the institutes and groups involved, including STFC National Laboratories University of Birmingham, University of Bristol, Brunel University London, University of Cambridge, University of Edinburgh, University of Glasgow, Imperial College London, King's College London, University of Lancaster, University of Leicester, University of Liverpool, University of Manchester, University of Oxford, Queen Mary University of London, Royal Holloway University of London, STFC Daresbury, STFC Particle Physics Department, STFC Technology Department, STFC ISIS, University of Sheffield, University of Sussex, University College London, University of York, University of Warwick.	

Establish:

- DRD-UK

Research programme average 2.9M/yr, 4 yrs

- Centre for doctoral training

Recognition of need – big success of community efforts need to translate into funding – with longterm strategy

Early Stage R&D- UK initial priority projects

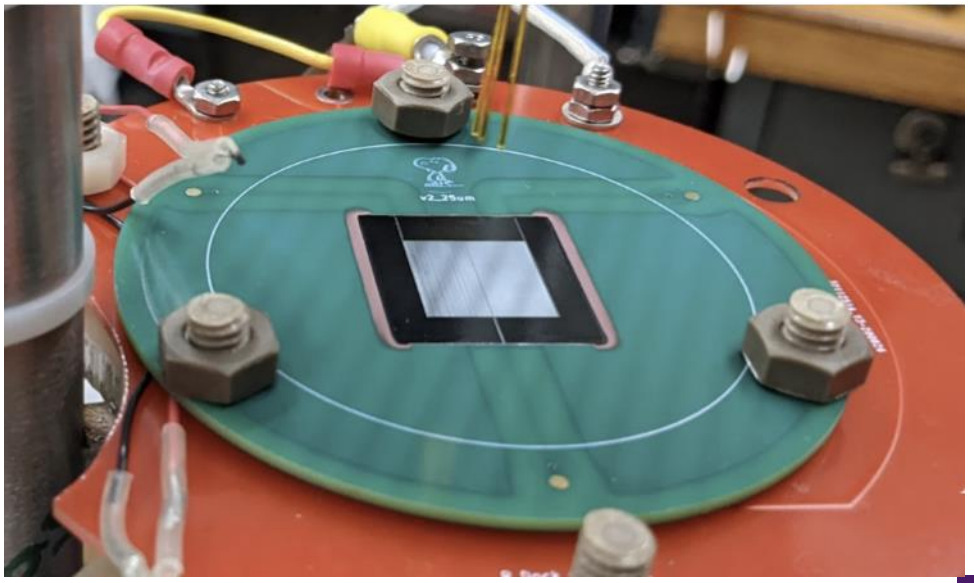
Photon Detector for Vacuum Ultraviolet Frontier

PI: Elena Gramellini

- Most light emitted in argon and xenon is in the VUV (vacuum ultraviolet) range - DUNE, DarkSide, LZ, nEXO…
- Silicon Photomultipliers (SiPMs) have typical efficiency < 20%:

  - aim for factor two (and potentially more) improvement
- Apply strategies proven in astro and medical:

  CCD, quantum optics, and digital mammography
- Use metasurfaces and novel graphene coatings on silicon and selenium

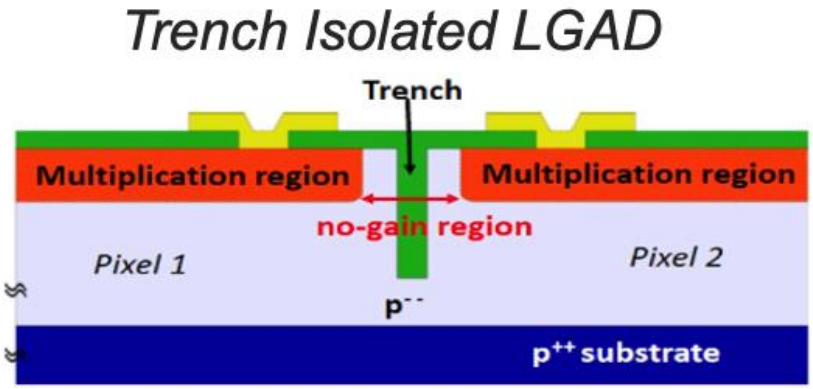


Early Stage R&D- UK initial priority projects

4D Tracking detectors

PI: Richard Bates

- Hybrid pixel detectors, LGADs, with 10ps picosecond timing with few micrometre position resolution.
- Detector with internal gain produced by impact ionisation operated at a bias where the signal to noise ratio is maximal.
- UK industry: Teledyne e2v, Micron Semiconductor Ltd
- UK companies produced LGADs with the required gain, though small pixel devices are non-trivial due to controlling the device's high-field.



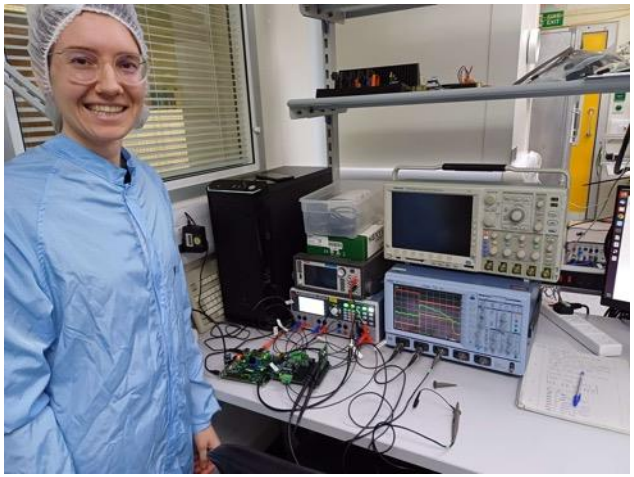
Early Stage R&D- UK initial priority projects

RAD-PIX:RADiation-tolerant monolithic PIXel

PI: Eva Vilella

- CMOS MAPS widely recognized as future of tracking detectors
- UK expertise in High Voltage CMOS sensor technology
- High radiation tolerance ($\geq 10^{16}$ n_{eq}/cm^2) and low-mass (200 μm), high spatial resolution, high data rate and low-power
- Use cases: ATLAS inner tracking replacement beyond Phase II, LHCb Upgrade II (mighty tracker), proton therapy
- Builds on/with RD50&DRD-3

& long relationship with CMOS foundry

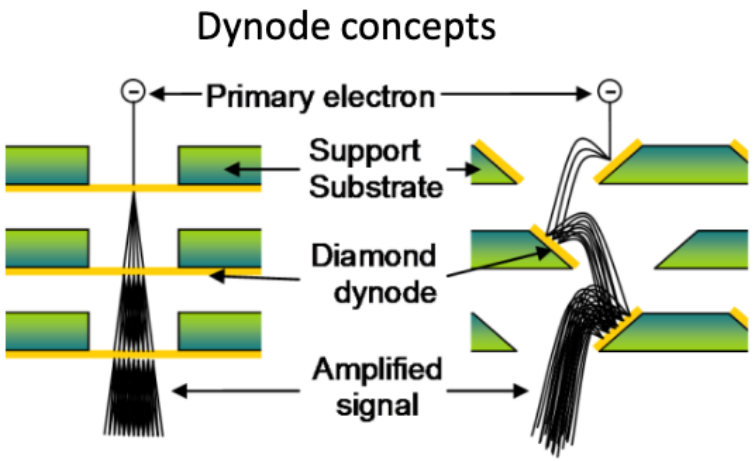


Early Stage R&D- UK initial priority projects

Novel vacuum photon detectors for PID

PI: Jon Lapington

- large area, good radiation hardness, excellent timing resobut limited lifetimes and rate capability.
- Develop novel gain structures using transmission dynode geometries to address the limitations.
- MCP-PMT with a single diamond transmission layer.
- Use cases: LHCb Upgrade II (TORCH), Belle II, SHIP, non-HEP
- Link to UK industry: Photek



Early Stage R&D- UK initial priority projects

Common interface ASIC

PI: Mark Prydderch

- Interface ASIC for detector readout, timing, and control.
- System-on-Chip (SoC) approach to the assembly of configurable, scalable interface ASICs from a library of verified sub-blocks.
- Enable experiment tailored ASICs to connect a range of specialised front-end ASICs to a common industry-standard off-detector interface (Ethernet)
- Use cases: SOLAIRE, next-generation high-intensity fixed target experiments.

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Project lead and contact email:	Chris Parkes, chris.parkes@manchester.ac.uk
STFC contact:	Sarah Verth

Institutes and groups involved in project

- List the institutes and groups involved, including STFC National Laboratories

University of Birmingham, University of Bristol, Brunel University London, University of Cambridge, University of Edinburgh, University of Glasgow, Imperial College London, King's College London, University of Lancaster, University of Leicester, University of Liverpool, University of Manchester, University of Oxford, Queen Mary University of London, Royal Holloway University of London, STFC Daresbury, STFC Particle Physics Department, STFC Technology Department, STFC ISIS, University of Sheffield, University of Sussex, University College London, University of York, University of Warwick.

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STFC Early Stage R&D

Science and Technology Facilities Council

Funding opportunity

Early stage research and development scheme 2024

Many thanks to STFC, advised to also use existing funding structures and make ~ five submissions.

- Full community discussions by UK coordinators, lead to around 30 distinct proposals.
- Steering board selected **five proposals** on short time scale
- Took account of: strategic importance to UK; scientific potential; timeliness to UK.
- Proposals each have PI and core team and are integrated with and will support the full UK communities working in their areas.

This is not the DRD-UK programme – it is a first set of interests
DRD is mid-TRL levels. Strategic long-term programme.