STFC Early-Stage research and development scheme: Intention to submit (ItS)

To apply for the STFC Early-stage research and development scheme, all applicants are required to complete the below pro forma and submit it to **KEGroup@stfc.ac.uk**

Please title the email **Early-Stage research and development scheme ItS**

Any applications received which have not submitted this this version of the form will not be accepted.

These ItS will be assessed internally by a sift panel who will determine if the project is eligible for the scheme. They will determine if

- the applicant and lead institution meets the STFC criteria for holding a grant.
- the project TRL is suitable for the scheme
- the project has been developed from STFC science and fits within the STFC remit
- the project is of potential benefit to the PPAN community and/or the wider UK community

Applicant details

Lead applicant name:	Iain Sedgwick
Lead applicant e-mail:	iain.sedgwick@stfc.ac.uk
Lead institution:	STFC RAL

If the project is planned as part of a larger collaboration, please state the names and affiliations of all partner organisations	**Imperial College London:** Paul Dauncey **STFC-RAL**: Seddik Benhammadi, Jens Dopke, Nicola Guerrini, Herman Larsen, Iain Sedgwick, Fergus Wilson. **University of Birmingham**: Laura Gonella, Karol Krizka, Nigel Watson. **University of Sussex**: Fabrizio Salvatore.
Project details	CMOS sensors; 3D stacked imaging technology; tracking detector; digital electromagnetic calorimeter.
Please state the proposed title of the project:	A 3D stacked, reconfigurable CMOS sensor for tracking and digital electromagnetic calorimetry.

Please mark with an X the relevant box, stating the remit area you work in

Quantum Science	Particle physics	Astronomy	Particle astrophysics	Solar and planetary science	Nuclear Physics	Accelerator science	Supporting Computing science	Other (please state)
	X							

Please mark with an X the relevant box, stating the remit area the project is looking to target

Quantum Science	Particle physics	Astronomy	Particle astrophysics	Solar and planetary science	Nuclear Physics	Accelerator science	Supporting Computing science	Other (please state)
	X							X-rays and cryo-electron microscopy

Science and Technology Facilities Council

Please provide a brief (less than 300 words) overview of the project, including high level aims and objectives
This project will progress the development of a reconfigurable CMOS sensor taking advantage of 3D stacked CMOS imaging technology. The proponents have already worked on two prototype iterations in a 180 nm CMOS imaging process, the DECAL sensor. This sensor features demonstrated reconfigurable readout options for use in outer tracking and pre-shower detectors in strip mode, and in digital electromagnetic calorimeter (ECAL) detectors in pad mode, presenting a cost-effective solution to instrument thousands of square meters at future experimental facilities. 3D technology is the optimal choice to continue the development of this sensor. The decoupling of sensor and analogue functionality on one layer, from the digital functionality on a separate layer, enables higher logic density in a smaller pixel pitch with respect to monolithic CMOS sensors at the same technology node. The technology also has the potential for reduced power consumption and offers stitching with a larger number of metal layers to enable efficient power and signal distribution and higher yield. The 3D DECAL development could integrate higher reconfigurability within a smaller pixel size and a low power budget, in a larger size device. It will deliver the capability of counting pixels per cluster needed for digital ECAL, enable high precision tracking and integration in large digital ECAL systems, and provide device sizes compatible with large area coverage, at a lower price than finer CMOS imaging nodes. In this first iteration, the proponents aim at adding a third readout mode to the DECAL sensor for use as a pixel detector in inner layers, while decreasing the 55 μm pixel pitch of the existing prototypes, and optimising the pixel front-end design for low power. The development will be made using the TowerJazz 180 nm 3D CMOS imaging process, offered in one of the four annual MPW runs at this foundry.

Please provide a brief (less than 300 words) overview of • who the project will benefit • how the project has been developed from STFC science and technology

Science and Technology Facilities Council

This project will benefit the international and UK DRD efforts in the development of key technologies identified by the ECFA roadmap to enable the ambitious physics programme at future experimental facilities. It proposes a strategic R&D project on reconfigurable 3D CMOS sensor for use in pixel, tracking, pre-shower and digital ECAL systems. The work is aligned with the DRD-UK tasks 3.3 and 6.1, and with the ECFA DRDT 3.4, 6.1 and 6.2. This proposal will provide the basis for a larger international collaboration within the international DRD3 and DRD6 efforts with colleagues at DESY, Humboldt University of Berlin, National Technical University of Athens, SLAC, University of Oregon who expressed interest in this development.

This work will be the first demonstration of the use of a commercial 3D CMOS imaging technology for application in particle physics, and it will present an opportunity to gain expertise in this technology for other applications that could significantly benefit of its advantages over standard CMOS imagining processes. In particular, 3D stacking technology distinctive advantages in terms of signal and power distribution will be capable of underpinning larger and faster detectors for X-rays and cryo-electron microscopy. Large sensors for 100keV electron microscopy will benefit from proven and reliable 3D integration. The proximity between pixel and progressing/storing electronics is also ideal for large and ultra-fast burst mode imagers, a niche but growing market.

The expertise of the proponents, the use of an already prototyped sensor design and of a process offered already for large volume commercial applications will de-risk the project.

Previous work on the DECAL sensor [1-5] was funded through the STFC grant ST/N002911/1 and it has reached TRL 4.

[1] P. P. Allport et al. “First tests of a reconfigurable depleted MAPS sensor for digital electromagnetic calorimetry”. In: *Nucl. Instrum. Meth. A* 958 (2020), p. 162654. DOI: 10.1016/j.nima.2019.162654.
[2] Seddik Benhammadi et al. “DECAL: A Reconfigurable Monolithic Active Pixel Sensor for use in Calorimetry and Tracking”. In: *PoS* TWEPP2019 (2020), p. 040. DOI: 10.22323/1.370.0040.
[3] P. Allport et al. “A reconfigurable CMOS sensor for tracking, pre-shower and digital electromagnetic calorimetry”. In: *Nucl. Instrum. Meth. A* 978 (2020), p. 164459. DOI: 10.1016/j.nima.2020.164459.
[4] I. Kopsalis et al. “Evaluation of the DECAL Fully Depleted monolithic sensor for outer tracking and digital calorimetry”. In: *Nucl. Instrum. Meth. A* 1038 (2022), p. 166955. DOI: 10.1016/j.nima.2022.166955.
[5] Philip Patrick Allport et al. “DECAL: A Reconfigurable Monolithic Active Pixel Sensor for Tracking and Calorimetry in a 180 nm Image Sensor Process”. In: *Sensors* 22.18 (2022), p. 6848. DOI: 10.3390/ s22186848.