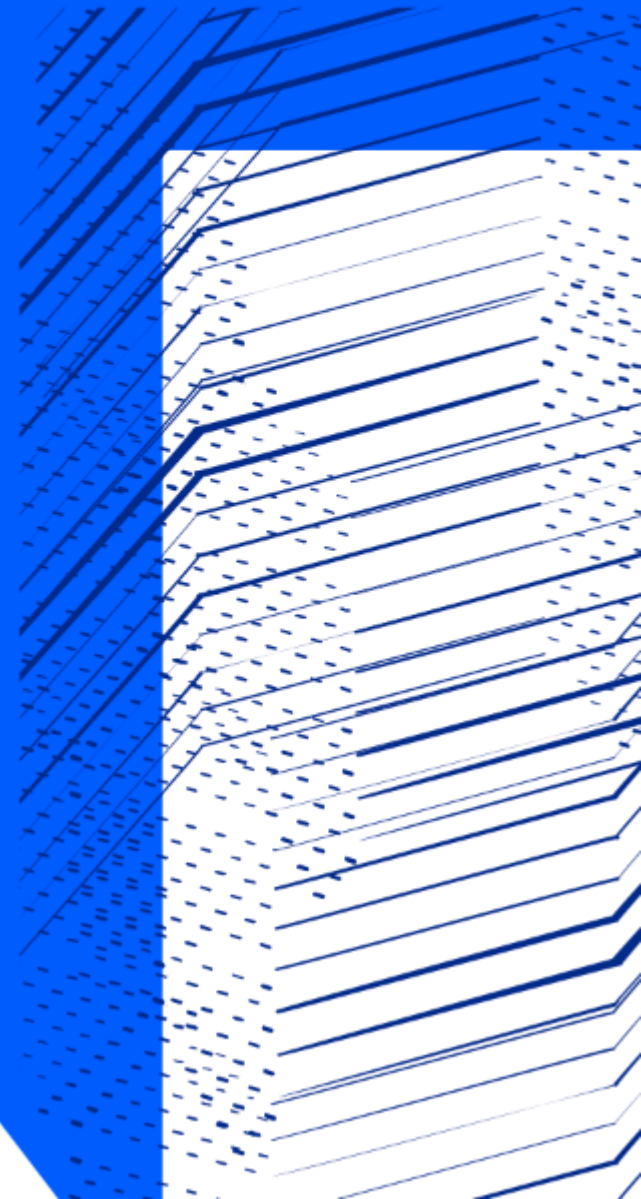




Science and
Technology
Facilities Council

CMOS Sensor Development for Particle Physics in TD

26/04/2023



Agenda

1 CMOS Sensor Design Group

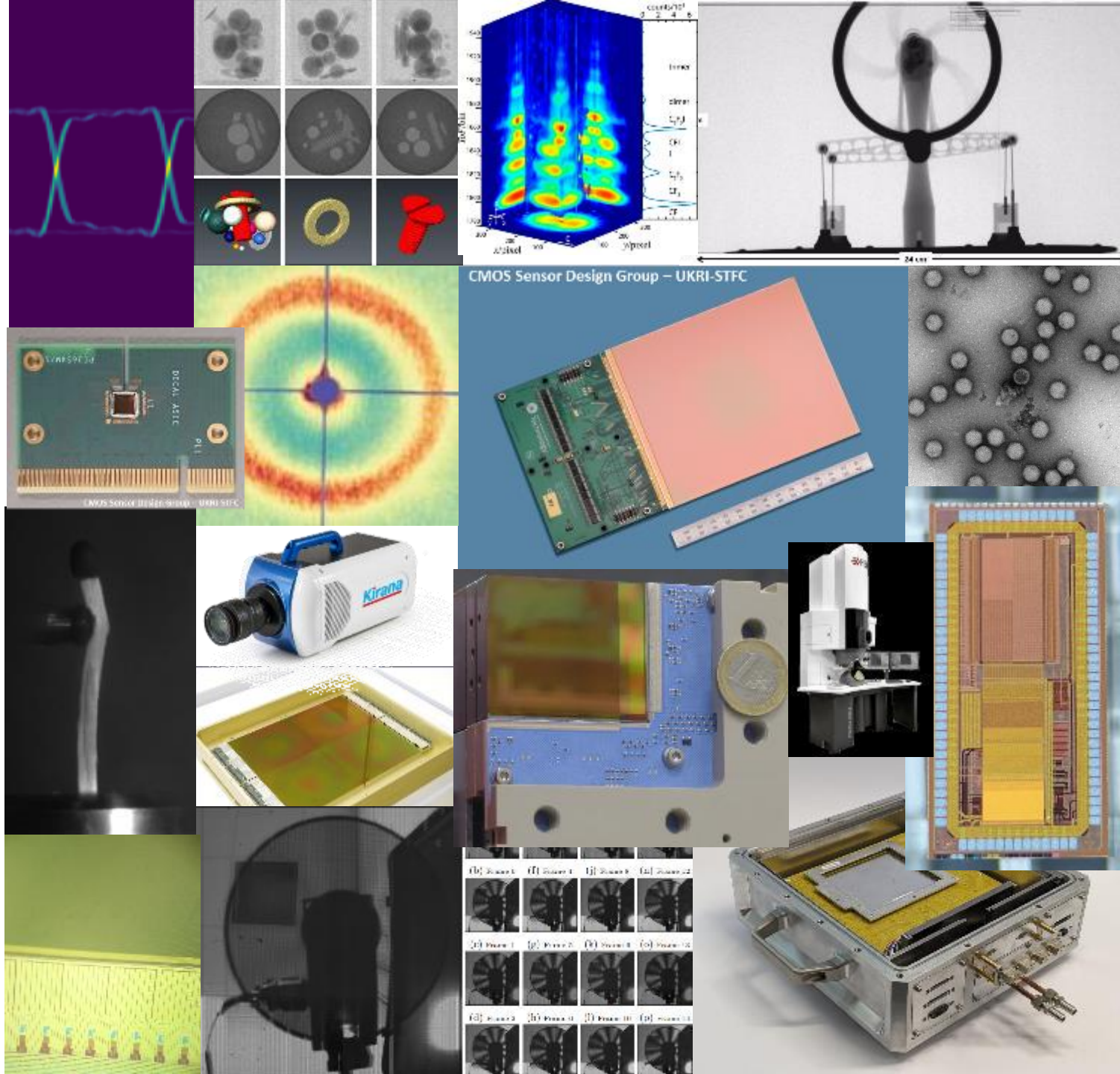
- 8 Designers, 1 Test Engineer
- Group Leader: Nicola Guerrini
- Share office with ASIC Design Group

2 Particle Physics Activities

- Electron Ion Collider/ITS3
- DECAL
- DRD Programme
- MALTA3

3 Other Activities

- Electron Microscopy: TEMAPS, QEM, C100
- Soft X-ray: PERCIVAL
- Raman Spectrometry: IRIS
- High Speed Imaging: KIRANA, TPM
- Large Area X-ray: LASSENA



Electron Ion Collider/ALICE ITS3

What and Why?

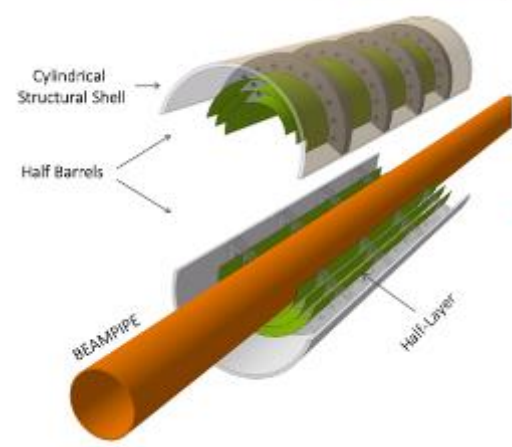
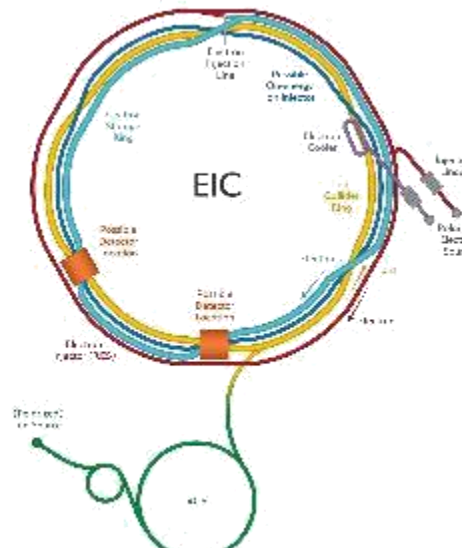
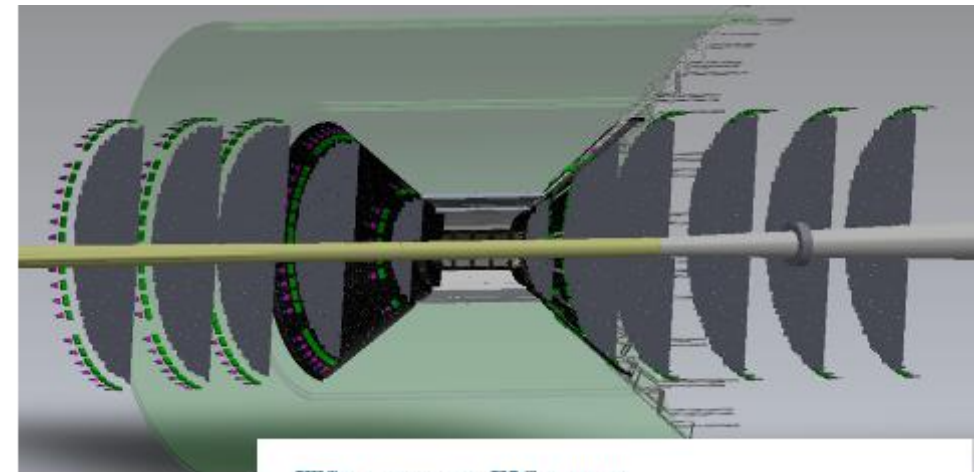
- **The EIC** will be built at BNL to study role of quarks and gluons in proton structure.
- 65nm chip envisioned for the ALICE ITS3 upgrade has very similar specifications, so the goal is to use the same chip.
- Project is therefore also an opportunity to engage with CERN and work at a 65nm CIS node.

Other Personnel/Institutes Involved

- PPD, Brunel, Birmingham, Lancaster, Daresbury, Liverpool, Oxford

Schedule and Funding

- Machine operational ~2030
- UKRI Infrastructure Fund
 - Preliminary Activity
 - Full Proposal



ITS3 sensor vs. EIC sensor

- The ITS3 sensor specifications even **exceed the EIC requirements**
 - Chosen technology: TJ 65 nm imaging process (ISC)
 - **Higher granularity and lower power consumption** with respect to current simulation baseline (ITS2/ALPIDE-like)
 - **Shorter integration time, lower fake hit rate** (and better time resolution) than required at the EIC

Specifications		
Parameter	ALPIDE (prototype)	ITS3 sensor (this proposal)
Technology node	65 nm	65 nm
Detector thickness	20 μm	20 μm
Pixel size	21 x 21 μm	15 x 15 μm
Chip dimensions	1.1 x 1.1 cm	1.0 x 1.0 cm
Power and volume density	1 W/cm²	0.5 W/cm²
Integration time	1 μs	0.5 μs
Material budget	1.00 MIP/cm²	0.50 MIP/cm²
Max particle rate/cm²	100 MIP/cm²	100 MIP/cm²
Power consumption	40 mW/cm²	20 mW/cm²
Integration efficiency	1.00%	1.00%
Pixel size	21 x 21 μm	15 x 15 μm
Pixel readout frequency	1 x 10⁷ Hz/cm²	1 x 10⁷ Hz/cm²
Time resolution	2.5 ns	1.5 ns

Preliminary EIC MAPS sensor requirements compiled by Birmingham & RAL CMOS

Parameter	EIC (Birmingham & RAL CMOS)
Technology	65 nm
Detector thickness	20 μm
Pixel size	21 x 21 μm
Chip dimensions	1.1 x 1.1 cm
Power and volume density	1 W/cm²
Integration time	1 μs
Material budget	1.00 MIP/cm²
Max particle rate/cm²	100 MIP/cm²
Power consumption	40 mW/cm²
Integration efficiency	1.00%
Pixel size	21 x 21 μm
Pixel readout frequency	1 x 10⁷ Hz/cm²
Time resolution	2.5 ns

[1] From EIC white paper, [2] ITS2/ALPIDE specification

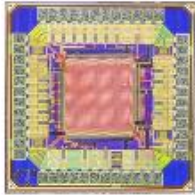
Electron Ion Collider/ALICE ITS3

Ongoing Work

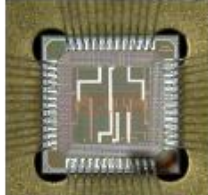
- Submitted various circuit blocks in 65nm
 - LVDS-CML drivers and receivers
 - I2C block
 - PLL
- Support to development of high yield logic for MOSS
- Currently working on SLDO for serial powering and other 65nm IPs



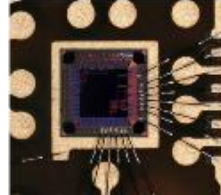
APTS (CERN)



DPTS (CERN)



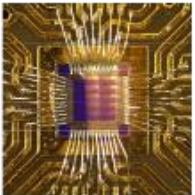
RO (CPPM)



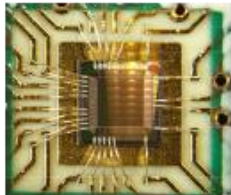
Pixels (DESY)



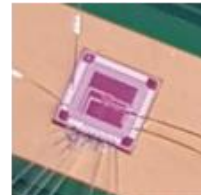
CE65 (IPHC)



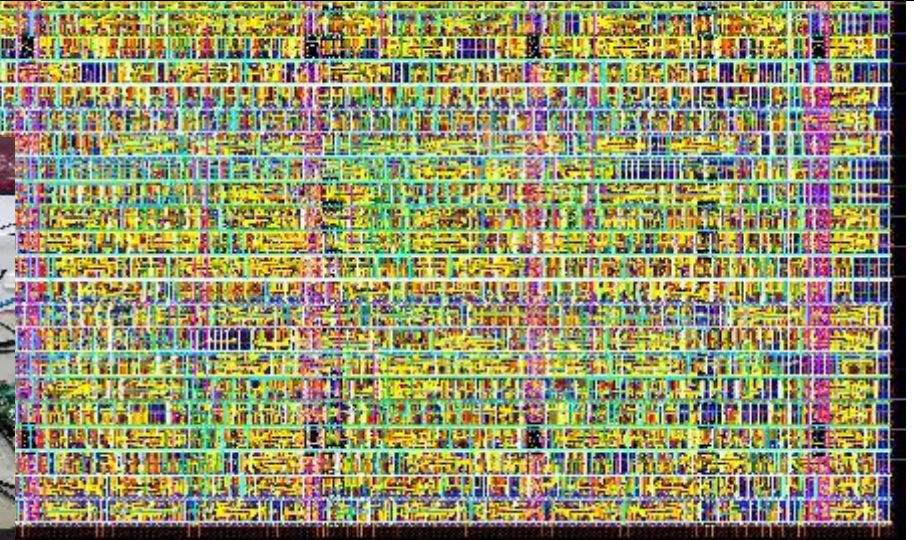
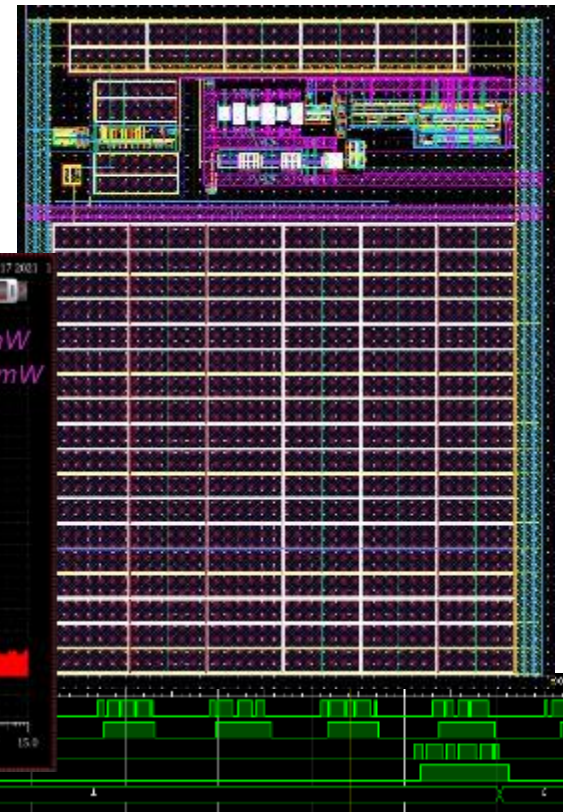
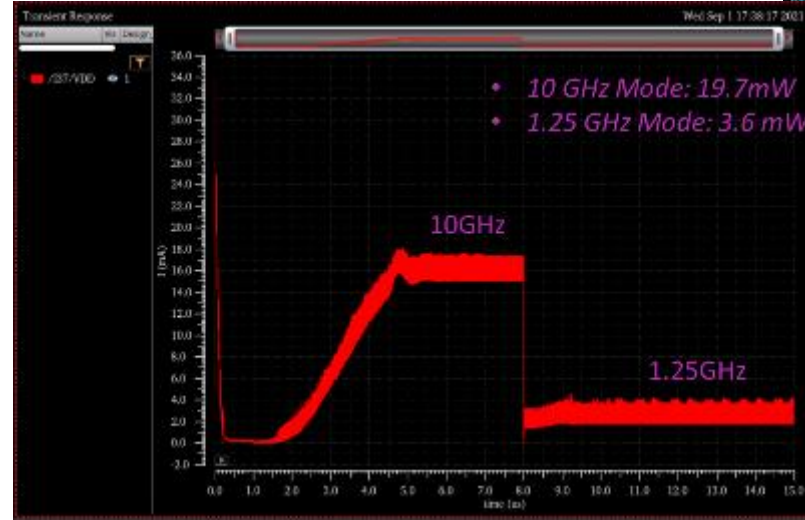
Bandgap (NIKHEF)



VCO (NIKHEF)



CML (RAL)



Science and
Technology
Facilities Council

DECAL

What and Why?

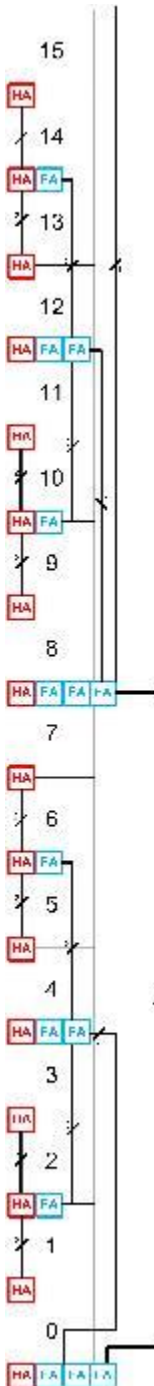
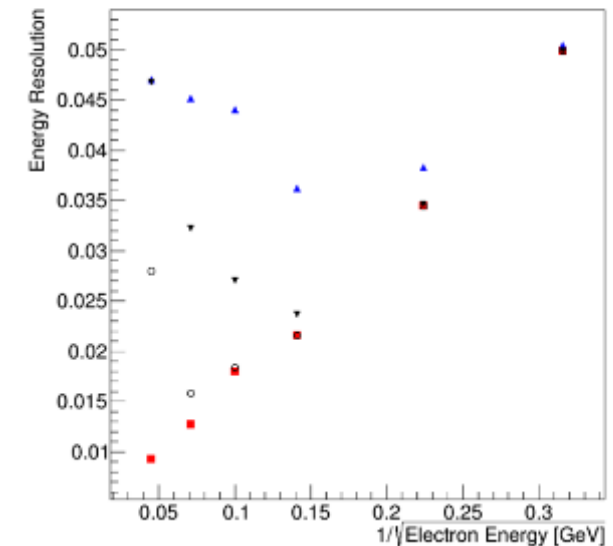
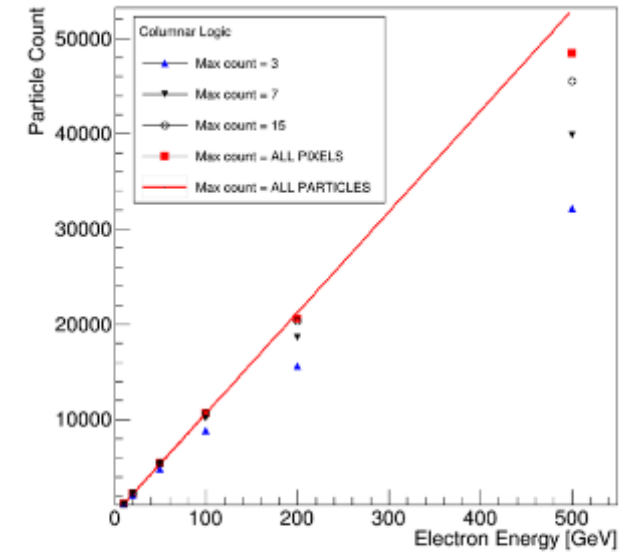
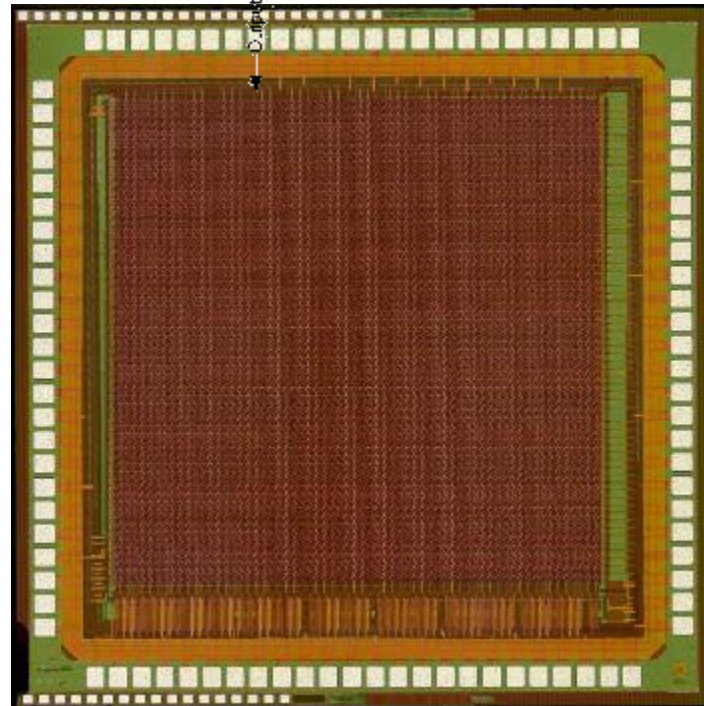
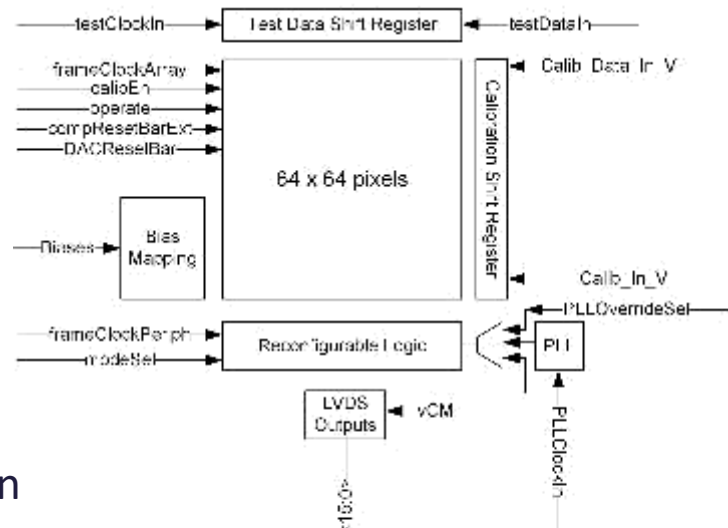
- Demonstrator chip for Digital Electromagnetic Calorimetry
- Re-configurable to operate as strip tracker
- Counts hits/chip (pad) or hits/column (strip)
- Goal is to reduce costs with re-configurable chip

Other Personnel/Institutes Involved

- PPD, Birmingham, DESY, UCL, Humboldt

Schedule and Funding

- Currently none
- Some idea to submit a proposal to DRD6



DRD Programme

What and Why?

- CERN's programme for Research and Development
- Currently starting up
- Aiming for Letter of Intent and collaboration forming later this year

Other Personnel/Institutes Involved

- Very many...
- In TD: Marcus French, Iain Sedgwick, Mark Willoughby (DRD7)...

Schedule and Funding

- Idea is that DRD approval will help release money from funding agencies

DRD1: Gaseous Detectors

DRD2: Liquid Detectors

DRD3: Solid State Detectors

DRD4: Photon Detectors and PID

DRD5: Quantum and Emerging Technologies

DRD6: Calorimetry

DRD7: Electronics and On-detector processing

DRD8: Integration

DRD9: Training

MALTA3

What and Why?

- MALTA family is technology demonstrator for high granularity, high radiation hardness MAPS
- Approached about providing previously developed high speed serialiser to be used in the design

Other Personnel/Institutes Involved

- CERN

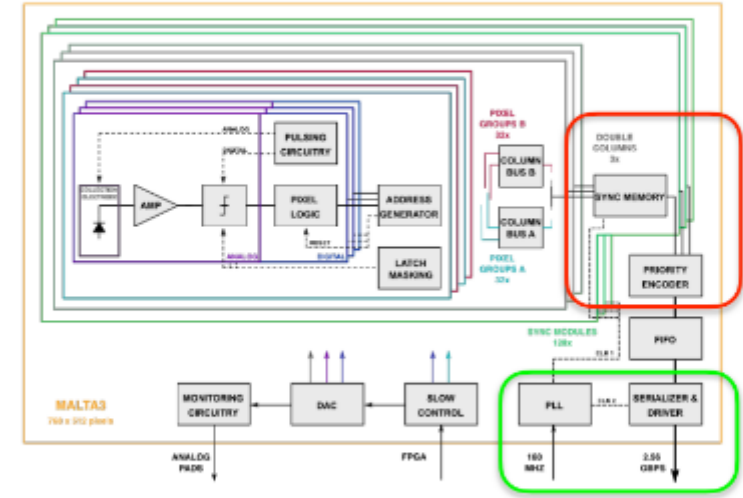
Schedule and Funding

- Currently none
- Some Cfl last year, but difficult to respond rapidly to such requests

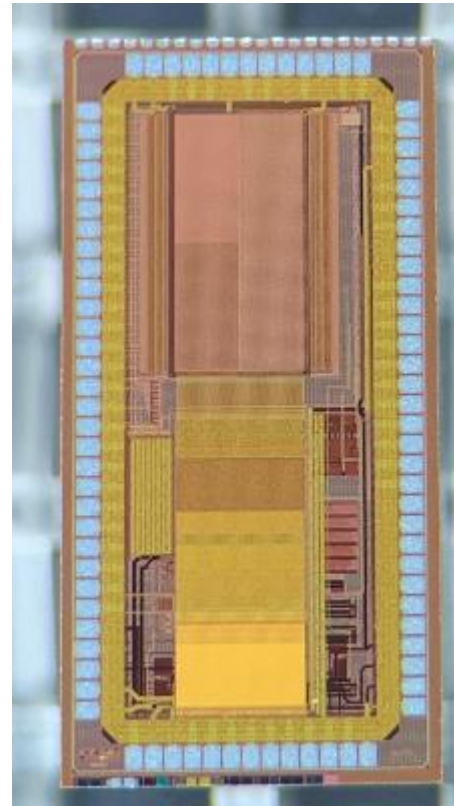
Outlook: MALTA3 with integrated hit time tagging

- Integrate time-stamping and data serialiser directly on sensor in periphery
- Developed in same TJ180 process as MPW chip (submission 2023)

- Modular 24-column block design to scale to desired sensors matrix size up to full-reticle size (2x3 cm)
- Improved timing reference pulse and masking

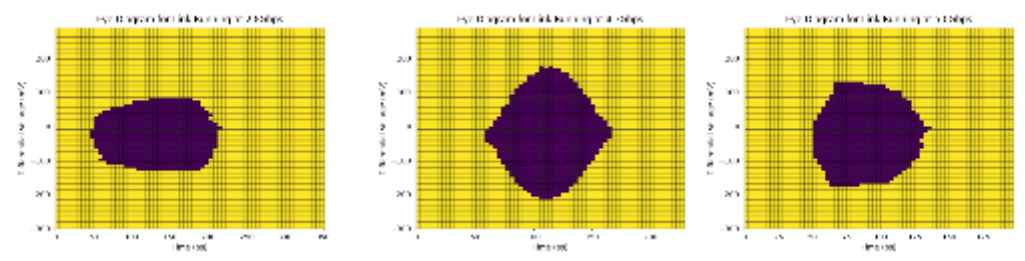


New for MALTA3 5-bit fine time synchronisation memory & readout logic



stamping of
s on-chip
stamping logic
3GHz
ized high-
output

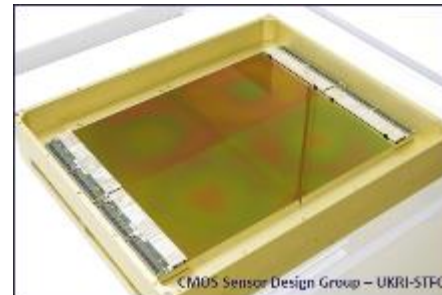
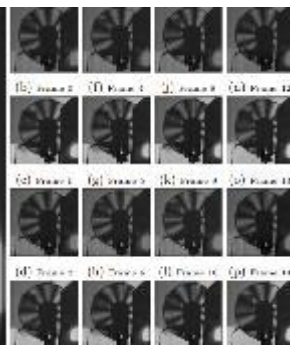
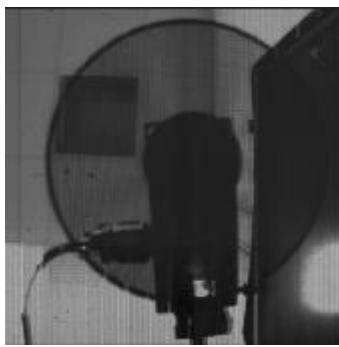
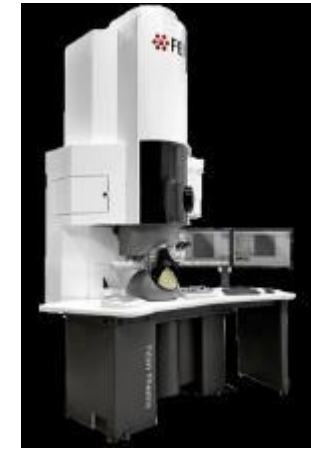
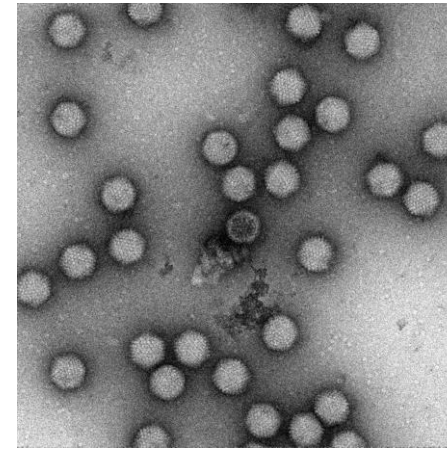
Block diagram of MALTA3
STFC "Precise" chip (PLL & serialiser already demonstrated on silicon)
D. Dobrijevic TWEPP 2022



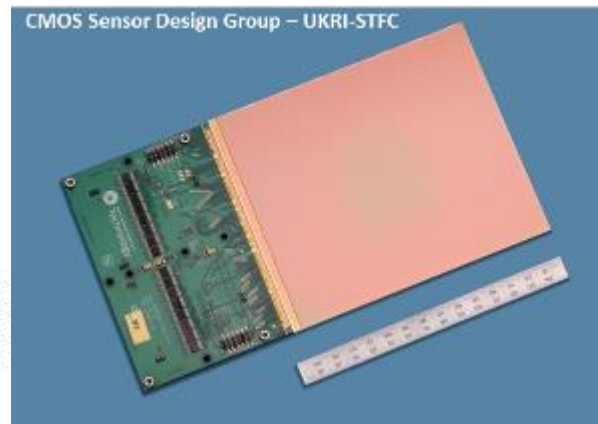
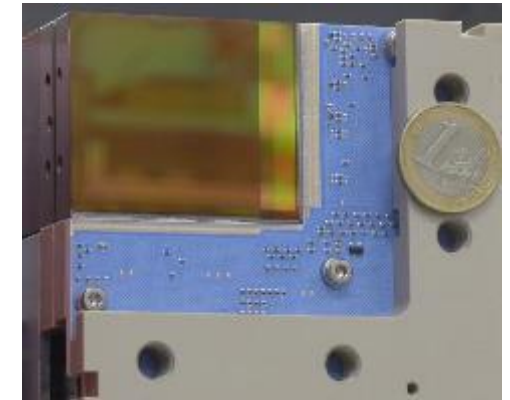
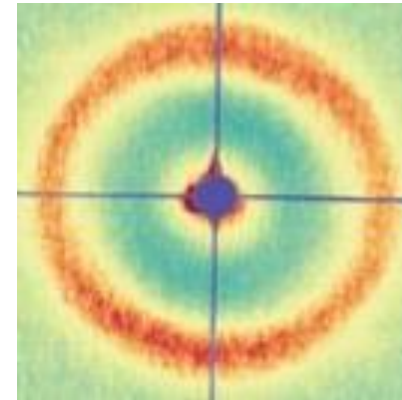
Other Activities

Also active in other fields

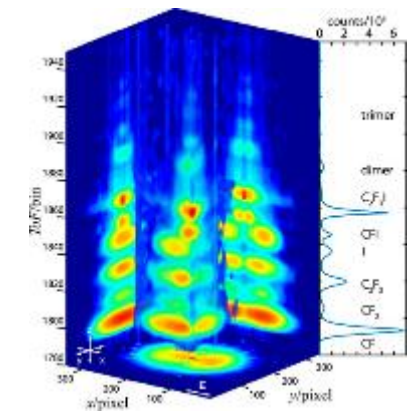
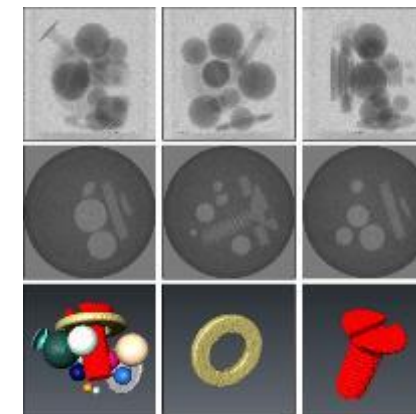
- Electron Microscopy: TEMAPS, QEM, C100
- Soft X-ray: PERCIVAL
- Spectrometry: PImMS, IRIS
- High Speed Imaging: KIRANA, TPM
- Large Area X-ray: LASSENA



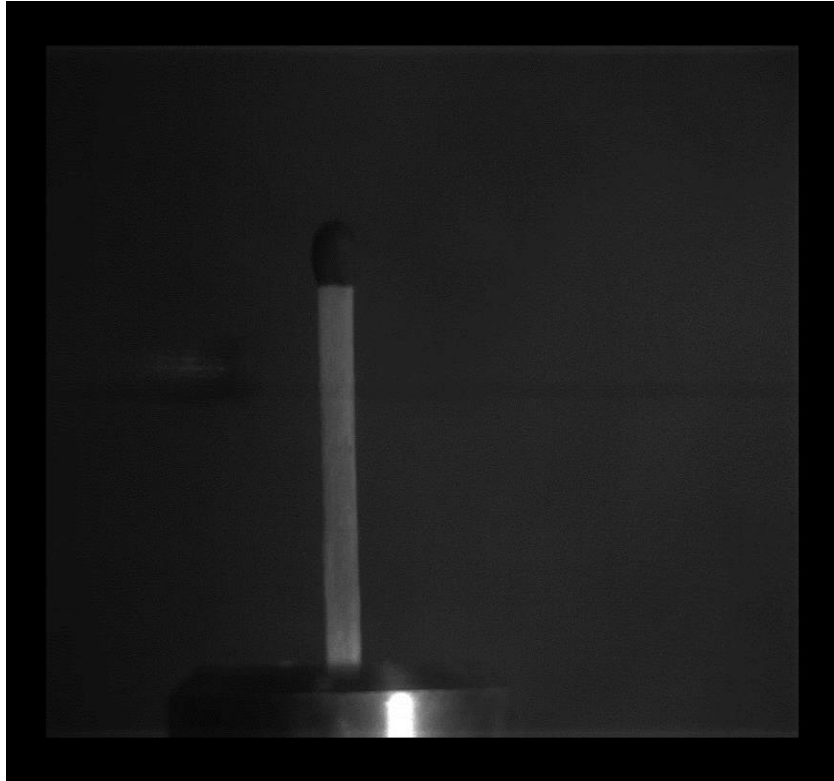
CMOS Sensor Design Group – UKRI-STFC



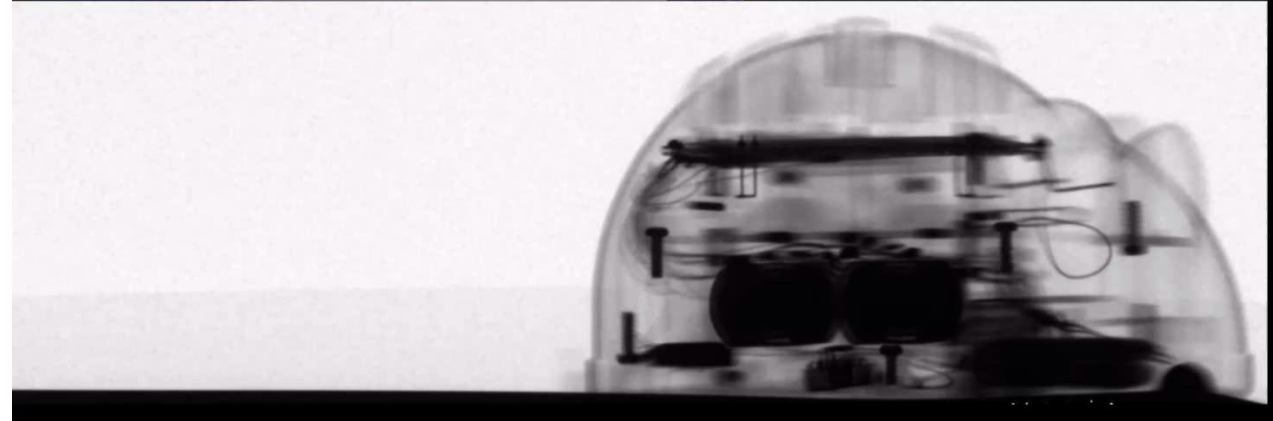
CMOS Sensor Design Group – UKRI-STFC



Thanks for your attention!



This X-ray video is taken using the Lassena Wafer Scale CMOS sensor developed by STFC. Four sensors were used here and combined into a single detector. The sensors are 12 cm x 14 cm, 6.7 MPixels and can operate at 30 frames per second. This results in the whole detector having 26.8 MPixels and an area of 24 cm x 28 cm. The detector can generate 1.5 GB of images per second. The image sensors are inefficient at detecting X-rays, therefore a Scintillator is used as the X-ray detection medium. The X-rays are converted into 550 nm light by the scintillator that is then detected by the image sensor. The scintillator used in this detector is Caesium Iodide doped with Thallium.





Science and
Technology
Facilities Council

Thank you



Science and Technology Facilities Council



@STFC_matters



Science and Technology Facilities Council