

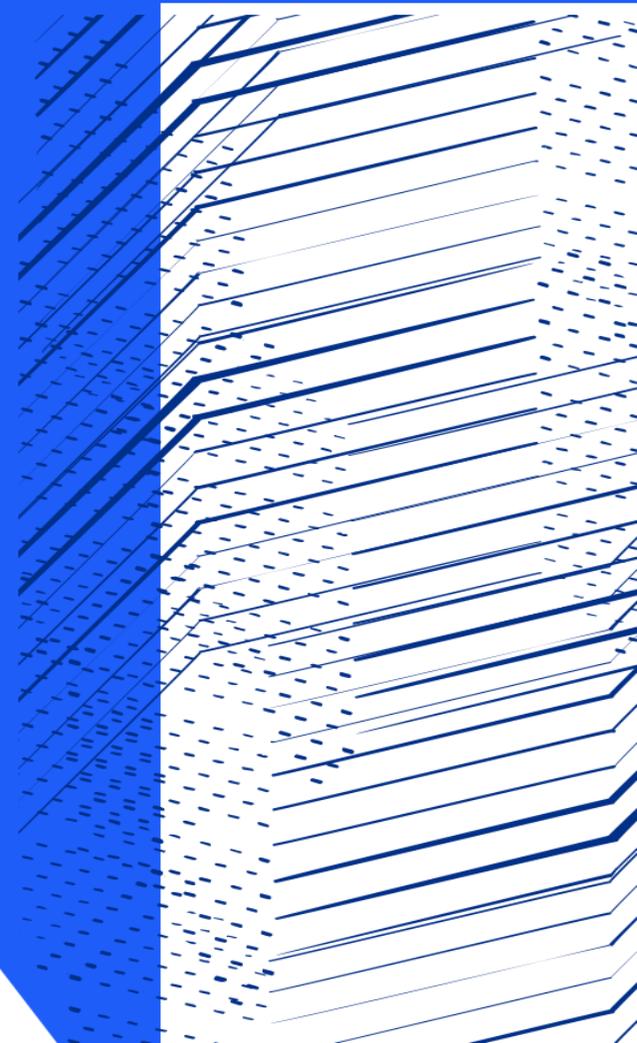


Science and
Technology
Facilities Council

An overview of HEXITEC and HEXITEC MHz and its applications

Dr Diana D Caprotti et al

8th of July 2025



Agenda

1 Who are we - UKRI-STFC-RAL

An introduction to the UKRI Science and Technologies Facilities Council Rutherford Appleton Laboratory.

2 HEXITEC

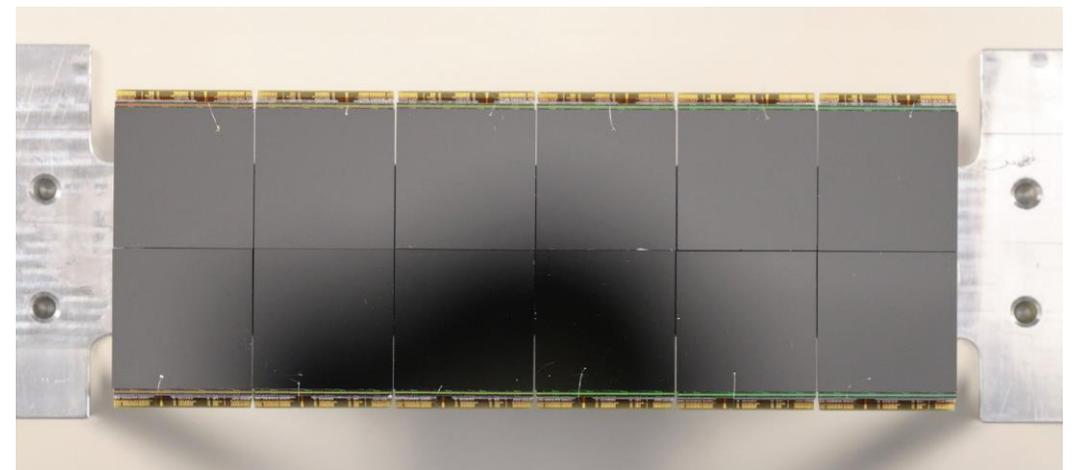
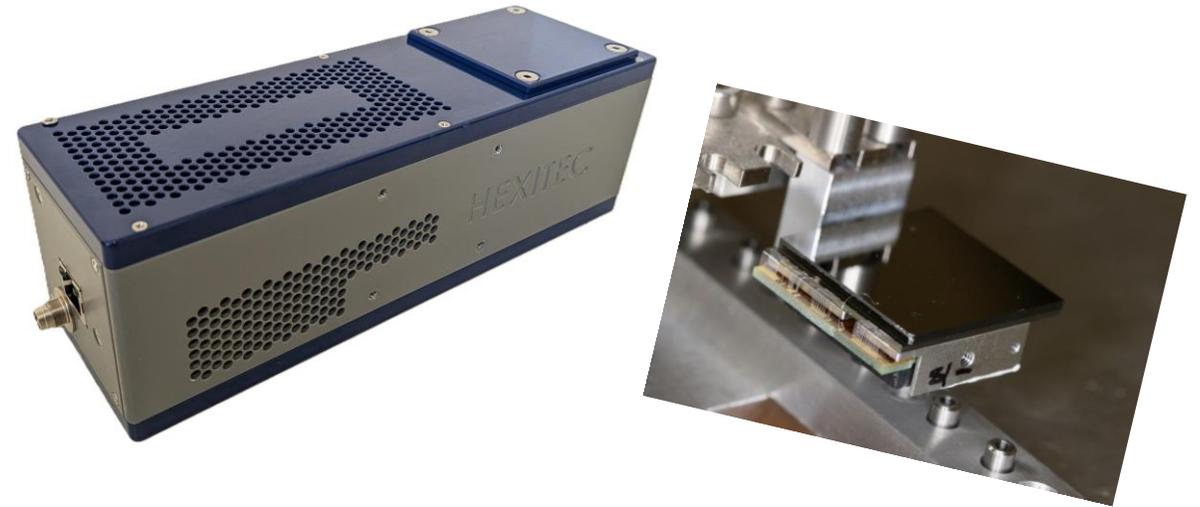
Introducing the latest version of the technology, its architecture, initial results and camera status

3 HEXITEC applications

An overview of some of HEXITEC applications - credit to our collaborators

4 HEXITEC_{MHz}

Introducing the latest version of the technology and latest results



Who we are



Department for
Science, Innovation
& Technology



UK Research
and Innovation



Science and
Technology
Facilities Council



Arts and
Humanities
Research Council



Engineering and
Physical Sciences
Research Council



Biotechnology and
Biological Sciences
Research Council



Economic
and Social
Research Council



Research
England



Natural
Environment
Research Council



Innovate
UK



Medical
Research
Council



Science and
Technology
Facilities Council

Who we are



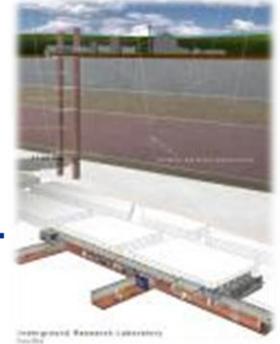
UK Astronomy Technology Centre
Edinburgh, Scotland



Polaris House
Swindon, Wiltshire



Boulby Underground Laboratory
North Yorkshire



Daresbury Laboratory
Sci-tech Daresbury Campus, Liverpool City Region



Rutherford Appleton Laboratory
Harwell Didcot, Oxfordshire



Chilbolton Observatory
Stockbridge, Hampshire



...and around the world

Who we are

Rutherford Appleton Laboratory



Home to:

Central Laser Facility



ISIS



Diamond Light Source



RAL Space

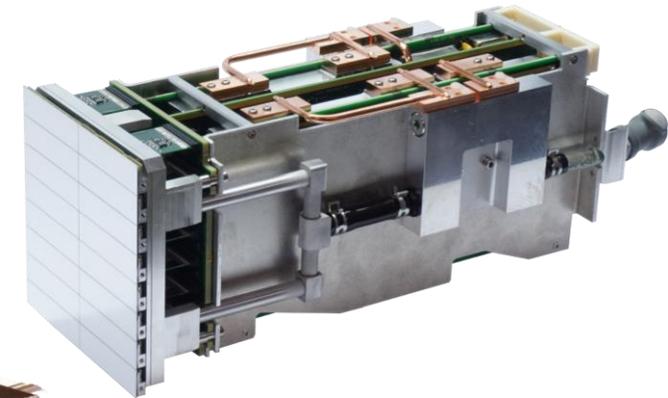
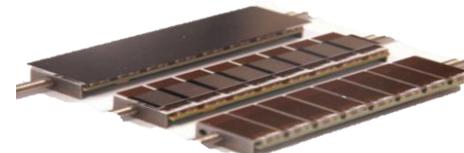
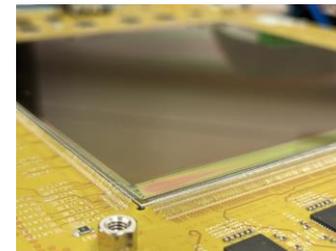
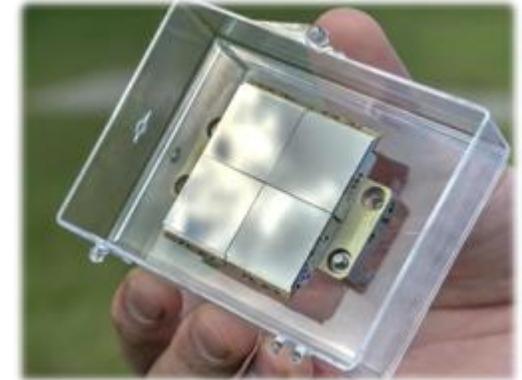
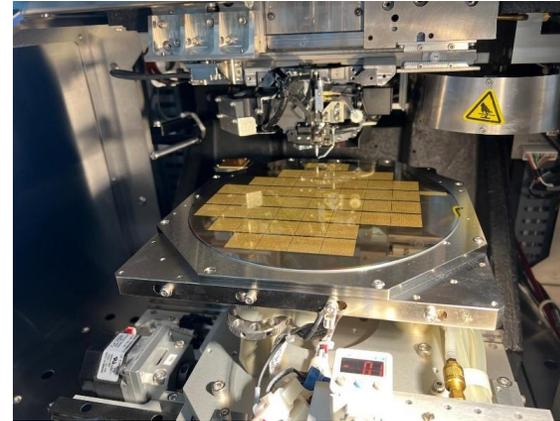
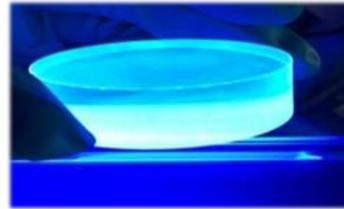
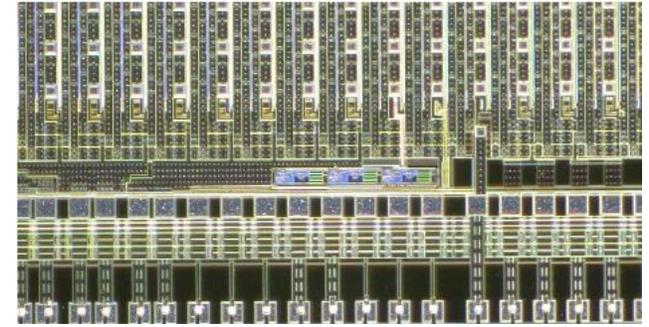


Who we are

Technology's Detector and Electronics Division

- ASIC design
- CMOS sensors design
- Detector Development
- Electronics system design
- Interconnect

One stop shop for detector systems



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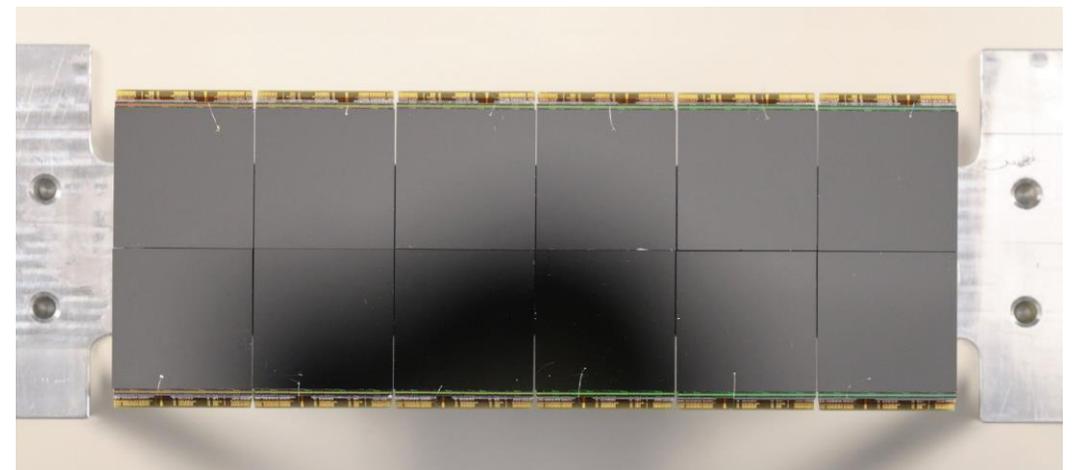
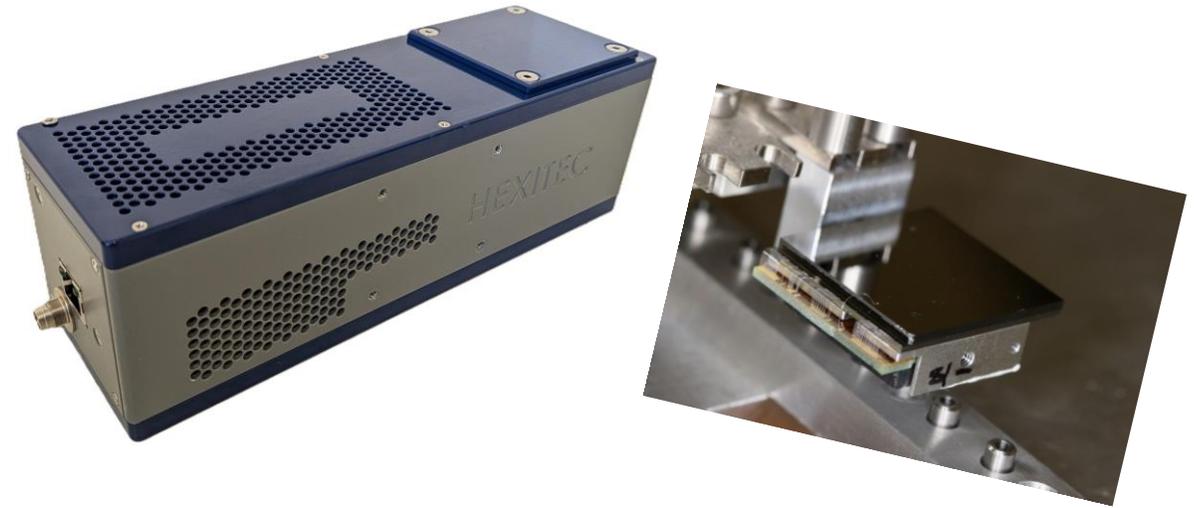
An overview of the HEXITEC system

3 HEXITEC applications

An overview of some of HEXITEC applications - credit to our collaborators

4 HEXITEC_{MHz}

Introducing the latest version of the technology and latest results



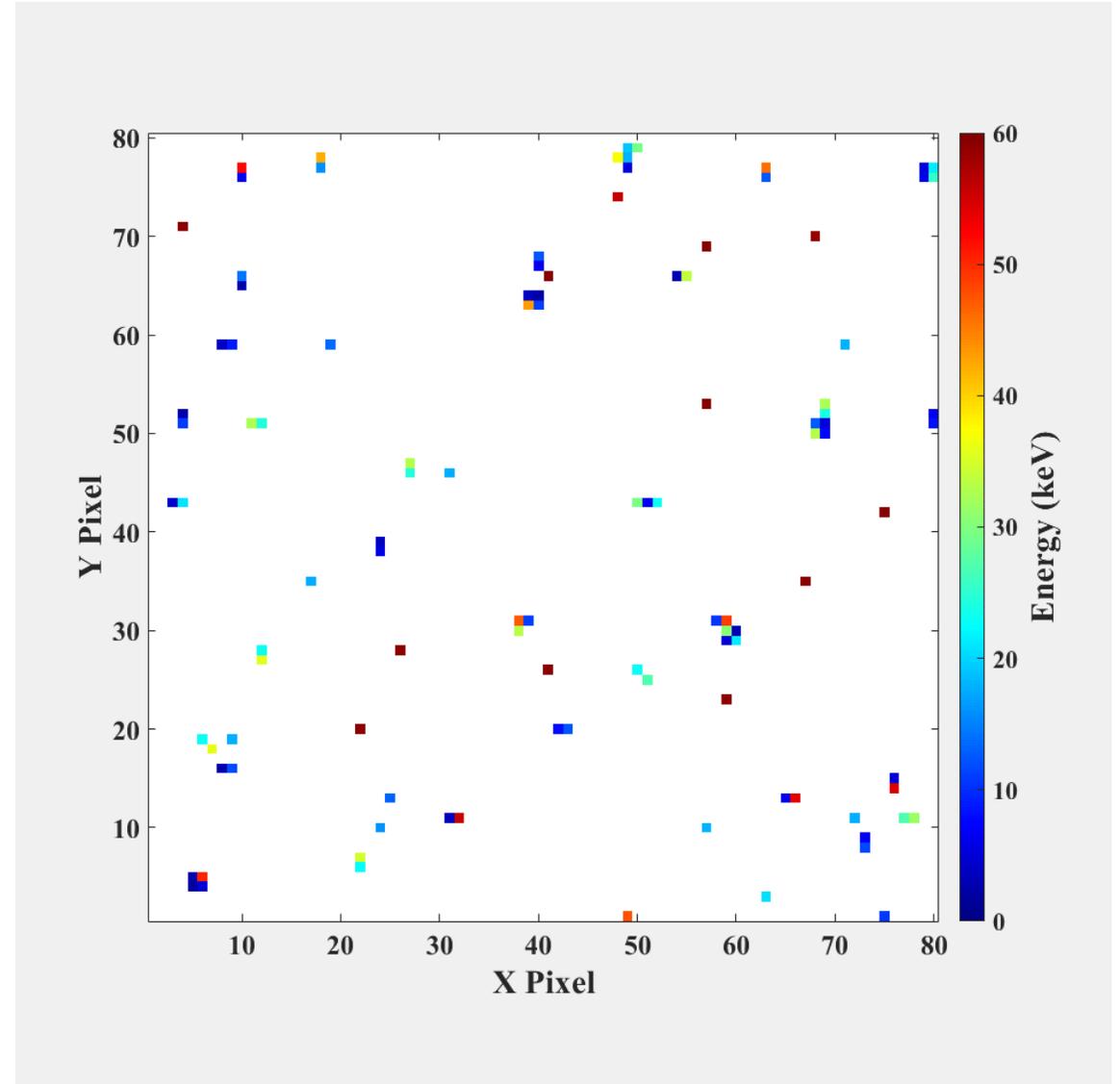
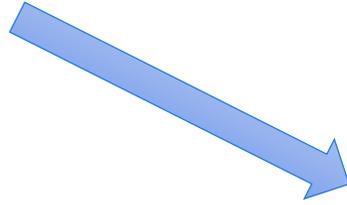
The HEXITEC system

- Priority: High resolution hard X-ray spectroscopy
- 250 μm pixel pitch choice
 - Limited charge sharing events
 - Moderate spatial resolution
- 20 \times 20 test chip delivered in 2009
- Full 80 \times 80 system delivered in 2014
- 2014+ large area systems delivered

Parameter	Value
Pixel Pitch (mm)	250
Array Size	80 \times 80
Max Frame Rate (kHz)	9.3
High Gain (keV)	2 – 200
Low Gain (keV)	6 – 600
FWHM _{@60keV} (keV)	< 1
Max flux rate (photons s ⁻¹ mm ⁻²)	< 2 \times 10 ⁴

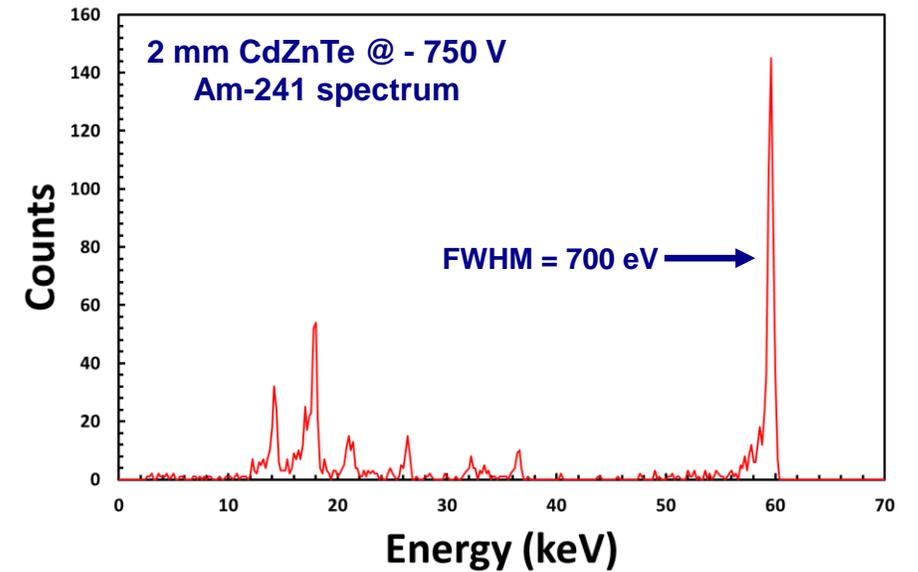
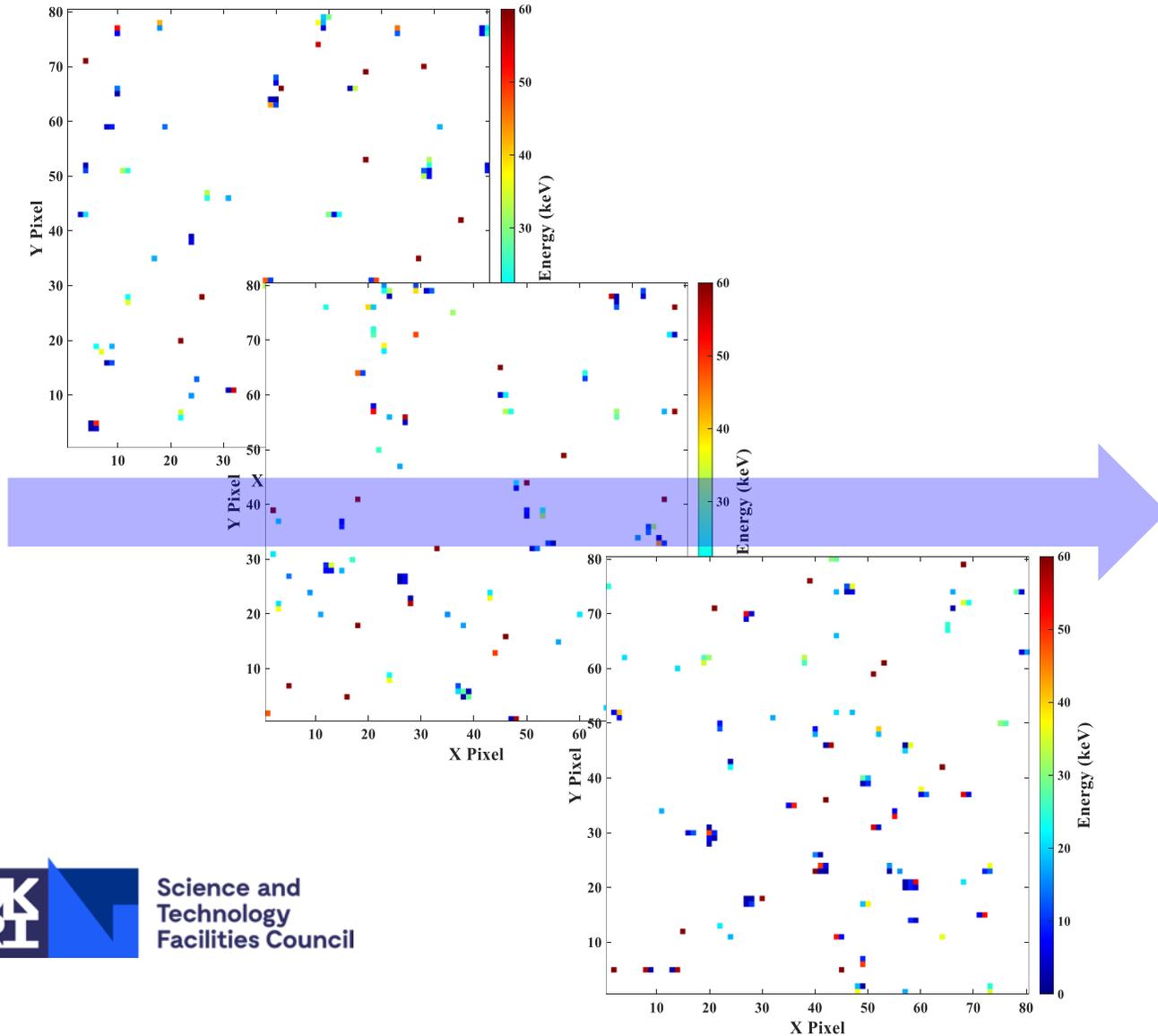
The HEXITEC system

- Examples of typical frames of data
- 2mm CdZnTe sensor @ - 750 V
- 2 keV noise threshold applied
- $y = mx + c$ calibration
- HEXITEC records the position and energy of each interaction



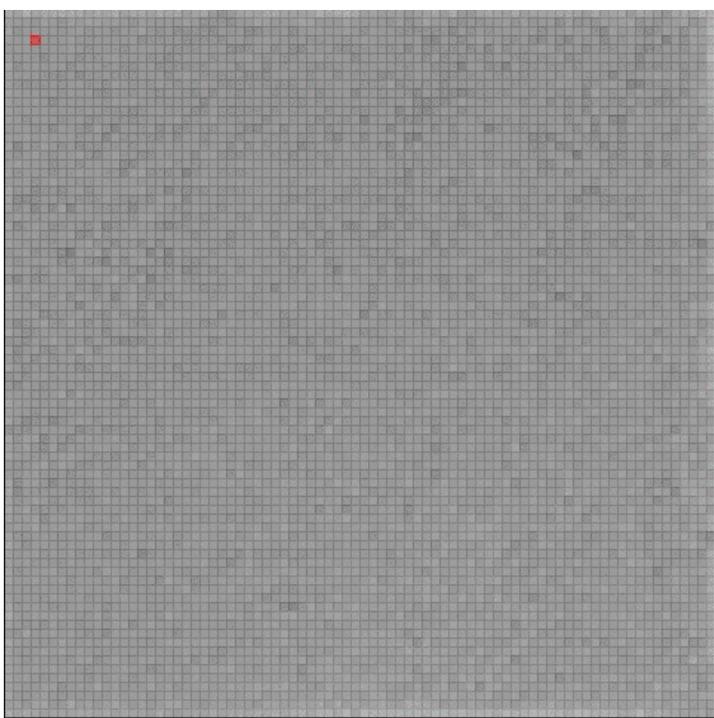
The HEXITEC system

HEXITEC
HIGH ENERGY X-RAY IMAGING TECHNOLOGY

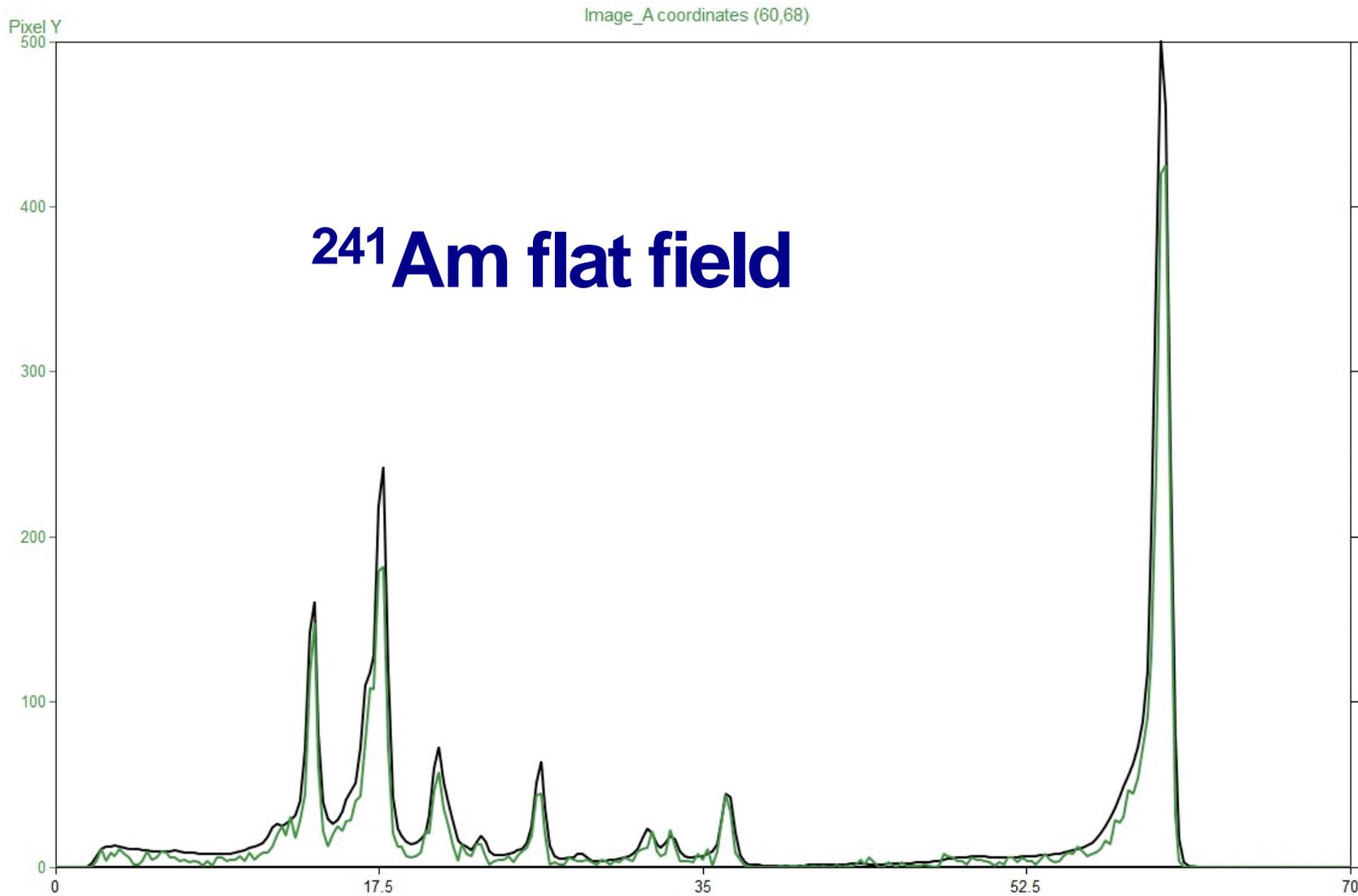


Energy values histogrammed for each pixel across many frames

Result: high resolution spectra!



80 Pixels



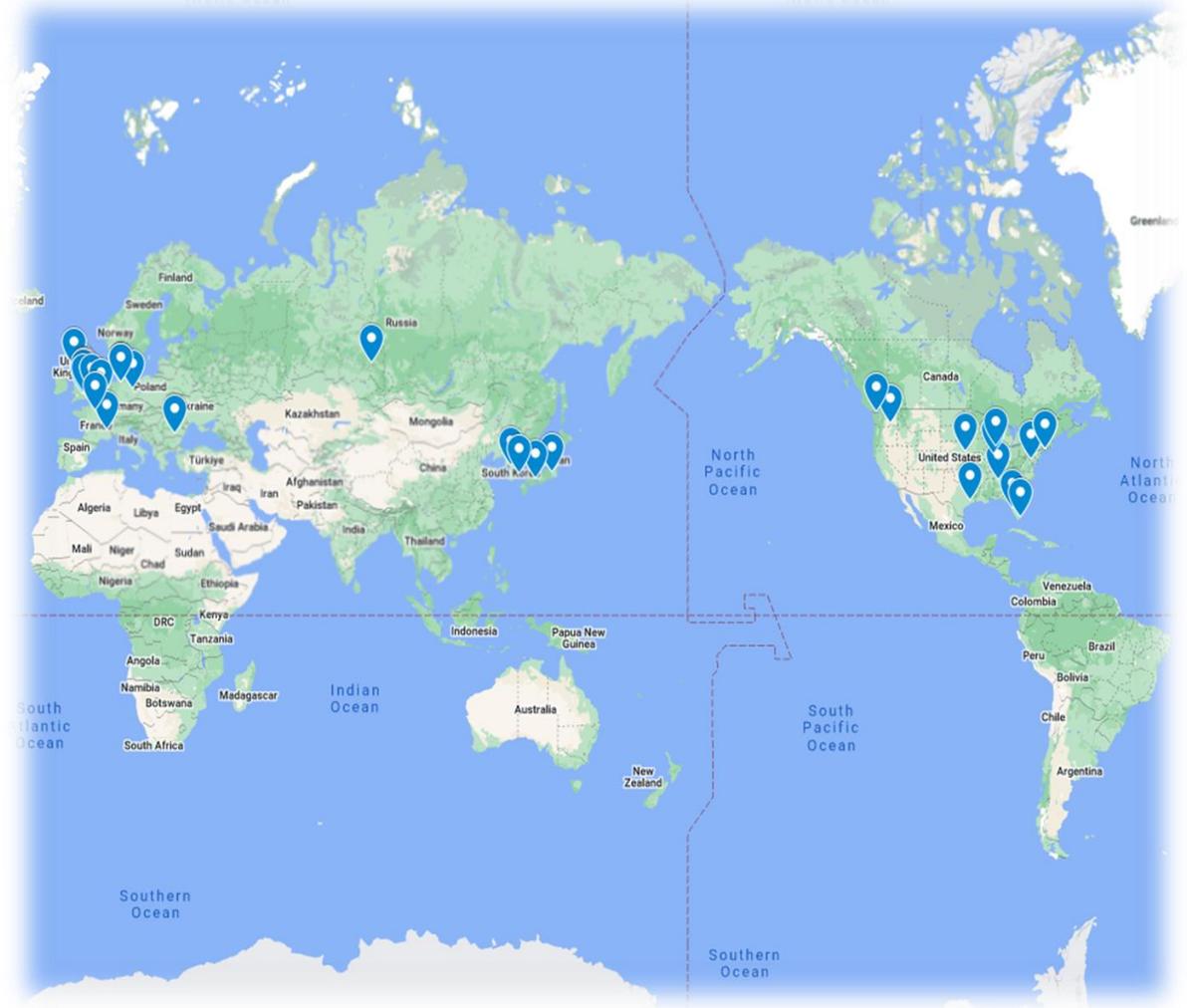
keV

The HEXITEC system

HEXITEC

HIGH ENERGY X-RAY IMAGING TECHNOLOGY

- Detector Module
- Gig E System
- 2x2 System
- 2x6 System
- 2x8 System



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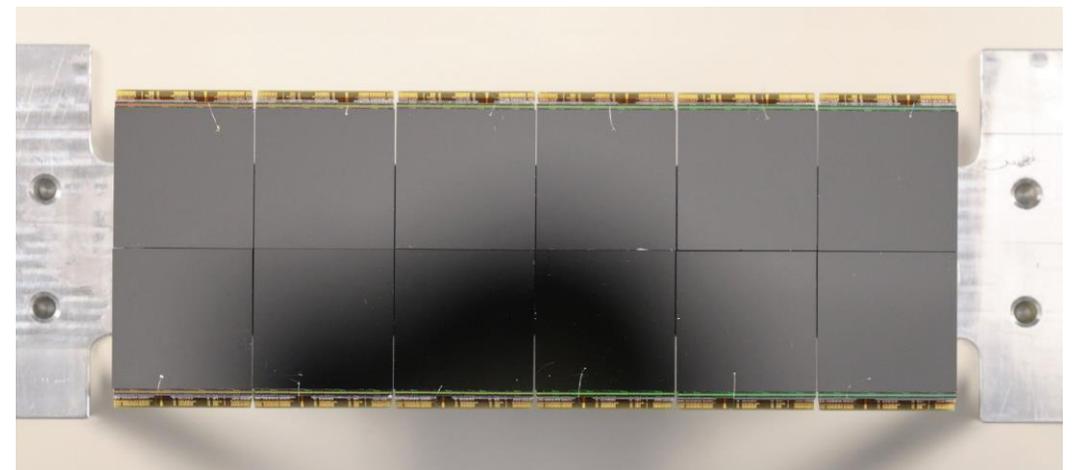
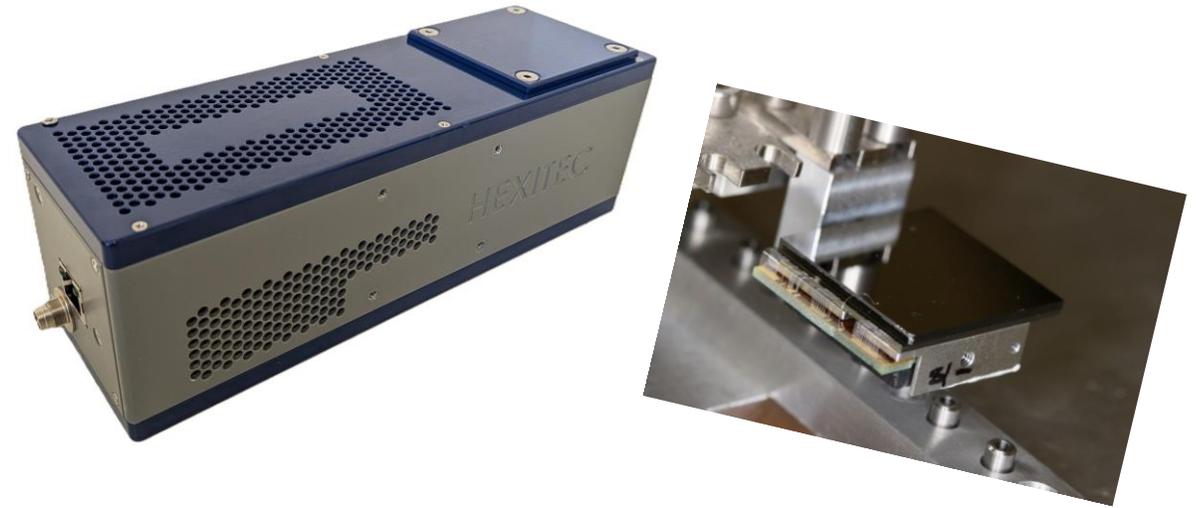
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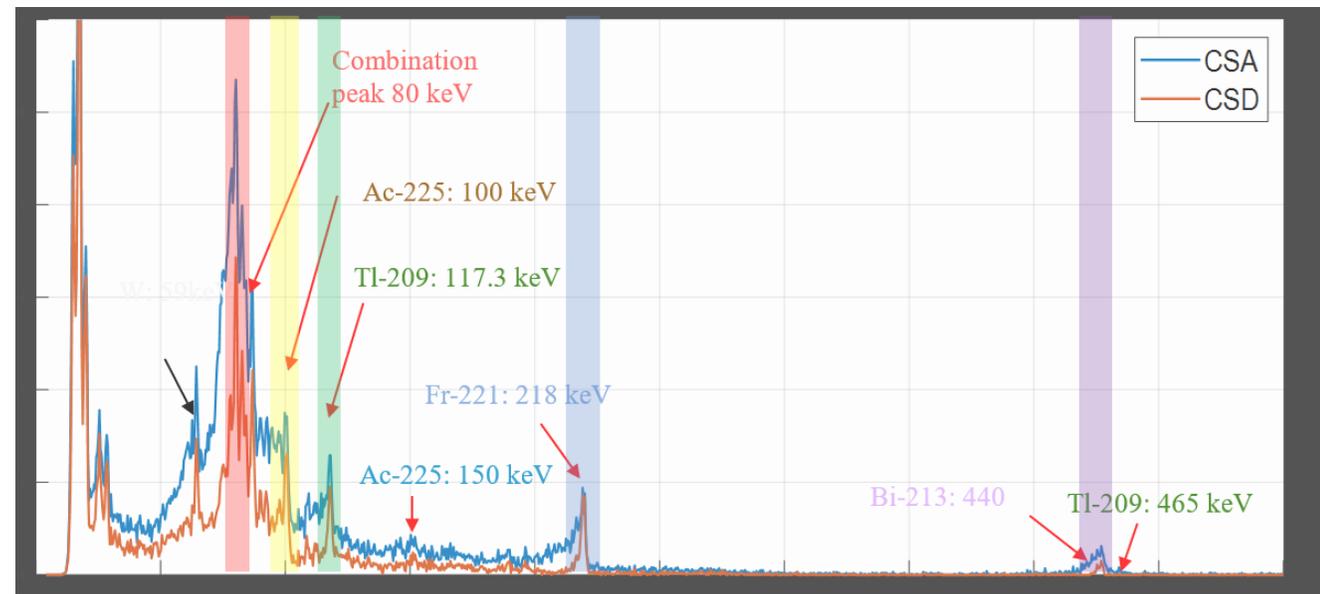
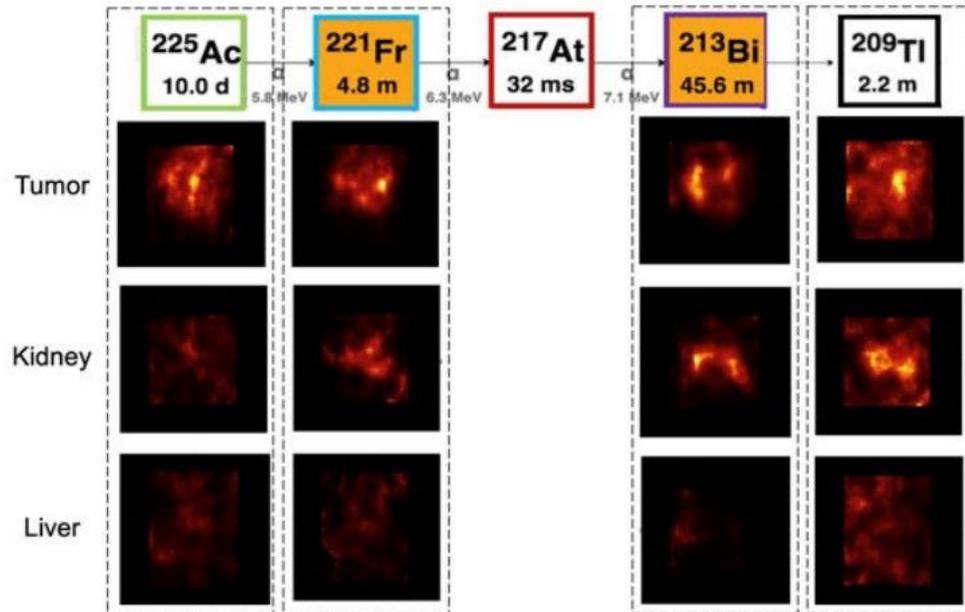


Nuclear Medicine

- HEXITEC licensed to MH3D on the alpha-SPECT mini
- Target market: radiopharmaceutical development for Targeted Alpha Therapy



Distribution of Ac-225-Labeled Antibody in Mouse



K-edge Imaging

- Transmission Imaging to differentiate between different Al alloys
 - Using machine learning and neural networks to differentiate between different Al alloys

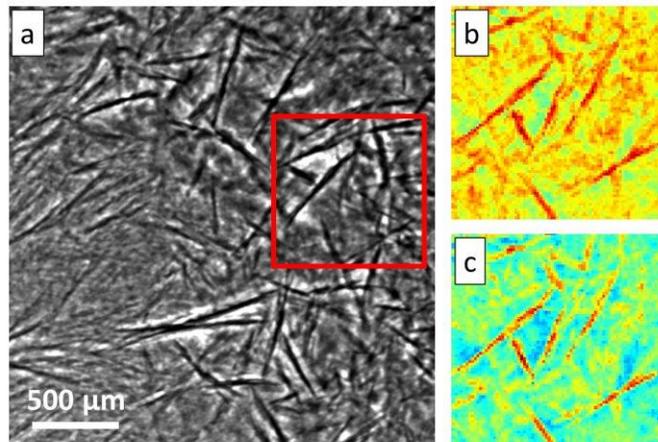


Figure 8.5: (a) A radiograph of an Al-Pt-Er alloy as prepared by arc melting, using the NSI apparatus. The red square indicates the field of view in the HEXITEC in (b) and (c). (b) Qualitative HEXITEC map of Er. (c) Qualitative HEXITEC map of Pt.

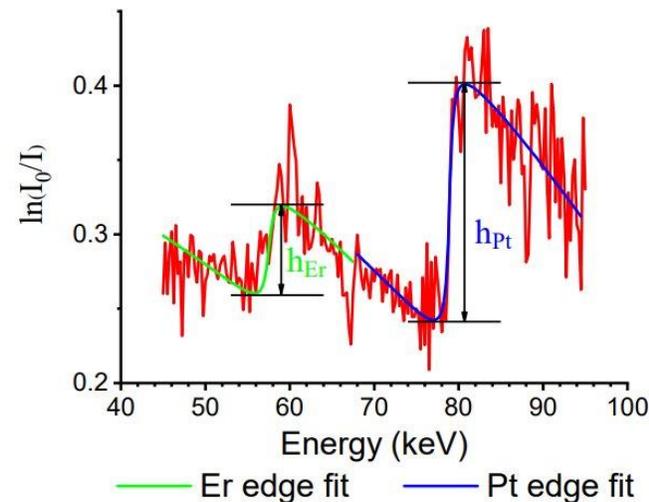
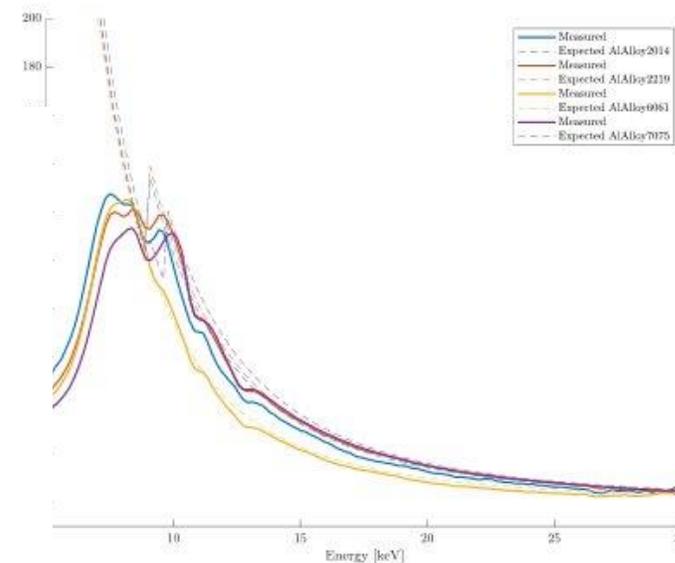
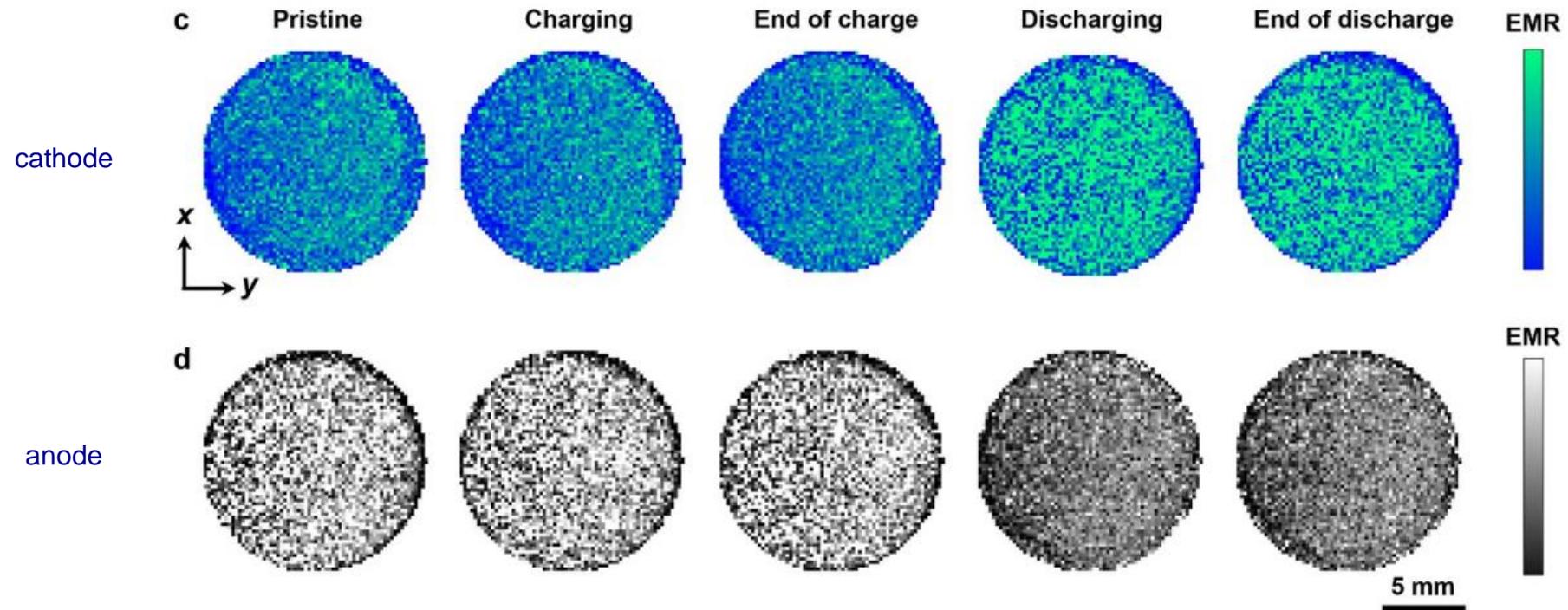


Figure 8.4: An example spectrum of $\ln(\frac{I_0}{I})$ as a function of photon energy from one pixel of the HEXITEC. h_{Er} and h_{Pt} are the sizes of the Er and Pt K-edges in the spectrum. The green and blue curves are the best-fit curves of the Er and Pt edges respectively.



Compton Scattering

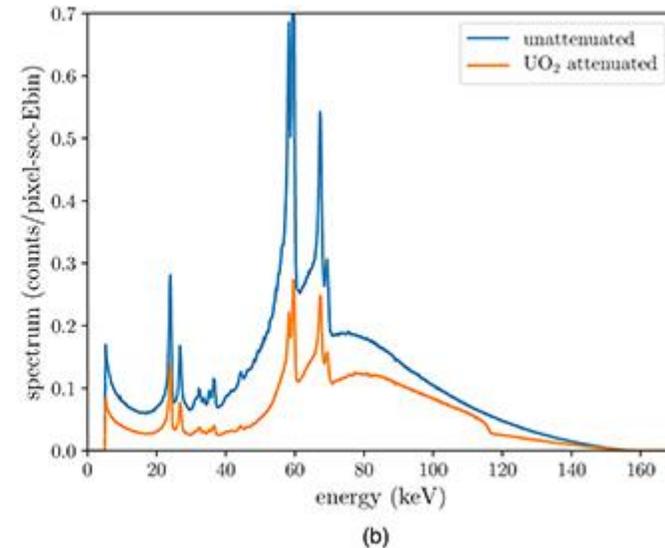
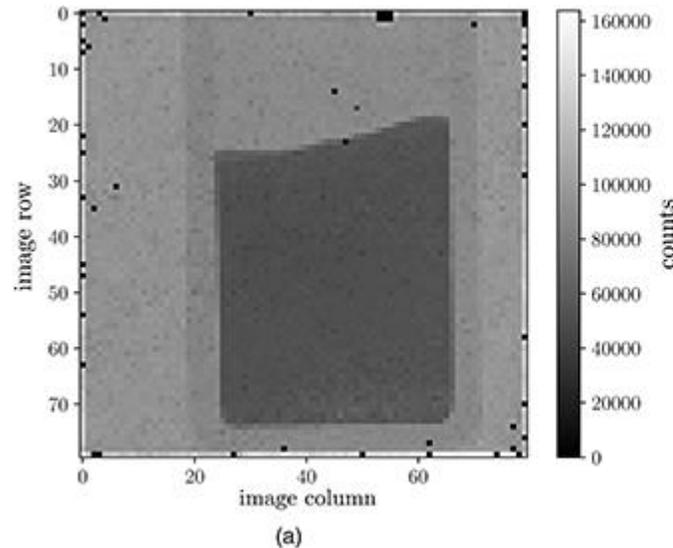
- Measuring and imaging Li^+ ion diffusion *in operando* inside a solid-state Li metal battery
 - Compton scattering intensity related to electron density and thus charge in the battery



Uranium quantification

- Uranium quantification in Nuclear Fuel:
 - Determine the mass of Uranium and Uranium Oxide powders using spectral radiography

A radiograph of the depleted UO powder



- $\sigma = 0.62\%$ with HEXITEC compared to $\sigma = 0.20\%$ COMPUCEA, but COMPUCEA destroys the sample
- HEXITEC provides a stable and accurate non-destructive characterisation of Uranium

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HEXITEC_{MHz}

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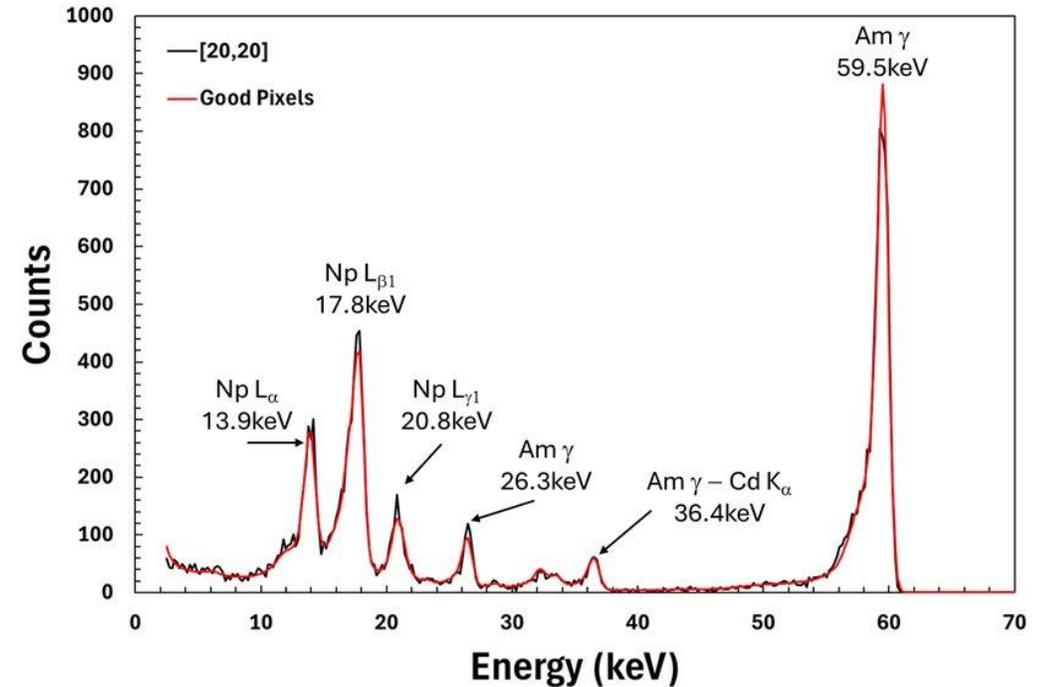
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HEXITEC MHz spec

HEXITEC_{MHz}

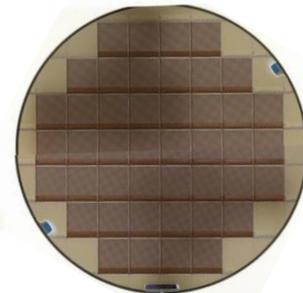
Parameter	HEXITEC	HEXITEC MHz
Pixel Pitch (mm)	250	250
Array Size	80 × 80	80 × 80
Max Frame Rate (kHz)	9.3	1000
Digitisation	Off-chip	On-chip
Detector type	Track + hold	Integrating
Energy range (keV)	2 - 600	2 - 300
FWHM _{@ 60 keV} (keV)	< 1	<1
Max flux rate (photons s ⁻¹ mm ⁻²)	< 2×10 ⁴	> 10 ⁶
Power consumption (W)	1.5	15



Designed in TSMC 180 nm

Full spectroscopy @ 2×10⁶ ph s⁻¹ mm⁻²

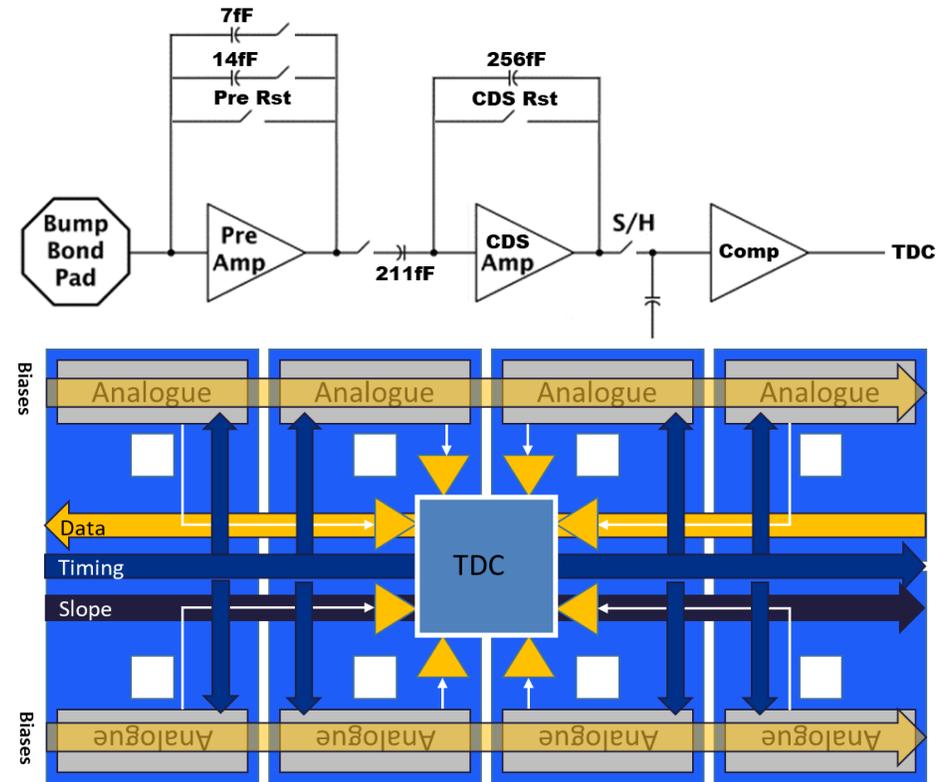
Similar energy resolution capabilities to HEXITEC



HEXITEC MHz architecture

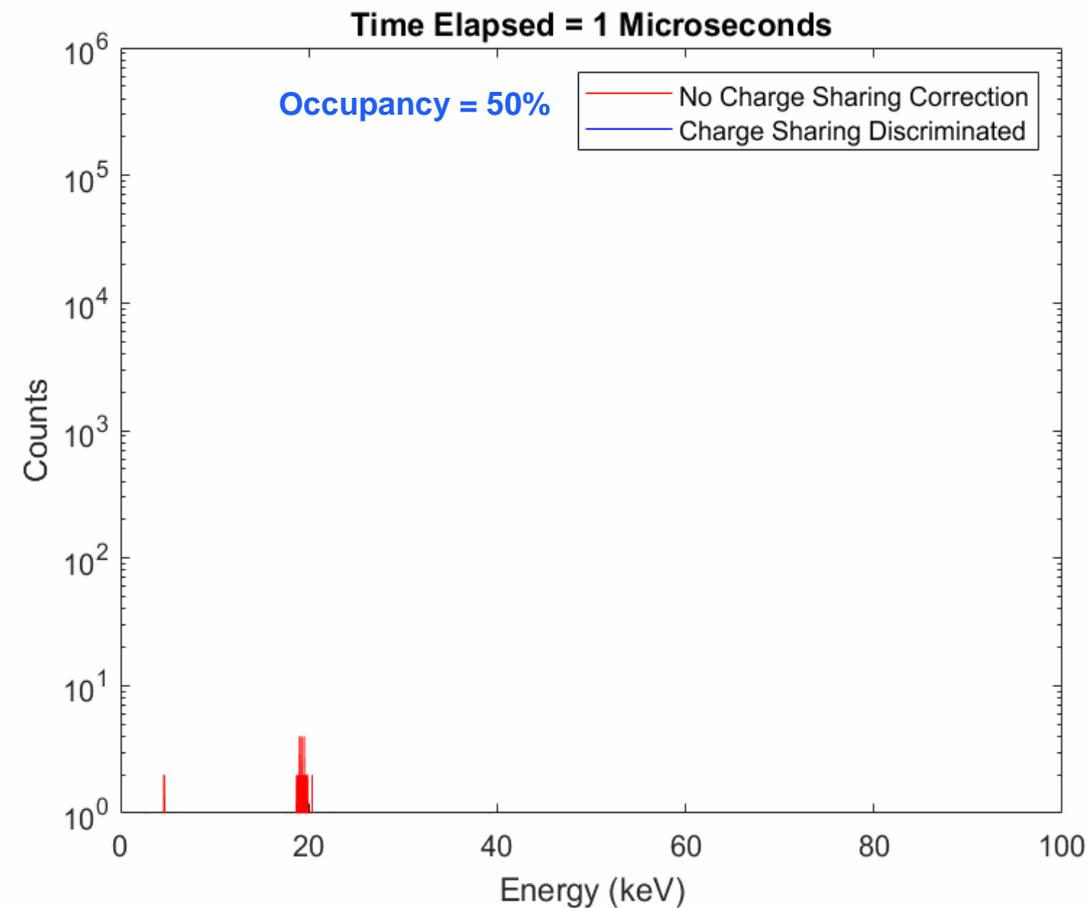
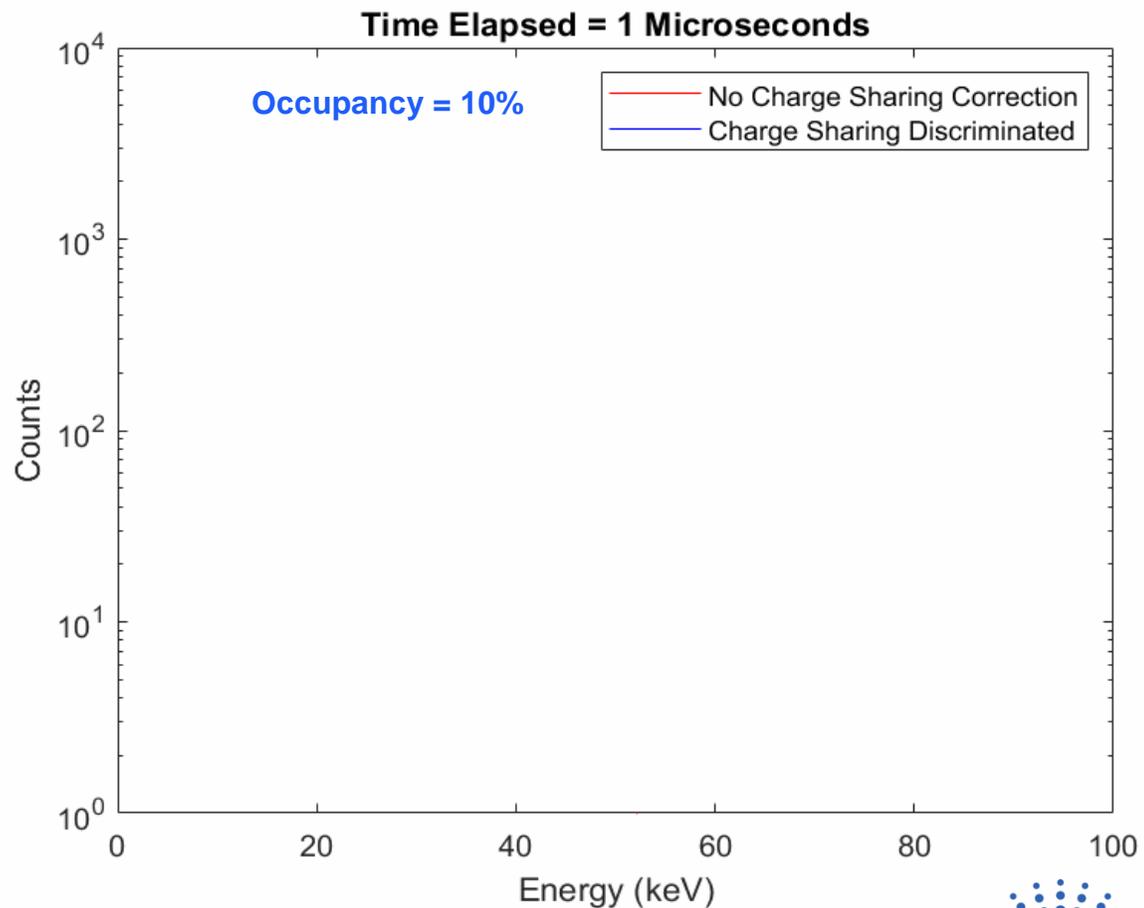
HEXITEC_{MHz}

- Integrating architecture
- $t_{\text{int}} = 900 \text{ ns}$, $t_{\text{reset}} = 100 \text{ ns}$
- Front end noise ~ 100 electrons
- TDCs shared in a 4×2 'super-pixel'
- 12-bit data out for each pixel
- $20 \times 4.1 \text{ Gb s}^{-1}$ serialisers
- Total data rate $\approx 10 \text{ GB s}^{-1}$ \longrightarrow FPGA histogramming of data set \longrightarrow 25 MB time slice

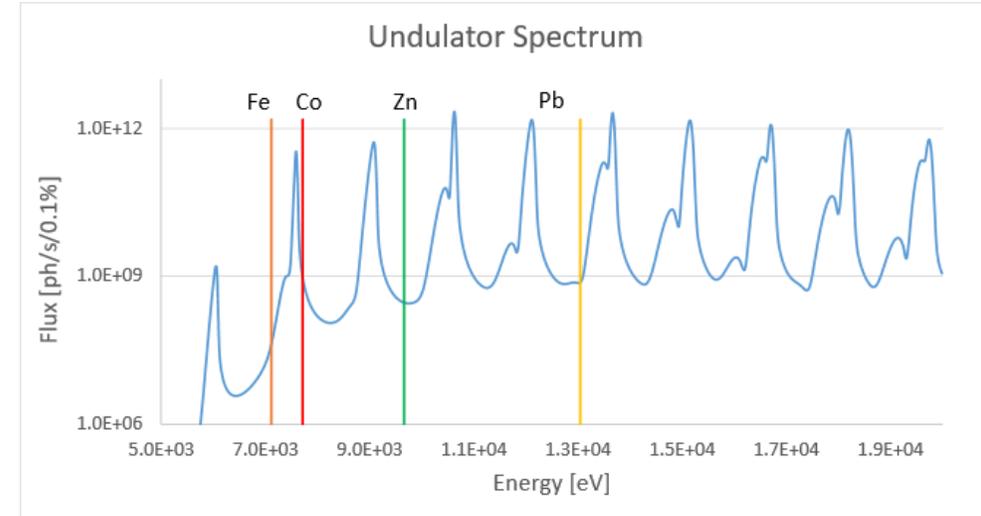
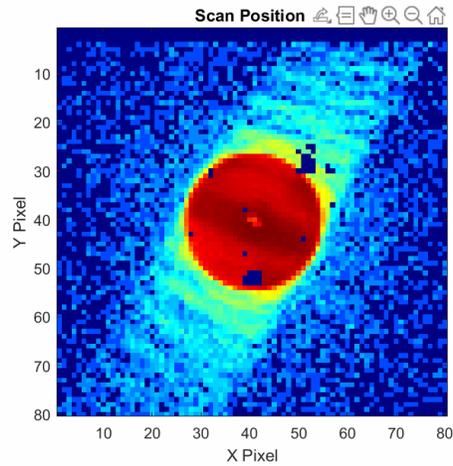
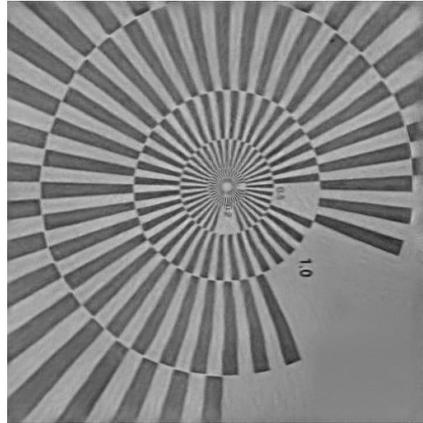
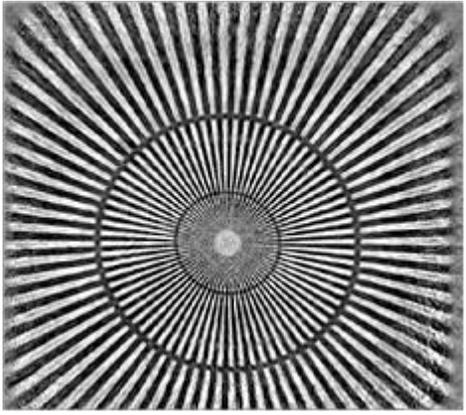


HEXITEC flux results

HEXITEC_{MHz}



Hyperspectral Ptychography **HEXITEC**_{MHz}



Ptychographic phase image of a test target (40 μm field of view). Data was recorded with a monochromatic beam on the single-chip HEXITEC detector.

- Match undulator spectrum with the absorption edges of the elements of interest
- HEXITEC-MHz enables simultaneous quantitative element-specific tomographic ptychograph with high spatial resolution

Final remarks

HEXITEC and HEXITEC MHz are spectroscopic detectors for use with high Z materials.

We are always looking for new collaborations and applications.

Please get in touch via hexitec@stfc.ac.uk

HEXITEC
HIGH ENERGY X-RAY IMAGING TECHNOLOGY

HEXITEC*MHz*

Thank you for listening!