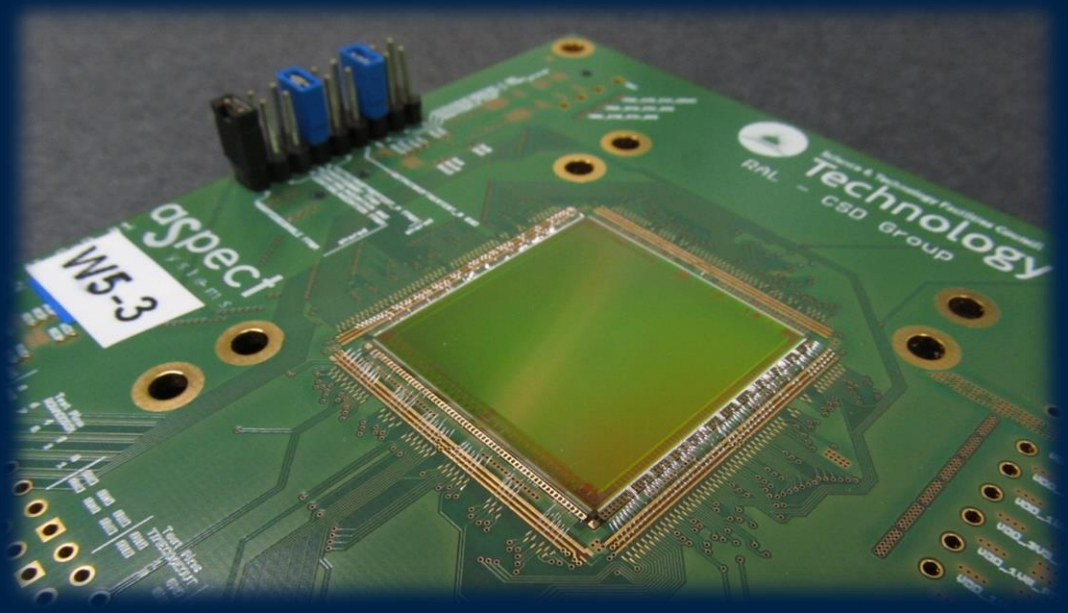
PImMS

Pixel Imaging Mass Spectrometry



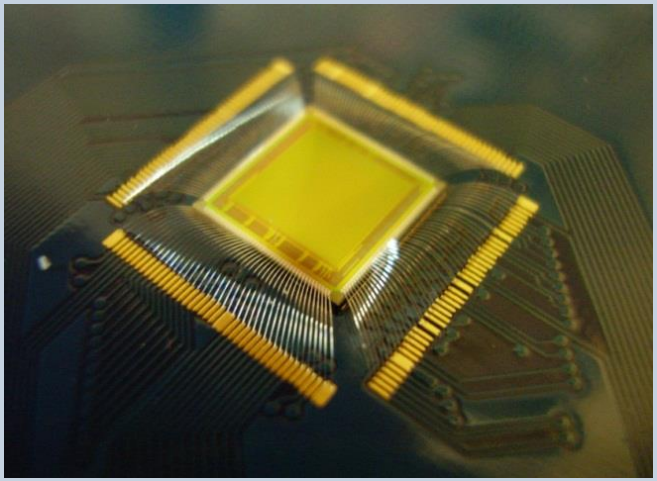
Jaya John John, on behalf of the PImMS Collaboration

18 September 2013, HV CMOS Meeting, QMUL

UNIVERSITY OF OXFORD
DEPARTMENT OF PHYSICS
DEPARTMENT OF CHEMISTRY
Science & Technology Facilities Council
Rutherford Appleton Laboratory

What is PImMS?

- A CMOS sensor designed for mass spectrometry and related fields
- Event-triggered: stores timestamps for significant events, up to 4 per pixel
- Readout is digital: four 12-bit timestamps per pixel (no amplitude information)
- Also has analogue readout mode, used for focusing of lenses



PImMS 1

- 0.18µm INMAPS technology – 615 transistors per pixel
- Used the TPAC sensor from ILC calorimetry as a starting point
- The timing structure for many mass spectrometry experiments is similar to the ILC bunch timing

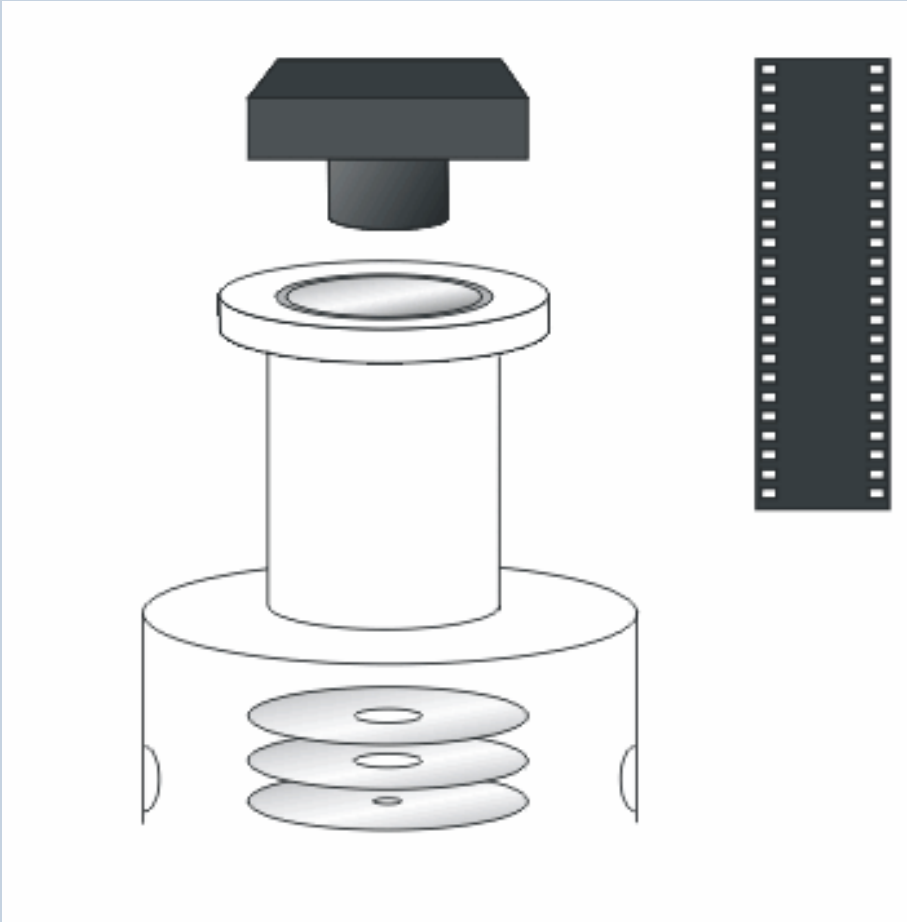
Pixel Imaging Mass Spectrometry

An idea of the mass spectrometry context:

Combines time-of- flight MS with 2D ion imaging.

We can image:

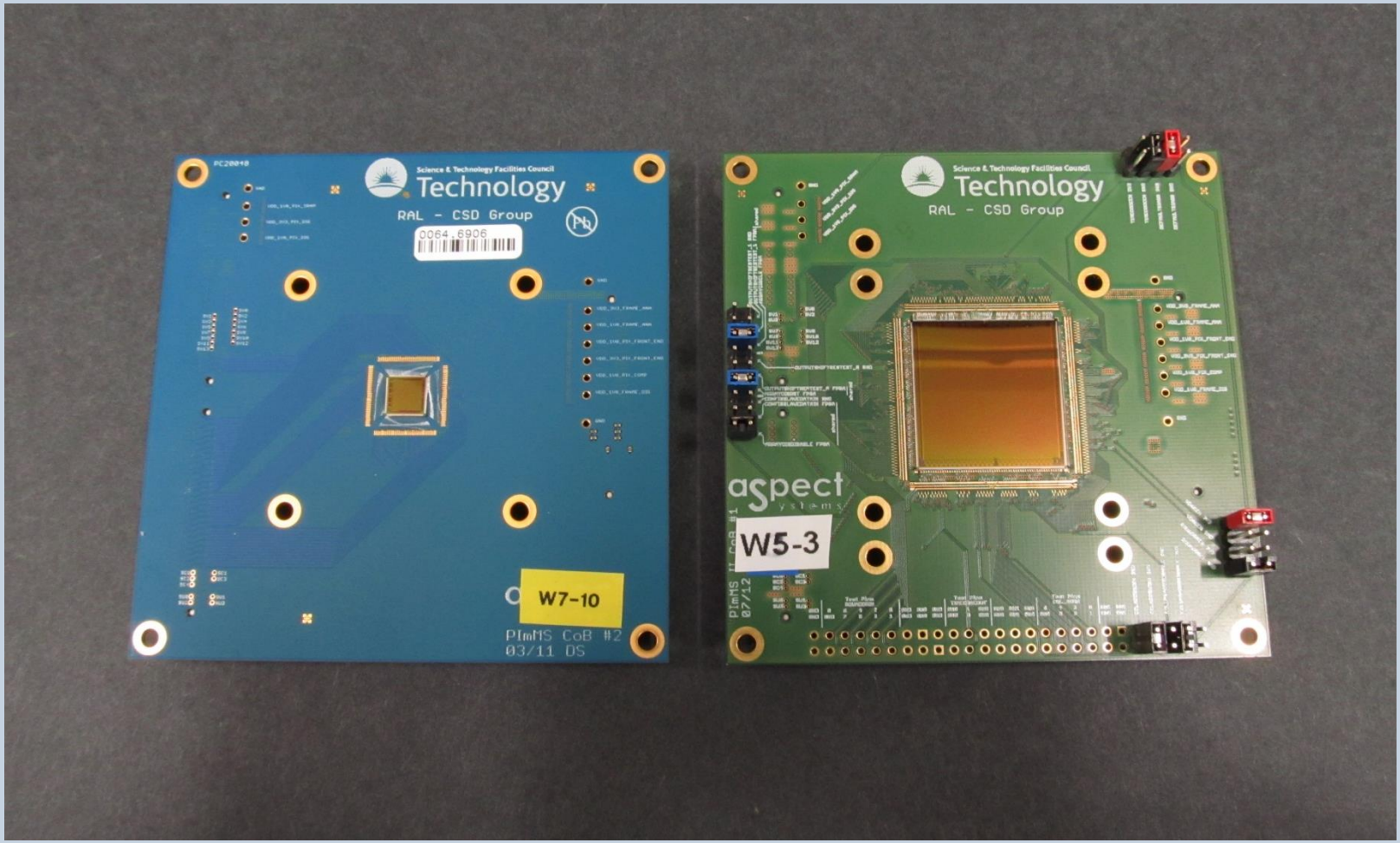
- The velocities of the ions at their point of formation -- giving info on fragmentation dynamics, or
- The positions of the ions at their point of formation – used in surface imaging or parallel acquisition of multiple mass spectra from an array of samples



PImMS sensors: specifications

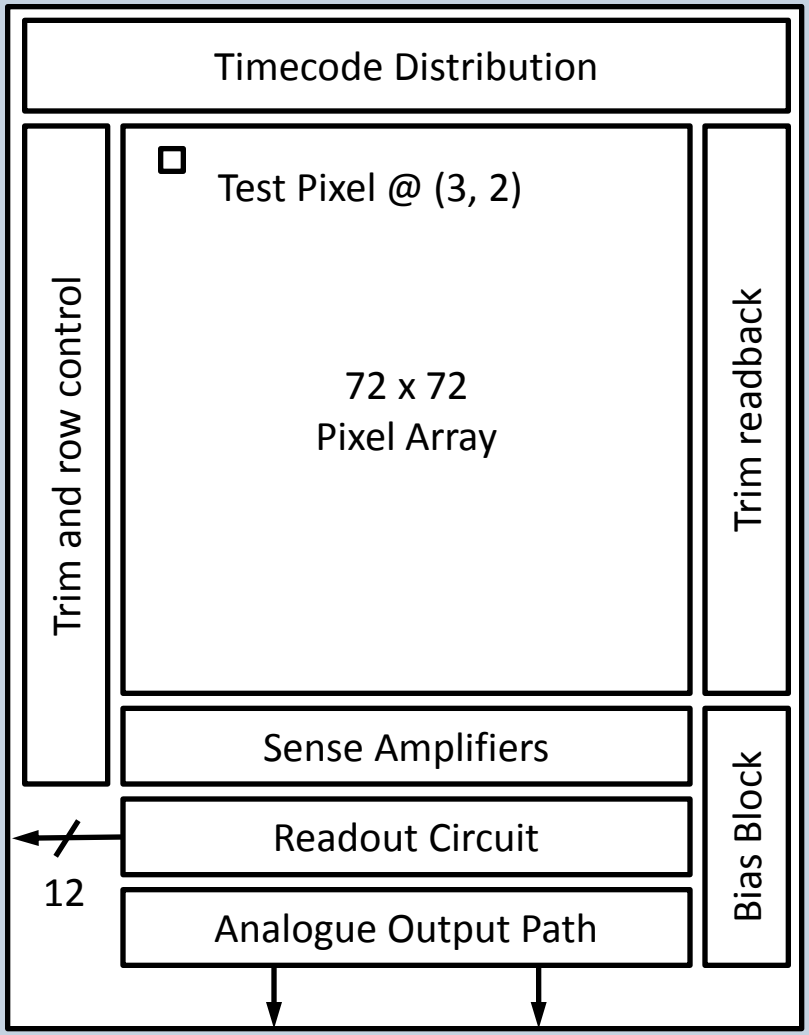
Spec	PImMS1	PImMS2
Array size	72 x 72 pixels	324 x 324 pixels
Active area	5mm x 5mm	22.7mm x 22.7mm
Sensor size	7mm x 7mm	25.4mm x 26.1mm
Pixel size	70µm x 70µm	
Pixel threshold trim	4 trim bits + 1 masking bit per pixel	
Timestamp storage	Four 12-bit registers per pixel	
Test pixel	1 test pixel with access to inner analogue nodes	
Time resolution (timecode period)	Initial spec: 50ns Simulation target: 25ns	
Current performance	12.5ns	
Substrate	5µm epi	5µm epi 18µm high-resistivity epi

PImMS1 and PImMS2

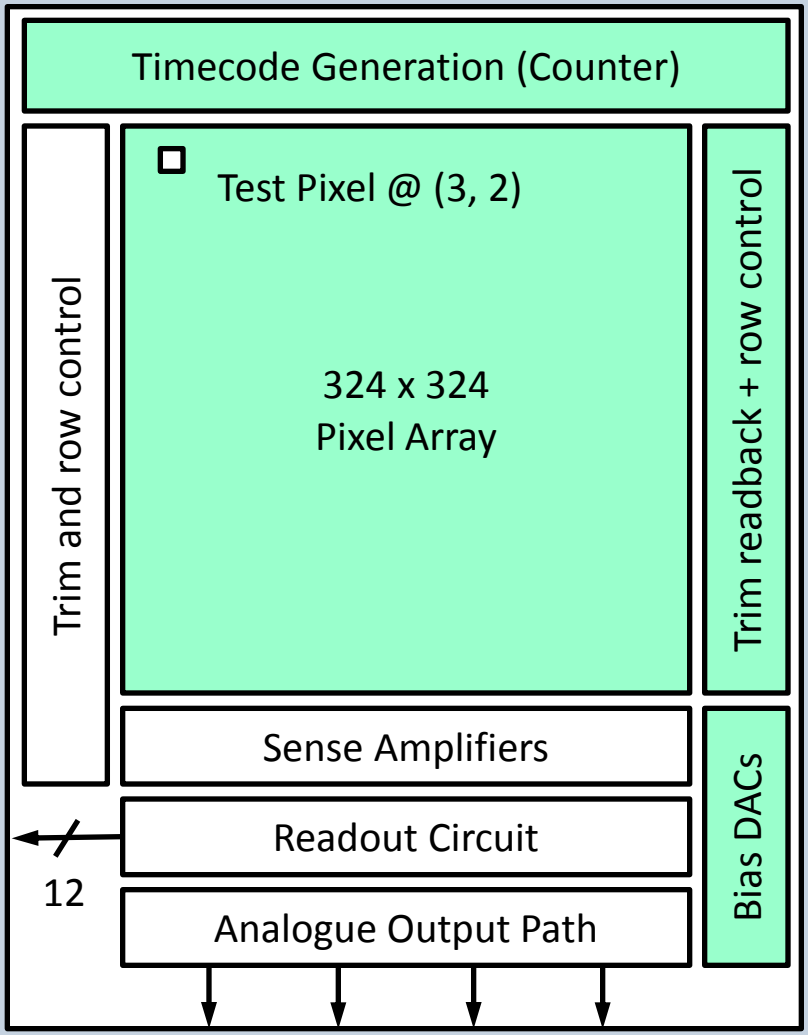


PImMS sensors: overview

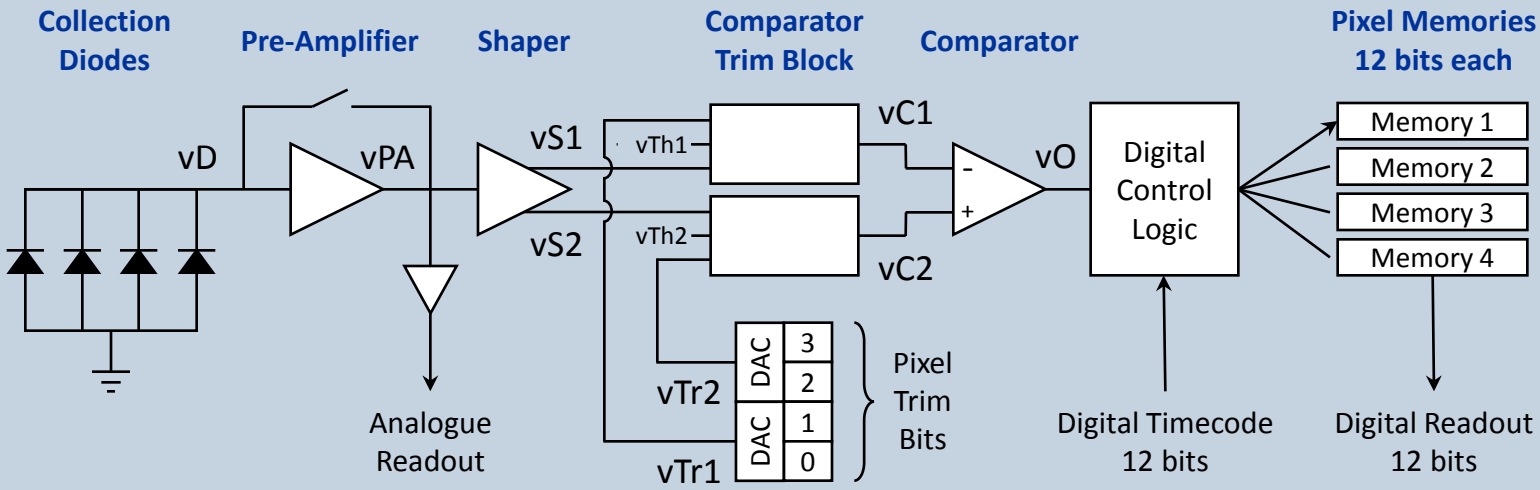
PImMS1

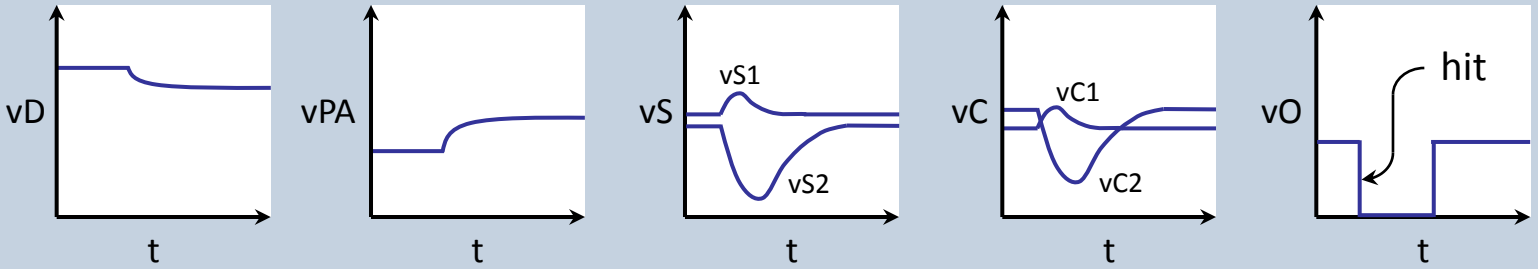


PImMS2



PImMS pixel

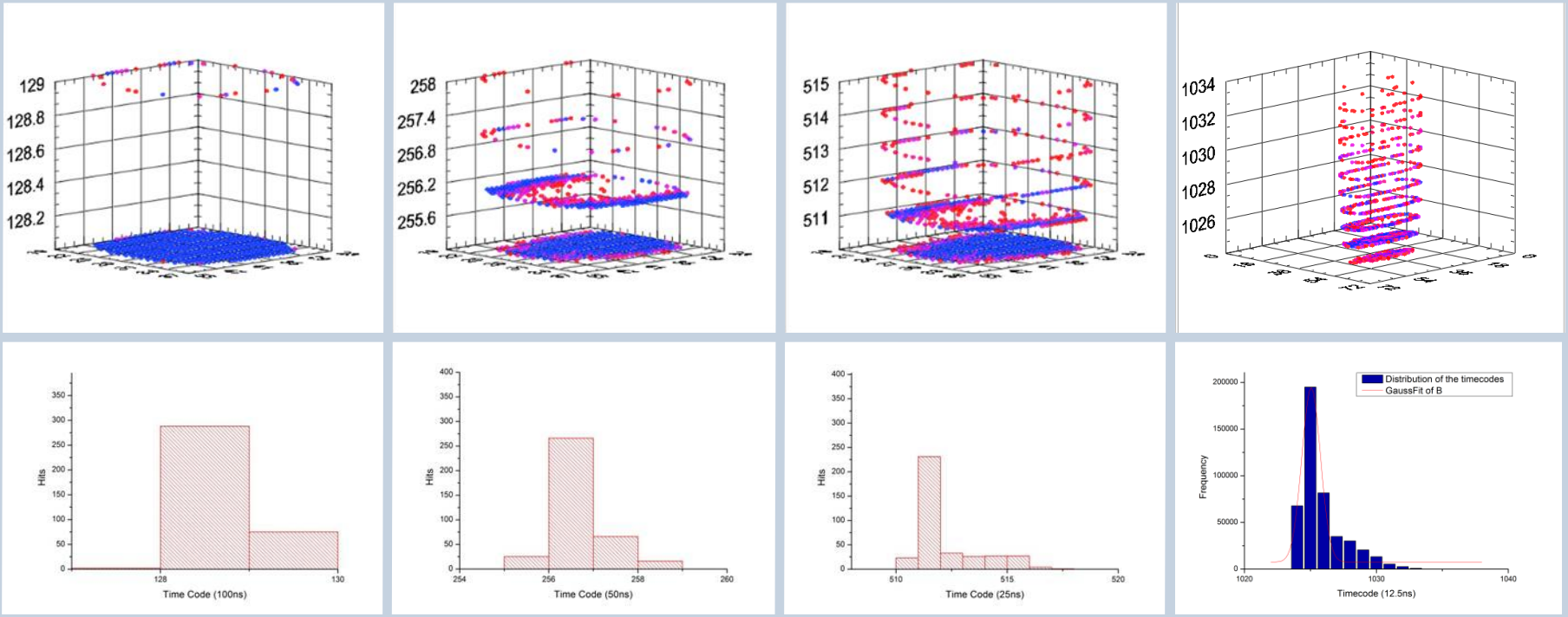

Collection Diodes
Pre-Amplifier
Shaper
Comparator Trim Block
Comparator
Pixel Memories 12 bits each
vD
vPA
vS1
vS2
vTh1
vTh2
vC1
vC2
vO
Digital Control Logic
Memory 1
Memory 2
Memory 3
Memory 4
vTr2
vTr1
DAC
3
2
1
0
Pixel Trim Bits
Analogue Readout
Digital Timecode 12 bits
Digital Readout 12 bits


vD
t
vPA
t
vS
vS1
vS2
t
vC
vC1
vC2
t
vO
hit
t

PImMS1 characterisation: timing resolution

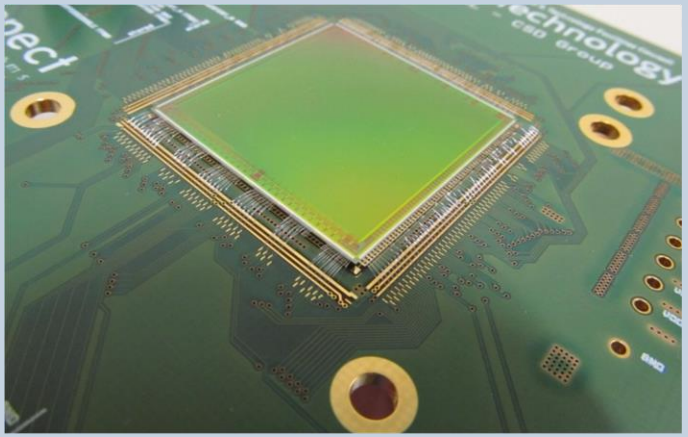
- Testing with timecodes at increasing speeds, using a low-power laser pulse generator
- The edges of the laser spot have progressively lower intensity, showing the degree of timewalk, ~125ns

100ns ***50ns*** ***25ns*** ***12.5ns***



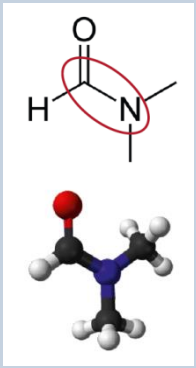
Status and future work

- Currently commissioning PImMS2:
  - Debugging DAQ e.g. analogue readout
  - Working towards calibration of sensor (pixel trimming routine)
- Much interesting characterisation ahead:
  - Absolute calibration with ^{55}Fe
  - Timing resolution and jitter
  - Laser scans across pixel array and within pixels
  - Quantifying thresholds versus input levels in mass spectrometry
- Supporting further developments in neutron detection

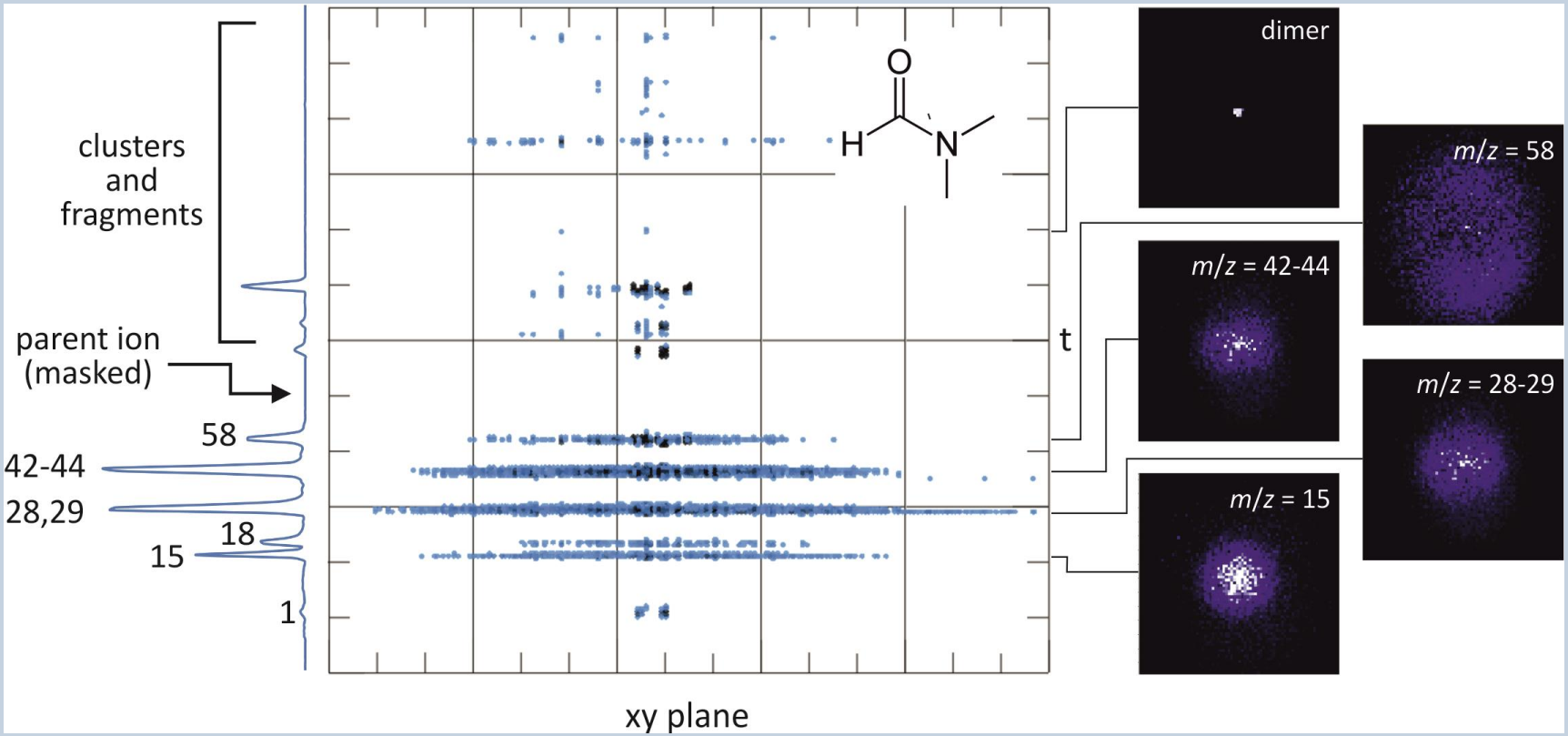


PImMS 2

Applications: velocity map imaging

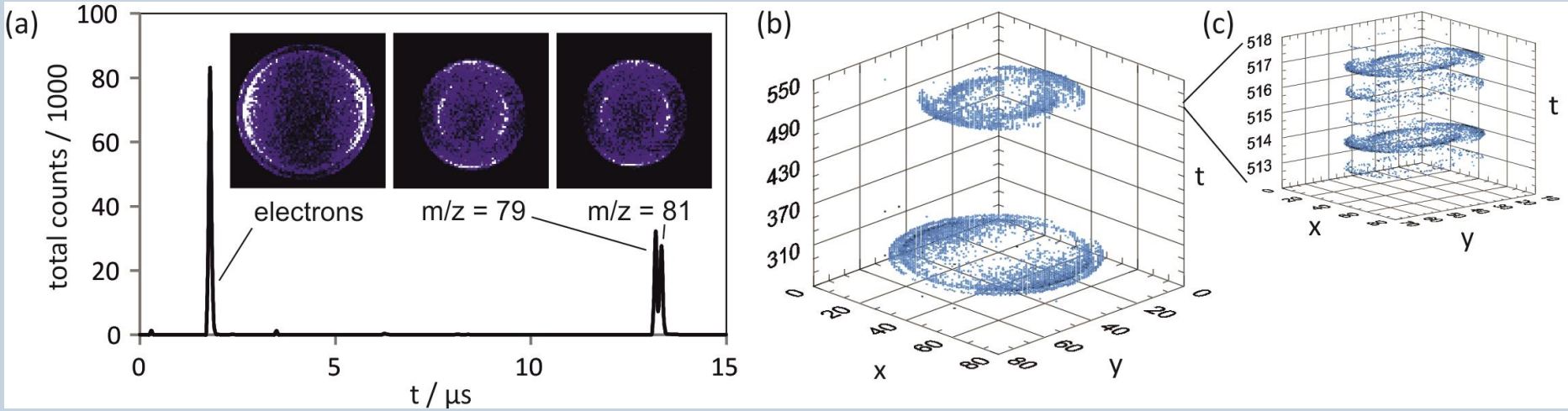


- N,N-dimethylformamide (DMF) is a prototype molecule for studying peptide bond cleavage.
- PImMS data on the 193 nm photolysis of DMF is shown below.



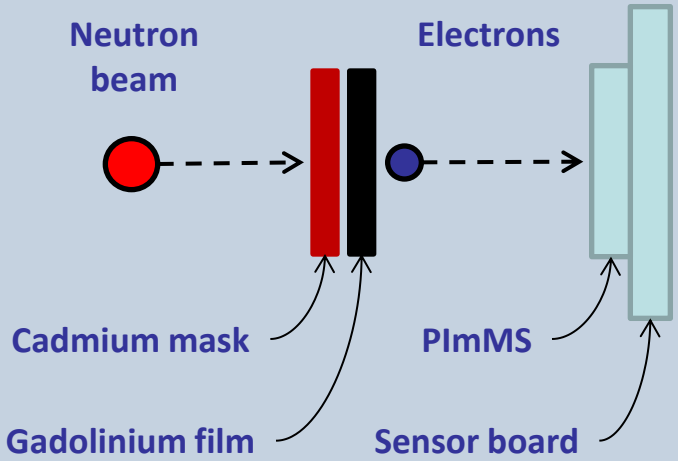
Applications: coincidence imaging

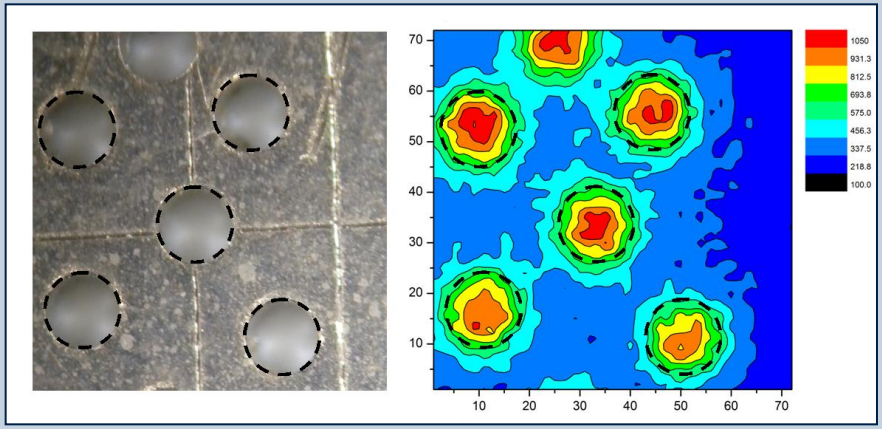
- Here bromine gas (Br_2) is dissociated. By switching the polarity of the ion optics, first the electrons are imaged, then the ions.
- (a) shows the mass spectrum including $^{79}Br^+$ and $^{81}Br^+$
- (b) shows the mass intersections for the electrons and Br ions
- (c) zooms in on the two isotopes, $^{79}Br^+$ and $^{81}Br^+$



Applications: neutron detection

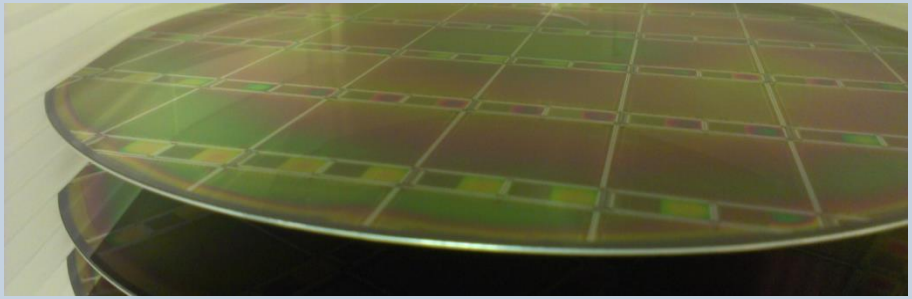
- Daniel Pooley of ISIS' Neutron Detectors Group is developing a neutron detector based on PImMS, working with Jason Lee
- Gadolinium is thinly sputtered onto the surface of PImMS (4µm) which creates showers of electrons immediately above the pixel array
- Here are early results using a cadmium mask to demonstrate neutron sensitivity:





Thank you. Questions?

PImMS2 wafer:



The PImMS Collaboration

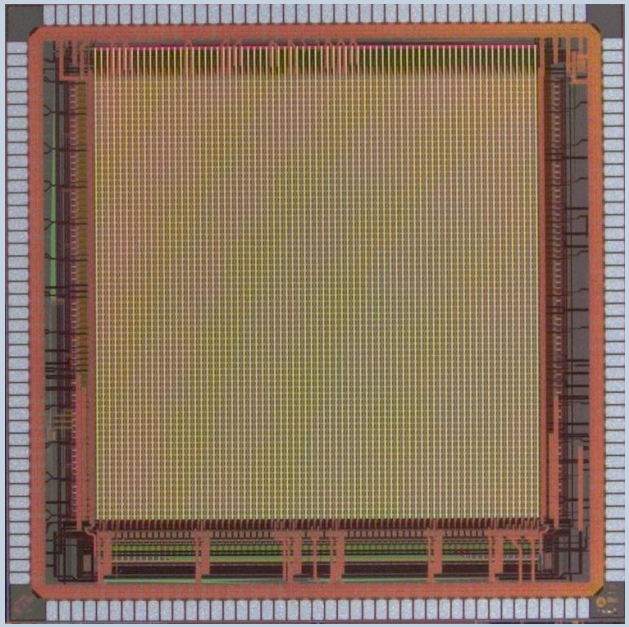
Mark Brouard, Kasra Amini, Edward Halford, Alexa Lauer, Craig Slater, Benjamin Winter
Claire Vallance, James Bull, Cécilia Cauchy, Sara Gardiner, Simon-John King, Jason Lee, Laura Lipciuc
Department of Chemistry, University of Oxford

Richard Nickerson, Laura Hill, Jaya John John
Department of Physics, University of Oxford

Renato Turchetta, **Daniel Pooley**, Andy Clark, Jamie Crooks, Ben Marsh, Iain Sedgwick
STFC Rutherford Appleton Laboratory

The support of the STFC, ICONIC, EPSRC, ERC, RC-UK and ISIS Innovation Ltd. are gratefully acknowledged.

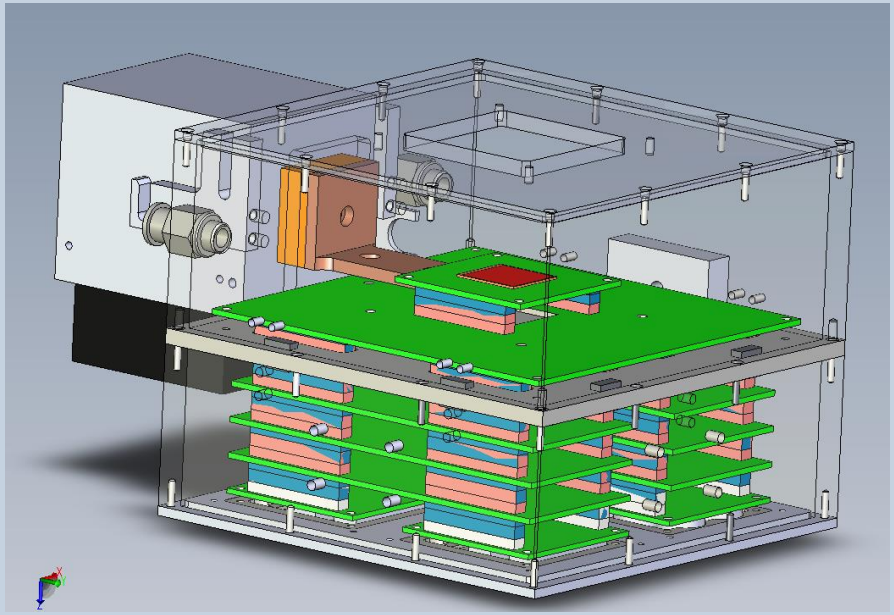
Backup slides

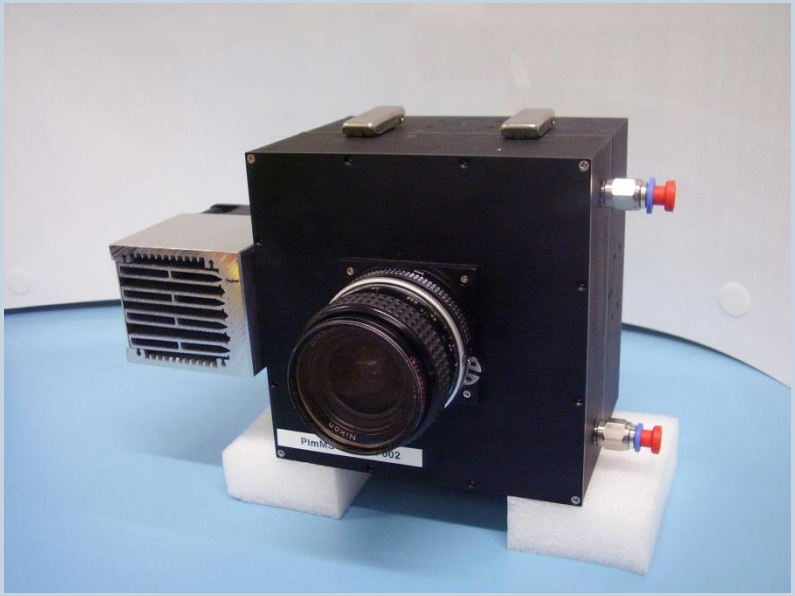


PImMS 1

Readout: camera

- USB control and readout
- F-mount SLR lens
- C-mount SLR lens also possible – delivers more light to sensor





- Cooling system based on copper finger and Peltier device
- Connection for nitrogen/dry air flushing