



RAL Particle Physics Department and RAL CMOS Sensor Design Group

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Peter Philips, Jens Dopke, Craig Sawyer, Zhige Zhang,
New post-doc, and CMOS Sensor Design Group

- Overview of Particle Physics Department (PPD)
Silicon projects
- PPD and TD lab facilities
- Overview of CMOS Sensor Design Group. Part of STFC Technology Department (TD).
- Summary and Resources.

Some Current Projects



James Clerk Maxwell Telescope
Hawaii



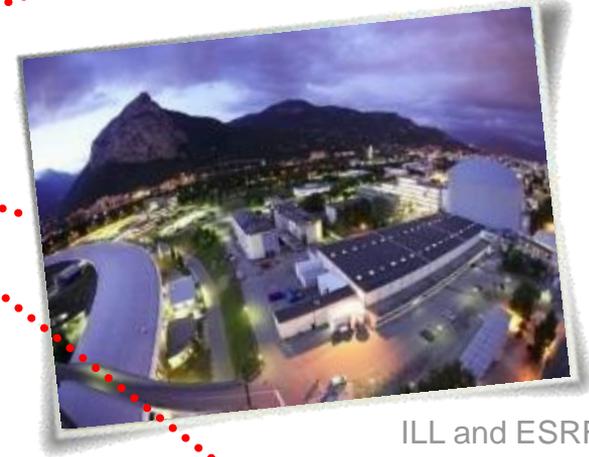
RAL: ISIS & Diamond;



CERN: LHC



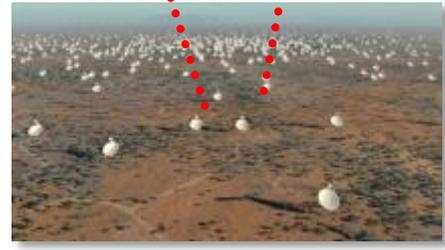
ESA: Top Sat



ILL and ESRF



ESO: Alma Array

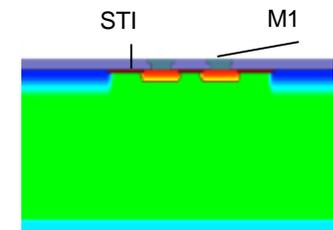
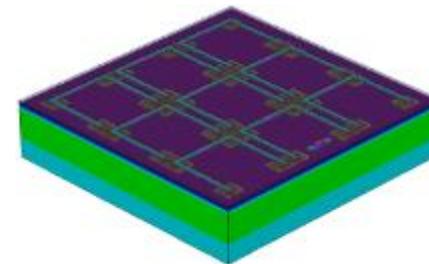
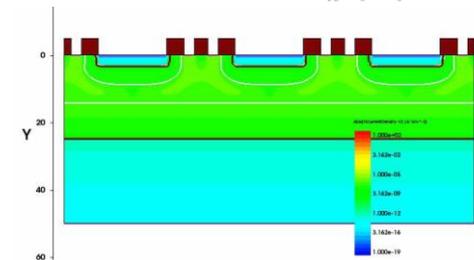
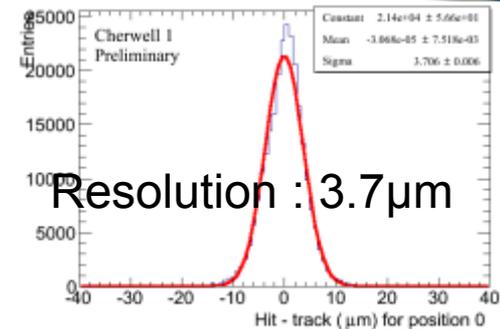


SKA



ESS

- Cherwell MAPS sensor (25x25 μm)
 - 0.18 μm CMOS Not rad hard
 - Prototype for tracking and digital calorimetry
 - Charge collection by diffusion
 - Tested and Paper out soon
- CHESS-2
 - Testing rad hard HV-CMOS sensors
- OverMOS 1, 1.1, 2.0 MAPS prototype sensor
 - Rad Hard Pixel Monolithic HR-CMOS
 - Multiple structures and substrates
 - Charge Collection by drift
 - Under going testing
- DECAL MAPS sensor (50x50 μm)
 - 0.18 μm Rad Hard Pixel Monolithic HR-CMOS
 - 40MHz global shutter
 - Charge Collection by drift
 - Configurable with in-pixel electronics
 - For digital calorimetry and outer tracking at FCC
 - In design stage for 2017
- ATLAS
 - Tracker upgrade HVMUX
 - Si and GaN
- LC and FCC Design Studies



PPD is a member of ATLAS, CMS, LHCb, T2K, MICE, MINOS, Dark Matter, Dune, AIDA-2020

- HEPAPS CMOS MAPS sensor

- 0.25um CIS TSMC/IBM
- Developed 'ad hoc' radiation models

- DNW CMOS MAPS

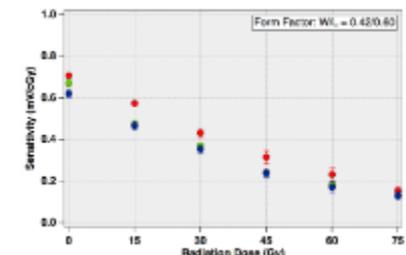
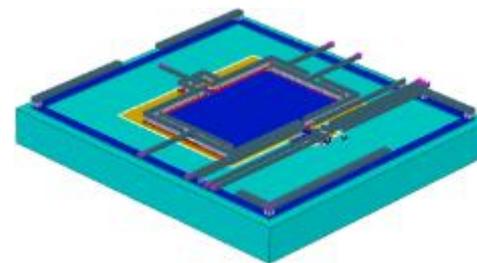
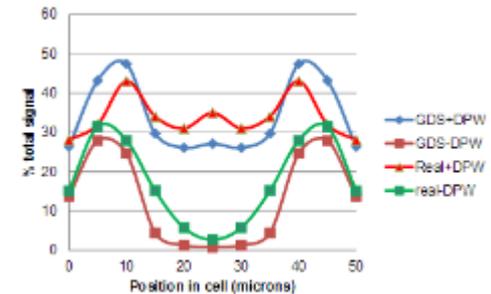
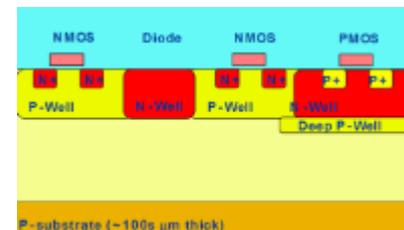
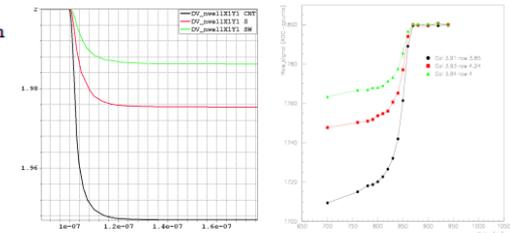
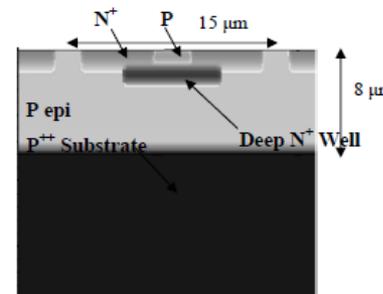
- Triple Well for Charge collection by drift

- TPAC for CALICE

- 50x50 um pixels tracking ECAL for ILC
- 0.18um MAPS based Si-W 'TeraPixel' system
- Deep PW for improved CCE
- Extensive beam and laser test

- CMOS dosimetry

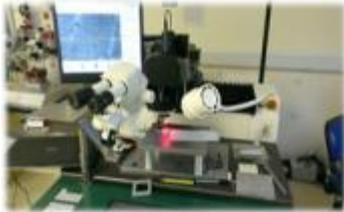
- 0.18um SL CMOS FG based dosimeter
- Aimed at biomedical applications
- Sensitivity to 1 rad gamma doses



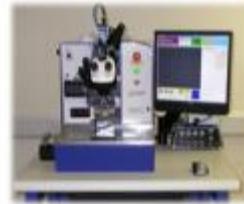
PPD is a member of ATLAS, CMS, LHCb, T2K, MICE, MINOS, Dark Matter, Dune, AIDA-2020



Multiple cleanrooms
Multiple wire-bonders
Bump-bonders
Inspection equipment
Metrology lab
3-D printing facilities



Aluminium wedge bonders.
Above: Hesse and Knipps Bondjet 715M
Right: Hesse and Knipps Bondjet BJ820



Gold ball bonders.
Left: Palomar 8000
Above: Questar Q2119



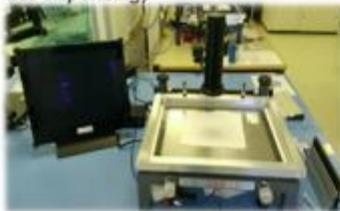
Pull/shear tester.
XYZTec Condor 100



Inspection microscopes.
Above: Vision engineering Lynx
Below-left: Smartscope 250
Below: Keyence VHX1000



Conductive epoxy deposition.
Left: Asymtec serial dot dispenser
Below: Screen printing (parallel dot dispensing)

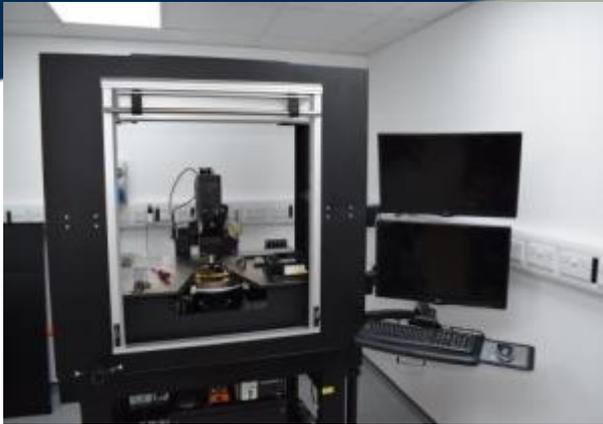


Indium bump depositor.
Above: JLS Designs MPS800

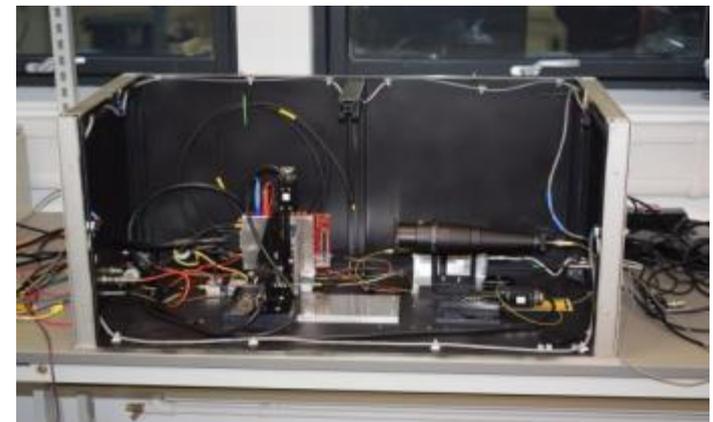
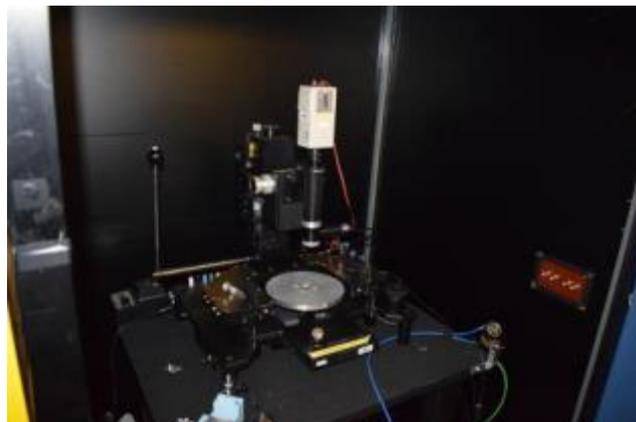


Flip chip bonder.
Below: SET
FC150



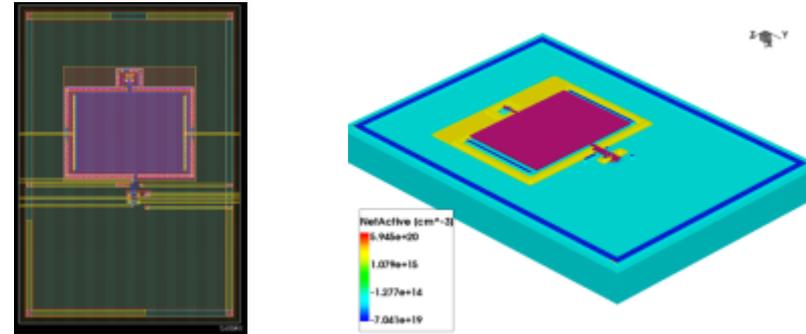


- Pulsed 3 wavelength laser with 2um beam spot accuracy and <math><1\mu\text{m}</math> XYZ motorized stage for sensor testing
- TCT laser
- Thermal camera
- Environmental chambers
- N2 cooling system for live sample testing
- 3-D printers
- Laser Cutting facility
- Keithley Semi-Conductor analyzer CS4200 with HV – CV - PG units
- Impedance analyzer
- DAQ facilities (ATCA, HSIO, ATLYS, ITS-DAQ, NI DAQ)

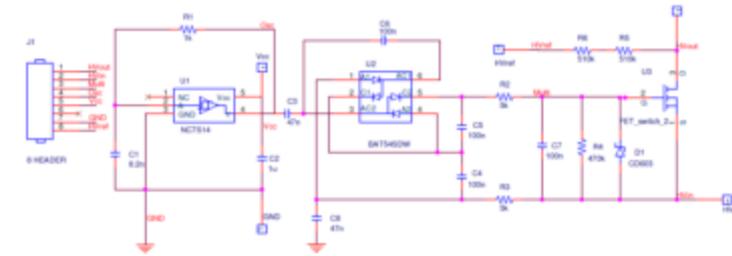


PC farm for Synopsys TCAD simulations

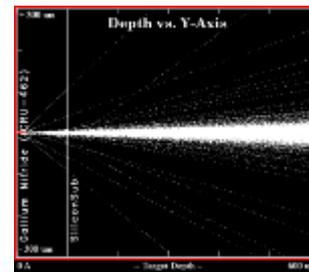
PC farm for Cadence ASIC design



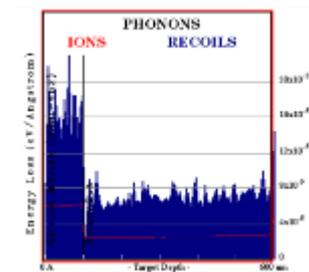
Orcad – PCB design and SPICE simulation (HVMUX)



SRIM simulations
(GaN irradiation with 26MeV p+)



Easy access to ISIS, DIAMOND



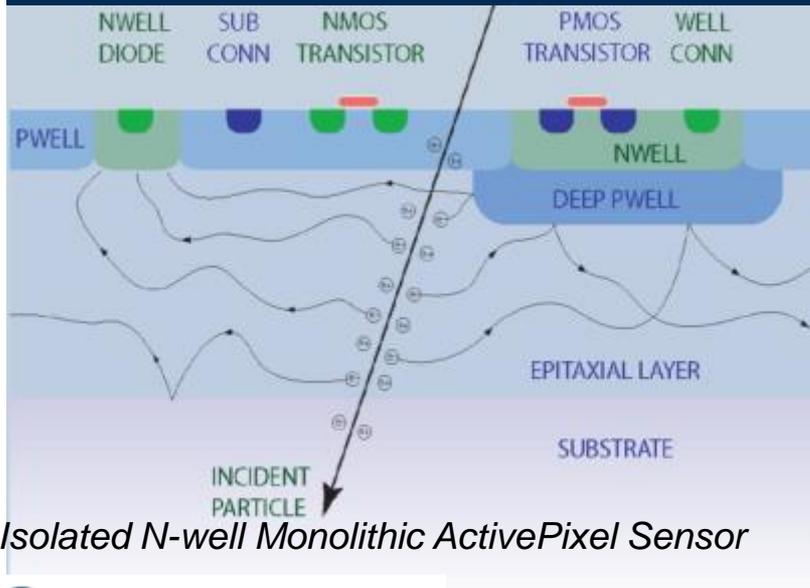


PImMS

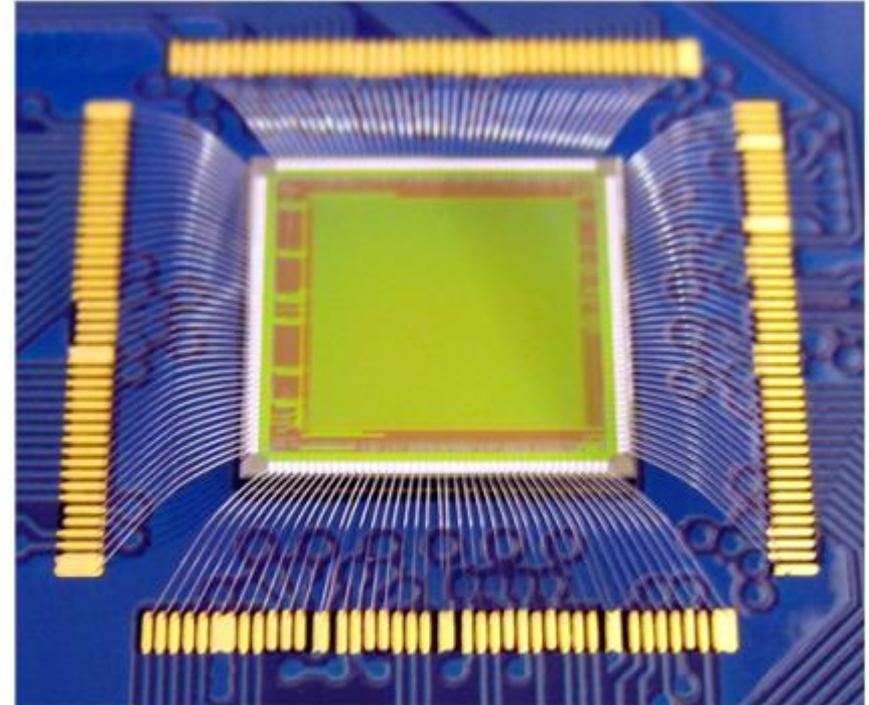
Pixel Imaging Mass Spectrometry



The INMAPS process



Isolated N-well Monolithic ActivePixel Sensor



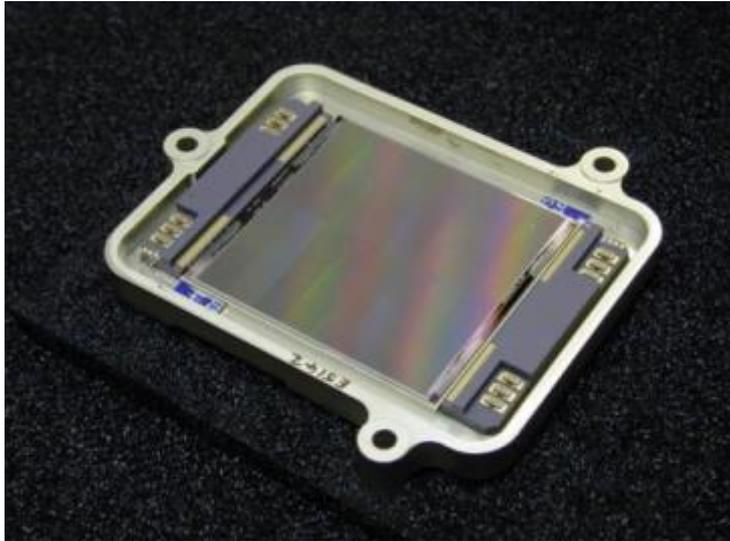
- 0.18 μ m CMOS fabrication
- PImMS pixel: 615 transistors per pixel
- Over 3 million transistors in total for PImMS1



RAL Space Camera System with e2v CCD

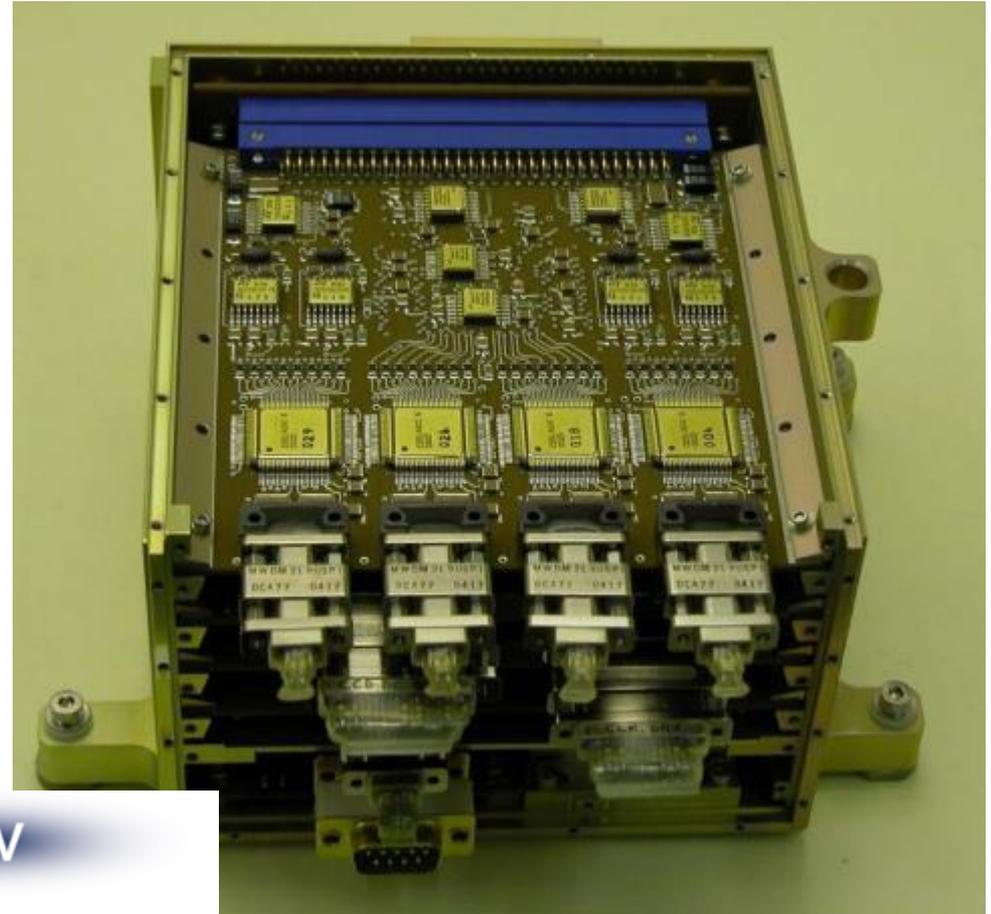
Science & Technology
Facilities Council

www.stfc.ac.uk



e2v technologies CCD203

- 4k x 4k pixels (12 μm pixel)
- Quad readout at 2 Mpixels/s



e2v





- PPD has a history of working with the CMOS Design group and close collaboration with TowerJazz semiconductor foundry
- PPD's current focus is high speed, rad hard, Monolithic Active Pixel Sensors (MAPS) for future experiments such as LHC upgrades, LC, FCC, etc.. for both Digital Calorimetry and Tracking. Also interest in radiation effects in wide band gap materials for use in HEP
- CMOS Design group wants to get more involved in HEP sensors
- Potential to link up with STFC ASIC group's work on RD53.
- Proposed PPD Effort:
 - New post-doc with Birmingham (0.2)
 - E. Giulio Villani (0.2 FTE)
 - Zhige Zhang (0.2)
 - Jens Dopke (0.2)
 - Fergus Wilson (0.1)
 - Steve McMahon (0.05)
 - Craig Sawyer (0.1)
 - Peter Philips (0.05)



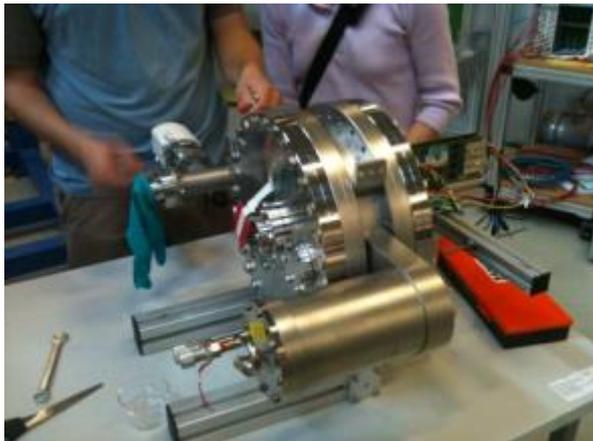
PERCIVAL – Pixelated Energy Resolving CMOS Imager, Versatile and Large

Develop a wafer scale, high frame rate CMOS imager for low energy X-Ray detection

Sensor design by RAL.

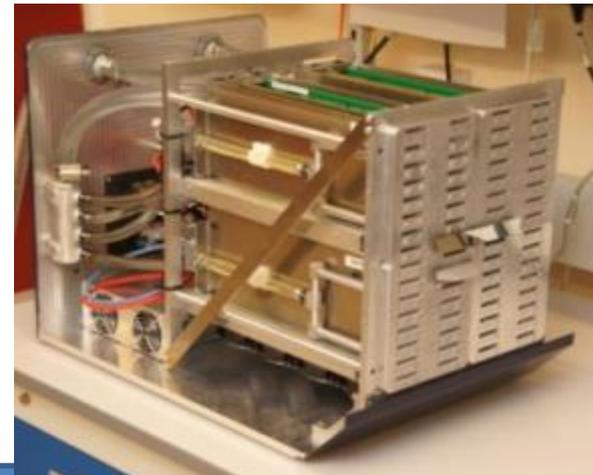
All devices use the TJ 0.18um process

Backthinning carried out under contract with the NASA Jet Propulsion Laboratory (JPL)



Large Pixel Detector

- Built by STFC for the European XFEL
- **1 Megapixel** - 500um pixels
- **4.5MHz frame rate**
- **High dynamic range**, 1 to 1×10^5 photons per pixel per pulse. Using parallel gain stages.
- **512 frame memory depth** continuously stores all three gains, overwriting whenever a veto is received.
- Output data rate **~10GByte/s** per megapixel



Excalibur

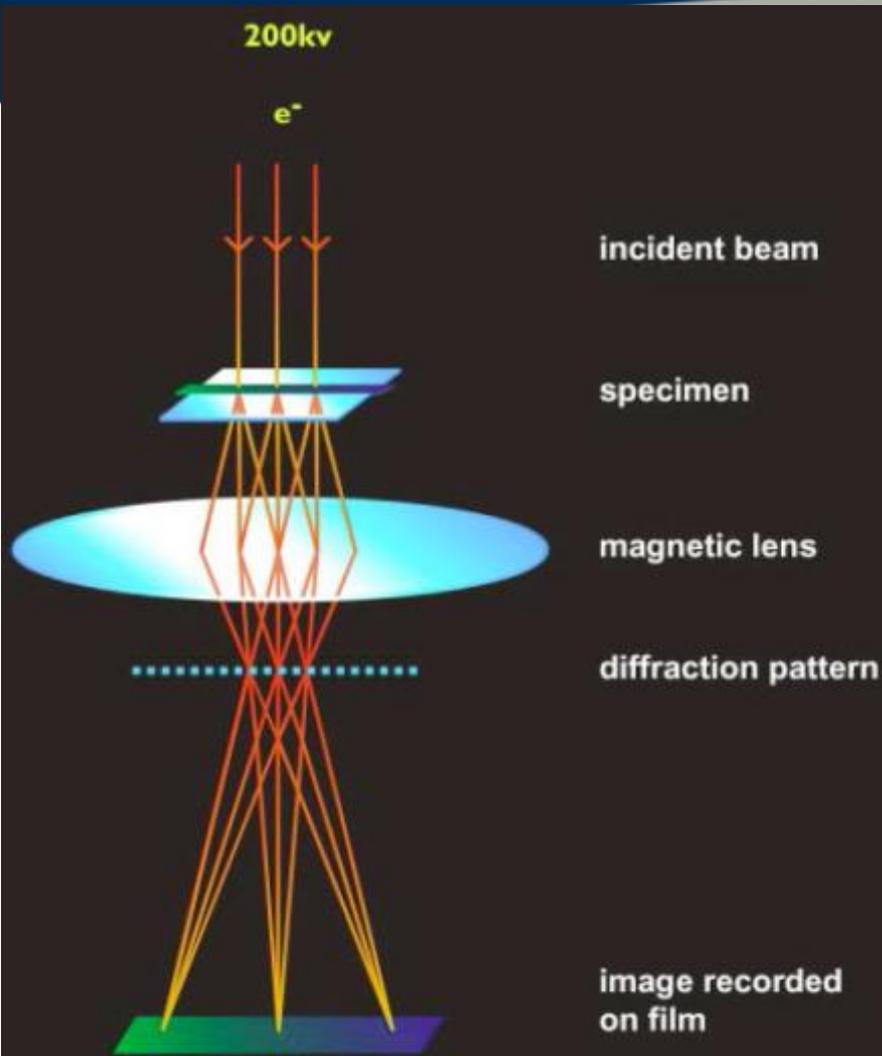


- 48 Medipix readout chips
- 3 Mpixels @55 microns pitch
- 1 kHz frame rate

Merlin

Quad Medipix3 system
Zero Dead Time Between Frames
Spectroscopic Imaging with no external Cooling System
Compact Size
55pm pixels
1200 Frames Per Second
1 ps Exposure Time
5 keV - 17 keV Range
12 and 24 Bit Counter Modes
Commercially available

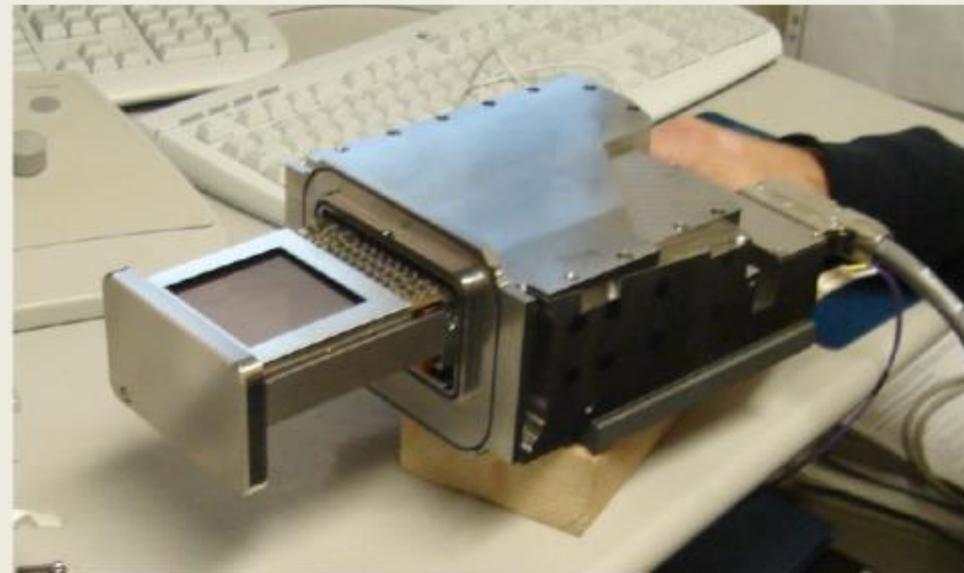




Falcon (MAPS) JINSTdoi:10.1088/1748-0221/6/03/C03003

FEI

2013



McMullan, Faruqi, Clare & Henderson
arXiv:1406.1389[physics.ins-det]

Supporting consortia: MRC-LMB, Max Planck
Institute, FEI and STFC

Backup slides - Neutron imaging



Science & Technology
Facilities Council

www.stfc.ac.uk

