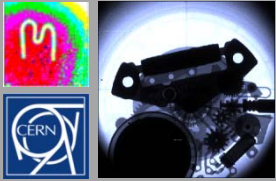# AUTOMATIC TESTING OF MEDIPIX WAFERS
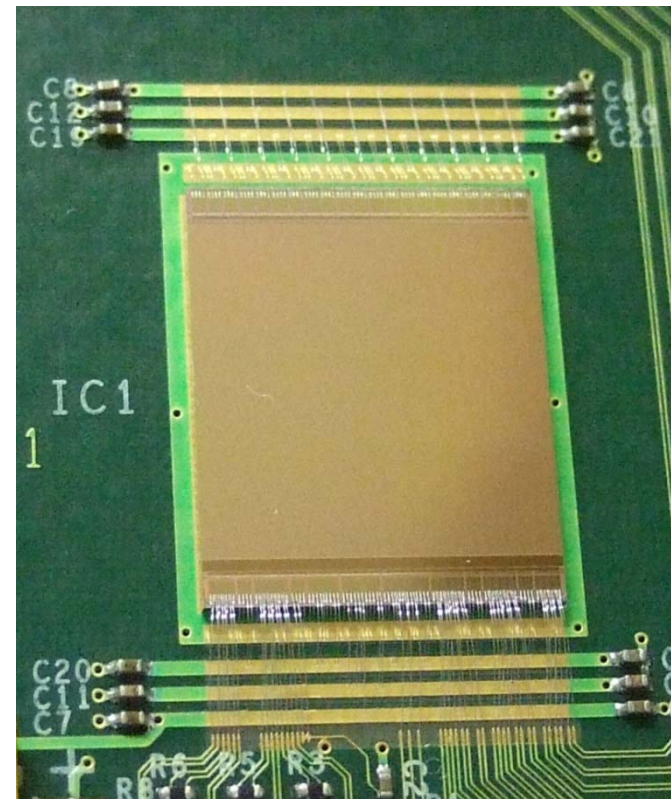
**Developing systems to measure Medipix chips**

**Richard Plackett - CERN – April 2nd**
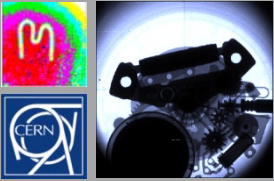
# Outline

- **The Medipix Project**
  - **Hybrid Pixel Detectors**
  - **The Medipix Chips**
  - **'Real World' Applications (and HEP)**

- **Automatic Wafer Testing**
  - **Motivating Automatic Testing**
  - **Tools Available**
  - **Using Optical Feedback**
  - **Giga-Pixel Chip Imaging**
  - **First Results**
  - **Next Steps**

- **Further Work**
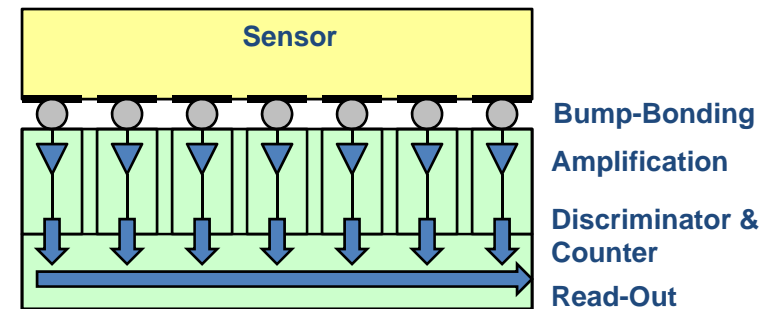


The newly arrived Medipix3 chips
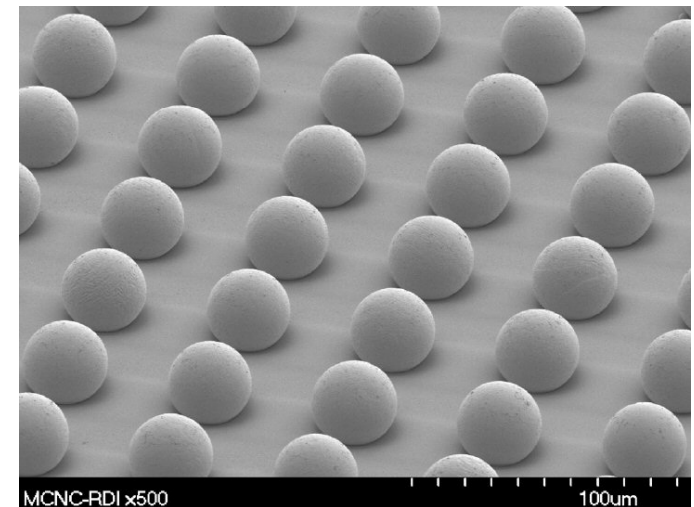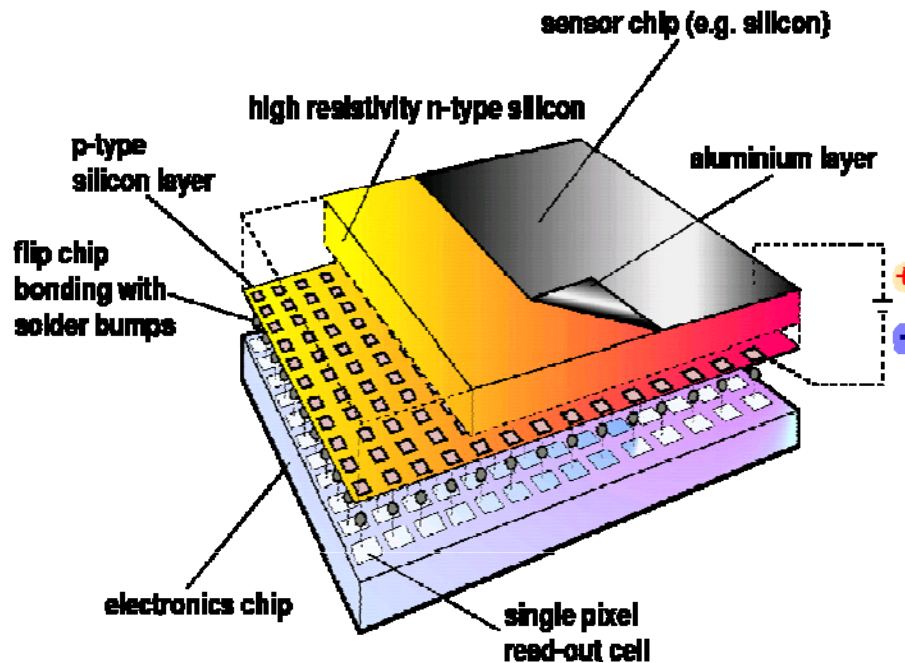
# Hybrid Pixel Detectors

Hybrid Detectors are a 'sandwich' of a sensor and read-out chip.

Each pixel can have its own analogue and digital elements.. Amplification, shaping, discrimination, counters etc.
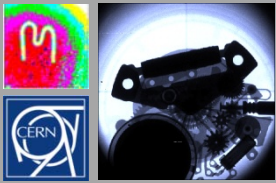
Very short connections to read-out reduce cross talk and noise.



**Sensor**

Bump-Bonding

Amplification

Discriminator & Counter

Read-Out



sensor chip (e.g. silicon)

high resistivity n-type silicon

p-type silicon layer

aluminium layer

flip chip bonding with solder bumps

+

-

electronics chip

single pixel read-out cell



MCNC-RDI x500     100um

High density solder bump bonding is a key technology
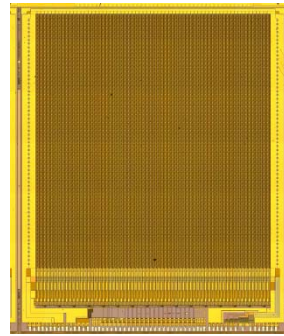
ACEOLE meeting, CERN (2nd April 2009)          Richard Plackett
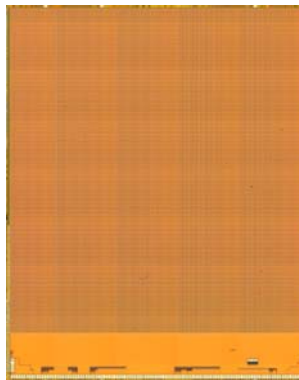
# Medipix Chips

## Medipix1 (1997)
Proof of concept, photon counting,
64x64 pixels, 3 bit threshold tuning
1um CMOS

## Medipix2 (2002)
Photon counting , 55um pixels,
256x256, Positive and negative
sensors, Pixel level leakage
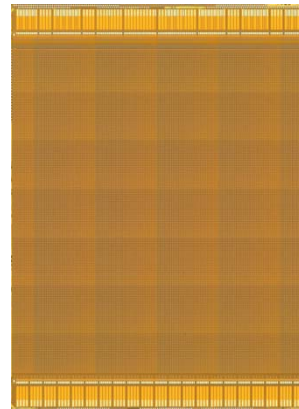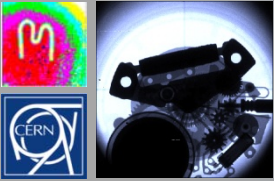compensation, 3 side tile-able
Upper and lower threshold levels
250nm CMOS

## Timepix (2006)
As Medipix2, with additional..
Time over threshold energy measurement
Accurate time of arrival count

## Medipix3 (2009)
55um pixels, 256x256,
charge sharing summation,
2 thresholds and 2 counters per pixel,
quad pixel spectroscopic mode,
continuous readout mode,
130nm CMOS

ACEOLE meeting, CERN (2nd April 2009)          Richard Plackett

# Modes of Operation

## Photon Counting

Count hits over threshold rather than simply accumulating charge
Available with all Medipix chips

## Time over Threshold

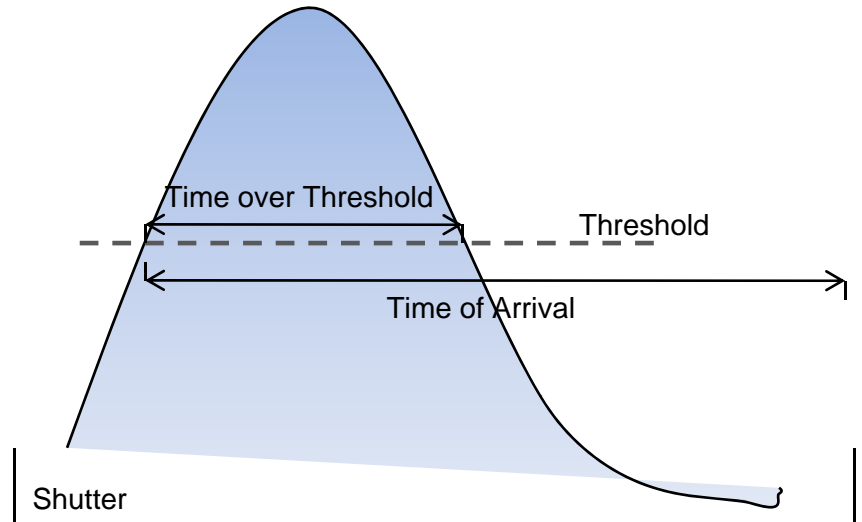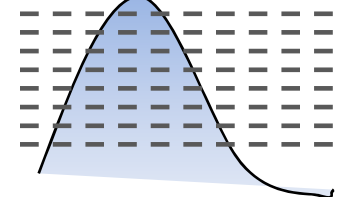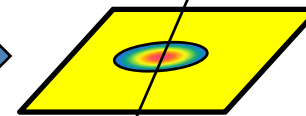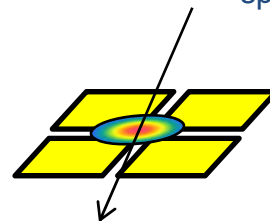Measure the time a hit passes a threshold for a measurement of the energy deposited in the sensor.

## Time of Arrival

Measure the time from a hit until the 'shutter' is closed



## Charge Summing

If a 'cluster' of hits is found, allocate all the charge to the hardest hit pixel. This combats charge sharing.
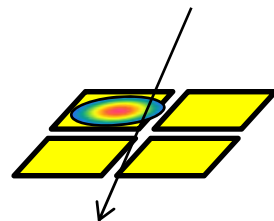
## Spectroscopic Pixels

Using 4 pixel 'superpixels' the many thresholds and counters give 8 levels of energy resolution whilst losing a factor of 2 spatial resolution

ACEOLE meeting, CERN (2nd April 2009)                Richard Plackett

# The Collaboration

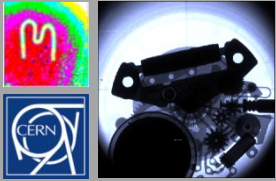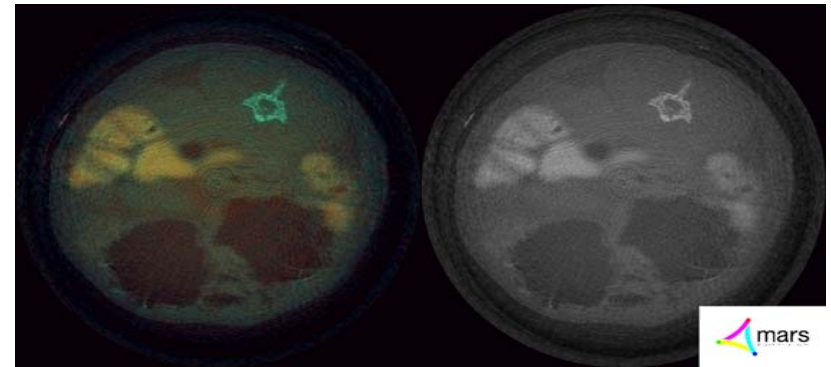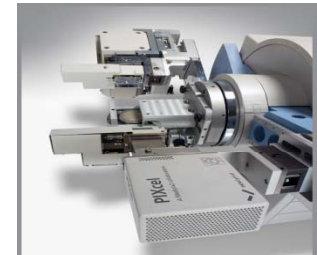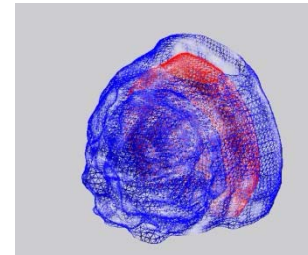## People are doing lots of things with Medipix chips

**Medipix CT**
The MARS project in NZ is making a 'colour' multi spectral CT scanner.

**Medipix XRD**
PANalytical (NL) is selling Medipix chips in its X-Ray Diffraction systems.

**Medipix in Space**
Will fly in 2010 as part of the LUCID cosmic ray flux experiment.

**Medipix to Mars**
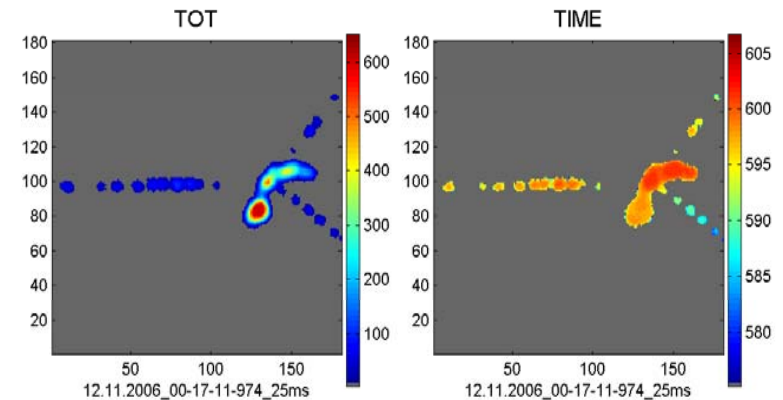Is being used in Houston to characterise Astronaut dosage for long term interplanetary missions.
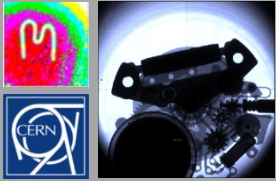
**Medipix Tomography**
Medipix is used in several high-res tomography studies with x-rays and neutrons at Erlangen, CTU an Bogotá.

**Medipix TPC**
Timepix was developed for use in next generation Time Projection Chambers, demonstrated by Freiburg.

ACEOLE meeting, CERN (2nd April 2009)                    Richard Plackett

# More Collaborators

**Medipix Electron Microscopy**
Enhancing new electron microscopy systems in collaboration with Leiden & Cambridge.

**Medipix Photon Detectors**
New HPDs and Micro channel plate photon detectors from Glasgow and Berkley.

**Medipix at SLSs**
The Detector groups from ESRF and Diamond Synchrotron Light Sources are part of the collaboration.
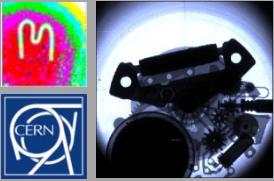
**Medipix in the LHC**
ATLAS and CMS are using Medipix chips as radiation monitoring devices providing real-time neutron monitoring.

**Medipix Mass Spectroscopy**
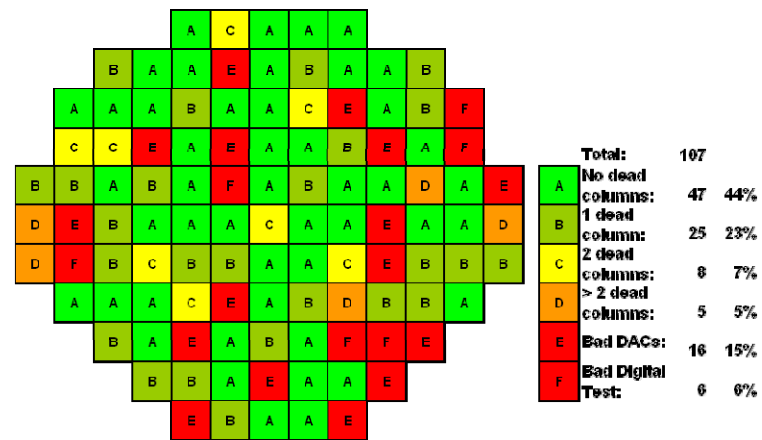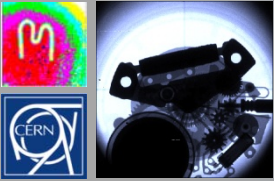New generation imaging-spectroscopy systems at Kiev are using Medipix in fields such as proteomics.

ACEOLE meeting, CERN (2nd April 2009)          Richard Plackett
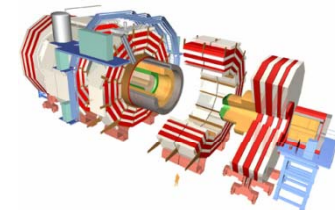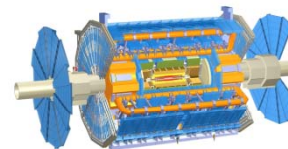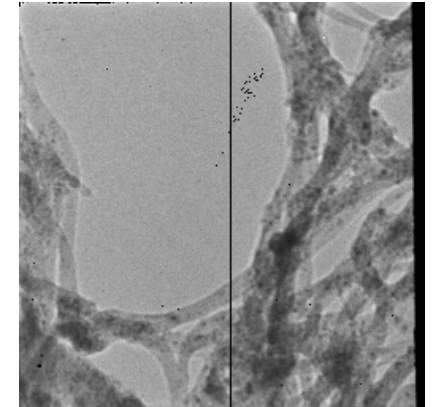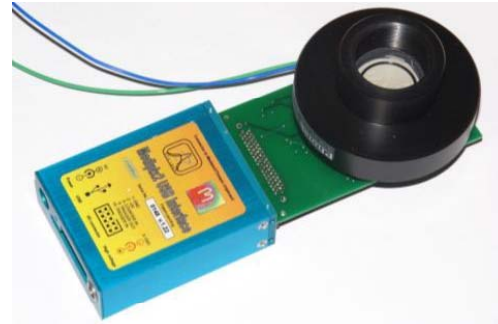
# Motivating Automatic Measurements

- **Medipix3 chips have a 32 bit serial number that must be burnt on, so \*All\* new chips have to pass through a probe station once.**

- **For Medipix2/Timepix basic probing ~3 or 4 minutes per test so operators are continuously working for several hours to complete a wafer.**

- **Currently each chip has to be positioned and contacted by hand which is VERY time consuming…     (100 chips per wafer)**

- **CERN is a production center and our collaborators rely on us to provide them with chips and assemblies.**

- **For PANalytical a well controlled and characterised supply is commercially necessary**

I ALWAYS HAVE TO POSTPONE WHAT I *WANT* TO DO FOR WHAT I *HAVE* TO DO!

| | | | | | |
|---|---|---|---|---|---|
| Total: | 107 | | | | |
| No dead columns: | 47 | 44% | | | |
| 1 dead column: | 25 | 23% | | | |
| 2 dead columns: | 8 | 7% | | | |
| > 2 dead columns: | 5 | 5% | | | |
| Bad DACs: | 16 | 15% | | | |
| Bad Digital Test: | 6 | 6% | | | |

ACEOLE meeting, CERN (2nd April 2009)                    Richard Plackett

# Tools Available

- **Suss MicroTec PA200 'semiautomatic' probe station**
  - **Already used to for previous chips**
  - **Can be controlled via IP**
  - **Video feedback from microscope**
  - **Micron accuracy on chuck**

- **Matlab**
  - **Training provided by ACEOLE**
  - **Easy image processing**
  - **Good control development libraries**
  - **Rapid development**

- **Pixelman**
  - **Medipix Readout Software**

Camera integrated into microscope provides an optical feedback

Probe card powers and read out chips whilst still on the wafers

4 degree of freedom vacuum chuck provides accurate wafer positioning

ACEOLE meeting, CERN (2nd April 2009)          Richard Plackett
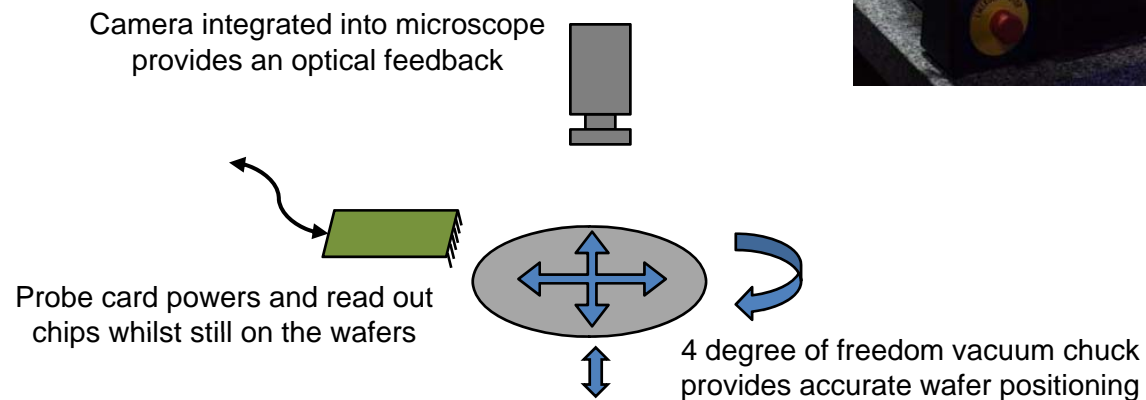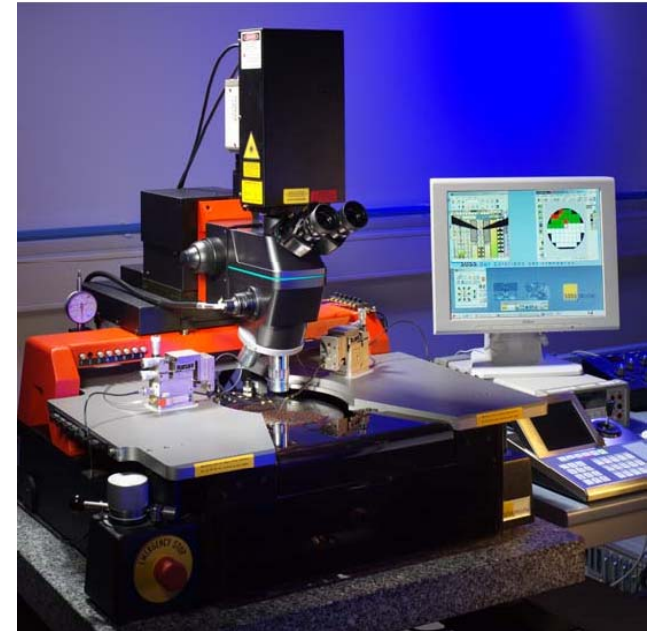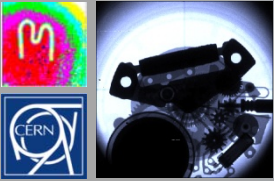
# Optical Feedback

To trust the autonomous alignment and positioning we wanted some feedback .   Using the video feed from the microscope camera..

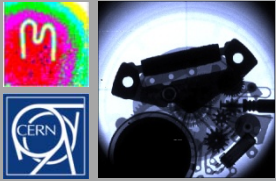- **And the alignment marks on chips…**



Medipix1 'branding'

Medipix2 / Timepix alignment marks

Medipix3 alignment marks

- **Then cross correlate … apply some cuts … peak finding … reducing multiple solutions…**

- **We can have some confidence that the wafer is where we wanted it.**

- **This approach allows us to be general – will work for all Medipix wafers and beyond.**

ACEOLE meeting, CERN (2nd April 2009)          Richard Plackett

# Example : Pad Finding

Video feed



Reference



Correlation Matrix



Apply Probability Cuts



Output Matrix

ACEOLE meeting, CERN (2nd April 2009)          Richard Plackett
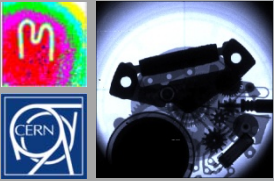
# Giga-Pixel Chip Imaging

**Accurate positional control of the wafer lets us use the probe station as a giga-pixel camera to image the chip.**
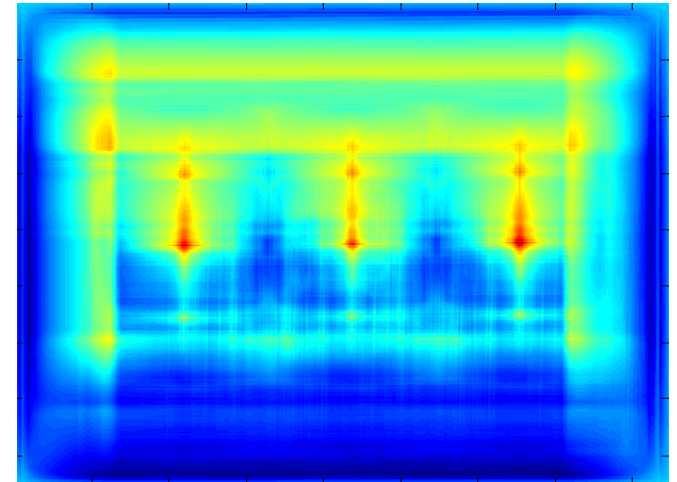
ACEOLE meeting, CERN (2nd April 2009)          Richard Plackett

# Automatic Test Results

- **Currently able to test Medipix2 / Timepix**

- **Probe positioning accurate to ~1um**

- **Wafer alignment and mapping <20mins**

  - **Each chip is individually positioned with optical feedback and its location stored**
  - **Angular alignment to better than 0.01 degrees**

- **Each chip tested in less than 1 minute**

  - **Analogue and Digital parts of the chip are tested**
  - **Voltage levels are optimised and saved**

- **Has re-try capability to overcome bad contacts**
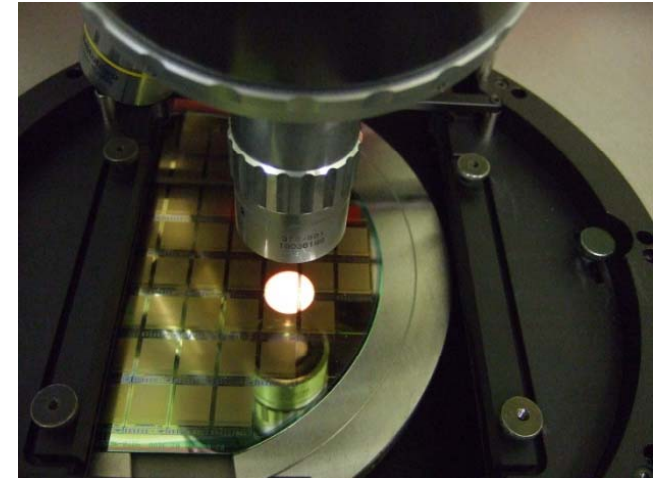


An action shot of the probe system

**Wafer testing time has reduced from a day to 2 hours**

**Operator only needed to start the system not run it continuously**

ACEOLE meeting, CERN (2nd April 2009)          Richard Plackett
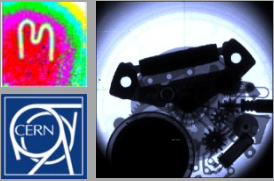
# Next Steps in System Development

## Increasing Robustness and Finalising system

- Introducing more checks into critical functions
- Feedback from analysis routines to re-check chips if necessary
- Automatically produce a wafer map when tests complete



## Assembly Testing

- 21 assemblies in one run
- Individual optical alignment of assemblies ready
- Different tests for each assembly easy to script
- Individual probe height adjustment is still required
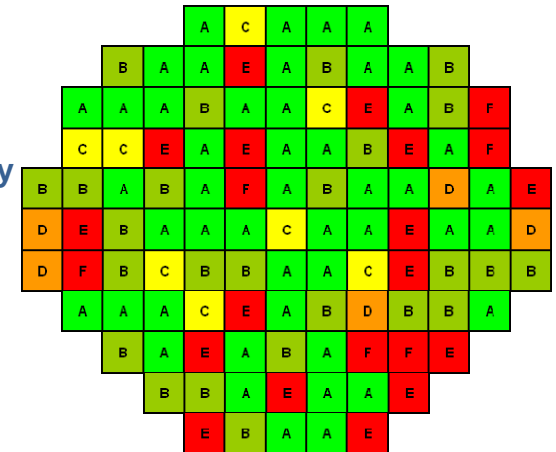
## Medipix 3 – Testing and Identity Burning

- System designed to work with multiple wafer types
- Modular code means tests can be performed with minimal risk to wafers.
- Need to be VERY careful with book-keeping.
- Additional 3.3V voltage supply needs to be integrated.
- Require Medipix3 readout system before we can start.

ACEOLE meeting, CERN (2nd April 2009)

Richard Plackett

# Future Work

- **Characterising sensors at different temperatures**
  - Work has begun preparing a cryostat, modified pieces have already been received from the workshop.
  - We plan to measure a series of sensors GaAs, CdTe, Si etc
  - We will also use it for 'mechanical' proving

- **Using XRD to analyze stresses in bonded assemblies**
  - XRD Training provided at PAN as part of ACEOLE scheme
  - Will modify the PAN system to perform crystal stress measurements over the sensor surface.

- **Super-LHC Test-beams**
  - Tests this summer to see if Medipix technology will be suitable for some upgrade proposals.

- **CERN @ School**
  - I am working with the Langton Star Center, a secondary school project to help develop projects for a distributed cosmic ray detector based on the Timepix chip.
  - Initially 10 USB detectors will be sent to begin training staff in their operation.
  - GPS timing hardware has to be developed and integrated.
  - Links to the LUCID cosmic ray satellite project.

Medipix Project

Hybrid Detectors

Medipix Chips

Applications

Automatic Testing

Motivation

Tools

Optical Feedback

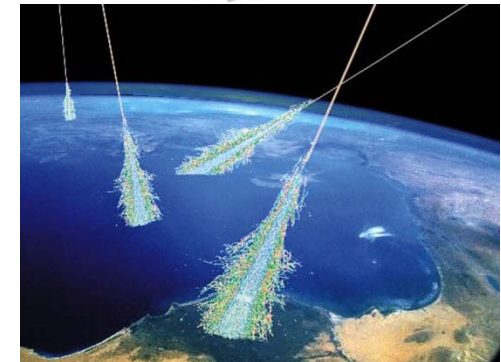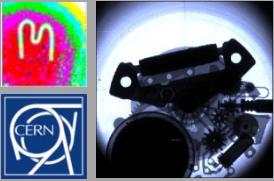Chip Imaging

First Results

Next Steps

Further Work

ACEOLE meeting, CERN (2nd April 2009)

Richard Plackett

# Summary

- **The Medipix Chips are VERY versatile and the collaboration is active in many areas.**

- **Need to automatically test chips by the wafer.**

- **Has to be very reliable and accurate.**

- **Wafers have been successfully tested automatically.**

- **Enhancements for Medipix3 and assemblies in development.**

- **Several other projects now beginning to take shape.**

**~Thank you for your attention~**

ACEOLE meeting, CERN (2nd April 2009)          Richard Plackett