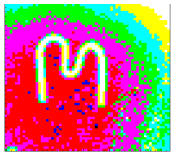
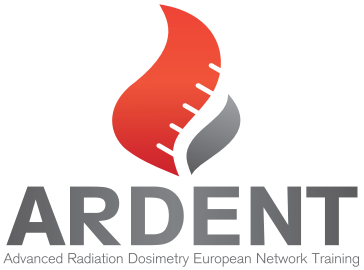
Erik Fröjdh





Hybrid Pixel Detectors for Radiation Protection

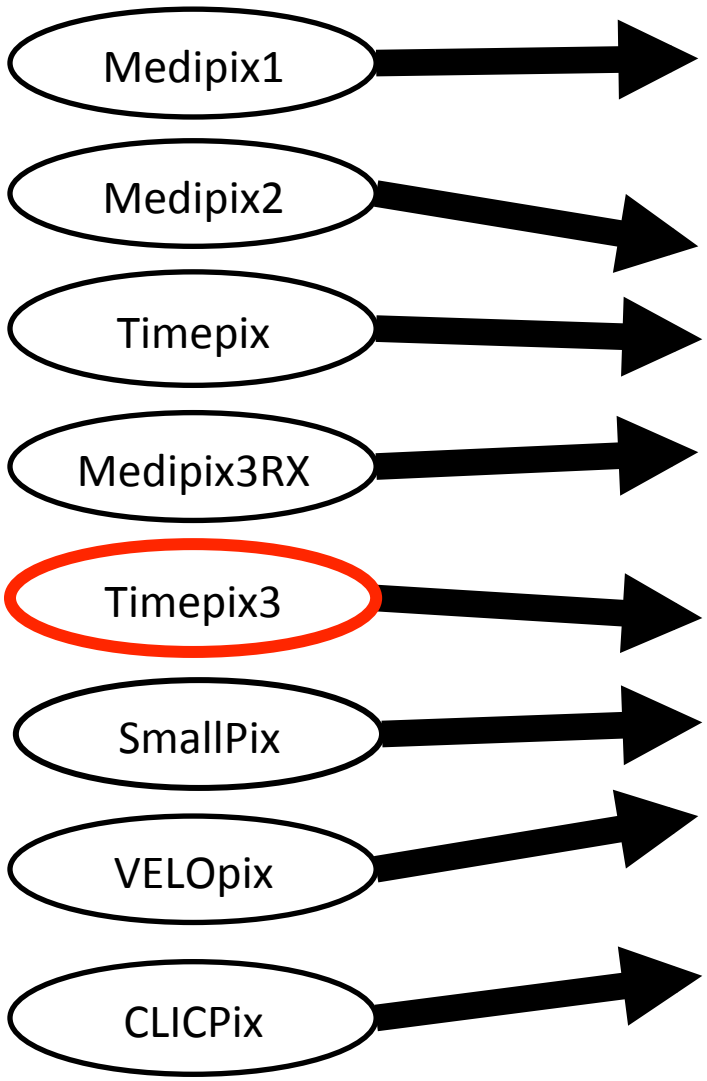
Outline

- Medipix Collaboration
- Hybrid pixel detectors
- Signal formation
- Mixed field response
- Ongoing projects
  - ATLAS-MPX
  - ISS
- Demonstration
- Summary and Conclusions

Medipix Collaboration

- Two active collaborations, Medipix2 and Medipix3
- About 20 members both universities and research institutes.
- Large variety of applications, from X-ray imaging to time of flight mass spectrometry and particle tracking.
- ASIC design and coordination done at CERN

Development Path



1um SCAMOS 64 by 64 pixels
Photon Counting Demonstrator (1997)

250nm IBM CMOS, 256 by 256 55um pixels
Full photon counting (2002)

Analogue (ToT) and Time Stamping (ToA) (2006)

130nm IBM CMOS, 256 by 256 55um pixels
Photon Counting, Spectroscopic, Charge Summing, Continuous Readout (2012)

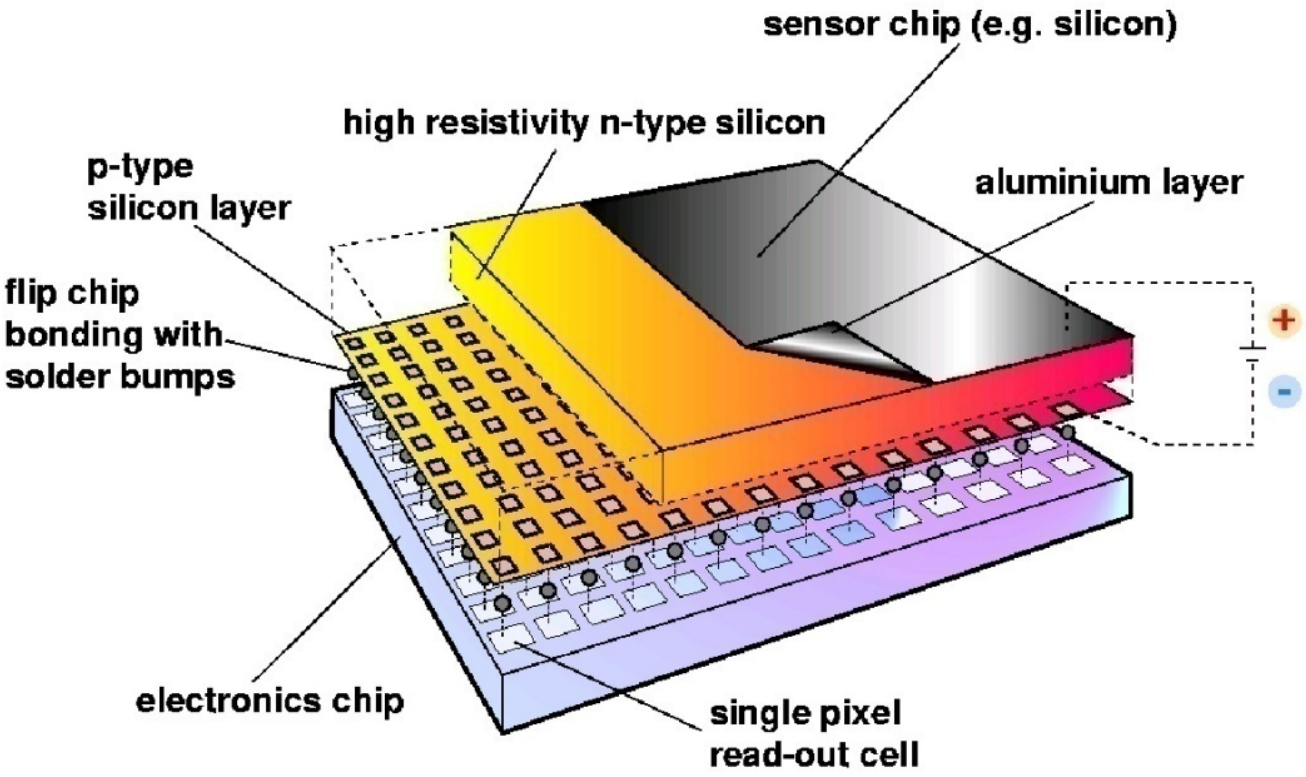
Fast front end, Simultaneous ToT and ToA <20 Mcounts/cm^2/s (2013)
Fast front end, Simultaneous ToT and ToA (2013) 0-suppressed
Future LHCb readout – Data driven 40MHz ToT 12Gb/s per chip (2013) ~500 Mcounts/cm^2/s

65nm, ~20um pixels
Future Hybrid Pixel Time tagging layer for the LCD project (20??)

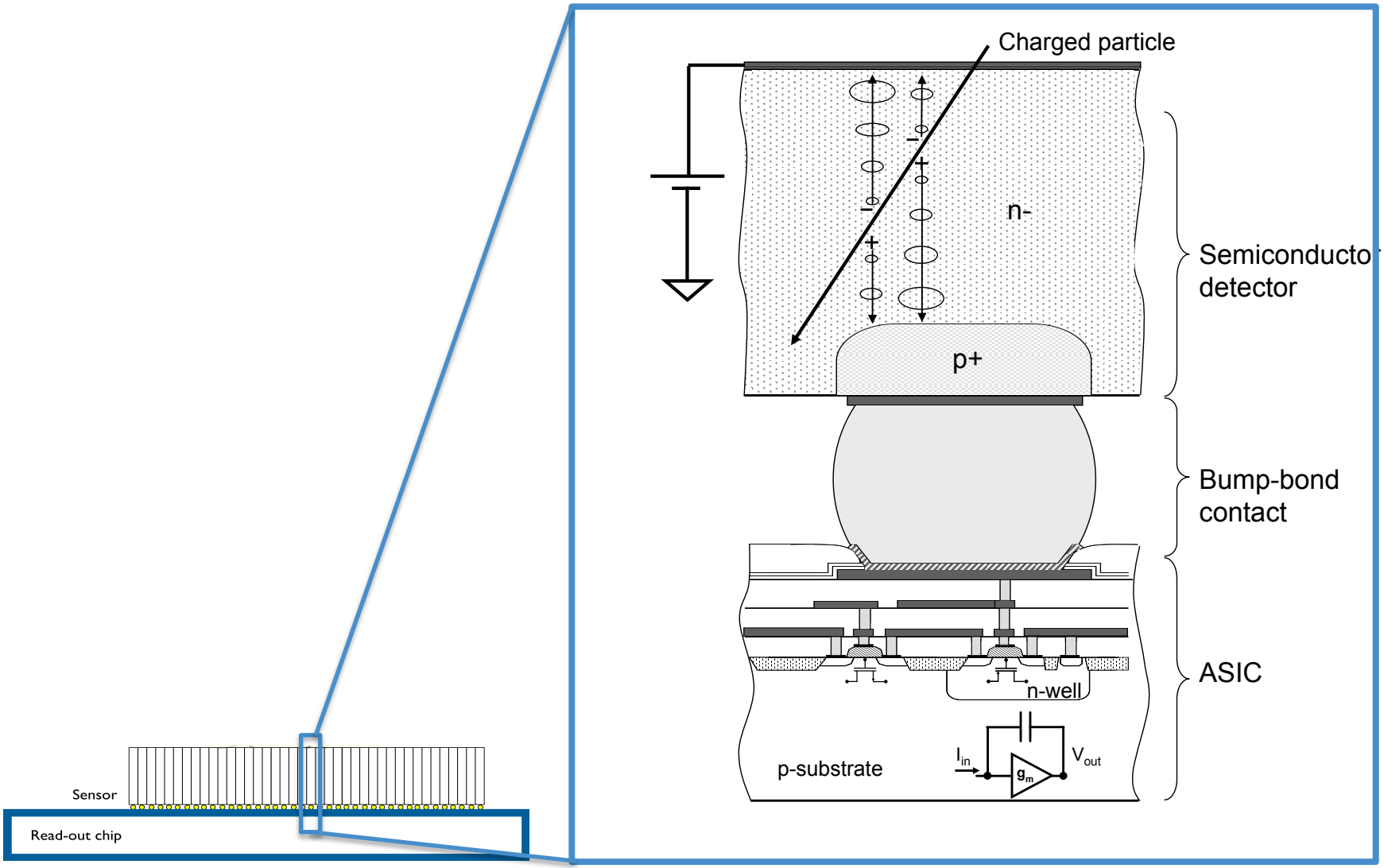
The Medipix2 Collaboration

Institut de Fisca d'Altes Energies, Barcelona, Spain 
University of Cagliari and INFN Section thereof, Italy 
CEA, Paris, France 
CERN, Geneva, Switzerland, 
Universitat Freiburg, Freiburg, Germany, 
University of Glasgow, Scotland, UK 
Universita' di Napoli and INFN Section thereof, Italy 
NIKHEF, Amsterdam, The Netherlands 
University of Pisa and INFN Section thereof, Italy 
Laboratory of Molecular Biology, Cambridge, England, UK 
Mid Sweden University Sundsvall, Sweden, 
Czech Technical University, Prague, Czech Republic 
ESRF, Grenoble, France 
Academy of Sciences of the Czech Republic, Prague 
Universität Erlangen-Nurnberg, Erlangen, Germany 
University of California, Berkeley, USA 
University of Houston, Texas, USA 

Hybrid Pixel Detectors



Hybrid Pixel Detectors

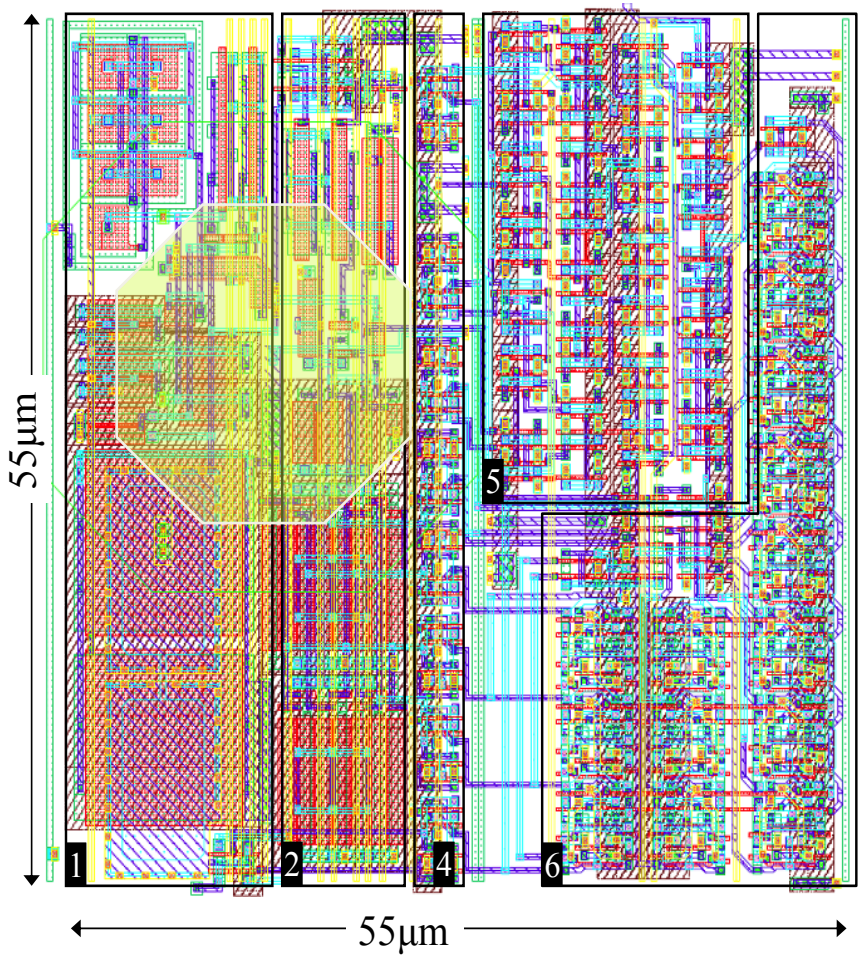


Timepix

- Hybrid Pixel Detector
- 256x256 pixels
- 55um pixel pitch

- Single Photon Processing
  - Time-over-Threshold
  - Time of arrival
  - Photon Counting

Capable of operating in both electron and hole collection mode



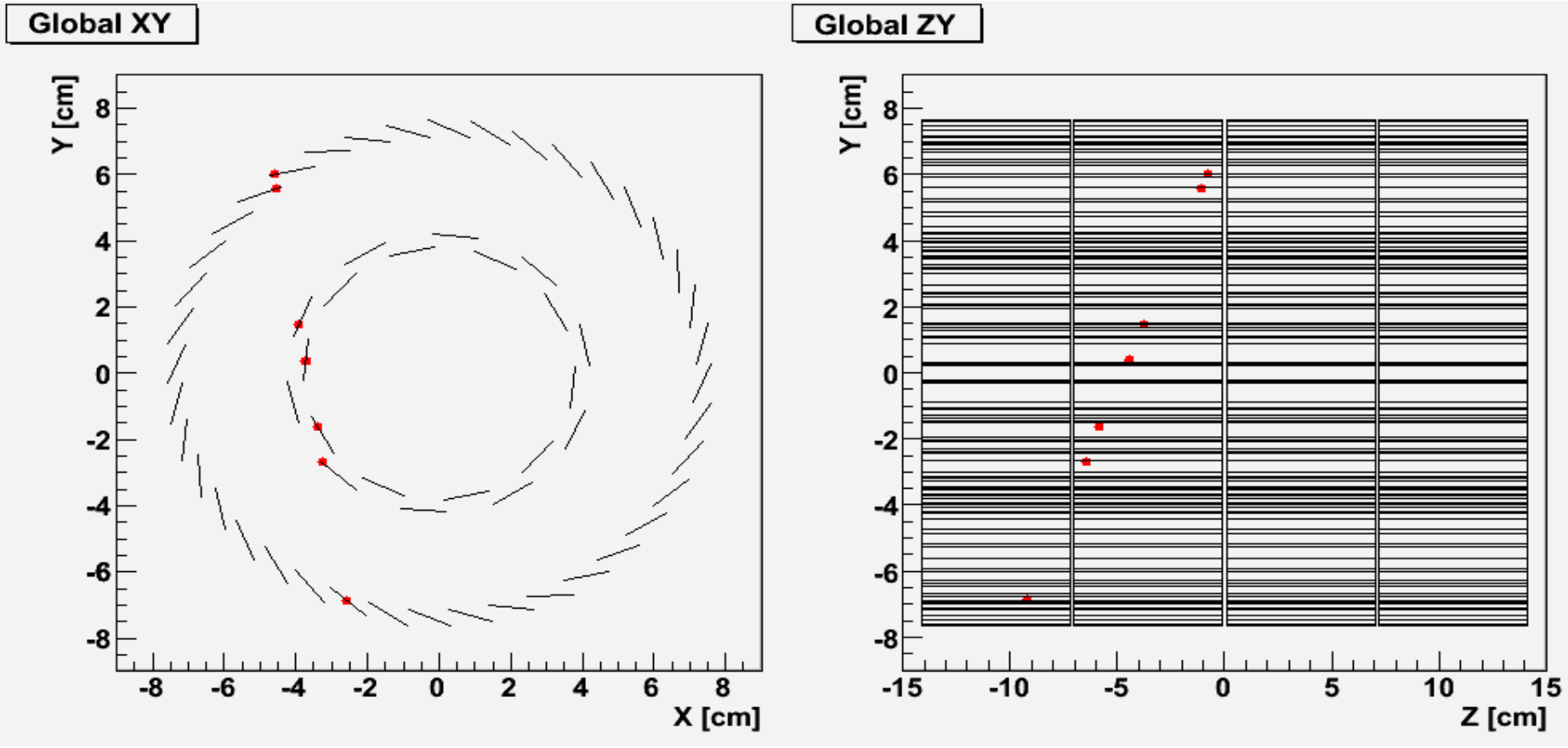
~ 500 transistors / pixel

Benefits of Single Photon Processing

- Each sensor pixel has its own dedicated readout circuit
- That circuit is sensitive *only* to the tiny electrical pulses generated by ionizing radiation in the sensor and not to other background noise
- Because of this hybrid pixels deliver clean noise-free images

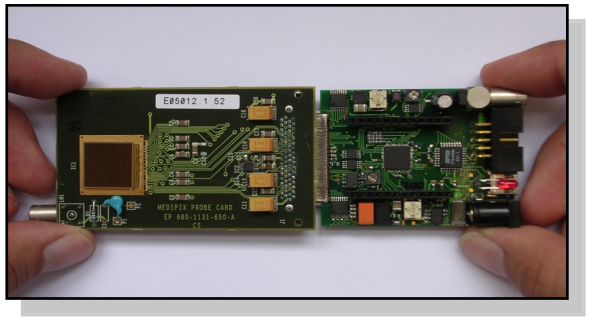
M. Campbell

Cosmic Particles in the Alice Experiment

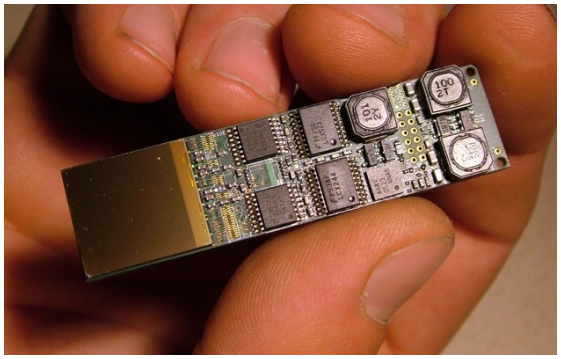


Timepix

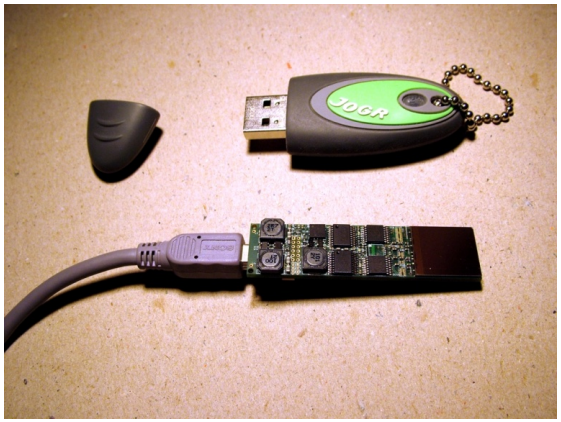
- Compact system 15x60mm for the USB Lite read out including sensor
- USB Connection to standard PC
- Pixelman control software allowing scripting and plugins



Usb read out



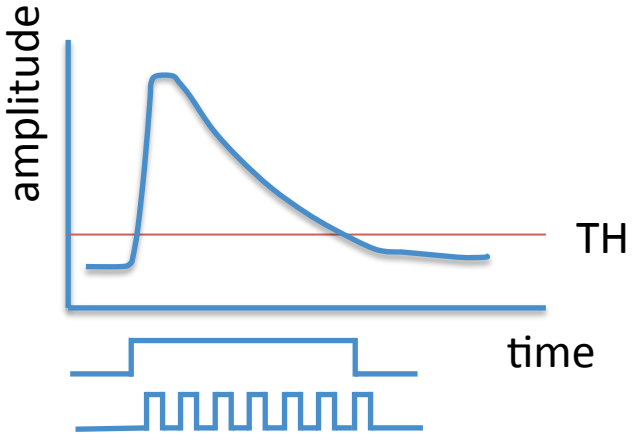
Usb lite



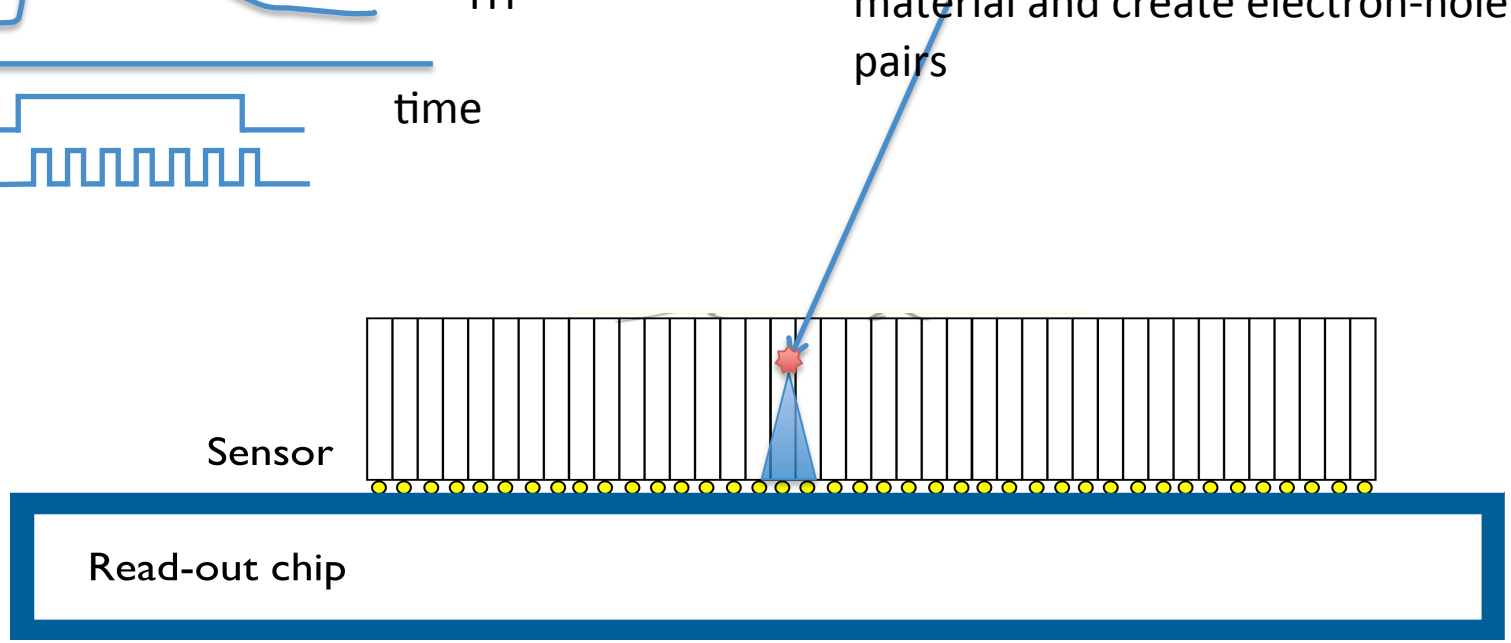
Usb lite

Pictures courtesy of IEAP Prague

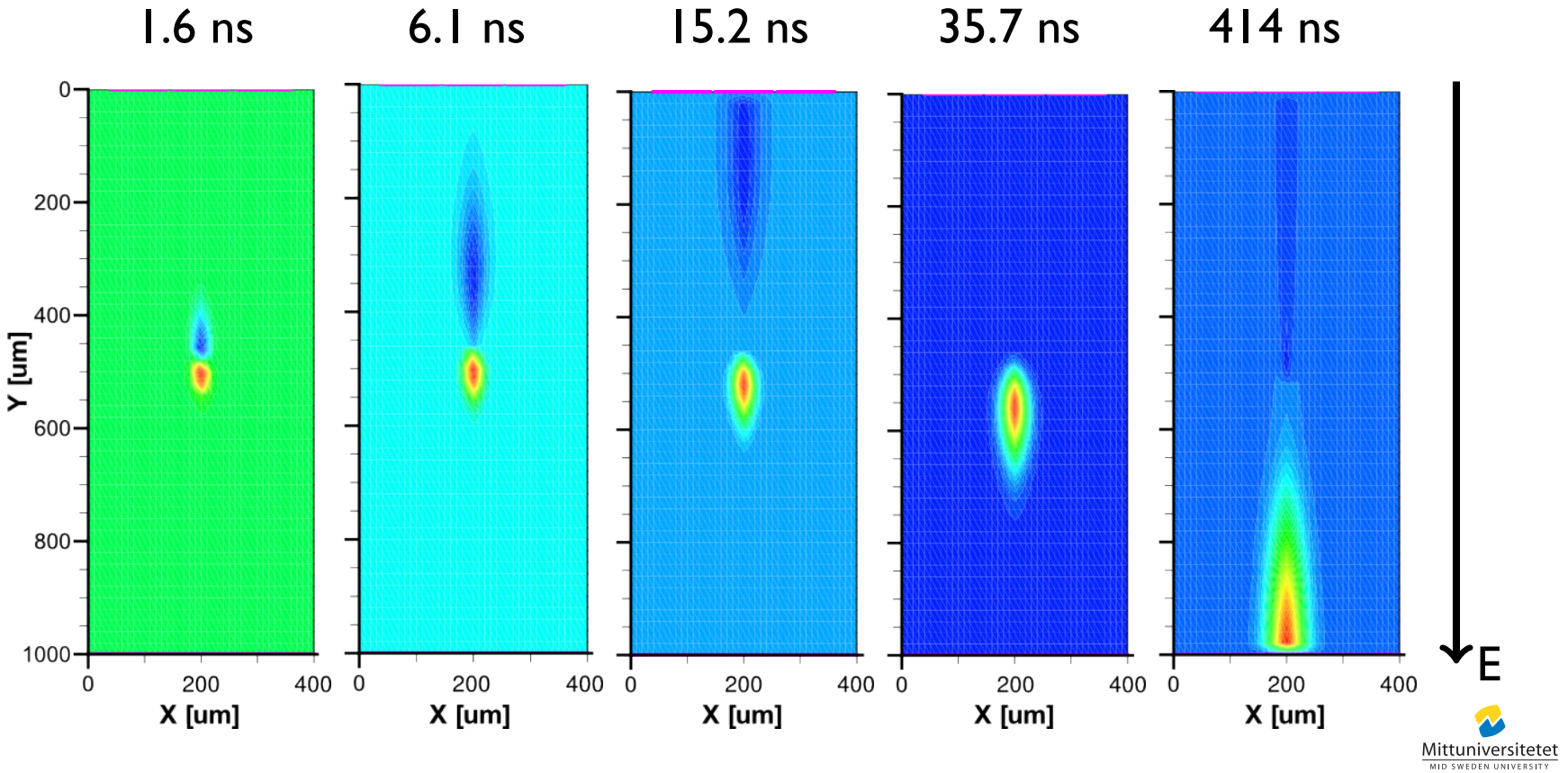
Signal Formation



- Moving charge induces a signal on the read out pad
- Pulse height is proportional to the deposited energy
- In order to detect a particle it has to interact with the sensor material and create electron-hole pairs



Charge carrier simulation CdTe

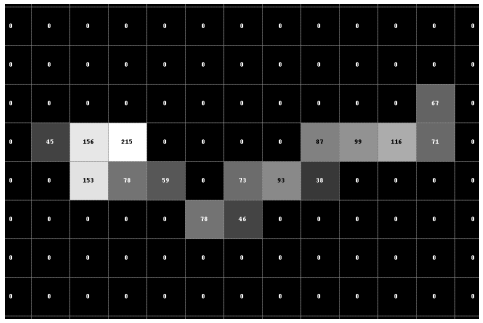


By David Krapohl, Mid Sweden University

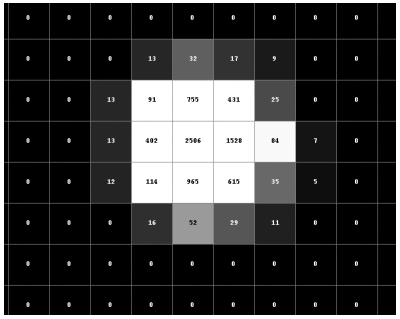
Basic Particle Identification

- Mixed radiation fields poses problems for dosimetric measurements.
- An advantage of a pixelated detectors is that particles can be identified by their track shape.
- This is based on the different ways the particles interact in the sensor.

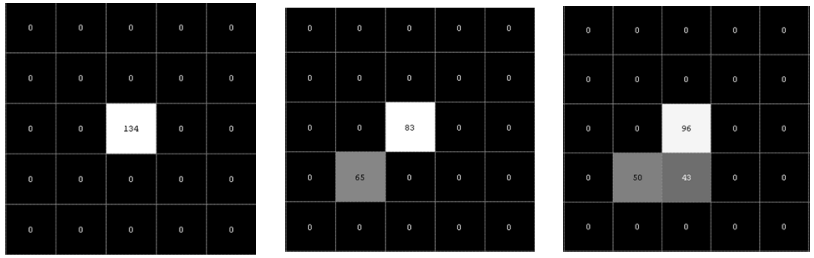
Basic Particle Identification



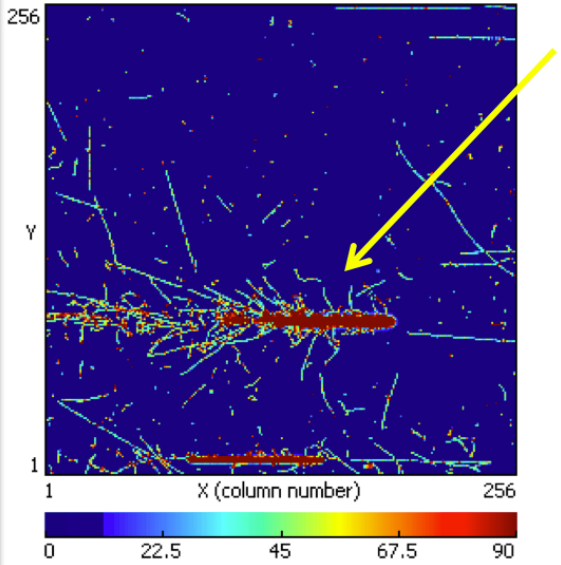
0.5MeV Electron (^{90}Sr)



5.5MeV Alpha (^{241}Am)



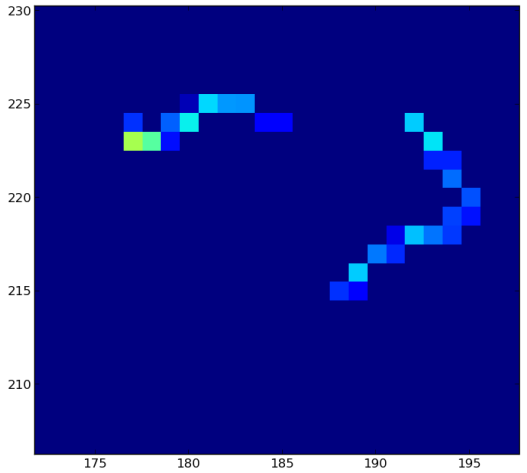
60keV Photons (^{241}Am)



Pb ion with delta rays
Erik Heijne [2]

Basic Particle Identification

- Possible to categorize particles using track and energy information
- Some types of particles are hard or impossible to separate
- Additional convertors and filters improve the detection specificity



β^- radiation or Compton electrons?

Neutron Detection

- Neutron have no charge and are therefore not directly detectable by Coulomb interactions in the sensor.
- Thermal neutrons are detected by the production of secondary radiation by neutron capture in a convertor layer
- Ex. n + 6Li → α (2.05 MeV) + 3H (2.73 MeV)
- Fast neutrons can be detected by elastic scattering in the sensor layer but for increased efficiency and specificity a hydrogen rich converter material as Poly ethylene is used.

Neutron Detection

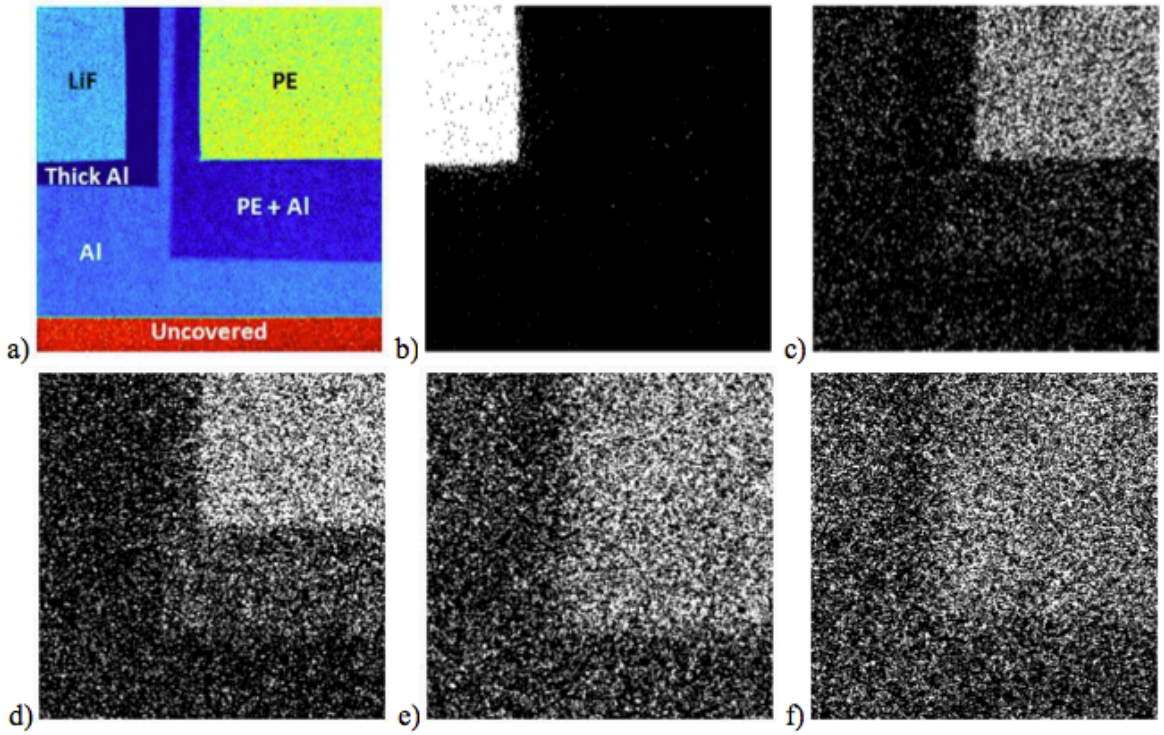
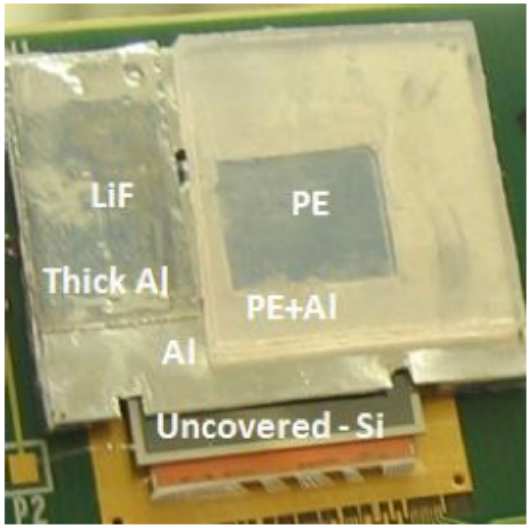


Figure 50. a) X-ray radiogram of conversion layers above one of the ATLAS-MPX devices. Integrated response of the device set to high threshold mode to b) thermal neutrons (25 meV) and to fast neutrons of c) ^{252}Cf (2.1 MeV); d) ^{241}AmBe (4.5 MeV); e) Van de Graaff accelerator (14 MeV) and f) cyclotron (2 - 30 MeV).

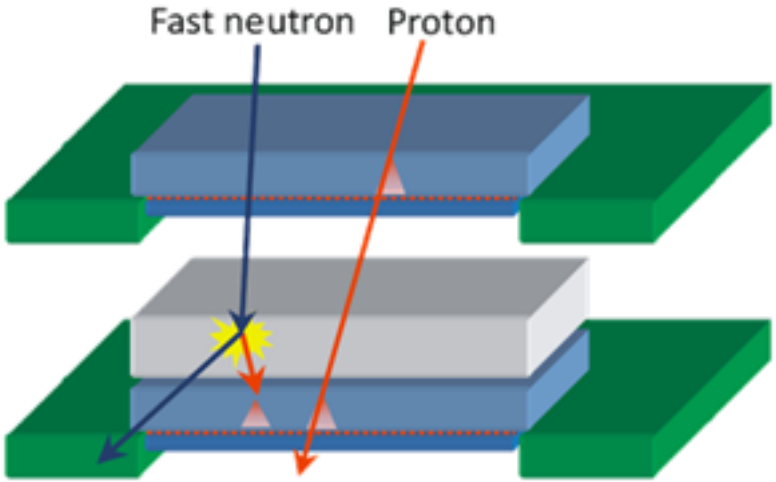


Medipix2MXR with different convertors.

Work done by Z. Vykydal [1]

Improved Neutron Detection

- To separate heavy charged particles form neutron response test have been made with a multi layer detector.
- **Interactions registered in both layers**
  - Low LET signatures – minimum ionizing charge particles (muons, energetic electrons,...)
  - High LET signatures – highly ionizing charged particles (~10 MeV protons,...)
- **Interactions registered in single layer only**
  - Low LET signatures – photon interactions in one of the sensitive layers
  - High LET signatures – fast neutron interactions in polyethylene region or thermal neutron interactions in 6Li region



Example of particle identification using a two layer detector

Work done by Z. Vykydal [1]

ATLAS-MPX Network

- 16 Medipix2MXR detectors with neutron convertors
- Placed in the ATLAS experimental cavern
- Installed in 2008 before the first LHC beam
- Proposed upgrade to Timepix detectors

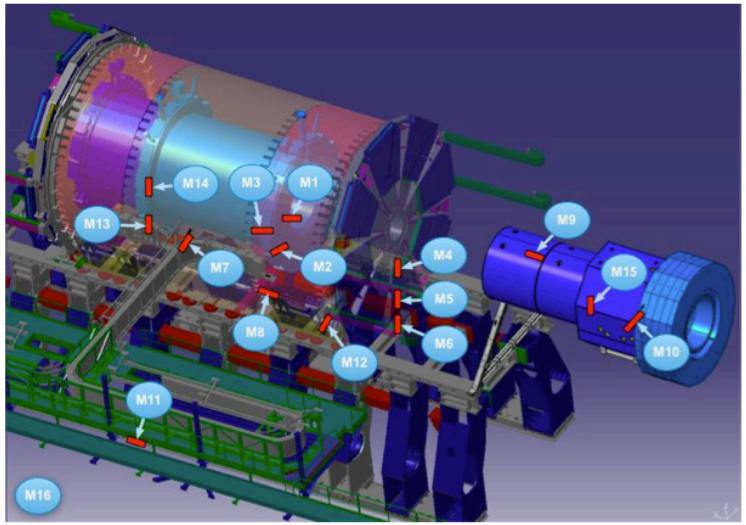
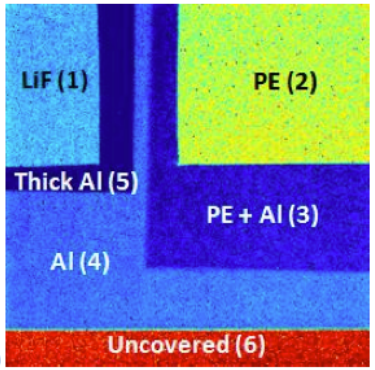
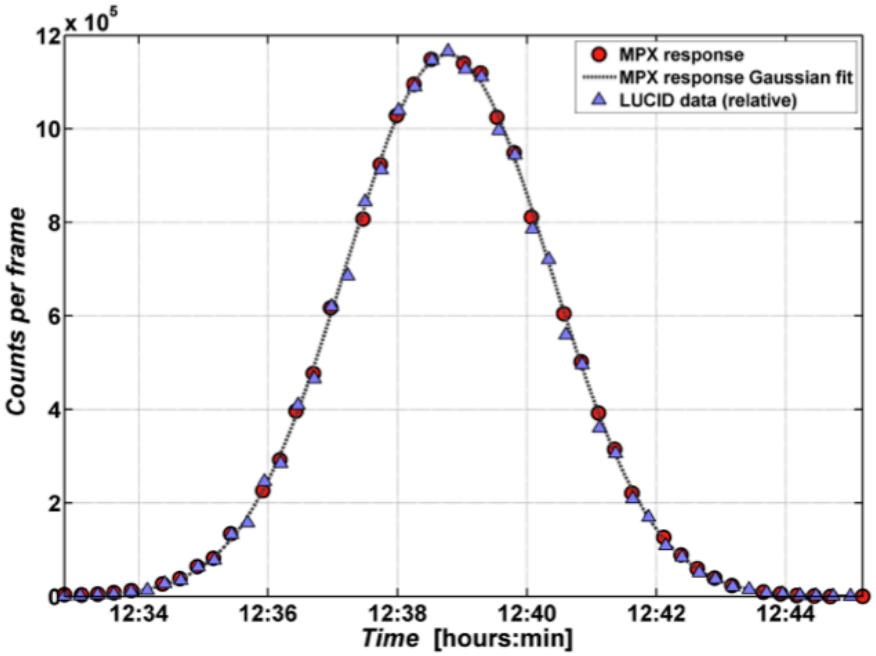


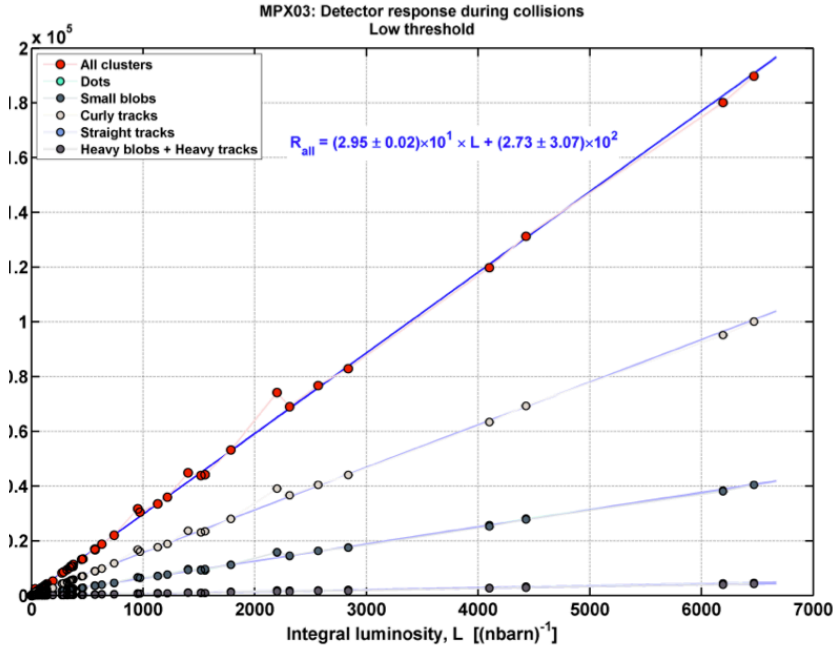
Figure 34. The network of ATLAS-MPX detectors in ATLAS.



Work done by Z. Vykydal [1]

ATLAS-MPX

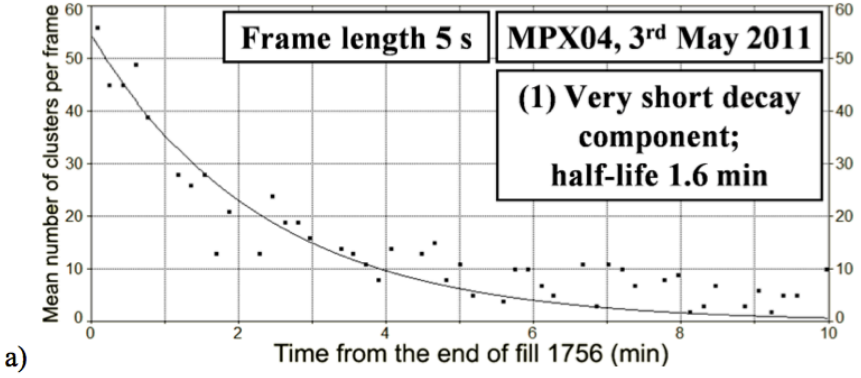




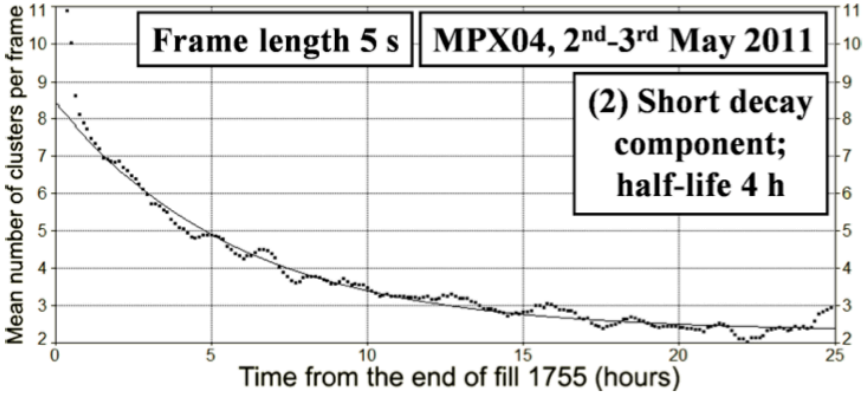
Good agreement with beam luminosity and other instruments

Work done by Z. Vykydal [1]

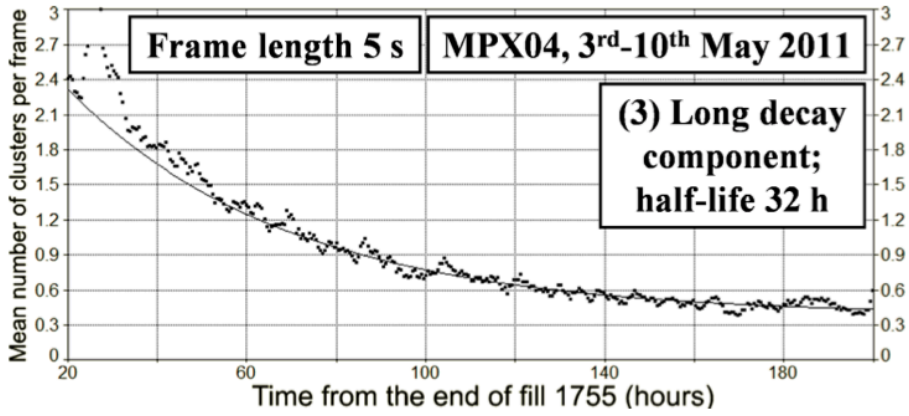
Radioactive Activation



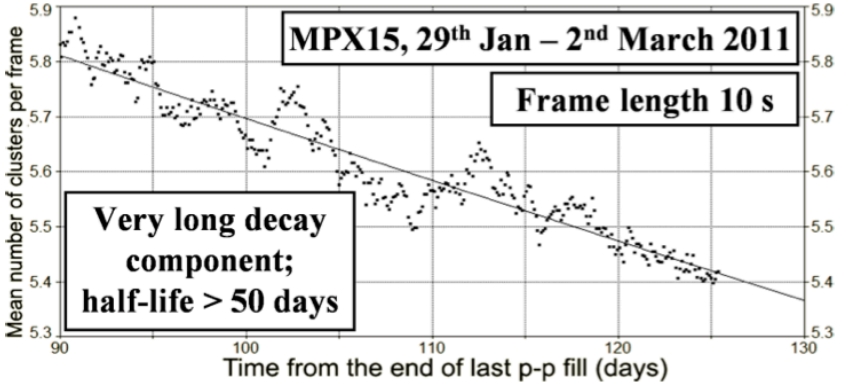
a)



b)



c)



d)

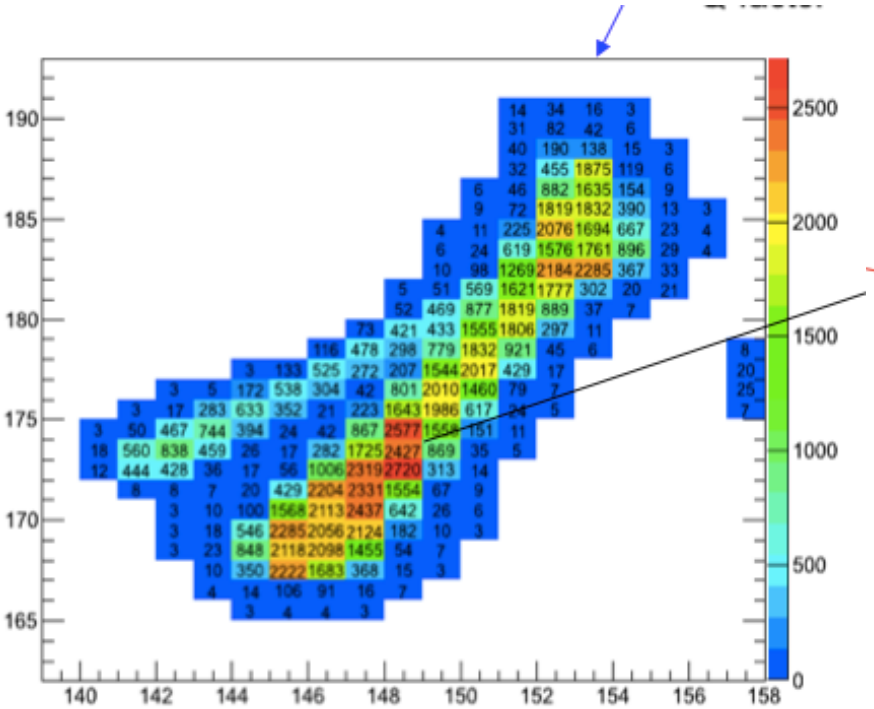
Work done by Z. Vykydal [1]

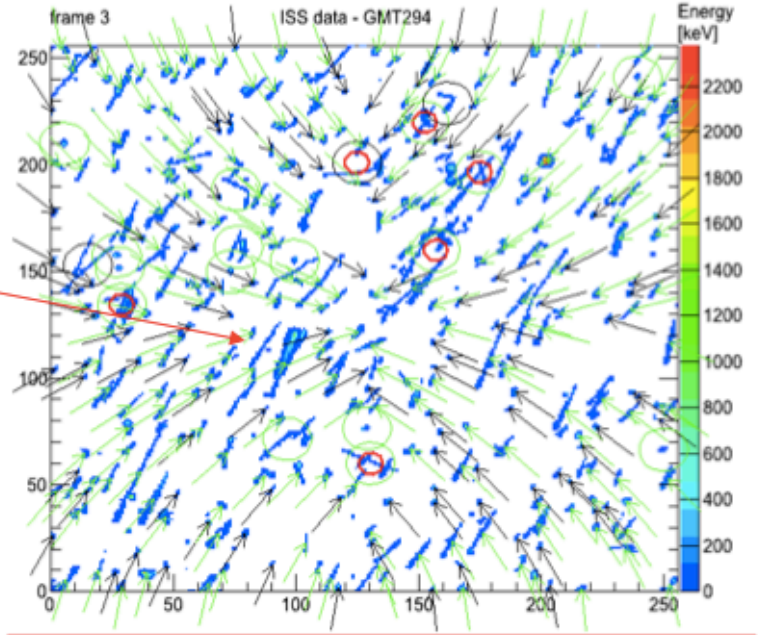
Timepix Detectors at ISS

- 5 Timepix Usb Lite detectors with 300um Si sensors are currently in operation at the ISS
- Evaluated as an option for radiation field monitors and personal dosimeters
- Mixed radiation field
- Important to get the right quality factor for heavy ions


KAVANDI
105
UF-1
CXIII
EMERGENCY USE
FIRE PORT

Timepix Detectors at ISS





Heavy fragment found in a very busy frame.

Heavy Ion fragment, Q factor ~ 25

Demonstration

Why use Hybrid Pixel Detectors for Mixed Field Radiation Measurements?

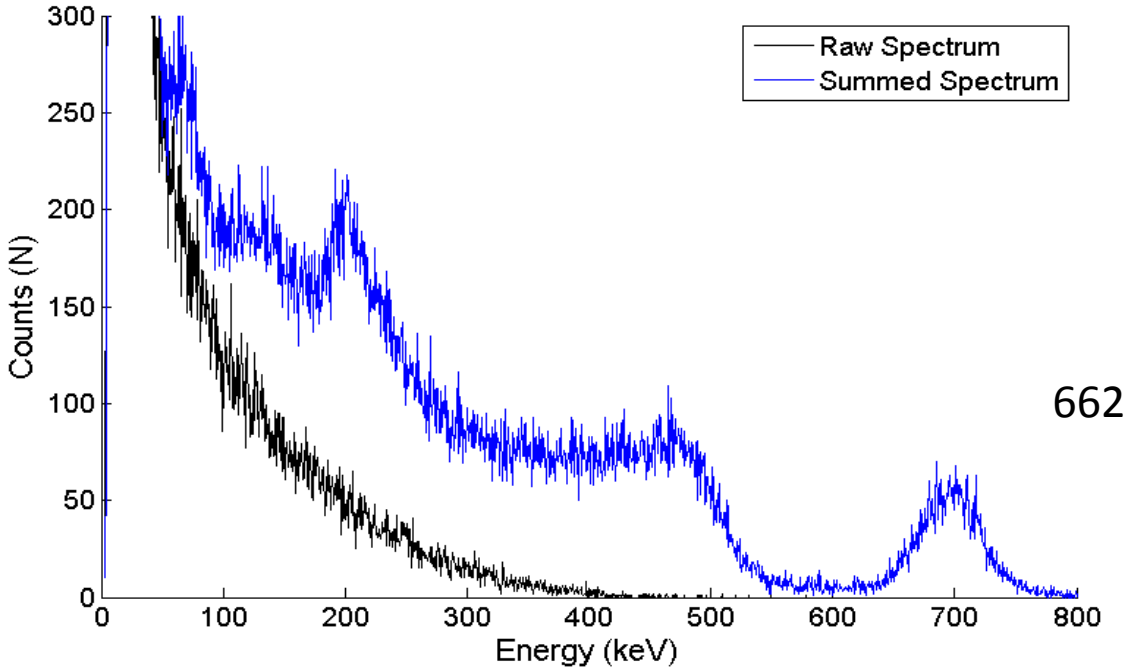
- The chip is sensitive only to the tiny electrical pulses generated by ionizing radiation in the sensor and not to background noise
- No background noise and multiple channels gives a high dynamic range (more then 9 orders of magnitude)
- Energy information, track shape, different convertors and provides a high specificity in a mixed field
- Flexible system, the use different sensor materials, filters, converters and stacking to tailor to a specific radiation field.

Referenses

[1] Vykydal Z., *Evaluation of Radiation Field Properties with Pixel Semiconductor Detectors Operating in Particle Tracking Mode,* PhD. Thesis, Albert-Ludwigs-Universität Freiburg, 2012

[2] Heijne E., *Measurements and possible identification of secondary GeV ions in the SPS H8 beam during the January 2013 LHC lead run*, Presentation at the Medipix Meeting 30 January 2013

Cluster Summing



662keV