ARDENT
Advanced Radiation Dosimetry European Network Training

THE ARDENT PROJECT AND DETECTORS USED WITHIN THE GROUP

UNIVERSITY OF ONTARIO INSTITUTE OF TECHNOLOGY
27TH NOVEMBER, 2013

ANDREJ SIPAJ

OVERVIEW

- The ARDENT project
  - INT infrastructure
  - Technologies
  - Training
- Detectors used within ARDENT
  - Medipix/Timepix
  - CR-39
  - Silicon micro-dosimeters
  - GEMPIX
- Medical development within ARDENT

THE ARDENT PROJECT

ARDENT

February 2012 – January 2016

Advanced Radiation Dosimetry European Network Training initiative

Marie Curie Initial Training Network under EU FP7 – 4 M€

8 Full Partners and 6 Associate Partners

Coordinator: CERN, Scientist-in-Charge: Dr. M. Silari

CERN (coordinator), Switzerland
AIT Vienna, Austria
SL Siebersdorf, Austria
CTU- IAEP Prague, Czech Republic
IBA Dosimetry, Schwarzenbruck, Germany
Jablotron, Prague, Czech Republic
MI.AM, Milano, Italy
Politecnico of Milano, Italy

ST Microelectronics, Italy
University of Erlangen, Germany
University of Houston, USA
University of Ontario, Canada
University of Wollongong, Australia
INFN Laboratori Nazionali di Legnaro, Italy

Marie Curie ITN

Initial Training Networks

Researchers within the first five years of their career

- Improving skills
- Integration in established research teams
- Enhancement of career prospects

- Universities
- Research Centres
- Companies
- Small and Medium Enterprises

Successful proposals from a network receive funding for up to 4 years to cover costs of the researchers and for network activities including conferences and equipment

Development of advanced instrumentation for radiation monitoring…

Three main technologies

- Gas detectors [e.g., gas electron multipliers (GEM), tissue equivalent proportional counters (TEPC)]
- Solid state detectors [e.g., Medipix, silicon micro-dosimeters]
- Track detector techniques [e.g., CR-39, nano-dosimeters]

We can still add detectors / technologies we think are worth investigating!

Objectives & Applications

- Main objectives
  - Radiation dosimetry
  - Micro- and nano-dosimetry
  - Photon and neutron spectrometry

- Applications
  - Characterization of radiation fields at particle accelerators (research, industry, medical)
  - Characterization of radiation fields on-board aircrafts and in space
  - Assessment of secondary dose to RT patient
  - Measurement of properties of clinical hadron beams

Researchers

- 15 Early Stage Researchers (ESR)
  - 4 at CERN: Eleni Aza (GR), Erik Frojd (SE), Stuart George (GB), Silvia Puddu (IT)
  - 1 at AIT, Vienna: Andrej Sipaj (SK)
  - 1 at SL, Vienna: Jayasimha Bagalkot (India)
  - 3 at CTU, Prague: Benedikt Bergmann (DE), Kevin Loo (AU), Ivan Calcedo (CO)
  - 2 at IBA Dosimetry, Schwarzenbruck: Francesca Bisello (IT), Michele Togno (IT)
  - 1 at Jablotron, Prague: Vijayaragavan Viswanathan (India)
  - 1 at MI.AM, Milano: Alvin Sashala Naik (Mauritius)
  - 2 at the Politecnico, Milano: Chris Cassell (AU), Eleni Sagia (GR)

- Up to 1/3 of time can be spent on secondments
- Work performed within the project to be used for PhD
- Generous training allowance for researchers

Training

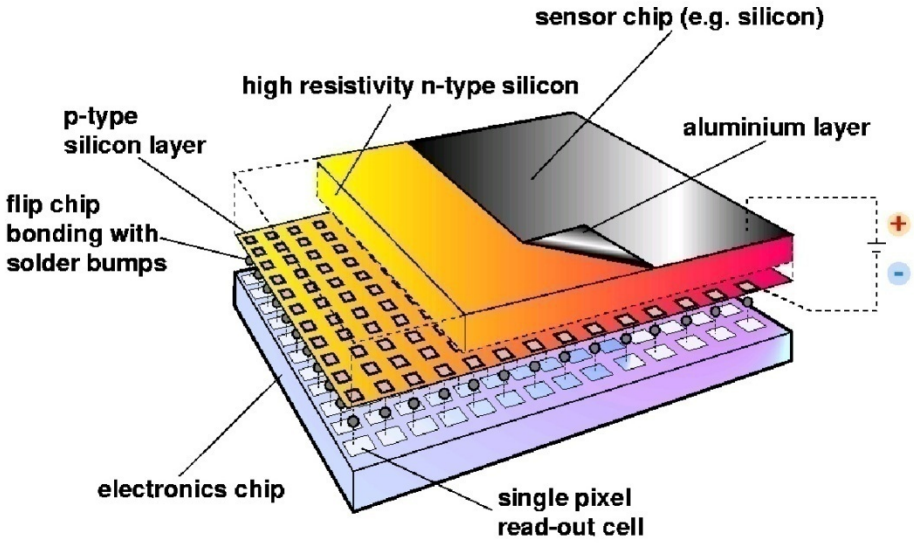
- Individual PhD-specific training program
- Hands-on / experimental work
- ARDENT training courses within the annual workshops
- Courses and schools
- Complementary training (e.g. language, business and administration)
- International conferences (many!) – just one example:
  - Workshop: “New Detector Technologies in Radiation Dosimetry and its Applications”, IEEE NSS/MIC conference, Seoul, Korea, October 2013 / Chairs M. Silari and A. Rosenfeld

DETECTORS USED WITHIN THE GROUP

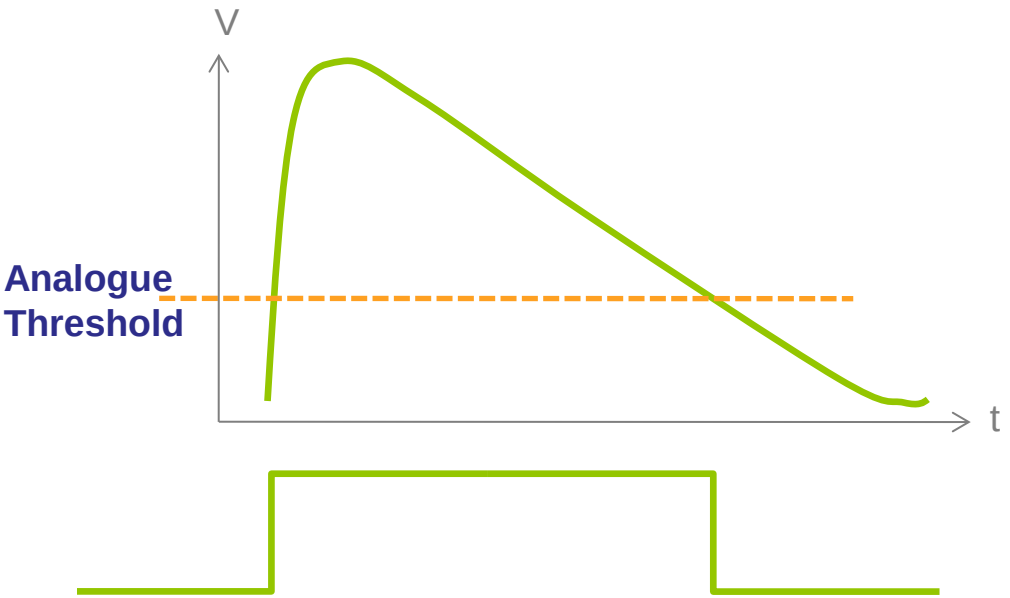
Medipix and Timepix

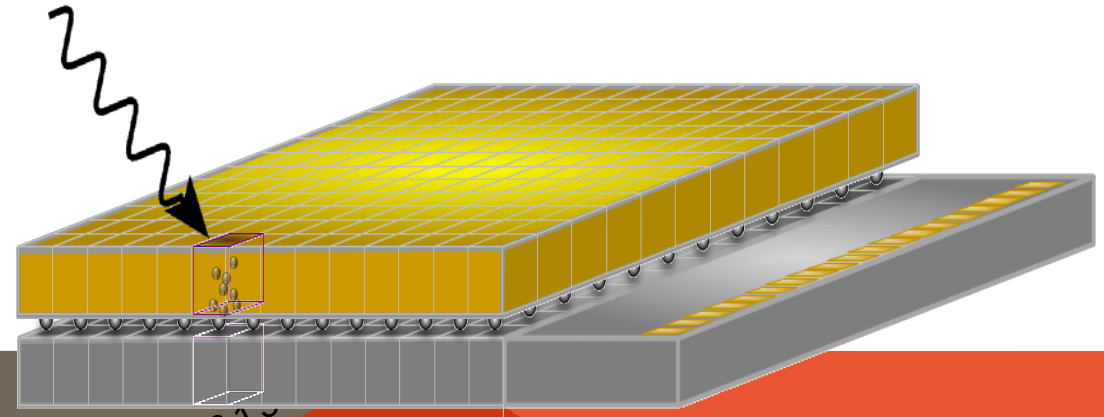
- Development: International Collaboration with seat at CERN
- Bump-bonded with Pb/ Sn
- 65536 pixels in 256 columns and 256 rows
- Pixel pitch: 55 µm
- Size of the matrix: 14 mm (2 cm2)
- 0.25 µm CMOS

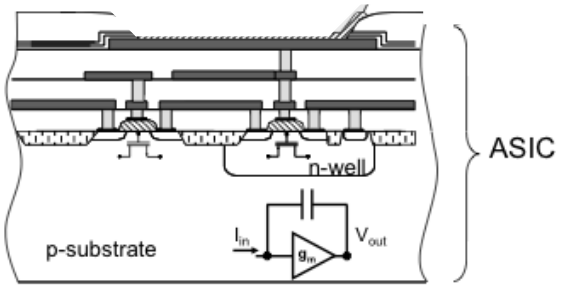
Let you see the radiation in 2D



Working principle

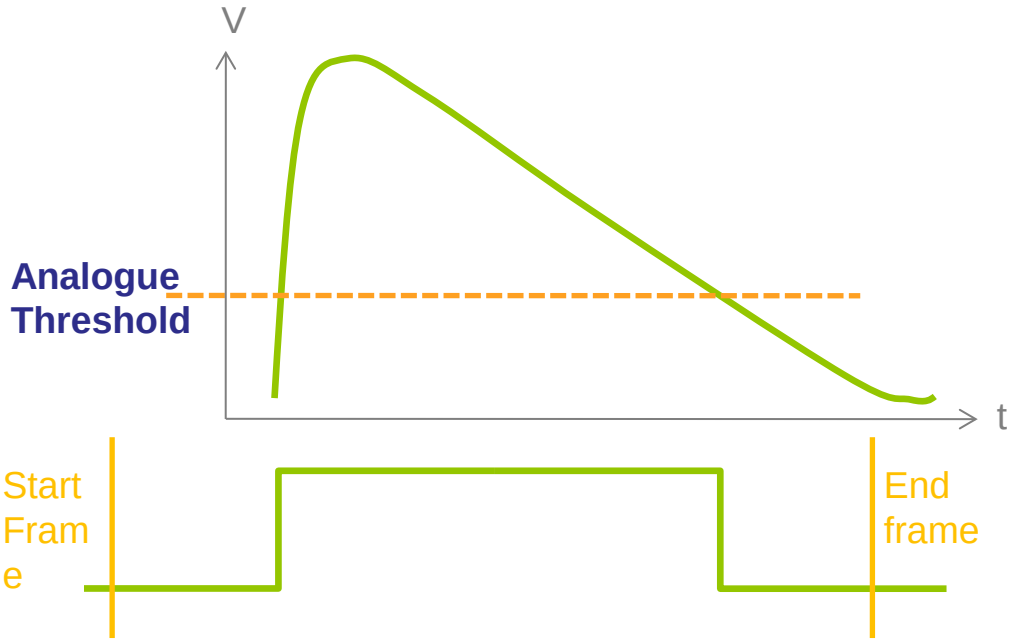






*by Winnie Wong

Working principle

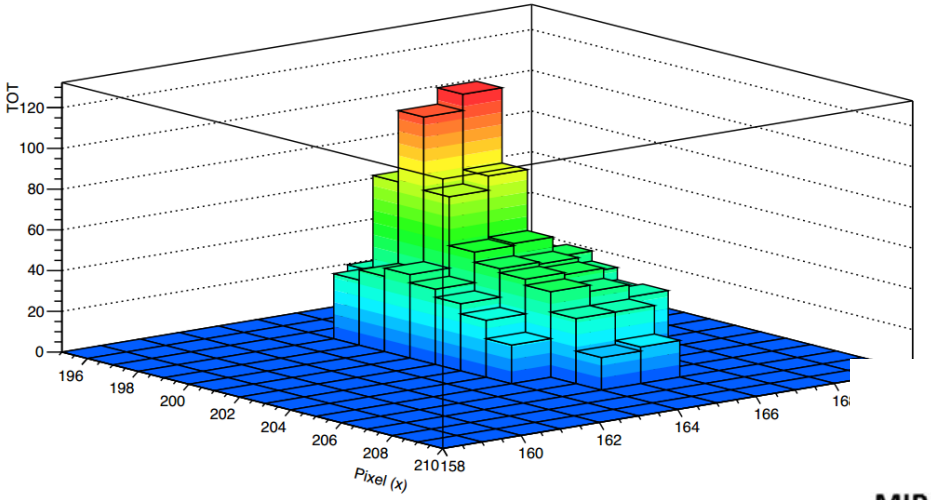


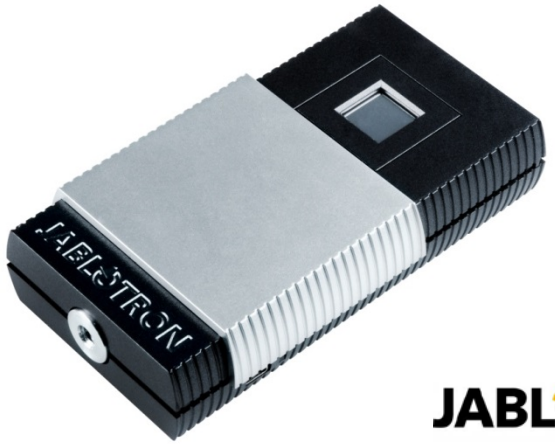
Counting (Medipix2,3 & Timepix)

Time of Arrival (ToA) (Timepix)

Time over Threshold (ToT) (Timepix)

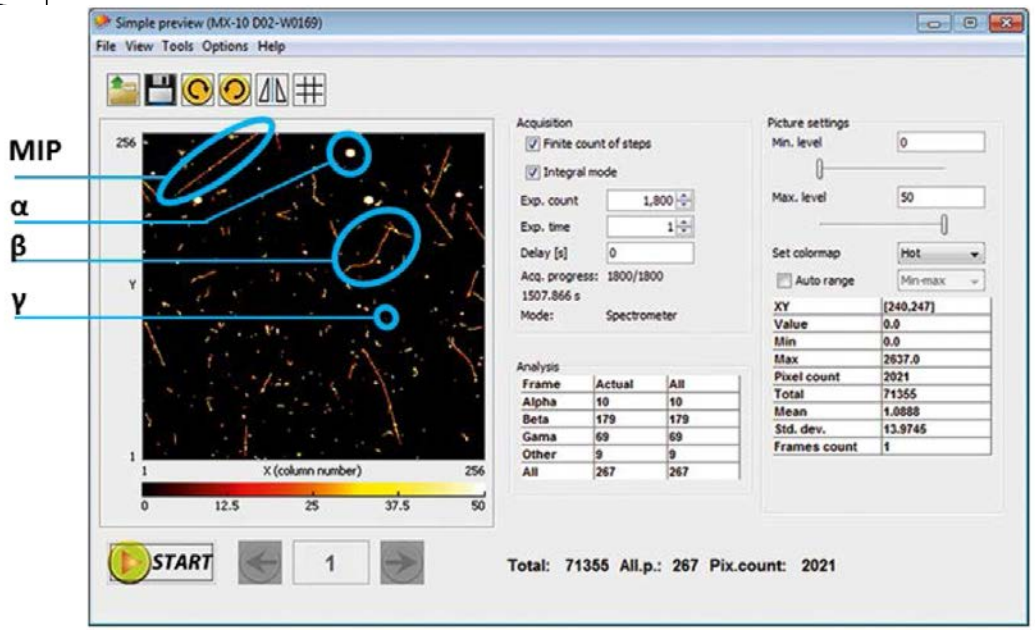
Medipix and Timepix





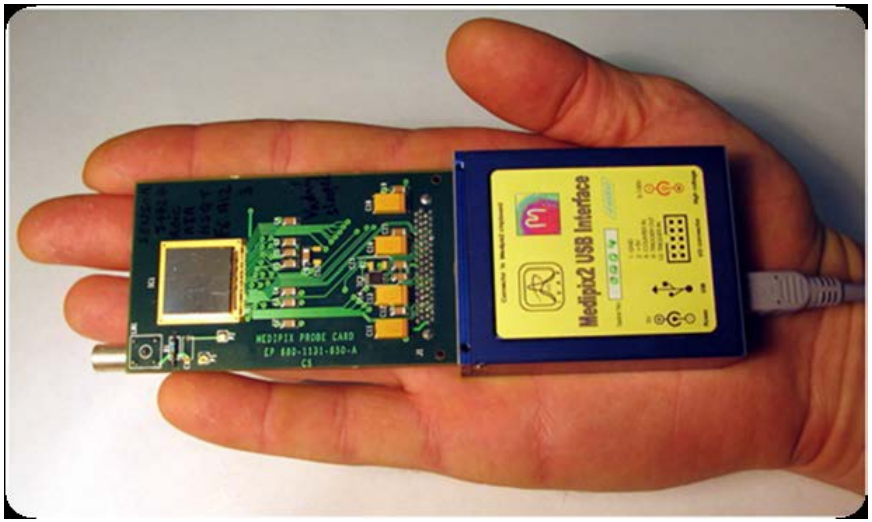
JABLOTRON
CREATING ALARMS

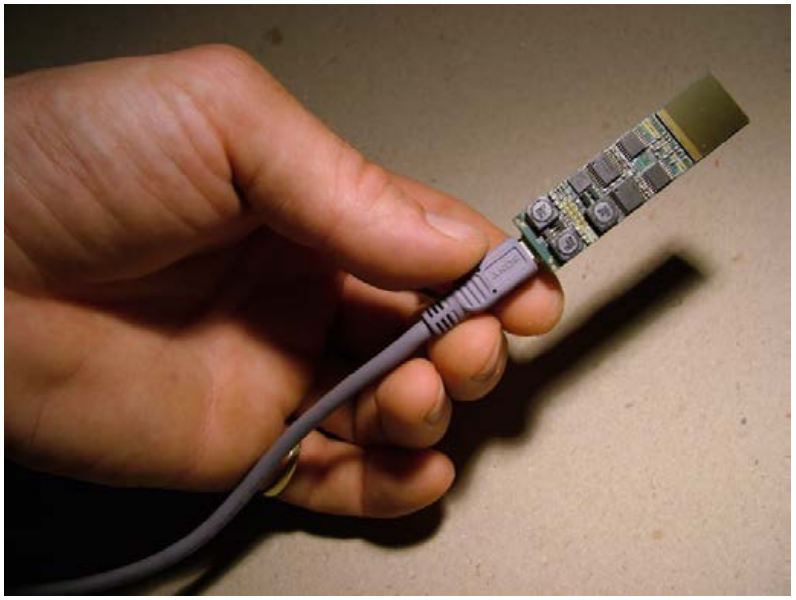
Visualization of particles using Pixelman software



Medipix and Timepix

- Use USB standard for detector read-out and data acquisition control
- Plug & Play
- Fully USB powered
- Externally triggered
- Compact size of interface

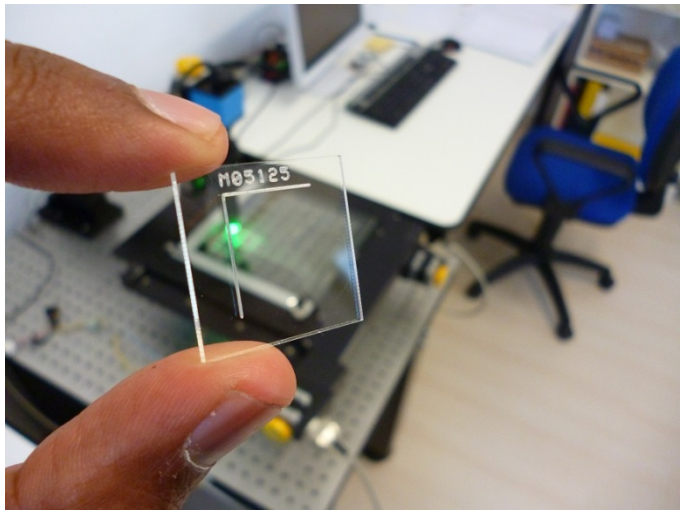




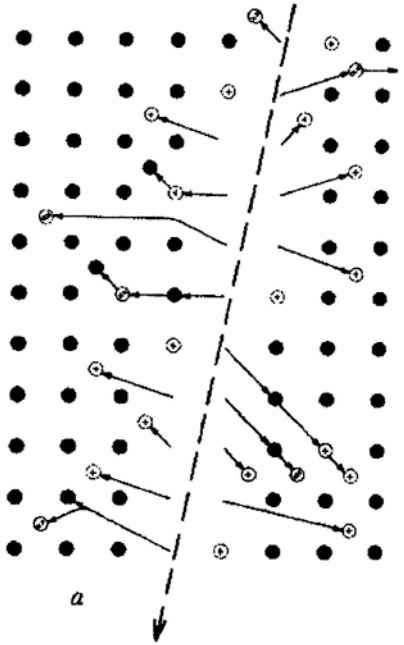
- USB Lite interface is miniaturized version
- Very compact size of 60 mm x 15 mm

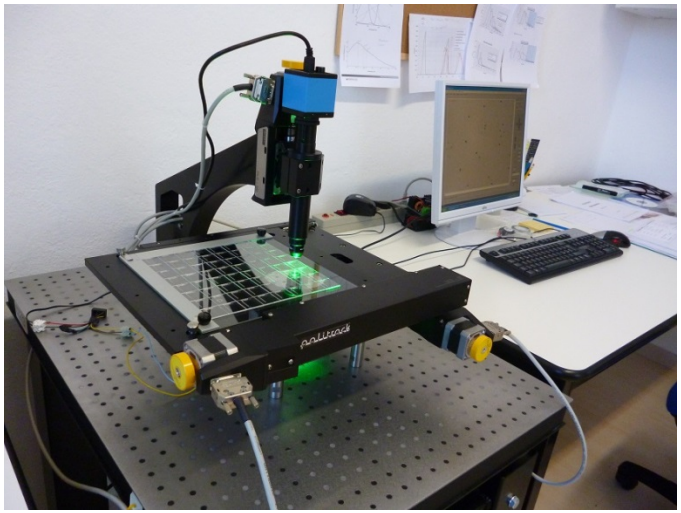
CR-39

- Similar to pixel detector but ANALOGUE
  - Irradiate CR-39 plastic with ions
  - Etch the CR-39
  - Place under microscope to evaluate the tracts



Intercast™ CR-39 detector

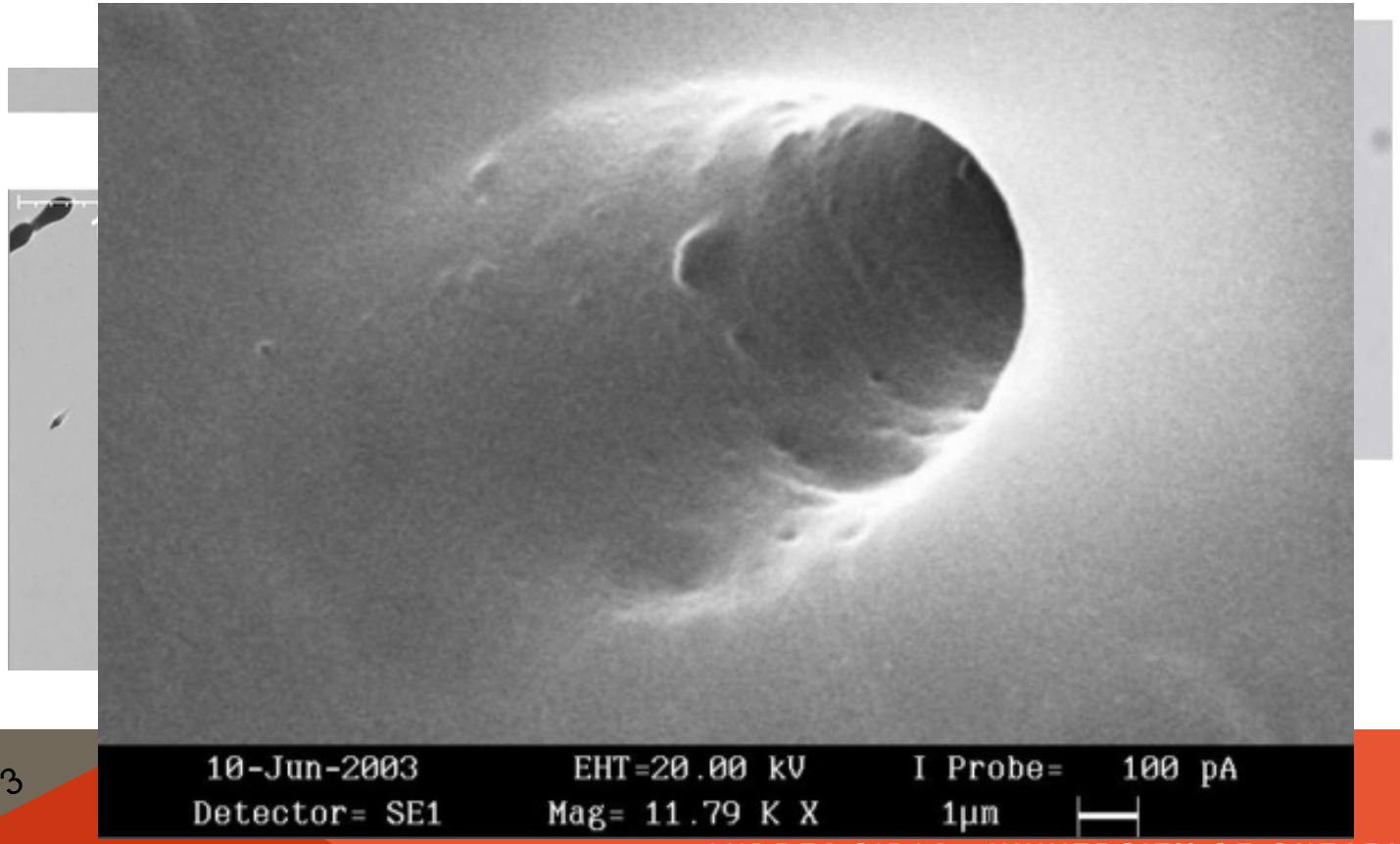




Politrack™ Reader

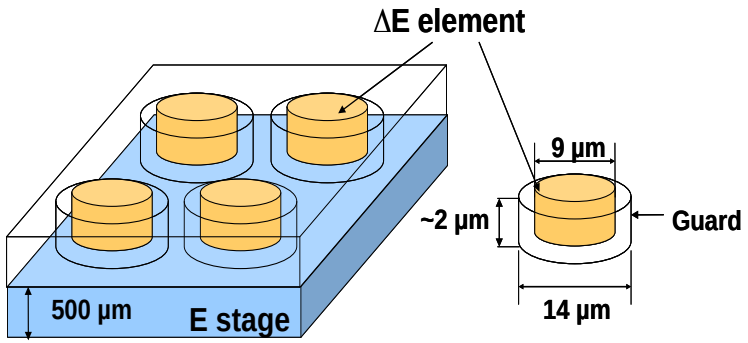
CR-39

- POLITRACK system automatically analyze the track detectors
  - Calculate particle LET and impinging angle.
  - Direct estimate of the equivalent dose



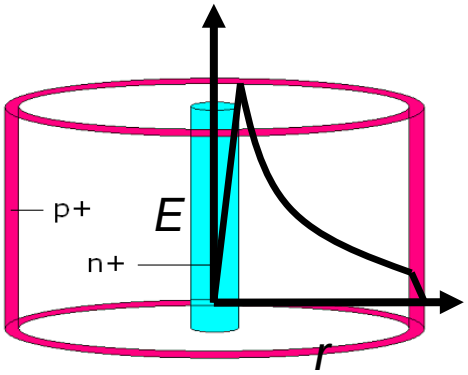
Segmented silicon telescope

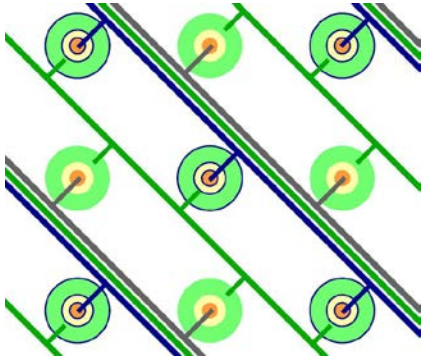
- Matrix of cylindrical ΔE elements (about 2 μm in thickness) and a single residual-energy E stage (500 μm in thickness)
- the nominal diameter of the ΔE elements is about 9 μm and the width of the pitch separating the elements is about 41 μm
- more than 7000 pixels are connected in parallel to give an effective sensitive area of about 0.5 mm2
- the ΔE stage acts as a microdosimeter while the E stage provides the LET-dependent correction for tissue-equivalency

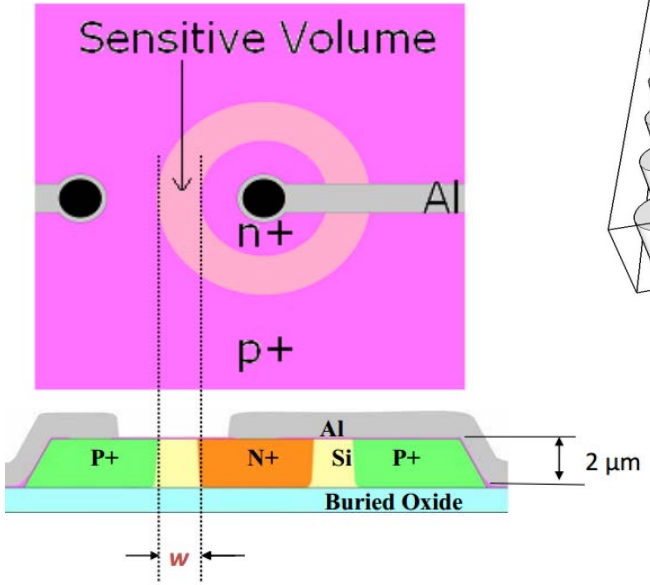


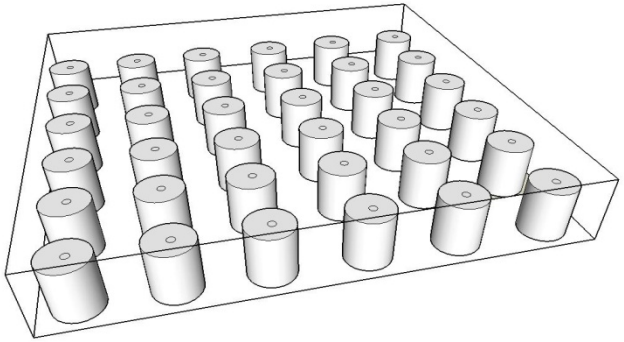
Si MESA microdosimetry

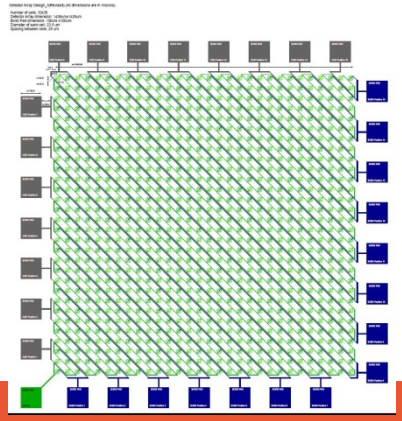
- 3D silicon mesa p-n junction array with internal charge amplification produced at UNSW SNF.





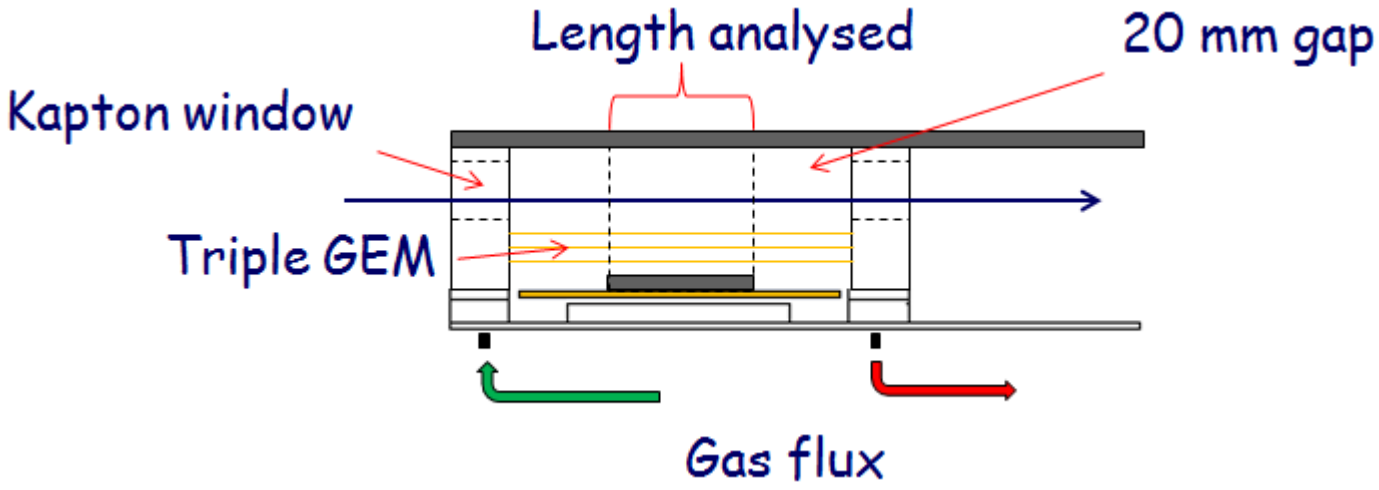






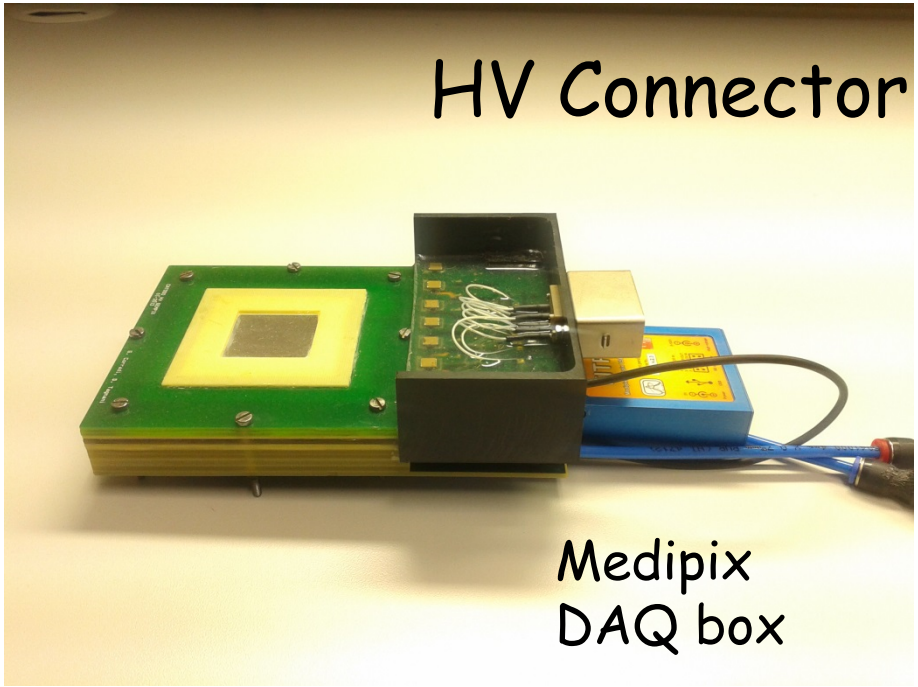
Future work on existing prototype…

- GEMPIX
  - Triple GEM detector mounted on quad Medipix
  - Same idea as basic Medipix but significantly larger drift region
  - Can be tissue equivalent

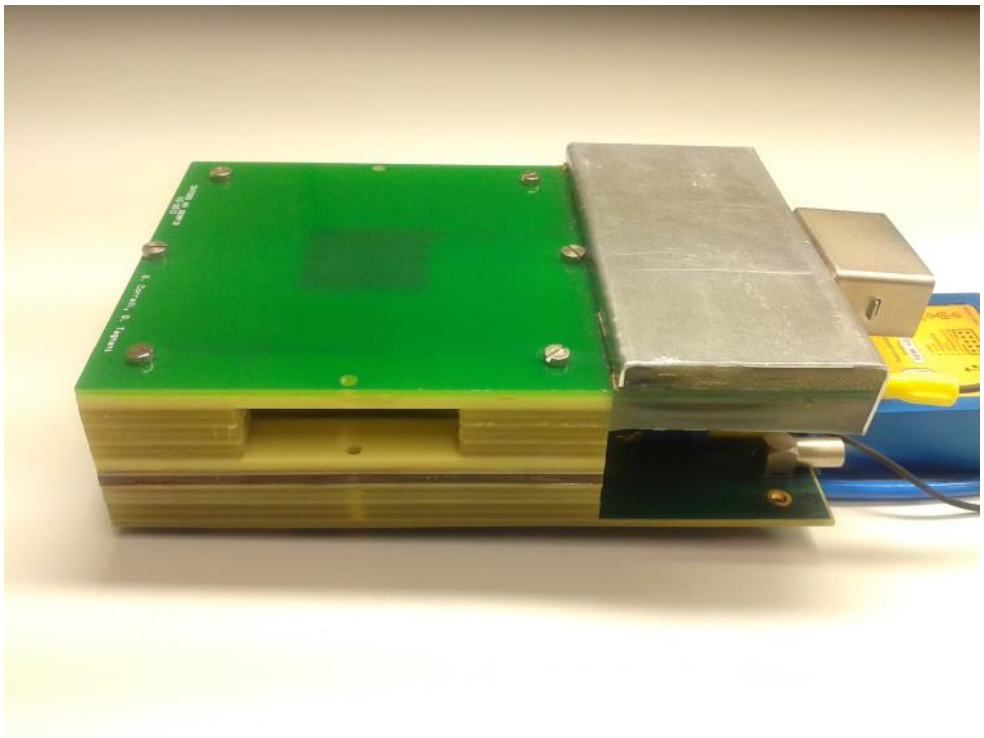


GEMPIX

- Two prototype of GEMPIX



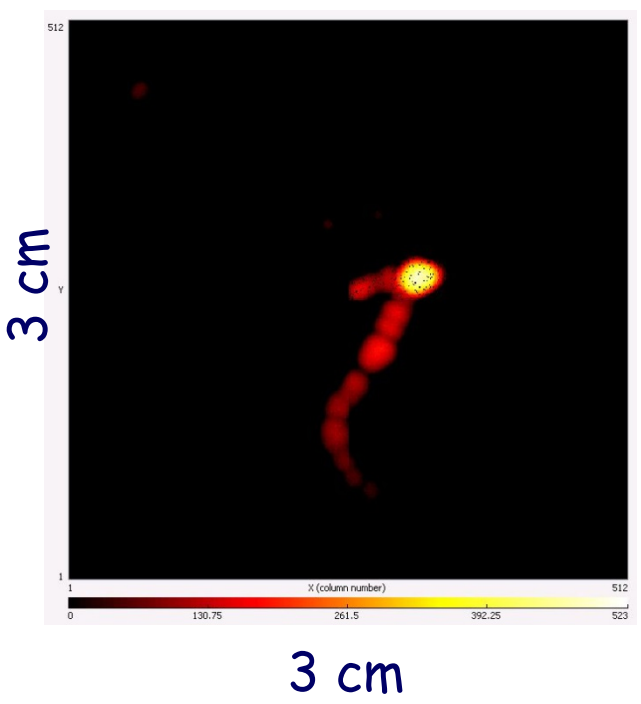
Head-on detector

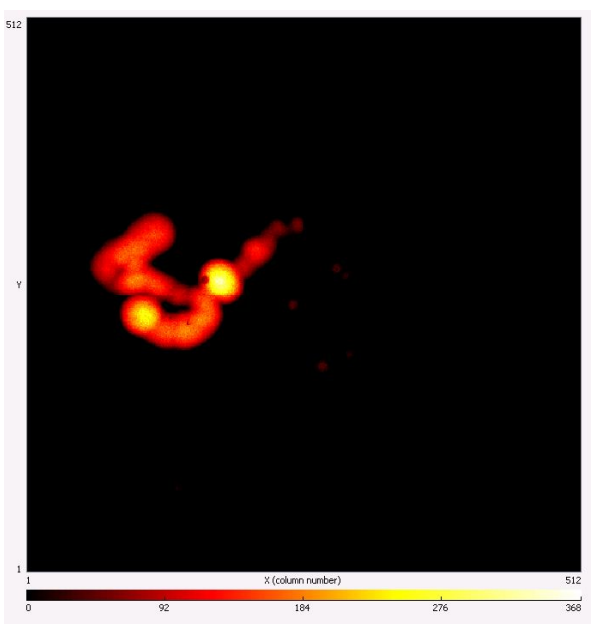


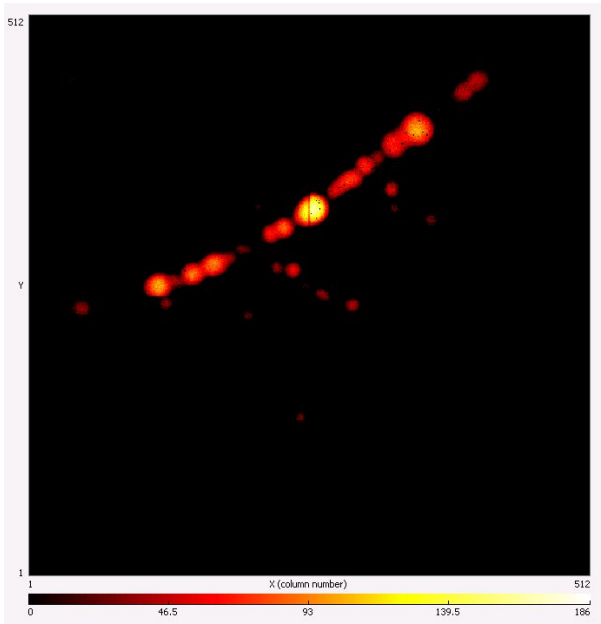
Side-on detector

Cosmic rays with a gas AR/CO2 70:30

- These are the first pictures taken with the GEMPIX







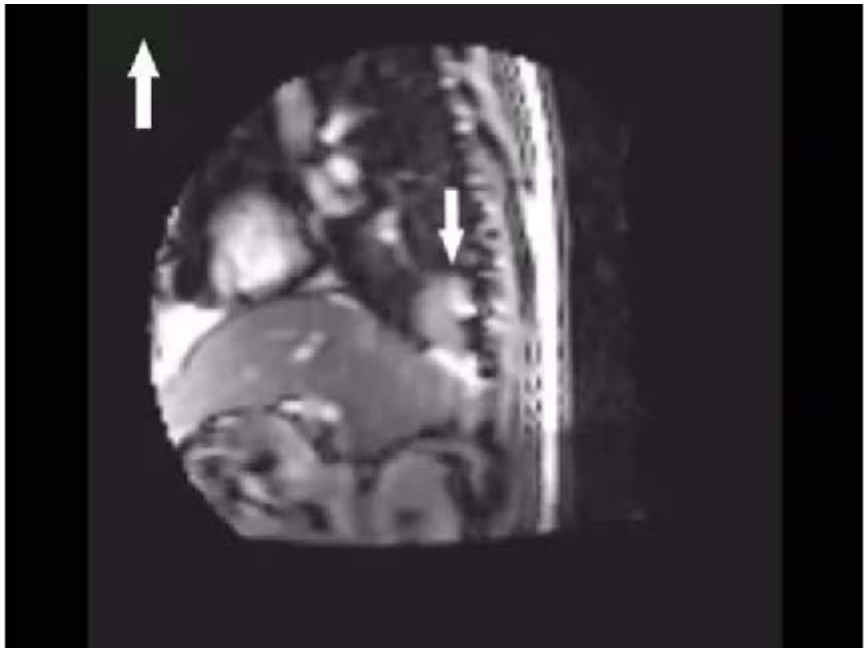
MEDICAL DEVELOPMENT WITHIN ARDENT

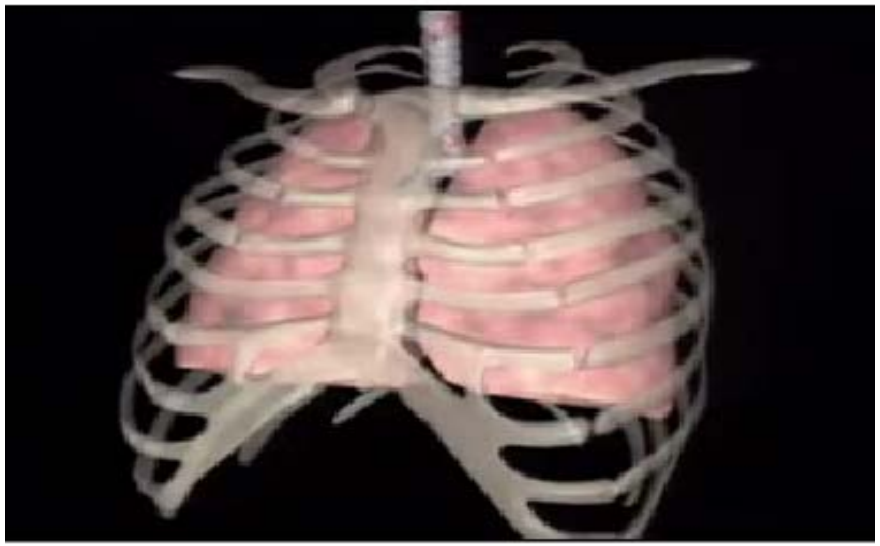
Areas

- Prostate cancer, viewing the radioactive seeds implanted into patient without the use of X-ray or CT scan
- Analysing diagnostic X-ray tube spectra
- Measurement of scattered radiation during CT scans
- Measurement of radiation in moving targets inside patients

Irradiation of moving targets

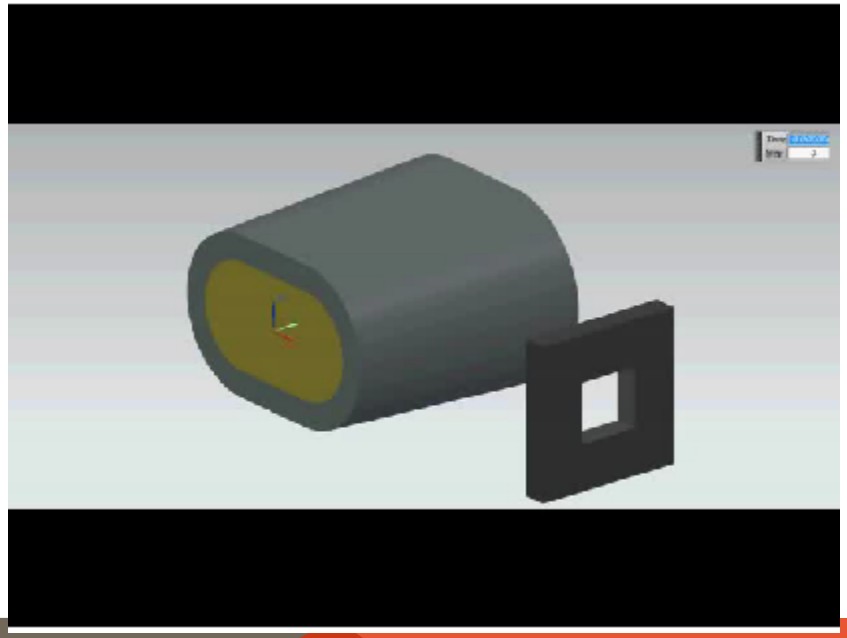
- Objective: Measure dose of moving lung tumor (online and offline) in order to validate treatment planning system
  - Is the prescribed dose by doctor actually being delivered to tumor/ surrounding tissues???
    - The tumor is not moving alone in human body

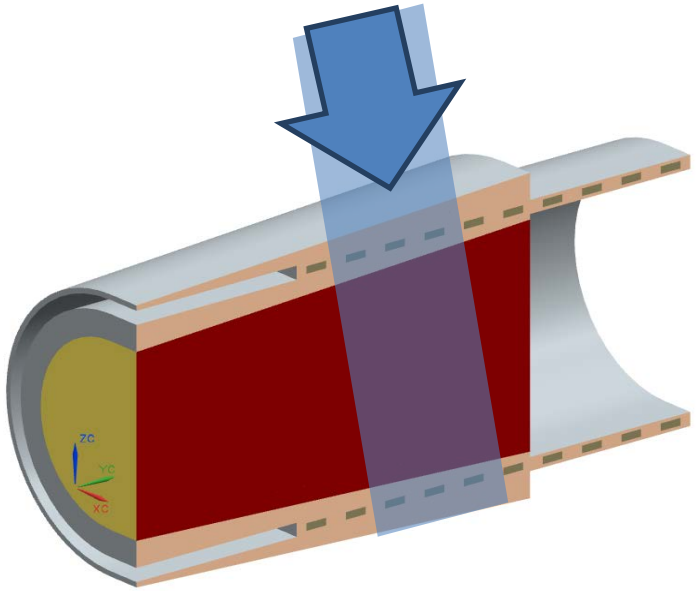




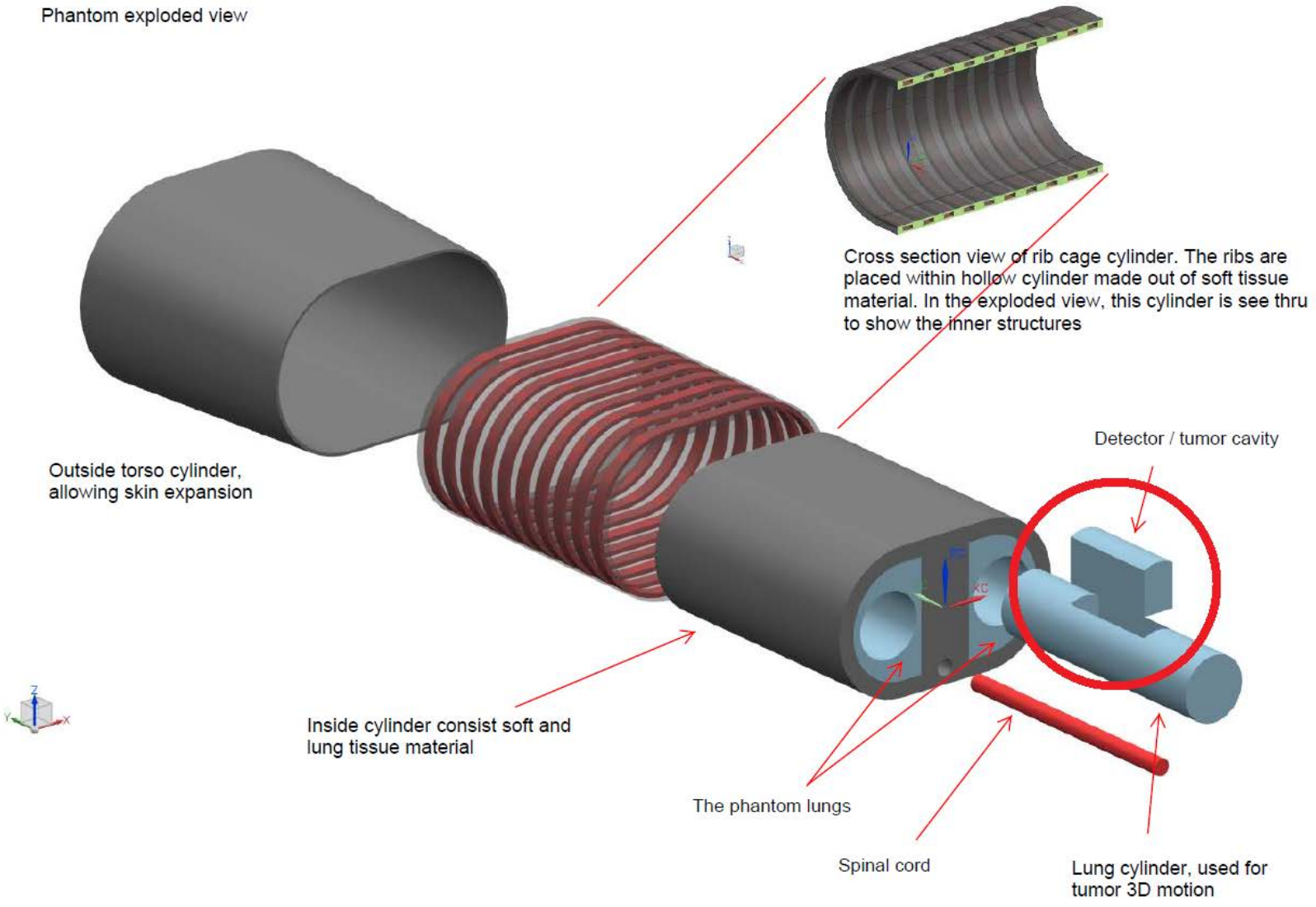
Irradiation of moving targets

- Motion platform/ human phantom must be developed prior to the radiation measurements
  - Tissue equivalent
  - Anthropomorphically correct
  - Approximately accommodates human breathing motion





Detection


Phantom exploded view
Cross section view of rib cage cylinder. The ribs are placed within hollow cylinder made out of soft tissue material. In the exploded view, this cylinder is see thru to show the inner structures
Outside torso cylinder, allowing skin expansion
Detector / tumor cavity
Inside cylinder consist soft and lung tissue material
The phantom lungs
Spinal cord
Lung cylinder, used for tumor 3D motion

HAVE A GREAT DAY!

Thank you for your attention ….