A short summary of "ARDENT"

Advanced **R**adiation **D**osimetry **E**uropean **N**etwork **T**raining

www.cern.ch/ardent

Marco Silari (DGS-RP)

ARDENT

February 2012 – January 2016

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), Geneva, Switzerland
AIT Vienna, Austria
CTU - IAEP Prague, Czech Republic
IBA Dosimetry, Schwarzenbruck, Germany
Jablotron, Jablonec nad Nisou, Czech Republic
MI.AM, Piacenza, Italy
Politecnico of Milano, Italy
Seibersdorf Laboratories, Austria

INFN Legnaro National Laboratories, Italy
ST Microelectronics, Italy
University of Erlangen, Germany
University of Houston, USA
University of Ontario, Canada
University of Wollongong, Australia

The 18 ARDENT researchers


Stefan Gohl– ESR 16


Eleni Aza – ESR 1


Andrej Sipaj – ESR 6

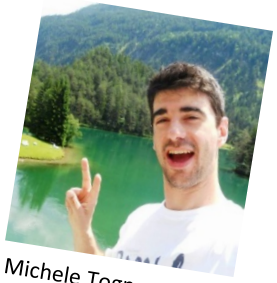

Elena Sagia – ESR 14


Alvin Sashala Naik - EESR 13


Stepan Polansky – ESR 18


Benedikt Bergmann ESR 9


Silvia Puddu – ESR 3


Michele Togno - ESR 11


Natalia Kostiukhina ESR 17

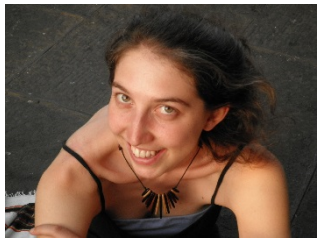

Jayasimha V. BAGALKOTE ESR 5


Vijayaragavan Viswanathan ESR 12


Kevin Loo – ESR 8


Stuart George – ESR 4


Ivan Caicedo – ESR 7


Francesca Bisello – ESR 10


Erik Frojd – ESR2


Chris Cassel – ESR 15

Development of advanced instrumentation for radiation monitoring

Three technologies

- Gas detectors: gas electron multipliers (GEM), ion chambers
- Solid state detectors: Medipix, silicon detectors
- Combined silicon-gas detector
- Track detector techniques: CR-39

Development of advanced instrumentation for radiation monitoring

Main objectives

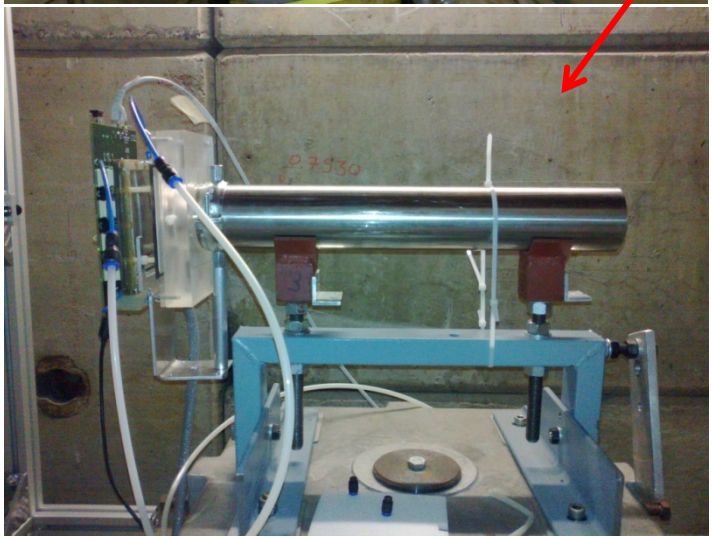
- Radiation dosimetry
- Microdosimetry
- Neutron and photon spectrometry

Applications

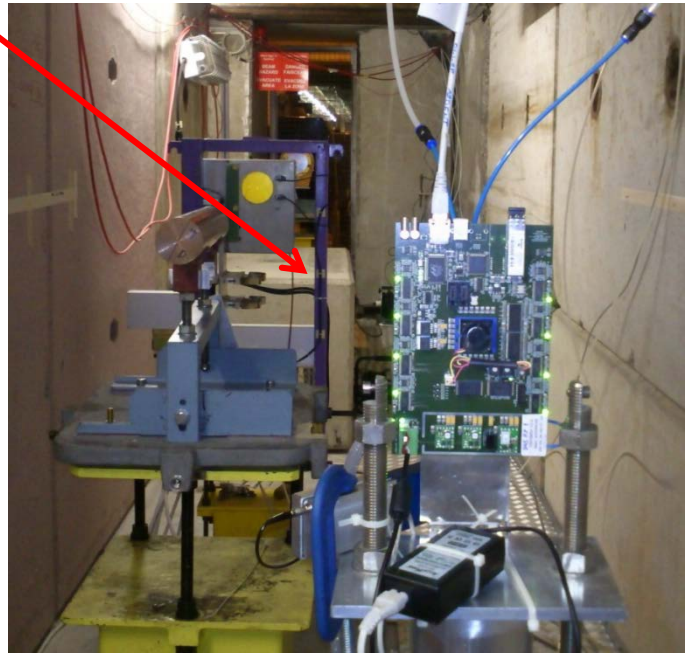
- Characterization of radiation fields at particle accelerators
- Characterization of radiation fields on-board aircrafts and in space
- Medical applications: diagnostics and therapy

GEM/Timepix measurements at CERF

Eleni Aza and Silvia Puddu (GEM), Stuart George (Timepix)

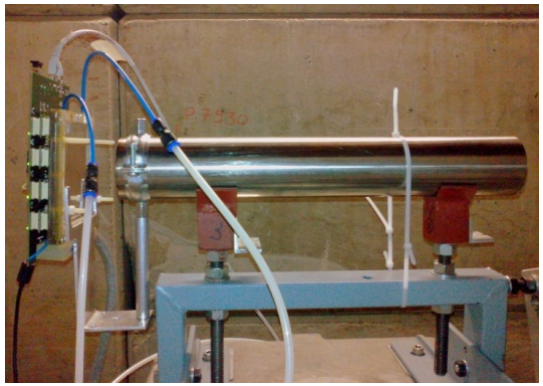


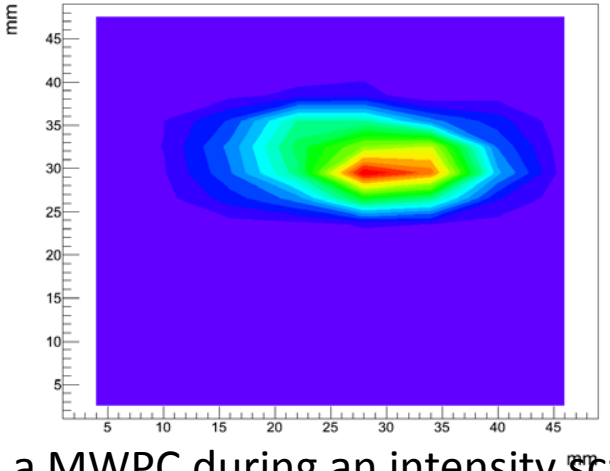
- CERF @ CERN: mixed field of secondary particles (p, π, e^-, γ, n) from spallation reactions
- Measurements with Timepix:
  - mixed field analysis
- Measurements with GEM:
  - beam monitoring
  - measurements of individual radiation components



The Triple GEM detector as beam monitor

Experimental set-up

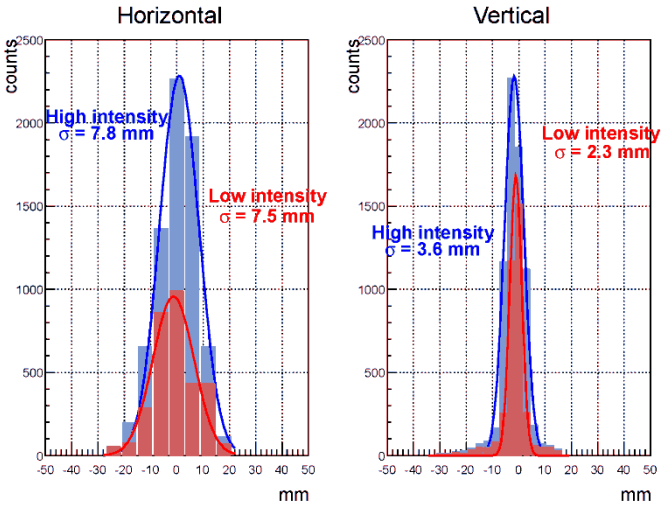




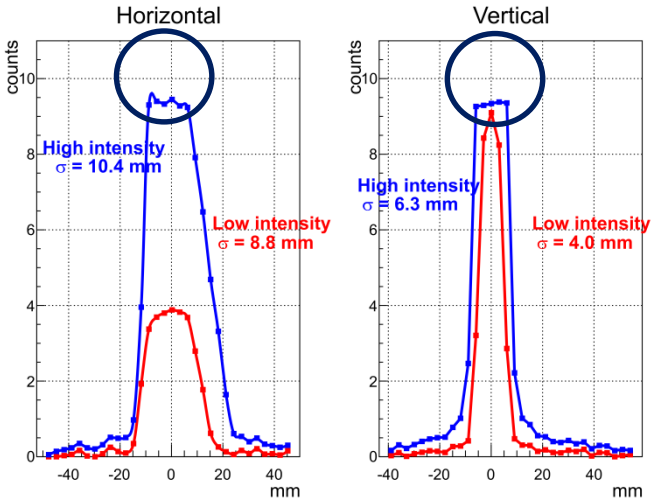
Beam image

$0.6 \pm 0.1\%$ **efficiency**

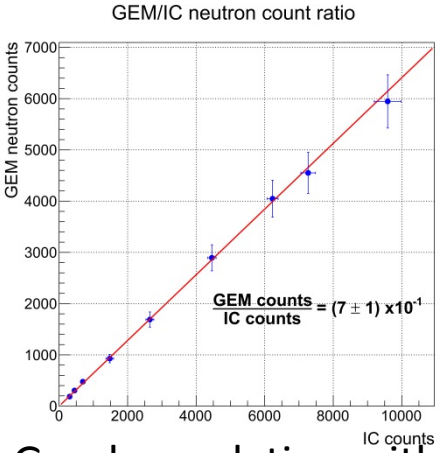
Beam profile comparison to a MWPC during an intensity scan



GEM

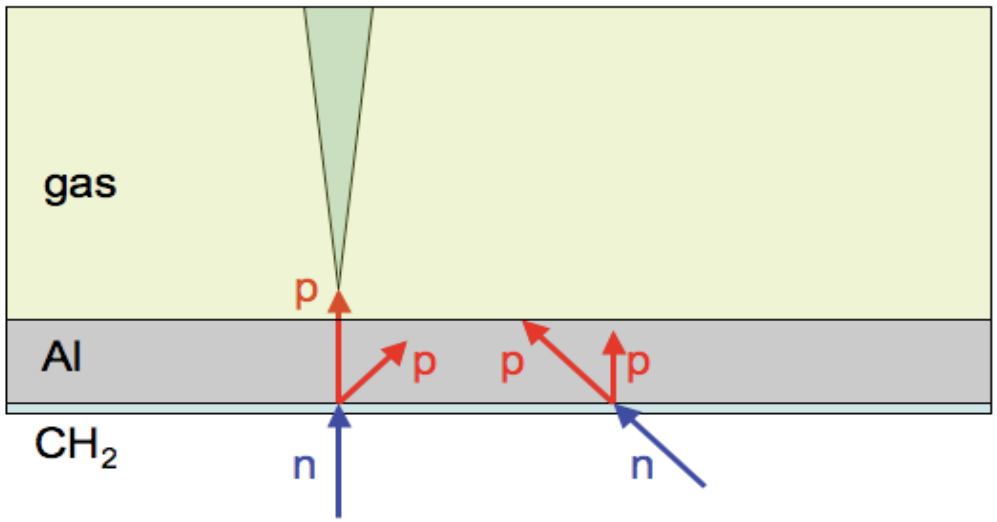


MWPC (saturates)



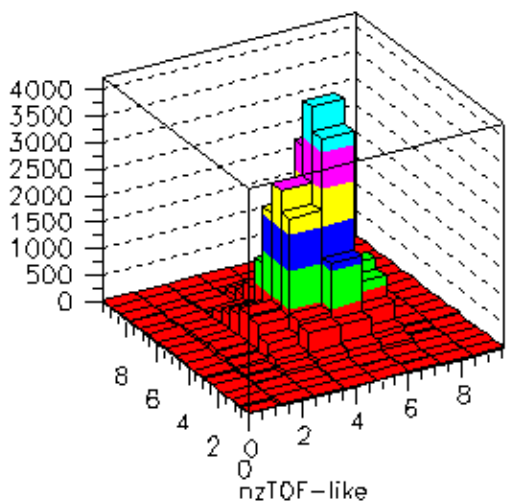
Good correlation with IC reference monitor

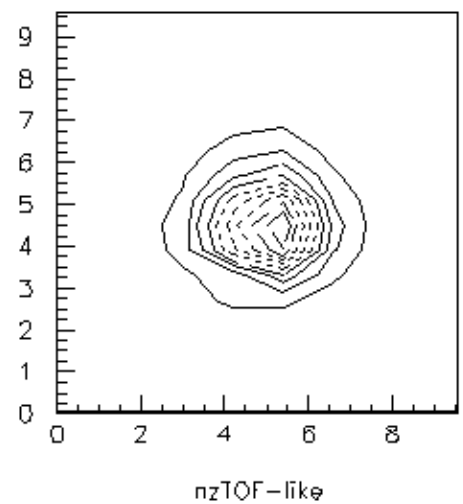
Fast neutron detection with GEM



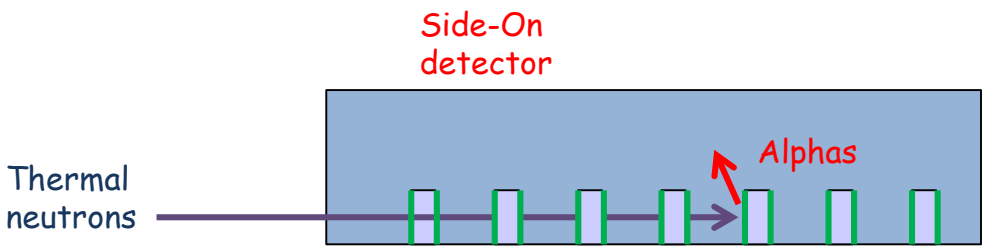
Fast neutrons:

- Head on detector
- Converter: PE + Al
- Low sensitivity to γ background at chosen WP



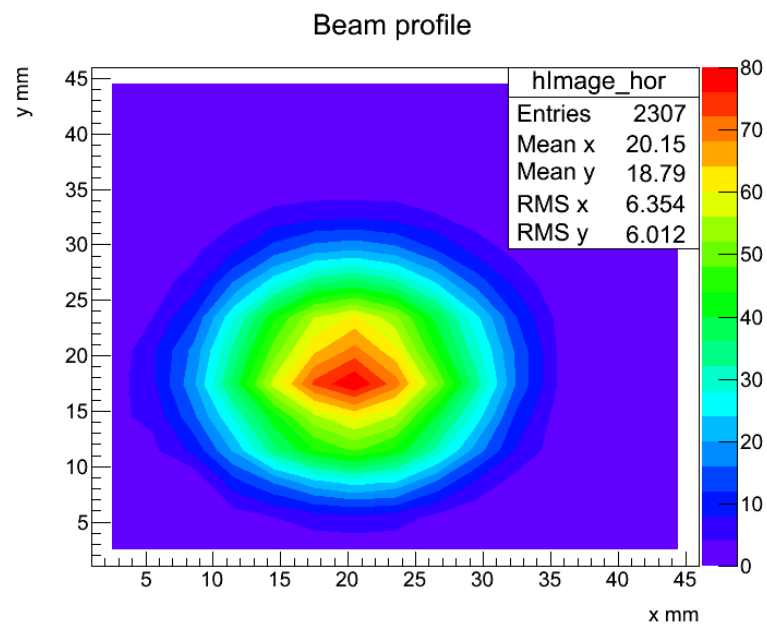


Thermal neutron detection with GEM



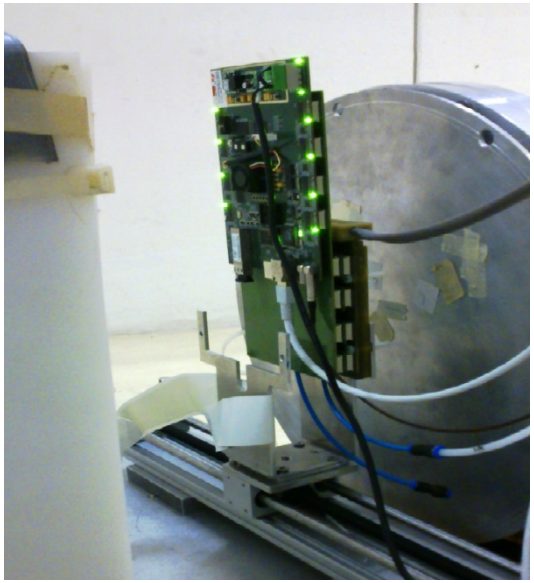
Thermal neutrons:

- Converter: series of slices of ^{10}Bo
- Delay: 12 ms
- Low sensitivity to γ background at chosen WP
- Beam image reconstructed from several step positions

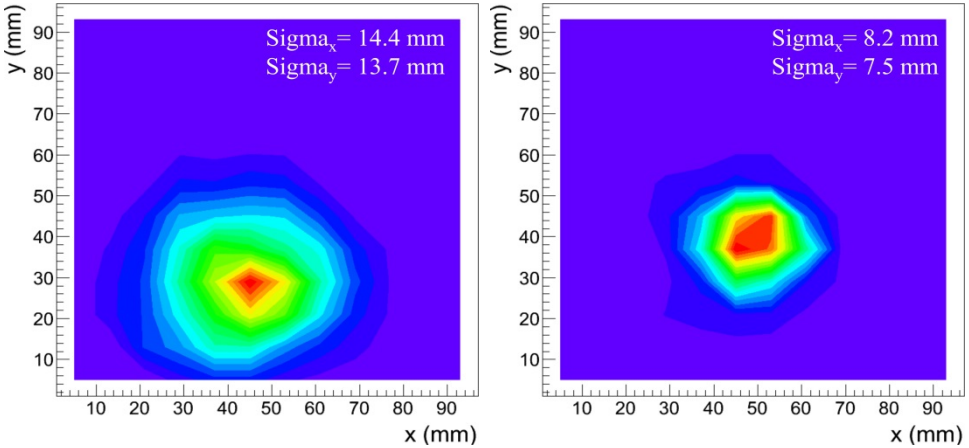


Characterization of neutron time-of-flight facility with the GEM detector (nTOF, CERN)

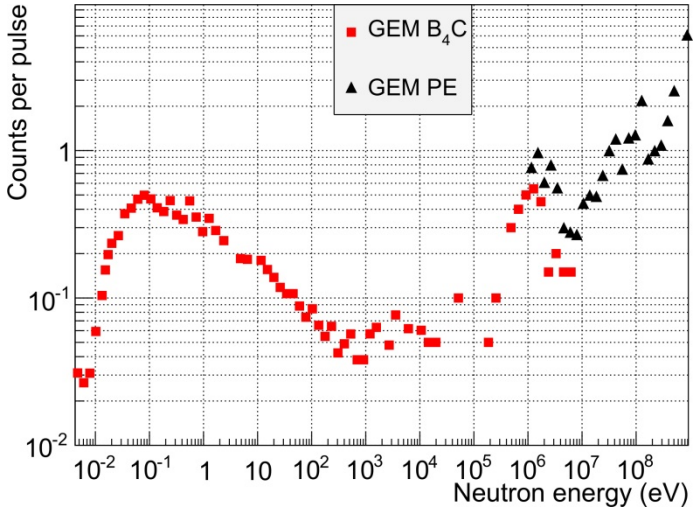
20 GeV/c protons on lead target
Neutron detectors placed at EAR1 and Beam dump (185 and 200 m)
Active area 10x10 cm^2 and pad size 8x8 mm^2



Slow and fast neutron profile at 200 m



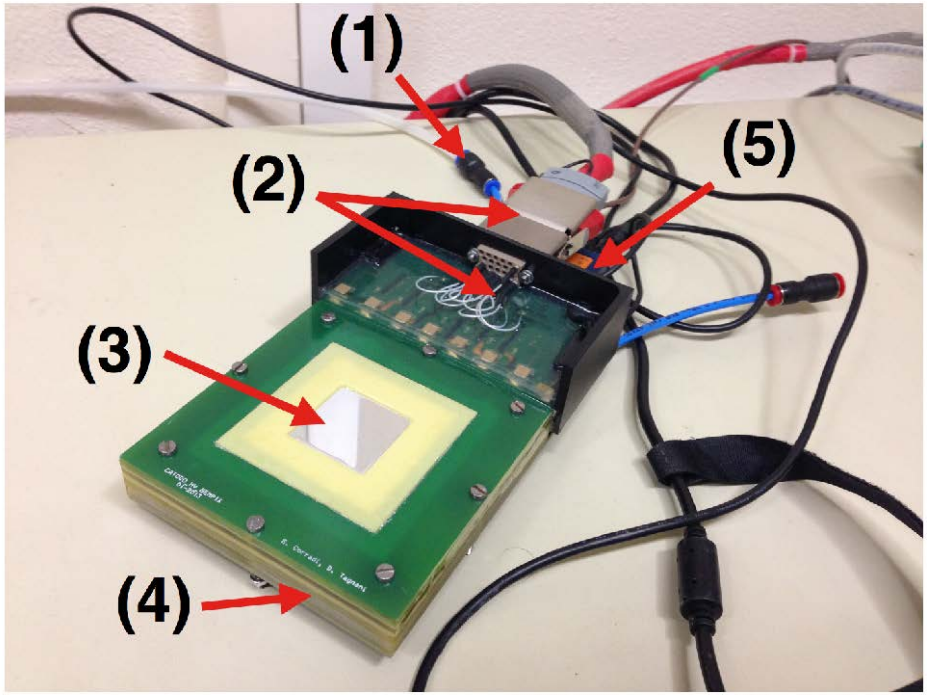
Energy spectrum measured at 200 m



The GEMPix - An Ultra Pixellated Gas Detector

Stuart P. George (CERN)

The Gempix combines two CERN developed technologies, GEM detectors and the Timepix to produce a gas detector with 55 µm readout granularity

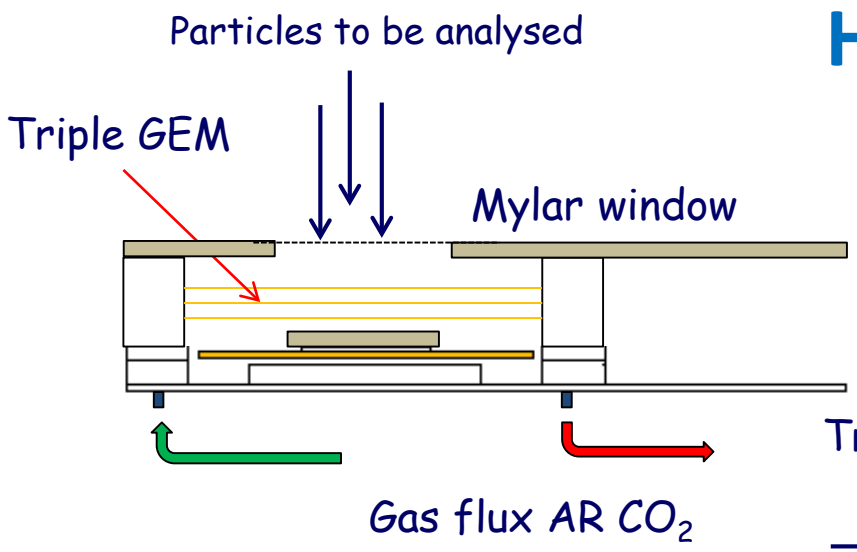


(1) Gas Supply
(2) High Voltage
(3) Entrance Window
(4) GEM Foils
(5) FITPix Readout

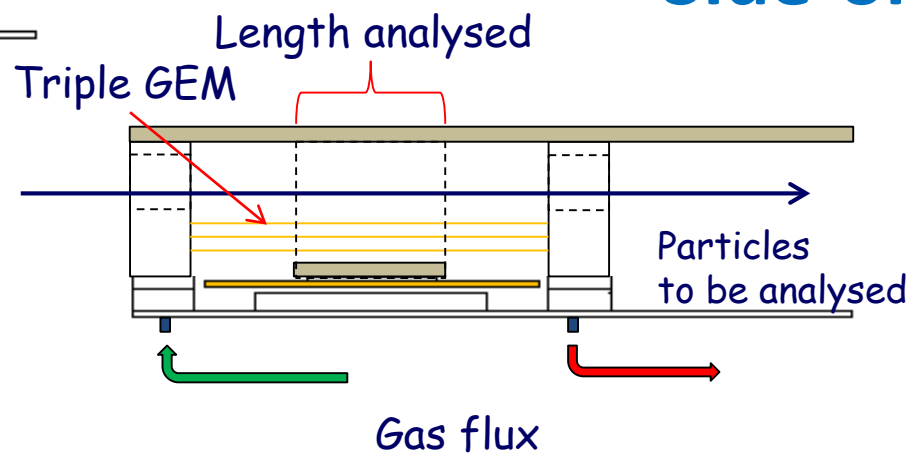
Sensitive area = 3 x 3 x 1.2 cm^3

GEMPix: two working modes

Head-on



Side-on



The detector is a naked quad Medipix :
The active area is 9 cm^2
The particle track is analysed with 512 pixel in 3 cm length
This is equivalent to 30 microns of tissue … with 17 samples/micron

Determination of ^{55}Fe in radioactive waste

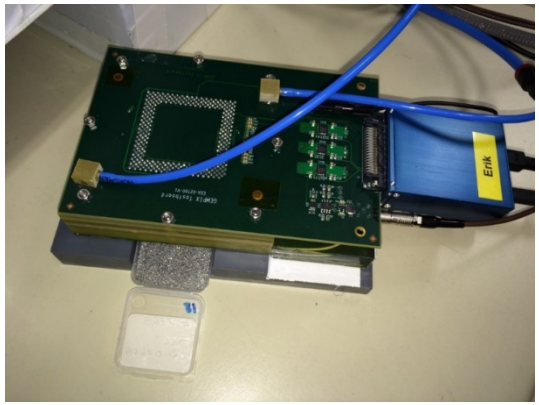
Silvia Puddu and Stuart George (CERN)

The sample is reduced to a powder with a milling machine

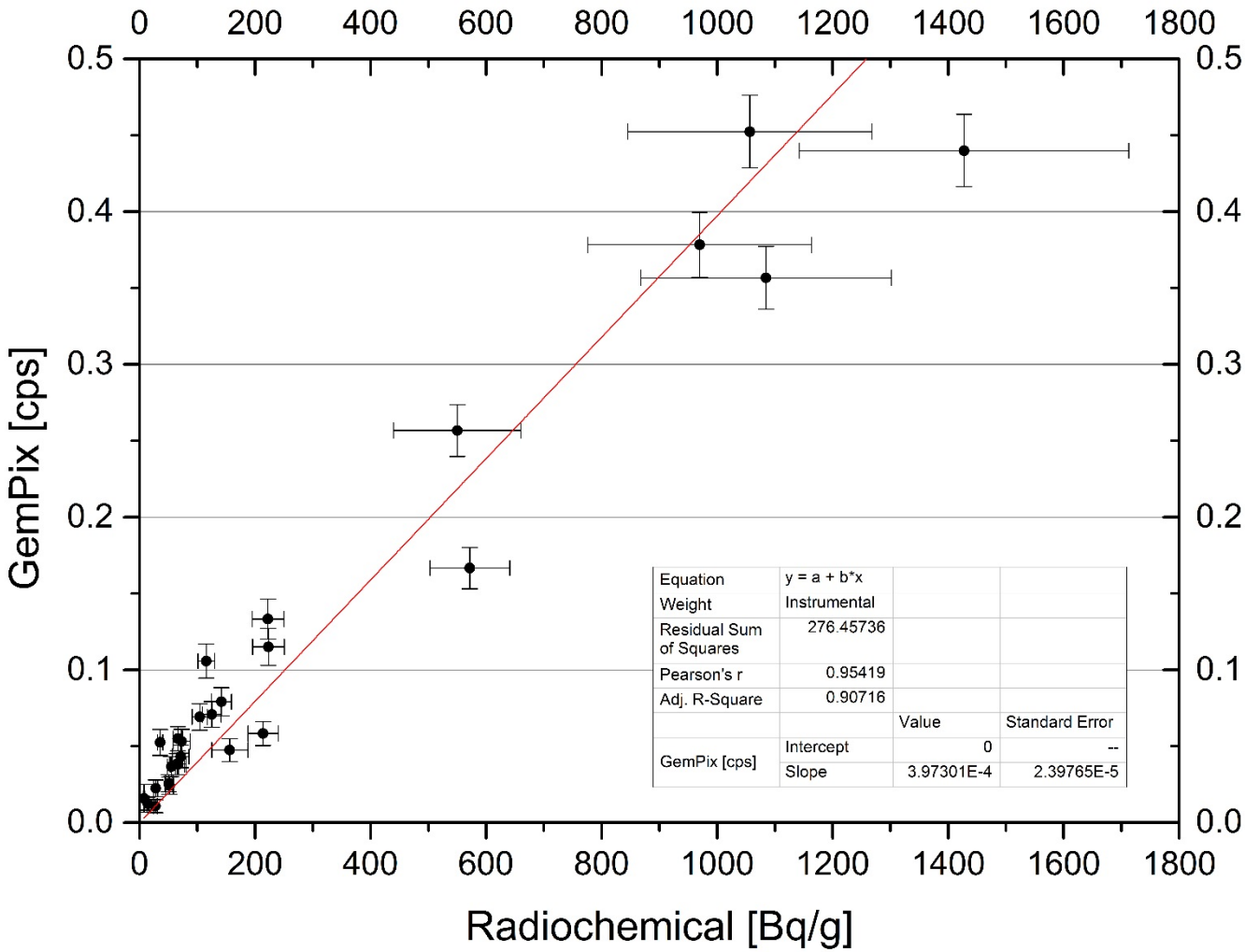
Filtered at 50 mm grain with a mesh

Finally the sample is put below the detector for the measurement

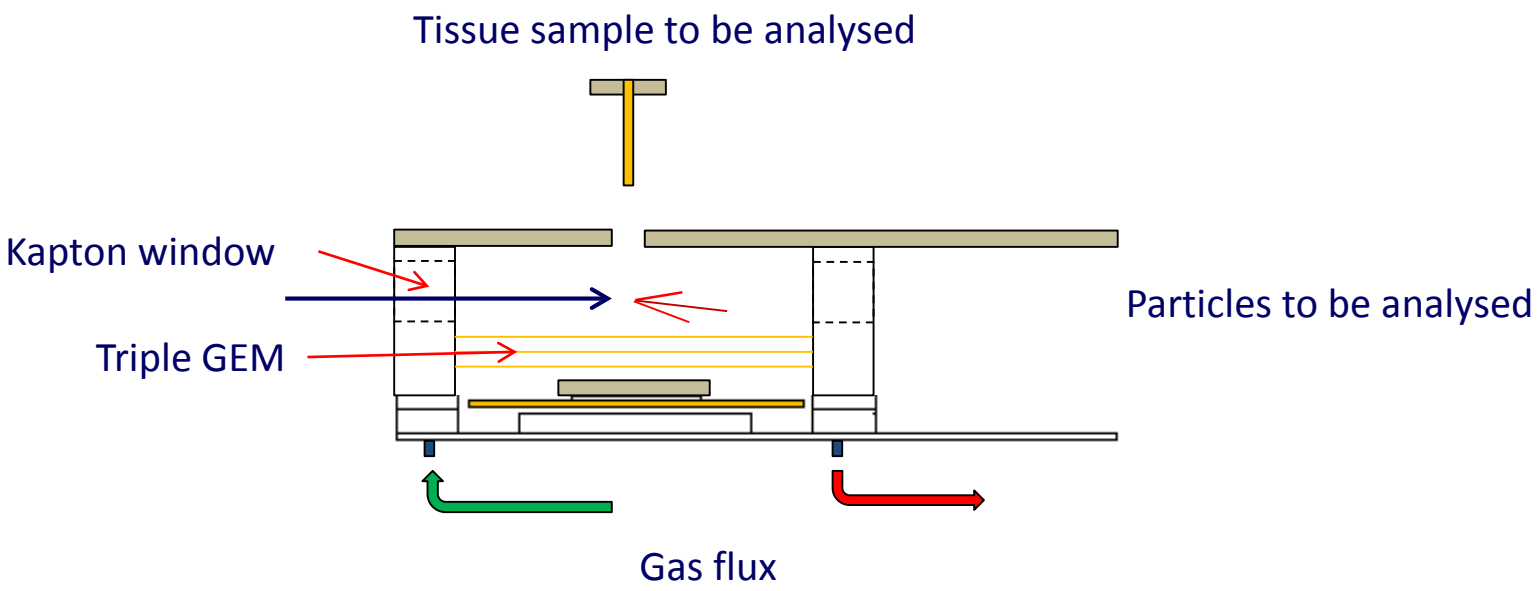
Next the powder is attached to a double-side tape in a small plastic box 3x3 cm^2



Results: GEMPix versus radiochemical analysis



GEMPIX: detector for tissue samples

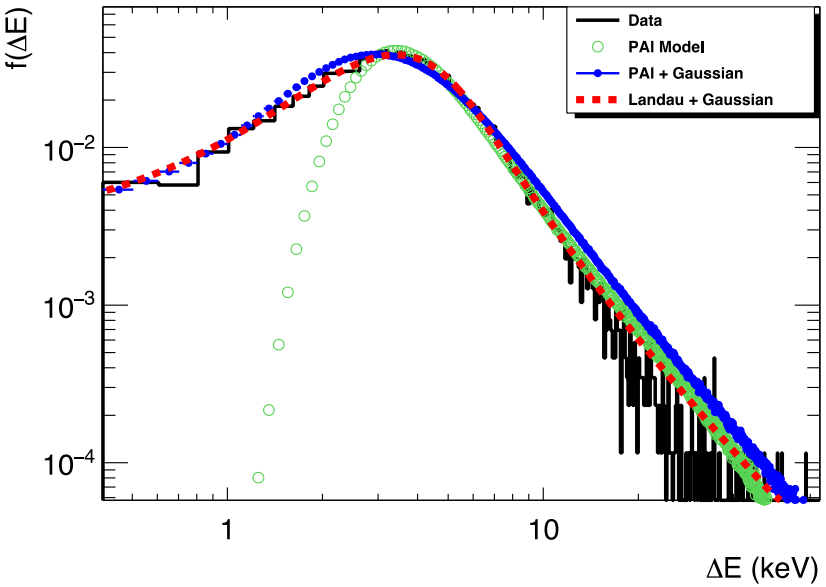


The detector is a quad naked medipix :
The active area is 9 cm^2
The particle track is analysed with 512 pixel in 3 cm length
This is equivalent to 30 microns of tissue … with 17 samples/microns

Track reconstruction (Microdosimetry?)

3D Path

Angular Resolution



Spatial resolution of track reconstruction is ~120 µm, should be further improvable in the future.

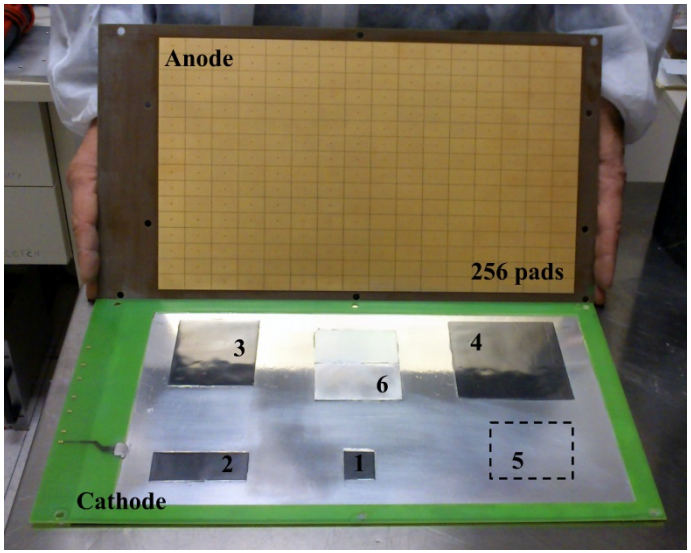
GEM-based Neutron Spectrometer

Eleni Aza (CERN)

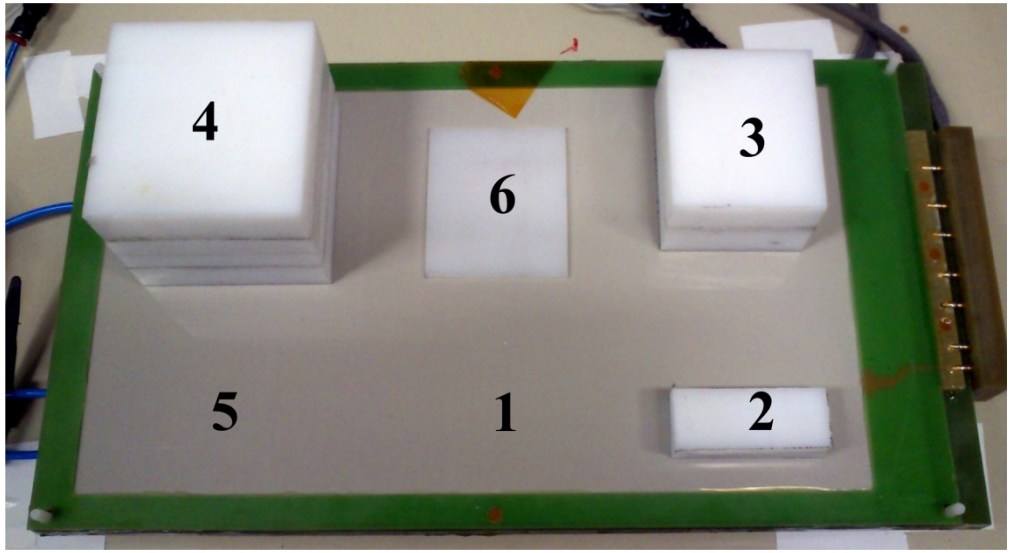
Neutron conversion board read-out by a GEM detector
Active area 35x21 cm^2
and pad size 22x13 mm^2 (256 pads)

Regions defined for different energy ranges
Reg 1-4 employ B_4C and PE for 1 meV – 5 MeV
Reg 5 & 6 employ PE and Al for 3 – 100 MeV

Inside



Outside



LUPIN

Chris Cassell (POLIMI)

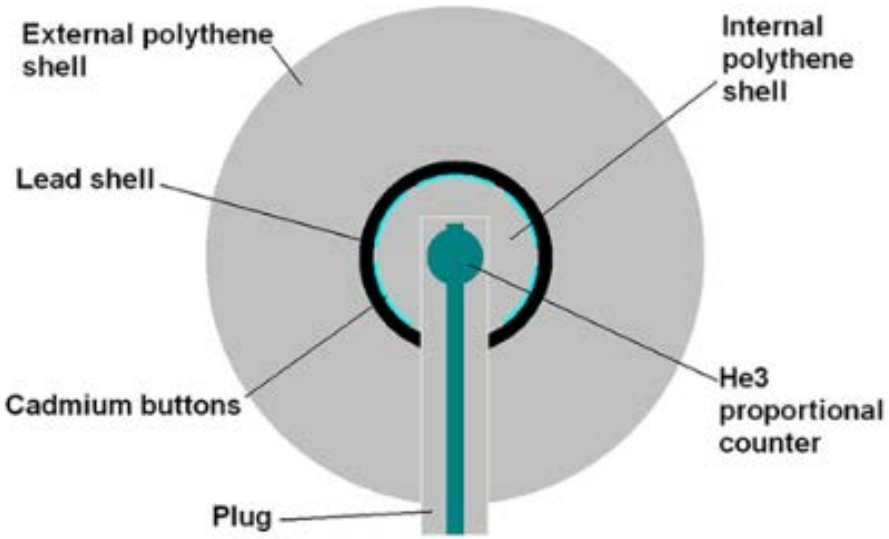
Proportional counter
^{3}He or BF_3

+

Moderator
(response function reproduces the curve of the **neutron fluence to H*(10)** conversion coefficients)

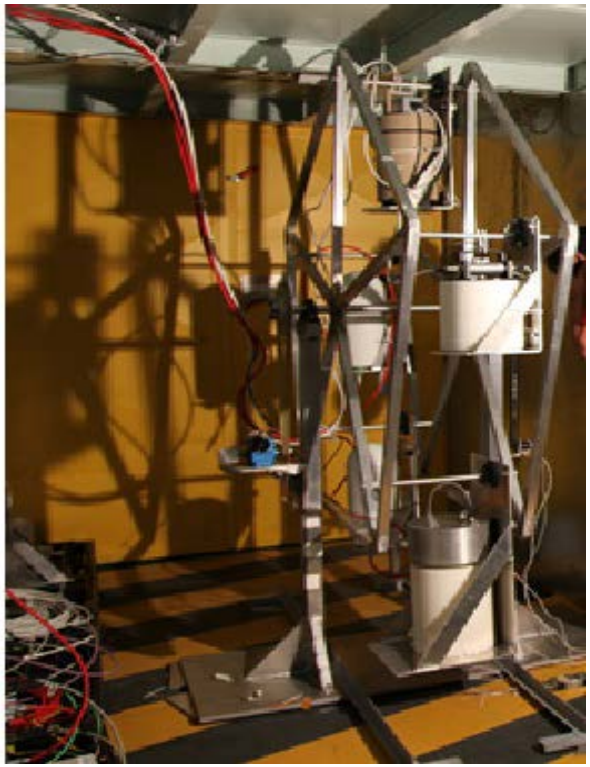
+

Innovative front end electronics



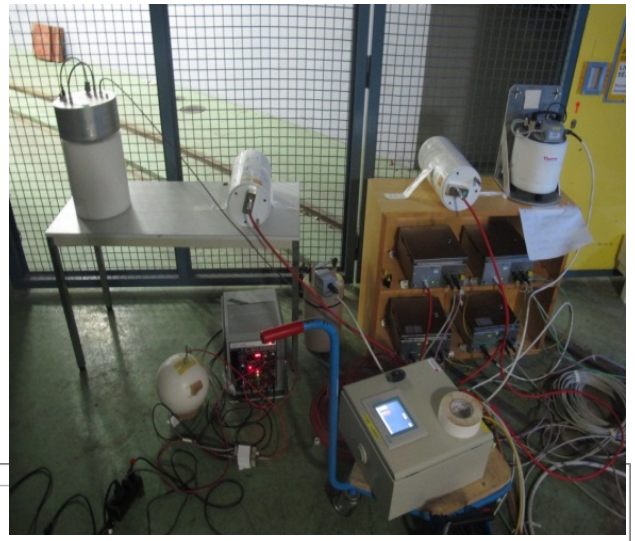
Measurements in pulsed neutron fields at CERN (just two examples)

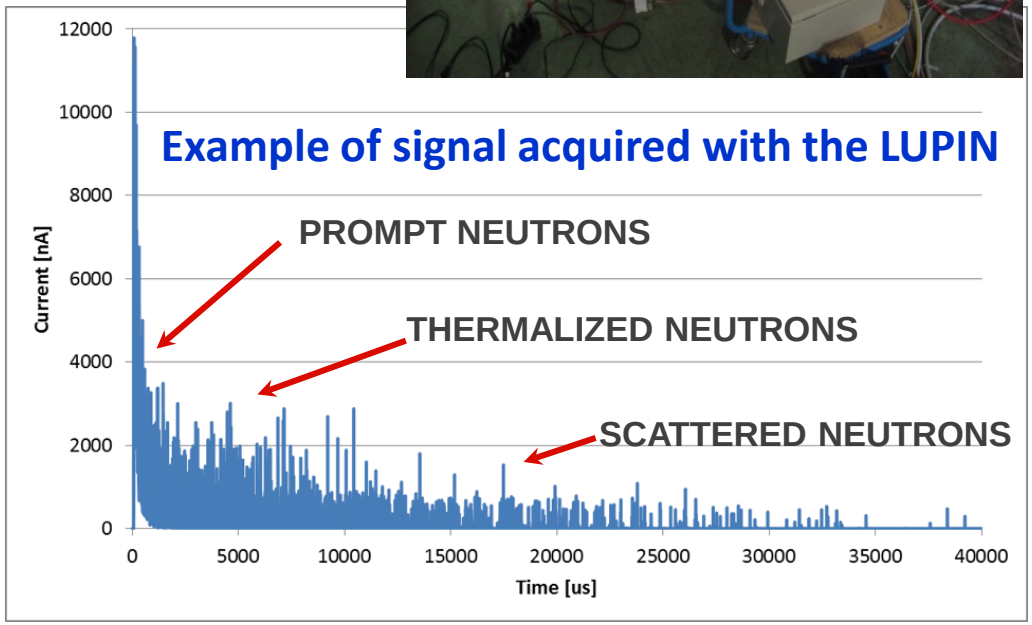
HiRadMat



Detectors mounted on carousel

Access to the PS tunnel

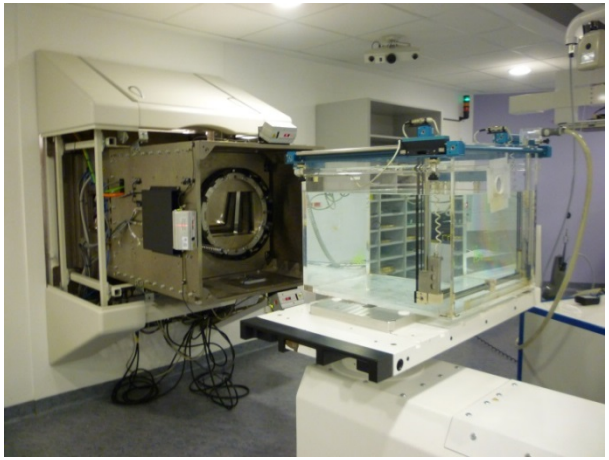




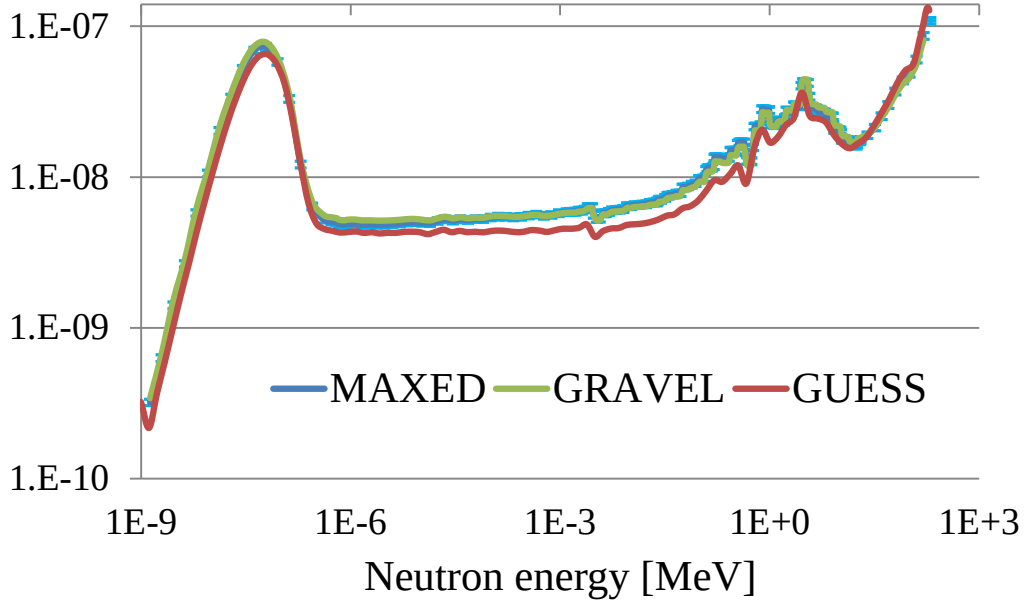
Neutron spectrometry with the BSS (Proton Therapy Centre, Essen)

Eleni Aza (CERN) and Chris Cassell (POLIMI)

230 MeV/c protons on water phantom
Spectrum measured inside the treatment room



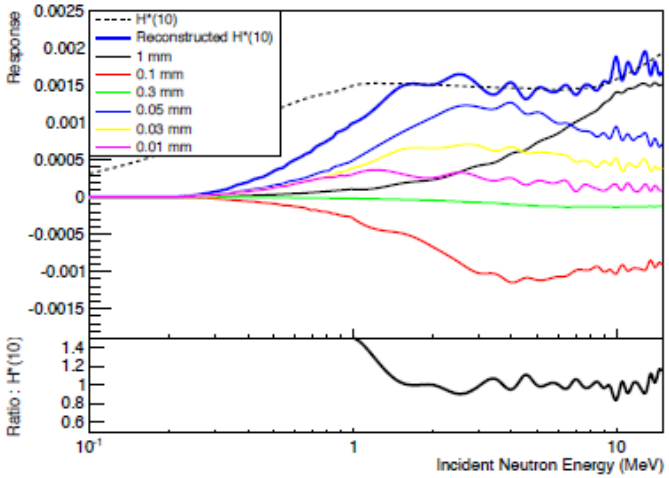
Neutron fluence per unit lethargy (/cm^2/proton)



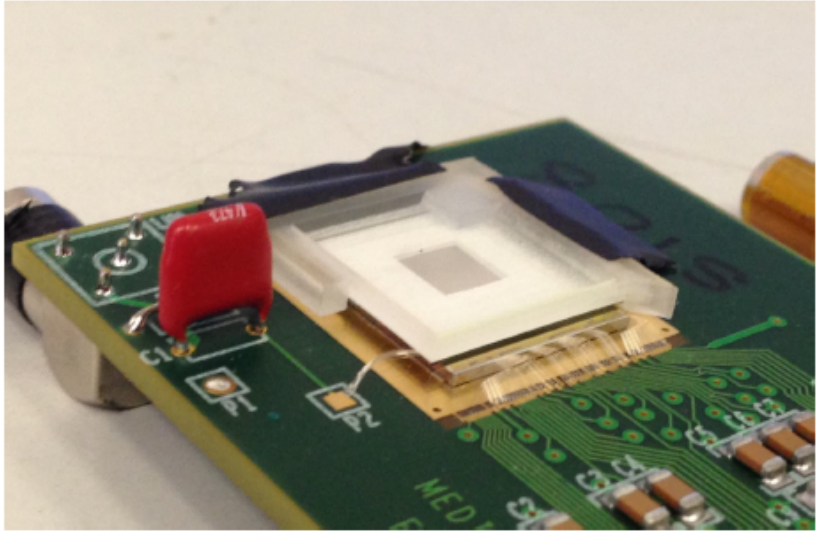
Neutron dosimetry with structured plastic converters

Stuart P. George (CERN)

- Multilayer plastic converters should be able to provide an energy independent response for fast neutron dosimetry



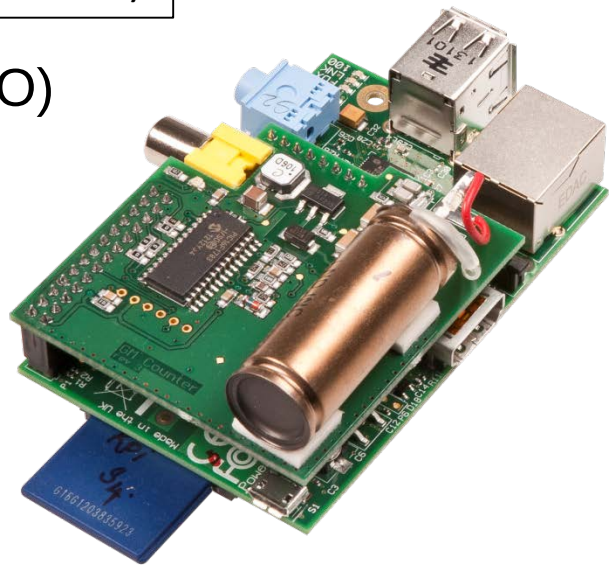
- Experimental evaluation of 3D printer prototypes over fast energy range

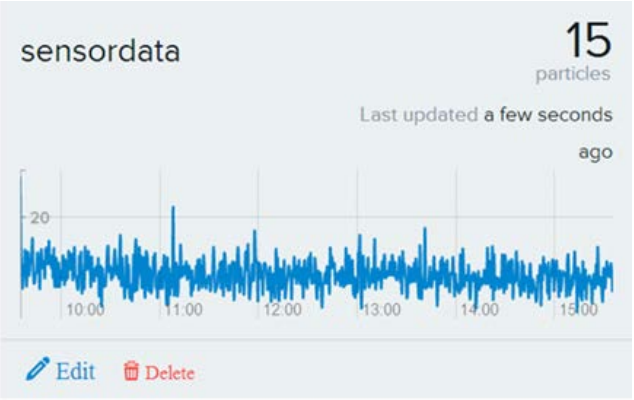


Development of low cost radiation monitor

Vijayaragavan Viswanathan (Jablotron)

- Czech Radiation Protection Institute (SURO)
  - Low cost radiation monitors
  - Deploy all across the country
  - Wired or wireless based device
  - Cloud connectivity to monitor remotely
- Prototype
  - Raspberry-Pi based device
  - First prototype ready
  - Ongoing experiments and calibration activity
- Next steps
  - Include other blocks like Temperature, Humidity, Pressure
  - Ensure the device environment
  - Mechanical design
  - Testing and deployment



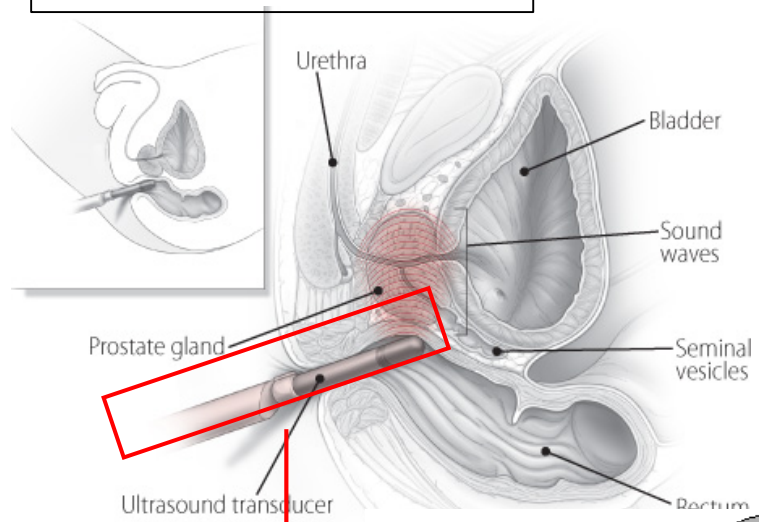


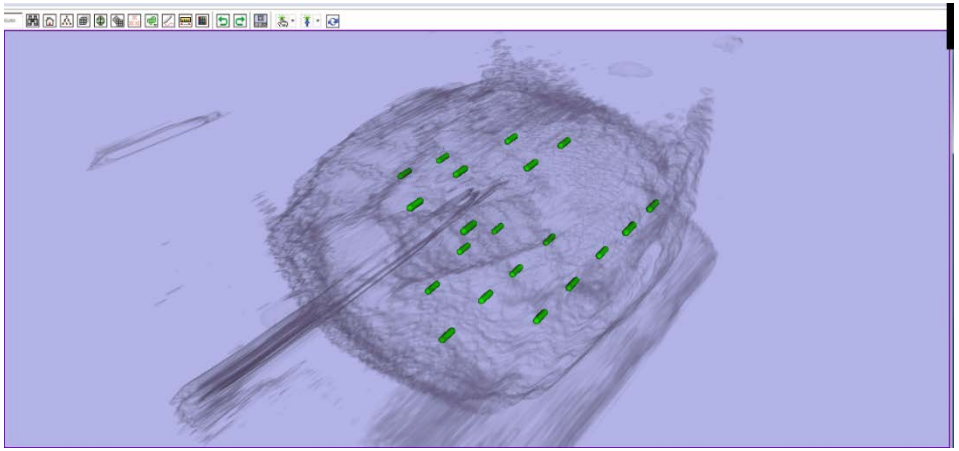
Remote monitoring

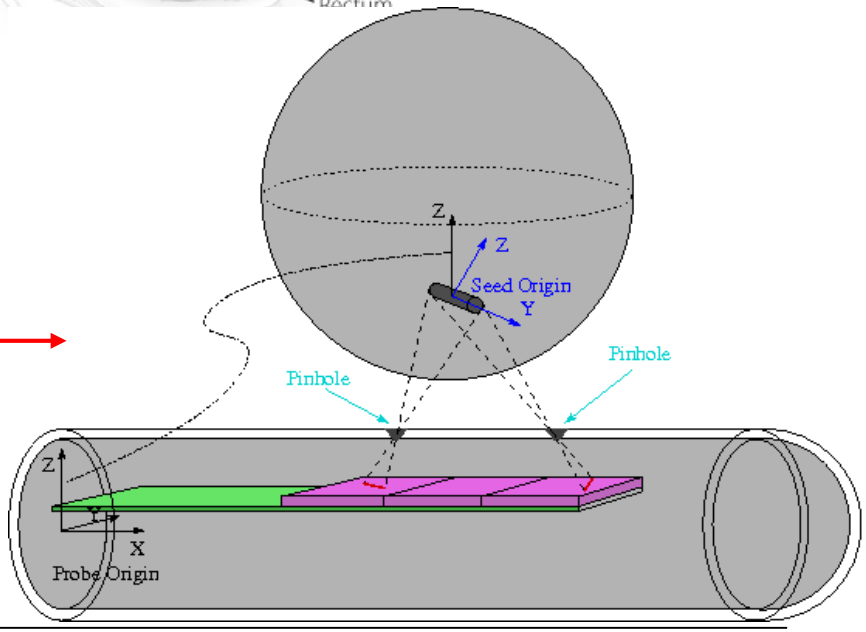
BrachyView – Medipix in cancer treatment

Kevin Loo (CTU Prague)

- Use Medipix to develop brand new, ultra-functional, in-body imaging probe
- Currently, doctors use a combination of ultrasound, X-rays, CT for implant verification



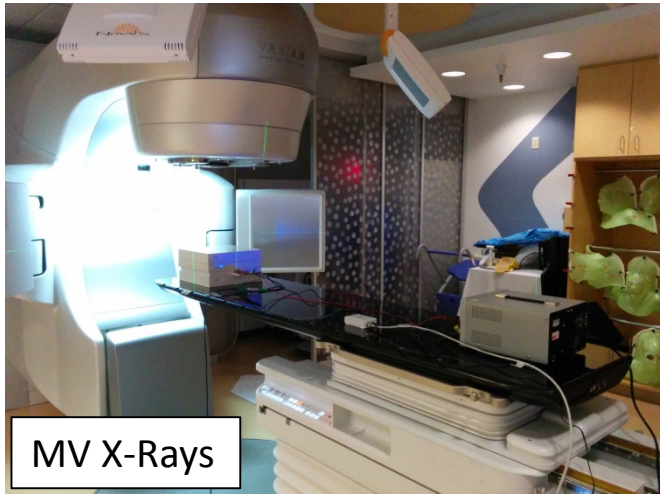


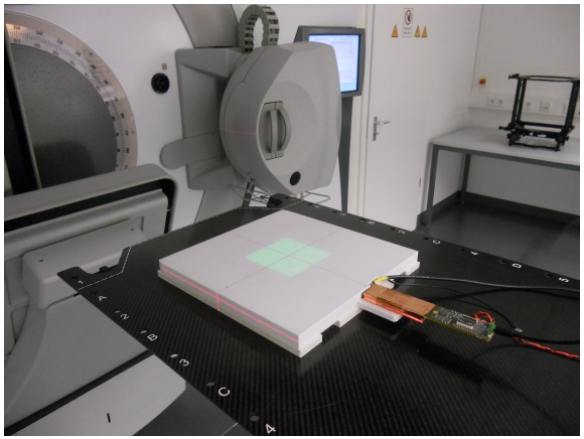


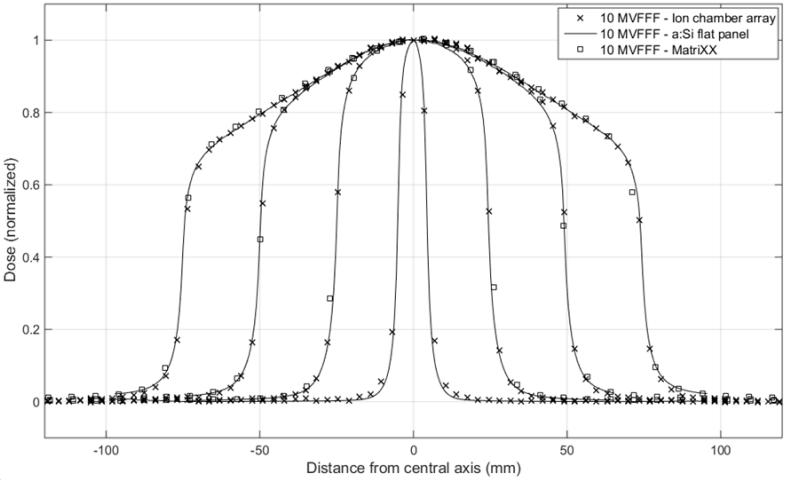
Ionization Chamber Array for External Beam Radiotherapy

Michele Togno (IBA Dosimetry)

Development and characterization of a new air vented ionization chamber array technology for machine & patient quality assurance in external beam radiotherapy.

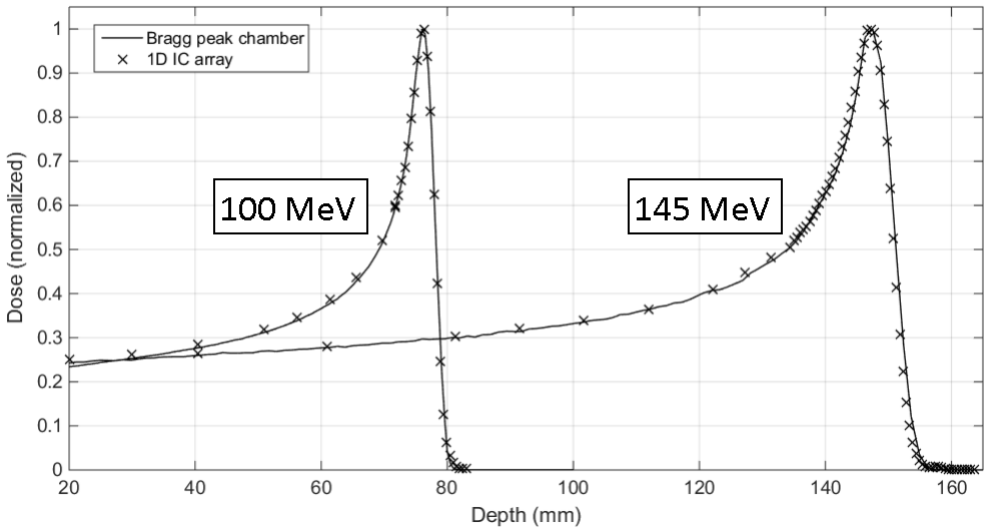


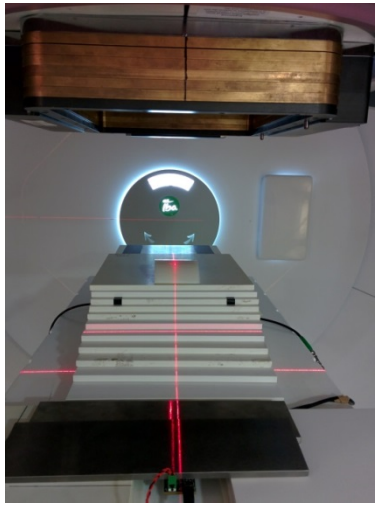




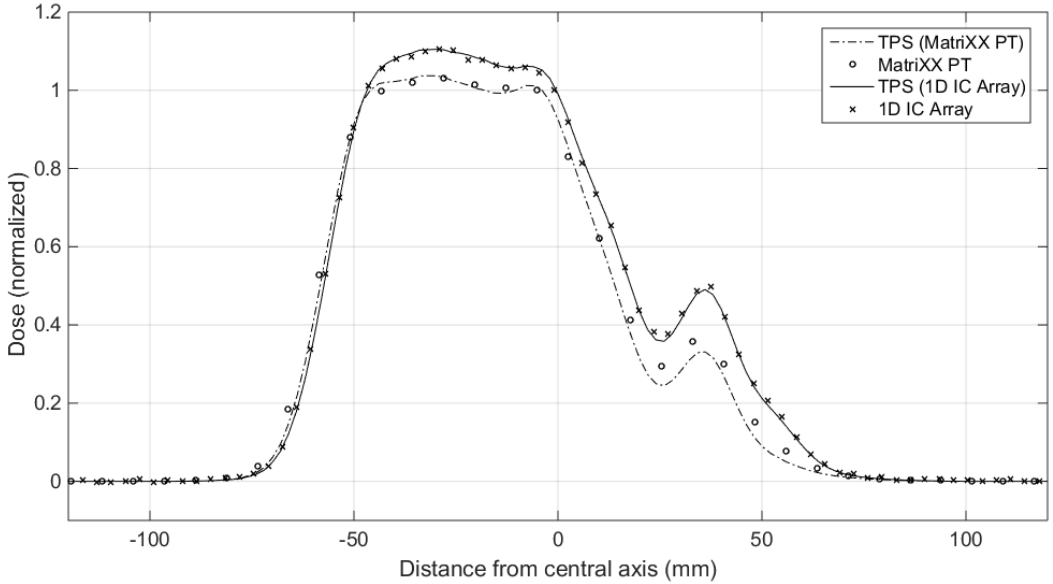
Ionization Chamber Array for External Beam Radiotherapy

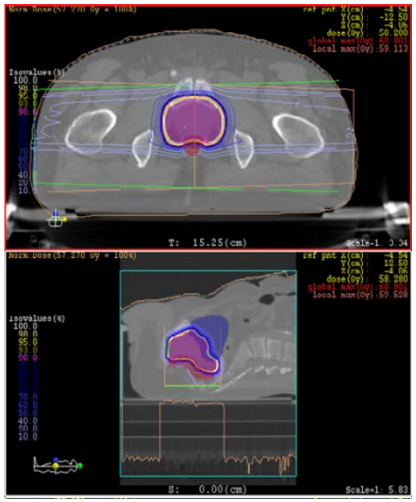
Proton beams characterization: example of measured Pristine Bragg peak at different energies





Example of patient plan verification for an Intensity Modulated PT treatment of prostate tumor.

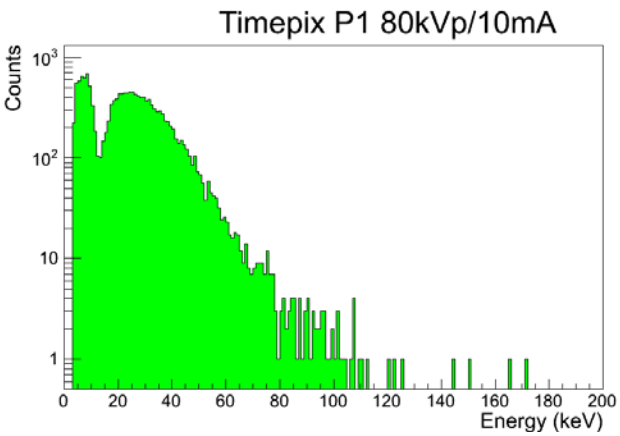


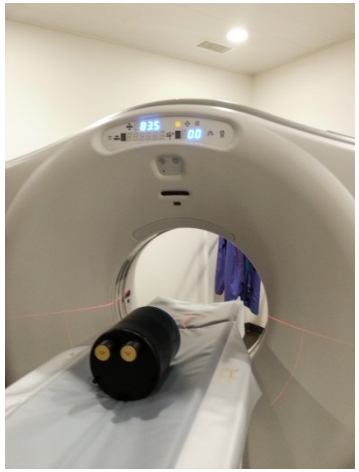


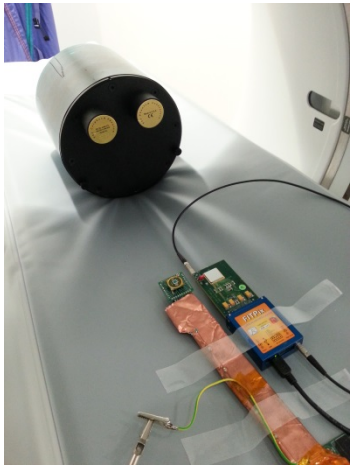
Scattered radiation in a CT room

Erik Frojdh (CERN)

- **Dosepix** and **Timepix** detectors with a 300 µm Si sensor
- Measurements performed at CHUV in Lausanne
- Ge Medical Systems Discovery CT750 HD CT-scanner
  - at 80 kVp and 120 kVp
- Measured scattered radiation during **scan of an abdomen phantom**



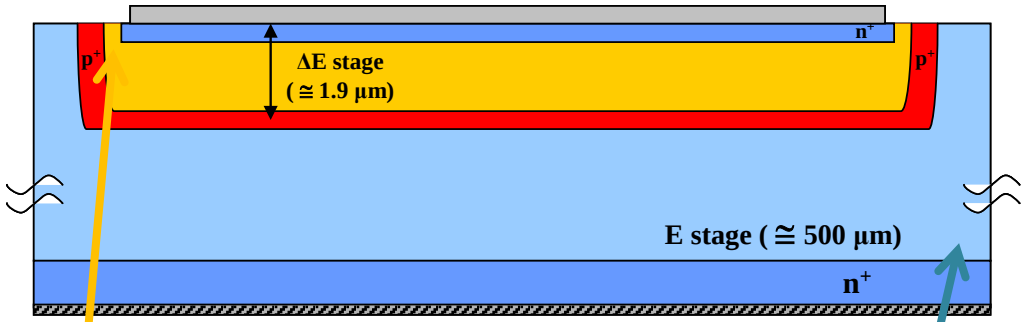




Silicon microdosimeter

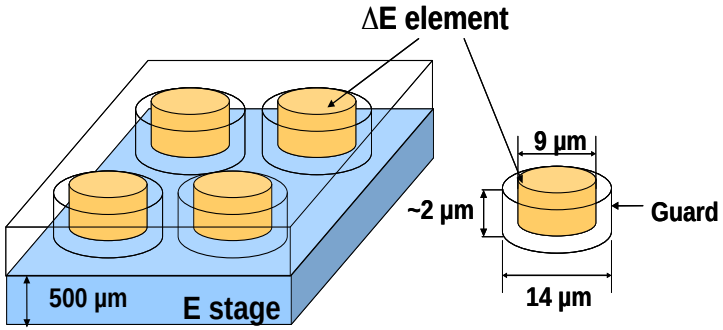
Elena Sagia (Polytechnic of Milano)

Monolithic silicon telescope



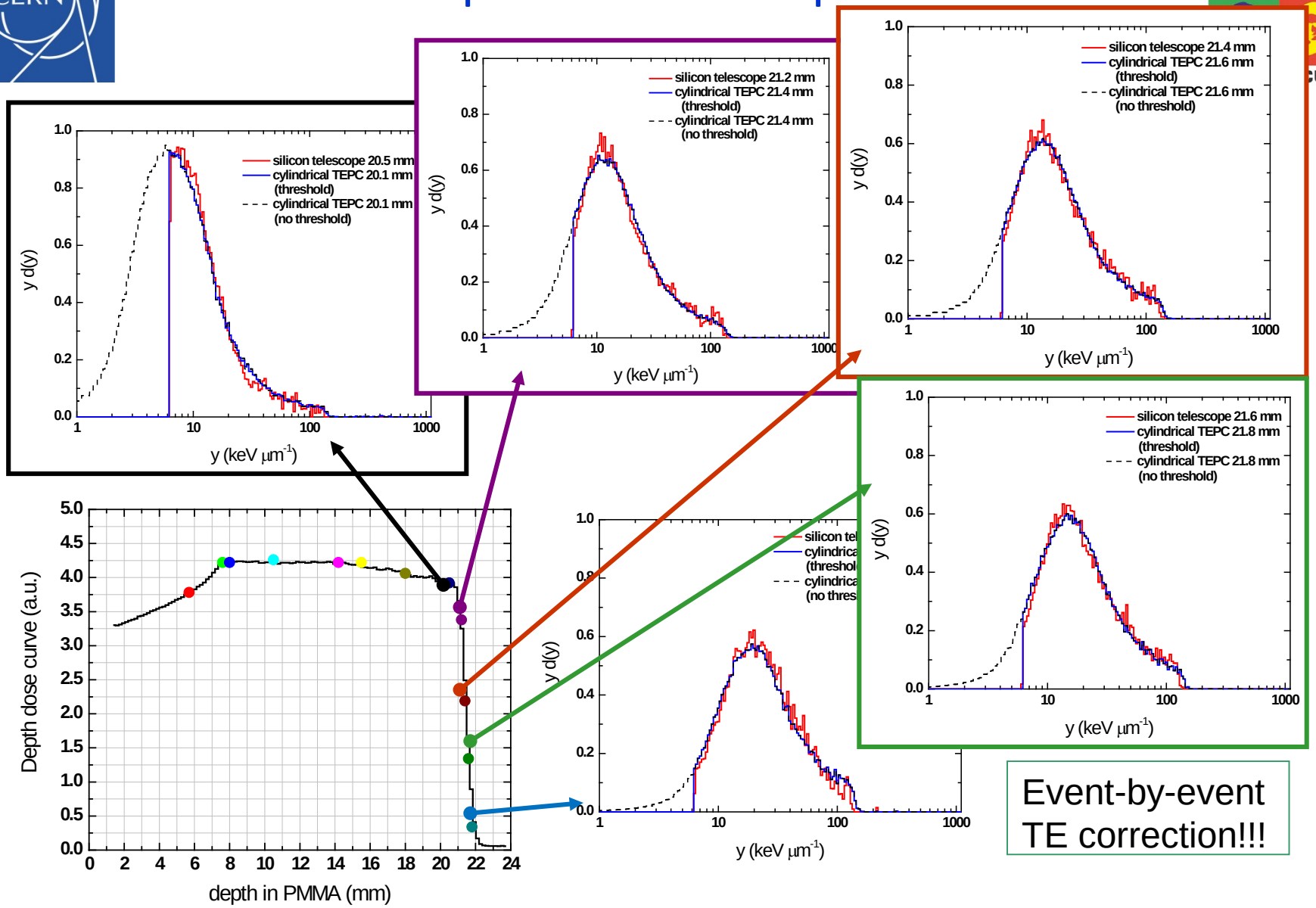
<u>Silicon telescope</u>:
a thin ΔE stage (1.9 µm thick)
coupled to a residual energy stage
E (500 µm thick)
on the same silicon wafer.

- **Segmented ΔE stage**



- **7000 pixels in parallel**
- **Sensitive area 0.5 mm^2**
- **Minimum detectable energy limited to about 20 keV by the electronic noise**

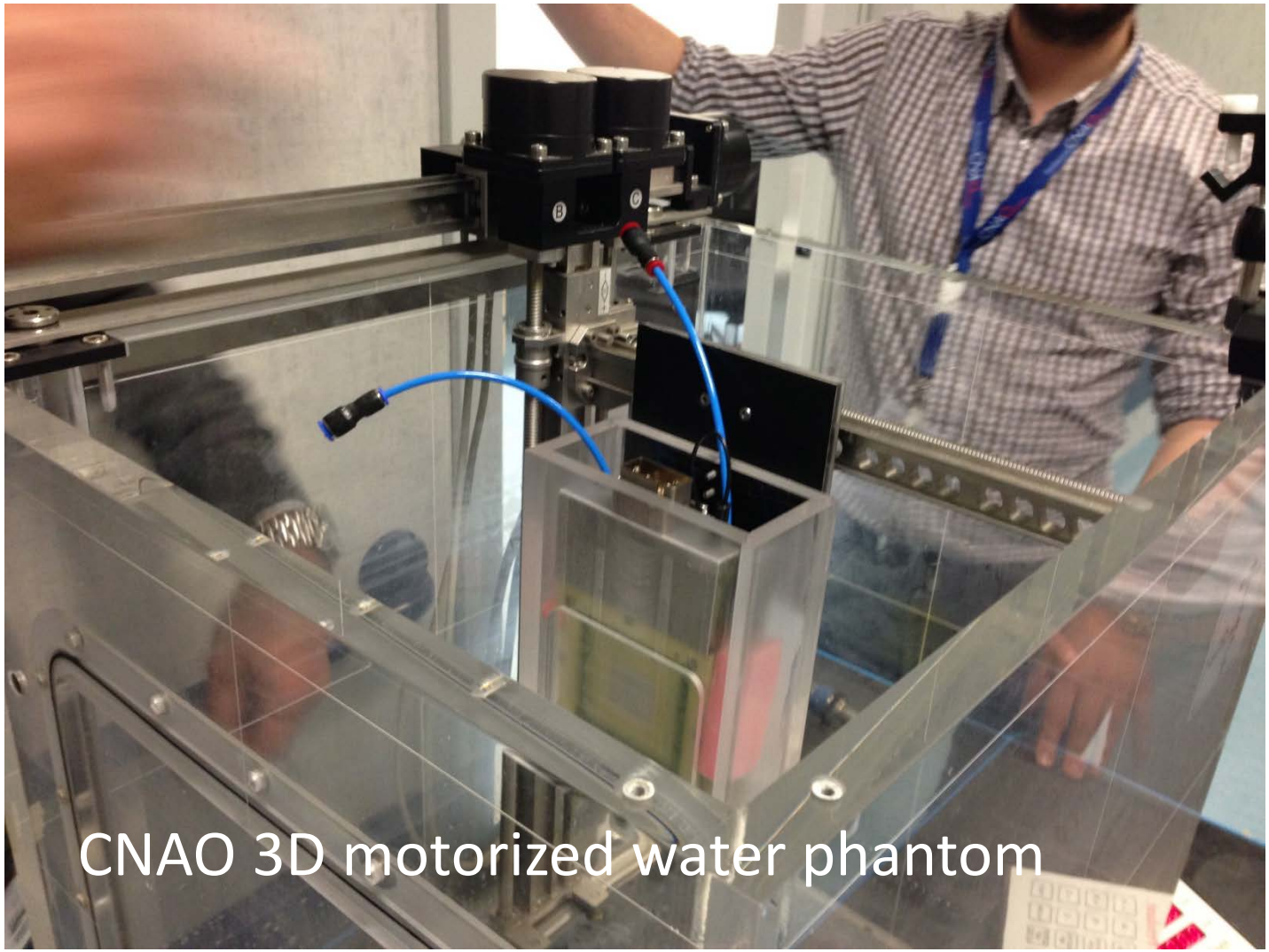
62 MeV proton – Distal part of SOBP



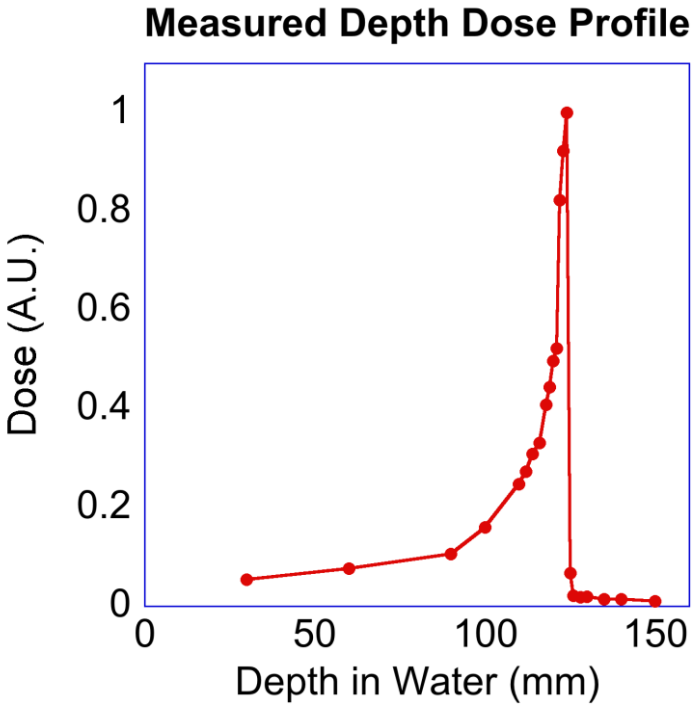
Event-by-event TE correction!!!

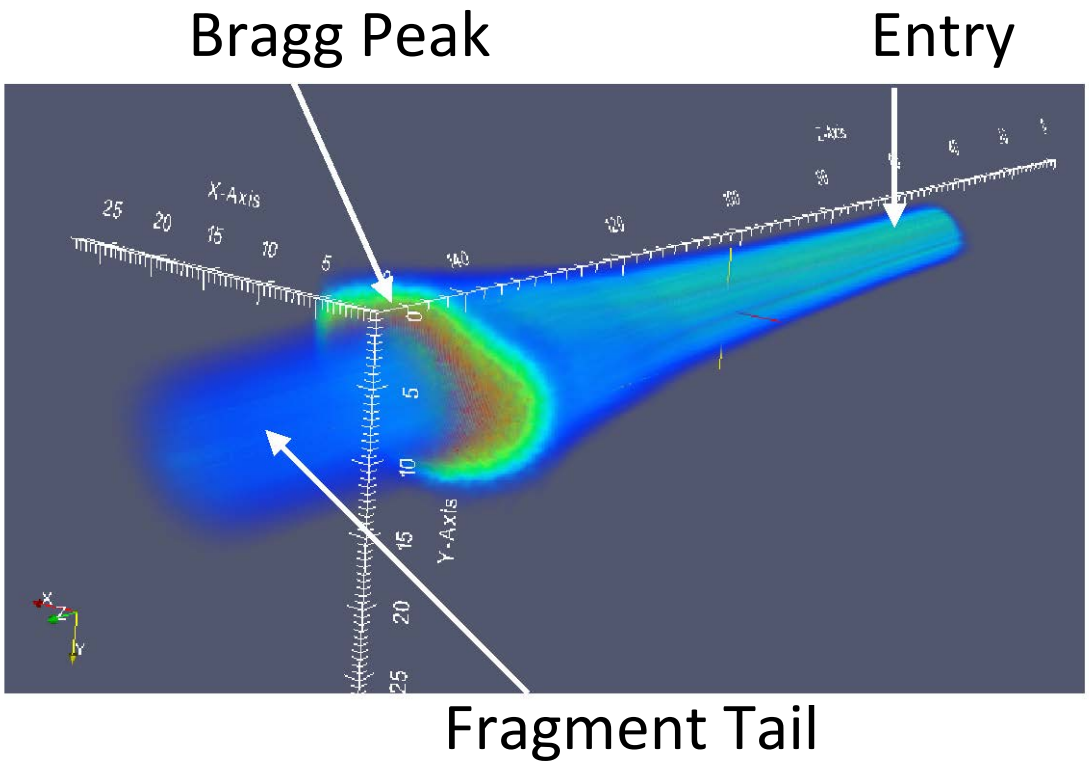
GEMPix: 3D energy deposition in water phantom

Stuart George (CERN)



GEMPix: 3D energy deposition in water phantom

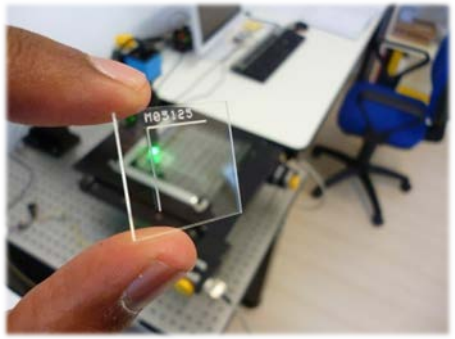




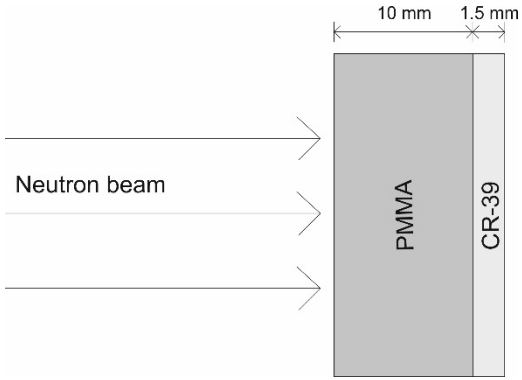
23 depths in water with the CNAO (Pavia Italy) clinical carbon ion beam (5.10^8 ions/depth).

Neutron dosimetry with CR-39 detectors

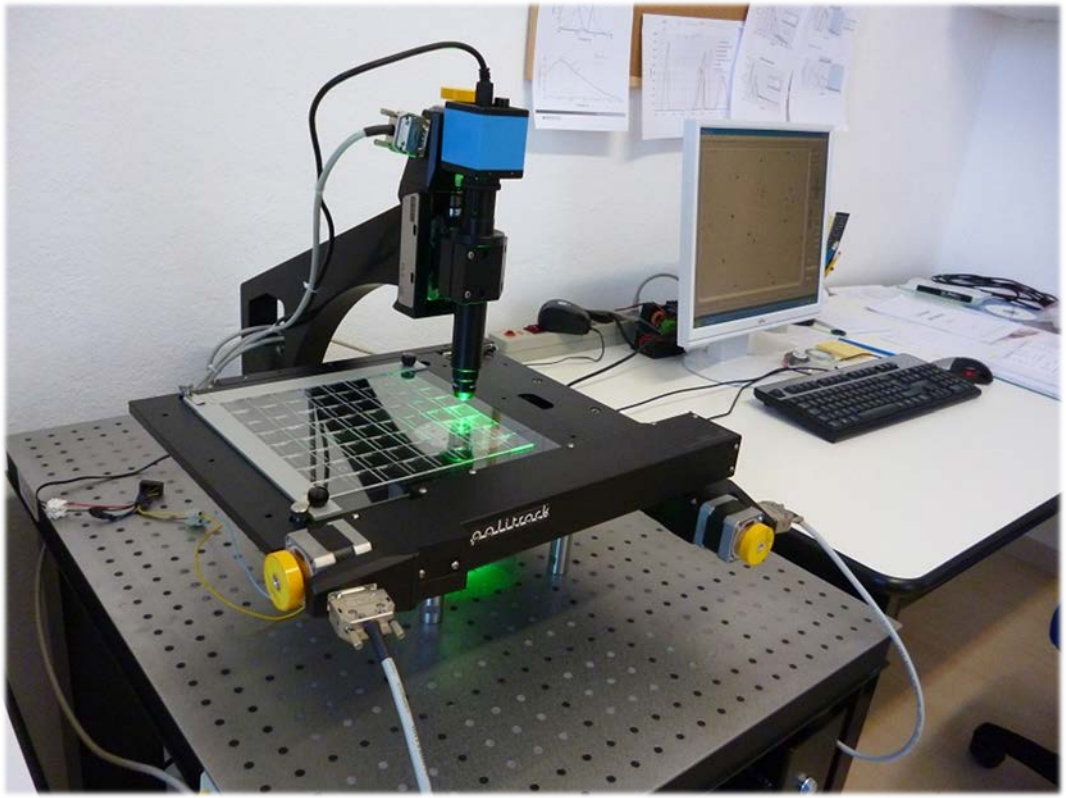
Alvin Sashala Naik (MI.AM)



Intercast CR-39 track detector



Fast neutron dosimeter based on the intercast CR-39

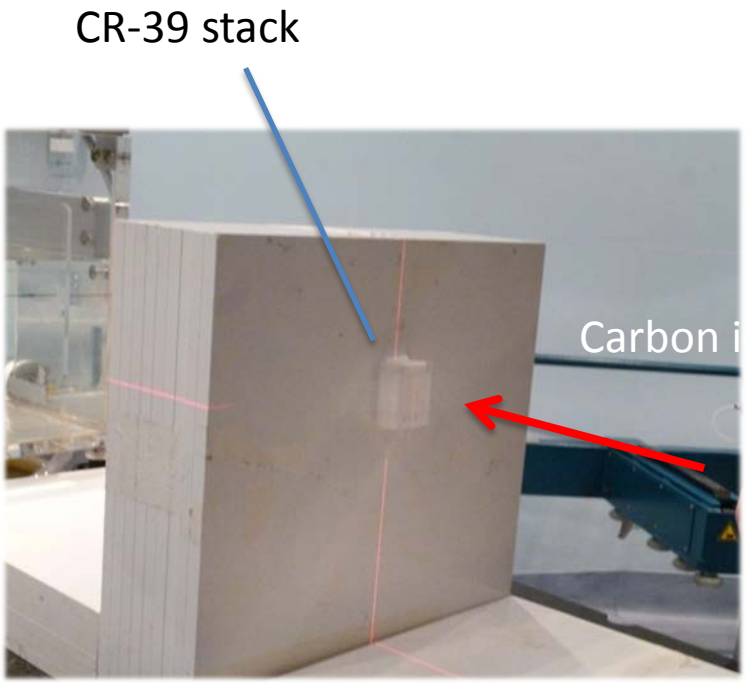


Politrack™ instrument

The Politrack™ instrument was developed by the Politecnico di Milano and commercialised by Mi.am SRL.

Spectrometry using CR-39 detectors for hadron therapy beam diagnostics (Carbon ions)

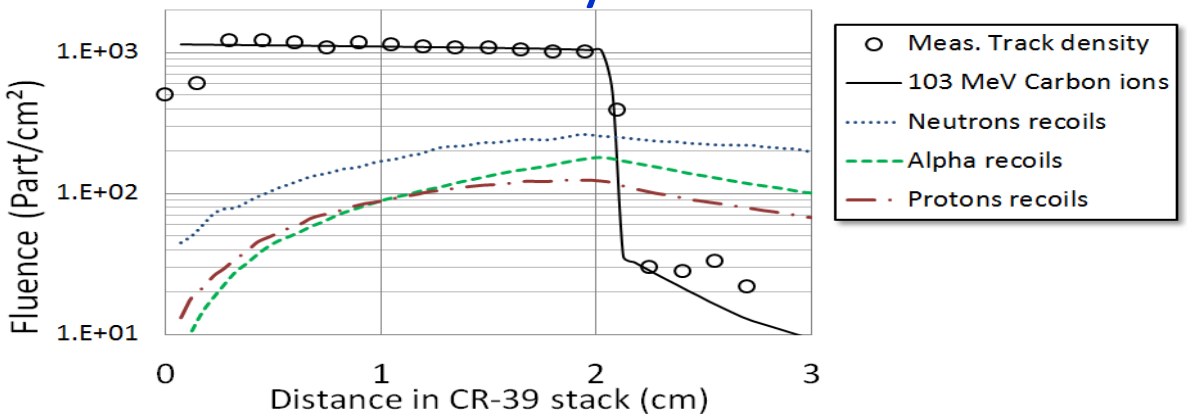
Experiment at CNAO hadron therapy centre in Pavia, Italy

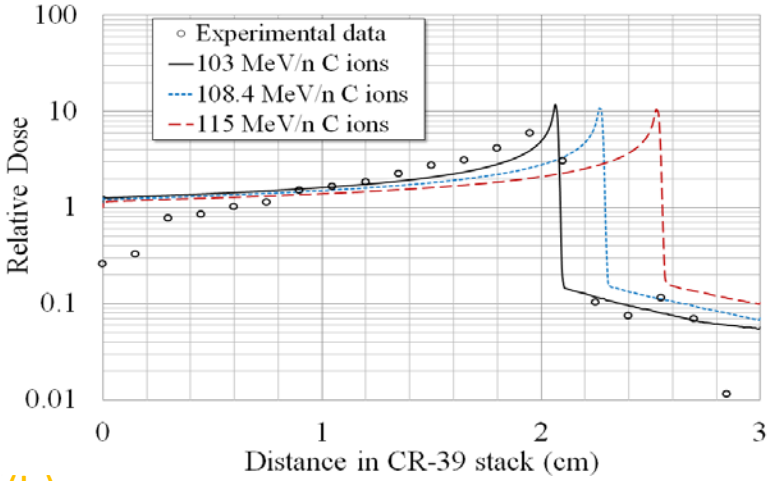


Irradiation of CR-39 detectors with Carbon ions of 108.4 MeV/nucleon

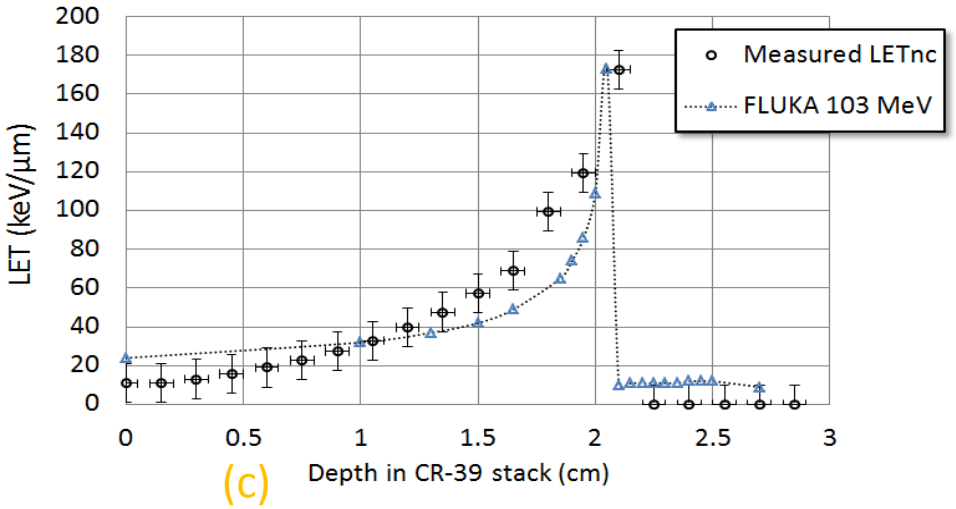
In-beam LET spectrometry and dosimetry of heavy ions

(a)





(b)

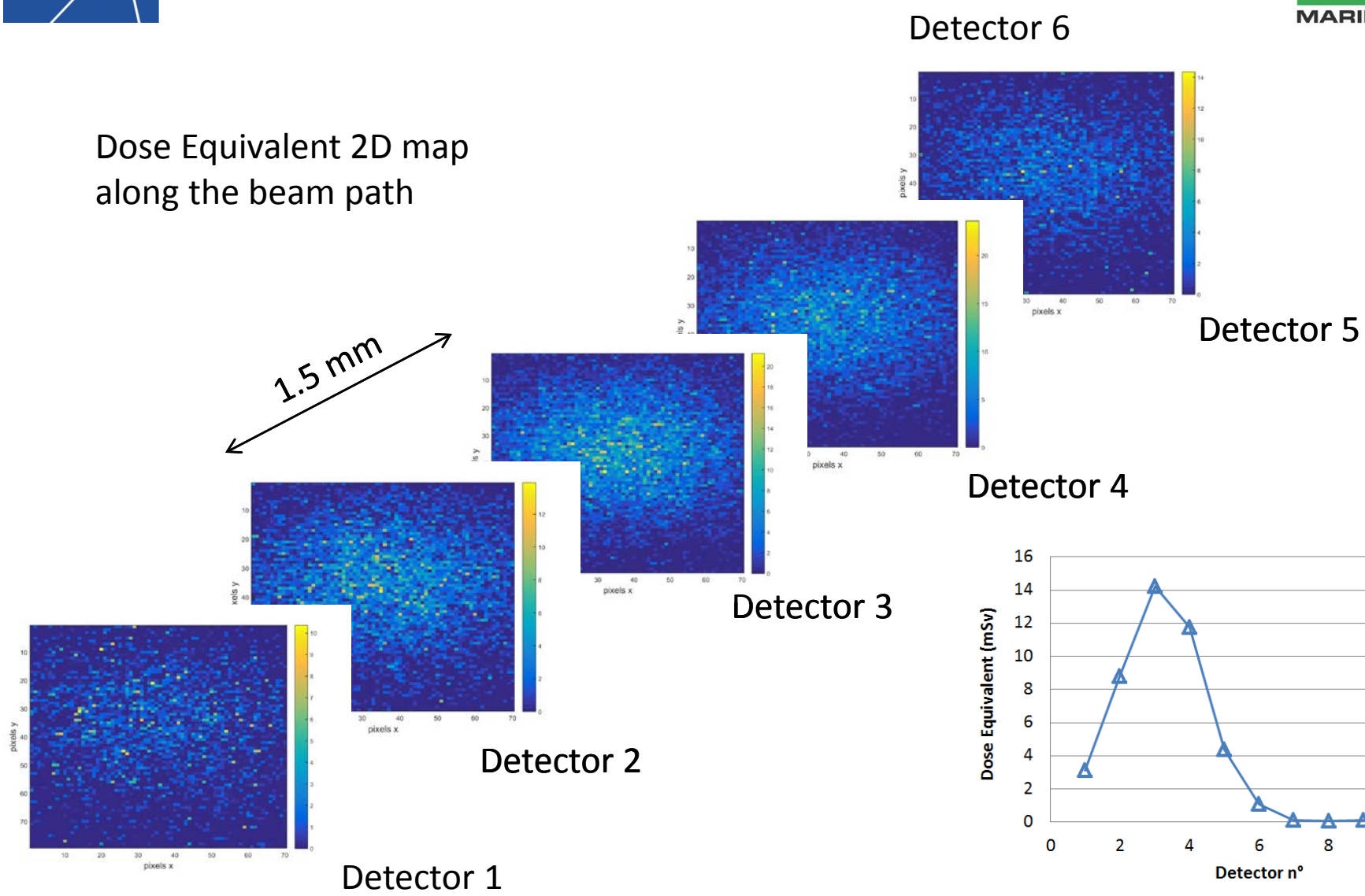


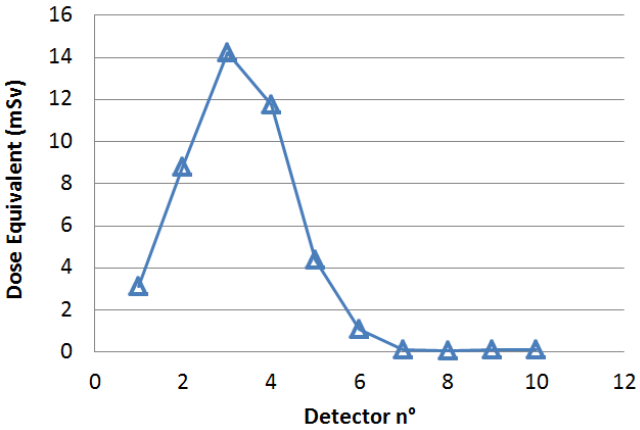
(c)

Preliminary results from measurements of the fragmentation of Carbon ions in a stack of CR-39 detectors at CNAO.
(a) Fluence to depth curve, (b) Dose to Depth curve, (c) mean lineal energy of the Carbon beam with respect to depth in the CR-39 stack.

In-beam LET spectrometry and dosimetry in proton beam

Dose Equivalent 2D map along the beam path

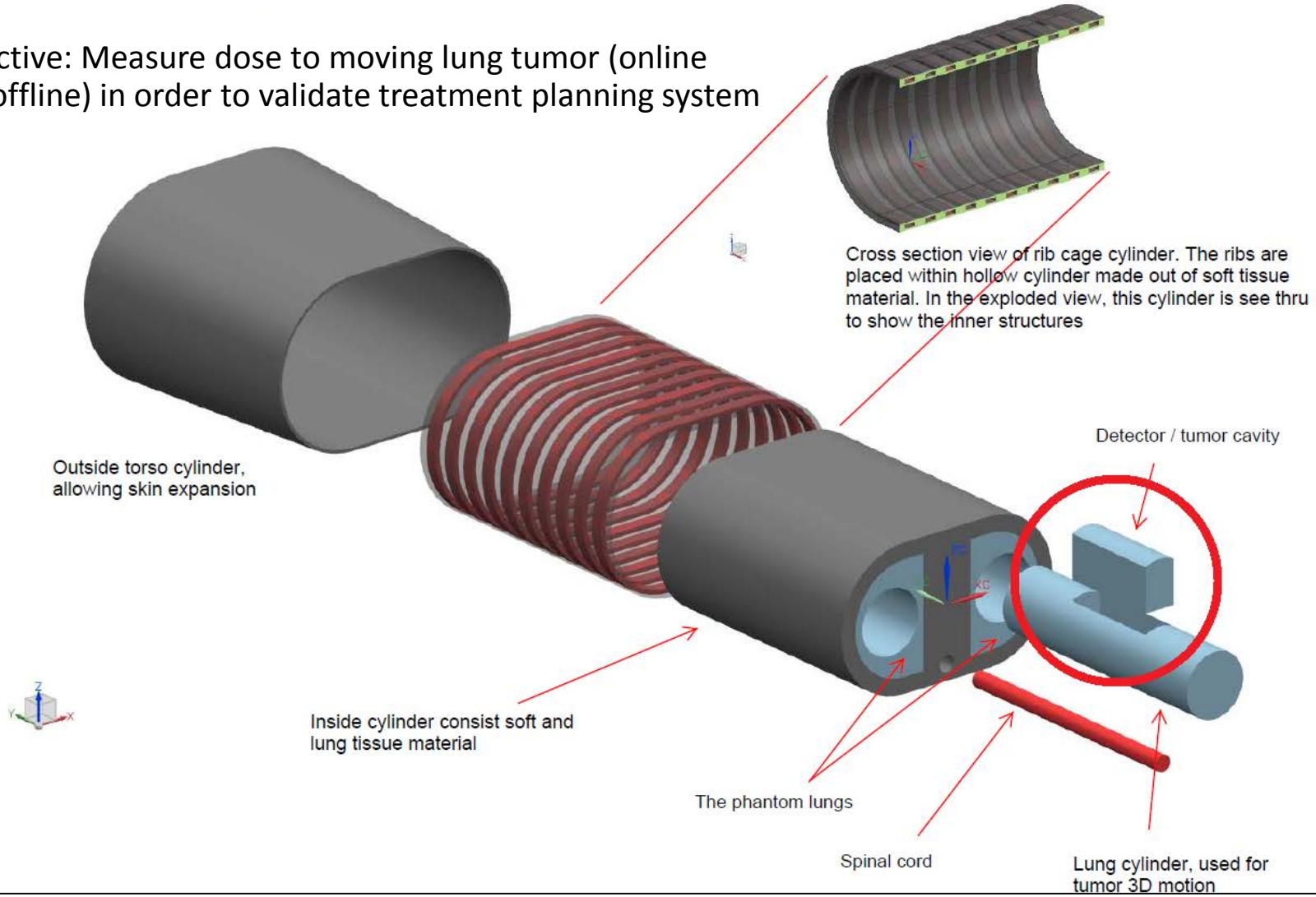




Heterogeneous Breathing Thorax Phantom

Andrej Sipaj (AIT)

- Objective: Measure dose to moving lung tumor (online and offline) in order to validate treatment planning system



ACKNOWLEDGEMENTS

All supervisors and scientists from the various partner institutions

At CERN, special thanks to:

Michael Campbell, Jerome Alozy

Fabrizio Murtas, Matteo Magistris, Daniel Perrin, Doris Forkel-Wirth