The GEMPix detector for energy deposition measurements in Hadrontherapy

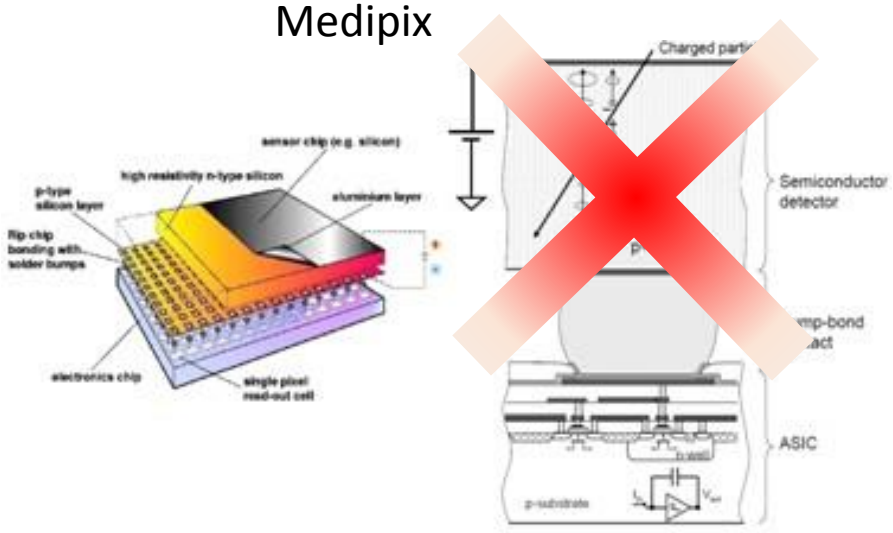
F. Murtas[1,2] , M. Silari[1], S. George[1], J.Lindner[1]

A. Rimoldi[2,3], A. Tamborini[2], M. Ciocca[4] and A. Mirandola[4]

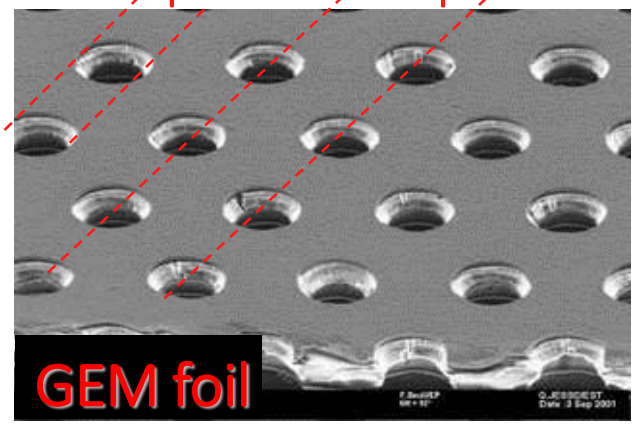
1) CERN, 2) INFN, 3) Università di Pavia,
4) Unità Fisica Medica CNAO

Two Micro Pattern Detectors

Medipix

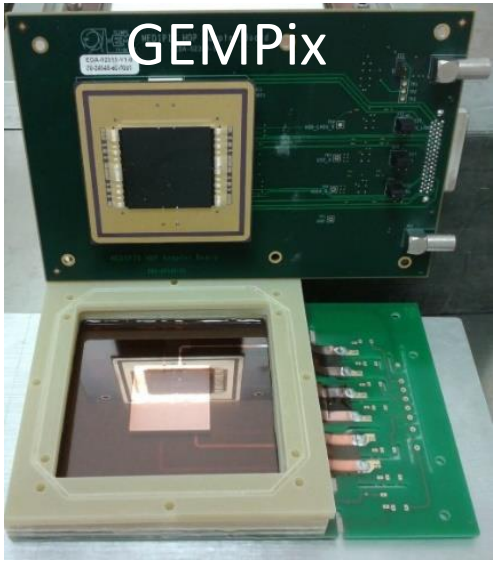


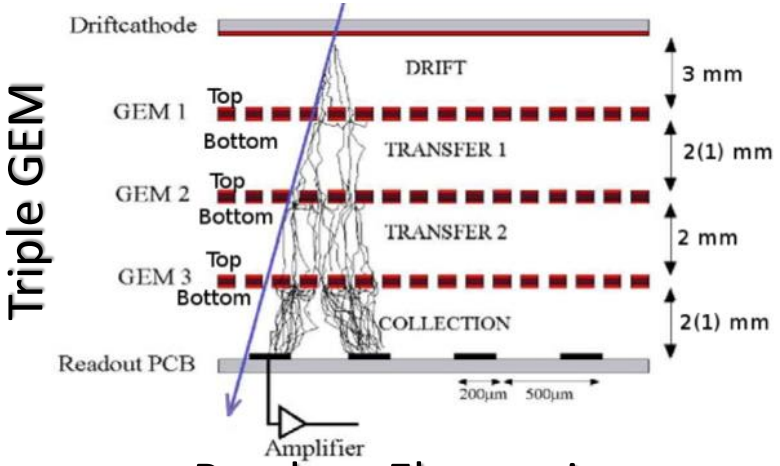
Gas Electron Multiplier



4 Timepix chips

Triple GEM



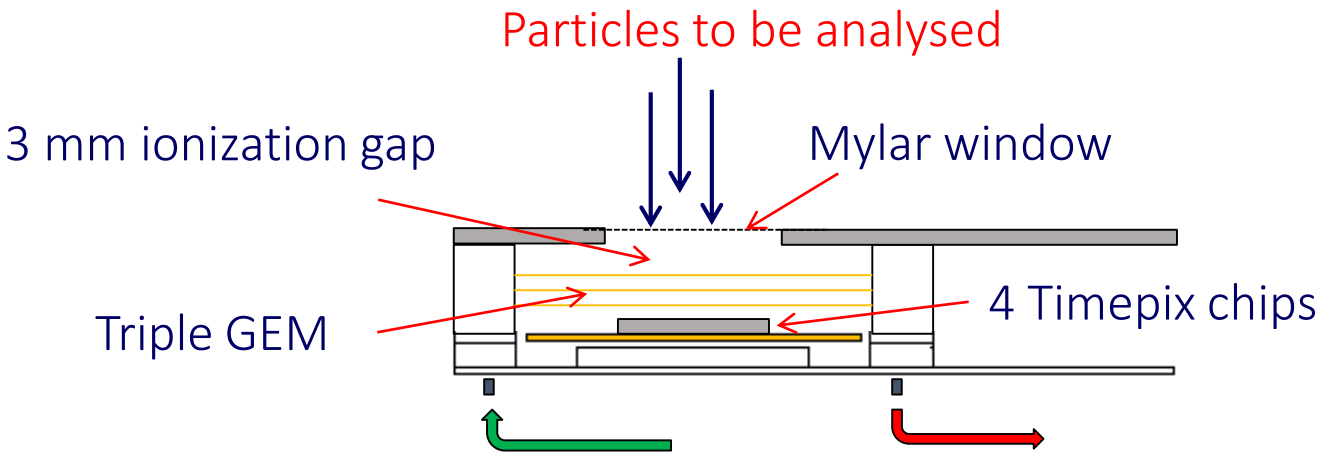


Readout Electronics

GEMPix Detector

This innovative **gas detector** has been designed in the ARDENT framework within a collaboration between CERN and INFN.

It is a **triple GEM** detector read be a **4 naked Timepix** (no silicon sensor):



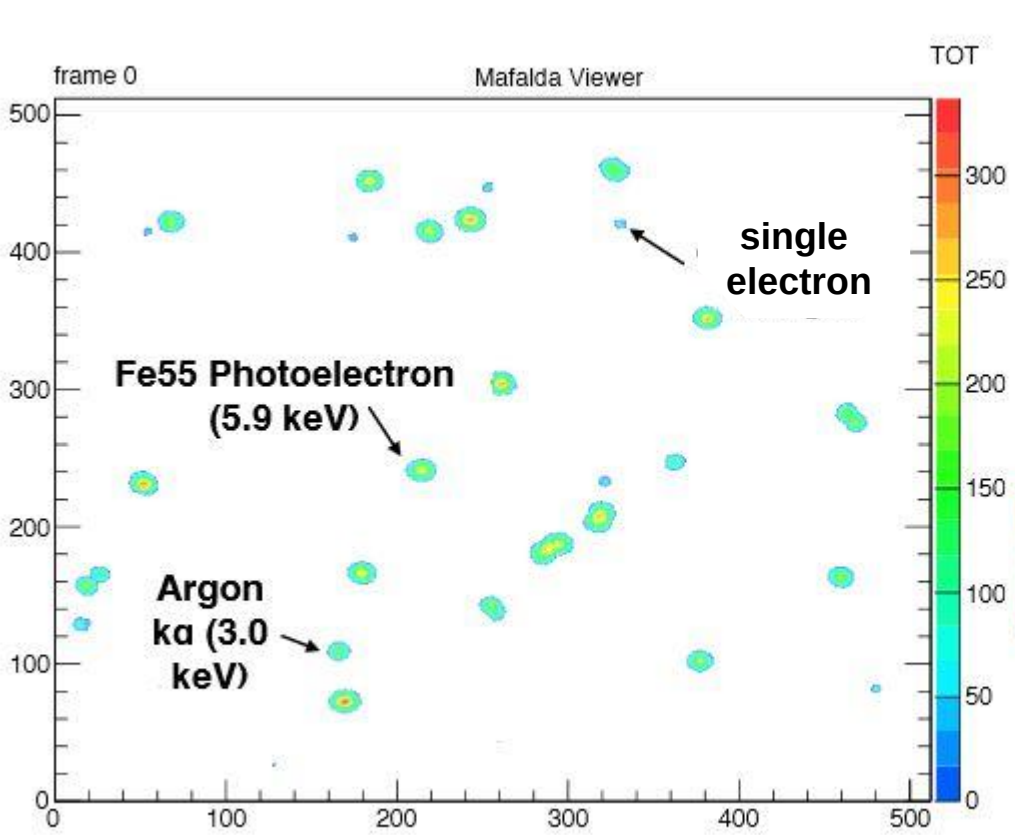
Active area is 9 cm^2

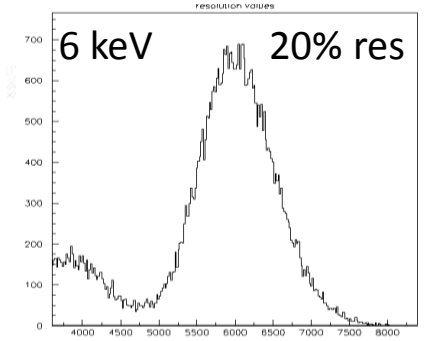
Gas flux Ar CO_2CF_4 or **Tissue equivalent gas**

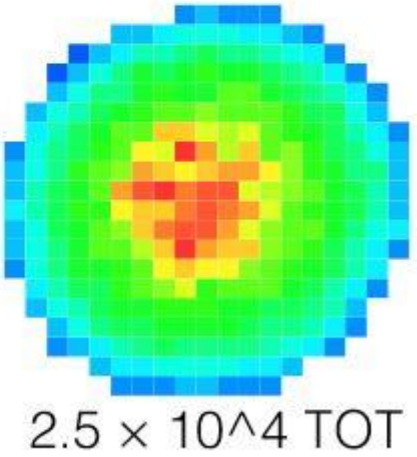
In three years we found several applications for this type of detector: Radioactive waste, Micro dosimetry, Hadrontherapy, Radiotherapy, Radon Monitor … but also Dark Matter Research !

Single particle detection

X-ray detection 6 keV from ^{55}Fe (1 sec frame)





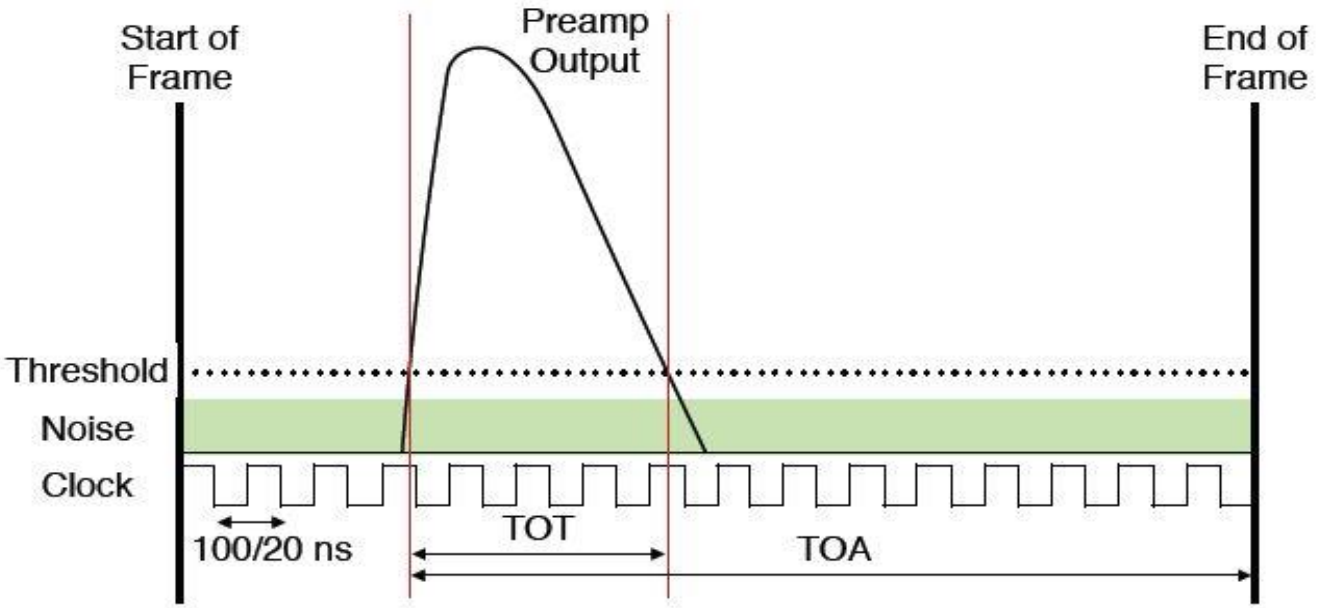


Cluster Charge

The Timepix software PIXELMAN can recognize the cluster and measure in real-time its energy

Time and charge measurements

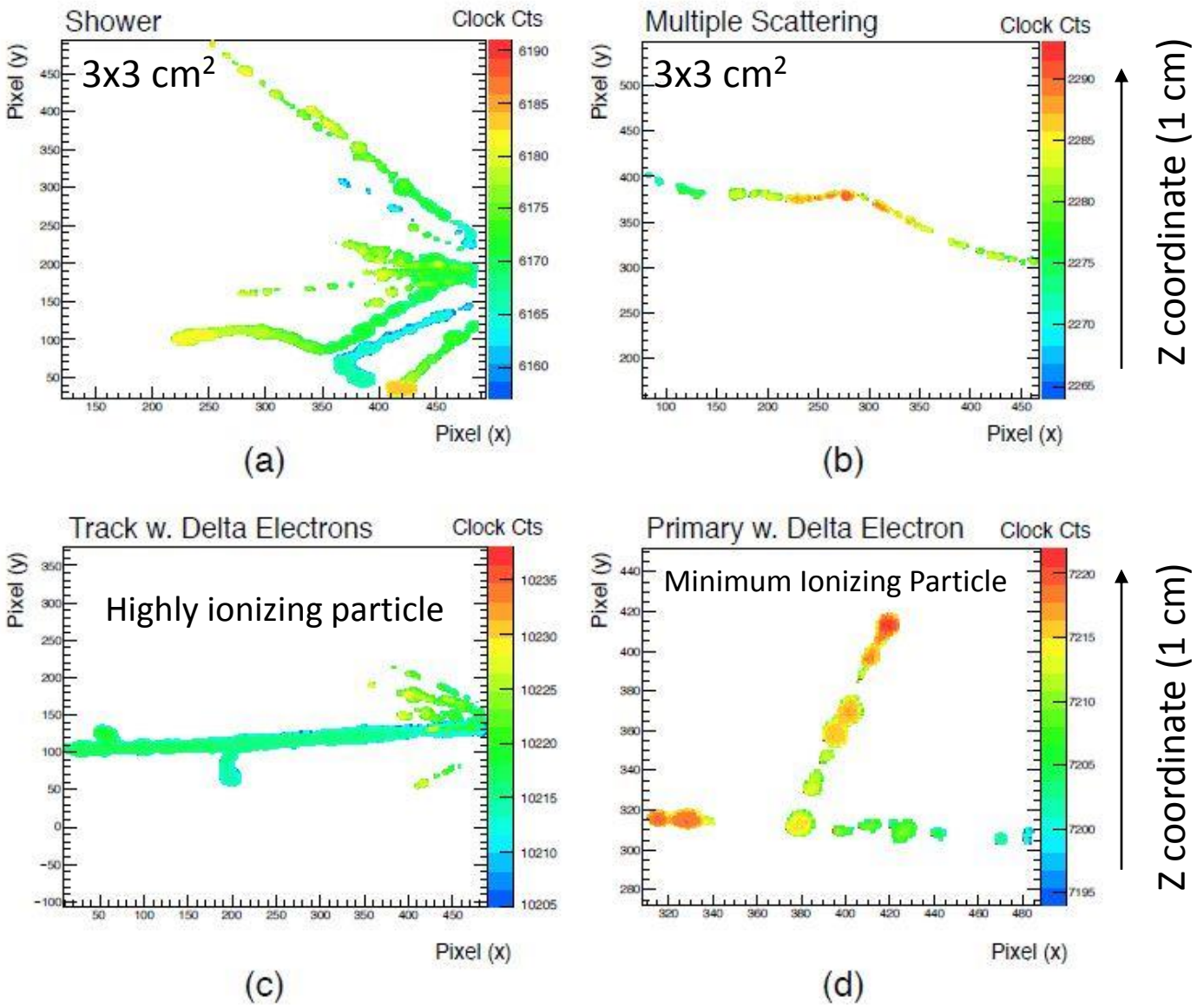
The Timepix Pixel



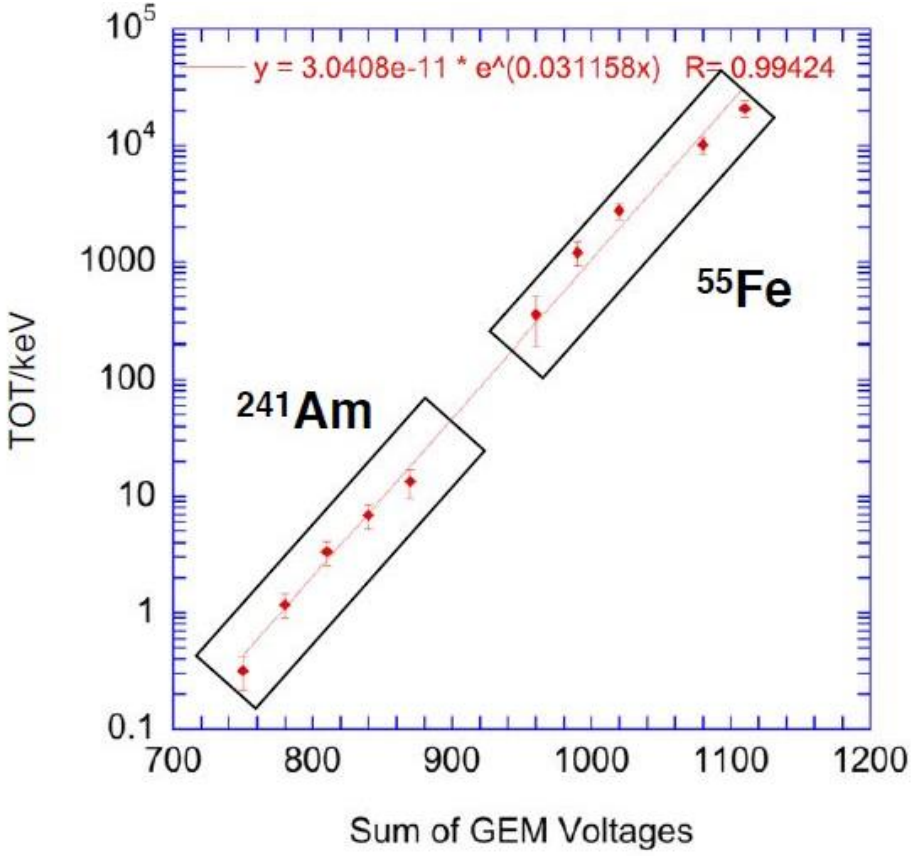
- Medipix (pulse counting)
- TOA (Time of arrival) **3D single track reconstruction**
- TOT (Charge surrogate measurement as a Wilkinson ADC) **Charge and dE/dX**
- TOA/TOT achieved with an on chip clock synchronised to all pixels (up to 100 Mhz, but 50 stable)

Improvements foreseen with TIMEPIX3 chips

3D particle track reconstruction



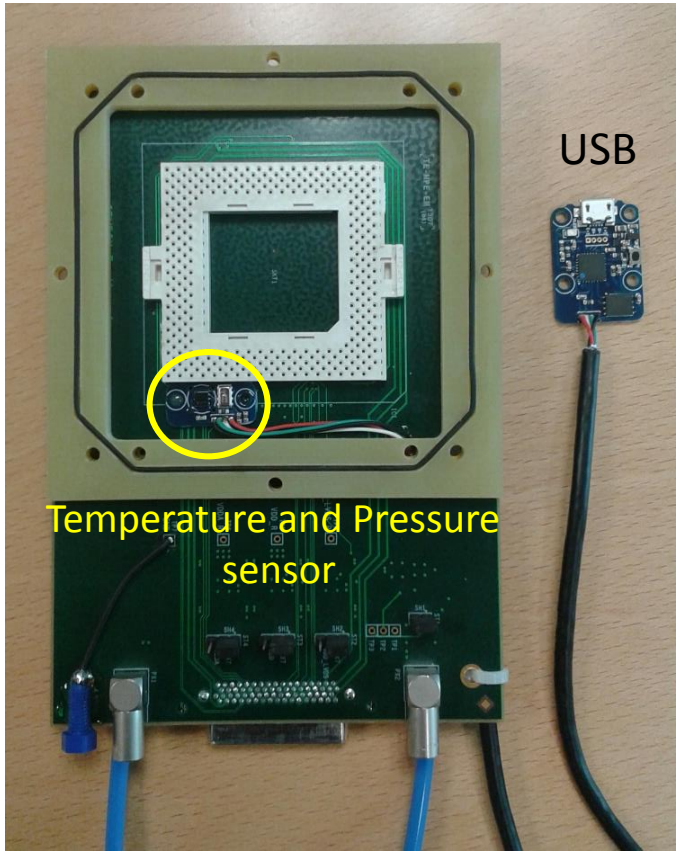
Gain vs HV settings



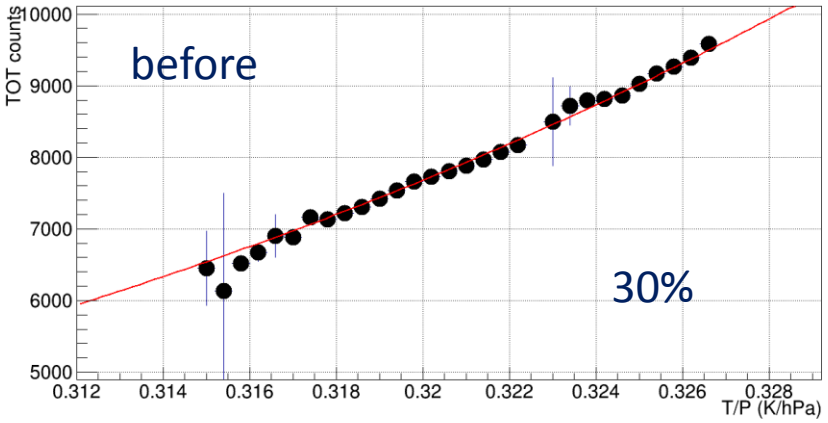
Changing the triple GEM voltage the gain of the detector is defined from ionization chamber up to 10^4

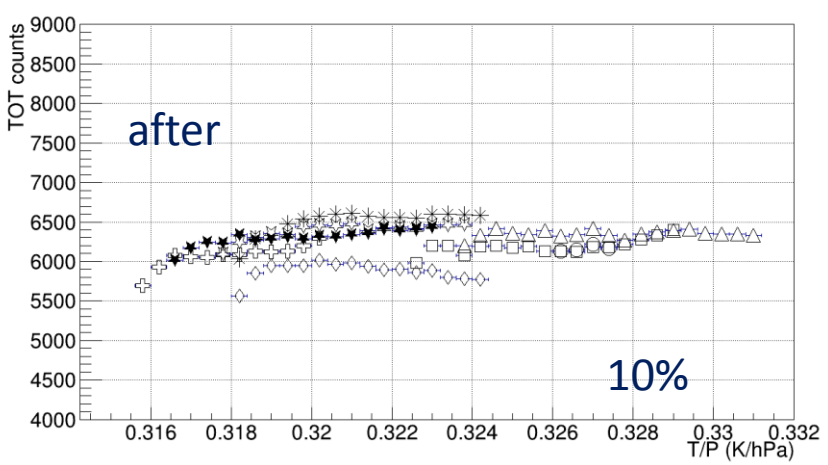
Energy Calibration and TP correction

The temperature and the pressure measured inside the detector allow the realtime HV correction to obtain gain stability



Online HV correction





Measurements on treatment Carbon beam at CNAO (Pavia)

332 MeV/A Carbon Ion Beam

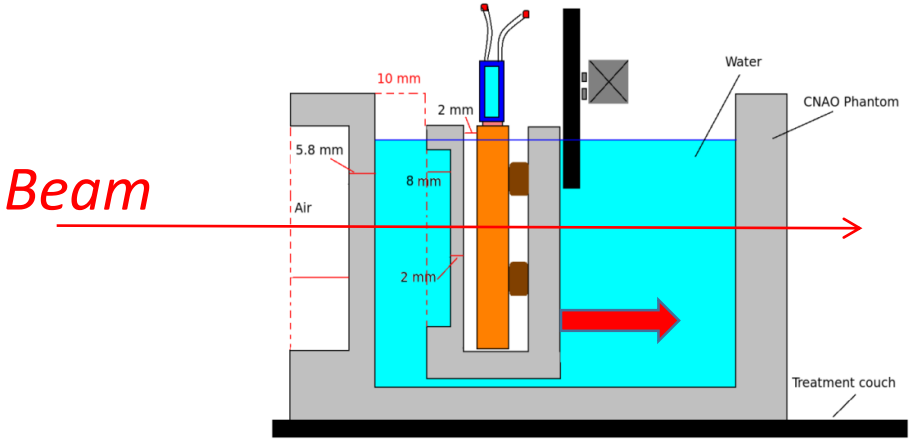
33 different depths throughout water phantom

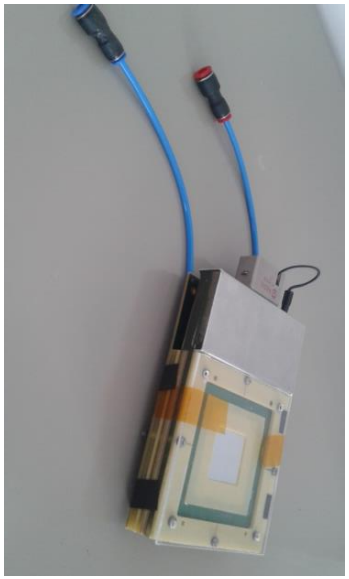
Each position given spot $8x10^6$ carbon ion treatment

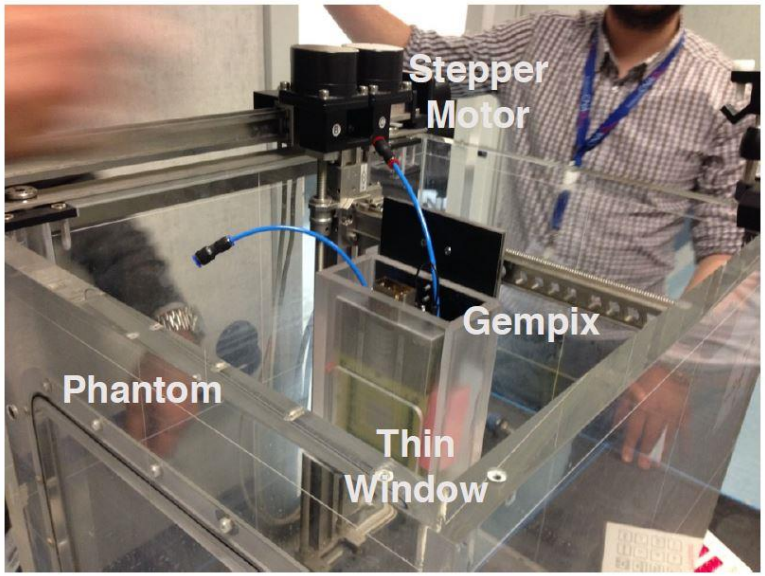
F.Murtas 19/2/2016 ICTR-PHE 2016 Geneva

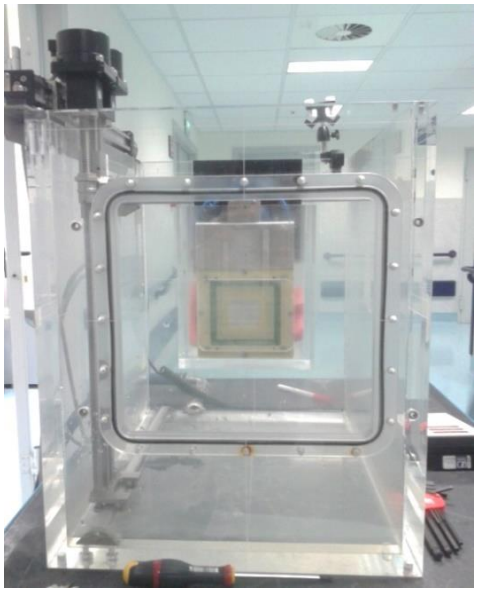
Measurements at CNAO

The GEMPix has been inserted inside the water phantom

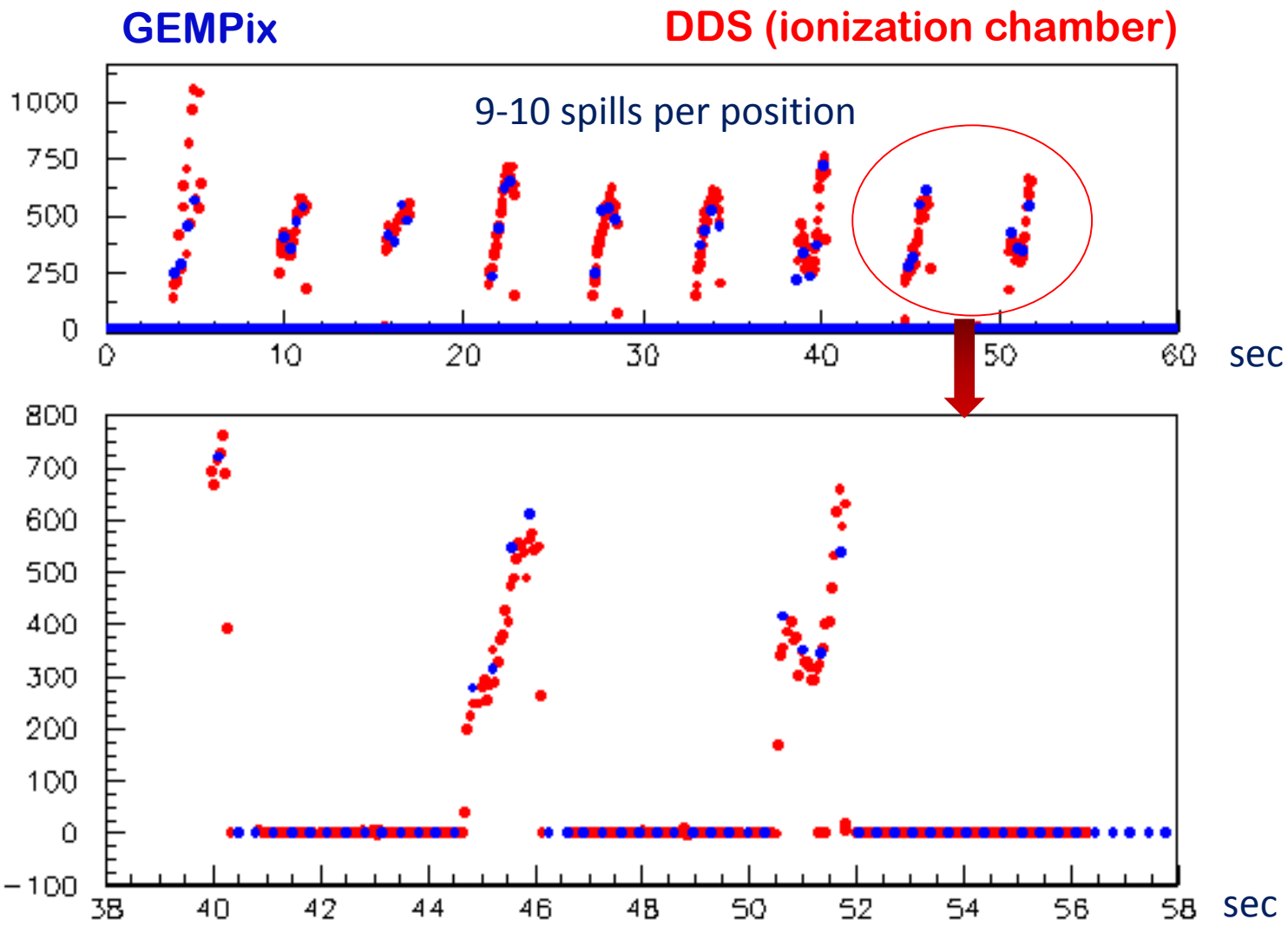








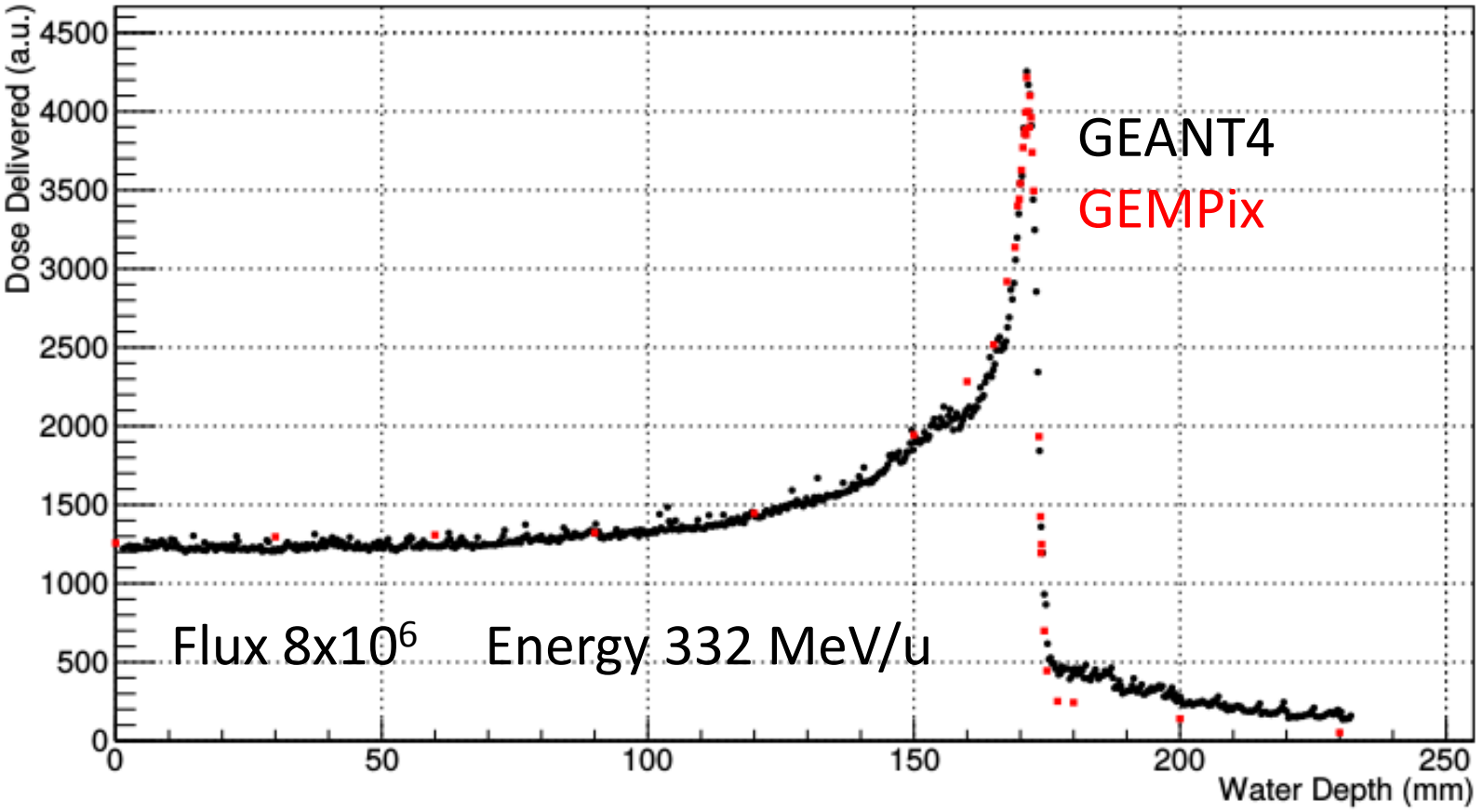
Comparison DDS and GEMPIX



Good agreement on beam time evolution between GEMPix and DDS

Comparison with GEANT4

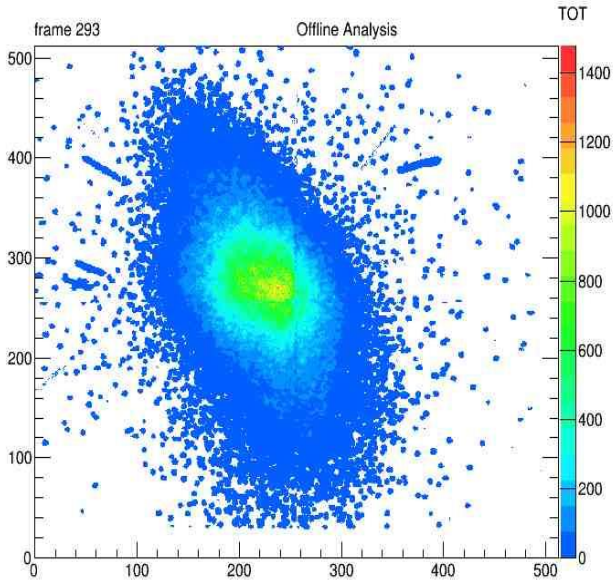
33 measurements in depth to reconstruct the carbon ion Bragg Peak



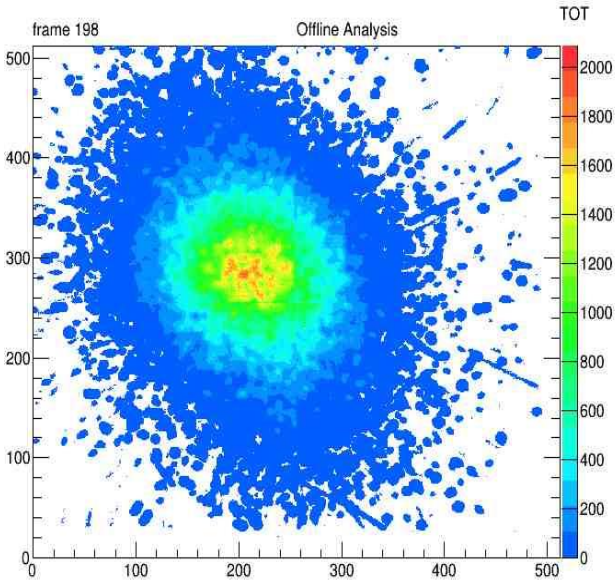
Good agreement with GEANT4 simulation

2D Single spot

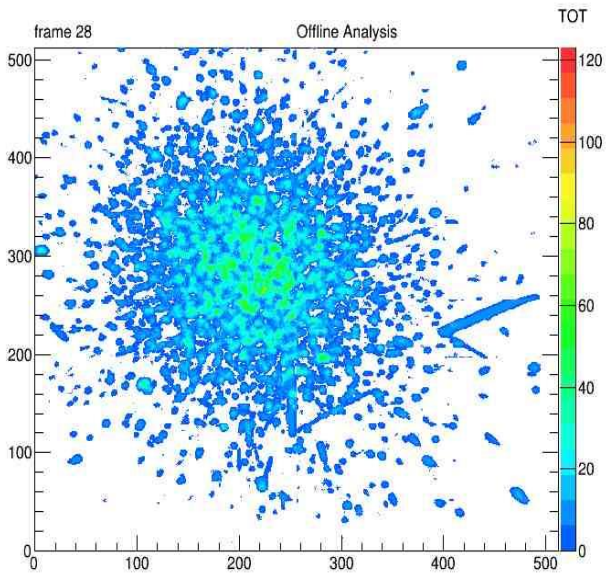
Plateau



Bragg Peak



Tail

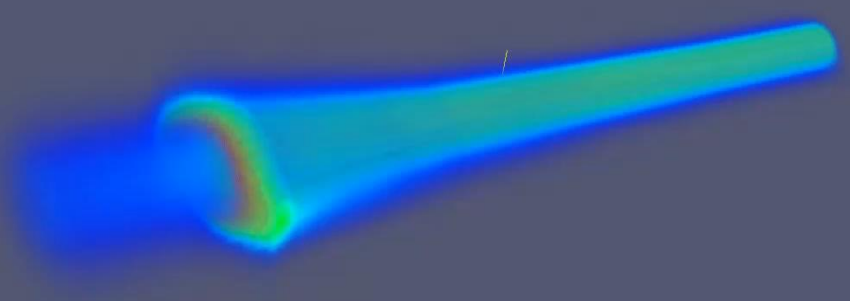


Beam spot taken on Plateau, Bragg Peak and Tail

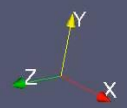
Frame length : 20 ms and 100 ms (before and after the Bragg peak).

3D Carbon Ion Beam at CNAO

Flux 8×10^6 Energy 332 MeV/u



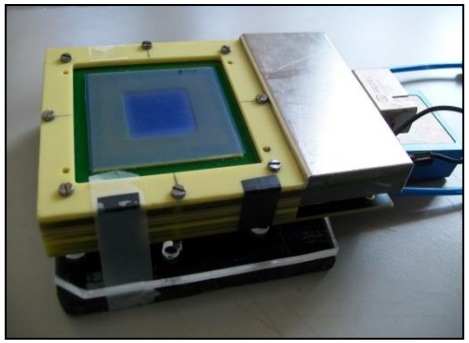
Fragments

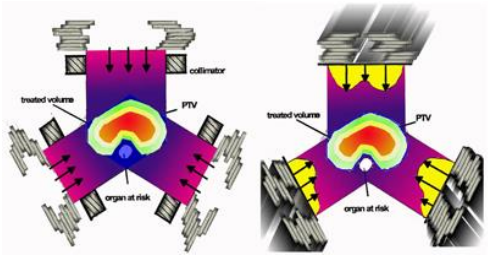


GEMPix for Radiotherapy

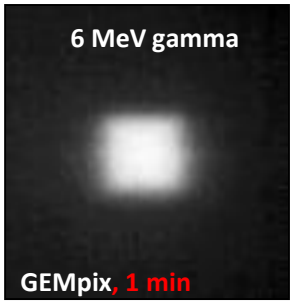
POSTER 25

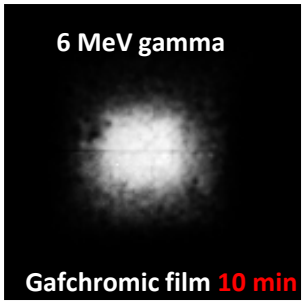
GEMPix detector (8cm^2 GEM detector read by 55x55µm pixels, 262 000 channels)
- 2D measurements of energy released in IMRT (Policlinico Tor Vergata Roma)

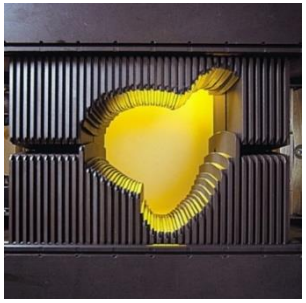


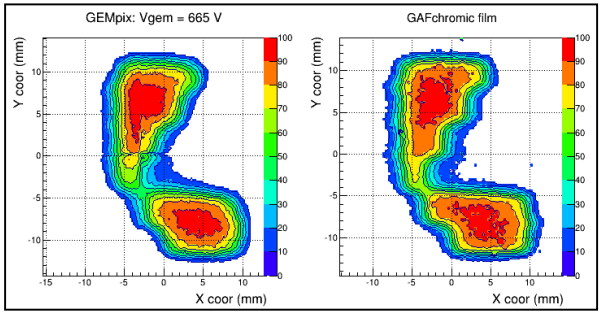


Intensity Modulated Radiation Therapy (IMRT)









F. Murtas , G. Claps, D. Falco
CERN, INFN, PTV

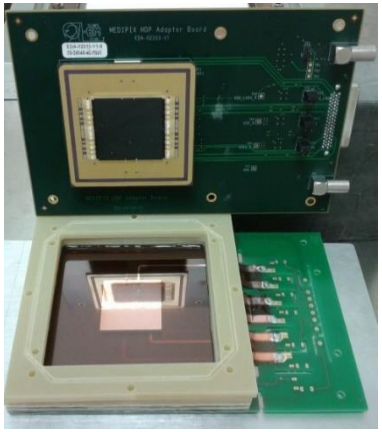
An optimal agreement between GEMPix and gafchromic film is obtained
Real-time measurements with GEMPix allows fast Quality Assurance procedure

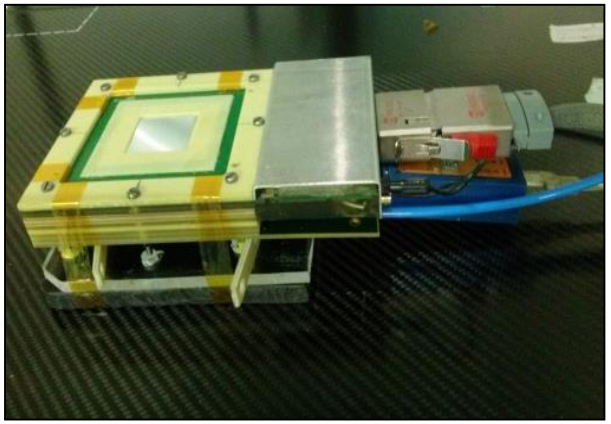
Possible use in microbeam proton therapy for beam diagnostics

Summary

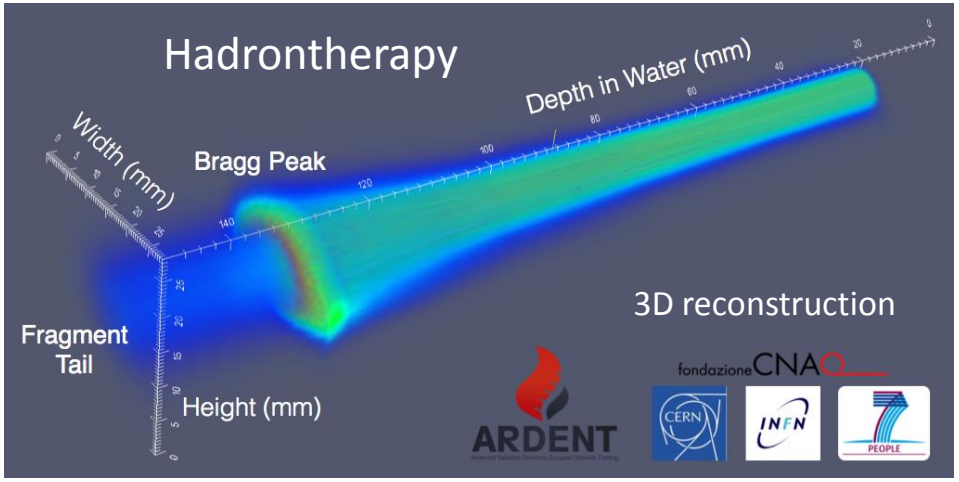
- A 3D reconstruction of the Carbon Ion Beam in a water phantom has been performed at CNAO
- Work is underway to perform the measurements much faster (20 min) using better integration with the CNAO beam delivery system.

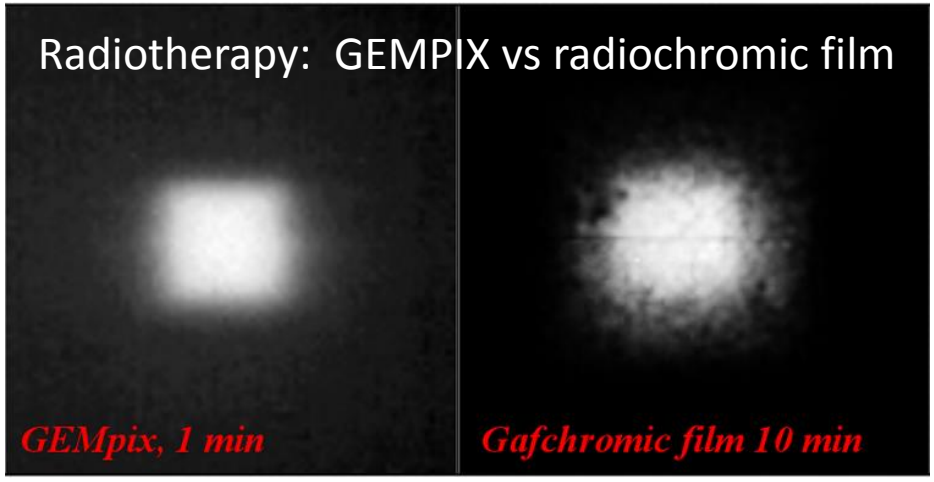
  In this application it may be useful for Quality Assurance
- Possible use in micro beam diagnostics
- A GEMPix based on the new Timepix3 ASIC will solve many of the dead time issues in tracking and beam monitoring.





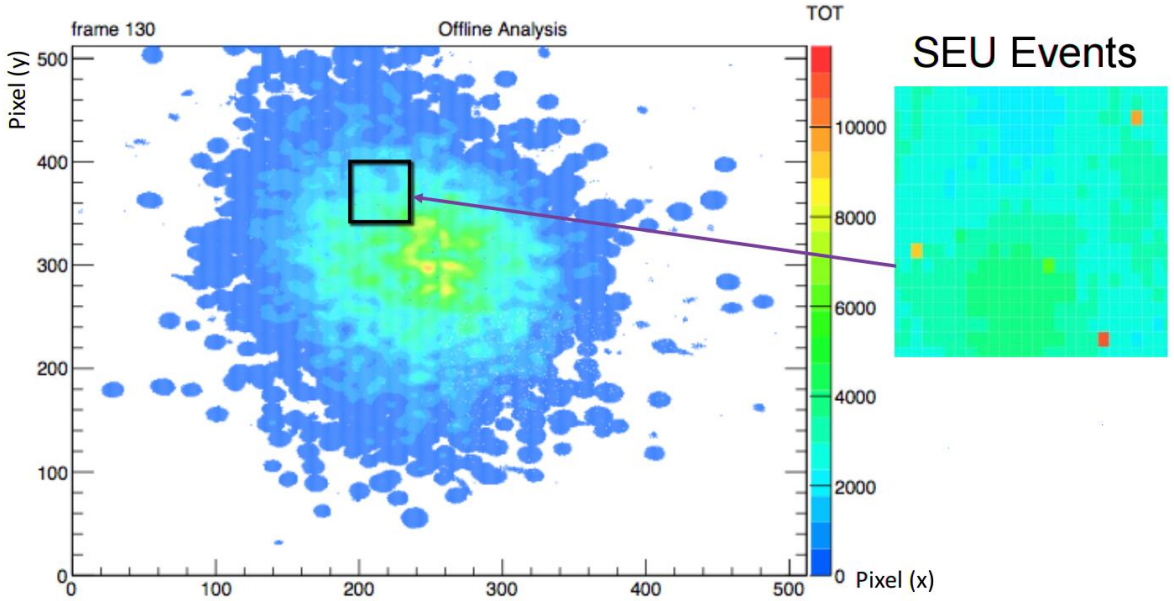
Thanks for your attention

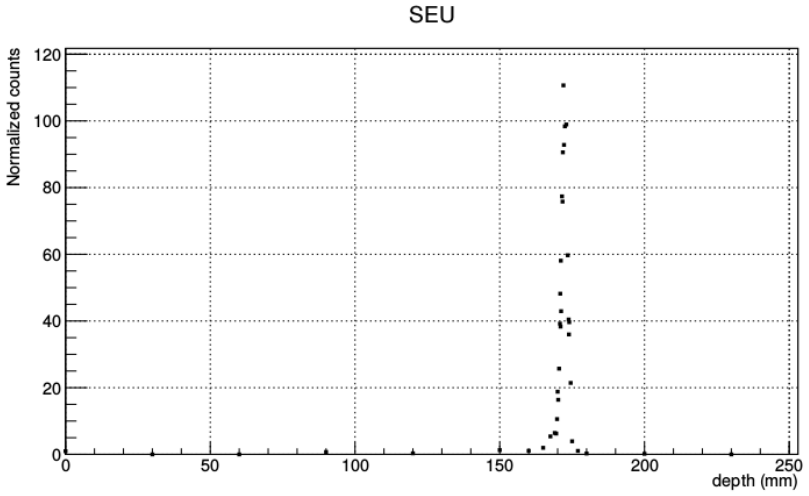




Backup slides

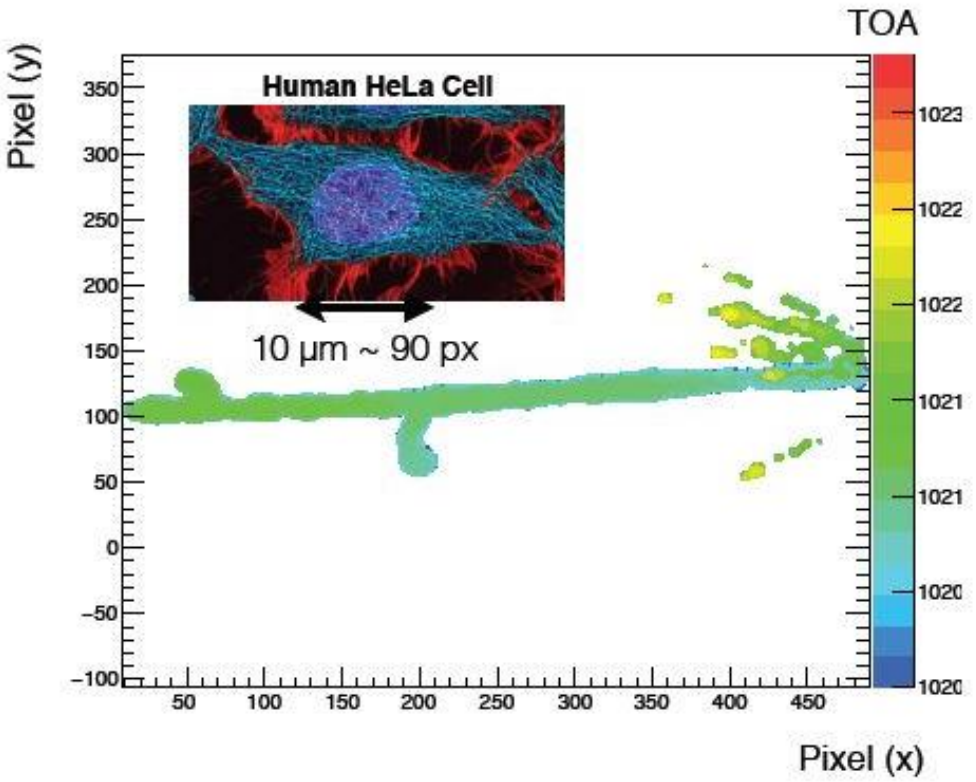
Single event Upset (SEU)





Microdosimetry

- The study of radiation interactions at the scale of cellular structure
- The number of atoms in a 5 mm path in gas is about the same as in a cellular nucleus
- Typical instrumentation is a single low pressure gas volume or silicon volume
- Gas pixel detectors offer the ability to examine each track individually



GEMPix applications

GEMPix Detector (8 cm^2 GEM detector read by 55x55μm pixels, 262 000 channels)

- Radioactive waste ^{55}Fe measurements at CERN (LEP, PS, SPS, LHC)
- 3D measurements of energy released in water phantom in Hadrontherapy treatment facility (CNAO Pavia)
- Gamma ray monitor for Radiotherapy dose measurement (Policlinico Tor Vergata, Rome)
- X-ray monitor in Inertial Fusion test facility (Petal, France)
- X-ray monitor in KSTAR Tokamak reactor (Korea)
- Proton tomography prototypes (Nikhef, The Netherlands)
- Dark matter prototype for directional dark matter searches with carbon nanotubes
- Dark matter prototype for NITEC: a Negative Ion Time Expansion Chamber for directional Dark Matter search