

The GEMPix detector for energy deposition measurements in Hadrontherapy

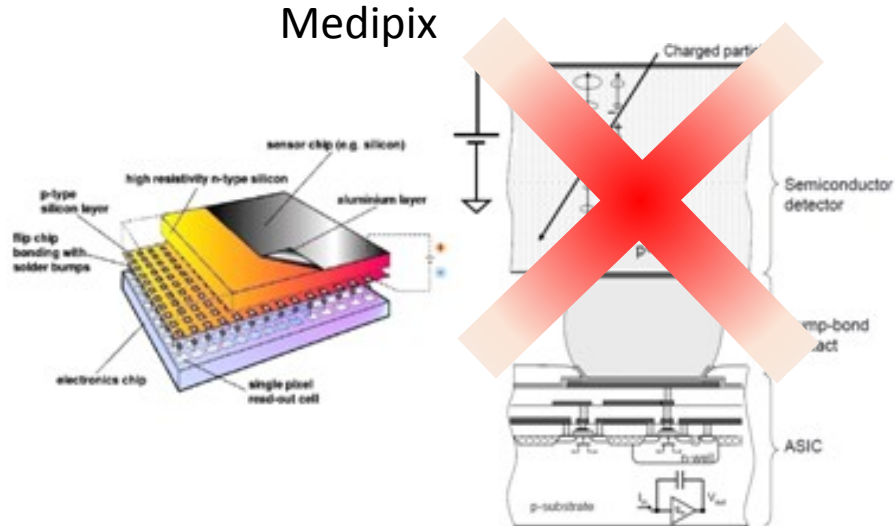
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1) CERN, 2) INFN, 3) Università di Pavia,
4) Unità Fisica Medica CNAO

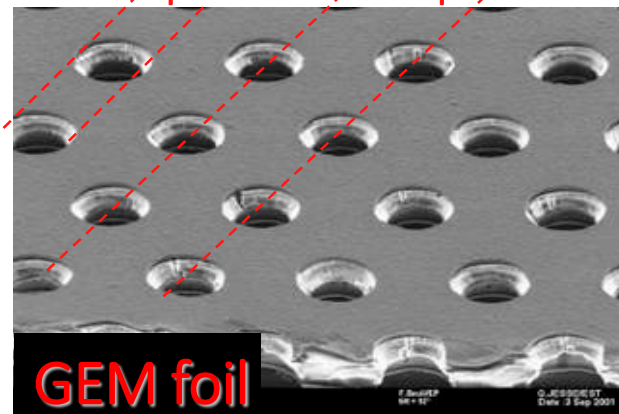


Medipix



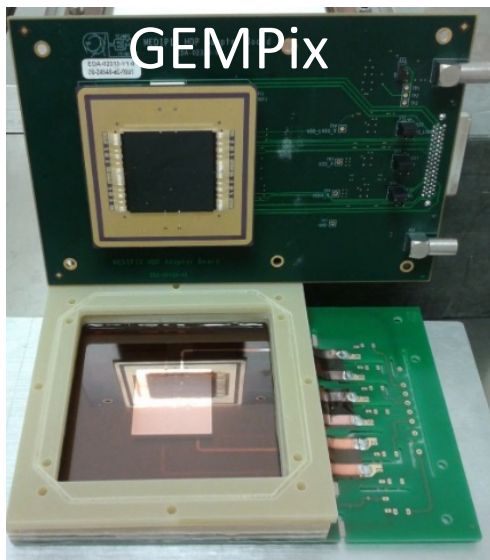
Gas Electron Multiplier

70 μm 140 μm



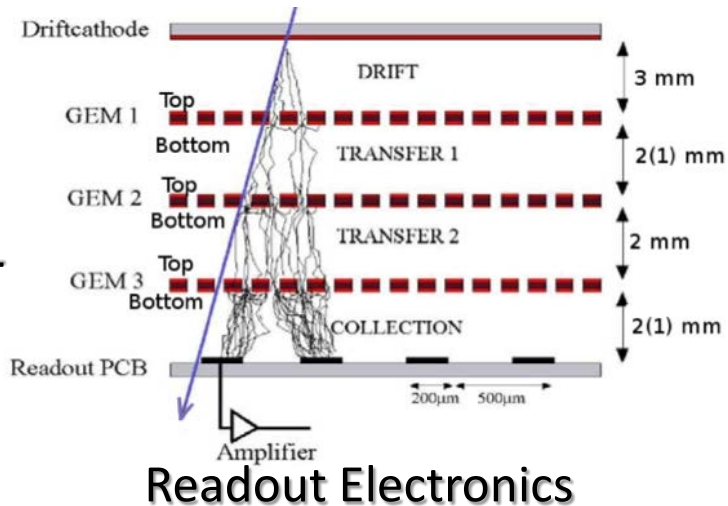
GEMPix

4 Timepix chips



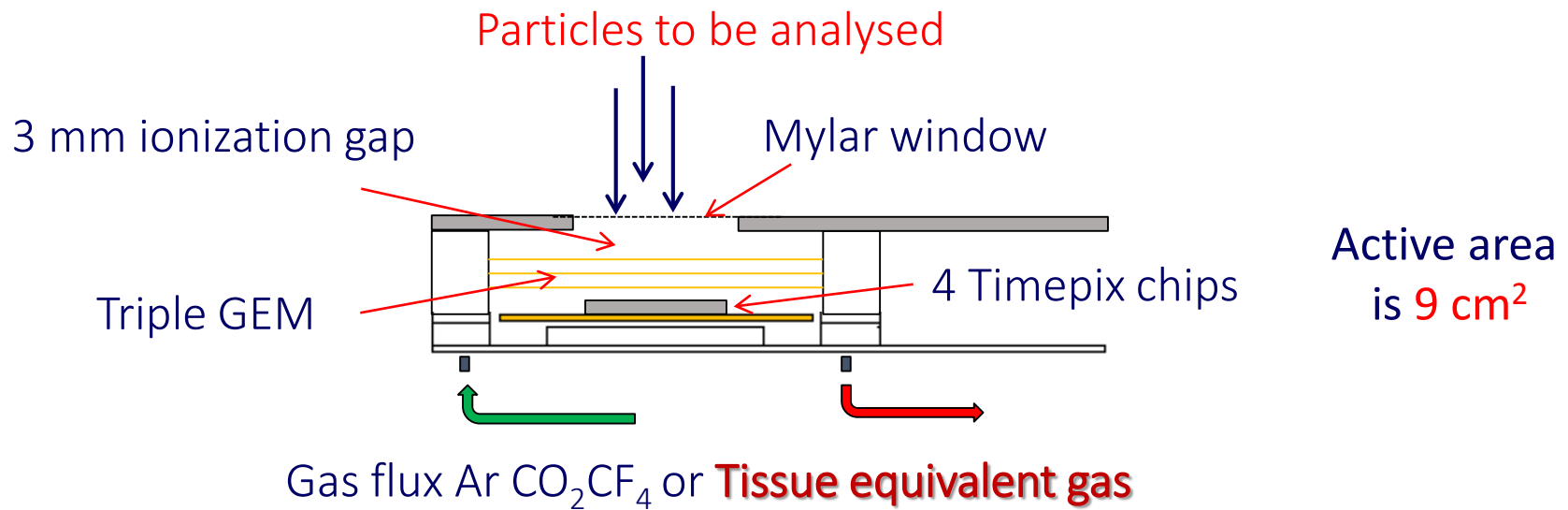
Triple GEM

Triple GEM



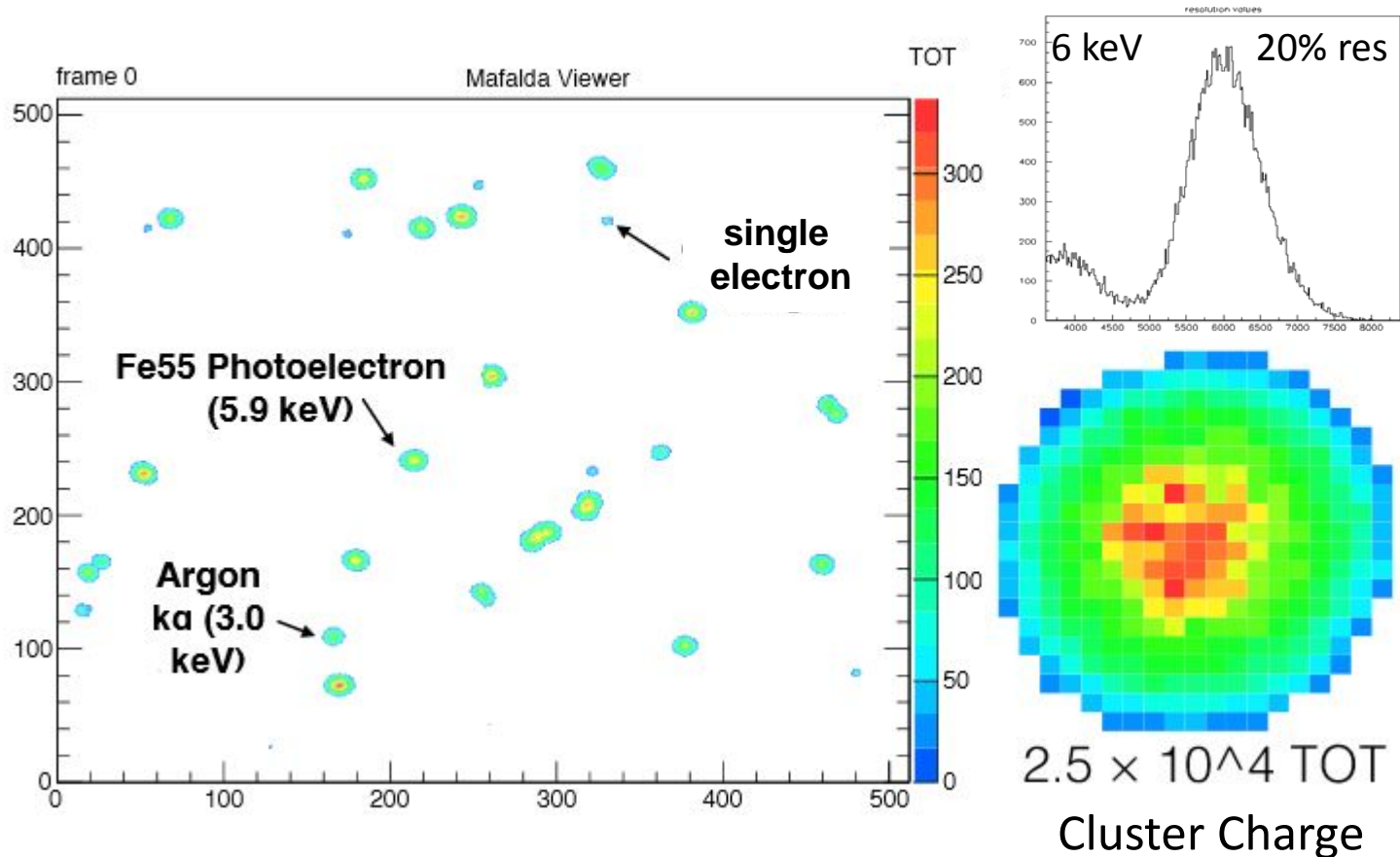
This innovative **gas detector** has been designed in the **ARDENT** framework within a collaboration between CERN and INFN.

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



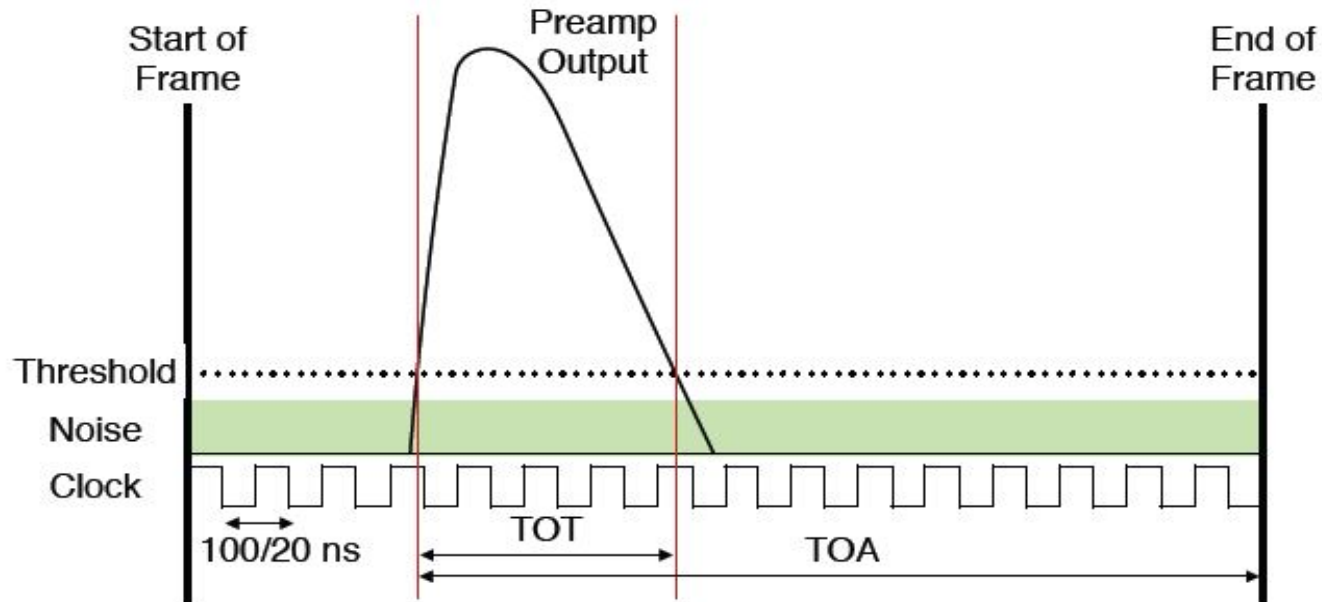
In three years we found several applications for this type of detector: Radioactive waste, Micro dosimetry, **Hadrontherapy**, **Radiotherapy**, Radon Monitor ... but also Dark Matter Research !

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



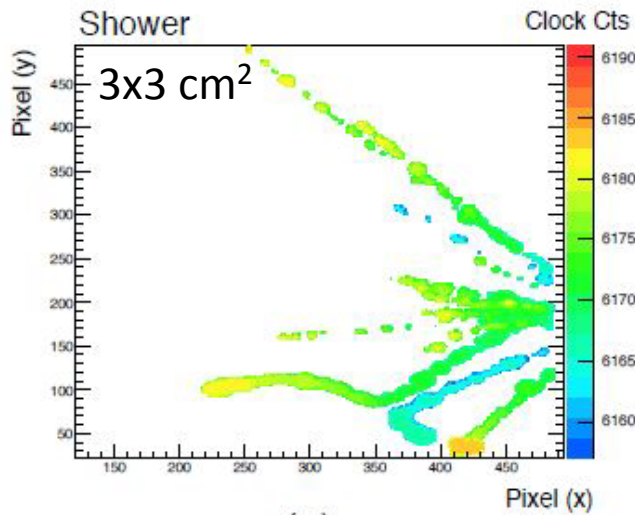
The Timepix **software PIXELMAN** can recognize the cluster and measure **in real-time** its energy

The Timepix Pixel

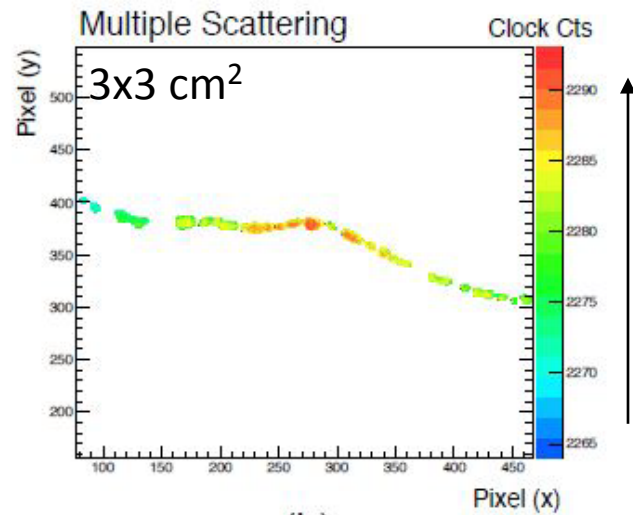


- Medipix (pulse counting)
- TOA (Time of arrival) **3D single track reconstruction**
- TOT (Charge surrogate measurement as a Wilkinson ADC) **Charge and dE/dX**
- TOA/TOT achieved with an on chip clock synchronised to all pixels (up to 100 Mhz, but 50 stable)

Improvements foreseen with TIMEPIX3 chips

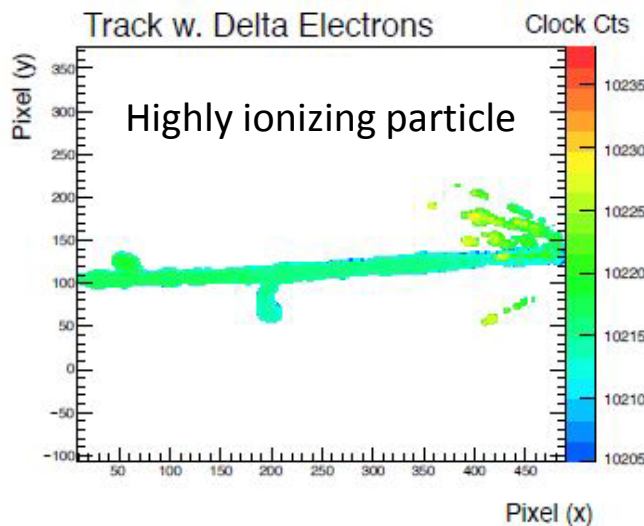


(a)

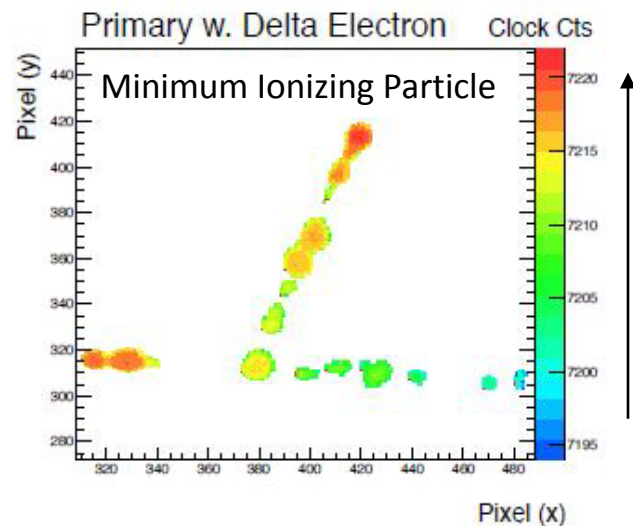


(b)

↑
Z coordinate (1 cm)

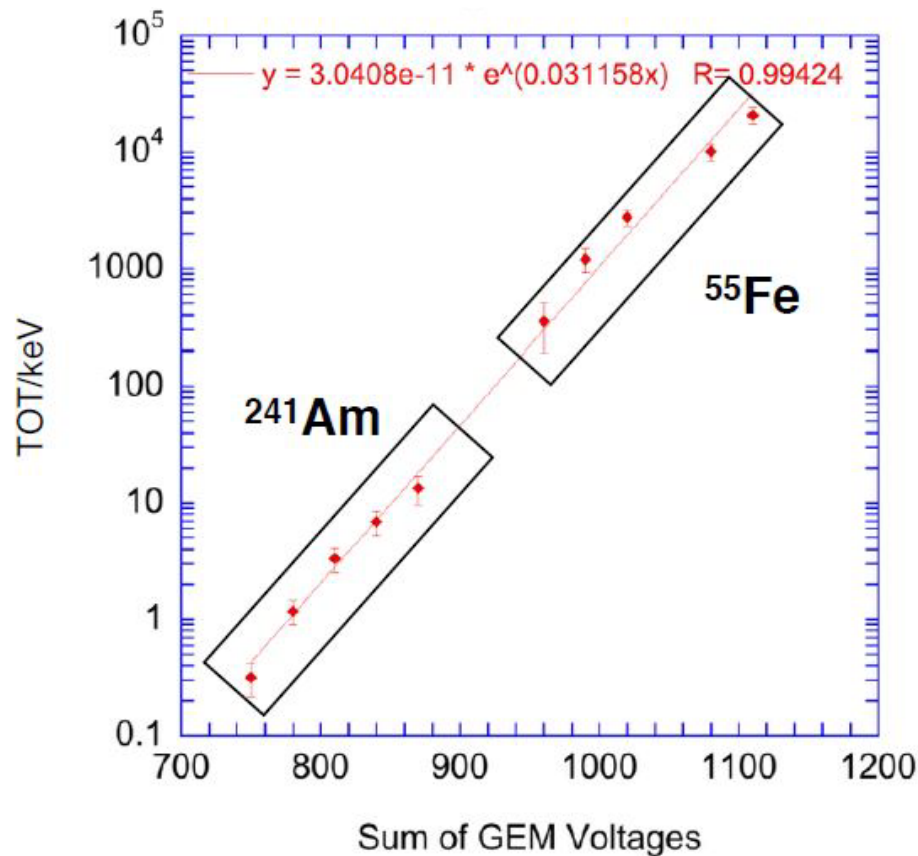


(c)



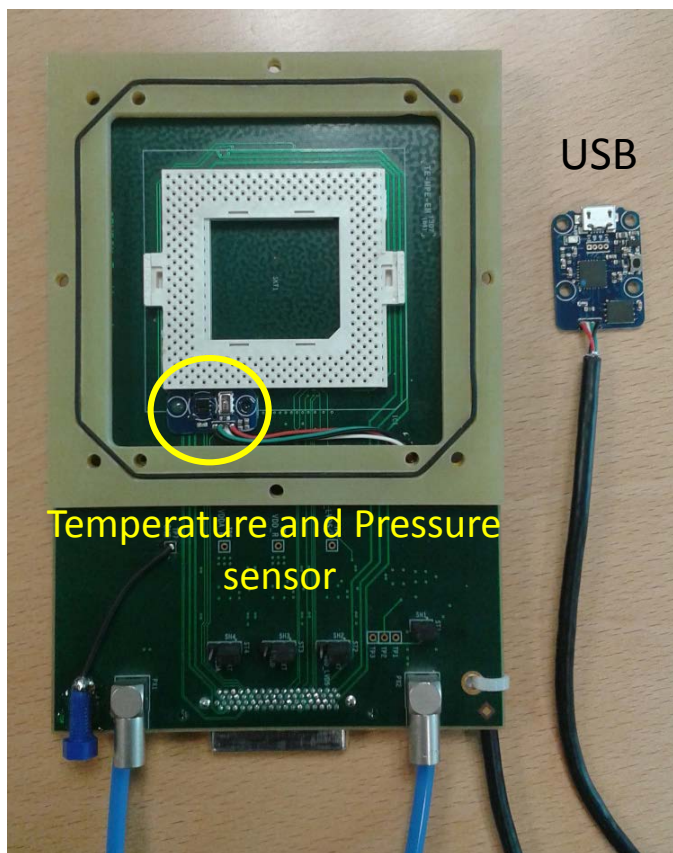
(d)

↑
Z coordinate (1 cm)

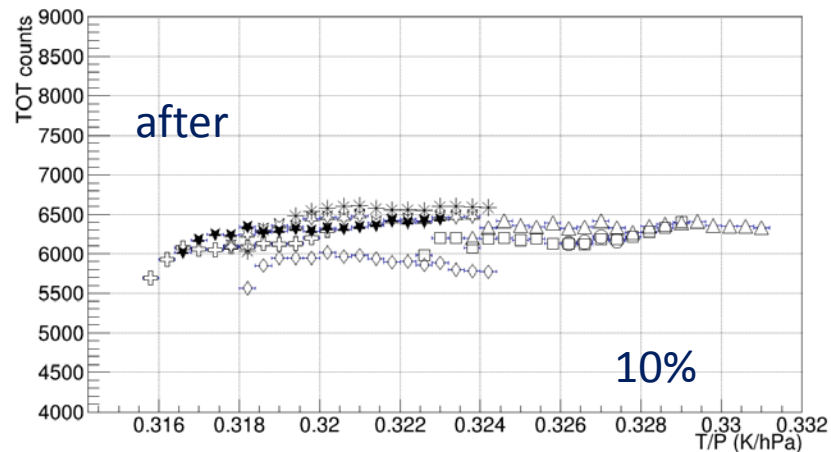
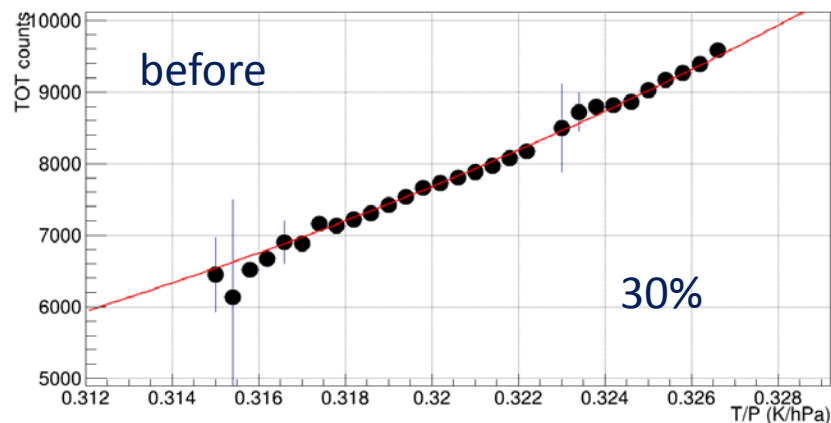


Changing the triple GEM voltage the gain of the detector is defined
 from ionization chamber up to 10^4

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



Online HV correction



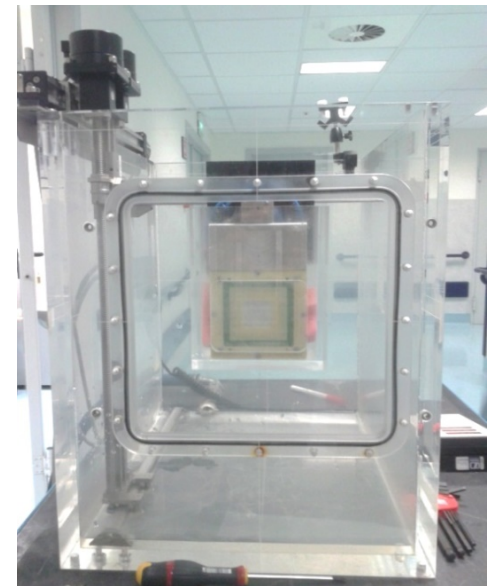
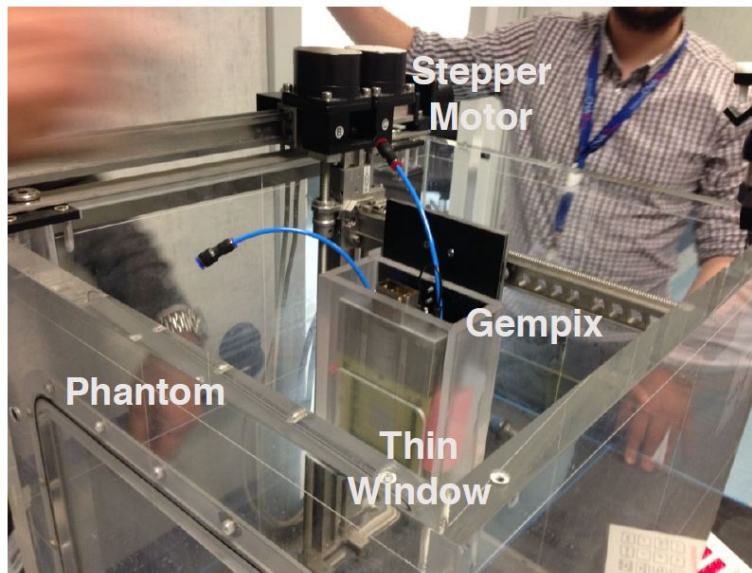
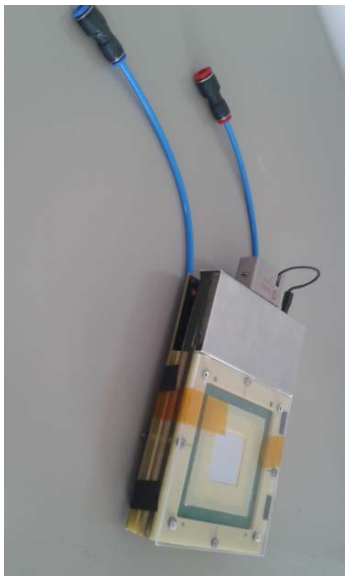
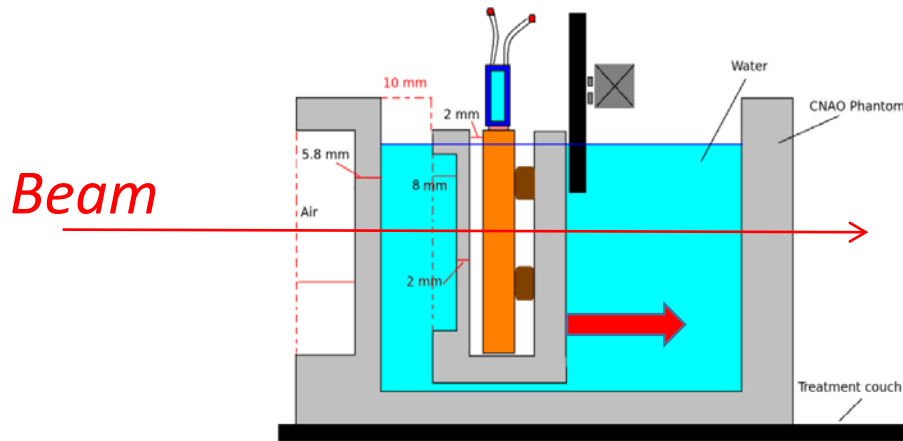
Measurements on treatment Carbon beam at CNAO (Pavia)

332 MeV/A Carbon Ion Beam

33 different depths throughout water phantom

Each position given spot 8×10^6 carbon ion treatment

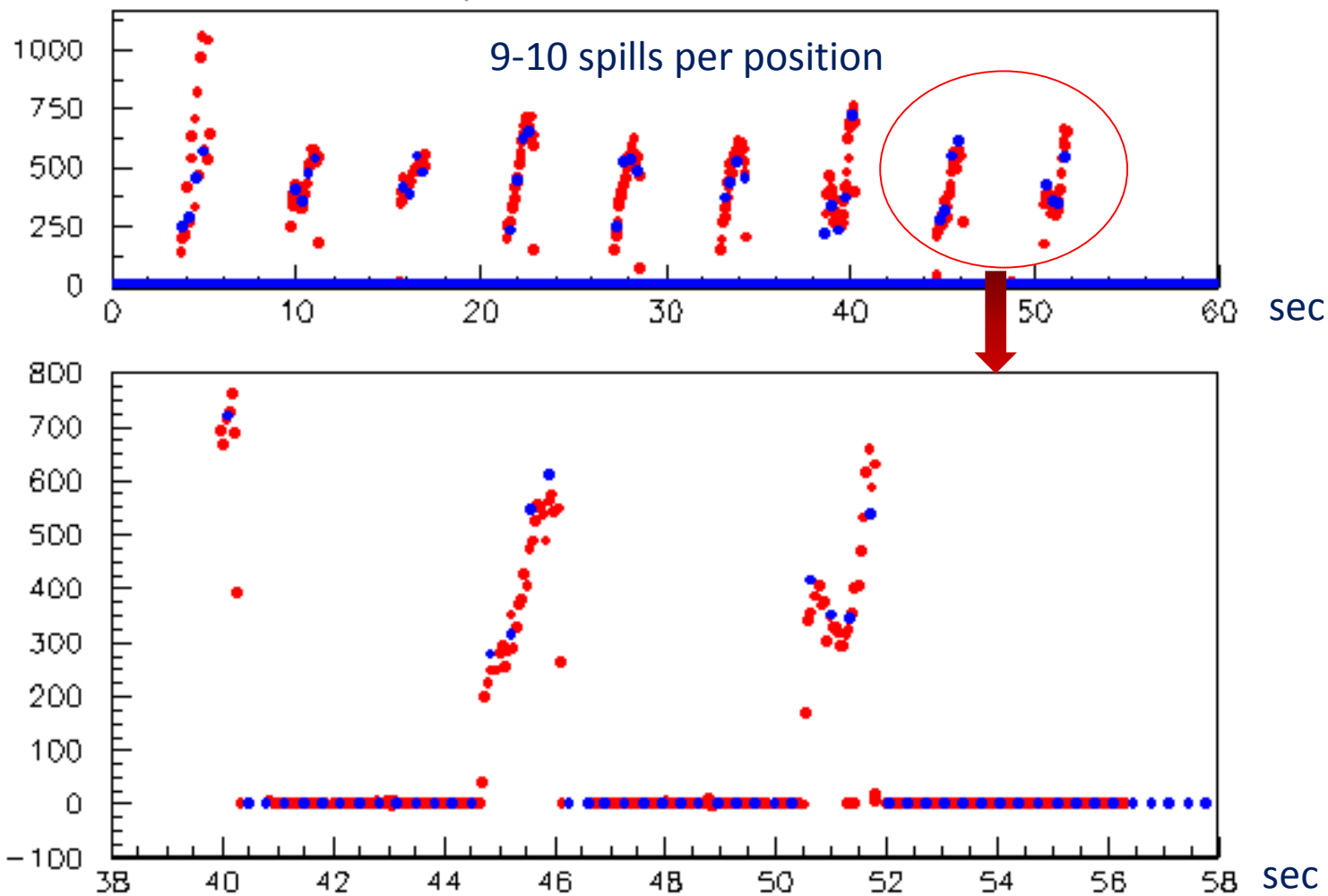
The GEMPix has been inserted inside the water phantom



Comparison DDS and GEMPIX

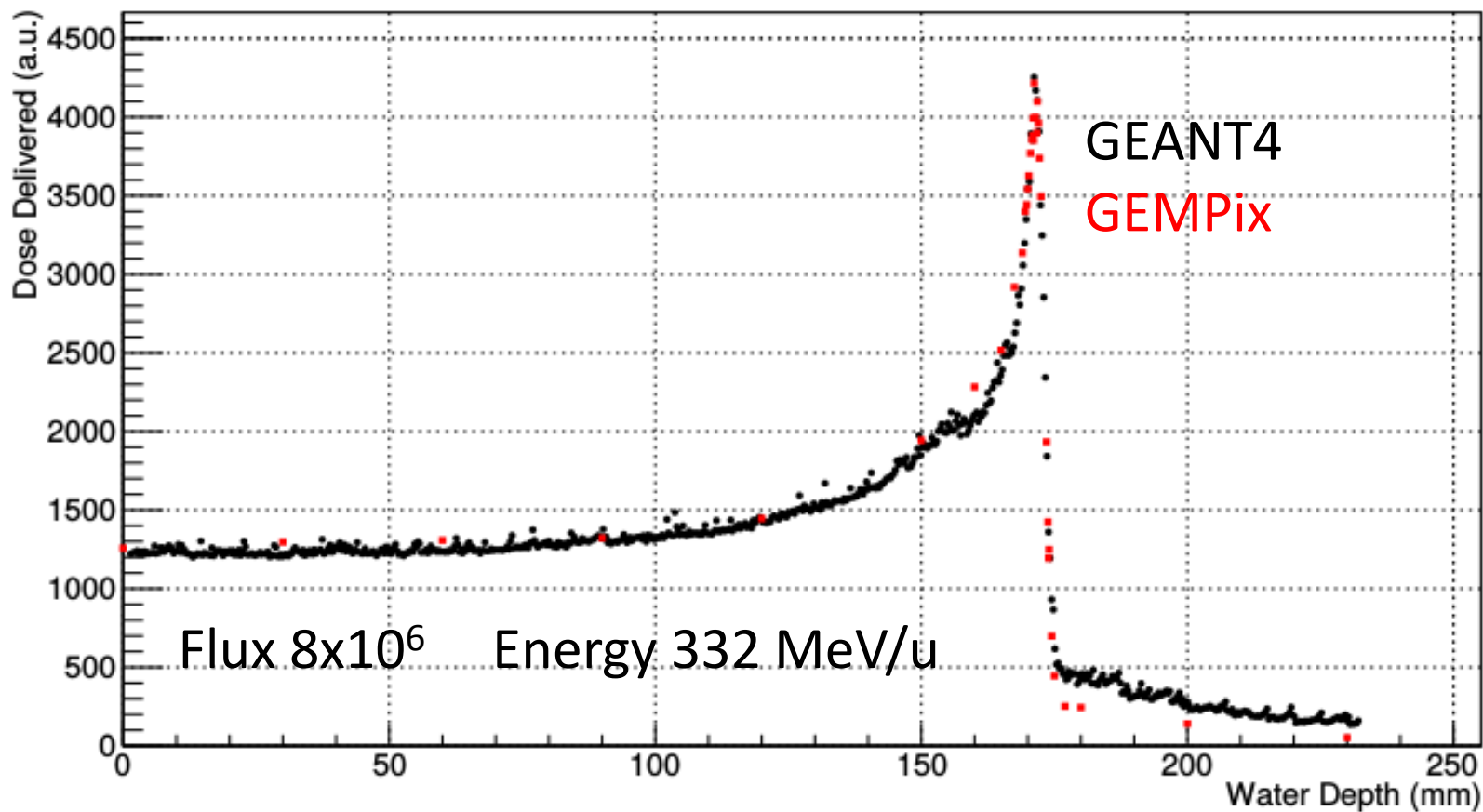
GEMPIx

DDS (ionization chamber)



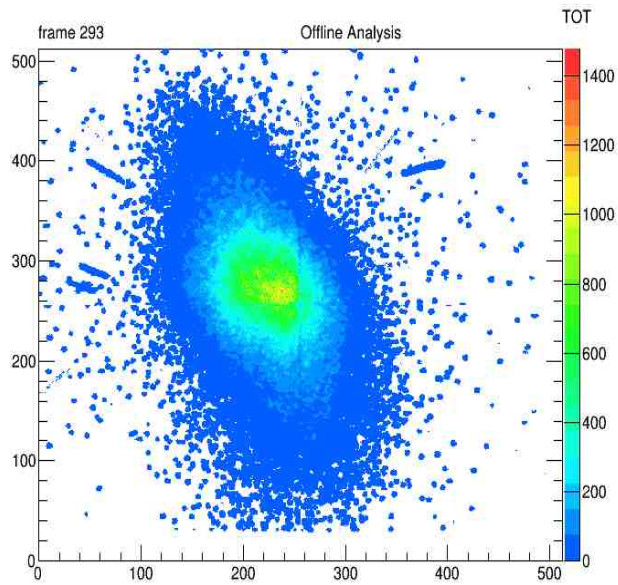
Good agreement on beam time evolution between GEMPIx and DDS

33 measurements in depth to reconstruct the carbon ion Bragg Peak

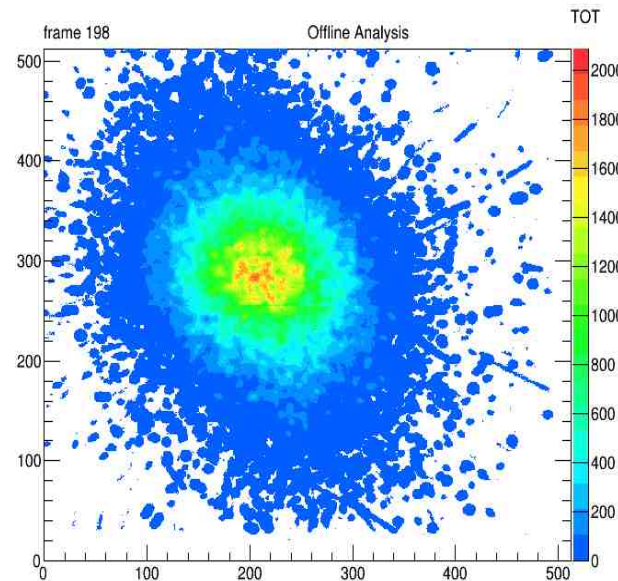


Good agreement with GEANT4 simulation

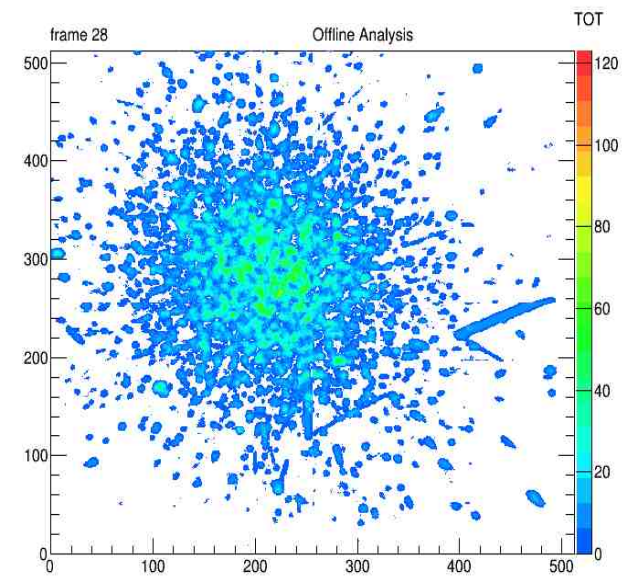
Plateau



Bragg Peak



Tail

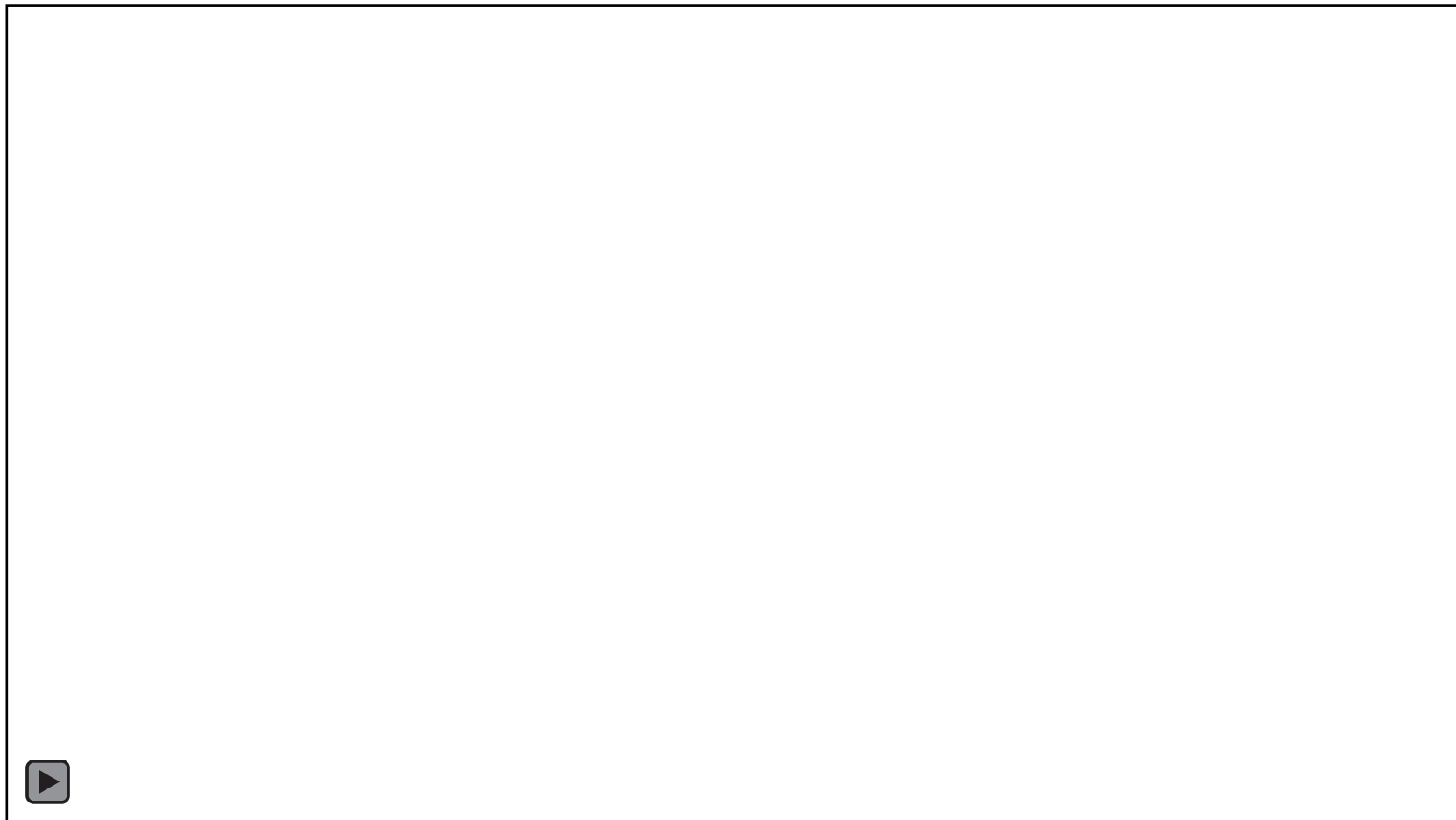


Beam spot taken on Plateau, Bragg Peak and Tail

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

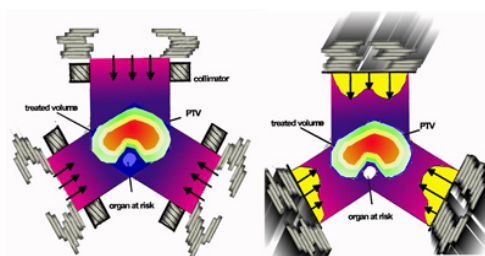
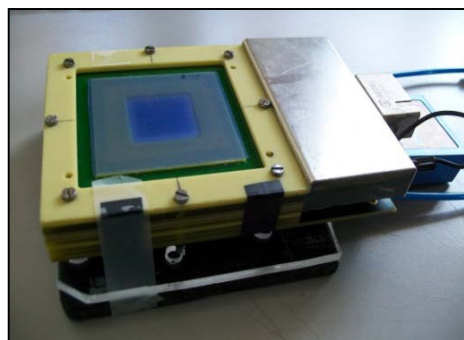


3D Carbon Ion Beam at CNAO

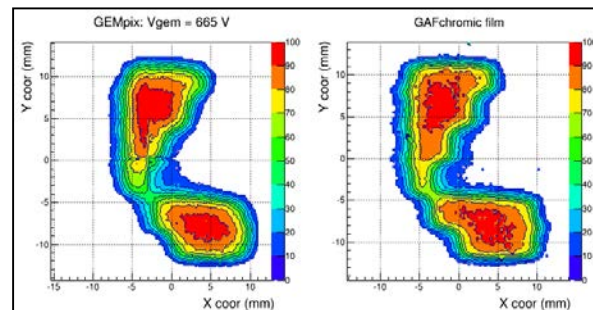
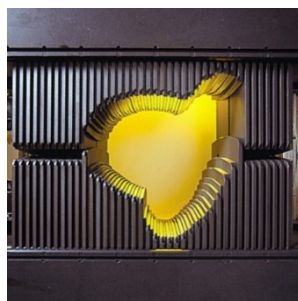
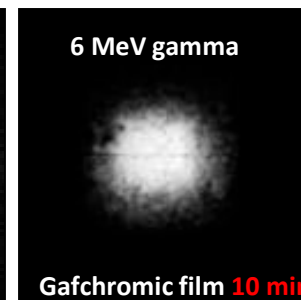
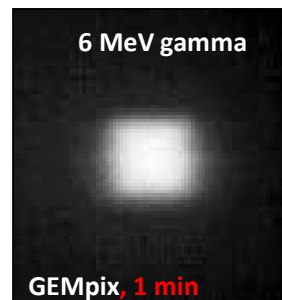


POSTER 25

GEMPix detector (8cm² 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)



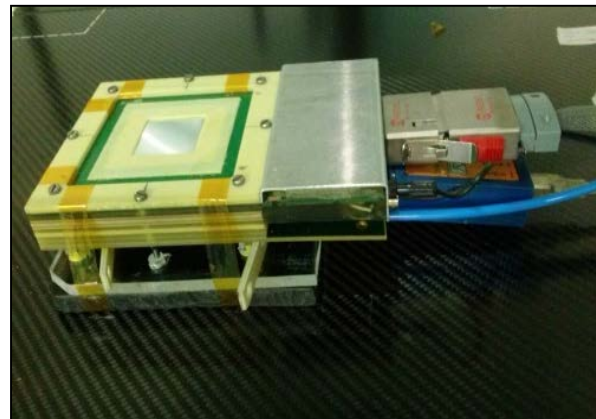
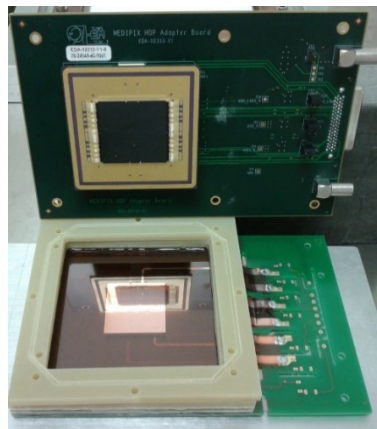
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CERN, INFN, PTV

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

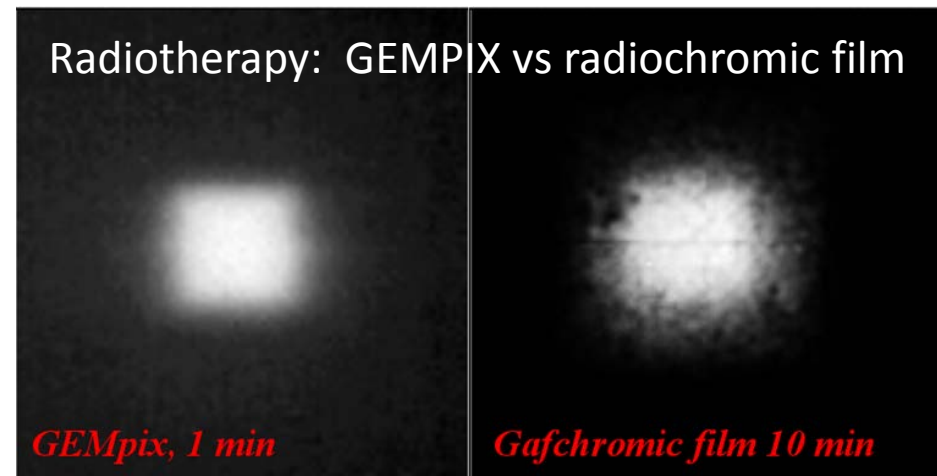
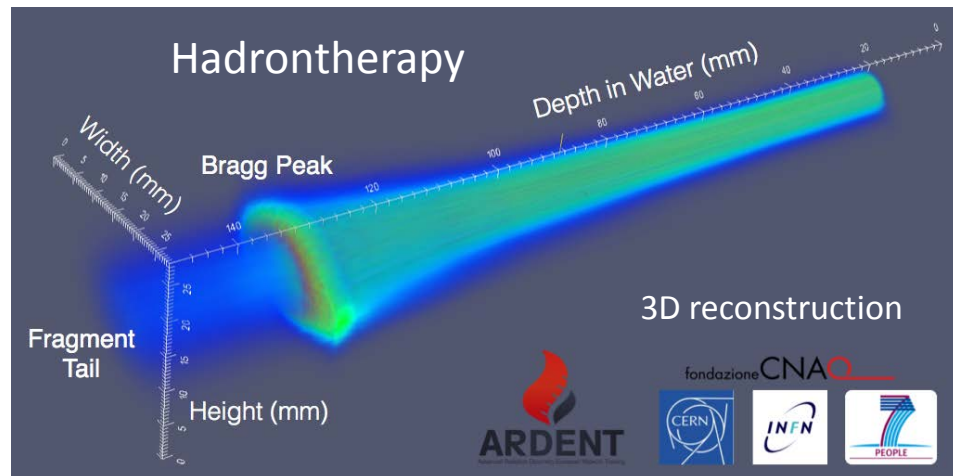
Possible use in microbeam proton therapy for beam diagnostics

- 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.



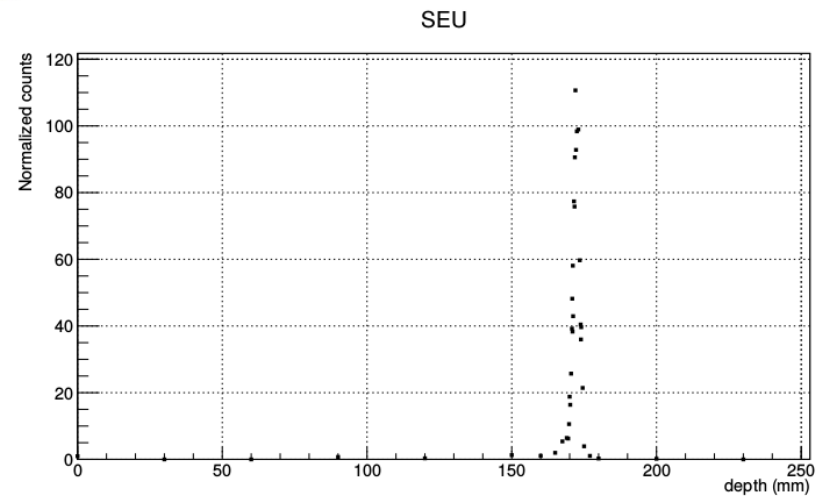
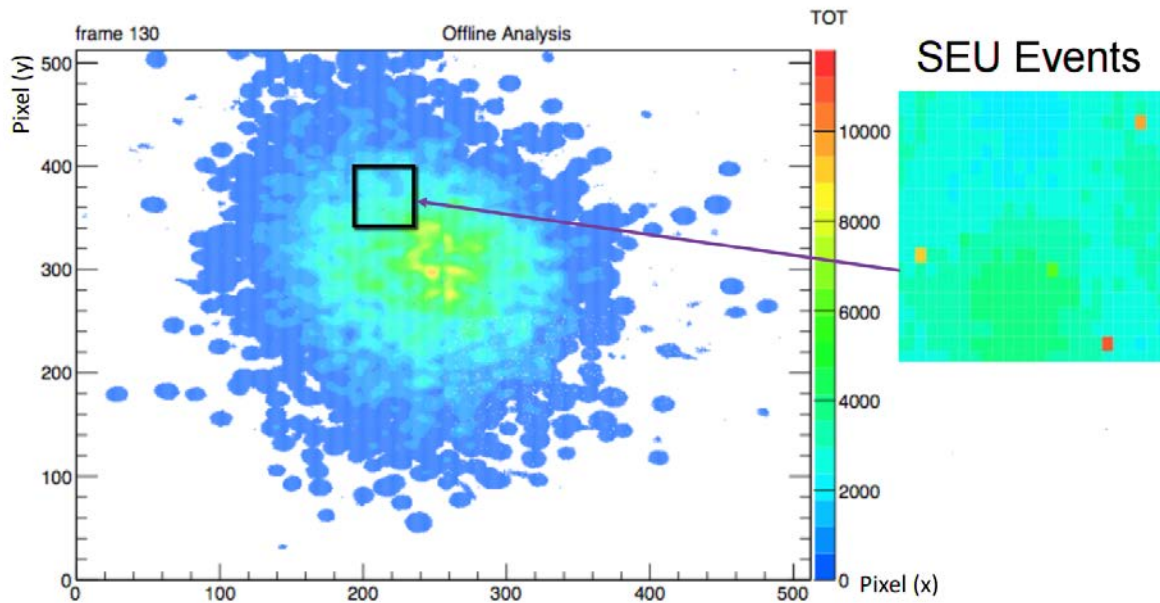
Thanks for your attention



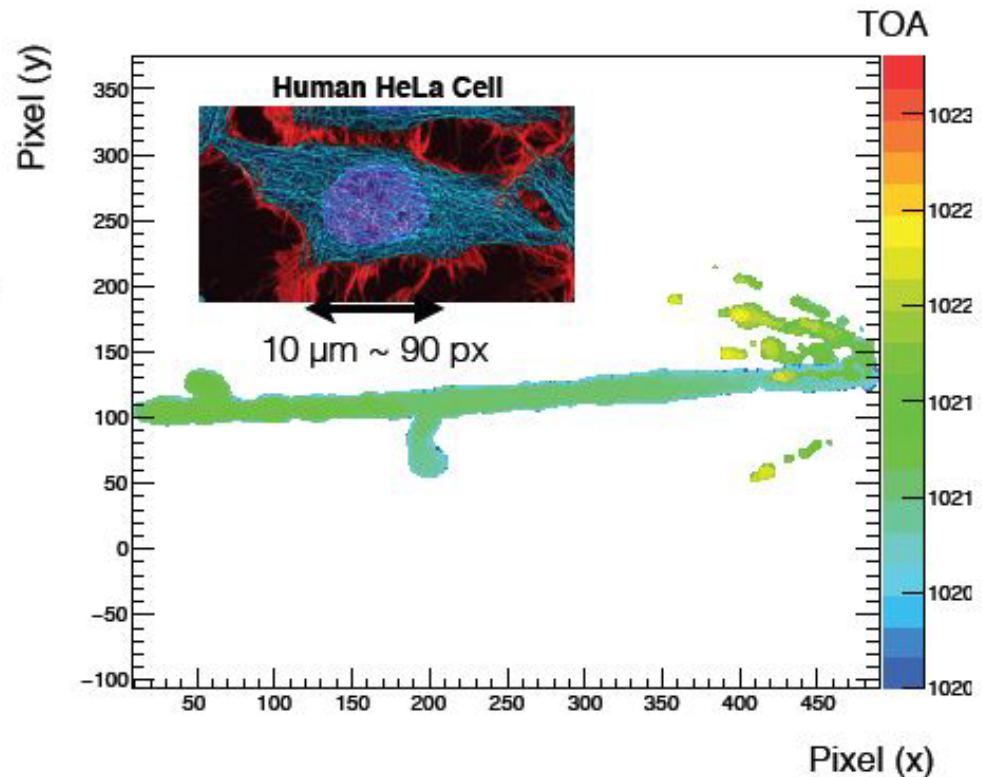


Backup slides

Single event Upset (SEU)



- 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 cm² GEM detector read by 55x55μm pixels, 262 000 channels)

- **Radioactive waste** ⁵⁵Fe 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

