The GEMPix detector for energy deposition measurements in Hadrontherapy

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Two Micro Pattern Detectors

- Medipix
- Gas Electron Multiplier (GEM)
  - Foil: 70 µm, 140 µm
- Triple GEM
- GEMPix
- 4 Timepix chips
- Readout Electronics

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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 **4 naked Timepix** (no silicon sensor):

- **Particles to be analysed**
- **3 mm ionization gap**
- **Mylar window**
- **Triple GEM**
- **4 Timepix chips**
- **Gas flux Ar CO₂ CF₄ 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!

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Single particle detection

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

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

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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**

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3D particle track reconstruction

(a) Shower
3x3 cm²
Pixel (y) vs Pixel (x)
Z coordinate (1 cm)

(b) Multiple Scattering
3x3 cm²
Pixel (y) vs Pixel (x)
Z coordinate (1 cm)

(c) Track w. Delta Electrons
3x3 cm²
Pixel (y) vs Pixel (x)
Z coordinate (1 cm)

(d) Primary w. Delta Electron
3x3 cm²
Pixel (y) vs Pixel (x)
Z coordinate (1 cm)

Highly ionizing particle
Minimum Ionizing Particle

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Gain vs HV settings

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

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

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The GEMPix has been inserted inside the water phantom
Comparison DDS and GEMPIX

Good agreement on beam time evolution between GEMPix and DDS

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Comparison with GEANT4

33 measurements in depth to reconstruct the carbon ion Bragg Peak

Good agreement with GEANT4 simulation

Flux $8 \times 10^6$  Energy 332 MeV/u

GEANT4
GEMPix
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 $8 \times 10^6$ Energy $332$ MeV/u

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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)

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

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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 cm² 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