Microbe_IT

Hybrid Detector for Microdosimetry (HDM)

E. Pierobon, M. Missiaggia, M. Castelluzzo, F. Tommasino, L. Ricci, E. Scifoni, V. Monaco, M. Boscardin, C. La Tessa

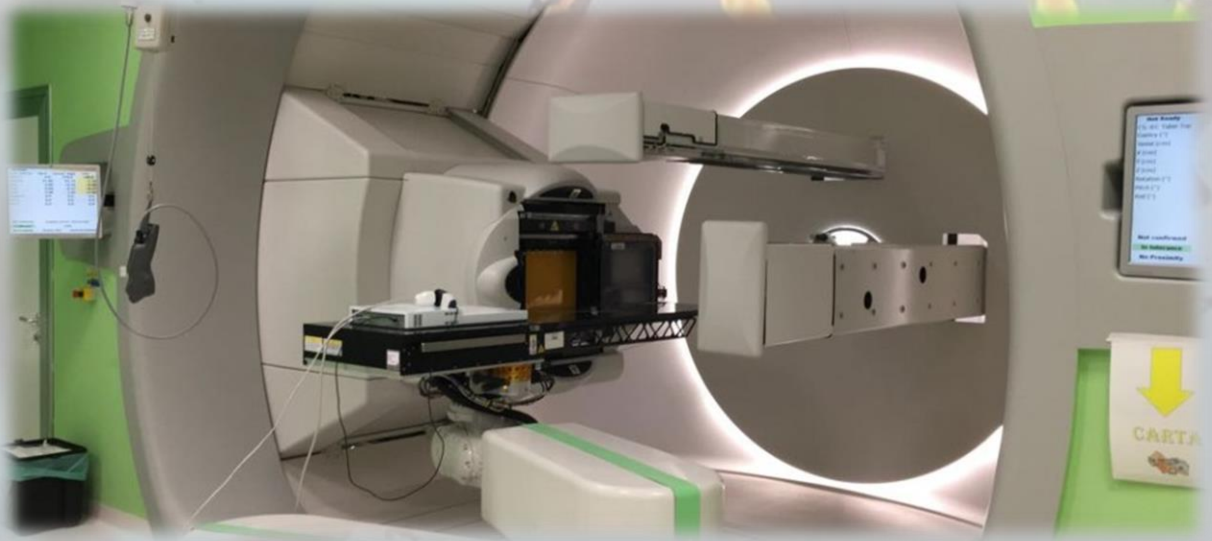
UNIVERSITY OF TRENTO

FONDAZIONE BRUNO KESSLER

TIFPA
Trento Institute for Fundamental Physics and Applications

Radiotherapy fundamentals

- Inactivate the tumour by depositing energy in the body
- Minimize the dose to the healthy tissue
- Treatment planning and delivery is based on the Treatment Planning System (TPS)



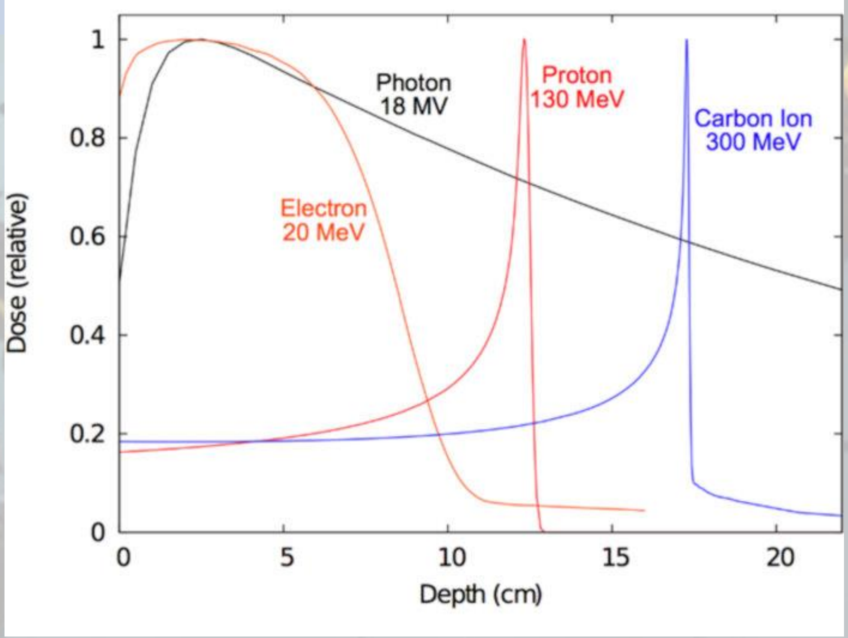
Radiotherapy fundamentals

- TPS requires physical and biological quantities to describe the radiation interaction and effects
- The key ingredient is the dose

$$D = \frac{E}{m}$$

- It depends on
  - Energy
  - Particle species

} Radiation quality



Kaiser, Adeel et. al 10.3791/58372.

From Physics to Biology

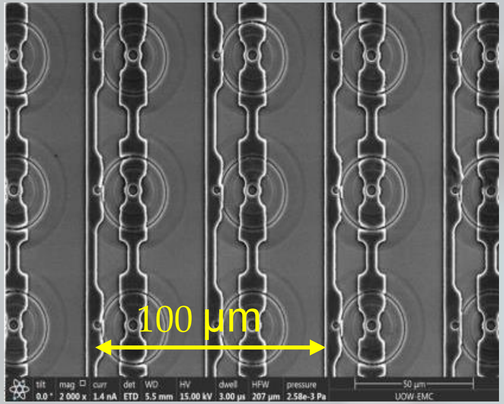
- Radiation damage occurs at cellular level
- The most sensitive target to radiation is DNA
- Describing the energy deposition in a scale comparable to the cell nucleus improves the biological damage assessment

MICRODOSIMETRY

Microdosimetry

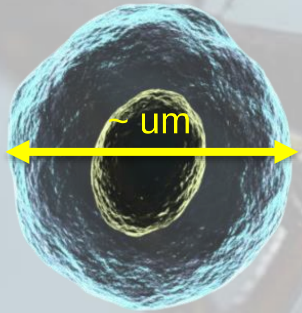
Two detection strategies:

- Micro-sized



Silicon detectors

≃



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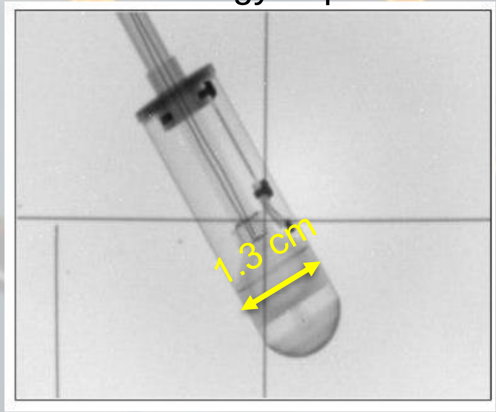
- Micro-equivalent in terms of energy deposition



Gas detectors

Better spatial resolution:

- dimensions of few micrometers

Tissue-equivalent:

- energy deposition is the same as micrometric tissue

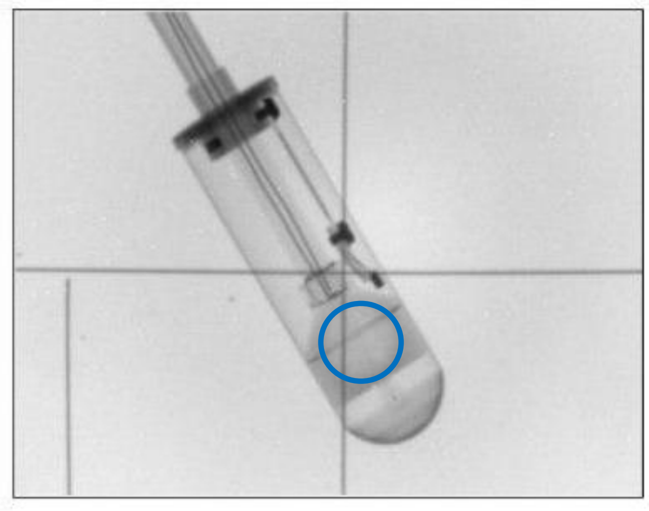
Detector (HDM) MCL

Basic quantity: lineal energy *y*

$$y = \frac{Energy\ deposited}{MCL}$$

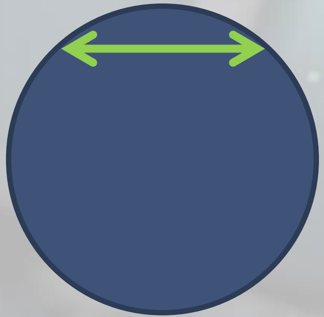
Energy recorded in the detector

Mean Chord Length: most probable particle track length in isotropic and uniform radiation field



For a spherical geometry [our TEPC (*Tissue Equivalent Proportional Counter*) detector]

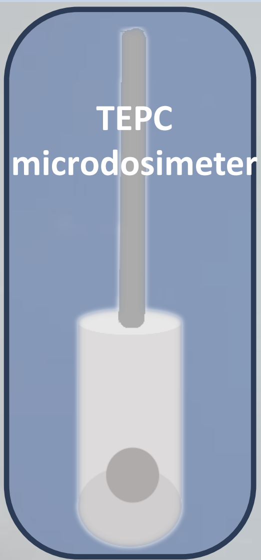
$$MCL = \frac{2}{3}d$$



What if the real track length is used?

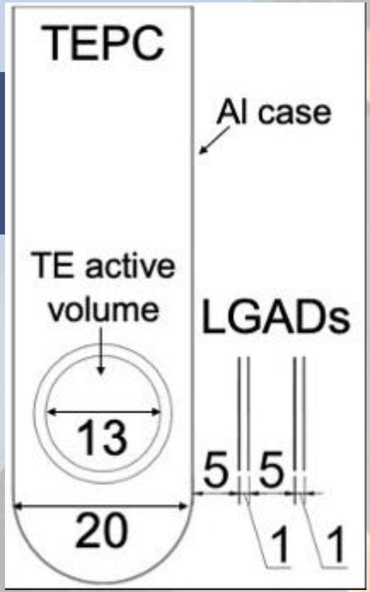
Need of a tracker

Detector(s) (HDM)

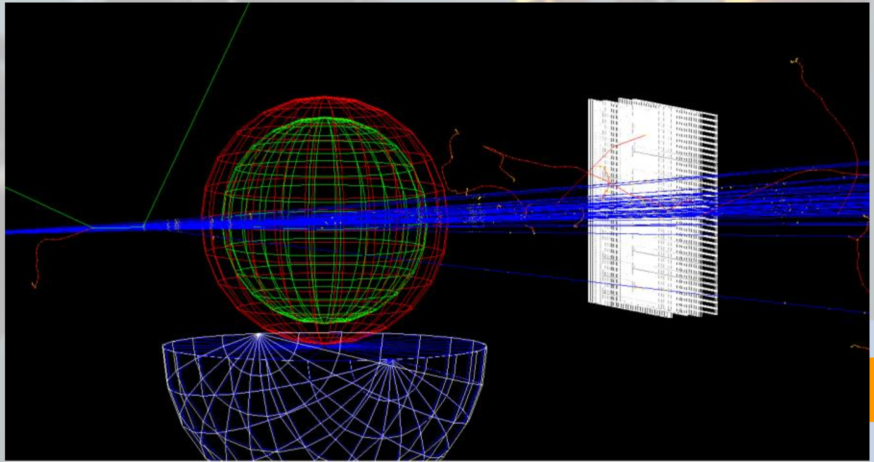


Records energy deposition in tissue equivalent material

Reconstruct particle track

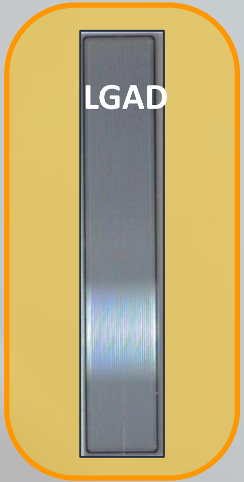


Units in mm



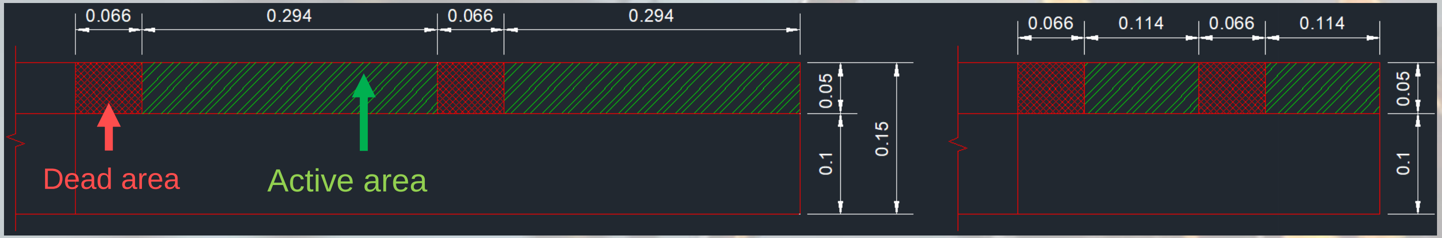
Detector (HDM): LGADs

Two LGAD geometries produced at FBK



34 strips per sensor

71 strips per sensor

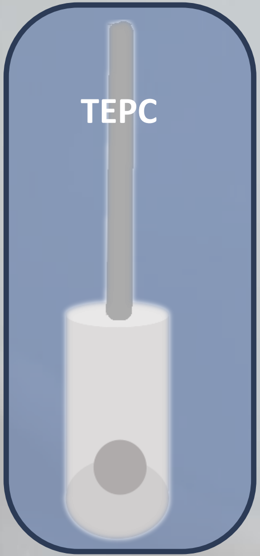


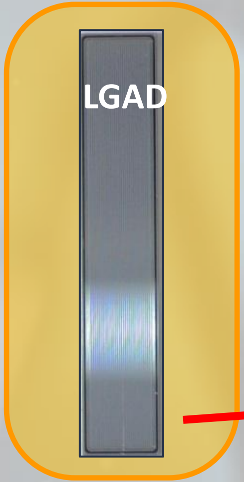
Units in mm

- pitch 360 µm
- better fill factor
- less channels to read

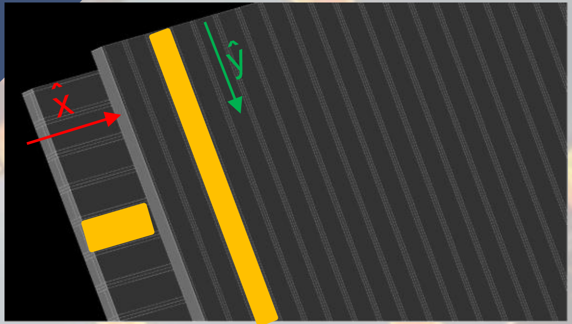
- pitch 180 µm
- better spatial resolution

Hybrid (HDM): tracking

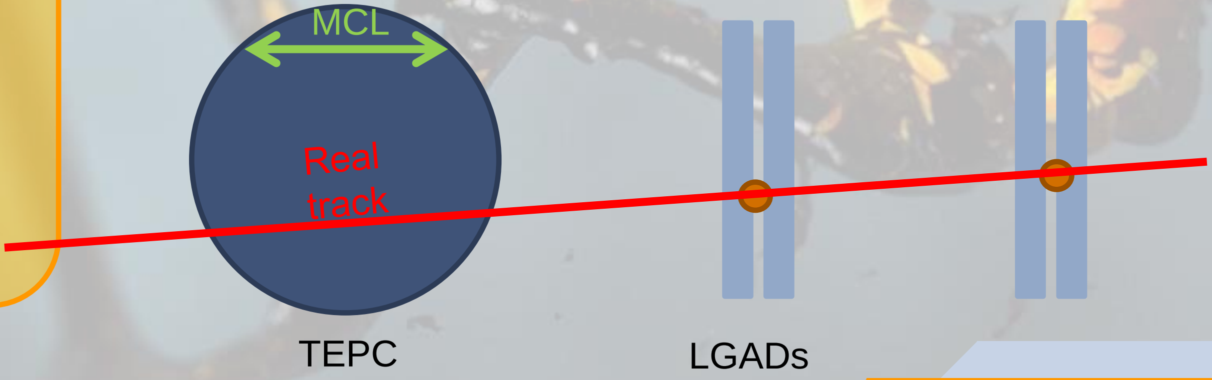




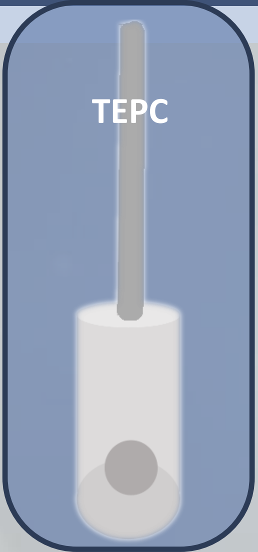
Strip is activated

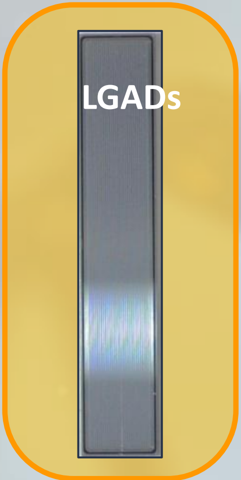


4 Planes (2-$\hat{x}$, 2-$\hat{y}$) to reconstruct the track



HDM: tracking





- Low Tracking efficiency:

	Not detected by at least 1 layer	Not detected by any layer
^{1}H	97%	85%
^{12}C	85%	25%

71 strips configuration

Machine learning techniques to improve tracking efficiency

HDM data →

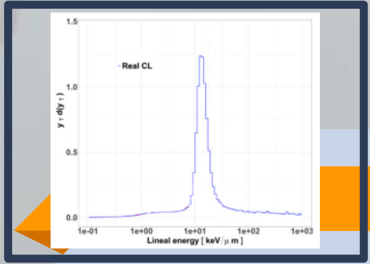
RF MODULE 1: Missing values fill

→

RF MODULE 2: Tracking algorithm

→

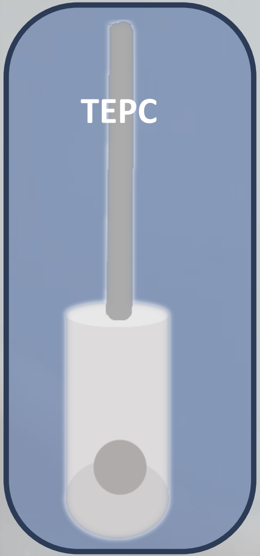
OUPUT: microdosimetric spectra



Missiaggia, M., Pierobon, E., et al. "Machine learning techniques for therapeutic energies particle tracking in microdosimetry." To be submitted to Physics in Medicine & Biology (2022)

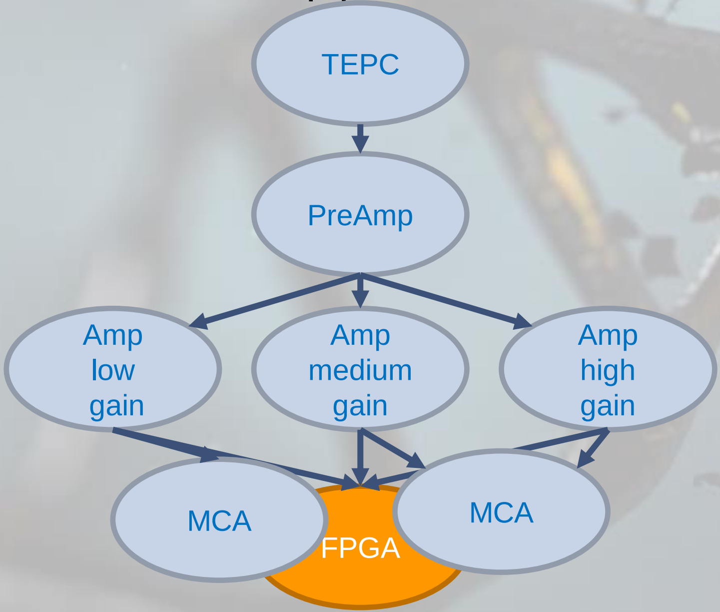
TEPC readout

Information on the energy deposition

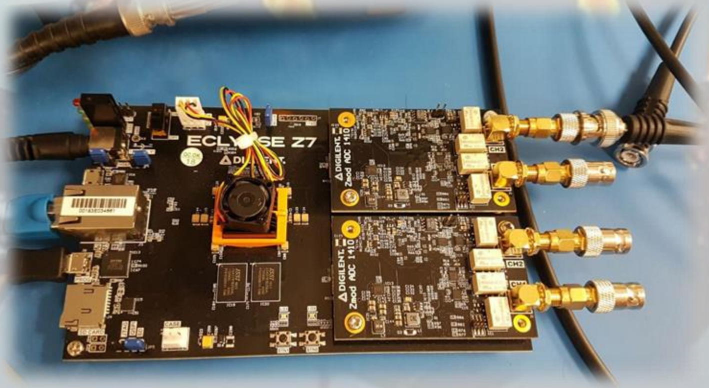


Current acquisition chain

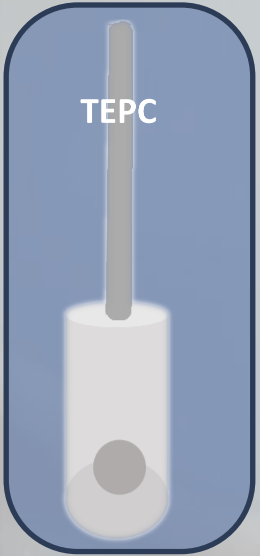
New acquisition chain



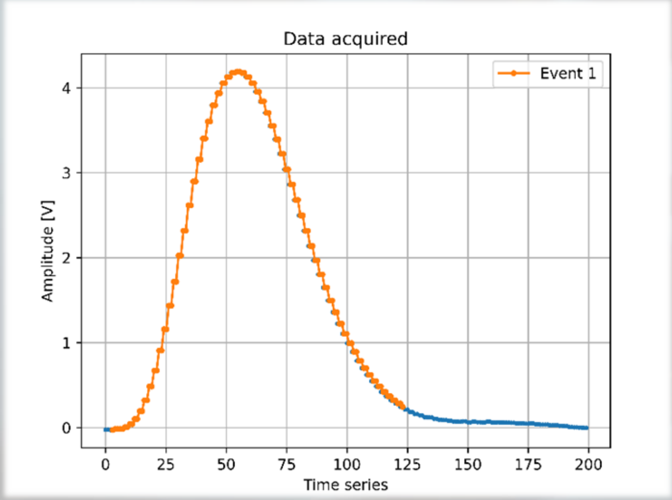
Eclypse Z7: Zynq-7000



TEPC readout



First experimental data acquired with new readout at the 25 MeV proton cyclotron CYRCé (Strasbourg, IPHC)



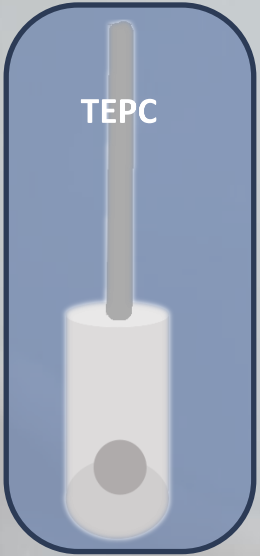
Whole temporal series is acquired

- \+ No information lost in MCA
- \+ Custom operation in real time
- \+ All experiment data is safely stored

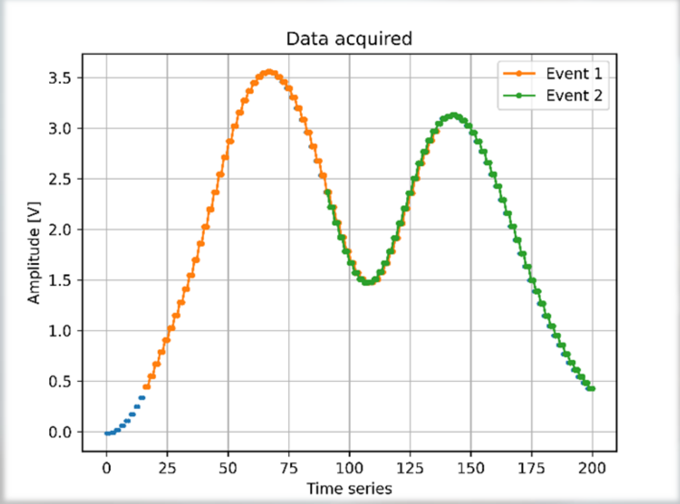
- \- High data flow to manage (40Mbps)

± Data analysis to implement

TEPC readout



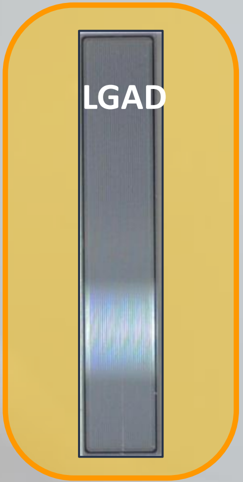
Results are promising especially
to deconvolve pile-up



Data analysis must recognize pile-up condition

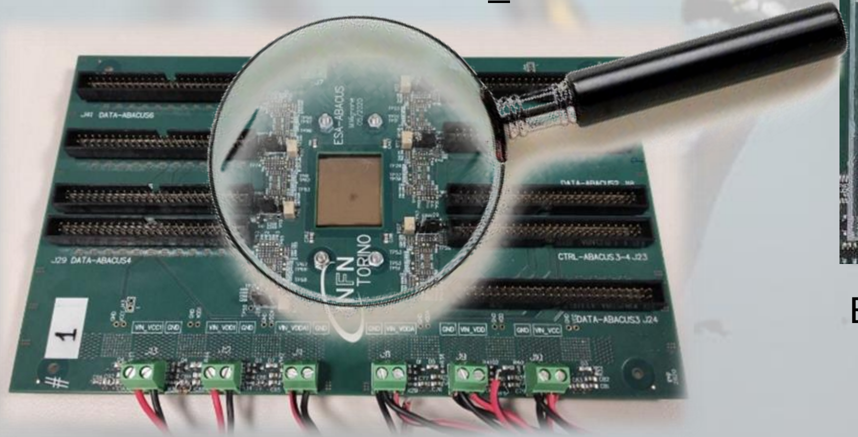
Another application of machine learning to extract all the information from the signals

LGADS readout

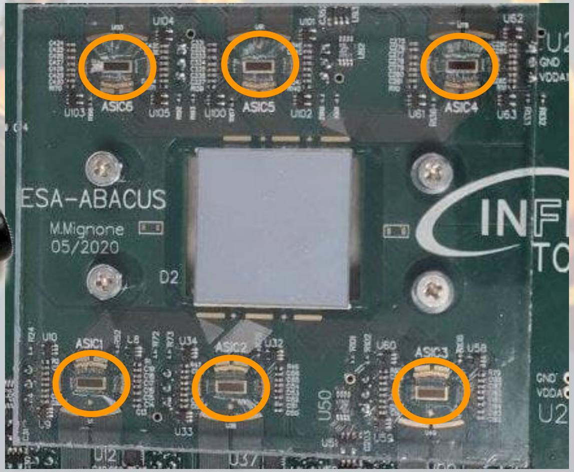


Readout based on ESA_ABACUS and ABACUS chip developed by INFN-TO for MoVe IT

ESA_ABACUS board



ABACUS chips



Each chip read a maximum of 24 LGADs

LGADS readout

Direct interface with ESA_ABACUS

Currently under debugging

Digital signal coming from ESA_ABACUS is processed thanks to FPGA Xilinx model zc702

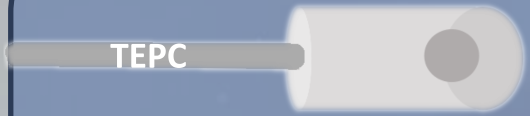
71 strips of LGADs x 4 layers = 284 channel to read ⟹ 4 ESA_ABACUS boards Mounting 3 ABACUS chip each ⟹ 4 zc702 FPGAs

HDM: to summarise

- This work is part of the MICROBE_IT project funded by INFN (CSN V)
- Detector feasibility study published
  - ✓ Missiaggia, M.; Pierobon, E.; et al. (2021). A novel hybrid microdosimeter for radiation field characterization based on TEPC detector and LGADs tracker: a feasibility study. Frontiers in physics .
- HDM is capable of:
  - ✓ Measure particle real track length in TEPC
  - ✓ Improve TEPC spatial resolution
  - ✓ Provide a superior radiation field characterization

HDM improved radiation quality description results in a more accurate dose calculation in TPS.

HDM: to summarise



- FPGA new readout testing
- Preliminary test at GSI with mimosa

LGAD

- ABACUS chip and ESA_ABACUS board debugging
- Develop FPGA firmware to read ESA_ABACUS

- Communication between TEPC and LGADs readout
- Data analysis

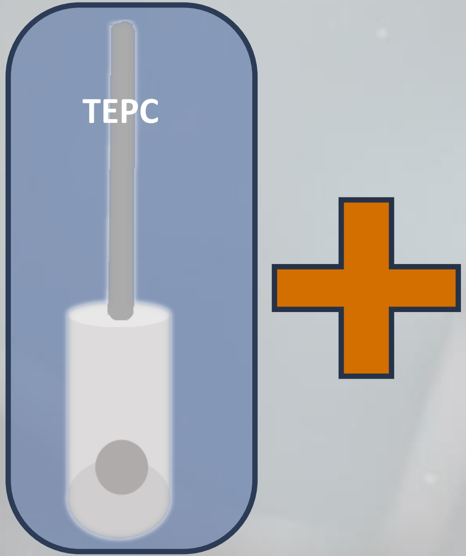
In progress

//TODO

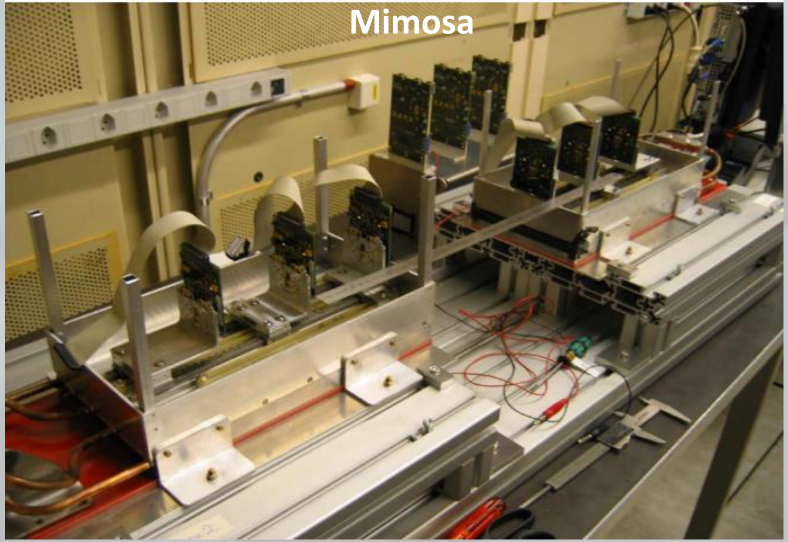
Thank you for your attention

Backup slides

HDM: preliminary test



Preliminary test with an existing tracker (CMOS pixel) available at GSI



BNL, December 2010, Marc Winter

Experimental setup to be discussed in these days

GSI facility. 56-Fe beam?

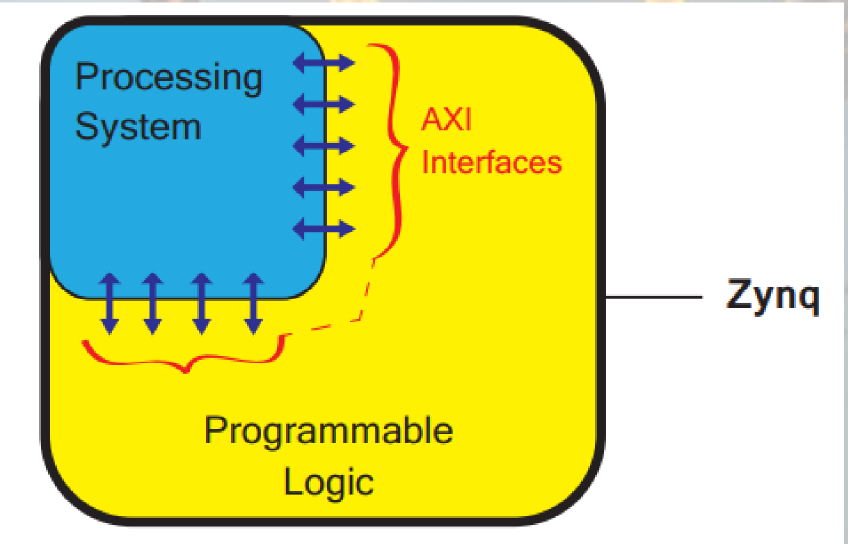
Other ions?

FPGA

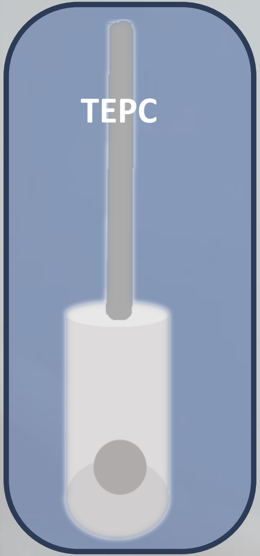
Zynq FPGA architecture

+

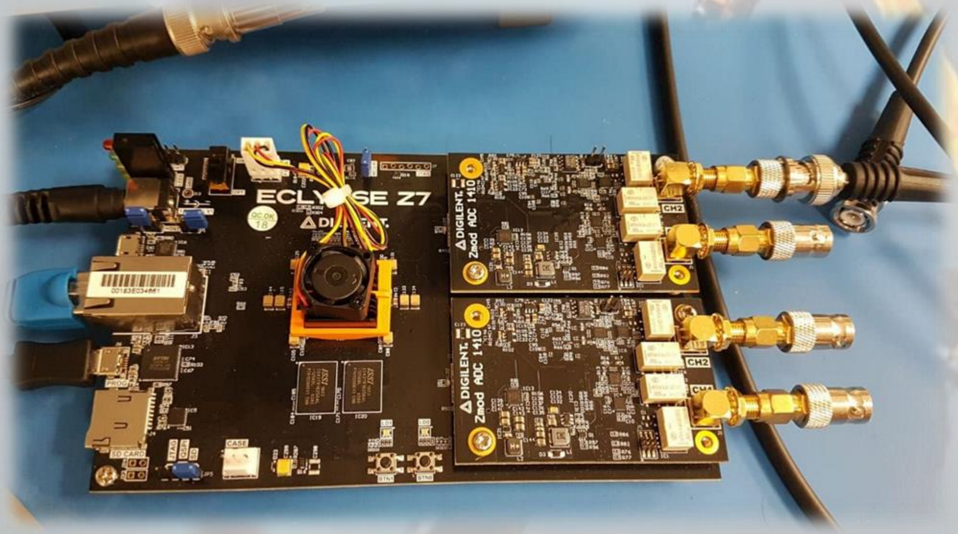
- ARM processor
- Programmable Logic



THE HYBRID DETECTOR HDM: TEPC readout

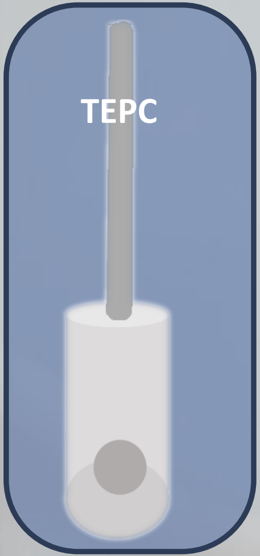


TEPC readout using Eclypse Z7: Zynq-7000 (FPGA)

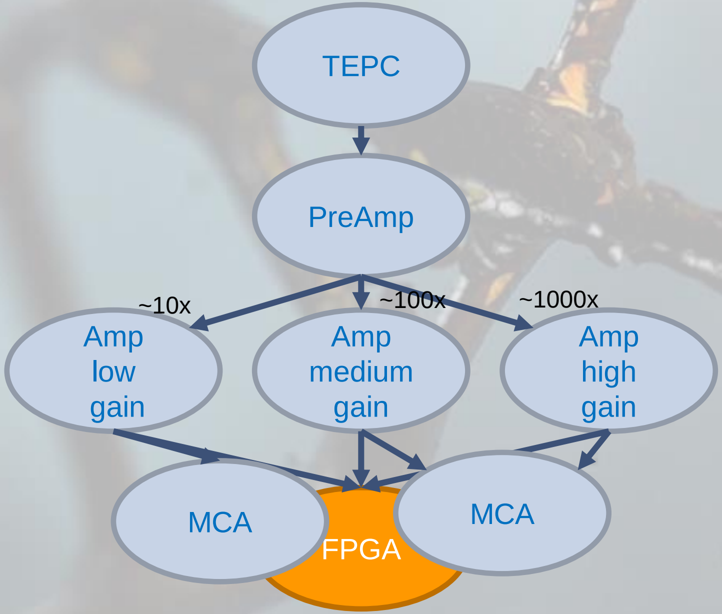


Equipped with
4 ADCs

THE HYBRID DETECTOR HDM: TEPC readout



New acquisition chain



TEPC

Energy deposition is the same:

$$\Delta E_{TEPC\ gas} = \Delta E_{Tissue}$$

Mass stopping power

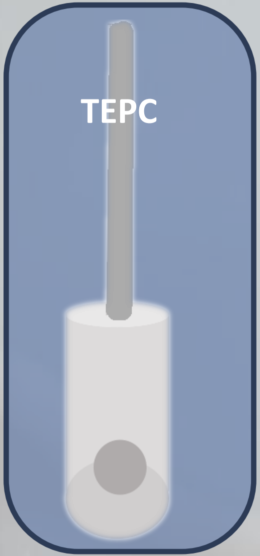
Diameter

Density

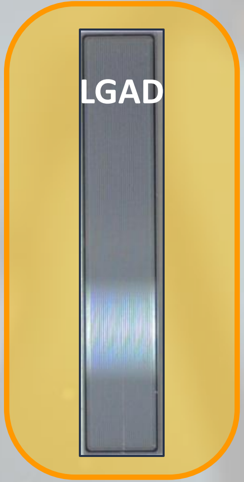
$$\Delta E_{TEPC} = \left(\frac{S}{\rho}\right)_{TEPC} (D\rho)_{TEPC}$$

$$\Delta E_{Tissue} = \left(\frac{S}{\rho}\right)_{Tissue} (D\rho)_{Tissue}$$

Hybrid (HDM)



Energy deposited



Tracking

Two readout systems to implement