UNIVERSITÀ DI TRENTO

TIFPA Trento Institute for Fundamental Physics and Applications

FONDAZIONE BRUNO KESSLER

Hybrid LGAD-based detector design for microdosimetry applications

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1

MICRODOSIMETRY

Introduction and Applications

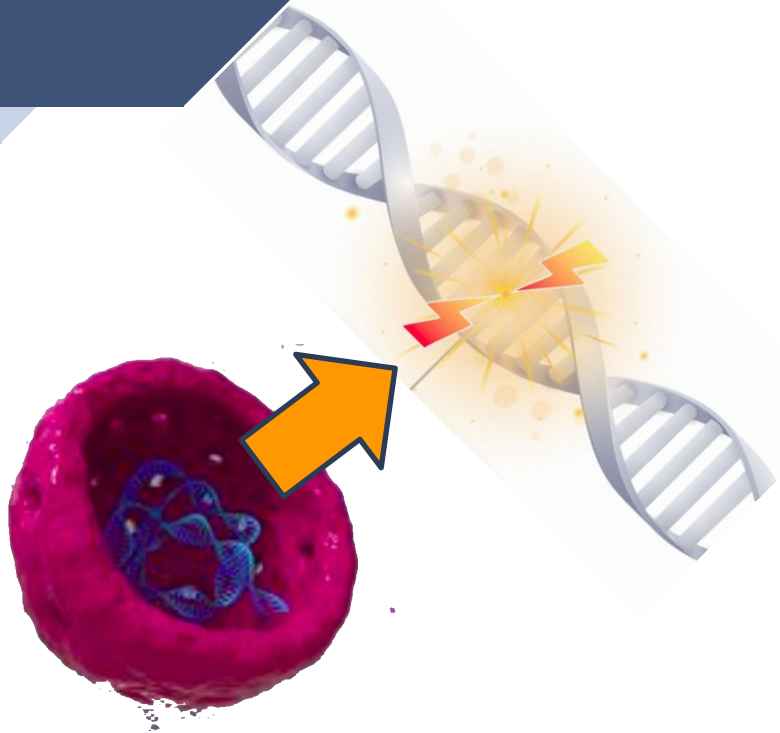
MICRODOSIMETRY GOAL

Estimate of biological parameters from direct physics measurements, so:

- Assessment of the radiation quality
- Evaluation of the physical dose

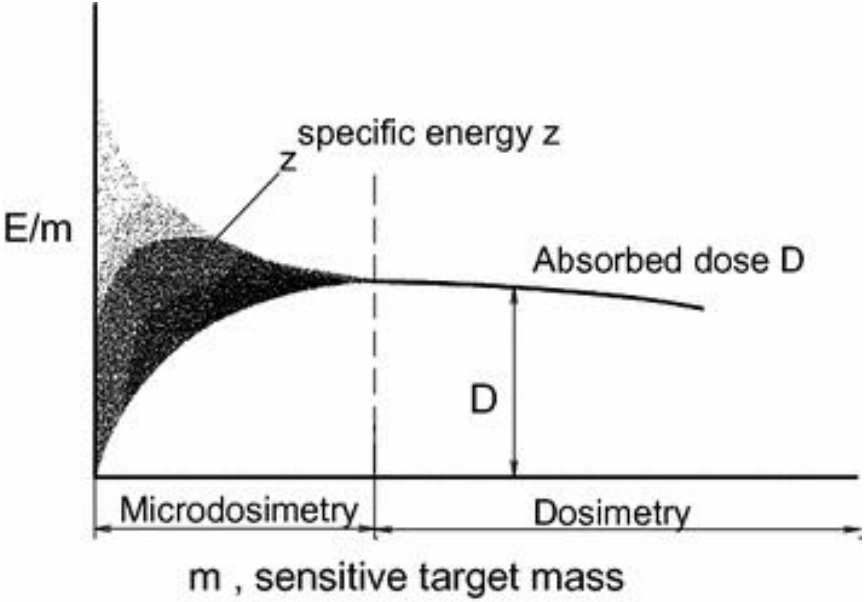
MICRODOSIMETRY GOAL

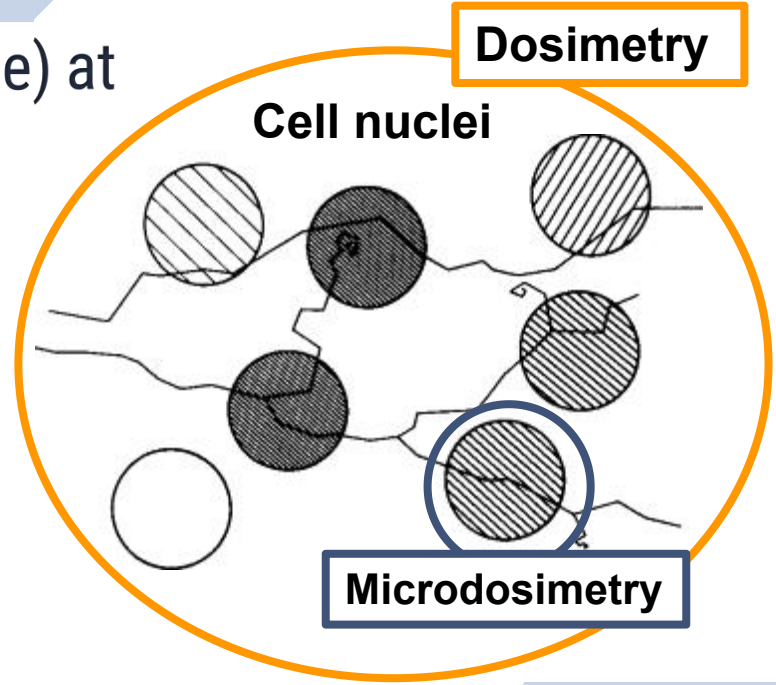
The physical parameters describing the radiation field are obtained by measuring the radiation effects in tissue at a micrometer scale (same of a **cell nucleus**, where the main radiation damage occurs)



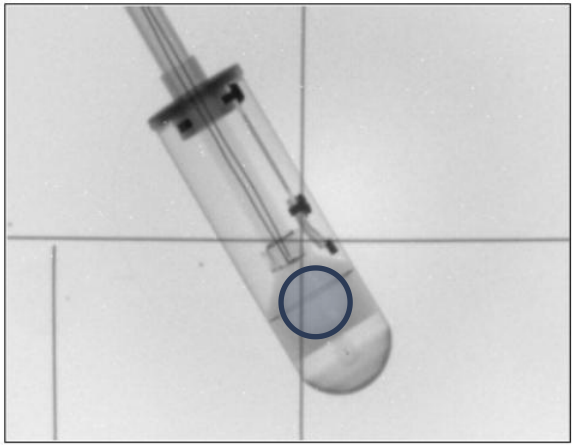
MICRODOSIMETRY GOAL

The energy deposited in the mass (dose) at this volume scale is **stochastic**





Gas Detector:
Tissue Equivalent Proportional Counter



ACTIVE REGION: sphere filled with propane gas at **low density**

- **Real diameter** of the active region ➡1.2 cm
- **Tissue-Equivalent diameter** of the active region ➡ 2 μm

APPLICATIONS OF MICRODOSIMETRY

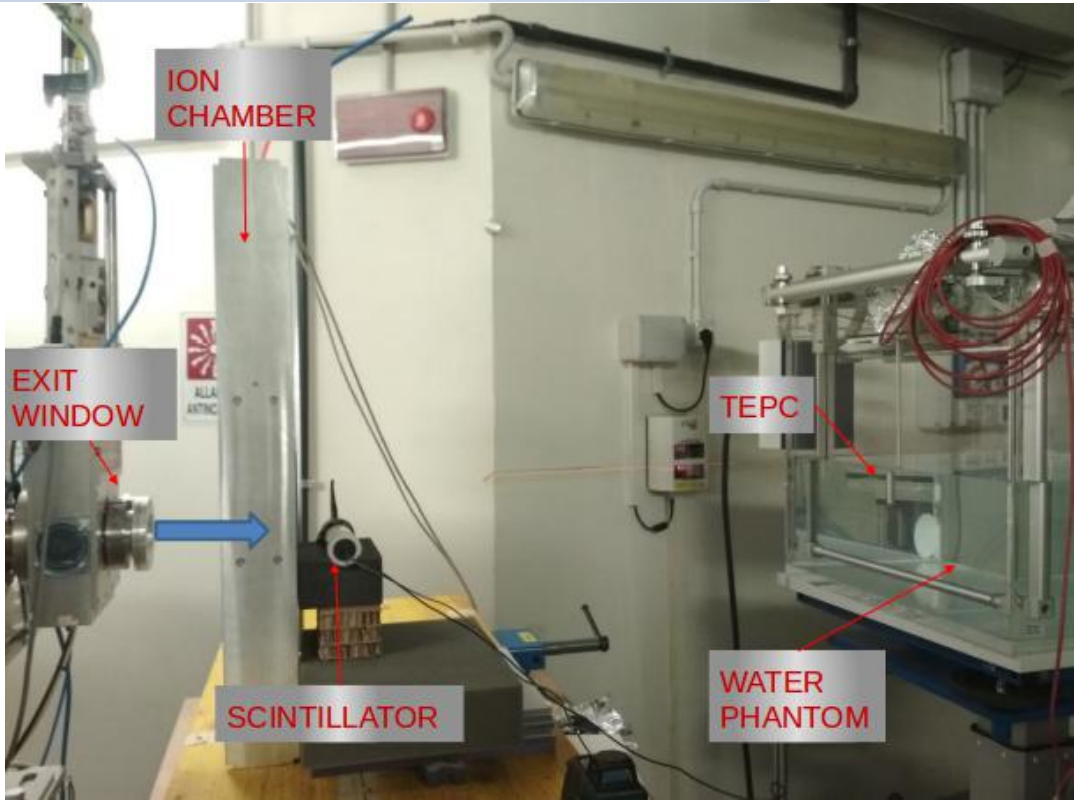
RADIOTHERAPY

RADIATION PROTECTION IN SPACE

2

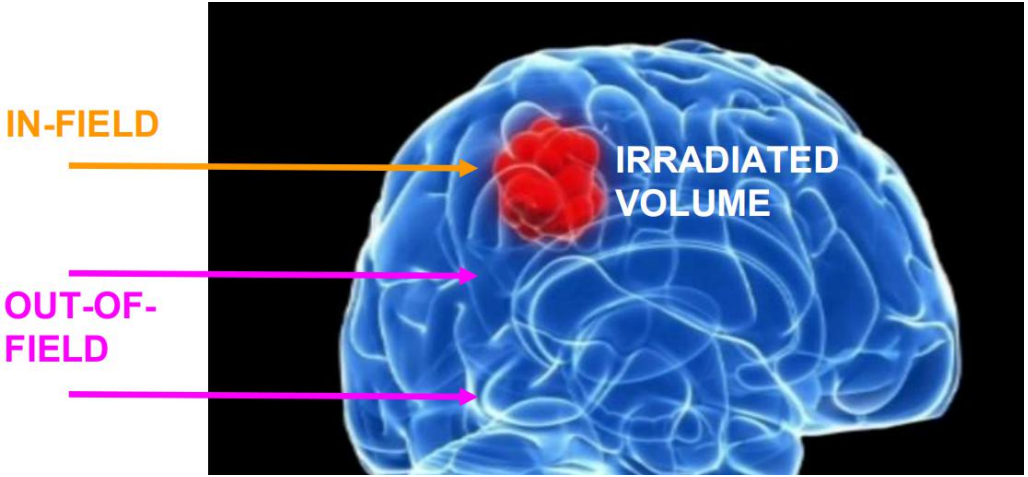
MEASUREMENTS & DATA ANALYSIS

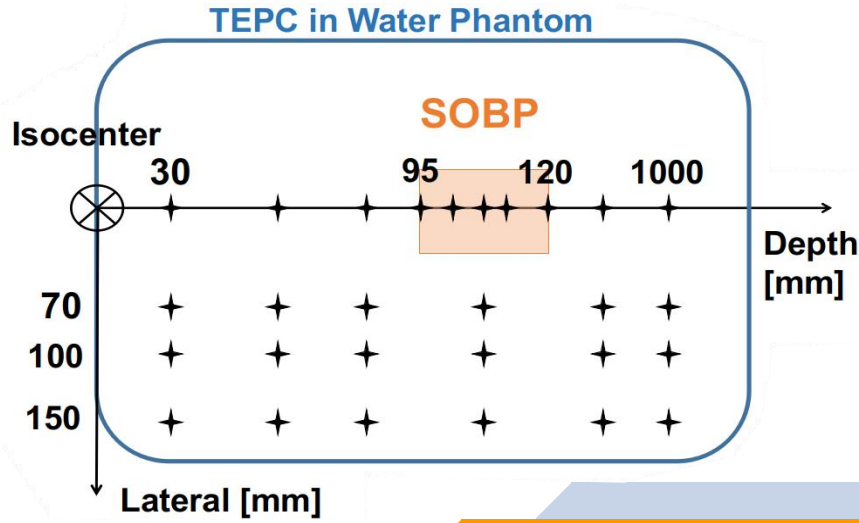
MEASUREMENTS WITH TEPC



MEASUREMENTS WITH TEPC

The TEPC can be placed both **in- and off-beam** in the water phantom to reproduce the tumor and its surrounding normal tissue



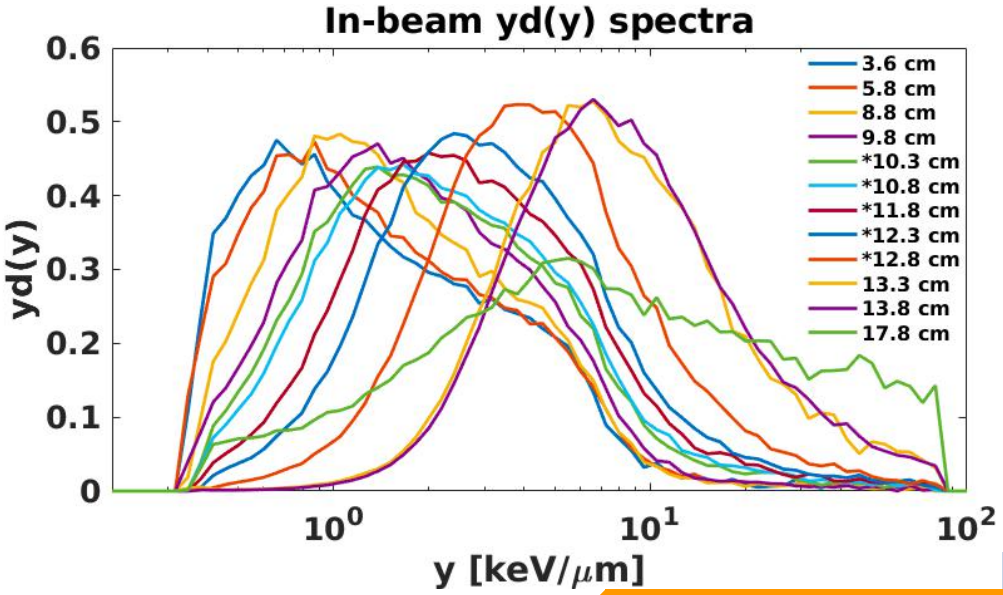


MEASUREMENTS WITH TEPC

Microdosimetric **spectra**, **mean values** of the distributions and **biological dose** have been obtained:

- *f(y)* frequency of particle with a given lineal energy ***y*** (energy deposited over the **mean chord length** of TEPC)

- *yf(y)* and *yd(y)* distributions (*d(y)=yf(y)*)

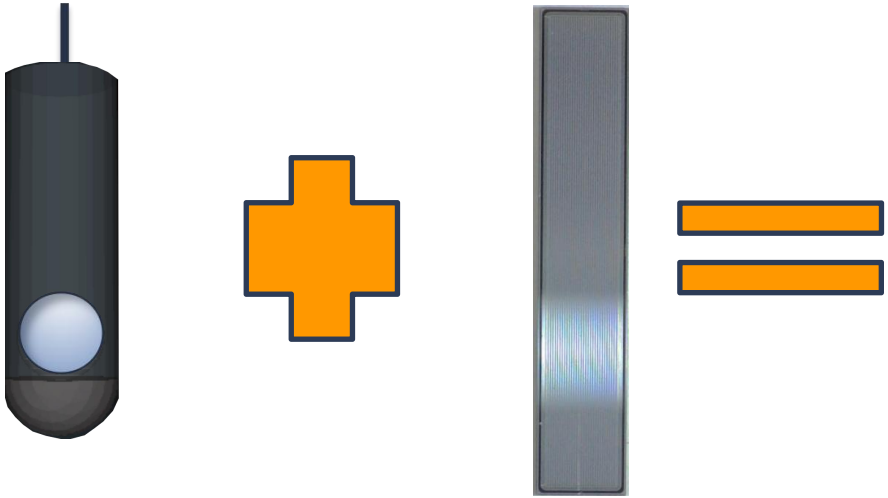


3

THE NEW DETECTOR

Hybrid detector: TEPC + LGAD

IDEA OF THE HYBRID DETECTOR: TEPC + Silicon System



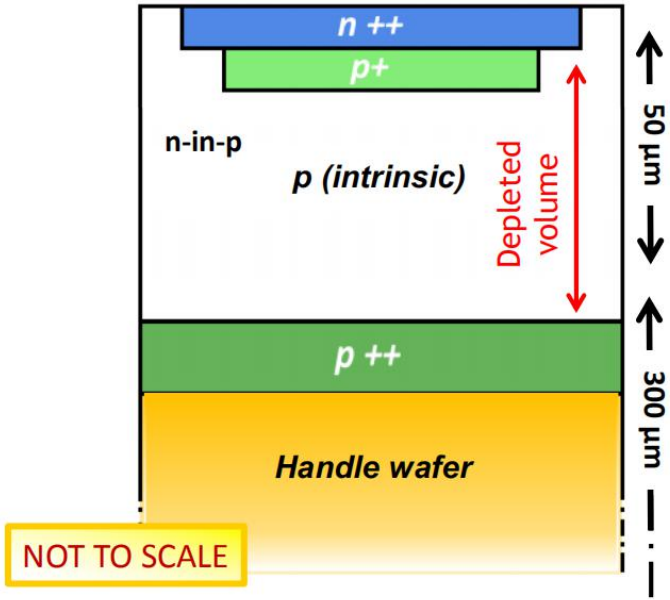
INFORMATION on:

- Energy deposition of all particles traversing the TEPC
- Particles tracking (with 4 layers of strips) and particle detection

➡ Correction of the mean chord length value with the real path length of the particles

LGAD (Low Gain Avalanche Diode)

- Avalanche Diode with a **low gain** (5–10)
- LGAD merges the best characteristics of traditional silicon sensors with the main feature of Avalanche Photodiodes (APD), using n-in-p silicon diodes with a low and controlled internal multiplication mechanism



LGAD (Low Gain Avalanche Diode)

- The LGADs are produced at FBK(Trento) while the read-out chip ABACUS have been developed at University of Turin within the Move-it project
- Existing dimension to start to play with: 0,56 cm x 1,5 cm
- 50 μm of active thickness, 300 μm of passive thickness (but can be further thinned till 70-100 μm)

LGAD (Low Gain Avalanche Diode)

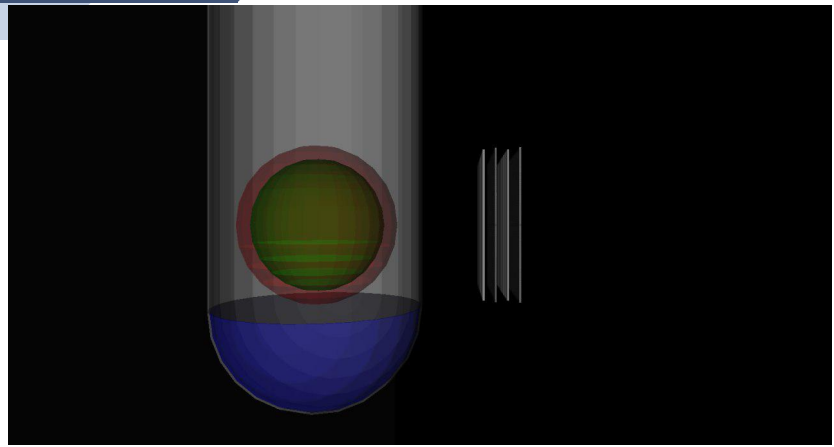
Two LGAD geometries are now being produced at FBK, which are both 14 mm squares, more suitable for our application:

- 34 strips per sensor
- pitch 360 μm
- better fill factor
- less channels to read

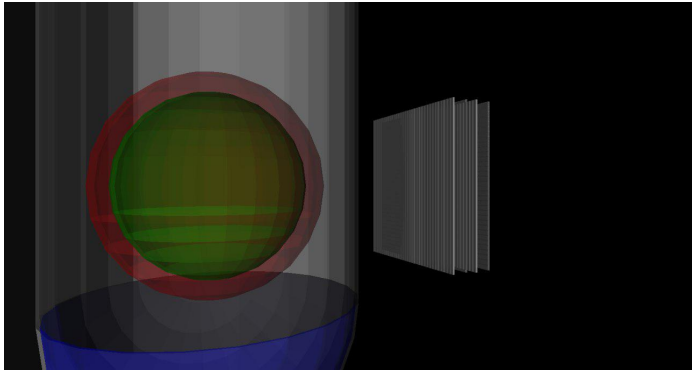
- 71 strips per sensor
- pitch 180 μm
- better spatial resolution

GEANT4 SIMULATIONS

The simulations presented here were run with the following setup:

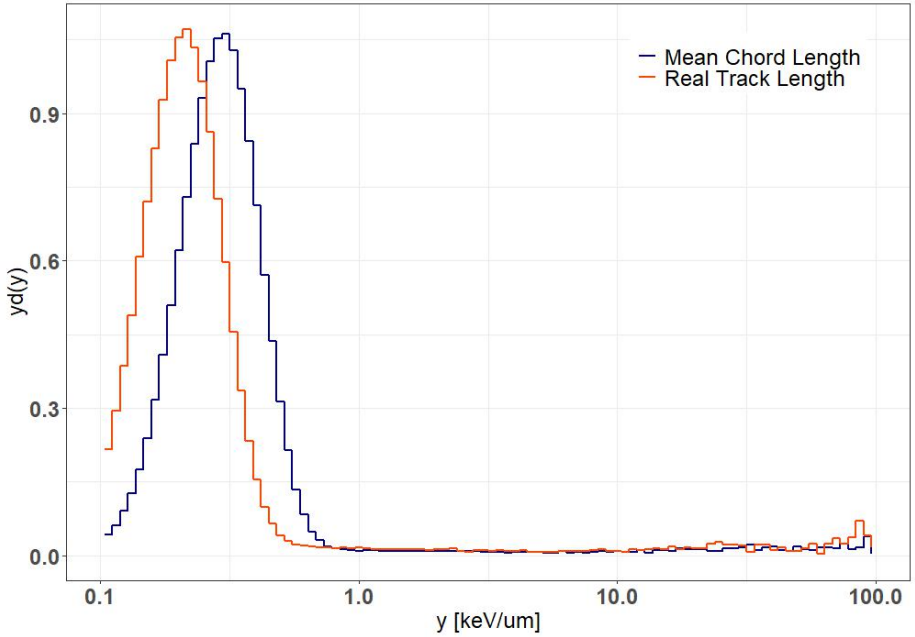


- BEAM = **150 MeV protons,** pencil beam
- SCORING POSITION = **50 mm** along the beam direction (plateau region)



GEANT4 SIMULATIONS

Final goal: Assess the difference between the TEPC lineal energy spectrum calculated with the mean chord length or with the real length



Error on mean value for the yd(y) distribution is in the order of 30%

GEANT4 SIMULATIONS: Track length analysis

We are now evaluating the difference between the real track length of particles traversing the TEPC with the track length obtained from the 4 LGADs system:

34 strips system

- Error on tracking is in the order of **9%**

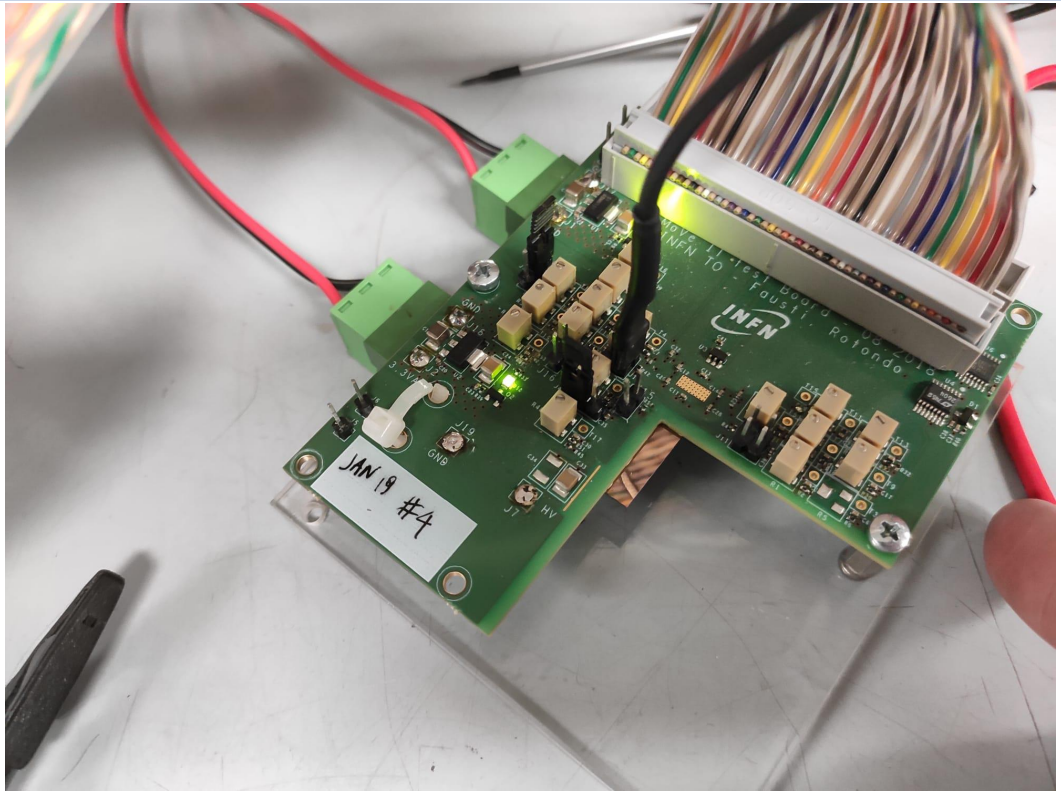
71 strips system

- Error on tracking is in the order of **6%**

(But around 30% of events in common between TEPC and 4 LGADs are rejected due to multiple scattering)

Additional tests with different tracking algorithms are needed!

TEST BOARD FOR LGAD CHIP



We manage to see a signal from the chip!

- We are now starting FPGA programming for reading the strips of a single LGAD

WORK IN PROGRESS AND FUTURE STEPS

Additional MC simulations of the hybrid detector with GEANT4

Readout system based on FPGA

Tests with protons at Trento Protontherapy Center

THANK YOU FOR YOUR ATTENTION