Hybrid LGAD-based detector design for microdosimetry applications

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MICRODOSIMETRY

Introduction and Applications
Estimate of biological parameters from direct physics measurements, so:

- Assessment of the radiation quality
- Evaluation of the physical dose
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)
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
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MEASUREMENTS & DATA ANALYSIS
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.
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 (\( d(y) = yf(y) \))
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
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)
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
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)
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 $y_d(y)$ distribution is in the order of 30%
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!
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

- Readout system based on FPGA
- Additional MC simulations of the hybrid detector with GEANT4
- Tests with protons at Trento Protontherapy Center
THANK YOU FOR YOUR ATTENTION