Parametrized simulation of the μRWELL response with PARSIFAL software

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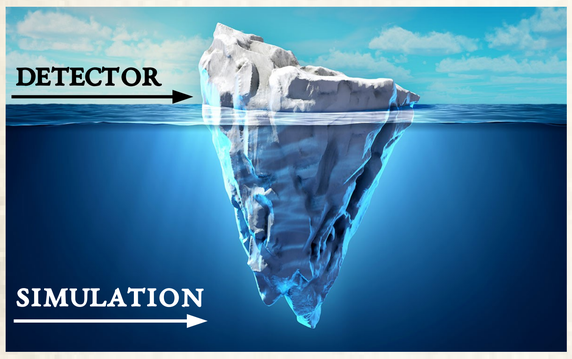
on behalf of CGEM-IT, RD_FCC, EURIZON groups of Bologna, Ferrara, Laboratori Nazionali di Frascati, Torino

Preamble

The simulation is a hidden component of the design and realization of a detector



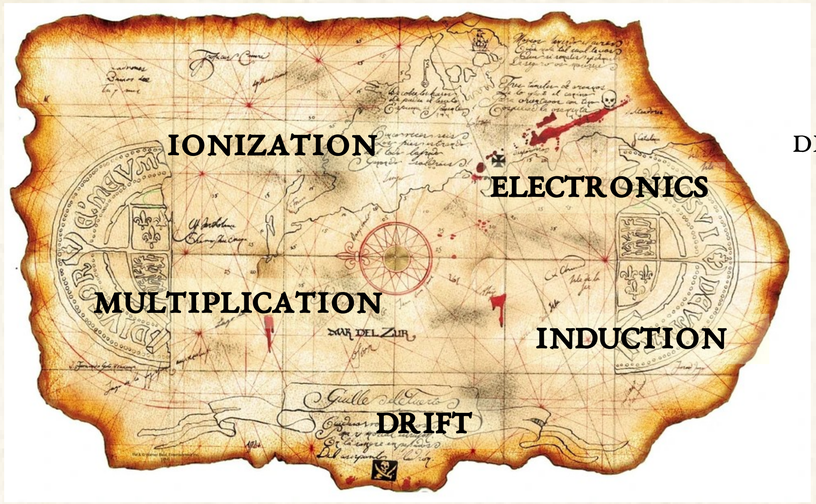
DIGITIZATION PURPOSE

real experiment → raw data → reconstruction

simulation → Monte Carlo points → digitization

Chapter 1 – the origin of the quest

The hero, Parsifal, is searching for the sacred Graal: a fast and reliable simulation of the response of a micro pattern gas detector to the passage of the ionizing particle



PARSIFAL
PARAMETRIZED **SIM**ULATION

GEANT4	
IONIZATION	← POISSON (PRIMARY) + SECONDARY IONIZATION
DETECTOR GAIN	← POLYA DISTRIBUTION
ELECTRON DRIFT	← TRANSVERSE / LONGITUDINAL DIFFUSION
RESISTIVE	← THIS POSTER
INDUCTION	← RAMO THEOREM
ELECTRONICS	← APV25
RECONSTRUCTION	
ANALYSIS	

PROCEDURE

- EACH PHYSICS PROCESS (IONIZATION – GAIN – ELECTRON DRIFT – INDUCTION – ELECTRONICS) IS TREATED **SEPARATELY AND INDEPENDENTLY** [1]
- A GARFIELD++ [2] MICROSCOPIC SIMULATION IS RUN **ONCE–AND–FOR–ALL** TO EXTRACT THE PARAMETERS WHICH ARE SET AS INPUT IN PARSIFAL
- A **SAMPLING FROM PARAMETRIZED DISTRIBUTIONS** IS USED IN PARSIFAL TO GET FAST AND RELIABLE RESULTS

Chapter 2 – the first trial: the triple–gem

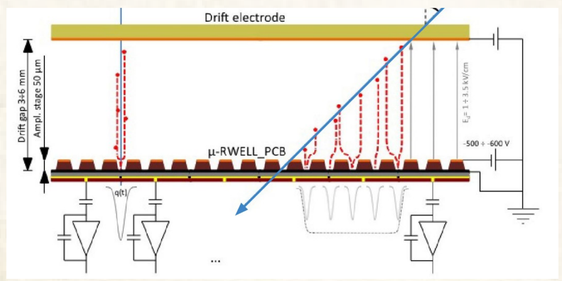
The hero, Parsifal, simulates the response of a triple–gem to the passage of a particle [3] and showed its success @ ACAT19 [4]

Chapter 3 – the second trial: the μRWELL

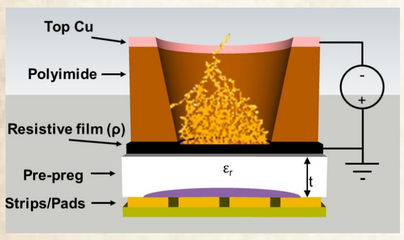
The hero, Parsifal, challenges a new type of tracker, which has an additional ace in the hole: a resistive layer that spreads the electron avalanche, quenches possible sparks and fires more anodic strips. Must add to the simulation a proper treatment of this peculiarity: the presence of the Diamond Like Carbon resistive layer

MICRO RESISTIVE WELL [5]

- MICRO–PATTERN GAS DETECTOR (MPGD)
- COMPACT
- SPARK–PROTECTED
- SINGLE STAGE OF AMPLIFICATION



PRINCIPLE OF OPERATION

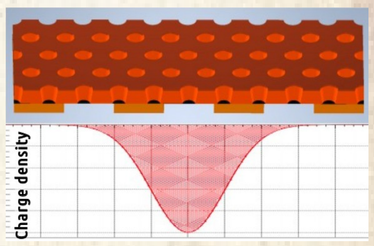


- HV BETWEEN THE COPPER TOP LAYER AND THE DLC RESISTIVE → ELECTRONS **AMPLIFICATION** IN THE HOLE (WELL)
- CHARGE DISPERSION ON THE RESISTIVE LAYER WITH $\tau = RC$
- R = ANODE SURFACE RESISTIVITY; C = CAPACITANCE PER UNIT AREA
- SEGMENTED STRIP READOUT

CHARGE DENSITY SPREAD ON THE RESISTIVE LAYER [6, 7]

$$\rho(x,y,t) = \frac{N q_e}{2\pi\,(2ht + w^2)} exp\left[-\left(x^2+y^2\right) / \left(2\,(2ht+w^2)\right)\right]$$

- N = number of electrons in avalanche
- Q_e = electron charge
- h = 1/RC
- t = time
- w = width of the avalanche
- x, y = position coordinates



ADAPTATION TO ONE–DIMENSIONAL STRIP

$$\rho(x,t) = \frac{q}{\sqrt{2\pi}\left[\sigma_0\left(1+\frac{t-t_0}{\tau}\right)\right]} exp\left[-\frac{(x-x_0)^2}{2\sigma_0^2\left(1+\frac{t-t_0}{\tau}\right)^2}\right]\Theta(t-t_0)$$

- q charge the avalanche
- x_0 electron starting position
- σ_0 width of the avalanche
- t_0 starting time of the track
- $\tau = RC$

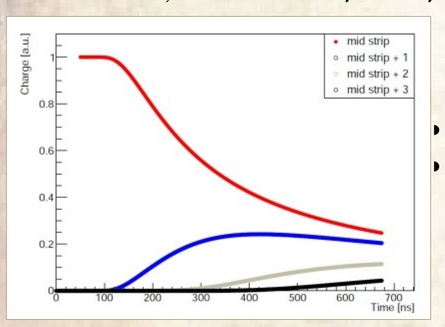
ELECTRONICS (APV – 25)

$$Q_{shaped}(t) = Q_{preamp}\left(\frac{t-t_0}{\tau}\right)\exp\left(-\frac{t-t_0}{\tau}\right)$$

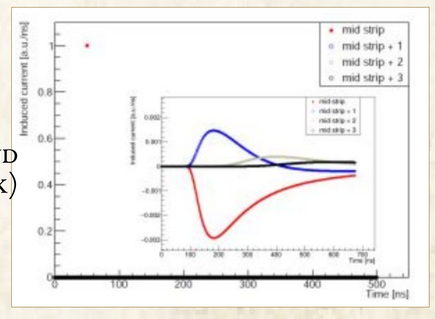
- Q_{preamp} = integrated charge
- t_0 starting time of the track
- τ shaping time of the APV25

Chapter 4 – the duel with the single charge

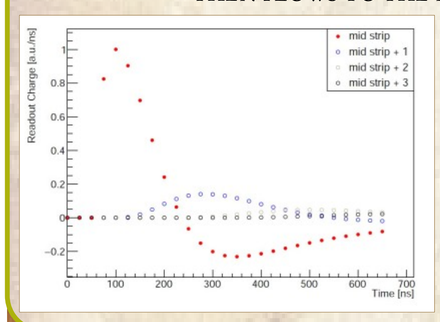
The hero, Parsifal, handles a signel charge entering the amplification well and inducing a current on the readout strips: a spread is applied to it, depending on $\tau = RC$



- A SINGLE CHARGE q=1 IS INJECTED @ t_0 = 50 ns ON THE MIDDLE STRIP
- THE CHARGE IS SPREAD WITH A τ = 10 ns



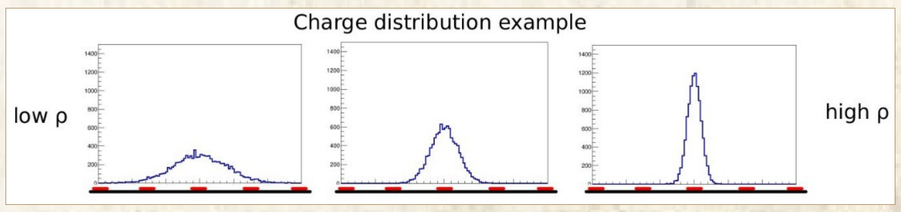
- THE CURRENT IS A DELTA ON THE MIDDLE STRIP AND THEN FLOWS TO THE NEIGHBORING ONES (BLUE, BLACK)

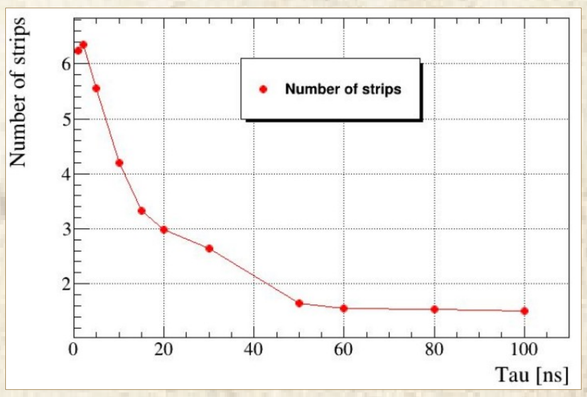


- THE ELECTRONICS HAS A SHAPING TIME = 50 ns

Chapter 5 – the attack of the many electrons

The hero, Parsifal, faces a 10000 events, producing many electrons which are multiplied in the wells and induce a current on the readout strips





IF τ > 60 ns, THEN THE RESISTIVITY IS TOO LARGE TO OBSERVE ANY SPREAD

Epilogue

The hero, Parsifal, continues his quest...
follow him for more adventures!

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- PARSIFAL FOR TRIPLE – GEM, AVAILABLE @ https://github.com/Hilldar/PARSIFAL.git (BRANCH triplegem)
- PAPER AVAILABLE ON ARXIV https://arxiv.org/abs/2005.04452
- PAPER SUBMITTED TO COMPUTER PHYSICS COMMUNICATIONS

References

[1] AMOROSO A ET AL, ARXIV 2005.04452
[2] BONIVENTO W ET AL, IEEE TRANS. NUCL. SCI. 49 (2002) 4
[3] HTTPS://GARFIELDPP.WEB.CERN.CH/GARFIELDPP/
[4] BENCIVENNI G ET AL, 2015 JINST 10 P02008
[5] FARINELLI R, ACAT 2019 PROCEEDINGS
[6] DIXIT MS ET AL, NIM A 518 (2004) 721-727
[7] DIXIT MS & RANKIN A, NIM A 566 (2006) 281-285

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