Development of new DLC deposition techniques for a TOF-PET detector based on the Fast Timing MPGD (FTM)

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INFN sez. Bari

Towards a PRIN Proposal

TOF-PET chat

February 9th 2018, Bari

Development of new DLC deposition techniques for the development of the Fast Timing MPGD TOF-PET detector

PRIN linea Sud
INFN sez. Bari + Universita di Salento (+ Universita di Napoli?)

- WP 1 Development of DLC deposition techniques
- WP 2 Design and Simulation of the TOF-PET FTM detector
- WP 3 Test of the TOF-PET FTM detector in the Lab and with beams
- WP 4 Simulation of the TOF-PET system with GATE

WP 1: Development of DLC deposition [Uni Lecce]

Reqs:

FTM needs a in-house (Italian) production of DLC deposition on kapton foils, with emphasis on high uniformity of the resistivity, with a good process control, eventually also cost-effective and scalable to large surfaces.

- *Here need input from Anna Paola, WP largely in hands of Uni Lecce*
- Larger facility (Vacuum chamber + $x - y$ position system for laser + target
- Measurement facilities?
- PhD / Assegni?
- Consumables ? Gas, Carbon targets, ...
- Peolple engaged + FTE? (funding depends on co-financing of entities)

WP 2: Design and Simulation

[INFN Ba]

Design and Simulation of the TOF-PET FTM detector

- GEANT simulation of material interactions
  already started with Raffaella, see poster attached
- ANSYS simulation of Electric Field
- GEANT + GARFIELD integrated simulation of detector response
- SPICE simulation of signal picked up on external strips
- *Borsa* for PhD student would be good

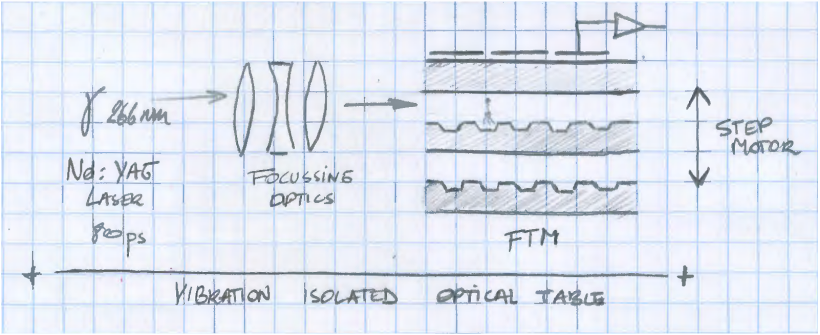
WP 3: Test of the TOF-PET FTM detector

[INFN Ba & Uni Lecce]

- in the Lab with UV-laser
- in the Lab with ^{22}Na source
- and with beams

WP 3.1: Test with UV-laser

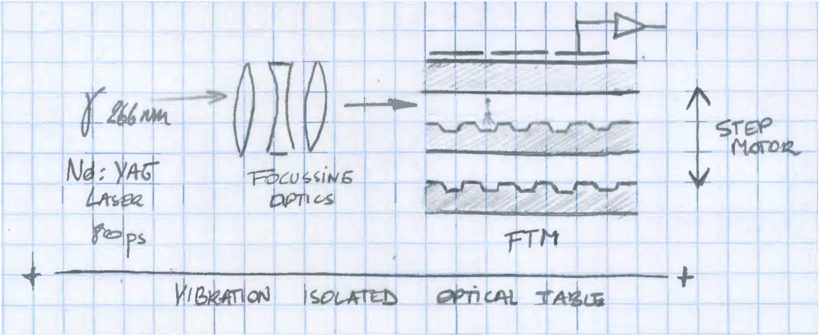
[INFN Ba & Uni Lecce]



- Experience in Lecce, necessity to have working setup for future prototypes in Bari
- Necessity since X-ray tests are increasingly more difficult for very thin gaps
- Idea Alice TPC test system, $\sim 40\,\mu$J/pulse enough for ionization on impurities through double photon-process. Test for RPC performed in the past in Lecce

WP 3.1: Test with UV-laser

[INFN Ba & Uni Lecce]



- High Quality Laser beam required since final focus at long distance of center of detector (~ 30 cm) while beam $< 100\,\mu$m required in entire gas volume $\Rightarrow$ No (cheap) Laser Diodes, but more expensive Diode Pumped Solide state lasers (Nd:YAG quadrupled to 266 nm)
- Advantage if possible to buy laser with pico-second pulses (will allow time resolution measurement in the lab) but price will be high

WP 3.1: Test with UV-laser

[INFN Ba & Uni Lecce]

- Would like to perform first tests in Lecce but install full system in Bari
- Inventariable: Laser, Optical Table, Step motor with μm precision
- Consumables: Lenses, Optical Instr, Mechanics (dark box) Cables, Gas
- *Borsa* for PhD student to work on this setup

WP 3.2: Test with ^{22}Na source

[INFN Ba]

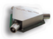
- Setup: ^{22}Na source, LYSO+SiPM (ref) & TOF-PET FTM
- equipment already partially bought with project for Gr-V: CAEN Gamma-Kit with SiPM
  (need to check whether 250 GS/s are ok. is SiPM fast enough?)
- Need to study how to correlate output from SiPM (through CAEN digitizer) and FTM (through MOSAIC)
- FATIC board (FTM) has input for LVDS signals from Scint / SiPM / MCP-PMTs (but needs LVDS!)
- *Assegno* for DAQ / Electronics programmer?

WP 3.2: Test with ^{22}Na source [INFN Ba]

CAEN Gamma Kit with SiPM, LYSO, BGO & CsI crystals:

The **SP5600** is a General purpose Power Supply and Amplification Unit, integrating up to two SiPMs in a mother & daughter architecture allowing for easy mounting and replacement of the sensors. The basic configuration features two channels with indipendent gain control up to 50 dB and provides the bias voltage (up to 100 V) to the sensors with gain stabilization. Each channel can provide a digital output generated by the fast leading edge discriminators. A timing coincidence of the two channels is also available.

The **DT5720A** is a CAEN Desktop Waveform digitizer housing 2 channels 12 bit 250 MS/s ADC with a dedicated charge integrating firmware (DPP-PSD) for real time pulse processing.



The Mod. **A315** splits one input on two output signals. All the connectors are LEMO female type. The splitter is adapted for 50 Ohm lines. The device is completely passive (no power supply is required); the amplitude on each output is one half of that on the input.

SP5606 is mini-spectrometer for gamma ray detection. The spectrometer is composed of a mechanical structure that houses a scintillating crystal, coupled to a dedicated SiPM. Three different crystals are available: CsI, LYSO and BGO. The spectrometer is equipped with a bottom support to allows an easy connection to the SP5600 via the splitter A315, to avoid saturation effects.

The **Gamma absorption tool** allows to perform gamma attenuation measurements. It is a modular tool and its design allows an easy connection to the SP5606 bottom support.

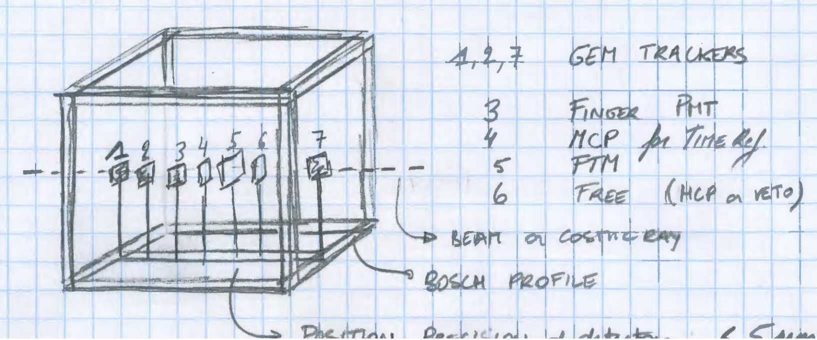
WP 3.3: Test with beams

[INFN Ba]

Why beams?

Study detector in controlled environment, Ref/Benchmark w.r.t other MPGDs, we are also interested in the HEP application although it is not the (main) goal of the PRIN

Results obtained for timing and efficiency would be the same as for a FTM with HEP finality (spatial resolution, charge spreading, ageing, would be all different

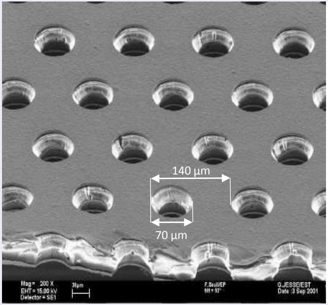


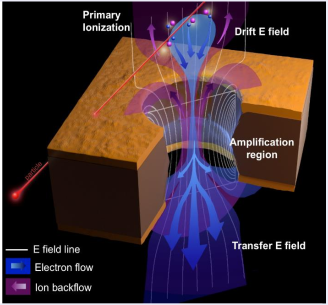
WP 4: Simulation of the TOF-PET system with GATE [Uni Napoli?]

- Need to translate the performance of the FTM to the performance of the TOF-PET system
- Interface between *Detector Physics Speak* and *Medical Physics Speak*
- Study very important to show that we are serious and to present our detector to the Med Phys community
- Input from (Southern) group with Med Physics experience in PET and simulation very welcome. Napoli?
- *Borsa* for PhD student to work on these simulations

Micro Pattern Gaseous Detector (MPGD)

Example: Gas Electron Multiplier (GEM)



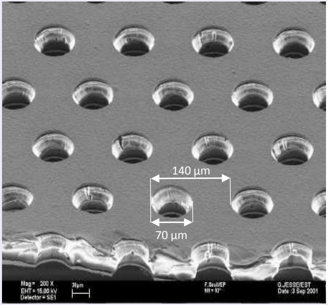


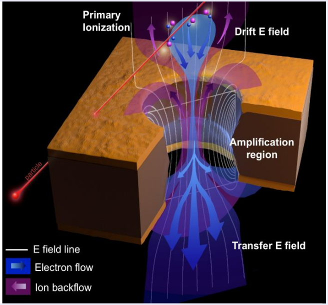
Advantages:

- Photo-lithographic techniques allowed to produce **Micro Patterned detectors**
- Main Characteristics: High rate capability ($> 50\,\mathrm{MHz/cm^2}$), good spatial resolution ($50\,\mu$m), high efficiency ($\geq 95\,\%$), time resolution of $\mathcal{O}(5$–$10\,\mathrm{ns})$
- flexible detector structures (cfr. cylindrical trackers for KLOE and BES-III)

Micro Pattern Gaseous Detector (MPGD)

Example: Gas Electron Multiplier (GEM)



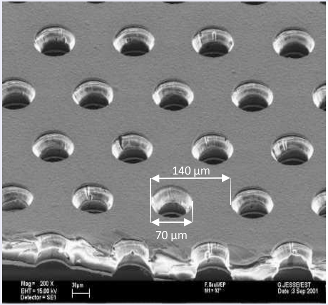


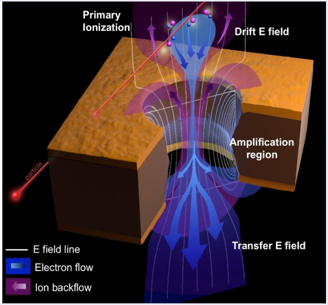
Advantages:

- Two separated regions: **drift region** (creation of electron-ion pairs) and **gain region** (multiply drifted electrons to observable electric signal)
- Rate capability is improved by fast collection of postive ions
- MPGD Time resolution driven by fluctuations in creation of electron-ion pairs

Micro Pattern Gaseous Detector (MPGD)

Example: Gas Electron Multiplier (GEM)

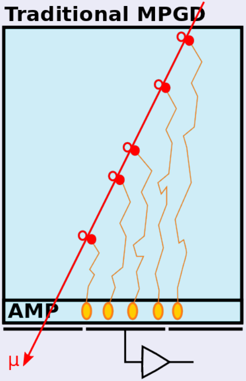




Drawbacks:

- Single Stage Gain limited to few 10^3 ⇔ Wire detectors: 10^4–10^5
- Recently μ-RWELL: Gains of few 10^4 with LHCb Triple-GEM Gas ($Ar:CO_2:CF_4$)
- Discharges Limits Maximum Gain and provoking irriversible damage

Fast Timing MPGD Principle



σ_t driven by distance fluct's

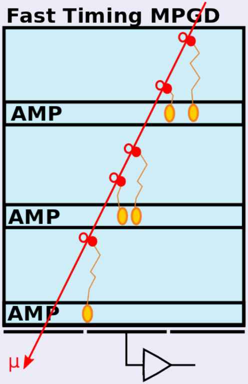
$$\sigma_t \propto 1/(\lambda v_{\text{drift}})$$

$$\lambda = \# \text{ primary cls}$$

electron-ion pairs created close to amplification structure result in fast signals

Fast Timing MPGD: split drift volume in N layers, each with own amplification structure

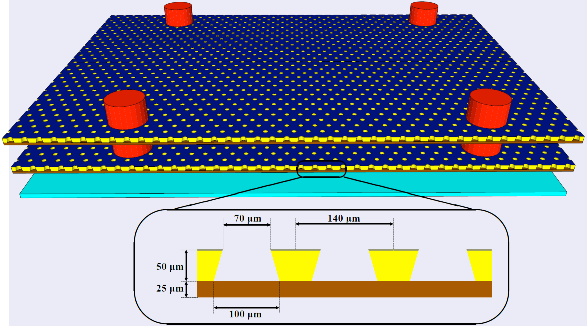
$$\sigma_t \propto 1/(\lambda v_{\text{drift}} N)$$

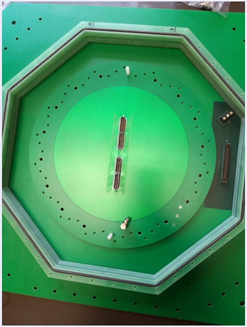


- **resistive structure ⇒ signal from any layer induced in readout**
- **resistive structure ⇒ limits development of discharges**
- **time resolution should improve with N = number of layers**

New FTM Prototype (FTM-v4) :: Design

4-layer prototype: (extendible to 16 layers)





Single layer specifications:

- Drift layer: 250 μm drift layer (Red: Dupont Coverlay spacers)
- Gain layer: 50 μm kapton (Yellow: GEM foil: 70 μm hole, 140 μm pitch)
- Support Layer: 200 μm (Brown: Pre-Preg (glue) + FR4 PCB)
- Resistive coating: 10–100 nm, $\sim$ 100 M$\Omega/\square$ (Blue: Diamond Like Carbon: DLC)

FTM Challenges (General)

FTM requirements:

- detection of single photo-e^- (closest) instead of all e- in drift
  (i.e. factor 10 reduction in charge)
- detection with single amplification layer
  (Triple GEM has amplification divided in three stages)

Therefore:

⇒ need high gain structure, with low spark/discharge rate

⇒ need low noise detector and low noise electronics

⇒ need electronics that can process pulse with low charge ($10^4 e^- = 1.6\,\text{fC}$)

⇒ need electronics that can process and preserve a fast pulse

This Meeting:

- Discuss Future plans for Electronics (FATIC v2)

FTM Challenges (TOF-PET)