Journées de lancement des projets PE et PTC

16-17 November 2017

Saclay

RADIAMM:

Radiation hard DIAmond-based secondary emitter for development of an ultra-fast timing MicroMegas detector

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DRF/IRFU/SEDI

The "Picosec" Project

Started as an RD51 common fund project:

Fast Timing for High-Rate Environments: A Micromegas Solution

Awarded 3/2015

Collaborating Institutes:

- **CEA (Saclay)**
  T. Papaevangelou , I Giomataris, F. Iguaz, M. Kebbiri, M. Pomorski, T. Gustavsson, E. Ferrer-Ribas, D. Desforge, I. Katsioulas, G. Tsiledakis, O. Malliard, P. Legou, C. Guyot, P. Schwemling
- **CERN**
  L. Ropelewski, E. Oliveri, J. Bortfeldt, F. Brunbauer, C. David, J. Frachi, D. Gonzalez-Diaz, M. Lupberger, H. Müller, F. Resnati, T. Schneider, L. Sohl, P. Thuiner, M. van Stenis, R. Veenhof, S. White1.
- **NCSR Demokritos**
  G. Fanourakis
- **NTU Athens**
  Y. Tsipolitis
- **University of Thessaloniki**
  I. Manthos, V. Niaouris, K. Paraschou, D. Sampsonidis, S.E. Tzamarias
- **University of Science and Technology of China (USTC), Hefei**
  Zhiyong Zhang, Jianbei Liu, Zhou Yi

[1] *Present Institute: University of Santiago de Compostela*
[2] *Also University of Virginia.*

2014:
- Submission of the proposal (June)

2015:
- First prototype
- Tests with fs laser
- Publication at MPGD2015 proceedings

2016:
- Laser test (May)
- New chamber
- 3 runs with RD51 muon beam

2017:
- Laser test with new chamber (January)
- New detectors (resistive, pixelated)
- 3 runs with RD51 muon beam

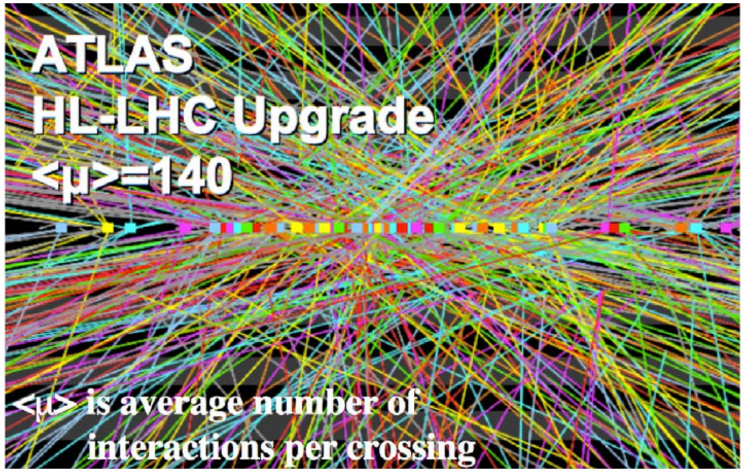
Motivation: why ~10 ps are interesting?

High Luminosity Upgrade of LHC:

- To mitigate pile-up background.
- ATLAS/CMS simulations: ~150 vertexes/crossing (RMS 170 ps).
- 10 ps timing + tracking info.

Extra detector requirements:

- Large surface coverage.
- Multi-pads for tracking.
- Resistance to aging effects.



PID techniques: Alternatives to RICH methods, J. Va'vra, accepted in NIMA, https://dx.doi.org/10.1016/j.nima.2017.02.075

State-of-art precision timing

Solid state detectors

- Avalanche PhotoDiodes: (σ_t ~ 20 ps)
- Low Gain Avalanche Diodes (σ_t ~ 30 ps)
- HV/HR CMOS (σ_t ~ 80 ps)

➔ *Radiation hardness ?*

Gaseous detectors

- RPCs: (σ_t ~ 30 ps)

➔ *High rate limitation*

- MPGDs (σ_t ~ 1 ns)

Question:

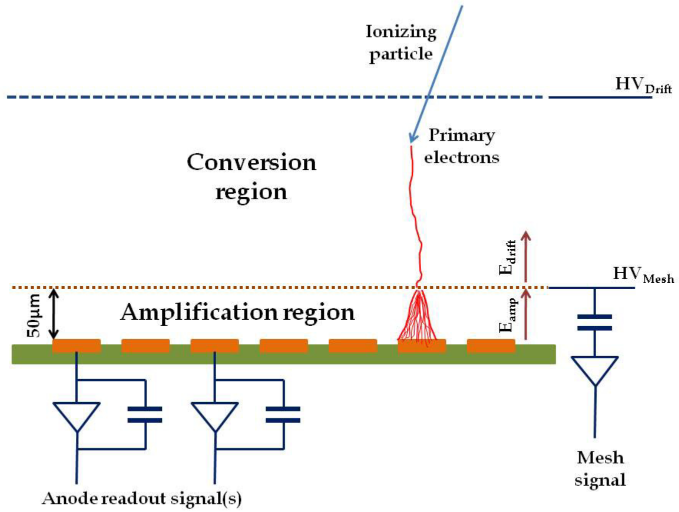
Can a *MicroPattern Gaseous Detector* reach a timing resolution of the order of ***few tens of picoseconds?***

➔ *performance improvement by* ***~2 orders of magnitude***

➔ ***First step: proof of concept***

➔ ***Next steps: Large-area, position-sensitive, radiation hardness***

The Micromegas detector



Conversion region
Radiation create electrons, which drift to the readout plane.

Amplification region
Electrons are amplified & the charge movement induces signals.

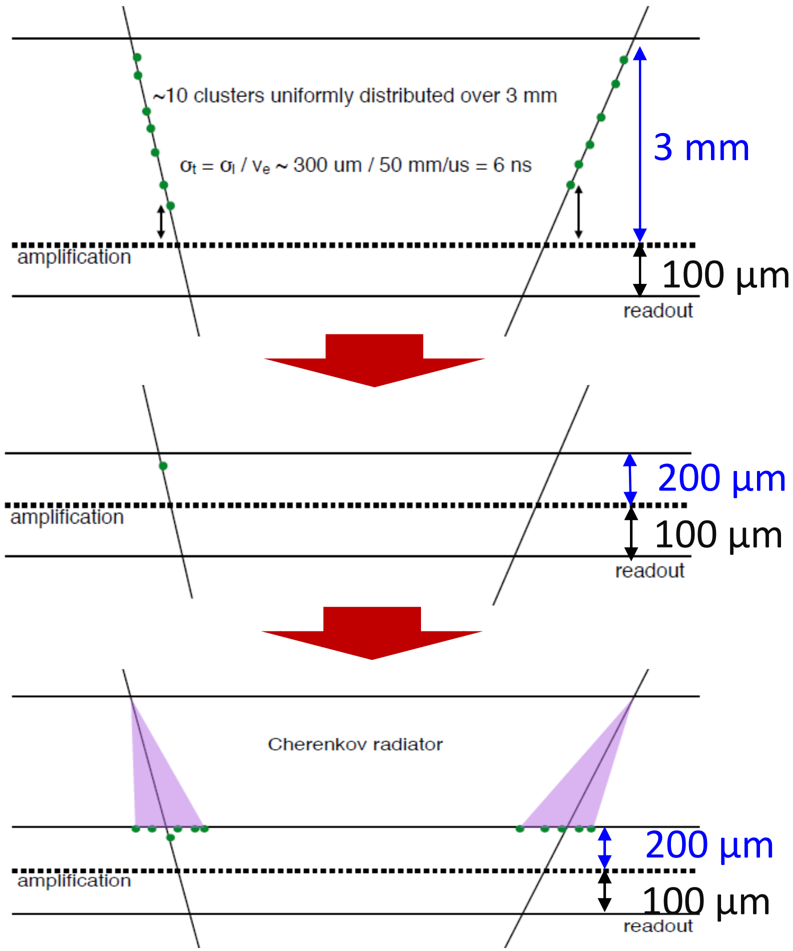
Interesting features for many applications:

Simplicity, Granularity, Homogeneity, Scalability, High rate capabilities, Radiation hardness

Timing limitation factors:

- **Large conversion region:** charges created in different positions.
- **Diffusion effects:** ~0.3 mm/cm$^{0.5}$ -> **~6 ns for 3 mm drift distance!**

Improving the Micromegas timing



Standard MPGD detector:

- **Large ionization volume.**
- **Big diffusion (~ns).**

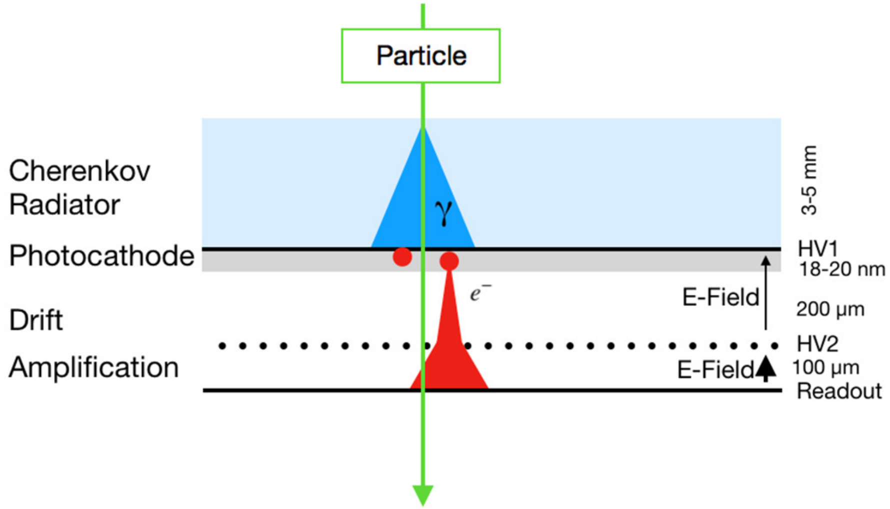
Drift gap is reduced:

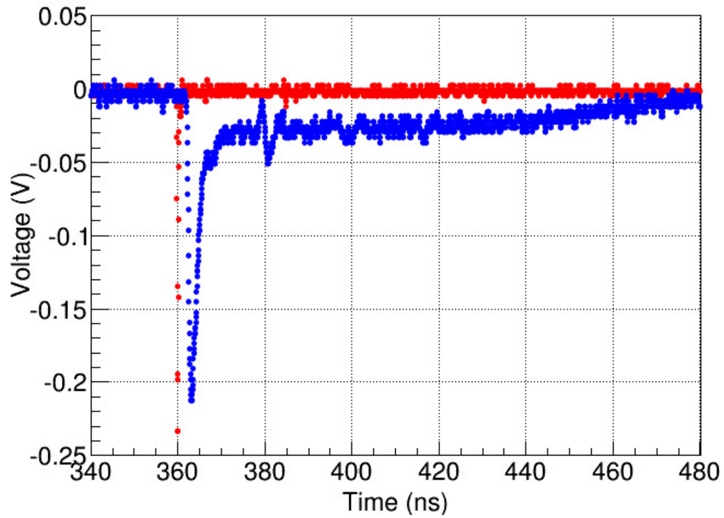
- **Diffusion limited.**
- **Preamplification.**

Cerenkov radiator:

- **Primary electrons localized in time & space.**

The Picosec detector

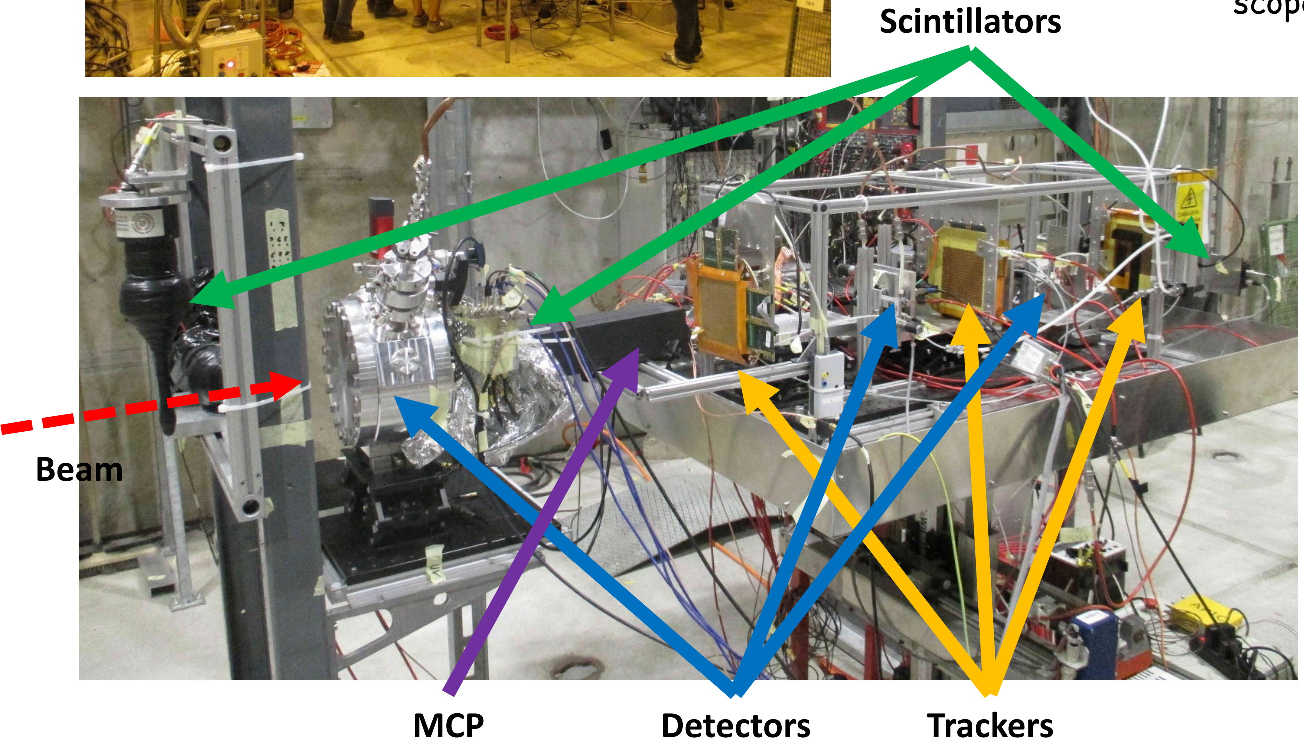


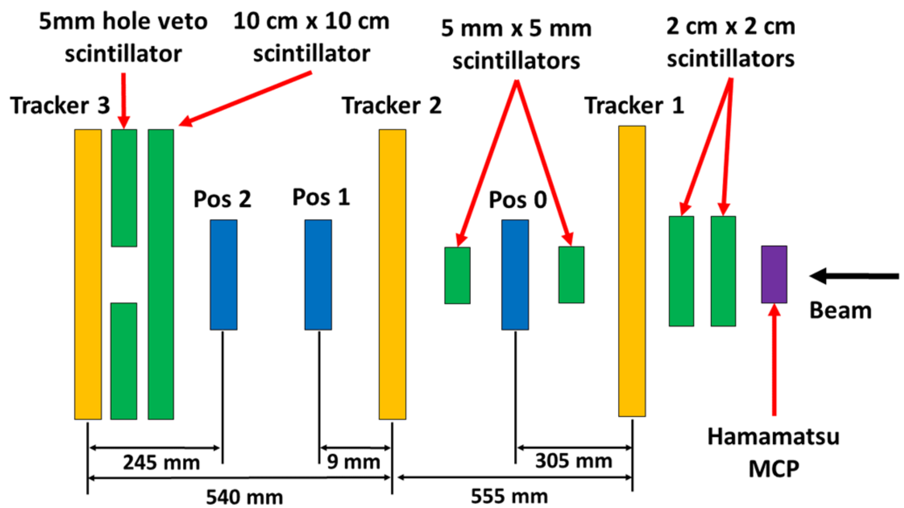


- A particle produce Cerenkov radiation.
- Photons produce electrons in the photocathode.
- Electrons are amplified by a two stage Micromegas detector.
- Two signal components:
  - Fast: ***electron peak*** (~1 ns). -> Timing features.
  - Slow: ***ion tail*** (~100 ns).

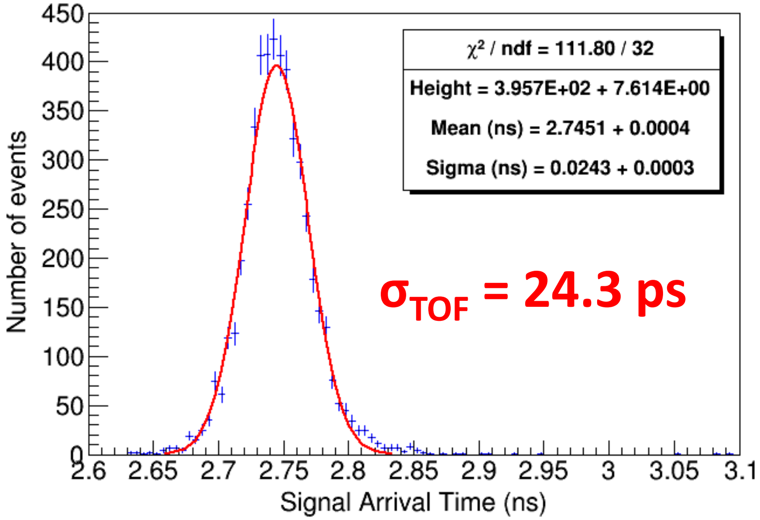
Beam tests with 150 GeV muons @ CERN SPS H4

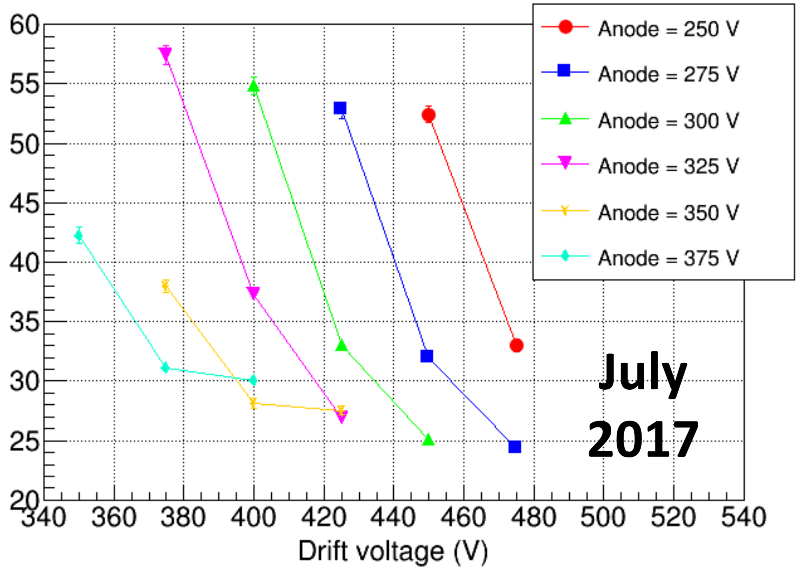
- Trigger: coincidence of two 5x5 mm2 scintillators and a veto downstream (avoid showers)
- Tracker: three GEMs to measure where the triggered particle passed (reject showers too)
- Time reference: two Hamamatsu MCP-PMTs (160 ps rise time)
- Tracking acquisition: APV25 + SRS
- Timing acquisition: CIVIDEC C2 preamp + 2x 2.5 GHz LeCroy scopes (synchronised with the tracker) and SAMPIC





Results of beam tests: 24 ps





- Best result: **24 ps** (bulk MM + Cr/CsI photocathode).
- Optimum operation point: Anode +275V / Drift – 475V.
- Nphe = **10.1 ± 0.7**
- Result repeated in two different beam campaigns.

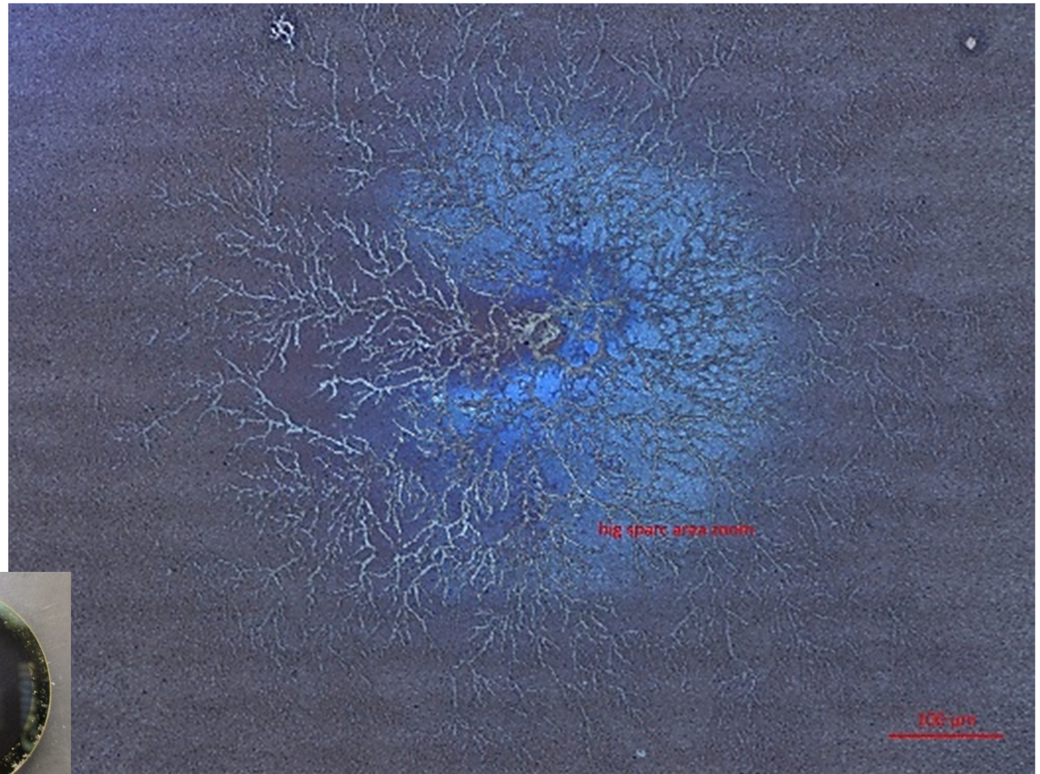
More info: http://irfu.cea.fr/Phocea/Vie_des_labos/Seminaires/index.php?type=6&id=4015 (seminar by F. Iguaz)

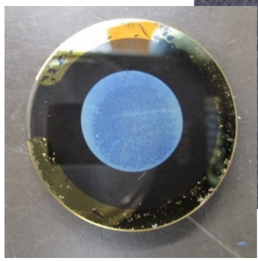
Next steps

- Spark quenching in the mm gap *(ongoing)*
  - ✓ Resistive Micromegas
- Spark quenching in the drift/preamp gap *(under consideration)*
  - ✓ Resistive mesh
  - ✓ Protection or robust photocathode
  - ✓ Graphite - DLC
- Multichannel readout
  - ✓ Pads / pixels
  - ✓ Strips
  - ✓ Multi-channel electronics

Most critical: *an efficient & robust photocathode against sparks & ion feedback*

➔ RADIAMM project





A picture of sparks in a CsI photocathode

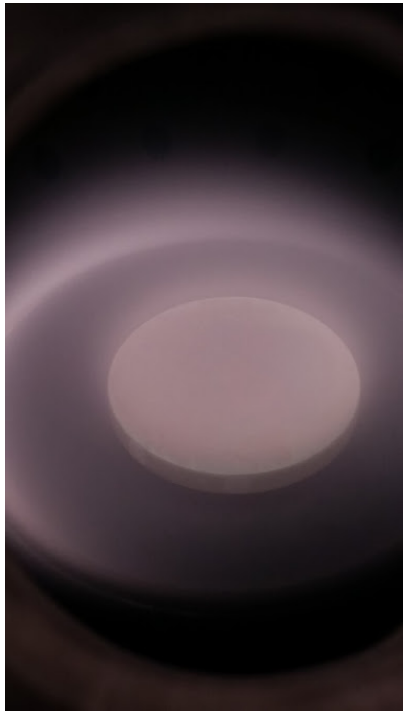
The RADIAMM project

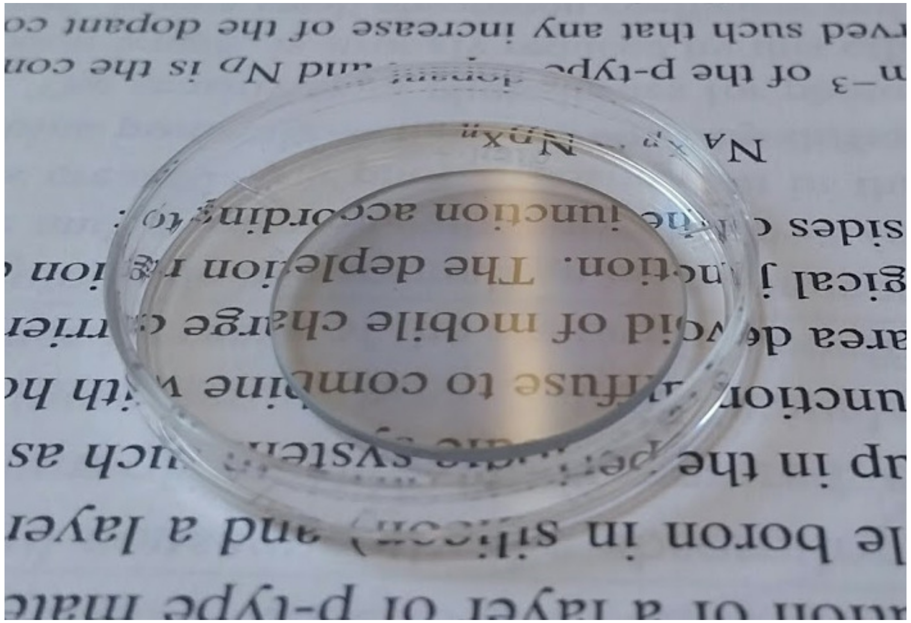
A 3-year project, starting on 1st November 2017 with objective:

RAdiation hard DIAmond-based secondary emitter for the development of an ultra-fast timing MicroMegas detector

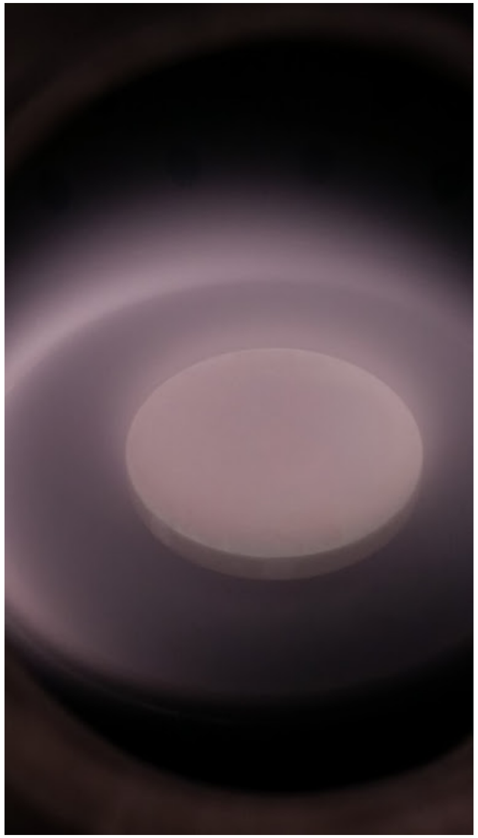
Main Partners:	Partner tasks:
➢ CEA/DRF/Irfu/DEDIP (Thomas Papaevangelou)	➢ Coordination ➢ Multi-channel detector ➢ Establish a test bench for QE measurements and aging tests
➢ CEA/DRT/List/DM2I/LCD (Michal Pomorski)	➢ Diamond photocathode ➢ ***Secondary Emitters***
➢ CEA/DRF/Iramis/Lidyl/DICO (Thomas Gustavsson)	➢ Time resolution measurements for the multi-channel prototype

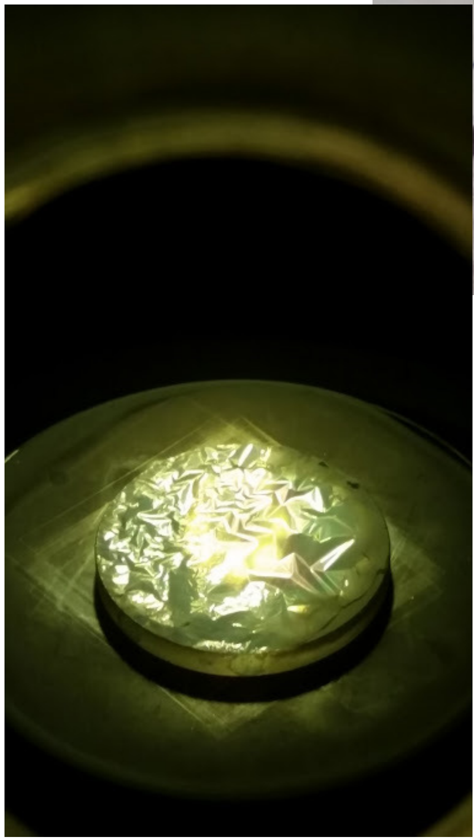
BNCD growth on quartz

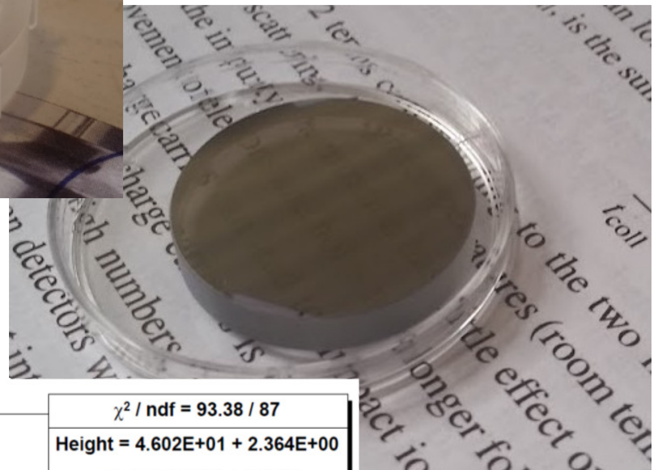


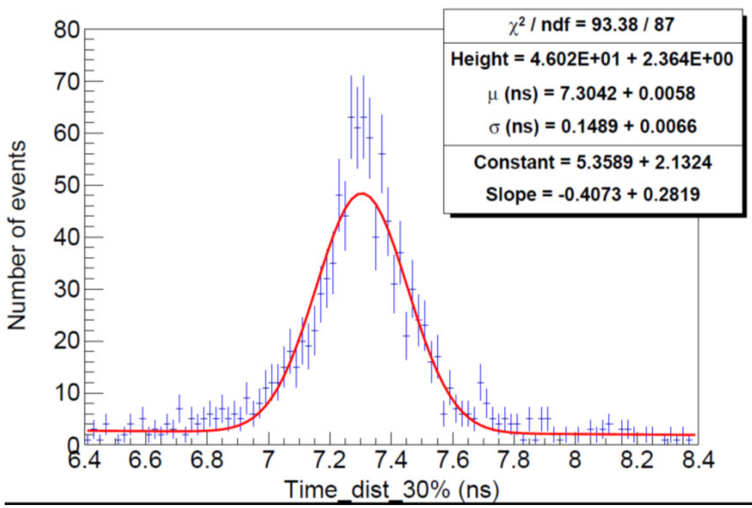


BNCD growth on MgF2









Conclusions - Outlook

We have coupled a Micromegas detector with a radiator / photocathode in order to **surpass the physical constrains on precise timing with MPGDs**, aiming to an important improvement of their performance (~two orders or magnitude are needed in order to be considered for the HL-LHC upgrade)

- The detector has been tested with a **femtosecond UV laser** in order to investigate **the time spread of single photoelectrons**.
  σ_t ~ 70 ps for single p.e. has been measured for strong drift field with a standard bulk Micromegas in **semi-transparent** mode, without gas circulation.

- The Micromegas photodetector has been tested with 150 GeV muon beam. Data taking is on-going.
  σ_t ~ 25 ps has been measured for 3 mm MgF2 + 5.5 nm Cr substrate + 18 nm CsI photocathode. The estimated number of photoelectrons for this photocathode was: **$\langle N_{p.e.} \approx 10$**

- Results from various radiator/photocathode setups are pending.

  ➔ *Still some margin for improvement: gas / drift gap / photocathode studies & optimization*

  ➔ ***Single p.e. result very interesting for less efficient but more robust photocathodes** (metallic, praphite/DLC, polycrystalline diamond…)*

The **RADIAMM** project aims to address:

- ***Multiple-pad readout performance***
  - ✓ Design a pixelated prototype (~5x5 cm^2)
  - ✓ Readout Electronics (Sampic/FAMMAS amplifiers)
- ***Radiator & photocathode aging / radiation hardness***
  - ☞ IBF, photon feedback, discharges
  - ☞ Particle flux (high rate tests @ IRAMIS / SEDI)
  - ☞ Deterioration with time
  - ✓ Metallic photocathodes
  - ✓ **DLC / polycrystalline diamond photocathodes**
  - ✓ *Operation in reflective mode*
- ***Polycrystalline diamond as secondary emitter***
  - ✓ Replace the crystal + photocathode with secondary electron emitter
    - ☞ Robustness / radiation hardness
    - ☞ No radiator - flexible choice of substrate material
    - ☞ Possibility to increase thickness towards 1 μm!
  - ✓ Investigate materials with high secondary electron yield. (Doped-) diamond deposition, DLC, graphene…

  - ☞ *multi layer detector*
  - ☞ *graphene layer for photocathode protection ?*

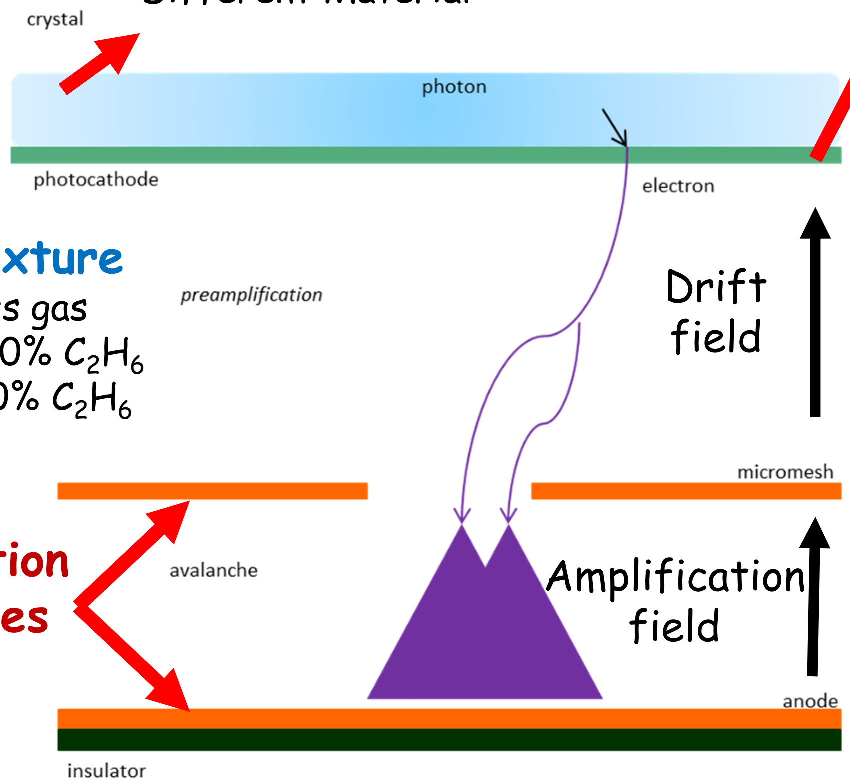
Detector optimization

Crystal:
- Different Thicknesses of MgF2 (2,3,5mm)
- Different Material

Photocathode:
1) CsI and different:
- producer (CERN, Saclay)
- thicknesses (11, 18, 25, 36nm)
- metallic interface (Al, Cr) & thicknesses (Cr 3, 5.5nm)

2) Pure metallic
- Al(8nm), Cr (10,15,20nm)
- Diamond, B-doped Diamond

Gas Mixture
- Compass gas
- CF4 + 10% C_2H_6
- Ne + 20% C_2H_6



Operation voltages

Micromegas:
- standard bulk
- bulk with 6 pillars
- thin mesh bulk
- Resistive (different values)