AIDA innova

Advancement and Innovation for Detectors at Accelerators

Second Project Review meeting

Thursday 20 June 2024
CERN

WP7 report: Gaseous Detectors

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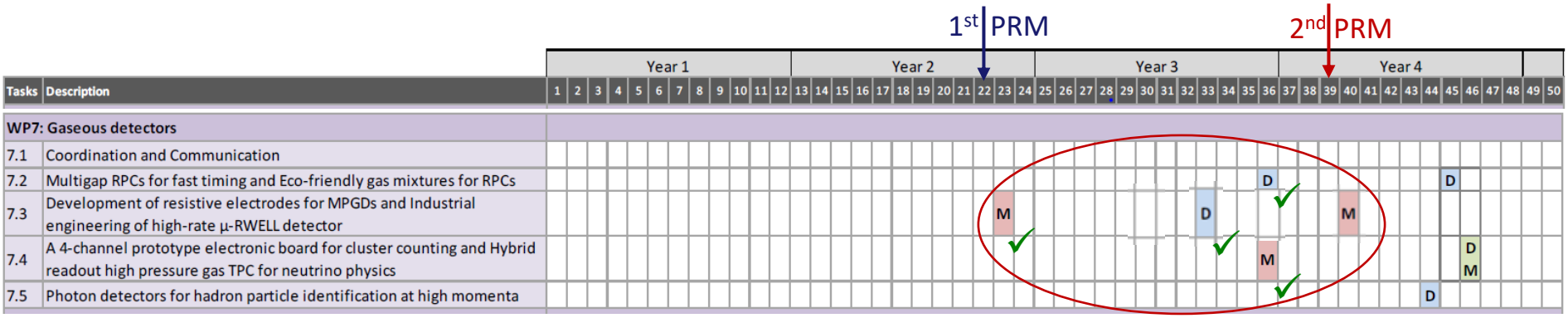
The Goal of WP7, Gaseous Detectors:

- The aim of the activities of WP7 is to advance gaseous detectors for instrumenting large areas and volumes to match the challenging requirements of future experiments in terms of resolution, timing, rate capability and radiation hardness.
- The pursued technologies are RPCs, MPGDs for muon systems or hadron calorimeters, drift chambers, high-pressure TPCs for long-baseline neutrino experiments and Ring Imaging Cerenkov detectors for particle identification.
- The work includes the construction, with industrial partners, of small prototypes and their test, the study of new materials such as diamond-like carbon and the search for eco-friendly gas mixtures.

Task Overview

- **Task 7.1: Coordination and Communication** (S. Dalla Torre, BS)
- **Task 7.2: RPC sector** **3 tasks**
  - 7.2.1: Multi-gap RPCs (MRPCs) for fast timing (C. Williams)
  - 7.2.2: Shower development in SDHCAL (Mary-Cruz Fouz)
  - 7.2.3: Eco-friendly gas mixtures for RPCs (B. Mandelli, D. Piccolo)
- **Task 7.3: MPGD sector, Technology and engineering** **2 tasks**
  - 7.3.1: Development of resistive electrodes for MPGDs (P. Verwilligen)
  - 7.3.2: Industrial engineering of high-rate μ-RWELLs (G. Bencivenni)
- **Task 7.4: Large volume gaseous detectors** **2 tasks**
  - 7.4.1: A 4-channel electronic board for cluster counting (F. Grancagnolo)
  - 7.4.2: High pressure gas TPC for neutrino physics (X. Lu, D. Gonzalez Diaz)
- **Task 7.5: PID sector** **1 task**
  - Photon detectors for hadron Particle ID at high momenta (S. Dalla Torre)

Milestones & Deliverables

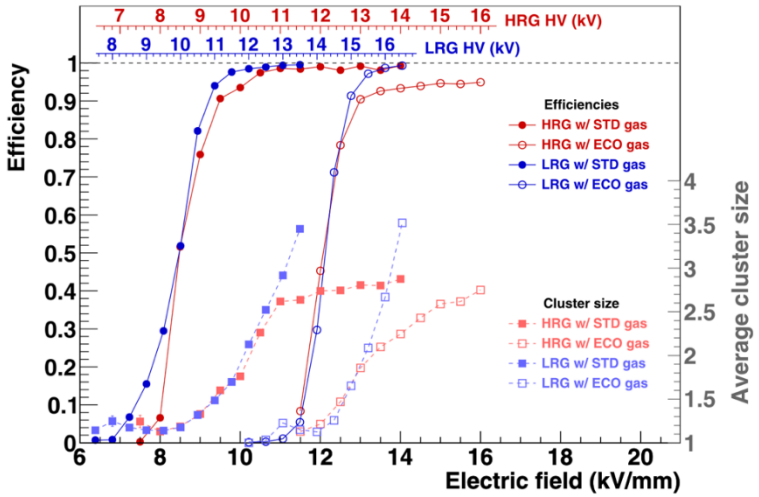


Several Deliverables and Milestones came up since the 1st Project Review Meeting:

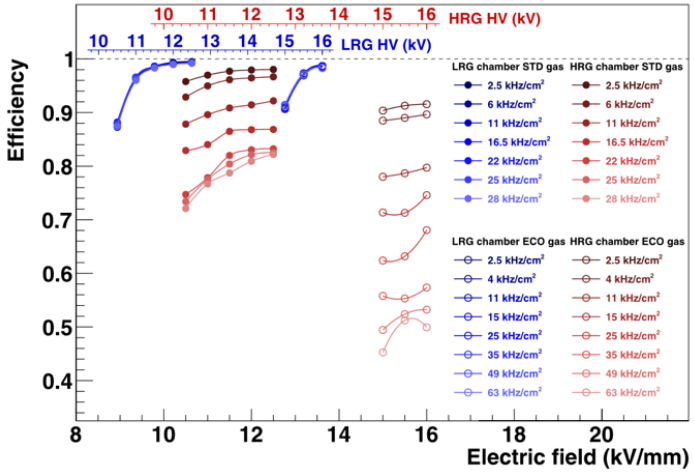
- Milestone MS26: *Production of DLC with ion beam deposition and pulsed laser deposition*, due in M23 and has been achieved on time.
- Deliverable D7.3: *Production with industry of small-size prototypes of μ-RWELLs,* due in M30, has been delayed to M33 and achieved.
- Milestone MS27: *Build a 0.3×0.3 m^2 prototype and the readout plane with the new structure,* due in M36, has been delayed to M40.
- Deliverable D7.2: *Characterisation of small size MRPC prototypes for fast timing and high rates*, due in M36, has been achieved.
- Milestone MS28*: Identification of a gas mixture for neutrino physics in an optical TPC, due in M36,* has been achieved.
- **Some details and results will be presented in the following slides, together with progress and plans towards the remaining milestones and deliverables.**

Task 7.2.1: MRPCs for fast timing

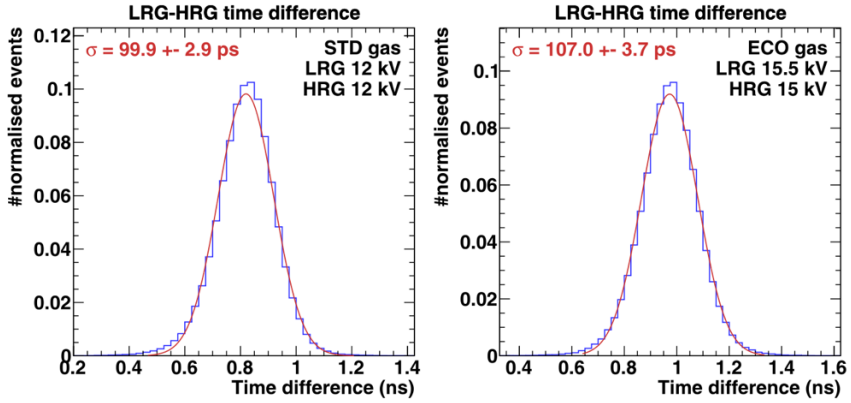
- **MRPC developments for fast timing (D7.2)**:
  - MRPC with 10 layers and 230μm gaps.
  - Glass sheets with low-resistivity (LRG ~10^9 Ωcm), and high-resistivity glass (HRG ~10^{12} Ωcm) used.
  - Standard (98% $C_2H_2F_4$ 2% SF_6 GWP 2040) and ECO (100% HFO1234ze GWP 6) gas mixtures were used.



- **Good performance of LRG, even with ECO gas, but at much higher voltage (+4kV).**
- **Rate performance with beam spot of 4 cm²**

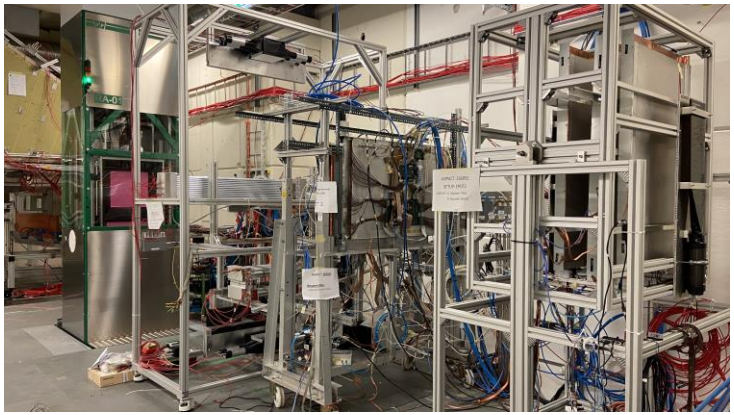


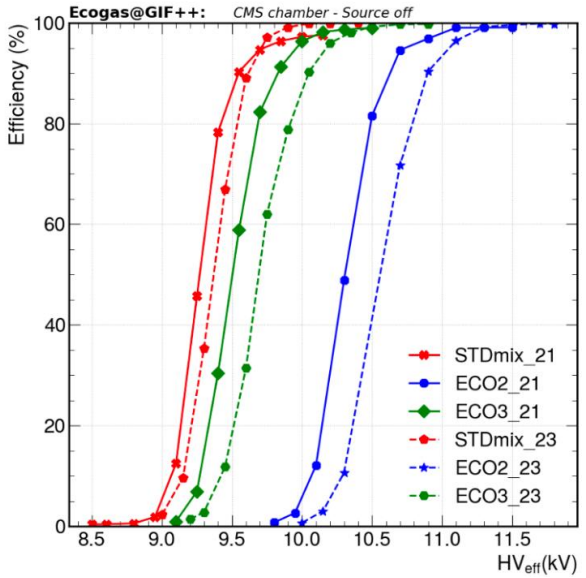
- **Time resolutions measure: ~100ps**



Task 7.2.3: Eco-friendly RPC Gas Mixtures

- Set-up installed at GIF++ facility
  - 12 TBq ^{137}Cs source → Long-term aging test
  - H4 Muon beam in some periods of the year → Test-beam to study detector performance
- RPCs from ALICE, ATLAS, CMS, EP-DT and SHiP tested
- Two eco-friendly gas mixtures tested:
  - STD (GWP 1482): 95.2% R134A, 4.5% iC_4H_{10}, 0.3% SF_6
  - ECO2 (GWP 485): 60% CO_2, 35% HFO, 4% iC_4H_{10}, 1% SF_6
  - ECO3 (GWP 529): 69% CO_2, 25% HFO, 5% iC_4H_{10}, 1% SF_6
- Since July 2022: long-term aging test started with ECO2 gas mixture, monitoring the currents
  - Goal is to collect about 1 C/cm^2





2021

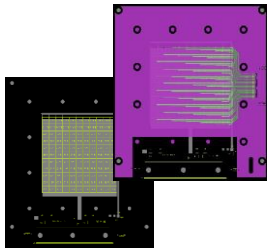
2023

- **Performance comparison for different gas mixtures after irradiation (~120 mC/cm^2)**

Task 7.3.2: Industrial Engineering of µ-RWELL

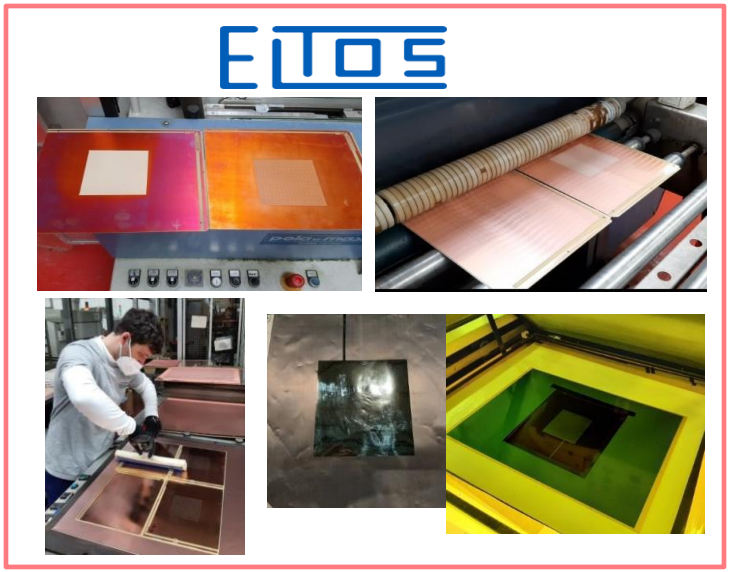
µ-RWELL technology transfer loop (LNF – CERN – ELTOS)

LAYOUT design

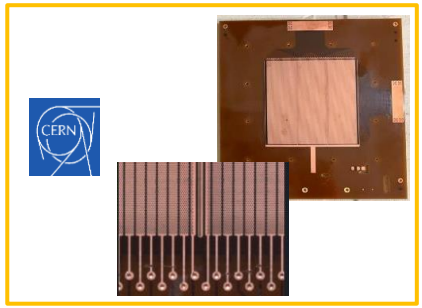


Feedback from tests

PCB production



Final detector manufacturing



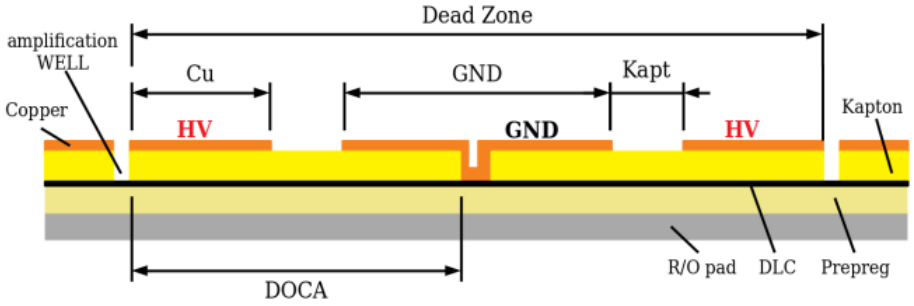
DLC foil production (*)

***DLC Magnetron Sputtering machine co-funded by CERN and INFN**

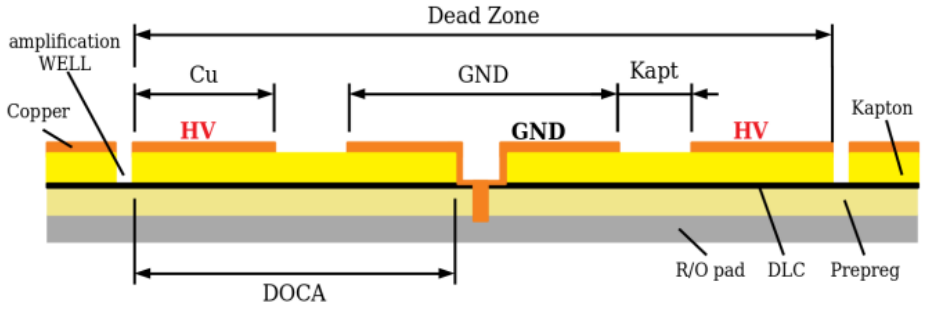
Task 7.3.2: Industrial Engineering of μ-RWELL

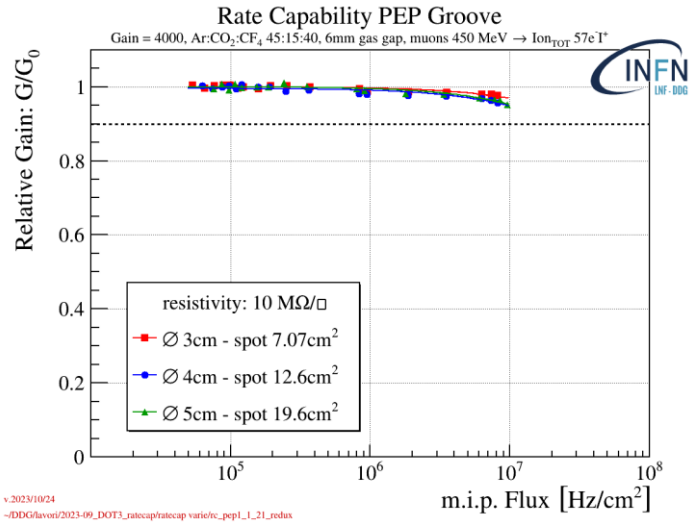
Two high-rate configurations with grounding networks realized and tested:

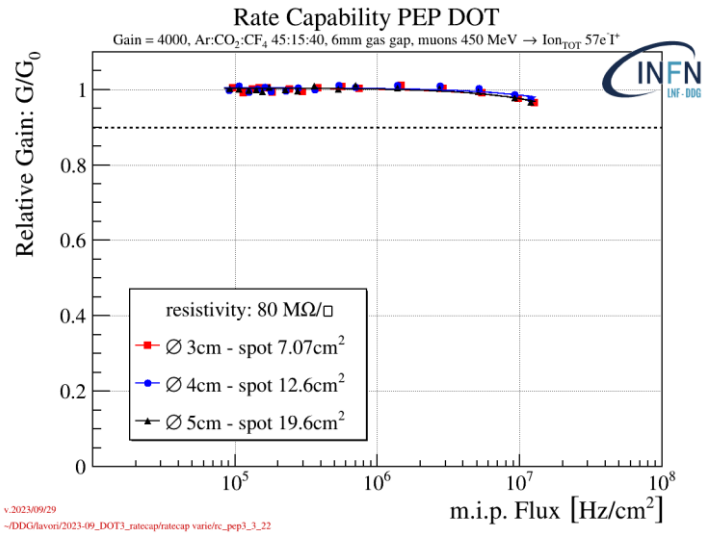
PEP-Grove layout



PEP-DOT layout (2-3% less dead zone)







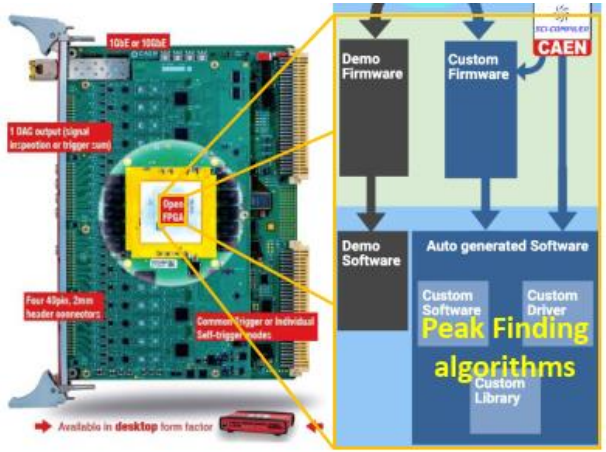
- **A 0.3×0.3 m² prototype is currently under construction and will be tested shortly (MS27)**

Task 7.4.1: Cluster Counting

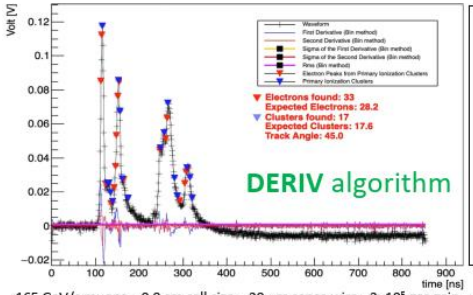
- **Cluster counting in gaseous detectors is mainly a matter of the read-out electronic chain**
- **Several hardware and software approaches are pursued**

1. **ADC32RF45 or LMH6522) + FPGA KCU105**
2. **NaluScientific**
   - 4ch ASoCv3
   - 32ch HDSoCv1

3. **CAEN VX2751**



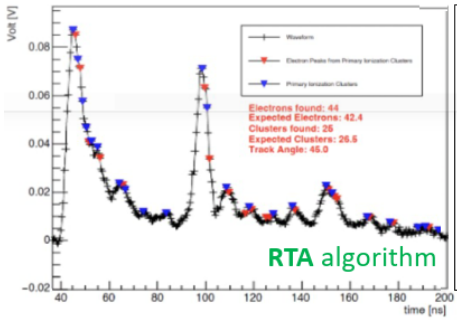
- **Peak finding algorithms**



Compute the first and second derivative over a pre-defined number of bins and compare them to thresholds in terms of a r.m.s. value, where. r.m.s. is a measurements of the noise level in a control region of the waveform.

165 GeV/c muons – 0.8 cm cell size – 20 μm sense wire - 2×10^5 gas gain – 90% He/10% iC_4H_{10} (m.i.p.: 12 clusters/cm) - 45° track angle –12 bits at 1.2 Gsa/s

- DERIV is based on the 1st and 2nd derivative of the digitized signal function



Define a digitized pulse template with raising and falling exponentials.

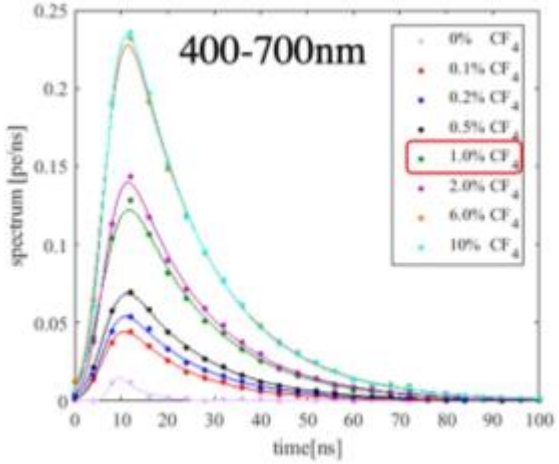
Scan the data waveform by comparing it to the template, normalized to the amplitude, and construct a χ^2. If above threshold, subtract the found peak from the waveform and iterate until no new peaks are found.

same as above except 80% He/20% iC_4H_{10} (m.i.p.: 18 clusters/cm)

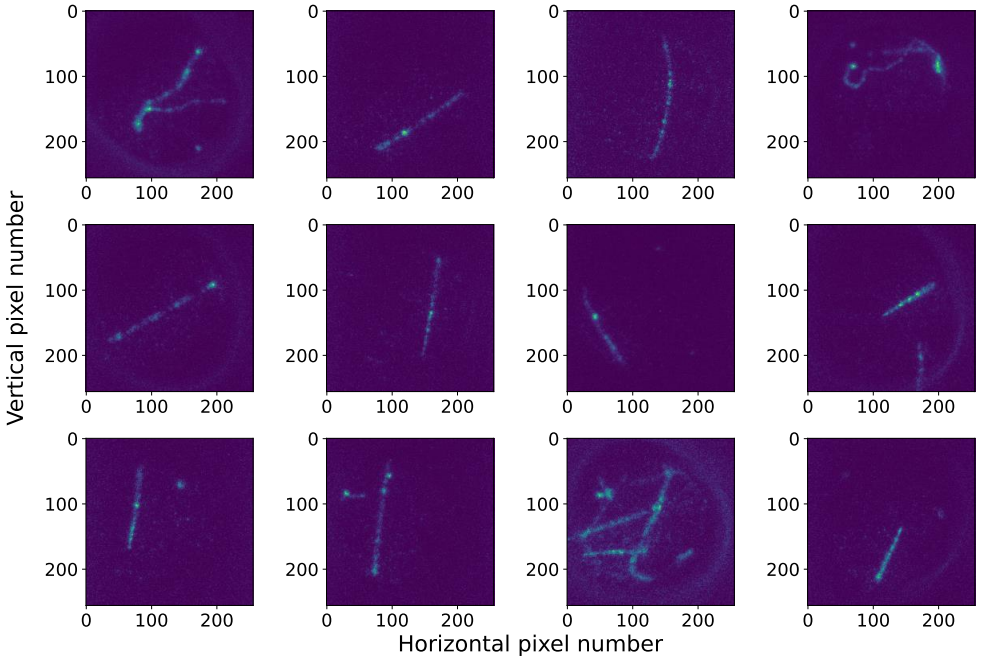
- RTA is based on a bin-by-bin matching of the signal waveform with a normalized search template

Task 7.4.2: Hybrid readout for a high-pressure gas TPC

- **Two main goals:**
  - Optical read-out of photoluminescence, combined with charge read-out for 3-D images
  - Innovative gas mixtures with scattering off different nuclei
- The team demonstrated the possibility of doing time-tagging and accurate particle tracking simultaneously using an Ar-based TPCs at 10 bar with the addition of 1% CF_4 (which acts as WLS)
- It can be used in next-generation neutrino experiments.



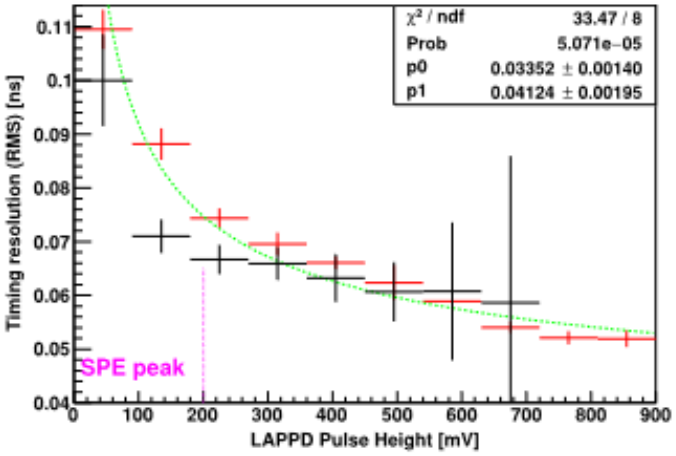
- Scintillation light time profile for α-tracks



- Cosmic rays detected from luminescence by a CCD camera in Ar/CF_4 (99%/1%)

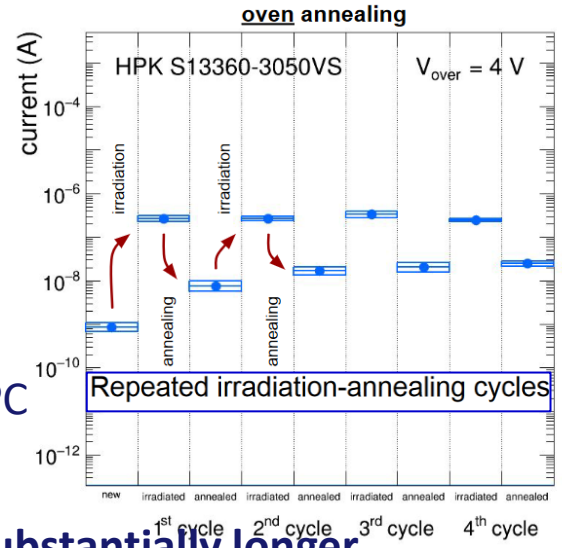
Visible-light Photo Detectors insensitive to magnetic fields

1. **LAPPDs:** Time resolution assessment completed and published (NIM A 1058 (2024) 168937)
   Cherenkov photons generated in a quartz lens radiator at the CERN PS test beam



Response from two different LAPPD pads, detecting single photons (black) or with a probability for more than 1 photon (red)

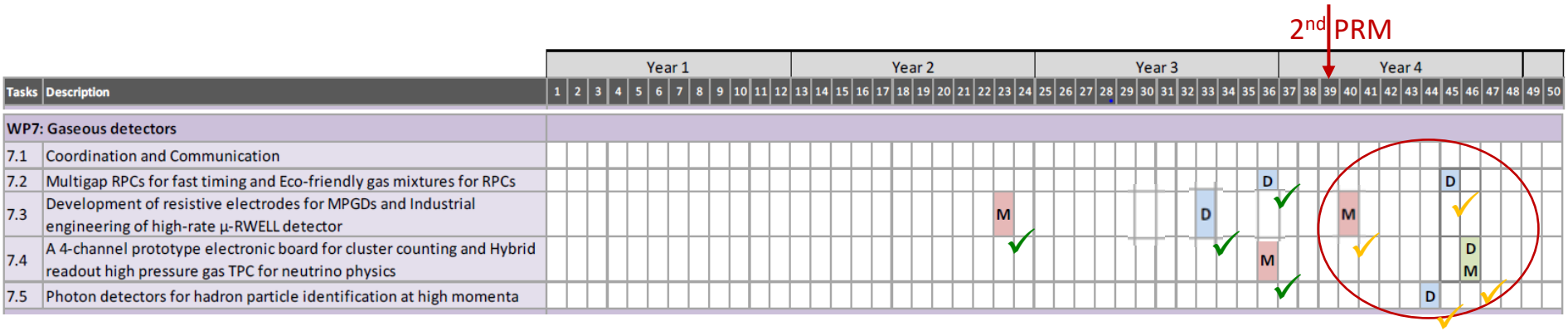
SPE time resolution ~75ps



2. **SiPMs:** recovery of radiation damage by thermal annealing proven, also iterating cycles; current measured at – 30°C
   Annealing cycles in oven at 175°C – 30 min
   Irradiation at each cycle: 10^9 n_{eq}/cm^2

→ **The sustainable integrated dose for SIPMs is made substantially longer**

Milestones & Deliverables



Deliverables and Milestones coming up in the time ahead :

- Milestone MS27: *Build a 0.3×0.3 m^2 prototype and the readout plane with the new structure,* delayed to M40, on track
- Deliverable D7.5: *Small-size prototype of a MPGD single photon detector for compact RICH detectors* due in M44, on track.
- Deliverable D7.2: *Validation of the eco-friendly gas mixtures for RPCs at GIF++,* due in M45, on track.
- Deliverable D7.4: *A small-scale TPC prototype with hybrid charge/optical read-out and a hydrogen rich gas mixture with high scintillation yield,* due in M46, tbc.
- Milestone MS29: *Design electronics for cluster counting and production of a 4-channel prototype,* due in M46, on track

- **Good progress in all tasks of WP7**