2^{nd} AIDAinnova Annual meeting Valencia

WP7 report: Gaseous Detectors

Silvia Dalla Tore (INFN-Trieste), Burkhard Schmidt (CERN)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004761.

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 (A. Deisting)
- **Task 7.5: PID sector** **1 task**
  - Photon detectors for hadron Particle ID at high momenta (S. Dalla Torre)

Partners

		Beneficiaries							Associated Partners				
	7.1	CERN	INFN-Trieste										
	7.2.1	INFN-Bologna	LIP-Coimbra	Univerity of Clermont-Ferrand	PICOTECH SAS				Tsinghua University	Shenzhen Institute of Advanced Technology	Seoul National University Bundang Hospital	IRIS Co.	Benemérita Universidad Autónoma de Puebla
	7.2.2	CNRS - IP2I	CNRS - LPC	CNRS - OMEGA	CIEMAT								
Tasks	7.2.3	CERN-EPDT	INFN-Frascati	INFN-Roma2	INFN-Bologna	INFN-Bari	INFN-Torino	Ghent University					
	7.3.1	INFN-Pavia	INFN-Bari	INFN-Lecce									
	7.3.2	INFN-Frascati	INFN-Bologna	INFN-Ferrara	CERN	ELTOS							
	7.4.1	INFN-Lecce	CAEN										
	7.4.2	RHUL	UOXF	INFN-Bari	USC	CERN	CSIC-IFIC						
	7.5.1	INFN-Trieste	INFN-Bari	INFN-Bologna	Charles University				USTC	INCOM			

- **Strong collaboration with industry (yellow boxes)**
- **Wide and solid links also outside Europe**
- **Bi-lateral agreements with non-European partners have been signed last year**

Milestones & Deliverables

		Year 1												Year 2												Year 3												Year 4														
Tasks	**Description**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
WP7: Gaseous detectors																																																			
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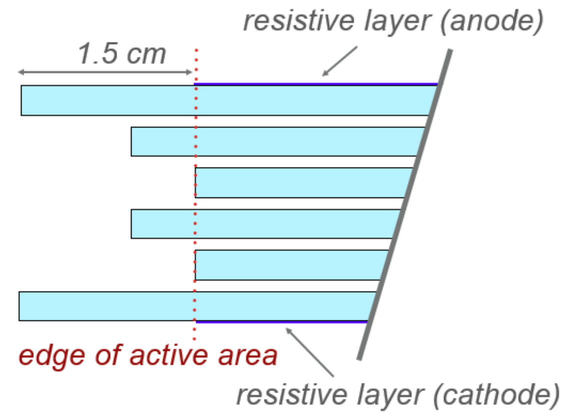
7.4	A 4-channel prototype electronic board for cluster counting and Hybrid readout high pressure gas TPC for neutrino physics																																				M										D M				
7.5	Photon detectors for hadron particle identification at high momenta																																												D						

- The first milestone of WP7 has been successfully achieved!
- We have a couple of Deliverables and Milestones coming up.
- I will address the plans and progress towards the achievement of these milestones and deliverables.

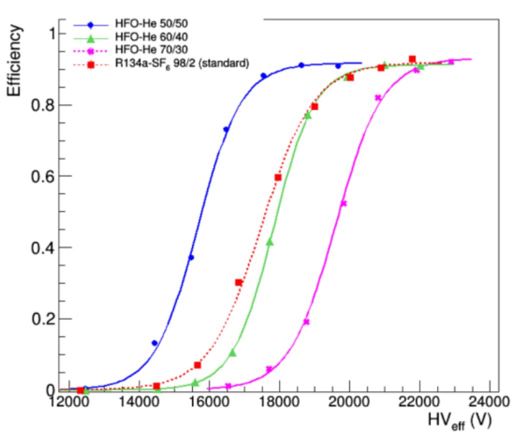
Ongoing work for Task 7.2.1

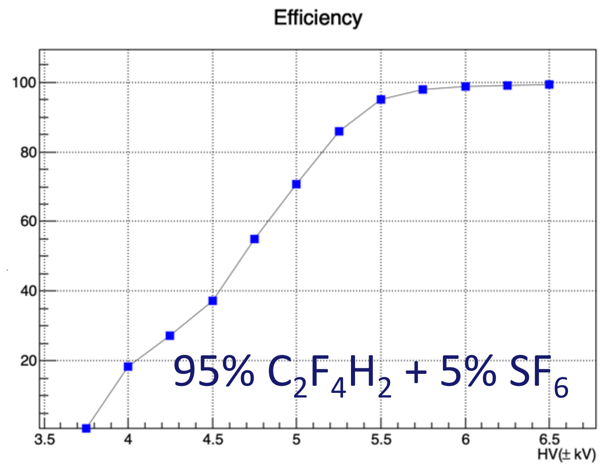
Task 7.2.1: MRPCs for fast timing

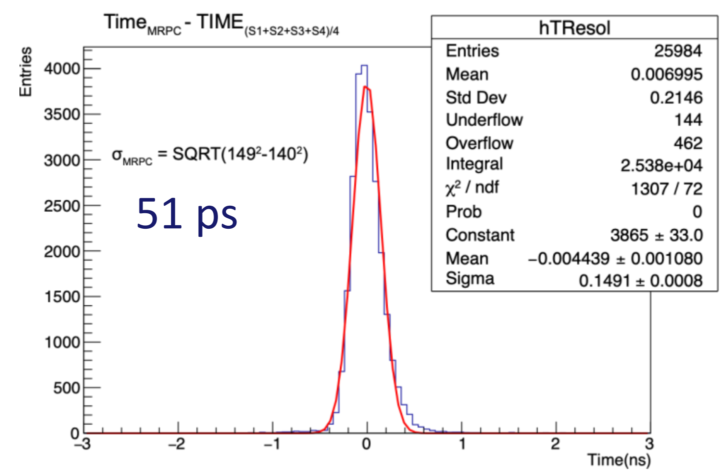
- **MRPC developments for fast timing**:
  - Construction of gas-tight boxes and readout boards in Bologna to produce series of MRPCs.
  - Glass sheets include new low-resistivity glass (10^9 Ωcm), 10 layers with 230μm gaps, made with coated nylon lines.
  - High dark current issues in the edge area have been solved.



- **Beam-tests at T10 at CERN ongoing:**



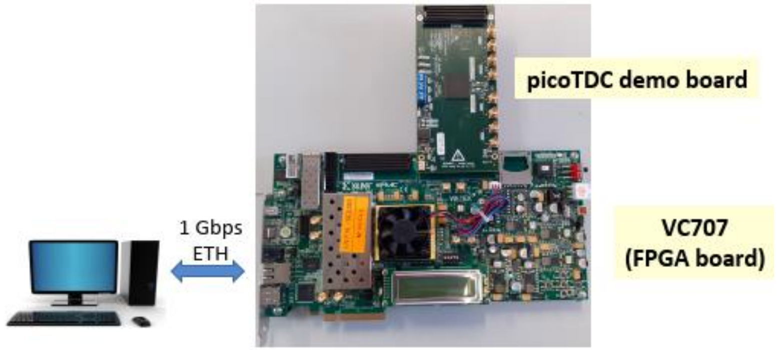


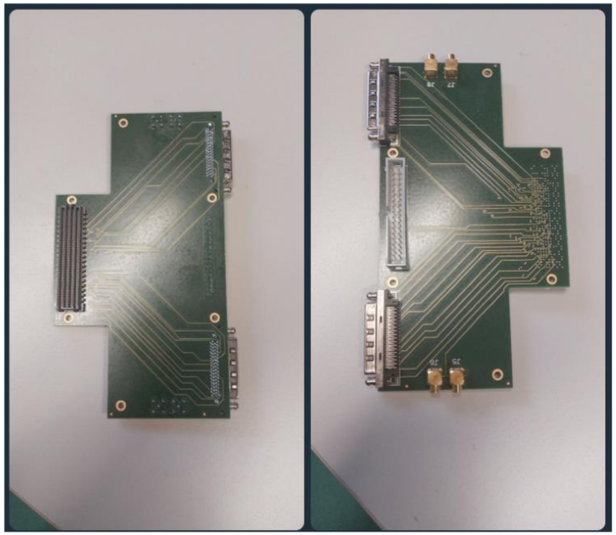


Task 7.2.1: MRPCs for fast timing

- **picoTDC cards for MRPC**
  - time resolution of picoTDC better than 5 ps, readout with NINO ASIC.
- **Status:**
  - Test setup needed to evaluate picoTDC coupled with the VC707 Xilinx FPGA board completed
  - Designed and produced FMC adapter card to connect MRPC NINO FEA to picoTDC
  - Use on test beams in spring 2023 at CERN
- **Outlook:**
  - As a second step, we are designing a custom board with 2 picoTDCs and 1 FPGA for higher channel count and higher data rates with USB-C interface.

  → **A general purpose card for beam- and lab-test**

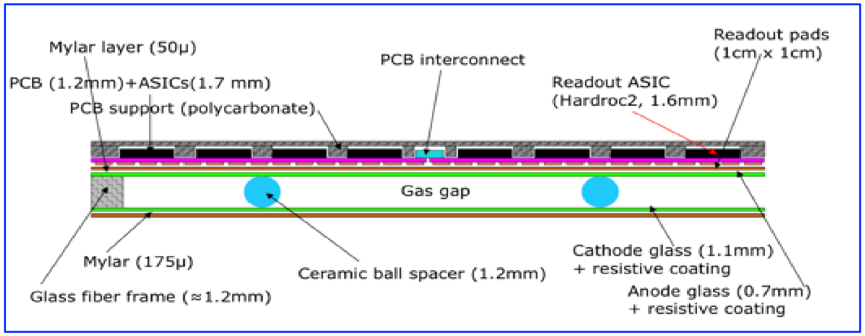




Task 7.2.2: Shower development in SDHCAL

- *Detector*: **GRPC (Glass Resistive Plate Chambers)** operating in **avalanche mode**

GRPC Sketch



- **1x1 cm^2 pads, Semi-Digital Readout**:
  2bits **-** 3 thresholds, counting how many/which pads have a signal larger than one of the 3 thresholds

- **Embedded electronics:**
  PCB separated from the GRPC by a mylar layer (50μm).
  HARDROC (**HA**dronic **R**pc **R**ead**O**ut **C**hip) & related connections

➢ **General goal**: Extend SDHCAL to include timing information (100 - 200ps resolution) for 5D-calorimetry (space, amplitude & timing)

➢ **Implementation**: Build small multi-gap RPC (MRPC) equipped with a new version of electronics with timing capabilities to prove the final performance

Ongoing work for Task 7.2.2

Task 7.2.2: Electronics for SDHCAL

Petiroc2A/B   Baseline ASIC

Has some limitations:
- difficult to chain, limited digital logic, dead-time

➢ Only for exploring the capabilities.

- 32 channels
- on-chip TDC
- Time resolution below 40ps

Developed at CNRS-OMEGA partially thanks to AIDA2020 for CMS-muon upgrade

NINO   Other ASICS being or to be used

- ASIC designed for the ALICE MRPC (TOF array)
- 8 channels, Time resoltion ~50 ps

LiROC+picoTDC

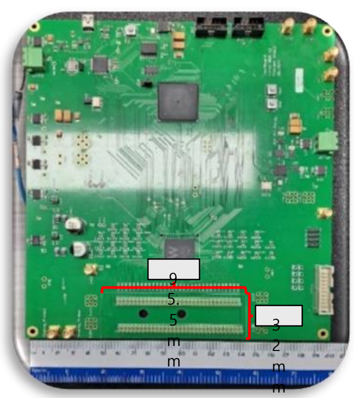
Board is under development by the WEEROC company

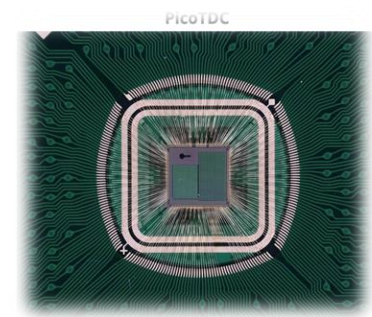
Based on LiROC + picoTDC

64-channel ASIC

64 channel TDC ASIC

Time resolution <12 ps



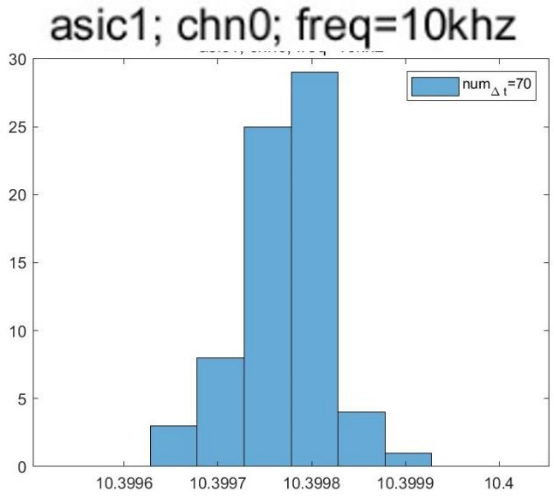


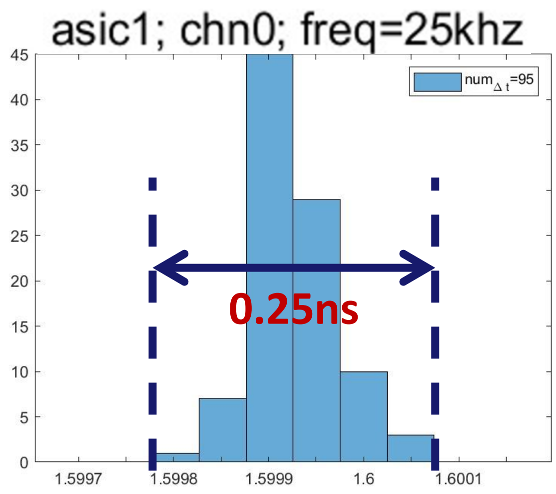
Task 7.2.2: Tests with Petiroc2B ASIC

Same signal injected into two chips (with a double-pass).

$\mathbf{\Delta t_{12}}$: Δt between two Petiroc2B chips of each hit.

$\overline{\Delta t_{12}}(\mu s)$	$\mathrm{std}(\Delta t_1)(ps)$	$\mathrm{std}(\Delta t_2)(ps)$	$\mathrm{std}(\Delta t_{12})(ps)$	$f_{sig}(kHz)$
5.8000	41.0912	49.5356	73.5276	25
5.7999	48.6895	51.9453	78.4336	10

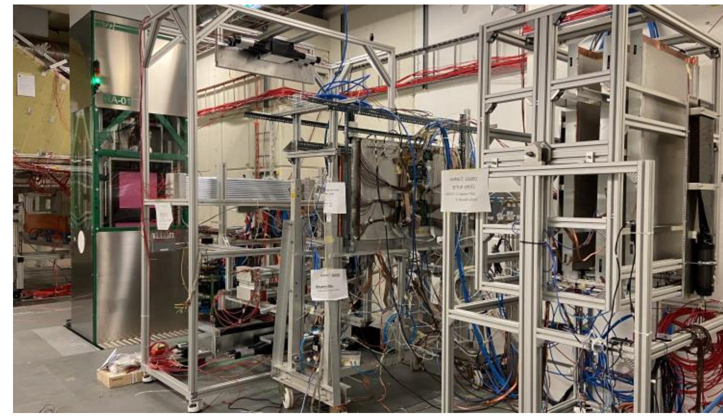




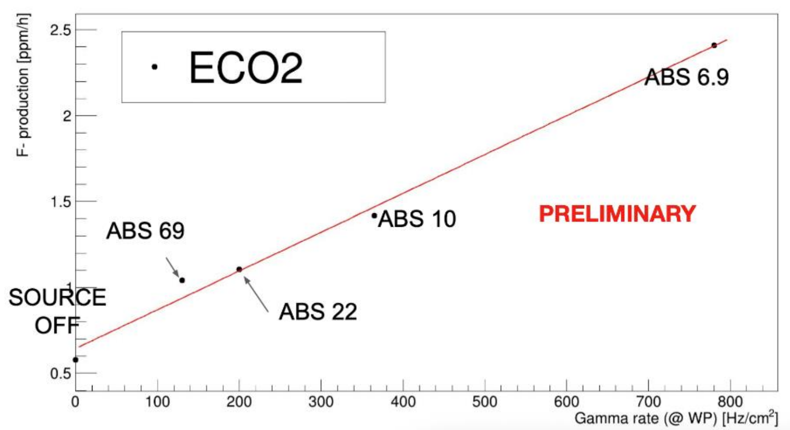
Ongoing work Task 7.2.3

Task 7.2.3: Eco-friendly gas mixtures for RPCs

- 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 LHCb/SHiP tested
- Two eco-friendly gas mixtures tested:
  - STD: 95.2% R134A, 4.5% iC_4H_{10}, 0.3% SF_6
  - ECO2: 60% CO_2, 35% HFO, 4% iC_4H_{10}, 1% SF_6
  - ECO3: 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
  - Dedicated F^- measurements performed before starting irradiation campaign

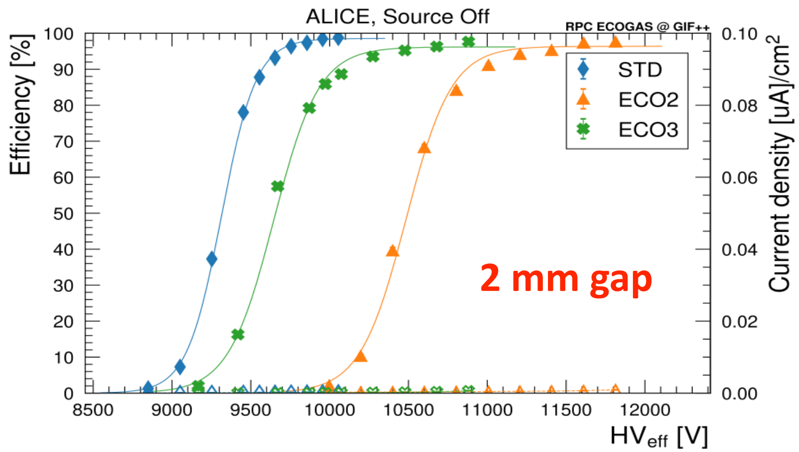


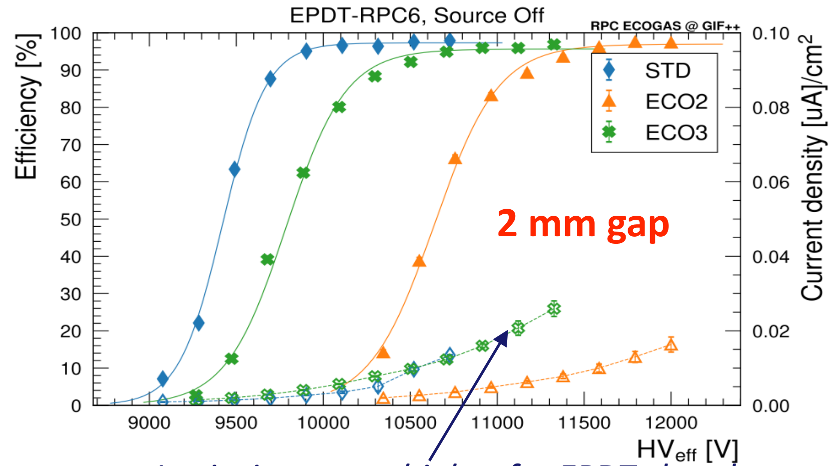
F-production vs gamma rate



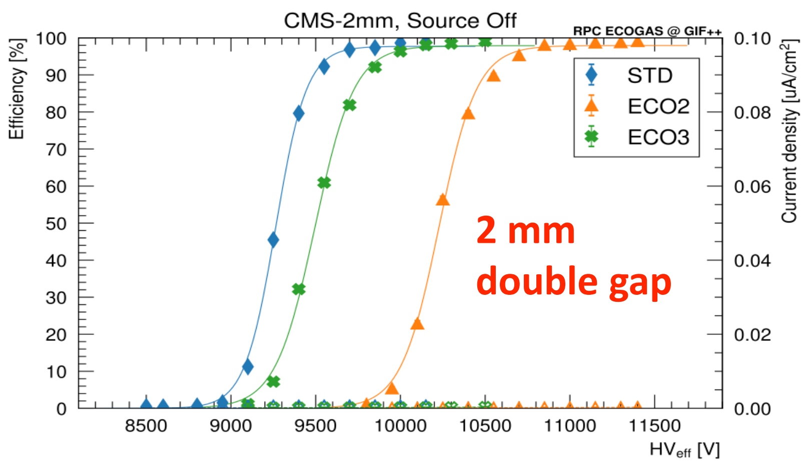
Ongoing work Task 7.2.3

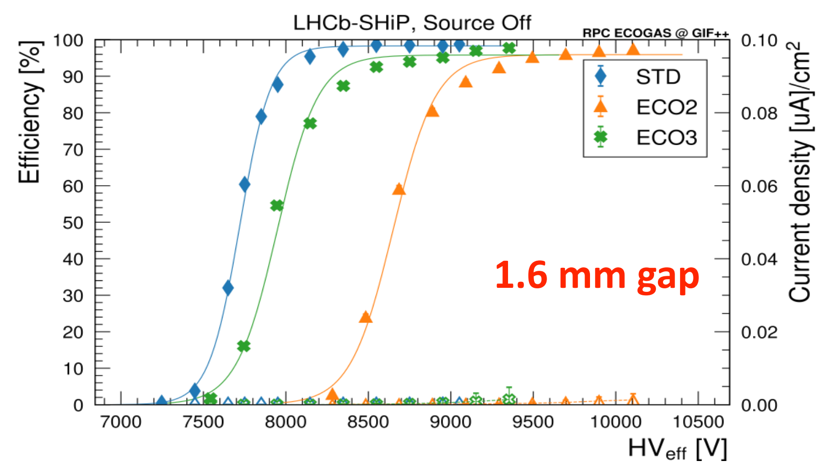
Task 7.2.3: Eco-friendly gas mixtures for RPCs, Test-beam results





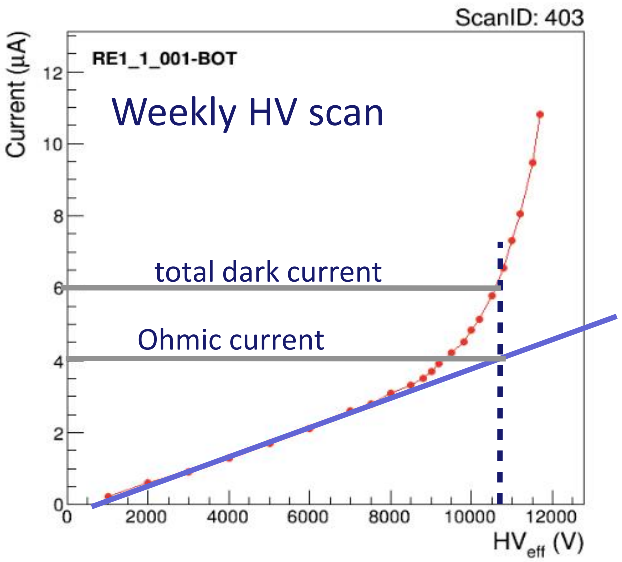
Intrinsic current higher for EPDT chamber





Task 7.2.3: Eco-friendly gas mixtures for RPCs, long term ageing test

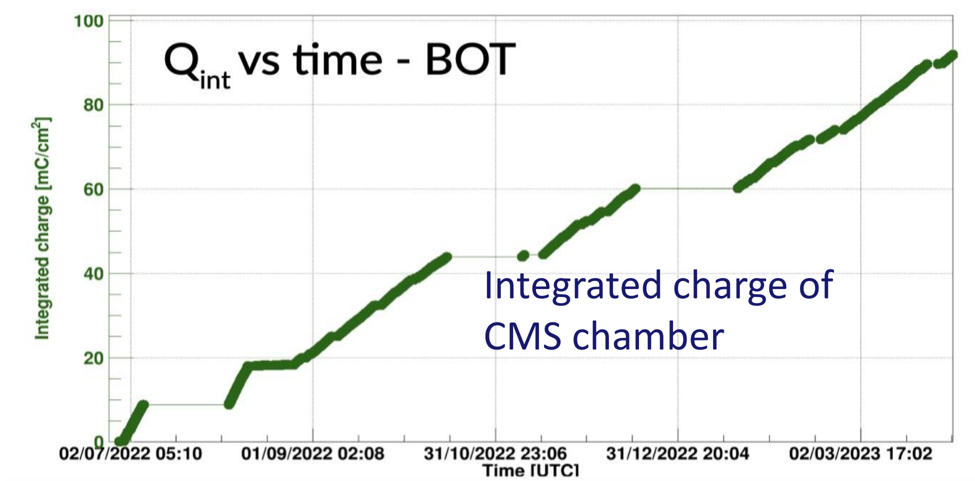
HV scan with source OFF



Every week:
- HV scan with source off
- Extract the dark and ohmic current
- Chamber operated @ low efficiency under irradiation

Aging started August 2022

50 - 250 mC/cm^2 depending on the chamber

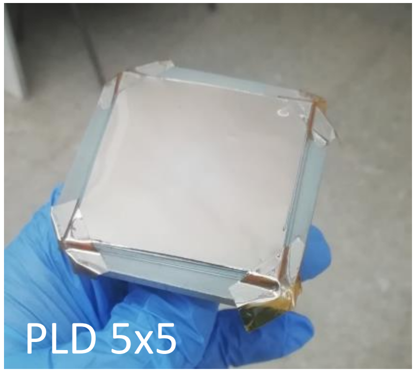


Task 7:3.1: Development of resistive electrodes for MPGDs

➢ High-Resistive GEM with DLC (Diamond-Like-Carbon) electrodes

- Pulsed-Laser-Deposition (PLD) foils of up to 5x5 cm^2 produced
- Ion-Beam-Deposition (IBD) mask for 10x10 cm^2 are waiting for etching result on 7x7 cm^2 foil
- Latest foils kept under vacuum and put in vacuum sealed bag for transport to CERN.
- Etching tests at CERN were done recently

➢ **This activity is related to Milestone M23**



AIDA innova

Milestone Report Task 7.3.1

Production of DLC with ion beam deposition and pulsed laser deposition

A.P. Caricato; A. Valentini; P.Verwilligen

Diamond-Like Carbon (DLC) resistive layers are a key ingredient for increasing the rate capabilities of Micro-Pattern Gaseous Detectors (MPGDs). Their production method and related quality is studied by ion beam deposition and pulsed laser deposition. The current DLC sample size will be scaled up gradually to 10×10 cm^2, their quality is assessed for the production of detector-grade amplification structures.

Preview

Page: 1 of 22 Automatic Zoom

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Grant Agreement No: 101004761

AIDAinnova

Advancement and Innovation for Detectors at Accelerators

Horizon 2020 Research Infrastructures project AIDAINNOVA

MILESTONE REPORT

PRODUCTION OF DLC WITH ION BEAM DEPOSITION AND PULSED LASER DEPOSITION

Indexed in

OpenAIRE

Publication date:
February 28, 2023

DOI:
DOI 10.5281/zenodo.7690626

Keyword(s):
WP7

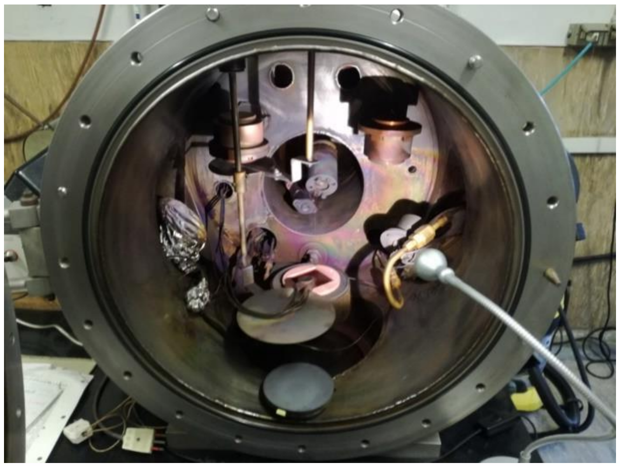
Grants:
European Commission:
- AIDAinnova - Advancement and Innovation for Detectors at Accelerators (101004761)

Communities:
AIDAinnova

- Report delivered on time in month 23 (February 2023)
- 22 pages – 15 figures – Introduction to various PVD techniques for DLC

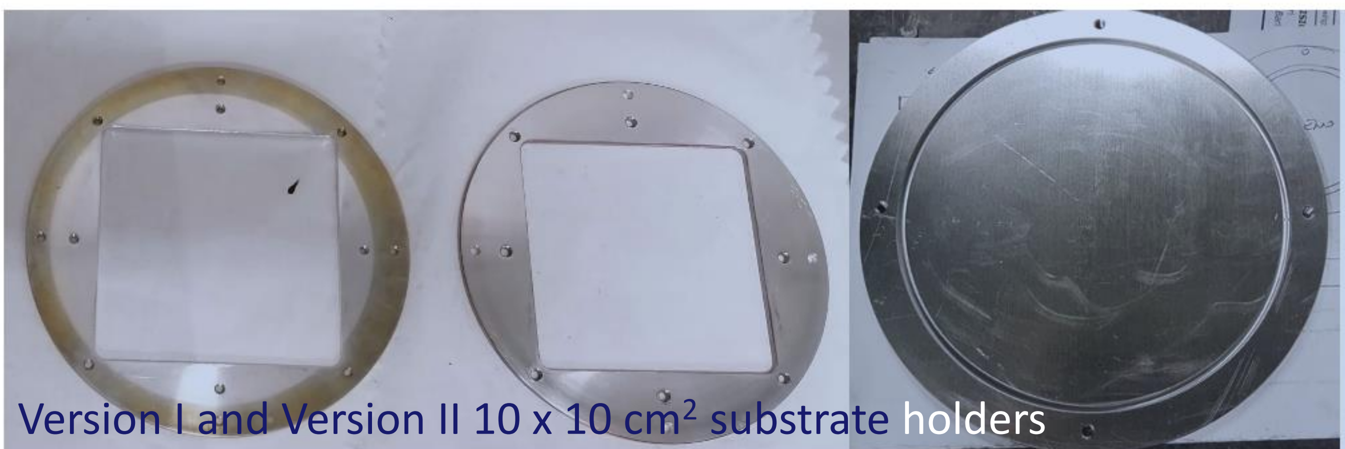
Ion Beam Sputter Deposition

- Obtained correct recipe for 100MOhm/sq DLC covered by 500nm Cu layer
- Scaled up production to 10x10 cm^2

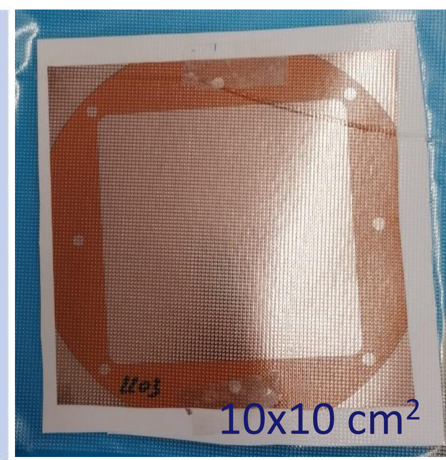


Tab. 2 Parameters for main and assistance ion beam sources for the deposition of a multi-layer DLC-Ti-Cu film

		Main ion source			Assistance ion source				Notes	
	step	V_{beam}	I_{beam}	Ar	V_{beam}	I_{beam}	Ar	H_2	time	thickness
1	PI cleaning	-	-	-	150V	1A	5.1 sccm	4.0 sccm	300s	-
2	DLC layer	800V	50mA	2.5sccm	80V	50mA	7.3 sccm	2.0 sccm	7200s	50 nm
3	DLC cleaning	-	-	-	150V	1A	5.1 sccm	-	300s	-
4	Ti interlayer	1300V	35mA	2.5sccm	-	-	-	-	1260s	10 nm
5	Cu layer I	1000V	50mA	2.5sccm	-	-	-	-	720s	30 nm
6	Cu cleaning	-	-	-	150V	1A	5.1 sccm	-	300s	-
7	Cu layer II	1200V	60mA	2.5sccm	-	-	-	-	8520s	470nm

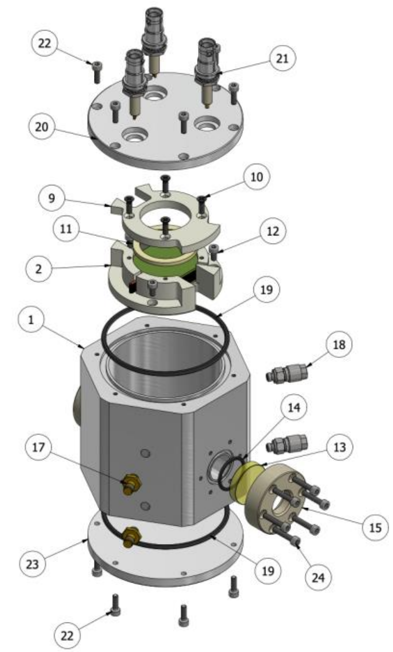


Version I and Version II 10 x 10 cm^2 substrate holders



10x10 cm^2

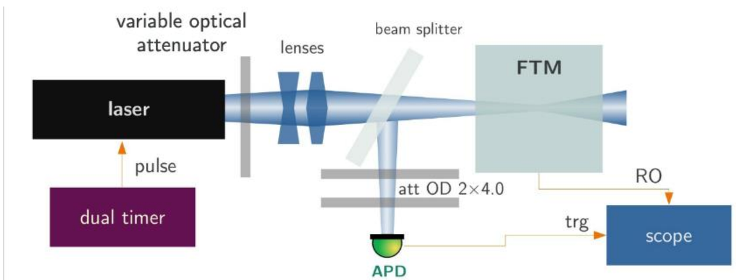
Test of the DLC foil

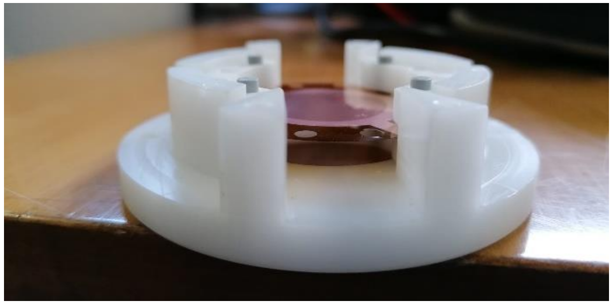


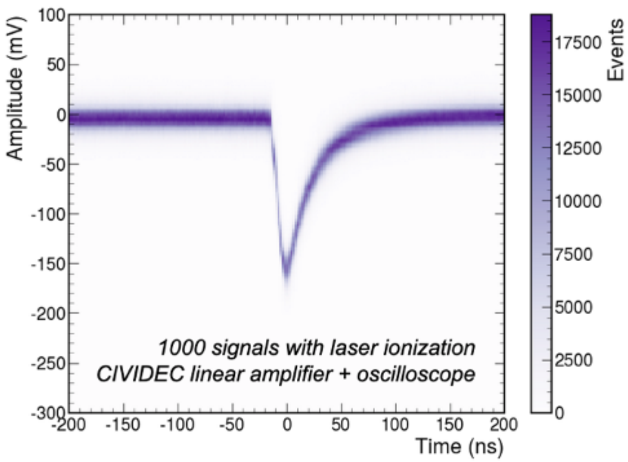
Test of the DLC foil inside the small-size detector

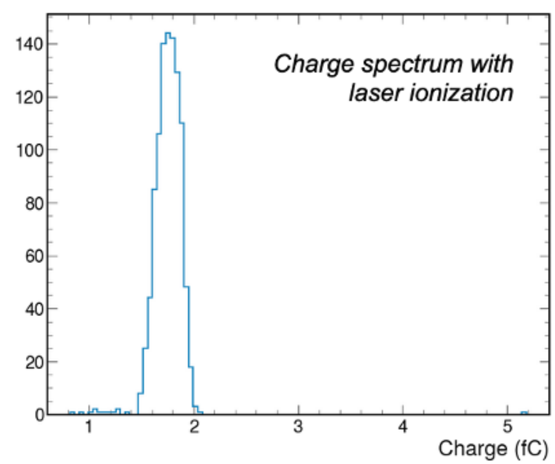
Setup has both quartz (UV-laser) as mylar (^{55}Fe) window

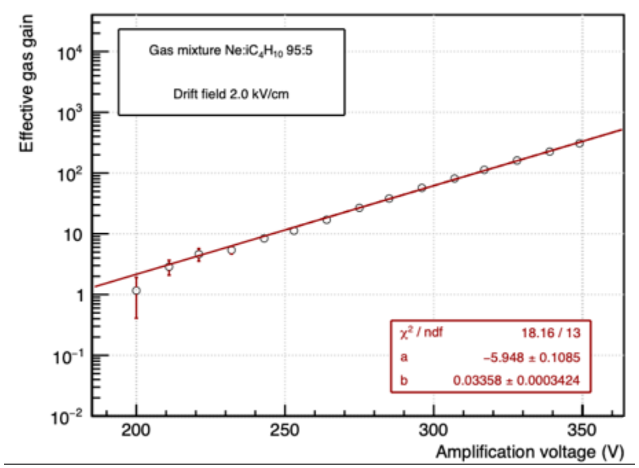
- Stable operation under 450V in Ar:CO_2:iC_4H_{10} 93:5:2
- Signals clearly visible (150mV) and 1.75fC
- Gain up to 500 measured – not bad for a first production foil











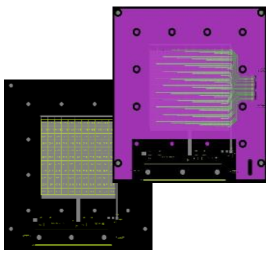
Ongoing work Task 7.3.2

Task 7:3.2: Industrial engineering of high-rate μ-RWELL detectors

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

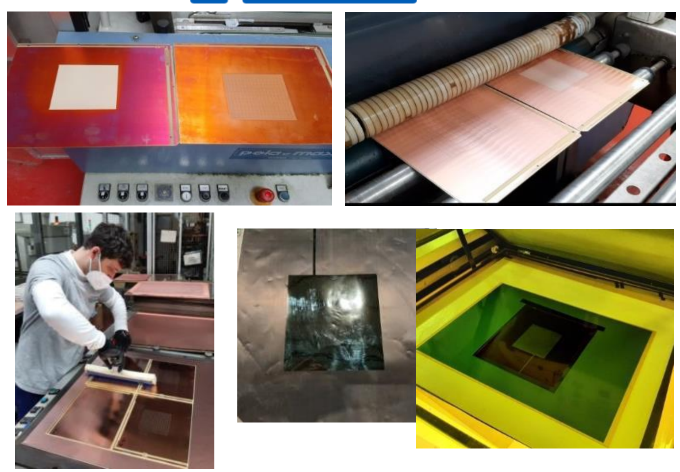
Feedback from tests

LAYOUT design

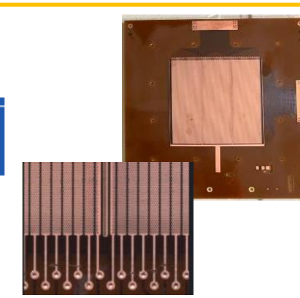


DCL foil production (*)

PCB production



Final detector manufacturing



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

Ongoing work Task 7.3.2

Task 7:3.2: Knowledge Transfer, achievements in 2022

Step 0 - Detector PCB design @ **LNF**

Step 1 - CERN_INFN DLC sputtering machine @ **CERN (+INFN)**
- delivery foreseen by the end of Oct. 2022
- **INFN** crew tbd & trained

Step 2- Producing readout PCB by **ELTOS**
- pad/strip readout

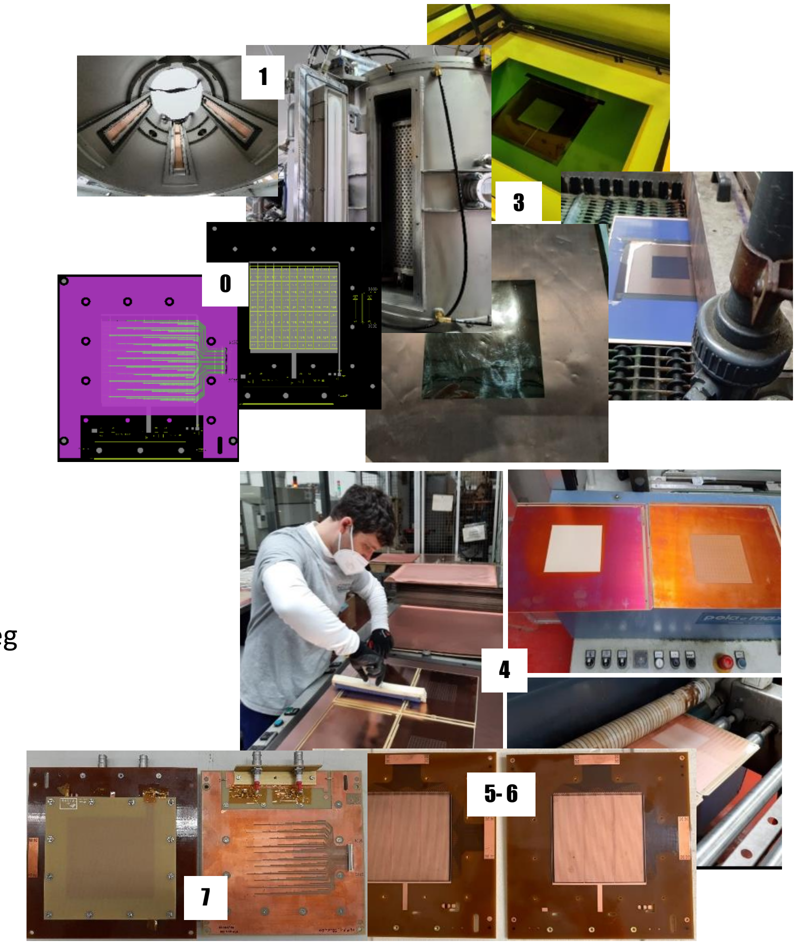
Step 3 - DLC patterning by **CERN**
- photo-resist → patterning with BRUSHING-machine

Step 4 - DLC foil gluing on PCB by **CERN**
- double 106-prepreg → 2x50µm thick
- PCB planarizing w/ screen printed epoxy → single 106-prepreg

Step 5 - Top copper patterning by **CERN** (in future by **ELTOS)**
- Holes image and HV connections by Cu etching

Step 6 - Amplification stage patterning by **CERN**
- PI etching → plating → ampl-holes

Step 7 – Electrical cleaning and detector closing @ **CERN**



Ongoing work Task 7.3.2

Task 7:3.2: Knowledge Transfer, objectives for 2023

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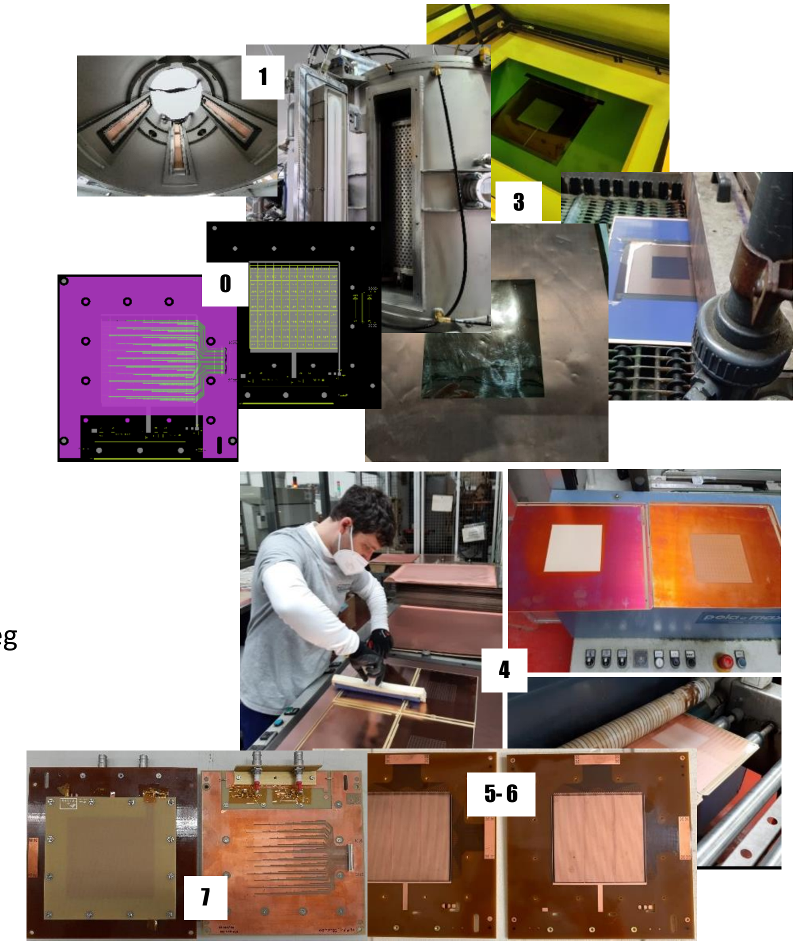
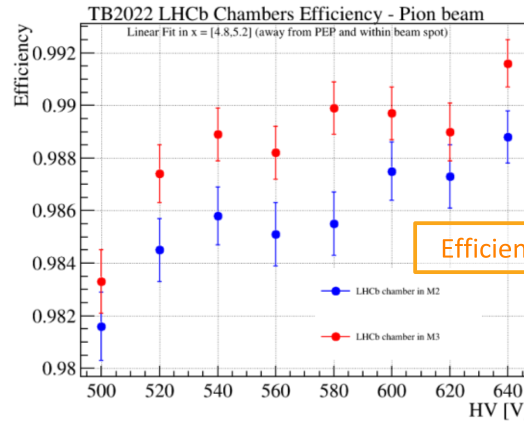


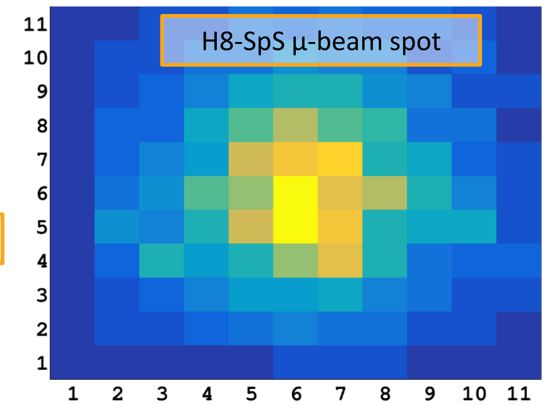
Ongoing work Task 7.3.2

Task 7:3.2: µ-RWELL layouts co-built by ELTOS & CERN (Oct.'22)

µ-RWELL – pad readout

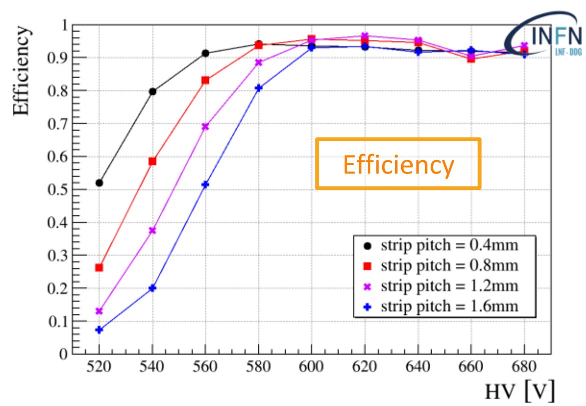
High rate

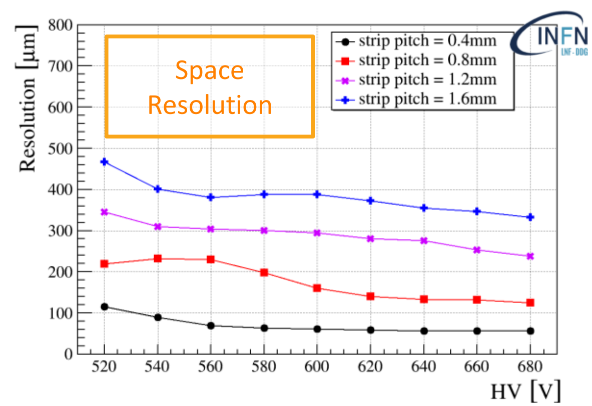




µ-RWELL – 1D readout

Tracking

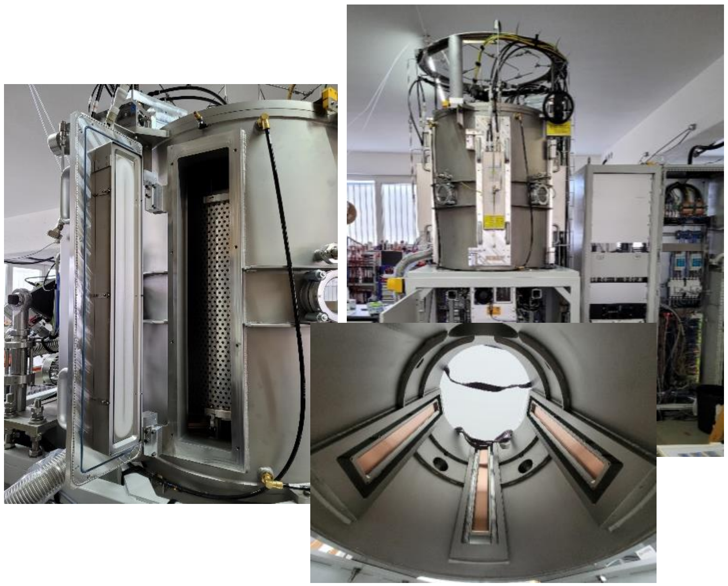




Task 7:3.2: Update on the CERN-INFN DLC machine

31st Oct. 2022 – Delivered
31st Oct. - 4th Nov. 2022 – Commissioning & test training
21st - 23rd Nov. 2022 – First DLC sputtering test, N_2 doping
5th - 9th Jun. 2023 – Second DLC sputtering test

- Ar + C_2H_2 doping

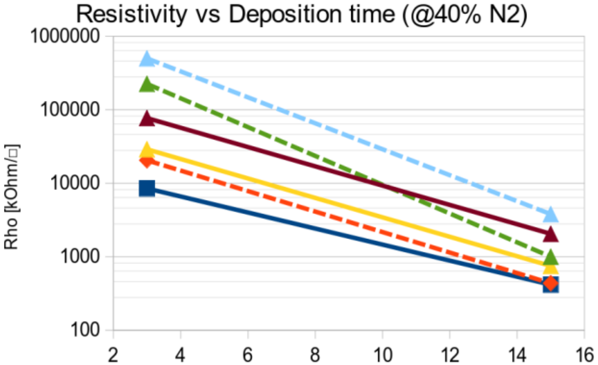


Some technical features:

- **Flexible** substrates up to 1.7m×0.6m
- **Rigid** substrates up to 0.2m×0.6m

Five cooled target holders, arranged as two pairs face to face and one on the front, equipped with five shutters.

The machine shall be able to **sputter or co-sputter different materials,** in order to create a coating layer by layer or an adjustable gradient in the coating.



Ongoing work Task 7.4.1

Task 7.4.1: A 4-channel prototype electronic board for cluster counting

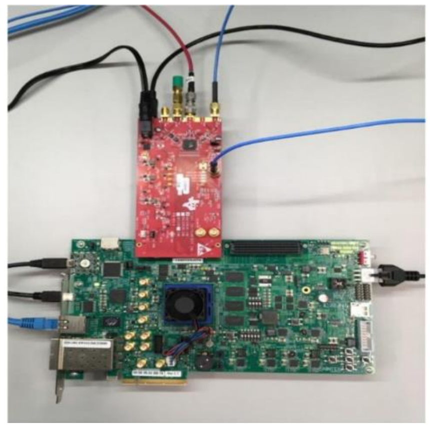
- Cluster counting in gaseous detectors is mainly a matter of the read-out electronic chain
- 3 hardware and 3 software approaches are pursued

TEXAS INSTRUMENT ADC32RF45

purchased

Tests will soon start

- **ADC32RF45** directly compatible (no need of **JESD204B** software license) with **Xilinx Kintex UltraScale KCU105** and high performance in terms of: noise, ENOB, isolation between channels.



NALU SCIENTIFIC

ASoC V3 DESIGN DETAILS

Compact, high performance waveform digitizer

- High performance digitizer: 3+ Gsa/s
- Highly integrated
- Commercially available, low cost, patented design
- 5mm x 5mm die size

Parameter	Spec
Sample rate	2.4-3.6GSa/s
Number of Channels	4
Sampling Depth	16kSa/channel
Signal Range	0-2.5V
Number of ADC bits	12 bits
Supply Voltage	2.5V
RMS noise	~1.5 mV
Digital Clock frequency	25MHz
Timing resolution	<25ps (see below for details)
Power	120mW/channel
Analog Bandwidth	850MHz
Serial interface	Up to 500 Mb/s***

- Calibration memory access
- PLL on chip
- Isolated analog/digital voltage rings
- Serial interface
- Self triggering
- Completed DOE Phase II SBIR
  - Eval cards avail
  - Custom boards under dev

IEEE NSS 2021

NALU Scientific

The 4 channel evaluation board has arrived in Lecce

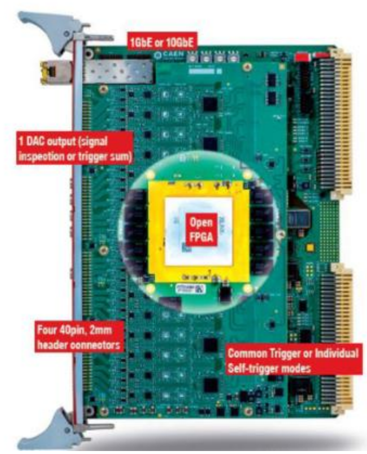
950 MHz, 2.5-3.6 Gsa/s 12bit

Connection with CAEN

We'll continue our tests until CAEN produces the new high-performance digitizer (**VX2751**).

In the meantime, we will

- start testing their lower performance digitizer **VX2740**, received recently
- begin to get familiar with their **"OPEN FPGA" system**

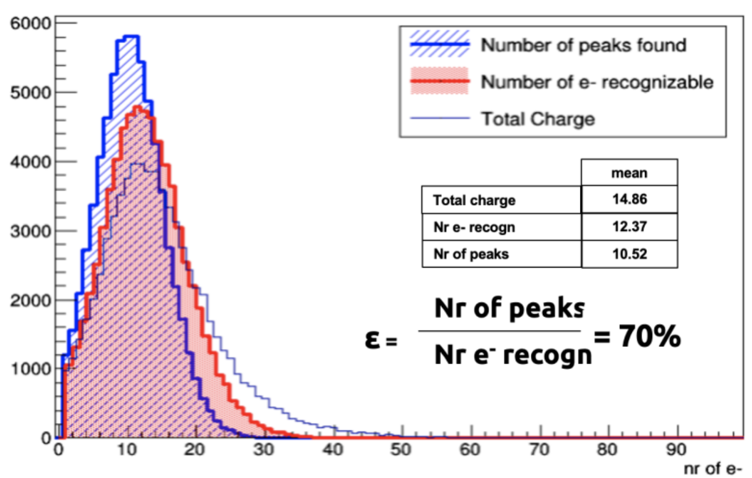


Task 7.4.1: Software development, Derivative algorithm

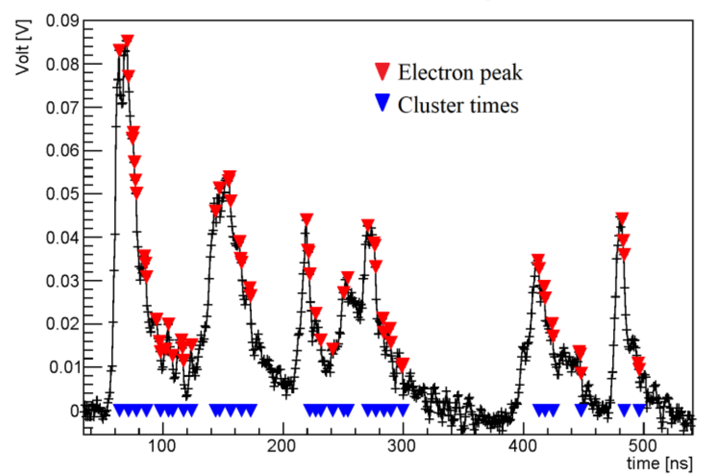
- A first simple tested algorithm of peak finder is based on the first and second derivative of the digitized signal function *f*, is defined for each time bin i, *Δb* being the number of bins over which the average value of f is calculated:

$$f'(i) = \frac{f(i) - \bar{f}(i - \Delta b)}{\Delta b} \qquad f''(i) = f'(i) - f'(i-1)$$

- A peak is found when *Δf*, *f'* and *f"* are above pre-defined threshold levels.



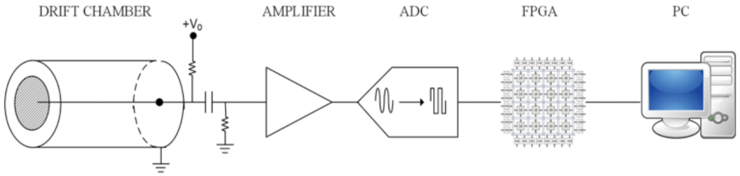
2 cm drift tube Track angle 45°



Ongoing work Task 7.4.1

Task 7.4.1: Algorithm implementation

The verified solution for a **single channel**



- Implement on a board with **multiple channels**,
- Three different approaches are currently being pursued:
  - **TEXAS INSTRUMENT ADC32RF45**
  - **NALU SCIENTIFIC ASoCv3 and HDSoC**
  - **CAEN digitizer VX2751**
- First task (in particular, for the first and second case) is implementing the **data transfer to the DAQ system** to take advantage of the 10Gbit/s standard:
  - optical fiber with SFP + connectors
  - SFP + to RJ45 adapters
- Second task is finding the most efficient way to **store the elaborated information** before the data transfer.

➢ **On track for 4-ch system board (ADC + FPGA) engineered (support from CAEN) (M36)**

Task 7.4.2: Hybrid readout for high-pressure gas TPC for ν - physics

- **Two main goals:**
  - optical read-out of photoluminescence, combined with charge read-out: 3-D images
  - innovative gas mixtures with scattering off different nuclei

- **ALICE MWPC testing at RHUL**
  - Equipped with CCD camera and charge readout, using α particles and Fe^{55} source

- Explore feasibility to use MWPCs in a HPgTPC for ν - physics

- **Warwick TPC platform**
  - Identification of novel gas mixtures
  - Develop high-granular optical RO- system for HPgTPC to enhance resolution.

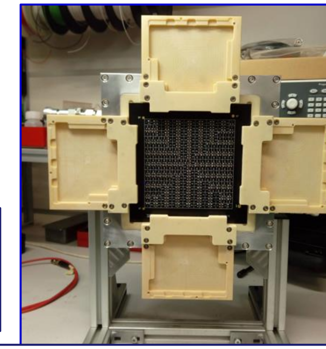
- Measure low-momentum hadrons from ν-N interactions to image ν-events.

Ongoing Work Task 7.5

Task 7.5. Photon detectors for hadron particle identification at high momenta

- **A bridge between gaseous detectors and PID, with focus of the detection of single photoelectrons**
- **3 R&D lines are pursued:**
  1. **MPGD-based PDs**

Design, construction and characterization of a small pad-size **prototype**



  2. **Visible light PDs insensitive to B-fields**
     - **A. SiPMs:** 7 different SiPMs from 3 producers under systematic studies

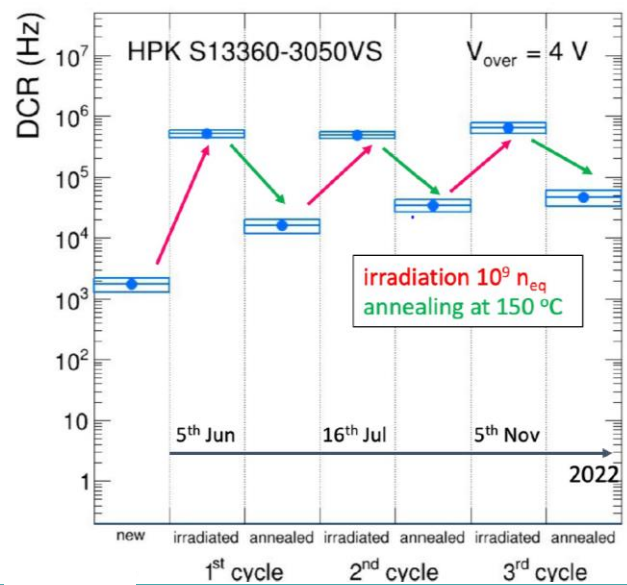
Systematic characterization at different temperatures before and after irradiation

board	sensor	uCell (μm)	V_{bd} (V)	PDE (%)	DCR (kHz/mm²)	window	notes
HAMA1	S13360 3050VS	50	53	40	55	silicone	legacy model Calvi et. al
	S13360 3025VS	25	53	25	44	silicone	legacy model smaller SPAD
HAMA2	S14160 3050HS	50	38	50		silicone	newer model lower V_{bd}
	S14160 3015PS	15	38	32	78	silicone	smaller SPADs radiation hardness
SENSL	MICROFJ 30035	35	24.5	38	50	glass	different producer and lower V_{bd}
	MICROFJ 30020	20	24.5	30	50	glass	the smaller SPAD version
BCOM	AFBR S4N33C013	30	27	43	111	glass	commercially available FBK-NUVHD

HAMAMATSU PHOTON IS OUR BUSINESS

ON Semiconductor

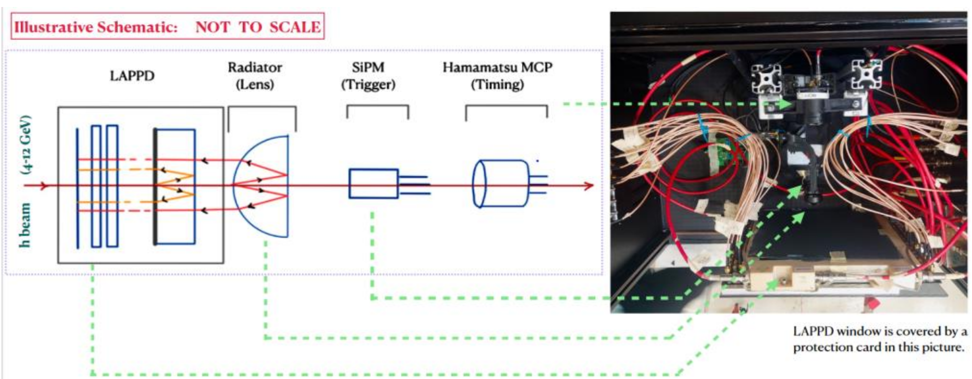
BROADCOM

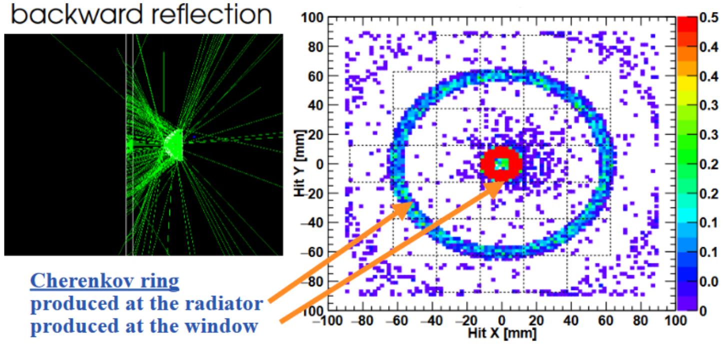


Task 7.5. Photon detectors for hadron particle identification at high momenta

2. **Visible light PDs insensitive to B-fields**
   - **B. LAPPDs: time resolution measured in test-beam at CERN PS in October 2022**

     Cherenkov photons were generated in a quartz radiator

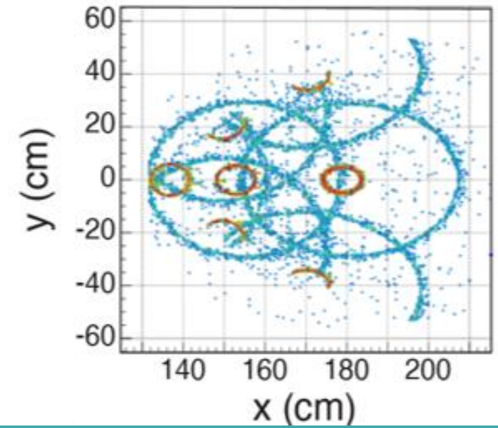




Time resolution: 80 ps (Prelim.)

3. **Comparative assessment by simulations using as input the photo-sensor performance from R&D lines 1. and 2.**

Initial simulation studies:



Summary

Overview of Deliverables and Milestones

		Year 1												Year 2												Year 3												Year 4													
Tasks	Description	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
WP7: Gaseous detectors																																																			
7.1	Coordination and Communication																																																		
7.2	Multigap RPCs for fast timing and Eco-friendly gas mixtures for RPCs																																				D									D					
7.3	Development of resistive electrodes for MPGDs and Industrial engineering of high-rate μ-RWELL detector																							M							D						M														
7.4	A 4-channel prototype electronic board for cluster counting and Hybrid readout high pressure gas TPC for neutrino physics																																				M										D M				
7.5	Photon detectors for hadron particle identification at high momenta																																												D						

- 1st WP7 milestone successfully fulfilled in February 2023
- We are on track with the milestones for the 3rd year
- However, for one deliverable (scheduled for Month 30) we are late by a few month, probably 6.
  - The schedule will be finalized in the next month
- Planned activities for this year are progressing well !