

DRD1 WORK PACKAGES

Goals, status, endorsements

06.10.2025

P. Gasik (GSI/FAIR + TU Darmstadt)

Work Packages

Strategic R&D and Long-Term Funding

- **Concept of Work Packages**

- Introduced to follow the ECFA Detector R&D Roadmap recommendation to “Establish long-term strategic funding programs” (GR6).
- Formally covered in the MoU, which provides an agreement framework between parties (Institutions and Relevant Funding Agencies).

- **Work Packages in the MoU of the DRD1 Collaboration**

- Core (require signature for amendment):
 - Procedures for establishment and updates.
- Annexes (DRD1 Specific - require approval but not signature for updates):
 - DRD1 procedures: General Clauses, Participation, Addition and Withdrawal of Institutions, Approvals and Reviews
 - Updated status: Institutions, Funding Agencies, Deliverables, Resources, Management.



Work Packages

DRD1 Scientific Organization

Gaseous

- | | |
|-----------------|---|
| DRDT 1.1 | Improve time and spatial resolution for gaseous detectors with long-term stability |
| DRDT 1.2 | Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes |
| DRDT 1.3 | Develop environmentally friendly gaseous detectors for very large areas with high-rate capability |
| DRDT 1.4 | Achieve high sensitivity in both low and high-pressure TPCs |

DRDTs

1.1	1.2	1.3	1.4	Work Packages	WG1	WG2	WG3	WG4	WG5	WG6	WG7	WG8
●		●		Trackers/hodoscopes	Technologies	Applications	Gas and material studies	Detector physics, simulations and software tools	Electronics for gaseous detectors	Detector production	Common test facilities	Training and dissemination
●	●	●		Drift chambers								
●	●	●		Straw chambers								
●	●	●	●	Tracking TPCs								
●		●		Calorimetry								
●	●	●		Photon detection (PID)								
●		●		Timing detectors								
●	●	●	●	Reaction/decay TPCs								
●		●		Beyond HEP								



Work Packages

Work Packages at the time of the DRD1 Proposal (December 2023)


DRD1

DRD1 EXTENDED R&D PROPOSAL Development of Gaseous Detectors Technologies v1.5

Abstract

This document, realized in the framework of the newly established Gaseous Detector R&D Collaboration (DRD1), presents a comprehensive overview of the current state-of-the-art and the challenges related to various gaseous detector concepts and technologies. It is divided into two key sections.

The first section, titled "Executive summary", offers a broad perspective on the collaborative scientific organization, characterized by the presence of eight Working Groups (WGs), which serve as the cornerstone for our forthcoming scientific endeavours. This section also contains a detailed inventory of R&D tasks structured into distinct Work Packages (WPs), in alignment with strategic R&D programs that funding agencies may consider supporting. Furthermore, it underlines the critical infrastructures and tools essential for advancing us towards our technological objectives, as outlined in the ICTA R&D roadmap.

The second section, titled "Scientific Proposal and R&D Framework", delves deeply into the research work and plans. Each chapter in this section provides a detailed exploration of the activities planned by the WGs, underscoring their pivotal role in shaping our future scientific pursuits. This DRD1 proposal reinforces our unwavering commitment to a collaborative research program that will span the next three years.

On line version: <https://cernbox.cern.ch/s/PPTB5r0M3NY52Vh>
 DRD1 Website: <https://drd1.web.cern.ch/>

Geneva, Switzerland
January 9, 2024

I.2 Scientific Organization of the DRD1 Collaboration	21
I.2.1 Scientific Organization	22
I.2.1.1 Working Groups	23
I.2.1.2 Common Projects	25
I.2.1.3 Work Packages	25
I.2.2 Work Packages	26
I.2.2.1 WP1: Trackers/Hodoscopes	26
I.2.2.2 WP2: Inner and Central Tracking with PID Capability, Drift Chambers	28
I.2.2.3 WP3: Inner and Central Tracking with PID Capability, Straw and Drift Tube Chambers	28
I.2.2.4 WP4: Inner and Central Tracking with PID Capability, Time Projection Chambers	29
I.2.2.5 WP5: Calorimetry	30
I.2.2.6 WP6: Photo-Detectors	32
I.2.2.7 WP7: Timing Detectors	33
I.2.2.8 WP8: TPCs as Reaction and Decay Chambers	33
I.2.2.9 WP9: Beyond HEP	35

Work Packages

Between establishment and endorsement

- First 9 DRD1 WPs established at the time of the DRD1 proposal approval
- 2024-2025: scientific activities organized within a WP framework
 - WP meetings
 - Workshops
- Resource planning
 - Existing resources used for the ongoing activities
 - When possible – discussion with WP-FAs on future funding
 - Application for resources
- Endorsement procedure
 - Preparation of the WP endorsement procedure within WPs (coordinated with the SCB), MB, CB and RB (most recently)
 - We are ready to start first endorsements

WP Scientific Activities

(based on the contributions from WPLs)

WP1

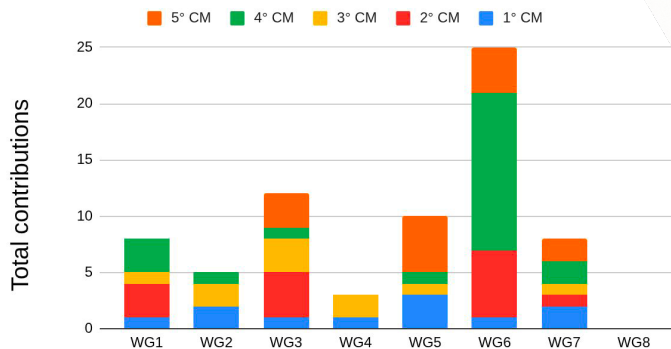
Trackers, Hodoscopes, Large Area Muon Systems

R. Farinelli, M. Iodice, G. Pugliese

WP1: Trackers, Hodoscopes, Large Area Muon Systems

- 8 tasks define the WP1. From the proposal up to now, an update of the task activities has occurred to include new feedback from institutes during the WP1 workshops.

- [1st DRD1—WP1 Workshop, March 7, 2024](#)
- [2nd DRD1—WP1 Workshop, November 14, 2024](#)
- [3rd DRD1—WP1 Workshop, September 25, 2025](#)



Many WP1 contributions in DRD1 WG sessions – see also this week

TASK 1	TASK 2	TASK 3	TASK 4
New RPC and TGC Structures	New Resistive MPGD Structures	New Front-end electronics	Optimization of scalable multichannel readout systems
D1.1: Design, construction, and tests of single/multi-gap surface resistivity RPC with DLC electrodes.	D2.1: Large area (approximately 50cm x 50cm) prototypes based on resistive elements and novel MPGD architectures for high particle rates (range 100 kHz/cm ² – few MHz/cm ²) particle rates, 2D readout, <100um space resolution, about 10ns timing resolution, high gain (above 104) to ensure stability and providing a good margin for nominal working point	D3.1: Design, production and validation of a new ASIC chip for MPGDs based on a new architecture for next MPGD and a technical note about the chip expected performance.	D4.1: Design, implementation, and optimization of novel Scalable Readout Systems for Gaseous Detectors
D1.2: Design, construction, and test of innovative TGC and RPC structures with current (HPL, glass) and novel resistive materials (phenolic glass, GaAs, etc.) working comfortably up to 130 kHz/cm ²	D2.2: Large area MPGD prototypes for low/medium rates (few-100 kHz/cm ²) for large surface coverage (0.1000 m ²), optimized in terms of performance (precise tracking – below 100 um and timing – few ns) and overall cost	D3.2: Integration and performance assessment of a Bi-CMOS SiGe heterojunction technology FE ASIC, with various detectors technologies, and Design of an increased performance ASIC with ultimate time resolution (< 10 ps) and possibility of local zero suppression and daisy chaining	D4.2: Development of scalable high-speed processing and interface FPGA IP blocks for the DAQ ecosystem.
D1.3: Design, construction, and test of prototypes of TGC and RPC trackers structures (made of multiple independent gas gaps and readout electrodes) suitable for 3D space-time tracking, with millimetric space resolution and up to 100 ps time resolution.	D2.3: Support and update of the modelling and simulation framework for the study of induced signals in detectors with resistive elements	D3.3: Development of a radiation hard multichannel TDC board and integration in a detector setup	D4.3: Development of scalable DAQ software for high-speed data transport.

TASK 5	TASK 6	TASK 7	TASK 8
Eco-friendly gases	Manufacturing	Longevity on large detector areas	New Detector Structures
D5.1 Test and characterization of RPCs operated with low-GWP (HFO) and new eco-gas mixtures.	D6.1: DLC production with C.I.D (CERN-INFN DLC machine)	D7.1 Studying the impact of integrated current and unknown gas-induced ageing effect on the long-term performance of the detector. Studies with eco-gas mixtures.	D8.1: Design, construction, and test of prototypes (area of 30x10 cm ²) composed of Resistive Cylindrical Chamber (RCC), with different resistive materials and read-out electrodes.
D5.2 Compatibility of the new eco-gases with gas system components	D6.2: Industrial co-production of MPGD (micro-RWELL, Micromegas) and RPC	D7.2 Development and test of gaseous detectors operated with new recuperation and recirculation systems.	D8.2: Hybridization of an RCC with a drift tube, and performance study
D5.3 search for CF4 alternatives	D6.3: MWPC- and GEM-based chamber production using industry-standard printed circuit boards with option of integrated electronics.	D7.3: Characterization of detectors constructed from industry-standard production methods in terms of ageing, environmental robustness (humidity, temperature cycling), mechanical stability (vibration, stress load) and gamma irradiation.	D8.3: Construction and test of a curved MPGD prototypes with cylindrical and tubular shapes

WP1 activities

• New RPC and TGC structures

- INFN-BA: Timing with RPC-based (HPL or glasses)
- Cavendish: RPC-based (HPL or glasses) tracker for ANUBIS experiment
- INFN-LNF: sRPC high-rate
- ROMA Tor Vergata: RPC with Gallium Arsenide electrodes
- MPP: large size RPC and Multigap
- Weizmann: TGC

Status of the art of the R&D at INFN Bari

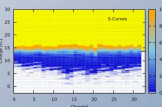
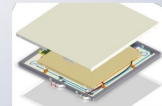
Improved timing RPC

A double-gap glass RPC (1.4 mm gas gap and 1.1 mm glass electrode thickness) was tested with a new readout electronics based on **FATIC2 chip** adapted for RPC signals TDC time resolution ~ 100 ps

Preliminary calibration (S-Curves and threshold scans) of the new electronics was performed at INFN RPC Lab with low charge thresholds (DRD1 WP7B)

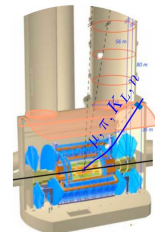
➤ **Plan:** fine tune the electronics integration and perform dedicated performance studies with cosmic muons. The detector will be operated with the CMS standard gas mixture and few ecofriendly mixture candidates

➤ For 2025, requested to INFN: a CAEN PicoTDC for timing measurements and an additional MFC to test the detectors with 4 primaries gaseous mixtures → ecofriendly candidates



WP1 T1 STATUS AND PLANS: D1.2

- Overview of project:
 - instrument ceiling of ATLAS cavern with RPC-based tracker (~ 2500 m²)
 - → unique sensitivity to long-lived particles at EW scale
- State of the art:
 - constructed prototype using ATLAS BIS7 technology, looking at cost-effectiveness (focus on gas gap materials)
- Plans for 2024:
 - survey of HPL manufacturers / low resistivity
- Milestone:
 - pre-production construction end of 2025
- Deliverable:
 - alternative gas-gap materials / materials
- Resources are confirmed as per table



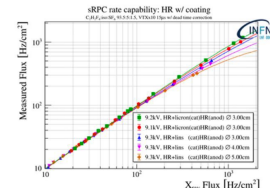
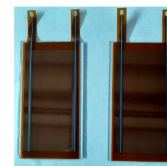
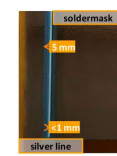
OLEG BRANDT + CAVENDISH LABORATORY



DRD1
Gaseous Detector Technologies

WP1 – T1: High-rate layout

A measurement of the rate capability (defined as the radiation flux corresponding to an efficiency drop of 20%) of a preliminary **high-rate layout (introducing two conductive lines for fast current evacuation)** has been performed by irradiating the detector with a 5.9 keV X-ray gun with a spot size comparable with the pitch of the conductive grid realized on the DLC (**1.6 GOhm/sq**).



Rate capability of ~ 1 kHz/cm² with X-ray

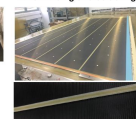
The implementation of **conductive lines** on the DLC introduces some instability at higher voltage, sensibly reducing the plateau width w.r.t. the baseline version. **New layouts under evaluation**

TGC production and testing

Cathode board spraying with graphite



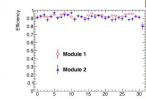
Wire winding and soldering



Single gap assembly



Cosmic ray test of EIL4 triplet with new ATLAS readout system



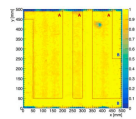
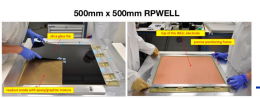
WP1 activities

- New RPC and TGC structures
- New Resistive MPGD Structures
 - INFN-Bologna, INFN-Ferrara, INFN-LNF: u-RWELL Tracking detectors for muon systems at future colliders
 - INFN-LNF: u-RWELL for high rates (mostly related to R&D for LHCb)
 - INFN-Roma2: u-RWELL detectors for the EPIC tracking at EIC (2D readout)
 - IRFU-CEA-Saclay: MPGD Trackers
 - Weizmann: RPWELL and RWELL
 - CERN: New resistive MPGD structures and 2D readout
 - LMU: Large area Micromegas (floating strips and resistive)
 - INFN-Roma3 and INFN Napoli: Micromegas for large area muon systems and High/Low rates applications
 - IFIN-HH: Simulation
 - Jefferson Lab: Thin-gap MPGD Tracker for ePIC Detector @ the EIC; Large MPGD Trackers for Experiments @ JLab

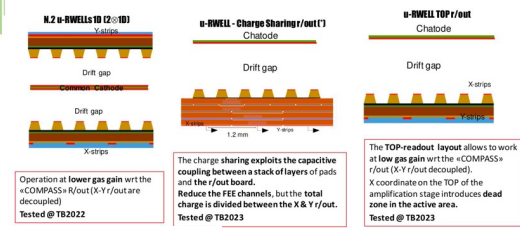
RPWELL and RWELL methods and challenges

- Production of (large area) detectors with precise and cost effective techniques
 - standard PCB (FR4, drill, etching)
 - Uniform response¹
- Resistive materials
 - Semi conductive glass
 - Developing novel composite materials
- Developing assembly methods for large area towards industrialization¹
- Integration with SRS-VMM3a electronics

¹⁾ Zavazava, D., et al. "Towards a large-area RPWELL detector: design optimization and performance." JINST 20(2019): P08009.
Luca Masetti - INFN University of Naples University - 20191014

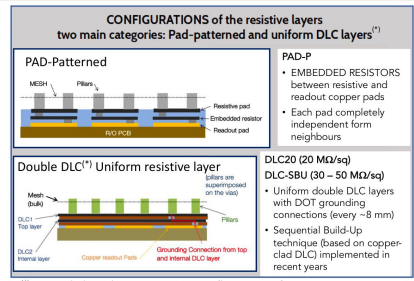
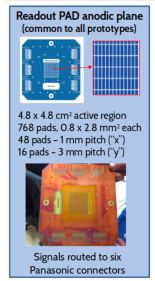


WP1 - T2/T8: Tracking μ -RWELL (LNF, Ferrara, Bologna, Torino)



The Small Size Prototypes

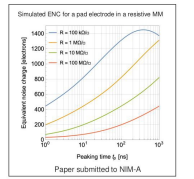
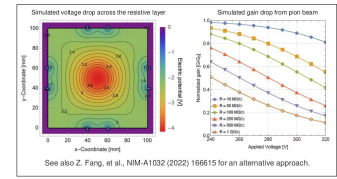
Several Prototypes built and tested with a common readout layout but different spark protection systems



T2: New resistive MPGD structures and 2D readout optimization

In synergy with WG4

In addition to the signal indication simulations for different resistive MPGDs, topics such as thermal noise coming from resistive elements and rate-capability studies can be explored for different technologies. Possibly, the effect of resistive materials in quenching discharges in current hydrodynamic models could be implemented.



WP1 activities

- New RPC and TGC structures
- New Resistive MPGD Structures
- New Front-End Electronics
 - INFN TO, INFN BO, INFN FE: TIGER integration with resistive MPGD
 - INFN TO: TORA development for MPGD and wire-based detector
 - CERN, IFIN-HH, UNSTPB, UniTbv: FEE for SRS and simulation
 - CEA: Design of SALSA Chip for MPGD
 - INFN RM2, HKU: ASIC TDC-based production for RPC
 - CIEMAT, ICTEA/U.OVIEDO: ASIC TDC-based integration with new detector
 - MPP: FEE for high rate and fast recovery baseline
 - IRFU: SALSA
 - Weizmann: RPWELL and RWELL tracking elements with SRS-VMM3a.

Torino Readout (for) AMBER ASIC

- MPGD and compatible Wire detectors
- Target specific application
- Limited complexity
- Reuse existing solutions (ToASt)
- 65nm
- Two step features design v1, v2

Will depend on the FE optimisation results

Detector	MM	Straw
Channels/ASIC	64	64
Power/channel	≤ 25	≤ 10
Input capacitance	≤ 550	20-100
Input charge	1-100	1-1000
Input impedance	$\leq 50 \Omega$	<i>tbd</i>
Max rate	≤ 0.5	≤ 0.18
Peaking time	150-300	25-150
Time resolution	1-2	≤ 1
Charge resolution	8	10
Gain	10-20	2
ENC @10 pF	500-1000	
ENC 1 @550 ?	1000-	
ENC pF	3000	3000
Threshold range	<i>tbd</i>	0.15
Clock frequency	200	200

TIGER (Torino Integrated Gem Electronics for Readout)
64-channels ASIC
charge and time readout

Sample & Hold
Time-over-Threshold

Parameters	Value
Input Charge	2-50 fC
Input Capacitance	Up to 100 pF
Data Rate	60 Mbit/s
Readout Mode	Trigger-less
Non-linearity	$<1\%$
Charge Collection Time	60 ns
Time resolution	<5 ns
Power Consumption	<12 mW/ch
Technology	110 nm process

GEMROC (GEM Read Out Card)

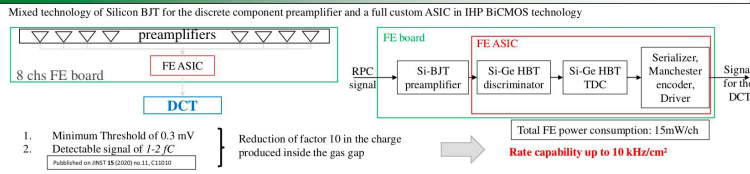
Power the FEBs
Monitor chips voltages and temperature
Configure the chips
Receive timing signals
Control data acquisition via optical links/Ethernet

10/03/2025

IFD 2025 | New LaMM and TORA ASIC @ AMBER

1

BI Front-End electronics



- Strategy behind the integration of the TDC directly within the FE ASIC:
- Less sensibility to the various sources of noise, implying better overall performance
 - "Easier" to achieve the required time resolution (100ps) for the second coordinate measurement with 1cm space resolution
 - Reduction in the complexity of the connections with an external system
 - No complex cables calibration are required in order to achieve the desired space resolution (1 cm) for the second coordinate measurement

ATLAS phase-I RPC FE electronics (BIS78 project)
This is the FE board I developed for the pilot project of the BI. The BI electronics will inherit most of the architecture

WP1 activities

- New RPC and TGC structures
- New Resistive MPGD Structures
- New Front-End Electronics
- Optimization of Scalable Readout System
 - INFN FE: development new FPGA for TIGER
 - CERN, IFIN-HH, UNSTPB, UniTBv: upgrade SRS
 - CIEMAT, ICTEA/U.OVIEDO: development new FPGA for time digitization

TIGER+GEMROC

TIGER (Torino Integrated Gem Electronics for Readout)
64-channels ASIC
charge and time readout

Sample & Hold
Time-over-Threshold

Parameters	Value
Input Charge	2.50 fC
Input Capacitance	Up to 100 pF
Data Rate	60 MHz/ch
Readout Mode	Triggerless
Non-linearity	<1%
Charge Collection Time	60 ns
Time resolution	<5 ns
Power Consumption	<12 mW/ch
Technology	110 nm process

INFN-Torino

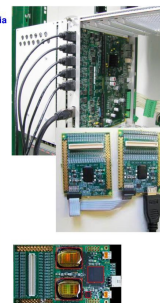
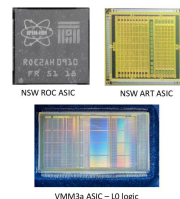
GEMROC (GEM Read Out Card)

Power the FEBs
Monitor chips voltages and temperature
Configure the chips
Receive timing signals
Control data acquisition via optical links/Ethernet

INFN-Ferrara

JINST.12.C07017

MOBRO-DRD1 WP1 WPML WORKSHOP 7 MARCH 2024



Time digitization readout electronics

CIEMAT has recently developed an FPGA-based readout board

- Performs time digitization of up to 228 channels
- At present, 800 ps resolution
- Built around Microsemi PolarFire FPGA
- lpGBT CERN transceiver (10.24 Gbps),
- And 2 VTRX+: up to 6 high speed lanes fully available (61,44 Gbps)
- Radiation tolerant

O(200) boards are being produced for its HL-LHC Upgrade and will need to operate to high standard of reliability (CMS Muon DT upgrade)

Modifications of present board to accommodate to future detector designs can be envisioned and will be studied.

Interconnection with additional electronics or modification of the board could also provide dE/dx capability building on the TDC on FPGA already implemented.

Goal: understand potential detectors that could benefit from this development and study the best way of adapting/redesigning if needed



WP1 activities

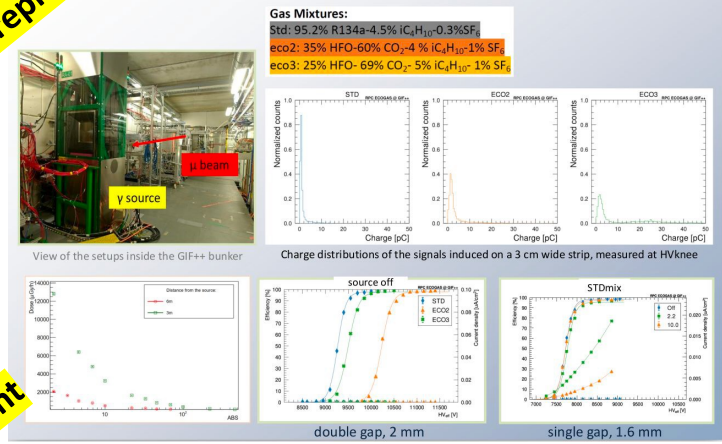
- New RPC and TGC structures
- New Resistive MPGD Structures
- New Front-End Electronics
- Optimization of Scalable Readout System
- Eco-friendly gases

- Cavendish: eco-gas for RPC
- INFN-Ba, INFN-LNF, INFN-RM2, INFN-TO: eco-gas for RPC, testbeam, aging
- U. Florida: Gas gain, timing, F- production, CF4 alternative
- IGPC: CF4 alternative, simulation
- CERN: eco-gas for RPC, gas chromatograph and mass spectrometer
- U. Michigan: gas mixture system
- MPP: eco-gas for RPC

CF4 replacement

SF6 replacement

Status of the art of the R&D
on-going at home-labs and in the framework of the RPC EcoGas@GIF++ Collaboration



Overview



...substitutes for the high-GWP molecules in the standard gas mixture, $C_2H_2F_4$ and SF_6 , suitable for experiments in high-radiation background environments.

Current focus: SF_6 replacement with $C_3H_2ClF_3$ (GWP = 1) → Promising results from : G. Protera et al 2022, JINST 17 P05005

Studying RPC performance and longevity at the GIF++ on 1 mm RPC small-size prototypes (produced at MPI)

Two beam tests campaigns during 2024, focusing on STD-like and $C_2H_2F_4$ / $C_3H_2ClF_3$

1. MIX1 : 94.7% $C_2H_2F_4$ /4.7% $i-C_4H_{10}$ /0.6% $C_3H_2ClF_3$

2. MIX2 : 94.3% $C_2H_2F_4$ /4.7% $i-C_4H_{10}$ /1% $C_3H_2ClF_3$

3. MIX3 : 63.3% $C_2H_2F_4$ /30% CO_2 /4.7% $i-C_4H_{10}$ /2% $C_3H_2ClF_3$

4. MIX4 : 53.3% $C_2H_2F_4$ /40% CO_2 /4.7% $i-C_4H_{10}$ /2% $C_3H_2ClF_3$

“STD-like”: Directly replace mixture and used for aging

Optimization of the concentration

Overview of the projects: eco-gas studies

R&D on new eco-friendly gas mixtures for RPC detectors

- Studies on replacements of both $C_2H_2F_4$ and SF_6 for RPC detectors
- Studies focused on current LHC RPC systems
- Characterisation of RPC performance in laboratory
- Ageing campaign and long-term performance studies

Studies on eco-gas properties and mixture quality

- Studies on new eco-gas properties
- Cross-section, chemical reaction, gas degradation, etc.
- Several gas analyses techniques
- Gas chromatography, Mass spectrometer, Ion Selective Electrode, UV-visible spectroscopy

Studies on new gas system components

- Optimisation of gas system components and their validation with new gases
- Mass Flow Controllers, regulation valves, etc.
- Safety and environmental aspects
- Flammability studies, PFAS degradation, etc.

Task 5.1

Tasks 5.1 and 5.2

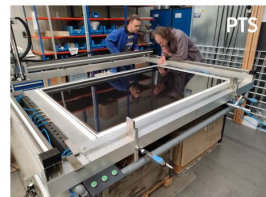
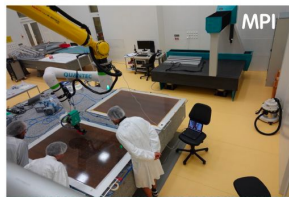
Task 5.2

C2H2F4 replacement

- New RPC and TGC structures
- New Resistive MPGD Structures
- New Front-End Electronics
- Optimization of Scalable Readout System
- Eco-friendly gases
- Manufacturing
 - INFN-LNF, INFN-RM3, INFN-NA: DLC sputtering
 - INFN-LNF, INFN-FE, INFN-BO: μ RWELL manufacturing to industry
 - INFN-Roma3, INFN-Napoli: MM manufacturing to industry
 - INFN-Roma2: Optimization of RPC mass production for Phase2
 - MPP: German industrial partners for RPC gas gap production. RPC assembly stand. sMDT tube assembly line
 - Wigner RCP: Lightweight MWPC technologies
 - Univ. Michigan: squared drift tubes

- Production of thin-gap RPCs established at three places:
 - MPI for Physics,
 - Mirion technologies in Munich,
 - PTS Maschinenbau in Dillingen.
 - Timeline
 - 2022: Optimization of the production steps.
 - 2023: Qualification of the production with small-size (50x40 cm²) prototypes.
 - 2024: Production of full-size prototypes and start of an aging test as final qualification step.
- Thin gap RPCs**

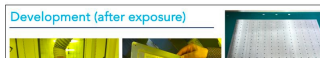
Thin gap RPCs



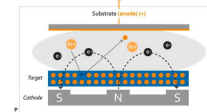
Micromegas Production at ELTOS



We are currently making efforts to transfer the technology of mesh bulk manufacturing to a PCB company. It's important to note that bulk processing is not a standard practice within the PCB industry.



WP1 - T6 : DLC sputtering (LNF, RM3, Napoli)

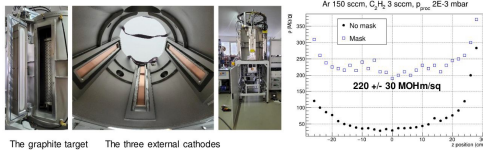


- Technical features:**

- 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.

CID allows to sputter or co-sputter different materials, to create a coating layer by layer or an adjustable gradient in the coating.



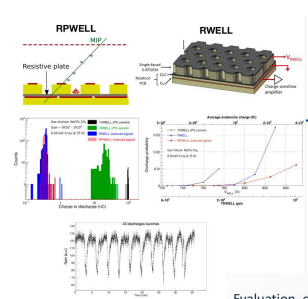
Machine co-funded by CERN and INFN. R&D led by INFN LNF, Roma3 and Na

WP1 activities

- New RPC and TGC structures
- New Resistive MPGD Structures
- New Front-End Electronics
- Optimization of Scalable Readout System
- Eco-friendly gases
- Manufacturing
- Longevity on large detector area
 - INFN-BA, INFN-LNF, INFN-RM2, INFN-TO: RPC eco gas ageing test campaign
 - Weizmann: MPGD characterization of discharge rate and intensity
 - IGPC: Characterization of electrode materials from longevity studies and devising the standardized investigation protocol

Discharges RPWELL and RWELL

- Characterization of discharge rate and intensity¹
- Discharge effect² on detector operation and readout
- Characterization of resistive materials³ and development of new composite materials



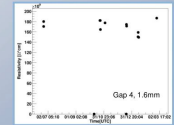
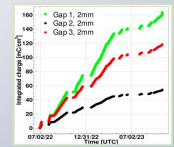
1) Jash, Abhik, Luca Moleri, and Shikma Bressler. "Electrical breakdown in Thick-GEM based WELL detectors." *Journal of Instrumentation* 17.12 (2022): 120101.
2) Jash, A., L. Moleri, and S. Bressler. "Electrical discharges and their effect in a Resistive Plate WELL detector." *NIMA* (2023): 167540.
3) Jash, Abhik, Luca Moleri, and Shikma Bressler. "Discharge quenching mechanism and RPWELL performance with tunable 3D printed resistive plates." *arXiv preprint arXiv:2401.15611* (2024).



Eco-gas ageing

Evaluation of the impact of the integrated current and ECO2-induced ageing effect on RPCs, on a long-term scale:

- ageing test campaign at CERN GIF++ on RPCs characterized by different layouts (already on-going @ABS 2.2, strong synergy with WP1-T5, D5.1)
- systematic performance studies, at different irradiations, during dedicated beam tests at CERN GIF++ (spring/summer 2024, schedule yet to be approved, strong synergy with WP1-T5, D5.1)
- Systematic resistivity measurements (with the Argon method)

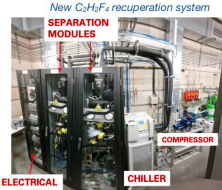
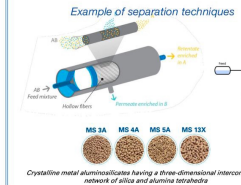


CERN, 7 March 2024

Status of the art: gas recuperation systems

Task 7.2: Development and test of gaseous detectors operated with new recuperation and recirculation systems.

- Gas recuperation systems
- Several gas recuperation systems developed in the last ~15 years
 - Dedicated R&D necessary
 - Different separation principles depending on the gas mixture and detector
 - No available plants in industry
 - Gas mixtures are very specific for particle detectors, not used in industry
 - Fundamental to recuperate GHG and reduce emissions



7 Mar 2024

WP1 activities

- New RPC and TGC structures
- New Resistive MPGD Structures
- New Front-End Electronics
- Optimization of Scalable Readout System
- Eco-friendly gases
- Manufacturing
- Longevity on large detector area
- New Detector Structures
 - INFN FE, INFN LNF: Cylindrical μ RWELL
 - INFN FE: Tubular μ RWELL
 - INFN RM2, MPP, UGEV, HKU: Resistive Cylindrical Chamber
 - USTC: Cylindrical μ RGroove

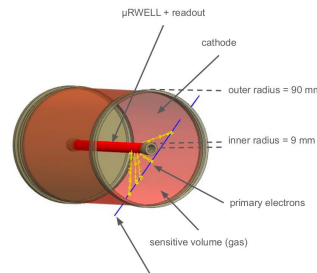
μ Rtubes in a nutshell

The basic idea is to develop a **tubular MPGD** working as a radial TPC: the readout on the inner cylinder and the cathode on the outer one.

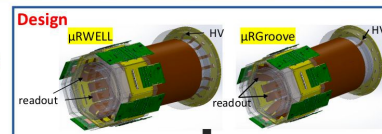
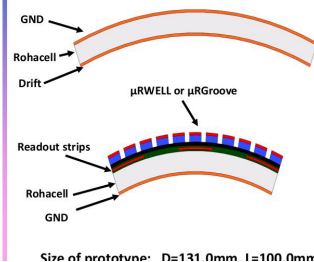
The signal is **amplified** by a μ RWELL as a single stage amplification and the readout is instrumented with strips parallel to the axis.

The main concept of the project is based on the convergent electrical field lines which introduce two important points:

1. it reduces the transverse diffusion of the electrons
2. it **minimizes the number of channels** with respect to the sensitive volume



R&D status: C-MPGD mechanical design

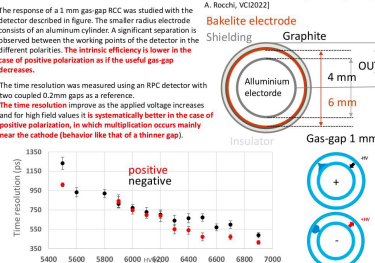


DETECTOR DESCRIPTION AND RELIMINARY RESULTS (1 mm GAS-GAP)

[Development of Resistive Cylindrical Chambers, R. Cardarelli, XVI Workshop on Resistive Plate Chambers and Related Detectors]
[Moderation of the avalanche gas discharge through a quasi-uniform electric field device: the Resistive Cylindrical Chamber, A. Rocchi, VC2022]

The response of a 1 mm gas-gap RCC was studied with the detector described in figure. The smaller radius electrode consists of an aluminium cylinder. A significant separation is observed between the working points of the detector in the different polarities. **The intrinsic efficiency is lower in the case of positive polarization as if the useful gas-gap decreases.**

The time resolution was measured using an RPC detector with two coupled 0.2mm gaps as a reference.
The time resolution improves as the applied voltage increases and for high field values it is **systematically better in the case of positive polarization**, in which multiplication occurs mainly near the cathode (behavior like that of a thinner gap).



Resistive cylindrical chambers



WP2

Drift chambers

Nicola De Filippis

WP2: Drift chambers



Task	Performance Goal
Development of front-end ASIC for cluster counting	Design/construction/test of a prototype of the frontend ASIC for cluster counting (with High bandwidth, High gain, Low power consumption, Low mass)
Development of a scalable multichannel DAQ board	Working prototype of a scalable multichannel DAQ board (with High sampling rate, Dead-time-less, DSP and filtering ability, Event time stamping, for Track triggering)
Mechanics: new wiring procedures and new endplate concepts	Conceptual designs of novel wiring procedures (feed-through-less wiring procedures) and full design of innovative concepts of more transparent endplate (< 5% X ₀).
Increase rate capability and granularity	Measurements of performance on prototypes of drift cells at different granularities (smaller cell size and shorter drift time) and with different field configurations (higher field-to-sense ratio).
Consolidation of new wire materials and wire metal coating	Evaluation of the electrostatic stability of wires with High yield strength, Low mass, low Z, High conductivity. Study of aging effects. Evaluation of existing or a sputtering facility for metal coating of carbon wires.
Study ageing phenomena for new wire types	Tests of prototypes built with new wire types at beams and irradiation facilities. Measurement of performance on total integrated charge and establish charge collection limits.
Optimization of gas mixing, recuperation, purification and recirculation systems	Measurement of the performance of hydrocarbon-free gas mixtures with High quenching power, Low-Z, High radiation length. Design of a recirculating system.

Started

Started

Advanced

To be restarted

Started

To be started

Not started

- Laboratoire de Physique des 2 Infinis Irène Joliot-Curie(IJCLab) not in the MoU
- INFN, Bari (INFN-BA)
- INFN, Lecce (INFN-LE)
- INFN, Rome (INFN-RM)
- US cluster (US):
 - U. Mass Amherst, U. Michigan, Irvine, Tufts U., BNL, FIT, U. Florida, U. Wisconsin
- Nankai University (Nankai U.) not in the MoU
- Tsinghua University (Tsinghua U.)
- Institute of High Energy Physics, Chinese Academy of Sciences (IHEP-CAS)
- Wuhan University (Wuhan U.)
- Jilin University (Jilin U.)
- University of Science and Technology of China (USTC)
- Institute of Modern Physics, Chinese Academy of Sciences (IMP-CAS)
- Bose Institute (Bose)

March 2025	
28 Mar	WP2 -Drift Chambers meeting
October 2024	
10 Oct	WP2 -Drift Chambers meeting
July 2024	
18 Jul	WP2 -Drift Chambers meeting
May 2024	
17 May	WP2 -Drift Chambers meeting
April 2024	
10 Apr	WP2 -Drift Chambers meeting
March 2024	
01 Mar	WP2 -Drift Chambers meeting

Challenges

Electrostatic stability condition: $\frac{\lambda^2 L^2}{4\pi\epsilon w^2} < \text{wire tension} < YTS \cdot \pi r_w^2$

λ = linear charge density (gas gain)
 L = wire length, r_w wire radius, w = drift cell width
 YTS = wire material yield strength

The proposed drift chambers for FCC-ee and CEPC have lengths $L = 4 \text{ m}$ and plan to exploit the **cluster counting** technique, which requires gas gains $\sim 5 \times 10^5$.

This poses serious constraints on the drift cell width (w) and on the wire material (YTS).

⇒ **new wire material studies**

Non-flammable gas / recirculating gas systems

Safety requirements (**ATEX**) demands stringent limitations on flammable gases;

Continuous increase of **noble gases cost**

⇒ **gas studies**

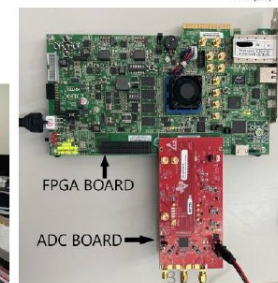
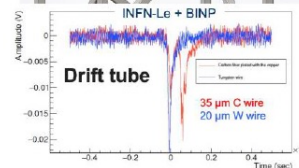
Data throughput

Large number of channels, high signal sampling rate, long drift times (slow drift velocity), required for **cluster counting**, and high physics trigger rate (Z_0 -pole at FCC-ee) imply data transfer rates in excess of $\sim 1 \text{ TB/s}$

⇒ **on-line real time data reduction algorithms**

New wiring systems for high granularities / / new end-plates / new materials

- **reduction of the material budget**



Assessment of the **Cluster Counting/Timing technique** with real data and simulation

WP2 Tasks

- Development of a front-end ASIC for cluster counting
- Development of a scalable multichannel DAQ board

G. De Robertis and F. Loddo from INFN Bari + J. Verdejo Palacios (Ph.D)

Bari: Enable testing of the HDSoc v1 (Naluscientific) waveform digitizer → starting to develop a dedicated communication block to interface MOSAIC with HDSoc v1.

- ✓ MOSAIC Board Key Features
- Designed for detector testing in high-energy physics.
 - Supports 10 high-speed serial links (up to 6.6 Gbps) and 126 slower LVDS channels.
 - Xilinx XC7A200T FPGA with:
 - 215,360 Logic Cells, 730 Block RAMs (12.8 MB)
 - 16 Low-Power Gigabit Transceivers (up to 6.6 Gb/s)
 - High-speed data transfer via DDR3
 - Gigabit Ethernet interface with 120 MB/s transfer rate
 - Integrated 8-bit microprocessor for configuration & monitoring



- ✓ Waveform Digitizer HDSoc v1 Features
- Sampling Rate: 1 GSa/s
 - 32 channels
 - 2k Sample Buffer
 - > 600MHz Analog Bandwidth
 - < 100 ps Timing Resolution
 - Internally configurable triggering schemes

- Plans
- Final design and implementation of the MOSAIC-HDSoc interface block
 - Initial firmware test with simulated data.
 - Full integration and testing with the HDSoc waveform digitizer.



The excellent performance of the cluster finding algorithms in offline analysis, relies on the assumption of being able to transfer the full spectrum of the digitized drift signals. However ...

- according to the IDEA drift chamber operating conditions:
- 56448 drift cells in 112 layers (~130 hits/track)
 - maximum drift time of 500 ns
 - cluster density of 20 clusters/cm
 - signal digitization 12 bits at 2 Gsa/s

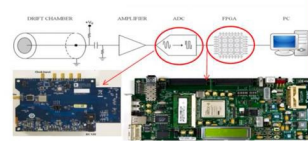
- and to the FCC-ee running conditions at the Z pole
- 100 kHz of Z decays with 20 charged tracks/event multiplicity
 - 30 KHz of $\gamma\gamma \rightarrow$ hadrons with 10 charged tracks/event multiplicity
 - 2.5% occupancy due to beam noise
 - 2.5% occupancy due to hits with isolated peaks

Reading both ends of the wires, ⇔ data rate ≥ 1 TB/s !

Solution consists in transferring, for each hit drift cell, instead of the full signal spectrum, only the minimal information relevant to the application of the cluster timing/counting techniques, i.e., the amplitude and the arrival time of each peak associated with each individual ionisation electron.

Interest by any French institute ?

This can be accomplished by using a FPGA for the real time analysis of the data generated by the drift chamber and successively digitized by an ADC.



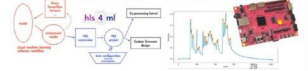
Single channel solution has been successfully verified.

© Chavakis et al., The Use of FPGA in Drift Chambers for High-Energy Physics Experiments May 31, 2017 <https://arxiv.org/abs/1705.08863>

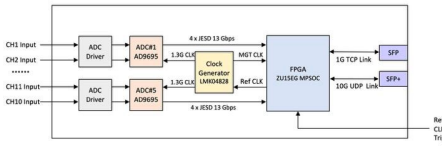
With this procedure data transfer rate is reduced to ~ 25 GB/s

Extension to a 4-channel board is in progress. Ultimate goal is a multi-ch. board (128 or 256 channels) to reduce cost and complexity of the system and to gain flexibility in determining the proximity correlations between hit cells for track segment finding and for triggering purposes.

Implementing ML algorithms on FPGA for peak finding

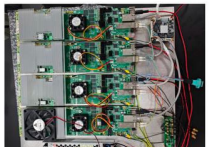


ADC and Readout board

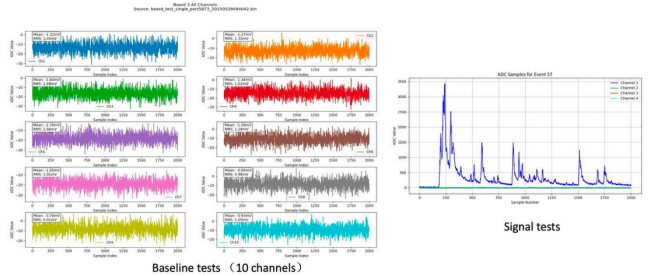


Electronics for the CEPC DCH prototype

- 10ch ADC board (AD9695)
- Sampling rate: 1.3 Gsps@ 14 bit
- Xilinx Ultrascale+ ZU15EG Readout Board



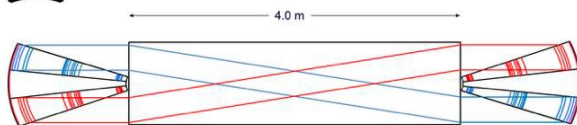
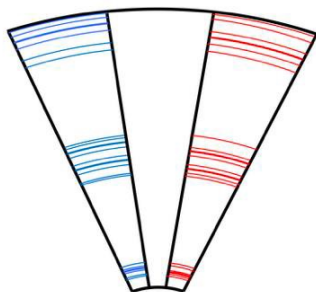
Preliminary tests of the readout electronics



- Development of a front-end ASIC for cluster counting
- Development of a scalable multichannel DAQ board
- Mechanics: new wiring procedures and new endplate concepts

IDEA DC prototype

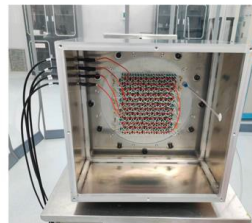
Prototype wiring proposal



- Finished the prototype construction, cabling and HV training
- Gas mixture: $\text{He}/i\text{C}_4\text{H}_{10} = 90/10$
- Commissioning and preliminary testing with cosmic-ray are ongoing



Gas sealing

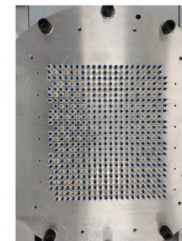


Cabling

- Feedthroughs are employed for positioning and fixing wires
- Vertical wiring technology is adopted



wiring



Feedthroughs



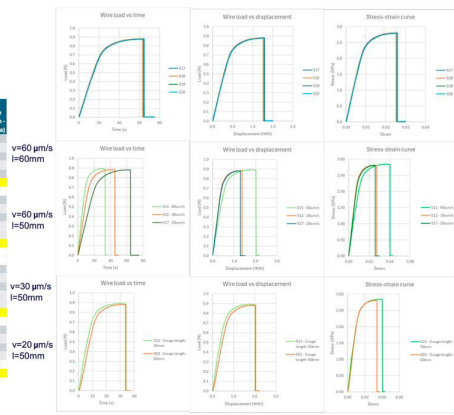
WP2 Tasks

- Development of a front-end ASIC for cluster counting
- Development of a scalable multichannel DAQ board
- Mechanics: new wiring procedures and new endplate concepts
-
- Consolidation of new wire materials and wire metal coating

W+Au wire test

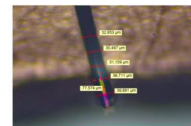
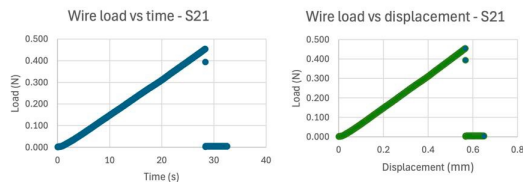
Wire diameter: 20μm

Experiment	Target length (words)	Target length (tokens)	Yield (tokens)	Effective length (tokens)	Effective length (words)	Yield (tokens)	Yield (words)	Yield (tokens)	Yield (words)
	Length (words)	Length (tokens)	Yield (tokens)	Effective length (tokens)	Effective length (words)	Yield (tokens)	Yield (words)	Yield (tokens)	Yield (words)
1	2.020	172.831	0.9991	16.75	16.75	4.056	1.682	1.682	1.682
2	2.020	172.831	0.9990	32.02	32.02	4.227	1.680	1.680	1.680
3	2.020	172.831	0.9990	48.03	48.03	4.227	1.680	1.680	1.680
4	2.020	172.831	0.9991	64.04	64.04	4.227	1.680	1.680	1.680
5	2.020	172.831	0.9991	80.05	80.05	4.227	1.680	1.680	1.680
6	2.020	172.831	0.9991	96.06	96.06	4.227	1.680	1.680	1.680
7	2.020	172.831	0.9991	112.07	112.07	4.227	1.680	1.680	1.680
8	2.020	172.831	0.9991	128.08	128.08	4.227	1.680	1.680	1.680
9	2.020	172.831	0.9991	144.09	144.09	4.227	1.680	1.680	1.680
10	2.020	172.831	0.9991	160.10	160.10	4.227	1.680	1.680	1.680
11	2.020	172.831	0.9991	176.11	176.11	4.227	1.680	1.680	1.680
12	2.020	172.831	0.9991	192.12	192.12	4.227	1.680	1.680	1.680
13	2.020	172.831	0.9991	208.13	208.13	4.227	1.680	1.680	1.680
14	2.020	172.831	0.9991	224.14	224.14	4.227	1.680	1.680	1.680
15	2.020	172.831	0.9991	240.15	240.15	4.227	1.680	1.680	1.680
16	2.020	172.831	0.9991	256.16	256.16	4.227	1.680	1.680	1.680
17	2.020	172.831	0.9991	272.17	272.17	4.227	1.680	1.680	1.680
18	2.020	172.831	0.9991	288.18	288.18	4.227	1.680	1.680	1.680
19	2.020	172.831	0.9991	304.19	304.19	4.227	1.680	1.680	1.680
20	2.020	172.831	0.9991	320.20	320.20	4.227	1.680	1.680	1.680
21	2.020	172.831	0.9991	336.21	336.21	4.227	1.680	1.680	1.680
22	2.020	172.831	0.9991	352.22	352.22	4.227	1.680	1.680	1.680
23	2.020	172.831	0.9991	368.23	368.23	4.227	1.680	1.680	1.680
24	2.020	172.831	0.9991	384.24	384.24	4.227	1.680	1.680	1.680
25	2.020	172.831	0.9991	400.25	400.25	4.227	1.680	1.680	1.680
26	2.020	172.831	0.9991	416.26	416.26	4.227	1.680	1.680	1.680
27	2.020	172.831	0.9991	432.27	432.27	4.227	1.680	1.680	1.680
28	2.020	172.831	0.9991	448.28	448.28	4.227	1.680	1.680	1.680
29	2.020	172.831	0.9991	464.29	464.29	4.227	1.680	1.680	1.680
30	2.020	172.831	0.9991	480.30	480.30	4.227	1.680	1.680	1.680
31	2.020	172.831	0.9991	496.31	496.31	4.227	1.680	1.680	1.680
32	2.020	172.831	0.9991	512.32	512.32	4.227	1.680	1.680	1.680
33	2.020	172.831	0.9991	528.33	528.33	4.227	1.680	1.680	1.680
34	2.020	172.831	0.9991	544.34	544.34	4.227	1.680	1.680	1.680
35	2.020	172.831	0.9991	560.35	560.35	4.227	1.680	1.680	1.680
36	2.020	172.831	0.9991	576.36	576.36	4.227	1.680	1.680	1.680
37	2.020	172.831	0.9991	592.37	592.37	4.227	1.680	1.680	1.680
38	2.020	172.831	0.9991	608.38	608.38	4.227	1.680	1.680	1.680
39	2.020	172.831	0.9991	624.39	624.39	4.227	1.680	1.680	1.680
40	2.020	172.831	0.9991	640.40	640.40	4.227	1.680	1.680	1.680
41	2.020	172.831	0.9991	656.41	656.41	4.227	1.680	1.680	1.680
42	2.020	172.831	0.9991	672.42	672.42	4.227	1.680	1.680	1.680
43	2.020	172.831	0.9991	688.43	688.43	4.227	1.680	1.680	1.680
44	2.020	172.831	0.9991	704.44	704.44	4.227	1.680	1.680	1.680
45	2.020	172.831	0.9991	720.45	720.45	4.227	1.680	1.680	1.680
46	2.020	172.831	0.9991	736.46	736.46	4.227	1.680	1.680	1.680
47	2.020	172.831	0.9991	752.47	752.47	4.227	1.680	1.680	1.680
48	2.020	172.831	0.9991	768.48	768.48	4.227	1.680	1.680	1.680
49	2.020	172.831	0.9991	784.49	784.49	4.227	1.680	1.680	1.680
50	2.020	172.831	0.9991	800.50	800.50	4.227	1.680	1.680	1.680
51	2.020	172.831	0.9991	816.51	816.51	4.227	1.680	1.680	1.680
52	2.020	172.831	0.9991	832.52	832.52	4.227	1.680	1.680	1.680
53	2.020	172.831	0.9991	848.53	848.53	4.227	1.680	1.680	1.680
54	2.020	172.831	0.9991	864.54	864.54	4.227	1.680	1.680	1.680
55	2.020	172.831	0.9991	880.55	880.55	4.227	1.680	1.680	1.680
56	2.020	172.831	0.9991	896.56	896.56	4.227	1.680	1.680	1.680
57	2.020	172.831	0.9991	912.57	912.57	4.227	1.680	1.680	1.680
58	2.020	172.831	0.9991	928.58	928.58	4.227	1.680	1.680	1.680
59	2.020	172.831	0.9991	944.59	944.59	4.227	1.680	1.680	1.680
60	2.020	172.831	0.9991	960.60	960.60	4.227	1.680	1.680	1.680
61	2.020	172.831	0.9991	976.61	976.61	4.227	1.680	1.680	1.680
62	2.020	172.831	0.9991	992.62	992.62	4.227	1.680	1.680	1.680
63	2.020	172.831	0.9991	1008.63	1008.63	4.227	1.680	1.680	1.680
64	2.020	172.831	0.9991	1024.64	1024.64	4.227	1.680	1.680	1.680
65	2.020	172.831	0.9991	1040.65	1040.65	4.227	1.680	1.680	1.680
66	2.020	172.831	0.9991	1056.66	1056.66	4.227	1.680	1.680	1.680
67	2.020	172.831	0.9991	1072.67	1072.67	4.227	1.680	1.680	1.680
68	2.020	172.831	0.9991	1088.68	1088.68	4.227	1.680	1.680	1.680
69	2.020	172.831	0.9991	1104.69	1104.69	4.227	1.680	1.680	1.680
70	2.020	172.831	0.9991	1120.70	1120.70	4.227	1.680	1.680	1.680
71	2.020	172.831	0.9991	1136.71	1136.71	4.227	1.680	1.680	1.680
72	2.020	172.831	0.9991	1152.72	1152.72	4.227	1.680	1.680	1.680
73	2.020	172.831	0.9991	1168.73	1168.73	4.227	1.680	1.680	1.680
74	2.020	172.831	0.9991	1184.74	1184.74	4.227	1.680	1.680	1.680
75	2.020	172.831	0.9991	1200.75	1200.75	4.227	1.680	1.680	1.680
76	2.020	172.831	0.9991	1216.76	1216.76	4.227	1.680	1.680	1.680
77	2.020	172.831	0.9991	1232.77	1232.77	4.227	1.680	1.680	1.680
78	2.020	172.831	0.9991	1248.78	1248.78	4.227	1.680	1.680	1.680
79	2.020	172.831	0.9991	1264.79	1264.79	4.227	1.680	1.680	1.680
80	2.020	172.831	0.9991	1280.80	1280.80	4.227	1.680	1.680	1.680
81	2.020	172.831	0.9991	1296.81	1296.81	4.227	1.680	1.680	1.680
82	2.020	172.831	0.9991	1312.82	1312.82	4.227	1.680	1.680	1.680
83	2.020	172.831	0.9991	1328.83	1328.83	4.227	1.680	1.680	1.680
84	2.020	172.831	0.9991	1344.84	1344.84	4.227	1.680	1.680	1.680
85	2.020	172.831	0.9991	1360.85	1360.85	4.227	1.680	1.680	1.680
86	2.020	172.831	0.9991	1376.86	1376.86	4.227	1.680	1.680	1.680
87	2.020	172.831	0.9991	1392.87	1392.87	4.227	1.680	1.680	1.680
88	2.020	172.831	0.9991	1408.88	1408.88	4.227	1.680	1.680	1.680
89	2.020	172.831	0.9991	1424.89	1424.89	4.227	1.680	1.680	1.680
90	2.020	172.831	0.9991	1440.90	1440.90	4.227	1.680	1.680	1.680
91	2.020	172.831	0.9991	1456.91	1456.91	4.227	1.680	1.680	1.680
92	2.020	172.831	0.9991	1472.92	1472.92	4.227	1.680	1.680	1.680
93	2.020	172.831	0.9991	1488.93	1488.93	4.227	1.680	1.680	1.680
94	2.020	172.831	0.9991	1504.94	1504.94	4.227	1.680	1.680	1.680
95	2.020	172.831	0.9991	1520.95	1520.95	4.227	1.680	1.680	1.680
96	2.020	172.831	0.9991	1536.96	1536.96	4.227	1.680	1.680	1.680
97	2.020	172.831	0.9991	1552.97	1552.97	4.227	1.680	1.680	1.680
98	2.020	172.831	0.9991	1568.98	1568.98	4.227	1.680	1.680	1.680
99	2.020	172.831	0.9991	1584.99	1584.99	4.227	1.680	1.680	1.680
100	2.020	172.831	0.9991	1601.00	1601.00	4.227	1.680	1.680	1.680
101	2.020	172.831	0.9991	1617.01	1617.01	4.227	1.680	1.680	1.680
102	2.020	172.831	0.9991	1633.02	1633.02	4.227	1.680	1.680	1.680
103	2.020	172.831	0.9991	1649.03	1649.03	4.227	1.680	1.680	1.680
104	2.020	172.831	0.9991	1665.04	1665.04	4.227	1.680	1.680	1.680
105	2.020	172.831	0.9991	1681.05	1681.05	4.227	1.680	1.680	1.680
106	2.020	172.831	0.9991	1697.06	1697.06	4.227	1.680	1.680	1.680
107	2.020	172.831	0.9991	1713.07	1713.07	4.227	1.680	1.680	1.680
108	2.020	172.831	0.9991	1729.08	1729.08	4.227	1.680	1.680	1.680
109	2.020	172.831	0.9991	1745.09	1745.09	4.227	1.680	1.680	1.680
110	2.020	172.831	0.9991	1761.10	1761.10	4.227	1.680	1.680	1.680
111	2.020	172.831	0.9991	1777.11	1777.11	4.227	1.680	1.680	1.680
112	2.020	172.831	0.9991	1793.12	1793.12	4.227	1.680	1.680	1.680
113	2.020	172.831	0.9991	1809.13	1809.13	4.227	1.680	1.680	1.680
114	2.020	172.831	0.9991	1825.14	1825.14	4.227	1.680	1.680	1.680
115	2.020								

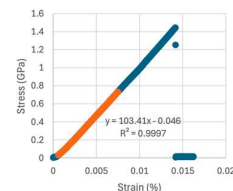


Monofilament C wire test

Specimen number	Tensile Strength (GPa)	Young module (GPa)	R ²	Effective test time (s)	Total wire elongation (mm)	Elongation (%)	Wire diameter: 33.5µm
21	1.445	103.413	0.9997	28.350	0.567	1.418	v=20 µm/s l=40mm
22	1.732	102.886	0.9996	33.725	0.675	1.686	
23	2.120	103.973	0.9999	41.375	0.828	2.069	
24	2.247	98.236	0.9986	45.650	0.826	2.283	
25	2.247	107.915	0.9996	41.425	0.829	2.071	
Average Set	1.958	103.284	0.999	38.105	0.762	1.905	



Stress-strain curve - S21



Tests started in a small clean room at INFN Bari:

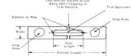
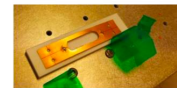
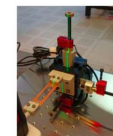
- Tungsten coated with gold
- Molibden coated with gold
- Carbon monofilament

Setup:

- 3 axis picometer motor (30nm step)
- Digital dynamometer (acc. 0.001N)

Standard ASTM D 3379 – 75

- **Scope:** Tensile Strength and Young's modulus for High-Modulus (>21 GPa) Single-Filament Materials (gage length > 2000*wire diameter)
- **Summary:** The filaments are center-line mounted on special slotted tabs. The tabs are gripped so that the test specimen is aligned axially in the jaws of a constant-speed movable-crosshead test machine. The filaments are then stressed to failure at a constant strain rate.



WP2 Tasks

- Development of a front-end ASIC for cluster counting
- Development of a scalable multichannel DAQ board
- Mechanics: new wiring procedures and new endplate concepts
- *Increase rate capability and granularity*
- Consolidation of new wire materials and wire metal coating
- *Study ageing phenomena for new wire types*
- *Optimisation of gas mixing, purification, and recirculation systems*

WP3

Straw and Drift Tube Technologies

Junjie Zhu, Oliver Kortner, Peter Wintz, Daniel Bick, Roberto Petti, Katerina Kuznetsova, Temur Enik

WP3: Straw and Drift Tube Technologies

Institute	Contributions						
	T1	T2	T3	T4	T5	T6	T7
GSI					X		X
GTU	X	X	X		X		
IFIN-HH			X	X	X		X
IITG	X	X	X	X	X		X
IITK				X	X		
INFN-TO				X			
INP-Almaty	X	X	X	X	X	X	X
MPP	X	X	X	X	X		
NISER	X		X				
RU Bochum			X	X	X		X
U Hamburg	X	X	X			X	
U Punjab	X		X	X			
U South Carolina		X	X	X	X		X
U Duke		X					
U Delhi	X	X		X			
BNL				X			
FIT				X			
JLab				X			
U Mass. Amherst				X			
U Michigan	X	X	X	X			
UC Irvine				X			
U Wisconsin				X			
Tufts University	X	X	X				

2024 committments, updates for institutes which left.
US cluster institutes marked in blue.

Project	Title	Project Leader
WP3-FCC (WP3A)	Straw chamber and drift tube technologies for applications at FCC-ee/hh	Oliver Kortner Junjie Zhu
WP3-HAD (WP3B)	Straw chamber technologies for hadron physics applications	Peter Wintz
WP3-DM (WP3C)	Large area straw detector for Dark Sector applications	Daniel Bick
WP3-NEU (WP3D)	Straw chamber technologies for neutrino physics applications	Roberto Petti
WP3-MPT (WP3E)	Optimization of straw materials and production technologies	Temur Enik
WP3-RO (WP3F)	Optimization of electronic readout	Katerina Kuznetsova

Task	Performance Goal
Optimize straw materials and straw production technologies	Development of thin straw film tube walls (20...30 μm and below) with robust metallization, low cross-talk and resistance to ageing effects
Develop and improve application-specific straw tube designs	• Small diameter straws (5 mm) with fast timing (< 100 ns). • Ultra-thin straws with tube walls < 20 μm (X/X0 < 0.02%). • Ultra-long straws with thin walls (~ 30 μm) and 4 m length
Optimize the detector mechanical system	Development of self-supporting straw modules and/or control of material relaxation with precise straw position alignment
Optimize the front-end electronics (ASIC) and read-out system	Leading- and trailing-edge time readout and/or charge readout down to sub-ns precision
Enhance the tracker measurement information	3D/4D tracking with high-resolution, PID via the particle-specific dE/dx information. The goals are spatial straw resolutions of 150 μm or better, time t0 extraction with O(ns) resolution and dE/dx resolution better than 10%
Enhance the detector longevity	Ageing resistance of O(1 C/cm) for thin-wall straws
Optimize the online / offline software	Develop SW and methods for straw tube and electronics simulations, straw calibration, pattern recognition, tracking, and PID and tracker alignment

- Presentations in WGs
- Topical Workshops
- Beam tests
- Detector School



Mini-Workshop on Straw Tracker R&D for a Future Electron-Positron Higgs Factory

📅 Oct 14, 2024, 9:00 AM → Oct 15, 2024, 4:30 PM US/Eastern
📍 335 West Hall (University of Michigan)

WP3 project activities

– Straw and drift tube technologies for FCC-ee/hh

- Straw detector implementation in FCC-ee simulation framework
- Optimization of straw parameters and detector layout with $X/X_0 \sim 1\%$
- Cluster counting (dN/dx) readout for PID including simulation
- Drift tubes (sMDT) for FCC-hh

– Straw technologies for hadron physics applications

- Minimal material budget by self-supporting straw modules
- 4D+PID central tracker, 4D by t_0 extraction
- PID by dE/dx ($p/K/\pi < 1$ GeV/c) using TDC time-over-threshold
- Application: PANDA@FAIR

– Large area straw detector for Dark Sector applications

- Straw tubes up to 5m length
- Large detector planes (~ 50 m²) in vacuum
- Novel methods for straw alignment and relaxation compensation
- Application: SHiP@CERN

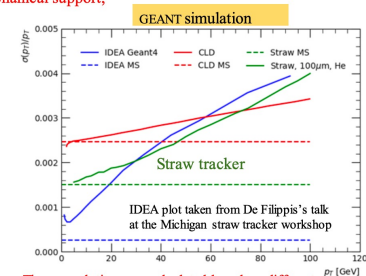
A straw tracker proposal

Slide by Junjie Zhu

- Propose to build a thin-wall straw inner tracker for FCC-ee
- Benefits of straws: low material budget, a single unit for each straw, radial symmetric electric field, triggering, PID with dN/dx, straws with different radii can be used in different regions, low wire density, simpler endplate structure
- **Challenges:** thin straw production, long thin straw assembly, mechanical support, PID with dN/dx, ...
- Straw tracker concept and performance studies

- Implemented a geometry inside the FCC-ee simulation framework, $\sim 1.2\%$ X_0 for 100 layers of straws with a wall thickness of 12-20 μm
- Implementation of the detector geometry inside GEANT
- Momentum resolution studies with a python fitting program with MS effects included

An example layout:
O(60k) straws, coverage: R between 0.3-1.8 m and a length of 4-5 m
Diameters 1.0 - 1.5 cm, single hit resolution: ~ 100 μm
10 superlayers (each 10 layers), Stereo angle: 2-5 degrees



These resolutions are calculated based on different assumptions and should be viewed with a grain of salt.

June 20th, 2025

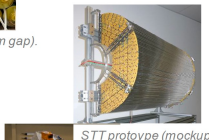
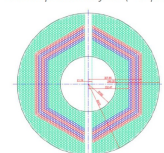
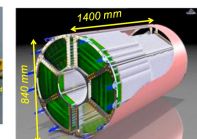
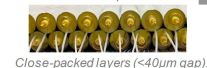
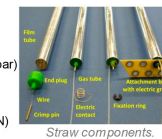
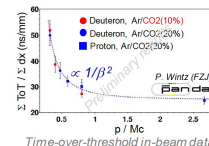
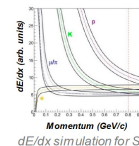
P. Wintz - WP3 Report

Straw Chamber Technologies for Hadron Physics

Slide by Peter

4D+PID Central Straw Tracker in 2T solenoidal B-field

- 19 axial + 8 stereo-layers ($\pm 3^\circ$)
 - 27 μm Al-mylar film, 10mm diameter, 1400mm length, Ar/CO₂ drift gas (2 bar)
 - Minimal number of straw components and minimized material thickness
- Low material budget
 - Close-packed straw layers, self-supporting by gas overpressure ($\Sigma F=32\text{KN}$)
 - $X/X_0 \sim 1.3\%$ total and 0.04% per straw layer
- Drift time and time-over-threshold for PID using TDC time readout
 - resolution: $\sigma(r) < 150\mu\text{m}$, $\sigma(z) \sim 2\text{-}3\text{mm}$; $\Delta p/p \sim 1\text{-}2\%$
 - $p/K/\pi$ - separation for momentum < 1 GeV/c
- Particle rates < 1 MHz/straw, < 10 kHz/cm²



Prototype with 3×3kg Pb bricks on top.

June 20th, 2025

P. Wintz - WP3 Report

p. 11

WP3 project activities

STRAW TRACKER FOR NEUTRINO PHYSICS

Slides by Roberto Petti

86 modules
~220,000 straws

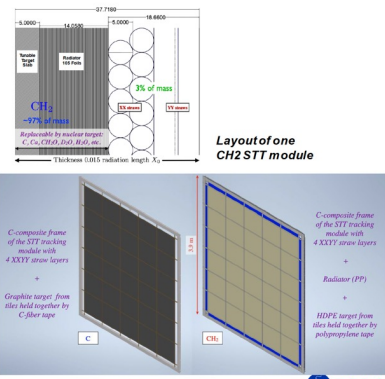
average straw length 3.2 m
maximal straw length 3.8 m
internal gas volume ~14 m³
nominal gas pressure ~2 bar
Gas mixtures:
Xe/CO₂ & Ar/CO₂ 70/30

Straw Tube Tracker (STT) for SAND

"Solid" H
670 kg

Removable targets

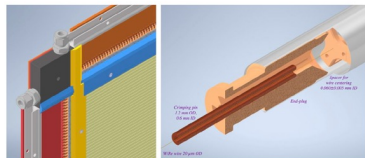
"Solid" H from subtraction
between CH₂ and C



- **Straw technologies for neutrino physics applications**
 - ~ 220k straws, 5mm diameter, 19µm wall, up to ~4m length
 - 3D tracker with transition radiation detection (gas: Xe/CO₂ & Ar/CO₂)
 - “Solid hydrogen target” concept in neutrino physics application
 - Flexible modules: target/radiator and “transparent” straw planes
 - Application: SAND@DUNE

STRAW TRACKER FOR NEUTRINO PHYSICS

Slides by Roberto Petti

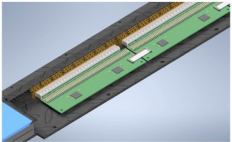


Self-supporting tracking module with 4 XYY straw layers
Self-centering of wires with precision spacers

Low-power readout boards integrated into C-fiber frame (64 channels each)

VMM3a for initial data
Custom ASIC with dual sub channels for time and charge measurements

Self-cooling design



WP3 project activities

Ultrasonic welding (USW) technology optimization:

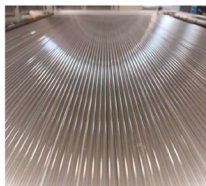
Slide by Temur Enik

Running/Future Detectors:

NA62,
COMET,
SHIP,
DUNE,
SPD, ...



Straw material: PET
Production lines: mostly laboratories



4 m long 5 mm diameter
straws wall thickness: 19 μm
metallization: double-sided Al
(DUNE type)



4 m long 20 mm diameter
straws, wall thickness: 36 μm,
metallization:
50nm(Cu)+20nm(Au)
(SHIP type)

Advancing the USW technology :

production from double-side Al-metallized film



destruction of the
ultrasonic head with
aluminum oxide

Double Al-metallization:
• allows to increase the straw quality keeping
its cost low compared to Cu/Au-coated films
• however makes USW problematic
• removing the metallization from the film
side-band improves the production process

removing the Al-coating with a laser
during the welding process



P. Wintz - WP3 Report

p. 16



June 20th, 2025

Optimization of electronic readout:

Slide by Katerina Kuznetsova

Readout for trackers with Particle Identification option: simultaneous
readout of time-at-threshold (tracking) and signal charge (PID):

- two shaping branches (fast for tracking + slow for charge)
- single branch with compromising parameters

- MPGD and Wire detectors compatible
- Target specific application
- Limited complexity
- Reuse existing solutions (ToAST)
- 65nm

Final ToRA v1 parameters

Channels	64		
Size	4.3×2.6	mm ²	
Power	640	mW	
Supply voltage	1.2	V	
Gain	2.6, 9.12	mV/fC	
Peaking time	25, 50, 150, 250	ns	
Main clock	200	MHz	
Time resolution	1.44	ns	r.m.s.
Input polarity	both		

Will depend on the FE
optimization results

ToRA v1: 2025

ToRA v2: 2026-28

Maksim Alexeev (Torino)

Torino Readout (for) AMBER ASIC

Detector	MM	Straw	
Channels/ASIC	64	64	
Power/channel	≤ 20	≤ 10	mW
Input capacitance	≤ 350	20-100	pF
Input charge	1-100	1-1000	fC
Input impedance	≤ 50 Ω	100 Ω	Ω
Max rate	≤ 0.5	≤ 0.18	MHz
Peaking time	150-500	20-100	ns
Time resolution	1-2	≤ 1	ns
Charge resolution	8	10	bits
Gain	10-30	2	mV/fC
ENC @10 pF	500-1000		e ⁻
ENC @150 pF	1000-2000		e ⁻
ENC @60 pF		3000	e ⁻
Threshold range	100	0-15	fC
Clock frequency	200	200	MHz

single branch, prototype production
submitted 5/25, delivery expected 9/25

configurable double branch



June 20th, 2025

P. Wintz - WP3 Report

p. 17

– Straw technologies for neutrino physics applications

- ~ 220k straws, 5mm diameter, 19 μm wall, up to ~4m length
- 3D tracker with transition radiation detection (gas: Xe/CO₂ & Ar/CO₂)
- “Solid hydrogen target” concept in neutrino physics application
- Flexible modules: target/radiator and “transparent” straw planes
- Application: SAND@DUNE

– Optimization of straw materials, production technologies

- New production technologies, e.g. ultrasonic welding of PET-film
- Standardization of straw components and production technologies
- Broad range of straw parameters (diameter, wall, length, coating ..)
- Quality assurance methods for O(100k) straw productions

– Optimization of electronic readout

- Developments incl. simulation and ASIC designs
- Broad application range for high/low rates, fast/medium timing

WP3 project activities

– Straw and drift tube technologies for FCC-ee/hh

- Straw detector implementation in FCC-ee simulation framework
- Optimization of straw parameters and detector layout with $X/X_0 \sim 1\%$
- Cluster counting (dN/dx) readout for PID including simulation
- Drift tubes (sMDT) for FCC-hh

– Straw technologies for hadron physics applications

- Minimal material budget by self-supporting straw modules
- 4D+PID central tracker, 4D by t_0 extraction
- PID by dE/dx ($p/K/\pi < 1$ GeV/c) using TDC time-over-threshold
- Application: PANDA@FAIR

– Large area straw detector for Dark Sector applications

- Straw tubes up to 5m length
- Large detector planes (~ 50 m²) in vacuum
- Novel methods for straw alignment and relaxation compensation
- Application: SHiP@CERN

– Straw technologies for neutrino physics applications

- ~ 220 k straws, 5mm diameter, 19 μ m wall, up to ~ 4 m length
- 3D tracker with transition radiation detection (gas: Xe/CO₂ & Ar/CO₂)
- “Solid hydrogen target” concept in neutrino physics application
- Flexible modules: target/radiator and “transparent” straw planes
- Application: SAND@DUNE

– Optimization of straw materials, production technologies

- New production technologies, e.g. ultrasonic welding of PET-film
- Standardization of straw components and production technologies
- Broad range of straw parameters (diameter, wall, length, coating ..)
- Quality assurance methods for O(100k) straw productions

– Optimization of electronic readout

- Developments incl. simulation and ASIC designs
- Broad application range for high/low rates, fast/medium timing

WP4

Tracking TPCs

F. García, J. Kaminski

WP4: Tracking TPCs

Task	Performance Goal
IBF reduction	Further developments and studies aiming to reductions of $\text{gain} \times \text{IBF} < 1 \dots 5$
PixelTPC development	Study in more detail various approaches to the pad plane configuration and its amplification structures optimized with respect to resolution and the IBF
Optimization of the amplification stage and its mechanical structure, and development of low X/X0 field cages (FC)	Implementing new ideas already developed and further investigate the increase of the homogeneity of the field cage (FC) and to lower the material budget of its components
FEE for TPCs	To develop an SRS-based readout system for smaller scale experiments and test setups with different types of TPCs. Also, the development of low power electronics and Front-End Electronics cooling
Gas mixture	Studies of new gases suitable for different TPC applications. Particular attention will be given to a low environmental impact (e.g. low GWP) and the effect of varying the gas pressure

- We are not ready yet for the endorsement. Preparations are ongoing to reach that stage.
- There is a wide range of activities that reach a critical mass to pursue the endorsement by the collaboration.
- Most of the groups are concentrating their efforts in high-granularity pixel readout for different applications.

WP4: ongoing activities

Leaders and Groups	Activities and Sites
E. Oliveri - GDD	- TimePix4 test with a triple GEM detector - TimePix4 test with a μRWELL 
A. Obertelli/P. Gasik – GSI/TUD	GEM+MMG TPC with VMM3a base readout: HYDRA pion tracker 
B. Voss - GSI	- Tracking using VMM3a base readout - Integration of TimePix3 - Integration of TimePix3 for tracking for MIXE 
M. Heiss - PSI	- Test with GEM-TPC for tracking for MIXE experiment - Integration of pixel readout with VMM3a - Integration of TimePix3 for tracking for MIXE 
H. Ferreira – IEAP/CTU	- Tests of Cylindrical GEM-TPC with VMM3a - Test of Cylindrical GEM-TPC with TimePix3 - Test of Cylindrical GEM-TPC with TimePix4  
F. Garcia - HIP	- Tracking using VMM3a base readout - Integration of TimePix3 for tracking to a GEM-TPC - Integration of the TimePix4 for tracking to a GEM-TPC - Integration of TimePix3 for tracking for MIXE 

WP5

Gaseous calorimeters

I. Laktineh

WP5: Gaseous Calorimeters

Task	Performance Goal
Conception, construction and characterization of large sampling elements for calorimeters	Large and thin gaseous detectors are needed for future calorimeters. However, one needs to ensure that the response of such detectors is uniform in terms of efficiency and particle cluster size . The two previous are used to reconstruct the energy when binary or multi-threshold readout is used. The gaseous detectors need thus to be conceived and built having in mind such a uniformity. To achieve such a uniformity, precise mechanical structure should be adopted. In addition, the gas distribution system of the detectors should enable a uniform renewal of the gas inside the detectors.
Timing performance of gaseous detectors for calorimeters	Recent studies have shown that time information could help to separate close-by showers but also to evaluate the contribution of delayed neutrons. Some gaseous detectors can provide excellent time information . However a good uniformity of time performance is needed to properly exploit such an interesting feature
Readout electronics for calorimeter gaseous detectors	Development of novel Scalable Readout Systems for Gaseous Detectors. Development of new FPGA-based readout system that matches the data throughput of the electronics

Conception of small detectors of the different technologies

Realization of large detectors ($> 1\text{m}^2$) with different technologies

Construction and performance studies of large detectors of different technologies

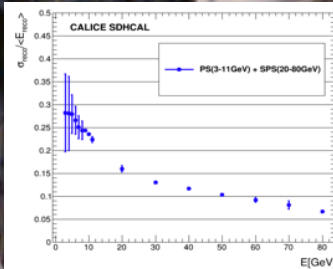
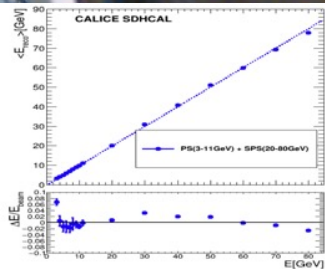
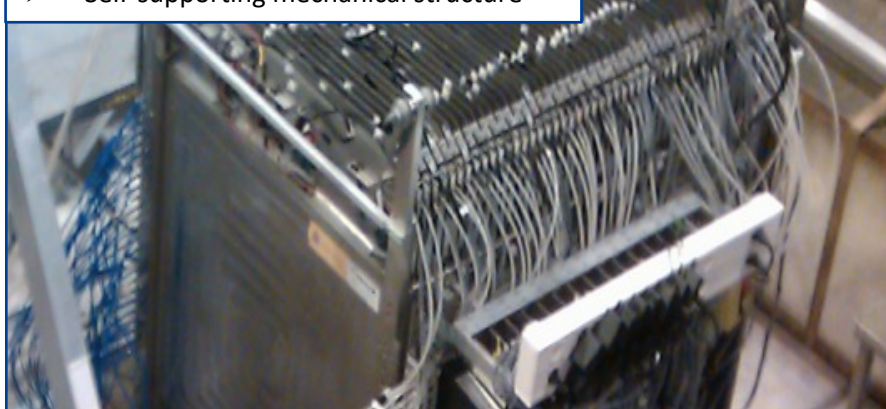
Country	Collaborating Institution	Town
France	IP2I	Lyon
Spain	CIEMAT	Madrid
Belgium	VUB	Brussels
South Korea	SKKU	Suwon
China	SJTU	Shanghai
Germany	MPP	Munich
Israel	WIS	Rehovot
Italy	INFN-Ba	Bari
Italy	INFN-RM3	Rome
Italy	INFN-Na	Naples

- For Endorsement Readiness
 - Clarification of the participation of various groups
 - Clarification of committed resources
- Scientific work is ongoing!
- Regular WP5 scientific meetings organized!

WP5: Tasks Activities

CALICE Semi-Digital Hadronic Calorimeter (SDHCAL)

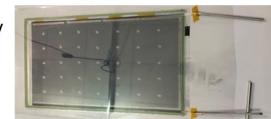
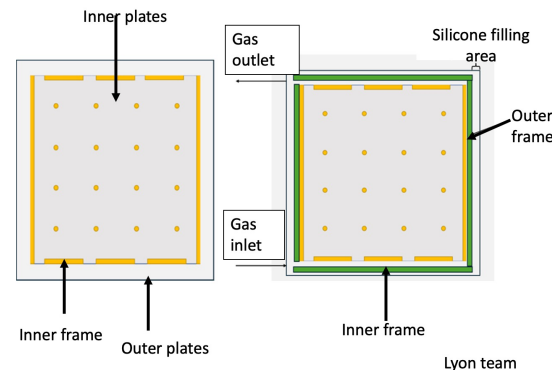
- 48 layers ($\sim 6\lambda_I$)
- 1 cm X 1 cm granularity
- 3-threshold, 500000 channels
- Power-Pulsed
- Triggerless DAQ system
- Self-supporting mechanical structure



Studies showed that precise time information (σ_t better than 150 ps/hit) can improve on close-by hadronic showers separation leading to better PFA performances → MRPC

MRPC are usually built with **fishing lines** → Homogeneity issues

Using **spacers** and appropriate gas circulation system ensures better uniformity



Anode (last plate with coating)



4-gap RPC



Lyon team

Production of circular spacers by a Taiwanese company following a discussion between IP2I, Kyoto University and Taiwanese groups of Academia Sinica and NC (all now parts of DRD1). This makes the MRPC fabrication much simpler

Panel Group 佳值集團

Contact person : Sean Chen 陳傑雄 TEL: +886222212510

Mobile: +886987625807 email: sean@panel.com.tw

<http://www.panel.com.tw/?lang=en>

Production limitation of Mylar sticker

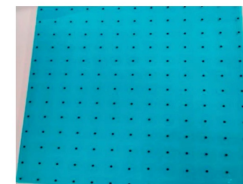
thickness : min = 0.07mm, max = 1.5mm

diameter : min = 1mm

distance : min = 1mm

In our case : 0.26mm = 0.25mm Mylar + 2* 0.05 tapes

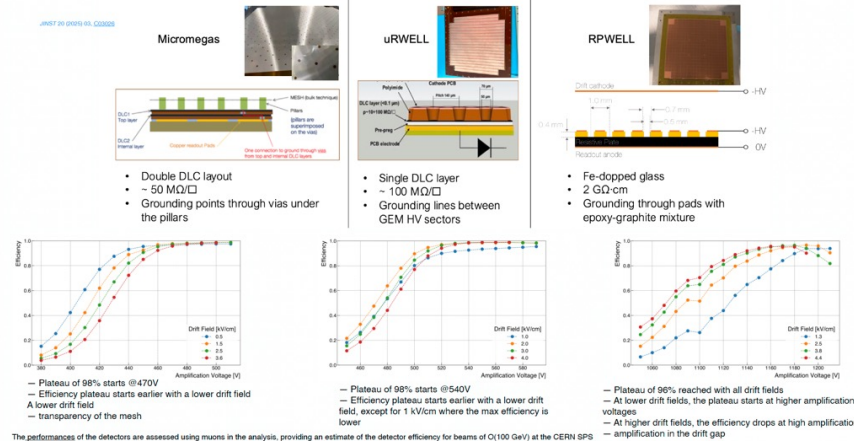
Teflon and Kapton are also possible.



Diameter 2 mm
Pitch 2 cm

The company will produce for us also the strips for gas circulation





WP5: Future Activities

- For MRPC, study time response homogeneity
- For MPGD, conception of large surface detectors
 - Common work on precision mechanics
- Discussion on using different variants of CALOROC ASIC developed by OMEGA within DRD6

MPGD-HCAL

Finalize the studies with digital/semi-digital readout for the small prototype:

- Current semi-digital thresholds not optimized for MPGDs

- Development of a new cell prototype of $\sim 2\lambda$, including 8 $20 \times 20 \text{ cm}^2$ chambers plus 4 $50 \times 50 \text{ cm}^2$ chambers:
 - 2 MicroMegas and 2 μRWELL $50 \times 50 \text{ cm}^2$ under production $\rightarrow$ ready in July/August
 - μRWELL produced with new grounding schema to reduce dead area (ground dots instead of ground lines)

New cell prototype

• Triple-GEM tracker

- Moveable to scan entire surface

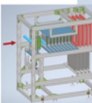
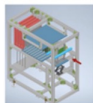
• 1λ with $20 \times 20 \text{ cm}^2$

- 8 dets, $8 \times 2 \text{ cm}$ steel

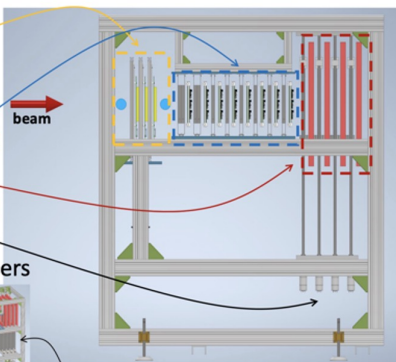
• 1λ with $50 \times 50 \text{ cm}^2$

- 4 dets, $4 \times 4 \text{ cm}$ steel

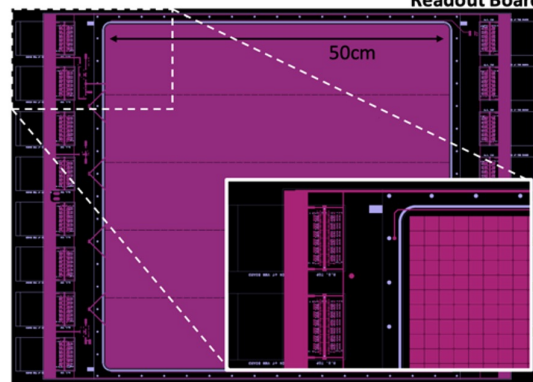
- Allows to insert / extract steel absorbers



Absorbers extracted



Readout Board



WP6

Gaseous photodetectors

F. Tessarotto, S. Dasgupta

WP6 status

DRD1 WP6 not ready to start the endorsement procedure.

Change of participants:

DE-NAT-TUM decided to leave WP6

IT-INFN.PI decided to join WP6

WP6 scientific activity is ongoing in several of the listed Institutes

Deliverables/milestones unchanged

WP6 starting date to be decided

Updated resources table being prepared

Task ID	Task	Performance Goal	ECFA DRD Theme
T1	New robust UV photoconverters for gaseous photon detectors	Robustness against accumulated charge dose: < 20% deterioration of quantum efficiency for 100 mC/cm ²	1.1, 1.2, 1.3
T2	Increase photon detection efficiency	Photoelectron efficiency in gas $\geq 75\%$ of that under vacuum	
T3	Suppression of ion feedback to the photocathode, increase of stability and longevity	Stable detector operation at gain of 10^5 . IBF reduction down to 10^{-4} Stable operation in harsh environment (10^{11} neq/cm ²)	
T4	Gaseous photon detectors sensitive to visible light	Sustained photosensitivity to visible light in gaseous photon detectors	
T5	Spatial resolution and readout granularity	Spatial resolution ≤ 1 mm	
T6	Time resolution	Time resolution ≤ 100 ps	
T7	Modelling and simulation of gaseous photon detectors	Accurate simulation of IBF to the photocathode, gain and stability	
T8	Large area coverage	Gain and QE variation $\leq 10\%$ over 1 m ² area with $\leq 10\%$ dead area.	
T9	Readout electronics for single photon signals	New frontend ASIC chip with 64 channels, ENC 0.5 fC at 20 pF	

WP6 status

Updated WP6 Institute list

DRD1 WP6 not ready to start the endorsement procedure.

Change of participants:

DE-NAT-TUM decided to leave WP6

IT-INFN.PI decided to join WP6

WP6 scientific activity is ongoing in several of the listed Institutes

Deliverables/milestones unchanged

WP6 starting date to be decided

Updated resources table being prepared

Country	Collaborating Institution	Town	Institution Code	Contact
China	University of Science and Technology of China	Hefei	CN-USTC	Jianbei Liu
Finland	Helsinki Institute of Physics	Helsinki	FI-HIP	Francisco Garcia Fuentes
Greece	Aristotle University of Thessaloniki	Thessaloniki	GR-GSRI.AUTH	Dimitrios Sampsonidis
India	National Institute of Science Education and Research, Bhubaneswar	Bhubaneswar	IN- NISER	Shuddha Shankar Dasgupta
Israel	Weizmann Institute of Science	Rehovot	IL-WIS	Shikma Bressler
Italy	INFN Sezione di Padova	Padova	IT-INFN.PD	Gianmaria Collazuol
Italy	INFN Sezione di Padova	Pisa	IT-INFN.PI	Federico Pilo
Italy	INFN Sezione di Trieste	Trieste	IT-INFN.TS	Fulvio Tassarotto
Portugal	University of Aveiro	Aveiro	PT-UA	Joao Veloso
Switzerland	European Organization for Nuclear Research	Geneva	CH-CERN	Eraldo Oliveri
USA	Facility for Rare Isotope Beams, Michigan State University	East Lansing	US-FRIB-MSU	Marco Cortesi

WP7

Timing Detectors

F. Brunbauer, I. Deppner, D. Gonzalez Diaz, I. Laktineh

WP7: Timing Detectors

- WP7 Project A**
High-rate, high-granularity precise timing with MPGDs
- WP7 Project B**
High-rate, large, precise timing (M)RPC



Task ID	Task	Performance Goal	ECFA DRD Theme
T1	Optimize the amplification technology towards large-area detectors	Uniformity over size of $O(m^2)$ (time resolution, rate capability, efficiency)	1.1, 1.3
T2	Enhance timing performance	Time resolution < 50 ps up to 30 kHz/cm^2	
T3	Enhance rate capability	Time resolution < 200 ps up to $100 \dots 150 \text{ kHz/cm}^2$	
T4	Spatial resolution and read- out granularity	Spatial resolution of mm with low number of readout channels	
T5	Stability, robustness and longevity	- IBF $< 1\%$ with < 100 ps time resolution for single photoelectrons - Stable, high-gain operation	
T6	Material studies	- Radiation-hardness - Longevity	
T7	Gas studies for precise timing applications	- Eco-friendly mixtures - Recuperation - Ageing mitigation CO_2-based mixture with geometrical quenching	
T8	Modelling and simulation of timing detectors	Modelling and simulation of timing detectors	
T9	Readout electronics for precise timing	- Low-noise FEE - High input capacitance - Large dynamic range – Fast rise time - Sensitivity to small charges - Multi-channel readout solution for timing detectors	
T10	Precision mechanics and construction techniques	Precise mechanics (μm) over relatively large active areas (hundreds of cm^2)	
T11	Common framework and test facilities for precise timing R&D	Test bench for precise timing studies	

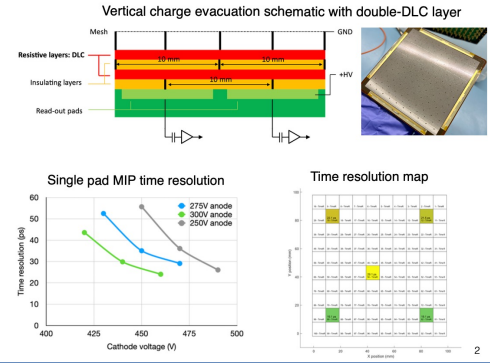
High-rate resistive Micromegas

The **resistive voltage** drop on high-resistivity anodes used for protection limits the achievable rate capability.

To combine resistive protection with **MD/sq** anode layers with higher rate capability, a **vertical charge evacuation** layout with double DLC layers and interconnections was implemented on a 10x10 cm² multi-pad prototype.

Time resolution and uniformity of response were characterised in a **MIP test beam campaign**.

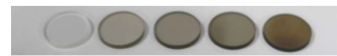
Rate capability will be compared to single resistive layer in future lab and particle beam tests.



Schematic not drawn to scale

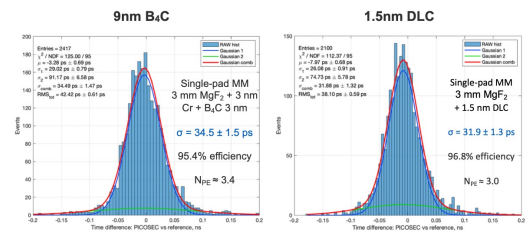
Photocathode robustness

Evaluation of time resolution, quantum efficiency (number of photoelectrons / MIP) and detection efficiency for different carbon based photocathodes.



To increase robustness, different alternatives to CsI are being investigated:

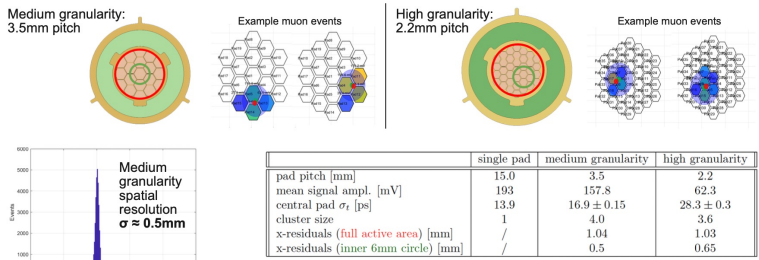
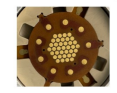
- Diamond-Like Carbon (DLC)
- Boron Carbide (B₄C)
- Nanodiamonds
- Carbon nano-structures
- Graphene



IBF and air exposure observations: L. Söhl, PhD dissertation, <https://universite-paris-saclay-hal.science/hal-03167729/>.
Air exposure observations: M. Lisowska, PhD dissertation, 2024.
QE ageing studies: M. Lisowska's master thesis, <https://cds.cern.ch/records/2885929>

Increased readout granularity

For 3.5 mm readout pad pitch, comparable timing performance was observed on the central pad, despite only having partially contained events, with most charge centered around the particle trajectory.

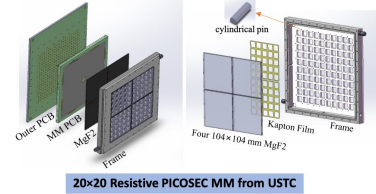


Both timing and spatial resolution are worse for the high granularity readout, most likely due to the smaller signal amplitudes and imperfect pad connections.

Schematic not drawn to scale

20x20 cm² PICOSEC Micromegas

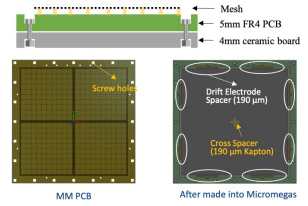
Design of 20x20 PICOSEC MM prototype



20x20 Resistive PICOSEC MM from USTC

Micromegas board

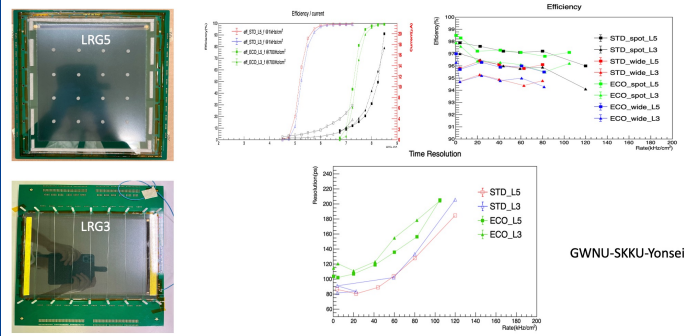
- Featuring a whole 20cmx20cm Micromegas
- 400 pads arranged on the 2 X 2 area, aligned with the crystals
- FR4 board bonded with a ceramic plate, and screws added on the edge to further strengthen



- Assembly structure similar to that of the 10x10 PICOSEC MM
- Assembling of the four 104x104x3 mm MgF2 as photocathode
 - MgF2 crystals placed directly on the frame with cylindrical pins ($\Phi 1.5$) for positioning
 - Kapton films (12.5um) underneath to compensate for thickness variation between crystals
- Pogo pins soldered onto the Outer PCB to extract signals

Schematic not drawn to scale

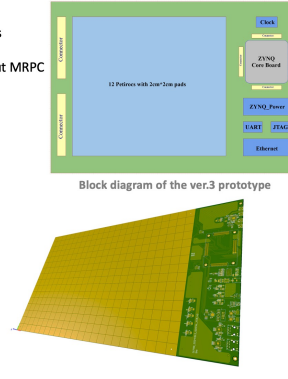
2X4-gaps detectors with low-resistivity glass and two different construction methods (fishing lines and spacers) were built exposed to PS beams. Results seem slightly better with the new technique for both standard and eco-friendly gases.



Panels with pickup strips are common and used by many groups

ASU with 1cm x 1 cm pickup pads are being designed to read out MRPC PETIROC ASIC with their internal TDC (45 ps resolution) will be used (12/ASU).

- 2 cm * 2 cm pads; 16 rows * 24 columns; 384 channels; 12 ASICs.
- ZYNQ core board integrated.
- IO: Ethernet * 2 (PL and PS), micro USB * 2 (JTAG and UART), FFC connector * 4 (2 for power and 2 for signals).
- This is the outer board. The idea is to connect with the inner board to cover the whole 1 m * 0.33 m active area.
- 3 pairs of inner and outer boards form a whole 1 m * 1 m active area.
- The PCB is under production.

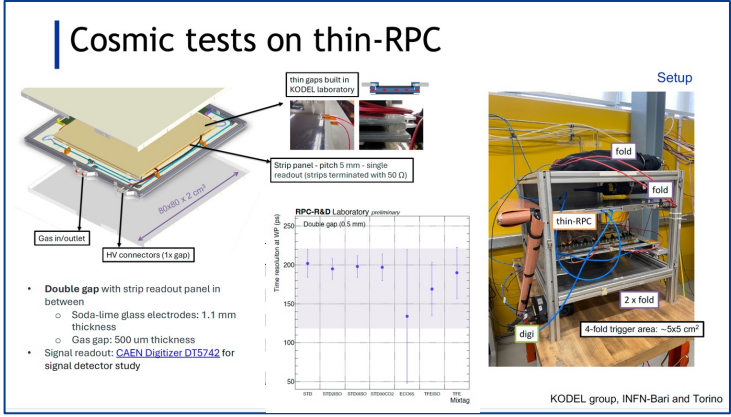


Block diagram of the ver.3 prototype

3D design drawing of the ver.3 prototype

SJTU team

Cosmic tests on thin-RPC



- Double gap with strip readout panel in between
 - Soda-lime glass electrodes: 1.1 mm thickness
 - Gas gap: 500 um thickness
- Signal readout: CAEN Digitizer DT15742 for signal detector study

KODEL group, INFN-Bari and Torino

CALOROC1B: SiPM vs SNR

Omega

- ❑ The SiPM configuration has a direct impact on the SNR
 - SNR for 1p.e is proportional to Q/C (larger SiPM cap decrease SNR)
 - Gain of 1.8e5 electrons per p.e (table below)
- ❑ CALOROC1b will be able to readout SiPM in the range ~ 500 pF to 10 nF
 - Timing measurements will focus on the MIP (~15ps)

Operation modes	1 SiPM of 530pF Caloroc1B	1 SiPM of 2.5nF Caloroc1B	4 SiPM of 2.5nF Caloroc1B	1 SiPM of 530pF Caloroc1A
Cin	530pF	2.5nF	10nF	560pF
Dynamic range in charge (Noise - Max)	2.6fC-190pC	12fC-770pC	48fC-3.1nC	20fC-320pC
Input time constant (occupancy related)	100ns	500ns	500ns	10ns
Jitter @ MIP (~400fC)	35ps	110ps	470ps	400ps
SNR @ 1p.e (~30fC@gain=1.8e5)	10	2.4	0.6	1.44

C. de La Taille ORNL 7-10 Jun 2024 SiPM: S14160-3010PS 3x3mm (530pF) / S14160-6010PS 6x6mm (2.5nF)

- Clear Synergies with WP1 and WP5
- A lot of progress for several different tasks
- Not all the groups are as involved as we would like
- Additional organisation efforts are still needed .

WP8

Reaction/Decay TPCs

E. Ferrer Ribas, D. Gonzalez Diaz, A. Bross, M. Cortesi, F. Monrabal, G. Dho

WP8: Reaction/Decay TPCs

• WP8 Project A

High-Pressure TPCs for precision studies of neutrino interactions

• WP8 Project B

TPCs for low-energy nuclear physics

• WP8 Project C

Electroluminescence-based TPCs for Rare-Event Searches and other

R&D on pure noble-gas amplification

WP8 Project D

Radiopure and/or low-energy TPCs for precise track imaging and/or

calorimetry with avalanche-based readouts

- WP8 kick-off (for endorsement) to be organized soon
- Re-vitalization of the WP8 plans
- Clarification of WP-FA involvements (DOE case!)

Task ID	Task	Performance Goal	ECFA DRD Theme
T1	Enhanced operation of optical readout across gas densities	• O(mm)-sampling, O(MeV)-threshold, O(ns)-timing for ν-interactions • Large-area amplification structures (≥ 50 cm x 50 cm) at optical gain $\sim 10^4$ • Tracking of low-energy nuclei (down to 10-100 keV) with good PID	1.2, 1.4
T2	Enhanced operation of charge readout across gas densities	• Large-area MPGDs (≥ 50 cm x 50 cm) at $\sim 10^3 \dots 10^4$ gain • Large-area MPGDs (≥ 50 cm x 50 cm) with a large dynamic range • O(1 keV) threshold across pressures (100 mbar...10 bar) in O(1000 cm³) technology demonstrators • IBF suppression of $G \cdot IBF = 10$ or better	
T3	Enhanced operation of pure or trace-amount doped noble gases	• EL operation at 2 m (15 bar) and 0.5 m (> 20 bar) scale, with $< 10\%$ deformation • Single-electron thresholds on large areas for mixtures of noble gases • MPGD concepts with enhanced EL response (up to or above 1000 ph/e) • Improve light collection for large volumes • Integrated, low-power and radiopure electronics for EL-based tracking	1.4
T4	Ultra-low-energy reconstruction of highly ionizing tracks (including R&D on negative-ion readout)	• Tracking of low-energy nuclei (down to 10...100 keV) with good PID • High dynamic range for the reconstruction of low and highly ionizing particles • Single electron counting at O(100 μm) in 3D, and diffusion at the thermal limit	1.2, 1.4
T5	Determination of the interaction time (T0)	• Develop new gaseous WLS and novel gaseous scintillators, comparable or better than CF₄ • Demonstration of T0-determination for low energy deposits with at least O(cm) resolution	1.4
T6	Microscopic gas properties and gas handling	• Develop the science and technology of novel eco-friendly gases • Derive microscopic parameters for new gases	1.3, 1.4
T7	Radiopurity	• Background levels below 10^{-6} c/keV/cm²/s for axion research and at least x10 more radiopure cameras • New radiopure amplification structures and techniques	

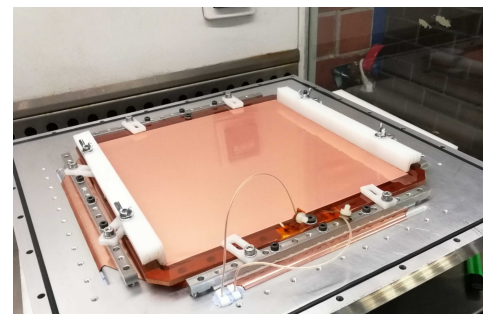
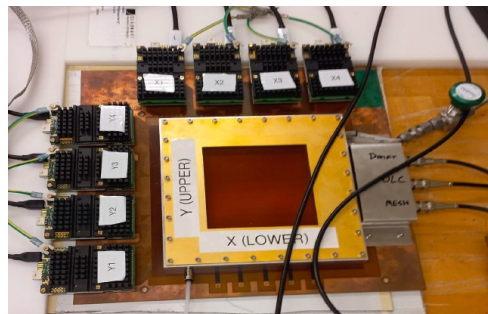


Radiopure TPCs for precise track imaging and/or calorimetry with avalanche-based readouts

- TPCs of different shape and size with MPGDs
- GEMs and MM
- Optical and charge readout

CAPA-UNIZAR

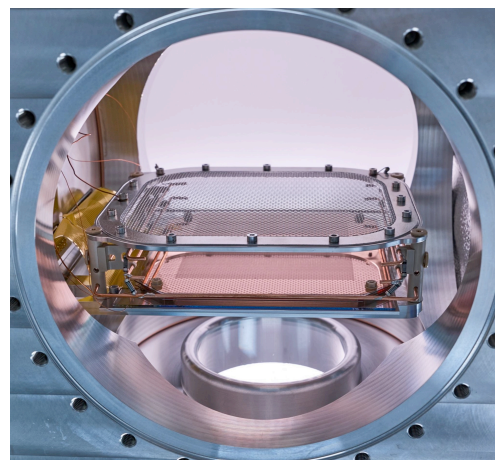
U. Hawaii



TREX-DM



CYGNO



Migdal

ANU (Australia)
 HIP (Finland)
 IRFU-CEA (France)
 LPSC Grenoble (France)
 Hamburg U (Germany)
 UNI Bonn (Germany)
 GSSI (Italy)
 INFN Roma1 (Italy)
 KOBE (Japan)
 LIP (Portugal)
 CAPA-UNIZAR (Spain)
 CERN (Switzerland)
 UK-RAL (UK)
 U Manoa Hawaii (USA)
 US-UNM (USA)

WP8D

- **Build large detectors that keep the performance of small prototypes**

- Charge or optical readout
- Imaging through reduced diffusion (possibly negative ion drift)
- T0 resolution for fiducialisation

- **Focus on gas properties**

- Both in diffusion and avalanches and scintillation
- Use of H-rich or negative ion drift mixture
- Radon purification

- **Amplification stage development**

- Low radioactivity
- Improve granularity, gain, optical response

D8D.1	Large volume prototypes	Development of technology demonstrators operated in the range 0.1bar...1bar characterised by large readout area above 10 cm x 10 cm [T1, T2], high pixelization, diffusion close to thermal limit [T4], superior energy resolution [T3], O(1cm) sensitivity on Z0 [T5] determination and large dynamic range. Detector operation can be electron or negative-ion mode, both optical or charge readout
-------	-------------------------	---

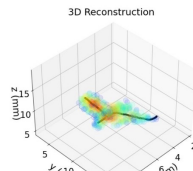
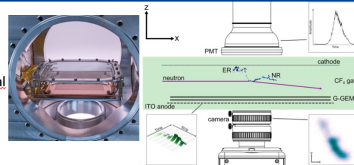
D8D.2	Gas properties studies and management	Characterization, modelling and optimization of mixtures containing noble gases, SF ₆ , CF ₄ and H-compounds [T6] both in optical/charge and electron / negative-ion response, and optimisation of their purification, radioactive purity and distribution [T7]
-------	---------------------------------------	---

D8D.3	Radiopure amplification structures	Develop suitable amplification structures (MPGD including ones modified with solid wavelength-shifters), radiopure photosensors and radiopure construction techniques for charge and optical imaging [T1, T2, T4, T7]
-------	------------------------------------	---

WP8D Highlights

3D Imaging: MIGDAL (RAL)

- Low pressure TPC with pure CF_4 for Miedel effect measurement
- Double GEM optical and charge readout (2D with camera and orthogonal direction with ITO strips)
- Very important to employ the synergic readout to retrieve 3D tracking



Carsten Steger algorithm to extract line from diffused track then convolution of complementary signals

Towards D8D.1 and D8D.3

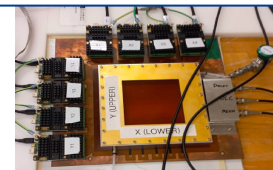
<https://dx.doi.org/10.1088/1748-0221/18/07/C07013>

G.Dho

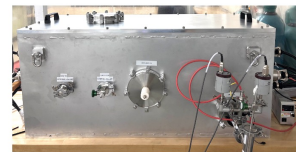
9

Going Big and Radiopure: Hawaii

- Gas TPC with MM and strip readout (200 μm pitch)
- 40 l detector with 20x20 cm^2 readout area and 2 50 cm drift region back-to-back
- Radioclean components inside the vessel
- Digitization between internal and external vessel
- Readout planes completed at CERN now in transit to Hawaii



Determined optimal MM configuration



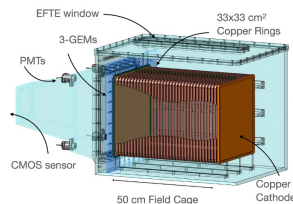
Towards D8D.1 and D8D.2

G.Dho

12

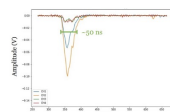
3D Imaging: CYGNO (GSSI, INFN)

- Atmospheric pressure TPC with He:CF_4 gas for rare event searches
- Three thin GEMs and optical readout (2D camera and multiple PMTs)
- Merge the two detectors to enable 3D reconstruction
- Exploit topology of PMT tracks and their different responses
- Applied to alphas



$$\begin{aligned} L_{\text{eff}} &= c \frac{L}{R_{\text{eff}}} \\ R_{\text{eff}} &= \sqrt{x_0^2 + y_0^2 + z_0^2} \end{aligned}$$

One can retrieve from PMT signals x,y coordinate and L (light yield at GEM)



Resolution of about 1 cm

<https://arxiv.org/abs/2506.04973>

G.Dho

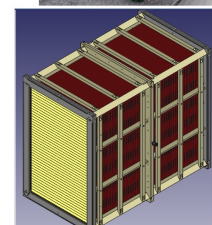
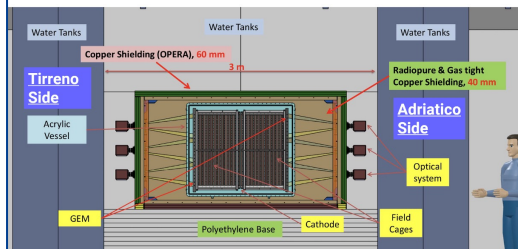
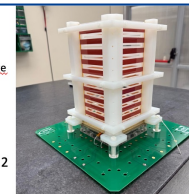
10

Going Big and Radiopure: CYGNO (GSSI, INFN)

- Demonstrator of 0.4 m^3 design about to be concluded
- 80x50 cm^2 readout area and 2 back-to-back 50 cm drift
- Total 6 gCMOS cameras and 16 PMTs
- Will be hosted at LNGS and start taking data in about 1 year

Radiopure with internal field cage structure of Nylon66

Towards D8D.1 and D8D.2



G.Dho

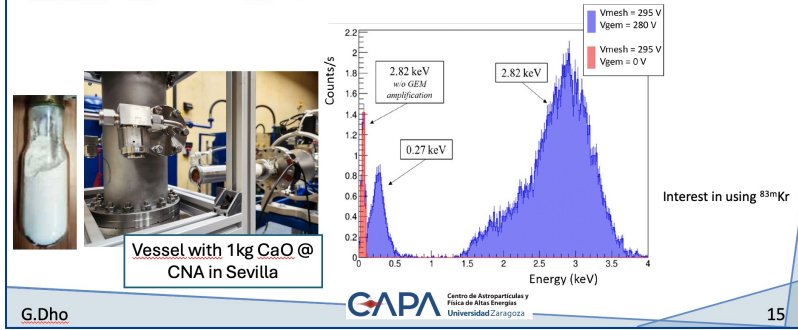
13

WP8D Highlights

Low Energy Threshold: TREX-DM

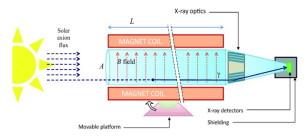
- With new amplification structure they tried a volume calibration.
- Gas target Ar-iso (99/1), with diffused ^{37}Ar (obtained after activating CaO with neutrons)
- Emissions at 2.82 keV (90%) and 0.27 keV (10%)

Excellent energy threshold down to 200 eV

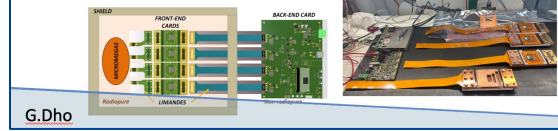
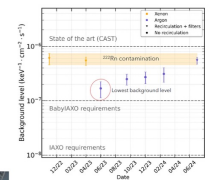


Radiopure: IAXO (CAPA)

- Noble gas based TPC as target to convert X-rays produced by axion conversion in cavity

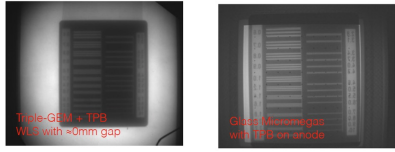


- Study on possible replacement of Ar (due to ^{39}Ar) with xenon or neon
- They require Rn purification
- Development of new radiopure frontend to be placed inside the shielding (lower noise) To be tested



Improve Optical structure: CERN

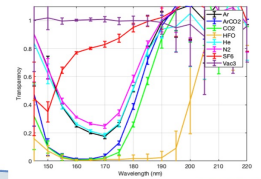
- Study of the effect of solid WLS on glass plate as a function of the gap from amplification stage (Ar/CF₄ 80/20, optical readout)



Best result with no gap, but not as good as MM

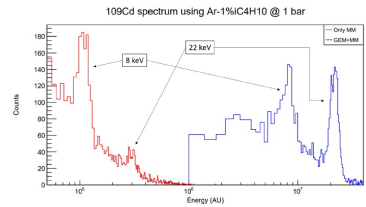
- Study of the transparency of gases to the VUV light emitted during amplification

Towards D8D.2

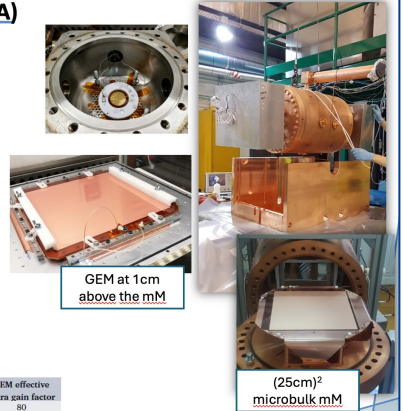


Low Energy Threshold: TREX-DM (CAPA)

- TPC with pressures up to 10 bar for light WIMP search (LSC)
- Focus on low energy threshold and selectable target (Ne or Ar)
- MM amplification structure. Development with preamplification with GEM on top



Pressure (bar)	V _{max} (V)	V _{max} (V)	Preamp. factor	V _{max} (V)	GEM effective extra gain factor
1	(GEM + MM system)	(GEM + MM system)	85	(only-MM system)	80
	290	285		293	



Towards D8D.2 and D8D.3

WP9

Beyond HEP

D. Varga, G. Croci, J. Bortfeldt

WP9: Beyond HEP

Muography, Medical physics and Neutron sciences with strong interconnections

T1	Cost efficient large-size outdoor detector structures: design and construction	
T2	Mechanical and environmental stability of detectors under outdoor or extreme conditions	
T3	Detector portability and low maintenance operation	
T4	Cost efficient, low power, long-lived Front-End and DAQ systems	
T5	Detector configuration optimization and simulation methods for surface- and underground environments for muons and neutron experiments	
T6	Benchmarking performance, infrastructures and knowledge transfer	
T7	Optical readout MPGDs for biomarker imaging and beam characterization in ion beam therapy	
T8	Gaseous photon detectors for in-beam monitoring for ion beam therapy and imaging	
T9	Beam monitors with high temporal resolution for ion beam therapy and space radiation simulation	
T10	Innovative neutron converter geometries in combination with gaseous amplifying structures for high-rate, efficient, low background detectors	
T11	Spatial resolution, readout granularity and rate capability impact on neutron imaging and dosimetry	
T12	Study of Gamma Ray sensitivity and neutron discharge probability	

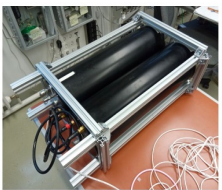
- May 30 2024: WP9 Kick-Off Meeting
- December 17 2024: WP9 MoU Preparation Meeting
- several sub-group meetings
- Now with a clarified MoU and participant list, WP9 can move towards the endorsement phase



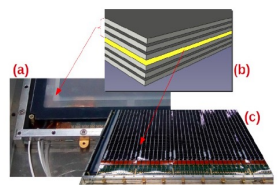
Task 1, 2, 3: Detector structures



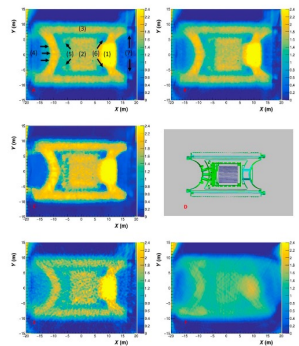
- Large size, cost efficient**
- Extreme conditions** (outdoor, underground, underwater)
- Low maintenance** (little to no gas flux)



06/18/25 MWPC: Wigner



RPC: LIP Coimbra



IRFU-CEA (Micromegas)

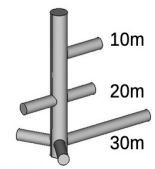
Task 4, 5, 6: Electronics, optimization, benchmarking



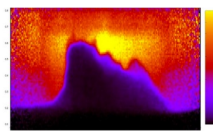
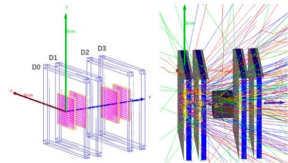
Low power FEE and DAQ solutions (solar- or battery operation)

Detector configuration optimization (simulations including detector parameters, background physics, ...)

Bechmarking: performance definition and evaluation, characterization sites



06/18/25

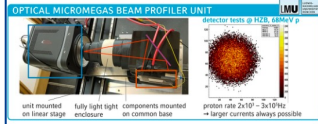


Task 7: Ongoing activities



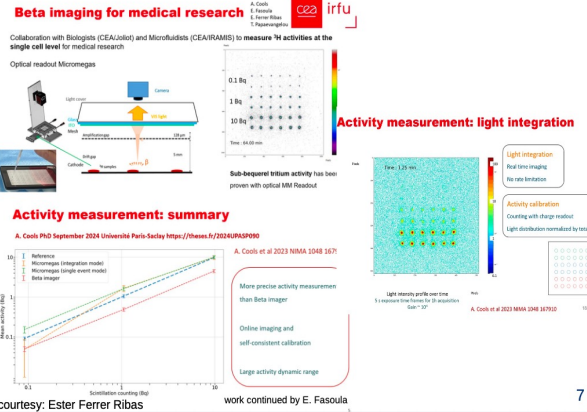
Optical readout MPGDs for biomarker imaging and beam characterization in ion beam therapy

institutes: CEA Saclay, LMU Munich



- Optical readout MM beam profiler in proton beams
- QA of 100x100mm² bulk glass MM developed for pre-clinical beams, anticipated R&D on clinical QA system with optical readout MM

06/18/25



7

Task 8: Ongoing activities

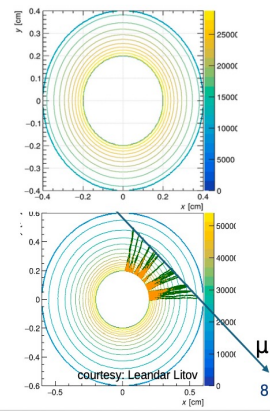


Gaseous photon detectors for in-beam monitoring for ion beam therapy and imaging (Sofia)

Detectors for online dose monitoring via beam induced PET activation

- Resistive cylindrical chambers
 - Massively parallel HPC Simulations [ongoing]
 - Non freon based gas mixtures
 - Efficiency and time resolution estimation
 - Prototyping [in near future]
 - Glass tubes design, Ar based mixtures
- Glass multigap RPC
 - Prototype ready
 - FE electronics to be developed

06/18/25



8

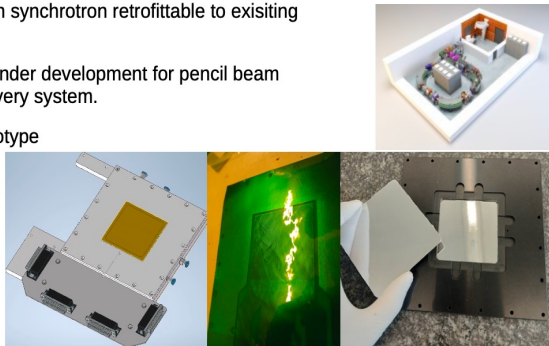
Task 9: Ongoing activities



Beam monitors with high temporal resolution for ion beam therapy and space radiation simulation (LMU Munich, MedAustron, GSI)

MedAustron development: compact proton synchrotron retrofittable to existing X-ray vault

- Micromegas beam monitor chambers under development for pencil beam scanning. To be integrated in dose delivery system.
- LMU currently develops functional prototype
- development cycle according to the applicable legal stipulations to be started after successful tests



Task 10, 11, 12: Ongoing Activities

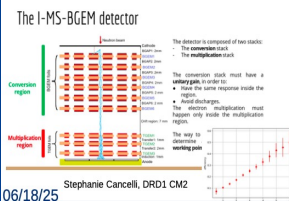


Task 10: Innovative neutron converter geometries in combination with gaseous amplifying structures for high-rate, efficient, low background detectors
institutes: U Milano – Bicocca, Bonn U, LIP Coimbra, AGH Krakow, Hamburg U, CEA Saclay, ESS Lund, FBK Trento, NUAA Nanjing U

Task 11: Spatial resolution, readout granularity and rate capability impact on neutron imaging and dosimetry
institutes: U Milano – Bicocca, Bonn U, Hamburg U, CEA Saclay, ESS Lund, NUAA Nanjing U

Task 12: Study of Gamma Ray sensitivity and neutron discharge probability
institutes: U Milano – Bicocca, NUAA Nanjing U

The I-MS-BGEM detector



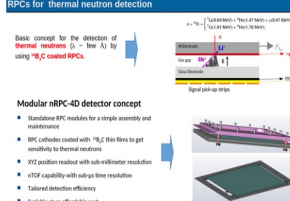
Stephanie Cancelli, DRD1 CM2

RPCs for thermal neutron detection

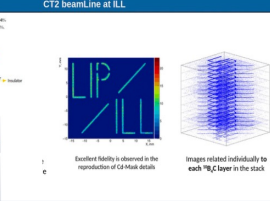
Basic concept for the detection of thermal neutrons: $n + {}^{10}\text{B} \rightarrow \alpha + {}^7\text{Li}$ by using ${}^{10}\text{B}_2\text{C}$ coated RPCs

Modular nRPC-4D detector concept

- Standalone RPC modules for a simple assembly and maintenance
- BPC cathodes coated with ${}^{10}\text{B}_2\text{C}$ thin films to get sensitivity to thermal neutrons
- K_2F position readout with sub-millimeter resolution
- nRPC capability with sub-ns time resolution
- Tailored detector efficiency



CT2 BeamLine at ILL



Excellent fidelity is observed in the reproduction of Cd Mask details

Images related individually to each ${}^{10}\text{B}_2\text{C}$ layer in the stack

NEXT STEPS

DRD1 MoU - Current Status

DRD1 Collaboration Memorandum of Understanding CERN-MoU-2025

14 July 2025

Memorandum of Understanding for the Detector Research and Development 1 (DRD1) Collaboration Concerning Gaseous Detectors

between

THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH, "CERN", an Intergovernmental Organization having its seat in Geneva, Switzerland, as Host Laboratory

on the one hand,

and

the Collaborating Institutions/Funding Agencies of the DRD1 Collaboration

on the other hand,

14 July 2025

Page 1 of 137

- MoU text frozen on July 14
- Distributed via DocuSign
- First MoU signed on July 22

docuSign



Your document has been completed

[VIEW COMPLETED DOCUMENT](#)

RCS Director Office
RCS-Director.Office@cern.ch

All parties have completed Please sign with DocuSign: Memorandum of Understanding for the DRD1 Collaboration .

On behalf of Joachim Mnich, CERN Director for Research and Computing please find attached for your signature (DocuSign) the Memorandum of Understanding for the Detector Research and Development 1 (DRD1) Collaboration Concerning Gaseous Detectors.

Kindly review the document and complete the digital signature process (page 12).

For any further details please do not hesitate to get back to us.

Many thanks for your help.
Kind regards,
Marika

This allowed us to:

- Establish the Resources Board (together with the Collaboration Board, the highest institutional body of the DRD1 Collaboration)
- Initiate the process for the endorsement of Work Packages

IMPORTANT: MoU signatory funding agencies (RB) are not necessarily or exclusively the funding agencies supporting the activities in the WP. All contributing funding agencies – whether represented in the RB or not – will be involved in the approval of, or any changes to, the terms of the MoU for the WP to which they contribute.

Tasks

Institutions (EOI)

Deliverables (but no timeline)

Management

Task ID	Task	Performance Goals	ECFA DRD Items
6.3	Work Package 1: Trackers, Indopropers, Large Area Mass Systems		
6.3.1	Descriptions		
71	New RFC and TGC systems	Adhere RFCs and TGC with a high-gain capability (ranging from 0.1 MHz/cm ² to 1 MHz/cm ²) and/or improve tracking resolution (from 1000 km to 100 km) and/or improve system's materials, and data structures	
72	New Receiver MRD Structures	Development of large area receiver MRD capable of efficient and accurate detection of signals of English (2.1) as well as low medium rates (0.2)	
73	New Front-end electronics	Front-end equipped with W-L, 1 GHz, High density channel. Radiation hardness. Time delay of (10) ps; local noise suppression, local noise amplification	
74	Optimization of variable imbalanced resonant systems	Development of novel Self-Scalable Resonant Structures for Gravitational Detection. Development of a new TGC based resonant system that matches the data throughput of the electronics.	1.1.
75	Easy-to-use gains	Reduce RGC emissions from the detectors and define new ecological gain parameters that maintains useful performance to the current gain parameters	
76	Manufacturing	Constructing and producing cost-effective methods for developing high-quality, high-gain systems with low noise and low RFC, TGC, MWPC, and MRD analysis in order to be suitable for various industrial products	

Country	Cooperating Institution	Team	IRB-UC Code	Contact
Belgium	Vrije Universiteit Brussel	Brussel	IRB-UC 06	Michael Tytgat
China	University of Science and Technology of China	Hefei	CN-US/TC	Jianhui Luo
France	Institute of Research into the Environment and the Urban, Ecia, Université Paris-Saclay	Gif-sur-Yvette	FR-FR/UC-04	Manon Vandecasteele
Germany	Leibniz-Max Planck Institute of Science and Technology, University of Munich	Munich	DE-MP/UC	Oskar Böttcher
	Max-Planck-Institute for Physics, Munich	Munich	DE-MP/UC	Oliver Merten
Hungary	HUNREN Wigner Research Centre for Physics	Budapest	HU-HUN/UC	Dezso Varga
Israel	Weizmann Institute of Science	Rehovot	IL-WI/UC	Shirley Bruckstein
Japan	DNFN Science & Data, University of Tsukuba	Utsunomiya	JP-TS/BN-01	Paula Croci
Italy	DNFN Science & Data, University of Bologna	Bologna	IT-TS/BN-02	Paolo Croci

[illegible]

CEU/MAE/2017	Measurement of Cybersecurity	DSD/1 Colloquium
DI.1	New frontiers and DAAQ systems Completion of the innovative AASCC Road design: completion of comprehensive programme documentation; of applicable, standardisation of the requirements for the first three design it will be a full-scale project; DAAQ systems protecting for ground detection, aiming to push the boundaries in terms of timing, volume, resources, multi-linked data acquisition and performance, for large systems [74]	FR-REU/CEA, RU-RO/RS, IN/INP, IN-SP/RS, IN/INP, RO/IA/ADITYA, RO/IA/INSPIRE, RO/IA/RS, ES-CEMAT, IN/INOVATI, IN-SP/RS, IN/INP, US-UTL, US-STRAF, IL-AB
ME.21	Review of the state of AASCC and DAAQ systems Definition of requirements for next generation of in-situ mission systems [75, 76]	
6.6 Contributions of Participating Institutions and Funding agencies to the project		
Not currently applicable ^a		
6.7 Management Structure of the Work Package		
The management structure of the Work Package is described in Annex 4.1.		
6.8 Person Carrying Holding Functions of Specific Responsibility in the Work Package		
Function	Name	Initiation Code
Work Package Leaders	Gabrielia Pogonina	IT-INSP/BA
	Rosanna Favalloni	IT-INSP/BO
	Maria Jelicic	IT-INSP/BA

NO Funding Agencies and NO Contributions of Participating Institutions

WP endorsement procedure drafting timeline

- ✓ Drafting by the committee
- ✓ The draft circulated within SCB on 15.11.2024
- ✓ Discussion in the SCB on 22.11.2024
 - WP Leaders are encouraged to get feedback from the WP Institutes (WP-FAs) and discuss
- ✓ Discussion in the MB on 29.11.2024
 - Draft with additional comments from SCB; expected endorsement from the MB
- ✓ DRD1 Collaboration Meeting, WP session on Monday, 09.12.2024 - procedure presentation.
 - Open discussion within the Collaboration
- ✓ Presented to CB on 12.12.2024
 - Presented for the endorsement of the CB
- ✓ Updated and endorsed by MB/CB on 25/26.02.2025
- ✓ Informative meeting: CB, RB, WP-Fas
- ☐ Approval by DRD1 RB

Key aspects of the procedure

- **Follow articles 8.6 and 18.4** of the MoU (see backup)
- **Define a clear time flow**
- **Avoid duplicating work.** Clear list or required documentation without overlapping or duplication.

Proposed list of documents needed for the endorsement:

1. MoU Annex 6 (updated with all tables)
 2. Work Package Executive Summary for Internal DRD1 Scientific and Resource Endorsement
 3. WP Leader Presentations for Scientific Coordination Board
 4. WP Leader Presentations for Resources Board
-
- **Simplify the collection of the required information** for the endorsement process. Using common templates – see documents attached.

Resource endorsement: Annex 6 tables (existing in MoU and to be included)

1. Description

Task ID	Task	Performance Goal	ECFA DRD Theme
T1	New RPC and TGC structures	Achieve RPCs and TGC with a high-rate capability (ranging from 10 kHz/cm ² to 1 MHz/cm ²) and/or improved timing resolution (reaching sub-ns to ps levels) using new resistive materials and fine structure.	1.1, 1.3
T2	New Resistive MPGD Structures	Development of large area resistive MPGD capable of efficient and stable operation under conditions of high rates (D2.1) as well as low/medium rates (D2.2)	
T3	New Front-end electronics	Frontend operation up to 0.1...1 GHz; High density channel; Radiation hardness; time resolution (< 10 ps); local zero suppression; higher FE gain amplification	
T4	Optimization of scalable multichannel readout systems	Development of novel Scalable Readout Systems for Gaseous Detectors. Development of a new FPGA-based readout system that matches the data throughput of the electronics	
T5	Eco-friendly gases	Reduce GHG emissions from the detectors and define new ecological gas mixtures that maintains similar performance to the current gas mixture	
T6	Manufacturing	Constructing and exploring cost-effective methods for producing high-quality, high-performance large area resistive MPGD, and new RPC, TGC, MWPC, and sMDT suitable for low to medium rates with industrial production	

3. Funding Agencies

Country	Funding Agency	Funding Agency Code	Representative	Institution(s) represented ⁴

⁴ Only if different from Funding Agency

6. Persons Currently Holding Functions of Specific Responsibility in the Work Package

Function	Name	Institution Code
Work Package Leader	Nicola De Filippis	IT-INFN.BA

2. Participating institutions

The institutions listed in the following table have expressed interest¹² in joining and contributing to the Work Package but have not yet secured the required support from their Funding Agencies.

Country	Collaborating Institution	Town	Institution Code	Contact
Belgium	Vrije Universiteit Brussel	Brussel	BE-VUB	Michael Tytgat
China	University of Science and Technology of China	Hefei	CN-USTC	Jianbei Liu
France	Institute of research into the fundamental laws of the Universe, CEA, Université Paris-Saclay	Gif-sur-Yvette	FR-IRFU-CEA	Maxence Vandenbroucke

4. Start And End Date, Deliverables and Time Scale

Number	Title	Description	Start Date	End Date	Participating Institutions
D1.1	Large area RPC, MPGD, TGC, MWPC, and sMDT prototypes	Design, construction, and test of RPC, MPGD, TGC, MWPC and sMDT prototypes with advanced solutions for extensive surface coverage [T1,T2,T6], optimized for medium-high flow rates (range tens kHz/cm ² – few MHz/cm ²), precise tracking (100 μm) and timing (few ns). This includes considerations for the compatibility of eco-friendly gases. [T5, T7]			BE-VUB, CN-USTC, CN-CUHK, CN-HKU, CN-HKUST, FR-IRFU-CEA, DE-LMU, DE-MPP, HU-HUN-REN, IL-WIS, IT-INFN.BA, IT-INFN.BO, IT-INFN.FE, IT-INFN.LNF, IT-INFN.NA, IT-INFN.RM2, IT-INFN.RM3, JP-KOBE-U, RO-UNSTPB, RO-IFIN-HH, RS-IOFH-BG, CH-CERN, CH-UNIGE, TR-ISTINYE, UK-PHY-CAM, US-UFL, US-TJNAF-JLAB
MI.1.1	Review of Detector Prototypes	Examining the status and future prospects of innovative resistive materials, novel structures, and challenges in hybridizing RPC, MPGD, and TGC. This evaluation includes compiling of a comprehensive report highlighting comparative performance, along with the respective advantages and disadvantages of			

5. Contributions of Participating Institutions and Funding Agencies to the Work Package

Deliverable	Institution Code	Funding Agency Code	Investment (kCHF)	Person Power ^d (FTE/y)
D1.1				
D1.2				
D Total				

Latest time		-5 week to CB		-3 week to CB	-2 week to CB		CB Date
SCIENTIFIC REVIEW and ENDORSEMENT	Requirement	- Updated Annex 6 with all tables - WP Executive Summary		- Updated WP Executive Summary - Referee report - Annex 6	- All documents and presentations ready - Summary of WP-FA acknowledgements 1h Dedicated SCB/MB Meeting for the WP Scientific Review		SCB and MB recommendation to CB
	Action	- All documents sent to the Work Packages Coordinator, the Resource Coordinator, and the WP Internal Referee - Referee report is prepared within 2-week time period. - The Referee works together with WPLs to “improve” the WP Executive Summary.		Documents sent to SCB and MB by WPs Coordinator	1) Open session (30’) - WPL or WPPL present with all WP members present. Open to all collaboration. 2) Closed session (30’) - Internal referee presents their report; SCB and MB members may ask questions. WPLs, WPPLs and WP-Members present		
	Outcome		WPs Coordinator and Resources Coordinator receive the referee report and updated WP Executive Summary	Any major concerns identified by the respective board members shall be communicated before the dedicated SCB meeting	Final referee report and SCB minutes		WP Endorsement by CB
Latest time		-4 week to RB		-2 week to RB		RB Date	
RESOURCES ENDORSEMENT	Requirement	Updated Annex 6 with all tables		75% of acknowledgements expected (otherwise, needs to be discussed in the SCB endorsement)		30’ Dedicated RB Meeting 30’ per WP project	
	Action	The annex is distributed to the RB and pertinent WP-FA and requests for acknowledgement in 2 weeks		Summary of pertinent WP-FA acknowledgements of existing Resources are sent to SCB and RB		1) Closed session (30’) - WPL presents resource tables and a list of acknowledgements (100% expected)	
	Outcome					WP Endorsement by RB and pertinent WP-FAs	

WP Endorsement: next steps

- Approval of the WP Endorsement Procedure by RB
- Endorse WP internal referees
- Initiate endorsement of first WPs

WP ID	Title	Annex	Ready for endorsement
WP1	Trackers, hodoscopes, large area muon systems	6.3	✓
WP2	Drift chambers	6.4	✓
WP3	Straws and drift tubes	6.5	✓
WP4	Tracking TPCs	6.6	
WP5	Gaseous calorimeters	6.7	
WP6	Gaseous photon detectors	6.8	
WP7	Timing detectors	6.9	✓
WP8	Reaction/decay TPCs	6.10	
WP9	BHEP applications	6.11	✓

SUMMARY

- WP Scientific is ongoing despite of long MoU drafting and signing procedure
- Sign up to a WP → , this way you may get funded in your FA
- The procedures per country were not clear, but they ARE getting clarified in many cases
- If this is not yet the case with your QP-FA, sign up anyway, it is good to collaborate
- Many WP and WP projects are ready for endorsement
- Clarification of committed resources from WP-Fas, ongoing or to be restarted;
Need more communication with institutes to understand the status, resources and plans
- Templates to be circulated, work towards endorsement can start now!

BACKUP

WP ENDORSEMENT PROCEDURE

Special DRD1 Meeting - Meeting with Funding Agencies

17.09.2025

P. Gasik (GSI/FAIR + TU Darmstadt)

Baseline - MoU rules (WP relevant)

- **Article 8.6**

The terms of **each Work Package**, Working Group and Other Work Entity **shall be approved by the Collaboration Board and the Resources Board** and, in case that a Work Package, Working Group or Other Work Entity is funded at least partially by sources other than the Common Fund of the Collaboration, **also require the explicit approval⁸ of all contributing Funding Agencies**.

- **Article 18.4**

The Collaboration shall have authority to decide on any update of information in the Annexes, without the need for signature of a corresponding Amendment. **Changes to Annexes 6, 7 or 8 affecting resources contributed by a Funding Agency shall require the approval by all Funding Agencies contributing to the Work Package**, Working Group or other Work Entity, as the case may be.

- **Annex 4.1.4: Resources Board**

For the approval of Work Packages, Working Groups and/or Other Work Entities **under Article 8.6 and for updates of resources of Work Packages**, Working Groups and/or Other Work Entities **under Article 18.4, representatives of the contributing Funding Agencies shall be invited to the pertinent meeting of the RB.**

⁸ Explicit approval may take the form of a minuted vote in the Resources Board session, a confirmation of a funding grant compatible with the Funding Agency's engagement or a written statement attached to the minutes of the Resources Board

Baseline - MoU rules (WP relevant)

Annex 6.1.1: General Clauses

A Work Package may consist of multiple projects.

Documents substantiating the proposed approvals or acceptance of review results shall be provided to the pertinent bodies and Funding Agencies not later than two weeks before the decision-making meeting(s).

Annex 6.1.2: Participation, Addition and Withdrawal of Institutions

Institutions wishing to participate in a Work Package shall be members of the DRD1 Collaboration.

Adding (an) Institution(s) to an existing Work Package gives rise to an update of the Work Package's terms.

Institutions and/or Funding Agencies wishing to withdraw from a Work Package and terminate their obligations under the Work Package's terms shall give not less than six months' notice in writing to the Work Packages Coordinator, the pertinent Work Package Leader(s), the Co-Spokespersons, the Collaboration Board Chair and Deputy, and, if applicable, their Funding Agency/Agencies

Annex 6.1.3: Approvals

The approval procedure for establishing a Work Package including its initial terms is set out in Article 8.6.

The approval procedure for updates of the terms of a Work Package is set out in Article 18.4.

Baseline - MoU rules (WP relevant)

Annex 6.1.4: Reviews

Prior to establishing a Work Package and annually once a Work Package is established, both the Scientific Coordination Board (SCB) and the Management Board (MB) shall review the Work Package scientifically, addressing in particular

- The alignment of the Work Package with the ECFA Detector R&D Roadmap document;
- The progress in the scientific programme of the Work Package and its objectives (only for the annual reviews);
- A detailed list of expected deliverables and milestones of the Work Package;
- The Work Package's collaboration and interaction with Working Groups, other Work Packages and other DRD collaborations;
- The availability and usage of the resources of the Work Package.

The SCB and the MB shall report to the Collaboration Board with a recommendation on whether to establish or continue the Work Package.

WP Internal Referee

- Upon the establishment of the Work Package, the Work Packages Coordinator will nominate, in agreement with the Management Board (MB), an **Internal Referee**. The Referee should be one of the members of the MB. The SCB and the MB must endorse the nomination.
 - Being a member of the MB assures that the person is up to date with DRD1 and WP activities
 - Nominated MB members may ask an expert from outside MB for support
 - Internal referee from the institute that does not participate in the WP
- Referee(s) **work together** with WPLs (see also next slides). (S)he is not a single person to decide on the endorsement, but is preparing the background for discussion in the SCB
- The goal of the procedure is an endorsement.
 - Research line compatible with ECFA, synergies within collab and other DRDs, etc. Status of Milestones and Deliverables.
- The referee is preparing a report, following the template
 - Findings, comments, and recommendations
 - The report helps in the Scientific Endorsement; it serves as a baseline for minutes.
- SCB and MB shall establish the list of referees after the procedure is approved

WP Internal Referee – nomination criteria

- **MB members**
 - Consider elected/nominated MB members (15 in total)
 - Ex-officio members are primarily not considered (e.g. SPs, CB chairs, SCB chairs, RCB chairs)
- **Try to avoid a WP Leader being an internal referee for another WP**
- **WP with sub-projects:** a WP Internal Referee overlooks endorsement of the entire WP, asking for help from experts outside the MB, to support him/her with the WP sub-projects
- **Need to identify 9 WP internal referees.**
 - Candidates for the WP internal referees identified they will be asked for their consent
 - Priority to fix WP Internal Referees for WPs closest to being endorsed
 - Compile a list and present it to MB/SCB/CB for endorsement

7.4.1 Work Package 1 - Trackers, Hodoscopes, Large area muon

7.4.1.1 Description
The project's primary objective is to advance the development of active gaseous detectors for trackers, hadronscopes, and large-area muon systems for the LHC experiments. The goal is to enhance their stability, robustness, long-term performance, and to integrate their manufacturing with industrial partners.

[illegible]

7.4.1.2 Start And End Date, Deliverables and Time Scale
The Work Package starts on January 1st, 2024 and ends on December 31st, 2024

Updated version of **MoU**
Annex 6

Referee report,
following the WP
Executive Summary
document layout.
Findings, Comments ,
and Recommendations
for each part

Work Document Page Scientific Endorsement

For the dedicated Scientific Coordination Board Meeting (SCB) and the Work Packages Coordinators one month before the date of the Dedicated SCB Meeting.

WP1	Trackers, Hodoscopes, Large area muon systems	
Management		
Role	Name	Institute
WP (Project) Leader		
Work Package Endorsement Process		
SCB Dedicated	dd/mm/yyyy	
Meeting		
RCB Dedicated	dd/mm/yyyy	
Meeting		
auCB Meeting	dd/mm/yyyy	
Motivation		
The project's primary objective is to advance R&D in sensitive gaseous detectors for trackers and calorimeters, and large-area muon systems at future facilities. The goal is to enhance the stability, robustness, long-term performance, and cost-effective manufacturing with industrial partners.		
ECFA Roadmap Themes		
1.3 Improve time and spatial resolution for gaseous detectors with long-term stability	Concise review of ongoing activities in line with ECFA Roadmap Themes	
DDT1.3 - Develop environmentally friendly gaseous detectors for very large areas with high-rate capability.	Concise review of ongoing activities in line with ECFA Roadmap Themes	

WP Executive Summary

A concise review of the status of the WP activities.

(It will include a section – not for endorsement – presenting long-term plans and additional requests for funds)

Please check the attachments ([LINK](#))

Work Scientific

Work Package #
Scientific Endorsement
Template



20' minutes presentation for the Scientific Coordination Board (reflecting the review)

[illegible]Work Package Scientific Endorsement – Referee Report

To be filled by the Referee. The first version will be shared with the WPLs and WPC to work on the Executive Summary document and presentations to be presented to the SCB during the WF Endorsement. After the meeting (closed session), the final report will be provided to the Resource Board and Collaboration Board.

[illegible]

Please check the attachments [\(LINK\)](#)
Resource endorsement relevant

Work Package #
Resource Endorsement
Template



10' minutes presentation for the Resource Coordination Board

Note

- Resources endorsement
 - **The Resources Board and the pertinent WP Funding Agencies** will organise a resource review
 - RB = all DRD1 FAs signing the MoU
 - WP Funding Agencies = FAs committing resources for WP activities
- In the case of a WP with sub-projects:
 - Full WP is endorsed, with all sub-projects
 - If a sub-project is not ready to be endorsed, its tables will be simply not updated. Still, all pertinent WP-FAs will be notified.