DRD1 Community Meeting WG3: Gas and Material Studies

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K. Dehmelt (Stony Brook University) - MPGD

D. Piccolo (INFN Frascati) - RPC, MRPC

A. Pastore (INFN Bari) - RPC, MRPC

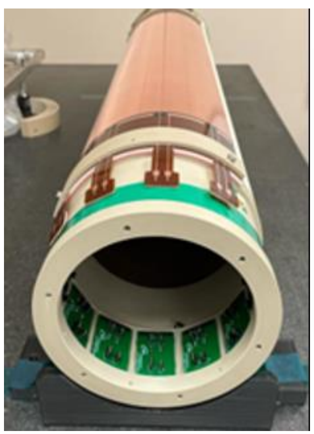
S. Roth (RWTH Aachen University) - TPC

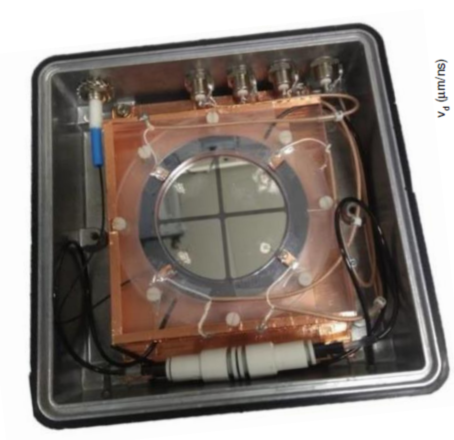
F. Renga (INFN Roma) - Large Drift Chambers

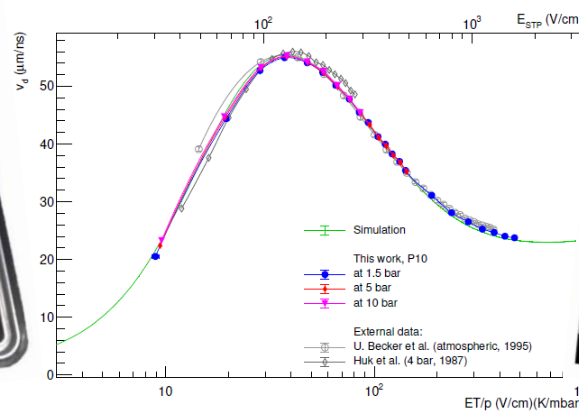
B. Alvarez Gonzalez (University of Oviedo - ICTEA) - Large Drift Chambers

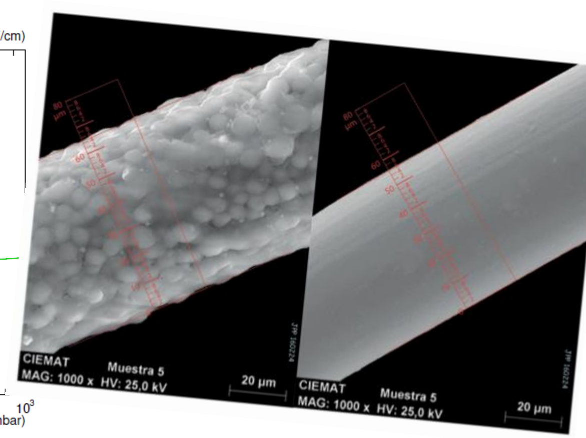
At the core of gaseous detector technologies

address common key issues related to gas and materials in the development of future gaseous detectors









At the core of gaseous detector technologies

Common research areas:

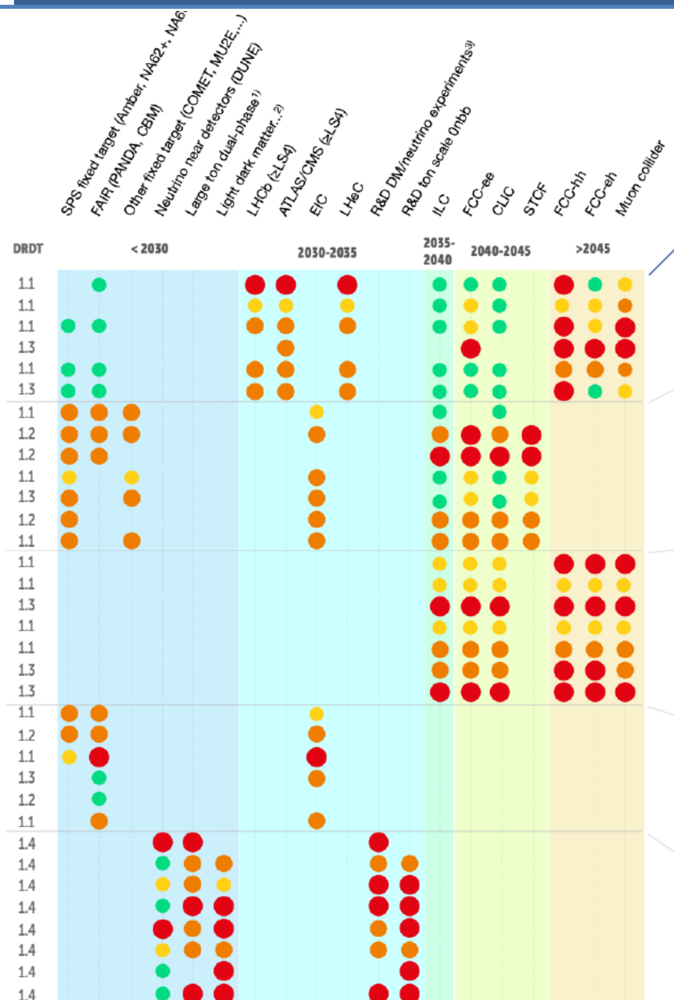
Gas	**Systems for gaseous detectors**	Materials	**Long-term operations**

At the core of gaseous detector technologies

Main common research topics:

Gas	Systems for gaseous detectors	Materials	Long-term operations
• Gas properties • Eco-gas studies • Light emission in gases for optical Read-Out • ….	• Gas systems • Gas recirculation and recuperation systems • Sealed detectors and systems • ….	• Resistive electrodes • Solid converters • Photocathodes • Novel materials • Material properties • Light materials • ….	• Current and gas-induced ageing effects • Radiation hardness • Outgassing • ….

Links with ECFA challenges



Must happen or main physics goals cannot be met — Important to meet several physics goals — Desirable to enhance physics reach — R&D needs being met

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

Muon system

Proposed technologies: RPC, Multi-GEM, resistive GEM, Micromegas, micropixel Micromegas, μRwell, μPIC ...

- Rad-hard/longevity
- Time resolution
- Fine granularity
- Gas properties (eco-gas)
- Spatial resolution
- Rate capability

Inner/central tracking with PID

Proposed technologies: TPC+(multi-GEM, Micromegas, Gridpix), drift chambers, cylindrical layers of MPGD, straw chambers

- Rad-hard/longevity
- Low X_0
- IBF (TPC only)
- Time resolution
- Rate capability
- dE/dx
- Fine granularity

Preshower/ Calorimeters

Proposed technologies: RPC, MRPC, Micromegas and GEM, μRwell, InGrid (integrated Micromegas grid with pixel readout), Pico-sec, FTM

- Rad-hard/longevity
- Low power
- Gas properties (eco-gas)
- Fast timing
- Fine granularity
- Rate capability
- Large array/integration

Particle ID/TOF

Proposed technologies: RICH+MPGD, TRD+MPGD, TOF: MRPC, Picosec, FTM

- Rad-hard (photocathode)
- IBF (RICH only)
- Precise timing
- Rate capability
- dE/dx
- Fine granularity

TPC for rare decays

Proposed technologies: TPC+MPGD operation (from very low to very high pressure)

- Low power
- Fine granularity
- Large array/volume
- Higher energy resolution
- Lower energy threshold
- Optical readout
- Gas pressure stability
- Radiopurity

Gas Properties
Eco-gases studies
Light emission in gas
Gas recuperation and recirculation systems
Gas systems
Sealed detectors and systems
Resistive electrodes
Solid converters
Photocathodes
Novel materials
Material properties for detector and infrastructures
Light (low material budget) materials
Precise mechanics
Ageing
Outgassing
Radiation hardness

Interconnections with DRD1 Working Packages

Materials → Resistive electrodes
Long term operation → Rad. Hard.

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3 y
T1	New resistive RPC materials and production techniques for resistive layers	- Develop low-cost resistive layers - Increase rate capability	WG3 (3.1C, 3.2D), WG6, WG7 (7.1-5)	1.1, 1.2	- HPL, low resistivity glass - Semiconductors - Printed resistive patterns - DLC-sputtered electrodes for surface-dissipation in RPCs	- Design, construction and test of prototypes with new production techniques
T2	New resistive MPGD structures	- Stable up to gains of $\mathcal{O}(10^6)$ - High gain in a single multiplication stage - High rate capability (1 MHz/cm^2 and beyond) - High tracking performance	WG3 (3.1C, 3.2D), WG4, WG6, WG7 (7.1-5)	1.2	- High-rate DLC layout for micro-RWELL	- Design, construction and test of prototypes with new resistive materials - Modelling and Simulation (signal induction) - MPGD prototypes based on resistive elements for tracking
	2D readout optimization	- Development of low-granularity 2D-readout with high tracking performance			- Layouts based on low resistivity DLC film and charge sharing	- Design, construction and test of prototypes with low-granularity 2D-readout

Table 1: WP1 (Part I) - a work package on genuine trackers/hodoscopes

Large area Muon systems, inner tracking/vertexing - all technologies

Gas → Gas properties, Eco-gas studies, sealed detectors ..
Systems → Gas recirculation and recuperation systems, …

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3 y
T5	Eco-friendly gases	- Guarantee long-term operation - Explore compatibility and optimized operation with low-GWP gases	WG3 (3.1A, 3.1B, 3.2C), WG4, WG7 (7.1-4)	1.1	- Ageing studies - Leak mitigation and maintenance of existing systems - Gas simulation: drift velocity, diffusion	- Test and characterization of gaseous-detection technologies with low-GWP gases (broadly)
T6	Manufacturing	- Construction of large-area detectors at low cost - Modular design - Technology transfer strategy and training center for production	WG3 (3.2E), WG6, WG8	1.3	- Optimization of the manufacturing procedure to minimize time-consuming or costly steps	- Design and manufacturing of large-area detector - Large-area DLC production - CERN: MPGD based manufacturing capabilities and large-area modules (design and prototyping). Note: MPT Workshop
T7	Thinner layers and increased mechanical precision over large areas	- Test to experience the ultimate limits to thinning down the detector	WG3 (3.2E), WG5, WG7 (7.1,2)	1.3		
T8	Longevity on large detector areas	- Study discharge rate and the impact of irradiation and transported charge (up to C/cm^2)	WG1, WG3 (3.1B, 3.1D, 3.2B), WG4, WG7 (7.1,3)	1.1	- Discharge probability - Ageing	

…and others DRD1 Working Groups

Gas → eco-gas studies
Materials → Resistive electrodes, solid converters
Systems → Gas recirculation and recuperation systems, ..
Long term operation → ageing effects

T3	Mechanics: develop new wiring procedures and new end-plate concepts	- Feedthrough-less wiring - More transparent end-plates ($X < 5\% X_0$)	WG3 (3.1C)	1.1, 1.3	- Separate the wire support function from the gas containment function	- Conceptual designs of novel wiring procedures - Full design of innovative end-plate concepts
T4	Increase rate capability and granularity	- Smaller cell size and drift time - Higher field-to-sense wire ratio	WG3 (3.2E), WG7 (7.2)	1.3	- Higher field-to-sense wire ratio allows increasing the number of field wires, decreasing the wire contribution to multiple scattering	- Performance evaluation on drift-cell prototypes at different granularities and with different field configurations
T5	Consolidate new wire materials and wire metal coating	- Electrostatic stability - High YTS - Low mass, low Z - High conductivity - Low ageing	WG3 (3.1C)	1.1, 1.2	- Establish contacts with companies producing new wires - Develop metal coating of carbon wires	- Construction of a magnetron sputtering facility for metal coating of carbon wires
T6	Study ageing phenomena for new wire types	- Establish charge-collection limits for carbon wires as field and sense wires	WG3 (3.2B), WG7 (7.3,4)	1.1, 1.2	- Build prototypes with new wires as field and sense wires	- Prototype tests in-beam and at irradiation facilities - Measurement of performance and dependence on total integrated charge
T7	Optimize gas mixing, recuperation, purification and recirculation systems	- Use non-flammable gases - Keep high quenching power - Keep low-Z - Increase radiation length - Operate at high ionization density	WG3 (3.1B, 3.2C), WG4, WG7 (7.4)	1.3	- ATEX and safety requirements - Attention to the cost of gas - Hydrocarbon-free mixtures	- Study the performance of hydrocarbon-free gas mixtures - Implement a complete design of a recirculating system

Table 3: WP2 - a work package on inner and central tracking with PID

Drift chambers

Straw chambers

Table 4: WP3 (Part I) - a work package on inner and central tracking with PID

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3y
T1	Optimize straw materials and technology	- Develop thin films and metallization - Resistance to ageing - Low cross-talk - Establish material relaxation control - Gas leakage control - Compatible with operation in vacuum	WG1, WG3 (3.1C, 3.2B), WG6, WG7 (7.1-4)	1.1 1.2 1.3		- Design and production of materials - Production of straw tubes
T3	Optimize straw tracker mechanics	- Develop self-supporting modules - Control relaxation - Develop a method for straw alignment	WG1, WG3 (3.2E), WG6, WG7 (7.1)	1.1 1.2 1.3	- Design of all mechanical tools - QA	- Develop assembly technique - Prototype construction

Table 5: WP3 (Part II) - a work package on inner and central tracking with PID

T6	Longevity	- Ageing resistance > 1 C/cm for thin-wall straws - Ageing resistance > 10 C/cm for straws and highest particle rates	WG1, WG3 (3.2B), WG7 (7.2)	1.1	Test at various DRD1 test facilities	Prototype measurements

Table 7: WP4 (Part II) - a work package on inner and central tracking with PID

TPCs

T6	Gas mixture	Optimize: - Longevity - Ageing - Discharge probability - Drift velocity - Ion mobility	WG1, WG3 (3.1D, 3.2A, 3.2B), WG4, WG7 (7.1-3,5)	1.1	- Discharge probability, ageing, gas properties - Optimization of the HV working point - Optimization wrt. the expected resolution (aim for <100 μm) - Cluster ions	- Lower the discharge probability of readout units by 1-2 orders of magnitude down to $\sim 10^{-14}$ per hadron - Avoid secondary discharges in MPGD stacks

…and others DRD1 Working Groups

Table 8: WP5 - a work package on calorimetry.

T2	Gas Studies	- Gas mixture operation with low environmental impact (low-GWP)	WG3 (3.1B, 3.2C), WG4, WG7 (7.1-4)	1.1,1.3	- Improvement of recuperation and recirculation systems - Longevity studies - Ecological gas mixtures without F-gases	- Performance stability results with lower % of fresh gas - Identification of an eco-gas mixture with performance comparable to the standard one
T3	Mechanics optimization	- Uniform response over large surface ≈1-2 m^2	WG3 (3.2E), WG7 (7.1-2)	1.1	- Optimization of detector structures to minimize dead area - Development of large-scale MPGD construction techniques - Production of high planarity, large-area PCBs for MPGDs - Mechanical fabrication of very thin High-Pressure Laminate and glass RPCs - Uniform resistivity - Uniform gas gain	- Construction of a first full-scale prototype and performance assessment - Establish QC and QA procedures for mass production

Several technologies, f.e. RPC, GEM, µRWELL, PICOSEC, ..

Table 9: WP6 - a work package on gaseous photon detectors.

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3y
T1	Increase photocathode efficiency and develop robust photoconverters	Improve: - Longevity - QE - Extend to the visible range - Rad-hardness up to 10^{11} n_{eq}/cm^2	WG3 (3.1C), WG6, WG7 (7.1-4)	1.1	- Study hydrogenated nanodiamonds - Study diamond-like carbon (DLC)	- Demonstrate the performance of nanodiamond-powder photocathodes in terms of their chemical reactivity and ageing - Provide a detailed characterization of QE of new photocathode materials, e.g. DLC
T3	Gas studies	- Develop eco-friendly gas radiators and, in particular, explore alternatives to CF_4	WG3 (3.2A), WG4, WG7 (7.2,4)	1.1, 1.3	- Identification of eco-friendly gas mixtures free from greenhouse gases - Alternatives to CF_4 for optical readout	

Several technologies, f.e. Multi-MicroMegas, M-THGEM, GEM, ..

Gas → eco-gas studies
Materials → Resistive electrodes, solid converters
Systems → Gas recirculation and recuperation systems, ..
Long term operation → rad. hard., ageing effects

Table 10: WP7 - a work package on gaseous timing detectors.

T2	Enhance timing	- Time resolution < 20 ps up to 30 kHz/cm^2	WG3 (3.2A, 3.2D), WG4, WG7 (7.2)	1.1	MPGD:PICOSEC	- Present large area MPGD timing detector capabilities in beam
T3	Enhance rate capability	- Time resolution < 50 ps up to 100-150 kHz/cm^2	WG3, WG4, WG7 (7.2)	1.3	RPC: - Gap thickness - Number of gaps - Thin, low-R glass - Single cell layout - GaAs timing RPC - Resistive Cylindrical Chamber RCC PICOSEC: use at high rate	- Provide a prototype for >100 kHz/cm^2 rate capability
T4	Material studies	- Rad-hardness - Longevity	WG3, WG7 (7.3,4)	1.1-1.3	- Low-resistivity glass - Spacers - Photocathodes - Photoconverters - GaAs - HPL or phenolic glass	
T7	Gas studies	- Eco-friendly mixtures - Recuperation - Ageing - CO_2 based mixture with geometrical quenching	WG3 (3.2A, 3.2B, 3.2C), WG7 (7.2-4)	1.3	- Low-GWP solutions for saturated-avalanche operation	- Gas mixtures for MPGD(PICOSEC) based timing detectors (replacement of Ne, CF_4, C_2H_6)

Several technologies, f.e. RPC, tRPC, RCC, PICOSEC, ..

…and others DRD1 Working Groups

Table 11: WP8 (Part I) - a work package on TPCs

T3	Enhanced operation of pure or trace-amount doped noble gases	- Operation of m^2 and ton-scale detectors with single-electron sensitivity and near-Fano level energy resolution	WG1, WG3 (3.2C) WG6, WG7	1.4 (and DRD2)	- Enhancement of electroluminescence (EL) yield in noble gases (scalability, light output). - Single-electron detection. - Near-Fano energy resolution. - Stabilization of trace-amount doping (mixing, purification). - Barium tagging. - Stable amplification in dual-phase detectors. - Develop novel amplification structures	- Developing large-area ($\geq m^2$-scale) EL amplification: keeping energy resolution and single-electron sensitivity. - Imaging in low-diffusion gas. - A viable concept for Barium tagging or a viable roadmap towards it. - Very large-area ($\geq 10m^2$-scale) camara-based 3D imaging. - Operation of resistive-protected detectors.

Gas → gas properties, eco-gas studies
Materials → solid converters
Systems → Gas systems

Table 12: WP8 (Part II) - a work package on TPCs

T5	Determination of the interaction time (T_0)	- Achieve a viable timing signal while keeping low electron diffusion and high amplification of the ionization signal	WG3 (3.1A)	1.4 (and DRD2)	- T_0 sensitivity for accelerator-based neutrino TPCs. - T_0 sensitivity in the reconstruction of low-energy nuclear recoils, via scintillation light or minority carriers in case of negative-ion TPCs. - Explore the applicability of alternative methods (diffusion, positive ions) - T_0-determination on spherical counters.	- Demonstration of track reconstruction and T_0-tagging for minimum ionizing particles at $\approx$1MeV-threshold and high pressure.
T6	Modelling	- Develop a microscopic framework for computing scintillation and negative-ion yields, and transport	WG3 (3.1A, 3.2A), WG4	1.3,1.4	- Modelling primary scintillation. - Modelling secondary scintillation. - Modelling ion transport and avalanche for electronegative mixtures. - Modelling space charge.	- Develop a framework for optical simulation that is integrated as part of the standard community tools, or develop a concrete implementation path towards it.
T7	Gas mixtures and gas handling	Study new gas mixtures, operated in conditions of high purity	WG3 (3.1B, 3.2C), WG6, WG7	1.3, 1.4	- New gas mixtures for optical readout. - New gas mixtures for negative-ion readout. - Recirculation and recuperation systems. - Purification of low-quenched mixtures.	- Develop alternatives to CF_4-based mixtures operated in open loop, or a viable path towards it.
T8	Radiopurity	- Improve manufacturing process and purification as well as material-selection standards	WG3		- Radon emanation studies - Mitigation of gaseous radioactive isotopes - Material selection - Develop radiopure amplification structures and radiopure optical cameras.	- Develop MPGDs and manufacturing techniques with high radiopurity.

Outcomes: a few examples

Reference	Description	Deliverable Nature
D3.3.1	Gas properties: drift velocity, diffusion for e- and ions, gain measurements, light emission, attachment, etc.	Common gas properties database
D3.3.2	Characterisation of new eco-friendly gases: gas properties, cross-section, etc.	New data for the integration in Magboltz and Garfield++ (collaboration with WG4)
D3.3.3	Development of gas recirculation and recuperation systems	New design and knowledge transfer
D3.3.4	Longevity and ageing studies for different technologies	Report for a common approach
D3.3.5	Resistive material: characterisation of different materials	Common resistive material database and procedures
D3.3.6	Characterisation of material for the construction of detectors: material properties, compatibility, outgassing, etc.	Common construction material database
D3.3.7	Mechanics: compression, rigidity, machining precision, etc.	Common approach for the different technologies

Table 13: WG3 - Common Objectives

Summary

The DRD1 WG3 aims to address key issues, related to gas and material studies, common to all gaseous detector technologies under development for future applications

The WG3 main research topics are well linked with the ECFA themes and strongly connected to all the tasks currently foreseen for the DRD1 Working Packages

Shared resources, facilities and expertise will be key ingredients to achieve the WG3 common objectives which will also take advantage of synergies with other DRD1 WGs