DRD1 Collaboration proposal

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on behalf of the **DRD1 Collaboration**

DRD1 proposal

I Executive summary (35 pages)

- Introduction
- Scientific organization of the DRD1 Collaboration
- Collaboration Organization
- Resources and Infrastructure
- Partners and Their Fields of Contributions
- Steps towards the formation of DRD1 Collaboration
- DRD1 Implementation Team

II Scientific Proposal and R&D Framework (102 pages)

- Research topics and Work plan

  (8 sections, one per Working Group)

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 ECFA 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/QOTuKXTQQ9FQV0Y`
DRD1 Website: `https://drd1.web.cern.ch/`

Geneva, Switzerland
December 1, 2023

Link to the very last version

Scientific organization of DRD1

- Following the **General Strategic Recommendations** (ECFA Detector R&D Roadmap), the DRD1 Collaboration aims to promote the development, diffusion, and applications of gaseous detectors, towards the implementation of the **four ECFA Detector roadmap themes***
- **Community-driven (“bottom-up”) collaboration** with the cross-disciplinary R&D environment and exchange: common infrastructures (labs, workshops), common R&D tools (software and electronics)

DRD1 pillars:

1. Community-Driven Collaboration
2. Recognition and Support for Young R&D Experts
3. Dynamic and Open R&D Environment
4. Global Network and Access to Facilities
5. Support for "Blue-Sky" R&D
6. Efficient Resource Pooling
7. Increasing Research Potential

I.7 DRD1 Implementation Team

I.7.1 Roles covered during the DRD1 Implementation Phase

In this section, the roles covered during the formation of the collaboration are listed.

Task Force Conveners
Anna Colaleo, Leszek Ropelewski;

Implementation Team Florian Brunbauer , Silvia Dalla Torre , Klaus Dehmelt , Ingo Deppner , Esther Ferrer Ribas , Roberto Guida , Giuseppe Iaselli , Jochen Kaminski , Barbara Liberti , Beatrice Mandelli , Eraldo Oliveri , Marco Panareo , Francesco Renga , Hans Taureg , Fulvio Tessarotto , Maxim Titov , Joao Veloso , Peter Wintz

Proposal Review Team
Amos Breskin, Paul Colas, Jianbei Liu, Supratik Mukhopadhyay, Atsuhiko Ochi, Emilio Radicioni

Working Groups Conveners
WG1: P. Colas, I. Deppner, L. Moleri, F. Resnati, M. Tygat, P. Wintz
WG2: G. Aielli, , D. Gonzalez Diaz, R. Farinelli, F. Garcia, P. Gasik, F. Grancagnolo, G. Pugliese
WG3: K. Dehmelt, B. A. Gonzalez, B. Mandelli, G. Morello, D, Piccolo, F. Renga, S. Roth, A. Pastore
WG4: M. Abbrescia, M. Borysova, P. Fonte, O. Sahin, R. Veenhof, P. Verwilligen
WG5: R. Cardarelli, M. Gouzevitch, J. Kaminski, M. Lupberger, H. Muller
WG6: G. Charles, R. De Oliveira, A. Delbart, G. Iaselli, F. Jeanneau, I. Laktineh
WG7: A. Ferretti, R. Guida, G. Iaselli, E. Oliveri, Y. Tsipolitis
WG8: E. Baracchini, F. Brunbauer, M. Iodice, B. Liberti, A Paoloni

Work Package Coordinators
Overall Coordination: P. Gasik
WP1: G. Aielli, R. Farinelli, M. Iodice, A. Ochi, G. Pugliese
WP2: N. De Filippis, F. Grancagnolo
WP3: P. Wintz
WP4: D. Gonzalez Diaz, E. Ferrer Ribas, F. I. Garcia Fuentes, P. Gasik, J. Kaminski
WP5: I. Laktineh
WP6: F. Brunbauer, S. S. Dasgupta, P. Gasik, F. Tessarotto
WP7: F. Brunbauer, I. Deppner, D. G. Diaz, I. Laktineh
WP8: D. G. Diaz, E. Ferrer Ribas, F. I. G. Fuentes, P. Gasik, J. Kaminski
WP9: J. Bortfeldt, G. Croci, D. Varga

Liasons Persons
DRD2: D. G. Diaz
DRD4: F. Tessarotto
DRD5: F. Brunbauer
DRD6: I. Laktineh
DRD7: M. Bregant, S. Martoiu

US-CPAD: M. Titov, S. E. Vahsen
US-FCC/ILC: M. Hohlmann, G. Iakovidis, B. Zhou

Big APPRECIATION to the DRD1 COMMUNITY for great TEAMWORK, which allowed to shape the “legacy document” for the gaseous detectors domain for decades to come

* See backup slides

RD51 vs. DRD1 Collaboration

Worldwide coordination of the research in the field to advance the technological development of gaseous detector technologies

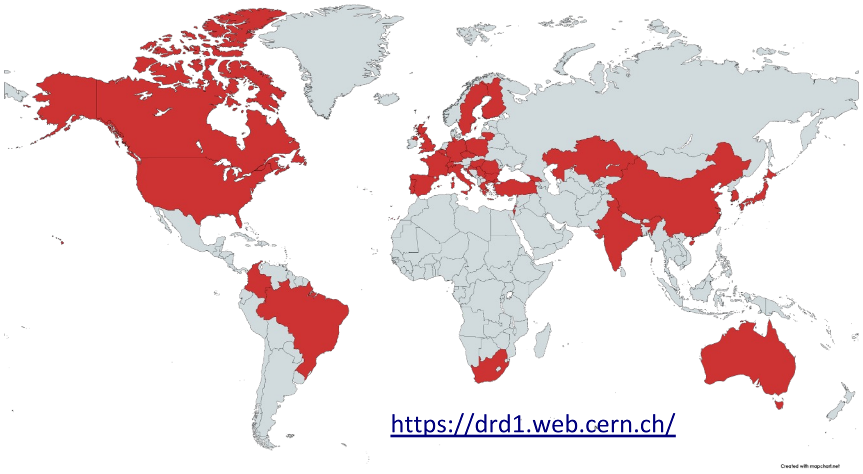
RD51

Micropattern Gaseous Detectors

- ~450 Participants from 89 Institutes in 31 Countries

DRD1

Large Volume Detectors, MPGD, RPC, TPC, WIRE



- >700 participants from 157 institutes in 33 countries

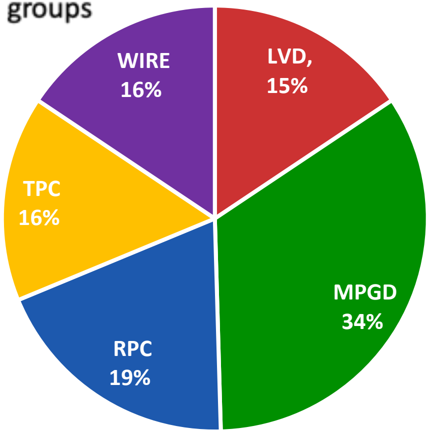
  + 4 Industrial, Semi-Industrial partners and Research Foundations

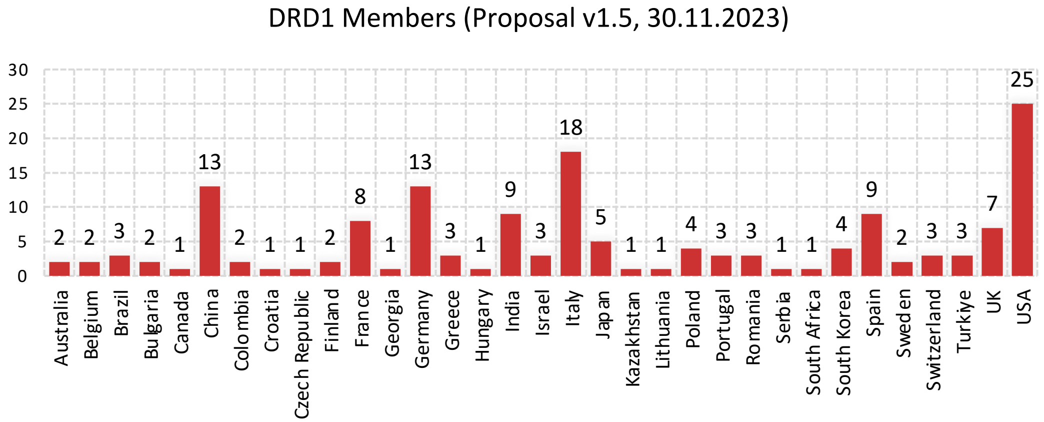
DRD1 Collaboration

https://drd1.web.cern.ch/

- Worldwide coordination of the research in the field to advance the technological development of different gaseous detector technologies (Large Drift Chambers, MPGD, RPC, TPC, wire)

224 Entries in total
157 groups





- >700 participants from 157 institutes in 33 countries

  + 4 Industrial, Semi-Industrial partners and Research Foundations

Working Groups

The scientific organization is structured in eight Working Groups, the core of the scientific collaboration:

- supporting the development of novel technologies and the consolidation of existing ones,
- facilitating the exchange of ideas and fostering synergies between institutes,
- playing a crucial role in identifying, guiding, and supporting strategic detector R&D directions, facilitating the establishment of joint projects between institutes.

DRDTs

DRDT 1.1	DRDT 1.2	DRDT 1.3	DRDT 1.4	Work Packages
●	●	●		Trackers/hodoscopes
●	●	●		Drift chambers
●	●	●		Straw chambers
●	●	●	●	Tracking TPCs
●		●		Calorimetry
●	●	●		Photon detection (PID)
●		●		Timing detectors
●	●	●	●	Reaction/decay TPCs
●		●		Beyond HEP

Forum for discussion on common topics

- WG1: Technologies
- WG2: Applications
- WG3: Gas and material studies
- WG4: Detector physics, simulations and software tools
- WG5: Electronics for gaseous detectors
- WG6: Detector production
- WG7: Common test facilities
- WG8: Training and dissemination

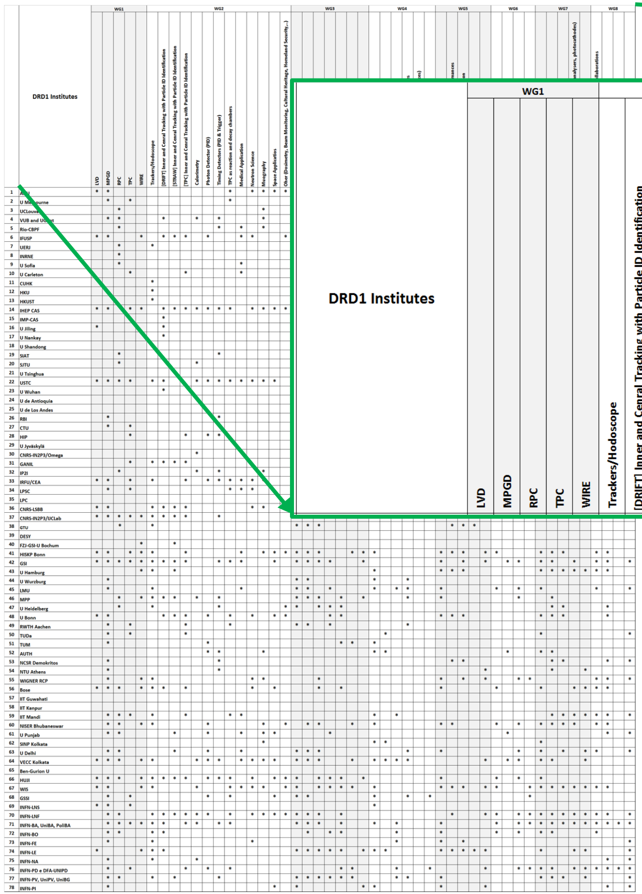
Working group tasks

The collaborative structure of DRD1 keeps RD51 structure in Working Groups

Working-group conveners coordinate R&D tasks of the respective working groups. Two coordinators elected through a nomination process, approved by MB and CB

WG 1	WG 2	WG 3	WG 4	WG 5	WG 6	WG 7	WG 8
Technologies	Applications	Gas and material studies	Detector physics, simulations, and software tools	Electronics	Detector production	Common test facilities	Training and dissemination
Large Volume Detectors (Drift chambers, TPCs)	Trackers/Hodoscope	Measurement of Gas Properties	Garfield++	Front-End Electronics for Gaseous Detectors	Common Production Facilities and Equipments	Detector Laboratories Network	Knowledge Exchange and Facilitating Scientific Collaborations
MPGDs	Inner and Cenral Tracking with PID Capabilities: - Drift Chambers - Straw tubes - TPC	Studies on Eco-friendly Mixtures	Simulation of Large Charges and Space Charge	Modernised Readout Systems (DAQ): high performances	QA/QC	Test Beam Common Facilities	Training and Dissemination Initiatives
RPCs, MRPCs	Calorimetry	Ageing and Outgassing studies	Simulation of Detectors with Resistive Elements	Modernised Readout Systems (DAQ); FE Integration	Collaboration with Industrial Partner	Irradiation Common Facilities	Career Promotion
TPC	Photon Detector (PID)	Gas sytems	Modelling and Simualtion of Eco-friendly Mixtures	Modernised Readout Systems (DAQ): portability	Gaseous Detector FORUM (know-how)	Specialized laboratories (outgassing/ageing, gas analysers, photocathodes)	Outreach and Education
Straw tubes, TGC, CSC, drift chambers, and other wire detectors	Timing Detectors (PID & Trigger)	Materials studies: - novel material (nanomaterial) - new material for wire - new converter	Optimization of Simulations (time, hw/sw resources)	Instrumentation (e.g. HV,LV, monitoring)		Common instrumentation and sofware	
New amplifying structures	TPC as reaction and decay chambers	Photocathodes	Specific Proceses (e.g. Electroluminescence)				
	Beyond HEP - Medical Application - Neutron Science - Muography - Space Applicatios - Oher (Dosimetry, Beam Monitoring, Cultural Heritage, Homeland Security,..)	Precision Mechanics					

Contributions of DRD1 Institutes to the Working Groups



The interest of each DRD1 Institute in the collaborative tasks undertaken within the Working Groups will be regularly updated and documented in the publicly accessible repositories of the DRD1 Collaboration.

Contributions of DRD1 Institutes to common facilities

#	DRD1 Institutes	A: Detector Characterization Laboratory	B: Manufacturing and Production Workshop	C: Assembly Facilities	D: Clean Rooms	E: Gas system design and production	F: Mechanical Workshop	G: Electronics Workshop	H: Analysis Laboratory	I: Metrology Laboratory	J: Radioactive Sources (active, passive)	K: Irradiation Facilities	L: Test Beam	M: Other
1	ANU	*			*	*	*	*			*	*	*	*
2	U Melbourne	*	*	*	*						*			*
3	UCLouvain		*		*		*	*					*	
4	VUB and UGent	*		*	*		*	*			*			
5	Rio-CBPF					*	*	*						
6	IFUSP	*			*		*	*	*		*	*	*	
7	UERJ	*												
8	INRNE	*												
9	U Sofia	*												
10	U Carleton			*	*									
11	CUHK													
12	HKU													
13	HKUST													
14	IHEP CAS	*	*	*	*									
15	IMP-CAS													
16	U Jiling				*									
17	U Nankay													
18	U Shandong													
19	SIAT													
20	SJTU			*	*									
21	U Tsinghua													
22	USTC	*	*	*	*									
23	U Wuhan													
24	U de Antioquia													
25	U de Los Andes													
26	RBI													
27	CTU	*												
28	HIP	*	*		*						*		*	
29	U Jyväskylä													
30	CNRS-IN2P3/Omega													
31	GANIL	*		*	*	*	*	*			*		*	
32	IP2I	*	*				*				*			
33	IRFU/CEA	*	*	*	*		*			*	*			
34	LPSC											*		
35	LPC													
36	CNRS-LSBB	*	*	*	*			*		*	*			*
37	CNRS-IN2P3/IJCLab	*	*	*	*		*	*	*		*		*	
38	GTU													
39	DESY													
40	FZJ-GSI-U Bochum	*	*		*		*	*			*			
41	HISKP Bonn				*	*	*	*			*	*	*	
42	GSI	*		*	*	*	*	*			*	*	*	
43	U Hamburg	*			*		*				*		*	
44	U Wurzburg	*									*			
45	LMU	*	*	*	*	*	*	*			*	*		
46	MPP	*	*	*	*	*	*	*		*	*			
47	U Heidelberg			*	*		*	*			*		*	
48	U Bonn	*	*	*	*	*	*	*			*	*	*	
49	RWTH Aachen	*			*	*	*	*			*			
50	TUDa	*					*	*			*			*
51	TUM	*			*		*				*			
52	AUTH			*	*									
53	NCSR Demokritos	*			*		*	*			*	*	*	
54	NTU Athens											*	*	
55	WIGNER RCP	*	*	*	*	*	*		*		*			
56	Bose	*		*							*			
57	IIT Guwahati													
58	IIT Kanpur													
59	IIT Mandi	*		*	*		*	*	*	*	*			*
60	NISER Bhubaneswar	*		*	*		*				*			
61	U Punjab	*	*	*	*		*	*	*					
62	SINP Kolkata	*					*				*			
63	U Delhi	*	*	*	*	*	*	*	*		*			
64	VECC Kolkata	*		*	*		*				*		*	
65	Ben-Gurion U													
66	HUJI	*	*		*	*	*	*	*		*			
67	WIS	*	*	*	*	*	*	*	*		*			
68	GSSI	*									*			
69	INFN-LNS	*									*			
70	INFN-LNF	*		*	*	*	*	*			*	*	*	
71	INFN-BA, UniBA, PoliBA	*	*	*	*		*	*		*	*			
72	INFN-BO	*					*	*						
73	INFN-FE	*			*		*	*						
74	INFN-LE	*		*	*	*	*	*			*			
75	INFN-NA	*			*		*	*	*		*			
76	INFN-PD e DFA-UNIPD													
77	INFN-PV, UniPV, UniBG	*		*	*		*	*			*	*		
78	INFN-PI	*			*		*	*	*		*	*		*

The available facilities at the DRD1 Institutes will be also regularly updated and documented in the publicly accessible repositories, together with the contact person and access modality.

Organization of the collaboration activities

Following the indication of ECFA Detector Panel two areas of Detector R&D :

- ”Blue-sky” R&D (competitive, short-term responsive grants, nationally organised)
- Strategic R&D via DRD Collaborations (long-term strategic R&D lines) (address the high-priority items defined in the Roadmap via the DRDTs)

Two types of DRD1 joint projects will be implemented:

Common projects

For low-TRL (blue sky) R&D, or other short term generic projects

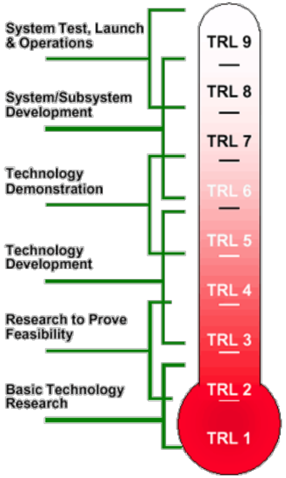
Work Packages

Strategic R&D targeting the priority programmes outlined in the updated European Strategy for Particle Physics

Common projects

- **Common Projects (CP)** support **low TRL (blue-sky) R&D** considered of interest by the collaboration, **or generic projects that are vital for the community and require** special backing:
  - Technology R&D projects towards development of novel techniques, improvements of existing technologies, characterization methods and dedicated tools;
  - Development and optimization for novel applications;
  - Improvement of the technology transfer to industry;

- **Well-defined path (RD51 experience):** DRD1 Common Fund (details will be clearly defined in the MoU) supports CP with matching resources from participating Institutes.
  - a minimum number of participating Institutes to encourage collaborative effort between groups.
  - limited in time
  - limited funding support from the collaboration (example 20-30k/y)



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Technology readiness levels

Large number of groups in DRD1 ensures strong R&D!

Common fund and common investments

A Common Fund will be established, supported by limited and fixed yearly contributions from each DRD1 institute. This fund will serve as a valuable resource for supporting activities of common interest within the collaboration, for example:

- Common Projects
- Software and Electronics development
- Common Facilities
- Collaboration events and Collaboration Management.

COMMON FUND is fundamental for the future DRD1 activities

Common investments, such as materials and infrastructure, within the DRD1 Collaboration, will be covered, depending on the interest in the community and the required resources:

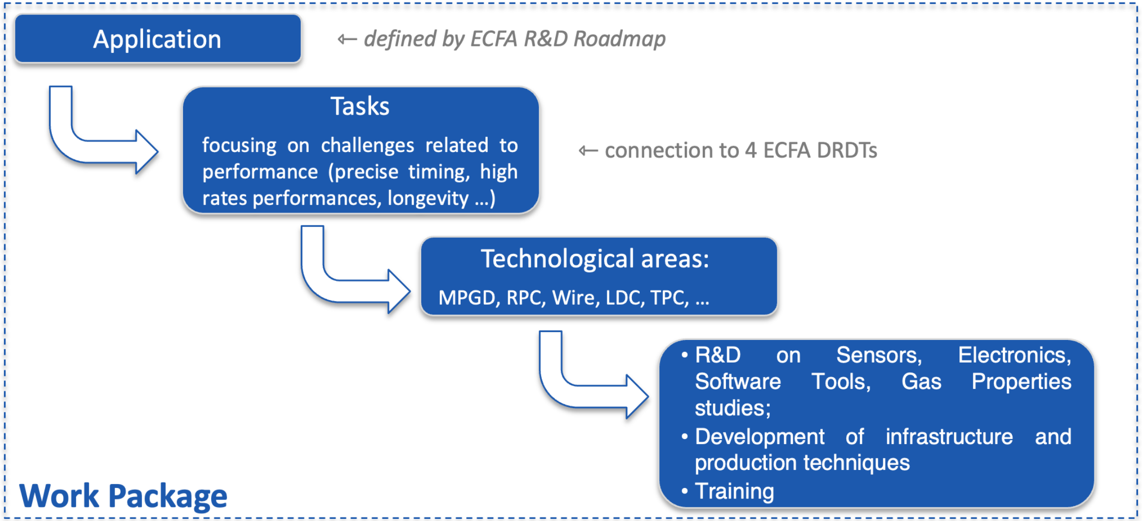
- by common funds
- by mechanisms similar to the Work Packages

This cooperative approach allows for the sharing of expenses related to essential requirements like base material, production or testing equipment, large-scale electronics production or other procurement activities.

Work Packages

Strategic R&D (according to the ECFA Detector R&D Roadmap) **is organized in Work Packages**

- group activities of the Institutes with **shared research interests** around **Applications** with a focus on a **specific task(s)** devoted to a specific DRDT challenge, typically related to specific **Detector Technologies and** to the development of **specific tools or infrastructure**



Currently envisaged WPs:

- **WP1: Trackers/hodoscopes**
- **WP2: Drift chambers**
- **WP3: Straw chambers**
- **WP4: Tracking TPCs**
- **WP5: Calorimetry**
- **WP6: Photo-detectors**
- **WP7: Timing**
- **WP8: Reaction/Decay TPCs**
- **WP9: Beyond HEP**

- **There is no obligation to participate in a WP to be a member of DRD1.**

WP tables - explanation

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Milestones/Deliverable 12M	24M	36M	Institutes
T1	New RPC structures	- Develop low-cost resistive layers - Increase rate capability from 10 kHz to 1 MHz per cm^2 - Improve timing resolution from sub-ns to ps levels	WG1, WG2, WG3, WG4, WG5, WG6, WG7, WG8	1.1, 1.2, 1.3	**M1.1** **Review of Detector Prototypes:** examining the current status and future prospects of innovative resistive materials, novel structures, and challenges in hybridizing Resistive Plate Chambers (RPC) and Micro-Pattern Gas Detectors (MPGD). This evaluation includes compiling of a comprehensive report highlighting comparative performance, along with the respective advantages and disadvantages of available technologies. **[T1, T2, T5, T6, T7, T8]** **M1.2** **Review of the status of the art of ASICs and DAQ systems,** and definition of the requirements for next-generation large area muon systems. **[T3, T4]**	**M2.1** **Detector Prototypes Enhancement:** building upon the insights from M1.1. Proof of rate capability above 100 kHz/cm^2, assessing the status and potential improvements of RPC and MPGD detectors, informed by feedback from the previous phase. **[T1, T2, T5, T6, T7, T8]** **M2.2** **Design and Simulation studies of new ASIC**: Building blocks for MPGD and RPC and technical note(s) about the chips expected performance. **[T3]** **M2.3** **Design of a novel readout system for Gaseous Detectors:** assessment of performance achievements based on DAQ modelling. **[T4]**	**D1** **Large area RPC and MPGD prototypes:** design, construction, and test of RPC and MPGD-based prototypes **[T1, T2]** with advanced solutions for extensive surface coverage **[T6]**, optimized for medium-high flow rates (range tens kHz/cm^2 – few MHz/cm^2), precise tracking (100 µm) and timing (ns and sub-ns time resolution). This includes considerations for the compatibility of eco-friendly gases. **[T5, T7]** **D2** **New frontend and DAQ systems:** completion of the innovative ASICs' final design; compilation of comprehensive production documentation; if applicable, initiation of the engineering run for the first chip, should it be in an advanced stage **[T3]**. DAQ system prototyping for gaseous detectors, aiming to push the boundaries in terms of timing, radiation resistance, multi-channel high rate acquisition and performance, for large systems **[T4]**.	INFN-BA, UniBA, PoliBA, INFN-LNF, INFN-RM2, UniRomaTOV, INFN-BO, INFN-FE, INFN-NA, INFN-RM3, INFN-TO, IRFU/CEA, IFIN-HH, Istinye U, CERN, CIEMAT, LMU, WIS, Wigner, U Kobe, U Cambridge, USTC, U Oviedo, UNSTPB, UTransilvania, VUB and UGent, U Genève, U Hong Kong, MPP, BNL, FIT, JLab, MSU, Tufts, UC Irvine, U Florida, U Massachusetts, Amherst, U Michigan, UW–Madison, IGPC
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 (100 µm) - Development of low-granularity 2D-readout with high-tracking performance						
T3	New Front-end electronics	- New front-end - 1 fC threshold - High-sensitivity electronics to help achieve stable and efficient operation up to ≈MHz/cm^2 - High granularity detector capability						
T4	Optimization of scalable multichannel readout systems	- Front-end link concentrator to a powerful FPGA with possibilities of triggering and ≈20 GBit/s to DAQ for high-rate experiment -Develop robust, compact, and low power DAQ for low-rate experiment						
T5	Eco-friendly gases	- Guarantee long-term operation - Explore compatibility and optimized operation with low-GWP gases						
T6	Manufacturing	- Technological transfer for cost-effective production of high-quality, high-performance large area resistive MPGD. - Reliable production of homogeneous resistive large DLC foils with the CERN-INFN sputtering machine						
T7	Longevity on large detector areas	- Study discharge rate and the impact of irradiation and transported charge (up to C/cm^2) - Study the impact of low-GWP gases and new materials on high radiation hardness environment						
T8	New Hybrid-multi-technologies Structures	- Development of new ideas of detector structures and hybridization						

Example Work Package Table: WP1 - Trackers/Hodoscopes

- **Task**
- **Performance goal**

  - *Challenges defined in ECFA Roadmap*
  - *Community feedback*

- **DRD1 WGs** — *Link to DRD1 WGs activities*
- **ECFA DRDT** — *Connection to ECFA DRDTs*
- **Milestones/ Deliverables** — *Top-level milestones and deliverables for the first three years of a WP activity. Based on detailed annexes (>330 pages), to be signed as MoU addenda.*
- **Institutes** — *List of institutes interested in joining a WP. Estimate on available/additional resources and commitment to tasks/deliverables provided in detailed annexes.*

Resource and infrastructures: Work Package

Resource and Participation Tables are presented in the proposal as cumulative data:

- gathering ”confidential material" from institutes,
- no commitment is assured at this stage
- institutes need to verify with their FAs the potential consideration of proposed resources.
- the final commitment will be provided only at the time of submission of Work Package for approval

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP1	Trackers/Hodoscopes	651	516	501	47.45	50.9	50.7
WP2	Inner and Central Tracking with PID Capability, Drift Chambers	394	163	167	19.45	21.45	23.45
WP3	Inner and Central Tracking with PID Capability, Straw and Drift Tube Chambers	163.5	70	65	32	37.3	40.3
WP4	Inner and Central Tracking with PID Capability, Time Projection Chambers	268	268	253	15	15	14.5
WP5	Calorimetry	150	150	150	12.75	12.75	12.75
WP6	Photo-Detectors	275	325	315	11.9	11.4	11.4
WP7	Timing Detectors	420	311	311	24.1	21.7	20.7
WP8	TPCs as Reaction and Decay Chambers	495	505	405	78.35	73.05	72.55
WP9	Beyond HEP	803	783	694	40.5	37.5	35.2
	SUM	**3456**	**3091**	**2861**	**281.5**	**281.05**	**281.55**

Cumulative information about
<u>existing resources</u>
2024-2025-2026

FAs can have different approval steps

Resource and infrastructures: Work Package

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WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP1	Trackers/Hodoscopes	716	1040	670	21.8	23.55	23.55
WP2	Inner and Central Tracking with PID Capability, Drift Chambers	79	89	93	3.15	8.4	9.15
WP3	Inner and Central Tracking with PID Capability, Straw and Drift Tube Chambers	525	325	330	11.7	12.9	12.9
WP4	Inner and Central Tracking with PID Capability, Time Projection Chambers	238	238	238	11.3	11.3	11.3
WP5	Calorimetry	50	50	50	1	1	1
WP6	Photo-Detectors	180	270	250	4.6	5.1	5.6
WP7	Timing Detectors	257	307	346	3	5.5	6.9
WP8	TPCs as Reaction and Decay Chambers	516.5	471.5	436.5	35.1	40	40
WP9	Beyond HEP	140	225	275	15.9	20.4	23.9
	SUM	**2701.5**	**3015.5**	**2688.5**	**107.55**	**128.15**	**134.3**

Cumulative information about
additional resources needed
2024-2025-2026

FAs can have different approval steps

Resource and infrastructures: Work Package

WP	Description	Material (2027-2029) [kCHF/year]	FTE/year (2027-2029)
WP1	Trackers/Hodoscopes	1365	73
WP2	Inner and Central Tracking with PID Capability, Drift Chambers	328	28
WP3	Inner and Central Tracking with PID Capability, Straw and Drift Tube Chambers	438	49
WP4	Inner and Central Tracking with PID Capability, Time Projection Chambers	501	26
WP5	Calorimetry	200	14
WP6	Photo-Detectors	538	17
WP7	Timing Detectors	651	27
WP8	TPCs as Reaction and Decay Chambers	943	113
WP9	Beyond HEP	973	58

Cumulative information about resources for material and FTE projection >2027

Resource envelope necessary if progress aligns with expectations by 2026, following milestones and deliverables.

Collaboration formation

Approved steps at the "2nd DRD1 Community meeting", June 2023

- **July 2023:** Submit DRD1 Extended Proposal to DRDC after consultation.
- **August 2023:** Form Provisional DRD1 Collaboration Board, one representative per institute.
- **September 2023:** Initiate DRD1 Search Committee formation, endorsed by the Provisional Collaboration Board.
- **Oct-Nov 2023:** DRD1 Search Committee seeks Spokespersons and CB Chair nominations.

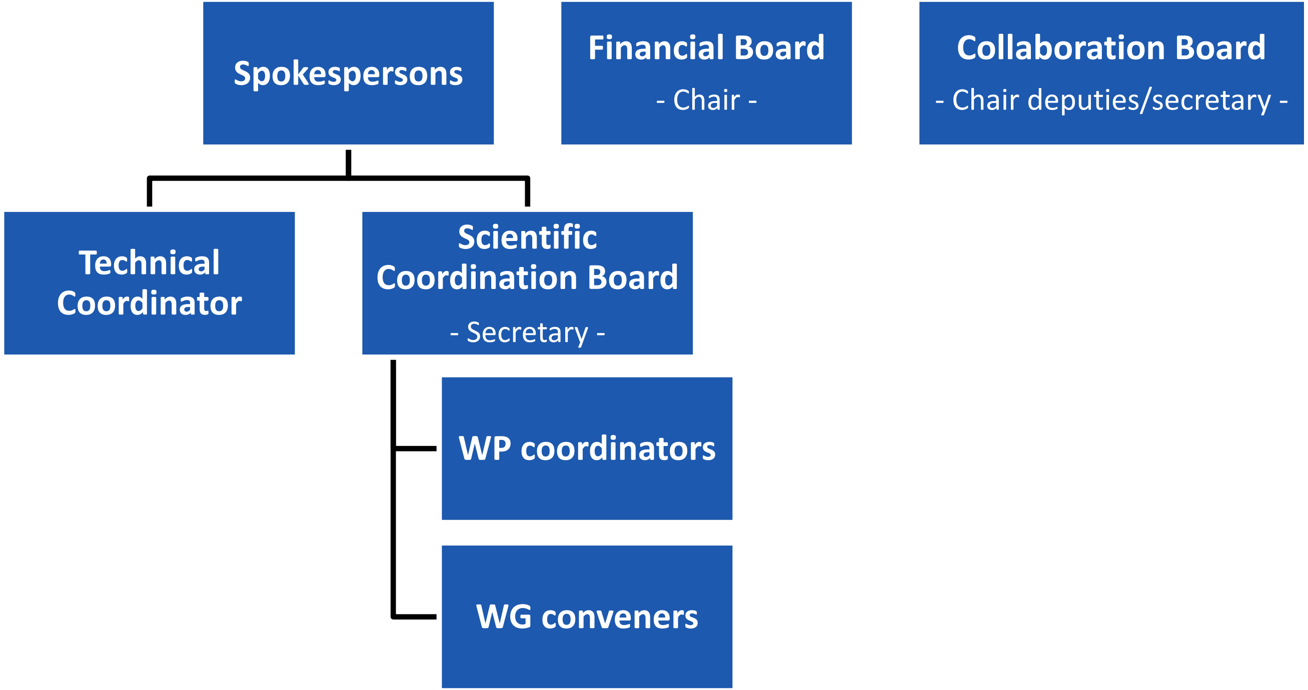
today

- **8 Dec 2023:** open meeting where candidates for Spokespersons and CB Chair present their statements.

  Afterwards, the electronic election campaign
- **29 Jan 2024:** hold the DRD1 Collaboration Meeting at CERN and establish collaboration bodies.

Collaboration bodies and management organization (proposal)

- The final DRD1 organization will be defined and approved once the elected management is in charge



Synergies with other DRDs

DRD1 recognizes the importance of synergistic collaborations with other DRDs to optimize resource utilization, avoid duplication, and enhance overall impact on detector research and development.

DRD2: Liquid Detectors - Diego Gonzalez Diaz

- ✓ Collaboration on dual-phase amplification with exploration in DRD1 for wires, meshes, and structures, and support in detector manufacturing techniques. Support for the study of liquid-phase signal induction and light amplification.
- ✓ Collaborative efforts in simulation, gas/liquid recirculation, system purification, fluid-dynamics simulations, UV-photon detection, radiopurity, and material selection

DRD4: Photon Detector & PID - Fulvio Tessarotto

- ✓ Collaborative studies on gaseous photon detectors and eco-friendly gas solutions.
- ✓ Joint work packages for detector and radiator gases.

DRD5: Quantum and Emerging Technologies - Florian Brunbauer

- ✓ Exploiting synergies between advanced materials in DRD5 and DRD1's Gas and Material Studies.

DRD6: Calorimetry - Imad Laktineh

- ✓ DRD1 specializes in developing gaseous detectors for calorimeters and their performance studies (gain, timing, rate capability), eco-friendly gases. Collaboration with DRD6 on overall system issues, including services and integration.
- ✓ **Collaborative Exchange:** DRD6 discusses readout electronics and DAQ, facilitating potential collaboration with DRD1 groups on similar developments for diverse applications.

DRD7: Electronics and On-Detector Processing - Sorin Martoiu, Marco Bregant

- ✓ Collaboration opportunities for electronics advancements and ASIC design.
- ✓ Interest in sharing front-end building blocks and co-designing with DRD7.
- ✓ Support from DRD7 in technology access and cooperation frameworks.

Synergies with the US groups and programs

- Strong participation of the US community in the DRD1 process (25 US institutes signed the DRD1 proposal)

- US - CPAD link persons: **M. Titov, S. Vahsen**
- US - FCC/ILC: **M. Hohlmann, G. Iakovidis, B. Zhou**

- Communication between DRD1 and US community is well-advanced
  (e.g. recent DRD1 talk at the CPAD workshop, Nov. 2023)

Summary

- **DRD1 Collaboration proposal** is a result of the great work of the Implementation Team and the whole gaseous detector community
  - Implementation Team: about 50 people covering all involved technologies
  - Meeting: more than 30 DRD1 Implementation Team meetings in 2023 and two large community meetings in spring and summer
  - Proposal: peer-reviewed internally and made continuously available to institute representatives and to the full community for reviewing and feedback during the full process.

- **The DRD1 R&D framework** is structured, supported, and enhanced through transversal **Working Groups**, which function as collaborative hubs to support the Strategic R&D initiatives undertaken by DRD1 members across different **DRD1Work Packages**

- The DRD1 proposal seeks to **preserve and enrich the legacy of RD51** taking the advantages coming from a broader community and a wider array of technologies, facilities, tools and developments.

- **DRD1 is ready and eager to start activities in January 2024**
  - Timely progress towards the MoU signature will facilitate the start-up of the WP and DRD1 collaboration activities

- **We are looking forward to a positive review!**

BACKUP

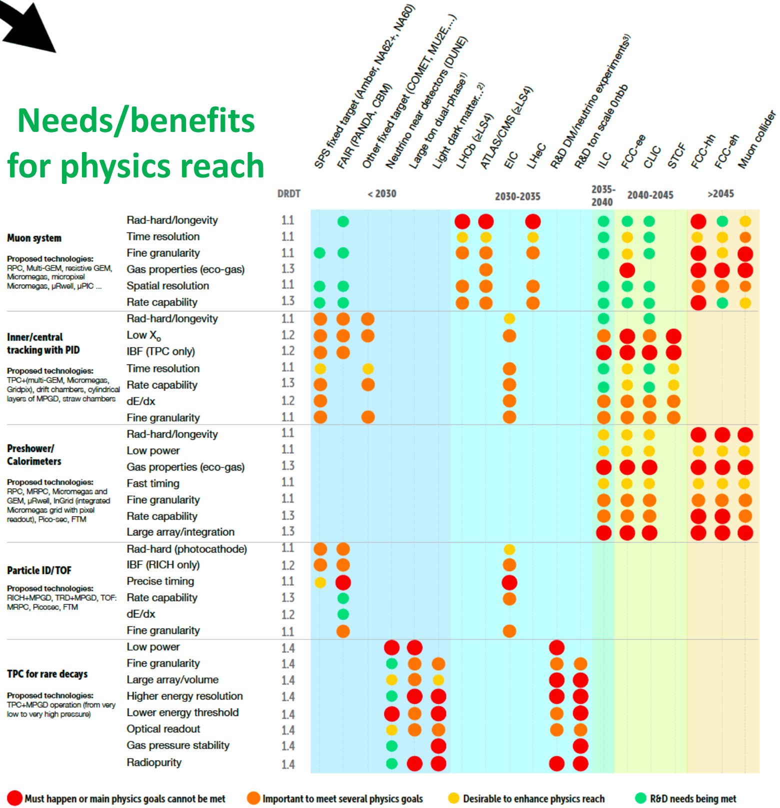
ECFA DETECTOR R&D ROADMAP CONTENT: TF1

Performance targets and main drivers from facilities

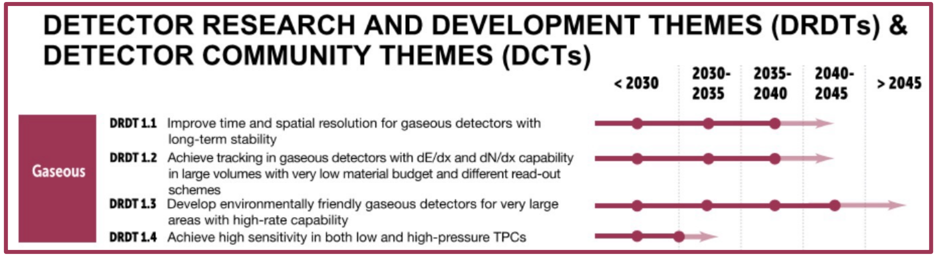
Facility	Technologies	Challenges	Most challenging requirements at the experiment
HL-LHC	RPC, Multi-GEM, resistive-GEM, Micromegas, micro-pixel Micromegas, μ-RWELL, μ-PIC	Ageing and radiation hard, large area, rate capability, space and time resolution, miniaturisation of readout, eco-gases, spark-free, low cost	**(LHCb)**: Max. rate: 900 kHz/cm² Spatial resolution: ~ cm Time resolution: O(ns) Radiation hardness: ~ 2 C/cm² (10 years)
Higgs-EW-Top Factories (ee) (ILC/FCC-ee/CepC/SCTF)	GEM, μ-RWELL, Micromegas, RPC	Stability, low cost, space resolution, large area, eco-gases	**(IDEA)**: Max. rate: 10 kHz/cm² Spatial resolution: ~60-80 μm Time resolution: O(ns) Radiation hardness: <100 mC/cm²
Muon collider	Triple-GEM, μ-RWELL, Micromegas, RPC, MRPC	High spatial resolution, fast/precise timing, large area, eco-gases, spark-free	Fluxes: > 2 MHz/cm² ($\theta<8^0$) < 2 kHz/cm² (for $\theta>12^0$) Spatial resolution: ~100μm Time resolution: sub-ns Radiation hardness: < C/cm²
Hadron physics (EIC, AMBER, PANDA/CMB@FAIR, NA60+)	Micromegas, GEM, RPC	High rate capability, good spatial resolution, radiation hard, eco-gases, self-triggered front-end electronics	**(CBM@FAIR)**: Max rate: <500 kHz/cm² Spatial resolution: < 1 mm Time resolution: ~ 15 ns Radiation hardness: 10^{13} neq/cm²/year
FCC-hh (100 TeV hadron collider)	GEM, THGEM, μ-RWELL, Micromegas, RPC, FTM	Stability, ageing, large area, low cost, space resolution, eco-gases, spark-free, fast/precise timing	Max. rate 500 Hz/cm² Spatial resolution = 50 μm Angular resolution = 70 μrad (η=0) to get Δp/p≤10% up to 20 TeV/c

Example: Muon systems

Needs/benefits for physics reach



Detector R&D themes



DRD1 PILLARS

Scientific organization of DRD1: the pillars (I)

The DRD1 Collaboration aims to promote the development, diffusion, and applications of gaseous detectors, following the 3 General Strategic Recommendations (GSR) outlined in the ECFA Detector R&D Roadmap Document.

The following pillars form the foundation of this Collaboration:

1. **Community-Driven Collaboration**: The Collaboration is driven by the community, providing a vital forum for exchanging ideas and establishing synergies to minimize duplicated efforts.

2. **Recognition and Support for Young R&D Experts**: The Collaboration will promote proper recognition and support for the careers of instrumentation R&D experts. This support will be facilitated through the member institutes and their interface with the scientific community and institutions.

3. **Dynamic and Open R&D Environment**: The Collaboration will strive to create and maintain an up-to-date, dynamic, and open R&D environment. This environment will support the development of necessary tools such as simulation and electronics, as well as the infrastructure required to undertake R&D on novel detectors and to validate their performances against the demanding specifications of future facilities and applications.

Scientific organization of DRD1: the pillars (II)

The DRD1 Collaboration aims to promote the development, diffusion, and applications of gaseous detectors, following the 3 General Strategic Recommendations (GSR) outlined in the ECFA Detector R&D Roadmap Document.

The following pillars form the foundation of this Collaboration:

4. **Global Network and Access to Facilities:** Leveraging its worldwide international network, the DRD1 Collaboration will facilitate access to testing facilities and advanced engineering support, available at DRD1 research laboratories and institutes.

5. **Support for "Blue-Sky" R&D:** The Collaboration will actively support "Blue-sky" R&D, which can lead to breakthroughs driven by technology. Common resources will be allocated, leveraging the aforementioned R&D environment.

6. **Efficient Resource Pooling:** The Collaboration aims for the most efficient pooling of resources through joint projects that will undergo international review. It will promote and support research plans that attract long-term funding, enabling the community to effectively address future technical challenges. These efforts will also help to build strong relationships between institutes and industrial partners.

7. **Increasing Research Potential**: By adding critical mass to the needs of individual institutes, the Collaboration aims to reduce research costs and enhance potential and results.

WORK PACKAGES

WP1 – Trackers/Hodoscopes

Challenges

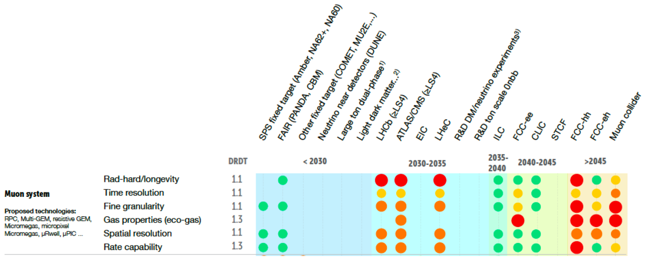
- Extend the state-of-the-art rate capability by at least one order of magnitude
- Improve time resolution at the level of sub-ns for RPC and O(ns) for MPGD
- Enable reliable and efficient operation with suitable low-GWP gas mixtures
- Establish large-scale serial production and cost reduction procedures

➢ ECFA R&D tasks are all covered

Goals

- Develop and validation of RPC and MPGD-based prototypes with advantage solutions for extensive surface coverage and optimized for medium-high flow rates with associated fine granularity readout, precise tracking and timing
- Develop a new frontend and readout systems that push the detector boundaries in terms of timing, radiation resistance, and performance

One project associating different technologies



#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Milestones/Deliverable			Institutes
					12M	24M	36M	
T1	New RPC structures	- Develop low-cost resistive layers - Increase rate capability from 10 kHz to 1 MHz per cm^2 - Improve timing resolution from sub-ns to ps levels	WG1, WG2, WG3, WG4, WG5, WG6, WG7, WG8	1.1, 1.2, 1.3	**M1.1** **Review of Detector Prototypes:** examining the current status and future prospects of innovative resistive materials, novel structures, and challenges in hybridizing Resistive Plate Chambers (RPC) and Micro-Pattern Gas Detectors (MPGD). This evaluation includes compiling of a comprehensive report highlighting comparative performance, along with the respective advantages and disadvantages of available technologies. **[T1, T2, T5, T6, T7, T8]** **M1.2** **Review of the status of the art of ASICs and DAQ systems,** and definition of the requirements for next-generation large area muon systems. **[T3, T4]**	**M2.1** **Detector Prototypes Enhancement:** building upon the insights from M1.1. Proof of rate capability above 100 kHz/cm^2, assessing the status and potential improvements of RPC and MPGD detectors, informed by feedback from the previous phase. **[T1, T2, T5, T6, T7, T8]** **M2.2** **Design and Simulation studies of new ASIC**: Building blocks for MPGD and RPC and technical note(s) about the chips expected performance. **[T3]** **M2.3** **Design of a novel readout system for Gaseous Detectors**: assessment of performance achievements based on DAQ modelling. **[T4]**	**D1** **Large area RPC and MPGD prototypes:** design, construction, and test of RPC and MPGD-based prototypes **[T1, T2]** with advanced solutions for extensive surface coverage **[T6]**, optimized for medium-high flow rates (range tens kHz/cm^2 – few MHz/cm^2), precise tracking (100 μm) and timing (ns and sub-ns time resolution). This includes considerations for the compatibility of eco-friendly gases. **[T5, T7]** **D2** **New frontend and DAQ systems:** completion of the innovative ASICs' final design; compilation of comprehensive production documentation; if applicable, initiation of the engineering run for the first chip, should it be in an advanced stage **[T3]**. DAQ system prototyping for gaseous detectors, aiming to push the boundaries in terms of timing, radiation resistance, multi-channel high rate acquisition and performance, for large systems **[T4]**.	INFN-BA, UniBA, PoliBA, INFN-LNF, INFN-RM2, UniRomaTOV, INFN-BO, INFN-FE, INFN-NA, INFN-RM3, INFN-TO, IRFU/CEA, IFIN-HH, Istinye U, CERN, CIEMAT, LMU, WIS, Wigner, U Kobe, U Cambridge, USTC, U Oviedo, UNSTPB, UTransilvania, VUB and UGent, U Genève, U Hong Kong, MPP, BNL, FIT, JLab, MSU, Tufts, UC Irvine, U Florida, U Massachusetts, Amherst, U Michigan, UW–Madison, IGPC
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 (100 μm) - Development of low-granularity 2D-readout with high-tracking performance						
T3	New Front-end electronics	- New front-end - 1 fC threshold - High-sensitivity electronics to help achieve stable and efficient operation up to ≈MHz/cm^2 - High granularity detector capability						
T4	Optimization of scalable multichannel readout systems	- Front-end link concentrator to a powerful FPGA with possibilities of triggering and ≈20 GBit/s to DAQ for high-rate experiment -Develop robust, compact, and low power DAQ for low-rate experiment						
T5	Eco-friendly gases	- Guarantee long-term operation - Explore compatibility and optimized operation with low-GWP gases						
T6	Manufacturing	- Technological transfer for cost-effective production of high-quality, high-performance large area resistive MPGD. - Reliable production of homogeneous resistive large DLC foils with the CERN-INFN sputtering machine						
T7	Longevity on large detector areas	- Study discharge rate and the impact of irradiation and transported charge (up to C/cm^2) - Study the impact of low-GWP gases and new materials on high radiation hardness environment						
T8	New Hybrid-multi-technologies Structures	- Development of new ideas of detector structures and hybridization						

WP1 – Trackers/Hodoscopes

Institutes

- 39 institutes from 17 countries

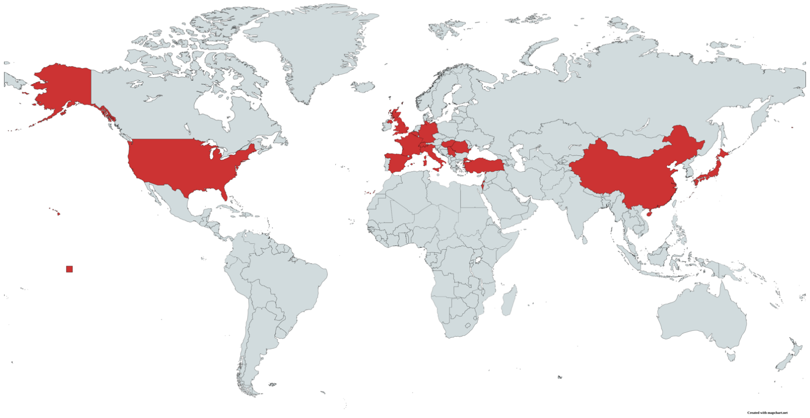
Institute	T1	T2	T3	T4	T5	T6	T7	T8
	TASK							
INFN-BA	x				x		x	
INFN-BO		x	x					
INFN-FE		x	x	x				x
INFN-LNF	x	x			x	x	x	x
INFN-NA		x				x	x	
INFN-RM2	x	x	x		x	x	x	x
INFN-RM3		x				x	x	
INFN-TO			x					
Kobe	x	x						
CERN		x	x	x	x		x	
U. Cambridge	x				x		x	
LMU		x						
ICTEA U Oviedo			x					
CIEMAT			x					
Wigner RCP			x			x	x	
Max Plank								x
Univ of Geneva								x
Hong Kong								x
Weizmann		x					x	
IRFU		x	x					
USTC		x						x
VUB					x			
IFIN-HH		x	x	x				
UNSTPB		x	x	x				
UniTBv			x	x				
ISU	x		x	x	x		x	
e+e- US Cluster	x		x	x	x	x	x	
IGPC - Belgrade					x		x	

Existing

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP1	Trackers/Hodoscopes	651	516	501	47.45	50.9	50.7

Additional (not existing)

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP1	Trackers/Hodoscopes	716	1040	670	21.8	23.55	23.55



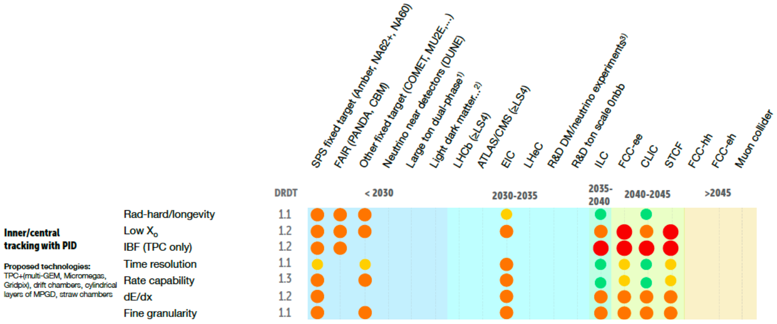
WP2 – Drift Chambers

Challenges:

- Development of front-end ASIC for cluster counting/a scalable multichannel DAQ board
- New wiring procedures and new endplate concepts
- Consolidation of new wire materials and wire metal coating / ageing phenomena
- Increase of the rate capability and granularity
- Optimization of gas mixing, recuperation, purification and recirculation systems

Goals:

- Achieving efficient cluster counting and cluster timing performances by using FPGA based architecture
- Completion of a cylindrical sector of a full length drift chamber prototype aimed at testing all mechanical properties.
- Performance of K-p separation in the momentum range from 2 to 30 GeV/c based on a scalable front-end/digitizer/DAQ electronics chain for cluster counting.



#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Milestones/Deliverable 12M	Milestones/Deliverable 24M	Milestones/Deliverable 36M	Institutes
T1	Front-end ASIC for cluster counting	- High bandwidth - High gain - Low power - Low mass	WG1, WG2, WG3, WG4, WG5, WG7	1.1, 1.2, 1.3	**M1.1** **At least 80% efficiency** of the cluster counting/timing with resolution in dn/dx smaller than 30% for a single hit. [T1] **M1.2** **Design of the frontend ASIC** optimized for cluster counting. [T1]	**M2.1** **Completion of the mechanical design** of the full length drift chamber prototype. [T3] **M2.2** **Validation of the tension recovery scheme.** [T3]	**D1** **Realization of a scalable front-end/digitizer/DAQ** electronics chain for cluster counting/timing. [T1-T2] **D2** **Performance of K-π separation** in the momentum range from 2 to 30 GeV/c. [T1-T2]	CNRS-IN2P3/IJCLab, INFN-BA, UniBA, PoliBA, INFN-LE, INFN-RM1, U Massachusetts, Amherst, U Michigan, UC Irvine, Tufts, BNL, FIT, U Florida , UW–Madison, U Nankay, U Tsinghua, IHEP CAS, U Wuhan, U Jilin, USTC, IMP-CAS, Bose
T2	Scalable multichannel DAQ board	- High sampling rate - Dead-time-less - DSP and filtering - Event time stamping - Track triggering						
T3	Mechanics: wiring procedures, new end-plate concepts	- Feed-through-less wiring procedures - More transparent end-plates ($X < 5\% X_0$) - Transverse geometry						
T4	High rate High granularity	- Smaller cell size and shorter drift time - Higher field-to-sense ratio						
T5	New wire materials and wire metal coating	- Electrostatic stability - High YTS - Low mass, low Z - High conductivity - Low ageing						
T6	Study ageing phenomena for new wire types	- Establish charge-collection limits for carbon wires as field and sense wires						
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						

WP2 – Drift Chambers

Institutes

- 20 institutes in 5 countries
- All R&D tasks covered

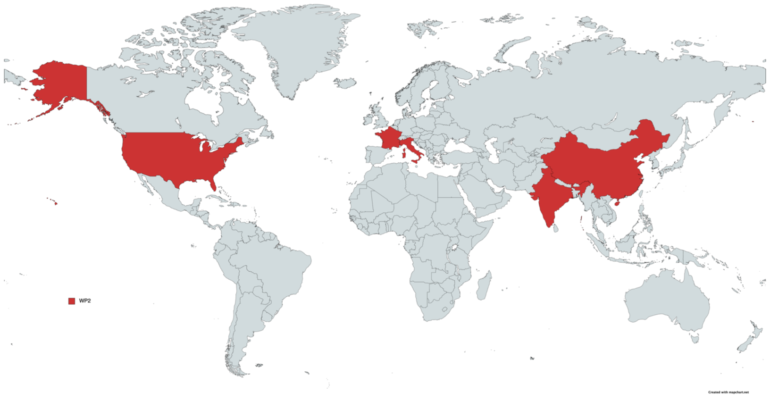
	Tasks						
Institute	T1	T2	T3	T4	T5	T6	T7
IJCLab-IN2P3			x	x	x	x	
INFN-BA	x	x	x	x	x	x	x
INFN-LE	x	x	x	x	x	x	x
INFN-RM				x	x	x	x
US Cluster	x		x				x
Nankai U				x			
Tsinghua U	x						
IHEP-CAS	x		x	x			x
Wuhan U				x			
Jilin U				x			
USTC				x		x	
IMP-CAS				x		x	
Bose						x	x

Existing

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP2	Inner and Central Tracking with PID Capability, Drift Chambers	394	163	167	19.45	21.45	23.45

Additional (not existing)

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP2	Inner and Central Tracking with PID Capability, Drift Chambers	79	89	93	3.15	8.4	9.15



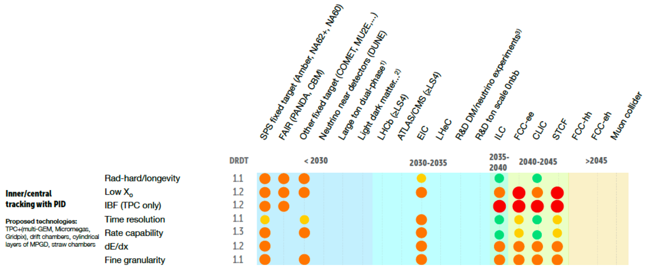
WP3 – Straw and Drift Tube Chambers

Challenges and goals

- Straw tube wall film thickness < 20µm for low X/X0 < 0.04% per straw
- Straw diameter ≤ 5mm for high rate capability of O(100 kHz/cm²)
- Straw length up to 4m with thin film tube walls
- Extending tracking information to 4D (3D-space and T0) and dE/dx for PID
- ASIC design for high-resolution leading-/trailing edge time and charge readout
- Very large straw detector volumes of O(10m³) and in vacuum
- Extending detector longevity by increasing material purity
- Developing new production techniques, like ultrasonic film tube welding to minimize the usage of glue

List of projects

1. Drift tube developments for high-rate applications (e.g. at FCC-ee/hh)
2. Straw chamber technologies for hadron physics applications (e.g. 4D+PID, low X0, ..)
3. Large area straw detector for Dark Sector applications (e.g. 4m ultra-long straws)
4. Straw chamber technologies for neutrino physics applications (e.g. low X0, large area)
5. Optimization of straw materials and production technologies (e.g. standardizing, ..)
6. Optimization of electronic readout (new ASIC designs, versatile applications, ..)



#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Milestones/Deliverable 12M	Milestones/Deliverable 24M	Milestones/Deliverable 36M	Institutes
T1	Optimize straw materials and production technologies	- Thin film materials - Film metallization - Low cross-talk - Resistance to ageing - Production techniques	WG1, WG2, WG3, WG4, WG5, WG6, WG7, WG8	1.1, 1.2, 1.3	**M1** **Work plan consolidation:** finalise work package objectives and decide final straw designs including simulation studies. Setting up laboratories, production and test facilities. Tendering and procurement of materials. **[T1-T7]**	**M2.1** **Prototype design and construction:** optimization of straw materials, designs and production technologies for low radiation length, thin-wall tubes, small diameter tubes, long tubes and straws with enhanced longevity. **[T1-T3, T6]** **M2.2** **Optimization of the prototype mechanical system** with low material budget and high mechanical precision. Development of the alignment method. **[T3, T5, T7]** **M2.3** **Optimization of front-end electronic and ASIC design** based on existing ASICs and simulation studies for fast timing, signal leading and trailing edge time readout with high resolution and charge measurement for PID. **[T4, T5]**	**D** **Prototype tests and results:** performance of prototype designs and measurement resolutions (3D-space <150 µm, time t0 of O(1 ns), dE/dx < 10%). **[T1-T7]** Evaluation of WP tasks with review of further enhancement and new potential. **[T1-T7]**	GTU, FZJ-GSI-U Bochum, U Hamburg, MPP, IITG, IITK, NISER Bhubaneswar, U Delhi, U Punjab, INFN-TO, INP-Almaty, JU-Krakow, IFIN-HH, CERN, U South Carolina, U Duke, BNL, FIT, JLab, U Massachusetts, Amherst, U Michigan, UC Irvine, UW–Madison, Tufts
T2	Develop straw tubes of 5mm diameter	- Thin film wall - Fast timing < 100 ns - Rates ≃ 50 kHz/cm²						
	Develop straw with ultra-thin film walls	- Film wall < 20 µm - X/X0 ≃ 0.02% / straw - Film metallization						
	Develop ultra-long straws with thin film walls	- 4-5 m tube length - Film walls < 30 µm - Good mechanical properties						
	Develop straws with ultra-small diameter	- Diameter < 4mm - Rates > 500 kHz/cm² - Fast timing <50ns - Charge load >10 C/cm						
T3	Optimize the detector mechanical system	- Develop self-supporting modules - Control material relaxation - Straw alignment method						
T4	Optimize the front-end electronics (ASIC) and readout system	- Leading and trailing edge time readout - Charge readout - Time readout with sub-ns precision						
T5	Enhance the tracker measurement information (3D/4D and PID via dE/dx)	- Spatial resolution < 150 µm - Time t0 extraction with O(ns) resolution - dE/dx resolution <10% - p/K/π-separation						
T6	Enhance the detector longevity	Ageing resistance up to - 1 C/cm for thin-wall straws - >10 C/cm for straws for highest particle rates						
T7	Optimize the online-/offline software	- Straw tube simulation - Straw calibrations - Tracking simulation - Pattern recognition - Tracking and PID - Tracker alignment						

WP3 – Straw and Drift Tube Chambers

Funding comments

- Existing: excl. already spent costs of materials, infrastructures, devices..
- Additional: planned funding applications in 2023/24

Institutes

- 26 institutes in 9 countries
- All R&D tasks covered (T1-T7)

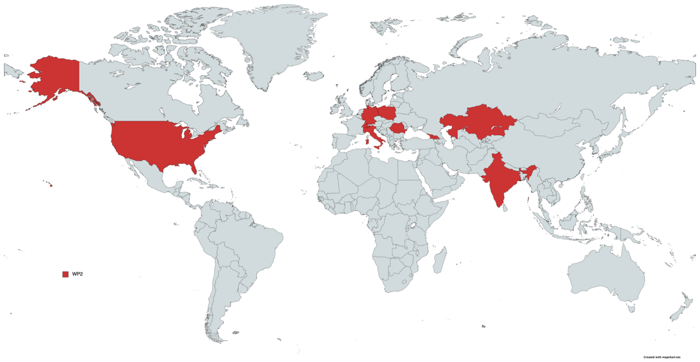
	Tasks						
Institute	T1	T2	T3	T4	T5	T6	T7
CERN	x	x	x				
FZJ			x	x	x		x
GSI					x		x
GTU	x	x	x		x		
IFIN-HH			x	x	x		x
IITG	x	x	x	x	x		x
IITK				x	x		
INFN-TO				x			
INP-Almaty	x	x	x	x	x	x	x
JU Krakow		x				x	
MPP	x	x	x	x	x		
NISER	x		x				
RU Bochum			x	x	x		x
U Hamburg	x	x	x			x	
U Punjab	x		x	x			
U South Carolina		x	x	x	x		x
U Duke		x					
U Dehli	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 Uni	x	x	x				

Existing

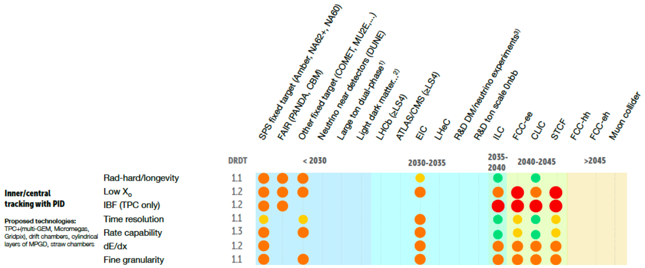
WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP3	Inner and Central Tracking with PID Capability, Straw and Drift Tube Chambers	163.5	70	65	32	37.3	40.3

Additional (not existing)

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP3	Inner and Central Tracking with PID Capability, Straw and Drift Tube Chambers	525	325	330	11.7	12.9	12.9



WP4 – Tracking TPCs



Challenges and goals

- High rate,
- Low mass,
- Granularity,
- dE/dx & cluster counting
- Ion backflow suppression,
- Gas mixture optimization and Eco gas mixtures

Single WP project

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Milestones/Deliverable 12M	Milestones/Deliverable 24M	Milestones/Deliverable 36M	Institutes
T1	IBF reduction	- Reduce IBF in case of gated operation - Reduce IBF in case of ungated operation	WG1, WG2, WG3, WG4, WG5, WG6, WG7	1.1, 1.2, 1.3, 1.4	**M1** **Evaluation of various readout technologies:** studies of various gas amplification and readout technologies including pixelised structures to estimate their potential performance in a TPC. **[T1, T2, T4, T5]**	**M2.1** **Improvement of dE/dx performance:** experimental tests to optimize the dE/dx resolution in various gas mixtures.**[T1, T2, T5]** **M2.2** **Improvement of IBF performance:** experimental tests to reach an IBF performance optible with gain×IBF < 5. **[T1, T2, T5]** **M2.3** **Electronics** implemented in the SRS and ready for operation with small-scale prototypes. **[T4]**	**D** **Prototype TPC** A small scale prototype detector with good spatial and dE/dx resolution to fulfil the requirements of future accelerators with a gated or ungated operation mode of the TPC. **[T1-T5]**	IFUSP, U Carleton, IHEP CAS, U Tsinghua, HIP, U Jyväskylä, IRFU/CEA, TUDa, U Bonn, GSI, Wigner, INFN-BA, UniBA, PoliBA, INFN-RM1, U Iwate, CERN, PSI
T2	pixelTPC development	- Develop different technologies for pixelized readout - Build small prototypes to verify spatial resolution - Study dE/dx resolution						
T3	Optimization of mechanical structure	- Reduce material budget of mechanical and electrical field cage - Reduce material budget of the endcap, in particular, the cooling infrastructure						
T4	FEE for TPCs	- Develop a low-power ASIC for TPC readout - Implement a readily available ASIC, which fulfils MPGD-TPC requirements in the Scalable Readout System - Increase the readout rate of TPC-readout with SRS						
T5	Gas mixtures	- Study drift properties of gas mixtures to find low diffusion gases - Study gases with low $\omega\tau$ for improved performance of TPCs in magnetic fields - Study eco-friendly gases.						

WP4 – Tracking TPCs

Institutes

- 16 institutes in 10 countries
- All tasks covered

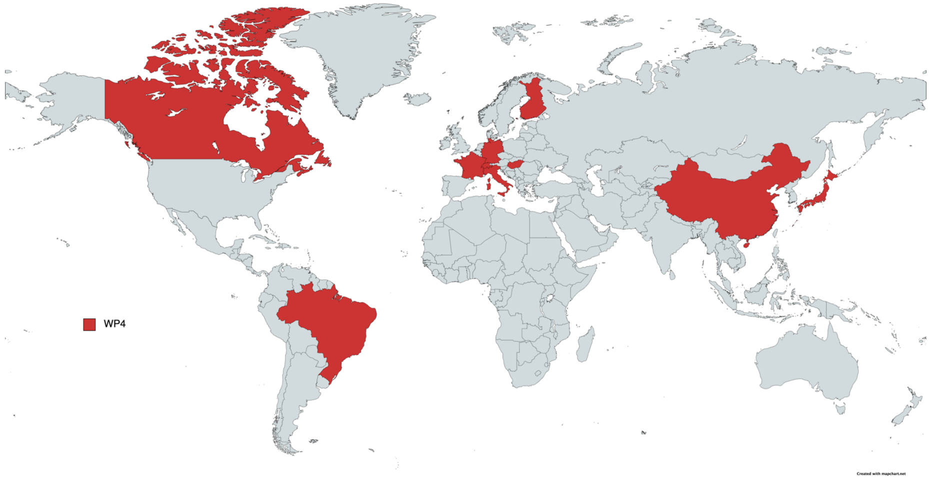
	Tasks				
Institute	T1	T2	T3	T4	T5
USP				x	
U Carleton	x	x			
IHEP-CAS	x	x		x	x
U Tsinghua				x	
HIP	x		x		x
U Jyväskylä	x				
IRFU/CEA	x			x	
U Bonn	x	x	x		x
TU Da	x		x		
GSI	x			x	x
RCP	x				
INFN-Bari			x		x
INFN-Roma1	x	x			
IU	x		x		
CERN		x			
PSI	x	x			

Existing

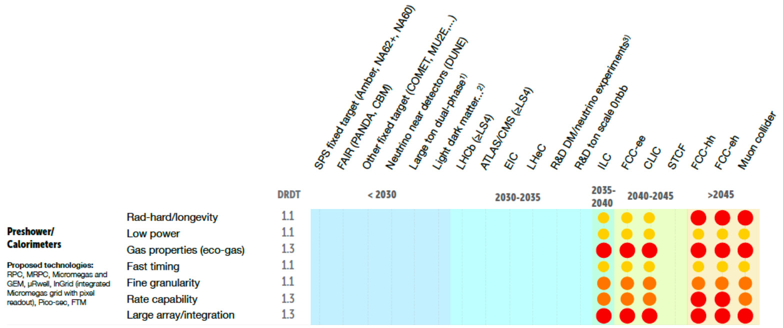
WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP4	Inner and Central Tracking with PID Capability, Time Projection Chambers	268	268	253	15	15	14.5

Additional (not existing)

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP4	Inner and Central Tracking with PID Capability, Time Projection Chambers	238	238	238	11.3	11.3	11.3



WP5 – Calorimetry



Challenges

- Realization of thin and large surface detectors with high efficiency, excellent uniformity and high-rate capabilities operated with eco-friendly gases
- Very good time resolution
- Embedded readout electronics

Goals

- To provide high granular hadronic calorimeters with active media made of gaseous detectors to efficiently apply the PFA techniques and at the same time provide good energy resolution

One project associating different technologies

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Milestones/Deliverable 12M	Milestones/Deliverable 24M	Milestones/Deliverable 36M	Institutes
T1	Conception, construction and characterization of large sampling elements for calorimeters	- High efficiency with thin large detectors - Compactness of the active unit including cassettes and possible cooling system - Uniformity in terms of thickness, resistivity and gas circulation	WG1, WG2, WG4, WG7	1.1, 1.3	**M1** **Construction of medium-sized gaseous detector** fulfilling the requirements on efficiency and small dead zones. **[T1]**	**M2.1** **Uniformity study** including efficiency and cluster size distribution with medium-size detectors. Expected timing performance better than 3 ns in the case of MPGD, 0. ns for RPC and 0.15 ns for MRPC with 4 gaps. **[T2]** **M2.2** **Construction of large and thin detectors** (few mm) of different technologies (MRPC, RPC, MM, µRWELL, RPWELL) with small dead zones (< 2% dead zone). We propose to build detectors larger than 50 cm × 50 cm in the case of MPGD and larger than 100 cm × 100 cm for (M)RPC, featuring dead zones < 2%. The detectors should feature an efficient gas circulation to be used as active layers in granular calorimeters. **[T1]**	**D1** **Performance and uniformity** studies of the large and thin detectors of different technologies. Performance goals in terms of: - detector uniformity: < 10% in terms of efficiency an in terms of cluster size **[T1]**, - time resolution below few ns **[T2]**, - high detection rate capabilities up to a few kHz/cm^2 **[T4]**, to be obtained with different kinds of gas mixtures. **D2** **The readout electronics [T3]** associated with pickup pads of the order of $1\ cm^2$: - threshold down to a few fC for MPGD and tens of fC for (M)RPC - time resolution better than 100 ps	IP2I, CIEMAT, VUB and UGent, GWNU, SJTU, MPP, WIS, INFN-BA, UniBA, PoliBA, INFN-RM3, INFN-NA
T2	Timing performance of gaseous detectors for calorimeters	- Timing performance of different technologies - Uniformity of the detector response in terms of timing						
T3	Readout electronics for calorimeter gaseous detectors	- Low-jitters readout electronics - Low power consumption per channel - Active Sensitive Unit (ASU) of large size with good flatness						
T4	High-rate capability gaseous detectors for circular collider calorimeters	- High-rate capability exceeding a few KHz in case of (M)RPC and tens of KHz in case of MPGD - Impact of high particle rate on the detector performance (efficiency, spatial resolution, timing..etc)						

WP5 – Calorimetry

Existing

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP5	Calorimetry	150	150	150	12.75	12.75	12.75

Funding comments

- The foreseen developments on detectors is already available or almost sure to be available
- Existing readout electronics could be used to characterize but new and more performant ones need to be produced in common with other WPs in DRD1 and DRD6.

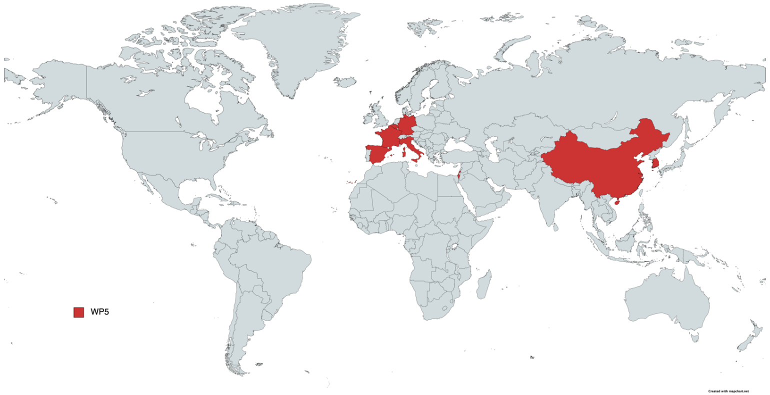
Additional (not existing)

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP5	Calorimetry	50	50	50	1	1	1

Institutes

- 10 institutes from 8 countries
- Most of all are also involved in DRD6 (calorimetry)
- Most of them have already worked together on a given technology but in this proposal, common studies will be an essential feature
-

	Tasks			
Institute	T1	T 2	T3	T4
IP2I	x	x	x	x
CIEMAT			x	
VUB	x			
GWNU	x	x		
SJTU			x	
MPP	x	x		
WIS	x	x		x
INFN-BA		x		x
INFN-RM3				x
INFN-NA				x



WP6 – Photo-detectors

Challenges and goals

- Gaseous Photo-Detectors:
  - Large area
  - Low cost
  - Low material budget
  - Magnetic insensitivity
- Hadron identification at colliders + other applications

➢ **Improve performance**

➢ **Explore visible gaseous PDs**

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Milestones/Deliverable 12M	24M	36M	Institutes
T1	Development of robust UV photoconverters for gaseous photon detectors	- Robustness against accumulated charge dose: < 20% deterioration of quantum efficiency for 100 mC/cm^2	WG1, WG2, WG3, WG4, WG5, WG6, WG7	1.1, 1.2, 1.3	**M1** **Design and production of small-size photon detector prototypes**, e.g. THGEM + Micromegas equipped with hydrogenated nanodiamond photocathode **[T1]**, PICOSEC Micromegas equipped with novel photocathodes **[T6]**, Double Micromegas photon detectors **[T3]**, etc. to test the proposed technological improvements.	**M2** Results of simulations and measurements of IBF suppression **[T7, T3]**, photocathode robustness **[T1]**, a test of small-size prototypes **[T2, T5]** and new readout development, with low noise at low input capacitance **[T9]**.	**D1** **Demonstrator prototypes** for Large area Double Micromegas **[T8]**, Space resolution < 1 mm **[T5]**, Time resolution < 200 ps **[T6]**, IBF < 1%. **Test bench** for visible sensitive photocathodes studies **[T4]**. **D2** **Report** on novel robust photocathode performance **[T1]** and PDE achievements **[T2]**. **D3** **New ASIC chip** prototype integration **[T9]**.	AUTH, USTC, NISER Bhubaneswar, CERN, WIS, INFN-PD, DFA-UNIPD, INFN-TS, HIP, U Aveiro, MSU, TUM
T2	Increase the photon detection efficiency	- Photoelectron efficiency in gas ≥ 75% of that under vacuum						
T3	Suppression of ion feedback to the photocathode, increase of stability and longevity	- Stable detector operation at 10^5 gain. - IBF reduction down to 10^{-4} - Stable operation in harsh environment (10^{11} n_{eq}/cm^2)						
T4	Develop gaseous photon detectors sensitive to visible light	- Sustained photosensitivity to visible light in gaseous photon detectors						
T5	Increase spatial resolution and readout granularity	- Spatial resolution ≤ 1 mm						
T6	Increase 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 ≤ 10% over 1 m^2 area with ≤ 10% dead area.						
T9	Readout electronics for single photon signals	New frontend ASIC chip with 64 channels, ENC 0.5 fC at 20pF						

WP6 – Photo-detectors

Existing

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP6	Photo-Detectors	275	325	315	11.9	11.4	11.4

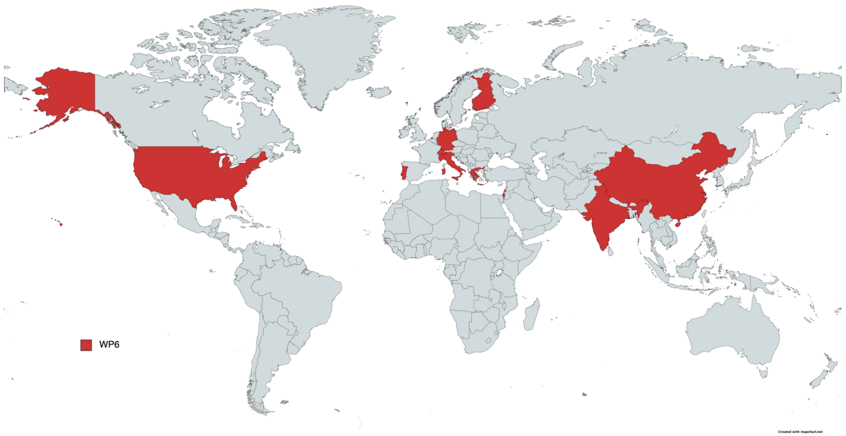
Institutes

- 11 institutes from 10 countries
- All tasks covered

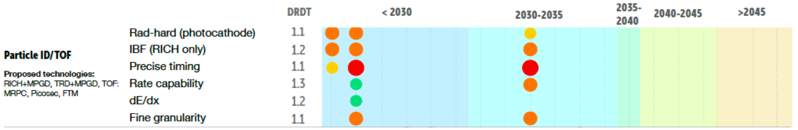
Additional (not existing)

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP6	Photo-Detectors	180	270	250	4.6	5.1	5.6

	Tasks								
Institute	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9
AUTh			x			x		x	
USTC	x		x	x	x	x	x	x	x
NISER	x	x	x		x	x	x	x	x
CERN	x	x				x	x		x
WIS		x	x	x			x		
INFN-PD	x	x	x		x		x		x
INFN-TS	x				x	x		x	x
HIP			x	x		x			
Aveiro	x	x	x		x		x	x	x
FRIB		x	x	x			x	x	x
TUM	x		x						



WP7 – Timing Detectors



Challenges

- Eco-friendly gases: decreasing availability, increasing cost of GH gases
- Detector ageing: operational instabilities/ageing in harsh environments,
- Front end electronics: timing performance, low power, robustness

Goals

- Development of scalable precise timing detector with operational stability and long term robustness
- High-rate capability and spatial resolution with suitable FE electronics for the required readout granularity

Two projects based on different technologies

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

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Milestones/Deliverable 12M	Milestones/Deliverable 24M	Milestones/Deliverable 36M	Institutes
T1	Optimize the amplification technology towards large-area detectors	- Uniformity over m^2 (time resolution, rate capability, efficiency)	WG1, WG2, WG3, WG4, WG5, WG6, WG7	1.1, 1.3	**M1.1** **Prototypes review** (proof of concept, enhancing time resolution, active area of about 100 cm^2): status and perspectives. **[T1, T2, T5, T10]** **M1.2** **Common activities and material studies**: Support and development of modelling and simulation (time resolution, rate capabilities) tools and testing facilities (time resolution, rate capability, space resolution, gas and material studies). **[T3, T4, T6, T7, T8, T11]**	**M2.1** **Prototypes suitable for large area coverage systems** review: status and perspectives. **[T1, T3, T10]** **M2.2** **Multichannel readout electronics**: evaluation (on small prototypes, 100 cm^2 active area) of different multichannel readout solutions. **[T9]**	**D** **Prototypes with time resolution below 200 ps based on RPC/MRPC and MPGD technologies**: demonstrate the scalability of the technologies targeting m^2 size coverage. Prototypes will be characterized in terms of time resolution, rate capability, space resolution, efficiency and multi-hit response. Different examples of multichannel readout electronics will be provided. **[T1, T3, T4, T5, T9, T10]** **Guidelines for future developments**: At the end of the three years, development directions will be summarized based on future facilities' requirements and the achievable performances of the studied solutions. Status and strategies towards the use of sustainable gas mixtures will be given. **[T7]**	AUTH, CERN, CIEMAT, CNRS-IN2P3/Omega, DGIST, GWNU, HYU, HIP, INFN-BA, UniBA, PoliBA, INFN-PV, UniPV, UniBG, INFN-RM2, UniRomaTOV, IRFU/CEA, IP2I, JLab, LIP-Coimbra, MPP, RBI, SIAT, SJTU, U Heidelberg, U Kyoto, U Tsinghua, USTC, VUB and UGent
T2	Enhance timing performance	- Time resolution < 50 ps up to 30 kHz/cm^2						
T3	Enhance rate capability	- Time resolution < 200 ps up to 100-150 kHz/cm^2						
T4	Spatial resolution and readout 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	- Accurate modelling of charge transport and signal induction processes in precise timing detector geometries						
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						

WP7 – Timing Detectors

Institutes

- In total: 26 institutes from 14 countries
- Project A: 9 institutes from 9 countries
- Project B: 17 institutes from 10 countries

(A) High-rate, high-granularity precise timing with MPGDs											
Institute	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
AUTh		x	x		x	x	x		x	x	
IRFU/CEA	x	x			x	x					
CERN	x	x	x	x	x	x	x		x	x	
INFN-PV	x	x	x			x	x			x	
JLab	x	x		x						x	
RBI		x				x					
USTC	x	x			x						
LIP		x						x	x		
HIP	x	x	x		x						

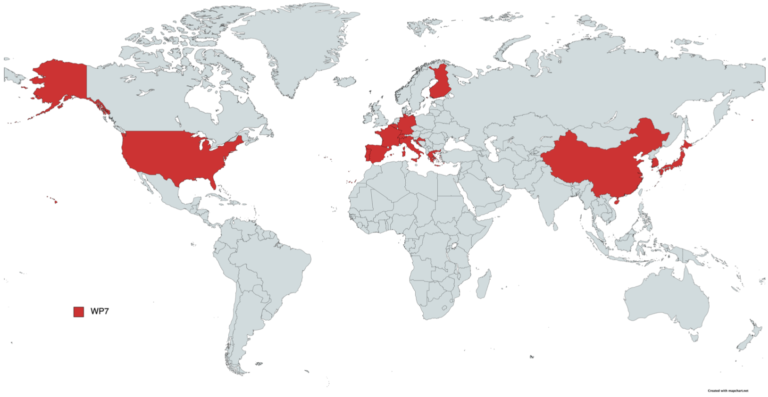
(B) High-rate, high-granularity precise timing with MPGDs											
Institute	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
IP2I		x		x		x			x		
CIEMAT		x		x							x
VUB		x		x							x
GWNU				x							x
SJTU				x					x		
OMEGA				x					x		
U Heidelberg			x	x							
Kyoto U				x							x
LIP		x		x				x		x	
Tsinghua		x	x	x		x					
SIAT-CAS				x							x
DGIST				x					x		
MPP				x	x					x	
INFN-Bari		x		x	x						
INFN-RM2		x		x	x						
Hanyang U				x	x						
CERN				x	x		x				

Existing

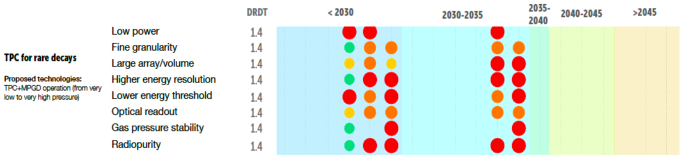
WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP7	Timing Detectors	420	311	311	24.1	21.7	20.7

Additional (not existing)

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP7	Timing Detectors	257	307	346	3	5.5	6.9



WP8 – TPCs as Reaction and Decay Chambers



Fundamental challenges:

- Achieving track-reconstruction of low-energy nuclei and electrons, at granularities going from a few mm down to potentially tens of um and close to the thermal diffusion limit. [T1, T2, T4]
- Operating in a broad range of pressures going from a few tens of mbar to tens of bar, with energy-reconstruction performing generally down to ~1keV threshold if not less. [T2, T3]
- Achieving high and uniform amplification in nearly pure or weakly-doped noble gases. [T3]
- Increasing optical throughput (primary and secondary). [T1, T4, T5, T6]
- Developing more suitably scintillating and/or eco-friendly gas mixtures as well as recuperation systems. [T1, T5, T6]
- Enhancing the radiopurity of the amplification structure and of the TPC as a whole. [T7]

Four projects:

A High-Pressure TPCs for precision studies of neutrino interactions.

B TPCs for low-energy nuclear physics.

C Electroluminescence-based TPCs for Rare-Event Searches and other R&D on pure noble-gas amplification.

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

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Milestones/Deliverable			Institutes
					12M	24M	36M	
T1	Enhanced operation of optical readout across gas densities	- $\mathcal{O}$(mm)-sampling, $\mathcal{O}$(MeV)-threshold, $\mathcal{O}$(ns)-timing for ν-interactions. - Large-area amplification structures ($\gtrsim$ 50 cm $\times$ 50 cm) at optical gain $\sim 10^4$. - Tracking of low-energy nuclei (down to 10-100 keV) with good PID.	WG1, WG2, WG3, WG4, WG5, WG6, WG7	1.1, 1.2, 1.3, 1.4	**M1.1** **Review and design**: review of TPC technologies for reaction/decay studies: status and perspectives; design/construction of small R&D chambers. **[T1-T7]** **M1.2** **Development and tuning of simulation tools**: design, development and/or tuning of modelling and simulation tools (IBF, ionization, optical response, Geant4). **[T1-T7]**	**M2.1** **Construction of prototypes**: start construction of technology demonstrators for large area coverage. **[T1-T7]** **M2.2** **Characterization of key technologies**: characterize electronics, amplification structures and overall TPC behaviour in small R&D chambers, comparison with simulations. **[T1-T7]**	**D1** **TPC commissioning and proof of principle demonstration**: characterization of mid-size technology demonstrators for reaction/decay studies, focusing on energy and tracking thresholds, energy resolution, dynamic range and IBF. **[T1-T7]** **D2** **Analysis and definition of next steps**: establish guidelines for future developments based on requirements from future facilities and the achieved/achievable performances. **[T1-T7]**	ANU, AstroCeNT, CERN, DIPC, Fermilab, GANIL, CNRS-IN2P3/UGA, GSSI, HIP, IFAE, Imperial, INFN-BA, UniBA, PoliBA, U Bonn, RHUL, RWTH Aachen, STFC-RAL, U Bonn, IGFAE/USC, INFN-PD, DFA-UNIPD, INFN-RM1, IRFU/CEA, ISNAP, LIP-Coimbra, MSU, SINP Kolkata, U Aveiro, U Coimbra, U Genève, U Hamburg, UH Manoa, U Indiana, U Kobe, U Liverpool, U Bursa, U New Mexico, UPV, U Vigo, U Warwick, CAPA, IFIC
T2	Enhanced operation of charge readout across gas densities	- Large-area MPGDs ($\gtrsim$ 50 cm $\times$ 50 cm) at $\sim 10^3 - 10^4$ gain. - Large-area MPGDs ($\gtrsim$ 50 cm $\times$ 50 cm) with a large dynamic range. - $\mathcal{O}$(1 keV) threshold across pressures (100 mbar-10 bar) in $\mathcal{O}$(1000 cm^3) technology demonstrators. - IBF suppression by G*IBF=10 or better.						
T3	Enhanced operation of pure or trace-amount doped noble gases	- EL operation at 2m (15bar) and 0.5m (>20bar) 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.						
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 $\mathcal{O}$(100 µm) in 3D, and diffusion at the thermal limit.						
T5	Determination of the interaction time (T_0)	- Develop new gaseous WLS and novel gaseous scintillators, comparable or better than CF_4. - Demonstration of T_0-determination for low-energy deposits with at least $\mathcal{O}$(cm) resolution.						
T6	Microscopic gas properties and gas handling	- Develop the science and technology of novel eco-friendly gases. - Derive microscopic parameters for new gases.						
T7	Radiopurity	- Background levels below 10^{-6} c/keV/cm^2/s for axion research and at least $\times$10 more radiopure cameras. - New radiopure amplification structures and techniques.						

WP8 – TPCs as Reaction and Decay Chambers

Institutes

A 15 institutes in 7 countries

B 8 institutes in 6 countries

C 9 institutes in 4 countries

D 15 institutes in 11 countries

(A) High-pressure TPCs for precision studies of neutrino interactions

Institute	T1	T2	T3	T4	T5	T6	T7
RWTH Aachen						x	
U Indiana		x				x	
U Geneva			x				
IFAE			x				
U Liverpool	x		x				x
RHUL		x					
Imperial C.		x					
INFN-Bari	x	x					
IGFAE	x				x	x	
UVigo					x	x	
U Warwick	x	x				x	
Fermilab	x	x				x	
INFN Padova	x	x				x	
IFIC	x				x		
U Uludag					x	x	

(B) TPCs for low-energy nuclear physics.

Institute	T1	T2	T3	T4	T5	T6	T7
MSU		x	x				
ISNAP		x				x	
IGFAE	x					x	
RIKEN		x					
SINP		x					
IRFU/CEA		x					
WIS	x	x				x	
GANIL		x				x	

(C) Electroluminescence-based TPCs for RE Searches and other R&D on pure noble-gas amplification.

Institute	T1	T2	T3	T4	T5	T6	T7
DIPC			x		x	x	x
IFIC			x			x	
UPV			x				
LIP-Coimbra			x				
IGFAE			x				
U Coimbra			x				
U Aveiro			x			x	
Astrocent			x				
WIS			x		x		x

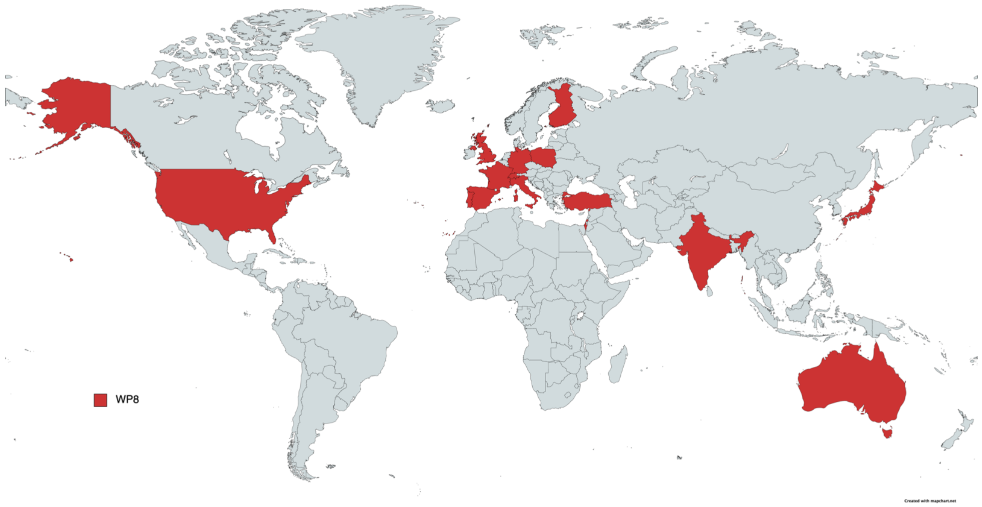
(D) Radiopure TPCs for precise track imaging and/or calorimetry with avalanche-based readouts

Institute	T1	T2	T3	T4	T5	T6	T7
GSSI	x			x	x		
IRFU/CEA		x		x			x
INFN-Roma1	x			x		x	x
RAL	x	x		x			
HIP	x	x		x			
UH Manoa	x	x		x			
New Mexico	x	x		x			
CERN	x						
CAPA/UNIZAR		x				x	x
LIP-Coimbra			x			x	
ANU	x	x		x		x	
IN2P3/UGA	x			x		x	
U Hamburg	x	x		x	x	x	x
U Kobe				x			x
U Bonn				x			

WP8 – TPCs as Reaction and Decay Chambers

Institutes

- 41 institutes from 16 countries
- All projects/tasks covered



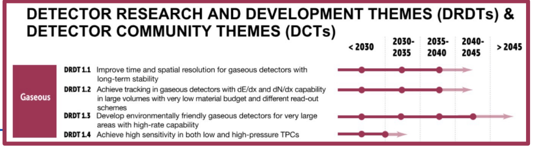
Existing

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP8	TPCs as Reaction and Decay Chambers	495	505	405	78.35	73.05	72.55

Additional (not existing)

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP8	TPCs as Reaction and Decay Chambers	516.5	471.5	436.5	35.1	40	40

WP9 – Beyond HEP



Key application areas (projects):

- cosmic muon imaging (muography) and large area applications; public safety and mining industry
- dosimetry/beam monitoring and medical imaging applications (PET, CT, X-ray, SPECT, Gamma cameras, or X-ray fluorescence imaging)
- fast/thermal neutron imaging with solid converters for neutron science, neutron beam monitoring, tomography and nuclear waste monitoring

Common challenges:

- Portable and recirculating gas systems
- Sealed detectors or ultra-low gas consumption
- Operational stability in outdoor natural or extreme environments
- Cost-efficient solutions for robust large detectors
- Very low maintenance level
- Neutron converters
- Front-End electronics radiation hardness
- Low material budget
- Physics applications (e.g neutron differential cross section studies)
- Efficiency
- Low background materials
- Environmental-friendly gas mixtures
- Large Area granularity
- Sensitivity

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Milestones/Deliverable 12M	24M	36M	Institutes
T1	Cost-efficient large-size outdoor detector structures: design and construction	- Robust, cost-efficient large detectors - Design chain, materials and construction compatible with outdoor use	WG1, WG2, WG3, WG4, WG5, WG6, WG7	1.1, 1.3	**M1.1** **Muon imaging and extreme environment solutions:** evaluation of proposed technologies and solutions leading to applicability in environments and configurations relevant to BHEP. This includes maintenance-free operation, extreme or outdoor temperature- and humidity ranges. **[T1-T6]** **M1.2** **Evaluation of detector technology for medical applications:** characterization of application-specific radiation fields and of different gaseous detectors for beam monitoring, beam characterization and photon-based imaging using detailed simulations and already existing prototypes. Assessment of suitability of respective detector technology and customization of design to application. **[T7-T9]** **M1.3** **Study of neutron converter materials realisation processes:** definition of realisation processes and characterisation of solid/gas converters of different areas. Estimation of expected detection efficiency. Evaluation of intrinsic background due to employed materials and definition of common strategies to limit it. **[T10-T12]**	**M2.1** **Muon imaging and extreme environment demonstrations:** demonstration of the technological concepts and proposed solutions in conditions relevant to BHEP applications: field installation of cosmic imaging detectors, demonstration of portability and low (zero) flow operation. **[T1-T6]** **M2.2** **Characterization of prototype detectors for medical applications:** demonstration and characterization of the developed prototype detectors in pre-clinical and clinical environments, for medical photon detection and in space radiation simulating beams. Optimization of detector performance. **[T7-T9]** **M2.3** **Characterisation of key aspects of gaseous neutron detectors:** determination of efficiency and maximum achievable rate capability of different detector prototypes. Evaluation of gamma-ray sensitivity and neutron discharge probability. Measurement of spatial resolution and image capability reconstruction.Determination of radiation hardness of front-end electronics. **[T4,T10-T12]**	**D1 Performance evaluation of cosmic imaging detectors and operation in extreme conditions:** summary report on prototype performance, including available and demonstrated technological solutions to address long-term outdoor operation (more than 1 year, temperature 0 – 40 deg), portability (meeting ASTM shipping standards), longevity, low power (below 10 W). Critical comparison of various technologies and solutions, identification of general guidelines for high-performance instruments and for technological transfer towards commercialisation. **[T1-T6]** **D2** **Performance evaluation of detectors for medical applications:** assessment and description of realization, operation and performance of different detector technologies in clinical and pre-clinical environments, for medical photon detection and related applications. Description of integration possibilities. **[T7-T9]** **D3** **Performance evaluation of gaseous neutron detectors:** comparison of performances of the different detector technology prototypes in terms of efficiency (1-40% for thermal neutrons), rate capability (order MHz/cm^2), background suppression, spatial resolution (sub-mm) and image capability reconstruction. Determination of the most suitable technologies for specific applications. Definition of next steps for future gaseous neutron detectors development. **[T10-T12]**	UNIMIB, IRFU/CEA, NISER Bhubaneswar, U Coimbra, LMU, Wigner, U Bonn, AGH-Krakow, ESS, Istinye U, U Hamburg, U Sofia, VUB and UGent, CNRS-LSBB, GSI, UCLouvain, MedAustron, OXY, U Johannesburg
T2	Mechanical and environmental stability of detectors under outdoor or extreme conditions	- Mechanical stability during transportation - Long-term sustainment of daily and yearly temperature cycling - Compatibility with medical equipment guidelines						
T3	Detector portability and low maintenance operation	- Portable structure, low weight, integrity - Fast installation and low maintenance need - Low or zero gas consumption						
T4	Cost-efficient, low power, long-lived Front-End and DAQ systems	- Low power, high channel number, high efficiency - Readout optimized and operating in an intense neutron field						
T5	Detector optimization and simulation methods for muons and neutrons	- Low background for surface- and underground muon imaging - Optimized structures using novel neutron converters						
T6	Benchmarking performance, infrastructures and knowledge transfer	- Definition of benchmarking parameters for muography, medical and neutron science - Characterization of benchmark sites, comparative measurements						
T7	Optical readout MPGDs for bio-marker imaging and beam characterization in ion beam therapy	- Ability to measure sub-Becquerel activities in single cells - Reliably determine pre-clinical and clinical beam parameters with well-characterized detector						
T8	Gaseous photon detectors for in-beam monitoring for ion beam therapy and imaging	- Optimization of detector concept with good time resolution for in-beam range verification - Study detection efficiency for annihilation photons and temporal resolution						
T9	Beam monitors with high temporal resolution for ion beam therapy and space radiation simulation	- Monitor clinical ion beams at normal and high dose rates with μs resolution - Monitor space radiation simulating secondary beams at high and low fluence in real-time						
T10	Study of Innovative neutron converters with gaseous amplifying structures for high-rate, efficient, low-background detectors	- Optimizing 2/3D solid-state large area and gaseous converters - Enhancement of combined converter and amplification structures -Evaluation and limitation of intrinsic background.						
T11	Spatial resolution, readout granularity and rate capability impact on neutron imaging and dosimetry	- Enhancement of spatial resolution and evaluation of image-capability reconstruction, sensitivity and dosimetry capability.						
T12	Study of Gamma Ray sensitivity and neutron discharge probability	-Evaluation of gamma rays sensitivity at high flux facilities -Study of neutron-induced discharge probability -Study in clinical environments						

WP9 – Beyond HEP

Institutes

- 18 institutes in 13 countries
- All tasks covered

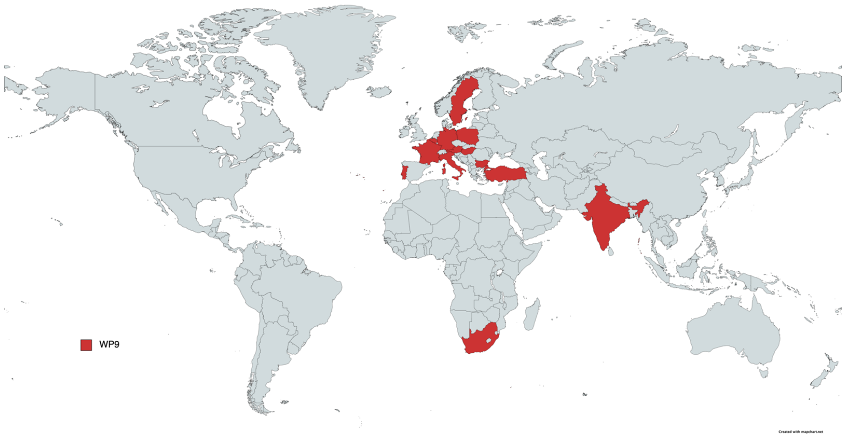
Tasks												
Institute	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
UNIMIB				x						x	x	x
Bonn										x		
UCL		x	x	x								
LIP	x		x		x					x	x	
ISU	x	x			x							
Wigner	x	x	x	x	x	x						
AGH										x		
Hamburg										x	x	x
Saclay	x	x	x	x	x		x			x	x	x
LMU			x				x		x			
SOfia								x				
MedAustron		x							x			
VUB			x		x	x						
LSBB						x						
NISER	x			x	x							
ESS						x				x	x	
GSI									x			
UJ								x				

Existing

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP9	Beyond HEP	803	783	694	40.5	37.5	35.2

Additional (not existing)

WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP9	Beyond HEP	140	225	275	15.9	20.4	23.9



RESOURCES

Resource and infrastructures

A Common Fund will be established, supported by limited and fixed yearly contributions from each DRD1 institute. This fund will serve as a valuable resource for supporting activities of common interest within the collaboration.

Examples of such activities include

- Common Projects
- Software and Electronics development
- Common Facilities
- Collaboration events (such as meetings, conferences, workshops, schools, and training events), and Collaboration Management.

The Collaboration Board, composed of one representative from each collaborating institute, will be responsible for coordinating the financial planning and addressing other resource-related matters.

To ensure transparency and accountability, the specific contribution details, including the amount and frequency of contributions, will be clearly defined in the MoU.

- This agreement, to be signed by all member institutes, will serve as the guiding document for financial obligations and expectations within the collaboration.

Resource and infrastructures

Common investments, such as materials and infrastructure, within the DRD1 Collaboration, will be covered, depending on the interest in the community and the required resources:

1) by common funds

2) by mechanisms similar to the Work Packages.

- For what concerns this option, and drawing inspiration from the RD51 Collaboration model, the participating parties in DRD1 will have the flexibility to collectively agree on cost-sharing for these common investments.

"RD51 MoU Article concerned (9.3): *Independently from the RD-51 Common Fund, Parties to the RD-51 Collaboration may agree amongst themselves to share costs for common projects, such as submission of wafer production or other procurements*"

This cooperative approach allows for the sharing of expenses related to essential requirements like base material, production or testing equipment, large-scale electronics production or other procurement activities.

Resource and infrastructures: Work Package

Strategic R&D targeting mainly the priority programmes outlined in the updated European Strategy for Particle Physics, but not only.

WP should highlight the following:

- Technologies to be studied and performances to be expected with respect of the set goals
- Key R&D deliverables (at least one per year/task) in the coming three years
- Estimated costing
- List of institutes
- Resources available:
  - Manpower (FTE)
  - Committed budget
  - Additional budget

- *DRDC will check that a rough estimation of the resources (FTE /funds) matches the demand given by the scientific program*
- *DRDC will not scrutinize strategic funds: they cannot judge on resources necessary to develop certain technologies*
- *CERN RRB is only for money on CERN accounts*

COLLABORATION STRUCTURE

Collaboration body: Management board structure (proposal)

- ***Management Board (~20 people):*** **CB-wide elected members** + ex-officio (SPs, CB Chair/Deputy, CB/MB Secretary, Scientific Secretary, Technical Coordinator, Resource Coordinator)
  - ***Objective***:
    - fair representation of all DRD1 detector communities, geographical regions, including diversity aspects (e.g. young researchers), coordination body among gas detector technologies, including Common fund issues
  - ***Mandate***:
    - oversee *strategic implementation of the DRD1 collaboration priorities* (in achieving and complying with established scientific goals and FA policies);
    - *ensure « GLOBAL » nature* of the DRD1 activities; *develop future DRD1 strategy* for common technology developments & assets, as an input for the CB discussions & approval

Collaboration body: Collaboration board and Financial Board (proposal)

- ***Collaboration Board (1 representative per research institute)*** + ex-officio (SPs, CB Chair/Deputy, CB/MB Secretary, Scientific Secretary, Technical Coordinator, Resource Coordinator)
  - ***Mandate***:
    - policy and decision-making body of the DRD1 Collaboration

- ***Finance Board: FA-nominated representatives, WP Coordinators*** + ex-officio (SPs, CB Chair/Deputy, Scientific Secretary, Technical Coordinator, Resource Coordinator)
  - ***Mandate***:
    - define strategy to initiate/review/prolong/terminate WPs; coordinate preparation for DRDC reviews and CERN DRD1 finance reviews

Collaboration body: scientific coordination board (proposal)

- ***Scientific Coordination Board (~20-25 people):* WG Conveners + WP Coordinators** + ex-officio (SPs, CB Chair/Deputy, Scientific Secretary, Technical Coordinator, Resource Coordinator)

    - ***WG Conveners:*** two/WG, proposed by the MB; subject to CB endorsement
    - ***WP Coordinators:*** proposed by CB representatives, participating in WP; subject to MB/CB endorsement

  – ***Mandate:***
    - *Execute the DRD1 Core Scientific Program* (as defined by the DRD1 Management, MB/CB, and FA).
    - Fair representation of different gas detector technologies & research areas

- *Regular meetings of extended MB (MB + Scientific Coordination Board) are envisaged;*

Collaboration meetings

- **Collaboration Meetings**
  - Regular collaboration meetings will be organized to provide a forum for collaboration members to discuss progress, share updates, and address any challenges.
  - These meetings will promote collaboration and ensure alignment with the overall goals and objectives of the collaboration.

- **Communication Channels**
  - Effective communication channels will be established to facilitate seamless information exchange among collaboration members.

- **Collaboration website, the use of email lists, and the integration of online collaboration tools**
  - to enable real-time communication and document sharing.
  - **website already implemented: https://drd1.web.cern.ch/**

Collaboration organization

Reporting and Evaluation

- Collaboration members will be expected to regularly submit progress reports on their activities.
- These reports will be subject to evaluation by the pertinent committees, including DRDC, to guarantee accountability and assess the overall progress of the collaboration.

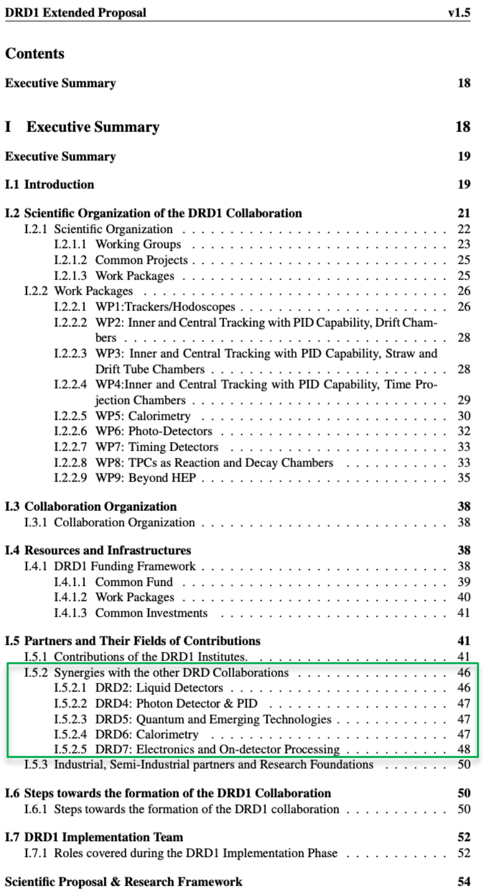
Intellectual Property and Publication Policy

- Clear guidelines will be implemented to address intellectual property rights and publication policies.
- Collaboration members will be actively encouraged to publish their research findings while also adhering to any confidentiality requirements and ensuring the proper acknowledgement of the collaboration and its members.

Support from CERN will be needed on how to manage the industrial and semi-industrial partners

DRDS INTERPLAY

Synergies with other DRDs and US


DRD1 Extended Proposal v1.5

Contents

The following people act as DRD1 link persons in other DRD areas:

- DRD2 - liquid detectors - Diego Gonzalez Diaz
- DRD4 - photon and PID - Fulvio Tessarotto
- DRD5 - quantum technologies - Florian Brunbauer
- DRD6 - calorimetry - Imad Laktineh
- DRD7 - electronics - Sorin Martoiu, Marco Bregant

DRD1 – DRD2 Interplay

Link person: Diego Gonzalez Diaz (diego.gonzalez.diaz@cern.ch)

DRD2-DRD1 Overlap:

- Study of **Dual-phase amplification in gas o in vapour phase** achieved through wires, meshes, and thick-GEM structures
  - may require gaseous detector optimizations/operation in extreme conditions in the framework of DRD1.
- Operation of wires and MPGD structures directly in the liquid phase for signal induction and even light amplification

➢ There are groups working on readout/amplification in dual phase or liquid involved in DRD1 community

Technological Overlap:

- Possibility of sharing **detector manufacturing techniques** between DRD1 and DRD2 communities:
  - The DRD1 community can provide expertise in the production techniques of detectors (MPGD or mesh or wire) in the liquid or vapour phase.

Simulations and Transport:

- In DRD2 simulations of electron-ion transport either in Monte Carlo or through Boltzmann-based techniques might be beneficial for DRD1 community (e.g., simulation of space-charge and charge-recombination)
  - attractive synergic/complementary approach with Garfield++/Magboltz transport in gas

Areas of Cross-Fertilization:

- Gas/liquid recirculation.
- System purification.
- Fluid-dynamics simulations.
- UV-photon detection.
- Radiopurity and material selection.

DRD1 – DRD4 Interplay

Link person: Fulvio Tessarotto (fulvio.tessarotto@ts.infn.it)

Gaseous photon detectors studies:

- innovative detector architectures
- innovative photoconverters

➢ They are included in a DRD1 WP; links and synergies with DRD4 activities.

TRD R&D present in both DRDs, with relevant overlaps and synergies

- included in DRD1 for systems using gaseous photon detectors,
- included in DRD4 for systems using solid-state or alternative photon detectors.

Studies of eco-friendly gas solutions: low GWP gases; leakless systems, recycle or destruction; alternative solutions. Common studies and developments.

- Two specific WPs (one for detector gases in DRD1 and one for radiator gases in DRD4).
- A single cross-DRD WP, if possible, could represent the best solution.

DRD1 – DRD5 Interplay

Link person: Florian Brunbauer (florian.brunbauer@cern.ch)

Possible synergies between DRD5 activities **on advanced materials (quantum & nano materials)** and DRD1 (mainly in WG3 - Gas and Material studies) should be exploited:

- DRD5 includes a work package focused on materials, aiming to facilitate collaboration between material scientists and detector developers.
- The goal is to identify common interests and facilities for evaluating promising materials under conditions relevant to high-energy physics (HEP) experiments.

➢ The platform created by DRD5 provides an opportunity for fruitful exchanges and cooperation between material scientists and detector developers.

DRD1 – DRD6 Interplay

Link person: Imad Laktineh (imad.baptiste.laktineh@cern.ch)

Clear separation in the development of gaseous-detectors-based calorimeters between the DRD1 and the DRD6.

- DRD1 focuses on developing **gaseous detectors for the calorimeters**, benefiting from the expertise and know-how of the gaseous detectors community for what concerns the gain, the timing performance, the rate capability, and the eco-friendly gases to be used to operate them.
- DRD6 addresses issues related to the calorimeter system, including services and integration.
- **Readout electronics** and DAQ are discussed within DRD6, with **potential exchange** with other DRD1 groups working on similar developments for different applications.

DRD1 – DRD7 Interplay

Link persons: Sorin Martoiu (Sorin.Martoiu@cern.ch), Marco Bregant (Marco.Bregant@cern.ch)

- Following DRD7 Organization and Proposal Submission Calls (*)
- Identify tasks integrated into the DRD1 Work Packages that may develop into (DRD7) common generic development concerning ASIC and/or DAQ across our collaborations.
- Merge common tasks within the various DRD1 Work Packages (See tables in next slides).
- The possibility of exchange between DRD1 and DRD7 communities, with coordination from relevant bodies, of building blocks and IPs (ASIC sub-blocks, FPGA IPs or software components) is to be explored.

- (*) **Proposals for R&D projects involving electronics and data processing** can be included in either detector-related DRDs or in DRD7, taking into account the following guidelines:
  - Projects **in DRD7** will target common generic developments or exploration of cutting-edge technologies requiring negotiated access to frameworks and complex design flows. They may involve high costs, expert coordination or unique expertise, and can only be effectively delivered as a common community effort. They will follow design practices enabling later volume production in the industry and/or using COTS components.
  - Projects **in individual DRDs** will target developments driven by DRD-specific requirements. They will typically be smaller-scale prototypes exploring or benchmarking novel concepts or technologies and delivering demonstrators. They will focus on diversity and originality, but will not necessarily be suitable for large-scale production.

DRD1 – DRD7 Interplay

- **Common electronics tasks within the various DRD1 Work Packages**

Task	Performance goal	Comments	Possible deliverables next 3-5 y
(Muon systems) New front end electronics	- 1 fC threshold - Geometrical avalanche quenching - High sensitivity electronics and new detector structures to achieve stable and efficient operation (rate, occupancy) up to O(MHz/cm2)	- Study of the integration of the FE electronics in the detector Faraday cage - Study of the integration of electronics and readout PCB	- Conceptual electronics design based on gas detector simulation and experimental measurements - Development and test of a front-end prototype
(Large-volume drift chambers) Front-end ASIC for cluster counting	- High bandwidth - High gain - Low power - Low mass	achieve efficient cluster counting and cluster timing performances	full design, construction and test of a first prototype of the front-end ASIC for cluster counting
(Straw chamber) Electronic readout, ASIC	- Time readout with sub-ns precision - Leading edge and trailing edge time readout	- Dedicated R&D on ASIC	- ASIC - Readout system
(Time Projection Chambers) Low-power FEE	•< 5 mW/ch for >1e6 pad TPC - ASIC development in 65 nm CMOS	•continuous vs. pulsed	- Present stable operation of a multi-channel TPC prototype with a low-power ASIC
(Gaseous photon detectors) FEE	- High input C - Low noise - large dynamic range	•	- present an ASIC concept/prototype
(Gaseous timing detectors) Low-noise FEE	- High input C - large dynamic range - Fast rise time - sensitivity to small charge - Low noise	•	Define an ASIC

DRD1 – DRD7 Interplay

- **Common DAQ tasks within the various DRD1 Work Packages**

Task	Performance goal	Comments	Possible deliverables next 3-5 y
(Muon systems) Scalable multichannel readout system	•Front-end link concentrator to a powerful FPGA with possibilities of triggering an O(20GBit/s) to DAQ	- FPGA based architecture - FPGA with embedded processing for triggering and ML - Basic firmware and software can be bootstrapped from existing readout system	First prototype by end of 2024 for commissioning at test beams
(Large-volume drift chambers) Scalable multichannel DAQ board	- High sampling rate - Dead-time-less - DSP and filtering - Event time stamping - Track triggering	- FPGA based architecture - ML algorithms-based firmware	working prototype of a scalable multichannel DAQ board
(Straw chamber) Electronic readout, ASIC	- Time readout with sub-ns precision - Leading edge and trailing edge time readout	- Dedicated R&D on ASIC	- ASIC - Readout system