1st DRD1 Collaboration meeting

Work Packages

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Working Groups

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

DRDTs

Forum for discussion on common topics

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

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

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

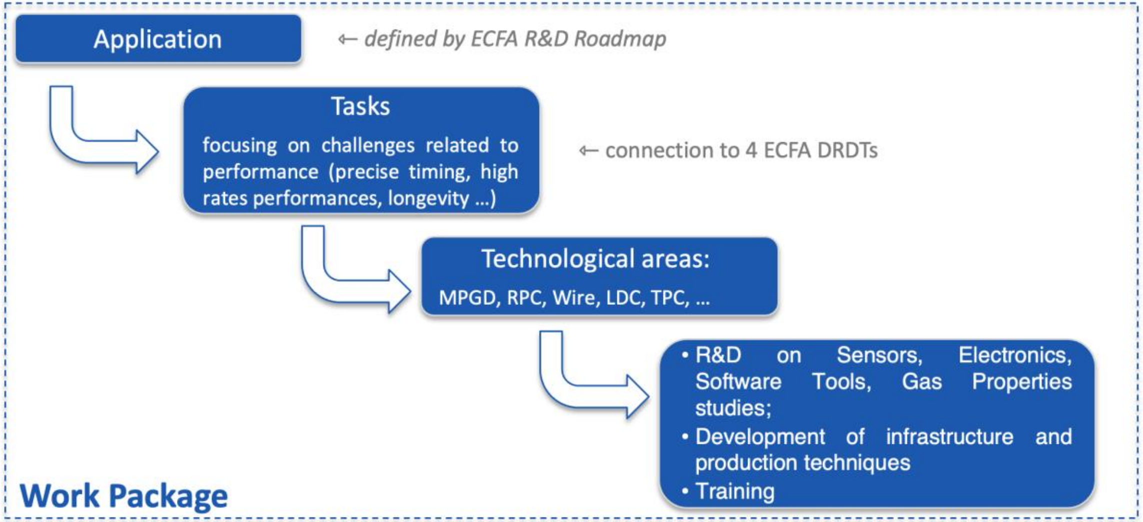
Work Packages

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

Work Packages

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

- WPs consolidate activities across institutes with shared research interests, encompassing applications, challenges, technologies, detector technologies, and tasks outlined by Working Groups.



Application

← *defined by ECFA R&D Roadmap*

Tasks

focusing on challenges related to performance (precise timing, high rates performances, longevity ...)

← connection to 4 ECFA DRDTs

Technological areas:

MPGD, RPC, Wire, LDC, TPC, ...

- R&D on Sensors, Electronics, Software Tools, Gas Properties studies;
- Development of infrastructure and production techniques
- Training

Work Package

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**

- It is not required to be involved in a WP to be a member of DRD1
- It is required to be a member of DRD1 to contribute to a WP

WP functions

- Encompass **long-term projects** with significant **strategic R&D** goals and corresponding funding lines.
- Active contribution to the scientific program, R&D environment, infrastructure, and tools within DRD1.
- Integration of activities from Working Groups, where feasible (e.g., simulation, electronics).
- Way to **get funding** and a way to **get involved** in strategic R&D!

open for discussion

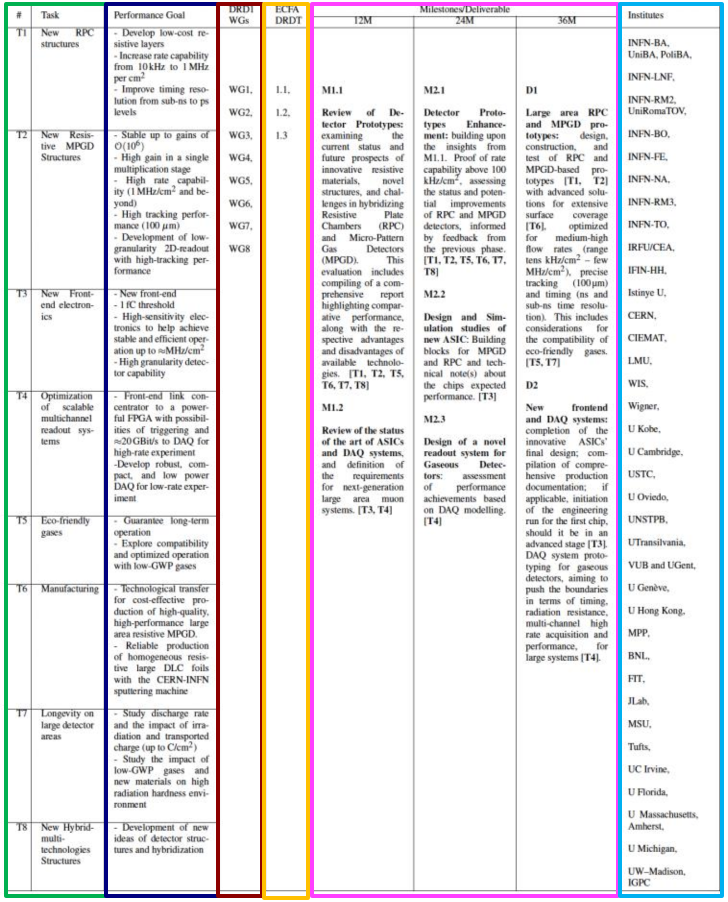
WP funding

- Funding for WPs is provided to participating institutes by their respective **Funding Agencies** through major lines aligned with ECFA detector R&D priorities.
- Funding Agencies approve their Resource commitment in the WPs.
- Participating institutes **maintain control** and **operational auth**ority over the allocated resources.

Extended proposals

- In the course of the DRD1 proposal preparations, **nine WPs were established**, incl. ad-interim coordinators
- **A great** collaboration- and community-building **effort**! Bottom-up approach!
- Each Work Package has its own structure, detailed working plan description, incl. deliverables and milestones
- Extended proposals submitted as an additional document (333 pages) with the DRD1 proposal → **base for MoU addenda**
- See presentations today to learn about various WPs!
- See also: https://drd1.web.cern.ch/wp

WP tables in the DRD1 proposal



#	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						

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.*

WP tables in the DRD1 proposal

#	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**	**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	**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	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, 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						
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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**

○ **DRD1 W**

- Challenges defined in ECFA Roadmap

- Comp

ities

liverables for the first three

ed on detailed annexes (>330

signed as MoU addenda.

- List of institutes interested in joining a WP. Estimate on available/additional resources and commitment to tasks/deliverables provided in detailed annexes.

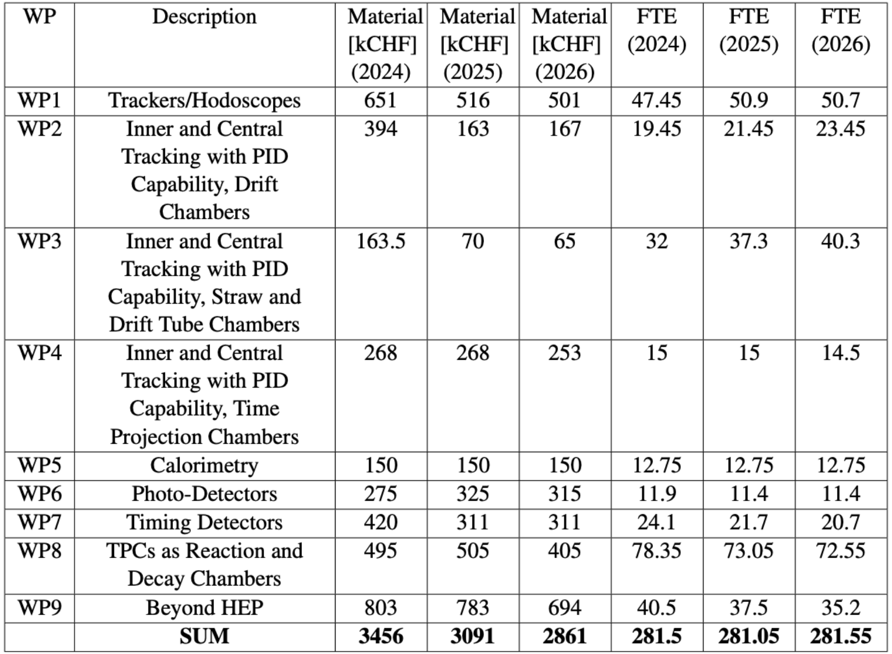
122 institutes from 32 countries have signed up for activities in various WPs!

This is 75% of DRD1

WP Resources

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

WP Resources

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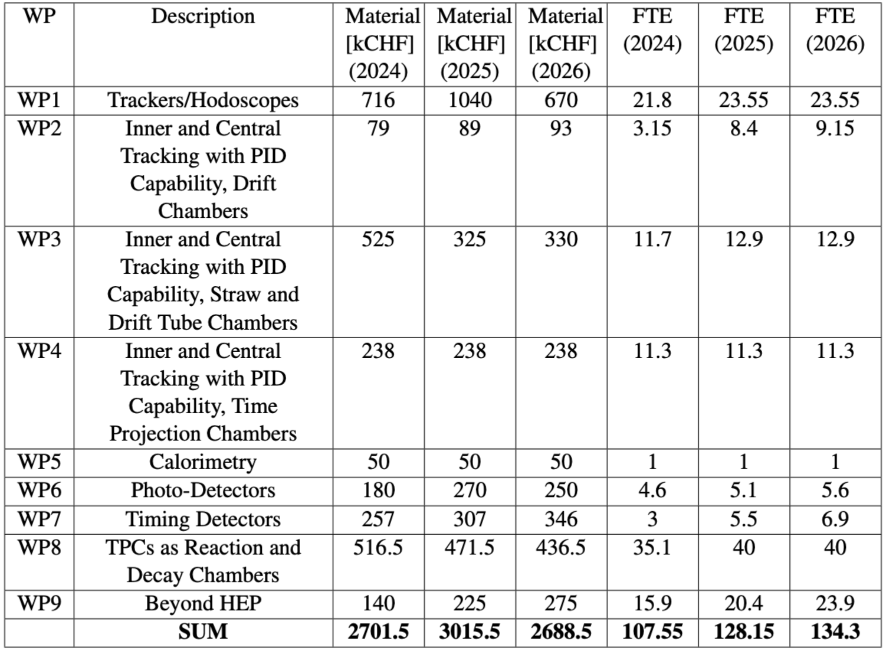
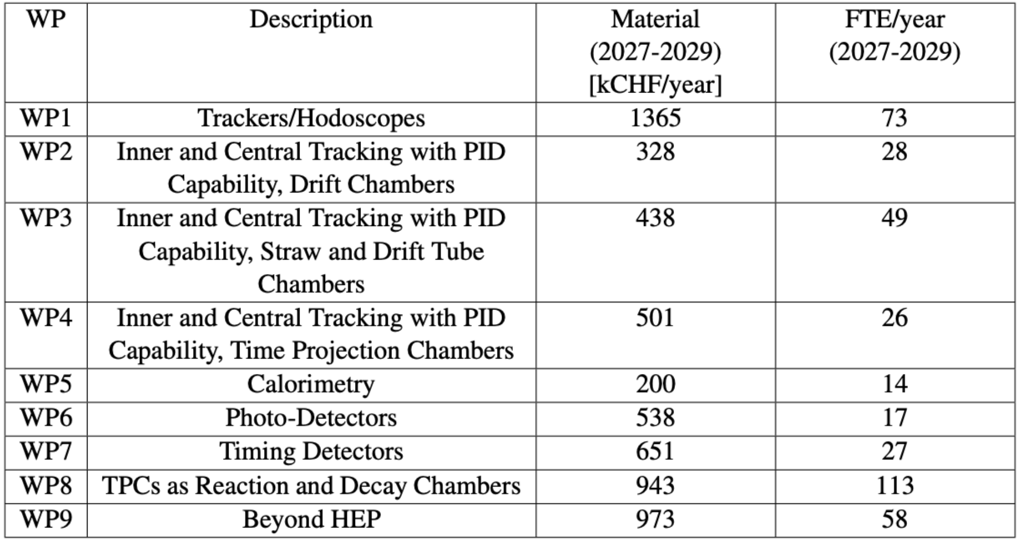


WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP1	Trackers/Hodoscopes	716	1040	670	21.8	23.55	23.55
WP2	Inner and Central Tracking with PID Capability, Drift Chambers	79	89	93	3.15	8.4	9.15
WP3	Inner and Central Tracking with PID 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

WP Resources



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.

WP approval and reviews

- **WPs can be initiated at any time** and are internally organized and coordinated by participating institutes dedicated to the specific WP.
- WP members actively engage in internal assessments, evaluating goals, milestones, and deliverables and define their internal organization within subprojects.
- Internal scientific review by the **Scientific Coordination Board**, considering the involvement of other WPs and WGs.
- The **Resource Board** evaluates resource consistency.
- **Approval** involves WP coordinators, DRD1 FA representative of the WP, overall WP coordinator. SPs, CB chair/deputy.
- **Final approval** by the Management Board and Collaboration Board.

- A formal agreement is established among participating institutes, Funding Agencies, DRD1 management, and the host lab (CERN). Work Package Agreements are included as **annexes** in the **DRD1 Memorandum of Understanding** (MoU).
- WP coordinators report to DRD1 and WP undergo review by the Detector Research and Development Committee (DRDC). Those procedures of reviewing is defined by DRDC

Today, tomorrow, on Thursday

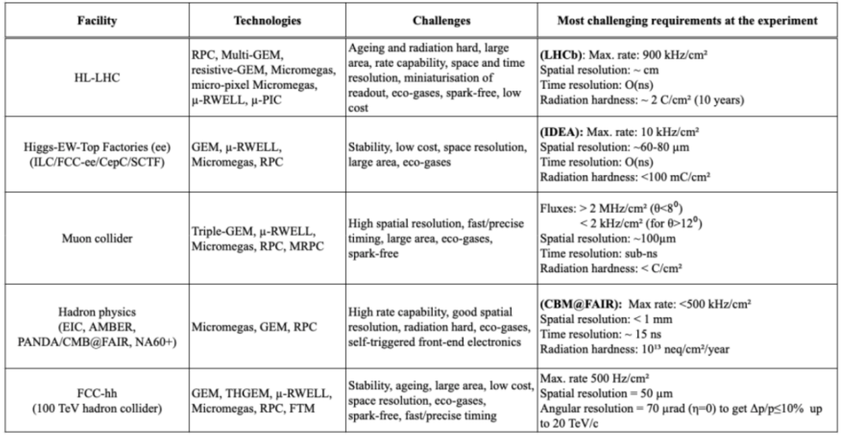
- All WPs currently included in the DRD1 proposal will be presented today and tomorrow
- Present the WP, and discuss next steps!
- On Thursday we will have a plenary discussion (everybody is welcome) to further discuss next steps, WP approval process, WP structure, FA contacts, formalities, MoU addenda etc
- The outcome of these discussions will serve as input to the CB meeting, DRD1 constitution, MoU addenda, etc.

- **Your active participation is highly appreciated!**

BACKUP

ECFA DETECTOR R&D ROADMAP CONTENT: TF1

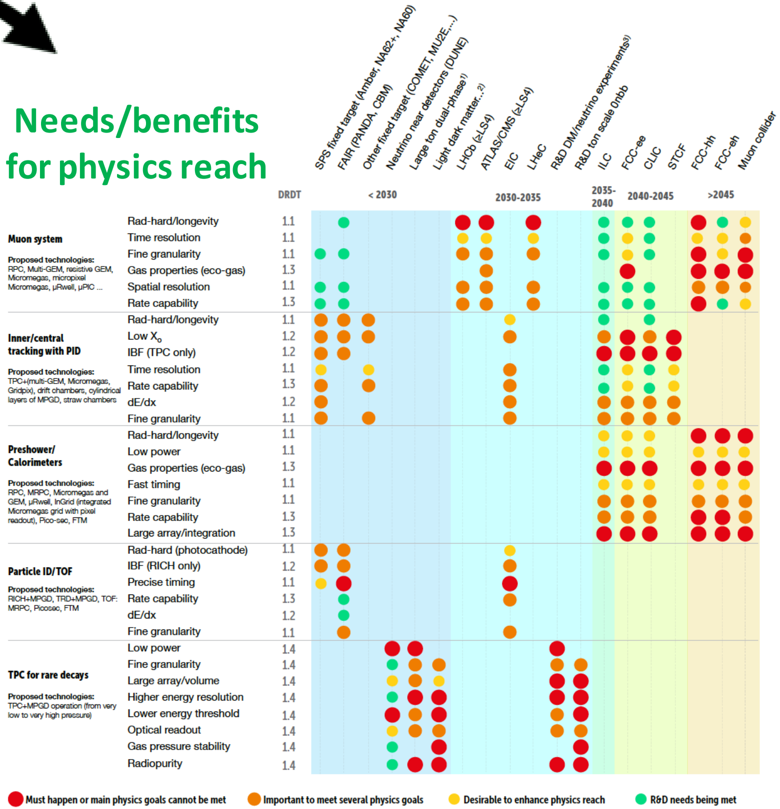
Performance targets and main drivers from facilities



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 (θ<8⁰) < 2 kHz/cm² (for θ>12⁰) Spatial resolution: ~100μm Time resolution: sub-ns Radiation hardness: < C/cm²
Hadron physics (EIC, AMBER, PANDA/CBM@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: 10¹³ 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

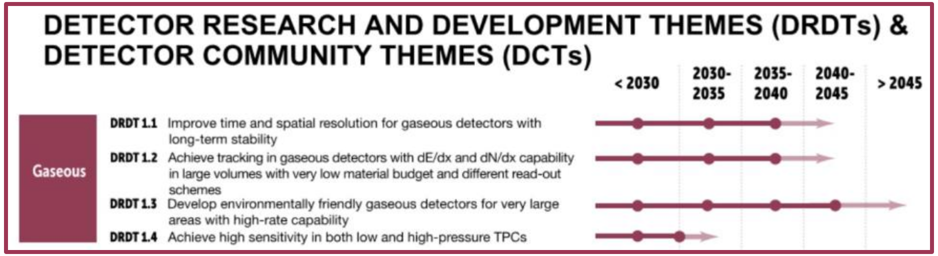
Needs/benefits for physics reach



		DRDT	< 2030						2030-2035						2035-2040	2040-2045			>2045		
			SPS fixed target (Amber, NA62+, NA60)	FAIR (PANDA, CBM)	Other fixed target (COMET, MU2E,...)	Neutrino near detectors (DUNE)	Large ton dual-phase1)	Light dark matter...2)	LHCb (≥LS4)	ATLAS/CMS (≥LS4)	EIC	LHeC	R&D DM/neutrino experiments3)	R&D ton scale 0nbb	ILC	FCC-ee	CLIC	STCF	FCC-hh	FCC-eh	Muon collider
Muon system **Proposed technologies:** RPC, Multi-GEM, resistive GEM, Micromegas, micropixel Micromegas, μRwell, μPIC ...	Rad-hard/longevity	1.1		🟢					🔴	🔴		🔴			🟢	🟢	🟢		🔴	🟢	🟡
	Time resolution	1.1							🟡	🟡		🟡			🟢	🟡	🟢		🟡	🟡	🟠
	Fine granularity	1.1	🟢	🟢					🟠	🟠		🟠			🟢	🟡	🟢		🔴	🟡	🔴
	Gas properties (eco-gas)	1.3								🟠						🔴			🔴	🔴	🔴
	Spatial resolution	1.1	🟢	🟢					🟠	🟠		🟠			🟢	🟢	🟢		🟠	🟠	🟠
	Rate capability	1.3	🟢	🟢					🟠	🟠		🟠			🟢	🟢	🟢		🔴	🟢	🟡
Inner/central tracking with PID **Proposed technologies:** TPC+(multi-GEM, Micromegas, Gridpix), drift chambers, cylindrical layers of MPGD, straw chambers	Rad-hard/longevity	1.1	🟠	🟠	🟠						🟡				🟢		🟢				
	Low X_0	1.2	🟠	🟠	🟠						🟠				🟠	🔴	🟠	🔴			
	IBF (TPC only)	1.2	🟠	🟠											🔴	🔴	🔴	🔴			
	Time resolution	1.1	🟡		🟡						🟠				🟢	🟡	🟢	🟡			
	Rate capability	1.3	🟠		🟠						🟠				🟢	🟡	🟢	🟡			
	dE/dx	1.2	🟠								🟠				🟠	🟠	🟠	🟠			
	Fine granularity	1.1	🟠		🟠						🟠				🟠	🟠	🟠	🟠			
Preshower/ Calorimeters **Proposed technologies:** RPC, MRPC, Micromegas and GEM, μRwell, InGrid (integrated Micromegas grid with pixel readout), Pico-sec, FTM	Rad-hard/longevity	1.1													🟡	🟡	🟡		🔴	🔴	🔴
	Low power	1.1													🟡	🟡	🟡		🟡	🟡	🟡
	Gas properties (eco-gas)	1.3													🔴	🔴	🔴		🔴	🔴	🔴
	Fast timing	1.1													🟡	🟡	🟡		🟡	🟡	🟡
	Fine granularity	1.1													🟠	🟠	🟠		🟠	🟠	🟠
	Rate capability	1.3													🟠	🟠	🟠		🔴	🔴	🟠
	Large array/integration	1.3													🔴	🔴	🔴		🔴	🔴	🔴
Particle ID/TOF **Proposed technologies:** RICH+MPGD, TRD+MPGD, TOF: MRPC, Picosec, FTM	Rad-hard (photocathode)	1.1	🟠	🟠							🟡										
	IBF (RICH only)	1.2	🟠	🟠							🟠										
	Precise timing	1.1	🟡	🔴							🔴										
	Rate capability	1.3		🟢							🟠										
	dE/dx	1.2		🟢																	
	Fine granularity	1.1		🟠							🟠										
TPC for rare decays **Proposed technologies:** TPC+MPGD operation (from very low to very high pressure)	Low power	1.4				🔴	🔴						🔴								
	Fine granularity	1.4				🟢	🟠	🟠					🟠	🟠							
	Large array/volume	1.4				🟡	🟠	🟡					🔴	🔴							
	Higher energy resolution	1.4				🟢	🔴	🔴					🔴	🔴							
	Lower energy threshold	1.4				🔴	🟠	🔴					🟠	🔴							
	Optical readout	1.4				🟡	🟠	🟠					🟠	🟠							
	Gas pressure stability	1.4				🟢		🔴						🔴							
	Radiopurity	1.4				🟢	🔴	🔴					🔴	🔴							

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

Detector R&D themes



DETECTOR RESEARCH AND DEVELOPMENT THEMES (DRDTs) & DETECTOR COMMUNITY THEMES (DCTs)

DRDT 1.1 Improve time and spatial resolution for gaseous detectors with long-term stability

DRDT 1.2 Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes

DRDT 1.3 Develop environmentally friendly gaseous detectors for very large areas with high-rate capability

DRDT 1.4 Achieve high sensitivity in both low and high-pressure TPCs

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

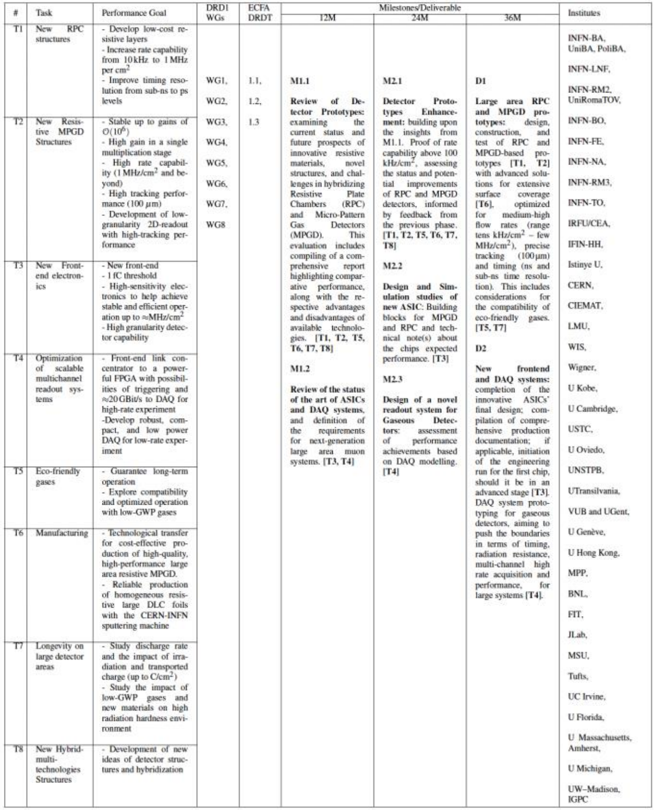
➢ ECFA R&D tasks are all covered

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

		DRDT	< 2030						2030-2035						2035-2040	2040-2045			>2045		
			SPS fixed target (Amber, NA62+, NA60)	FAIR (PANDA, CBM)	Other fixed target (COMET, MU2E,...)	Neutrino near detectors (DUNE)	Large ton dual-phase$^{1)}$	Light dark matter...$^{2)}$	LHCb (≥LS4)	ATLAS/CMS (≥LS4)	EIC	LHeC	R&D DM/neutrino experiments$^{3)}$	R&D ton scale 0nbb	ILC	FCC-ee	CLIC	STCF	FCC-hh	FCC-eh	Muon collider
Muon system	Rad-hard/longevity	1.1		🟢					🔴	🔴		🔴			🟢	🟢	🟢		🔴	🟢	🟡
	Time resolution	1.1							🟡	🟡		🟡			🟢	🟡	🟢		🟡	🟡	🟠
Proposed technologies: RPC, Multi-GEM, resistive GEM, Micromegas, micropixel Micromegas, µRwell, µPIC ...	Fine granularity	1.1	🟢	🟢					🟠	🟠		🟠			🟢	🟡	🟢		🔴	🟡	🔴
	Gas properties (eco-gas)	1.3								🟠						🔴			🔴	🔴	🔴
	Spatial resolution	1.1	🟢	🟢					🟠	🟠		🟠			🟢	🟢	🟢		🟠	🟠	🟠
	Rate capability	1.3	🟢	🟢					🟠	🟠		🟠			🟢	🟢	🟢		🔴	🟢	🟡



#	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

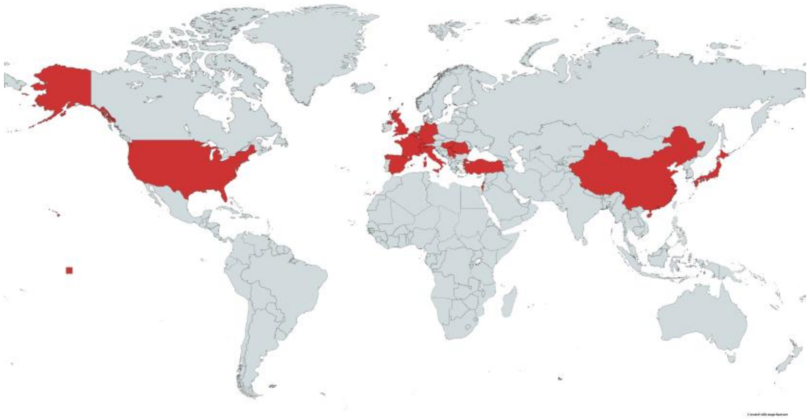
	TASK							
Institute	T1	T2	T3	T4	T5	T6	T7	T8
INFN-BA	x				x		x	
INFN-BO		x	x					
INFN-FE		x	x	x				x
INFN-LNF	x	x			x	x	x	x
INFN-NA		x				x	x	
INFN-RM2	x	x	x		x	x	x	x
INFN-RM3		x				x	x	
INFN-TO			x					
Kobe	x	x						
CERN		x	x	x	x		x	
U. Cambridge	x				x		x	
LMU		x						
ICTEA U Oviedo			x					
CIEMAT			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



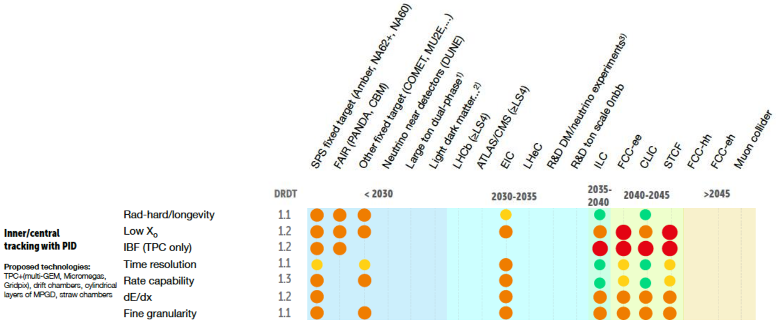
WP2 – Drift Chambers

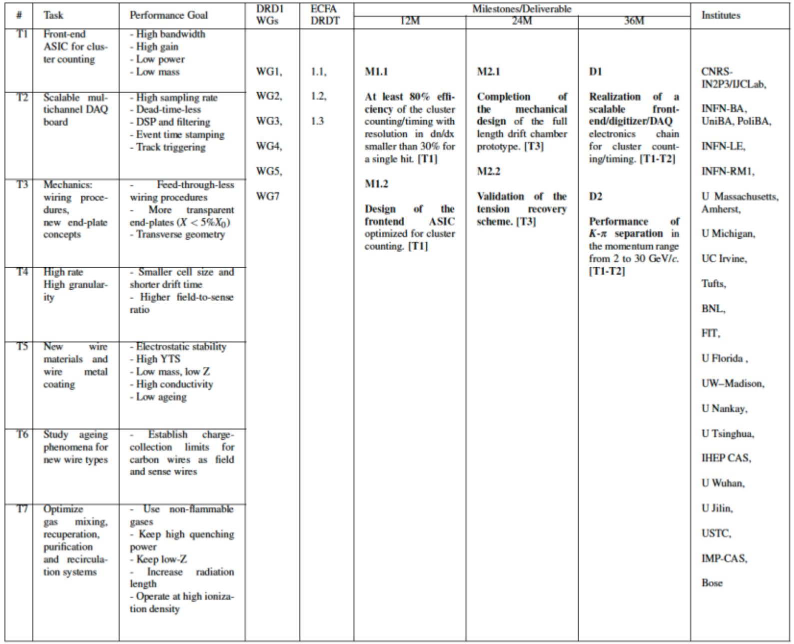
Challenges:

- 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	24M	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						

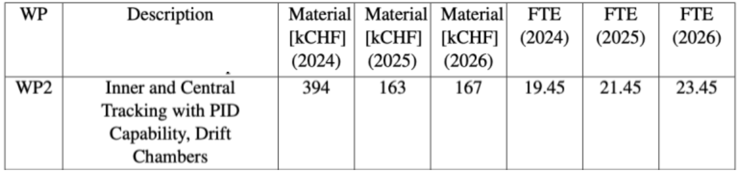
WP2 – Drift Chambers

Institutes

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

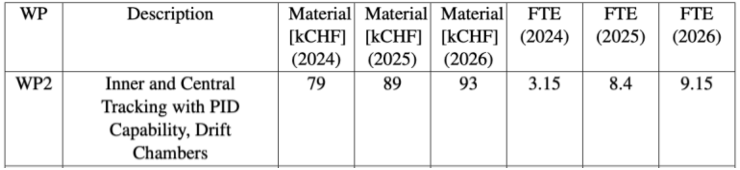
	Tasks						
Institute	T1	T2	T3	T4	T5	T6	T7
IJCLab-IN2P3			x	x	x	x	
INFN-BA	x	x	x	x	x	x	x
INFN-LE	x	x	x	x	x	x	x
INFN-RM				x	x	x	x
US Cluster	x		x				x
Nankai U				x			
Tsinghua U	x						
IHEP-CAS	x		x	x			x
Wuhan U				x			
Jilin U				x			
USTC				x		x	
IMP-CAS				x		x	
Bose						x	x

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

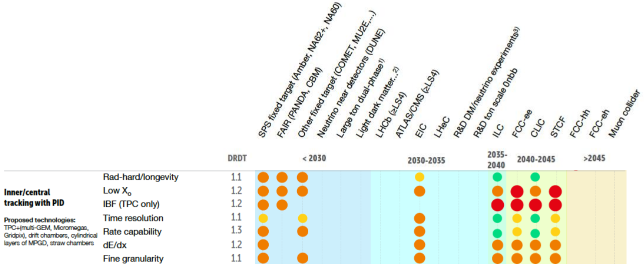
Challenges and goals

- Straw tube wall film thickness $< 20\mu m$ for low $X/X0 < 0.04\%$ per straw
- Straw diameter $\leq$ 5mm for high rate capability of $O(100\ kHz/cm^2)$
- 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 $O(10m^3)$ and in vacuum
- Extending detector longevity by increasing material purity
- Developing new production techniques, like ultrasonic film tube welding

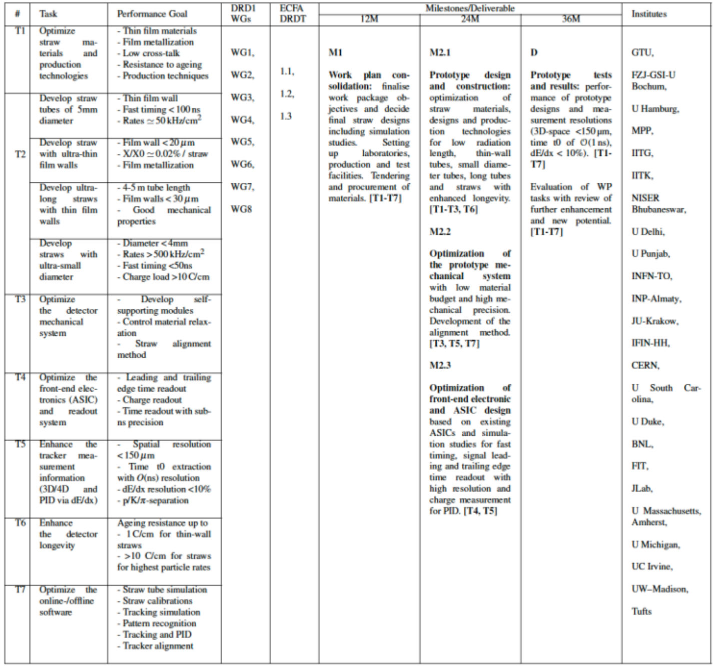
  to minimize the usage of glue

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, ..)



		DRDT	< 2030						2030-2035						2035-2040	2040-2045			>2045		
			SPS fixed target (Amber, NA62+, NA60)	FAIR (PANDA, CBM)	Other fixed target (COMET, MU2E,...)	Neutrino near detectors (DUNE)	Large ton dual-phase$^{1)}$	Light dark matter...$^{2)}$	LHCb (≥LS4)	ATLAS/CMS (≥LS4)	EIC	LHeC	R&D DM/neutrino experiments$^{3)}$	R&D ton scale 0nbb	ILC	FCC-ee	CLIC	STCF	FCC-hh	FCC-eh	Muon collider
Inner/central tracking with PID	Rad-hard/longevity	1.1	🟠	🟠	🟠						🟡				🟢		🟢				
	Low X_o	1.2	🟠	🟠	🟠						🟠				🟠	🔴	🟠	🔴			
	IBF (TPC only)	1.2	🟠	🟠											🔴	🔴	🔴	🔴			
Proposed technologies: TPC+(multi-GEM, Micromegas, Gridpix), drift chambers, cylindrical layers of MPGD, straw chambers	Time resolution	1.1	🟡		🟡						🟠				🟢	🟡	🟢	🟡			
	Rate capability	1.3	🟠		🟠						🟠				🟢	🟡	🟢	🟡			
	dE/dx	1.2	🟠								🟠				🟠	🟠	🟠	🟠			
	Fine granularity	1.1	🟠		🟠						🟠				🟠	🟠	🟠	🟠			



#	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 $\mathcal{O}$(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 $\simeq$ 50 kHz/cm^2						
	Develop straw with ultra-thin film walls	- Film wall < 20 μm - X/X0 $\simeq$ 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/cm^2 - 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)

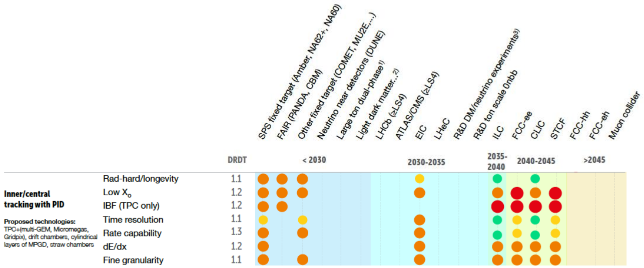
WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP3	Inner and Central Tracking with PID Capability, Straw and Drift Tube Chambers	525	325	330	11.7	12.9	12.9

WP4 – Tracking TPCs

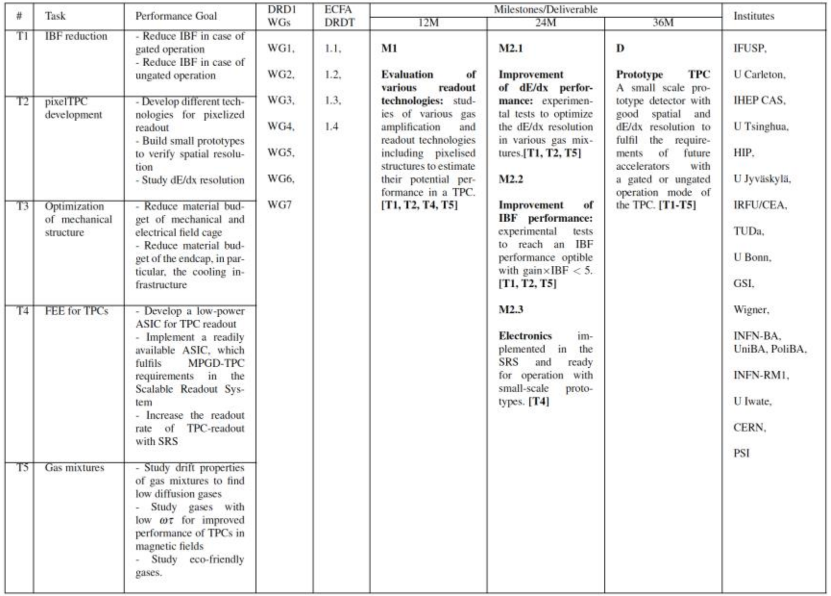
Challenges and goals

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

Single WP project



		DRDT	< 2030						2030-2035						2035-2040	2040-2045			>2045		
			SPS fixed target (Amber, NA62+, NA60)	FAIR (PANDA, CBM)	Other fixed target (COMET, MU2E,...)	Neutrino near detectors (DUNE)	Large ton dual-phase[1]	Light dark matter...[2]	LHCb (≥LS4)	ATLAS/CMS (≥LS4)	EIC	LHeC	R&D DM/neutrino experiments[3]	R&D ton scale 0nbb	ILC	FCC-ee	CLIC	STCF	FCC-hh	FCC-eh	Muon collider
Inner/central tracking with PID **Proposed technologies:** TPC+(multi-GEM, Micromegas, Gridpix), drift chambers, cylindrical layers of MPGD, straw chambers	Rad-hard/longevity	1.1	🟠	🟠	🟠						🟡				🟢		🟢				
	Low X_0	1.2	🟠	🟠	🟠						🟠				🟠	🔴	🟠	🔴			
	IBF (TPC only)	1.2	🟠	🟠											🔴	🔴	🔴	🔴			
	Time resolution	1.1	🟡		🟡						🟠				🟢	🟡	🟢	🟡			
	Rate capability	1.3	🟠		🟠						🟠				🟢	🟡	🟢	🟡			
	dE/dx	1.2	🟠								🟠				🟠	🟠	🟠	🟠			
	Fine granularity	1.1	🟠		🟠						🟠				🟠	🟠	🟠	🟠			



#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Milestones/Deliverable 12M	24M	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.						

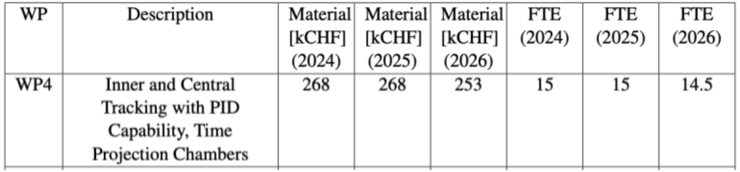
WP4 – Tracking TPCs

Institutes

- 16 institutes in 10 countries
- All tasks covered

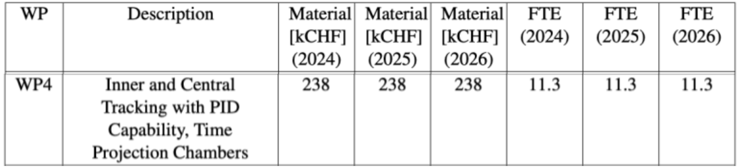
	Tasks				
Institute	T1	T2	T3	T4	T5
USP				x	
U Carleton	x	x			
IHEP-CAS	x	x		x	x
U Tsinghua				x	
HIP	x		x		x
U Jyväskylä	x				
IRFU/CEA	x			x	
U Bonn	x	x	x		x
TU Da	x		x		
GSI	x			x	x
RCP	x				
INFN-Bari			x		x
INFN-Roma1	x	x			
IU	x		x		
CERN		x			
PSI	x	x			

Existing

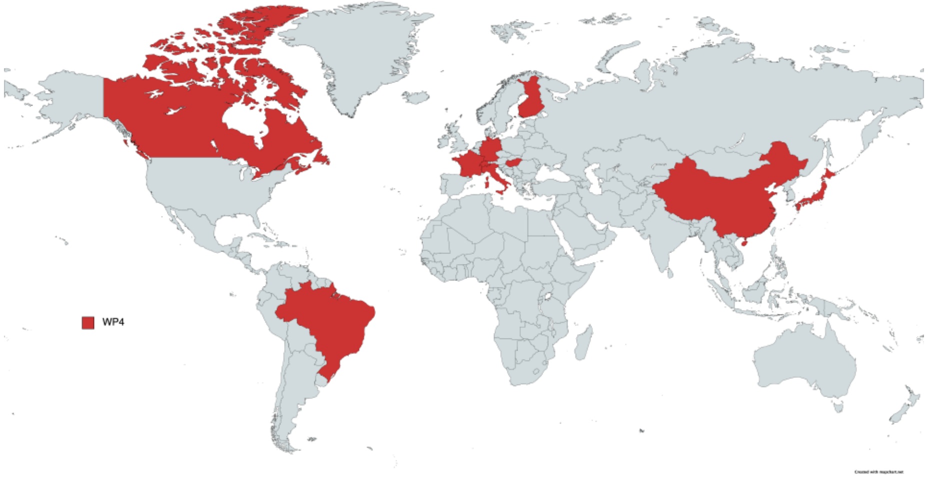


WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP4	Inner and Central Tracking with PID Capability, Time Projection Chambers	268	268	253	15	15	14.5

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

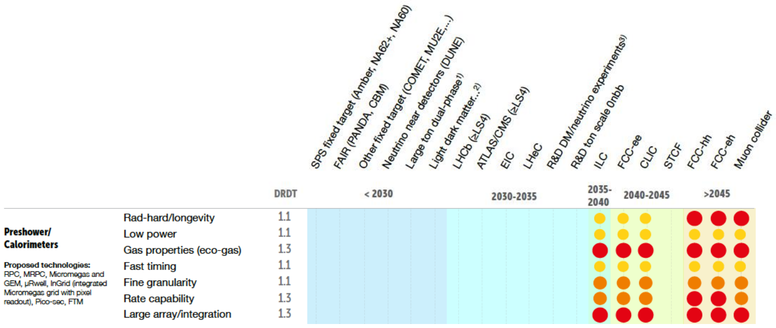
Challenges

- 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



		DRDT	SPS fixed target (Amber, NA62+, NA60)	FAIR (PANDA, CBM)	Other fixed target (COMET, MU2E,...)	Neutrino near detectors (DUNE)	Large ton dual-phase1)	Light dark matter...2)	LHCb (≥LS4)	ATLAS/CMS (≥LS4)	EIC	LHeC	R&D DM/neutrino experiments3)	R&D ton scale 0nbb	ILC	FCC-ee	CLIC	STCF	FCC-hh	FCC-eh	Muon collider
			< 2030						2030-2035						2035-2040	2040-2045			>2045		
Preshower/ Calorimeters **Proposed technologies:** RPC, MRPC, Micromegas and GEM, μRwell, InGrid (integrated Micromegas grid with pixel readout), Pico-sec, FTM	Rad-hard/longevity	1.1													🟡	🟡	🟡		🔴	🔴	🔴
	Low power	1.1													🟡	🟡	🟡		🟡	🟡	🟡
	Gas properties (eco-gas)	1.3													🔴	🔴	🔴		🔴	🔴	🔴
	Fast timing	1.1													🟡	🟡	🟡		🟡	🟡	🟡
	Fine granularity	1.1													🟠	🟠	🟠		🟠	🟠	🟠
	Rate capability	1.3													🟠	🟠	🟠		🔴	🔴	🟠
	Large array/integration	1.3													🔴	🔴	🔴		🔴	🔴	🔴

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Milestones/Deliverable			Institutes
					12M	24M	36M	
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.

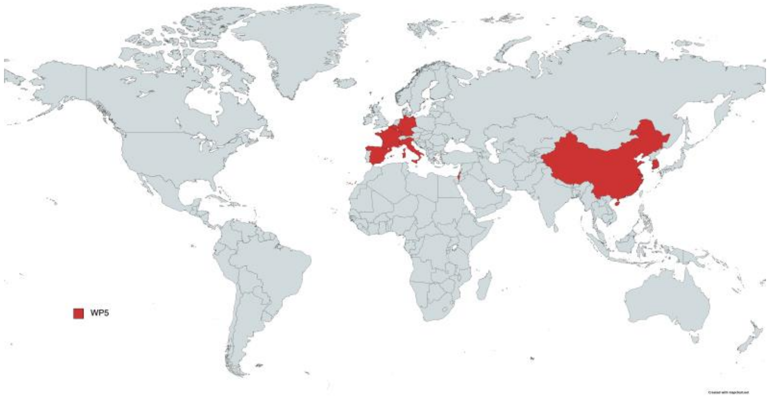
Additional (not existing)

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

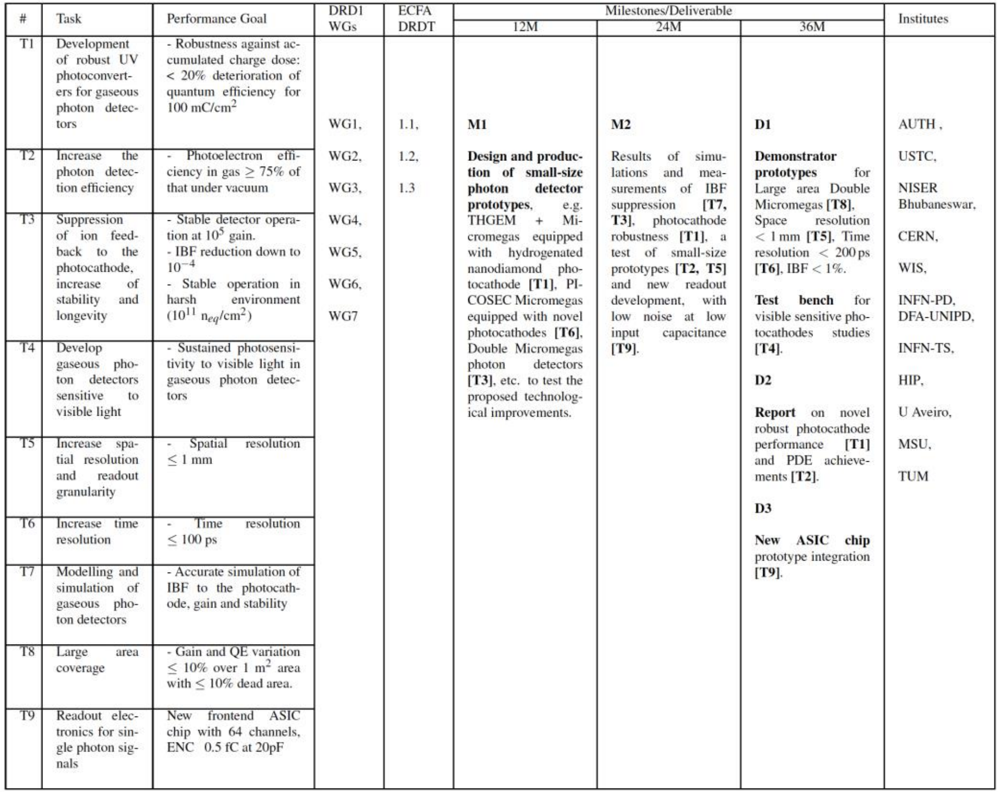
Challenges and goals

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

➢ **Improve performance**

➢ **Explore visible gaseous PDs**

		DRDT	SPS fixed target (Amber, NA62+, NA60)	FAIR (PANDA, CBM)	Other fixed target (COMET, MU2E,...)	Neutrino near detectors (DUNE)	Large ton dual-phase[1]	Light dark matter...[2]	LHCb (≥LS4)	ATLAS/CMS (≥LS4)	EIC	LHeC	R&D DM/neutrino experiments[3]	R&D ton scale 0nbb	ILC	FCC-ee	CLIC	STCF	FCC-hh	FCC-eh	Muon collider
			< 2030						2030-2035						2035-2040	2040-2045			>2045		
Particle ID/TOF **Proposed technologies:** RICH+MPGD, TRD+MPGD, TOF: MRPC, Picosec, FTM	Rad-hard (photocathode)	1.1	🟠	🟠							🟡										
	IBF (RICH only)	1.2	🟠	🟠							🟠										
	Precise timing	1.1	🟡	🔴							🔴										
	Rate capability	1.3		🟢							🟠										
	dE/dx	1.2		🟢																	
	Fine granularity	1.1		🟠							🟠										



#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Milestones/Deliverable			Institutes
					12M	24M	36M	
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 $\geq 75\%$ 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 $\leq 10\%$ over 1 m^2 area with $\leq 10\%$ dead area.						
T9	Readout electronics for single photon signals	New frontend ASIC chip with 64 channels, ENC 0.5 fC at 20pF						

WP6 – Photo-detectors

Institutes

- 11 institutes from 10 countries
- All tasks covered

Existing

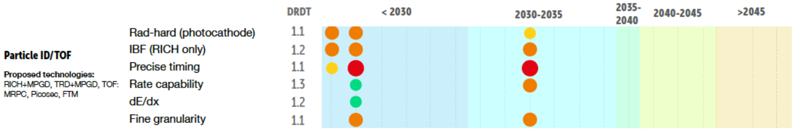
WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP6	Photo-Detectors	275	325	315	11.9	11.4	11.4

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	T1	T2	T3	T4	T5	T6	T7	T8	T9
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



Particle ID/TOF

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

	DRDT	< 2030	2030-2035	2035-2040	2040-2045	>2045
Rad-hard (photocathode)	1.1	🟠 🟠	🟡			
IBF (RICH only)	1.2	🟠 🟠	🟠			
Precise timing	1.1	🟡 🔴	🔴			
Rate capability	1.3	🟢	🟠			
dE/dx	1.2	🟢				
Fine granularity	1.1	🟠	🟠			

Challenges

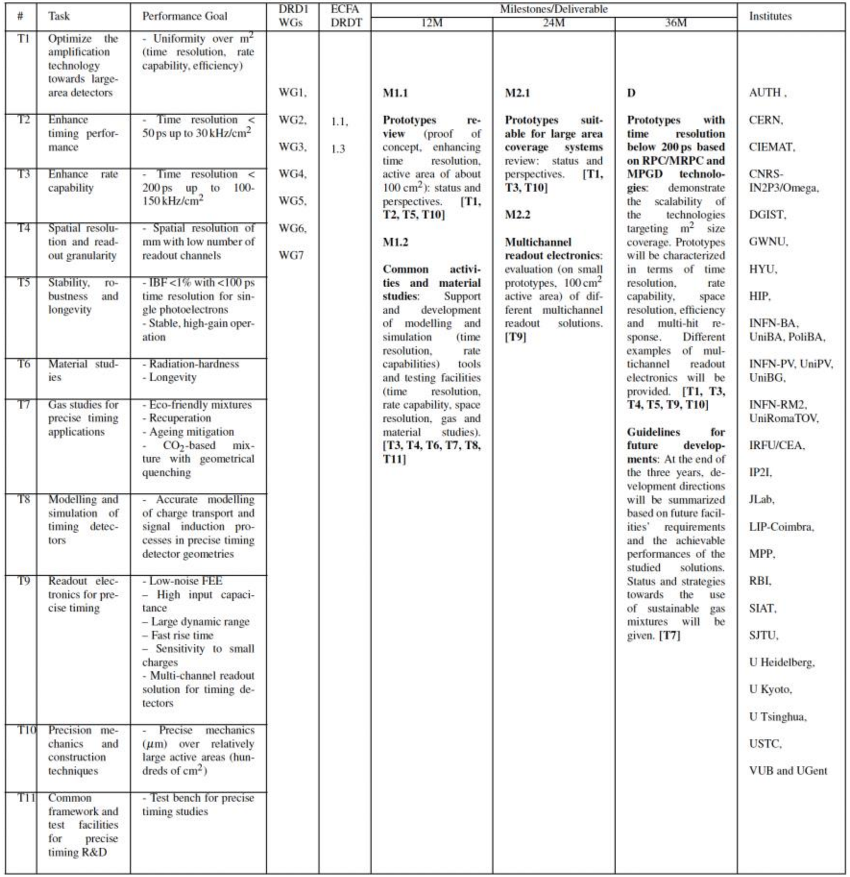
- Eco-friendly gases: decreasing availability, increasing cost of GH gases
- Detector ageing: operational instabilities/ageing in harsh environments,
- Front end electronics: timing performance, low power, robustness

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	24M	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]

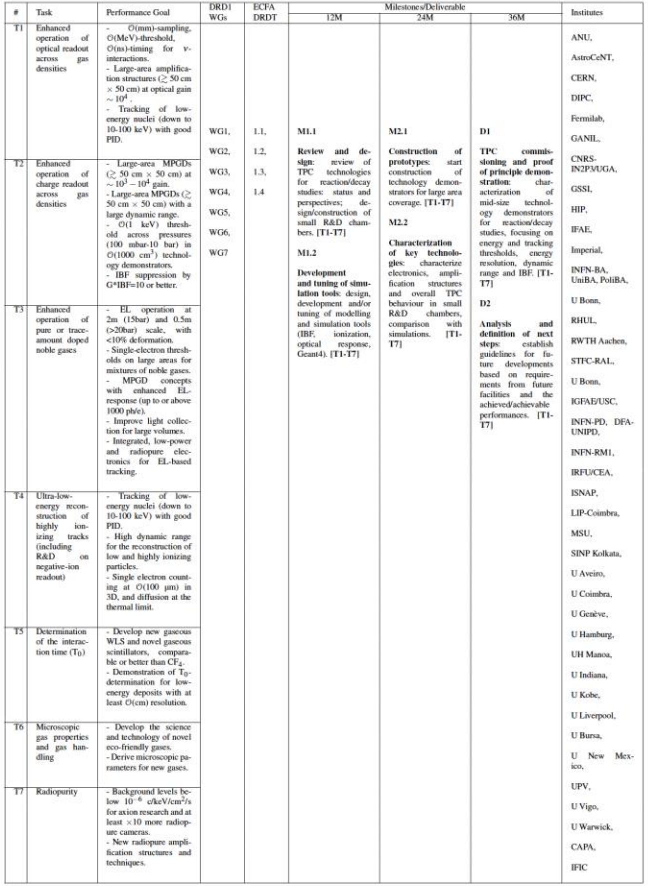
Four projects:

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 × 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 × 50 cm) at $\sim 10^3 - 10^4$ gain. - Large-area MPGDs ($\gtrsim$ 50 cm × 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 ×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

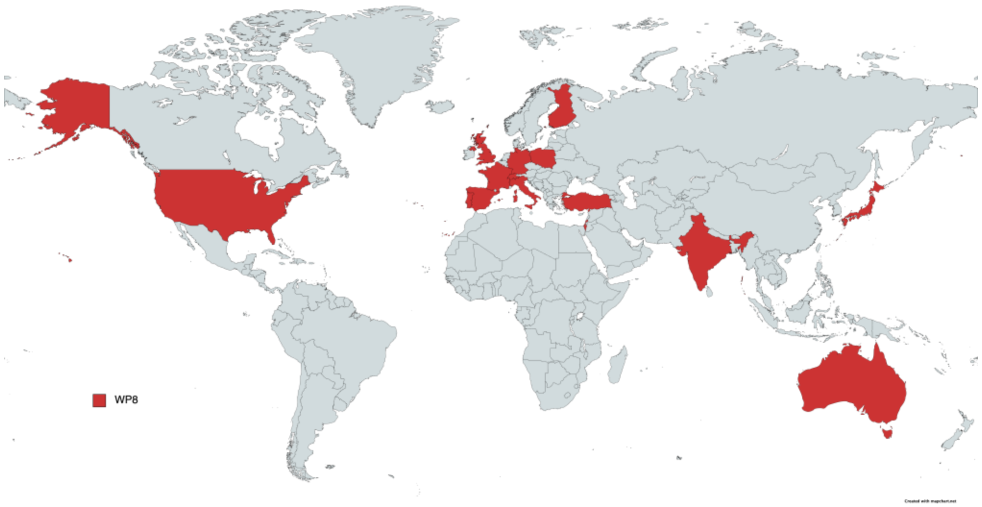
(D) Radiopure TPCs for precise track imaging and/or calorimetry with avalanche-based readouts

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			

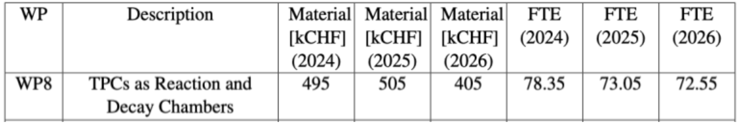
WP8 – TPCs as Reaction and Decay Chambers

Institutes

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

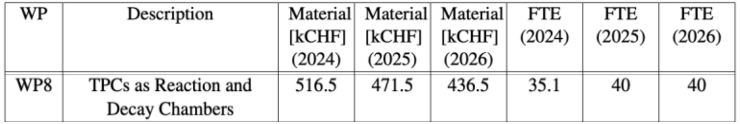


Existing



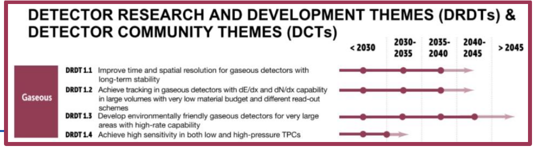
WP	Description	Material [kCHF] (2024)	Material [kCHF] (2025)	Material [kCHF] (2026)	FTE (2024)	FTE (2025)	FTE (2026)
WP8	TPCs as Reaction and Decay Chambers	495	505	405	78.35	73.05	72.55

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


DETECTOR RESEARCH AND DEVELOPMENT THEMES (DRDTs) & DETECTOR COMMUNITY THEMES (DCTs)

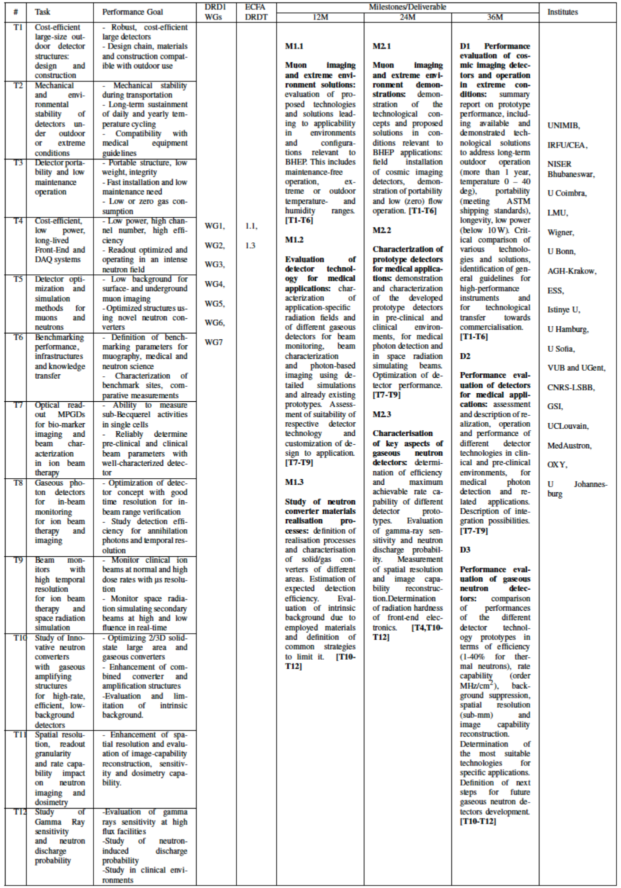
DRDT 1.1 Improve time and spatial resolution for gaseous detectors with long-term stability
DRDT 1.2 Achieve tracking in gaseous detectors with dE/dx and dN/dx capability in large volumes with very low material budget and different read-out schemes
DRDT 1.3 Develop environmentally friendly gaseous detectors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

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			Institutes
					12M	24M	36M	
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

Institute	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
	Tasks											
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