WP1
Large-area, precision muon trackers

R. Farinelli, M. Iodice A. Ochi, G. Pugliese

DRD1 Community Meeting

CERN – June 22, 2023

WP1: Large Area, Precision Muon Systems

Section 4.2.1 TRACKERS/HODOSCOPES (LARGE AREA MUON SYSTEMS, INNER TRACKING/VERTEXING) of the DRD1 EXTENDED R&D PROPOSAL

Gaseous detectors in Large area muon systems:

- offer the ability to easily instrument very large surfaces, with good space-time resolutions, high efficiency and are lightweight.

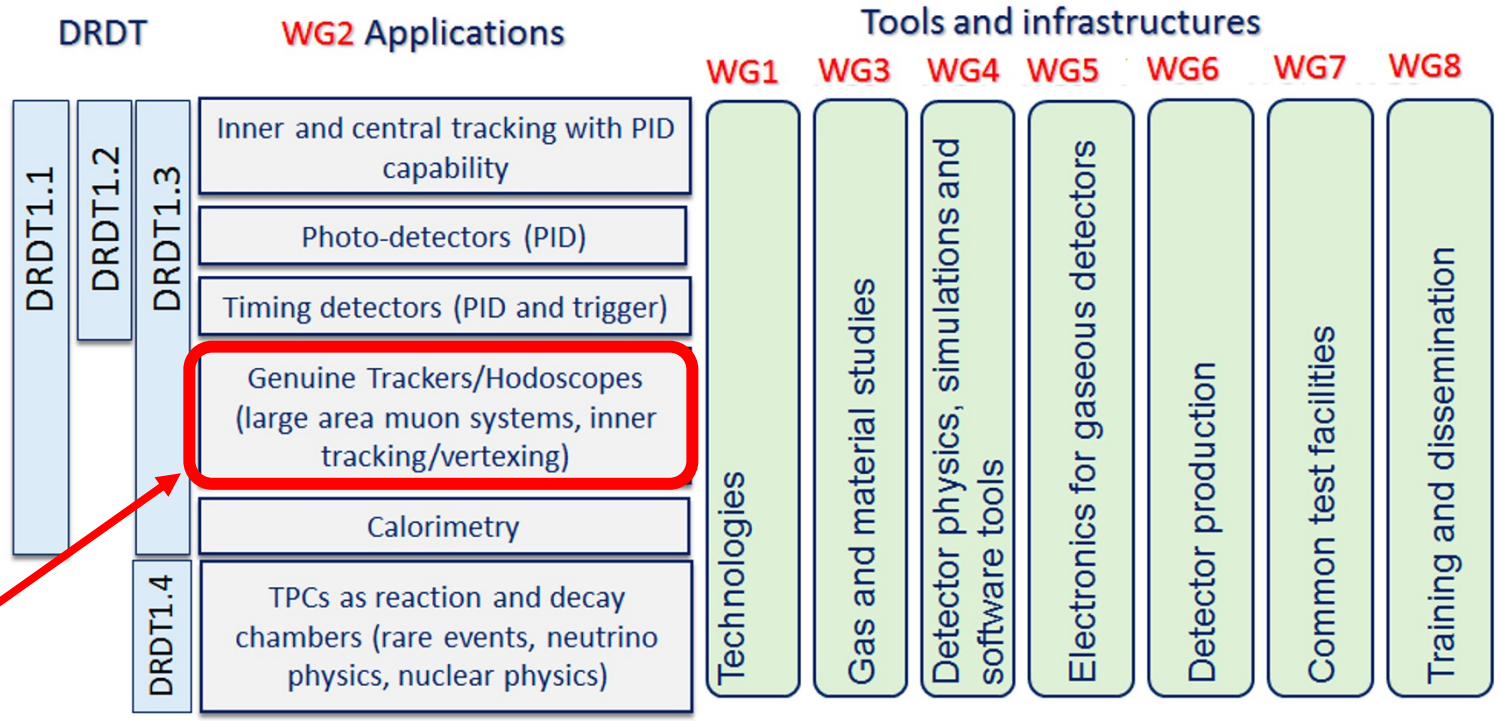
- Moreover, such systems play a key role in tracking and time-tagging particles from rare-event decays and long-lived particles over large detection volumes

Main Challenges for Large Area Muon System

- Extending the state-of-the-art rate capability by at least one order of magnitude up to ≈MHz/cm^2 with longevity compatible with decades of operation
    - low-noise electronics
    - new detector materials and geometries increasing signal pick-up,
    - innovative materials with lower resistivity yet ensuring spark-quenching
    - fine granularity readout to reduce the occupancy

- enabling reliable and efficient operation with suitable low-GWP gas mixtures.
- Improve in time resolution at ns level and up to 10-100 ps for applications aimed at extending the reconstruction power in very high-rate collider experiments (e.g. pile-up mitigation)
- large-scale serial production;
- low-rate applications involving muon tracking in HEP as well as muon tomography over large areas

WP1: Large Area, Precision Muon Systems

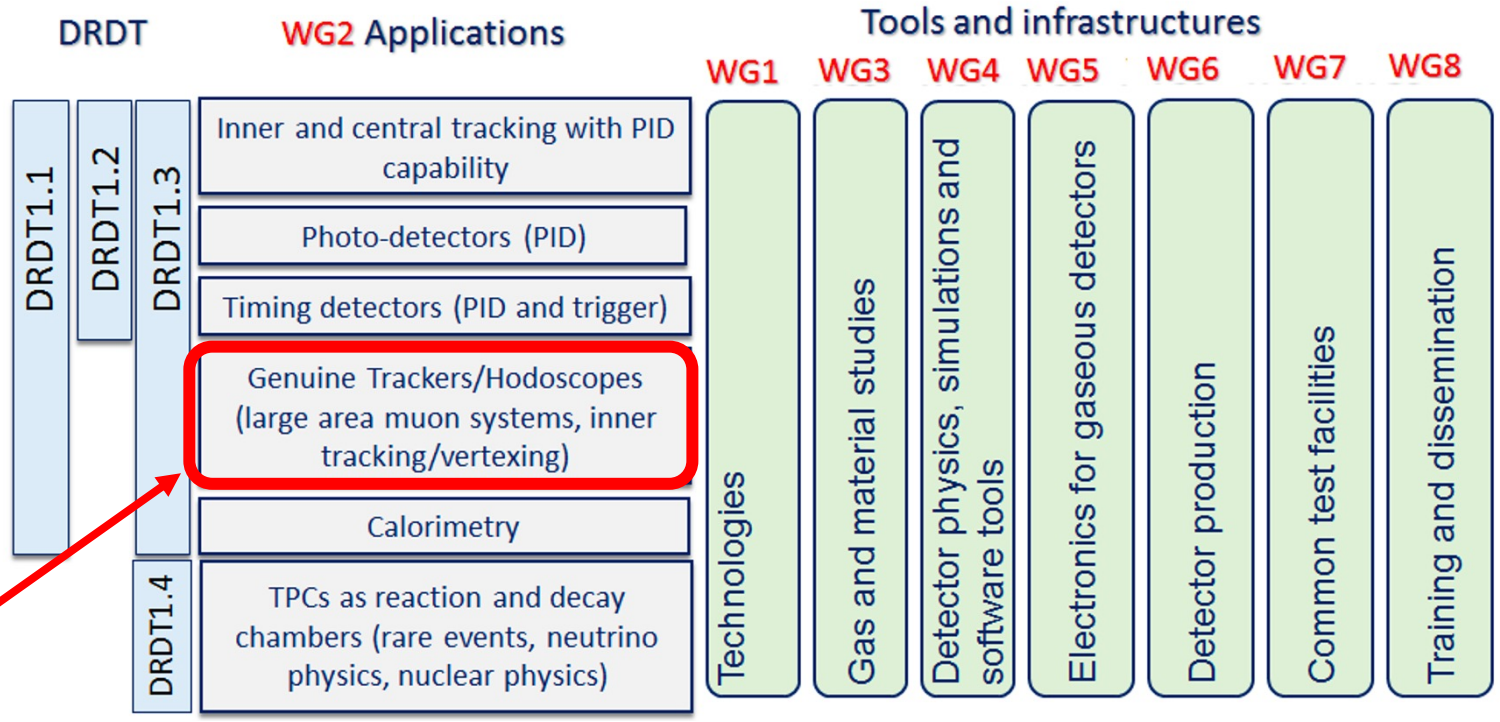


WP1 Applications:

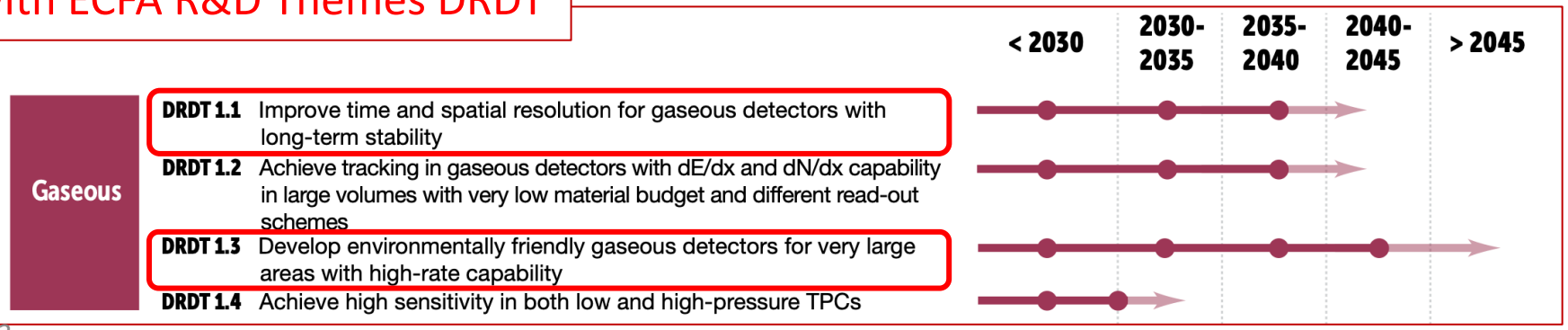
Future electron colliders (ILC/C3, FCC-ee, CepC), Muon collider, Hadron Physics, FCC-hh, muography.

Technologies: RPC, Micromegas, GEM, micro-RWELL, gridPix, μ-PIC, FTM, TGC, CSC, MWPC).

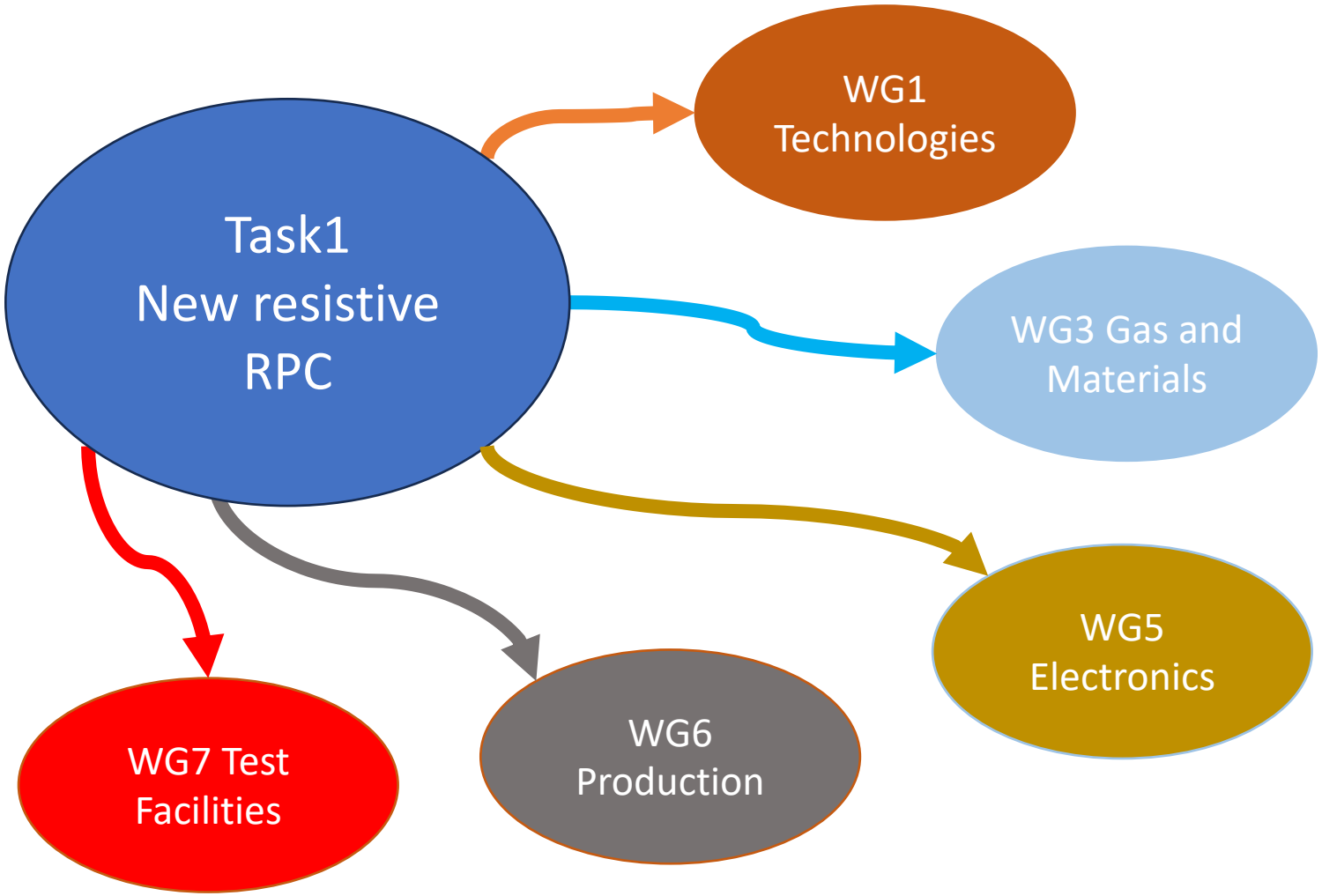
WP1: Large Area, Precision Muon Systems



WP1 connection with ECFA R&D Themes DRDT



WP1: Connections with WG – example of Task1



WG8 Training and Dissemination

Essential for all R&D activities

WP1: List of tasks as it appears now in the draft Extended Proposal

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3 y	Interested Institutes
T1	New resistive RPC materials and production techniques for resistive layers	- Develop low-cost resistive layers - Increase rate capability	WG3 (3.1C, 3.2D), WG6, WG7 (7.1-5)	1.1, 1.2	- HPL, low resistivity glass - Semiconductors - Printed resistive patterns - DLC-sputtered electrodes for surface-dissipation in RPCs	- Design, construction and test of prototypes with new production techniques	INFN-RM2, INFN-PD, INFN-BO, U Kobe, INFN-PV, WIS, INFN-LNF, CERN, IPPLM, U Bolu-Abant, U Cambridge, HYU
T2	New resistive MPGD structures	- Stable up to gains of $\mathcal{O}(10^6)$ - High gain in a single multiplication stage - High rate capability (1 MHz/cm^2 and beyond) - High tracking performance	WG3 (3.1C, 3.2D), WG4, WG6, WG7 (7.1-5)	1.2	- High-rate DLC layout for micro-RWELL	- Design, construction and test of prototypes with new resistive materials - Modelling and Simulation (signal induction) - MPGD prototypes based on resistive elements for tracking	USTC, INFN-PD, INFN-NA, INFN-RM3, INFN-LNF, INFN-FE, INFN-PV, INFN-BO, U Kobe,WIS, IRFU/CEA, IPPLM, LMU, U Bolu-Abant, CERN
	2D readout optimization	- Development of low-granularity 2D-readout with high tracking performance			- Layouts based on low resistivity DLC film and charge sharing	- Design, construction and test of prototypes with low-granularity 2D-readout	INFN-LNF
T3	New front-end electronics	- 1 fC threshold - High-sensitivity electronics to help achieving stable and efficient operation up to ≈MHz/cm^2	WG5, WG7 (7.1,2)	1.1	- Integration of FEE in the detector Faraday cage - 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 - High throughput multichannel FE (peak time/amplitude based VMM3a): performance studies and optimization.	IFIN-HH, INFN-FE, INFN-BA, INFN-BO, INFN-TO, IRFU/CEA, IPPLM, INFN-RM2, U Cambridge, CERN
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	WG5	1.1, 1.2	- 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 the end of 2024 for commissioning at test beam - SRS/VMM3a Readout: Continuous and trigger mode, distributed systems, synchronization with other DAQs.	IFIN-HH, INFN-BO, U Bonn, IPPLM, CIEMAT, CERN

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3 y	Interested Institutes
T5	Eco-friendly gases	- Guarantee long-term operation - Explore compatibility and optimized operation with low-GWP gases	WG3 (3.1A, 3.1B, 3.2C), WG4, WG7 (7.1-4)	1.1	- Ageing studies - Leak mitigation and maintenance of existing systems - Gas simulation: drift velocity, diffusion	- Test and characterization of gaseous-detection technologies with low-GWP gases (broadly)	U Oviedo, CERN, U Wurzburg, INFN-BA, INFN-LNF, INFN-BO, INFN-PV, IRFU/CEA, U Coimbra, VUB and UGent, IP-PLM, LMU, U Aveiro, INFN-RM2, Istinye U, HYU
T6	Manufacturing	- Construction of large-area detectors at low cost - Modular design - Technology transfer strategy and training center for production	WG3 (3.2E), WG6, WG8	1.3	- Optimization of the manufacturing procedure to minimize time-consuming or costly steps	- Design and manufacturing of large-area detector - Large-area DLC production - CERN: MPGD based manufacturing capabilities and large-area modules (design and prototyping). Note: MPT Workshop	U Heidelberg, USTC, WIS, GSI, INFN-NA, INFN-RM3, INFN-LNF, INFN-BO, UW–Madison, IPPLM, LMU, INFN-RM2, Istinye U, Wigner, CERN
T7	Thinner layers and increased mechanical precision over large areas	- Test to experience the ultimate limits to thinning down the detector	WG3 (3.2E), WG5, WG7 (7.1,2)	1.3			INFN-BA, INFN-LNF, IPPLM, LMU, INFN-RM2
T8	Longevity on large detector areas	- Study discharge rate and the impact of irradiation and transported charge (up to C/cm^2)	WG1, WG3 (3.1B, 3.1D, 3.2B), WG4, WG7 (7.1,3)	1.1	- Discharge probability - Ageing		WIS, INFN-NA, INFN-RM3, INFN-BA,INFN-LNF, IRFU/CEA, U Coimbra, IPPLM, LMU, INFN-RM2, INFN-BO
T9	Low-mass MPGDs for inner-tracking at low-energy ee colliders	- development of low-mass planar cylindrical mechanics	WG5		- low-mass cylindrical micro-RWELL for Inner tracker	- Prototype test	INFN-LNF
T10	Develop robust, compact, and low power DAQ for low rates	- 256 channel readout - 100 W or less - 1200 cc DAQ volume - Rugged design for remote (<1 km), e.g. underground operations	WG5		- Muon rates from few Hz to few events per day	- Deployed and tested at depth	OXY

UNREADABLE on slides

DRAFT

WP1: example Task1 and Task2

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3 y	Interested Institutes
T1	New resistive RPC materials and production techniques for resistive layers	- Develop low-cost resistive layers - Increase rate capability	WG3 (3.1C, 3.2D), WG6, WG7 (7.1-5)	1.1, 1.2	- HPL, low resistivity glass - Semiconductors - Printed resistive patterns - DLC-sputtered electrodes for surface-dissipation in RPCs	- Design, construction and test of prototypes with new production techniques	INFN-RM2, INFN-PD, INFN-BO, U Kobe, INFN-PV, WIS, INFN-LNF, CERN, IPPLM, U Bolu-Abant, U Cambridge, HYU
T2	New resistive MPGD structures	- Stable up to gains of $\mathcal{O}(10^6)$ - High gain in a single multiplication stage - High rate capability (1 MHz/cm^2 and beyond) - High tracking performance	WG3 (3.1C, 3.2D), WG4, WG6, WG7 (7.1-5)	1.2	- High-rate DLC layout for micro-RWELL	- Design, construction and test of prototypes with new resistive materials - Modelling and Simulation (signal induction) - MPGD prototypes based on resistive elements for tracking	USTC, INFN-PD, INFN-NA, INFN-RM3, INFN-LNF, INFN-FE, INFN-PV, INFN-BO, U Kobe,WIS, IRFU/CEA, IPPLM, LMU, U Bolu-Abant, CERN
	2D readout optimization	- Development of low-granularity 2D-readout with high tracking performance			- Layouts based on low resistivity DLC film and charge sharing	- Design, construction and test of prototypes with low-granularity 2D-readout	INFN-LNF

WP1: Tasks (defined so far)

TASK 1	TASK 2	TASK 3	TASK 4
New resistive RPC materials and production techniques for resistive layers	New Resistive MPGD Structures	New Front-end electronics	Optimization of scalable multichannel readout systems

TASK 5	TASK 6	TASK 7	TASK 8
Eco-friendly gases	Manufacturing	Thinner layer and increased mechanical precision over large areas	Longevity on Large Detector Areas

TASK 9	TASK 10
Low-mass MPGDs for inner-tracking at low-energy ee colliders	Compact and low power DAQ for low rates
SUGGEST TO INCLUDE IN TASK 2	Beyond HEP Could be moved to the new WP9

WP1: Institutes Expression of interest *as of today*

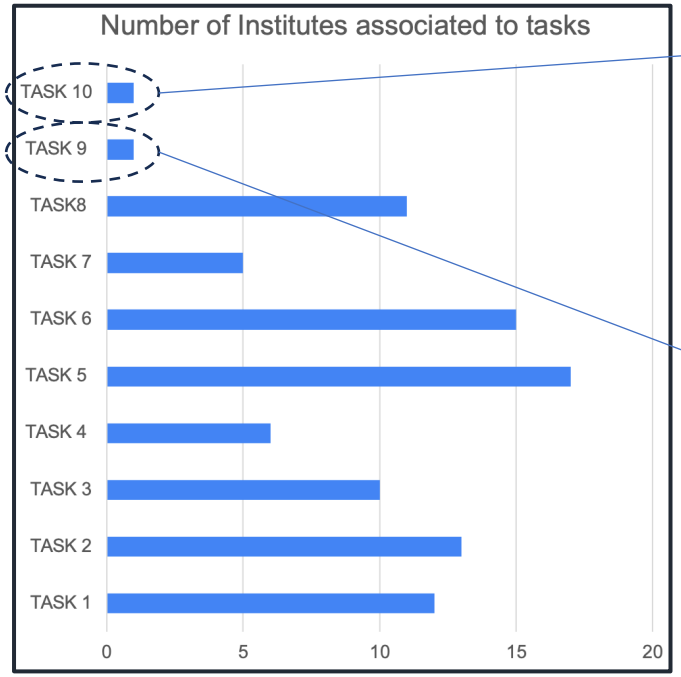
35 Institutes (so far)
Participating to
WP1 Strategic R&D

On average sharing their work
on 2.6 Tasks

STILL OPEN !

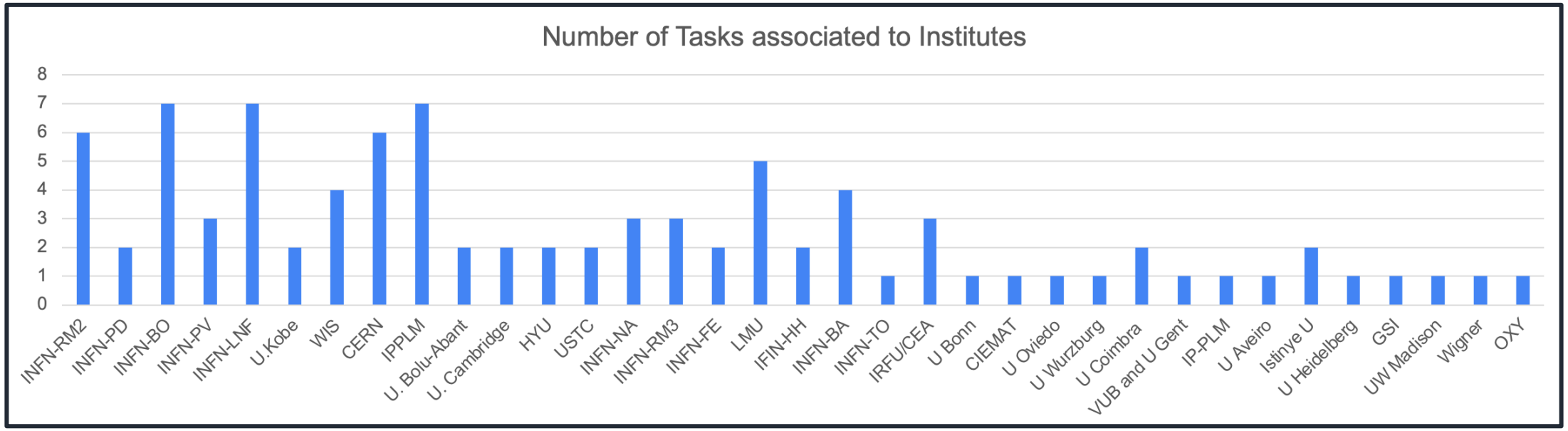
	TASK 1	TASK 2	TASK 3	TASK 4	TASK 5	TASK 6	TASK 7	TASK8	TASK 9	TASK 10	
INSTITUTES	New RPC	New Reistive MPGD(*)	New Front-end electronics	Scalable Readout systems	Eco-friendly gases	Manufacturing	Thinner layer / mechanical precision	Longevity on Large Detector Areas	Low Mass MPGD for Inner Tracking	Compact and low power DAQ for low rates	TOTAL
INFN-RM2	Task1		Task3		Task5	Task6	Task7	Task8			6
INFN-PD	Task1	Task2									2
INFN-BO	Task1	Task2	Task3	Task4	Task5	Task6		Task8			7
INFN-PV	Task1	Task2			Task5						3
INFN-LNF	Task1	Task2			Task5	Task6	Task7	Task8	Task9		7
U.Kobe	Task1	Task2									2
WIS	Task1	Task2				Task6		Task8			4
CERN	Task1	Task2	Task3	Task4	Task5	Task6					6
IPPLM	Task1	Tsk2	Task3	Task4	Task5	Task6	Task7	Task8			7
U. Bolu-Abant	Task1	Task2									2
U. Cambridge	Task1		Task3								2
HYU	Task1				Task5						2
USTC		Task2				Task6					2
INFN-NA		Task2				Task6		Task8			3
INFN-RM3		Task2				Task6		Task8			3
INFN-FE		Task2	Task3								2
LMU		Task2			Task5	Task6	Task7	Task8			5
IFIN-HH			Task3	Task4							2
INFN-BA			Task3		Task5		Task7	Task8			4
INFN-TO			Task3								1
IRFU/CEA			Task3		Task5			Task8			3
U Bonn				Task4							1
CIEMAT				Task4							1
U Oviedo					Task5						1
U Wurzburg					Task5						1
U Coimbra					Task5			Task8			2
VUB and U Gent					Task5						1
IP-PLM					Task5						1
U Aveiro					Task5						1
Istinye U					Task5	Task6					2
U Heidelberg						Task6					1
GSI						Task6					1
UW Madison						Task6					1
Wigner						Task6					1
OXY										Task10	1
TOTAL	12	13	10	6	17	15	5	11	1	1	91

WP1: Institutes Expression of interest *as of today*



TASK 10
Compact and low power DAQ for low rates
Beyond HEP - Could be moved to new WP9

TASK 9
Low-mass MPGDs for inner-tracking at low-energy ee colliders
SUGGEST TO INCLUDE IN TASK 2



NEXT STEPS 1/2

We are planning to organise meetings with the Institutes contact persons to:

- Share current work/experience and future planning within groups
- Confirm that Institutes want to commit to WP1 table.
- Better define the precise perimeters of the tasks – reshape tasks
- Define a list of deliverables
- Identify possible synergies, and possibly how the Institutes would cluster together
- Strengthen the collaboration

After this first step, all Institutes participating in WP1 will be contacted to report on specific projects, propose deliverables, and, CONFIDENTIALLY, report on available/requested resources.

A template will be provided for this new “survey”

NEXT STEPS 2/2

The purpose of this survey is to:

- Make sure that we reach the full community, all the institutions willing to commit on strategic R&D
- Ensure a precise alignment of Institutions with the proposed deliverables
- The proposed deliverables must be supported, and the achievements must be accomplished within the stated deadline.
- Define a comprehensive list of tasks and deliverables. The institutions linked to them will strengthen the connections among individuals who share the same R&D goals

Why do we want, CONFIDENTIALLY, details (as FTE covered/requested) by the groups?

- Have a complete overview of the workforce joining strategic R&D enterprise
- Ensure that a defined list of deliverables are within the reach of the Community