WP4 - Inner and Central Tracking with PID (TPC)
WP8 - TPC as Reaction and Decay Chamber
(Rare Events, Neutrino Physics, nuclear physics)

E. Ferrer Ribas, F. Garcia Fuentes, P. Gasik, D. Gonzalez Diaz,
J. Kaminski, F. Renga

Workpackages 4and 8 are described in chapter 4.2 of the extended DRD1 proposal:
https://indico.cern.ch/event/1273991/attachments/2668256/4624404/RD_EXTENDED-PROPOSAL__DRD1.pdf

WP4 – Inner and Central Tracking with PID (TPC)

Table 6

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3y	Interested Institutes
T1	IBF reduction	- Gain×IBF ≈ 1-2 - IBF optimization together with energy resolution and discharge stability	WG4, WG7 (7.1-2,5)	1.2	- Hybrid stacks - Gating GEM - Distortion corrections - Space-charge monitoring - Development of simulation tools - Operation in magnetic fields	- Provide a large-area prototype with a uniform IBF distribution of G*IBF=5 keeping the energy resolution at a tolerable level - Present a structure with stable settings for G×IBF of 1-2 - Determine the ion blocking power of a GEM-based gate - Provide systematic studies and simulations of IBF performance for the most common structures in (high) magnetic fields - Introduce an IBF calculator (Garfield-based) for optimization of the HV parameters	IFUSP, GSI, U Bonn, IRFU/CEA, USTC, KEK-IPNS, DESY, GANIL, RWTH Aachen, INFN-PD, IP-PLM, CERN, PSI, U Bursa, SBU, WIS, U Coimbra, U Aveiro, Wigner, SINP Kolkata
T2	Pixel-TPC development	- Produce 50000-60000 GridPixes to read out a full TPC - Achieve dN/dx counting-resolution < 4%	WG5, WG7 (7.1-2,5)	1.1	- InGrids (grouping of channels) - Low-power FEE - Optimization of pixel size (>200 μm) or cost reduction	- Provide a large-area pixel-based (InGrid) readout module - Measuring IBF for Gridpix. Reduction with double-mesh - Present dN/dx measurements in beam - Small area prototypes of MPGD/TimePix hybridisation.	U Bonn, U Carleton, WIS, CERN
T3	Optimization of the amplification stage and its mechanical structure, and development of low X/X_0 field cages (FC)	- Uniform response across a readout unit-area. - Keep $\sigma_{dE/dx} \approx 4\%$ - Point resolution of <100 μm - Minimize static distortions by reducing insensitive areas - Minimize $E \times B$ - Achieve E-field homogeneity at $\sim 10^{-4}$ level	WG1, WG4, WG6, WG7 (7.1-2,5)	1.1 1.2	**Minimization of static distortions:** - Algorithms for distortion corrections - Field shaping wires - Minimize GEM frame area (use thicker GEMs) - Laser systems **Main ampl. stages:** - Encapsulated resistive-anode MMG - Multiple GEM - GridPix - Hybrids **FC:** - high-quality strips, suspended strips - module flatness	- Provide a solution for a large-volume TPC with $\mathcal{O}(10^6)$ pad-readout by means of pre-production of several readout modules of comparable quality	IRFU/CEA, U Bonn, IHEP CAS, USTC, GANIL, CNRS-IN2P3/IJCLab, GSI, RWTH Aachen, INFN-RM1, INFN-PD INFN-BA, IPPLM, PSI, U Bursa, SBU, BNL, WIS, IFAE

Table 7

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3y	Interested Institutes
T4	Low-power FEE	- <5 mW/ch for >10^6 pad TPC - ASIC development in 65 nm CMOS	WG5	1.3	- Continuous vs. pulsed	- Present stable operation of a multi-channel TPC prototype with a low-power ASIC	IHEP CAS
T5	FEE cooling	- Operate 10^6 channels per end-plate	WG5	1.2	- Two-phase CO_2 cooling - Micro-channel cooling with 300 μm pipes in carbon fiber tubes - 3D printing: complex structures, performance optimization, material selection	- Present a prototype of a cooling system for the 10^6 pad TPC option	IRFU/CEA, U Lund, INFN-PI, INFN-LE, INFN-PD
T6	Gas mixture	Optimize: - Longevity - Ageing - Discharge probability - Drift velocity - Ion mobility	WG1, WG3 (3.1D, 3.2A, 3.2B), WG4, WG7 (7.1-3,5)	1.1	- Discharge probability, ageing, gas properties - Optimization of the HV working point - Optimization wrt. the expected resolution (aim for <100 μm) - Cluster ions	- Lower the discharge probability of readout units by 1-2 orders of magnitude down to $\sim 10^{-14}$ per hadron - Avoid secondary discharges in MPGD stacks	CERN, IFUSP, GSI, TUM, IHEP CAS, GANIL, USTC, CNRS-IN2P3/IJCLab, IRFU/CEA, CNRS-LSBB, RWTH Aachen, U Bonn, Bose, INFN-RM1, INFN-LE, INFN-PD, INFN-BA, IPPLM, USC/IGFAE, U Bursa, SBU, U Warwick, U Aveiro, U Bolu-Abant

Tasks

Tasks based on community survey in February/March:

Task 1: IBF reduction
Task 2: Pixel-TPC development
Task 3: Optimization of the amplification stage and its mechanical structure and development of low X/X0 field cages
Task 4: Low power FEE
Task 5: FEE cooling
Task 6: Gas mixtures

Should we regroup the tasks?
Along the lines of final applications?

WP 8 – TPC as Reaction and Decay Chamber (Rare Events, Neutrino Physics, nuclear physics)

Task 1: Enhance operation of optical readout across gas densities
Task 2: Enhance operation of charge readout across gas densities
Task 3: Enhance operation of pure or trace-amount doped noble gases
Task 4: Ultra-low-energy reconstruction of highly ionizing tracks (including R&D on negative-ion-readout)
Task 5: Determination of the interaction time (T0)
Task 6: Modeling
Task 7: Gas mixtures and gas handling
Task 8: Radiopurity

Table 11

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3y	Interested Institutes
T1	Enhanced operation of optical readout across gas densities	- Achieve an ionization-energy threshold of at least $\mathcal{O}$(keV) in the range 10 mbar to 10 bar (and, in the case of noble gases, to saturated vapours and even to the liquid state) with a scalable concept. - Reconstruction of MeV-nuclei of variable stopping power, with mm and sub-mm sampling.	WG1, WG6, WG7	1.2, 1.4	- High optical gain across gas densities in pure CF_4 and CF_4-based mixtures with keV-sensitivity. - Fine track sampling capabilities in the range of 10's of μm to few mm. - Adaptations in optics and camera readout to cover larger areas, at low granularity and with drift-time information (3D-readout). - Simultaneous detection of low and high ionization particles.	- Low-pressure nuclear track reconstruction at ≈10 keV. - Low-pressure electron-track reconstruction with the simultaneous reconstruction of nuclear tracks at ≈100 keV. - MIP tracking at 10 bar in argon-based gas mixture. - Reconstruction of MeV-nuclei with mm and sub-mm sampling at varying pressure and gas conditions. - Stability of reconstruction of nuclear-reaction byproducts over a large range of primary ionizations.	CERN, GANIL, ANU, IRFU/CEA, USC/IGFAE, GSSI, INFN-RM1, INFN-PD, INFN-BA, INFN-LNF, U New Mexico, STFC-RAL, IFIC, U Liverpool, U Genève, U Warwick, U Coimbra, Fermilab, MSU, HUJI, U Bursa, U Bolu-Abant, WIS, DIPC, U Hamburg, IFAE, AUTH
T2	Enhanced operation of charge readout across gas densities	- Achieve an ionization-energy threshold of at least $\mathcal{O}$(keV) in the range 10 mbar to 10 bar (and, in the case of noble gases, to saturated vapours and even to the liquid state) with a scalable concept. - Reconstruction of MeV-nuclei of variable stopping power, with mm and sub-mm sampling.	WG1, WG5, WG6, WG7	1.2, 1.4	- High avalanche gain across gas densities in CF_4, H_2, He, Ar, Xe -based TPCs with keV-sensitivity. - Fine track sampling capabilities in the range of 10's of μm to few mm. - High-density and low-power electronics, with the ability to self-trigger. - TimePix-based charge readouts.	- Low-pressure nuclear track reconstruction at ≈10 keV. - 1 keV ionization-energy threshold at high pressure. - Few MeV's-proton tracking at 10 bar in argon-based gas. - Reconstruction of MeV-nuclei with mm and sub-mm sampling at varying pressure and gas conditions. - Stability of reconstruction of nuclear-reaction byproducts over a large range of primary ionizations.	IRFU/CEA, GANIL, U Bonn, ANU, U Zaragoza, U Colorado, Fermilab, UH Manoa, MSU, RWTH Aachen, HUJI, U Bursa, U Bolu-Abant, U Warwick, WIS, CNRS-IN2P3/UGA, ISNAP, U Coimbra, INFN-LNS, SINP Kolkata, U Hamburg, U Aveiro, U New Mexico, AUTH
T3	Enhanced operation of pure or trace-amount doped noble gases	- Operation of m^2 and ton-scale detectors with single-electron sensitivity and near-Fano level energy resolution	WG1, WG3 (3.2C) WG6, WG7	1.4 (and DRD2)	- Enhancement of electroluminescence (EL) yield in noble gases (scalability, light output). - Single-electron detection. - Near-Fano energy resolution. - Stabilization of trace-amount doping (mixing, purification). - Barium tagging. - Stable amplification in dual-phase detectors. - Develop novel amplification structures	- Developing large-area ($\geq m^2$-scale) EL amplification: keeping energy resolution and single-electron sensitivity. - Imaging in low-diffusion gas. - A viable concept for Barium tagging or a viable roadmap towards it. - Very large-area ($\geq 10m^2$-scale) camara-based 3D imaging. - Operation of resistive-protected detectors.	DIPC, IFIC, U Manchester, U Liverpool, U Coimbra, LIP-Coimbra, AstroCeNT, Ben-Gurion U, WIS, U Aveiro, AUTH

Table 12

#	Task	Performance Goal	DRD1 WGs	ECFA DRDT	Comments	Deliv. next 3y	Interested Institutes
T4	Ultra-low-energy reconstruction of highly ionizing tracks (including R&D on negative-ion readout)	- Tracking of $\mathcal{O}$(10keV) nuclear tracks in a concept scalable to m^2 and beyond	WG1, WG5, WG6, WG7	1.2, 1.4	- Track reconstruction of nuclei down to 10 keV energies or below. - Simultaneous tracking of nuclei and electrons. - Accurate dE/dx-sampling for electron and nuclei identification. - ML for complex topologies. - Negative-ion TPCs for 3D-tracking on large areas, and associated electronics. - Optical readout in a negative ion TPC. - Track-reconstruction on spherical counters.	- A technology demonstrator in the m^2 scale, with $\mathcal{O}$(10keV) tracking-threshold for nuclear tracks at $\mathcal{O}$(10's of μm) sampling.	CERN, GANIL, ANU, IRFU/CEA, GSSI, INFN-RM1, INFN-PD, U New Mexico, STFC-RAL, MSU, UH Manoa, U Kobe, IHEP CAS, USTC, U Bolu-Abant, LIP-Coimbra, U Warwick, WIS, CNRS-IN2P3/UGA, ISNAP, U Coimbra, INFN-LNS, SINP Kolkata, U Hamburg, AUTH
T5	Determination of the interaction time (T_0)	- Achieve a viable timing signal while keeping low electron diffusion and high amplification of the ionization signal	WG3 (3.1A)	1.4 (and DRD2)	- T_0 sensitivity for accelerator-based neutrino TPCs. - T_0 sensitivity in the reconstruction of low-energy nuclear recoils, via scintillation light or minority carriers in case of negative-ion TPCs. - Explore the applicability of alternative methods (diffusion, positive ions) - T_0-determination on spherical counters.	- Demonstration of track reconstruction and T_0-tagging for minimum ionizing particles at $\mathcal{O}$(1 MeV)-threshold and high pressure.	IFIC, U Liverpool, AstroCeNT, Ben-Gurion U, U Zaragoza, GSSI, USC/IGFAE, Fermilab, DIPC, ANU, WIS, U Hamburg, U New Mexico
T6	Modelling	- Develop a microscopic framework for computing scintillation and negative-ion yields, and transport	WG3 (3.1A, 3.2A), WG4	1.3,1.4	- Modelling primary scintillation. - Modelling secondary scintillation. - Modelling ion transport and avalanche for electronegative mixtures. - Modelling space charge.	- Develop a framework for optical simulation that is integrated as part of the standard community tools, or develop a concrete implementation path towards it.	CERN, U Bursa, USC/IGFAE, IFIC, U Aveiro, AstroCeNT, GSSI, U Kobe, INFN-BA, WIS, DIPC, U Coimbra, SINP Kolkata, U Hamburg, U Aveiro, AUTH
T7	Gas mixtures and gas handling	Study new gas mixtures, operated in conditions of high purity	WG3 (3.1B, 3.2C), WG6, WG7	1.3, 1.4	- New gas mixtures for optical readout. - New gas mixtures for negative-ion readout. - Recirculation and recuperation systems. - Purification of low-quenched mixtures.	- Develop alternatives to CF_4-based mixtures operated in open loop, or a viable path towards it.	USC/IGFAE, DIPC, U Coimbra, CERN, U Liverpool, GSSI, INFN-RM1, U Zaragoza, Fermilab, RWTH Aachen, U Warwick, WIS, DIPC, ISNAP, U Hamburg, U Aveiro, U New Mexico, AUTH
T8	Radiopurity	- Improve manufacturing process and purification as well as material-selection standards	WG3		- Radon emanation studies - Mitigation of gaseous radioactive isotopes - Material selection - Develop radiopure amplification structures and radiopure optical cameras.	- Develop MPGDs and manufacturing techniques with high radiopurity.	USC/IGFAE, DIPC, U Liverpool, GSSI, U Zaragoza, U Hamburg

DRD1-WG5 ↔ DRD7

Regroup:
1- Electroluminescence-based TPCs.
2- High Pressure TPCs for neutrino beams.
3- TPCs for nuclear physics.
4- TPCs aimed at providing event directionality down to keV-energies.
5- Radiopure TPCs with keV energy-threshold for rare event searches.

TPC – Community Meeting

July 5th 2023 via zoom

14:30 - 15:30 Discussion on WP4
16:00 - 17:00 Discussion on WP8

Both sessions will start with an introduction into DRD1 and the concepts of Working Groups and Work Packages
Followed by a discussion on participation possibilities and tasks