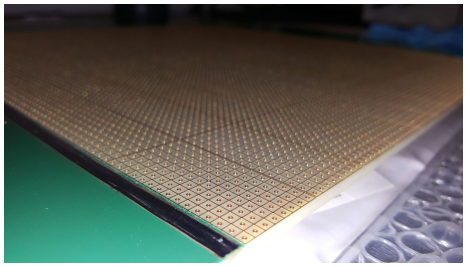
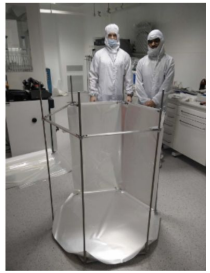
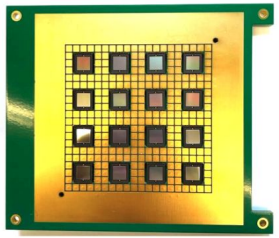
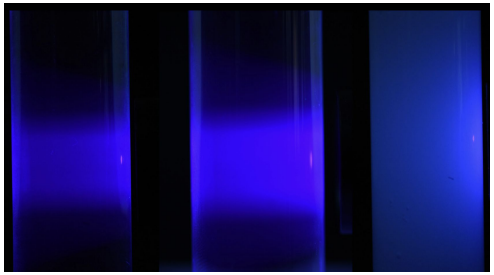


DRD2: Liquid Detectors

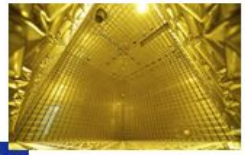
Giuliana Fiorillo
Roxanne Guenette

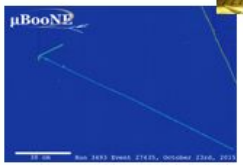
4th Meeting of the DRDC
13 November 2024

Our scientific communities

Neutrinos

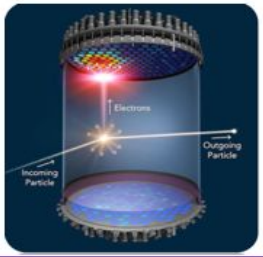
- Oscillation precision measurements (δ_{CP}, mass ordering, θ_{23} octant, sterile νs)
- Neutrino interactions (from CEvNS to DIS)
- Astro neutrinos





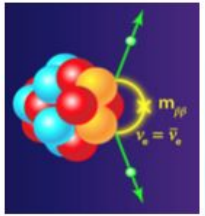
Dark Matter

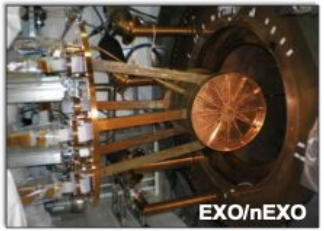
- Direct detection (WIMPs, …)



0νββ

- Search for Majorana neutrinos

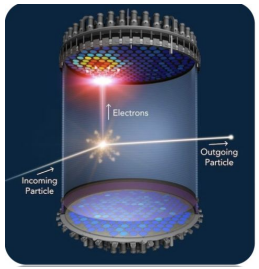


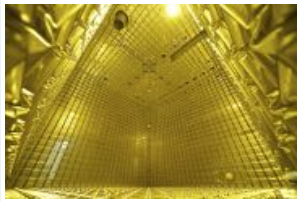


Our technology communities

Noble Elements

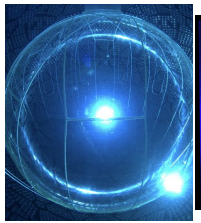
- Argon & Xenon
- Ionisation charge & transport
- VUV Scintillation, light propagation & detection

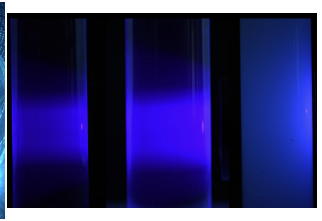




Liquid Scintillators

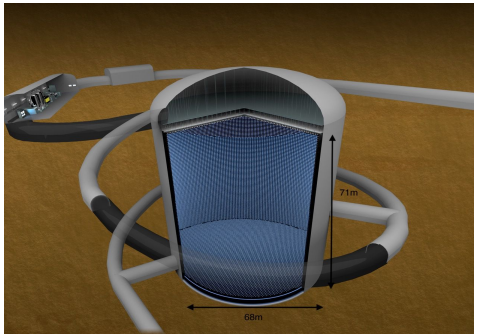
- Visible Scintillation, light propagation
- Scintillator properties
- Isotope loading





Water Cherenkov

- Cherenkov light, light propagation
- Doping for n-capture



Main drivers	*DUNE programme; Hyper-K programme; neutrino near detectors; neutrino telescopes; multi-tonne scale dark matter detectors; light dark matter detectors; tonne-scale 0vbb experiments; low-energy scintillator neutrino detectors.*

Our roadmap

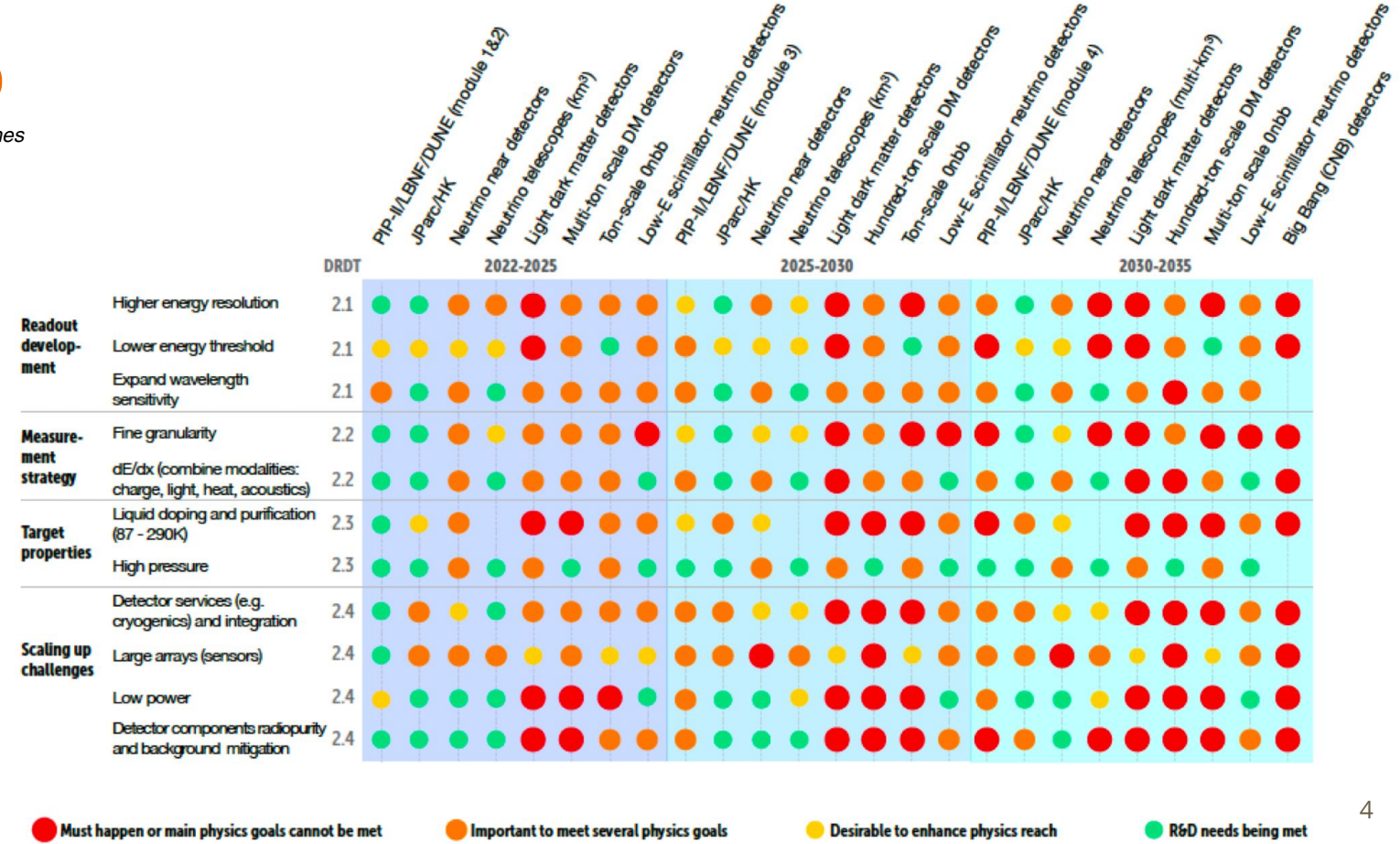
Detector R&D Research Themes

DRDT 2.1 - Develop readout technology to increase spatial and energy resolution for liquid detectors

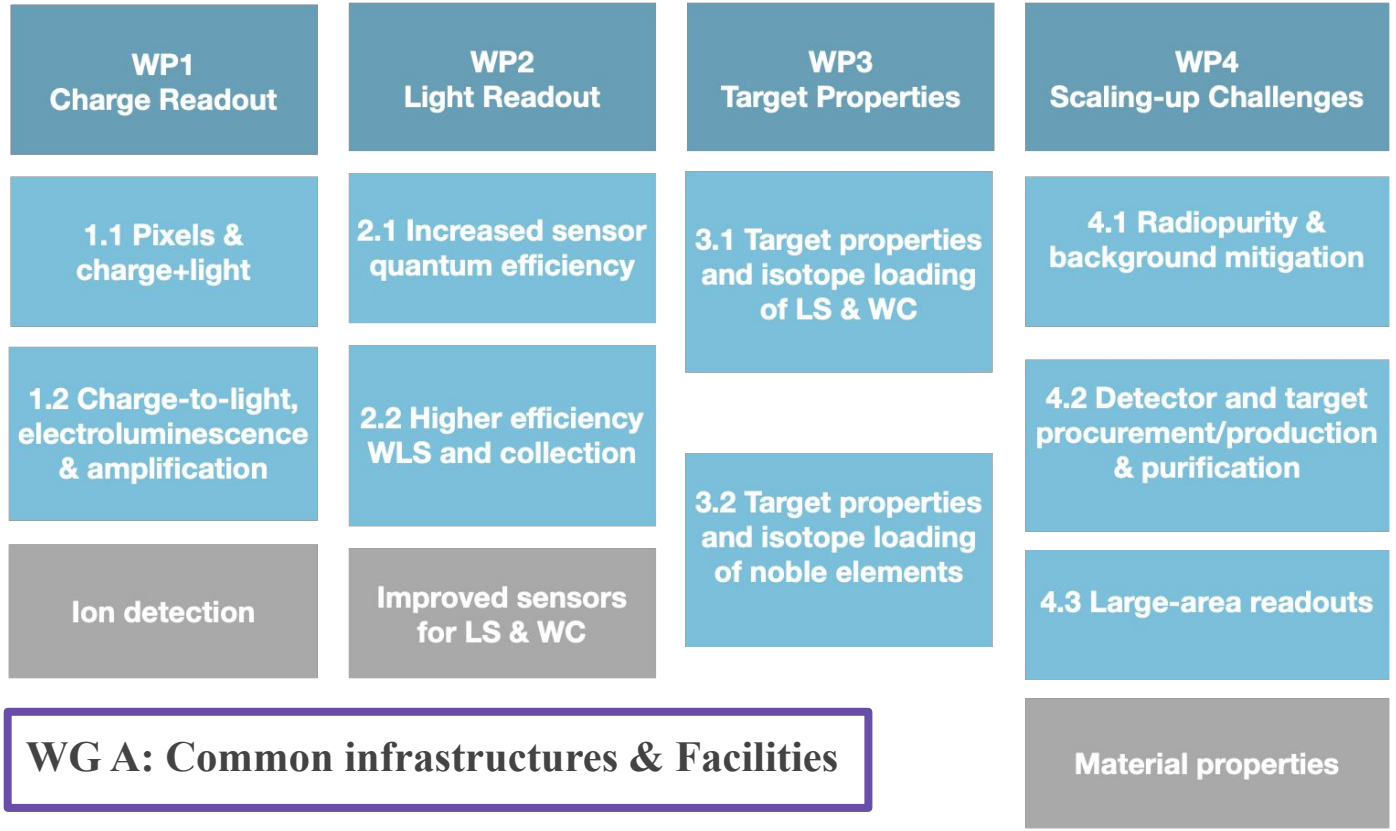
DRDT 2.2 - Advance noise reduction in liquid detectors to lower signal energy thresholds

DRDT 2.3 - Improve the material properties of target and detector components in liquid detectors

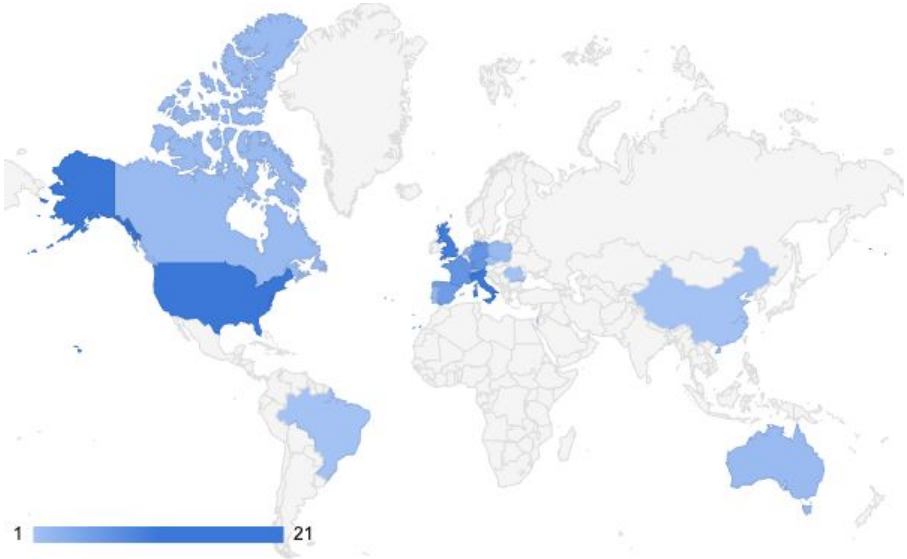
DRDT 2.4 - Realise liquid detector technologies scalable for integration in large systems

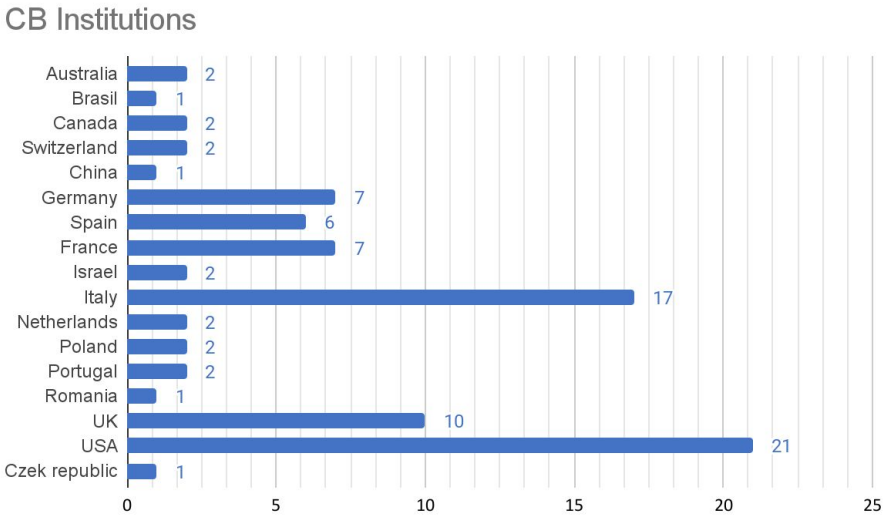


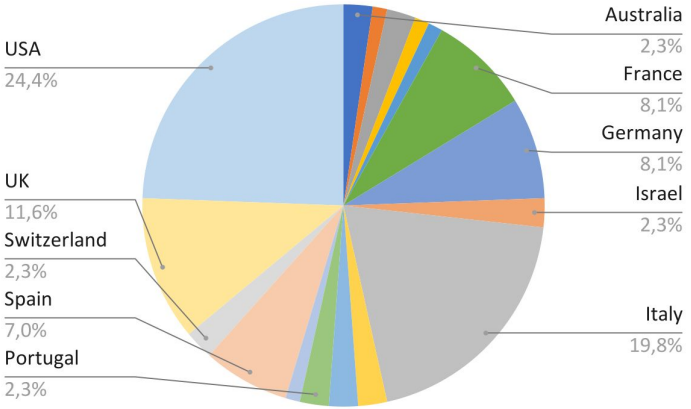
Our scientific strategy: Work Packages



The DRD2 Collaboration



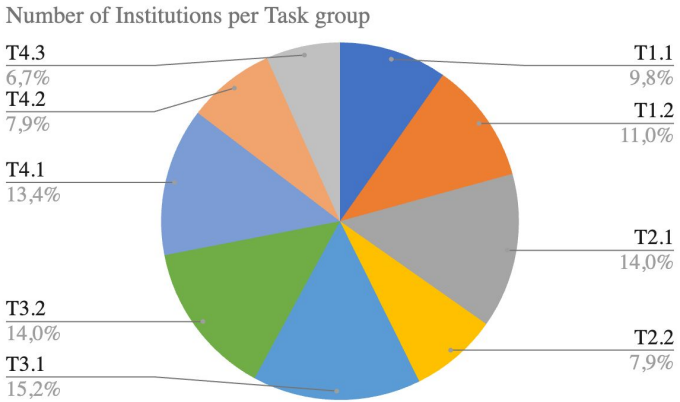


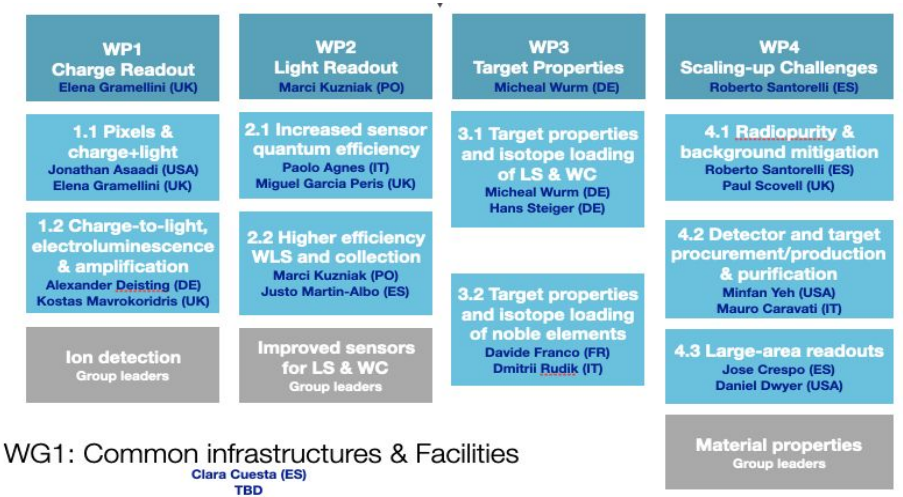


86 Participating Institutions
17 Countries
205 Members

Progress in DRD2 since approval

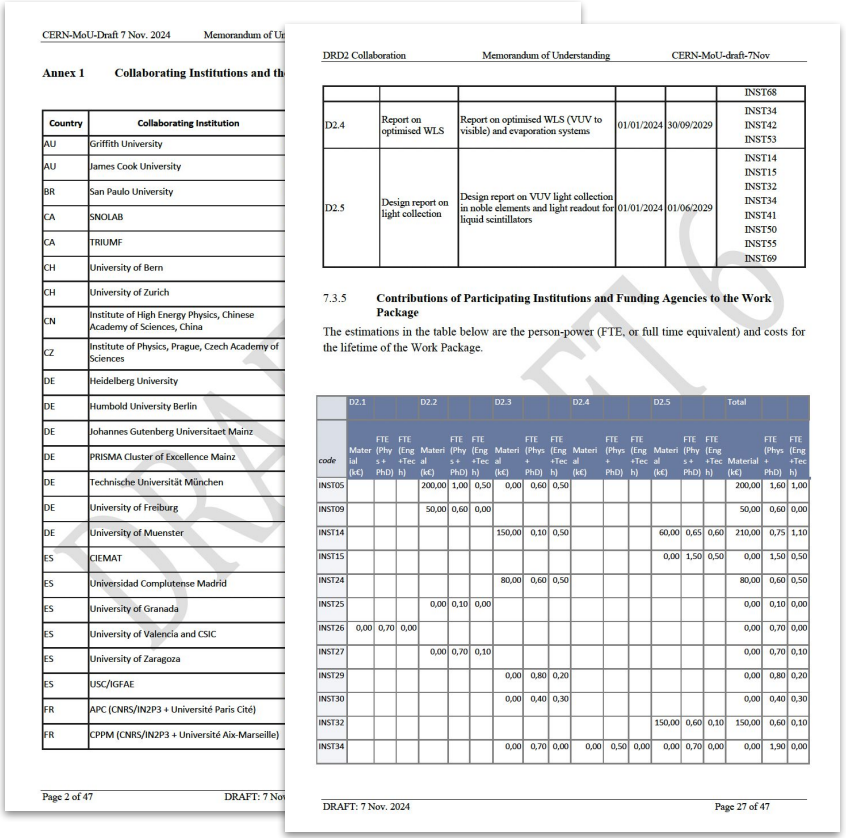
- First Collaboration Meeting (02/2024) (indico link)
- CB Chair election: Walter Bonivento
- Co-spokespersons election: Giuliana Fiorillo, Roxanne Guenette
- All WP/Tasks leaders appointed and approved
- Creation of first WG and appointment of 1 convener
- Series of Topical Workshop to engage the community (indico meetings)





Progress in DRD2 since approval

- A lot of work done on consolidating the Deliverables and the “commitments” of each Tasks to prepare the MOU Annexes
- Concerns from many of our members on interactions with funding agencies, commitments and lack of funding… under discussion
- We send the **draft** MOU Annexes to Helge Meinhard as requested on 8 Nov., but we need to solve the concerns of our groups before making them public



CERN-MoU-Draft 7 Nov. 2024 Memorandum of Ut

Annex 1 Collaborating Institutions and th

Country	Collaborating Institution
AU	Griffith University
AU	James Cook University
BR	San Paulo University
CA	SNOLAB
CA	TRIUMF
CH	University of Bern
CH	University of Zurich
CN	Institute of High Energy Physics, Chinese Academy of Sciences, China
CZ	Institute of Physics, Prague, Czech Academy of Sciences
DE	Heidelberg University
DE	Humbold University Berlin
DE	Johannes Gutenberg Universitaet Mainz
DE	PRISMA Cluster of Excellence Mainz
DE	Technische Universität München
DE	University of Freiburg
DE	University of Muenster
ES	CIEMAT
ES	Universidad Complutense Madrid
ES	University of Granada
ES	University of Valencia and CSIC
ES	University of Zaragoza
ES	USC/IGFAE
FR	APC (CNRS/IN2P3 + Université Paris Cité)
FR	CPPM (CNRS/IN2P3 + Université Aix-Marseille)

Page 2 of 47 DRAFT: 7 Nov

DRD2 Collaboration Memorandum of Understanding CERN-MoU-draft-7Nov

					INST68
D2.4	Report on optimised WLS	Report on optimised WLS (VUV to visible) and evaporation systems	01/01/2024	30/09/2029	INST34 INST42 INST53
D2.5	Design report on light collection	Design report on VUV light collection in noble elements and light readout for liquid scintillators	01/01/2024	01/06/2029	INST14 INST15 INST32 INST34 INST41 INST50 INST55 INST69

7.3.5 **Contributions of Participating Institutions and Funding Agencies to the Work Package**

The estimations in the table below are the person-power (FTE, or full time equivalent) and costs for the lifetime of the Work Package.

	D2.1			D2.2			D2.3			D2.4			D2.5			Total		
code	Material (k€)	FTE (Phys + PhD)	FTE (Eng +Tech)	Material (k€)	FTE (Phys + PhD)	FTE (Eng +Tech)	Material (k€)	FTE (Phys + PhD)	FTE (Eng +Tech)	Material (k€)	FTE (Phys + PhD)	FTE (Eng +Tech)	Material (k€)	FTE (Phys + PhD)	FTE (Eng +Tech)	Material (k€)	FTE (Phys + PhD)	FTE (Eng +Tech)
INST05				200,00	1,00	0,50	0,00	0,60	0,50							200,00	1,60	1,00
INST09				50,00	0,60	0,00										50,00	0,60	0,00
INST14							150,00	0,10	0,50				60,00	0,65	0,60	210,00	0,75	1,10
INST15													0,00	1,50	0,50	0,00	1,50	0,50
INST24							80,00	0,60	0,50							80,00	0,60	0,50
INST25				0,00	0,10	0,00										0,00	0,10	0,00
INST26	0,00	0,70	0,00													0,00	0,70	0,00
INST27				0,00	0,70	0,10										0,00	0,70	0,10
INST29							0,00	0,80	0,20							0,00	0,80	0,20
INST30							0,00	0,40	0,30							0,00	0,40	0,30
INST32													150,00	0,60	0,10	150,00	0,60	0,10
INST34							0,00	0,70	0,00	0,00	0,50	0,00	0,00	0,70	0,00	0,00	1,90	0,00

DRAFT: 7 Nov. 2024 Page 27 of 47

WP1 Charge Readout: Progress

WP1.1 Pixels & charge+light

(J. Asaadi & E. Gramellini)

- Consolidated the scientific programme to 3 Deliverables: TPC pixelation, Pixel scalability, Charge + Light readouts

	Title	Description	Institutions
D1.1	Pixel readout prototype	Prototype of lower power and lower pixel thresholds to the limit of CMOS capabilities	5
D1.2	Large-scale pixel readout design	Design of a pixel readout with O(100 million) channels	4
D1.3	Light-sensitive pixel readout design	Design (simulation and prototype) of maximal photocathode coverage and QE in an integrated fC charge and VUV light sensing scheme for pixel TPCs	7

WP1 Charge Readout: Progress

WP1.1 Pixels & charge+light

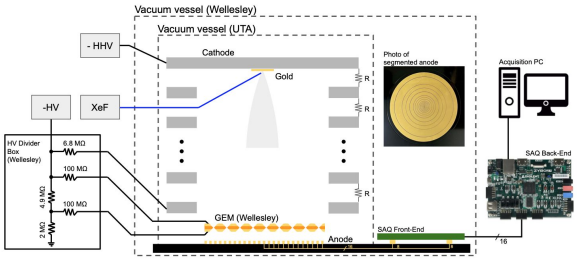
(J. Asaadi & E. Gramellini)

CH: Bern
ES: University of Granada
IT: INFN BO, MIB
UK: Imperial, Manchester
US: SLAC, MIT, UTA, Wellesley

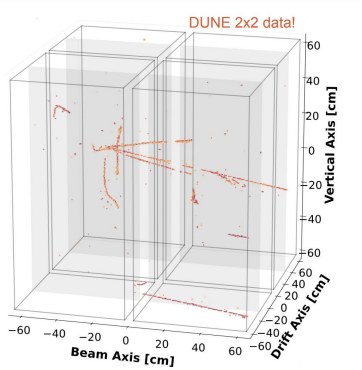
Scientific progress:

D1.1 First operation of a multi-channel Q-Pix prototype with COTS component

(JINST 19 (2024) 06, P06007)

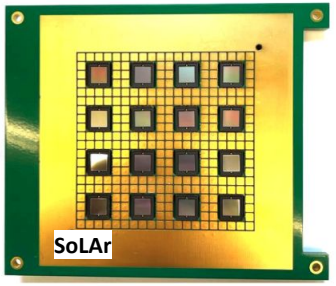


D1.2 Deployment and operation of the LArPix readout concept in the 2x2 demonstrator on the NuMI beam



From Andrew Cudd at NuFact

D1.3 Data analysis from the first SoLAr prototype (accepted in JINST)



WP1 Charge Readout: Progress

WP1.2 Charge-to-light, EL & Amplification

(A. Deisting & K. Mavrokoridris)

- Consolidated the scientific programme to 3 Deliverables: camera and SiPM-based particle tracking, novel devices for charge amplification in single- and dual-phase, large-scale demonstrators

	Title	Description	Institutions
D1.4	Prototype for imaging light readout	Prototypes for light imaging of charge amplification with cameras and SiPMs	2
D1.5	Report on novel charge amplification devices	Report on novel devices for charge amplification in single- and dual-phase detectors	12
D1.6	Report on large-scale tests for amplification devices	Report on large-scale tests in single- and dual-phase LAr and LXe detectors	4

WP1 Charge Readout: Progress

WP1.2 Charge-to-light, EL & Amplification

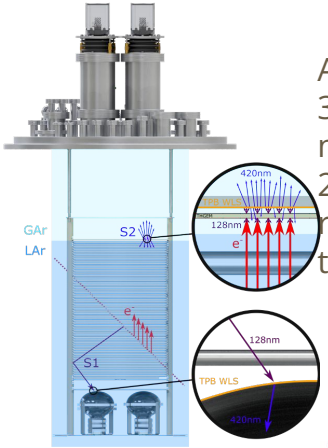
(A. Deisting & K. Mavrokoridis)

AU: Griffith, James Cook
BR: University of São Paulo
DE: Mainz, Freiburg
FR: LPNHE
IL: Tel Aviv University
NL: Nikhef
PT: LIP Coimbra
UK: Liverpool, Manchester
US: UC Riverside

Scientific Progress:

D1.4 Publications towards imaging light readouts

Demonstration of energy resolution with SiPMs imaging plane (NEXT-White)
Contreras, T., et al., *J. High Energ. Phys.* **2024**, 112

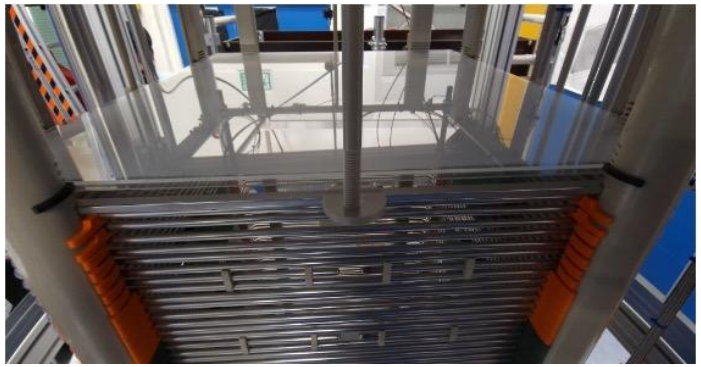


ARIADNE, demonstration at scale of full 3D optical TPC:
new ARIADNE run finished in summer 2024: 3 TPX cameras installed, with the remaining ¼ of the detector dedicated to Darkside type SiPMs

https://iopscience.iop.org/article/10.1088/1748-0221/14/06/P06001

https://www.mdpi.com/2410-390X/4/4/35

D1.5 New charge amplification structure



Glass THGEMs (54cm x 54cm) for ARIADNE

WP2 Light Readout: Progress

WP2.1 Increase sensor quantum efficiency

(P. Agnes & M. Garcia Peris)

- Consolidated the scientific programme to 3 Deliverables: effort targeted at efficiency in the VUV and at cryogenic temperatures, complementarity with WP1 of DRD4

	Title	Description	Institutions
D2.1	Sensor development for VUV sensitivity	Development and characterization of organic photosensors, coatings and passivation methods and of SPAD geometry for VUV detection	7
D2.2	Prototype SPAD arrays	Prototypes and characterization of new SPAD arrays for 3D-intergrated FSI and BSI, analog BSI and monolitich arrays	8
D2.3	Report on VUV-optimized sensor	Report on the performance of new VUV-optimised sensors in term of PDE, noise and application to rare-event seraches	8

WP2 Light Readout: Progress

WP2.1 Increase sensor quantum efficiency

(P. Agnes & M. Garcia Peris)

Scientific Progress:

D2.1 Funding updates

1. Funding secured to acquire and test large area organic semiconductors.
2. Funding available (Open University) for VUV optimised coating technologies for CMOS detectors.
3. Funding proposal submitted (STFC) to test graphene coating (Oxford, Manchester) on existing SiPM devices.

D2.2 Arrays & funding updates

- 3D integrated FSI-SPAD arrays (Sherbrooke+Teledyne-DALSA): First prototypes late 2024

- Funding secured for 3D integrated BSI-SPAD arrays (Heidelberg-TRIUMF-Fraunhofer)

- BSI-SPAD arrays (Bo-SLAC-FBK): 2 engineering runs (INFN IBIS) 1 planned (INFN IBIS_NEXT). Funding available

- Funding secured for a production run of monolithic CMOS-SPAD arrays (Fermilab-GlobalFoundries). First delivery expected in March 2025.

D2.3 Facility networks updates

- Detailed characterization setups for detection efficiency.
  - ➔Setup assembly ongoing at INFN-Naples and INFN-LNGS, CIEMAT.
  - ➔Setup operational at TRIUMF

- Operation in LAr and LXe for noise rates of single photon detection.
  - ➔Setup operational at INFN-Ferrara and TRIUMF
  - ➔Funding allocated at INFN-LNGS/GSSI

- Operation for rare-event search experiments.
  - ➔Funding available at UC Riverside and University of Tel Aviv for small scale TPCs

WP2 Light Readout: Progress

WP2.2 Higher efficiency WLS and collection

(M. Kuzniak & J. Martin-Albo)

- Consolidated the scientific programme to 2 Deliverables: WLS and light collection optimization

	Title	Description	Institutions
D2.4	Report on optimised WLS	Report on optimised WLS (VUV to visible) and evaporation systems	3
D2.5	Design report on light collection	Design report on VUV light collection in noble elements and light readout for liquid scintillators	10

WP2 Light Readout: Progress

Scientific Progress:

WP2.2 Higher efficiency WLS and collection

(M. Kuzniak & J. Martin-Albo)

D2.4: Finalized analysis of a large-scale PEN WLS test at CERN (in collaboration with the Neutrino Platform)

- ➢ Optimal reflector/WLS combination previously selected with bench top measurements (Goldbrunner et al., LIDINE 2023)
- ➢ **4 m^2 of commercial industry grade PEN + ESR tested over 2 weeks in a 2 tonne LAr dewar**
- ➢ LY consistent with expectation, with no evidence for degradation (V. Gupta et al., LIDINE 2024)

Led by Astrocent, CERN, U. Edinburgh, U. Hawaii, Nikhef, TUM, Uni. Zurich

D2.4: other updates

- ●Ongoing efforts on optimized PEN synthesis
  - ○Custom synthesised PEN already as good or better than commercially available PEN, but still less efficient than TPB
- ●Complementary WLS characterization/qualification facilities:
  - ○Setup for cryogenic WLS characterization operational at Astrocent (Choudhary et al., LIDINE 2024)
- ●In parallel, new promising polymeric materials under investigation
  - ○PVN:(Kuźniak et al., LIDINE 2024)
- ●Strong interest in all the above from the DUNE community

D2.5: Publications

- ●Novel simulation method for large-area metalenses
  - ○A.Martins et al., J. Opt. Soc. Am. B **41**, 1261-1269 (2024)
- ●First VUV metalenses
  - ○A.Martins et al., arXiv:2401.11315

WP3 Target Properties: Progress

WP3.1 Target properties and isotope loading of LS & WC

(H. Steiger & M. Wurm)

- Consolidated the scientific programme to 2 Deliverables: hybrid Cherenkov/scintillator systems, opaque scintillators, and isotope loading for neutrinoless double-beta decay (0νββ) searches and neutron tagging

	Title	Description	Institutions
D3.1	Ton-scale demonstrators of novel liquid scintillators	Lab- and ton-scale demonstrators for hybrid and opaque scintillators, publication on properties and performances and improved microphysics models	16
D3.2	Demonstrators for liquid target loading	Demonstration of high Gd loading at ton-scale and of high concentration of isotope loading	9

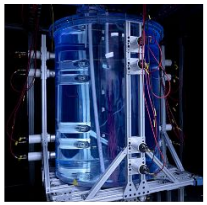
WP3 Target Properties: Progress

WP3.1 Target properties and isotope loading of LS & WC

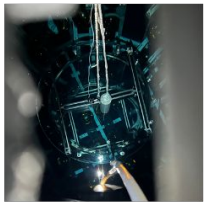
(H. Steiger & M. Wurm)

Scientific Progress:

D3.1: Progress at ton-scale on hybrid (water-based) scintillators detectors:

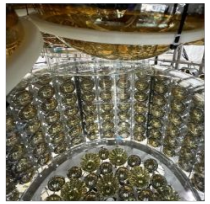


BNL prototypes: 1-ton → 30-ton
- production, purification and characterization of WbLS
- status: construction of 30-ton prototype is on-going



ANNIE (FNAL): SANDI Acrylic Vessel
- hybrid reconstruction of beam neutrinos (GeV range)
- recent deployment of SANDI vessel with 365kg of Gd-loaded WbLS

→ detection of final-state neutrons
→ Cherenkov/scintillation separation with PMTs & LAPPDs



EOS (Berkeley)
- hybrid detection at MeV energies
- detector complete, final preparations for filling with WbLS

→ coordinated program of German/US groups
→ link to BUTTON in the UK

D3.1 : demonstration of Cherenkov/scintillation separation in novel bi-solvent slow scintillators
→ with small-scale lab setup (Berkeley)
→ **new collaborative effort** to demonstrate in larger vessel (30L scale) in a particle beam at INFN-LNL Legnaro (TUM/**Padova**/Mainz)

D3.1 : group of **INFN Milano** (Caccianiga) recently joined DRD2 for lab-scale characterization of hybrid scintillators

D3.1 : two joint publications on bi-solvent slow scintillators and water-based liquid scintillator using Triton-X (TUM/Mainz)

D3.2 : tellurium-doping of LAB-based conventional and slow scintillators with high loading factors, using different techniques
→ Oxford/SNOLab, **IHEP Beijing** (recently joined DRD2), TUM

WP3 Target Properties: Progress

WP3.2 Target properties and isotope loading of noble elements

(D. Franco & D. Rudik)

- Consolidated the scientific programme to 2 Deliverables: noble liquids microphysics + properties of mixtures

	Title	Description	Institutions
D3.3	Measurement of noble liquid response for low-energy recoils	Characterization of NL response to low-energy recoils and design of low-energy calibration systems	10
D3.4	Measurement of noble liquids mixtures properties	Characterization and measurement of properties of NL mixtures	13

WP3 Target Properties: Progress

WP3.2 Target properties and isotope loading of noble elements

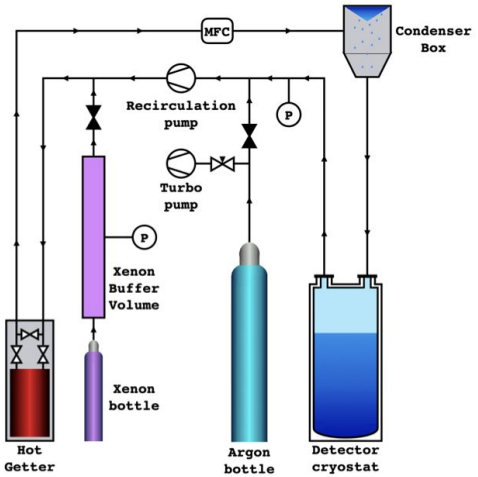
(D. Franco & D. Rudik)

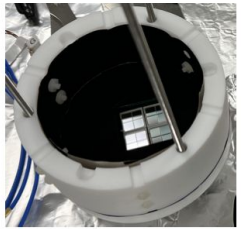
CN: IHEP, CAS
ES: University of Granada
FR: APC, LPNHE, Mines Paris
IT: GSSI, INFN LNS, Milano, Napoli
PT: LIP Coimbra
UK: Uni Edinburgh
US: Colorado State, LLNL, UC Riverside

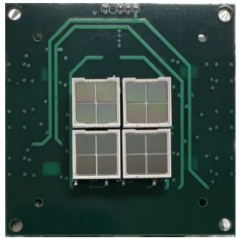
Scientific Progress:

D3.4: Publication

- EUV scintillation from xe-doped LAr
  - P.Agnes et al., X-ArT
    https://arxiv.org/abs/2410.22863







WP4 Scale-up Challenges: Progress

WP4.1 Radiopurity and background mitigation

(R. Santorelli & P. Scovell)

- Consolidated the scientific programme to 3 Deliverables: radioassay techniques, low-bckgd materials, bckgd evaluation

	Title	Description	Institutions
D4.1	Report on improved radioassay techniques	Demonstration of radioassay techniques at required sensitivity for next generation of rare-event search experiments	8
D4.2	Report on low-background materials	Report on the development of novel materials, material selection, and clean treatment/manufacturing processes	8
D4.3	New tools for background evaluation	Development of new tools for background simulations and measurements of cross-section materials	6

WP4 Scale-up Challenges: Progress

WP4.1 Radiopurity and background mitigation

(R. Santorelli & P. Scovell)

Scientific Progress:

D4.1: Radioassay Techniques

- Recent addition of Underground Labs (Canfranc, Boulby, Modane, Rustrel)
  - Agreement to coordinate
- Plans for a virtual workshop

Radioassay @ Boulby, UK

Radioassay @ LSC, Spain

WP4 Scale-up Challenges: Progress

WP4.2 Detector and target procurement/production & purification

(M. Caravati & M. Yeh)

- Consolidated the scientific programme to 2 Deliverables: production & purification facilities, radiopurity assesment and verification

	Title	Description	Institutions
D4.4	Mass production facilities	Purification and production plants for liquid targets	8
D4.5	Demonstration of UAr purification technology	Demonstration of improved purification technologies on testbeds	5

WP4 Scale-up Challenges: Progress

WP4.2 Detector and target procurement/production & purification

(M. Caravati & M. Yeh)

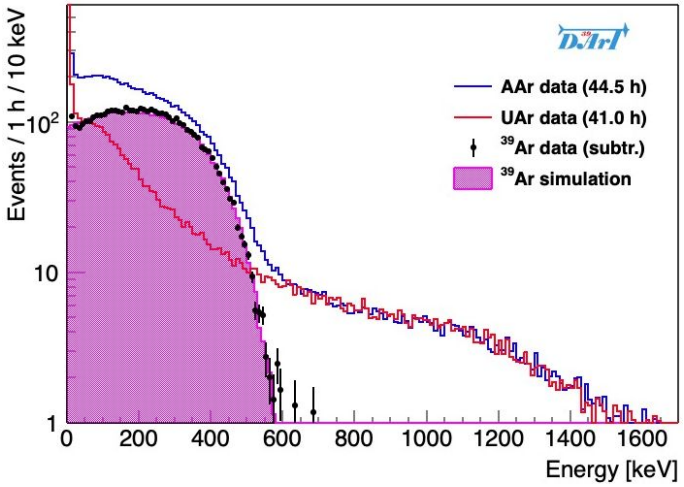
CA: SNOLAB
DE: Muenster, JGU Mainz
ES: CIEMAT
IT: GSSI, INFN Cagliari
UK: University of Oxford
US: BNL, LLNL, UC RIverside

Scientific Progress:

D4.5 Demonstration of UAr purification technology

DArT @ LSC

- Concept validated by measurement of ^{39}Ar spectrum by comparing AAr and UAr with DArT in a test cryostat
- ArDM detection refurbished for single-phase operation
- Full setup for ^{39}Ar ready by January 2025



Single electron

- cryogenic setup under advanced testing at INFN Cagliari

WP4 Scale-up Challenges: Progress

WP4.3 Large-area readouts

(J. Crespo & D. Dwyer)

- Consolidated the scientific programme to 2 Deliverables: mid-scale and large-scale facilities for integration tests

	Title	Description	Institutions
D4.6	Medium-scale integrated testing facilities	Development of mid-scale facilities for large-area readout assembly and characterization at cryogenic temperature	6
D4.7	Report on large-area readout	Report on large-scale light and charge readout systems	5

WP4 Scale-up Challenges: Progress

WP4.3 Large-area readouts

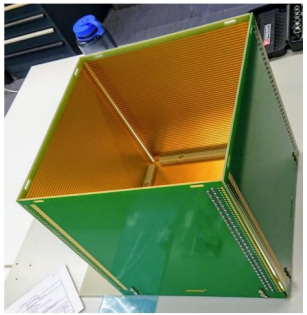
(J. Crespo & D. Dwyer)

Scientific Progress:

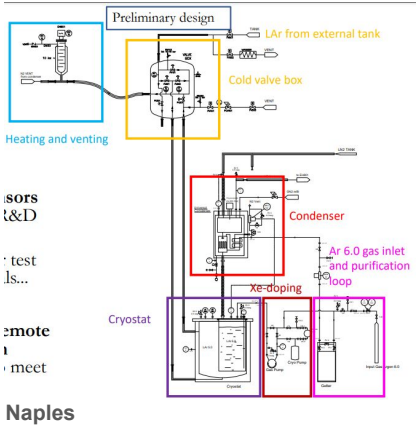
CH: UZH
ES: CIEMAT
IT: INFN Napoli, LNGS
US: LBL, MIT, Stony Brook

D4.6: Testing Facilities

CIEMAT

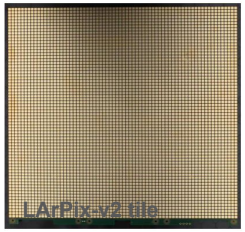


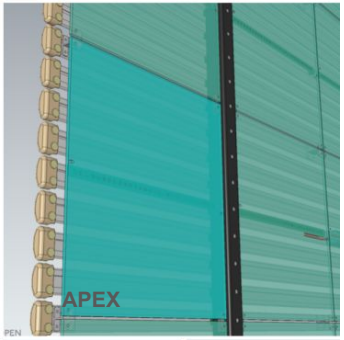
LArTPC kit



Naples

D4.7: Large-scale integration





Xenoscope

WG A: Common Infrastructure and Facilities

Slower progress here because nominated one co-convener stepped down, the other one is on parental leave and we needed a better picture of the facilities (work undertaken by the Tasks)

We plan to use the Working Group to mitigate the inclusion of groups who cannot commit to Deliverables

Summary of progress

All Tasks have made progress and have planned for scientific exchange activities (workshops, task meetings…)

General Collaboration Meeting to be held at CERN (TBC) on 11-13 February 2025

We succeeded into bringing together the different communities, we now need to maintain momentum!

Thank You

Backup

WP1.1

D1.1	Pixel readout prototype	Prototype of lower power and lower pixel thresholds to the limit of CMOS capabilities	T1.1.G1.D1	Prototype of lower power and lower pixel thresholds to the limit of CMOS capabilities
				removed
D1.2	Large-scale pixel readout design	Design of a pixel readout with O(100 million)	T1.1.G2.D1	Design of a pixel readout with O(100 million)
D1.3	Light-sensitive pixel readout design	Design (simulation and prototype) of maximal photocathode coverage and QE in an integrated fC charge and VUV light sensing scheme for pixel TPCs	T1.1.G3.D1	Design (simulation and prototype) of maximal photocathode coverage and QE in an integrated fC charge and VUV light sensing scheme for pixel TPCs
				removed

WP1.2

D1.4	Prototype for imaging light readout	Prototypes for light imaging of charge amplification with cameras and SiPMs	T1.2.G1.D1	Prototype demonstrating particle tracking (2030)
				removed
				removed
D1.5	Report on novel charge amplification devices	Report on novel devices for charge amplification in single- and dual-phase detectors	T1.2.G2.D1	Report on novel devices to for charge amplification in dual-phase detectors (2027)
				removed
				removed
			T1.2.G2.D3	Report on the feasibility of novel amplification strategies for single- and mixed-phase detectors
			T1.2.G2.D4	Theoretical models of electron transport in LAr/LXe, and simulation models of PMT, SIPM pulse shapes
D1.6	Report on large-scale tests for amplification devices	Report on large-scale tests in single- and dual-phase LAr and LXe detectors	T1.2.G3.D1	Report on LAr / dual phase Ar large scale tests with TPX readout (2030)
			T1.2.G3.D2	Report on large scale tests with a single-phase LXe and dual-phase Xe charge-to-light conversion stage (2030)

WP2.1

D2.1	Sensor development for VUV sensitivity	Development and characterizationof organic photosensors, coatings and passivation methods and of SPAD geometry for VUV detection	T2.1.G1.D1	Characterization of low-noise, high fill-factor organic photosensors
			T2.1.G1.D2	Purpose-optimised coatings and passivation strategies for LAr/LXe wavelengths
			T2.1.G1.D3	Designs of SPAD geometries optimized for VUV sensitivity
D2.2	Prototype SPAD arrays	Prototypes and characterization of new SPAD arrays for 3D-intergrated FSI and BSI, analog BSI and monolitich arrays	T2.1.G2.D1	Prototype of 3D integrated FSI-SPAD arrays and characterization
			T2.1.G2.D2	Prototype of 3D integrated BSI-SPAD arrays and characterization
			T2.1.G2.D3	Prototype of analog BSI-SPAD arrays and characterization
			T2.1.G2.D4	Prototypes of cryogenic monolithic SPAD arrays and characterization
D2.3	Report on VUV-optimized sensor	Report on the performance of new VUV-optimised sensors in term of PDE, noise and application to rare-event seraches	T2.1.G3.D1	PDE vs. λ,T, angle measurement
			T2.1.G3.D2	Report on sensor noise characterisation
			T2.1.G3.D3	Paper on rare-event search application

WP2.2

D2.4	Report on optimised WLS	Report on optimised WLS (VUV to visible) and evaporation systems	T2.2.G1.D1	Technical report of optimized WLS (2027)
			T2.2.G1.D2	Construction of a large-area multi-source evaporation system (2027)
D2.5	Design report on light collection	Design report on VUV light collection in noble elements and light readout for liquid scintillators	T2.2.G2.D1	Design report of VUV light collectors at cryogenic temperatures (2028)
			T2.2.G2.D2	Design report of light readout for liquid scintillator (2028)
				removed

WP3.1

D3.1	Ton-scale demonstrators of novel liquid scintillators	Lab- and ton-scale demonstrators for hybrid and opaque scintillators, publication on properties and performances and improved microphysics models	T3.1.G1.D1	Demonstration of hybrid scintillator (hLS) performance in lab-scale and ton-scale experiments (2028)
			T3.1.G1.D2	Demonstration of opaque scintillator (oLS) performance in ton-scale setup (2028)
			T3.1.G1.D3	Publications on properties of novel target media and detector concepts (2027)
			T3.1.G1.D4	Improved microphysics model for organic liquid scintillators (2028)
D3.2	Demonstrators for liquid target loading	Demonstration of high Gd loading at ton-scale and of high concentration of isotope loading	T3.1.G2.D1	Demonstration of > 0.1% Gadolinium loading in ton-scale setups (2027)
			T3.1.G2.D2	Demonstration of ββ isotope loading in scintillators on several per-cent level (2028)

WP3.2

D3.3	Measurement of noble liquid response for low-energy recoils	Characterization of NL response to low-energy recoils and design of low-energy calibration systems	T3.2.G1.D1	Characterization of NL response to low energy recoils (2028)
				removed
			T3.2.G1.D2	Design and commissioning of techniques for low-energy calibrations (2029)
				removed
				removed
				removed
D3.4	Measurement of noble liquids mixtures properties	Characterization and measurement of properties of NL mixtures	T3.2.G2.D1	Characterization of thermodynamics of Xe-doped LAr (2028)
				removed
			T3.2.G2.D2	Measurement and modeling of doped NL response (2028)

WP4.1

D4.1	Report on improved radioassay techniques	Demonstration of adioassay techniques at required sensitivity for next generation of rare-event search experiments	T4.1.G1.D1	Demonstration of improved sensitivity for surface contamination, Rn emanation, and bulk contamination assays.
			T4.1.G1.D2	Report on a comprehensive cross-calibration for low background screening and assay across EU
				removed
D4.2	Report on low-backgro und materials	Report on the development of novel materials, material selection, and clean treatment/manufacturing processes	T4.1.G2.D1	Development and demonstration of novel materials for background suppression
			T4.1.G2.D2	Technical report on surface treatments and clean protocols for low background experiment
				removed
				removed
D4.3	New tools for background evaluation	Development of new tools for background simulations and measurements of cross-section materials	T4.1.G3.D1	Improvement of the Codes for tracking and estimating backgrounds in rare event searches
			T4.1.G3.D2	Measurement of cross-section for materials relevant to low-background experiments
				removed
				removed

WP4.2

D4.4	Mass production facilities	Purification and production plants for liquid targets	T4.2.G1.D1	Scale-up Purification and Production facility for (Metal doped & Water based) LS/WC (2027)
			T4.2.G1.D2	Massive xenon production and purification plant (2027)
				removed
			T4.2.G1.D3	Pilot-scale UAr purification technology development (2027)
D4.5	Demonstration of UAr purification technology	Demonstration of improved purification technologies on testbeds		removed
				removed
			T4.2.G2.D1	Facilities for liquid argon radioactivity, purity, and single electron emission characterization (2027)

WP4.3

D4.6	Medium-scale integrated testing facilities	Development of mid-scale facilities for large-area readout assembly and characterization at cryogenic temperature	T4.3.G1.D1	Photodetector facility (2026)
			T4.3.G1.D2	TPC-testing facility (2026)
			T4.3.G1.D3	Distributed pixel LArTPC systems (2026)
	removed			removed
			T4.3.G2.D4	Scalable readout for large photodetector systems (2029)
D4.7	Report on large-area readout	Report on large-scale light and charge readout systems	T4.3.G2.D1	Report on large scale photodetection in a field cage (2026)
			T4.3.G2.D2	Design of O(10 million) pixel readout (2029)
			T4.3.G2.D3	Report on operation of large fill-factor UV sensors in LXe (2026)