# Update on DRD4 MoU

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# DRD4 Collaboration

- DRD4 approved by CERN Research Board in December 2023
- DRD4 structure
  - 5 Work Packages (WPs), subdivided in Tasks, with internal milestones and deliverables
  - 6 Working Groups (WGs)
- Main roles (SP, CB chair, WP leaders, WG conveners) elected
- 74 institutes joined DRD4 at the time of the Proposal
  - Additional institutes joined later (2 in January, 1 in June, 4 to be approved in October)
- DRD4 Constitution will be approved at the forthcoming CB Meeting (October 22$^{nd}$)
  - Document drafted by the CMC (Constitution and Membership Committee) charged with this task by the CB in June
- WP Deliverables tables
  - See next slides

# WP1 Deliverables table

| WP1: Solid-state photodetectors | | | Start date | End date |
|---|---|---|---|---|
| **D1.1** | Demonstrator of BSI SiPM array (M36) | The work will be focused on the backside illuminated (BSI) technology of SiPMs. A carefully designed device's electric field and dopant layer configuration, together with the uniform light entrance window on the backside of the detector, will enable advanced processing, such as plasma doping or evn more advanced solutions, which could eventually provide both an enhanced PDE and a better radiation tolerance. The main objective is designing, fabricating, and characterising new types of photon detectors, which will follow the first demonstration of BSI SiPMs obtained by thinning SiPM wafers to about 10 um, with an anti-reflective coating on the backside and bonded to a glass substrate for mechanical stability. In collaboration with the SiPM producers, the requirements and possibilities for custom BSI SiPMs will be reviewed. Early BSI samples will be evaluated and characterized, and further design steps will be defined. We will characterize the sensor timing properties, cross talk, after pulsing, and determine sensors' optimal operating conditions. | 01/01/2024 | 31/12/2026 |
| **D1.2** | Demonstrator of CMOS-SPAD monolithic sensor (M36) | The goal of this task is implementation and characterization of CMOS-SPAD sensors for light detection in high energy physics, mainly for RICH and calorimetry application. Standard CMOS processes provide a mature and reliable technology, which allows the co-integration of SPADs and electronics at low costs. Combining SPAD and CMOS readout electronics on a single chip with a custom read-out can provide digitized output signals with low power consumption and fast read-out. The goal of the CMOS-SPAD activity is the development of a technology platform for the design, production, and commissioning of digital silicon photomultipliers (SiPMs) based on a planar monolithic sensor in a standard CMOS technology with the processing electronics and the sensitive element in the same substrate. The monolithic structure of the sensor simplifies the assembly of large-area detectors. | 01/01/2024 | 31/12/2026 |
| **D1.3** | Report on achieved state-of-the-art fast and radiation hard SiPMs and analysis of prospects (M36) | The goal of this task is establishing the protocols and compare the performance of existing and newly developed technologies from different producers. It consists of the following specific objectives:<br>1 Establish characterization setups and procedures that would allow comparison of the results between different labs for quantification of radiation effects.<br>2.Characterize the irradiated SiPMs and determine the working conditions when used in extreme environments. Test operation of SiPMs with associated electronics in a wide range of temperatures down to -200 deg.C.<br>3. Develop procedures for the annealing of SiPMs after and during irradiation. The annealing has great potential to improve SiPM performance after irradiation however a widely accepted standard doesn't exist yet.<br>4. Study and quantify other mitigation measures enabling the use of SiPM in highly irradiated areas, e.g., using smaller SiPMs to reduce the radiation-sensitive volume and macro- and micro-light collectors to maximize the yield and extend operation at low temperatures. | 01/01/2024 | 31/12/2026 |
| **D1.4** | Demonstrator of the ultra-fast SiPM with optimized readout electronics (M36) | The goal of this task will be will be optimization of the timing of the integrated system comprising photon sensors and front-end electronics. The specific objectives of this task are study of the timing properties of single channel SiPMs by using high power amplifier and study of the impact of packaging and interconnections on the timing. Based on knowledge gained, several building blocks of the future ASIC will be designed and verified. A demonstration multichannel sensor using a FastRICH/ FastIC+ chips will be build and its properties characterized to enable the design of an improved sensor, which will be the task of the next 3 year period. | 01/01/2024 | 31/12/2026 |

# WP2 Deliverables table

| WP2: Vacuum-based photodetectors | | | Start date | End date |
|---|---|---|---|---|
| **D2.1** | Production of new MCPs | Production and characterisation of a new generation of MCP-PMT using innovative techniques. We will develop new MCP either with low resitivity lead glass or other materials (alumina, silicon, etc) with smaller pitch to reach better spatial and time resolution. ALD techniques will be tested to prolong the lifetime of the new MCP | 01/01/2024 | 31/12/2026 |
| **D2.2** | Production of new photocathodes | Production and characterisation of photocathodes either transmissive or reflective made of different materials using different structures and in particular a granular one to improve on the spatial resolution | 01/01/2024 | 31/12/2026 |
| **D2.3** | Development of new readout systems | Production and test of read-out system demonstrators able to fully exploit simeltoneously timing and spatial resolution of the MCPs (tens of microns and tens of ps). The development will use the PICMIC and Timepix concepts as baseline to advance the state of the art. | 01/01/2024 | 31/12/2026 |

# WP3 Deliverables table

| WP3: RICH and other imaging detectors for future experiments | | | Start date | End date |
|---|---|---|---|---|
| **D3.1.1** | Optimized Aerogel Radiator Module Prototype for future RICH Detectors | A comprehensive characterization of a prototype aerogel radiator module for future RICH detectors, optimized for different refractive indices and module sizes. The performance will be evaluated under various operating conditions, with optical properties assessed in the laboratory and validation conducted through beam tests. This will provide essential insights for improving radiator design in future RICH detector applications. | 01/01/2024 | 31/12/2026 |
| **D3.1.2** | Demonstrator of interferometer for gas refractive index monitoring | Accurate monitoring of the refractive index is crucial for ensuring precise Cherenkov angle measurements in future RICH detectors. Variations in the refractive index, caused by changes in temperature, pressure, or gas composition, introduce systematic uncertainties that can affect the reconstruction of the Cherenkov angle. To address this, a demonstrator of an interferometer system will be developed to measure and continuously monitor the refractive indices of radiator gases with very high resolution, ensuring optimal performance stability for next-generation RICH detectors. | 01/01/2024 | 31/12/2026 |
| **D3.2** | Prototype of a fully functional and autonomous module for a cluster of Single-Photon Sensitive devices for Imaging Arrays (from sensors to DAQ), including local cooling for SiPMs and an autonomous calibration system. | The aim of this task is to develop and prototype a modular, scalable, imaging array module for future RICH detectors integrating single-photon sensitive devices, along with a cooling system, specifically designed for SiPM arrays and an autonomous calibration system for time alignment and performance monitoring. It will serve as both a technological demonstrator and a real detector for laboratory and test-beam studies. | 01/01/2024 | 31/12/2026 |
| **D3.4** | Development and testing of a prototype compact RICH cell for future colliders | This deliverable focuses on the testing and validation of the first fully functional prototype compact RICH detector cell for future colliders. The prototype module will integrate all key components, including various radiators (aerogel, gases), mirrors, and photodetectors (such as SiPMs). Measurements will evaluate system performance under different operating conditions. | 01/06/2024 | 31/05/2027 |
| **D3.5.1** | Review of available frameworks for fast Cherenkov optical photon tracing within the context of Geant4 simulations | This task involves assessing existing frameworks that support fast photon tracing, particularly focusing on their integration with the Geant4 environment. The evaluation will compare frameworks based on several performance factors, including computational efficiency, scalability, accuracy of photon propagation, ease of implementation, compatibility with different detector geometries, and support for advanced features such as GPU acceleration. | 01/01/2024 | 31/12/2026 |
| **D3.5.2** | Review of approaches for PID algorithms, including those based on Machine Learning (ML) and Artificial Intelligence (AI) | This deliverable involves a thorough review of particle identification (PID) methodologies, with a focus on cutting-edge approaches using ML and AI. In addition to these advanced techniques, traditional algorithms will be considered. The review will assess factors such as processing speed, accuracy, robustness to noise, adaptability to high-multiplicity environments like the High-Luminosity LHC (HL-LHC), and potential for scalability and parallelization to accommodate large datasets. The aim is to identify the most effective strategies for enhancing PID performance in future detectors. | 01/01/2024 | 31/12/2026 |
| **D3.5.3** | Review of external software tools used by the community | This deliverable involves conducting a thorough survey and assessment of external software tools widely used in the community, including CAD for geometrical optics ray tracing and specialised tools for modelling the internal workings of PMT/MCP-PMT/SiPM. The objective is to map these resources, assess their relevance and performance, and evaluate their potential for integration into RICH detector simulations and data analysis workflows. | 01/01/2024 | 31/12/2026 |

# WP4 Deliverables table

| WP4: Time of Flight Detectors | | | Start date | End date |
|---|---|---|---|---|
| **D4.1** | Fully characterized prototype TOF detector, with a report on design and performance (M36) | The goal of this task is to design high precision timing ($\sigma_t$ ▯ 10-15 ps) ToF detectors based on high refractive index solid Cherenkov radiators read out by an array of silicon photomultipliers (SiPMs).<br>A key activity of this task is the optimization of the SiPM optical couplings because reflections occur at all SiPM interfaces leading to both photon losses and multiple-reflection background.<br>A software tool to simulate the thin-film interference and the complex-matrix form of the Fresnel equations will be developed for studying different anti-reflective coatings and various radiator surface texturing with the aim to achieve a higher photon detection efficiency by minimizing the reflections. The deliverable will be the characterization of a TOF prototype based on the radiator-SiPM configuration resulting from the simulations. | 01/01/2024 | 31/12/2026 |
| **D4.2** | Prototype of array of cooled, mm-scale segmented SiPMs with integrated readout, with report on design and performance (M36) | This task will build on the SiPM-based photon sensors developed within WP4.1 and described in D1.4. It will be closely aligned with the WP4.1.4 and WP4.4.1 sub-tasks with the bulk of the effort taking place in years 2 and 3, towards the end of the 3 year project.<br>The task will involve extensive and long term testing and characterization of segmented SiPMs (with and without coupling to thin Cherenkov radiators) and associated electronics, including timing resolution, dark noise and irradiation effects and recovery techniques, maximum count rate, crosstalk, and photon counting uniformity.<br>An option to be studied is a system in package solution for FastIC+, developed in WP4.1.4, which integrates 4 dies in a BGA package to provide a 32 channel readout element with the goal of developing a 256 channel module to readout different SiPM sizes. | 01/01/2024 | 31/12/2026 |
| **D4.3** | Demonstrator of a lightweight mechanical support for a TOF detector, with report on generic techniques, procedures,and materials for lightweight structures (M36) | A survey will be undertaken on existing design types used to develop prototypes for specific detector types including barrel, end-cap and wall-type detectors such PANDA, EPIC, Torch, SuperB, and utilised to establish a baseline for design of lightweight support structures.<br>This will be used to develop conceptual designs for endcap and wall-type devices, informed by existing devices such as Torch and Super Tau Charm Facility.<br>The final deliverable will be a demonstration of a lightweight mechanical support for a TOF detector will be provided by a prototype (TBD, but e. g. Torch). This deliverable will also include a report extracting the ideas, methods, techniques, and procedures used to develop generic lightweight support structures for TOF detectors using solid radiators. | 01/01/2024 | 31/12/2026 |
| **D4.4** | Completion of commissioning of an optical laboratory(s) for characterizing the performance of solid TOF radiators (M36) | Several existing static optical laboratories already have capabilities to test radiators for different TOF instruments. These facilities will be made available as robust stationary systems for radiator characterization and reported upon within the first year.<br>Since transportation of large systems is impratical, options will be explored to a make transportable facility.<br>A "shopping list" of necessary hardware, and recipe of methods and techniques required to equip and commission an optical laboratory, including ways to make mobile, will be developed using lessons learned and best practices already established.<br>The final deliverable at the end of the project will be the commissioning of generic optical lab for solid TOF radiators. | 01/01/2024 | 31/12/2026 |

# WP5 Deliverables table

| WP5: SciFi tracking and Transition Radiation Detectors | | | Start date | End date |
|---|---|---|---|---|
| **D5.1.1** | Interim report on the candidates for prototype fibre(s). | The deliverable should summarize investigations and efforts at identifying possible scintillators technologies that could be made into a scintillating fibre that are an improvement over the standard fibre by investigation of literature, through contacts with industry, or developments or modifications to existing technology.  Physical sample shouled be studied for their relevant parameters to determine their feasibility as a new fibre before proceeding to producing fibre samples. | 01/01/2024 | 01/04/2026 |
| **D5.1.2** | Final performance report on the development of prototype fibres | Assuming the first deliverable 5.1 has a feasible scintillator to be investigated further, scintillating fibres should be produced with an industry partner and developed further. Parameters such as light yield, attenuation length and radiation hardness up to LHC or future accelerator doses will be studied, with a short report explaining the outcomes. | 01/01/2024 | 31/12/2026 |

# Open questions

- Deliverables Start/End dates Vs DRD4 official approval period
  - Deliverable dates should be shifted systematically, compared to those that appeared in the Proposal? Or should this be done on a case-by-case basis?
  - Will there be any push-back or comments from the DRDC about changing such deadlines?
  - May specific Deliverables (e.g. ASIC design and production) extend over a period of more than 3 years?
- DRD4 defined a set of Milestones in the Proposal document to monitor progress of each activity (as intermediate steps towards the Deliverable), but they do not appear in the MoU Tables as they are not called Deliverables
  - Shall we maintain those Milestones as internal targets?
  - Will the DRDC wish to control that they are achieved?