(R&D Milestones and Timeline are as put in the formal P6 project schedule and bounced off all early 2023, text in blue is our interpretation of status based on the detector R&D day of March 25, 2024)

Appendix: R&D Milestones & Timeline

February 26, 2023

Particle ID

eRD101 (mRICH)

- Validate production readiness of a Ring-Imaging Cherenkov Detector as matched with photosensors and readout electronics on the electron-side end cap of the EIC detector, including validation by prototypes that the EIC requirements can be met. [March 2025] - obsolete

eRD102 (dRICH)

- Validate production readiness of a dual Ring-Imaging Cherenkov Detector as matched with photosensors, readout electronics, and integrated cooling on the ion-side end cap of the EIC detector, including validation by prototypes that the EIC requirements can be met. [March 2025] - multiple validations done and setting up component QA. Demos ongoing. On track for completion.

eRD103 (hpDIRC)

- Validate production readiness of a new high-performance DIRC detector by DIRC bar characterization, and vertical-slice prototype cosmic and beam tests including a realistic readout box. [June 2025] - ingredients exist for characterization and cosmics/beam tests with readout box. Intent can be completed with one sensor.

eRD110 (photosensors)

- Ensure applicability of SiPM readout for Ring-Imaging Cherenkov detectors. This implies validation of operation in the single photon regime, and studies of irradiation and in-situ annealing to ensure operation in a "radiation damaged and annealed" mode is possible. [September 2022] - complete
- Establish production readiness of a LAPPD/HRPPD-based photon-sensor readout for a Ring-Imaging Cherenkov Detector on the electron-side end cap of the EIC detector, including validation by prototype beam tests. [September 2024] – obsolete, risks accepted and put in risk registry; captured as PED effort

eRD112 (AC-LGAD/ToF)

- Validate production readiness of the AC-LGAD detectors in the barrel region, the forward side end cap of the EIC detector, and the far-forward Roman Pot beam line detectors. This includes sensor prototypes, ASIC demonstrator, and full-scale parts tested and finalized. [September 2026] - ASIC demonstrator can only be beyond CD-2.

Calorimetry

eRD105 (SciGlass)

- Scintillating glass scaled up and characterized to >15X0. Prototype tested in electron beam. [May 2023] - complete
- Beam test results of 5 x 5 prototype documented. R&D to implement final projective geometry of scintillating glass completed. [September 2024] – completed apart from final document; further work moved to generic detector R&D.

eRD106 (fwd EMCal)

- Validate production readiness of the EM calorimeter in the forward ion direction by optimizing uniformity and efficiency of light collection with SiPM readout, integration of final readout, and common beam test with hadron calorimeter prototype. [June 2025] - R&D to validate production readiness is complete.

eRD107 (fwd HCAL)

- Validate production readiness of the hadron calorimeter in the forward ion direction by machining and characterization of tiles, prototype module production, integration of final readout, and common beam test with EM calorimeter prototype. [June 2025] – on schedule to complete, planned CERN test beam run in August 2024.

eRD115 (barrel EMCAL)

- From December 2022 Calorimetry Review: Move towards tests of prototypes or more detailed engineering test articles as soon as possible. Since single-component tests were done, interpreted as: “The performance, including response to pions, needs to be benchmarked in a prototype of the hybrid integrated system.” [Summer 2025] – on schedule to complete, but dependent on FBTF beam availability.

Tracking

eRD108 (MPGD)

- Complete beam test validation of cylindrical μRWELL with prototype [September 2023] - Complete with small-size prototypes. As part of PED effort a full-scale engineering test article is made to address mechanical stability which is the largest operational issue.
- Complete validation of use of light-weight cylindrical Micromegas with 2D readout patterns as derived from the earlier used cylindrical technology [December 2024] - Full scale prototype with 2D readout projected ready late this CY to finalize design choice.

eRD104 (Service Reduction)

- Develop powering scheme based on serial powering to mitigate service space needs of DC-DC scheme. [December 2023] - A serial powering scheme has been developed but relies on development of an Ancillary ASIC. The specifications and technology choice are being finalized. Prototyping of blocks is planned this calendar year (2024).
- Evaluate radiation tolerant FPGAs and high-speed fiber optic transmission option with beam test. Complete prototype multiplexing firmware. [December 2024] - The readout and slow control scheme has been developed in conjunction with the powering scheme.

The core components are the VTRx+ optical link and lpGBT. Test setups for this scheme are in place. Funding delays and supply chain issues have so far prevented beam test(s).

eRD111 (Si Tracker)

- Report completed on barrel and disc cooling options, allowing cooling choice [December 2023] - ITS3 has demonstrated air cooling is feasible for their array of vertex layers. Air cooling by forced convection has been investigated for anticipated power density profiles associated with the foreseen EIC Large Area Sensor. Air cooling is considered a viable option for SVT operations near ambient temperatures. The power dissipation in the EIC LAS sensor periphery has to be reduced compared to the MOSAIX periphery and power dissipation in the Ancillary ASIC need to be well below that of the EIC LAS.
- R&D completed for stitching of sensors [September 2024] - Sensor tiling studies on the staves of the outer barrel layers and the endcap disks, paired with foundry insights, have shown that single segments with 5 or 6 stitched Repeated Sensor Units will result in an EIC LAS that meets SVT acceptance and other requirements.

eRD113 (Si Sensors/ITS3)

- End-of-R&D Milestone: EIC vertex sensor quantification finalized [September 2026] (Note: link in P6 to EIC large area sensor production start [February 2027]) - ER2 (MOSAIX) submission is aimed for at end of 2024. ER3 submission later with minimal modifications of MOSAIX. ER3 submission and sensor test would complete the milestone. EIC test efforts of MLR1 have been completed and are continuing with ER1 and preparations for ER2.

Electronics

eRD109 (ASICs/FEEs)

- Develop a streaming readout solution for the EIC calorimeters with SiPMs and the associated PCBs and cabling infrastructure. Decide between options using COTS devices or directly starting from existing ASICs. [September 2025] - Decision is made for COTS (forward and backward EM calorimeter) versus ASICs. COTS specifications complete in FY24, with engineering test article in FY25. For ASICs/H2GCROC evaluation ongoing, LFHCAL tests at CERN May 2024. Further H2GCROC development done as in-kind by OMEGA/IN2P3 group to create CALOROC that is compatible with streaming. CALOROC1 is FY24/FY25, CALOROC ready for construction FY26.
- Develop a streaming readout solution specific to the Ring-Imaging Cherenkov (RICH) particle identification detectors with SiPMs. This may require a modification of an existing ASIC design. [December 2025] - ALCOR development done as in-kind by INFN. ALCORv2 32 pixel 8 x 4 in FY24, ALCORv3 64 pixel 8 x 8 in FY25, ALCORv4 ready for construction in FY26.
- Develop a streaming readout solution specific to particle identification detectors with LAPPDs and/or MCPMTs. This requires a novel ASIC in 130 nm CMOS technology that meets the requirements set by EIC providing a precise time measurement with a TDC combined with an Analog Digital Converter (ADC) for the amplitude measurement. [December 2026] - Can use tentative FCFD or EICROCx in smaller footprint. Need timing

which drives small parasitics, small chip may lead to larger traces, not optimal. Thus, EICROC1 with smaller traces is preferred above the 32 x 32 EICROC2. In FY24 we also check if FCFD works as is and is a suitable alternate. Baseline is EICROC variation assuming OMEGA/IN2P3 group can do this, with FY25 for alternate choice as needed.

- Develop a low-mass streaming readout solution specific to the barrel-region AC-LGAD at an EIC Detector, including design of the power delivery and readout service system. This includes a decision between redesign of existing ASICs or use of third-party ASIC solutions [September 2025]. - Decision complete – redesign of existing ASIC. EICROC is done as in-kind by OMEGA/IN2P3. EICROC0 exist with 4 x 4 channels, power reduction in next version. Design of EICROC1 ongoing (4 x 16 to 8 x 32 variations possible). EICROC2 with 32 x 32 in FY26. For barrel AC-LGAD (strip) use FCFD. FCFDv1 with added interfaces in FY24/FY25, synergy with FNAL/DUNE, FCFDv2 ready for construction in FY26.
- Develop a streaming readout solution specific to the MPGD-based tracking detectors. This requires a modification based on previous ASIC designs to include compatibility with streaming readout, a new CMOS technology, and 64-channels. [March 2026]. - Much done as in-kind by CEA/USP. 4-channel SALSA submitted April 2024. Variations in FY24/FY25 – may need PED for ERRs, SALSA ready for construction in FY26.