Gaseous Detectors for Hadron Physics Infrastructures (GD4HPI) Letter of Intent for HORIZON-INFRA-2025

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1 Research objectives

Innovative instrumentation is key to the success of particle and hadron physics experiments worldwide. As recommended by the European Strategy Update for Particle Physics[*], the community has defined a global detector R&D roadmap[†] to define and boost strategic R&D in six key technology domains for existing and future facilities. Gaseous detectors, including MPGD (Micropattern Gaseous Detectors), RPCs (Resistive Plate Chambers), wire-based detectors, and TPCs (Time Projection Chambers) were identified as one key technology area. Long-term research on these detector technologies is organized Europe-wide in a CERN-based Detector Research and Development Collaboration (DRD1).

The participants of this activity are active in experiments at CERN (AMBER, SHiP), GSI/FAIR (CBM, FRS, SFRS), JLAB (Hall A), and other international research centers. Their research & development of gaseous detectors is targeting towards multi squaremeter sized, high rate capable detectors with high spatial and excellent temporal resolution, and with low material budget. The reduction of the material budget will reduce the multiple scattering for an enhanced spatial resolution of low momentum or highly ionizing particles (e.g. highly ionized nuclei). Other applications include the use of TPCs in experiments to track low-momentum recoil particles or nuclei, e.g. the tagged DIS experiment at JLAB or a planned high-pressure TPC to fully resolve the hadronic final state in neutrino - nucleus interactions at the Hyper Kamiokande experiment. Further applications at GSI/FAIR intend to precisely track heavy ions and their fragments through a spectrometer (FRS/SFRS) allowing for lowest possible material budget only. Here, very low-pressure TPC technology may serve to minimize material in vacuum windows, otherwise the dominant contribution to multiple scattering and tracking imperfection.

While detector design and initial research is often performed in smaller groups in local laboratories, new devices finally need to be tested under realistic conditions at particle accelerators. Common test beam infrastructure and organization are a prerequisite for the efficient use of precious beam time at existing facilities. We propose to construct a general-purpose beam telescope to be used as tracking and timing reference for gaseous (and other) large-area tracking detectors. The active area covered by the telescope should cover at least $20 \times 20\,\mathrm{cm}^2$. At present, no such telescope exists. The beam telescope proposed here will consist of several different subdetectors produced by the participating groups. In total, we will build 8 layers of MPGD-based tracking detectors, which will each give 2D space points with spatial resolution of about $50\,\mu\mathrm{m}$. This will result in a track resolution at the Device under Test of better than $20\,\mu\mathrm{m}$. Timing with a resolution better than $1\,\mathrm{ns}$ will be obtained by scintillators or MRPCs. We aim for a rate capability of at least $50\,\mathrm{kHz/cm}^2$. The

[*] https://cds.cern.ch/record/2721370/files/CERN-ESU-015-2020%20Update%20European%20Strategy.pdf

[†] https://cds.cern.ch/record/2784893/files/Synopsis%20of%20the%20ECFA%20Detector%20R&D%20Roadmap.pdf

benefit of using detectors with interchangeable shape, but different gas amplification stages is given by the additional degree of optimization options. As a common data acquisition platform, we plan to use the SRS system developed with RD51/DRD1 at CERN. To simplify operation, the signals from the detectors will be read out using a common ASIC with a wide dynamic range and allowing for triggered and untriggered readout. Several candidates will be investigated, e.g. the VMM3a (ATLAS NSW), CTR16 (GSI), or ToRA (Torino). A common software package for track reconstruction will be developed that will make use of advanced tracking algorithms based on Kalman filters, general broken-line fits, etc. We plan to also investigate the use of Machine Learning techniques for tracking. The telescope will be an ideal instrument to develop and validate these technologies.

In addition to being an extremely valuable service tool for the development of future particle detector technologies within the particle physics community, the commonly built and operated beam telescope will help to train the next generation of particle physicists by allowing them to conduct beam tests, analyze the data and characterize their new devices in a simple and accessible way.

2 Connection to Transnational Access (TA) infrastructures and/or Virtual Access (VA) projects

While the plan is to originally install the newly built telescope at the ELSA accelerator at Bonn University, and to make it available for users there, we plan to design it in a modular way, such that it can easily be duplicated or even moved to different infrastructures across Europe. The new Research and Technology Center Detector Physics (FTD) at Bonn University provides all the infrastructure needed for maintenance of the detectors. An additional, complementary site of installation may be a test beam-line at GSI/FAIR with heavy ion beams. Here the special challenges encountered with the detection of highly charged primary particles may be addressed.

3 Estimated budget request

Category	Type	Task	Amount
Personnel	PhD (40 k€/year)	GEM	160 k€
	PhD (40 k€/year)	Micromegas	160 k€
	PhD (40 k€/year)	Electronics	160 k€
	PhD (40 k€/year)	DAQ, Tracking	160 k€
Invest	Detector hardware	Telescope	100 k€
	Electronics	Telescope	100 k€
Travel	Common beam times		60 k€
	Workshops, conferences		40 k€
Total			940 k€

4 Participating and partner institutions

RWTH Aachen University, Bonn University, Glasgow University, GSI Helmholtzzentrum für Schwerionenforschung GmbH, LMU Munich, Torino University.