

OSTraD

Opaque Scintillating Tracking Detectors

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1. Research objectives

Opaque scintillation detectors have been devised a few years ago in the field of low energy neutrino physics [1]. Because they are white-opaque, these scintillators confine the produced light in the vicinity of an energy deposition [2]. When threaded with wavelength-shifting fibres, they allow to resolve the morphology of energy depositions, which in turn yields for the first time particle ID between electrons, positrons, and gamma-rays at MeV-scale energies [3].

Recently, this technology gained additional attention in the field of tracking detectors. Again, the opacity of the medium allows confining the scintillation light in a tube close to the track. With their high light yield, these scintillators allow to detect tracks over a wide range of energies down to MeV-scale events. These tracking detectors lend themselves to a variety of usage cases.

In the context of tracking detectors, the research objective of this LoI is the transfer of the opaque scintillation technology from the astroparticle community to the hadron community, specifically by demonstration of the detection of particle tracks in an opaque scintillation tracker prototype. As initial computer simulations show, electron tracks of few centimetres length are expected to be seen for electron energies above 7 MeV. Similarly, other particle tracks and more complex events structures such as showers can be resolved in high detail. It is our goal to construct an opaque fibre-instrumented scintillation detector capable to demonstrate the detection of low energy particle tracks. We expect this to be achievable with a device of order 10 litres volume instrumented with order 100 fibres.

The successful demonstration will have immediate impact in two fields of research: searches for light dark matter (LDM) and studies of nuclear interactions. Regarding the first field, the DarkMESA experiment is aiming to measure LDM created via dark bremsstrahlung in the beam dump of the Mainz Energy-recovering Superconducting Accelerator (MESA) in Mainz, Germany [4]. This LDM, should it exist, is expected to deposit their energy in DarkMESA via electron scattering resulting in electron tracks. These tracks can be resolved in direction and pointed back to the beam dump with the technology of opaque scintillation trackers. This yields a powerful discrimination strategy against background events having random directions.

Regarding the second field, the study of nuclear interactions, opaque scintillation trackers can be a viable technology for near detectors at current and future neutrino beam experiments such as T2K, DUNE or HyperK. Super-Kamiokande, HyperK, and also DUNE (in its later phase of operation) use water-Cherenkov detectors as their far detectors. Using an opacified emulsion of water and a small amount of about 1% liquid scintillator, the near detectors could provide a detector medium similar to pure water, but with largely lowered energy threshold and

additional resolution power for tracks. The near detectors therefore can provide an unprecedented understanding of neutrino nucleus interactions. This medium will be qualified in the prototype, as well.

- [1] A. Cabrera, A. Abusleme, J. dos Anjos, et al. "Neutrino Physics with an Opaque Detector". In: Commun. Phys. 4 (2021), p. 273. doi: 10.1038/s42005-021-00763-5. arXiv: 1908.02859 [physics.ins-det].
- [2] C. Buck, B. Gramlich, and S. Schoppmann. "Novel Opaque Scintillator for Neutrino Detection". In: JINST 14.11 (2019), P11007. doi: 10.1088/1748-0221/14/11/P11007. arXiv: 1908.03334 [physics.ins-det].
- [3] J. Apilluelo, L. Asquith, E. F. Bannister, et al. "The Stochastic Light Confinement of LiquidO". In: (2025). arXiv: 2503.02541 [physics.ins-det]
- [4] M. Christmann et al. "Light Dark Matter Searches with DarkMESA". In: PoS EPS-HEP2021 (2022), p. 129. doi: 10.22323/1.398.0129.

2. Connection to Transnational Access infrastructures (TAs) and / or Virtual Access projects (VAs)

To achieve the objectives of our Lol, access to beam facilities, where this technology could potentially become a tool in the future, is crucial to understand and demonstrate the tracking capabilities of our detector technology for various particle types. In the current MAMI and upcoming MESA facilities in Mainz, Germany, gamma-rays and electrons of few MeV up to more than one GeV can be measured. Access to the Proton Synchrotron (PS) at CERN allows us to study proton interactions up to order 10 GeV in our technology demonstrator. MAMI is already operational and can be used in the beginning of the project for electron and gamma-studies. Over the course of the project, MESA (upon completion of construction) as well as PS during the middle of CERN's Long Shutdown 3 in 2028 become available, providing additional opportunity for measurements.

3. Estimated budget request

We request funding for a postdoctoral researcher over 2 years. The postdoc will allow to conduct a technology transfer between participating institutions by performing the design, construction, commissioning and operation of the detector prototype as well as the execution of beam times at MAMI/MESA and the CERN/PS. We further request funding for direct project costs related to the construction of the prototype. In addition, we request funding for the organisation of two topical in-person-workshops to allow building an European network under Mainz leadership for the establishment of the technology in hadron physics. The workshops will be interleaved with online-events. In total, we request funds of 250k€.

4. Participating and partner institutions

JGU Mainz and all other LiquidO institutions (see list in ref. [1,3])