Cryogenic detection of scintillation light with large area SiPM arrays for next generation neutrino and dark matter experiments

The collection of scintillation light is a fundamental technique for the detection of neutrino or dark matter interactions in cryogenic environments. The continuous development and deeper understanding of such technique are fundamental to advance the results in these fields.

In the present work, a development for the photon detection modules of the DUNE experiment (horizontal drift TPC – Time Projection Chamber) is successfully carried out. The design of electronic boards for the readout of such modules, as well as the successful test of the largest functional unit to be installed in the detector, is presented.

To enhance the response of the photon detection system in liquid argon TPCs, the very first large-scale xenon doping of liquid argon was performed in the DUNE prototype ProtoDUNE-SP. It allowed measuring the fundamental rate constants governing the scintillation, and for the first time with such granularity at low xenon concentrations. It was proved that the increased Rayleigh scattering length improves light collection uniformity, and that a few parts per million of xenon can recover most of the light quenched by nitrogen.

The second module of DUNE (vertical drift TPC) will host the photon detection system on its cathode plane, at -300 kV, therefore requiring the use of power over fiber technology instead of copper cables. To bias silicon photomultipliers (SiPM) in such environment, a novel DC-DC boost converter working in cryogenics was designed. First, a proof-of-concept prototype was tested and characterized at liquid nitrogen temperature, then a full prototype integrated with the DUNE electronics was successfully realized.

Scintillation light detection is also the technique used by dark matter direct-search experiments using NaI(Tl) crystal. The best example is DAMA, the only detector reporting a long-standing positive observation of dark matter. To confirm and to extend the physics reach of NaI(Tl)-based experiments, a new generation of dark matter detectors is needed. The ASTAROTH project is presented, highlighting how using SiPM at cryogenic temperatures could overcome current limitations. Two main results are reported: the characterization of a crystal at cryogenic temperatures, and the development of a dedicated SiPM array with its relative front-end electronics for crystal readout.

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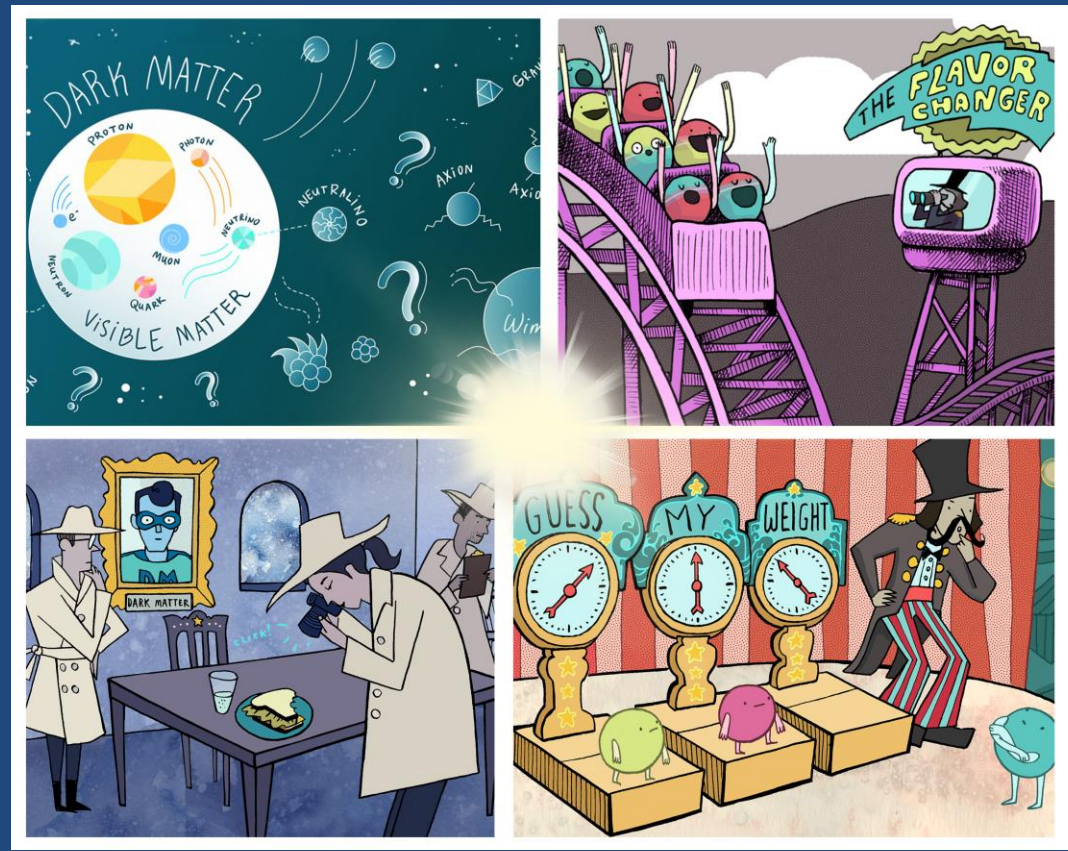

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