Using a GridPix detector in dark matter search

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Dark matter in the universe

We want to understand the unexplained abundance of dark matter [1]. Several experiments are taking data, others are planned.

Dual-phase gas element TPC

Current experiments use PMTs to detect charge via secondary scintillation. Within the DARWIN R&D framework [2] we look into alternatives for a direct charge readout.

The detector must fulfill the following requirements:

- operation in ultra-pure noble gas environment,
- thermal robustness at low temperatures: $T_{\text{Xe}} = 165$ K, $T_{\text{Ar}} = 87$ K
- low outgassing material and radio-purity (not discussed here),
- low power consumption (not discussed here)

GridPix detector

- amplification grid on Timepix chip
- 65k pixels with 55 µm pitch
- single $e^-$ detection efficiency > 95 %
- time information of track ⇒ μTPC

Cryogenic studies in liquid N$_2$

Test thermal robustness by immersing a GridPix into liquid nitrogen at $T_{\text{N}_2} = 77$ K. Damage of the grid can be minimised by applying glue to the grid borders, but not prevented. ⇒ Change material composition.

Acknowledgements

We thank F. Resnati and D. Lussi (ETH Zürich) from André Rubbia’s ArDM group at CERN for their tremendous support. This work was partly supported by the Marie Curie network for particle detectors.

Gas gain measurements at room temperature

Measurements with argon-based mixture (Ar/iC$_4$H$_{10}$ 90/10) and ultra-pure argon (Ar 6.0, i.e. 99.9999 % purity).

Gain curve for Ar/iC$_4$H$_{10}$ 90/10 (left) and event display of GridPix integrating $^{55}$Fe conversions over 1 s in Ar 6.0 (right).

Confirmation in an operational dual-phase argon TPC

In collaboration with ETH Zürich we operated a GridPix in the ArDM test cryostat at CERN.

We wanted to measure $\alpha$ conversions of $^{241}$Am in ultra-pure Ar 6.0:

- at room temperature,
- just above $T_{\text{Ar}} = 87$ K,
- in dual-phase, i.e. above the liquefied Ar.

To fit our GridPix setup into the cryostat at CERN we built components like a 100 leads signal cable with a vacuum-proof feedthrough, printed circuit boards and connectors, all made of low outgassing material.

Results of measurements in the cryostat

$^{241}$Am event measured with GridPix at room temperature ⇒ gas gain.

PMT signal at low grid voltage ⇒ $S_1$ and $S_2$ signal (i.e. scintillation in liquid and gas) at $T_{\text{Ar}}$.

Although the gas gain was too low at $T_{\text{Ar}}$ to measure signals with GridPix, the principle of gas amplification was working: the delayed peak at higher grid voltage after the $S_2$ peak (right) proves a second scintillation in the gas amplification region of the GridPix.

Outlook

- Change grid material (with matching coefficient of thermal expansion) to achieve thermal robustness.
- Repeat the measurements with gaseous and dual-phase xenon at room temperature and at $T_{\text{N}_2}$, respectively.
- Determine noise thresholds of the Timepix chip at various temperatures.
- Improve GridPix’s gain properties by change the grid’s support structure.

References