Measurement of performance parameters of silicon photomultipliers for LDMX TS prototype

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Introduction

New theoretical developments have motivated “hidden sector” dark matter with mass below the proton mass. The Light Dark Matter Experiment (LDMX) will use an electron beam to produce dark matter in fixed-target collisions. A low current, high repetition rate (37.2MHz) electron beam extracted from SLAC’s LCLS-II will provide LDMX with sufficient luminosity to explore many dark matter candidates. Using a novel detector design, LDMX is expected to definitively search for thermal relic dark matter with masses between 1 MeV and several hundred MeV.

. Experimental setup

- The experiment includes a trigger system, a tracker, a tungsten target and calorimeters. The electron beam derived from SLAC will be subjected on the tungsten target and the energy and momenta of collision products will be anayzed by the calorimeters.

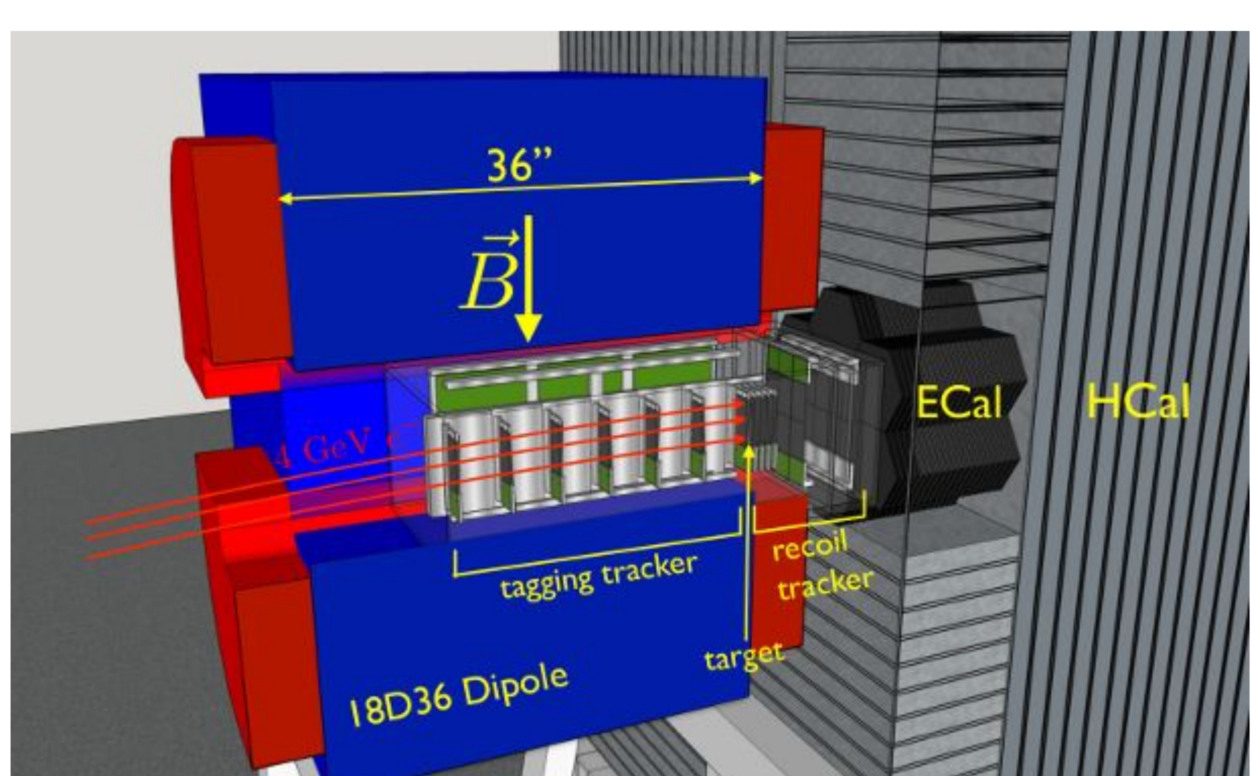
•Trigger scintillators: For triggering

•Trackers: Measures momentum

•Ecal: Measure energy of electrons

•HCal : Veto hadronic events escaping ECal.

• The key towards dark matter detection is accurate measurement of missing energy (MET) and momentum.

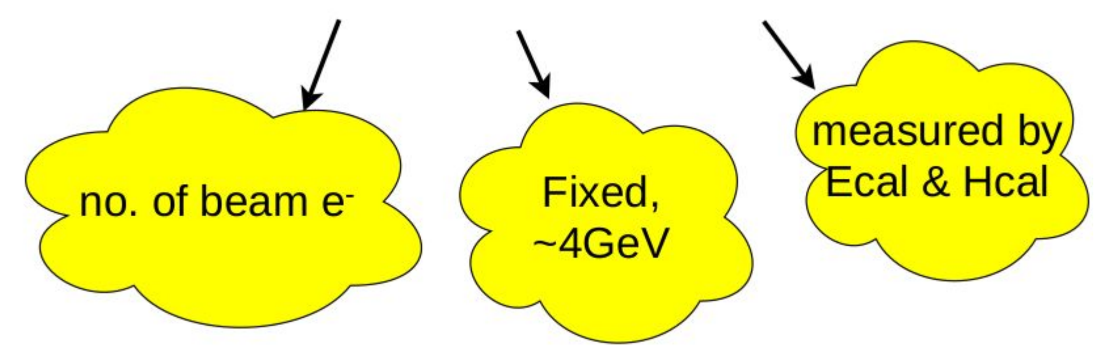


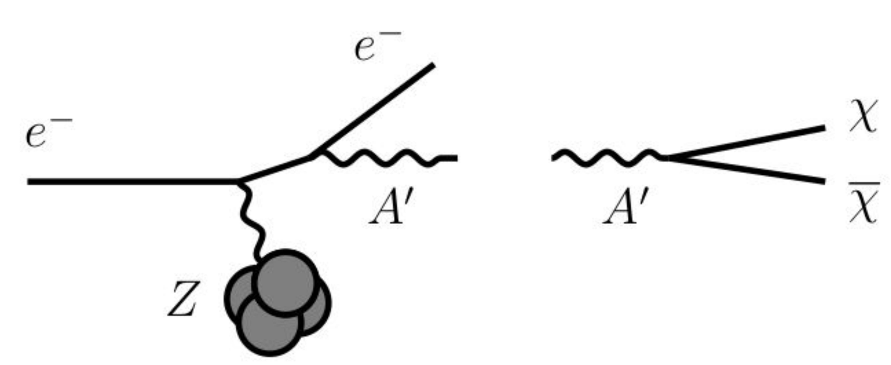
LDMX conceptual design

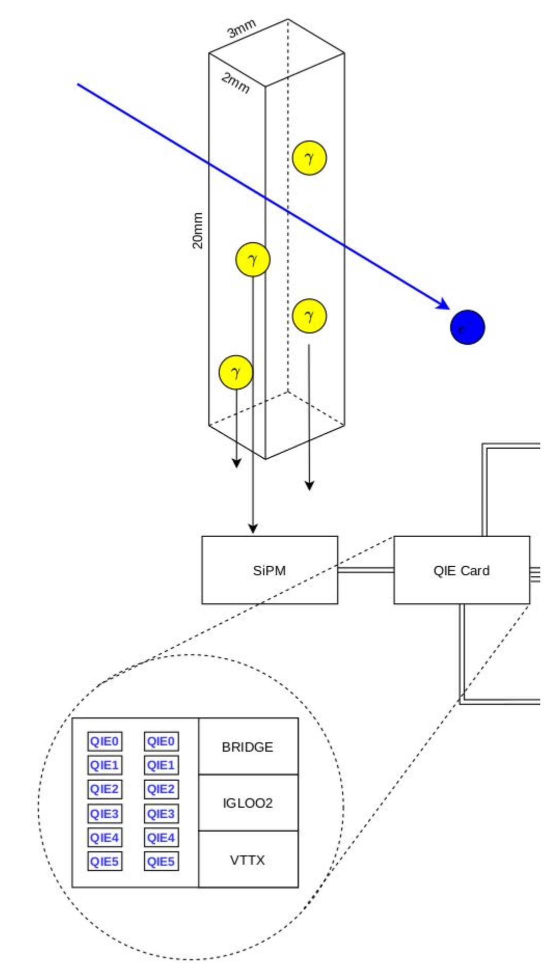
Need for trigger scintillator (TS)

- Electron beam will have a frequency of 37.2 MHz.. This demands fast triggering.
- Trigger scintillators count no. of beam electrons in every event.
- It is important to have a precise counting of electrons
  - Overestimation would lead to fake METs from photon backgrounds.
  - Underestimation would lead to lower signal efficiency.

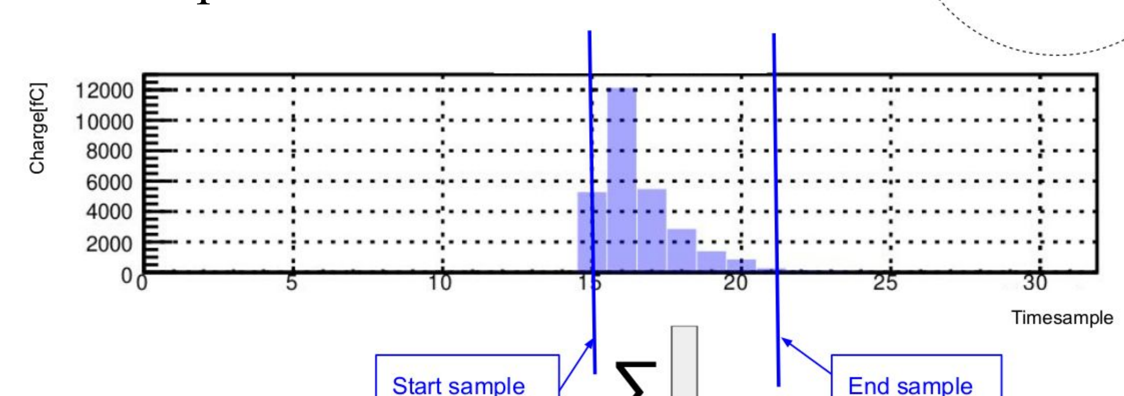
Missing energy = $n \times E_{beam} - E_{measured}$

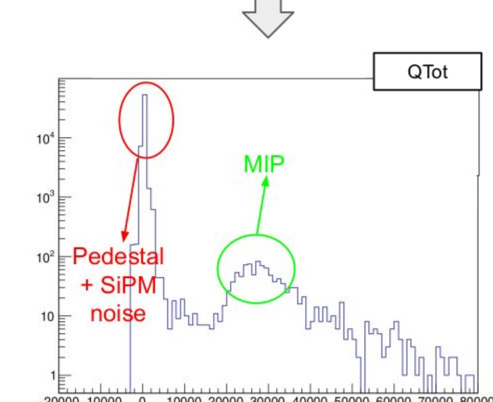






Potential DM production channel[1]



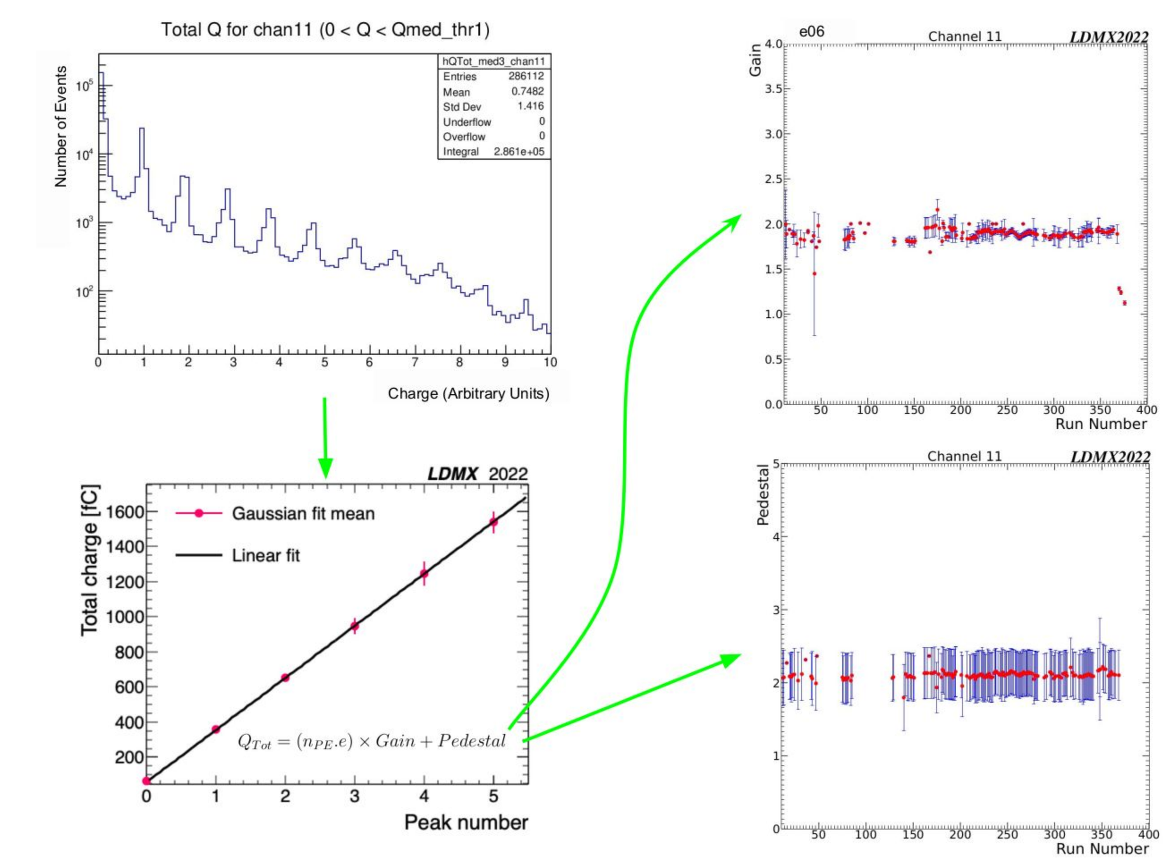


Test beam experiment

- The LDMX test beam experiment was performed in April 2022 to test the performance of the TS module using different beam configurations.
- Photoelectrons collected by SiPMs measured as ADC counts by QIE electronics.
- Linearization of ADCs give amount of charge deposited on SiPMs.
- These charge distributions were analyzed to measure the calibration parameters for the SiPMs.
- An effective trigger also has a high signal to noise (S/N) ratio, meaning low fake rates.

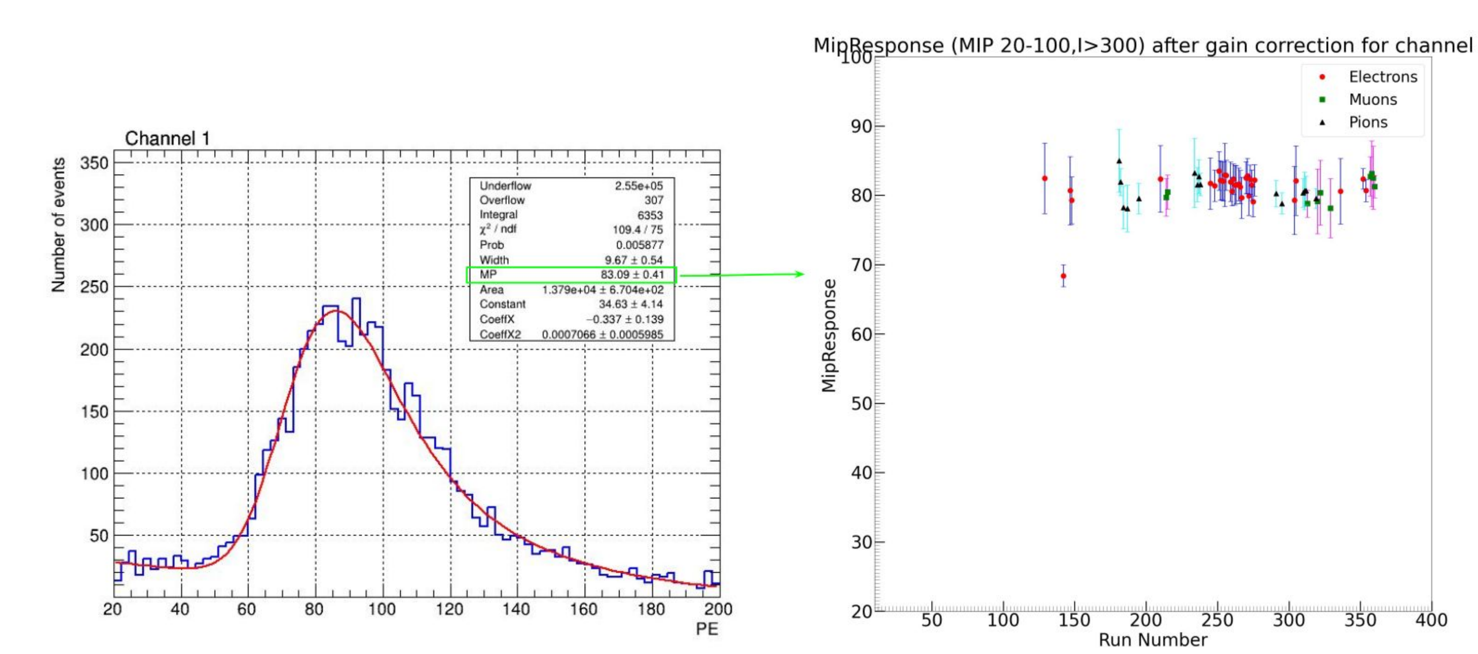
SiPM performance parameters

- SiPM gains and pedestals are the key performance parameters
- Obtained from linear fits on sums of charge distributions
- Over the period of test beam experiment, stability is observed in the performance parameters



MIP response

- Extracting response to MIPS from most probable value of a landau convoluted with gaussian (signal) mixed with a polynomial background.
- Background added to fit the lower tails properly.
- A stable and large response to MIPS was observed, with S/N ~ 80 implying very negligible fake MET rates from SiPM noise.



References

[1] T. Akesson *et al.* , Light Dark Matter Experiment [arXiv:1808.05219 [hep-ex]].