The beam test results of the USTC-IME LGADs at different irradiation fluence at DESY and CERN PS/SPS beam for ATLAS HGTD upgrade

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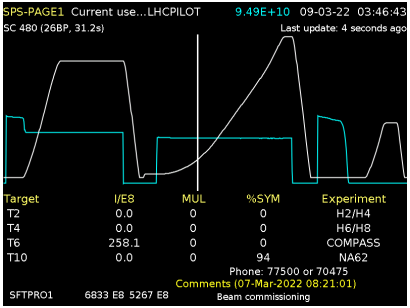
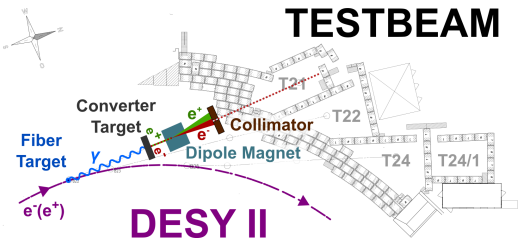
Outline

- Introduction to the test beam at DESY and SPS.
- Introduction to the analysis
- Results for test beam with USTC sensors
- Summary

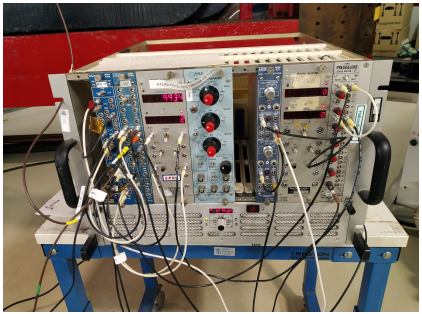
SPS vs DESY





- The SPS@CERN accelerates protons received by the PS ($\sim 26 GeV$) to 450 GeV.
  - SPS in turn feeds the LHC, will take protons to about 13.6 TeV (for Run 3).
- SPS give a pulse of protons, followed by a interval with no beam.
  - These protons hit a target and produce pions (120 GeV) that are used in the test beam.
- DESY is a synchrotron: electrons are accelerated in the DESY ring and will emit photons via bremsstrahlung interaction.
  - These photon give origin to a electron-positron pair.
  - Using a magnet and collimators, we obtain a clean continuous electron (6 GeV) beam.

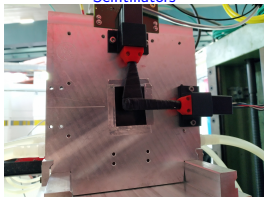
Implementation of a BUSY signal



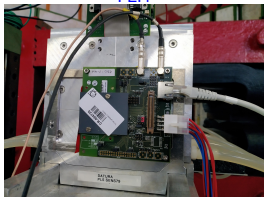
- In order to save the information from the telescope, we need to stop data taking by introducing a busy signal.
  - This is not necessary at SPS, since the beam is not continuous.

Trigger

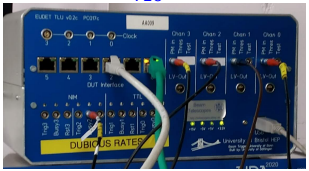
Scintillators



FEI4

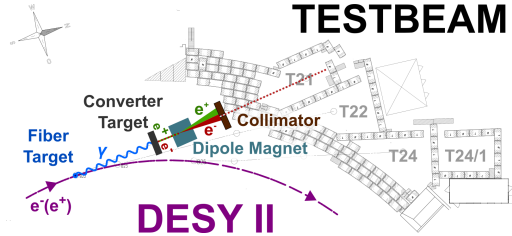


TLU

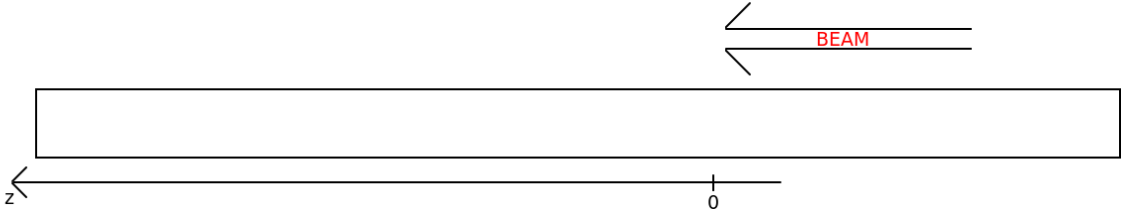


- Normally, one just uses a couple of scintillators in each side of the telescope to trigger on a electron passing in every MIMOSA plane.
- On the far side, a FEI4 trigger board is used for fast triggering, instead.
- A Trigger Logical Unit (TLU) uses the coincidence of four channels:
  0. Busy signal
  1. FEI4
  2. Scintillator 1
  3. Scintillator 2
- Trigger logic: !0 & 1 & 2 & 3

Experimental setup 1/6: Beam

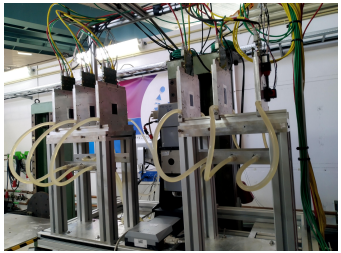


Magnet not in use



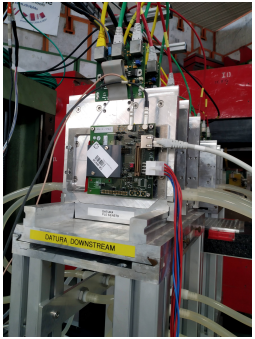
Experimental setup 2/6: Telescope

MIMOSA telescope
M1z = 73.6 cm
M2z = 65.9 cm
M3z = 58.4 cm
M4z = 24.1 cm
M5z = 12.1 cm
M6z = 0 cm

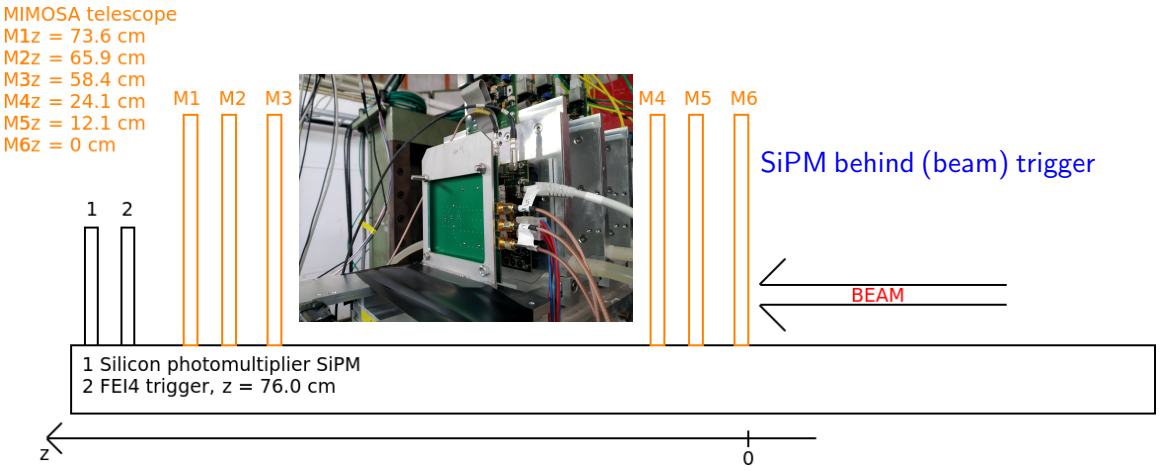


Experimental setup 3/6: FEI4 trigger

MIMOSA telescope
M1z = 73.6 cm
M2z = 65.9 cm
M3z = 58.4 cm
M4z = 24.1 cm
M5z = 12.1 cm
M6z = 0 cm



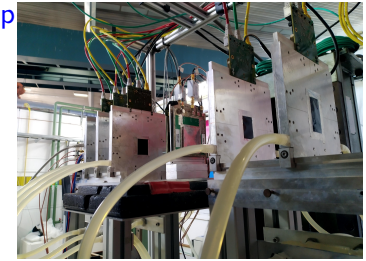
Experimental setup 4/6: Silicon photomultiplier



Experimental setup 5/6: Device under test (DUT)

MIMOSA telescope
M1z = 73.6 cm
M2z = 65.9 cm
M3z = 58.4 cm
M4z = 24.1 cm
M5z = 12.1 cm
M6z = 0 cm

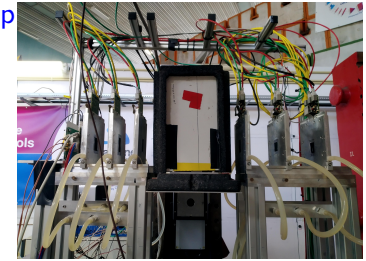
2 DUTs setup



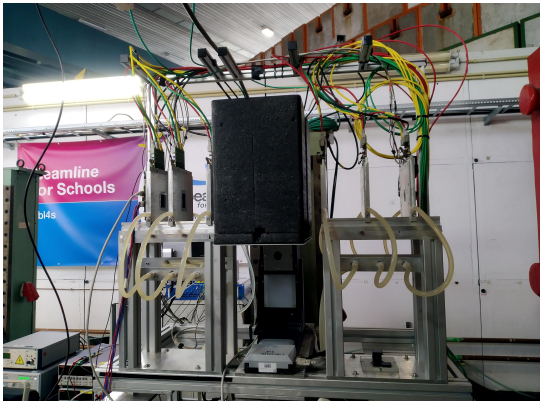
Experimental setup 6/6: Cooling chamber

MIMOSA telescope
M1z = 73.6 cm
M2z = 65.9 cm
M3z = 58.4 cm
M4z = 24.1 cm
M5z = 12.1 cm
M6z = 0 cm

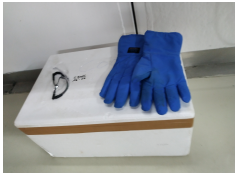
2 DUTs setup

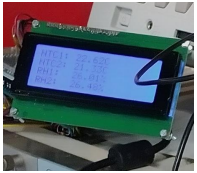


Final setup with cooling



- Cooling made with dry ice
  - only at DESY.
- Monitor temperature from Control Room:
  - Refill dry-ice if $T > -25°C$.
- Monitor also humidity:
  - Toggle usage of dry air.

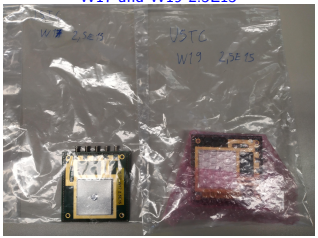


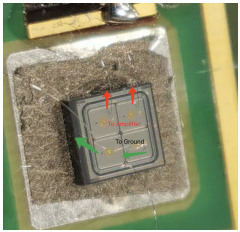


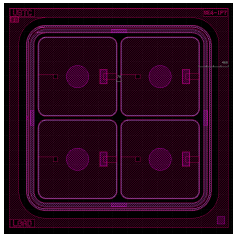
Device under test from USTC

W17 0E15 and 1.5E15

W17 and W19 2.5E15



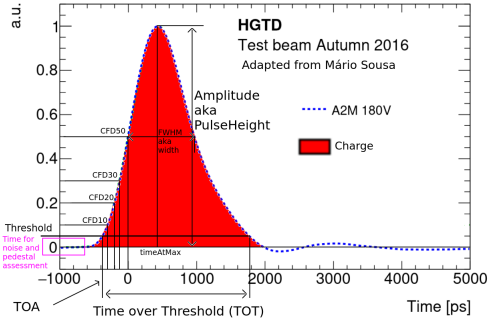




- 4 DUT single pads tested in DESY:
  - W17 unirradiated
  - W17 irradiated at 1.5×10^{15} and 2.5×10^{15} 1 MeV n equivalent.
  - W19 at 2.5×10^{15} 1 MeV n equivalent.
- 4 2x2 pads unirradiated: W17 and W19 with inter-pad (IP) gap of 3 and 7.

Analysis introduction

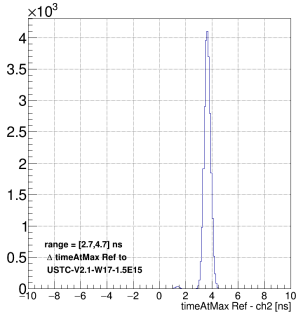
Osciloscope pulse analysis

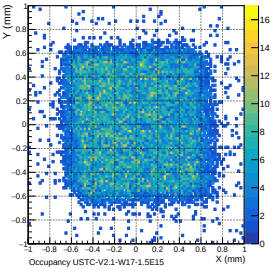


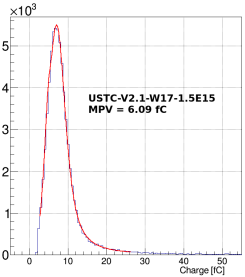
- Figure adapted from TB paper.
  - arXiv:1804.00622v3
  - **See original: figure 7(b)**

TOT	Time over threshold.
TOA	Time of arrival.
Amplitude	Maximum of the pulse.
width	Full width half height.
CFDxx	Constant fraction discriminator above xx%.
timeAtMax	Time at maximum of pulse.
Pedestal	Average of voltage before pulse (∼6ns).
Noise	Standard deviation of voltage before pulse.
X/Ytr	Intersection of reconstructed track with DUT.

Test beam analysis



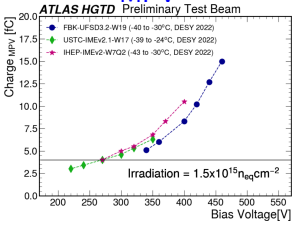


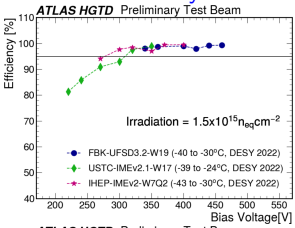


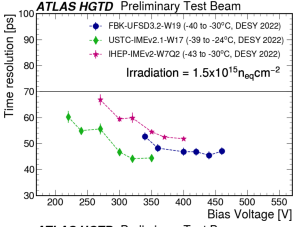
- timeAtMax (DUT-reference) within 1 ns from maximum of distribution.
- Using MIMOSA planes reconstruct a track passing through the DUT at (Xtr,Ytr).
- Take events in the centre of the DUT and measure the charge.
- Most probable value from a Landau fit.
- Efficiency measured as how many events have more than 4 fC.

MPV | Efficiency | Time resolution*

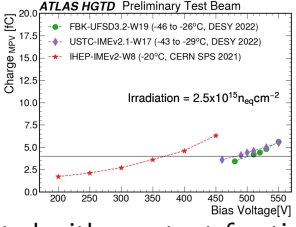
1.5E15

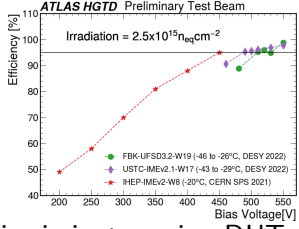


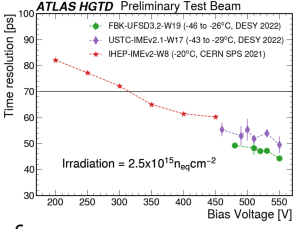




2.5E15





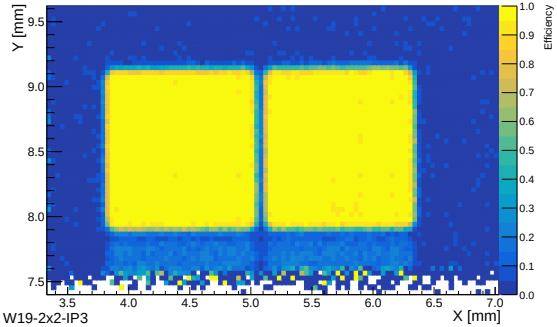


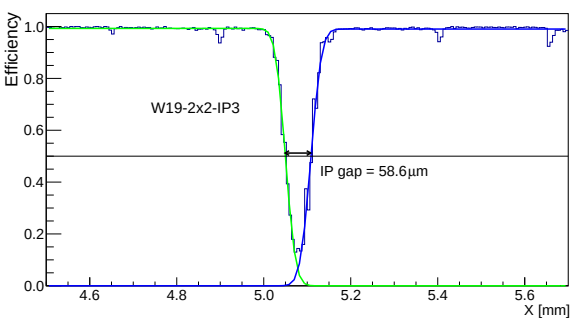
* calculated with constant fraction discriminator using DUTs vs reference.

- Value given from σ of Gaussian fit to difference distribution.

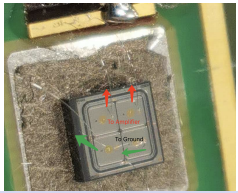
Meeting HGTD specifications!

A look ahead to on-going analysis





- 2x2 USTC sensor with two pads connected to amplifier and two connected to ground.
- Projection in X-axis fitted with two error functions.
  - error function: $f(x) = a + \frac{b}{2} \times \mathrm{erf}\{\frac{\sqrt{2}(x-c)}{d}\}$
- Inter-pad gap determined from the distance between the 50% of the convolved functions.



Summary and outlook

- Several HGTD sensors measured at test beam in DESY and PS/SPS in 6 sessions during this year.
  - Including 8 sensors produced in USTC.
- Results from DESY presented at 10th Beam Telescopes and Test Beams workshop.
  - USTC-W17 meets already HGTD specifications.
- On-going analysis probing already the inter-pad region for USTC sensors.
- More to come from this year test beams: testing the new ALTIROC 2.0
  - Stay tuned...