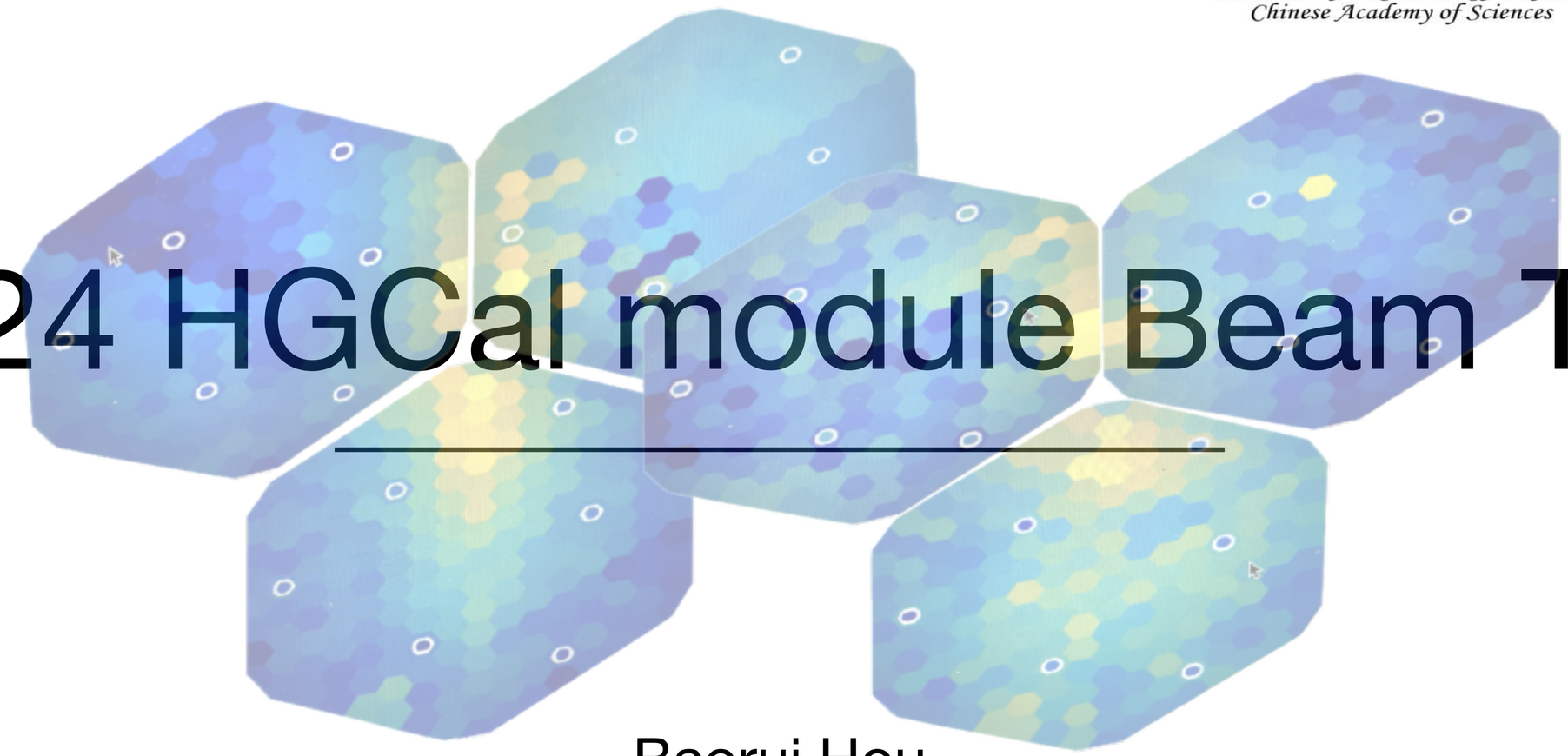
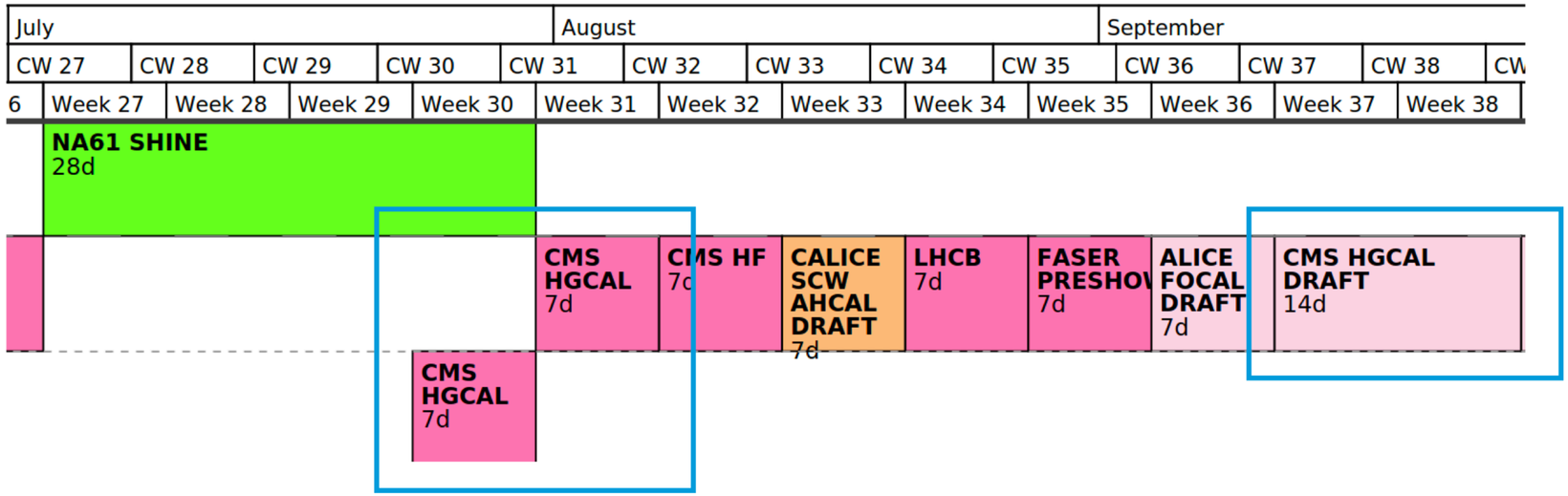


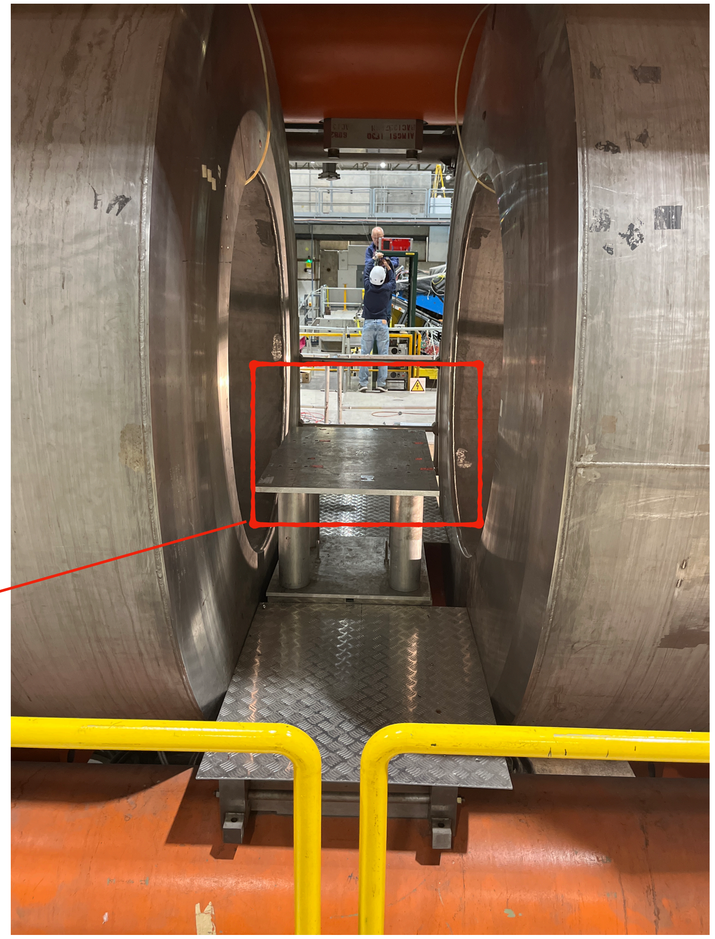
2024 HGCal module Beam Test

Baorui Hou
On behalf of HGCal Group

CLHCP 2024 11.15

2024 HGCal Beam Test





Test area

- Test on the SPS-H2 beam line (Electron, Muon), inside the M1 magnet.
- First beam test: 24 July - 7 August 2024 (First week as secondary user).
- Second beam test: 11 - 25 September 2024(Both weeks main user).
- Goals:
  - ➡ Operation of larger trains than 2023(3 modules vs 1 per train).
  - ➡ Operation of HGCAL silicon modules in a magnetic (**1st time**) → study the effect on the Signal/Noise (S/N) with muon beam and on larger signals with electron beam.
  - ➡ Study Time of Arrival (ToA) performance after the trimming of the Time-to-Digital Converter (TDC).
  - ➡ Verification of pre-production HGCROCv3B and production ECONs.

Setup for 1st beam test

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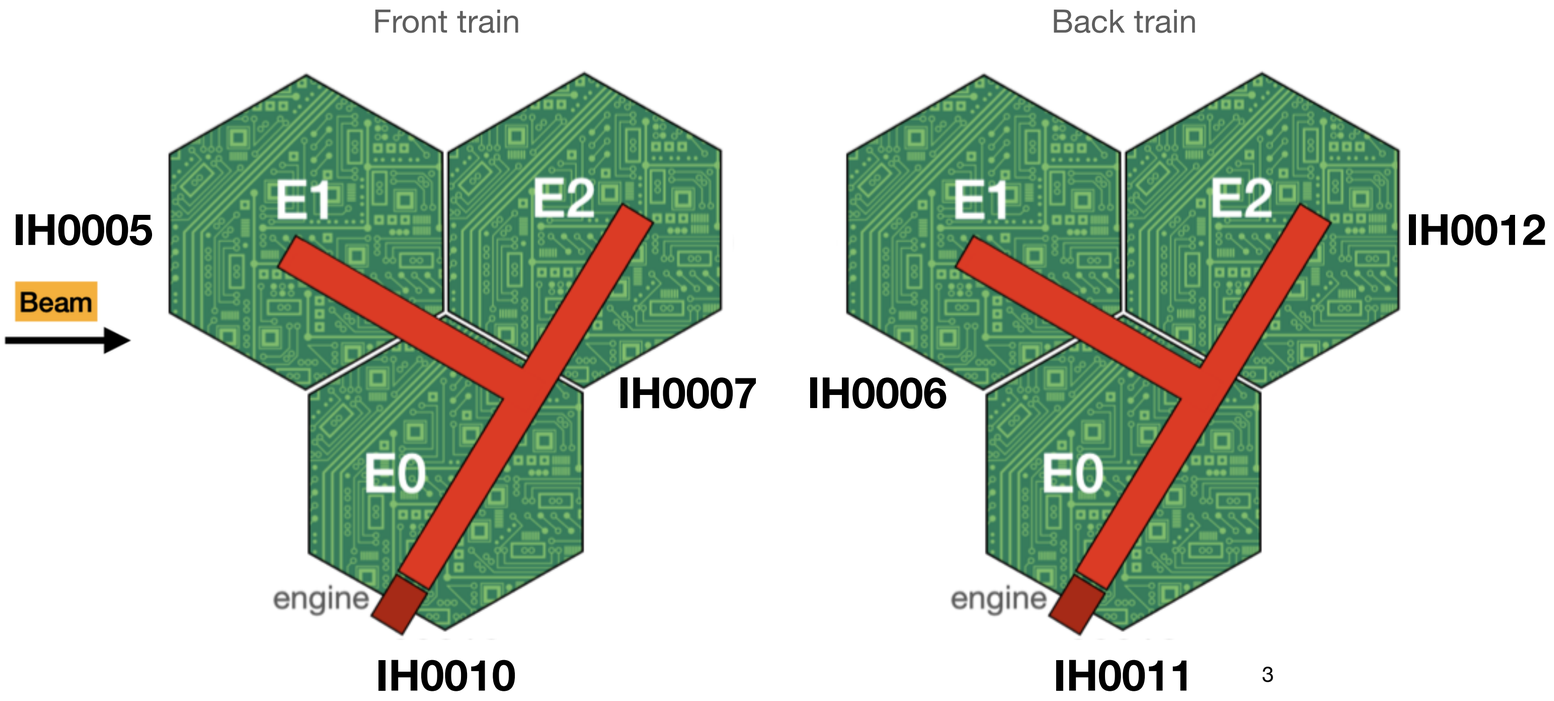
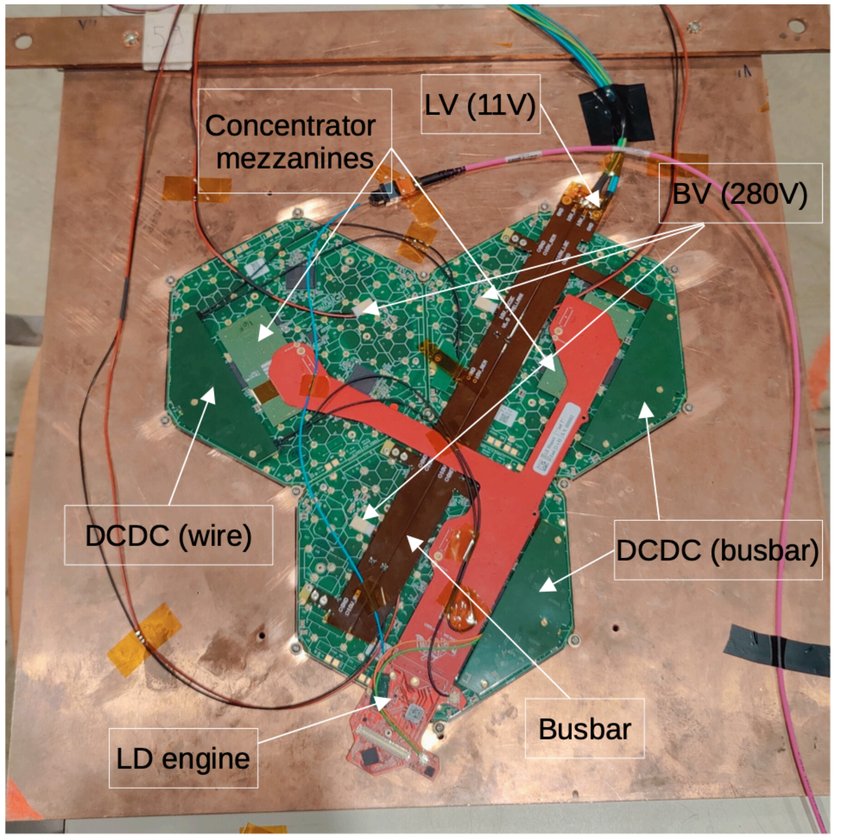
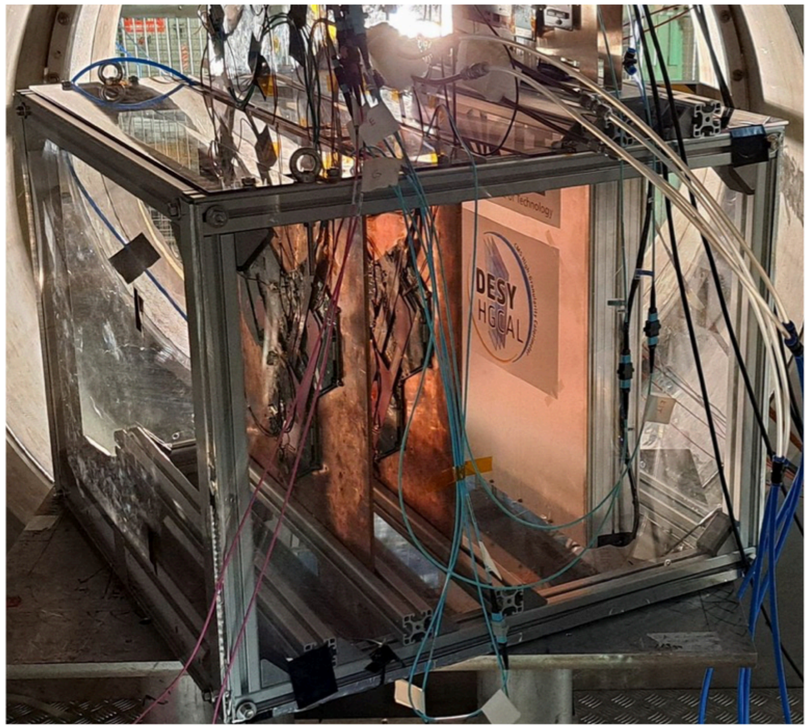
- Low Density (LD) pre-series modules equipped with HGCROCv3A (Application-Specific Integrated Circuit, ASIC) and prototype ECONs (Endcap Concentrators) were used.
- 2 identical layers assembled with 3 LD silicon modules (300 μm thick sensor) with a T-shape wagon and LD engine.

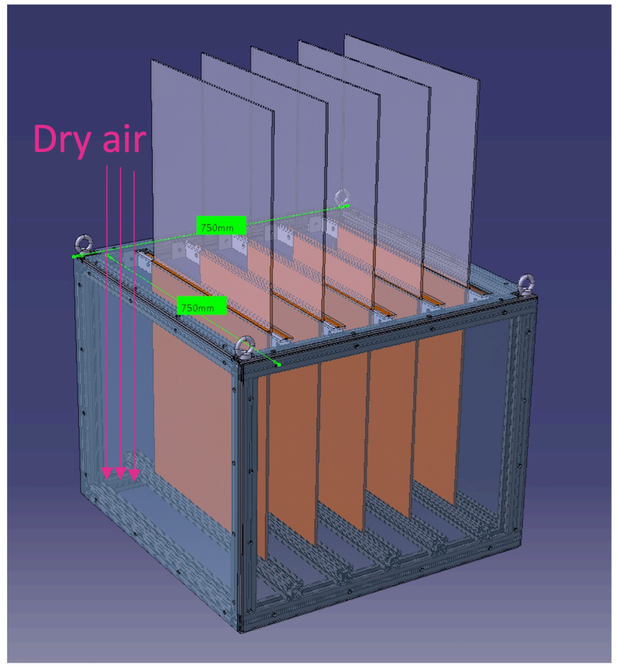


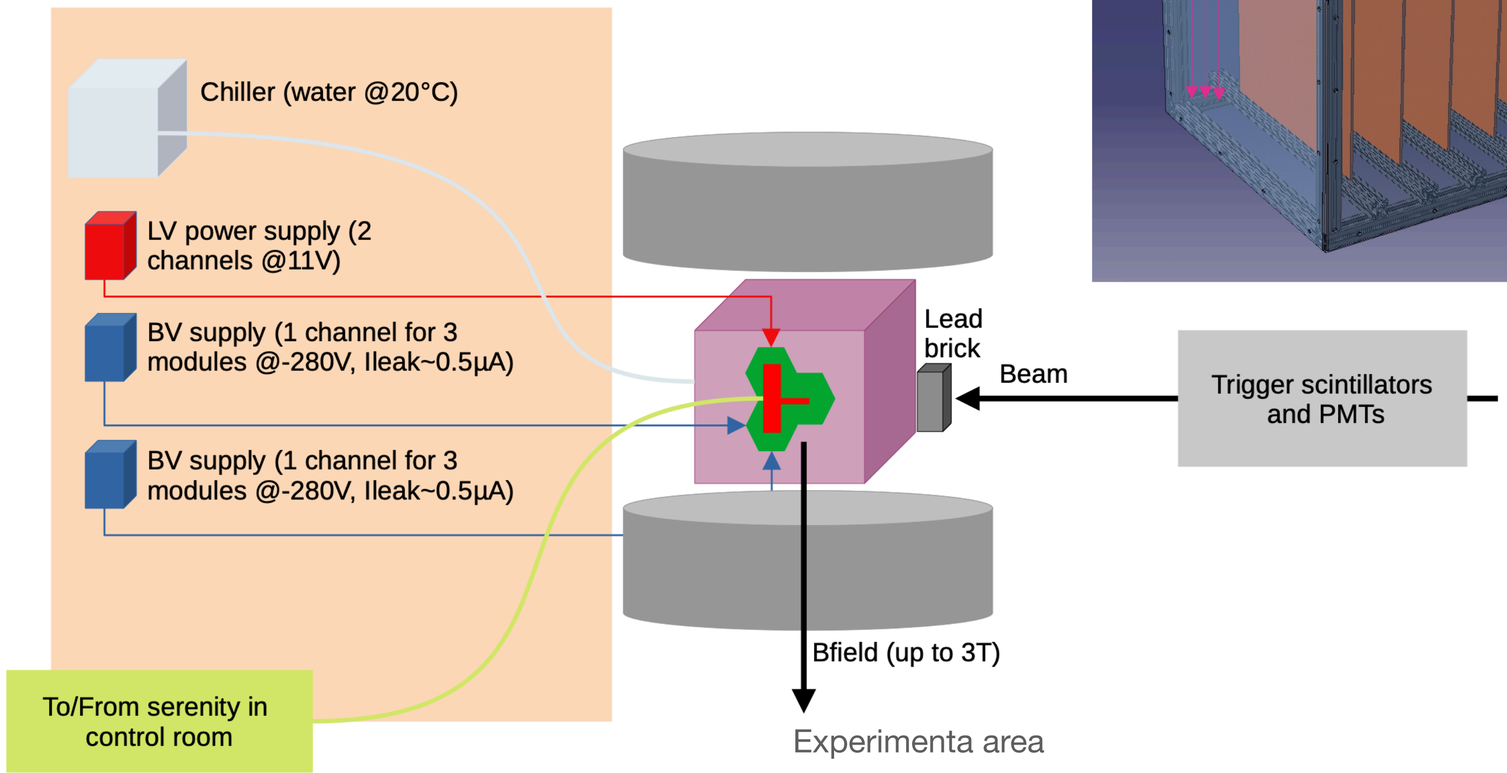


Setup for 1st beam test

- Due to the need for the module to operate in a dry environment, Module trains were placed in a box with dry air.
- The module generates heat during operation. Modules mounted on copper plates, water cooled at 20ºC. Dig holes in the copper to secure the modules.

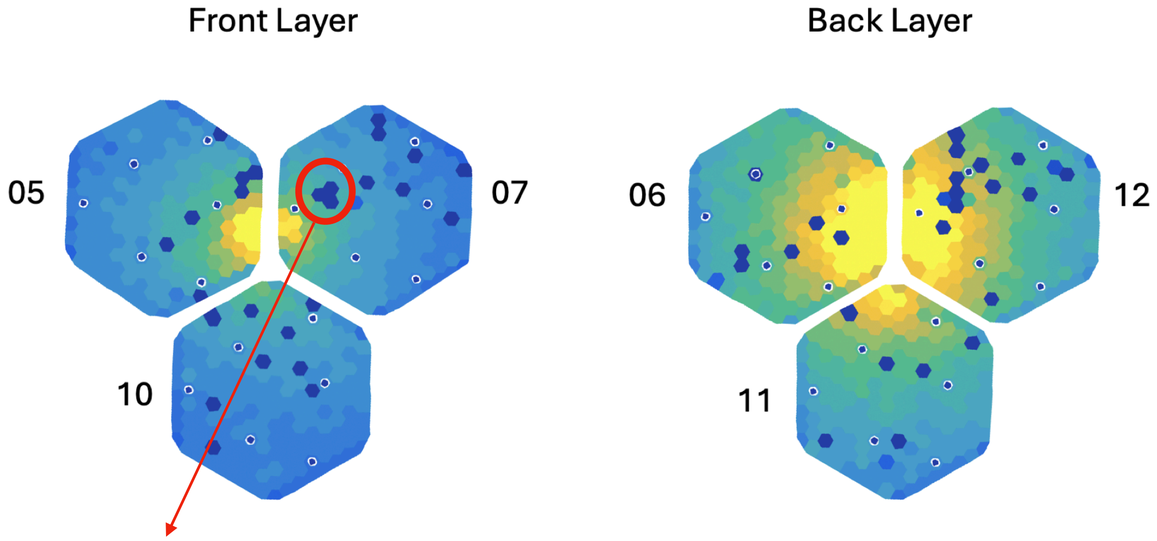




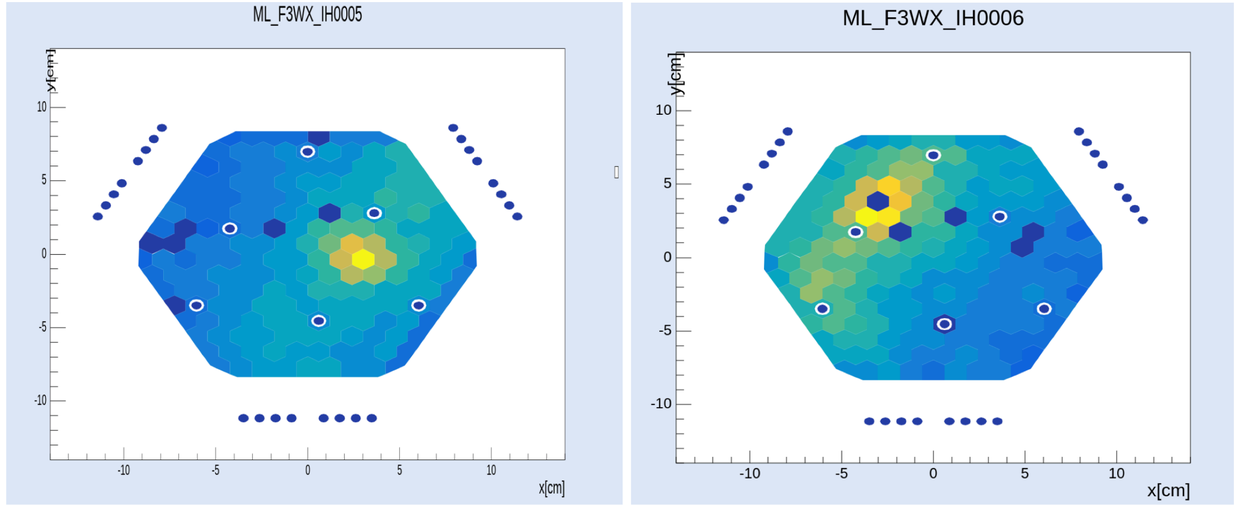


1st Beam Test Highlights

- Signal of beam was found after adjusting various latencies.
- Standard deviation of the ADC from data acquired with electron@200GeV , B@3T.



modules perpendicular to the beam.

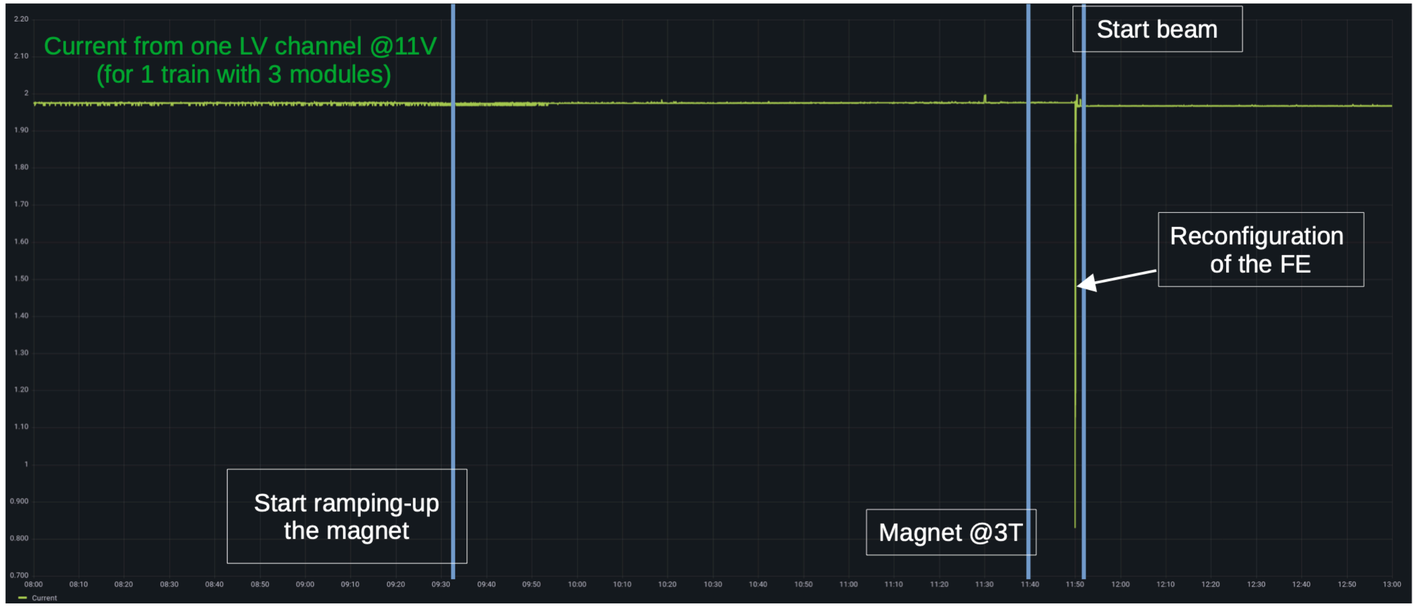


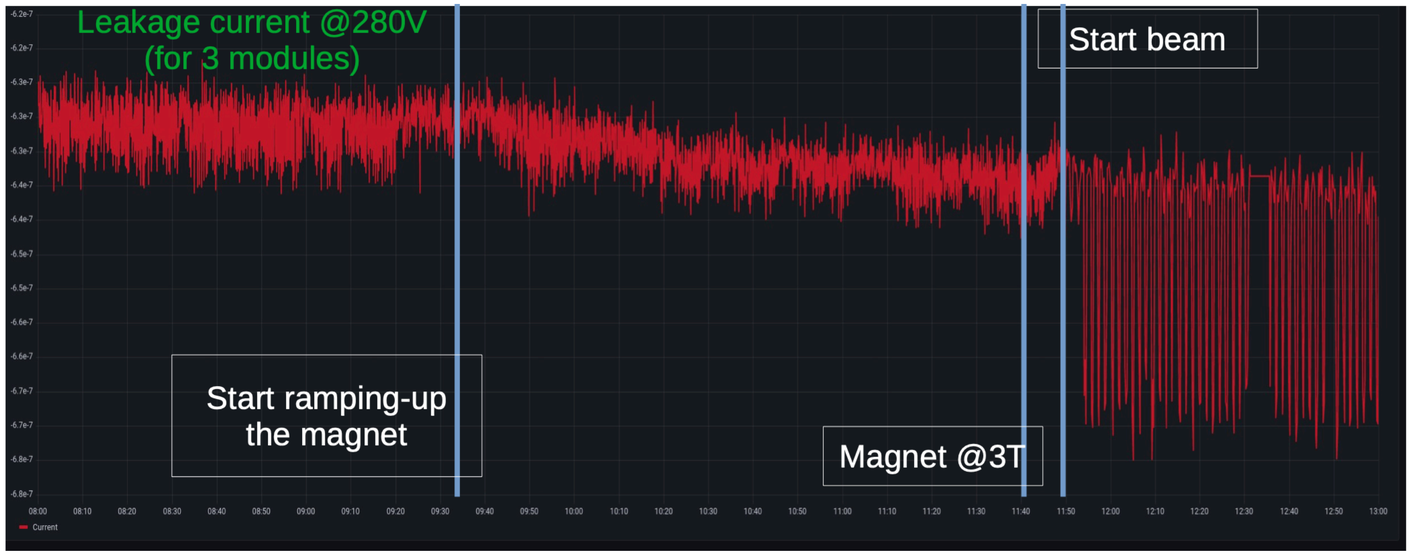
modules 30° rotation to the beam.
Z-scale is not the same on the 2 modules

- Stable operation in 3 T magnetic field.
  Rotations 0°, 30° and 90° wrt. beam.

1st Beam Test Highlights

- No obvious effect has been detected with the magnetic field on the low voltage power (11 V) or on the bias voltage (280 V).

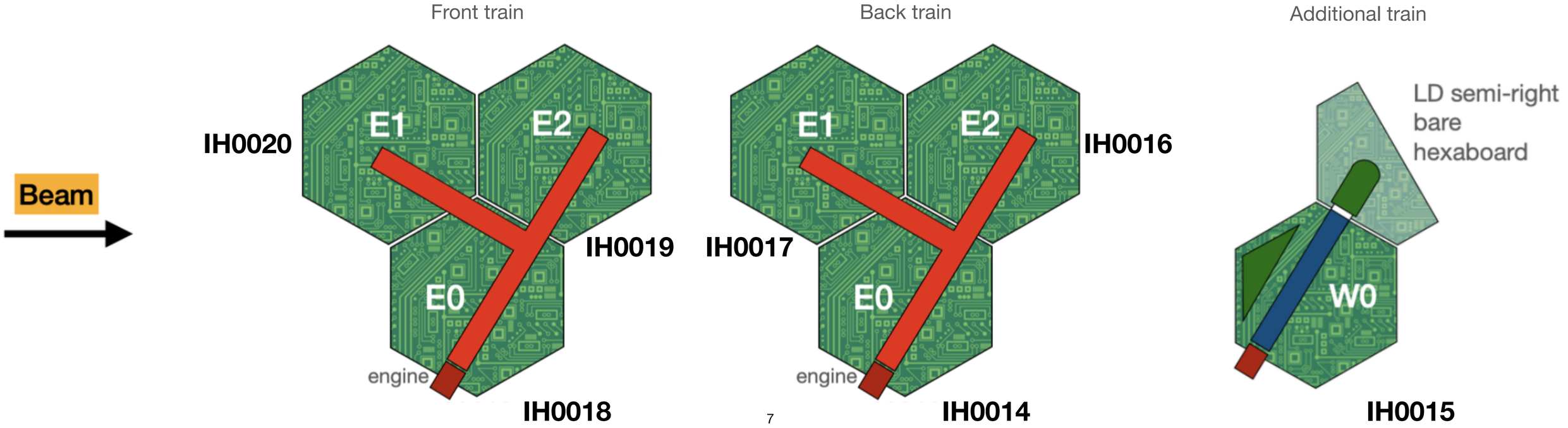




- A brief summary of 1st beam test:
  - ➡A successful operation of a larger train.
  - ➡The whole system works well with 6 modules in magnetic field.
  - ➡A normal performance of pre-series module with prototype ECONs.

Setup for 2nd beam test

- The same experimental area @M1 magnet with 1st TB.
- Pre_production modules equipped with HGCROCv3B and production ECONs were used.
- Add the additional layer to verify a more complex system (3 trains).
- Most of the data were acquired with the pass through mode.



2nd Beam Test Highlights

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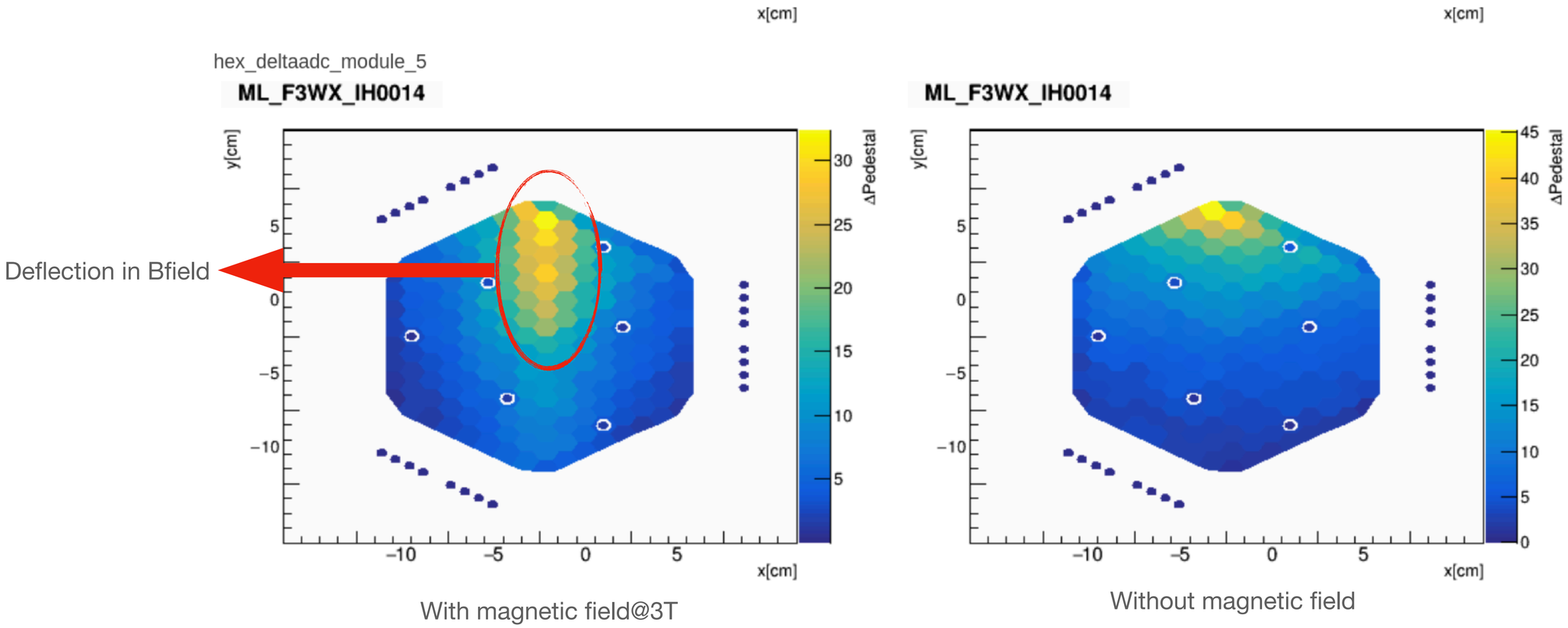
- Beam spot in magnetic field.

Electron@200 GeV.



The pre-production module with production ECONs works in magnetic field@3T.

2nd Beam Test Highlights

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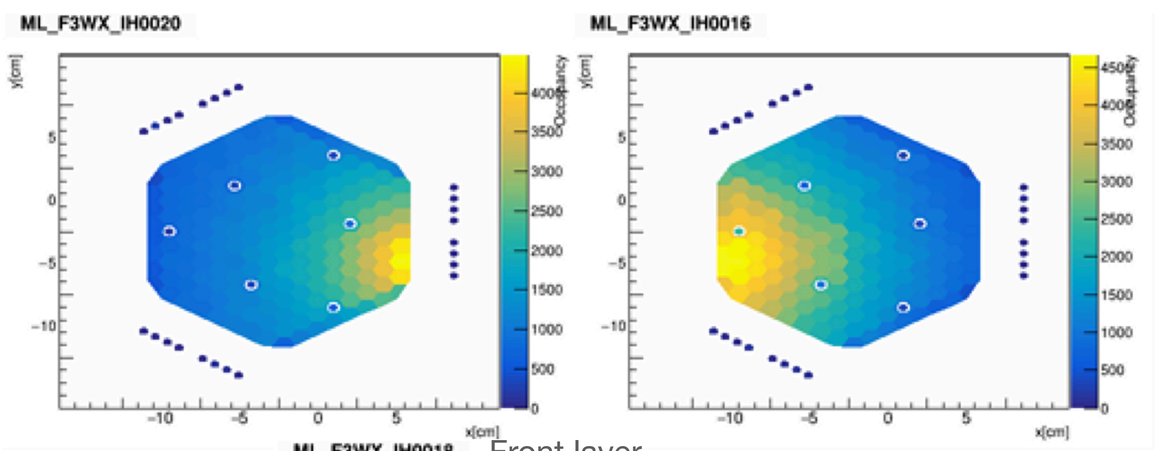
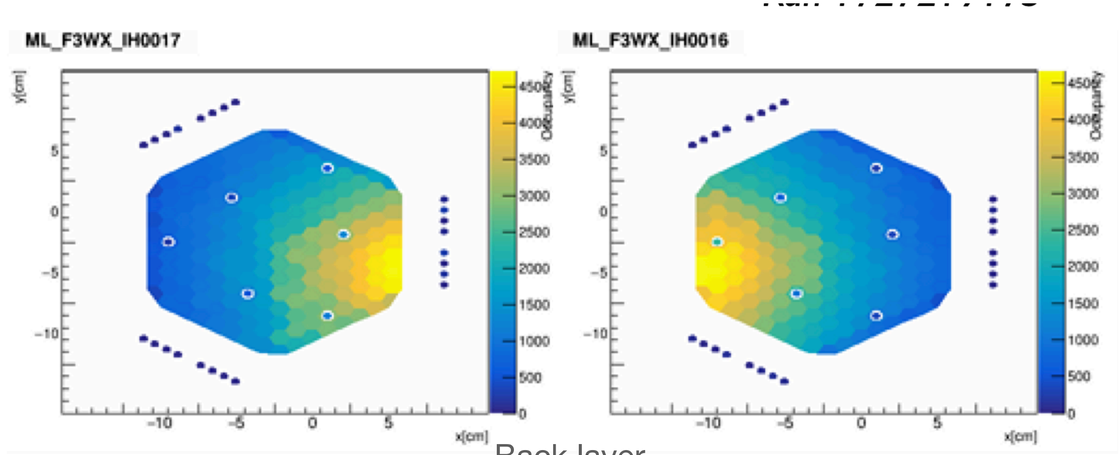
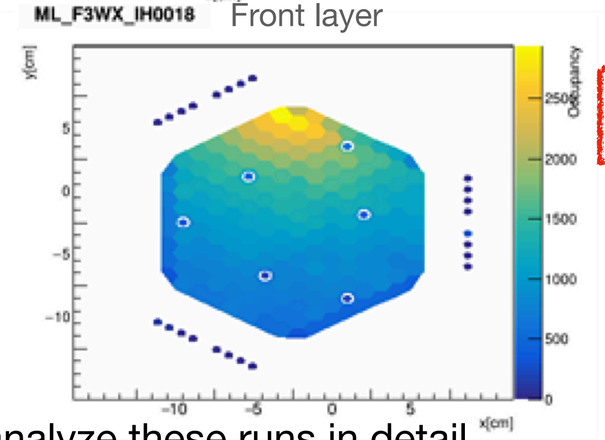
- Occupancy with Zero suppression.
- A better performance (no dead cell) than July TB of pre-production modules with production ECONs.



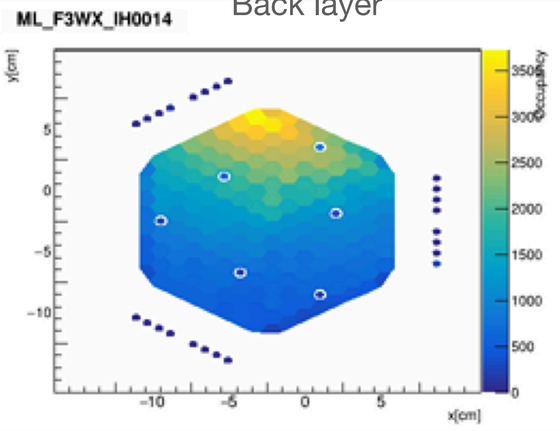
Front layer



Back layer



Electron@200 GeV.

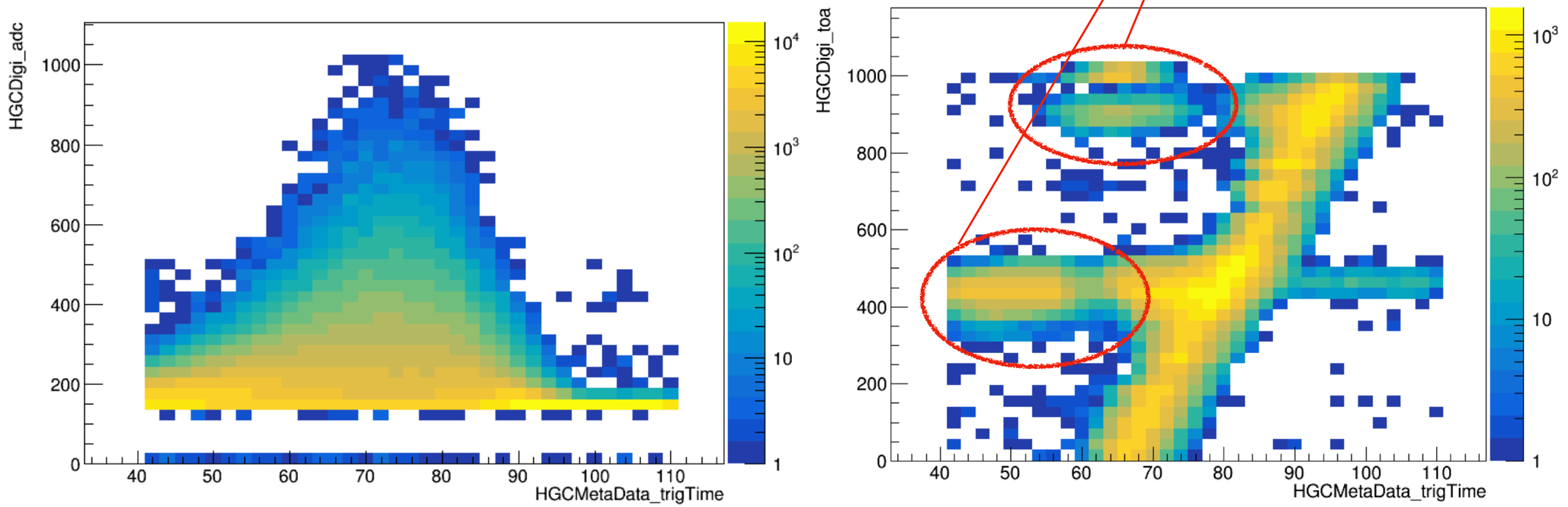


- Next step is to analyze these runs in detail

Beam Test Data Analysis

- Prompt reconstruction and DQM (Data Quality Monitor) was steered automatically.
- In total of over 3.3 $\times$ 10^9 events were unpacked and monitored (5 TB of data).
- A selection of interesting runs to re-reconstruct needs to happen.
- Many analysis topics:
  Comparing noise/(S/N) with/without magnetic field, ToA studying, Triggering study etc.

Under analysis



An example of Analog-to-Digital Converter (ADC) (left) and ToA(right) from one channel as a function of trigger time.

Summary of 2024 HGCal Beam Test

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- An overall positive results of the two beam tests.
- No observation of any bad obvious effects with system in magnetic field(@3T).
- We have obtained huge amounts of data from pre-production modules and production ECONs.
- The pre-production modules and production ECONs have no problems for now.
- We have accomplished our goals of testing the production of (some) constants.
- There are a handful of topics to analyze.(Offline software, Time studies…).
- All 13 modules used in the two TBs are all produced by IHEP.

Back up

- Endcap Concentrators[1] (ECONs):

  The digitized data undergo processing and zero-suppression along two independent paths, managed by two Endcap Concentrators: the trigger path, by the ECON-T ASIC, and the data path, by the ECON-D ASIC. The former produces Level-1 Trigger primitives for each bunch crossing, whereas the latter forwards data packets to the acquisition system at an average L1 rate of 750 kHz. These ASICs operate in tandem, sharing a foundational infrastructure, synchronized clocking mechanisms, and input/output protocols, while drawing upon established silicon-proven Intellectual Property for enhanced efficiency and reliability.

- High Granularity Calorimeter ReadOut ASIC[2] (HGCROC):

  The front-end readout ASICs for CMS HGCal.