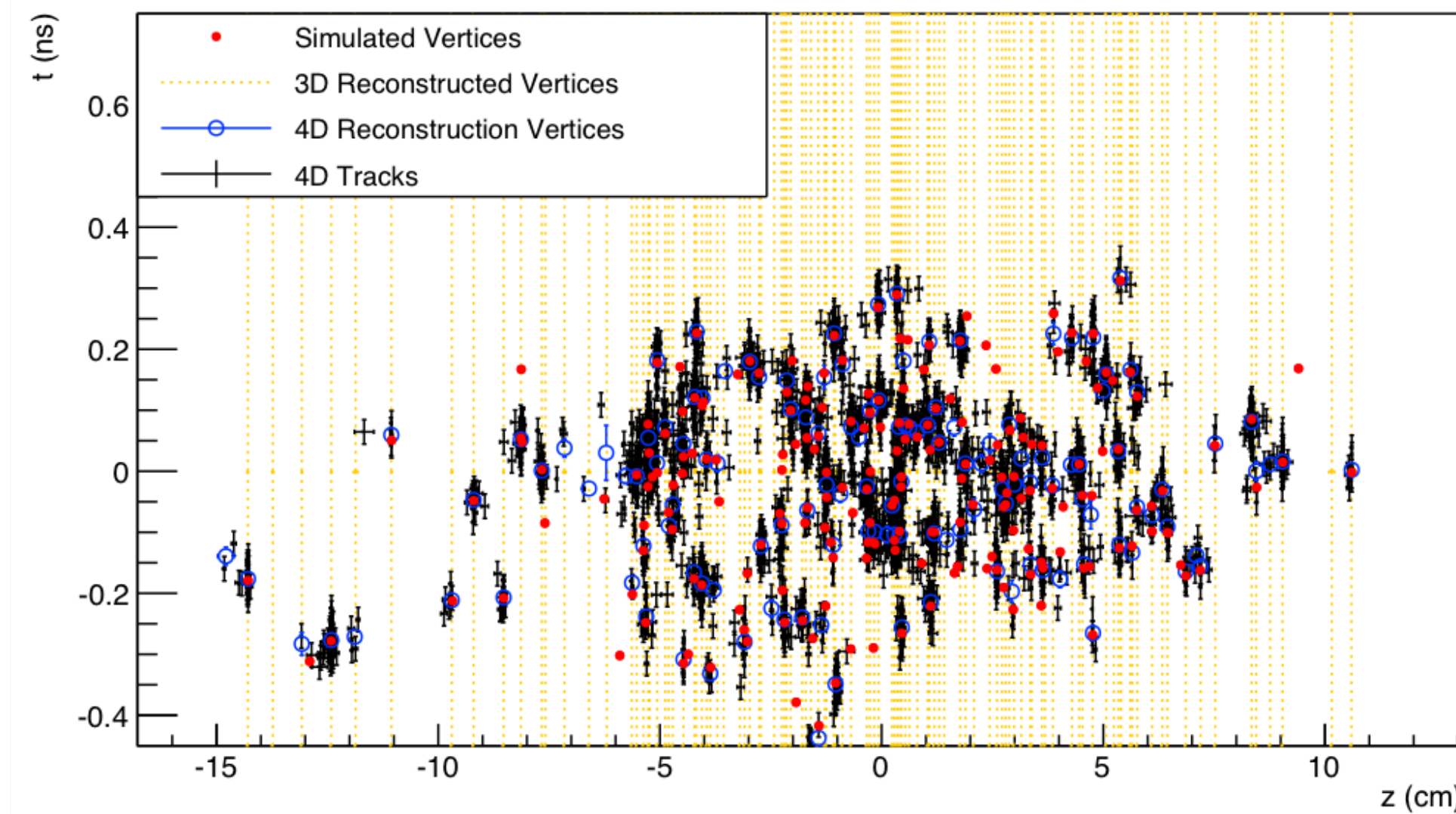


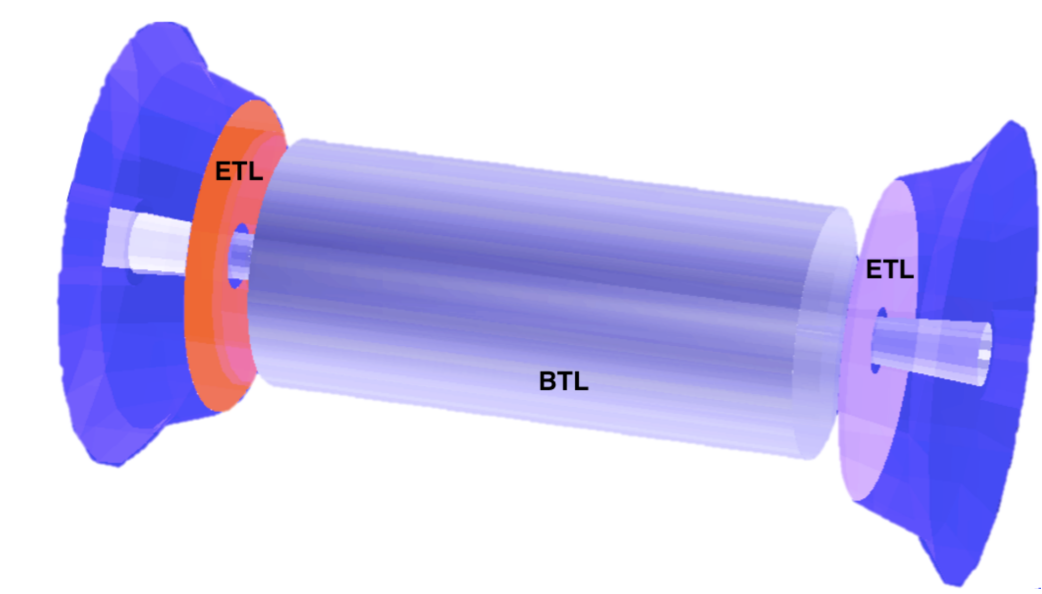
## Motivation

- The High Luminosity LHC will drastically increase the number of interactions per bunch crossing
  - From 40 → 200 interactions
- Use timing to increase vertex resolution for interactions that overlap in space, but not time
- By using a precision of 30-50ps per track we expect to be able to maintain Run2 physics performance



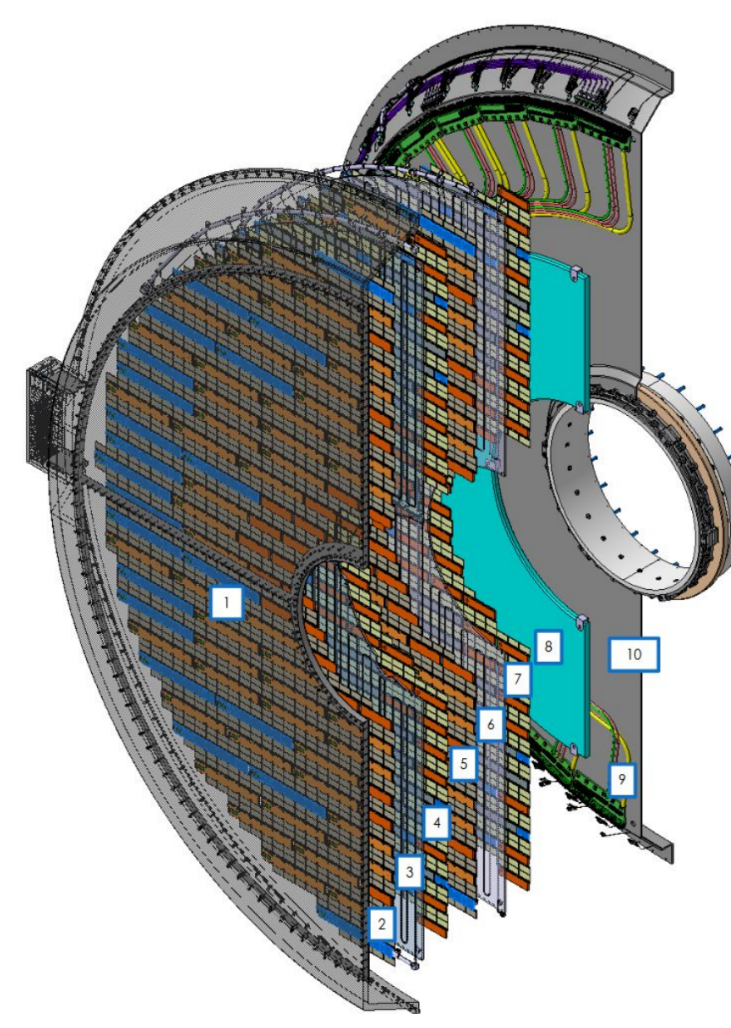
## MIP Timing Detector

- Installed between the tracker and the calorimeter, providing coverage up to  $|\eta| < 3$
- Distinct radiation fluence at  $3000\text{fb}^{-1}$ 
  - Barrel:  $1.7 \times 10^{14} n_{eq}/\text{cm}^2$
  - Endcap:  $1.5 \times 10^{15} n_{eq}/\text{cm}^2$



## ETL Structure

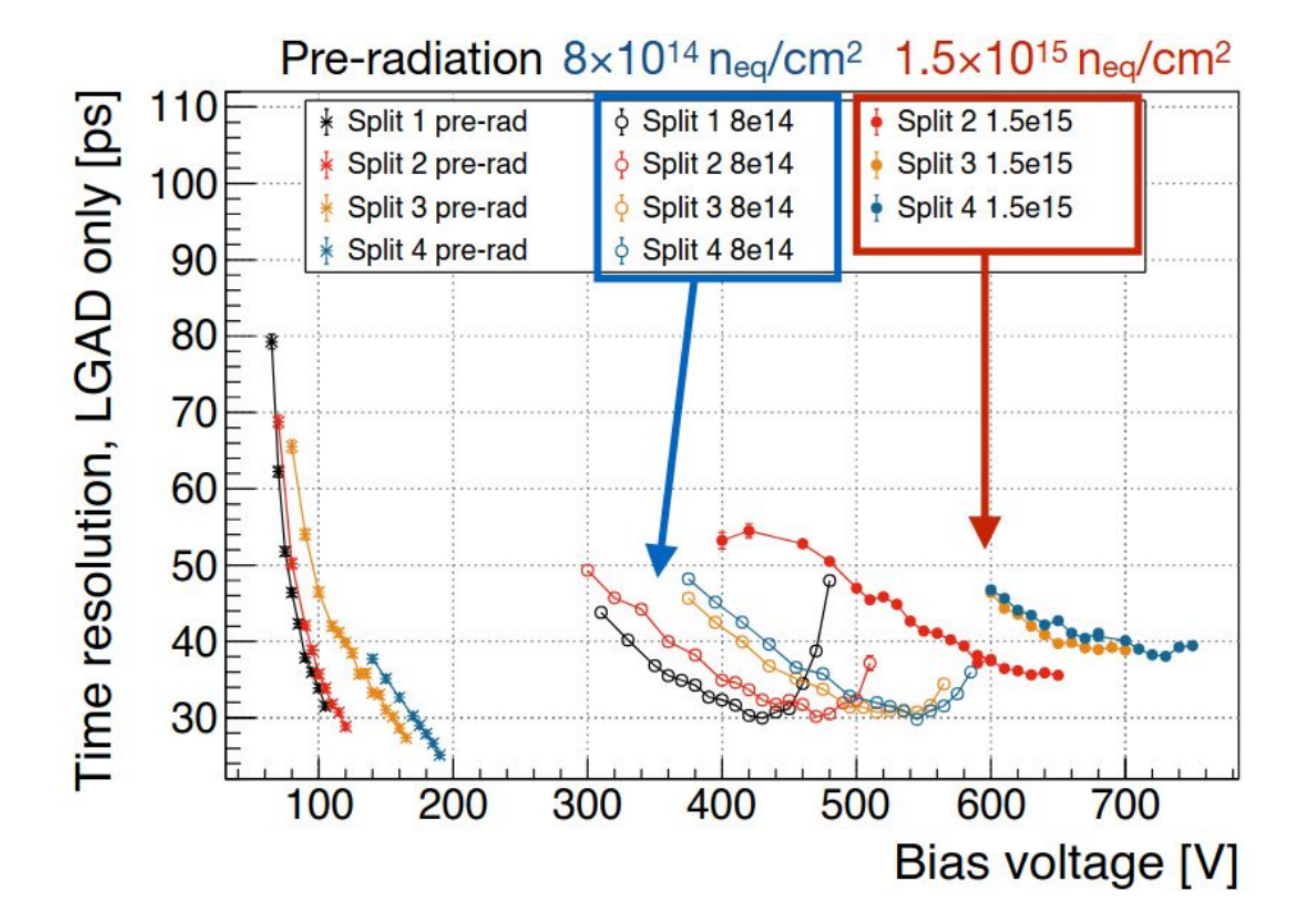
- Radius:  $315\text{mm} < r < 1200\text{mm}$
- z-position:  $\pm 3\text{m}$ , 99mm thick
- Two discs per endcap with modules covering both sides of the discs → expect  $\approx 2$  hits per track
- $\approx 8000$  modules total across both endcaps,  $\approx 8$  million total channels



## Sensors

### Low Gain Avalanche Detectors (LGADs)

- Good radiation hardness
- Relatively thin sensor
- Low gain → low noise, fast rising pulse
- Resolution of  $\approx 30$  ps for a charge deposit between 15-35fC
- Maintain performance after irradiation, up to 40ps resolution at 10fC under end of life conditions



Per hit resolution

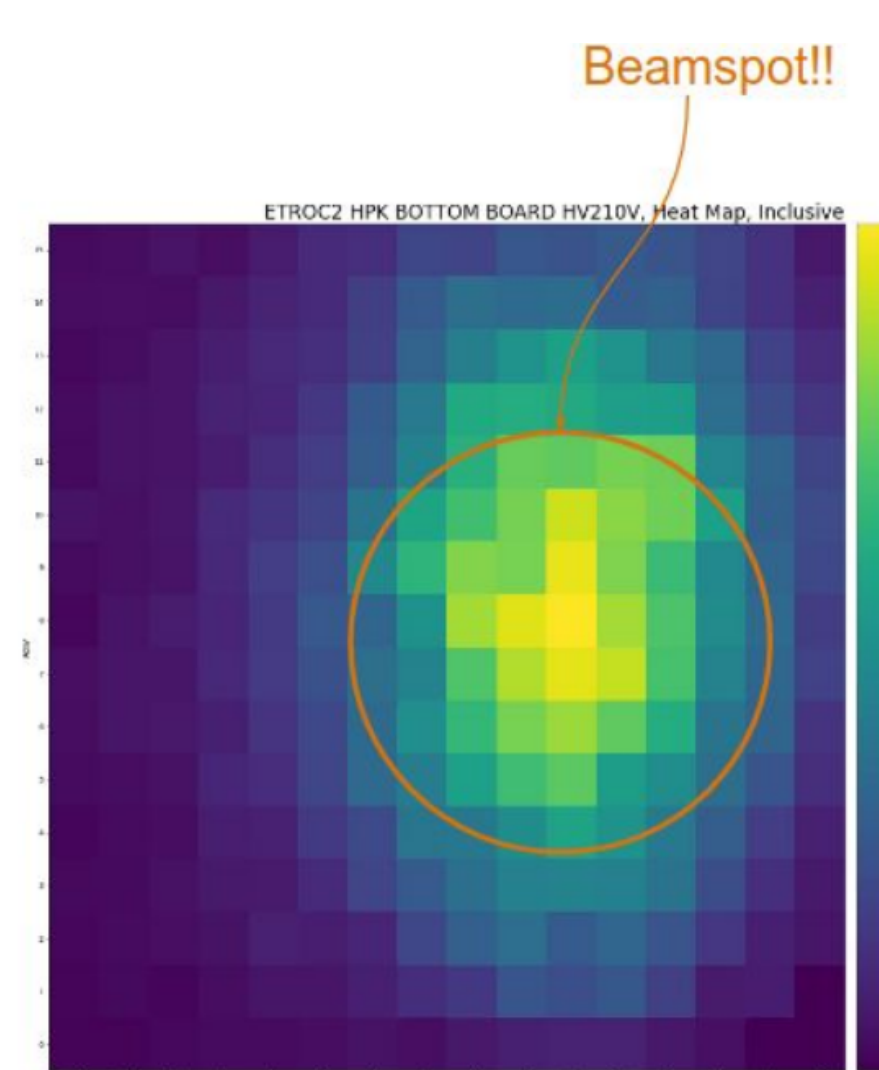
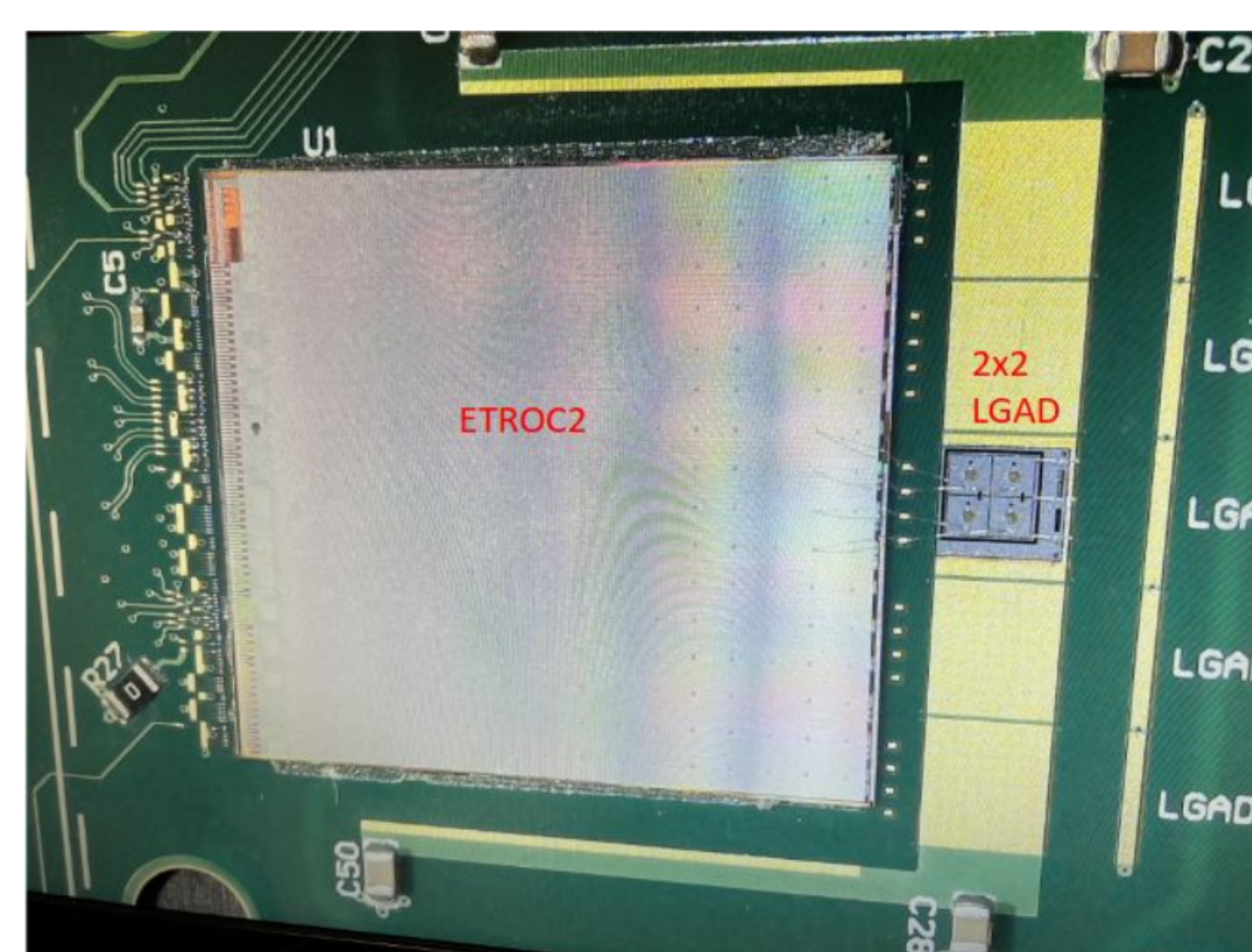
## Readout

### Constraints

- Low gain from LGADs → low charge from sensors
- Readout contribution to time resolution has to be under 40ps
- Low power budget of 1W per chip → need custom low power ASIC

### ETROC2

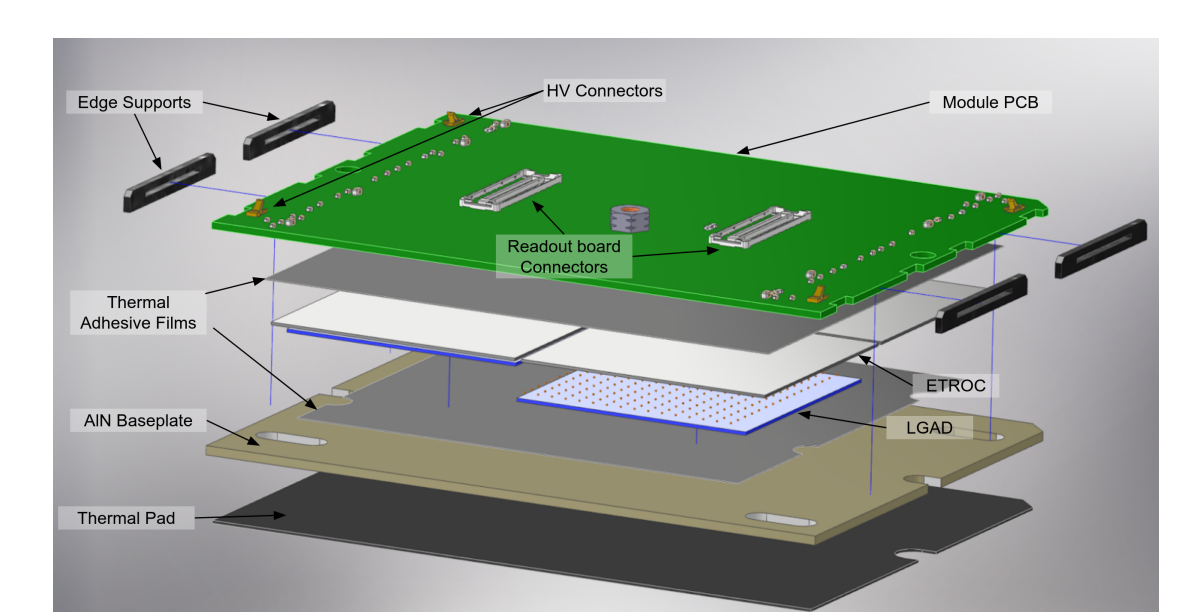
- Prototype: 16x16 pixels with full functionality, expected performance demonstrated
- ETROC2 + 2x2LGAD testbeams recently completed
- Testing with 16x16 LGADs ongoing



Beamspot image from 16x16 LGAD testing

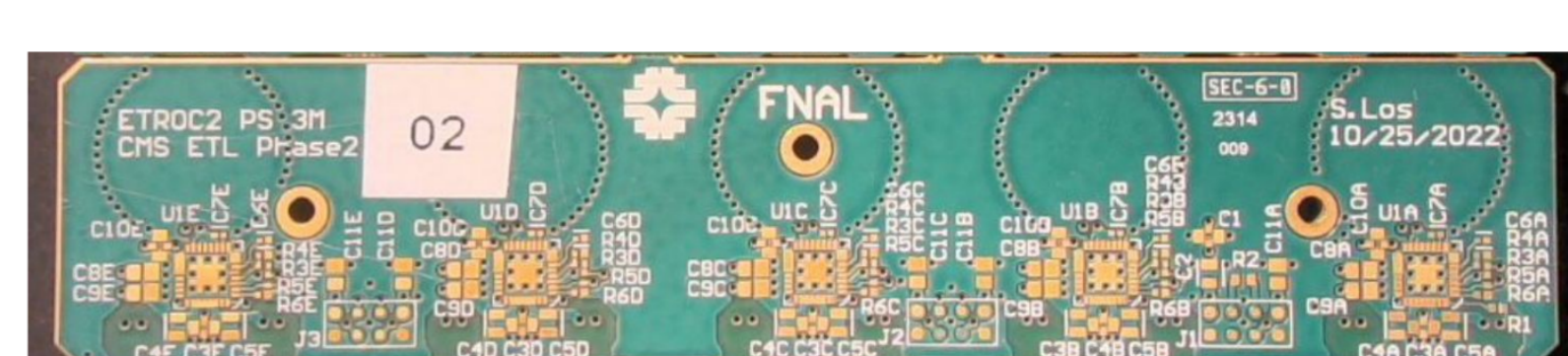
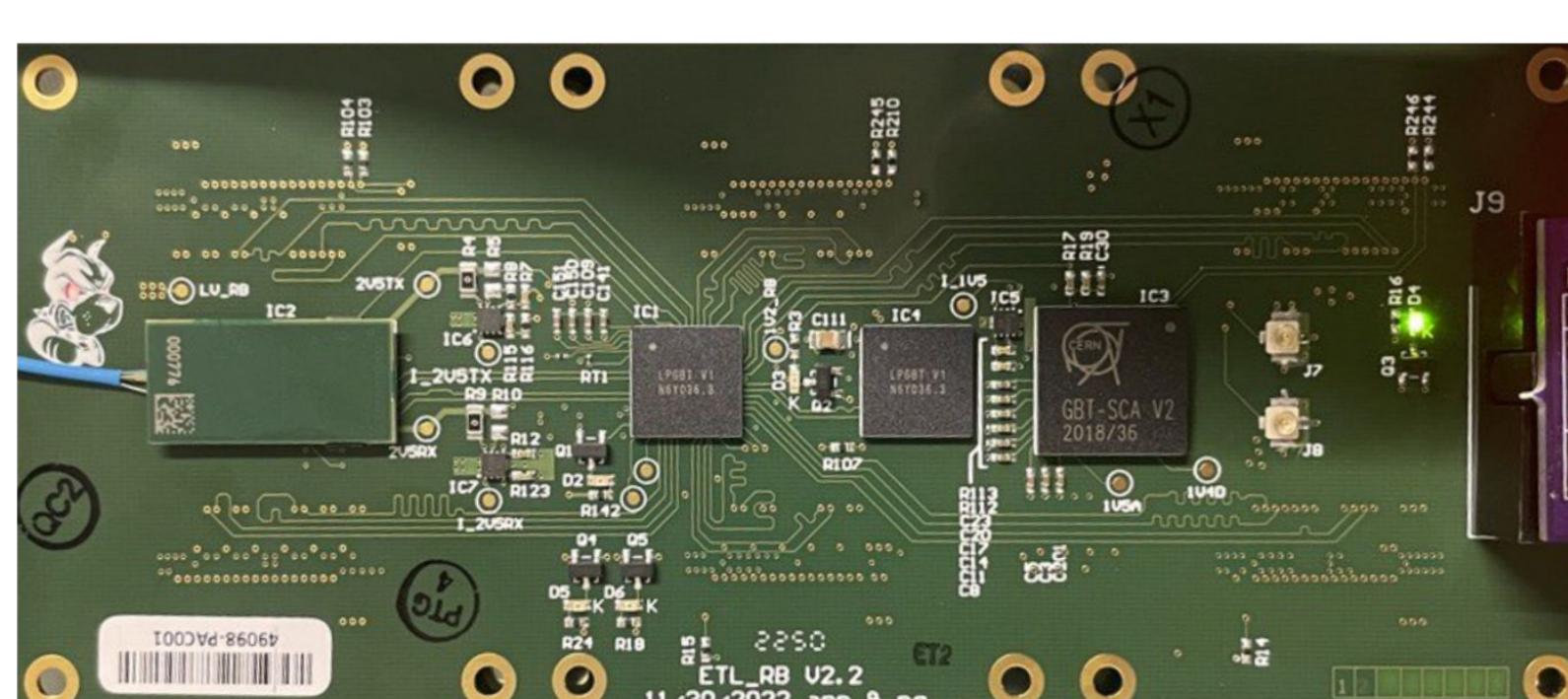
## Modules

- Each module will be made up of 4 LGADs, bump bonded to 4 ETROC2s
- Thermal interface provided by an AlN base plate
- Electrons provided by module PCB
- Assembly will occur at several sites, throughput testing recently completed



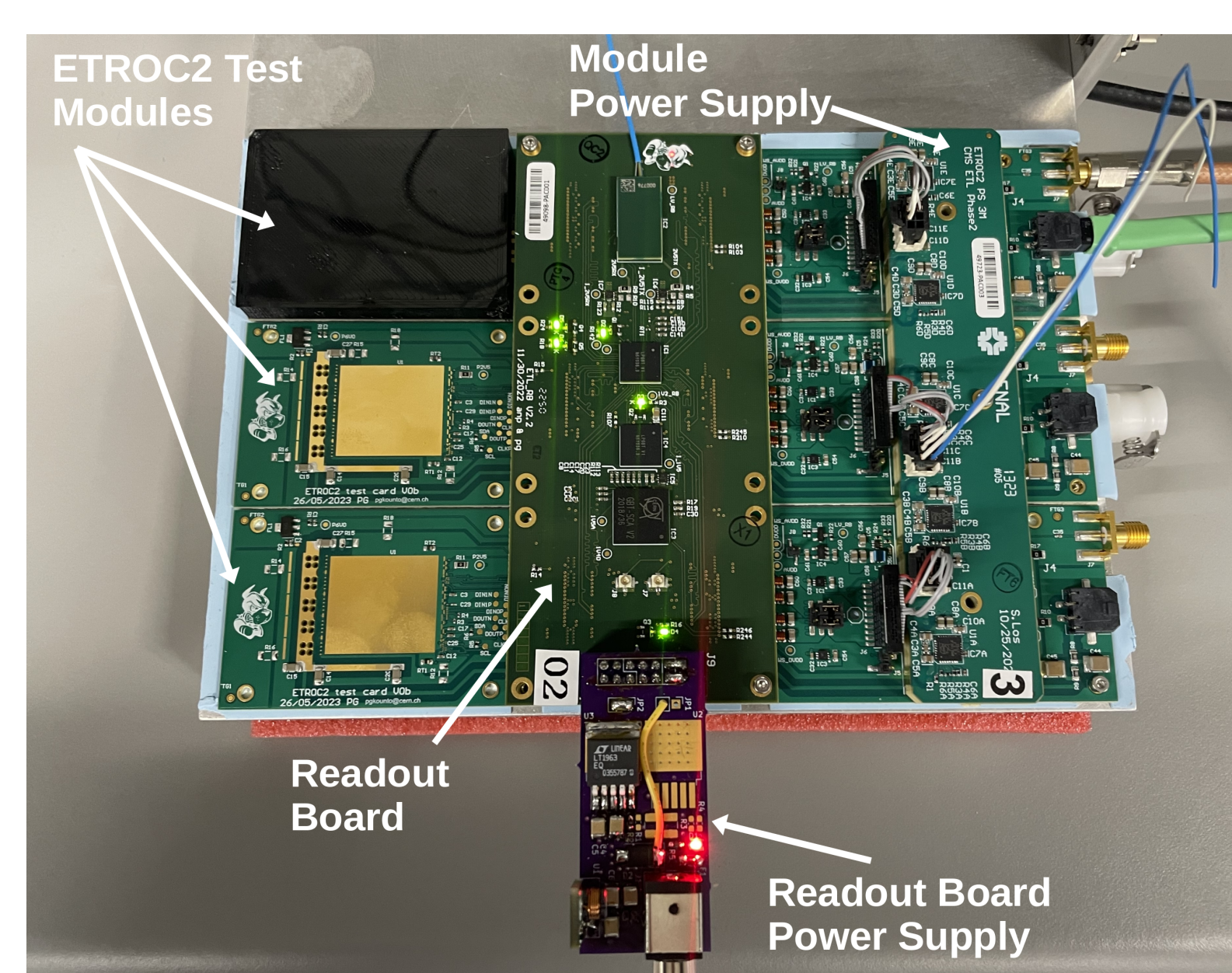
## Front End Electronics

- Readout board based on CERN's radiation hard GBT chip-set and Optical Link Module, VTRx+
- Custom power board designed by Fermilab

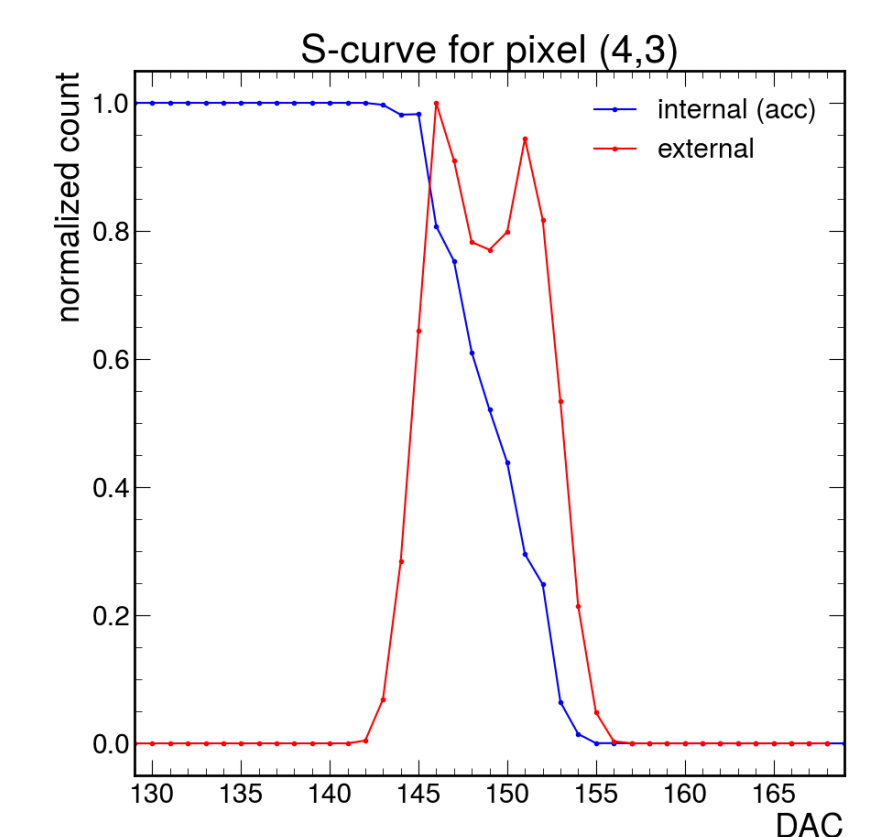
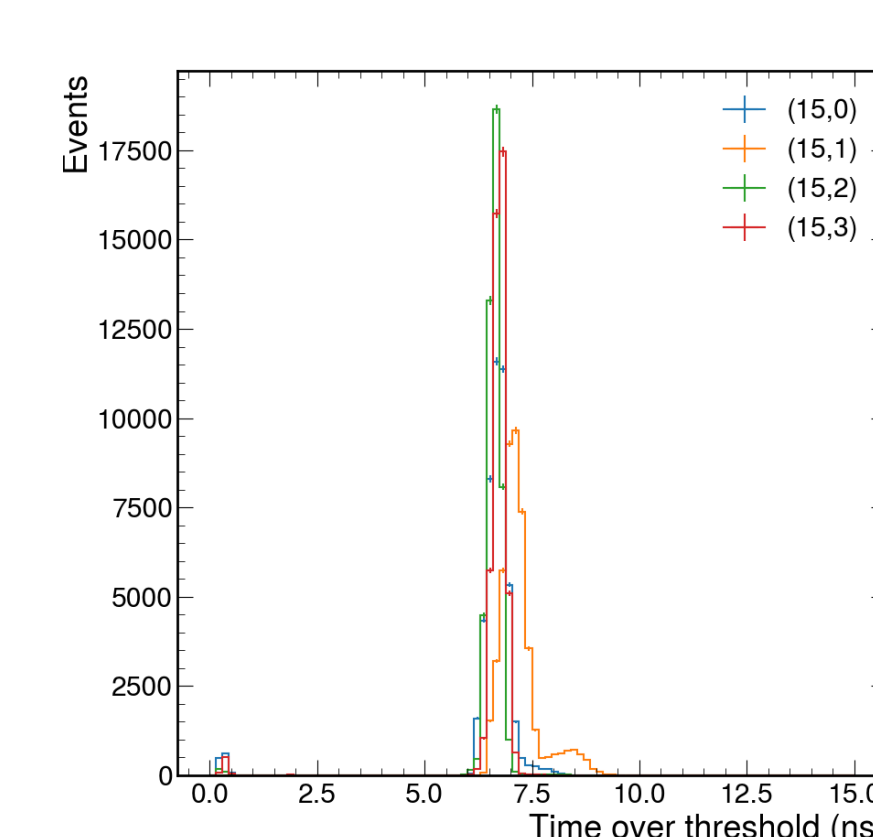


## Test System

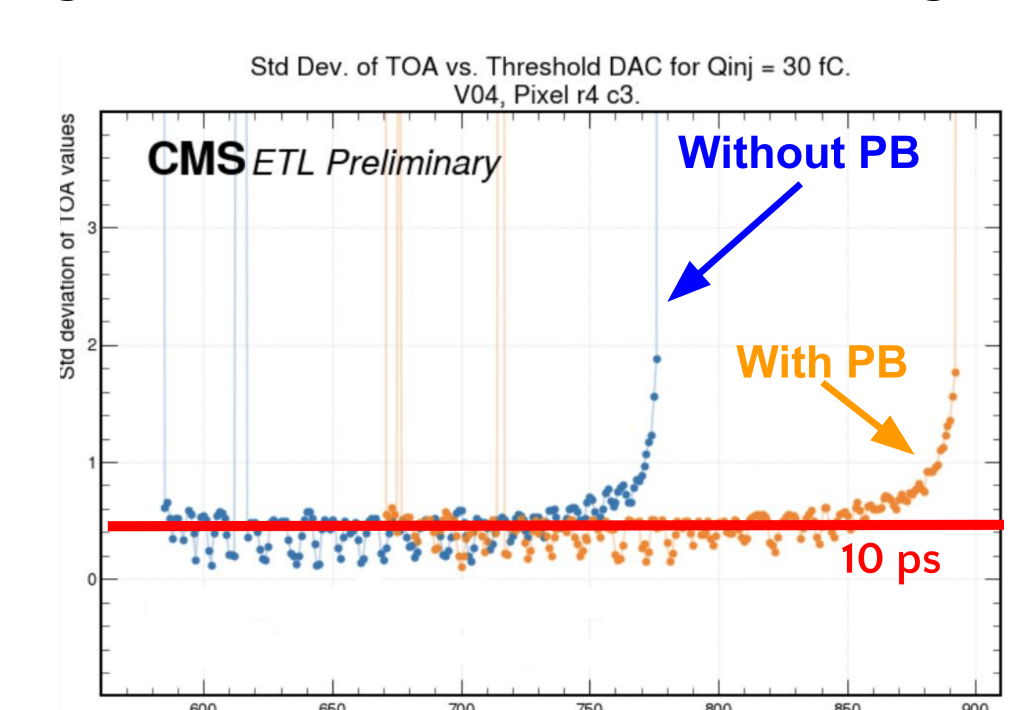
- Running hardware integration tests of all components
- Demonstrated full readout chain up to the DAQ with bare ETROC2
- Preparing for testbeam using a fully setup system with bump bonded LGADs
- Will be used to module testing by assembly sites



## Test Results



- Performance of 2x2 LGAD using a laser as signal
- Internal testing to find threshold bias voltage for a ETROC2 pixel



- Demonstration that adding the power board does not affect performance

## TDR

CMS Collaboration "A MIP Timing Detector for the CMS Phase-2 Upgrade." CERN-LHCC-2019-003