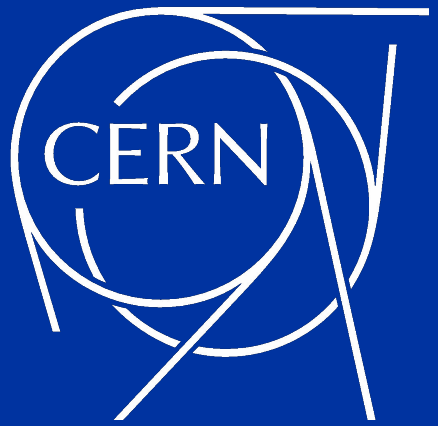


OPTIMA,

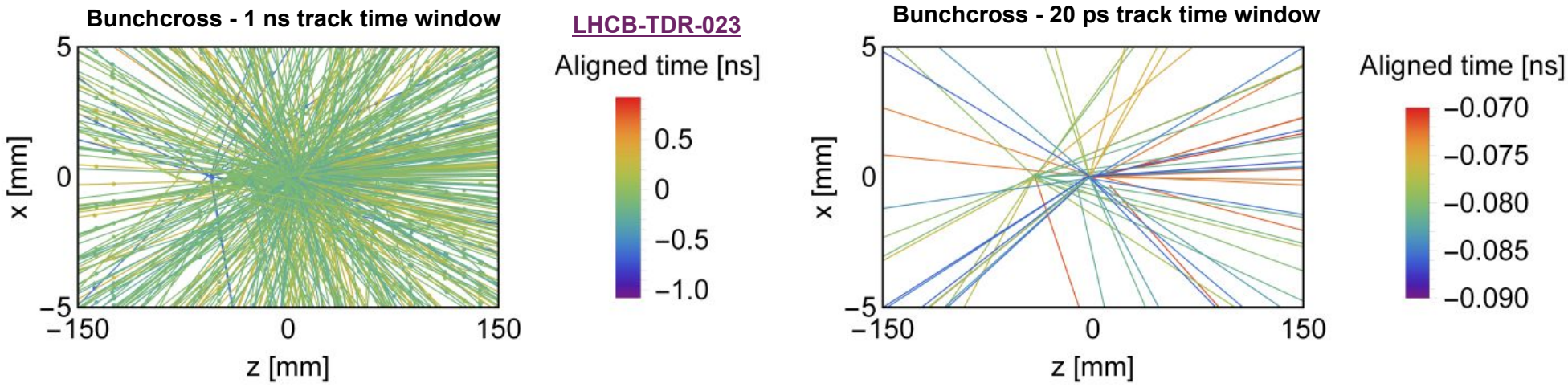
a board dedicated to Optimized Precision Timing for Multichannel Acquisition

Federico De Benedetti

2nd DRD3 week

Introduction

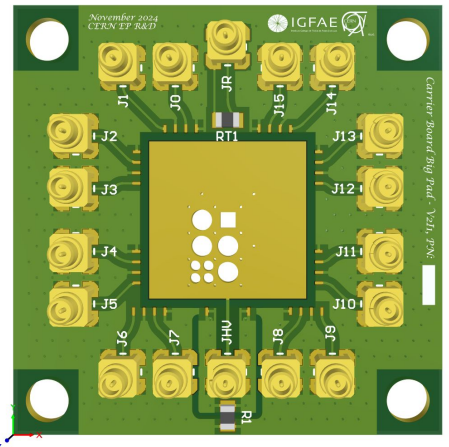
- Detector upgrades for HI Lumi LHC will face new challenges:
  - Increased radiation tolerance
  - Fine space resolution
- Pileup requires new strategies to discriminate tracks
  - Introduction of **timing** for vertex detectors (LHCb)
- Timing requirements can be very strict (**20 ps track time** resolution)
- The R&D has to consider several aspect and employ tools able to cope with the required time resolution
- It is fundamental to validate the performance of silicon sensor
  - Test beam with telescopes and dedicated readout boards

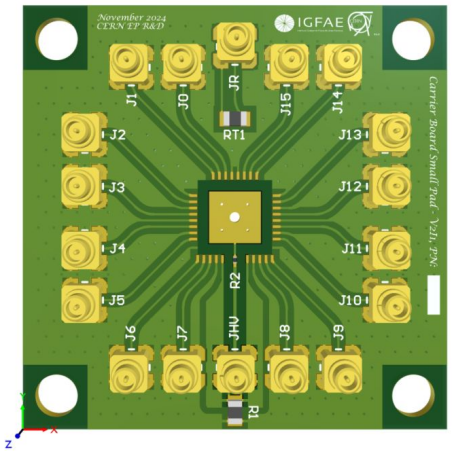


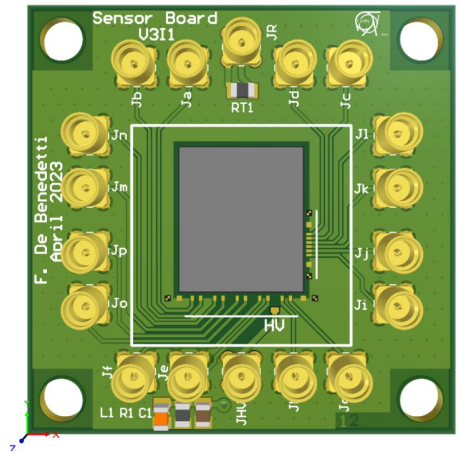
Introduction

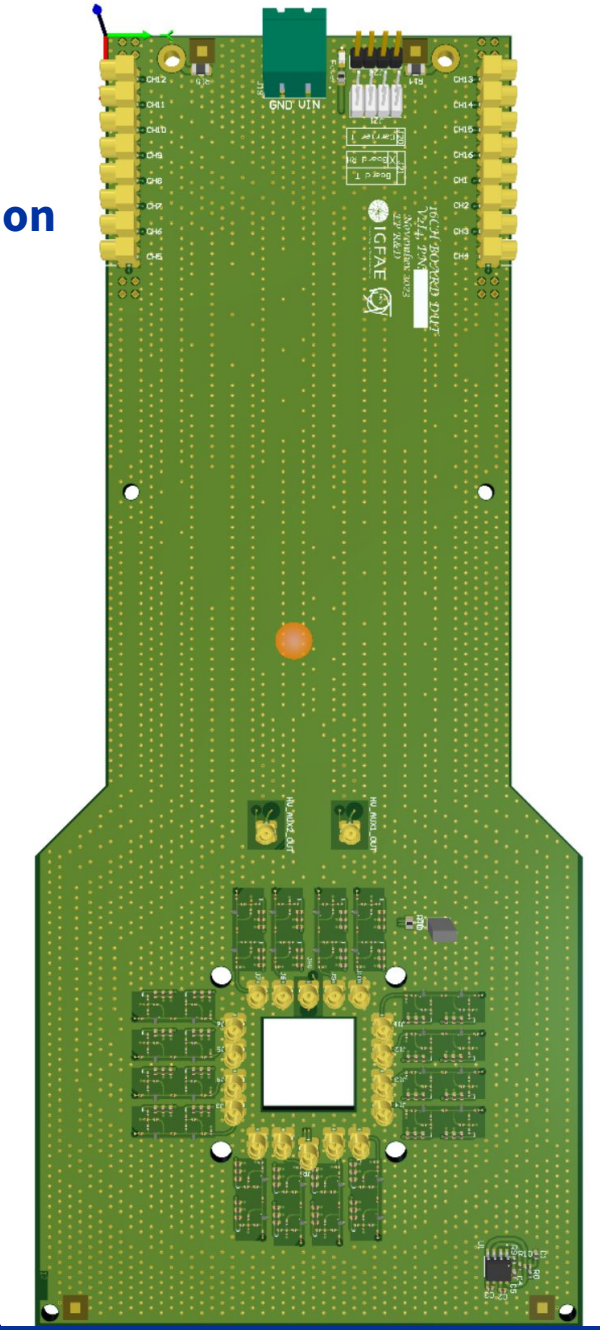
OPTIMA, a board dedicated to Optimized Precision Timing for Multichannel Acquisition

- **Project Goals**
  - Develop a common platform for non-hybridized silicon sensor characterization
  - **Precision timing** and **multichannel** application
  - Targeting lab and test beams characterization environments
  - Cooling support for irradiated sensor campaigns
  - Hot-swappable carrier boards:
    - Fast sample turnaround
    - Irradiating sensor board only
    - Different flavours for sensor wire bonding
  - Integration with Timepix4 telescope
  - Environmental monitoring on board





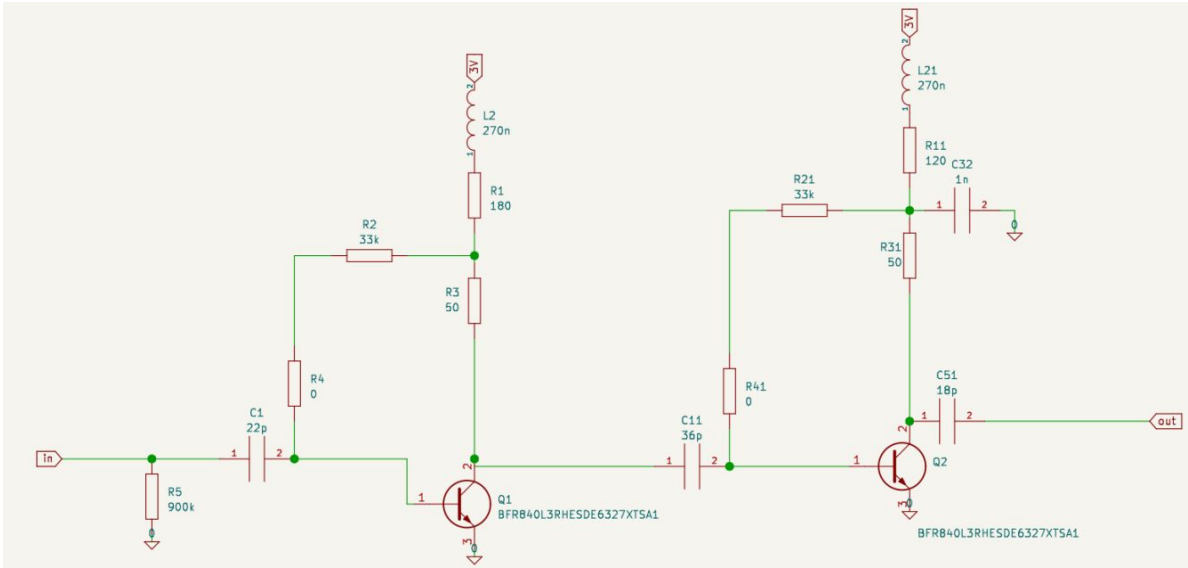




Introduction

OPTIMA, a board dedicated to Optimized Precision Timing for Multichannel Acquisition

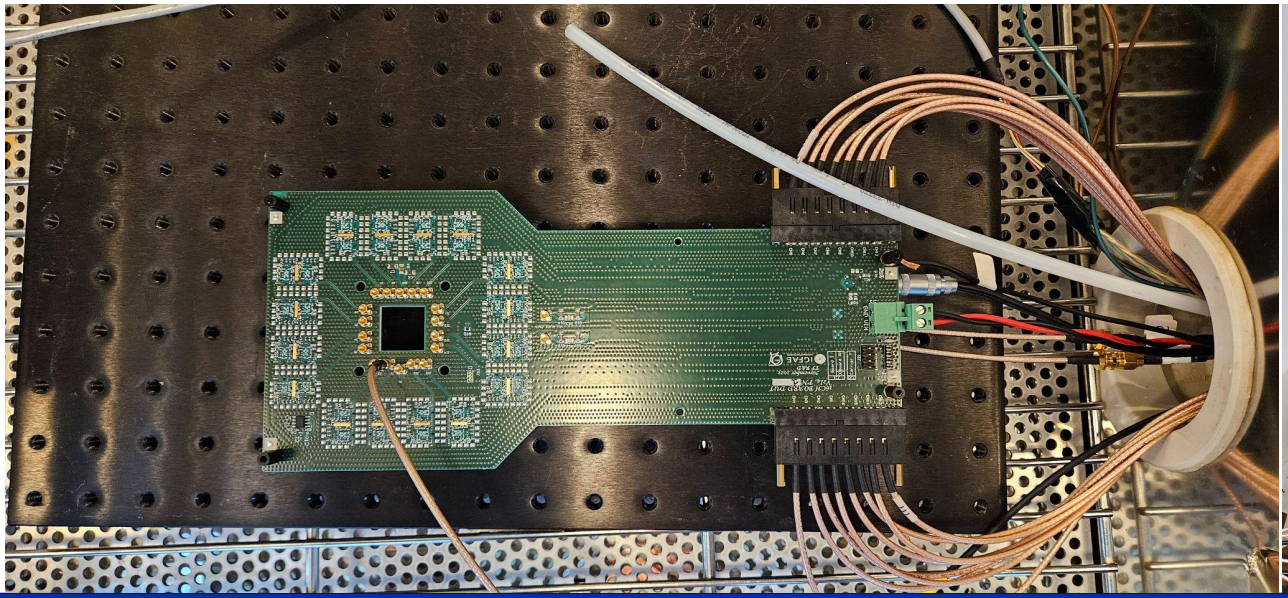
- **Circuit**
  - NPN transistor SiGe heterojunction
  - Two stage TransImpedance Amplifier (TIA)
  - 3 High voltage lines with bidirectional LPF
- **Layout**
  - Common interface based on MMCX connectors
  - 6 layers with shielded internal lines
  - Power can be regulated via LDO or direct connection
  - Temperature and humidity for environmental control
  - Mechanical compatibility with Timepix4 telescope box
  - Design with bandwidth > 6GHz
  - Small packaging with 0201-size components for multichannel integration
  - Independent Shielding per channel
  - 18 mm x 18 mm central opening for test beam
  - SMD components
- **Multiple board produced in the past, first board compatible with the Timepix4 telescope received beginning of this year**

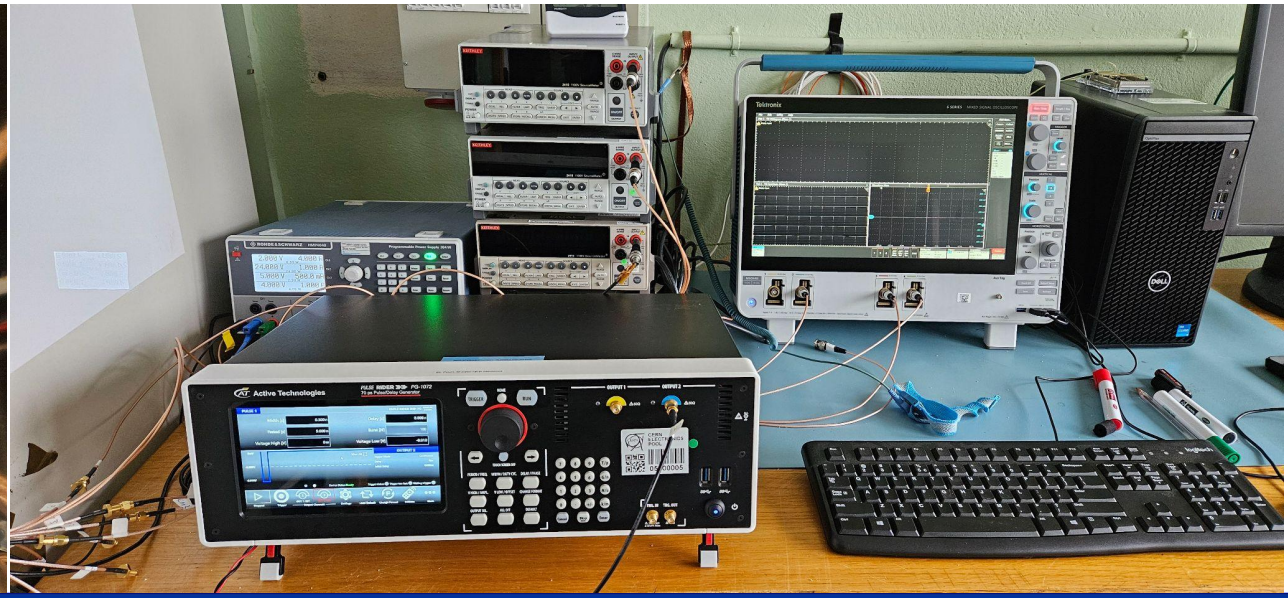


Lab Tests

Setup

- OPTIMA has been characterized in the lab
- Fast pulser (jitter <7ps, T_{rise} and T_{fall} < 70ps) and oscilloscope (10 GHz) used
- Investigating several parameters
  - Jitter
  - Gain
  - SNR
  - Noise
  - Fall time

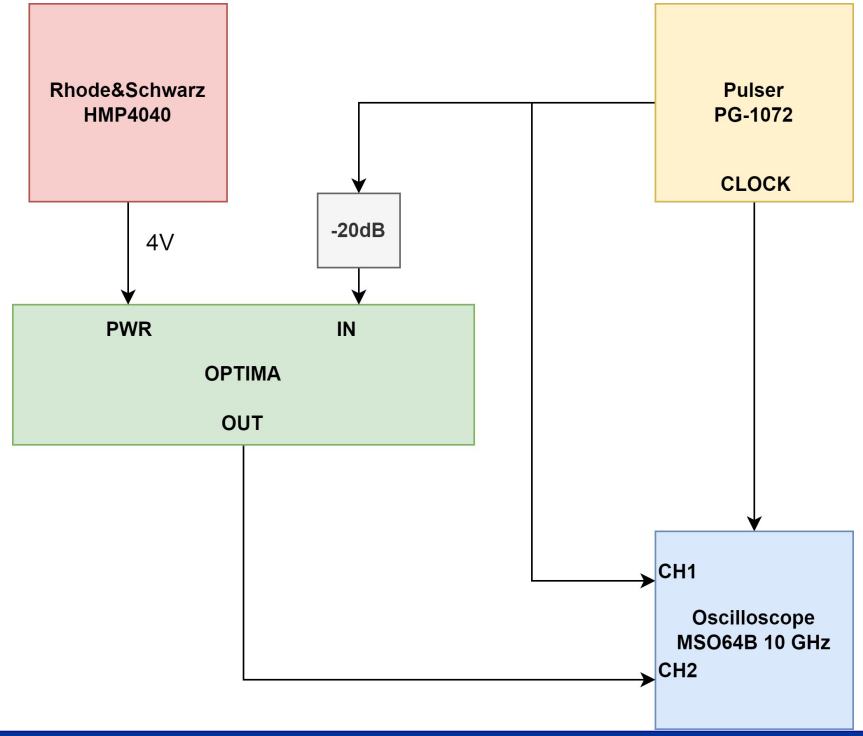


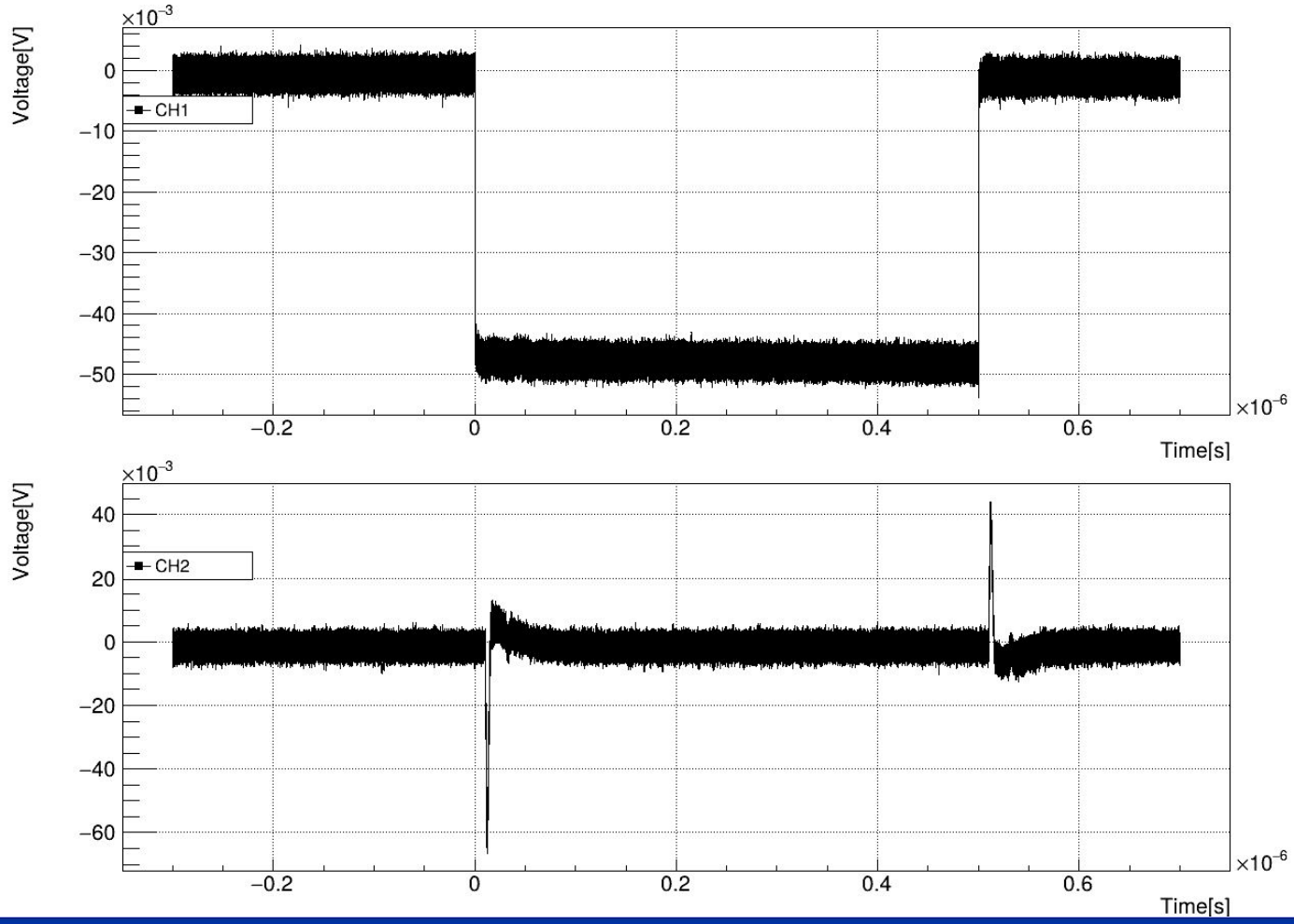


Lab Tests

Signal Shape

- Pulser reference on channel CH1
- Pulser OPTIMA channel on CH2 (attenuated)
- Channel sweep in voltage
- Different power supply settings
- Waveform analysis from the oscilloscope

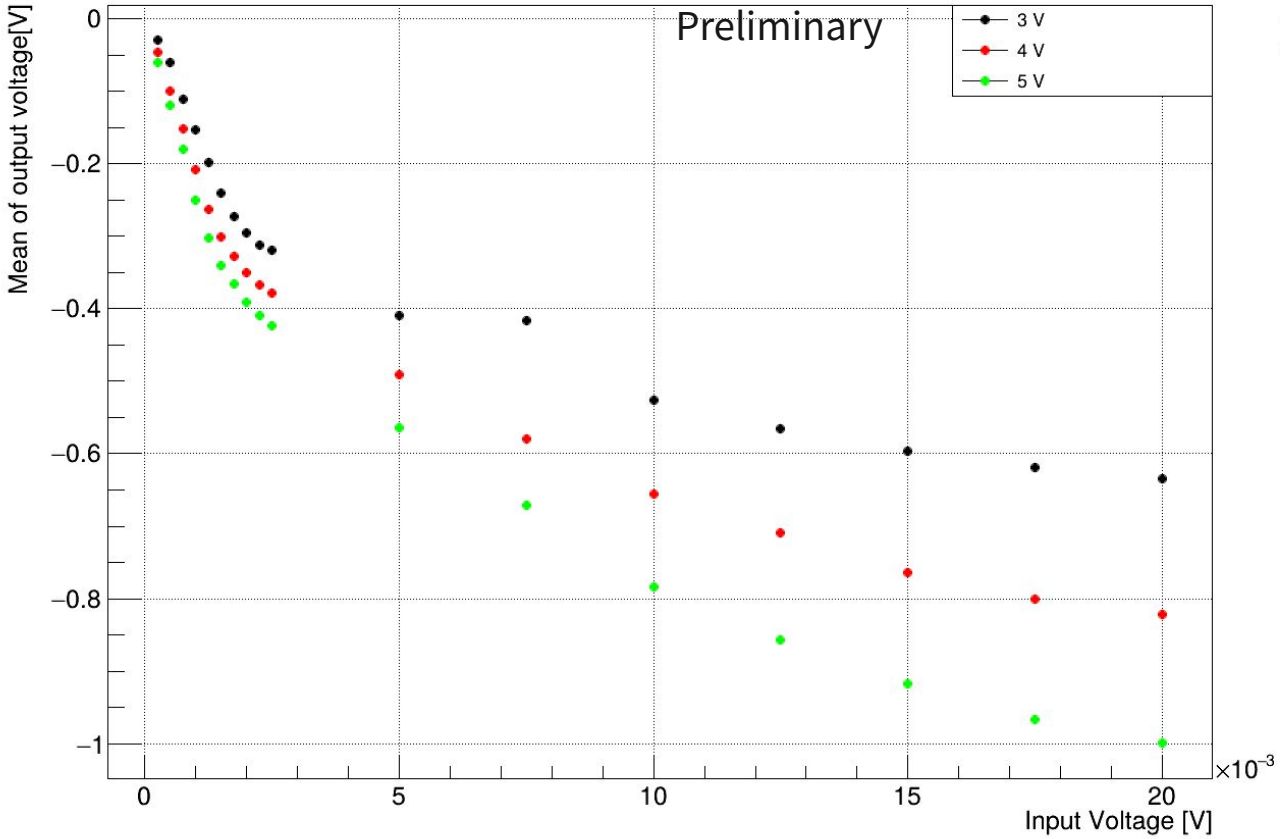


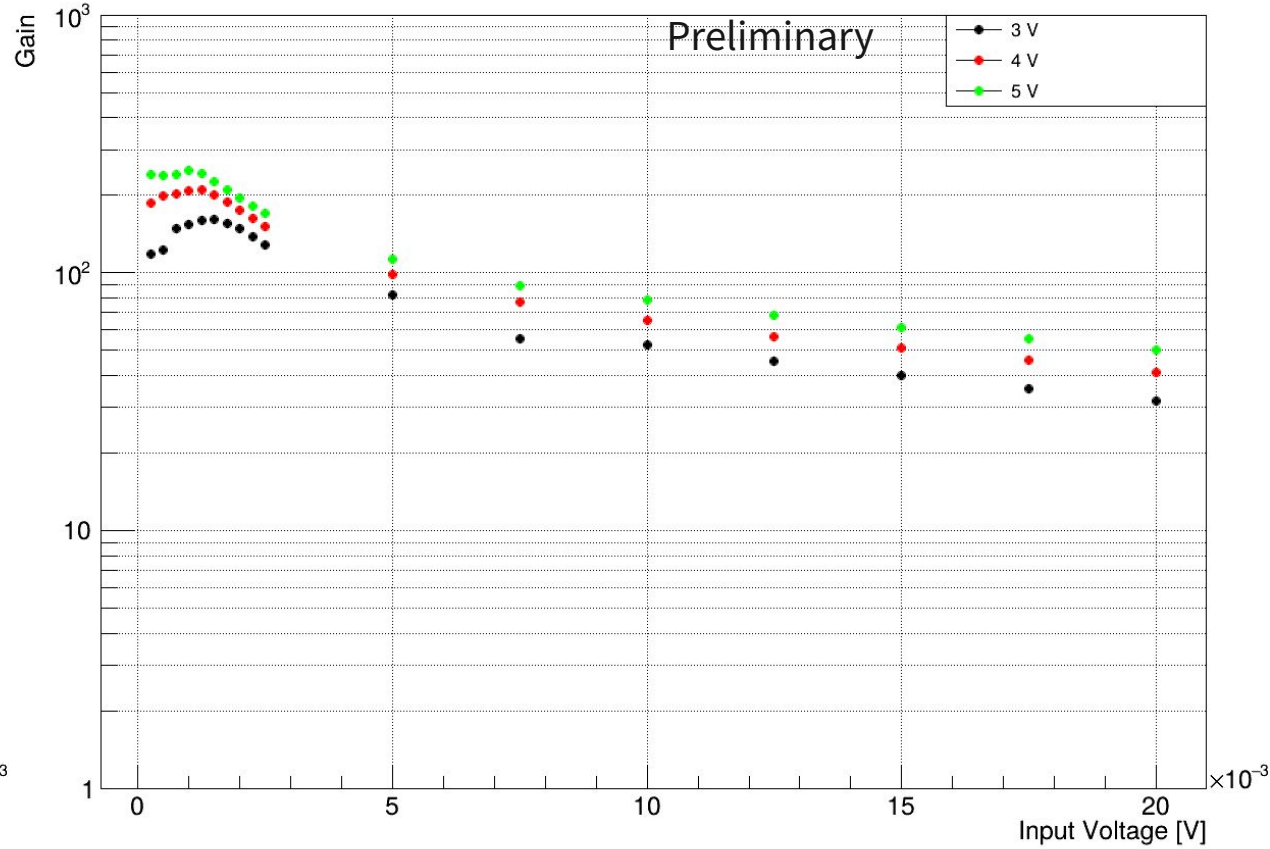


Lab Tests

Gain Scan

- Output voltage depends on Vin and power supply => useful knob to tune the operational point
- Gain is in specifications, circuit saturate for input voltages >5mV (as expected)

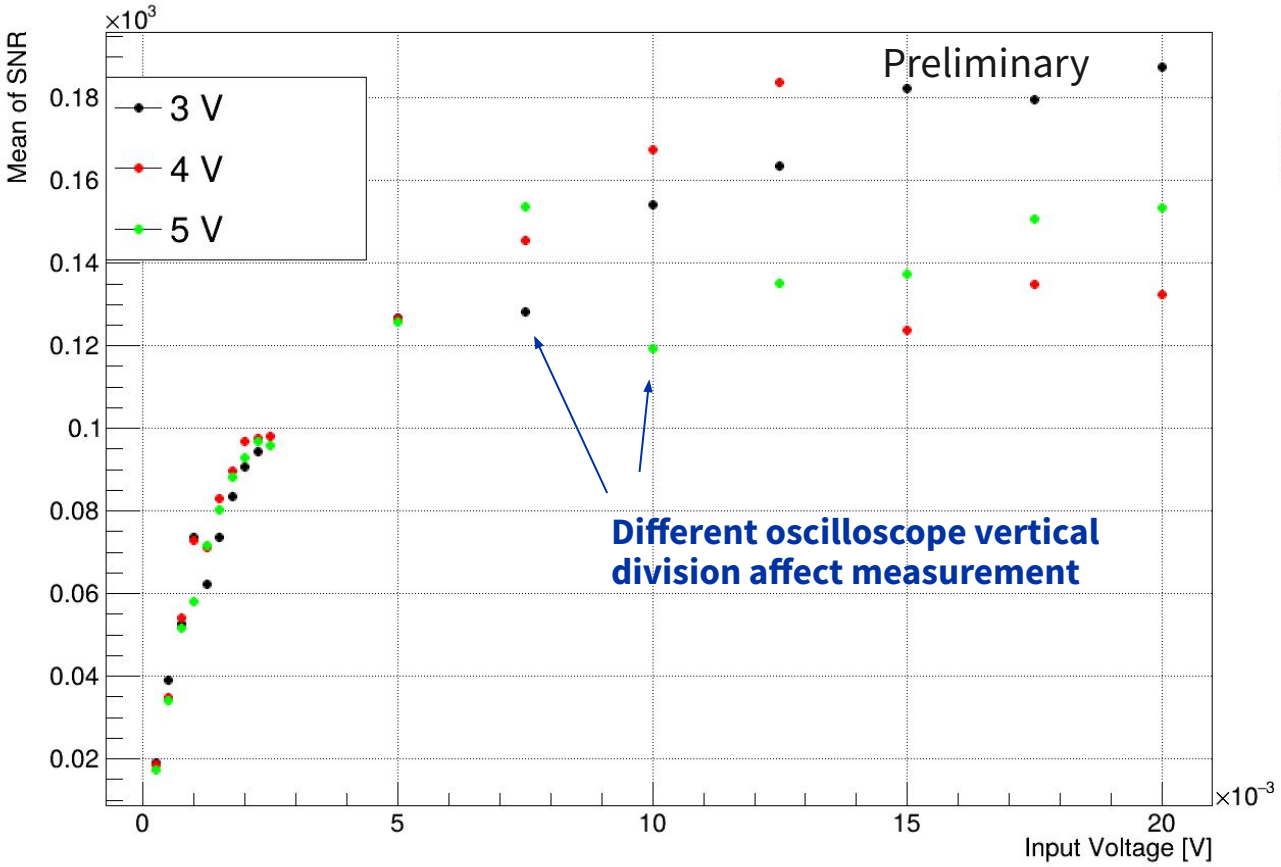


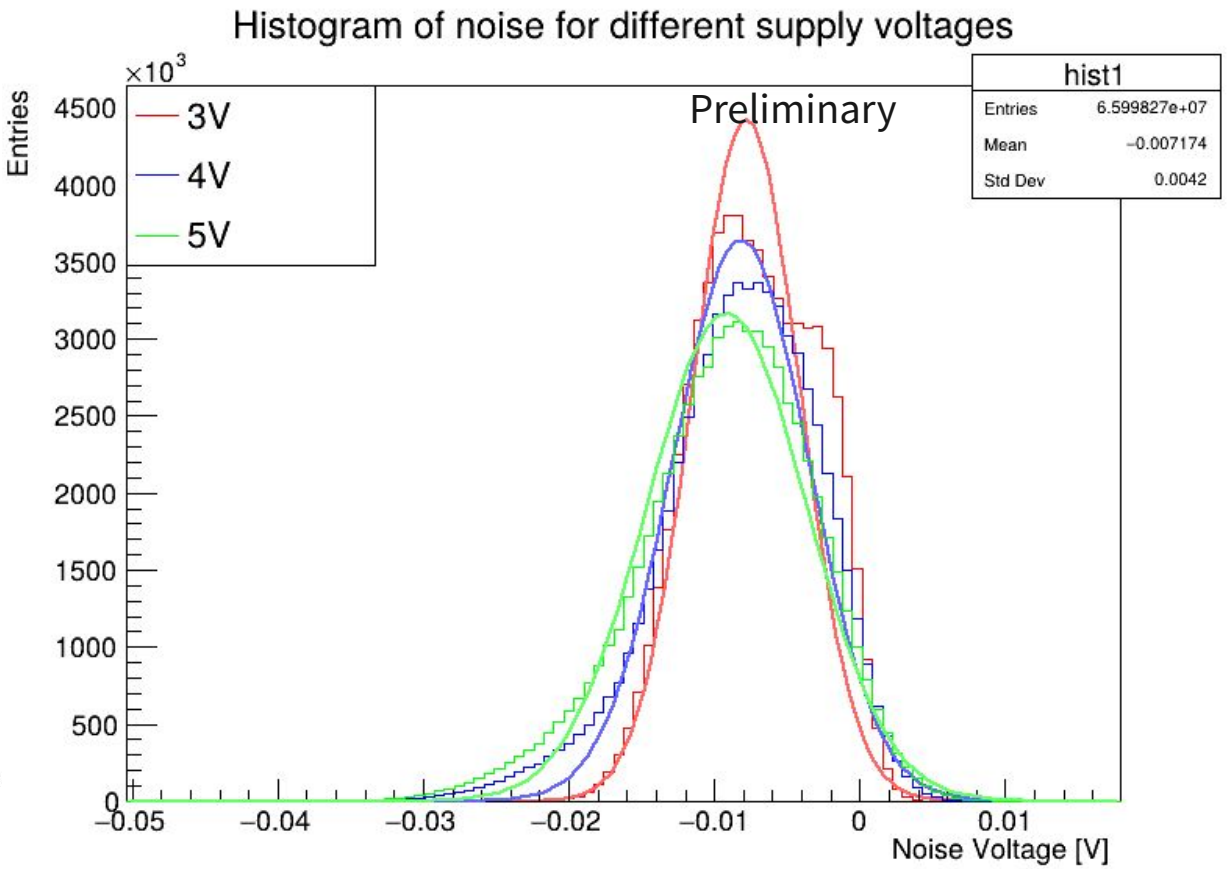


Lab Tests

SNR

- Noise is fairly independent on the power supply setting
- SNR is always >10 even for very low input signals (<1mV)

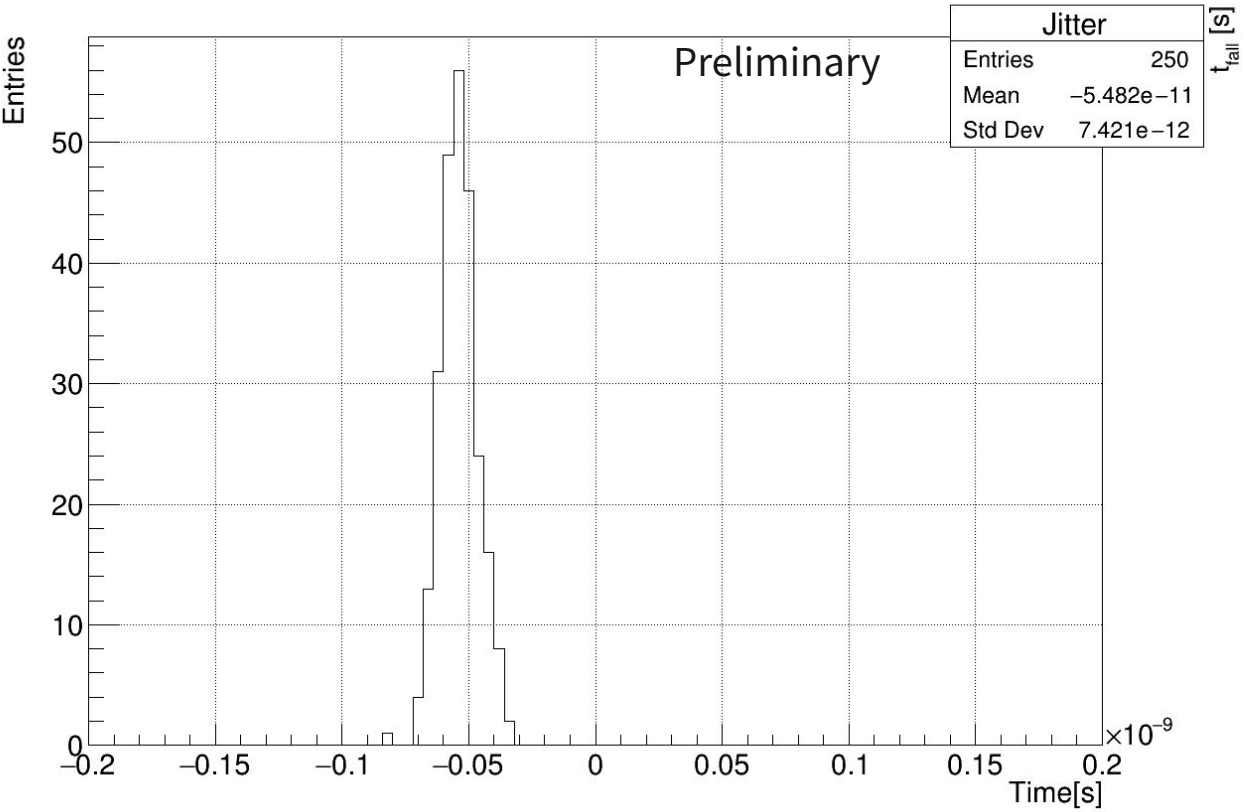


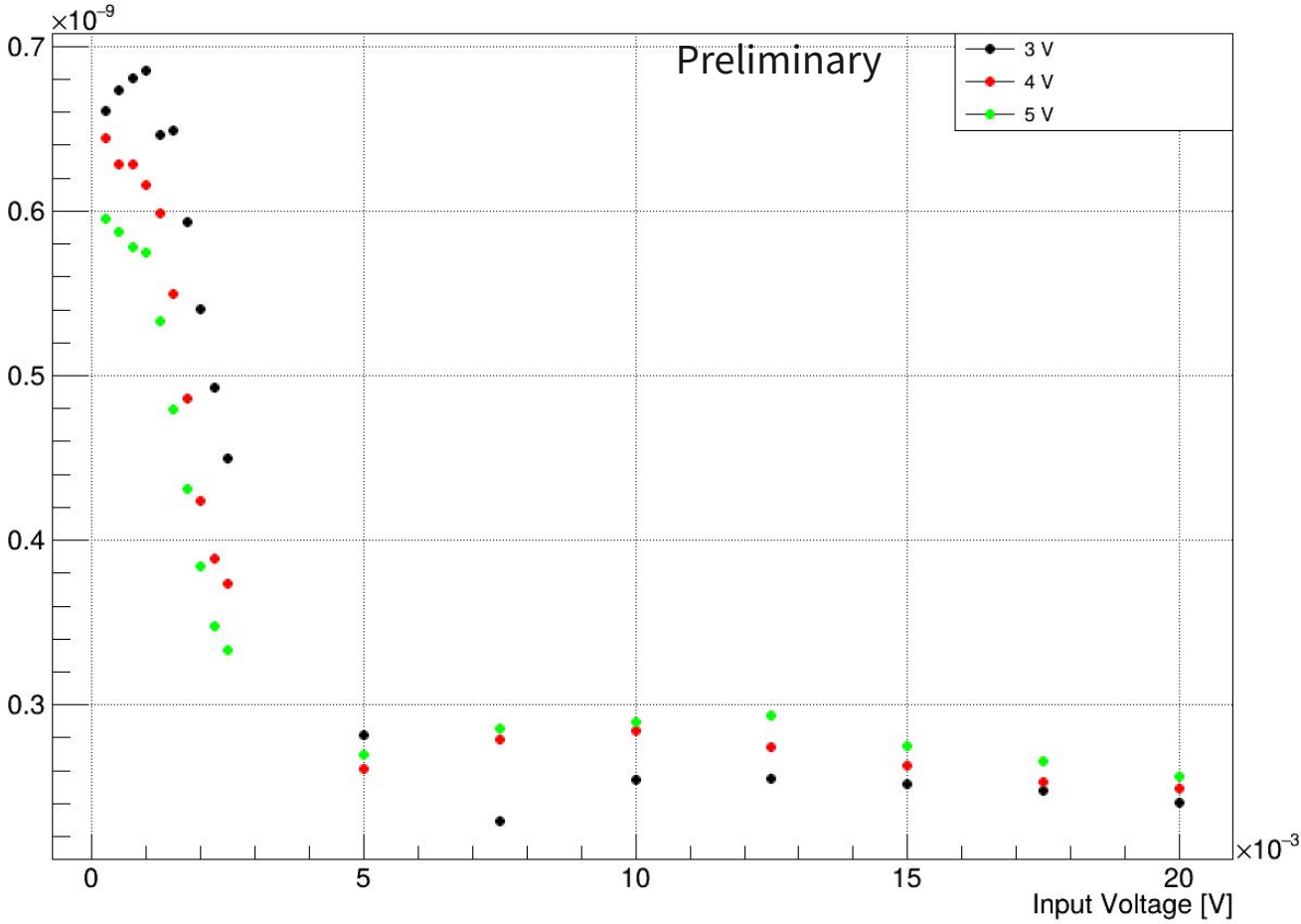


Lab Tests

T fall and Jitter

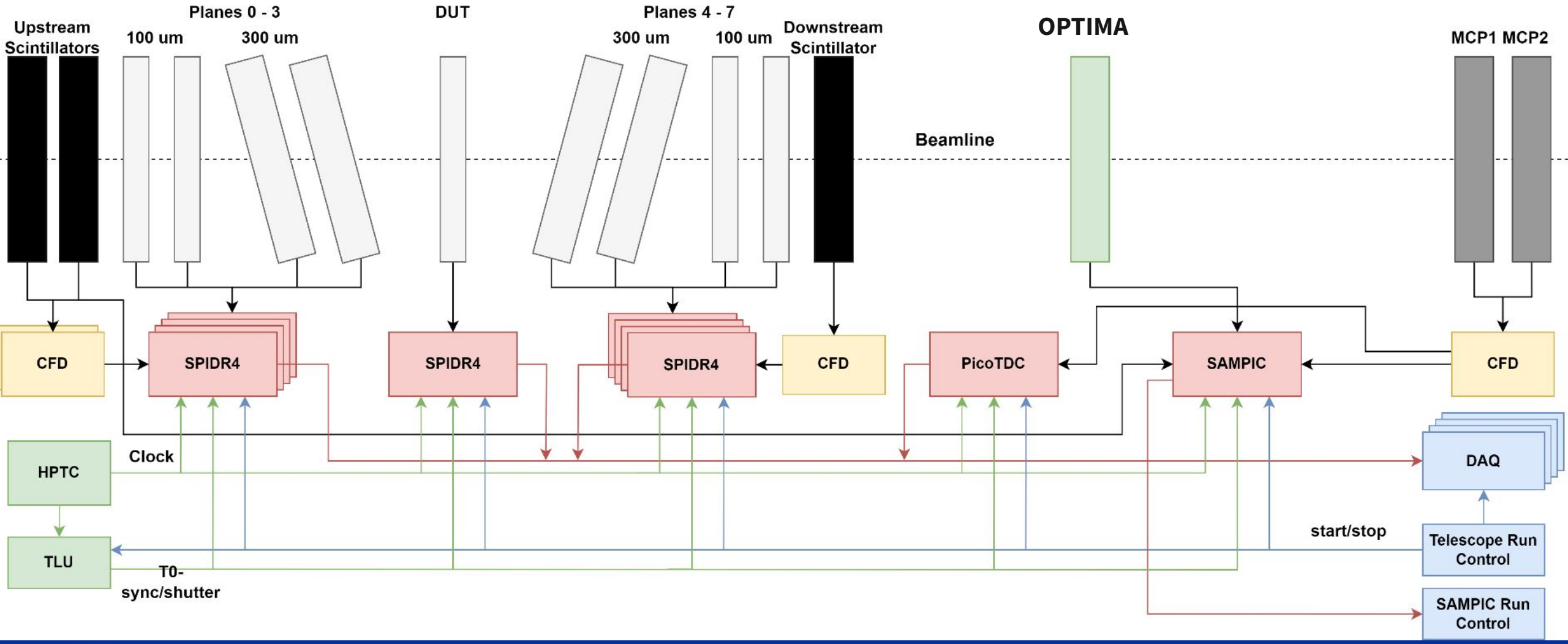
- OPTIMA jitter dominated by pulser jitter





Test Beam

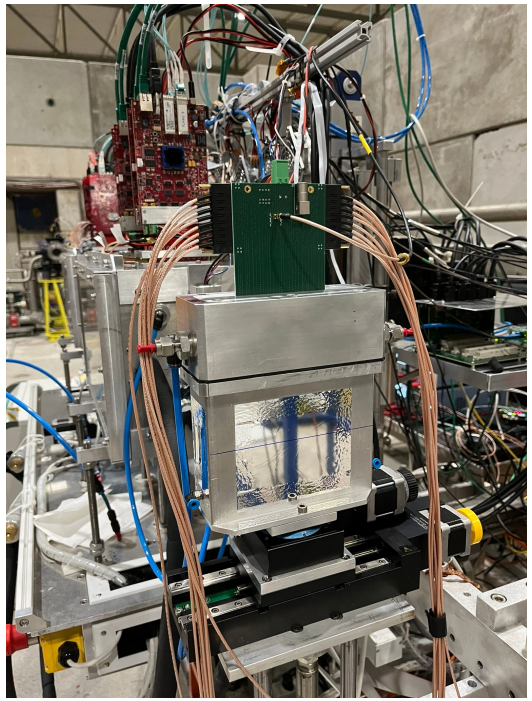
Proposed Test Beam Setup Diagram With Timepix 4 on SPS

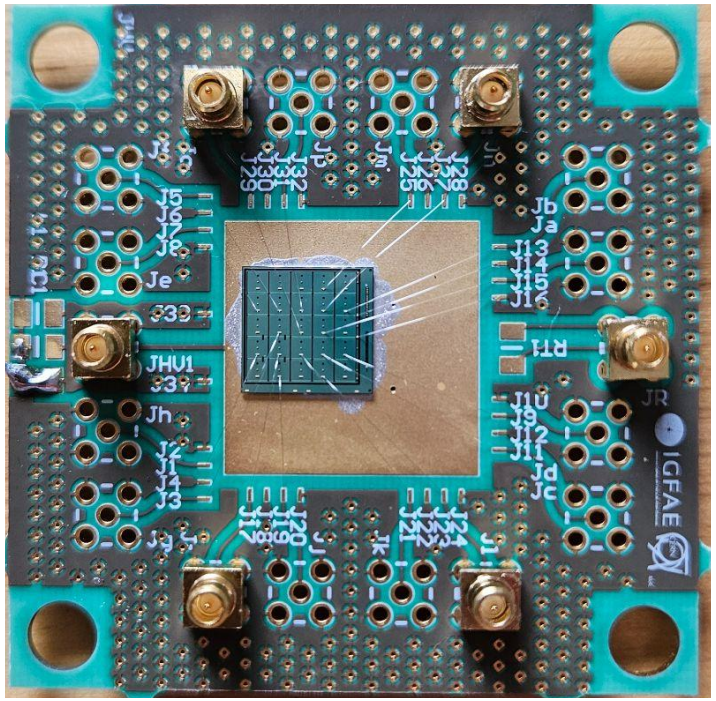


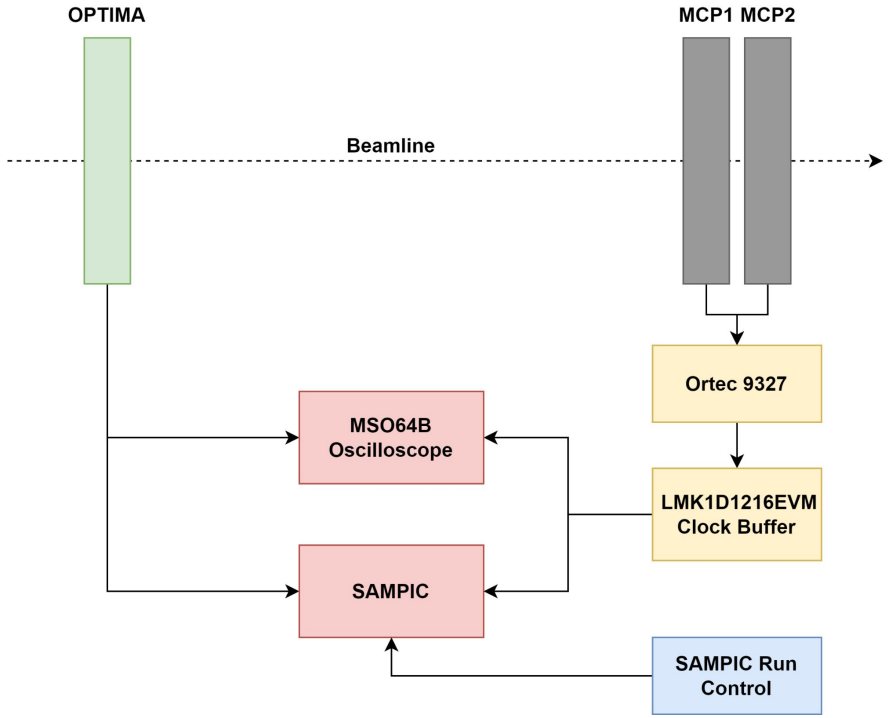
Test Beam

First Test Beam Setup

- First test beam in August this year using 5x5 LGAD matrix (16 channels)
- Checking mechanical integration with Timepix 4 telescope
  - OPTIMA installed on a stage, rotation and X,Y translation
- Checking timing performance with MCP as reference
  - Two scenarios: oscilloscope and SAMPIC connected in parallel





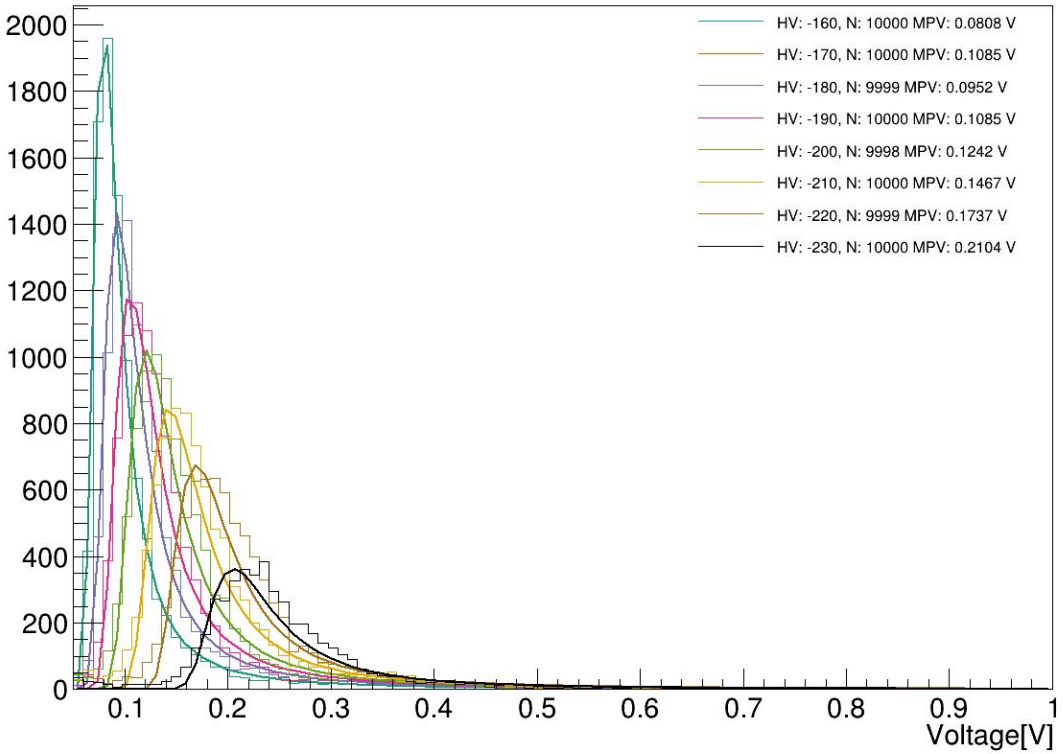


Test Beam

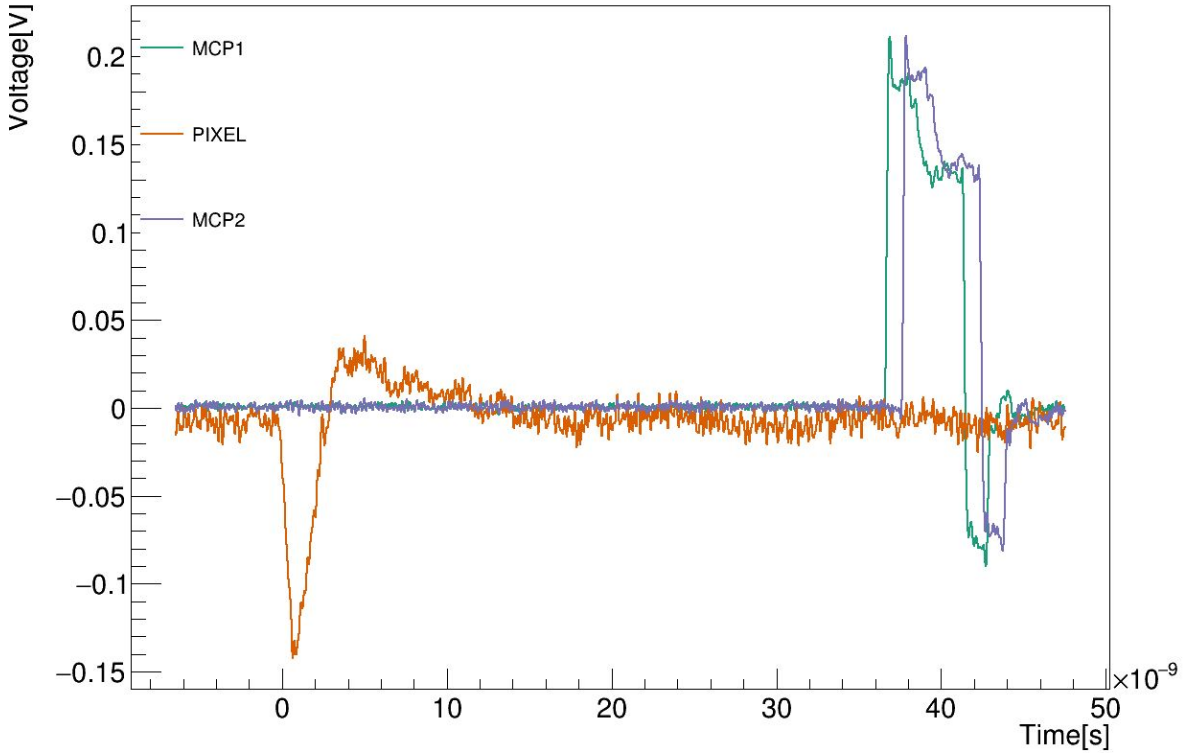
Oscilloscope Preliminary Results, Signal Shape and Landau

- 5x5 LGAD with a target of ~30 ps, gain of ~15
- Timing performance validation
- Noise validation

Landau Distributions



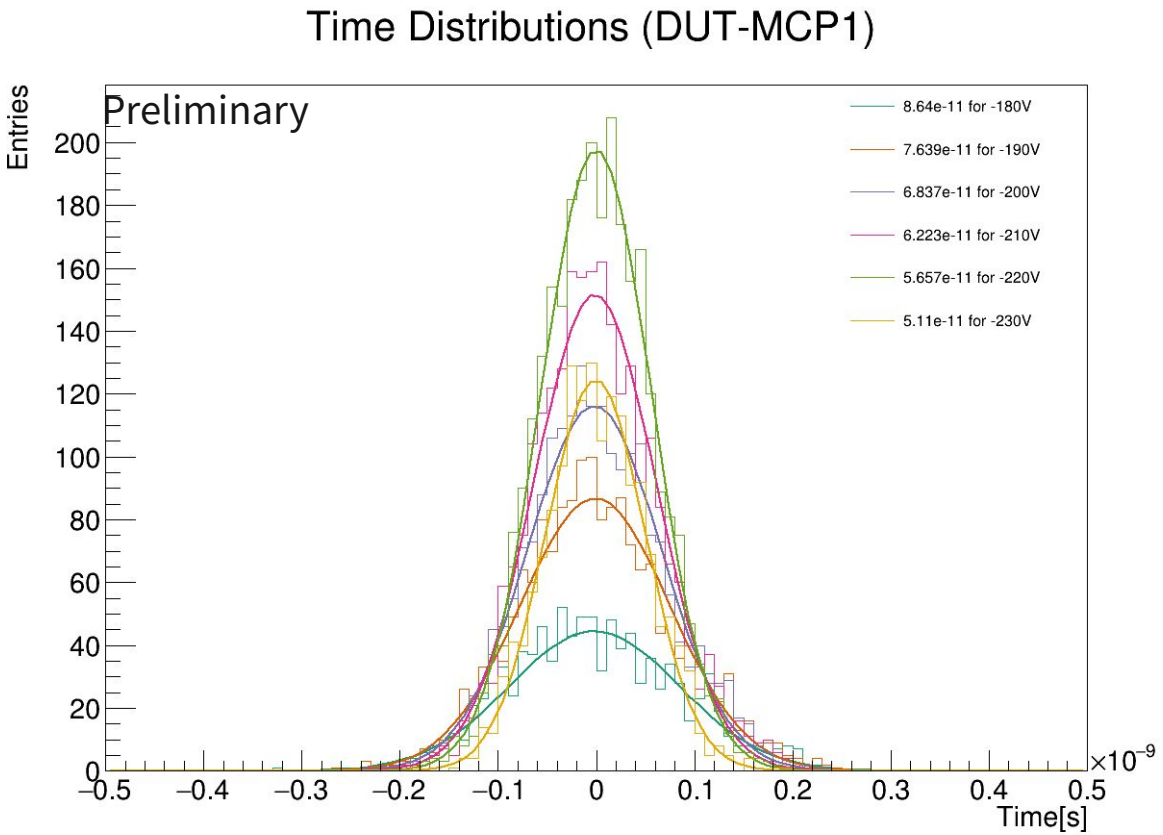
Waveform Plot

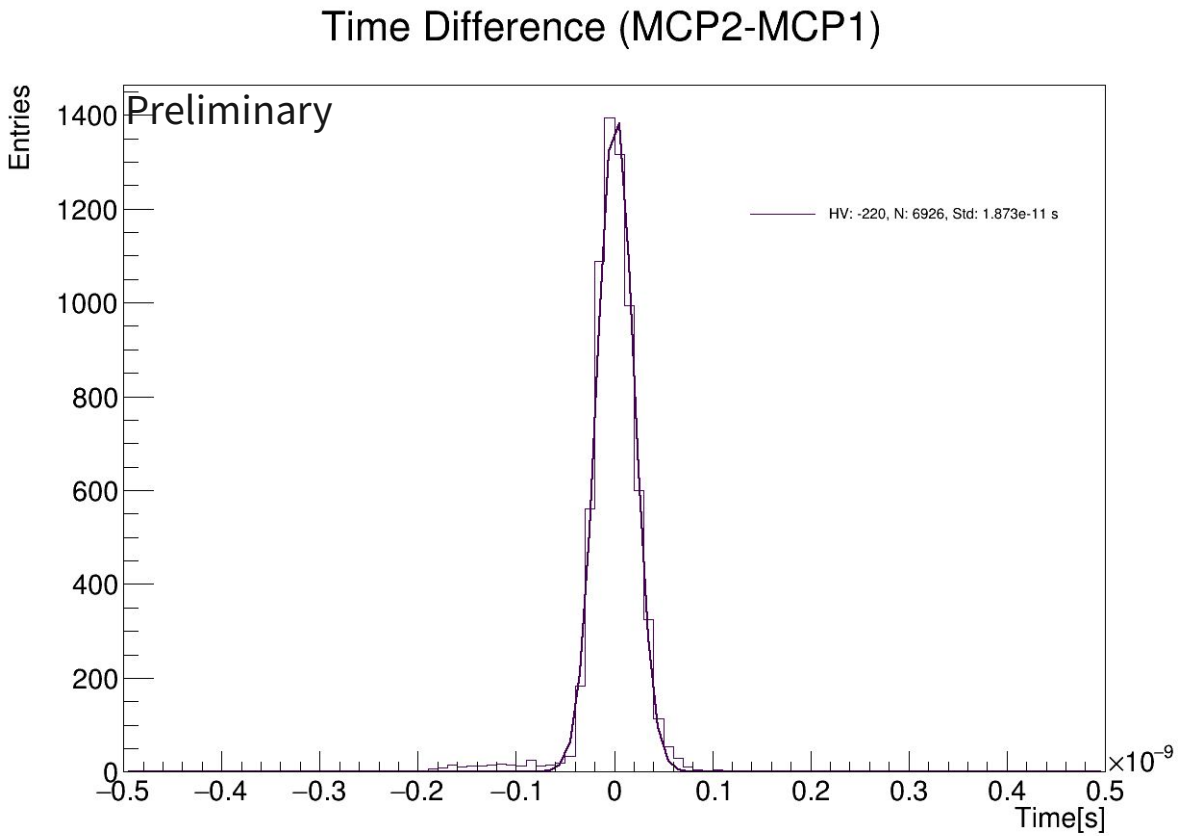


Test Beam

Oscilloscope Preliminary Results, Time Distribution High Voltage Scan

- Pixel hits parsed with CFD to extract time distribution
- MCP resolution is ~18 ps, best DUT resolution is ~50 ps (can improved in the analysis)
- Sensor temperature 35 Celsius



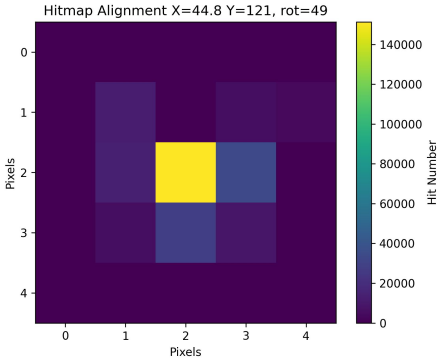


Test Beam

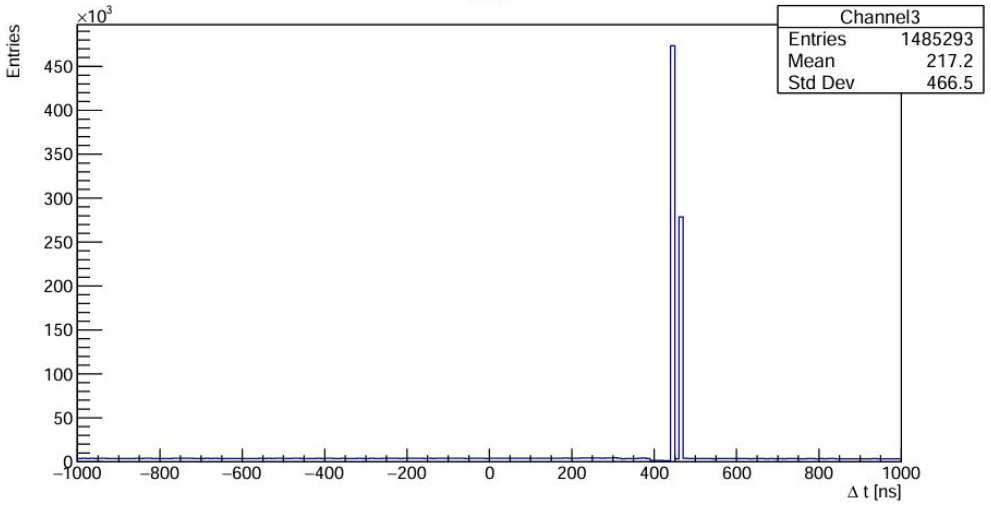
Telescope Performance and SAMPIC Preliminary Results

- **Telescope**
  - Flexible and powerful tool to test and characterise novel sensor technologies reconstructing tracks at high rate

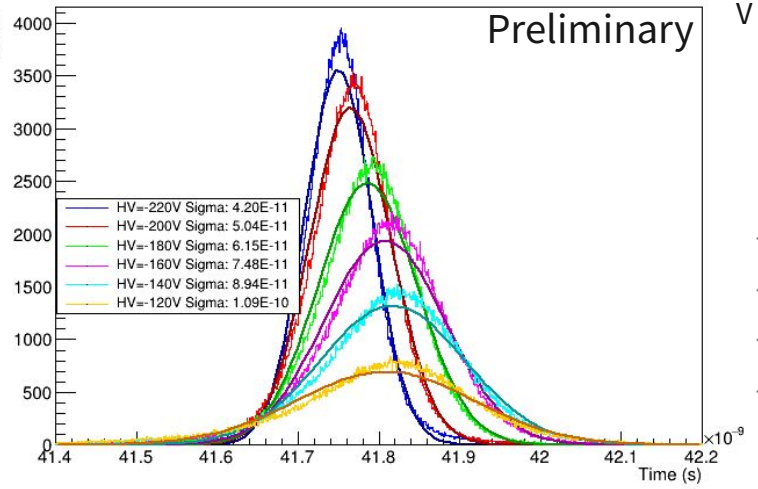
    4D tracking results with the Timepix4 telescope, Characterisation of fast sensors at the Timepix4 Telescope
  - Current preliminary performance: pointing resolution at DUT 2.5 um, track time resolution 90 ps
- **Test beam preliminary results from October test beam**
  - OPTIMA board + SAMPIC connected to scintillator + T0 to run in triggerless mode
  - Time **correlation** with the telescope was successful using LGAD and 3D
  - Decoder implemented in the Kepler analysis framework
  - Data being analyzed -> preliminary results show time resolution of **~40ps** (LGAD)



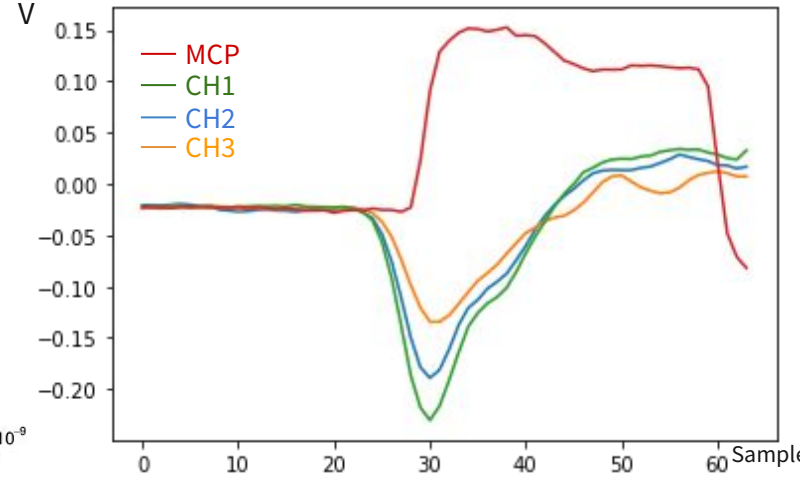
Correlation with TPX4 Ch3



SAMPIC Time diference (DUT-MCP1) ch5

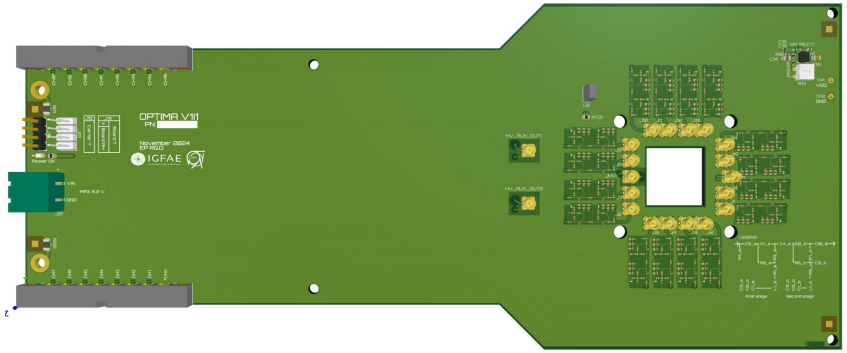


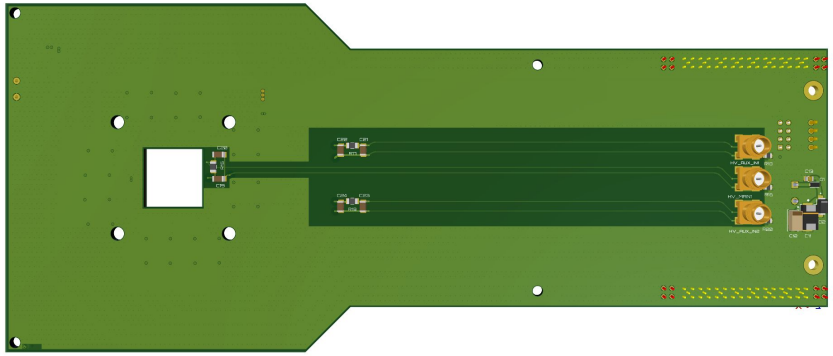
Multichannel acquisition



Conclusions and Next Steps

- **Conclusions**
  - OPTIMA, a board dedicated to Optimized Precision Timing for Multichannel Acquisition, has been presented
  - The results from lab characterization show excellent performance in terms of gain, noise and jitter
  - First test beam results show timing performance close to sensor's specification (LGAD)
  - The mechanical and electrical integration with the Timepix4 telescope was successful
  - The SAMPIC time stamps have been correlated with the telescope system, enabling the analysis with the Timepix4 software framework
- **Next steps**
  - Finalize data analysis with LGAD and 3D sensors
  - Sensor characterization using track information from Timepix4 telescope, analysis in Kepler
  - A new OPTIMA version is being submitted with improvements in the high voltage shielding and analog front-end
    - 5 assembled board expected delivery in January 2025
  - Integration of the run control with Timepix4 software environment





Thank you!