

TMS Electronics Preliminary Design Review

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Preliminary Design Review

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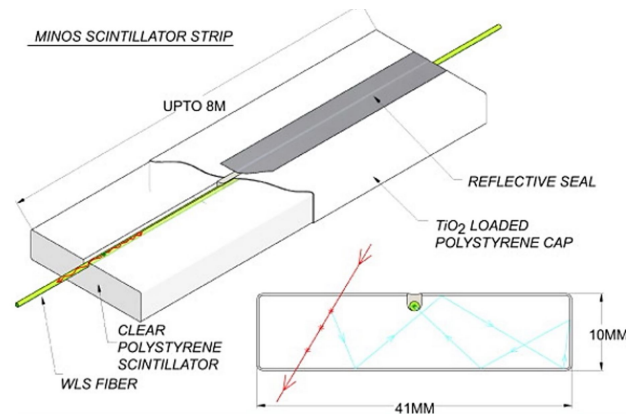
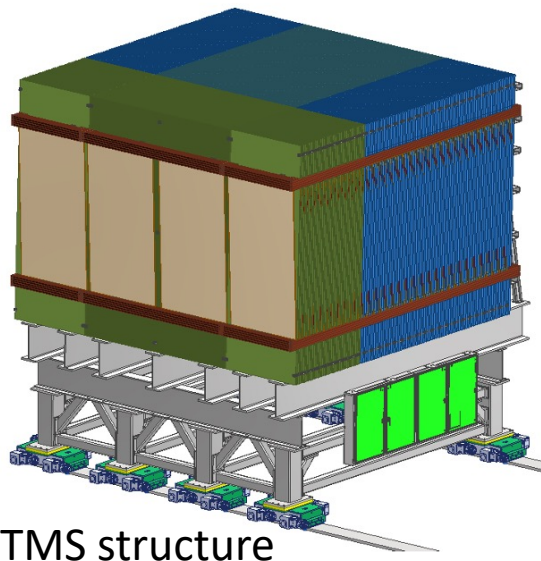


Vittorio's presentation

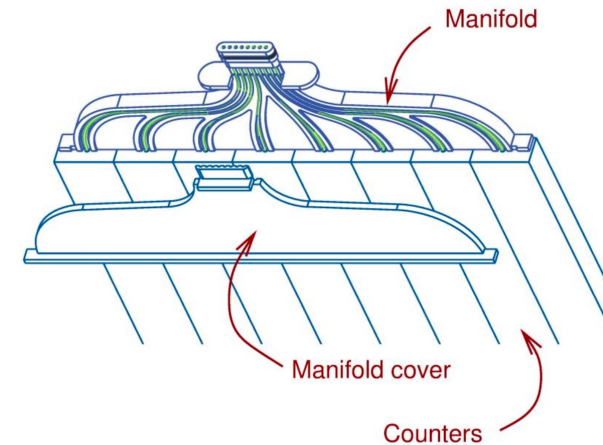
Introduction

The Muon Spectrometer (TMS)

- 100 scintillator panels interspersed with steel layers
- (Near) vertical and horizontal scintillator strips with embedded WLS fiber (1.4 mm diameter)
- 19,200 channels (192 channels per layer)



Conceptual scintillator detail



Scintillator module

Requirements

Timing resolution of 2-3 ns is sufficient

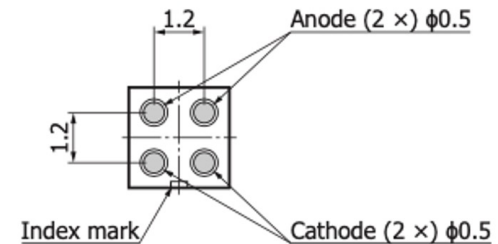
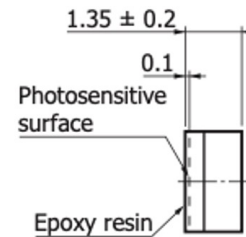
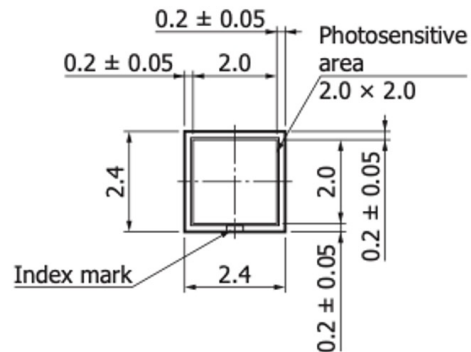
- 1.2 MW LBNF beam expect ~ 120 nu interactions in TMS per spill
 - 0.2 evts per 19ns RF bucket
 - don't expect event confusion

Dynamic Range: 10-bit ADC is adequate

- allows to resolve signal amplitudes that differ by up to a factor of 1000

Photosensors

- SiPM from Hamamatsu Photonics K.K.
 - Multi Pixel Photon Counters (MPPC)
 - S13360-2050VE



Tolerance unless otherwise noted: ± 0.1

Wavelength shifting (WLS) fiber

- Kuraray Y11 double clad
- diameter: 1.4 mm

Photosensors

MPPC: S13360-2050VE

Item	Specification
Effective photosensitive area	2.0 mm × 2.0 mm
Pixel pitch	50 μm
Number of pixels	1584 pixels
fill factor	74%
Package type	Surface mount
Breakdown voltage (V_{BR})	53 ± 5 V
Peak sensitivity wavelength	450 nm
Photo detection efficiency	40%
Gain	1.7×10^6
Dark count	300 kcps (typ.)
Crosstalk probability	3%

Characteristics at $V_{BR} = +3V$ and 25° C.

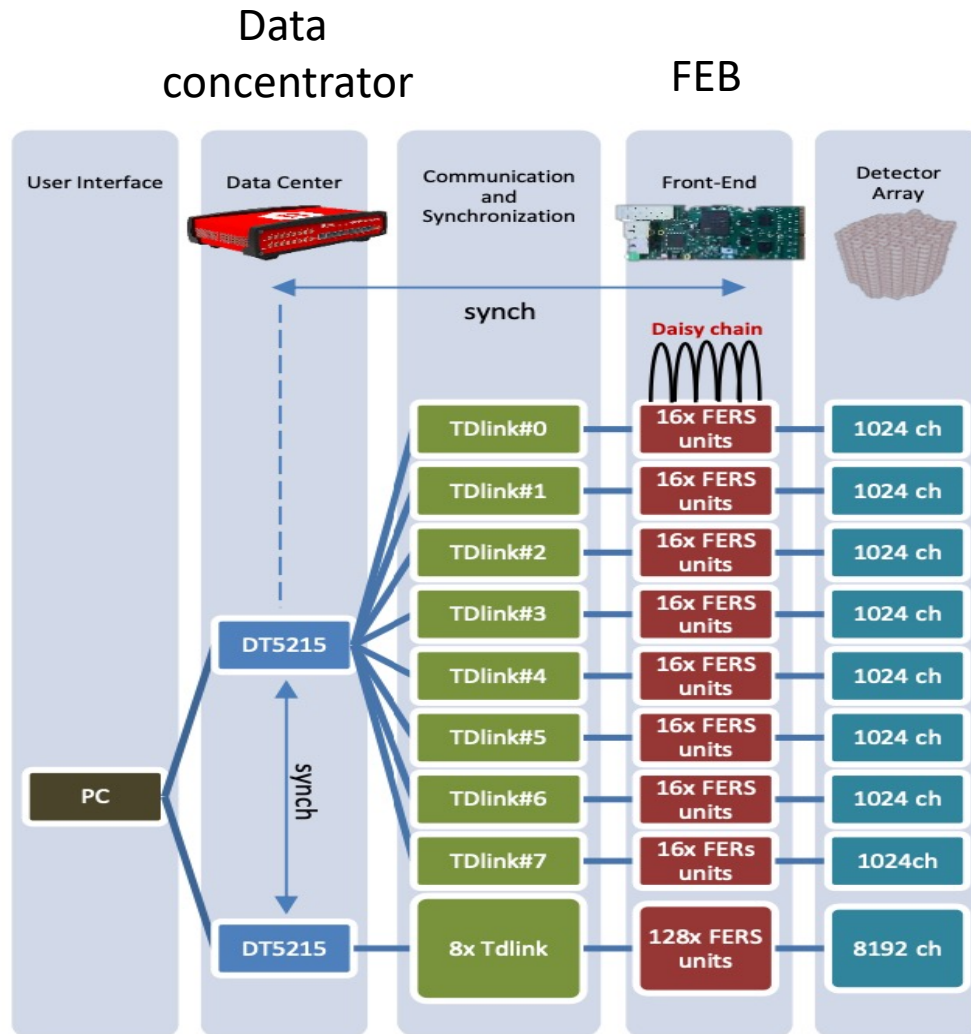
- Packaged in standard reels for pick-and-place mounting
- Expect grouping of MPPCs with similar V_{BR} (<0.15V) in a reel

MPPC-PCB

(*not yet designed* but have experience from T2K MPPC64-PCB)

- mounting of 8 MPPCs onto single PCB
 - requires 2400 MPPC-PCBs
- PCB:
 - routes V_{Bias} and enables signal readout
 - RC filter for every channel
 - 1.7mm thick; 4 layer board
 - 10 coax conductor SamTech connector on backside
LSHM-110-02.5-L-DV-A-S
 - Temperature sensor
 - LED for calibration

Readout Electronics Overview



Conceptual structure of Readout electronics

Front End Electronics

Purpose:

- digitize MPPC signal,
- record signal time stamps,
- make data available for readout

Hardware: **CAEN A5202** readout module

- Uses two Citiroc-1A chip (32 channels each)
- Physical dimensions: ~7 cm x 17 cm
- Power supply: A7585D; range: 20 – 85V (1mV steps)
- Interface for readout, synchronization and control
- Trigger options (global/external, self trigger)

Quantity required: 300 **A5202** modules (3 per layer)

Citiroc-1A Schematic

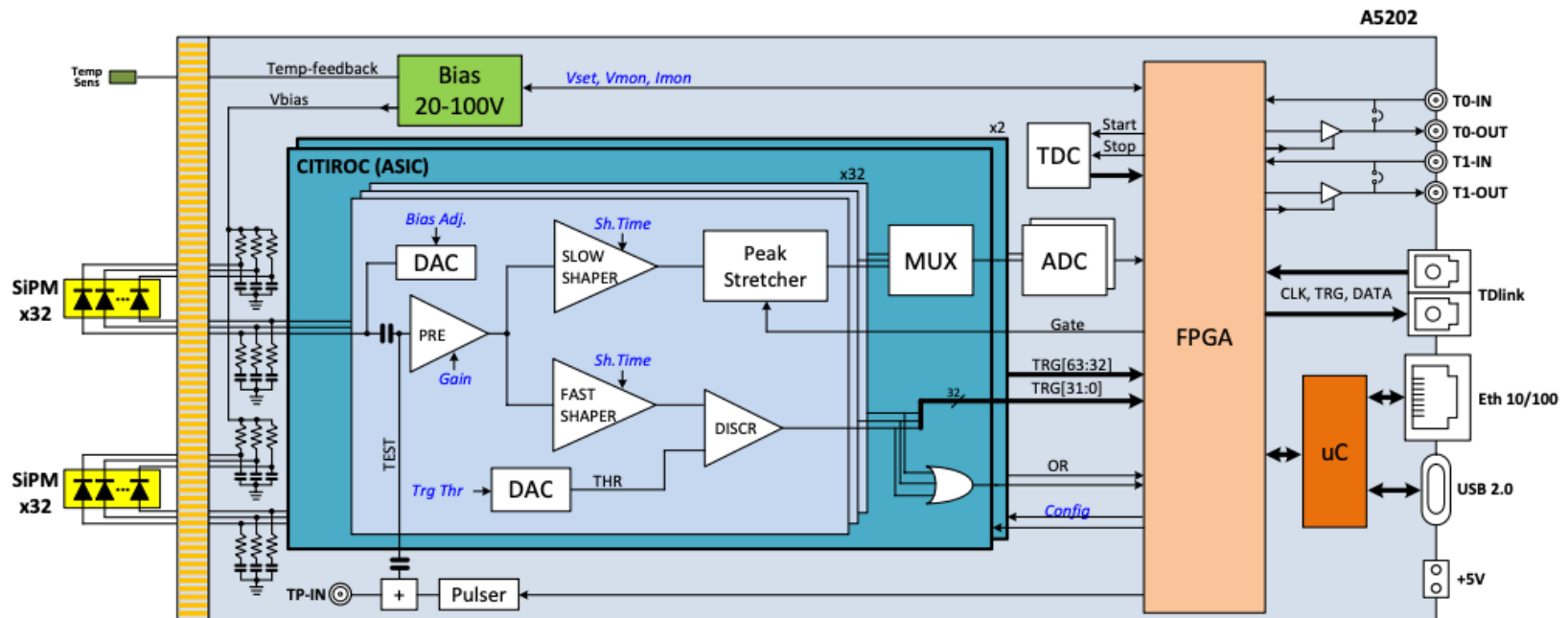
Each channel:

Preamplifier (low gain and high gain; programmable) followed by

- slow shaper, pulse height detector
- Fast shaper, discriminator (for counting, time stamping, ToT, trigger generation)

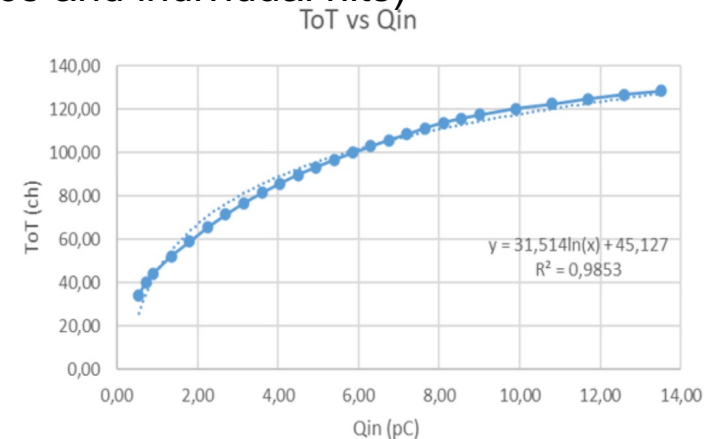
Sequential conversion by 13 bit ADC

Bias voltage modulation (8 bit DAC), range 2.5V or 4.5V



A5202 Acquisition Modes

- Spectroscopy mode:
 - best signal resolution
 - reads 64 channels simultaneously: requires $\sim 10\mu s$ \rightarrow system dead time
- timing mode
 - Channels acquire data independently (channel ID, time stamp, ToT) \rightarrow dead time free
 - Uses common start or stop signal; hits belonging to time window are saved
 - Time stamp granularity: 0.5 ns (for time reference and individual hits)
 - ToT dynamic range: $\sim 32.7\ \mu s$ (16 bit)
- [counting mode]
- Trigger Options
 - Global/external
 - Logic combinations of self triggers (AND, OR, Majority)



A5202 Interfaces

- Input edge card connector with 140 contacts at 0.8 mm pitch (HSEC8-170)
 - Uses 128 lines to connect to SiPM anodes (signal) and cathodes (V_{bias}): 2 lines/SiPM
 - Remaining lines for temp. sensors, I2C clock/data, several grounds
- Custom Interface to MPPC cable connector (*not yet designed*):
 1. Convert SamTech connector to HSEC8-170
 2. Plan to use single conductor + shield per SiPM → non-standard for A5202
 3. Integrate LED trigger pulse
- TD Link (4.25 Gbit/s duplex link, optical fiber, uses LC connectors)
 - Daisy chain up to 16 x A5202 modules (→1024 channels)
 - Physical connection to data concentrator module
 - High throughput (readout bandwidth of ~80MB/s), slow control, timing synchronization

Concentrator Modules

Purpose:

- Time synchronization
- Data readout management and event building
- Data processing and reduction (optional)
- Link to host computer

Hardware: **CAEN DT5215** concentrator module

- Manages up to 8 TDLinks (8192 readout channels)
- Connected to host computer (1/10GbE or USB 3.0)
- Linux based onboard computer
- Possibility to upload custom algorithms (data processing/reduction)

Quantity required: **3 to 4** (minimum versus more symmetrical layout)

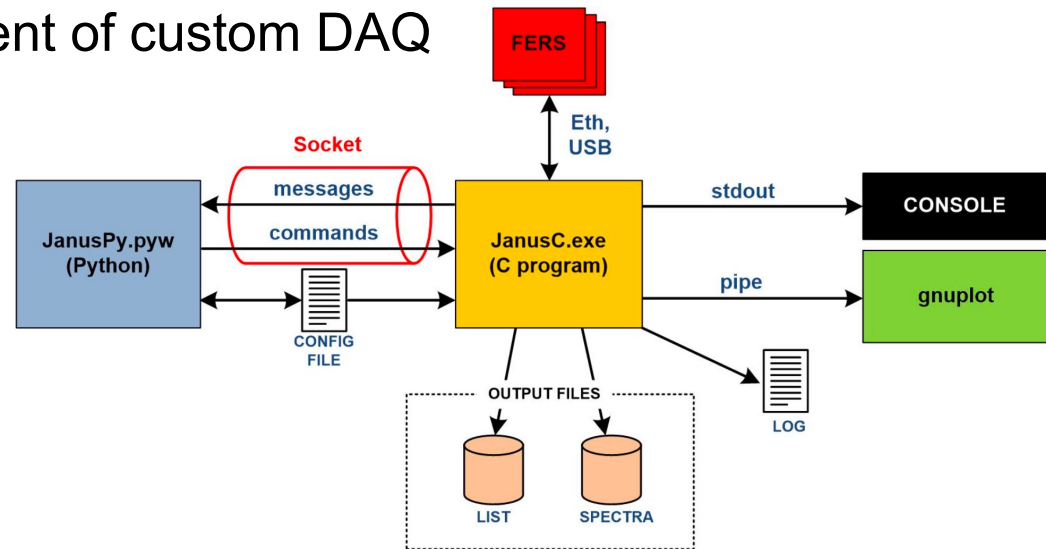
TMS DAQ

A5202 fully supported by CAEN Janus software

- Provides GUI for control and data plotting
- Open source
- Runs on Linux and windows
- Requires Python release 3.8.1 or later
- Platform for development of custom DAQ

Data output file format

- Binary or ASCII
- Header
- Body
 - Triggered channels
 - ToA and ToT (in timing mode)



Electronics Interfaces

- MPPC-PCB to WLS fiber
 - Concept exists, development in progress
- TMS DAQ system and global ND DAQ
 - Discussion in progress
- ...

Prototyping/Development Tasks

- FEB performance tests
 - Acquisition mode limitations (high rate, p.e. resolution, linearity)
 - Trigger configurations (global, self)
 - Network of DT5215 and multiple A5202s
 - Timing Synchronization
 - Sensitivity to magnetic fields
 - Slow control options/capabilities
- Cable to A5202 interface board
- MPPC-PCB
- DAQ tests:
 - Robustness of FEB network
 - Integration into global DAQ

QA/QC Plan Overview

- Components to be inspected
 1. SiPM (Hamamatsu MPPCS13360-2050VE)
 2. Front-end boards (CAEN A5202 + custom interfaceboard)
 3. Concentrator Modules (CAEN DT5215)
 4. Cables/Connectors (SamTechHLCD-10, fiberoptics)
 5. Interfaces

1. QA/QC for MPPCs

Hamamatsu MPPC S13360-2050VE

Quantity: 19,200 + spares mounted in groups of 8 onto custom PCB

Checks (after MPPC mounting onto PCB): To be performed in lab

- Mounting accuracy
 - (x,y)-position *by assembly company*; possibly z-position (e.g. height)
- Optical inspection with microscope/camera of photosensitive area
- Functional performance test:
 - Minimal:
 - Record p.e. spectra in response to LED signal (fixed T)
 - Dark rate versus threshold at nominal operating V_{bias}
 - Extended (likely not needed):
 - Record p.e. spectra and dark rate as function of V_{bias}

2. QA/QC for Frontend Boards

CAEN 5202 + custom interface board

Quantity: 300 + spares

To be performed in lab

Checks (for all 64 channels; includes custom interface boards to MPPC cables)

- Channel alive and able to record p.e. spectra in response to MPPC+LED signal
- Time stamping and ToT
- high gain and low gain preamps for expected range of parameter settings
- Bias voltage modulation
- Sample internal and external trigger configurations
- LED pulse generation
- TD Link to concentrator module (timing synchronization, data throughput, communication)
- ...

3. QA/QC for Concentrator Modules

CAEN DT5215

Quantity: 4 + spares

To be performed in lab

Checks (details of tests TBD) :

- Timing synchronization
- Data readout and event building
- TDLinks to 8 Frontend boards
- Communication to host computer
- ...

4. QA/QC for Cables/Connectors

SamTech HLCD-10, fiber optics

Quantity: 2400 + spares

Checks (details of tests TBD) :

- Connect to MPPC board and FE board for integrity test
- Interconnect CAEN 5202 and DT5215 with fiber optics for integrity test
- ...

To be performed in lab

To be performed post installation

5. QA/QC for Interfaces

Quantity: various

Checks (details of tests TBD) :

- MPPC to WLS-fiber connection
- Integral check: MPPC to CAEN A5202
- TMS DAQ to global DAQ
- ...

Prior to and after module installation

Immediately following module installation

Summary

- TMS Electronics based on well proven commercial off-the-shelf technology from CAEN
 - 300 FE modules (A5202) with 64 channels each
 - 3-4 data concentrator modules (DT 5215)
- A number of custom parts will be required
 - MPPC-PCB
 - Interface board + cable matching
 - Power distribution system
 - Enclosures, cooling and mounting

Backup Slides

Alternate MPPC

- Custom MPPC with circular sensitive area
 - Diameter of 1.5 mm
 - Secured permissions to use this custom design
- Extra production cost

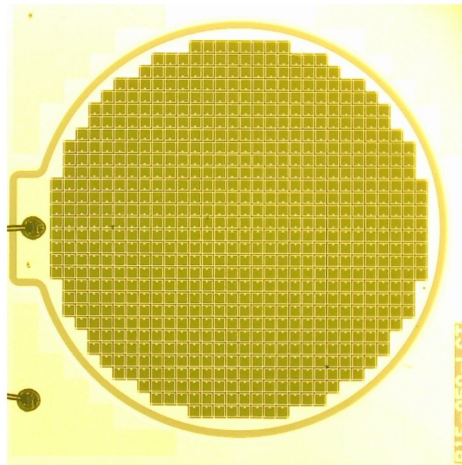
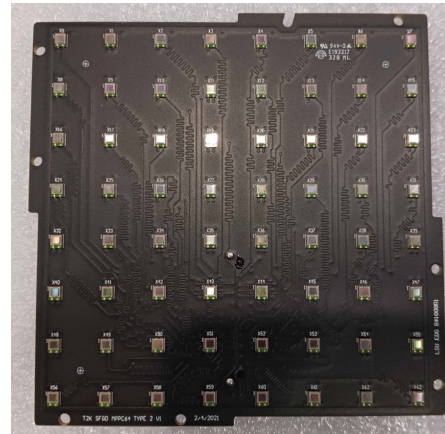
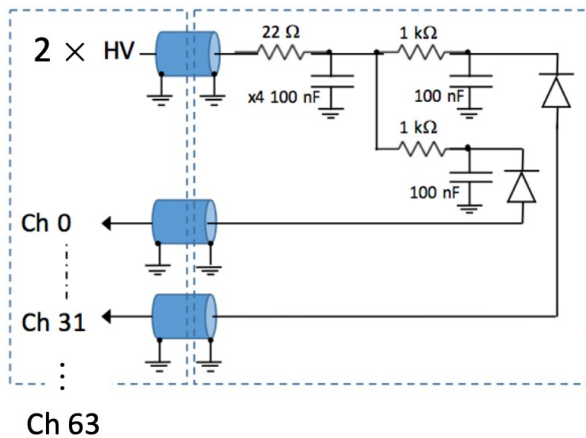


Figure 20: Microscopic photo of one MPPC used for INGRID Water Module and the T59 WAGASCI detector. The size of a pixel is $50 \times 50 \mu\text{m}^2$ and the diameter of sensitive area is 1.5 mm.

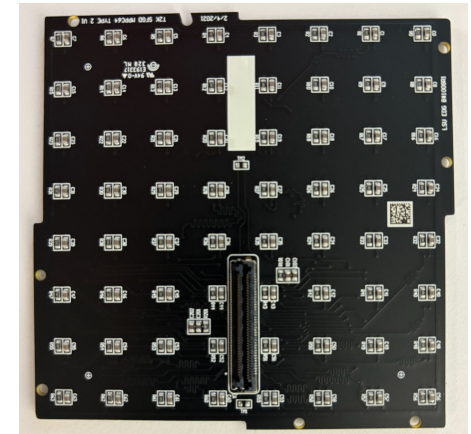
MPPC-PCB

experience from T2K MPPC64-PCB

- routes V_{BIAS} and enables signal readout
- RC filter for every channel
- 1.7mm thick; 4 layer board
- 80 pin SamTech connector on backside
- Temperature sensors



MPPC side



connector side

LED Calibration

Purpose:

- check light response and proper channel functioning
- Gain calibrations and tuning
- Illuminate fibers to include WLS-MPPC interface in check
- Calibration operation of A5202
 - Spectroscopy mode: obtain “finger plots”
 - Timing mode: CHECK viability to obtain “finger plots”

