



Front-end electronics and mechanical design of the HGND for BM@N experiment

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EoS and neutron flows measurements at the BM@N

- EoS describes the relation between density, pressure, energy, temperature and the **isospin asymmetry**
- The study of E_{sym} density dependence is very important for the understanding of astrophysical phenomena like supernovae and neutron stars.
 - The radius of a neutron star depends on the symmetry energy behaviour at high nuclear matter density.

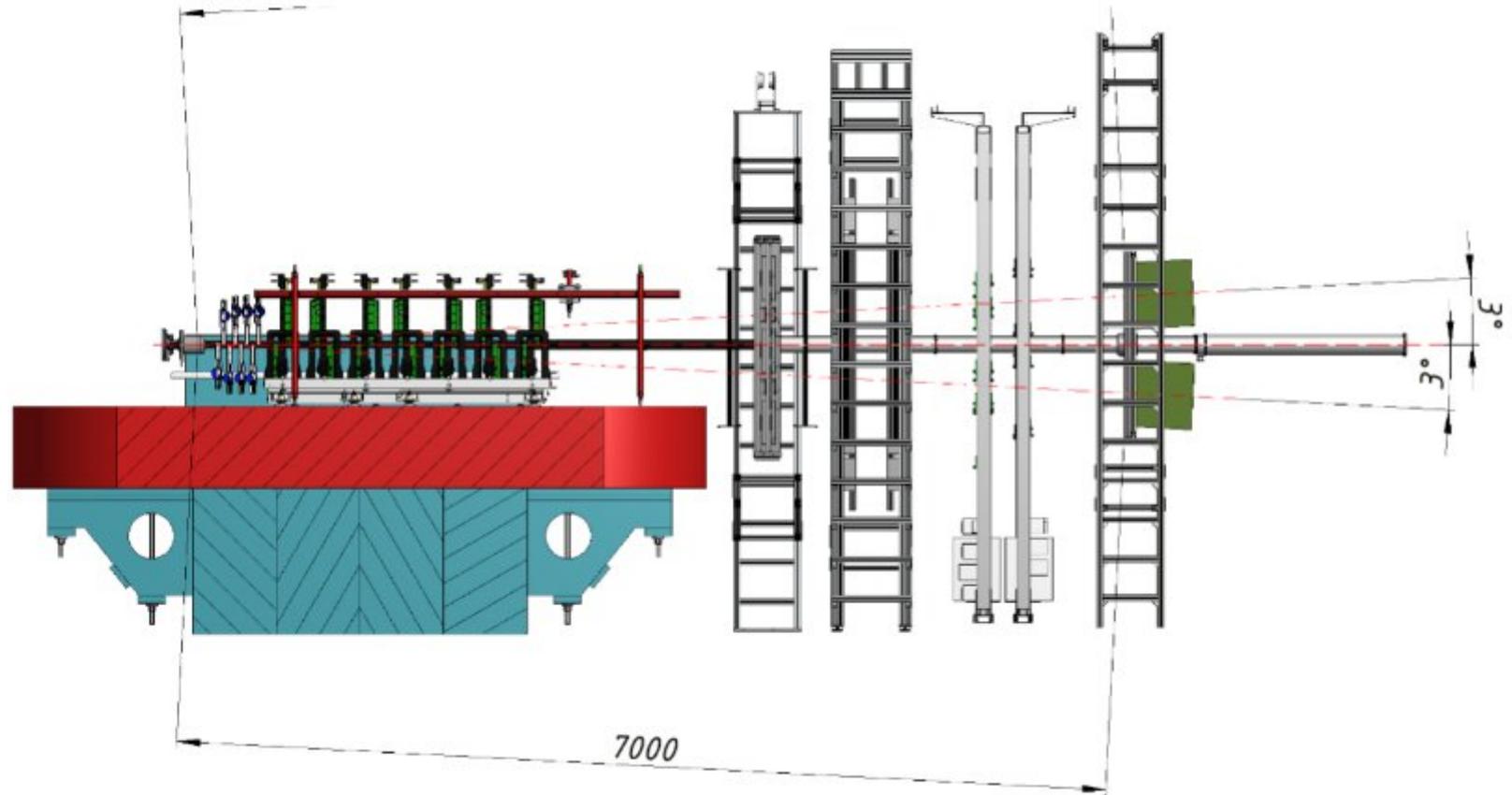
$$E_A(\rho, \delta) = E_A(\rho, 0) + E_{\text{sym}}(\rho)\delta^2 + O(\delta^4)$$

Symmetric matterSymmetry Energy $\delta = (\rho_n - \rho_p)/\rho = (N-Z)/A$

- Collective flows of charged particles are **a sensitive probe** of E_{sym} at high densities at intermediate energies where reaction dynamics is largely determined by the nuclear mean field.
- Measurements of ratio of neutrons/protons flows at nuclear matter density range $(2-4)\rho_0$ can be performed at nearest perspectives only at the BM@N.
- **Neutron detector to measure neutrons flows is needed.**

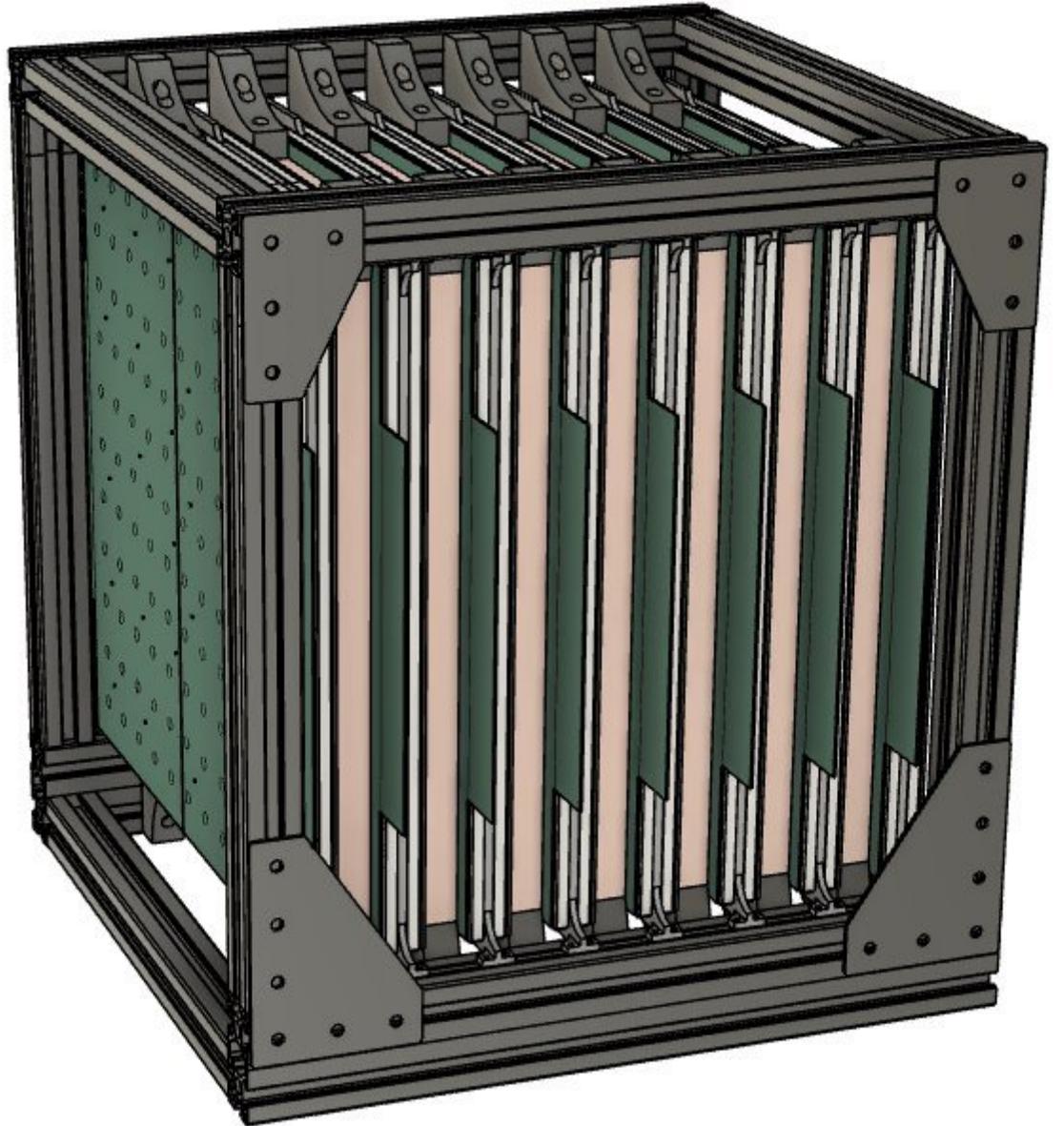
Detector arrangement

- Detector for high-energy neutron flow measurement
- ToF method with T0 as the “start” signal source
- 7m measurement distance
- Detector is split into 2 “blocks” for improved acceptance



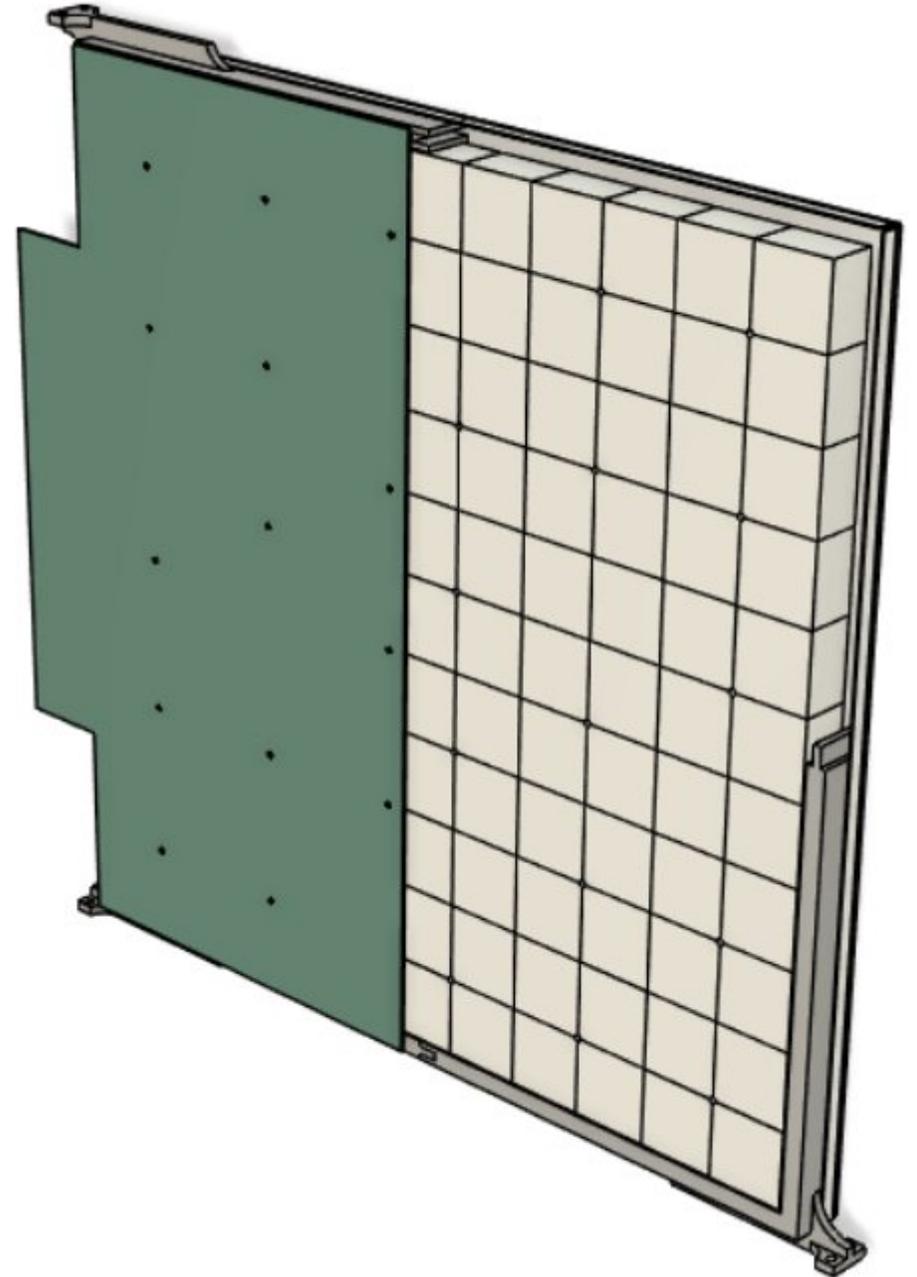
Detector “block”

- Each block consists of:
 - A VETO-layer
 - 8 Cu absorbers
 - 8 sensitive layers
 - 11x11 grid of scintillations each
- Assembly is light-tight and air-cooled
- Framing is built with light-weight Al profiles

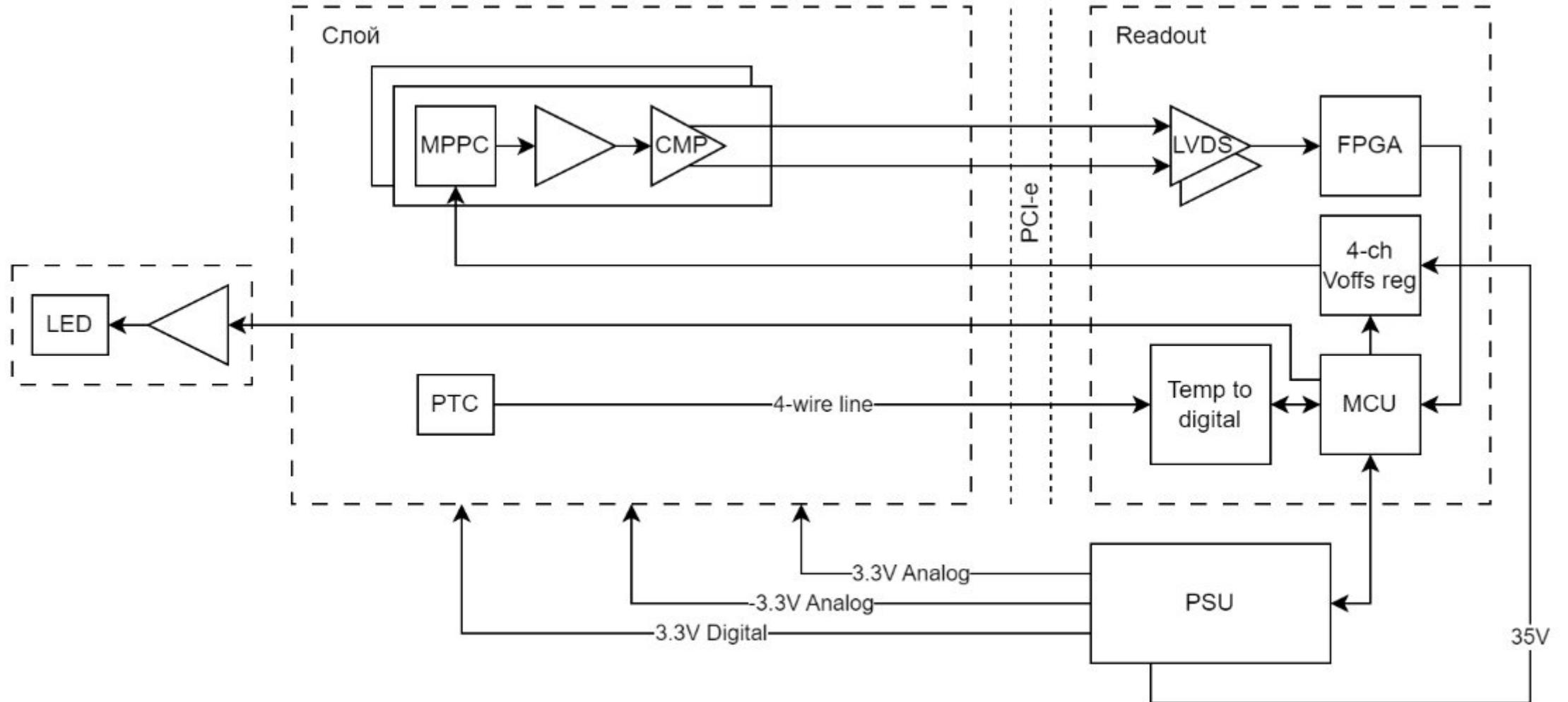


Detector layer

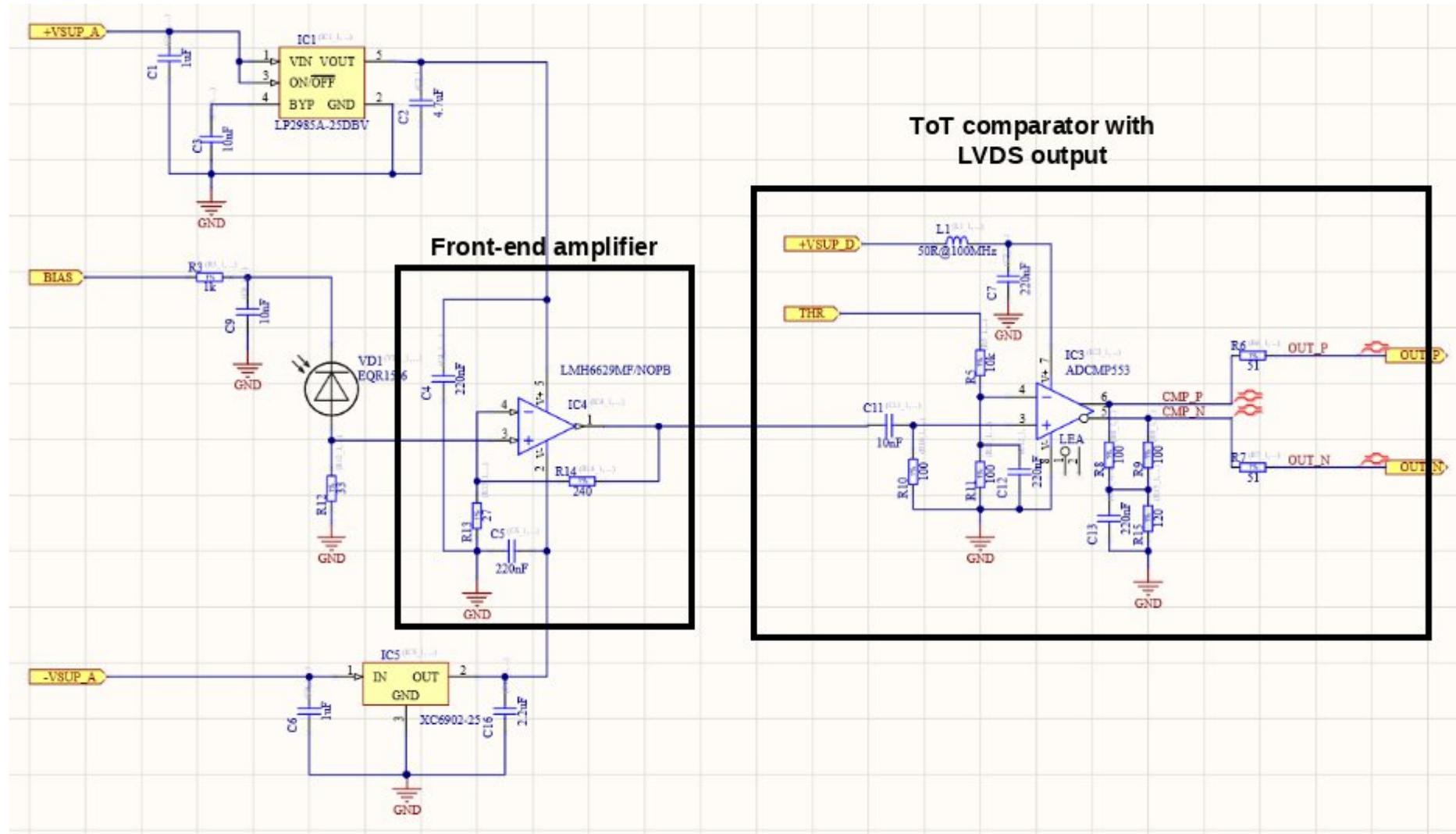
- Each layer consists of:
 - 11x11 grid of individual scintillator tiles
 - A front-end readout board
 - An LED calibrator board
- Layer is assembled in a light-tight 3D-printed casing
- Readout boards connects to the data collection equipment via edge connectors



HGND electronics architecture



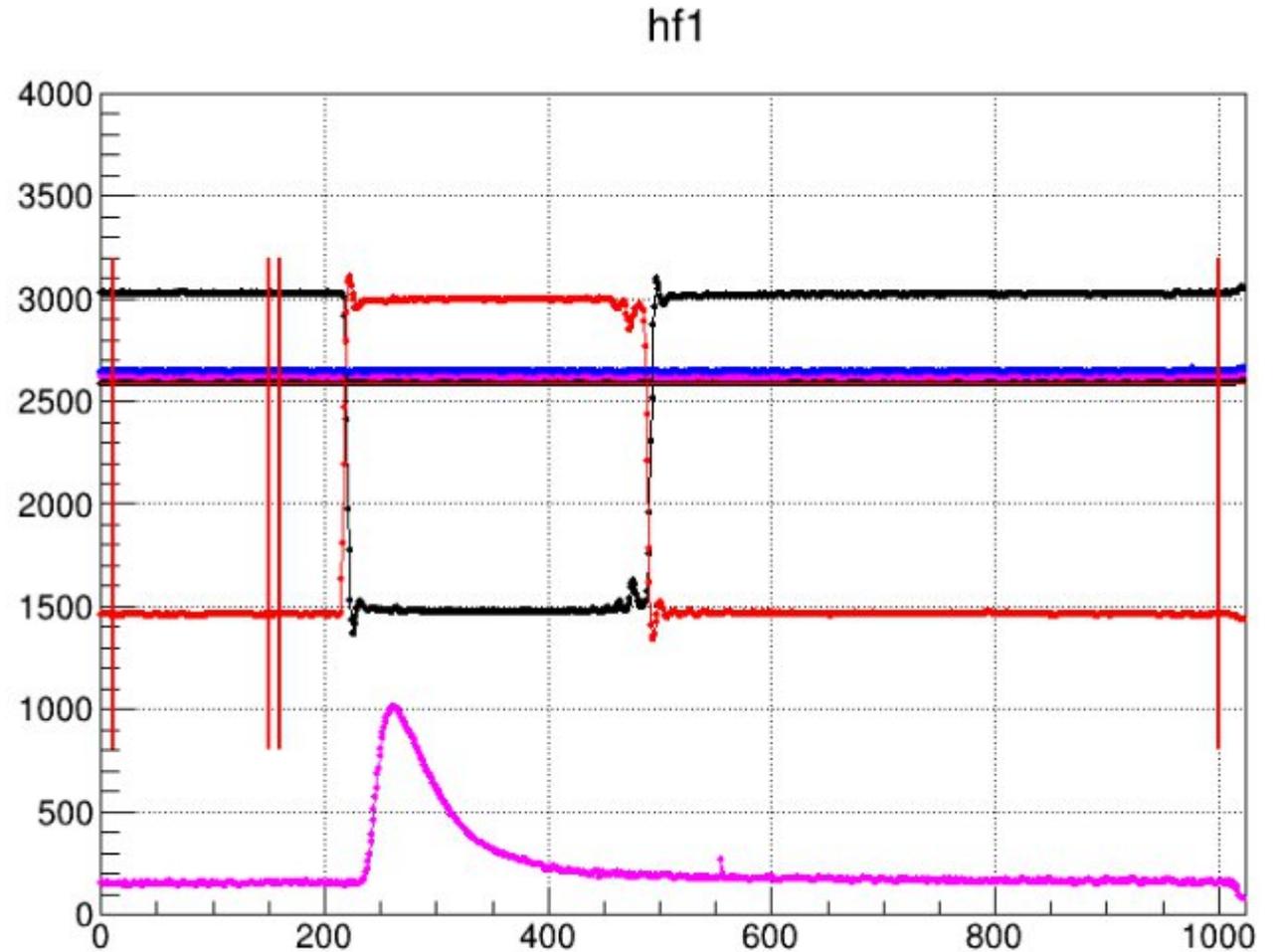
Front end electronics

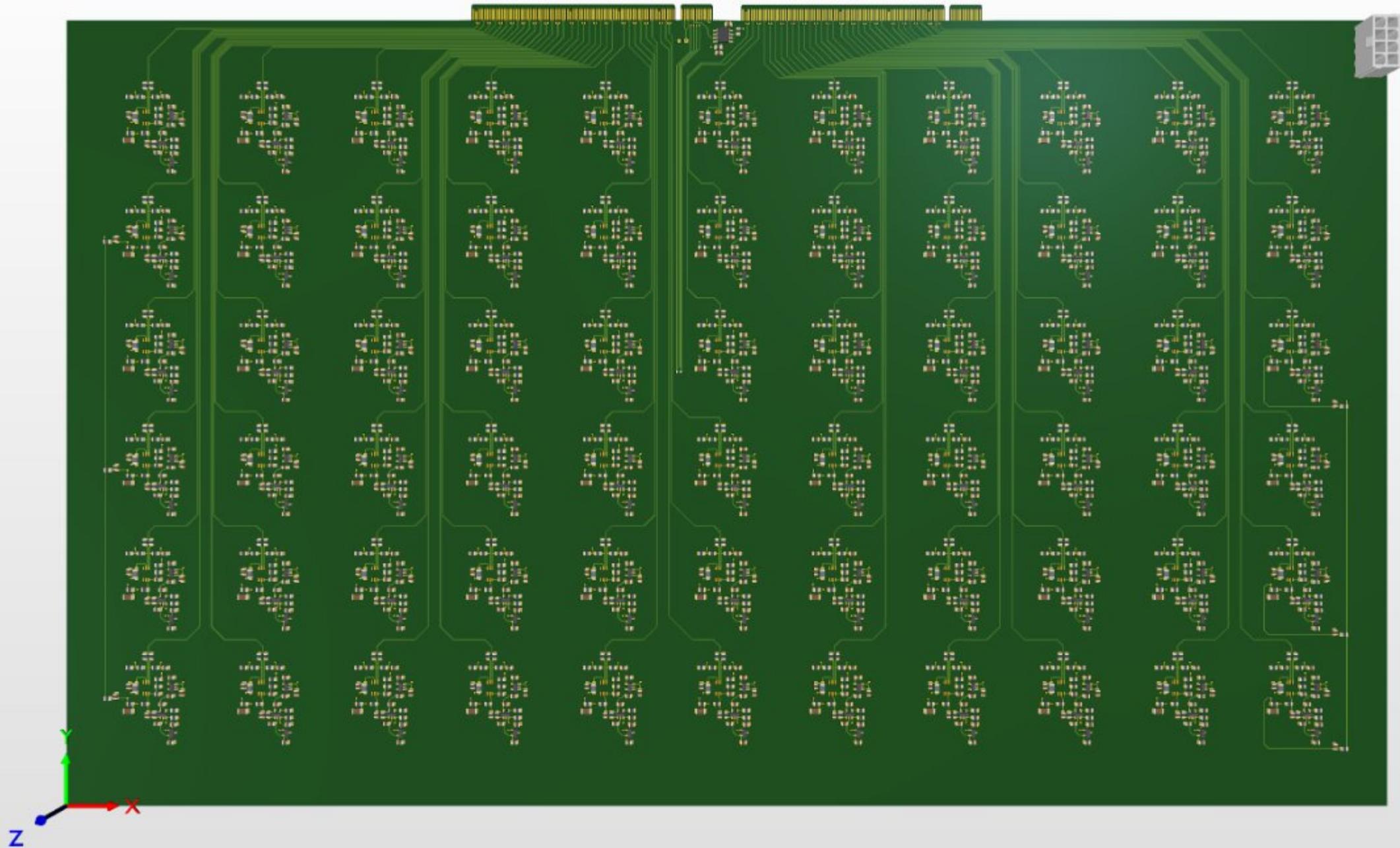


- 20dB amplification
- $2.2 \text{ nV}/\sqrt{\text{Hz}}$ noise level
- Per-channel supplies
- Variable threshold (common for the half-layer)
- LVDS output

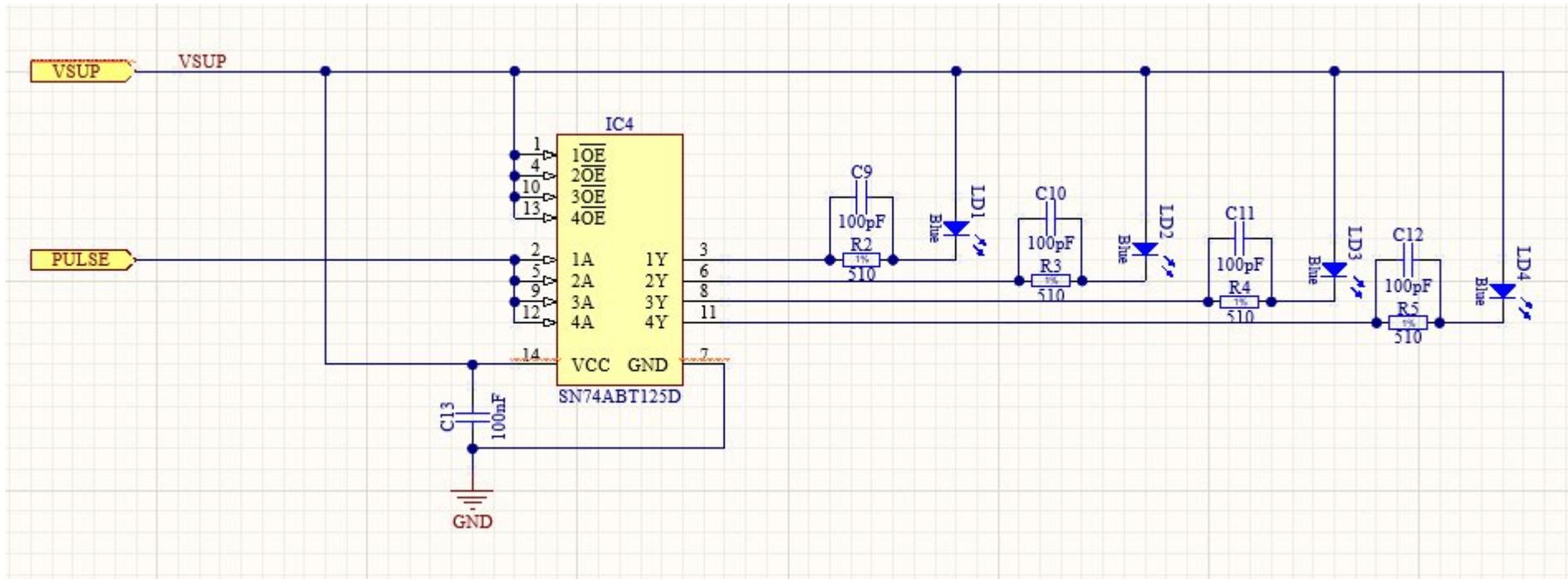
ToT method

- Vast amount of channels creates a dataflow and wiring concern
- A ToT method is chosen for amplitude and timing measurements
- Amplitude data allows for slewing correction of timing measurements
- See the correction methodology at [arXiv:2308.08341](https://arxiv.org/abs/2308.08341)

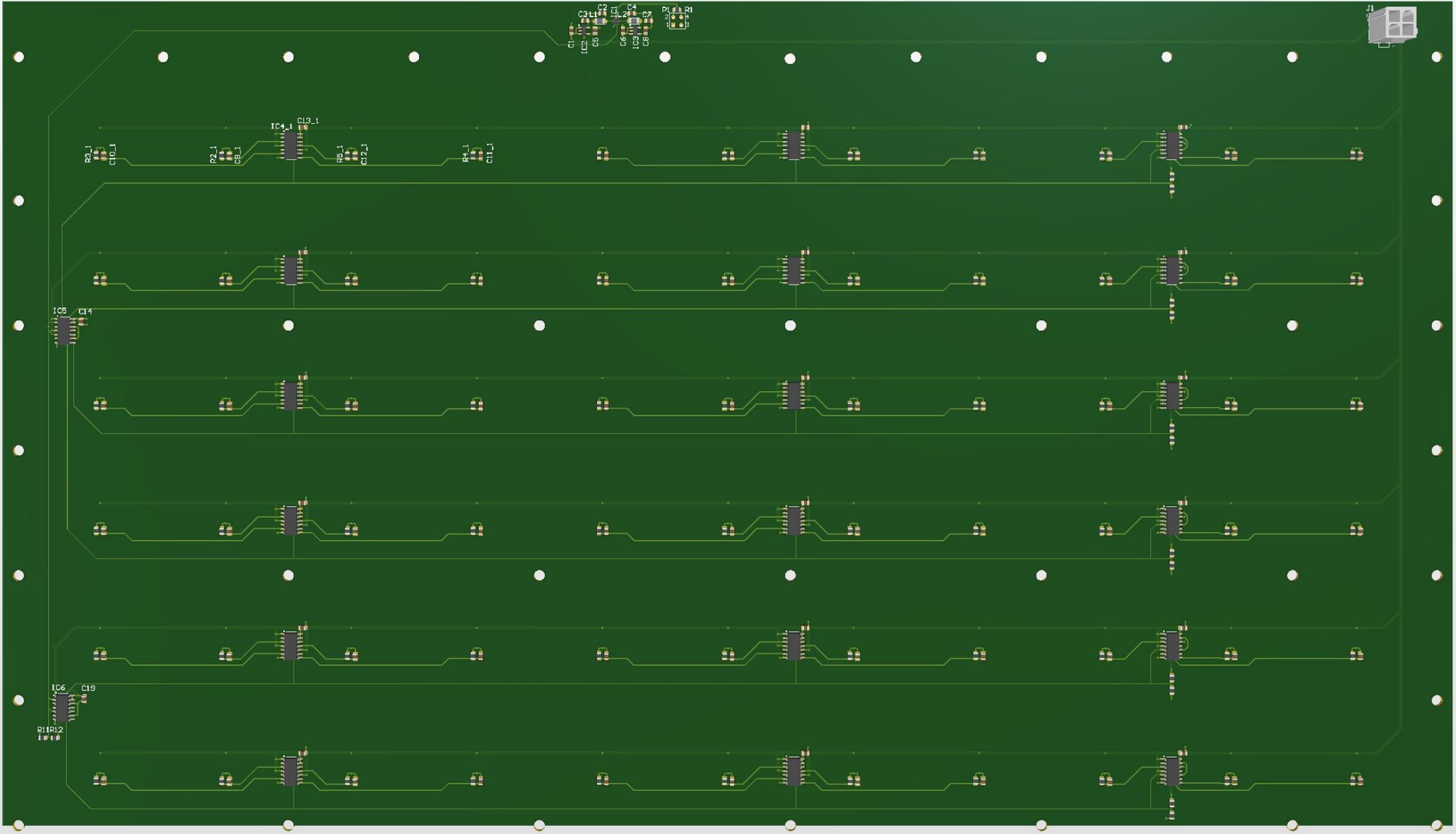




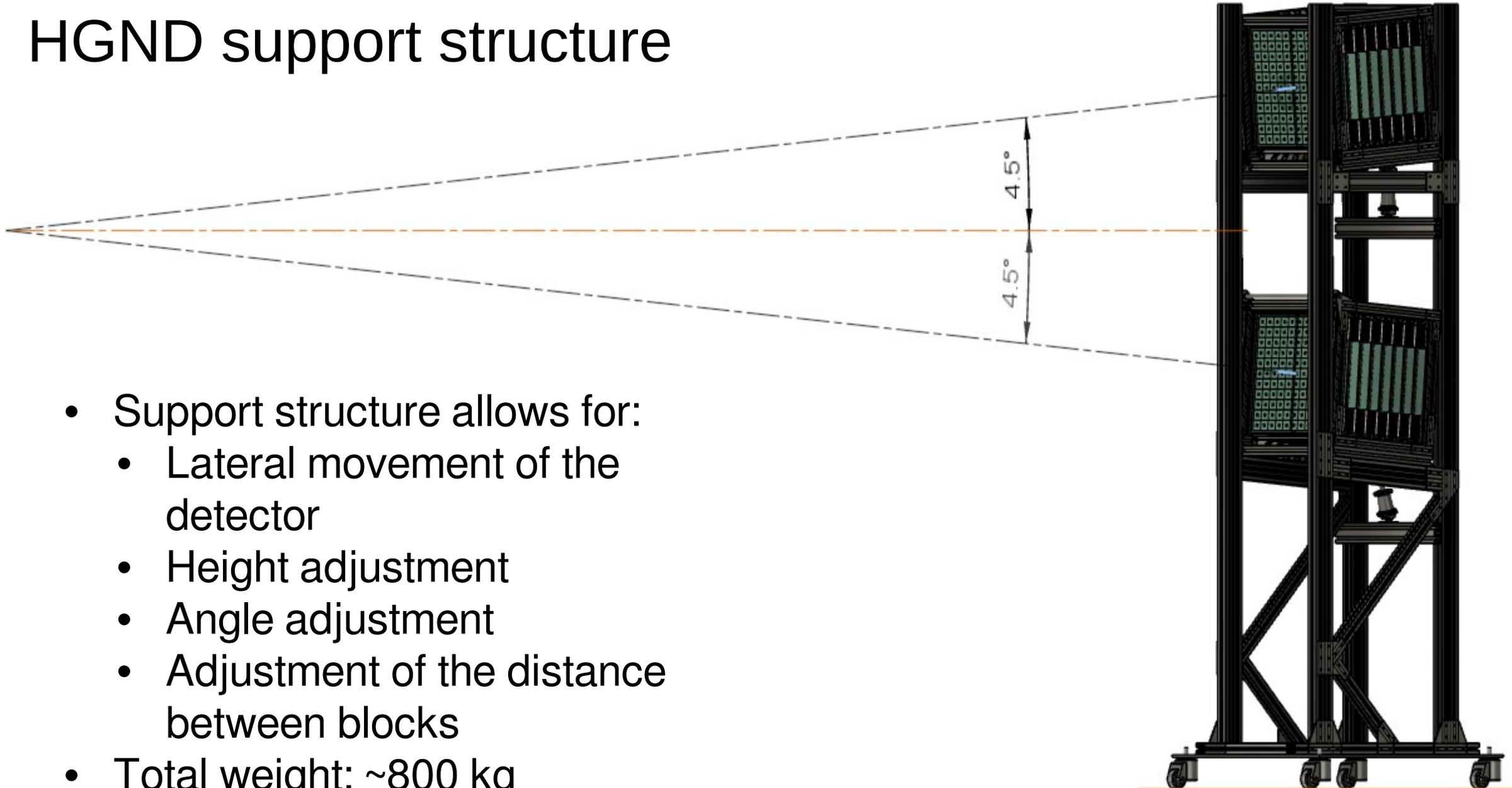
LED pulser



- LVDS-driven
- Buffer network with terminated impedance-matched traces
- Simultaneous illumination of all 66 channels

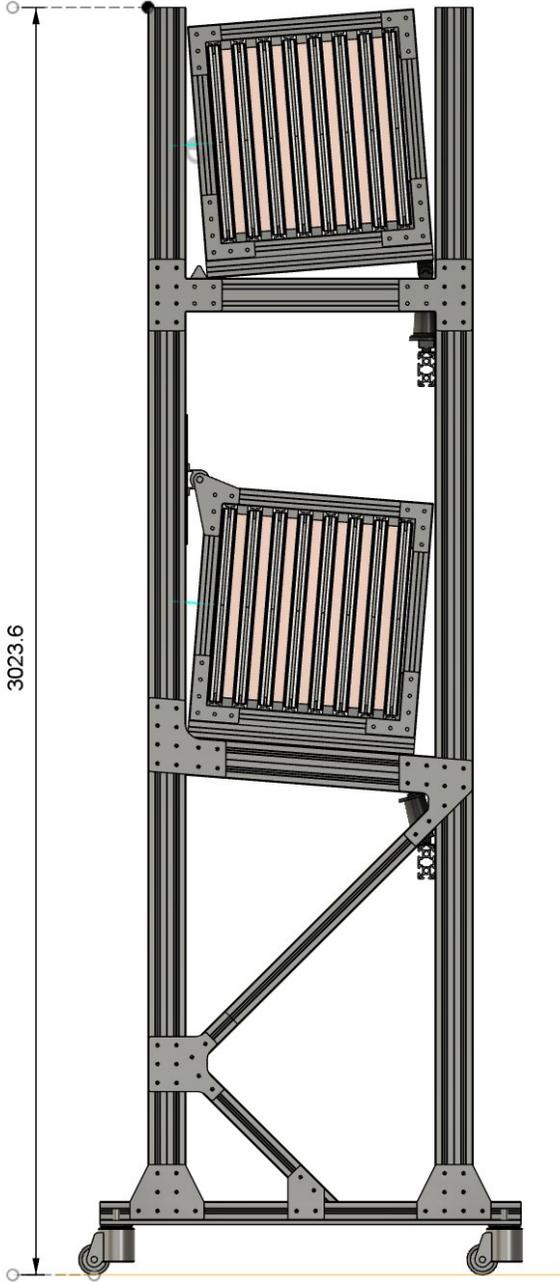
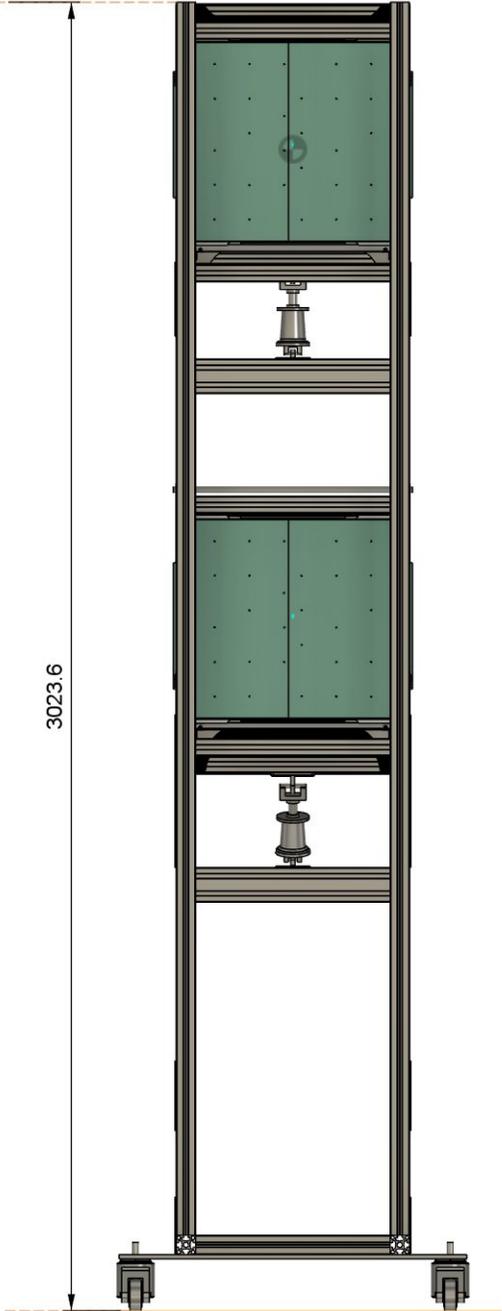
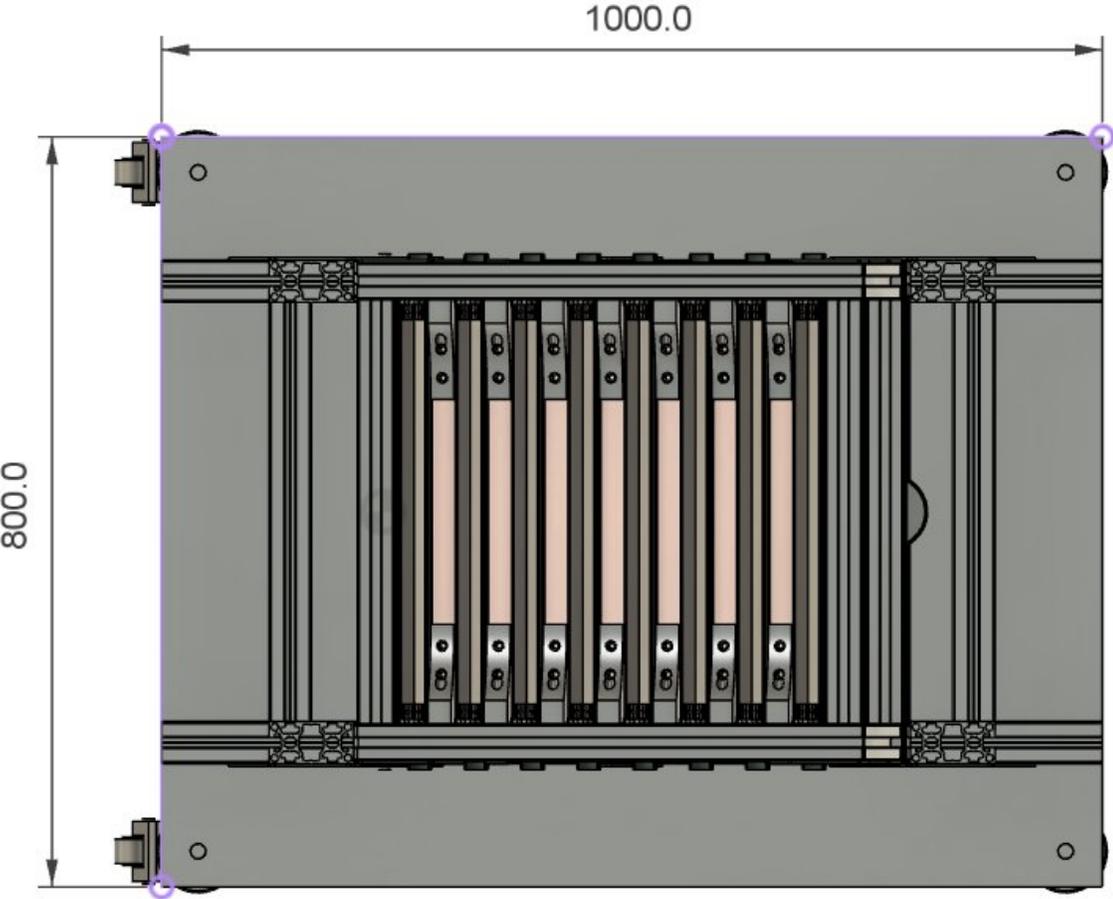


HGND support structure

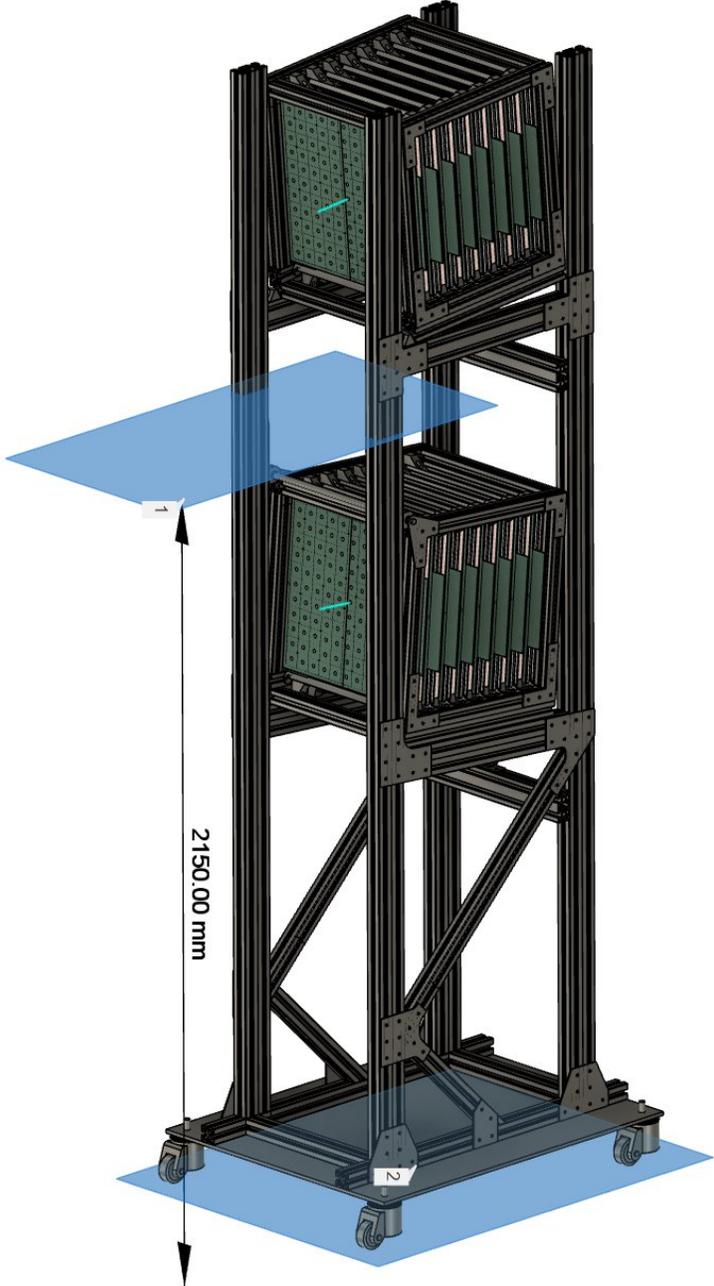


- Support structure allows for:
 - Lateral movement of the detector
 - Height adjustment
 - Angle adjustment
 - Adjustment of the distance between blocks
- Total weight: ~800 kg

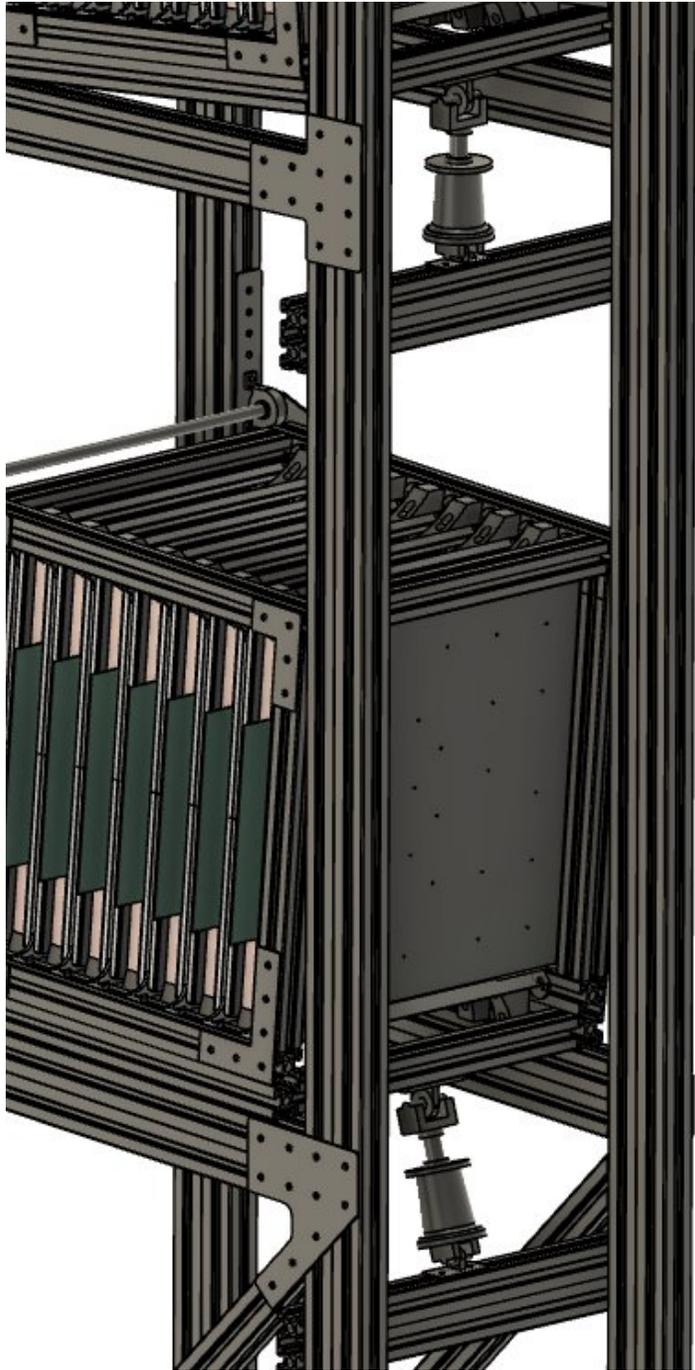
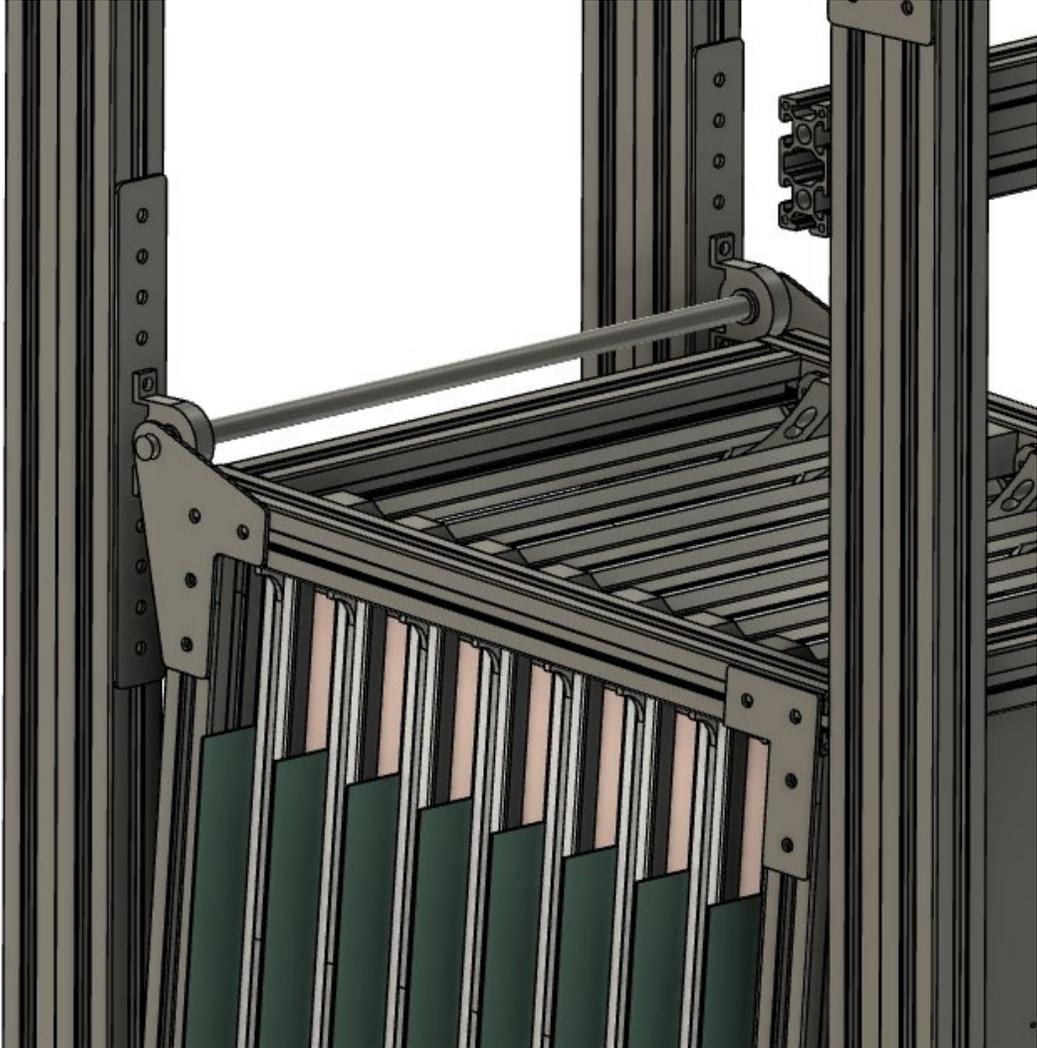
HGND support structure



HGND support structure

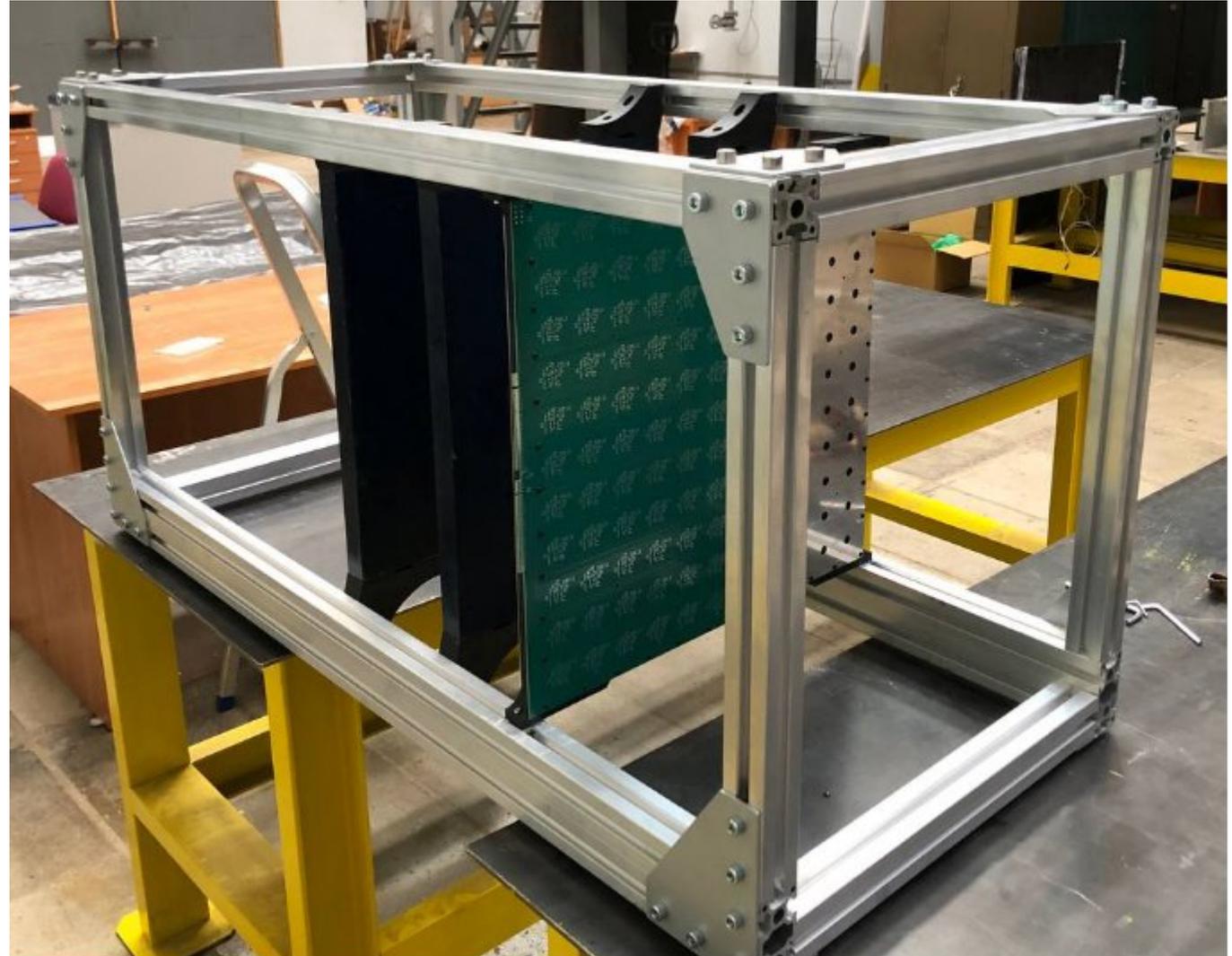


HGND support structure



HGND mechanical mock-up

- A mock-up of the HGND block has been assembled at INR
- Mock-up allows to test:
 - Loading-unloading of the converters using hoists
 - Mounting-unmounting of the detector layers
 - Framing deformation and sag under load



HGND test assembly

- A prototype of the readout board is under assembly
- A prototype of the LED board is completed
- A prototype case for the detector layer is completed
- Full-readout-chain tests are expected by Fall

