

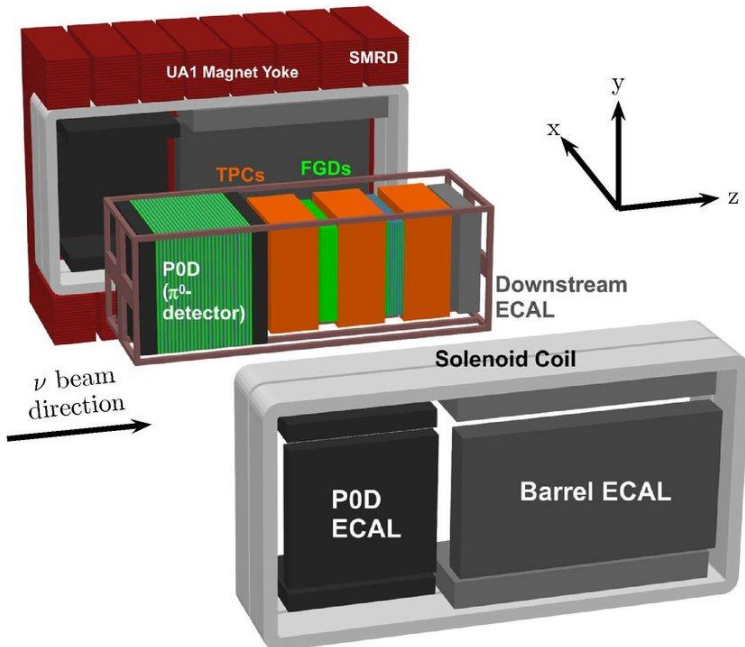
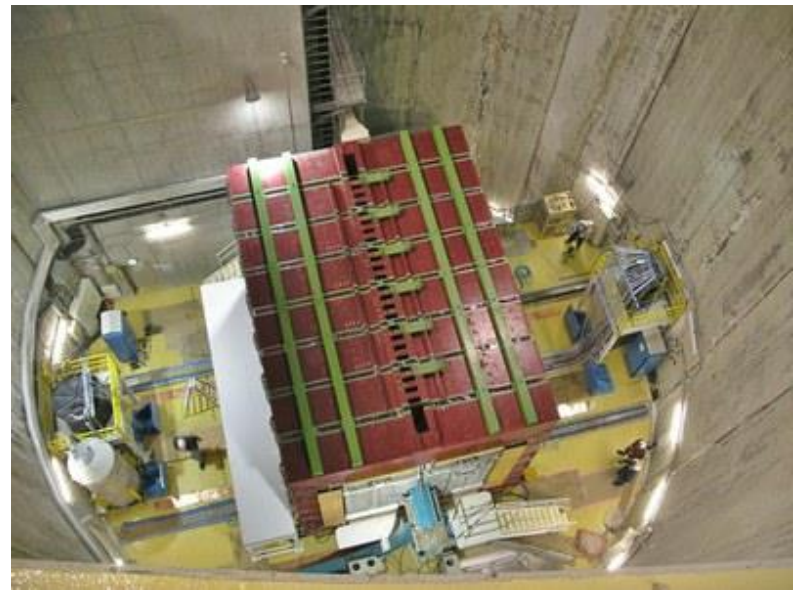
T2K Near Detector Upgrade: Super Fine-Grained Detector

Christopher Mauger for the T2K
collaboration

University of Pennsylvania

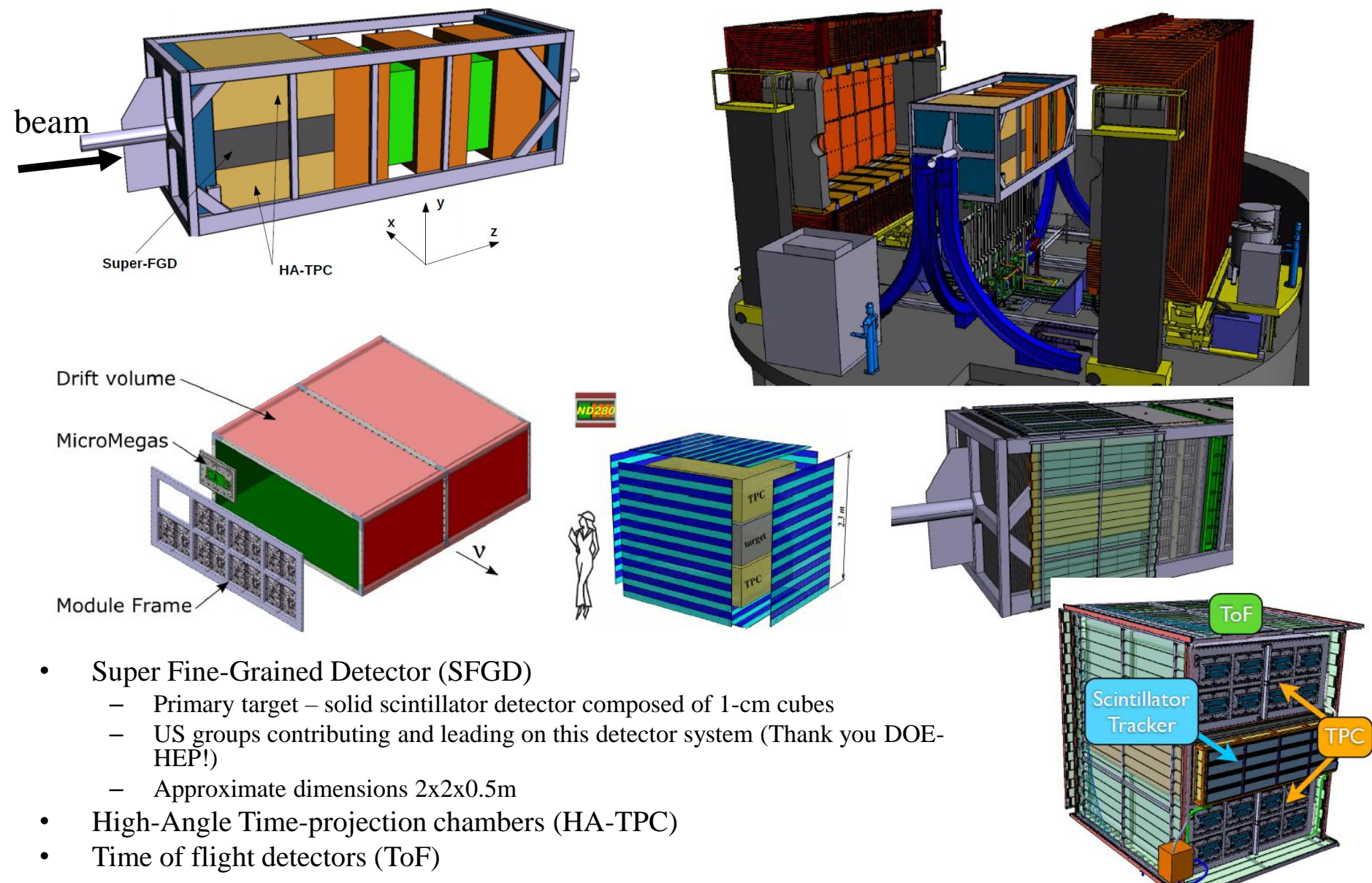
14 July 2020

T2K Experiment and Near Detector

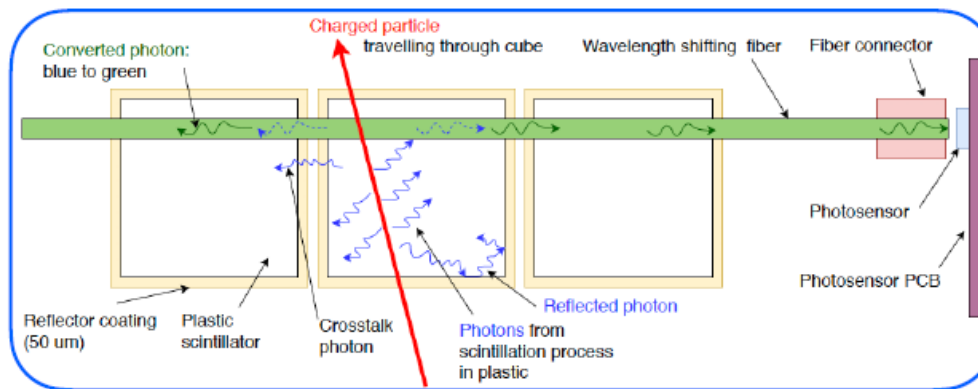
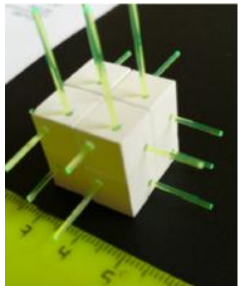
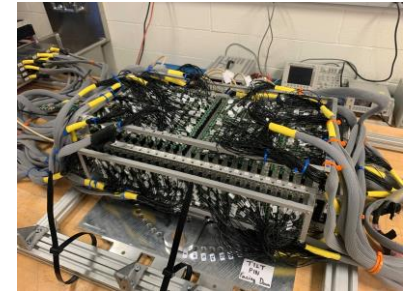
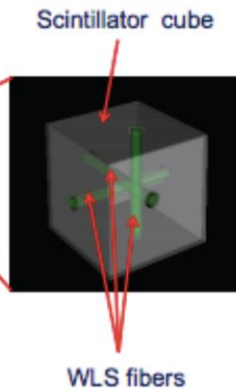
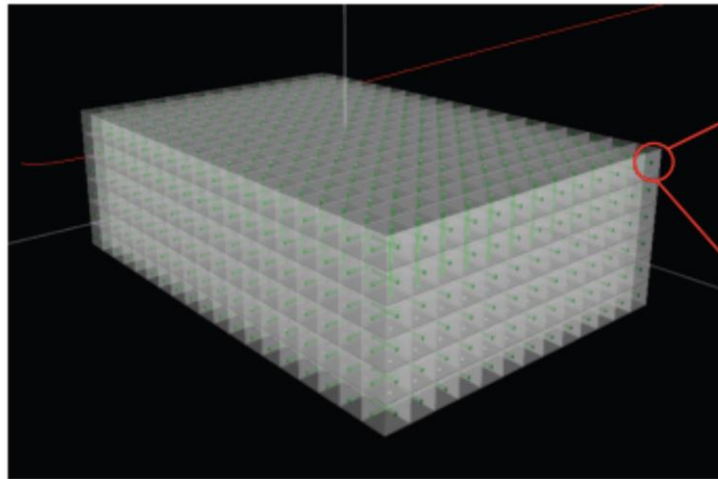


- Near Detector – detailed studies of neutrino and anti-neutrino beams in high flux environment
- Excellent forward-particle measurements
- Far detector – isotropic measurement of event signatures ₂

Overview of the Upgrade Detector



Super Fine-Grained Detector: SFGD



- 1x1x1 cm³ cubes
- Polystyrene scintillator
- 1.5% paraterphenyl
- 0.01% POPOP
- Chemical etched reflector
- WLS fiber Kuraray Y11
- 2-clad (∅=1mm)

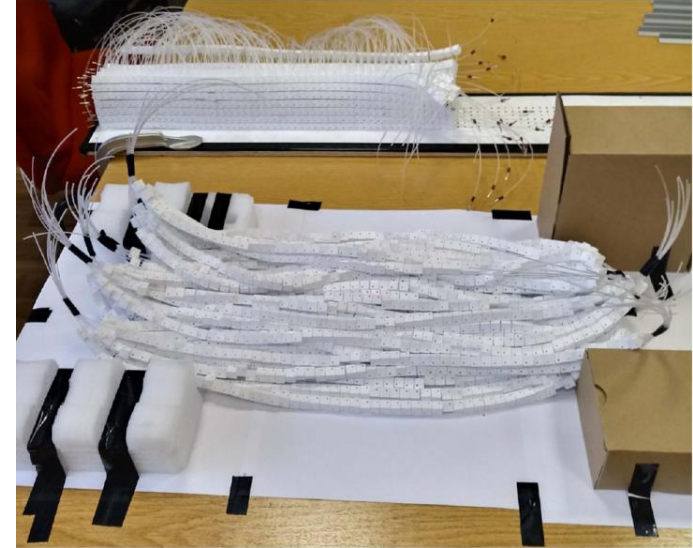
- 3D-array of 1-cm scintillator cubes (184x192x56)
- Fibers run the length (or width or height) of the detector – 3-fibers in each cube
- Low-occupancy experiment – 3D view of events (4π– like acceptance)
- Prototype detectors – efforts described in next talks

Cube Production/Assembly Completed!

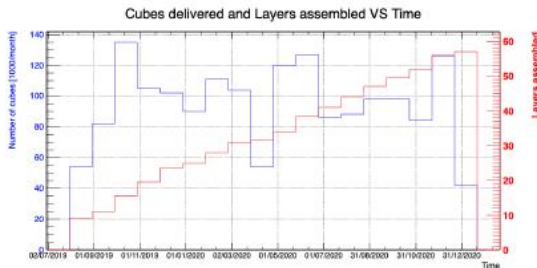
First layers



All (56) layers



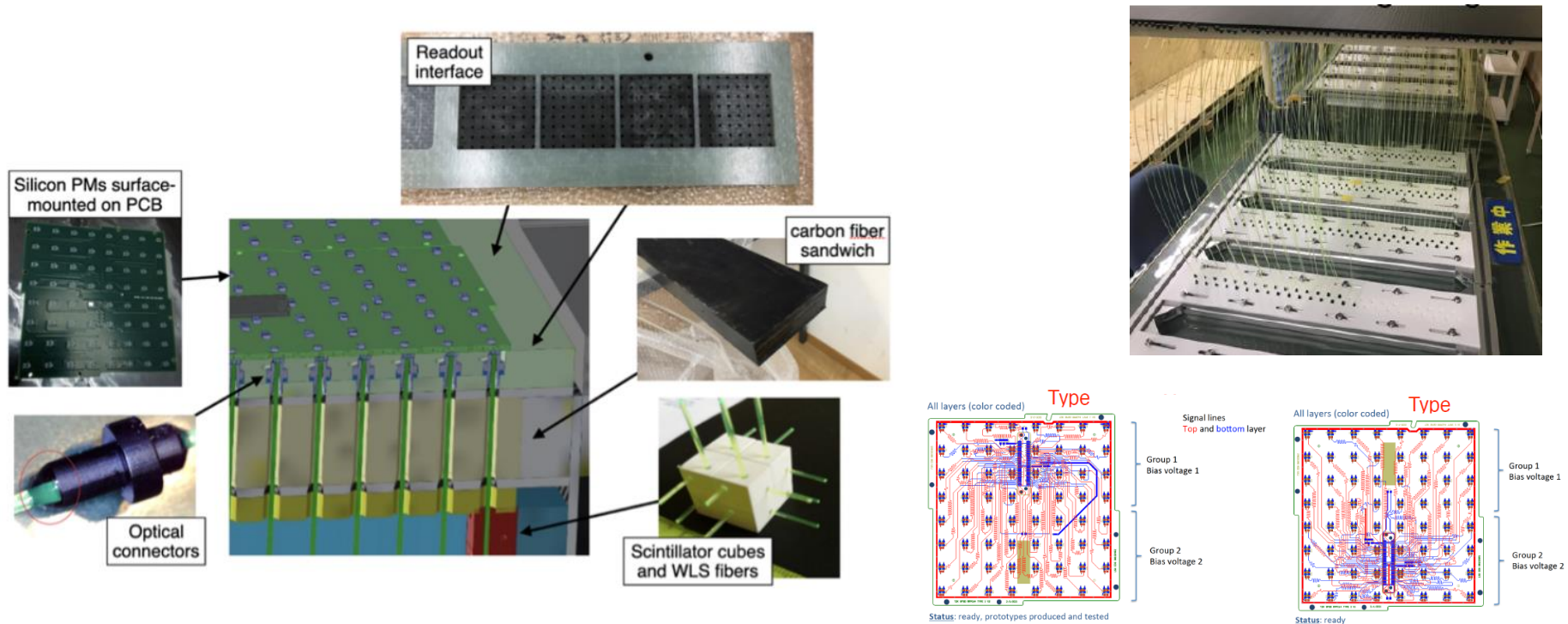
1 Layer = 184 x 192 cubes (baseline design)



All cubes have been produced by Uniplast and layers have been assembly at INR

- Cube production, finishing, QC completed – about 2 million cubes
- Initial assembly completed with fishing line (completed on schedule during the pandemic)
- Cubes aligned in strings
- Assembled into planes
- Planes stacked and aligned for the full detector
- Final optical fiber insertion done at J-PARC

Light-readout scheme



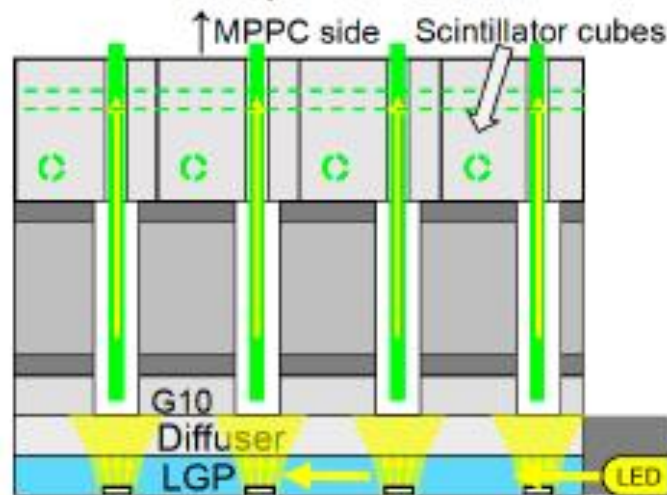
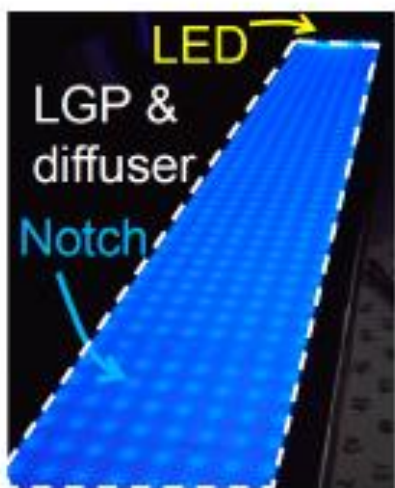
- Wave-length shifting fiber aligned with the MPPC via hardware design
- MPPC is surface mounted onto the PCB screwed into the box plate
- Fibers glued to optical connectors more than half completed – total of 56,382 fibers

LED Calibration

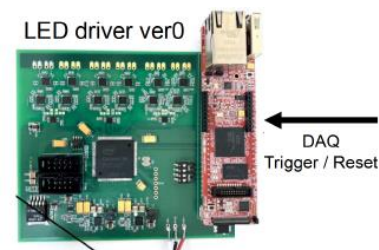
Concept of light propagation for the system

This concept can distribute uniform light with thin space using a small # of LEDs

- The light guide plate (LGP) has notches which scatter light
- Notches on the LGP are placed at the same pitch as the fiber

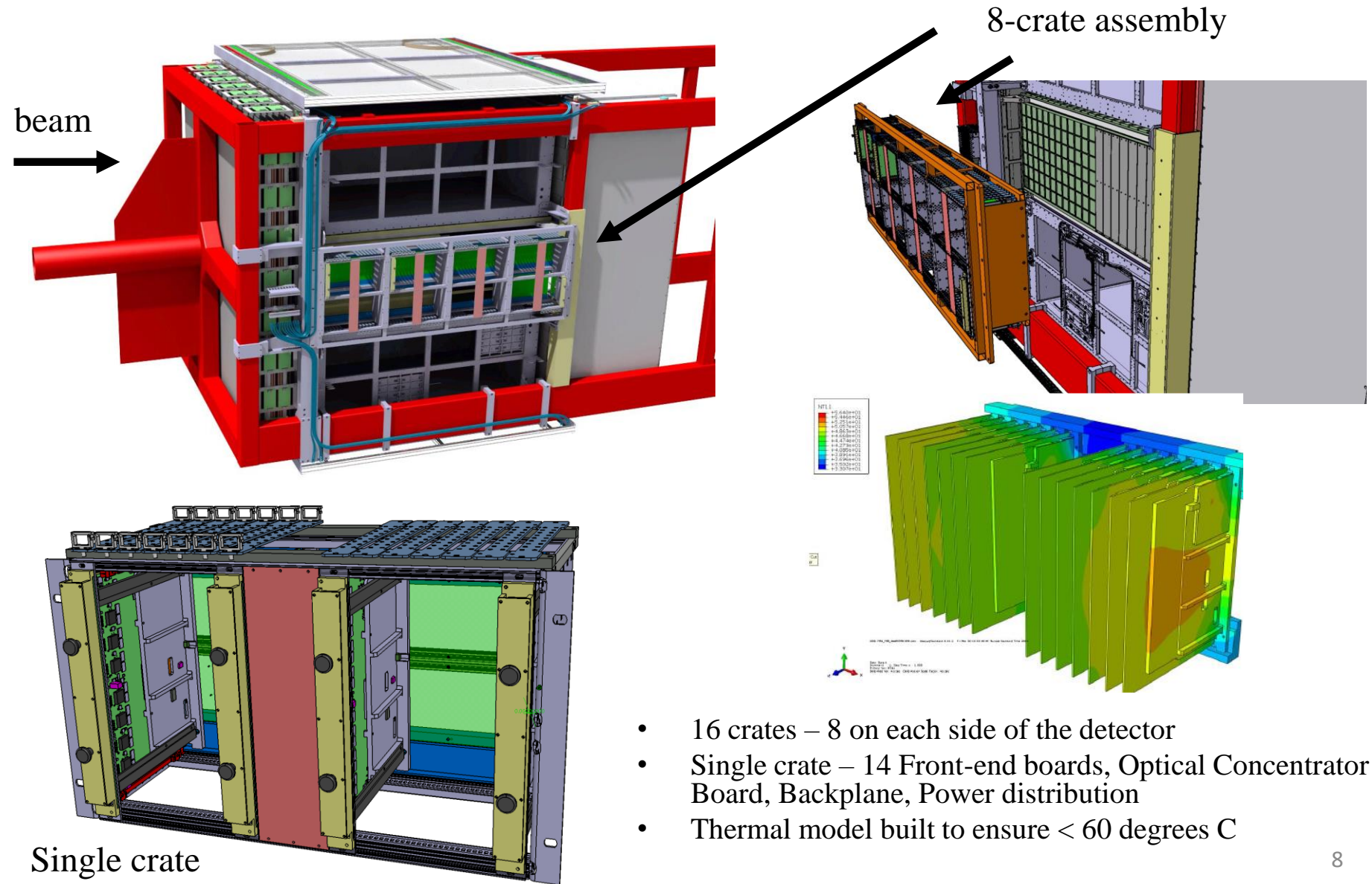


- LED Calibration – employs side of fiber not read out to inject light into the fiber
- System has been prototyped
- Production beginning soon



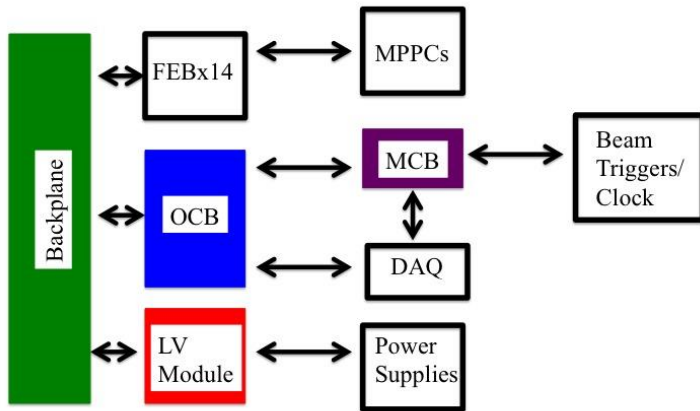
Pulse height and width can be controlled by FPGA
One LED driver covers 12 LGP modules
There are 8 LED drivers to cover all modules

Electronics I



Electronics II

SFGD Electronics Architecture

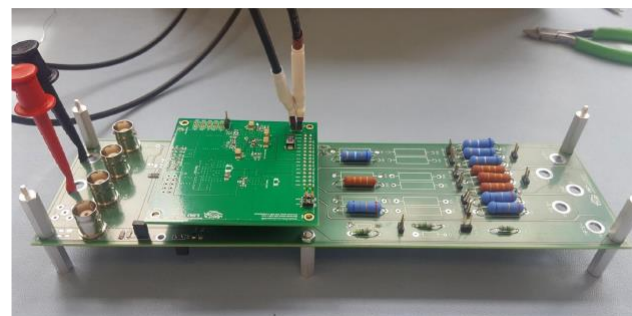
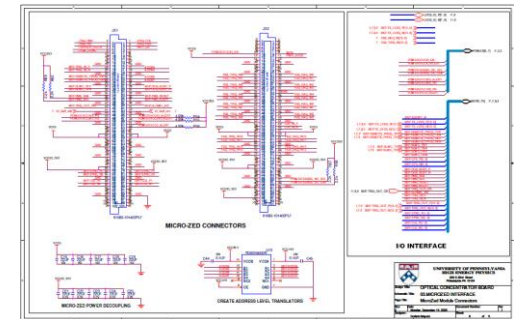
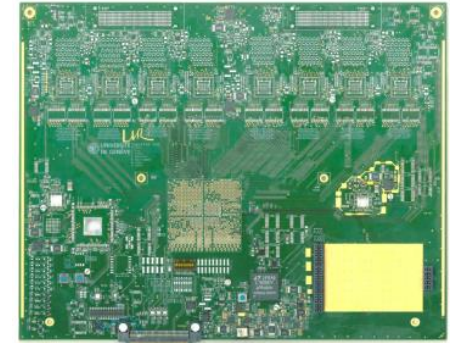
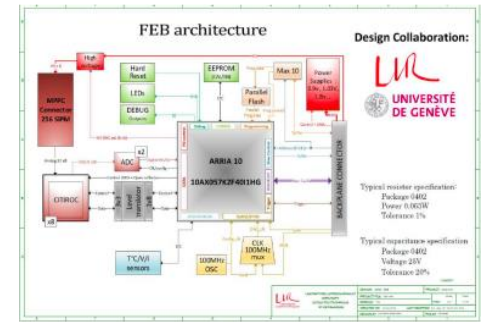


Master Clock Board (1 board) – external to magnet, hardware connections to the beam triggers

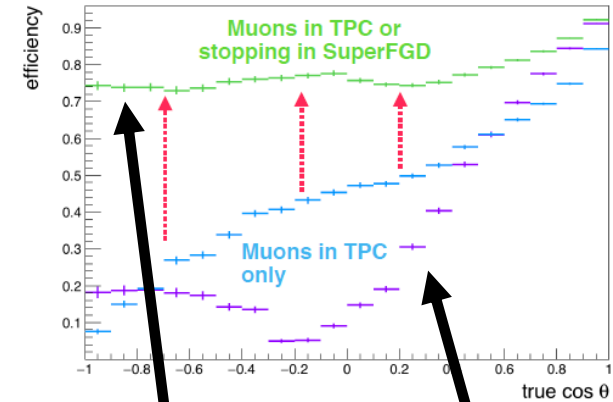
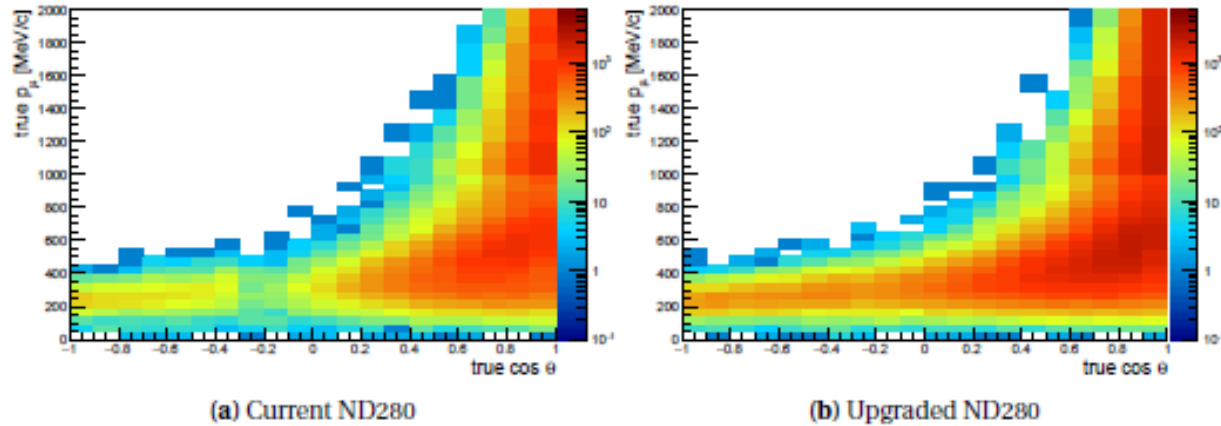
Power Distribution – ideally as much local DC/DC conversion happens on FEBs, current testing DC/DC converters in magnetic fields (current operation 0.2T, qualify to 0.4T)

Front-End Board (14 boards per crate) – analog processing, ADC, bias voltage to the MPPCs
 CITIROC chip – 32 channels, 8 chips per FEB
 Prototype boards undergoing testing

Optical Concentrator Board (1 board per crate) – initial data aggregation, switchyard to outside world
 Firmware under development



Performance of Upgraded Detector

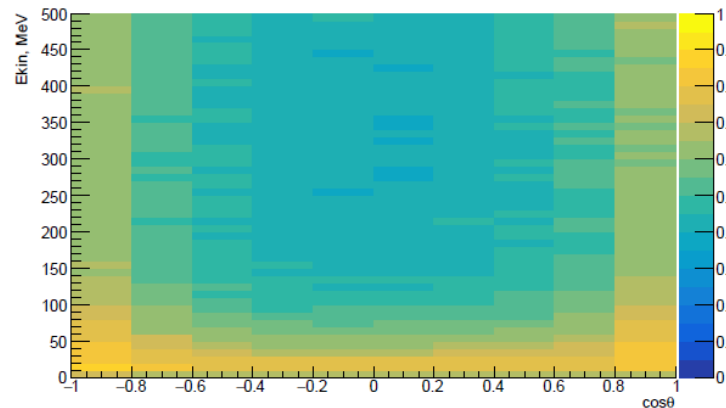
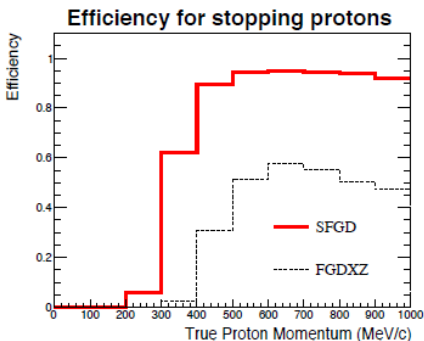


Current ND 280

Upgraded ND 280

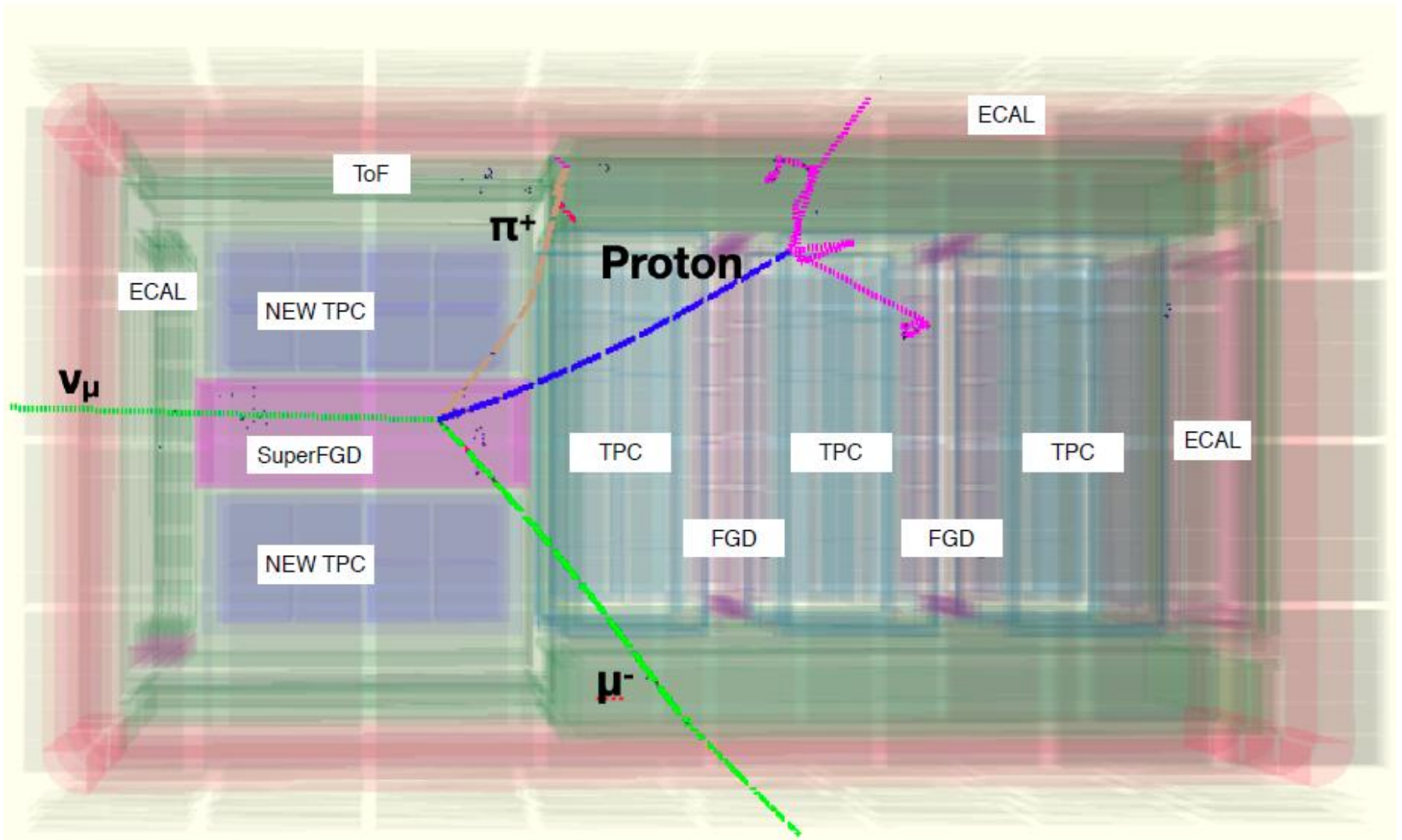
For 10^{21} POT

| Selection | Current-like | Upgrade-like |
|-------------------------------------|--------------|--------------|
| ν_μ (ν beam) | 100632 | 199605 |
| $\bar{\nu}_\mu$ ($\bar{\nu}$ beam) | 32671 | 60763 |
| ν_μ ($\bar{\nu}$ beam) | 16537 | 29593 |



- Greatly improved performance for transverse particles
- Excellent neutron detection *and* neutron measurement of kinetic energy via time of flight *within* the SFGD
- Momentum by range – 3% for stopping muons
- Excellent low-momentum performance – 300 MeV/c momentum threshold for protons

Simulated Event in Upgraded ND



Schedule

- Original plan
 - Assemble and commission most elements at CERN before shipping to J-PARC
 - Commissioning completed at J-PARC by March 2022
- COVID-19 impacts on design, prototyping efforts
- Plan under consideration
 - Assemble cubes in the box, insert fibers into the cubes in summer of 2022 on the surface at J-PARC
 - Initial testing of electronics on the surface
 - Lower everything into the pit
 - Final assembly and commissioning complete by end of calendar year 2022
- First beam in January of 2023
- Details still being worked out, looking for additional time savings

Summary

- T2K continues to be an exciting experiment
- Upgrade detector employs a novel approach to achieve 3D reconstruction
- New results with well-measured transverse momentum will provide greater constraints on the neutrino interaction models
- The prospect of detailed understanding of outgoing neutron kinematics for the first time in an oscillation experiment is very exciting
- Despite the pandemic, effort are proceeding well – anticipate first beam in early calendar 2023