NP07

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T2K ND280 Upgrade Status

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On behalf of the NP07 groups
T2K and the ND280 Role

Far detector
Super Kamiokande

Near detector complex

J-Parc
Neutrino Beam

Create Neutrino’s off-axis beam $\nu_\mu$ or $\bar{\nu}_\mu$

Measure oscillated beam @SK

Characterize beam and $\nu$ interactions @ND280

$\nu_\mu \rightarrow \nu_\mu$

$\nu_\mu \rightarrow \nu_e$
Current ND280 sketch

Event display of basket elements

Current limitations

- Tracks w/o TPCs (high angle).
- Tracks w/o TPCs (low momentum).
- Limited timing information \(\Rightarrow\) no direction information
- No neutron info
- Poor electron/photon separation
- High detection threshold
Upgraded ND280

- Replace P0D by new subdetectors
- 2 High Angle TPCs
  - Drift volume
  - MicroMegas
  - 8 ERAM
  - New read-out concept
- 1 SuperFGD
  - 192 cm x 56 cm x 182 cm
  - 1 cm³
  - Novel detector concept
- 6 ToF panels
  - 150 ps time resolution

Milestones

- 2018 → TDR
- arXiv:1901.03750

149th SPSC Meeting
Upgraded ND280

- Upgraded ND280 covering similar phase space coverage as SuperKamiokande
- Significant lower energy threshold
- Neutron detection capability

Much better constraint on beam and better cross section measurements!
More than 120 researchers from 26 institutes from 10 countries involved!

**Europe:** France (CEA Saclay, LLR, LPNHE), Germany (RWTH), Italy (INFN Sezioni di Bari, Napoli, Legnaro, Padova, Roma 1), Poland (IFJ Pan, NCBJ, WUT), Russia (INR and Dubna), Spain (IAFE), Switzerland (University of Geneva, ETHZ) + CERN

**Japan:** University of Tokyo, KEK, Kyoto University, Tokyo Metropolitan University

**US:** Louisiana State University, University of Colorado, University of Pennsylvania, University of Pittsburgh, Stony Brook University, University of Rochester

MoU signed in 2020 between participating institutes and CERN (NP-07/ND280 Upgrade project)
- 192 x 182 x 56 cubes
- Mechanical box for ~2t
- ~56k fiber/MPPCs
- ~56k readout channels
Excellent sagging behaviour following load test at CERN
SFGD: Assembly

(i) Support system assembly

(ii) First cube layer assembly

(iii) All 56 layers assembled

(iv) Stop panels removed

(v) Box closure

(vi) Transfer to new support
SFGD: Assembly

(vii) Horizontal fibers assembly
(viii) Wall MPPCs assembly
(ix) Vertical fibers assembly

(x) Top MPPCs assembly
(xi) LED calib. modules assembly
(xii) Light barrier/cables assembly
SFGD: First Events

• First cosmics seen!
• MPPC finger plots recorded
• Until now commercial electronics with limited #channels
• Production of final electronics ongoing and expected to be delivered in summer
• Reduced number of FEBs already at J-PARC and used to test the full detector with final electronics
• Commissioning on surface in August 2023 at J-PARC

Successful completion of vertical slice test => launch of full production
SFGD: Neutron Testbeam

- Neutron testbeam at LANSCE with prototypes in 2019+2020
- Important measurement to demonstrate the neutron detection capability
- Energy spectrum at facility covers the most relevant range for T2K
- Good agreement between prediction and data
HA-TPC

- 2 HA-TPCs assembled out of field cage halves with central cathode
- Resistive Anode MM (ERAM) readout
- Composite material walls
- Both a novelties for full-size TPCs
HA-TPC: FC0 HV Issues

• Field cage 0 arrived at CERN in spring 2022
• Very unusual HV behaviour: non-linear and large time scales to stabilize
• Took 6-8 months to understand the problem fully and to adapt production process
• Production of FC1 started in November 2022

High but not infinite resistivity layer
HA-TPC: HV Issue Solutions

- Improved QC during each production step (samples and final FC)
- Larger distance between mirror strips and Twaron layer

**Internal Twaron layer**

Twaron = 50% resin + 50% Aramide fiber
HA-TPC: FC1 Production
HA-TPC: ERAM Production

- ERAM production ongoing at MPGD workshop
- QC performed with test bench in bldg. 182
- Some performance effects observed over production time for gain
- Within requirements and enough ERAMs for 1\textsuperscript{st} TPC available
HA-TPC: FC1 Tests at CERN

• Intensive tests after arrival at CERN: metrology, gas tightness, HV
• All tests were passed successfully
• Since 26th of April running with cosmics at 27.5 kV
• Stable operation with 10+ millions of cosmics
• FC2 will arrive 19th of May
• Bottom TPC will be shipped to J-PARC in July

CERN contribution
• Detector fully installed at CERN on the baby basket and being operated since September
• Since last week all detector working with all final HW components (cables, PS, DAQ, SC)
• Preliminary tests successful of all custom made software
• Preliminary results show the system is working fine
• Some channels need to be fixed before shipping
• Shipping will take place in June
• All panels will be shipped in a box designed to allow testing on surface at J-PARC without further handling
ND280 Preparation

• Preparation of ND280 for data taking well advanced
• Due to COVID pandemic ND280 was not operated for several years
• New magnet chiller installed and tested
• Electronics cooling system upgraded to handle higher power consumption
• Basket modification has been completed
• All subdetectors have been tested and ready for data taking in autumn
• Old gas system has been removed and new gas system has been installed (CERN contribution)
Project Schedule

- Project advanced well in the last year
- We expect to finish the installation by end of March 2024 (incl. commissioning) corresponding to end of JFY 2023
- Still some uncertainties in schedule but on several week scale
- Schedule of neutrino beam still unknown and will be decided in late summer
- Milestones:
  - 1st week of July 2023: Installation of the bottom and the downstream TOF panel
  - 1st half of August 2023: Arrival of the bottom TPC at J-PARC
  - 08.2023: Commissioning of the SuperFGD electronics at J-PARC on surface
  - 2nd half of August 2023: Installation of bottom TPC in the basket
  - September 2023: Start installation of the SuperFGD in the basket
  - 1st of November 2023: possible neutrino beam with bottom TPC+SFGD+part of TOF
  - December 2023: Installation of top TPC (if no beam in November)
  - Mid of December 2023: Completion of ND280 Upgrade installation with installing the last TOF panels
Testbeam 2024+

• Requesting testbeam time in 2024: 3-4 weeks
• Preferred time period: summer or autumn 2024 with TPC and TOF groups
• FC0 will be recovered beginning of 2024 and 4 ERAMs available
• Scanning of one horizontal half of final FC
• Testbeam 09/2022 useful but very different FC and vertical scanning was not possible
• Precise scan of one TOF bar with high statistics (parallel to TPC data taking)
• Important to understand detector responses to different particle types
• SuperFGD group might request testbeam in 2025
Conclusions

• NP07 advanced well in the last year
• SuperFGD assembly completed at J-PARC and first cosmics seen
• HA-TPC serious production issue was solved and FC production progresses well
• TOF ready for shipping to J-PARC
• Installation of new detectors will start this summer
• Some schedule uncertainties remaining but on weeks scale
• ND280 Upgrade expected to be completed by March 2024
• Testbeam plans for 2024 to understand better detector performance
• Several publications and presentations related to NP07 over the years
Backup Slides
Model explaining the extra current

- Voltage
- HV
- Strip Voltage
- Resistive Layer Voltage
- Cathode
- Anode

\[ R = 2.5 \, \text{M\Omega} \]

\[ R' = \text{Resistance between a strip and resistive layer across kapton} \]

\[ R'' = \text{Surface resistance all over the resistive layer} \]
Model explaining the extra current

Current flowing from strips to resistive layer (or vice versa) according the sign of Vdrop and proportionally to Vdrop → extra current drawn by resistive layer from strips of the half cage on the Anode side and pushed back to strips of the other half cage → extra current flowing in parallel to the divider current, along the resistive layer
Track angle and number of clusters

Mostly vertical tracks

Most of the tracks cross the whole TPC → 64 clusters

Reconstruction not able to distinguish between upper going and downstream going tracks
dEdx mean and resolution vs drift

- Small dependence of dEdx on the drift distance → reduction of (2±0.5)%
- dEdx resolution ~ 17% → expected since we are mixing different particles and different momenta
  - Could be improved by equalizing the ERAM HV?
Sim & Reco

- Time resolution and ToF Sim & Reco developments from single bar data
- Waveform changing due to different impact of the light propagation and reflexion
- Finite number of position currently available. Test beam data next year to improve the simulation