J-PARC neutrino beamline and neutrino detectors

2019-Nov.-18, CERN-KEK committee meeting

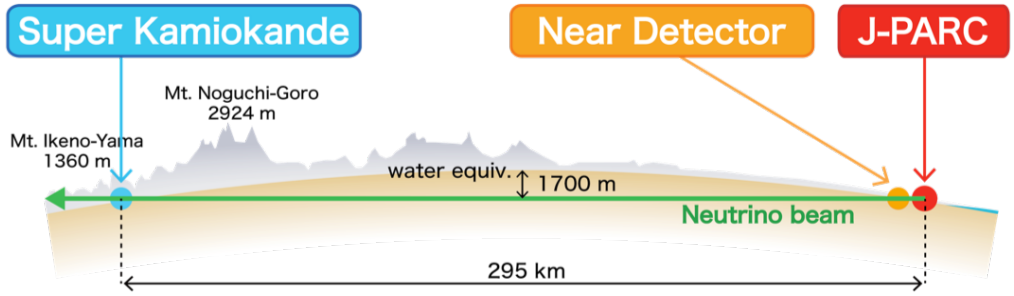
K.Sakashita(KEK/J-PARC)

Long baseline neutrino oscillation experiment in Japan

Super-Kamiokande
(ICRR, Univ. Tokyo)

J-PARC Main Ring
(KEK-JAEA, Tokai)

T2K



$$Prob.(\nu_\mu \to \nu_e)$$

same?

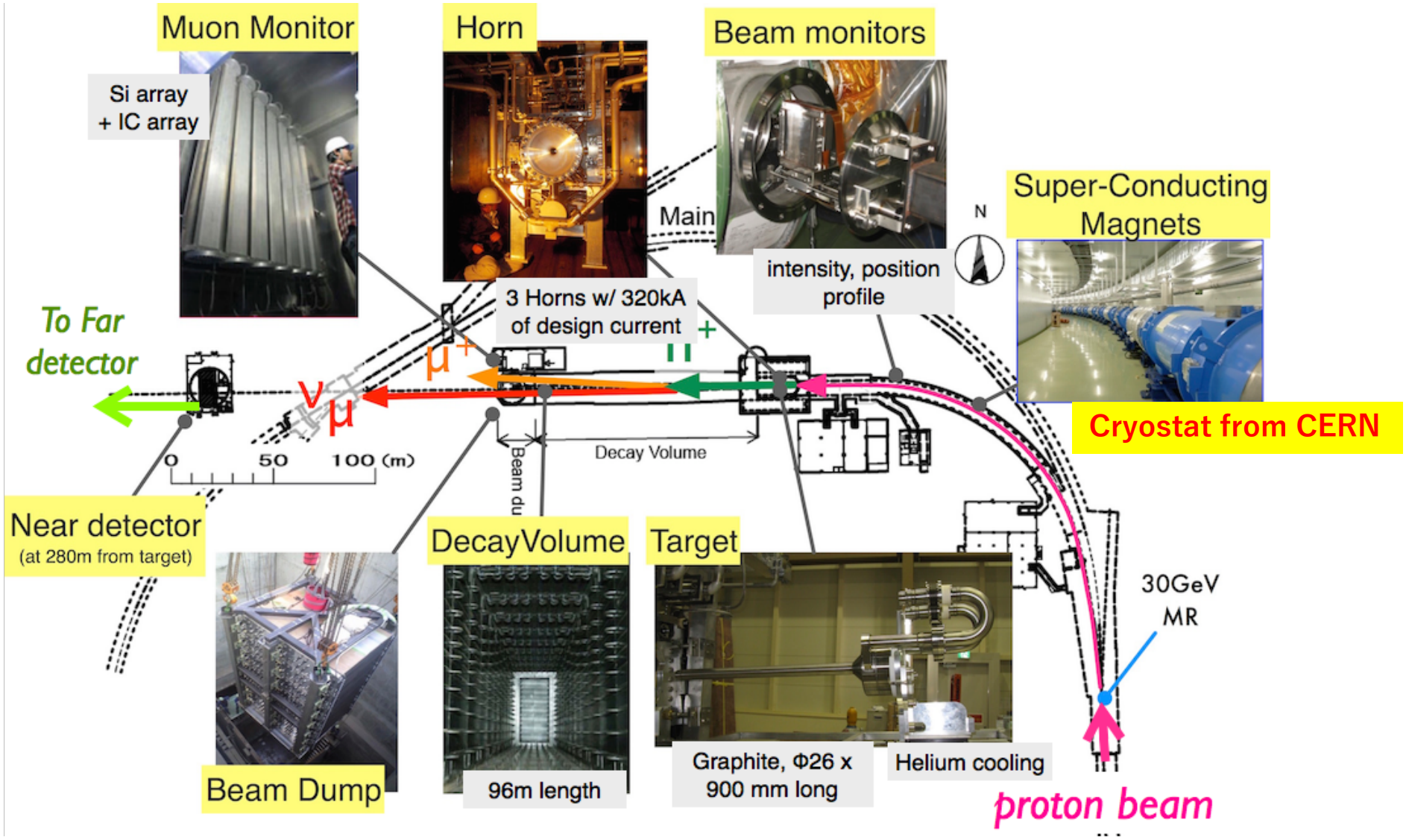
$$Prob.(\bar{\nu}_\mu \to \bar{\nu}_e)$$

The main physics motivations at present is

- **CP violation in neutrino oscillation**

→ hint for the origin of matter dominate universe

J-PARC neutrino facility

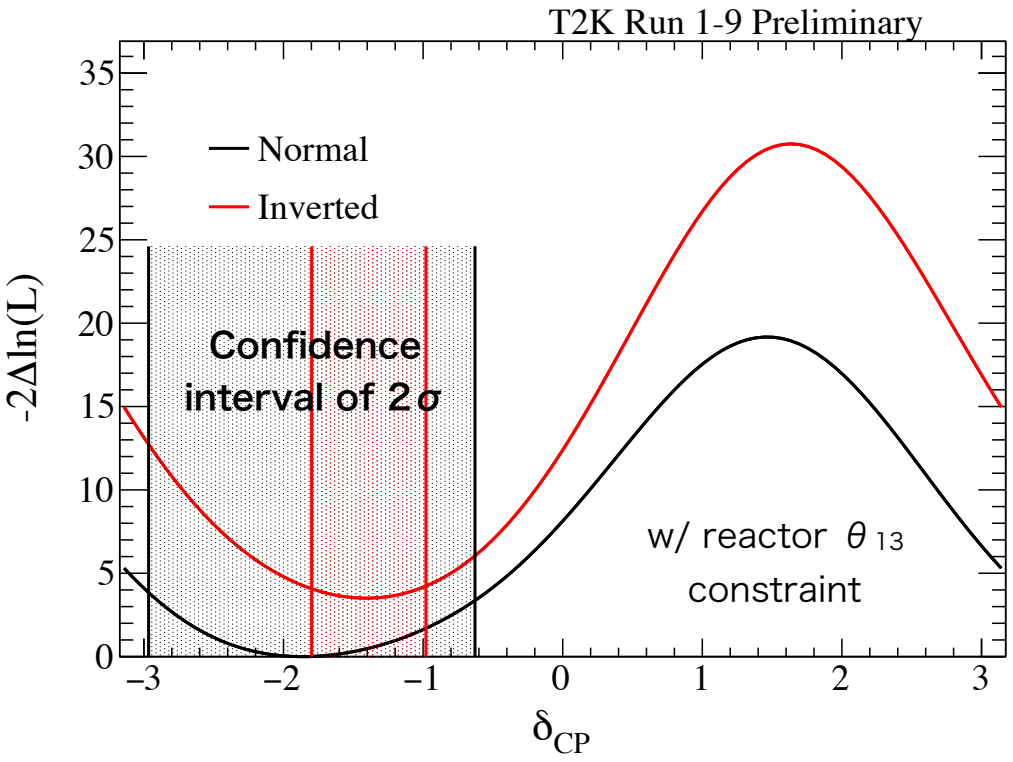


- **~485kW stable operation**
- **519kW (single shot) beam extraction to ν beamline was successfully performed with no major issues**

T2K and T2K-II

T2K indicates CP violation in neutrino oscillation with 3.16 x 10^{21} protons on target (POT) data (~2018)

Toward a discovery of CPV, we plan to accumulate more data up to 2x10^{22} POT by 2027 (T2K-II)

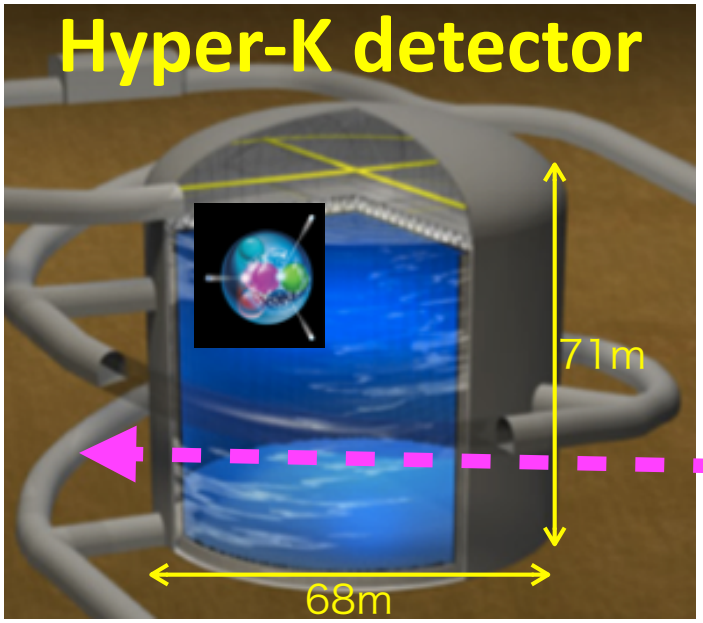


Toward >3σ CPV sensitivity, we plan

- **Upgrade of beam power 0.5MW → 1.3MW**
- **Upgrade of near neutrino detector to reduce systematic error**
- **Flux error reduction w/ hadron production measurements**

CPV search with Hyper-K

- **Discovery (5σ) of CPV is highly expected!**



- 260kt Water Cherenkov
- 186 kt fiducual : 8x Super-K
- high-QE PD w/ 40% (2x Super-K)

- 1.3 MW ν-beam
- Upgraded ND/IWCD

Aim to start construction in 2020 and start operation in 2027

Expected number of ν_e appearance signal and background

	Appearance signal	Wrong sign signal	Beam ν_e background	NC background
Neutrino mode	1600	20	260	130
Antineutrino mode	1200	200	320	200

Total	T2K(now)
2010	68
1920	19

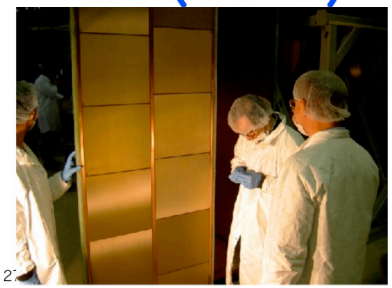
Both beam power upgrade and reduction of syst. error are also crucial for Hyper-K

Cooperation between CERN and neutrino experiments in Japan

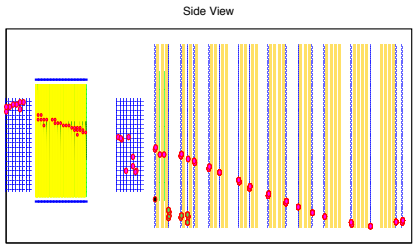
- 90s-2002 K2K
  - Neutrino beamline (horn etc)
  - HARP p(12.9 GeV/c) + Al → $\pi^{\pm}$ $K^{\pm}$ for K2K flux
- 2003-2009 T2K (CERN RE 13)
  - T2K-Europe: ~250 (~50%) of T2K signatories
    - France, Germany, Italy, Poland, Spain, Switzerland, UK
  - SC magnet for proton beam transport
  - Neutrino beam line (horn, etc)
  - R&D for ND280 TPC
  - Beam tests of ND280 electromagnetic calorimeter
  - Refurbishment and shipping, donation of UA1/NOMAD magnet
- 2006 – future NA61
  - 2012-2017 T2K members of NA61 contributed to TPC, F-TOF, trigger
  - Future programme essential for T2K-II, HyperK
- Baby-MIND (CERN-NP05)
  - A part of T2K-Wagasci detector@ND280 and data taking started
- 2016-2021 T2K ND280 upgrade
  - CERN NP07
- 2018- CERN neutrino group joins to T2K
- Possible contribution to HyperK

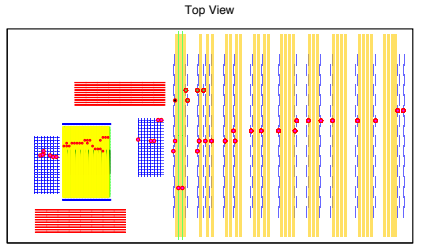
CERN and T2K (Magnet)

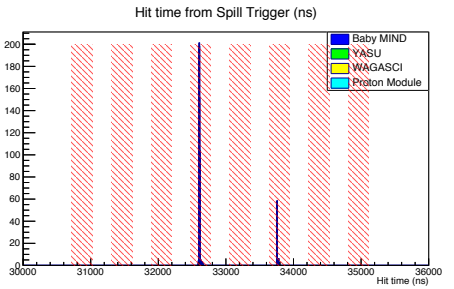
CERN and T2K (TPC)

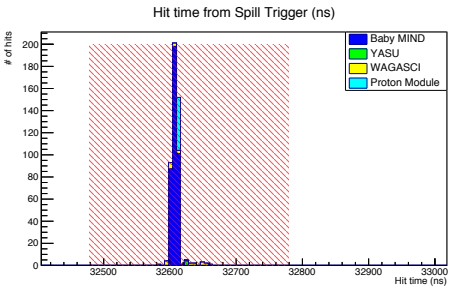


Event display@Baby-MIND









Beamline upgrade toward 1.3MW

	Achieved	Target
Beam power [MW]	0.5	1.3
	~x3	
# of protons per pulse	2.6 x 10^{14}	3.2 x 10^{14}
	+30%	
Rep. Time [sec]	2.48	1.16
	~1/2	

- Increasing cooling capability for the heat generated by beam
- Accepting high repetition rate(~1Hz) beam
- Increasing capability of radio-active waste
- Realizing safe and stable operation

Upgrade works in progress w/ international and domestic collaboration

Workshop for CERN/J-PARC-KEK collaboration on high intensity accelerator/beamline was held on 2019.Oct. @CERN

https://indico.cern.ch/event/847104/

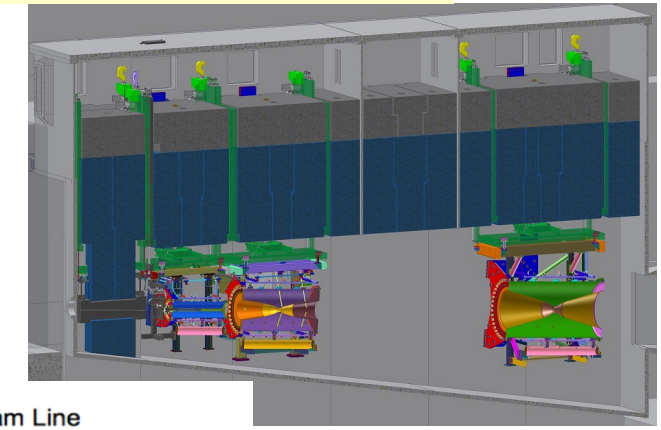
Common technical challenges toward high intensity facility

Horn magnet R&D

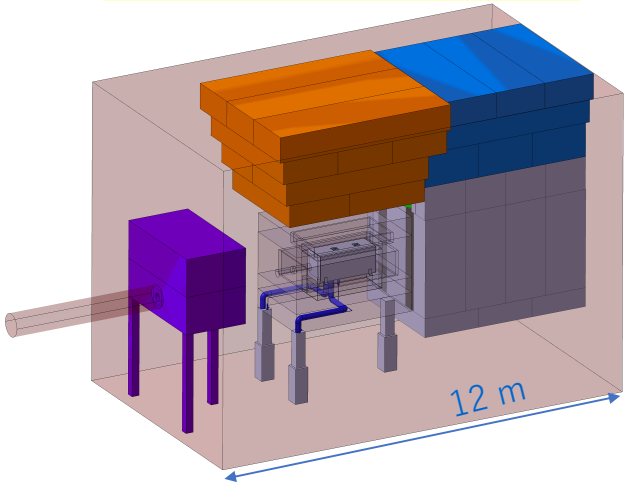
R&D, know-how exchange on radiation safety protection

(e.g. Tritium handling in the water, air)

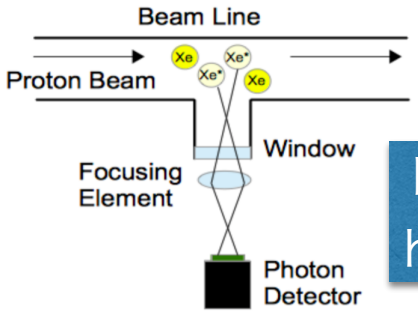
J-PARC Neutrino Facility Target Station



CERN Beam Dump Facility Target Station Design



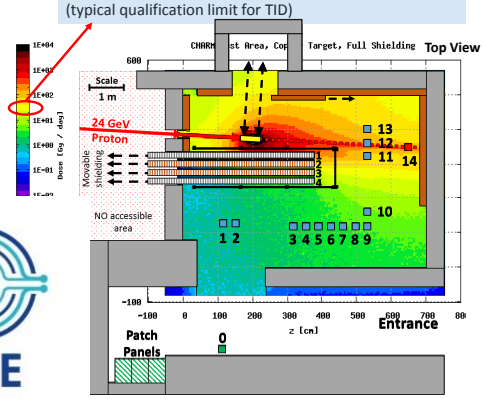
Remote maintenance scheme



Beam monitors for high intensity beam

Radiation effects on the electronics

With 40 Gy/day it is possible to achieve 200 Gy in 1 week (typical qualification limit for TID)



Readout electronics

PLC (for control, Interlock)

CHARM

R2E

New cooperation w/ CERN for these items to realize high beam power facilities is under discussion w/ relevant people

RaDIATE Collaboration Activities

- RaDIATE (Radiation Damage In Accelerator Target Environment) international collaboration is organizing high-intensity proton irradiation experiment at BNL-BLIP facility
  - Test specimens provided by participating accelerator labs.
  - Post-Irradiation Examination (PIE) being conducted at participating reactor/fusion energy research institutions with hot-cell facilities
- Collaboration is also conducting an in-beam thermal shock destructive inspection at CERN's HiRadMat facility
  - Including irradiated/damaged specimens at BLIP (BeGrid2)
  - Beam exposure completed in 2018, shipment / PIE in preparation

(slides courtesy fo T.Ishida)

CERN-JPARC Cooperation: Amendment No.2

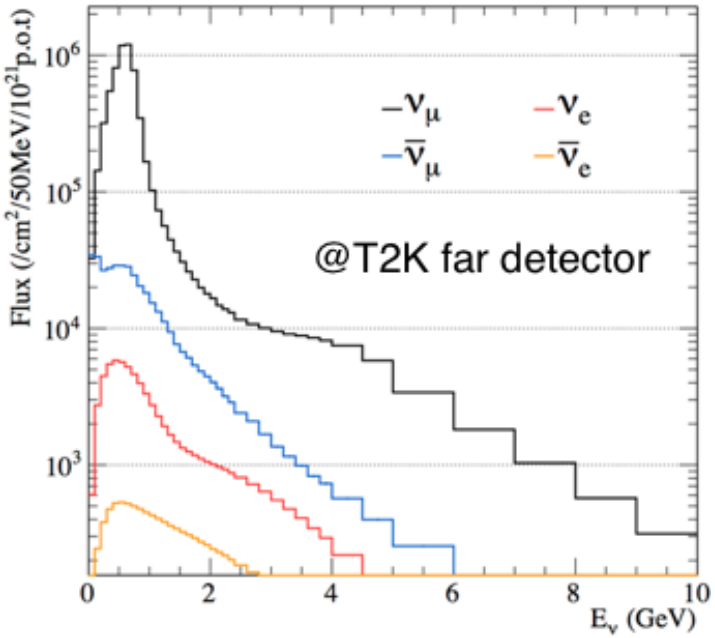
- Cooperation in the Development of Proton Accelerators, since 2009
- Expand the cooperation to the fields of high-intensity accelerator target facilities and relevant technologies
- At J-PARC:
  - Developments for novel target materials (Highly-ductile tungsten for SNS/muon target, SiC composite for muon/neutrino target …)
  - Upgrade of MR FX abort dump
  - Experience on target facility operation
- At CERN
  - Various needs on TCD materials
  - Thermal shock study at HiRadMat facility
  - New target facility design (CENF/BDF)

In effect on 29 July 2019

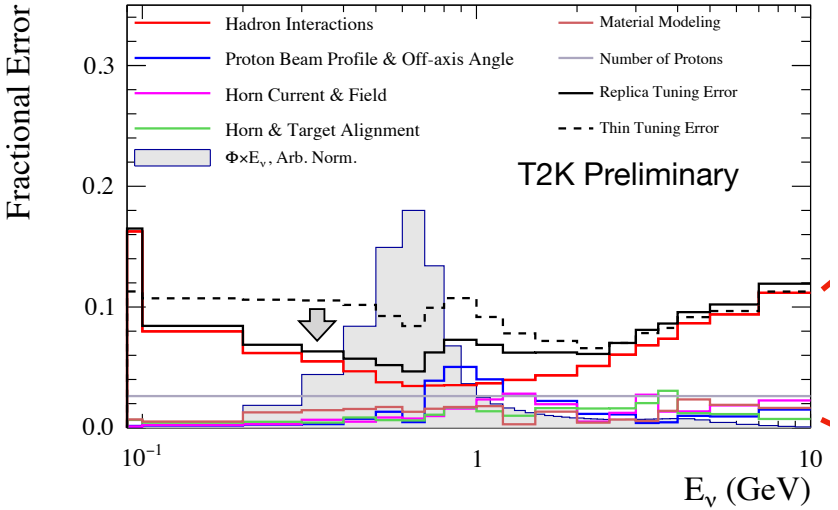
Hadron production

- Thanks to NA61/SHINE experiment, T2K flux prediction with ~5% uncertainty was achieved with replica target data
- For T2K-II and HK, total flux uncertainty down to 3~4% is desired
- We proposed new measurements to achieve this goal → Addendum of NA61/SHINE was submitted to SPSC

CERN-SPSC-2018-008, SPSC-P-330-ADD-10 (2018)

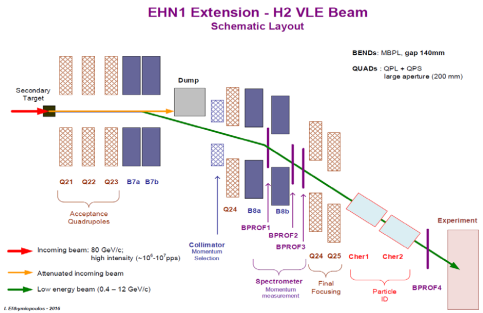


SK: Neutrino Mode, ν_μ



Possibilities for (Very) Low Energy beams at CERN North Area

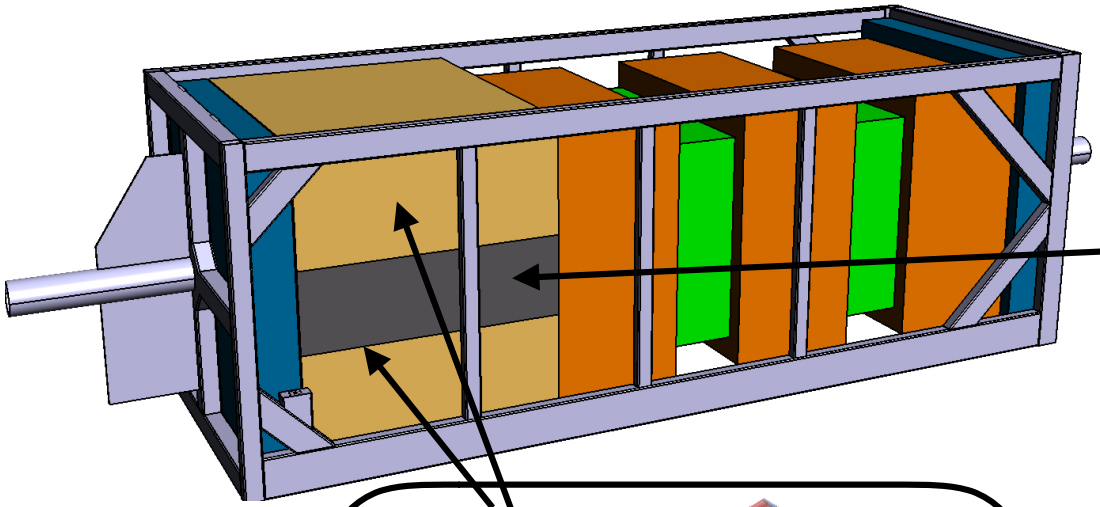
N. Charitonidis (CERN, EN-EA)

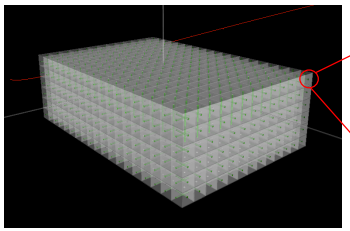


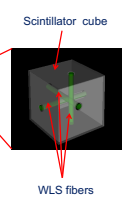
Investigating a possibility to build a tertiary beam line in order to perform a low momentum interaction measurement

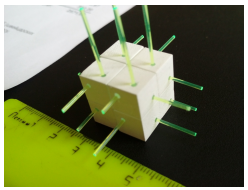
ND280 Upgrade

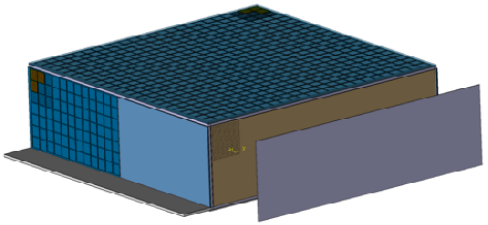
Replacing part of ND280 with new detectors in 2021
for better understanding of neutrino-nucleus interaction



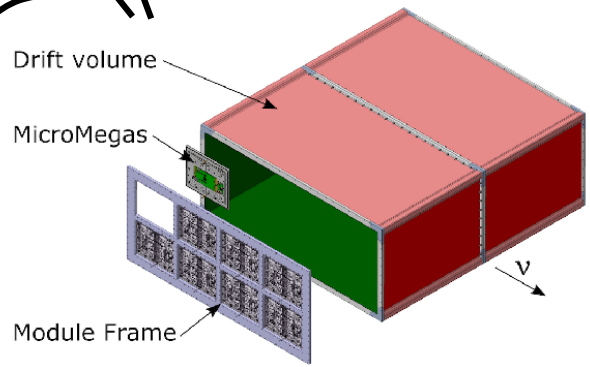




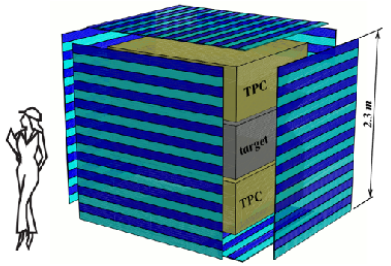




A highly segmented
scintillator detector (**SuperFGD**)



Two new **High-Angle TPC**s



TOF planes
all around

CERN EP-NU has been member of project since Jan 2018

Approved as Neutrino Platform project NP07 in March 2019

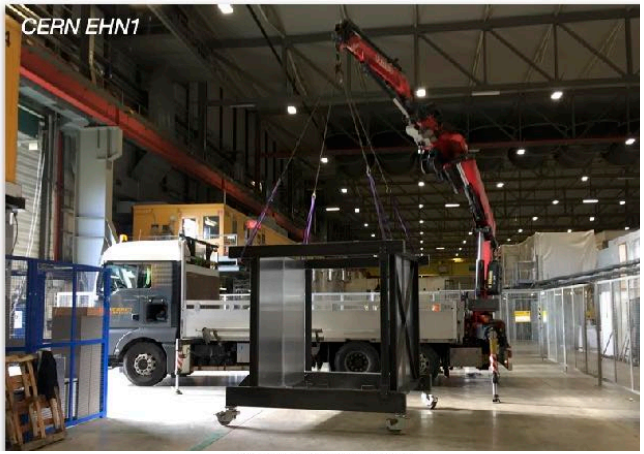
(slides courtesy fo M.Yokoyama)

ND280 Upgrade (**NP07**)

CERN has been playing key roles in almost all aspects of the project

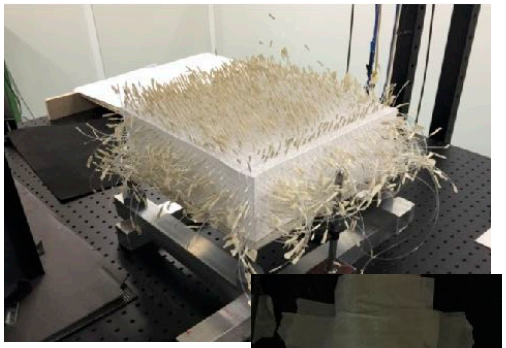
Test beams for prototypes of
SuperFGD, TPC, TOF
in summer 2018

HA-TPC prototype test
Development of gas system
and resistive micromegas

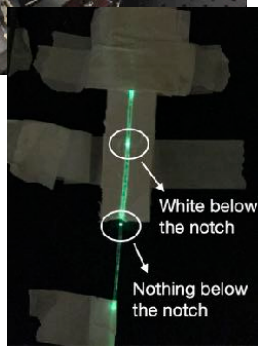


Assembling room in EHN1

Mockup “mini-basket”
for **TOF** plane assembly
and test **integration** of
sub-detectors



SuperFGD mechanics
and calibration



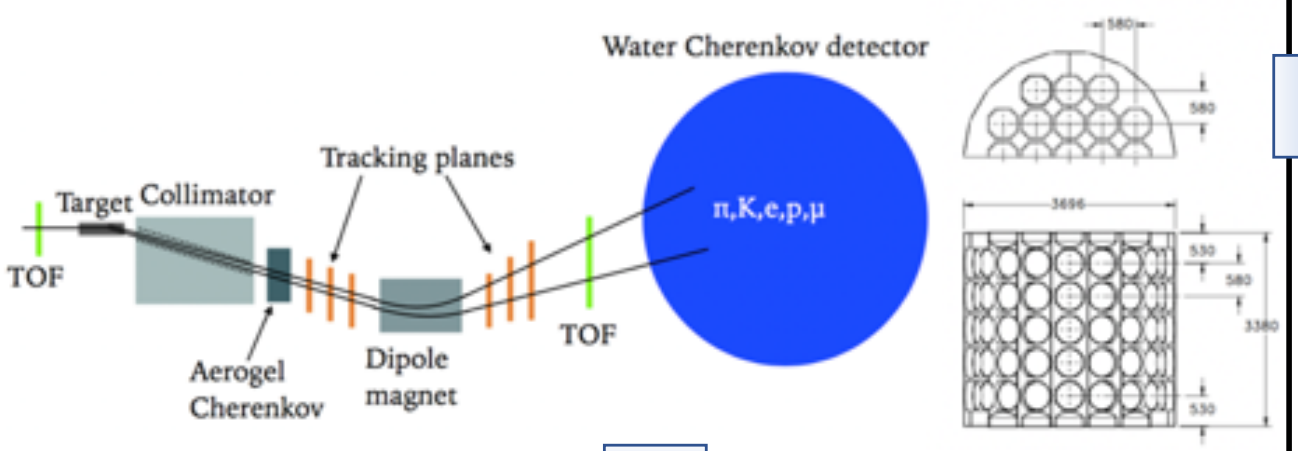
TOF assembly @EHN1

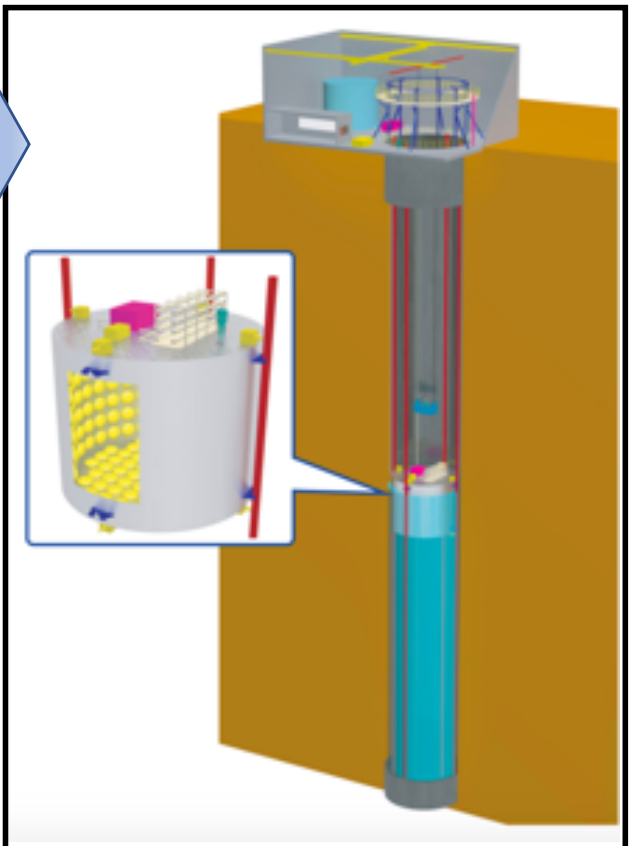
Software and **analysis** development

Meetings ~3 times / year at CERN

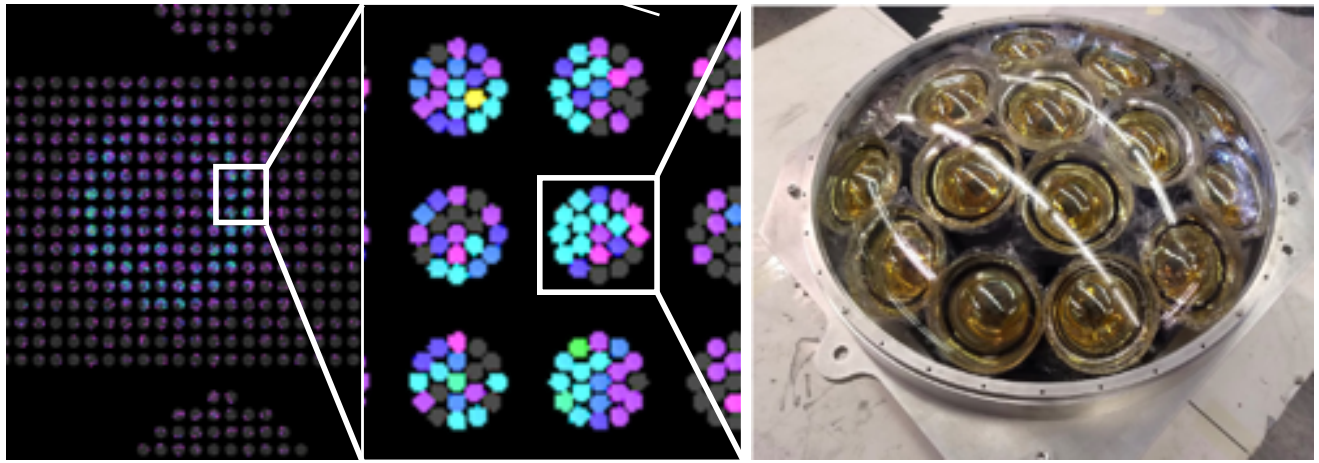
Beam Test at CERN for IWCD and Multi-PMT

Beam test at CERN with 3-4m scale detector





IWCD: Intermediate Water Cherenkov Detector for HK



New photo-sensor (Multi-PMT) for HK and IWCD

(slides courtesy fo M.Ishitsuka)

Hyper-Kamiokande

Possible collaboration with CERN on HyperK Project

- Electronics and DAQ system
  1. Technical helps from experts in designing the front-end electronics modules, HV system and timing synchronization system. Same technologies are extensively used in the accelerator experiments.
  2. Technical helps from experts in designing the special water-tight pressure tolerant cables, connectors and enclosures. Especially, mechanical engineering supports are anticipated.
  3. Participation to the technical reviews of the electronics and DAQ system.

Summary

- T2K indicates CP violation in neutrino oscillation. We aim to discover the CP violation in T2K-II (Upgrade of J-PARC neutrino beamline and Near detector) and HK
- Essential cooperation between CERN and Japan on T2K beam and ND280 so far
- Many collaboration works with CERN are in progress and expected for T2K-II and HK

backup

HiRadMat Workshop July 2019 @ CERN

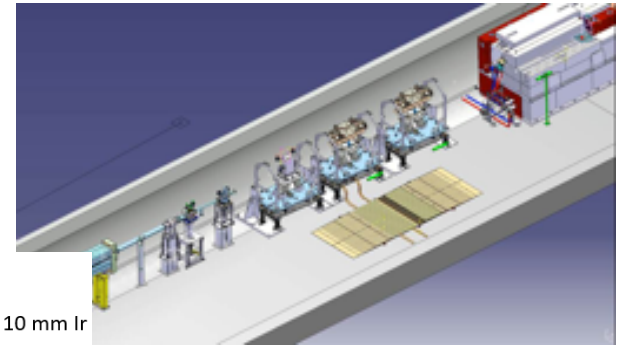
https://indico.cern.ch/event/767689/

75 peoples from 20 institutions

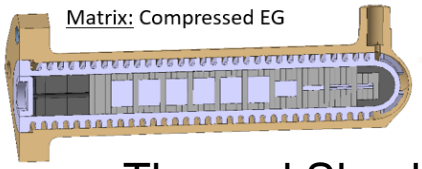
From J-PARC

- Masatoshi Futakawa (Vice Director, SNS/ADS)
- T.Nakadaira (Neutrino Section Leader)
- S.Makimura, Shin-ichiro Meigo, T.Ishida

CERN

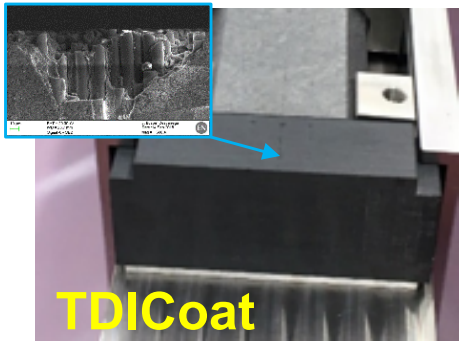


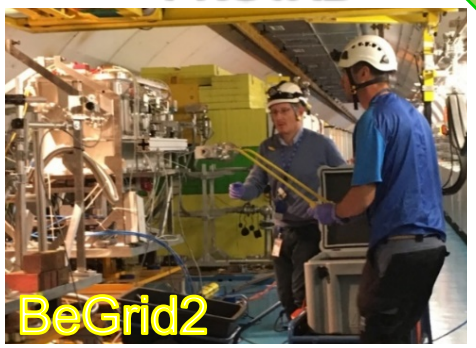
Target 5:
Core: Ø 10 mm Ta +
Ø 10 mm W + W-1.1TiC + Ø 10 mm Ir
+Ø 2 mm Ta tube
Matrix: Compressed EG

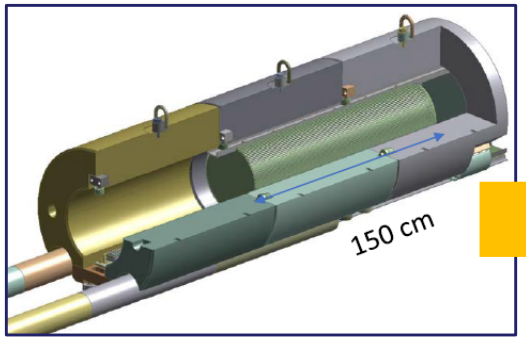


HiRadMat
High-Radiation to Materials

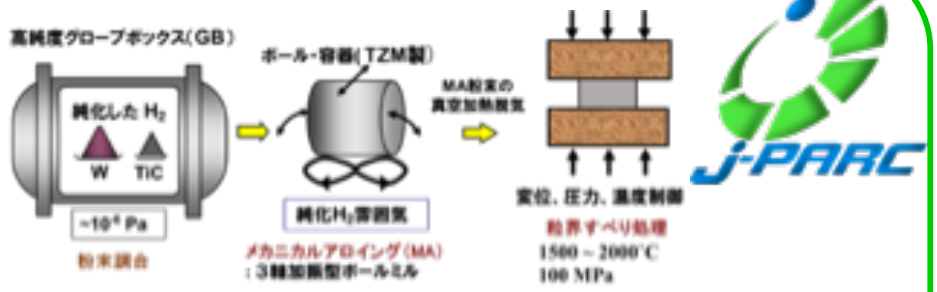
Thermal Shock Studies: **PROTAD**

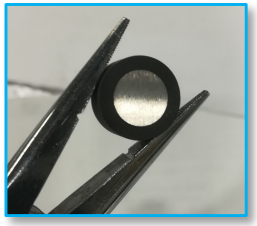




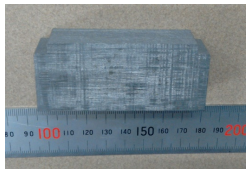


PSB 10kW Beam Dump:
air-cooled CuCrZr core



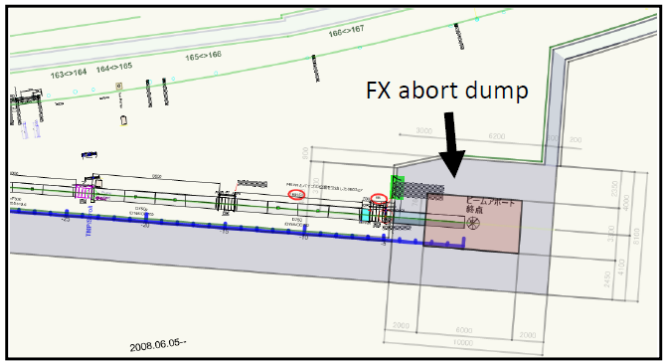


Fabrication of Highly-Ductile Tungsten TFGR W-TiC



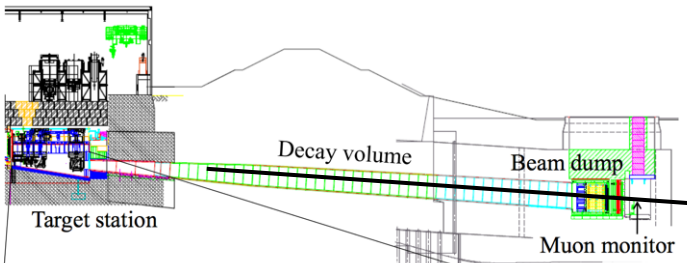
NITE SiC/SiC Composite

Materials highly Irradiated at BNL assembled at PNNL



Fast-Extraction Dump upgrade 7.5→ 30kW

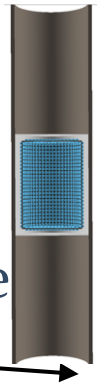
Intermediate Water Cherenkov Detector (IWCD)



$$E_\nu = \frac{m_\pi^2 - m_\mu^2}{2E_\pi(1 - \beta_\pi \cos\theta)}$$

1~2 km baseline

1-4° off-axis angle



- 1kilo-ton water Cherenkov detector located at 1-2km from the neutrino target and its position can be moved up/down to make measurements at different off-axis angle