TRIUMF

Canada's national laboratory
for particle and nuclear physics
and accelerator-based science

Status of the Canadian group and plan of T2K

T2K-Canada made essential contribution to T2K

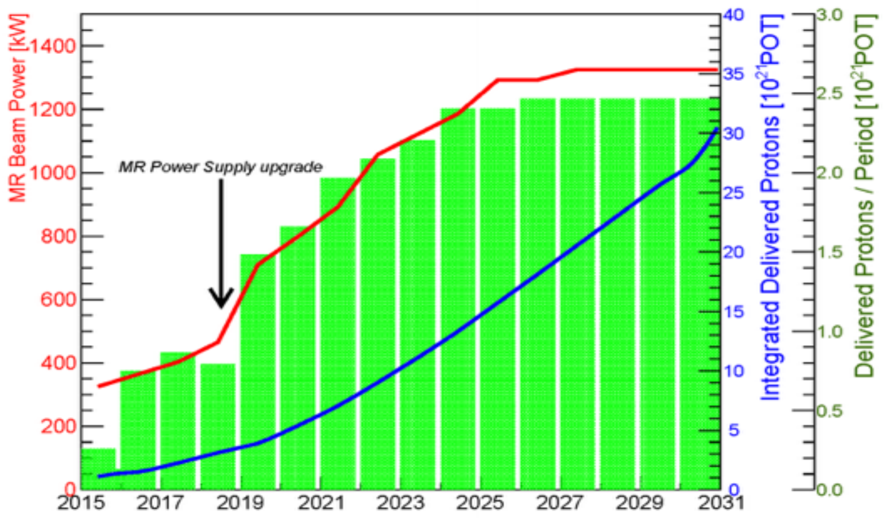
- Break-through concepts on all the areas
  - ν_e appearance and CP violation instead of τ appearance
  - off-axis beam, dual extraction/abort kicker
  - FODO lattice for extraction, service cell (hot cell)
  - OTR and SiPM technologies
  - Analysis: Beam analysis, BANFF, fiTQun
- Reliable and exceptional contributions to the detectors
  - FGD, TPC, OTR, remote handling: not possible without Canada
  - Slow control, Data base, t2k.org
- “Service” works
  - Computing: Local network, ND280 Tier-1, SK code to work outside Kamioka
  - ND280 scaffolding, cooling water, Dry air, Gas hut, Air conditioner in NA
  - Operation and calibration of FGD, TPC, and OTR
  - Analysis conveners and other positions

Status of the Canadian group

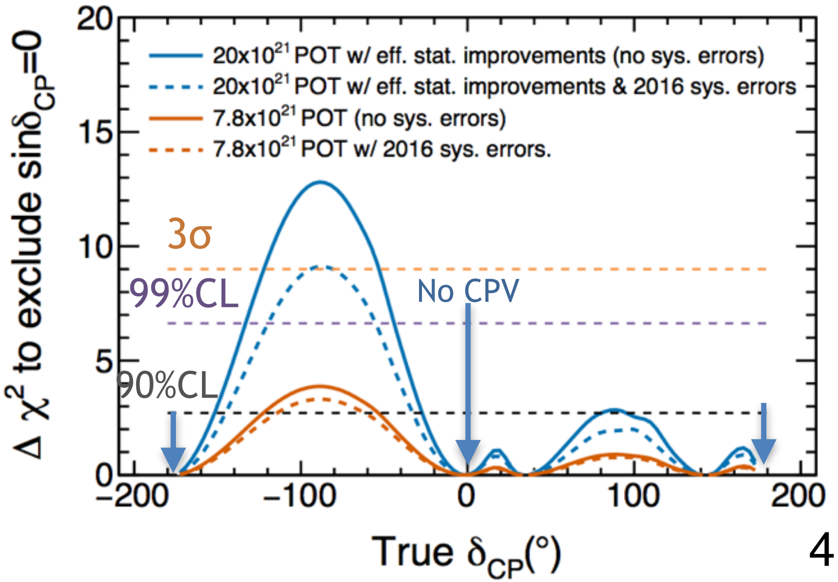
- The first phase of T2K-Canada collaboration is ending:
  - At TRIUMF, Akira Konaka is the only research scientist left with fraction of time by Thomas Lindner
    - 10 scientists at TRIUMF in addition to engineers during the early days of T2K
    - TRIUMF plans to strengthen the neutrino group: M.Hartz and a new staff
      - We are requested by TRIUMF to show our plan to continue
  - Departure of big contributors
    - FY2017: Hiro Tanaka (Toronto), Roman Tacik (TRIUMF/Regina)
    - End of FY2018: Dean Karlen (UVic), Scott Oser (UBC)
- Building up the renewed neutrino group with new goals
  - T2K-II program does not appear to resonate with the community
    - Always less than expected beam time, No prospect for E61(NuPRISM) during T2K-II
  - A program leading to HyperK is a baseline for the Canadian group
    - Program to challenge reducing the systematic uncertainties

T2K-II (ArXiv:1609.04111)

- T2K in the next decade (- 2026)
  - MR power supply upgrade requires funding
    - intensity to ramp up 0.4 to 0.75MW
  - Smaller upgrades expected from HK funding
    - to go up to 1.3MW
    - Horn current upgrade: x1.1 neutrino flux
  - x1.4 Acceptance improvement with FiTQun
    - half of this already done with larger fiducial volume



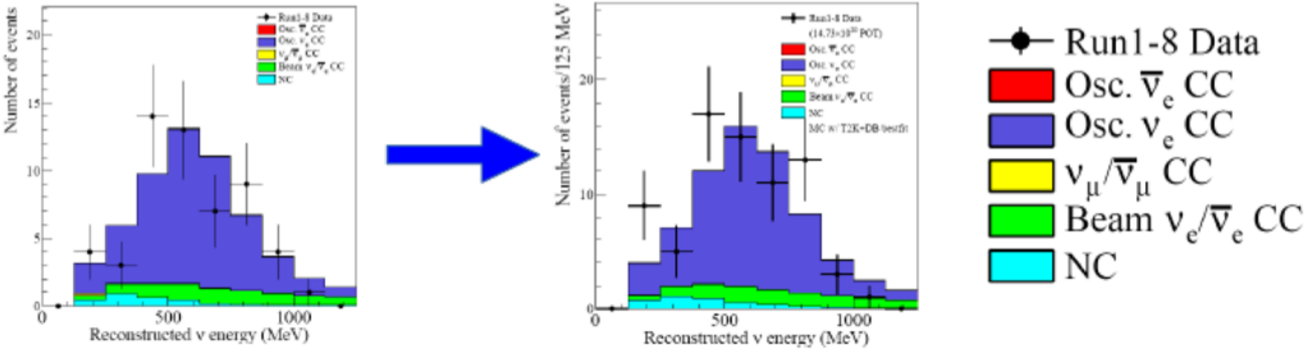
- T2K-II received Stage-1 by J-PARC PAC
  - 3σ CP violation sensitivity @ δ=-π/2
  - $60M/year continuous MR operation needed
  - Improvements in acceptance and systematic uncertainties are required:
    - ND280 upgrade is supposed to cover this (?)



fiTQun improvement in SK samples

Samples		fiTQun Selection		Original SK selection	
		Candidates	Purity	Candidates	Purity
Neutrino beam	1-ring e-like	69.5	81.2%	56.5	81.4%
	1-ring μ-like	261.6	79.7%	268.7	68.1%
	1-ring, 1π, e-like	6.9	78.8%	5.6	72.0%
Antineutrino beam	1-ring e-like	7.6	62.0%	6.1	63.7%
	1-ring μ-like	62.0	79.7%	65.4	70.5%

- Increased efficiency of electron-like samples
- **23% more events from same data**



Remaining improvement is the multi-ring (CC1π) analysis, requiring better calibration

Canadian initiatives on systematic uncertainties

	% Errors on Predicted Event Rates, Osc. Parameter Set A					
	1R μ-Like		1R e-Like			
Error Source	FHC	RHC	FHC	RHC	FHC CC1π	FHC/RHC
SK Detector	1.86	1.51	3.03	4.22	16.69	1.60
SK FSI+SI+PN	2.20	1.98	3.01	2.31	11.43	1.57
ND280 const. flux & xsec	3.22	2.72	3.22	2.88	4.05	2.50
$\sigma(\nu_e)/\sigma(\nu_\mu)$, $\sigma(\bar{\nu}_e)/\sigma(\bar{\nu}_\mu)$	0.00	0.00	2.63	1.46	2.62	3.03
NC1γ	0.00	0.00	1.08	2.59	0.33	1.49
NC Other	0.25	0.25	0.14	0.33	0.98	0.18
Total Systematic Error	**4.40**	**3.76**	**6.10**	**6.51**	**20.94**	**4.77**

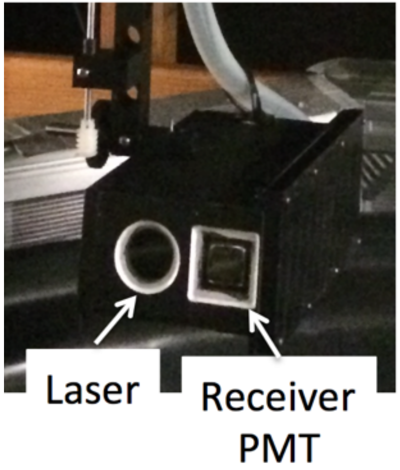
- Neutrino cross sections
  - IWCD (E61/NuPRISM)
    - ν_e cross section
    - NC and beam ν_e
    - Nuclear effect
    - Neutron tagging
- Detection efficiency (calibration)
  - E61 beam test @ Fermilab
    - Bottom-up calibration
- Neutrino flux
  - Hadron production experiment @ Fermilab
    - hybrid emulsion spectrometer

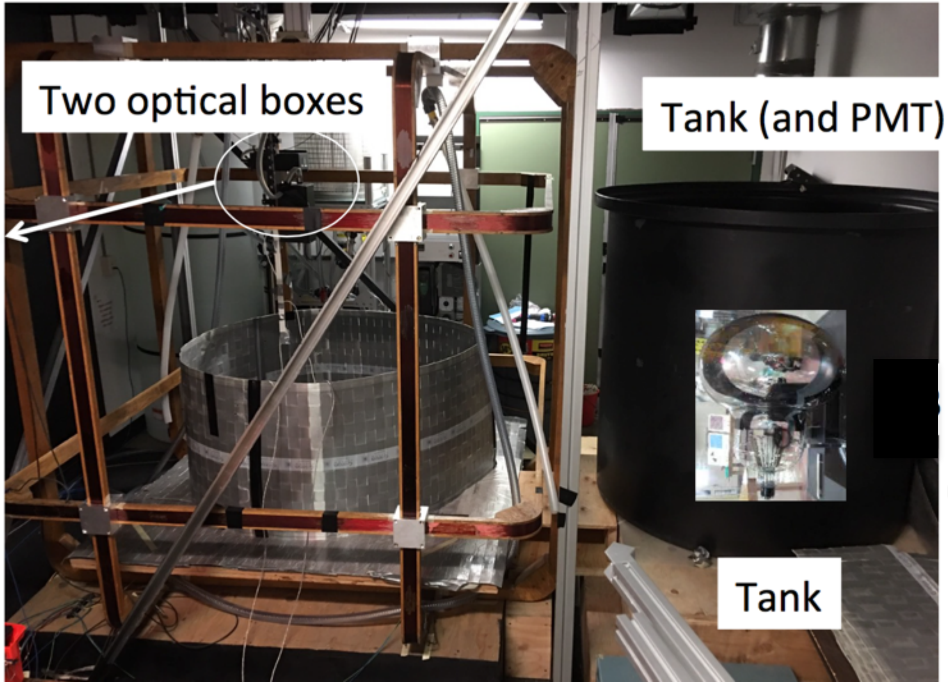
Canadian group's plan on T2K

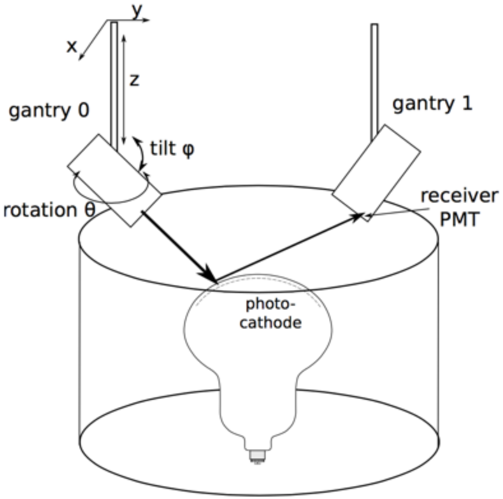
- T2K program leading to the Canadian HyperK activities
  - Beam
    - OTR along with the Hadron production experiment @Fermilab
    - Remote handling/accelerator contributions if we get support from TRIUMF
  - SK
    - SK "bottom-up" calibration along with the E61 beam test @Fermilab
      - multi-ring analysis for T2K (CC1π) and SK (oscillogram, mass hierarchy)
  - ND280
    - Winding down the Canadian contributions to end in FY2018
      - Important to make a full transition by the end of March 2019
- Strengthening of the group and focus on program is required
  - E61 beam test, Hadron production, SK
  - E61(IWCD/NuPRISM) and HyperK for the future

Photosensor Test Facility (PTF) at TRIUMF

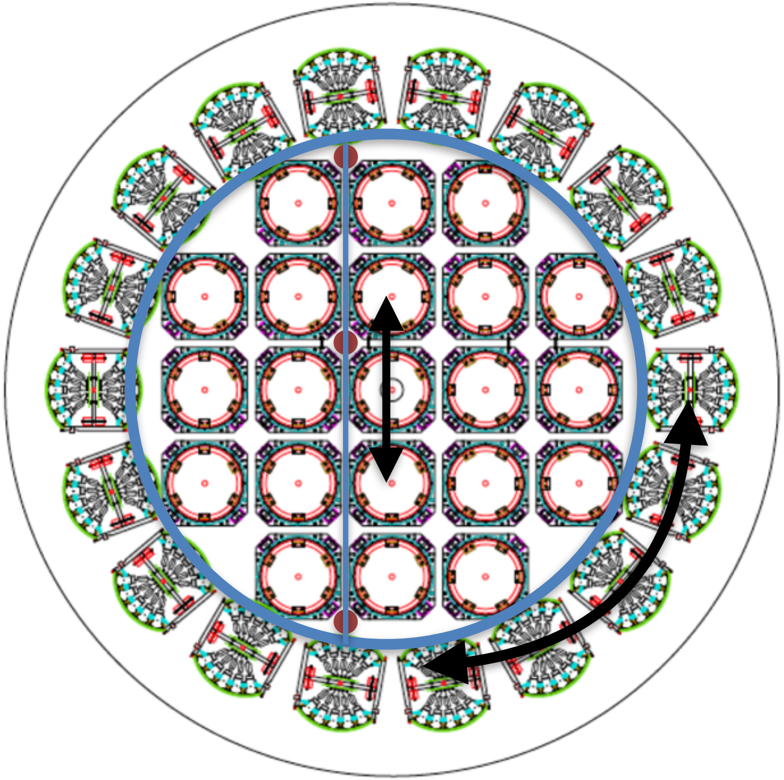
- Robotic arms with laser and PMT
  - laser light with polarization
  - monitor PMT
  - magnetometer
- Magnetic shielding
  - compensation coil, Giron shield

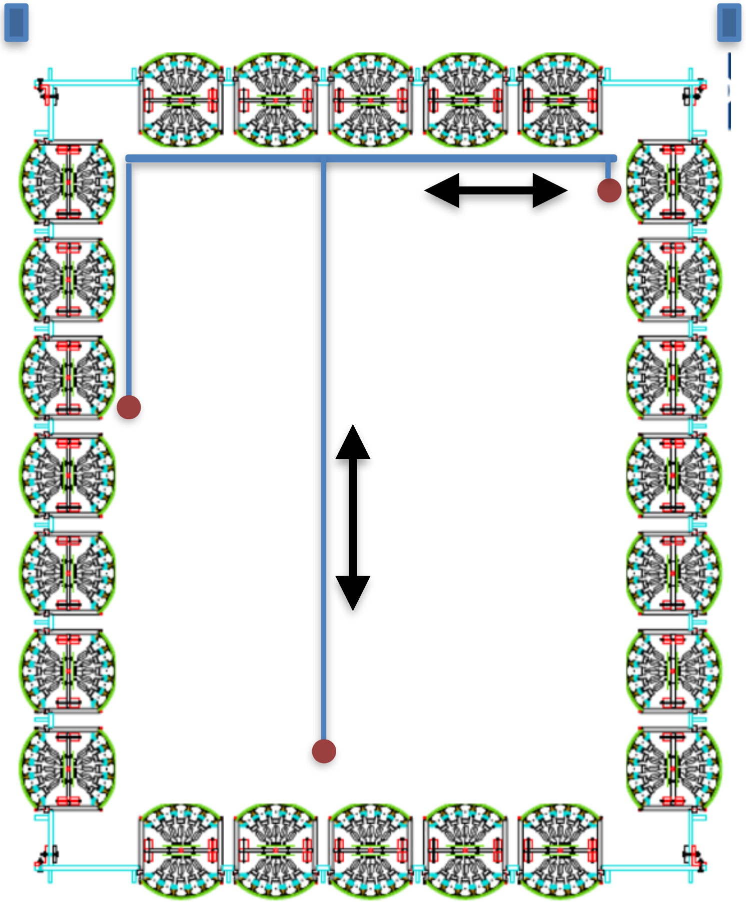






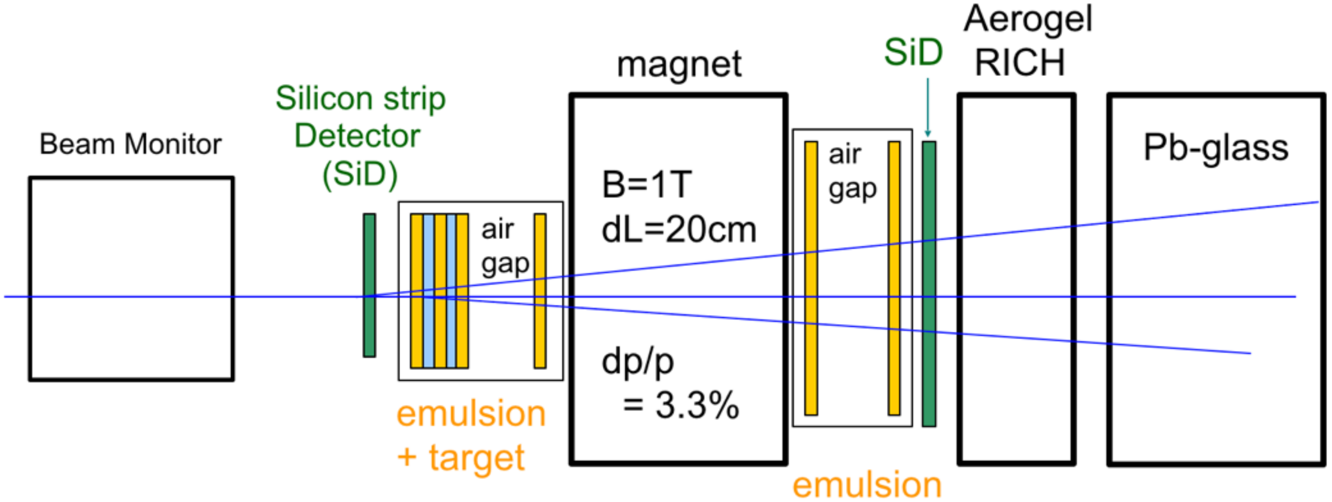
Laser source deployment system for E61 beam test





Use the same light source deployed at different positions
(SNO calibration was in single plane)

- Hybrid emulsion spectrometer
  - Emulsion+target, silicon strip, magnet, particle ID Cherenkov
  - minimize the material for precision emulsion tracking right next to target
- Secondary hadron beam at Fermilab (p,π, μ, e up to 120GeV/c)
  - Silicon strip detector at the facility to match the timing
- The first beam from January 2018 with the upstream components

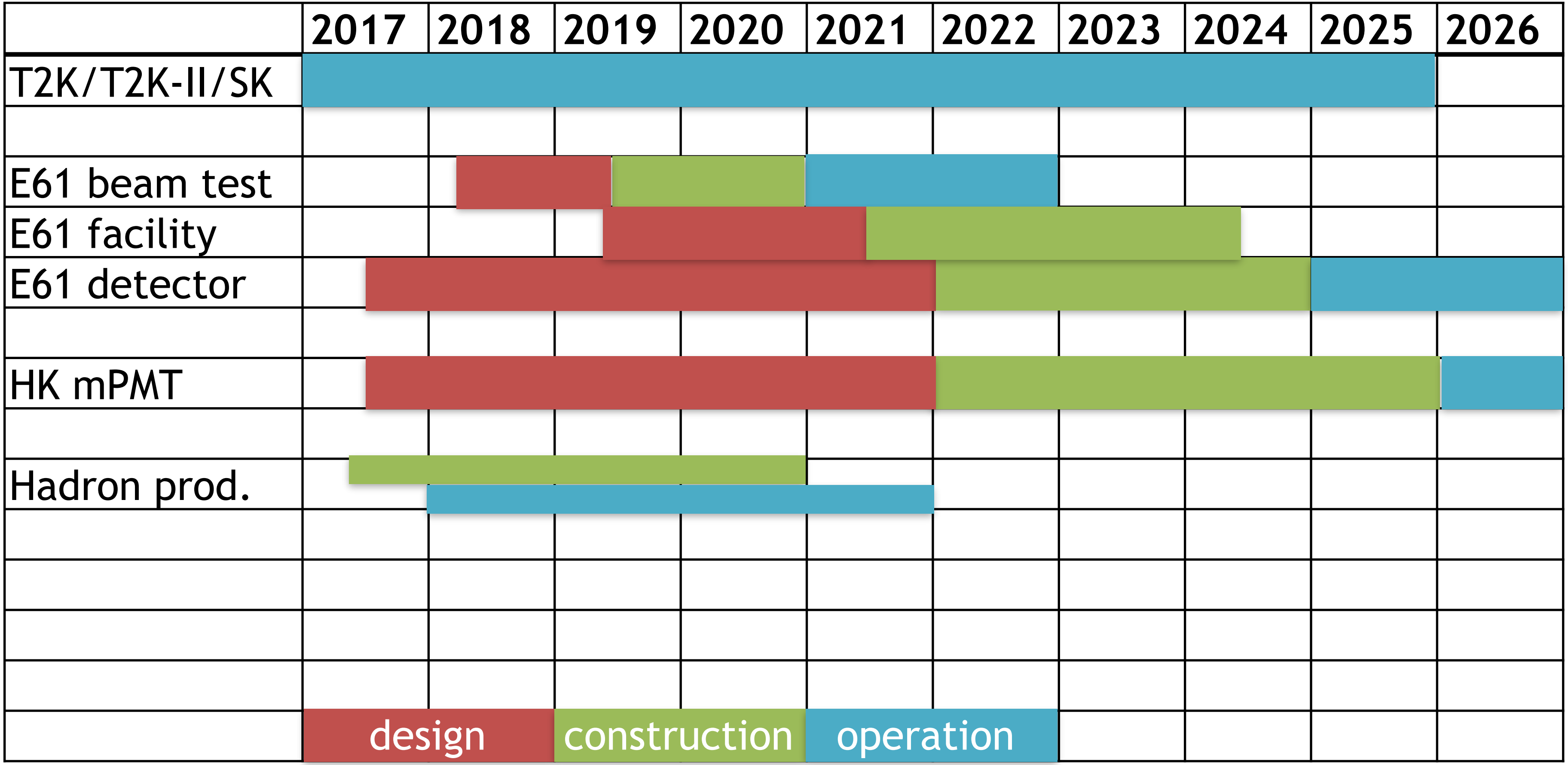


Emulsion: Nagoya
Silicon: Available at Fermilab
Pb-glass: KEK (recycled)
A-Rich: Canada, KEK
Magnet: Toho or Fermilab

Potential research program between T2K and HyperK

- T2K-NOvA combined analysis
- Hadron production experiment at Fermilab
  - Ring-imaging Cherenkov counter development
  - Reduction of neutrino flux systematics in T2K
  - Reduction in atmospheric neutrino flux systematics for SK
    - CP violation and oscillogram (matter effect) in atmospheric neutrinos
- E61 beam test at Fermilab
  - mPMT development
  - Detailed study of water Cherenkov responses for e, π, μ, K, and p
  - Test the bottom-up calibration method for SK
    - along with the SK PMT characterization at photosensor test facility
    - multi-ring analyses for T2K(CC1π) and SK(proton decays, mass hierarchy)
- R&D and design works for E61 and HyperK

Timelines


2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
T2K/T2K-II/SK
E61 beam test
E61 facility
E61 detector
HK mPMT
Hadron prod.
design
construction
operation