TRIUMF

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

T2K and HyperK status

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June 7, 2019

@ IPP AGM

Computing for T2K and HyperK

- T2K
  - T2K Tier-1 at TRIUMF; second Tier-1 at RAL
    - MC production and data processing
  - SK event reconstruction (fiTQun) developed by Canada
  - Currently 1 peta-byte of storage and 500 cores in Canada

- HyperK
  - IWCD (NuPRISM) design study
    - Monte Carlo production and analysis
  - Near future
    - Hybrid 20-inch PMT + multi-PMT simulation and analysis
    - Develop analysis based on Machine Learning technique (GPU)
    - Similar level or more than T2K CPU and storage resources

Challenges and requirements

- Support for large groups spanning multiple institutions
  - allow same resources to be shared by multiple PI groups
  - allow PI's to delegate technical details to experts in the group
- Support to install softwares required for the collaboration
  - DIRAC tools for grid storage and job submission
    - plugging T2K and HyperK virtual organizations
  - CERN VM File System for software distribution
  - System packages to live in standard locations
- Smooth access to home disks
  - avoid slow downs in loggin in and job submissions

Canadian T2K/HyperK collaboration

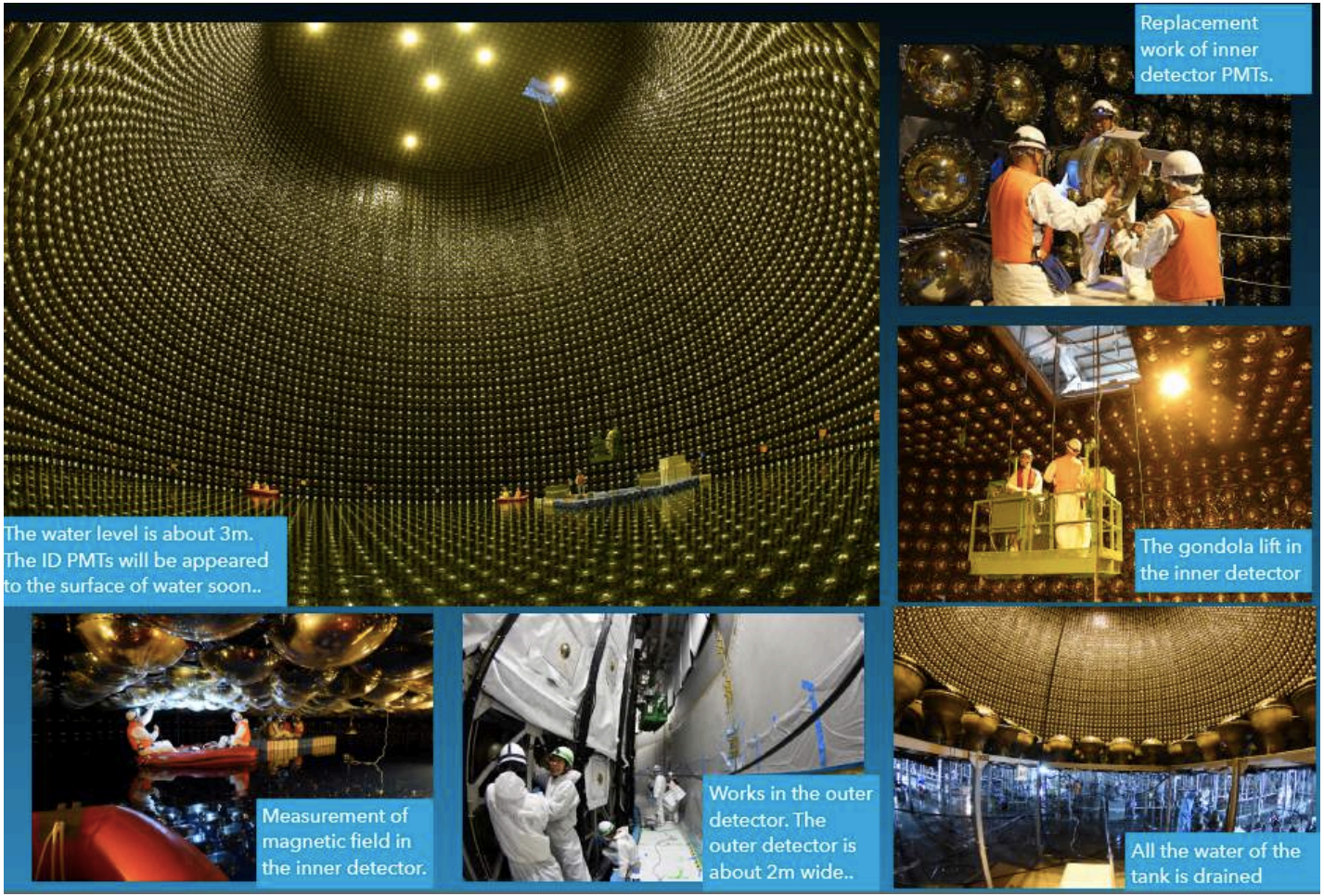
- Four T2K graduate students completed PhD in 2018
  - Elder Pinzon Guerra (York)
  - Sophie Berkman (UBC)
  - Jiae Kim (UBC)
  - Fady Shaker (Winnipeg/Manitoba)
- Postdoc moved to faculty position in 2018
  - Mark Scott (TRIUMF) → Imperial college of London

- HyperK-Canada collaboration is formed (12 faculties)
  - UVic, TRIUMF, BCIT, Winnipeg, Regina, Toronto, York, Carleton
    - Two new research scientists at TRIUMF: Mark Hartz, Patrick de Perio
  - Focus on HyperK along with T2K, SuperK, and EMPHATIC
  - Successful NSERC grant request in FY2019-21
  - Preparing 2019 CFI-IF grant request for IWCD/NuPRISM

T2K and SuperK operation

- T2K status
  - Priority is the intensity upgrade
    - double the repetition rate by upgrading the MR power supply
  - FY2019: May-June run is postponed to November or later
    - magnet failure in the transfer line between Booster and MR
  - FY2020: Limited beam time similar to FY2019
  - FY2021: Shut down for power supply installation
  - FY2022: High Intensity beam (750kW) available
    - further upgrade towards 1.3MW for HyperK
- SuperK status
  - FY2018: successfully completed leak repair for Gd loading
  - FY2019: loading Gd for neutron tagging: SK-Gd

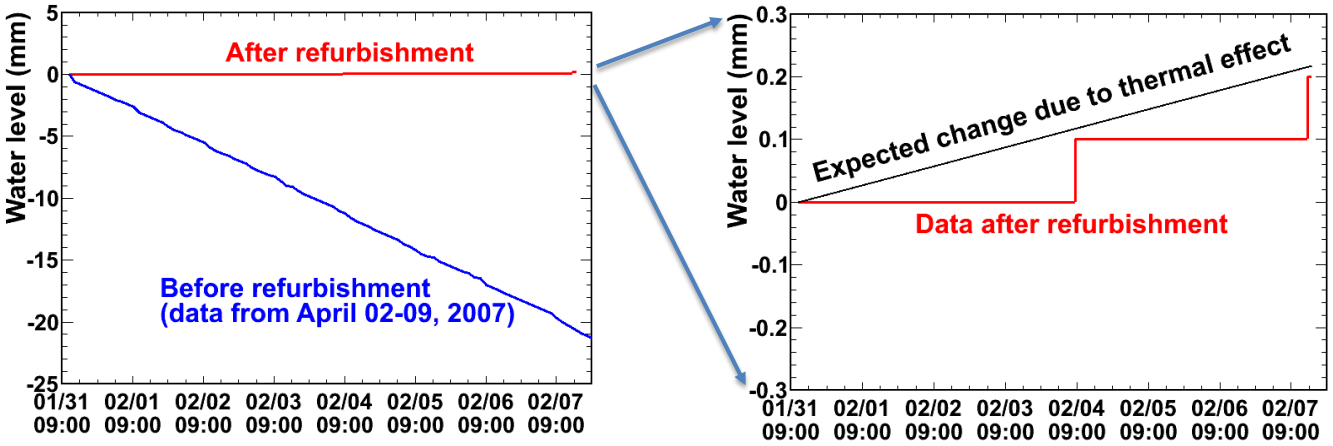
SuperK tank repair for Gd loading (summer 2018)



- Put the seal on the welded joint of the stainless steel tank
  - Also cleaned the surface
- Replaced broken PMT's
  - installed some HK PMT's

Water Leakage from SK tank

After filling the tank completely with water, we started the water leakage measurement from 11:30 on 31st January to 15:52 on 7th February, 2019. (7 days 4 hours 22 minutes in total)

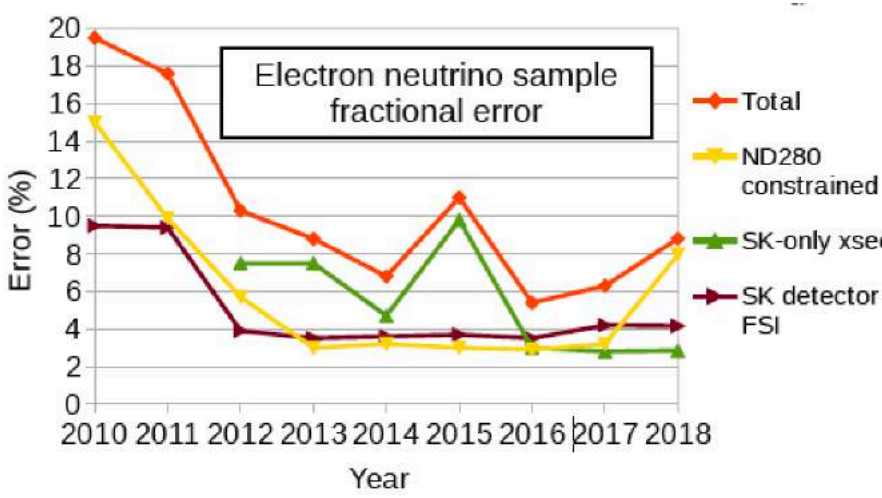


Conclusion

- Currently we do not observe any water leakage from the SK tank within the accuracy of our measurement, which is less than 0.017 tons per day.
- This is less than 1/200th of the leak rate observed before the 2018/2019 tank refurbishment.

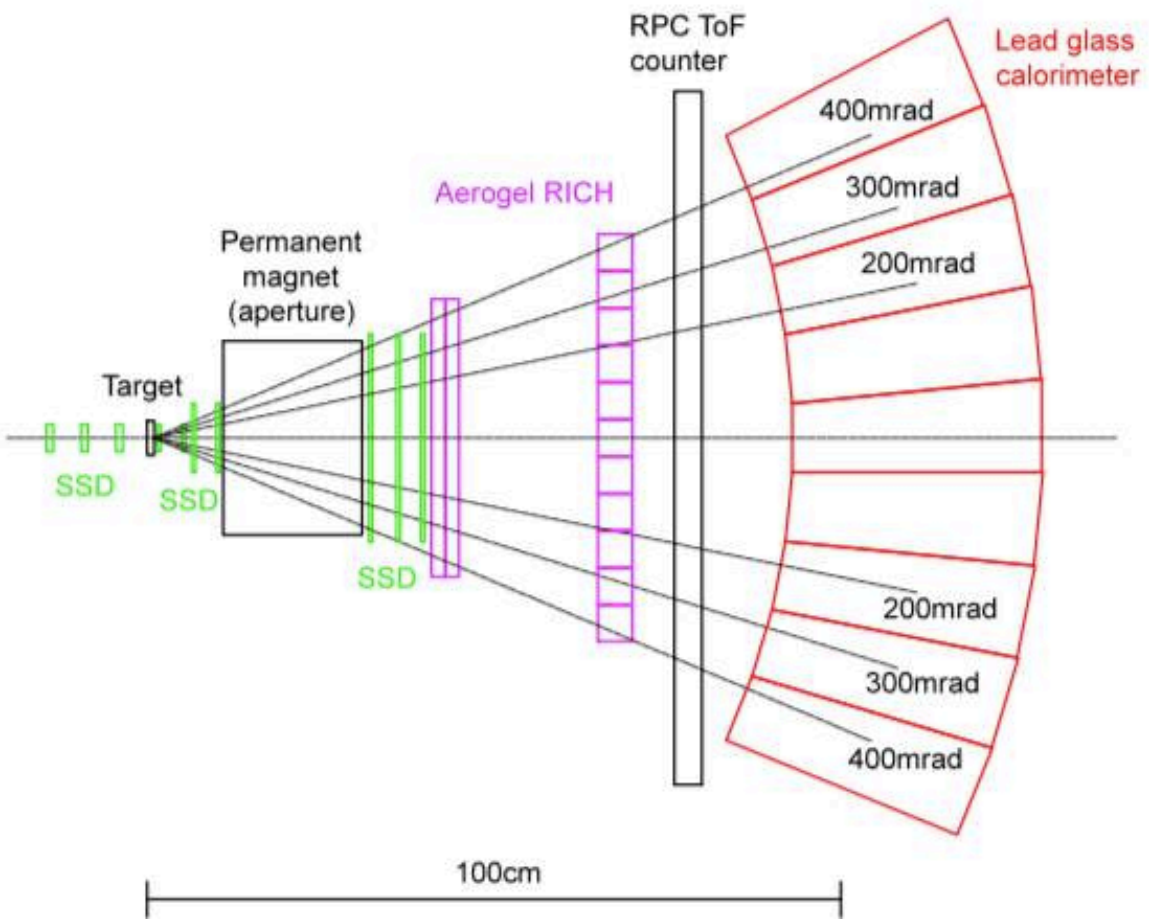
Systematic uncertainties in T2K

- Systematic uncertainties improved over the years but appears to be limited
  - low-hanging fruit already done
    - some errors based on theoretical models
  - 8.8% error need to be suppressed well below HK statistical error of 3%

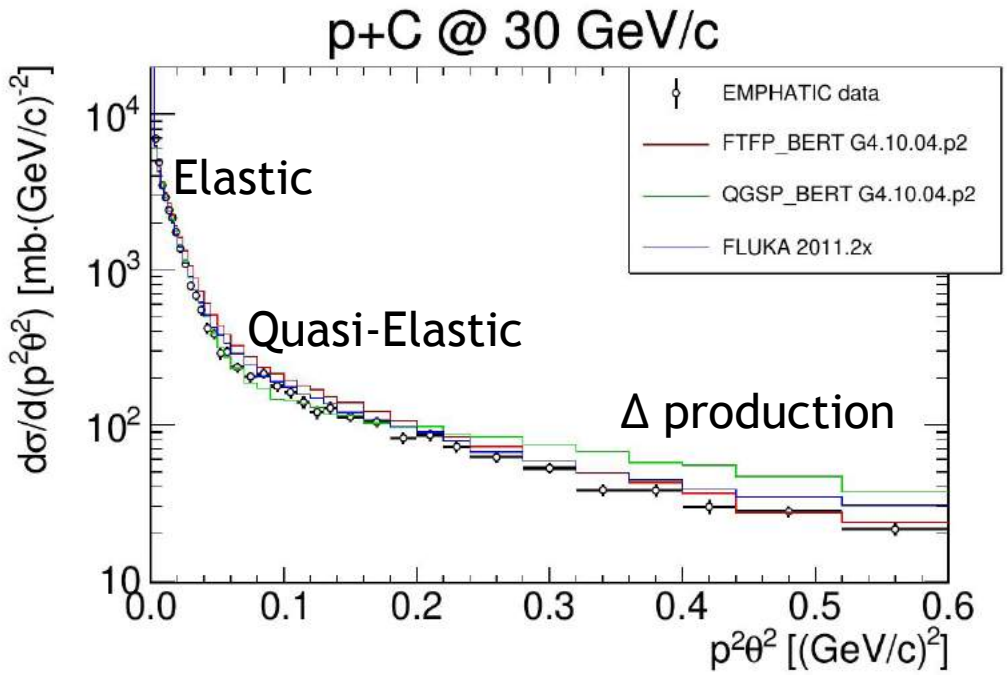


- Systematic uncertainties and 3 pillars: **Canadian initiatives**
  - Flux
    - hadron production **EMPHATIC**
  - Cross section
    - NUPRISM approach **IWCD/NuPRISM**
  - Detector (SK) efficiency
    - Calibration **Bottom-up water Cherenkov calibration and E61 beam test**

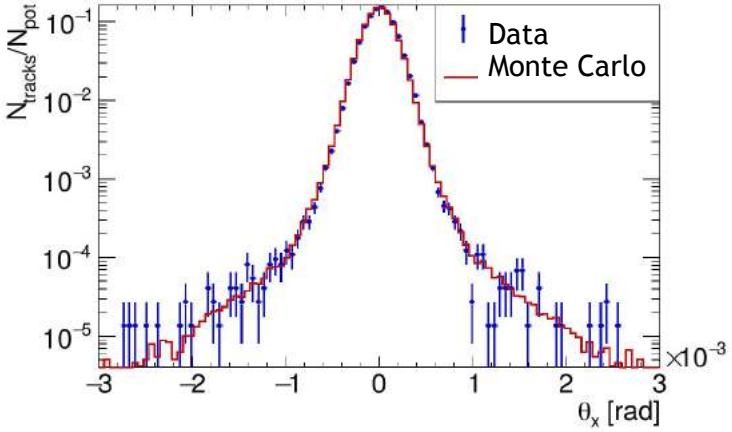
EMPHATIC set up



- Compact and full forward coverage
- Spectrometer
  - silicon strip
  - permanent magnet
- Aerogel RICH
  - π/K/p to 7GeV/c
- RPC
  - ToF below 2GeV/c
- Lead glass
  - e, μ identification
  - γ, neutron detection



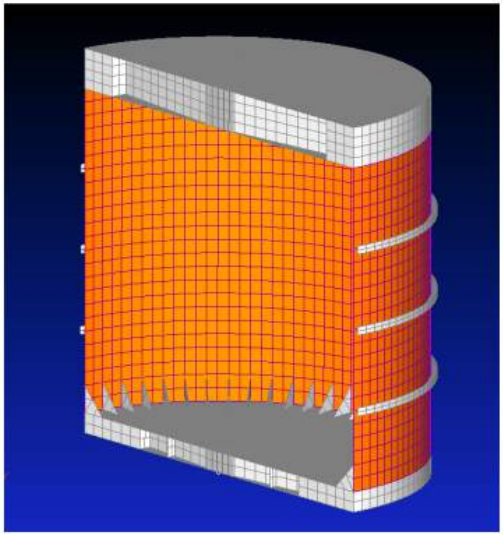
Result was announced in May by Matej Pavin (TRIUMF) at Fermilab Wine and Cheese seminar

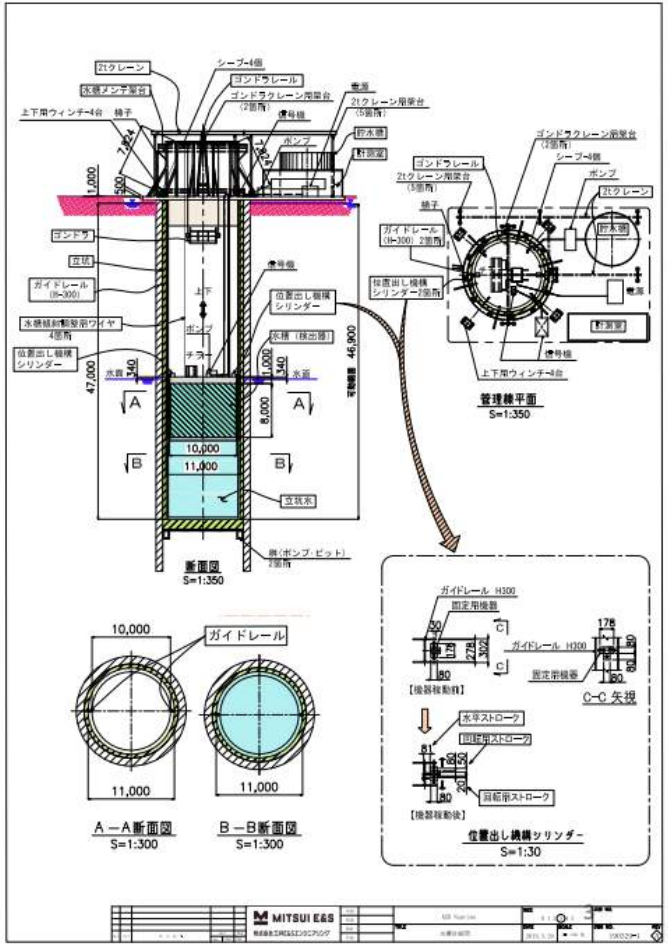


Differential cross sections scales with $t \sim p^2\theta^2$
- update of the 1966 data (Belattini et. al.)
- 20-60% difference between data and MC

0.2mrad in angular resolution

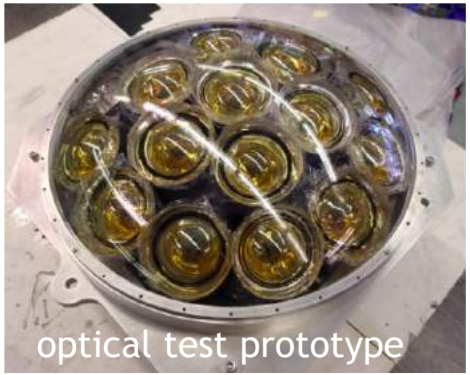
Progress in IWCD/NuPRISM facility design

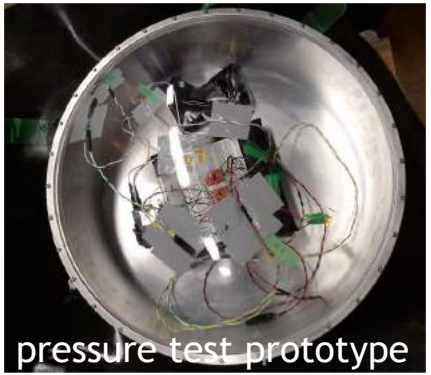




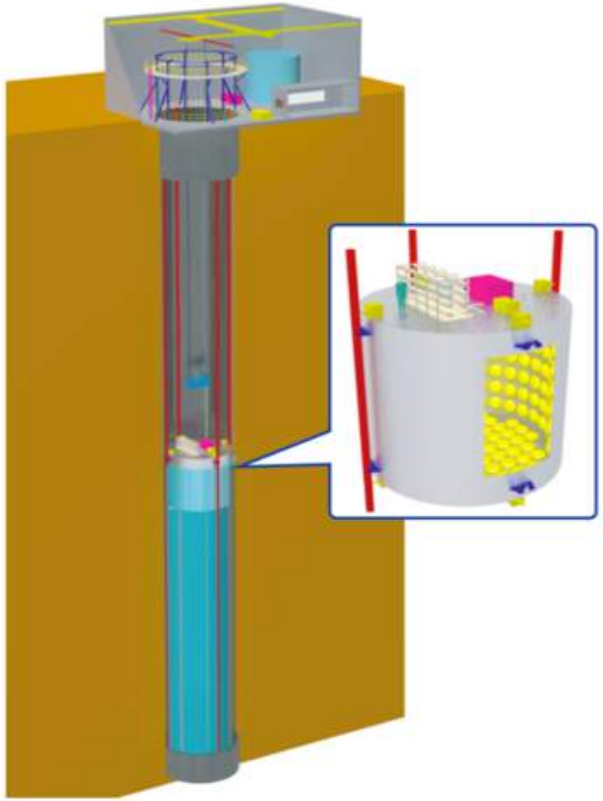
- control vertical position of tank by buoyancy
  - adjust the tilt by wires
  - fix rotation by guide rails
- IWCD facility will be requested by KEK in June

FY2018 RTI: prototype

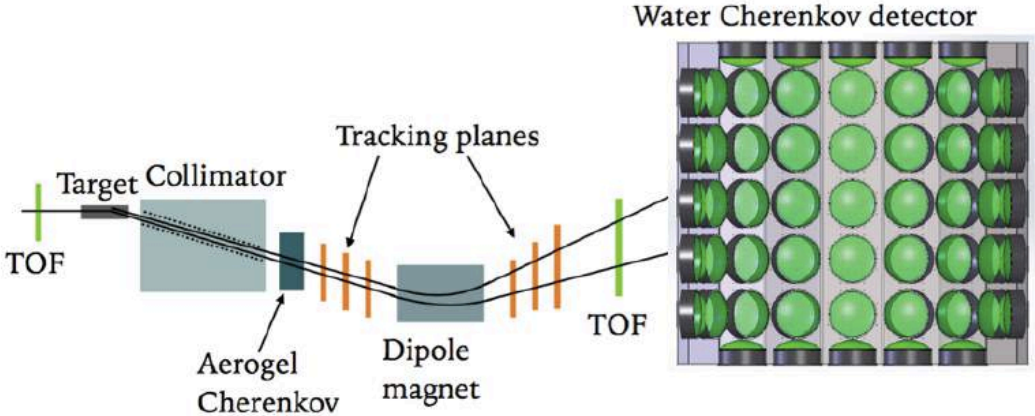




CFI-IF proposal (2019)
IWCD/NuPRISM

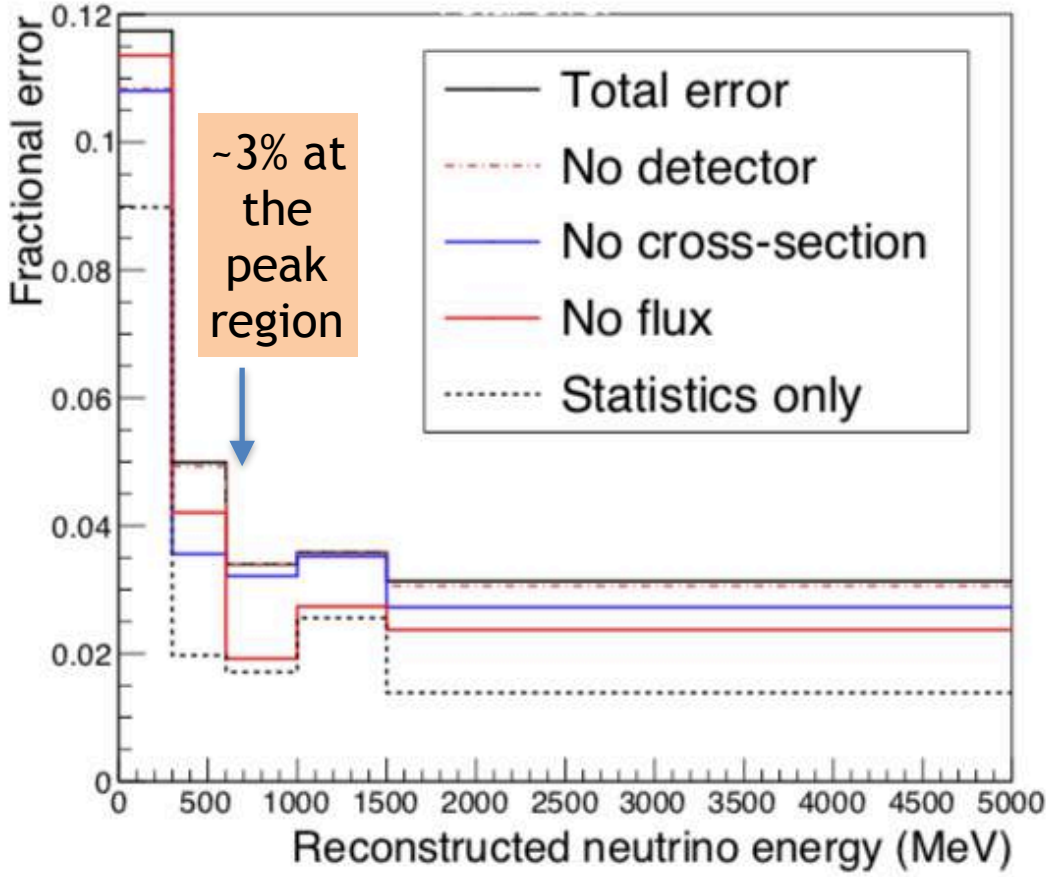


FY2019 RTI: beam test prototype



Systematic error for IWCD ν_e cross section measurement

- NCγ cross section (lower energy) and flux systematic uncertainties are significant
  - EMPHATIC hadron production experiment
  - e/γ separation using machine learning



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HyperK - Canada

MACHINE LEARNING WORKSHOP
APRIL 15-17, 2019

Experts:
K.Terao (SLAC)
W.Fedorko (TRIUMF)

MC data challenge

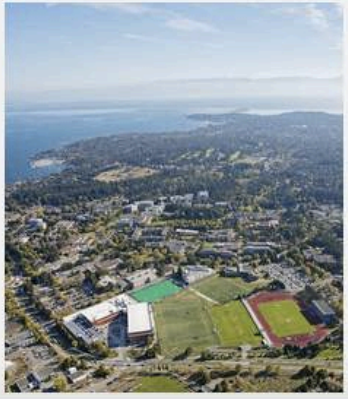
Machine learning for water Cherenkov detectors

The VISPA research centre at the University of Victoria is hosting a workshop on the application of machine learning techniques for water Cherenkov detectors. The workshop will be held on the campus of the University of Victoria from April 15-17, 2019.

The workshop will include tutorials and working sessions using GPU servers to allow participants to gain experience in machine learning techniques. The focus will be on developing techniques to analyze simulated photosensor data from the proposed intermediate and Hyper-Kamiokande water Cherekov detectors. Participation is by invitation only.

The workshop is made possible with support from the University of Victoria Office of the Vice-President Research.

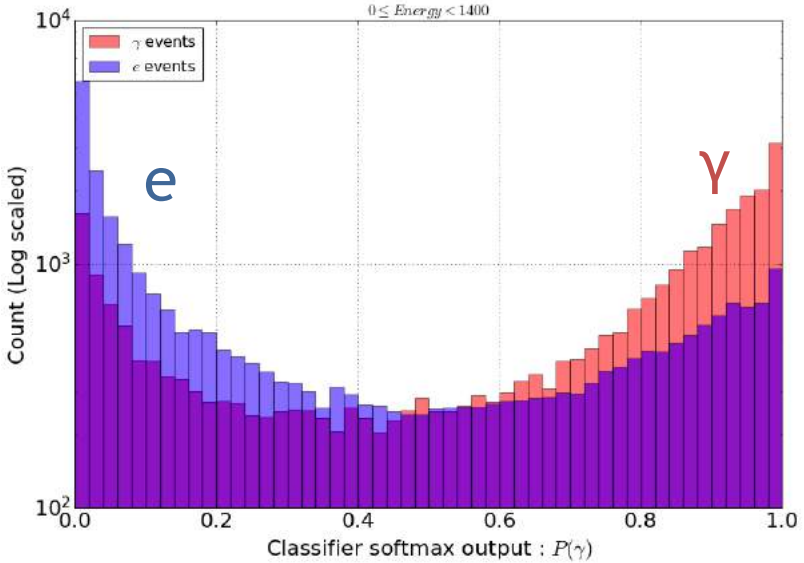
University of Victoria | Victoria Subatomic Physics & Accelerator Research Centre

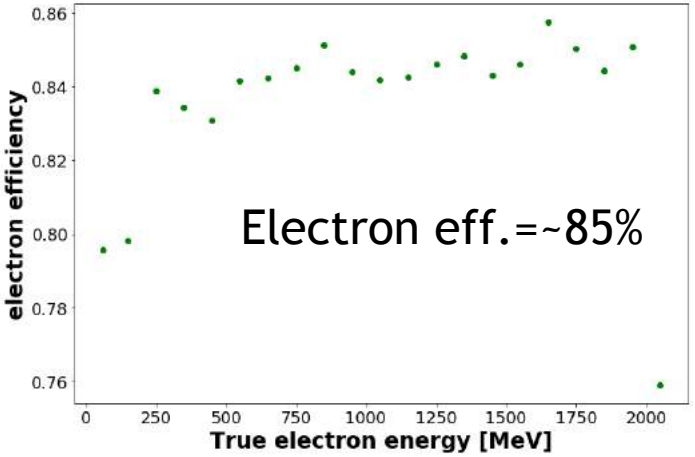


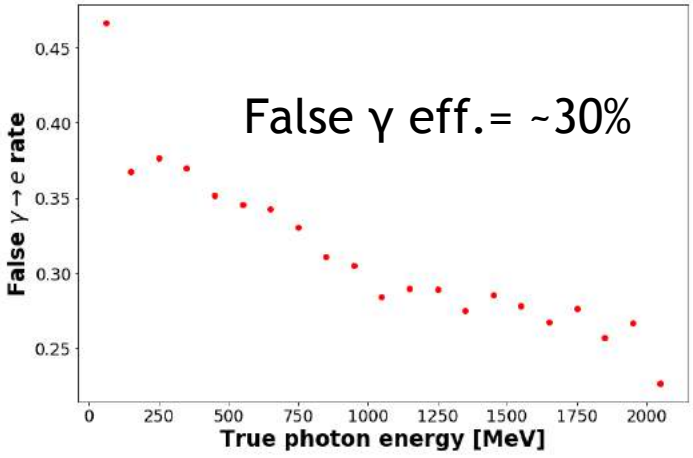
HK members from Canada, Japan, Europe, and US joined

Preliminary study of electron/γ separation

- Initial look at the e/γ separation during the Machine Learning workshop
  - Convolutional Neural Network on e/γ/μ Monte Carlo samples
    - reducing the γ background down to 30% with an electron signal efficiency of 85%







Pilot project of TRIUMF Data Science group

- Water Cherenkov event reconstruction
  - Machine Learning
  - Variational Autoencoder
- TRIUMF-Helmholtz collaboration
- Active development
  - coop students
    - very popular subject
  - postdocs

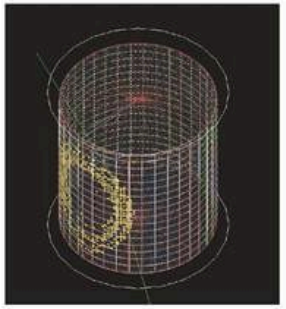
Data Science and Quantum Computing

Pilot Projects

TRIUMF has established a program in Data Science and Quantum Computing in order to enchance it's scientific impact, utilizing it's national network, international collaborations and industry contacts. Several pilot projects, where applications of Machine Learning could have a major impact have been identified to kick start this activity.

Event Reconstruction in Water Cherenkov Detectors for the Hyper-Kamiokande Project

The Hyper-Kamiokande experiment is set to begin operations in the middle of next decade. One of the major science goals of this experiment is to measure the CP violating phase in the neutrino sector. Precise knowledge of this parameter can tell us if neutrinos are responsible for the matter-antimatter asymmetry observed in the Universe. One of the major systematic uncertainties limiting this measurement stems from the unknown rate of neutrino interactions producing gamma backgrounds to the main electron neutrino signal. The goal of this project is to develop deep learning techniques for particle identification and multi-ring event reconstruction in a water Cherenkov detector. It will focus on simulations of Hyper-K detectors including NuPRISM - a major TRIUMF initiative. The project will explore accepted supervised training



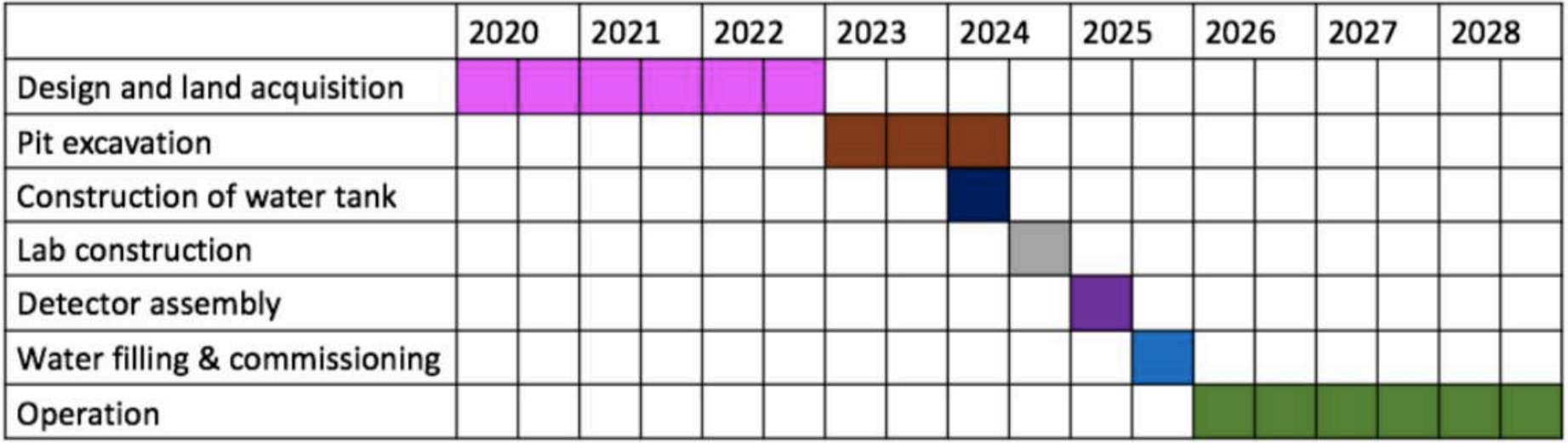
hyper-K event display

Status of the HyperK project

- In September 2018, President of the University of Tokyo announced to start HyperK construction in 2020
  - significant budgetary contribution from the University of Tokyo
- HyperK funding forum (HKFF)
  - 1st meeting on Jan.11: information, country plans, SuperK open tank tour
    - Kajita, Gonokami (Tokyo president), Isogai (MEXT director)
    - Mike Roney (IPP), Joshua Hodgson (Canadian embassy)
  - 2nd meeting on June 27: NOI on international contributions
- HyperK advisory committee (HKAC)
  - June 25-26: Review of the HyperK technical report
- IWCD (NuPRISM) officially becomes part of HyperK
  - facility design work under way for the KEK budget request in June
- multi-PMT identified as the main candidate as the 2nd ID PMT
  - 5k-10k mPMT in addition to 20k 20-inch PMT's from Japan
- Full MEXT budget announcement expected in the end of August 2019

Backup

IWCD schedule

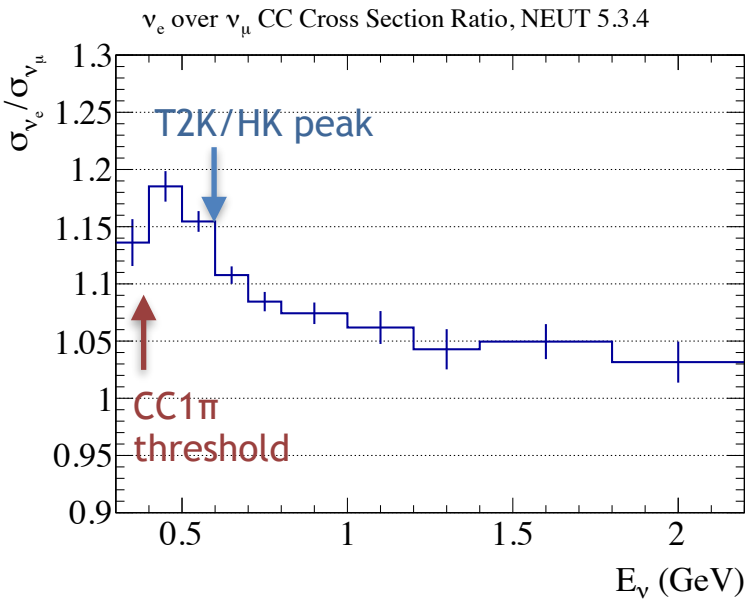


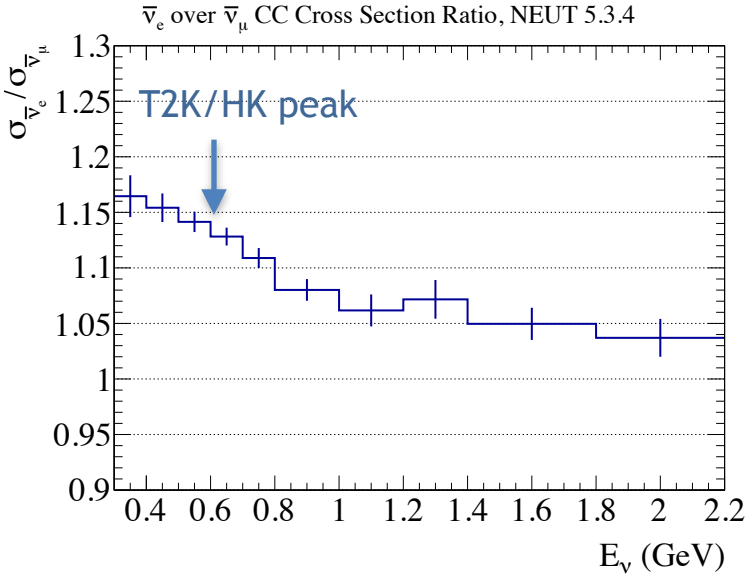
Test experiment design

Test experiment construction

Test experiment operation

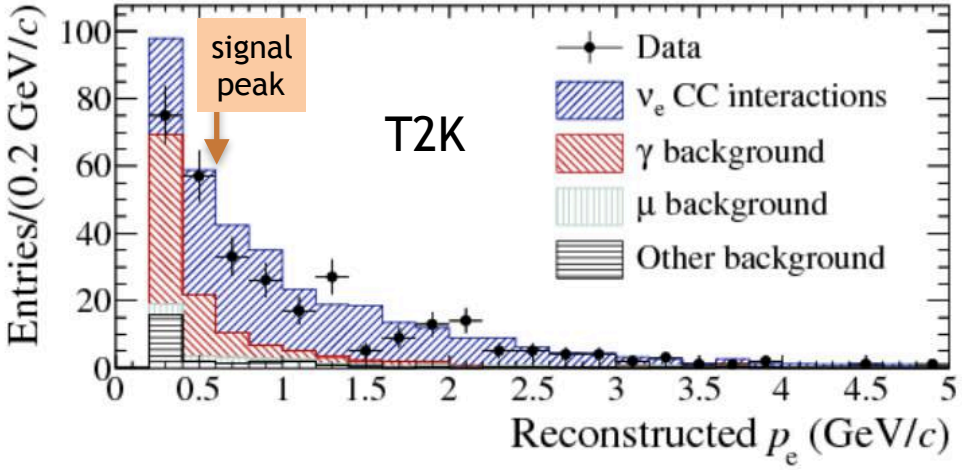
$\sigma(\nu_e)/\sigma(\nu_\mu)$ difference

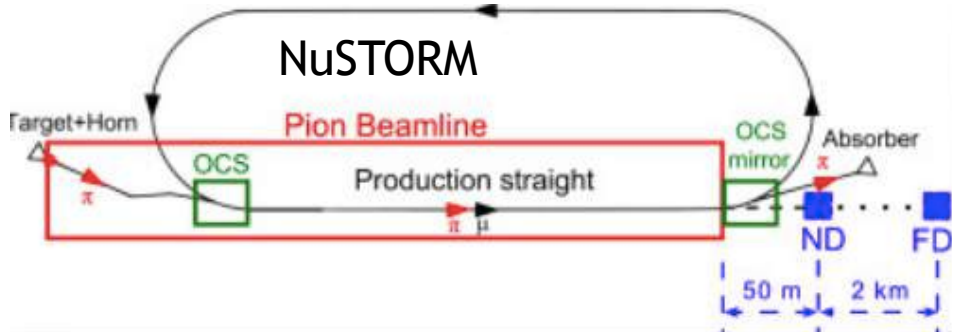




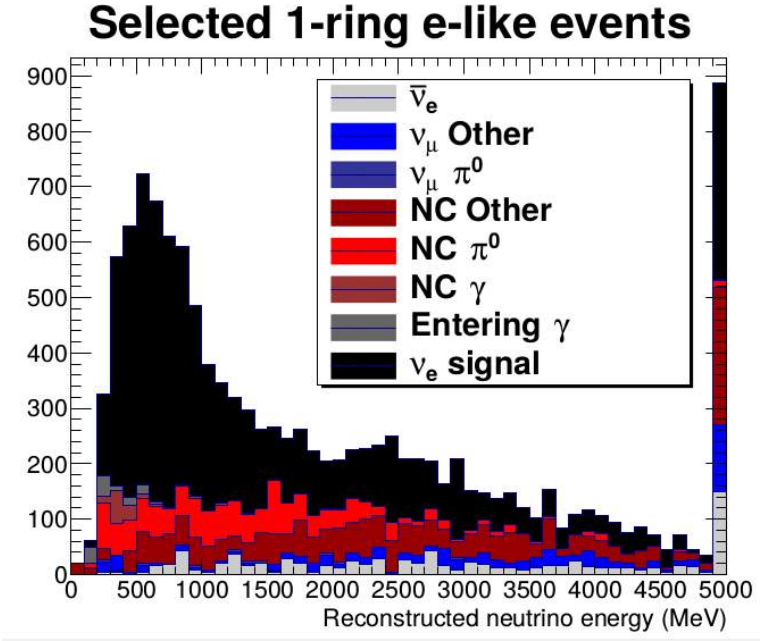
- Near detector observes ν_μ and far detector observes ν_e
  - "educated guess" of 3% systematics (could be 5% or more) is assinged in T2K
- ~15% difference in $\sigma(\nu_e)/\sigma(\nu_\mu)$ cross sections at ~0.6GeV
  - In addition, significant energy dependence and $\nu/\bar{\nu}$ difference
  - Nuclear effect would be different, causing uncertainty

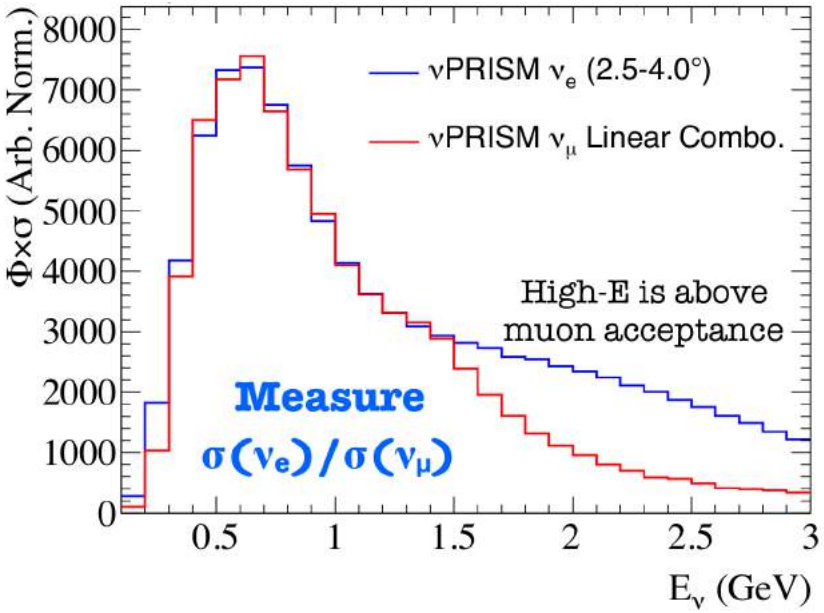
- T2K near detector is limited by external γ backgrounds
  - fully active shielding of outer veto is essential for ν_e detection (IWCD)
- suppress large ν_μ background
  - larger off-axis angle (IWCD)
  - tighter ν_e/ν_μ cut (IWCD)
- flux systematics is large: 5-10%
  - NuSTORM/ν-factory: too expensive
  - match the ν_e/ν_μ flux in IWCD to cancel the flux systematics





$\sigma(\nu_e)/\sigma(\nu_\mu)$ by IWCD flux matching





- good background suppression for IWCD
- emulate the IWCD ν_e flux by IWCD ν_μ flux linear combination
  - cancelling the flux systematics
    - precisely test the difference in the kinematical phase space

Statement of the president of the University of Tokyo

Funding outlook in Japan

- The “Hyper-Kamiokande project”
  - Hyper-Kamiokande detector (UTokyo)
  - J-PARC upgrade to 1.3MW (KEK)
  - Intermediate neutrino detector (facility) (KEK)
- Budget request for the project submitted to MEXT from UT/KEK for JFY2019 budget
- MEXT budget request to MOF (End of Aug. 2018)
  - Hyper-K detector construction for JFY2019 is not included. Instead “Seed funding” for the Hyper-K project is requested.
  - Budget to upgrade the beam power is requested separately.

Funding outlook (continued)

- In the Japanese system, “funding for feasibility study” implies “seed funding.”

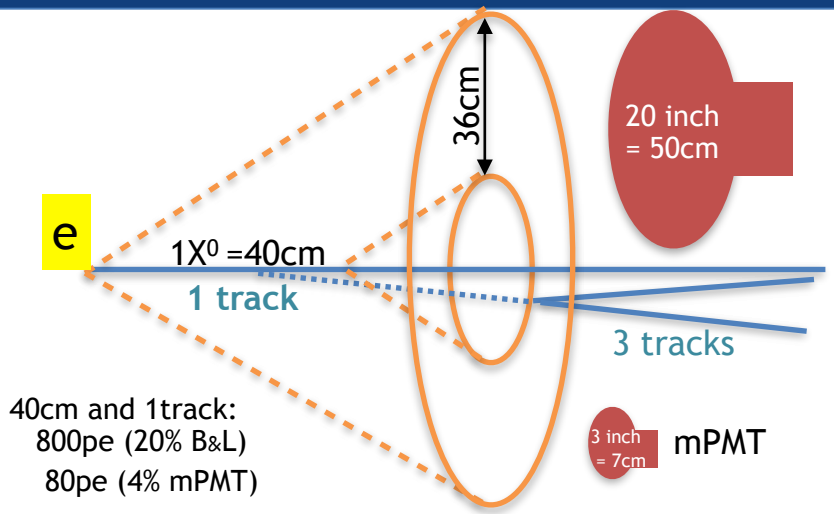
For example;

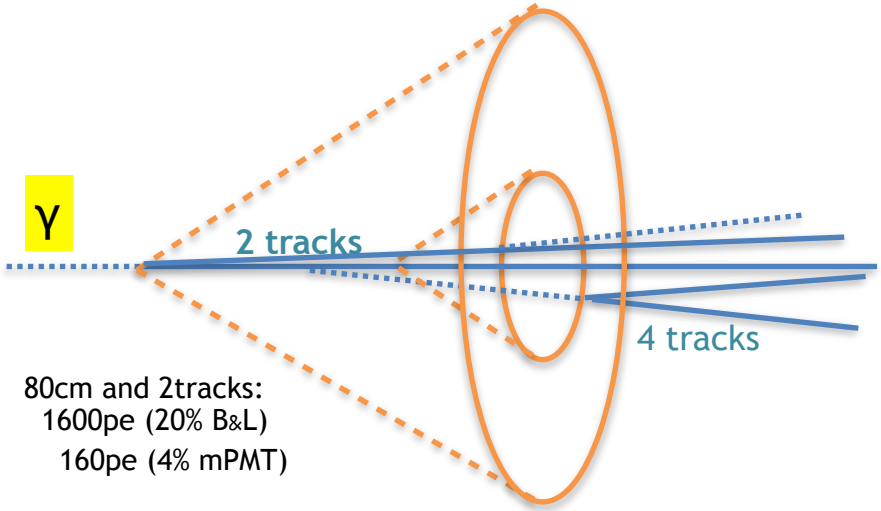
✓Super-Kamiokande received the “funding for feasibility study” in 1990, and the construction budget was approved in 1991.

✓Other examples include: Subaru telescope (8m telescope at Hawaii), ALMA telescope in Chili (for 2 years), and TMT (30 meter telescope in Hawaii).

H.Aihara (vice president) at European strategy neutrino town hall meeting

e/γ separation with mPMT





- First ~1 radiation length carries e/γ separation information
  - e: 1track, γ: 2 tracks
  - mPMT granularity and timing is required to identify the difference: IWCD
  - Could it be done for HypeK far detector?
    - even 4% coverage by mPMT could work: 80pe for electron verses 160pe for γ