Water Cherenkov Development for the Hyper-K project

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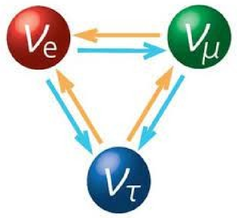
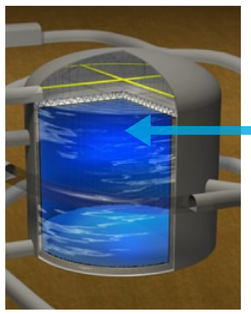
1. Neutrino Oscillations

- Neutrinos are the member of the elementary particles in the Standard Model of particle physics
- Neutrinos interact with matter extremely weakly via the weak interaction
- Neutrinos were supposed to have exactly zero-mass
- The discovery of ν oscillation revealed that neutrinos have non-zero masses
- The ν oscillation has not been understood fully yet



Hyper-K detector



295km

Accelerator ν produced at J-PARC

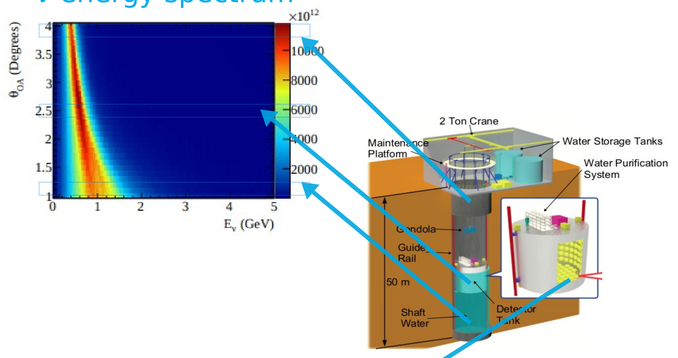
2. Hyper-K Project and the long-baseline program

- A next generation underground neutrino experiment in Japan
  - 260 kton scale water Cherenkov detector
  - Construction has began in 2020
  - Data taking is expected to start in 2027
- Rich physics programs
  - ν oscillations/astronomy and nucleon decay searches
- Long-baseline program
  - One of the unresolved problems in the Universe is the imbalance between matter and anti-matter
  - If oscillation of ν is different from ν̄'s one, it provides information that could explain the origin of the imbalance
  - The program will study oscillations of νμ → νe and ν̄μ → ν̄e, using νμ /ν̄μ beam produced at J-PARC

2. Intermediate Water Cherenkov Detector (IWCD)

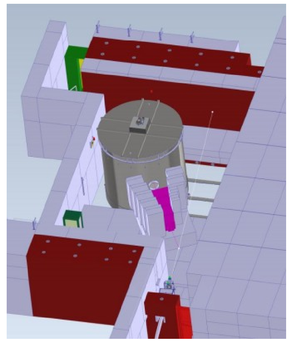
- To achieve the long-baseline program with the designed precision, an accurate prediction of ν interaction rate at Hyper-K is essential
- IWCD will play the important role by measuring the rate before the oscillation with the same detector technology as Hyper-K
  - Sub-kton scale water Cherenkov detector
  - Located at about 1 km from the ν source
  - Vertically movable, changing ν flux
  - Plan of Gadolinium loading to enhance capability of neutron detection

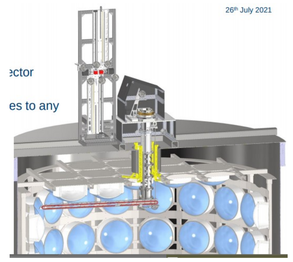
ν energy spectrum



New photo sensor module
- 19 3-inch PMTs/module

- Photmuliplier tubes (PMTs) are used to detect Cherenkov light originating from ν interaction
- PMTs used in IWCD are required to have finer granularity and better timing resolution compared to larger PMTs
- The multi-PMT module is being developed for IWCD





3. Water Cherenkov Test Experiment (WCTE)

- The detector response of IWCD needs to be understood within <1%
- The same detector components used in IWCD will be studied by using a 50 ton scale water Cherenkov detector at CERN
- Results of the experiment will be crucial inputs to both current and future experiments such as SK-Gd and ESSνSB as well as Hyper-K
- Operation is planned in 2023

4. Summary

- The Hyper-K project is a next generation neutrino experiment
- A log-baseline program is planned to reveal remaining known nature of neutrinos
- IWCD is planned to achieve the goal of the long-baseline program
- To achieve the requirement for IWCD, WCTE is also planned
- The TRIUM neutrino group is leading the developments of both IWCD and WCTE

Discovery, accelerated