Beam ν + atmospheric ν combined analysis

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Introduction

- The fitter, Osc3++, for the combine analysis of beam neutrino and atmospheric neutrino has been developed and validated
  - The result of beam neutrino using Osc3++ and the one using hk-simpleFitter are consistent.
- Combined analysis of beam neutrino and atmospheric neutrino can increase the sensitivity of MH and the precision of CP measurement.

- The sensitivity with Korean detector, which is assumed to be in Mt. Bisul, will be reported in this talk.

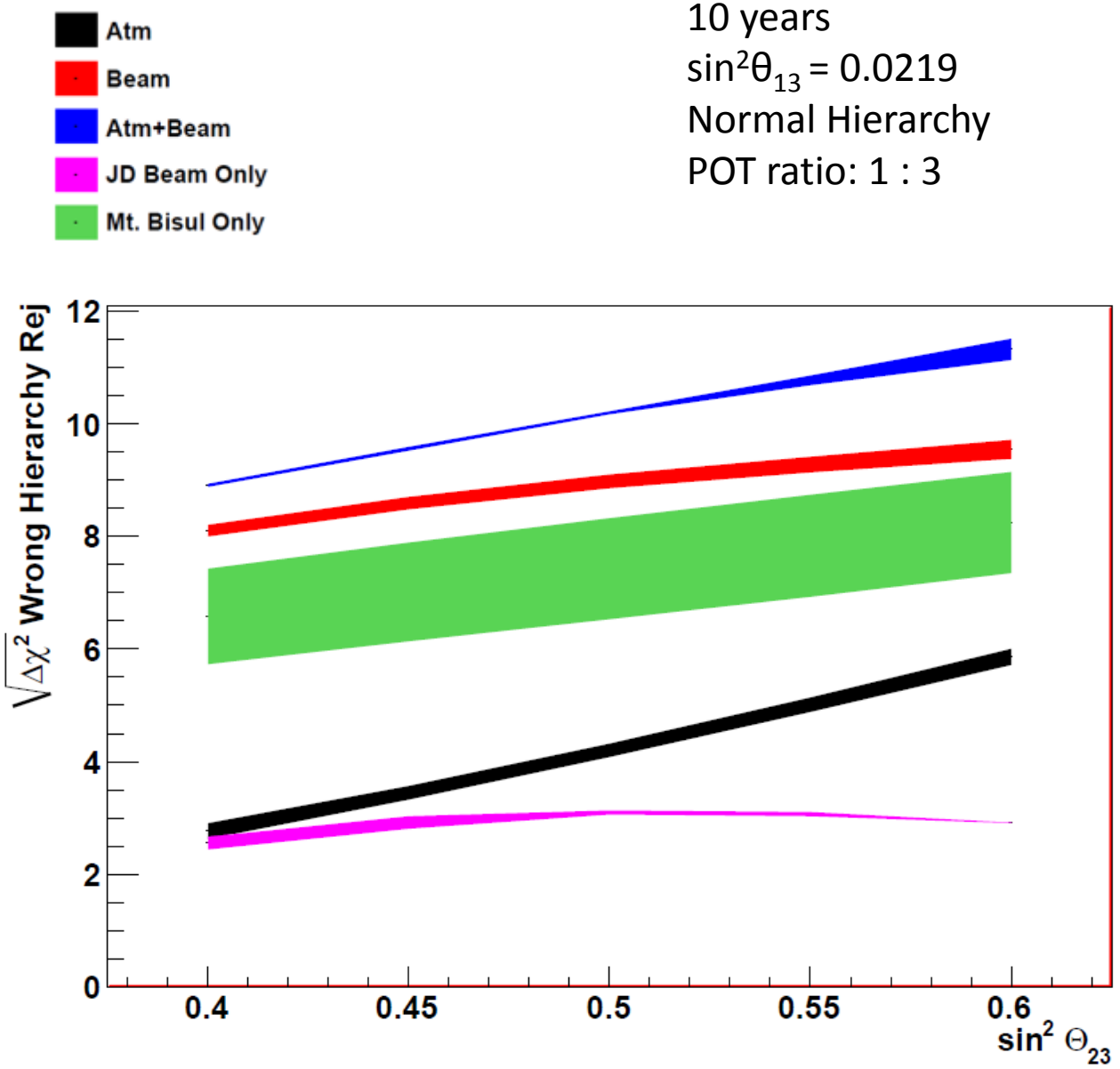
Conditions and assumptions for this study

- Samples
  - Beam: νμ, νμbar, νe, νebar
    - Both of Korean Detector (KD) and Japan Detector (JD) were used.
    - Only reconstructed energy information is used.
      - Each samples has 56 bins.
  - Atmospheric: all 19 samples currently used for Super-K currently
    - SubGeV and MultiGeV, e-like sample and mu-like sample, single ring and multi-ring samples.
    - Both of energy and direction are used. The number of bins is 2224.
    - The performance of Korean Detector is assumed to be the same as the Japan Detector, including the observed neutrino energy spectrum and uncertainties.

Mass Hierarchy

Korean Detector has very high mass hierarchy, although it is rely on the $\delta_{CP.}$

After combine with Japan Detector and atmospheric, the mass hierarchy can reach 9σ!



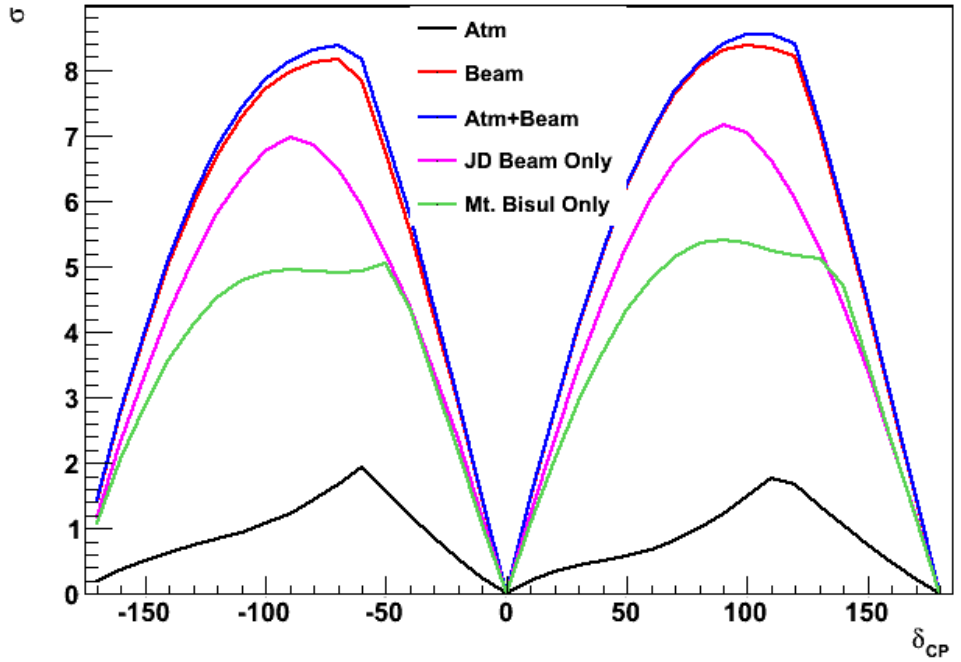
10 years
$\sin^2\theta_{13} = 0.0219$
Normal Hierarchy
POT ratio: 1 : 3

Error bar represents the effect from the uncertainty of δCP.
(Only $\delta_{CP} = 0$ and π are tested.)

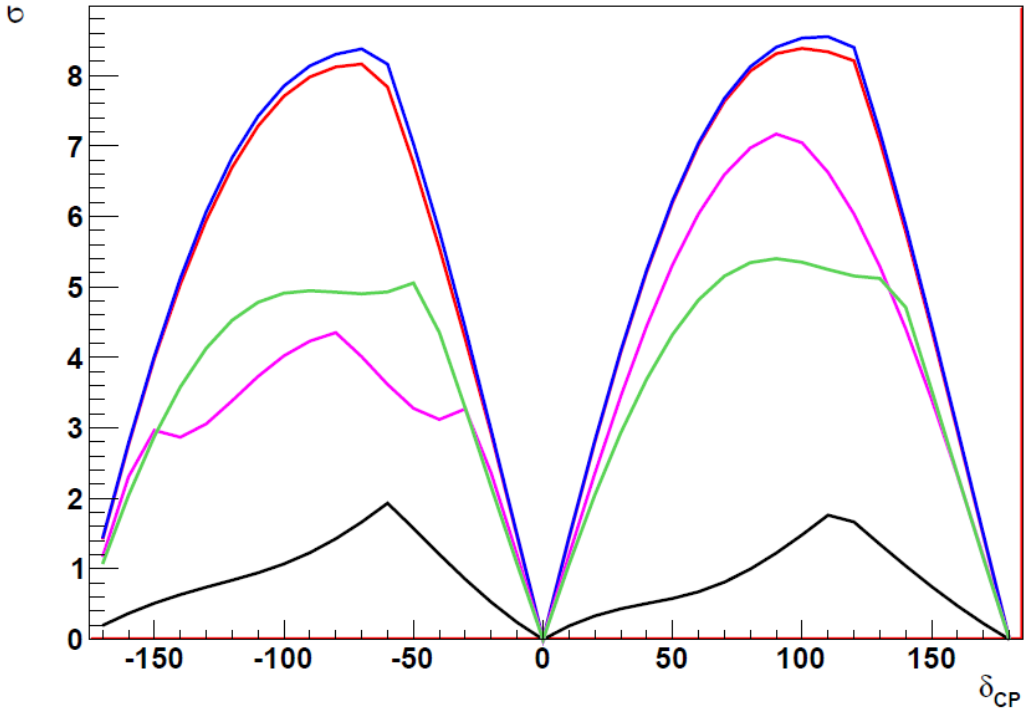
CP violation sensitivity

10 years
$\sin^2\theta_{13} = 0.0219$
Normal Hierarchy
$\sin^2\theta_{23} = 0.5$
POT ratio: 1 : 3

Known Mass Hierarchy (NH)



Unknown Mass Hierarchy



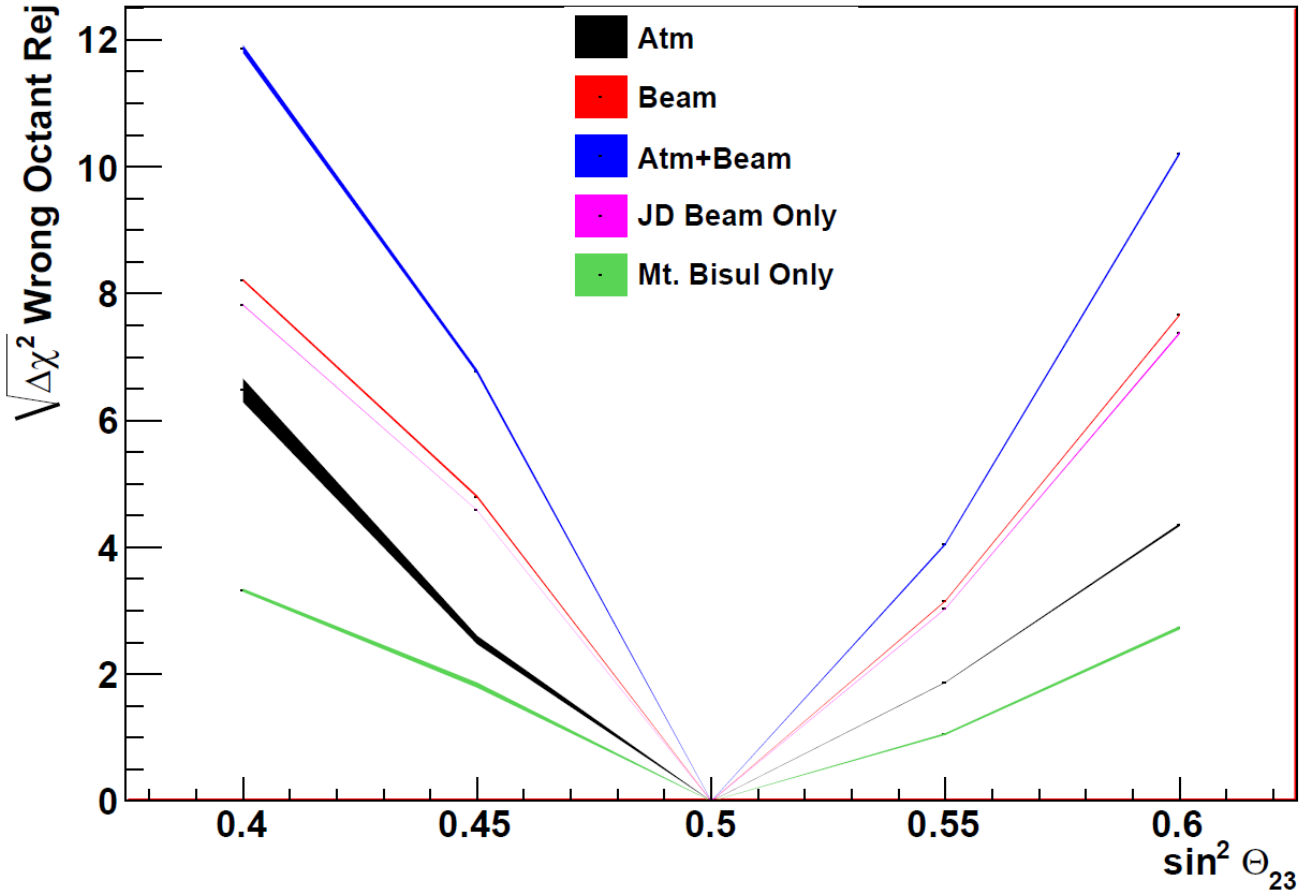
The degeneracy observed on Japan Detector due to the unknown mass hierarchy can be resolved by Korean Detector

Octant sensitivity

10 years
$\sin^2\theta_{13} = 0.0219$
Known Normal Hierarchy
POT ratio: 1 : 3

Beam neutrino observed by Japan Detector and atmospheric neutrino samples have high octant sensitivity.

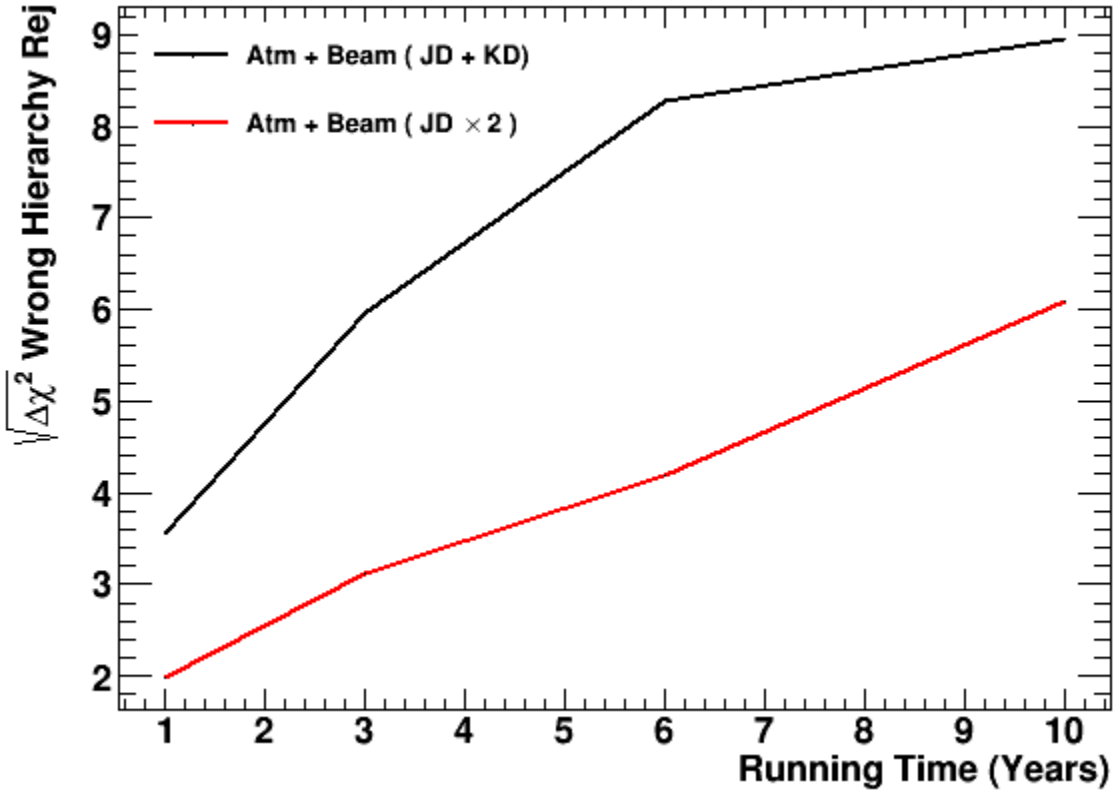
The reason is considered from the high statistics.



Mass hierarchy sensitivity vs running time

$\sin^2\theta_{13} = 0.0219$
$\sin^2\theta_{23} = 0.5$
Normal Hierarchy
POT ratio: 1 : 3
(Staging only for JD ×2)

Comparing with 2 Japan Detectors, the configuration of Japan Detector + KD Detector have higher sensitivity.
Since the baseline length from J-PARC to Korean detector is very long.



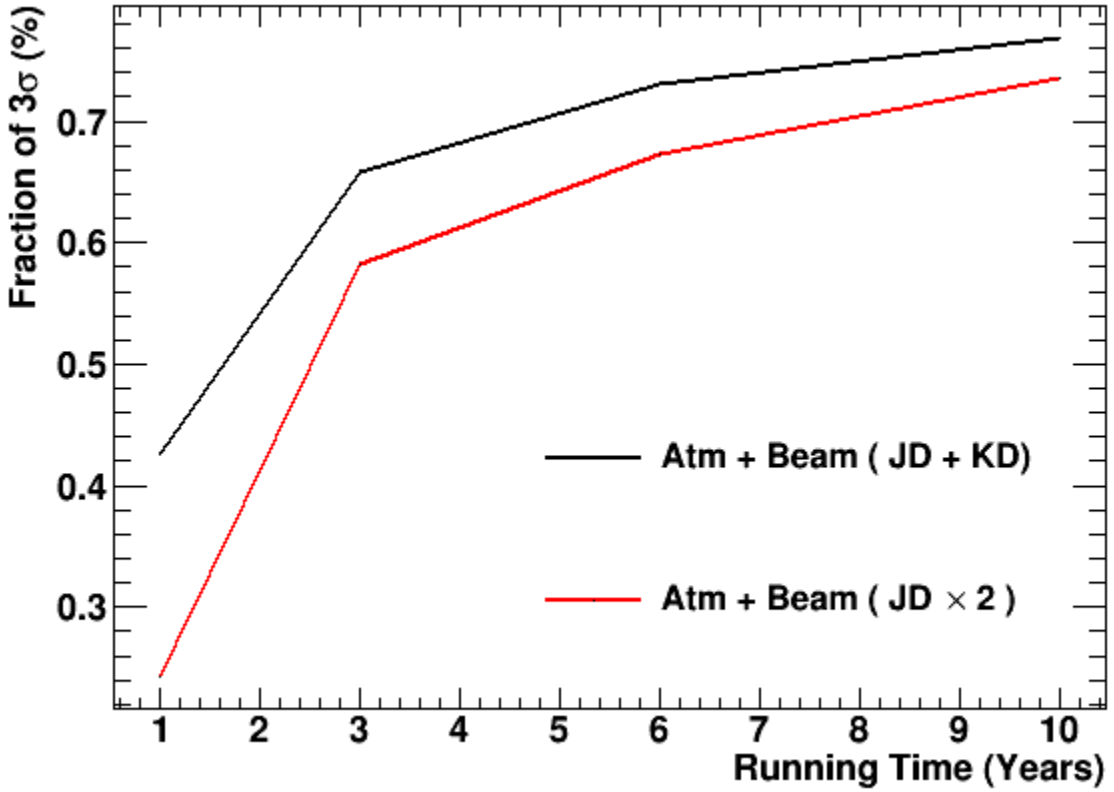
CP violation sensitivity vs running time

10 years
$\sin^2\theta_{13} = 0.0219$
$\sin^2\theta_{23} = 0.5$
Known Normal Hierarchy
POT ratio: 1 : 3
(Staging only for JD ×2)

The reason that why the configuration with Korea Detector is the exposure time.

For the 2 Japan Detectors case, the second detector would start to run from 6th year,
while the Korea Detector starts to observe since the 1st year.

There are always a difference with a factor of 2 on exposure time between 2 Japan Detector configuration and JD + KD configuration until
6th year.

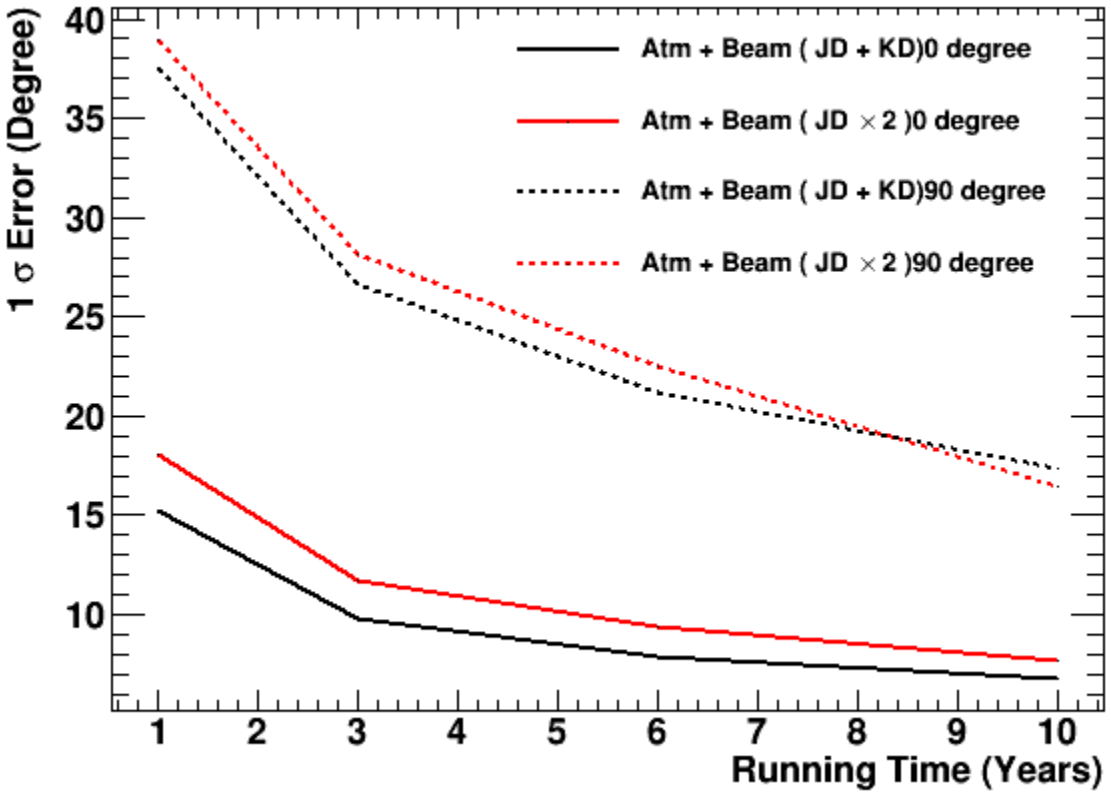


Uncertainty of δ_{CP} vs running time

10 years
$\sin^2\theta_{13} = 0.0219$
$\sin^2\theta_{23} = 0.5$
Known Normal Hierarchy
POT ratio: 1 : 3
(Staging only for JD ×2)

The advantage from long exposure time is not so obvious when δ_{CP} = 90 degree.

The number of the observed events are Korea Detector is only 1/3 ~ 1/2 of the Japan Detector, while it is critical to measure the δ_{CP} precisely.



Summary

- The fitter, Osc3++, for the combine analysis of beam neutrino and atmospheric neutrino has been developed
- Combined analysis of beam neutrino and atmospheric neutrino can increase the sensitivity of MH and the precision of CP measurement.
- The configuration with Korean Detector, which is assumed to be on Mt. Bisul, has longer beam length and longer exposure time than the baseline design: two Japan Detectors.
  - It can help to resolve the mass hierarchy and discover the CP violation.
  - The improvement on the δ_{CP} measurement is not as significant as the other two.