

Low energy calibration

Yusuke Koshio for Calibration w.g.
with suggestions from Astro-physics w.g.
Kamioka observatory,
ICRR, Univ. of Tokyo
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Energy calibration

- * Track range of high energy stopping muon (10-1 GeV/c)
- * Cherenkov angle of low energy stopping muon (500-200 MeV/c)
- * Invariant mass of π^0 's produced by atmospheric neutrino interactions (~130 MeV/c)
- * Momentum of decay electron (~50 MeV/c)
- * LINAC and DT (4-20 MeV)



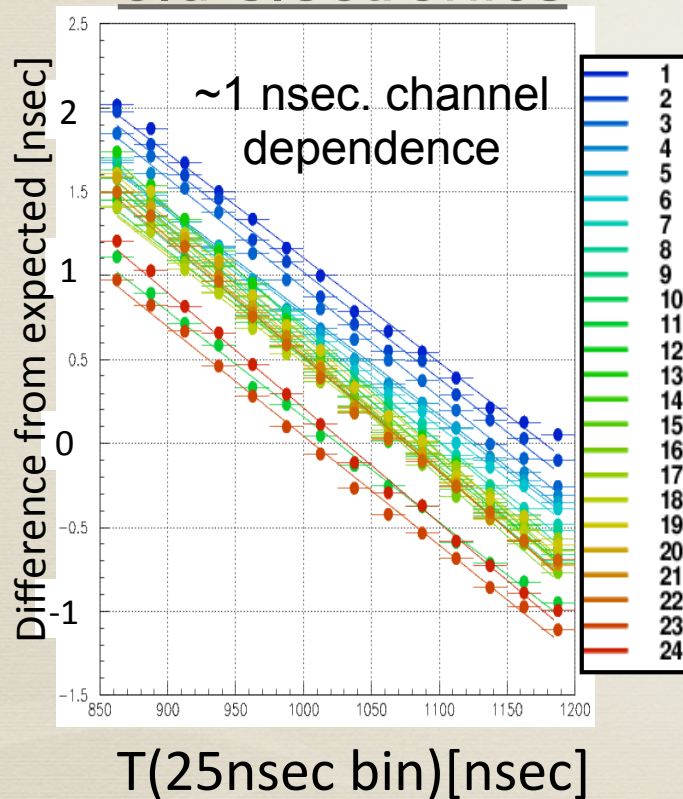
Requirement for calibration from astro-physics

- * The fiducial volume uncertainty will be important for all the measurements.
 - **Timing calibration** is crucial.
 - Reconstructed **vertex calibration** at the several position around the fiducial edge should be performed.
- * Important observation for HK solar neutrino will be day-night asymmetry.
 - **Position dependence of the water quality**, especially top-bottom asymmetry, should be monitored.
- * Precise **energy calibration** will be lower priority in the case of 20% photo-coverage since the energy spectrum measurement in solar neutrinos, e.g. up-turn to the vacuum oscillation region, is quite difficult.

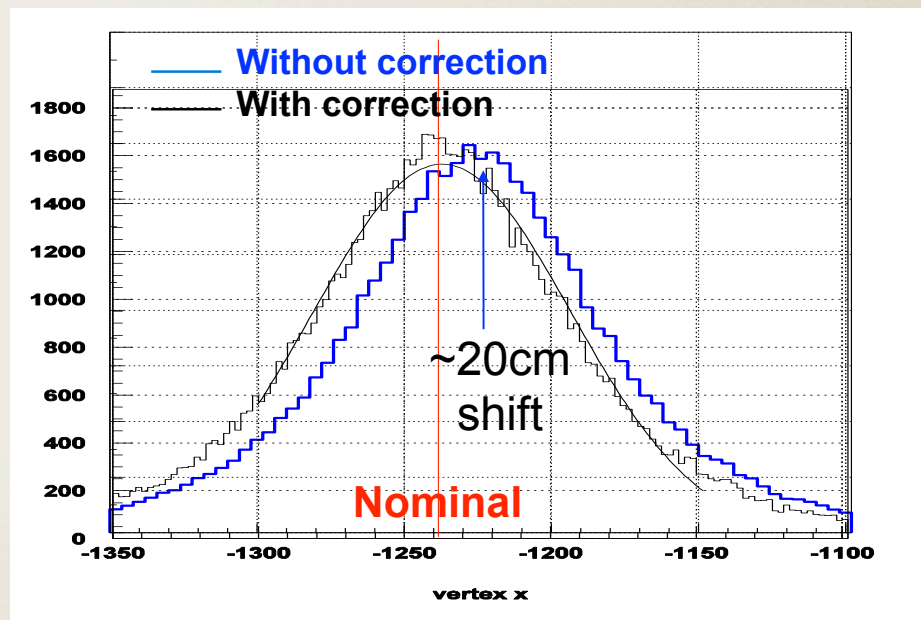
Timing calibration

From the SK experience

old electronics



Vertex shift by Ni calibration



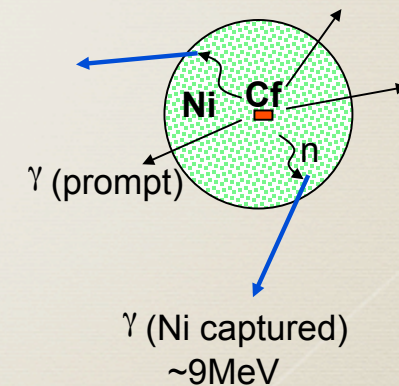
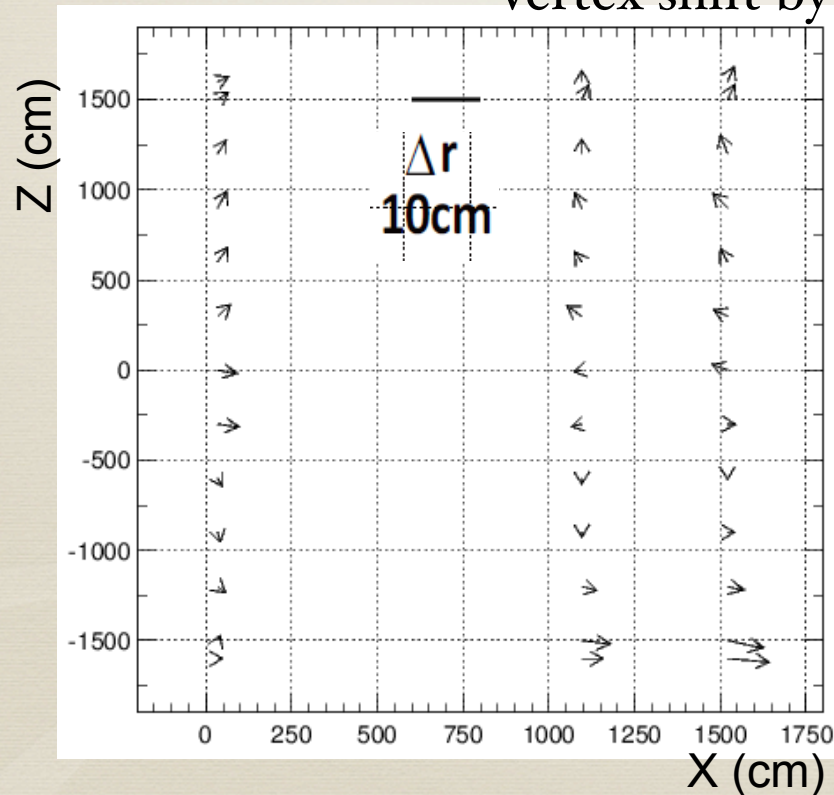
Any ~nsec level systematic dependence is not acceptable

Vertex calibration

From the SK experience

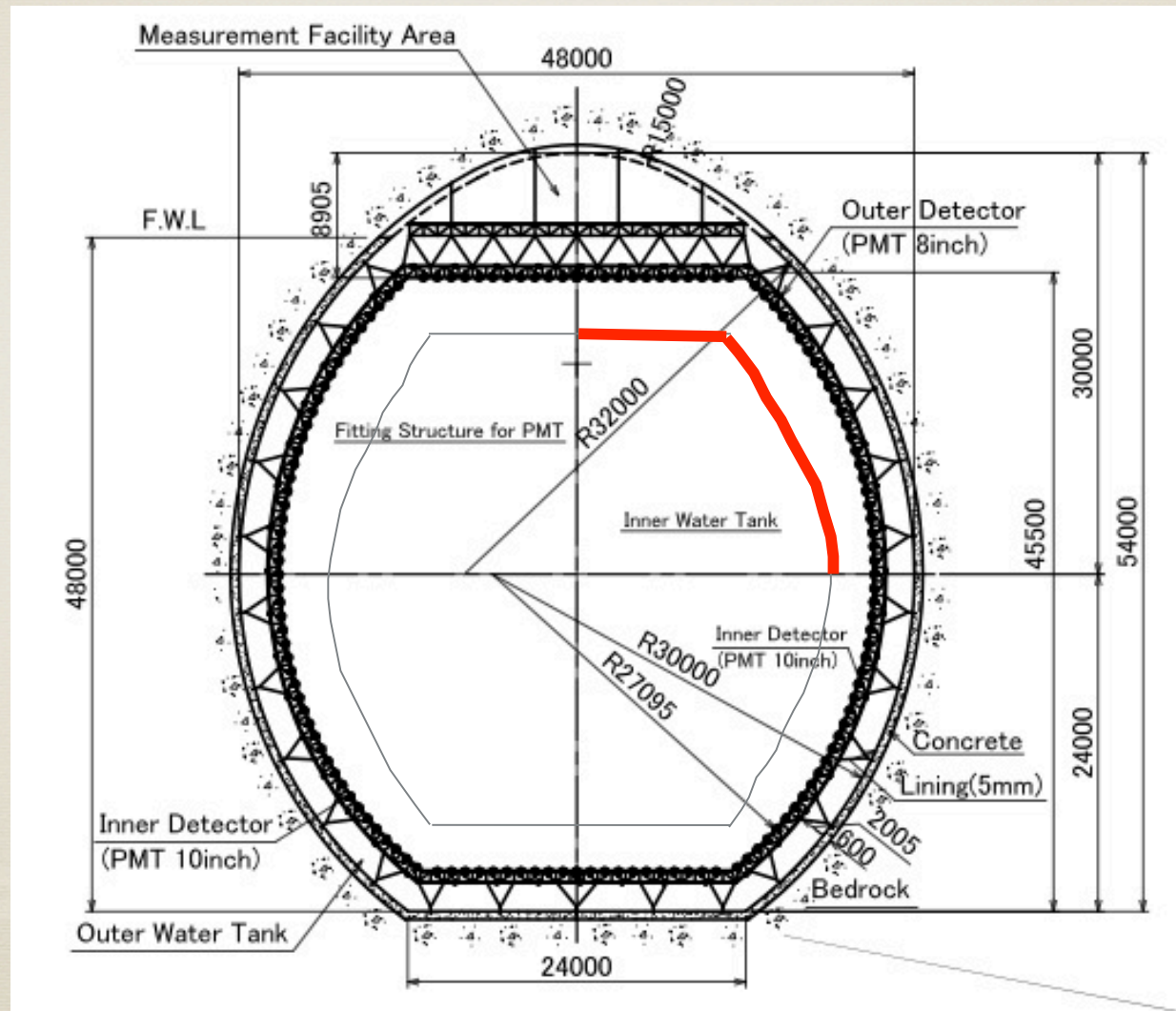
For estimation of the fiducial volume uncertainty, a calibration around the fiducial edge is important.

Vertex shift by Nickel calibration



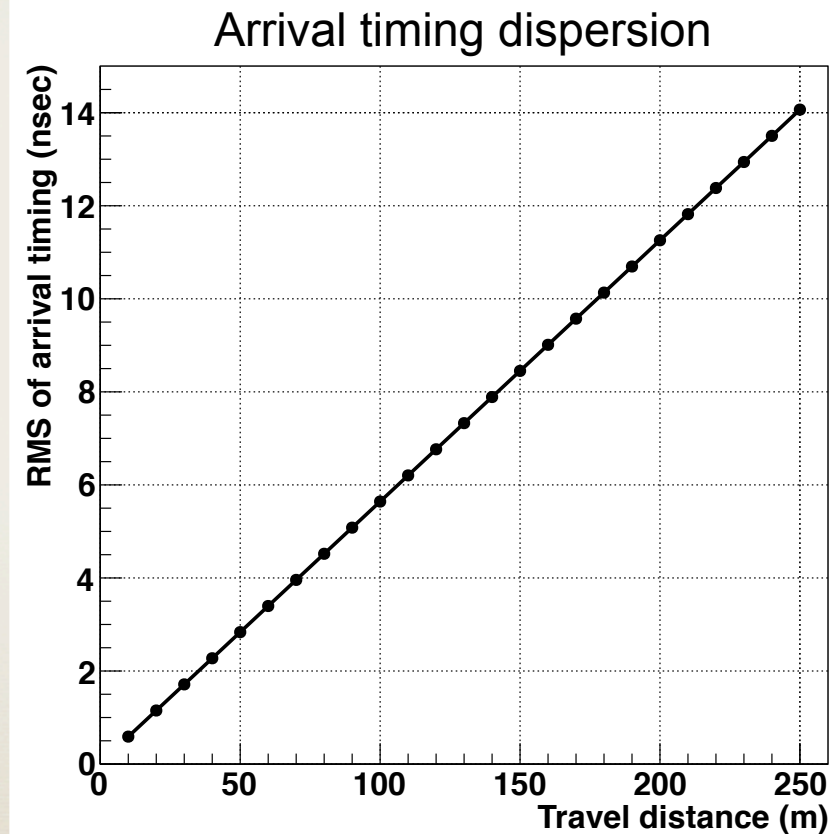
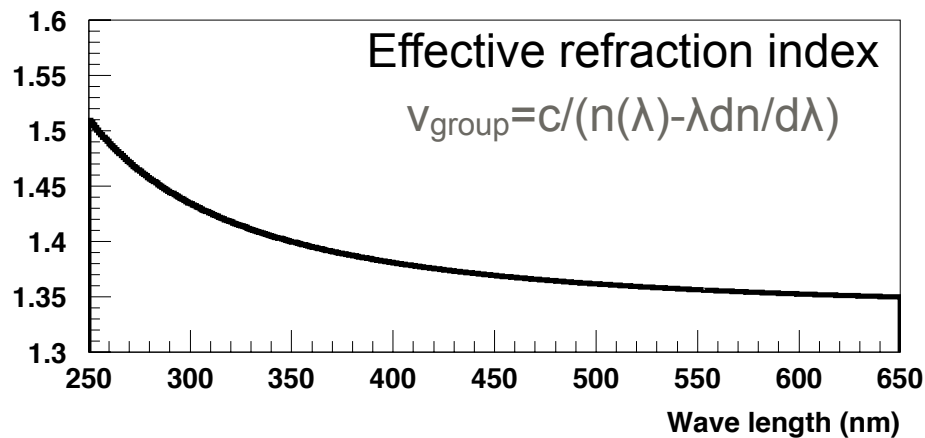
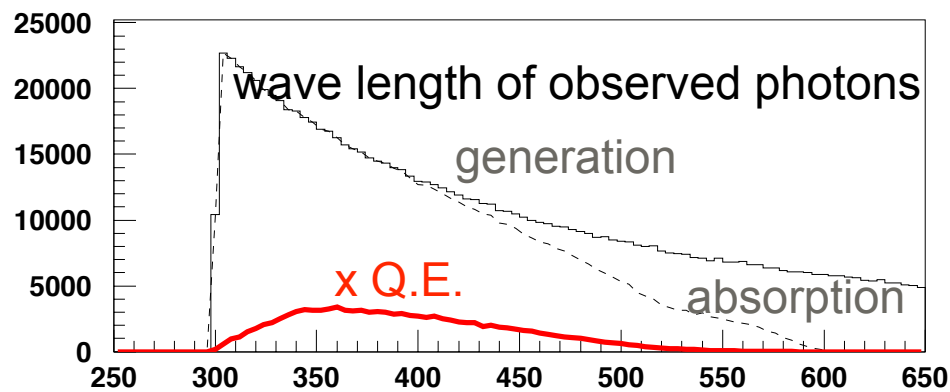
**Fiducial volume uncertainty
0.1%**

Calibration at fiducial edge



Vertex calibration

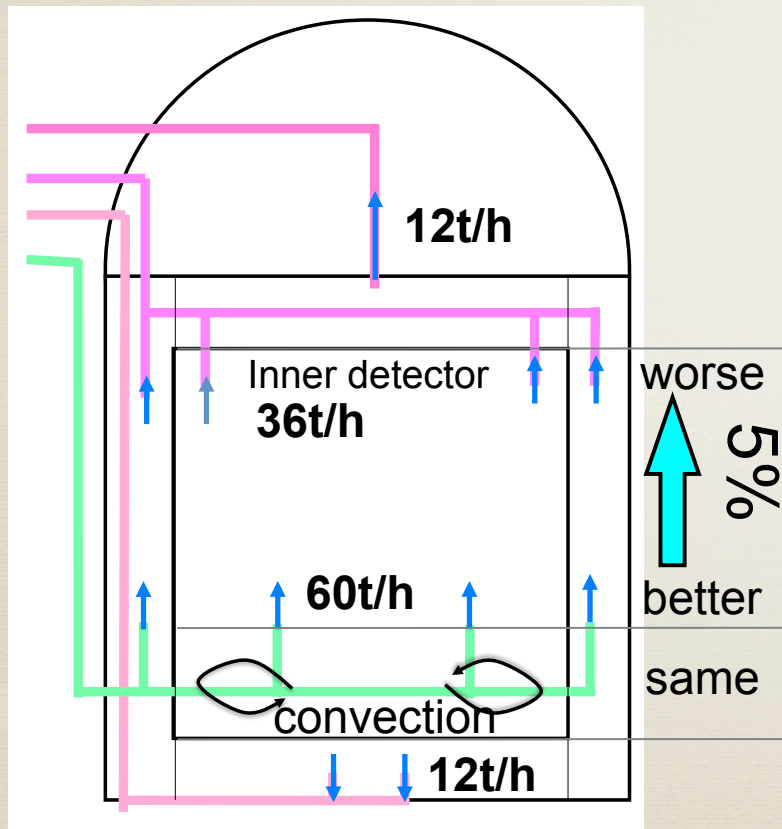
Water Cherenkov detector : Arrival timing has dispersion



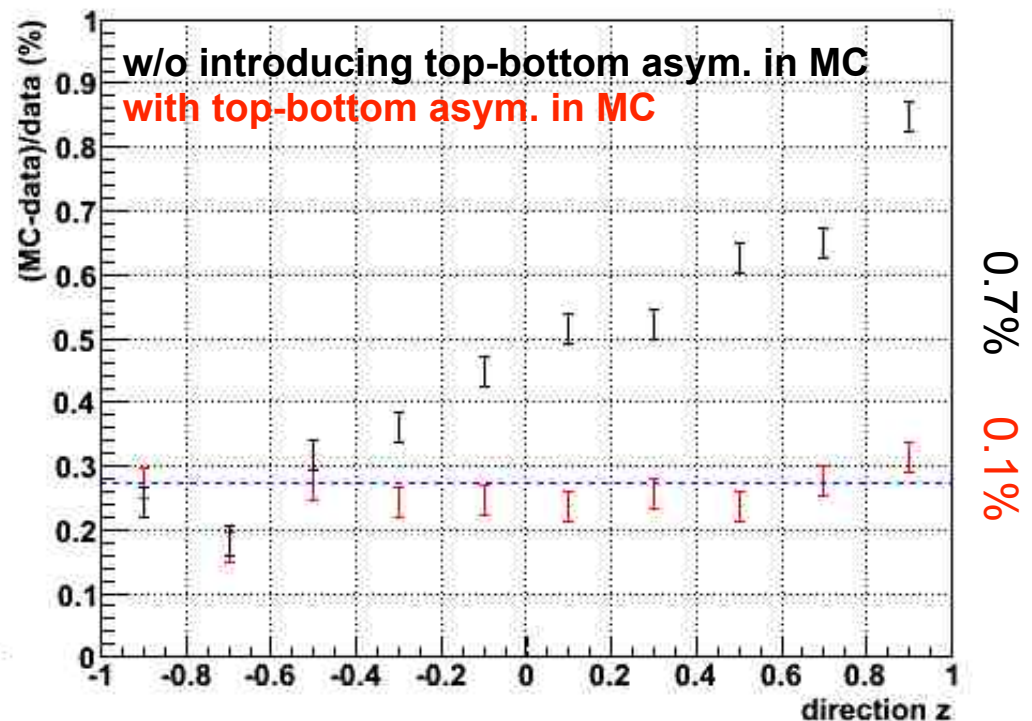
Need full simulation

Water quality

From the SK experience

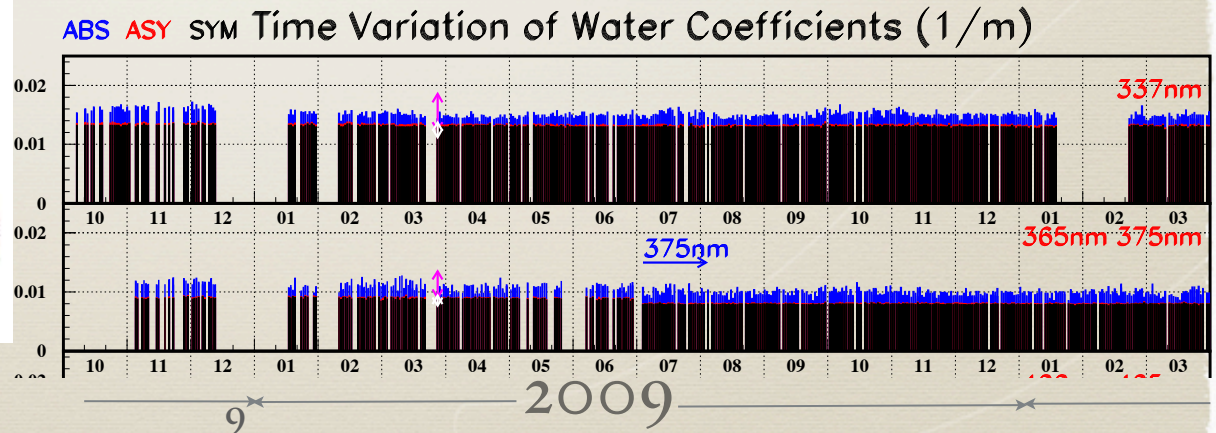
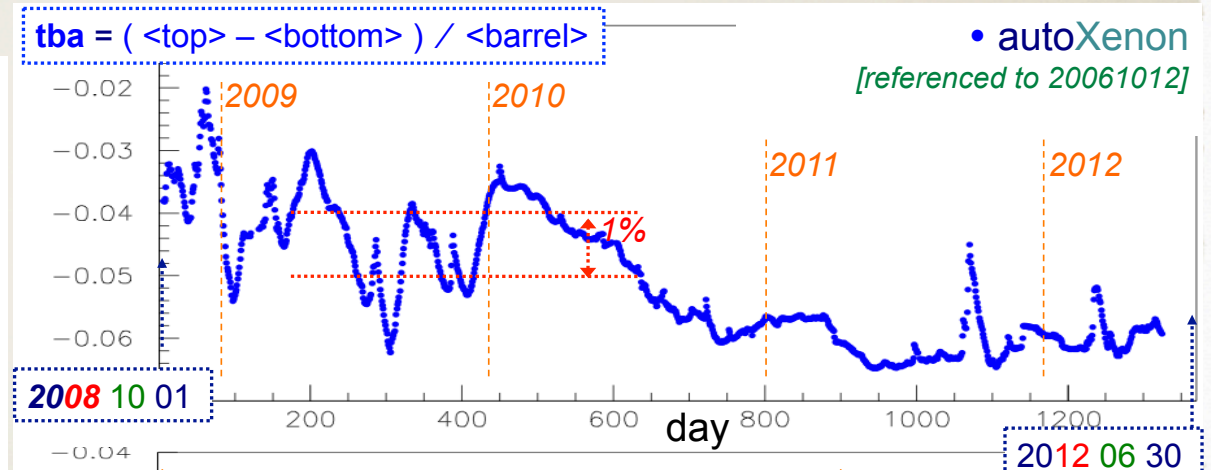
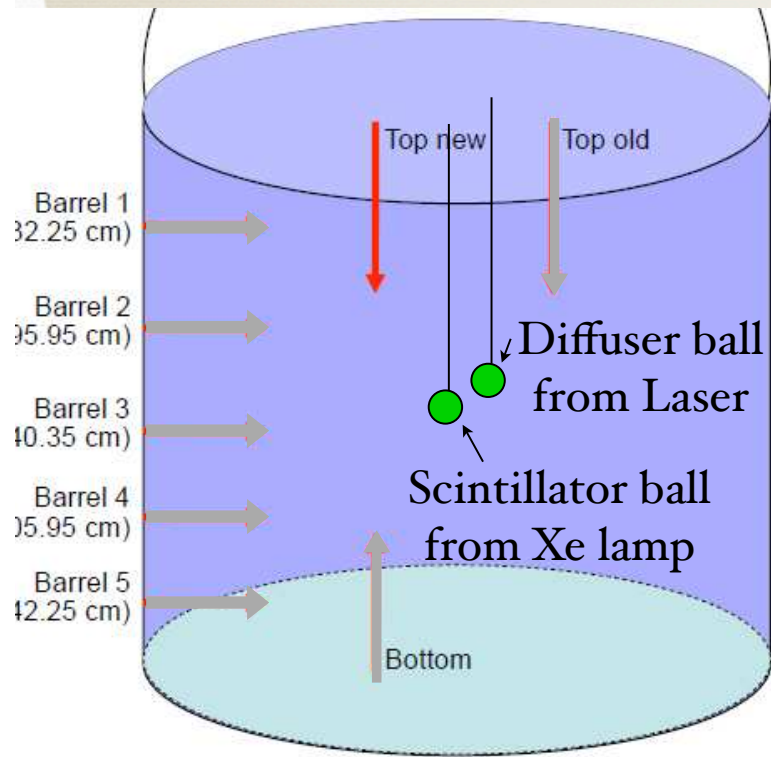


Zenith angle dependence
of the energy scale done
by DT calibration



Water quality

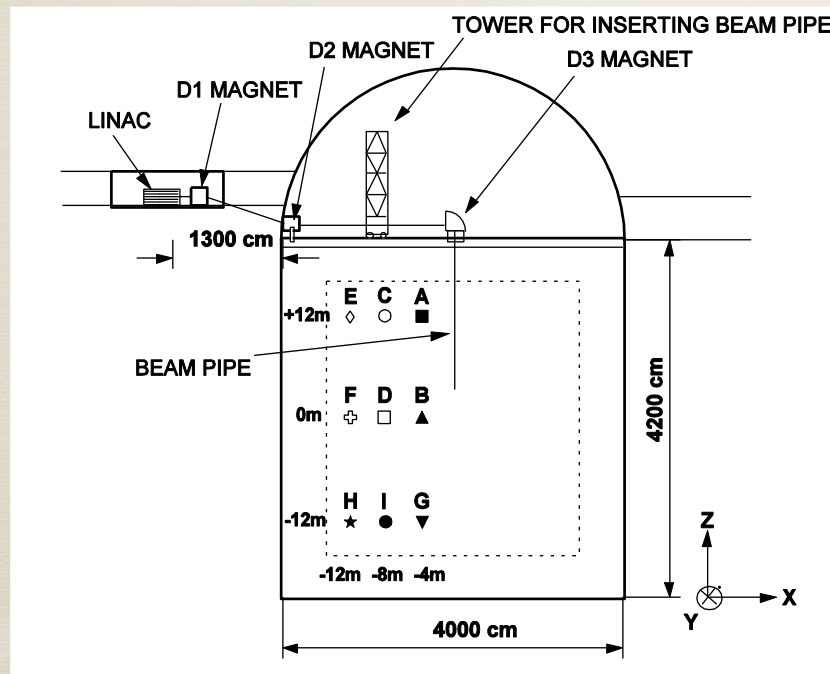
Long term stability check is also important



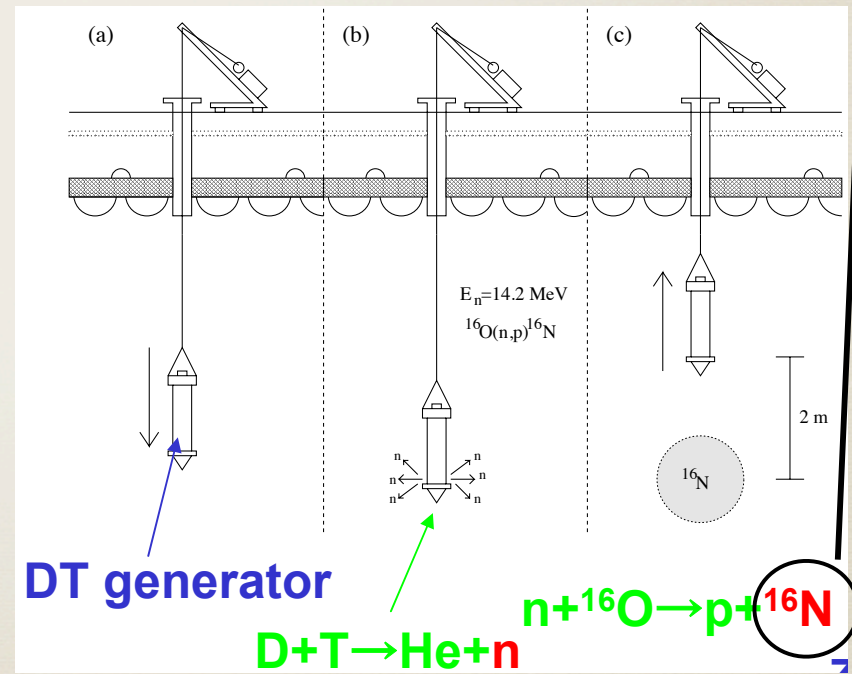
Energy calibration

From the SK experience

LINAC : monochromatic electron beam



DT : β 4.3 + γ 6.1 (66%)
 β 10.4 MeV (28%)



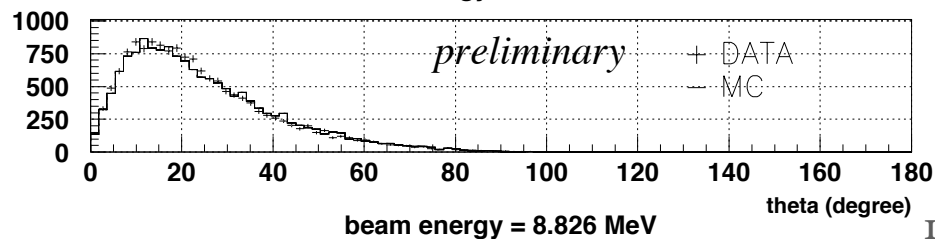
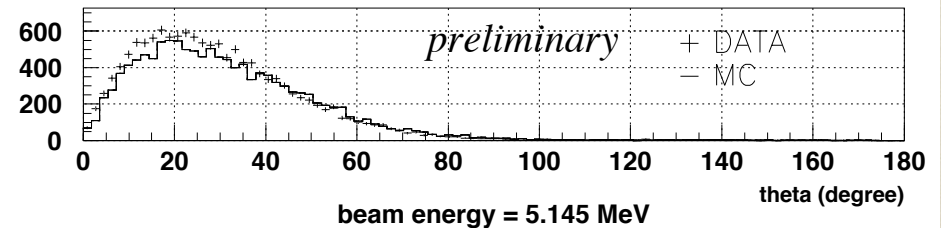
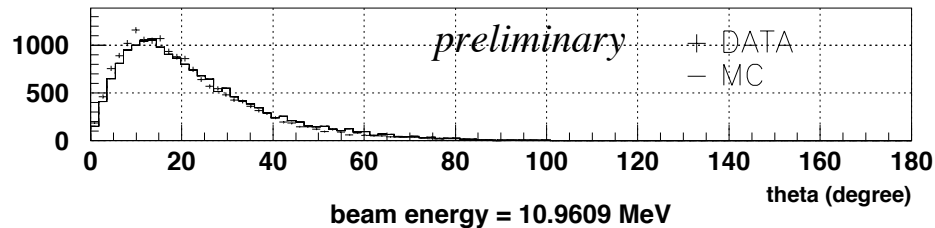
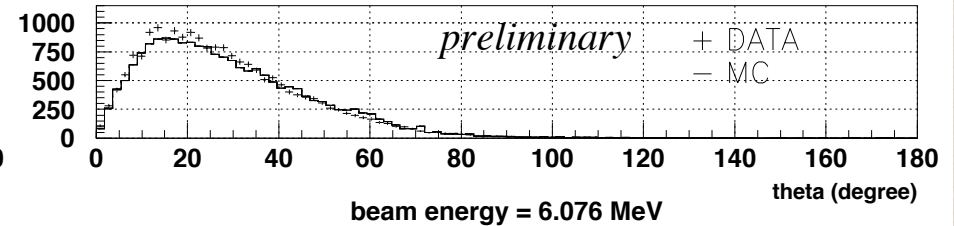
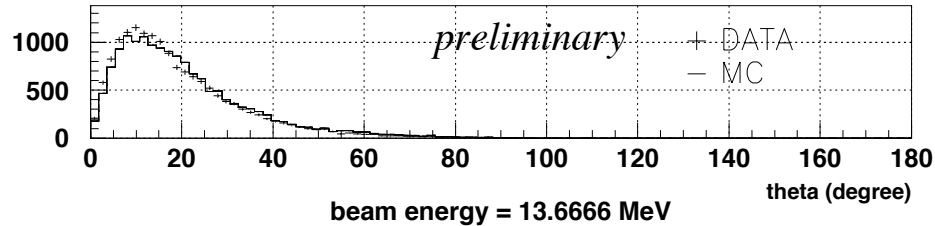
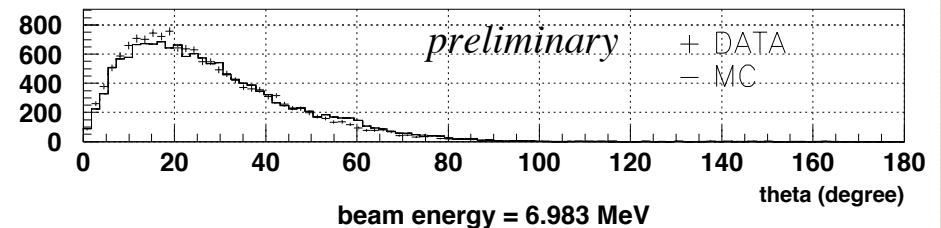
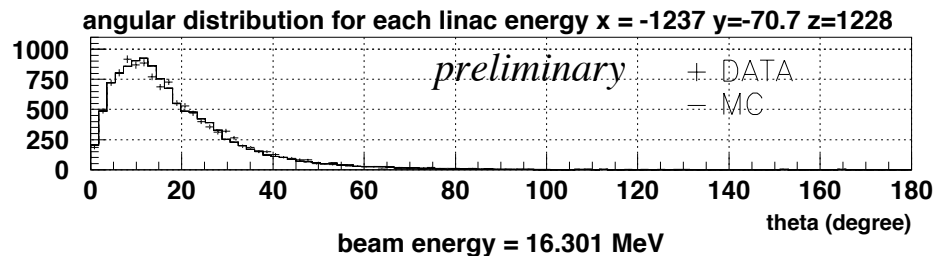
Uncertainty of absolute energy scale is $\sim 0.5\%$

Idea for HK

- (1) Same as SK, LINAC and DT in every position
 - Need if the solar neutrino spectrum is a target. (seems to be very hard.)
- (2) Combination of several tools.
 - Compare LINAC and DT in 40% coverage segmentation (if exist) or SK, and only DT in every position.
- (3) Higher energy calibration is preferable for SN neutrinos
 - Development new sources, e.g. pT generator (19.8MeV γ)

Directional calibration

From the SK experience



LINAC