Background Study for thin Hyper-K OD

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Introduction

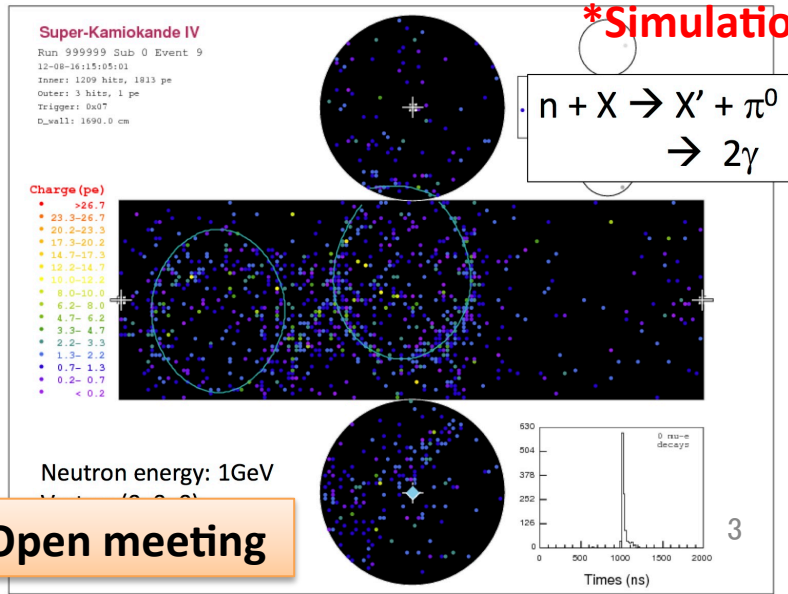
- **With thinner OD of Hyper-K, external background will be increased due to less shielding by OD water layer.**
  - **High-energy background**
    - **High-energy neutron**
  - **Low-energy background**
    - **Low-energy gamma**
  - **Direct cosmic muon background (Common.)**

- **Direct muon background will not be discussed. Here, the muon detection efficiency of OD is considered as same as current OD. It will easily reject the direct muon background.**

High-energy background

- **At Hyper-K 1st Open meeting, the background for atmospheric neutrino and proton decay was discussed by Okumura-san.**
- **Here I review his study and discuss the effect of thinner OD.**

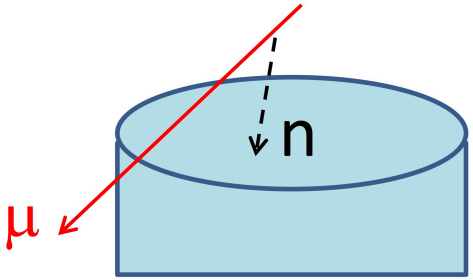
- High-energy neutron generated by cosmic muon and its π^0 production was simulated. (SK 50 years)
- Spallation radioisotopes is not problem in high energy analysis. (E>30MeV)



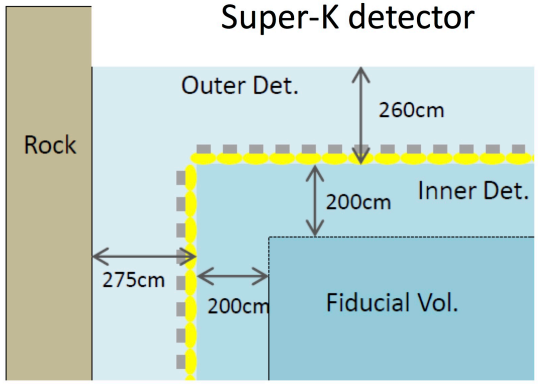
Okumura, HK 1st Open meeting

Shielding against neutron

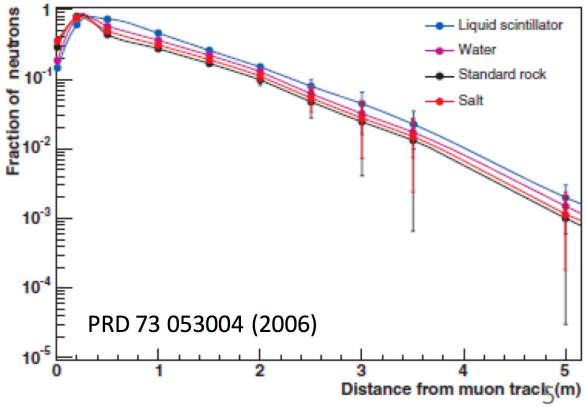
1. Self-shielding by water
   - 4.6~4.7 meter shield around fiducial volume can attenuate neutron significantly
2. Coincidence with primary cosmic muons
   - neutrons are spatially correlated with muon track
   - Using large detector, neutron events can be rejected by taking coincidence with muons



Super-K detector



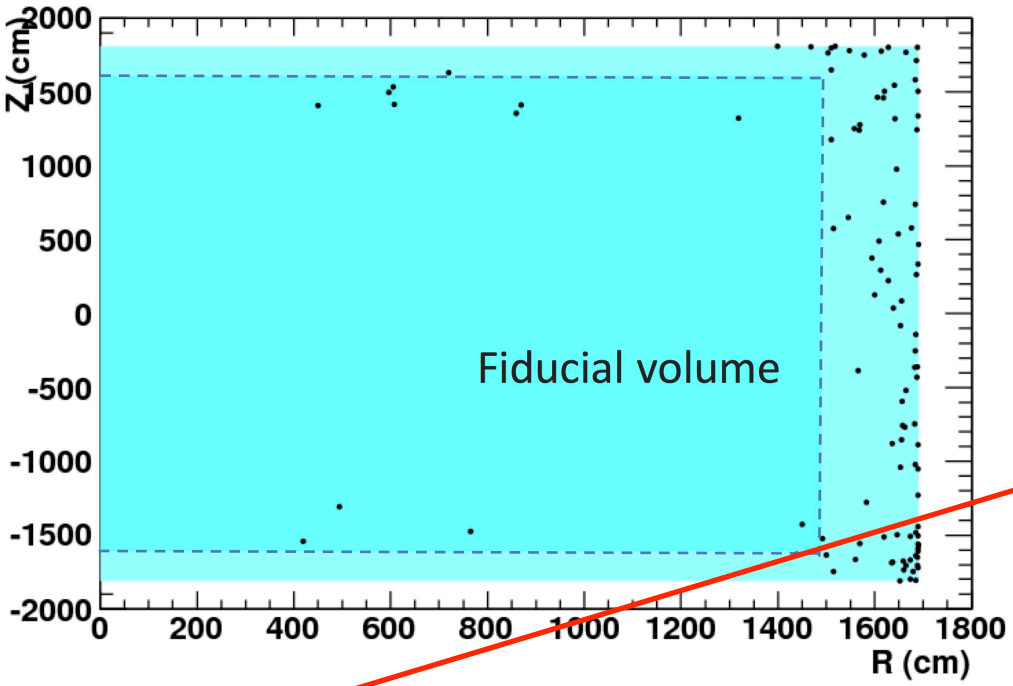
Lateral distribution from muon track



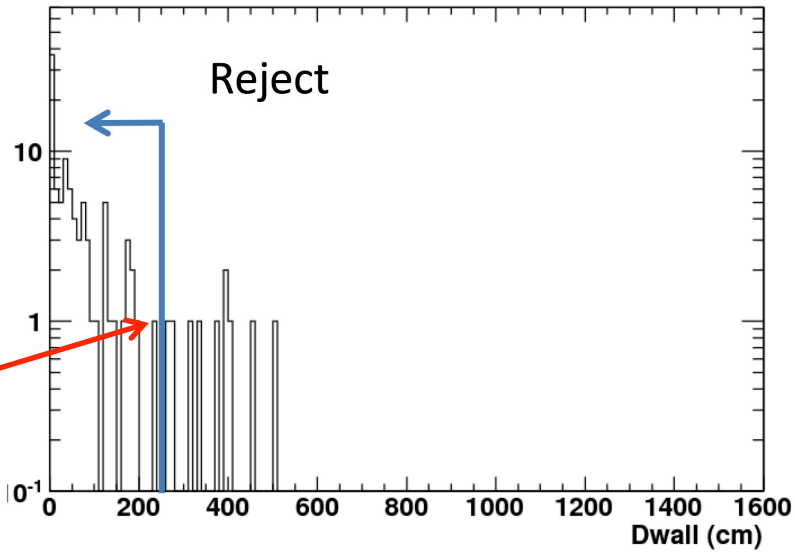
- **Shielding effect will be decreased, when the detector get thinner. (OD 2.5m -> OD 1.0m)**

Reconst. vertex distributions

After FC cut
(nhitac<16 && Evis>30 MeV)



Fiducial cut :
(distance to nearest detector wall : dwall) < 200 cm



- **11 events for distance to wall > 200,**
- **26 events for distance to wall > 100 (OD 1.5m)**
- **42 events for distance to wall > 50 (OD 1.0m)**

Event summary and BG estimate

	N (/50yr)	Event / year (SK site)
Entering neutrons	4.5×10^8	8.9×10^6
w/o muon coincidence	1.1×10^7	2.1×10^5
FC	105	2.1
FCFV	11	0.2

Number of FVFV events in one year at Super-K:
~3000 events / year / SK

Background rate of FCFV events at Super-K site :
0.2 / ~3000 = 7×10^{-3} %

26 events for OD 1.5m
42 events for OD 1.0m

- The rate of spallation products is studied by I. Shimizu at HK 4th Open Meeting. ×2 for Mozumi and ×4 for Tochibora. (In water.)
- Assuming these factors, BG rate at HK will be
  - OD 1.5m : 0.03 % (Mozumi) – 0.07 % (Tochibora)
  - OD 1.0m : 0.05 % (Mozumi) – 0.11 % (Tochibora)
- It is almost same as okumura-san's study.(before. 0.07) ~0.1% BG rate will be OK.

The factor was 8 at Okumura-san's study.

Summary for High-E

- **Background rate of neutron produced by cosmic ray muons in rock was discussed.**

- **The neutron background is negligibly small (the order of 0.1%).**
  - **The OD muon detection efficiency is assumed to be same as current SK OD.**

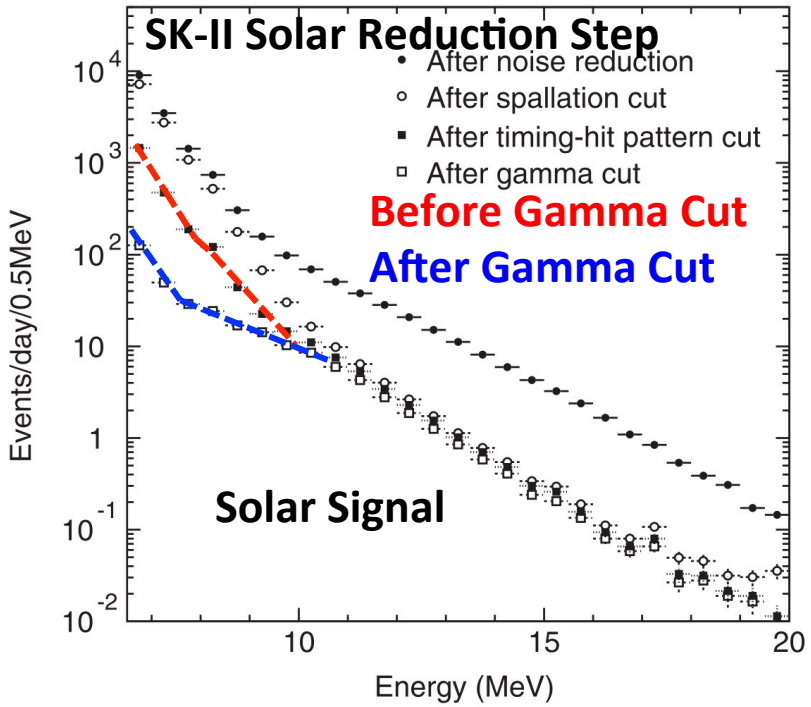
  - **K^0_L was also studied by Okumura-san and negligible with 50yr simulation.**
  - **This time, the neutron flux was almost same as before. So K^0_L will be also negligible.**

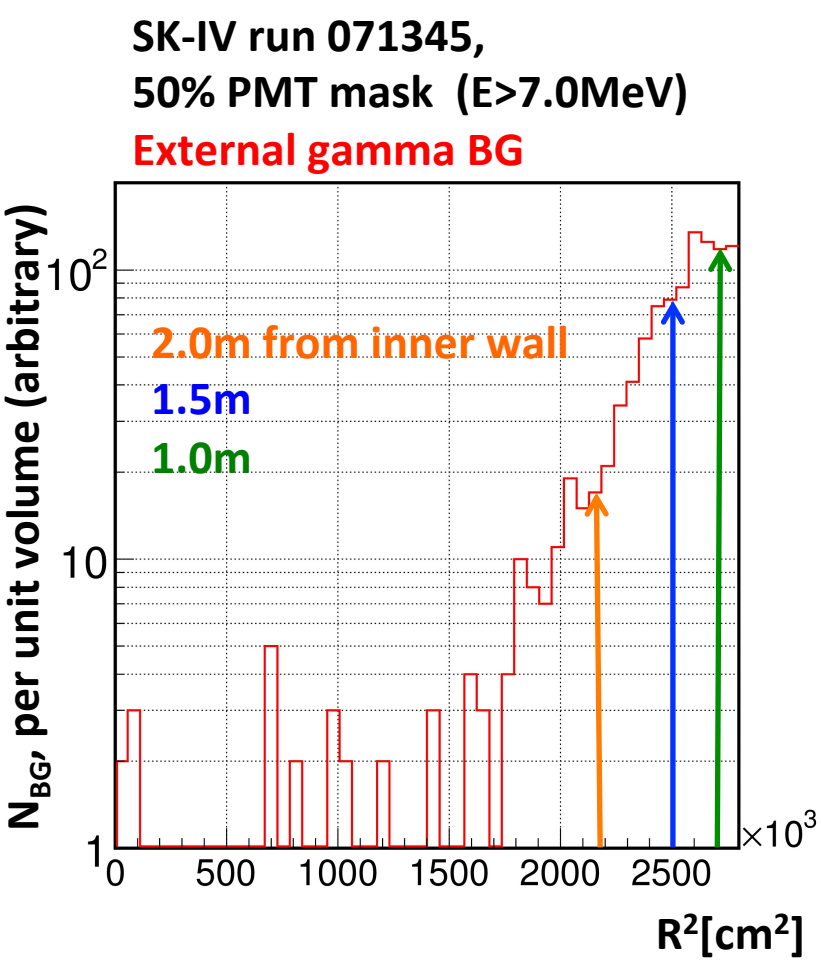
Low-Energy Background

- **The main external background for low energy analysis is incoming gamma-ray.**
- The source of γ is not determined. The possible candidates are :
  - Radioisotopes in PMT and FRP(only for SK-III, IV)
  - Radioisotopes in Bedrock around SK
- Only the γ from rocks can be increased due to less shielding effect with thinner OD.
- Here, we won't separate these incoming BG for conservative estimation.
- **Incoming Muon will not be discussed here.**
- Muon spallation products is a BG of low energy analysis. The spallation reduction, including muon reconstruction is done by ID. So the effect of thin OD can be ignored.

External gamma-ray background

- With thin OD, γ-ray background can be increased by 4-6 times.
- It will not affect to SRN search region, E > 18 MeV.
- **For solar 7 – 10MeV analysis, the effect is not negligible.**



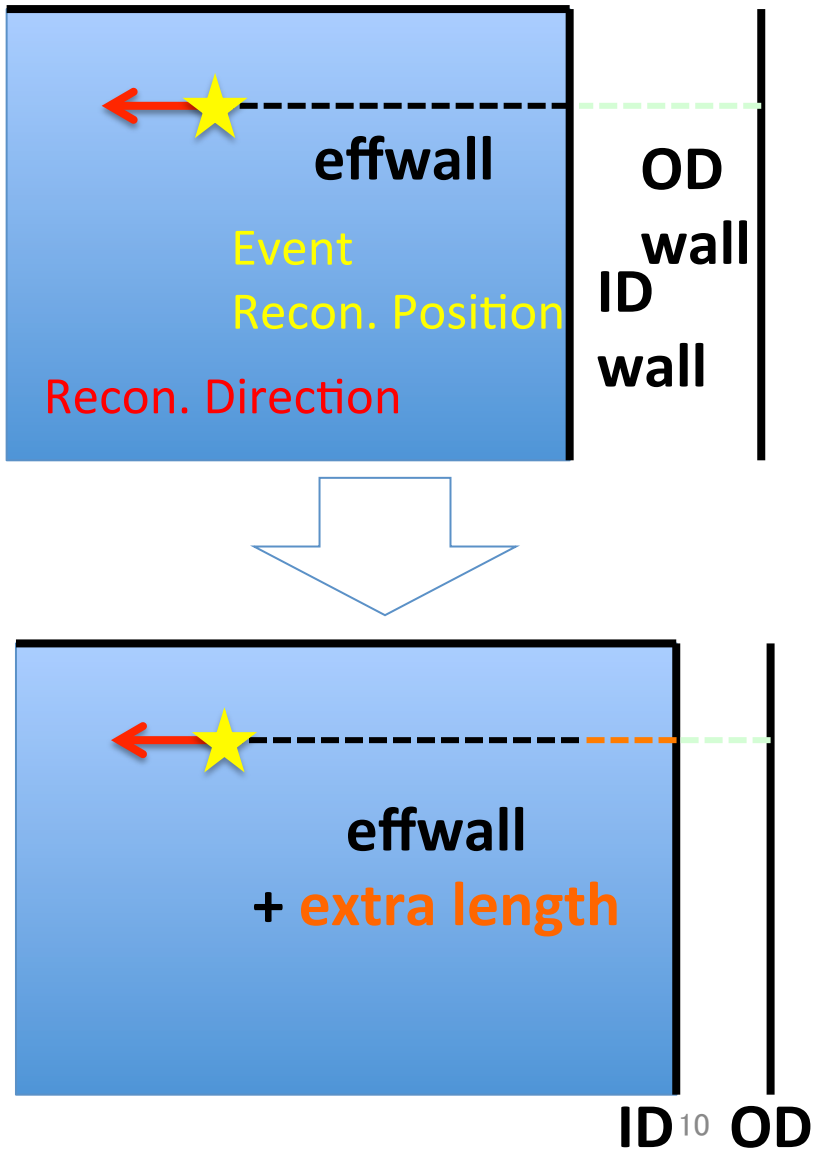


OD 1.5m : ×~4 of curernt BG

OD 1.0m : ×~6 of current BG

Gamma-ray Reduction at Low-E

- For gamma-ray reduction, we apply a cut to effective distance between event and ID wall (effwall).
- If we add extra length to effwall, it will cancel the effect of thin ID.
  - For 1.5m OD, effwall+1m
  - For 1.0m OD, effwall+1.5m



Signal Efficiency with longer effwall

- The solar signal efficiency will be decreased by adding extra length to effwall.
- The effect is estimated with toy MC. (uniform 8MeV γ MC with SK-II.)

Solar signal efficiency with thin OD

Effwall cut + L	7-7.5 MeV cut	8-8.5 MeV cut	9-10 MeV cut	10-30 MeV cut
L = 0 m (OD 2.5m, SK)	66%	79%	91%	95%
L = 1m (OD 1.5m)	62%	74%	87%	91%
L = 1.5m (OD 1 m)	60%	72%	85%	89%

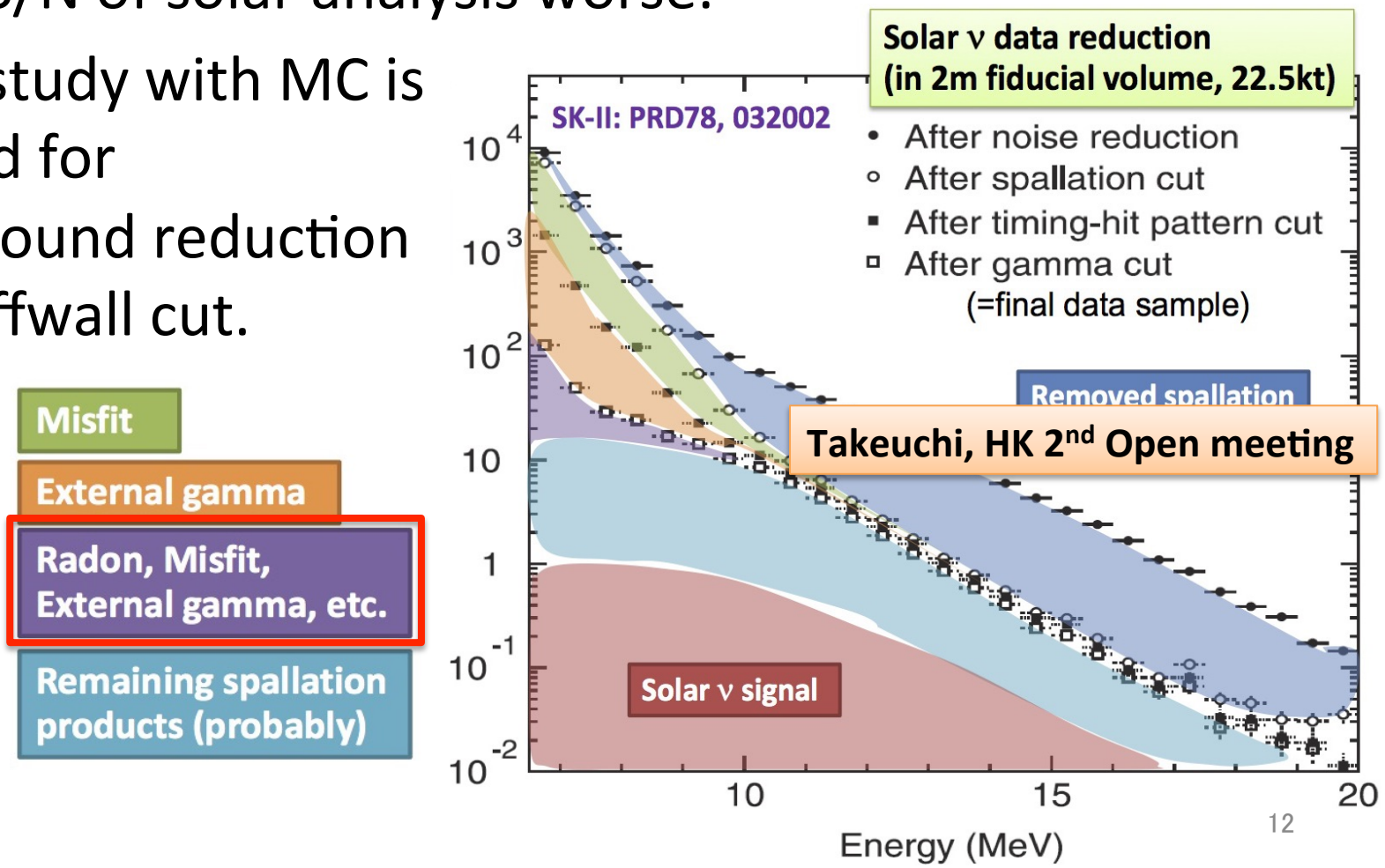
91-94%

94-96%

- The signal efficiency can be decreased to 91-94% (OD 1.5m) or 94-96% (OD 1.0m). This will be acceptable.

Reduction Step at SK-II

- Unclear background is left after reduction step at SK-II.
- If it is remaining (and not reducible) gamma, it will make S/N of solar analysis worse.
- More study with MC is needed for background reduction with effwall cut.



Summary for Low-E

- **The dominant external background for low energy is gamma.**
- **An estimation was done by assuming that all of gamma is coming from bedrock.**

- With 1.5m OD or 1.0m OD, the amount of background will be increased by 4 or 6 times of current SK analysis.
- The increased gamma-ray will be dealt with increased effwall cut.
- It will affect on solar analysis and it will reduce the signal efficiency to 91-94% or 94-96%. For now, the number is acceptable.

- More study with MC will be needed to prove the reduction with effwall cut.
- Thight FV also can be a option for external background.