JSNS^2 Detector Construction

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High Energy Accelerator Research Organization (KEK)
with JSNS^2 Collaboration

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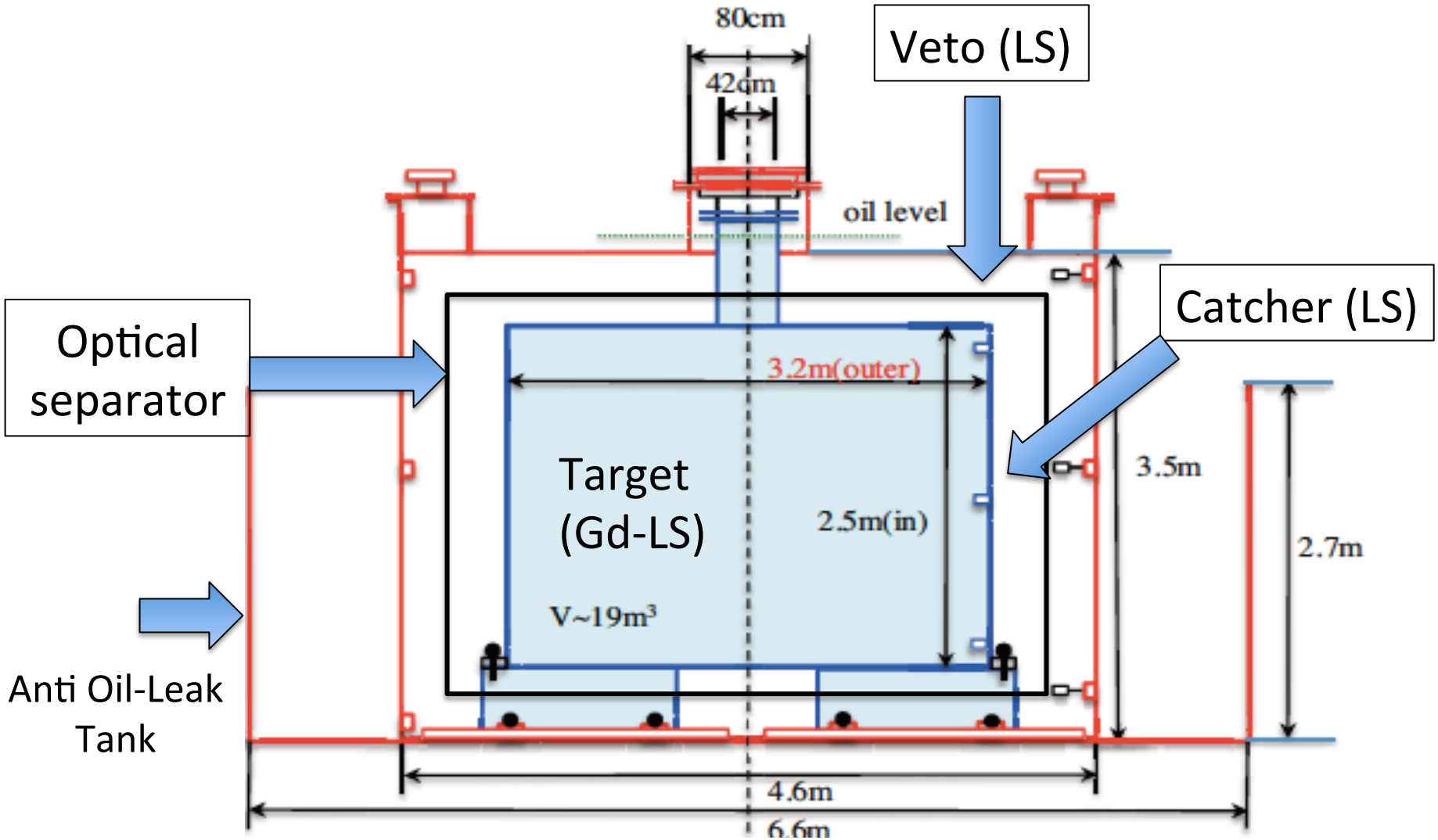
KPS Fall 2017, HICO, Korea

Contents

- Concept of the JSNS^2 Detector
  - Target / Catcher / Veto
  - Optical separator
- PMT Installation scheme
- Production of Gd-LS / LS
  − DayaBay / RENO
- Filling / extracting scheme
- Calibration / Monitoring
- Summary

Concept of the JSNS^2 Detector

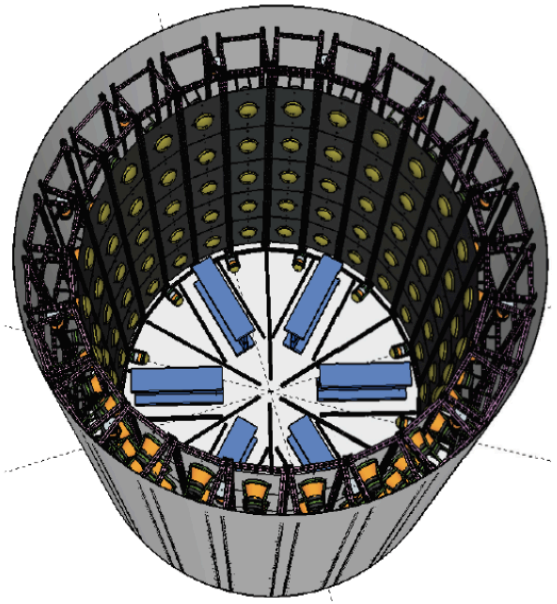


Concept of JSNS^2 Detector

	Radius[m]	Height[m]	Filled with	Volume [m^3]	Material
Target	1.6	2.5	Gd-LS	19.3	Acrylic
Catcher	1.85	3.0	LS	35 in total	**
Veto	2.3	3.5	LS		Stainless steel
Anti oil-leak tank	3.3	2.7	air	84	Stainless steel

- Target + Catcher 193, 8 inch PMTs
  (Barrel : 24 × 5 , Top / Bottom : 36 with 3 rings)
- Veto 48, 5 inch PMTs

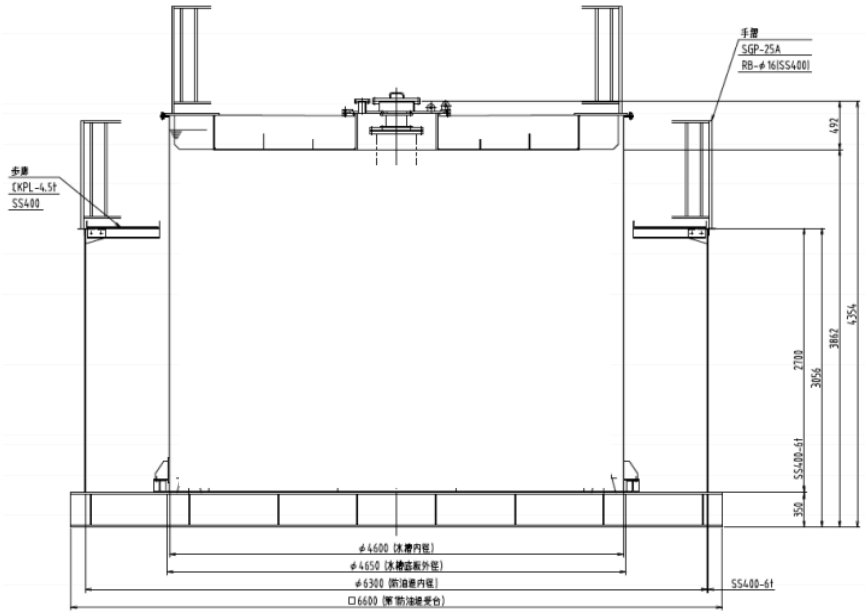
** Optically separated with PMT structures
➔ LS can passing through between
"Catcher" and "Veto" region



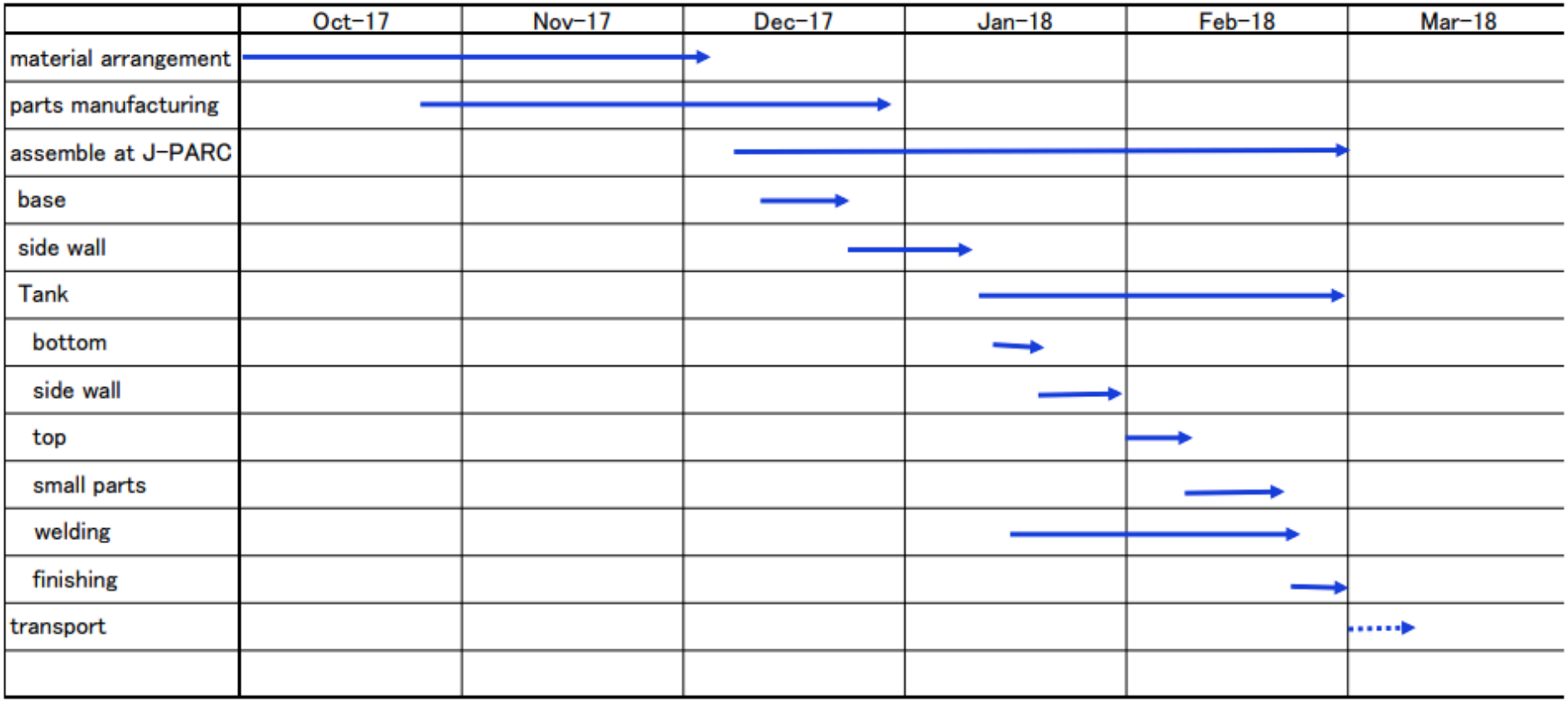
Status of Preparation of Detector vessels

Acrylic vessel
- Under preparation of detailed design / bidding documents
- Bidding will be started around next Apr

Stainless steel
- Finished the bidding procedure
- Morimatsu win the bid (http://www.morimatsu.jp)



Construction schedule of Veto vessel + Anti-oil leak Tank

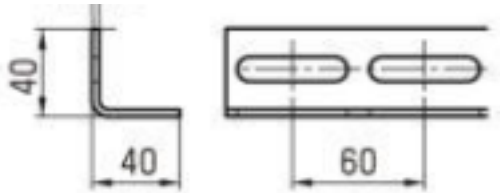


Detailed schedule was made by company.

➔ Construction will be finished until Mar, 2018.

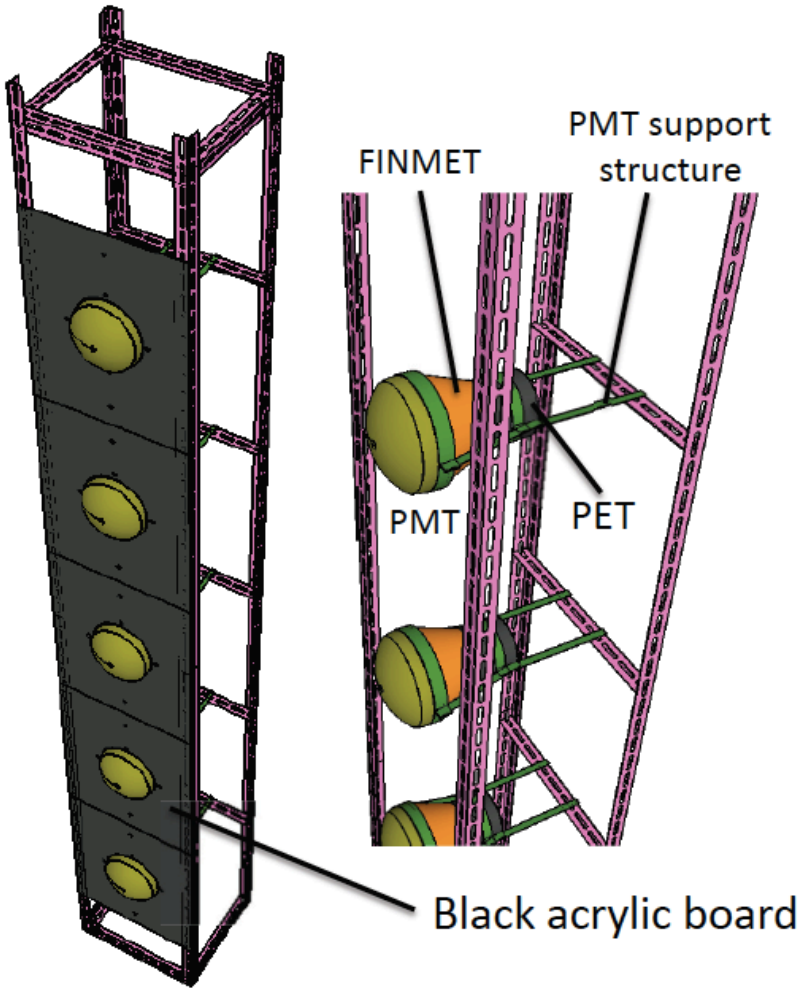
Optical separator with PMT Support Structures

Barrel
- 5 PMTs in one column
- Frame is made by L-angle



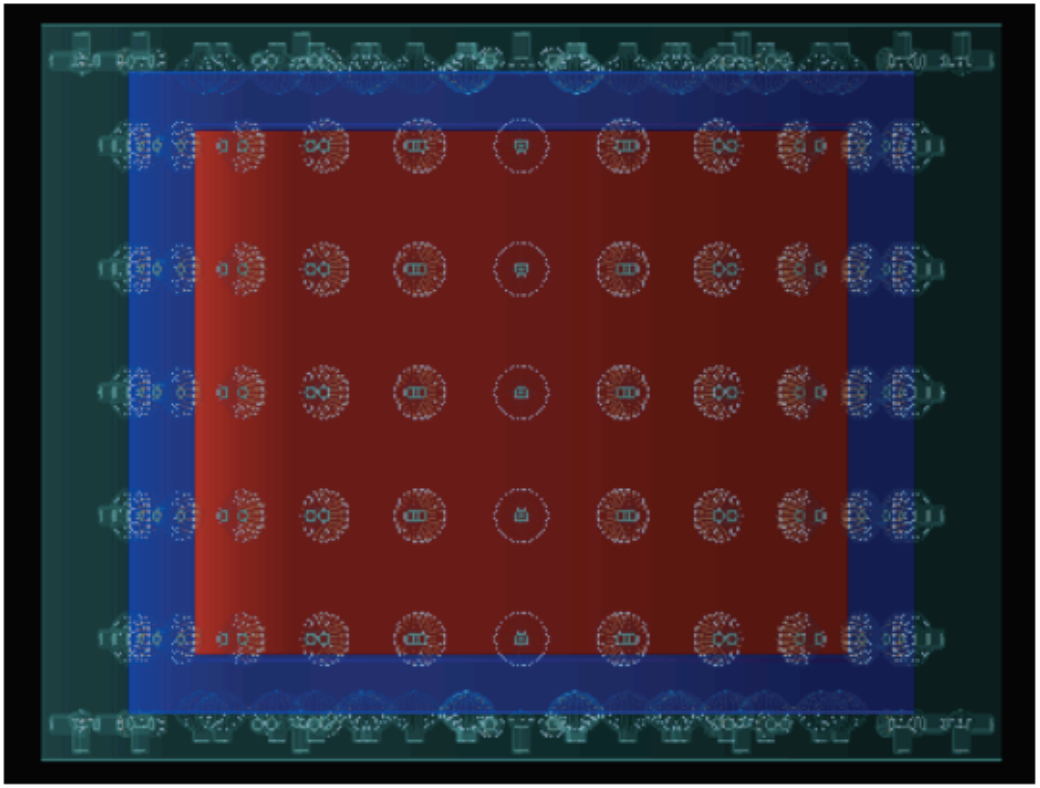
3mm thickness

Top / Bottom
- Three ring shape
  (6, 12, 18 PMTs)
- Frame is made by L-angle

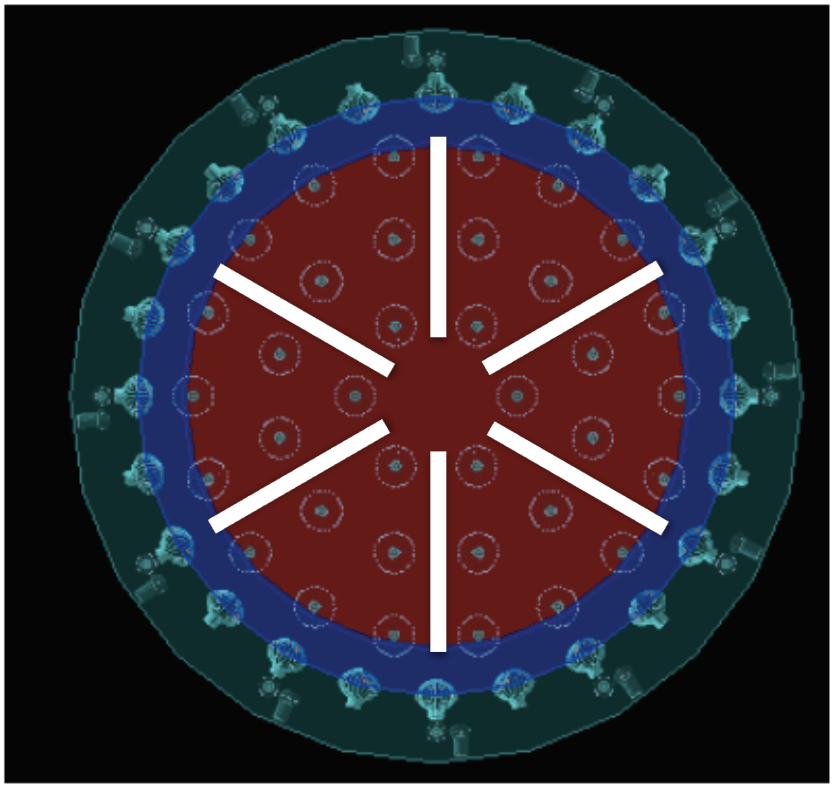


PMT positions

- Drew with MC



Side view



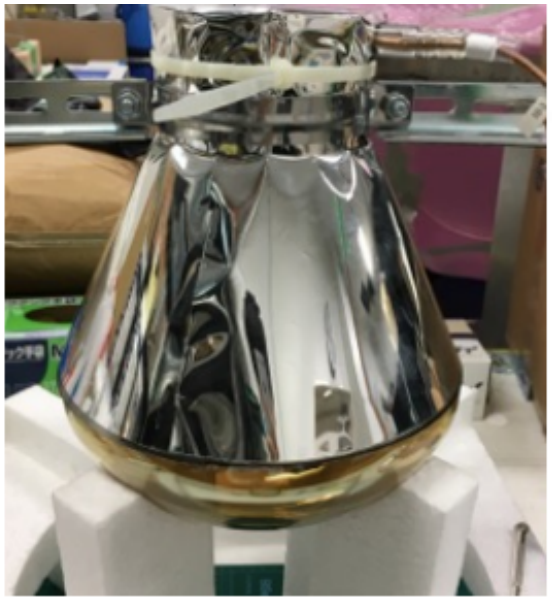
Top view

Assemble Covers to PMTs

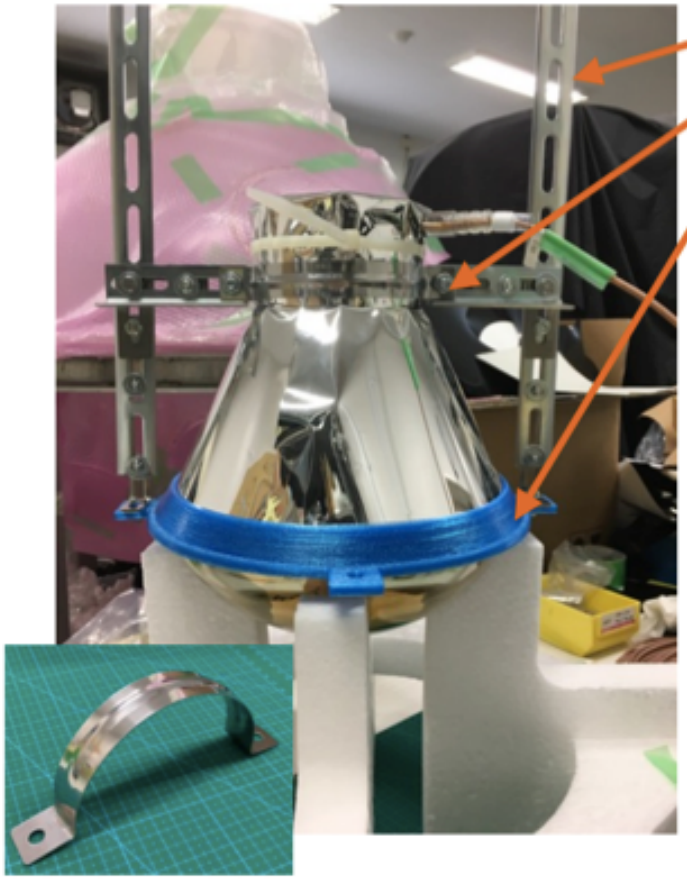
Three different layers to cover individual PMTs

- **Black PET** : Avoid flashing from PMT
- **FINEMET** : Shielding of magnetic field
- **RuireMirror** : Increase reflectivity to increase light collection efficiency of Veto

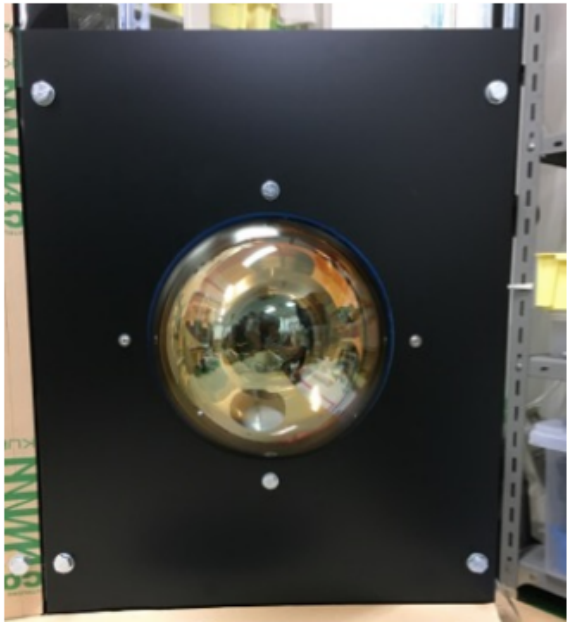
Inner to Outer



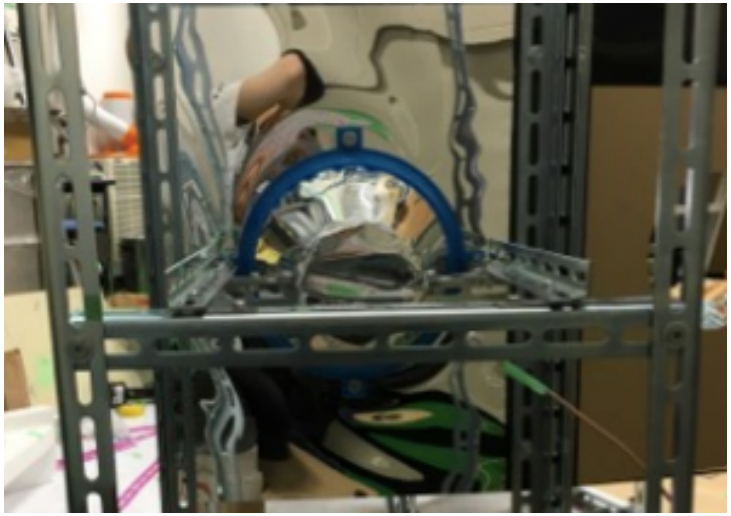
Attach PMT to L-angle



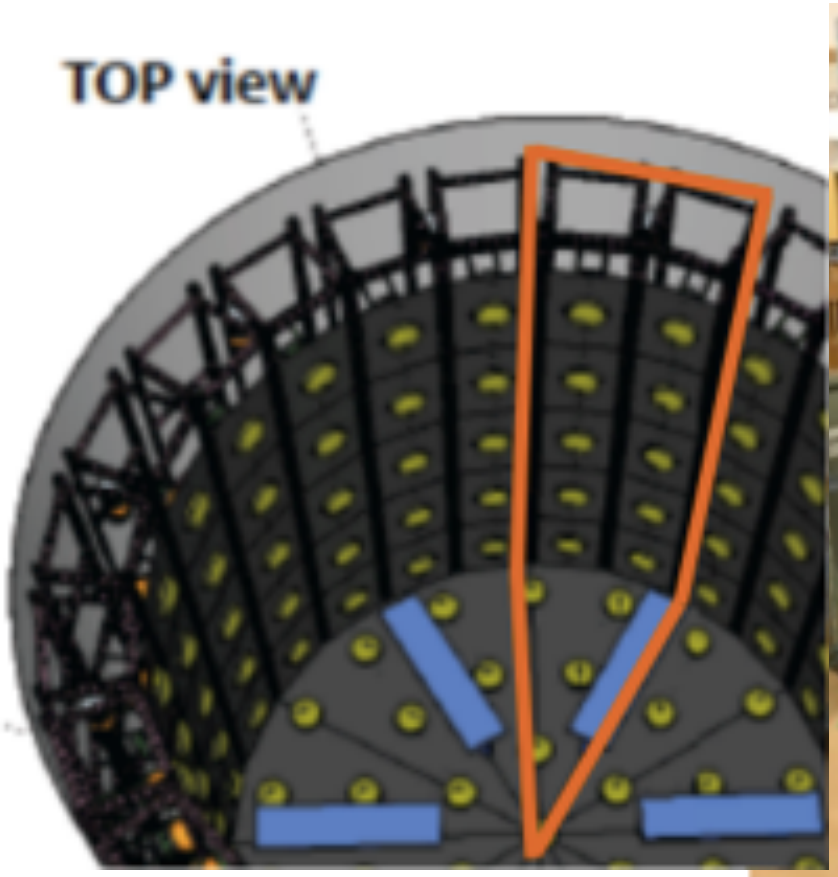
Front View

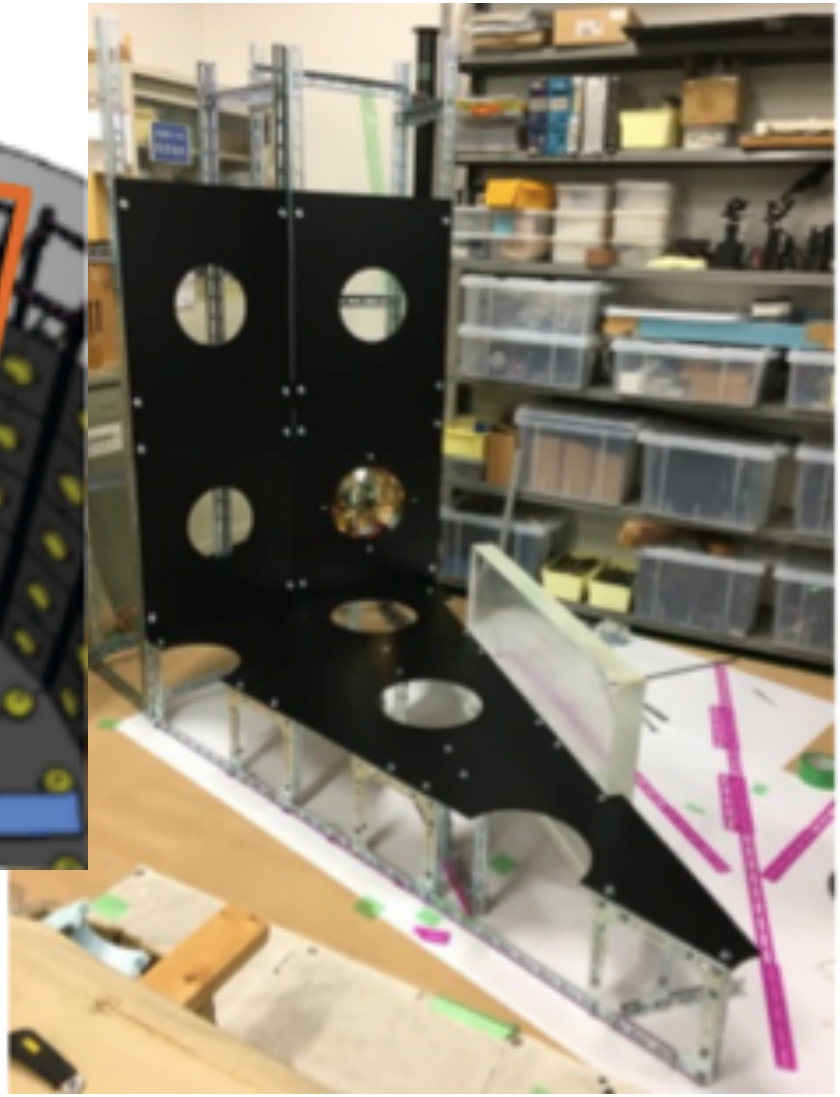


Rear View



Installation test of Barrel / Bottom pieces

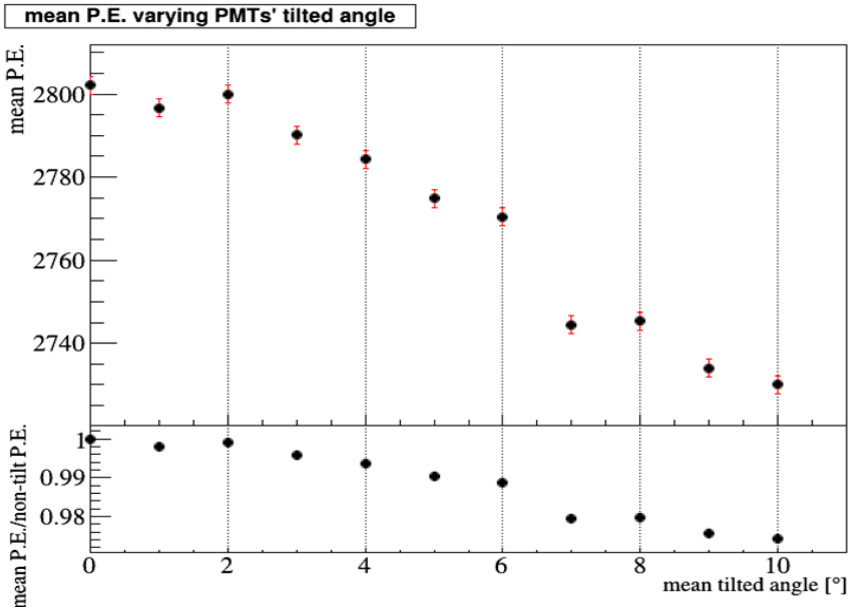


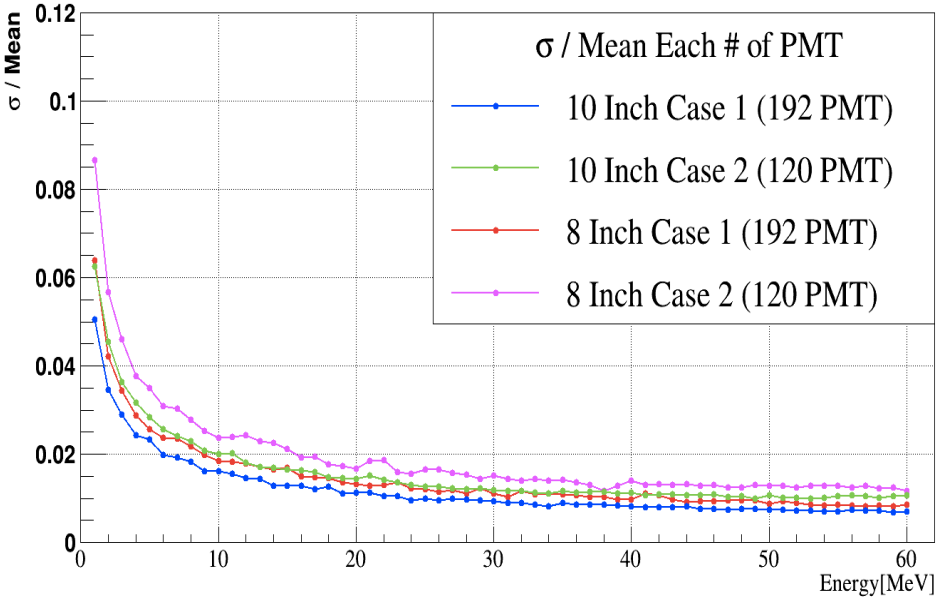


Monte Carlo studies with poster presentation

- Study of PMT configuration in the JSNS^2 experiment.
 by HyoungKu Jeon, P2-pa.124

- Study of Effect of PMT Tilt on Charge Collection in the JSNS^2 Detector
 by Sanghoon Jeon, P2-pa.128



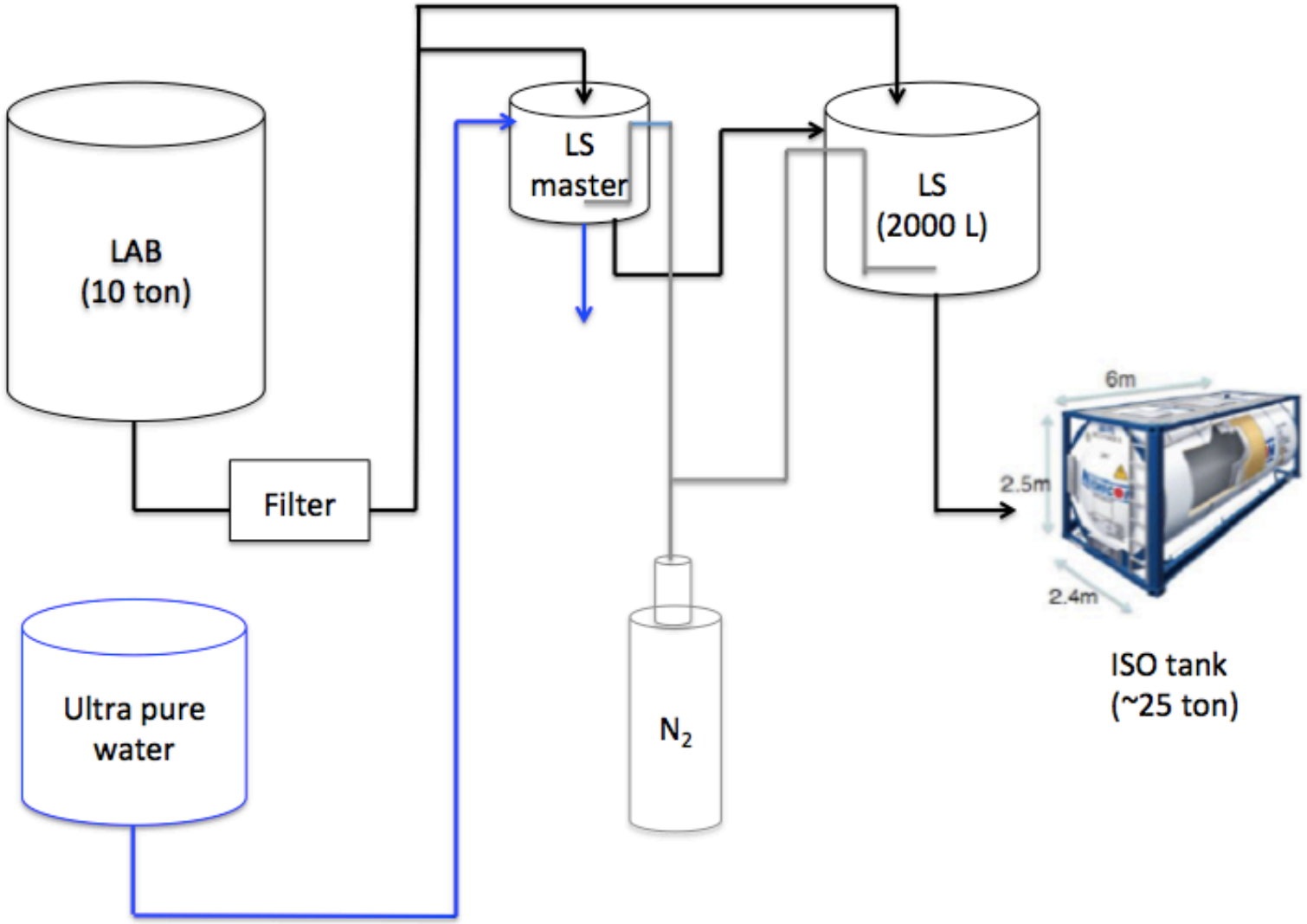


Production of Gd-LS / LS

Produce at RENO site after refurbishing the production facility.

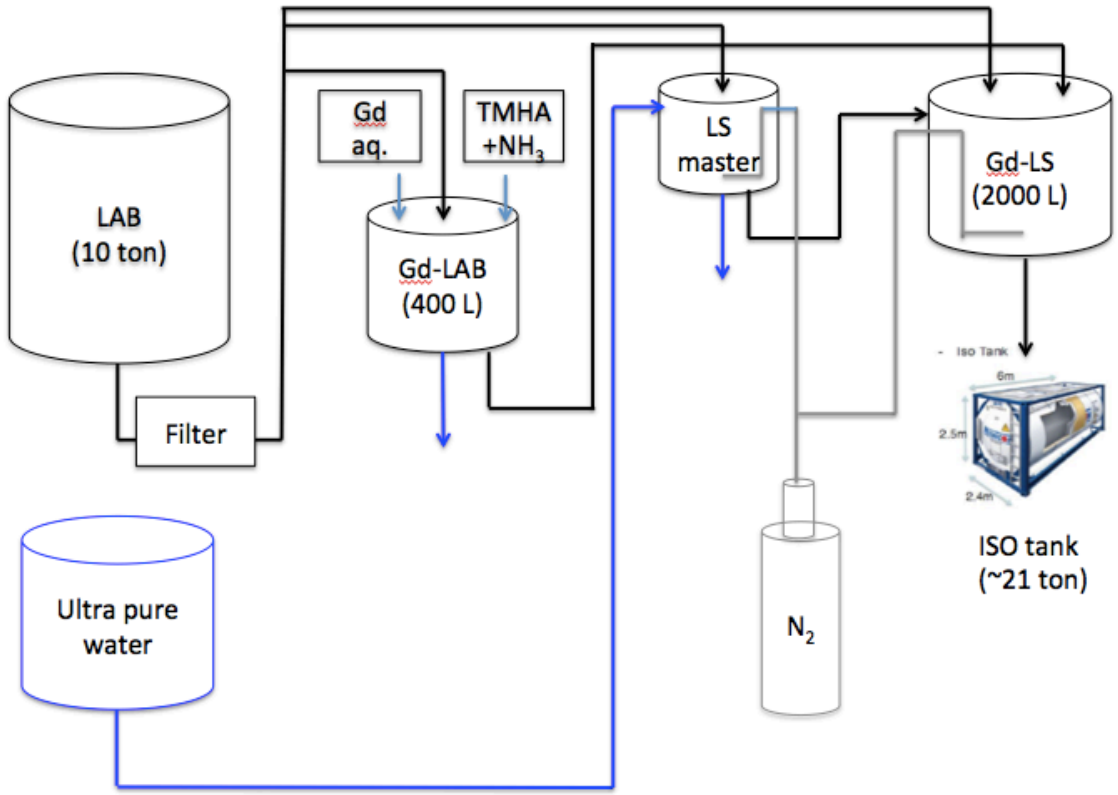
Production of LS

Production scheme at RENO site



Production of Gd-LS

Production scheme at RENO site



Or, there is possibility of Donation from DayaBay.
- Got positive response from Spokes person of Daya Bay at Jul, 2017.
- Letter of donation is under discussion.

Filling and extracting of Gd-LS / LS

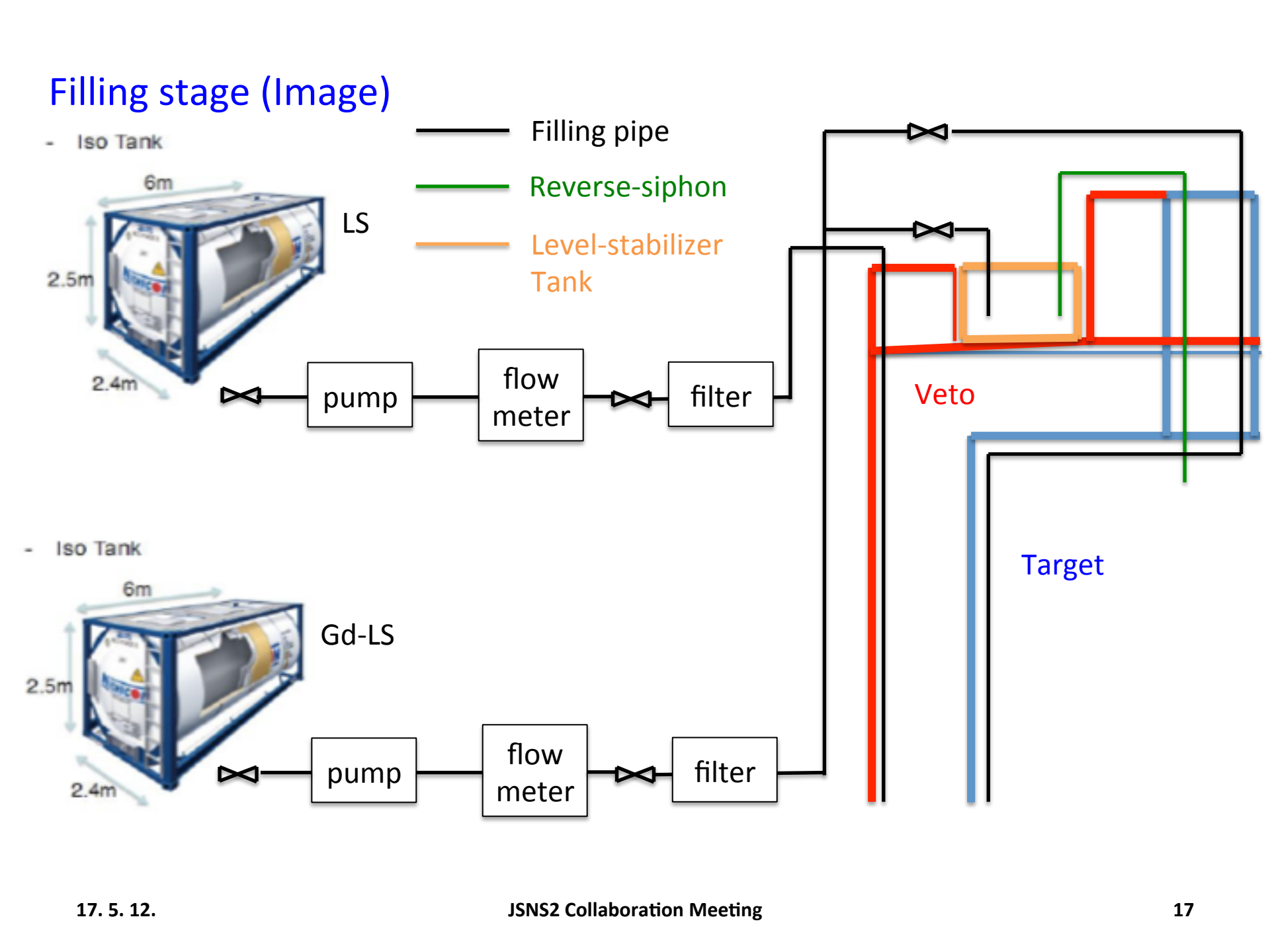
- If emergency is happen at mercury target, detector is required to be moved within one week.
  ➔ Filling or extracting should be finished within few days.

- Flow path of Gd-LS should be not any metallic material.
  ➔ MEGA 960 from TREBOR company. (DC also used it)
  Flow path is made by PFA / PTFE
  Max 95 LPM (5.7 ton / hour), 5.5 m suction lift.

- Liquid height of target, gamma-catcher, veto should be similar.
  ➔ Need to install flow meter, and distance measurement sensor.

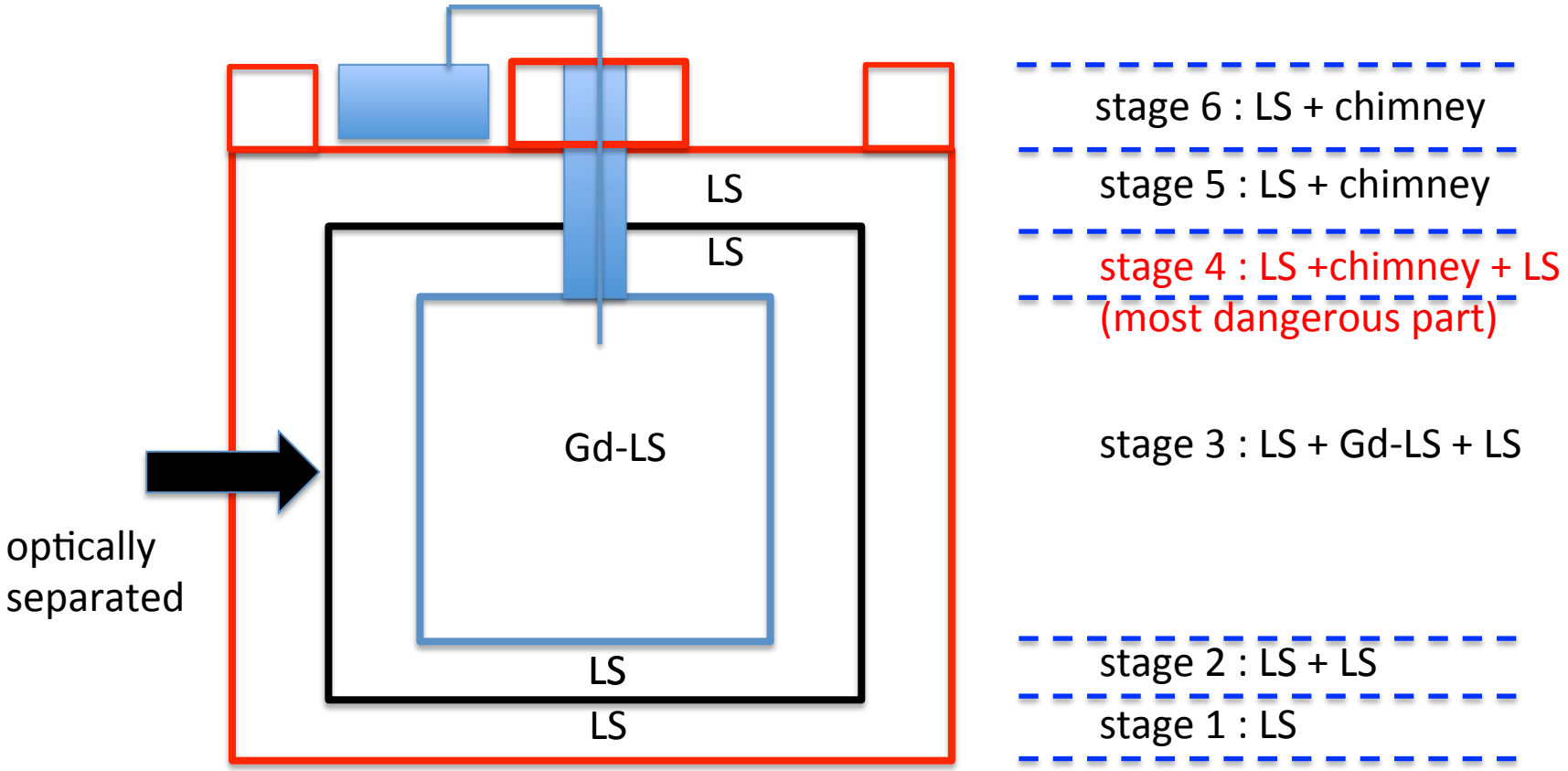
- Filter will be used to prevent dust.

Filling stage (Image)



Filling stage

- We assumed that even with optically separation,
  liquid can go through between gamma-catcher and veto.
  (stage 1,2 and stage 4, 5 can be combined)



Flow rate

Flow rate is roughly proportional to area.

- Volume of PMT, optically separation, installation part (~ 4000 L) is considered evenly.
- Max flow rate is assumed to 30 LPM in reality (30% of maximum capacity).

	Target [LPM]	Catcher + Veto [LPM]	Height [cm]	Volume Tatget [L]	Volume C + V [L]	Time [h]
stage 6	0.1	1	12	4 + tank	tank'	few
stage 5	0.1	30	25	8	4000	2.2
stage 4	0.1	30	25	8	4000	2.2
stage 3	30	29.5	250	19350	19000	10.8
stage 2	0	30	25	0	4000	2.2
stage 1	0	30	25	0	4000	2.2
Total				19370	35000	19.6

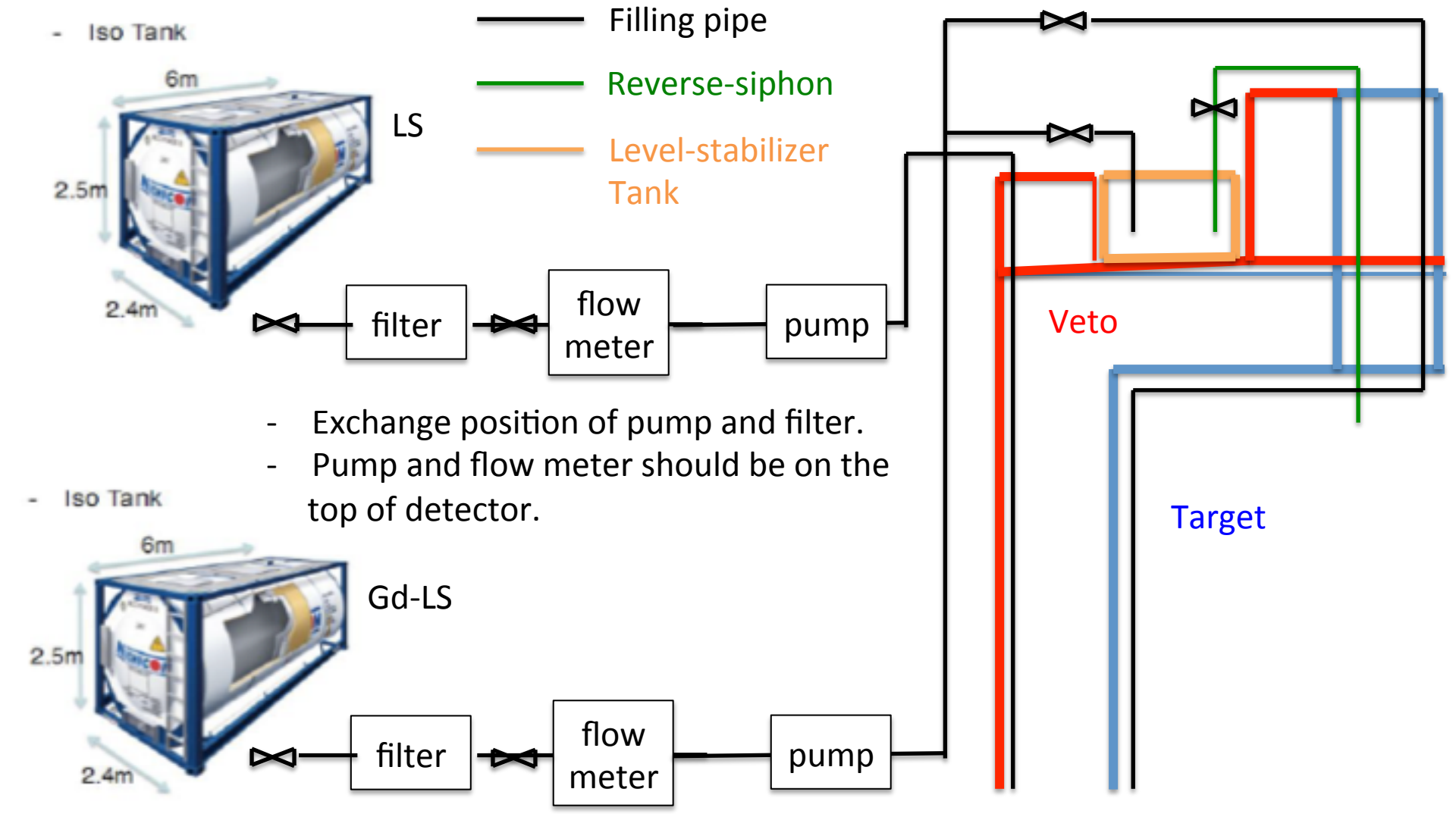
Detector Information.

Target : 160 cm (Outer radius) , 250 cm (Inner height), chimney (10 cm radius), 30 mm thickness

Catcher : 25 cm , 25 cm (top/bottom , side)

Veto : 25 cm, 45 cm thickness (top/bottom, side)

Extracting stage (Image)



Overview of Calibration

Energy conversion function : Number of photoelectrons (PMTs) ➔ MeV
- Need to consider non-linearity due to quenching
- almost constant value at higher energy
- Prompt signal coms from “positron”

One of candidate ➔ $p.e./MeV = P1 - \frac{P2}{1-\exp(-p3*E-\mathrm{P4})}$

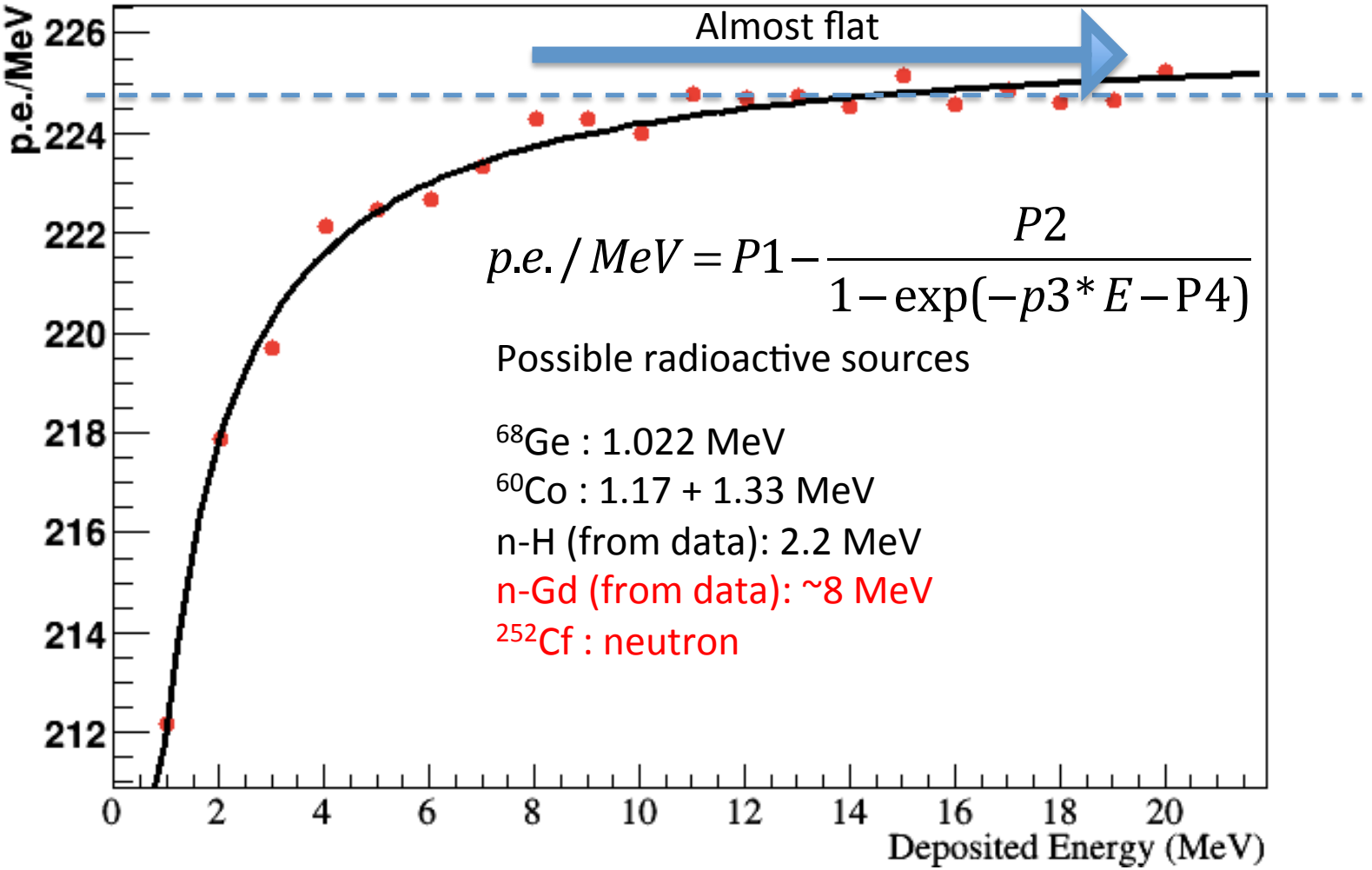
Possible Information from
- Radioactive source : ^{137}Cs, ^{68}Ge, ^{60}Co, ^{252}Cf, ...
- Neutron captured from data : n-H, n-C, n-Gd, ...
- Continuous spectrum : ^{12}B, Michel electon

Possible correction from Monte-Carlo simulation
- Difference between “gamma” and “positron”
- Difference between “single gamma” and “several gammas”
- Difference between “fixed vertex position “ and “uniformly distributed at target”

Check of stability according to “time” and “spatial distribution”.

Study for Calibration (Low Energy)

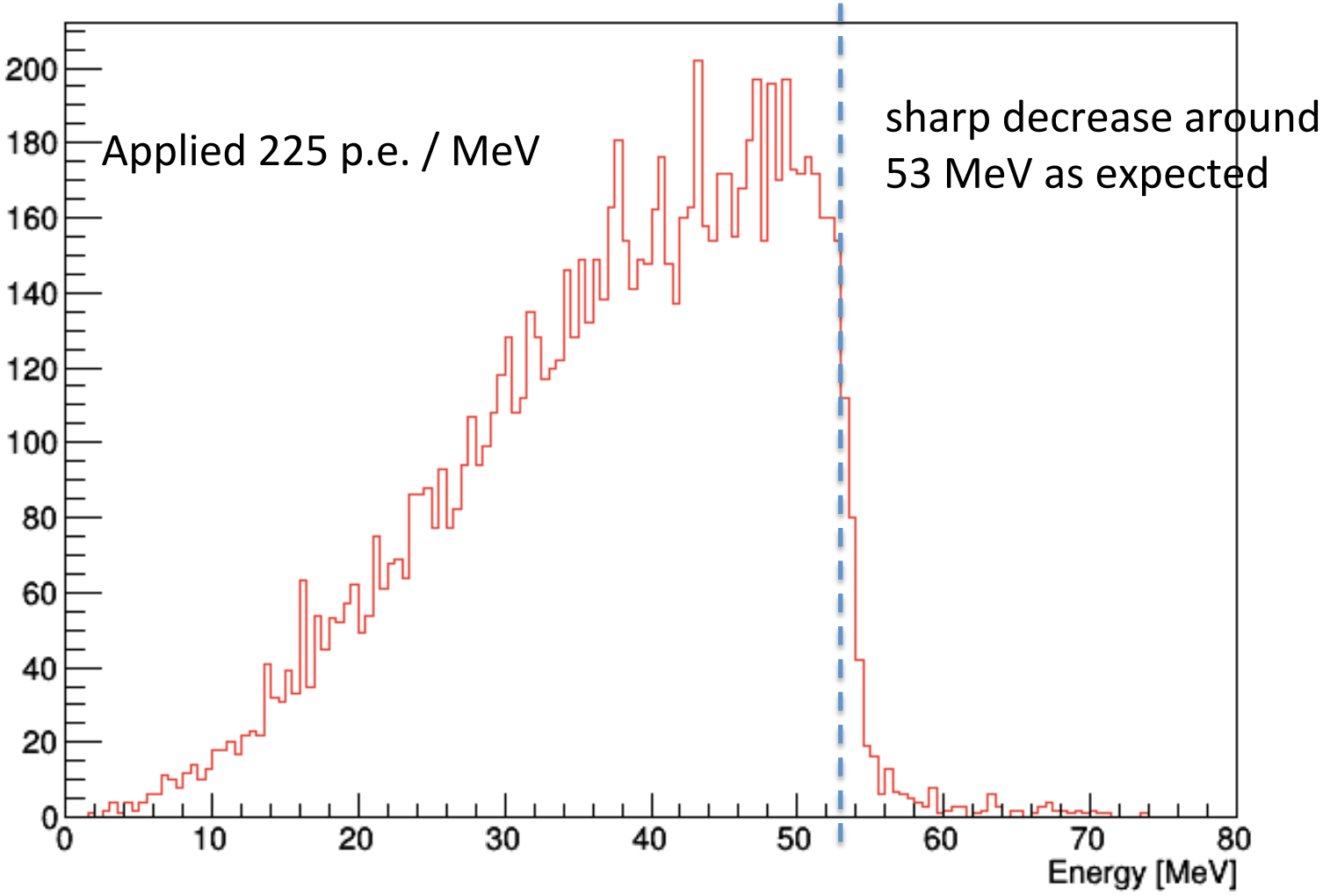
MC : Positron (Prompt signal) at center (10,000 p.e. / MeV)



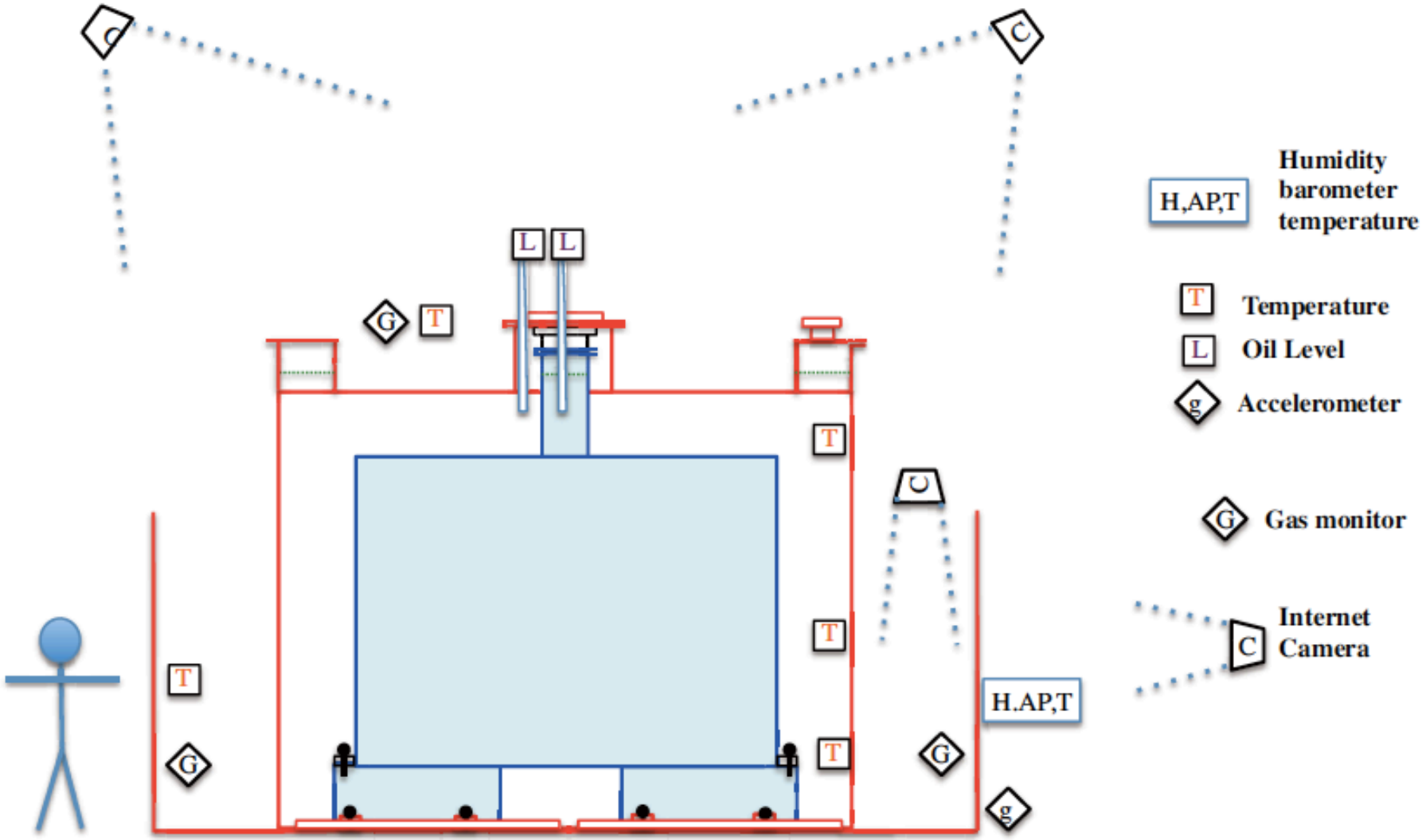
Study for Calibration (High Energy)

MC : Michel electron (10,000 p.e. / MeV)

- Order of 100 Hz is expected at data taking period



Monitoring sensors



Summary

- The JSNS^2 experiment is preparing to perform sterile neutrino search at J-PARC.
  ➔ Direct test of LSND
- Stainless steel vessel will be constructed until Mar, 2018.
- PMT installation scheme is under development with mock-up test.
- LS will be produced from RENO site after refurbishment.
  (Gd-LS also can be produced from RENO or possible donation from DayaBay)
- Many efforts is on-going for filling / extracting / calibration.
- Aim to start experiment at JFY 2018.

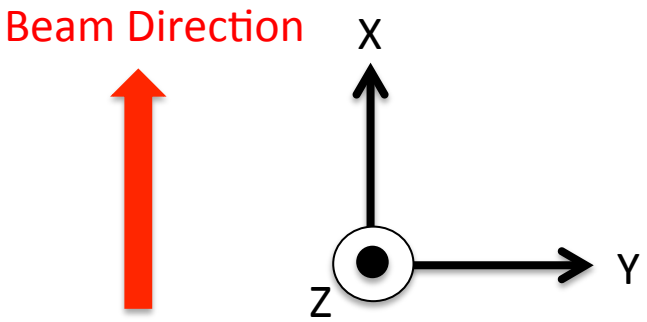
backup slide

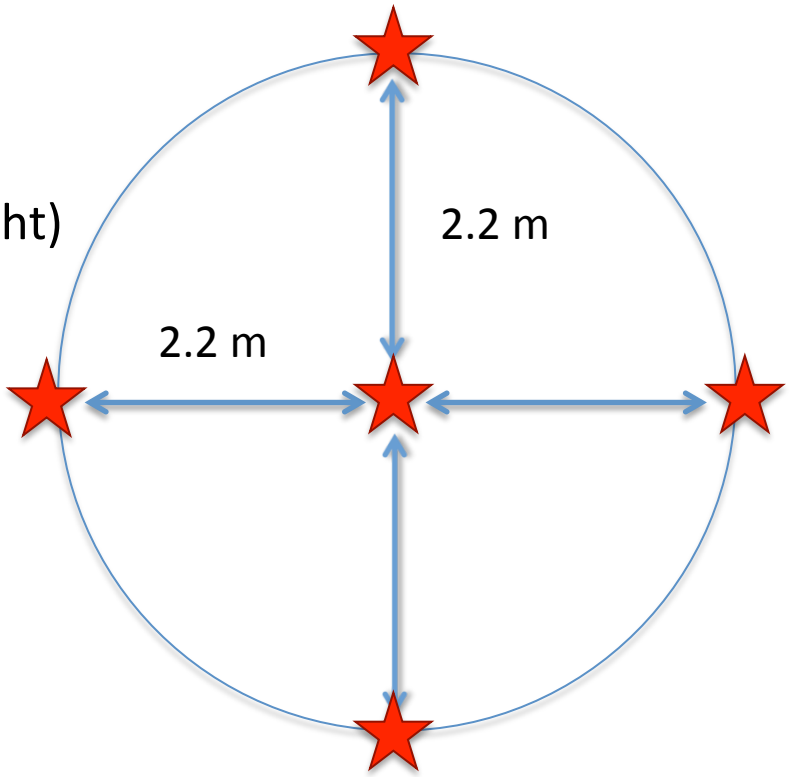
Magnetic field strength measurement (For Decision of FINEMET)

Usual magnetic filed strength ➔ around 1000 mG
- Measurement was performed with magnetometer.
- Fluxmaster, up to 2000mG.
- Reproducibility was measured ~10 mG at each direction.

Location
- 24m baseline
- 5 points
- 2 different height (floor, 1.3 m height)

Three perpendicular direction



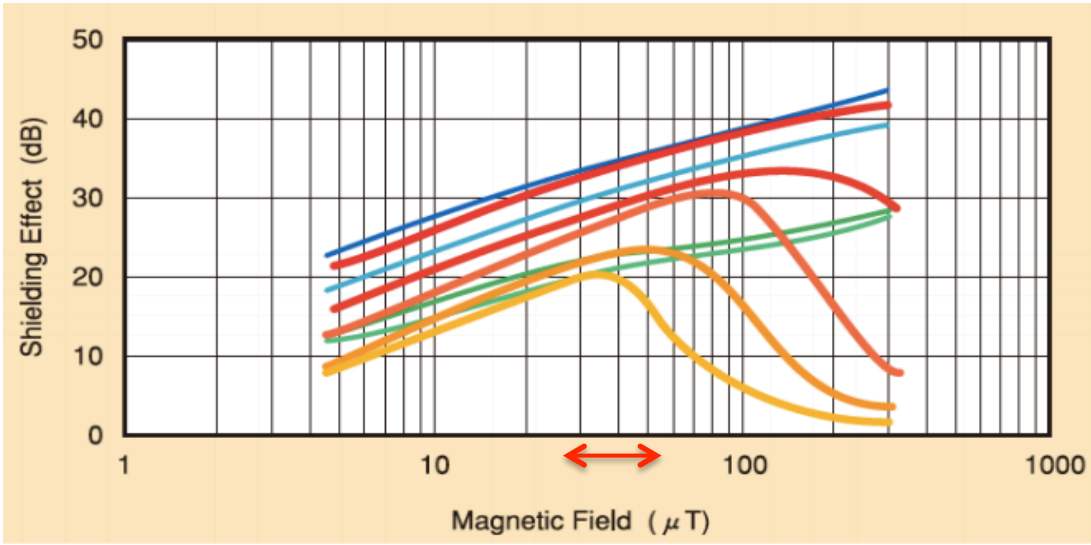


Magnetic field strength ➔ 300 to 500 mG without FINEMET

24 m 1.3m height	X (mG)	Y (mG)	Z (mG)	Total (mG)
1	- 309	- 3	- 233	387
2	- 317	- 20	- 186	368
3	- 292	- 22	- 159	333
4	- 336	18	- 140	364
5	- 378	- 5	- 92	389

24 m Floor	X (mG)	Y (mG)	Z (mG)	Total (mG)
1	- 227	15	- 233	326
2	- 291	- 97	- 82	318
3	- 71	- 36	- 465	472
4	- 353	- 24	225	419
5	- 478	10	- 40	480

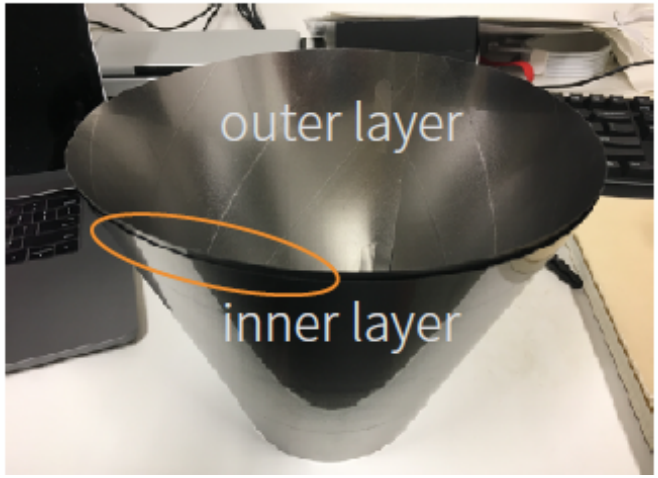
Effect of FINEMET : prevent effect from magnetic field



	Thickness	Weight* ratio
MS-FR 20 layers	2.4 mm	57
MS-FR 8 layers	0.96	23
MS-FR 4 layers	0.48	11
MS-FR 2 layers	0.24	6
MS-FR 1 layer	0.12	3
PC Permalloy	1.0	100
PC Permalloy	0.5	50
Oriented Si steel	0.7	61
Oriented Si steel	0.35	31

*Weight ratio:
the ratio of weight to PC Permalloy (1.0mm thickness) for same area

Measured magnetic filed at on-site : 30 – 50 μT
➔ Prepared 2 layers of FINEMET



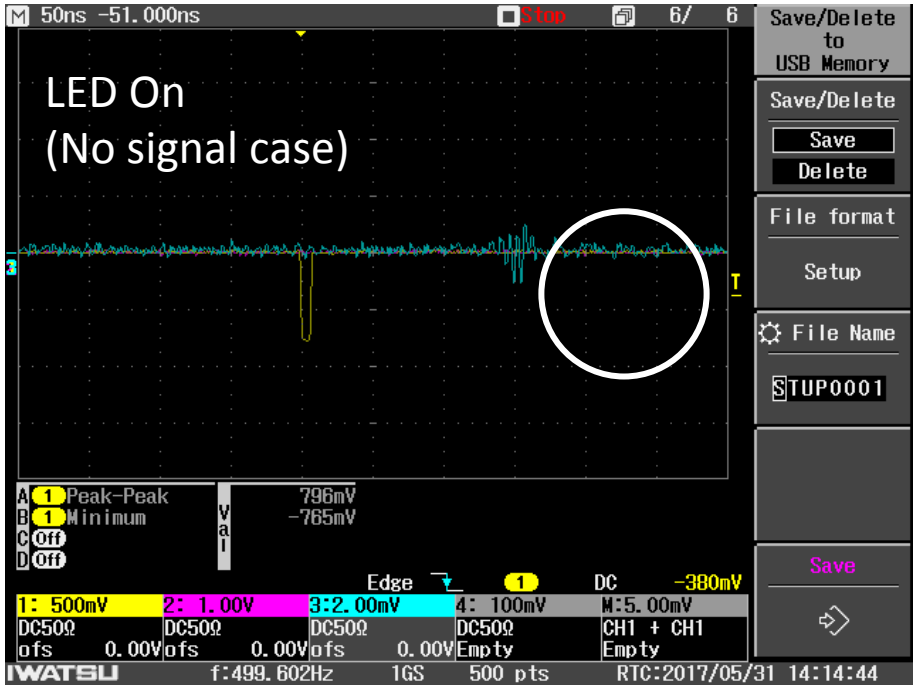
cf) We put outer layer to inside only for demonstration purpose.

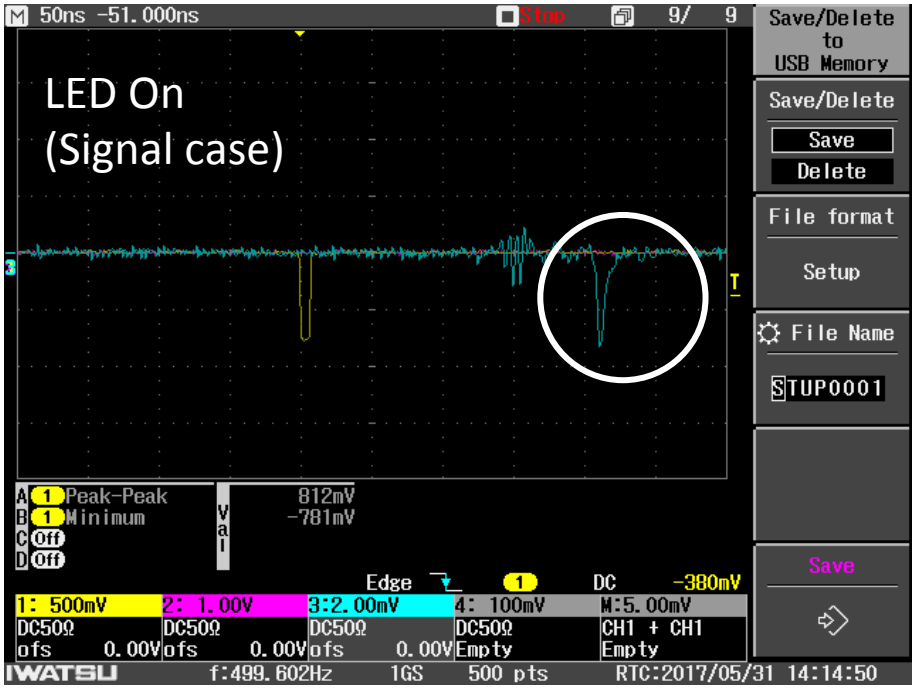
Measured magnetic field before / after cover with FINEMET.
- One component of direction

Before	After	Before	After
387	111	-360	-170
-486	-49	471	284

Effect of FINEMET to PMT gain

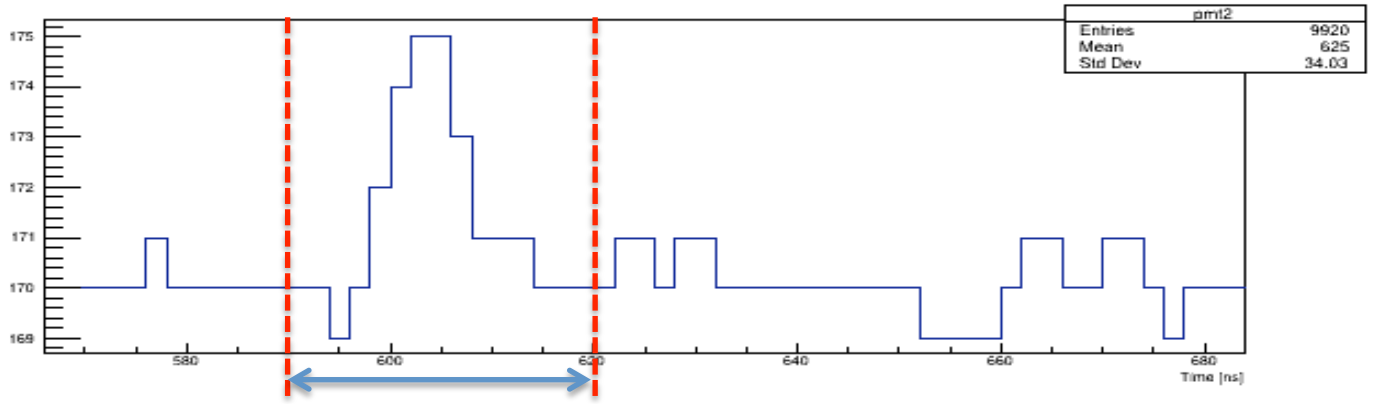
- Data taking with FADC
- 2 layers of FINEMET
- Used Blue LED with NIM module to match single photon electron



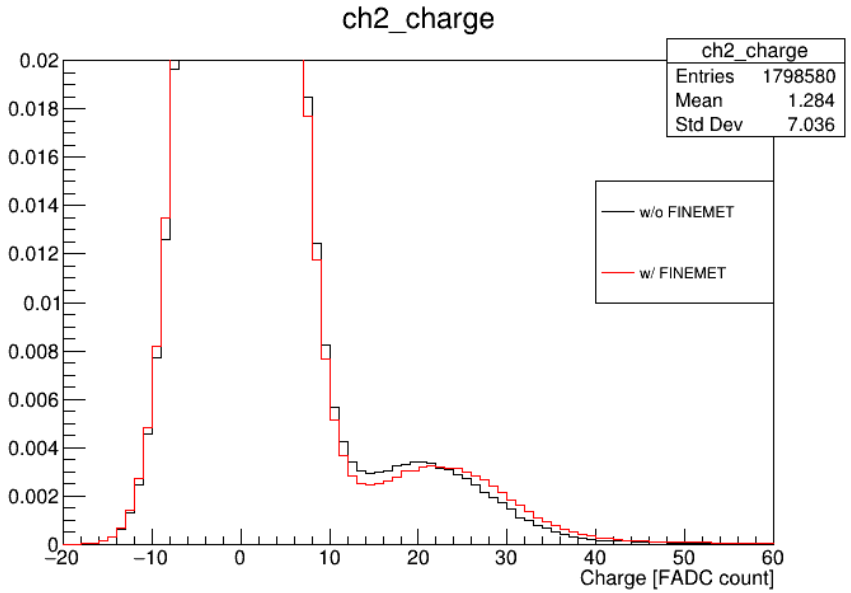


Effect of FINEMET to PMT gain

Typical signal shape



30 ns integration window

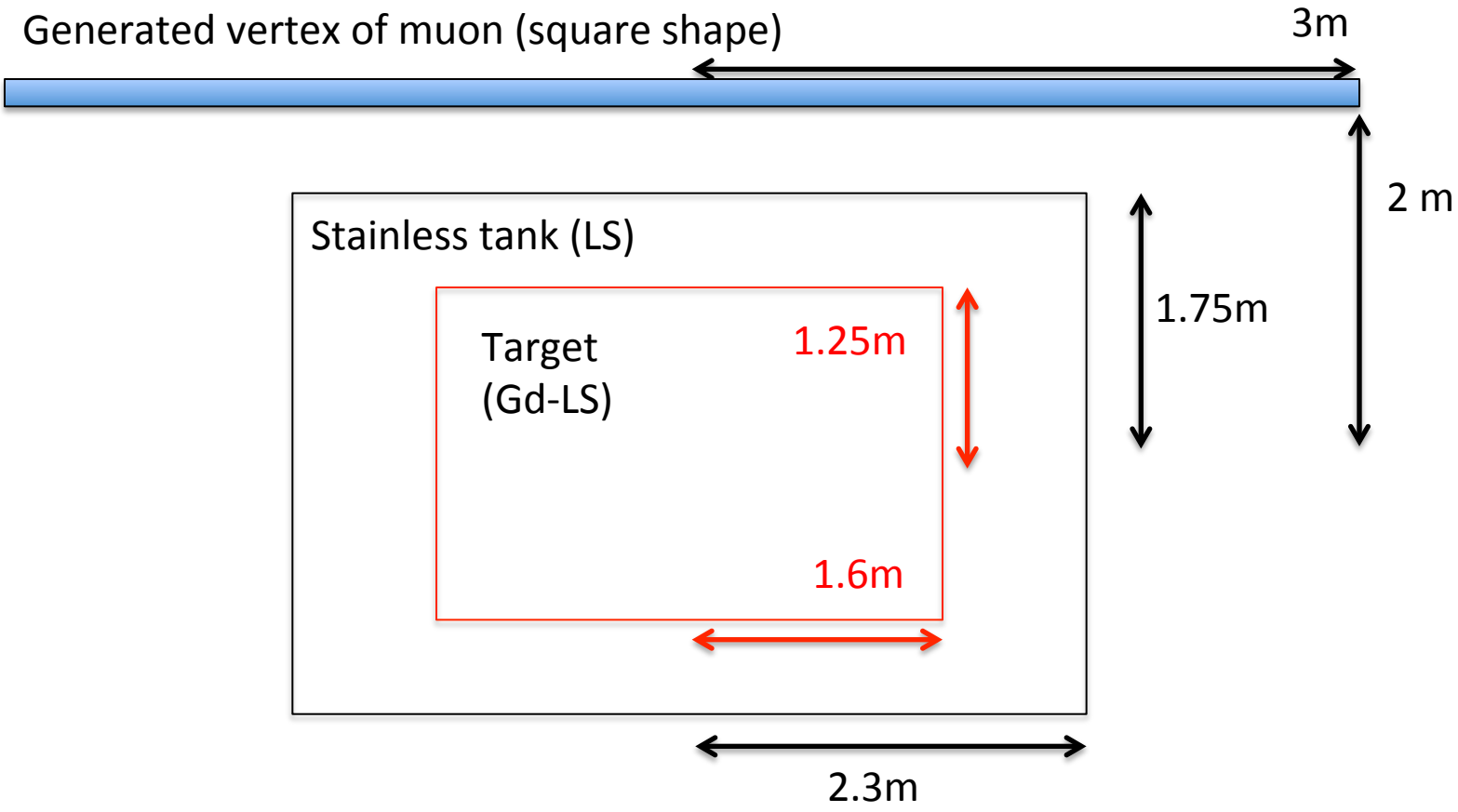


Single gauss fitting

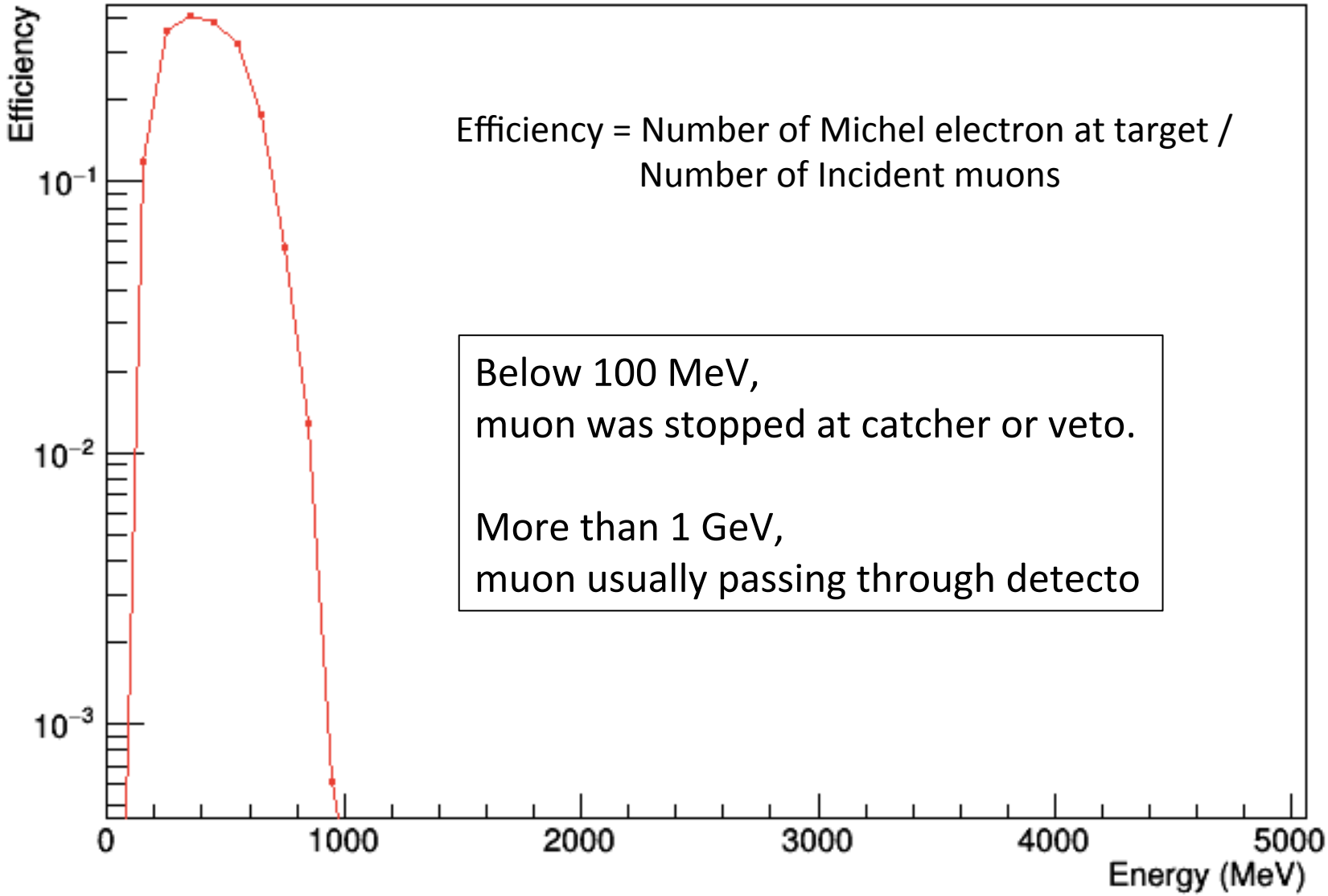
SPE peak : 19.5 ➔ 22.2 (14 % increase)

How many michel electron will be happened inside of detector

- Generate vertex, momentum of muon after considering $\cos^2\theta$ dependence
- 2M event



Rough estimation of rate of michel electron at detector.



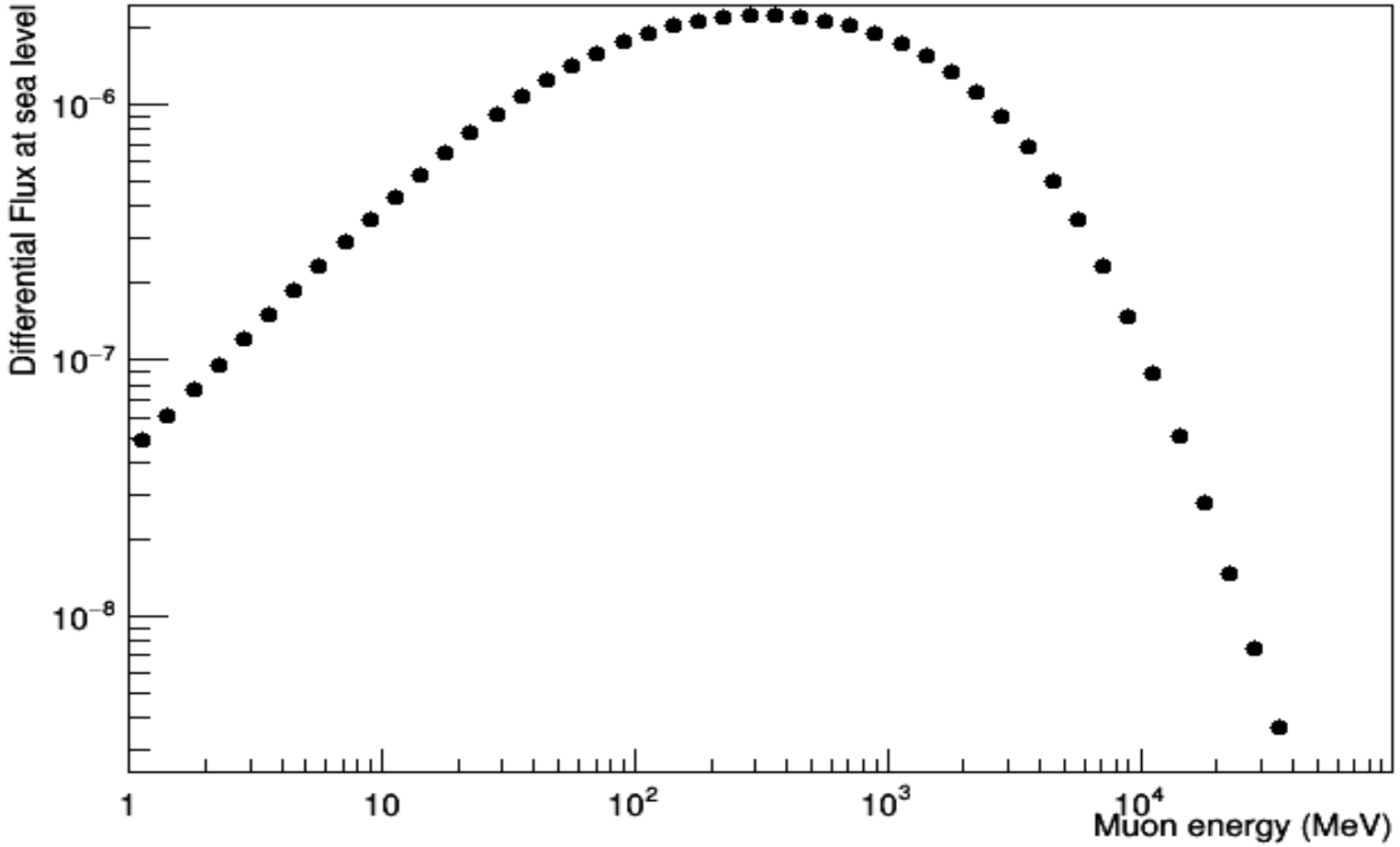
Efficiency = Number of Michel electron at target / Number of Incident muons

Below 100 MeV,
muon was stopped at catcher or veto.

More than 1 GeV,
muon usually passing through detecto

Rough estimation of rate of michel electron at detector.

Muon flux at sea level



Rough estimation of rate of michel electron at detector.

Efficiency of michel electron with muon flux

➔ Area of “muon flux * michel efficiency” / Area of “muon flux”
➔ 5.1 %

Assumed muon rate : 1 Hz / 10*10 cm^2

Area of detector surface :
160cm * 160cm * 3.14 (top) + 2 * 3.14 * 160 cm * 250 cm (side) = 331584 cm^2
➔ 3.3 KHz

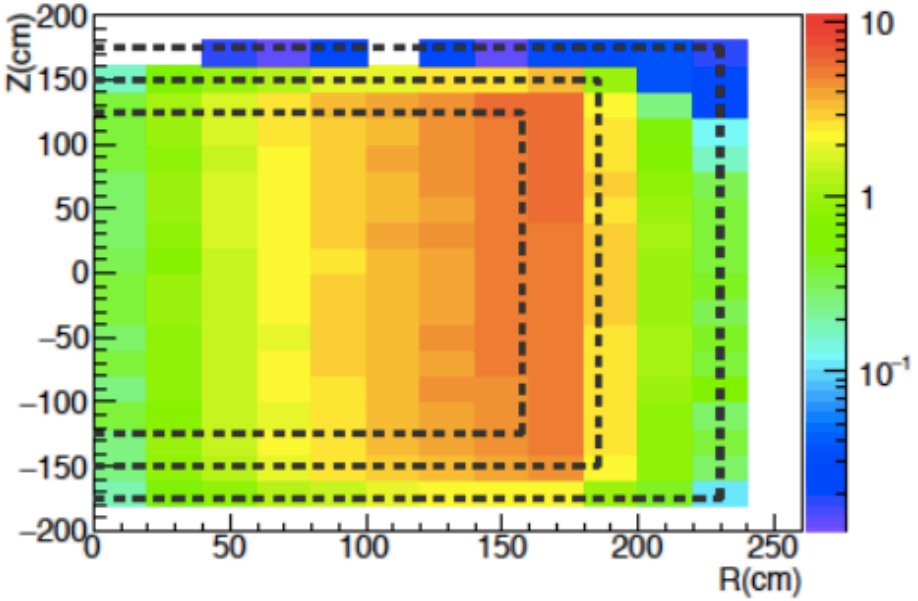
Michel electron rate : 3.3 KHz * 5.1 % = 172 Hz (order of 100 Hz)

➔ Enough statistics to get while data taking

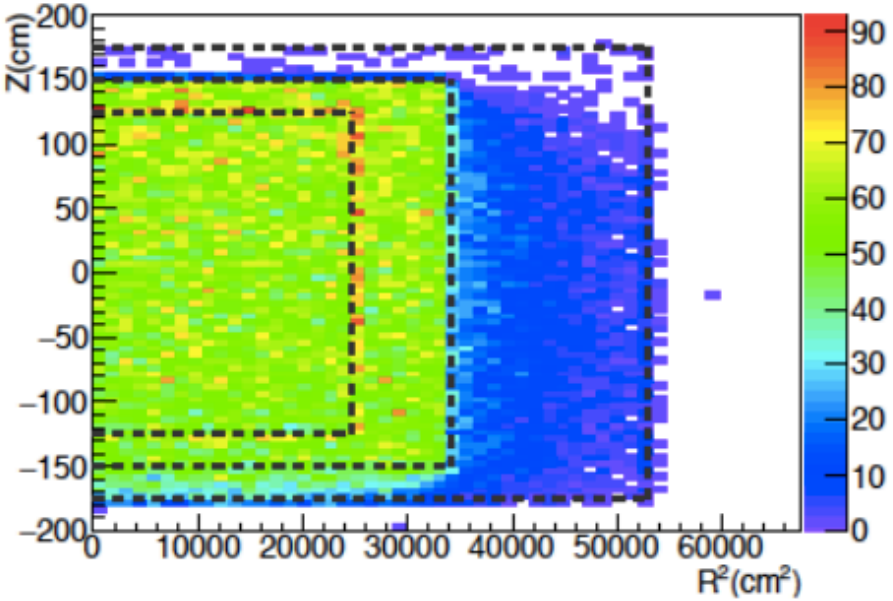
Cross-check by Furuta-san

Michel e rate (>20MeV Edep in ID) in RZ map

Michle e rate (Hz/400cm^2) in RZ map



R^2Z map (events/bin)



Around Z axis ~ 0.4Hz/bin => 4300events/3h/bin
Around acrylic wall ~ 4Hz/bin => 43000events/3h/bin
(24Hz/m^3 in ID)

Almost uniform in ID.

1000 events / 4 min,
with uniform distribution