# Status of Short BaseLine Neutrino Experiment (SBL) in Korea

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on the behalf of SBL Collaboration

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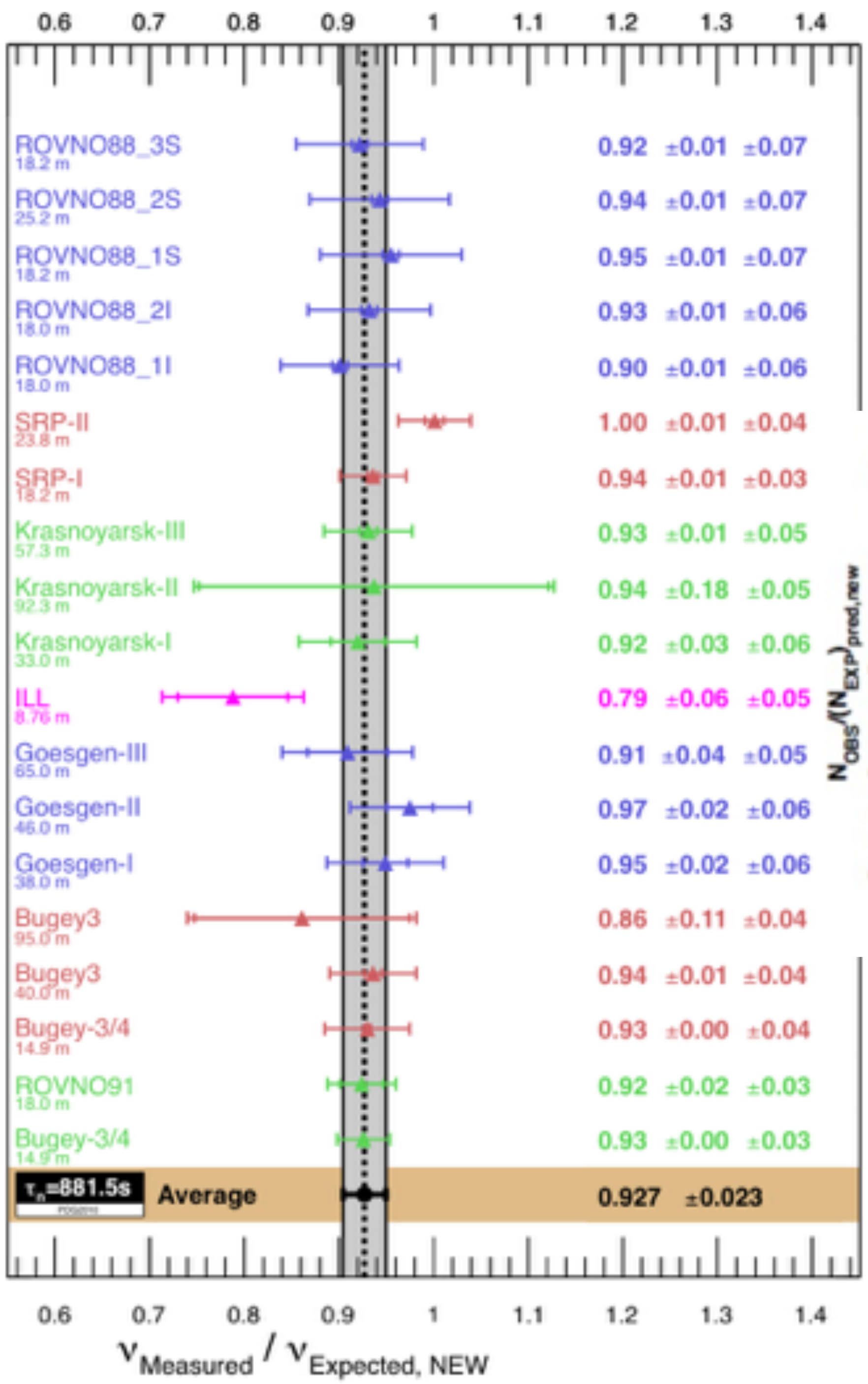
AAP 2014

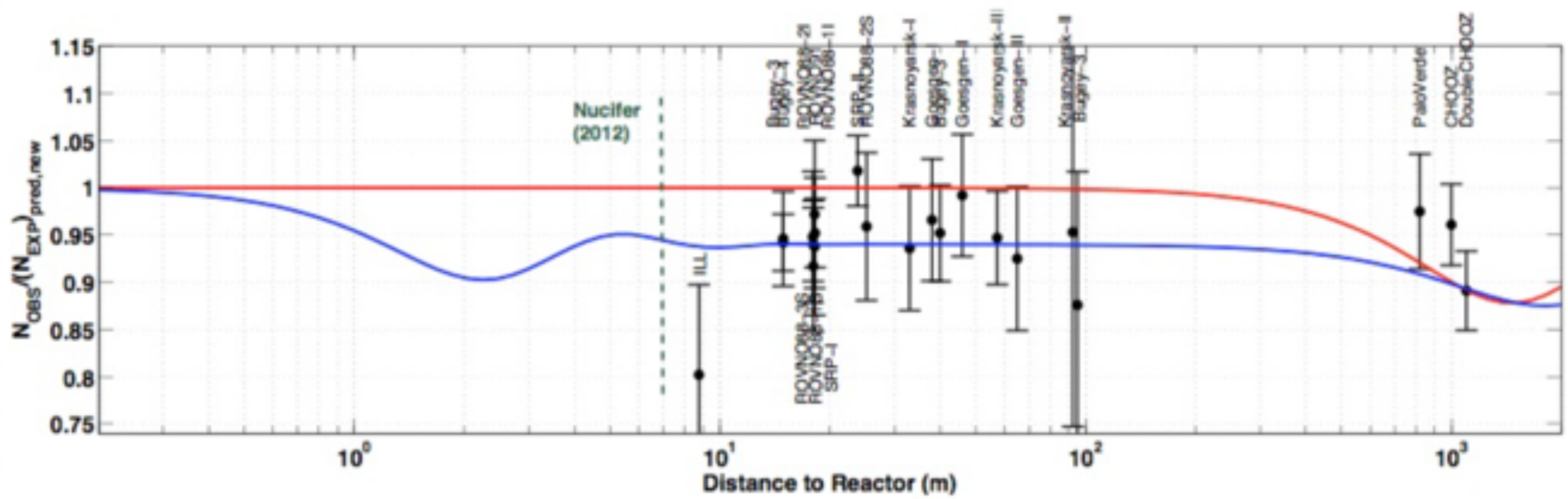
# Outline

- Reactor antineutrino anomaly
- Short baseline experiment and detector deployment sites in Korea
- Prototype detectors
  - Measurement of backgrounds above ground
  - Test on capability of PSD
  - Detector and background simulation
- Main detectors
  - Conceptual design and deployment site
  - Schedule and plan
- Summary

# Reactor antineutrino anomaly




- red line shows the theoretical expectation of 3 active neutrino mixing
- blue line is for including new neutrino mass state



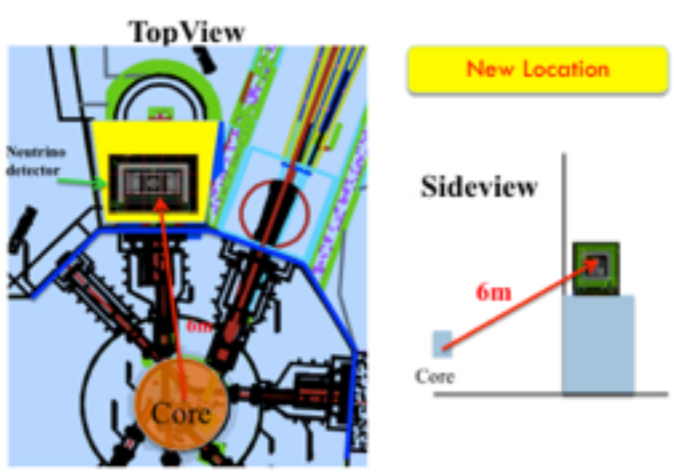

Average is 0.927+/-0.023

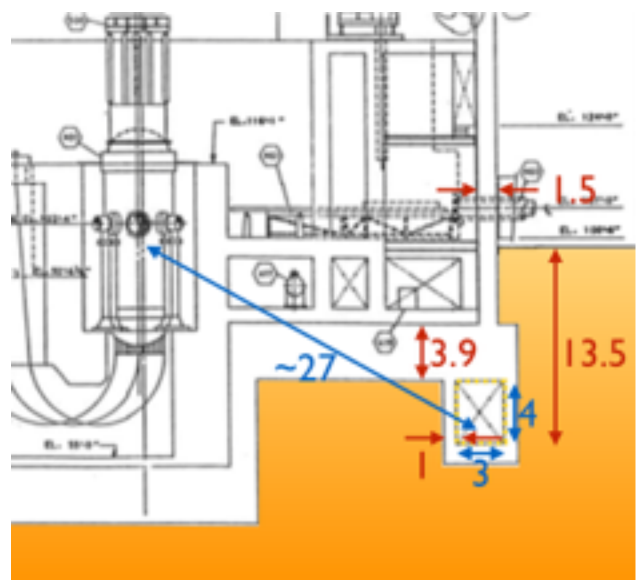
# Short BaseLine Neutrino Experiment (SBL)

- Collaborators: 25 researchers from 8 universities and institutes
  - Sejong Univ.: 2
  - IBS: 7
  - Chonnam Nat'l Univ.: 5
  - Chonbuk Nat'l Univ.: 3
  - Chung-Ang Univ.: 2
  - KRISS: 2
  - Kyungpook Nat'l Univ.: 2
  - KAERI: 2

# Detector deployment sites: 3 candidates

- HANARO
- HANBIT(old name: Yonggwang)
- GIJANG



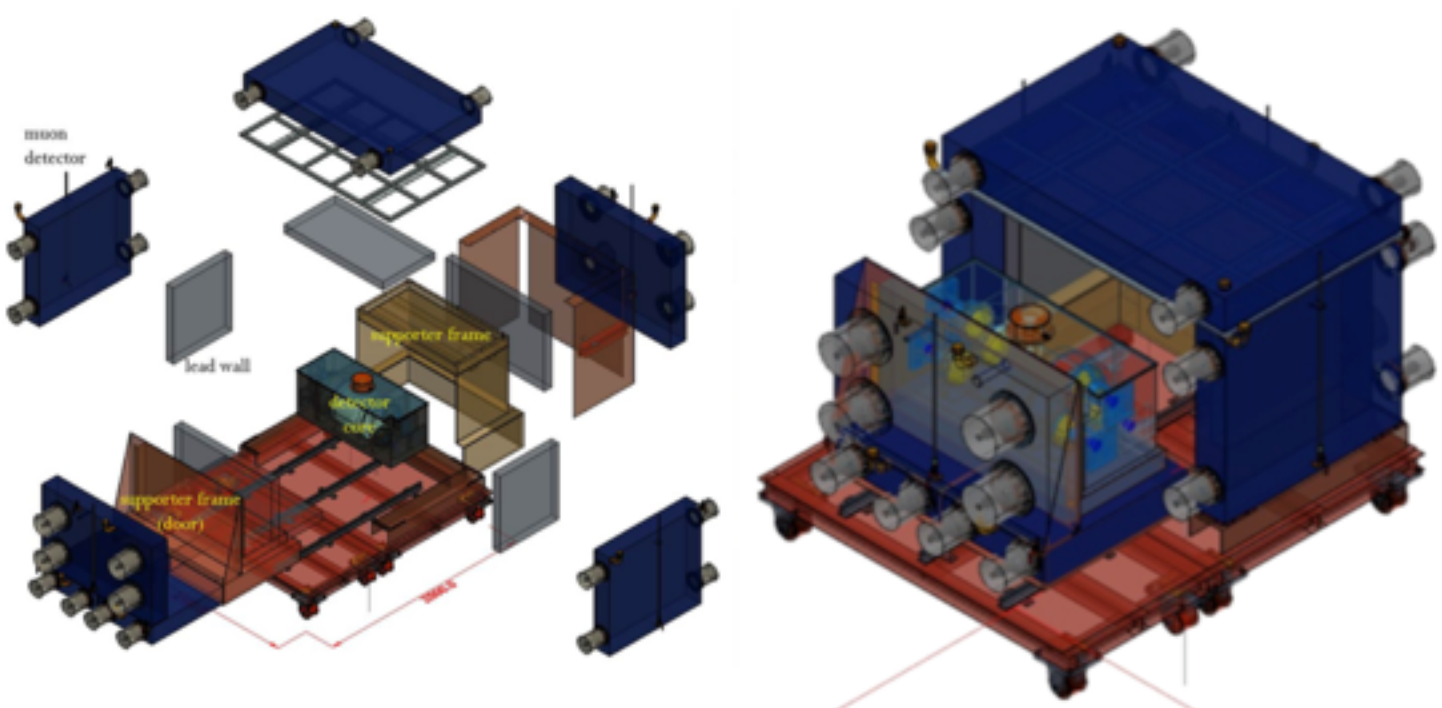



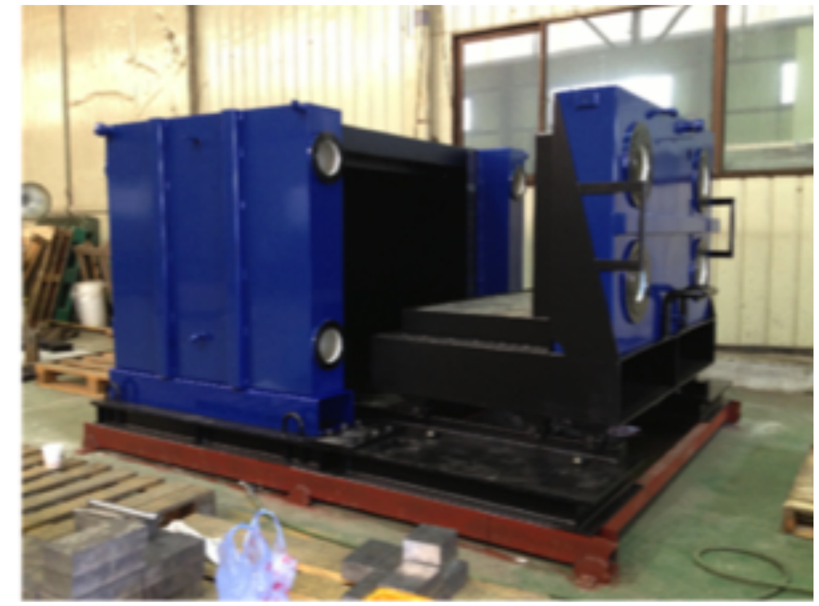

| Candidates | Baseline | Thermal | # of events/day | Overburden | S/N (w/ PSD) |
|---|---|---|---|---|---|
| HANARO | 6m | 30 MW | ~250 | - | ? |
| HANBIT | ~27m | 2.8 GW | ~1200 | 10~23 m.w.e | >5 |
| KIJANG | 5m | 15 MW | ~180 | ~ 23 m.w.e | ~1 |

# Increased Backgrounds above ground

- Main background events are from cosmic muons and neutrons and should be reduced and rejected relative to signal
  - Overburden over the detector is crucial to the ratio of signal to background
  - Detector requires good sensitivity of particle identification by PSD
- We made a prototype detector for the background studies above ground
  - We measured background events for different overburden over the detector at two places
    - KT1 lab with little overburden
    - Sejong lab with ~1.5 m.w.e overburden
  - We tested the capability of PSD with different target material filled in prototype detector
    - LAB-based LS
    - DIN-based LS: UG-F

# Prototype detector

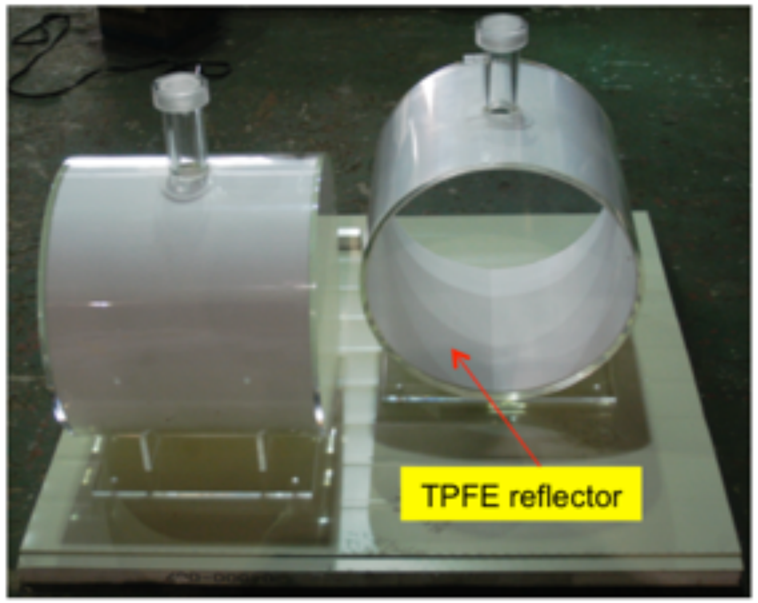


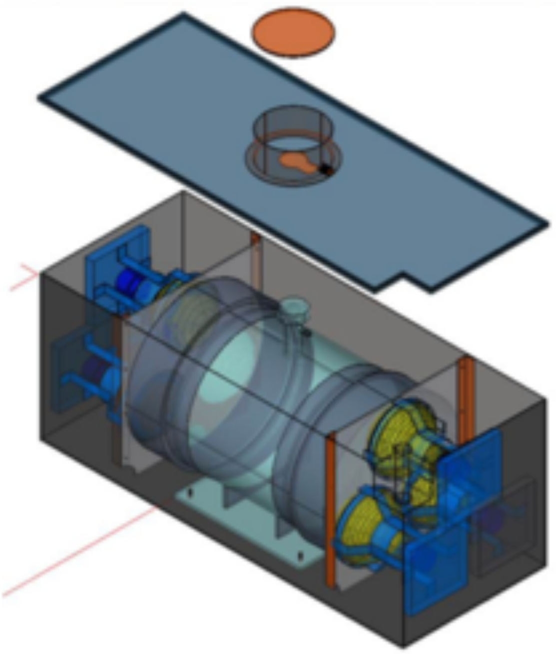



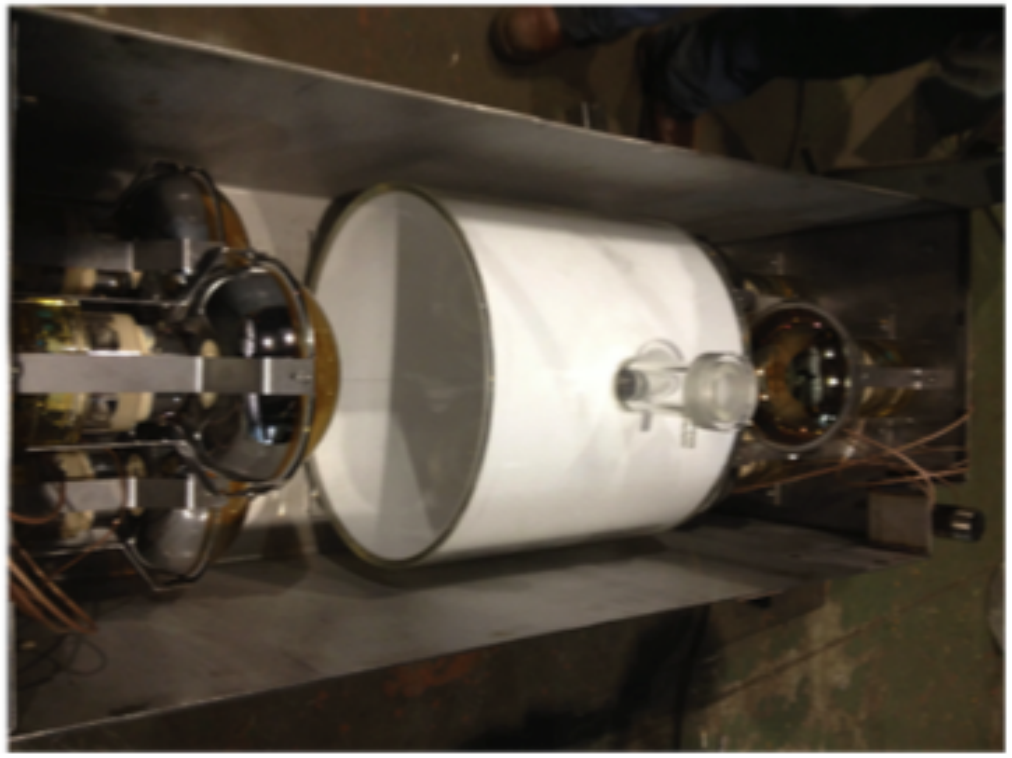
- Muon veto
  - 7 cubic steel chambers with 25cm thickness to cover 4π
  - filled with liquid scintillator
- Lead shield
  - 10cm thickness
  - to block external gammas

# Prototype detector

- Dark box
  - 1.3x0.5x0.5m$^3$ rectangular stainless steel vessel
  - filled with ~280L of non-scintillating mineral oil
  - covered with mu-metal to shield against magnetic field
- Target
  - 50L of 0.5% Gd loaded LS (LAB-based)
  - 5mm thick teflon sheet are installed inside target vessel
- PMT
  - 6x8” PMTs (Hamamastu R5912)

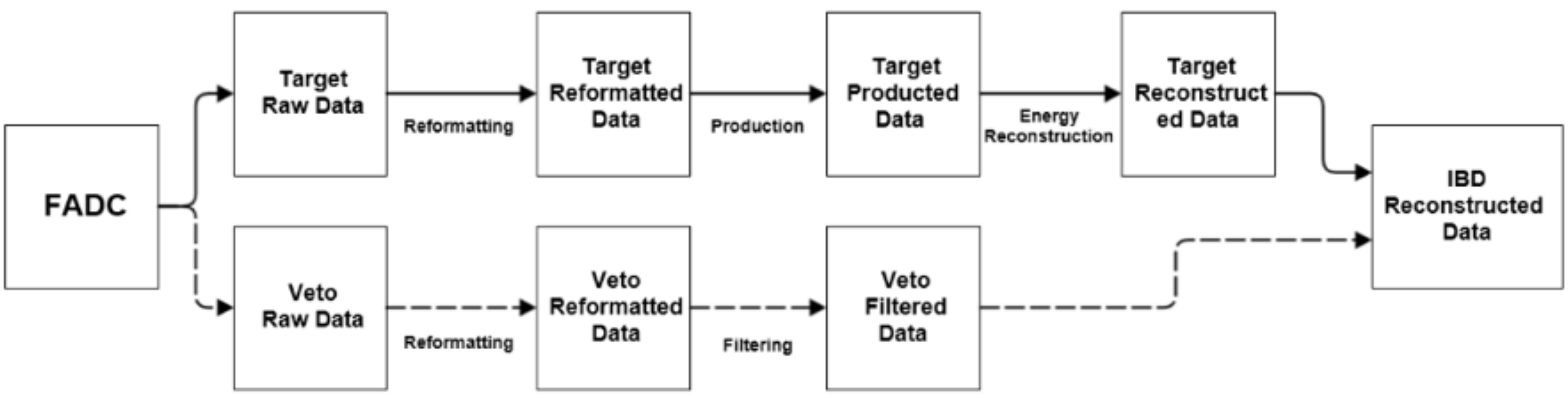




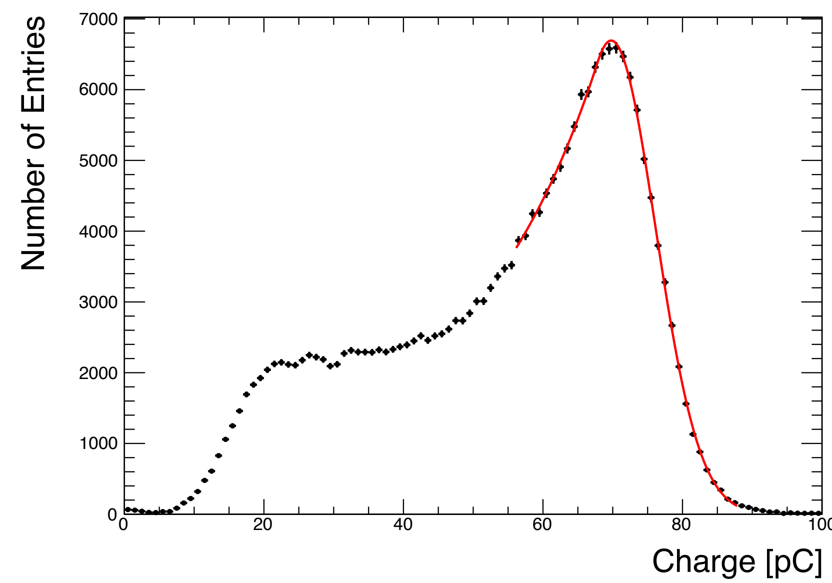
# DAQ system

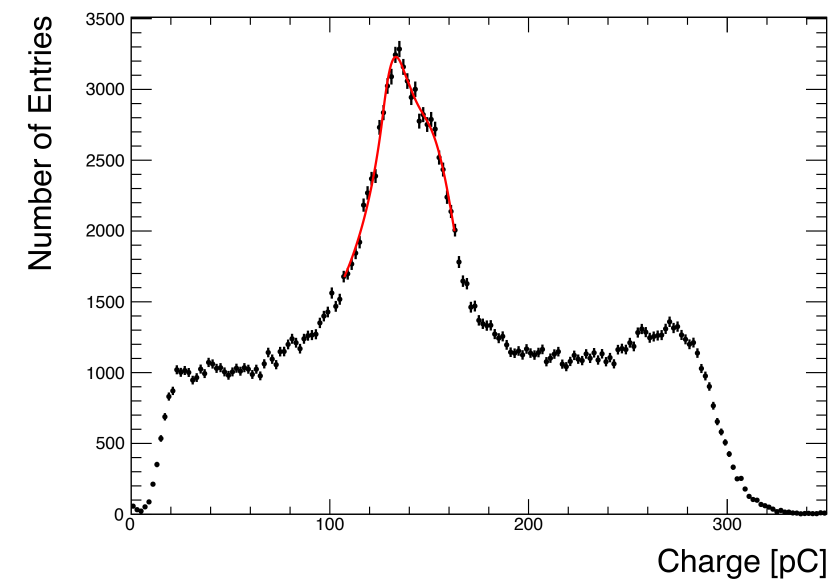
- Main electronics for Target PMT signal
  - Fast digitization: 500MHz Flash ADC
  - 4 ch input, 12 bit dynamic range
  - $V_{pp} = 2.5V$
- Muon Veto Electronics
  - Slow digitization: 64MHz Flash ADC
  - Charge sensing with FPGA

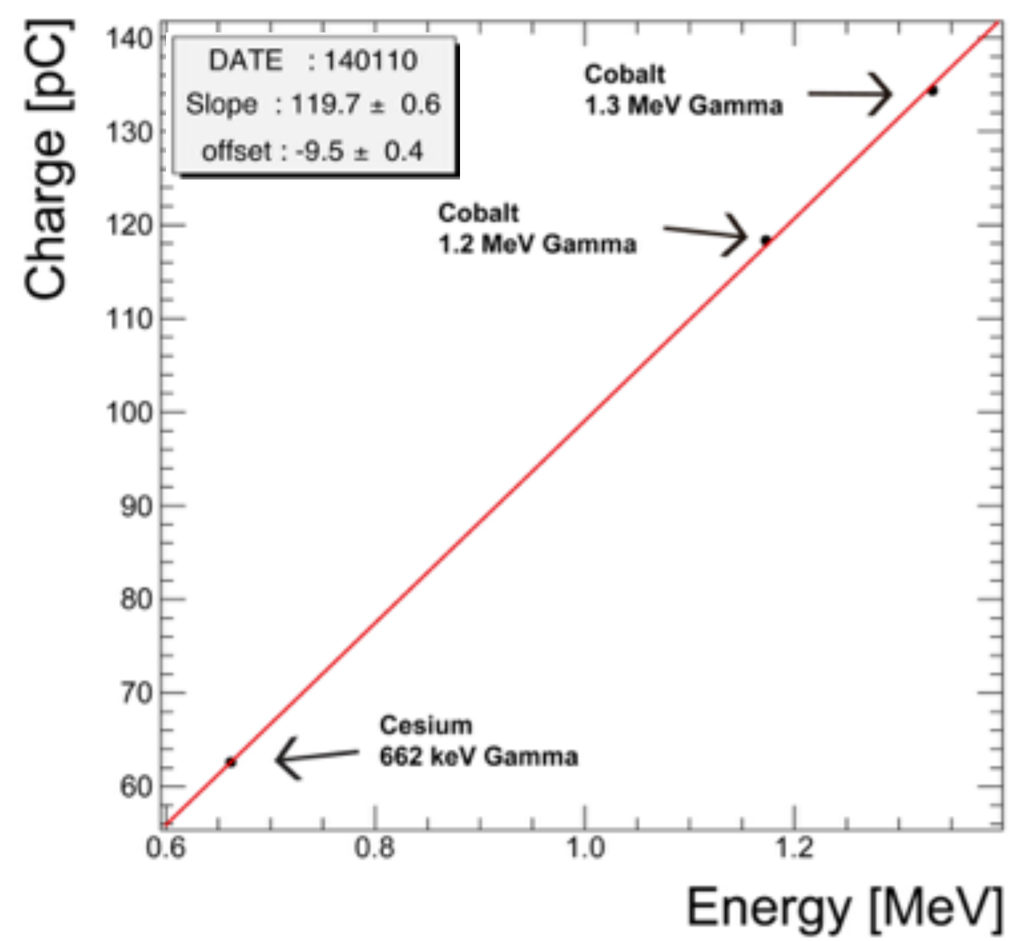


# Energy calibration and linearity

- Gamma sources of $^{137}Cs$ and $^{60}Co$ are used for energy calibration
- Gamma sources are set into the center of target through the chimney
- Crystal ball function is used in charge spectrum fit to handle the low energy tail by escaping gamma
- Total light yield is 680 p.e./MeV



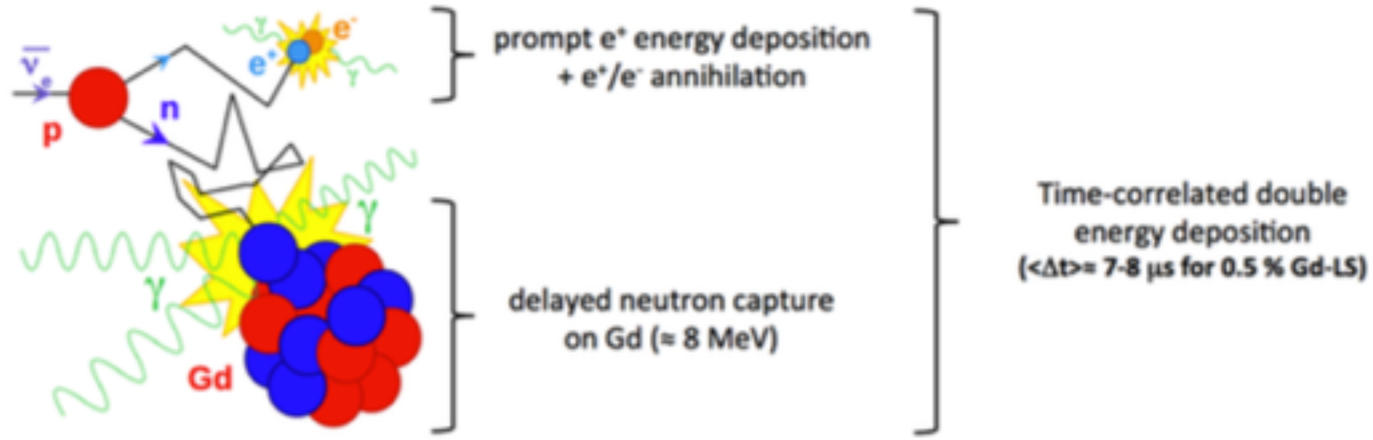



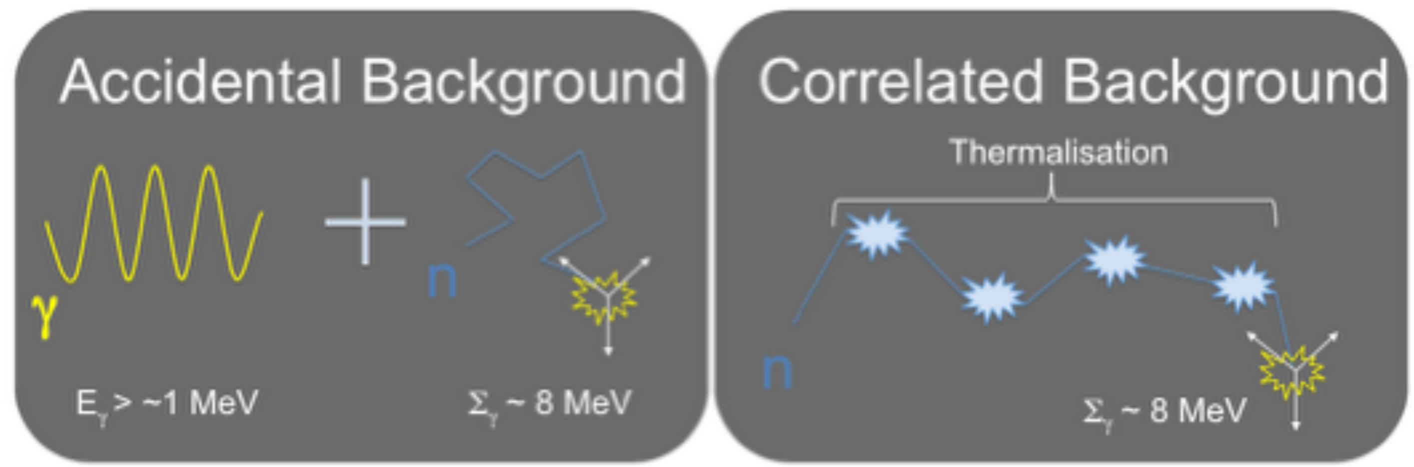
# Signal and background: neutrino-like event selection

- Inverse beta decay:

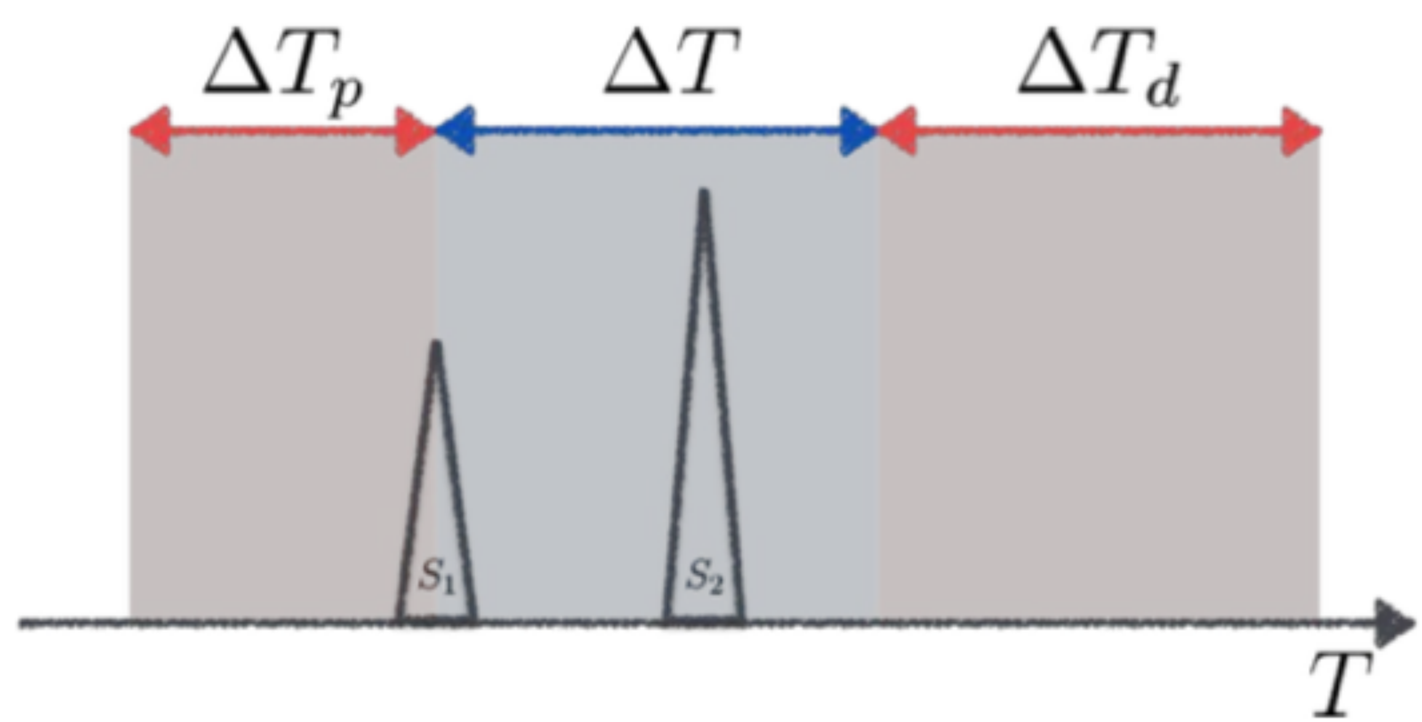
$$\overline{\nu_e} + p \rightarrow e^+ + n$$




- Backgrounds:



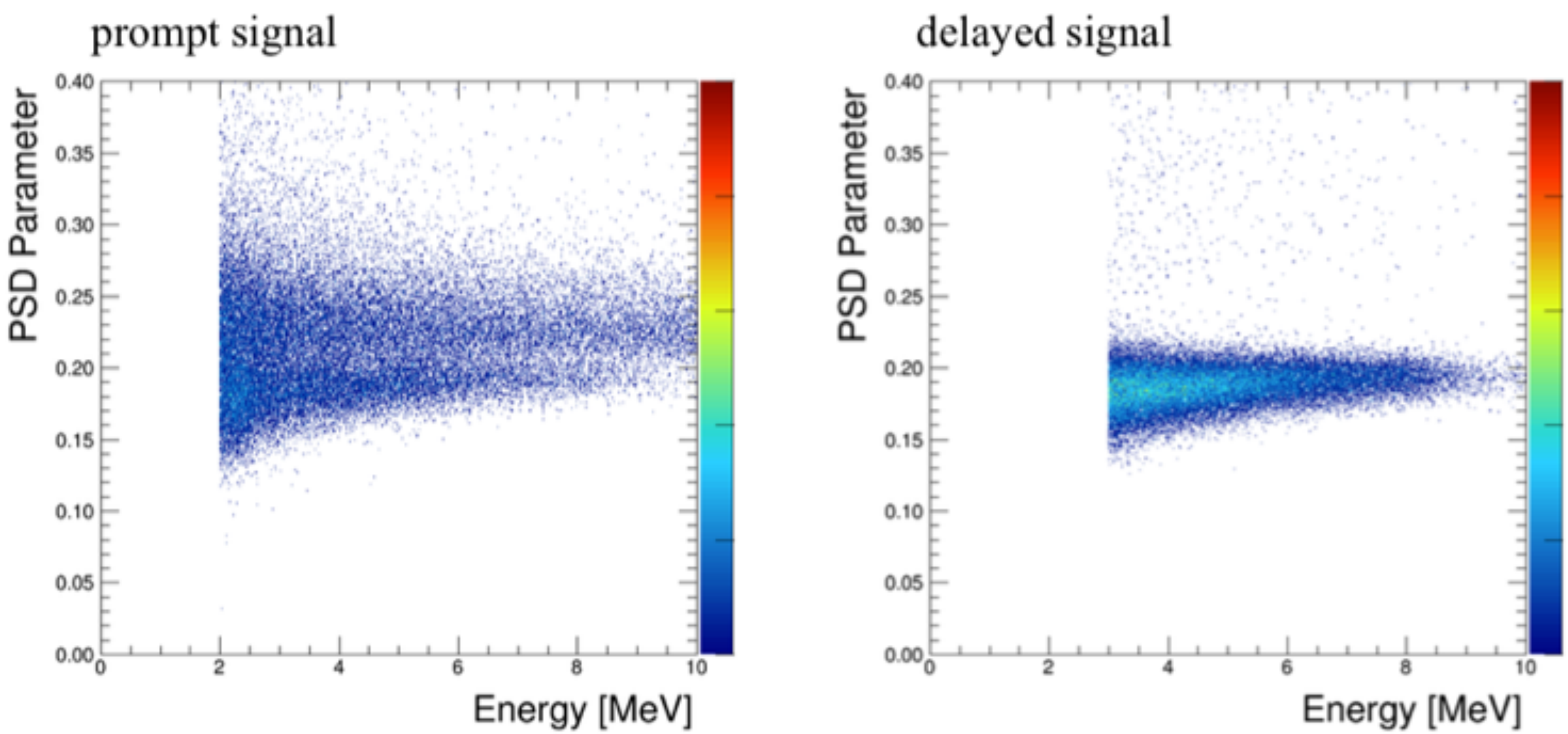

- Selection cuts for neutrino-like event
  - time difference: $3.0\mu s < \Delta T < 30\mu s$
  - prompt energy: $2.0\text{MeV} < E_{s1} < 10\text{MeV}$
  - delayed energy: $3.0\text{MeV} < E_{s2} < 10\text{MeV}$
  - multiplicity: $\Delta T_p = 30\ \mu s$, $\Delta T_d = 100\mu s$



# Measurement of backgrounds above ground

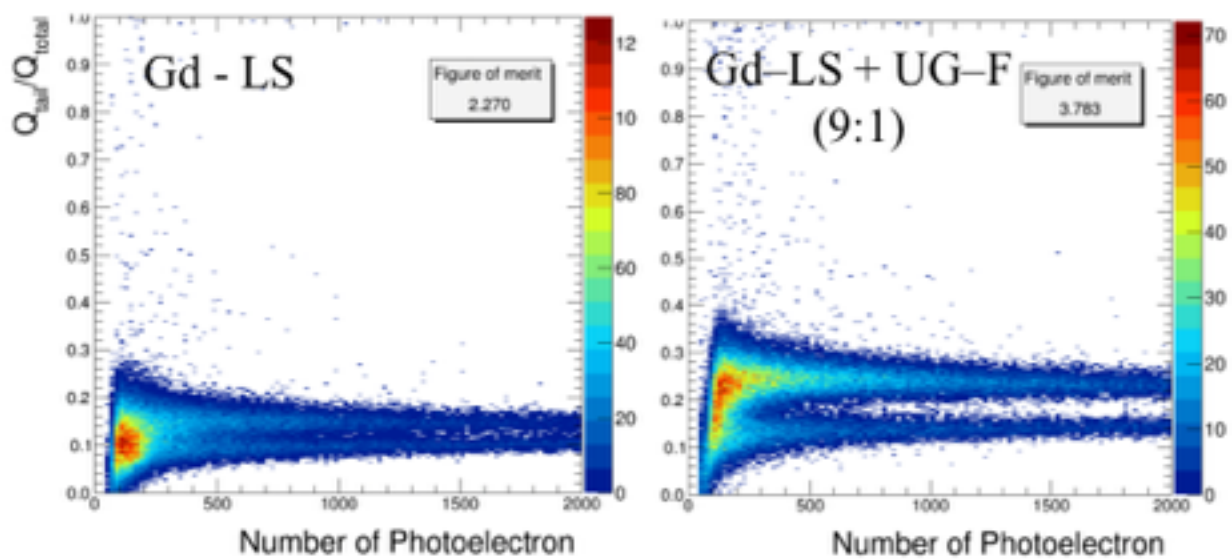
| place | overburden | target material | neutrino-like events [/day] | | rejected fraction by PSD |
|---|---|---|---|---|---|
| | | | w/o PSD | w/ PSD | |
| Sejong lab | ~1.5 m.w.e | LAB-based GdLS | 670 | 304 | 55% |
| KT1 lab | - | LAB-based GdLS | 4400 | 2720 | 38% |
| | - | UG-F GdLS | 3920 | 2075 | 48% |

# Pulse Shape Discrimination(PSD): LAB-based GdLS

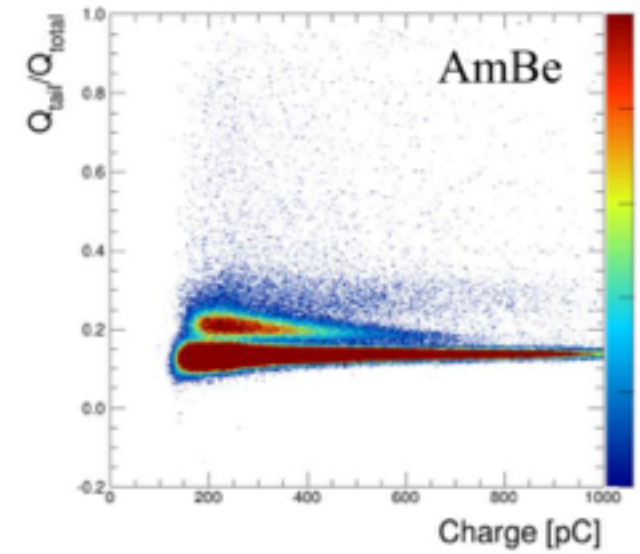


# Pulse Shape Discrimination(PSD): UG-F GdLS

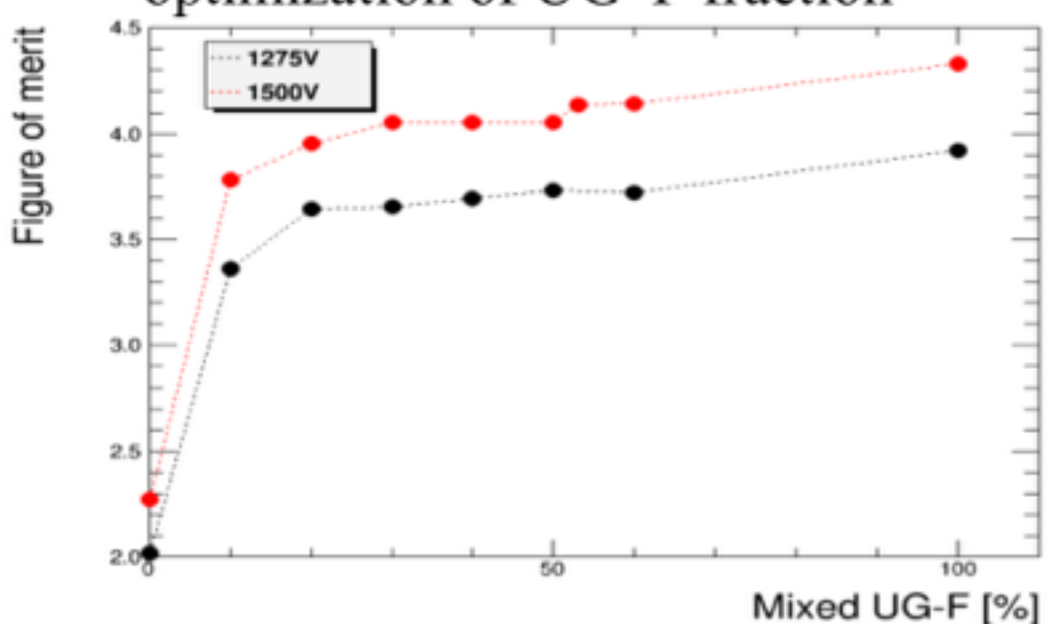
Gd – LS + UG – F in small cell

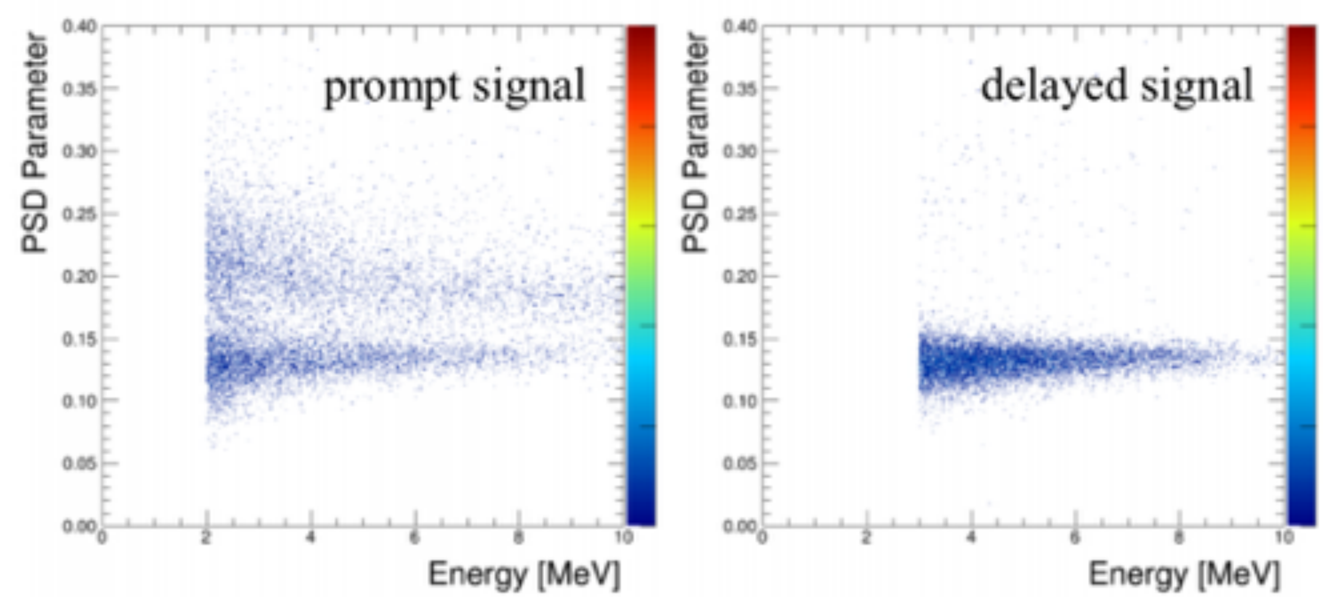



Gd – LS + UG – F in prototype



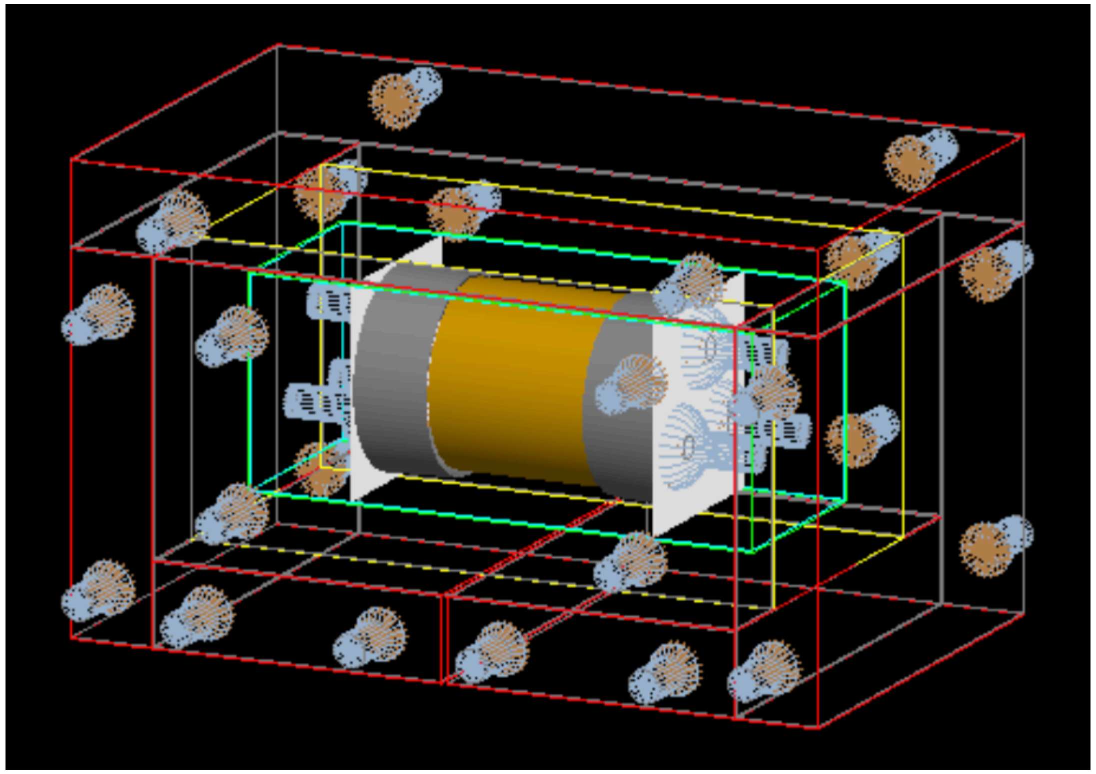

optimization of UG–F fraction

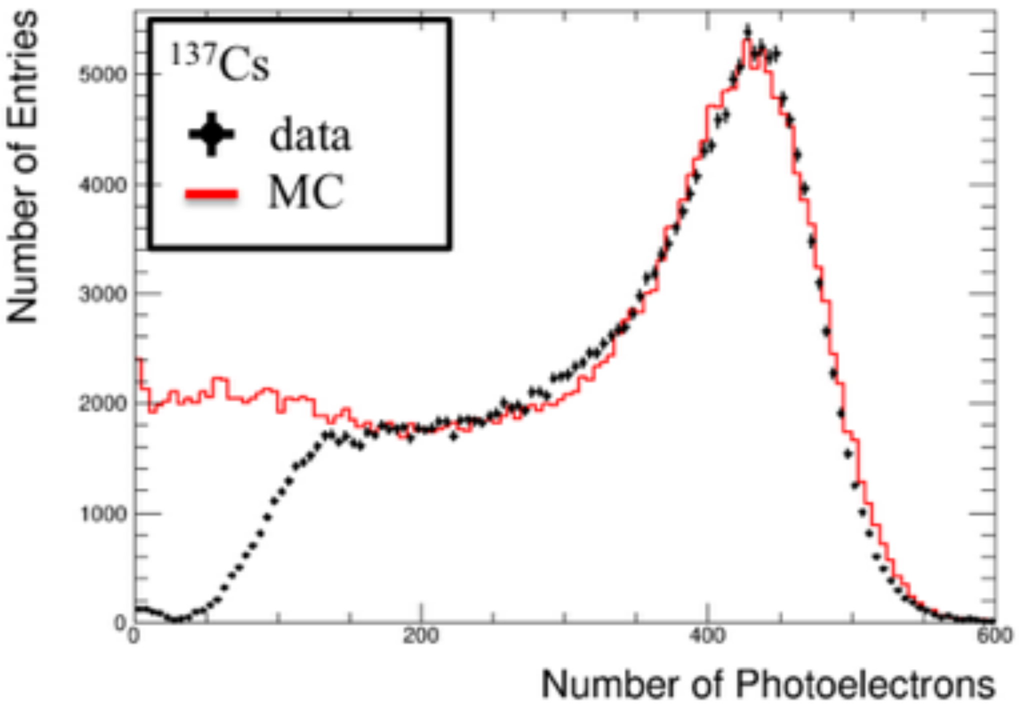


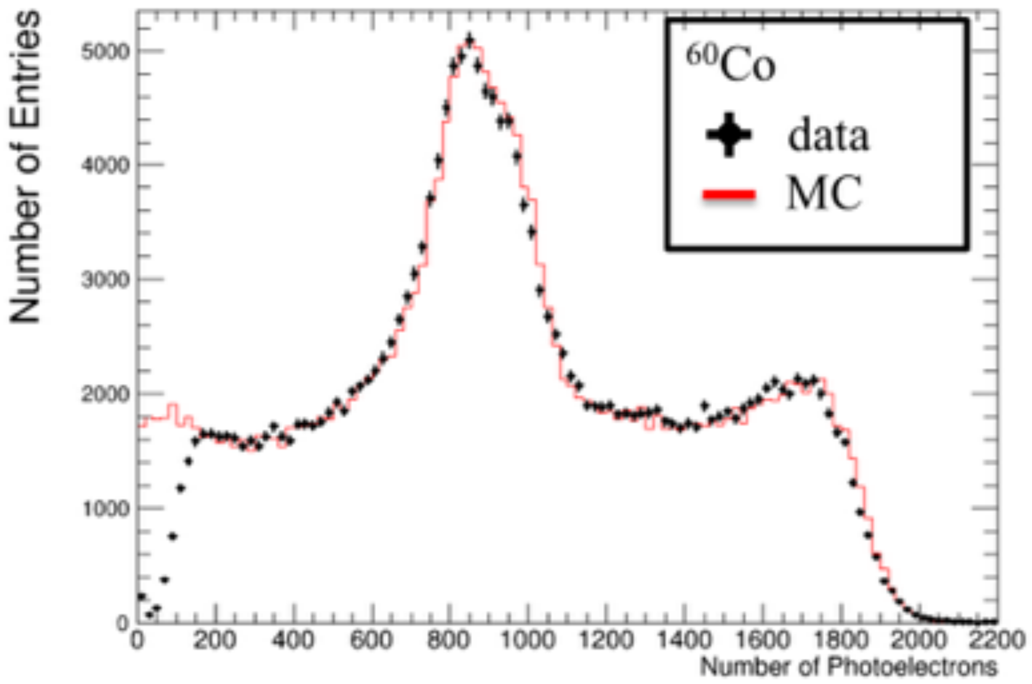



# Detector simulation

- Geant4.9.6.02 based simulation was performed
- Comparison of Data to tuned MC with gamma sources
  - Detector simulation is tuned by data
  - Simulation is in good agreement with data

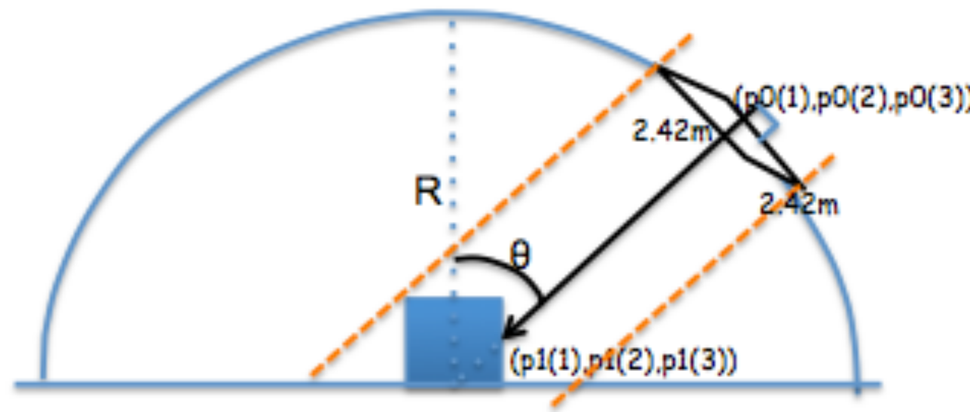


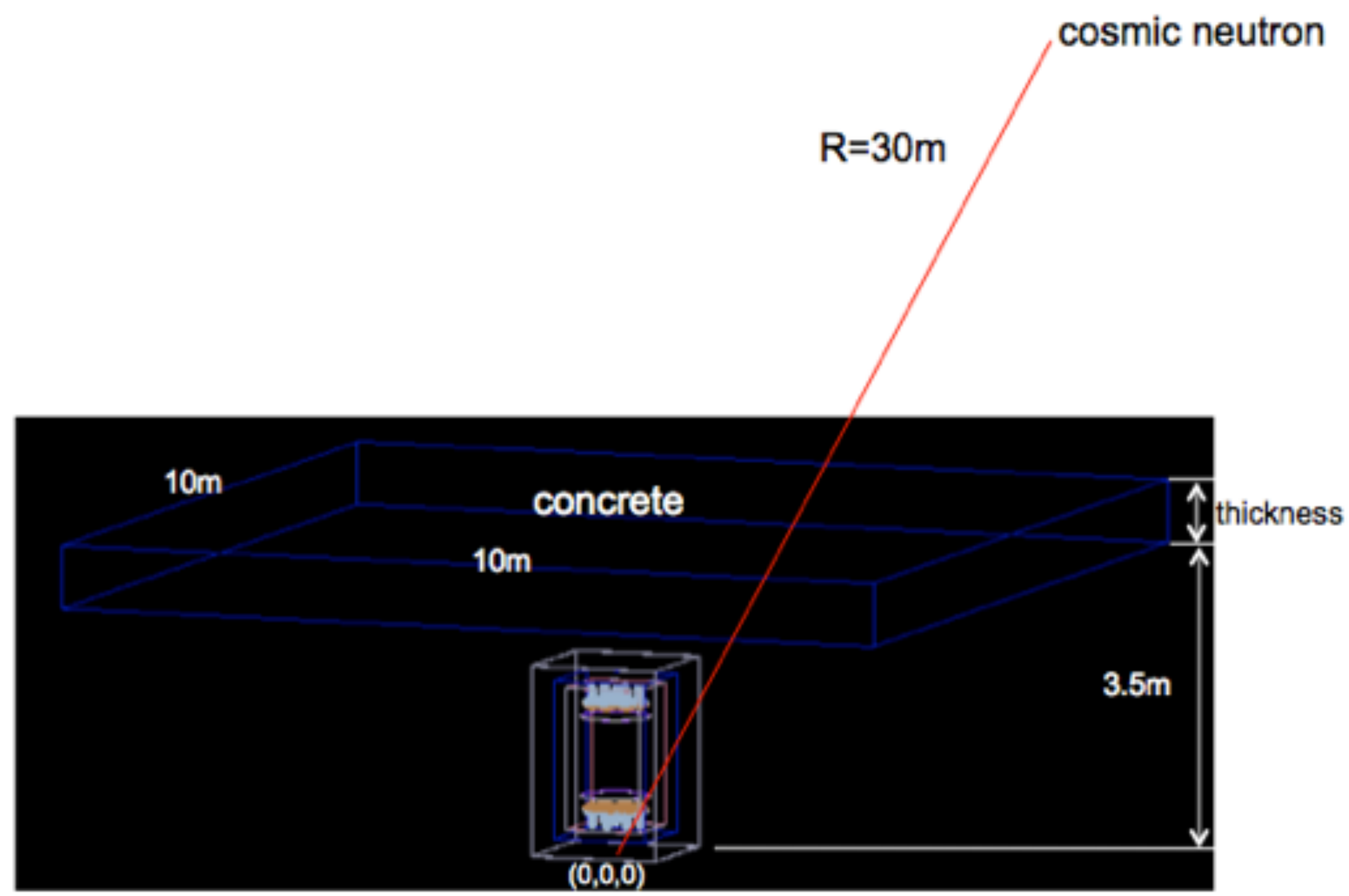


# Background simulation
# - work in progress -

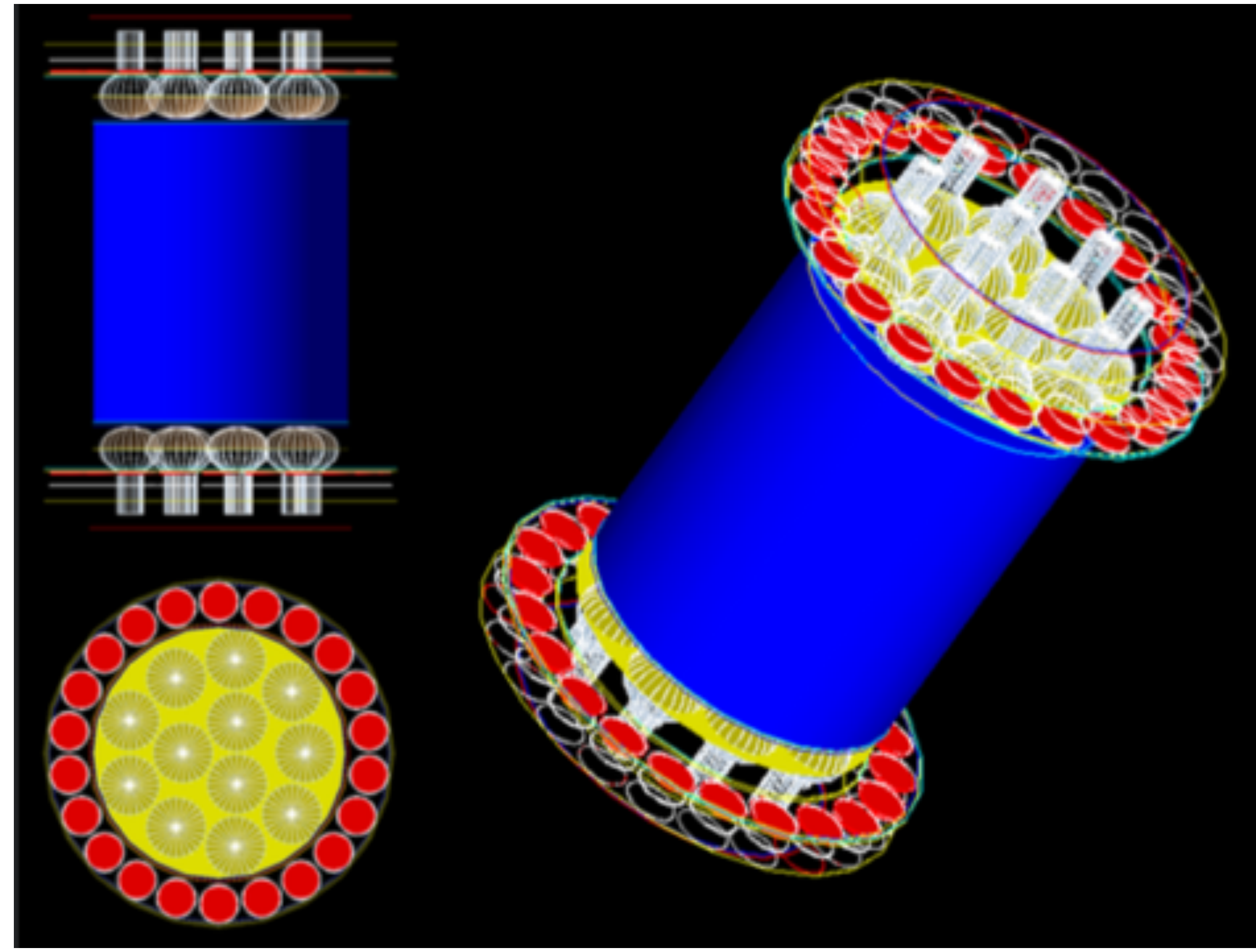
- We have been simulating the comic muons and neutrons separately according to the distributions expected at the sea level
  - Cosmic muon and muon-induced neutron simulation: using modified Gaisser-parameterization
  - Cosmic neutron simulation: using CRY(Cosmic-ray Shower Library) software developed at LLNL
  - Hadronic models of muon and neutron are used in the simulation
- In simulation, we are considering thick concrete overburden in the area of 10mx10m over the detector to compare with Data

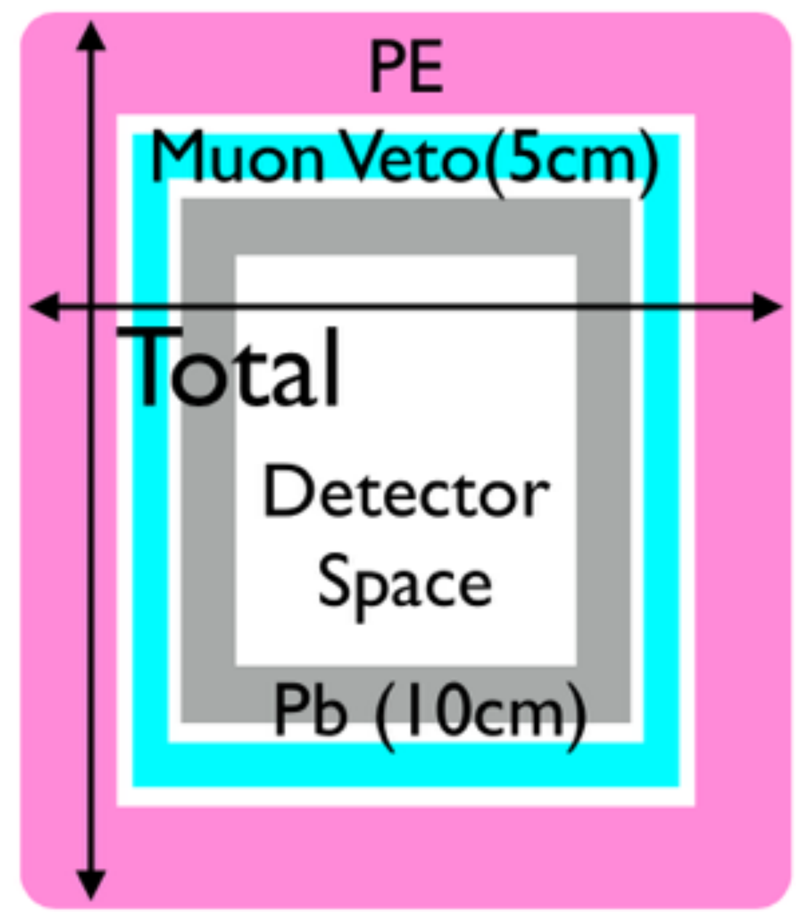


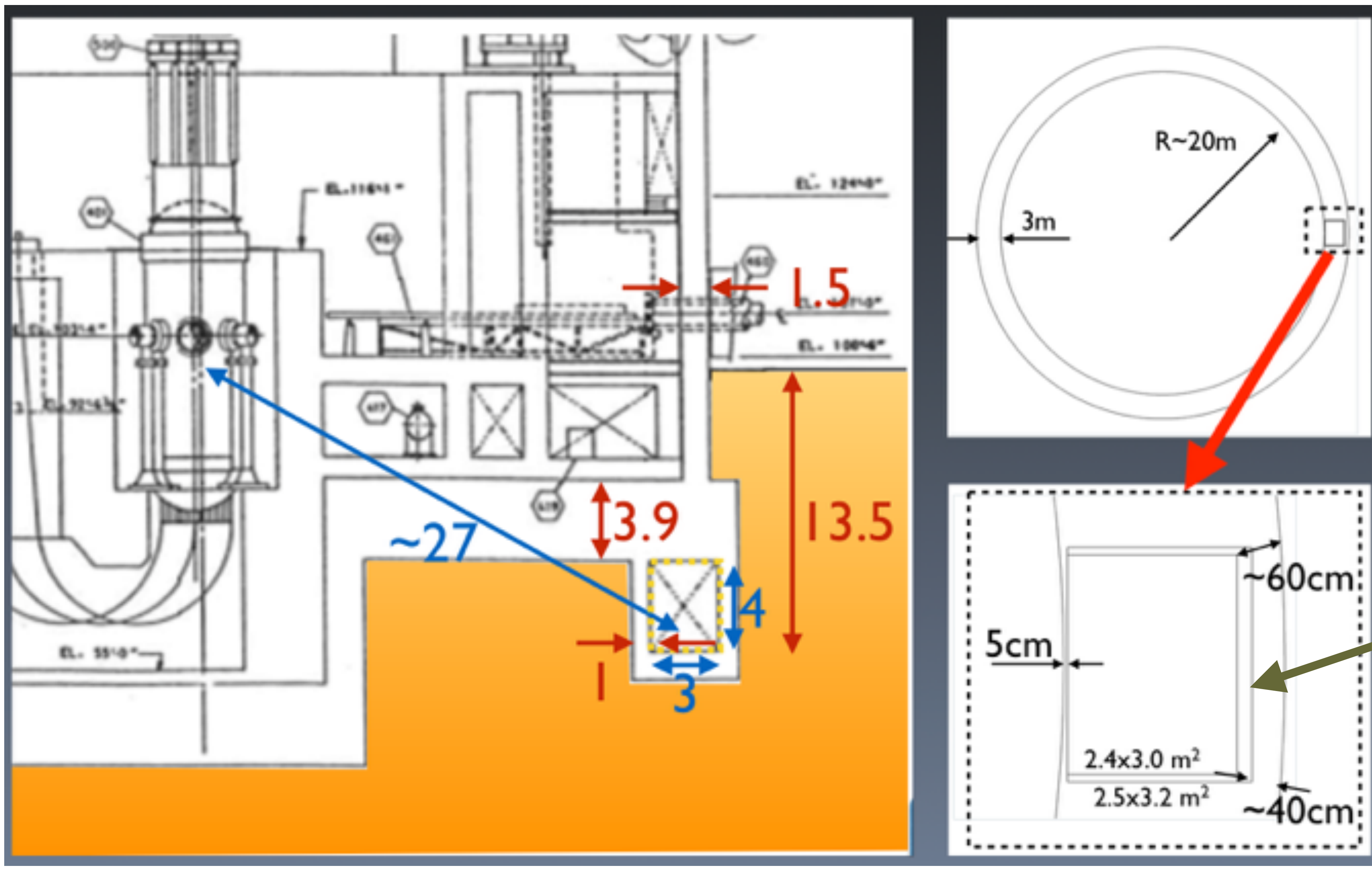
# Main detector

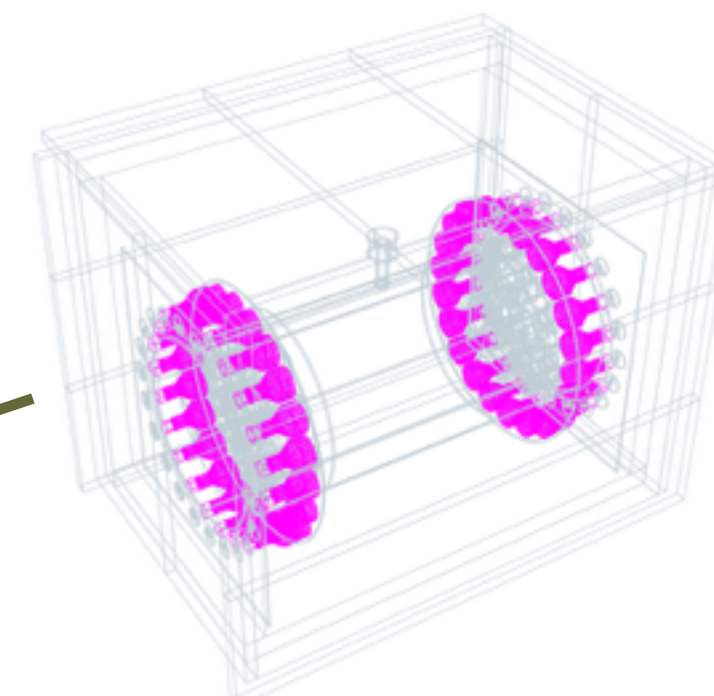
- Homogeneous target
  - ~500L of GdLS
  - ϕ85cmxH100cm cylindrical tank
  - ~68 PMTs
- Passive shields
  - Lead shield to block external gammas
  - PE shield to block neutron
- Muon detector
  - Plastic scintillator with 4π coverage
  - Veto cosmic muons
- We're optimizing main detector design with dimensions of $2.5x2.5x3m^3$, ~30ton





# Tendon gallery of HANBIT reactor and detector deployment



# Schedule and plan

| Time | Plan |
|---|---|
| ~ 2015.04 | completion of main detector construction |
| 2015.04 ~ 2015.05 | test on main detector |
| 2015.06 | deployment of main detector in the tendon gallery |
| 2015.08 ~ | it will start taking data |

# Summary

- Prototype detector constructed and measured backgrounds above ground
  - We measured background events for different overburden over the detector at two places
  - It is found that cosmic neutron backgrounds can be reduced ~10 times when we have about 1.5 m.w.e overburden
  - We tested the capability of PSD with different target material filled in prototype detector and it showed good separation power of PSD in prompt signal, 55% rejected with ~1.5 m.w.e overburden
- We will construct main detector with optimized design and will deploy it in the tendon gallery of HANBIT reactor
  - Background measurements with prototype detector show that overburden over the detector is crucial to the ratio of signal to background
  - Tendon gallery of HANBIT reactor is the best place to reduce cosmic neutron backgrounds

# Backup

# Feasibility test with ~500L homogeneous detector

Using $\chi^2$ as described in hep-ex/1307.2859 (K.M. Heeger *et al.*)

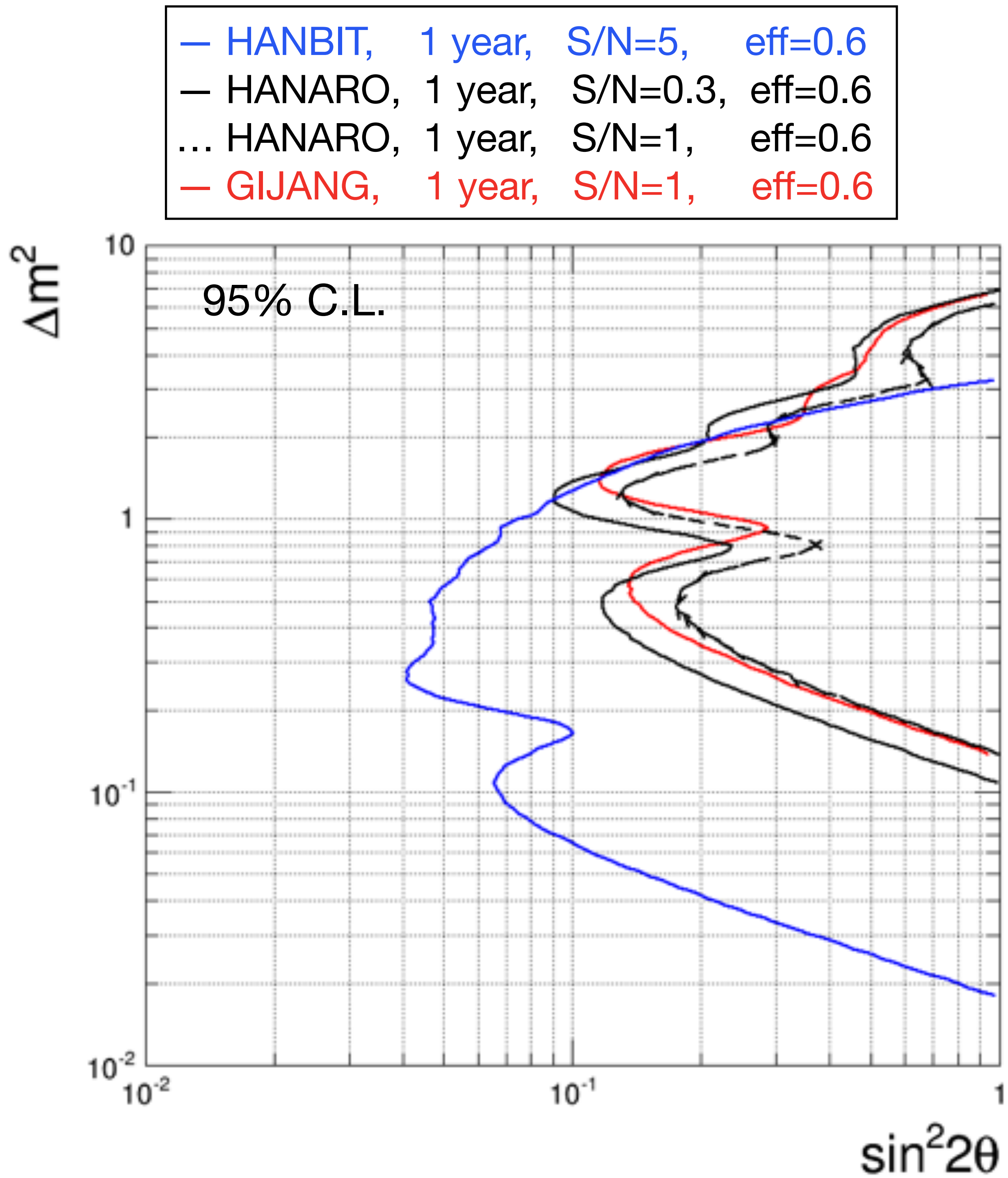
$$\chi^2 = \sum_{i,j} \frac{\left[M_{ij} - (\alpha + \alpha_e^i + \alpha_r^j)T_{ij} - (1+\alpha_b)B_{ij}\right]^2}{T_{ij} + B_{ij} + (\sigma_{b2b}B_{ij})^2} + \frac{\alpha^2}{\sigma^2} + \sum_j \left(\frac{\alpha_r^j}{\sigma_r}\right)^2 + \sum_i \left(\frac{\alpha_e^i}{\sigma_e}\right)^2 + \frac{\alpha_b^2}{\sigma_b^2}$$

minimize $\chi^2$ with respect to the nuisance parameters $\{\alpha, \alpha_r^j, \alpha_e^i, \alpha_b\}$

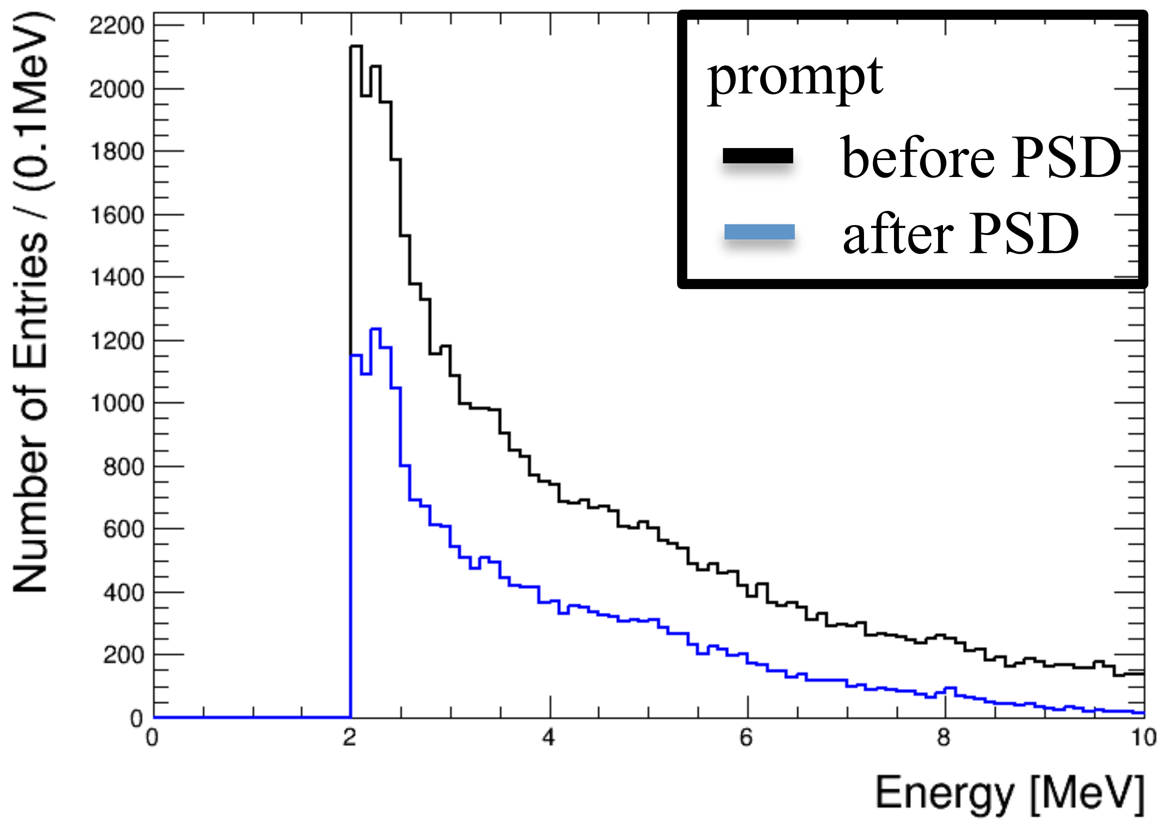
- Detector response:
  - energy resolution: 10%/√E
  - position resolution: 15cm
  - detection efficiency: 60%

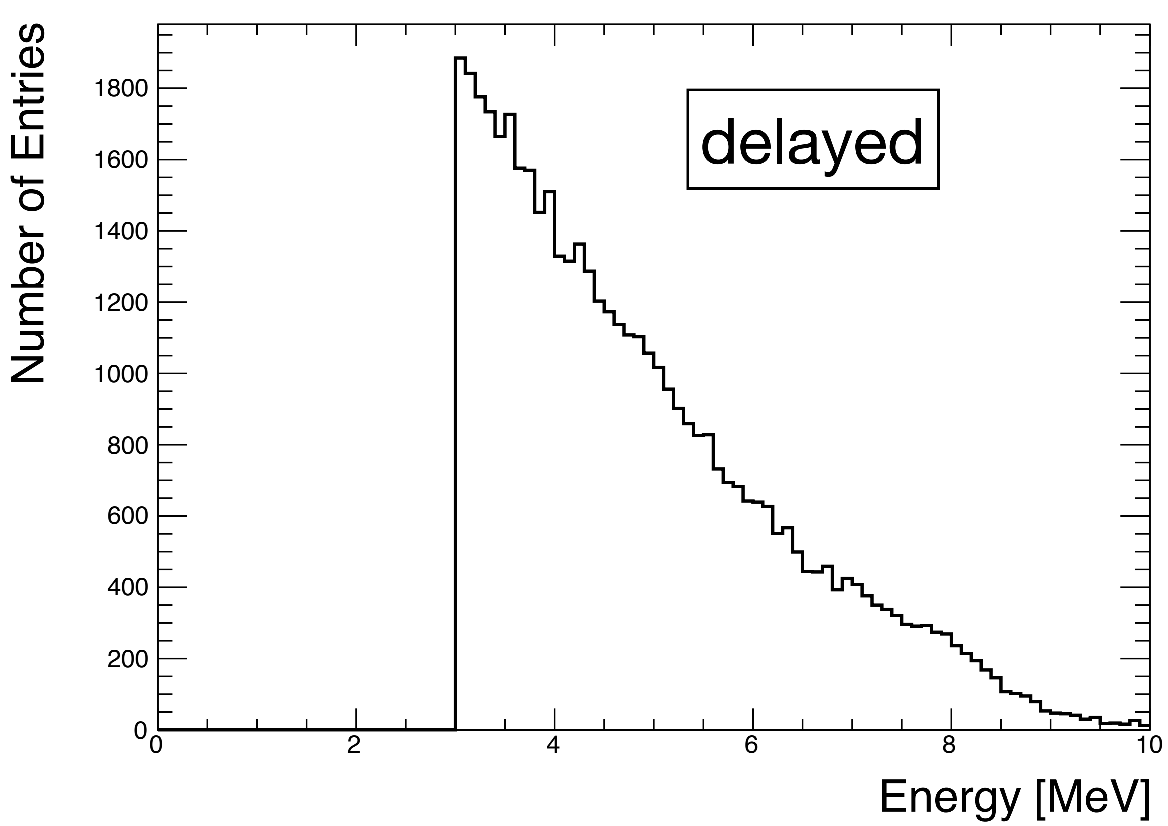
- Signal to background

# Feasibility test with ~500L homogeneous detector

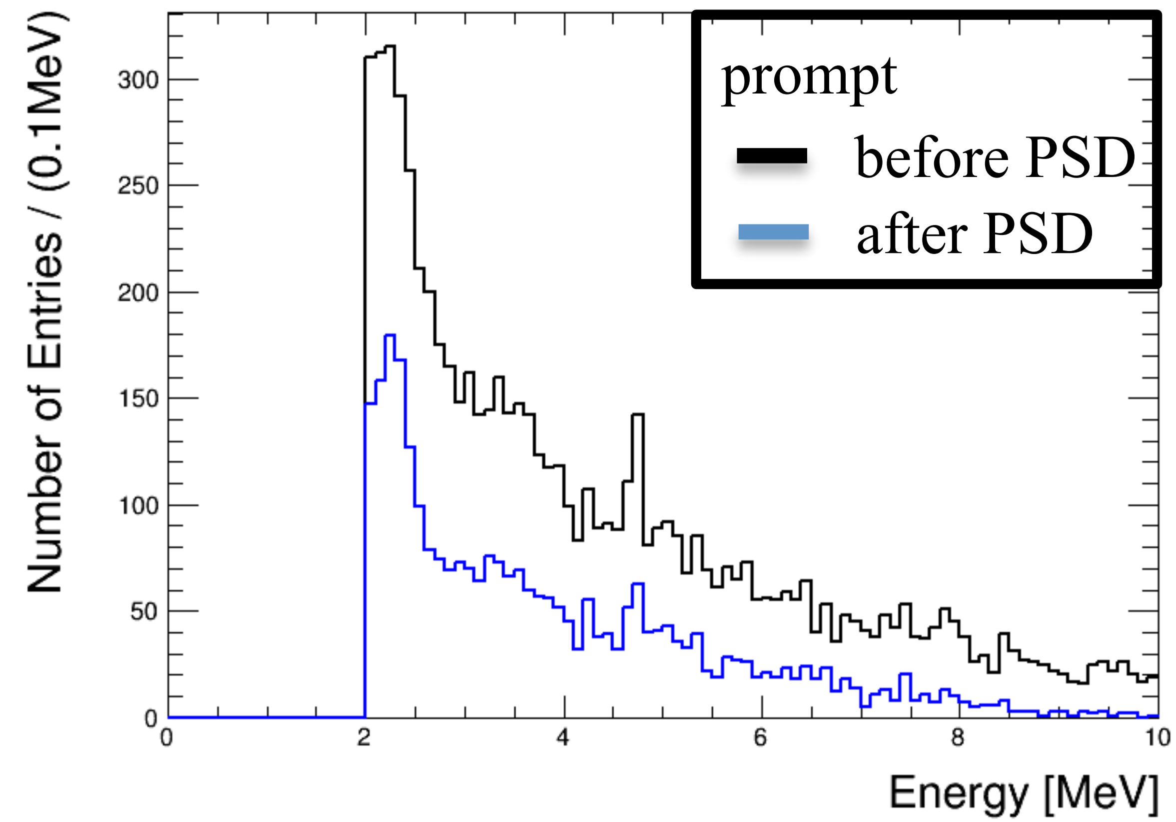


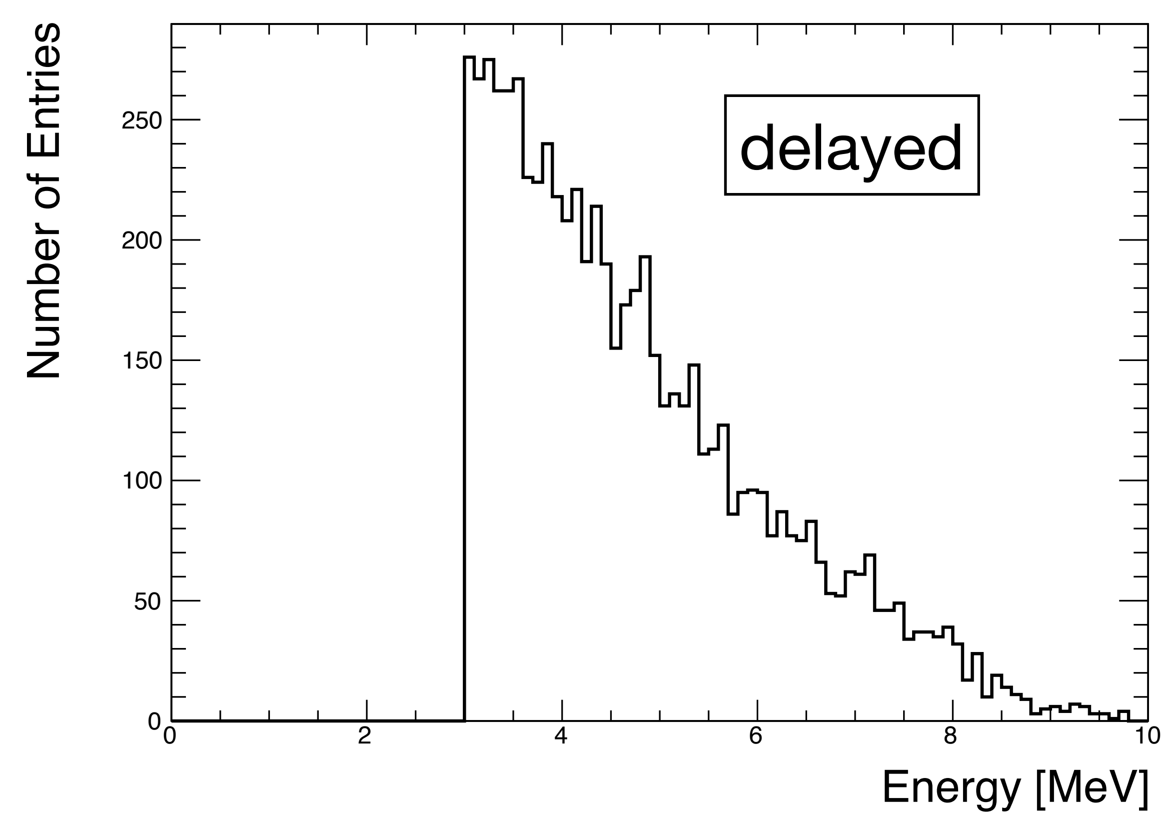
- KT1 Lab.: little overburden




- Seeding Lab.: ~1.5 m.w.e overburden

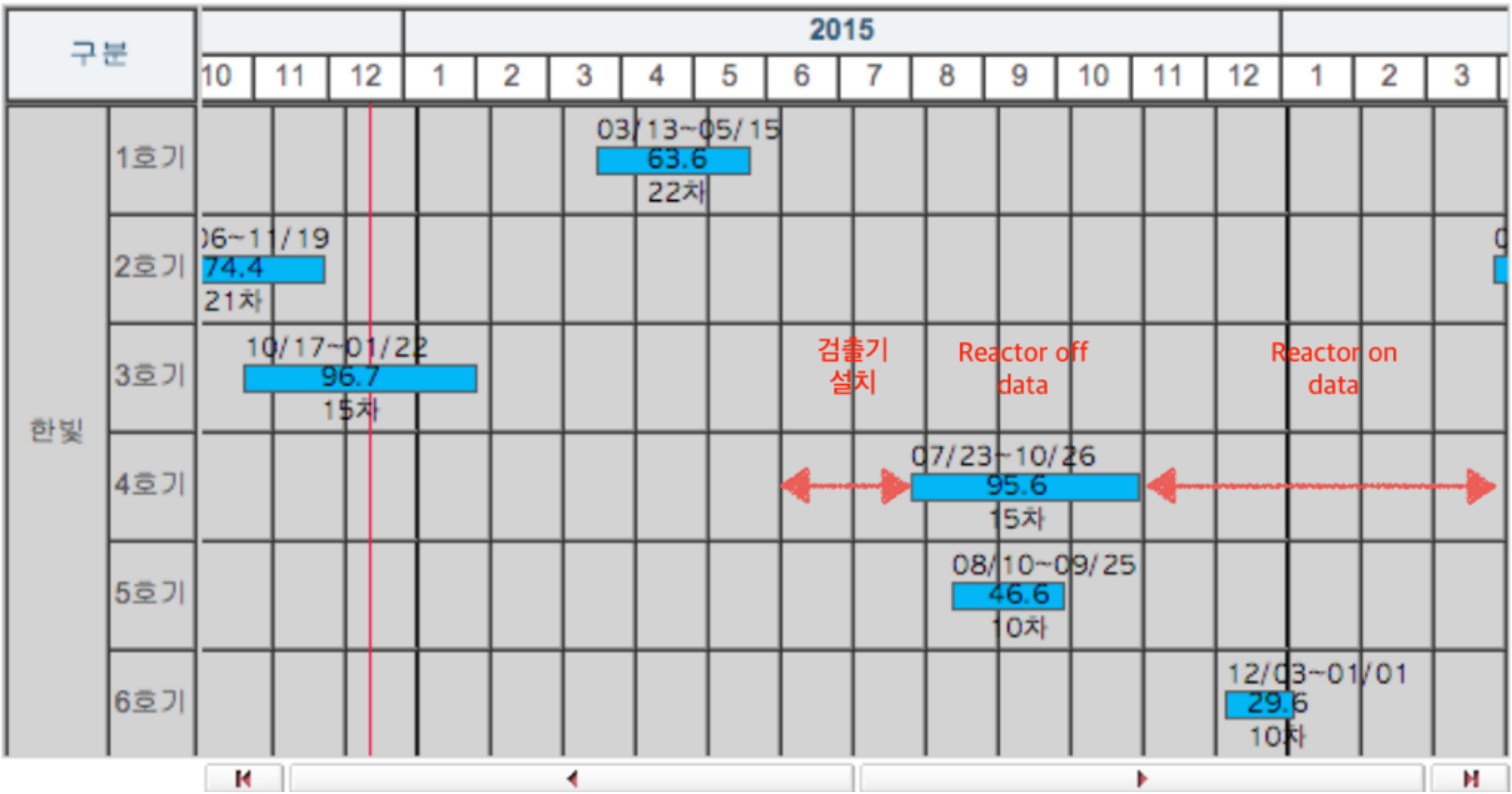


# 계획예방정비

※ 기간을 Click 하시면 주요작업이 조회 됩니다.

2015 검색



# 원자로 모니터링

(from RENO)