R&D of
Tohoku reactor monitor Ⅰ

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Introduction

- Double Chooz Japan Group is going to develop a reactor neutrino detector for future neutrino experiment. As an application, we are now developing a small neutrino detector for neutrino monitor.

- We are aiming at …
  - Possibility of measure neutrinos from **lower power reactor** such as researcher reactor **on ground level**.
  - The detector is **more simple** because of the lower cost.

Introduction

- We developed a prototype detector with 0.76tons at JOYO.
  - The prototype detector was set up on ground level at JOYO site in 2006, and we try to measure neutrinos and the BG at the reactor site in 2007.
  - The goal of this measurement was to distinguish between reactor-on and off by the neutrino detection.
  - Statistically significant neutrino excess was not observed, but we understand the BG well.
  - As one more object, we want to observe the first detection of fast reactor neutrinos.

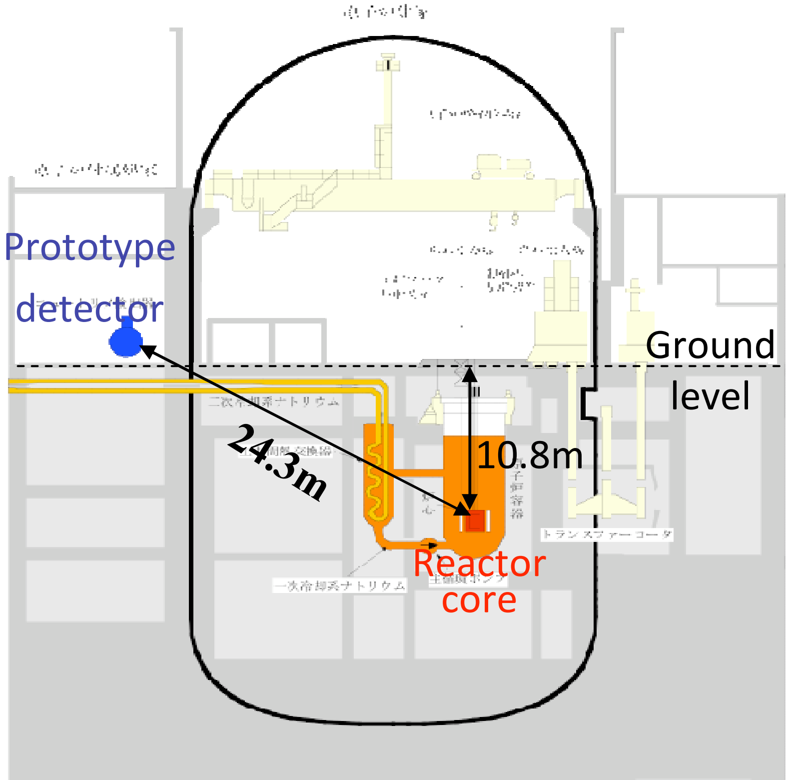
- We designed a new detector which is upgraded from JOYO detector.
  - We measured PSD ability of upgraded Gd-LS and we designed an upgraded detector. Then, S/N estimation was curried out with the MC simulation. (this talk)
  - Now we are constructing the upgraded detector at RCNS. (next talk)

Fast experimental reactor JOYO

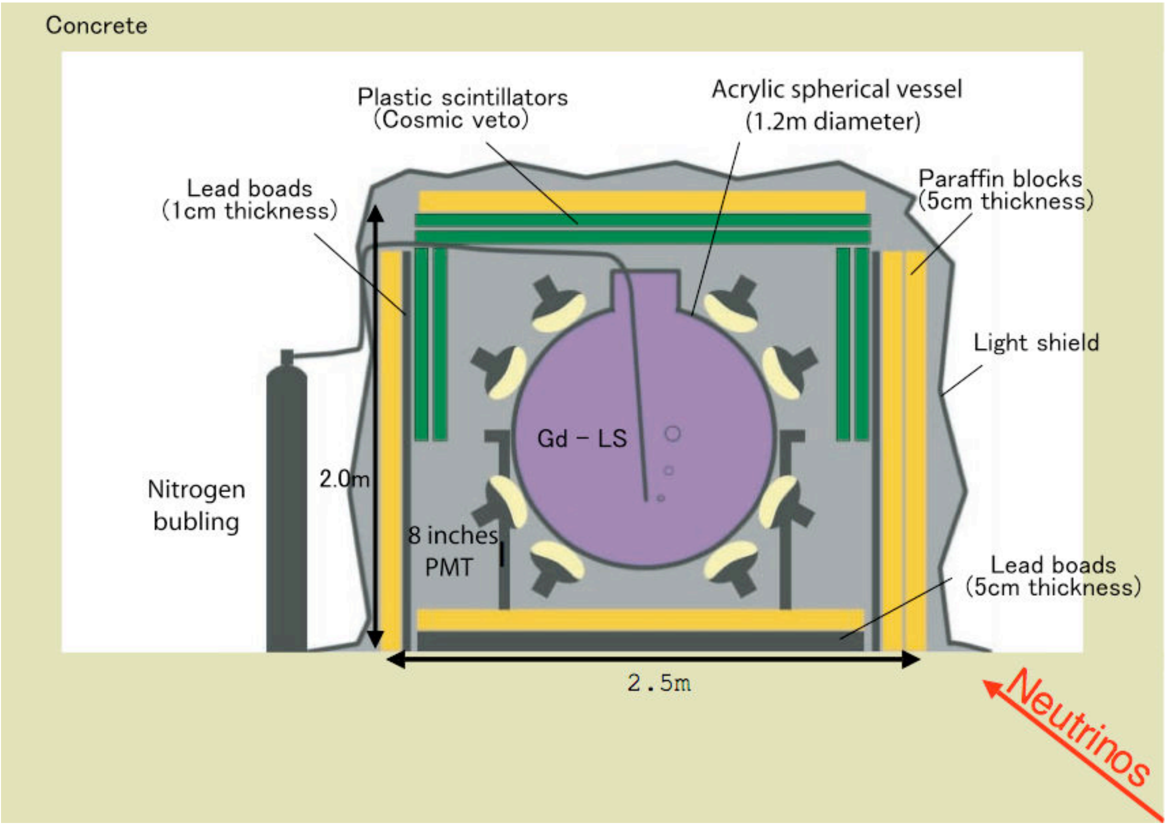
- Fast Reactor : Joyo
- Thermal power = 140MW
  - (1/20 general reactor)
- Fuel : U(70wt %), Pu(30wt %)
- Operated by JAEA
- Operation days / Cycle : 60(rest 1cycle)

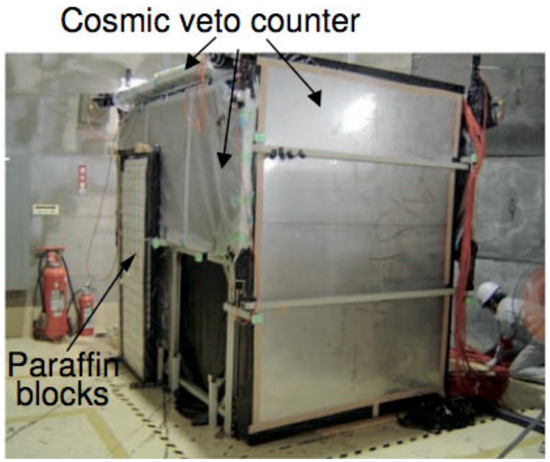
  → Easy on/off data taking
- ~162 $\nu p \rightarrow e+ n$ reactions/day

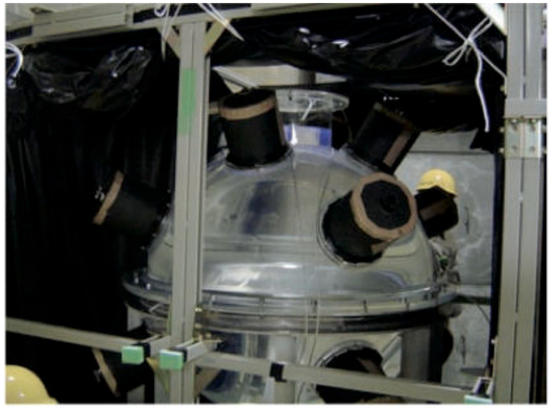
- We will visit the fast experimental reactor JOYO tomorrow.



Setup in JOYO site







Prototype detector

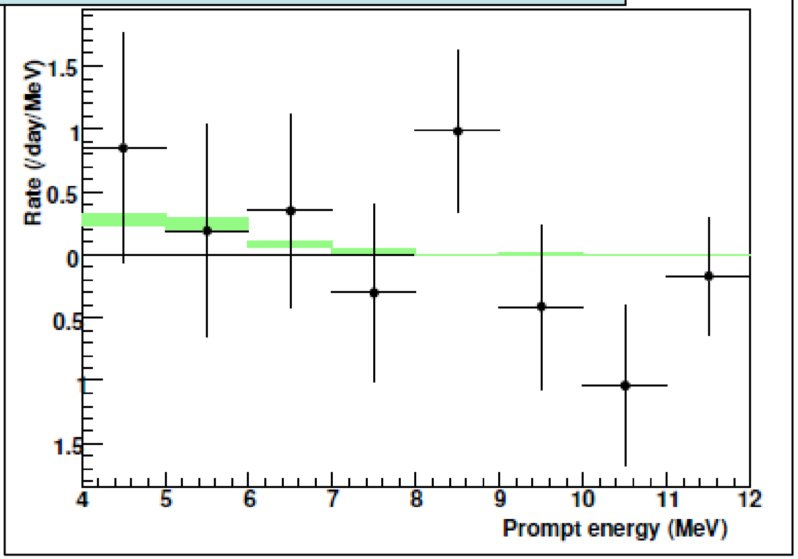
- 0.05%Gd LS : 10%BC521+15%PC+75%isoParaffin oil, 900L
  - BC521 is commercial Gd (0.5w%) loaded liquid scintillator.
- 8”PMT’s : R5912,16 PMT’s(10%), covered each by μ -metall
- Cosmic veto counters : cover top hemisphere of Acrylic sphere

The result of JOYO measurement

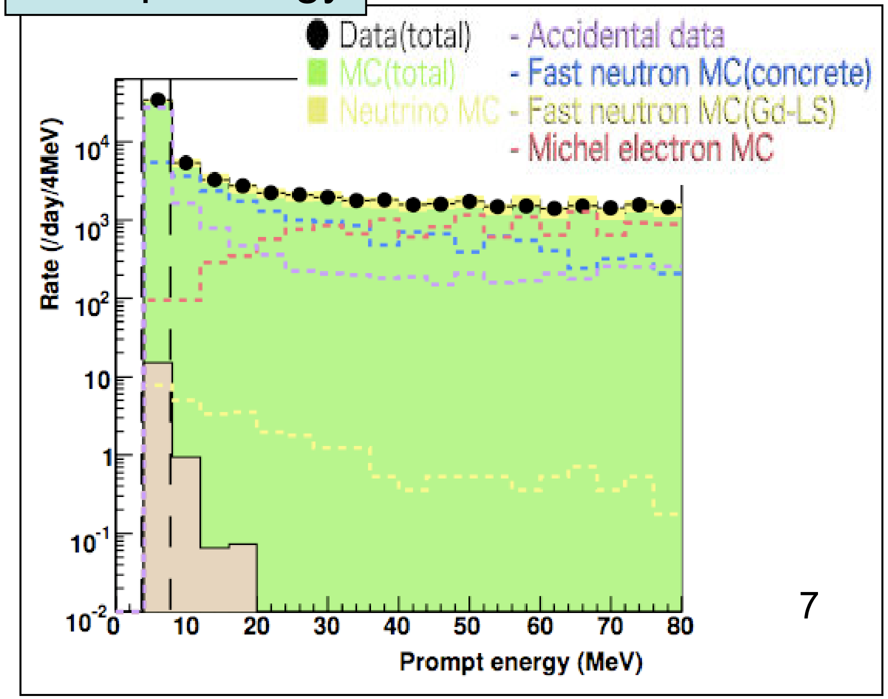
- Data and expected neutrino rate after the selection agreed within the error.
- Observations of significant neutrino excess have not been statistically established in this analysis.
- We were able to understand the BG.

neutrino rate (ON-OFF)	**1.1±1.2(MC:0.49) /day**
neutrino efficiency	**0.3%**
Total BG	**17.0±1.0/day**
S/N	**1/35**

Energy spectra of neutrino candidate and expected rate



Prompt Energy



Summary of problems for JOYO measurement

- The statistics of reactor-on and off data was not enough, due to the aging of Gd-LS.
- The fast neutron background was too much as against the neutrino signals, and S/N ratio was 1/35.
- It is impossible to lower the threshold level of trigger below 3MeV, due to environmental gamma-rays.
- Poor efficiency of fiducial cut due to one layer structure.

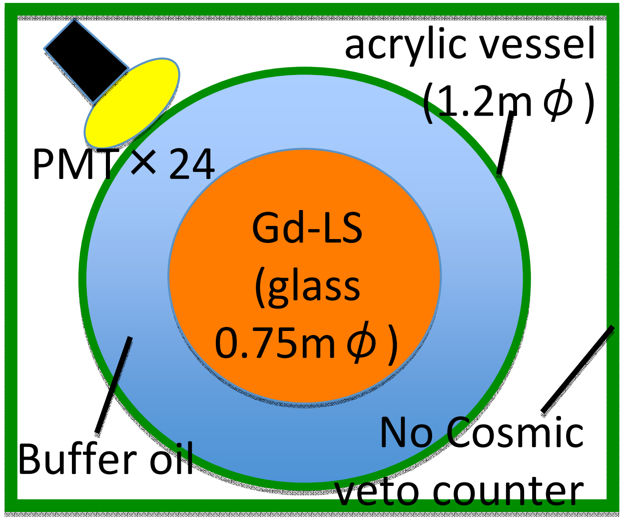
↓

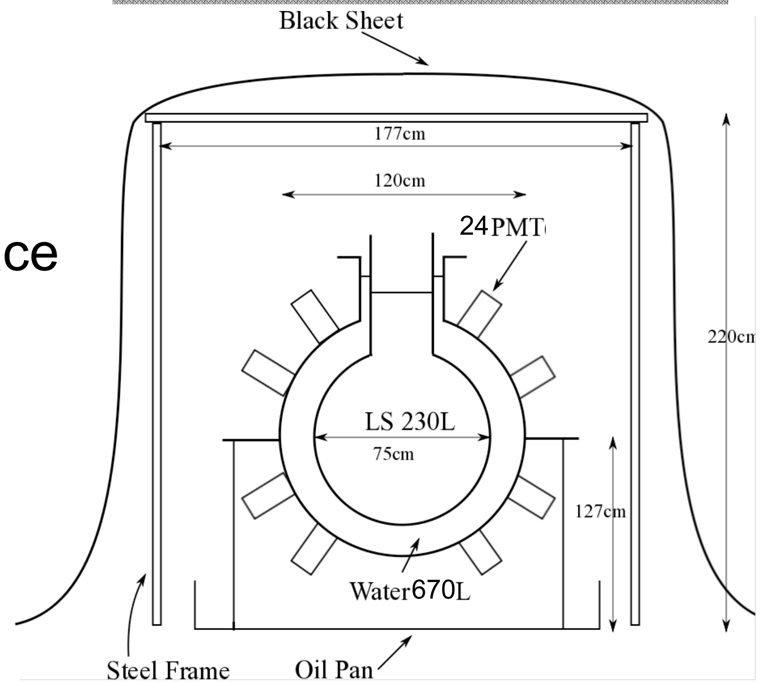
Next experiment

- Reinforcement shields for the fast neutron and environmental gamma-rays by arrangement of buffer oil layer and implement of Gd-LS with ability for **PSD**.
- Development of stable scintillator to Gd.

The upgraded detector design

- The target volume is decreased to 230L from 900L.
- The buffer layer with thickness of 20cm is implemented.
  - BO component is Paraffin oil (100w%).
  - The event vertex radii are reconstructed well.
  - In measurement we use BIG Glass flask.
    - It is bearable for chemical attack of PC.
- Non-shield of Pb or Paraffin and no cosmic veto counter.
  - Cheaper, Easier arrangement, Save space
- 8 PMTs of 10inches are added to improve light correction efficiency.
  - And signal data is taken by FADC
- Upgraded target Gd-LS

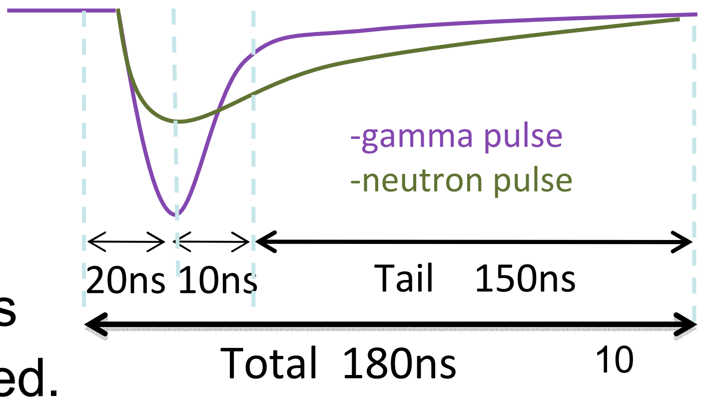




Improvement of the Gd-LS with PSD ability

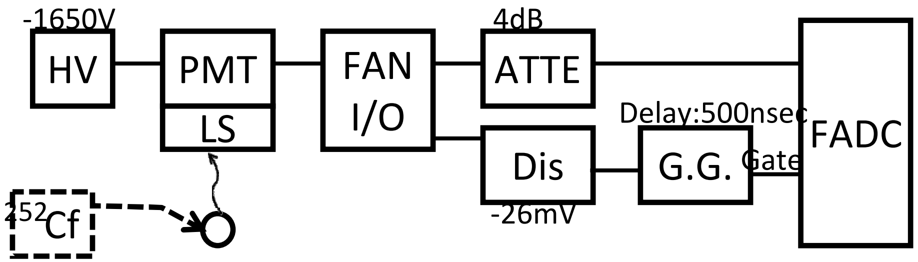
- The target of the upgraded detector is Gd loaded liquid scintillator (~Gd : 0.05w%).
  - The preliminary composition :
    - PC (Pseudocumene) (~90w%), BC521 (~10w%) and PPO (~3g/l).
    - The PC is increased from 15% to 90%.
  - It is expected to stabilize Gd-LS and improve the PSD ability.
  - Light yield of this scintillator is ~12.5 photon/keV.
    (9.4 photon/keV at JOYO)

- PSD (pulse shape discrimination)
  - Tail charge of the neutron signal is larger than that of gamma signal.
  - We can discriminate neutron from gamma rays by pulse shape analysis.
  - But it is said that PSD ability decreases when the size of the detector is enlarged.



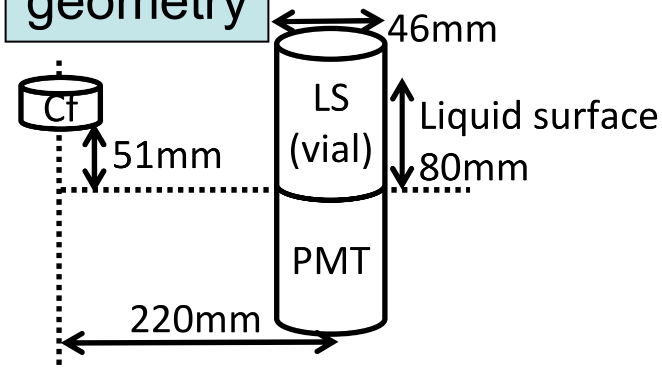
PSD Performance test of New Gd-LS at vial size

Electronics logic

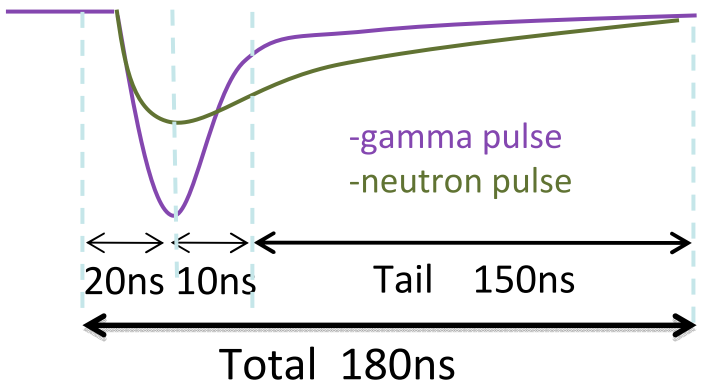


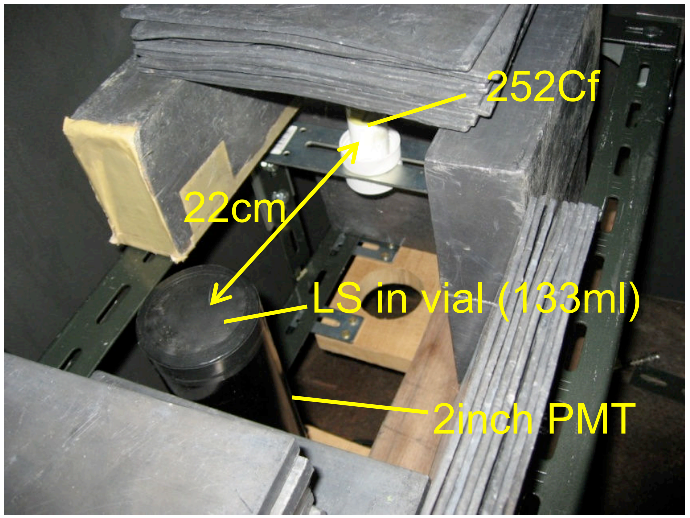
Cf252 : 2M[Bq]
3.8neutron+7.8gamma / 1SF

geometry



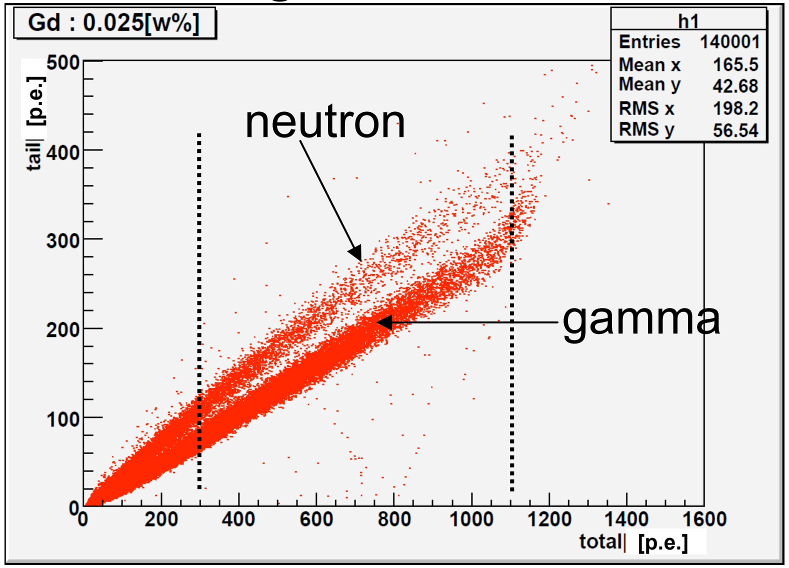
Pulse definition



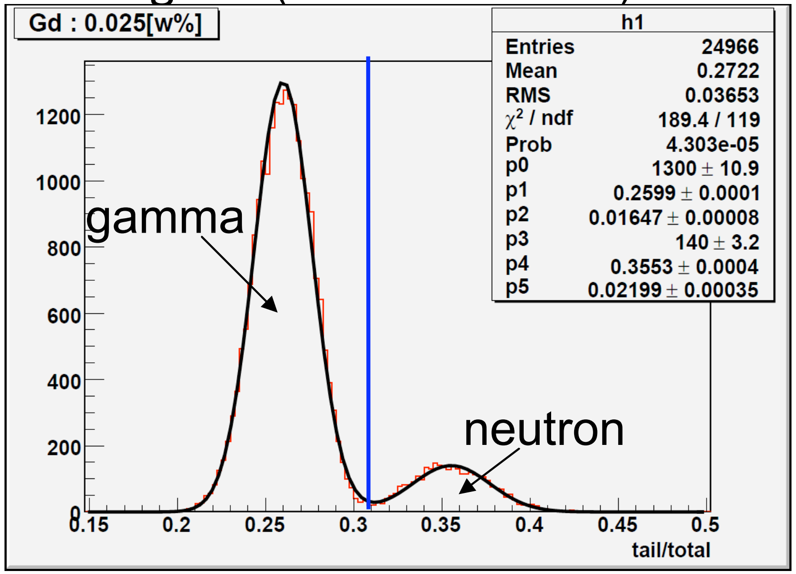


The gamma rays and neutrons are distinguished at the ratio of Tail charge to Total charge.

1. 2D histogram of tail charge and total charge

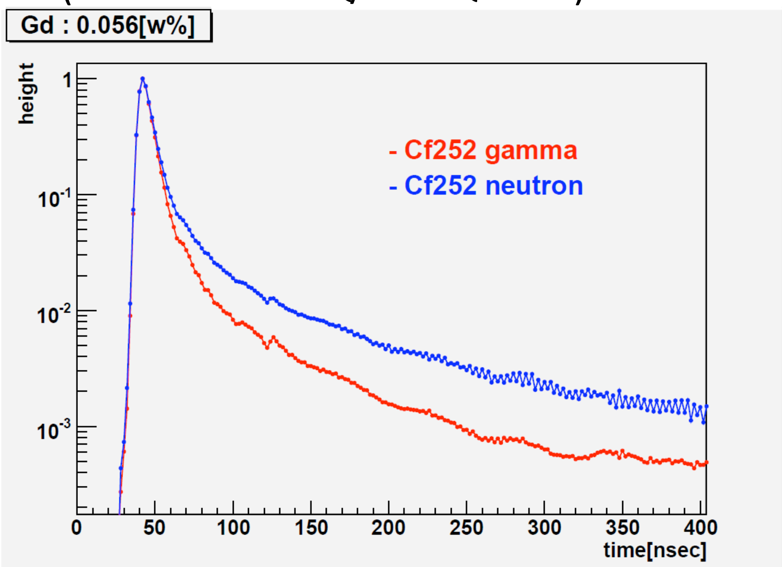


2. Two gauss fit of tail/total charge histogram (300<totalQ<1100)

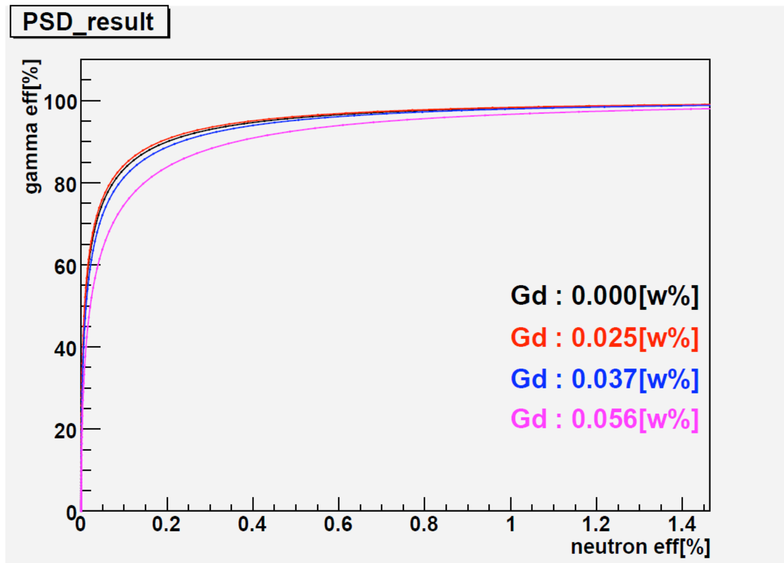


3. Mean pulse after discrimination.

(neutron -> tailQ/totalQ>0.31)



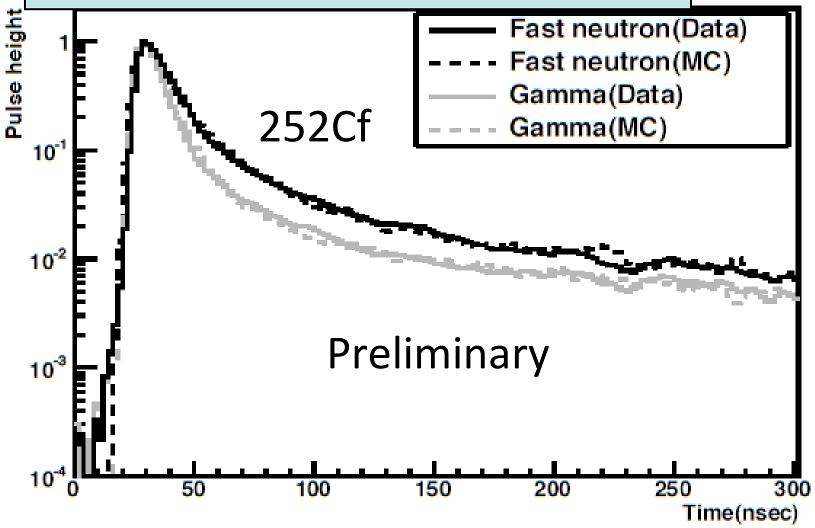
4. Efficiency graph



The MC condition of upgraded detector

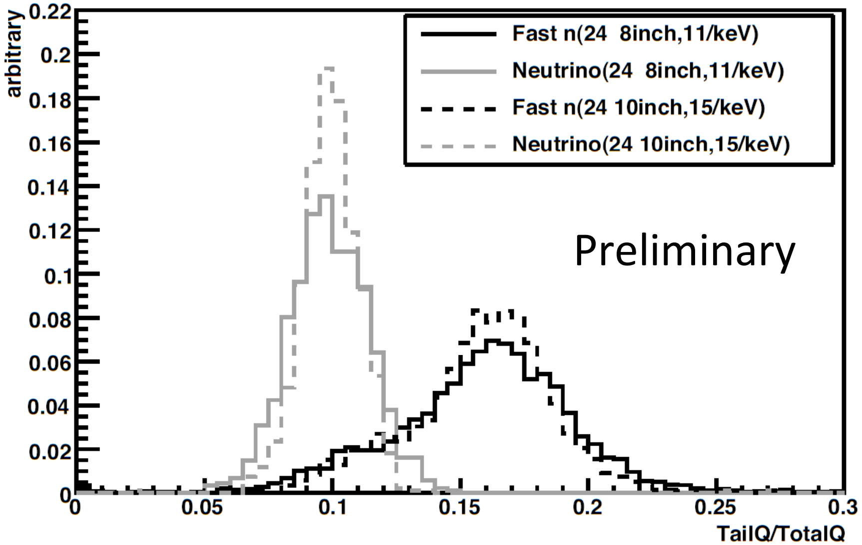
- MC condition for S/N estimation.
  - We use geant4 simulation. (G4version4.9.0.p01)
  - Geometrical set up is almost the same as upgraded detector design.
  - Thermal power is assumed as JOYO & Monju data.
  - Only the fast neutron is considered as the BG. And its generator data was tuned by JOYO measurement data.
  - Trigger threshold levels for prompt and delayed signals are assumed as the energy of 3 MeV.
  - MC Wave forms of neutrino and fast n events were tuned by comparing with the measured data of 252Cf with vial size LS.

Wave forms of vial data and MC



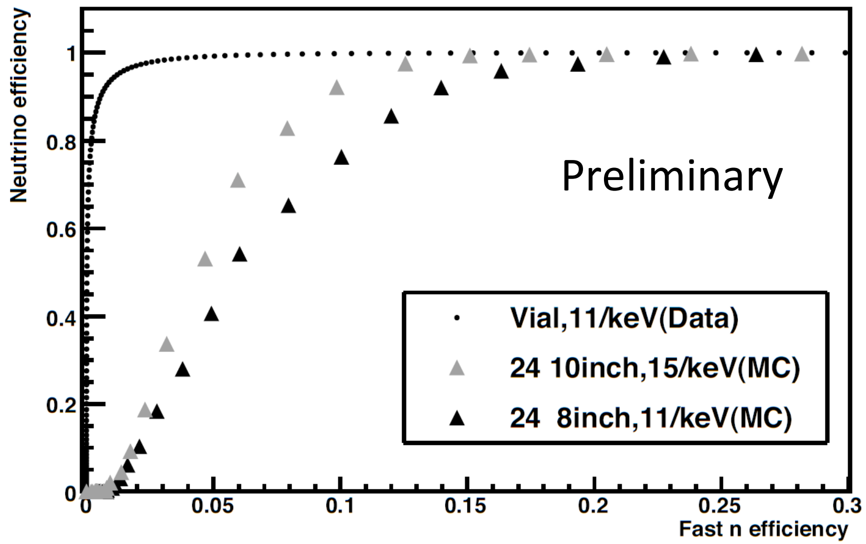
PSD ability of the Gd-LS with MC estimation

Charge ratio of Tail and Total
(Neutrino and fast n BG at Joyo site)



※3<Eprompt<6MeV, 3<Ed<9MeV, 3<Δt<100us

Cut efficiency
(Measured data and MC)



- The PSD ability tends to fall down when the target volume becomes bigger. But in case of the upgraded detector size, PSD cut is also expected to be useful.

- **Tail/Total < 0.1 Fast neutron exclusion is 94%**
  - **(Neutrino efficiency ~ 54%)**

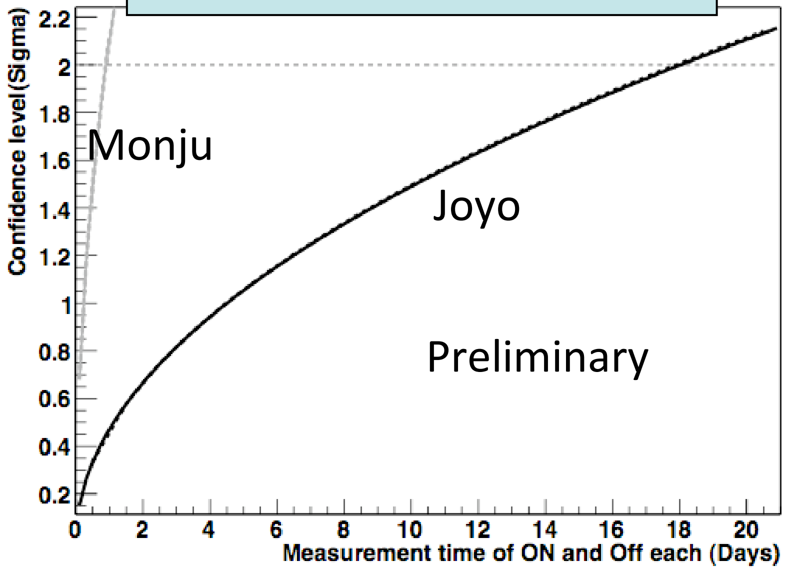
MC result of S/N estimation

(upgraded detector)

Neutrino and fast n rate after each cut (cut efficiency)

Cut	Neutrino(/day)	BG(/day)
3<Ep<6MeV 3<Ed<9MeV 3<Δt<100us	7.0±0.2	985±14
Tail/Total<0.1	3.8±0.2 (0.54)	58.5±3.4 (0.06)
Rp<25cm	3.1±0.2 (0.82)	19.7±2.0 (0.34)

Achievable confidence level for neutrino observation



Expected S/N and Neutrino rate

Detector	Reactor	Neutrino(/day)	Fast n(/day)	S/N
Prototype detector	Joyo(140MWth)	0.49	17.2	1/35
New detector	Joyo(140MWth)	3.1	19.7	1/6.4
	Monju(714MWth)	15.5		1/1.3
	PWR(3GWth)	66.4		1/0.3

It is expected to improve the neutrino efficiency (5.5 times) by the measurement with the new detector.

Summary

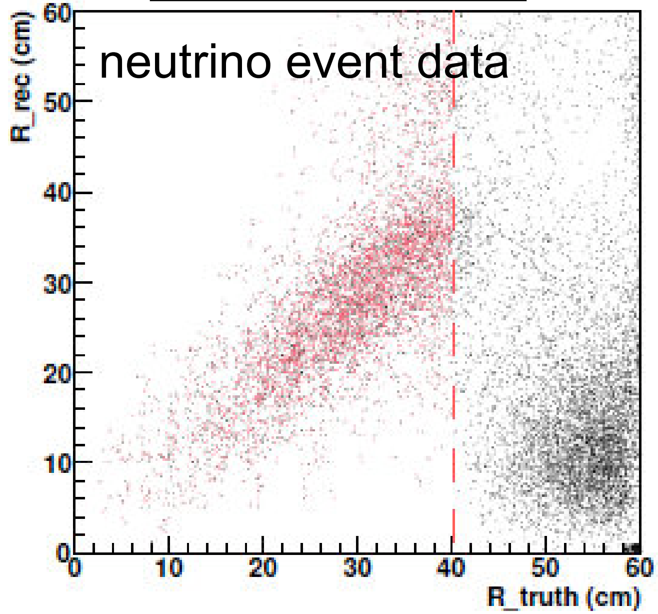
- We measured the background at Joyo site with prototype detector for R&D of a compact reactor neutrino monitor.
- An upgraded detector with buffer oil layer and PSD ability was designed, and the S/N estimation was carried by MC simulation.
- Now we are developing upgraded detector at RCNS. Current status of the construction and preliminary data will be presented in the next talk.

END

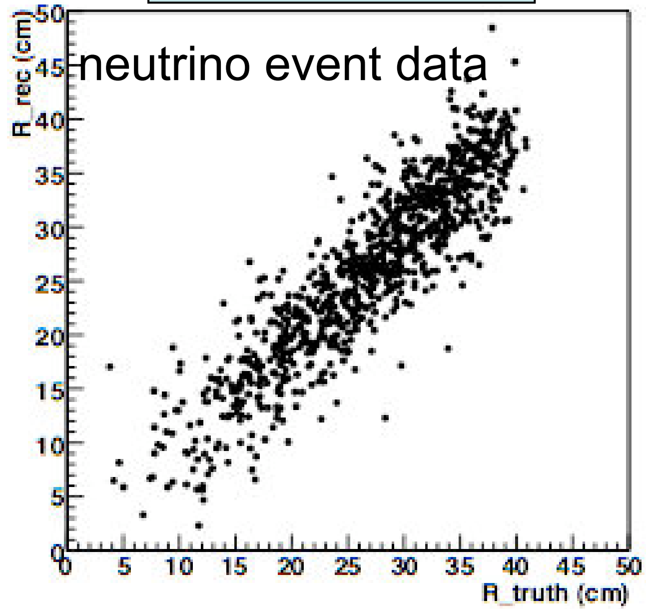
Back up

Improvement of vertex radius reconstruction at MC study

KASKA prototype



The new detector



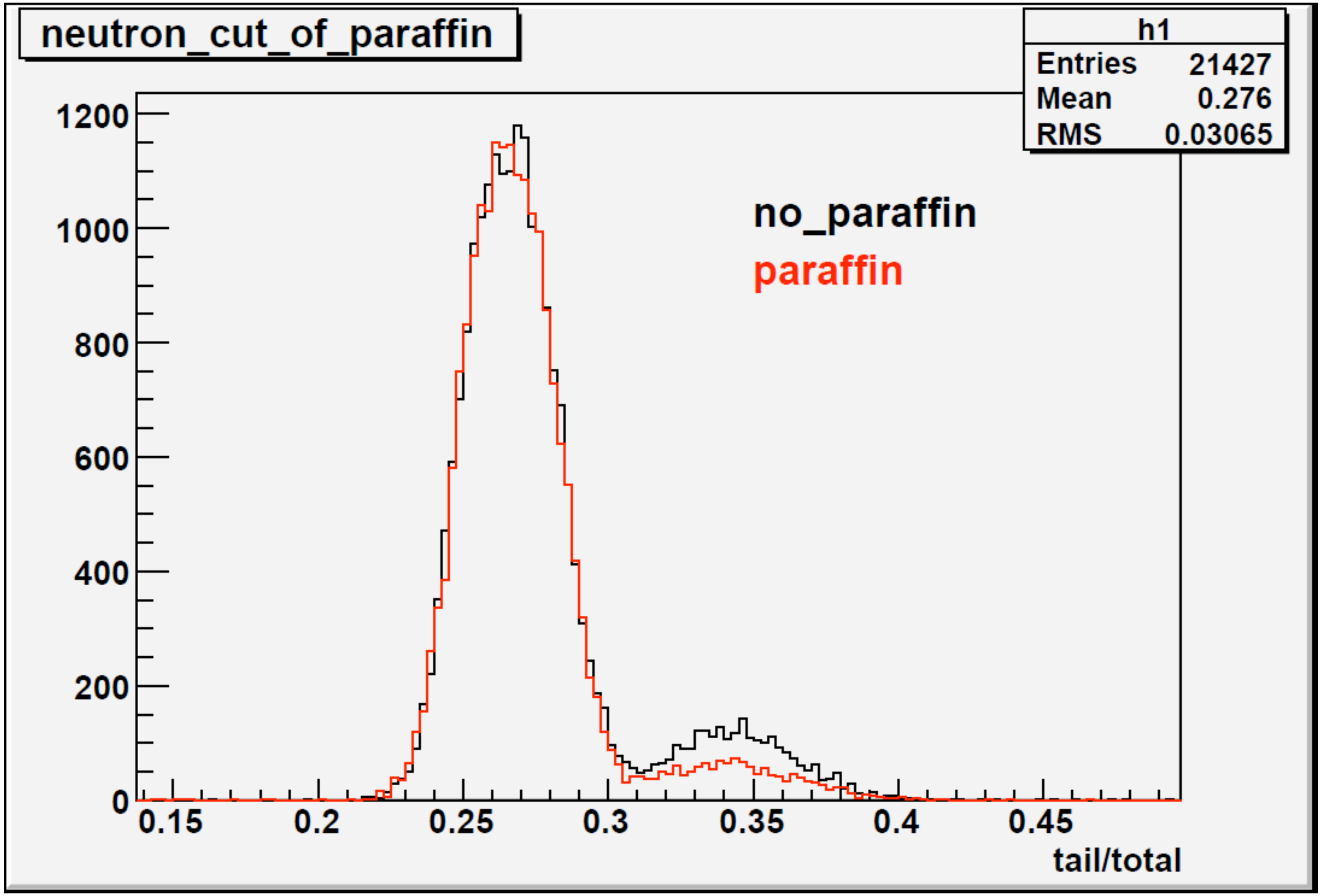
- Events with the vertex radii above 40cm are reconstructed badly, because PMTs are mounted on the target volume directly and it is hard to calculate exactly the solid angle of events with the vertex near the photocathode surface.

- The radii are reconstructed well due to addition of buffer layer.

- Improvement of radius resolution 11.4cm (under 40cm) → 5.2cm (all range)

表 7.2: 最終のカット条件によるニュートリノとバックグラウンドのイベントレート

cut *condition*	*Accidental* [/*day*]	*Michel* e^- [/*day*]	*Fast n* [/*day*]	*Total BG* [/*day*]	*Neutrino* [/*day*]
$3 \leq E_{prompt}$ $3 \leq E_{delayed}$	314539±19820	84165±1310	7756±39	403760±19863	11.5±0.31
$3.5 \leq E_{prompt} \leq 6$ $4 \leq E_{delayed} \leq 9$	82.4±3.0 (0.00026)	1432±170 (0.017)	613±11 (0.079)	2127±170 (0.0053)	5.7±0.22 (0.50)
$5.0 \leq \Delta t \leq 100$	78.3±2.9 (0.95)	161±57 (0.11)	545±10 (0.89)	784±58 (0.37)	4.1±0.18 (0.72)
$0.08 \leq \frac{tailQ}{totalQ} \leq 0.155$	∼78.3±2.9 (∼1)	∼161±57 (∼1)	30.0±2.5 (0.055)	∼269±57 (∼0.34)	2.6±0.14 (0.63)
$0 \leq R_{prompt} \leq 25$ $0 \leq R_{delayed} \leq 40$	∼0.46±0.03 (∼0.0059)	$\sim 1.7e^{-3} \pm 0.6e^{-3}$ (∼0.00001)	5.6±1.1 (0.19)	∼6.1±1.1 (∼0.023)	1.1±0.09 (0.42)


neutron_cut_of_paraffin
h1
Entries 21427
Mean 0.276
RMS 0.03065
no_paraffin
paraffin
1200
1000
800
600
400
200
0
0.15
0.2
0.25
0.3
0.35
0.4
0.45
tail/total