Fast Reactor Neutrino Detection with KASKA Prototype Detector : A Status Report

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and M.Takamatsu JAEA

Outline

Report of fast reactor neutrino detection with KASKA prototype detector at Joyo Experimental Reactor taking data from this fall.

Contents

- KASKA experiment
- Prototype detector and its motivations
- Preliminary result of prototype detector : Gadolinium spectrum
- Experimental Fast Reactor : Joyo
- First data of Fast Reactor experiment
- Summary

KASKA experiment

(Measurement θ_{13} peoject)

KAShiwazaki-KAriwa nuclear power station

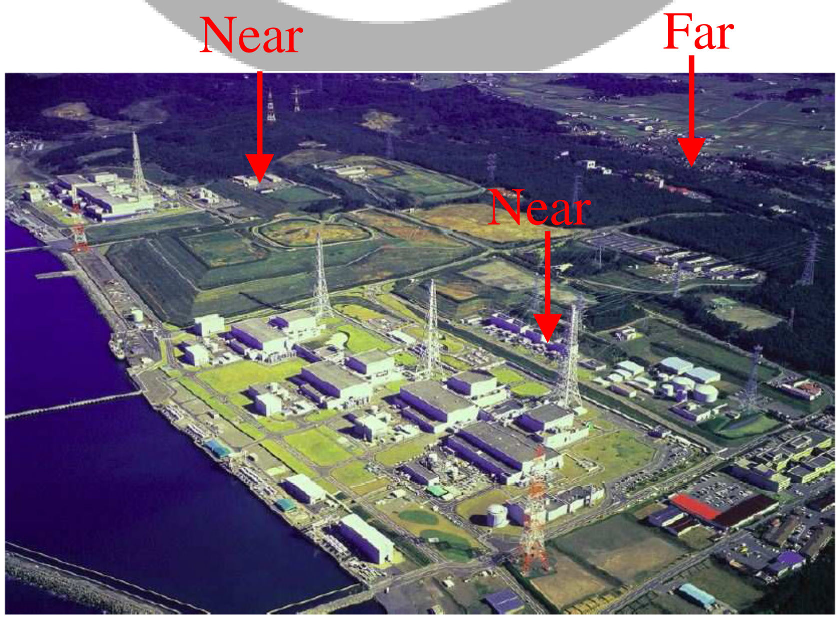
Located at Niigata prefecture in Japan

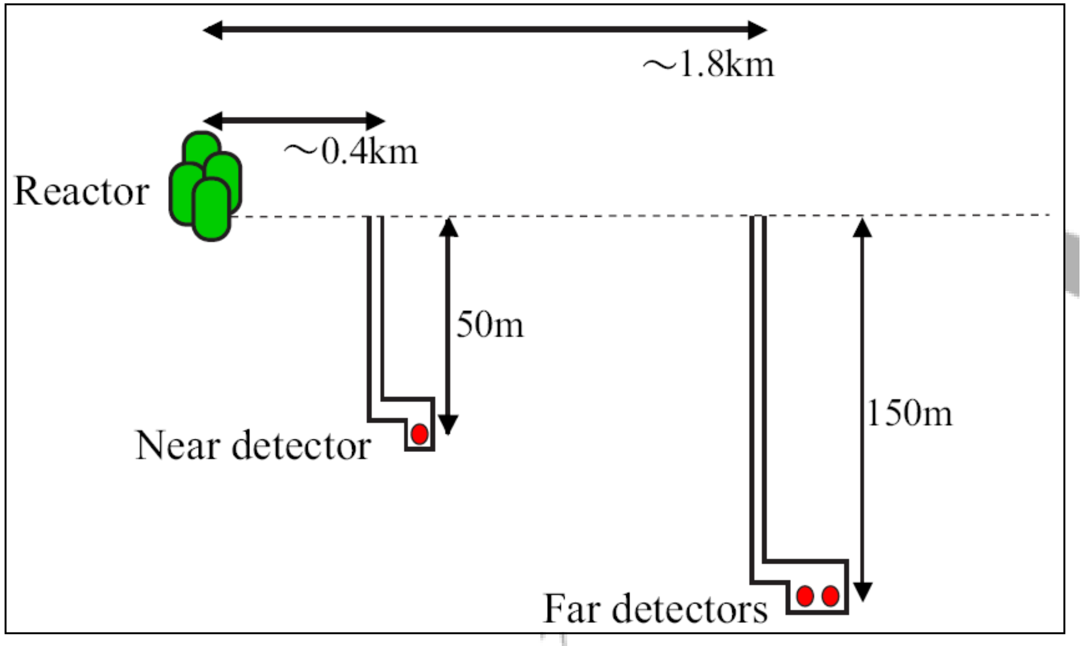
Largest thermal energy in the world (24.3GWth)

→ the most powerful neutrino source

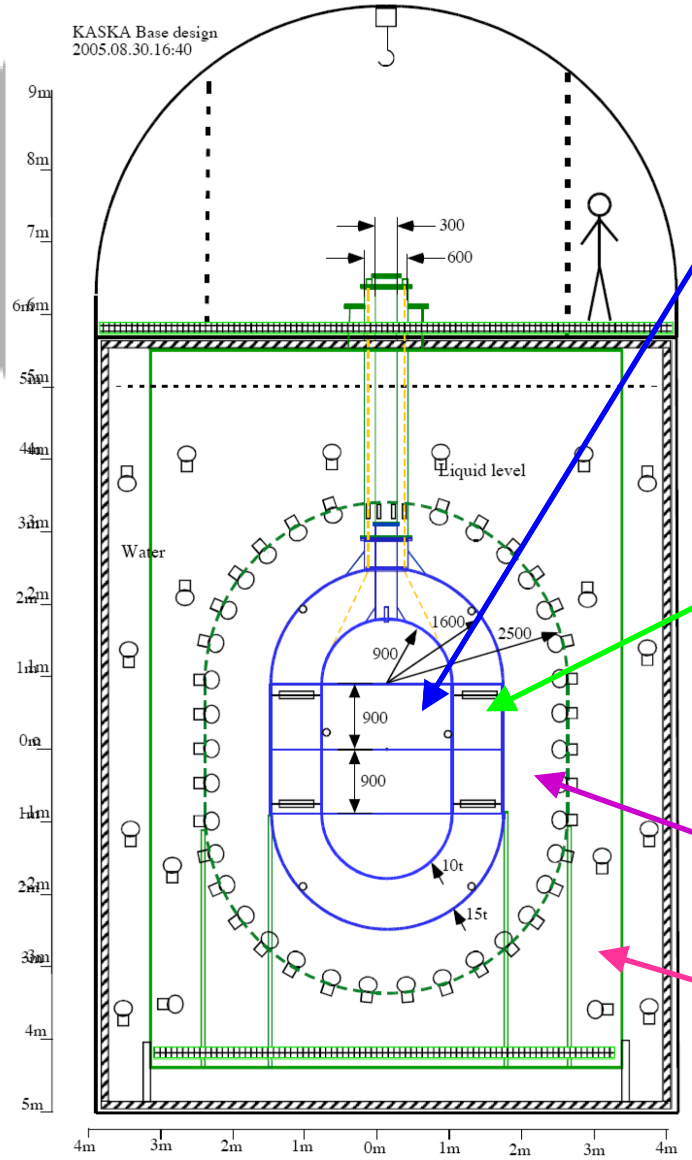
7 reactors in two clusters

Location of far detector is optimized by oscillation maximum





KASKA detector



Region Ⅰ: ν_e target → 9 tons 0.1 %
Gadolinium liquid scintillator (Palo verde type)
UV-transparent acrylic vessel
diameter : 1.4m

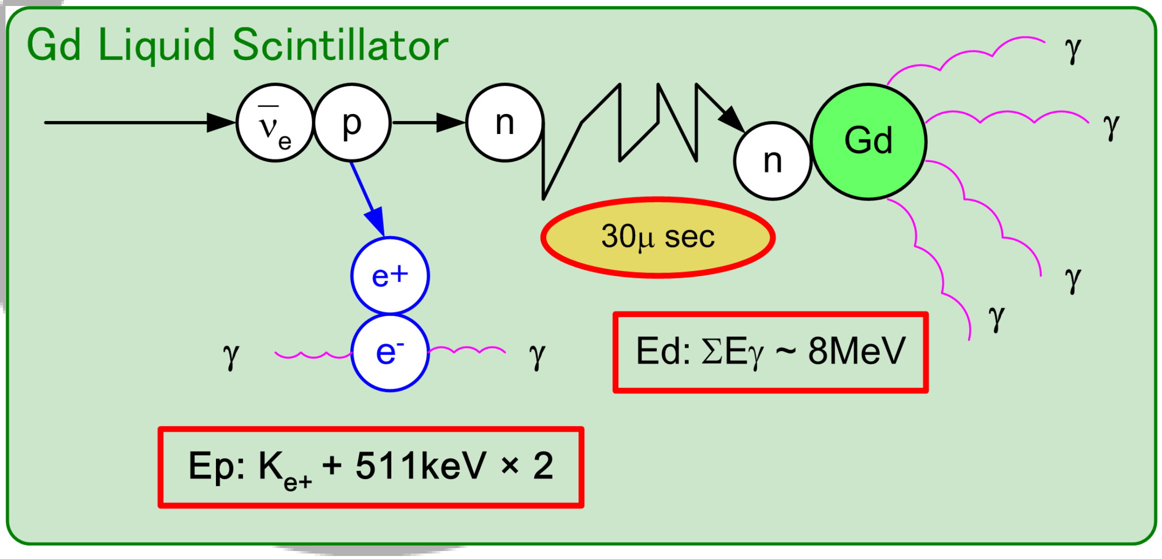
(Gadolinium : the largest neutron cross section among all the elements)

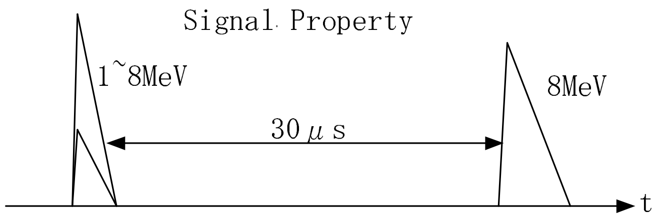
Region Ⅱ : γ catcher → Normal liquid scintillator
UV-transparent acrylic vessel
thickness of region Ⅱ : 70cm
diameter : 4.1m

Region Ⅲ : Inner buffer oil
Thickness of region Ⅲ : 115cm

Region Ⅳ : Outer buffer oil
Thickness of region Ⅳ : 50cm

Principle of the detection anti-neutrino





$$\bar{\nu}_e + p \rightarrow e^+ + n$$

Delayed signal

$$n + Gd \rightarrow Gd' + \gamma's(\sum E_\gamma \sim 8MeV)$$

(Energy spectrum Gd gamma rays not well known)

Prompt signal

$$e^+ + e^- \rightarrow 2\gamma(0.511MeV \times 2)$$

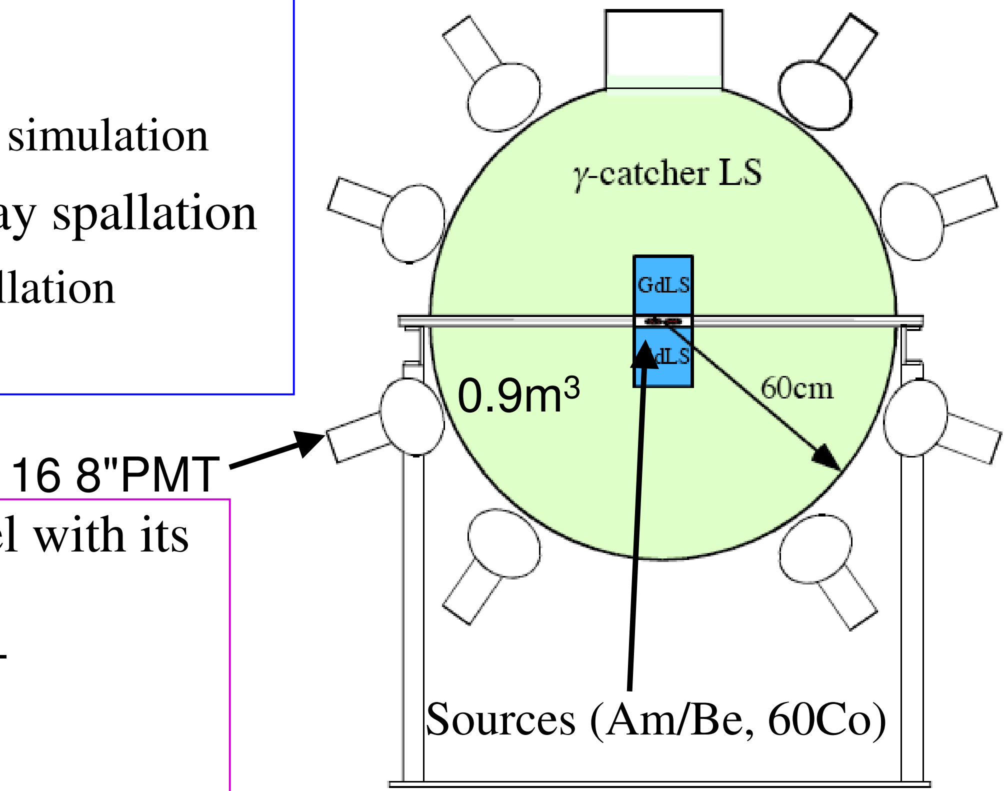
KASKA prototype detector

Motivations

- Test of γ -catcher
  - Study of Gadolinium spectrum
  - Taking advantage of this study to full simulation
- Background estimation from cosmic ray spallation
  - Unknown nuclides created by the spallation because of its large atmic number

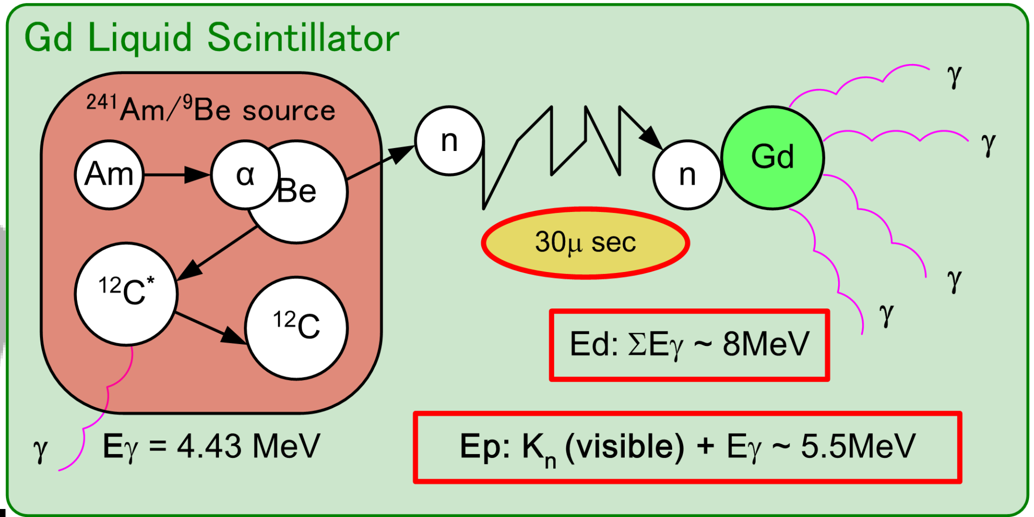
Setups

- UV-transparent spherical acrylic vessel with its diameter 1.2m → Region Ⅱ part
- LS contents : pseudocumene(13.5%) + isoparaffin(86.5 %) + PPO, BisMSB
- 16 8”inch PMTs
- Acrylic box : 6.75 liters, 0.1% Gd LS, → Region Ⅰ part
- A drawer at the center of the box

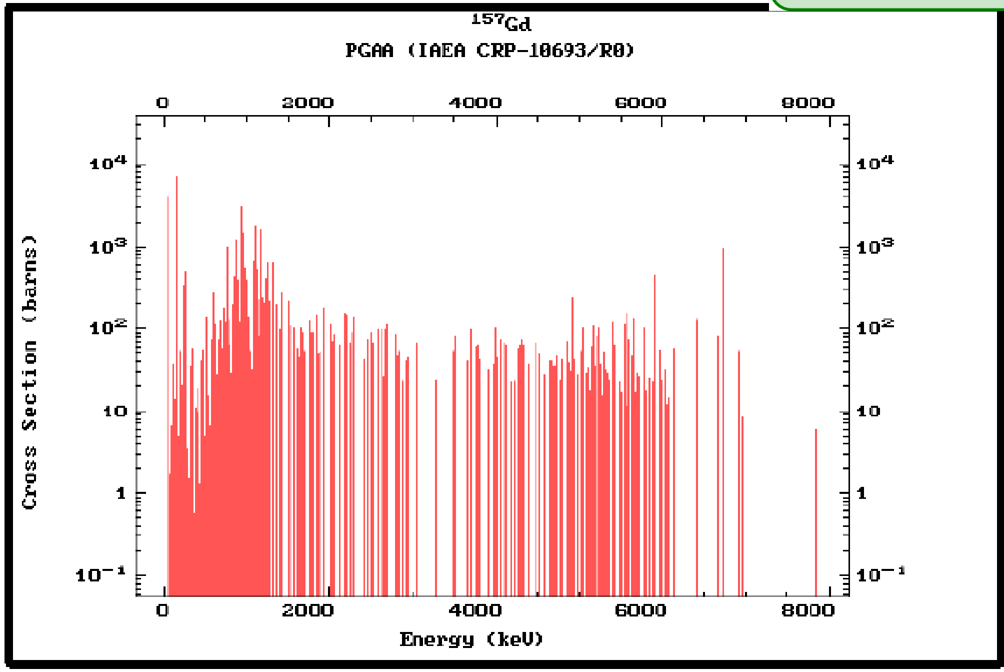


Am/Be source

Neutrino like signal



Population of gamma-ray from Gd

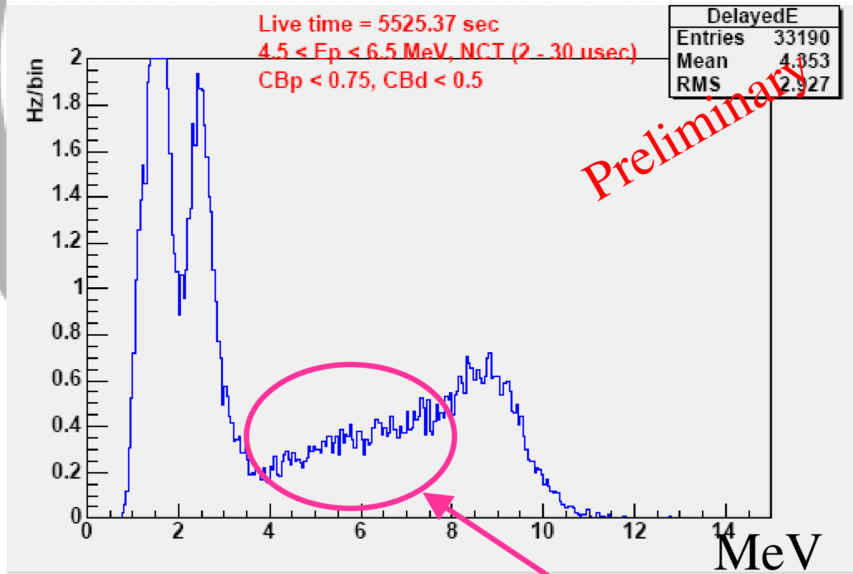


Use this population in our MC simulation

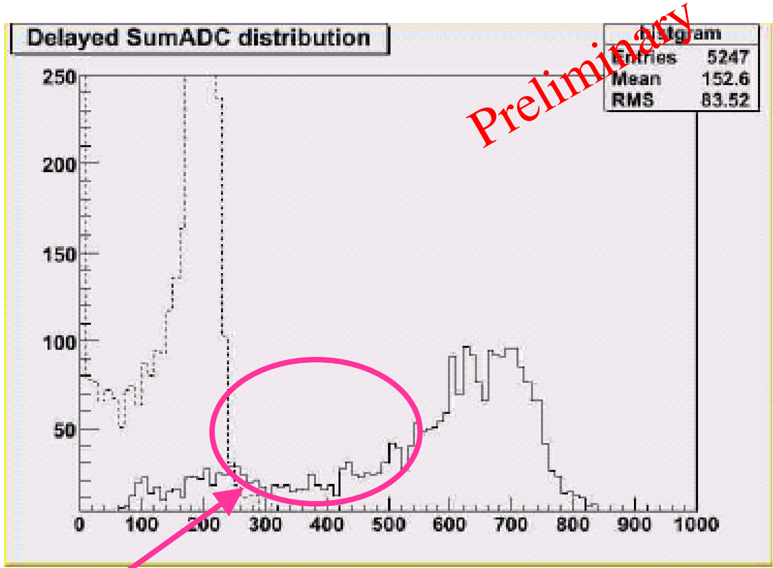
Check the conbination of gamma-rays from Gd comparing to prototype data

Comparing to simulation data

prototype Data



Simulatio MC



Difference between prototype and simulation

→ The conbination of γ rays causes

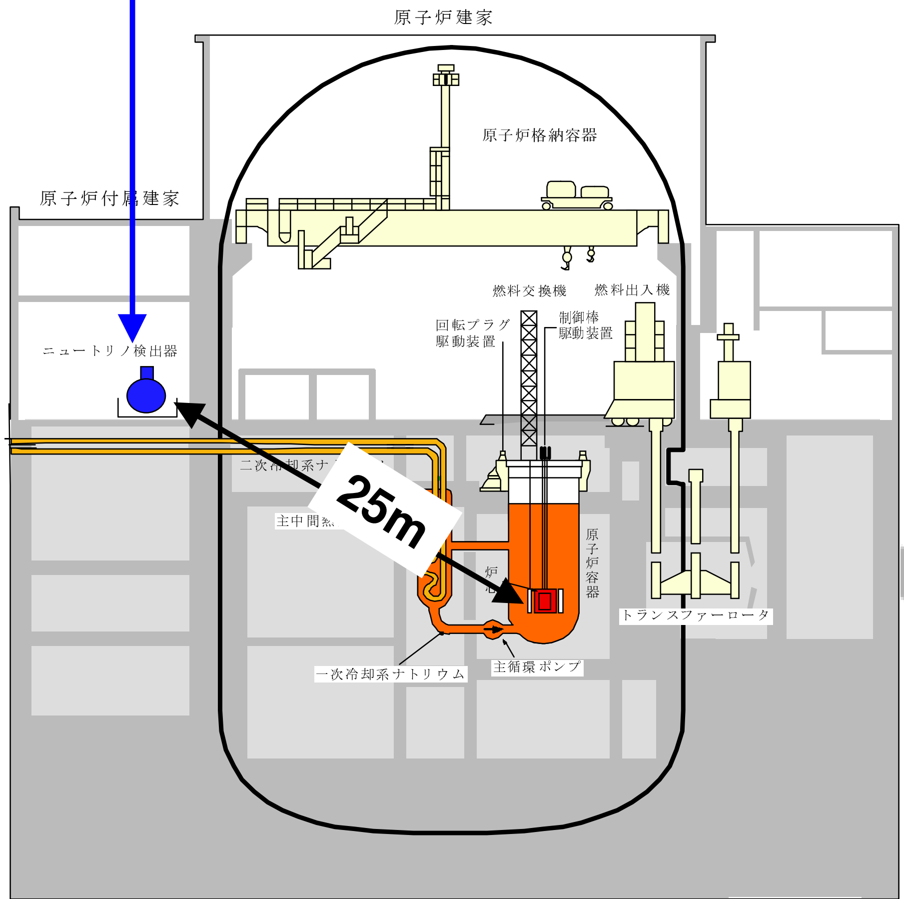
→ Necessary to improve simulation

Experimental Fast Reactor : Joyo

In order to test the prototype

(http://www.jaea.go.jp/04/o-arai/joyo/indexs.htm)

KASKA prototype detector



- Fast Reactor : Joyo
- P_{th}=140MWth
- Fuel : U(70wt %), Pu(30wt %)
- Operated by JAEA
- Operation days / Cycle : 60

  → Easy on/off data taking
- L~25m
- ~160 $\nu\, p \rightarrow e^{+}\, n$ reaction/day

Now data taking !

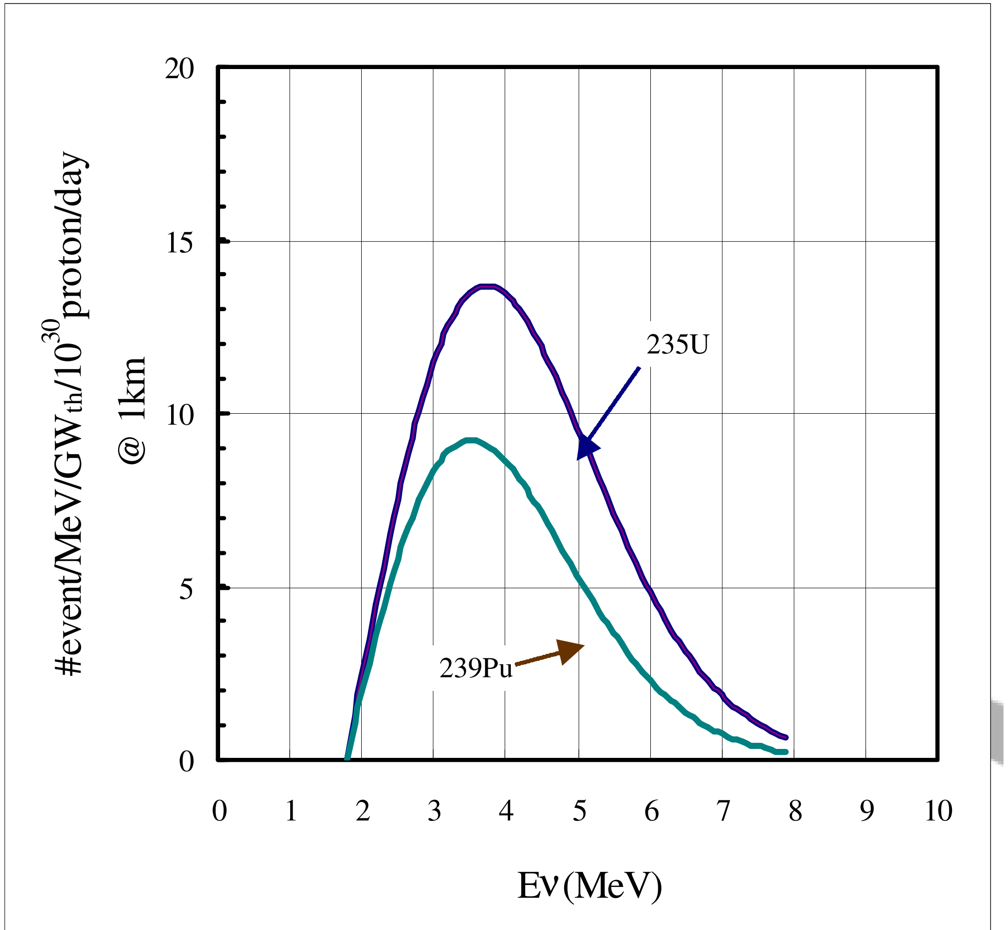
Fast Reactor

Joyo Fast Reactor
Fuel : Uranium, Pulutonium
→ Pu rich neutrino

Light Water Reactor
Fuel : Uranium
→ U rich neutrino

Conbine two datas → Deternination of U and Pu neutrino spectra separately !

This test can only measure reactor on/off

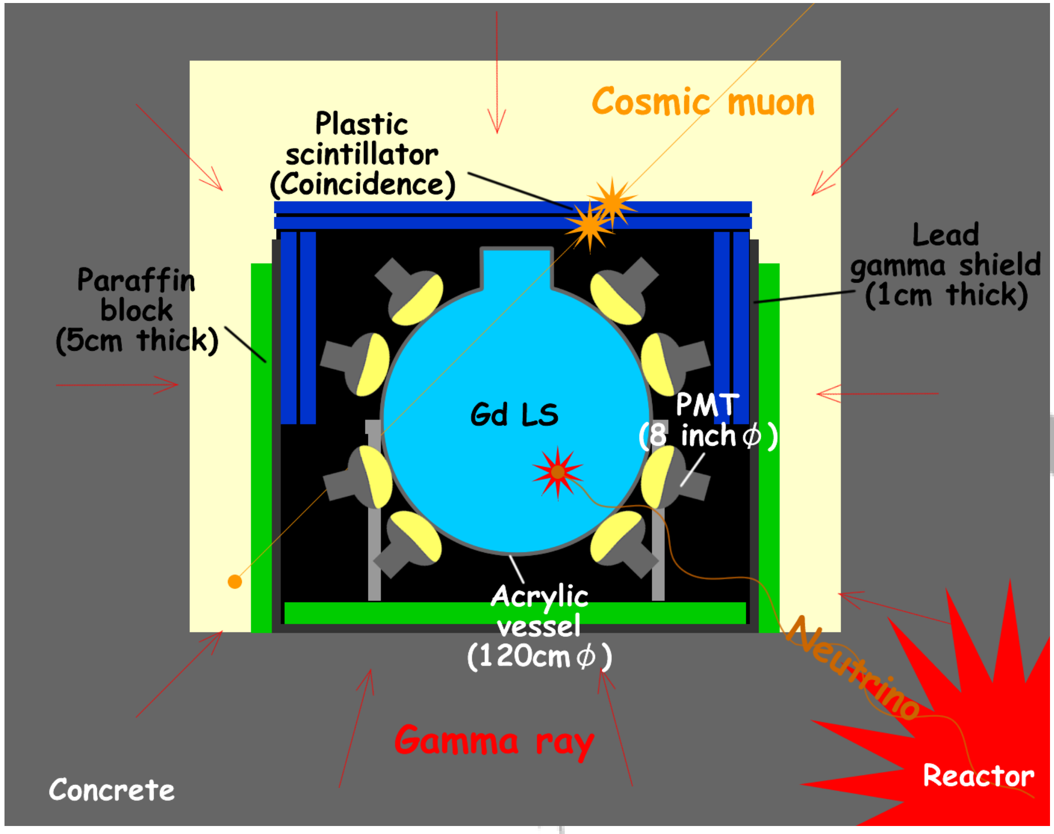


Setup at Joyo

- Motivation
  - First fast reactor neutrino detection
  - Observation of reactor on/off with detection neutrinos
- Detector setups
  - Detection region : 900 liters (whole detector)
  - LS contents
    - Pseudocumene : 15%
    - Isoparaffin : 75%
    - BC-521 : 10%
  - Cosmic ray counters
  - Paraffin blocks
  - Lead blocks

Shields are incomplete (cosmic ray counter, parrafin blocks)

→ We are installing now



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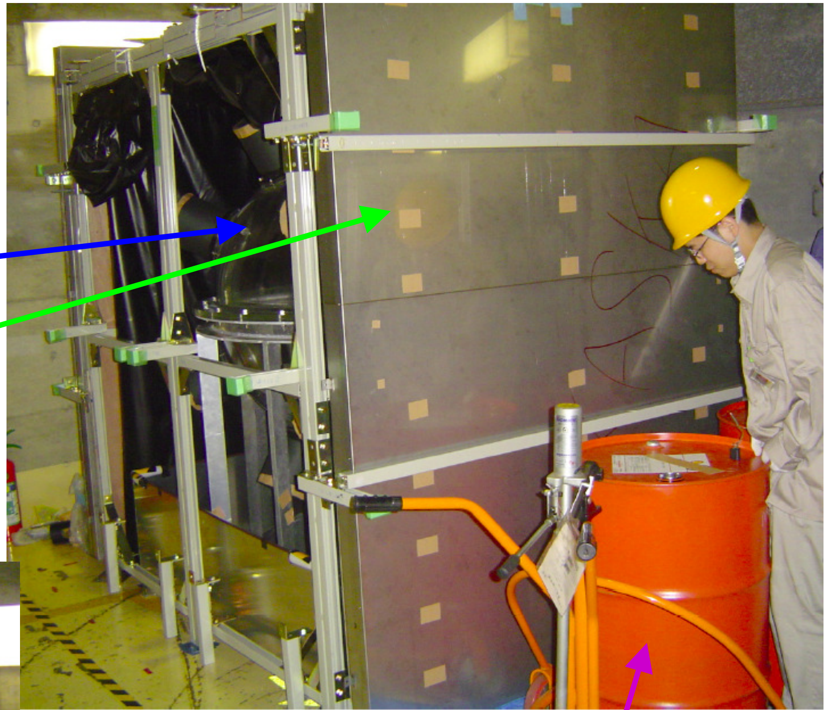
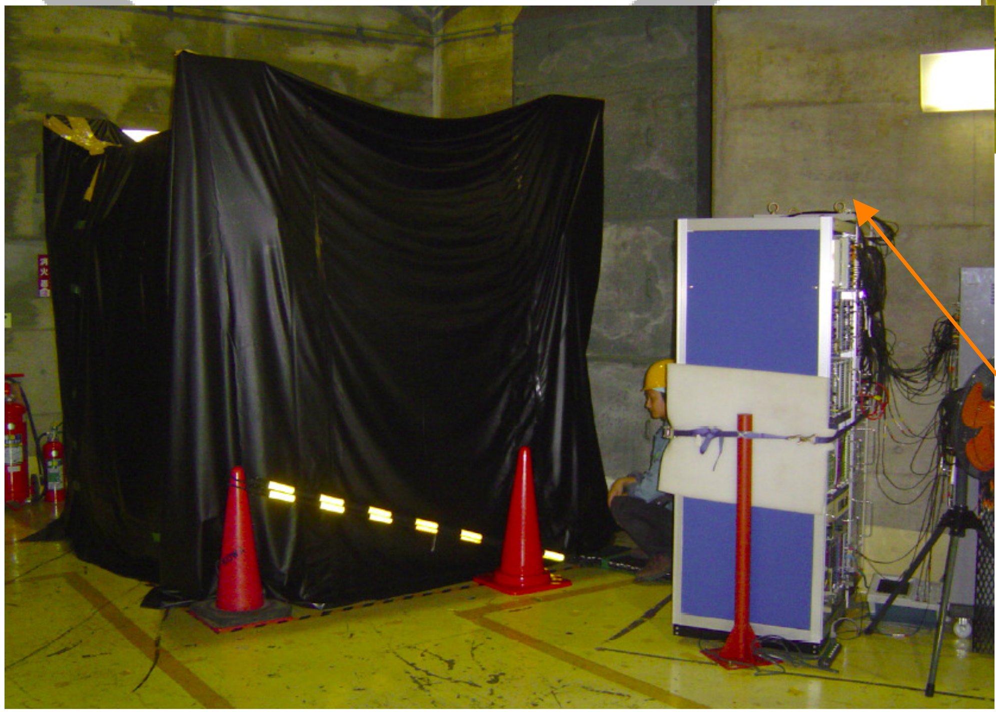


Acrylic sphere

Cosmic-ray anti counter

Gd-LS

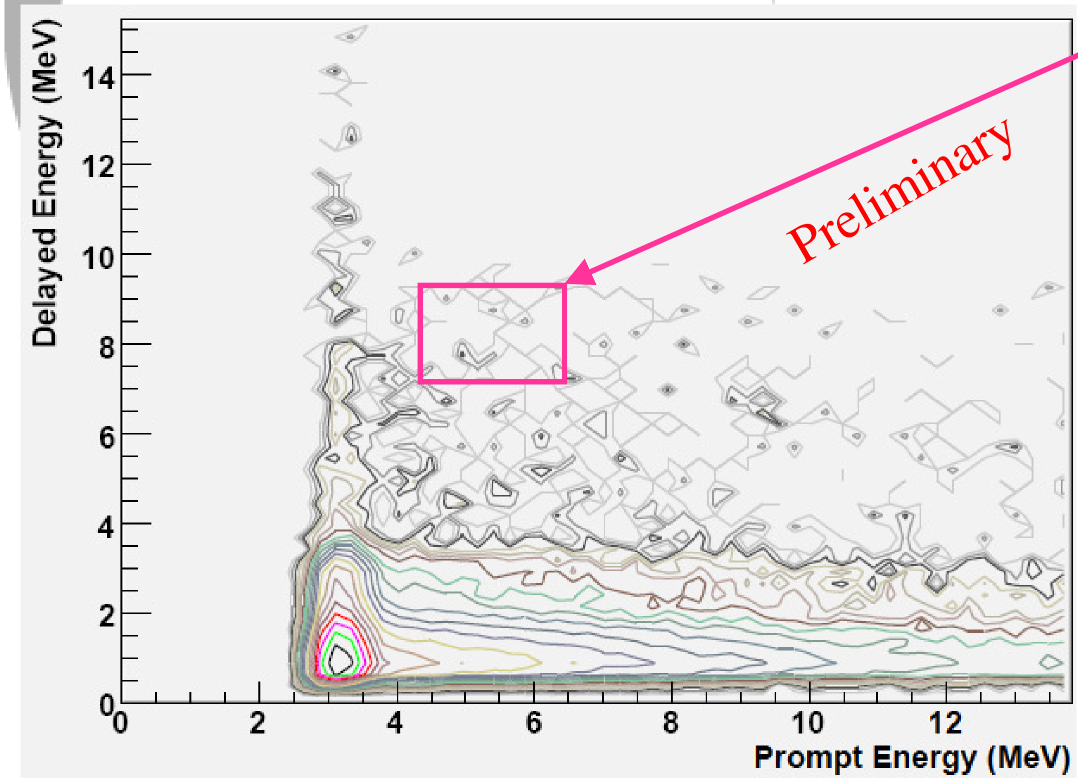
2006.9.20



Reactor is behind the wall

BG measurement @ Joyo

No source in the detector



Neutrino window
prompt energy : 4.5 ~ 6.5 MeV
delayed energy : 7.5 ~ 9.5 MeV
2usec < ⊿t < 50usec

(Neutrino events can be observed)

Count the events in this area to estimate a S/N ratio

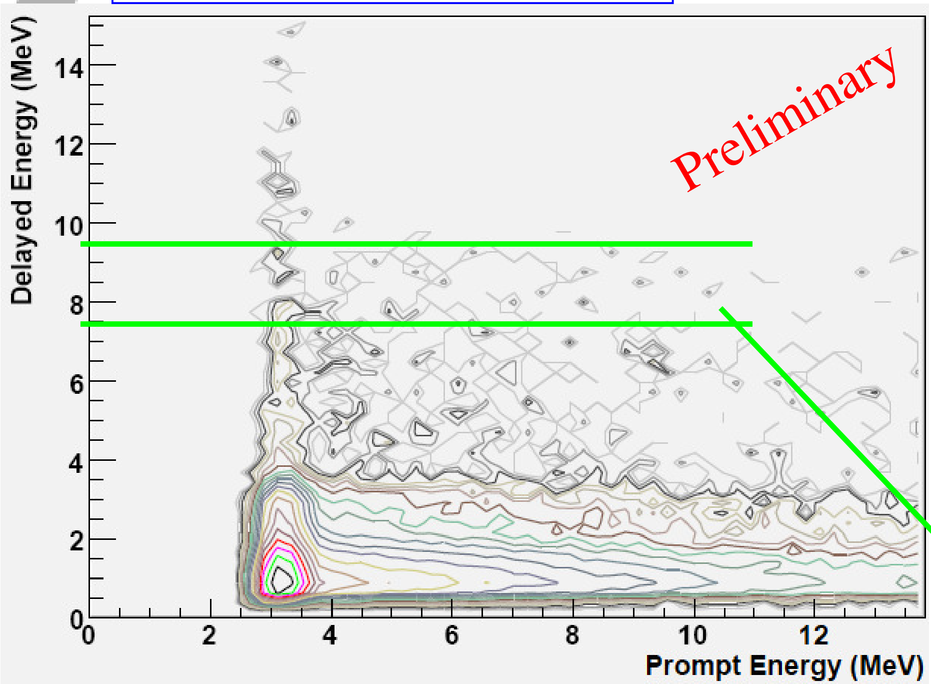
258 [events/day]

Current S/N status (ν events / Background events)

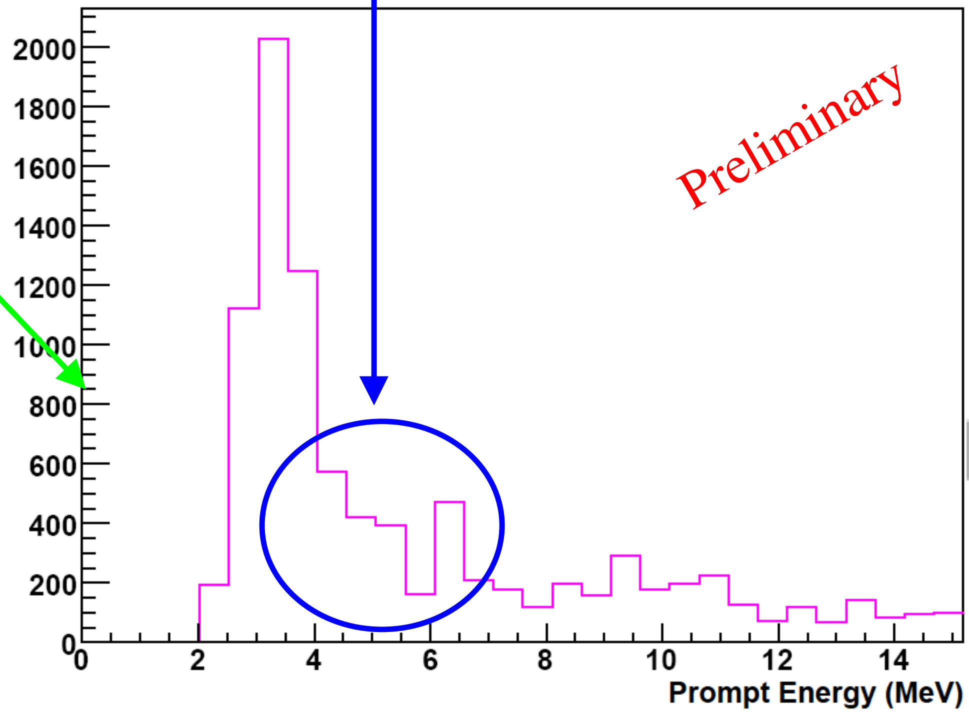
- S : expected neutrino event
- $S = 1.2\times10^{-5}[/ton/GWt/s]@1km\times(1/40)^2$ = 160 [events/day]
- W=0.72 ton, P=0.14GW, T= 1[day]=86400[s]
- Efficiencies (total = 0.0089)
  - Prompt energy (4.5 ~ 6.5MeV) = 0.36
  - ⊿t (2 ~ 50 usec) = 0.58
  - Gd's energy selection = 0.19
  - Charge balance cut = 0.31
- S = 1.4 [events/day]
- N : background events = 258 [events/day]
- S/N requirement = at least 1/10 (to achieve 3 sigma)
  - S/N = 1.4 / 258 ~ 1 / 184
  - 100 days operation S → 140 events
  - Necessary to improve S/N by 18 times

First data of fast reactor experiment

2D histgram of reactor ON



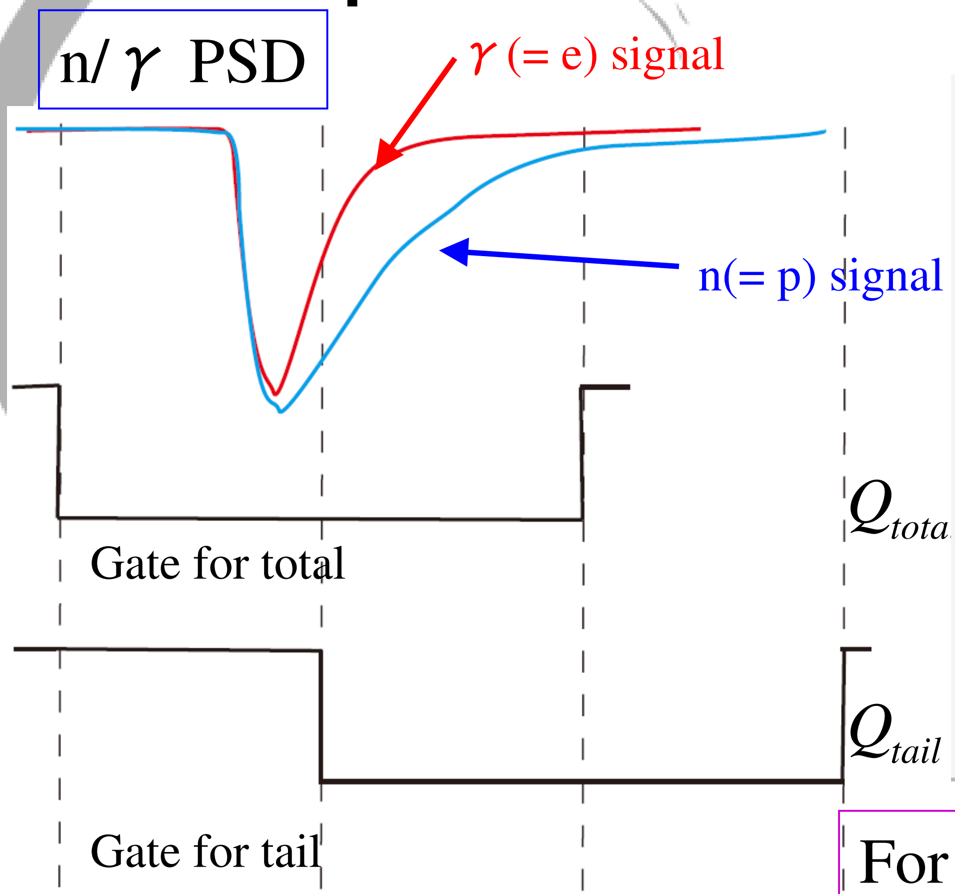
2~3 neutrino events are expected in this region (2 days)

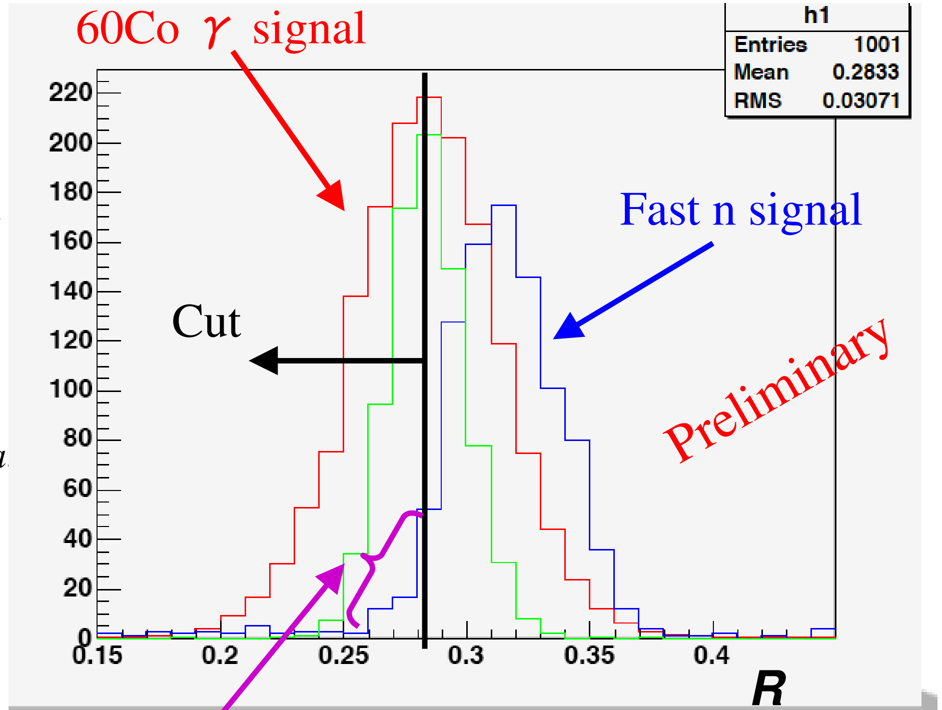


Select these events in this range and project to X axis

→ under analysis

Expected S/N improvement





$R \equiv \frac{Q_{tail}}{Q_{total}}$ is different for γ and n

For 50% γ efficiency, n rejection rate > 90% →S/N becomes more than 5 times better (S/N ~ 1/37)

Complete shields → ? times better : S/N aim at 1/10 (3 sigma)

Summary

- Preliminary result of the prototype detector: Gadolinium spectrum
- The protototype is taking real neutrino data at Joyo
- First Fast Reactor experiment
- Data taking until June, 2007

End of talk

Thank you very much for your attention !

Warning !
I am a graduate student, so please ask me questions slowly in plain English.

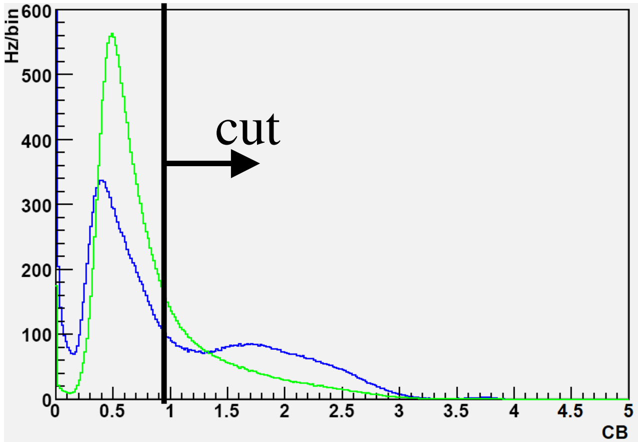
Backup slides

Charge balance cut

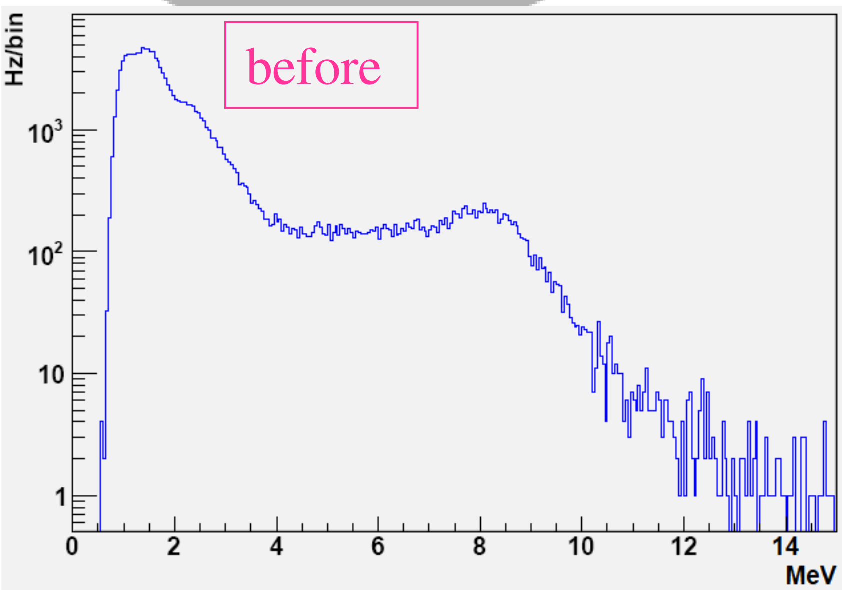
Calculate standard deviation of 16 ADCs each event and cut events using this value

$$\sigma = \sqrt{\frac{(\overline{a^2})}{(\overline{a})^2} - 1}$$

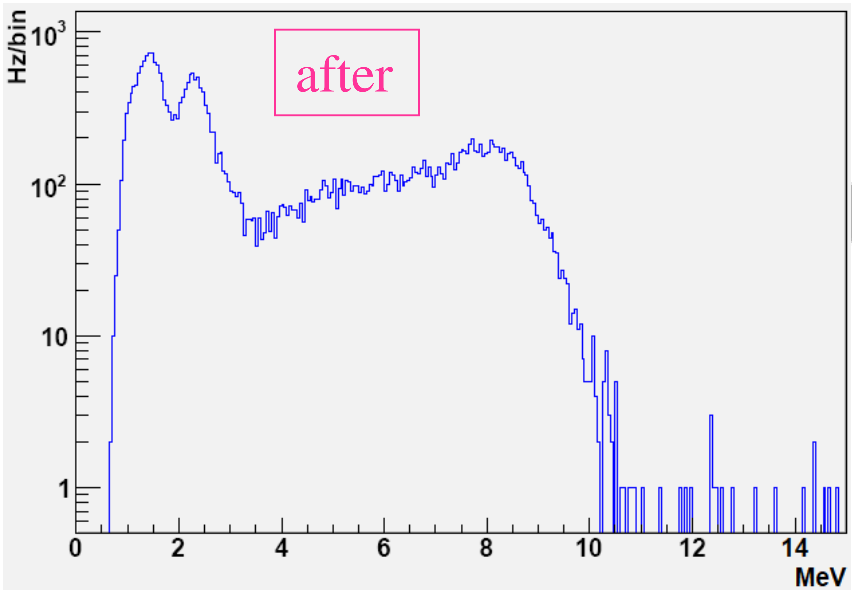
To reduce events reacting near the surface
(ex. enviromental background)



Ex.) Delayed energy of Gd-LS box + Am/Be data

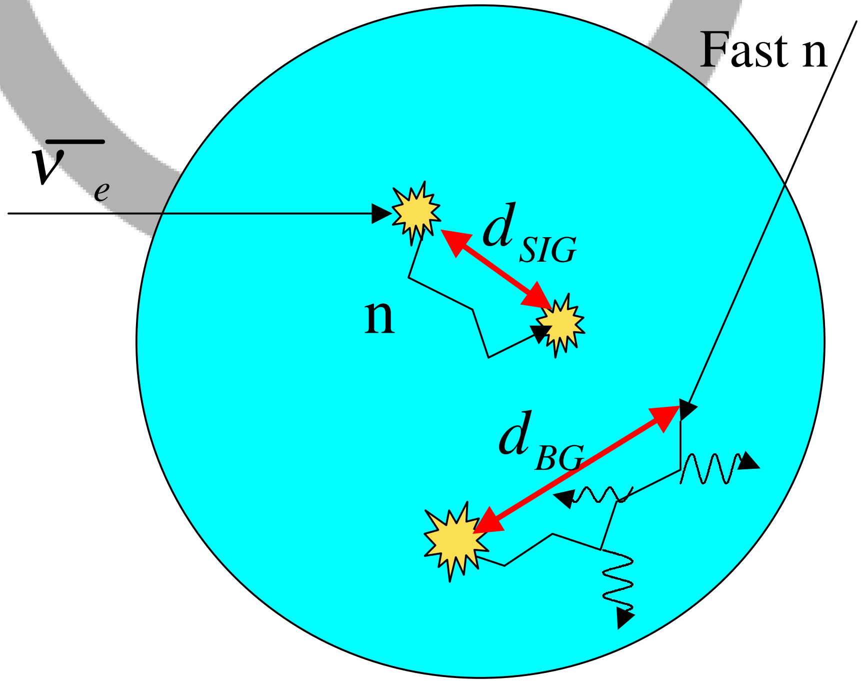


cut



Prompt deayed distance cut

The reaction position between prompt signal and delayed siganl is relatively close



$$d_{SIG} < d_{BG}$$

Efficiencies

- Gd efficieny :
  - The probability of neutron absorption in Gd-LS
  - The neutron is absorbed by Gadolinium with this probability.
- ⊿t cut :
  - ⊿t is the time between prompt signal and delayed signal.
  - We cut the events using this ⊿t value.
  - The neutron is absorbed tytically 30us after prompt signal in Gd-LS.