Measurement of reactor neutrinos using plastic scintillator cube

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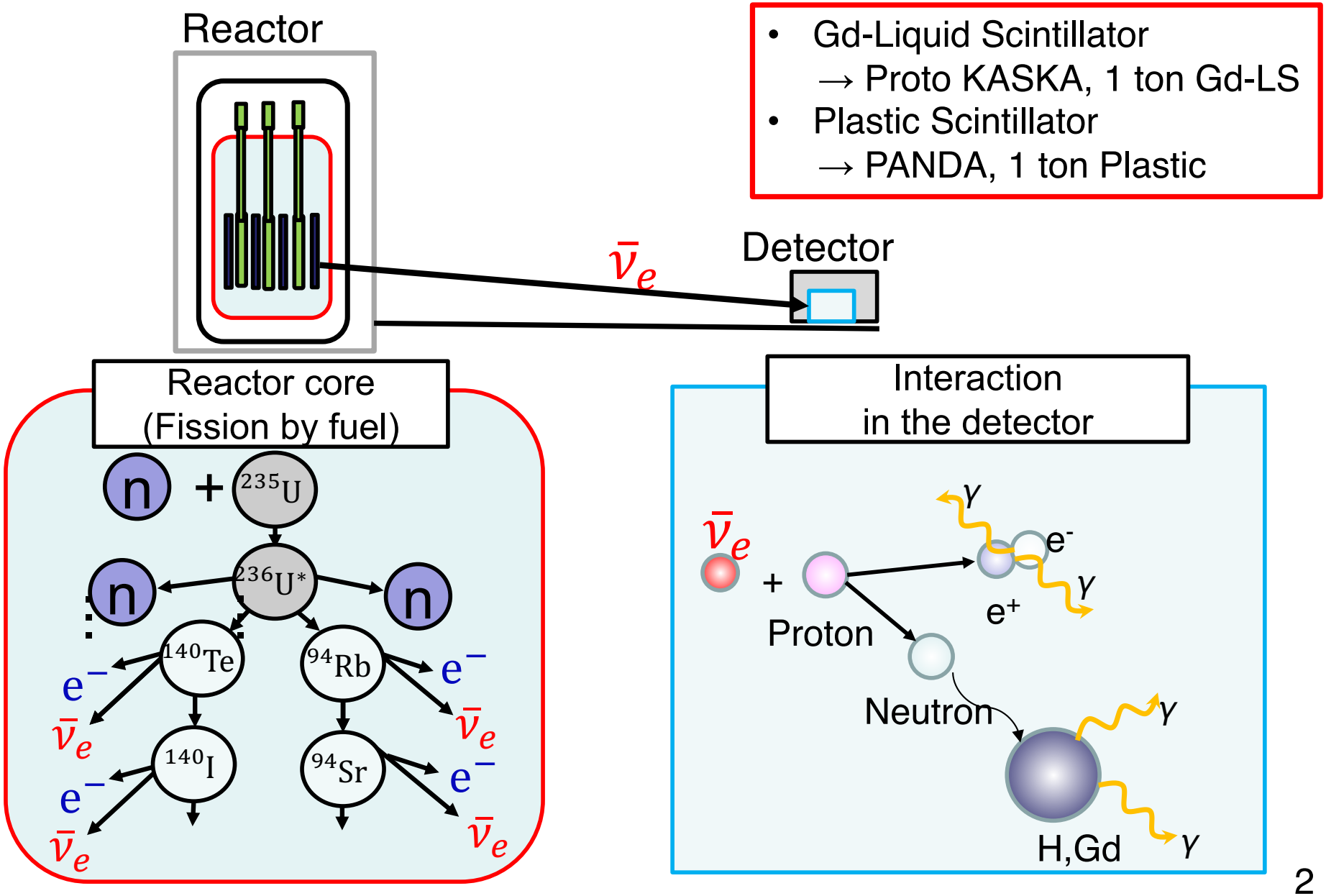
Reactor Neutrino Monitor



- Gd-Liquid Scintillator
  → Proto KASKA, 1 ton Gd-LS
- Plastic Scintillator
  → PANDA, 1 ton Plastic

Measurement of reactor neutrinos using plastic scintillator array

Plastic Anti-Neutrino Detector Array (PANDA Detector)

Try to measure reactor neutrino

2006 2007 2008 2009 2010 2011 2012 2013 2014~2019

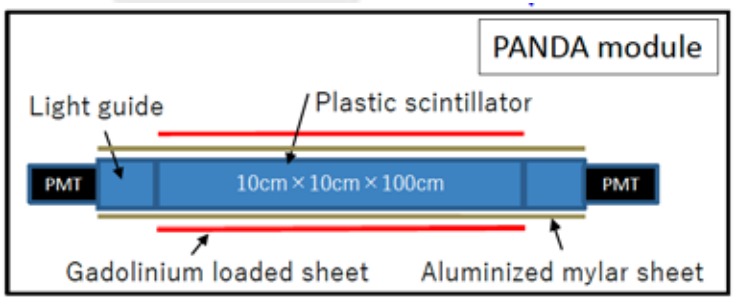
Start of Project

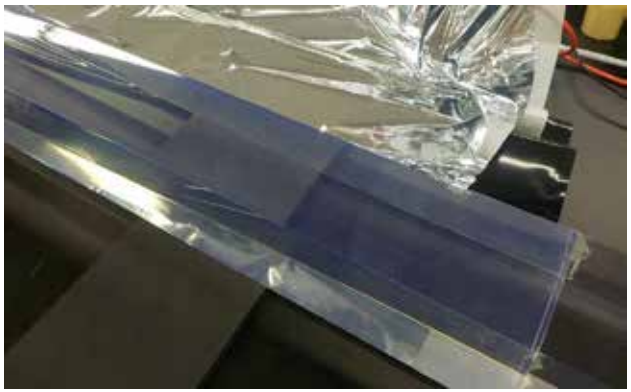
PANDA 16

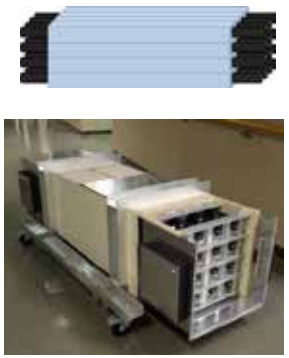
PANDA 36

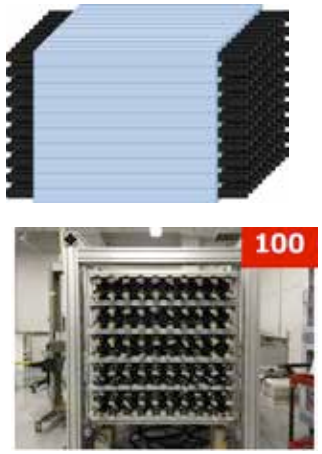
PANDA 64

PANDA 100









- Scintillator BC-408
- Target volume : ~1 t (1 x 1 x 1m)
- Read out by CAEN 792 (ADC)
- No anti-background material

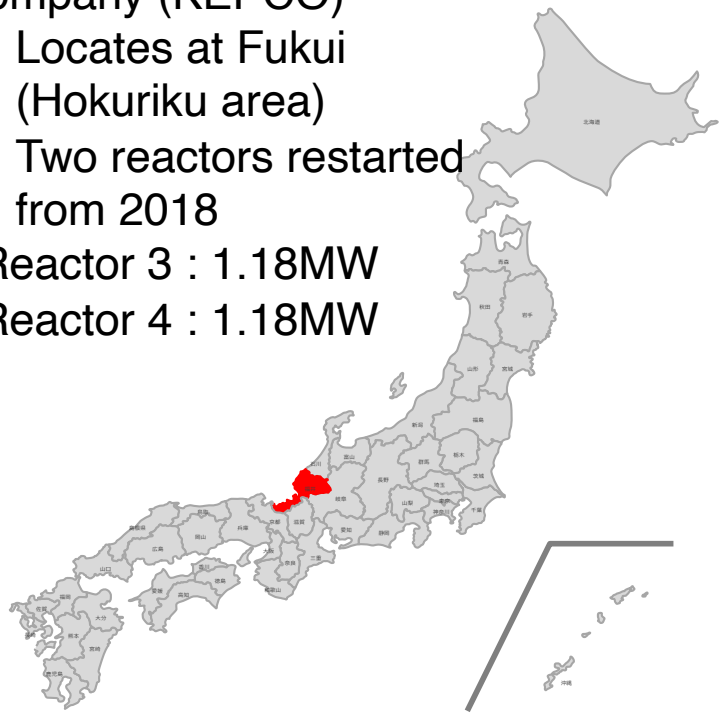
Tokyo University
Kitasato University
Fukui University
Tokyo Metro University
Tohoku University

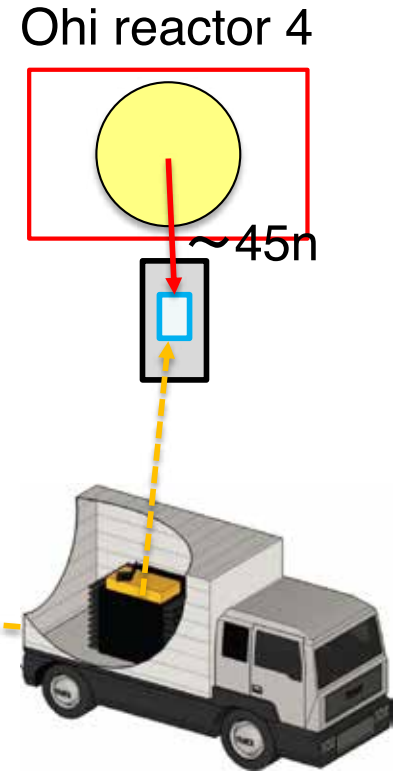
PANDA experiment at Ohi power reactor

Operated by Kansai Electric Power Company (KEPCO)

- Locates at Fukui (Hokuriku area)
- Two reactors restarted from 2018

–Reactor 3 : 1.18MW
–Reactor 4 : 1.18MW





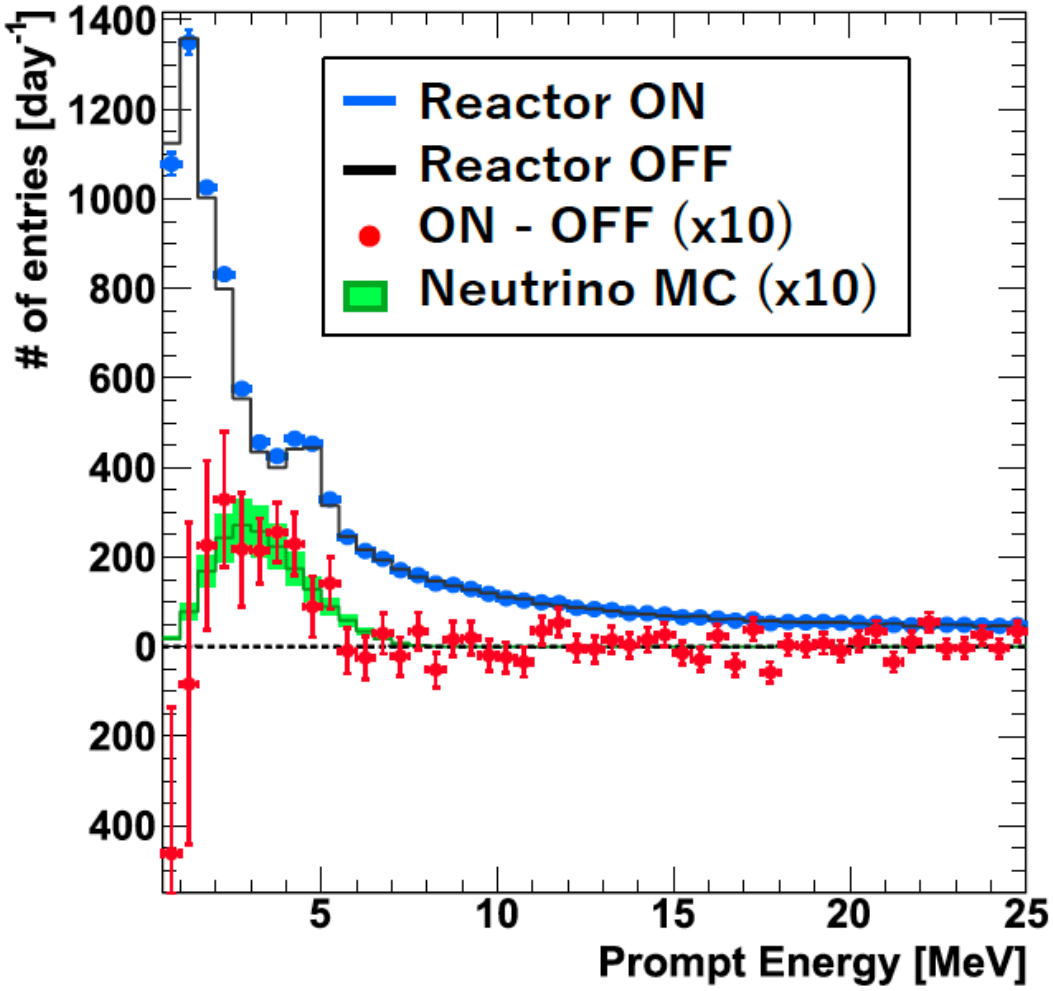
Experiment at 2019

Measurement of reactor $\bar{\nu}_e$ energy spectrum by On – Off subtraction

- Reactor ON : 38 days (2019.5.28 – 7.4)
  → Neutrino + Back ground
- Reactor OFF : 33 days (2019.7.5 – 8.7)
  → Back ground only

Neutrino extraction

T. Konno ,AAP 2019



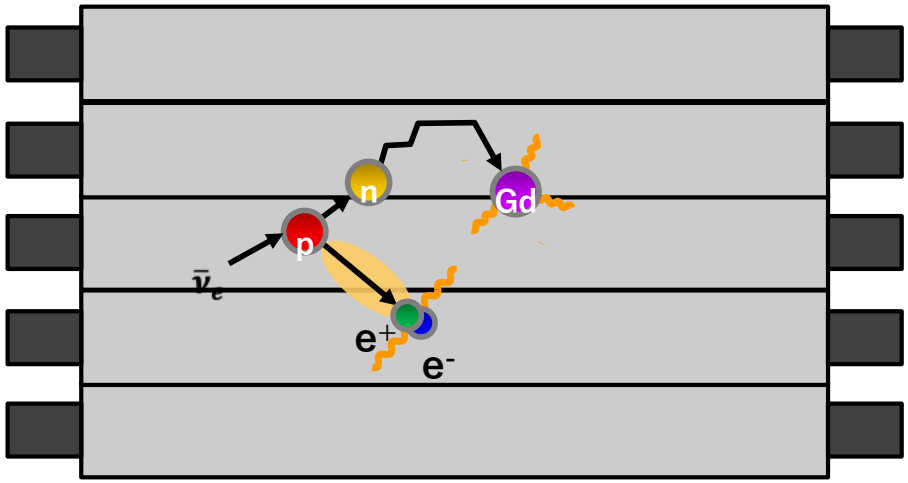
- ON,OFF: Accidental subtracted OFF/ON ration; +0.91±0.05%
- Error of ON -OFF from stat
- IBD events; 177.6 ±38.7(/day)
- Compared MC

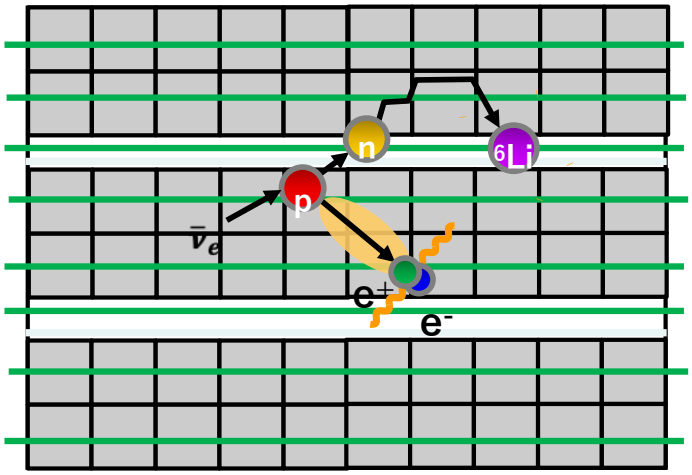
Succeeded measurement of neutrino spectrum

Next step
- Improvement of reactor neutrino sensitivity
- Reduce Background
- Detection efficiency

Next ;High vertex resolution

- Need to reduce gamma BG





✓ Energy separation
⇒ 10 x 10 x 100 cm unit
→ Build to 1m^3 unit
Position separation
⇒ PMT both-ends readout
→ resolution ~20 cm in module
difficult to separate positron from annihilation γ
=> cannot reduce contingencies

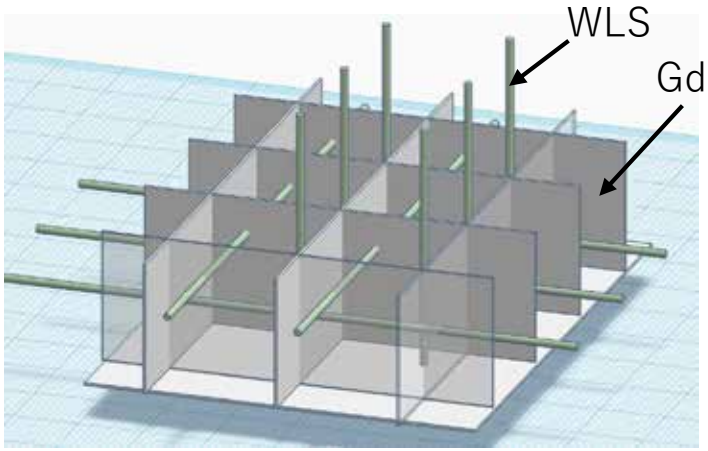
✓ n-Gd capture particles are indistinguishable from γ-rays=> environmental γ-rays, etc.

✓ High vertex resolution
Small scintillator unit
⇒ 2 x 2 x 2 cm module
→ Build to 1m^3 unit
& SiPM both-ends readout
to separate positron from annihilation γ

⇒ delayed coincidence

Start this project from 2022

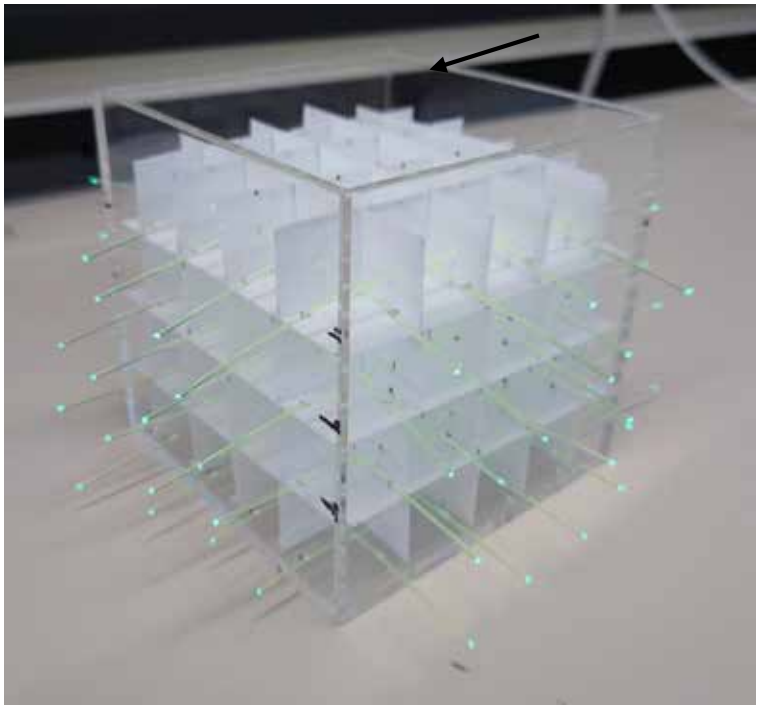
Plastic scintillator cube



How to make ?

- ✓ Scintillation material in each grid filling pellets / set cubes
- ✓ Through WLS
- ✓ SiPM readout
- ✓ ….

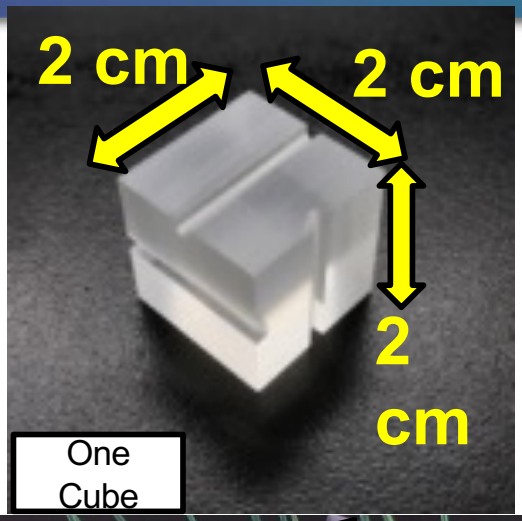

Pellets scintillator



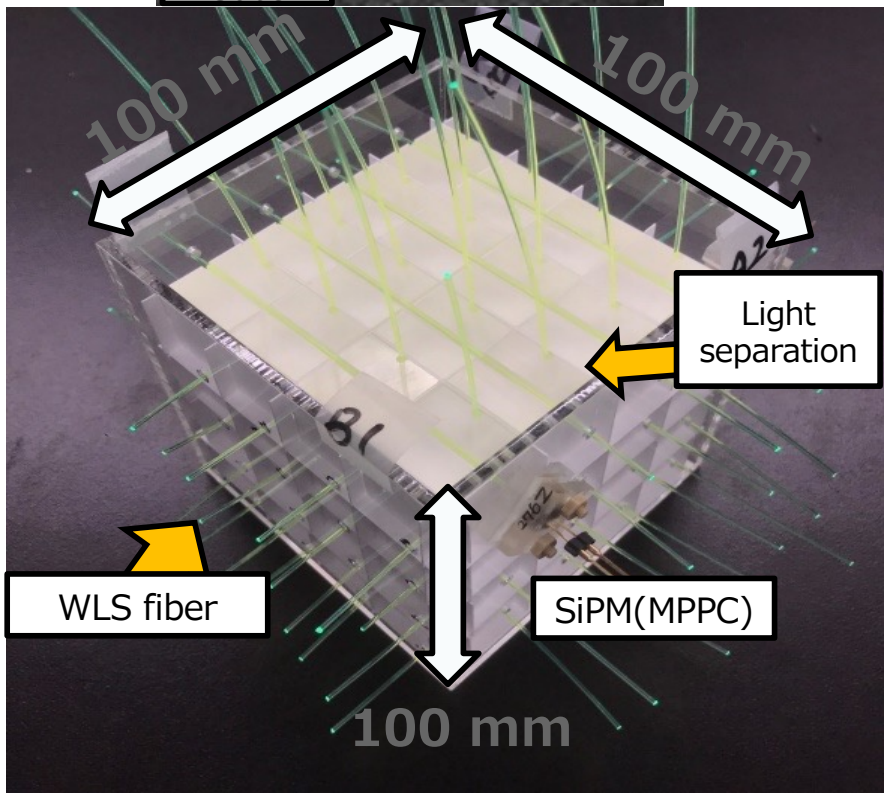
Detector mockup of about 10 cm

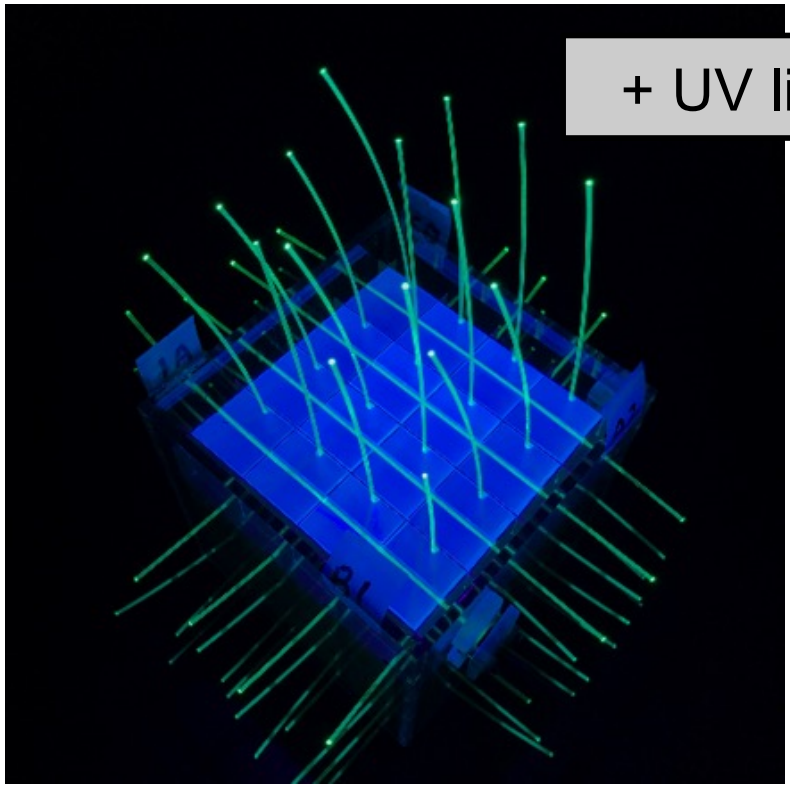
- ➢ Plastic scintillator pellets (about 2~3mm)
- ➢ Reflective material is the partition plate Furukawa Electric MCPET 0.5mm thick
- ➢ 3D readout with WLS fiber Kuraray Y-11 (ϕ 1mm)
- ➢ Not SiPM

Test detector

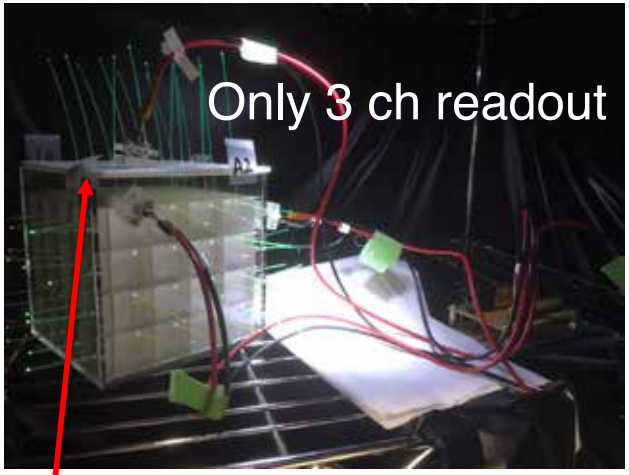


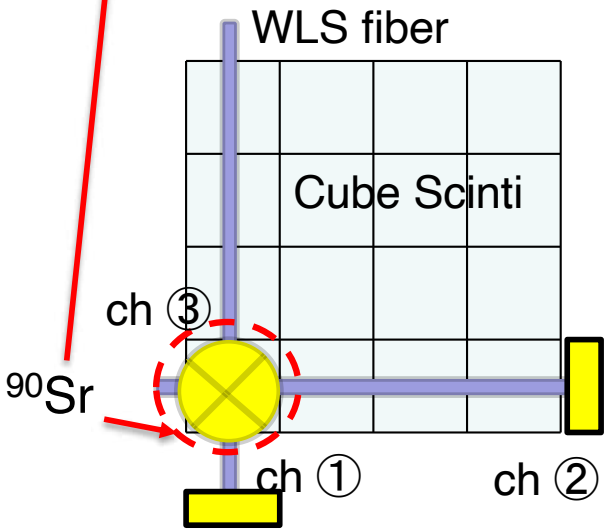
principle demonstrator
- $10cm^3$ ($4 \times 4 \times 4$ cells)
- SiPM readout
- Light separation
- e+ detection(beam test)

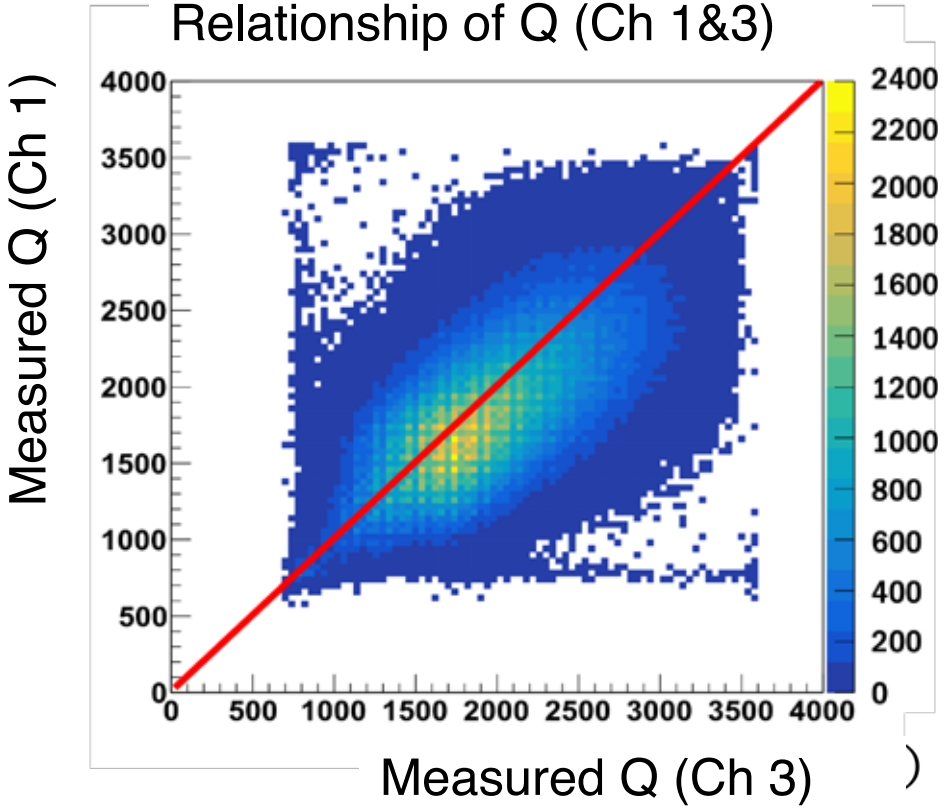




Readout test

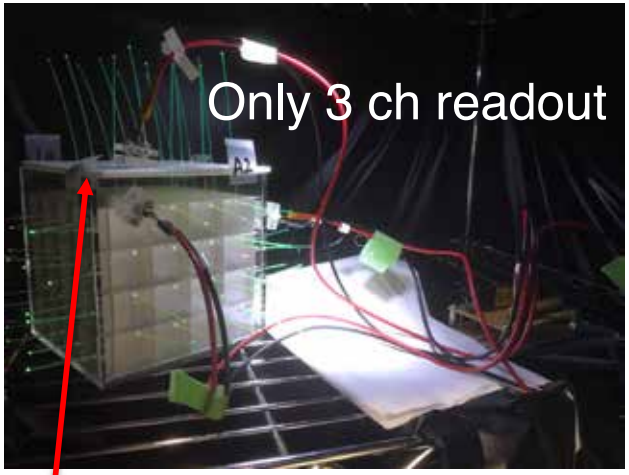


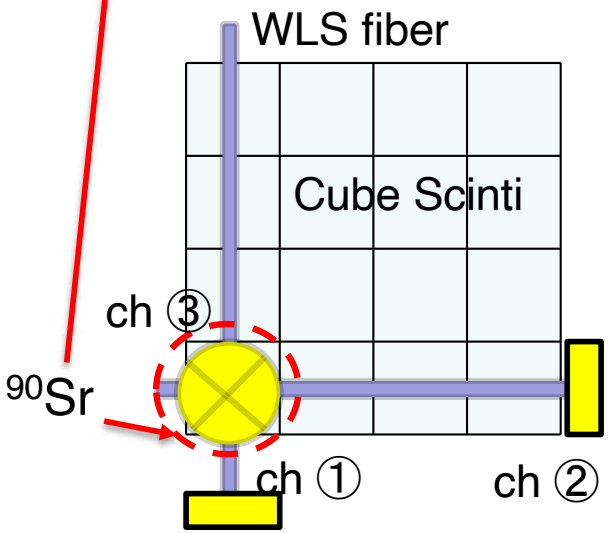


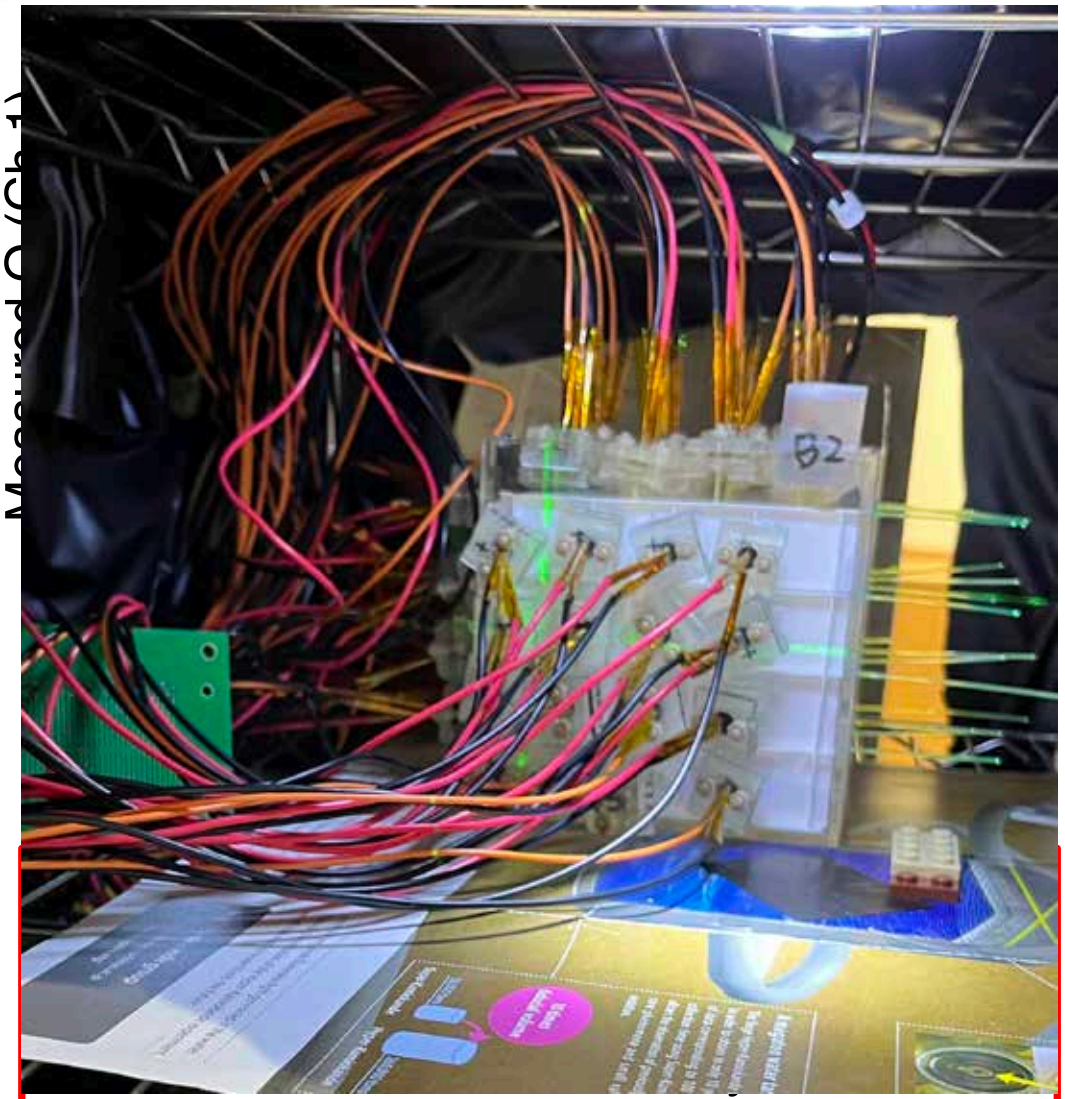


- Observation of light in the same cell
- Confirms positional synchronization measurement on a cell-by-cell.
- Next beam test 64 ch readout

Readout test





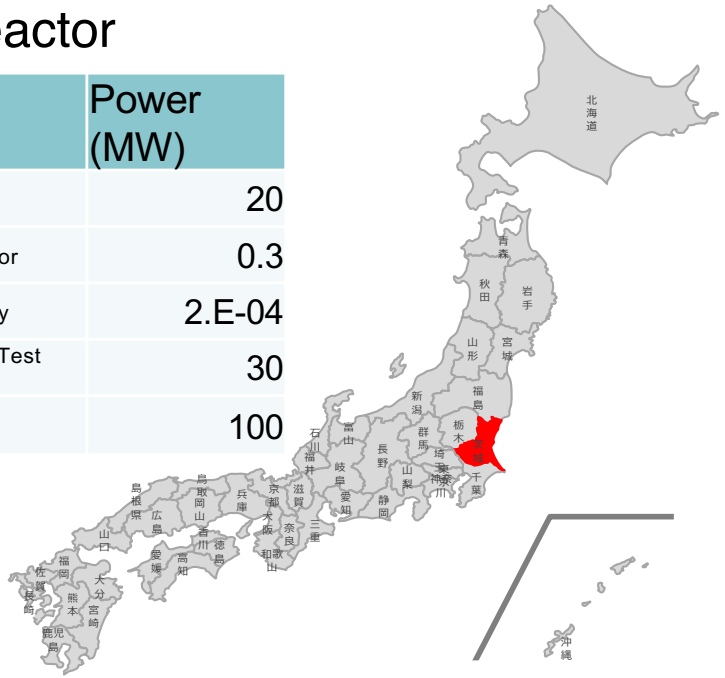


- Next beam test 64 ch readout

Reactor Site; research reactor

JAEA's 5 research reactor

Location	Name		Power (MW)
Tokai	JRR-3	Japan Research Reactor 3	20
	NSRR	Nuclear Safety Research Reactor	0.3
	STACY	Static Experiment Critical Facility	2.E-04
Oarai	HTTR	High Temperature Engineering Test Reactor	30
	JOYO	Fast Breeder Research reactor	100



Pros:

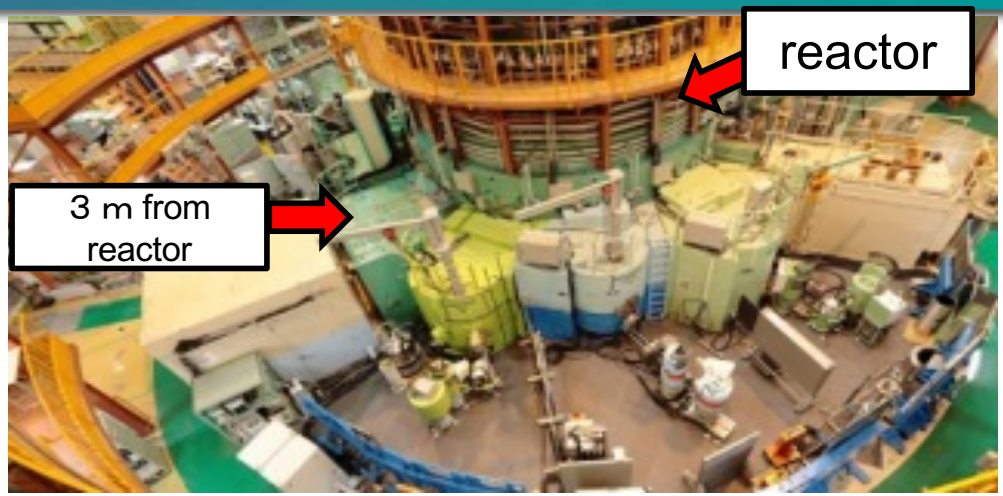
- Detector set in close (~ a few m)
- Short cycle operation (26 days)
- Easier to Obtain operation information in detail
- Easier to access for research

Cons:

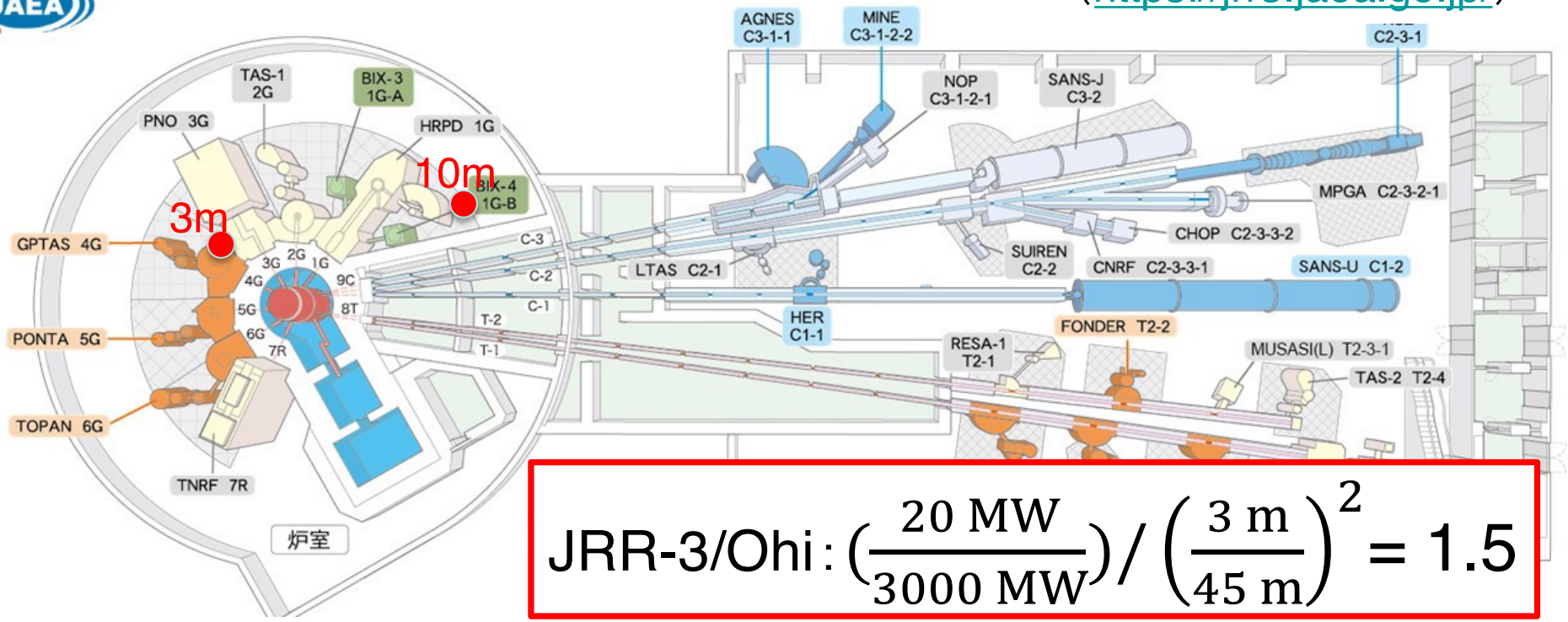
- Neutrino source has a finite size near the reactor location
- Low power
- High back ground
- Restriction on installation location

JRR-3

JRR-3
Japan research reactor No.3
20MW



(https://jrr3.jaea.go.jp/)

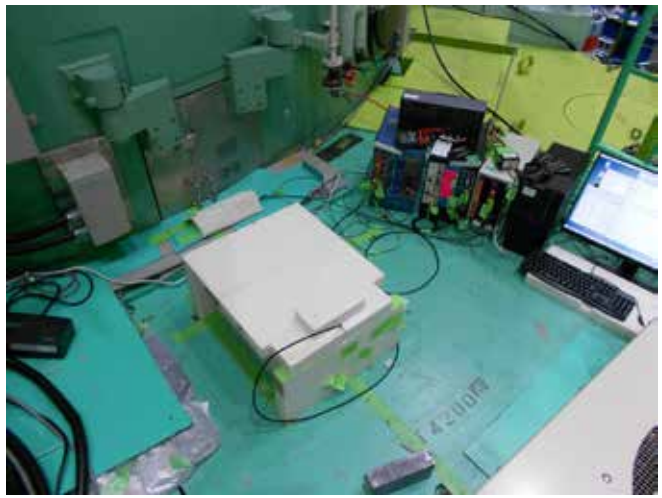


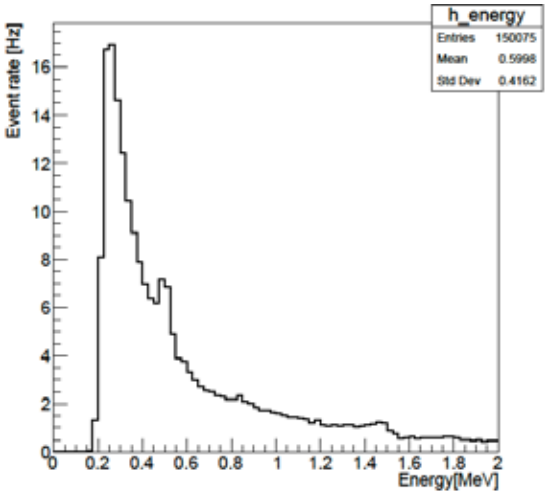
$$\text{JRR-3/Ohi}: \left(\frac{20\ \text{MW}}{3000\ \text{MW}}\right) / \left(\frac{3\ \text{m}}{45\ \text{m}}\right)^2 = 1.5$$

JRR-3 BG measurement

10m location; back of 1G BL

3m location; on 3G BL

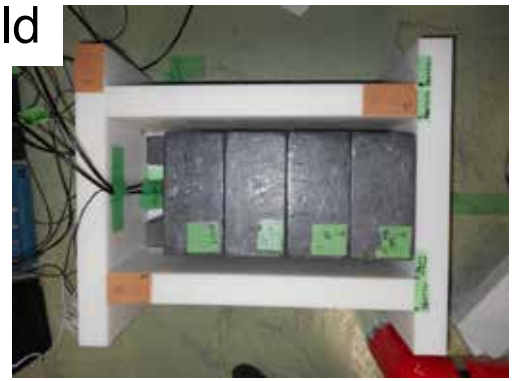




Gamma spectrum
(Non calibration)

Neutron;He-3
γ; NaI,

Shield

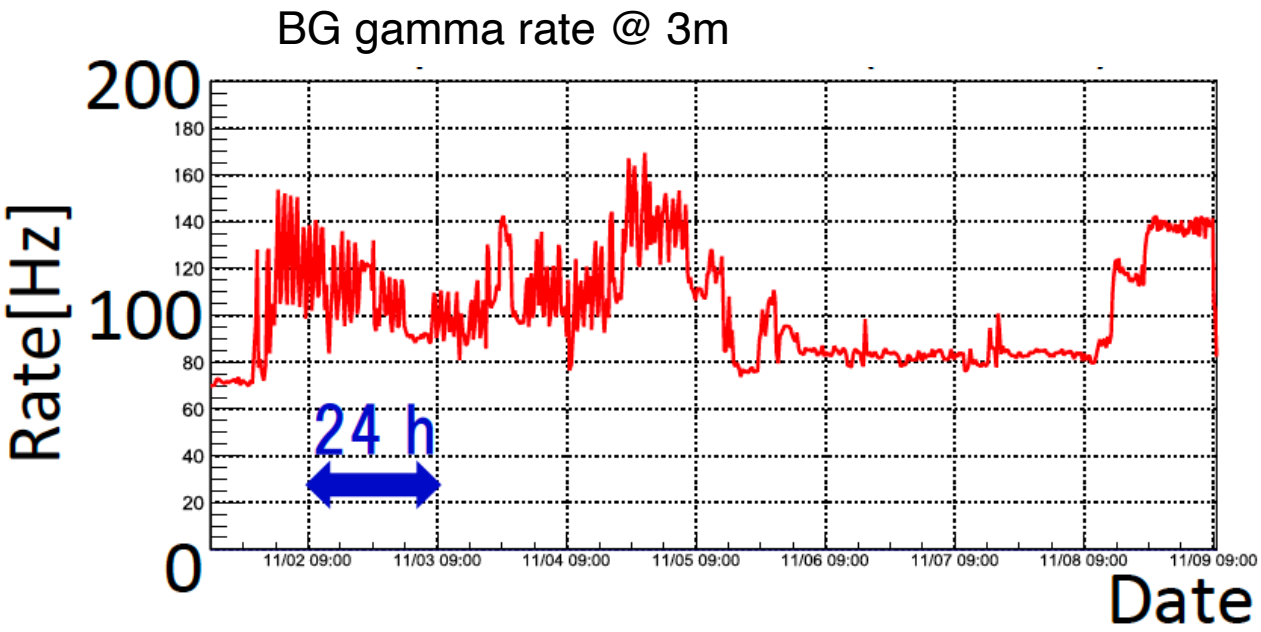


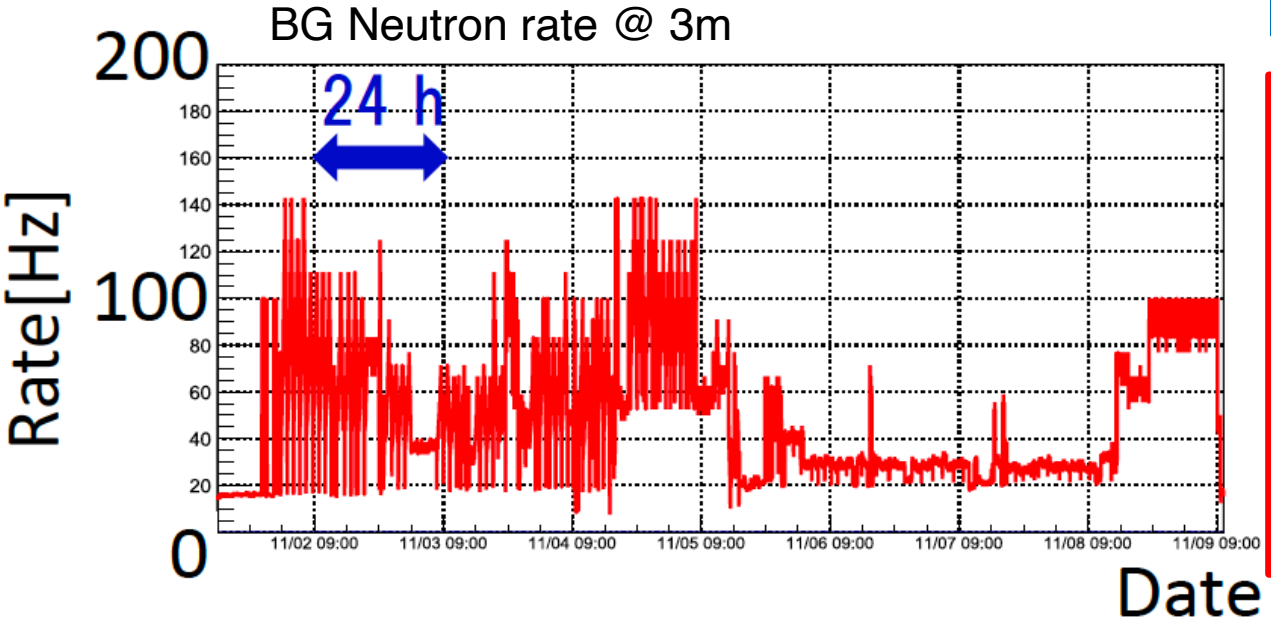
5 x 25 x 50cm BPE plates

5 x 10 x 20cm Pb blocks

	No Shield (Hz)	Shield (Hz)
γ	130	5
n	3 - 4	0.02

BG measurement; 1 week





- Non stable
  gamma; x 2.4
  Neuron x 15
- The rate of γ and neutron tend to synchronize
  → Common source ?
  fuel state/ neutron beam ?
- Required to understand the causes of variation for detection efficiency

- ✓ The cause of the time variability of the dose is under investigation.
- ✓ Need to suppression of fluctuation (change of location, add shielding) at JRR-3

Summary

- In Japan, reactor monitors with neutrino IBD signal detection using plastic scintillators have been developing.
- Cell-type detector is developed for the next PANDA.
  A prototype was assembled and testing.
- Background measurements were performed at the research reactor JRR-3.
- Next, beam test with electron beam for test detector.
  An investigation of the cause of variation of BG should be conducted.

Thanks!

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