

Performance of prototype neutron detectors for LAMPS (Large Acceptance Multi-Purpose Spectrometer) at RAON

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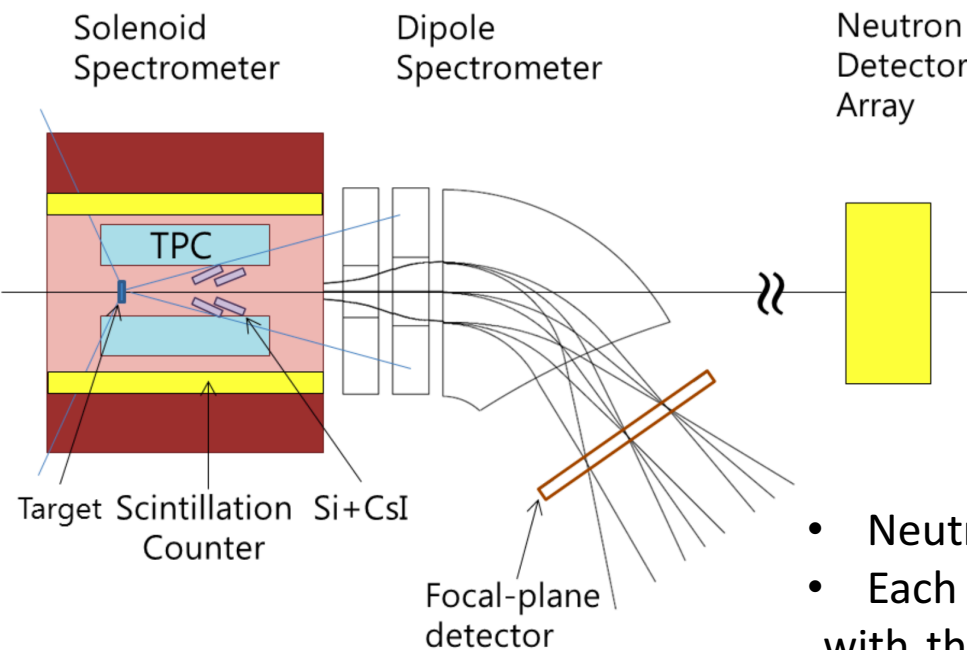
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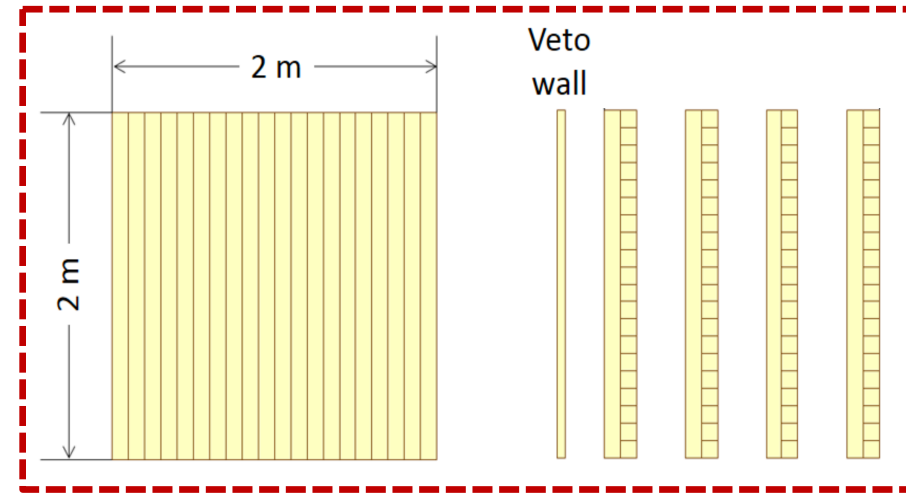
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Introduction



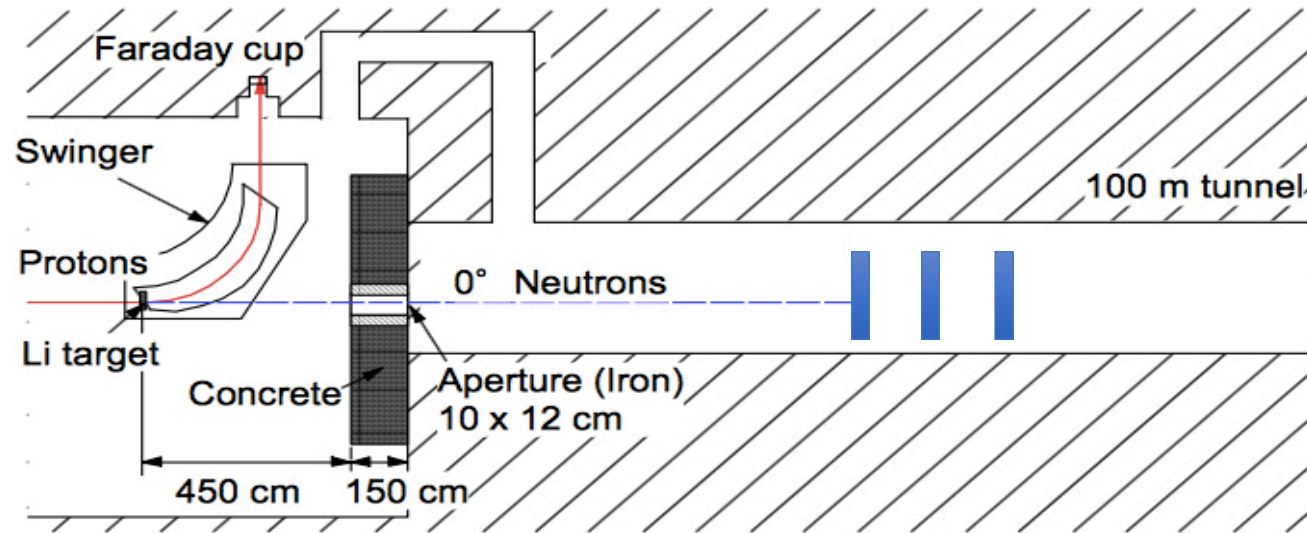
Neutron detector array



- Neutron detector array consists of 8 layers.
- Each layer is composed of 20 scintillators with the size of 10cm*10cm*200cm.

- LAMPS(Large Acceptance Multi-Purpose Spectrometer) will be installed at the rare-isotope beam facility, RAON.
- LAMPS will be used to study nuclear symmetry energy that is crucial to understand the neutron-rich matter.
- Neutron detector is for measuring high energy neutrons in the forward region.

N0 beam line at RCNP



Proton beams impinging the Li target produce quasi mono-energetic neutron

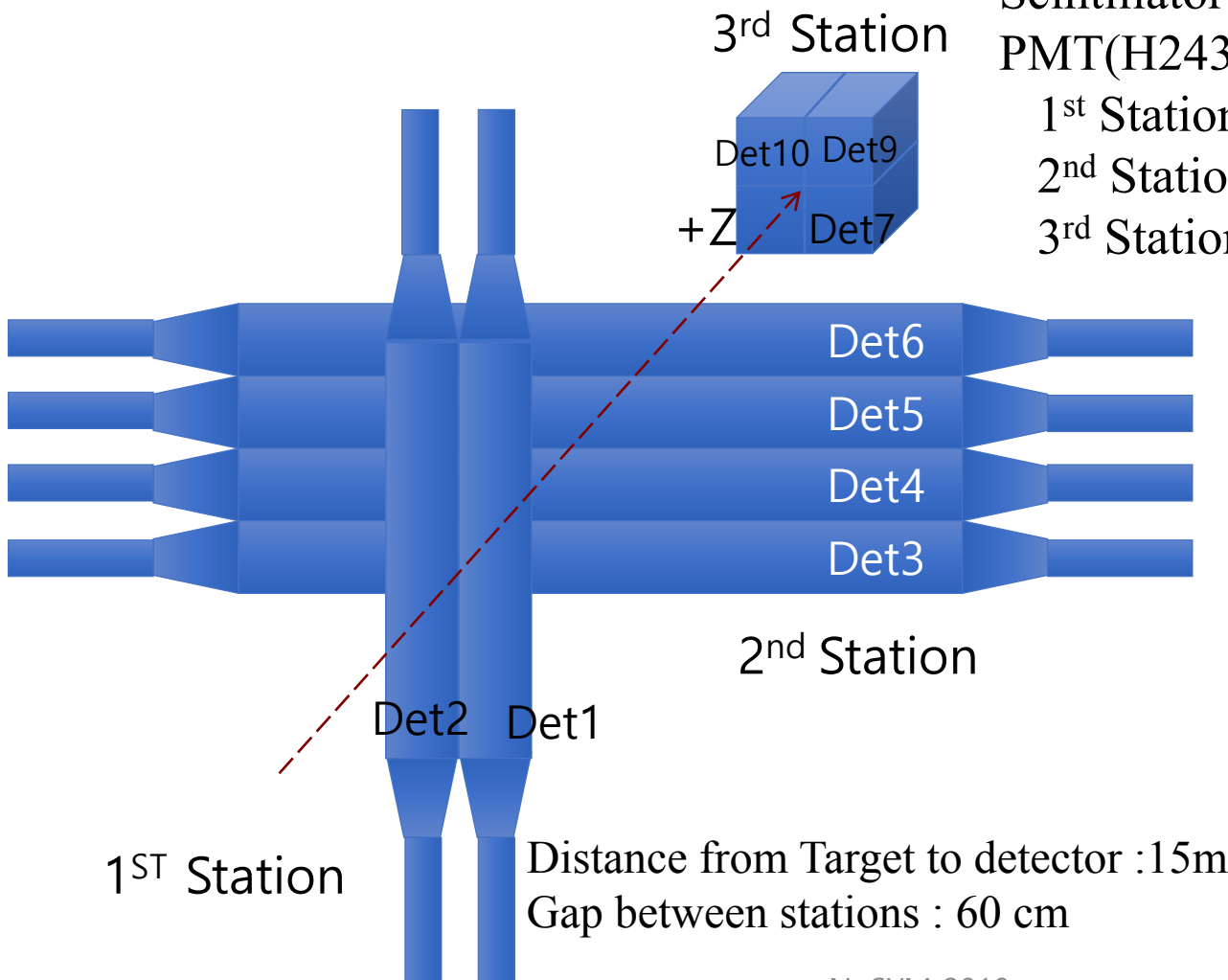
- Target : 1cm thick $^{\text{nat}}\text{Li}$ (^6Li 7.6% and ^7Li 92.4%)
- $\text{P} + ^7\text{Li} \rightarrow \text{n} + ^7\text{Be}$
($Q_{\text{g.s.}} = -1.64$ and $Q_{1\text{st}} = -2.08$ MeV)

The amount of the background neutrons above 3MeV is less than 1.5 %. (NIM A629 (2011) p43)

- ✓ Beam information
 - Current : 10 nA
(Neutron flux : 1×10^{10} n/sr/ μC)
 - beam chopper: 1/9
 - Energy : 65 MeV, 392MeV

- ✓ Data taking
 - Flash ADC 12 bit 500MSa/s

Experimental Setup



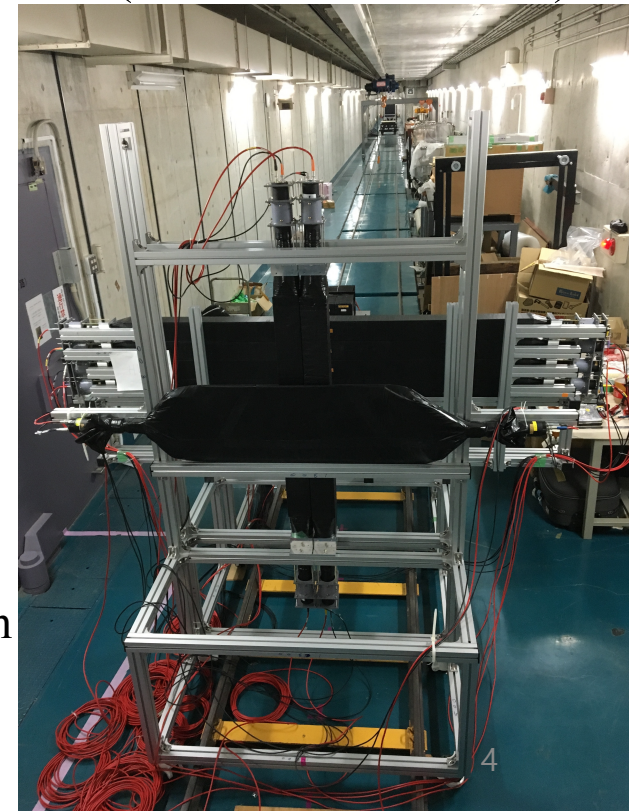
Scintillator (BC408) : 11

PMT(H2431-50 Hamamatsu) : 18

1st Station : 2 (10cm*10cm*100cm)

2nd Station : 4 (10cm*10cm*200cm)

3rd Station : 4 (10cm*10cm*20cm)



Position & Time resolutions (cosmic-ray)



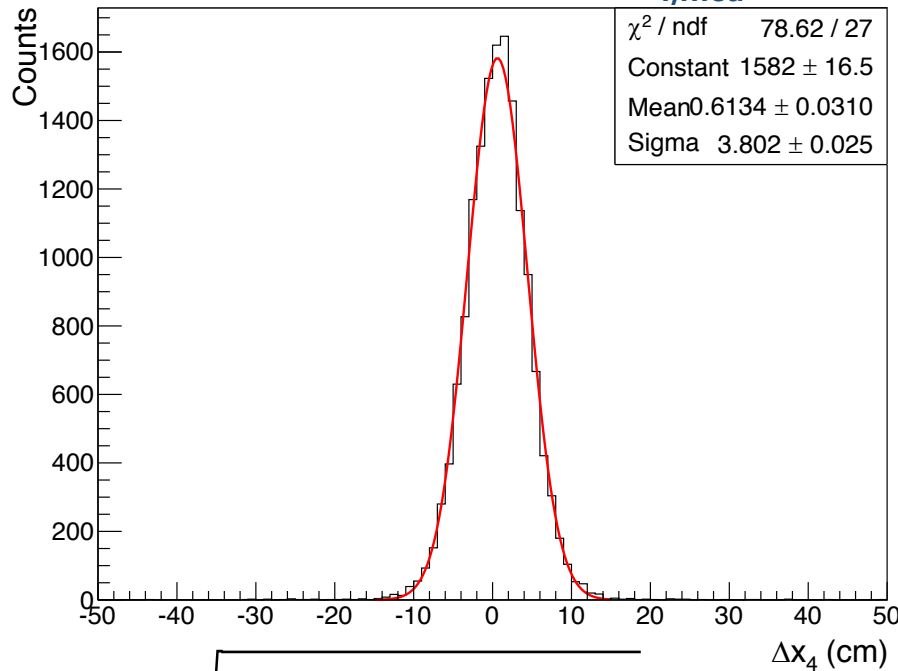
With two PMTs, we can measure hit position and hit time.

$$\text{Hit position} = (T_{\text{left}} - T_{\text{right}}) v_s / 2$$

$$\text{Hit time} = ((T_{\text{left}} + T_{\text{right}}) - L_{\text{det}} / v_s) / 2$$

$v_s : 15 \text{ cm/ns}$

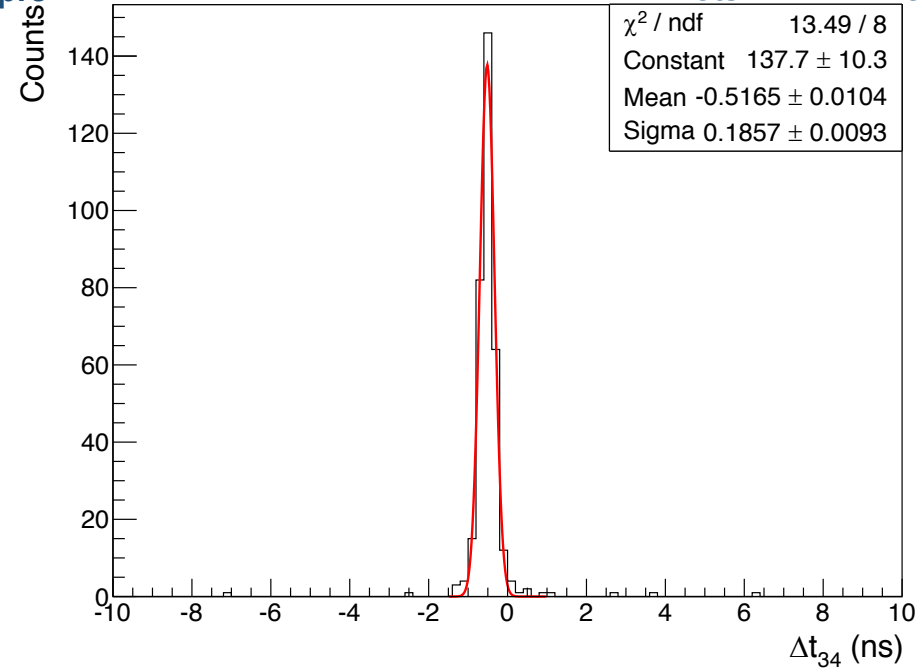
position difference between $X_{4,\text{mea}}$ and $X_{4,\text{pre}}$



$$\sigma(\Delta x_4) = \sqrt{\left(\frac{3}{2}\sigma_x\right)^2 + \left(\frac{1}{2}\sigma_x\right)^2 + (\sigma_x)^2} \quad \therefore \sigma_x = 2.03 \text{ cm}$$

position resolution : 4.78 cm

Time difference between t_{Det3} and t_{Det4}



$$R_t = \frac{FWHM(\Delta t_{34})}{\sqrt{2}} = 308 \text{ ps}$$

time resolution : 308 ps

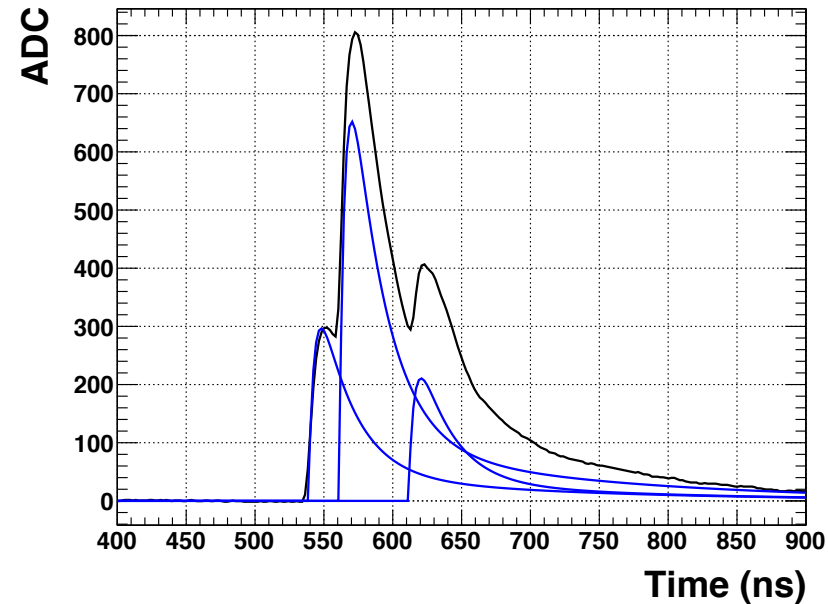
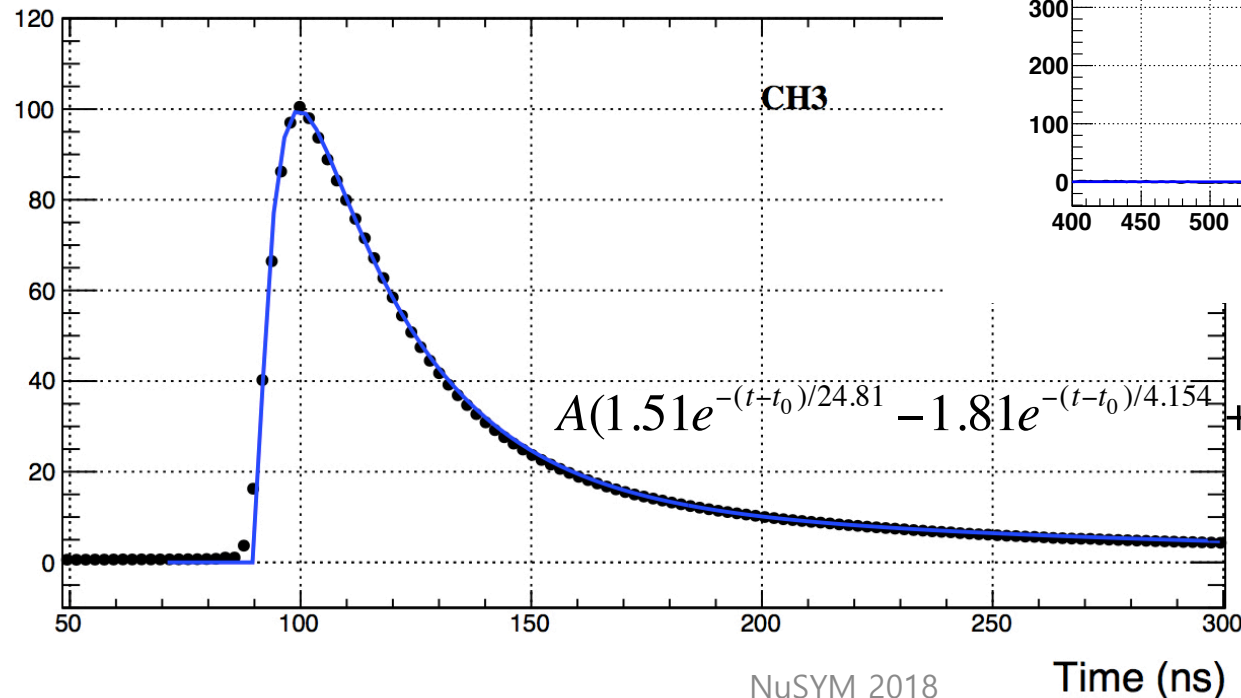
Waveform (392MeV)



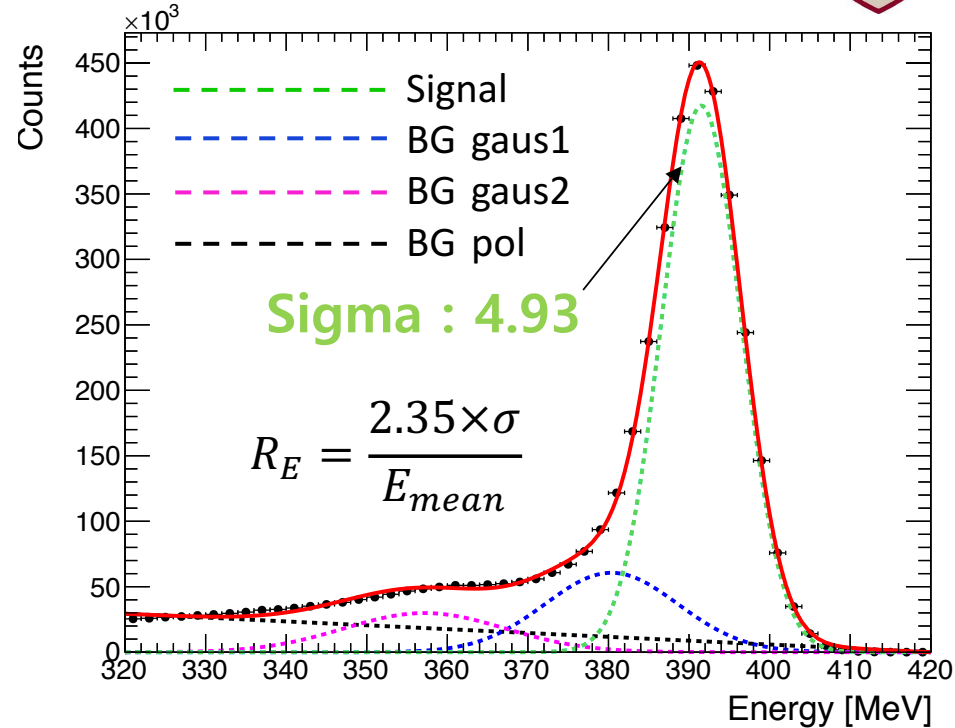
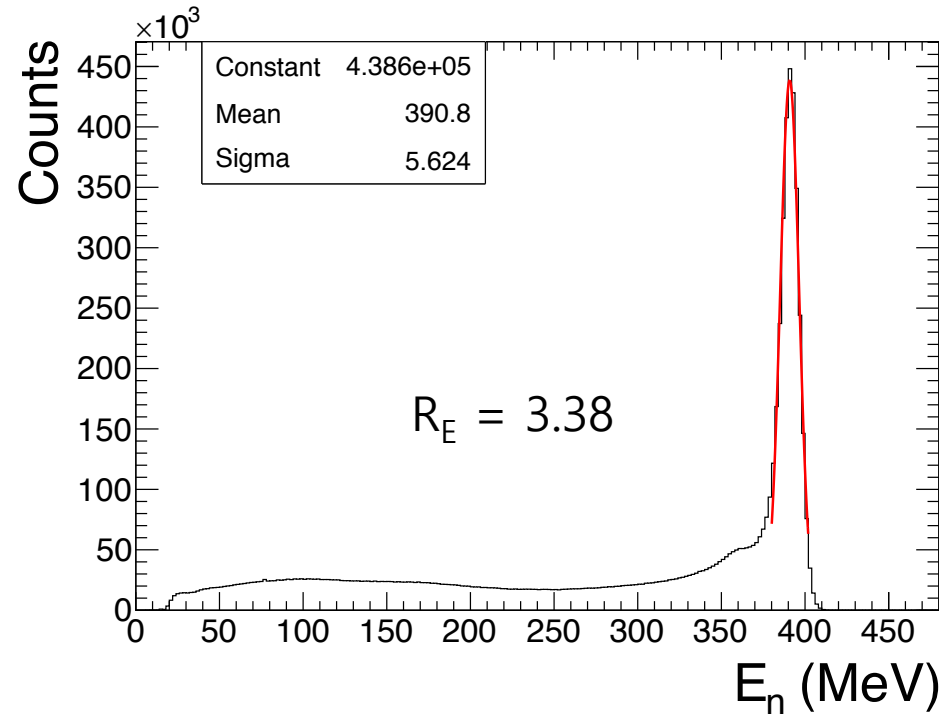
- FADC500
500 MSa/s, 12 bit resolution, 8channel
=> It allows to separate pile-up events.

A : pulse height
 t_0 : starting time

ADC fraction



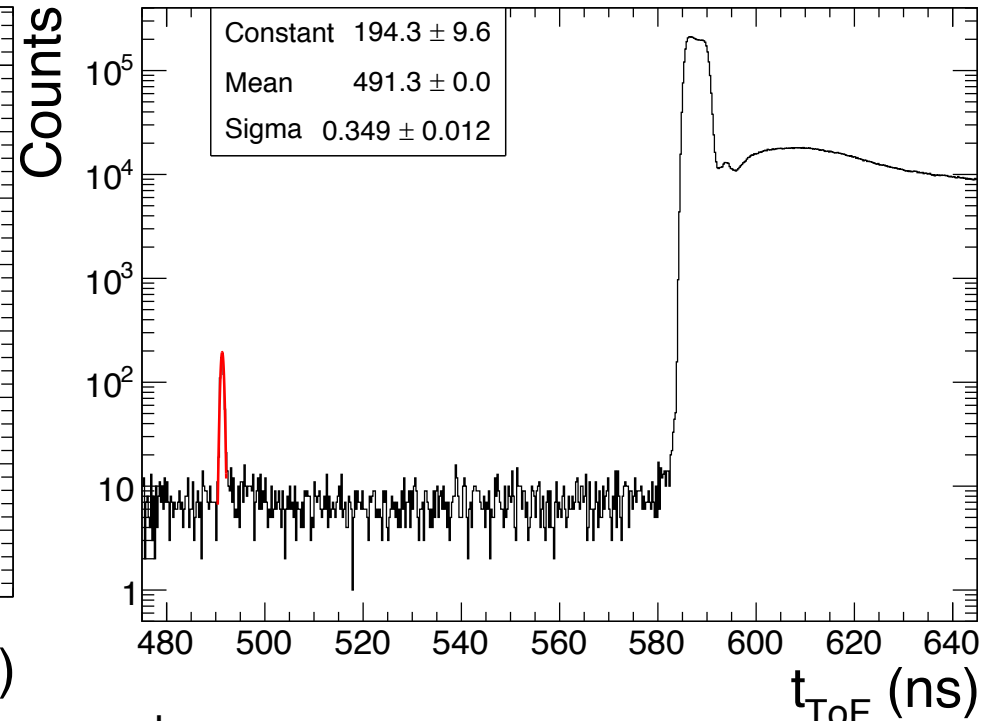
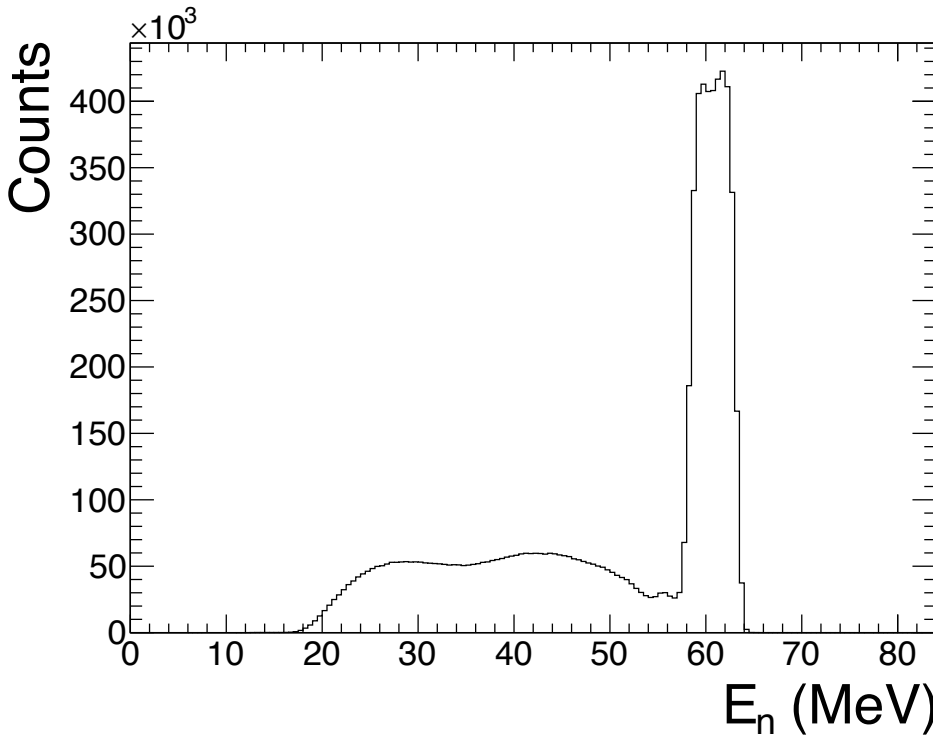
E_{ToF} spectrum (392 MeV)



energy resolution : 2.96 %

- The fraction of neutrons in the peak region is about 40 %.
- Most of the continuum comes directly from the $^{\text{nat}}\text{Li}(p, xn)$ reaction. ex) $^7\text{Li}(p, n^3\text{He})\alpha$
- The small peaks 10 and 30 MeV lower than the peak arose from the transition to the excited state of ^7Be . NIMA 629(2011) 43.

E_{ToF} spectrum (65 MeV)



- 1 cm thick target gives a large energy spread.
(4.69 MeV energy loss for 65 MeV proton)

➡ Energy spectrum cannot give reasonable energy resolution.

$\Delta\tau$: FWHM of prompt gamma-ray

Δx : effective thickness of the neutron detector

v : neutron velocity

$$\Delta t = \sqrt{(\Delta\tau)^2 + (\Delta x/v)^2} = 0.97 \text{ ns}$$

$$\begin{aligned} \frac{\Delta E}{E} &= \gamma_L(\gamma_L + 1) \left[\frac{\Delta t}{t} \right] \\ &= 1.07(1.07 + 1) \left[\frac{0.97 \text{ ns}}{141.4 \text{ ns}} \right] \\ &= 0.015 \end{aligned}$$

energy resolution : 1.5 %

Efficiency

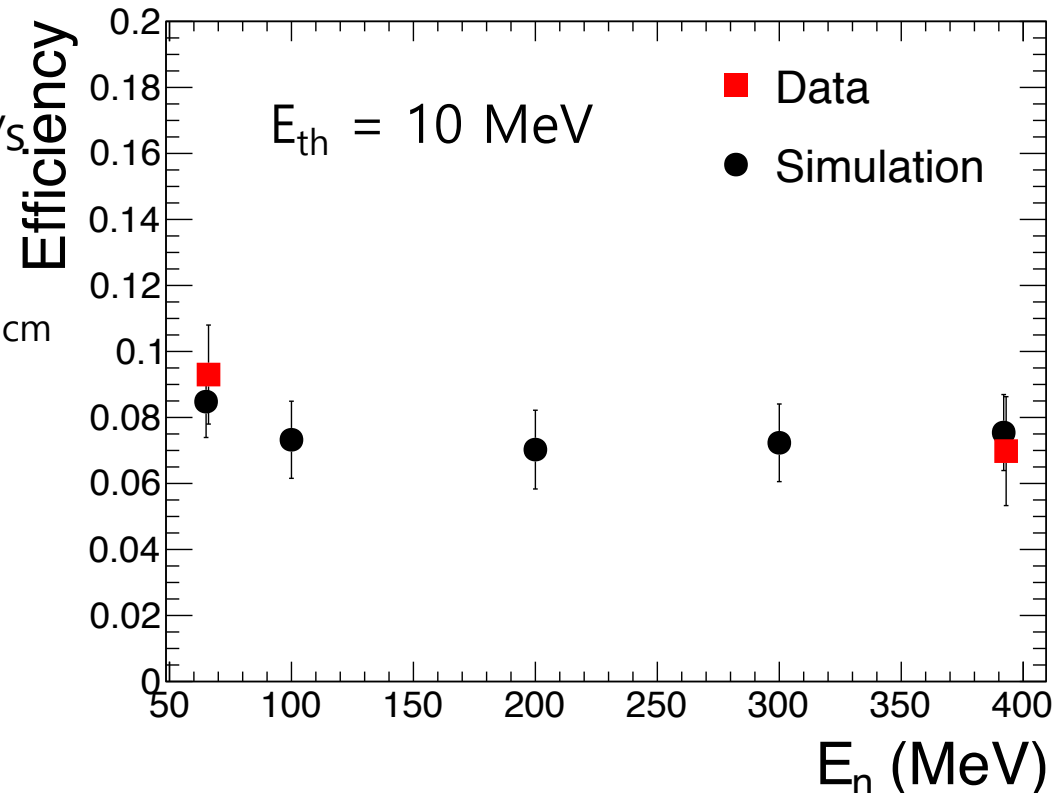
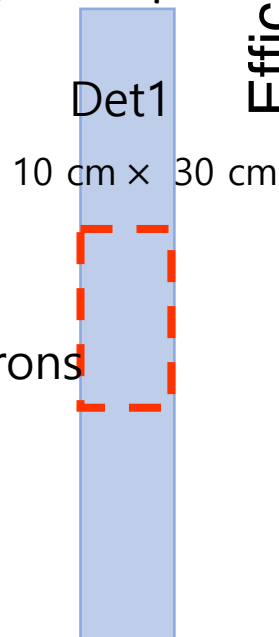


- neutron production rate at peak-region : $(0.96 \pm 0.15) \times 10^{10}$ (n/sr/ μ C).
NIM A629 (2011) p43
- beam current : 10 nA , detector width : 10 cm
- Beam size at 15 m : 25 cm $\times$ 30 cm

- neutron rate entering Det1 :
 0.96×10^{10} n/sr/ μ C $\times$ $(0.03/15^2)$ $\times$ 0.01μ C/s
 $= 13000 \pm 2000$ n/s

- Data taking time
65 MeV : 3210 s
392 MeV : 3320 s

- Number of detected neutrons
65 MeV : $(3.9 \pm 0.2) \times 10^6$
392 MeV : $(3.0 \pm 0.5) \times 10^6$



Experiment data shows good agreement with simulation

Summary



- LAMPS(Large Acceptance Multi-Purpose Spectrometer) will be installed at the rare-isotope beam facility, RAON.
- We performed beam-test with neutron beams at 65 MeV and 392 MeV at N0 beam line of RCNP.
- Detector performance was obtained.

beam	65 MeV	392 MeV
Energy resolution R_E		2.96 %
R_E (from gamma)	1.5 %	(3.2 %)
Efficiency	9.3 ± 1.5 %	7.0 ± 1.7 %
Cosmic-ray		
Position resolution	4.78 cm	
Time resolution R_t	308 ps	

Thank you for your attention

