Development of New Compact Neutron Camera for Safe Proton Therapy

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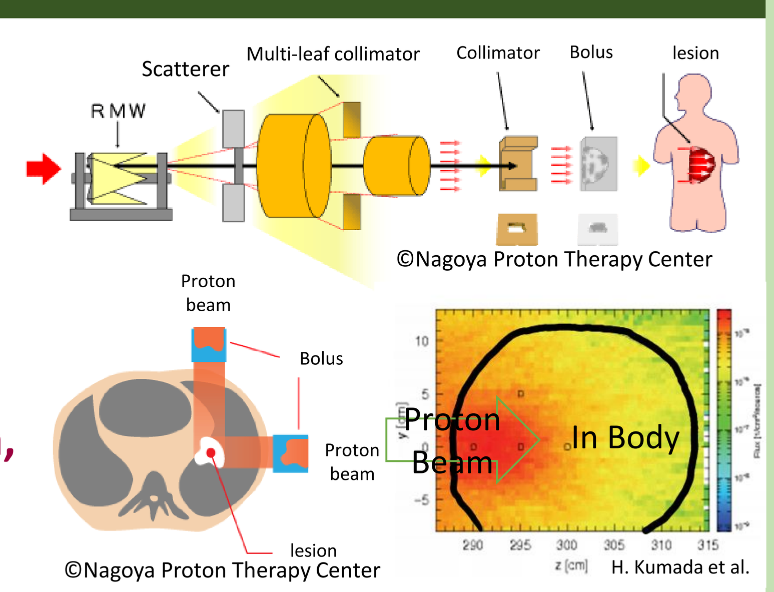
Abstract

Proton therapy causes less damage to healthy tissue compared to other radiation therapies; however, the possible damage caused by secondary, fast neutrons is almost unknown. In some simulations, neutron dose amounts to ~10% of the proton dose; therefore, a real-time visualization of the neutron dose is anticipated. We have developed a neutron camera that can visualize the direction and intensity of fast neutron sources. The camera consists of eight units of a plastic scintillator (EJ-299-34) coupled with a compact PMT (R9880U). Four units act as front-scatterers (FS), while the remaining units act as back-scatterers (BS), which are placed 30 cm behind the FS. By measuring both the pulse shape and Time-of-Flight between the FS and BS, neutron/gamma discrimination is possible. Further, we measured the energy of protons recoiled at FS to determine the direction of incident neutrons. Specifically, we demonstrate that a ^{252}Cf neutron source is correctly imaged with an angular resolution of 15.5 deg (FWHM). In addition, fast neutrons emitted from the brass block irradiated by 70 MeV were successfully monitored in real time. Finally, we present our prospects for future clinical applications. We introduce dose estimation algorithm. This time we make preliminary algorithm to estimate the brass phantom dose. After we estimate the camera dose, we convert the dose at the camera to the dose at brass phantom by using this algorithm.

1. Introduction

Secondary dose in proton therapy

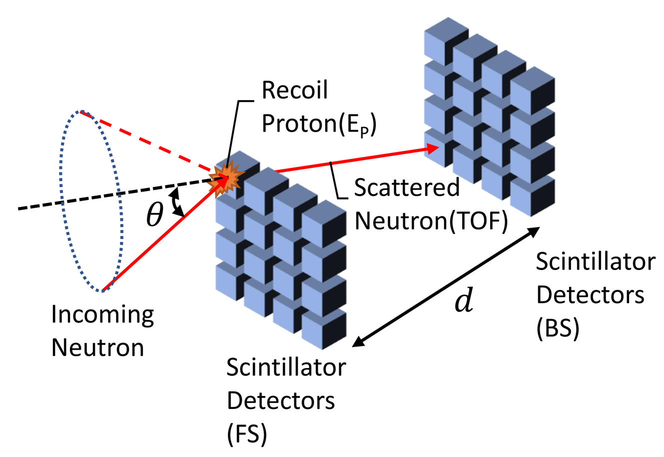
- Second particles are produced in collimator and in the patient body
- Almost of secondary particles are fast neutron
- **In this study, we introduce a novel neutron camera, which can be used in proton therapy and can visualize the neutron source direction.**



2. Material and Methods

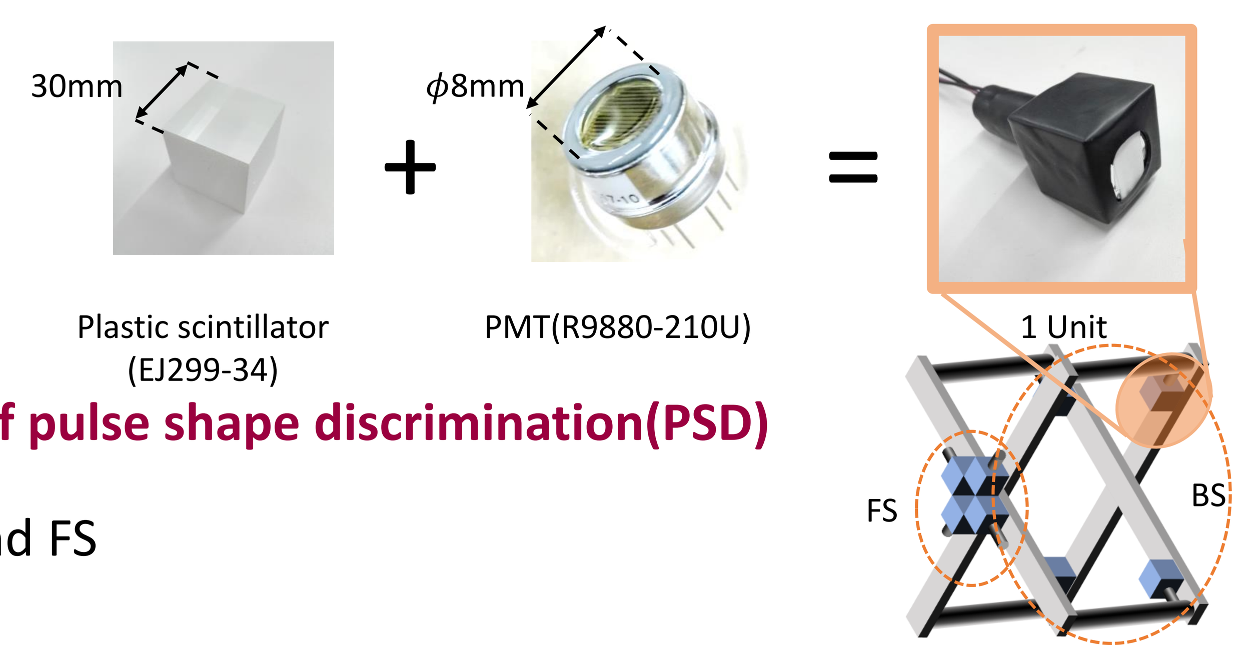
Basic principal of the neutron camera

- Measure the recoil proton energy (E_p) in FS
- Measure time-of-flight (TOF) between FS and BS
- Calculate the scattered neutron energy (E_{n1}) using the TOF
- Calculate the scattering angle of the scattered neutron using the equation: $\tan\theta = \frac{E_p}{E_{n1}}$



Material and character of the neutron camera

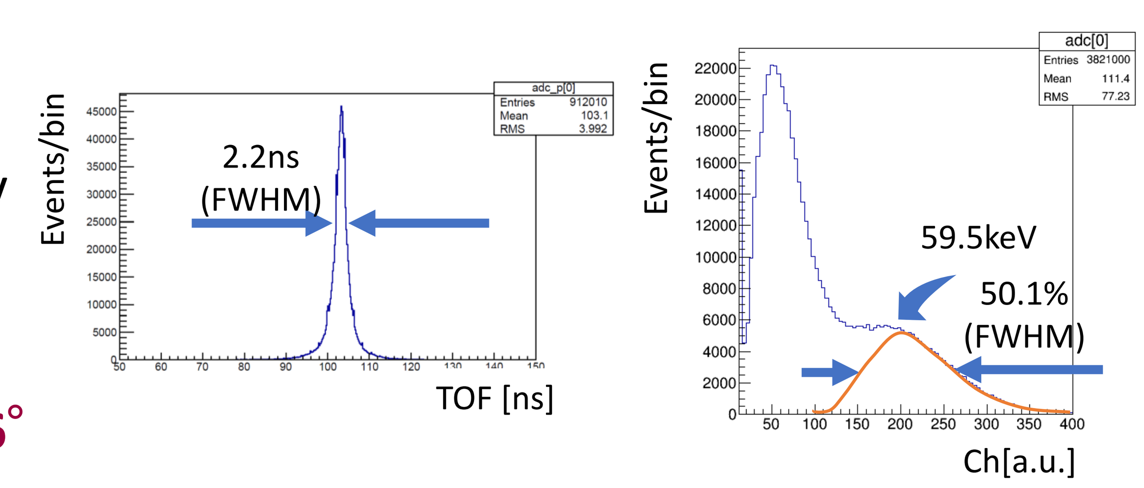
- Scintillator pixel size : 30 × 30 × 30mm^3
- PMT diameter : 8mm (**Ultra bialkali**)
- **EJ 299-34 is capable of pulse shape discrimination(PSD)**
- BS placed 30 cm behind FS



3. The basic performance

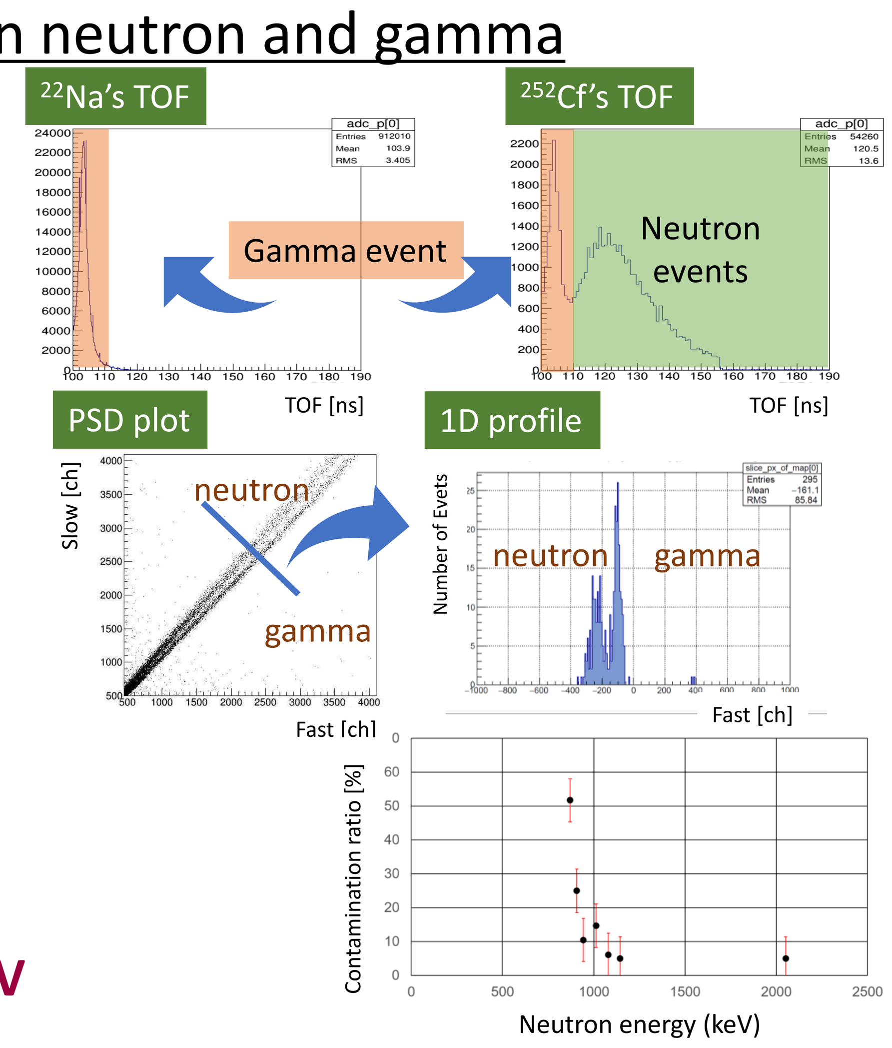
Time resolution and energy resolution

- The measured time resolution is 2.2 ns and energy resolution is 50.1 % (FWHM) at 59.5keV
- This implies that **the angular resolution of the camera is approximately 6°** if we measure a 500 keV monochromatic neutron source.



The resultant discrimination between neutron and gamma

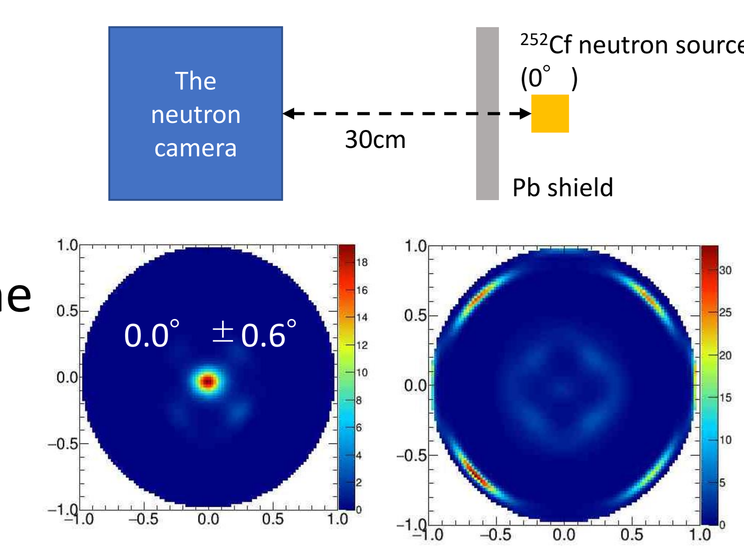
- The time-of-flight(TOF) of the gamma signals is typically smaller than 10 ns
- EJ299-34 plastic scintillators enable pulse shape discrimination (PSD)
- **We combine the TOF method and PSD method**
- Reject gamma signals better than using only one method
- **The contamination ratio is less than 20 % for neutron events above 1 MeV**



4. Imaging of neutron source

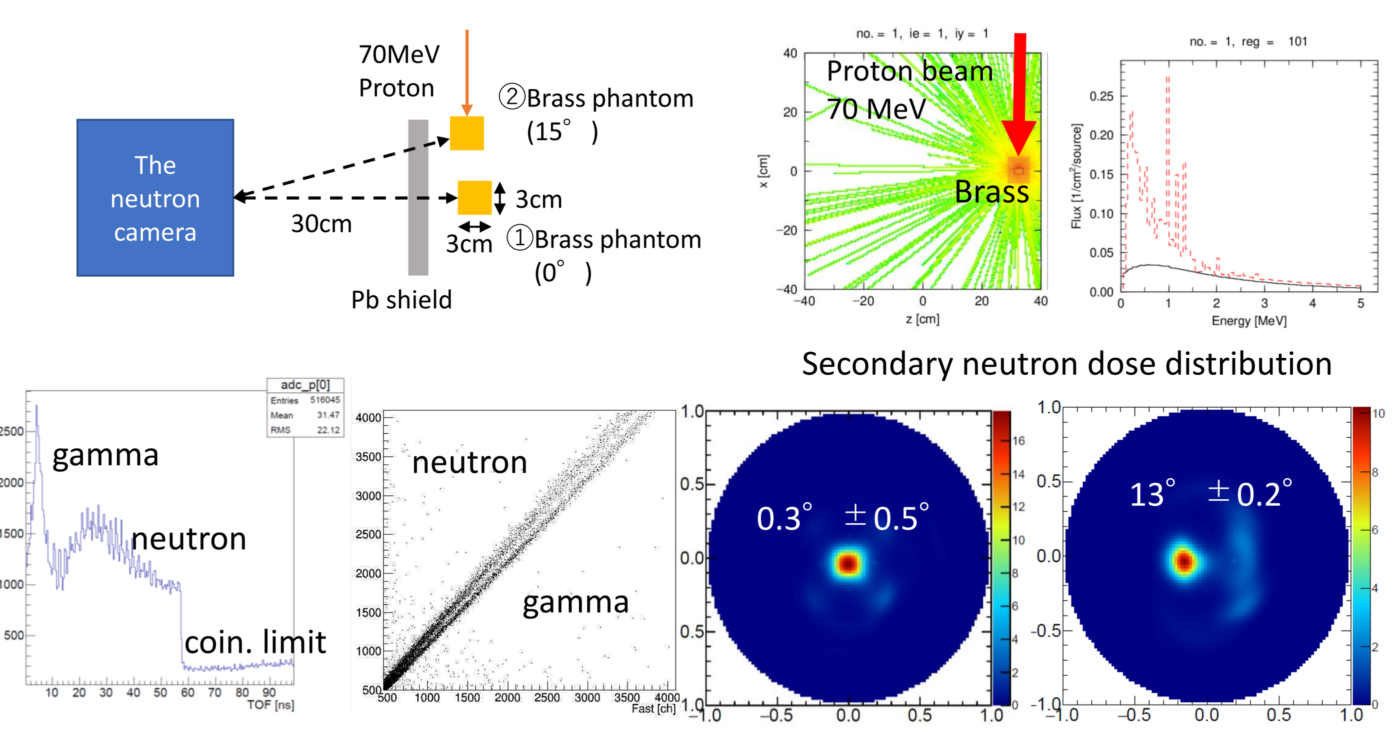
252Cf neutron source

- ^{252}Cf neutron source emitting neutrons with an average energy of 2 MeV
- We successfully identified the direction of the neutron source
- **The angular resolution is 15.5°**



Imaging of secondary neutron source at 70 MeV proton beam line

- Proton : 70 MeV
- Brass : $\phi = 3$cm
- We successfully identified secondary neutron source direction



5. Conclusion and future work

Conclusion

- We identified ^{252}Cf and secondary neutron source direction

Future work

- Separation gamma noise signals by energy threshold
- Estimation of neutron dose