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The Development of Time-of-Flight Neutron Detector for Measurement of Ion Temperature in Fast Ignition Experiment
高速点火核融合統合実験におけるイオン温度測定用中性子計測器の開発

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In order to understand fast heating mechanism, measurement of fuel ion temperature is strongly necessary in fast ignition. Background noise originated from gamma ray is serious problem for measuring fusion neutron in fast ignition experiment. The scintillation afterglow of intense gamma ray was suppressed by using newly-developed liquid scintillator. Other background noises will be suppressed by lead shield and neutron collimator. Ion temperature in fast ignition will be measured by newly-developed neutron detector.

1. Introduction

Fast ignition is one of the most promising alternative ignition schemes in inertial confinement fusion. In order to understand fast heating mechanism, the measurement of the fuel ion temperature is essential. In the experiment in 2002, the ion temperature in the fast ignition experiment was estimated from the experimentally observed neutron yield and fuel density [1], and the Time of Flight (TOF) neutron spectrometer with the high energy resolution has been strongly desired.

In the fast ignition experiments, the background signals originated from intense high energy x-rays generated from target (we refer as γ-rays) is serious problem. The scattered γ-rays from the target bay wall (we refer as γ'-ray) or the neutrons generated via (γ, n) reaction from the constructions, such as target vacuum chamber (we refer as γ-n), also interferes neutron measurement. Thus the neutron detector with the equipments for shielding the harsh backgrounds is needed. In this paper the development of the TOF neutron detector for the ion temperature measurement with the countermeasures against backgrounds for the fast ignition experiment will be presented.

2. Gamma-ray-derived noise

Background noises derived from gamma ray at DD fusion neutron arrival time are scintillation afterglow of intense first gamma-ray signal, second gamma ray reflected from wall in the experiment room and high-dose neutron via gamma-n reaction. Figure 1 shows signal of conventional neutron detector in fast ignition experiment.

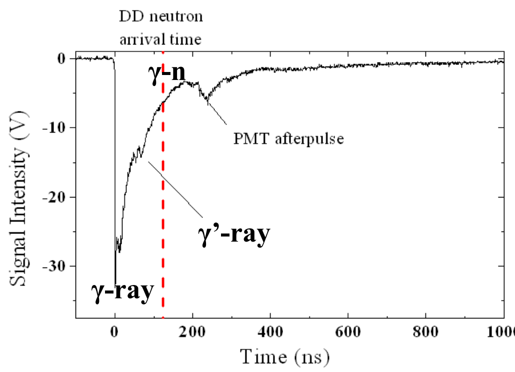

Fig. 1 Signal of conventional neutron detector in fast ignition experiment. Background noise existed at DD neutron arrival time.

2.1 Scintillator size and location

Ion temperature can be measured by neutron spectrum Dopper broadening. In our experiment, ion temperature of 1 keV with ther neutron yield of 106 should be measured. From these requirements, the limitation can be calculated as follows. Limitations of energy resolution are (1) time resolution of detector and (2) time uncertainty of scintillator thickness.

In order to detect 100 neutrons when neutron yield is 10^6, detection efficiency larger than 10^{-4}

was needed. (3) Detection efficiency is product of geometrical efficiency determined by the solid angle of detector and absolute detection efficiency.

Thus detector design for measurement of ion temperature is shown in fig.2. Detector is determined to set at 5 m from target chamber center with 2-cm thickness scintillator in order to make detector smaller and have higher diction efficiency. Scintillator was designed to be divided 7 channels whose diameter is 20 cm ϕ in order to obtain enough photo collection efficiency.

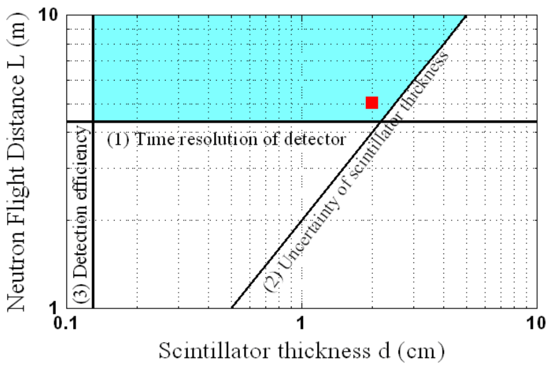

Fig. 2 Geometrical design of detector. Tinted region is satisfied with requirement.

2.2 Reduction of γ-ray signal

A low-afterglow and fast-decay liquid scinitillator by using oxygen-quenching method was developed for suppress the residual scintillation tail from the intense γ-rays [2]. A liquid scintillation detector with a gated photomultiplier tube was developed for the neutron yield measurement in experiment in 2010. The γ-ray signal was successfully suppressed, and the fusion neutron was observed [3]. The multichannel liquid scintillation detector with the designed size discussed above will be constructed.

2.3 The reduction of γ'-rays and γ-n backgrounds

The γ'-ray from target bay wall and γ-n was designed to be suppressed by careful locating of the detector and the design of the neutron collimators. The detector covered with the lead shield is designed to be located in the concrete "cave" under the target chamber to suppress γ'-rays and γ-ns. Furthermore the γ-ns from target chamber are shielded by a neutron collimator. Figure 3 shows the schematic of our designed neutron TOF detector. By using these equipments, ion temperature will be diagnosed in next fast ignition experiment.

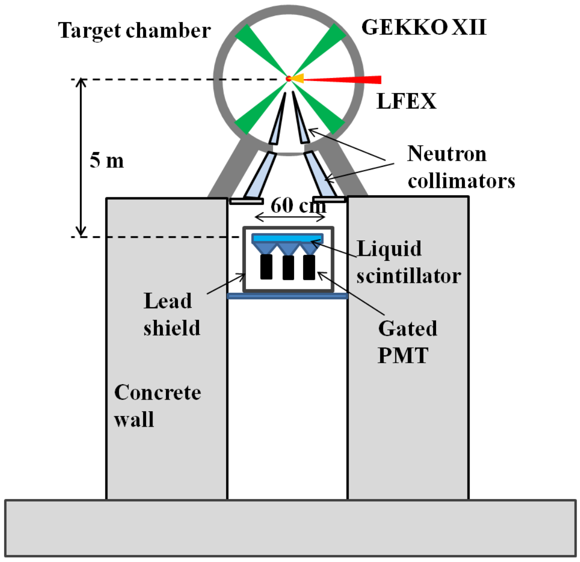

Fig. 3 Schematic of the designed neutron TOF detector for the fast ignition experiment.

5. Summary

The noises originated from γ rays is serious problem for measuring fusion neutron in fast ignition experiment. The tail of the scintillation decay from intense γ-ray was suppressed by using a newly-developed liquid scintillator. [2] Other background noises were designed to be suppressed by the lead shield and the neutron collimator. The detector can measure the ion temperature down to 1 keV at the neutron yield of larger than 10^6.

Acknowledgments

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References

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