I. 13. Development of a Neutron Beam Profile Monitor

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We have developed a neutron beam profile monitor to be used in the construction of the new neutron beam line at CYRIC 5th target room. Two plastic scintillator bar detectors were utilized to scan across the beam, one horizontally and the other vertically to obtain the projected beam intensity distributions. We prepared, as the control unit, a VME on-board PC module, a motorcontroller, a scaler, and a discriminator which were inserted in 7-spanned VME crate. We bring the scanner unit and the VME crate into the beam line and connect the on-board PC to the Ethernet. We can access the PC from anywhere Ethernet connections can be reached in order to control the system and acquire beam profiles. We also aim to apply the beam profile monitor for high energy photon beam profiling with tungsten converter wires attached before the detectors. We call it “GAMERA” from the abbreviation of “GAMma caMERa”.

DESIGN

Knowing the profile of the beam is very crucial for the construction of a new beamline. The shape, size, intensity, and core to halo ratio are the important information to decide the quality of the beam and the forthcoming experiments. We have been developing a new neutron beam line at CYRIC 5th target room. The details of the development of the beam line. Details for planned experiments can be seen in Maeda’s article in this annual report. In the beam development, the beam profile monitor is strongly needed.

The beam profile monitor is required to have the following features,

- It should detect neutrons with energy ranges from 10MeV to 100MeV.
- It should also be applied to high energy photon beam profiling.
- The position resolution should be less then 5mm.
- It should take beam profiles independent from the other DAQ systems.
- It should be easily handled and maintained.

In order to satisfy those requirements, we designed the scanning type beam profile monitor from 3 parts: neutron detectors, scanner with linear motion mechanisms, and a control and DAQ unit.
We chose bulk plastic scintillator (NE102A) for material of the neutron detector. We made a scintillator bar of 5x5x200mm³ and attached it to the photo-multiplier tube (Hamamatsu R1450) with optical grease. In the case of photon beam profiling, a tungsten wire of 2mmφ is placed before the scintillator to convert high energy photons into electron-positron pairs. GAMERA is designed to count all the signals from the discriminator, discrimination level should be carefully chosen. In neutron beam profiling, because background is mainly from slow neutrons and the γ rays, discriminator level should be set as high as to enhance the signal from fast neutron. In photon beam profiling, because background is mainly from electrons and positrons, discriminator level should be set as high as excluding signal from passage of single particle. The detection efficiencies were calculated for neutrons and photons using Geant 3.21 based simulation. The simulator for neutron beam calculates reactions of neutrons of 20MeV inside the plastic scintillator and energy losses of the relevant charged particles. When we set the threshold at 2MeV, the detection efficiency is roughly 0.2%. For the simulation of gamma beam, energy deposit by electrons and positrons converted from 100MeV photon in the tungsten converter is calculated. When we set the threshold at 1.3MeV, the detection efficiency is roughly 4%.

The outline drawing of the scanner unit is shown in Fig. 1. Two scanners are placed on the unit; one scans horizontally and the other vertically. The scanning length is both 200mm. We utilized a pulse motor, a ball screw, and a rotary encoder to assure precise linear motion. We also attached two limiting switches and an electromagnetic break to prevent the scanner to move in destructive motion. All the elements are controlled by a VME pulse motor controller.

In order to make GAMERA portable and easy to handle, we adopted the VME bus system which gradually come to be used in the field of particle physics experiments in succession to CAMAC. VME has following characteristics for our use:

**Portable** One crate can have a PC module and some IO modules init to build a stand alone control and DAQ system.

**Common in the factory automation** Because the motion control is the main subject in the factory automation, we can easily find a suitable module for controlling pulse motors.

**Common in the particle physics experiments** Signals from a photomultiplier attached to a plastic scintillator are easily handled by electronics dedicated to the particle physics. Not only the scaler which was used in our system but ADC and TDC modules on VME standard can also be used to build a simple DAQ system.

We inserted a on-board PC module a motor controller module, a discriminator module, and a scaler module in the 7-spanned VME crate.

The PC module itself is made of Pentium-II 400MHz, 128MB SDRAM, 12GB HDD and other legacy interfaces and Ethernet interface. It works as an ordinary PC in spite of its compactness. We chose vine linux 2.1 (kernel version 2.2.10) as an OS for the PC.
module for easy network access and economy system construction. Only at the setup period, we connect a keyboard and a display to the module. After the setup of network is finished, we can access the module via Ethernet from anywhere. The PC module utilizes the Tundra Semiconductor Universe PCI/VME bridge inside and we installed the VME driver for linux developed by J. Hannapel. Other useful documents for accessing VME from linux can be found elsewhere and we mostly referred to K. Nakayoshi's report on which described was basic performances of a DAQ SYSTEM using the VME CPU module. Sample programs for VME data access were also supplied by J.Hannapel, and all of our programs for controlling and taking data from VME modules originate from them.

BEAM PROFILING

We placed GAMERA at 50cm downstream from a neutron collimator in the 5th target room. The neutron beam was created from primary proton beam of 20MeV bombarded on a 9Be target of 11.7mg/cm². The swinger is set at 20 degrees from horizon. Taking the kinematics and the target thickness into account, neutron beam energy ranges from 17.883MeV to 18.150MeV. We used a 40 cm long iron collimator of 50mm diameter. The center positions of both scanning arms was set at the beam line so that they could cover +/-10cm around the beam center. The detectors were programmed to move from -75mm to +75mm with 5mm interval and to stop for 190 seconds after each movement. We set a deuterized neutron detector at 10m downstream from the collimator and used it as the reference counter for the normalization of beam intensity fluctuation.

A NIM discriminator and a CAMAC scaler were also used to count the divided signals of GAMERA detectors. The counts taken from GAMERA were compared to the counts from CAMAC scaler and they showed the good agreement within some systematic errors estimated from the difference of discriminator levels and counting times between them. We are sure our VME system is working correctly.

Our interest is now in reconstructing the 2-dimensional beam profile from vertically and horizontally projected beam intensities. We have tried two methods of reconstruction. One method brutally finds 2-dimensional matrixed beam intensity with least deviation from the horizontal and vertical scanned data. Here I will describe the other method which is based on the simulation result for beam collimation. From our simulation, collimated neutron beam profile is well fitted by Saxon-Woods' form:

\[ I(r) = \frac{I_0}{1 + \exp \left( \frac{R-r}{d} \right)}. \]

I(r) is beam intensity at distance r from the center of the beam, R is a beam radius and d is a diffuseness. Because width of peaks in horizontal and vertical scanned data are different, data were fitted with the assumption that the beam is axisymmetric to both
horizontal and vertical axes. The fitting parameters are $I_0$, RH, RV, $dH$, and $dV$ (the subscript H denotes "Horizontal" and V denotes "Vertical"). Normalized counts and fitting results are shown in Fig. 2. The 2-dimensional intensity distribution derived from the fitting is shown in Fig. 3. These reconstruction methods are argued in detail in Y. Kobayashi's master thesis.

**SUMMARY**

We have developed scanning-type beam profile monitor: GAMERA. It was tested at the CYRIC 5th target room using neutron beam of 18MeV. It proved to be able to measure the beam profile and also able to reconstruct the 2-dimensional intensity distribution with help of simulation results. We are sure that GAMERA can be used for further development of the neutron beam line at CYRIC. This is the first trial of the construction of a full VME based DAQ system. Its portability and reasonableness will be the good example for the construction of future DAO systems.

**References**

1) Dynatem DRC1.
3) Comet SD701.
4) Advanet ADVME1805.
6) The VME Linux Project.

![Diagram](image)

Fig. 1. The outline drawing of the beam profile monitor scanner unit.
Fig. 2. Normalized GAMERA counts fitted by Saxon-Woods form (a) is the horizontal scanned data and (b) is the vertical one. The curves show the result of the fitting by a Saxon-Woods shaped function.

Fig. 3. The fitting result shown as 2-dimensional beam profile.