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Design and construction of the first prototype ionization chamber for CSNS and PA beam loss monitor (BLM) system*

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Abstract Design and construction of the first prototype ionization chamber for CSNS and Proton Accelerator (PA) beam loss monitor (BLM) system is reported. The low leakage current (<0.1 pA), good plateau (≈800 V) and linearity range up to 200 Roentgen/h are obtained in the first prototype. All of these give us good experience for further improving the ionization chamber construction.

Key words spallation neutron source, proton accelerator, beam loss monitor, ionization chamber, plateau curve, linearity

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1 Introduction

The on-schedule China Spallation Neutron Source (CSNS)[1] is composed of the accelerator, the target station, the spectrometer, and also their necessary service facilities mainly. For the construction of a large current linear proton accelerator (PA), which is composed of a H^- ion linear accelerator and a fast-cycle synchrotron, one of the key difficulties existing in theory and technology is the beam loss, which is the bottle-neck factor determining the final power level of this kind of accelerator. Thus, the solution to the beam loss is exactly in the first place and the large effort has been put on it for PA.

To monitor the beam loss by measuring the number of lost beam particles in a certain time and their locations at the area close to the beam pipe, the beam loss monitor (BLMs) is required and should be installed in a proper position of the accelerator pipe and also of the beam transport pipe.

There are two different kinds of BLMs developed so far. One is based on the scintillation counter with fast time response, which is usually installed in the key places of the accelerator and is a part of the accelerator safety interlock. Once the abnormality of beam loss is measured in these places, the interlock will be started up immediately and the beam then be shut down to prevent the accelerator from damage. The other one is the ionization chamber with a relatively long time response, which is placed at more positions along the accelerator pipe. Because of that the performance of the scintillator will largely deteriorate after suffering long time radiation, the ionization chambers are sometimes used for the interlock to replace the scintillation counter. An example is JPAR in Japan[2)]. The design and construction of the first prototype of this kind of beam loss monitor (ionization chamber) and the experimental results of its performance are reported in this paper.

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2 Mechanical construction and specification of the ionization chamber

The schematic diagram of the ionization chamber prototype is shown in Fig. 1. And its real photograph after construction is shown in Fig. 2. The chamber consists of the high voltage electrode and the signal electrode, whose materials are both nickel, and are fixed in two ceramic rings, respectively. A stainless steel tube (the wall thickness is 0.1 mm) is acted for the shield.

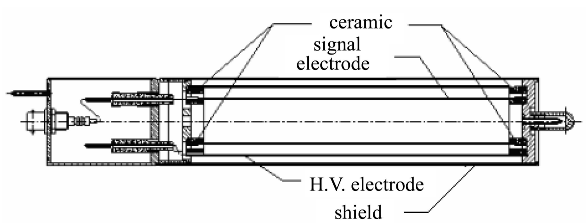

Fig. 1. The schematic diagram of ionization chamber assembly.

The specifications of the ionization chamber are given in Table 1.

Table 1. Specifications of the ionization chamber.

active length/cm	17.4
outer radius/cm	1.905
inner radius/cm	1.270
volume/cm^3	110
gas fill and pressure	725 mmHg Ar
gamma sensitivity/(pA/(R·h^{-1}))	12

Fig. 2. The prototype ionization chamber.

3 Performance tests of the ionization chamber

3.1 Test layout

The performances of the ionization chamber are tested by using ^{60}Co γ source. The test layout is showed in Fig. 3. The radiation intensity can be adjusted by the distance between the chamber and the ^{60}Co source. The signal current of the chamber is first fed into a high-impedance electrometer of Keithley 6517A through the low noise cable made by Keithley Corp., then passed sequentially through the GPIB488 and USB interfaces, and finally is read out by an online computer. The program running for readout is implemented by LABVIEW and the operating high voltage (Negative bias) of the chamber is provided by the electrometer itself.

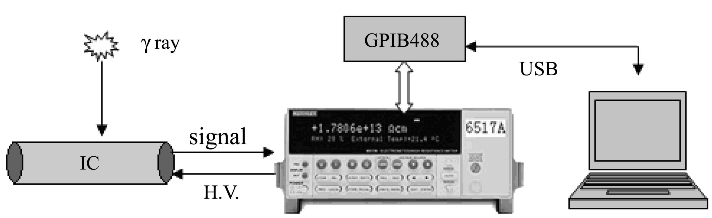

Fig. 3. The test layout of the ionization chamber.

3.2 Leakage current of the ionization chamber

Leakage current level is the key quality to evaluate the performance of an ionization chamber. The measured results of leakage current for this prototype chamber are shown in Fig. 4(a) and 4(b). Of these, Fig. 4(a) shows the high voltage dependence of leakage current, one can see that the current is almost constant for the different voltage settings. Fig. 4(b) shows the results for multi-measurements under the same high voltage of 300 V, which demonstrates that the average leakage current is actually very small, i.e., lower than 0.1 pA.

3.3 Plateau curve of the ionization chamber

Using the layout shown in Fig. 3, we also get the saturated current plateau curve of the ionization chamber, as shown in Fig. 5.

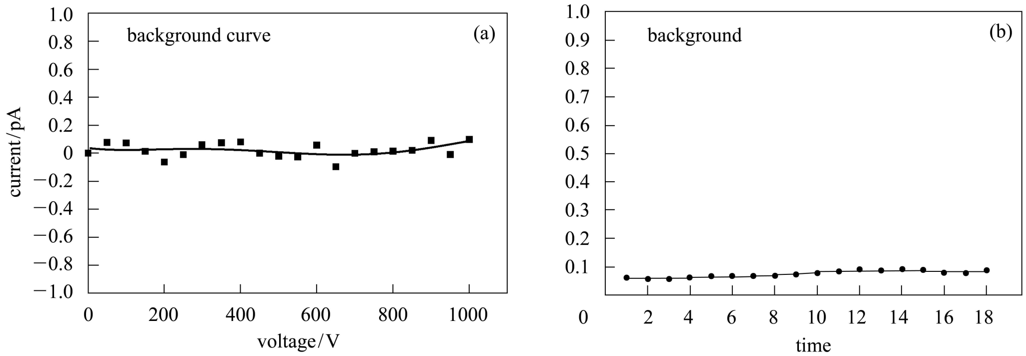

Fig. 4. (a) High voltages dependence of the leakage current; (b) Multi-measurements of leakage current under high voltage of 300 V (negative bias).

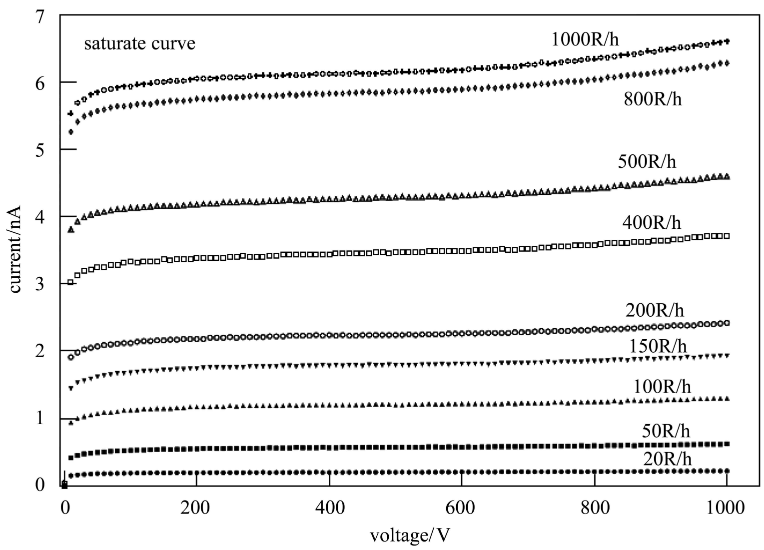

Fig. 5. The plateau curve of the ionization chamber measured by ^{60}Co source.

One can see that the plateau starts from a much lower voltage of about 50 V for a wide range of radiation level (20 to 1000 Roentgen/h), and the width of the plateau is more than 800 V. For the fact that the plateaus of the above four curves which correspond to the high radiation level (>200 R/h) are not very flat, compared with the low radiation ones, we can understand from the theory of recombination in cylindrical ionization chambers[2, 3] that the higher the dose rates, the higher the recombination. Therefore, the measured saturated currents are much less than those assuming all charges are collected by the electrode. The ionic charge collection efficiency increases when the applied voltage of ionization chamber goes up, so the measured currents increase gradually and slowly start from 600 V.

3.4 Linearity of the ionization chamber

The measured currents corresponding to various radiations are listed in Table 2. The linearity of the ionization chamber can be drawn out by plotting the measured currents in plateau area with the radiation intensity, as shown in Fig. 6. The up-limitation of the prototype chamber's linearity can be up to about 200 R/h under the applied voltage of 600 V. From the saturated current on the plateau at the linearity range we can get that the measurement gamma-ray sensitivity is about 12 pA/(R·h^{-1}).

Table 2. The measured currents corresponding to various radiations.

radiation/(R/h)	measured current/nA
20	0.21
50	0.58
100	1.22
150	1.81
200	2.26
400	3.49
500	4.31
800	5.89
1000	6.13

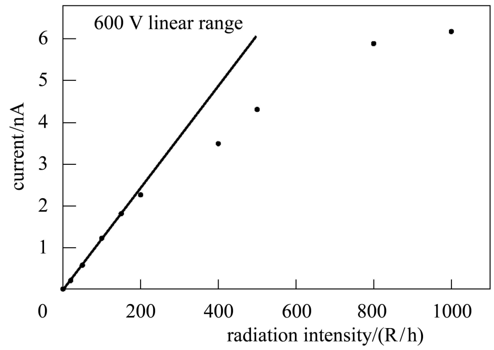

Fig. 6. The linearity of the ionization chamber.

4 Conclusions and discussions

The first prototype ionization chamber used for beam loss monitor for CSNS and PA is designed and constructed. The expected goals of the first prototype ionization chamber are reached. The low leakage current (<0.1 pA), good plateau (≈800 V) and linearity range up to 200 R/h are obtained in the first prototype. The experience we gained will largely benefit the improvement and enhancement on constructing the future ionization chambers. Some other performance tests for the chamber such as energy response will be covered by our further studies.

The ionization chamber reported here can operate stably. We hope that the applied high voltage of the ionization chamber can reach up to 3000 V and finally the optimized operating high voltage can reach between 1000 V and 2000 V to meet the requirements of CSNS and PA BLM.

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