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Design Study of a Beam Loss Monitor for the PEFP 100-MeV Proton Linac

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1. Introduction

A beam loss monitor (BLM) is widely used diagnostics device for commissioning as well as for machine protection from the radiation damage due to beam loss. In the PEFP 100-MeV proton accelerator, short ionization chamber is being considered as BLM sensor. In this paper, physical design of ionization for PEFP 100-MeV accelerator is described.

2. Beam Loss Monitor Design

2.1 Purpose and Criteria of Beam Loss Monitor

Beam Loss Monitor detects the radiation, secondary particles caused by collision between lost beam particles of accelerator and accelerator components like DTL tanks, beam pipes and collimators. The purposes of beam loss monitoring are machine protection from severe damage by radiation and measurement of beam loss position roughly.

In normal operation, the PEFP 100-MeV proton linac satisfies the requirement, 1W/m loss limit. Therefore, 1W/m, the 0.03125% of beam power, becomes lower limit of BLM signal. The upper limit of BLM signal is defined at 1% loss of beam power; 0.96kw for 20-MeV linac and 1.6kw for 100-MeV linac. These upper and lower limits would be connected to the dynamic range of electronics to analyze BLM signal.

Ionization chamber is commonly used BLM in hardron accelerator because of its simplest form, radiation hardness and good linearity, uniformity and stability. Moreover, since gamma ray, sensitive to ion chamber, attenuates much more rapidly than neutron with the distance from radiation sources, it is easy to measure loss position. [1]

Ionization chamber being considered as BLM of the PEFP 100-MeV proton linac is concentric cylindrical chamber and is filled with argon gas.

2.2 Ion Chamber Signal Amplitude and Sensitivity

The lower limit of BLM signal is determined as 1nA under the consideration of radiation dose of expected loss, electronics specifications and Ion Chamber Characteristics. Radiation absorbed dose at 1W/m is 0.355rad/sec, which is obtained from the MCNPX calculation. Since more than 1 nA signal should be detected at incident ionization energy of 0.355rad/sec, the intrinsic sensitivity of ionization chamber should be 282nC/rad. The sensitivity depends on volume of the argon gas and the volume of ionization chamber can be determined as 442cm^3.

2.3 Collection Efficiency and Response Time

Effective gap between outer radius and inner radius can be derived from the collection efficiency. Ionization chamber is recommended that the collection efficiency is larger than 0.7.
Collection efficiency is given by [2]:

$$f = \frac{1}{1+\frac{z^2}{6}} \quad \text{, where } \quad z^2 = \frac{\beta}{6ek_1k_2}\frac{d^4q}{V^2}p \qquad (1)$$

d is the effective gap, e is the electron charge, k_1 and k_2 is the electron and the ion mobility, beta is the first Townsend recombination coefficient, V is the biased voltage to be applied to ion chamber and q is ionization charge density.

The ionization charge density q is defined by [3]

$$q = \frac{dE}{dx}\frac{\rho}{W} \qquad (2),$$

where $\frac{dE}{dx}$ is the loss energy, ρ the is density of gas, and W is the W-value, which is the required energy to produce one ion pair.

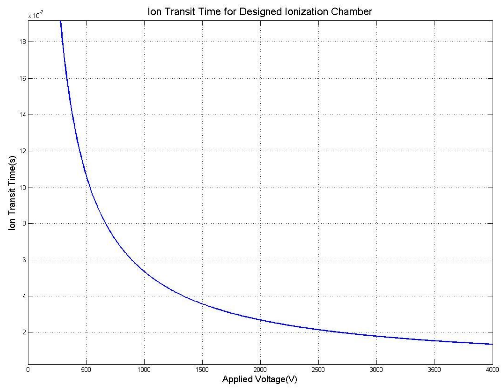

Fig. 1. Response Time of Ion Chamber

We set the collection efficiency to 0.97 and the biased voltage to 2000V. From the above equations effective gap is given by 1cm. The response time of the ionization chamber is 0.27 us in case that the electron is used to extract the BLM signal. If we use the positive ion to signal source, the response time gets 1000 times slower. The response time gets faster with increased applied voltage and its relation is given by Fig. 1.

2.4 Geometry of Designed Ionization Chamber

Outer radius of ionization chamber is set to 3.5cm because the total size of ionization chamber should be not too big to be installed on the 48.8mm radius beam pipe as well as it should have enough large volume with being maintained 1cm effective gap size.

According to the above procedure, the ionization chamber design parameter is given by Table. 1.

Table. 1. Design Parameters of Ionization Chamber

parameter	value
outer radius (a)	3.5cm
inner radius (b)	2.5cm
effective gap (D)	1cm
active length (l)	23.45cm
volume	442cm^3

3. Conclusions

We designed the ionization chamber as the beam loss monitor for the PEFP 100-MeV proton linac. We derived and obtained ionization chamber geometry parameter under the consideration of the signal amplitude, the sensitivity and the collection efficiency. In the future, we would have a beam test this ionization chamber in the 20-MeV proton linac, which is a part of 100-MeV proton linac after engineering design.

Acknowledgement

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