Proton Beam Energy Monitor for PEFP DTL

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1. Introduction

In order to measure the proton beam energy of the PEFP drift-tube linac(DTL), a gas scattering energy monitor has been constructed. The main method for beam energy measurement is to be a time of flight (TOF) using the BPPM (Beam Position and Phase Monitor), but a complementary method is being designed in case that the beam current is so low that the BPPM could not work or an energy distribution is required.

2. Concept of gas scattering energy monitor

The energy monitor is comprised of gas scattering chamber, collimator, and surface barrier detector. The operating principle of the apparatus is to use gas scattering and collimator. Beam going through the first collimator is spread out by multiple Coulomb scattering with scatter gas and is attenuated through the second collimator [1]. The reduced beam flux allows the silicon surface barrier detector to be utilized. A gas of high atomic number such as Xe is to be used to increase the scattering angle.

The Si surface barrier detector (Ortec, CL-035-025-5) for beam energy measurement only works well with very small particle fluxes such that the probability of two particles arriving within the resolution time of the detector is low. The actual time resolution doesn't depend on detector (charge collection time of less than 1us for up to ~mm depletion depth), but on the associated electronics such as amplifier, multi-channel analyzer (MCA). The reasonable time resolution is expected to be around 10 μs and so, the proton rate is needed to reduce to ~10^4 per second. In the case of 10 μA beam, the beam current must be attenuated to less than 10^{-9} of its original flux. Because the accelerated beam from DTL blows up, the flux of particle in the beam will be reduced through the front collimator and gas scattering system even with no gas. The attenuation factor should be estimated by simulating the drift effect and is assumed to be ~10^{-5} in our calculation. The gas scattering energy monitor is therefore required to give an additional attenuation of ~10^{-3}.

3. Gas scattering calculation

Since the rms multiple scattering varies approximately as $Z^{1/2}$, a gas of high atomic number such as Xe should be chosen. A SRIM code was used to evaluate the multiple scattering distributions of 20 MeV proton beams in 0.7 m thick, 10 and 100 Torr Xe gas (see Fig. 1). The calculated flux attenuation through the

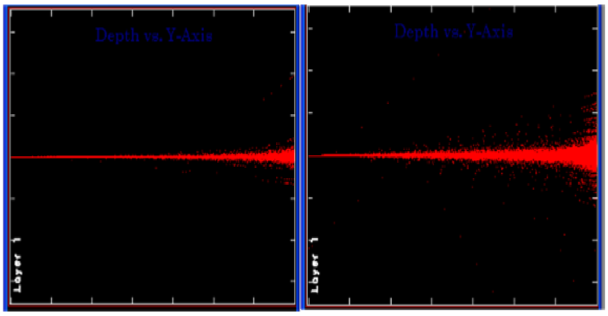

Figure 1. Gas scattering calculation by SRIM code: left for 10 Torr Xe, and right for100 Torr Xe.

0.2 mm dia. collimator is 2.7 x 10^{-3} and the energy loss is 72 keV for 10 Torr Xe. The calculated rms energy distribution at 20 MeV DTL is ±37.5 keV, which is comparable to the energy resolution of the Si detector (30 keV).

4. Fabrication

Fig. 2 shows a constructed gas scattering energy monitor. The gas scatter is a Xe gas chamber in the form of a 0.7 m long beam pipe closed off at both ends by diaphragm (or collimator) with a 0.2 mm dia. aperture at its center. In order to measure the beam current simultaneously, a faraday cup is installed in front of the Xe gas chamber. The faraday cup has a 0.6 mm dia. aperture at its center for beam transmission into the Xe gas chamber.

The calculated conductance of the collimator with a 0.2 mm dia. and 2 mm thickness is 2.01 x 10^{-7} m^3/s and the throughput of the gas cell is 5.32 x 10^{-5} Pa • m^3/s, being within a range of the dosing valve (Leybold EV016 DOS AB). With the pumping speed of 0.4 m^3/s in the buffer cell, we assure that the buffer cell can maintain the pressure of below 10^{-6} Torr.

5. Conclusion

The gas scattering energy monitor has been fabricated to measure the proton energy at the exit of the PEFP DTL. The energy loss for 20 MeV proton beam in the 10 Torr Xe chamber is 72 keV and the flux attenuation is estimated to be 2.7 x 10^{-3}. It is expected the gas scattering energy monitor will be used to measure the energy distribution of the DTL extracted beam for different RF power settings.

ACKNOWLEDGMENT

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REFERENCE

[1] J.P. Duke, D. J. S. Findlay, et al., “Measurements of Beam Energy Using the Gas Scattering System in the ISIS RFQ Test Stand”, EPAC 2002, France, June 2002.

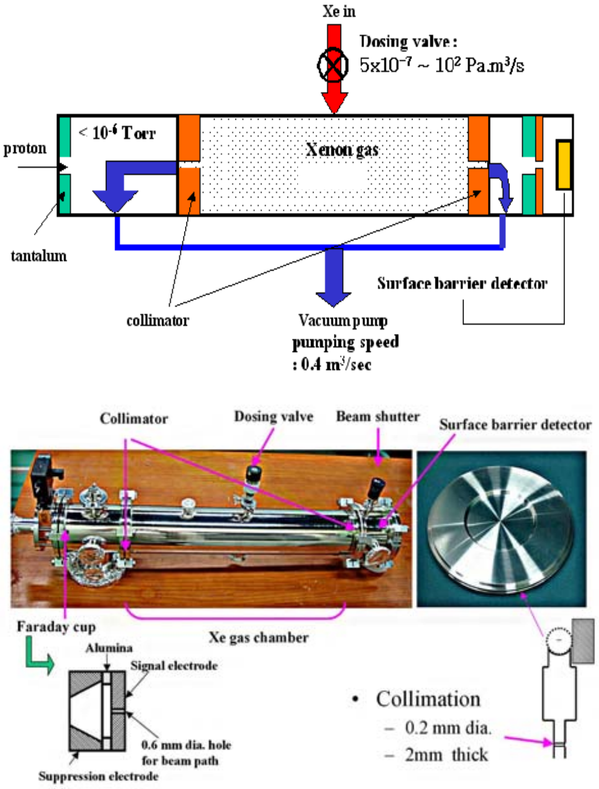

Figure 2. Schematic (top) and photo (bottom) of gas scattering energy monitor.