BEAM TRANSVERSE PROFILE MONITOR FOR IFMIF-EVEDA ACCELERATOR

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Abstract

In the framework of the IFMIF-EVEDA project, a high deuteron beam intensity (125 mA - 9 MeV) prototype accelerator will be built and tested at Rokkasho (Japan). CEA-Saclay group and Ciemat-Madrid (Spain) are responsible of the beam instrumentation from the ion source to the beam dump. One of the most challenging diagnostic is the Beam Transverse Profile Monitor (BTPM). CEA-Saclay group investigates such a monitor based on residual gas ionization. This monitor uses a high electric field to drive the products (electrons and ions) of ionization to micro-strips. A priori, no primary amplification is required due to the high beam intensity. Nevertheless, in order to study the feasibility, a prototype will be tested in a proton beam.

INTRODUCTION

This paper is devoted to the description of a non-destructive profiler prototype for the IFMIF-EVEDA project. In a first part, the context of this project will be briefly given. The second part will present the prototype, its principle, the expected counting rates, the design and some issues addressed to a future preliminary test.

CONTEXT

The International Fusion Materials Irradiation facility (IFMIF) aims at producing an intense flux of 14 MeV neutrons, in order to characterize materials envisaged for future fusion reactors. The primary mission of IFMIF is to provide a materials irradiation database for the design, construction, licensing and safe operation of the Fusion Demonstration Reactor (DEMO) [1]. In such a reactor, high neutron fluxes may generate up to 30 dpa/fpy (displacements per atom / full power year). IFMIF facility is based on two high power cw drivers (175 MHz) delivering 125 mA deuteron beams at 40 MeV each, colliding a liquid lithium target.

In the framework of the "Broader Approach", the IFMIF-EVEDA (Engineering Validation and Engineering Design Activities) project includes the construction of an accelerator prototype with the same characteristics as IFMIF, except 9 MeV instead of 40 MeV for the incident deuteron energy. Most of the components of the accelerator are developed by France, Italy and Spain. Commissioning of this accelerator at Rokkasho is foreseen for 2013.

France (CEA-Saclay) and Spain (Ciemat-Madrid) are responsible of the beam instrumentation from the RFQ to the beam dump.

One of the relevant IFMIF issues is to avoid lithium boiling at beam-target crossing (5×20 cm^2), thus placing stringent conditions on the beam spot. In particular, beam intensity fluctuations must be kept below ±5 %. Consequently, non-destructive beam profile monitors have to be designed to drive safely the beam in a very hard radiation background of neutrons and γ, and to precisely monitor the transverse beam profile and intensity fluctuations, especially just upstream the target. CEA-Saclay has decided to investigate such a monitor based on residual gas ionization.

BEAM TRANSVERSE PROFILE MONITOR (BTPM) PROTOTYPE

The BTPM prototype is based on the ionizations, induced by the beam particles, of the residual gas contains in the beam pipe of the accelerator. It will be first tested with a proton beam.

Accelerator parameters

Below are listed the parameters of the IFMIF accelerator:

- Deuteron cw linear beam (175 MHz ≡ 5.7 ns).
- Energy range: 5 to 9 MeV (40 MeV for IFMIF).
- Beam intensity: 125 mA which represents 4.5 10^9 deuterons/burst (250 mA close to IFMIF target).
- Vacuum pipe: 10^{-5} mb (target region) and 10^{-7} elsewhere.

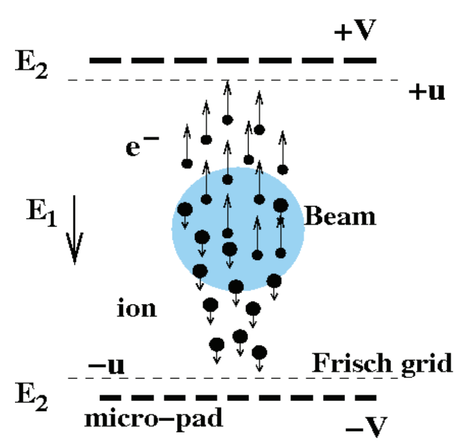

Figure 1: Transverse cross-section of a BTPM. Ionized pairs are sketched in the electric field.

Principle

Along the passage of the charged beam particles, some molecules of the residual gas are ionized, leading to the creation of electron/ion pairs, as sketched in Figure 1.

If a transverse electric field is applied, the produced particles, electrons and ions, drift along the field lines toward the anode and the cathode respectively. The motion of these particles induces currents, which can be detected on micro-pad. The Frisch grid, transparent to particles provided a good field ratio E1/E2, allows shielding against the beam electromagnetic field and restricts the active volume in which the current is read by the micro-pad.

Feasibility

Counting rate has been estimated to determine if amplification is required or not. Unfortunately, ionization data for deuteron are sparse. Thus, proton data have been used and extrapolated to 40 MeV [2]. The dominant residual gas is H_2 [3], so calculations were done using the $H^+ + H_2 \rightarrow H^+ + H_2^+ + e^-$ cross-section reactions. Taking into account the conditions defined above, the number of electron/ion pairs is around 3500 per burst, for a 1 cm detector thickness. The induced currents due to ionized particles are 100 nA for the electrons and 25 nA for the H_2^+ ions. With such currents, no amplification should be required. Usually, Multi Channel Plates (MCP) are used as amplifiers when primary currents are too weak. However, MCPs are very radiation sensitive and would not cope with the hard IFMIF radiation environment.

The time taken by electrons and ions are 5 ns and 280 ns respectively, for a 20 cm drift distance. Since position resolutions are better with ions than electrons [3][4], the profiles will be extracted from ion signals. Nevertheless, electron signals are big and fast, and could be exploited to give some rough information with wider strips…

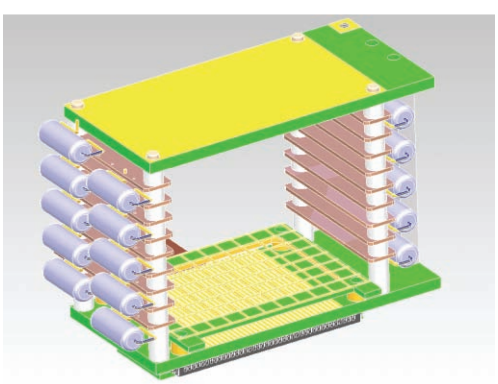

Figure 2: BTPM prototype.

The BTPM prototype design

In order to check the response of our BTPM, we have designed a first version of prototype, which will be tested at Saclay proton beam. Figure 2 shows the drawing of this prototype. This prototype is 5x5x4 cm^3 (4 cm in beam direction) with a 4x3 cm^2 micro-pad area made of 32 strips. The electric potential is applied to the upper plate while micro-pad is grounded via electronics. The electric field uniformity is insured by 9 rod pairs (left and right sides) degrading regularly the field by means of resistors.

Preliminary test

A first test is foreseen in July 2008 at Saclay, with the SILHI source [5], which delivers a proton beam of 95 keV up to 100 mA. In order to measure ion and electron signals, we will change the polarity of the voltage. Rotating the monitor by 90° will give access to vertical or horizontal axis. Below are listed the various topics we want to check or investigate:

- Principle of the detector.
- Optimization of voltage versus beam intensity and energy.
- Noise, background shielding.
- Counting rates: at 95 keV, ionization cross-sections are ~ 300 times greater than for 40 MeV.
- Position resolution measurement.
- Data acquisition.

This test will permit improvements to adapt a new detector to our requirements (simultaneous electrons/ions detection, new electronics, mechanical shape…). This one will be tested on the Saclay IPHI proton beam [6] of 3 MeV up to 100 mA, in fall 2009.

If this prototype is validated, a final design will be launched, leading to the delivery at the end of 2012 at Rokkasho.

Conclusion

We have presented a prototype of a non-destructive Beam Transverse Profile Monitor for IFMIF-EVEDA project. Such a BTPM has to deal with huge flux of neutrons and γ. A preliminary test is foreseen in June 2008 to answer various issues like the possibility to work without charge amplifier.

REFERENCES

[1] IFMIF Comprehensive Design Report, January 2004.
[2] E. Surrey at al., Report for TASK EVEDA technology programme, 2007.
[3] R. Anne et al., NIM A329 (1993) 21-28.
[4] K. Wittenburg, "Experience with the residual gas ionization beam profile monitors at the DESY proton accelerators", EPAC'92, Berlin, March 1992, p.1133.
[5] R. Hollinger et al., "High current proton beam investigations at the SILHI-LEBT at CEA/Saclay", Linac 2006, Knoxville, August 2006, p. 232.
[6] P.-Y. Beauvais et al., "Installation of the French high-intensity proton injector at Saclay", Linac 2006, Knoxville, August 2006, p. 153.