BEAM TRANSVERSE PROFILE MONITOR BASED ON RESIDUAL GAS IONIZATION FOR IFMIF-EVEDA ACCELERATOR

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Abstract

Within the framework of IFMIF-EVEDA project, a high-intensity deuteron (125 mA - 9 MeV) prototype accelerator will be built and tested at Rokkasho (Japan) in order to validate the future IFMIF accelerator. One of the most challenging diagnostics is the Beam Transverse Profile Monitor (BTPM), which has to be a non-interceptive device. Two R&D programs have been initiated: one based on residual gas fluorescence developed by CIEMAT Madrid (see J. Carmona et al. contribution) and another one based on residual gas ionization developed at CEA Saclay [1]. The principle of the last one is to measure the current induced by ionization electrons, drifting under an electric field influence, towards several strips to get a one-dimension projection of the transverse beam profile. Preliminary results of a first prototype tested on the IPHI Saclay accelerator will be shown, as well as a new prototype design. In the new design several improvements have been carried out. The new detector will be tested soon with continuous and pulsed beam at higher energy.

INTRODUCTION

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 future Fusion Demonstration Reactor (DEMO) [2]. 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 continuous drivers (175 MHz) delivering 125 mA deuteron beams at 40 MeV each, colliding with 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 a lower energy of 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. Accelerator parameters are

- 125 mA cw deuteron beam at 175 MHz (5.7 ns)
- Vacuum pipe pressure level: 10^{-5} mbar (at target region) and below 10^{-7} mbar elsewhere.

In such high current accelerator, non-interceptive diagnostics are required. This paper will focus on a Beam Transverse Profile Monitor (BTPM) based on beam residual gas ionization.

Firstly, we will present the main beam test results which were obtained using a first prototype. A new prototype was designed with respect to conclusions coming from the previous test. This will be described in a second part.

FIRST PROTOTYPE

This monitor is based on the ionization induced by the beam particles on the residual gas of the accelerator beam pipe [3] (Fig. 1). An electric field is applied between two parallel plates, on which electrons and ions are collected. A high voltage is applied to the upper plate while the lower plate is grounded. The lower plate consists of 32 conductive strips covering a 4x3 cm^2 surface. On each side of the active area 9 thin pads are set regularly in voltage in order to insure the electric field uniformity (each resistor is 60 MΩ). This monitor is fixed on a flange (DN100), which is held on the accelerator beam pipe.

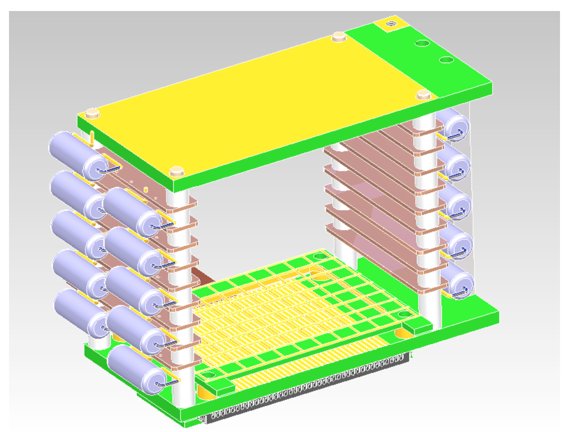

Figure 1: First prototype drawings.

Front-End Electronics

The currents induced by charges on the strips are read-out by a front-end electronic card developed in our group. The 32 channels are connected, via a kapton bus, to this card (Fig. 2).

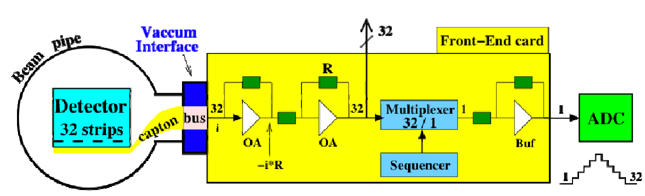

Figure 2: Front-end electronic sketch.

A transimpedance circuit converts all strip currents in voltage at 33 MHz. After the amplifiers, multiplexer and sequencer stages, a profile of the beam is given every 1060 ns.

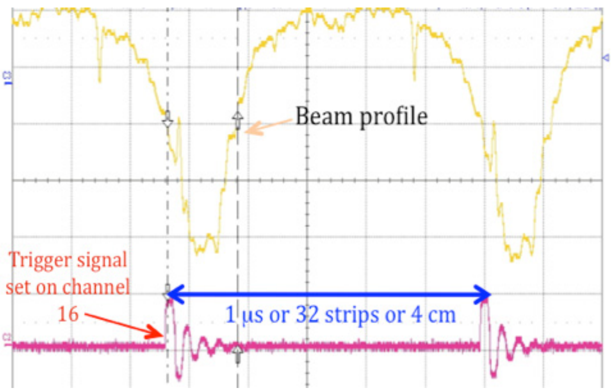

Figure 3: Beam profile seen on an oscilloscope every 1060 ns, which correspond to the 32 strips, lay out over 40 mm.

The oscilloscope picture of such a profile can be seen in Fig. 3. This card reads the strip currents with a bandwidth below 3 MHz and has a sensitivity down to 1 nA due to a high gain of 1.2 mV/nA. The equivalent input noise is around 0.8 nA.

Monitor Beam Test

This monitor was tested in July 2008 at Saclay, on the IPHI (Injector of Proton at High Intensity) source accelerator [4]. A continuous proton beam of 75 and 95 keV was delivered at beam intensity up to 12 mA for our test. Firstly we have checked that we observed an ionization signal by varying the residual gas pressure at constant beam intensity (1.2 mA). The pressure ratio is about 3.5 and this is this is good agreement with the data reported in Fig. 4 for different HV values.

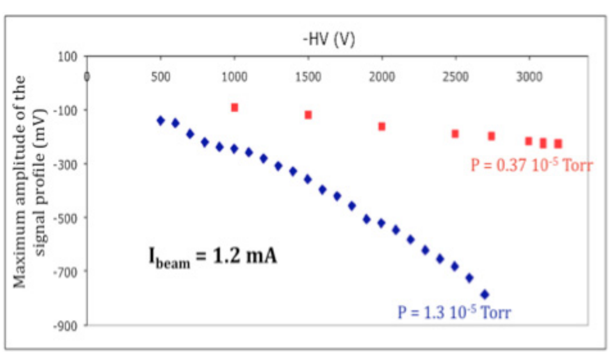

Figure 4: Maximum amplitude response for a 1.2 mA beam intensity at 2 vacuum pressures.

Extrapolating our data to IFMIF conditions at the beam dump level (I_{beam}=125 mA, E=40 MeV, P=10^{-5} mb) [5], have shown that enough signal can be picked up with such a monitor. So, no ionization amplifiers, like MCPs (Multi Channel Plates) which are radiation sensitive, are required in this hard radioactive environment (γ and neutrons). Some other lessons were withdrawn from these tests, which have been taken into account to build the second prototype.

They concern mainly:

- Electric breakdown and short cuts,
- Water-cooling system conditioned for higher beam intensity.
- Beam profile resolution,
- Good behavior of the electronic Front-end.

SECOND PROTOTYPE

The second prototype was designing taking into account these remarks. Figure 5 shows this new prototype, which is still in design progress.

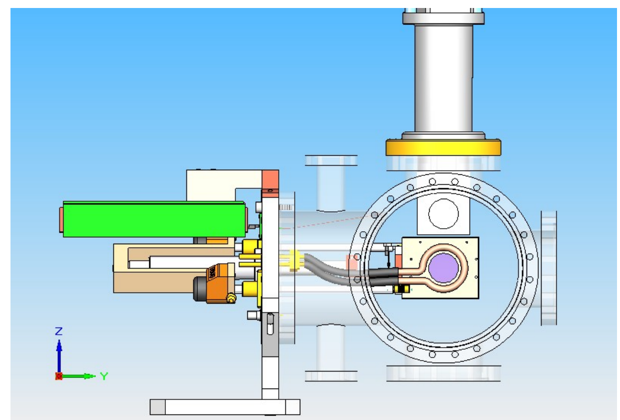

Figure 5: In horizontal, the monitor mounted on a piston, with its front-end electronic card on the left (green). In vertical, the SEM grid profiler is shown.

Improvements

The main improvements withdrawn from the first prototype test are listed below.

A cooling water system is fixed on a copper shield with an aperture to let the beam pass through it. It will allow to work at higher beam intensity.

A secondary emission grid monitor (vertical) will allow to compare profiles obtained with both monitors in same beam conditions. These monitors with a help of pistons can be moved in beam position without modifying machine conditions.

Numerous electric breakdowns appeared during the test. Ceramic will be used to avoid them. For example, two kinds of strip plane are designed: one with strips deposited on a ceramic plane, and the other one with conductive wires, welded on contacts deposited on ceramic. Plastic insulators are replaced by ceramic ones.

Electronics: only currents are measured up to now. Current integration is necessary to manage low currents encountered at high energy for which ionization cross sections decrease drastically, and to work at low beam pipe pressure.

Tests

Two campaigns of tests are foreseen with this prototype:

- On IPHI source, at the beginning of July 2009. Tests will be done at high intensity and low energy, but with an un-pulsed beam.
- At higher beam energy with a pulsed beam, in order to check the behavior of the BTPM (image current at the vacuum wall…)

During these tests, we should have to pay attention on the space charge, which play an important role on the resolution of the beam profile (due to electrons and ions trajectories).

CONCLUSION

At full current and cw beam operation, no interceptive profiler can be set in the beam of IFMIF-EVEDA. A non-interceptive transverse beam profile prototype, based on residual gas ionization, has been presented. Promising beam test results were used to improve this new prototype. It will be tested in July 2009.

REFERENCES

[1] P. Abbon et al., "Beam Transverse Profile Monitor for IFMIF-EVEDA", Bad Kreuznach; adweb.desy.de/mdi/CARE/Bad_Kreuznach/ABI_workshop_2008.html, December 11-12, 2008.
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[5] E. Surrey et al., Report for TASK EVEDA technology programme, 2007.