PROFILE-, CURRENT- AND HALO-MONITORS OF THE PROSCAN BEAM LINES

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Ionization chambers and secondary emission monitors will be used as current monitors and in a multi-strip configuration as profile monitors at the PROSCAN beam lines. A thin and thick version of these detectors are discussed as well as a 4-segment ionization chamber detecting the beam halo.

INTRODUCTION

In the PROSCAN facility (Fig. 1) a 250 MeV proton beam of 1 to 500 nA will be extracted from the COMET cyclotron. After a degrader where the energy can be adjusted in the range from 230 to 70 MeV, it can be delivered (at a maximum current of 10 nA) into one of four areas: Two gantries, an eye treatment room and a material irradiation area. Fast changes of beam energy are foreseen for the spot-scanning treatment of deep-seated tumours in the new Gantry 2. Several diagnostics will be used to control the beam parameters in different modes of operation. The first components will be taken into operation 2004.

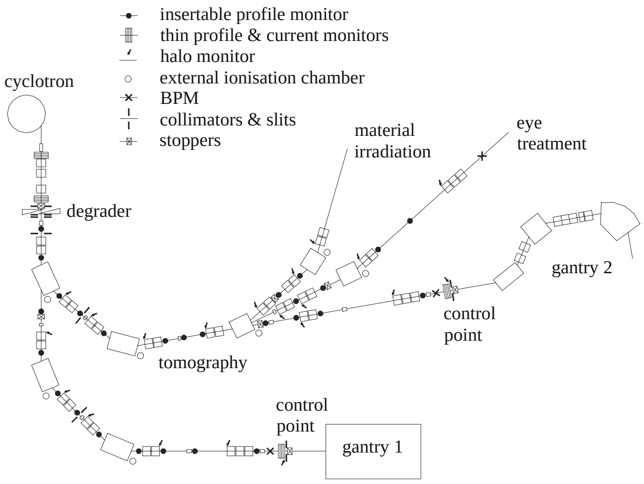

Fig. 1: Overview of beam lines.

THIN PROFILE AND CURRENT MONITORS

In front of the degrader and at the "control point" in front of the gantries, profile and current monitors are inserted permanently in the beam. (In addition, retractable monitors are available at the exit of the cyclotron.) The ratio of the currents is rapidly monitored as a safety measure. These monitors must be very thin to prevent excessive scattering of the beam.

Planar ionization chambers (IC) and multi-strip ionization chambers (MSIC) are used to obtain enough signal from the small beam currents (0.1 to 40 nA). These are formed by a stack of alternating high voltage (HV) and measurement planes made from titanium foils of 6 μm thickness. The planes are separated by a gap of only 2 mm filled with ambient air. A bias of +2 kV is applied. The high electric field counteracts the non-linearity due to recombination and reduces the charge collection time (~15 μs). For the expected beam parameters under standard operation, recombination effects should be below 5 % (calculated according to [1]). Nevertheless, with smaller beam diameters, recombination effects are dominant at higher beam currents. In order not to get signals compromised by this, the same devices are placed in vacuum and used as multi-strip secondary emission monitors (MSSEM) and current monitors (SEM) at the locations near the cyclotron and in front of the degrader. (Nevertheless, at low beam current the signal is too low for the electronics used.) Titanium is known for the stability of its secondary emission coefficient against ageing [2].

"1 broader + 30 regular + 1 broader"-strip patterns with 1 mm pitch are used for the measurement of (the projections of) the vertical and horizontal beam profiles. The dual total-current measurements used by the machine control system and by the safety system are performed with additional planes and the presence of the high voltage at the HV-planes is monitored by a separate readback.

The pre-tensioned foils (full or with the etched strip pattern) will be mounted on the supporting frames made from thick-film plated ceramic board (Fig. 2). This is done using non-conducting glue while electrical connection to the printed circuit pattern is done with small strings of conducting glue. As an alternative, soldering is under evaluation, which requires a thin sputtered silver coating of the outer parts of the foil.

The integrity of the strips can be checked by capacitively coupling a voltage pulse or AC-signal to the strip ends opposed to the read-out.

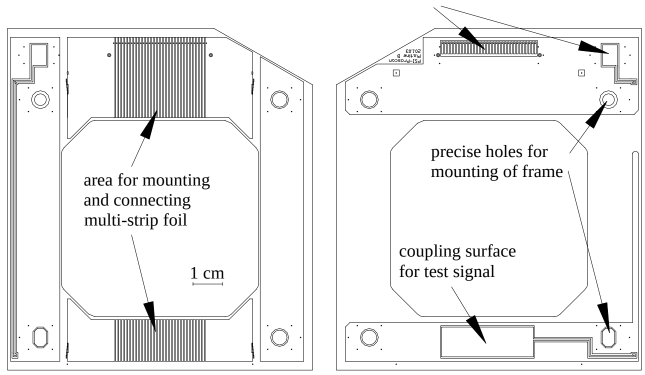

Fig. 2: Supporting frame for multi-strip foil.

The IC/MSIC measurement head is separated from the vacuum by a box with thin (35 μm) titanium windows, which are clamped between flanges.

A doubly shielded 40-wire twisted-pair cable is used to transport the signals to the electronics located some 40 meters away outside of the concrete shielding. The very low signal levels require the omission of ground loops, cables with little microphonics, good-quality cable shields, filtering of the HV at the detector and an own cable support, separate from magnet cables, AC cables and water pipes in order to reduce electro-magnetic and microphonic noise.

INSERTABLE PROFILE MONITORS

Insertable MSIC monitors, successively introduced into the beam by pressured-air actuators, yield the input information for the calculation of a beam envelope with the "Transport" code [3]. (Since these monitors are not thin, only a measurement at one location at a time is possible.) As in the case of the thin monitors, the electronics used allow for the measurement of the temporal development of a beam profile.

Metallized ceramic 0.63 mm thick boards separated by 4 mm wide air gaps provide the strip pattern and HV- electrodes. With one exception, a HV of +0.6 kV is sufficient to suppress the effect of recombination on the measured currents to below 10 % at the expected beam current densities and beam energies.

The strip pattern will be adjusted in the directions transversal to the beam to the requested accuracy of 0.1 mm to the reference given by the flange of the vacuum box.

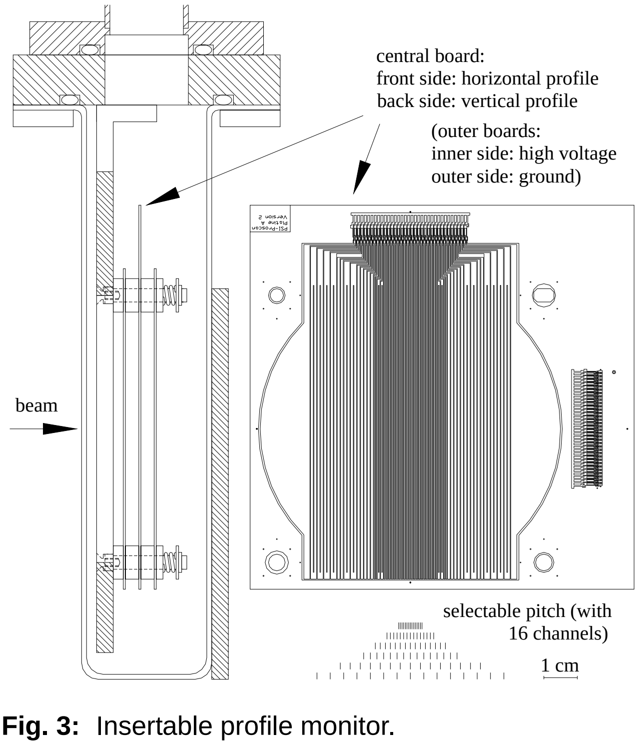

Fig. 3: Insertable profile monitor.

The pitch of the metallized strips varies from 0.5 to 1 and 2 mm (plus one broader strip at each side). 2x 68 strips are fed to the outside by flexible-printed-circuit cables.

With two exchangeable printed circuit boards placed in an electrically shielded box at the top of the profile-monitor feed-through the signals are routed to the 2x 16 channels of the electronics. With this arrangement, a strip pitch of 0.5, 1, 1.5, 2, 3 or 4 mm can be chosen for a "1 broader + 14 regular + 1 broader"-strip arrangement in each plane. This variability allows for the adaptation of the strip pitch to the expected range of beam profile width. This is required due to the limited number of only 16 channels per plane that is foreseen for most of the monitors. Simulations [4] indicate that for 16 channels beam position and width can be measured accurately if the FWHM beam width is in the range 1x to 10x strip pitch and the profile is of conventional shape. A pattern with varying strip pitch can also be chosen to further enlarge the range of possible beam profile width of a fixed configuration.

At three successive locations, a higher resolution is foreseen for beam tomography. A "1 broader + 30 regular + 1 broader"-strip arrangement in each plane will be realized by doubling the number of cables and electronic modules. At these locations, the available strip pitch is 0.5, 1 or 2 mm.

HALO MONITORS

"Halo-monitors" are placed around modified bellows adjacent to the quadrupole doublets and triplets (Fig. 4). These 4-segment ionization chambers, which protrude circumferentially 5 mm into the beam pipe of 90 mm diameter, give enough signal to detect traversing beam current fractions of below 1 pA. This provides a much more sensitive loss control than the external ionization chambers located near the dipole magnets and should also give an online control of the stability of the beam settings.

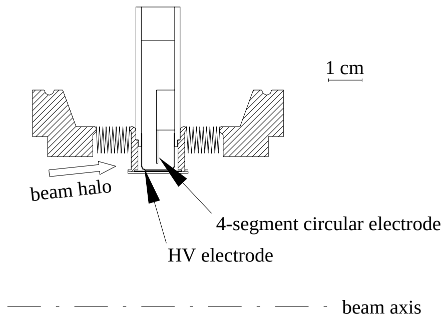

Fig. 4: Halo monitor.

REFERENCES

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[3] http://people.web.psi.ch/rohrer_u/trans.htm

[4] R. Dölling, *Auswertung von MSIC-Messungen und Einfluss der Streifenzahl auf die Genauigkeit von Profilschwerpunkt und -breite*, PROSCAN-document P24/DR84-305.0.