CLOSING PLENARY SUMMARY OF WORKING GROUP F DIAGNOSTICS AND INSTRUMENTATION FOR HIGH-INTENSITY BEAMS*

M.Wendt#, Fermilab, Batavia, IL 60510, U.S.A.
T. Toyama, KEK, Ibaraki, Japan

Abstract

Summary of the working group F activities, presented in the closing plenary session.

OVERVIEW

Working group F was charged with presentations and discussions on diagnostics and instrumentation of high-intensity beams. We had 2 sessions spanning a total time of 3-½ hours, in which 10 talks were presented. The presentation time for each talk had to be limited to 15-20 min., in order to allow sufficient time (5-10 min.) for some discussion. This procedure went quite well, thanks to the discipline of the speakers.

A final 1 hour discussion was held as joint session with working group E (simulations).

PRESENTATIONS

Except for the last one, all presentations of working group F were focused on a specific beam instrument, most on the technology beam profile measurements:

Y. Hashimoto: **Profile Monitor Using a Carbon Graphite Foil for the J-PARC**

Yoshinori presented a minimum invasive beam profile SEM, based on a new graphite foil technology. The 1.6-2.0 μm thick, self supporting target material offers a low density (Z = 6), and was tested extensively with various proton and heavy ion beams. While the foil survived a total dose of >5x10^{20} protons (500 MeV) with a spot size of 45x15 mm^2, it broke after 1 hour operation on a 3.2 MeV, 3 μA Ne^+ beam of 8 mm^2 spot size due to overheating (1400^0 C). Seven monitors have been build, using a laser cutting method to from a pattern of 67 foil strips, 3 mm wide at 4.5 mm pitch (also tested: 1 mm width, 2 mm pitch), epoxy glued into the 190x310 mm opening of a Al_2O_3 ceramic frame. A 32 channel analog integrator with ~30 μsec time constant interfaces the signals of the SEM foil strips through a 10-bit ADC to a CAMAC system into the J-PARC EPICS control system. Beam halo (transverse tails) could be characterized by increasing the gain of these channels by a factor 2000.

M. Hori: **Time-resolved SEM Monitor with large Dynamic Range for R&D of Linac 4**

The CERN Linac 4 will operate with a chopped beam pattern, which gave the motivation for the development of a profile monitor with high time resolution. Masaki preferred a robust, reliable "classical" technology for this important monitor: SEM in connection with gated HV grids. He presented many details on precision mechanics for the different wire and foil technologies required for various grids, i.e. SEM target and five acceleration HV grids. The avalanche diode switched HV supplies requires matched impedance RF transmission lines, a UV laser test demonstrates HV rise/fall times of ~200 psec. Performance tests and optimization were made at the Orsay proton linac, as well as with a 700 psec Nd:YAG laser system. A spatial resolution of ≤2 mm, and a time resolution ≤1 nsec could be demonstrated, the linear dynamic range covers 5 to 5x10^8 secondary electrons.

W. Blokland: **Non-Invasive Beam Profile Measurements using and Electron-Beam Scanner**

In collaboration between the Budker Institute and ORNL a novel electron-beam scanner was developed, to perform non-invasive beam profile measurements at the SNS proton accumulator ring. Wim introduced the measurement principle of a low-energy (typically 60 keV) electron beam, scanned under 45^0 through the proton beam, measuring the proton beam profile as reconstructed image of the deflected electrons. Layout, technical details and simulations of the system were presented, as well as many measurements with the two installed scanners (horizontal and vertical) at the SNS proton ring. Wim explained the importance of data fitting algorithms and calibration procedures to improve the measurement performance. The 20 nsec deflection sweep of the electron beam is fast compared to the ~1 μsec proton bunch length and allows time-sliced profile measurements. Other topics discussed in this presentation were the influence (rejection) of external magnetic fields, as well as comparing performance and accuracy of the electron-beam scanner profile measurement to harp wire monitors.

P.-A. Duperrex: **Beam Current & Transmission Measurement Challenges for High Intensity Beams**

The operation of the proton accelerator complex at PSI relies on the precise monitoring of beam currents and transmission, e.g. towards the target area. Pierre-Andre discussed the development of a quarter-wave coaxial resonator, and its application as current transmission monitor, required to replace an out-of-order unit in a high radiation, difficult to access area. While the coaxial cavity resonator, here operated at the 2nd harmonic of the proton bunch frequency is a simple, rugged device, its temperature sensitivity was known. Nevertheless, the new MHC5 replacement unit had some issues due to the drift

* This work was supported by Fermi National Accelerator Laboratory, operated by Fermi Research Alliance, LLC under contract No. DE-AC02-07CH11359 with the United States Department of Energy
#manfred@fnal.gov

of its resonance frequency with temperature, and Pierre-Andre performed some in-depth analysis, including computations of EM fields and temperature distributions. After water cooling optimizations, the residual uncertainty of the transfer function of the resonator was compensated by a new pilot signal schema, which was presented in great detail. Pierre-Andre summarized his session with the results of beam studies in 2010, demonstrating a very well performing current transmission monitoring, despite temperature variations of the coaxial resonator beam detector.

E. B. Holzer: **Commissioning and Optimization of the LHC BLM System**

The beam loss monitoring (BLM) system, with ~3600 ion chambers and ~300 SEM detectors, is crucial for the safe operation of the LHC, as the stored beams have a high damage potential. Eva gave an overview of the system in terms of concept and layout, including details on BLM families, thresholds, integration times, etc, she also discussed the operational protection strategy for the LHC. She pointed to the rigorous validation test and system commissioning procedures, which are mandatory for a seamless, false-free operation of the BLM system. On the operational aspects Eva remarked, that none of the 24 beam losses so far was missed by the BLM system, also no avoidable quench passed the BLM protection. However, some very few hardware failures needed maintenance, and the noise levels at some detectors are higher than anticipated due to very long cable runs. The operational experience during the 2010 run let to a few modifications to accommodate very high, as well as distributed losses. Finally Eva presented recent observations of fast losses (UFOs) in the LHC, which need to be studied in detail as their loss mechanism is unknown.

C. Gabor: **Status Report of the RAL Photo-Detachment Beam Profile Monitor**

The laser-based photo-detachment of the loose bound second electron of the H^- particles is an elegant, non-invasive method for profile measurements of H^- beams. Christoph presented the application of this technology in the low energy section, at 70 keV – upstream the LEBT, of the Front End Test Stand R&D project at RAL. He explained the details of the integrated design of separator magnet and electron collector, i.e. a *Faraday* cup to detect the detached electrons, which needs to be compact to minimize a blow-up of the passing H^- beam. The operational experience demonstrated the proof of principle, but also identified issues caused by background noise signals from secondaries and ion beam instabilities. By scanning grid, bias, and suppression ring voltages empirically, a setting with acceptable ratio of photo-detached electrons to background noise could be found. Christoph summarized that this technique needs more R&D, including a redesign of the electron detector to minimize the interference with the H^- beam, to enable the final goals, i.e. tomography and emittance measurements in 2D and 4 D phase space.

P. Forck: **Beam Induced Fluorescence Monitor Developments at the GSI Heavy Ion Facility**

Peter presented development and operational experience of a gas beam profile monitor for the GSI UNILAC heavy ion linac. Locally N_2 fluorescence gas is injected, which generates photons when passed by an ion beam. The read-out system utilizes an optical system which includes a double MCP (gain: 10^6), a P46 phosphor screen, a fiber-optics bundle and image intensified CCD cameras (ICCD). Peter showed many results, using different ion beam species, beam energies, and gas pressures, which demonstrated the measurement robustness, even when the N^2 pressure is varied substantially (over 6 orders of magnitude). Peter also discussed the characteristics of other rare gases which could be used instead of N_2 for this application. He finalized his presentation with some details on an alternative read-out, i.e. an electron multiplication CCD (emCCD), which offers a five times better spatial resolution and lower background noise.

J. M. Carmona: **First Measurements on Non Interceptive Beam Profile Prototypes for Mid-High Intensity Hadron Accelerators**

Another gas fluorescence beam profile monitor was discussed in WG-F, this one was presented by Jose Miguel, and will be applied at the IFMIF-EVEDA deuteron accelerator. Main technical differences to the GSI version are in the photon read-out system, Jose experimented with an intensified rad-hard CID camera (prototype 1), as well as with a multi-anode PMT (prototype 2), and so he could omit the use of a fiber-optics bundle for radiation shielding. He presented the evaluation with beams of both prototypes, as well as comparisons with a wire scanner at the Centro Nacional de Acceleradores CNA Seville/Spain. Som ten μA beam current was used, at a beam energy of 9 MeV for deuterons, respectively 18 MeV for protons, simulating IFMIF-EVEDA conditions. A very good agreement was demonstrated between the three profile monitors, the dynamic range fulfills the requirements, some minor pros and cons could be worked out between ICID and PMT read-out.

K. Satou: **IPM Systems for J-PARC RCS and MR**

The concept of the J-PARC ionization profile monitor (IPM) was already presented in the Main Ring (MR) diagnostics talk, given at the HB2008. Now Kenichirou gave many technical details, including read-out electronics, operating modes and the specifications for the IPMs to be applied to the J-PARC rapid-cycling synchrotron (RCS) and MR. The IPM has a turn-by-turn capability and uses an integrated electron generator array (EGA) for self-calibration to check for aging effects of the MCP. E and B guide field are generated by an array of equidistant electrodes and a 3-pole wiggler magnet. A

beam based calibration, however, identified a substantial discrepancy between measured IPM beam profiles, and the expected values by a factor of two! Kerichirou discussed a recovery plan, based on a new layout of the E guide field electrodes to achieve a linear field distribution. He also discussed another issue, a large, delayed negative charge (error) signal. It was observed in electron collection mode at the MR-IPM, and may be caused by an unwanted electron emission of the EGA, or electrons attracted outside the IPM by some fringe fields. In his summary, Kerichirou pointed to the fact, that the J-PARC IPMs need some additional R&D.

M. Wendt: **Beam Instrumentation for High-Intensity, Multi-GeV Superconducting Linacs**

Several new high-intensity, high-energy linacs are proposed, most based on superconducting RF (SCRF) acceleration, similar to the operational SNS linac. This presentation discusses requirements and issues of beam diagnostics related to a SCRF environment, e.g. low power losses, cleanliness, non-invasive diagnostics, avoid moving parts, etc. Presenting Fermilab's Project X as an example, the beam instrumentation R&D activities are discussed in frame of the beam test facilities, currently under construction at Fermilab. Technical details on some instruments are given, e.g. bunch shape monitor, fast Faraday cup, beam halo monitor, proposed laser diagnostics, etc., as well as first beam studies at the Project X test accelerator.

DISCUSSIONS

Together with working group E (simulations) we had a discussion session, which was initiated by a presentation from SNS:

A. Aleksandrov: **Challenges of Reconciling Theoretical and Measured Beam Parameters at the SNS Accelerator Facility**

After a short introduction to SNS, Sasha discussed beam simulation tools for the design stage and for modeling an existing machine. He presented an informal, but very impressive table, summarizing the agreement, i.e. not so good (bad!), good, very good, or "no clue", between simulation and beam measurement in SNS accelerator areas, e.g. RFQ, MEBT, DTL, etc. and beam domains, e.g. transverse, longitudinal, halo, etc. In his following discussion he presented many examples, comparing real world measurements with simulating the existing machine.

The following discussion went quickly into the direction of simulation tools. As Sasha pointed out, most of these tools have limited scope, even if a broadband, universal utilization is advertised. Another important topic was on the accuracy of field models for magnets, cavities, etc. needed by the simulation tools. With respect to beam diagnostics, everyone agreed, more is better, as long as the beam quality is not compromised, which can be challenging in low-energy, space charge driven machine areas (LEBT, MEBT).

CONCLUSION

We had presentations of state-of-the-art monitors in the invited talks, including some new technologies. Improvements, challenges, but also wrong directions in beam diagnostic devices were discussed in the contributed talks. As in past workshops, the direction goes to minimum or non-invasive techniques for beam profile measurements, which seem to be the most important, while challenging R&D activity.