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

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Abstract

Summary of 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 3 sessions spanning a total time of 330 minutes, in which 13 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 turned out quite well, even though some presentations went longer, not every topic required the anticipated discussion time.

A final discussion session of 110 minutes was held as joint session with working group D (operations).

PRESENTATIONS

The presentations of working group F can be split into three categories:

Overview of Beam Instrumentation at a Facility

In these presentations the speakers gave an overview with some details on the various beam instrumentation and diagnostics systems at their beam facility. The discussion was focused on very specific issues.

S. Assadi: **Overview of Beam Instrumentation for High-Power Operation of the Spallation Neutron Source**

Saeed gave a very brief overview of the SNS facility and the various intercepting and non-intercepting beam instrumentation. He discussed in detail the laser wire H^- beam profile monitoring systems, starting from the principle of operation to the real-world practical problems, e.g., alignment issues, stray effects of guide field magnets, laser beam waist control, etc. The presentation was supplemented by many beam study and measurement results. Finally a new, non-invasive electron beam profile monitor project was presented, intended to characterize the transverse proton beam profile in the accumulator ring.

M. Wendt: **Beam Instrumentation for Future High-Intensity Hadron Accelerators at Fermilab**

Several new beam facilities for high energy physics are planned at Fermilab, the most dominant being Project X, which includes an 8 GeV SCRF H^- linac, delivering high-intensity beams to support neutrino physics with >2 MW beam power at 120 GeV. The presentation summarized current beam diagnostics activities at Fermilab for beam profile and loss monitoring, and, with a few examples, gave an impression of the challenges ahead.

J. Pozimski: **Beam Diagnostics at the RAL Front-End Test Stand – First Results and New Ideas**

The presentation of Juergen was focused on transverse beam profile and emittance measurement methods, to be applied to the front-end test stand project at RAL. He compared results of a new pepper pot to a slit-slit scanner, which led to a significant improvement in the understanding of the beam dynamics in the LEBT. Furthermore, the activities on laser detachment beam profile measurements were presented, including a rotatable system for full 2D tomography. Finally an emittance reconstruction algorithm from several beam profile measurements based on a maximum entropy method was discussed.

I. Podadera-Alesida: **HEBT Diagnostics for Commissioning, Control and Characterization of the IFMIF-EVEDA**

The new International Fusion Material Irradiation Facility (IFMIF) was presented with respect to requirements and challenges to the beam instrumentation in the HEBT. This beam facility is envisioned to test materials for future, post ITER, fusion reactors, and will be located at Rokkasho, Japan. Two 10 MW deuteron beam accelerators, each supplying 250 mA beam current at a beam energy of 40 MeV are focused on a target to produce the neutron flux for the material irradiation. Beam orbit control, beam loss monitoring and related MPS issues, as well as the monitoring of a 20x5 cm transverse beam profile of flat particle distributions were discussed.

S. Payne: **Beam Diagnostics at ISIS**

After a short introduction to the ISIS beam facility, Steve explained a serious beam steering problem, not observed by the standard beam loss monitors, resulting in a hole burned by the high intensity beam in one of the dipole vacuum chambers. For the investigation a set of scintillators and PMTs were mounted to allow an installation between the chamber and magnet core to observe the local beam losses. In this way the problem could be identified and resolved by improving the beam trajectory. Lots of discussion was raised by the repetitive failure of commercial data acquisition hardware (NI PXI crate), which is located in the center of the accelerator, outside the radiation shielding. It turned out to be a hard disk error, probably due to neutron exposure. Using a

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different disk reduced the trip rate substantially, but did not eliminate it completely. Other topics presented were on IPMs, electron cloud investigation, and a stripper foil beam monitor.

K. Satou: **Beam Diagnostic System of the Main Ring Synchrotron of J-PARC**

An introduction to J-PARC and its Main Ring Synchrotron was followed by an overview of the beam instrumentation and the related requirements to characterize the beam properties. Details on the beam position, current, loss, tune, and profile monitors were presented. Beam loss monitoring and machine protection is crucial at 1 MW of beam power. When operating at 50 GeV only 0.1 % of beam losses are tolerable (equivalent to 0.5 W/m). BPMs are based on the typical electrostatic electrodes, however to extend the low frequency response a signal transformer (ratio 2:15) is applied. Beam profile monitoring is realized by Flying Wires, Multiwires and IPMs. The IPMs include an electron generator to calibrate the MCP, also a multi-MCP IPM was developed to characterize beam halo.

Presentation of a Specific Beam Instrument or Diagnostics Method

These presentations were focused on a specific beam instrumentation system or analysis method. More details could be presented, often in connection with in-depth beam studies.

C. Allen: **Extracting Information Content within Noisy, Sampled Profile Data from Charged Particle Beams**

Christopher gave a short introduction into the 1D projection of profile data, measured by a wire scanning method. He presented the goal to extract two representative values from the measured data points, i.e., beam position μ, and size σ, assuming a Gaussian particle distribution. In presence of noisy or sometime unreliable data he discussed different techniques to fit the data. Problems rise in cases of extremely noisy source data, but also in the presence of beam halo, i.e., non-Gaussian beam characteristics.

T. Toyama: **Beam Loss Monitoring Using Proportional Counters at J-PARC**

The use of proportional counters for beam loss monitoring at J-PARC is based on the experience at the KEK proton synchrotron. Several improvements on the apparatus were presented, including a different gas type (Ar 99 %, CO_2 1 %), and an improved calibration procedure. Details on the read-out electronics, as well as results from radiation and beam tests were presented. These beam loss detectors promises a fast response time (~100 ns) and high dynamic range, however, an observed saturation problem needs to be further investigated.

A. Zhukov: **SNS Beam Loss Monitor System Overview: Detectors, Measurements, Simulations**

In a short introduction, the requirements of beam loss monitoring at SNS were outlined. Various types of loss detectors are in operation, i.e., ion chambers are used at most locations, as well as two different kind of neutron detectors, and a scintillator / PMT detector combination for use at low beam energy (<20 MeV) locations. In the latter case, one of the challenges appeared to be a background signal due to cavity X-rays, which could be resolved by waveform subtraction in the signal processing. Other topics in the presentation were EMI interference problems in the detector signals, beam halo studies, decay time of the activation, read-out electronics, software, and beam-line simulations.

T. Gorlov: **Computation of Space-Charge Effect in Allison Scanner and its Application to the Measurement of Emittance**

Details of the SNS LEBT were presented, followed by an introduction to the Allison scanner apparatus to measure beam position and divergence, i.e., the beam emittance. Simulations of the response of the scanner to a beam, computed with and without space charge effects, were discussed, resulting in a reconstruction algorithm to compute the true emittance. The method needs to be expanded to non-Gaussian beam distributions, and the simulations have to be confirmed by beam measurements.

C. Deibele: **Status and Implementation of Wideband Feedback System for e-p Instabilities in Long Proton Bunch Machines**

First, Craig presented the motivation for this transverse feedback system, showing a fast rising electron cloud instability, observed in the SNS accumulator ring at bunch charges >5 μC. He presented many details on individual components of the system, e.g., stripline beam pickups and kickers, power amplifiers, digital signal processing, etc. He pointed out the need for a flat open loop frequency response (1-300 MHz) in magnitude and phase, as well as the demands of high power amplification (400 W). Many details on the digital signal processing were presented, as well as first preliminary measurement results on the bench. However, an analog based system will be commissioned prior to this final digital system being put into operation.

Operational Aspects of Beam Instrumentation

Operational aspects with respect to beam control and day-to-day operation were discussed in two presentations from Fermilab accelerators, the Booster synchrotron and the NuMI high-intensity beam-line.

B. Pellico: **Fermilab Booster Diagnostics, Monitors and Software for Operation Control of Residual Radiation**

Bill gave a comprehensive introduction to the Fermilab Booster synchrotron, starting with a little history, up to the present operation. He outlined all the beam diagnostics systems involved, and the need for web-based access to the beam measurements to achieve a high up-time of the accelerator. Activation and the control of beam losses is one of the most demanding issues for a high-intensity machine operating for more than 30 years. The presentation was completed with many examples of instrumentation systems, beam studies and measurements,

data visualization software, and an outlook to upcoming diagnostics projects.

***S. Childress:* Beam Diagnostics Required to Safely Transport and Target a 2-MW, 120-GeV Proton Beam**

Sam introduced the topic with the current operation of the NuMI beam-line, designed for up to 400 kW of beam power. He outlined the very complex beam permit system, which monitors about 250 parameters, and the need for superb beam loss control. Details of various beam instruments were presented, along with measurement results and beam studies. In the final slides Sam summarized the need to upgrade and improve beam instrumentation systems to allow operation at much higher beam power.

DISCUSSIONS

Apart from the discussions within or just after each of the presentations, a formal joint discussion session with working group D (operations) was held on Thursday. Some of the discussed topics were:

- Recording of radiation
  - Compare BLMs and TLDs
- Beam loss monitoring
  - BLM coverage
  - Compare BLMs and power losses
  - Calibrate BPMs with tiny beam under controlled, forced beam loss conditions
  - Monitoring of the beam on the target
- Beam halo
  - IPMs (J-PARC) with dedicated MCPs for beam core and tails, 10^{-4} sensitivity
  - Crawling wire and BLM
  - Crystal collimator (bending, reflection of beam halo)
  - BLM calibration using tin multiwires in the 10^{-6} – 10^{-7} regime
- Longitudinal bunch distribution and phase space measurements
  - Wire-based electron stripping arrival time measurement
  - Laser-based photo detachment and sampling
- Beam gap monitoring with high resolution (10^{-9}), e.g., beam gap extraction to a BLM
- Long term stability of BPM data (automatic calibration and gain correction system)

CONCLUSION

Many new techniques and technologies to monitor high-intensity beams were presented and discussed. “Hot” topics were:

- Beam loss monitoring and machine protection
- Transverse beam profile measurements and emittance characterization
- Novel, non-invasive beam monitoring methods, e.g., IPM, H^- laser wire, e-beam profile monitor.
- Measurement of transverse and longitudinal beam halo /tails.

Bottom line, state-of-the-art beam instrumentation systems are crucial to successfully operate high-intensity beam facilities in a safe and reliable manner!

We thank all the speakers and contributors of working group F!