BEAM DIAGNOSTICS, COLLIMATION, INJECTION/EXTRACTION, TARGETRY, ACCIDENTS AND COMMISSIONING: WORKING GROUP C&G SUMMARY REPORT

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INTRODUCTION

The performance of accelerators with high beam power or high stored beam energy is strongly dependent on the way the beam is handled, how beam parameters are measured and how the machine is commissioned. Two corresponding working groups have been organized for the Workshop: group C "Beam diagnostics, collimation, injection/extraction and targetry" and group G "Commissioning strategies and procedures". It has been realized that the issues to be discussed in these groups are interlaced with the participants involved and interested in the above topics, with an extremely important subject of beam-induced accidents as additional topic. Therefore, we have decided to combine the group sessions as well as this summary report. Status, performance and outstanding issues of each the topic are described in the sections below, with additional observations and proposals by the joint group at the end.

BEAM INSTRUMENTATION AND DIAGNOSTICS

Successful commissioning and efficient operation of an accelerator are clearly related to reliable and trustful beam instrumentation and diagnostic. Besides general instruments like beam position monitors and beam current monitors, high intensity accelerators need dedicated diagnostics for this special purpose. This typically includes beam profile monitors with the emphasis on halo measurements as well as beam loss monitors (BLM) for machine protection. Comprehensive descriptions of PSI, SNS, HERA and LHC BLM and protection systems were discussed during our joined sessions.

An overview of a complete set of instruments for the J-PARC accelerator complex was given by N. Hayashi (J-PARC), illustrating the complex needs of diagnostic instruments in the different stages of a high intensity accelerator chain:

Beam Position Monitor (BPM)

- normal BPMs in Main Ring: 186 shoebox type with large diameter, 130 - 377 mm;
- 324-MHz BPM: sensitivity at Linac frequency, useful for painting studies.

Beam Current Monitor

- DCCT: Bergoz type, frequency range DC to 10 kHz, dynamic range 150 mA-15 A;
- beam current transformers SCT, MCT (0.5-ms injection process monitor), and FCT (RF feedback control);
- wall current monitor for RF feed-forward control;

Profile Monitor

- multi-wire: destructive monitor, used for commissioning (single pass) beam;
- Ionization Profile Monitor (IPM): extended high gain MCPs in halo region of beam;
- Gas Sheet Profile Monitor;
- Beam Loss Monitor (BLM): Main Ring > 300
- scintillator+PMT: fast response; but degraded with large loss, radiation damage;
- proportional chamber type: Ar+CO2(1%);
- air-filled ionization chamber: slow response (~1msec); stable.

Others

- quadrupole pickup monitor: successful tests at KEK-PS with 4 electrode pick-up;
- wire scanner: rotating flying wire at KEK-PS, speed of 20 m/s to survive in high-intensity beam;
- SEM grids: installed at beam transfer and injection/extraction lines, little destructive, has to survive high level radiation, still looking for good wire material;
- Coherent Tune Monitor: conventional; exciter system: a pair of stripline electrodes; dedicated BPM: quad parallel electrodes.

A typical problem of high-intensity accelerators is the high dynamic range. The instruments must work with low-intensity beams during commissioning as well as for high intensity. Especially the transversal beam profile monitors require a very high dynamic range when using for transversal beam halo measurements. An overview was given by K.Wittenburg (DESY) about recent non-destructive beam profile and halo monitors with the focus on the dynamic range. The techniques used for transverse and longitudinal halo measurements are as follows.

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Transversal Halo:

- Wire scanners, still "state-of-the-art" instruments for very high dynamic range up to 10^8. Different successful readouts: logarithmic amplifiers, counting schemes with telescope detectors or the "vibrating-wire" technique.
- Synchrotron Radiation (SR) with coronagraph has potential (dynamic range 10^6 to 10^7), but limited to high-energy beams (HERA, LHC and Tevatron).
- IPM and LPM sufficient for profiles but with some background issues for halo. Dynamic range $\approx 10^3$. A new idea to overcome this limitation is under development at J-PARC.
- Laser-based profile monitor works well for H^- beams at SNS. Also suitable for bunch length measurement. Dynamic range $\approx 10^3$.
- Electron beam technique (E-Probe) for profile determination still under development. Not intended for beam halo measurements so far. Dynamic range $< 10^2$.

Longitudinal Halo ("Beam-in-Gap"):

- SR with high potential, but limited to high energy.
- Temporal beam loss distribution measurements are very sensitive but applicable in transversal halo only, therefore with larger uncertainty.
- Extended IPM for bunch length measurement still under development (GSI), but useful for all energies and all hadron beams. Might also be useful for Beam in Gap studies?

An Optical Transition Radiation (OTR) detector for beam profile monitoring of intense proton and antiproton beams at Fermilab was presented by Vic Scarpine (FNAL). Thin foils were used to minimize beam scattering since OTR is a surface phenomenon. Commercial imaging technologies, especially radiation-hardened CID cameras were used to acquire the beam information. OTR has the advantage that the image can provide 2-D information on various parameters like: transverse profile and shape (tilt), transverse position, emittance, intensity, divergence, energy, and even 3-D information like bunch length and longitudinal profiles. Initial prototype measurements indicate that OTR detectors can be suitable profile monitors for powerful beams, although more studies of foil damaging are still necessary.

A very detailed study of the correction of unevenness in Recycler longitudinal beam profile was presented by K.Y. Ng (FNAL). The sources of the uneven profile were identified by RF voltage imperfection and beam loading of just a few volts. A compensation of the unevenness of the beam profile has been successfully performed and an automation of the compensation procedure has been designed and is being built, hoping that the compensation could be performed in the future just by pushing a button.

Philippe Legou (Saclay) gave a description of a new high-rate charged particle detector which is used as a beam spectrometer for the NA48II experiment. It measures precisely the kinematics characteristics of particles at a rate of 20 MHz with minimum amount of material in the beam. The performance of this detector is very good and no damage after two years of running was observed even at that high repetition rate with a very low cost realization (printed circuit board technology).

During our discussion sessions we focused on two topics, namely:

Which systems are most important for initial commissioning?

- At SNS: BPMs, Current Monitor, Loss Monitors.
- Screens or harps in Linacs and transport lines.
- BPMs in intensity mode useful for first turn(s) threading.

How does one "guarantee" working diagnostic systems on day one?

- Tests in advance, dry runs with all triggers and test signals + software.
- SNS: Used dry runs; after that, 2 beam shots proofed that all instruments are working.

BEAM COLLIMATION AND TARGETRY

High-power machines tend to be limited by beam losses, not by current limitations. It is a mandatory nowadays at high-power accelerators and high-energy colliders to concentrate beam losses at a few locations with collimators. Nikolai Mokhov (FNAL) gave an introductory talk on the subject "High-intensity beam collimation and targetry". The purpose of a collimation system is to protect components against excessive irradiation, minimize backgrounds in the experiments, maintain operational reliability over the life of the machine (quench stability among other things), provide acceptable hands-on maintenance conditions and reduce the impact of radiation on environment. Both normal operation and accidental conditions (abort kicker prefire etc.) have to be considered.

Practically all the collimation systems these days are two-stage ones. For each plane, they consist of a primary *thin scattering target*, followed by a few *secondary collimators* (scrapers) at the appropriate phase advances in the lattice. The purpose of a thin target is to increase the amplitude of the betatron oscillations of the halo particles and thus to increase their impact parameter on the scraper face on the next turns. This results in a significant decrease of the outscattered proton yield, total beam loss in the accelerator and scraper jaws overheating, as well as in mitigating requirements to scraper alignment. Besides that, the scraper efficiency becomes almost independent of accelerator tuning, there is only one significant but totally controllable restriction of accelerator aperture and only the scraper region needs heavy shielding and a dogleg structure. The system is built with corresponding design and engineering constraints in mind, satisfying appropriate radiation limits. Performance of the existing systems is quite impressive, in agreement with results of detailed sophisticated simulations, including recent achievements at the Tevatron with bent crystal collimation. Another novel approach is to use marble as a collimator shielding outer shell to substantially reduce residual activation.

Stefano Redaelli (CERN) considered in his talk “The LHC beam collimation” how the multi-stage halo cleaning system is designed, prototyped and built to deal with a 350-MJ 7-TeV proton beam. The system occupies two out of eight warm insertions for momentum (IR3) and betatron (IR7) cleaning, with local cleaning upstream of the interaction regions. It consists of one hundred collimators (primary, secondary, shower absorbers, tertiary, etc) with 500 degrees of freedom total. The proposed robust collimation system (Phase-I) can’t achieve the nominal beam intensity because of reduced efficiency and large impedance (small gaps, large resistivity are expected to lead to beam instabilities). R&D is underway on high-Z collimator materials for the Phase-II system.

Brennan Goddard (CERN) in his talk “Safe disposal of the LHC beams by extraction onto the beam dumping blocks” described a sophisticated system to protect the LHC machine, including unsynchronized beam aborts. Eva Barbara Holzer and Stefano Redaelli (CERN) discussed LHC BLM and collimation system commissioning (see section below).

For the collimation systems to be efficient, one needs good orbit control (automatic feedback) – to define loss locations. BLMs are as important as BPMs. It is a modern approach for accelerator complexes like LHC and J-PARC to build a realistic model of the machine for multi-turn beam loss, energy deposition and activation studies: read in MAD lattice, create complete geometry and magnetic field model with modern FLUKA / MARS / GEANT. The experience says it takes time and substantial efforts but always pays off.

The most important targetry issues - aimed at design of high-efficiency target systems and achieving their best performance – have been considered in Nikolai’s talk described at the beginning of this section. Current R&D on the neutrino experiment graphite targets and neutrino factory mercury jet targets was described. Nikolai gave also a talk on behalf of Nick Simos (BNL) “Experimental studies of targets and collimators for high-intensity beams”. Impressive results of beam tests with collimator and target materials were presented, including recent findings of self-annealing in 2D carbon-carbon composites for LHC collimators. Features of a “dream material” were described to get us to multi-MW beam power levels:

- low elasticity modulus;
- low thermal expansion;
- high heat capacity;
- good diffusivity to move heat away from hot spots;
- high strength;
- resilience to shock/fracture strength;
- resilience to irradiation damage.

Alexander Ryazanov (RRC) described “Shock wave propagation near 7-TeV proton beam in LHC collimation materials”.

INJECTION/EXTRACTION

Beam loss for injection and extraction of the synchrotron ring is a crucial part for a high-intensity proton machine. M. Tomizawa (KEK) reviewed the beam loss mechanisms related to linac-to-ring injection, ring-to-ring injection, one-turn extraction and slow extraction by showing the J-PARC as an example. Beam loss performance of injection/extraction obtained by the existing machines was discussed in the working session. The fraction of proton beam lost at slow extraction from existing machines (KEK PS, CERN PS and SPS, BNL AGS and FNAL MI) ranges from 1 to 20% that corresponds to beam loss power of 0.4 to 3 kW. The design goal for J-PARC is 0.25% beam loss or 2 kW of beam loss power.

M. Giovannozzi (CERN) presented the design and tests results of a novel multi-turn ejection from the CERN PS to the SPS. This extraction technique enables to transfer from the PS to the SPS with beam loss smaller than the present scheme.

The loss rates at H^- injection were discussed. Development of long-lived charge exchange foils is one of the key issues for high-intensity beam injection into proton rings. I. Sugai (KEK) showed performance of the HBC foil (hybrid type thick boron doped carbon foil), which has been developed by himself. They examined life time of HBC foils with thickness of 200-380 $\mu g/cm^2$ by using 3.3 MeV, 3 μA-Ne beam. Maximum life time achieved was 9800 mC/cm^2, which is roughly 400 times longer than commercially available foils. Less shrinkage due to beam irradiation was also observed. The beam test using 700 keV H^- is underway. T. Spickermann (LANL) reported results of beam tests of nanocrystalline DIAMOND foil which is being used for the PSR charge injection. A 450 $\mu g/cm^2$ thick nanocrystalline endured beam irradiation comparable with life time of LANL foils. Lifetime tests of the nanocrystalline DIAMOND foils are continued.

M. Shirakata (KEK) examined effects on the injected beam of nonlinear field in a large-aperture quadrupole magnet and of field interference between shift bump magnets and adjacent other magnets in the J-PARC RCS. Significant emittance growth by these effects was not seen, but foil hitting probability by the circulating beam is increased.

BEAM-INDUCED ACCIDENTS

As a part of the session, machine protection issues were discussed and some beam “accidents” were presented in detail, especially why they occurred although a protection system should have prevented accidents.

Nikolai Mokhov (FNAL) gave a description of the “Beam-induced damage to the Tevatron components and what has been done about it”:

- beam accident at Tevatron on December 5, 2003;
- detailed analysis of the sequence of events that led to damage;
- beam dynamics during the quench development;
- energy deposition in collimators;
- ablation of tungsten collimator;
- BLM and other system changes to prevent future accidents.

The initial reason of the large quench was found to be caused by a CDF Roman Pot reinserting itself back into the beam after it had been issued retract commands. The Roman Pot motion control hardware has since then been found to be faulty. This event prompted an investigation in order to describe the sequence of events to understand the damage imposed on the collimator devices. Analysis of the quench data and collimator damage along with dynamic simulations of misbehaved beam, energy deposition and ablation process in the collimators, have provided an explanation of the damage of Tevatron components, with good agreement with observations. Note that there was a strategy adopted many years ago when collider operation began it was better to run without the BLM's during a store to prevent accidental aborts from uncritical losses. After the event, the strategy was examined and changed. The biggest change made was the implantation of a new fast detection buffer inside the Quench Protection Monitor system that samples quench data at 5 kHz and determines a quench and pulls the abort in 2 msec instead of the 16 msec before the change. New BLM's, kicker AC and UPS systems, vacuum interfaces, and controls were designed and the system was documented at every level and captured in the Accelerator Division document database.

Kay Wittenburg (DESY) gave a survey of the "Very fast beam losses at HERA and what has been done about it". The HERA BLM system has an integration time constant of 5.2 ms, therefore beam losses on a faster time scale were not covered by this system while for losses on longer time scales the system efficiently protects the machine. Two typical scenarios were discussed.

First, mislead beam due to misfired kickers, machine not ready for injection, operation etc. These events are typically as fast as one turn. If such an event happens, no active protection system will be able to protect the machine and safe operation relies on beam absorbers at the correct location. Safe operation also requires reliable fast kicker systems.

Second, after an equipment failure (e.g., power supply trip) the beam starts to oscillate (position or size) with exponentially growing amplitude. Beam losses occur after a time that depends on the failure type and the beam can be lost within a very short time. Especially some power supplies at locations with very high β-functions were discovered to cause very fast losses on time scales of less than 5 ms. For this reason, new and improved active interlocks were added to the HERA machine protection system:

- the beam current decay rate is measured and a threshold was set to trigger a beam dump. In combination with BLM system both, fast and slow beam losses can be handled now very effectively;
- the internal power supply alarms were improved to a delay of less than 100 μs;
- the whole interlock system of HERA was made faster, including the electronics of the interlocks system and the electronics of the beam dumping system;
- monitors to detect fast magnet current changes were developed and installed for all critical electrical circuits.

All systems together efficiently reduced the numbers of dangerous losses (e.g. quenches) and no false beam dump triggers happened up to now.

Brennan Goddard (CERN) discussed the "Transfer line damage during high-intensity proton beam extraction from the SPS in 2004" with the main question of why the machine protection was inadequate. By means of a detailed study of the event, some interlock logic shortcomings were detected. The interlock system cannot detect any failure of a power converter in a window of about 5 ms before extraction. Some EMC problems, which became apparent when the beam intensity was increased, led to a septum power supply trip in during this time that was not detected. The beam was still extracted and damaged the vacuum pipe and a quadrupole magnet. A list of contributing factors was given:

- lack of preparation for high-intensity beam commissioning of extraction; no high-intensity commissioning procedures established → crucial steps were overlooked or ignored;
- inadequate acceptance tests of machine protection system (interlock and surveillance systems working together with equipment) without and with beam;
- insufficient understanding of risks: problems with the fast current decay monitoring of septum and EMC pick-up, which could have detected and solved without extracting beam;
- incorrect interlock logic – detected fault should always inhibit the beam first, before cutting the equipment (was requested but not implemented);
- high-intensity commissioning and beam tests were 'simultaneous', with no clear separation in terms of preparation, procedures, people, time, objectives and responsibility;
- delays and equipment problems reduced the time available for extraction commissioning and increased pressure to deliver high-intensity beam, at an unfavorable time very late in evening (16h into the test);
- problems which occurred (noise-induced trips, measuring bumped beam) were not solved before continuing to increase beam intensity – and were still present with full intensity.

The following improvements were implemented for 2006:

- commissioning to be carefully prepared (procedures, tests and commissioning steps);
- full formal acceptance tests of machine protection system defined and performed;
- “strapping” or by-passing of interlocks rendered impossible for high beam intensities; LHC-style interlocking has been implemented in SPS, with safe beam and interlock masking concept to allow flexibility in operation with low intensity beam;
- changes to pre-defined settings only possible by experts following agreed procedure, for example, after repeating a subset of acceptance tests with beam;
- problems encountered with critical systems to be solved before continuing;
- for high intensity, machine protection must take priority over efficiency;
- fixed conceptual problem with interlock from septum PLC by adding direct link to beam interlock system, with 10-ms delay on interlock to power supply;
- reduced the delay in SW surveillance to ~2 ms before extraction;
- added direct “sum fault” interlock from power supplies to beam interlock;
- added (HERA) Fast Current Change Monitors to 14 critical electrical circuits including the extraction septum magnet.

Pierre Schmelzbach (PSI) gave a detailed presentation about “Experience with high-power operation of the PSI proton accelerator facility”, discussing the danger of such high-power machine and a list of countermeasures:

- avoid wrong settings: HW-windows on power supplies, correlated settings;
- fast diagnostics to detect critical situations;
- passive protection (collimators);
- beam loss monitors;
- current monitors for transmission;
- beam centring by BPMs, Harps, heated sieve.

Even with a good protection strategy, thermal damage happened in the machine due to a defect of a high level interlock module.

In the discussion session the important questions were summarized. First, “What has been done about these accidents?

- all accidents were analysed very detailed;
- causes and consequences are well understood (lot of work);
- many weak points that could have led to accidents were identified and fixed (the weak points were not always related to the accident) ;
- fast detection of failures is clearly required, in the order of a few turns, many milliseconds are not enough;
- machine protection issues were very much discussed, this is clearly an issue of common interest;
- tools for data recording and analysis are vital (“post mortem”).

Second, a comprehensive discussion of beam accidents had followed the talks with topics on:

- Damage levels. Note that at the Tevatron and HERA, 2-3 MJ beams are manageable, while a LHC pilot beam at 7 TeV is dangerous at 10 kJ.
- BLM thresholds and quench levels:
- How to use BLMs and how to optimize their thresholds?
- How to define original threshold values?
- How often did one change threshold values?
- How did one change them technically and conceptually? Safe and Fast? Remote?
- Time integration, is it really necessary to have so many windows as suggested for LHC?
- BLM settings, response, sensitivity, Monte Carlo calculations.
- Injection beam losses at different machines.
- Dump kicker issues.
- Loss power on dump behind stripping foil.
- Stripping foil lifetimes.
- Post Mortem analysis of beam events.
- Reliability and availability studies - do we believe the results?

BEAM COMMISSIONING

Commissioning issues were thoroughly considered for existing machines and accelerators under construction.

Bob Zwaska (FNAL) “Commissioning of the Fermilab NuMI Neutrino Beam”: Machine protection, groundwater protection and precision beam are all important issues. The beam permit system has several functions:

- routinely inhibits beam when components fail;
- prevents extraction when magnets fail and do not have the correct currents;
- prevents extraction when beam is in the abort gap;
- inhibits beam on unusual behavior, e.g., orbit movement.

John Galambos (ORNL) “SNS commissioning strategies and tuneup algorithms”:

- first proton superconducting linac, uncertain output energy – need flexibility;
- heavy use of high level applications: ~40 integrated with online modeling were developed for commissioning (physicists wrote the applications);
- preparation and testing of applications, control system, diagnostics allowed rapid beam commissioning.

John Galambos (ORNL) “Beam loss management and machine protection in beam commissioning” discussed BLM and MPS requirements:

- fast loss: (determine thresholds during commissioning, fault studies) 20 μsec Detect-to-Beam Inhibit time;
- slow loss: (corrected for baseline, noise, and x-ray background); low level loss: "Soft" alarm through network and software trips for 10 second average after waveform correction;

- flexibility - SNS has been commissioned in phases, MPS configuration has to be flexible and reliable;
- reliability – the Machine Protection System must inhibit the beam when required; it must fail in a SAFE state;
- availability – the machine availability should be as high as possible; the MPS must be easy to configure and have a “friendly” operator interface; false trips must be minimized;
- linac loss level and MPS trip level determination (BLM calibration approach): calculate neutron yield and fault study.

Dong-o Jeon (ORNL) “The SNS linac commissioning-comparison of measurement and model” pointed out that beam halo is a concern:

- a new halo mechanism was experimentally verified through emittance measurements;
- the proposed “round beam optics” improves beam quality, reducing rms emittance and halo;
- beam loss reduced in the downstream linac;
- phase scan technique and acceptance scan technique were benchmarked;
- commissioning demonstrated the validity of the model and revealed the shortfall of the model as well.

Tadashi Koseki (KEK) presented “Commissioning scenarios for the J-PARC accelerator complex” and Masanori Ikegami (KEK) presented “Commissioning strategies for J-PARC linac and L3BT”. To minimize activation of the accelerator components, tuning is started with low beam intensities, and beam transportation to a proper dump should be established, and then fine tuning procedures are performed. Two years of beam commissioning of J-PARC accelerator complex will start in December 2006:

- Linac: two stages beginning Dec 2006;
- RCS: two stages beginning Sept. 2007;
- Main Ring: three stages beginning May 2008.

Plans include substantial pre-beam hardware checkout and testing. Thorough commissioning plans are developed. Commissioning results from Linac and RCS are expected by HB2008.

Jan Uythoven (CERN) “Safe LHC beam commissioning”: with the LHC 7-TeV proton beam with energy of 360 MJ stored in one beam, the commissioning of the MPS will play a very important role throughout the LHC commissioning period to avoid damage to the machine components and quenching of superconducting magnets and minimize down time. Overall unsafety of the core of the MPS has been calculated to be 2.3×10^{-4} / year.

Eva Barbara Holzer (CERN) “Commissioning and operational scenarios of the LHC beam loss monitor system”: Thorough analysis of beam loss duration and corresponding protection systems was performed. Beam losses and protection strategies are classified according to the time scale:

- ultra-fast losses → passive components (PC) for protection;
- fast losses (4 turns, 356 μs) → PC, protection collimators, BLM (damage and quench prevention);
- intermediate losses (~10 ms) → PC, BLM, quench protection system (QPS);
- slow losses (~10 s) → PC, BLM, QPS;
- steady state losses → PC, QPS (cryogenic system capability).

The BLM is the only system for quench prevention and the main system for damage protection in the time window of 4 turns to 10 ms. Beam abort channel over threshold needs a very high reliability (tolerable failure rate 10^{-7} per hour per channel). The hardware commissioning is well defined. Steps for initial threshold determination are defined (simulation and measurements). An open question is the management and changing of threshold tables: 1.4 million (4000 * 32 * 11) threshold values need to be taken into account.

Stefano Redaelli (CERN) “Commissioning of the LHC collimation system”: The beam cleaning system achieves the required cleaning vs. beam intensity on paper. Staged commissioning without compromising machine protection is proposed. A reduced system for initial LHC operation with relaxed positioning tolerance will be used. The proposed scenarios are validated with detailed simulations. The setup of a prototype collimator was successfully achieved at the SPS. Centering to the 50 μm level was routinely achieved. The methods to adjust the collimator gaps were worked out.

For LHC operation, several questions remain: Can we infer the settings at 7 TeV from setup at 450 GeV? How do we ensure a correct relative retraction of many collimators at different places? What is the expected halo population of the LHC beams? How to precisely setup skew collimators?

Brennan Goddard (CERN) “Safe disposal of the LHC beams by extraction onto the beam dumping blocks”: The LHC beam dump is a critical system for machine protection. Safety has been built into the design from the start. “Risks” are inherent in using pulsed kicker magnet systems. To limit the risks, conventional technological choices have been used with large redundancy, monitoring and failsafe components. Areas for concern are known and will be checked in commissioning. Reliability analysis was useful tool for finding weaknesses. It is recalled that a trigger is required: “No trigger = no dump”! Efforts are now being made to ameliorate effects of ‘beyond design’ failures, including possible upgrade. An increase dilution might be required with more drift length (longer tunnel – very expensive) or superconducting quadrupole magnets for further blow-up of the beam. For protection against an asynchronous dump, sacrificial devices might be an option.

To summarize, the key MPS and commissioning issues include:

- protection versus flexibility in early commissioning;
- configuration control of MPS parameters, BLM thresholds;

- bypass capabilities and bypass procedures;
- control of critical parameters (magnet set-points, etc.);
- extremely stringent requirements on MPS performance very early in commissioning at LHC;
- online modeling capabilities, essential for rapid beam commissioning progress;
- importance of "pre-beam" testing and "dry-runs" of diagnostics systems, applications software, magnet controls, etc.

PROPOSAL OF WORKSHOP ON MATERIALS

During the presentations and discussions it became clear that a better understanding of collimators, targets and beam absorbers is in the interest of many labs. For CERN, this is driven by the studies on LHC collimators and beam absorbers, and on the LHC beam dump block. A better understanding is also of interest for the CNGS target, for SPS absorbers (extraction protection) and transfer line protection collimators. For GSI, targets are (or will be) used for Super-FRS, High Energy Density experiments and for the production of antiprotons. For Fermilab, this is of concern for the Tevatron and Main Injector collimation systems, for neutrino production targets, for antiproton production targets, for ILC positron production targets, for pion production targets and for beam absorbers for neutrino factories and muon colliders.

It was proposed to organize a workshop on these issues, probably next spring in Europe. Some of the questions that could be addressed are:

- What are the relevant parameters for beam absorbers and targets (such as deposited beam energy, beam power, etc)?
- What materials are being used? What led to the choice of these materials?
- Where are the limits? What are the problems?
- Future perspectives (as an example, 2nd generation beam absorbers for LHC): are there materials that can stand the beam impact?
- Do we require renewable/disposable devices?
- What happens in case of shock impact (time constant ~μs)?
- What happens in case of continuous impact (time constant ~second)?
- What are the relevant physics effects to be considered?
- What are the codes for calculation?
- When do calculations for shock impact with mechanical engineering codes (e.g. ANSYS, AUTODYN, …) break down?
- Compare the results from different codes; possibly some simple test cases could be defined.
- Experimental evidence and experience with benchmarking.
- What happens to the object beyond melting and vaporisation temperature? (as an example, beam tunneling through materials).
- What material parameters are relevant? (for example, to formulate an equation of state).
- Are there new materials on the horizon? (e.g., robust with low electrical resistance).
- Short- and long-term effects of radiation? Is there an effect of the dose rate?
- What is the effect of the total dose on material properties, and on equation of state?
- Displacements per atom (dpa) are a quantitative measure of the irradiation a material has undergone. Is this a universal measure for different radiation fields?
- Is there temperature dependence during radiation? What about annealing?
- What to test and where to test? How to analyse test results?