SUMMARY: CONTROLLING THE BEAM TO THE LHC

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Abstract

Several aspects of controlling the SPS beam to the LHC are presented. Subjects include accelerator components - magnets and beam monitors, as well as the future transfer lines between the SPS and the LHC. Three papers covered requirements for hardware and software of the PS and SL control systems.

1 INTRODUCTION

This session covered a wide range of topics sharing only a rather broad definition of "Controlling". Certain presentations included activities which will bring new features to SPS operation in 1999 whilst others concerned longer-term developments. The coupling between the machines in the PS-SPS-LHC chain was an important aspect of the session.

2 ADDITIONAL QUADRUPOLES FOR THE SPS - WHAT CAN THEY BE USED FOR?

The existing proposal to raise the threshold of the microwave instability at low energies was briefly described. This is achieved by 4 additional quadrupoles in each SPS sextant which are used to lower γ_t. An alternative proposal was presented for additional quadrupoles to reduce capture losses in the LHC by raising the γ_t in the SPS in order to shorten the bunch length at extraction. This option became less relevant during the workshop as it was confirmed that a 200 MHz RF system will be installed in the LHC to avoid capture losses. A second proposal was to use quadrupoles to increase the bandwidth of the future Q loop. This functionality would require the quadrupoles to be installed at different vertical βs, which would not be ideal for schemes to adjust the optics. However benefits would include faster setting up of machine cycles and better control of the transverse emittance of the LHC beams.

It was demonstrated that quadrupoles could also be used to provide a γ_t jump - switching from high to low γ_t optics as the beam approaches transition. This would inevitably lead to some reduction in the transverse aperture of the machine and it is not known whether the aperture or collective effects associated with transition are more critical for these beams. Finally, a scheme was considered to smooth the dispersion function in order to reduce the peak dispersion below 3 m.

There are interesting alternative uses for additional quadrupoles but no strong arguments were found for a new proposal.

3 BEAM AND CONTROL REQUIREMENTS FOR TI 2 AND TI 8

These new beam lines will transport the beams from the SPS points 6 and 4 to the LHC points 2 and 8 respectively. TI 8 will be commissioned towards the end of 2003 ready for the LHC sector test at the end of that year. TI 2 will not be commissioned until mid 2005. The major features of these lines are their total length of almost 6 km and the high risks involved with the injection of the high intensity, high energy proton beam into the small aperture cryogenic magnet system of the LHC. In addition the lines will be commissioned and operated during a period when the SPS beams will also be required for the fixed target physics program. This operation will compete directly for beam time and so high efficiency is needed in switching on and off the beams and in setting up and operating the lines. The magnet system in TI 2 and TI 8 is built with warm magnets arranged in a FODO lattice with 4 dipoles per half-cell. For economic reasons the aperture of this long magnet system is small, leading to the necessity of tight trajectory control, within ±4.5 mm in both planes. Perfect matching is required to avoid emittance blow-up, and the total delivery tolerance for all sources of beam position error at injection into the LHC is $\pm 1.5\sigma$. The steering strategies for TI 2 were described. These beam requirements were translated into control requirements. Beam instrumentation, logging and interlock requirements were outlined.

The talk included a review of the operational scenarios for the lines and of the associated control software. It is assumed that the necessary software will be provided within the framework of SPS2001 software project (see section 6).

4 BEAM INSTRUMENTATION

The pilot MOPOS installation in sextant 3 of the SPS will be generalised to the whole machine for the 1999 start-up. This will bring new operational tools – contiguous turn measurements, simultaneous observations of first turn and closed orbit and an integrated set of diagnostics and configuration tools. Improved diagnostics of the time structure of the LHC beams are to be introduced in 1999. This individual bunch measurement system (IBMS) consists of new acquisition electronics that will be fitted to beam current transformers in TT 2, TT 10 and sextant 1. Position information will also be made available when this prototype LHC wide band electronics is used to acquire ring pickup signals in 2000. This development will also provide a tune measurement system with 40 MHz bandwidth.

Work in progress to improve the SPS Machine Protection System was also described. In 1998, a beam current drop interlock was introduced which protects machine components from beam damage following RF trips. In 1999 another fast interlock will be added, triggered by the ring beam loss monitors. A beam oscillation monitor will follow in 2000 that will provide protection in the case of failure of the horizontal or vertical damper system.

Following the shutdown of LEP in 2000, the LEP BPM detectors will be used to upgrade the position measurement system in TT 2 and TT 10. This work is motivated by the very tight emittance budget for the LHC beams but the system is being designed to provide position information for all beam types. In order to avoid complications due to gain switching logarithmic amplifiers have been chosen to cover the dynamic range of 90 dB.

Developments for emittance measurement and control in the context of the SLI project were reported. Optical Transition Radiation (OTR) screens are replacing SEM grids in TT 10. Advantages include increased spatial and time resolution. In 1998, measurements from OTR screens were used to measure emittance and to reduce trajectory variations between the PS bunches. This system will be improved in 1999 to preserve information from the beam tails and to provide bunch to bunch information for both transverse planes. Another OTR screen in LSS4 has been used to observe beam envelope variations in order to measure the mismatch at injection. The system is sensitive to filamentation blow-up to within 1% in the vertical plane and the horizontal results will be investigated next year. Amongst the other work reported was the installation of a test set-up of scrapers intended to remove the tails from LHC beams. First MDs are planned for 1999.

5 SPS SEQUENCING

The present facilities for changing the SPS supercycle will be inadequate in the LHC era. Improved flexibility is required to switch quickly between different operational modes of the beam as, for the first time, it will be necessary to serve conflicting clients in the same run. There may even be a need to alter the supercycle length on a frequent (some hours) basis in order to achieve optimum efficiency. The current timing and function generator software and hardware do allow machine components to switch between different supercycles. But there is no consistent implementation of this feature in the SPS hardware and software and no link with the sequencing of the CPS complex.

Improved timing and cycling strategies are being defined within the scope of the SPS2001 project. The major change is to centralise the accelerator timing for all the accelerators at CERN, today the SPS and LEP have independent sequencing control. A new Central Beam and Timing Facility (CBCM) is proposed by the SPS2001 project which will orchestrate the cycling of the whole of the CERN accelerator complex. Nevertheless the present SPS timing events will continue to be distributed by the local Master Timing Generator (MTG). But the repetitive supercycle with a fixed pattern of cycles will disappear. Apart from the impact upon cycling equipment, magnetic field control needs to be improved. In particular the power supply following error is currently treated on a supercycle basis and work was described which is aimed at predicting and correcting following errors when the supercycle is not fixed. Magnetic history has a significant effect on the beam behaviour at low energies. Results from MDs performed in 1998 were reported. Measurements of the injection orbit have illustrated that it is especially important to control the main dipole currents during the slope transitions. More observations are planned for 1999 with the work extending to the other main ring magnet systems.

6 SPS2001 SOFTWARE PROJECT

The main purpose of the SPS2001project is to generate the software to enact the fast and flexible cycle changes that will be needed for the combined LHC filling and fixed target operations. It is also important to review the current control software infrastructure in the light of the trends in computing equipment and methods. The current software represents a very large investment but no longer meets the operational requirements and is incoherent. As a result a fast cycle change takes over an hour. PCR operators would like to work with a standard MMI and need integrated equipment control. Related to this work is the convergence of the PS and SL control systems, which is motivated by shrinking resources, and the increasing demands for a combined monitoring and control of the LHC beam in order to provide the best conditions for beam tuning. In 1999, the SPS2001 project will produce the strategy for the operation of the SPS from 2001, mainly defining the required sequencing of the accelerator equipment. Sequencing will be under the control of the CBCM which will be an extension of the present PLS to include the SPS and LHC machines. The strategy for implementing the new software will also be produced and guidelines will be established with the equipment groups to define how the equipment services will be developed. In the longer term a first prototype of the new software is planned for June 2001 and a final version for the control of the new beam lines and the LHC sextant test in 2003. A project feasibility study has been completed and covered equipment, timing and cycles, the physics program, machine modes and interlocks and the LHC requirements. The project is now in the analysis phase that will end in December. An important software component required in 1999 is the standard PS and SL equipment access package, this will be provided by the PS/SL Controls convergence effort.

7 PS AND SL INTEGRATED MONITORING

The final topic of the session was motivated by the increasing frustration with the limited facilities for exchange of information between the MCR and PCR control rooms. Operations and development teams need access to the information necessary for them to adjust the transfer of the beam from the PS to the SPS. Therefore, the measurable PS accelerator quantities that determine the SPS beam properties should be equally accessible to both control rooms. It is very desirable to provide the same "picture" so that misunderstandings may be avoided. Problems have been experienced due to trivial differences in the controls infrastructure such as different font sets. Short-term improvements were suggested such as adopting the same standards for data logging; however, the PS/SL controls convergence project should aim to provide a comprehensive solution. Beyond these measures, there would still be a need to provide tools for the non-specialist to access the desired information and there will be extra demands on reservation strategies and mutual confidence. Future requirements for emittance preservation of the LHC beams and for the preparation of very high intensity fixed target operation will further increase the needs for fully integrated inter-accelerator control.

8 CONCLUSIONS

The conversion of the SPS to an LHC injector implies major developments in different areas of control. Emittance preservation of the LHC beam and the LHC injection tolerances lead to challenging requirements. The entirely new requirement to transform the SPS to a machine which must serve conflicting client requirements in the same operational run requires radical changes to the hardware and software controlling the dynamic settings of the machine. During the workshop, many people expressed their concern about the resources available to meet these challenges.