SPS beam instrumentation

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Abstract

The activities in SPS beam instrumentation can be classified into three categories:

- consolidation of existing equipment
- new installations motivated by the preparation of the SPS as LHC injector
- test installations of instruments foreseen for the LHC.

In the following text activities of all three domains are described. Everything related to emittance measurements is treated in a separate presentation by Roland Jung.

UPGRADE OF THE SPS ORBIT SYSTEM COPOS → MOPOS

During the 1998/1999 winter shutdown the upgrade of the SPS orbit system reaches its final state. After the previous transformation in BA3 for the 1998 operation period the electronics in all other surface buildings will be changed. The main changes are a replacement of the calibration and 200 MHz filter cards (TRIUMF collaboration), new digitising cards and a complete new acquisition system.

The following improvements can be expected:

- Higher accuracy due to frequent calibration cycles.
- improved resolution (3 μm rms noise floor achieved at 450 GeV beam energy) due to 13-bit ADCs.
- contiguous turn measurements and data analysis (equivalent to the LEP 1000-turn facilities)
- simultaneous first-turn, orbit and multi turn measurements; multi console usage.
- integrated configuration tools based on oracle data bases.
- New diagnostic tools for analog input signals and acquisition timing gates.

More details can be found in [1].

This new system will be made operational for the start up 1999.

TT2/TT10 NEW BPM SYSTEM

For some time already an upgrade of the trajectory measurement possibilities in TT10 has been requested by the SLI working group. The demand was 5 additional beam position monitors recuperated from TI12/TI18 after LEP operation and a new acquisition electronics allowing also to measure longer bunches (bunches with smaller momentum spread for dispersion measurements).

This project has been reviewed such that more monitors from the TI12/TI18 transfer lines will be used to equip in addition the TT2 transfer line with beam position monitors. An analysis of the signal levels obtained for all kinds of beams that will pass through these transfer lines has led to the choice of logarithmic amplifiers for the new acquisition electronics. A consequence of this choice is that the bandwidth can not be increased to 40 MHz, such that the position of individual bunches of the LHC type beams can not be measured with this system. This functionality will be provided by the system described below for a limited number of beam position monitors.

The new TT2/TT10 trajectory measurement system can be expected to be operational in the year 2001.

INDIVIDUAL BUNCH MEASUREMENT SYSTEM (IBMS)

During 1998 a front end acquisition system with 40 MHz bandwidth and the related beam synchronous timing has been designed and installed in BA1 and in building "Y" of the PS complex. This system is connected to three beam current transformers, one close after the extraction from the PS, i.e. in the transfer line TT2 (TRA126), a second transformer at the end of TT10 (BCT 102921) and the third transformer in the SPS ring (BCT 11657). Results of test measurements can be found in [1].

From the start up 1999 onwards the system will allow to measure the individual bunch currents of LHC type beams.

During the next shut down 6 beam position monitors, located close to these BCTs, will be added to the system. Each monitor will measure the beam position in both planes and the phase advance between the monitors will be chosen close to 90^0. The front end electronics for these position monitors will be the prototypes for the LHC orbit system.

MACHINE PROTECTION

A high intensity proton beam accelerated to 450 GeV can easily damage the vacuum chamber and a magnet in case it is completely lost at a given place. Altough during 1999 the SPS will be operated with lower total intensity a revision of the protection systems against main equipment failures is very important. The LHC type beams will represent a dangerous total intensity and proton beams for neutrino experiments will be requested also in the future.

Table 1 (reproduced from [1]) shows the time scales of beam impacts on the vacuum chamber after a failure of the most important equipment and the direct and indirect machine protection systems.

system	Delay	duration	Direct dump	Indirect protection
MAIN BENDS	15 ms	1 ms	6 ms	BLM 1,2,6
QUADRU POLES	15 ms	1 ms	9ms	BLM 1,2,6
RF	50 ms	2 ms	NO	Feedback, mom.scraper BCT
DAMPER	~100 turns	Some turns	NO	30mm excursion (HOR)

Table 1: Time scales of beam incidents after equipment failures and protection systems

Delay: time between equipment failure and beam hitting vacuum chamber.

Duration: duration of beam impact

Direct dump: delay between failure and beam dump

- The machine is well protected against failures in the power converters of the main bends and quadrupoles by direct dump links and by the beam loss monitor system.
- In case the Rf system fails the beam should be lost on the momentum scrapers. This as only protection is not safe enough and for that reason during the summer 1998 a protection based on the BCT (beam current transformer) has been implemented. This system memorises the total beam intensity after transition and then keeps reading the intensity in 5 ms intervals. In case the total loss is bigger than a predefined threshold the rest of the beams is dumped. This system is operational and has worked to satisfaction.
- In case of a damper failure a high intensity beam would become unstable after about 100 turns and then be lost after a few turns. As protection an old system exists that measures on a turn to turn basis the oscillation amplitude of the bunches. If for a large enough fraction of the bunches an oscillation amplitude of 30 mm is exceeded the beam is dumped in the consecutive turn.
  This system has only been built for the horizontal plane and is very difficult to maintain. The BI group proposes a new system for both transverse planes based on Digital signal processing techniques. The new system will preserve the functionalty of the old system, but it will have more built in post mortem diagnostics.
  The system should be ready for year 2001

Q LOOP

During the 1998 a system for real time control of the betatron tunes (q-loop) has been designed and installed in the SPS [1]. The feedback on the machine is made via the main QF-QD quadrupole string. The open loop bandwidth of the Magnet-vacuum chamber-power converter string has been measured to be 30 Hz. Hence a closed loop bandwidth for tune regulations at a few Hertz can still be expected with reasonable gain. Presently the tune measurements are based on chirp excitations and harmonic analysis of the resulting beam motion. PLL based tune measurements are foreseen for 1999.

The measurement system for betatron tunes is installed in BA@ close to the transverse damper (excitation) and the correction signals to the power converters in BA3 are sent via a new dedicated ATM link.

The q-loop including an application program should become operational in 1999.

CHROMATICITY FROM HEAD-TAIL PHASE SHIFT.

During 1997 and 1998 a new method for measuring the chromaticty has been developed in the BI group. The method is based on the excitation of a betatron oscillation of the beams followed by a sampling of the betatron motion of head and tail individually. In case of non –zero chromaticity the betatron frequency (more precisely the phase advance per machine turn) is different for particles in the head compared to tail particles. Half a synchrotron period after the excitation the head and tail motion have their biggest phase shift, which then can be used as a measure of chromaticty. More details on this method can be found in [2].

This method has successfully been tested in MD experiments and during 1999 an operational instrument will be constructed for the SPS. This demands the development of precise timing units and some front end electronics to suppress the DC-orbit signal in the position monitor. These developments will be made in collaboration with DESY, as a second identical system is requested for the HERA-p machine.

REFERENCES

[1] Summary of the 9th BI day 1998, edited by J.J.Gras, SL-Note-98-078(BI)

[2]The Measurement of Chromaticity via a Head-Tail Phase Shift, D.Cocq et al., Proceedings of the Beam Instrumentation Workshop BIW98, Stanford, CA, 1998.