Analysis of Uptime Efficiency of the SLC as Measured by Pulse Accounting

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Abstract

The repetition frequency of a linear collider can deviate substantially from nominal design values as a result of lost pulses. Pulses are typically lost as a result of a veto imposed by the many Machine Protection Systems. A system has been installed at the SLC to use the existing beam position monitor hardware to count every beam pulse that passes by each of the strategic locations. Also counted are the signals from various beam dumpers, as well as trigger signals generated by the MPS. Representative data of SLC running are shown that have been used to determine how to improve running efficiency.

INTRODUCTION

The goal is to quantify the efficiency and reliability of the accelerator performance in terms of the beam delivered by the individual systems. Identifying the contributions to loss in overall efficiency should help in determining which subsystems warrant the most effort to improve performance. The ultimate measure of accelerator performance is the useable luminosity delivered to the detector. However, this is determined by a complex mix of many parameters such as beam current, repetition rate, beam size and background levels in the detector. In order to provide an unambiguous measure of hardware reliability for delivering beams the Beam Pulse Accounting (BPA) system only takes note of the number of delivered beam pulses that pass a predetermined intensity threshold.

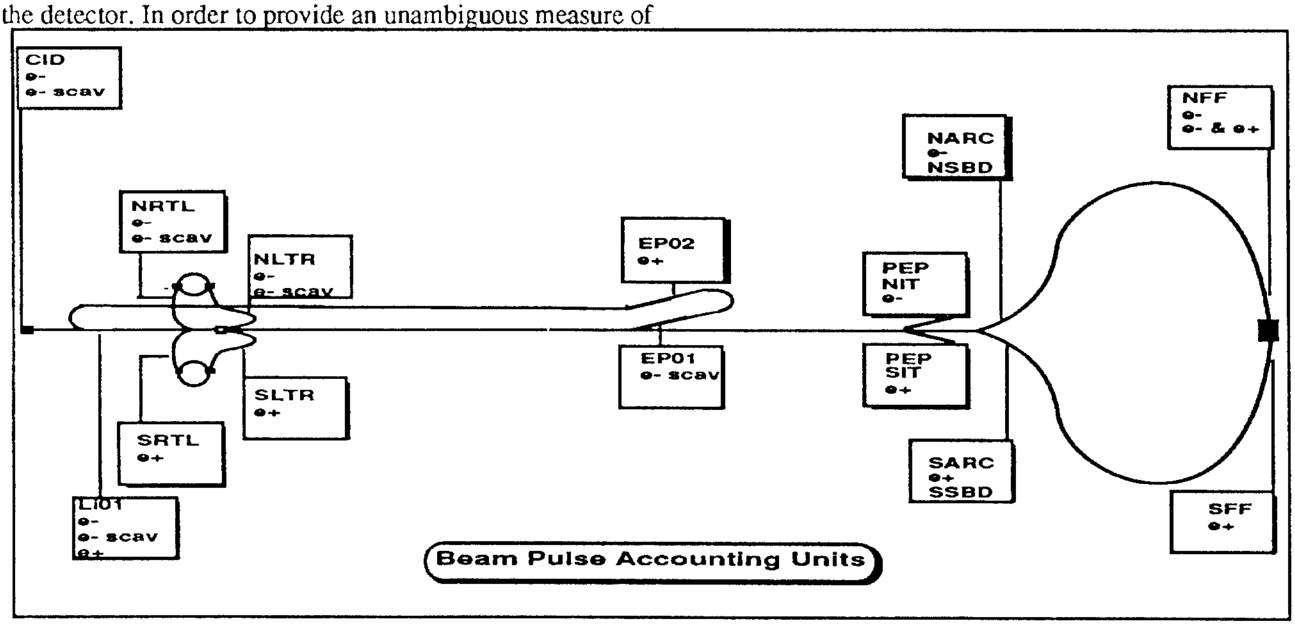
The system uses the existing beamline monitoring devices (BPMs) and adds on top of them a new system for counting and storing the number of beam pulses. This counting system had to satisfy a number of requirements:

1. The intensity threshold above which a beam pulse is counted is remotely programmable.

2. The dynamic range of the threshold setting is capable of handling a wide range of beam intensities encountered in the accelerator - from high currents in the injector to low currents for PEP injection.

3. The counting distinguishes between the different types of beam pulses - electrons, positrons and positron production bunches that can be present, as well as different beam modes for SLC and PEP running.

4. Since much information can also be gained from counting the number of times a pulser fires to veto a beam, provision is also made on each unit to count the signal from an auxiliary input. In the final focus the inputs are used to do coincidence counting of e- and e+ together with detector livetime signals.



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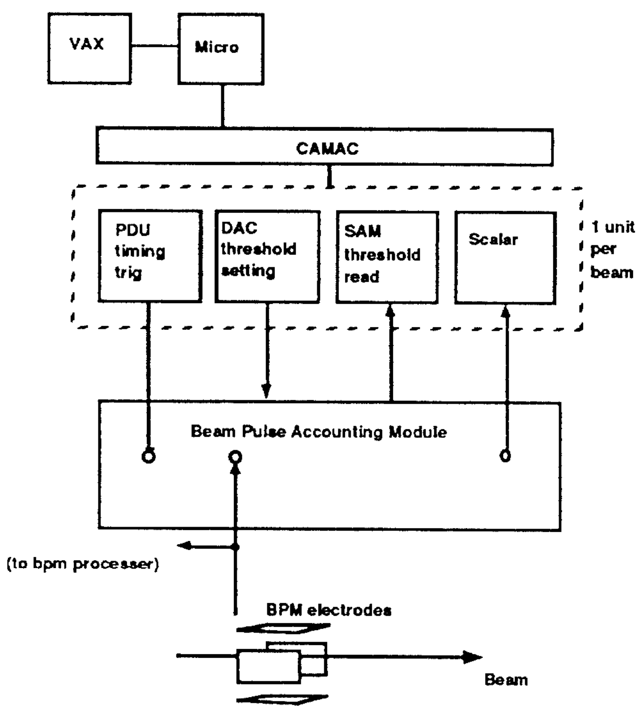
To assess the performance of individual accelerator systems the pulse accounting units are placed at strategic locations representing interfaces between systems. These locations are shown in fig. 1.

SYSTEM HARDWARE

A block diagram of the main components of the beam pulse accounting system is shown in fig.2.



Schematic of the Beam Pulse Accounting System

Figure 2

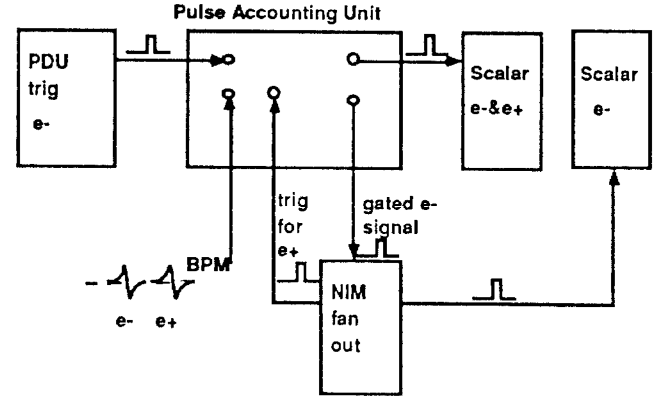
The voltage pulse from an existing BPM is split before going to a BPM processor. The signal is summed and passes through a comparator whose level is set remotely via an input signal from a digital-analog converter (DAC) module which is also read back from an output going to a signal aquisition module (SAM) module. The DAC/SAM combination appears as an AMPLifier device in the control software allowing it to be TRIMmed and monitored. The purpose of this threshold level is to allow counting only of pulses above a certain intensity level. Typically this level is set to be just above the noise level of the bpm signal, but it can be programmed to reject pulses below some other threshold value.

The Beam Pulse Accounting unit has a second input channel for a trigger signal supplied from a pulse delay unit (PDU) module. The gating of the beam pulse signal can thus be controlled with the standard TIMING software in the control system. The reason for gating the beam pulse signal is to distinguish between the different SLC bunches. In linac Sector 1, for example, an electron bunch, a positron bunch and a scavenger electron bunch are all present and separated by about 60 ns.

The gated signal is shaped and its output sent to a scalar module. The scalar is then read and cleared periodically by the control system.

A third input is also supplied on the beam pulse accounting unit to gate and count some arbitrary logic pulse signal to provide auxiliary information such as the occurrence of kicker pulses which would veto the beam.

The bpm input, PDU input, DAC input, SAM output, auxiliary input and scalar outputs together constitute one channel of the Beam Pulse Accounting module. Three of these channels are built into each module so that the unit is capable of counting all three beam signals from one bpm.



Beam Pulse Coincidence Setup

Figure 3

A special configuration of this unit is used in the final focus, shown in fig. 3, to make the unit also act as a coincidence counter for e- and e+. The output pulse going to the scalar to count e- is also used as trigger signal to gate the e+ signal which arrives approximately 30 ns later at the bpm.

PROCESS SOFTWARE

The on-line control system software performs four categories of tasks which are accessed from a touch panel for the SLC Control Program (SCP) software.

1. Setting up of the pulse accounting unit using the AMPL and TRIG features and reading the scalar using the SCLR feature. Several button macros make us of the correlation plot software to scan the AMPL and TRIG values to optimally set them.

2. A batch process is executed on the VAX which reads and clears all the scalars every 6 minutes. From this the average rate, expressed as pulses per second, is saved together with the integrated counts for each of the beams at each of the bpms. The integrated counts are recorded per hourly interval, per 8 hour shift, per day and per week.

3. The HISTory Buffer (HSTB) software archives each of these values and allows them to be individually plotted over a chosen time interval going back as far as one week. After one week the HSTB further condenses them to archive them for

longer term records. Fig. 4 shows a typical history plot of beam rate over 6 minute intervals as well as a plot showing the integrated counts per hour.

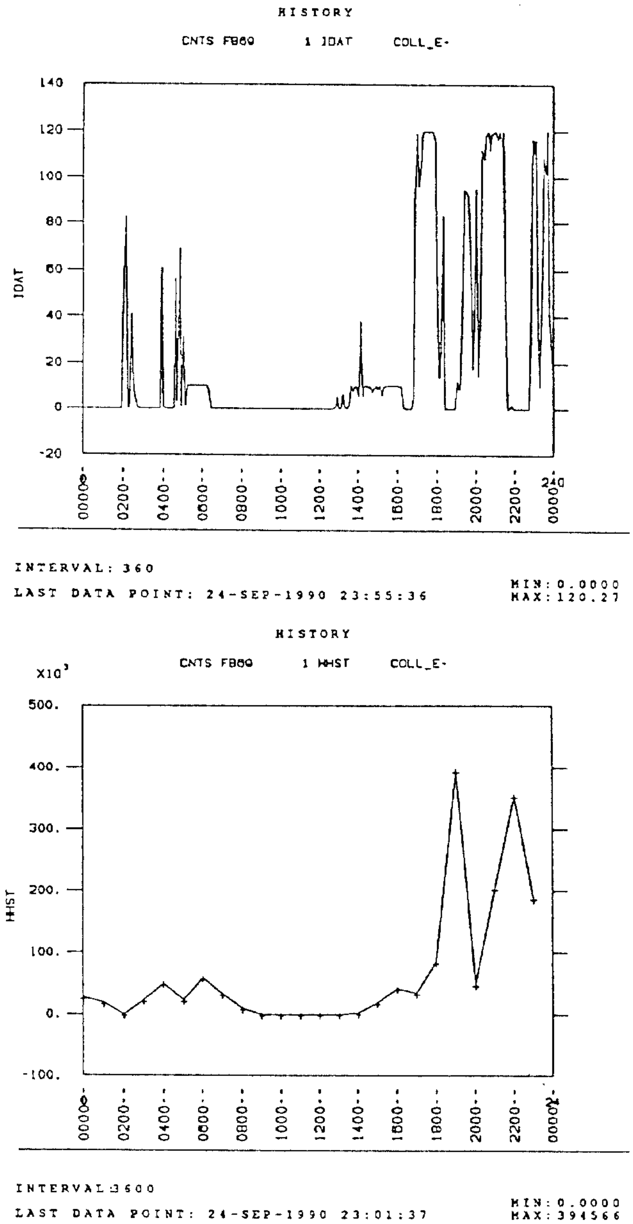


Figure 4 . Online history buffer data showing the recorded beam repition rate in pps (top) for e- reaching the IP, and the same data binned into integrated hourly counts (bottom).

4. Separate from the beam pulse acquisition software are a set of so-called pseudo scalars that count the number of pulses sent out by the Master Pattern Generator (MPG) to the timing system. This enables the number of beam pulses that should be transported in the machine to be compared to the number measured at the bpms. The MPG also has several inputs from the Machine Protection System that cause the machine either rate limit or switch off entirely. The number of beam pulses on which this occurs can also be counted thereby giving information on the frequency of trips from various causes around the machine. The data from the pseudo scalars is processed by the history buffering routines in exactly the same way as the beam pulse data.

MEASURING SLC PERFORMANCE

The on-line history plot software provides an immediate check on the running of the machine. It also provides basic statistics on the performance of the machine, such as the fraction of up-time. Further analysis can be done by exporting the data offline into spreadsheet type programs. This allows more useful comparisons to be made between the various machine subsystems and thus highlight the relative contributions to the pulses failing to make it to the detector at the interaction region (IP).

The example chosen in fig.5 shows the throughput of the collision electron bunches from electron gun (CID), through the North Linac To Ring (NLTR) beamline, the North Ring To Linac (NRTL), the North Arc (NARC), the North Final Focus (NFF) and the coincidence with positrons at the IP. The data is binned into 8 hour shifts during a 3 day period of machine physics. Also shown is the frequency of trips, or rate limiting, due to insertion of the damping ring complex FARCs, the Operator rate limit button and the scavenger lectron bunch extraction line MPS trips.

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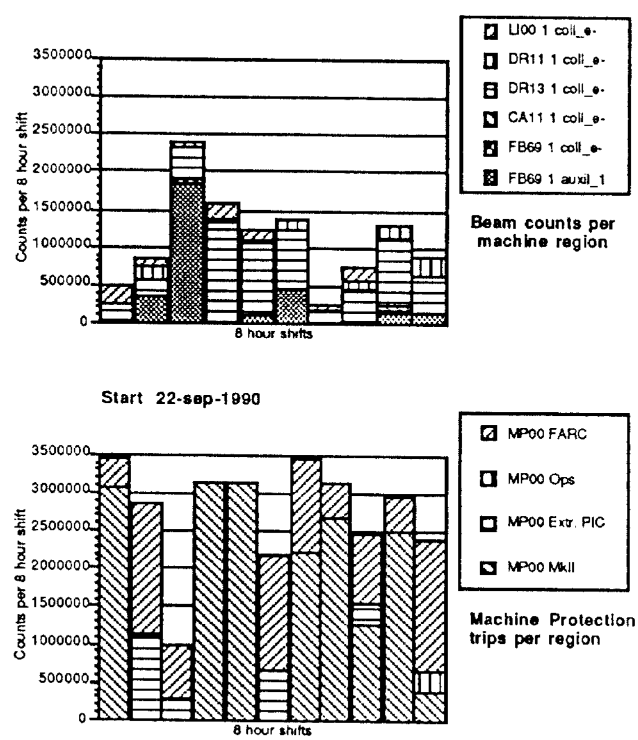

Figure 5. An example of how Beam Pulse Accounting data can be binned and different machine regions compared. The complementary data showing which part of the machine vetoed the beam pulses is shown in the lower half.