THE PERFORMANCE OF THE SIS AND DEVELOPMENTS AT GSI

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Introduction

The new heavy ion synchrotron SIS 18 at the GSI laboratory was completed [1] in April of 1989 and the commissioning [2, 3] ended in January 1990. Since then the machine is delivering beams for the fragment separator and since March of 1990 also to the Cave B target station and to the storage ring [4]. The inauguration ceremony for the new accelerator complex was held in April of this year. However, machine studies still go on either in particular beam development shifts or in parallel to production runs. This paper gives a survey on the first operation of the SIS and might serve as a guide to detailed and more illustrated papers in these proceedings.

Injection and Acceleration

The Unilac [5] now serves two functions: delivery of a variable energy beam of modest intensity to the low energy experimental areal for 49 pulses per second and delivery of a high intensity beam at a fixed energy of 11.4 MeV/u for the injection into the SIS at 1 pulse per second. Both beams, still with the same charge over mass ratio, are coming from two different ion sources, tuned to the appropriate intensities and pulse regimes. For ligth ions the SIS beam pulse is around 50 electrical μA, for very heavy ions the current pulse is about few μA due to losses in a second stripper.

In the transfer beam line an electric chopper cuts out a section of selectable length out of the Unilac pulse. For diagnosis purposes the latter must be 1 ms long. The width of the chopped portion is adjusted to the envisaged number of injected turns.

The injection pulse is routinely set for 20 turns, giving a current accumulation of 10 - 12. If required, intensity reduction up to a factor of 50 is performed by reducing the width of the injection pulse and for still further attenuation a beam degrader in the transfer line is available. Both measures are applied, once the machine is tuned up.

Some beam losses occur during rf trapping when the full aperture was filled. They will be reduced by decreasing the momentum spread with a debuncher in the transfer line and by eliminating the present closed orbit distortions. A fast beam transformer allows for a comfortable monitoring of injection process. A DC transformer with a sensitivity of around 1 μA displays the circulating beam during tapping, acceleration and extraction.

The time functions for dipoles, quadrupoles and the radio frequency are provided by function generators, which read the theoretically calculated values out of memory tables in the distributed VME controllers. The agreement of calculated and measured Q values is now improved to 0.005.

Q values can be measured by processing the signal from the position pick-ups, after a radial or vertical kick was given to the beam [6]. Transversal Schottky scans additionally give useful readings of Q values and chromaticity, as well [7]. Side bands in the longitudinal Schottky signals of the bunched beam allow for a convenient survey of the rf voltage value. So far, only one of the two rf cavities is in operation. The originally envisaged ramping speed of 10 T/s is limited to one third of this value as an agreement with the local power company.

Acceleration to the full magnetic rigidity of 18 T m was reached quite early in the commissioning phase, i.e. 1 GeV/u for Uranium and 1.7 GeV/u for Argon beams.

The high degree of accuracy and repeatability of set values and time functions allows for a completely blind operation of the machine. This is essential for low intensity runs. This occurs, when the user asks for an intensity reduction by orders of magnitude or when the beam from the Unilac is occassionally weak. The beam signal is then not visible during injection and acceleration. On the flat top then a spectrum analyzer is tuned in the zero-span mode to the bunch frequency and 10^4 circulating particles can be monitored with a good signal to noise ratio.

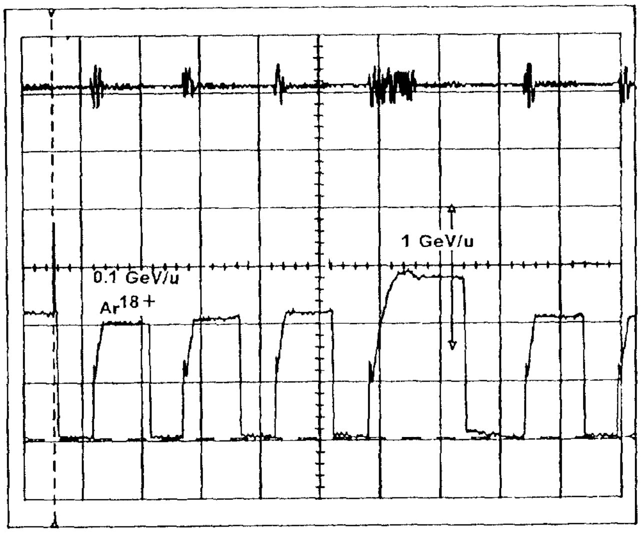
The Virtual Machines

The emphasis of the machine theorists that the beam should come on as calculated, when the hardware reacts with a predictable time lag [8] and a repeatable accuracy to the set values, led to the concept of a super cycle with as many as up to 16 different machine parameter settings. These parameters are entered into the control system and data tables are calculated and stored in the local VME memories. Then a supercycle can be composed with one or more virtual machines, they can be activated or disabled individually on command.

So far three machines have been used in a sequence, however, for the same ion: one fast extracted beam sent to the ESR and two slowly extracted beams send to two different experiments. The beam going to the fragment separator can be used for parasitic machine studies, as well. There are indications that memory effects in the magnets will show up, if one cycle is set up for full magnetic rigidity. No attempt has been made to correct for this empirically.

Example for two virtual machines in a supercycle:

The figure below shows the internal beam current signal. The lower pulses are accelerated to 100 MeV/u. The one higher pulse goes to 1 GeV/u. The increased height comes from the increased revolution frequency of the same particle number. The build up of the multiturn injection is not clearly visible. Then comes the dip of beam losses during trapping, followed by the current increase during acceleration. The beam was dumped by fast extraction. The upper trace is the "rf on" signal. Time scale is 1 s per division.



Extraction Performance

There are two extraction modes: fast and slow extraction. Fast extraction is routinely in use for accumulating bunches from many SIS cycles in the ESR. It is also used for tuning the beam line elements to the fragment separator or to the counter experiments in Cave B. The beam burst can conveniently be monitored on profile grids and optical screens. Only the experiment on high temperatures in matter [9], which actually is not yet operational, requires fast extraction.

Most of the experiments, and there are around 30 which have allocated beam times, rely for an efficient data taking on long beam spills of a few 100 ms with a decently constant particle flux. This has not yet been achieved during the commissioning phase and during the last 4 months of scheduled production runs.

Counters with a wide dynamic range for studies of the external beam are not yet available as a permanent and well calibrated installation in the beam dump. Instead, extraction tuning relied initially on the reading of a smooth decay of the circulating beam. This does not mean that constant beam was passing the extraction channel. An actual signal of the external beam was only available from the experimenters and, according to their particular detector set up, showed a more or less needle like time strikture, sometimes a smooth gaussian distribution over the spill time. The needles showed eratic periodicities and could not clearly be attributed to power supply ripple. The latter was checked repetitively.

For such a complete on-off signal, the usual cure with a closed loop regulation of the fast acting extraction quadrupoles would not help. It was concluded that if the "sharpness" of the resonance implies the strong susceptibility against Q fluctuations, than an introduction of Q spread should help. This was observed indeed: when the rf was left on during extraction, e.g. a larger momentum spread of the circulating beam, then the gaps between the spikes showed the tendency to fill up.

When finally a 100 Hz sequence of the needles was identified, and this periodicity is not natural for a 12 phase rectifier, it could be shown that the perturbing signal was injected by the DCCT and the power supply regulated against it. Therefore this ripple was not found on the error signal of the control loop. The manufacturer promised an easy cure.

Regulation devices for a closed loop control of resonance quadrupoles will be installed, as soon as a reliable wide range measurement of the external current is available. Part of the bio-medical program, the exploration of the raster scan, strongly relies on a decently constant particle flux.

For the slowly extracted beam there is presently still a limitation of the final energy to about 2/3 of the design value, because the angular deflection of the separated beam must be higher than predicted. This is attributed to a too strong closed orbit distortion at the location of the electrostatic septum. In autumn of this year a major shut-down is planned for a comprehensive realignment campaign. There are many mysteries, which hopefully will be cleaned away thereafter.

Tune-up

The SIS is still tuned-up by the experts, because a decent operating software on a higher level is not yet available. The tune-up of injection and acceleration is done in 15 minutes, when the beam is made available in the proper shape by the Unilac operators at the end of the transfer channel. The latter operation might take two hours. Then the optimisation of the slow extraction might take half an hour, depending on the desired energy. The tuning of the 200 m beam transport to Cave B takes less than half an hour. All these numbers include the struggle with still imperfect hardware performance. The machine then runs unattended over night or over weekends. A trip-off of a power supply, which might occur every shift, is reset by the Unilac operators. A retune of the beam is not necessary then.

Future Developments

a) In addition to a list of hardware clean-ups, a few have been mentioned here, several operational features of the SIS still await to be developed. Examples are: ultra slow extraction, bunch merging for an efficient beam transfer to the ESR, formation of highly compressed bunches [9], reinjection of treated beams from the ESR.
At the ESR the majority of physics experiments depend on the clear understanding and controlled manipulation of the various ring features. This is also beneficial for pure beam studies at the border line of instability phenomena [10].

b) There are other activities, envisaged since long, but not transformed into hardware. Some of them still belong to wake fields of the ending project. The Unilac was to some extend neglected in the past years and deserves maintenance attention. The already available beam intensities for light ions are dangerous to run. A new generation of high current beam diagnostic probes has to be devised and more sophisticated interlocks, as well. The control system awaits to be fully included into the new SIS architecture. Finally the demand for one hundred times higher intensities from the Unilac [5] for the very heavy ions becomes more vital than anticipated in the past. This will absorb a considerable engieneering capacity, which also is requested for the present and future experiments.

c) A study of a 20 on 20 GeV/u collider will be initiated this year. From the physics stand point this was considered since long to be the natural step into the future at GSI. From the machine standpoint it benefits from the high brillance beams of the ESR, post accelerated by the SIS. The short preparation time for a new refill by the high intensity injector chain can probably make acceptable short beam life times due to beam-beam effects at high luminosities.

References

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