THERAPY OPERATION AT GSI

U.Scheeler, D.Wilms
Gesellschaft fuer Schwerionenforschung, 64291 Darmstadt, Germany

Abstract

GSI is the heavy ion research center in Germany operating the three accelerators UNILAC (linac), SIS (synchrotron) and ESR (storage ring). Experiments are made on the fields of nuclear and atomic physics, plasma physics, nuclear chemistry, material research and biophysics. The most important program of the biophysics group is the study of the advantage of Carbon ions for cancer irradiation. The developed raster-scanning technique allows the direct 3D irradiation of irregular

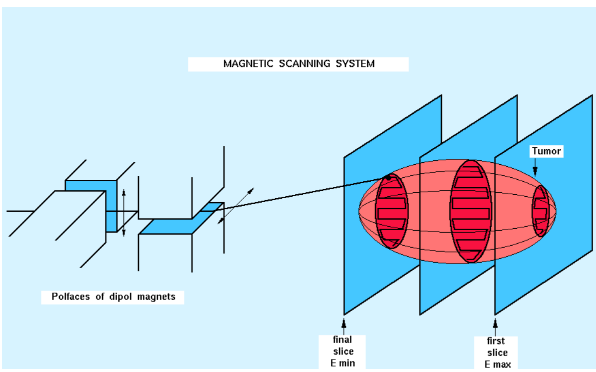


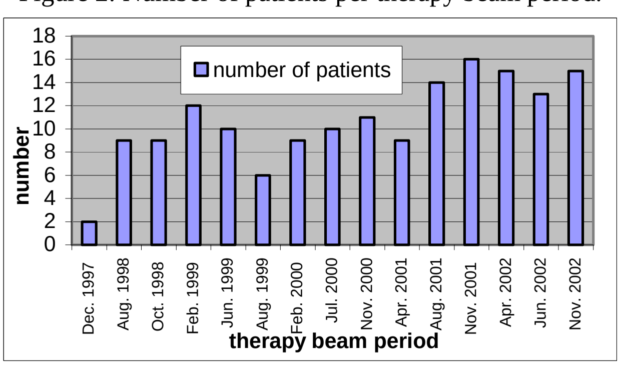
Figure 1: 3D irradiation system

shaped tumor and minimizes the dose in healthy tissue [1],[2]. This method requires the reliable request of a large variety of beam parameters (energy, intensity, beam-spot diameter) for sequential synchrotron cycles. Certain restrictions to the physics experimental program have to be considered during the treatment sessions. To deliver excellent conditions for the other experiments, these restrictions had to be kept as small as possible.

1 OVERVIEW

Within the last 5 years about 160 people suffering from tumors mostly in the head region have been treated. The first beam time took place in December 1997 without any time sharing with other experiments. Figure 2 displays the number of patients treated in the beam periods since 1997. During the following years per year 3 beam periods for patient treatment of about 32 days length took place, in parallel physics experiments were performed, but under certain restrictions during daytime. One of these restrictions is the limited beam energy for parallel experiments due to the influence of saturation effects of the SIS quadrupole magnet fields, that leads to a deterioration of the spill structure. Therefore the magnetic rigidity for parallel experiments was limited to 10 Tm (normal operation value up to 18 Tm). Due to safety aspects no fast extracted beam and no electron cooled beam is available for experiments behind the SIS.

Figure 2: Number of patients per therapy beam period.



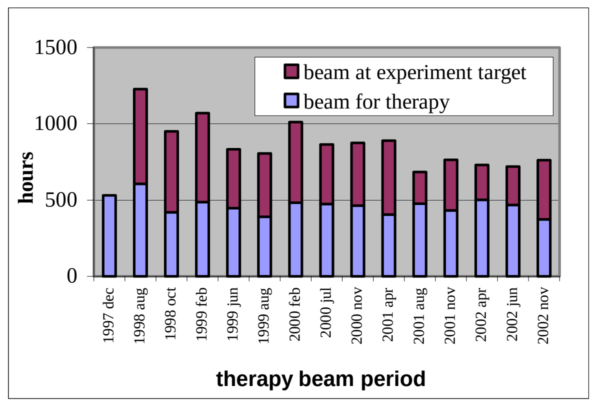


Figure 3: Target time for therapy and parallel experiments during therapy periods.

In Figure 3 the target time for the therapy and the parallel experiments is given. The about 500h available target time corresponds to 16 hours therapy operation time per day. The number of target hours for the other experiments varies due to the beam time scheduling. Up to the year 2000 a lot of physics experiments which used carbon beam took place. The request of having an additional isotope available at the SIS is in contradiction with requests of the UNILAC low energy experiments. Therefore the target time for the physics experiments is decreased after 2000.

2 ACCELERATOR SETUP

For the raster scanning technique the beam parameters of table 1 have to be available by request of the scanning system. The isotope is provided by the ECR- ion source at the High Charge State Injector, the intensity steps are performed by a rf-chopper system at the HLI, the energy steps are provided by the synchrotron SIS. The different beam diameters are produced by changing the setting of the last quadrupole doublet in the beam line to the treatment place CAVE M.

Table 1: Beam parameters at the isocenter CAVE M.

	range	step	rel. variation
isotope	$^{12}C^{6+}$	-	-
beam energy	80-430 MeV/u	255	Fixed
intensity	$2*10^6$-$2*10^8$	15	-50% +30%
focus	4-10 mm	7	25%
position hor.	5.0 mm	-	25% of focus
position vert.	3.7 mm	-	25% of focus

All settings are stored in nonvolatile storage chips, the access to the settings is made directly by the device control system. The setting for the UNILAC is done by using proofed operation data. In principle, the settings for the high energy part of the beam line (SIS and beam line to treatment place) are produced by scaling the data of the theoretical accelerator model. To reach the required values for position, the settings of various steering magnets are obtained by measuring and correcting the beam position behind the SIS and in front of the treatment place. The same procedure is done with the device settings responsible for focus and intensity variation. The irradiation sessions are performed within a special time sharing mode. When the irradiation starts, the request of all other beam cycles is disabled. The therapy supercycle is activated from the treatment control system, starting with the lowest requested energy up to the highest one. This means, that up to 30 minutes the activation of parallel experiments is prohibited [3].

3 BEAM TIME SCHEDULE

Every therapy beam time has a duration of about 32 days. Before the beam time starts 2 days are necessary for the preparation of the ion source. We need about 2 days for performing the various checks and the tuning of the accelerator-sections. 4 to 5 days are reserved for the commissioning of the treatment installations and the irradiation control system, e.g. checking the actions of those components, that switch off the beam on request within a few milliseconds. Furthermore, time is needed for test irradiations and for the verification of treatment plans. The next 22 days are filled with patients treatment. The corresponding schedule is given in table 2.

Table2: Daily schedule.

Time	Event
6:30	accelerator protocols
7:00	check of beam quality and safety system
9:00	patient irradiation (in parallel to physics experiments)
18:30	verification of irradiation plans, biological experiments
21:30	accelerator protocols
22:00	physics experiments

2 days are reserved for the case of longer unexpected breakdowns of any component and for development. The start and end times are not completely determined, they depend on the number of the patients and the complexity of the treatment plans. The nights are generally used for physics experiments. During the commissioning time of the accelerator (first 5 days) the carrying out of other experiments between 6:00 and 22:00 makes no sense. But when the patient treatment is started, there are breaks of 20 to 30 minutes between the irradiation times for positioning the next patient. These times are mostly used for physics experiments. The fraction of beam time for physics experiments is about 40-60%. The data for a typical day are displayed in table 3. They are extracted from the pulse to pulse logging of the SIS intensity, which are displayed at the GSI controls group web page [4].

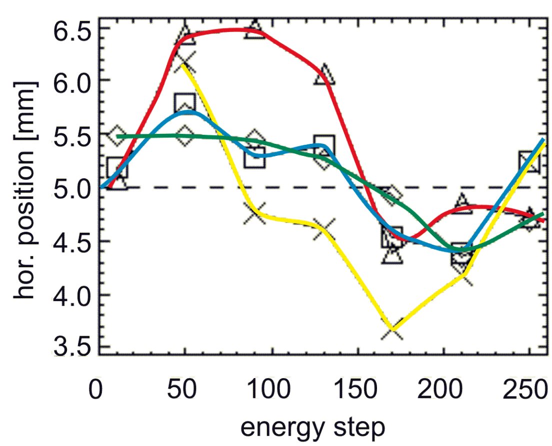
Table 3: Time sharing operation (28 of Nov. 2002).

Acc	Pulses	ratio (%)	beam time (h)
therapy	3963	41	4:37
exp1	504	5	2:17
exp2	2321	23	1:58
exp3	3100	31	4:26
sum	9888		13:18

4 ACCELERATOR OPERATION

Besides the accelerator tuning during the commissioning phase a lot of hardware checks have to be done to ensure a reliable and safe operation. For the optimization of the beam parameters expert systems are used. To provide the requested beam quality for the patient treatment a system to check the beam parameters

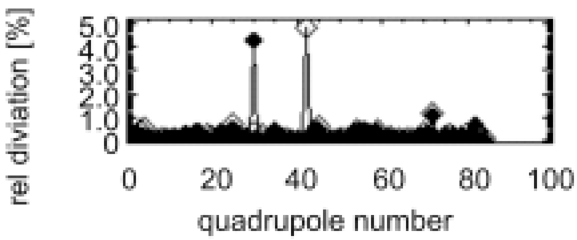
Figure 4: Calculated horizontal beam position at the treatment place for different beam diameters.



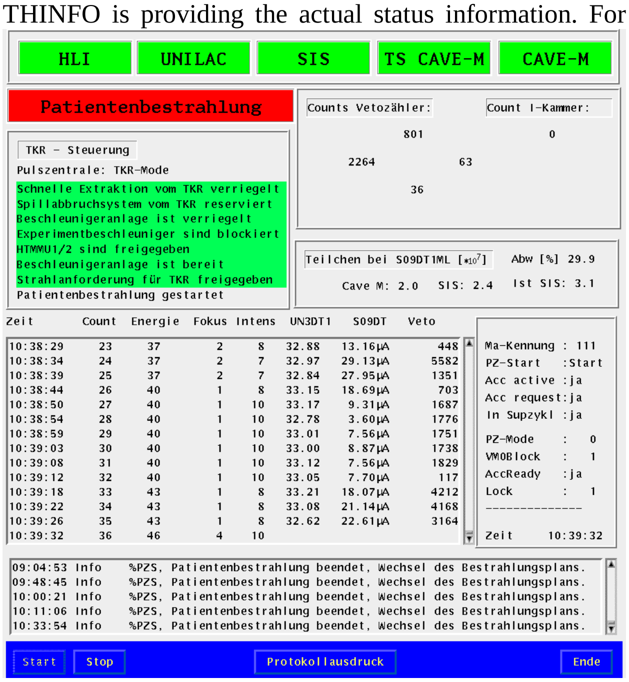
has been established. Every day at 6:30 and 21:30 a data protocol is made. The operators have to start prepared beam cycles and measured values of beam parameters are taken automatically. For example, Figure 4 displays the calculated horizontal beam position for different energies and different beam diameters at the treatment place, derived from measured beam diagnostic data. The calculation is based on measured positions at two beam profile grids in front of Cave M. Similar data are collected for the 15 intensity steps and for a special selection of device values.

For the therapy cycles the device values are measured and stored in special files. These data can be easily compared to reference values by graphical means. Figure 5 displays the relative deviation between set value and measured value of the current of the power supplies for all quadrupoles. The empty symbols corresponds to one measurement, the filled characters corresponds to another one.

Figure 5: Relative deviation of the current for quadrupole power supplies.



Due to the fact, that the irradiation is not controlled from the main control room (the therapy has its own control room near Cave M) the organization of communication between both places is important. Furthermore, the access to all accelerator components connected to the beam for therapy is disabled during the irradiation-time because of safety reasons. To reduce the direct communication (phone calls etc.) to a minimum level, both sides need to know what the other one is doing at the moment. For this purpose the computer program THINFO is providing the actual status information. For



the accelerator operators the information about the status of the irradiation is interesting. The therapy crew wants to know, whether the accelerator is working well or any component is out of order. The boxes at the top switch from grey to red colour if a component of the corresponding beam line breaks down. The dark red box indicates that the irradiation is running and turns to grey when it has finished. The green lines beneath show the status of several interlock functions concerning the safety system. This is connected to the disabled access to the accelerator components. In the large window at the lower left side information about the actual beam cycle (time, count, energy step, focus step, intensity step, the measured beam intensity) is displayed. On the right hand side information concerning the central pulse generator is displayed. The lowest box displays information about the therapy control system.

5 CONCLUSION

The patient treatment program has a great influence on the accelerator operation at GSI. Due to the requested beam quality additional installations and upgrades of many accelerator components had to be made. The reliability of the accelerator sections could be increased, and a better knowledge of the accelerator behavior in the time sharing mode was achieved. The improved scaling procedures of the settings reduce the tune up times for other experiments as well. The development of beam alignment and focusing procedures is concerned with therapy. A lot of smaller technical problems (jitter, ripple) were solved. Over the years for the operators some routine is developed, because the therapy requests keeps constant. Due to the restricted time regime the organization of the time sharing operation mode is difficult. The tune up times for the physics experiments have to be scheduled carefully. They are shifted mostly to the late evening, which is not the best time if any problem occurs. A compromise has to be found between stable therapy conditions and tune up possibilities and times for the other experiments. In principle, long range experiments have to be scheduled preferably. For the experiment scheduling the long carbon runs makes this task difficult. For difficult physics experiments we interrupt the patient treatment for one day to enable the accelerator tuning.

For the technical personal the support of all features for therapy operation parallel to the global upgrade of the accelerator is not easy. The checking everything works well needs 2 to 3 commissioning days in every beam time.

6 REFERENCES

[1]http://www-aix.gsi.de/~bio/home.html

[2] Haberer, Th. et al. , “Magnetic scanning system for heavy ion therapy,” Nucl. Intr. Meth. A330 (1993) p. 296

[3] H. Eickhoff et al. ‘Accelerator Control for the GSI Cancer Therapy Project’, EPAC 1998

[4]http://bel.gsi.de/acc/Online/online.html