Injection and Extraction-Performance at the SIS/ESR-Facility

H. Eickhoff, K. Blasche, U. Blell, B. Franzke, J. Pinkow
GSI, Gesellschaft für Schwerionenforschung mbH
D-64220 Darmstadt

Both the "Heavy-Ion Synchrotron" (SIS) [1] and the "Experimental Storage Ring" (ESR) [2] are designed for beam accumulation and beam extraction. The concepts are different in each machine according to the specific beam-properties and requirements. In this article a summary of the technical realisation of the injection and extraction systems and the operation results are given.

	type	duration
		(s)
SIS		
Injection	Multi-turn	1×10^{-6} - 5×10^{-4}
	fast	2×10^{-7} - 3×10^{-6}
Extraction	fast	2×10^{-7} - 3×10^{-6}
	slow	2×10^{-2} - 10
	stochastic	2 - 10
ESR		
Injection	fast	2×10^{-7} - 3×10^{-6}
Extraction	fast	2×10^{-7} - 3×10^{-6}
	slow	2×10^{-2} - 10 (*)
	stochastic	10 - 1000 (*)
	charge ch.	10 - 1000 (*)

(*) = estimated

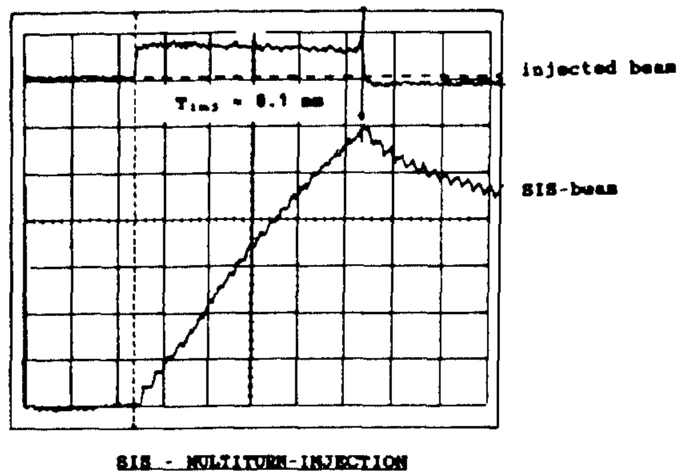

Figure 1: Multiturn-Injection at SIS
The upper trace shows the beam-transformer signal in the injection beam-line; the lower shows the beam accumulation in SIS over 20 turns.

The maximal achieved accumulation factor is near 30, which is close to the theoretical one, if the theoretical losses during the process are taken into account.

1 INJECTION MODES

1.1 *Multiturn-Injection (SIS)*

The UNILAC, the injector for the SIS, delivers the ion beam with a macropulse-length between 0.5 and 5 ms. In the SIS the beam is accumulated by stacking in the horizontal phase space ("Multiturn-injection") with 4 fast ramped bump-magnets.

The injection-line, designed for ions with a magnetic rigidity between 0.5 and 4.5 Tm, consists of an electrostatic "chopper", matching quadrupoles, an inflector magnet, and an electrostatic wire-septum.
The injected emittances are near 5π mm mrad both in hor. and vert. phase space; the SIS hor. acceptance is calculated to be about 200π mm mrad, corresponding to a maximal accumulation factor of 40.

1.2 *Fast Injection (ESR, SIS)*

After fast extraction at SIS the ion beam is injected into the ESR by means of "fast injection" with "bunch-to-bucket" transfer. The incoming beam is deflected to a stable injection orbit by a C-shaped kickermagnet, consisting of 3 modules in one vacuum vessel. The "double-shot" operation mode allows a rapid transfer of two times 2 bunches, that can be accepted by the ESR, within one SIS-cycle (see Fig. 2). Beam accumulation is done in the longitudinal phase-space by the RF-stacking method; during this injection process beam cooling by means of the electron-cooler is performed on the accumulation-orbit. Cooling on the injection orbit is possible as well, either with the electron-cooler and/or in the near future by stochastic cooling. This injection procedure has become a routine operation mode; improvements of the injection- and accumulation efficiency are necessary.

0-7803-1203-1/93$03.00 © 1993 IEEE

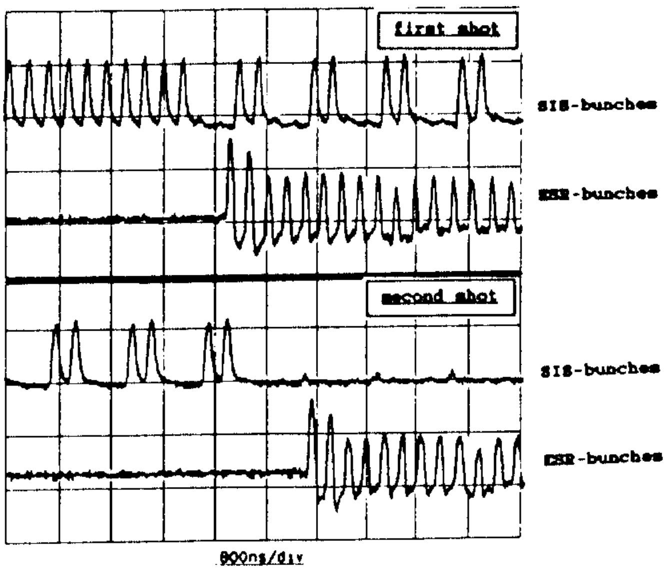

Figure 2: Fast Injection into the ESR.
Two times 2 out of 4 SIS bunches are injected.

For the SIS Reinjection mode the ESR serves as the Injector for the SIS. The cooled ion beam with a maximal magn. rigidity of 10 Tm is fast extracted from the ESR and injected ("bunch-to bucket transfer") into SIS for postacceleration up to 18 Tm and delivered to the experimental areas by means of fast or slow extraction. The fast inflecting device in SIS is the kickermagnet, that is also used for fast extraction; 4 auxiliary coils within special bending magnets create a local closed orbit bump to minimize the required kick-strength; the 3 magnetic injection septa are switched in series and connected to a special designed pulsed power supply.

2 EXTRACTION MODES

2.1 *Fast-Extraction (SIS, ESR)*

The fast extraction mode is used for beam transfer to the ESR and for experiments, which need high-intense pulse currents. The main device for this operation mode is the kickermagnet (also used for Reinjection), which is housed in two vacuum vessels. In total 9 parallel switched kicker modules can be excited sychronously at maximal beam rigidity, in order to deflect the beam into the extraction channel. The deflection time can be varied continously between 200 and 3000 ns; thus, a various number of bunches can be extracted. Due to the special power-supply design a second extraction is possible after at least 30 ms ("double-shot").
In the extraction channel the beam is deflected by 3 septum-magnets, which are switched in series and connected to the power-supply of the main dipoles; this extraction channel is used both for fast a slow extraction. The extraction efficiency can be estimated to be around 90%.

At the ESR a cooled ion beam with a magnetic rigidity between 1 and 10 Tm can be fast extracted to the SIS (SIS-Reinjection) with the ESR injection kicker. This mode was already successfully tested.

2.2 *Slow-Extraction modes (SIS, ESR)*

At SIS the Resonance-Extraction mode is used for most high energy experiments within a wide energy-range up to a maximum magnetic rigidity of 18 Tm. After acceleration the beam is gradually driven into a horizontal 1/3-order resonance by means of 6 sextupoles and two fast quadrupoles. The unstable particles are deflected into the extraction channel by an electrostatic wire septum.

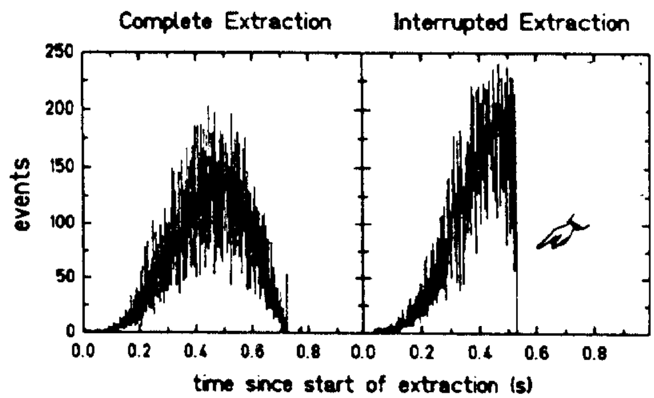

Figure 3: Slow (resonant) extraction at SIS with rapid spill interruption

Due to the quality of the magnet power-supplies, a spill duration of up to 7 s with moderate time structure on the spill is achieved. Extraction efficiencies around 85% were reached; beam emittances of 2 π mm mrad (horizontal) and 4 π mm mrad (vertical) were measured at high energies (1000 MeV/u) [3].
Fast interruption (about 200 μs) of the extracted beam is possible by the request of the experimentalists [4] (see Fig. 3).
Beside the 1/3-order resonance-extraction 2 additional slow extraction modes are under investigation at the ESR. The first mode is the beam extraction, which takes advantage from electron capture- and electron stripping-processes by the electron cooler and the internal gas-target, leading to a change of the magnetic rigidity of the circulating ions. Beam simulations show (see Fig. 4), that due to the different orbits these ions can be deflected into the extraction channel MS by 2 deflecting devices: one small septum magnet ESM for the ions having captured an electron and the electrostatic septum ES (that is also used

for the resonant extraction) for the stripped ions. (Fig. 4) The advantage of this type of extraction is the preservation of the excellent beam quality (emittance, momentum spread), that is achieved by the electron-cooling. The extraction time, which depends on the stripping- and capture cross-sections that can be reached, are estimated between some seconds up to several minutes.

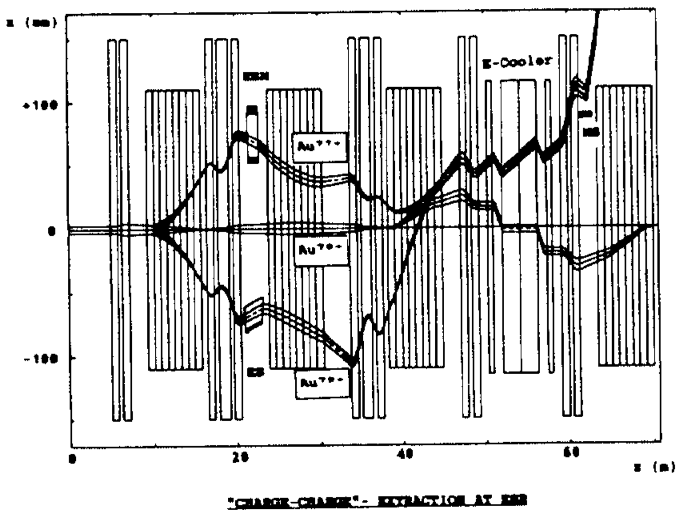

Figure 4: Different Orbits for Charge-change-Extraction Au+77 (electron capture in electron-cooler), Au+78 (injected beam), Au+79 (electron stripping in the gas-target)

A third slow extraction mode under investigation is the 'stochastic' extraction, that is used at LEAR for spill durations up to 1 hour. Within a thesis at GSI [5] experiments of this type of extraction have been performed at SIS in order to examine the spill performance for extraction times of some seconds.

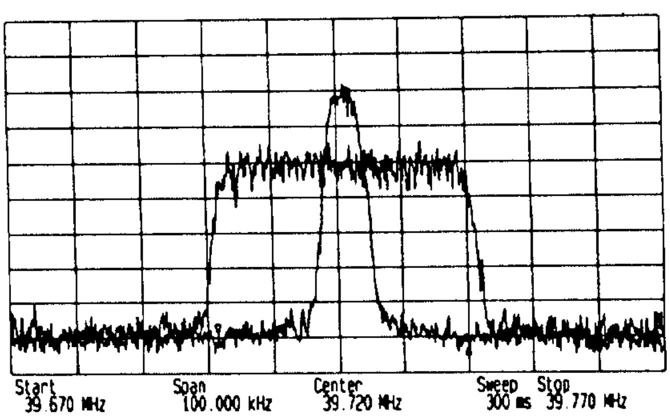

Figure 5: Shaping of an $^{18}O^{8+}$-beam at 697 MeV/u
Both the momentum-distribution before (gaussian) and after shaping with a noise of 4 kHz bandwidth, applied during 1 s with a voltage of U = 750 V, are shown.

Both low-frequency noise amplitudes used for the beam-shaping and the diffusion process to the 1/3 order resonance are created by means of a digital noise-generator connected via a mixer to one of the SIS accelerating cavities. Comparisons between the resonant- and stochastic extraction showed, that the spill-modulation is similar for extraction-times in the order of a few seconds; emittance measurements of the extracted beam indicate identical transverse emittances, but, as expected, in contrary to the resonant extraction a constant momentum of the spill for the stochastic extraction mode. It was also shown, that the influence of a power-supply ripple on the spill modulation is much poorer for the stochastic extraction. This extraction mode is intended especially for the ESR-operation in the stretcher mode for spill durations from a few seconds up to several minutes.

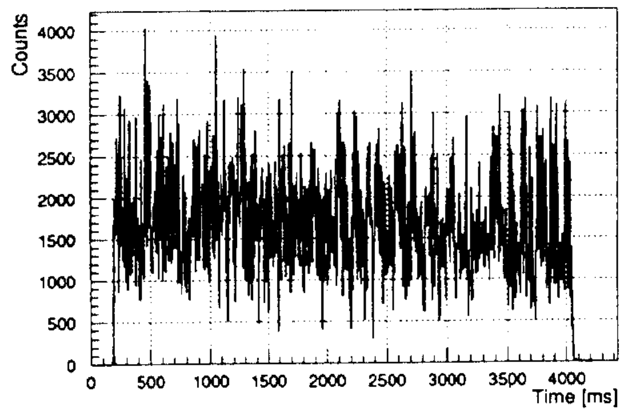

Figure 6: Stochastic extraction from SIS
The spill, measured by a scintillator in the extraction line, is shown

3 REFERENCES

[1] K.Blasche et al.; *The Heavy Ion Synchrotron SIS: A Report on New Design Features and on the Machine Improvement Program*; this conference

[2] B. Franzke et al.; *Results from Heavy Ion Beam Accumulation, Cooling, and Experiments at the ESR*; this conference

[3] M. Steineret al.; *Preliminary measurements of SIS18 beam parameters*; Nucl. Instr. and Meth. in Phys. Res. A312, p. 420-424

[4] Haberer et al.; to be pubished in Nucl. Instr. and Meth.

[5] J. Pinkow; Thesis; to be published