The Commissioning of the TRITRON

A. Cazan, G. Hinderer, H. J. Körner, J. Labedzki, P. Schütz, and U. Trinks

In September 1997 a $^{32}S^{+14}$ beam was accelerated in the Tritron for the first time continuously, increasing the energy from 40 MeV to 72 MeV. By this the feasibility of the Tritron - concept of a superconducting separated orbit cyclotron was demonstrated.

All components of the Tritron worked very reliably, stable and reproducibly:

- The cryostat has been kept cold at least below 80 K since January 1997, with only one warm up in August, needed for minor maintenance work on some probes during one day.
- The fields in the superconducting channel magnets are reproducibly correlated to the currents in the coils, they stay stable for many days. Within the limit of the detection efficiency of $\Delta B/B \simeq 10^{-4}$ no effects were observed affecting the field levels: neither hysteresis effects of the steel or magnetization of the superconductor, nor cross talking from neighbouring channels (when varying the currents by $\simeq 10^{-2}$), nor leakage of the currents in the superconducting switches and joints for the current bypasses of the coils. Once the optimum field settings for a certain beam energy have been found (with the cavities not yet switched on), they can be used for further runs with the same beam energy without any variations, even if the magnets had been warmed up in the meantime. This stable and reproducible tuning facilitates the beam funneling considerably.
- Though not being handled under special clean room conditions the quality factors of the cavities (f_{rf} = 170.7 MHz) stayed above the design value during a period of several years after the original electroplating procedure with PbSn: $Q_o \geq 3 \cdot 10^8$ at $U_{max} = 500kV$ in the gap, corresponding to a dissipated heat of less than 5 W per cavity. Coarse tuning is made by mechanical deformation, fine tuning by sapphire rods(slow) and piezoelectric actors (fast). An electronic control system provides for stability of phases ($1\,^\circ$) and amplitudes (10^{-3}). The reproducibility is of the same order. Actual phase and amplitude settings are made by observing the shift of the radial position of the beam half a betatron-oscillation downstream of the cavity.

Some work had to be done to stabilize the phase and energy of the beam injected from the tandem. Additional control systems had to be implemented into the existing ones. As standard a 40 MeV $^{32}S^{+14}$ beam was used, with the tandem voltage at 8 MV, the gas stripper in the terminal, and a post-stripper. Typical currents were 10 pnA. The ions were injected into the Tritron with the repetition rate of the orbital frequency $f_o = f_{rf}/h$ = 3.6 MHz with the harmonic number h = 47. The pre-buncher in front of the tandem modulated the dc-beam on this frequency, yielding ion bunches of 2 ns duration at the post-buncher behind the tandem. The post-buncher reduced this pulse length, resulting in a time focus at the post-stripper with a time spread of 200 psec and an energy spread of about $8 \cdot 10^{-3}$, which correspond approximately to the longitudinal eigenellipse on the first orbit. Due to the isochronism of the beam matching system between the post-stripper and the first cavity in the Tritron the pulse length was conserved. The post-buncher was operated at a frequency $23 \cdot f_o$ = 83.55 MHz. By varying the phase-difference between pre- and post-buncher the latter was used to correct energy deviations, which had been detected by the analysing magnet and the slit system behind the post-stripper. Phase deviations were detected by a pick-up probe near to the post-stripper and then corrected at the post-buncher. The resulting stability of the phases of the bunches at the first cavity in the Tritron was about $\pm 1^o$, the relative stability of the energy of the central particle of the bunches $\pm 4 \cdot 10^{-5}$.

On September 12th the phases and amplitudes of the six cavities of the Tritron were adjusted in a proper manner to accelerate a $^{32}S^{+14}$ beam, starting at an energy of 40.3 MeV. The beam was guided for the first time through 75 channel magnets along 6 turns with continuously increasing energy, finally resulting in 72 MeV. The currents in the channel magnets respectively the $B \cdot \varrho$-values follow a straight line with small deviations. These deviations show two oscillations, reflecting two coherent synchrotron oscillations with the expected number 0.5 per turn (see fig.1). The observed betatron-oscillation numbers and the momentum compaction factor were in agreement with theory. In two further test runs the transmission of the beam was improved considerably by optimizing the magnetic field settings.

The results of these first test runs demonstrate that the principle of the superconducting cyclotron with separated orbits works as anticipated. The experience of this year proves a very stable, reproducible and reliable operation of all components.

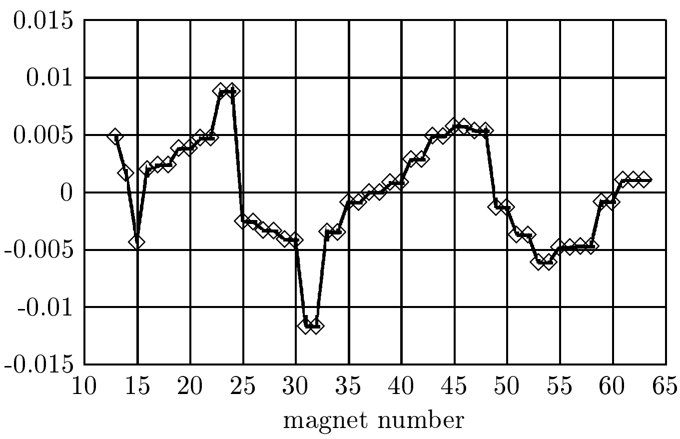

Fig. 1: The relative deviations from linear increase, $\Delta B \cdot \varrho/(B \cdot \varrho)$ versus the magnet number of turn 2 to 5, indicating two coherent synchrotron oscillations.