The TRITRON Development

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In 1996 the commissioning of the Tritron made further progress. The main activities concerned the following topics.

- Installation of additional position probes.
- Readjustment of the magnets.
- Final commissioning of the rf-control-system.
- Analysis of the properties of the injected ion beam.
- Optimization of the beam preparing system.
- Update and development of new control codes.
- Test runs with beams in the Tritron.

The geometrical aperture of the 240 channel magnets of the Tritron is extremely small (diameter 10 mm). The diameter of the bunches is about of 5 mm. A good alignment of the channel magnets is of fundamental importance.

In order to improve the centering of the beam and to get indications for misalignments of the channels an additional beam position probe system was installed. The original position probes (moving wires) exist in every second intermediate magnet sector only. Early in 1996 beam scrapers were inserted at the entrance of each channel magnet, without a significant reduction of the aperture.

Beam transport tests along the first two turns then revealed misalignments of the magnets of up to 5 mm in radial direction, caused by an unexpected deformation of the cold supporting torus, where the magnets and cavities are hanging on. A geodesic survey of the magnet positions after opening the cryostat confirmed the deformation. Readjustments of the magnets resulted in a reduction of the misalignments to 1 mm radially in the maximum, with minor shifts during about six months after several cooling cycles. The pattern of magnetic field values in the first 24 channels obtained for optimized beam transport along the first two turns corresponds rather well to the deviations of the magnets from the design orbit, when measured at room temperature. Further readjustments are planned to keep the deviations below 0.3 mm in the long term.

All six superconducting cavities can be operated at the design voltage of 500 kV with wall losses less than designed. When operating all cavities simultaneously at a maximum voltage of 400 kV the total heat load on the refrigerator due to the rf-power was measured to be less than 30 W. Fig.1 shows the quality factors Q of the six cavities as function of the maximum voltage in the gap, measured with the antennas strongly coupled to the field as needed for acceleration of the beam. For the cavities 4 and 5 the coupling was somewhat weaker, resulting in enhanced Q-values as shown in the two uppermost curves. The cavities were not treated by helium processing, which would shift the start of field emission to higher voltages. Note that the cavities were electro-plated with the superconducting Pb-Sn layer between 3.5 and 6 years ago and were exposed to laboratory air, whenever the cryostat was opened.

After some external sources of noise had been identified and decoupled from the cryostat, the phase and amplitude control system of the cavities was successfully taken into operation. The phases can be kept stable within 1^o and the amplitudes within 10^{-3}. The absolute phase of the rf-voltage at the passage of the bunches is determined by making use of the following calibration procedure. First, while the rf-field is switched off, the beam is centered in the five succeeding magnets. This length corresponds to half of a betatron-oscillation. Then the amplitude of the rf-voltage is put on maximum, and the rf-phase is shifted, until the beam is obtained well centered again. The bunches then cross the cavity at 0^o or 180^o without any energy shift. In case of 0^o the bunch is focused longitudinally and thus stays un-broadened, for 180^o the bunch is defocused, therefore the radial width is increased somewhat. This increase of the width is an indicator for the phase width of the bunch itself, it is used to optimize the pre- and post-buncher parameters. The absolute phase can be determined with a precision of about 3^o. The absolute amplitude value of the rf-voltage is calibrated to an accuracy of about 2% by observing the magnetic field values for centered beam with the rf-phases at 90^o resp. 270^o.

The energy gain in each cavity as well as the phases on the first turn have to follow a certain course according to an isochronous motion, at least in first order approximation. It is determined by the injection energy, the rf-frequency and the harmonic number of the revolution frequency. Because of the lack of knowledge of the precise value of the correct injection energy resp. the revolution frequency, the proper parameters have to be determined experimentally. This procedure was carried through several times. However the injection energy from the tandem turned out to be not sufficiently stable in the long term (design: $5 \cdot 10^{-4}$). Therefore the beam preparation system was investigated in some detail, revealing two major sources of troubles up to now. First the pairs of slits between the two 90^o - bending magnets in front of the Tritron are not well aligned. By this the signal for the energy control by phase shifts in the pre- resp. post-buncher is distorted. Secondly those phase shifts of up to 10^o are transferred by the succeeding isochronous beam guiding system to the rf-cavities of the Tritron, causing varying energy gain of the bunches. A corresponding phase control system is under development.

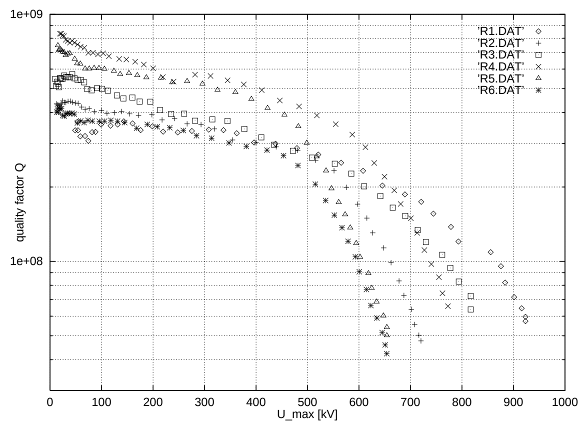

Fig. 1: Quality factors vice the voltage amplitude at the last beam hole for all cavities, measured in November 1996 with the antennas strongly coupled as under realistic beam conditions.