between the sources and the injection into the cyclotron has been equipped with new power supplies.

IMPROVEMENT OF VACUUM

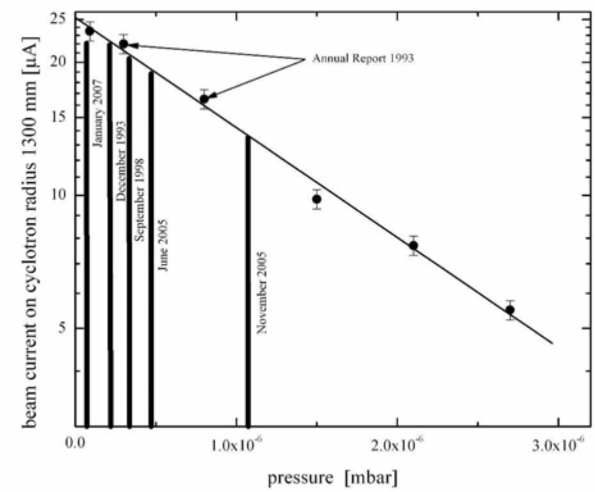

Figure 3: A semi-log plot of the beam intensity close to the extraction radius as a function of the measured pressure. The exponential fit includes all points and shows the limit for unrestricted pumping speed.

The upgrade of the vacuum system has proceeded. The replacement of the main turbo molecular pumps has been completed after the implementation of a new control system.

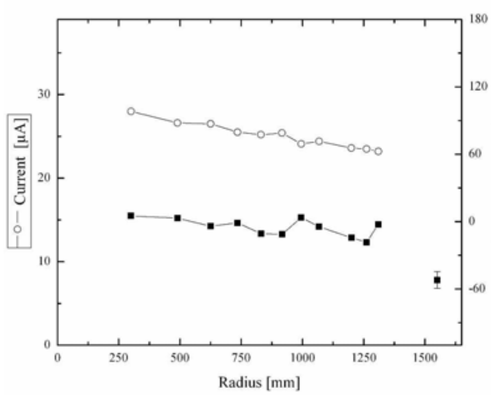

Figure 4: Beam transmission through the cyclotron, demonstrating the improved vacuum situation in 2006.

A vacuum leak at a welded flange was finally found and successfully fixed in the beginning of 2006. The polishing of critical surfaces, the installation of new vulcanized vacuum seals, where accessible, resulted in the recovery of the intolerable state of the vacuum system, which has reduced the performance for beam delivery of the injector in the second half of 2005. The pressure dependence of the intensity close to the extraction radius is depicted in fig. 3. The beam losses reached a critical level of over 50 % in November 2005. Shortly after the recovery from the shutdown the system has reached a pressure in the low 10^{-7} mbar regime. After some weeks the average pressure in the chamber decreased to values below $1 \cdot 10^{-7}$ mbar. The improved beam transmission through the cyclotron is given in fig. 4 for the case of unpolarized deuterons.

ADJUSTABLE AIR LINE

During the summer shutdown the damages at the linear tuning element of the central tuner became obvious during maintenance. Severe burn-out, scratches and broken contact springs made it necessary to overhaul the linear tuner completely. After refurbishment of the parts the operation has been continued delayed and with reduced working range for the frequency. The needed operational modes for COSY have been realized without problems. In summer 2007 the complete functionality has been recovered by an exchange of the support structure of the tuning element. The water cooled condensators with their motor driven positioning unit has been replaced successfully by a new construction.

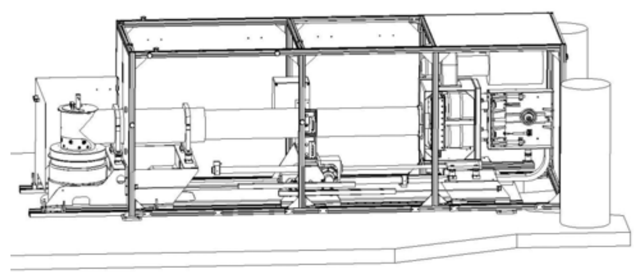

Figure 5: The new construction for the matching hardware on the top of the cyclotron magnet's yoke. The air line has been improved in summer 2006. The tuning condensators have been replaced in winter 2006.

SEPTUM OPERATION

A long term activity is the improvement of the extraction septum for the operation with deuteron beams at high momentum. Due to depositions on the isolator the usability of the septum is limited in case of operation at high voltages above 30 kV. The differential pumping system of the linear actuators has been replaced, providing improved leak rates in the vicinity of the septum. Two spare septa are manufactured to allow fast replacement.

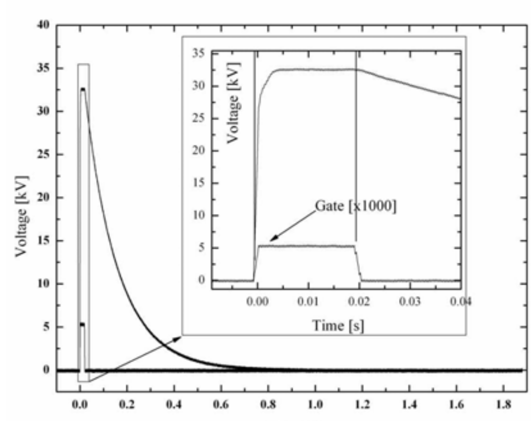

Figure 6: Performance of the pulsed extraction septum.

The availability of D$^-$ operation of the COSY injector is dependent on a reliable septum operation. To allow uninterrupted service the power supply for the septum has been pulsed for operation above 25 kV with rise times of around 100 ms. This mode of operation allowed the usage of an otherwise inoperable septum due to increasing loss of isolation. Over two years of operation between exchanges has been reached. Benefiting from the good experience with transistor switches for pulsed operation of the ion sources a switching circuit for the voltage of the septum has been realized for voltages up to 65 kV. With this switch rise times of about 2 ms are realized. The pulse width has been reduced to a fraction of the former set-up. The quality of the pulsing scheme is depicted in fig. 6. After reaching the desired deflecting voltage the voltage is kept constant until the end of the gating pulse. The slow decay in the unloaded test condition decreases under real test conditions due to the resistive load of the coated isolators of the septum deflector.

GAINS IN POLARIZED INTENSITIES

The colliding beams source itself provides polarized negatively charged protons or deuterons [6-7]. The original design value with respect to the attainable intensity had been 30 µA at the exit of the source. For several years that value had been a distant goal for routine operation [8-11].

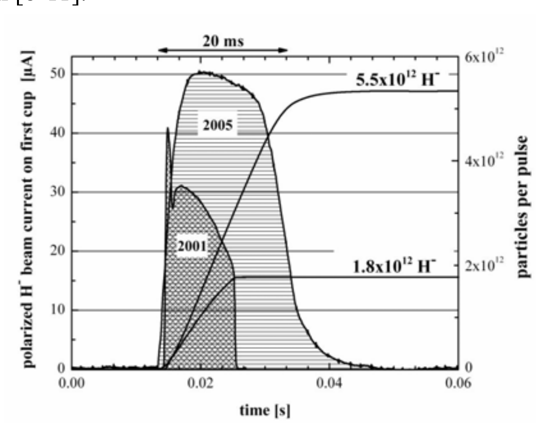

Figure 7: The gain in charged particles per pulse compared to the best result achieved in 2001.

A record value of 50 µA, surpassing the original design value, was achieved during a routine beam time in 2005 [12]. This was not the result of the optimization of a single component but the outcome of an optimization process that did not spare any component. Fig. 5 shows the pulse extracted from he source during that experimental run compared to a quit good pulse of a former setting used in 2001. The intensities of polarized beams extracted from the cyclotron exceeded 1.9 µA for deuterons and 2.0 µA for protons. With intensities of this magnitude it was possible to provide $2.6 \cdot 10^{10}$ polarized deuterons at maximum beam momentum in COSY for experiments. The time dependence of the unpolarized and polarized deuteron beam current during a cycle in the synchrotron is shown in fig. 8. The circulating beam current reaches 35.4 mA for unpolarized and 6.3 mA for polarized deuterons. The analysis of the signal from the beam current transformer demonstrates the capability to inject, to capture and to accelerate the beams with high efficiencies.

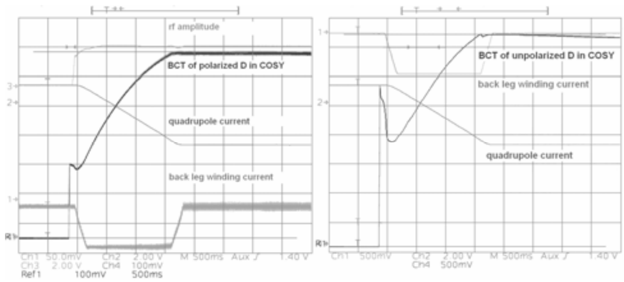

Figure 8: Deuteron beams in COSY.

ACKNOWLEDGMENTS

The authors like to thank the injector staff members Armin Kieven and Norbert Rotert, as well as Wolfgang Derissen from the IKP construction and Helmut Hadamek and his staff of the IKP workshop for their effective support of our endeavours in keeping the ion sources and the cyclotron JULIC operating reliably and to raising their performance.

REFERENCES

[1] W. Bräutigam et al; “H$^-$ operation of the cyclotron JULIC as injector for the cooler synchrotron COSY”; Proc. of Cyclotrons 1998, Caen, IOP (1999) p. 654.
[2] W. Bräutigam et al.; “Extraction of D$^-$ beams from the cyclotron JULIC for injection into the cooler synchrotron COSY”. Proc. of Cyclotrons 2001, East Lansing, AIP 600, (2001) 123.
[3] R. Maier, Cooler Synchrotron “COSY – performance and perspectives”, NIM A 390, (1997) p. 1.
[4] H. Stockhorst et al., “Progress and developments at the cooler synchrotron COSY“, 8th EPAC, (2002) p. 629.
[5] B. Lorentz et al., “Status of the cooler synchrotron COSY-Jülich”, 9th EPAC, Lucerne, (2004) p. 1246.
[6] W. Haeberli, NIM, 62, (1968) p. 355.
[7] R. Gebel et al.; “Polarized negative light ions at the cooler synchrotron COSY/ Jülich”; 10th Symp. on PNNIB, Kiev, Ukraine, AIP Conf. Proc. 763, New York, (2005) p. 282.
[8] R. Gebel et al.; “Negative ion sources at the injector cyclotron JULIC for the cooler synchrotron COSY”. Proc. of Cyclotrons 2004, Tokyo, Particle Accelerator Society of Japan, (2005) p. 287.
[9] P.D. Eversheim et al., “The Polarized Ion-Source for COSY”, Proc. of the SPIN 1996 Symp., Amsterdam.
[10] R. Weidmann et al., Rev. Sci. Instrum.,67 II, (1996) p. 1357.
[11] O. Felden et al., in Proc. of the workshop PST 2003, Novosibirsk, NIM A 536 Issue 3, (2005) p. 278.
[12] O. Felden et al., in Proc. of 11th EPAC, Edinburgh, (2006) p. 1705.