# Diagnostic Tools for the COSY-Juelich Synchrotron

J. Bojowald, K. Bongardt, J. Dietrich, H. Labus, H. Lawin, R. Maier KFA Jülich
and I. Mohos, KFA Jülich/KFKI Budapest

## Abstract

The cooler synchrotron COSY, a synchrotron and storage ring for medium energy physics, is being used for internal and external target experiments since fall 1993. The cooler ring has delivered protons up to now at 800 MeV. In this paper the used diagnostic tools in the COSY-ring are described. Results are presented for measurements during injection, acceleration and extraction. Almost all diagnostic components are installed and tested with beam. Special emphasis is given to the beam position monitors in the COSY-ring, which can measure in broad- and narrow-band mode.

## Introduction

COSY Jülich is a cooler synchrotron and storage ring with a proton momentum range from 270 to 3300 MeV/c. It has been conceived to deliver high precision beams for medium energy physics. Since its inauguration in April 1993 substantial progress in developing beams for the experiments has been achieved and the physics program has started with first measurements [1]. In this paper, the major diagnostic components for injection, acceleration and extraction are described.

## Acceleration of the accumulated beam

Up to now substantial progress has been made for accumulation and acceleration of particles in COSY. In Fig. 1, values for the particle intensity and the acceleration frequency are shown for a typical COSY-cycle. After 1.4 sec, at the end of the acceleration cycle, we have about $2 \cdot 10^9$ circulating particles at a frequency of 1.38 MHz, corresponding to a momentum of 1.5 GeV/c. After reaching the flat top values, the particle number stays constant, before the resonant extraction process starts.

The data are measured with a broadband wall current monitor [2], which is used also to observe and record the bunch shape.

## Measurement of closed orbit and betatron tune

In order to improve the acceleration effiency, the closed orbit values, and the betatron tunes are measured at injection, during acceleration and at flat top. The measurements are performed using the BPM-electronics [2] in the narrow-band mode (super-heterodyne methode). By this a good signal to noise ratio results even at low beam intensities. In order to make possible the tune measurements during the acceleration ramp, a PLL-controlled tracking generator was developed to produce the Local-Oscillator (LO)-signal for the mixer ciurcuits in the narrow-band measurement channels. The reference input signal is the COSY-rf. The LO-frequencies can be chosen equivalent to several harmonics (h = 1 - 10) of the COSY-rf, therefore the measurements can be carried out in a frequency range with low noise pickup. The spectral purity at frequency offsets of more than 8 Hz is better than - 60 dBc. Fig. 2 shows the block diagram.

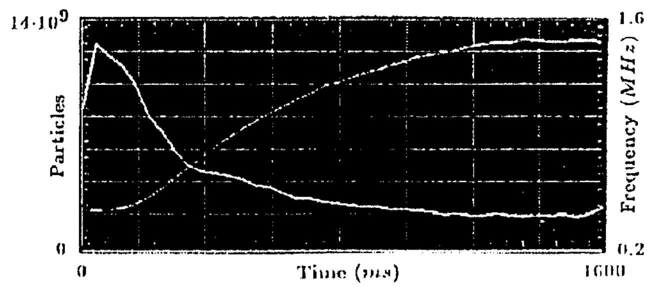


Fig. 1: Intensity ($2 \cdot 10^9$ /div) and acceleration frequency (0.2 MHz/div) against time (0.2 sec/div)

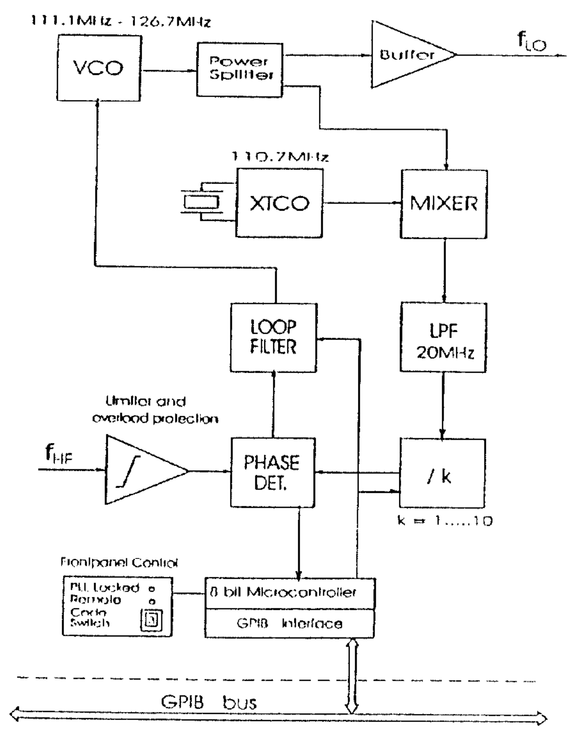


Fig. 2: Block diagram of the LO-tracking generator

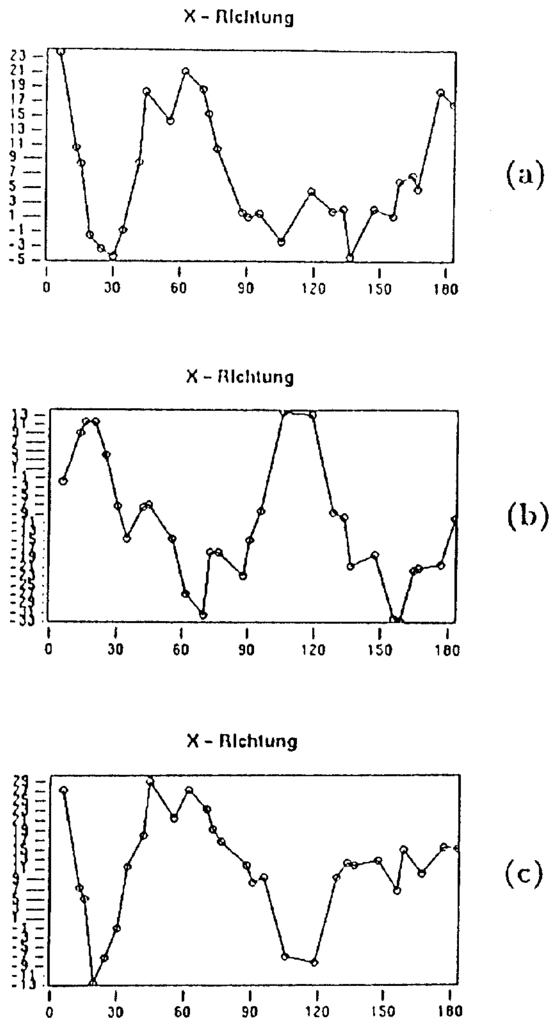


Fig. 3: Uncorrected horizontal closed orbit values (in mm) at injection (275 MeV/c) (a), during acceleration (1 GeV/c) (b) and at flat top (1.4 GeV/c) (c)

A strong change of the horizontal closed orbit during acceleration can be observed in this measurements. Probably it is caused by the significant variation of betatron tune, see Fig. 7. In Fig. 4, the uncorrected vertical closed orbit is shown, which is more or less constant during acceleration.

For measuring the betatron tunes quite precisely at injection or extraction energies, the beam is excited by a stripline unit and the signals of a beam position monitor (BPM) are monitored and analyzed by a spectrum analyzer; the tunes are extracted from the sideband peaks, which indicate the resonance of the betatron oscillation with the beam excitation [3].

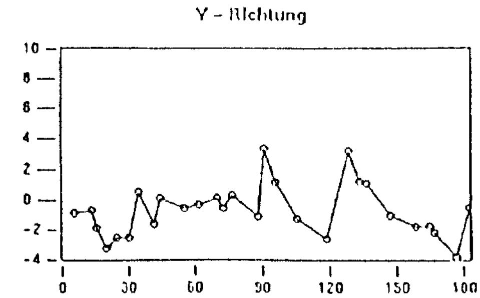


Fig. 4: Uncorrected vertical closed orbit (in mm)

During acceleration, up to now only the horizontal tune can be detected by firing a fast diagnostic kicker magnet within one revolution period. In Fig. 5, the forced damped oscillations around the uncorrected closed orbit are shown.

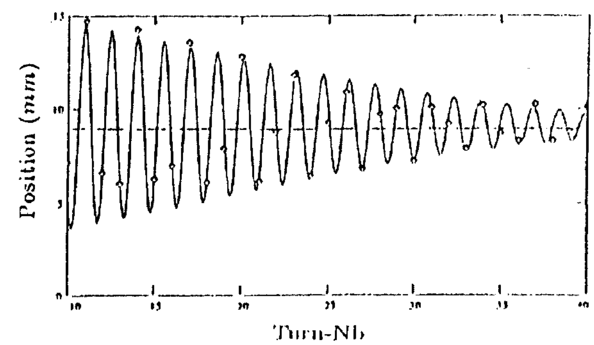


Fig. 5: Forced, damped oscillations around a 9 mm closed orbit

The crosses are the measured values from turn to turn, the broken line is the closed orbit value at this BPM, around 9 mm. The solid line is a fit for a damped oscillation, assuming a gaussian tune distribution [4]. The horizontal betatron tunes can be obtained from the oscillations either in time domain (Fig. 5) or in frequency domain by analyzing the betatron sidebands in the FFT-spectrum (Fig. 6). Both methods agree within their expected accuracy. The resulting horizontal tune values over one acceleration period are shown in Fig. 7. The tune change of about 0.05, which leads to a

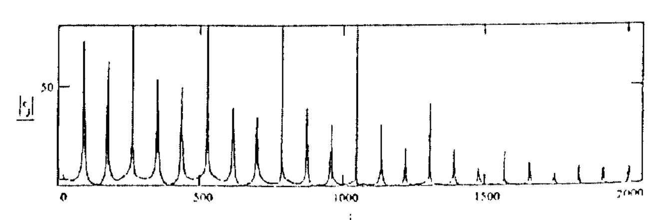

Fig. 6: FFT-spectrum of time signal from Fig. 5

2/3-resonance in this case, and especially the sharp decrease around a momentum of 1 GeV/c (at 1100 ms) can clearly be analyzed and give rise to a correction of the optics.

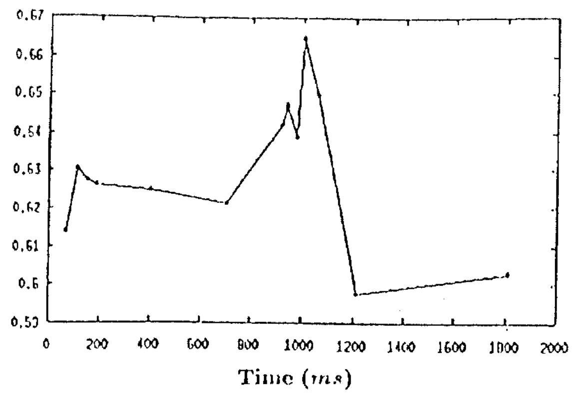


Fig. 7: Horizontal betatron tune over one acceleration period

Monitoring the Extraction Process

At flat top, the particles are slowly extracted over 1 sec by exciting a third order resonance. The beam is monitored by Multiwire Proportional Chambers [2] in the extraction beam lines, see Fig. 8. Integrating over the 64 wires in each plane gives the beam intensity during the extraction time, shown in Fig. 9. Also included are the traces of the sextupole power supply, the quadrupole power supply with "Q-jump" and the average COSY-beam current measured by the Beam Current Transformer (BCT).

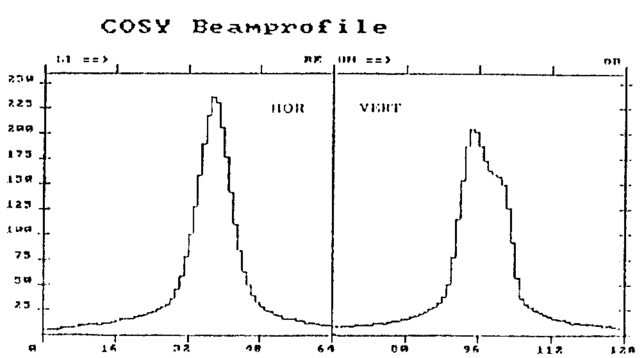


Fig. 8: Beam Profile of the extracted beam

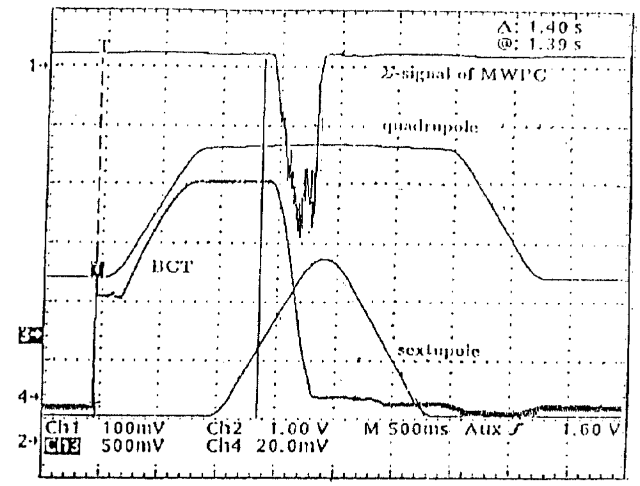


Fig. 9: Extracted Beam Intensity with the associated sextupole ramp, quadrupole ramp and average beam intensity in COSY measured with the BCT.

Acknowledgement

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References

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