The COSY - Jülich Project March 1992 Status

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Abstract

At present the cooler synchrotron COSY a synchrotron and storage ring for medium energy physics is being built at Jülich. The cooler ring will deliver protons in the momentum range from 270 to 3300 MeV/c. The phase space density of the circulating protons will be increased with electron cooling at injection and with stochastic cooling at momenta between 1500 and 3300 MeV/c. High luminosity internal experiments as well as high resolution external experiments will be possible.

Details of the lattice, to match the different ion optical requirements for cooling, acceleration, internal experiments and ultra-slow extraction are discussed. An overview and a realization status of the ion sources, the injector cyclotron, the ring, the injection and extraction beamlines are given. First experience on the commissioning of the injector complex is reported.

1. INTRODUCTION

The COSY facility consists of different ion sources, the cyclotron JULIC as injector, the injection beamline with a length of 100 m, the ring with a circumference of 184 m and the extraction beamlines to the external experimental areas. The high resolution beamline to the magnetic spectrometer BIG KARL, the beamline to the Time of Flight spectrometer and the beamline for medical therapy application [1] are under construction. In a later stage a fourth beamline will be added for polarization measurements.

The lattice of the COSY ring consists of two 52 m long 180^0 bending sections, which are separated by two 40 m long straight sections. The straights are designed as telescopic systems with a 1:1 image from the beginning to the end with a phase advance either π or 2π. Bridged by four optical triplets one straight section is dedicated for two internal target places TP 1 and TP2. The opposite straight section provides free space for the rf cavity, the electron cooler [2], scrapers, Schottky pick-ups and current monitors [3].

The two arcs are composed of six mechanically identical periods. Each of the mirror symmetric half cells is given a QF-bend-QD-bend structure leading to a six fold symmetry of the total magnetic lattice. By interchanging the focussing and defocussing properties additional flexibility for adjusting the tune is achieved. One of the bending arcs houses the injection and extraction devices, the stripping target, the magnet septum and bumper magnets for injection as well as the electrostatic and magnetic septa for extraction. The other arc offers space for a third internal target area TP3, which will make use of one of the ring magnets to separate 0^0 ejectiles, the diagnostic kicker and the elements for the ultra-slow extraction. At the intersection between straight sections and arcs the stochastic cooling pick-ups and kickers [4] will be installed. The basic machine parameters are summarised in Table I.

Table I

COSY Basic Parameters

Vacuum system	
pressure	10^{-10}-10^{-11} mbar
in the arcs	rectangular 150·60 mm²
in the straights	circular, ϕ 150 mm
RF system	
cavity type/ acceleration structure	symmetric re-entrant ferrite loaded
frequency range (h=1)	0.462-1.572 MHz
quality factor (at frequency)	8(400 kHz), 40(2 MHz)
max. rate of frequency increase	4 MHz/s
gap voltage (at duty cycle)	5 kV (100%), 8 kV (50%)
gap voltage dynamic range	55 dB
nominal/actual rf power	56/16 kW in push-pull
bending magnets	
number	24
radius	7 m
angle	15^0
field range	0.23-1.585 T
quadrupole magnets in the arcs	
number	24
no. of families	6
eff. length	0.3 m
aperture radius	85 mm
max. gradient	7.5 T/m
quadrupole magnets in the telescopes	
number	32
no. of families	8
eff. length	0.55 m
aperture radius	85 mm
max. gradient	7.5 T/m
sextupole magnets	
number	18
no. of families	7
eff. length	0.3/0.2/0.1 m
aperture radius	85 mm
max. strength	30 T/m²

The magnetic lattice of the ring has to match different ion optical conditions:

(i) the internal targets require low betatron functions and low dispersion

(ii) the slow extraction needs the horizontal tune near a third order resonance

(iii) the stochastic cooling demands a phase advance close to $(2n+1)\cdot\pi/2$ between the pick-up and kicker location for both planes

(iv) the electron cooler prefers low betatron amplitudes

These requirements can be fulfilled with the chosen working point. The beam and optical proporties are listed in Table II.

Table II

Beam and Optical Properties of COSY

momentum range	270-3300 MeV/c			
max. no. of stored protons	$2\cdot10^{11}$			
horizontal/vertical tune	3.38/3.38			
transition momentum	1860 MeV/c			
geometrical acceptance	horizontal:	130 π mm mrad		
	vertical:	35 π mm mrad		
	$\Delta p/p$:	$\pm$ 0.5%		
nat. chromaticity hor./vert.	- 5.2/- 4.5			
lattice function at	β_{hor}	β_{vert}	dispersion	
TP1:	5.6 m	5.9 m	0 m	
TP2:	1.6 m	5.1 m	0 m	
TP3:	6.0 m	22.2 m	10.1 m	
radii and divergences for an extracted emittance of 2.5 π mm mrad and $\Delta p/p$ of $1\cdot10^{-3}$ at	x/mm	x'/mrad	z/mm	z'/mrad
medical therapy area	3.25	1.34	1.88	1.24
Time of Flight	0.56	4.90	0.72	3.47
BIG KARL	0.45	7.14	0.43	6.92

2. ACCELERATOR COMPONENTS

Injector

With the low emittance H_2^+ source ($\lesssim$ 35 π mm mrad) particles have been injected into the cyclotron. Up to 150 μA of H_2^+ ions with an energy of 8.2 keV - needed for a cyclotron extraction energy of 80 MeV - have been transported to the hyperboloid inflector in the center of the cyclotron with almost 100% transmission in the source beamline and in the vertical cyclotron injection path. Measurements with this type of "pencil beam" have shown that the transmission through the source beamline and the cyclotron can be increased by reducing the beam emittance below the acceptance of the cyclotron. The source has shown reliable and stable performance over months of operation [5].

The H_2^+ ion source can be replaced by an H^-, D^- source. Due to the stripping injection process into the COSY synchrotron, this will be the way to store polarized protons or deuterons. The H^-, D^- source bought from the IBA company in Louvain-la-Neuve, Belgium, was designed to operate at an extraction voltage of about 30 kV. To adapt the source to the existing beamline (4.5 kV) two additional electrostatic electrodes are introduced. After a period of cyclotron operation with H_2^+ particles, the H^- source will be connected to the cyclotron to study the cyclotron performance for H^- ions.

After completion of the new cyclotron rf system in September 1991 measurements of the stability of amplitude and phase, the variation of frequency, the stable operation in the frequency range of 20 to 30 MHz have been performed. Under normal operation the amplitude stability refered to the maximum accelerating voltage of U_{max} = 45 kV was well below the specified value $U/U_{max} \lesssim \pm 1\cdot10^{-4}$ for all settings of voltage and frequencies in the tuning range. The phase stability refered to the output of the master oscillator proved to be $\lesssim \pm 0.3^0$. The maximum power of 100 kW exceeds the requirements for normal cyclotron operation, but the power is necessary to simplify the switching-on procedure to overcome the multipactor influence.

Accelerating system h = 1

The 50 kW rf acceleration system based on a ferrite-loaded, coaxial cavitiy, has been developed in close cooperation, and largely under contract with the Laboratoire National SATURNE and Tompson Tubes Electroniques. The accelerating system has been installed after measuring the rf properties. The fully digital synthesis and control of the low level acceleration voltage signals for the h = 1 acceleration system is beeing implemented [6]. Its synthesizer part was recently used for the system's acceptance test under actual ramp conditions for the COSY ring. The key characteristics for the high power part of the acceleration structure are given in Table I.

Injection and Ejection

The injection is a horizontal multi-turn process. Magnetic bumpers make a variable orbit deformation in the horizontal plane at the exit of the magnetic injection septum, permitting injection in successive turns.

For ejection a third order resonant extraction $3Q_h = 10$ is being considered. Phase and amplitude of the resonance will be controlled by the sextupole magnets. The first element of the extraction channel is the thin electrostatic septum adjustable both in angle and position.

The particles having been kicked by the electrostatic septum, are deflected by two magnetic septa. Table III summarizes the characteristics of the injection and extraction elements.

Table III

Characteristics of the Injection and Extraction Elements

magnetic injection septum	
deflection angle	0.34 rad at 0.6 GeV/c
magnetic field	1 T
gap	height: 64 mm, width: 110 mm
bumper magnets	
eff. length	0.35/0.7 m
field	58 mT/29 mT
rise time	10 ms
flat top	10 ms
fall time	20 ms
electrostatic ejection septum	
deflection angle	3.5 mrad at 3.3 GeV/c
eff. length	1 m
gap height	15 mm
max. voltage	150 kV
magnetic extraction septa	
deflection angle	2·87.5 mrad at 3.3 GeV/c
magnetic field	1.046 T
gap	height: 36 mm, width: 125 mm
length	2·969 mm

Vacuum System

The vacuum system is specified to operate at an averaged pressure below 10^{-10} mbar. To match this demand, each component is subject to an extended vacuum test. The procedure includes a pressure test in the 10^{-12} mbar range for sputter ion pumps, sublimation pumps and chambers. The valves and gauges are tested in the 10^{-11} mbar range. All parts have to fulfill an additional leak test.

Up to now approximately 500 vacuum components (about 90% of the whole vacuum equipment) have been checked. In general the defect items are below 5% of the total. Defect rates above the average have been found for the titanium sublimation pump cartridges (6%) and for the valves (remarkable 25% faults).

Control System

The control system is hierarchically organized with distributed intelligence and autonomous operation units for each accelerator component. Data communication is performed via local area network and field bus. The host systems are Unix based. On the field controllers a modular real time kernel RT/OS is running [7]. The computer hardware consists of RISC mini-computers from Hewlett Packard, VME-computers and G64 equipment controllers as an expansion of the VME-bus. The man-machine interface is being built using object based methods on top of the X-window system. First experience with the control system was gained during the commissioning of the source beam line and the cyclotron.

3. SUMMARY

Approximately 95% of the components of the facility COSY have been ordered or delivered. All magnetic elements for the ring, the injection and extraction beam lines have been installed in their final position. With the setups of the magnetic elements and power supplies for the ring measurements on stability, dynamic behaviour and permissible deviations are being completed. The commissioning of the injection beam line together with careful radiation protection measurements has been started. The upgrade of the high resolution spectrograph BIG KARL is in progress.

First injection into the cooler synchrotron and the commissioning are scheduled to start during summer 1992. Start of users' operation is aimed at April 1993.

4. ACKNOWLEDGEMENT

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