THE COSY–JÜLICH PROJECT

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R. Maier, U. Pfister and R. Theenhaus for the COSY–Team

Forschungszentrum Jülich GmbH,
Postfach 1913, D–5170 Jülich, Germany

Abstract

At present the cooler synchrotron COSY, a synchrotron and storage ring for medium energy physics is built at Jülich. The cooler ring will deliver protons and light ions in the momentum range of 275 to 3300 MeV/c. To increase the phase space density of the circulating protons electron and stochastic cooling will be used. The cooled beams will be used for experiments with internal and after slow extraction with external targets.
The facility consists of different ion sources, the cyclotron JULIC as injector, the 100 m long injection beam line, the ring with a circumference of 184 m and the extraction beam lines to the external areas. The start of the users operations is provided to be in autumn 1992. An overview of the machine, beam parameters and the status is given.

Introduction

The COSY ring is composed of two 180 degree bending arcs and two straight sections. The two arcs consist of six mechanical identical periods. The straights, bridged by four optical triplets, provide free space for internal target areas, for the RF stations and for the phase space cooling devices [1].

The magnetic lattice is based on a six fold symmetry. Each of the mirror symmetric half cell has a QF–bend–QD–bend structure. Additional flexibility of the tune is given by interchanging the focusing and defocusing quadrupoles. In the straights the momentum dispersion can be suppressed with the supersymmetry two. The straight sections are built as 1:1 telescopes. The phase advance in both telescopes can be either π or 2π. The machine and beam parameters are summarized in table 1.

The vacuum system is designed for pressures less than 10^{-10} hPa. The vacuum chambers have a diameter of 150 mm in the 40 m long straight sections and a rectangular cross section of 150 x 60 mm^2 in the two 52 m long bending arcs. The chambers will be manufactured from SS316LN.

The transverse stochastic cooling system will be built as a two band system with an overall bandwidth of 2 GHz. The first band ranges from 1 to 1.8 GHz the second band from 1.8 to 3 GHz. This system offers a cooling rate of $7 \cdot 10^{-2}$ Hz for 10^{10} protons. The minimal expected emittance is in the order of 1 π mm mrad.

The diagnostic instrumentation will consist of a system which measures the intensity, the orbit deviation, the phase relationship between the RF and the beam phase. Strip line units will excite the beam in both transverse planes. This will be used for fast measurements of the betatron tunes and also to evaluate stability thresholds of the beam [2]. The control system will be realized in hierarchical manner and will be devided into three major layers. The control operations will be partially implemented in the system layer, the work cells and the process I/O layer. In the system layer the model calculation and simulation are installed. Most of the accelerator components will have their own controller. They are built on the basis of VME systems to achieve autonomous functions.

momentum (kinetic energy) range		275–3300 MeV/c (40 MeV–2500 MeV)
injection momentum (kinetic energy)		275 MeV/c (40 MeV)
max. number of stored protons		$\leq 2 \cdot 10^{11}$
circumference		184 m
typical cycle	injection	$\leq$ 10 ms
	ramp up/down	1.5s/1.5s
	e–cooling	1–4s
	s–cooling	10–100s
internal target areas		4/6 m
bending magnets, No, radius, field at 3.5 GeV/c		24, 7 m, 1 67 T
arc quadrupoles, No, No of families, magnetic length, max. grad. at 3.5 GeV/c		24. 6, 0.29 m, 7.5 T/m
telescope quadrupoles, No, No of families, magnetic lenght, max. gard. at 3.5 GeV/c		32, 4, 0.65 m, 7.65 T/m
focusing structure		6 periods, seperated function FoBoDoBooBoDoBoF
betatron wave numbers		3.38, 3.38
γ_{tr}		2.06
Aperture limitation		$a_h = \pm$ 70 mm, $a_v = \pm$ 27.5 mm
geometrical acceptances		
	horizontal	130 π mm mard
	vertical	35 π mm mrad
		$\frac{\Delta p}{p} = \pm$ 0.5 %
vacuum system pressure		10^{-10}–10^{-11} hPa
bake out temperature		300 °C
pump down time		70 h
RF system		
frequency range (h=1)		0.462 – 1.572 MHz
gap voltage (at duty cycle)		5 kV (100%) 8 kV (50%)

Table 1: COSY Basic Parameters

An expert system is under development to support commissioning and operation. The layout of the COSY accelerator facility is given in figure 1. The internal target areas, the electron cooling section, the reserved sections for transverse stochastic cooling and the external experiment areas are clearly marked.

Accelerator components

Magnets

After successful testing and field measurements of the prototyp dipole the series manufacturing was started. The seventh magnet is under construction now. The unit cell and telescope cell quadrupoles prototypes are delivered. Field measurements and optimization of the end profiles are on the way. Series production will begin in September 1990. Sextupole magnets are ready to be assembled for the first prototypes of the long and short version. Steering magnets are under construction. The design of the different injection and extraction septum magnets are finished and all components are under construction.

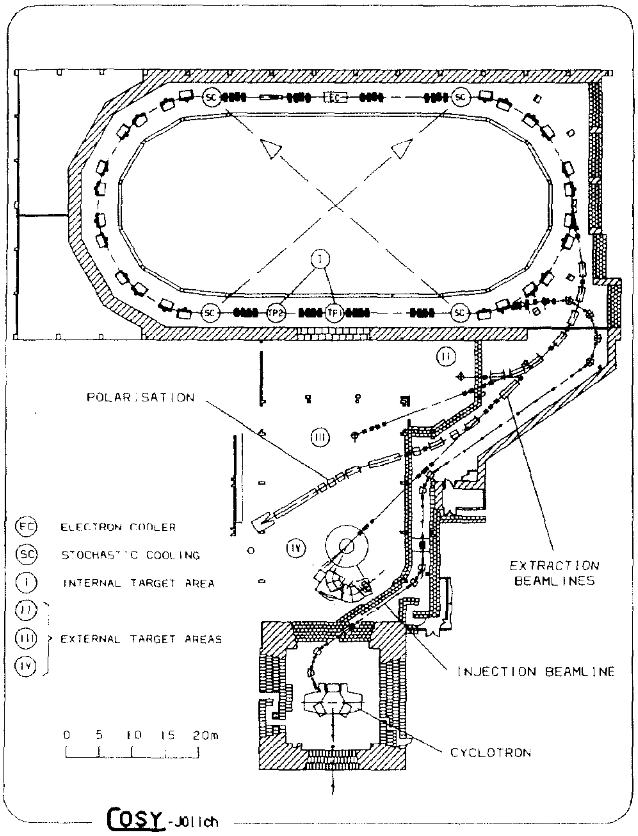

Figure 1: Layout of the COSY accelerator facility

Power Supplies

For the pulsed operation COSY needs an overall power between 3 MVA at injection energy and 15 MVA at final energy of 2.5 GeV. Thus very stable power converters with a wide dynamic operation area and nominal output powers in the range of about 100 kW to several MW are required for most of the magnets in the ring. The first converter of this type with an output current change from 200 A to 5000 A within 2 s has been installed mid '89 as main power converter for all field measurements. Figure 2 shows typical trapezoidal cycles of a dipole current together with the difference between demanded and actual values. The difference stays all the time within the given tolerances of $2x10^{-4}$ during the flat niveaus and $1x10^{-3}$ during the ramp periods.

The prototype converter for the quadrupole magnets is under commissioning. The main power supplies for the dipole– and quadrupole magnets are to be delivered end '90. The remaining power converters for the ring are ordered (bumpers, septa) or are under tendering (sextupoles, correction converters).

Concerning the slow dc power converters for the COSY injector the small converters for the trim coils are in operation, while the extremely stable converter for the main field is under commissioning.

Accelerating station h=1

The radio frequency acceleration system for COSY will employ a ferrite–loaded cavity scheme of the symmetric push–pull type [3] after originally a LEAR–type system had been explored as well. CW gap voltages in excess of 5 kV will be achieved by a pair of power amplifiers with total nominal output power of 50 kW. A provision for amplitude modulation will permit adiabatic trapping of the beam bunches

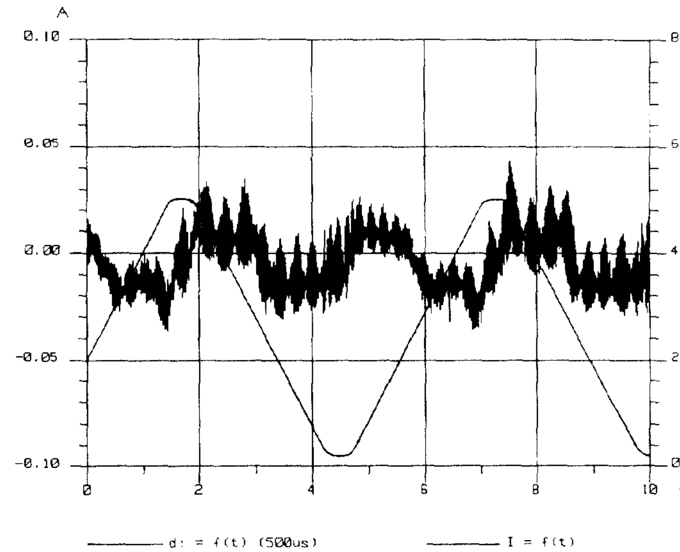

Figure 2:
Cycles of dipol current (right scale) together with the difference between demanded and actual valves (left scale)

after injection. During acceleration, the frequency has to be ramped from 450 kHz to 1.7 MHz. Polarisation currents of about 800 Ampturns will match cavity and amplifiers by ferrite bias in real–time. The main parts of this system will be fabricated by a cooperation between the Laboratoire National SATURNE, and Thomson Tubes Electroniques. Thus, the COSY rf system will be very similar to the systems used in the SATURNE ring, although it will run at considerably lower frequencies due to the much larger circumference of COSY.

Another specific demand on the COSY rf acceleration system will be imposed by the need for passing the transition point, where the rf phase has to be adjusted by ca. 180^0. At present, a fully digital (at ca. 20 MSPS, 14 bit) rf waveform synthesis and phase control is envisioned with the capability of a full 2π phase acceptance and adjustment range, independent of the specific choice of the transition and operation point. It will supply the proper acceleration waveform for amplification, with an integrated control feature to avoid synchroton oscillations of the beam bunch.

Slow extraction

Slow beam extraction is planned to take place via a 1/3–integer type, i.e. sextupole–driven resonance. The system will largely be modeled after a CERN–design [4]. A two–channel longitudinal drive system is fed by a common noise source. One (higher power) channel has a narrow noise spectrum with center frequency around the resonance. It serves for the rapid "sweep–out" of particles at resonance. The other channel serves at first to flatten the beam profile into a near–rectangle; thereafter, it generates a noise distribution (that is sweeping in center frequency) in between the original beam profile and the resonance to transport beam particles to the resonance. In the present design, the system will operate at a center frequency of h=10, with a minimum extraction time of 5 sec imposed by rf and kicker power limitations.

Electron cooler

An electron cooler of the active length of 2 m will be installed in the 7.2 m long free section of the cooler telescope (Fig. 1). The electron cooling will serve as a tool for beam preparation before acceleration. This offers highest storable phase space density in a fast cycling operation. The phase space condensation leads to a reduction of the transverse emittance of the injected beam down to the order of 1 π mm mrad, to the decreasing of the momentum spread (rms) to the order of 10^{-4}, and for bunch beam to shortening of the bunch length. In stage 1 the electron cooling will operate during the injection, using a 22 keV electron beam, in stage 2 after injection and acceleration to an intermediate flat top, using an 100 keV electron beam. The simulated cooling times for stage 1 and stage 2 operation for chosen lattice parameters are summarized in table 2 [5]. τ^* is the time rate to cool a beam of 15 π mm mrad emittance (both horizontal and vertical) down to 5 π mm mrad.

E_e [keV]	E_p [MeV]	I_e [A]	B [mT]	τ^* [s^{-1}]
22	40	1.8	84	1
100	184	4.0	150	4

Table 2:
Simulated cooling rates for stage 1 and stage 2 operation of the COSY electron cooler.

Experimental areas

For high luminosity experiments the ring will run with thin internal targets in the recircular mode. Two internal target stations will be available, they are located in the center of the target telescope (TP1) and TP2 between the two quadrupole quadrublets 7.3 m further downstream of TP1 (Fig. 1).

The ionoptical conditions in the target telescope can be varied over a wide range to match the experimental conditions in an optimized way. At TP1, for instance, the experimentator can choose between double achromatic beam or high spatial dispersion but no angular dispersion, small ß–function for small beam spot and long lifetime of the beam or large ß–function, which gives a parallel beam and allows for good angular resolution. The free length for experimental installations will be 4 m for TP1 and 6 m for TP2.

The extracted beam will be directed to three different target areas (Fig. 1). The target area II and III will be fed by direct beamlines without special ion optical request. The beamline IV is a high resolution beamline to the spectrometer BIG KARL, which allows for small spot sizes at the target. For a momentum of 2.25 GeV/c the expected beam sizes and divergences are 9.7 mm, 0.6 mrad in the horizontal and 4.5 mm, 1.1 mrad in the vertical direction. With an achromatic section which is the first part of the beamline system, the adaptation of the different working points and dispersion can be made. For the beamlines II and III a double achromatic and telescopic imaging will be possible. For the beamline IV to the BIG KARL spectrometer a doubly achromatic beam at the target point together with a small target spot sizes of $\leq$ 1 mm for an emittance of 5 π mm mrad will be available.

Theory

The basic design work for the COSY lattice is done. Special effort is given to the design of the components for the stochastic cooling. Model calculations for transverse cooling had been done to optimize cooling time and amplifier gain for a given final emittance and working point. One cooling system per plane can be used which allows to cool a number of stored protons in the range 10^8 ppp $\leq N \leq 10^{10}$ ppp at energies $T \geq 1.5$ GeV with a reasonable rate [6]. The model has been checked against the existing stochastic cooling systems at CERN and FNAL and it gives a good description of the existing data.

An extension to the code MICADO has been worked out. This code ORBIT uses the theoretical knowledge about the desired optics of the ring for the description of closed orbit corrections. This procedure helps to solve the ambiguities for the general closed orbit problem. The ORBIT program can be used for a control system of ring accelerators.

Extensive studies by particle tracking has been done for the description of the slow respectively ultraslow extraction. The 3rd order extraction resonance is driven by sextupoles and by a noise generator acting onto the longitudinal phase space. The required momentum spread of the COSY external beam ($\Delta p/p = 10^{-4}$) during extraction needs a special procedure for the tuning of the chromaticity.

The special modes of operation according to the different experiments using internal and/or external beams are under investigation. The influence of internal targets is studied by explicit tracking simulations taking into account the special physics of energy loss and Coulomb scattering processes.

Due to the electron cooling process at injection energy, the beam is transversely unstable, but for 10^9 ppp the growth rate is tolerable. For more than 10^{10} ppp an active damping resp. feedback systems are requested together with a transverse heating system in order to avoid problems with stop–bands in the tune diagram.

The analysis of the measurements of the magnetic field in the dipole magnets using the RAY TRACING program gives a procedure for the alignment and for special closed orbit corrections.

Summary

The accelerator building had been finished in May 1990. More than 70% of the equipment has been ordered and delivery has been envisaged within the foreseen time–schedule.

Between the external area III and IV an additional beamline for polarization experiments is under discussion. A combination of dipols and superconducting solenoids is foreseen to realize all spin directions.

Acknowledgement

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