© 1989 IEEE. Personal use of this material is permitted. However, permission to reprint/republish this material for advertising or promotional purposes or for creating new collective works for resale or redistribution to servers or lists, or to reuse any copyrighted component of this work in other works must be obtained from the IEEE.

THE COSY – JÜLICH PROJECT – FEB. 1989 STATUS

R. Maier, S. Martin, U. Pfister for the COSY team

Kernforschungsanlage Jülich GmbH
Postfach 1913, D–5170 Jülich, F.R. Germany

Abstract

The layout of COSY the cooler synchrotron and storage ring at Jülich is presented. Together with the most important design considerations an overview of the actual scheme and realization status is discussed. Details on the upgrading of the injector cyclotron, the injection and the extraction beamlines are given. The machine and beam parameters are shown.

Introduction

The technical description of COSY by the 1985 established COSY design group had been finished in July 1986. The project management started in February 1987. Since August 1987 the project had the formal approval of the company partners. The total budget of the facility without the money for personnel is limited to about 85 million DM. In December 1991 the commissioning will start and one year later the users operation will begin. The COSY facility consists of the cyclotron JULIC, the 100 m long injection beam line, the ring with a circumference of 184 m and the extraction beamlines to the experimental areas. Fig. 1 shows the COSY facility. The isochronous cyclotron JULIC will be extensively upgraded to optimize the beam parameters (10 μA H_2^+ ions of 80 MeV), to improve the reliability (main and correction power supplies, RF) and the operation (diagnostic, instrumentation and computer control).

The ionoptical design of the injection beamline consists of a matching section at the exit of the cyclotron, two achromatic arcs, the adaption arc to the ring and of three straights with FODO lattice structure. The beamline assembly maximizes the experimental areas.
The cooler synchrotron is build like a racetrack. The two arcs consist of six mechanical identical periods. They are interrupted by two 40 m long straight sections. The straights, subdivided by quadrupoles, provide free space for experimental set–ups, for RF and phase space cooling installations. The magnetic lattice of COSY is based on a six fold symmetry. Each period consists of two mirror symmetrical half cells with two bending magnets and two quadrupoles in each half. The focussing structure per period is given by QF–bend–QD–bend––bend–QD–bend–QF. It's possible to interchange the focussing and defocussing quadrupoles. This increases the flexibility of the ionoptical design. The lattice functions of one period in the arcs are shown in fig. 2. The straight sections are telescopic with a phase advance of 2 π to minimize the distortion of the lattice functions.
The vacuum system is designed for pressures less than 10^{-10} hPa. The vacuum chambers have a diameter of 150 mm in the straight sections and a rectangular cross section of 150 x 60 mm^2 in the bending arcs. The chambers will be manufactured from SS316LN. The candidate material for extra stress loaded chambers is Inconel 625. The technical data of the bending magnets, the quadrupoles, the sextupoles and the RF–system are summarized in table 1. The control and the diagnostic system is described elsewhere [4,5]. To yield beams of high phase space density stochastic and electron cooling is foreseen. The working range of the longitudinal and transverse stochastic cooling system is 0,5 to 3 GHz. The cooling equipment is divided in groups of working energies around 150, 800 and 1500 MeV. For the first operation period of COSY a system for medium energies will be built [6]. The electron cooling will be used for preparation of the beam at injection energy (40 MeV) in order to define the emittance and the momentum spread. Fig. 3 shows a drawing of the electron cooler.

General description

Power supplies

The 24 dipole magnets connected in series are fed by one power supply (1600 V, 5000 A dc). This power supply consists of a conventional 12 pulse thyristor controlled rectifier bridge connected in parallel via a big choke with a fast transistorized dc voltage source. The big bridge delivers about 90% of the required current while the fast voltage source acts as a ripple controller following the solution which has been chosen at GSI Darmstadt for the SIS/ESR machines.

The quadrupole magnets are split into 14 families, each family fed by one power supply (190 V or 270 V, +/– 550 A dc). All 14 power supplies are identical concerning the power block and control. The supplies will be equipped with transistorized switch mode modules for fast ripple control. The polarity change at the output of each power supply is achieved by means of a respective pole communicating switch to be activated only at zero current. Very stable dc currents are required during particle injection (235 A dipole current, 5 A ... 50 A quadrupole current) and during storage and particle extraction mode (900 A ... 5000 A dipole current, 50 A ... 500 A quadrupole current). The current shape and the tolerances are summarized in table 2.

Geodesy

The geodetic concept is as in other accelerator laboratories to achieve compatibility in hard– and software [7]. The selected measurement procedures,equipment and the alignment targets harmonize with the already existing geodetic network of the injector and the beamline.

Control

The control system is divided into three major layers. The functionalities are partially implemented in the system layer, the work cells and the process I/0 layer. In the system layer the machine (HP 9000 S850) for model calculation and simulation is installed and is under operation for the theory and design groups. The communication and backup machine (HP 9000 S840) is installed and maintains all the mailing traffic. Backup services are under tests with the file system of realtime kernel development. The power converter workcell is installed, the operating system is established and the integration in the control net is achieved.

In the different component groups of the process I/0 layer the evaluation of the operating system kernels for the VME system is finished. An UNIX based environment the SRTX/SEM combination from Stollmann (Hamburg) has been chosen. A cross software development system from HP (HP64000) including an assembler, a C–compiler and a linked editor is being installed.

Magnetic field measurement

Field measurements of the dipoles will be done by long integrating coils. The feed tables including control hardware and software are ready. The software for control readout and calibration of the integrators are implemented and tested.

The girder for the search coils including the fixations has been machined. One set of 10 coils was wired and calibrated. The layout of the hardware and software for this facility enables the measurements of multipoles with gradient .arch coils if necessary.

For a few dipoles at the locations of injection and extraction, point by point field measurement is required in the stray fields. This will be done with a small 3D–table and a temperature compensated carrier with 3 Hall probes measuring B_x, B_y, B_z.

Measurement of the multipoles will be done by slow rotating compensated coils. The complete measurement bench was built, assembled and tested. Hard– and software for control and data acquisition were tested successfully.

Injector cyclotron JULIC

RF–system

The major components of the existing RF system will be replaced in order to provide the necessary stability of the important RF parameters phase ($\Delta\varphi \approx 1°$) and amplitude (Δ U/U $\leq$ 2 ... 3 10^{-4}), to have sufficient RF power even under worse operation condition, and to support reliable operation and easy control. Not only the RF power generator with P_{out} = 100 kW in the frequency range of f = 20 to 30 MHz will be renewed but also the auxiliary system components and the dedicated computer control. Special components like installations within the vacuum chamber, the coaxial feedthru of the RF power line, the coupling loop, amplitude and phase detection units will be replaced.

The new transmitter excites the accelerating system by inductive coupling, i.e. the RF power will be injected into only one dee by a suitable loop. The resulting asymmetry in the voltage distribution over the 3–dee–system is less than 1% and is hence negligible. Extensive model measurements give reliable input for the layout of the impedance matching network. The existing frequency fine tuning system, which uses rotatable loops in the space between dees and dummy dees, will be replaced by a completely new construction. With the present RF oscillator removed from the top of the yoke an additional RF port becomes available at the end of the feeder line. A new tuning system will be connected to this port, not only for the slow tuning of the resonance frequency of the accelerating system but also for compensating of fast disturbances introduced into the system by mechanical vibrations.

The coarse frequency tuning system via panels will be preserved. It will be equipped with a new motion control in order to achieve the necessary precision.

Trim coils

The tuning of the isochronous field is performed by 3 pairs of sector coil arrangements (plates) mounted on the hill sectors of the pole tips inside the vacuum chamber. The coil construction made extensive use of epoxy resin for insulation and the mechanical fixing of the components. Radiation damage reduced the solidity of this organic material and resulted in short circuits and in the peel off of (watercooled) sheet metal covers. So cooling is reduced and large extremely outgassing surfaces occur in narrow slits and influence badly the vacuum pressure in the tank. For the H_2^+ ions, to be accelerated for COSY in the cyclotron, a vacuum pressure of $< 1 \cdot 10^{-6}$ hPa is required. As a consequence new trim coils were designed, optimized with respect to radiation damage as well as from vacuum point of view.

For the trim coils 14 power supplies (35 V, 120 A dc), the power supply (160 V, 150 A) for the mainfield and the power supply (40 V, 1000 A) for the compensating channel will be renewed.

Performance data

The upper energy of 2.5 GeV for protons is chosen, such that about 1 GeV excess energy in the c.m. system of pp collisions is available. This gives access to channels with strangeness and to some interesting mesonic states. The lowest threshold for strangeness production in the pp reaction is 2339 MeV/c (T = 1582 MeV) for pp $\rightarrow K^+ \Lambda^0 p$.

The lower bound of the energy (40 MeV), is given by the cyclotron JULIC delivering 80 MeV H_2^+ ions for stripping injection.

In the synchrotron mode the ring is designed to operate in the energy range from 40 to 2.5 GeV and to ramp the rigidity with a rate up to 6 Tm/s.

Emittance and momentum distribution

The H_2^+ ions beam delivered from the cyclotron has the following characteristics:

ϵ_h/ϵ_v = 3.2/6.4π mm mrad
$\sigma_{\Delta p/p}$ = $0.65 \cdot 10^{-3}$
N = $7.5 \cdot 10^5$ H_2^+ ions per bunch every 40 ns

The acceptance of the ring is filled by stripping injection up to 80%. During injection process the circulating beam will be moved away from the stripping target (25 mm/ms) to provide complete filling in the horizontal plane. Vertically the injected beam will be sweeped across the target. In this way $2 \cdot 10^{11}$ protons can be injected. The intensity is near the space charge limit at an energy of 40 MeV, for emittances 150/35 π mm mrad.

The momentum spread will grow to about $1.5 \cdot 10^{-3}$ (standard deviation), which is about the limit of the longitudinal microwave instability.

Summary

The main components of the ring, the bending magnets, quadrupoles and the corresponding power supplies have already been ordered. For other equipments like sextupoles, correctors, power supplies, DC current transformer, beam position monitor electronics, scrapers, viewers, ring RF and for the turnkey packet of the injection beamline the specifications have been written and for more than 90% tenders are in house.
A RF station working up to 200 kV at the cyclotron bunch frequency is under study.
The topping–out will celebrated at May, 31 1989. The cyclotron operation for nuclear experiments will stop in September 1989. From October 1989 to March 1990 the installation and modification of the cyclotron components will be done.

Acknowledgement

We are grateful for contribution by our colleagues from BESSY, CERN, DESY, GSI, CELSIUS, IUCF, LBL Berkeley, MPI Heidelberg, PSI, RWTH Aachen, SLAC, University of Dortmund and wish to recognize the stimulating discussions by the CANU members.

References

[1] U. Bechstedt et al., Cooler synchrotron COSY, Technische Beschreibung Jül–Spez–370, Sep. 1986.

[2] U. Pfister, Status of the COSY Jülich, First European Particle Accelerator Conference, Rome, June 1988.

[3] P. Krejcik et al., COSY lattice Description, First European Particle Accelerator Conference Rome, June 1988.

[4] N. Bongers et al., Expertsystem for COSY–Control, First European Particle Accelerator Conference, Rome, June 1988.

[5] R. Maier and U. Hacker, Beam Diagnostic for COSY Jülich, this Conference.

[6] N. Bongers et al., First Considerations on Stochastic Cooling in COSY Jülich, First European Particle Accelerator Conference, Rome, June 1988.

[7] A. Hardt, G. Kroel, Arbeitstreffen Geodesy an Beschleunigern, Jülich, 3./4. Mai 1988.

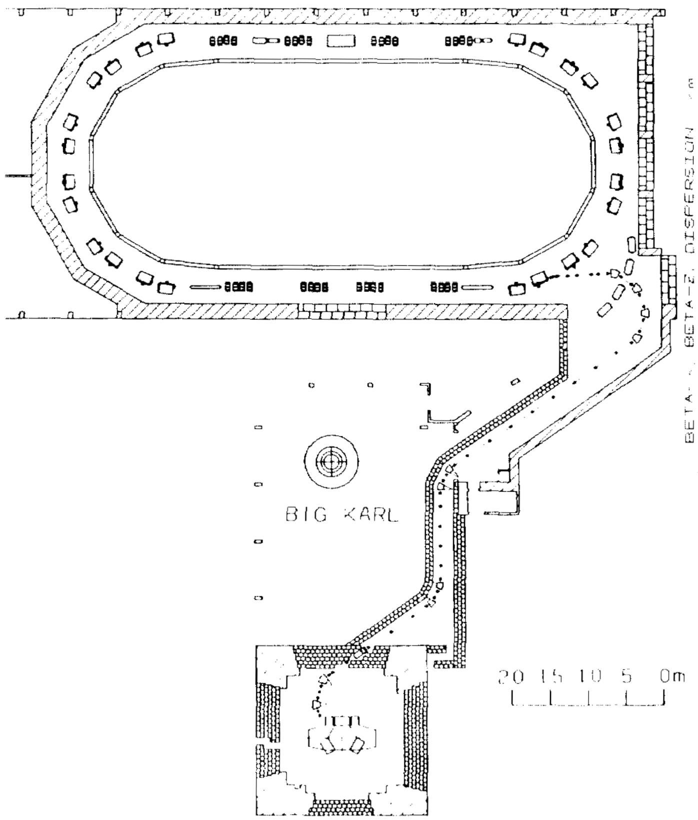

Figure 1: Layout of the COSY facility

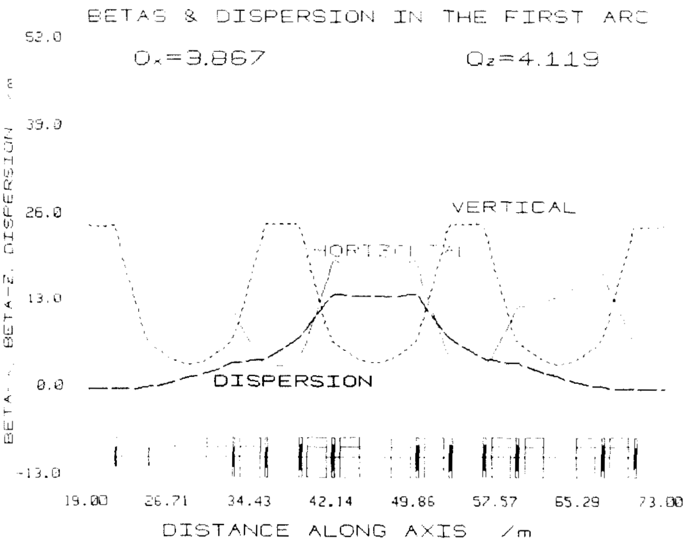

Figure 2: Lattice functions of the arc section

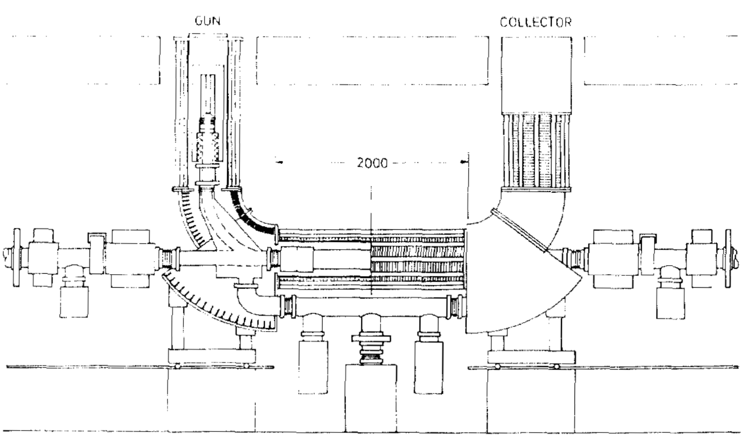

Figure 3: Drawing of the electron cooler

bending magnets:	24	
bending radius:	7	m
field at 3.5 GeV/c:	1.67	T
quadrupoles in bending sections:	24	
number of families:	3	
eff. length:	0.29	m
$\partial B/\partial r$ at 3.5 GeV/c:	7.50	T/m
quadrupoles in straight sections:	32	
number of families per sect.:	4	
eff. length:	0.65	m
$\partial B/\partial r$ at 3.5 GeV/c:	7.65	T/m
Sextupoles in bending sections:	10	
number of families:	3	
eff. length:	0.11,0.2,0.3 m	
$\partial^2 B/\partial r^2$ at 3.5 GeV/c:	15	T/m^2
Sextupoles in straight sections:		
number of families:	4	
eff. length:	0.2	m
$\partial^2 B/\partial r^2$ at 3.5 GeV/c:	13	T/m^2
rf–system (h=1):		
f at injection:	0.462	MHz
f at 3.5 GeV/c:	1.58	MHz
energy gain per turn:	1.3	keV
peak voltage:	5	kV
vacuum chamber:		
ϕ in straight section:	150	mm
bend region:	150x60	mm^2
vacuum:	$<10^{-10}$	hPa

Table 1: Technical data of the ring equipments

Operation modes

Period	Operation
I	Injection, cooling
II to IV	Acceleration
V	Storage
VI to VIII	ramp down

Period	Duration ms	Dipol current A	Tolerance $\delta I/I$	Quad. currents A	Tolerance $\delta I/I$
I	$\geq$ 10	$\leq$ 235	$\pm 4\cdot 10^{-4}$	5...42	$\pm 8\cdot 10^{-4}$
II	200	235...470	$\pm 8\cdot 10^{-4}$	5...84	$\pm 8\cdot 10^{-4}$
III	$\geq$ 1600	235..5000	$\pm 8\cdot 10^{-4}$	5..550	$\pm 8\cdot 10^{-4}$
IV	200	900..5000	$\pm 8\cdot 10^{-4}$	55..550	$\pm 8\cdot 10^{-4}$
V	$\geq$ 10..DC	900..5000	$\pm 1\cdot 10^{-4}$	55..550	$\pm 8\cdot 10^{-4}$
VI	200	900..5000	$\pm 5\cdot 10^{-2}$	55..550	$\pm 5\cdot 10^{-2}$
VII	$\geq$ 1600	5000...235	$\pm 5\cdot 10^{-2}$	550....5	$\pm 5\cdot 10^{-2}$
VIII	200	470...235	$\pm 5\cdot 10^{-2}$	84....5	$\pm 5\cdot 10^{-2}$

Table 2: Current and timing diagram of the dipol and quadrupoles