DESIGN ASPECTS OF THE INJECTION BEAMLINE FOR THE COOLER SYNCHROTRON AT KFA JUELICH

F. Anton, D. Krischel
Interatom GmbH
Accelerator and Magnet Technology
D-5060 Bergisch Gladbach 1, FRG

Abstract

The 100 m long injection beamline transports and matches the ion beam of the 45 MeV cyclotron JULIC to the Cooler Synchrotron COSY, which is under construction at KFA Jülich. The optics was laid out for some flexibility in different modes of operation, to account for the beam properties of the cyclotron and for the injection demands of COSY. On that basis, we report on the design of the beamline with its main components, like the magnets, the beam diagnostic instrumentation and the computer control system. The commissioning of the beamline will be in summer 1991.

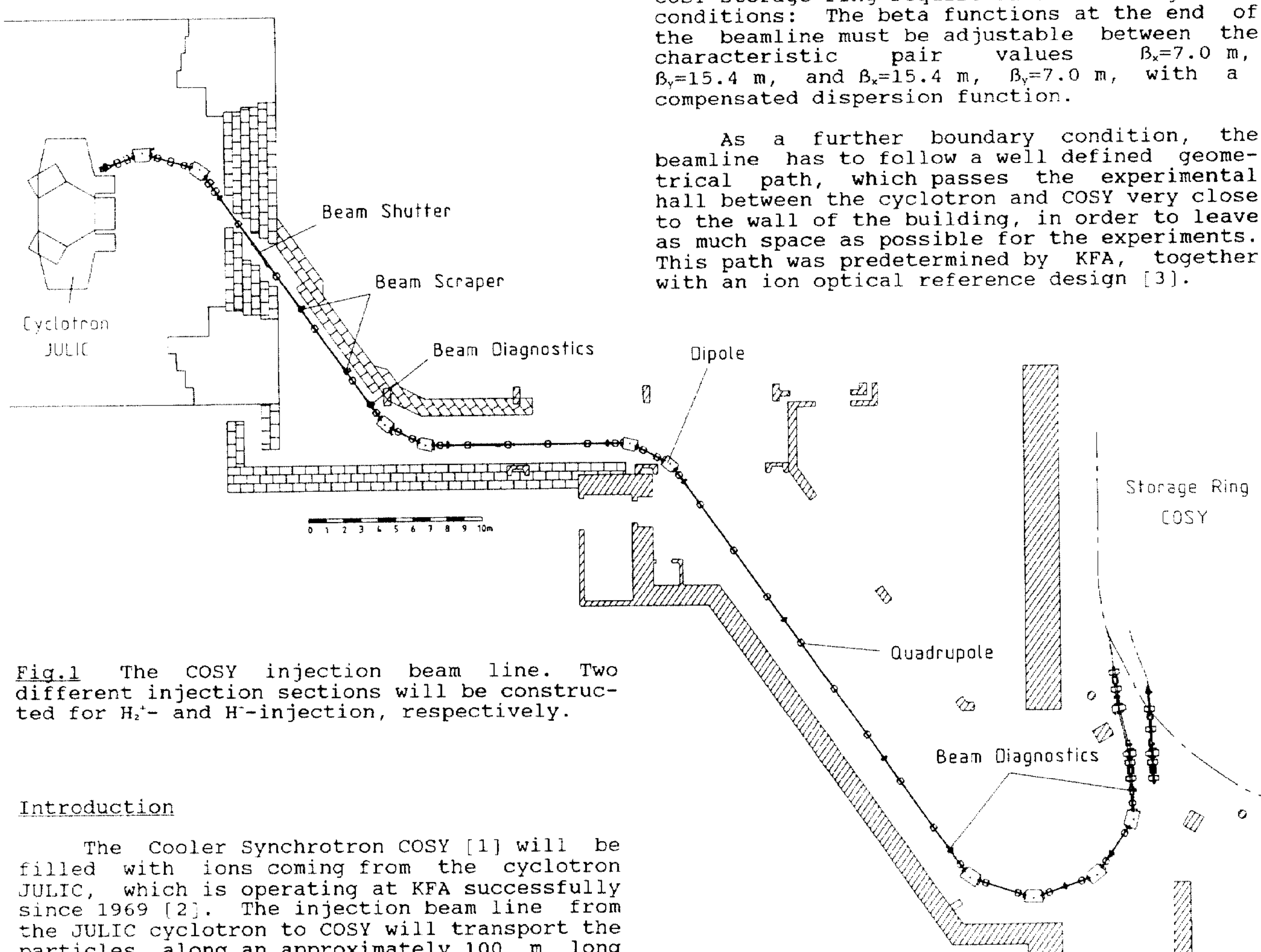

Fig.1 The COSY injection beam line. Two different injection sections will be constructed for H_2^+- and H^--injection, respectively.

Introduction

The Cooler Synchrotron COSY [1] will be filled with ions coming from the cyclotron JULIC, which is operating at KFA successfully since 1969 [2]. The injection beam line from the JULIC cyclotron to COSY will transport the particles along an approximately 100 m long path across the experimental area, and match the phase space coordinates of the beam to the optical conditions at the injection point of COSY. As these conditions vary according to different operational modes of the storage ring, the injection beamline has to provide flexibility in its optical transport properties. Interatom in 1989 got the contract for the design, construction, and commissioning of the beamline and all its subsystems.

Basic Conditions for the Layout

The boundary conditions for the optical transport properties are given by the cyclotron beam properties and the COSY injection requirements.

The cyclotron produces a beam with a maximum rigidity of 2 Tm, an emittance of ϵ_x=3.2 π mrad mm and ϵ_y= 6.4 π mrad mm, a Dispersion of D_x=-0.12 m and D_x'=-3.35 mrad/%, and a momentum spread of $\delta p/p$=0.15%. The Twiss parameters at the beginning of the beamline are β_x=7.4 m, α_x=-0.79 and β_y=26.0 m, α_y=-6.4.

The different operational modes of the COSY storage ring require different injection conditions: The beta functions at the end of the beamline must be adjustable between the characteristic pair values β_x=7.0 m, β_y=15.4 m, and β_x=15.4 m, β_y=7.0 m, with a compensated dispersion function.

As a further boundary condition, the beamline has to follow a well defined geometrical path, which passes the experimental hall between the cyclotron and COSY very close to the wall of the building, in order to leave as much space as possible for the experiments. This path was predetermined by KFA, together with an ion optical reference design [3].

Description of the System

The layout of the beamline is shown in Fig. 1. It consists of the following subsections: The cyclotron achromat, a FODO transfer line, the transfer achromat, another FODO line, the injection achromat, and the injection section.

The cyclotron achromat is slightly asymmetric, it serves for the matching of the beta functions and the dispersion. The transfer achromat (second order) is symmetric and incorporates a FODO unit transfer line. The dipole magnets of the injection achromat have edge focussing, which is chosen such that only one quadrupole strength is needed in this section. The optical functions β_x, β_y and D_x along the beam line are shown in fig. 2.

The injection section works as a telescope with a magnification factor of 1.5. Additional dipole magnets with deflections of 10° and 7°,respectively allow for flexibility in the beam path, as particles with different ratios of Q/A will be injected into COSY.

First operation of COSY will use H_2^+- and H^--injection. The two corresponding beam paths differ in the downstream end of the injection region. Both lines will be constructed (see fig.1). Only one of them, however, will be in place at a time. The left, which uses the two small dipoles, serves for H^-, the right is for H_2^+ and will have a deflecting magnet at its end, which is similar to a septum magnet.

In the injection region, a vertical beam bump of ±20 mm will be generated, which oscillates at a period of 330 μs and will increase the efficiency of the stripping injection in COSY.

The beamline is designed for flexibility in its optical properties, which is mainly achieved by six quadrupole parameters of the cyclotron achromat. The adjusting range of possible values for the Dispersion D_x and its derivative D_x', with the other optical functions being matched, is shown in fig. 3.

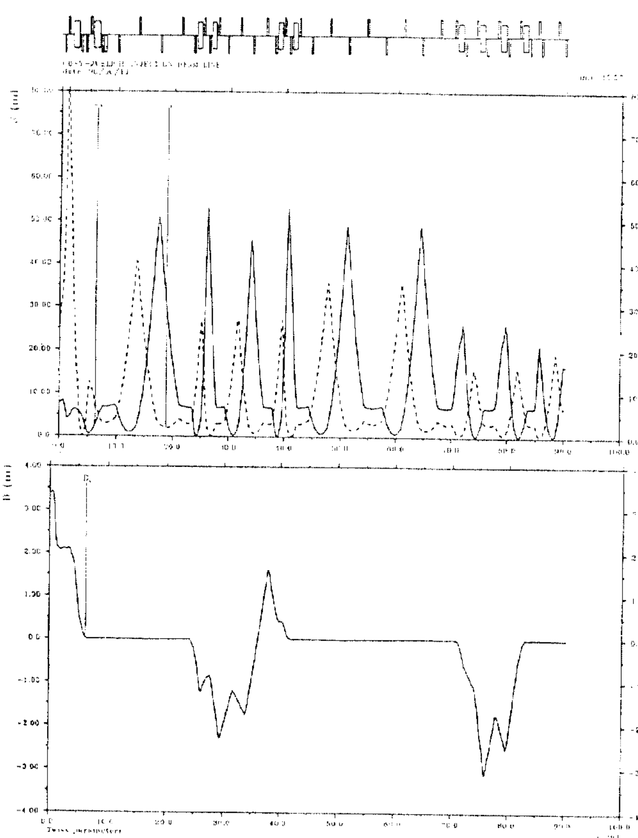

Fig.2 Optical functions β_x, β_y and D_x.

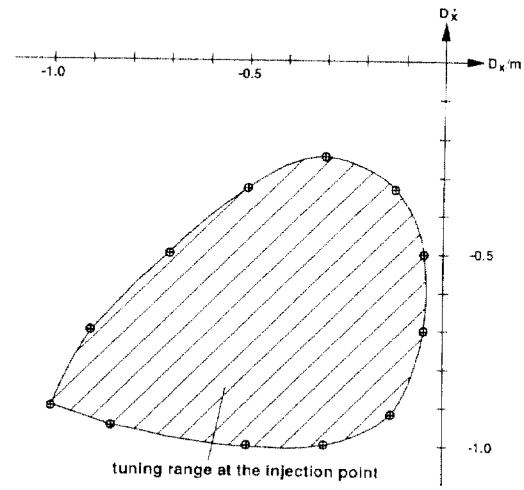

Fig.3 Adjusting range for D_x and D_x'.

Magnet Types

The injection achromat uses four dipole magnets with a deviation angle of 38.25° and a focussing edge of 10.3°. Two magnets of the same kind, driven at a slightly higher excitation, are used for the cyclotron achromat. The transfer achromat has four dipoles with a deflection angle of 27.5°. The gap height of all dipoles is 60 mm.

The 39 quadrupoles in the beamline, except the injection section, have an effective length of 300 mm and an aperture of 72 mm. The maximum gradient needed is 14.5 T/m. In the injection section, 6 quadrupoles with a larger aperture of 114 mm are needed, due to the bake out shirts and the vertical beam bump. However, only a gradient of 8.1 T/m is required here. Each quadrupole in this region has a mirror plate at one side to reduce end effects and cross talk with nearby dipoles.

For orbit correction, 10 x/y-steerer magnets are foreseen along the beam line, each consisting of a frame with two pairs of coils.

Beam Diagnostics

The beamline is equipped with eight x/y-beam profile monitors, located at the starting point of the beamline and at the end points of the seven subsections (achromats and FODO structures, respectively). Wire grids with 0.1 mm W-Re wires are used in order to get clearly detectable signals. For each direction (x and y), a number of 39 wires are used, spaced by 1.5 mm each, thus giving a good spatial resolution of the position (steering) and of the intensity profile of the beam. The wires are mounted on a frame with an aperture of 60 x 60 mm², which is moved accross the beam remotely inside a vacuum tank.

The electrical nA signals of the grids are electronically processed in multichannel charge amplifiers with FET multiplexers. In order to keep the cable lengths below 50 meter, two electronic cabinets at different places along the beamline are used, where each of them handles the signals of four x/y-grids.

For the definition of the emittance of the injected beam, two pairs of x/y-slits will be used, one of them 8 m, and the other 12.5 m behind the beginning of the first FODO line.

The beam current is measured by faraday cups. One is positioned at the beginning of the beamline, which at the same time serves as a security beam shutter. A second cup at this place, working as a security shutter only, gives the necessary redundancy. At the end of the first FODO line, and at the end of the injection achromat, respectively, further faraday cups are installed to control the beam current along the line.

A phase detection probe at the beginning of the line gives information on the longitudinal phase space of the cyclotron.

With its beam optical properties, the beamline provides an excellent tool for the diagnostics of the beam quality which is delivered by the cyclotron and injected into COSY. The beam emittance will be determined with the help of the grids in the downstream part of the beam line by variation of quadrupole focussing lengths.

The implementation of additional diagnostic equipment for the improvement of beam definition and emittance measurement is presently taken into consideration.

Control System

The injection beamline has its own computer control system, which is shown schematically in Fig. 4. The central part of the control system software is running on a workstation, where all physical parameters of the beamline are kept in a central database. The software originates from the control system of the electron stretcher and accelerator ELSA at Bonn University [4] and has been further developed. A menu system allows to display and modify interactively all parameters. Together with a mouse, quasi-analog adjusting of the parameters, like magnet currents and beam positions, is provided. Application programs, e.g. for orbit correction or emittance measurements, have direct access to all parameters of the beamline.

The physical setting and reading of the devices is carried out by a VME front-end system, which communicates with the workstation via an Ethernet branch. Control of electric drives for diagnostic components, like stepper motors for the slits, as well as the vacuum control etc. is done directly by VME interface cards. Power supplies and multichannel amplifier electronics of the diagnostic grids are collected in subgroups, which are adressed via V24 or IEEE488 sub-buses.

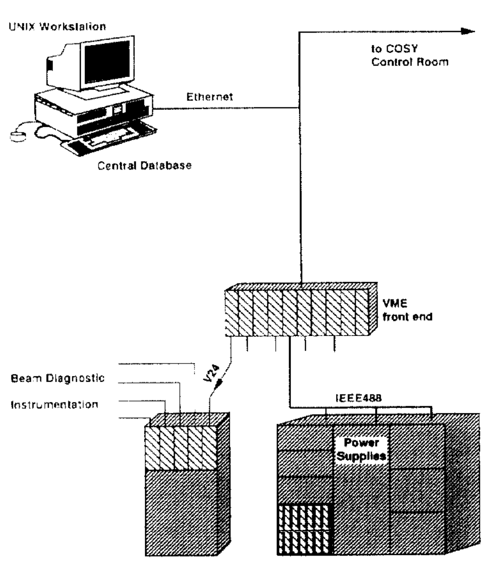

Fig.4 Control system of the beamline.

The full status information of the injection beamline control system is made available for the control system of the COSY storage ring and may be inspected or modified via a dedicated Ethernet communication process.

Vacuum System

The vacuum system of the beamline is fully metal sealed, and ion getter pumps are foreseen for pumping during operation.

In the first FODO section, where the beamline passes through the concrete screening of the cyclotron hall, a beam shutter inside the vacuum system is provided. A 1.4 meter long iron bar with a cross section of 60 x 60 mm^2 can be moved inside a vacuum tank vertically into the beam path to stop the primary ion beam. Attached to this bar, the iron is followed by polyethylene and boron to moderate and stop the secondary neutrons. The bar is encapsuled in order to meet the vacuum specifications.

In the first two thirds of the beamline, the vacuum conditions will be similar to the vacuum in the cyclotron, i.e. between 10^{-5} and 10^{-7} mbar. In the downstream end, however, the pressure has to be brought down to the UHV of the COSY ring, and at the end of the beamline a vacuum of better than 10^{-10} mbar will be maintained. Therefore, all vacuum materials in the injection achromat and in the following section are subject to special specifications and will be baked out during fabrication. Also, the vacuum system in the last part of the beamline will be baked out in situ. Two beam profile grids and a faraday cup in this section are correspondingly laid out for bake out.

Status of the Project

All main components for the beamline are under construction, or will be ordered shortly. The development of the control system is in progress. Installation of the magnets will start in November 1990, followed by the vacuum system early in 1991. Being well within the schedule, the beamline will be commissioned in summer 1991.

References

[1] U. Pfister et al., The COSY-Jülich Project - May 1990 Status, this conference

[2] W. Bräutigam et al., Upgrading JULIC as Injector for COSY-Jülich, 1st Eur. Part. Accel. Conf., Rome, 1988

[3] J. Reich, Reference Design of the Ion Optics of the COSY - Injection Beamline (in German), KFA Jülich, IKP, 1988 (unpublished)

[4] C. Wermelskirchen, The Control System of the Bonn 3.5 GeV Electron Stretcher and Accelerator ELSA (in German), BONN-IR-88-31, Bonn University, 1988