# A First Concept to Use the Cooler Synchrotron COSY-Jülich for Cancer Therapy

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Abstract

The objective of this contribution is to introduce COSY-Jülich to the radiotherapy community among particle beam users. The synchrotron and storage ring COSY-Jülich [1] will deliver protons with energies between 50 and 2500 MeV, i.e. it comprises the whole range of interest for medical applications (approx. 60 to 250 MeV). It has the option to accelerate other medically interesting light ions, such as $^{3}He^{2+}$, $^{12}C^{6+}$, $^{16}O^{8+}$ and $^{20}Ne^{10+}$. In the early phase of operation -presumably spring 1993- it will be able to store $2 \times 10^{10}$ protons and deliver a beam intensity of $5 \times 10^{8}$ protons/s. After full development, these numbers will be $2 \times 10^{11}$ protons and $2 \times 10^{10}$ protons/s. The initial beam intensity is already adequate to deposit a dose of 2 Gy in a tumor volume of 1 liter in 2-3 min. COSY-Jülich permits ultra slow beam extraction ($\geq$ 5 s) for easy beam scanning. Positioning of the beam should be better than $\pm$ 0.5 mm and energy variation from pulse to pulse better than $10^{-3}$. These and other parameters are discussed to illustrate the suitability of COSY-Jülich as a source for ion beam therapy.

## I. THE COOLER SYNCHROTRON COSY-JÜLICH

At present, the KFA is building a new accelerator for medium energy physics. It is a cooler synchrotron and storage ring, called "COSY-Jülich". Construction work and assembly will be finished in the second quarter of 1992 and start of users' operation is scheduled for spring 1993. By March 1992, more than 90 % of the accelerator components have been installed.

The COSY ring consists of two 180 degree bending arcs and two straight sections. It has a total circumference of 184 m. Each of the mirror symmetric half cells is given a QF-bend-QD-bend structure leading to a sixfold symmetry of the magnetic lattice. The straights are acting as 1:1 telescopes with a phase advance of either $\pi$ or $2\pi$. Bridged by four optical triplets each, they provide free space for the RF stations, for phase space cooling devices (electron and stochastic cooling) and for internal target areas. The main machine and beam parameters are given in table 1, the layout of the whole facility is shown in fig. 1.

In the first stage of development COSY-Jülich will deliver protons with energies between 50 and 2500 MeV and hence comprises the whole range of interest for medical applications which spans from approximately 60 to 250 MeV. $H_2^+$-ions will be injected into the upgraded isochronous cyclotron JULIC which serves as preaccelerator for COSY. Injection into the storage ring occurs by stripping. The injection beamline to the synchrotron is designed for particles of a maximum rigidity of 2 Tm. The storage capacity for protons will be ca. $2 \times 10^{11}$ and depending on the extraction mode approximately $2 \times 10^{10}$ protons with an energy of 250 MeV can be extracted per second. At a later stage, COSY might accelerate medium mass ions, as well. $^{3}He^{2+}$, $^{12}C^{6+}$, $^{16}O^{8+}$ and $^{20}Ne^{10+}$ e.g. are possible. For these heavier ions beam currents of 5-$10 \times 10^{7}$ particles/s are possible.

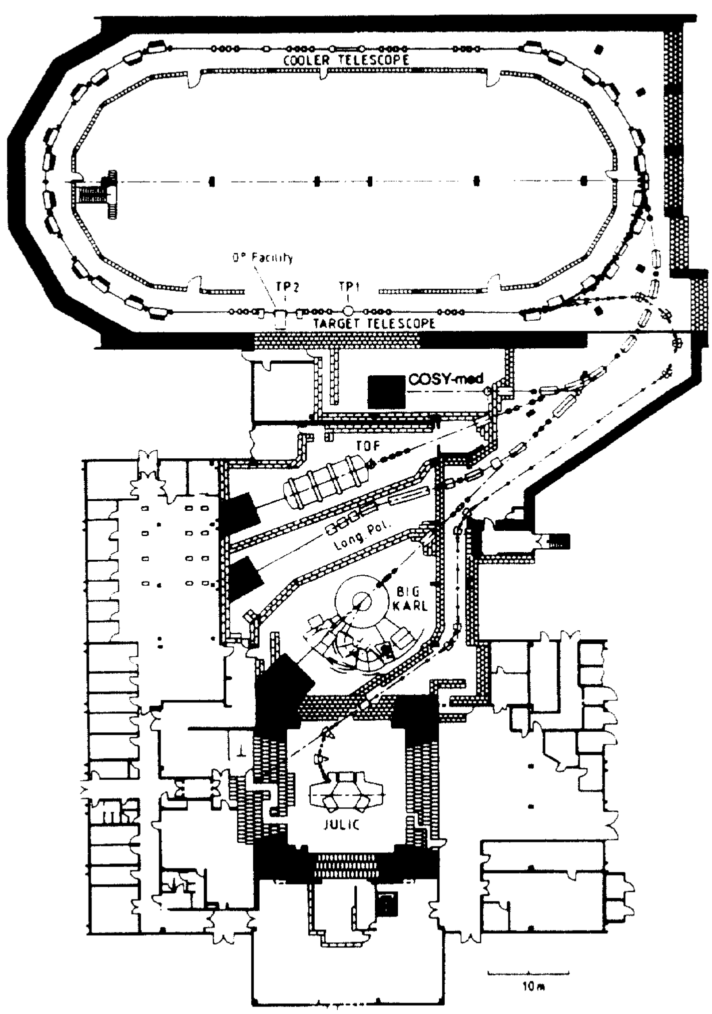


**Fig. 1. Layout of the COSY facility**

Positioning of the beam should be better than ± 0.5 mm and energy variation from pulse to pulse $10^{-3}$ or less. COSY-Jülich will permit ultra slow beam extraction (≥ 5 s) and a minimum spot size of about 2 mm, options which should facilitate beam scanning.

Table 1: COSY Basic Parameters

| | |
|---|---|
| synchrotron circumference (m) | 184 |
| number of dipoles | 24 |
| maximum field (T) | 1.6 |
| number of quadrupoles | 56 |
| maximum gradient (T/m) | 7.5 |
| ramping (GeV/s) | 1.3 |
| injection mode | $H_2^+$-stripping |
| vacuum (mbar) | $<10^{-10}$ |
| | |
| betatron tunes | 3.38/3.38 |
| acceptance $a_x/a_z$ (πmm mrad) | 100/30 |
| injection energy (MeV) | 40 |
| maximum energy (MeV) | 2500 |
| maximum no. of stored particles | $2x10^{11}$ |
| resonant extraction mode: | |
| spill time (s) | 0.01-10 |
| extraction efficiency (%) | 30 |
| ultra slow extraction mode: | |
| spill time (s) | 5-1000 |
| extraction efficiency (%) | >80 |
| extraction emittance $\varepsilon_x/\varepsilon_z$ (πmm mrad) | 2.5/2.5 |
| repetition time at 200 MeV (s) | typically 1-10 |
| extracted particles ($s^{-1}$)/(nA) | $<5x10^{10}/<10$ |
| duty cycle (%) | typically 50-90 |
| pulse to pulse beam stability: | |
| $\Delta p/p$ | $10^{-3}$ |
| $\Delta N/N$ | $10^{-2}$ |
| beam stability during pulse: | |
| $\Delta p/p$ | $10^{-3}$ |
| $\Delta N/N$ | >0.1 |
| | |
| injector | cyclotron |
| particles | $H_2^+$ |
| energy (MeV) | 40 |
| mode | cw |
| frequency (MHz) | 27.8 |
| current (μA) | 10 |
| ion source | modified multicusp |

## II. PLANS FOR A THERAPY SITE

In May 1991, a first proposal was publicly presented, describing the properties and advantages of the facility for potential medical applications. As soon as the "final spurt" of the COSY construction phase is over, design and cost comparison for various types of the medical site (COSY-med) will begin. The decision on the major components is anticipated for mid 1992. Right from the beginning of patient treatment, at least a horizontal and an inclined beam line should be available. However, plans for an isocentric gantry are also under way. To take full advantage of the dose localization capabilities of the charged particles a scanning system is intended for conformation therapy. The time schedule for the therapy site depends strongly on the completion of the synchrotron itself. Without major delays, the necessary constructional modifications of the future medical area could begin in early 1993. Parallel the magnets for the medical beam line should be built. Approximately a year later the patient immobilisation system should be installed and the dosimetry unit set about. Calibration, phantom studies and biological tests are estimated to last for about a year. Patient treatment is therefore not expected to begin before 1996.

In addition to providing the essential accelerator, the KFA offers further benefits for a proton therapy site: its Institute of Medicine has years of experience in imaging techniques, in particular PET and there is even a nuclear medicine clinic on the KFA grounds which can assist in patient preparation and interim care. The surrounding universities und research clinics have already been contacted and will be involved from very early on, as they will be the main users who bring in the specialist oncologists and select the appropriate patients.

## III. SUMMARY

COSY-Jülich will offer the whole range of beam energies of interest for medical applications. It provides a highly ordered beam of high stability and permits ultra slow extraction for easy scanning. Besides protons, COSY-Jülich can serve as a light ion source and support all irradiation techniques discussed today.

## IV. REFERENCES

[1] R. Maier, U. Pfister and R.Theenhaus, The COSY-Jülich Project, Proceedings of the European Particle Accelerator Conference, Nice, France, June 1990, 131-133.