# The Jyväskylä K130 Cyclotron Project

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## Abstract

A new $K$=130 MeV cyclotron with an external ECR ion source was funded in 1987 to replace the old MC–20 cyclotron. Main components of the $K$130 cyclotron will be produced commercially. They were orded in the end of 1988. Two ECR ion sources are under construction at our laboratory. The cyclotron will be controlled with a commercially available industrial control system. The installation of the cyclotron will start in spring 1990 in a new laboratory building at a new site.

## Background

In 1982 the Department of Physics, University of Jyväskylä, submitted a proposal to replace its present MC–20 cyclotron with an advanced superconducting cyclotron. When the superconducting cyclotron project was finally turned down in mid 1985, mainly on the basis of cost, a follow-up project was immediately begun by the Department of Physics. Its purpose was to find a less expensive but scientifically acceptable solution.

After considering realistically the new economical constraints and the short-term needs of the various research programs in the Department of Physics, a $K$=100–130 MeV cyclotron equipped with an ECR ion source was selected as a new accelerator.

In order to keep costs and own manpower needs down, the cooperation with a commercial firm was thought to be the most feasible method to obtain such a cyclotron. The main components of the cyclotron would be ordered from the commercial manufacturers. The Department of Physics would be responsible for the rest of the facility, including control systems, beam transport, installation and testing. The ECR ion source and injection would also be built locally.

A new proposal incorporating these ideas was submitted in March 1986, with an estimated cost of about 6 million USD (including taxes). In addition the Department of Physics would need to supply about 35 man-years of effort to complete the project. The proposal was accepted in September 1986 and the initial funding of the project was included in the national budget for the fiscal year 1987. The funding was allocated for years 1988–91.

The Department of Physics asked in spring 1987 the manufacturers of cyclotrons to send their official and binding offers for the main components of a $K$=100–130 MeV cyclotron. As a result Scanditronix AB, Sweden, was selected as the manufacturer of the major components for the new cyclotron. An official order was signed in December 1987. It included the complete $K$=130 MeV cyclotron magnet, vacuum chamber, extraction and RF systems and power supplies. According to the contract the delivery will take place in April 1990.

## Magnet and RF

The main parameters of the $K$130 cyclotron are given in table 1. Figure 1 shows the general lay-out of the cyclotron. The $K$130 cyclotron has three 58° spiral sectors and 15 circular correction coils. The bending limit of the magnet is 130 MeV and the focusing limit will be about 90 MeV. The magnet was computer designed and built without a scaled-

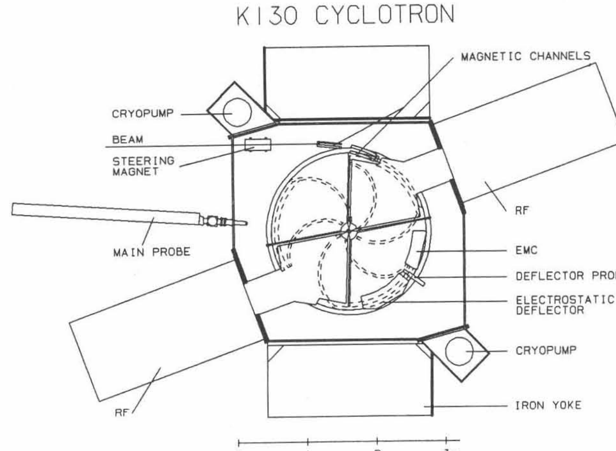


*Figure 1. Lay-out of the $K$=130 MeV cyclotron*

down model magnet. The method used in the computer design is decribed in a separate article by P.Heikkinen in these proceedings[1].

**Table 1. Parameters of the $K130$ Cyclotron**

| | | |
|---|---|---|
| MAGNET | | |
| pole diameter | 2.4 | m |
| pole gap, max. | 0.33 | m |
| min. | 0.174 | m |
| number of sectors | 3 | |
| spiral angle | max. 58 | degrees |
| weight | 308 | tons |
| trimming coils, circular | 15 | |
| harmonic | 4 | sets |
| conductor | hollow Cu | |
| power, main coils | 150 | kW |
| trim coils | 35 | kW |
| field at 400 000 At, hill | 2.1 | T |
| valley | 1.3 | T |
| average | 1.76 | T |
| extraction radius | 0.95 | m |
| bending limit | 130 | MeV |
| focusing limit | 90 | MeV |
| ACCELERATION SYSTEM | | |
| number of dees | 2 | |
| dee angle | 78 | degrees |
| beam aperture | 3.0 | cm |
| RF frequency | 10–21 | MHz |
| harmonic number | 1, 2, 3 | |
| max. dee voltage | 50 | kV |
| VACUUM | | |
| 2 cryo pumps | each 5000 | l/s |
| operating pressure | $10^{-7}$ | mbar |
| ION SOURCE + INJECTION | | |
| external ECR | | |
| axial + spiral inflector | | |
| EXTRACTION | | |
| dc electrostatic + EMC + 2 passive channels | | |
| PARTICLE ENERGIES | | |
| protons | 6–90 | MeV |
| other ions | $(0.2-1.0)\times 130\ q^2/A$ | MeV |

At this moment (April 1989) the the iron parts have been finished by Scanditronix. The magnet was transported to and assembled in Uppsala at the end of January 1989. The pole configuration and shimming are finished. The magnetic field mapping is in progress, and a major part of it will be finished by June 1989. The circular trim coils will be measured in August–September and the EMC at the end of 1989. The liners are in production and they will arrive at Scanditronix in the end of 1989 from a subcontractor. The stainless steel vacuum chamber is also in production and will be completed before the end of May.

The power amplifiers and the cavities of the RF system are in production and they will be ready for assembly during the summer 1989. The RF system will be ready for final assembly in October 1989.

## Extraction

A complete extraction system was ordered from Scanditronix. It consists of one electrostatic deflector (40°, 50 kV), one electromagnetic channel (EMC, 28°), two passive magnetic focusing channels, and one internal horizontal steering magnet for small corrections of the beam direction at the beam exit port. The desing of the extraction system will be completed before the end of May 1989, and the production of the components can be started immediately after the design is finished.

## ECR and Injection line

There are two similar ECR ion sources presently under construction in our laboratory. One source is for the The Svedberg Laboratory of Uppsala University and the other one is for our $K130$ cyclotron. They are slightly modified versions of the RT-ECR ion source at Michigan State University[2]. Design and construction have taken place as a collaboration between the three universities.

The main differences between these sources and the RT-ECR at MSU will be the construction on metric scale, and the use of NdFeB permanent magnets instead of $SmCo_5$ magnets in the hexapole. For the two plasma chambers only one microwave power transmitter (Varian 6.4 GHz/3.3 kW) is used with a tunable power divider between two stages. For experiments in atomic physics the source is designed to maintain a high voltage of 30 kV. The ion source is vertical.

The construction of the sources was started in spring 1988. All parts for the Uppsala source are now completed and will be transported to Uppsala in May 1989. The second ECR source will be ready for mounting in spring 1990.

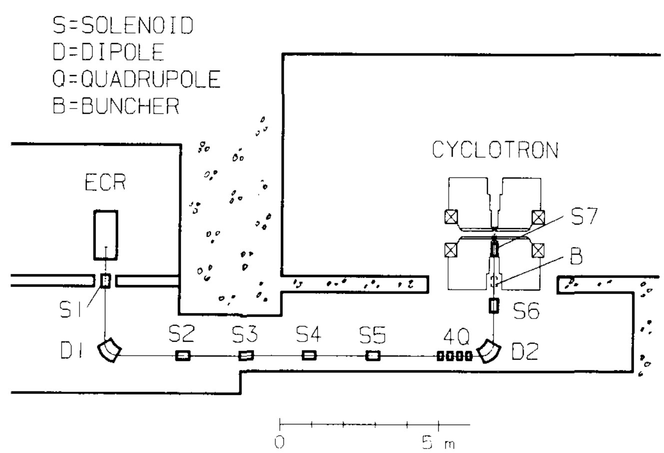


Figure 2. A sketch of the injection line

The lay-out of the injection line can be seen in figure 2. In designing the injection line the computer code TRANSPORT was used. All the focusing and bending components have been chosen to be magnetic.

The first focusing element after the ECR source is a 40 cm long solenoid, which forms a waist at the object of the double-focusing 90° analysing magnet having an analysing power of about 1/100 in mass with 1.0 cm wide slits. A provision is made to use the analysing magnet also as a rotatable switching magnet in order to send the beam either to the cyclotron or to the atomic physics experiments. The transfer line from the analysing slit to the four quadrupole matching unit consists of four 40 cm solenoids. The beam is bent up to the cyclotron axis with a second 90° dipole magnet. Through the cyclotron axis the beam is transported using two 40 cm solenoids close to the median plane of the cyclotron. A buncher will be installed later.

The vacuum pumping will be done by turbo and ion pumps in order to obtain an operating pressure of $10^{-5}$ Pa ($10^{-7}$ torr) in the injection line.

### Central Region

The central region will operate in constant-orbit mode via an approriate scaling of the injection voltage and the dee voltage. The possible harmonic modes of acceleration are $h = 1,2,3$. The central region has been designed so that all harmonic modes can be accelerated with the same dee geometry. This will save time upon change of mode and leads to mehcanical simplicity. Only the inflector has to be replaced when changing the harmonic mode. A spiral will be used as an inflector.

For numerical calculation of the orbits a self written program TRAJECTORY was used. The electric field shape in a retangular area of 6 cm by 6 cm around the centre of the cyclotron is obtained with RELAX3D4 program[3]. Outside this region the Gaussian approximation was used as described in ref.4. The program TRAJECTORY integrates the equation of motion in cartesian coordinates using the predictor-corrector method. The geometry of the central region for the $h = 2$ mode of operation is shown in figure 3.

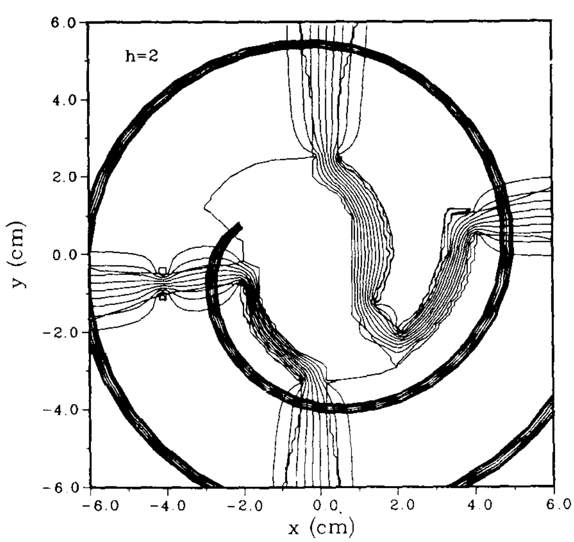


*Figure 3. Central region geometry and beam acceleration in second harmonic mode with an emittance of* $100\pi$ mm·mrad

### Control System

The new $K130$ cyclotron will be computer controlled. The control system is estimated to involve about 220 analog I/O signals and 770 digital I/O signals. These numbers do not include control of beam lines and experimental equipments. After a careful evaluation of control systems used in existing cyclotrons we decided to buy a commercially available automation system from the Finnish company ALTIM CONTROL Ltd. Their system is used extensively in process industry. Our decision was based on the economic and manpower aspects. We believe this will be the most economic and effective way to obtain the control system for the $K130$ cyclotron. The price of the control system mounts to 6 per cent of the total cost of the cyclotron.

A more detailed description of the control system of the $K130$ cyclotron can be found in a special contribution by Pekka Taskinen *et al.* in these proceedings[5].

### Building

The new cyclotron requires a new building, which has to be available in time for the delivery by Scanditronix. The desing of the new building is completed. The lay-out of the new laboratory can be seen in fig. 4. Due to the restrictions in funding for the building the new laboratory has to be built in two phases. The construction of the 1st phase which includes only the rooms needed for the cyclotron itself will be started at the end of May 1989. The second phase including mainly the experimental area will be built in 1991-92. Therefore the experiments with the new cyclotron facility cannot be started earlier than in 1993.

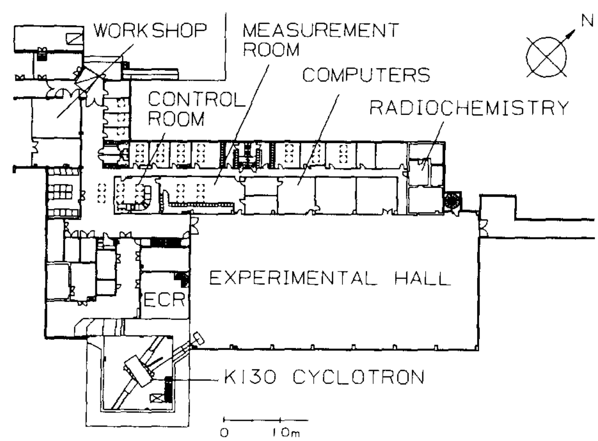


*Figure 4. Floor plan of the new cyclotron laboratory*

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