THE CERN SYNCHRO-CYCLOTRON

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ABSTRACT

Following a period of intense exploitation by many users after the completion of the improvement programme[1] in 1974 the CERN SC machine is now principally reserved for the Isolde programme. The heavy ion programme has been completed with acceleration of particles with charge/mass ratio from 1/3 to 1/4.

INTRODUCTION

Since the last conference in 1981 (IXth International Conference on cyclotrons, Caen (France)[2] the SC has operated for about 6000 hours in 1981 and 1982 (see Table 2).

MACHINE TIME DURING THE LAST THREE YEARS (in hours)

Particle	1981	1982	1983
Protons	2909	4297	3630
$^{12}C^{4+}$	2115	872	497
$^{3}He^{+}$	133	8	
$^{15}N^{5+}$	38		
$^{20}Ne^{7+}$	4		
$^{16}O^{6+}$	29		
$^{18}O^{6+}$		210	199
$^{3}He^{++}$		592	
Technical Development	256	100	169
Total	5484	6079	4495

Table 2

1982 was also the year of the 25th anniversary of the SC. Indeed, the 1st August 1957 was the day of the first beam of the oldest machine of CERN.

In 1983 due to financial pressures of the new big project LEP the CERN management decided to reduce drastically the number of hours of physics to 4000 hours per year and to move towards the situation with the SC as a machine dedicated to Isolde. Nevertheless the heavy ion programme foreseen is now implemented, the ion source being able to produce a workable beam current over the whole range of ions expected. Table 1 below shows what ions are available and at what intensities.

CATALOGUE OF SC BEAMS

Particle	Energy (MeV/N)	Extracted intensity (part./sec)	Frequency range (MHz)
Proton	602	$> 3\times10^{13}$	30.1 16.8
$^{3}He^{++}$	303	$> 3\times10^{12}$	20.3 13.9
$^{3}He^{+}$	85	$> 10^{13}$	10.1 8.5
$^{12}C^{4+}$	85	$> 10^{12}$	10.1 8.5
$^{15}N^{5+}$	85	$> 10^{11}$	10.1 8.5
$^{18}O^{6+}$	85	$\sim 3\times10^{11}$	10.1 8.5
$^{16}O^{6+}$	107	5×10^{9}	11.6 9.4
$^{14}N^{5+}$	97	$\sim 10^{9}$	10.8 9.0
$^{20}Ne^{7+}$	94	$\sim 5 \times 10^{9}$	10.6 8.9
$^{20}Ne^{6+}$	70	$\sim 3 \times 10^{10}$	9.1 7.7
$^{20}Ne^{5+}$	49	$\sim 3 \times 10^{11}$	7.6 6.6
$^{12}C^{3+}$	49	$> 10^{12}$	7.6 6.6

Table 1

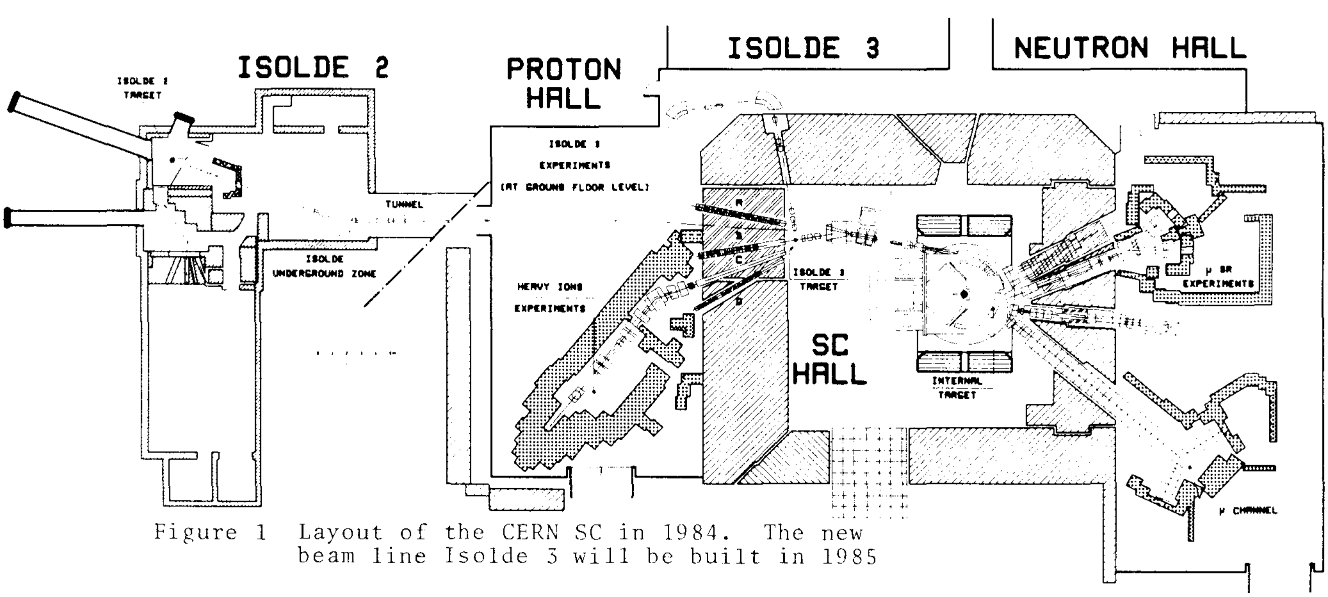

Figure 1 Layout of the CERN SC in 1984. The new beam line Isolde 3 will be built in 1985

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RF SYSTEM FOR HEAVY IONS

At the last conference B.W. Allardyce[2] gave, in 1981, a description of the new RF line[3] (in order to facilitate a fairly rapid change-over from one ion to another). This new line is now available and was used during the last run (February-March 1984).

Description of RF system

A solution had to be found to lower the frequency range used for proton acceleration (modulation from 30 to 16,8 MHz) to ranges suitable for the acceleration of heavier particles, e.g., for particles with a charge to mass ratio of 0,25 : modulation from 7,6 to 6,6 MHz is required. One of the boundary conditions was that the existing main elements of the RF system (DEE, Rotco) had to be kept compatible with the requirements for proton acceleration.

The solution was found by measurements on our 1:5 scale model and a software model as a lengthening of the resonator. In the middle of the halfwave resonator a coaxial line was inserted with a length of 1,2m and a Z of 11Ω to cover the band of the $^{3}He^{2+}$ frequencies (Z=50Ω for $^{12}C^{4+}$)[3]. Applying the same insertion with an higher Z resulted in lower frequencies covering 2 to 3 particle ranges. For operational reasons this would be welcome, but intensity of beam is lost due to the shorter useful time per cycle of the Rotco.

To cover only single particle ranges a two-step jump in Z is made in the inserted extension[4], i.e., the inner conductor was equipped at the Rotco side with a very large tube (Z=1,5Ω) followed on the DEE side by a very thin tube (2 up to 160Ω) (see Fig. 2). This Multi Frequency Range extension line (MFR line) permits switching from one range to another using an array of optimized tubes like in an organ and one or more of them are connected via remotely operated contact rings. Fine adjustment is done by vacuum capacitors in the Rotco-unit normally used for setting f_{min} for protons.

In this smallest section of the resonator (tube Ø=26..70 mm) most of the losses are produced. Nevertheless the total losses are several times lower than for protons using the same voltage of 20 kV at the Dee gap. Also the voltage stresses in the Rotco could be reduced by this 2 step extension by 30 to 50% in respect to protons. The main advantage of the MFR line lies in the fact that changes from one frequency range to another can be done quickly and without breaking the vacuum.

Further small changes were necessary on elements of the Rotco and the self-excited generator.

The coils in the Rotco supplying the interior with current for the motor, the bias, water and oil had to be increased four times in L for the low frequencies (for protons, parts of the turns are short-circuited).

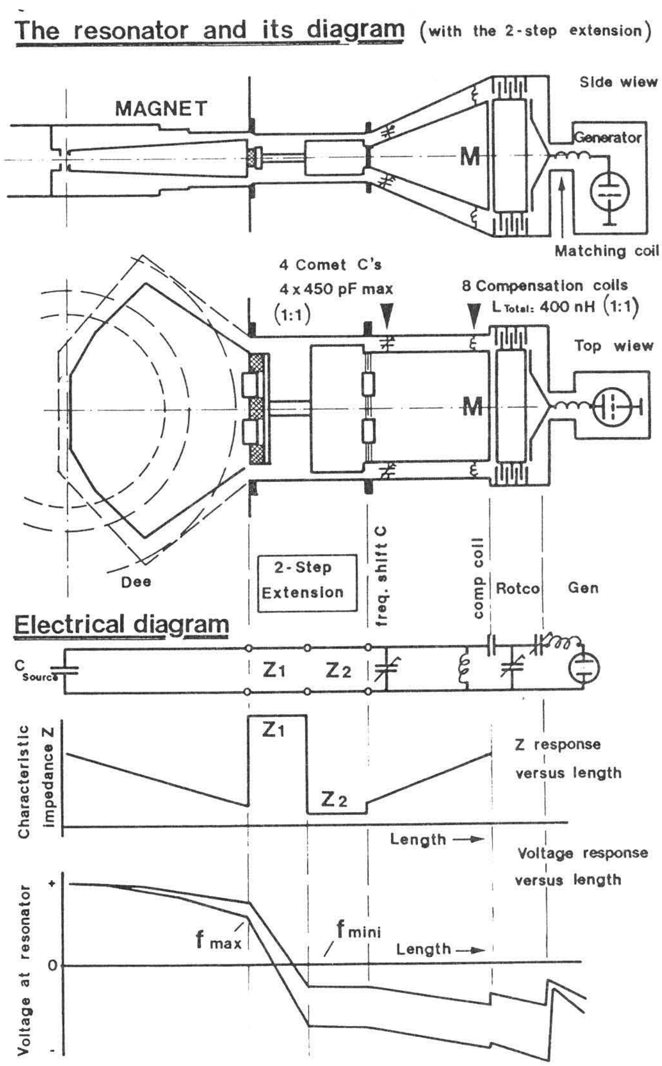
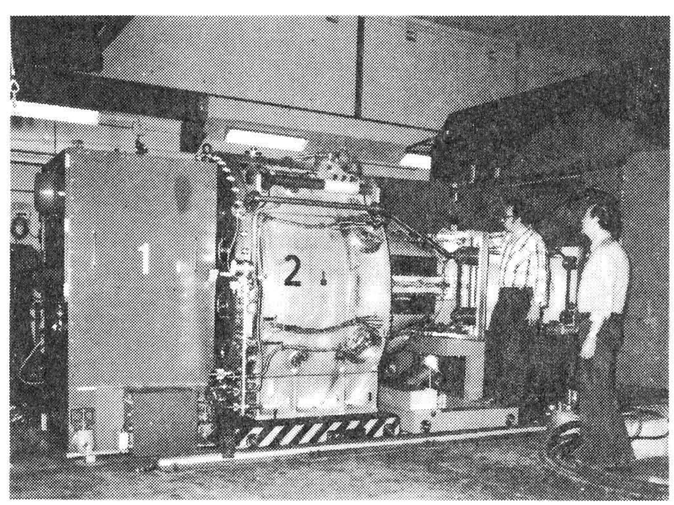


Figure 2



The photograph shows the whole RF system for heavy ions. Between the rotco and the vacuum tank the MFR line is inserted.

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The coupling from Rotco to generator had to be increased (due to the lower voltage at the Rotco) by more capacitance and a series L.

In the generator itself the feedback circuit had to be shifted to lower frequencies by using a high permeability ferrite core and the higher mode absorbers had to be tuned to lower frequencies to avoid parasitic oscillations (especially occurring in the conditioning periods).

FUTURE DEVELOPMENT

For the machine itself the situation is frozen and after the decision of the management to cut the machine to 4000 hours it will be dedicated for the major part of the time to the Isolde programme. However, the existing Isolde facility could not absorb so much running time by itself.

Consequently a proposal for a new installation called "Isolde 3" has been accepted. The production target is located in the SC hall and the isotopes after separation will be collected in the proton room at 1st floor level at the place where the Omicron experiment used to be (see Fig. 1).

The design of the new separator and associated beam transfer lines is underway and the exploitation is foreseen for 1986.

REFERENCES

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2) B.W. Allardyce, Proc. 9th International Conference on cyclotrons and their application, Caen (1981), p. 55.

3) R. Hohbach, $^{12}C^{4+}$ Acceleration; Measurements on the 1/5 scale RF model and investigation on the RF power system, CERN PS/CD Note 78-10, 17.7.78.

4) R. Hohbach, Investigation on the RF system of the synchro-cyclotron for the acceleration of light ions in the charge to mass ratio down to 1/4.