ION SOURCE AND CENTRAL REGION IN THE IMPROVED CERN 600-MeV SYNCHRO-CYCLOTRON

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Abstract

The new CERN SC proton source with its accessories is described. Predictions for beam intensity and quality are compared with experimental results.

1. Introduction

The aim of increasing the internal beam in the CERN SC by a factor 10 and improving its quality to permit an extraction efficiency above 50% made it necessary to pass from an open source axial injection to injecting in the median plane from a closed source. A number of theoretical and experimental studies[1][2] concerning the source and its surrounding electrodes have led to the present central region (Fig. 1 and 5), which combines the conflicting requirements of a high intensity (50 mA) pulsed injection and the weak focussing forces due principally to the conical electrodes. To ensure the intensity and quality needed it was necessary to make the positions of the source itself as well as the complete central region adjustable with high precision during operation. The new ion source equipment comprises :

(1) the ion source itself,

(2) the feeder and multifilament system,

(3) the central geometry with pneumatic contacts to Dee and ground,

(4) the axial support,

(5) the electronic control system.

2. The Ion Source

This is of the conventional hooded-arc hot-cathode type (Fig. 2) of rather small dimensions due to the high magnetic field (20 kG) and low RF voltage (15 to 30 kV). The copper chimney has outer and inner diameters of only 6 and 4 mm and the internal plasma column 2 mm. The cross-section of the filament (Fig. 3) is therefore also small (2 x 4.5 mm^2) which is partly the reason for the relatively short filament life of 60 to 80 hours. The nominal arc current density needed is of the order of 1.5 A/mm^2 requiring an arc of 3 to 5 A. The source is mounted 8.5 mm off centre in a box at the top of its feeder (Fig. 2) which itself is centred in the machine.

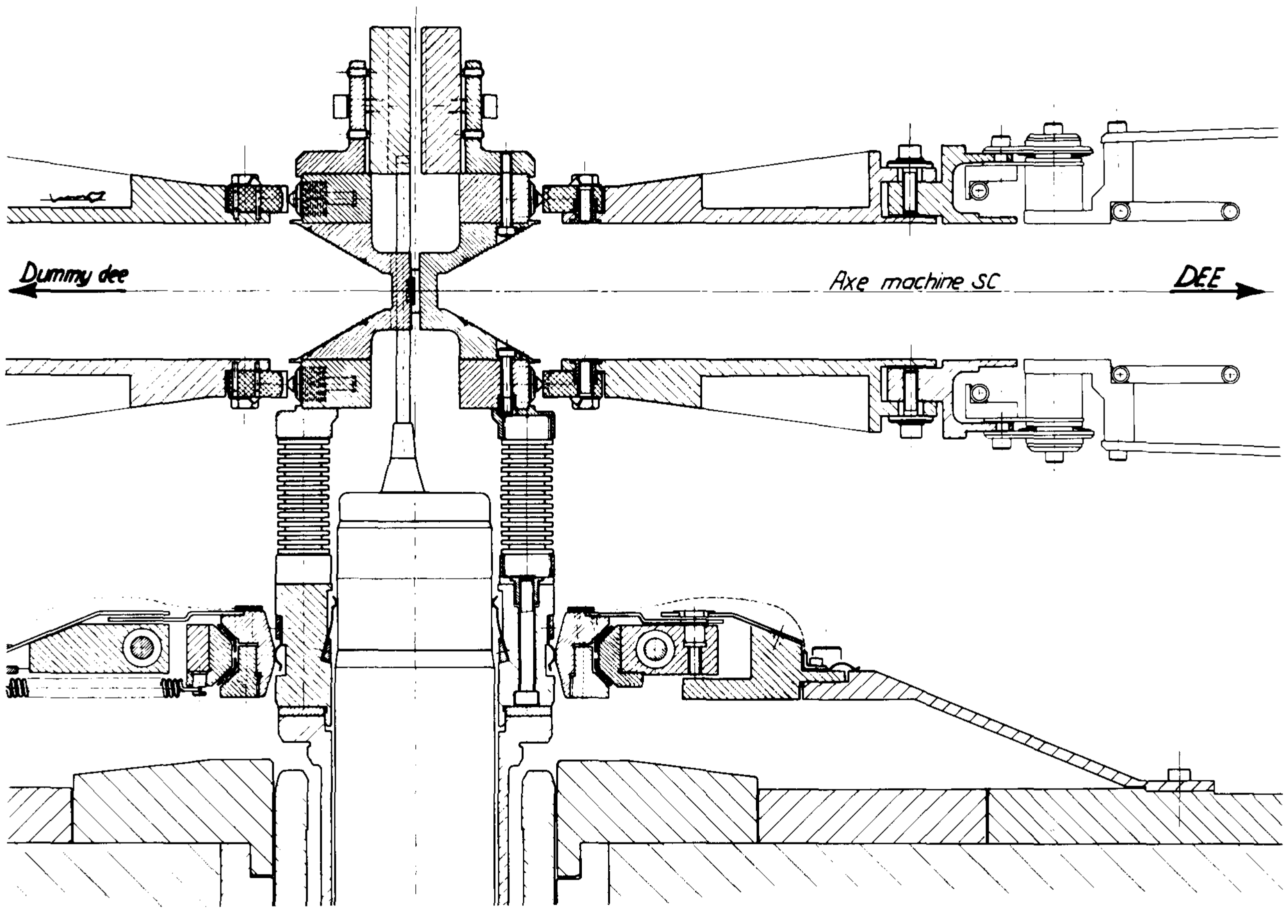

Fig. 1 Central Region

Proc. 7th Int. Conf. on Cyclotrons and their Applications (Birkhäuser, Basel, 1975), p. 371-375

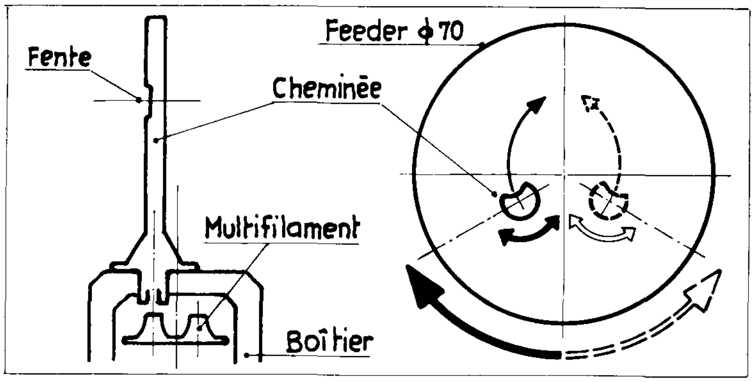

Fig. 2 Ion Source

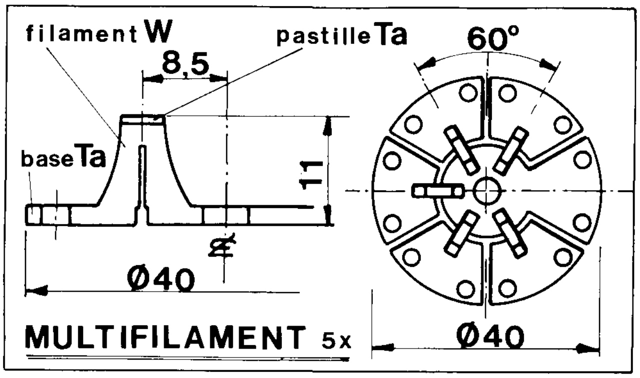

Fig. 3 Multifilament Arrangement

This allows to obtain both directions of rotation for the accelerated beam as indicated in the figure. The 1 x 10 mm^2 extraction slit is given a Pierce structure by machining within the thickness of the chimney. The chimney is internally tapered so that the plasma always touches the slit.

3. The Multifilament System

This was developed to compensate for the relatively short filament life and was made possible by the excentric positioning of the source on its feeder (Figs.2 and 6). It consists of a set of 5 filaments (Fig. 3) arranged such that they by a rotational movement successively may be brought in line with the axis of the source chimney for use. Each filament consists of a tungsten plate shaped with high precision (0.1 mm) to ensure that the hot point is perfectly centred. The emitting surface is a tantalum plate welded to the top of the filament. The individual filaments are powered via a common point and 5 terminations, the change-over being effected by thyristors. The rated filament current is 560 A.

4. The Feeder

This precision machined hard-chromium plated 70 mm stainless steel tube supports and positions the ion source and provides internally tubes for gas transport, filament current and cooling water (Fig.4).

Filament change-over is effected by rotating the multifilament stem to an accuracy of $1/10^0$ with a mechanism fitted to the feeder base.

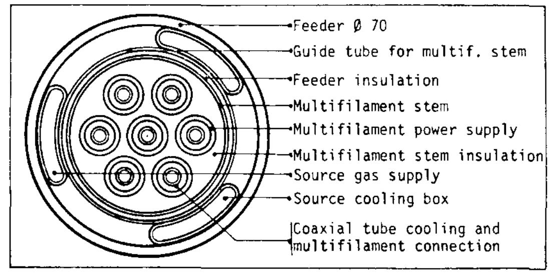

Fig. 4 Section of Feeder Tube

5. The Central Geometry

The adjustable central geometry serves two purposes :

(1) to allow optimal injection from the source slit into orbits which are exactly centred in the magnetic field[3])

and

(2) to provide an initial electric focussing at small radii where the magnetic field gradient is zero.

Its main components are two electrodes (Figs. 1 and 5) in contact with the Dee and Dummy-Dee respectively, each in the shape of two 60^0 half-cones reaching out to a radius of 5 cm and separated by the 30^0 tapered acceleration gap, their summits facing each other are joined together symmetrically around the median plane by a semi-cylindrical core (Fig. 6).

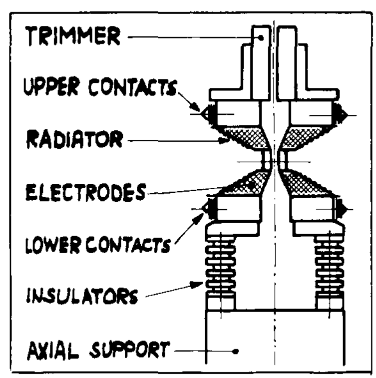

Fig. 5 Central Region Electrodes

The puller electrode is fixed to the Dee-side core facing the source chimney. Its slit of 2 x 12 mm^2 is inclined by 30^0 to the acceleration gap to compensate for the initial electrical phase shift of the injected protons. The nominal source to puller distance of 3 mm and the transverse distance between the two slits of 0.7 mm may be adjusted by moving the source within $\pm$ 1 mm to optimize the extraction optics during operation.

This geometry was selected as an optimum focusing compromise after orbit calculations[1]) in the chosen magnetic field and the electric field measured in an electrolytic tank. The cone core (Fig. 6) which narrows the acceleration gap near the geometrical centre, and which must provide sufficient mechanical support for the upper half-cones, has in fact been exactly shaped to allow the passage of the innermost trajectories.

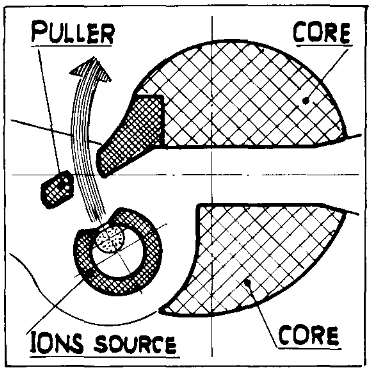

Fig. 6 Extraction Optics

Each electrode is mechanically supported by 5 boron nitrite insulators which on the Dee side hold the RF potential of 30 kV and a bias for counteracting multipactoring. To hinder any initial drift of the orbit centre, whereby the beam quality would suffer, the same bias is also connected to the Dummy-Dee side electrode, which is otherwise at RF earth.

At the top and bottom of each electrode are two segments each carrying 4 pneumatic contacts, which allow the central region adjustment of 10 mm in all directions. These pass an RF current of 85 A r.m.s. through the interelectrode capacitance. Each contact consists of 3 parts :

(1) a shaft guide assembly designed to withstand the transverse loads occuring during a lateral movement of the centre, especially when the central geometry is inserted from below and rotated into its nominal position,

(2) a bellow composed of 0.05 mm stainless steel disks welded together and silver coated to pass the RF current

and

(3) a replaceable tungsten-copper alloy (20%) nipple providing the actual contact against an opposite tungsten plate which is profiled to allow compression of the contracts during insertion of the geometry. This type of contact has very low inductance.

All components of the central geometry are designed to operate at 350°C in the most pessimistic case of beam loss. Since the safety margin for avoiding mechanical distortions, seizure of contacts and sparking is very small, a heat shield consisting of a fine tungsten grid may be fitted to the conical parts of the electrodes. These grids will receive the impinging beam energy lost on the electrodes and will due to the low thermal capacity reach high temperatures and therefore dissipate most of the energy outwards by radiation. This measure is not necessary for the present initial low current performance.

The central geometry has been made symmetric around the median plane. Thus by turning it "upside down" and by rotating the source position and chimney angle the opposite sense of rotation in an inversed magnetic field is achieved.

6. The Axial Support

This is a mechanical system (Fig. 7) located under the SC magnet with the following functions :

(1) introduction and extraction through an axial hole in the yoke[3)] under vacuum conditions of the source and central geometry together or separately,

(2) adjustment of the ion source position relative to the central geometry,

and

(3) adjustment of the central geometry position relative to the machine axis.

The axial support[5)] therefore consists of 2 similar adjustment systems, the narrower and longer support for the ion source being embedded in and carried by that for the central geometry. Each system consists of 3 eccentric tubes, one inserted in the next. The intermediate tube has an eccentricity equal and opposite to that of the two others. By rotating the tubes it is possible to locate an object (ion source or central geometry) mounted on the innermost tube anywhere within a circle of radius twice the eccentricity. The two systems may be withdrawn into separate air locks for repair and maintenance. The rotation of the tubes is performed remotely by stepping motors, and the angular position controlled by encoders. The positioning accuracy is 0.1 mm.

7. The Electronic Control System

The rather extreme conditions in the ion source necessitate an accurate setting and control of its parameters to maintain stable running conditions. Thus automatic regulation loops with extensive use of digital electronic techniques provide programmable and independent control of the arc current, the arc voltage and the gas flow to the source. This renders the setting and operation of the source a fairly simple task.

8. Beam Intensity

A computer program[4)] was developed to calculate the captured current using the nominal 30 kV Dee voltage and a repetition rate of 466 Hz for 6 measured frequency programs f(t) corresponding to different settings of the trim coils and capacitors on the rotating condenser. The results are shown in Fig. 8, where the abscissa is the value of dt/df at capture. In the figure is also reported a value obtained by scaling the nominal voltage and repetition rate a measurement performed in the SC at 20 kV and 25 Hz that gave I = 520 nA. Scaling to 30 kV by a factor 1.69 and to 466 Hz by a factor 18.64 gives a beam of 16.4 μA in acceptable agreement with theory.

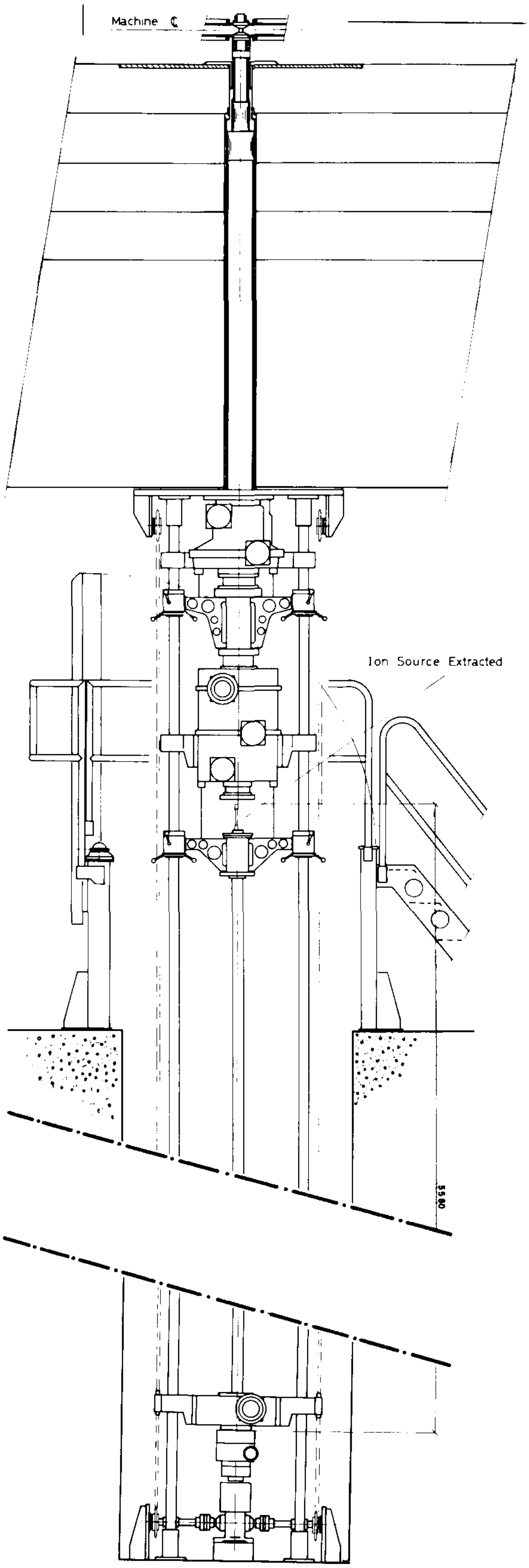

Fig. 7 Source Support

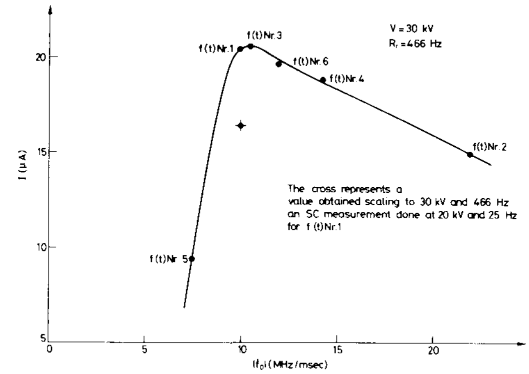

Fig. 8 Beam Intensity

9. Radial Quality

A maximum radial amplitude of 5 mm was measured in the improved SC by the conventional shadow method[6]. This result may be compared with model measurements giving from 7 to 10 mm depending on the initial df/dt. The discrepancy is in the favourable direction and may be due to a better magnetic shimming and a more accurate construction of the actual machine centre than in our central region model.

References

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6. R. Giannini, Results of shadow measurements in the SC, CERN MSC Report MSC/PR/4025, 1975.

DISCUSSION

J.J. BURGERJON: You have a filament made of tungsten, with a tantalum emitting surface. Why did you not make the whole filament out of tantalum, which is much easier to machine?

N. VOGT-NILSEN: The tungsten base was chosen due to its better mechanical properties at the very high temperatures we have to use in order to obtain the desired arc current density.

R. COHEN: What is the potential between anode and cathode when the arc is stuck? How long is it pulsed?

N. VOGT-NILSEN: About 200-230 V. The pulse length of the source is 30-40 μsec.

W. FISCHER: Is there any reason concerning plasma stability, why is the gas inlet so low near the filament and not in the middle of the chimney?

N. VOGT-NILSEN: The gas inlet at the chimney base is convenient with our very narrow chimney (6 mm diameter). An inlet nearer the exit slit would probably be more advantageous, but would require an oval-shaped chimney to enclose a gas feeder tube.

Y. JONGEN: Is your anticathode floating or at ground potential?

N. VOGT-NILSEN: It is floating.

M. REISER: You mentioned that the ion source can be moved into two different positions allowing injection of the beam in opposite direction. What are the reasons or advantages for this arrangement?

N. VOGT-NILSEN: The internal beam used for internal targets rotate in the opposite direction of that used for extraction.

D. LAMOTTE: Did you have any problem with the bellows of your contacts?

N. VOGT-NILSEN: No, we have not had any trouble so far.

D. LAMOTTE: What was the pressure?

N. VOGT-NILSEN: The lower contacts are at atmospheric pressure and the upper contacts are at 0.5 atm.