CURRENT STATUS OF THE ECR ION SOURCE PROJECT AT NSCL*

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Introduction

Figure 1 shows a comparison of the two NSCL superconducting cyclotrons for stand-alone, and then coupled mode operation with an average ECR, against a backdrop of the coupled mode operation with an internal PIG ion source. As a result of the large "K's" of these cyclotrons[1,2] high beam energies would be possible with an ECR stand-alone in either cyclotron, and there is also a gain at high A for the coupled cyclotron mode.

In addition, it has become quite clear that the demonstrated high reliability, long lifetimes, and relatively uncritical tuning of the ECR sources in use far exceeds the best possible situation with a PIG, and so from the operational stand-point alone an ECR could be justified. As a result, we have recently started a design study for a superconducting ECR at NSCL, and would like to report on the status of this work.

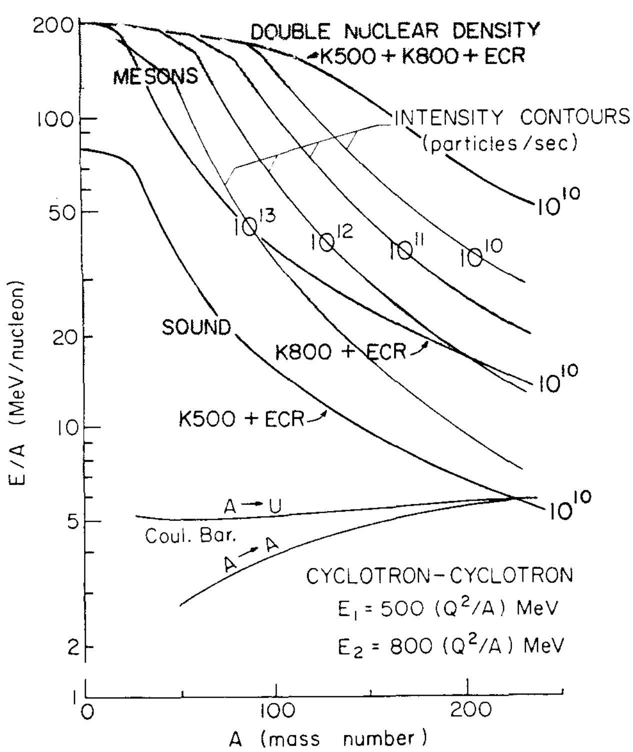

Figure 1. Energies from 1978 NSCL proposal and those anticipated with an ECR injecting the K500, K800, and K500 + K800.

Source Design

The basic source design is shown in Figures 2 and 3. The most striking features of this design are the vertical orientation, the use of an iron yoke, the placement of a cylindrical cryopanel in the second stage vacuum chamber, and of course the large size. After some general remarks about the design, each of the areas above will be discussed briefly.

The large size was chosen on the basis of the better charge state distributions coming from the larger existing sources,[2-5] resulting most likely from higher electron energies in the large sources, and also the view that poor external pumping is the main limit to further improvements in the C.S.D.[6] In addition, the experience gained in the laboratory's superconducting magnet program is highly compatible with the construction of a large source.

The magnetic field is produced by a combination of five solenoid coils and a hexapole structure, all superconducting. One small coil, residing in the second stage vacuum chamber along with the cryopanel, but at a radius smaller than the second stage coils, is intended to provide more precise local control of the magnetic field strength and shape in the injector stage. The remaining coils, which provide the minimum-B structure required in the second stage, reside in a common cryostat. The inner wall of the cryostat also forms the second stage vacuum chamber wall. The two solenoid coils at the center of the second stage provide for field trimming. The fields shown in Figures 4 and 5 are consistent with operating frequencies of 14 GHz in the first stage and 10 GHz in the second stage, but adjustment over a broad range is possible- for example, with this coil configuration it is possible to operate both stages at 14 GHz.

Vertical Orientation

For several reasons, we decided to have a look at a vertical source. The layouts of existing sources show a large assortment of coil supports and mounting devices, some of which look quite expensive. In addition, horizontal sources consume a lot of floor space, a commodity in short supply at NSCL. Then there is also the question of whether to inject into the top or the bottom of the cyclotrons- coming in from the bottom appears more desirable because the upper pole caps must rise to allow beam chamber access, and this could mean having to break the beam line or possibly removing some part of it when the cap went up. For these reasons we have chosen a vertical source, to be situated near ground level, with injection into a trench leading to the lower center plug of either cyclotron. It seems that the support structure- three struts holding the yoke, becomes quite simple in this design.

Iron Return Yoke

It is quite a surprise that existing sources have not employed an iron yoke, since it greatly improves the efficiency of the magnetic structure. We have found that the addition of a yoke reduces the current densities required to obtain a given field level, by returning a large percentage of the flux. More significantly, the yoke will reduce the fringe field in the extraction region, and this should improve the beam optics. In Figure 4 we show a calculation of the mirror field of this device, showing the contributions

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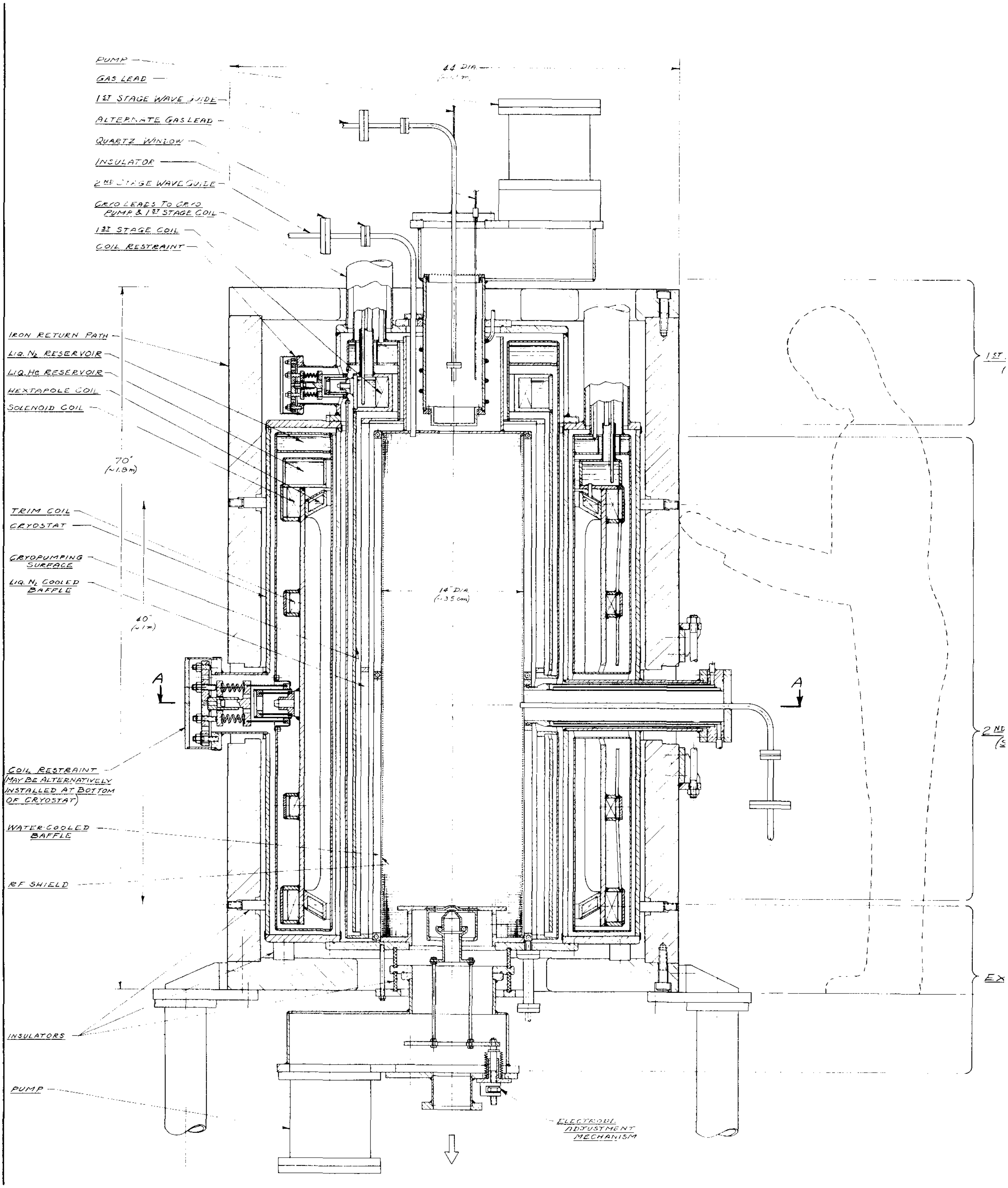

Figure 2. Engineering study for a vertical superconducting ECR with a return yoke and cryopanel pumping in the second stage. The main elements are indicated. Both radial and axial locations are shown for the admission of microwave power into the second stage.

coming from the coils and the yoke. In Figure 5 the field lines for this case are plotted. As can be seen, the field fails sharply as a result of the yoke.Even in these preliminary calculations this looks quite promising. The yoke will also be serve as an X-ray shield around the source.

Second Stage Pumping

There is a growing body of evidence that the plasma density in the second stage is strongly coupled to the neutral density because the gas recirculation rate is large, while the external pumping speeds have been low (see for example, Refs. 4 and 6). In as much as this is true, we have looked at locating a large He-cooled cryopanel within the second stage vacuum chamber, suitably screen from the microwaves and baffled, as best seen in Figure 2. Otherwise, we plan to use turbopumps in the injector and extraction regions for pumping, with the extraction region turbopump also providing the starting high vacuum for the cryopanel.

References

* Work supported by NSF under Grant No. PHY-83-12245.

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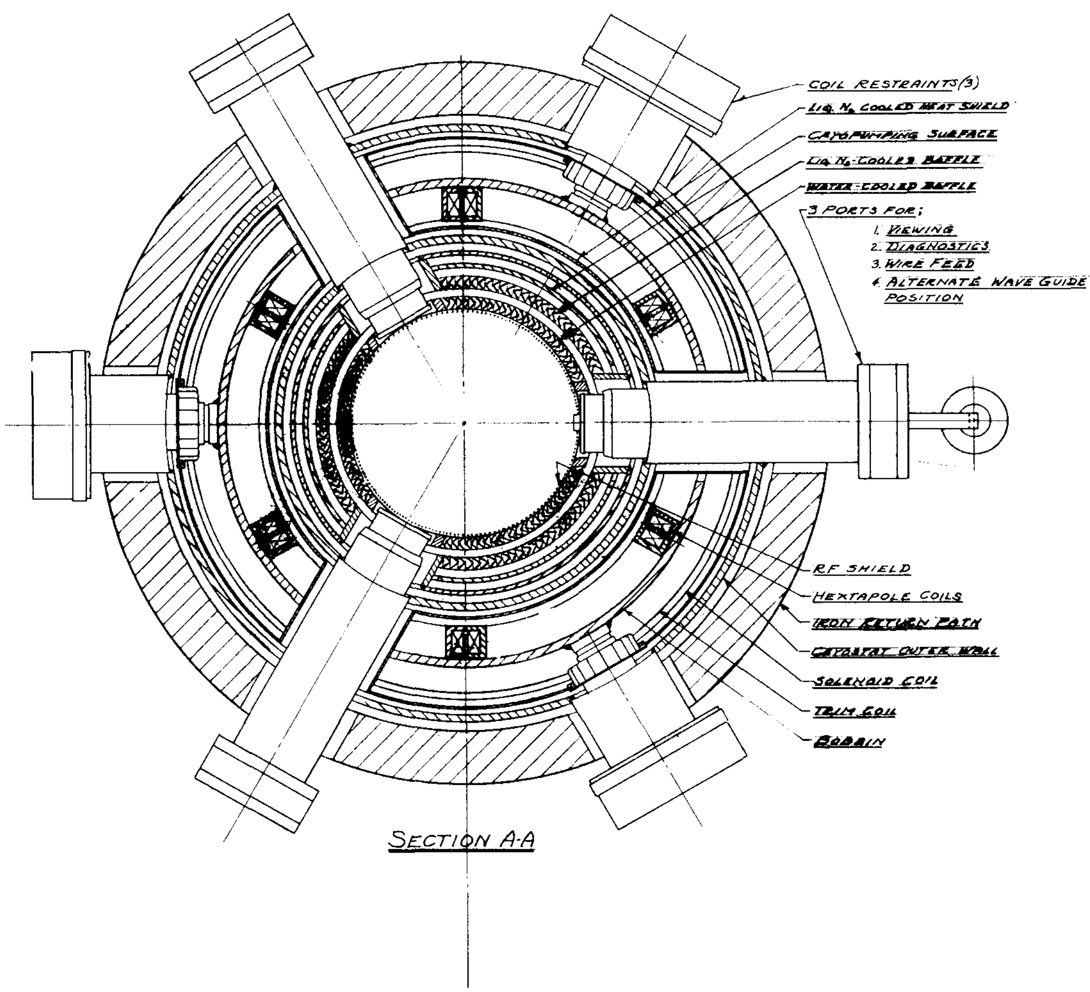

Figure 3. Cross-sectional view of the ECR shown in Figure 2.

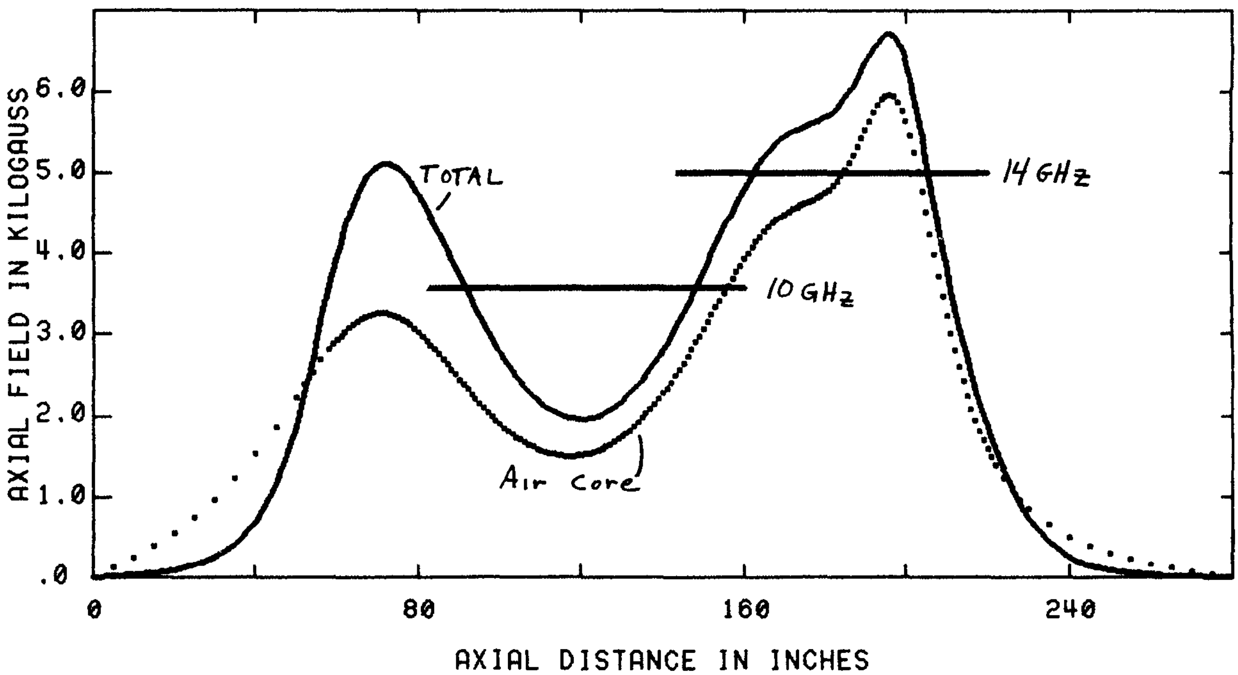

Figure 4. Magnetic field along the axis of the source, including the total field and the air core contributions from the coils.

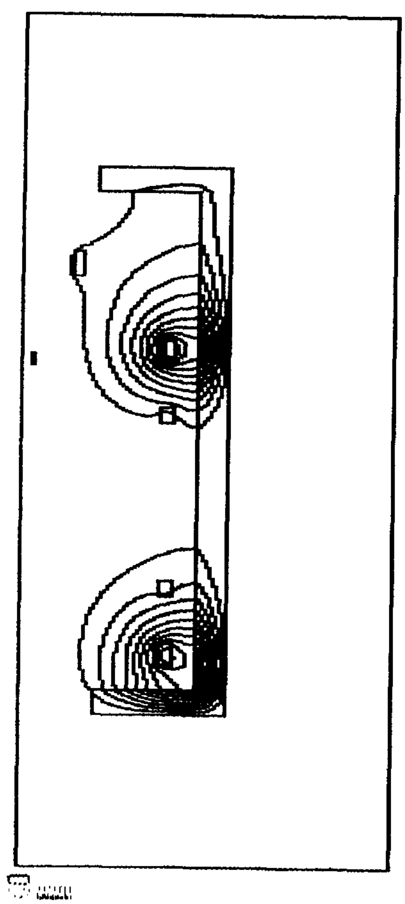

Figure 5. Flux lines through the source for the field levels in Fig. 4. The coils are indicated by their rectangular boundaries, and the yoke cross-section as the large "C" shaped surface. Note the effects of the small trim coils at the center of the second stage.

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