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ELECTRON VOLT SPECTROSCOPY ON THE SNS: INITIAL FACILITIES AND FUNCTIONAL DESIGN

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ABSTRACT

A brief description is presented of the instrumentation which it is anticipated will be available at the beginning of SNS operations for the development and scientific use of electron volt inelastic neutron spectroscopy.

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I INTRODUCTION

This report seeks to provide an outline description of the eVS beam line (S2) on the SNS, and all associated apparatus and facilities likely to be available for use within the eVS development program during the initial period of SNS operations. It is based, in part, on the decisions of a working party set up by the eVS User Group.

The eVS project on the SNS has as its present aim the development and scientific use of a spectrometer in which the scattered neutron energy is determined using a nuclear resonance absorption filter. Two basic methods of using absorption resonances will be investigated in tandem on the one beam line. The resonance detector spectrometer (RDS) relies on the detection of promptly emitted γ-rays after resonant neutron capture. The resonance filter spectrometer (RFS), on the other hand, detects neutrons and utilises the difference in signal between the filter being out of and in the beam.

A principal feature of any eVS design must be the ability to measure high energy transfers ($\hbar\omega \geqslant 0.5$ eV, say) with low associated momentum transfer $\hbar Q$ ($Q \leqslant 5$ Å^{-1}, say) - though values of $Q \sim 100$ Å^{-1} should also be available as an option. A review of the current status of eVS instrumentation development at various pulsed neutron facilities has been presented in a previous report [1], together with a discussion of some areas of scientific application. For more detailed descriptions of the techniques and experimental results see references [2] (RDS) and [3] (RFS) and further references therein.

The two detection methods will use a common collimation package, beam dump, data acquisition electronics (DAE), front end minicomputer (FEM), etc. and both, of course, view the same ambient(A) moderator. In this way it is hoped to ascertain their relative advantages and actual signal: noise limitations.

II BEAMLINE LAYOUT

Beyond the moderator, the eVS beamline has five major components: shutter, incident beam collimation, the Resonance Filter Spectrometer (RFS), the Resonance Detector Spectrometer (RDS) and the beam dump. The general layout of the beamline and the local experimental hall area is shown in Figure 1. More detailed diagramatic information on the beamline components external to the biological shield can be found in Figure 2.

The biological shield face is at 5.9 m from the target; nominal RFS and RDS sample positions are at 10 m and 11.5 m respectively with secondary flight paths of ~ 1 m in both cases. The beam dump drift tube terminates at the beam dump core at 16 m from the target.

Flexible bellows to either end of the RDS enable either it or the RFS to be reconfigured and re-aligned independant of the other.

III COLLIMATION

Broadly speaking the incident beam collimation package is designed so as to define a circular beam of diameter ~ 30 mm at a sample position ~ 10 m from the moderator. The sample views a 100 mm diameter circle inscribed on the 100 x 100 mm ambient (A) H_2O moderator at 89.3° to the moderator surface.

Given the desire to be able to measure electron volt energy transfers in inverse geometry at low Q we are constrained to use relatively high energy neutrons and detect at scattering angles $\phi \sim 2°$. Implied in this statement is the importance of a design that limits both the sample and the detectors' view of collimation surfaces directly illuminated by the moderator, and a choice of materials that reduces to a minimum problems associated with inelastic collimator transmission and γ-ray fluxes. The ability to collimate a relatively high energy neutron beam without introducing significant off-energy contamination is of paramount importance to the successful development of an eVS.

The eVS collimation may be divided into 3 sections: that within the shutter, the insert (i.e. within the biological shield or target station) and that external to the biological shield. Figure 3 gives a schematic view of the assembly.

The shutter collimation consists of nine octagonal irises separated by iron spacing sections and held within an iron shot/borax/resin moulding which serves to decouple the collimation from the surrounding bulk shielding. The irises are formed from 6 mm thick sintered boron carbide tiles set at 45° to one another. The inner surfaces of the iron sections are set back from the B_4C - defined beam edge such that they cannot be viewed directly from the sample and should not, therefore, contribute to the instrument background as an extended secondary source. For reasons of safety and to minimise neutron beam attenuation the shutter collimation, like the target vessel, has a helium atmosphere.

Within both the insert and external collimator sections the beam is defined by a series of twenty 50 mm thick circular section B_4C/(10%) Resin irises. This low hydrogen content mix should help to reduce the albedo of the inner, illuminated surface of the iris and moderation of the incident beam energies. Upstream of eight of these there is a 50 mm thick lead ring which serves to collimate the γ ray flux generated within both the target assembly and the collimation itself. γ collimation is particularly important when using a RDS-type system but will also be of benefit to a RFS-type system using scintillator detectors. The lead rings are set back from the beam edge and cannot be viewed directly from either sample or detector positions, thereby avoiding the secondary neutron emission problem inherent in the use of lead. It is also worth noting that relatively pure lead (~ 99.8%) has been used in the fabrication to avoid possible background problems arising due to the large antimony content of most low grade lead stock: antimony has a strong γ-emitting resonance at 6.24 eV. Downstream of each B_4C/resin iris there is a thin aluminium disc plasma spray coated with ~ 1 mm B_4C. These discs penetrate the epithermal beam sufficient to prevent a direct view of any iris from the sample or detector positions. In other words, no hydrogenous collimator surface material may be seen directly by either the sample or by any detector.

The gaps between iris assemblies are filled with a lead + iron shot, borax and resin moulding with an inner suface lining of B_4C/resin. The inner surfaces of these are set well back from the beam edge.

The insert and most of the external collimation is evacuated to ~ 1 mbar, individual sections being separated by thin aluminium windows. The vacuum window immediately upstream of the spectrometers is sufficiently far from the RFS detector positions that it cannot be viewed at $\phi > 5°$, and lower angle detectors will have only a limited view. This arrangement also allows relatively easy access to the final three collimator irises for modification, if necessary. The final vacuum window is at the end of the beam dump drift tube. A gap in the collimation just outside the biological shield facilitates the insertion of resonance absorption blocking filters.

The above collimation produces a circular beam with a waist diameter of ~ 30 mm at 9.6 m from the target and from which the umbra converges at 3.0 mrad and the penumbra diverges at 6.8 mrad. This gives an umbra diameter of ~ 28 mm at the RFS sample position, with a penumbra annulus of width ~ 4 mm. At full SNS intensity the neutron flux through this sample position will be $\Phi \sim 3\ 10^{7}$ n eV^{-1} s^{-1} at E = 1 eV (note, $\Phi \propto E^{-0.95}$ for $E \geqslant 1$ eV). Within the umbra the flux is ~ 5 10^{6} n eV^{-1} cm^{-2} s^{-1}. Provision has been made for the insertion of up to 250 mm of beam trimming collimation just upstream of the RDS; assuming a nominal 30 mm diameter beam/sample within the RDS, this implies a flux of ~ 4 10^{6} eV^{-1} cm^{-2} s^{-1}.

Two lithium glass scintillator monitors may be installed using vacuum feedthroughs into the collimation (at 6.5 m and 8.6 m from the target) and beam dump tube (at 13.5 m from the target). These low efficiency monitors have a fast response time, and their $E^{-\frac{1}{2}}$ efficiency makes them highly suitable for eV spectroscopy use.

IV DETECTION SYSTEMS AND ELECTRONICS

As described above, there will be two detection systems under development within the eVS project, one downstream of the other on the S2 beam line. A prototype RFS sample/detector chamber has been installed on a beam line at the WNR facility, Los Alamos, for tests, but has now been returned to RAL to form the basis of a RFS on the SNS. The RDS equivalent will be based on the existing system installed on the Harwell Linac as part of a Harwell/Oxford University/RAL collaboration.

The two spectrometers will share a common vacuum system and both will use the same standard SNS instrument DAE package. It is anticipated that a half share of a VAX 11/730 FEM will be available, which will be expected to serve the requirements of both systems. Incident and scattered beam neutron monitors will, of course, be common to the two instruments. Clearly, the two methods cannot be pursued simultaneously; during RFS runs the downstream RDS assembly will be left void (i.e. forming part of the beam dump drift tube), whilst for RDS runs it will be necessary to insert some collimation into the RFS sample/detector chamber. Having outlined the substantial areas of instrumentation overlap we now describe briefly the major features peculiar to each method.

a) RFS. The prototype design has been discussed in some detail elsewhere [4] and the salient features only will be summarised here. The incident flight path is $L_1 \sim 10$ m, the scattered flight path will normally be $L_2 \sim 1$ m though there exists an option to reduce this to $L_2 \sim 0.75$ m. Beam size and divergence has been discussed above. There are a total of twelve 10 atm. He-3 detector tubes available - 8 with active length 254 mm, 4 with active length 150 mm, all with diameter 25.4 mm. They are housed within a moulded B_4C/resin shielding block which allows the use of 1, 2 or 3 tubes in a triangular arrangement at $\phi \sim \pm 10°$, $\pm 15°$ and $\pm 20°$ and a four-detector square around the beam at $\phi \sim 5°$. It will be possible to extend the range of scattering angles downwards, in the future, by installing an array of scintillator detector elements. There is a 100 mm gap in the collimation at about 6.2 m from the target to facilitate the insertion of blocking filters; both the sample and the secondary beam fixed filters are suspended from a sample tank flange. Rotary vacuum feedthroughs allow the user to perform a full double difference experiment without breaking vacuum. There is a liquid nitrogen feed through/cold finger assembly mounted on the sample flange which may be used to cool a filter or, exceptionally, the sample.

It is anticipated that the vacuum tank will be lined internally with 3 - 6 mm of B_4C/resin (the resin concentration being limited to 5 - 10%) and/or sheets of Boral. External shielding will be an ad hoc arrangement of boraflex sheet, borated resin blocks and concrete. There is a close fitting 150 mm thick wax/borax shield wall just upstream of the sample tank.

b) RDS. The RDS will make use of the detector and sample boxes currently being used on the Harwell Linac. These will be positioned to give an incident flight path of approximately 11.5 m and scattered flight path of 1 m, though variations are possible.

Initially the gamma ray detector will be a high resolution, high purity Ge detector. The detector system has its own electronics, including an A.D.C., and can give output signals for events in pre-selected γ-ray energy bands as well as a digital signal which can be used to give 2-dimensional data analysis (i.e. T.O.F. and γ-ray energy) at some future date.

External shielding around the detector box will be similar to that used at Harwell, being 100 mm of lead surrounded by 300 mm of borated resin and concrete blocks. B_4C/resin sheets will be used as shielding inside the detector box to screen the Ge detector and lead shielding from scattered neutrons. Both lead and neutron absorbing materials will be used as collimation and shielding in and around the beam tube between the sample and detector boxes.

V OTHER FACILITIES AVAILABLE FOR eVS

Limited basic services will be available, such as single phase mains power to the instrument : other required services, such as cooling water, will by supplied on an ad hoc basis, though it is expected that a standard Sample Environment supply panel will be installed fairly soon after operations begin. The patch panel and all signal cables will be shared, initially, with the S1 beam line instrument POLARIS: provision of a completely independent data acquisition chain will be made as soon as practicable. A pillar crane, lifting capacity 1 tonne, has been installed between the S2 and S3 (SXD) beam lines and will be shared by the S1, S2 and S3 beam lines. A "Portakabin" instrument control cabin is available for eVS from which the user may communicate with the shared FEM, via a pericom VDU having graphics capability. The FEM will have access to the HUB computer via a Cambridge Ring, and thence to all standard SNS instrument software packages. Sample environment will normally be limited to ambient temperatures in vacuum.

VI eVS DEVELOPMENT

It is impossible to define, a priori, the precise line of development that the eVS project will take but it is possible to indicate the general directions as they now appear. Optimisation of the incident beam collimation together with both detector and general instrument shielding is important. The resonance filter technique must be pursued to lower scattering angles, which will necessitate the development of a low angle scintillator bank and a re-design of the scattered beam fixed filter assembly. The resonance detector must likewise be pushed to low angles using both high and low resolution γ detectors together with an investigation of coincidence or anti-coincidence techniques.

In parallel with the development of the instrumentation, and as a necessary part of it, the areas of science made accessible by the spectrometers will be investigated.

References

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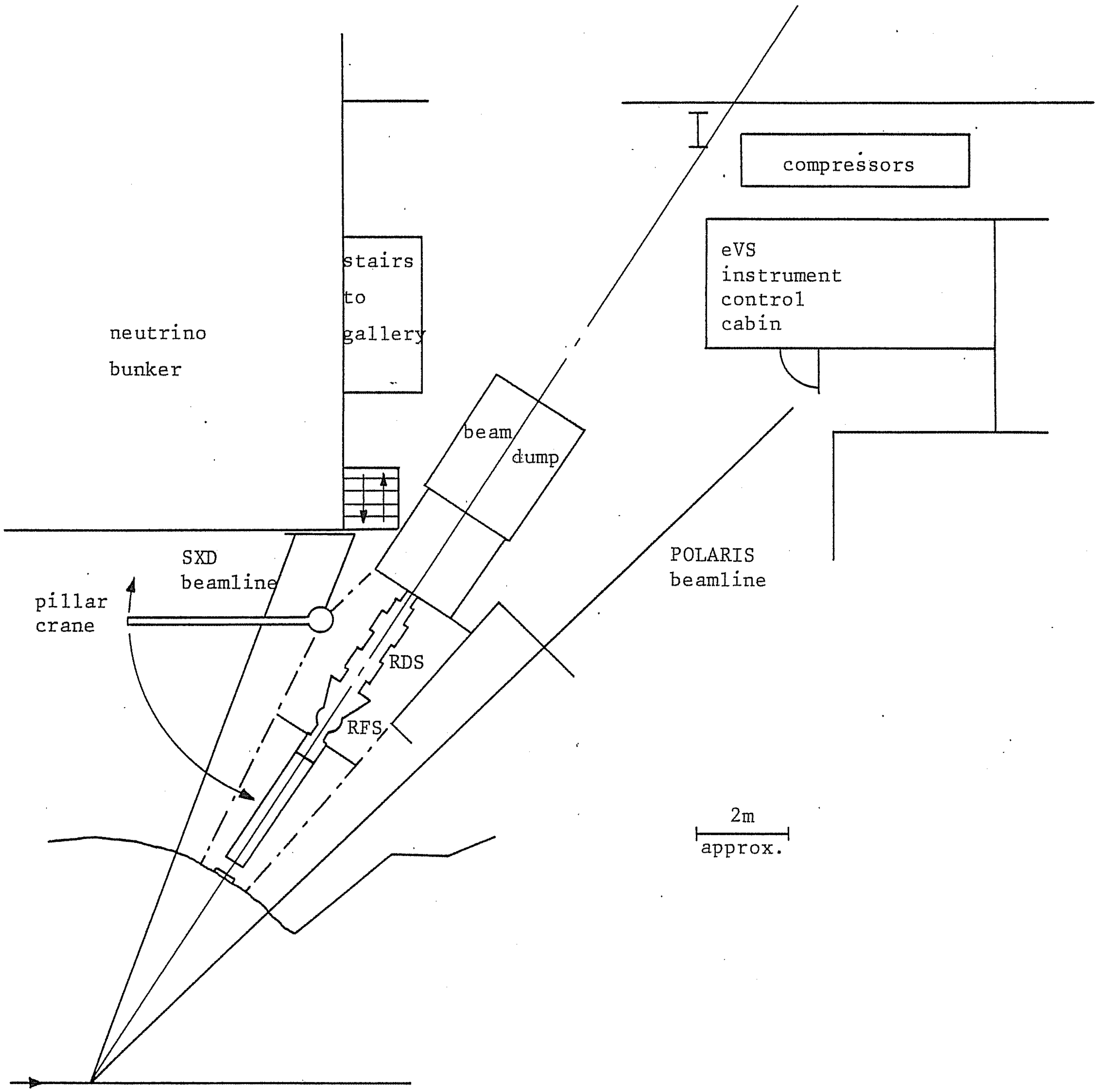

FIGURE 1 THE eVS BEAMLINE AND ITS ENVIRONS

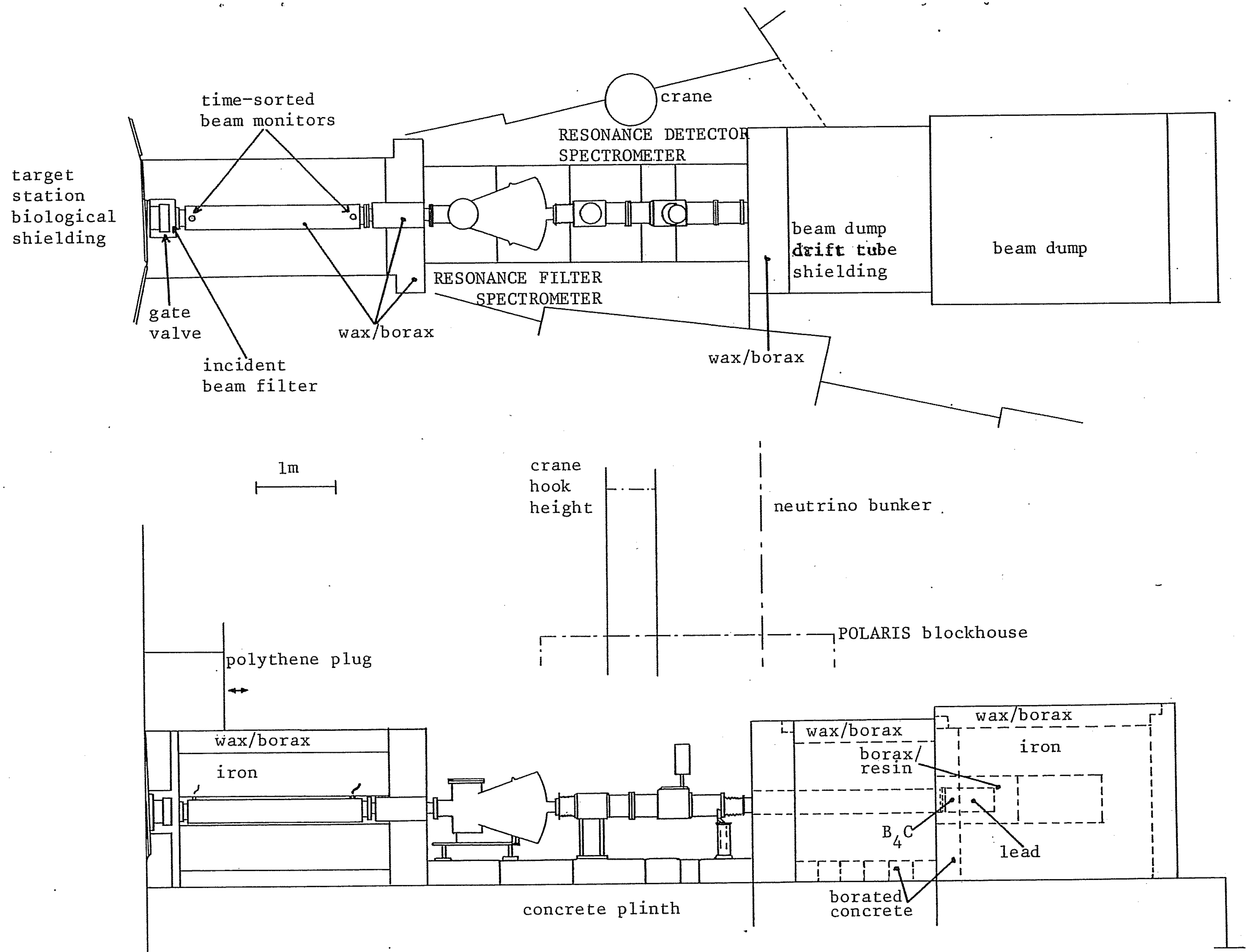

FIGURE 2 SCHEMATIC PLAN AND SECTION OF THE eVS BEAMLINE

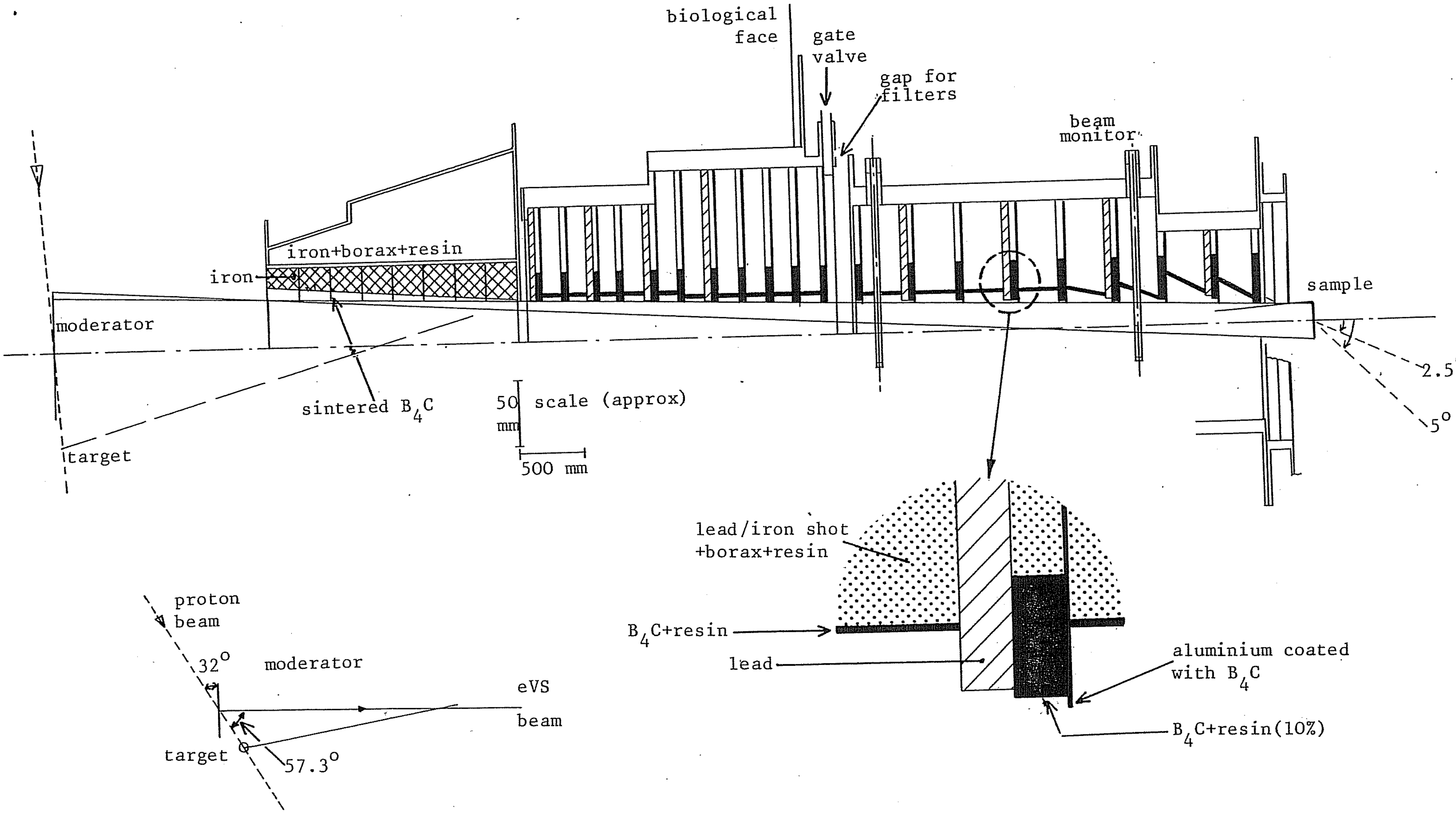

FIGURE 3 SCHEMATIC SECTION AND DETAILS OF THE eVS INCIDENT BEAM COLLIMATION ASSEMBLY