THE UNIVERSITY OF MANITOBA

MONOENERGETIC NEUTRON INDUCED RADIATION DAMAGE IN VICIA FABA BEANS AND SINGLE PHOTON EMISSION FOLLOWING DOUBLE K-SHELL IONIZATION OF RUBIDIUM

by

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ABSTRACT

The details of two separate projects are reported and the results prior to August 1977 are given. The first chapter details a study of the effects of high energy neutrons on a biological system. The biological system concerned was Vicia faba and the particular emphasis was placed on determining the Oxygen Enhancement Ratio (OER) (Ha73a). Beams of essentially monoenergetic neutrons were used to determine the OER which was found to be, 1.2±0.3 at 25.5 MeV and 1.1±0.5 at 36.6 MeV mean neutron energy. This represents a sizeable reduction in comparison to values obtained at lower neutron energies (Ha73b). Neutron induced spallation reactions in oxygen are discussed as a possible mechanism to explain the observed results. Also discussed are the implications of these findings for the field of cancer radiotherapy.

The second chapter describes an experiment designed to study two-electron single-photon transitions in the doubly ionized K shell of rubidium. An upper limit on the ratio of these transitions to one-electron single-photon transitions in a singly ionized K shell was established as 2.28×10^{-6} at a 95% confidence level. This value is compared to the results of theoretical calculations due to Gryzinski (Gr65), McGuire (McG73), and Aberg (Ab76).

Suggestions are made concerned with improving the sensitivity of the experimental system to these type of measurements.

ACKNOWLEDGEMENTS

I wish to acknowledge the supervision of Dr. J.S.C. McKee throughout these projects and the assistance and supervision of Dr. J. Birchall in the conducting of the experiments. I would like to thank all the cyclotron staff, and in particular the members of the P.I.X.E.-Neutron Group, for their continuing assistance and interest.

I would also like to thank Drs. A.F. Holloway and A.M. Sourkes and the staff of the Manitoba Cancer Treatment and Research Foundation for their help and advice during the neutron studies.

A COMMENT ON THE STRUCTURE OF THIS THESIS

This thesis consists of two chapters describing two separate projects undertaken with the cyclotron group at the University of Manitoba between August 1976 and August 1977. The cyclotron group is supported by an N.R.C. grant.

The University of Manitoba Cyclotron is a sector focussed cyclctron which produces pulsed beams of protons in the energy range 20 - 50 MeV at typical intensities of between 1 and 7 microamperes. Negative hydrogen ions are axially injected into the centre of the machine at 11 keV (Ba76) and deflected into the median plane by an electrostatic mirror. They are then accelerated by a 28 kV rf voltage. Extraction of protons beams of energies between 20 and 50 MeV is achieved by means of a thin Aluminum stripping foil and a small exterior magnet (see Fig. 1). When a beam of negative hydrogen ions passes through the stripping foil two electrons are removed, the magnetic field reverses, and the proton beam is swept out of the cyclotron field. The energy of extraction is chosen by adjusting the stripping foil angle and radius. Protons from the machine are transmitted to one of five separate experimental beam lines (see Fig. 2).

The first project to be described involves the study

of the effects of high energy neutron irradiation on a biological system, namely Vicia faba seedlings. The aim of the studies was to measure the Oxygen Enhancement Ratio (OER) of 20 to 40 MeV neutrons using the essentially monoenergetic neutron beam available at the cyclotron laboratory. It was felt that neutron beams in this energy range might have OERs much lower than those for lower energy. This is relevent to the field of radiotherapy. This topic forms the major part of my thesis and is discussed in Chapter 1.

The second project involved the study of atomic transitions in rubidium atoms with doubly ionized K shells. The recent work of Wolfli et al (Wo75,St77) using beams of heavy ions have shown that it is possible for a doubly ionized K shell to be filled by a correlated jump of two L electrons and the emission of a single photon which carries the entire energy of the transition. It was hoped to observe these transitions in Rb atoms using protons to produce the initial ionization. The results of these studies have made it possible to place an upper limit on the probability of such a transition. A description of these experiments and their results make up Chapter 2.

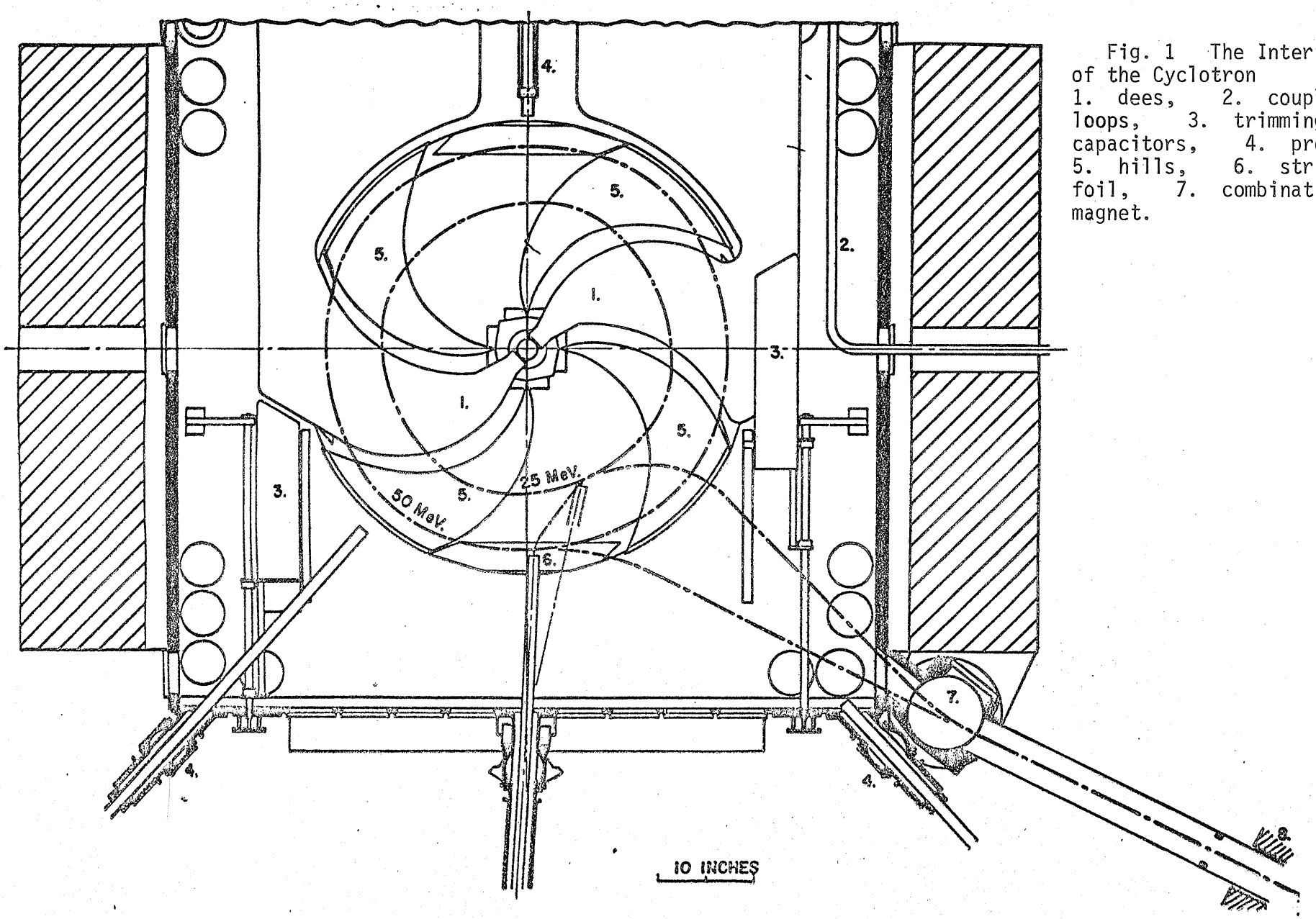
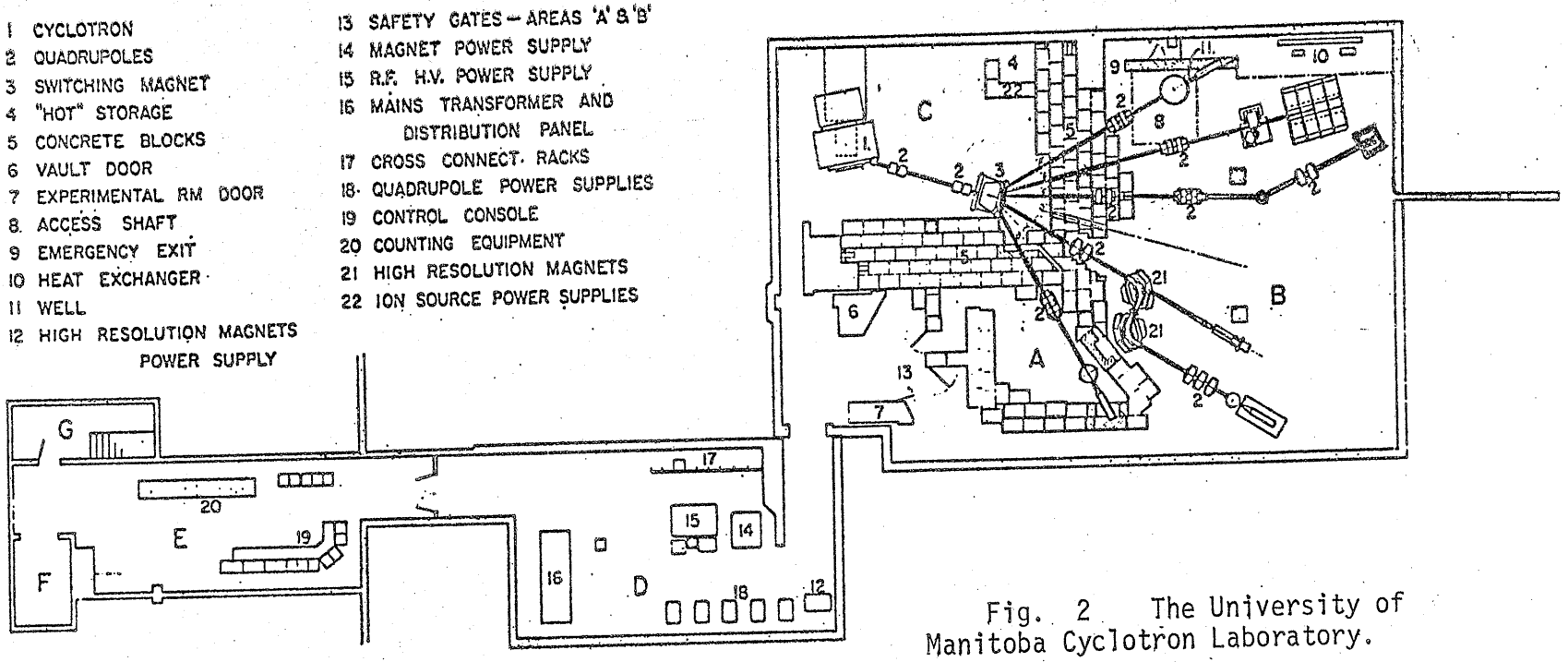


Fig. 1 The Interior of the Cyclotron
1. dees, 2. coupling loops, 3. trimming capacitors, 4. probes, 5. hills, 6. stripping foil, 7. combination magnet.

1 CYCLOTRON
2 QUADRUPOLES
3 SWITCHING MAGNET
4 "HOT" STORAGE
5 CONCRETE BLOCKS
6 VAULT DOOR
7 EXPERIMENTAL RM DOOR
8 ACCESS SHAFT
9 EMERGENCY EXIT
10 HEAT EXCHANGER
11 WELL
12 HIGH RESOLUTION MAGNETS POWER SUPPLY
13 SAFETY GATES — AREAS 'A' & 'B'
14 MAGNET POWER SUPPLY
15 R.F. H.V. POWER SUPPLY
16 MAINS TRANSFORMER AND DISTRIBUTION PANEL
17 CROSS CONNECT. RACKS
18 QUADRUPOLE POWER SUPPLIES
19 CONTROL CONSOLE
20 COUNTING EQUIPMENT
21 HIGH RESOLUTION MAGNETS
22 ION SOURCE POWER SUPPLIES



A EXPERIMENTAL AREA 'A' (CAVE)
B EXPERIMENTAL AREA 'B'
C CYCLOTRON VAULT
D ELECTRICAL ROOM
E CONTROL ROOM
F ELEVATOR
G STAIR HALL

Fig. 2 The University of Manitoba Cyclotron Laboratory.

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CYCLOTRON BASEMENT LAY-OUT WITH LEGEND
495.C

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CHAPTER I

MONOENERGETIC NEUTRON INDUCED RADIATION DAMAGE IN VICIA FABA BEANS

1. INTRODUCTION

The mechanism of radiation damage in a biological system is only beginning to be understood. It has been observed that the amount and nature of the damage which results depends not only on the biological system in question and on the incident radiation but also on a number of other factors such as the presence of oxygen or the point in the cell's cycle at which the irradiation takes place.

Of the various types of radiation studied to date, one of the least well understood is neutron radiation. Studies have shown that the effect of neutrons varies dramatically as a function of neutron energy. Also, at some energies the presence of oxygen in the system may have a large effect.

The aim of the studies described here was to examine the effect of high energy neutrons on a biological system. Specifically to use monoenergetic* beams of neutrons with energies between 20 and 40 MeV to induce damage in Vicia faba bean seedlings (Re59,Ha61). The particular effect which was hoped to observe was that

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*Monoenergetic for these experiments refers to a beam where the majority of neutrons have energies which differ from the mean energy by only a small amount.

induced by the presence of oxygen in the system at the time of irradiation.

Recent work by Harrison et al (Har75,Har76a,Har76b) at the University of Maryland Cyclotron has indicated that with neutrons in this energy range, the presence of oxygen in the biological system has only a minimal effect. These results were not expected on the basis of predictions obtained by extrapolating the data of Hall et al (Ha73b, Ha77) and others to higher energies and are in disagreement with earlier results of Berry (Be71). It was hoped that the present study would help resolve this disagreement and lead to a better understanding of the damage process. It was decided to conduct these experiments using a monoenergetic beam rather than the broad beams normally employed in this type of study (Har75). It was hoped that if the oxygen effect was indeed dependent on energy, this dependance could be firmly established.