Rutherford Laboratory

Technical leaflet

A8.1

THE EXTRACTED PROTON BEAM AT NIMROD

1. PURPOSE

Getting the proton beam out of a circular machine like Nimrod is a difficult and complex process. Nevertheless, it is very much worthwhile, since it allows much greater freedom in planning high-energy experiments.

2. MAIN COMPONENTS

The extraction system is shown schematically on the attached drawing. It consists chiefly of three important components:-

(i) a Target in Octant 3, whose essential purpose is to distort the path of the beam without otherwise disrupting it too much;

(ii) an Extractor Magnet in Straight Section 2, which catches the distorted beam (nearly one turn later), and bends it violently outwards, so that it crosses the aperture and comes out of Octant 3;

(iii) an Extractor Quadrupole in straight 7, it's function is rather more subtle: it ensures that protons which have lost different amounts of energy in the target all arrive at about the same point of exit from the machine.

3. SPILL ON TARGET

When the protons have been accelerated to full energy, 7 Gev, they are travelling around a circle of mean radius 740 inches, and are constrained by a field of 14 kGauss. The radial spread in the beam is about 13 cms and the vertical spread approximately 6 cms. By gradually increasing the magnetic field, (typically by 40 gauss in 200 milliseconds), the beam is driven towards the energy-loss target, made of Beryllium. Beryllium is used since it leads to suitably small scattering in the target.

4. TARGET

This target comprises a thin 'lip' which is 2.5 high, 2 mm thick in the beam direction and extends 1 cm radially outwards from the thick part of the target. The thick part of the target is 1 cm high, 3 cms wide in the radial direction, and 2.2 cms long in the beam direction.

5. ENERGY LOSS

Each proton traverses the lip a number of times losing about 0.6 Mev per traversal, and suffers a reduction in the amplitude of its betatron oscillation as well as a small decrease in its mean orbital radius. Ultimately the proton encounters the thick part of the target, loses about 6 Mev in passing through it, and takes up an orbit with radius of curvature sufficiently reduced to send it through the Quadrupole and Extractor Magnet. These are situated radially just inside the equilibrium position of the accelerated beam. The Extractor Magnet then bends the trajectories of the protons and causes them to emerge from the machine.

6. PLUNGING AND FLIPPING

The beam fills the aperture of the vacuum vessel at injection, but shrinks as acceleration proceeds. So, to prevent loss of particles by obstructing the beam during the earlier part of the acceleration process, the target is 'flipped' up from the floor of the vacuum vessel when the peak field has been attained. Furthermore, the Extraction Quadrupole and Magnet are plunged into the aperture from inside the ring at the appropriate time. The Extractor Magnet weighs about 1 ton and the Quadrupole about 0.15 tons; they are plunged through 40 cms in 300 milliseconds, once every two seconds.

7. QUADRUPOLE

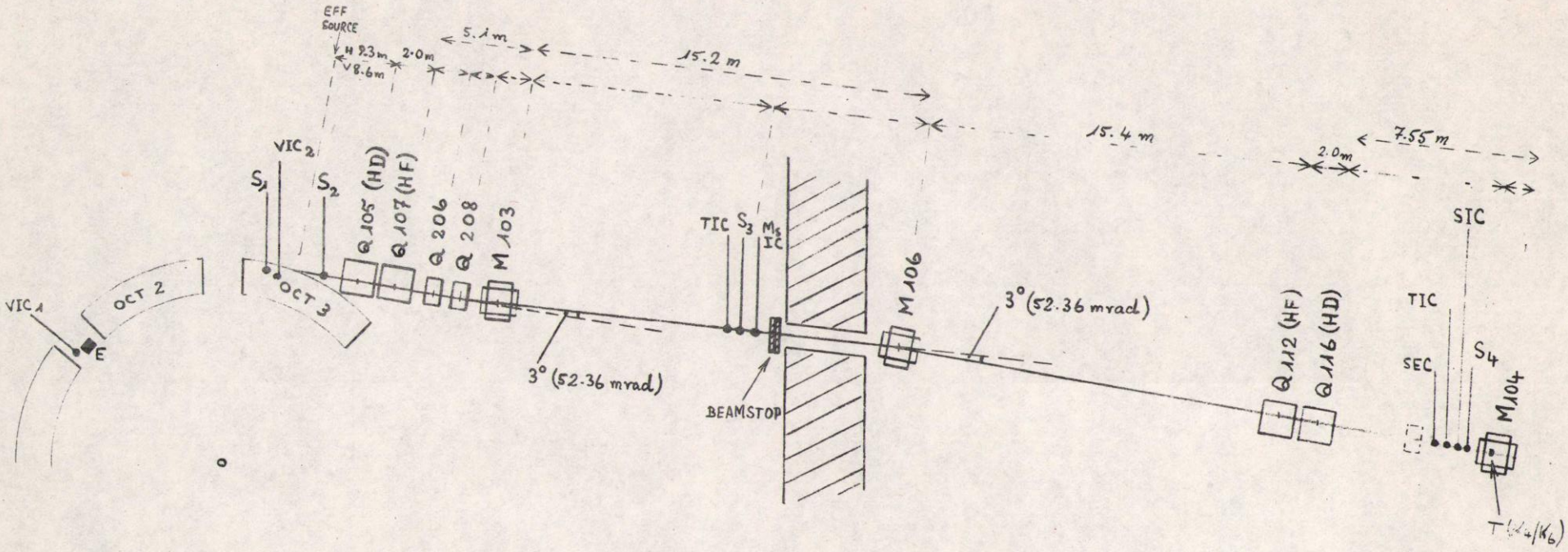
The energy loss in the target does not have a unique value, but is distributed about a mean. By the time they reach the Quadrupole's azimuthal position, the protons with energy losses larger than the mean have become displaced farther towards the centre of the machine than those with smaller losses. This effect may be corrected by energising the Quadrupole so that it is horizontally focusing, and the different protons emerge together from the machine.

8. GRADIENT ON EXTRACTOR MAGNET

Besides the main windings used to energise the Extractor Magnet, extra windings are provided which make it capable of producing a field with a radial gradient. Further windings, known as 'anti-reluctance' windings, reduce the unwanted effects that the energised magnet might have on the circulating beam. The radial gradient field produces focusing as well as bending, and assists the purpose of the Quadrupole in achieving "achromatic" behaviour.

9. EXTERNAL TRANSPORT SYSTEM

When the beam leaves the machine it behaves as if it had diverged from a spot source in Octant 3. It is converted into a parallel beam, in both the vertical and horizontal planes, by quadrupoles Q105 and Q107. The bending magnet M103 deflects the beam through an aperture in the shielding wall, and magnet M106 redirects it towards the external target. Close to the external target, quadrupoles Q112 and Q116 refocus the beam to a spot measuring a few millimetres vertically and horizontally.



VIC : Valve Ion Chamber

S : Scintillator

TIC : Total Ion Chamber

MsIC : Multistrip Ion Chamber

SEC : Secondary Emission Counter

SIC : Strip Ion Chamber

SCHEMATIC LAYOUT OF P1 BEAM LINE