RF Separator: Beam Stopper

by

R.D. Fortune

1. Introduction
2. Design Details
   2.1. Material
   2.2. Geometry
   2.3. Alignment in the beam
   2.4. Block drive mechanism
   2.5. Zero Position Checking (Zepoc)
   2.6. Scintillator Counters
   2.7. Mechanical connection to other beam components
3. Testing and Setting Up
   3.1. Drive tests
   3.2. Zepoc
4. Acknowledgements
5. References
1. Introduction

The central beam stopper, proposed by Montague in 1960, is that part of the RF Separator beam line which degrades the momentum of the unwanted part of the beam sufficiently for it to be removed from the beam by subsequent momentum analysis. In the RF Separator beam, momentum selection is made in the horizontal plane and mass selection in the vertical plane. The beam stopper then takes the form of a flat horizontal plate which intercepts only those particles suffering no net deflection which occupy the central region of the beam. It is, however, not quite as simple as that - the auxiliary requirements of variable high precision geometry and remote control and monitoring present some interesting technical problems. In this note are described briefly the more important design details and the techniques for setting up and testing the apparatus.

2. Design Details

2.1. Material: The principal modes of momentum degradation in the beam material are by nuclear interactions, in which the interacting particles lose a large fraction of their momentum, and by ionisation or excitation loss in which the particles lose momentum gradually in a large number of atomic electron collisions. Ideally, we require that the unwanted particles should not be deflected out of the beam stopper while in the process of losing the required amount of momentum in such a way that they remain within the angular acceptance of the following beam line. In other words we require a material which combines a high stopping power with a low scattering. In addition we are limited by beam optical considerations to a maximum beam stopper length of the order of a metre. Now the ratio of nuclear interaction mean free path to mean scattering length (which we require to be as small as possible) increases almost monotonically with increasing atomic number. We choose the material, then, with the lowest ratio allowing us to meet the length restriction - which is copper. In fact we have chosen its alloy brass
for its superior machinability and mechanical strength. In brass, the nuclear interaction m.f.p. is 11.8 cm and the mean scattering length 1.44 cm.

2.2. Geometry: Theoretically\(^{(3)}\), the beam is roughly circular in section in the region of the beam stopper and the beam stopper cuts out the middle third of it. A first approximation for the thickness required for this, is in the region of 20 mm. In view of the uncertainty as to the exact thickness required and in view of the usefulness of a variable thickness in setting up the beam, the thickness has been made variable up to 40 mm maximum. To allow for vertical misalignment of the beam stopper with respect to the beam, the mean height of the beam stopper can be varied by at least \( \pm 5 \) mm. The beam stopper can also be completely retracted from the beam. These characteristics are realised by the system of two sliding wedges shown in figure 1, in which the wedge angle is \( \Theta = \arcsin 0.2 \) and the range of movement for each block is 210 mm.

Particle leakage through the gap between the sliding blocks is prevented by stepping the blocks as shown in figure 2, where \( L \) is the minimum distance a particle incident in the region of the gap must traverse in the beam stopper. This arrangement allows reasonable mechanical tolerances \( \pm 0.1 \) mm on the machining of the sliding blocks and on the positioning of the guide rails. The step was decided on as 1 mm and the maximum allowable gap after alignment of the rails as 0.5 mm.

The dimension \( L \) was chosen to be 50 cm, equivalent to about 4.5 interaction lengths and to an ionisation loss\(^*\) of about 600 MeV/c. This gives an interaction probability for the strongly interacting beam component (the contaminant least desired in the separated beam) of 99\(^{\circ}\) and allows rejection of all charged contaminant if the acceptance of the subsequent beam line is better than \( \pm 3^{\circ} \).

2.3. Alignment in the beam: The area near the flange seating for connection of the beam stopper to adjacent beam elements, is marked with vertical \( \mathbb{V} \) and horizontal \( \mathbb{H} \) reference lines (figure 3) for alignment in the beam line of the beam stopper external vacuum box. Horizontal

\* With a beam momentum in the region of 10 GeV/c, the ionisation plus excitation loss is near the minimum on the loss v. momentum curve, i.e. about 1.5 MeV/gm cm\(^{-2}\).
hh and vertical vv lines are marked on the moving blocks such that when they are aligned on the blocks, the effective beam stopper thickness is 20 mm. When, in addition, the block lines are aligned on the vacuum box lines, the beam stopper is centred in the vacuum box. The position so found is also the Zepoc reference position in which the Zepoc electrodes are mechanically aligned (see paragraph 2.5).

Six adjustable feet are provided which enable the beam stopper to be adjusted in three mutually perpendicular directions for alignment in the beam line (see assy. dwg. no. AR 216-146-1). The three feet for horizontal position adjustment are attached directly to the underside of the vacuum box and enable the box to be displaced easily within a square of movement of side 30 mm, with a sensitivity of ±0.1 mm. The three feet for vertical position adjustment are located between the support frame and the 40 cm thick concrete block, and enable the vacuum box to be raised or lowered over a 30 mm range with the same sensitivity.

2.4. Block drive mechanism: The moving blocks are driven by independent screw drives, as shown in the assembly drawing no. AR 216-146-1. The chain and screw-shaft coupling for this drive traverses the vacuum box through double-O-ring sealed shafts. The layout of the drive as shown is economical in lateral dimension, which is of prime importance in the design of such beam elements. Each motor also drives a Sodeco "Impulse Generator" (Model TK 7) which, with separate forward and reverse outputs, gives one register-driving pulse per 0.1 mm displacement of the driven block. Limit microswitches prevent the moving blocks from being driven against the end stops or against each other. The drive circuit diagram is given in drawing no. AR 216-149-3.

2.5. Zero position checking: A Zero Position Checking device (4), referred to as ZEPOC, enables a reference position of each block to be checked with a precision of better than ±0.1 mm, independently of the functioning of the displacement measuring system. These reference positions have been chosen to correspond with the posi-
tion of the moving block when they have been aligned with their reference marks on the vacuum box (figure 3 and paragraph 2.3), i.e. thickness 20 mm and mean height zero. Note that if one then sets the port and starboard register counters \( N_p = +500 \) and \( N_s = -500 \), the thickness and mean height of the beam stopper are given subsequently by

\[
T = \frac{N_p - N_s}{50} \text{ mm}
\]

\[
H = \frac{N_s + N_p}{100}
\]

The Zepoc bridge circuit must be set to give minimum output (magic eye closed) when the Zepoc electrodes are aligned in the Zepoc reference position described. To do this, the bridge has to be set first for single minimum with the electrode approximately on the correct position by moving the block and its electrode across the fixed (wall) electrode and adjusting the bridge components. Once set for single minimum, the block is then left in its aligned position and its electrode is adjusted on it to align with the wall electrode, to regain the minimum output from the bridge circuit. This alignment can be done to ± 0.1 mm by leaving the adjustment screw half tightened and lightly tapping the electrode with a small hammer.

2.6. Scintillator counters: Although not essential to the operation of the beam stopper, it was decided that it would be useful to have a scintillator counter system attached to the moving blocks in such a way as to count only beam particles which did not hit the beam stopper (dwg. no. AR 216-146-1). These counters would serve as a monitor, after setting up the beam, of the centring of the beam stopper (difference of counts) and of flux of good particles (sum of counts) passing the beam stopper.

Three main difficulties arise in the design of such a counter system, to be mounted inside the vacuum box:
a) dissipation of heat from the photomultiplier HT resistor chain,
b) passage of a large number of electrical leads through the vacuum wall,
c) protection from wear of electrical connections and cables between the moving blocks and the wall of the vacuum box,
d) light sealing of the scintillator material (normal foil and tape procedure being inappropriate in vacuum due to degassing).

The electrical difficulties have been overcome by mounting the photomultipliers (56 AVP) in a vacuum tight cylinder at atmospheric pressure. The resistor chain and other local components are contained in one end of the cylinder so that only seven leads have to be taken out. They are taken out through a vacuum-tight tombac of 17 mm I.D., which serves also to protect cables and end connections from chafing.

Several methods were tried, unsuccessfully, to produce a light-tight surface on the scintillator which did not degas excessively: various paints, electro-deposition of silver, sputtering of aluminium. It was finally decided that it was easier to cover the end windows of the vacuum box, or the ends of the beam pipe, with a light-tight combination of mylar and aluminium foil.

2.7. Mechanical connection to other beam components:

Seating for the standard CERN beam pipe flange are machined at each end of the beam stopper. Normally an intermediate standard beam pipe tombac is connected first in order to avoid de-alignment of the beam stopper due to excessive rigidity in the beam line connections.
3. Testing and Setting Up

Once the slide rails have been adjusted for allowable gap <0.5 mm between the blocks, and the Zepoc electrode alignment made, the assembly should be very delicately handled during any essential displacement of the apparatus as a whole. If the beam stopper has been displaced or subjected to any mechanical shock, these fundamental adjustments should be carefully checked. Routine checks to be made before a run are given in the following sections:

3.1. Drive tests:

a) Local control box: check the proper functioning of the four motor-actuating push buttons. The box has also an external independent connection to FS security group, which causes the blocks to move so as to block the beam and vetoes any control command by any other group. Check the values of all fuses.

b) Drive mechanism: using the remote control box placed adjacent to the beam stopper (photo fig. 4), drive each block continuously over its entire range and note any signs (e.g. excessive motor loading or slowing) which would indicate that maintenance of the drive assembly is required. The normal couple required at the shaft of the motor directly is 0.75 kg cm, and in case of doubt on the stiffness of the drive, thus should be checked with a torque spanner on the easily accessible end of the motor shaft.

c) Microswitches: with remote control box, the operation of the five limit microswitches should be checked - and the functioning of the limit indicator lamps.

FS/5058
3.2. Zepoc: with test remote control box. Check and reset if necessary the bridge balance of the Zepoc circuits. In the event that there is no Zepoc indication at all due to complete misadjustment of the circuits, a first approximation to the mechanically aligned position may be obtained by referring to the microswitch end-stops: the Zepoc positions are approximately 98.5 mm in from these end stops (see ref. 4 for further details of alignment). Before going to the remote control station to make the next check, put the blocks in the Zepoc position.

Remote control at the annex: the blocks having been left in the reference position, it is convenient to set the remote control box register counters to the Zepoc nos. ± 500 before connecting the control cables. When this has been done, and the cables reconnected, check the operator of the microswitch limit indicator lamps and the bias setting of the Zepoc magic eye.

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General Assembly and Tests: J. Boud

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3) E. Keil, CERN Internal reports AR/Int. PSep/63-3 and
   AR/Int. PSep. 63-6.


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Fig. 1 Beam stopper: method of obtaining variable thickness and variable vertical position

Fig. 2 Beam stopper: method of avoiding leakage of beam particles through the gap between the blocks
Fig. 3 Beam stopper alignment
Zero reference position
Thickness = 20 mm; Height = 0
Fig. 4  Beam stopper: Remote control box