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BSRTMB aperture and operation considerations

ABSTRACT:

A new synchrotron radiation extraction tank has been designed and installed. This document describes the aperture restriction implication, how the actuator will be controlled and how the device will be operated.

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1. Introduction

For the HL-LHC era the synchrotron radiation (SR) based diagnostics need to be extended. For this purpose a second SR extraction point is needed. The most convenient location of the new source is in IP 4 not far from the existing one, but using the radiation produced from the D4 magnet, the present source is on the D3.

The new location poses additional constrains requiring a re-design of the extraction tank from scratch.

We profited from this fact by correcting certain design aspects that posed problems with the original design.

One of the main changes is that the mirror can now be moved closer to the beam w.r.t. the old design, exploiting the fact that the beam size shrinks increasing the energy. From simulations we know that the performance of the SR instruments improves observing the radiation emitted deep into the D4 magnet, i.e., the radiation that is closer to the proton beam.

In the new design the mirror can become an aperture restriction and need to be precisely controlled and the position interlocked.

Although this new BSRTM is not needed until run 4 we need to validate the new design, and in particular the potential RF heating, before LS3. This is the reason for the installation of the device described in this document.

Only the device on the left side of IP4 is installed: BSRTM.5L4.B1 which is of type BSRTMB

For all the details of the installation refer to the approved ECR document https://edms.cern.ch/document/2610870/1.0

2. Aperture restriction considerations

The extraction mirror acts as an aperture restriction in the horizontal plane.

The vertical aperture is given by the vacuum chamber diameter of 100mm (larger than the standard chamber of 80mm).

Figure 1 shows the top vie cross-cut of the new extraction tank. The mirror, beam and synchrotron radiation can be clearly identified.

The actuator is the dark blue plate that holds the vacuum flanges on which the mirror and the viewport are mounted.

The mirror and the viewport move as one part so that no net vacuum forces act on the actuator.

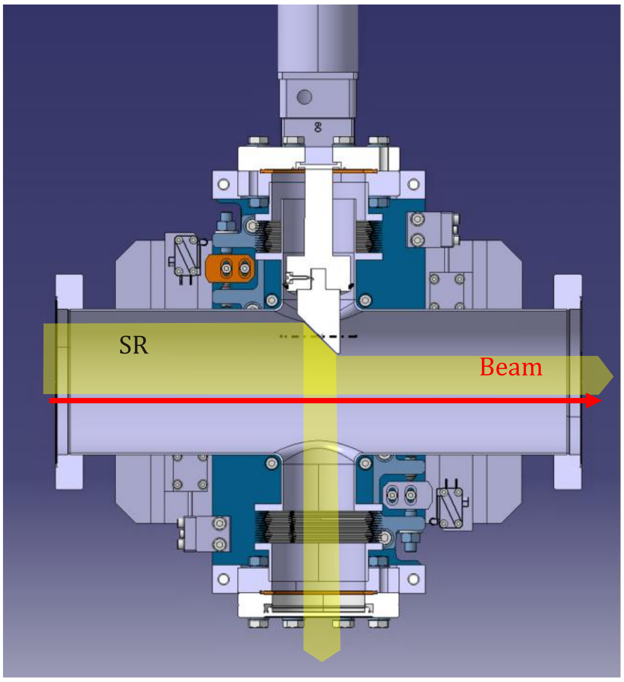

Figure 1 —Cross section (top view) of the new BSRTMB tank and mirror. The fused silica mirror is visible on the upper side (white slanted surface). The beam passes along the centre of the tank and the SR is extracted by the viewport visible on the lower part of the image. The position of the mirror in the image is close to the injection position (partially retracted).

2.1 Aperture calculations by BE-ABP

(source Riccardo De Maria 08-03-2021)

Members of the BE-APB group have calculated the limits for the protected aperture in the horizontal plane at the new BSRTM location for different energies.

The numbers reported below come partially from private e-mail exchanges and partially from the slides presented by Riccardo at the "195th HiLumi WP2 Meeting" https://indico.cern.ch/event/1072725/

2.1.1 Injection 450 GeV.

With the mirror edge at 22.9 mm from the circulating beam, including effects of shape tolerances and 1 mm alignment and ground motion tolerance we fulfil the minimum protected aperture requirements at injection of n1 = 13σ. Table 1 summarizes the results of the calculation.

Table 1 — Minimum required aperture at injection.

	BSRTM.5L4.B1	BSRTM.5R4.B2
Aperture x [mm]	**22.9**	22.9
Aperture y [mm]	100	100
Beta x [m]	**381.2**	381.2
Beta y [m]	263.4	243.1
Sigma x [mm]	**1.409**	1.409
Aperture x [σ]	**16.2**	16.2
Sigma y [mm]	1.172	1.1255

The beam tolerances used to calculate n1_h are:

emittance_norm = 2.5e-6 um

sigma error = 5%

dispersion error = 14%

orbit_error = 0.002

energy_error = 0.00086

2.1.2 Flat top 6500 GeV

With the mirror edge at 11.2 mm from the circulating beam, including all the relative tolerances as described in section 2.1.1 we fulfil the minimum protected aperture requirements at injection of n1 = 20σ. Table 2 summarizes the results of the calculation.

Table 2 — Minimum required aperture at flat top.

	BSRTM.5L4.B1	BSRTM.5R4.B2
Aperture [mm]	**11.2**	11.2
Beta x [m]	**381.2**	381.2
Beta y [m]	263.4	243.1
Sigma x [mm]	**0.371**	0.371
Aperture x [σ]	**30.2**	30.2
Sigma y [mm]	0.308	0.296

The beam tolerances used to calculate n1_h are:

emittance_norm = 2.5e-6 um

sigma error = 10%

dispersion error = 10%

orbit_error = 0.002

energy_error = 0.0002

3. Mirror position control and monitoring

The position of the actuator that supports the mirror is controlled by a step motor. The motor is equipped with a resolver that monitors its angular position.

The motor is controlled by a PXI system provided by BE-CEM which is based on the infrastructure used for the control of the LHC collimators.

The BSRTM device includes two limit switches and two linear potentiometers.

The limit switches are used to limit the motion of the step motor and gives an indication of the position of the actuator when this is fully retracted or fully inserted.

The full insertion of the mirror arm is limited by the limit switch, but also by a mechanical stopper and can in no case be inserted closer than ~10 mm from the circulating beam.

The two linear potentiometers provide a redundant continuous monitoring of the position of the actuator. This is in addition to the position calculated by the step motor/resolver system. In total there will be three different and independent monitors for the position of the mirror.

The position read by the potentiometers is continuously compared with an energy dependent limit. In case the position of the mirror is closer to the beam than the limit set for that energy an HW interlock will be triggered (BIS).

The position reference is established by the OUT limit switch and corresponds to a distance of the edge of the mirror to the axis of the chamber (nominal beam line) of 34.4 mm. A positive movement means moving the mirror closer to the beam.

The main purpose of this installation is the verification of the negligible RF induced heating. To this end two thermal probes, thermocouples of type E, are installed and used to monitor continuously the temperature of the mirror and of its support, both probes are inside vacuum. The thermal probes are read out by a FESA class under the responsibility of SY-BI and are continuously logged in NXCALS.

Add the description of the PXI system as well as the details of the logic for the BIS signal by BE-CEM.

4. Operation during run 3

At injection and during the energy ramp the mirror will be placed at 23 mm (plus δ) from the circulating beam, since there is no undulator on the D4 synchrotron radiation source the mirror could be fully extracted, however the aim of this test is to validate the beam induced RF effects. For this reason, we would like to position the mirror at the nominal position even if no SR light is available.

At flat top, when the energy has reached the steady value of 6.8 TeV, the mirror will be moved by a sequencer task to the flat top position of 11.2 mm (plus δ) from the circulating beam.

The limit will be stored in LSA as machine critical settings (MCS), for our purpose the minimum is to have two values, one for energies below 6.5TeV of 23 mm (plus δ) and one for energies above or equal to 6.5 TeV of 11.2 mm (plus δ).

The safety margins (δ) on the limit and positions must be evaluated once the noise in the position reading is known. The settings will be adjusted so that the minimum aperture is protected as required and at the same time the risk of spurious BIS trigger is reduced to a reasonable value.

The limit values to be stored and LSA need to be computed from the aperture limits and the position calibration.

Table 3 — LSA limits assuming a δ of 0.1 mm.

Energy [GeV]	Aperture limit [mm]	Margin [mm]	Offset [mm]	LSA limit Min [mm]	LSA limit Max [mm]
450	23.0	0.1	34.4	-1	11.3
6500	11.2	0.1	34.4	-1	23.1

4.1 Other operation considerations

From experience with the existing devices, which use the same materials for the tank and the mirrors, we do not expect any sensible out-gasing or UFO creation.

APPENDICES