COMMISSIONING AND FIRST PERFORMANCE STUDIES OF A SINGLE VERTICAL BEAM HALO COLLIMATION SYSTEM AT ATF2

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Abstract

A single vertical beam halo collimation system has been installed in the ATF2 beamline to reduce the background that could limit the precision of the diagnostics located in the post-IP beamline. On this paper the commissioning and first performance studies of a single vertical beam halo collimation system are reported. Furthermore realistic efficiency studies have been done using the simulation code BDSIM and compared with the first experimental tests.

INTRODUCTION

ATF2 is a Beam Delivery System (BDS) built after the ATF Damping Ring (DR) providing a scaled-down version of the Future Linear Collider (FLC) Final Focus System (FFS) [1]. The ATF2 main goal is to achieve a vertical beam spot size at the virtual IP of 37 nm within a nanometer level stability. The control of the beam halo that could be intercepted in the beam pipe producing undesired background is a crucial aspect for FLC and ATF2. A transverse beam halo collimation system feasibility and design study for reducing the background in ATF2 was done and reported in [2, 3]. In March 2016 a vertical beam halo collimation prototype has been installed in ATF2 with the main goal of reducing the background photons that could limit the performance of key diagnostic devices around the final focal point (IP), especially the Shintake Monitor (IPBSM) used for measuring the nanometer level vertical beam size and the Diamond Sensor (DS) used to investigate the beam halo distribution and the Compton recoil electrons [4, 5] (see Fig. 1). In this paper we present the results of the commissioning and first performance studies as well as a first comparison of the these measurements with realistic tracking studies done using the tracking code BDSIM [7].

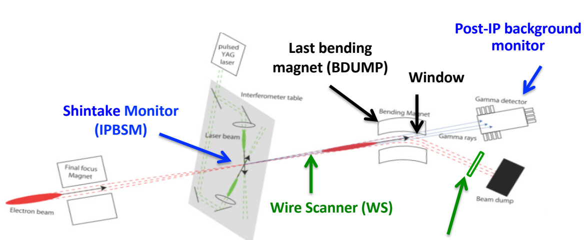

Figure 1: ATF2 post-IP scheme.

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VERTICAL BEAM HALO COLLIMATOR: INSTALLATION AND COMMISSIONING

Construction and First Calibration at LAL

The vertical collimation system has been manufactured and assembled at LAL. A description of the different components can be found in [3]. The main parts of the collimation system are the two rectangular Copper (Cu) jaws that can be moved independently. The minimum half aperture of the collimator is limited to 3 mm by a mechanical switch and the maximum half aperture is 12 mm. At 12 mm half aperture no collimation and wakefield impact is expected. The linearity response of the motors and the software to control de system were tested at LAL and the actuator precision measured was about 10 μm. The jaws were aligned with respect to external references (the flanges and back plane to determine a 3D axis) with a 3D machining before closing the vacuum chamber with indium seels. Furthermore a vacuum test at the level of 10^{-6} Pa was performed successfully.

First Performance Studies in ATF2

The vertical collimation system was installed in ATF2 the first week of March 2016 (see Fig. 2). A chassis was build in order to fix the collimator in the beamline and a laser tracker was used to align the vertical collimation system respect to external references with a precision of 0.5 mm. In addition a 10^{-8} Pa vacuum level test was performed and no leakage found.

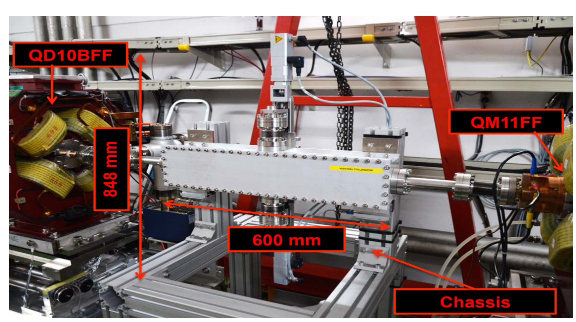

Figure 2: Vertical collimation system installed in ATF2.

Measurements were taken with the post-IP Wire Scanner (WS) [6], DS, and post-IP background monitor (CsI scintillator) in the March 2016 run in order to test the performance and the efficiency of the vertical collimation system with beam. During this run the beam energy was 1.3 GeV, the intensity ranging from 0.1-1 $\times 10^{10}$ electrons per bunch, and

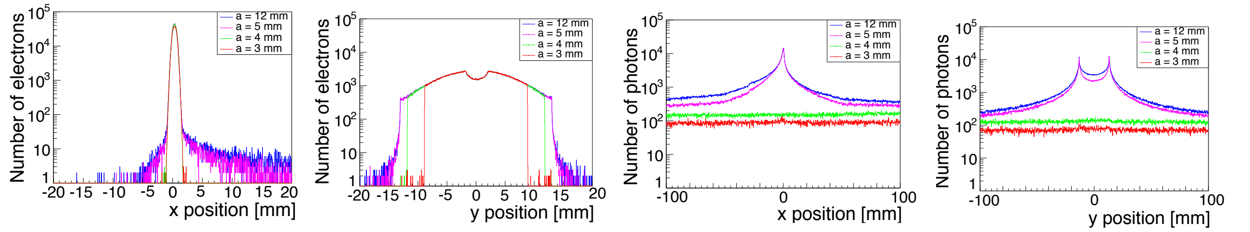

Figure 3: Horizontal and vertical distribution of primary electrons (first two plots) and secondary photons (last two plots) at the BDUMP window for the IPBSM photons.

the optics configuration used was 10 times the nominal β_x^* and the nominal β_y^* ($10\beta_x^* \times \beta_y^*$). With the post-IP WS and the DS the beam-jaws movement and alignment were studied. A symmetric vertical beam halo cut was measured with the post-IP WS and the vertical DS. As an example of these measurements the vertical beam halo distribution measured with the vertical DS with the collimator opened and close to 3 mm half aperture can be seen in Fig. 4. In

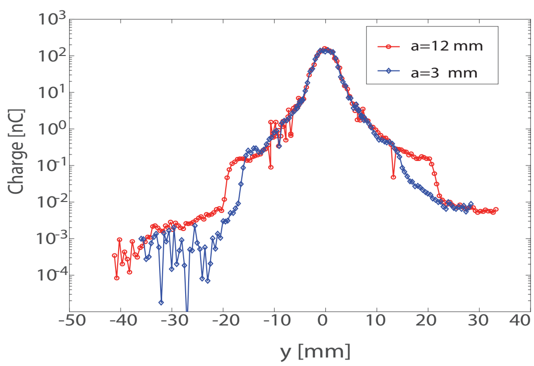

Figure 4: DS vertical beam halo distribution measurement.

addition measurements were performed using the post-IP background monitor for different collimator apertures and intensities. In Fig. 5 the signal of the background monitor

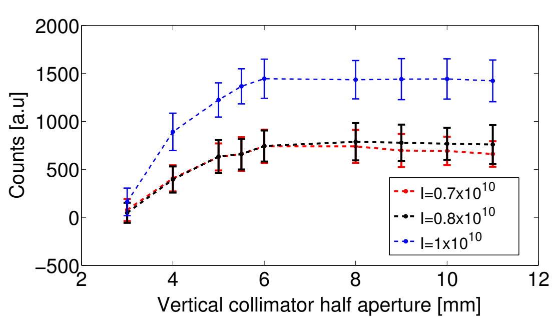

Figure 5: Post-IP background photons measurements.

is depicted as a function of the collimator half aperture for three different beam intensities. Each point is the average value of 100 pulses with the statistical mean error associated. A reduction of the background has been measured at the post-IP region for half apertures of the collimator smaller than 6 mm in agreement with tracking simulations reported in [2].

REALISTIC TRACKING SIMULATIONS USING BDSIM AND FIRST COMPARISON

The main source of background photons at the ATF2 post-IP region is due to the interaction of the vertical beam halo distribution with the beam pipe of the BDUMP that has a half aperture of 13 mm in the vertical plane (tightest vertical half aperture of the ATF2 beamline) and 28 mm in the horizontal plane. Beam halo tracking simulations have been performed with MADX and PLACET tracking codes in order to optimize the location and study the efficiency of a vertical collimation system in order to reduce the beam halo losses at the BDUMP beam pipe, these studies are reported in [2, 3]. These studies have been completed using tracking code BDSIM [7] an extension toolkit of Geant4 in order to study the efficiency of the collimator taking into account the emission of secondary particles and beam halo regeneration due to Electro Magnetic (EM) processes as ionization, bremsstrahlung, Cherenkov, and multiple scattering. The main goal of this study is to quantify the efficiency of the collimator in the reduction of photons that can reach the gamma detector of the IPBSM located after the BDUMP window. Furthermore the background generated by the collimator has been studied in order to verify that the EM shower produced by the collimator does not generate additional background photons in the IP region. Simulations have been performed of the ATF2 FFS considering the $10\beta_x^* \times \beta_y^*$ optics. A gaussian transverse beam halo distribution (x, x', y, y') with 10^6 electrons of 1.3 GeV has been generated from $\pm 3\sigma_{x,y}^{core}$ (only the beam halo tails are considered in these studies) with $\sigma_x^{halo} = 5\sigma_x^{core}$ and $\sigma_y^{halo} = 10\sigma_y^{core}$. No coupling between x-y planes has been taken into account. For the longitudinal distribution a gaussian model has been used with an energy spread of 0.08%. Multipoles and misalignments have not been taken into account. In Fig. 3 the horizontal and vertical distribution of electrons and photons at the BDUMP window for different half apertures of the vertical collimation system are shown. Notice that the primary vertical beam halo distribution overlap for a half aperture of 12 mm (collimator completely open) and 5 mm due to the fact that the expected cut of the BDUMP beam pipe is the same as the one of the collimator closed at 5 mm. The production of secondary photons along the beamline have been studied. Between the IP and the entrance of the BDUMP the distribution of photons is flat. At the the BDUMP window location (about 0.8 m from the

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entrance of the BDUMP) a not flat distribution of photons is observed with two picks in the vertical plane corresponding to the vertical edges of the BDUMP beam pipe as can be seen in Fig. 3 (last two plots). From these simulations we could conclude that the collimator is efficient in cleaning the vertical beam halo distribution in order to reduce the generation of background photons at the BDUMP and that the secondary photons generated by the collimator are absorbed before the IP region. In addition in Fig. 6 the relative reduction of background photons produced in the BDUMP before the window for different collimator apertures is compared with the post-IP background monitor measurements being the comparison compatible within the associated error.

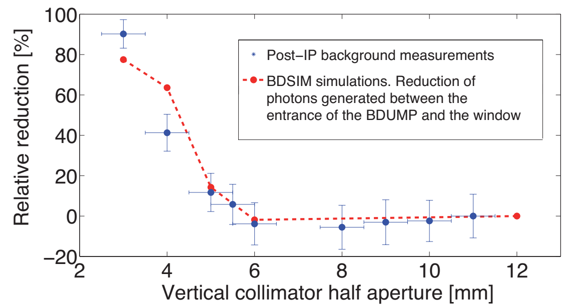

Figure 6: Comparison of the measured relative background reduction in the Post-IP with BDSIM simulations.

PRELIMINARY WAKEFIELD IMPACT MEASUREMENTS

The wakefield impact induced in the vertical collimation system has been studied by means of analytical calculations, 3D EM simulations and tracking studies using PLACET [8]. In order to complete the study the wakefield impact induced by the collimator on the beam orbit has been measured. using the ATF2 beam position monitors system formed by 45 C-band BPMs with 200 nm resolution in $\pm$ 1 mm range with 20 dB attenuation. In March 2016 run, orbit data have been recorded for a fix collimator half aperture of 4 mm and different collimator offsets respect to the beam. The analysis of the orbit data have been performed following the procedure in [9] and in order to subtract the orbit jitter the correlation between the collimator upstream and downstream BPMs is calculated using the Singular Value Decomposition method. Then, the residuals, $R = A'X - B'$, are calculated for each collimator offset where A' is the upstream BPMs readings, B' is the downstream BPMs readings and X is the correlation between upstream and downstream BPMs calculated for zero beam-collimator offset. Correlation between the measured beam position and the collimator offset is observed at two downstream BPMs (named as QF7FF and QD2AFF). An example of the correlation observed is shown in Fig. 7. From the linear fit of Fig. 7 the collimator wakefield kick, κ_T, can be calculated as:.

$$\kappa_T[\frac{V}{pCmm}] = \frac{p}{R_{34}[mm]}\frac{E[eV]}{eq[pC]} \quad (1)$$

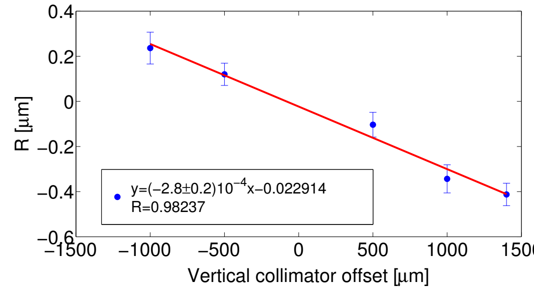

Figure 7: Residuals as a function of collimator offset.

where p is the slope of the linear fit, R_{34} is the corresponding transfer matrix element, E is the nominal ATF2 beam energy and eq is the measured charge of the beam. Taking into account the measurements at the two BPMs the average value obtained for the wakefield kick is $\kappa_T = 0.055 \pm 0.012\ V/pC/mm$ for a expected ATF2 bunch length between 6-8 mm. These preliminary measurements are compatible with the numerical simulations performed with CST PS [10] reported in [3] for a bunch length of 7 mm given a value of $\kappa_T = 0.048\ V/pC/mm$. The wakefield kick depends strongly on the bunch length therefore in a second campaign planned for May 2016 the bunch length is also planned to be measured in order to reduce uncertainties enabling the comparison of these results with simulations and analytical models.

SUMMARY AND FUTURE WORK

A vertical collimation system has been installed in the ATF2 beamline and the performance tested using the Post-IP diagnostic devices as the post-IP WS, the DS and the post-IP background monitor. The efficiency of the collimator has been demonstrated by measuring the background photons with the post-IP background monitor. A reduction of background is observed for collimator half apertures smaller than 6 mm. In addition, the relative background photons reduction measured in the post-IP region as a function of the collimator half aperture is compatible with the simulations performed with the tracking code BDSIM. A first attempt of measuring the wakefield impact induced in the collimator has been carried out for 4 mm half aperture. The wakefield kick obtained from these preliminary measurements is $\kappa_T = 0.055 \pm 0.012\ V/pC/mm$ (for a expected ATF2 bunch length between 6-8 mm) compatible with the value obtained from the numerical simulations performed with CST PS for a bunch length of 7 mm of $\kappa_T = 0.048\ V/pC/mm$. A second campaign of performance studies will be carried out in May 2016.

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REFERENCES

[1] G. R. White et al., "Experimental Validation of a Novel Compact Focusing Scheme for Future Energy Frontier Linear Lepton Colliders", Phys. Rev. Lett. 112,034802 (2014)

[2] N. Fuster-Martínez, A. Faus-Golfe, J. Resta-López, P. Bambade, S. Liu, S. Wallon, F. Toral, I. Podadera, K. Kubo, N. Terenuma, T. Okugi, T. Tauchi,"Design and Feasibility study of a transverse halo collimation system", IPAC14

[3] N. Fuster-Martínez, A. Faus-Golfe, J. Resta-López, P. Bambade, S. Liu, S. Wallon, F. Toral, I. Podadera, K. Kubo, N. Terenuma, T. Okugi, T. Tauchi,"Design study and construction of a transverse halo collimation system", IPAC15

[4] S. Liu, P. Bambade,F. Bogard, P. Cornebise, V. Kubytskyi, C. Sylvia, A. Faus-Golfe, N. Fuster-Martinez, D. Wang, S. Bai, J.Gao, T. Tauchi, N. Terenuma, "Status of Diamond Detector Development for Beam Halo Investigation at ATF2", IPAC14

[5] S. Liu, P. Bambade,F. Bogard, P. Cornebise, V. Kubytskyi, C. Sylvia, A. Faus-Golfe, N. Fuster-Martinez, T. Tauchi, N. Terenuma,"Investigation of beam halo using in vacuum diamond sensor at ATF2", IPAC15

[6] S. Liu, P. Bambade, N. Fuster-Martínez, A. Faus-Golfe, S. Bai, D. Wang, J. Gao,"Measurement of Beam Halo Transverse Distribution using wire scanners at ATF2", ATF-14-09 report

[7] http://twiki.ph.rhul.ac.uk/twiki/bin/view/PP/JAI/BdSim

[8] N. Fuster-Martínez, A. Faus-Golfe, A. Latina, J. Snuverink, "Geometric wakefield regimes study of a rectangular tapered collimator for ATF2", ATF2 report to be published

[9] J. Snuverink, R. Ainsworth, S.T. Boogert, F. J. Cullinan, A. Lyapin, Y. I, Kim, K. Kubo, T. Okugui, T. Tauchi, N. Terunuma, J. Urakawa, G. R. White, "Simulations and measurements of wake fields at the Accelerator Test Facility 2", PRST-AB Submitted to be published

[10] https://www.cst.com/products/cstps

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