ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-MOPRO033

DESIGN AND FEASIBILITY STUDY OF A TRANSVERSE HALO COLLIMATOR SYSTEM FOR ATF2

N. Fuster-Martínez, A. Faus-Golfe, J. Resta-López, IFIC (CSIC-UV)*
P. Bambade, S. Liu, S. Wallon, LAL
F. Toral, I. Podadera, CIEMAT
K. Kubo, N. Terunuma,T. Okugi, T. Tauchi, KEK

Abstract

This paper presents the design of a halo collimation system for the ATF2 beamline. The main objective is the reduction of background noise that limits 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 sizes and the future Diamond Sensor (DS) for measuring the beam halo. Beam tracking simulations have been performed to optimize the position and characteristics of the halo collimation devices. Furthermore the collimator wakefield-induced effect is being studied.

INTRODUCTION

Beam halo is a crucial aspect of future high-energy colliders, which must be controlled to enable the most ambitious luminosity configurations. ATF2 is a Beam Delivery System (BDS) built after the ATF Damping Ring (DR) and providing a scaled-down version of the ILC Final Focus System (FFS) [1]. The two main goals of ATF2 are: to obtain a vertical beam size at the IP of 37 nm and to stabilize the beam at the nanometer level. The ATF2 halo collimator system will play an essential role in two crucial processes: the reduction of the background noise at IPBSM by means of reducing the halo amplitude, mainly in the vertical plane; and the control of the halo extension, in the horizontal and vertical plane, to enable reliable measurements with the DS that will be located after the BDUMP at the end of 2014. In a first study of the background at the Shintake Monitor the possibility of doing collimation of 25 σ_y in the vertical plane and 6.6 σ_x in the horizontal plane was suggested [2]. A study to assess the feasibility and quantify the effectiveness of such a halo collimation system (vertical and horizontal) addressing the two above goals is being performed and first results are presented on this paper. As well as some preliminary results from the wakefield impact study.

TRACKING AND HALO COLLIMATOR EFFICIENCY STUDIES

Beam halo tracking simulations using MAD-X have been performed for the ATF2 beamline for $10\beta_x^* \times \beta_y^*$ optics, version v5.2, in order to optimize the location and aperture of a betatron halo collimation system. The study was performed for three different halo models: gaussian, uniform and a realistic model based on measurements done in ATF2 in 2005 with the following density parametrization as a function of sigmas [2]:

$$\begin{aligned} \rho_1 &= 0.22 \times N \times z^{-3.5}\ (H,V,\ 3 < z < 6) \\ \rho_2 &= 0.037 \times N \times z^{-2.5}\ (V,\ z > 6) \end{aligned} \tag{1}$$

where N is the number of particles of the distribution and z the number of sigmas. Only tracking results using the realistic halo model are presented on this paper. A transverse halo distribution (x, x', y, y') with 10^4 electrons of 1.3 GeV has been generated based on the parametrization given in the Eq.(1). The transverse amplitude of the halo at the beginning of the EXT line was from 3-45σ_x and from 3-72σ_y. No coupling between x-y planes has been taken into account. For the longitudinal distribution a gaussian model was used with an energy spread of 0.08%. Multipoles have been taken into account but not misalignments.

To have a high efficient collimation system for a given collimator half aperture, $a_{x,y}$, we need a high $\beta_{x,y}$ location and $D_{x,y} \approx 0$ for a pure betatron collimation. In addition we have considered that at least 0.6 m length available free space is needed for each halo collimation system (vertical or horizontal). The best location for a vertical betatron halo collimation system was found between the quadrupoles QD10BFF and QM11FF at s=60.69 m where $\beta_y = 7126.51$ m and the available free space is about 0.8 m. In order to reduce the horizontal halo the best location for a horizontal halo collimator was found between QD3FX and QD4FX at s=12.57 m where $\beta_x = 157.02$ m and the available free space is 2 m.

The loss map along the beamline has been studied for two different scenarios: a single vertical collimator system and a single horizontal collimator system. Figure 1 shows the loss map for the realistic halo model considering a single vertical halo collimation system for different half apertures of the collimator. The loss map has been constructed taken into account the remaining particles at different markers located at the end of some ATF2 components. In the plot some cavity BPMs, the vertical collimator added (COLLBY) in blue, the recently installed round tapered structure to reduce background between QD10AFF and QD11AFF with 8 mm half aperture corresponding to 30 σ_x and 27 σ_y (COLLB) in red, the IP, the BDUMP and the DS are indicated. Same kind of study has been done with the beam core and no losses have been observed along the ATF2 beamline.

In Fig. 2 the largest offset of the remaining particles, vertical halo amplitude, at the IP (bottom) and at the end of the BDUMP (up) are depicted as a function of half aperture

* Work supported by FPA2010-21456-C02-01 and by i-link 0704

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-MOPRO033

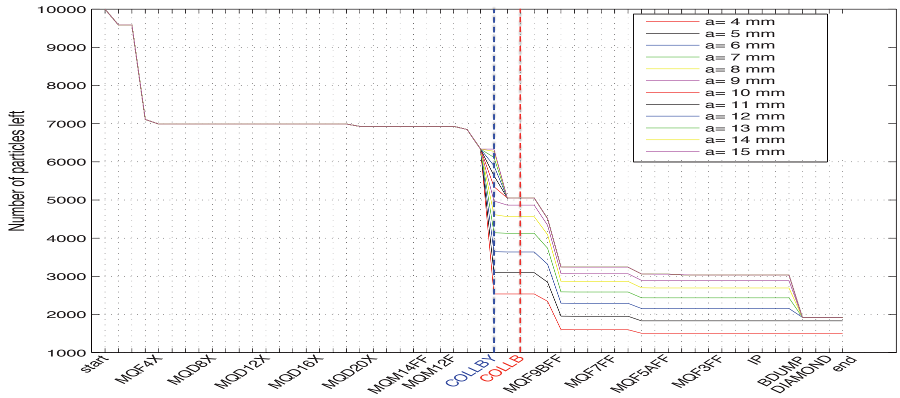

Figure 1: Loss map for a realistic halo model inserting a vertical halo collimation system (COLLBY) in the ATF2 beamline.

of the vertical halo collimator (note scale change). For a half aperture of 8 mm (27 σ_y) the vertical halo amplitude at the IP is reduced by 25% and no effect is observed at the BDUMP. For a half aperture of 5 mm ($17\sigma_y$) the vertical halo amplitude is reduced by 55% at the IP and about 5% at the BDUMP. The BDUMP has itself a racetrack chamber with a vertical half aperture of 13 mm (14 σ_y) and a horizontal half aperture of 28 mm (14 σ_y). Collimating the beam at 5 mm in the vertical plane avoids any losses at the BDUMP beam pipe, thereby reducing the probability of creating photonic background noise that will limit the performance of the diagnostic devices located after the BDUMP (gamma detector for the IPBSM and DS).

In the same way a similar study has been performed for a horizontal halo collimation system. For a half aperture of 5 mm (9 σ_x) the horizontal amplitude is reduced by 14% at the IP and about 8% at the BDUMP. Even for a very small half aperture of 2 mm (4 σ_x) we have losses at the BDUMP.

In these studies collimation effect was observed solely in the plane where collimators were applied, indicating negligible impact on the cross-plane coupling.

We consider that the most optimum halo collimator device will be a retractable one which gives more flexibility from operational aspects for different possible scenarios (optics and beam intensities) in terms of collimation efficiency and wakefield minimization. In the following only the vertical halo collimation system will be considered.

HALO COLLIMATOR WAKEFIELD IMPACT STUDIES

In this section the wakefield effect of a vertical retractable halo collimator type is studied. It is crucial to minimize the wakefield impact and to demonstrate that the impact on the beam for such a system can be tolerated. The wakepotential has been computed numerically using Computer Simulation Technology Particle Studio (CST PS) [3] for different collimator geometries and materials and compared with analytical calculations [4, 5]. The analytical calculations are based on the near axis approximation and only take into account the linear part of the wakefield kick (dipolar component).

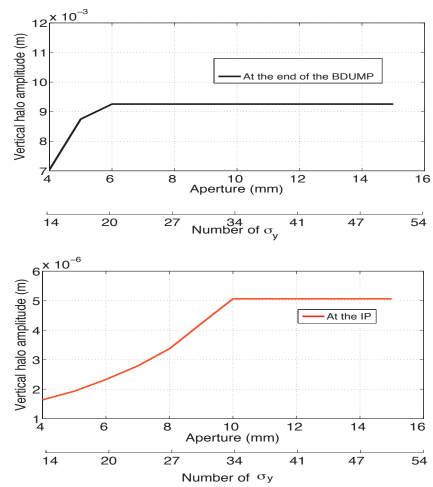

Figure 2: Vertical halo amplitude at the BDUMP and IP.

Geometry and Material Study

CST PS and analytical wakefield models have been used to study the influence of the geometrical parameters and the material on the wakefield kick given by a vertical rectangular tapered structure. Figure 3 shows the model simulated with CST PS. A gaussian bunch length of 7 mm has been considered and a bunch charge of 1 pC has been used instead of the actual ATF2 one of 1 nC in order to compare the results with other ongoing studies [6].

The half aperture, a, and the tapered angle, α, are geometrical parameters that have a big impact on the geometrical wakefield component while the flat part, L_f, will only contribute to the resistive wakefield component. Simulations have been done in order to optimize these parameters in

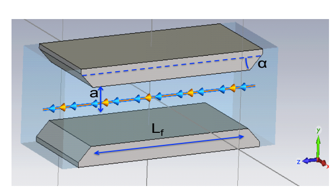

Figure 3: CST PS model.

ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-MOPRO033

terms of wakefield minimization. Figure 4 shows an example of the wakepotential obtained for a perfect electric conductor (Cu) structure with $\alpha = 3°$ and $L_f = 50$ mm as a function of the half aperture. From the CST PS simulations the average wakepotential, a_w, is calculated integrating the wakepotential over the longitudinal bunch distribution per mm offset.

Figure 5 shows the a_w obtained with CST PS compared with the r.m.s analytical kick for a gaussian distribution as a function of: a, α and L_f. For a vertical halo collimator with a half aperture of 5 mm $a_w < 0.05$ V/pC/mm, a complete study of the impact on the beam of this level of average wakefield kick is needed for a definite conclusion. The choice of the parameters used for these studies take into account the need to minimize the computing time. Calculations of the stopping power of Cu for electrons and the production of EM cascades based on a simplified model indicates that in order to stop a 1.3 GeV electron and the EM cascade produced we need at least a block of Cu of 100 mm length. However the impact on the wakepotential due to the length of the flat part, as can be seen in Fig. 5 is small in the range of 50 to 100 mm therefore a flat part of 50 mm has been considered.

The analytical kick has been calculated taking into account both contributions, the geometrical and the resistive one. The geometric wakefield model defines three different regimes depending on the beam and the collimator parameters. For the ATF2 beam parameters and the values of a and α considered on this study only two regimes are taken into account (inductive and diffractive). The resistive component is also calculated and added linearly to the geometrical component.

From this study was seen that the half aperture has a big influence on the wakefield effect and good agreement was found between CST PS simulations and analytical calculations. The influence of the tapered angle is close to linear for angles down to 10° and good agreement has been observed between simulations and analytical calculations for small angles (inductive regime) and angles bigger than 60° (diffractive regime). A small tapered angle, as much as the manufacture constraints allow, is required to minimize the wakefield effect. The influence of the flat part in case of considering a good conductor as Cu is very small compared with the effect of a and α (note the scale difference). Also the influence of the material has been studied being Cu the best candidates.

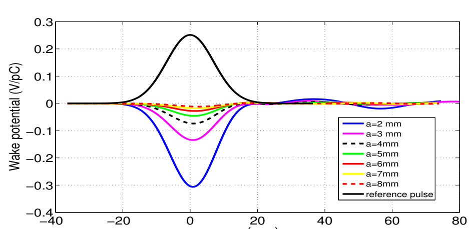

Figure 4: Wakepotential simulated with CST PS for different vertical halo collimator half aperture for 1 mm beam offset.

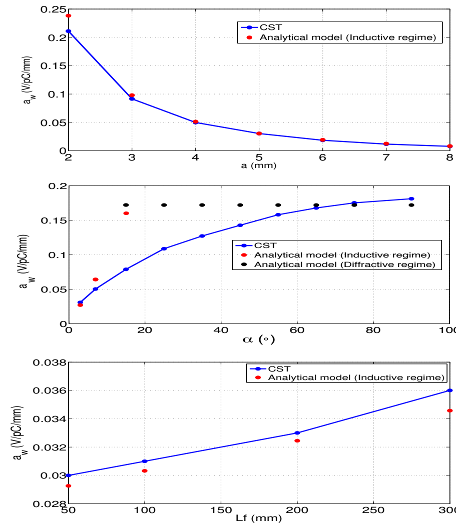

Figure 5: CST PS and analytical calculated average kick, a_w, as a function of a, α and L_f. The fix parameters for the corresponding cases are a=5 mm, α=3° and L_f=50 mm.

A first preliminary mechanical design of a vertical retractable collimator is in progress based on previous experiences [7–9].

CONCLUSIONS AND FUTURE WORK

The best location and the efficiency as a function of the half aperture for a vertical and a horizontal halo collimation system for ATF2 have been studied. For a vertical halo collimator half aperture of 5 mm (17 σ_y) the halo vertical amplitude is reduced by 55% at the IP and we do not have losses at the BDUMP. For a horizontal halo collimator device with a half aperture of 5 mm (9 σ_x) the reduction of the horizontal halo amplitude is about 14% at the IP and even for a very small half aperture we have losses at the BDUMP. In these studies no effect in the non collimating plane was observed. A retractable halo collimator type is being considered because of its flexibility in terms of operational aspects. Furthermore a wakefield study has been started in order to optimize the geometrical parameters and material of such a device. The wakefield impact on the beam orbit and emittance of such a structure is also being investigated as well as the effectiveness and impact including power deposition aspects for different operational modes (optics and beam intensities).

REFERENCES

[1] G. R. White et al., Phys. Rev. Lett. 112,034802.

[2] T. Suehara et al., arXiv:0810.5467v1 (30 Oct 2008).

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

[4] G.V. Stupakov, PAC01.

[5] A.Piwinski, DESY-HERA-92-04,1992.

[6] http://agenda.linearcollider.org/getFile.py/access?contribId=8&sessionId=3&resId=1&materialId=slides&confId=6132

[7] S. De Barger et al., SLAC-PUB-11752.

[8] D. Iglesias et al., THPS059, IPAC2011, San Sebastián, Spain.

[9] Y. Suetsugu et al., NIM A 513 (2003) 465-472.