

# REALISTIC BEAM HALO MODEL STUDY IN THE EXTRACTION LINE OF ATF2

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## Abstract

The understanding and control of the transverse beam halo distributions is an important issue to reduce sources of background noise in Future Linear Colliders (FLC) and specifically at ATF2. A realistic model of the beam halo in the old extraction line of the ATF damping ring was obtained in 2005, based on wire scanner measurements. Recently, new measurements were done in the new extraction line of ATF2, using both wire scanners, in 2013, and Optical Transition Radiation monitors (OTR), in 2014. The beam halo propagation through the ATF2 beamline by means of tracking simulations has been investigated using as input a purely Gaussian and uniform beam halo model.

## INTRODUCTION

ATF2 [1] is a scaled down version of the Final Focus System (FFS) of the FLC with the two main goals of obtaining a vertical beam spot size at the virtual Interaction Point (IP) of 37 nm and to stabilize the beam at the nanometer level. For the beam size measurement at the IP a novel technique is used based on a laser interferometer beam size monitor (Shintake monitor). The beam halo consists of tails extending far beyond the Gaussian core of the beam that could be intercepted by the beam pipe creating undesired photonic background. In FLC, such particle losses would be unacceptable and could have devastating effects on the experiments. In ATF2, halo hitting on the beam pipe after the IP can generate a large amount of background limiting the Shintake monitor performance. Therefore, it is of great importance to understand the beam halo distribution and to control the background that could be generated by it. In order to investigate the beam halo distribution in ATF2 measurements were done in 2013 in the EXT line and post-IP with the wire scanners following the procedure done in 2005 in the old ATF2 beamline [2]. Complementary, in 2014, measurements were taken with the multi-OTRs system which is located close to the EXT line wire scanners. All the data has been analyzed and a summary of the measurements done in the EXT line is presented on this paper. In addition to these measurements, by the end of 2014 a Diamond Sensor (DS) has been installed in the Post-IP line of ATF2 in order to perform dedicated beam halo measurements [3, 4].

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## BEAM HALO MEASUREMENTS IN THE EXT LINE OF ATF2

The ATF2 beamline is divided in three sections: the Extraction Line (EXT) with the diagnostics and matching sections, the Final Focus System (FFS) and the Post-IP line with some diagnostics and the dump. In Fig. 1 the location of the different devices being used to investigate the beam halo and background in the ATF2 beam line are depicted. In the EXT line we find the wire scanners and the OTR system and in the post-IP line we have one wire scanner and the recently installed DS.

### Wire Scanners Beam Halo Measurements

At ATF2 five wire scanners are used to measure the beam size at different locations. In our experiment the wire scanner named MW2X located in the EXT line was used. A Cherenkov detector and a Photomultiplier (PMT) at around 26 m downstream of MW2X is installed to detect the bremsstrahlung photons generated by the wire scanners when scanning the beam. A different set of beam halo measurements were performed in April, June and December 2013 using MW2X in the EXT line. During these runs the beam energy was 1.3 GeV and the beam intensity was between 5-7  $10^9$  electrons. The optics configuration used was ten times the nominal  $\beta_x^*$  and the nominal  $\beta_y^*$  at the IP ( $10\beta_x^* \times 1\beta_y^*$ ). The beam halo scans have been performed with different PMT voltages in order to increase the sensitivity of the wire scanner. Then, the data was normalized to the lowest voltage and left and right scans have been combined because the beam halo observed in the EXT line is symmetric. The data combined is fitted to a power function of the number of sigmas following the analysis done in [2]:

$$\rho_{V,H}/N = (A/N)X^{-b} \quad (1)$$

where  $\rho_{V,H}$  is the vertical and horizontal beam halo density respectively,  $N$  is the total number of particles,  $A, b$  are constants, and  $X$  is the number of sigmas.

In Fig. 2 it is shown all the data taken in 2013 with MW2X wire scanner corresponding to the vertical (top) and horizontal (bottom) beam halo distribution. The resulting fit for all the combined data is the following:

$$\begin{aligned} \rho_V/N &= (9 \pm 4)X^{-(7.3 \pm 0.3)} \quad 3 < X < 5 \\ \rho_V/N &= (0.001 \pm 0.001)X^{-(1.5 \pm 0.3)} \quad X > 5 \end{aligned} \quad (2)$$

1: Circular and Linear Colliders

A03 - Linear Colliders

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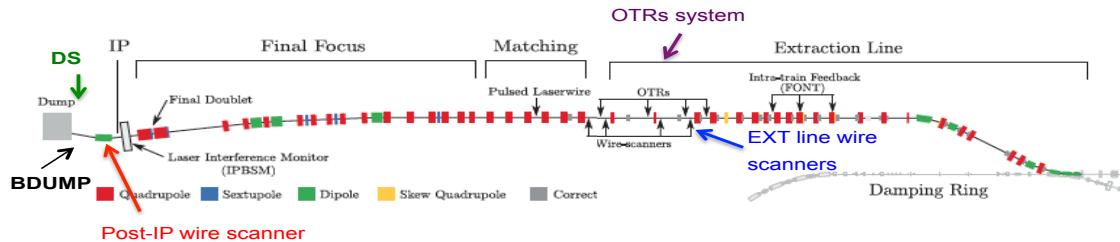


Figure 1: ATF2 beamline with the three different sections: EXT, FFS and the Post-IP line.

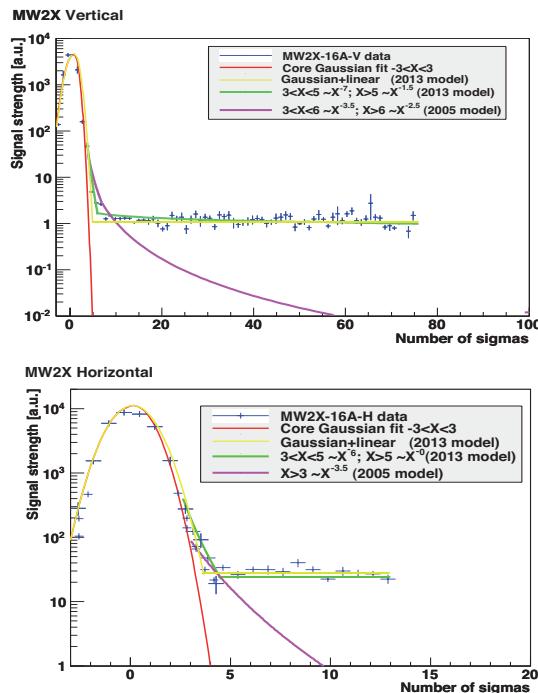


Figure 2: 2013 MW2X combined data and fitting.

$$\begin{aligned} \rho_H/N &= (4 \pm 1.4)X^{-(5.9 \pm 0.3)} \quad 3 < X < 5 \\ \rho_H/N &= (0.001 \pm 0.001)X^{-(0 \pm 0.3)} \quad X > 5 \end{aligned} \quad (3)$$

In addition to the power function fit, we also fitted the data to a gaussian plus linear function, the resulting fit can also be seen in Fig. 2 corresponding to the yellow curve. All the data taken in the 2013 campaign, including the post-IP wire scanners measurements, and the detailed analysis of each set of measurements can be found in [6]. From the parametrization point of view the power coefficients of the 2013 measurements are bigger than those resulting from the 2005 measurements up to  $5\sigma$ . The measured slope of the beam halo distribution is more abrupt and this could be due to the stronger focusing optics and tighter aperture elements of the ATF2 beam line in comparison with the old ATF2 beam line. Beyond  $5\sigma$  a uniform distribution is observed. From this new parametrization the amount of particles on the horizontal and vertical beam halo distribution can be calculated, being for both planes about  $10^{-3}$  of the total

number of particles of the beam which corresponds to the same amount measured in 2005. In 2014 the wire scanners were removed and recently a YAG screen has been installed in the EXT line close to where the MW2X wire scanner was with the aim of doing beam halo measurements. These measurements could be very useful in order to compare and validate the beam halo measurements performed with the MW2X wire scanner.

### First Attempt at Beam Halo Measurements with the Multi-OTR System

In the diagnostic section of the ATF2 beam line a multi-OTR system based on four OTR monitors is used to perform beam size and emittance reconstruction measurements. The light emitted when the electron beam goes through a metallic thin foil is collected by an optical system and recorded by a CCD camera. It has been observed that the vertical OTR intensity profile measured presents long tails in comparison with the horizontal one as can be seen in Fig. 3. We have compared the tails observed in the OTRs images with the wire scanner measurements to investigate whether these tails come from halo or from chromatic aberrations of the OTR optics themselves.

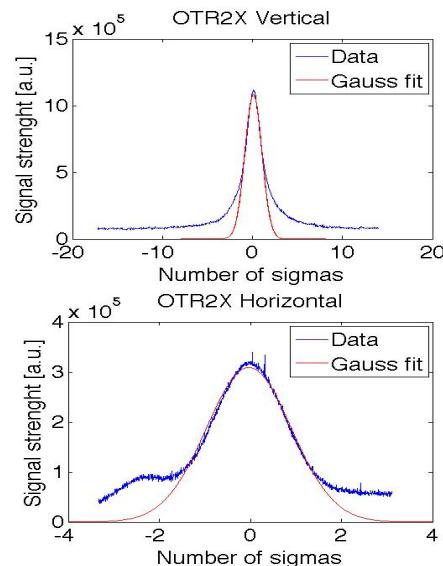


Figure 3: OTR2X vertical (top) and horizontal (bottom) beam profile images.

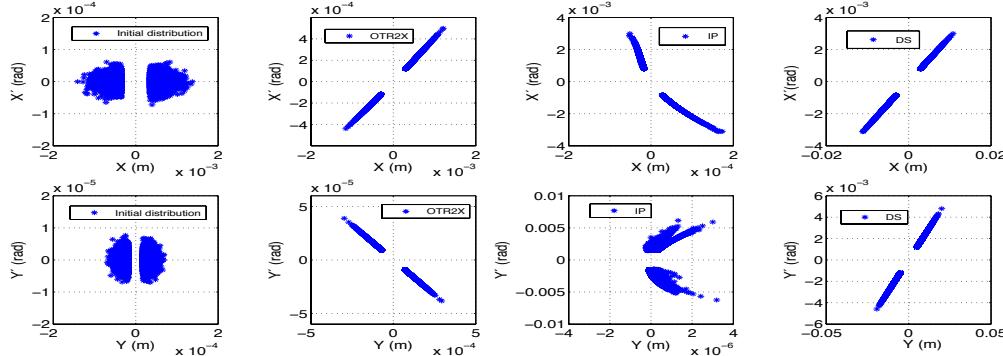


Figure 4: Gaussian beam halo model tracking through the ATF2 beam line. Phase space at: the beginning of the EXT line, OTR2X, IP and DS, note the difference on the scale, especially at the IP.

In the measurements made in 2013 with the wire scanners the difference observed between the number of electrons corresponding to the peak of the beam core and the beam halo was about  $10^3$ . However in the OTRs measurements the difference between the maximum signal (which has a linear dependence on the number of electron) and the signal value at which the observed tails start is 10 as can be seen in Fig. 3. In Fig. 5 the vertical image profile from OTR1X is compared with a vertical scan made with MW2X. All the data has been normalized to the number of particles. This plot shows the different dynamic range achieved with the wire scanners and OTRs.

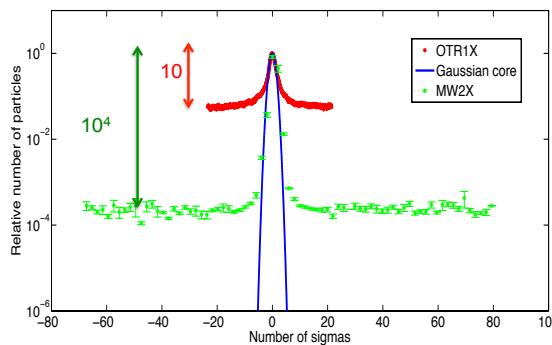


Figure 5: MW2X and OTR1X dynamic range comparison.

In addition, the fit coefficients between the four OTRs are similar between them but different from the wire scanners ones. Further investigations would be needed to understand better the origin of these tails but possible sources of these observed tails could be optical aberrations or the convolution of the diffraction pattern of the optical system with the beam halo distribution. In order to use the multi-OTR system to measure the beam halo distribution we need to increase the dynamic range of the OTRs. Possible ways to do it will be to use a CID camera instead of CCD camera, adapt an other thin foil with a hole in the center to not capture the light corresponding to the beam core or to use the coronagraph technique which has already been used for beam halo measurements [7].

## BEAM HALO TRACKING STUDIES

Beam halo tracking simulations using MAD-X have been performed for the ATF2 beamline for  $10\beta_x^* \times \beta_y^*$  optics in order to study the asymmetries observed in the OTRs tails. The study was performed for two different halo models: gaussian and uniform. The transverse amplitude of the halo at the beginning of the EXT line was generated from  $3-45\sigma_x$  and from  $3-72\sigma_y$ . 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. The loss map along the beamline has been studied for the different beam halo models and a similar behavior for all the different beam halo models is reported [8]. In Fig. 4 the beam halo phase space for the gaussian beam halo model is shown at the beginning of the EXT line, OTR2X, IP and DS. In the EXT line a linear behavior is observed while at the FF system due to non linear components of the magnets we could see different shapes for the X and Y beam halo phase space. The X and Y phase space at the four OTRs locations is similar and no asymmetries on the tails has been observed. Tracking simulations with a realistic model based on the 2013 measurements are in progress.

## CONCLUSIONS AND FUTURE WORK

The goal of this study was to update the beam halo model measured in 2005 in the old ATF2 beam line for the present one. Measurements with the wire scanners have been done, analyzed and a new model obtained. The wire scanners were removed in 2014 and a first attempt of beam halo measurement with the multi-OTR system in the EXT

line has been performed. The dynamic range of the OTR measurements is very small and ways to improve it are being investigated. Tracking simulations are being done for the ATF2 beamline using a gaussian and uniform theoretical model in order to compare them with the OTR measurements for a better understanding of the origin of the tails observed. Tracking simulations with a realistic model based on the 2013 measurements are also in progress.

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