

Conclusion and Prospects

Understanding of beam halo distribution is of great importance for the beam loss and background control of ATF2 and Future Linear Colliders. Measurement of beam halo distribution is a direct way for obtaining information on the beam halo. This thesis presents the research and development of diamond sensor (DS) for beam Halo and Compton spectrum diagnostics after the IP of ATF2.

Beam halo and Compton recoil electrons signal simulations have been performed using Mad-X and CAIN. The beam halo was generated using the parametrization based on the beam halo measurements using wire scanners (WS) done in 2005. The visibility of Compton recoil electrons in the presence of the beam halo was checked. The simulation results indicate that in order to measure the beam core, beam halo and Compton recoil electrons simultaneously, a large dynamic range of larger than 10^6 is needed.

A first attempt of beam halo measurements have been performed in 2013 using the currently installed WS in the EXT Line and at post-IP. Measurement results were analysed and compared with the measurements performed in 2005 in the old EXT line of ATF. The dynamic range of the measurements in 2013 was $\sim 10^3$, which is less than the measurements done in 2005 ($\sim 10^4$) due to less favourable background conditions. Nevertheless, we have found that the post-IP WS measured horizontal beam halo distribution is consistent (up to $\sim 6\sigma_x$) with the beam halo parametrization done in 2005. In addition we observed an asymmetrical vertical beam halo distribution in the post-IP WS measurements. This could be correlated with the tapered beam pipe installed between QD10BFF and QD10AFF magnets to reduce the background for the

10. CONCLUSION AND PROSPECTS

detectors in the vertical direction. However, more systematic measurements using the DS are required in the future to confirm this.

Since the dynamic range of the WS is limited, the main goal of this thesis was to develop a diamond sensor with a large dynamic range ($> 10^6$) for simultaneous measurements of beam core, beam halo and Compton recoil electrons.

For the characterization of DS, tests using α and β sources were performed in a clean room. Charge collection efficiency and lifetime of the diamond sensors have been studied. These studies provided important information for the understanding of the signal formation and saturation effect observed with extra high beam intensity ($10^9 e^-$). Further characterizations of diamond sensors were carried out using a ~ 3 MeV electron beam at PHIL, where a linear response up to 10^7 electrons was confirmed using the diamond sensor in air.

In vacuum diamond sensor (DSv) with four strips was developed to help cover the required large dynamic range. The first set of the DSv was tested at PHIL prior to the installation at ATF2 in November 2014. During the tests, signal correlations between different strips were observed. Large correlation ($\sim 20\%$) was found between the wide strips while the narrow strips are much less affected. The reasons for these correlations are under investigation.

At ATF2, the first set of the DSv was installed horizontally in November 2014 and measurements were performed in December 2014. The main goals of these measurements were first to understand the limits of our measurement system based on DSv, and then use the DSv to measure the horizontal beam halo distribution and investigate the possibility of probing the Compton recoil electrons.

The main achievements and results of this thesis are summarised as follow:

- We have mastered the DS technology through the R&D processes. The first in vacuum scanner based on a diamond strip sensor was successfully developed and implemented at ATF2. A dynamic range of $\sim 10^6$ was obtained and confirmed for the first time, covering both beam core and beam halo measurements. The DSv has been tested under ultra high beam intensity ($10^9 e^-$). Saturation effect of DSv has been observed and investigated. These studies are very valuable for the development of the field of high-radiation diamond detectors.

-
- The horizontal beam halo distribution was measured up to $\pm 20\sigma_x$ by DSv. The measurement results was compared to the the beam halo distribution previously measured using the wire scanners. We found that by normalising the beam halo distribution to the betatron beam size (σ_β), the distribution is quite consistent with the 2005 model and the post-IP WS measured distribution in 2013. This consistency may indicate that the beam halo at ATF2 is dominated by the betatron halo instead of energy halo, which seems not to be observable in the present measurements.
 - The possibility of probing the Compton recoil electrons has been studied by comparing the expected Compton recoil electrons signal level with the measured beam halo and signal pick-up level. The comparison reveals that under the present conditions, the signal from Compton recoil electrons is quite small comparing with the signal from beam halo and signal pick-up.

Based on the results obtained from the first measurement campaign in 2014, we have also found the following remaining issues, possible ways to solve these issues are also listed below:

- With the present design the dynamic range of the DSv is limited by the signal pick-up at the level of 10^3 electrons and by the non-linearity starting from 10^7 electrons. For the signal pick-up, shielding of the PCB will be applied for the next set of the DSv. The non-linearity response of the DSv due to large voltage drop on the $50\ \Omega$ resistor can be avoided by adding a smaller resistor. With these solutions, the dynamic range of the DSv can be further improved.
- Concerning the horizontal beam halo distribution, further measurements in high dispersion region are required to study the energy halo. Meanwhile, both in the WS and the DSv measurements, we observed more halo on the high energy side than on the low energy side. The reason for this asymmetry is still unknown.
- Under the present conditions, the signal from Compton recoil electrons is covered by the signal from beam halo and signal pick-up. The number of Compton recoil electrons can be increased by increasing the laser power. Nevertheless, in order to detect the Compton recoil electrons, shielding of the PCB of the DSv to get

10. CONCLUSION AND PROSPECTS

rid of the signal pick-up is essential. Besides, a collimator located upstream is planned to collimate the beam halo. Furthermore, an extra focusing quadrupole can be installed between the IP and the bending magnet to focus the beam halo and enable a clear measurement of the Compton spectrum.

A second set of DSv with shielding of the PCB has been installed vertically for vertical beam halo distribution measurement in April 2014. This vertical scanner will provide important information on the dependence of beam halo distribution on beam intensity for different beam optics, in particular for the ultra low β_y optics study. Besides, the asymmetrical distribution observed by the post-IP WS measurements can also be verified using this DSv. More systematic studies can be performed to understand the effect of the tapered beam pipe on the background.