

Simulation of ILC feedback BPM signals in an intense background environment

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Experiment T-488 at SLAC, End Station A recorded distorted BPM voltage signals and an accurate simulation of these signals was performed. Geant simulations provided the energy and momentum spectrum of the incident spray and secondary emissions, and a method via image charges was used to convert particle momenta and number density into BPM stripline currents. Good agreement was achieved between simulated and measured signals. Further simulation of experiment T-488 with incident beam on axis and impinging on a thin radiator predicted minimal impact due to secondary emission. By extension to worst case conditions expected at the ILC, simulations showed that background hits on BPM striplines would have a negligible impact on the accuracy of beam position measurements and hence the operation of the FONT feedback system

1 INTRODUCTION

The ILC beam-beam interaction produces a background environment that may affect the operation of feedback systems for beam alignment. One crucial element of the ILC feedback system is a stripline BPM placed near the interaction point in the extraction line. The operation of this feedback BPM in an intense background environment was tested at the T-488 experiment at SLAC EndStation A. T-488 operated in two modes. Firstly, a "high spray mode" in which the primary beam was directed off axis into a graphite torus producing a large background spray flux. Secondly, a "low spray mode" in which an on-axis beam impinging on a thin radiator resulted in a strong central beam and a lower flux of background charges [2].

In the high spray mode, BPM voltage signals visibly distorted from the usual bipolar doublet, were recorded (see figure 6). Accurate simulations that reproduced these high spray mode signal shapes were developed and are discussed in the first part of this paper. Experimental data from the low spray mode and high spray mode was combined to predict, by interpolation, the feedback BPM signal shapes expected at the ILC.

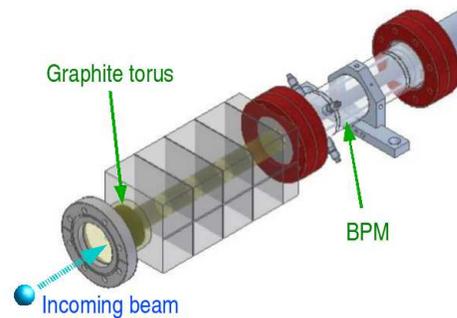


Figure 1: ESA T-488 module.

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2 SIMULATIONS

The T-488 experimental module, containing the lowZ graphite torus, stripline BPM and connecting flanges (see figure 1) was modelled using Geant. With an incident flux of 10^4 electrons at different offsets on the x-axis, the x-profile of the scattered beam at the upstream end of the BPM strips was recorded (figure 2).

The x-profile of the beam was considered to consist of two current components; an azimuthally symmetric background spray I_{spray} and a remnant of the original beam I_b . I_{spray} was taken to be a constant average from the axis to radius of 1.5cm, and thereafter neglected. The contribution of both components to an image current in the BPM striplines $I_s = I_s^b + I_s^{\text{spray}}$ can be calculated by solving the Laplace equation in 2 dimensions [3]. The stripline current from a beam current I_b situated at (r, θ) from the axis of a beampipe of radius b, which subtends the stripline with angle ϕ (figure 3) is

$$I_s^b = -\frac{\phi}{2\pi} I_b \left[1 + \frac{4}{\phi} \sum_{n=1}^{\infty} \frac{1}{n} \left(\frac{r}{b}\right)^n \sin\left(\frac{n\phi}{2}\right) \cos(n\theta) \right] \quad (1)$$

The contribution to the BPM current I_s^{spray} is found by writing a current element ΔI_{spray} in terms of the current density J_{spray} and a volume element.

$$\Delta I_{\text{spray}} = J_{\text{spray}} r dr d\theta \quad (2)$$

Substituting ΔI_{spray} for I_b on the right hand side of equation 1 and integrating over all r and θ gives the contribution for the whole beampipe filling spray. The second term in equation 1 becomes zero and the first term contains the entire beampipe spray current.

$$I_s^{\text{spray}} = -\frac{\phi}{2\pi} I_b^{\text{spray}} \quad (3)$$

Much of the beam spray has significant transverse momentum which leads to direct hits on and secondary emission from the BPM striplines (figure 4). The time dependency of hits and secondary emission is determined with the aid of Geant's time of flight (TOFG) parameter. The electrical weight of each hit is determined by the method of image charge. A single charge e moving effectively from infinity to the strip surface contributes an image charge of e. Emitted charges e moving from the surface to effective infinity, contribute -e.

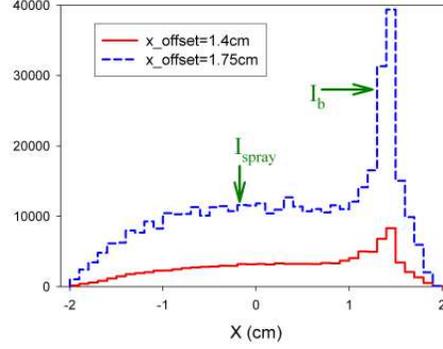


Figure 2: X-profile of beam at upstream end of BPM.

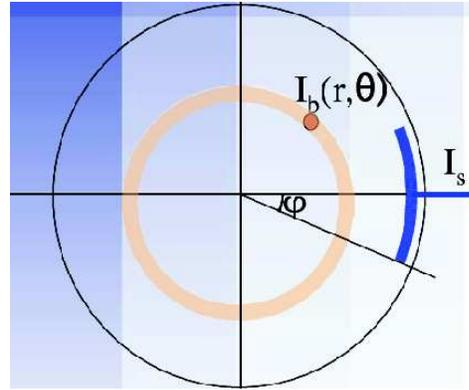


Figure 3: BPM x-y cross-section.

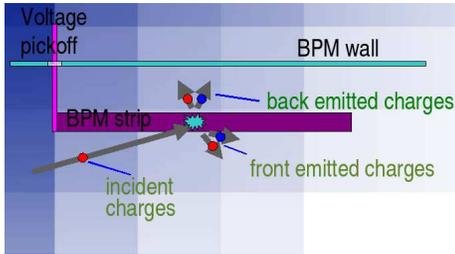


Figure 4: Hits and emission from BPM striplines.

Charges ejected from the back surface of the BPM strip quickly cross the 1mm gap between the strip and BPM wall and their contribution to the stripline current was taken to be entirely at the instant of emission. However for charges approaching or leaving the stripline tangentially, the contribution is a proportion of the charge. The extent of the tangential contribution is calculated by the transverse distance from the charge to the strip at either the upstream or downstream end of the strip, and the amount of image charge subtended by the stripline at that distance (see figure 5)

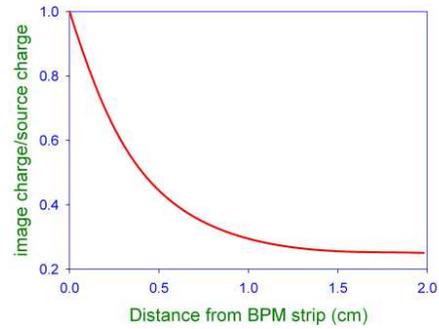


Figure 5: Stripline image charge variation with source charge distance.

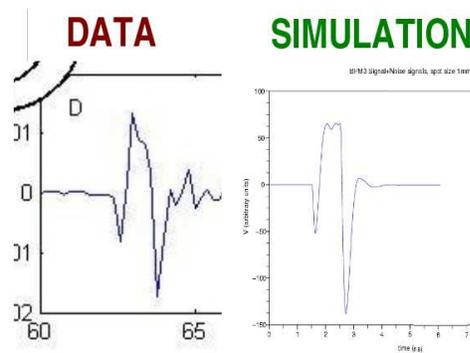


Figure 6: high spray mode BPM voltage signals.

3 NUMERICAL RESULTS

All the contributions to the stripline current were combined and the response of the oscilloscope that recorded them experimentally was simulated by use of a numerical second order, 1.2 GHz Butterworth low pass filter. Numerical calculations were performed using the Scilab program [4]. Comparison of experimental and simulated stripline signal showed good agreement, with the secondary emission signal superimposing a reverse bipolar doublet over the usual bipolar doublet (figure 6)

The distortion in BPM signal due to secondary emission may affect the amplitude of the difference signal used to drive the beam kicker in the feedback loop of the FONT system. The high spray mode of the ESA T-488 experiment however provides a background flux to beam signal ratio 3-4 orders of magnitude worse than that expected at the ILC. The ESA T-488 low spray mode provided a more realistic secondary emission to BPM signal ratio. No discernible effect on difference signal amplitude due to secondary emission could be determined beyond a 2% variation probably due to beam jitter, again in agreement with simulation (figure 7).

The expected effect on the ILC feedback BPM position measurements due to secondary emission was estimated by using Geant to simulate the number of incident hits on striplines for the T-488 low

spray mode and ILC parameter set 14 with anti-DiD field (figure 8). The ILC secondary emission to BPM signal ratio would be at least an order of magnitude smaller than that of the T-488 low spray mode and were therefore considered negligible

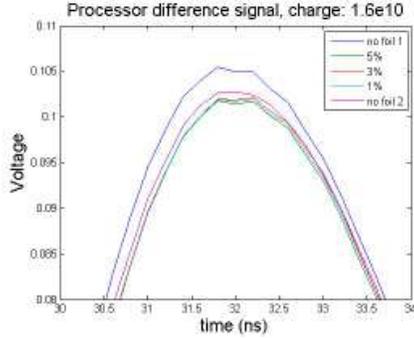


Figure 7: BPM difference signal in low spray mode (error bars of 2% not shown).

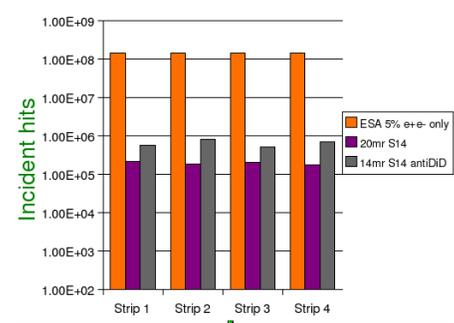


Figure 8: BPM stripline hits.

4 CONCLUSION

Distorted stripline BPM voltage signals were recorded at the ESA T-488 experiment with the incident beam off-axis and impinging on a lowZ graphite torus. The resultant charge spray was modelled using Geant and separated into a number of components. The effect on stripline current was calculated using the method of image charges, and the time response was filtered through a low pass numerical filter. Matching experimental and simulated signals gave confidence in the method employed. The simulations were applied to the T-488 low spray mode and no variation in BPM difference signal voltage amplitude beyond a 2% beam jitter was observed. The extent of background hits on the feedback BPM at the ILC, operating in its "worst case scenario" (in terms of pair background numbers) - parameter set 14 and anti-DiD solenoid field - was simulated. Since the effect at the ILC would be at least an order of magnitude smaller than that of the T-488 low spray mode, it was considered that pair backgrounds incident on BPM striplines at the ILC would have a negligible effect.

References

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