PIP-II Beam Current Monitor Fault Case & Beam Position Monitor Linearity Studies in CST Studio

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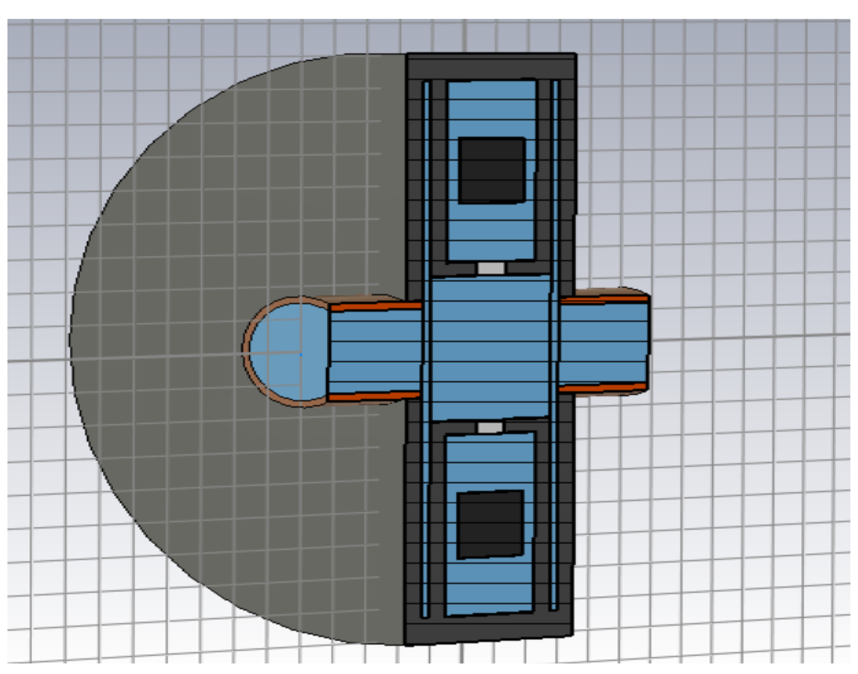
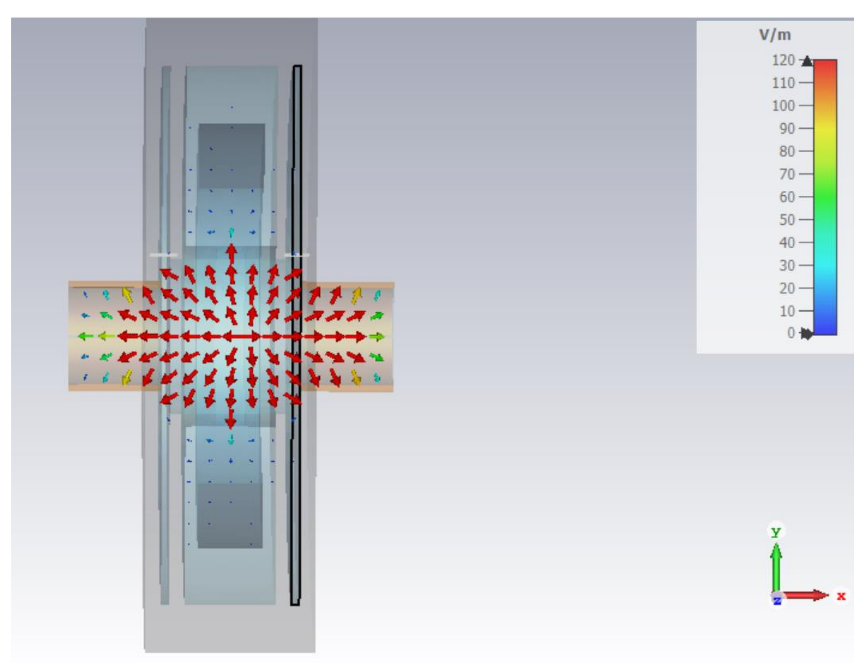
Introduction

The use of non-invasive sensors & systems to measure particle beam characteristics is a crucial part of modern accelerator control systems. As such, simulations predicting the behavior of these sensors are essential for guiding beamline control system design. This poster details the results returned by two beam sensor models created using CST Studio software: the signal linearity of an elliptical beam position monitor (BPM), and the fault cases of an AC current transformer (ACCT) beam current monitor (BCM).

BCM Fault Case Analyses



Cross section of the parametric BCM model. The ceramic gap, nanocrystal core, and flange gaps are visible.



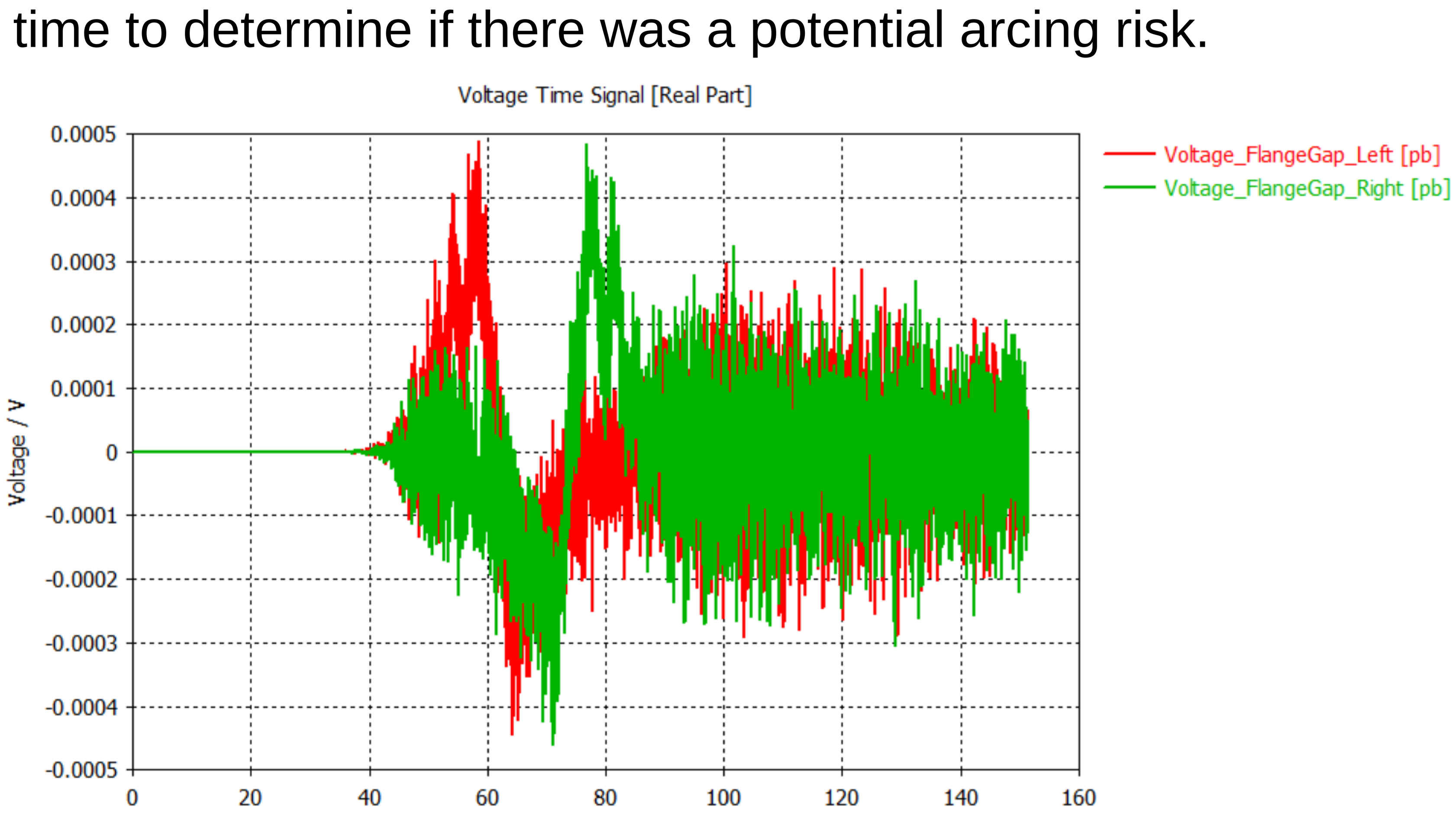
Cross section of the parametric BCM model, including fields for a single pulse of a β = .008, 10mA beam.

Gaps between the connecting flanges of a BCM and beam pipe are liable to be host to unwanted resonances that can cause vacuum arcing. This arcing can pose a serious safety risk and damage the beam's quality.

Using the CST Studio BCM model, 169.5MHz particle beams of varying current, pulse width, and β were passed through the ACCT, whose shape was also varied to match the geometry of BCMs along the PIP-II beamline.

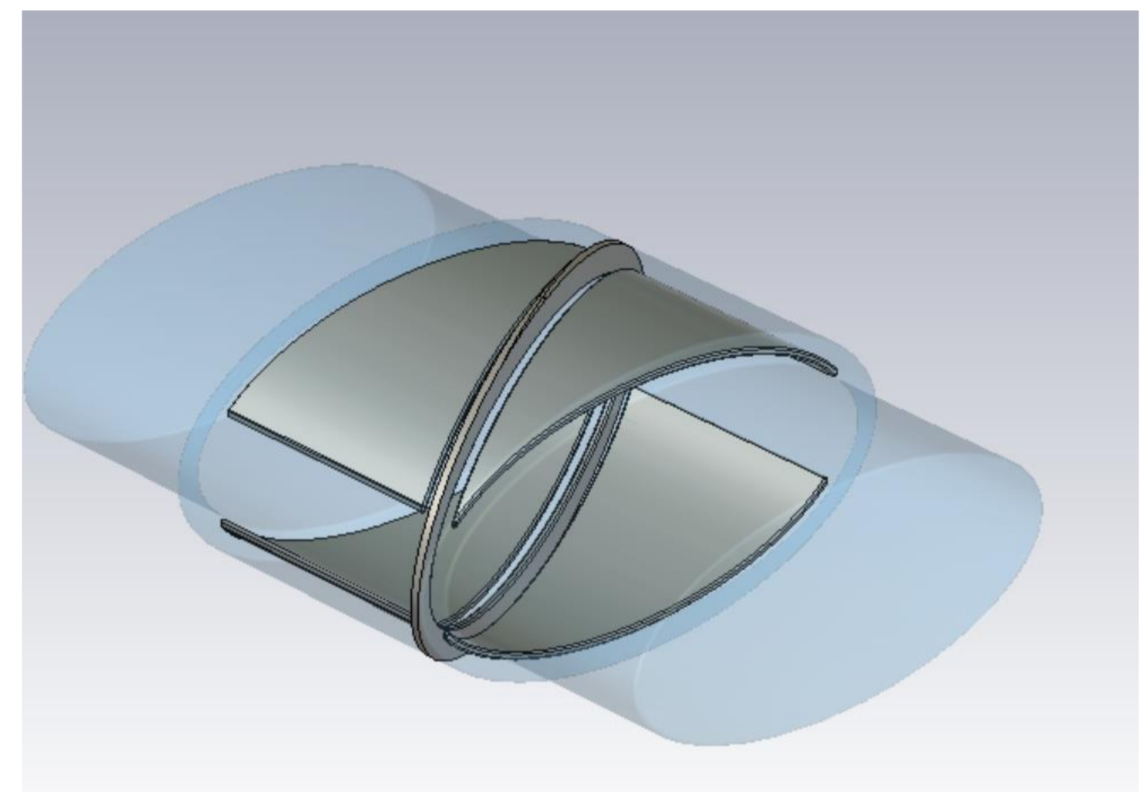
Parameter Name	Values of Interest
Beam β	.008, .067, .145, .256, .480, .541, .764, .842
Beam Pipe Aperture Radius (mm)	15, 25
Beam Current (mA)	1, 10
Beam Pulse Width (μs)	10, 550

The voltage between the flanges was then measured over time to determine if there was a potential arcing risk.



Partial graph of the voltages of the left and right flange generated by a single bunch of a 10mA, β = .008 beam at 169.5MHz through a 15mm aperture. Small voltages across the flanges confirm no risk of arcing for this case.

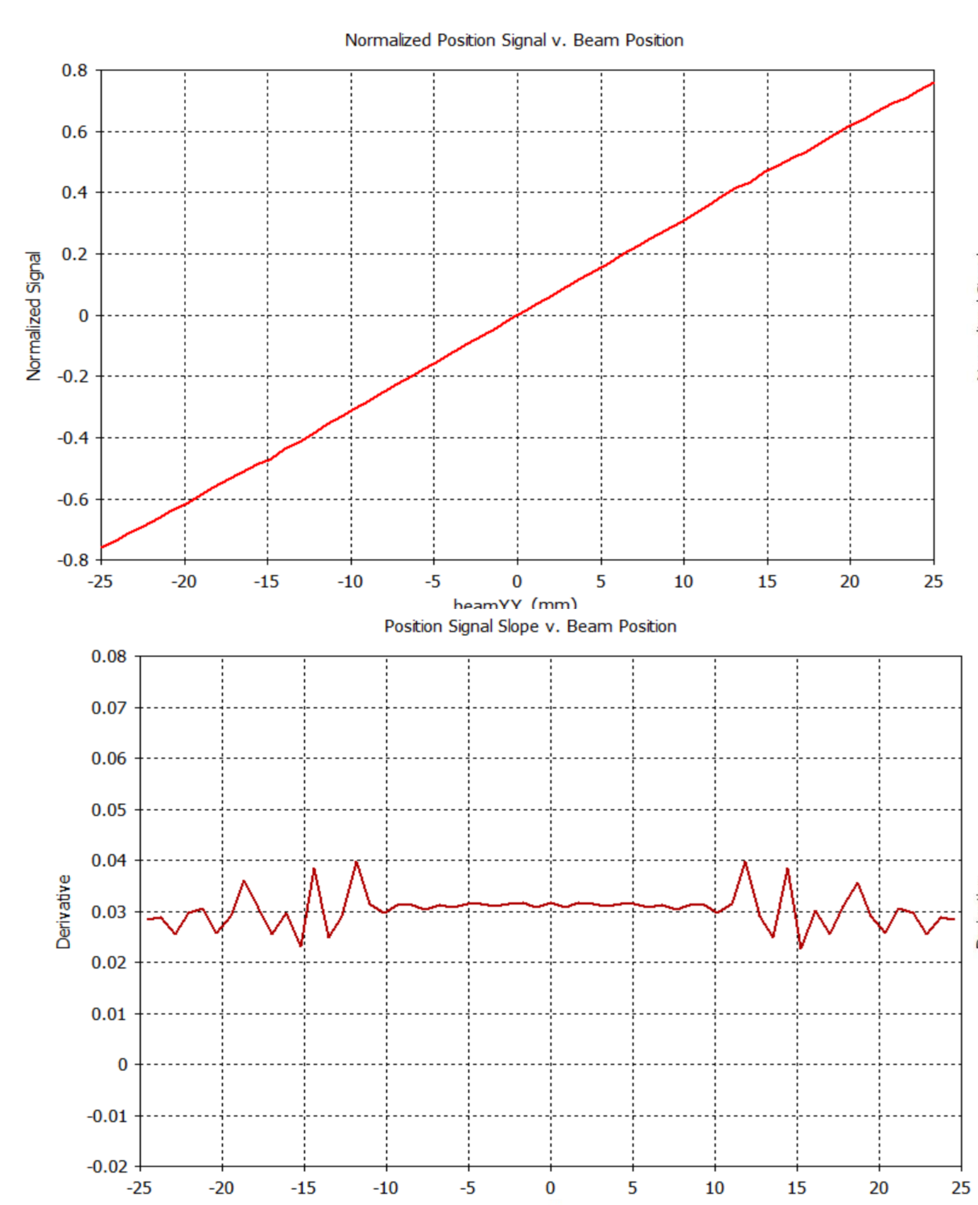
BPM Linearity Studies



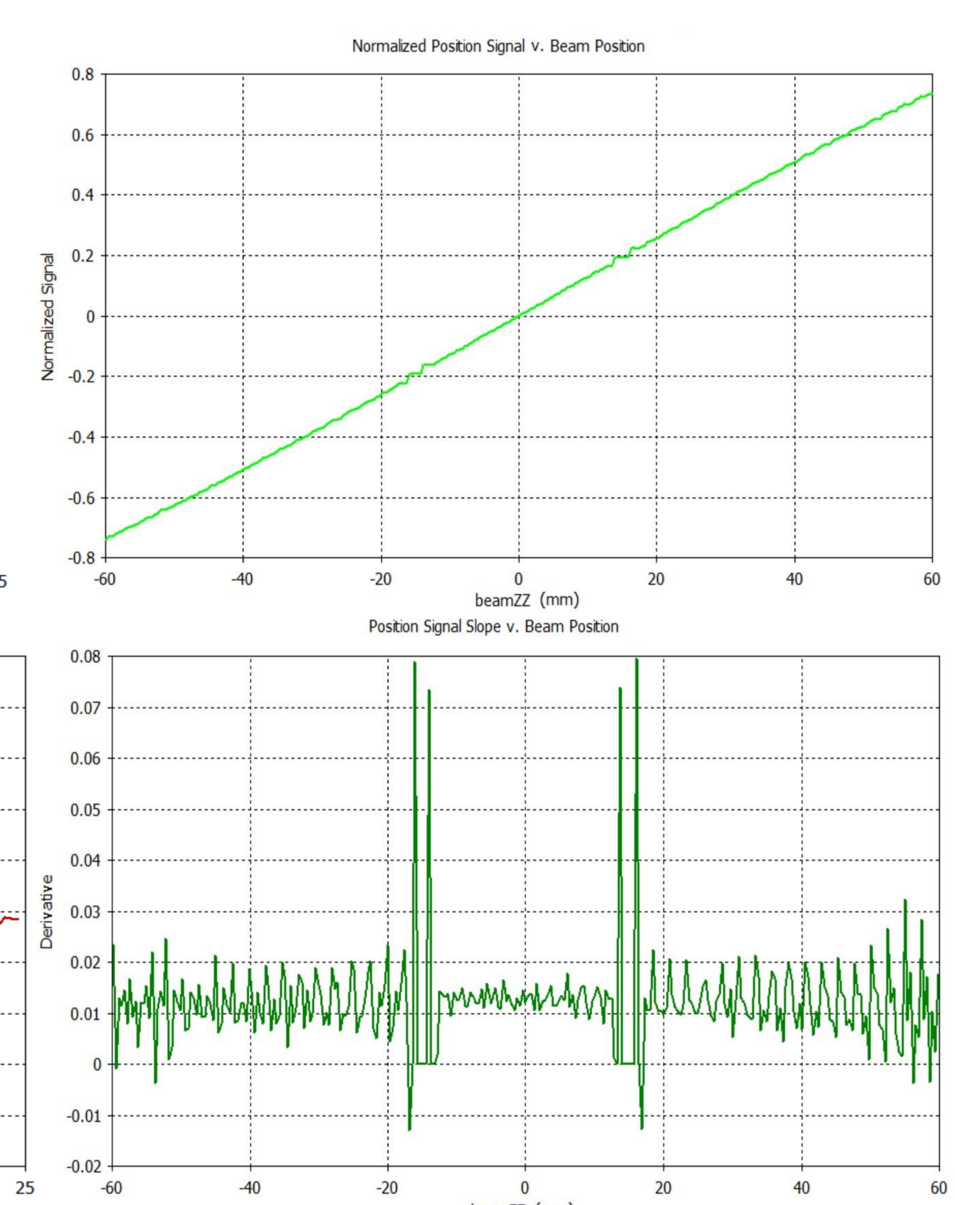
Isometric view of the parametric BPM model. Elliptical plates & metal guard ring are visible.

While ideally a BPM would return a perfectly linear position signal, the signals of physical BPMs often possess some degree of noise, due to the influence of unwanted phenomena such as capacitive coupling.

The above CST model was used to simulate the performance of an elliptical-plate BPM's position signal for a relativistic beam bunch (β=.8) with varying horizontal and vertical position, in pursuit of visualizing the influence of these unwanted effects.



Graph of the difference-over-sum position characteristic for a beam position vertical sweep (above) and the point-to-point slope of the graph (below).



Graph of the difference-over-sum position characteristic for a beam position horizontal sweep (above) and the point-to-point slope of the graph (below).

Conclusions & Next Steps

Initial BCM simulations have yet to indicate any risk of arcing with PIP-II beamline configurations. Initial BPM simulations showcase differing trends in position signal linearity for horizontal vs. vertical position sweeps, with the horizontal sweep returning a significantly noisier signal.

- BPM next steps would include examining potential causes for said variations, such as coarse model meshing, and methods of minimizing linearity variations.
- BCM next steps will entail research into frequency domain techniques to assist with the simulation of arbitrarily long beam pulses containing periodic gaussian particle bunches.

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