Mu2e Linac Analysis

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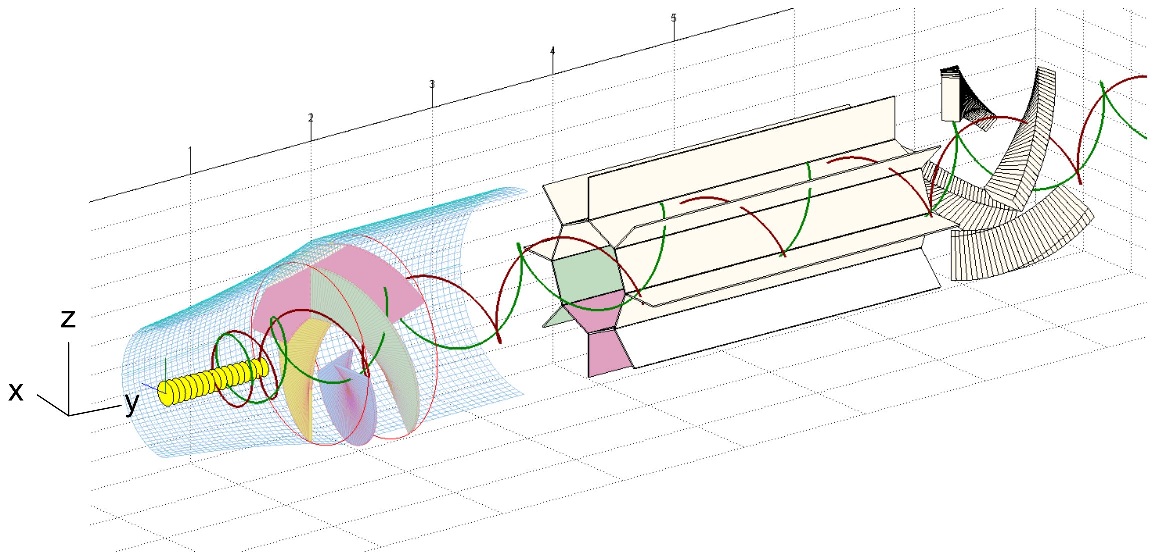

During the summer, I [Jason Dove] worked on analyzing the relationships between the electron tracks at the stopping target, the tracking chamber, and past the calorimeter. By better understanding how the position and momentum of a calibration electron near the calorimeter results in the position and momentum of an electron as it passes by the stopping target, I [Dove] hoped to be able to design a compact linac that would cover similar portions of the phase space that data electrons cover.

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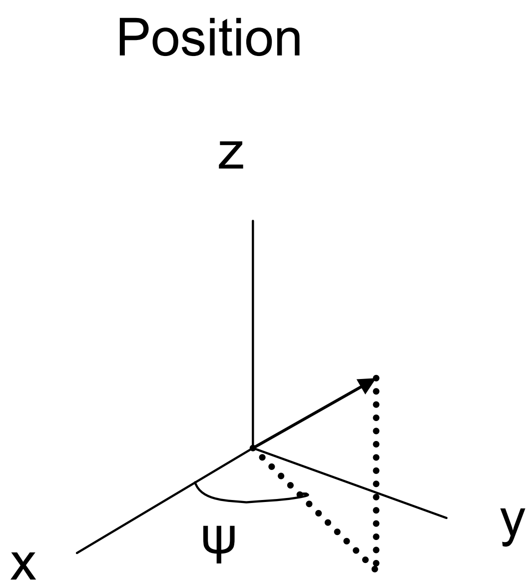
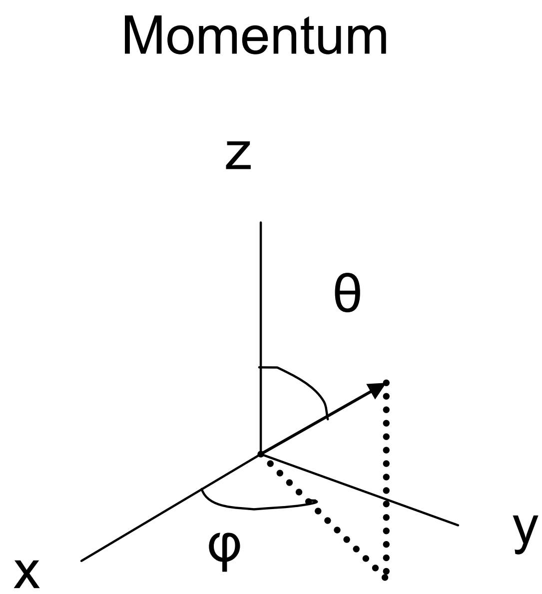
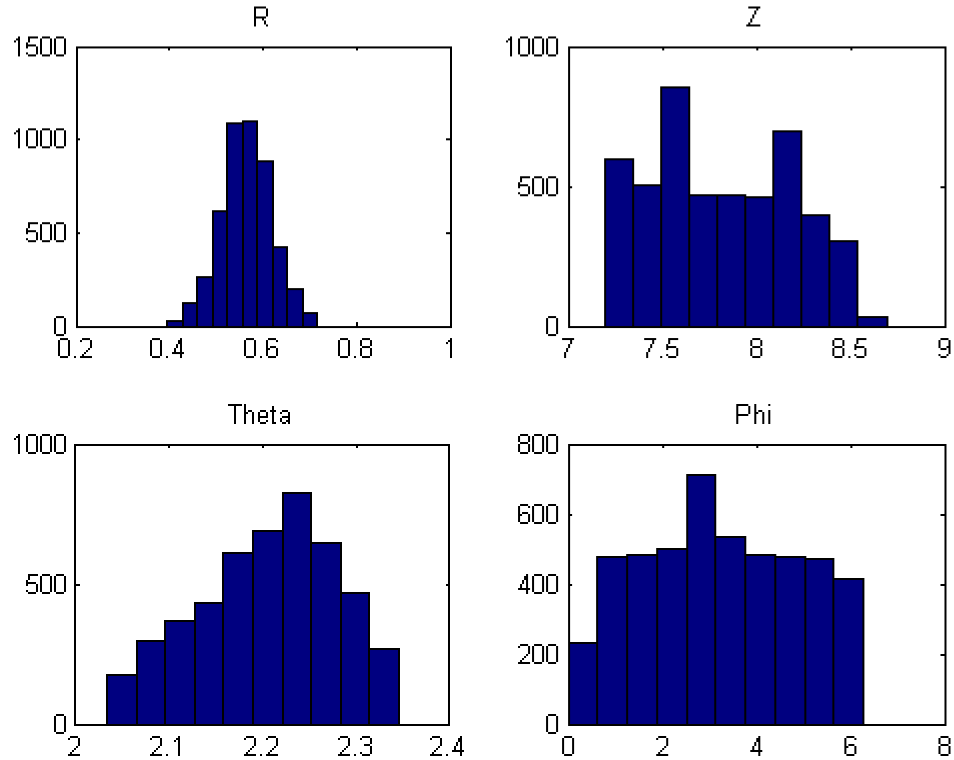




When describing the position of an electron, xyz and psi(ψ) coordinates are used. Psi refers to the angle measured from the positive x-axis of the projection of the position on to the xy-plane. Momentum is measured either with px, py, and pz representing the x y and z components of momentum, or with theta(θ) and phi(φ). Theta is the angle between the momentum vector and the z-axis, and phi is the angle measured from the positive x-axis to the projection of the momentum vector on to the xy-plane.

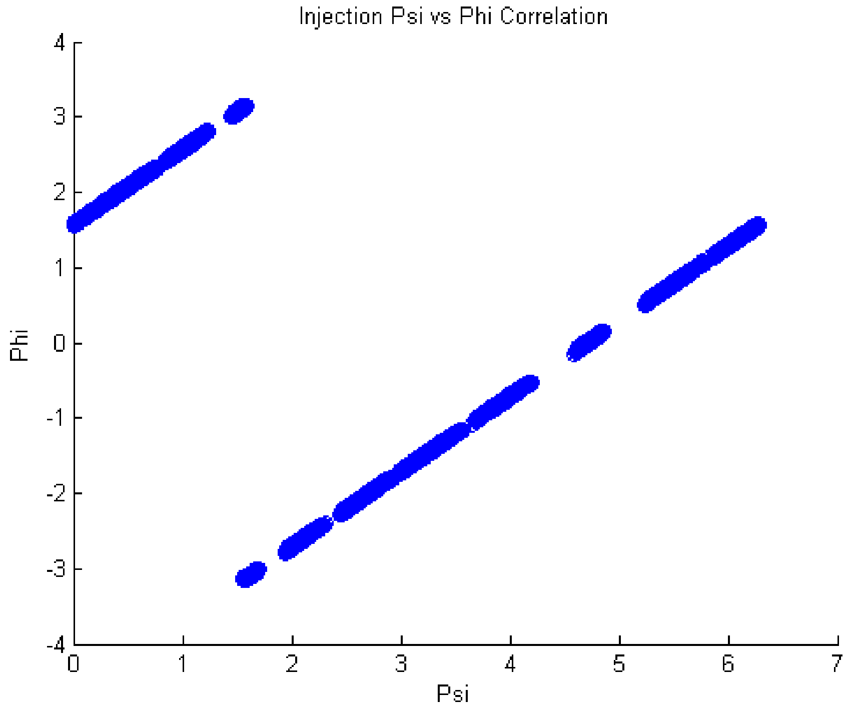
In order to discover where an electron would need to originate so that it lands on a specific target, positrons were traced from the target until they reached a desirable starting location. The initial track propagation function, made by Professor George Gollin, measured the magnetic field at the current position, then assumed the field was fairly uniform in a small neighborhood and propagated the track along a small section of a helix for one time increment. I replaced the Euler interpolation with a RK4 algorithm improving the accuracy from linear with step size to cubic with step size. I also reduced some of the computations and variable manipulations to lower the run time by a factor of six. For further run time improvement I was able to parallelize multiple tracks to be propagated simultaneously to make use of multi-cored systems.

Once I had a method of quickly backtracking an electron at the target to where it must originate, I needed to define a way to choose what part of the helix to inject from. By choosing the first point of maximum radius after the calorimeter (radius is defined as distance from the z-axis), I am able to place the linac out of the main beam line passing through the center of the detector. For simplicity, I chose target points only along the y-axis on initial trials without loss of generality due to the radial symmetry of the magnetic field. The destinations at the stopping target were chosen uniformly in z and r, and the momenta were chosen uniformly in solid angle.



Injection Parameters required to cover the targets uniformly over the y-axis

After looking at the injection positions and momenta I noticed that the radial position and theta angle were Gaussian.

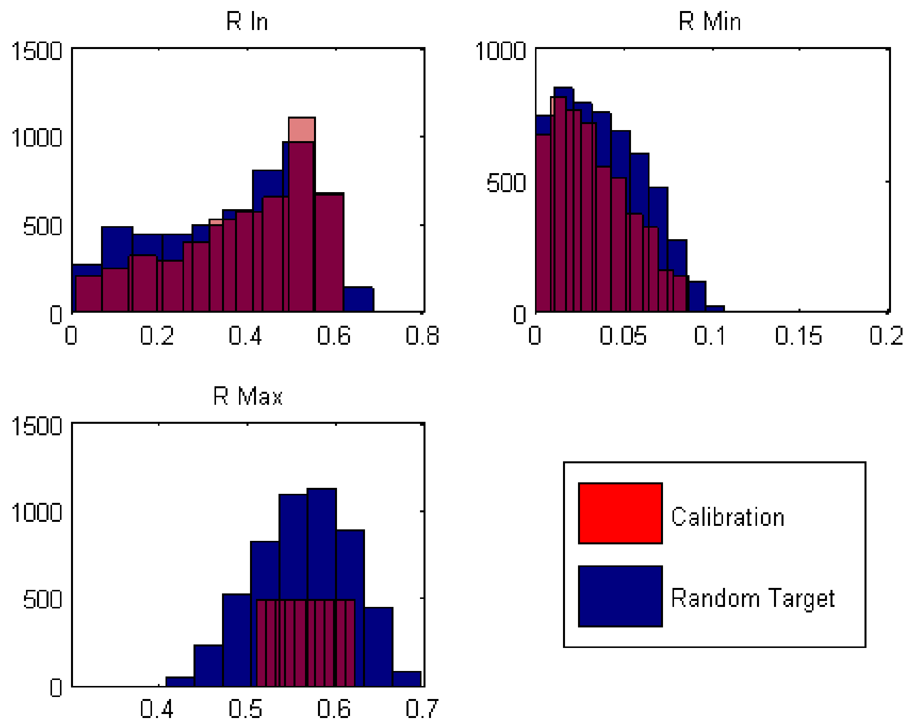


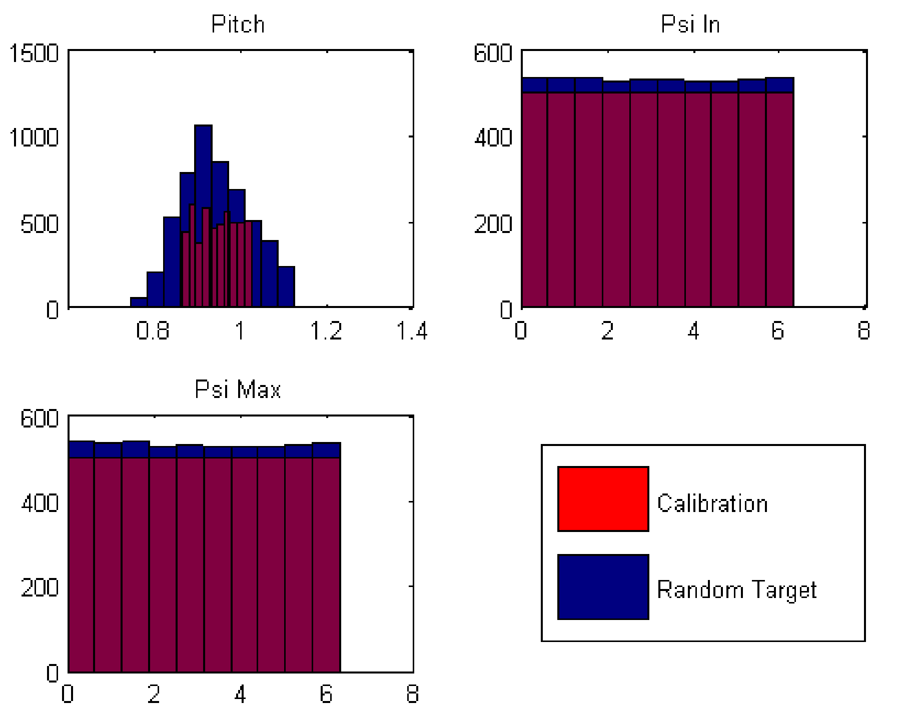
Graph showing that: phi ~ psi + pi/2

Also, the phi and psi angle were closely related to each other. By choosing only those injection points which landed within a standard deviation of the mean of the radius and z coordinates and within 1.3° of the expected phi value calculated from psi, I was able to cover 48% of the initial targets.

During the actual experiment, the majority of the data will be collected in the tracking chamber, so it is important that the chosen linac region illuminates similar portions of the tracking chamber as electrons born from the stopping target. Given the already developed machinery, it was simple to propagate a set of points from the targets to the tracking chamber and another set of points from the linac to the tracking chamber. The resultant tracks were observed through the tracking chamber on their way downstream. The parameters used to describe the tracks were:

- rIn = the radius from the z-axis as the track enters the tracking chamber
- rMin = the minimum radius in the tracking chamber
- rMax = the maximum radius in the tracking chamber
- pitch = theta
- psiIn = the psi angle when the track enters the tracking chamber
- psiMax = the psi angle when the track reaches its maximum radius.





Points picked randomly over the entire target to result in a uniform spatial distribution and momenta that are uniform in solid angle. Calibration points are picked deterministically uniformly over the restricted linac region

When the resulting distributions were compared, the calibration electrons mimic the target electrons except for the pitch and rMax parameters, where the linac covers a similar but smaller region due to my restriction of the linac phase space.