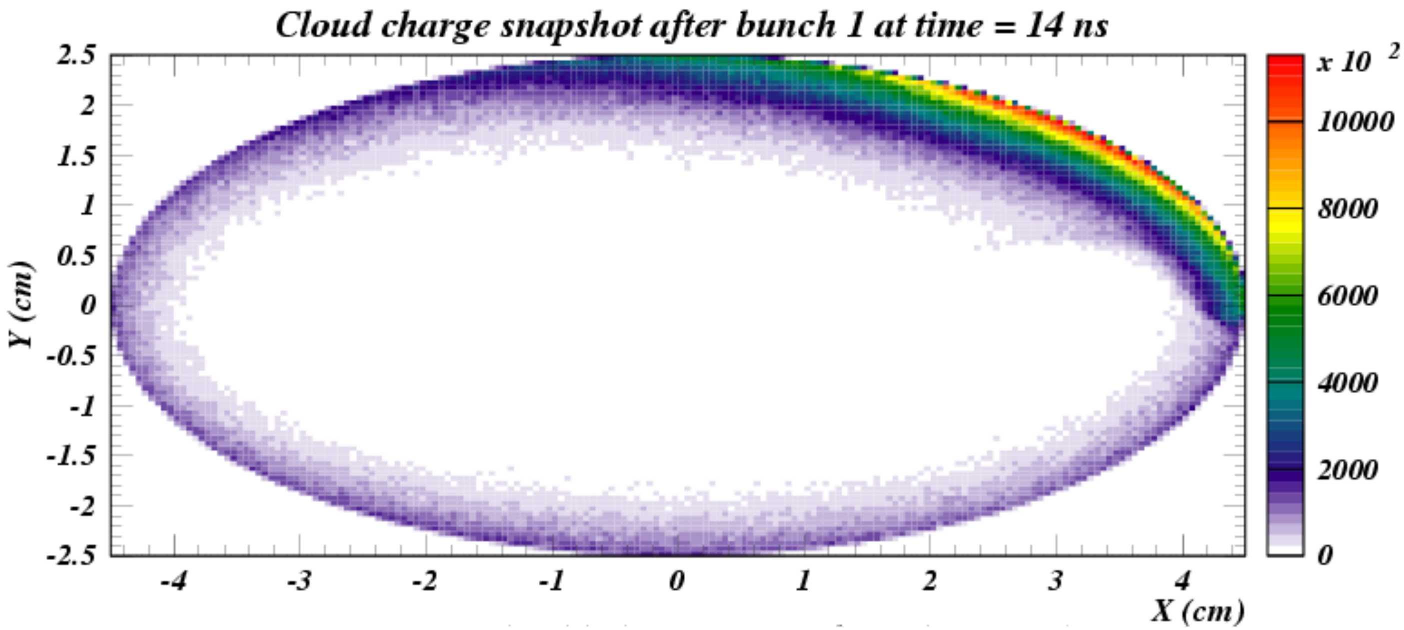
ILC Damping Ring R&D with the Cornell Electron Storage Ring Test Accelerator



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Project Overview

- Primary photo-electron energy distribution (ED) has never been known accurately
- Previously used a low energy Gaussian distribution that contained too few high energy photo-electrons
- Want to find correct energy distribution for positron and electron beams at 5.3 GeV and electron beam at 2.1 GeV

Ecloud Simulations

•The simulation requires a few dozen input parameters
•Can change the bunch current, the number of bunches (primarily one bunch for this project), the number of macroparticles, solenoid field strength and reflectivity among other things
•Photo-electron energy distribution is the one that I was primarily focused on
    -consists of three input parameters that correspond to: E_{max} p_1 p_2
•These numbers are plugged into

$$f(E) = E^{p_1} / (1 + E / E_o)^{p_2}$$

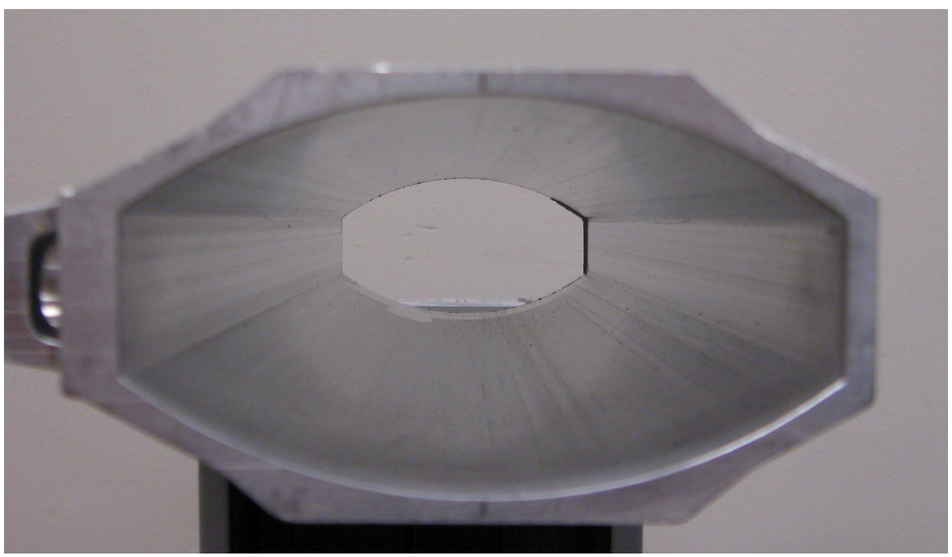
where

$$E_o = E_{\max}(p_2 - p_1) / p_1$$

to create an energy distribution.

Reflectivity

•A measure of how reflective the interior of the chamber is
•If reflective, light will bounce around the chamber
•In our simulations, the reflected light is evenly distributed around the chamber
•If no reflectivity, the synchrotron radiation hits a certain spot and all the photo-electrons are produced there
•Reflected light could stay in plane or go farther down the pipe
•The reflectivity we used for simulations was 20% for e+ and 33% for e-. This means that for the positron beam, 80% of the synchrotron radiation is turned into photo-electrons on the outside wall and the remaining 20% is evenly distributed around the chamber

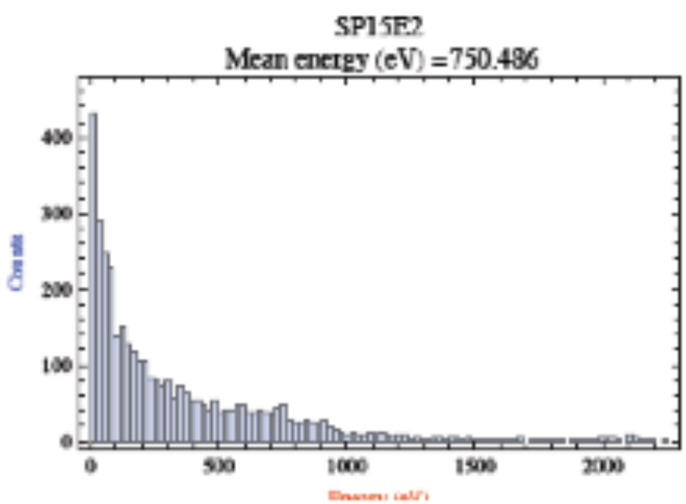


Synchrotron Radiation Photon Critical Energy

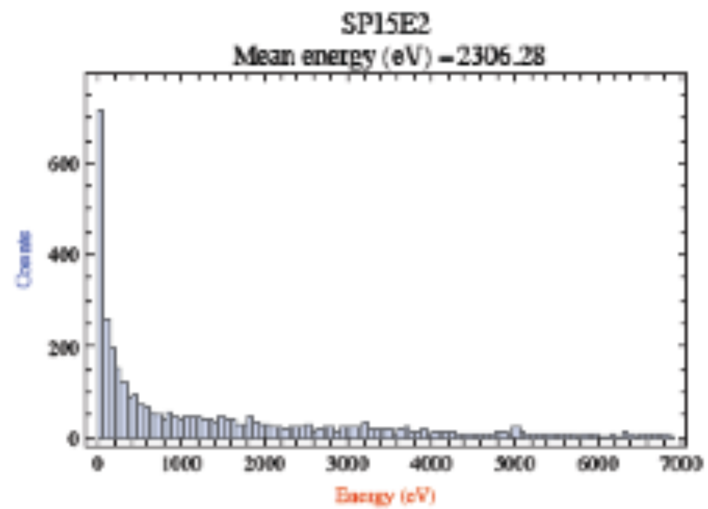
- Equal number of photons on either side of the critical energy value
- The critical energy equation is as follows: $E_c = \hbar c \frac{3\gamma^3}{2\rho}$

where ρ is the bending radius. Since the beams travel in opposite directions, the bending radius is different for each one. 90 m for e+. 60 m for e-.

Positrons



Electrons

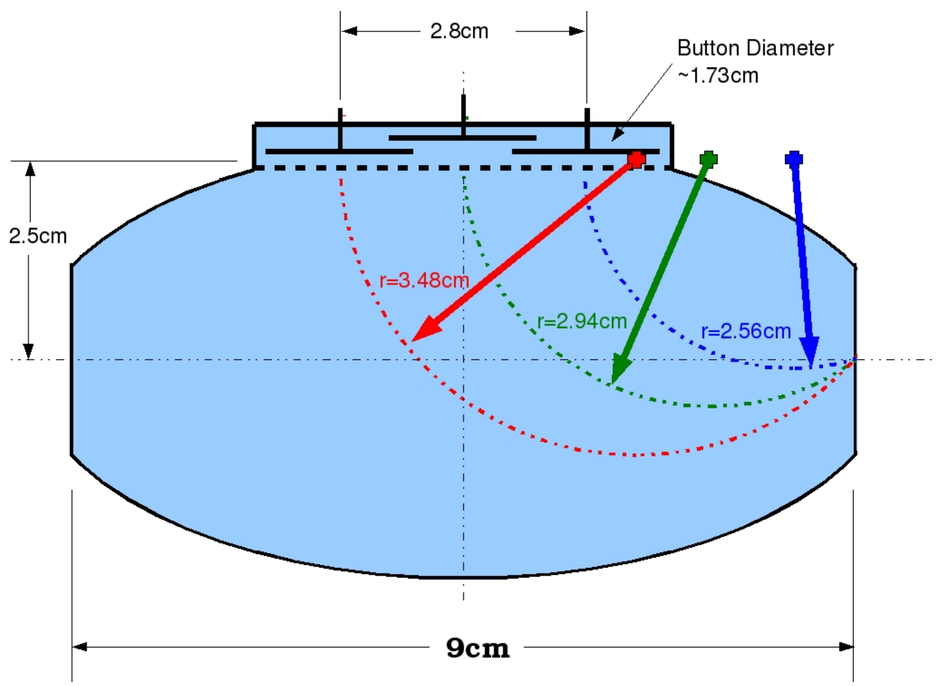


We originally thought that the same ED would work for both positrons and electrons for the 5.3 GeV beam, but the results proved otherwise. We then found that the critical energies for the positron and electron beam were different.

Solenoid-Off Vs. Solenoid-On

•For solenoid-off simulations, the signal is mostly made up of photo-electrons that are coming from the floor of the chamber

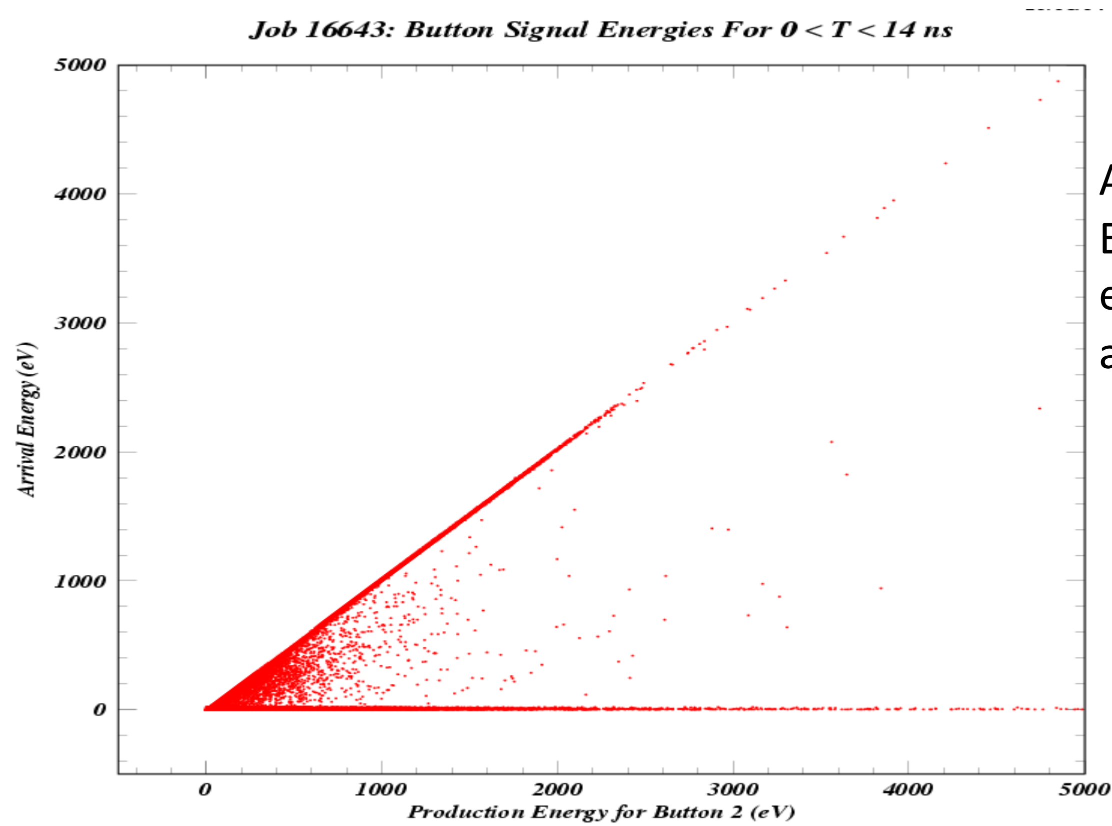
•For solenoid-on simulations, the signal will depend on the pe's formed on the outside wall with a certain energy and trajectory (to be discussed later)



The electrons must come in perpendicular (or very close to) in order to pass through the grating below the buttons

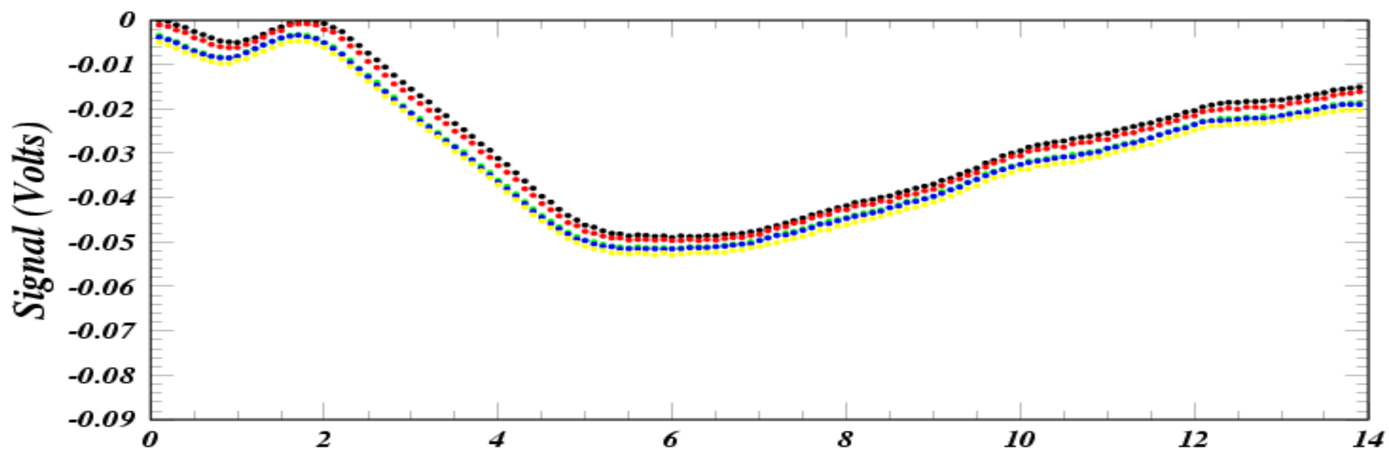
Electron Beam Kick

•Due to coulombic repulsion, the electron beam will suppress all primary photo-electrons with an energy below 50 eV (for an 8 mA bunch)
•By suppress, I mean push them back into the chamber wall
•The beam also lowers the energy of the higher energy primaries

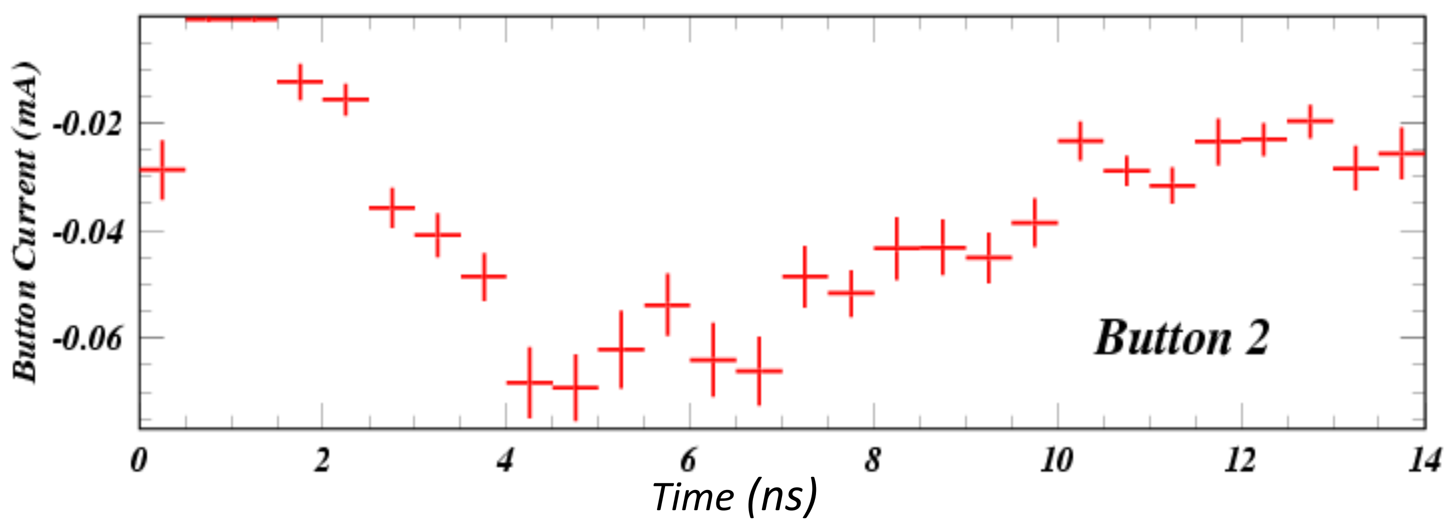


Arrival Energy vs. Production Energy. The low energy electrons are the ones most affected by the beam.

Solenoid-Off 8 mA e- 5.3 GeV ED: -20 0.18 4.0



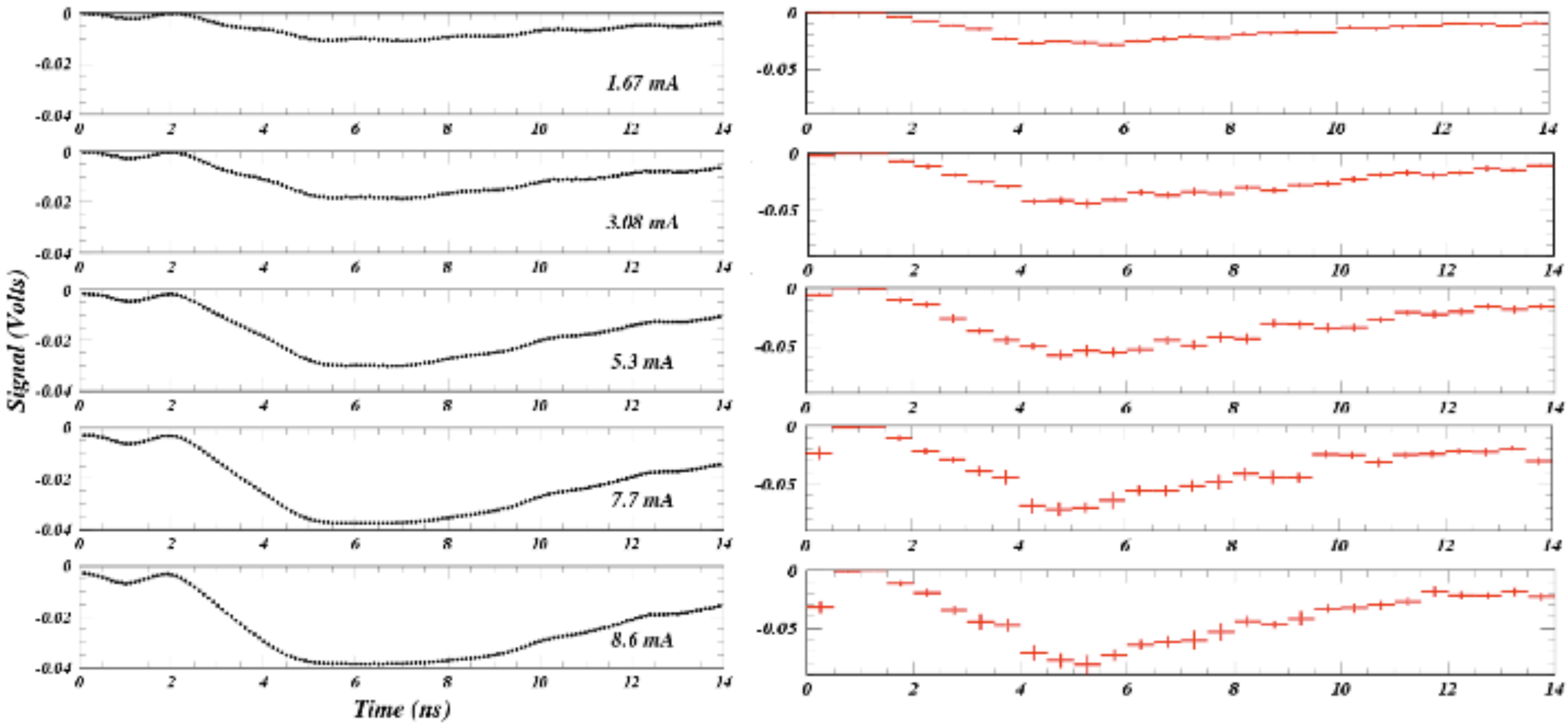
Data



Simulation

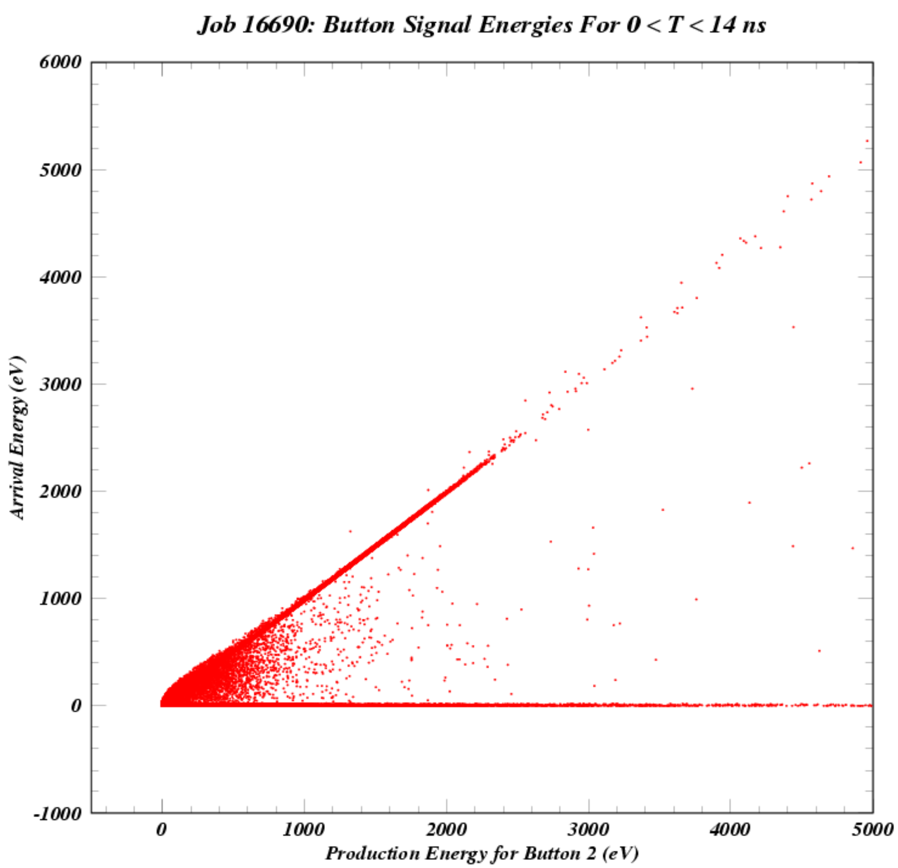
- The three numbers in the ED took a great deal of time to find
- Electron beam will also cause a small peak very early in the signal because it will push some of the primaries formed close to the buttons back into the buttons

Varying the current does not have an effect on the peak signal time for an electron beam. The signal is primarily made up of higher energy photo-electrons that are not affected very much by the beam kick. Higher current causes a larger cloud, stronger initial peak, and stronger peak signal because synchrotron radiation is stronger.



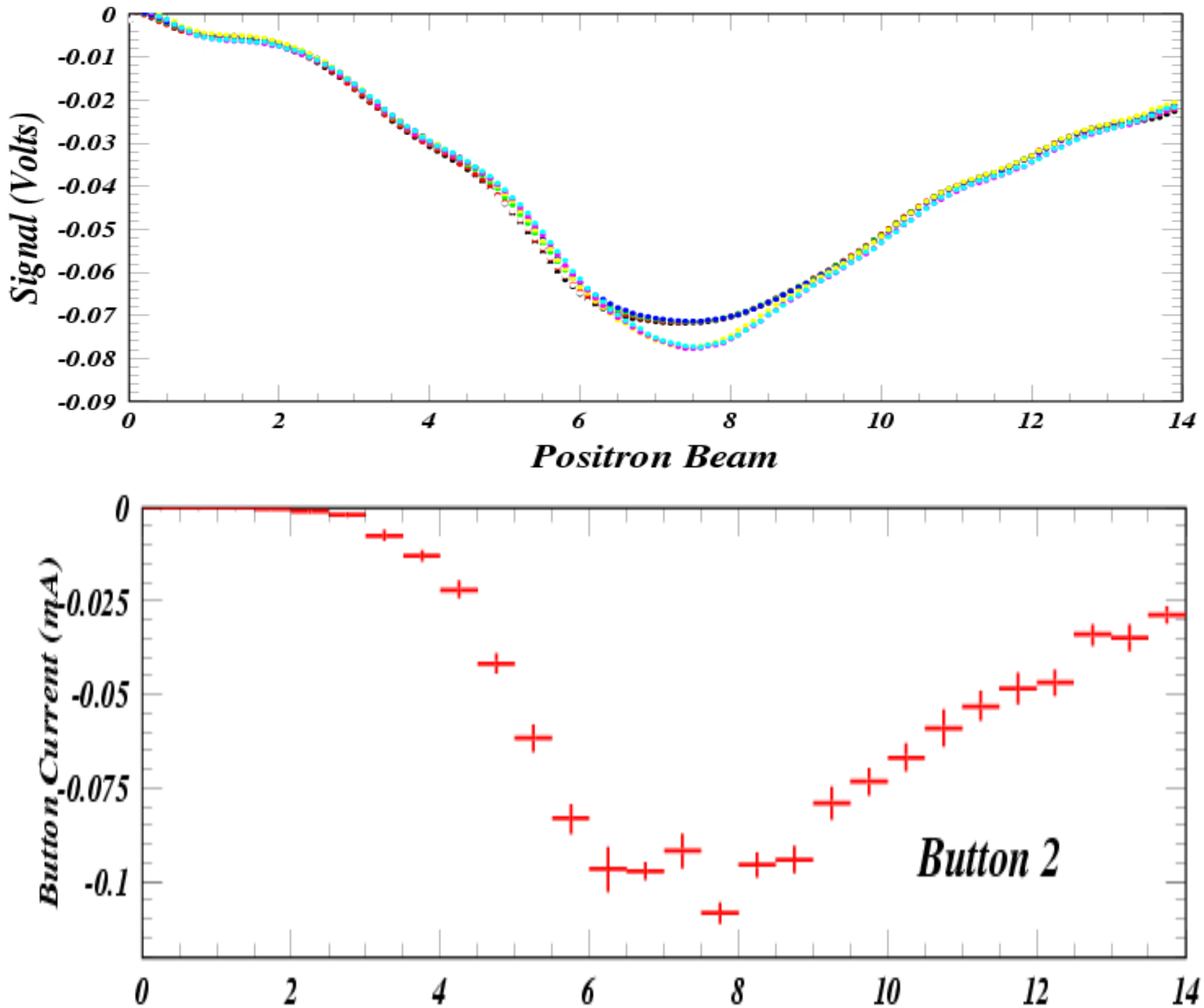
Positron Beam Kick

•Because of attraction between the positrons and electrons, the positron beam will increase the energy of the photo-electrons especially low energy ones
•The beam kick's energy increase will have an effect on what energy distribution works unlike the electron beam where beam kick only affects the photo-electrons that don't contribute to the signal



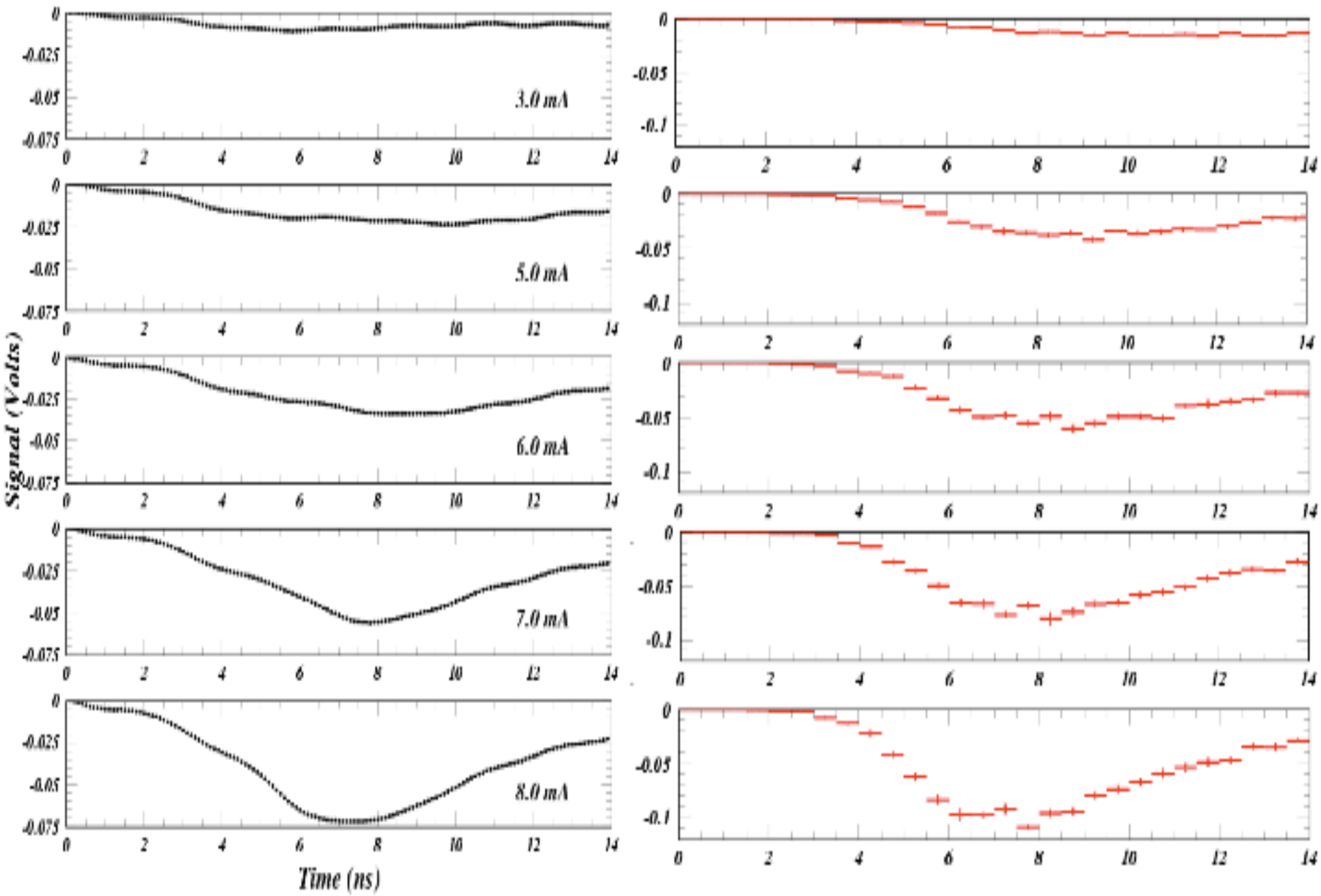
Arrival Energy vs. Production Energy.

Solenoid-Off 8 mA e+ 5.3 GeV ED:-12 0.8 4.5



Managed to get good agreement after tuning the three parameters in the ED.

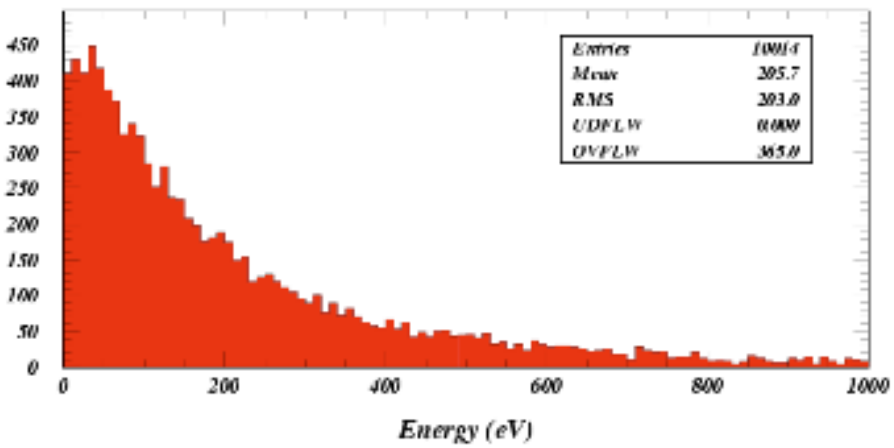
A higher bunch current for the positron beam has much more of an effect on the signal shape because the particle energy is more affected by the beam kick than for the electron beam.



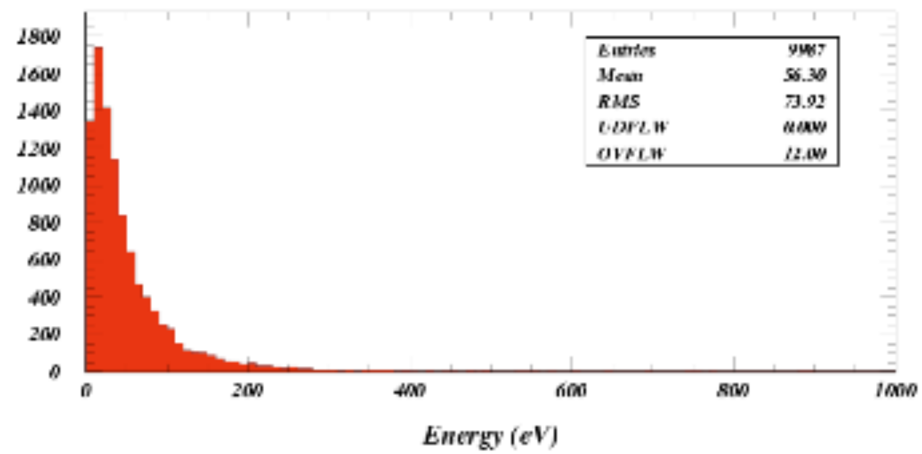
Note that the signal peak arrives earlier for higher bunch current. Higher bunch current will produce a stronger beam kick.

Energy Distribution Plots

Electron Beam ED:-20 0.18 4.0



Positron Beam ED:-12 0.8 3.5



These plots show the much greater number of high energy photo-electrons required to produce the correct signal shapes.

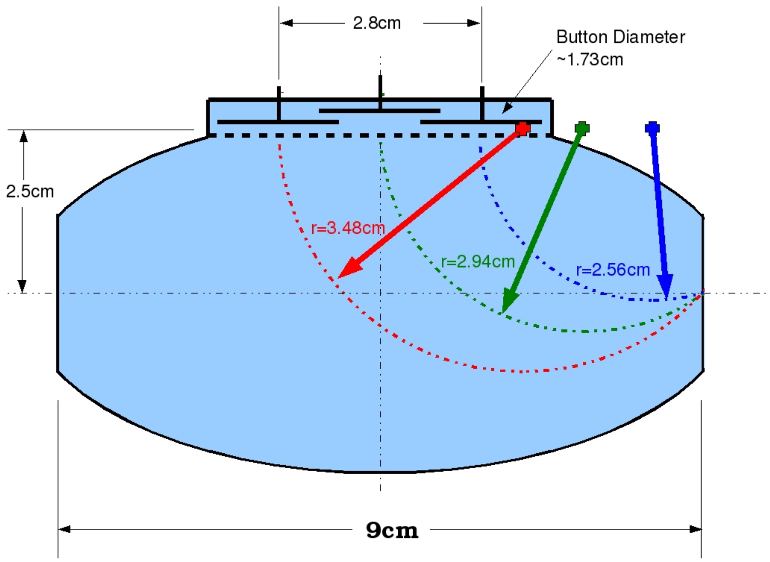
Determining Acceptable Energies for Button With Solenoidal Field On

Start with Lorentz Force Law (assume E-field is zero) and Centripetal Force set equal and solve for velocity:

$$v = \frac{qBr}{m}$$

then plug into kinetic energy equation:

$$E = \frac{1}{2}\frac{q^2}{m}(B^2r^2)$$



Using the radii from the graph on the left and .0020 T (20 G) for the magnetic field:

Button 1 (far right)- 230 eV

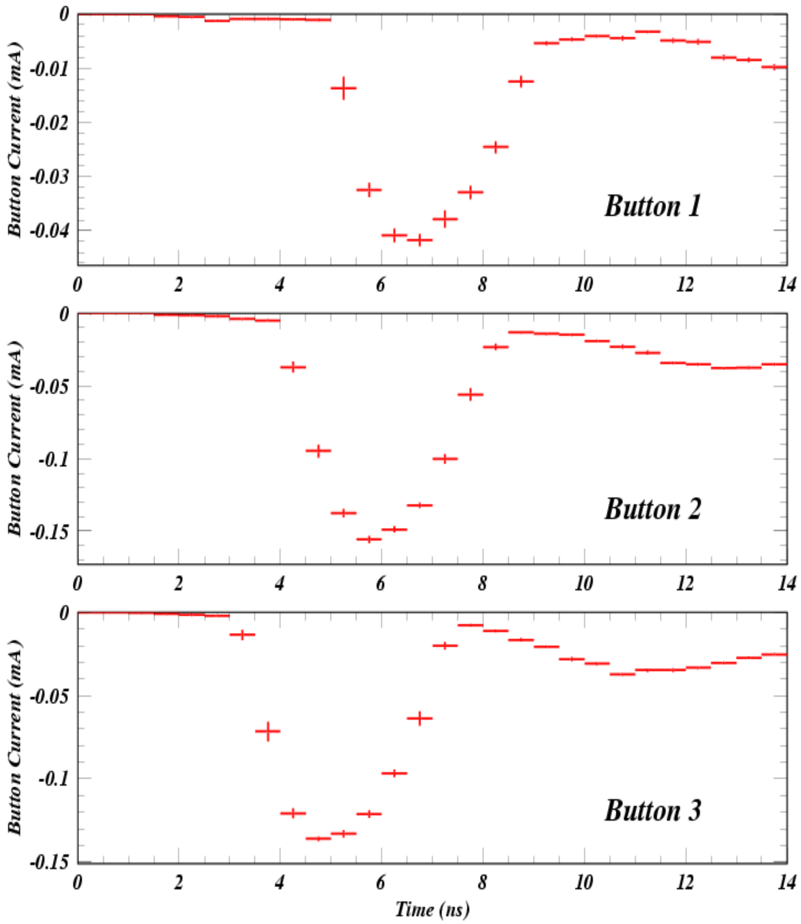
Button 2 (center)- 304 eV

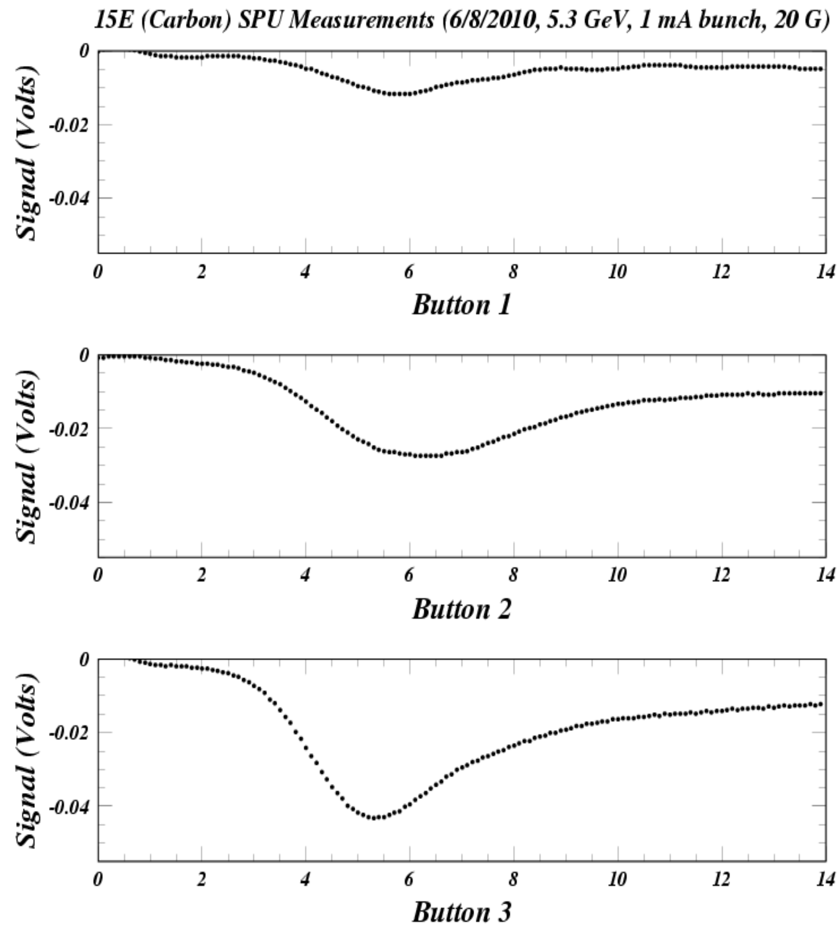
Button 3 (far left)- 426 eV

This is only for the center of each button.

Solenoid-On Data

5.3 GeV 1mA e- ED:-20 0.18 4.0 20 Gauss field



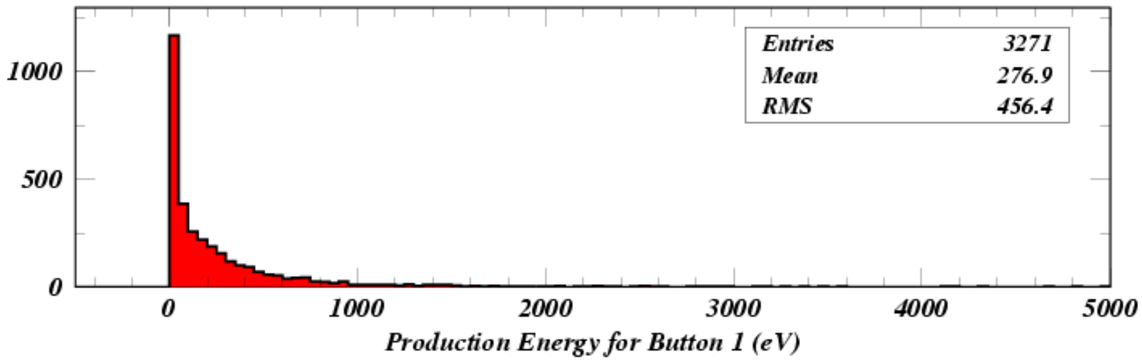


The signal is mostly from photo-electrons created on the outside wall. The same ED works for solenoid-on simulations. The secondary electron production spectrum needs to be fine tuned in order to smooth out the curve starting around 7 ns.

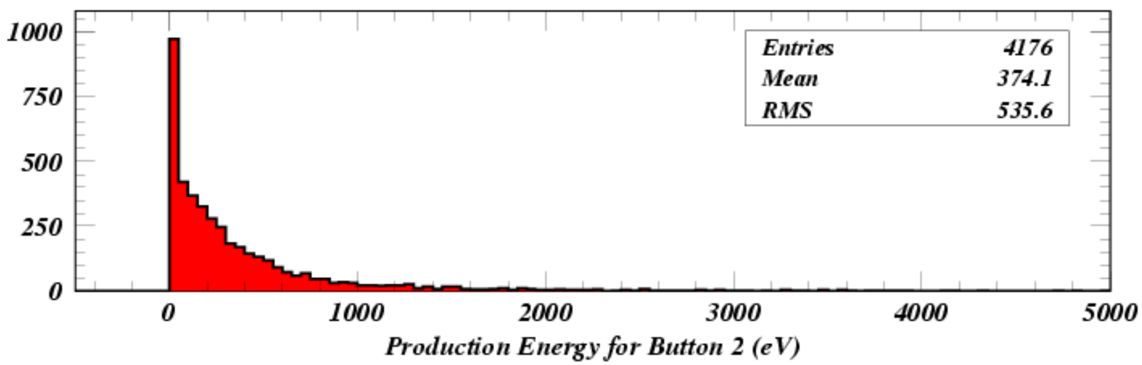
Production Energy for Each Button

5.3 GeV 1mA e- ED:-20 0.18 4.0 20 Gauss field

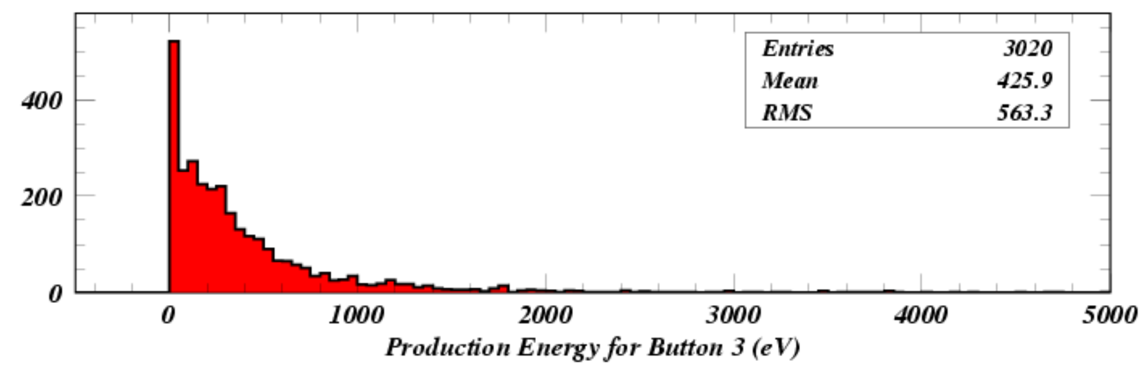
Production energies are close to theoretical values. The buttons accept a range of energies so the mean energy does not have to be exactly the required energy calculated previously.



Mean Energy for Button 1: 277 eV

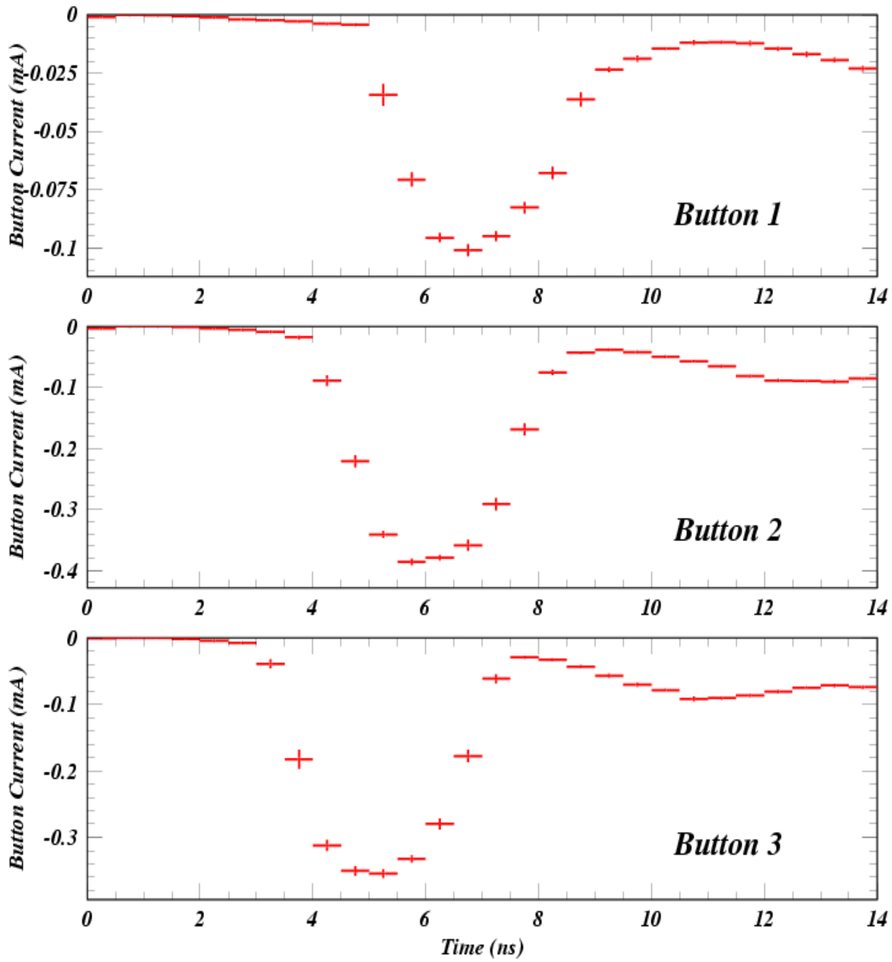


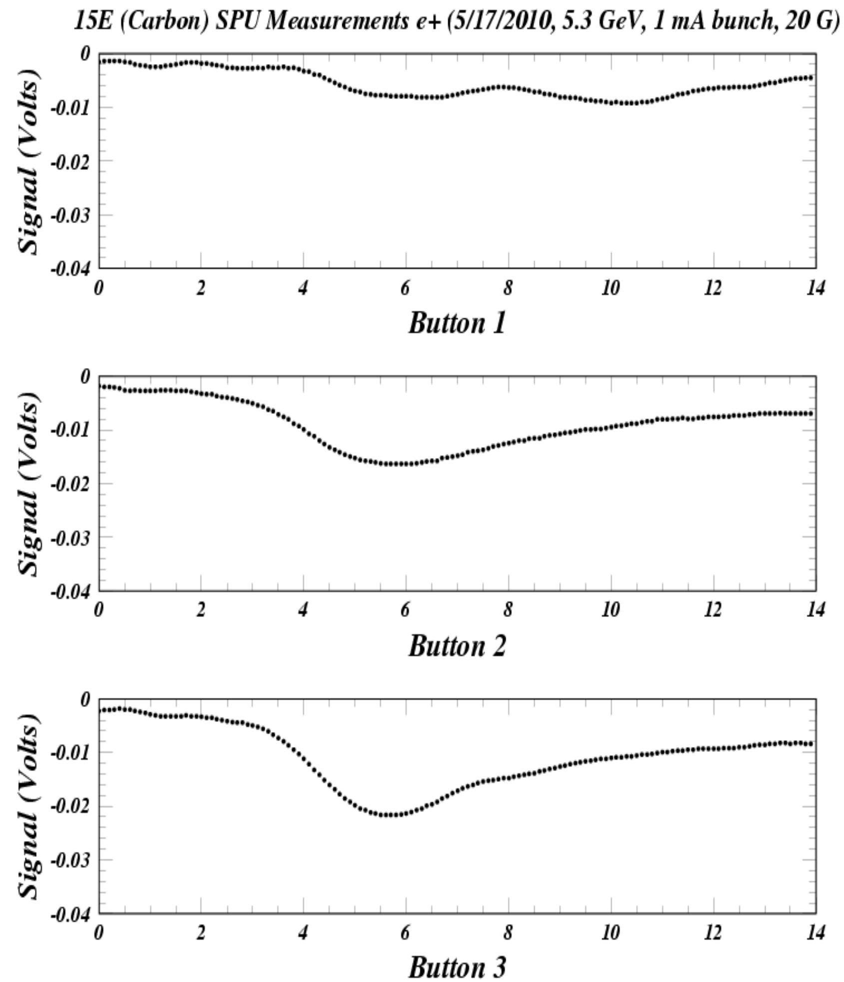
Button 2: 374 eV



Button 3: 426 eV

5.3 GeV 1mA e+ ED:-25 0.2 3.5 20G field



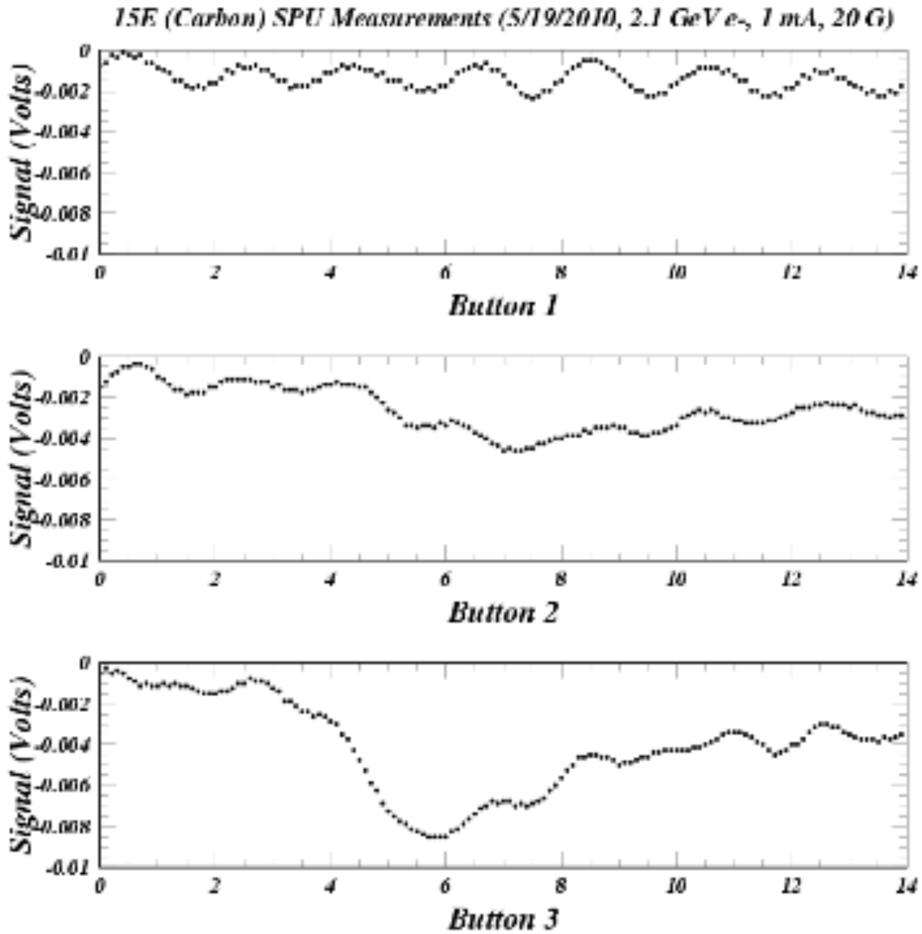


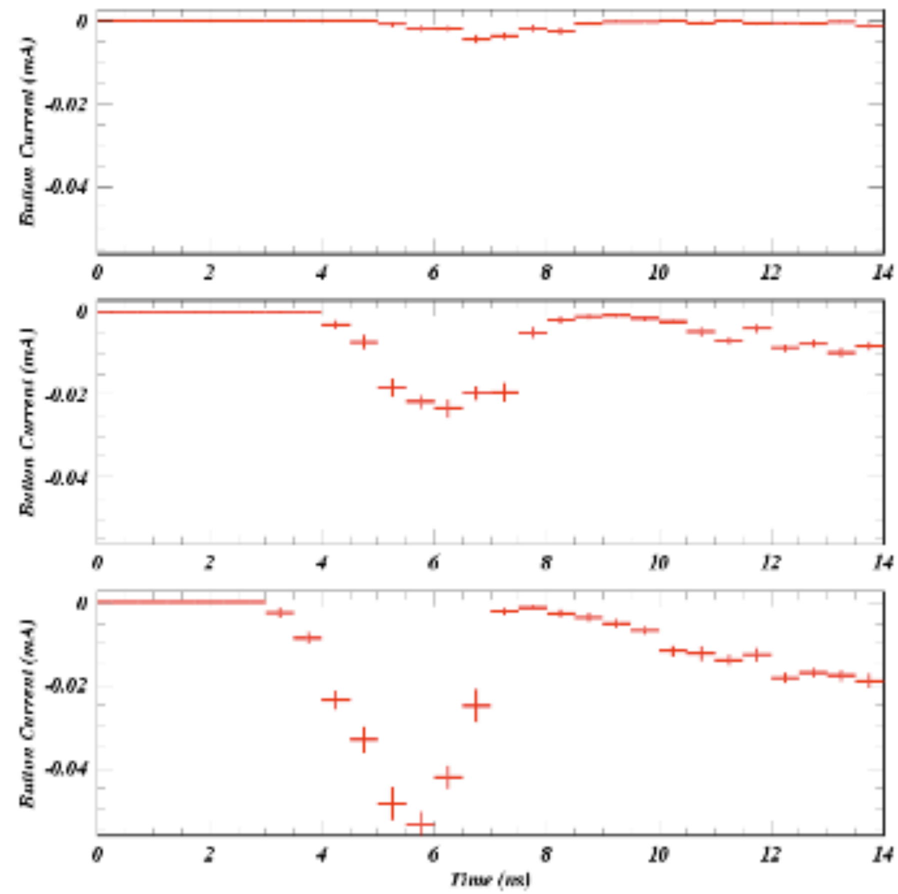
•For the the previous ED with solenoid-off, the solenoid-on peak signal time arrived almost two seconds too late. Since the photo-electrons are coming from a different part of the chamber, it was not necessarily expected to work.

• This meant that the energy was too low. I had to come up with a different ED for solenoid-on positron beam.

2.1 GeV Beam

1mA e- ED:-5 0.2 5.0 20 Gauss field





The critical energy for the 2.1 GeV beam is much lower than that of the 5.3 GeV beam which means it must have much lower photo-electrons. The new ED works when the reflectivity is set to 0%, otherwise there is too much contribution to the signal from primaries from other parts of the chamber.

Conclusions

•Prior to the new energy distributions, the same low energy (5 eV) ED was used for positron and electron beams at 5.3 GeV and the electron beam at 2.1 GeV. It was shown that the previous ED was wrong.
•The new energy distributions provide new information on the reflectivity
•The new energy distributions allow us to more accurately model the electron cloud and its effects

Future Work (for others) - Find a reflectivity for solenoid on and solenoid off that is same for both beams and energies
-Secondary electron distribution

I would to thank Jim Crittenden, my mentor, for guiding me through this research project and always taking time to answer my questions. I would like to thank Jon Sikora for helping me find data whenever I came to bug him about it.

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