Resolution of the Puzzle for ECLOUD Simulations of the Shielded Button Measurements for an Electron Beam

I. The Cause

II. The Solution

III. Effect of the Solution on the Simulation for a Positron Beam

IV. Premature Preview of the Consequences for Modelling Coherent Tune Shifts

V. Next Steps

-- 2 May: Added slides 10 and 11 to showing effects of cloud space charge force and grid size --

-- 5 May: Added slides 12 and 13 to showing effects of the beam kick and measurement data --

All material for this talk, including full sets of the analysis plots, may be obtained at www.lepp.cornell.edu/~critten/cesrta/ecloud/28apr10

Jim Crittenden

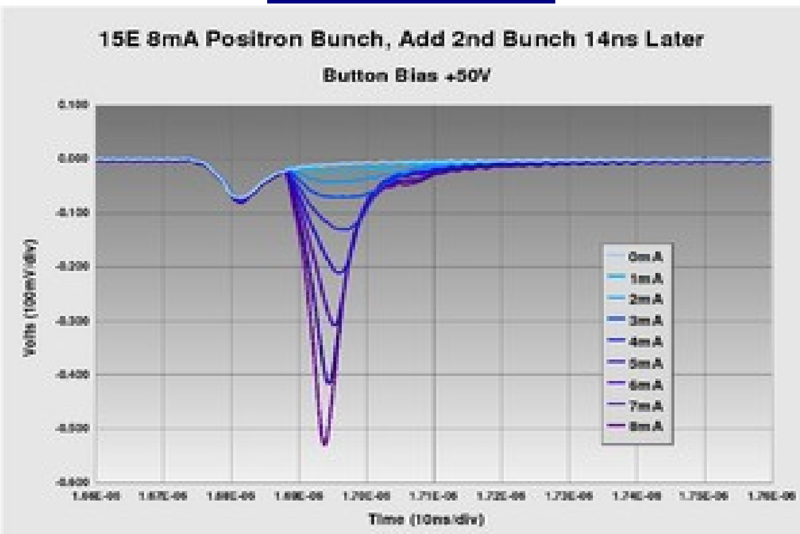
Cornell Laboratory for Accelerator-Based Sciences and Education

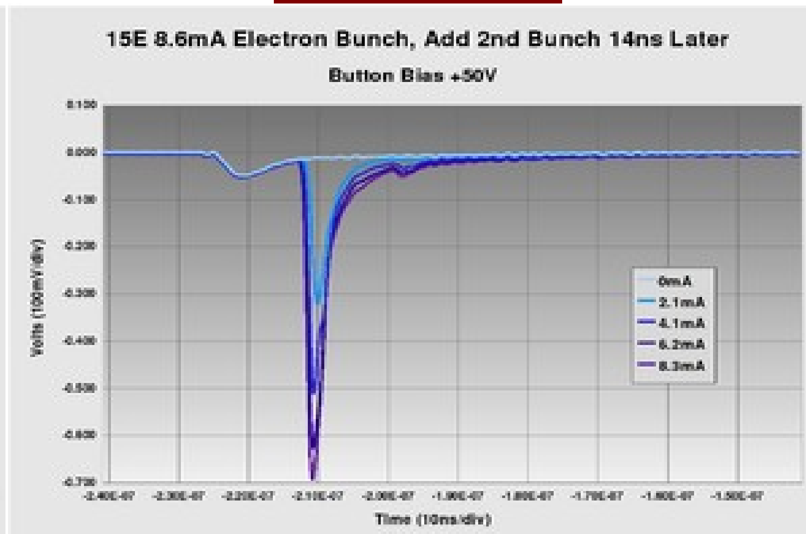
Electron Cloud Meeting

28 April 2010

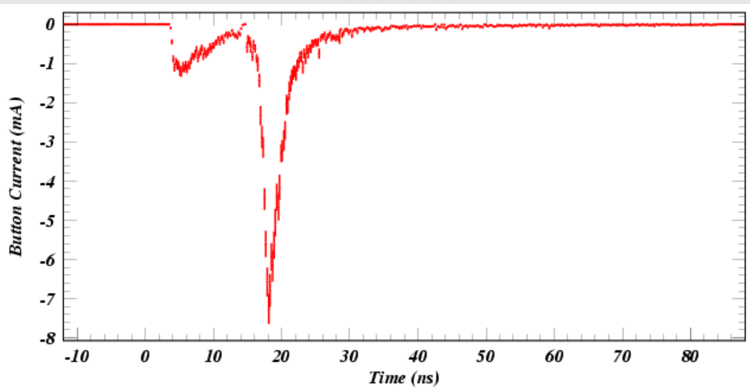
Status as of Last Week's Meeting

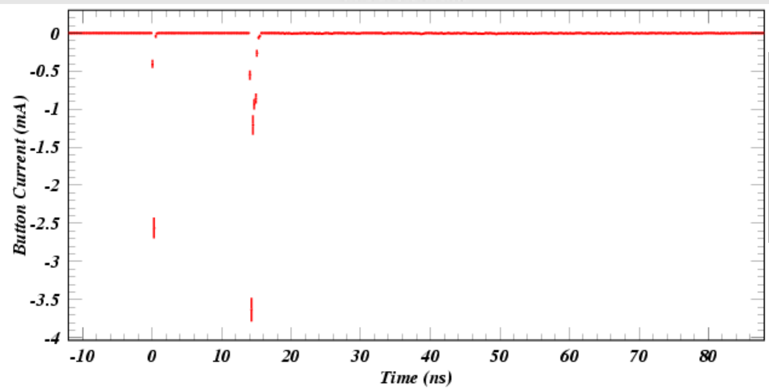
Positron beam	***Electron beam***





Measurements Central Button

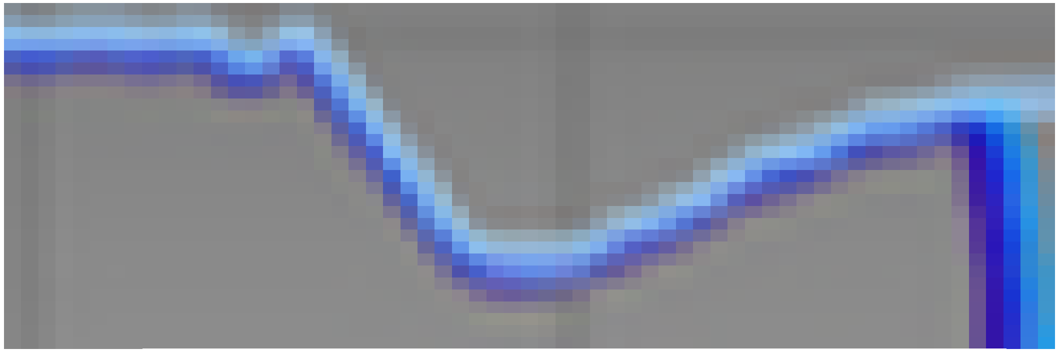




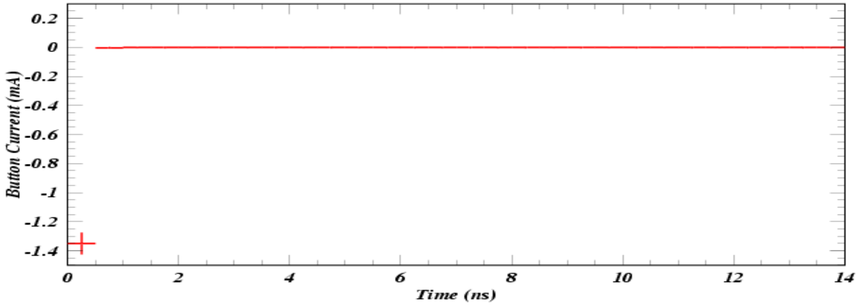
ECLOUD Simulation Central Button 2x8 mA

Movies showed that the cloud particles producing the e+ beam signal between the bunches originate on the floor of the pipe. For the electron beam, those particles are reabsorbed during the first bunch passage. Similarly, those produced on the ceiling are immediately reabsorbed, producing the prompt signal inconsistent with the measurement.

Electron Beam
Parameter Study: Energy Spectrum of Primary Photoelectrons



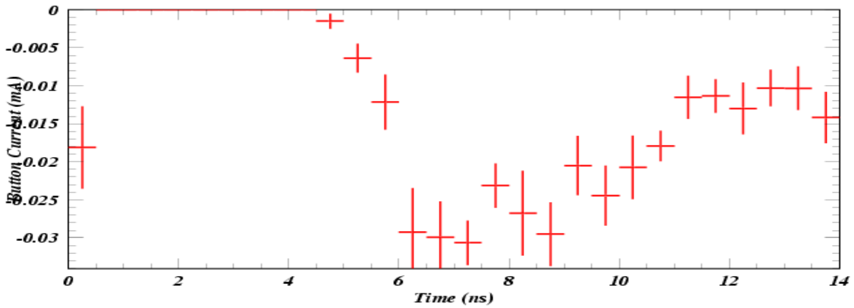
Measurements
Central Button



Primary p.e.

E_{peak} = 5 eV

σ_E = 5 eV



Primary p.e.

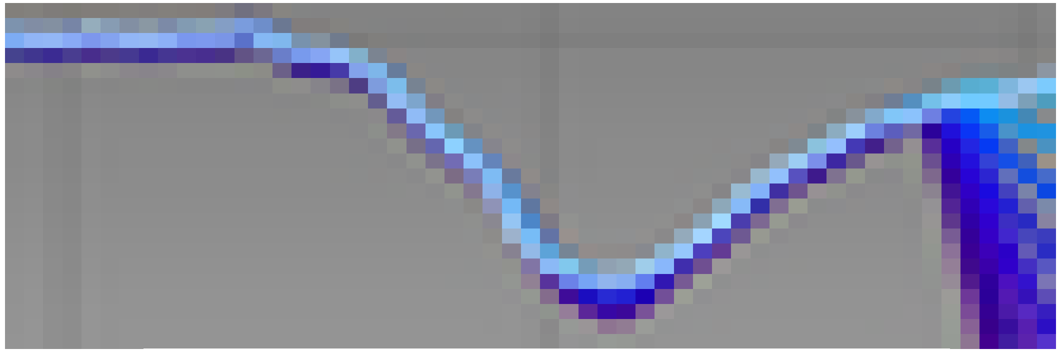
E_{peak} = 100 eV

σ_E = 100 eV

ECLOUD Simulation
Central Button
2x8 mA

The cloud particles produced on the floor must overcome the potential barrier of the electron beam to reach the ceiling. Their arrival time is very sensitive to the high end of the energy spectrum and to the production angular distribution. For example, the signal arrives at 12 ns for E_{peak} = 40 eV σ_E = 20 eV, rather than at 5 ns for E_{peak} = 100 eV σ_E = 100 eV.

How do the parameters improved for the electron beam affect the simulation for a positron beam?

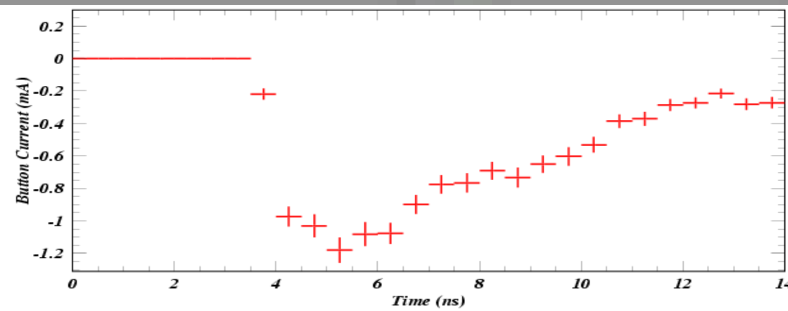


Measurements
Central Button

Primary p.e.

$E_{peak} = 5$ eV

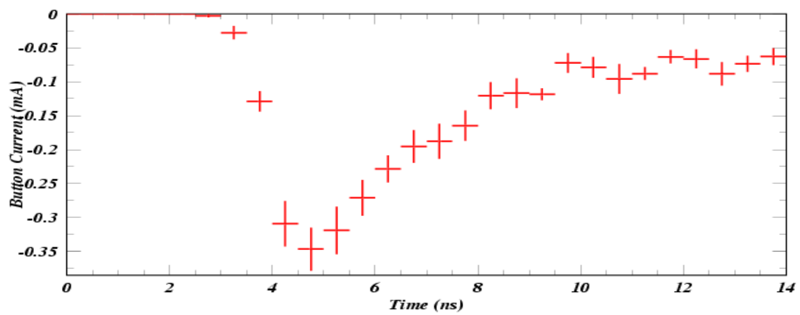
$\sigma_E = 5$ eV



Primary p.e.

$E_{peak} = 100$ eV

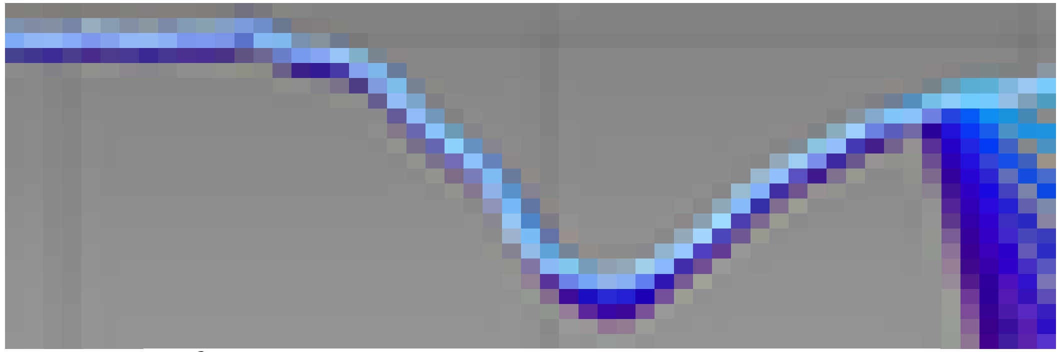
$\sigma_E = 100$ eV



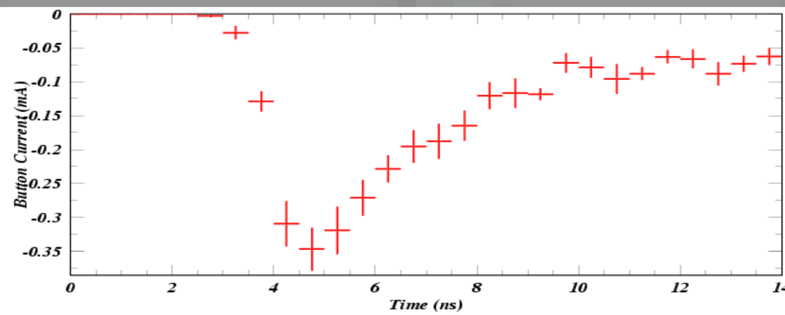
ECLOUD Simulation
Central Button
2x8 mA

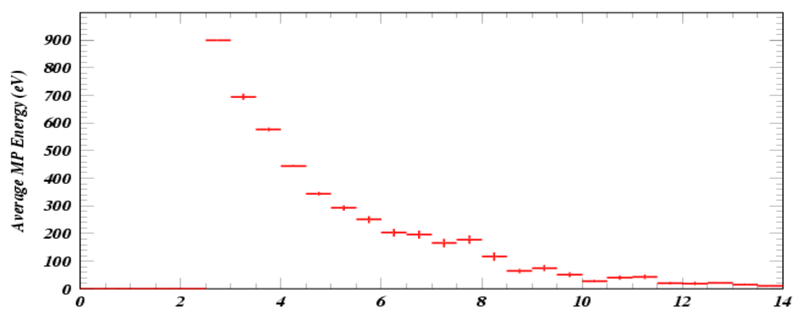
The parameters which improve the electron beam simulation also improve the positron beam simulation by moving the onset of the signal earlier. However, the simulated signal peaks about 3 ns too early.
Adding an contribution 0-50 eV will improve the positron model without affecting the electron model.

Positron Beam
Macroparticle Arrival Time and Arrival Energy



Measurements
Central Button





Primary p.e.

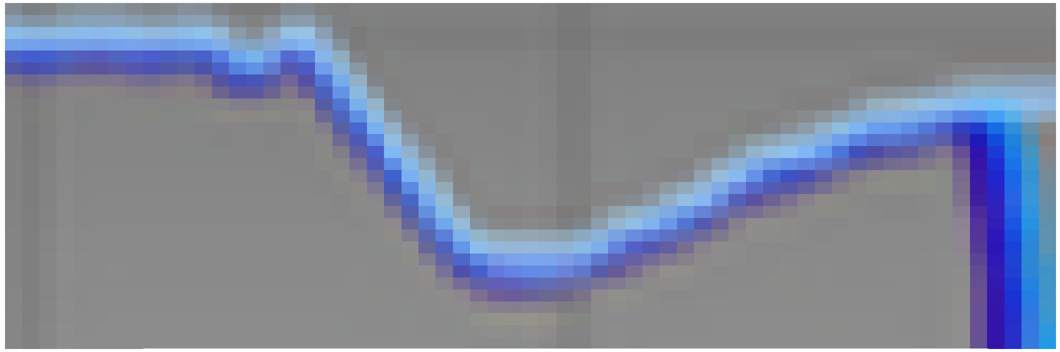
$E_{peak} = 100$ eV

$\sigma_E = 100$ eV

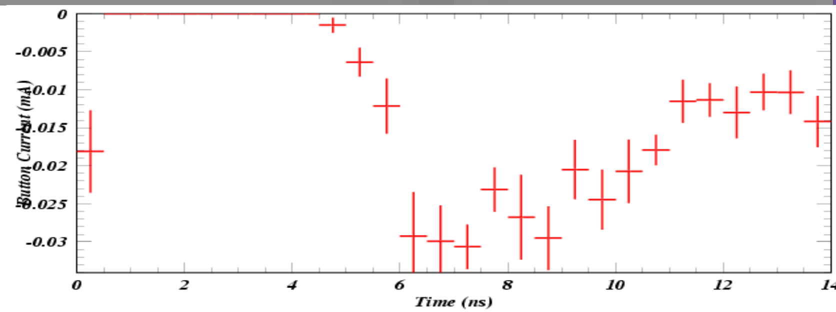
ECLOUD Simulation
Central Button
2x8 mA

The arrival time of the macroparticles is strongly correlated to the arrival energy. The earliest energy is 900 eV.
The energy spectrum (truncated gaussian) overemphasizes higher energies, though the maximum energy is about right.

Electron Beam
MP Arrival Time and Arrival Energy

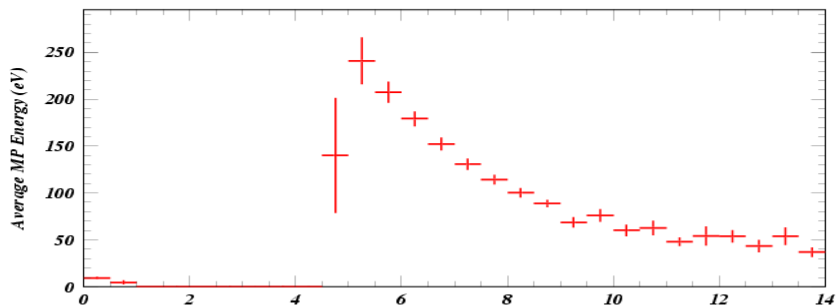


Measurements
Central Button



ECLOUD Simulation
Central Button
2x8 mA

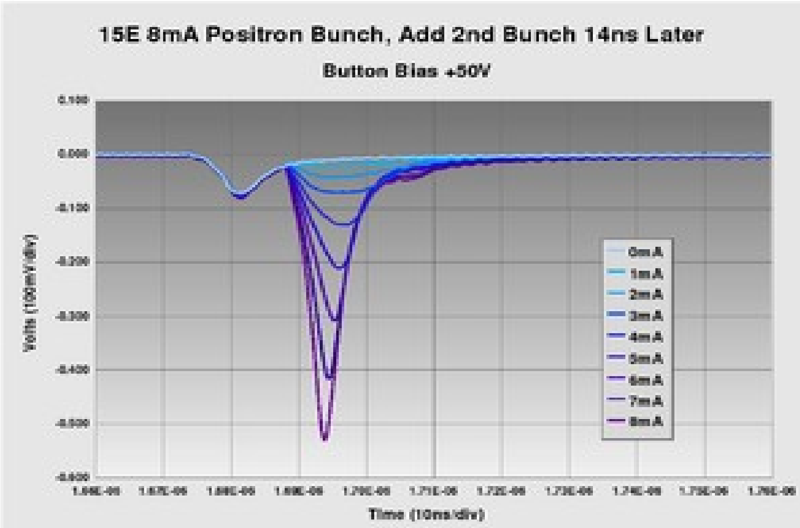
Primary p.e.
E_{peak} = 100 eV
σ_E = 100 eV

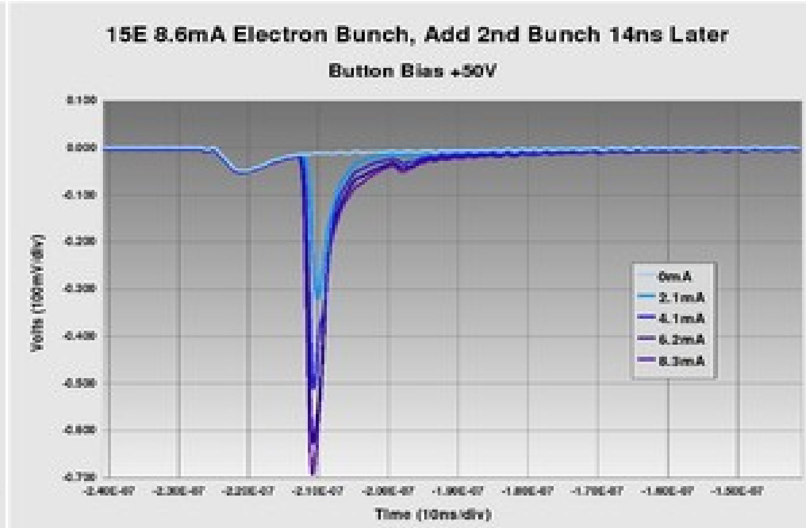


For the electron beam, the earliest energy is 250 eV, rather than 900 eV. This is not high enough to model the signal onset time.

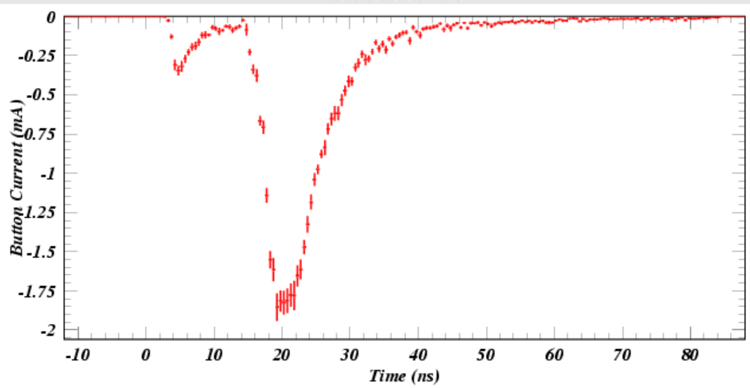
Full Measurement/Simulation Comparison for E_{peak} = 100 eV σ_E = 100 eV

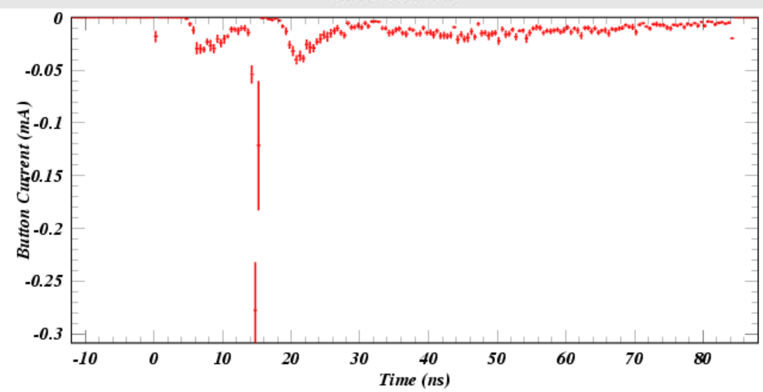
Positron beam | **Electron beam**





Measurements Central Button





ECLOUD Simulation Central Button 2x8 mA

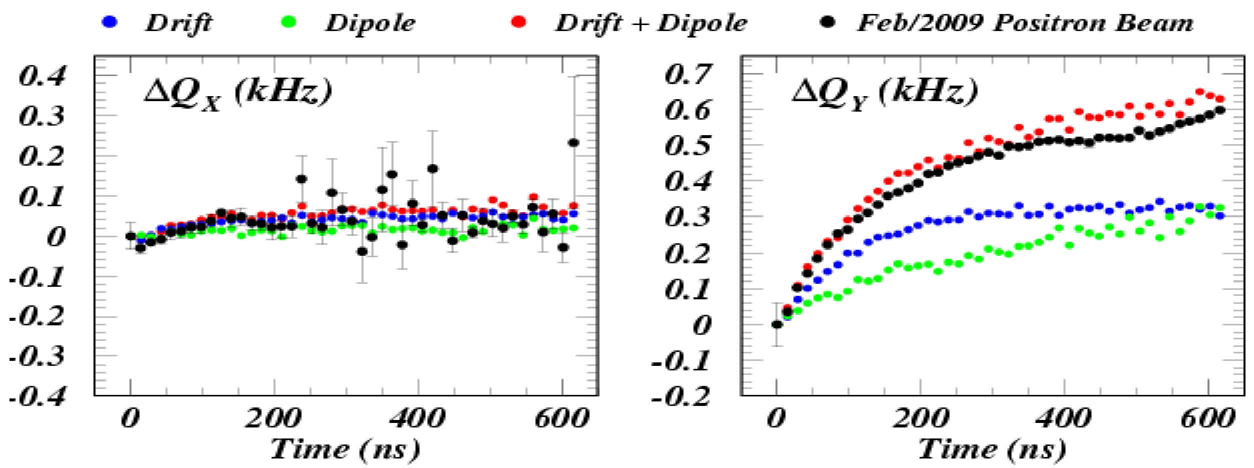
In addition to the work on the photoelectron energy spectrum, the electron beam simulation will require modelling of secondary production in the vacuum chamber holes. Recall that Joe already found this for the low-energy RFA signal. The second-bunch peak for the positrons is also sensitive to the photoelectron energy spectrum!

Premature Preview of the Effect of the Photoelectron Energy Spectrum on the Modelling of Coherent Tune Shifts
Example: 45 e+ bunches, 0.4 mA/bunch, 2.1 GeV

Primary p.e.

$E_{peak} = 5$ eV

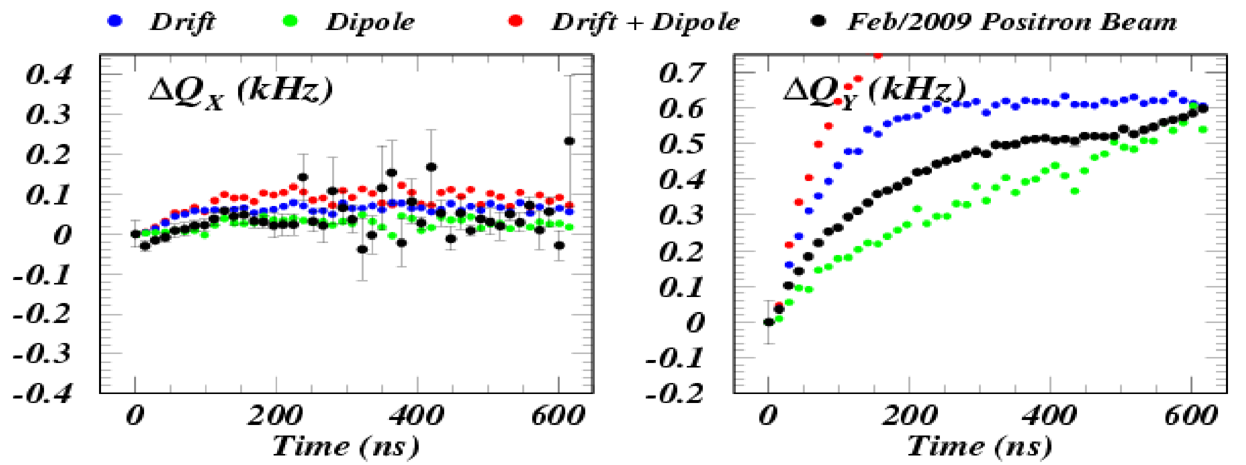
$\sigma_E = 5$ eV



Primary p.e.

$E_{peak} = 100$ eV

$\sigma_E = 100$ eV



The consequences of the photoelectron energy spectrum are exaggerated here, because it is too hard on average.

Next Steps

The shielded button signals represent a treasure trove of information on the photoelectron production kinematics.

A study using monochromatic photoelectrons showed a monotonic relationship between their kinetic energy (e-: 50-3000 eV, e+: 5-3000 eV) and their arrival time (e-:13 – 2 ns, e+: 12 – 2 ns).

An ill-conceived attempt to use this information to deadreckon the correct energy spectrum using the ECLOUD-implemented double Gaussian option failed.

A simple optimization procedure matching the modeled signal arrival distribution to the measurements will determine the photoelectron energy distribution independent of any assumption about its shape. Then we can just look at it to see what function it is!

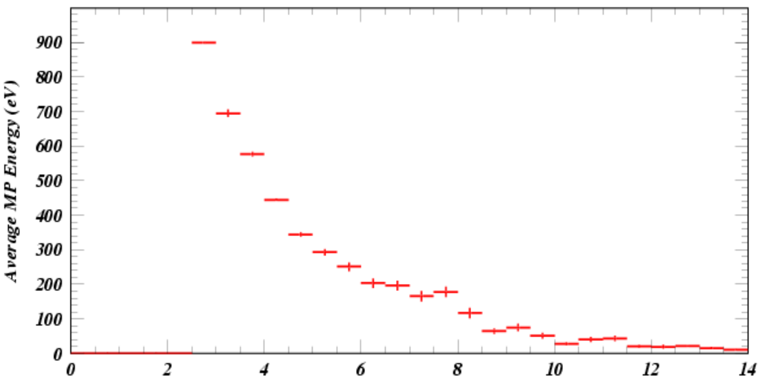
We may wish to include an angular production parameter (such as IPANGHEL) in the optimization.

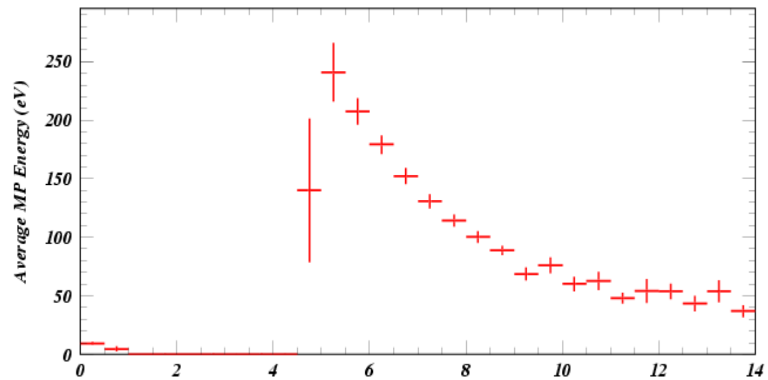
I have now included the production energies and angles in the output file for the macroparticles which produce the shielded button signal. And John has provided the data for the measurements. So we have everything we need.

This is an EASY and FUN job with a tremendous payoff. Interested?

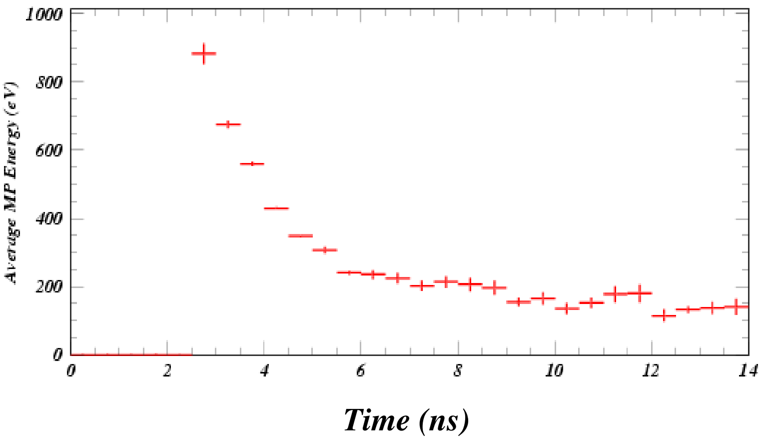
Contribution to the Arrival Energy Spectrum from the Space Charge Force of the Cloud

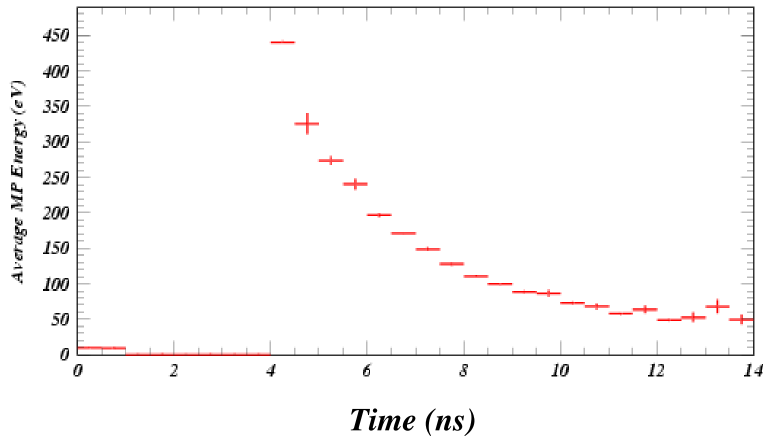
Positron beam | ***Electron beam***





Space charge force turned on

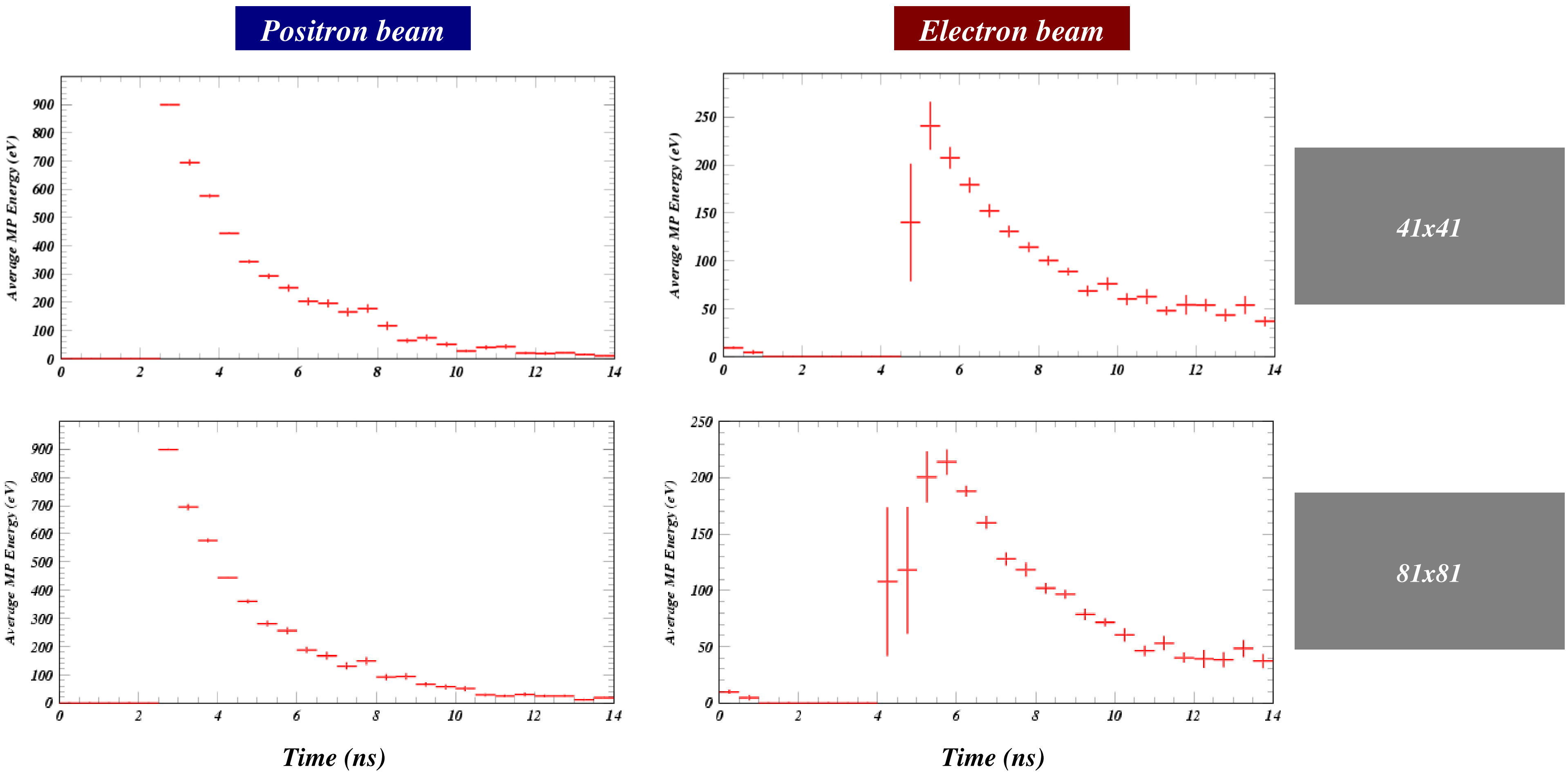




Space charge force turned off

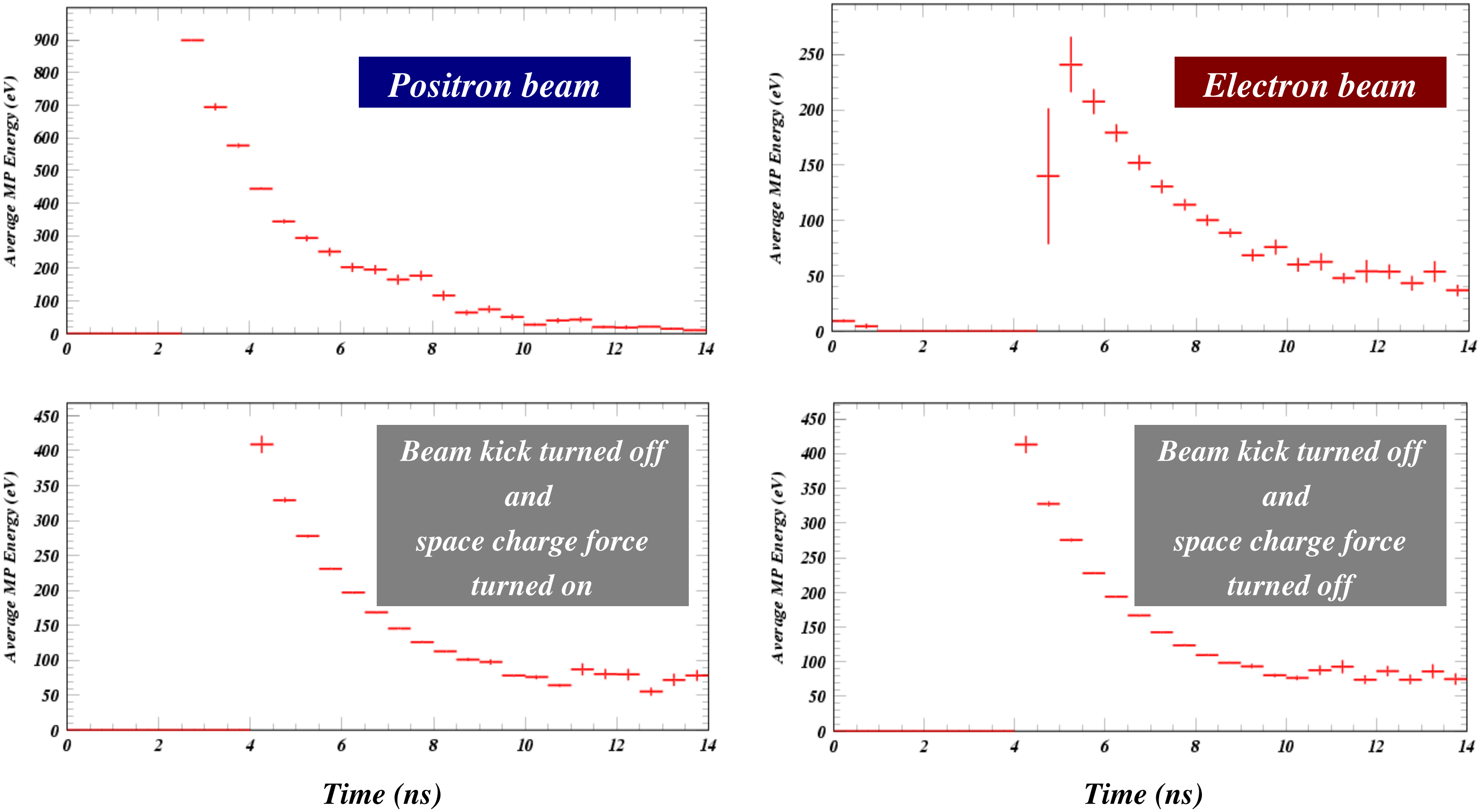
On slides 4 and 5 we showed that the maximum arrival energies for the signal macroparticles were 900 eV for the positron beam and 250 eV for the electron beam. Here we see that the space charge force of the cloud suppresses a low energy component in the case of the positron beam. For the electron beam simulation, the space charge force suppresses the high-energy signal, reducing the maximum energy from 400 eV to 250 eV and delaying the onset of the signal by about a nanosecond.

Is the 41x41 PIC grid fine enough ?



Since the space charge force is important in determining the arrival energies and times of the signal macroparticles, it is prudent check that the space charge grid is fine enough. Here we show that halving the distance between grid nodes does not substantially alter our conclusions.

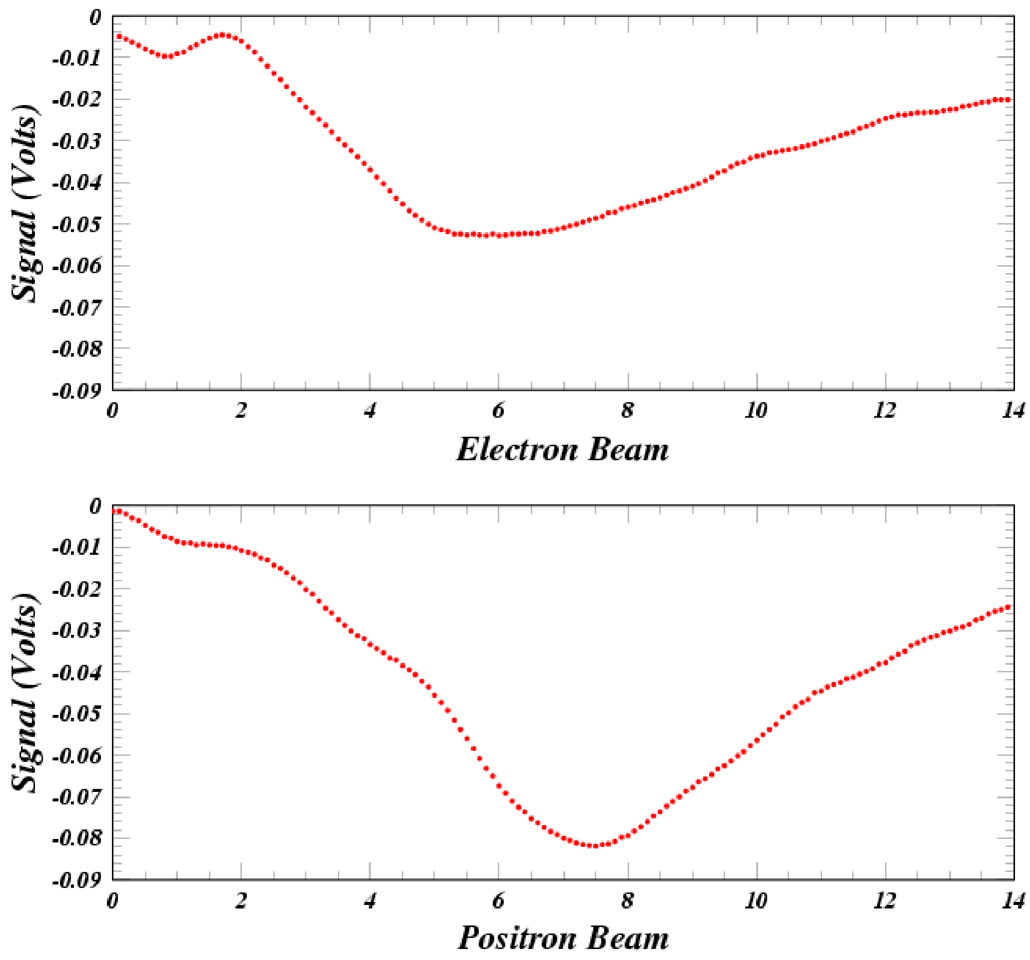
Contribution to the Arrival Energy Spectrum from the Beam Kick



Space charge force turned on

In the case of the positron beam, the beam kick raises the highest arrival energy from 400 eV (no beam kick) to 900 eV. The suppression of the low-energy tail for positrons and of the high-energy component for the electron beam arise from the combined effect of the beam kick and the space charge force of the cloud.

Shielded Button Measurements for 8 mA bunch



This is the data for the scope traces shown earlier.
The high quality of the measurement can be expected to provide accurate information on the photoelectron energy spectrum.