Final CLASSE REU Presentation, Summer 2011

- Ryan Badman
- James Crittenden

Comparing 2.1 and 5.3 GeV Shielded-Pickup Witness Bunch Data to ECLOUD Simulation Results

Introduction to the Electron Cloud

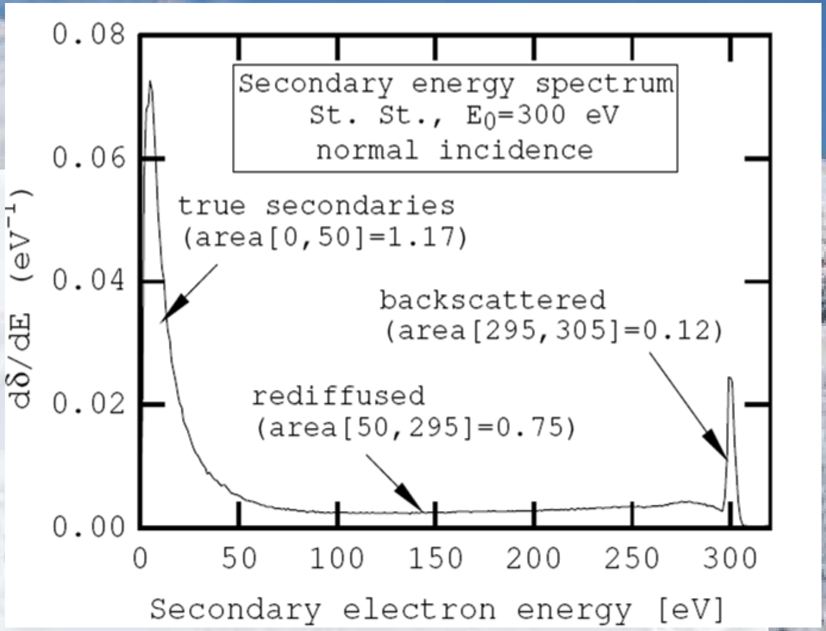
- Electron clouds are an important phenomenon to study in circular particle accelerators such as the LHC, the Cornell synchrotron, and the damping ring for the ILC.
- Low energy background electrons are normally present in high energy accelerators
- The generation and amplification of the electron cloud is caused by ionization of residual gas in the vacuum chamber and irradiation of the vacuum chamber by synchrotron radiation.

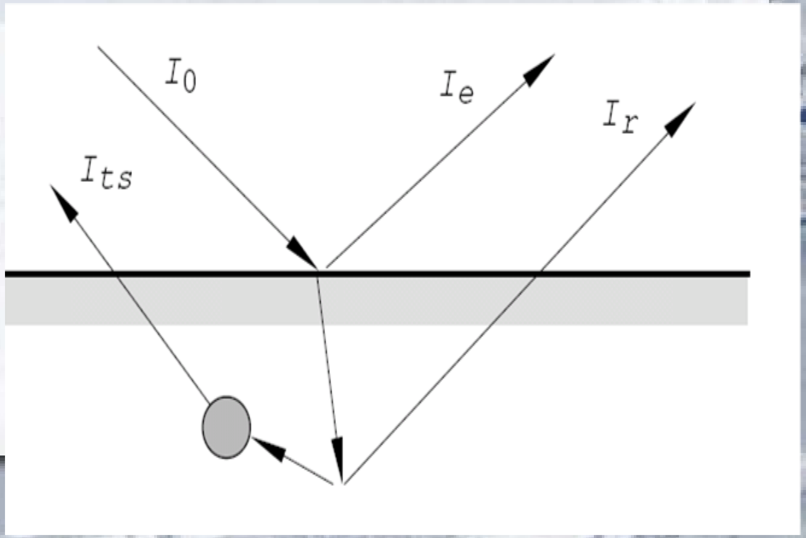
Effects of e- Cloud on the Beam

- These clouds can have many detrimental effects on the beam performance, including beam degradation and tune shift.
- Proton and positron beams are more vulnerable to cloud effects than electron beams because of Coulomb attraction due to opposite charge.
- The cloud can be mitigated by changing vacuum chamber surface roughness such as a sawtooth pattern on the chamber wall, coating the chamber with materials such as titanium nitride as used in this study, or by applying a solenoidal field

Three Types of Secondary Electrons

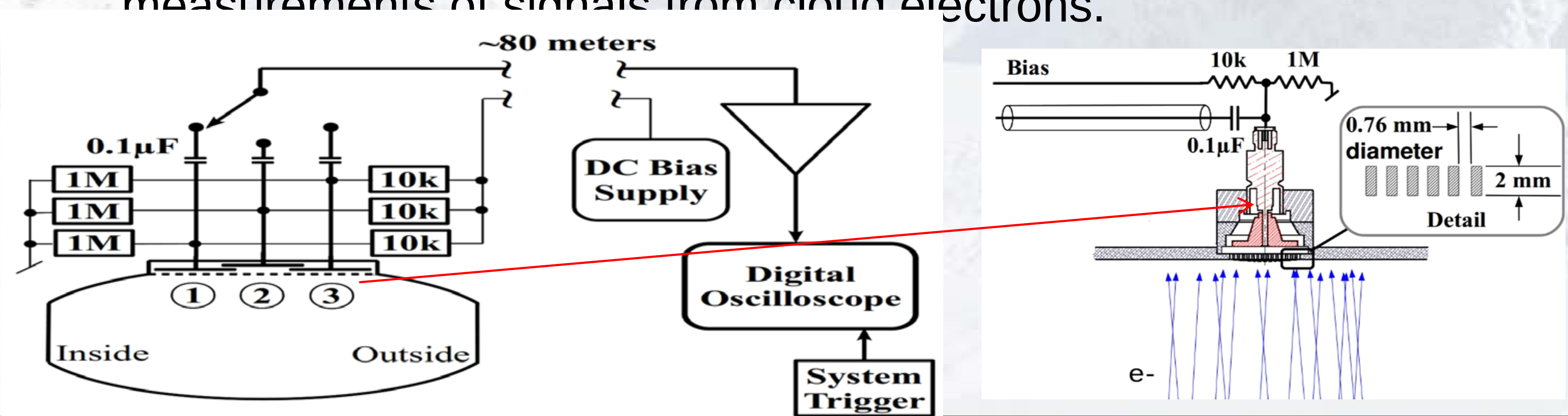
- When electrons collide with the vacuum chamber wall, they either:
- 1) scatter back elastically (the elastic secondaries)
- 2) interact with atoms inside the wall material and are reflected back out (the rediffused secondaries)
- 3)interact through complex processes with the chamber wall (the true secondary electrons)





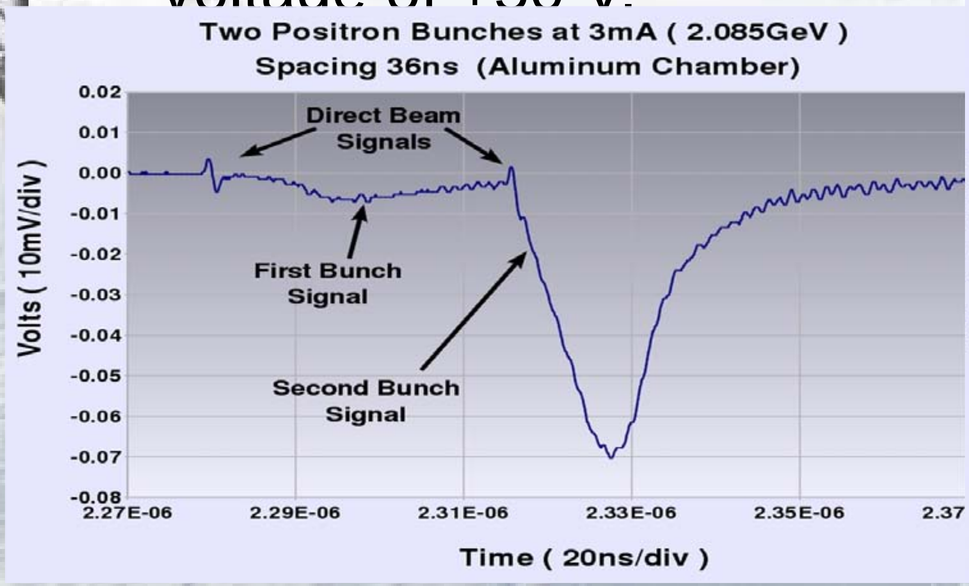
Measurements

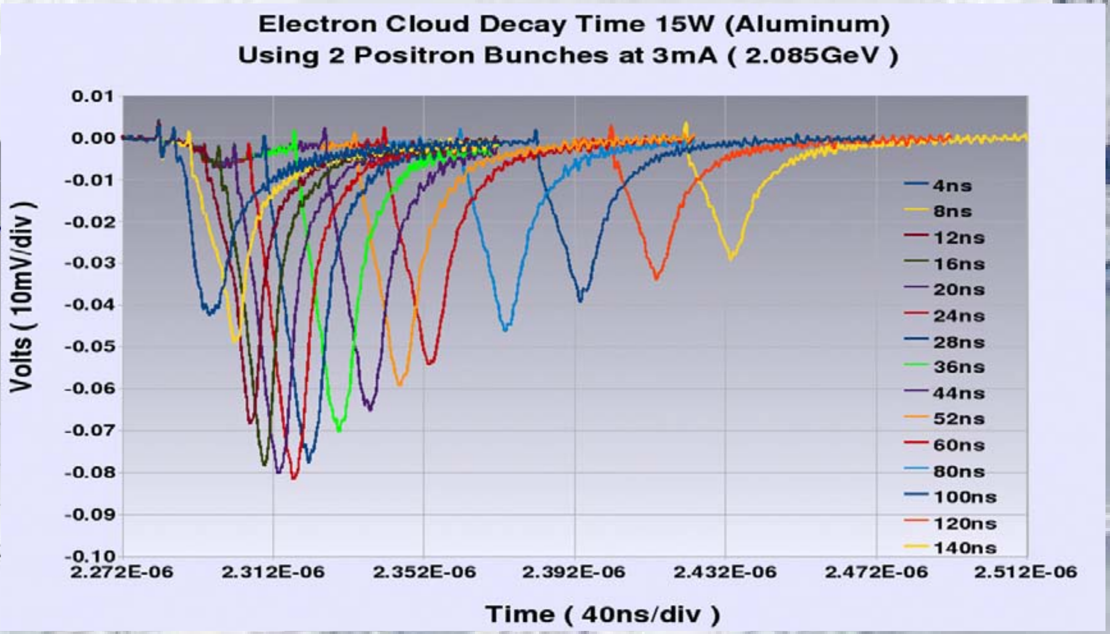
- This study focuses on a 1.1 m custom vacuum chamber coated in TiN in the west of the storage ring.
- Cloud development in the custom chambers is studied using time-integrating retarding field analyzers (RFA), and shielded-pickup detectors. The latter have given a wide range of time-resolved measurements of signals from cloud electrons.



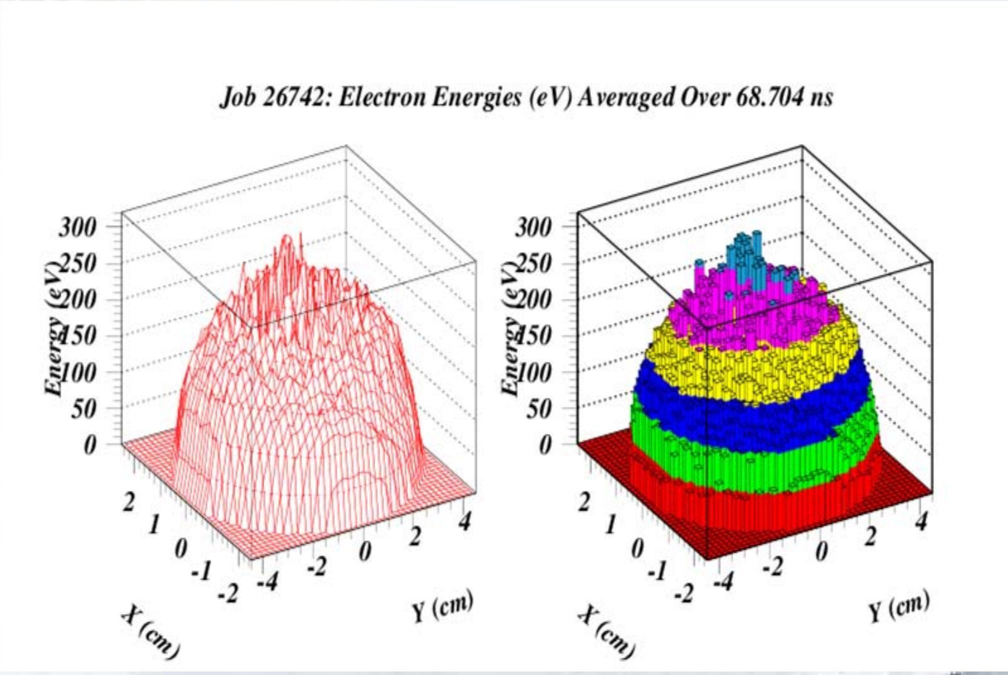
Witness Bunches

- Witness bunch scans use one leading bunch, and then one witness bunch at various delay times to study cloud decay over a period of time.
- This study focused on electron and positron beams of 2.1 and 5.3 GeV beam energy, a bunch spacing of 14 ns, and a bias voltage of +50 V.



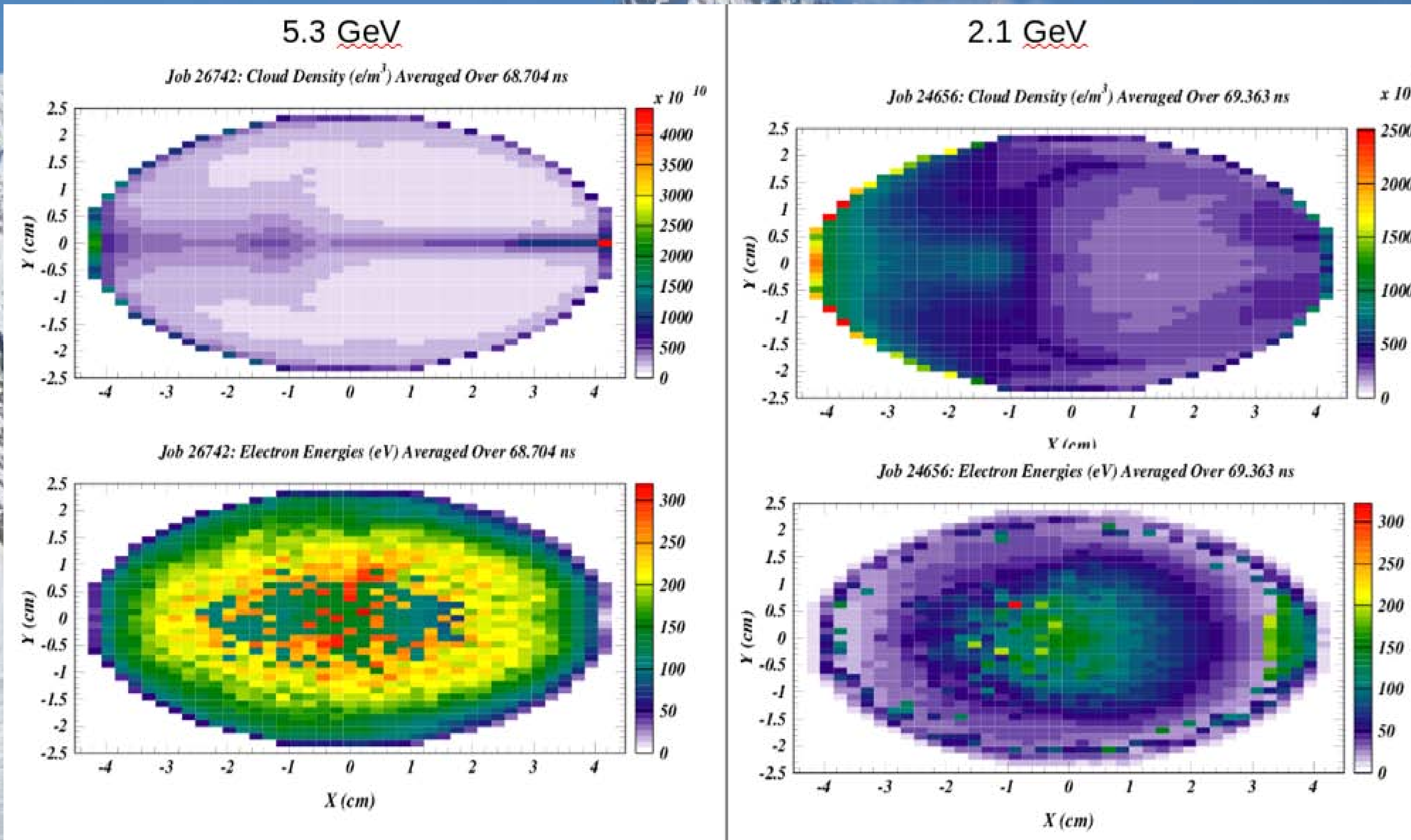


ECLOUD Simulations



- The program ECLOUD was used in this study to simulate electron cloud build up over the course of a bunch train, and can be set to either positron or electron bunches.
  - ECLOUD generates photoelectrons, performs the time sliced kinematics for cloud electrons, including beam kicks, space-charge forces, and magnetic fields if present. It also creates a detailed model of secondary electron production processes on the vacuum chamber wall.

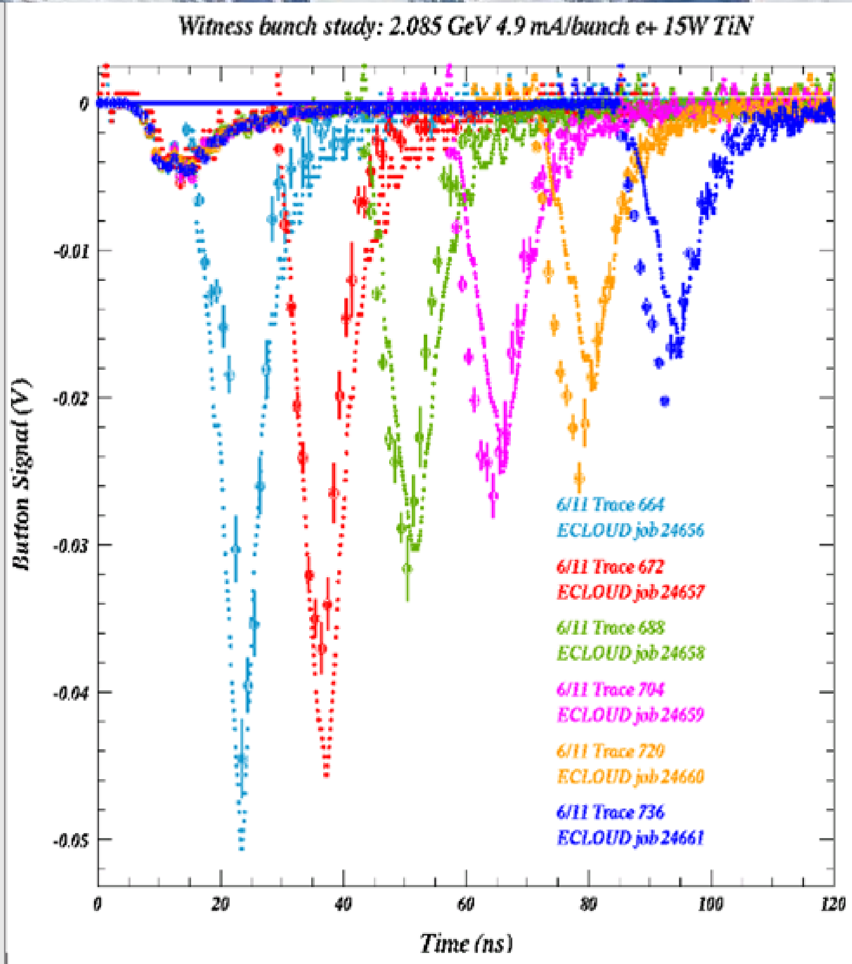
Example of ECLOUD Diagnostic Plots

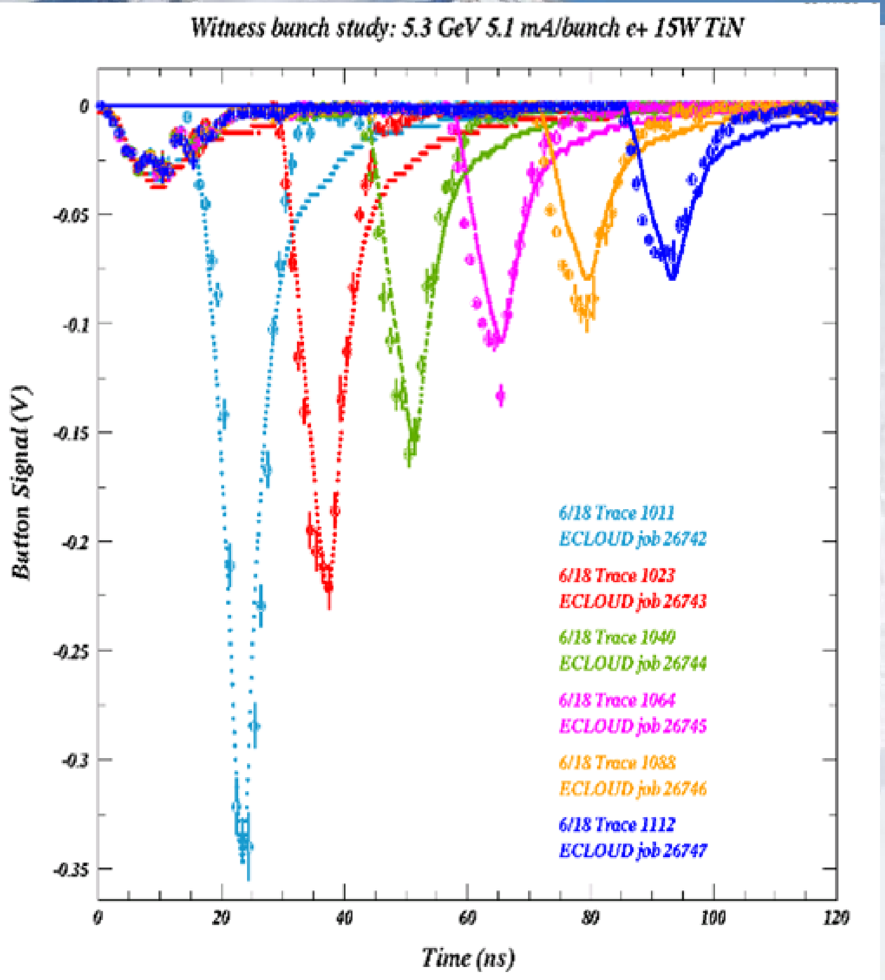


Results

- The main end results of this summer were:
- 1) Successfully matching simulations to data with the 2.1 GeV and 5.3 GeV 5 mA/bunch witness scans.
- 2) Optimizing the modeled secondary electron energy distribution using the 2.1 GeV and 5.3 GeV data.

Best Simulation Matches to 2.1 and 5.3 GeV





Changes in Secondary Energy Distribution

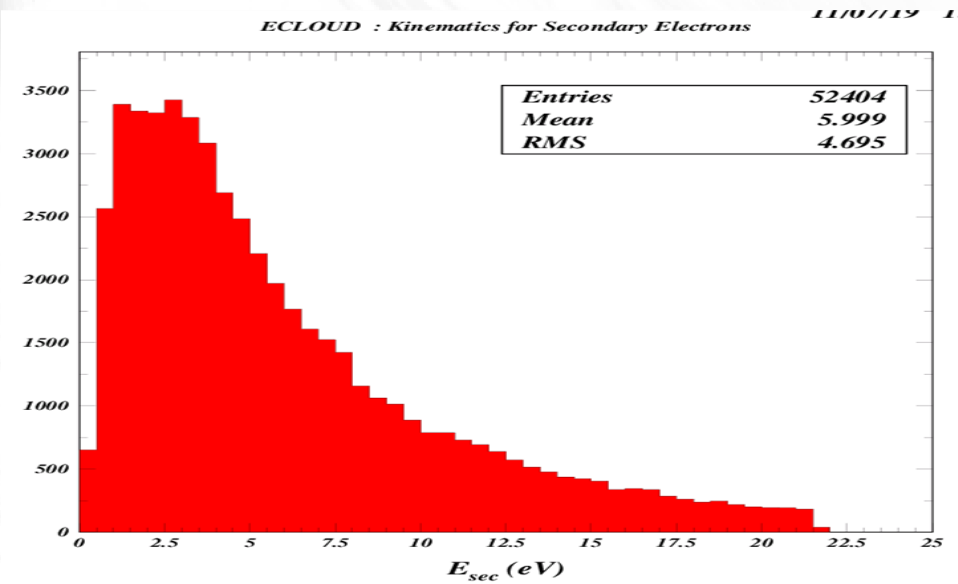
ECLOUD simulations prior to this work have used the distributions introduced by Noel Hilleret based on Phil.J.Res. 50 (1996), 375:

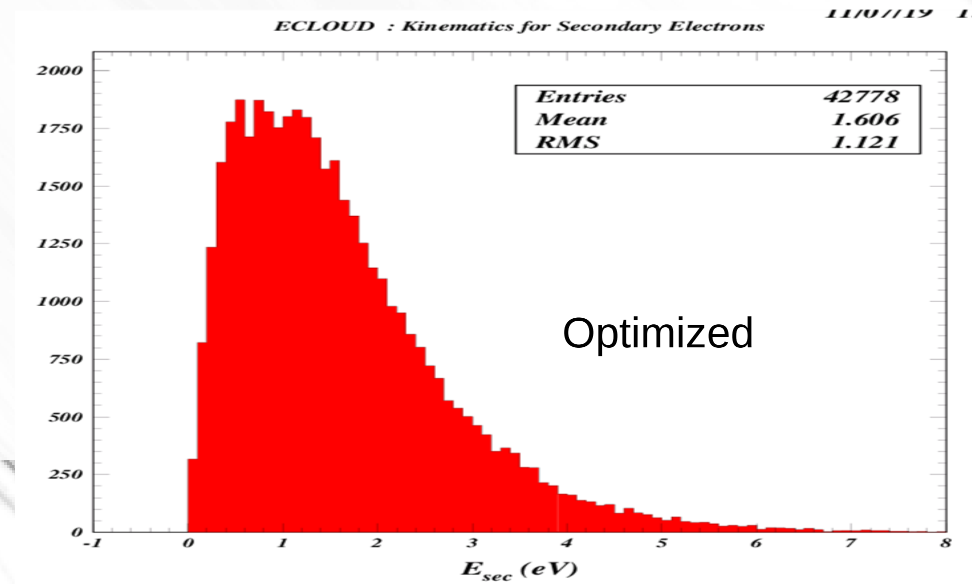
$$f(E_{sec}) \sim \exp(-\ln(E_{sec}/SEMAX)^2/2), \text{ with SEMAX=1.8 eV}$$

Use of a distribution attributed to **Miguel Furman** improved the comparison to data:

$$f(E_{sec}) \sim E_{sec} \exp (-E_{sec}/SEMAX), \text{ with SEMAX=0.8 eV}$$

As the next two slides will show, Noel's distribution has too many high energy e−, giving a broad late signal after the leading bunch

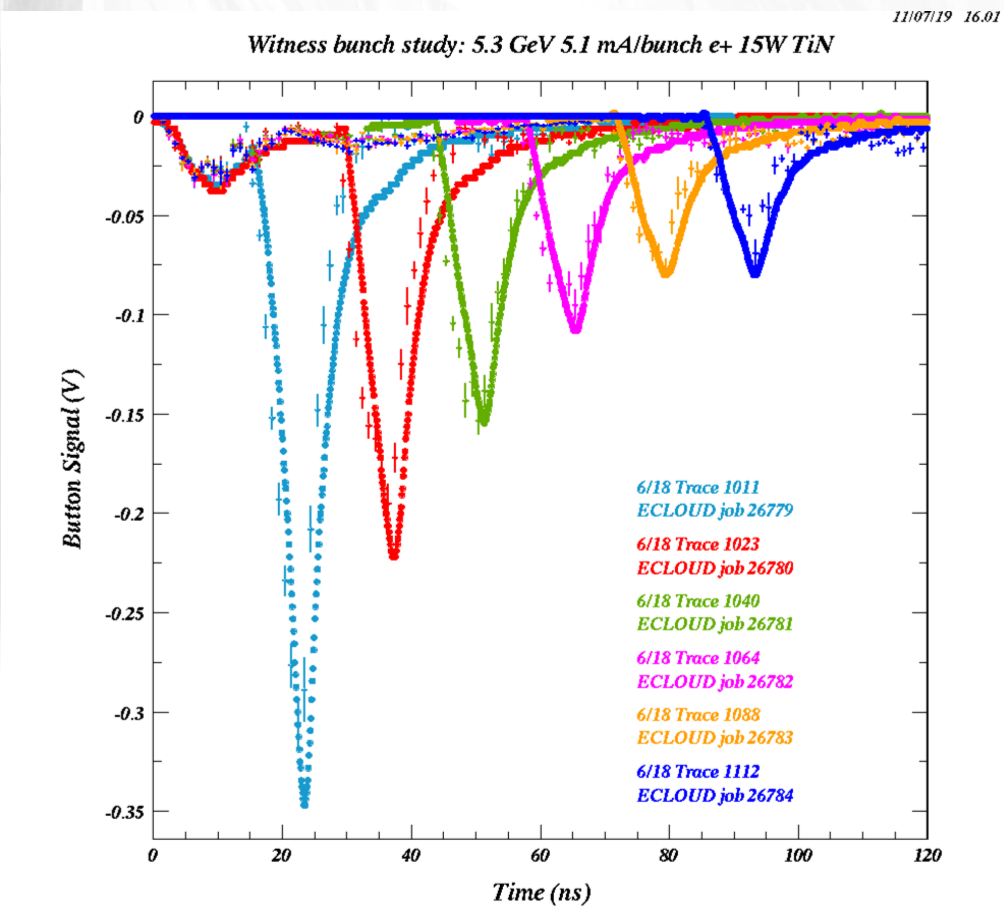




Original vs. Optimized

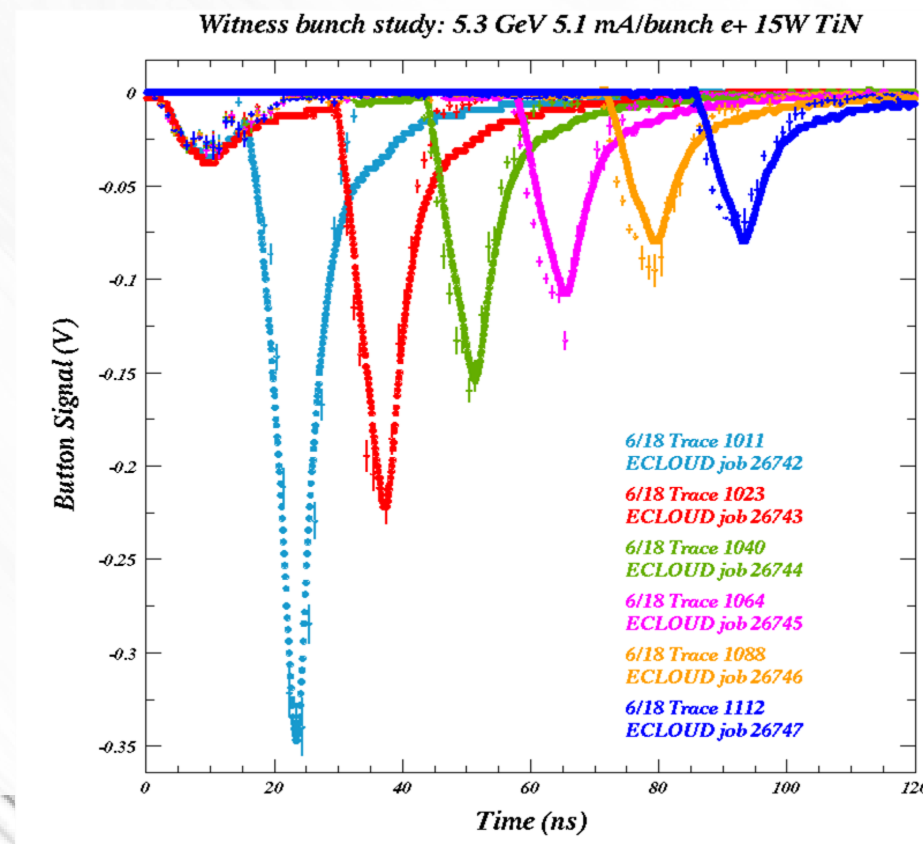
$f(E_{sec}) \sim \exp(-\ln(E_{sec}/SEMAX)^2/2)$

SEMAX=1.8 eV

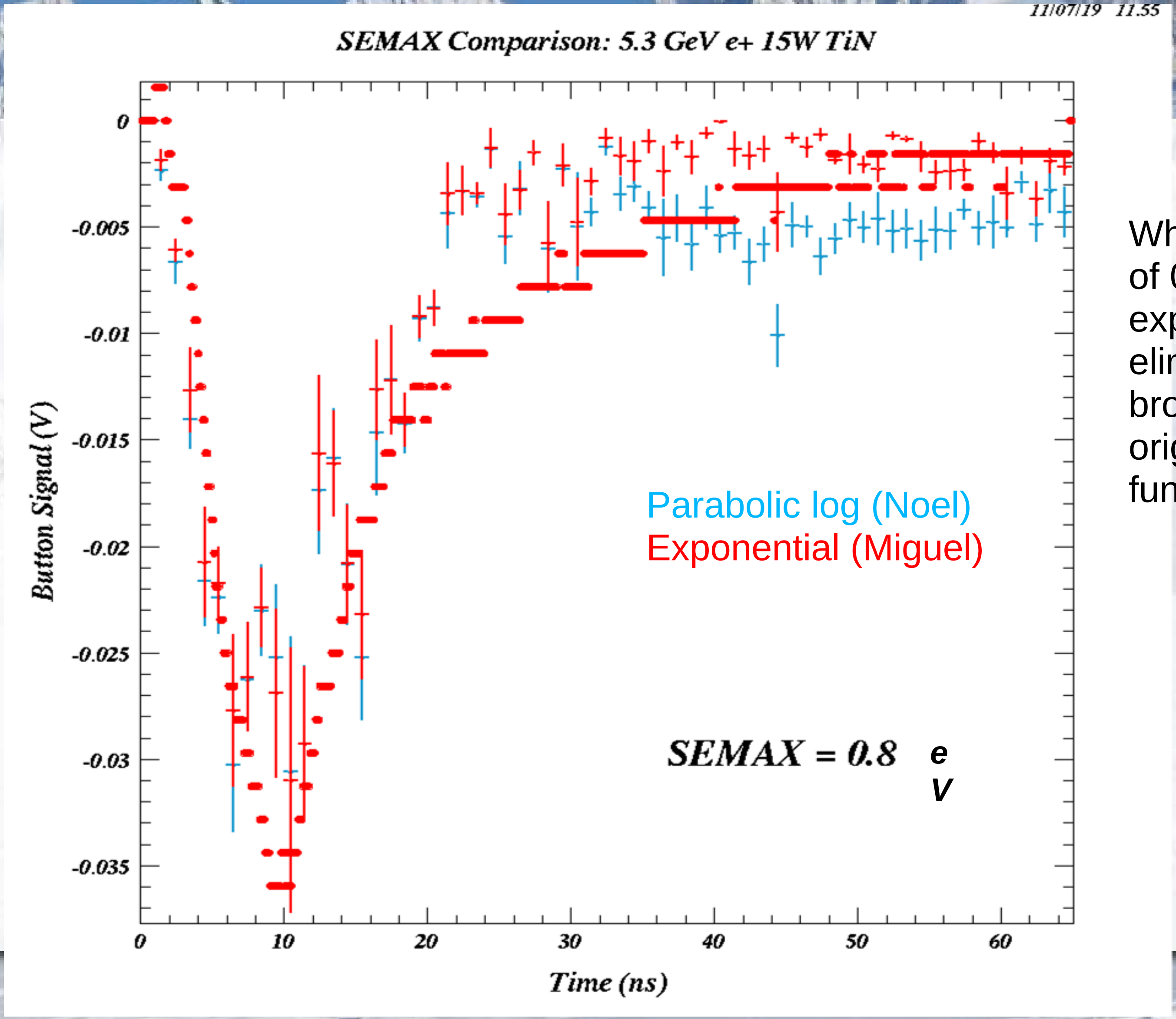


$f(E_{sec}) \sim E_{sec} \exp(-E_{sec}/SEMAX)$

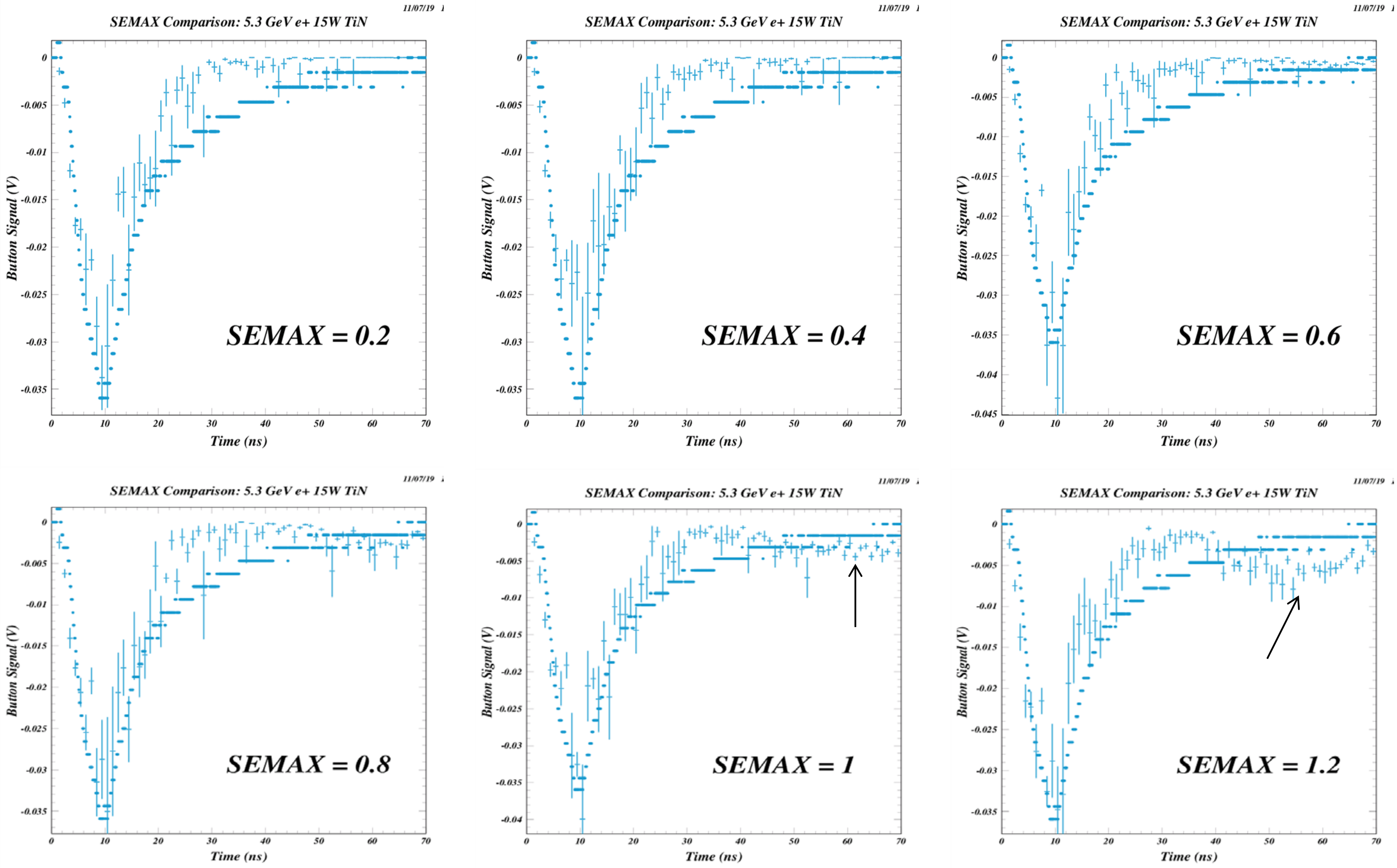
SEMAX=0.8 eV



Why Miguel's Distribution is Used



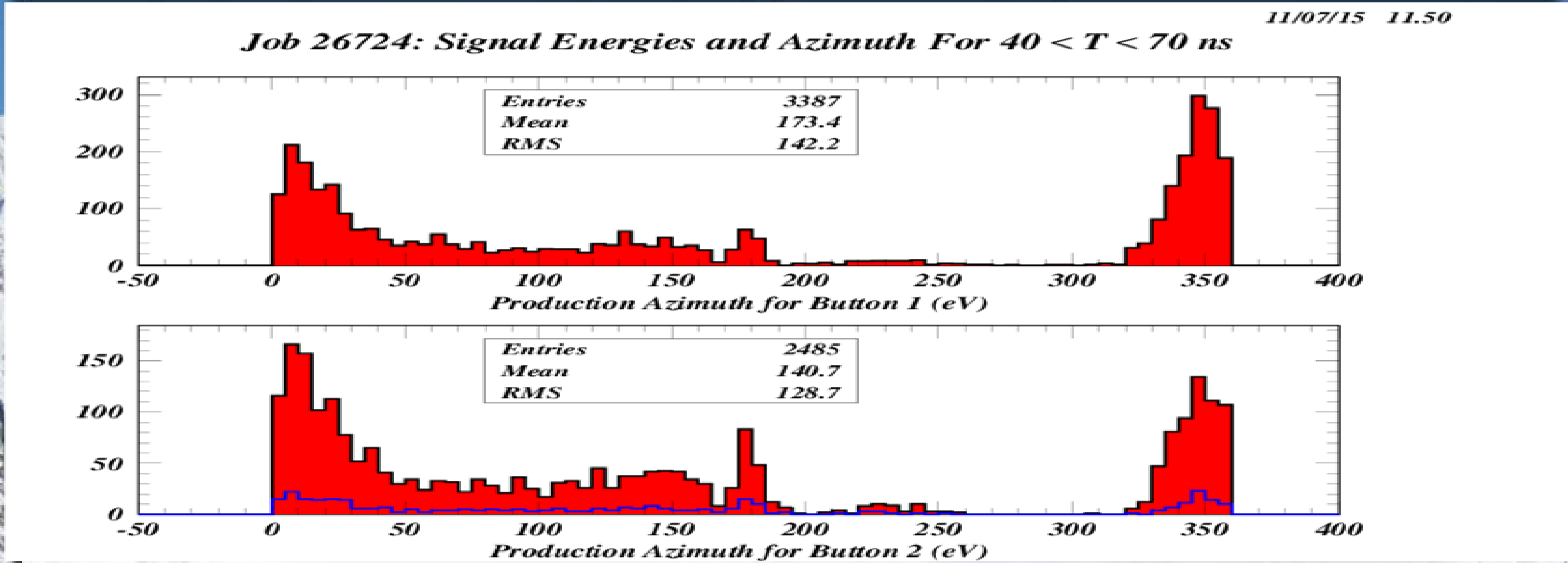
When the same optimal value of 0.8 eV is used for both, the exponential functional form eliminates the nonphysical late broad peak observed with the original ECLOUD parabolic log function.



Sensitivity to SEMAX Parameter (Miguel's function)

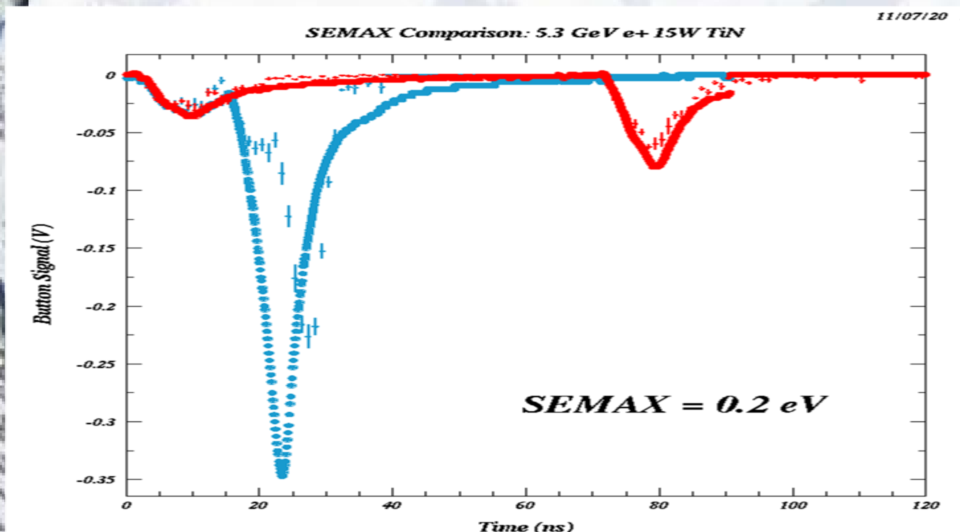
(Note the late simulation peak at SEMAX>0.8 eV that is not present in the data)

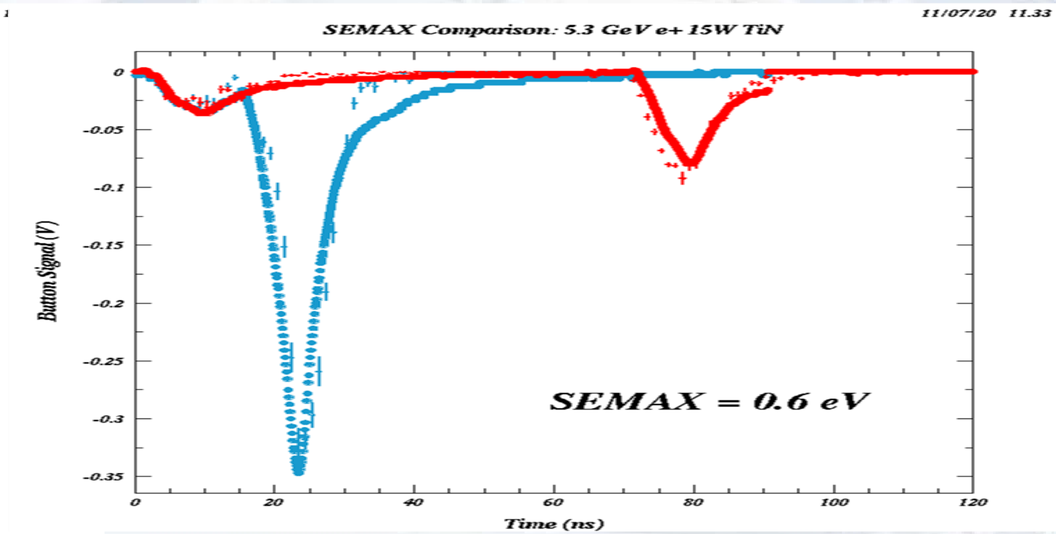
Where does late peak come from?

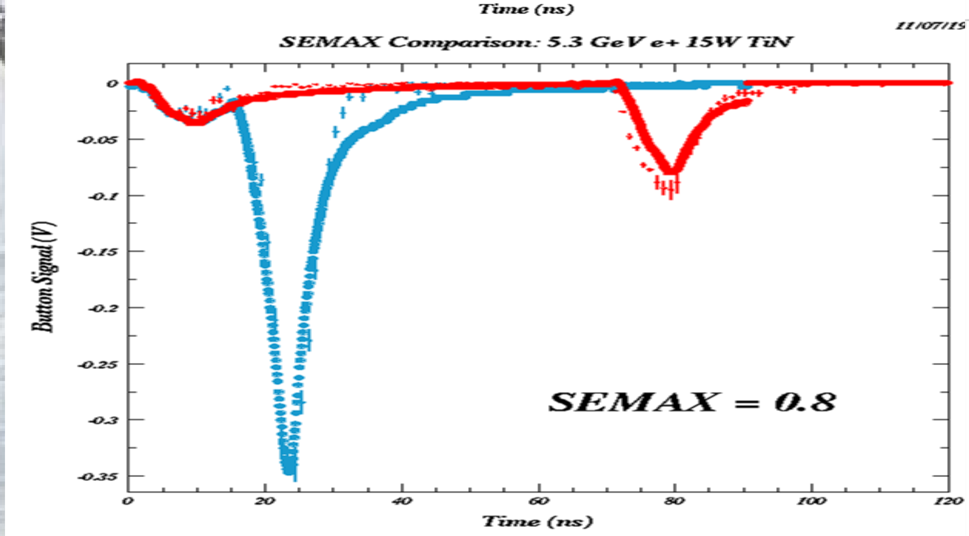


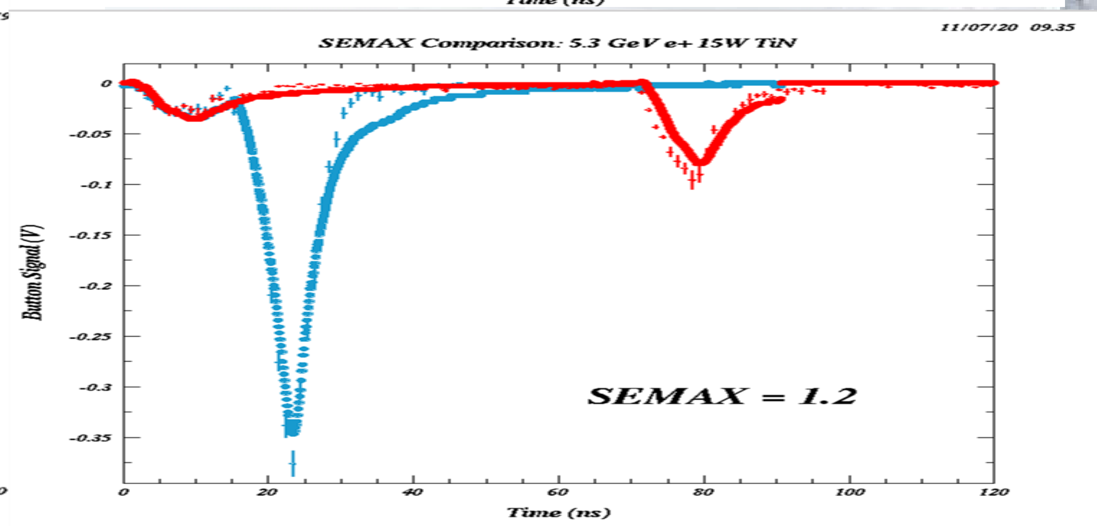
The azimuthal angle is defined to be 0 degrees at the outside wall of the beam pipe (the primary point of synchrotron radiation incidence) and increases counter clockwise around the beam pipe.
the upper left plot shows most electrons that cause the signal are originally produced at the top of the beam pipe (0 to 180 degrees) from direct photons.

Lower bound on SEMAX obtained from 14-ns witness bunch signal shape









Conclusions
(after ~ 1 terabyte of simulation data...)

1) 5.3 GeV and 2.1 GeV simulations have made great progress in describing the SPU witness bunch data.

2) The best SEMAX value is around 0.8 eV. Above 1.0 eV an unphysical, late, broad peak appears in the simulation. Below 0.8 eV, the 14-ns witness bunch signal shape simulation is poor.

3) The sensitivity to SEMAX appears to be about 0.2 eV!

4) Miguel's exponential distribution gives a better match than the Phil.J.Res. parabolic log function.