Modeling Shielded Pickup Measurements for Aluminum Test Chambers with ECLOUD

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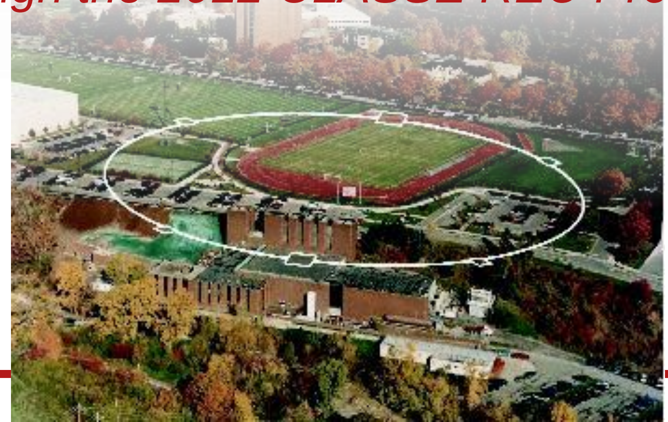
for the CESRTA Collaboration

through the 2012 CLASSE REU Program

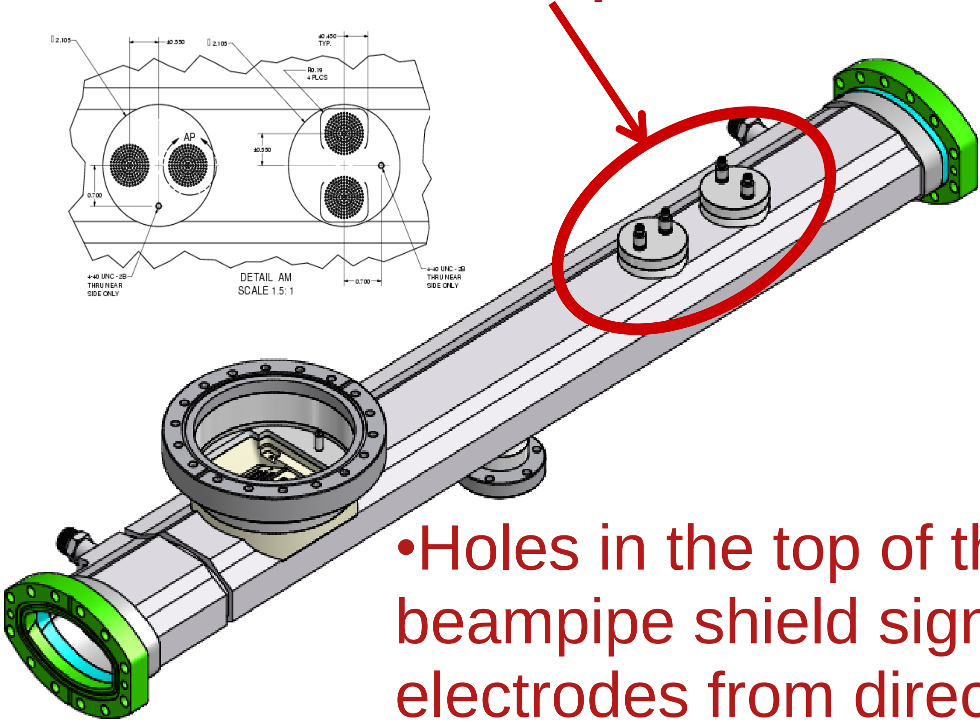


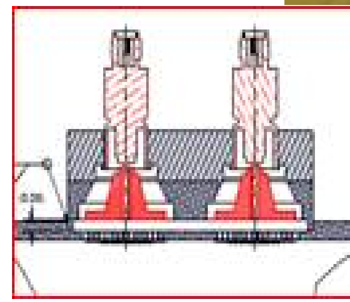
Electron Clouds

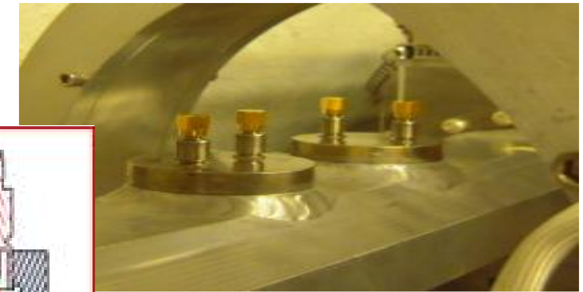
- Synchrotron radiation hits the wall of the beam pipe
- Photoelectric effect produces primary photoelectrons
- Primary electrons collide with the wall
  - Produce secondary electrons
  - Energy and angle of incident electron determine type of secondary process that occurs
- Cloud can disrupt the beam

SPU Detectors

•Shielded Pickup Detectors

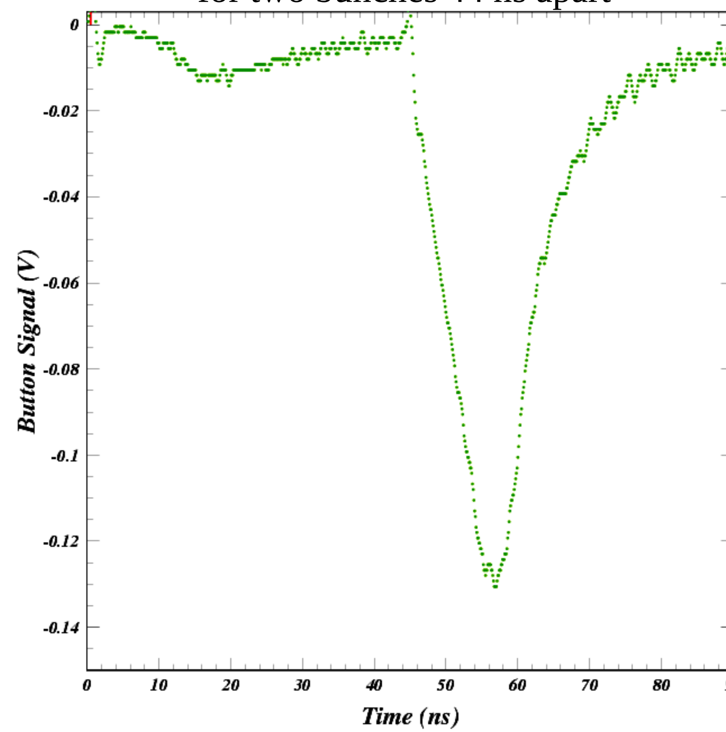






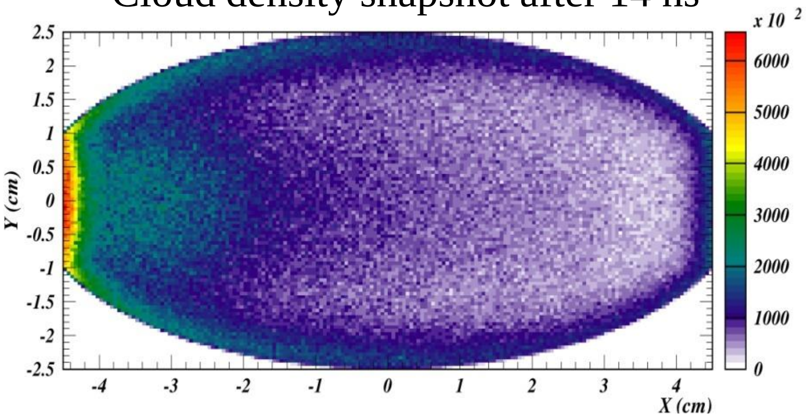
- Holes in the top of the beampipe shield signal electrodes from direct beam-induced signal
- Electrons enter through holes
- Hit the detectors ("buttons")
- Signal recorded by an 8-bit digitizing oscilloscope

Shielded pickup scope trace for two bunches 44 ns apart

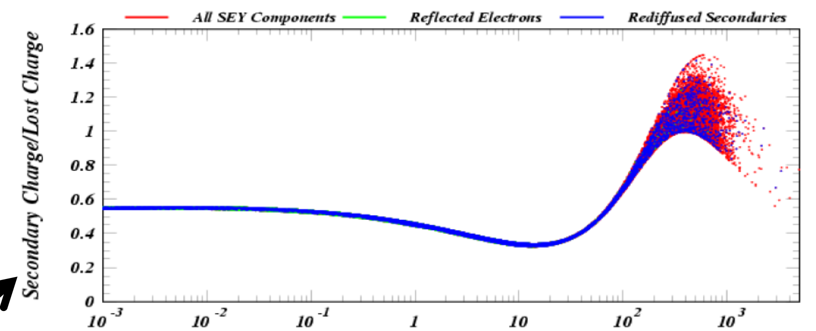


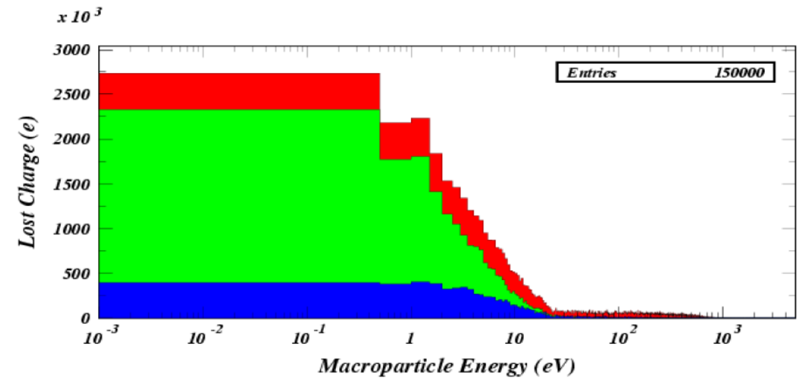
- CERN, 1990's
- Still under development here at Cornell
- Parameters for controlling:
  - Photoelectron generation
  - Cloud dynamics
    (magnetic fields, beam kicks, space charge forces)
  - Secondary yield models
- Added functions for simulating SPU measurements

Cloud density snapshot after 14 ns



Energy dependence of secondary yield Q_{out}/Q_{in}

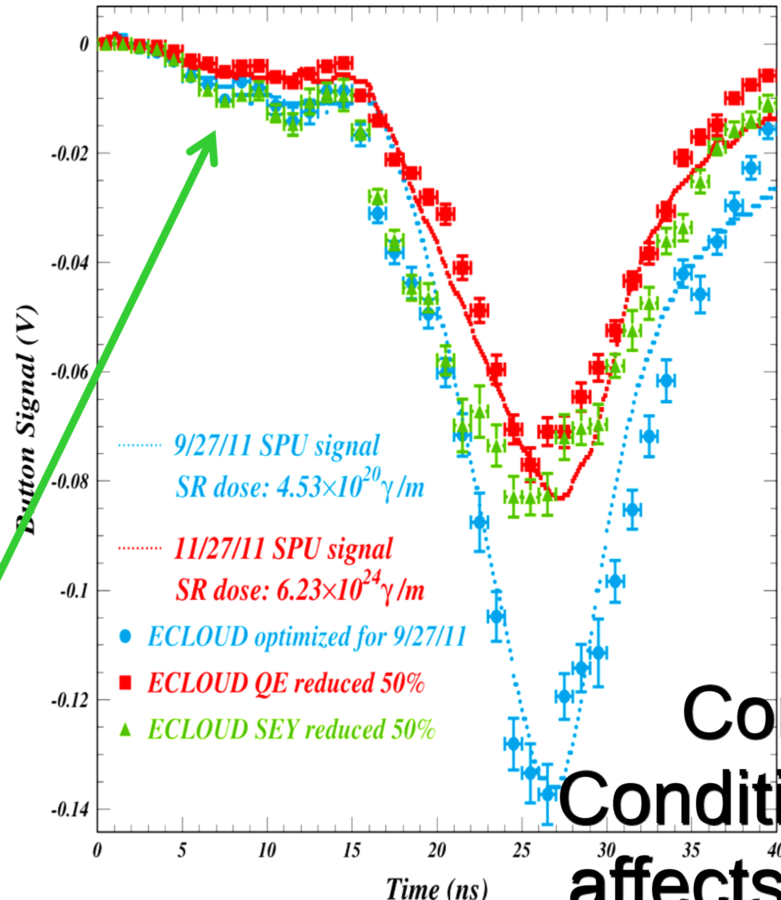




Conditioning Amorphous Carbon

- A test chamber coated with a-C:
  - SPU signal is reduced by exposure to SR

How does the initial model need to change to describe the reduction in signal between September and November?



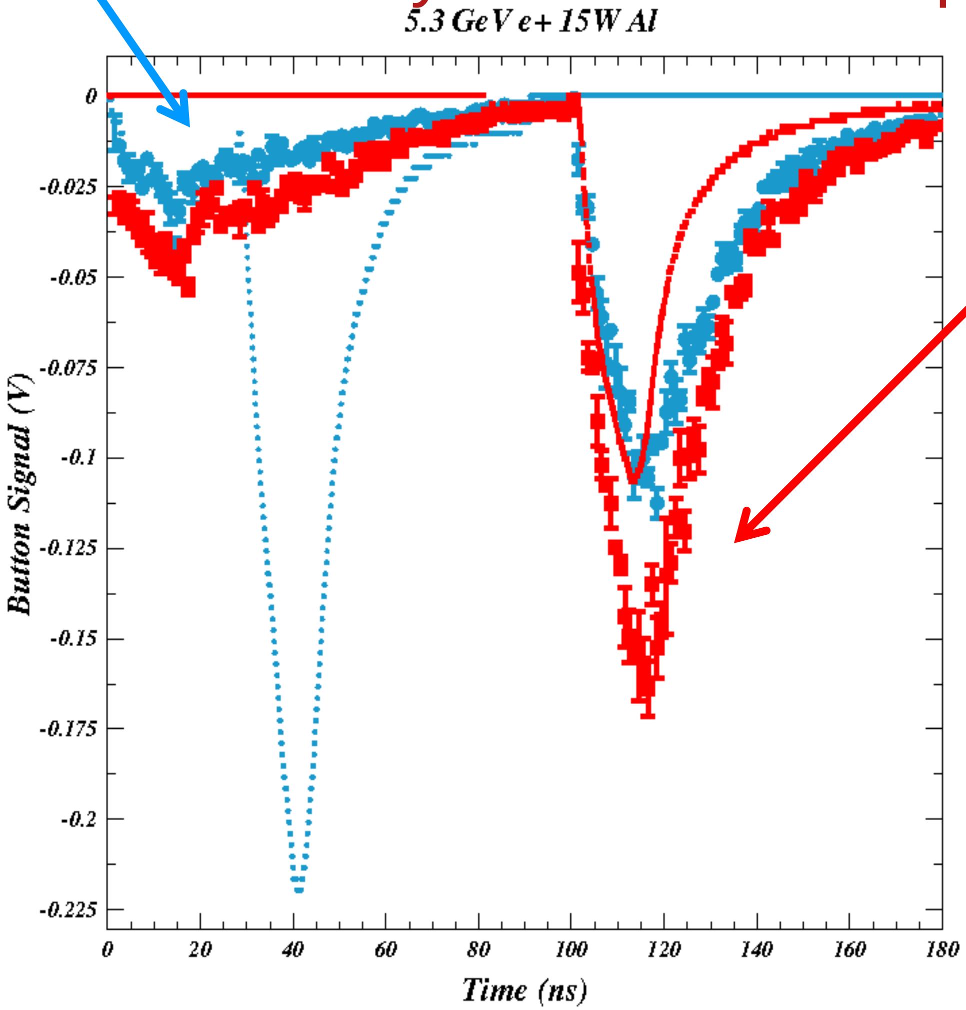
Reducing the QE fits!

Reducing the SEY isn't working here

Conclusion: Conditioning of a-C affects the QE, not the SEY

Old Model for Aluminum SPU Data

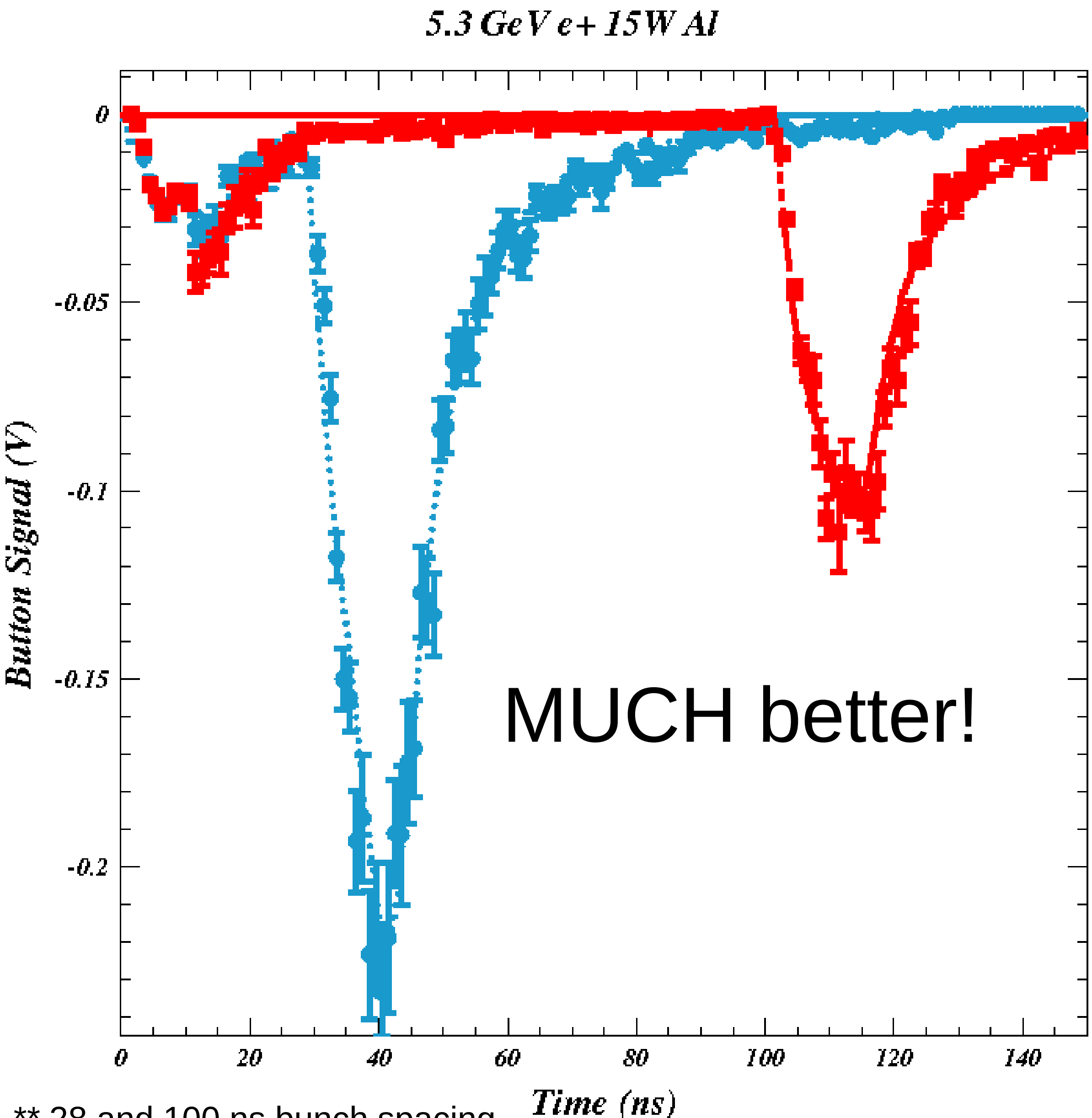
- Optimized model in the 2011 version of ECLOUD gave a reasonably accurate description of the measured signals



- Running the same input parameters
  - New photon modeling results from SYNRAD3D
  - More realistic chamber profile
- Problems!
  - Modeled signal too big!
  - Updated SPU response functions and primary electron models aren't turned on
  - Signal increases much too early

** 2 positron bunches, 100 ns bunch spacing

The New Model



** 28 and 100 ns bunch spacing

How did we get there?

- New photoelectron energy distribution
- Adjusted secondary yield parameters
- Adjusted quantum efficiencies
- Shifted horizontal beam position

New Photoelectron Energy Distribution

- Shape of the first pulse mainly depends upon the kinetic energy distribution for photoelectrons produced on the bottom of the beampipe by reflected photons
  - Higher KE = faster = earlier arrival time
- Sum of two power laws:

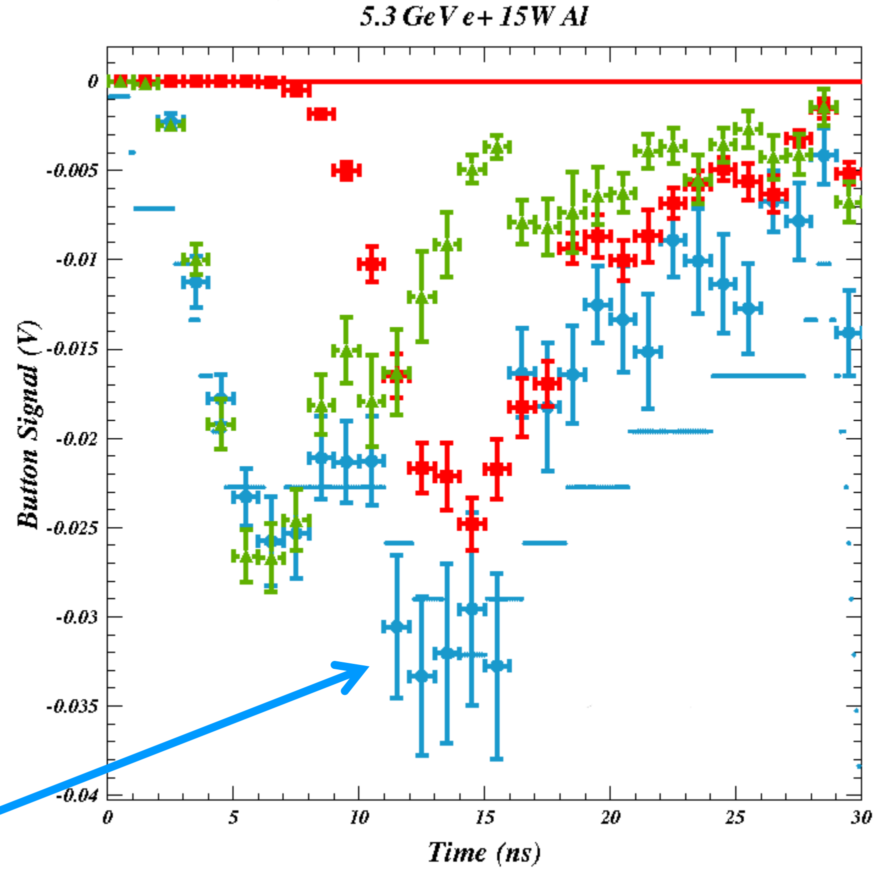
$$f(E) = \frac{E^{P_1}}{\left(1+ E/E_0\right)^{P_2}}$$

$$E_0 = E_{peak}\frac{(P_2 - P_1)}{P_1}$$

25% Low Energy:
E_{peak}=8 eV, P_1=2, P_2=9

75% High Energy:
E_{peak}=100 eV, P_1=3, P_2=6.3

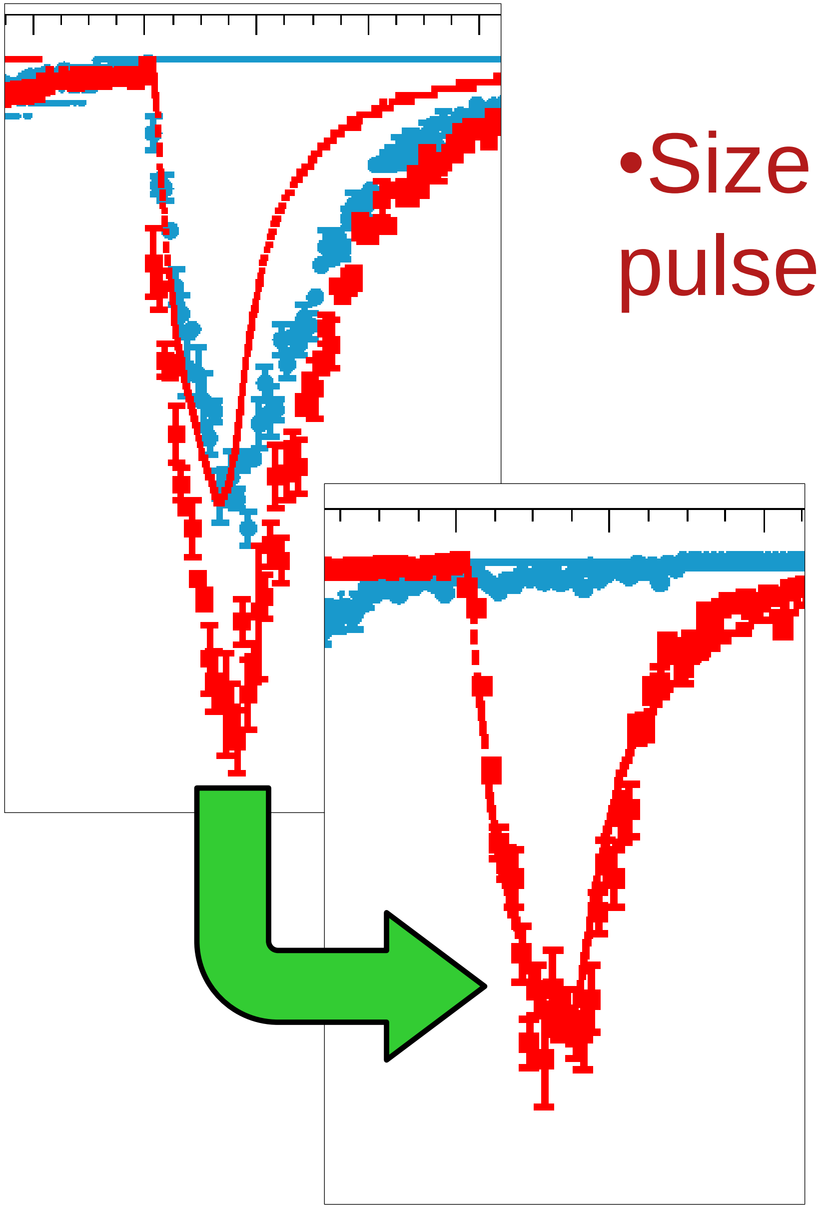
Sum of the Two



**Displaying first pulse only

- The size is dependent upon the quantum efficiency (# of e$^-$ per photon)

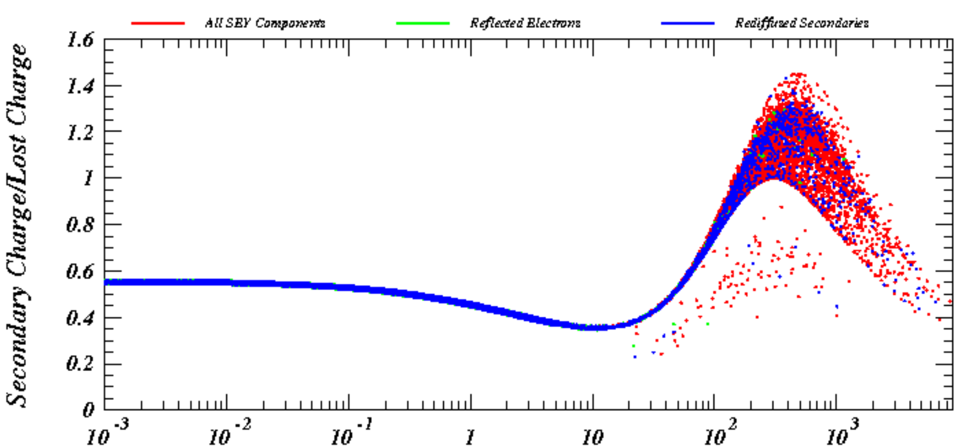
Fitting the Second Pulse

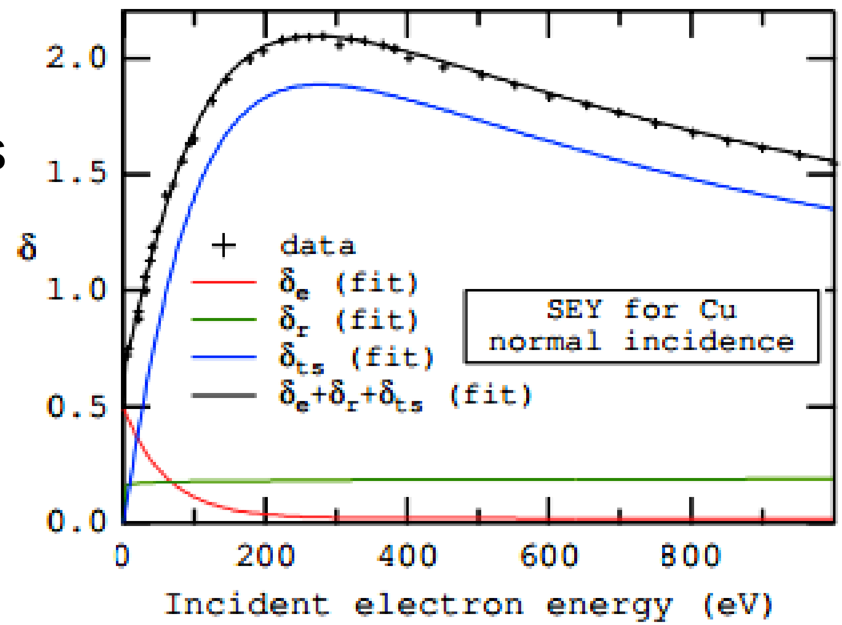


- Size and shape of the second pulse is determined by:
  - –Secondary electron yield
  - –Quantum efficiency
  - –Models of elastic reflection
  - –Energy distribution of secondary electrons

Secondary Yield Parameters

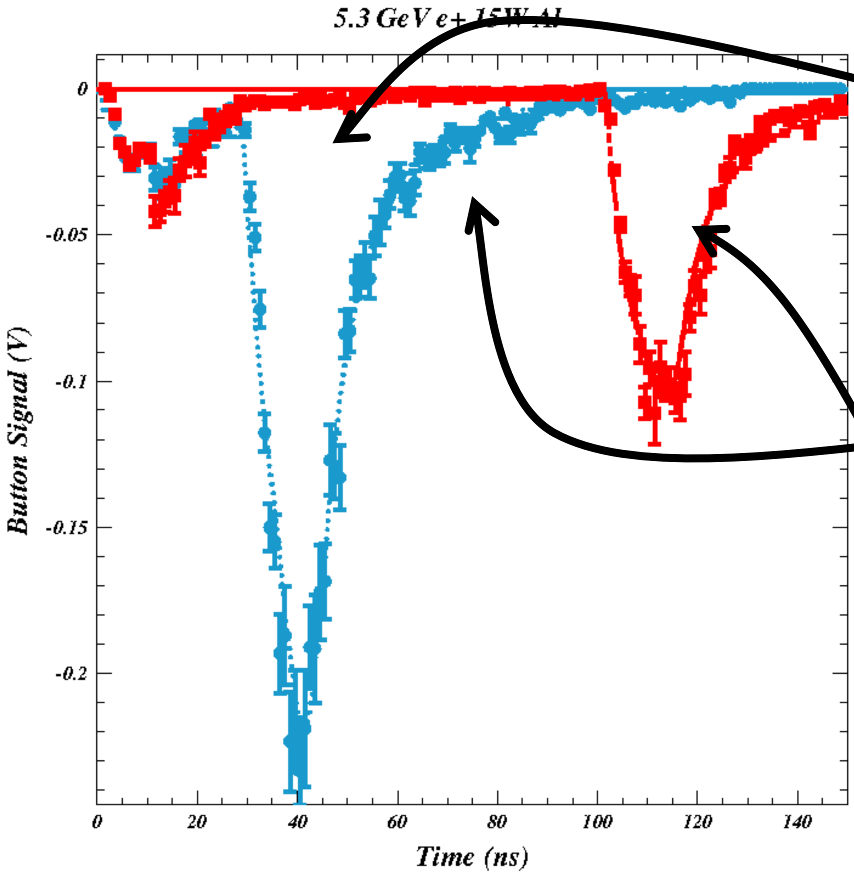
- Secondary yield is dependent upon the energy and angle of the incident electron
- Three components to total SEY:
  - –Rediffused (δ_{RED}) - Produces electrons of intermediate energy
  - –Elastic (δ_{EL}) – Dominates at low energy, conserves kinetic energy
  - –True Secondary (δ_{TS}) – Dominates at high energy, produces low-energy electrons





M.A. Furman and M.T.F. Pivi, *Probabilistic Model for the Simulation of Secondary Electron Emission*, Phys Rev ST-AB 5, 124404 (2002)

Secondary Yield Parameters



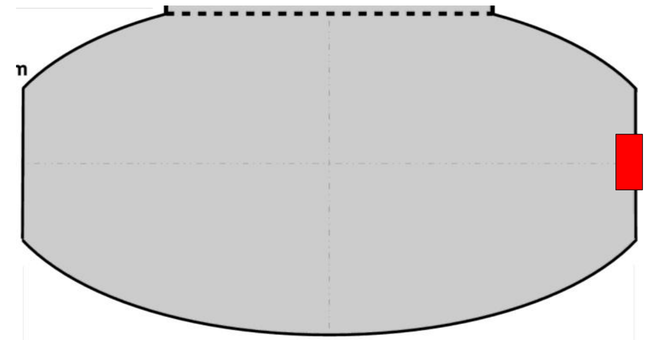
- Lots of high-energy electrons
  - Dominated by δ_{TS}
- Cloud decays
- More low-energy electrons
  - δ_{EL} has more influence

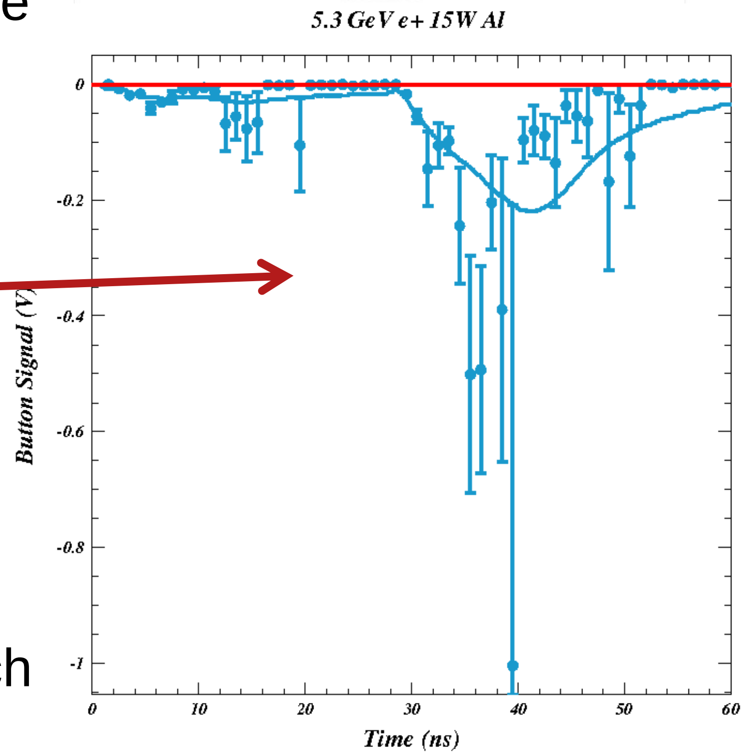
$\delta_{RED} = 0.1$	≈ 0.2 for Al
$\delta_{EL} = 0.5$	≈ 0.5 for Al
$\delta_{TS} = 0.9$	≈ 1.8 for Al

Why is the optimized δ_{TS} so low?

Quantum Efficiencies

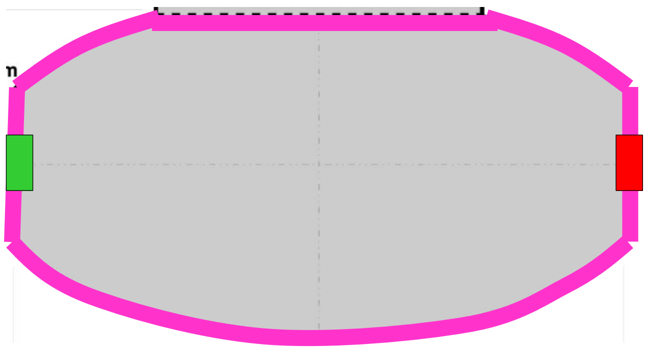
- Quantum efficiencies for direct and reflected photons
- First pulse dependent upon QER
- Second pulse more sensitive to QED
  - Photoelectrons produced on the sides of the chamber have a less direct path to the detector → don't make a signal until later
- Decrease QED to decrease second pulse?
  - Pulse not smaller but statistical errors much larger
  - Apparently less charge in the cloud means less cloud self-repulsion into the detector (and fewer wall collisions on the way, so each signal macroparticle carries more charge)

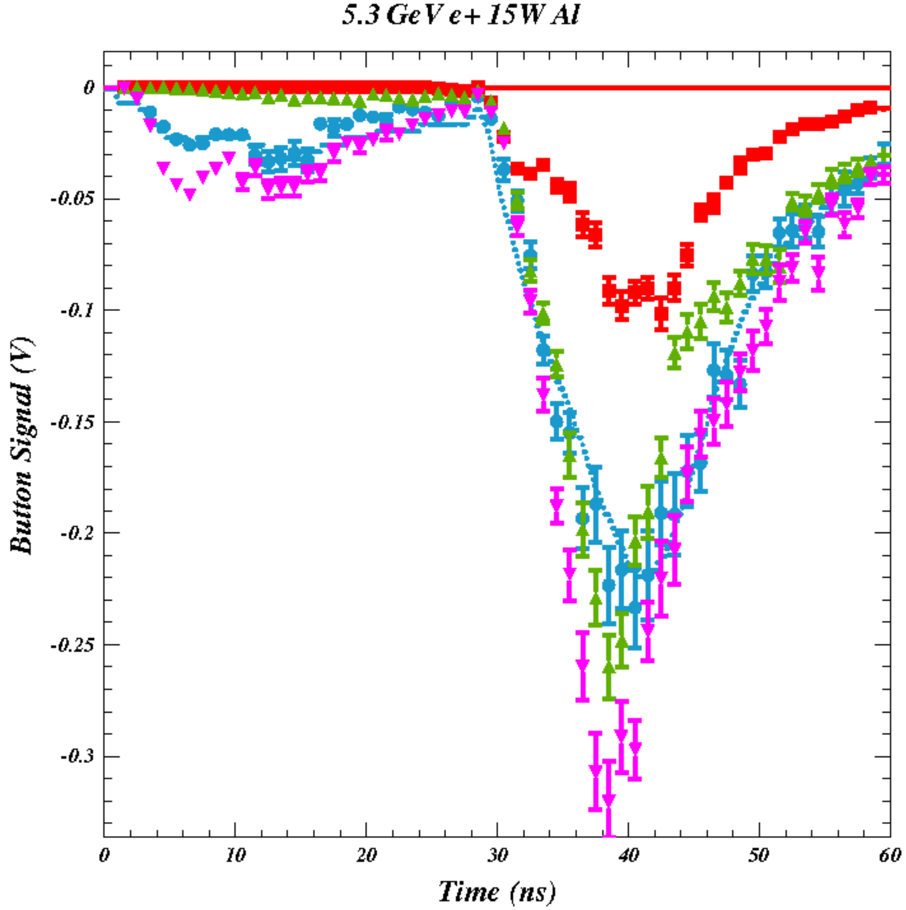




Quantum Efficiencies

- New QE feature of ECLOUD:
  - –More flexible QE assignment
  - –Three QE's instead of two



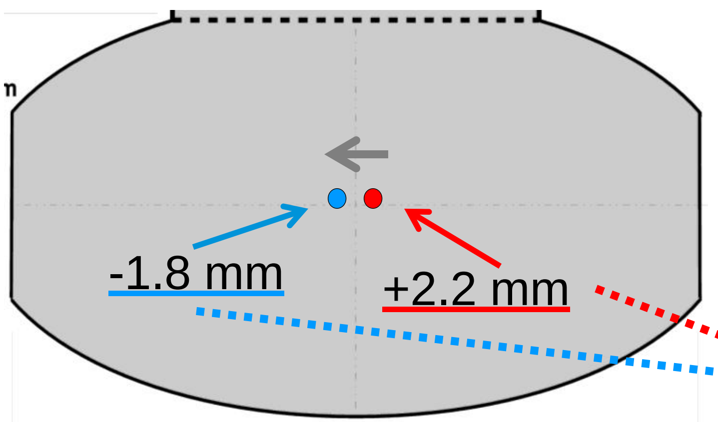


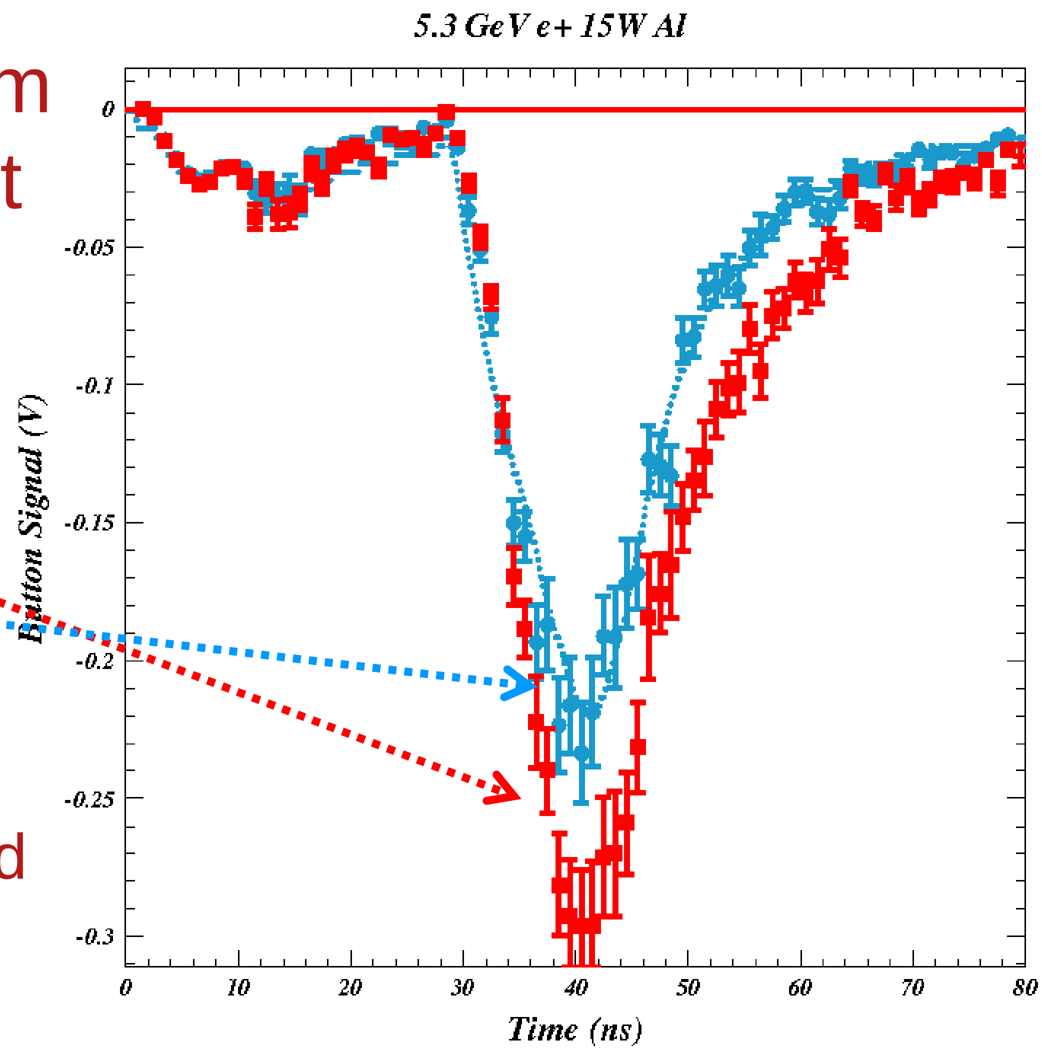
QED1	0.16
QED2	0.2
QER	0.24

- "**Sum**" – Smaller than the QER component alone!
  - –Cloud coming from the sides of the beampipe "blocks" the signal from the floor

Sensitivity to Horizontal Beam Position

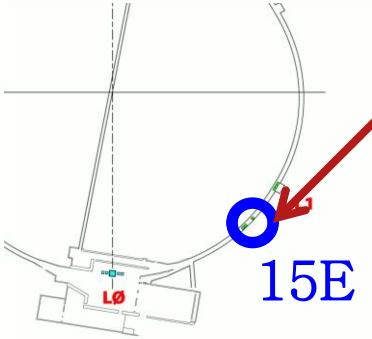
- Moving the modeled beam position away from the primary source point



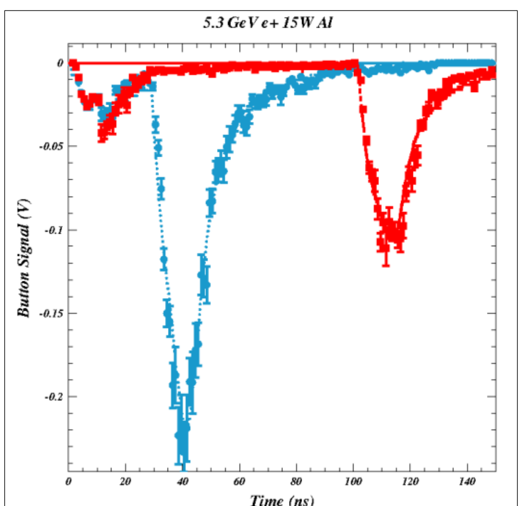


- Second pulse is sensitive to cloud profile when the second bunch arrives
  - ex., How much cloud is directly below the beam?

Looking Ahead



Unconditioned Al test chamber in 15E



- SPU data for unconditioned Al will be collected mid-August
- Data for conditioned Al will be collected in November
- The updated ECLOUD model will be used to help interpret the differences between the two data sets
  - Higher optimized δ_{TS} for unconditioned Al (closer to expected)?
  - Measure conditioning effects (δ_{TS}, δ_{red}, δ_{el})

Acknowledgments

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