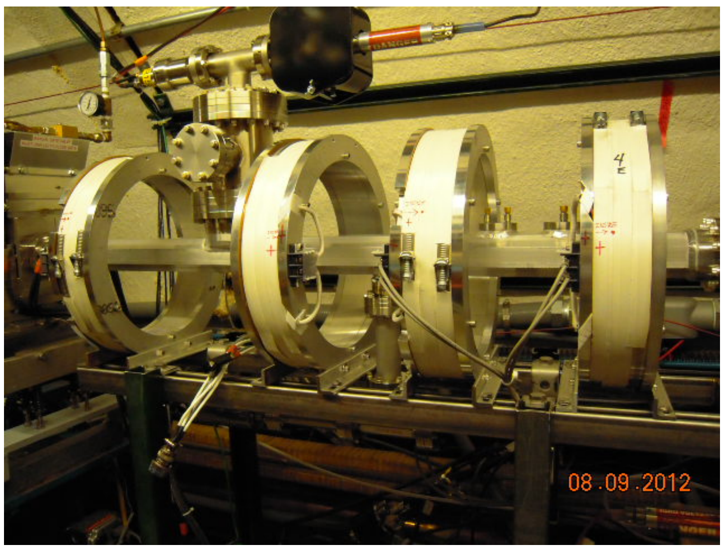
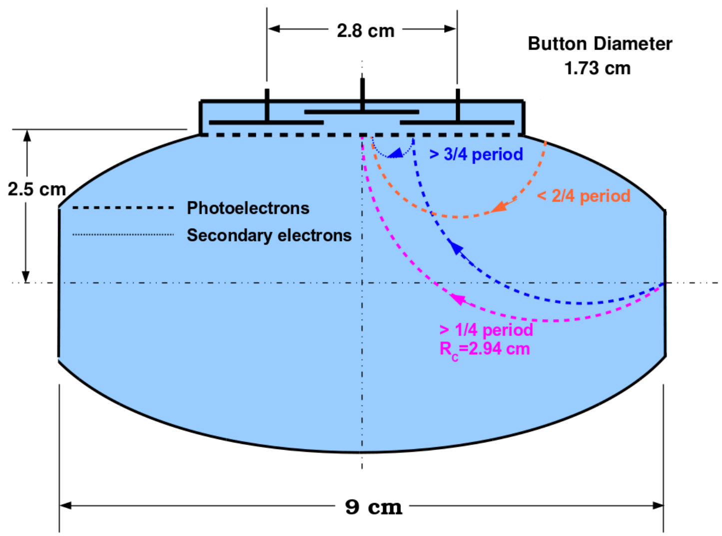
Cornell University
Laboratory for Elementary-Particle Physics

Progress on the ECLOUD Model for Electron Cloud Buildup in Longitudinal Magnetic Fields

– Improved understanding on where the signal electrons originate –
– Implementation of an acceptance model for the shielded pickup detector –

Previous work: see talks at the EC meetings on 25 July 2012 and 6 February 2013





Cyclotron Radius

$$R_C\,[\text{mm}] = 33\,\sqrt{E_{ev}}\,/\,B_G$$

Cyclotron Period

$$T_C\,[\text{ns}] = 357\,/\,B_G$$

Jim Crittenden

Cornell Laboratory for Accelerator-Based Sciences and Education

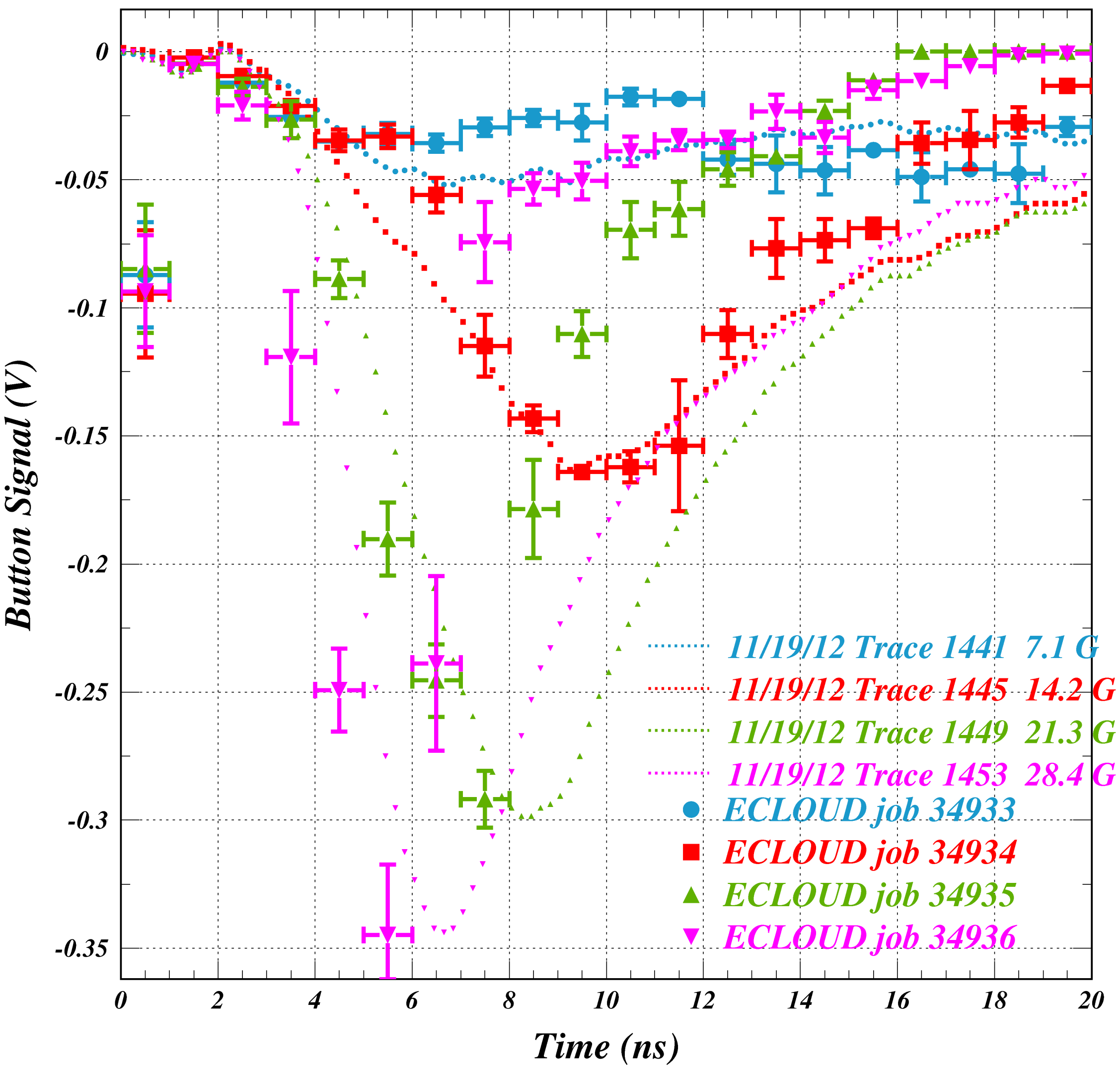
Electron Cloud Meeting

27 March 2013

Present Status of the Model

– Including SPU acceptance function for magnetic field –

Solenoid scan: 5.3 GeV 8 mA/bunch e- 15W TiN



5.3 GeV Electrons 8 mA/bunch
15W TiN-coated Al

Progress over the past four weeks

1) Signal shape for 14 G reproduces the measurement fairly well

2) Timing of leading edge scales approximately correctly from 7 to 28 G

3) Signal size also better

The standard SEY model for TiN works quite well.

Before addressing the remaining problems, first discuss how the model needed to be adapted compared to the well-understood field-free case.

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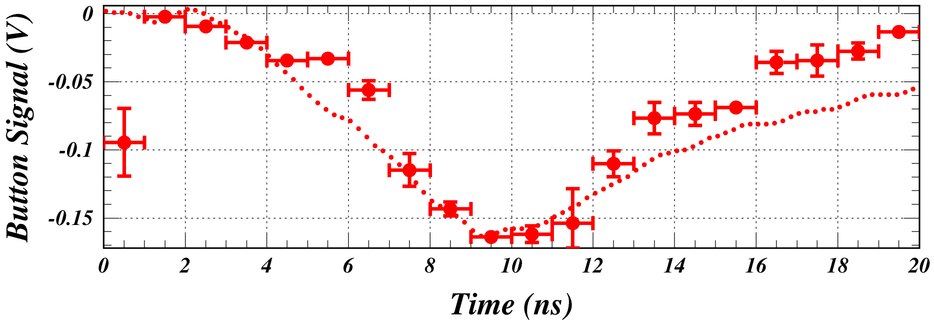
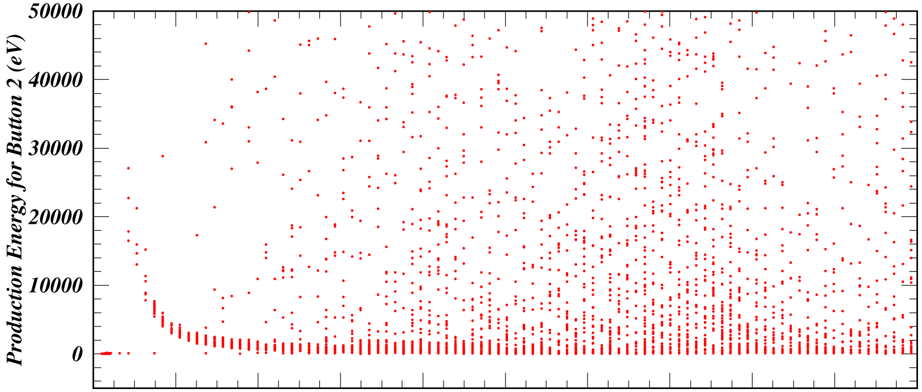
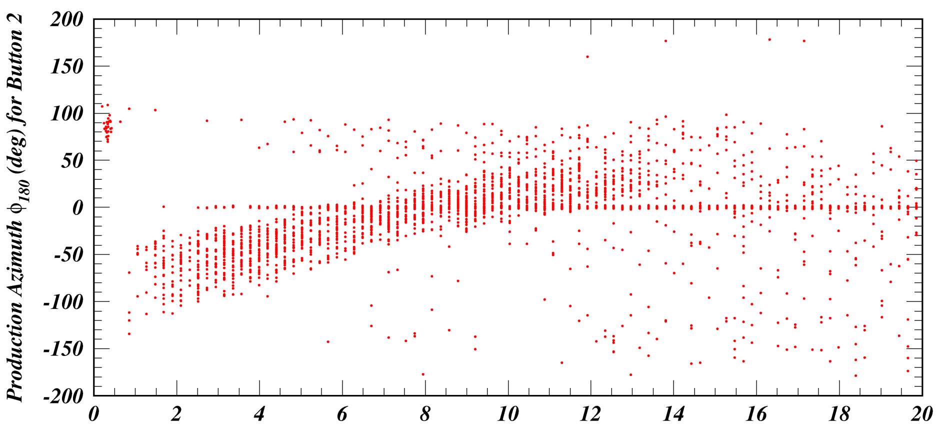
Signal Shape for 14 Gauss field
– Cyclotron period is 51 ns –







The leading edge of the signal is due to high-energy photoelectrons with large cyclotron radius produced between the bottom of the beampipe and the primary s.r. source point. They can arrive as early as 2 ns after bunch passage, even though the 1/4-cyclotron-period value is 13 ns. This match was achieved by using a uniform azimuthal distribution with reflectivity 45%, having been forced to abandon the SYNRAD3D distribution.

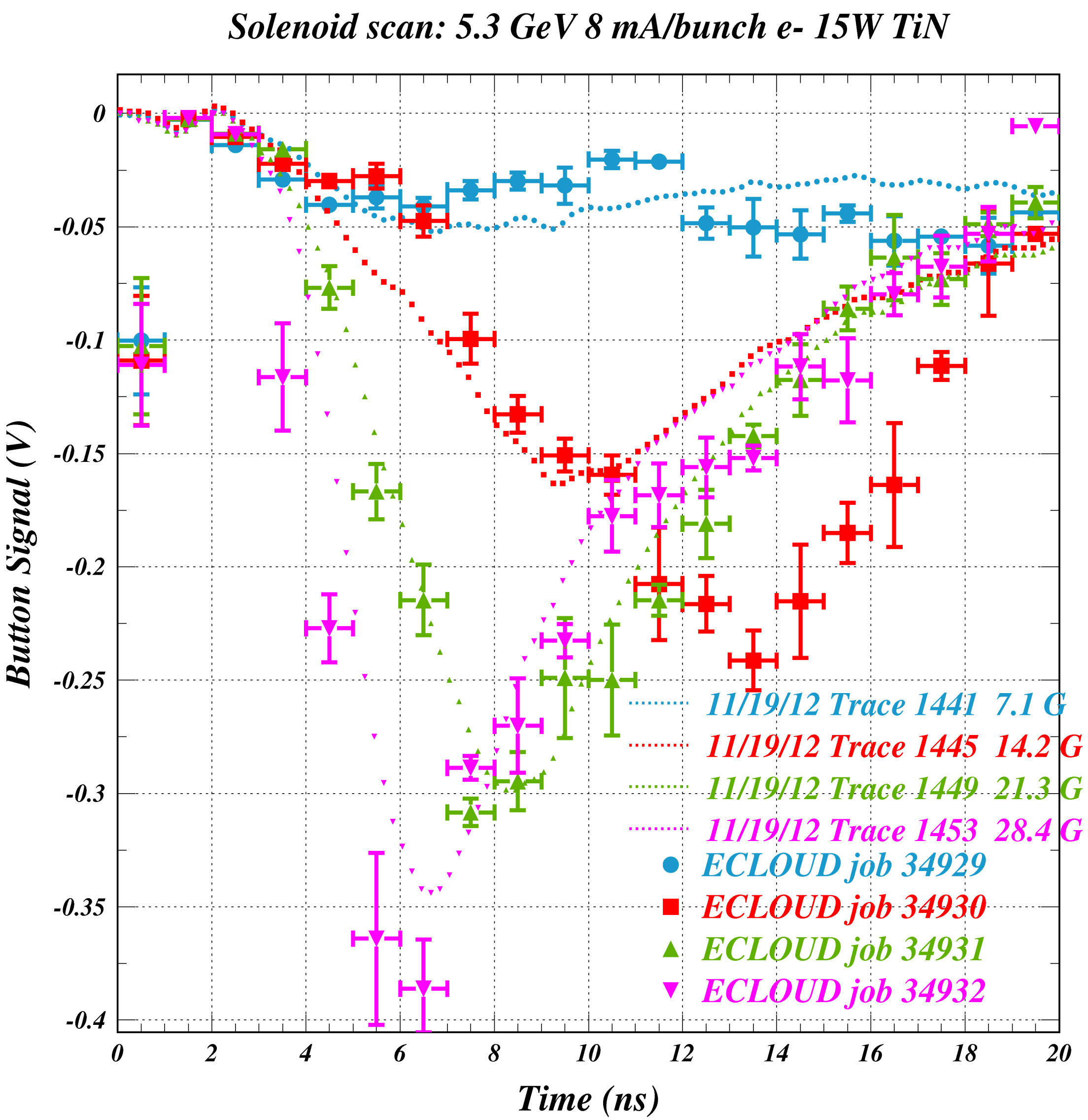
High-energy photoelectrons are also responsible for the tail of the modeled pulse shape. They are produced all over the beampipe, and strike the wall near the SPU detector, creating secondaries which curl into the holes in the beampipe. Note that the origin of such high energy photoelectrons is mysterious, since the critical energy is only 3.8 keV at 15W for 5.3 GeV electrons. Limiting the p.e. energy to 5 keV ruined the agreement.

For 14 G, the cyclotron radius is 2.4 mm for 1 eV, 7.1 mm for 9 eV. The minimum accepted cyclotron radius is 0.9 mm.

These tails are very sensitive to the energy distribution of the secondaries. As for the field-free case, the optimum characteristic energy is close to 1 eV with sensitivity at the 0.1 eV level.

Present Status of the Model

– Field-free SPU acceptance function (JRC/JM) –



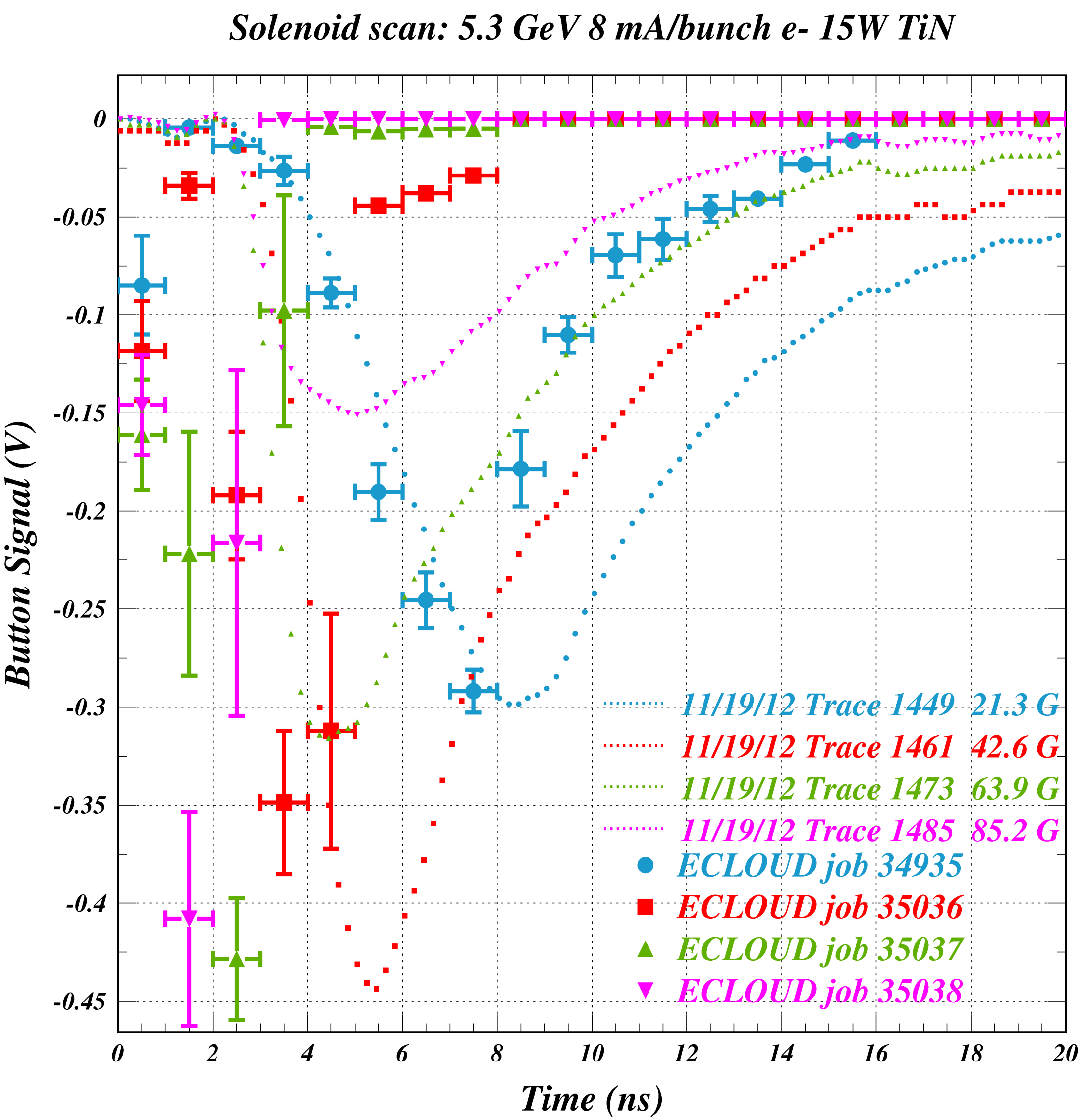
The enhanced tails of the modeled signals for 21 and 28 Gauss are primarily due to macroparticles which have cyclotron radii too small to pass through the holes in the beampipe.

Attempts were made to tune the acceptance model adjust the transition to the field-free limiting case as a function of cyclotron radius, but improvement was not obtained. The present model reverts to the field-free case at four times the minimum cyclotron radius.

It may be necessary to raise the cyclotron radius cutoff above the minimum to account for the button distance, but such a change further restricts the acceptance at high field, where the modeled signals are already suppressed compared to the measurement.

Present Status of the Model

– Highest Magnetic Field Strengths –



The Helmholtz coils extend the range of magnetic field strengths from 40 G to 140 G relative to the windings.
The 40 G field strength sufficed to cover the full range of photoelectron energies at 2.1 GeV (E_C = 230 eV for e- at 15W), but not at 5.3 GeV (E_C = 3.8 keV).
The Helmholtz coils now allow coverage of the full range of photoelectron energies at 5.3 GeV, i.e. the signal decreases to zero at the highest field settings.

The limiting behavior of the signal exhibits a lower bound to the arrival times which is not reproduced in the model.
John Sikora has now shown convincingly that the SPU time resolution is not responsible for the limiting behavior of the signals (see today's talk).

Next Steps & Remarks

Next Steps

Some tuning of the SPU arrival angle and energy acceptance as a function of longitudinal magnetic field is likely to be necessary. For example, the minimum accepted cyclotron radius may be larger than the 0.9 mm imposed by the hole geometry, because there is in addition a 2 mm distance between the outside wall of the beampipe and the button. Such an acceptance cutoff in cyclotron radius has been added to ECLOUD as an input parameter.

A systematic study of the dependence on the photoelectron energy spectrum must again be undertaken. In addition to the tuning of the energy distribution to match the signal shapes, the effect of imposing a high-energy limit relating to the synchrotron radiation critical energy must be studied.

Remarks

Our original goal of using the momentum-analyzing power of the adjustable solenoidal magnetic field strength to determine the photoelectron energy distribution at the primary source point must be modified to accommodate the contribution of photoelectrons produced by scattered photons.

In particular, these measurements are sensitive to photoelectron production over a more detailed range of production azimuth than were the tune shift measurements. They may therefore be instructive in refining the SYNRAD3D model parameters.