RECENT DEVELOPMENTS IN MODELING TIME-RESOLVED SHIELDED-PICKUP MEASUREMENTS OF ELECTRON CLOUD BUILDUP AT CESRTA

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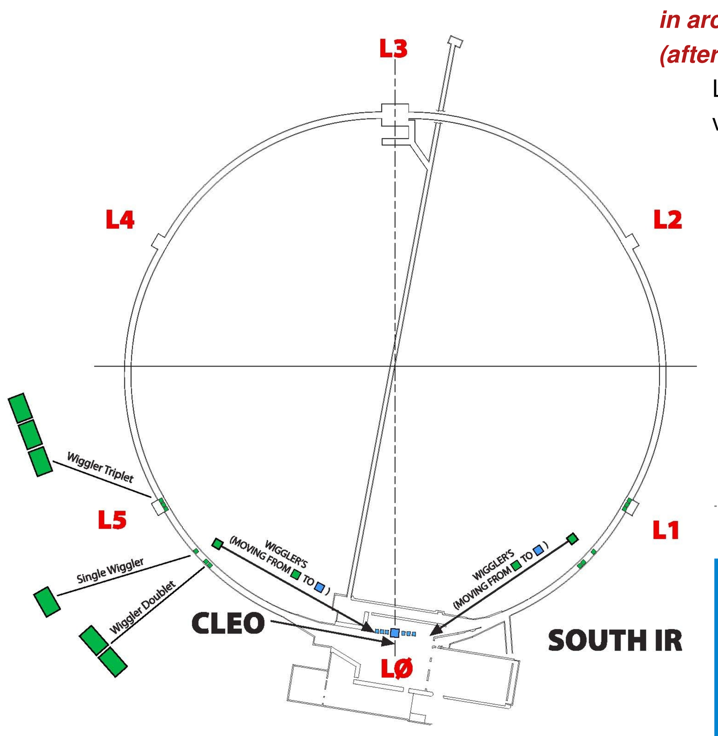
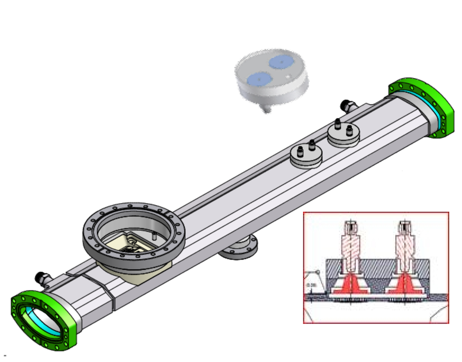
The Cornell Electron Storage Ring Test Accelerator (CESRTA) program includes investigations into the mitigation of electron cloud buildup using a variety of techniques in custom vacuum chambers. The CESR ring accommodates two such chambers equipped with BPM-style pickup detectors shielded against the direct beam-induced signal. The signals recorded by a digitizing oscilloscope provide time-resolved information on cloud development. Results for diamond-like carbon, amorphous carbon, and titanium-nitride coatings have been obtained and compared to those for an uncoated aluminum chamber. Here we report on extensions to the ECLOUD modeling code which refine its description of a variety of new types of in situ vacuum chamber comparisons. Our results highlight the sensitivity afforded by these measurements to model parameters such as the quantum efficiency for producing photoelectrons, their production location and energy distributions, as well as to the secondary yield and production kinematics. We use this sensitivity to draw conclusions comparing the photoelectron and secondary yield properties of the various vacuum chamber coatings, including conditioning effects as a function of synchrotron radiation dose. We find substantial conditioning effects in both the quantum efficiency for producing photoelectrons and for the secondary yield.

The CESRTA Reconfiguration July – October 2008

L3 Electron cloud experimental region
PEP-II EC Hardware:
Chicane, upgraded SEY station (commissioning in May 2009)
Drift and Quadrupole diagnostic chambers

New electron cloud experimental regions in arcs near L1 and L5 (after 6 wigglers moved to L0 straight)
Locations for collaborator experimental vacuum chambers





Custom vacuum chambers with shielded pickup detectors

Uncoated aluminum, and TiN, amorphous carbon, diamond-like carbon coatings

Electron cloud simulation package ECLOUD

- Originated at CERN in the late 1990's
- Widespread application for LHC, KEK, RHIC, ILC ...
- Under active development at Cornell since 2008
- Successful modeling of CESRTA tune shift measurements
- Interactive shielded pickup model implemented in 2010

I. Generation of photoelectrons
- A) Production energy, angle
- B) Azimuthal distribution (v.c. reflectivity)

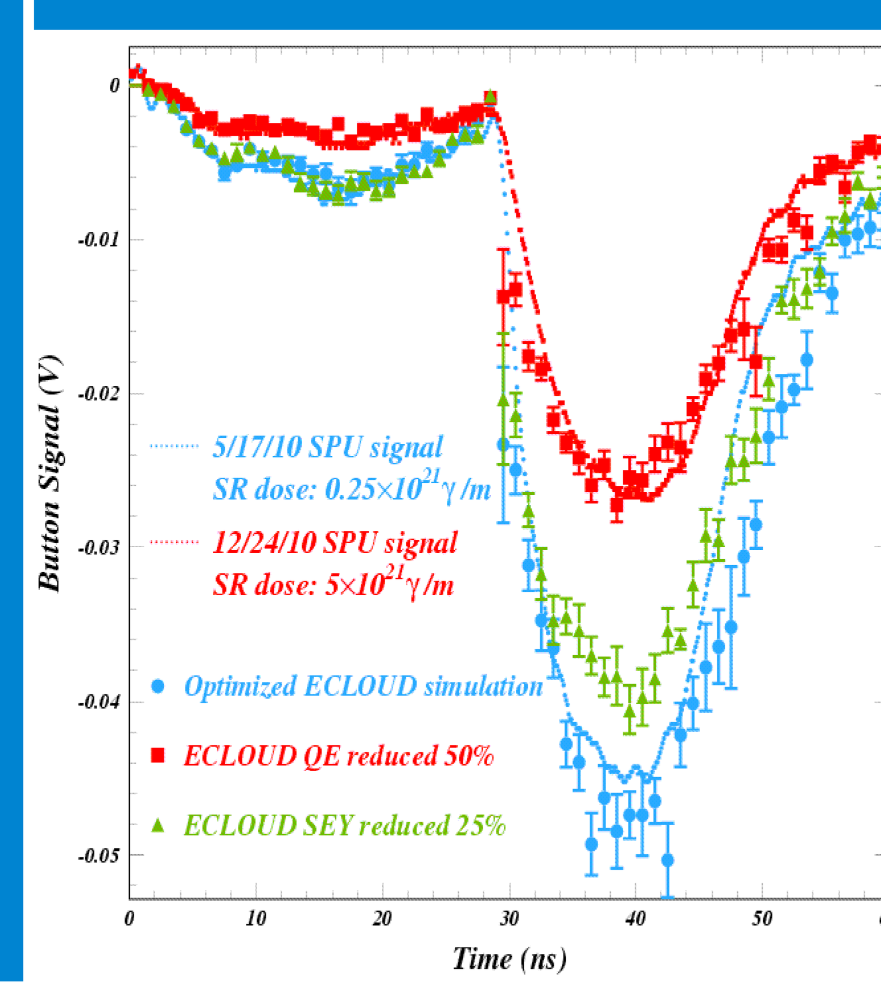
II. Time-sliced cloud dynamics
- A) Cloud space charge force
- B) Beam kick
- C) Magnetic fields

III. Secondary yield model
- A) True secondaries (yields > 1!)
- B) Rediffused secondaries (high energy)
- C) Elastic reflection (dominates at low energy)

IV. Shielded pickup model
- A) Acceptance vs incident angle, energy
- B) Signal charge removed from cloud
- C) Non-signal charge creates secondaries

In situ comparison of vacuum chamber surface mitigation techniques for identical conditions of beam energy, species, bunch current and position in the ring, i.e. same radiation environment

A challenge for the modeling !

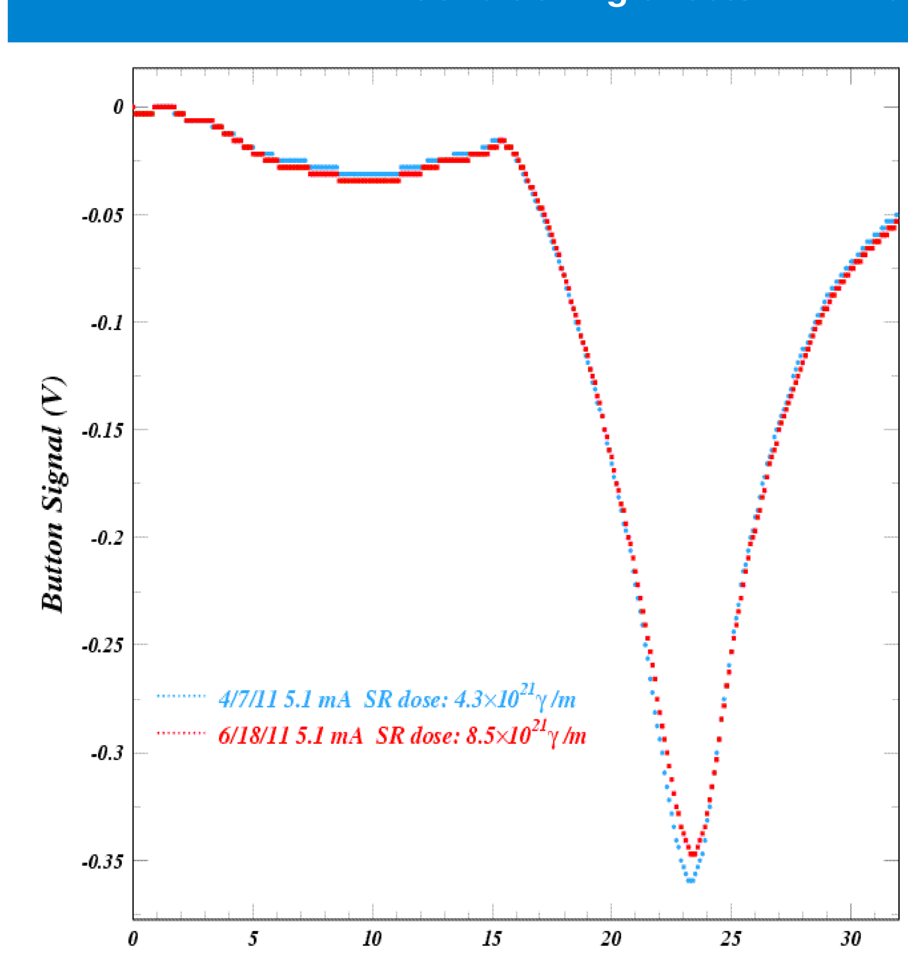


Shielded pickup signals measured in an amorphous-carbon-coated chamber in May (blue dotted line) and December (red dotted line) of 2010 for two bunches carrying 4.8×10^{10} 5.3 GeV positrons 28 ns apart. The synchrotron radiation dose increased by a factor of twenty during this time interval. The ECLOUD model optimized for the May data is shown as blue circles, the error bars showing the model statistical uncertainties.

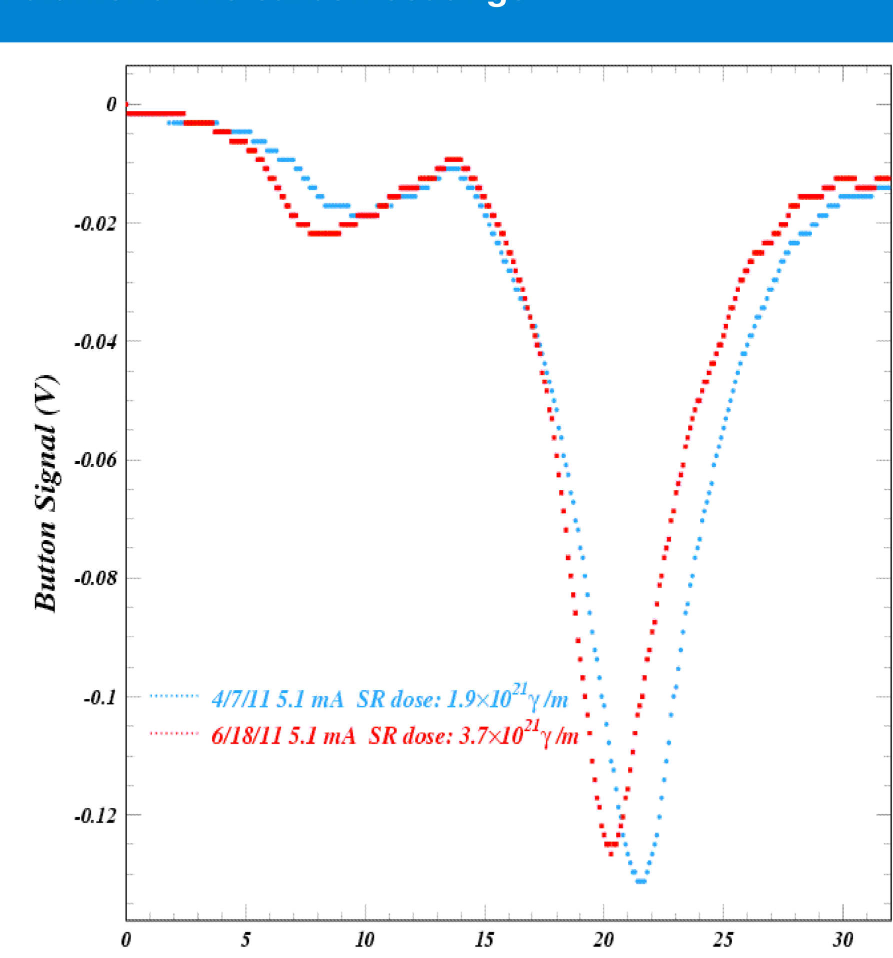
The leading bunch arises from photoelectrons produced on the bottom of the vacuum chamber. Careful tuning of the energy distribution and quantum efficiency for photoelectrons produced by reflected photons is required to reproduce its size and shape. The signal from the witness bunch includes additionally the contribution from secondary cloud electrons accelerated into the SPU detector by the witness bunch kick and is therefore crucially dependent on the secondary yield and production kinematics. Since the conditioning affects both signals similarly, we can conclude that the conditioning change is in the quantum efficiency rather than in the secondary yield.

The December measurement is reproduced by a 50% decrease in the modeled quantum efficiency for photoelectron production. A reduction in the secondary yield of 25% is inconsistent with the observed effect, since the leading bunch signal is unchanged.

Conditioning effects in TiN- and diamond-like carbon coatings

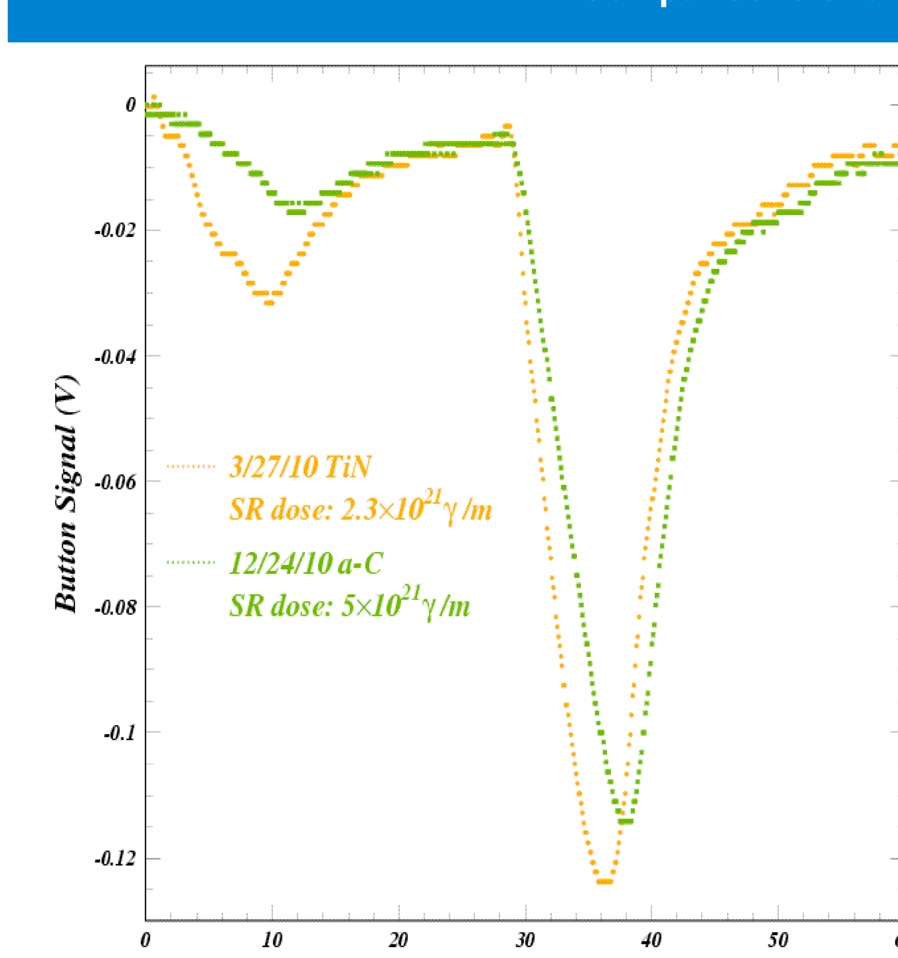


Both the quantum efficiency for reflected photons and the SEY change by less than a few percent over this range of radiation dose for the TiN coating.

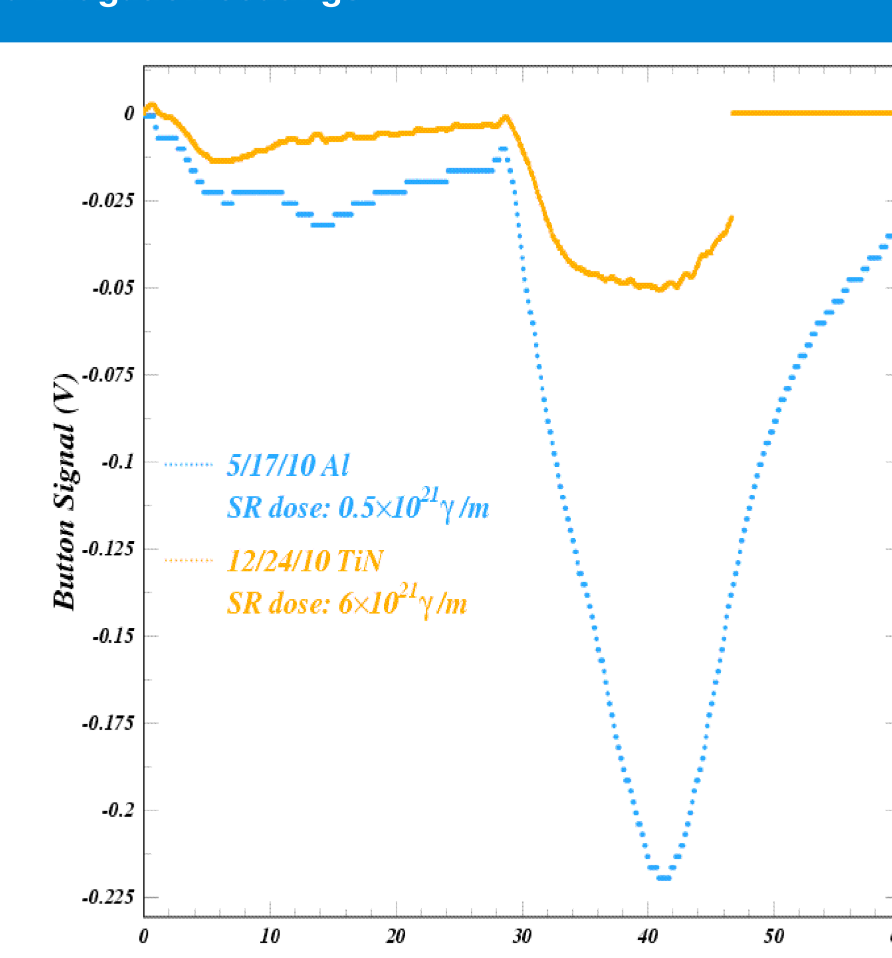


The diamond-like carbon coating exhibits an increase in quantum efficiency for reflected photons while the secondary yield decreases significantly.

Comparisons of cloud mitigation coatings



The carbon coating suppresses photoelectron production relative to the TiN coating, especially at high photoelectron energy.



The quantum efficiency for reflected photons and the secondary yield are both much smaller for conditioned TiN than for uncoated aluminum.

LEPP, the Cornell University Laboratory for Elementary-Particle Physics, and CHESS resources have merged and a new lab, (CLASSE), has formed. CLASSE develops and operates facilities and provides infrastructure for the study of beams and accelerators, photon science, particle physics and the early universe, serving students, the public and scientists from Cornell and elsewhere. LEPP's primary source of support is the National Science Foundation.