TIME-RESOLVED SHIELDED-PICKUP MEASUREMENTS AND MODELING OF BEAM CONDITIONING EFFECTS ON ELECTRON CLOUD BUILDUP AT CESRTA

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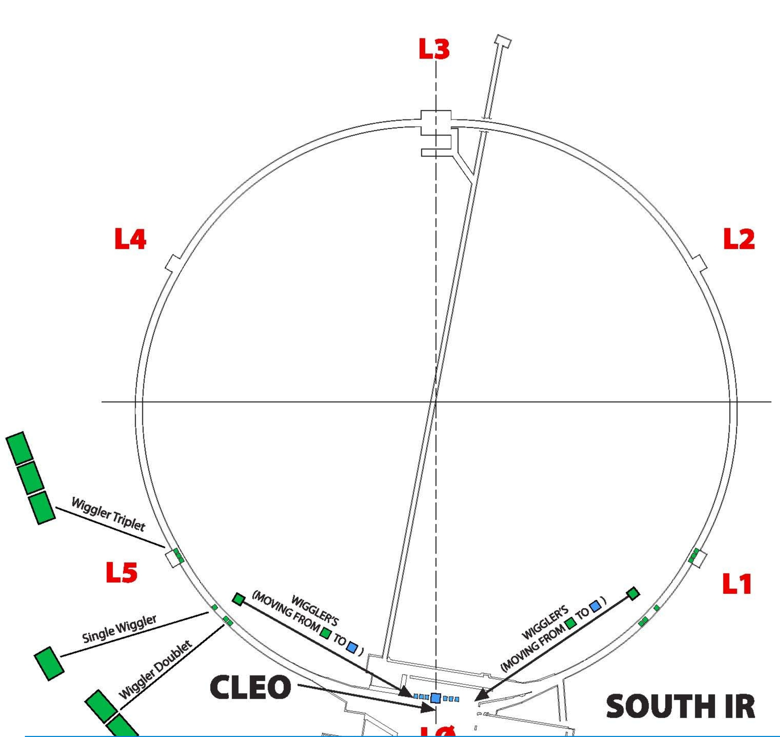
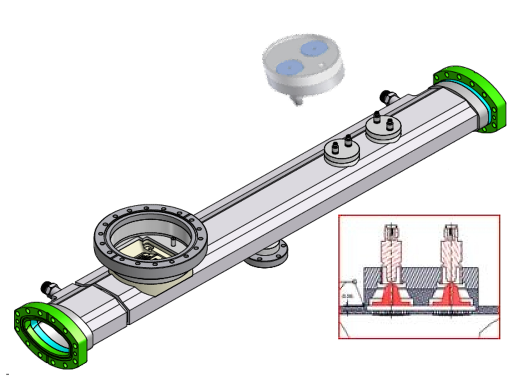
The Cornell Electron Storage Ring Test Accelerator program includes investigations into electron cloud buildup in vacuum chambers with various coatings. Two 1.1-m-long sections located symmetrically in the east and west arc regions are equipped with BPM-like pickup detectors shielded against the direct beam-induced signal. They detect cloud electrons migrating through an 18-mm-diameter pattern of holes in the top of the chamber. A digitizing oscilloscope is used to record the signals, providing time-resolved information on cloud development. We present new measurements of the effect of beam conditioning on a newly-installed amorphous carbon coated chamber, as well as on a diamond-like carbon coating. The ECLOUD modeling code is used to quantify the sensitivity of these measurements to model parameters, differentiating between photoelectron and secondary-electron production processes.

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 pickudetectors

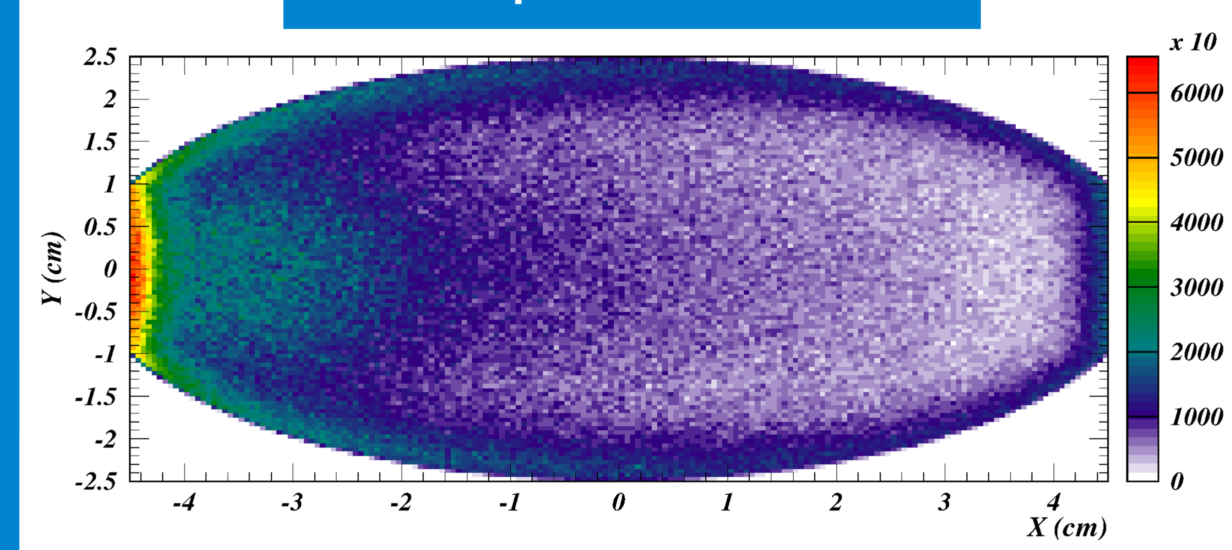
Uncoated aluminum, and TiN, amorphous carbon, diamond-like carbon coatings

Electron cloud simulation package ECLOUD

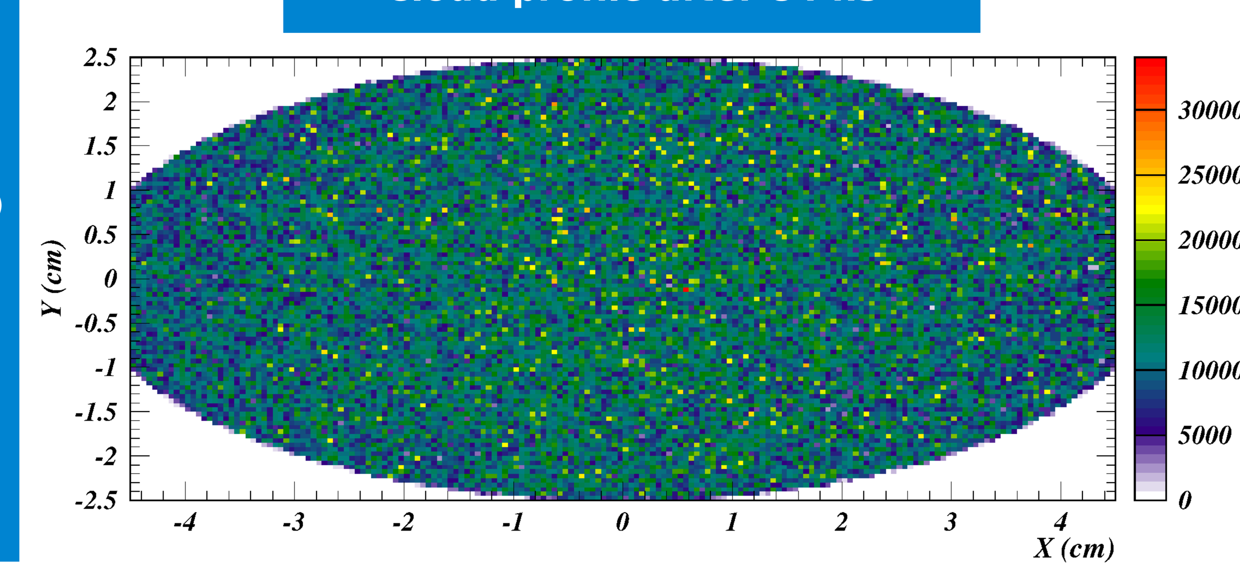
* Originated at CERN in the late 1990's
* Widespread application for LHC, KEK, RHIC, ILC ...
* Under active development at Cornell since 2008
* Successful modeling of CESRTA tune shift measurements
* Interactive shielded pickup model implemented in 2010

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

Cloud profile after 14 ns



Cloud profile after 84 ns



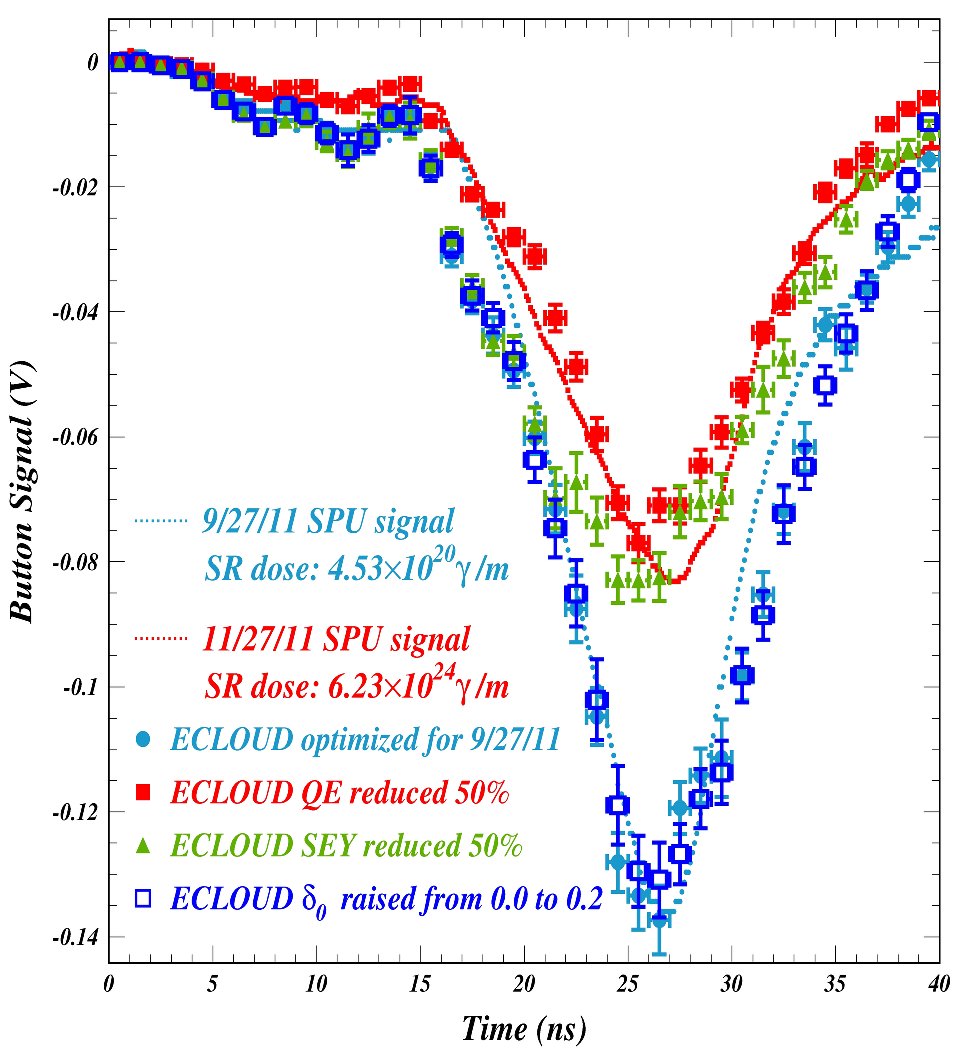
Electron Cloud Profile Time Development Prior to Passage of the Witness bunch

The cloud profiles shown here at the time of arrival of the witness bunch thus determine the number and arrival times of the signal macroparticles kicked into the detector by the beam kick from the witness bunch. The color code shows the electron density. After 14 ns the cloud is still very dynamic, while at 84 ns it has become quite uniform and low energy.

The leading bunch signal 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 assumed in the simulation.

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

SPU signals from the leading and 14-ns bunches



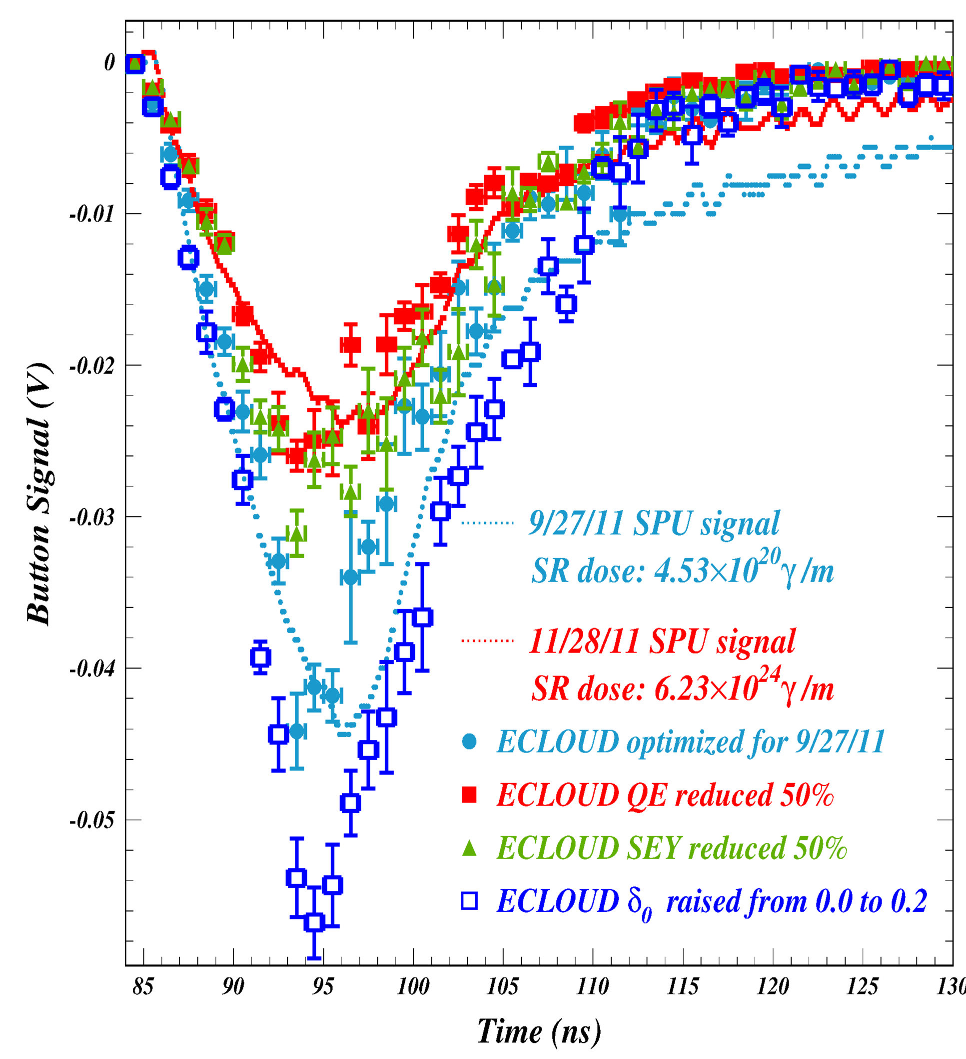
Conditioning Effects for an Unprocessed Amorphous Carbon Coating on Aluminium

Shielded pickup signals measured in an amorphous-carbon-coated chamber in September (blue dotted line) and November (red dotted line) of 2011 for two bunches carrying 4.8×10^{10} 5.3 GeV positrons 14 and 84 ns apart. The synchrotron radiation dose increased by four orders of magnitude during this time interval, corresponding to an integrated positron dose of 0.02 to 200 Amp-hours. The ECLOUD model optimized for the September data is shown as blue circles, the error bars showing the model statistical uncertainties.

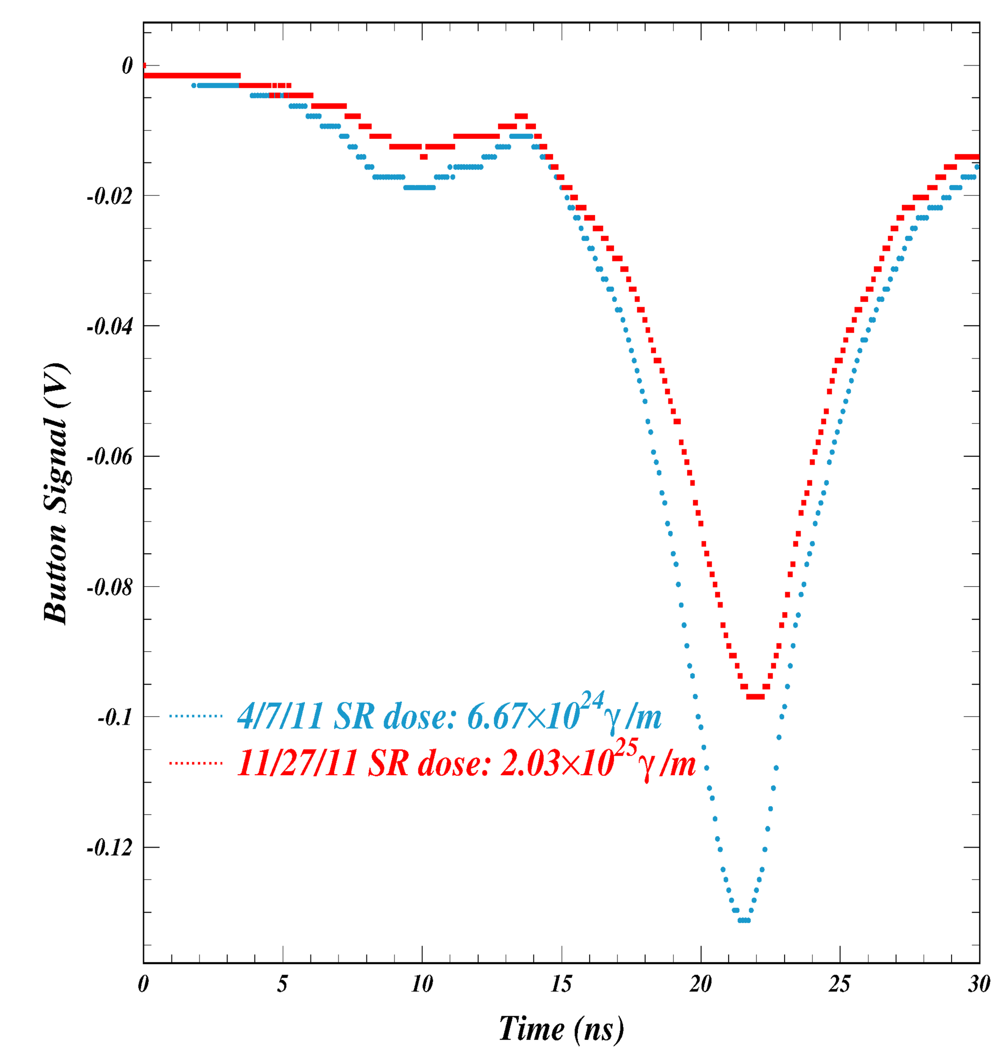
The November measurement is reproduced by a 50% decrease in the modeled quantum efficiency for photoelectron production. A reduction in the secondary yield of 50% is inconsistent with the observed effect, since the leading bunch signal is unchanged. This type of conditioning effect was also observed for a processed amorphous carbon coating, where the photon dose increased from 0.8×10^{24} to 18.2×10^{24} γ/m (IPAC11, WEPC135).

Additionally, a simulation is shown where the elastic yield value has been raised from 0% to 20%. The elastic yield is an important parameter, since it determines the overall lifetime of the cloud. Here we see that the 14-ns bunch signal is not sensitive to the value for the elastic yield, as is the 84-ns bunch signal shown in the next figure. One can conclude that the low value of the elastic yield was not a result of beam conditioning.

SPU signals from the 84-ns witness bunch



Beam conditioning for diamond-like carbon



Conditioning Effects for a Well-processed Diamond-Like Carbon Coating

This comparison of SPU signals recorded in April and November, 2011, shows that beam conditioning affects quantum efficiency in a manner similar to that for the amorphous carbon coating, and that this effect continues even after high beam doses.

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