Cornell Laboratory for
Accelerator-based Sciences and
Education (CLASSE)

CESRTA: A Comparison of EC Density Measurements at 5 GeV*

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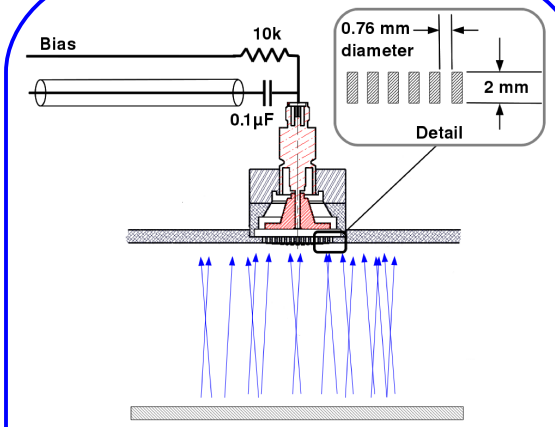
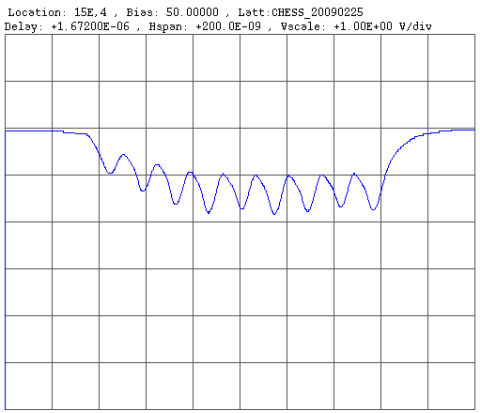
Comparison of EC Density Measurements

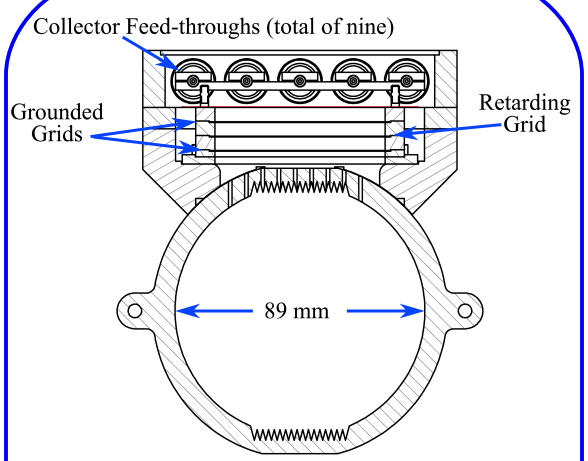
Measurement Techniques with Their Corresponding Signals

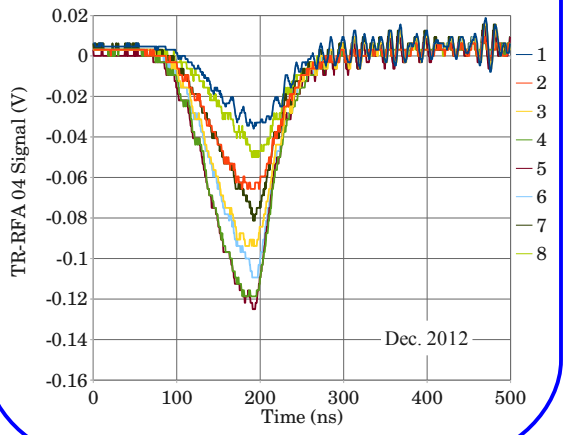
Shielded Pickup (SPU)



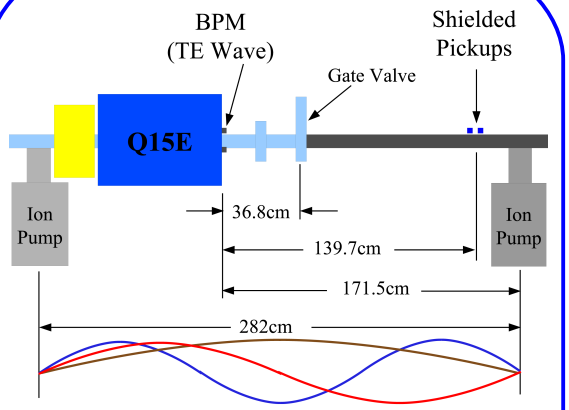


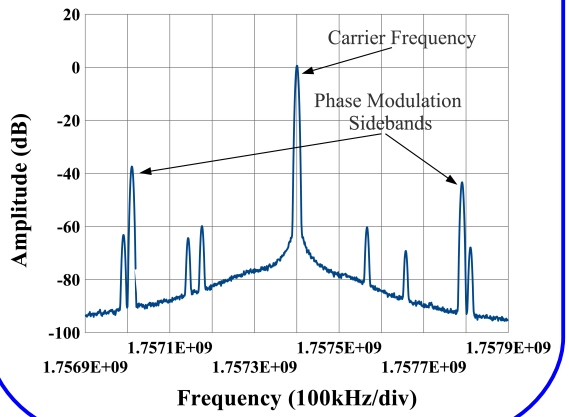
Time-Resolved Retarding Field Analyzer (TR-RFA)





TE Wave





Comparison of EC Density Measurements

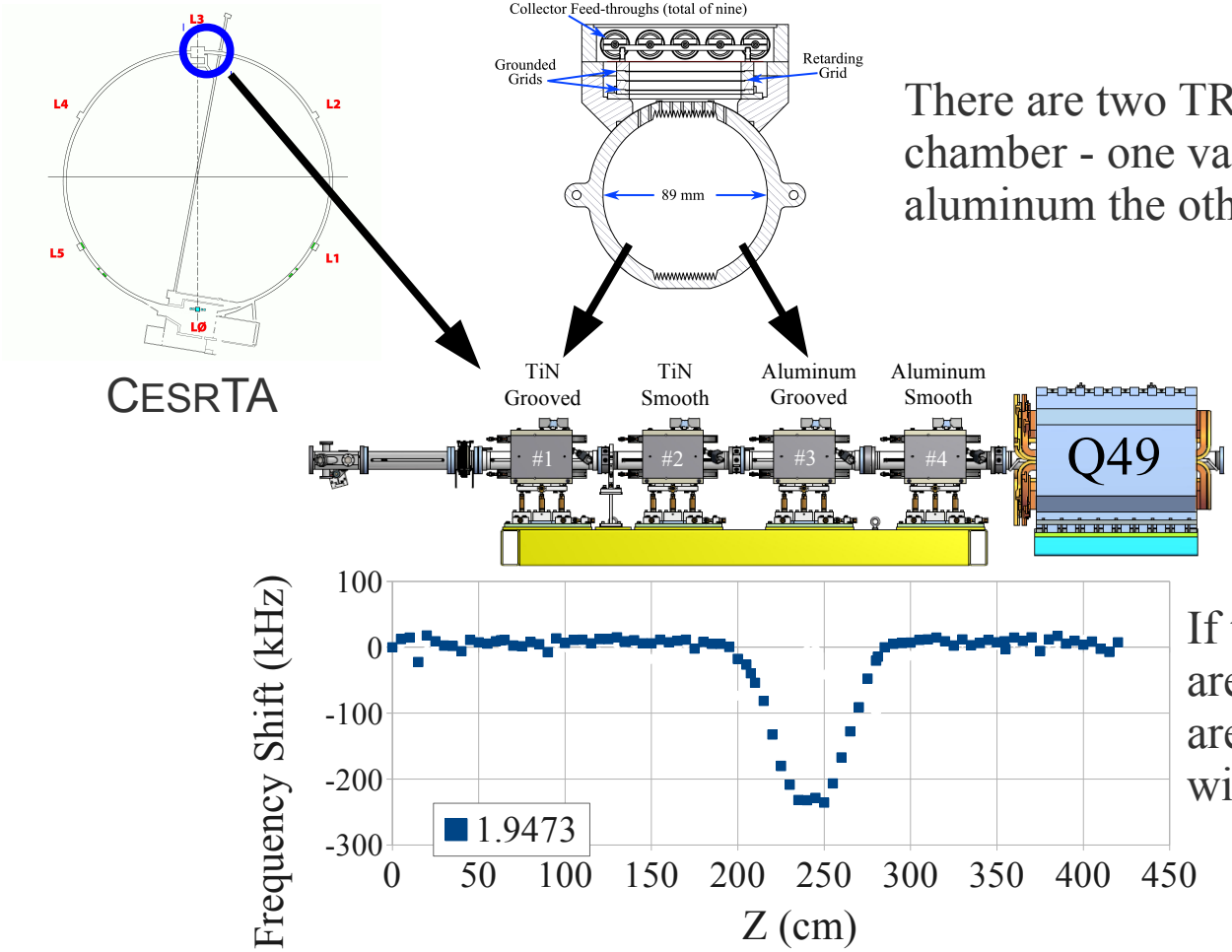
Comparing Signals from SPU, TR-RFA and TE Wave

- Both the Shielded Pickups and the Time Resolved RFAs sample the flux of electron cloud current onto the beam-pipe wall.
- For the data presented here, **no retarding field was used** in the TR-RFA, so they act much like a Shielded Pickup.
- The TE Wave measurement is sensitive to the volume within a resonant section of beam-pipe. The signal is proportional to EC density times E^2.

- Comparisons will be made between chambers of bare aluminum, and those with a coating of TiN.
- Comparisons will also be made between measurements when these chambers were first installed in August 2012 (0.55 amp-hours), and after significant beam conditioning (>600 amp-hours).
- All of the measurements presented here were made with 5.3 GeV positron beams.
- The bunch spacing is 14 ns and the storage ring revolution period is 2562 ns.

Comparison of EC Density Measurements

TR-RFA and TE Wave in Grooved Beam-pipe



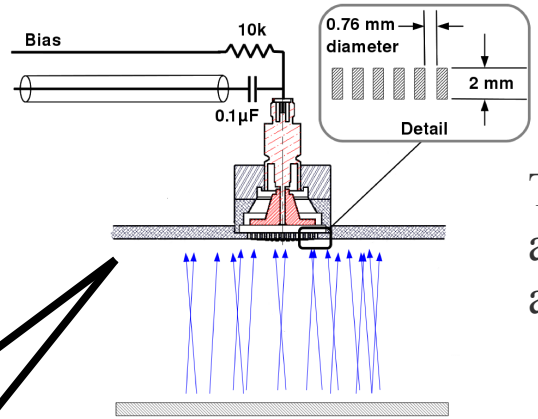
There are two TR-RFAs in grooved vacuum chamber - one vacuum surface is of bare aluminum the other coated with TiN.

If the correct resonant frequencies are chosen, TE wave measurements are sensitive only to EC density within the grooved beam-pipe.

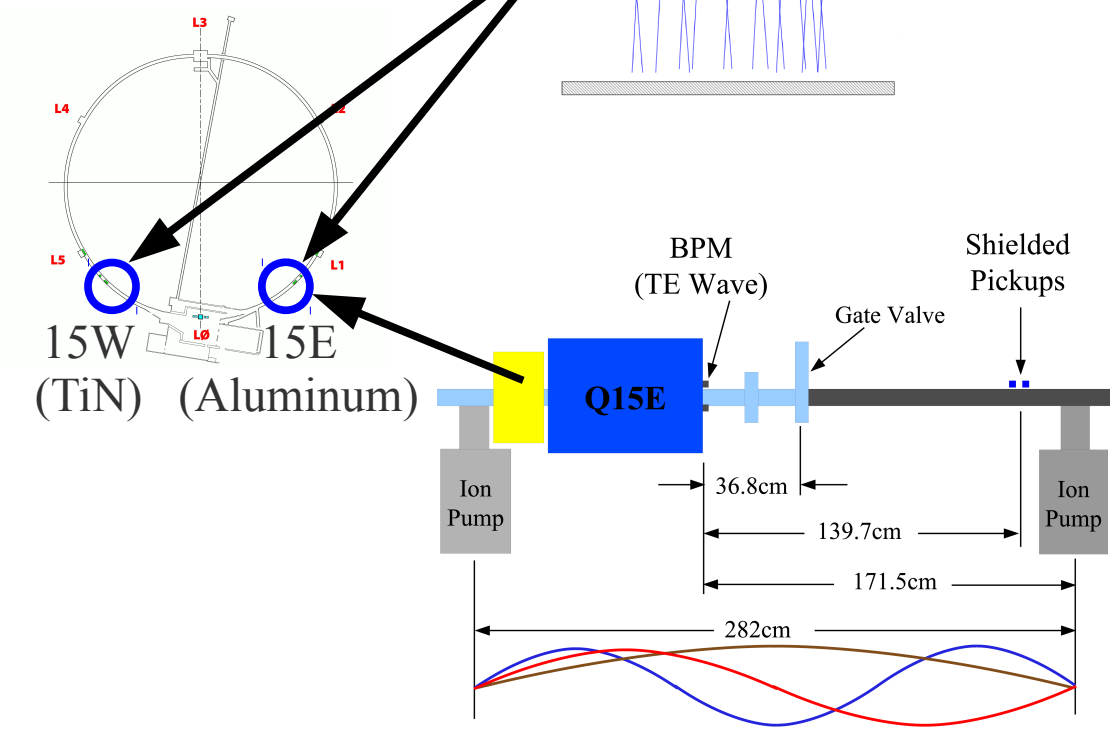
For example, this bead-pull measurement shows that the microwaves at 1.9473 GHz are confined to the grooved aluminum section of beam-pipe.

Comparison of EC Density Measurements

Shielded Pickup and TE Wave Measurements



There are two Shielded Pickups: one in aluminum beam-pipe at 15E, the other having a vacuum surface coated with TiN at 15W.



TE wave measurements have also been performed at 15E in the same section of beam-pipe as the SPU.

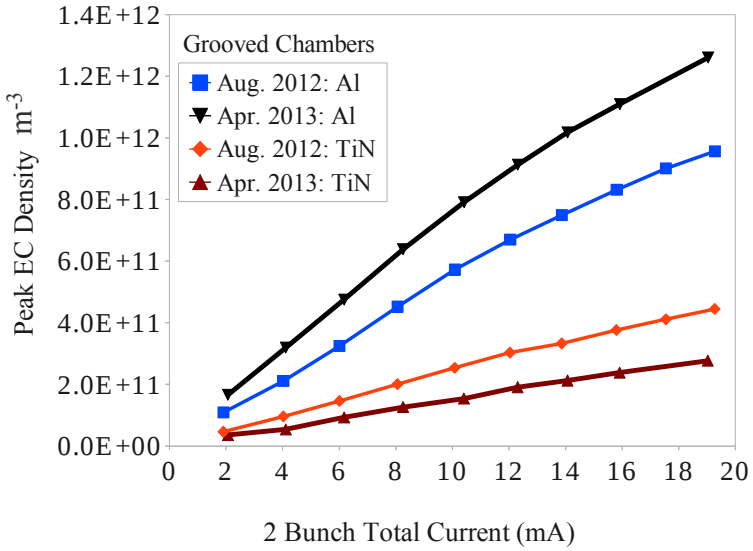
TE waves at 15E are confined to the 3 meter length of aluminum beam-pipe between two ion pumps. Microwaves are reflected by the longitudinal slots at the ion pumps.

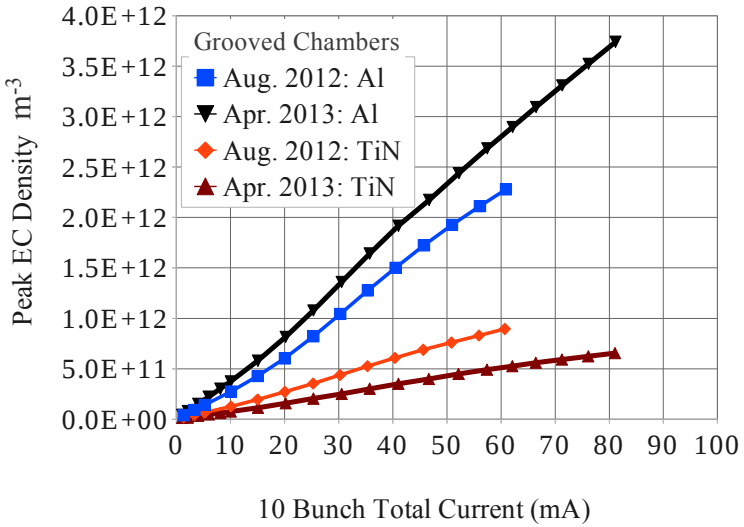
How Signals are Plotted

- Most signals will be plotted as a function of beam current.
- The signal from the SPU will be integrated to obtain the total charge detected by the SPU on each turn. (Because of amplification, the plotted values will be 100x the actual values.)
- The proper analysis of TE Wave data is still under development. Although the absolute calibration of this data may be incorrect, the same procedure was used for all of the plots, specifically:
  - Assume that the sideband amplitudes are produced only by phase modulation.
  - Approximate the time evolution of the EC density to be a pulse whose length is the length of the bunch train plus 100 ns.
- The TR-RFA data will not be plotted versus current, but example raw data will show the effect of TiN coating and of beam conditioning.
- I have NOT (yet) normalized any of the measurements for the photon flux.
- I have not included data with a dipole magnetic field.

Comparison of EC Density Measurements

TE Wave in Grooved Chambers of TiN and Aluminum

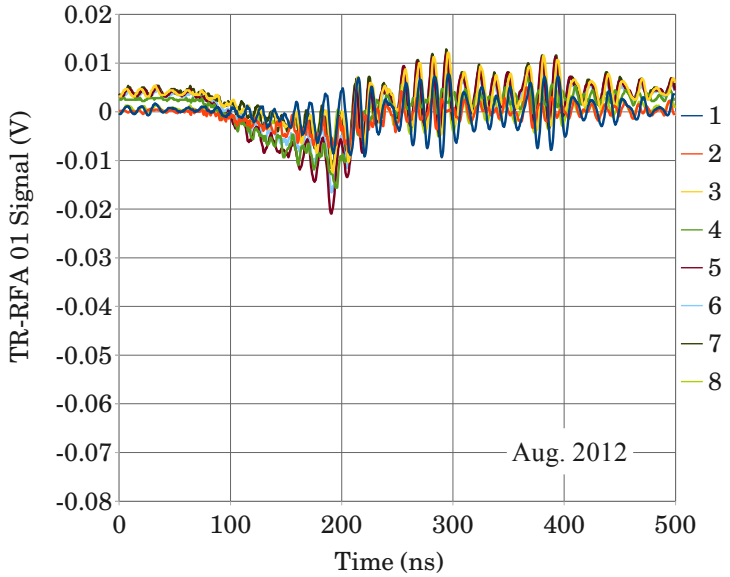


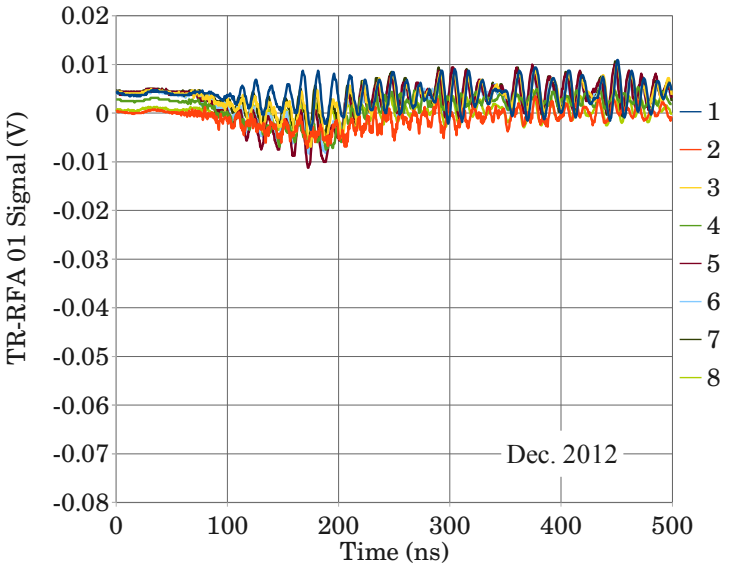


- Data is from the grooved chambers for 2 bunch and 10 bunch positron beams (14 ns).
- Both sets of data show the conditioning of TiN from August 2012 to April 2013.
- They also show the *increase* of the EC density in bare aluminum after processing.
- The grooved TiN and bare aluminum chambers also contain TR-RFAs.

Comparison of EC Density Measurements

TR-RFA Showing Beam Conditioning of TiN

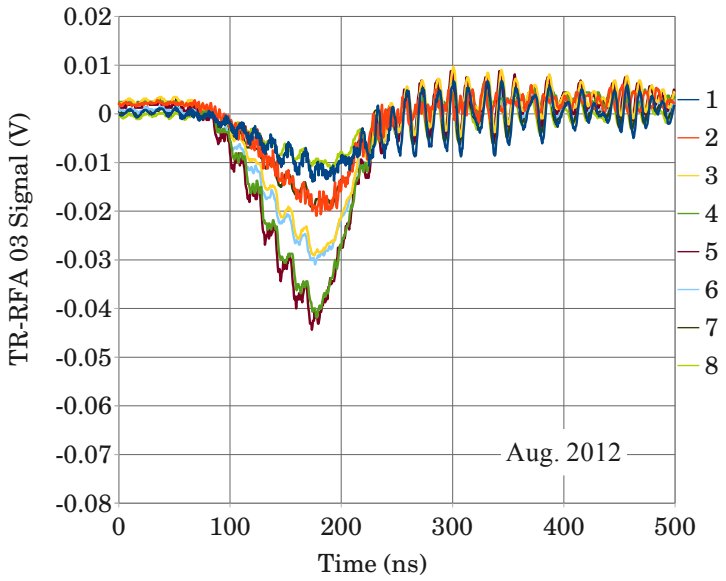


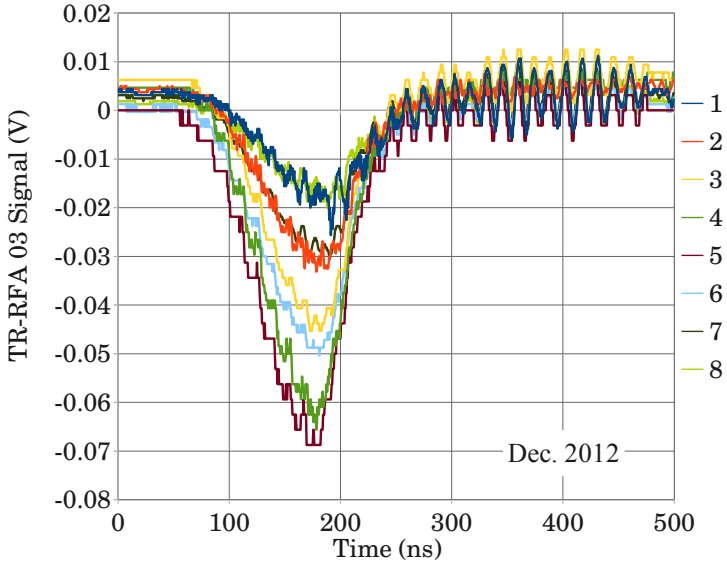


- TR-RFA data from the grooved chambers with a 10-bunch positron beam of 54mA total current (8.6 x 10^{10} /bunch) shows the conditioning of TiN from August to December 2012 (>600 amp-hours).
- The signals from 8 collectors are shown. The collectors are 6 mm wide and arranged across the detector to sample the electron flux at different horizontal positions.
- In this data, the magnetic field is zero.

Comparison of EC Density Measurements

TR-RFA Showing Increased Signal in Bare Aluminum

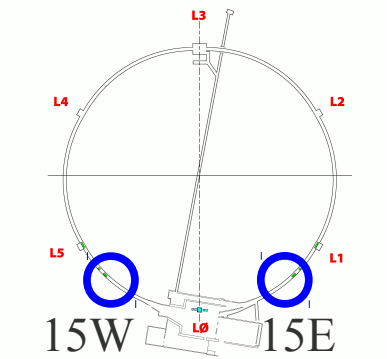


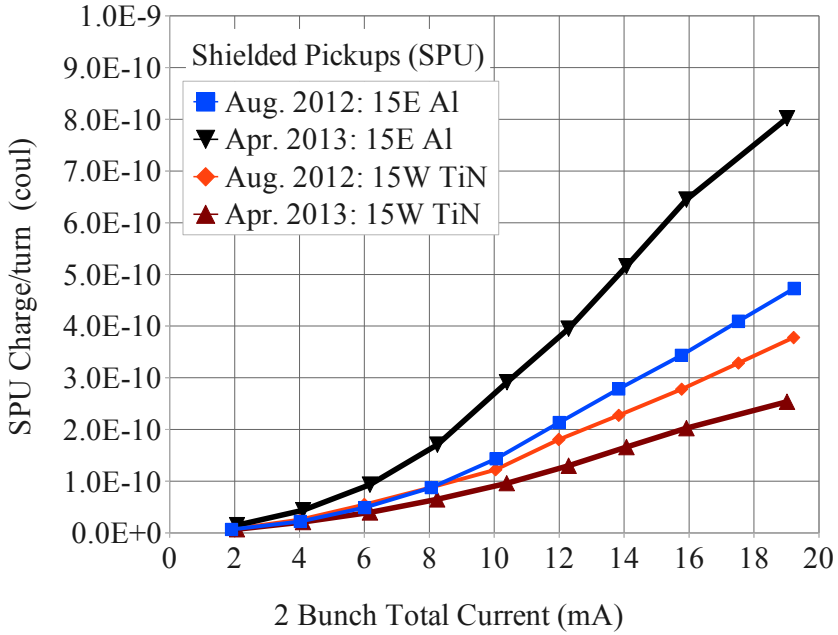


- This data is from the bare Al grooved chamber with a 10-bunch positron beam of 54mA total current (8.6 x 10^{10} /bunch) shows the *increased* signal of bare Al from August to December 2012.
- The largest signals are in collectors 4 and 5 that are near the horizontal center of the beam-pipe.

Comparison of EC Density Measurements

SPU Showing Beam Conditioning of TiN and Aluminum

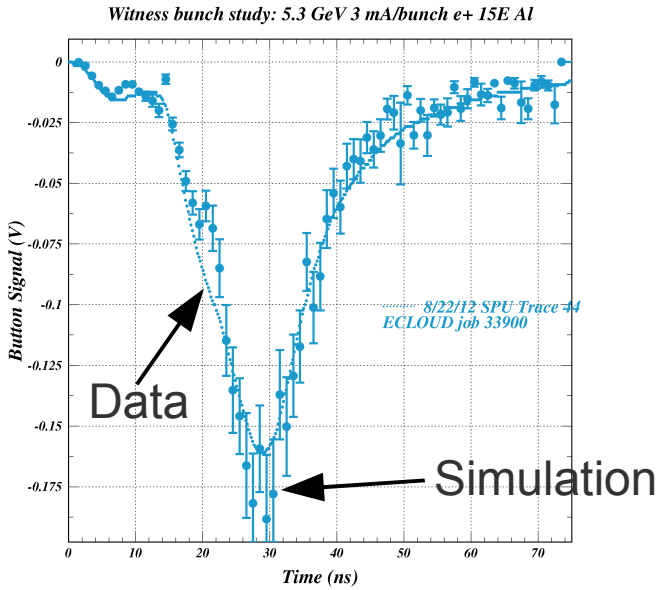




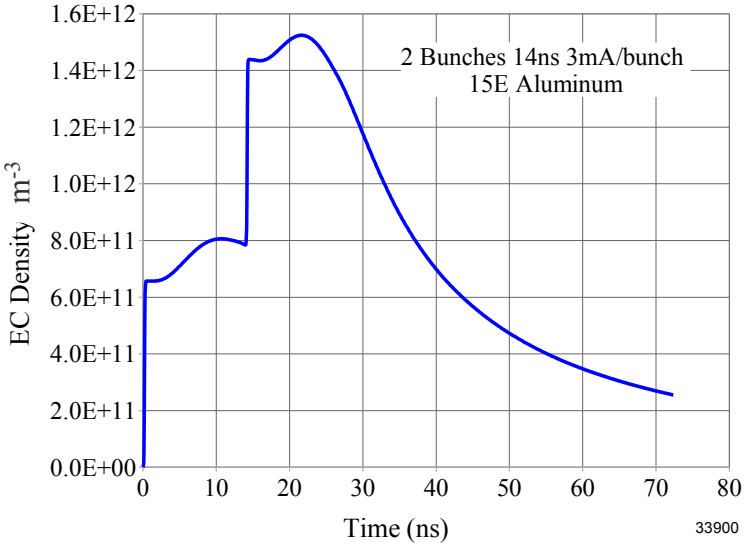
- Data is from 15W (TiN) and 15E (Aluminum)
- The plots are for 2 bunch (14 ns) positron beams showing conditioning of TiN from August 2012 (0.55 amp-hours) to April 2013 (>600 amp-hours).
- The data also shows an increase of signal in bare aluminum after processing.
- So, the increased signal in bare aluminum is not particular to the grooved chambers.

Comparison of EC Density Measurements

SPU Data and ECLOUD Simulation For Two Bunches in an Aluminum Chamber at 15E



SPU Data (dots) and ECLOUD simulation of the SPU signal (symbols with statistical error bars)

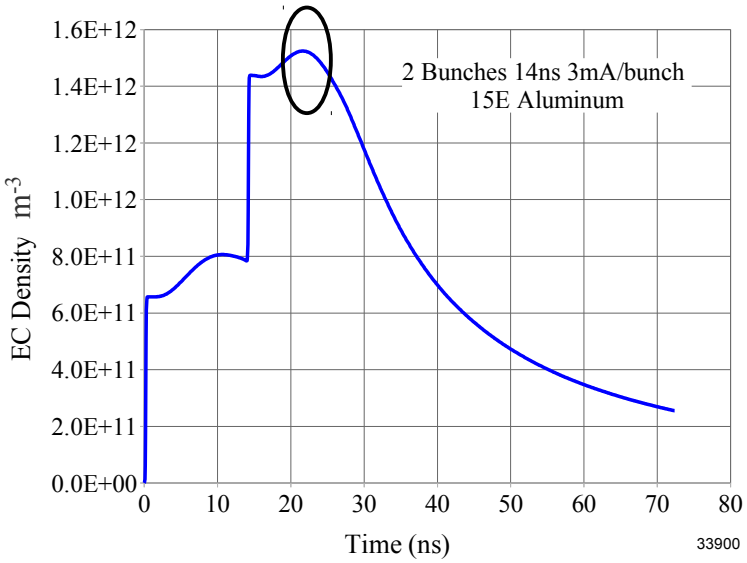


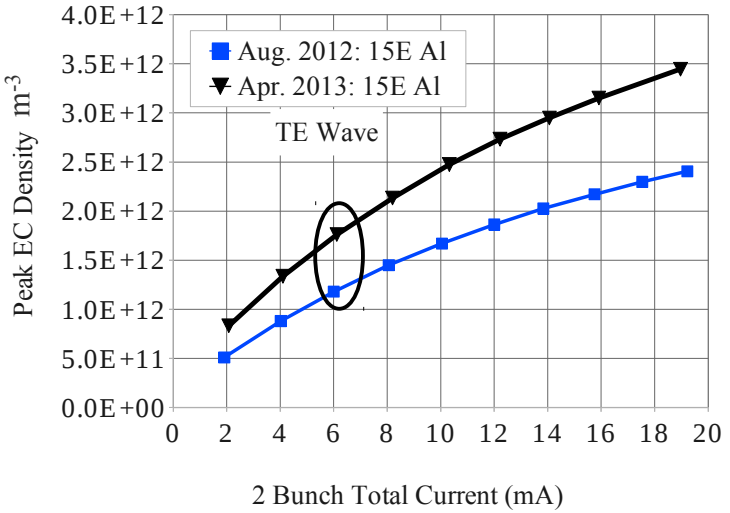
EC Density simulation from ECLOUD

- The left plot compares the measured SPU signal with the simulated SPU signal.
- The simulated SPU signal includes the EC density and SPU response.
- The right plot shows the simulated EC density used in that comparison.

Comparison of EC Density Measurements

Comparing Simulation with TE Wave Results at 15E

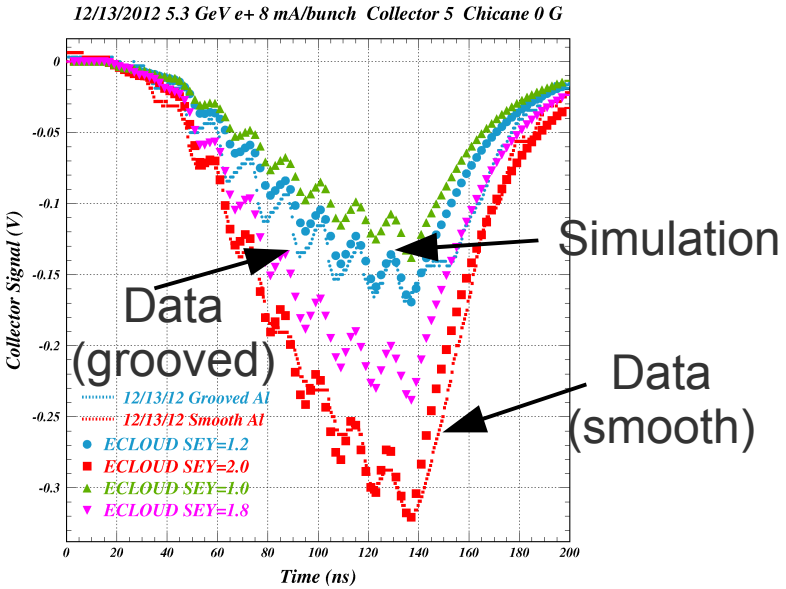




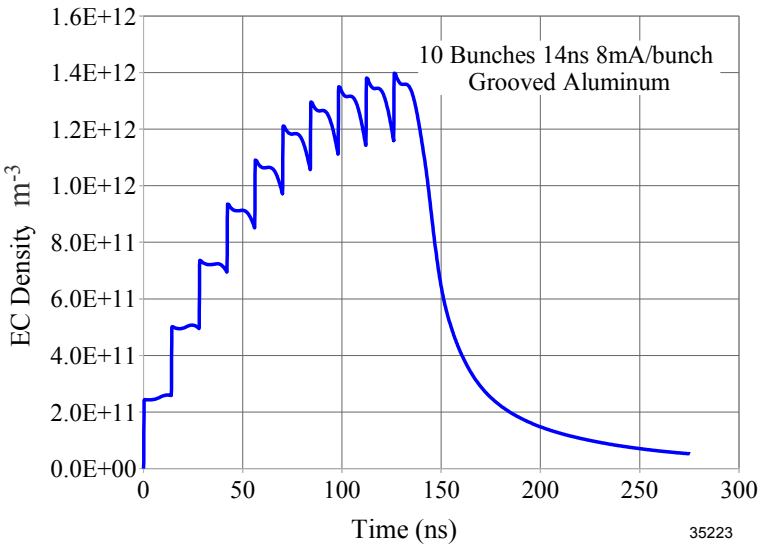
The peak EC density for 2 bunch simulation and TE wave data agree within a factor of 2.

Comparison of EC Density Measurements

TR-RFA Data and ECLOUD Simulation For Ten Bunches in Smooth and Grooved Chambers



TR-RFA data from smooth and grooved chambers are plotted with simulations using different SEY values.

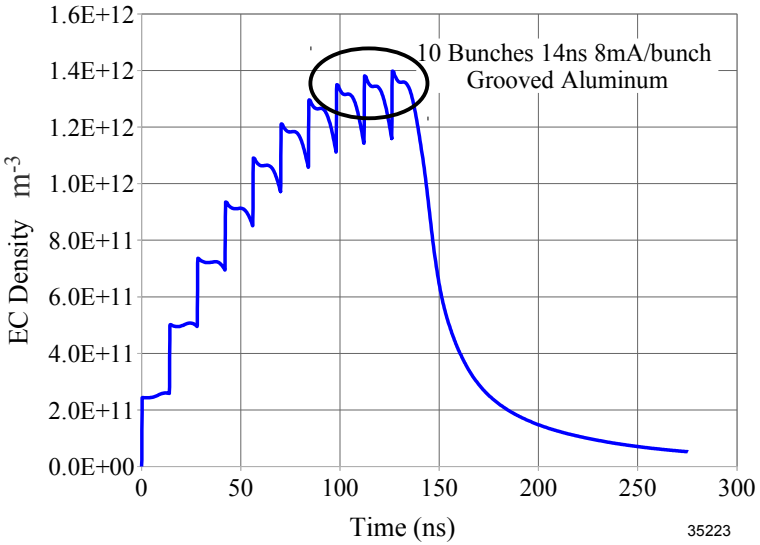


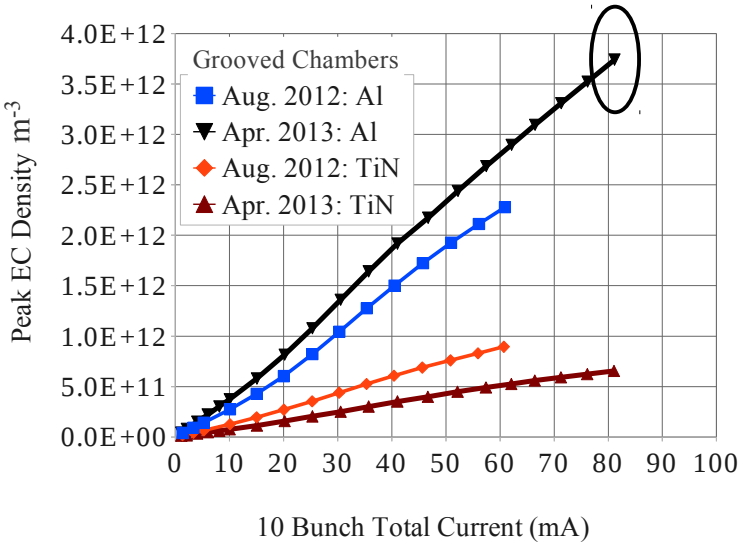
EC Density simulation from ECLOUD

- The left plot compares the measured TR-RFA signal with the simulated signals for different values of SEY. This gave an effective SEY for the grooved chambers.
- The right plot shows the simulated EC density used for the grooved chamber.
- The simulated signal includes the EC density and TR-RFA response.

Comparison of EC Density Measurements

Comparing Simulation with TE Wave Results

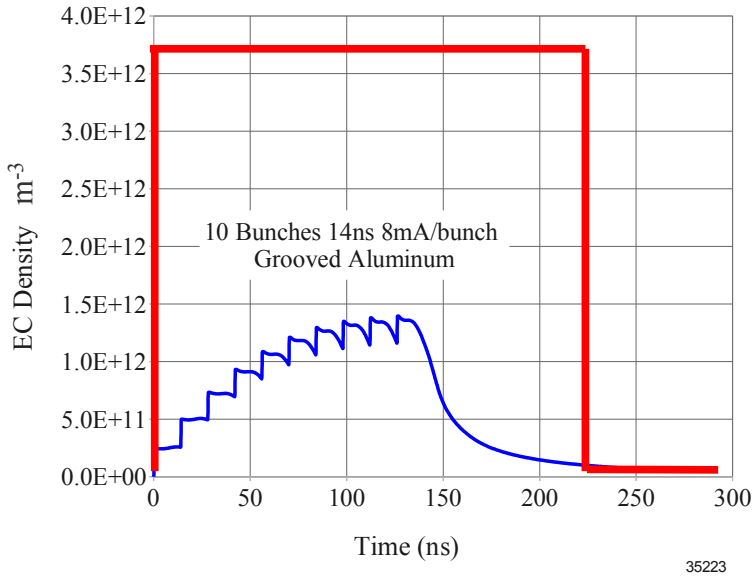


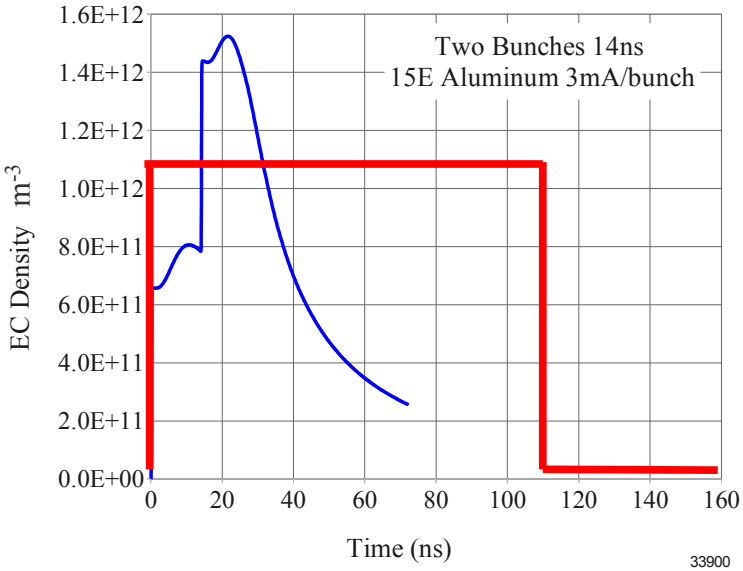


In this case, the TE wave measurement in the same chamber is higher than the simulation by more than a factor of two.

Comparison of EC Density Measurements

Comparing Simulation with TE Wave Assumptions





- The TE wave calculations have assumed an EC density that is a pulse having a width of the train length plus 100 ns (shown in red).
- This would be 226 ns for the 10 bunch train and 114 ns for the two bunches.
- These values are much longer than EC density given in the simulations (blue).
- Decreasing the widths would give a TE wave calculated EC density that is *even higher*.

- Further work is needed.

Summary and Future Work

- Under the same beam conditions, the EC density in a TiN coated chamber decreases after extensive beam processing (>600 amp-hours).
- In contrast, the EC density in a bare aluminum chamber increases with processing.
- The three measurement methods presented here agree qualitatively with this result.
- Data at intermediate stages of beam processing ($0.5 < I_{integrated} < 600$ amp-hours) should be examined to estimate the processing rate.

- ECLOUD simulations include the EC density and detector response.
- Simulation parameters have been adjusted to obtain a good match between the simulated and measured detector signals in both the SPU and the TR-RFA.

- A comparison of TE wave measurements with the improved simulations gives fair agreement with the 2-bunch SPU simulation, but poor agreement with the 10-bunch TR-RFA simulation.
- Additional work is required in TE wave analysis in order to connect these measurements with the results of simulations.

Comparison of EC Density Measurements

Thank you for your attention.

Additional information can be found in:

- "The CESRTA: Phase I Report," Tech. Rep. CLNS-12-2084, LEPP, Cornell University, Ithaca, NY (Jan. 2013). http://www.lns.cornell.edu/public/CLNS/2012/
- J. P. Sikora *et al*., "TE Wave Measurement and Modeling", in Proc. of ECLOUD'12, La Biodola, Isola d'Elba, Italy, June 5-8 2012.
- J.A. Crittenden *et al*., "Model Development for Time-Resolved Retarding Field Analyzer Measurements at CESRTA", in Proc. of IPAC'13, Shanghai, China, May 2013, MOPWA072, (2013).
- J. P. Sikora, *et al.*, "Time Resolved Measurement of Electron Clouds at CESRTA Using Shielded Pickups ," in Proc. of PAC'11, New York, NY, USA, August 2011, WEP195, p.1855, (2011).
- J.A. Crittenden, *et al*., "Electron Cloud Modeling Results for Time-resolved Shielded Pickup Measurements at CESRTA," in Proc. of PAC'11, New York, NY, USA, August 2011, WEP142, p.1752, (2011).
- J.P. Sikora, *et al*., "A Comparison of Electron Cloud Density Measurements at CESRTA", in Proc. of IPAC'13, Shanghai, China, May 2013, MOPWA071, (2013).