

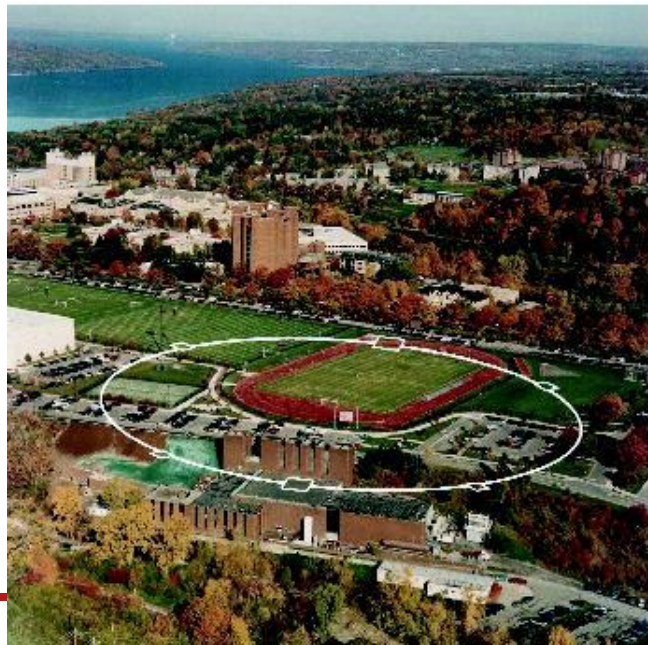


Cornell Laboratory for
Accelerator-based Sciences and
Education (CLASSE)

CESR TA Mitigation Studies & Inputs for the ILC DR Design

October 21, 2010

Mark Palmer
for the CESR TA Collaboration





- This talk represents what is essentially the first pass (of several which are anticipated) at taking the results from a wide range of experiments that have been conducted at CESR TA and incorporating them into design recommendations for the ILC damping rings
- Same disclaimer as given at ECLOUD`10, just 9 days ago
- **But...**
 - The CESR TA data is still under active analysis
 - Many of the analyses are still being developed
 - There is still cross-checking to do with both observations and analyses developed at other machines
 - There is still a great deal of cross-checking to do for internal consistency and validity of our results
 - **Nevertheless...**
 - A number of preliminary conclusions can be readily drawn
 - So, this is a project director's summary of a work still in progress...



- Inputs for ILC Damping Ring EC Mitigation Choice
 - Overview
 - Drift
 - Quadrupole
 - Bend
 - Wiggler
 - Photons and PEY
- Conclusion
- If time: RFA analysis status report

ECLOUD`10 Talks/Posters available at:

<http://edms.classe.cornell.edu/agenda/conferenceOtherViews.py?view=nicecompact&confId=10>



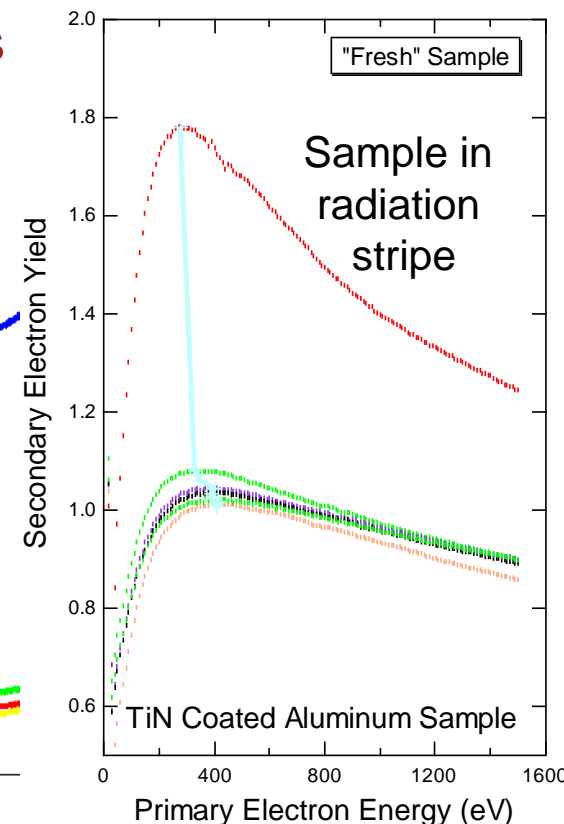
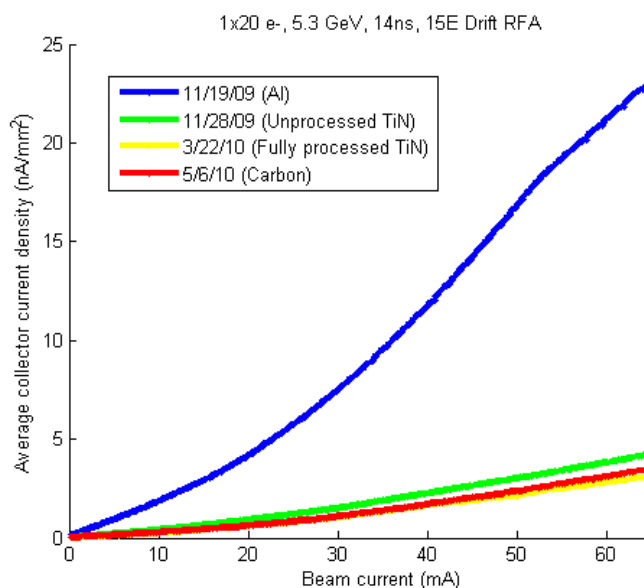
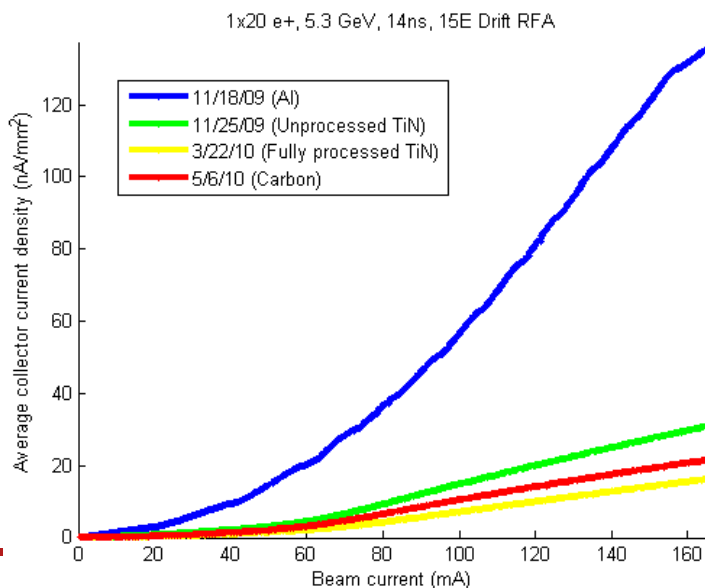
	Drift	Quad	Dipole	Wiggler	VC Fab
Al	✓	✓	✓		CU, SLAC
Cu	✓			✓	CU, KEK, LBNL, SLAC
TiN on Al	✓	✓	✓		CU, SLAC
TiN on Cu	✓			✓	CU, KEK, LBNL, SLAC
Amorphous C on Al	✓				CERN, CU
NEG on SS	✓				CU
Solenoid Windings	✓				CU
Fins w/TiN on Al	✓				SLAC
Triangular Grooves on Cu				✓	CU, KEK, LBNL, SLAC
Triangular Grooves w/TiN on Al			✓		CU, SLAC
Triangular Grooves w/TiN on Cu				✓	CU, KEK, LBNL, SLAC
Clearing Electrode				✓	CU, KEK, LBNL, SLAC

✓ = chamber(s) deployed ✓ = planned

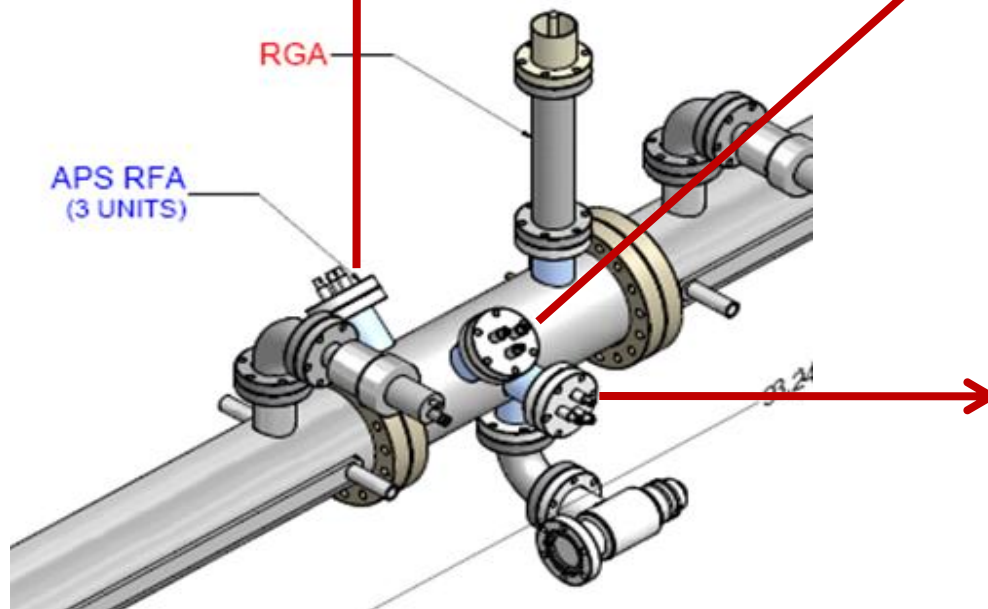
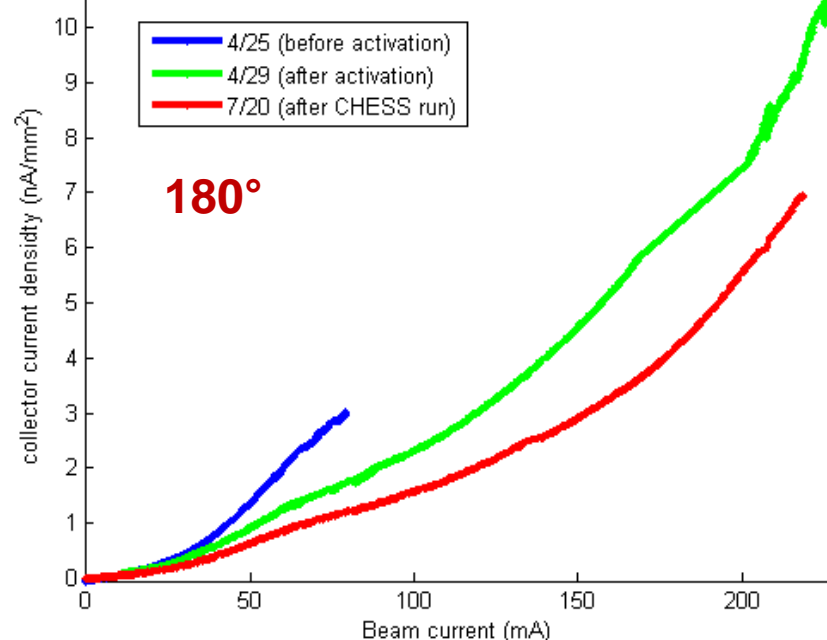
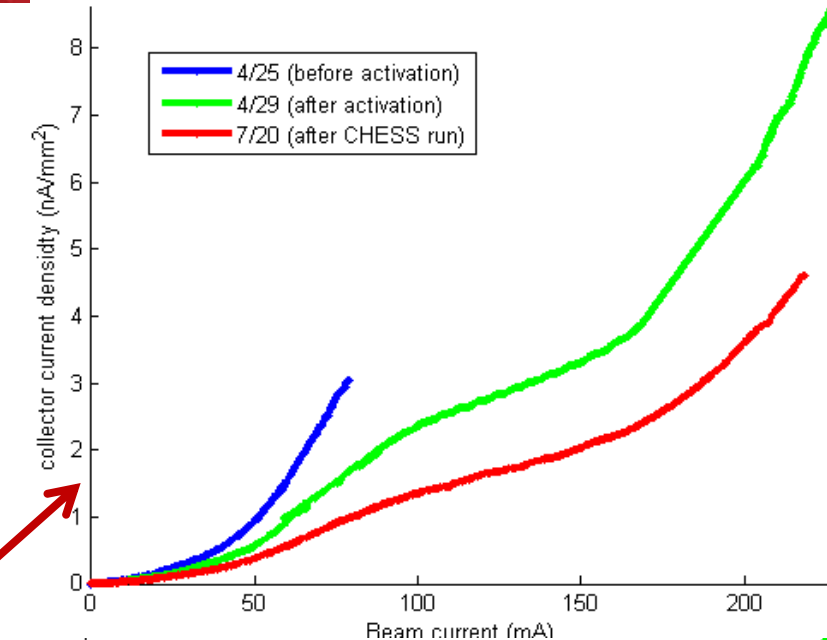
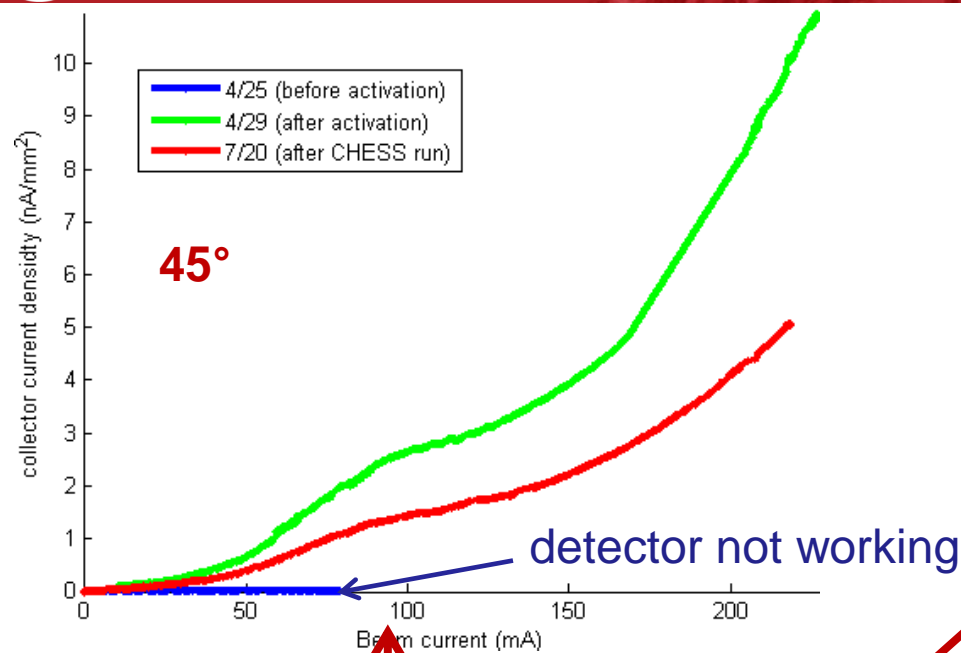


- Bare Al vs TiN coating vs amorphous C coating comparisons have been carried out using the Q15E/W test regions
 - Allows for detailed relative comparison as well as comparison with simulation to determine key surface parameters (ECLOUD10 talk and poster by J. Calvey)
 - EC performance of TiN and a-C found to be quite similar in regimes with significant SEY contributions as well as regimes which should be most sensitive to PEY
- NEG tests carried out in L3 region
 - Makes detailed comparison with Q15E/W tests more challenging
- Preliminary analysis of surface parameters indicates SEY performance by each of these 3 coatings
- Tests with other chamber types around the ring

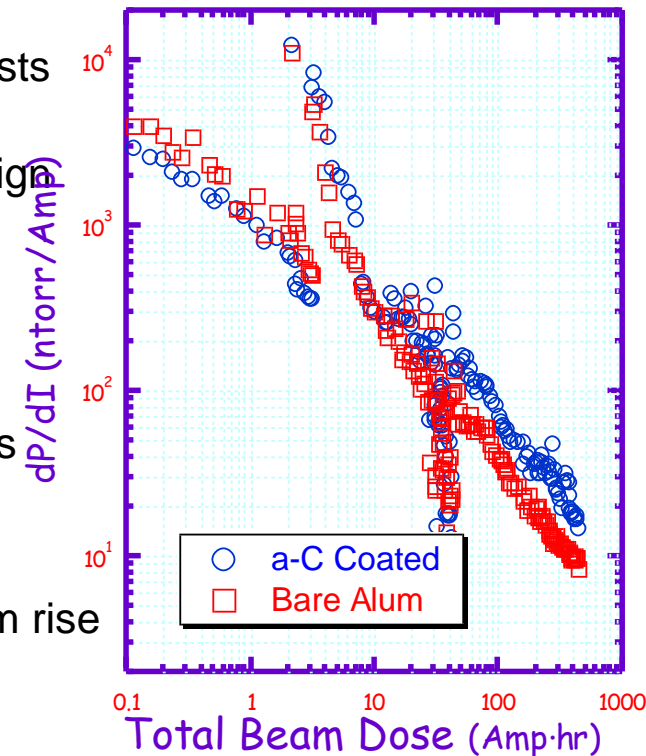
In Situ SEY Station



NEG Test Section Results



- **Efficacy**
 - At our present level of evaluation, TiN, a-C and NEG show performance consistent with peak SEY values near 1.
- **Cost**
 - TiN coating is simplest and cheapest, however, coating costs are not a major contribution to the overall DR cost
 - The use of NEG for vacuum does require that the ring design accommodate space for heating elements for activation
- **Risks**
 - Further monitoring of aging performance is desirable
 - The use of solenoid coils in addition to any of the coatings would likely assure acceptable EC performance in the drifts
- **Impact on Machine Performance**
 - NEG would benefit overall machine vacuum performance
 - a-C and TiN show somewhat higher beam-induced vacuum rise than bare Al
- **Caveats:**
 - Possible Si contamination?
 - 2 samples sent back to CERN after acceptance tests \Rightarrow presence of Si contamination in a-C chamber
 - Follow-on test of 1st a-C chamber (entire chamber sent to CERN) did not detect Si after beam exposure (surface wipe, not as thorough a test)
 - Surface parameter analysis is still not mature. Some caution should be exercised.




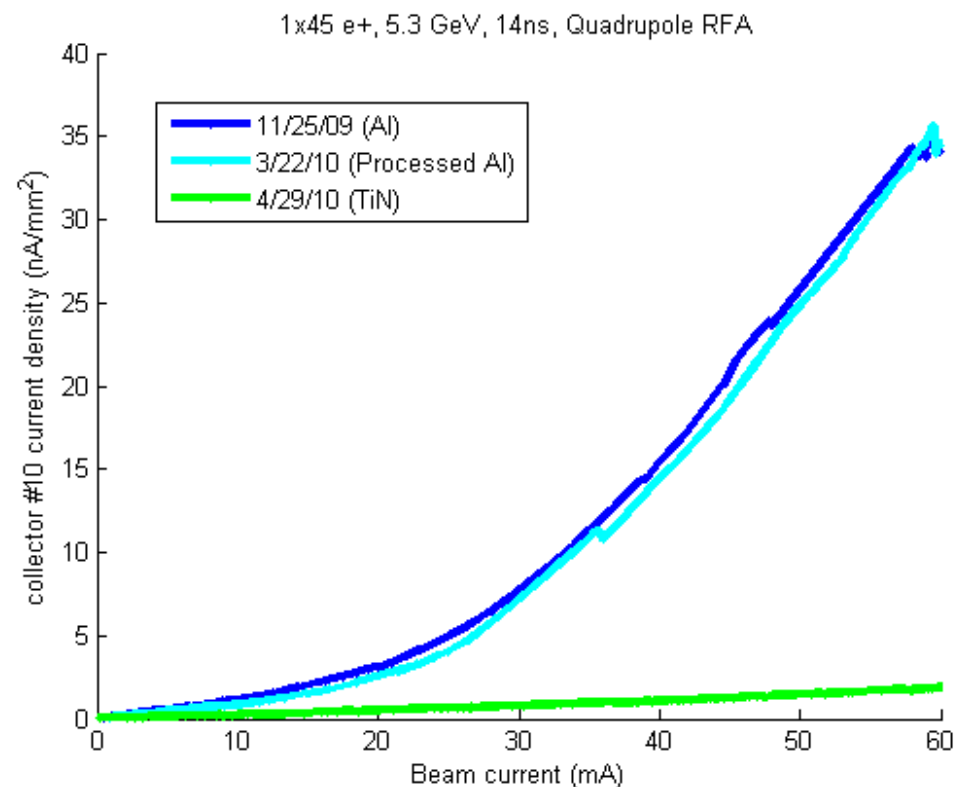
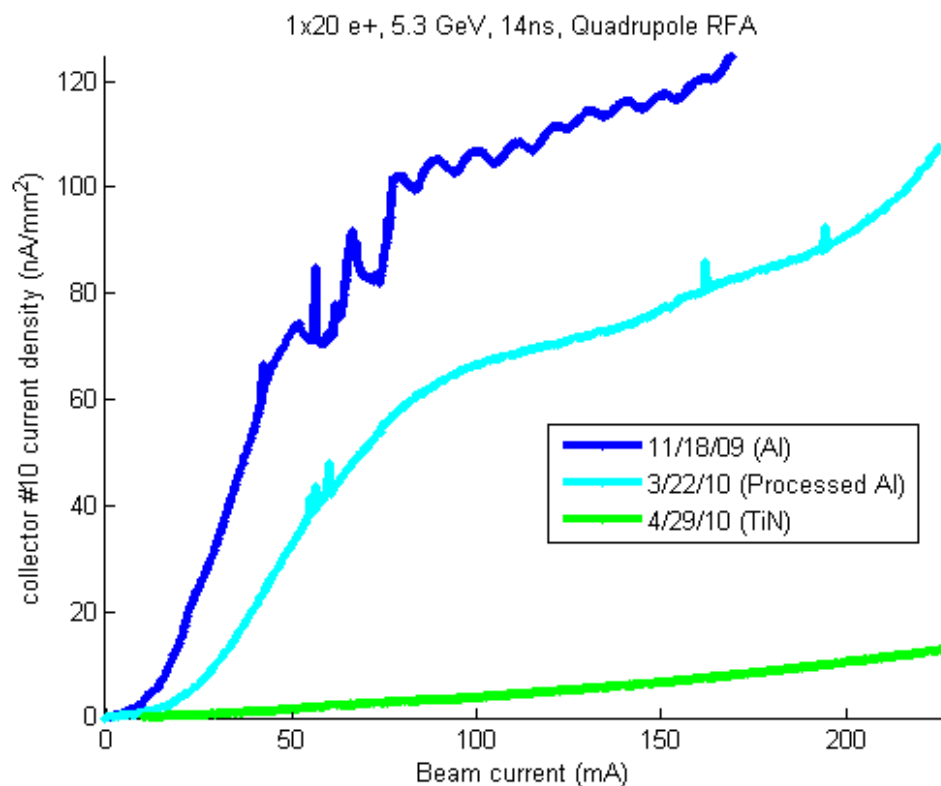


Overview of Mitigation Tests

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NEG on SS	✓				CU
Solenoid Windings	✓				CU
Fins w/TiN on Al	✓				SLAC
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Clearing Electrode				✓	CU, KEK, LBNL, SLAC

✓ = chamber(s) deployed ✓ = planned

- Left: 20 bunch train e⁺
- Right: 45 bunch train e⁺  Clear improvement with TiN
- Currents higher than expected from “single turn” simulations
 - Turn-to-turn cloud buildup
 - Issue also being studied in wigglers





- **Efficacy**
 - Strong multipacting on Al surface significantly suppressed with TiN coating
- **Cost**
 -
- **Risk**
 - Appears to be minimal with coating
 - Final evaluation of acceptable surface parameters in quadrupoles needed to decide whether coating (as opposed, say, to coating+grooves) is acceptable
- **Impact on Machine Performance**
 -



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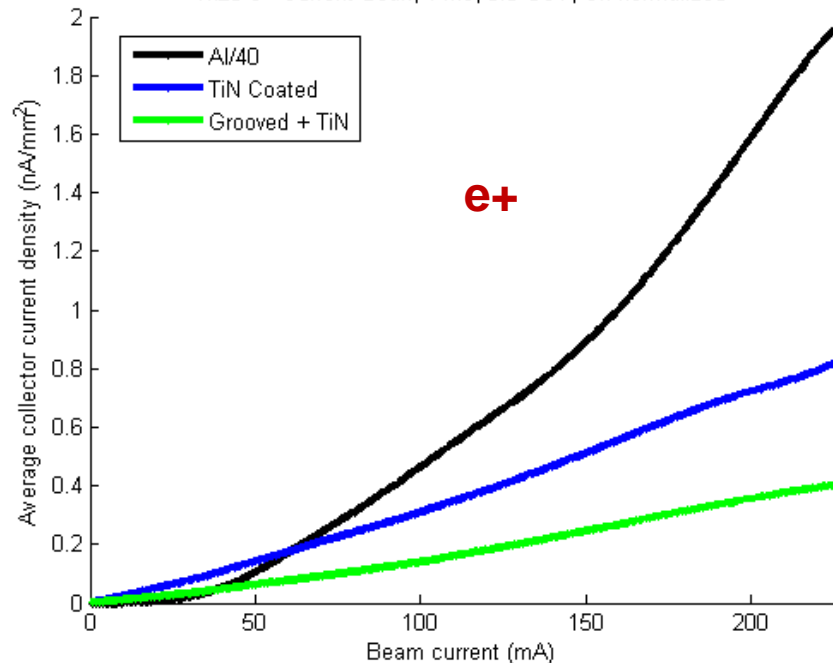
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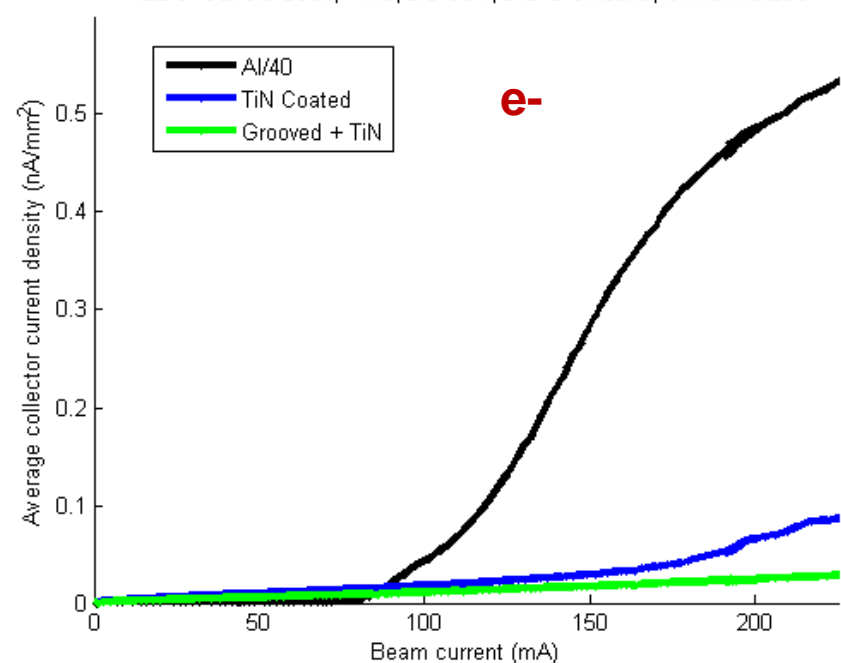
- 1x20 e+, 5.3 GeV, 14ns
 - 810 Gauss dipole field
 - Signals summed over all collectors
 - Al signals $\div 40$

Longitudinally grooved surfaces offer significant promise for EC mitigation in the dipole regions of the damping rings

1x20 e+ Current Scan, 14ns, 5.3 GeV, Un-normalized



1x20 e- Current Scan, 14ns, 5.3 GeV, 810 G Chicane, Un-normalized





- **Efficacy**
 - Of the methods tested, a grooved surface with TiN coating has significantly better performance than any other. Expect that other coatings would also be acceptable.
 - NOTE: Electrodes not tested (challenging deployment of active hardware for entire arc regions of the ILC DR)
- **Cost**
 - If grooves can be extruded, cost impact will not be high
- **Risk**
 - Principal concern is the ability to make acceptable grooved surfaces via extrusion
 - “Geometric suppression” limited by how sharp the tips and valleys of the grooves can be made
 - Coating helps ameliorate this risk
 - Machined surfaces of the requisite precision are both expensive and challenging
- **Impact on Machine Performance**
 - Simulations (Suetsugu, Wang, others) indicate that impedance performance will likely be acceptable



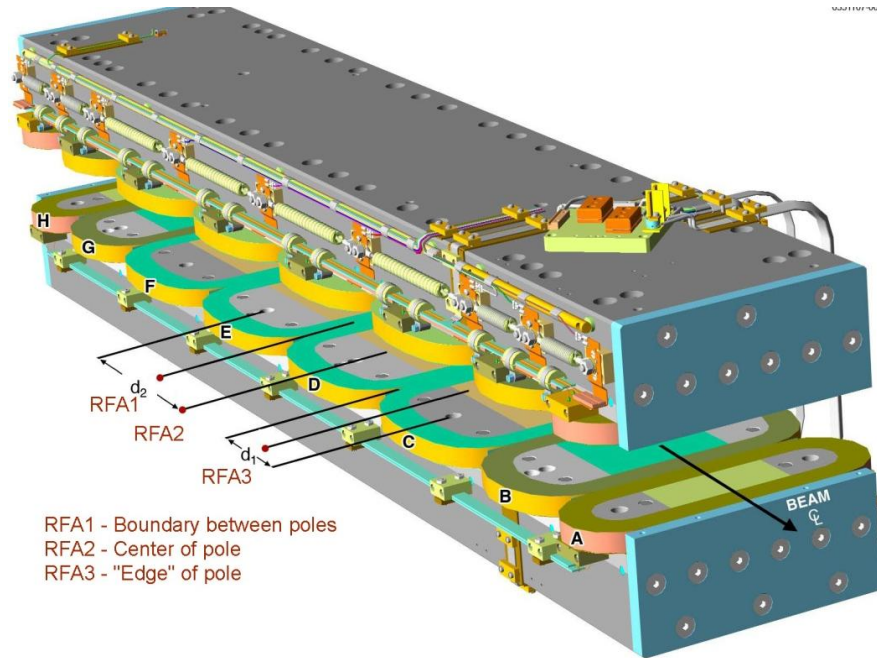
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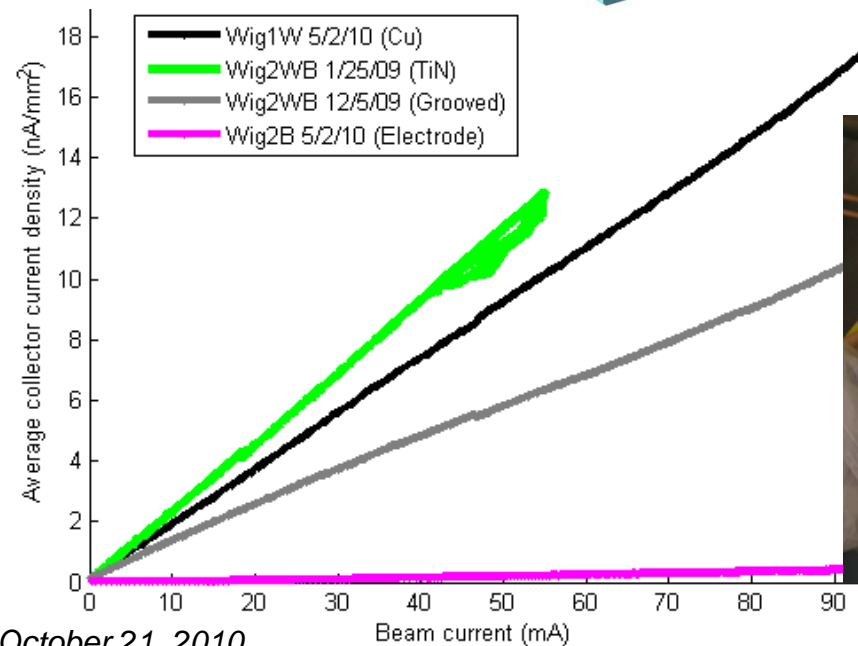
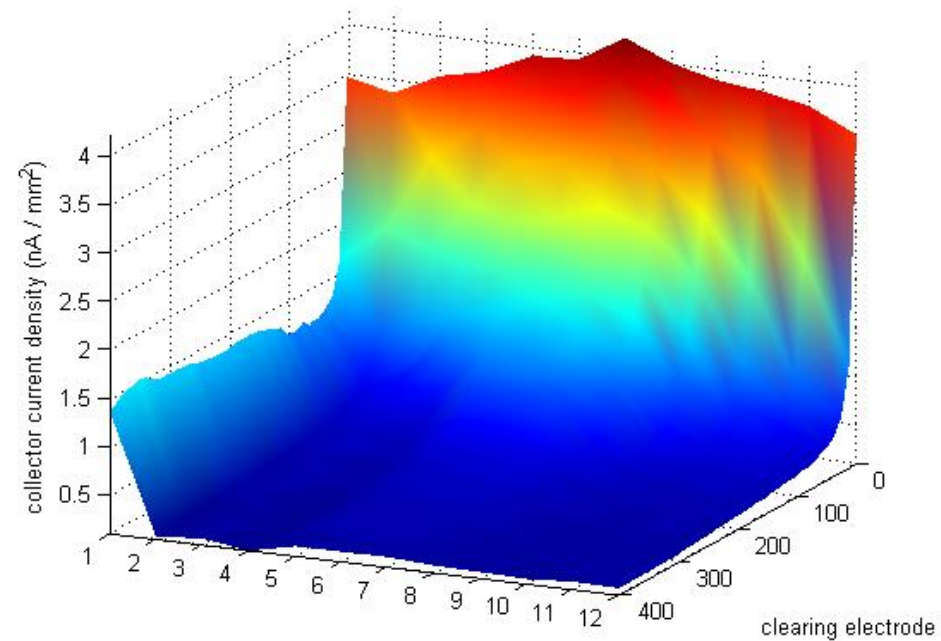


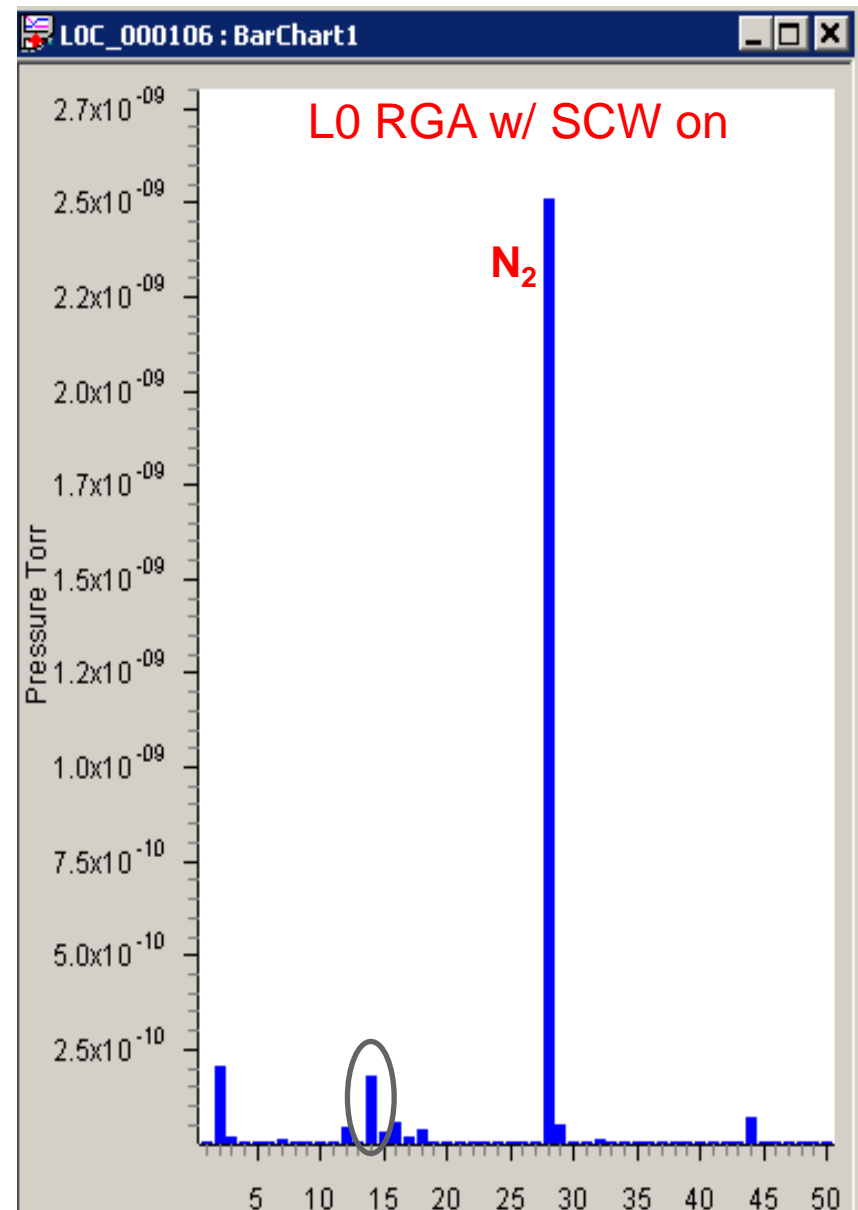
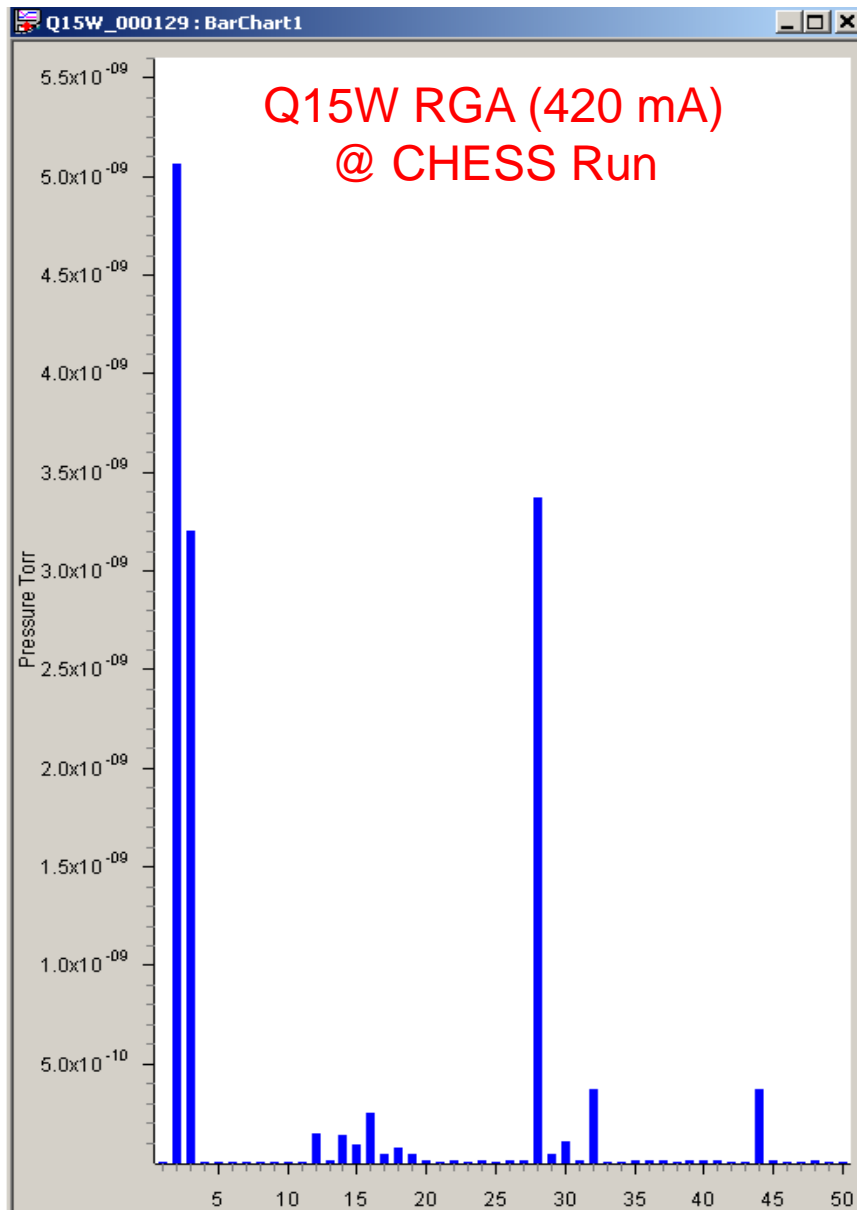
Wiggler Observations



RFA1 - Boundary between poles
RFA2 - Center of pole
RFA3 - "Edge" of pole

Run #2568 (1x20x2.8mA e+, 4 GeV, 14ns): 01W_G2 Center pole Col Curs





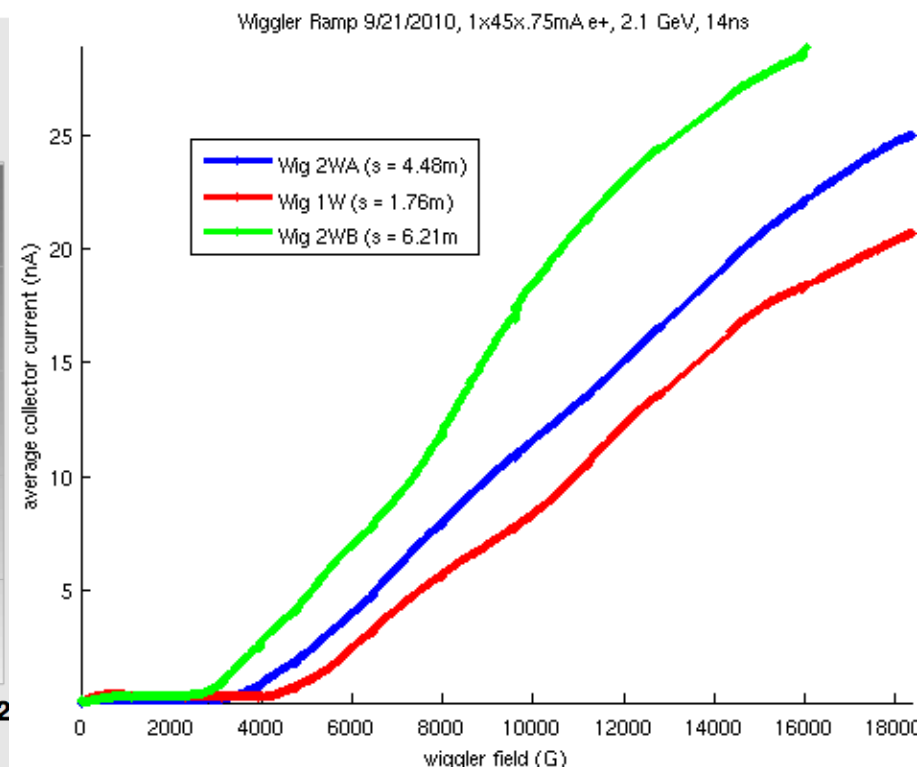
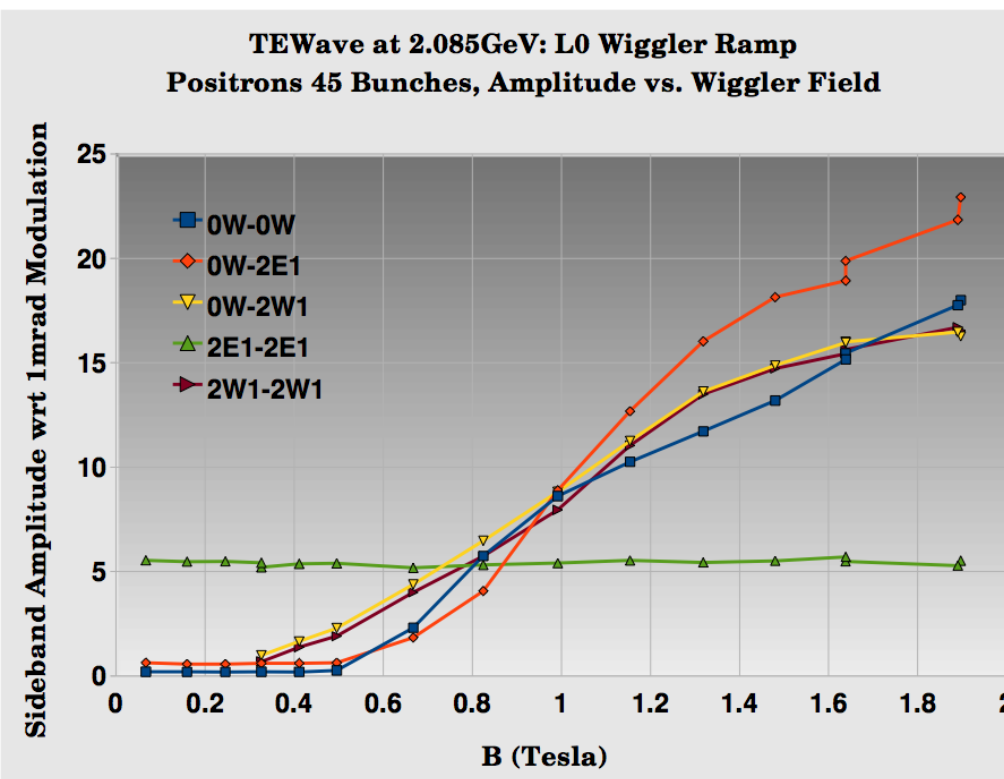


- **Efficacy**
 - Best performance obtained with clearing electrode
- **Cost**
 - Requirement for electrode application (addition E-beam welds) and HV vacuum feedthroughs will increase chamber cost
 - Also need power supplies and hardware to absorb HOM power
- **Risk**
 - Always concerns about electrode reliability
 - Thermal spray method offers excellent thermal contact
 - Ability to create “boat-tail” shape with no structural concerns helps to minimize HOM power
 - Feedthrough and HV connection performance probably single largest concern
- **Impact on Machine Performance**
 - Impedance should be acceptable for the limited length of the wiggler section (see, eg., evaluation by Y. Suetsugu)



- Our simulations and data indicate that we need to have a better photon and reflection transport model (see ECLOUD10 talks: QE fits in J. Calvey's talk, APS absorber-region data in K. Harkay's talk)
- Time-resolved measurements indicate that we also need to have a better PE spectrum (fitting of RFA data also requires this)
- Synrad3D offers a better reflection model, but there is still significant work to do
- Items still needing to be addressed
 - Diffuse scattering
 - As confirmed by our recent L0 wiggler measurements (see ECLOUD10 talks by J. Calvey, S. De Santis)
 - Surface roughness issues
 - As discussed yesterday
- Requirements for control of PE in the ILC DR (also the CLIC DR) make this a high priority for the upcoming months

- Plots show TE Wave and RFA response as a function of wiggler field strength
 - Beam conditions:
 - 1x45x~.75mA e+,
 - Normalized to beam current
 - 2.1 GeV, 14ns





- Mitigation performance:
 - Grooves are effective in dipole/wiggler fields, *but challenging to make when depth is small*
 - Amorphous C, TiN and NEG show similar levels of EC suppression so both coatings can be considered for DR use
 - TiN and a-C have worse dP/dI than Al chambers at our present level of processing
 - In regions where TiN-coated chambers are struck by wiggler radiation (high intensity and high E_c), we observe significant concentrations of N in the vacuum system
 - EC suppression with the clearing electrode in the wiggler is very good
 - No heating issues have been observed with the wiggler design in either CESR-TA or CHESS operating conditions
 - Further work remains to take RFA measurements in chambers with mitigations and convert these to the effective SEY of the chamber surfaces
 - Agreement between data and simulation continues to improve
 - Magnetic field region model requires full inclusion of RFA in simulation
 - In situ SEY measurements raise the question of how the SEY varies around the chamber azimuth



- Trapping and build-up of the EC over multiple turns in quadrupole and wiggler chambers
 - Experimental signature and seen in simulation
 - Further evaluation of impact on the beam is required
- Time-resolved studies (shielded pickups) [See Tuesday's Talk]
 - Being applied to understand SEY at ~ 0 energy, $\delta(0)$, which determines EC decay rates
 - Have already shown discrepancies in the PEY spectra being used (e- beam data)
- Photon transport models
 - Detailed 3D simulation show significant differences from models typically used
 - Significant implications for modeling assumptions in regions with high photon rates (arc and wiggler regions)
 - Likely still need to add some features (diffuse scattering, surface roughness) to the modeling
- Instabilities and sub-threshold emittance growth [See Mike Billing's Talk]
 - Measurement tools are rapidly maturing
 - Coordinated simulation effort with a focus on testing predictions
 - Systematic studies, so far, are showing many features that we can understand with our models, but also some surprises
 - This area needs continued effort including more detailed data-simulation comparisons

- The next steps

- Through mid-2011, we expect to focus heavily on analysis and detailed documentation of the studies that we've completed so far
 - Provide inputs for the ILC Technical Design
 - Identify key areas for follow-up
- Expect that we will want to conduct a number of additional experiments for further clarification
 - 2 week run planned for late December
 - Waiting on funding for Phase II program



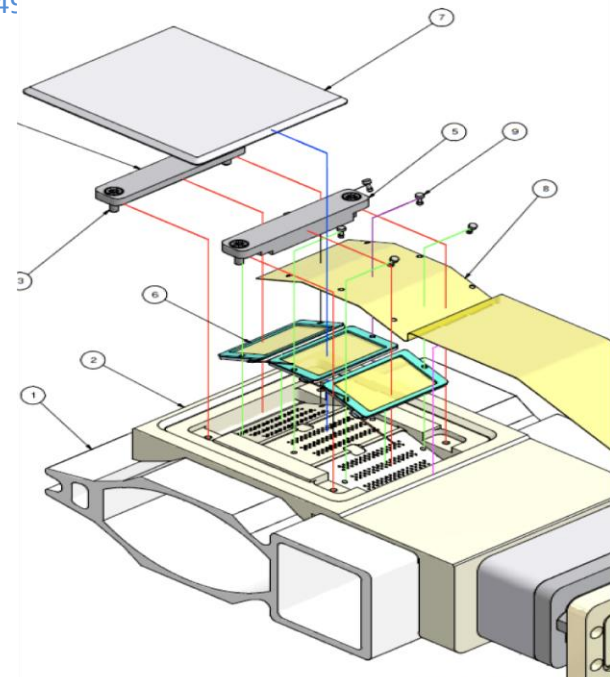
- Would like to spend a few minutes on one more topic, if time permits
- The following slides are from Joe Calvey, presented at ECLOUD`10
- One of the goals of the CESRTA simulation effort has been to make the attempt to take data obtained from the RFAs and to use it to evaluate surface parameters for the mitigations being tested...



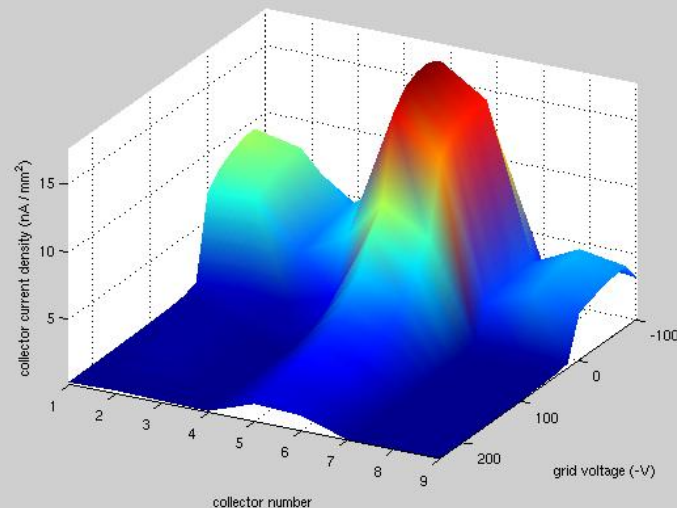
- Goal: Use RFA data to provide constraints on the surface parameters of the chamber --> a challenging exercise
- Requires cloud simulation program (e.g. POSINST or ECLOUD)
- Also need a model of the RFA itself
 - Method 1: post-processing
 - Perform a series of calculations on the output of a simulation program to determine what the RFA would have seen had it been there
 - Relatively easy, can perform an entire “voltage scan” on the output of one simulation
 - Method 2: integrated model
 - Put a model for the RFA in the actual simulation code
 - More self-consistent, can model effects of the RFA on the development of the cloud
 - Need to do a separate simulation for each retarding voltage

J. Calvey

40



Run #2983 (1x45x1.25mA e+, 5.3 GeV, 14ns): 13W_G2 B15W (drift) Col Curs



- RFAs consist of...
 - Holes drilled into the beam pipe to allow electrons to pass through
 - A “retarding grid” to which a negative voltage can be applied, rejecting any electrons which have less than a certain energy
 - A collector which captures any electrons that make it past the grid
 - Often there are several collectors arranged transversely across the top of the beam pipe
 - Left: CESR thin drift RFA
- So RFAs provide a local measure of the electron cloud density, energy distribution, and transverse structure
- There are two common types of RFA measurements
 - “Voltage scans,” in which the retarding voltage is varied, typically between +100 and -250V
 - “Current scans,” in which the RFA passively monitors while the beam current is gradually increased

- **Beam pipe hole secondaries**

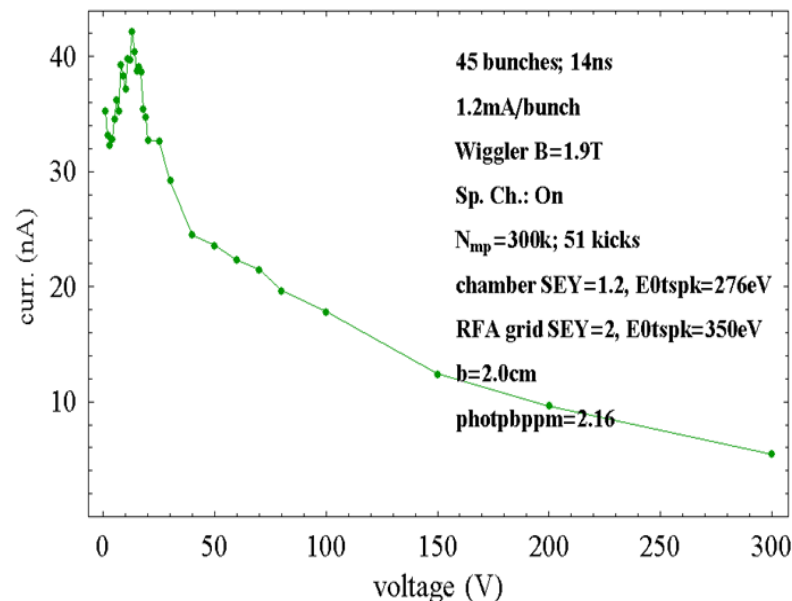
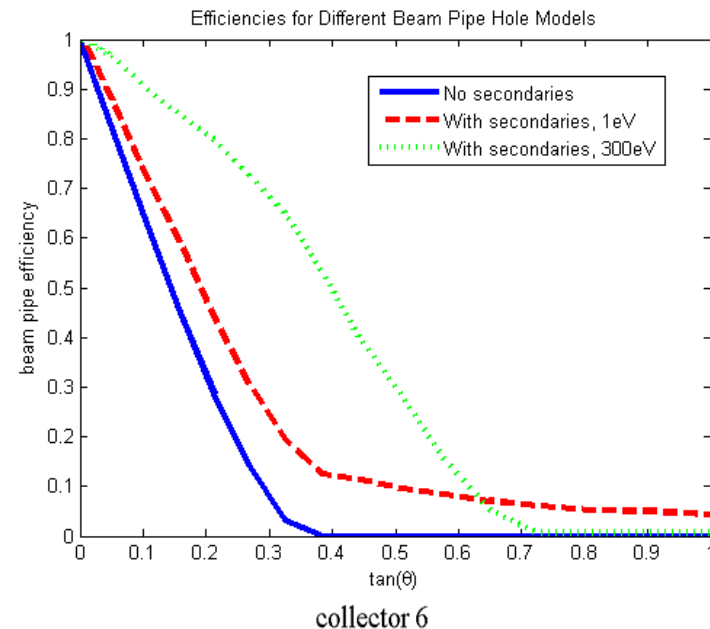
- Secondary electrons can be generated in the beam pipe holes in front of the RFA, leading to a low energy enhancement in the RFA signal.
- We have developed a specialized particle tracking code to quantify this effect.
- This code indicates low energy electrons maintain some probability of a successful passage even at high incident angle (due to elastic scattering)
- High energy electrons have a higher efficiency at intermediate angles (due to the production of "true secondaries."

- **Photoelectron model:**

- The traditionally used low energy photoelectrons do not provide sufficient signal for electron beam data with high bunch current.
- A Lorentzian photoelectron energy distribution with a wide width (~ 150 eV) has been added to POSINST.

- **Interaction with cloud:**

- The "resonant enhancement" has been observed qualitatively with integrated models in ECLLOUD in POSINST



J. Calvey



- Need a systematic method to extract best fit simulation parameters from large amount of data.
- 1. Choose a set of (related) voltage scans
- 2. Choose a set of simulation parameters
- 3. Do a simulation with the nominal values for each parameter
- 4. Postprocess the output of simulations to obtain a predicted RFA signal
- 5. For each data set and each parameter, do a simulation with a high and low value of the parameter, and determine the predicted RFA signal
- 6. For each data point in the simulated voltage scan, do a best linear fit to the curve of RFA signal vs parameter value. The slope of this line determines how strongly this point depends on the parameter
- 7. Try to find a set of parameters that minimizes the difference between data and simulation, assuming linear dependence of each voltage scan point on each parameter.
- 8. Repeat the process until fits stop getting better
- Simulations have been done for

beam conditions shown in table

Condx #	Run #	Bunches	Spacing (ns)	Energy (GeV)	Bunch Current (mA)	Species
20	2615	20	14	5.3	2.8	e+
21	2619	20	14	5.3	10.75	e+
22	2624	45	14	5.3	0.75	e+
23	2626	45	14	5.3	1.25	e+
24	2628	45	14	5.3	2.67	e+
25	2632	9	280	5.3	4.11	e+
26	2635	20	14	5.3	2.8	e-
27	2642	20	14	5.3	10.75	e-
28	2647	45	14	5.3	0.8	e-
29	2651	45	14	5.3	1.25	e-
30	2655	9	280	5.3	3.78	e-

J. Calvey





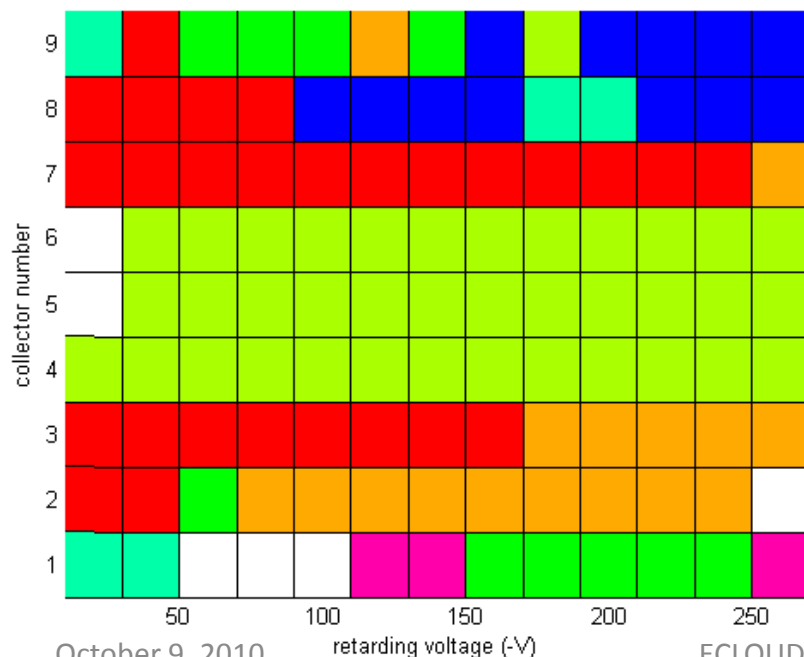
J. Calvey

- We want to understand where each parameter matters the most
 - Plots show the “strongest” (i.e. highest slope) parameter, as a function of retarding voltage and collector number, for various conditions
 - Color coded according to legend to the left
- Examples shown are for Aluminum chamber

	dtspk (true secondaries)
	P1rinf (rediffused)
	delta0 (yield at E=0)
	E _{max} (peak energy)
	e ⁺ quantum efficiency
	e ⁻ quantum efficiency
	primary energy width, e ⁺
	primary energy width, e ⁻
	beam displacement

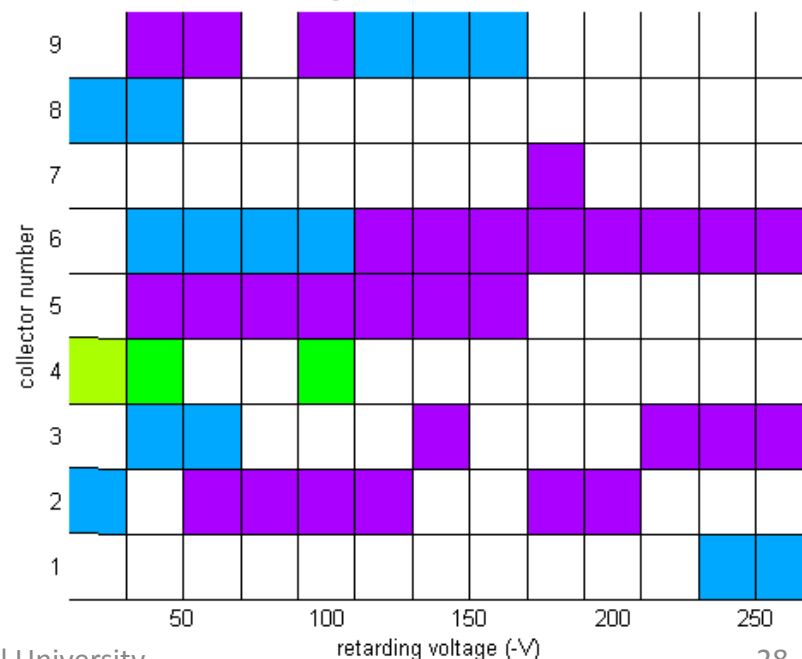
1x20x10.75mA, e⁺, 14ns

Strongest Parameter, Condx #21

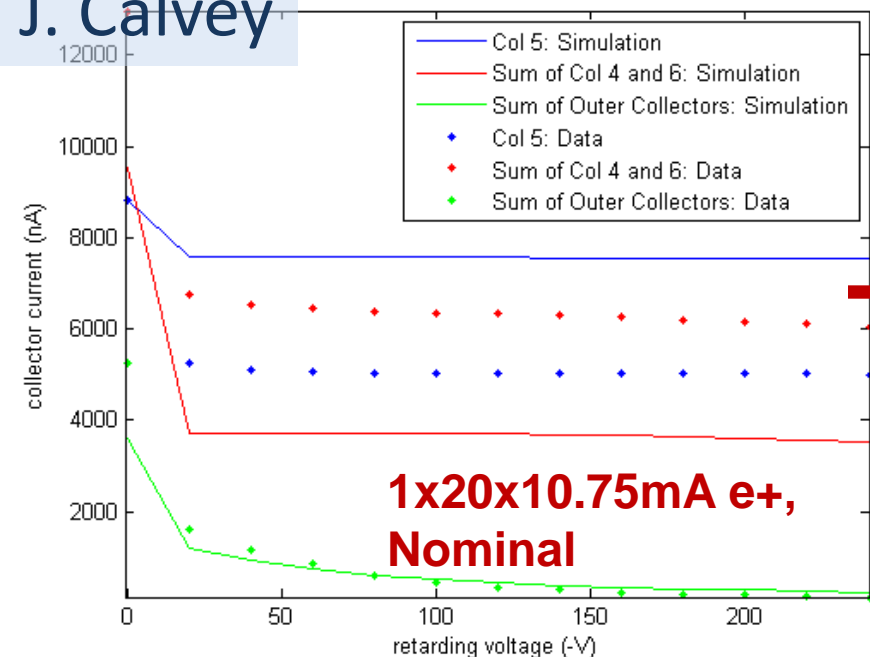


9x1x4 mA, e⁻, 280ns

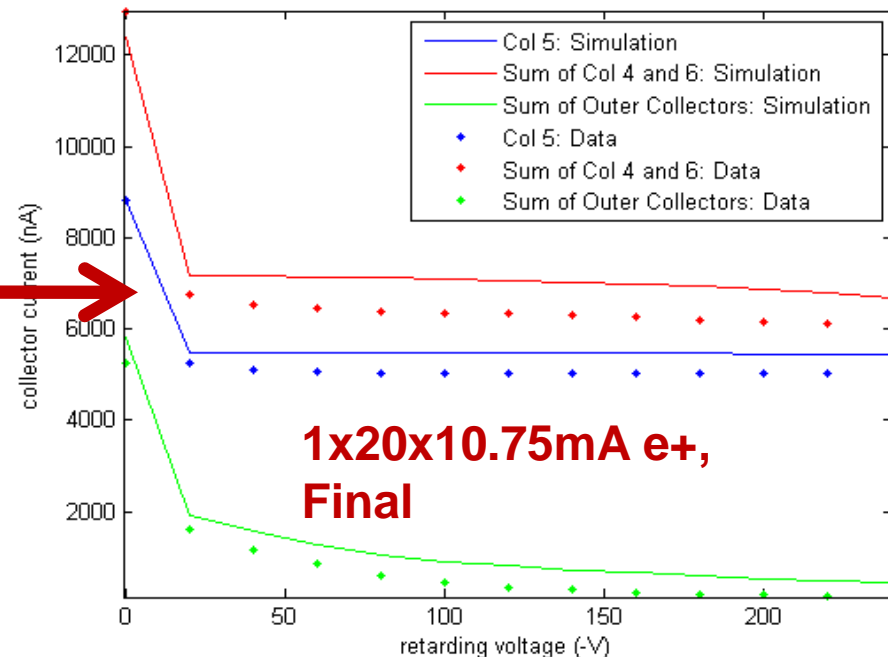
Strongest Parameter, Condx #30



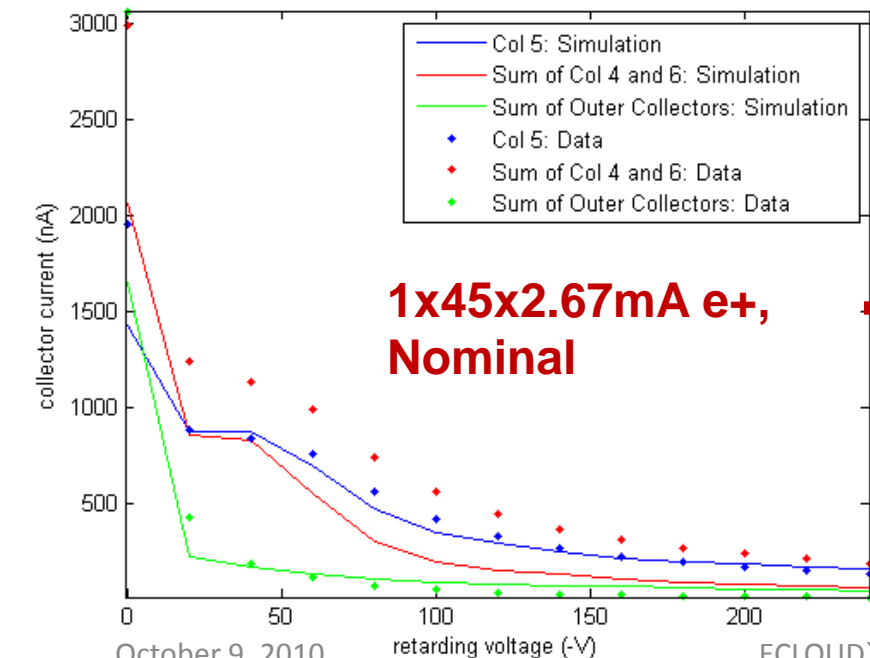
Base Parameters- Collector Comparison, Condx #21



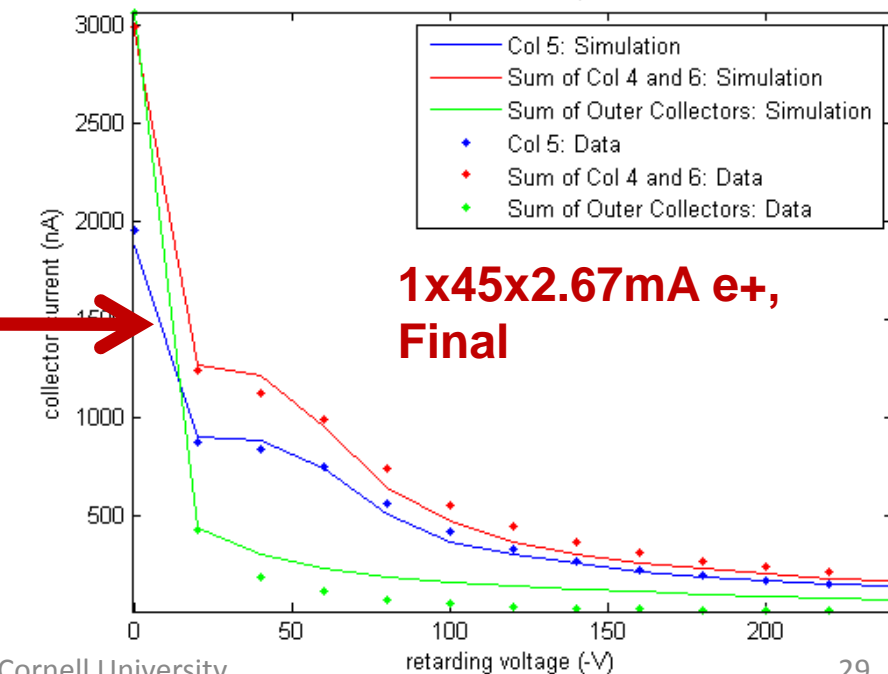
Final Parameters- Collector Comparison, Condx #21

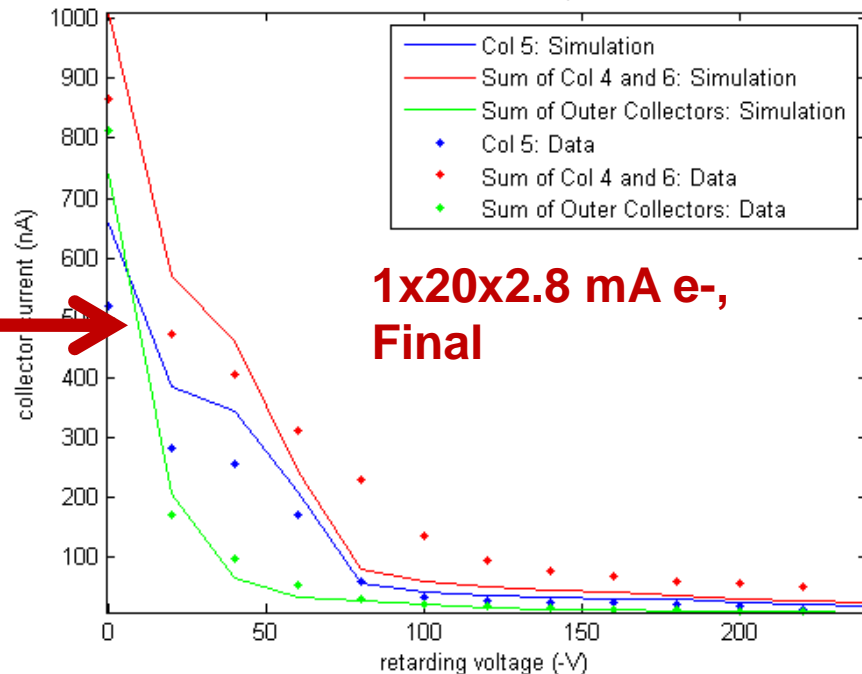
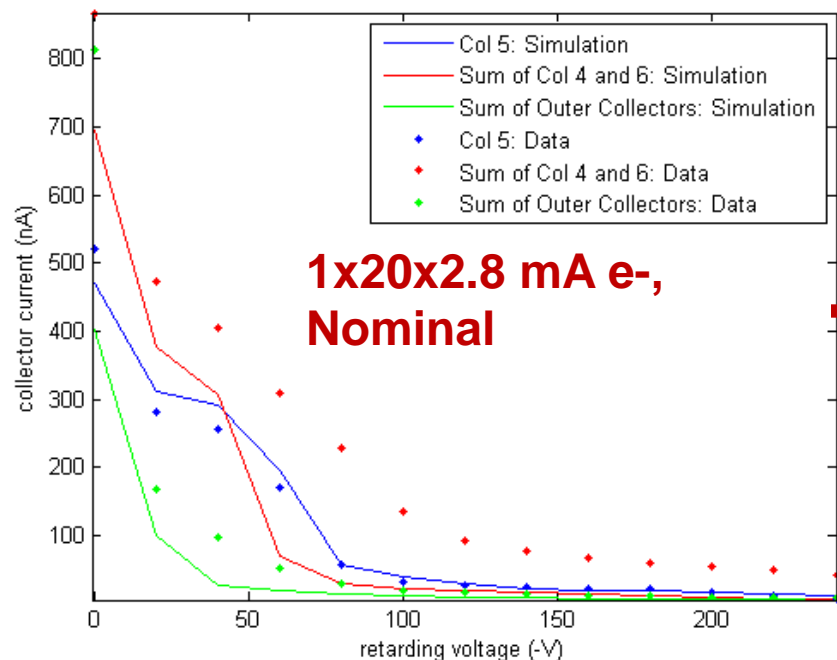
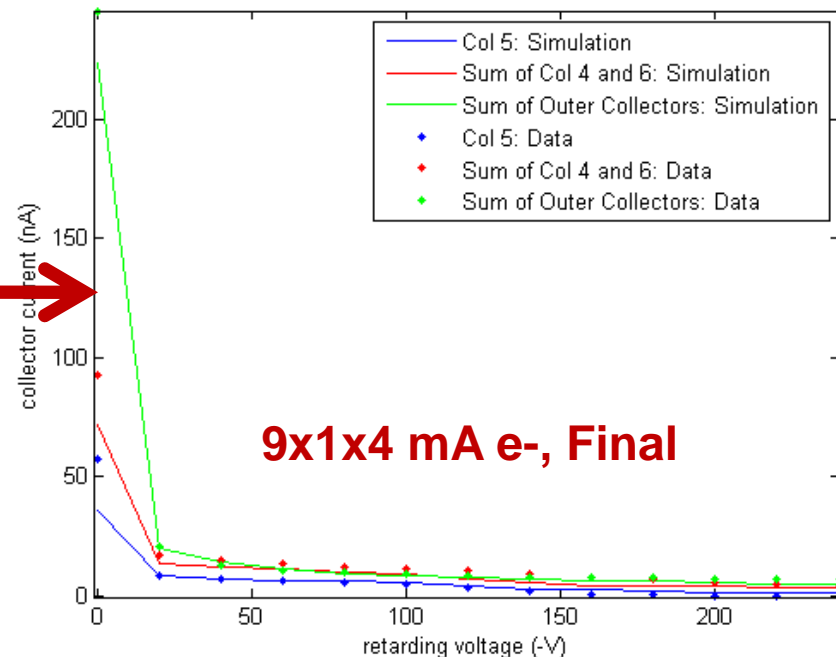
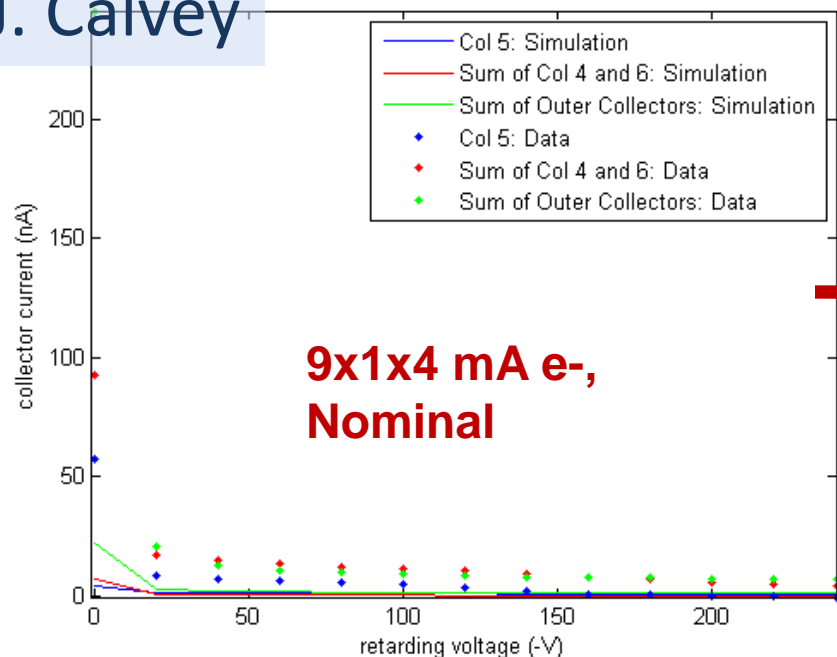


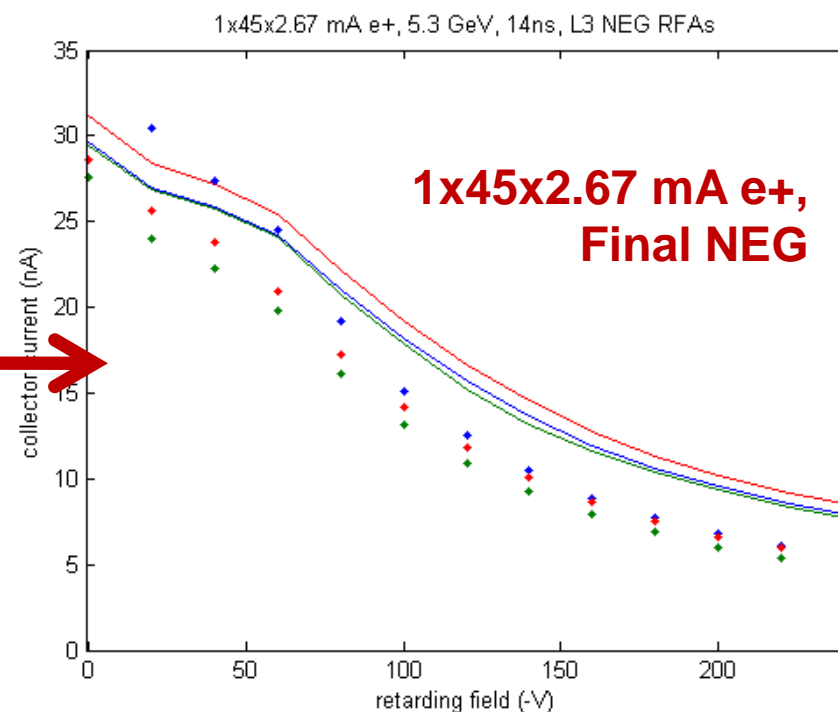
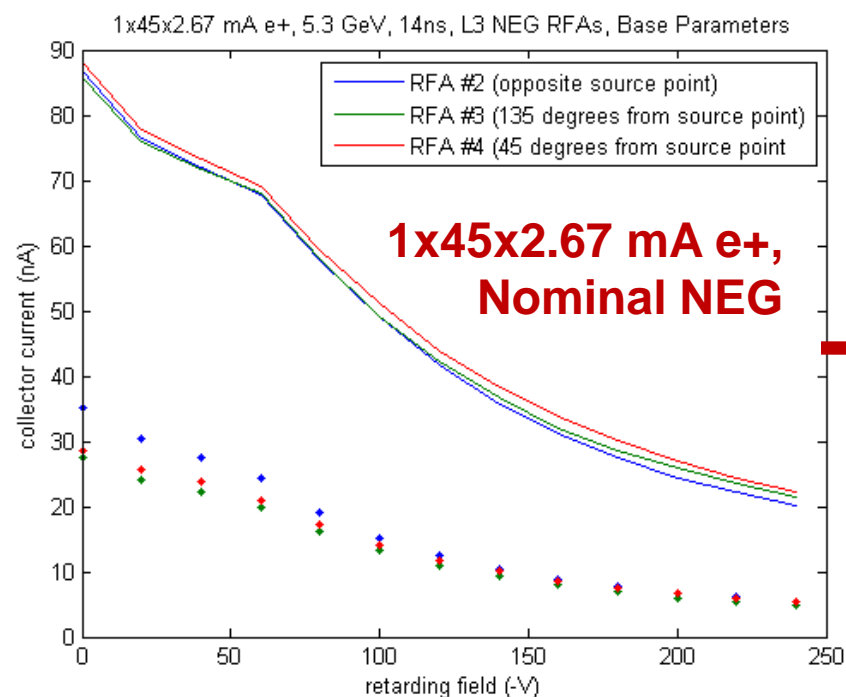
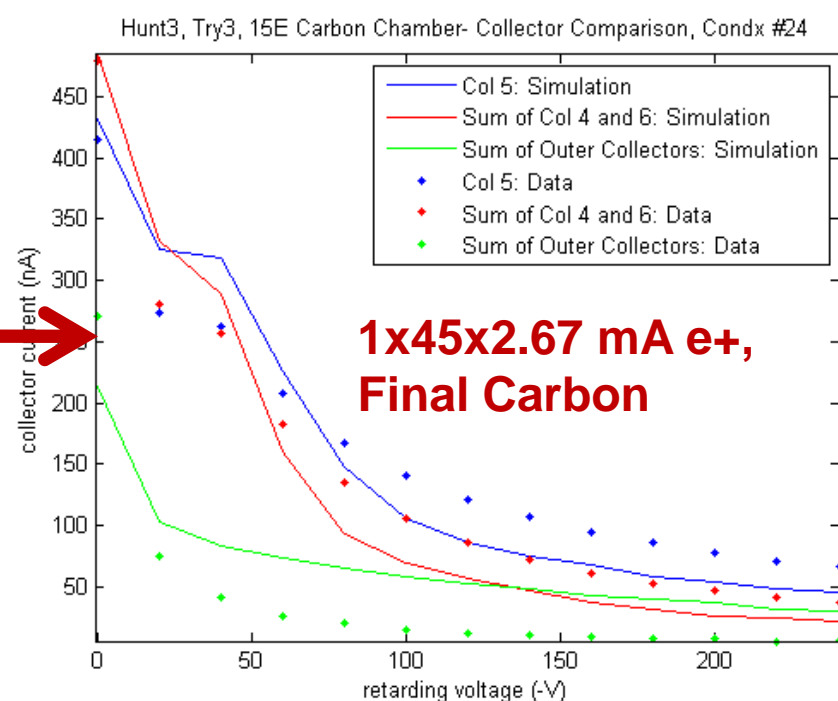
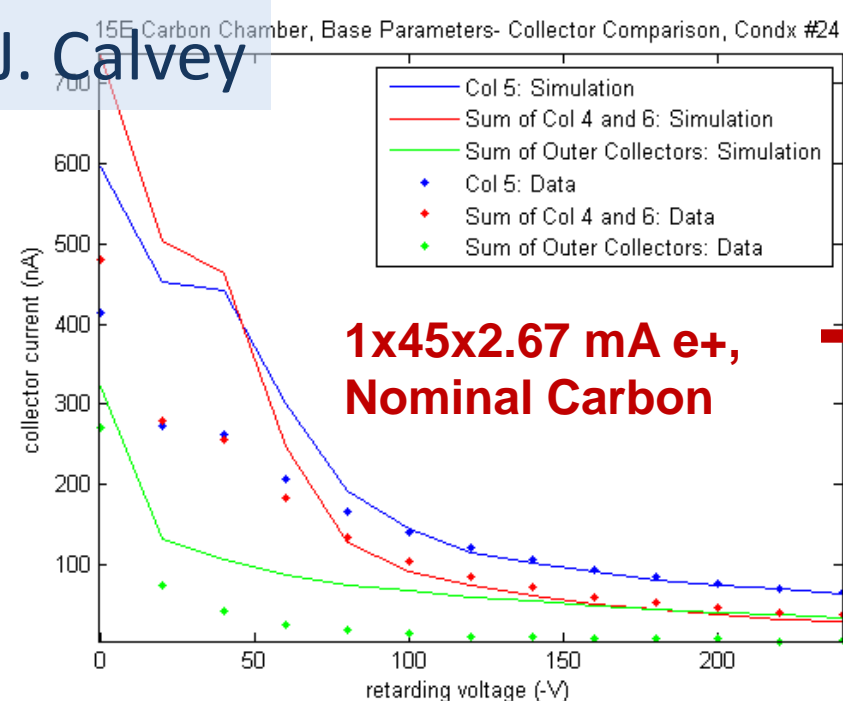
Base Parameters- Collector Comparison, Condx #24



Final Parameters- Collector Comparison, Condx #24







- Best fit parameters shown below
 - Note very low peak SEY ($\sim .9$) for Carbon and NEG coatings
 - Very low quantum efficiency for NEG is probably due to overestimation of photon flux
 - NEG chamber is in a straight section, far from any dipoles, so flux is difficult to estimate

Parameter	Description	Nominal Value(s)	Final Value: Al	Final Value: Carbon	Final Value: NEG
dtspk	Peak "true secondary" yield	1.8 (Al), .8 (C, NEG)	2.18	0.618	0.715
P1rinf	"Rediffused" yield at infinity	0.2	0.227	0.221	0.173
dt0pk	Total peak yield (δ_{\max})	2.0 (Al), 1.0 (C, NEG)	2.447	0.879	0.928
P1epk	Low energy elastic yield ($\delta(0)$)	0.5	0.416	0.26	0.452
E0tspk	Peak yield energy (E_{\max})	310 (Al), 500 (C, NEG)	314	486	500
queffp	Quantum efficiency	0.1	0.106	0.096	0.027