Code Benchmarking and Preliminary RFA Modelling for CesrTA

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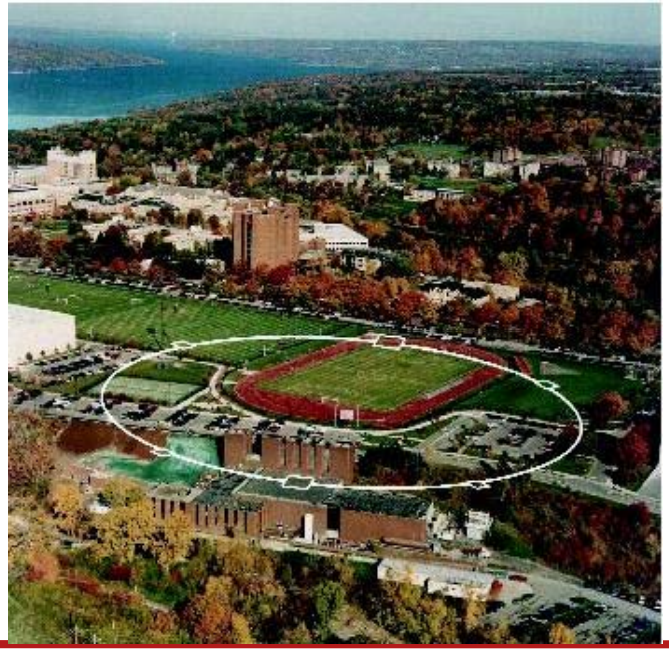
11/17/08

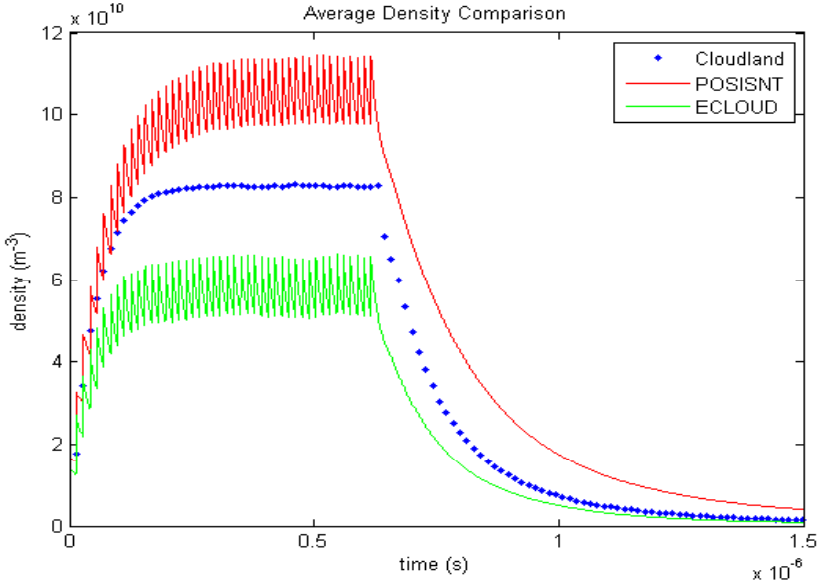


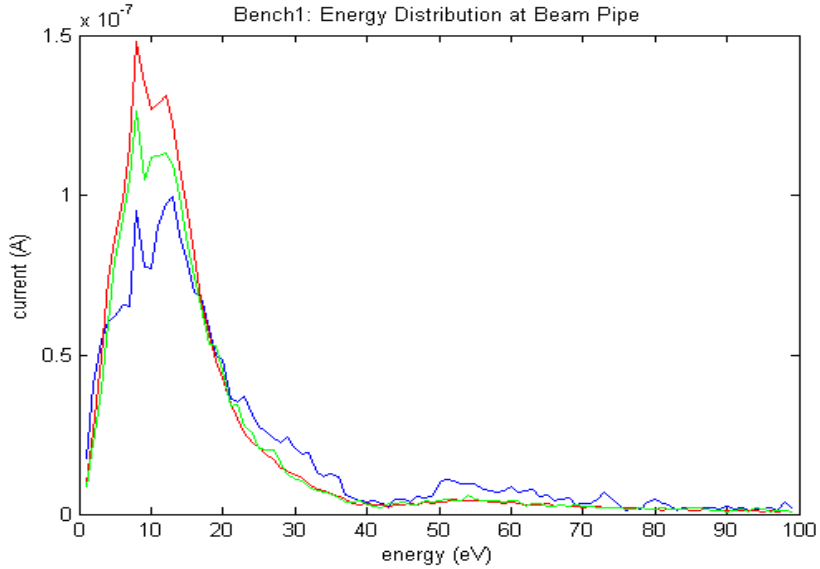
Three Areas of Research in Electron Cloud Simulation

- Code Benchmarking
  - Comparison of different simulation codes with canonical parameter sets
  - Three codes:
    - POSINST (M. Furman, M. Pivi)
    - ECLOUD (G. Rumolo, F. Zimmermann)
    - CLOUDLAND (L. Wang)
- Retarding Field Analyzer Comparisons
  - RFA data from a variety of beam conditions (July and November runs)
  - Different styles at different locations along the beam line
  - RFAs themselves need to be simulated
  - Gives time integrated cloud density at a specific location
- Tune Shift Comparisons (see G. Dugan's talk)
  - Gives ring integrated field gradient due to cloud vs time

Code Benchmarking

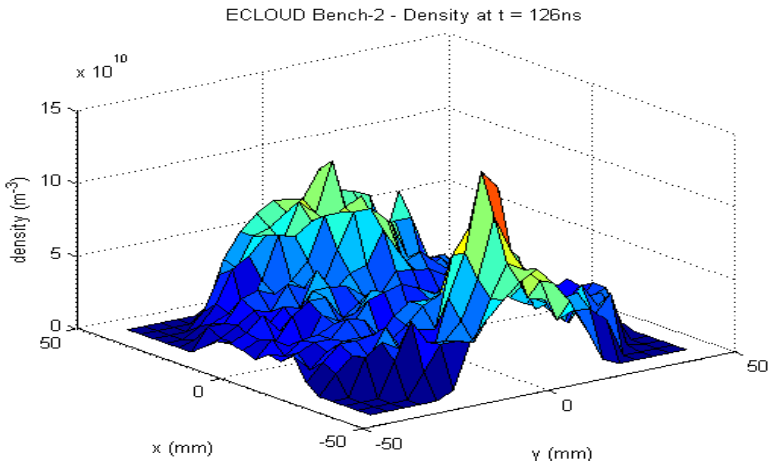
- Problem: simulation programs disagree significantly under certain conditions
  - Left plot: Average cloud density vs time for a train of 45 postiron bunches with 1mA/bunch, as predicted by the three codes
- Possible sources of discrepancies:
  - Different Secondary Electron Yield models
  - Different primary photoelectron models
- To compare the primary models independent of secondaries, we set the SEY to zero
  - Match is much better, but not perfect, due to differences in the angular distribution of primaries
    - Right plot: energy distribution of electrons that have collided with the beam pipe wall (no SEY)
    - The more strongly peaked the distribution is at normal emission, the more electrons will be near the center of the chamber when the next bunch comes, resulting in higher energy electrons
    - This will lead to bigger discrepancies when secondaries are included, since SEY depends on energy

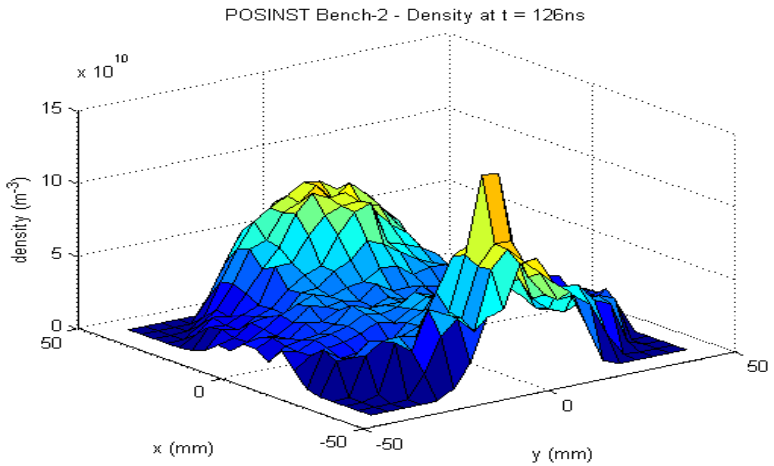


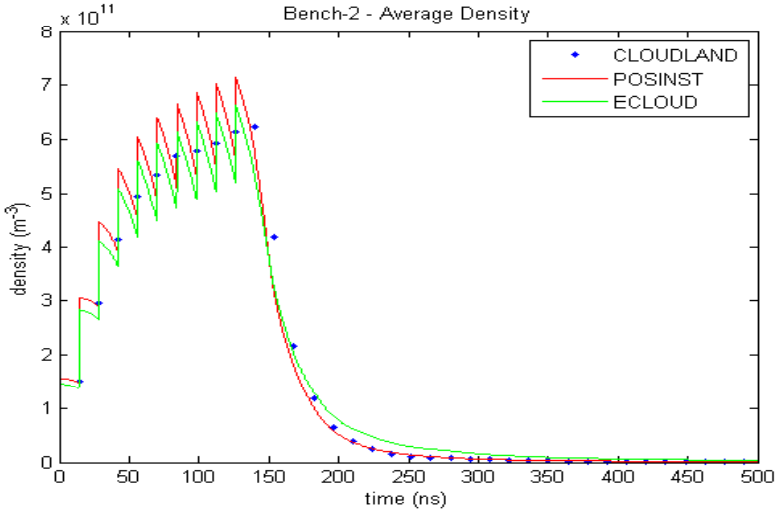


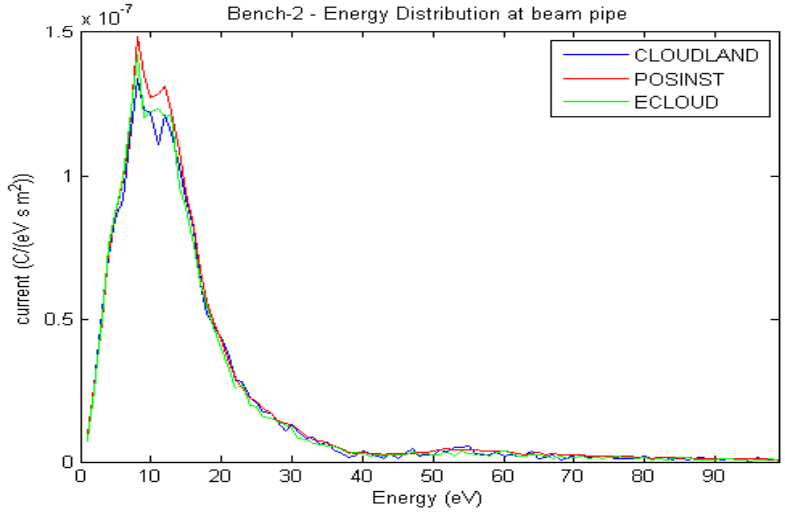
Primary Emission Models

- Next, we coded the same angular distribution for primaries into all three programs
- Match is essentially perfect!
  - reduces worries about systematic or statistical errors





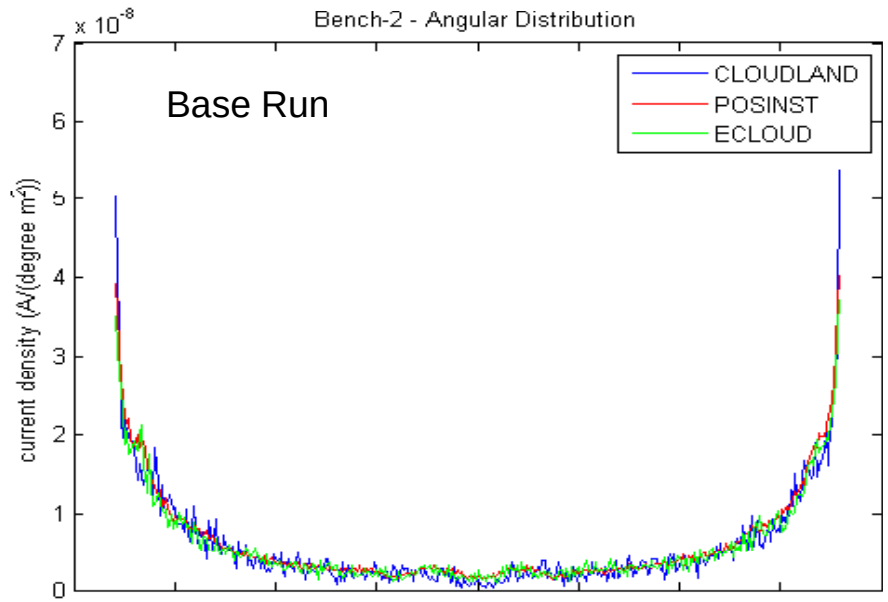


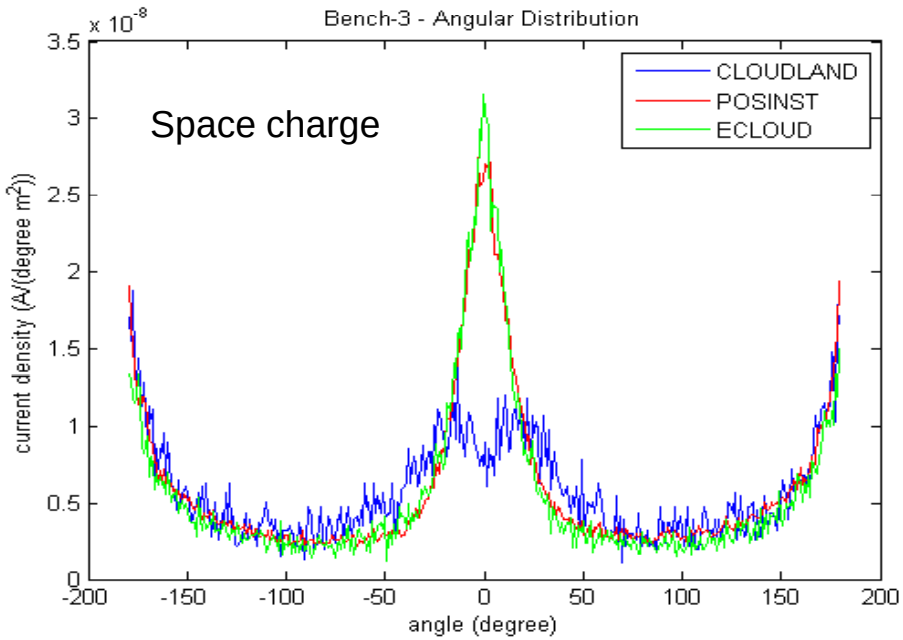


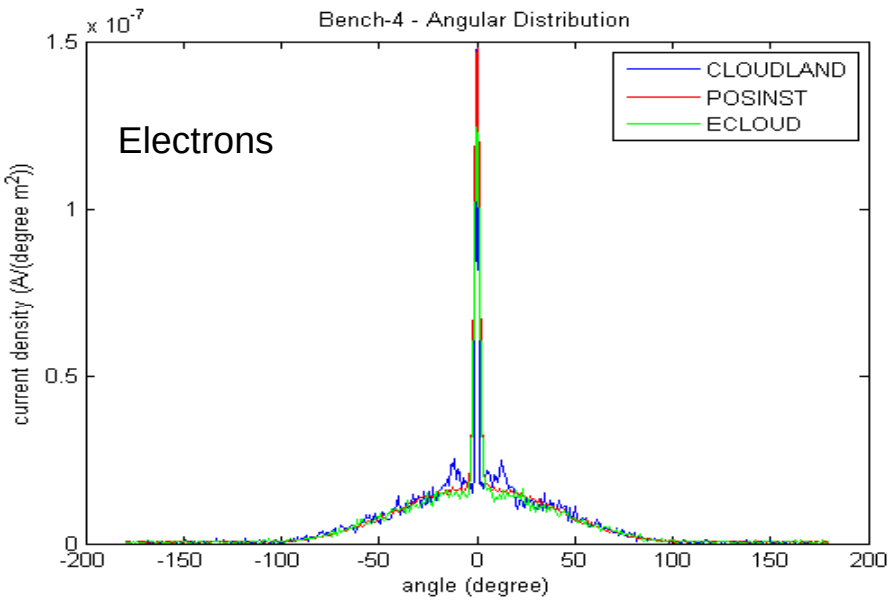
Primary Emission Models

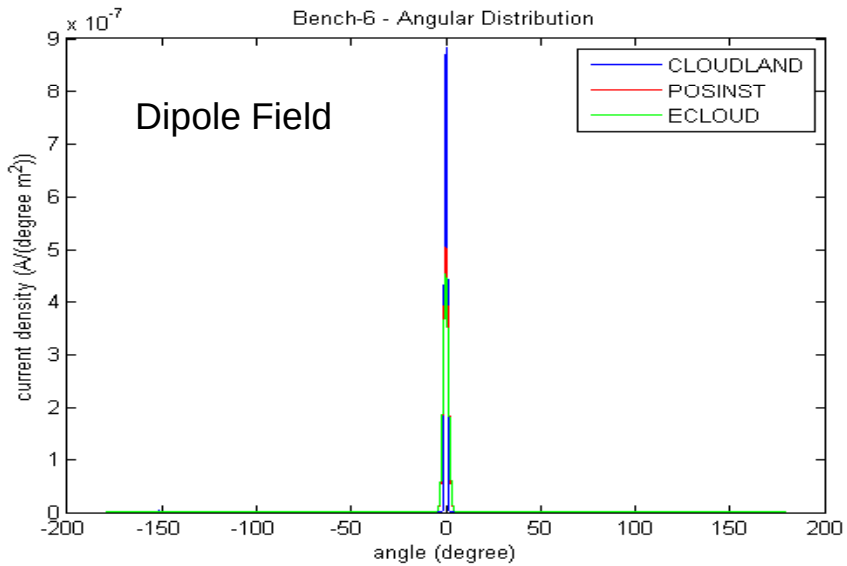
- Without SEY, it's generally easier to interpret the effects of adjusting other parameters
- We did several different runs, adjusting one thing at a time
  - Bench-2: Simplest possible case
    - Circular chamber
    - 10 bunches, 1mA/bunch, Positrons
    - No space charge or reflectivity
  - Bench-3: Same as Bench-2, but with space charge
  - Bench-4: Same as Bench-2, but with electrons
  - Bench-5: Same as Bench-2, but with reflectivity
  - Bench-6: Same as Bench-5, but with a 2011 Gauss dipole field
- Illuminating plot: azimuthal distribution of electrons that hit beam pipe wall
  - CLOUDLAND has strange dip at source point (0 degrees) in space charge run
    - Is this because CLOUDLAND is 3D?
    - Check with WARP-POSINST
  - With positrons, distribution strongly peaked opposite source point
  - Peaked at source point for electrons
  - Most cloud electrons can't get to the center of the pipe during bunch spacing, so the direction of the kick depends entirely on species
  - Space charge leads to peak at both points
    - Many electrons immediately pushed back into wall
    - Also spreads distribution out
  - Dipole leads to strong peak at source point

Azimuthal Distribution





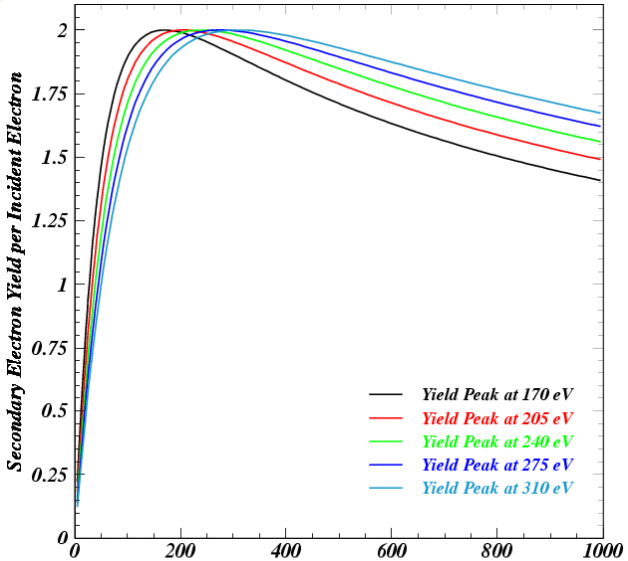


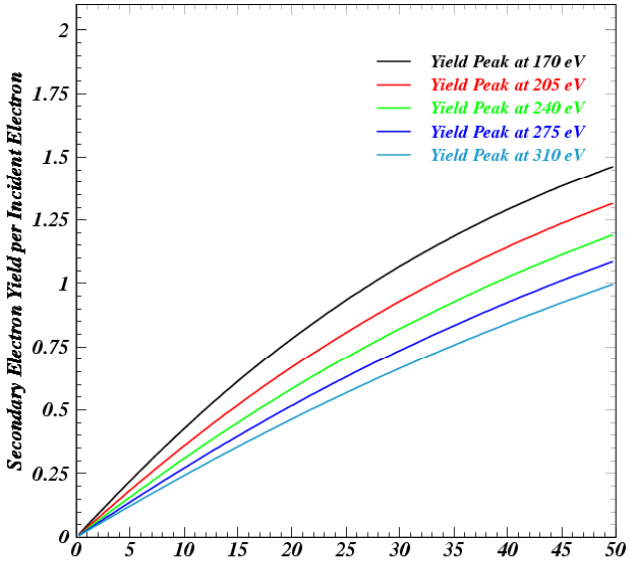


Secondary Emission Models

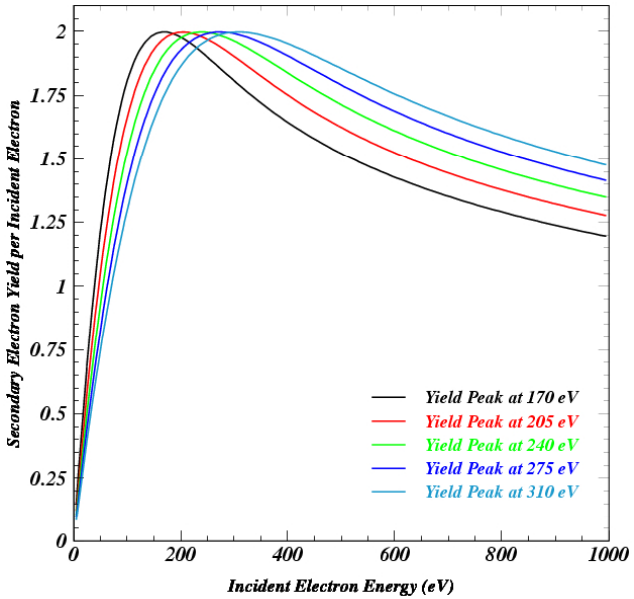
- Situation is considerably more complicated for secondary models
- ECLOUD and CLOUDLAND use a similar (but subtly different) model
- POSINST uses a more detailed model
  - Includes “rediffused” secondary electrons
    - Electrons with energy between a reflected primary and “true” secondary
- We are finding different parameterizations can lead to large discrepancies, even if the curves “look similar”
  - For example, turning off rediffused electrons in POSINST causes the other components to be scaled up in a way that is different than in ECLOUD or POSINST
  - Low energy behavior particularly important, since most of our electrons have < 25 eV
- Angular distribution also a concern

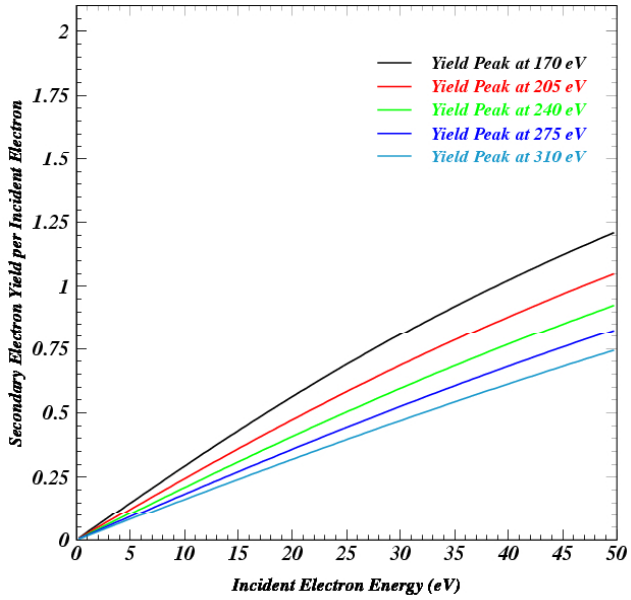
Charge Yield vs Energy
ECLOUD vs CLOUDLAND





ECLOUD





CLOUDLAND

Fortran functions
`sey_ecloud.f`
and
`sey_cloudland.f`
are posted on the CesrTA Electron Cloud Simulation wiki

Benchmarking Summary

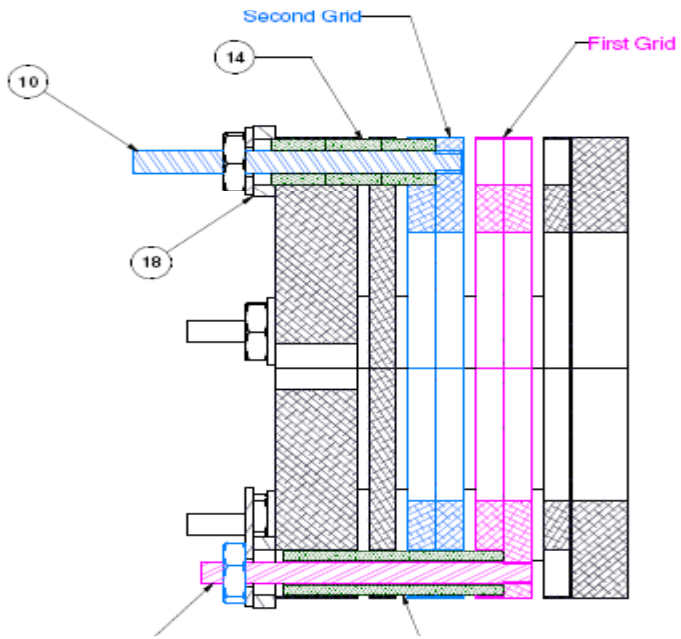
- Codes are in very good agreement if…
  - SEY is ignored
  - Angular distribution of primaries are set equal
- Most behavior without SEY is fairly intuitive
- Secondary Yield is problematic
  - Sensitive to specific parameterization
  - Especially sensitive to low energy yield
- Next steps:
  - Attempt to make SEY models as close as possible
    - Hard code different low energy yields?
  - Check agreement with WARP-POSINST
    - Relying on our Berkeley collaborators

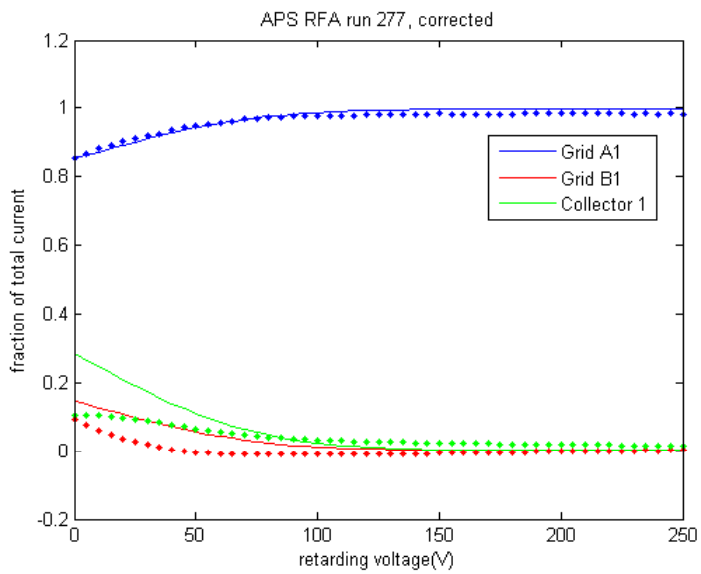
RFA Simulations

- We have lots of RFA data from July and November runs, sampling a large region of parameter space
  - 1.9 and 5.3 GeV
  - Electrons and positrons
  - Drift, dipole, and wiggler fields
  - Different bunch configurations and currents (e.g. 1x45x1 mA, 9x1x5 mA)
  - Four different types of RFAs
  - We recorded both collector and grid currents
- We are using a semi-analytical "simulation" to predict RFA currents
  - Performs a series of calculations on output of cloud simulation program (typically POSINST)
    - "output:" individual particles that collide with the beam pipe wall in region of RFA
  - We are also developing a full particle tracking simulation
    - Cross check with semi-analytical model
- Most data we have looked at is predicable and well understood
- However, we do see some idiosyncratic behavior
- Next slides discuss RFAs in order of increasing complexity

"APS Style" RFA

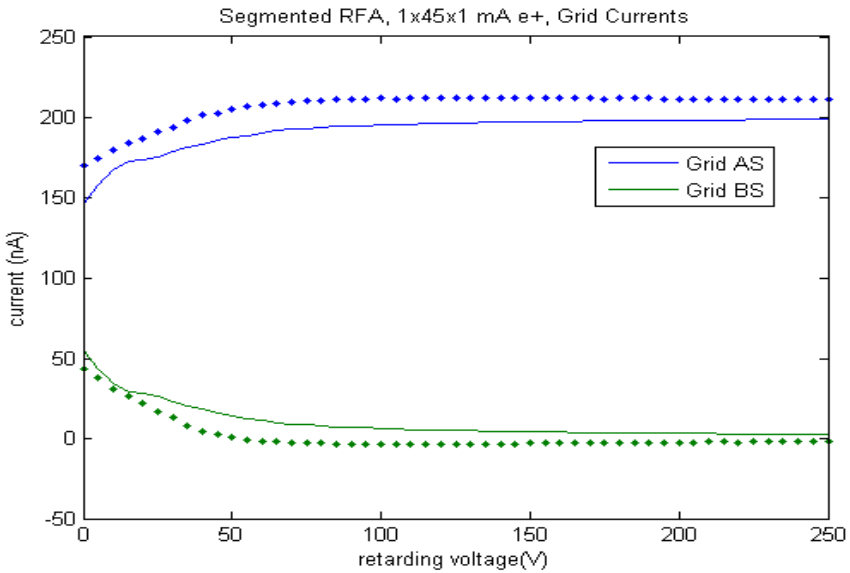
- Relatively simple
  - 1 grounded grid, 1 retarding grid, 1 collector
- Our simulations predicted a spike in current at low retarding voltage that was not seen in the July data
  - We now know this is because of an oscillating power supply
  - Once the simulation is corrected for this, it compares quite well to the data
- Plotted: currents in grounded grid (blue), retarding grid (red), and collector (green) vs retarding voltage, normalized to total current
  - This (and all subsequent plots) are for a 1x45x1 mA e+ configuration at 5.3 GeV
  - Simulation represented by solid line, data by dotted line
  - Simulation misses some structure at low retarding voltage

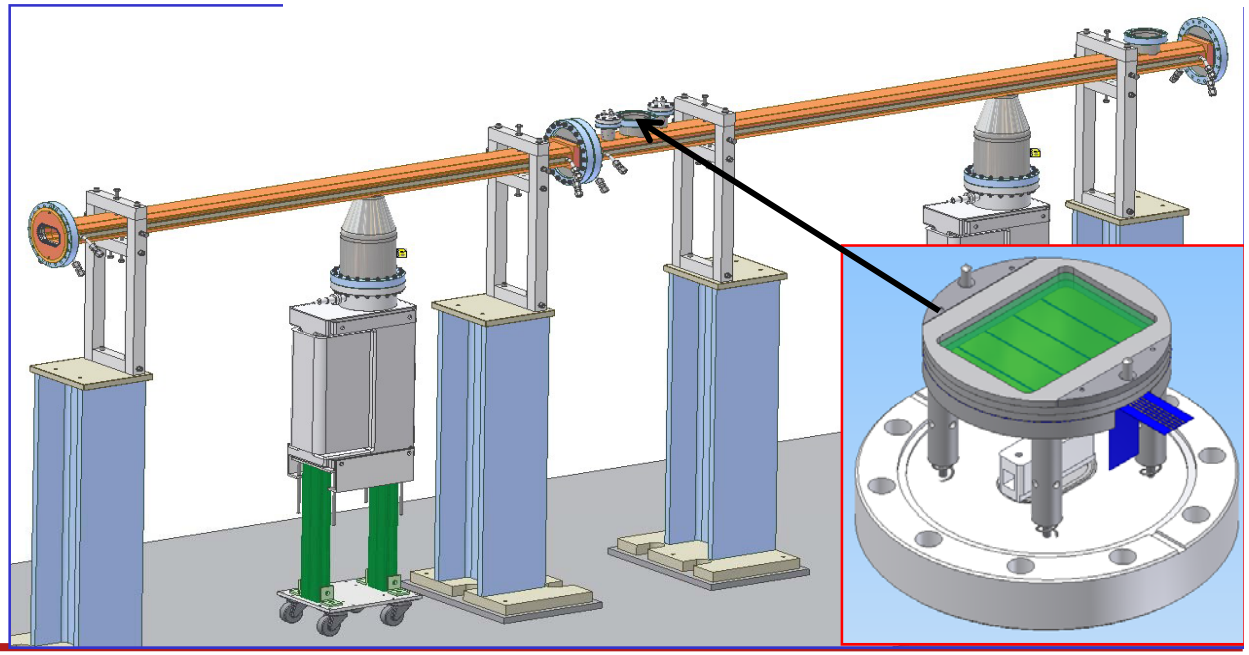




Segmented RFA

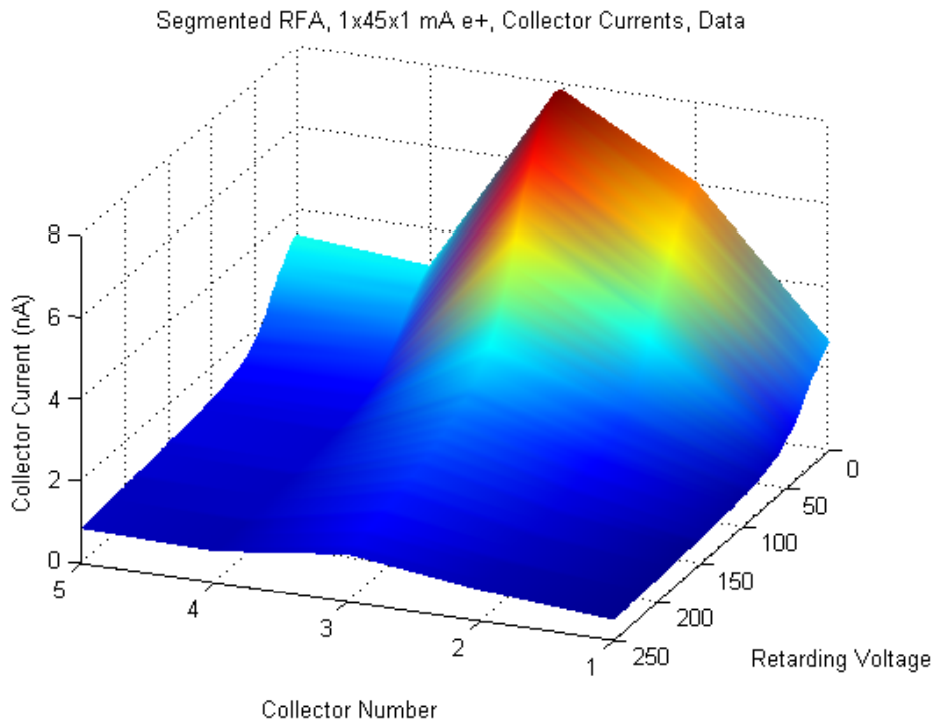
- Deployed between APS RFAs
- 2 grids, 5 collectors (probe azimuthal distribution of cloud)
- Simulation accurately predicts grid currents
  - Plot show absolute current!
  - Note that the retarding grid current goes negative in the data
    - Consequence of SEY?

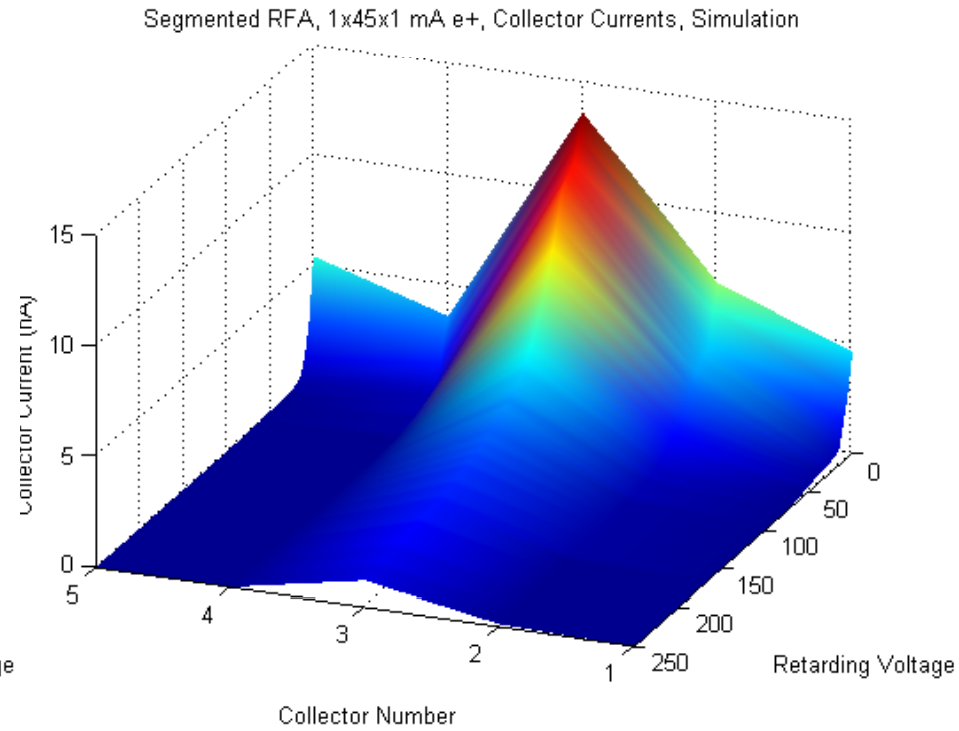




Segmented RFA

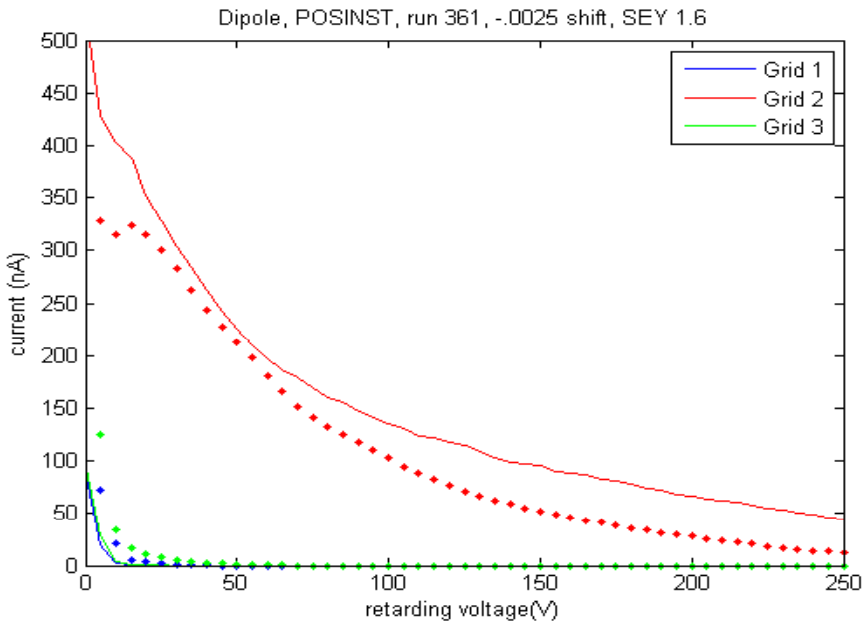
- Collector currents match qualitatively
  - Plots show collector current vs collector number (collector 1 is opposite source point) and retarding voltage
  - Data on left, simulation on right
- We will try to match the azimuthal distribution better by adjusting simulation parameters

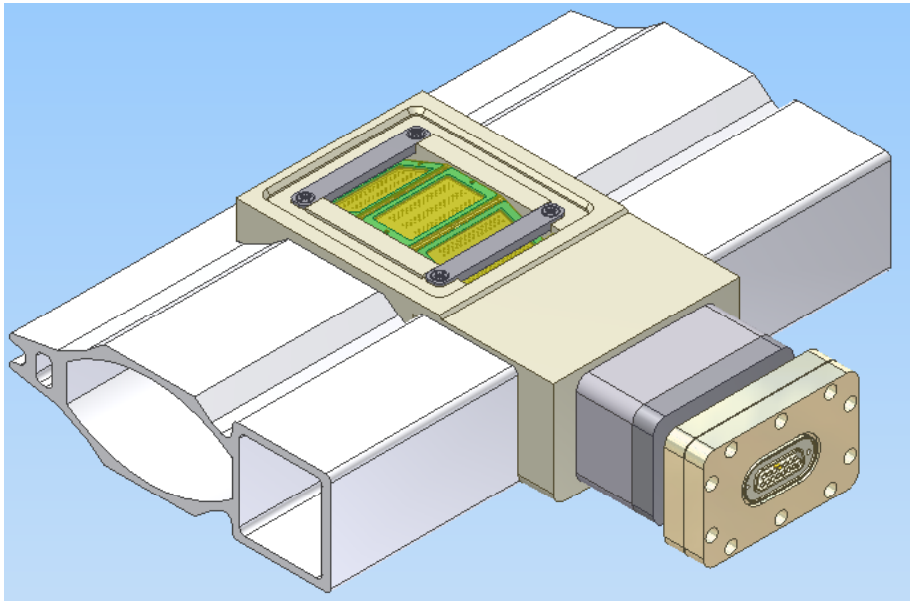




Thin Insertable RFA

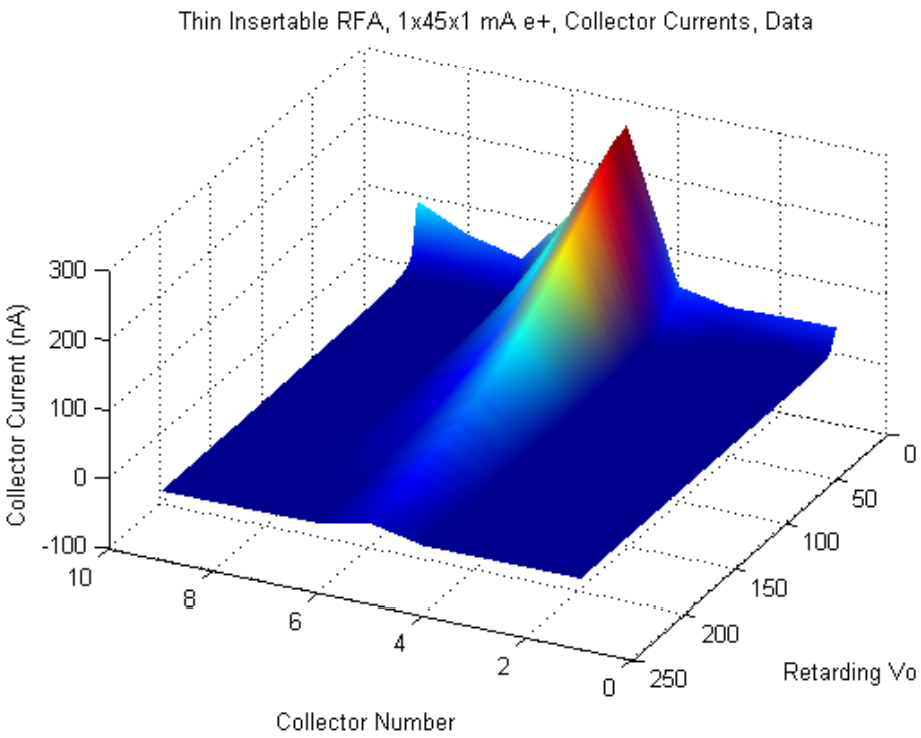
- No grounded grid, 3 retarding grids, 9 collectors
- We have data from both July and November runs
  - Investigate effect of conditioning
- One Thin RFA is in a drift region, one is in a dipole
- Some simple adjustments can be made to get the best comparison:
  - Adjust SEY parameters in POSINST (these plots are for an SEY peak of 1.6)
  - Shift RFA holes to represent a non-central beam
  - Comparison is quite good with these adjustments

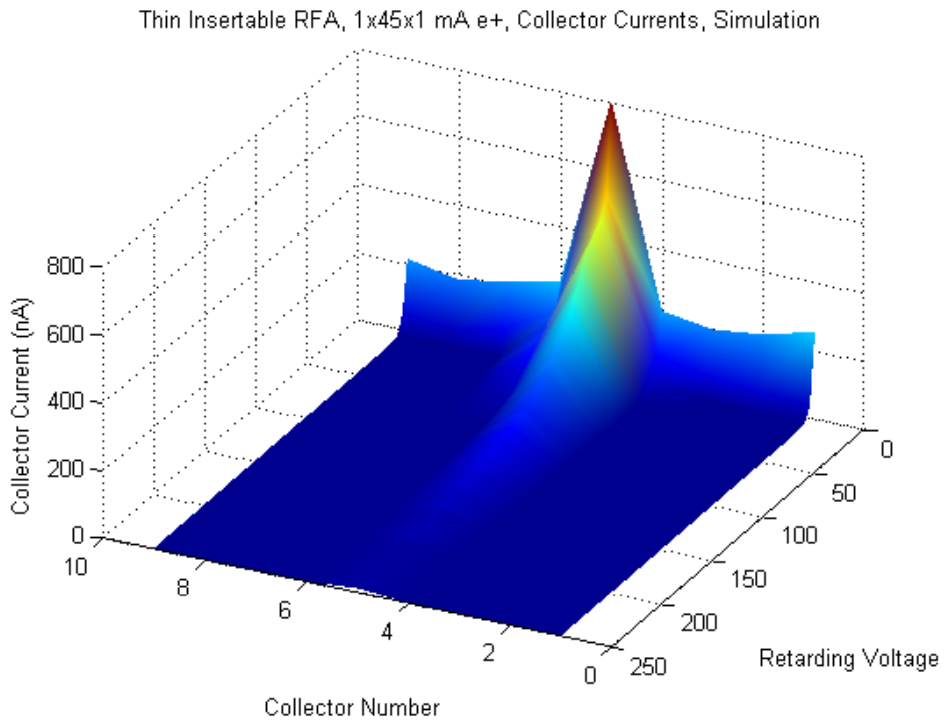




Thin Insertable RFA

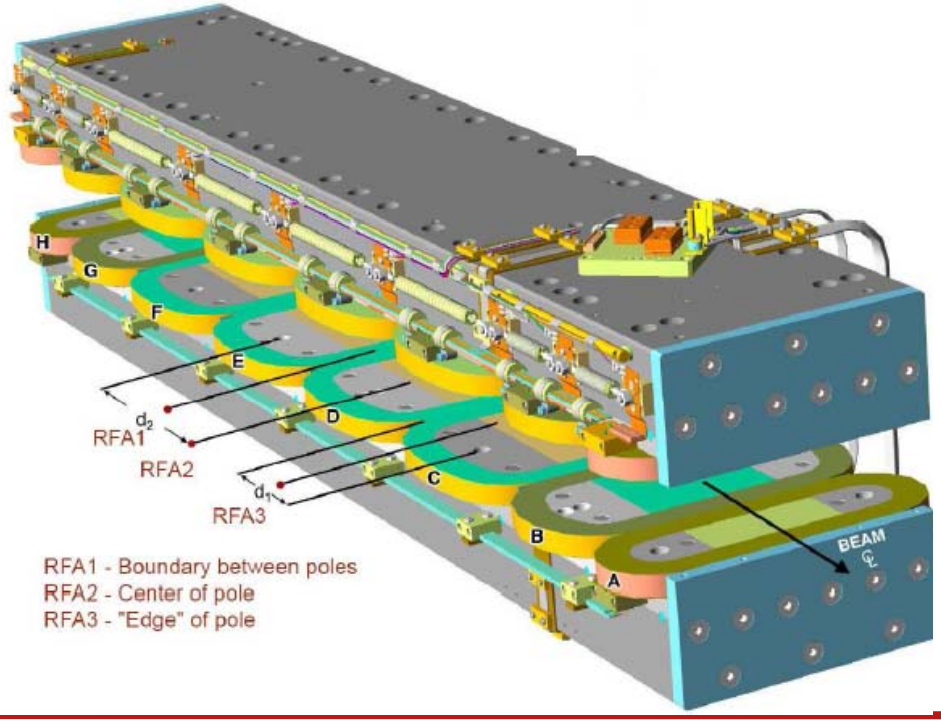
- As with Segmented RFA, collector data is matched qualitatively, but some adjustments are needed to obtain a quantitative fit
  - In particular, simulation predicts too high of a current spike at low retarding voltage, and a stronger central peak





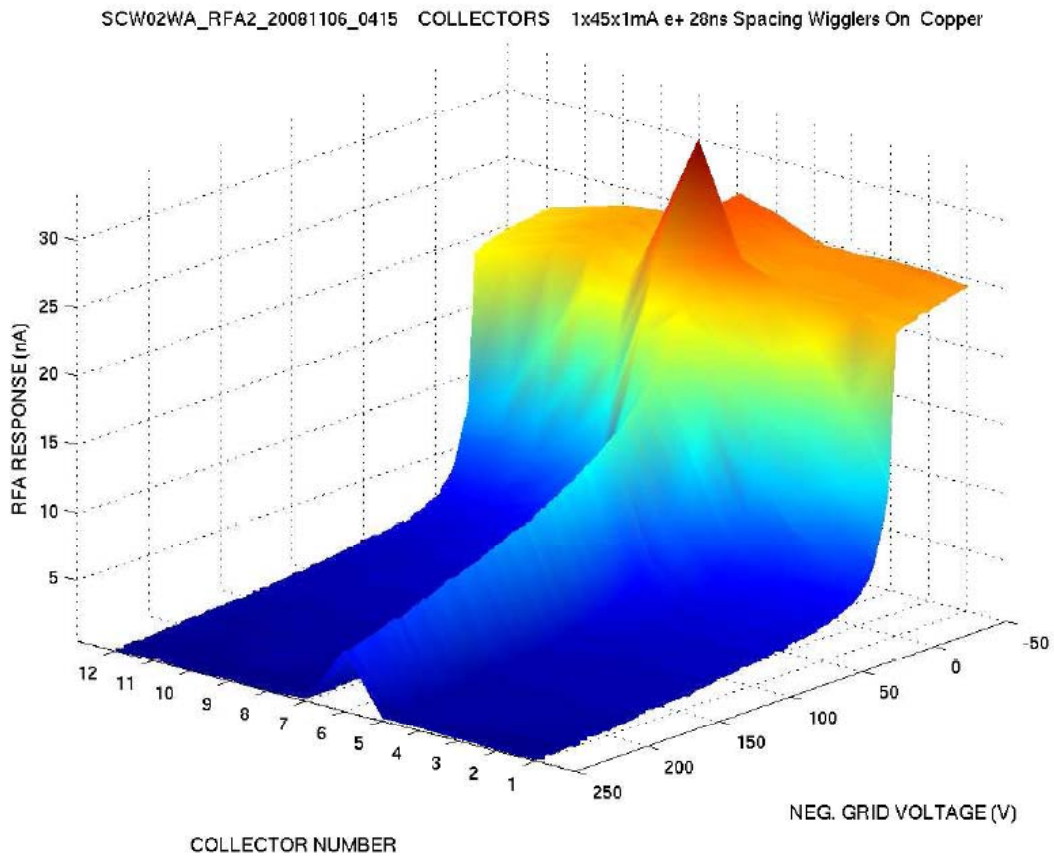
Wiggler RFAs

- Wiggler RFAs were commissioned during November run
- 12 collectors, 1 grid
- Three RFAs
  - One in center of pole
  - One in zero transverse field region
  - One in between
- We have one copper and one TiN coated wiggler chamber



Wiggler RFAs

- Most behavior is sensible
  - Essentially no current observed in longitudinal field region
  - Signal is highest in peak field
  - More current in center collector (due to multipacting)
- Some unexpected behavior
  - Peak near (but not at) zero retarding voltage for high current beams
- Have not simulated yet



RFA Summary

- We have a wealth of RFA data in a variety of beam conditions and locations around CESR
- Most observed behavior is sensible and compares well with simulation
- There are a few mysteries
  - Low energy divergence in simulation
  - Anomalous spike at 10 – 20 eV in Wiggler data
  - Precise azimuthal distribution is difficult to replicate
  - One particular case (9x1x5 mA e- in a dipole field) shows an current that increases with retarding voltage!
- We should be able to improve comparisons with data by adjusting parameters in cloud simulation programs
- We need a 3D simulation program to fully characterize the wigglers
  - WARP-POSINST (with help from LBNL)
- We have only done comparisons with a small percentage of our data, and need to do a thorough investigation before any definite conclusions can be reached
- Understanding RFA data and simulation programs will be a large step towards fully characterizing the electron cloud and evaluating the effectiveness of mitigation techniques.