Multipactor Simulations with VORPAL

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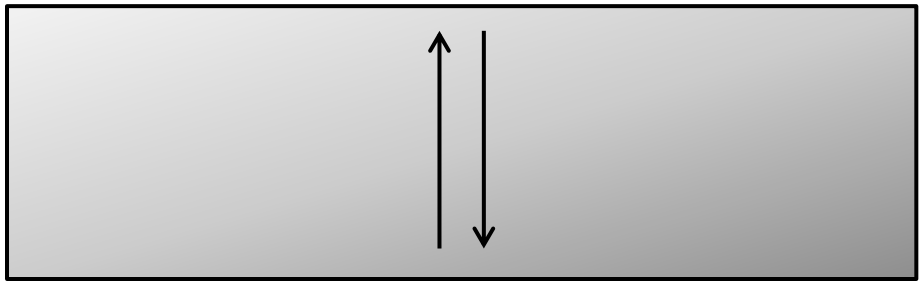
What is multipactor

- Self sustaining resonant free electron avalanche phenomenon.
  - Electrons impacting a surface cause secondary electrons to leave it which strike the same (or another) surface .....



- Amplification caused the probability of multiple secondary electrons
- Normally investigated in terms of onset
- The **level** of saturation is of interest when multipactor cannot be avoided or supressed
  - Power into components

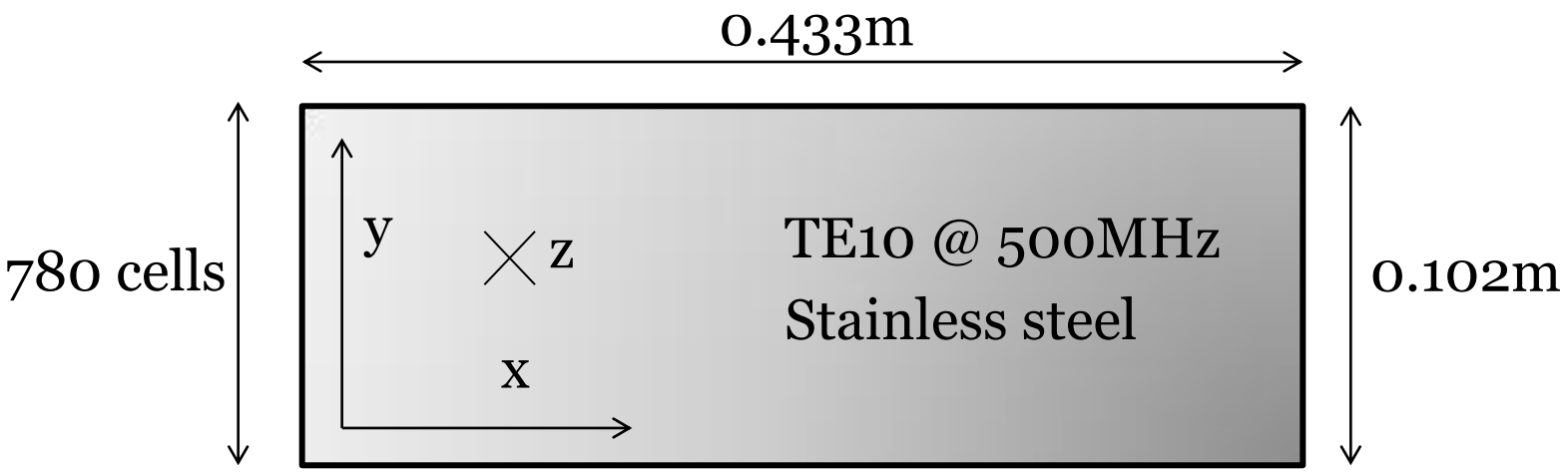
Multipactor

- Stability caused by electron trajectories resonant with the RF
- Amplification caused the probability of multiple secondary electrons

- Normally investigated in terms of onset
- The **level** of saturation is of interest when multipactor cannot be avoided or supressed
  - Power into components

What does the simulation look like?

- Results presented from a transverse 2D slice (looking down the waveguide in the direction of propagation)
  - Ease of interpretation of results and computational efficiency
  - Assumes drift in z is small
  - Assumes change in field in z is sufficiency small
  - 3D simulations do agree
- 400kW peak power level
- Furman-Pivi secondary emission model used

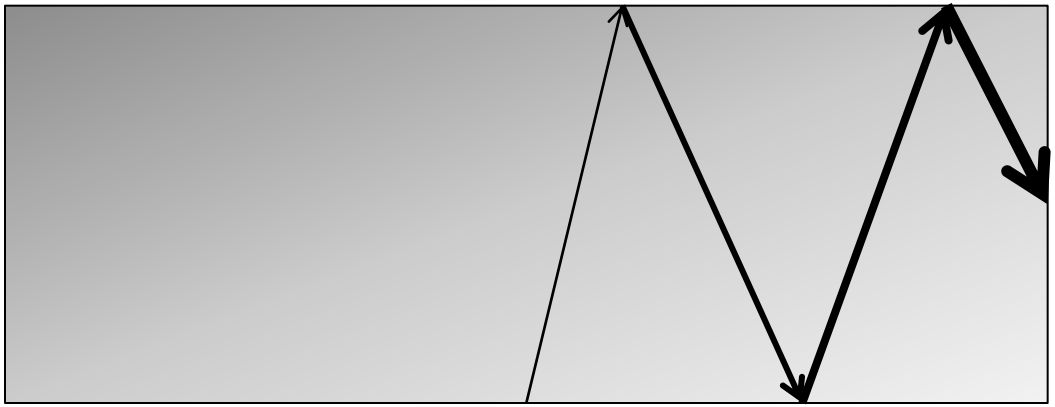


2D? I thought this was HPC?

- FDTD requires a lot of communication between nodes
- lancs2 uses gigabit network connections
- Above 4 nodes (32 cores) it got ***slower***
- 3D just too slow

Particle Implementation

- Two ways to represent the particles
  - Variable weight macro particles
    - Fewer particles
    - They won't stick around (end up with one MASSIVE particle)
    - Lower resolution



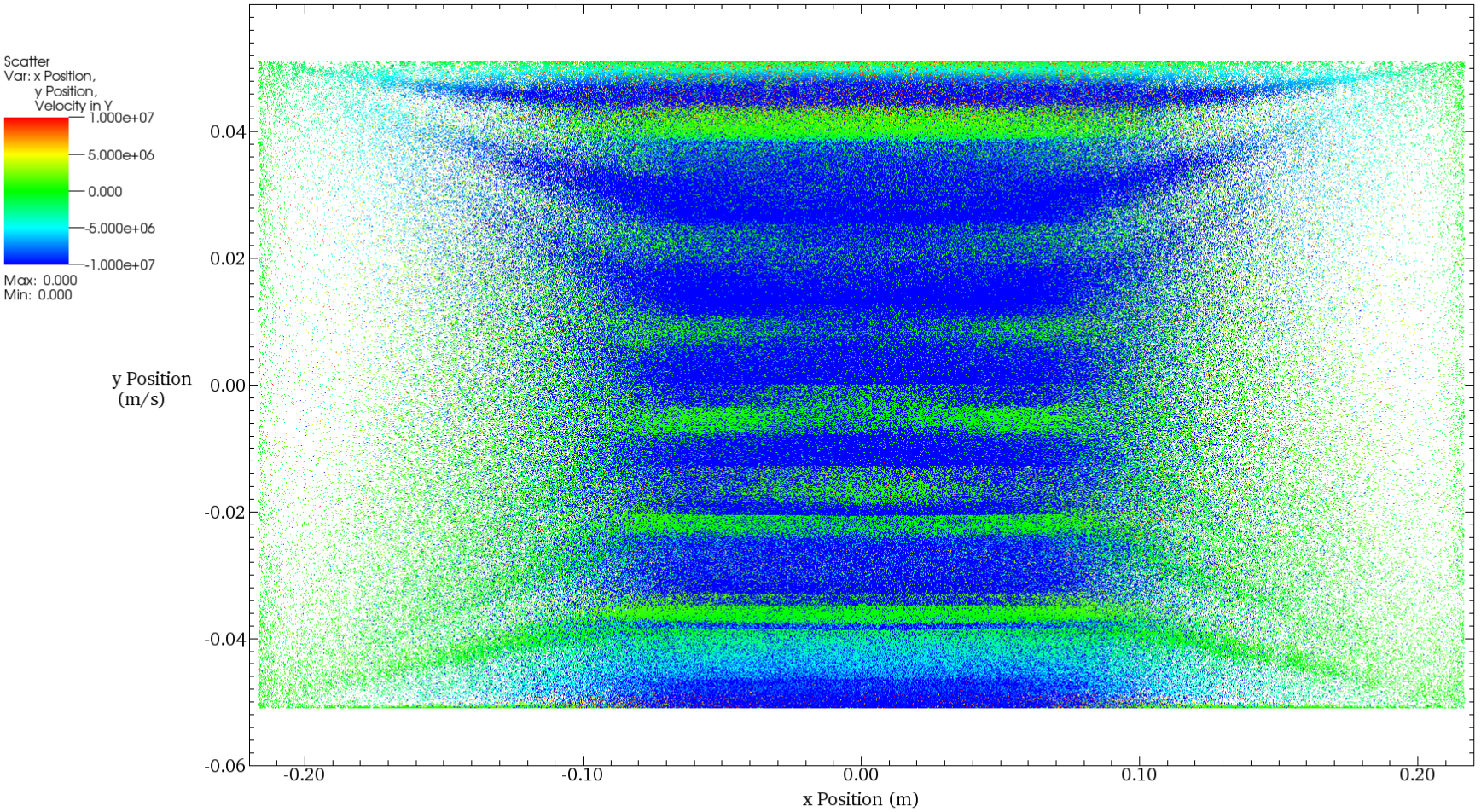
Particle Implementation

- Fixed weight macro particles
  - More particles (harder)
  - Stable
- Macro particles containing 10^7 electrons
- 10^7-10^10 particles

How to get the trajectories

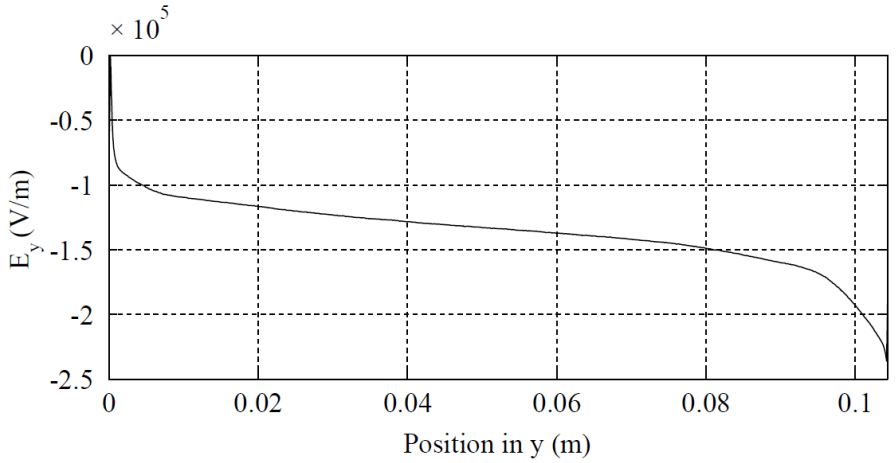
- Can't uniquely name fixed weight particles when using secondary emission.
- Have a secondary population with weight 1 as tracer particles.
- Unfortunately no trajectory statistics

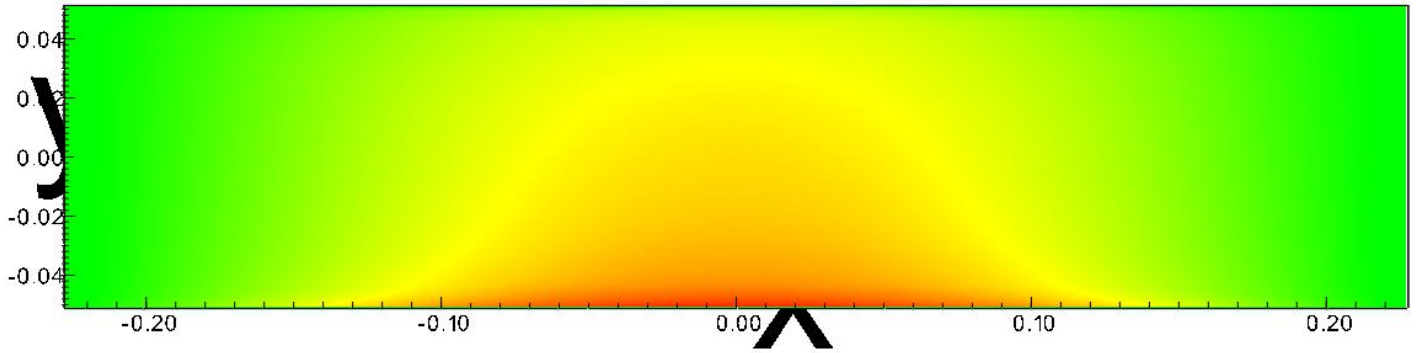
X, Y Plot (No space-charge forces)



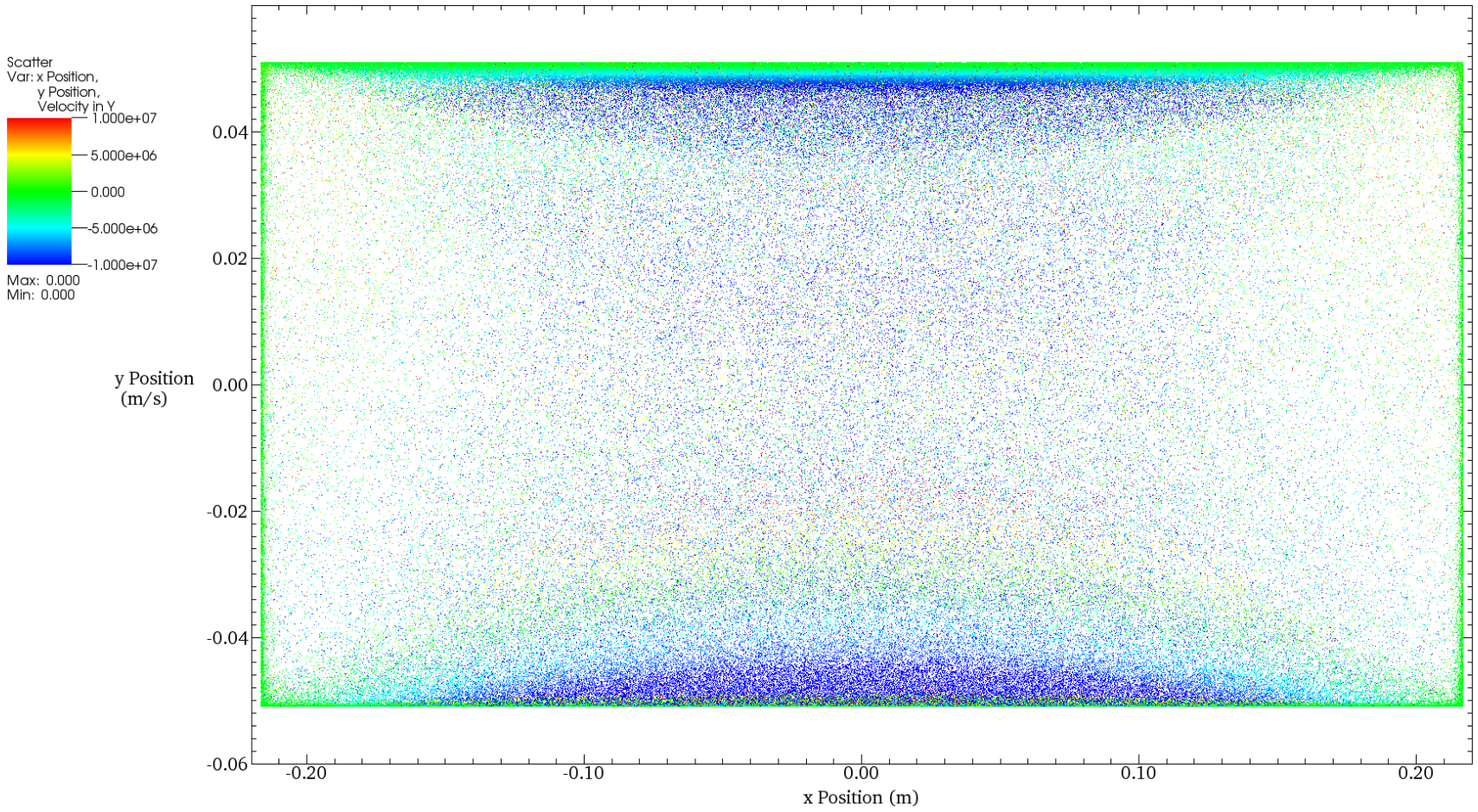
What changes with space charge?

- The electrons perturb the electric field to such an extent that electrons aren't accelerated away from the surface
- Space charge at surface shields electrons from accelerating field



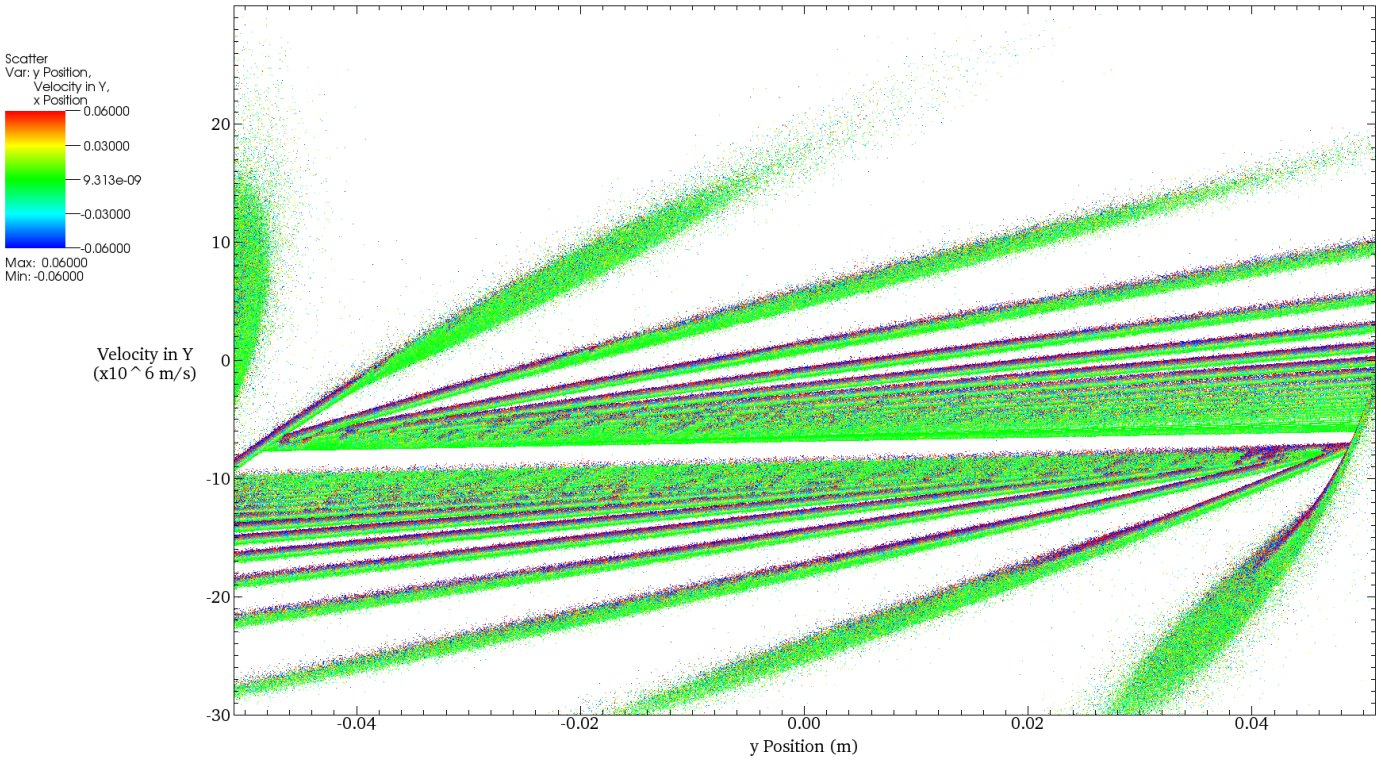


X, Y Plot

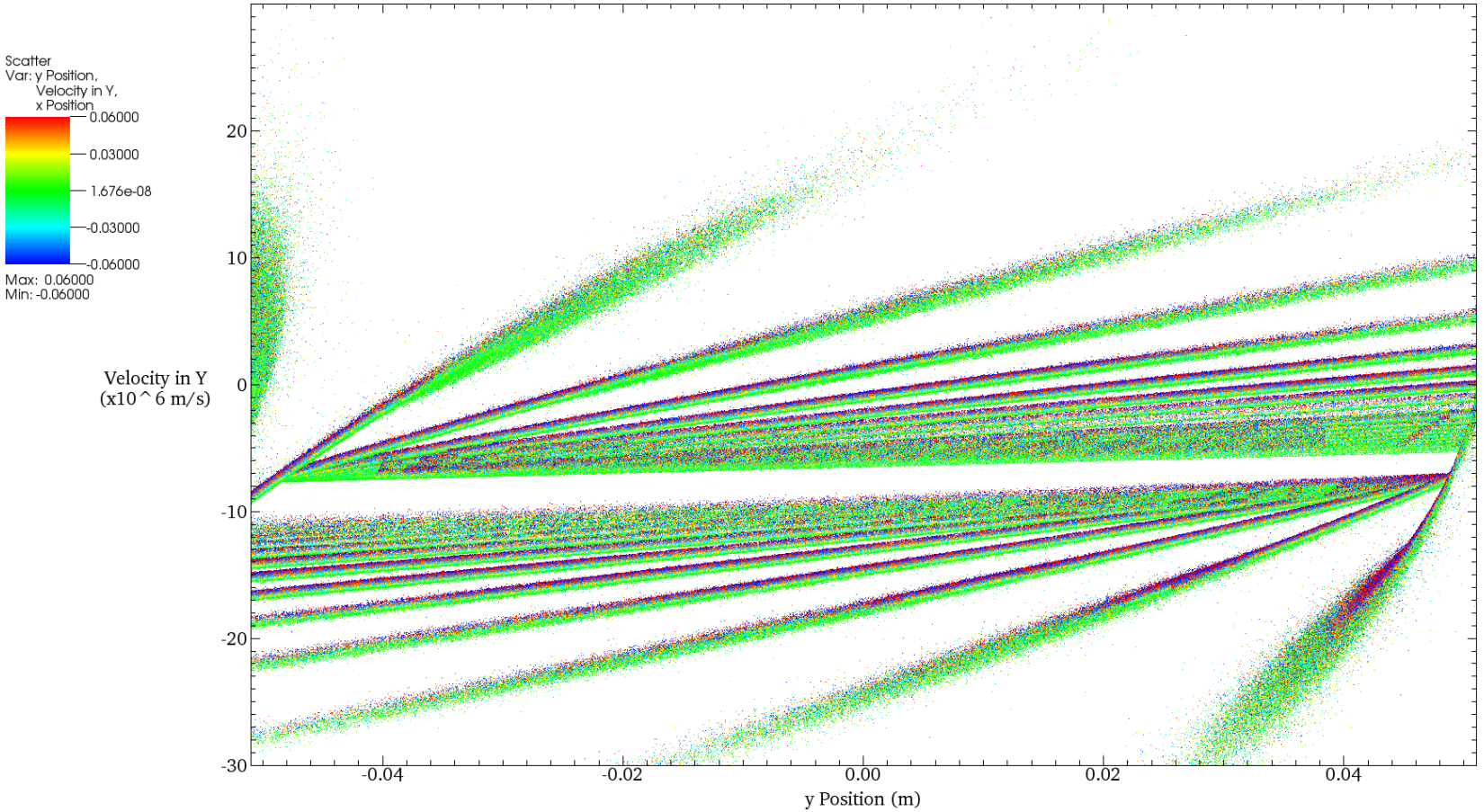

Scatter
Var: x Position,
y Position,
Velocity in Y
1.000e+07
5.000e+06
0.000
-5.000e+06
-1.000e+07
Max: 0.000
Min: 0.000
y Position (m/s)
0.04
0.02
0.00
-0.02
-0.04
-0.06
-0.20
-0.10
0.00
0.10
0.20
x Position (m)

Maybe there's another way to look at this?

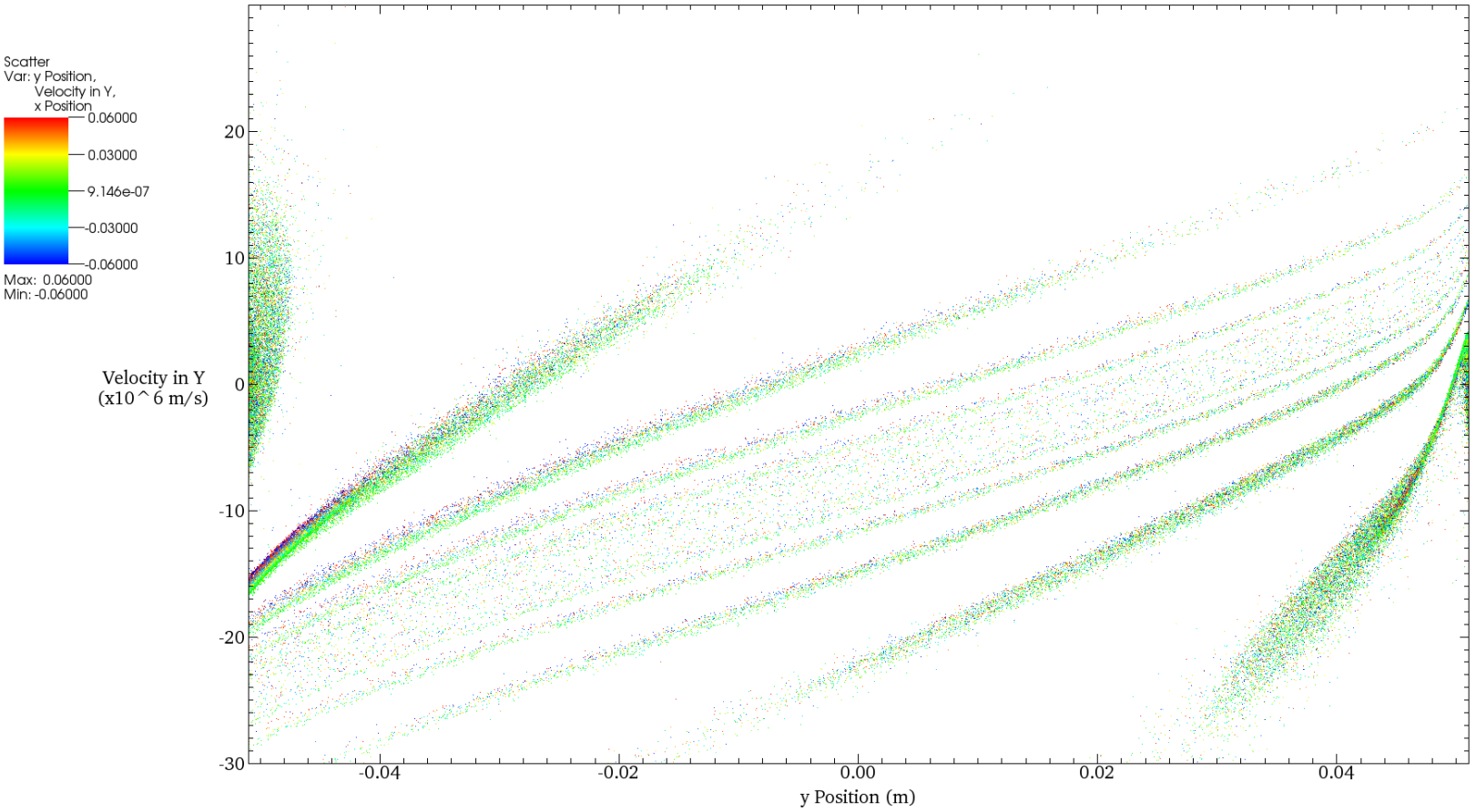
- The bunching is is much clearer if you plot the **velocity in y** against **y position**.



Y, Vy phase space (No space-charge forces)

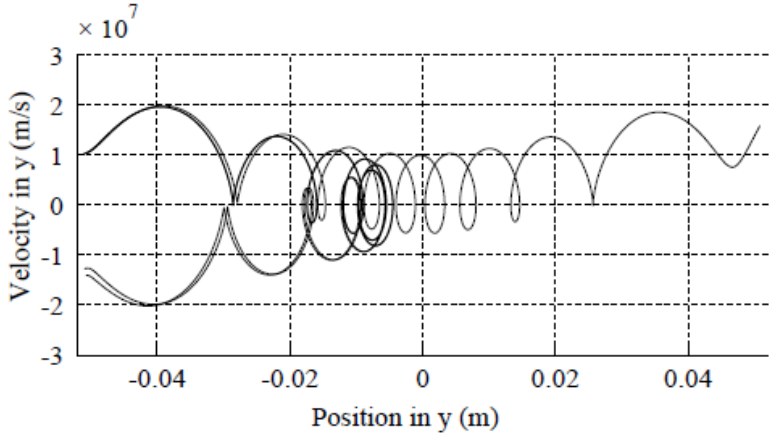


Y, Vy phase space

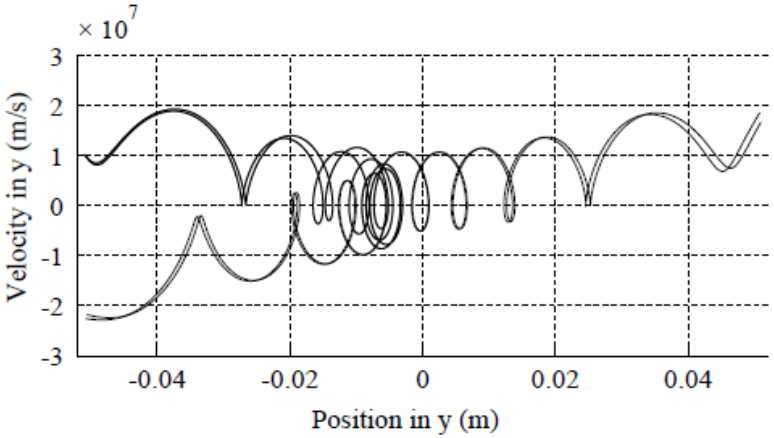


How the Populations Merge

- Only the high emission energy electrons can make it away from the surface
  - Reflected
  - Rediffused
- Some electrons can be turned round causing the merging of the populations



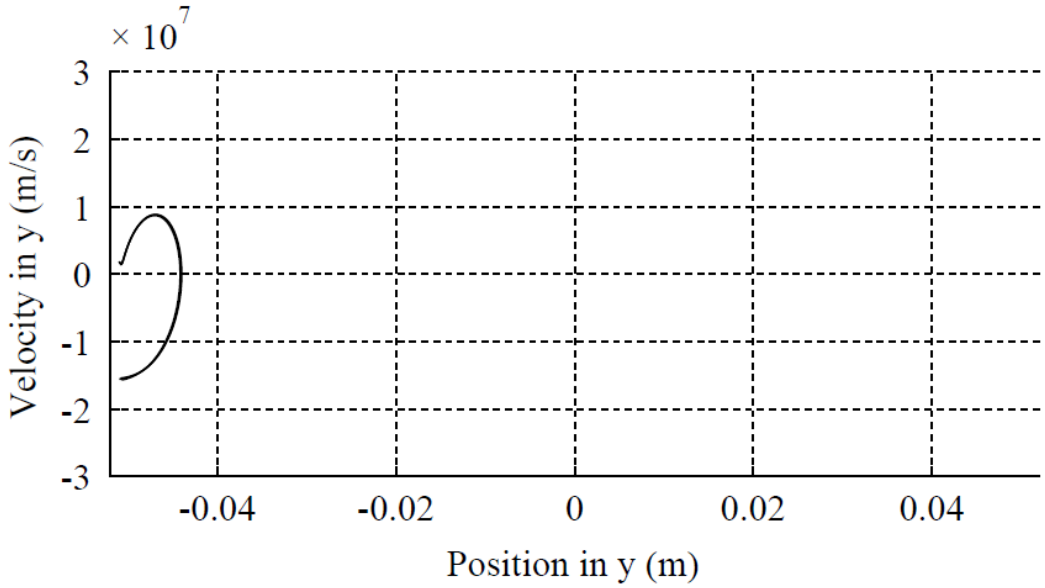
(a) θ_c



(b) $-\theta_c$

True Secondary Electrons

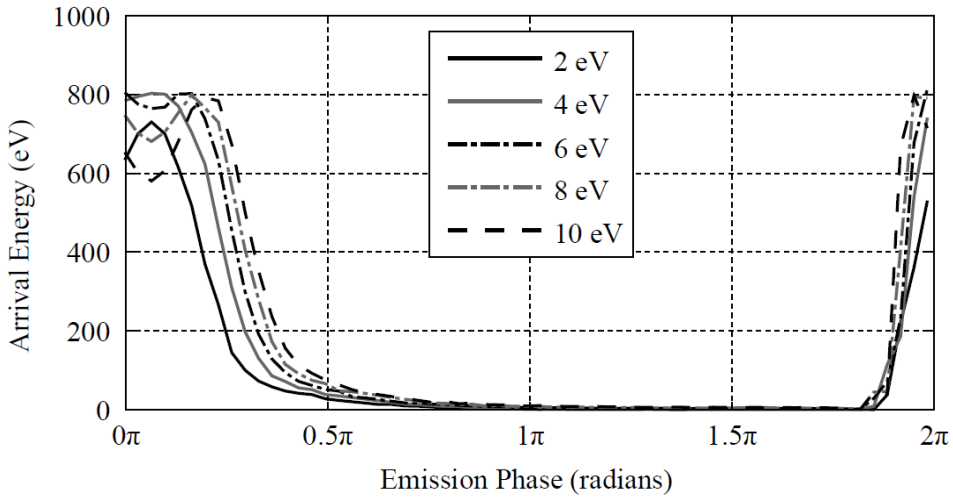
- Emitted at all phases at 1-10eV
- **None** make to the other side
- Single loop trajectory

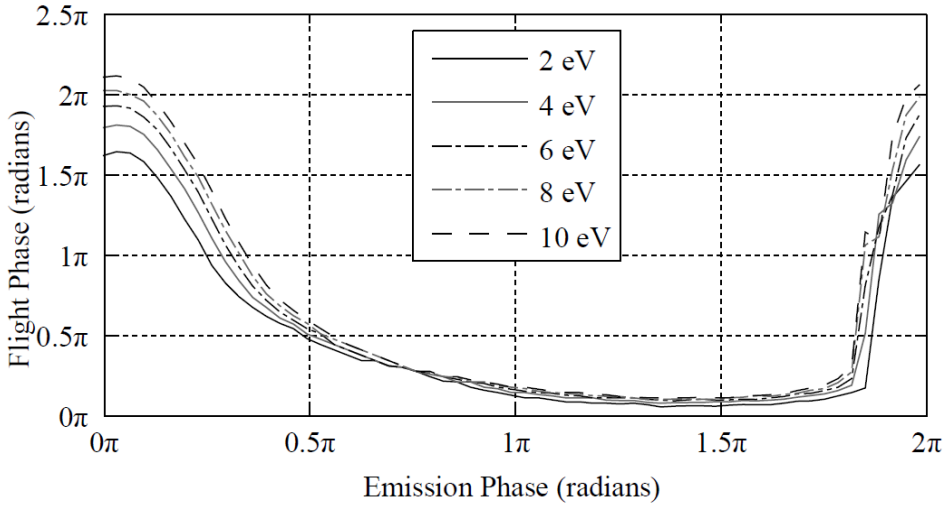


True Secondary Electrons

- High impact energy from low emission energy (80 times!)
- Or ~0eV impact energy

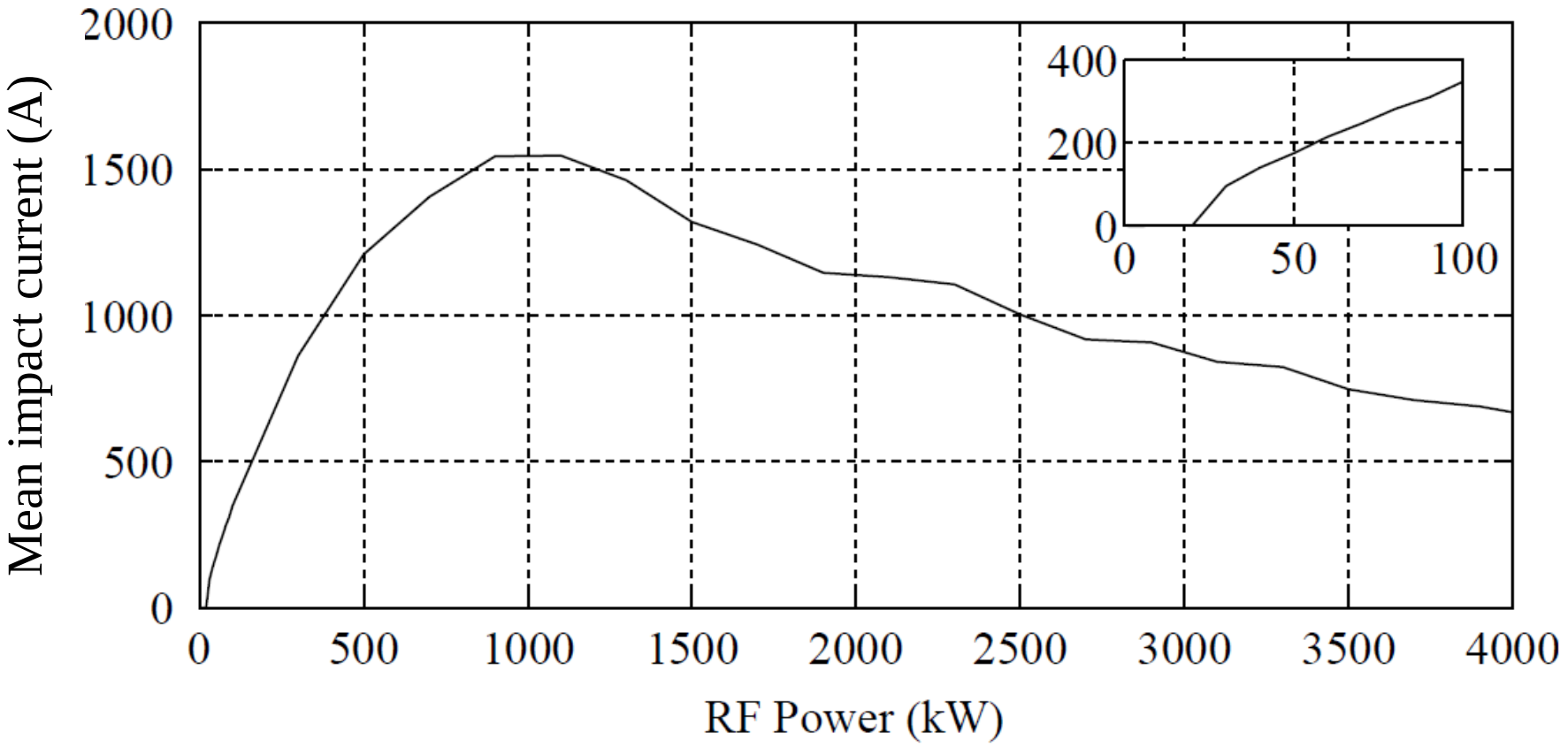
- 2π is a resonant flight phase
- Energies below 8eV are not resonant and contribute to the cloud





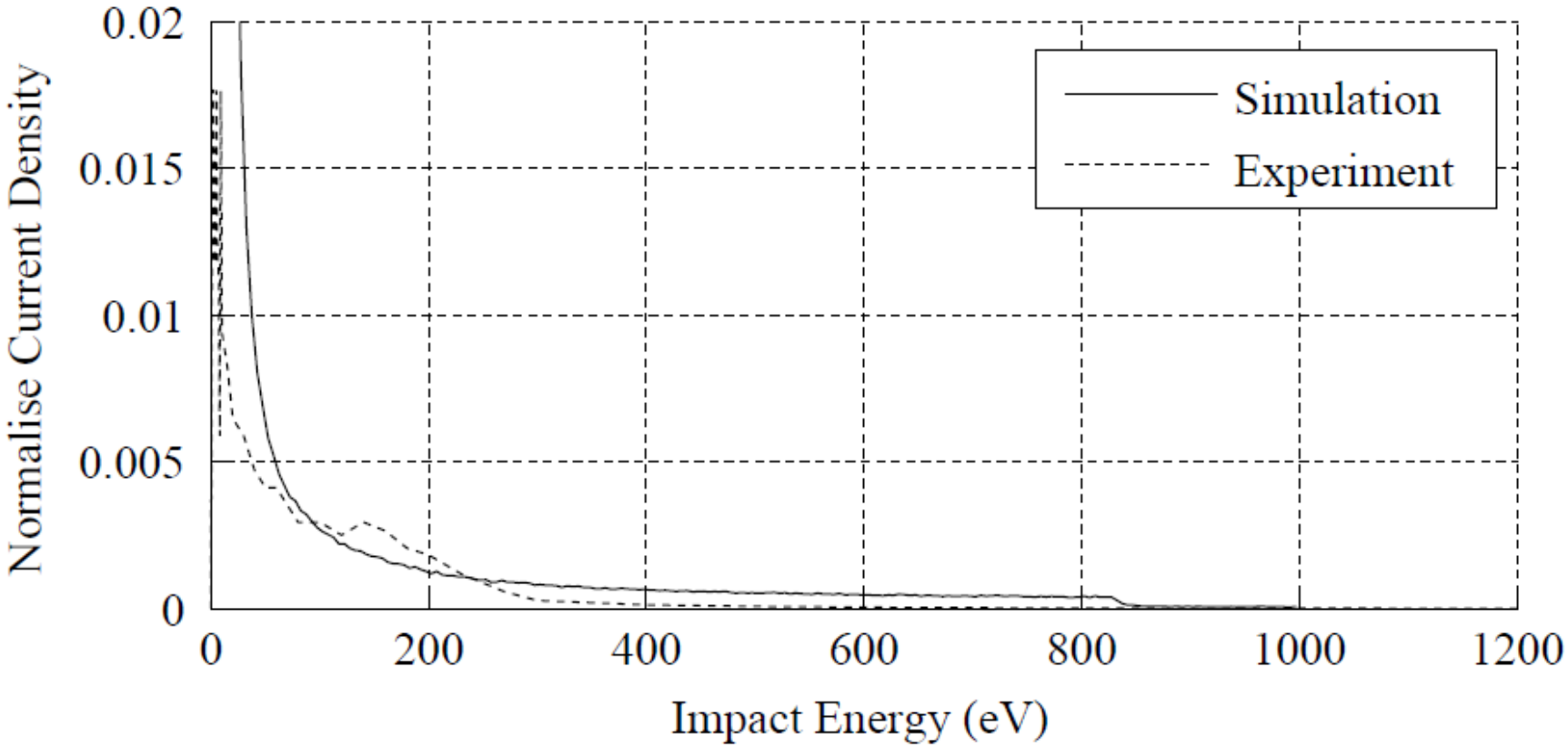
Power Dependence of Saturation Current

- The multipactor peaks then trails off as the SEY drops
- No bands!



Experimental Comparison

- Experimental data is differentiated faraday cup data.
- Both nearly “featureless”



Conclusions

- Very very time consuming on a single pc
- Pretty quick on even an unsuitable cluster
- Not all clusters are created equal
- Data analysis is more time consuming than the simulation