ArcPIC2D update:
Arc spreading through flat emission

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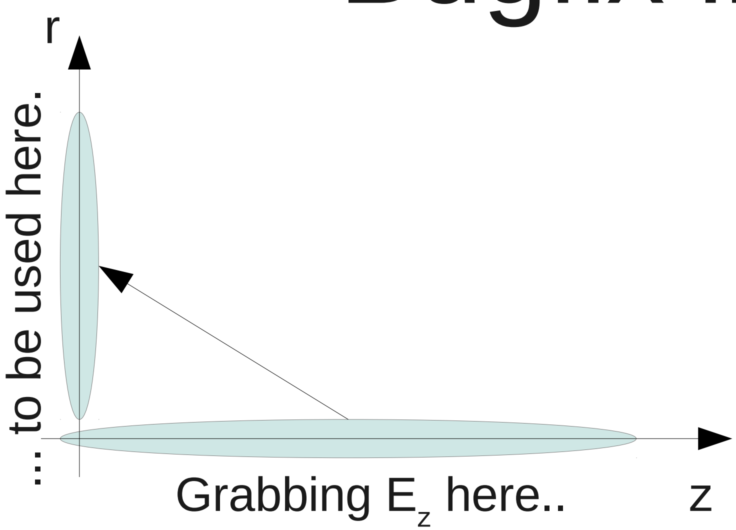
Outline

- Bugfix in flat emission
- Simulations:
  - Simulation #1
  - Simulation #2 – Convergence check of #1
  - Simulation #3 – Nominal voltage (pegged)
  - Simulation #4 – Nominal voltage (peg)
    & beta_flat = 1.0
- New plans
- Conclusions

Bugfix in flat emission



- Index error in the flat emission code led to wrong field being used

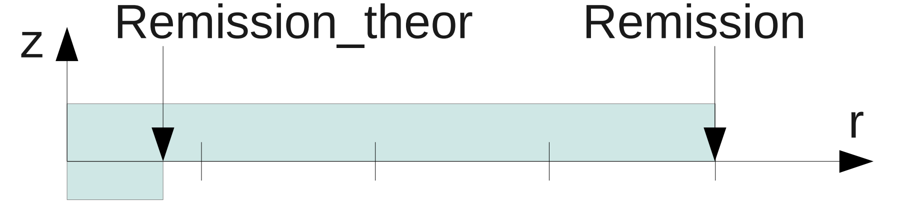
/pic2d/trunk/src/arcbound_original.cpp

```
@@ -356,7 +356,7 @@

// FN OUTSIDE THE FIELD EMITTER
for (unsigned int jj=0; jj<nr; jj++ ) {
-  field = Ez[jj+1];
+  field = Ez[(jj+1)*NZ];
  if (field < 0.) {
    // B=B_f, rescale the field to GV/m
    Eloc = - 2.69036254e-10*dz/SQU(Omega_pe)*sqrt(T_ref*n_ref)*field*beta_f;
@@ -523,7 +523,7 @@
        pa[np+k].p.r  += Rp*e2inj_step*pa[np+k].p.vr;
        pa[np+k].p.z  += Rp*e2inj_step*pa[np+k].p.vz;
        //No magnetic field, E = Ez on surface
-       pa[np+k].p.vz -= (Rp*e2inj_step-0.5)*2*Ez[jj+1];
+       pa[np+k].p.vz -= (Rp*e2inj_step-0.5)*2*Ez[(jj+1)*NZ];

        if ( pa[np+k].p.r < 0 ) pa[np+k].p.r = -pa[np+k].p.r; //Reflect on axis
        else if (pa[np+k].p.r > nr) pa[np+k].p.r = 2*nr - pa[np+k].p.r;
```

- Thus could not see the sheath
- Bug also present in FlexFN
- This invalidates older tests of flat emission
- But: Now we GET flat emission
- Results looks much more as expected :D

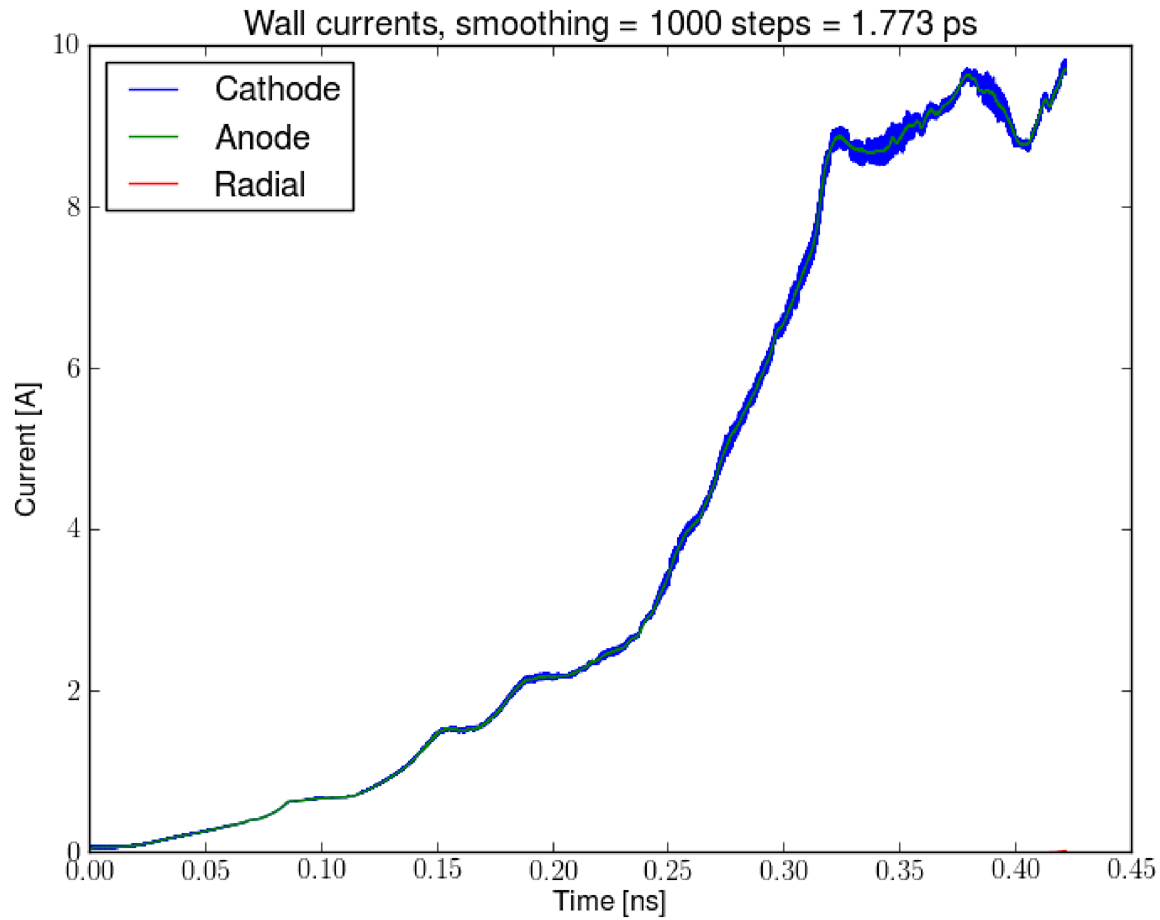
Simulations

- Only a few have so far been made with the fixed code (they take a while to run)
- All simulations with gapsize 6 µm (somewhat random choice)
- All simulations with the new emission model
  - Neutral evaporation from flat surface on flat surface (not center)
  - Flat emission starting at Remission_theor, not Remission
    - Geometrical interpretation?
  - Fractional timestep injection switched on



Simulation #1

- Name: test_currdens
- U = 5800 V
- Z = 6 µm
- E = 966 MV/m
- 0.5 pF local capacitator voltage source
- Beta = 35
- Beta_flat = 2
- Remission = 0.564189 µm
- Thresh_heatspike = 1e25 cm^{-2} s^{-1}
- Y_heatspike = 1
- No melting or erosion of tip
- SEY = 0.5
- dz = 0.1 µm
- Dt = 1.77 fs
- Nsp = 21.3

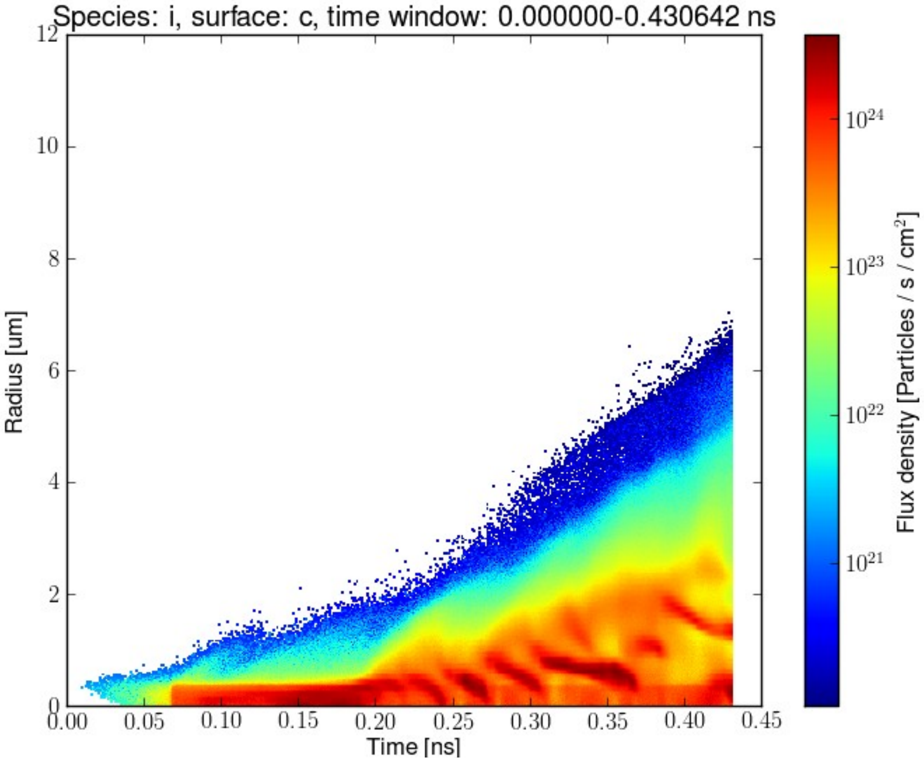


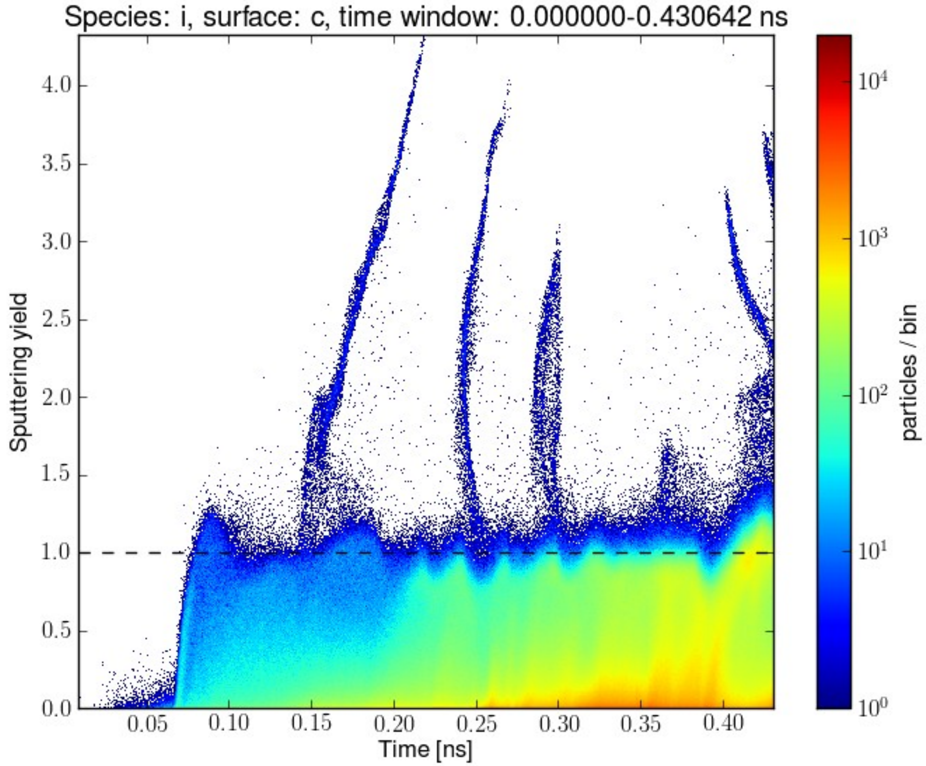
Simulation #1:
Particle- and particle density plots

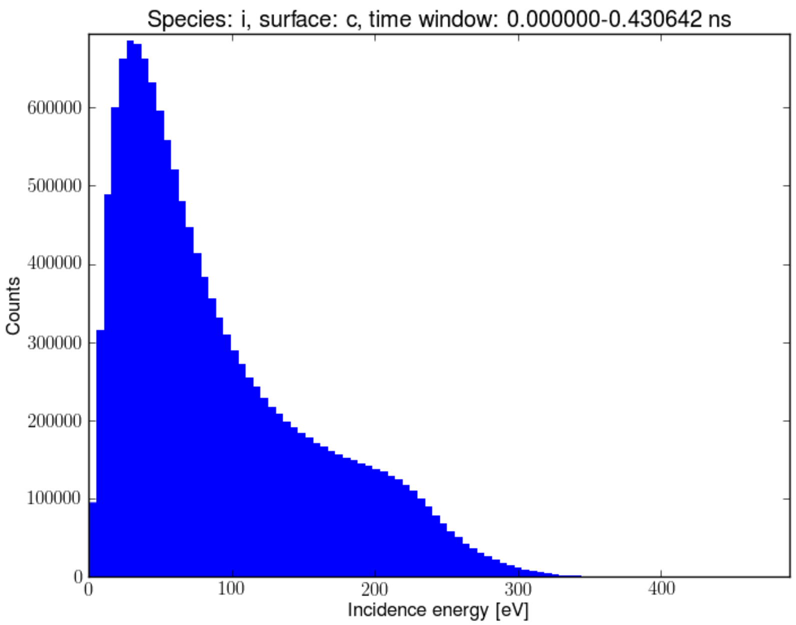
- Phases visible:
  - Emission
  - Ignition
  - Spreading
- Also see powerful oscillations which some ions “surf”
  - Electrostatic oscillations
  - May be a numerical instability...

Simulation #1: Potential and field plots

Simulation #1: Particle impacts

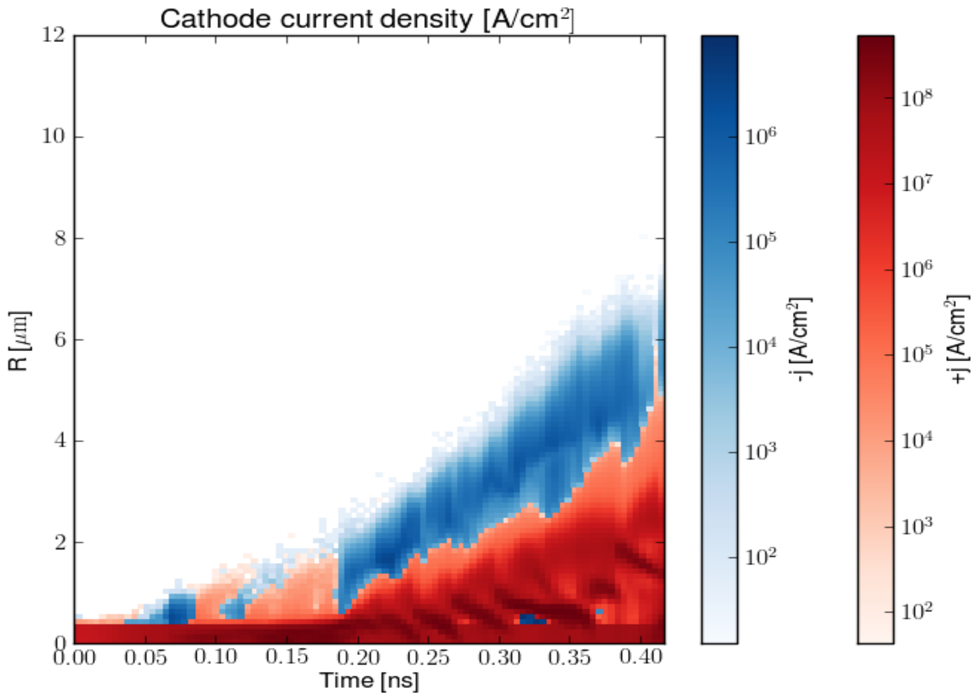


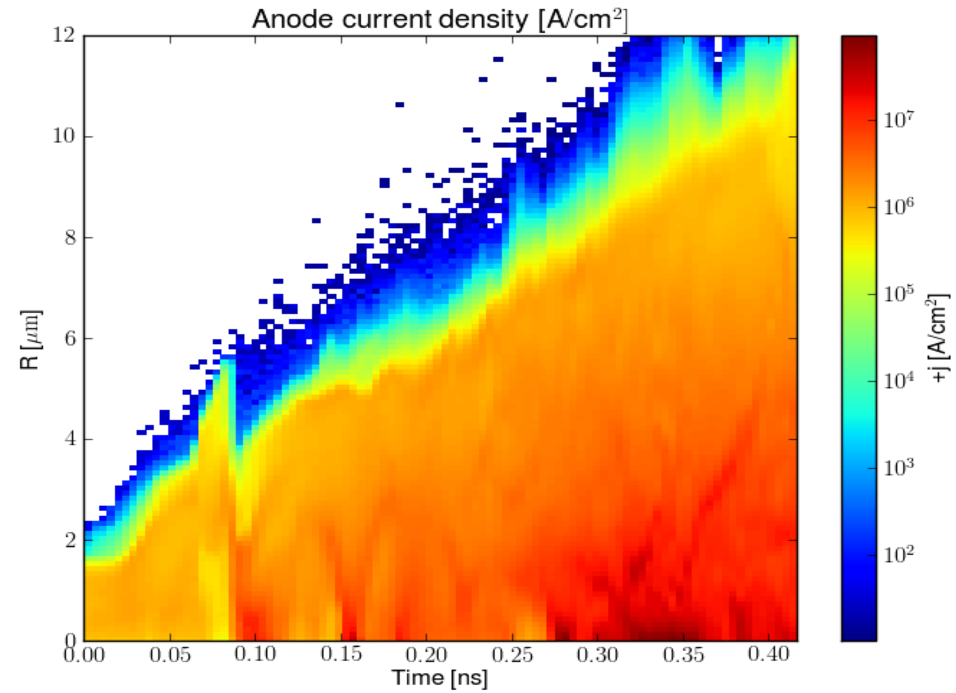




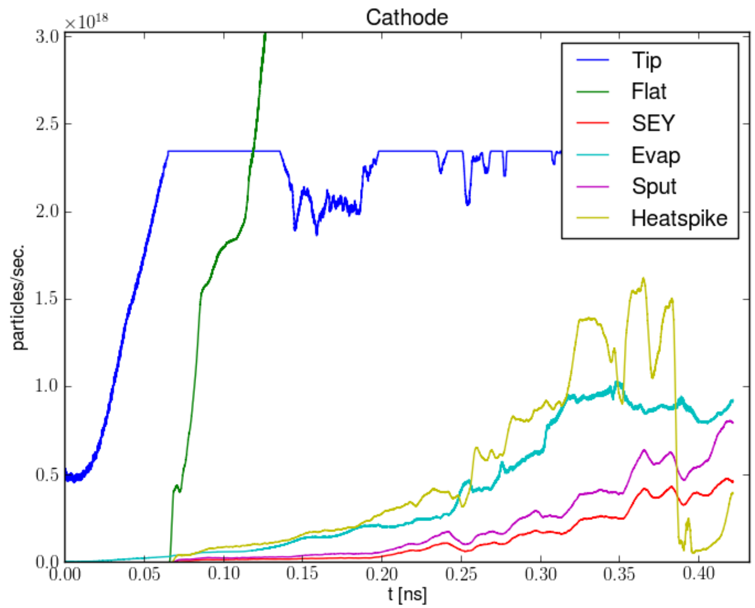
- See expansion
- Some structure in bombardment
- Energy mostly ~50 eV
- Flux density ~10^{23}-10^{24} ions/s/cm^2

Simulation #1: Surface current density



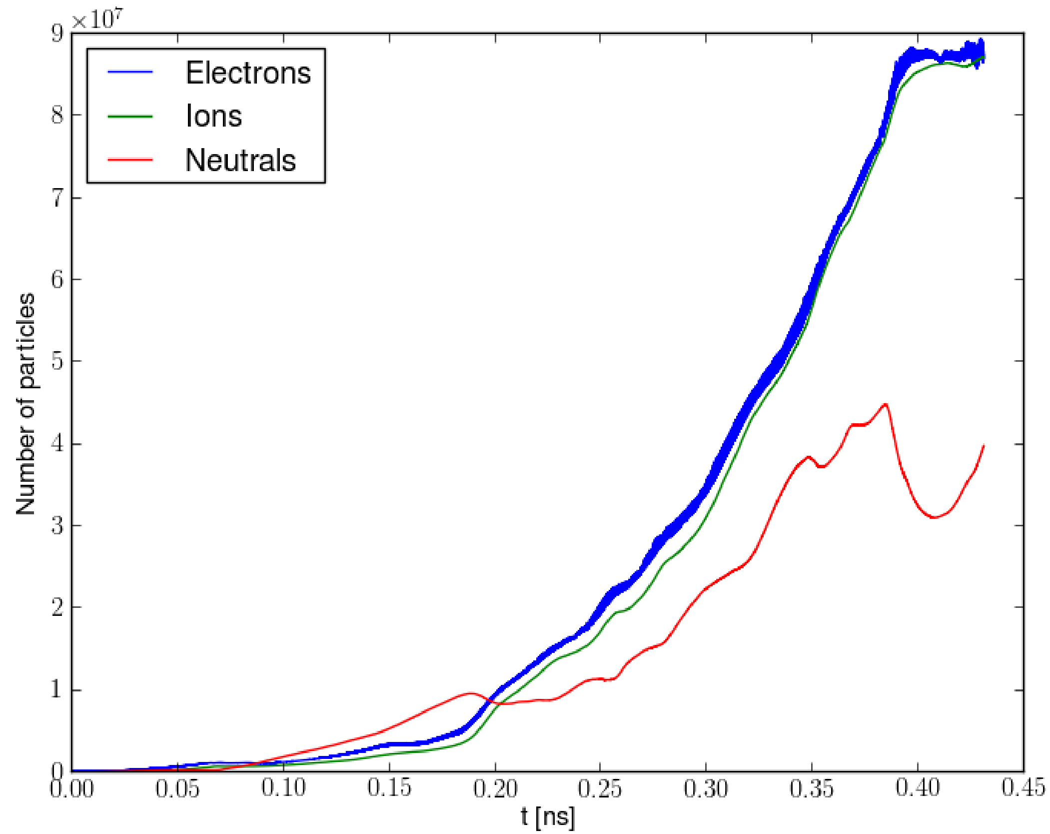


- See clearly that the arc is expanding
- Cathode: "Halo" of electrons hitting the surface
  - Speculation: Worms?



Simulation #1: Summary

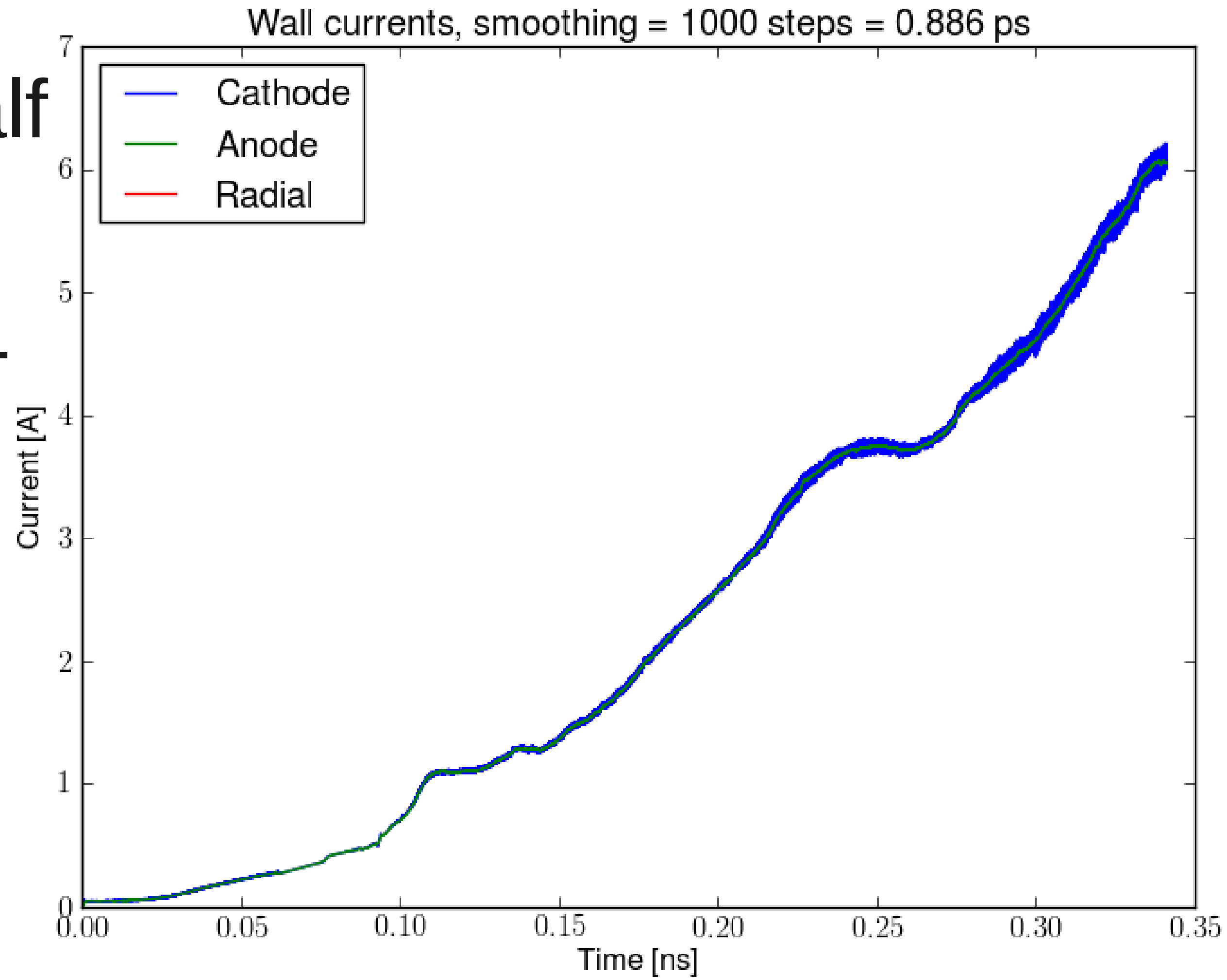
- Sheath now ignites flat surface
- Stable simulation – plasma spreading, not getting superdense
- Quasineutral and conducting plasma expands to fill volume
- Complete ionization of central part
- Rapid rise in current
- Capacitator voltage depleting
- Concentration of potential in remaining vacuum
    - Very high field here!
- Powerful oscillations



Simulation #2 – Convergence check of #1

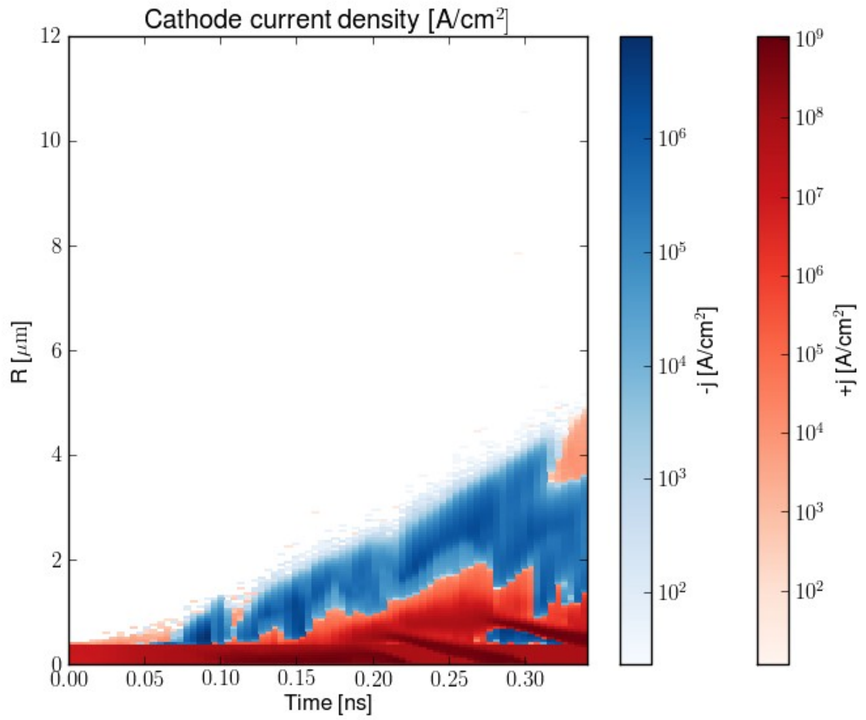
- Name: test_currdens_half
- Same physics parameters as #1
- Dz = 0.05 µm
- Dt = 0.89 fs
- Nsp = 10.7

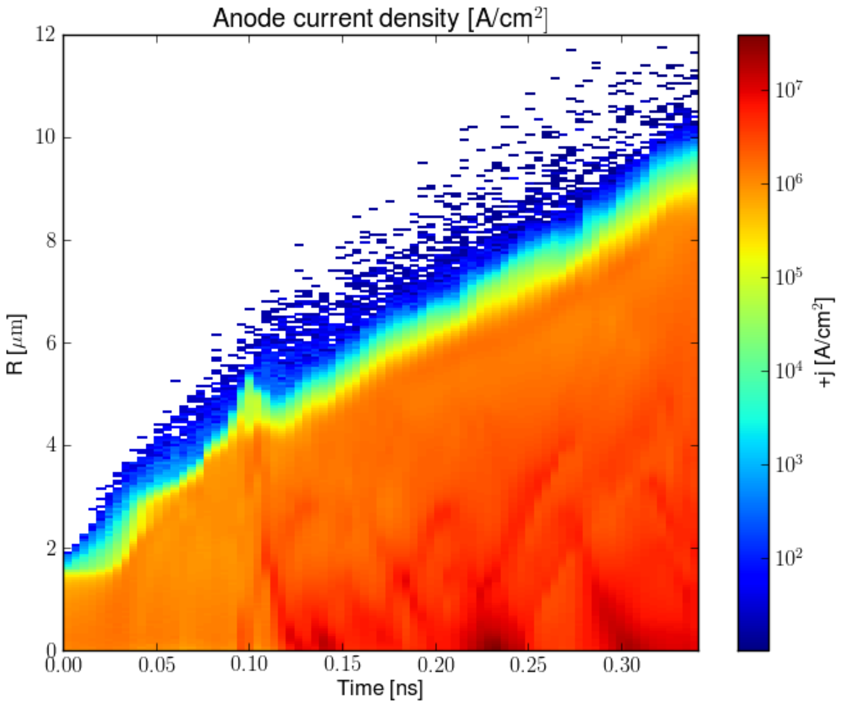
Half of #1



Simulation #2 – potential & density

Simulation #2 – current density

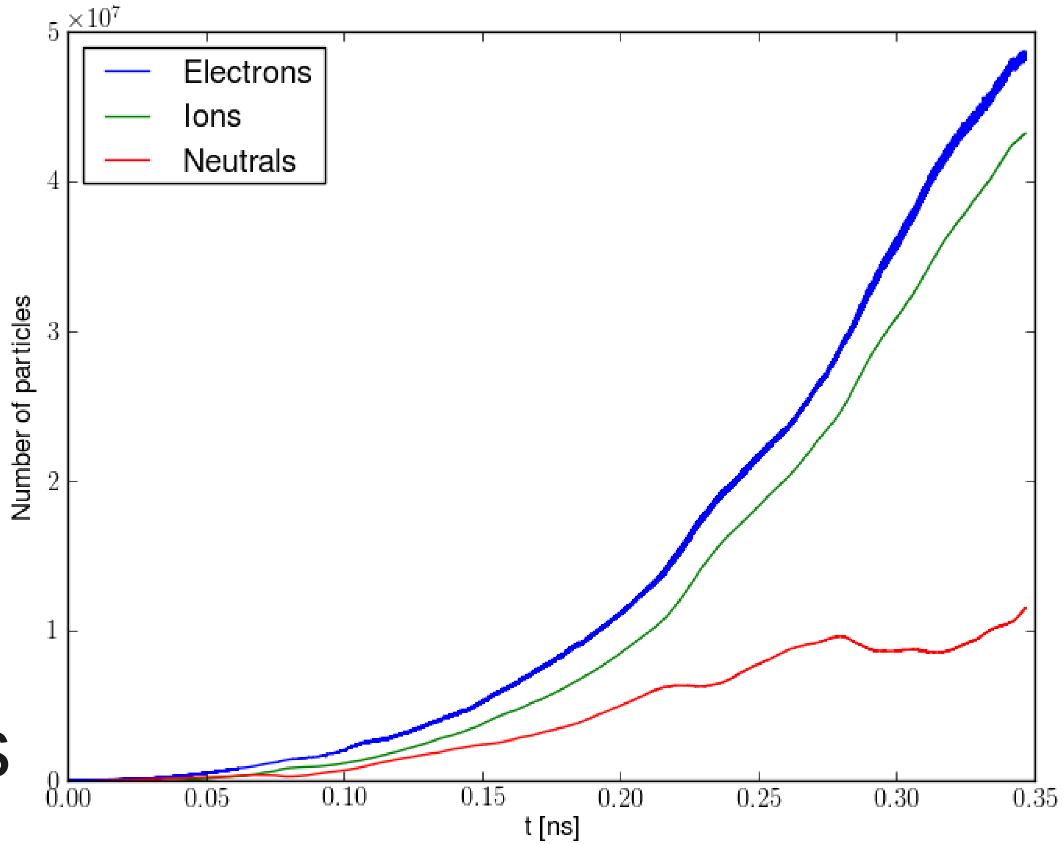




- Not yet filling gap
- Larger "electron halo"
- Slower growth
- Broadly similar to #1

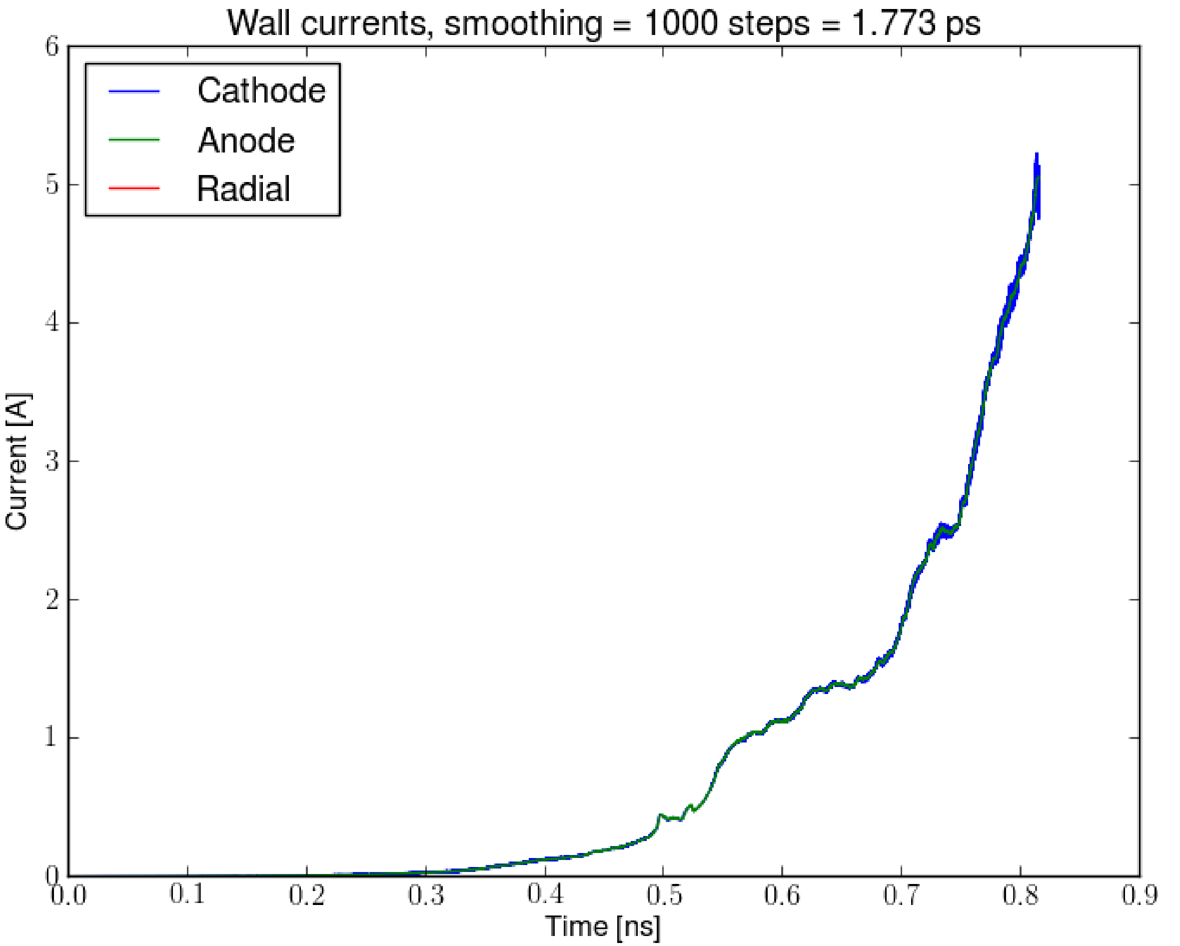
Simulation #2: Comparing to #1

- Broadly similar to #1
- Slower current rise
- Less “pulsing”
- Probably better converged
- Gap voltage and field may affect needed numerical parameters



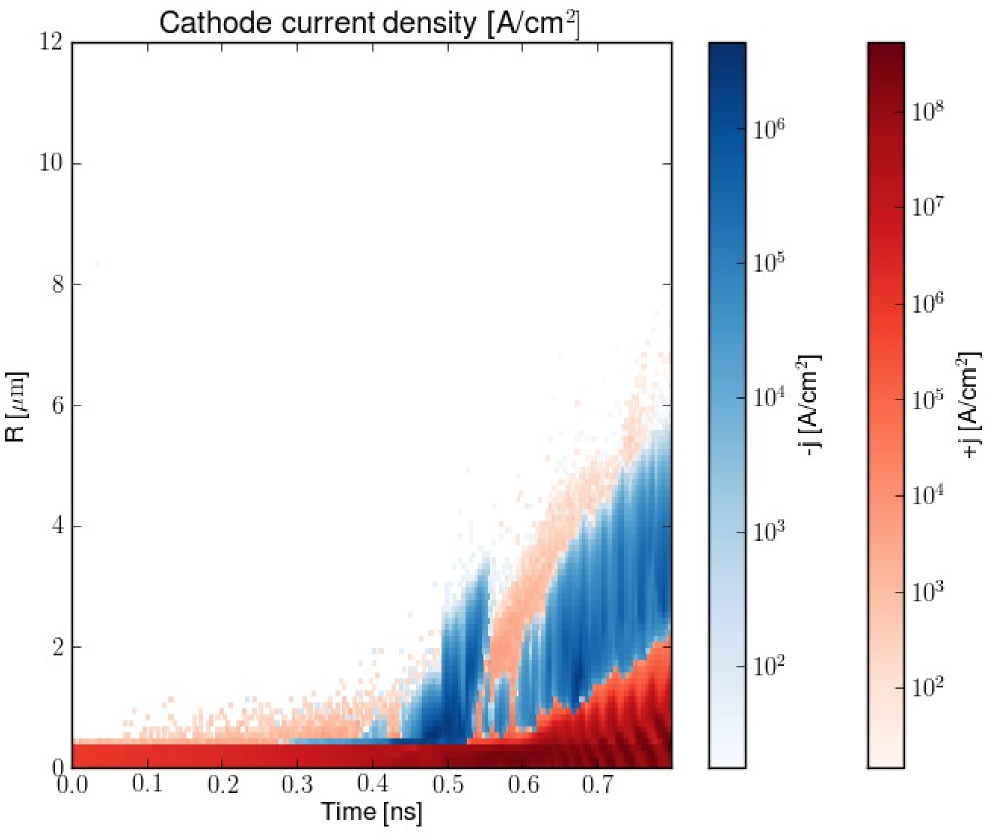
Simulation #3: Nominal voltage (pegged)

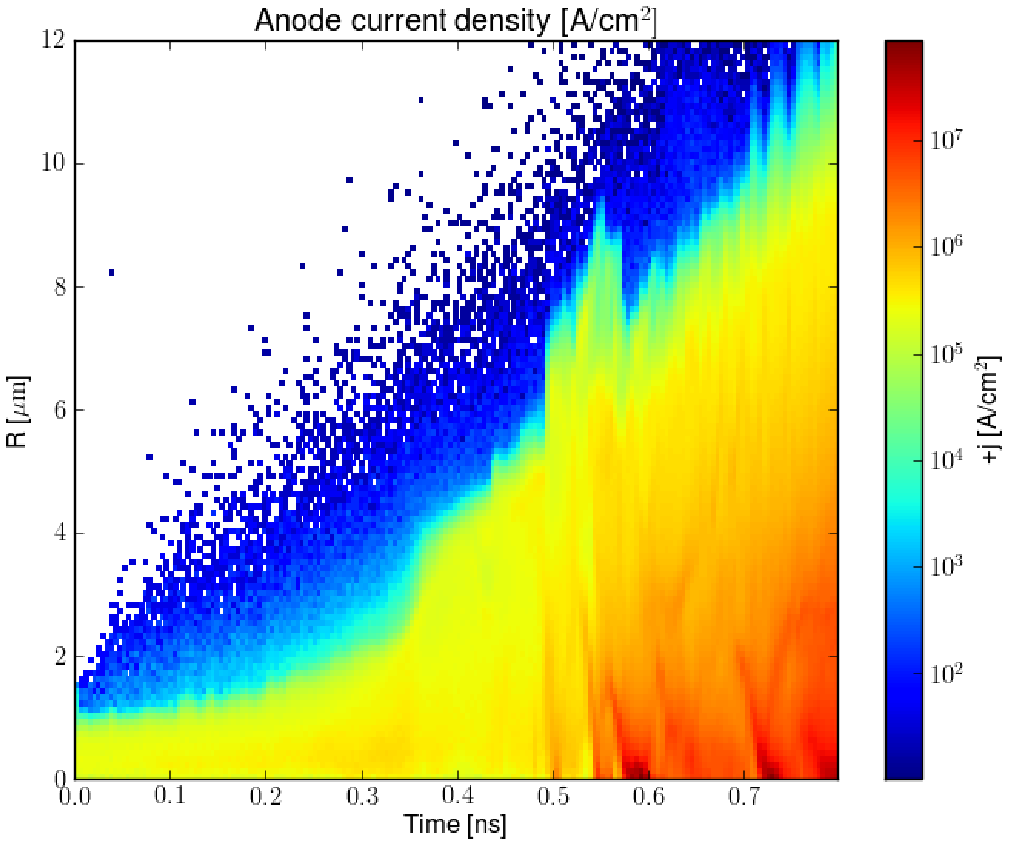
- Name: test_currDens_normVoltage
- Same physics & simulation setup as #1
- Exception:
  - U = 1740 V
  - E = 290 MV/m
  - FixedVoltage circuit (no capacitator)



Simulation #3 – potential & density

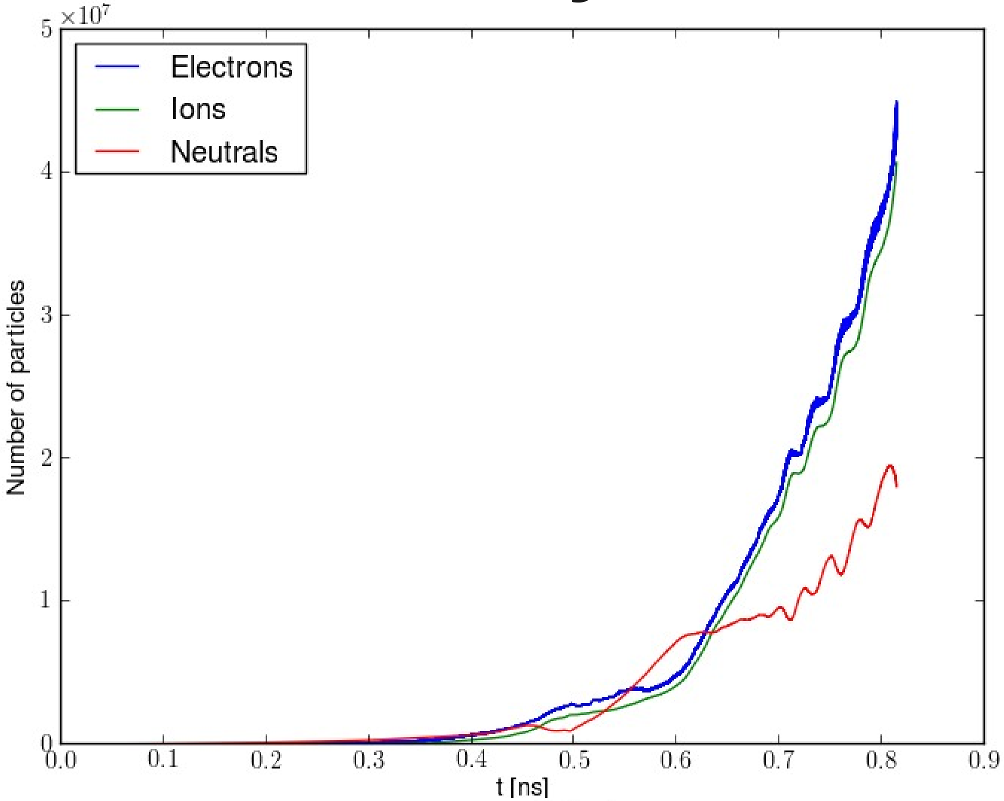
Simulation #3 – current density

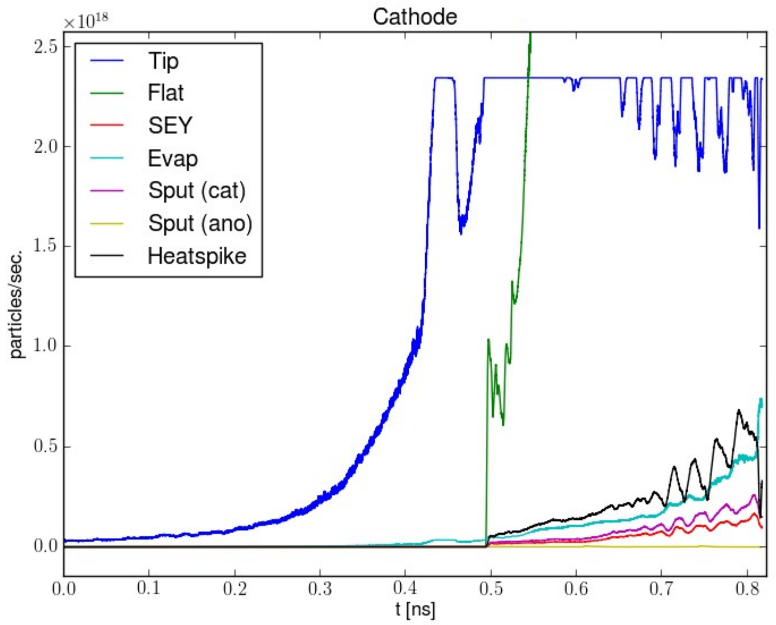




Simulation #3 – summary

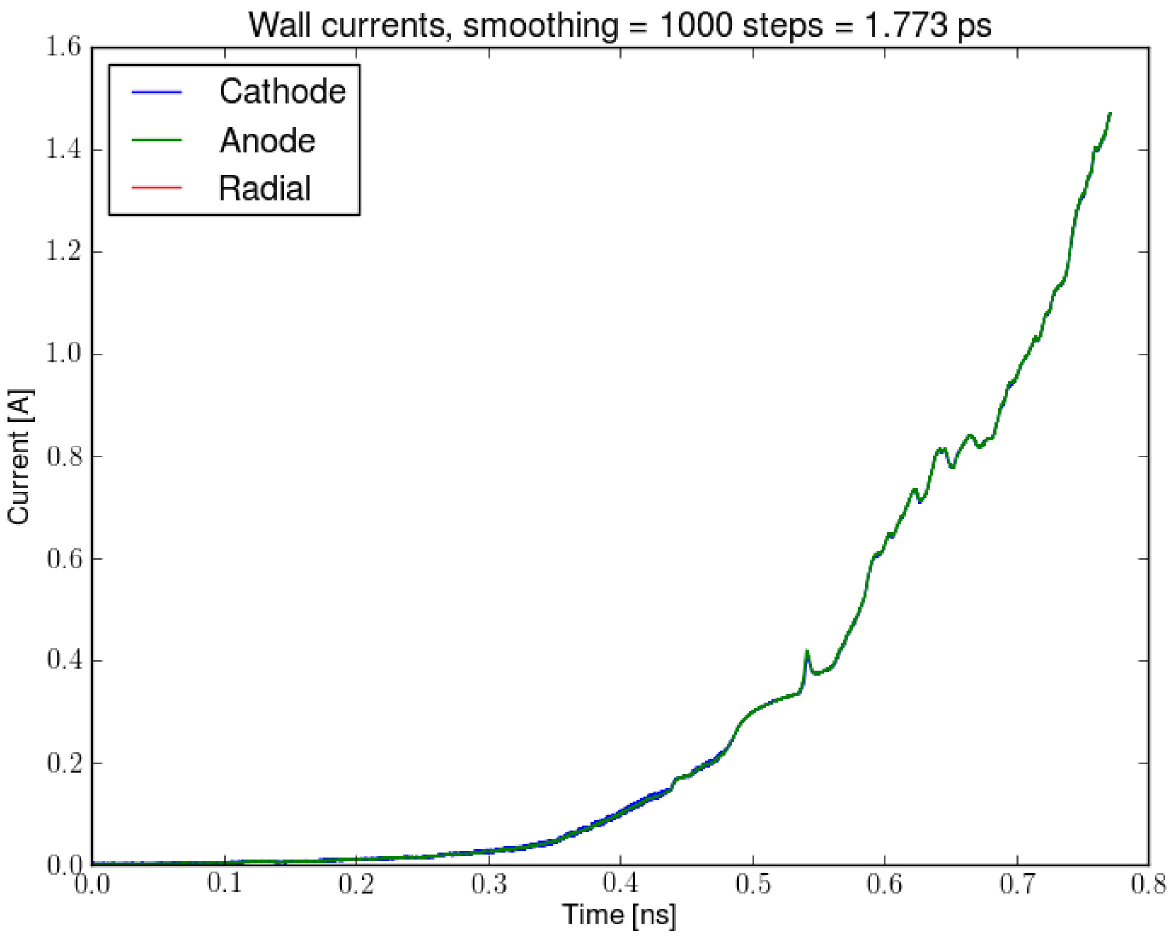
- Much slower rise than the high voltage runs
- Anode voltage pegged
- More neutrals produced
- Quite turbulent plasma





Simulation #4 – Nominal voltage (pegged) & beta_flat = 1.0

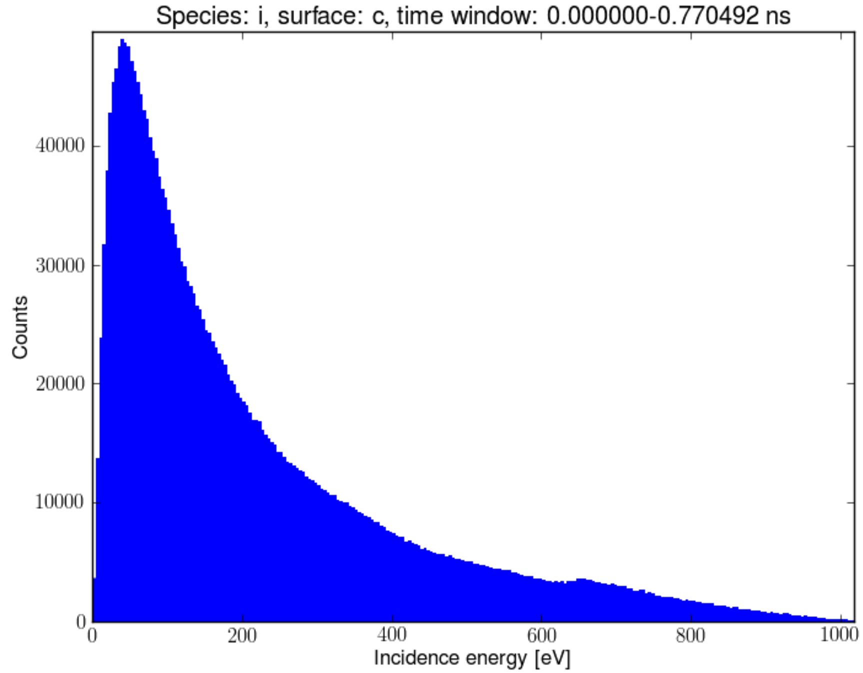
- Name: test_currDens_normVoltage_bf1.0
- Same setup as #3
- Exception: beta_flat = 1.0
- This leads to much slower runaway

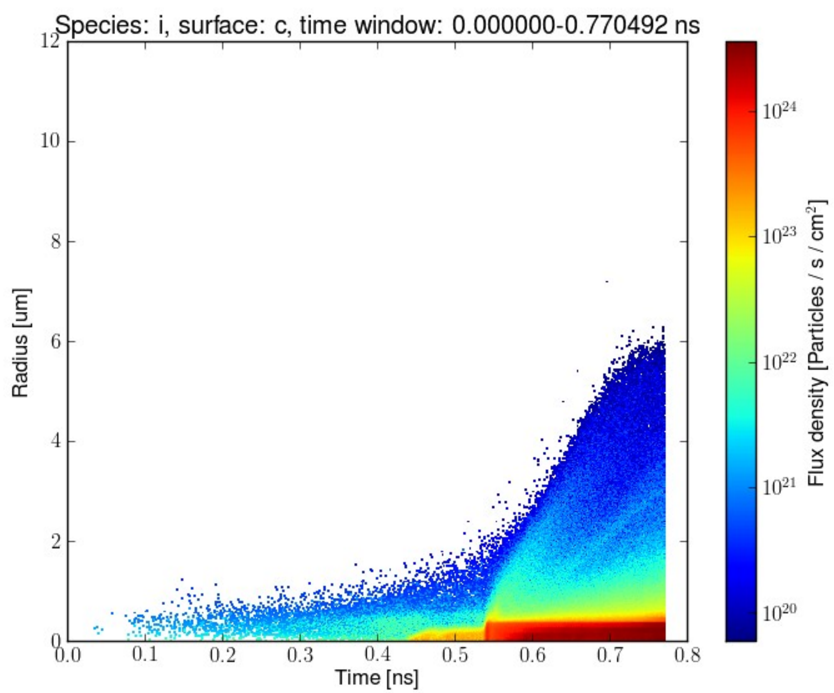


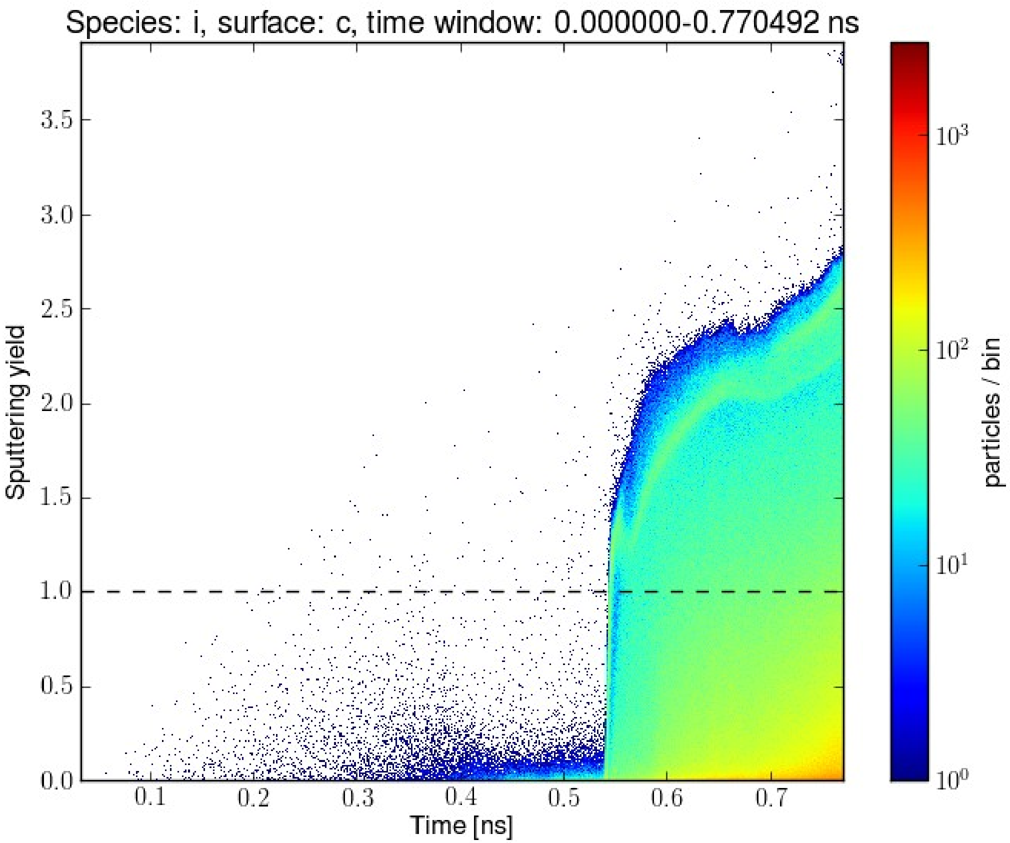
Simulation #4 – potential & density

Note that plasma here sits at much higher potential!

Simulation #4: Particle impacts

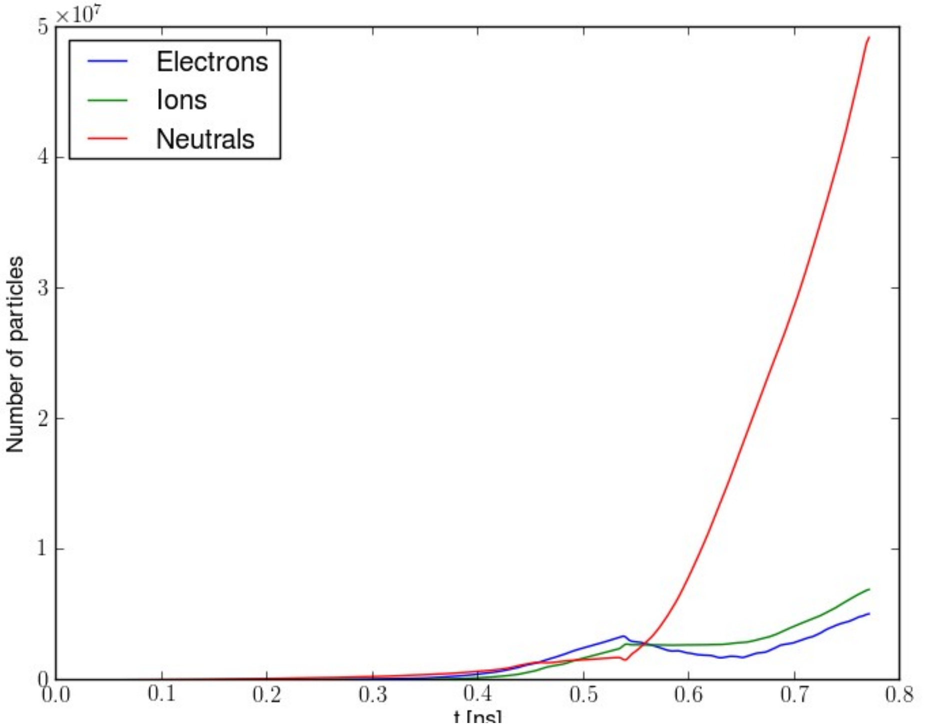


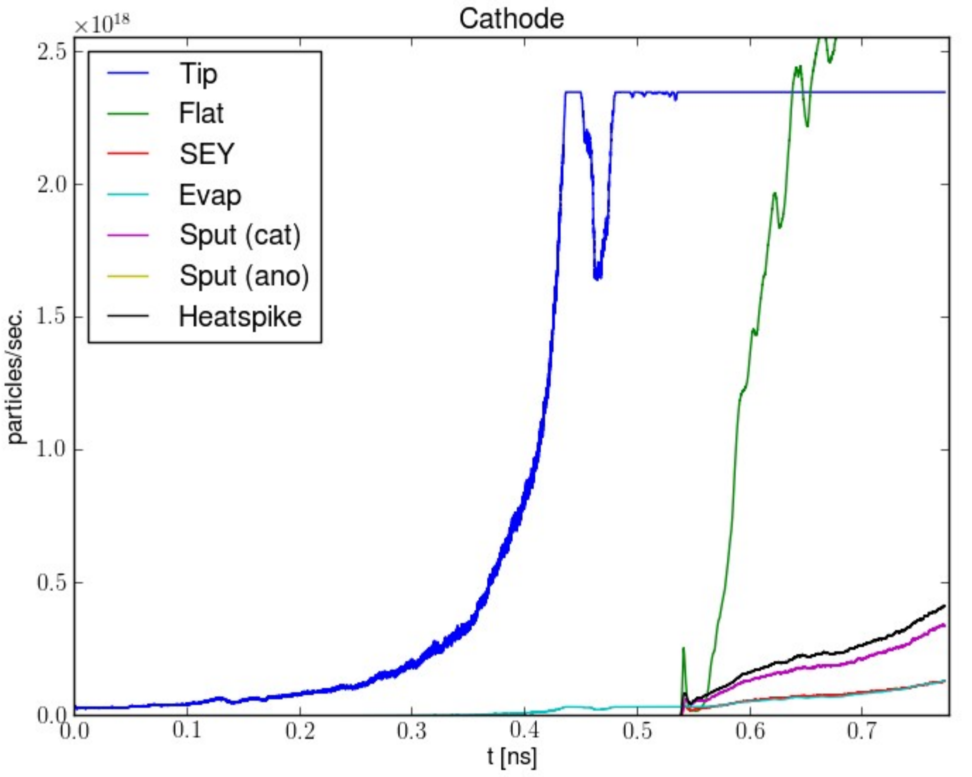




Simulation #4 – summary

- Much lower total currents
- Much more neutrals
- Much higher sheath voltage
    - Higher impactor energy
    - Distribution still peaking at 50 V
    - Average yield 0.7





New plans – short term (paper)

- Boundary conditions:
  MeVarc 5. November – 6½ weeks
  - Must finish most simulations in a few weeks
  - Then finish paper
- I'm going to Oslo to teach this week
- Simulations to be done:
  - Ignition parameters
    - Field / beta_tip / tip area
    - Neutral density / evap ratio
    - Injection area
  - Spreading parameters
    - Field / beta_flat
    - Heatspike / SEY parameters
    - Rbound

ALTERNATIVE:
This + field emission

New plans – longer term

- Full arc cycle simulation now appears possible
- Should implement Shockley-Ramo current calculation to reduce current noise
  - Especially if using series resistor
  - Loop over all charged particles
- Energy deposit in material & temperature
  - Could be done off-line (in post-analysis)
- Properly study effects of external circuit
  - Energy stored, energy flow
- Higher charge states, recombination, field ionization
- Binary output format, restore the restart functionality

Conclusions

- Fixed major bug in flat emission
- Ignition of flat surface now works
- See differences in runs with different fields, beta_flat etc.
- Need to understand convergence
  - Especially plasma oscillations