Numerical Simulation for UW-IEC Device

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Outline

- Simulation code
- Modeling
- Results
- Conclusions

Original PDS-1 code

PDS-1 (Plasma Device at Spherical bounding electrodes – 1 dimensional) code

- was developed by the plasma theory and simulation group at UC-Berkeley
- 1-D space and 2-D velocity space
- PIC (Particle in Cell) method and Monte Carlo collision scheme
- Has following atomic processes
  - Electron – Neutral gas collisions
    - Elastic collision
    - Excitation
    - Ionization
  - Ion – Neutral gas collisions
    - Scattering collision
    - Charge exchange collision

Modification

- IEC gridded system (by Dr. R. A. Nebel)
- Reflecting boundary at the origin (5mm from the origin)
- Ion impact ionization
- Recombination
- Tracking of fast neutrals (generated by charge exchange)
- Fusion reaction (ion-neutral, fast neutral-neutral, ion-ion)
- Energy dependence of secondary electron emission coefficient

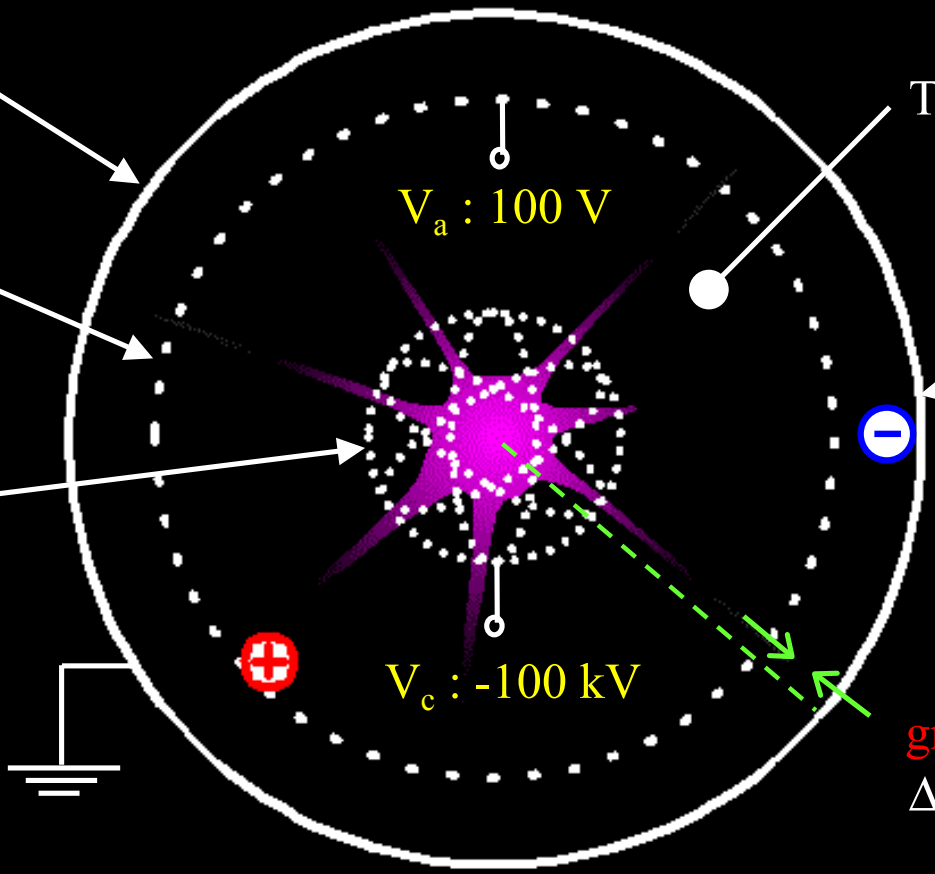
Modeling

Chamber
r_w : 30 cm

Anode
r_a : 25 cm
γ_a : 95 %

Cathode
r_c : 5 cm
γ_c : 92 %

time step
Δt : 100 ps



D^0 neutral gas
T : 300 K = 0.026 eV
p : 2 mTorr

D^+ ion

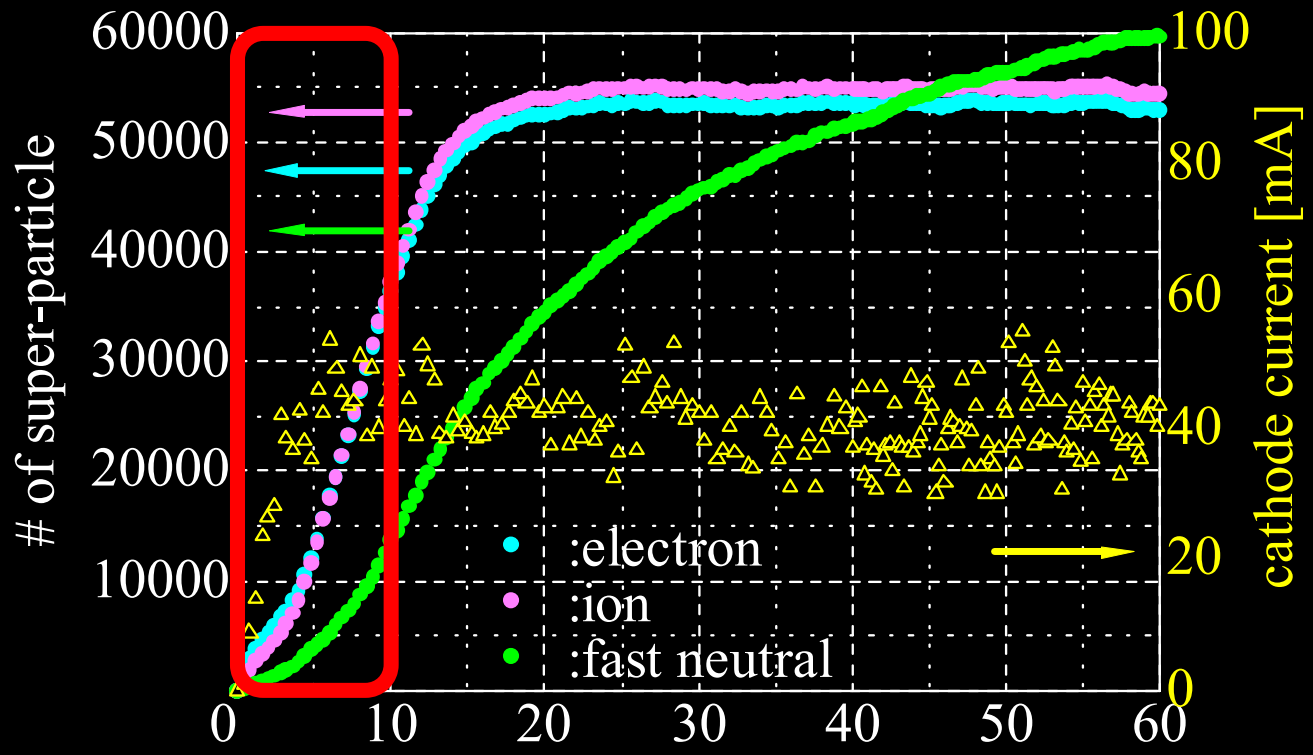
e^- injection
I : 5 A
E : 0 – 100 eV

particle weight
$2*10^7$ p/sp

grid spacing
Δr : 0.1 mm

Time Dependence of the # of super-particle

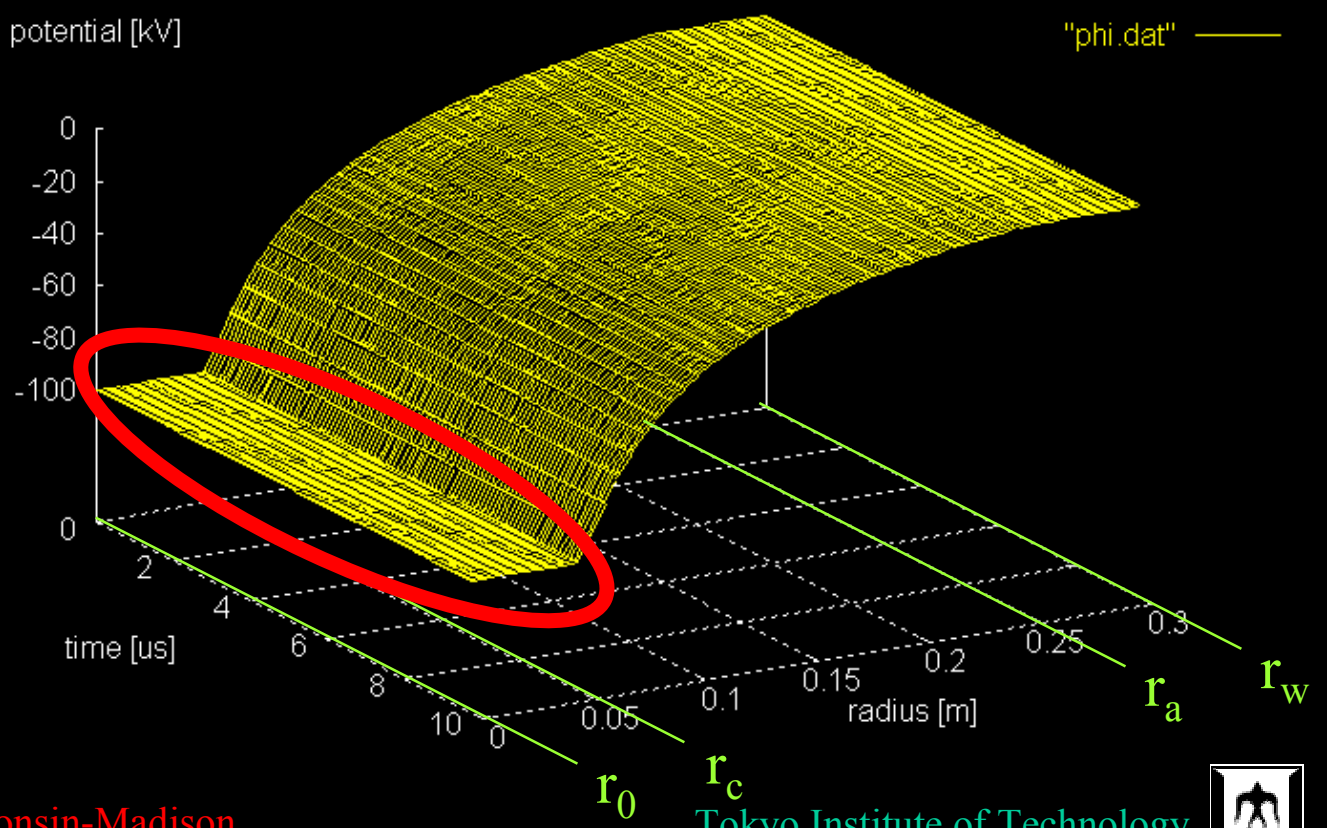
- The simulation reached almost steady-state in ~10 μs.
- Averaged cathode current was about 40 mA.



Potential Structure

Describing Child-Langmuir potential

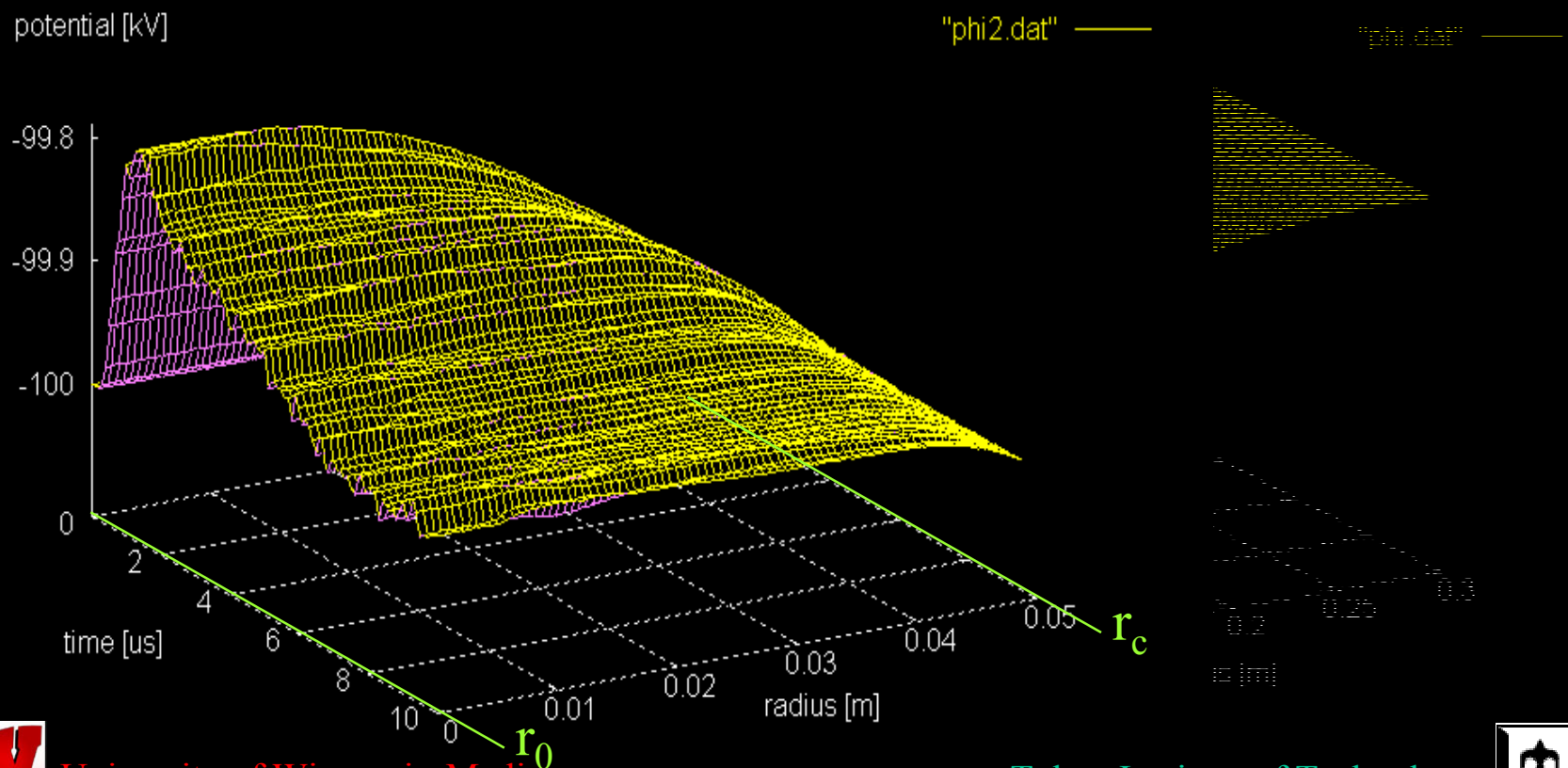
(0 – 10 us)



Potential Structure (inside the cathode)

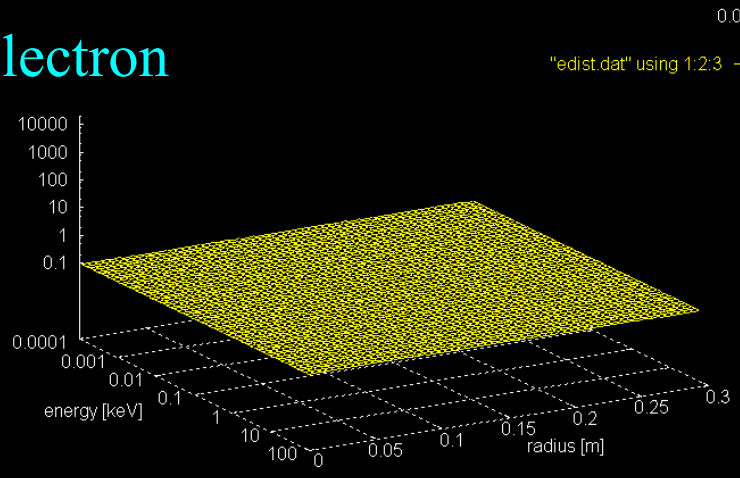
Small (~10 V) potential well was obtained.

(0 – 10 us)

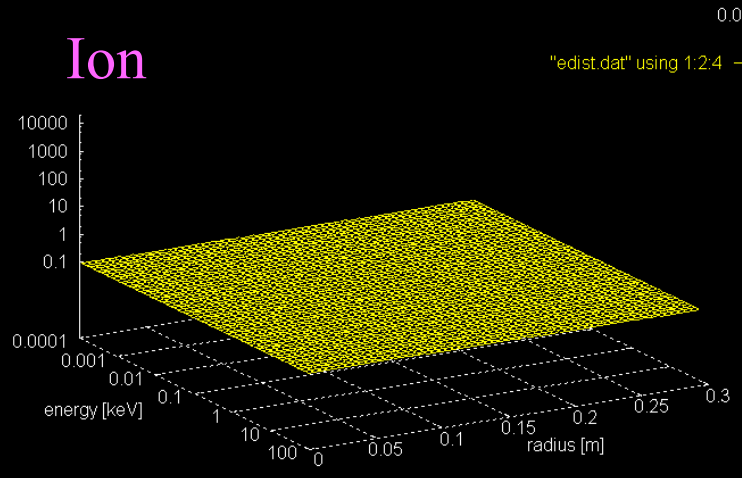


Energy Distribution (0 – 2 us)

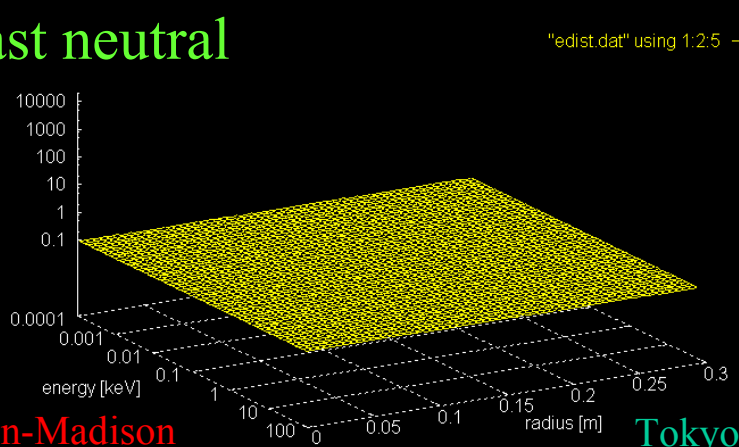
Electron



Ion



Fast neutral

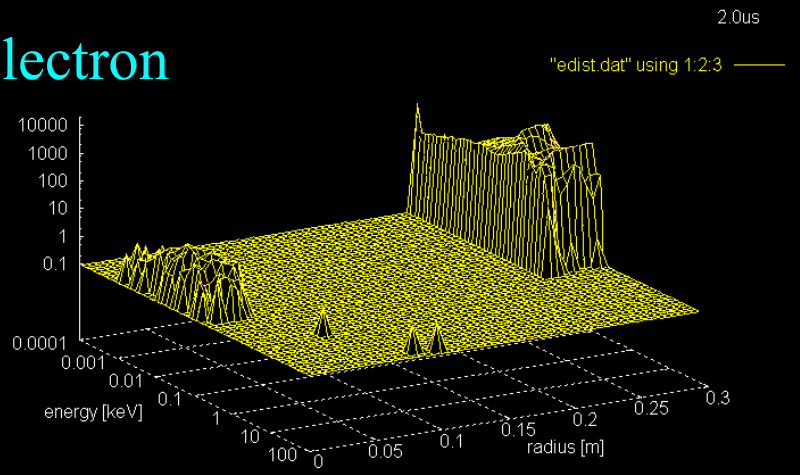


time

0.0 μs

Energy Distribution (2 – 4 us)

Electron



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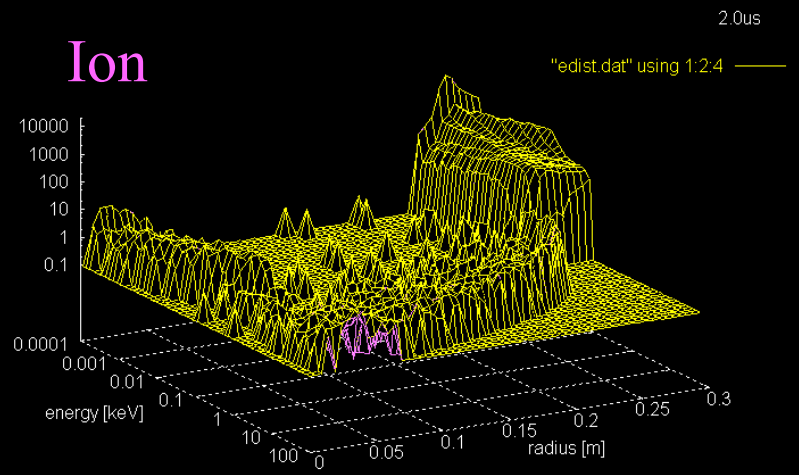
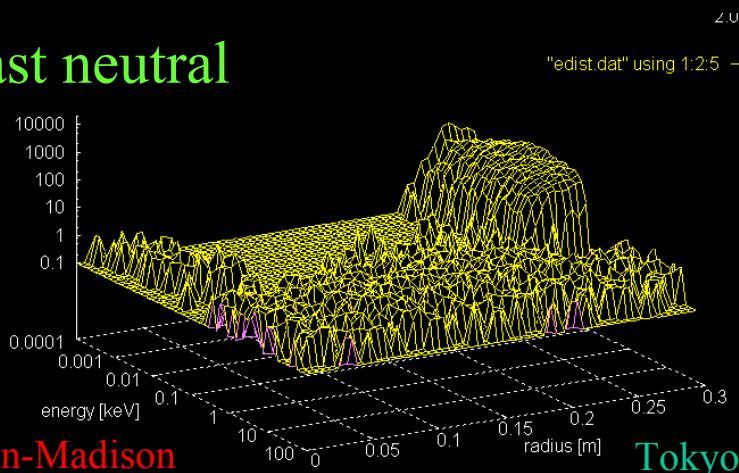


Fast neutral

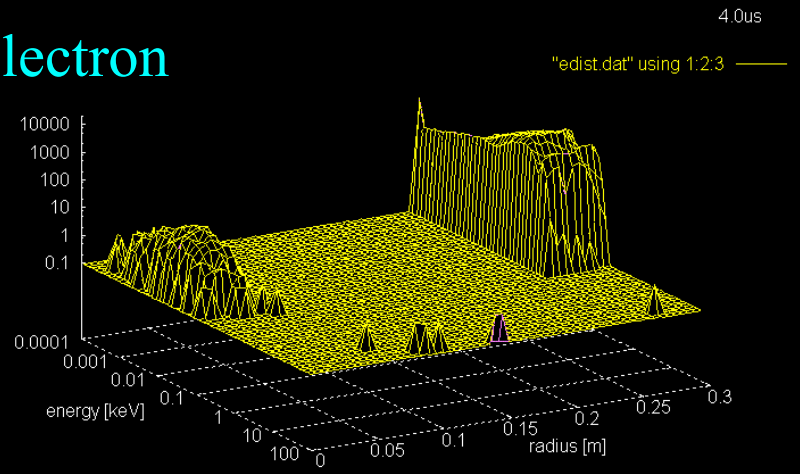


time

2.0 μs

Energy Distribution (4 – 6 us)

Electron



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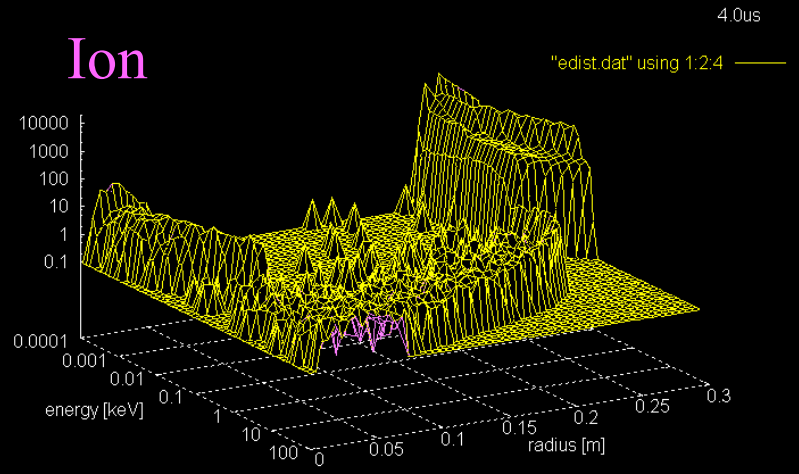
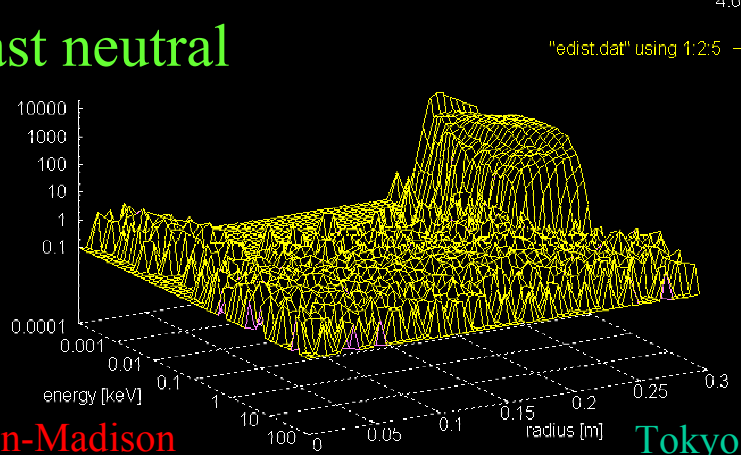


Fast neutral

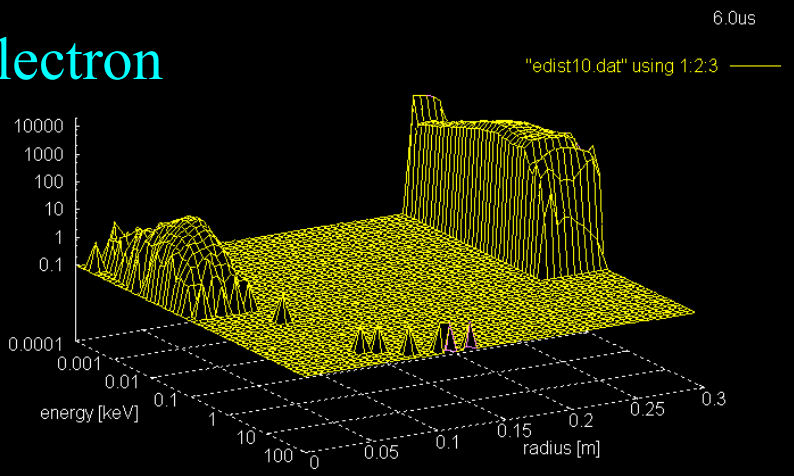


time

4.0 μs

Energy Distribution (6 – 8 us)

Electron



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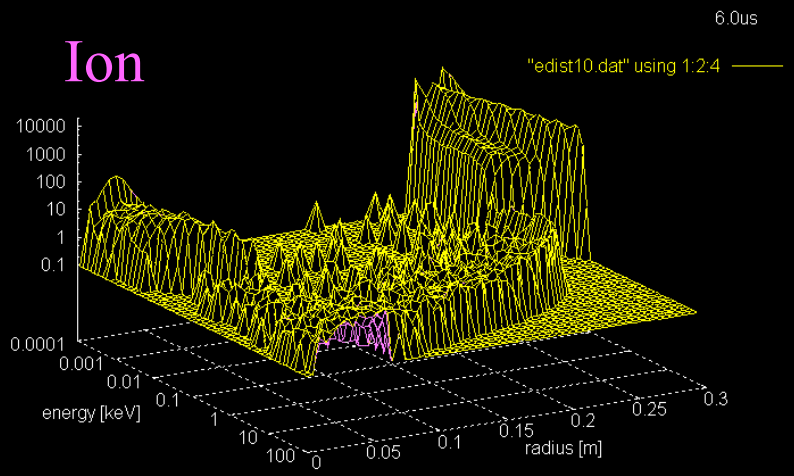
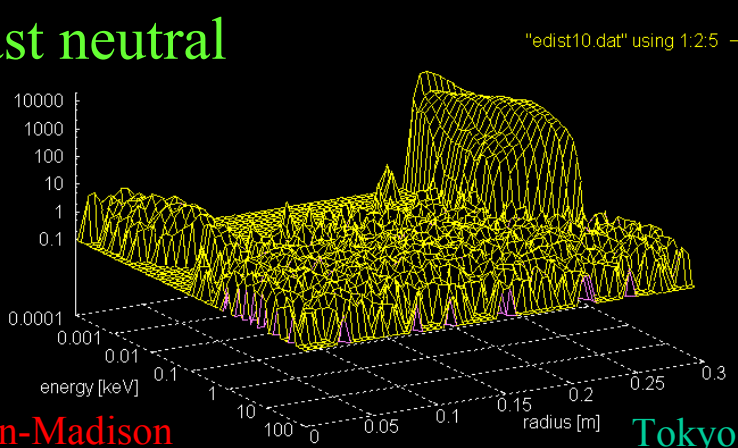


Fast neutral

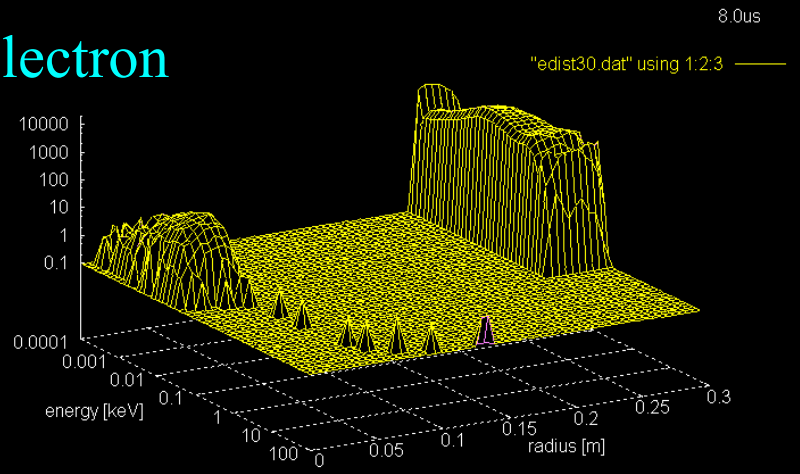


time

6.0 μs

Energy Distribution (8 – 10 us)

Electron



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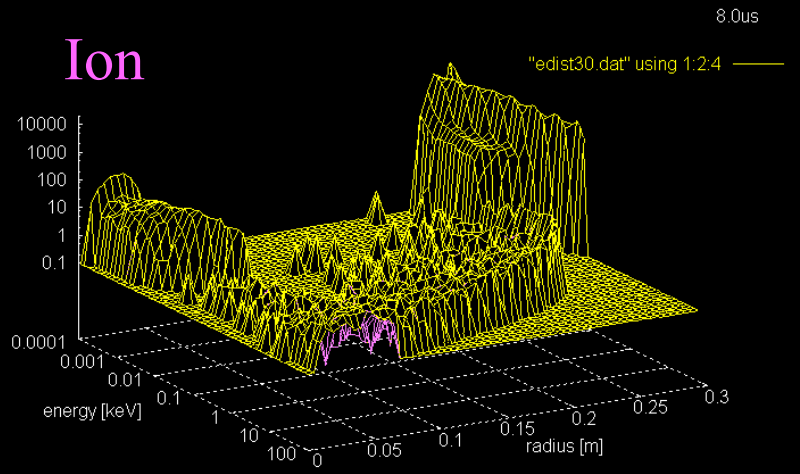
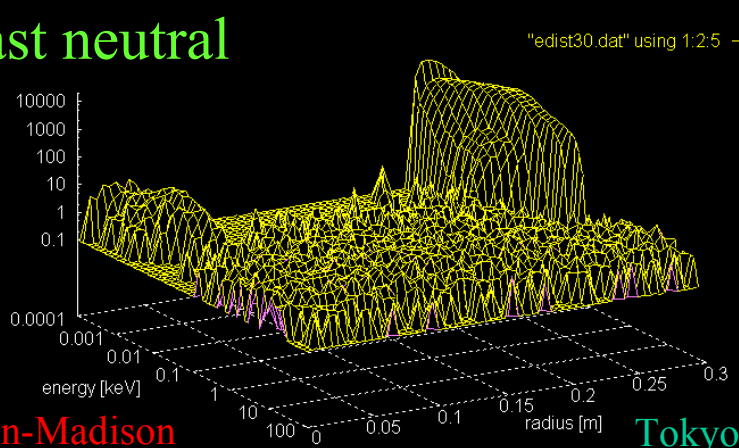


Fast neutral

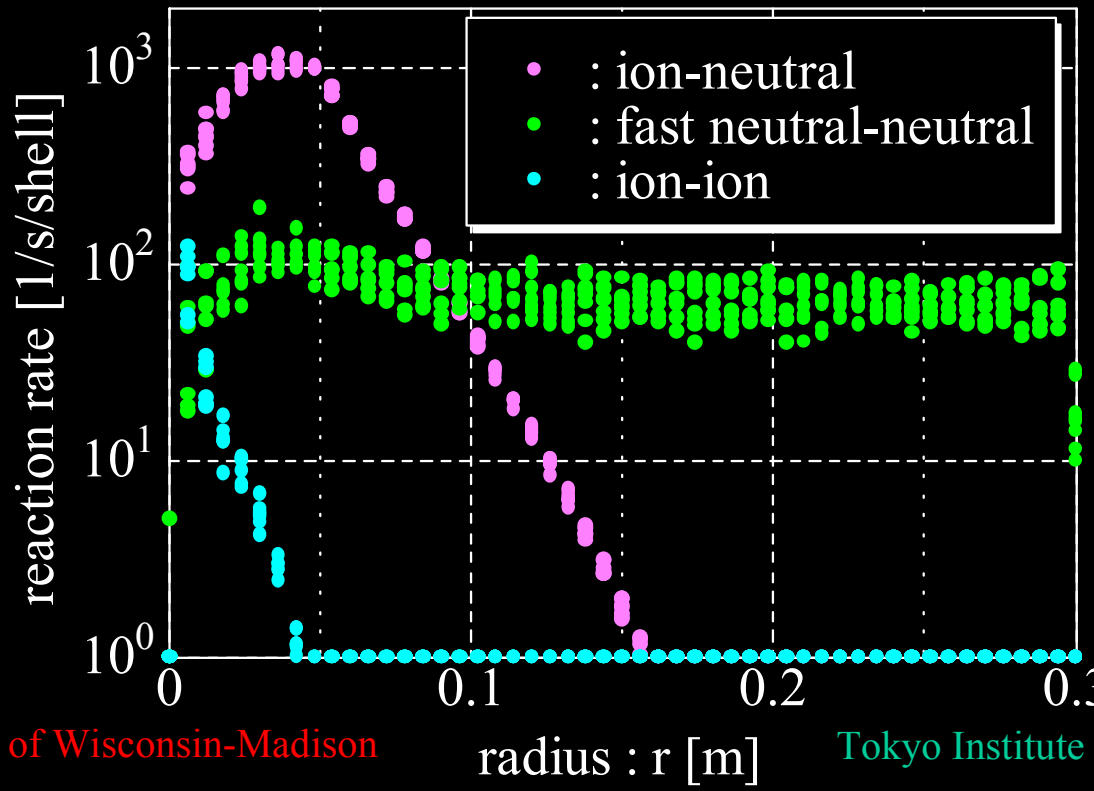


time

8.0 μs

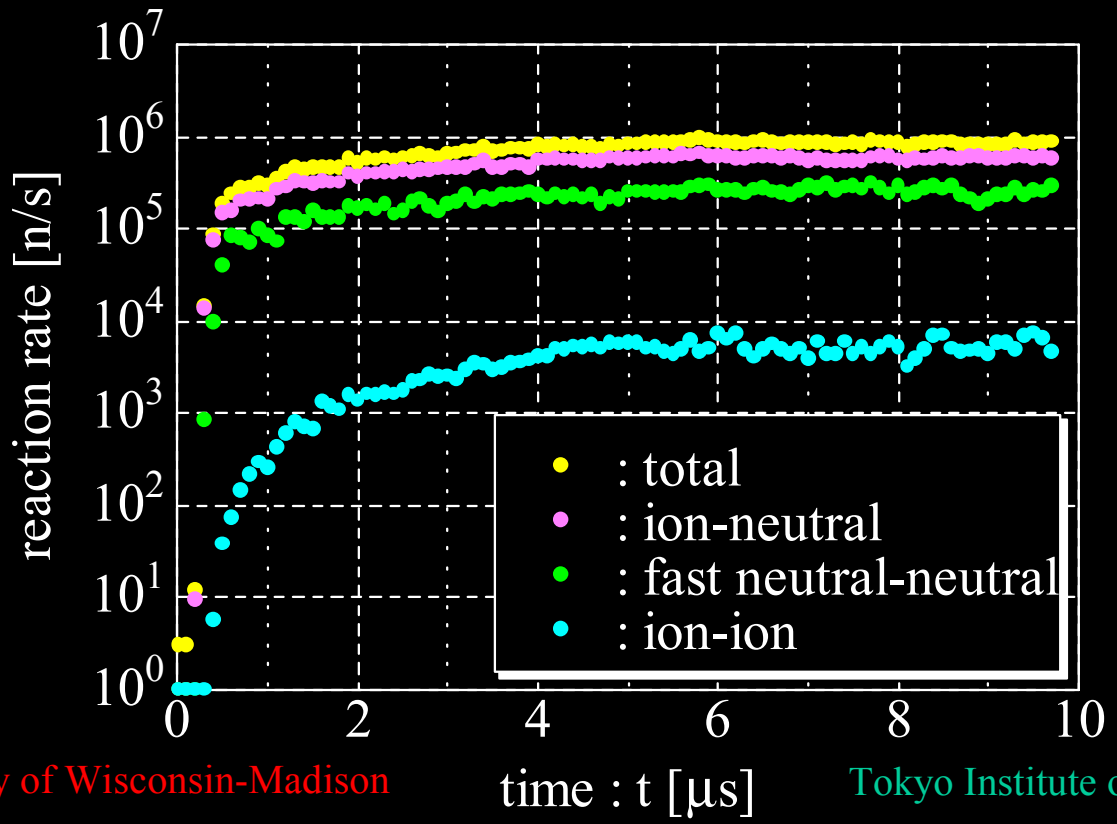
Distribution of fusion reaction (1/s/shell)

- Ion-neutral reactions increase approaching the center.
- Fast neutral-neutral reactions occur uniformly inside the device.
- Ion-ion reactions occur only inside the cathode.



Fusion Reaction Rate [1/s]

Averaged reaction rate was $8.8*10^5$ [n/s] (100 kV, 40 mA)
while experimental record is $1.3*10^7$ [n/s] (100kV, 30 mA)



Conclusions

- IEC plasma simulation, which models a real UW-IEC device, based on a PIC method with a Monte Carlo collision scheme was carried out
- Reasonable results were obtained
  - Approximate steady state
  - Typical potential profile
  - Basic behaviors of each particle
  - Distribution of fusion reactions
  - Reaction rate of $8.8*10^5$ [n/s]

Question?