# 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





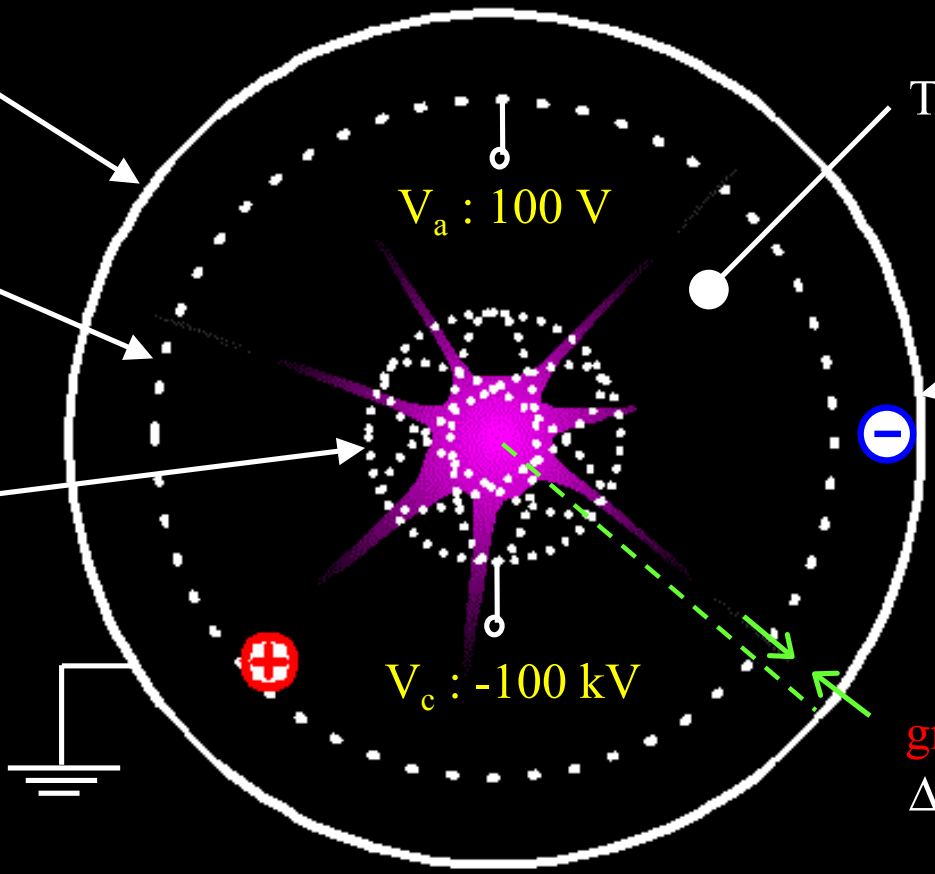
# Modeling

Chamber
$r_w$ : 30 cm

Anode
$r_a$ : 25 cm
$\gamma_a$ : 95 %

Cathode
$r_c$ : 5 cm
$\gamma_c$ : 92 %

time step
$\Delta t$ : 100 ps




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

$D^+$ ion

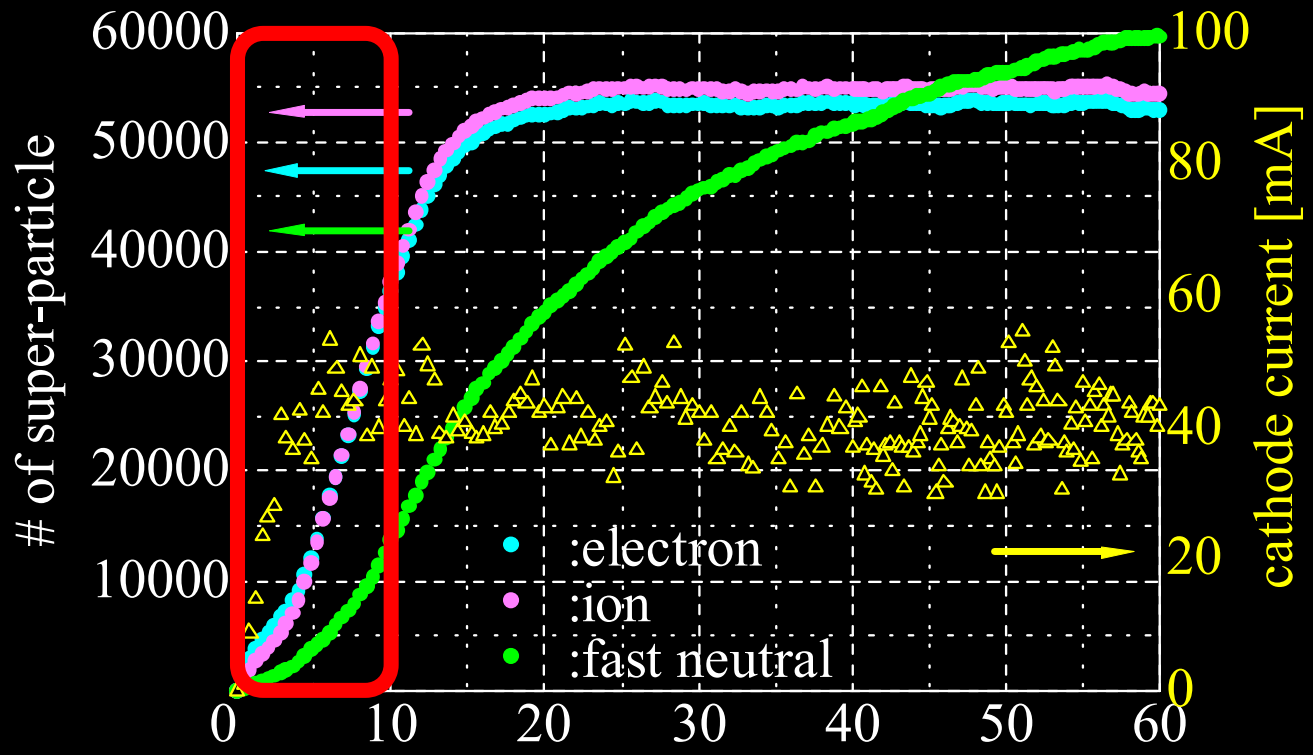
$e^-$ injection
I : 5 A
E : 0 – 100 eV

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

grid spacing
$\Delta r$ : 0.1 mm

# Time Dependence of the # of super-particle

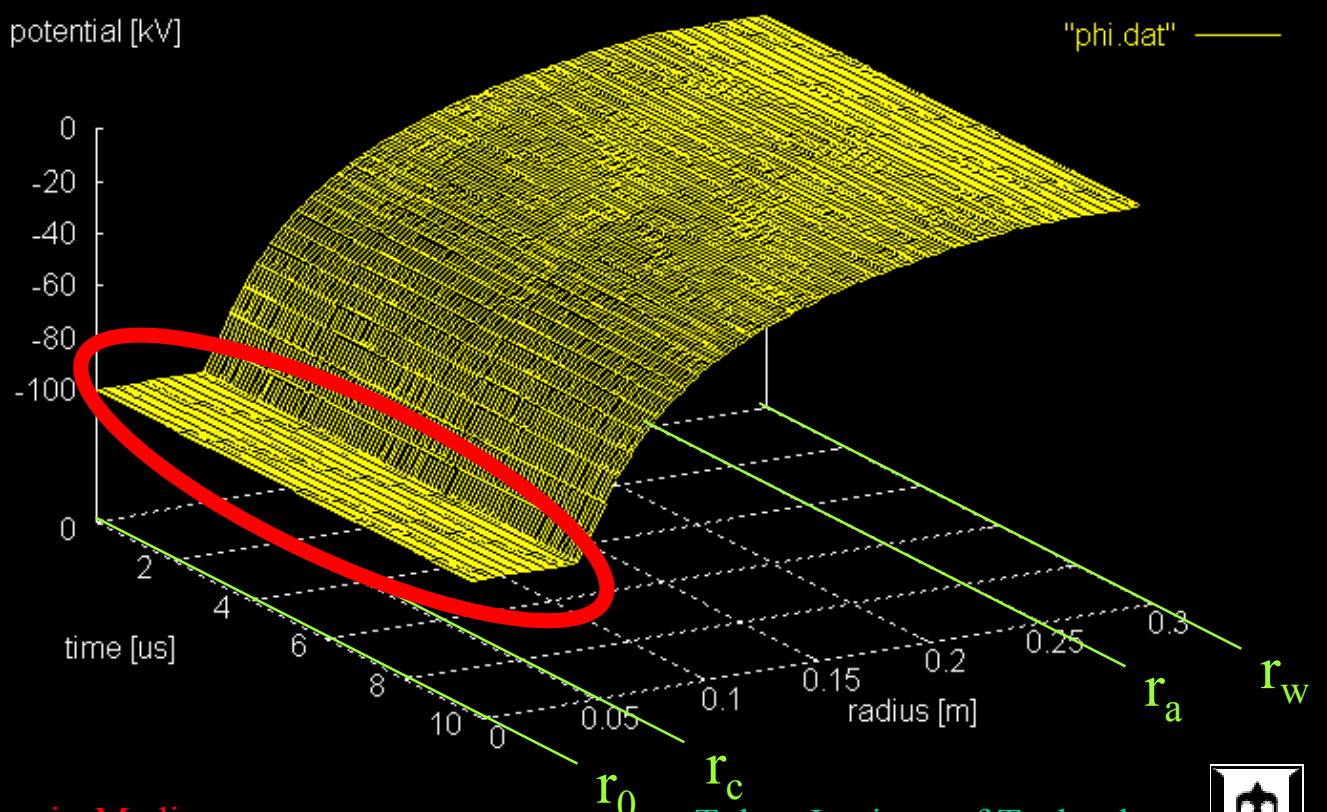
- The simulation reached almost steady-state in ~10 μs.
- Averaged cathode current was about 40 mA.



# Potential Structure

## Describing Child-Langmuir potential

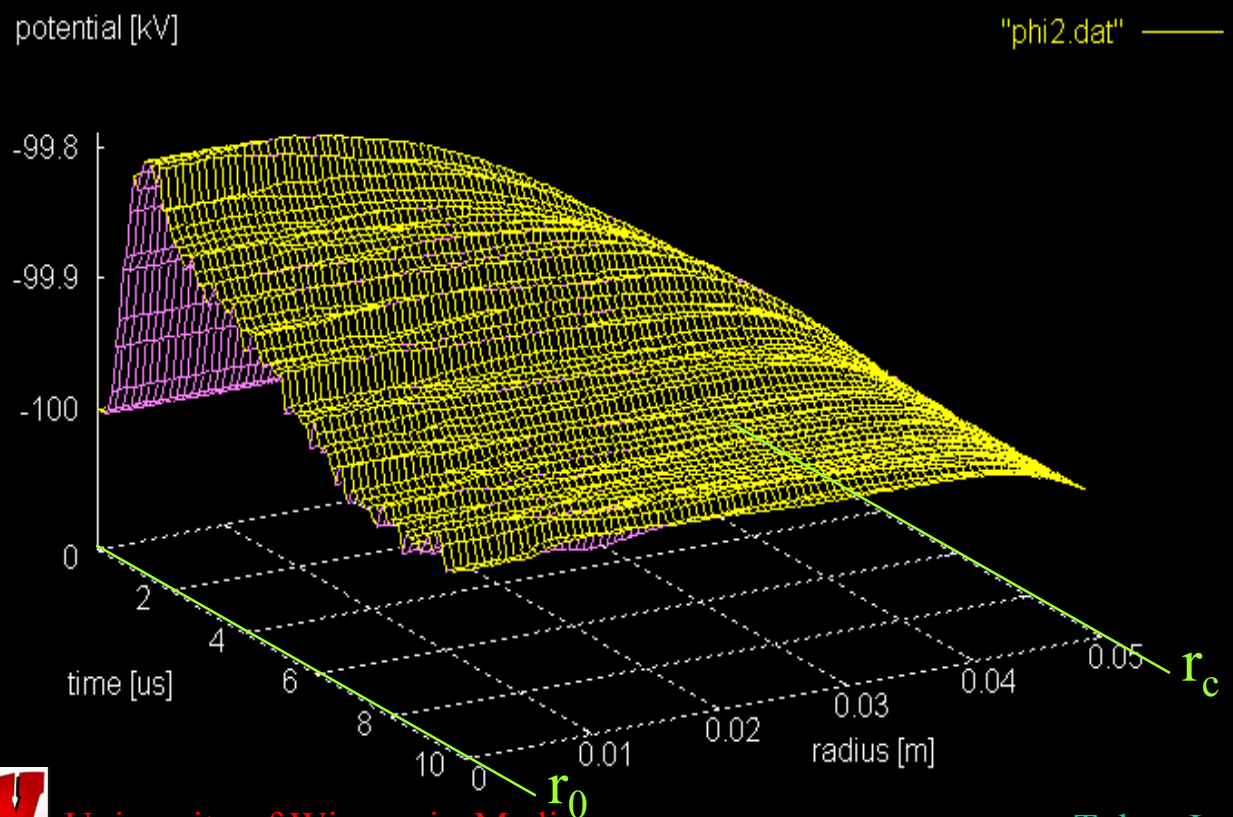
( 0 – 10 us )



# Potential Structure (inside the cathode)

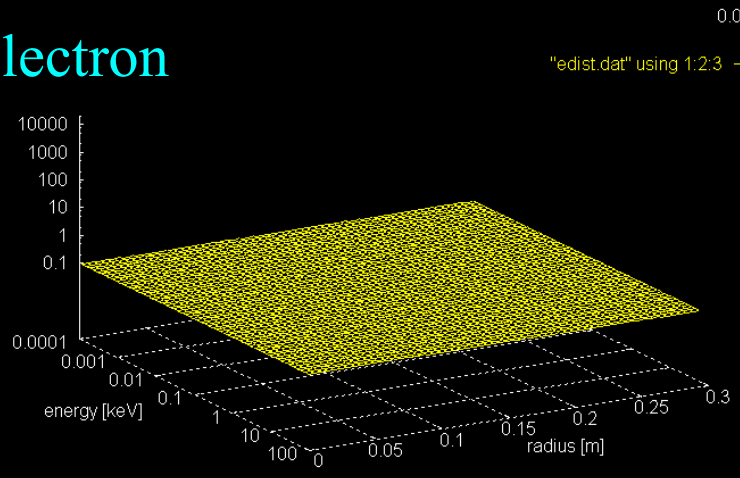
Small (~10 V) potential well was obtained.

( 0 – 10 us )

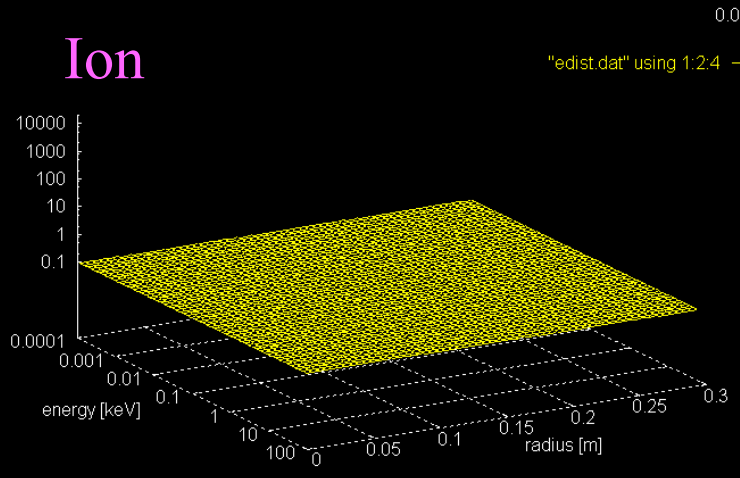


# Energy Distribution ( 0 – 2 us )

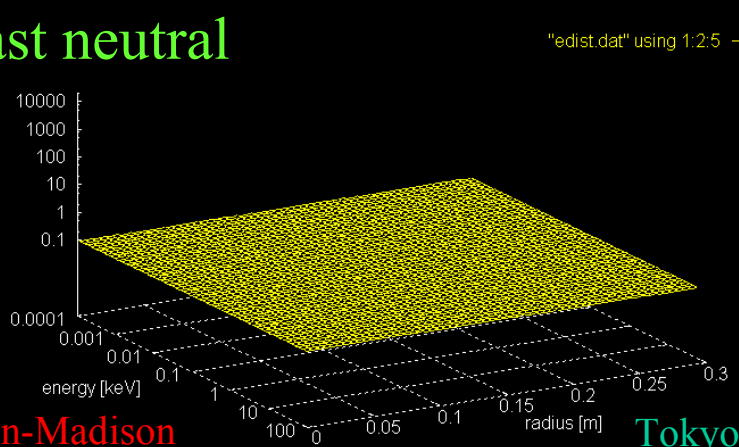
## Electron




## Ion




## Fast neutral

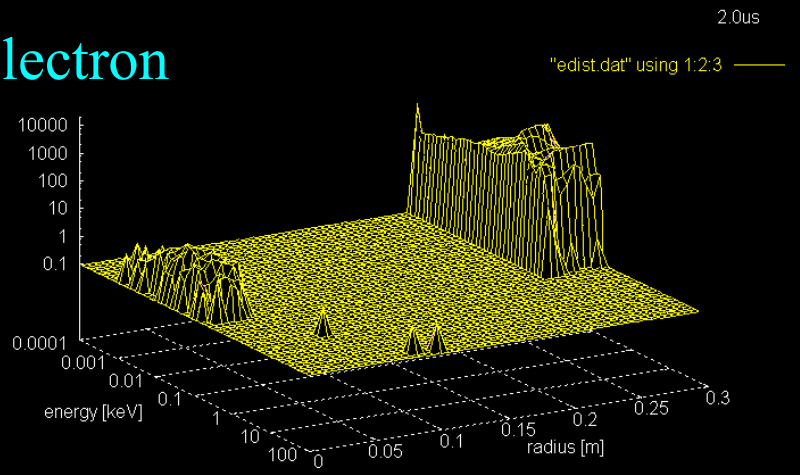



time

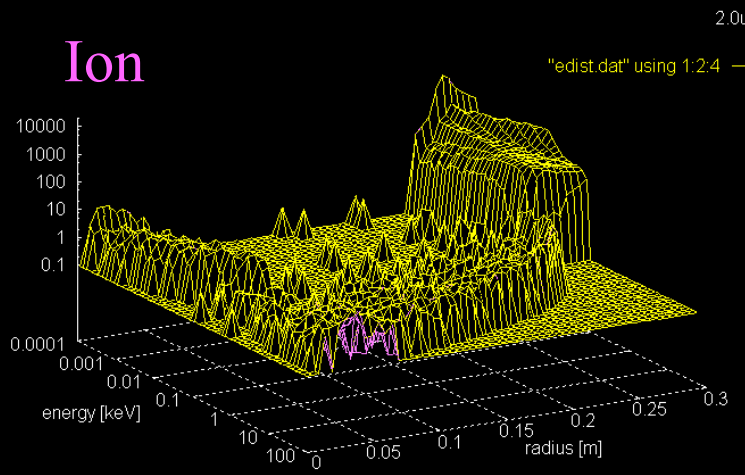
**0.0 μs**

# Energy Distribution ( 2 – 4 us )

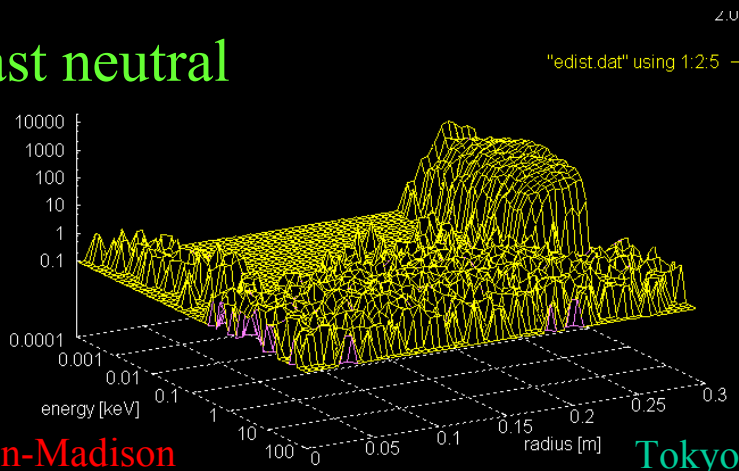
## Electron




## Ion




## Fast neutral

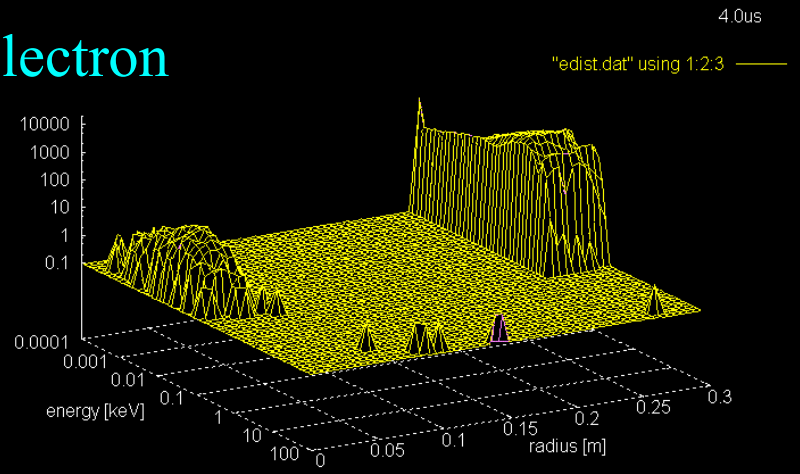



time

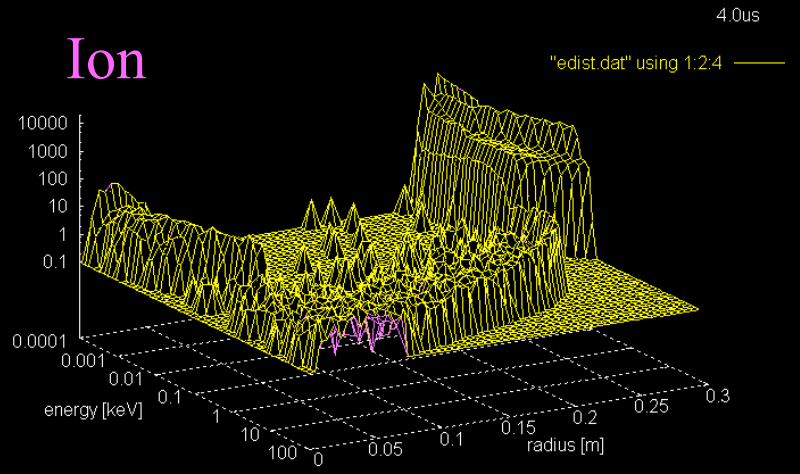
**2.0 μs**

# Energy Distribution ( 4 – 6 us )

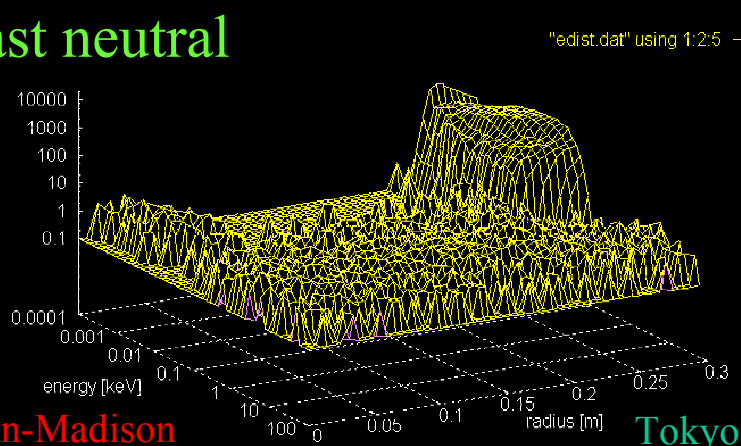
## Electron




## Ion




## Fast neutral

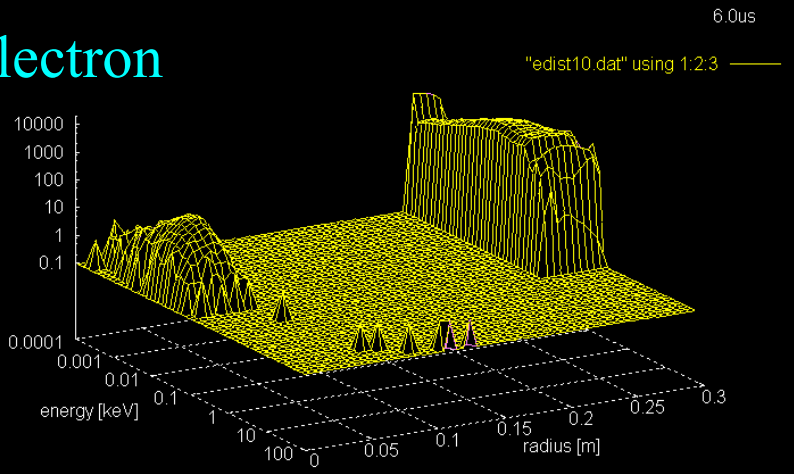



time

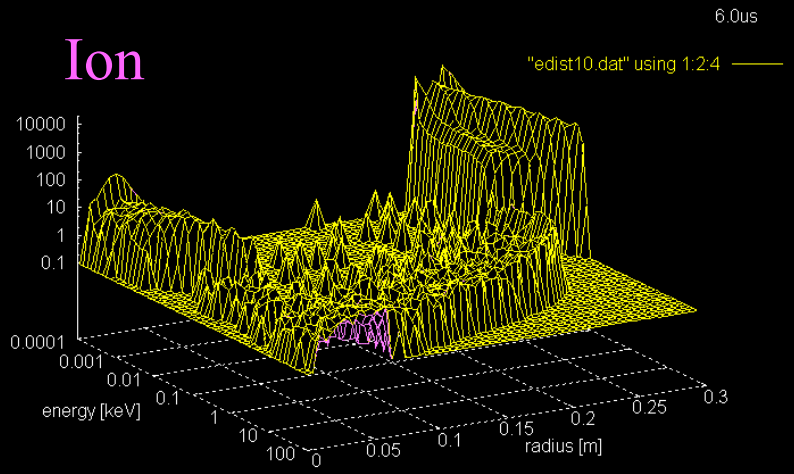
**4.0 μs**

# Energy Distribution ( 6 – 8 us )

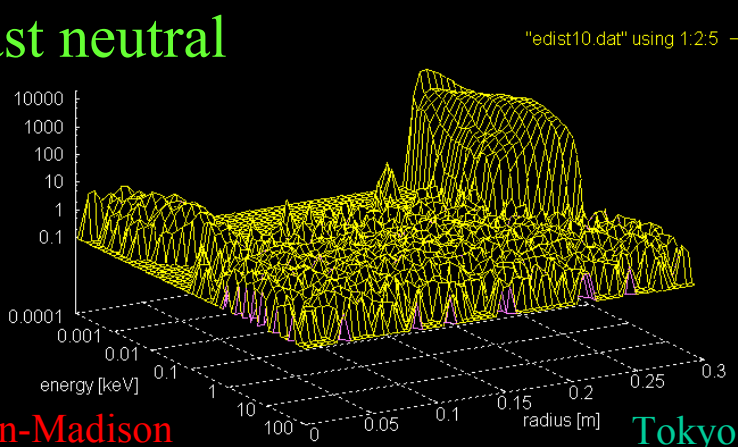
## Electron




## Ion




## Fast neutral

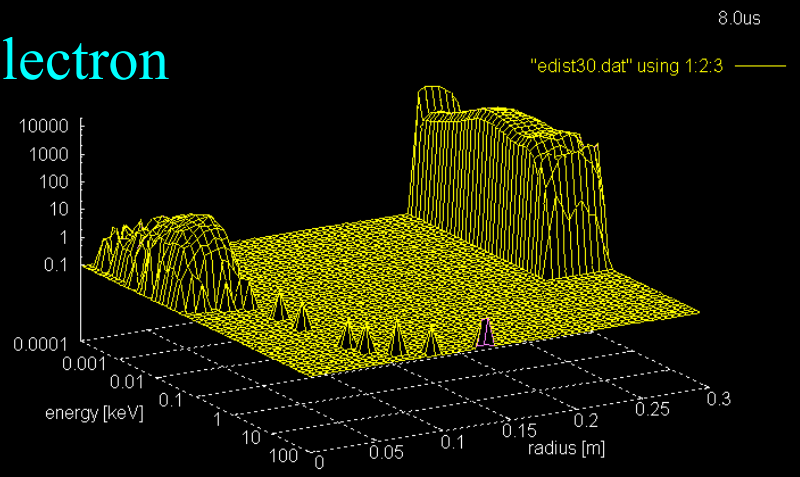



time

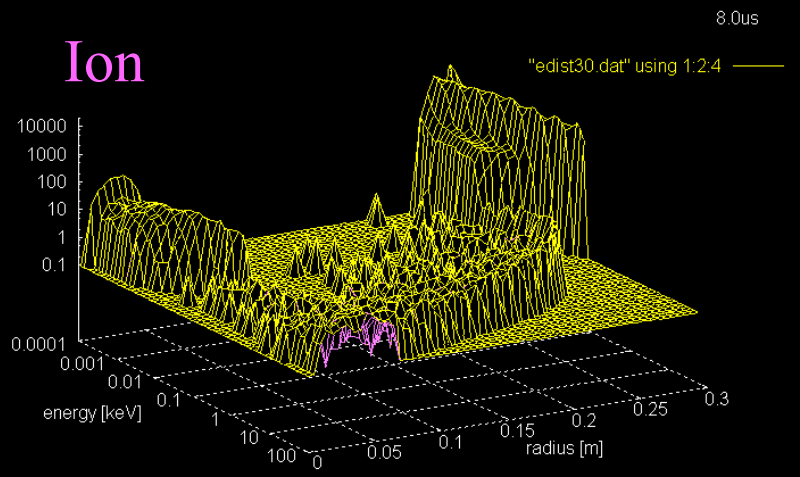
**6.0 μs**

# Energy Distribution ( 8 – 10 us )

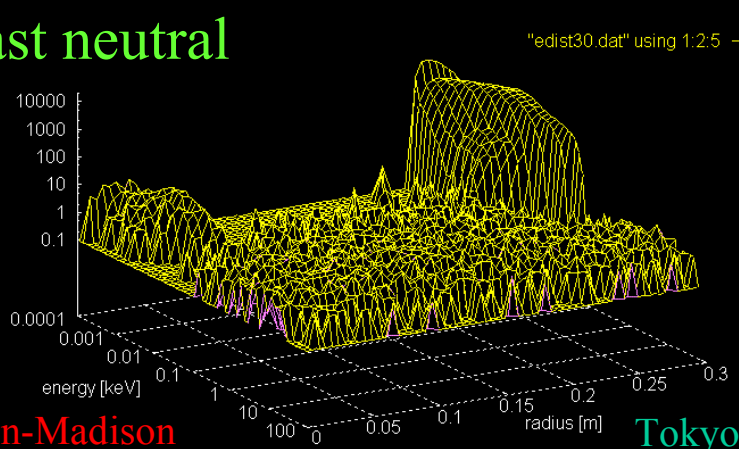
## Electron




## Ion




## Fast neutral

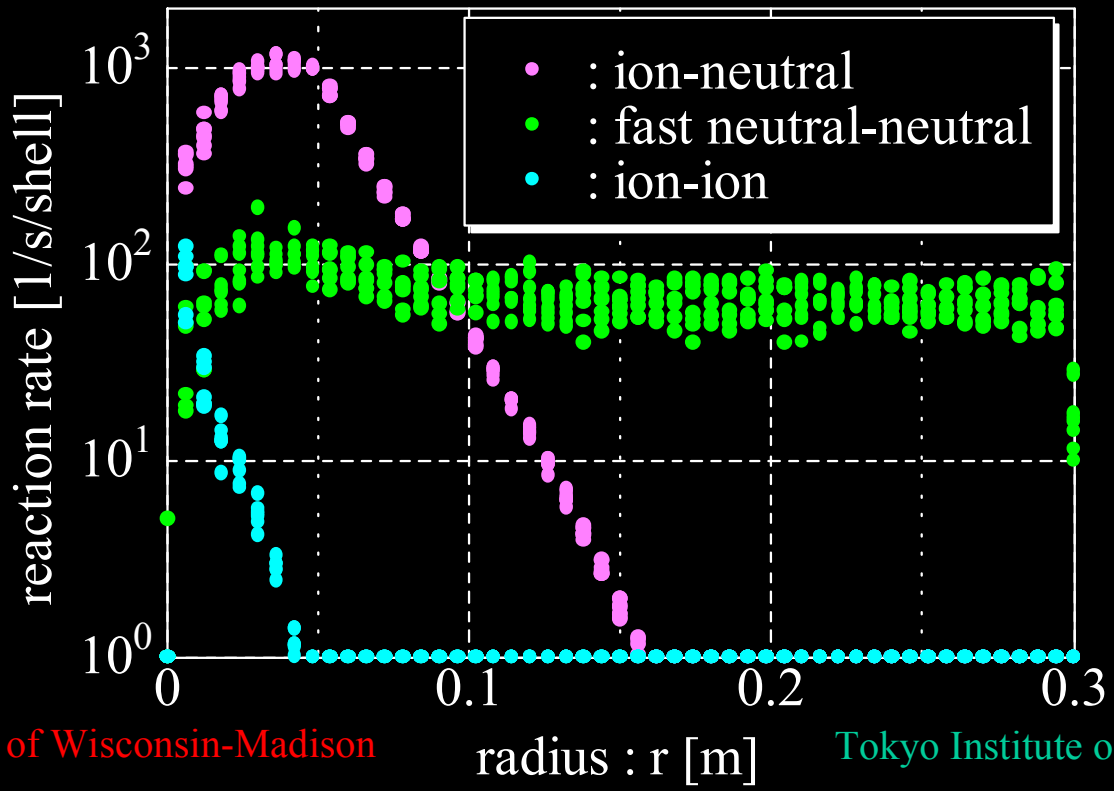



time

**8.0 μs**

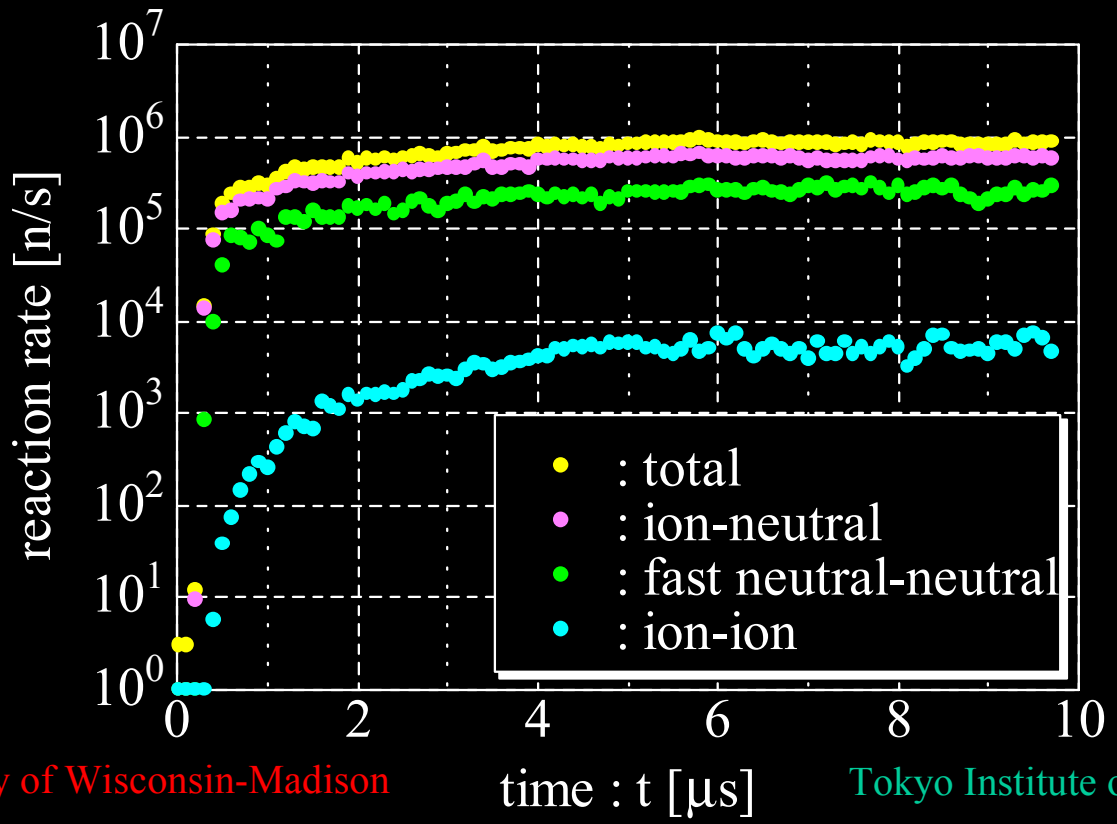
# Distribution of fusion reaction (1/s/shell)

- 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?