THE ROLE OF MICRO-PLASMAS FROM CHARGE ROLLERS IN PRINTER ENGINES*

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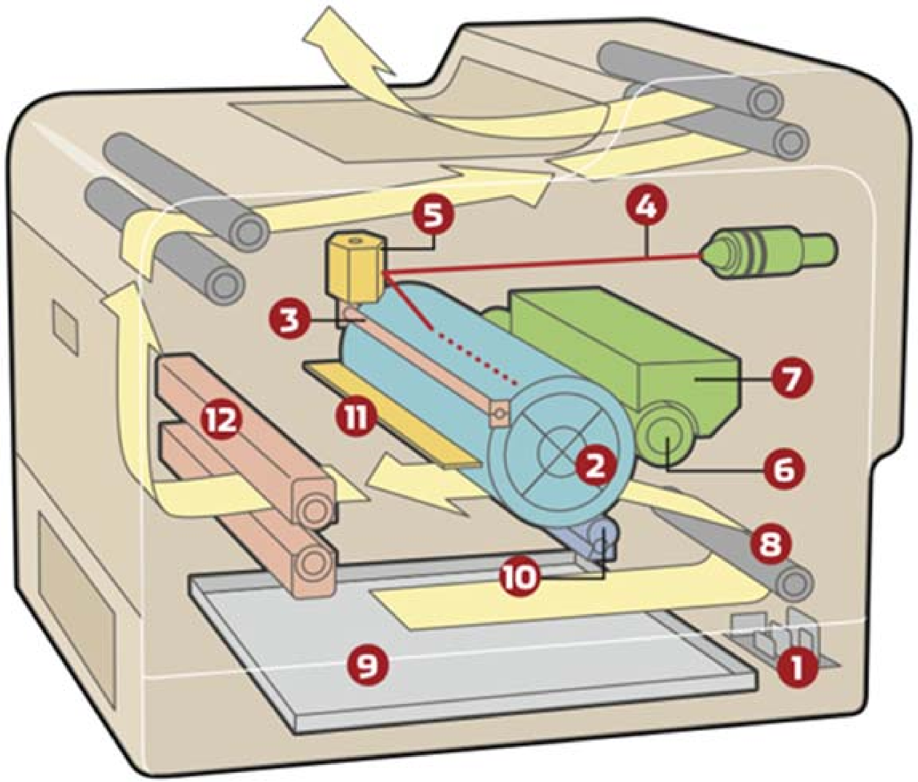
3rd ANNUAL MIPSE GRADUATE STUDENT SYMPOSIUM
3 Oct. 2012, East Lansing, MI

*** Work supported by Hewlett Packard Research Labs**

AGENDA

- Introduction to print engines
- Microplasmas on surfaces in a typical print engine
- Description of model
- Plasma dynamics on charge rollers (CR)
    - Microplasma sustained in air (1 atm)
    - Location, conductivity and photons
    - Moving surfaces
- Plasma dynamics of corona discharges for charging surfaces
- Concluding Remarks

LASER PRINTER AND ELECTROPHOTOGRAPHY



1. Controller Circuit, 2. Photoconductor, 3. Charge Roller (CR) or Corona, 4. Laser Beam, 5. Rotating Mirror, 6. Developer Roller, 7. Toner Hopper, 8. Roller Assembly, 9.Paper Tray, 10. Charge Roller (CR) or Corona, 11. Cleaning blade, 12. Fuser

- **Electrophotography is used in most electronic printers including laser printers.**
- **The electrophotography process generally consists of six steps:**
  - **Charging**
  - **Exposure**
  - **Development**
  - **Transfer**
  - **Fusing**
  - **Cleaning**

Ref:
- **http://www.theshopperwizard.com/?p=1582**
- **"Numerical Simulation of electrophotography Process", by Prof. Hiroyuki Kawamoto**

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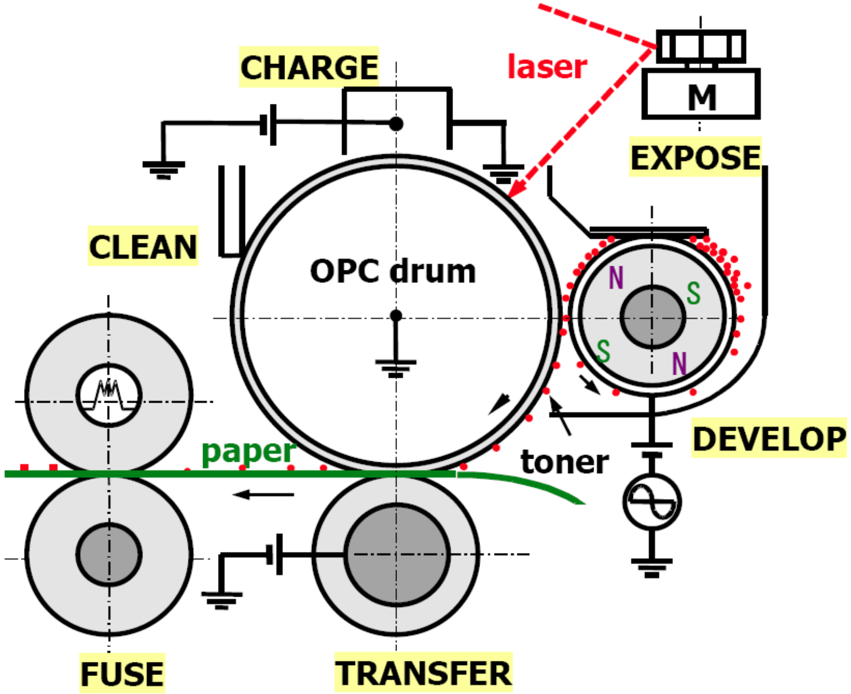
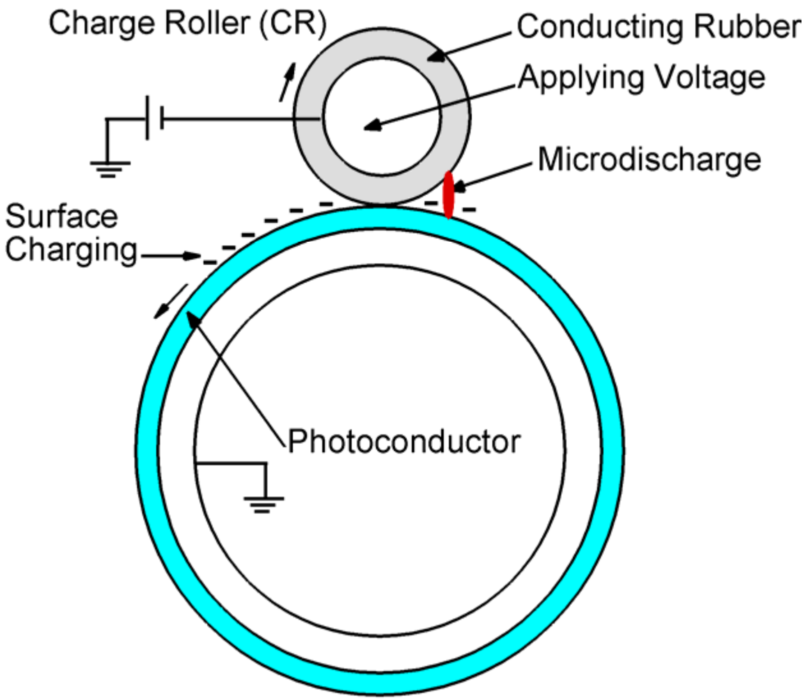
LASER PRINTER AND ELECTROPHOTOGRAPHY

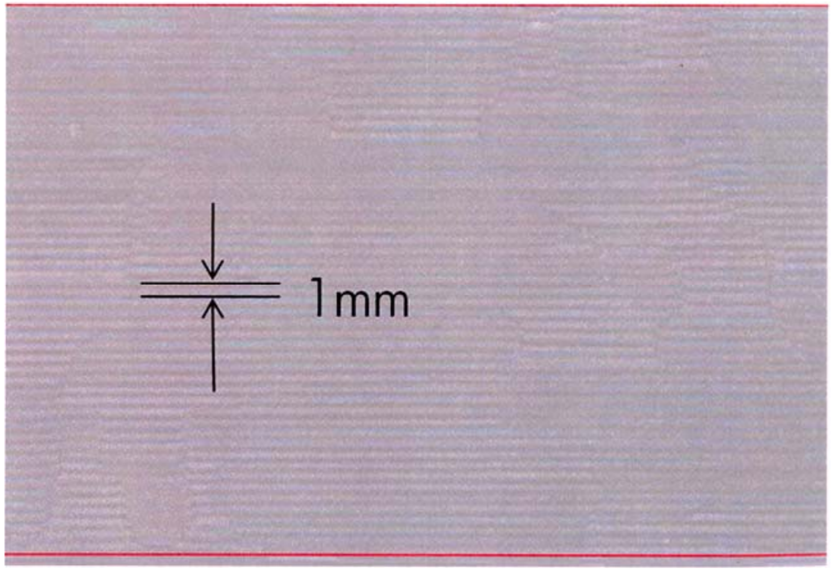
- Electrophotography as used in laser printers consists of six steps:
- Charging: A charge roller (CR) or corona discharge uniformly charges the surface of a photoconductor (PC).
- Exposure: A laser beam forms a latent image on PC surface.
- Development: Charged toner particles are electrically attracted to the latent image on PC.
- Transfer: Toner particles transferred from PC to a uniformly charged paper.
- Fuse: Toner particles are fused to paper by heating.
- Cleaning: PC is cleaned of residue charges and toner particles.



- Rate limiting step in uniformity and quality is charging of photoconductor.

Ref:
- "Numerical Simulation of electrophotography Process", by Prof. Hiroyuki Kawamoto
- D. M. Pai and B. E. Springett, Rev. Mod. Phys. 65, 163 (1993).





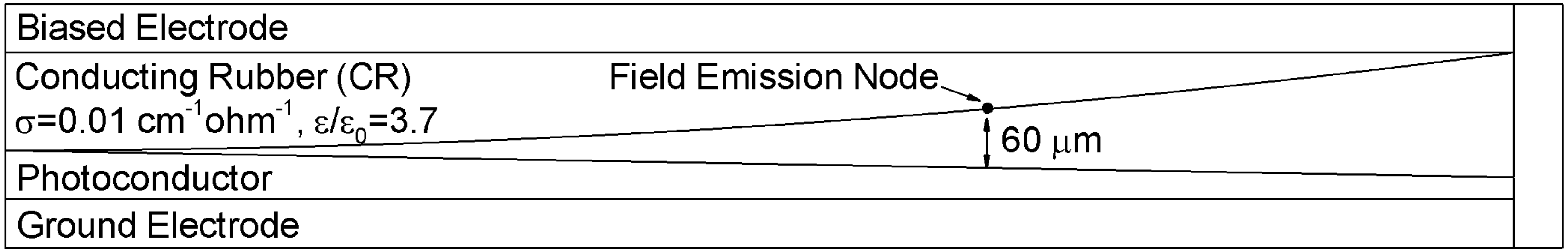
CHARGE ROLLERS – MICROPLASMA SOURCE

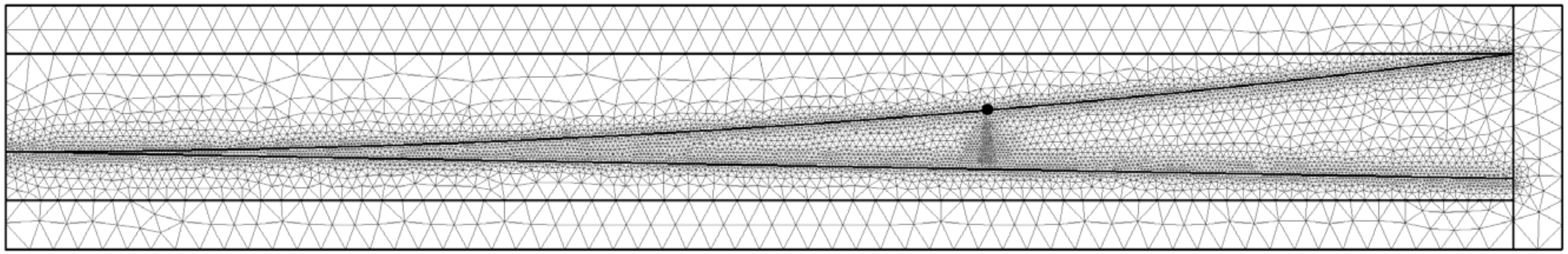
- **Charge rollers (CR) negatively charge the photoconductor (PC).**
- **CR – conducting rubber with dc, pulsed dc or ac voltage up to a few kV.**
- **In the small gap of the converging CR and PC, microplasmas spontaneously occur.**
- **Uniformity of printing indicates periodic self-pulsing.**

Ref: Patent:US5499078

CHARGE ROLLER: MODEL GEOMETRY

- **CR and PC cylinders**
  - **PC: Conducting rubber cathode (σ = 0.01 cm^{-1} Ω^{-1}) biased to a few kV**
  - **A ground electrode covered with PC.**
  - **Discharge initiated with current of 10^{-3} A-cm^{-2} for 10 ns.**
  - **Photoelectron emission from cathode.**
  - **1 atm dry air (N_2, N_2(v), N_2(A,B,C,a'), N_2^+, N_4^+, N, N(^{2}D), N(^{2}P), N^+, O_2, $O_2(a^1\Delta_g, b^1\Sigma_g^+)$, O_2^+, O_2^-, O_3, O^-, O, O(^{1}D,^{1}S), O^+ and electrons).**





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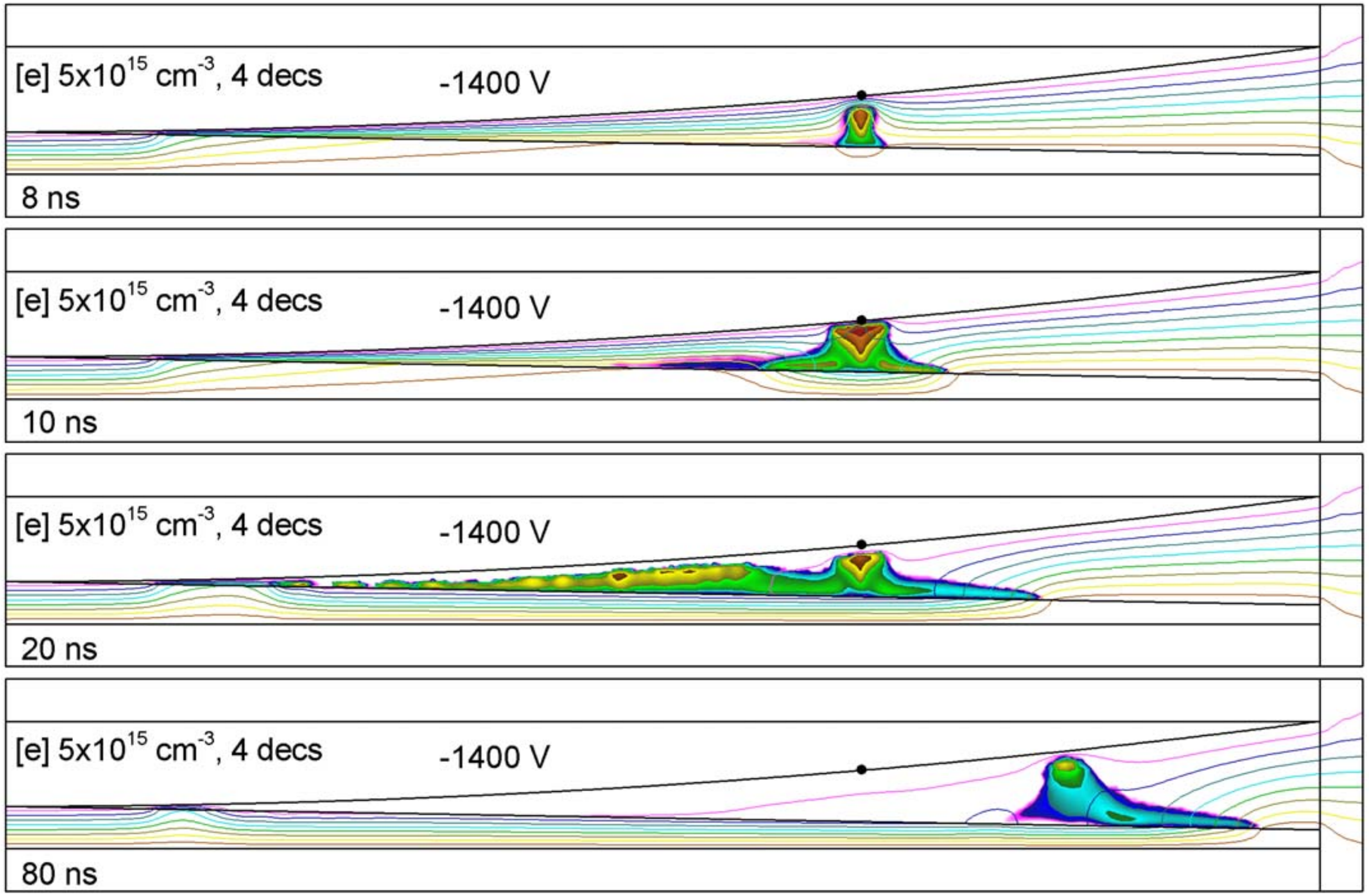
CR PLASMA DYNAMICS: [e]



60 μm gap

- **[e] 5 x 10^{15} cm^{-3} [4 dec]**
- **-1.4 kV (Contours)**

- **Avalanche at emission point produces streamer which spreads on and charges PC, reducing voltage, extinguishing local discharge.**

MIN  **MAX**

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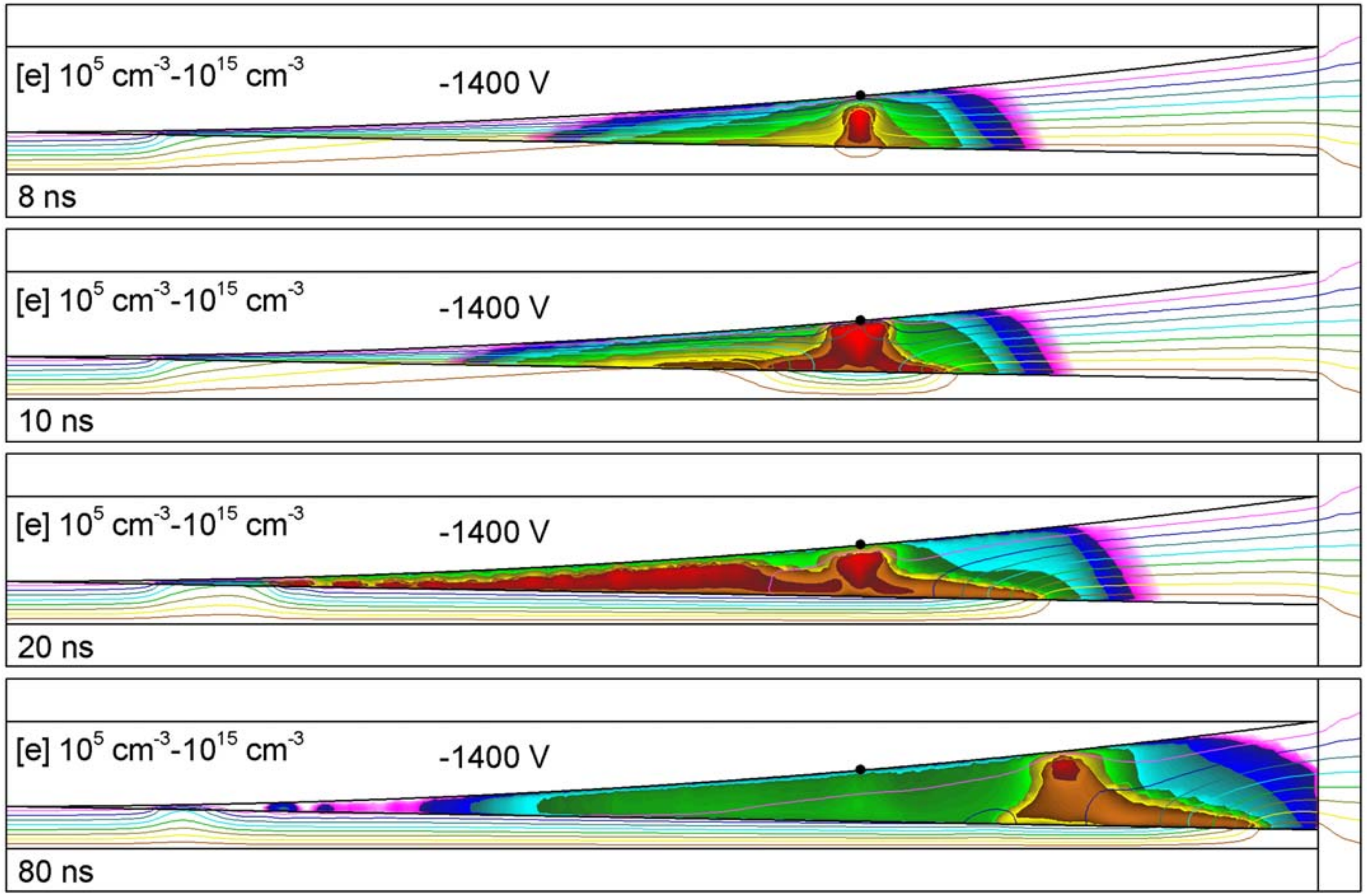
CR PLASMA DYNAMICS: [e]



60 μm gap

- **[e] 10^5 - 10^{15} cm^{-3}**
- **-1.4 kV (Contours)**

- **Laterally propagating electrons and secondary electrons help trigger the avalanche at smaller gap (higher E/N and T_e).**
- **Local field enhancement at edge of spreading plasma produces a cathode directed secondary discharge.**

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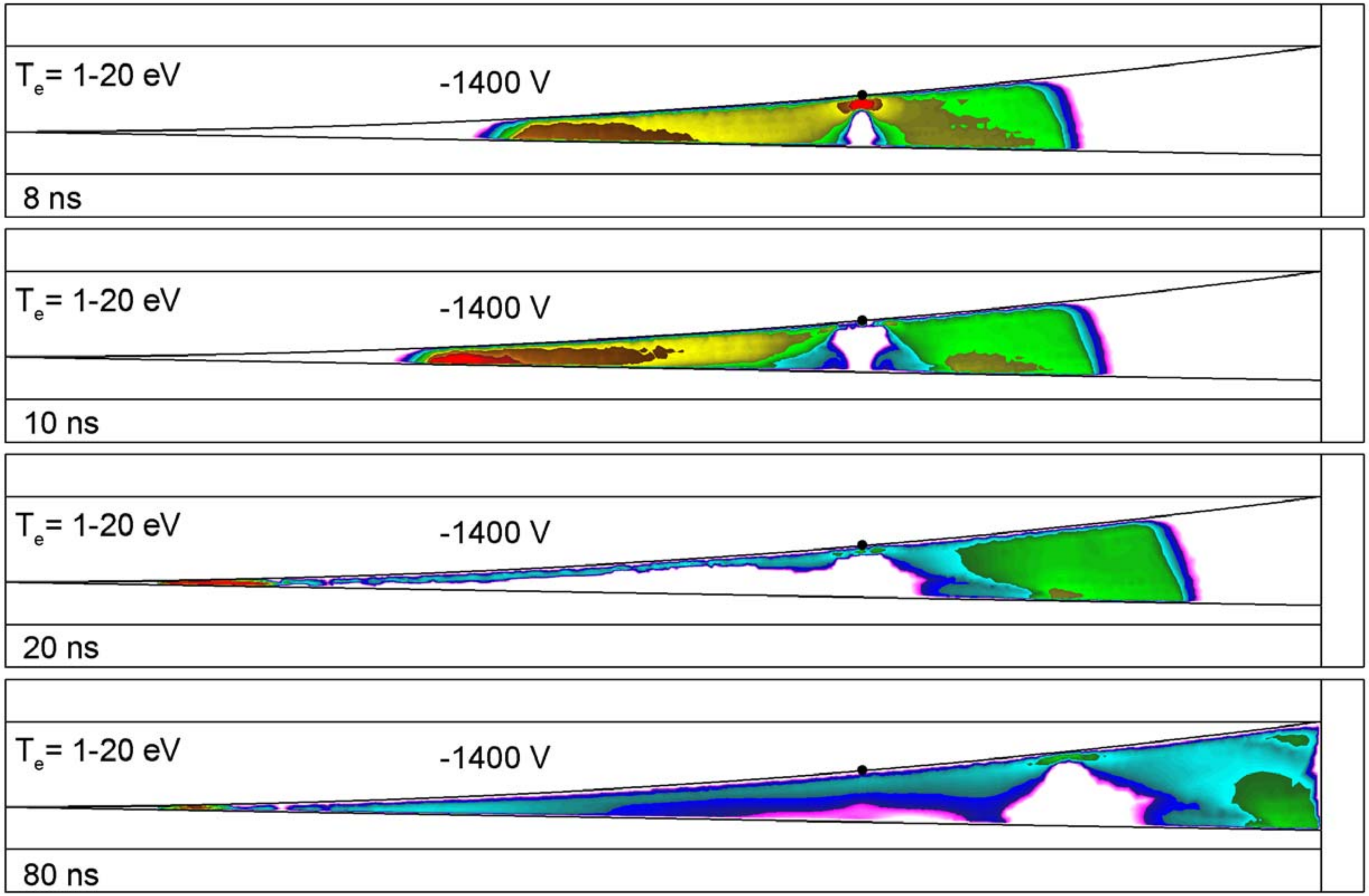
CR PLASMA DYNAMICS: T_e

60 μm gap

- **T_e**



MIN  **MAX**

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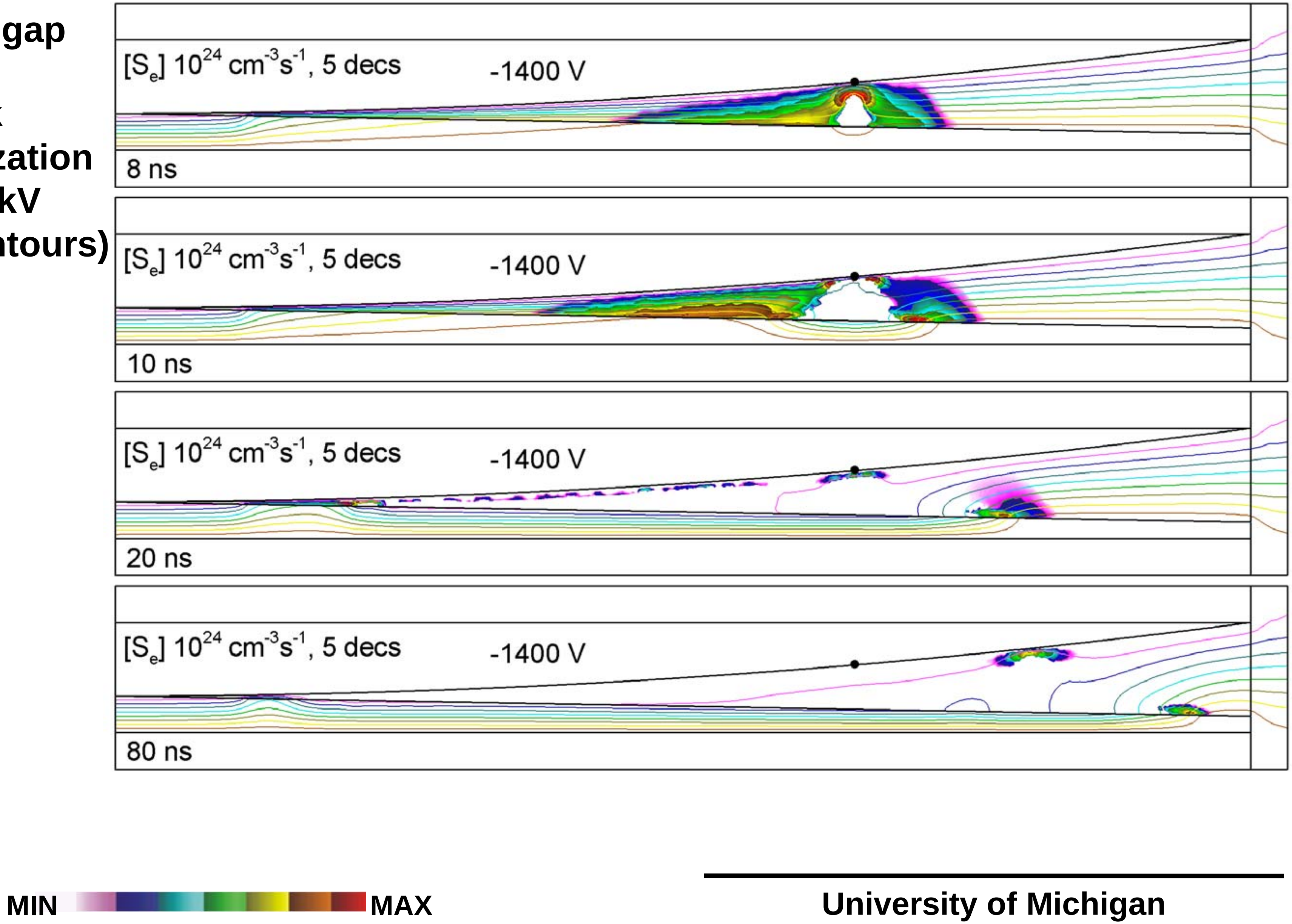
CR PLASMA DYNAMICS: S_e

60 μm gap

- **Bulk ionization**
- **-1.4 kV (Contours)**



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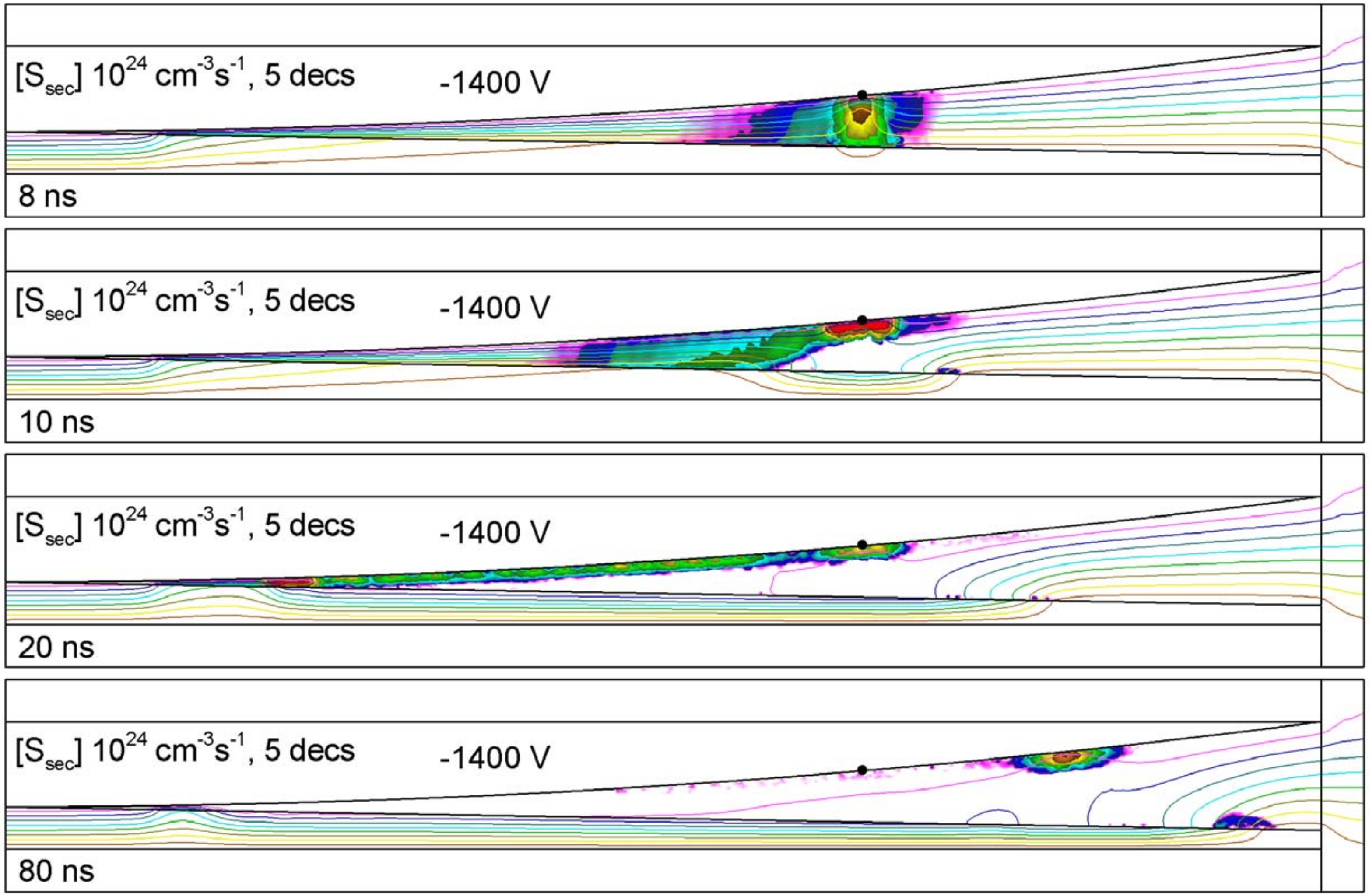
CR PLASMA DYNAMICS: S_{sec}

60 μm gap

- **Beam ionization**
- **-1.4 kV (Contours)**



- **Electron impact ionization source from bulk plasma and sheath accelerated secondary electrons are comparable.**

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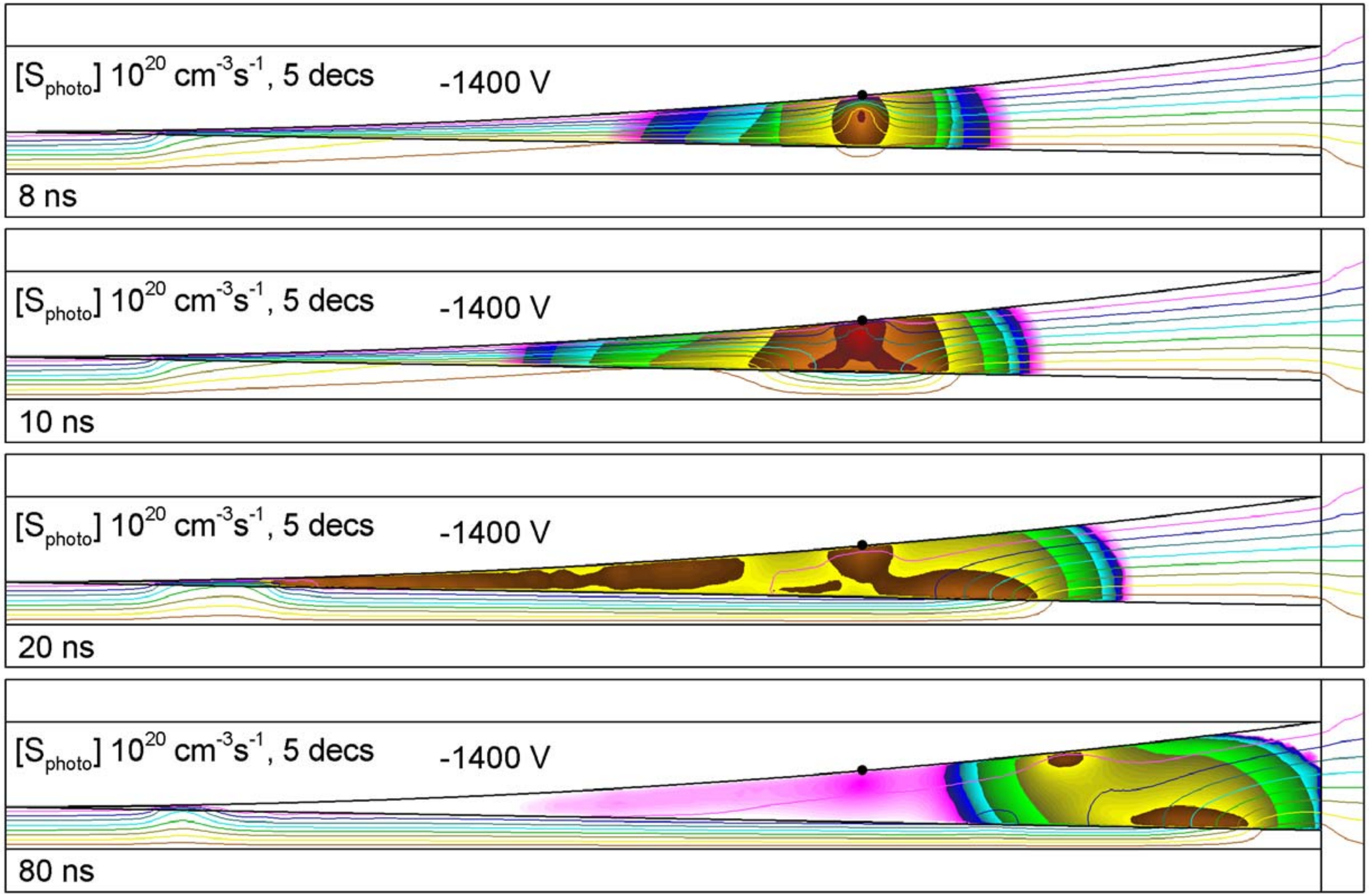
CR PLASMA DYNAMICS: S_{photo}

60 μm gap

- **Photo-ionization**
- **-1.4 kV (Contours)**



- **Photoionization is not large, but does provides remote seed electrons**

MIN **MAX**

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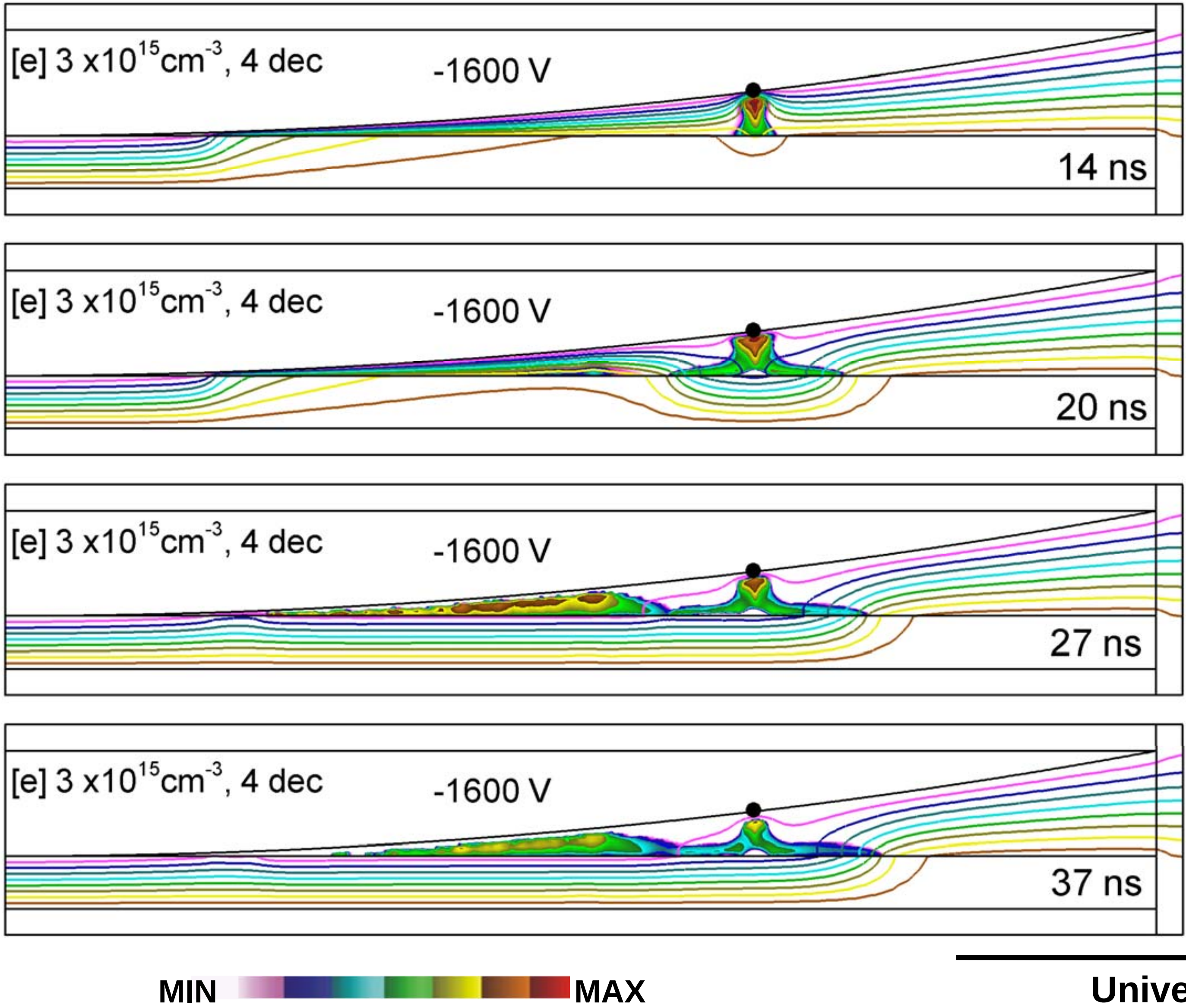
CR PLASMA DYNAMICS: LOCATION MATTERS

- **85 μm gap**



- **Location of initial emission matters.**
- **85 μm: Avalanche at emission point produces streamer and cathode directed secondary discharge.**

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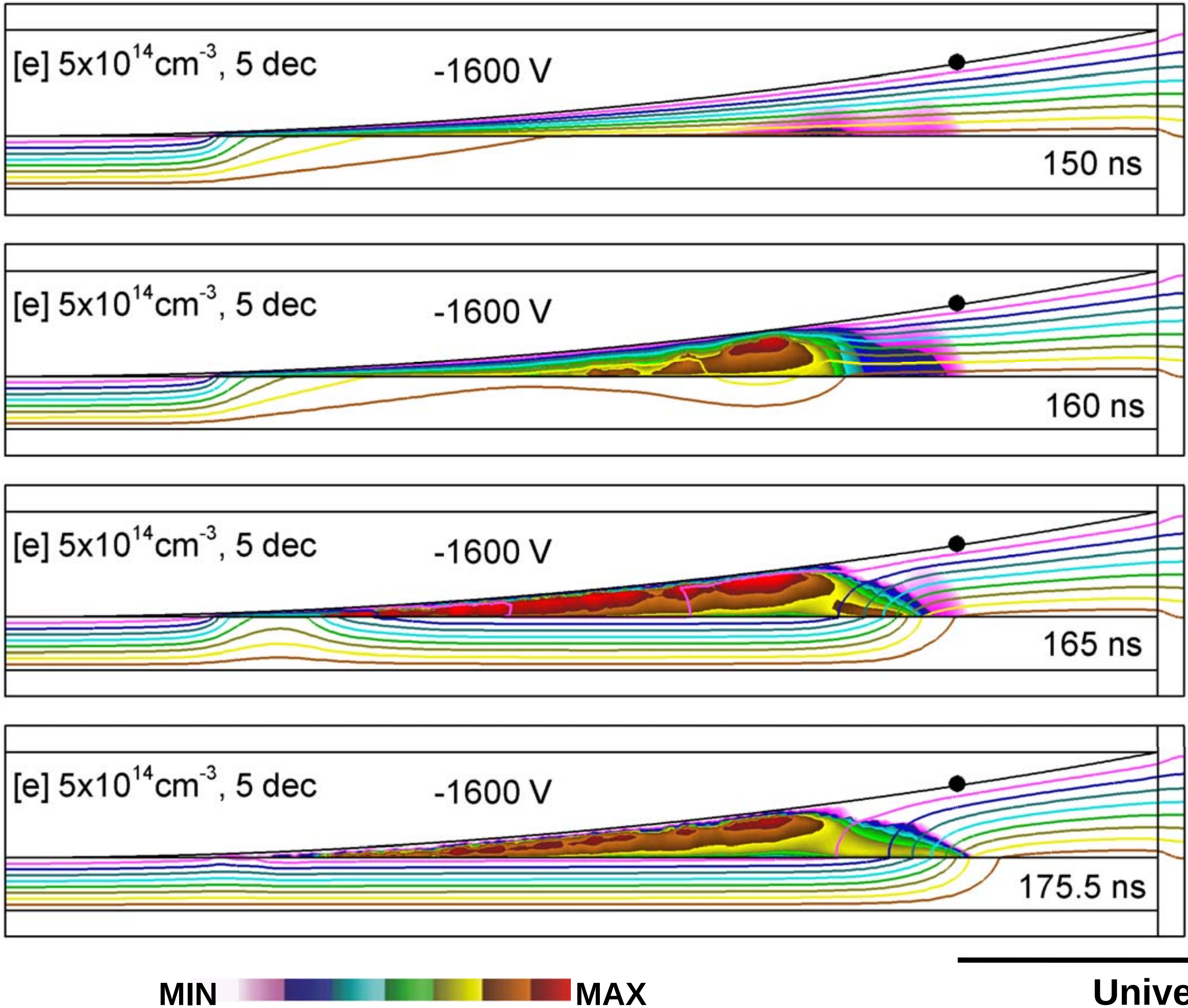
CR PLASMA DYNAMICS: LOCATION MATTERS

- **135 μm gap**



- **135 μm: Avalanche at smaller gap triggered by laterally propagation and secondary electrons.**

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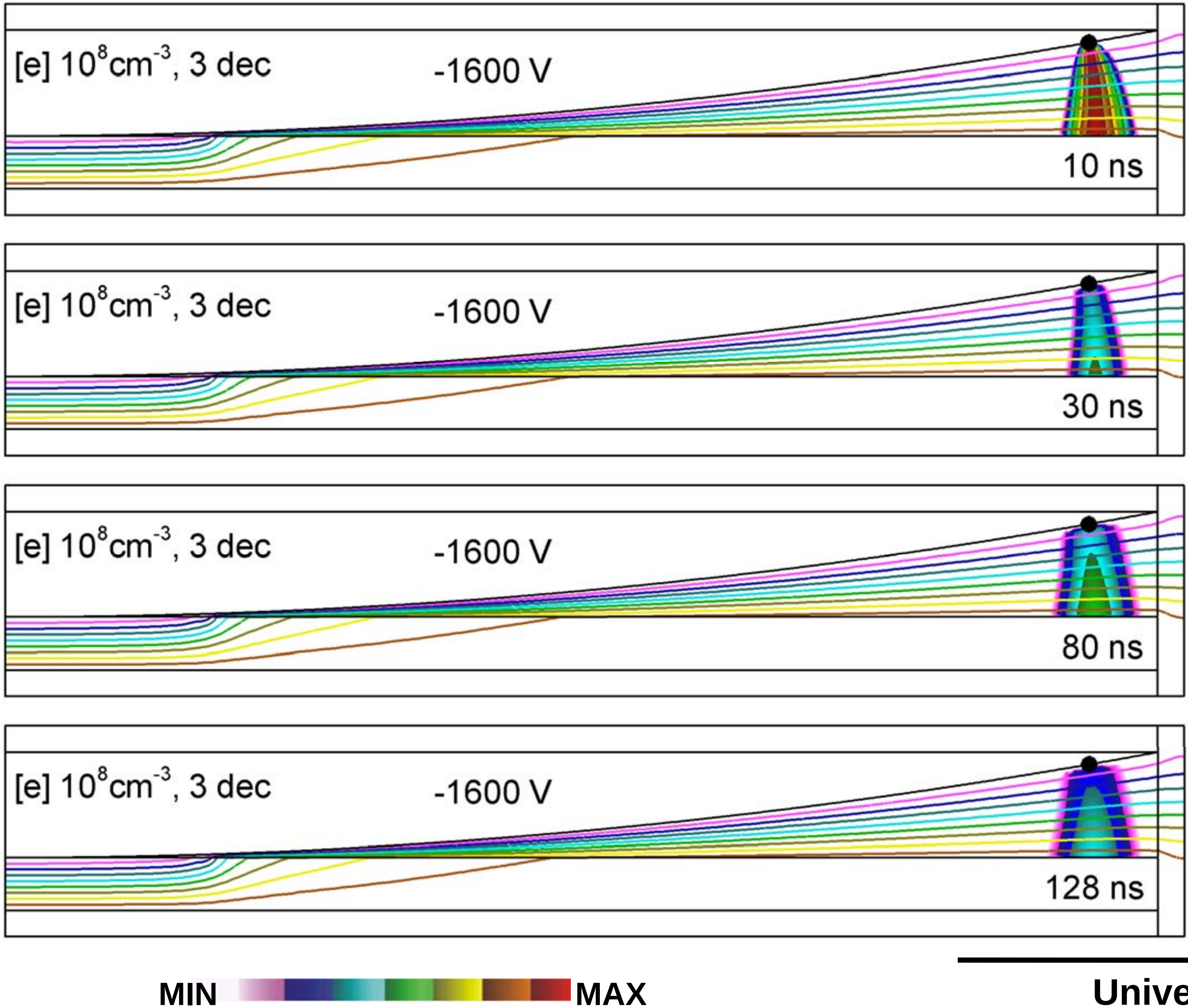
CR PLASMA DYNAMICS: LOCATION MATTERS

- **177 μm gap**



- **177 μm: Emission into sub-critical E/N - diffusion and photo-ionization unable to seed avalanche.**

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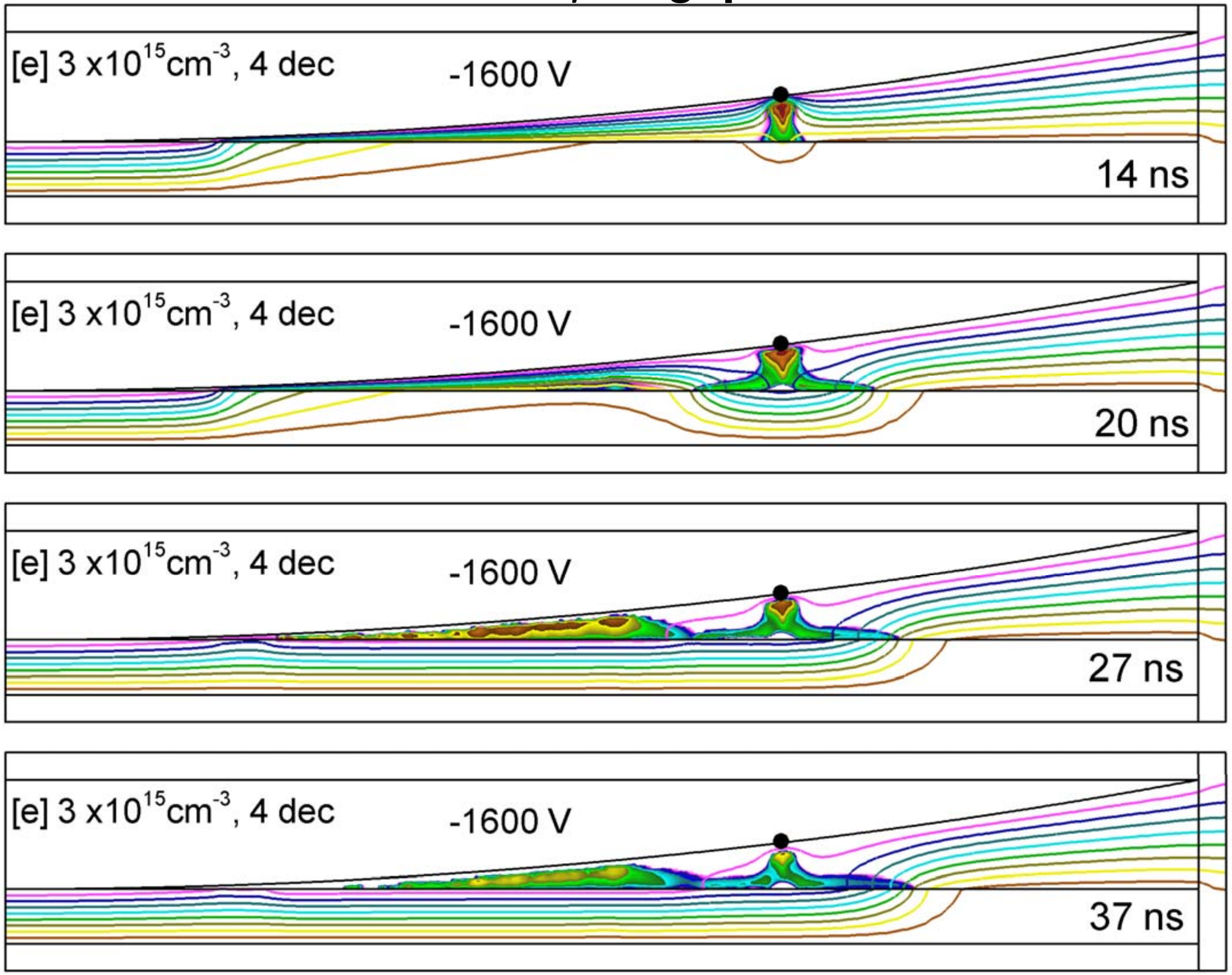
CR PLASMA DYNAMICS: σ MATTERS

- σ = 10^{-2} cm^{-1} Ω^{-1}
- 85 μm gap



- **Charge roller conductivity can be varied.**
- **With high σ, CR acts like a conductor and the voltage on CR is a constant.**

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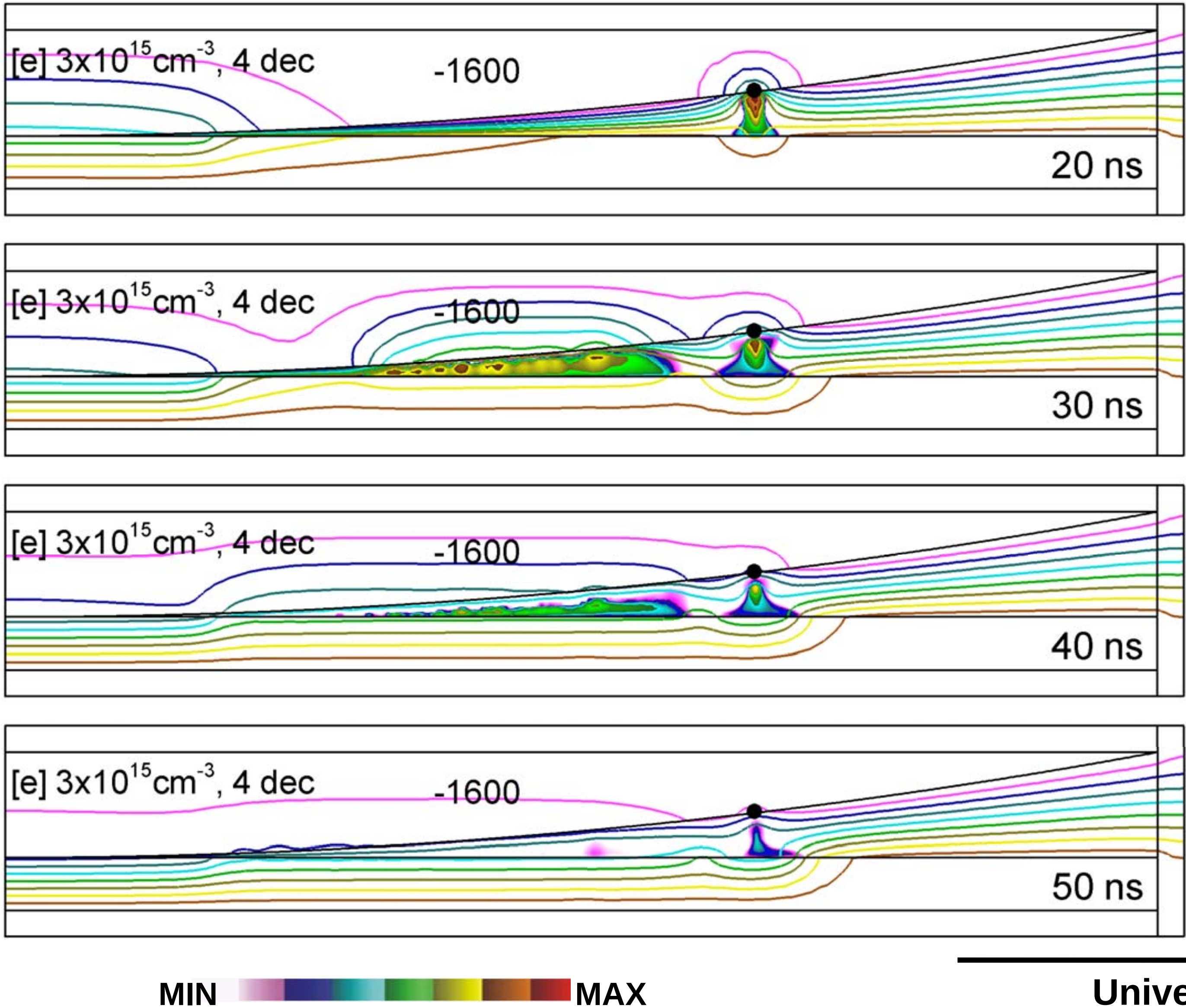
CR PLASMA DYNAMICS: σ MATTERS

- σ = 10^{-4} $cm^{-1}\Omega^{-1}$
- 85 μm gap



- With small σ, CR behaves like a DBD, microplasma in the gap is terminated by surface charging which is dissipated in eielectric relaxation time (ε / σ).
- Small σ limits charging of the photoconductor.

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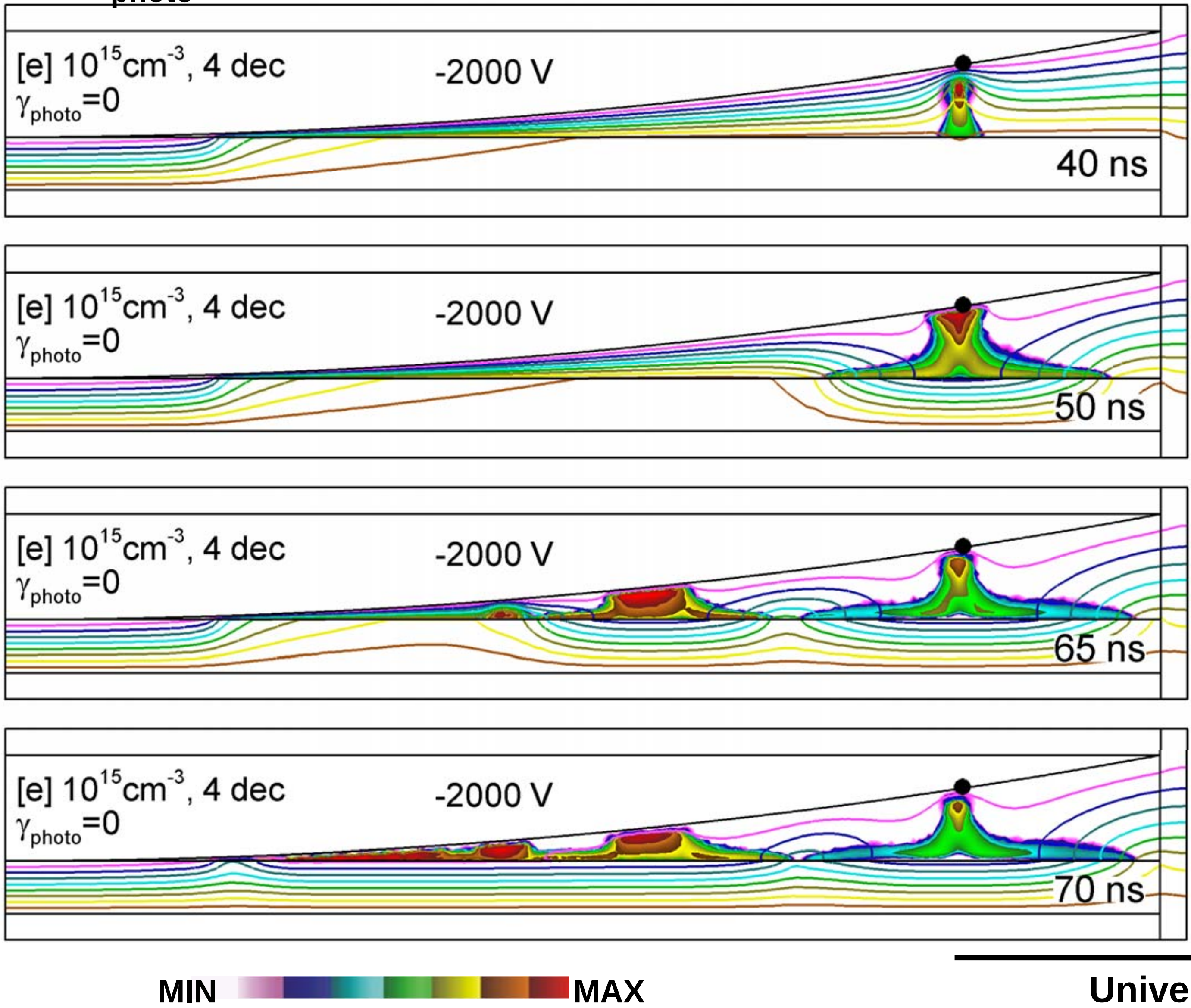
CR PLASMA DYNAMICS: γ_{photo} MATTERS

- $\gamma_{photo} = 0$
- 135 μm gap



- Dynamics of discharge spreading is sensitive to seeding of electrons by photoemission from CR (cathode).
- Without photoemission, diffusing electrons eventually reach avalanching E/N – more statistical and possibly less uniform.

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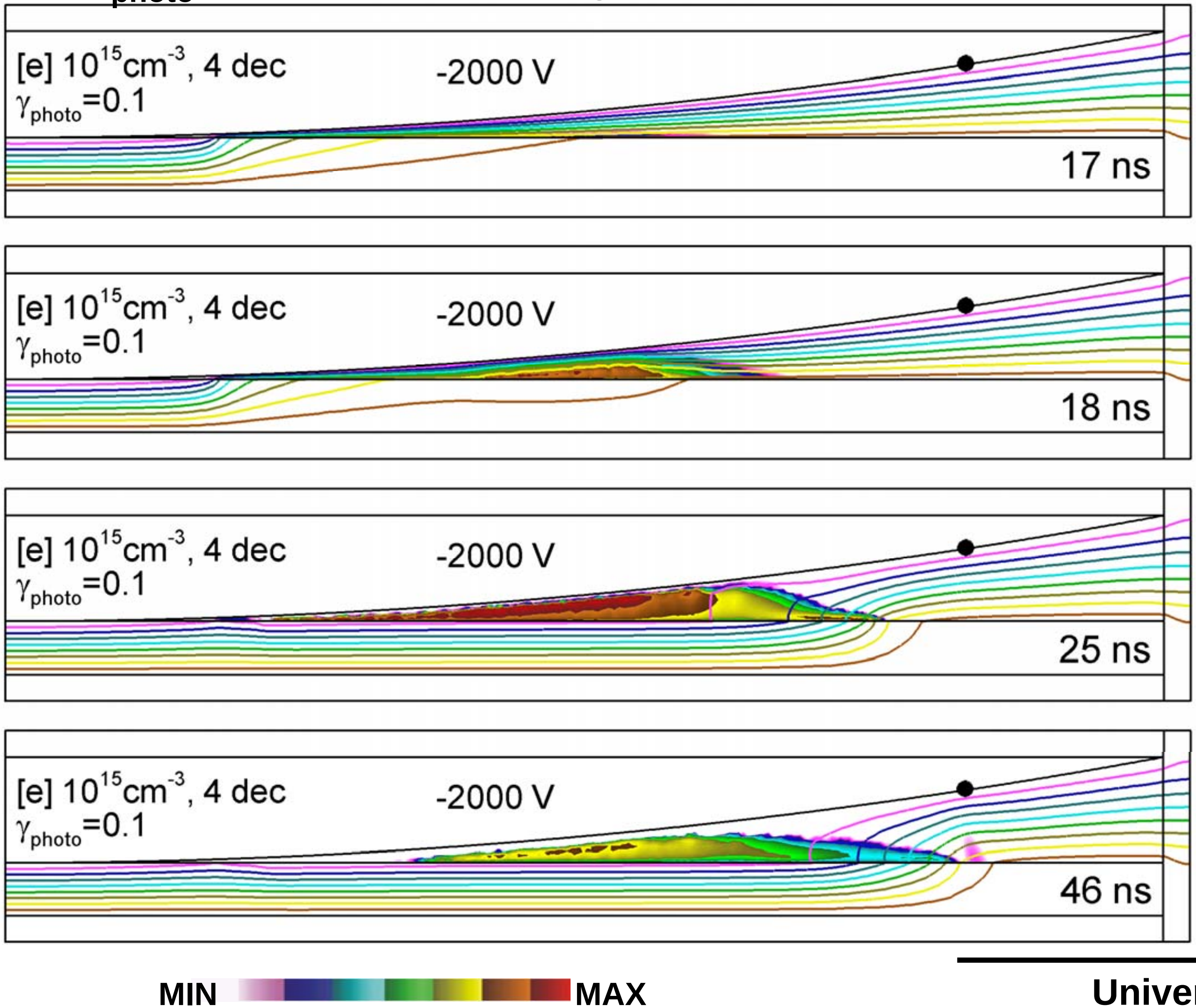
CR PLASMA DYNAMICS: γ_{photo} MATTERS

- γ_{photo} = 0.1
- 135 μm gap



- **With photoemission, discharge at high E/N occurs prior to emission point.**
- **Avalanche starts earlier with higher γ photo.**

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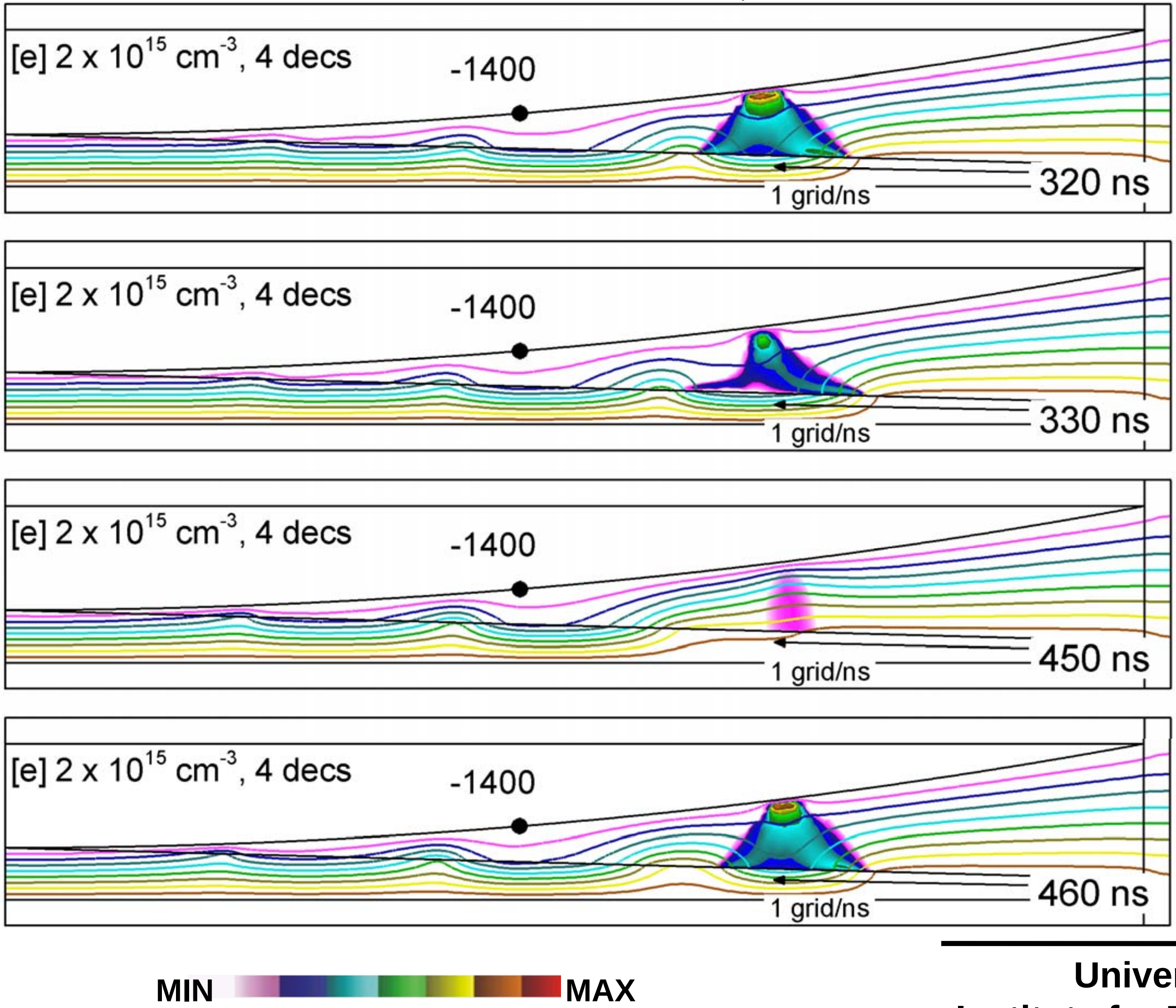
MOVING PHOTOCONDUCTOR

- “Rapidly” Moving Surface • 67 μm gap



- **In reality, both CR and PC rotate.**
- **Mimic with very rapidly moving surface.**
- **Moving CR brings in uncharged surface.**
- **Uncharged PC restores high E/N, enabling residual electrons to avalanche.**
- **Periodic re-ignition occurs and forms a periodic charging pattern.**

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CONCLUDING REMARKS

- The charging process of photoconductors in print engines with atmospheric pressure discharges in dry air have been computationally investigated.
- Laterally propagating electrons and secondary electrons help trigger the avalanche at smaller gap (higher E/N and T_e) than the initial emission.
- Local field enhancement at the edge of spreading plasma produces a cathode directed secondary discharge.
- Photoemission from the CR helps seed the ignition. Avalanche starts earlier with higher γ_{photo}.
- Plasma dynamics and charging uniformity are sensitive to the position of emission, conductivity of the CR and photoemission.
- With a moving surface, uncharged surface re-ignites the plasma and forms a periodic charging pattern.