

# Production of runaway electrons in conventional electric discharges.

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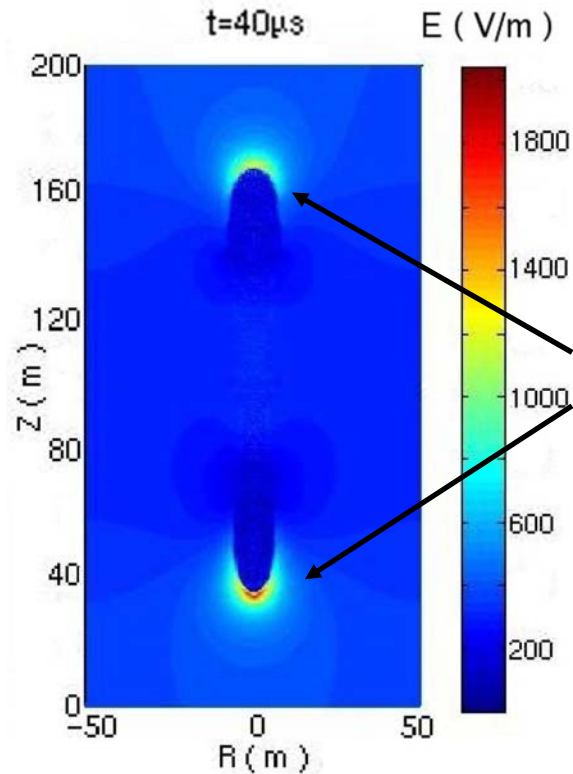
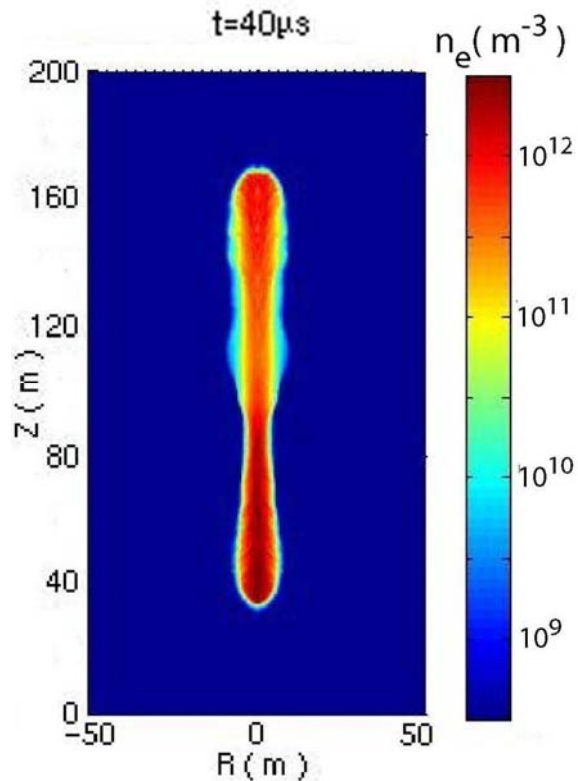
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- Introduction : Streamer discharges
  - Thermal runaway mechanism
  - Role in Terrestrial Gamma-ray Flashes ?
- Results from a new Monte Carlo Code
  - 'runaway' distribution function
  - probability for electron to runaway
  - 3D-like simulation of runaway production by streamer, comment on branching

# Streamer discharge

Streamers : - filaments of weakly ionised plasma propagating both along and against the electric field.  
- present in leader tips of lightning, in mesospheric discharge ( sprites ) ...



Enhancement of the field in the streamer heads

Can 'push' thermal electrons into the runaway regime

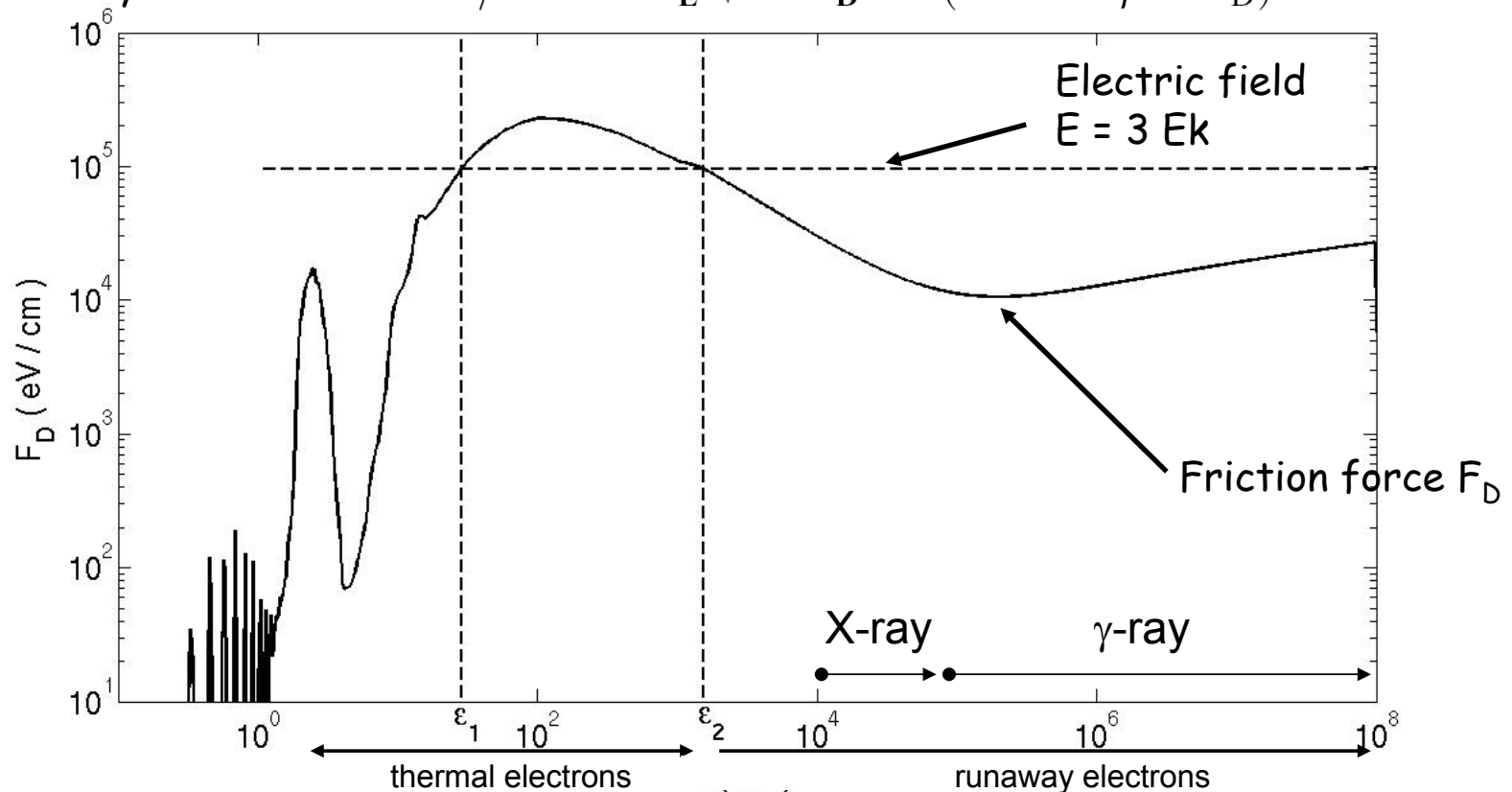
=> Role in TGF ?

# TGF and Runaway electrons

## Terrestrial Gamma-ray Flashes

- recently observed above thunderstorms
- Bremsstrahlung from high energy electrons
- thermal runaway electrons from streamers ?

Runaway electrons ? :  $d\epsilon/dt = \mathbf{v} \cdot \mathbf{F}_E + \mathbf{v} \cdot \mathbf{F}_D = v(-eE \cos \beta - F_D)$



# Preceding results

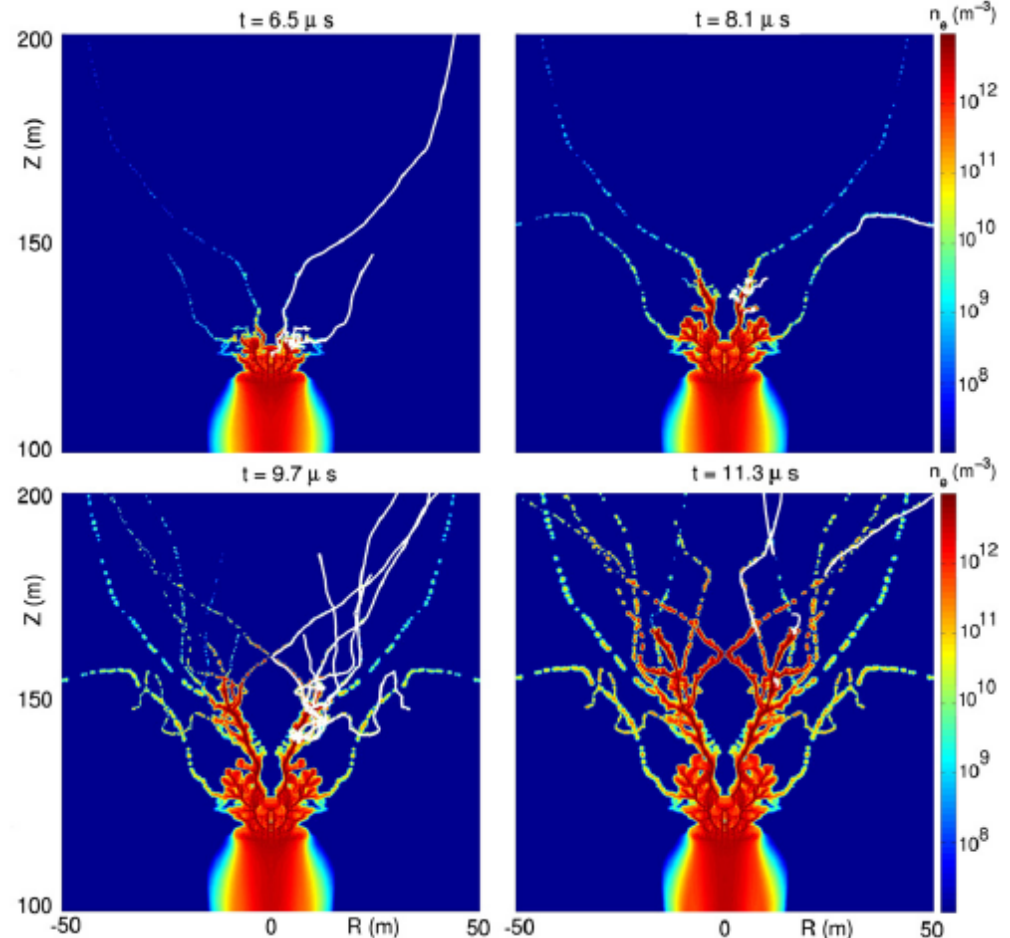
## First 3D-like simulation of runaway production by a streamer

(Chanrion & Neubert, JCP, 227, 2008)

Streamer initiated in a background field of  $3.E_k$   
Without photoionisation

Ionization trails are from runaway 'super'-electrons.  
=> influence the branching

Result need to be revisited ...



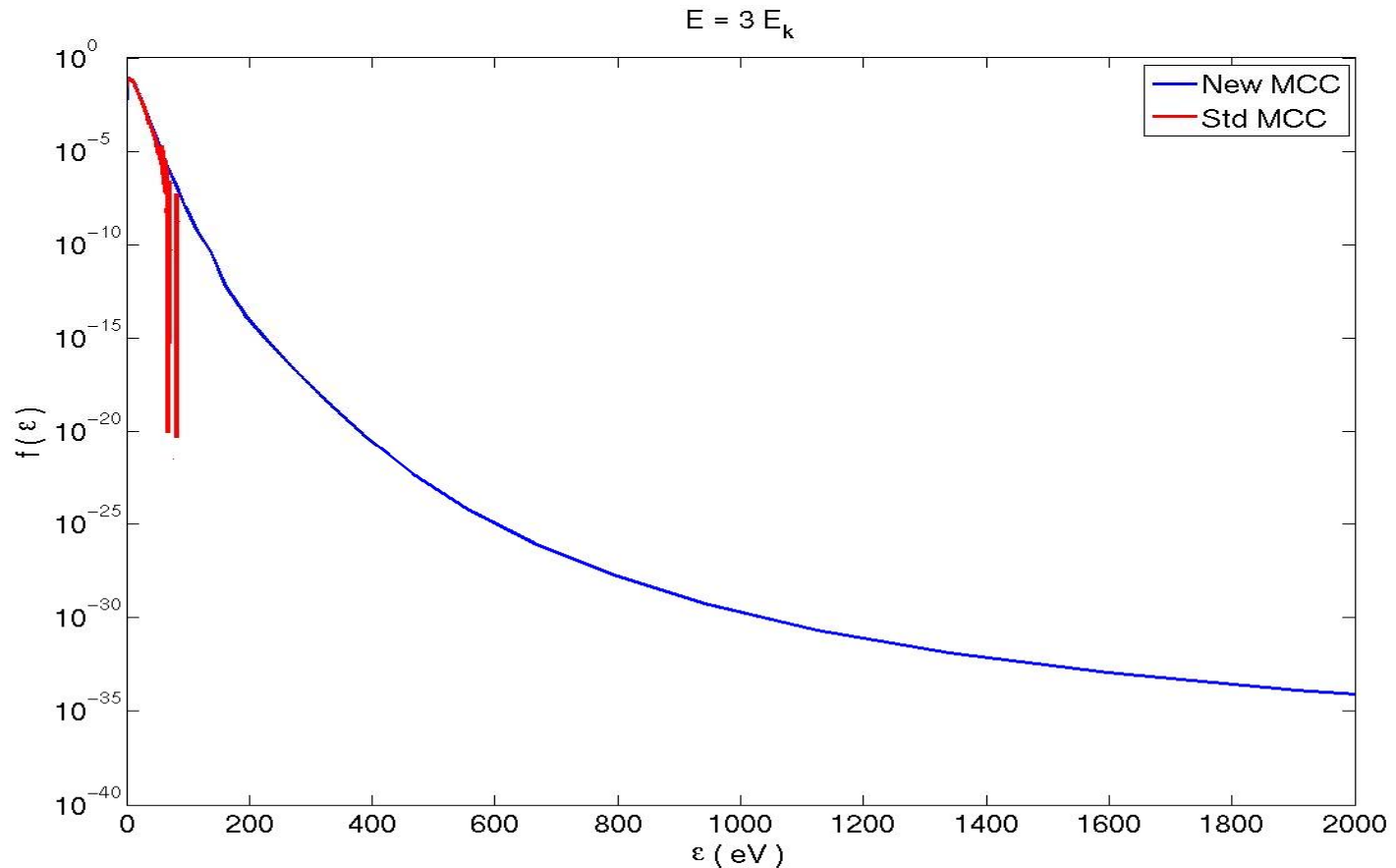
## Conventional Particle Code ( PIC-MCC )

- a computer particle represents a fixed number of real particles
- => Particles having a small probability to exist are not well described
- => Difficult to describe accurately the runaway electrons

## Our Specific PIC-MCC Code

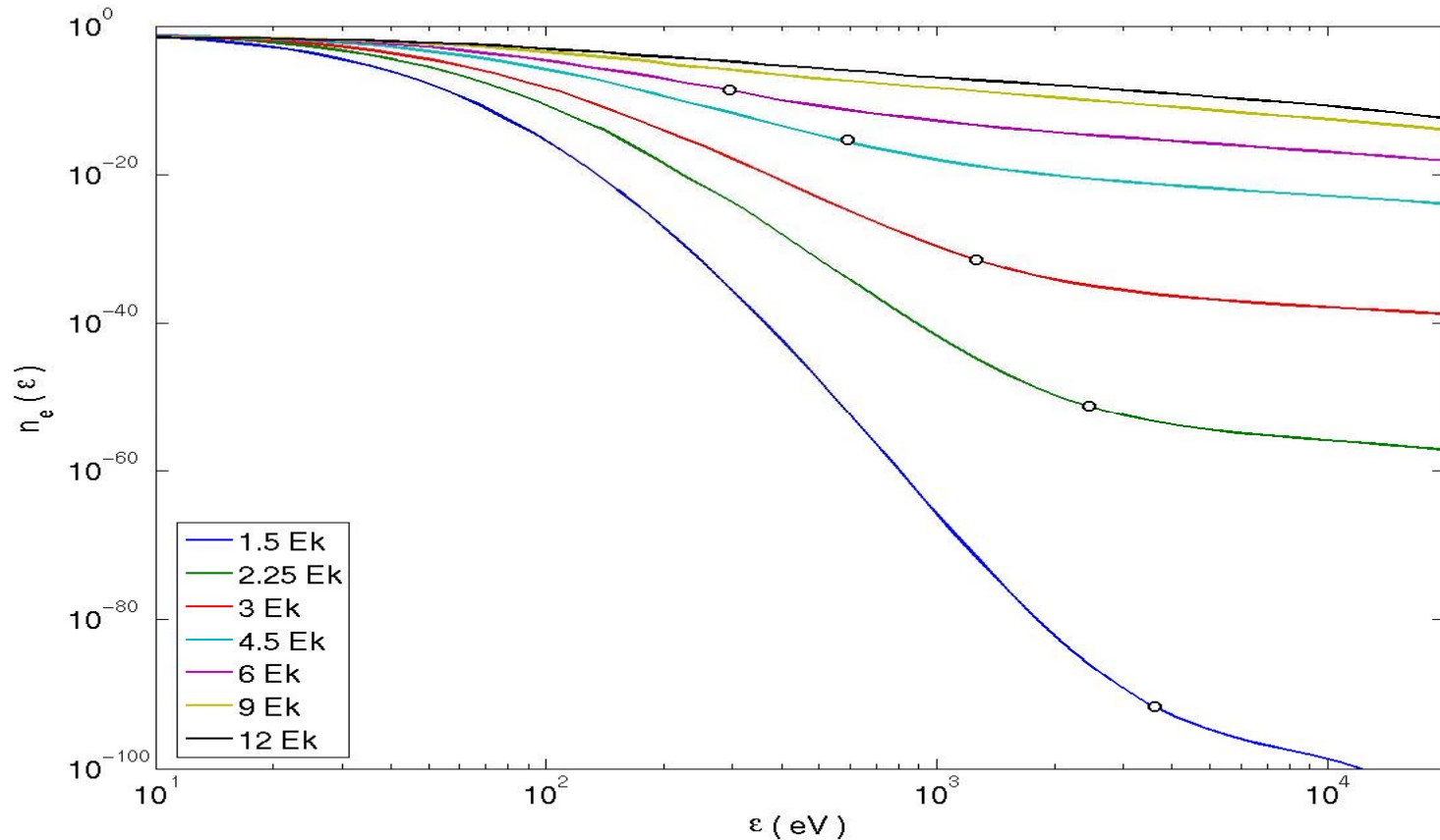
- computer particles of high energy are split
- => The 'particle' precision is independent of the particle energy
- => Accurate description of runaway electrons

# 1D results - The distribution function in a constant electric field.



$E_k$  is the conventional breakdown field ( $\sim 32\text{kV/cm}$  at STP)

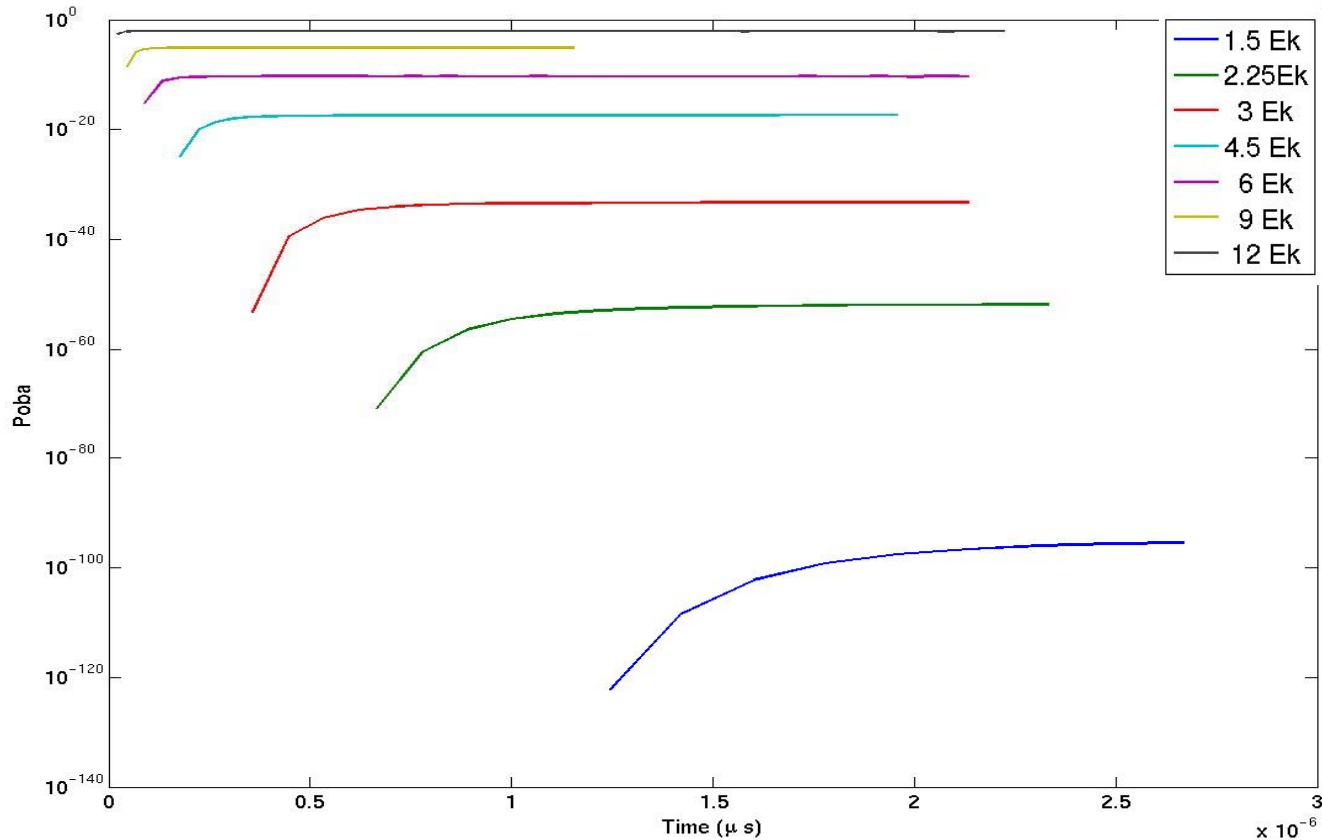
# 1D results - The distribution function in a constant electric field.



$E_k$  is the conventional breakdown field ( $\sim 32\text{kV/cm}$  at STP)

$\Rightarrow$  Reconstruction of the 'runaway' branch of the distribution.

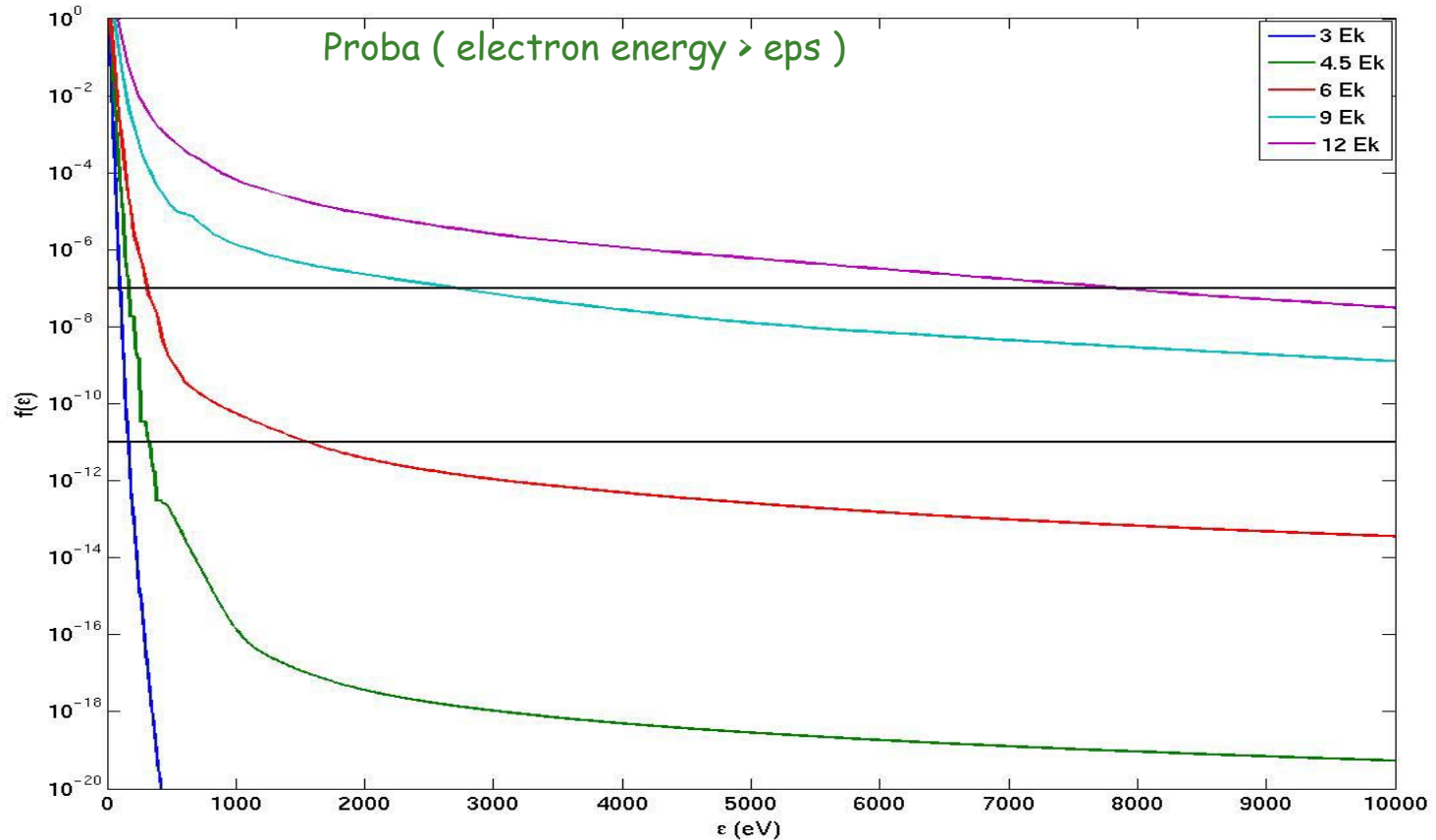
# 1D results - The probability to have a runaway.



Gives rough estimate of the field magnitude needed.

Meek criterion  $\rightarrow 10^9$  electrons in the streamer head  
 $\rightarrow E > 6 E_k$  needed

# 1D results - The distribution function in a constant electric field.



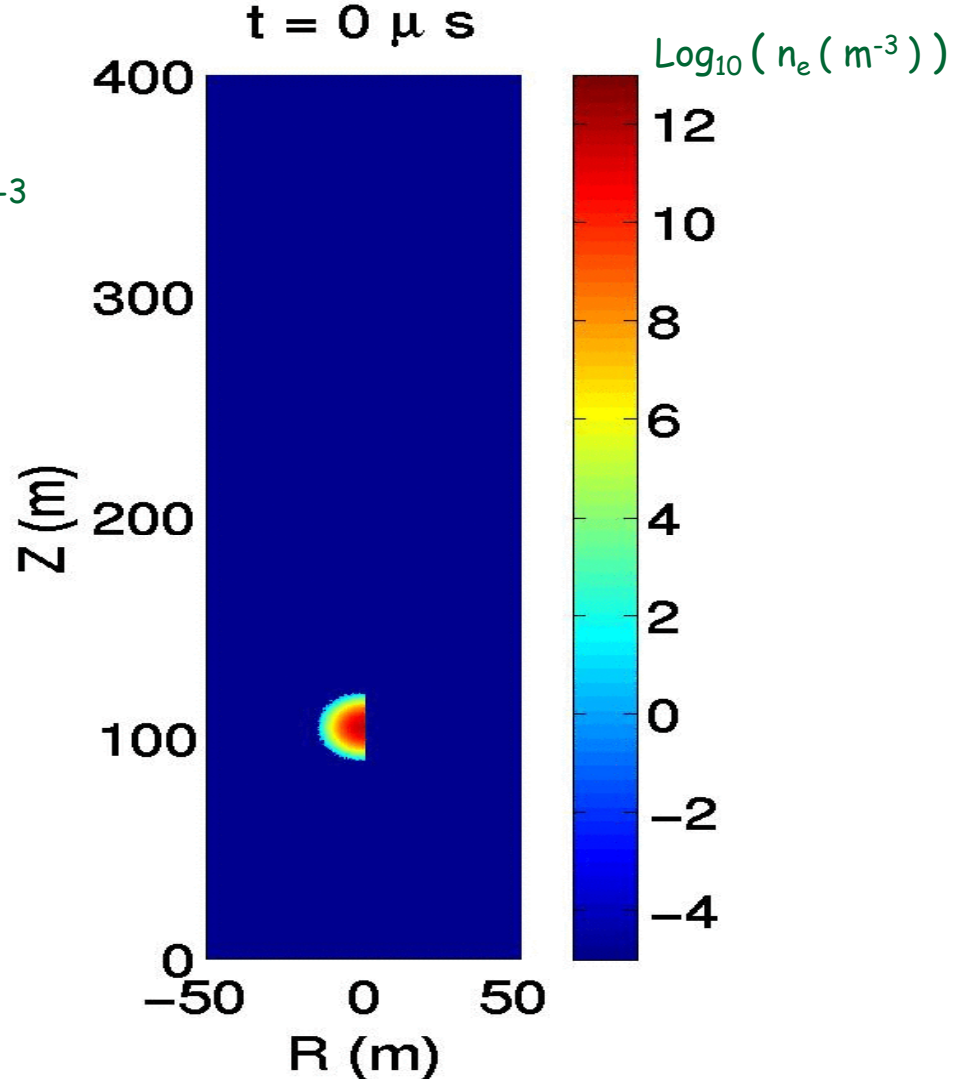
=> Need to improve the standard MCC

# 2D cylindrical results : Production of runaways by streamers

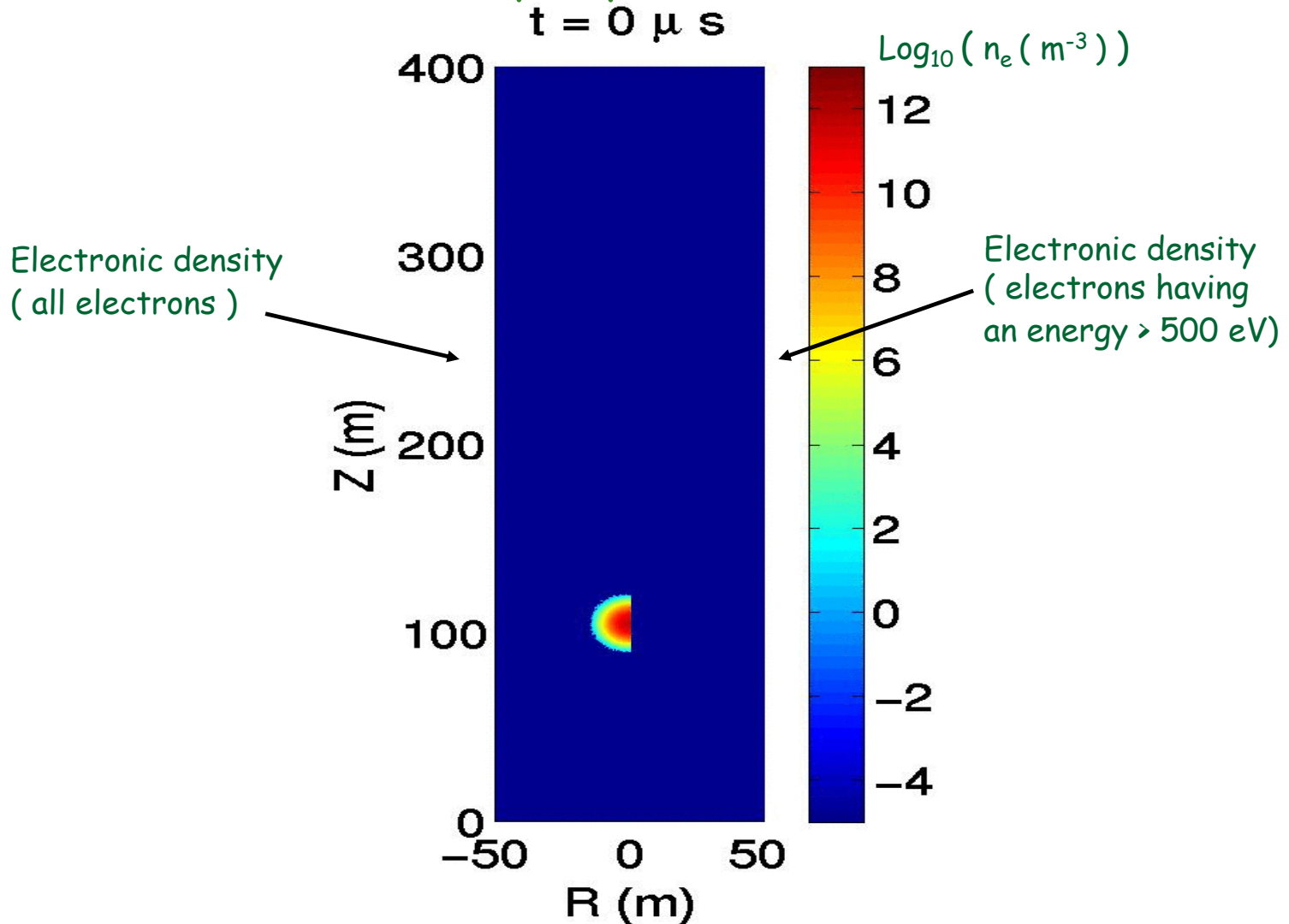
Same simulation case.

at 70 km height  
air density :  $1.61 \times 10^{21} \text{ m}^{-3}$   
field :  $660 \text{ V. m}^{-1} = 3.E_k$

Without photoionisation



# 2D cylindrical results : Production of runaways by streamers



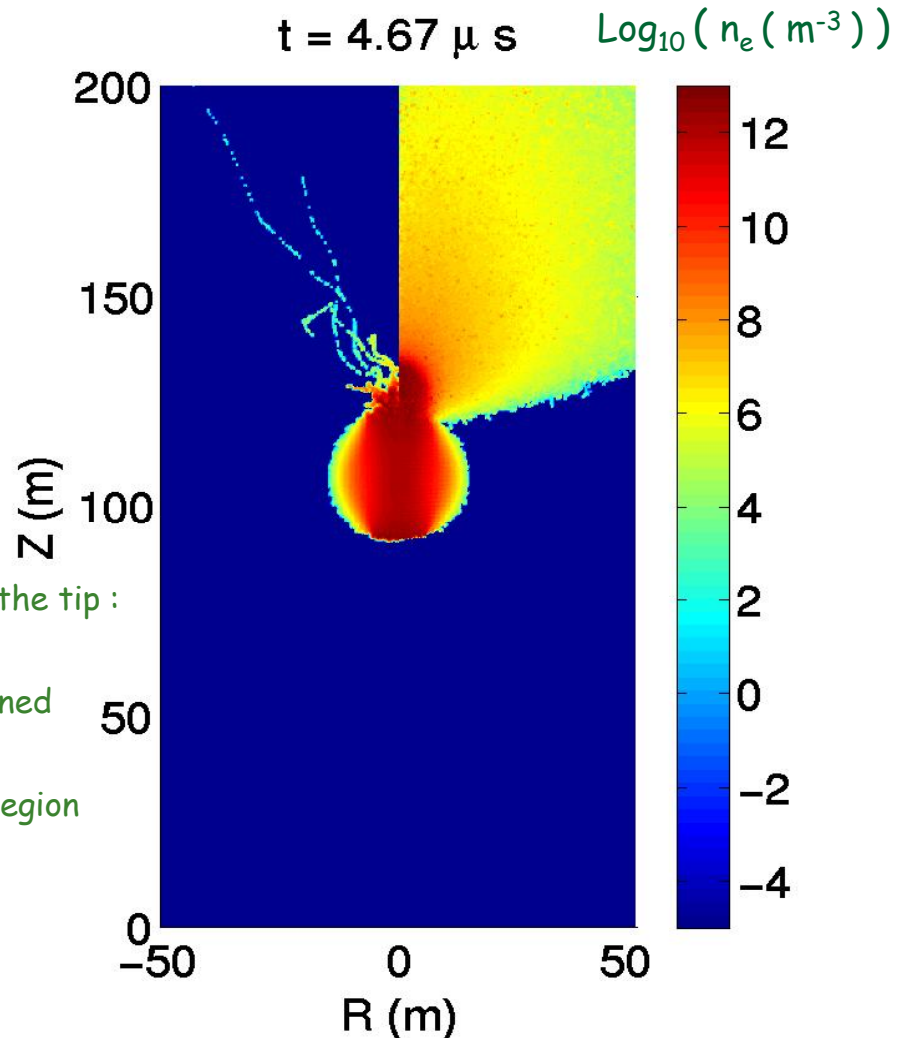
## 2D results :

### The comparison with / without the method

- No branching anymore.
- Influence streamer propagation ( similar to photoionisation )
- Not described by fluid simulation commonly used
  - First runaway electrons observed in an tip electric field of about  $5 E_k$
  - Maximal electron energy at the end of the simulation 200 keV.
  - Vertical flux of runaway electron far from the tip :  $5 \times 10^{11} \text{ m}^{-2} \text{ s}^{-1}$

Same order of magnitude of what obtained in Moss & Pasko (JGR,111)

Rescaled at 10 km, in a streamer region of lightning leader, it may lead to measurable X-ray flux



## Results from a new Monte Carlo Code.

- 'Runaway' distribution function
- probability to have runaway electrons.
- Field needed in the tip : 5-6  $E_k$
- 3D-like streamer simulation shows a beam of runaway which may delay the branching.
- rescaled to a streamer region of lightning leader, it may contribute in the TGF

## Future Work

- Simulation with photoionization to have the real dependence on the altitude
- Understand better the impact on the streamer propagation