Particle-in-Cell (PIC) kinetic simulations
07. Numerical tips and tricks in PIC simulations

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www.slido.com code: #B194

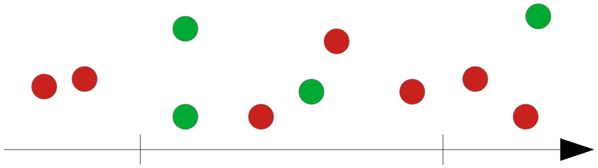
Computing time estimation

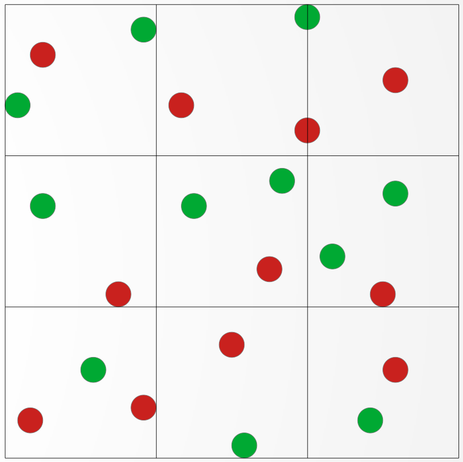
In each time step, the computing time is

$T \propto NX * NP$

proportional to NX (number of girds) and NP (number of particles)

1. estimated simulation time?
2. from 1D to 2D?





NX	$\rightarrow$	NX*NY
NP	$\rightarrow$	NP*NY
NX * NP	$\rightarrow$	NX*NY * NP*NY
T	$\rightarrow$	$NY^2 * T$

Simulation parameters

In case here we do not consider the numerical error and numerical stability.

1. What is the resolution we should adopt? Δx = ? Δt = ?

2. How long the simulation box/time should be? L = NX * Δx = ? T = NT * Δt = ?

Simulation parameters

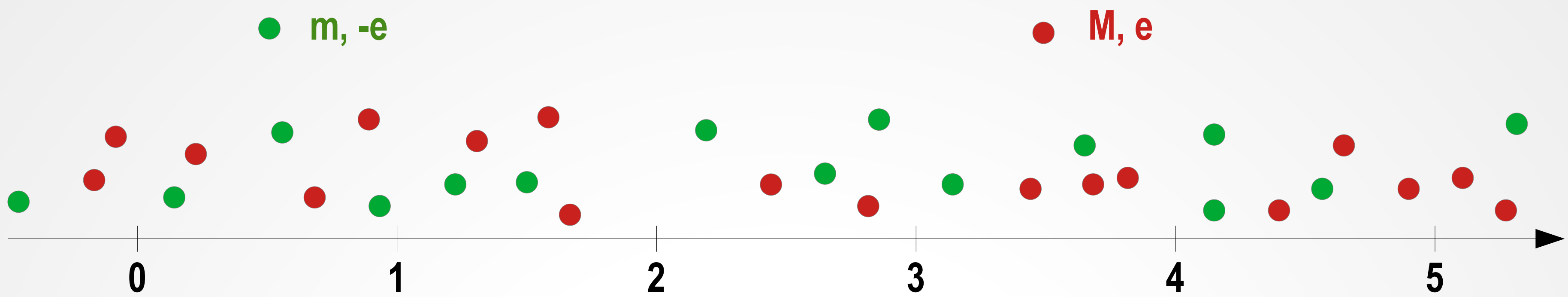
In case here we do not consider the numerical error and numerical stability.

1. What is the resolution we should adopt? Δx = ? Δt = ?
   The particle (electron) motions in plasma oscillation (and gyro-motion)

   (Courant condition: $c\Delta t < \Delta x$)

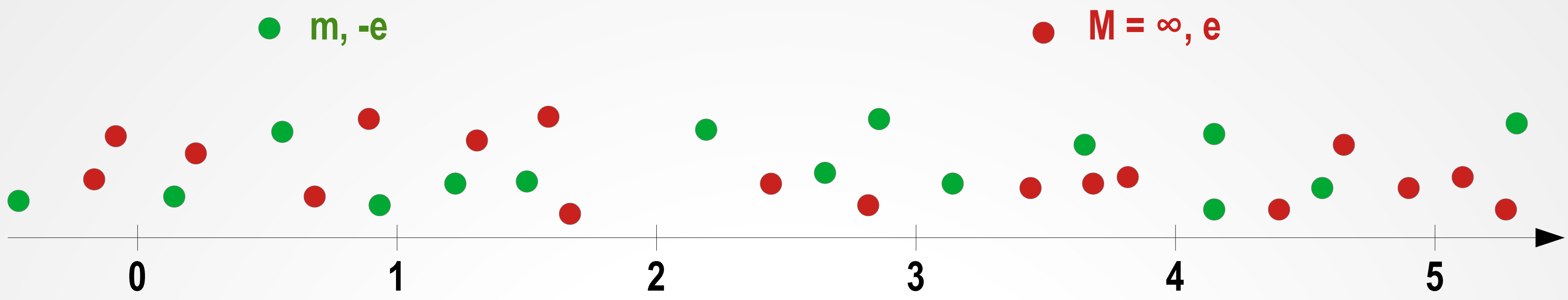
2. How long the simulation box/time should be? $L = NX * \Delta x$ = ? $T = NT * \Delta t$ = ?
   The spatial and time scale of the problems
   The wave length and the growth rate for the instability

Stationary ions



Number density	3	2	3	2	3
	3	3	2	3	3
	6	6	5	5	6
Density	3m+3M	4m+2M	3m+2M	2m+3M	3m+3M
Charge density	0	-2e	-e	e	0

Stationary ions



Number density	3 ~~3~~ 3 + avg(ion)	2 ~~3~~ 2 + avg(ion)	3 ~~2~~ 3 + avg(ion)	2 ~~3~~ 2 + avg(ion)	3 ~~3~~ 3 + avg(ion)
Density	3m + avg(ion)M	2m + avg(ion)M	3m + avg(ion)M	2m + avg(ion)M	3m + avg(ion)M
Charge density	3(-e) + avg(ion)e	2(-e) + avg(ion)e	3(-e) + avg(ion)e	2(-e) + avg(ion)e	3(-e) + avg(ion)e

While ions play no role in the problem……

Mass ratio

If there is a problem, we need a simulation box with $L = NX * \lambda_i$ and $T = NT * t_i$ for the evolution,

where $\lambda_i/\lambda_e = sqrt(m_i/m_e)$, $t_i/t_e = sqrt(m_i/m_e)$.
(t and λ are the characteristic time and a characteristic length for ion (i) or electorn(e))

Then the needed simulation time could be decried as

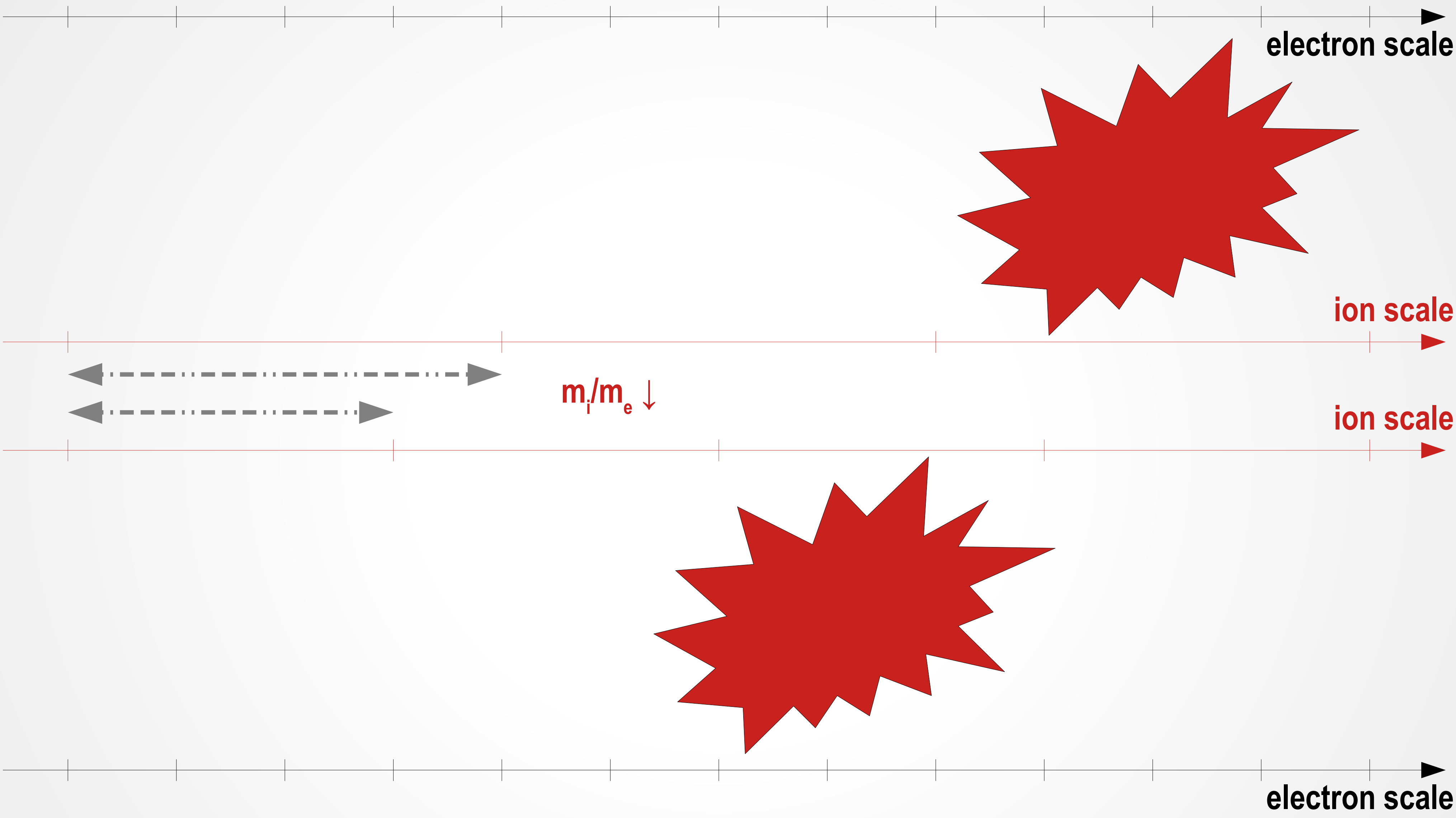
$$Time = (NX * \lambda_i) * (NT * t_i) = sqrt(m_i/m_e)*(NX * \lambda_e) * sqrt(m_i/m_e)*(NT * t_e)$$
$$= (m_i/m_e) * (NX * \lambda_e) * (NT * t_e)$$

In general the time and spatial resolutions are both depended on λ_e and t_e,
which are not really flexible.

But we can play with the mass ratio

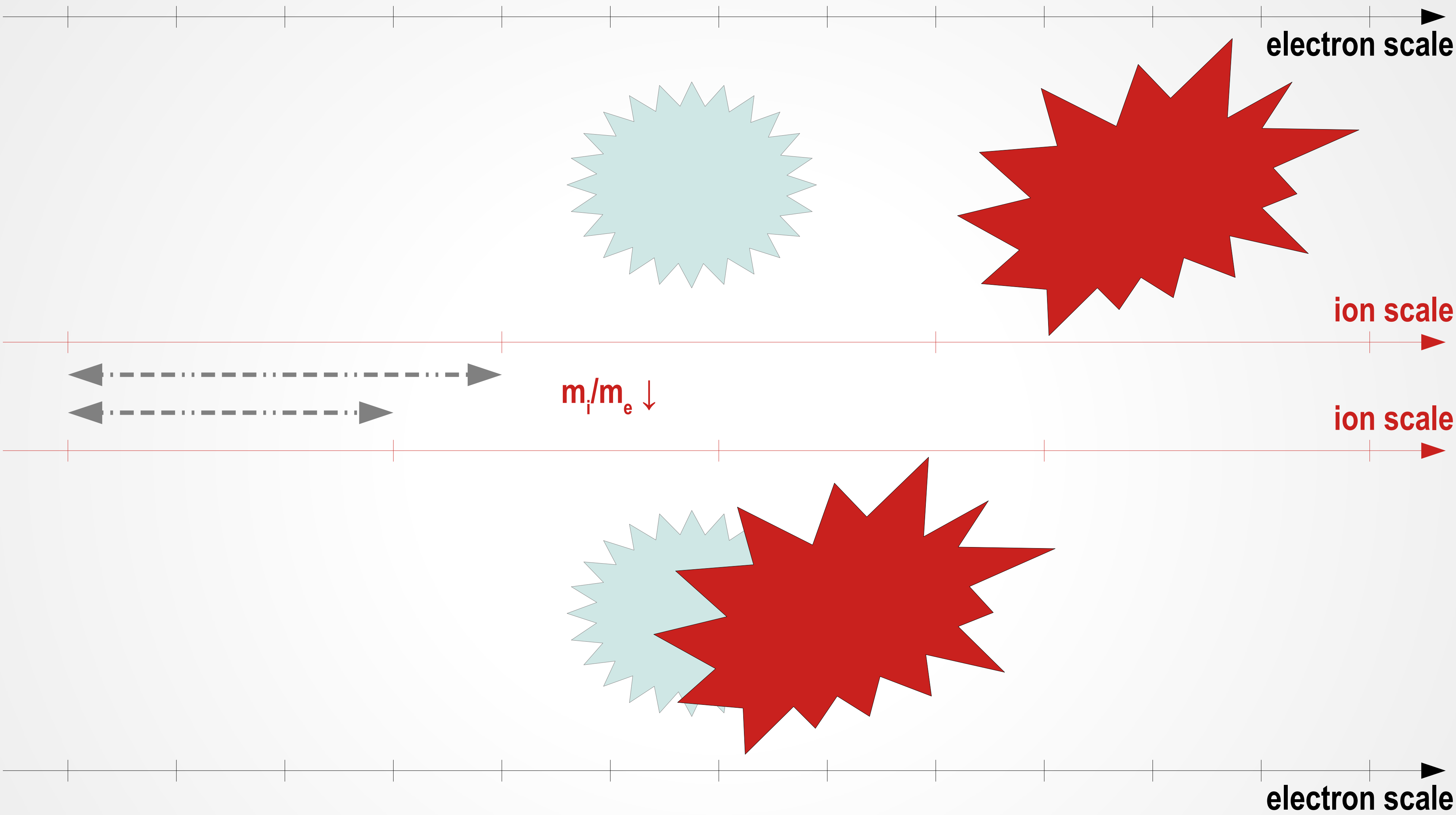
$m_i/m_e = 1836 \quad \rightarrow \quad m_i/m_e = 500, 100, 64, 16....$

Mass ratio



electron scale
ion scale
$m_i/m_e \downarrow$
ion scale
electron scale

Mass ratio


electron scale
ion scale
$m_i/m_e \downarrow$
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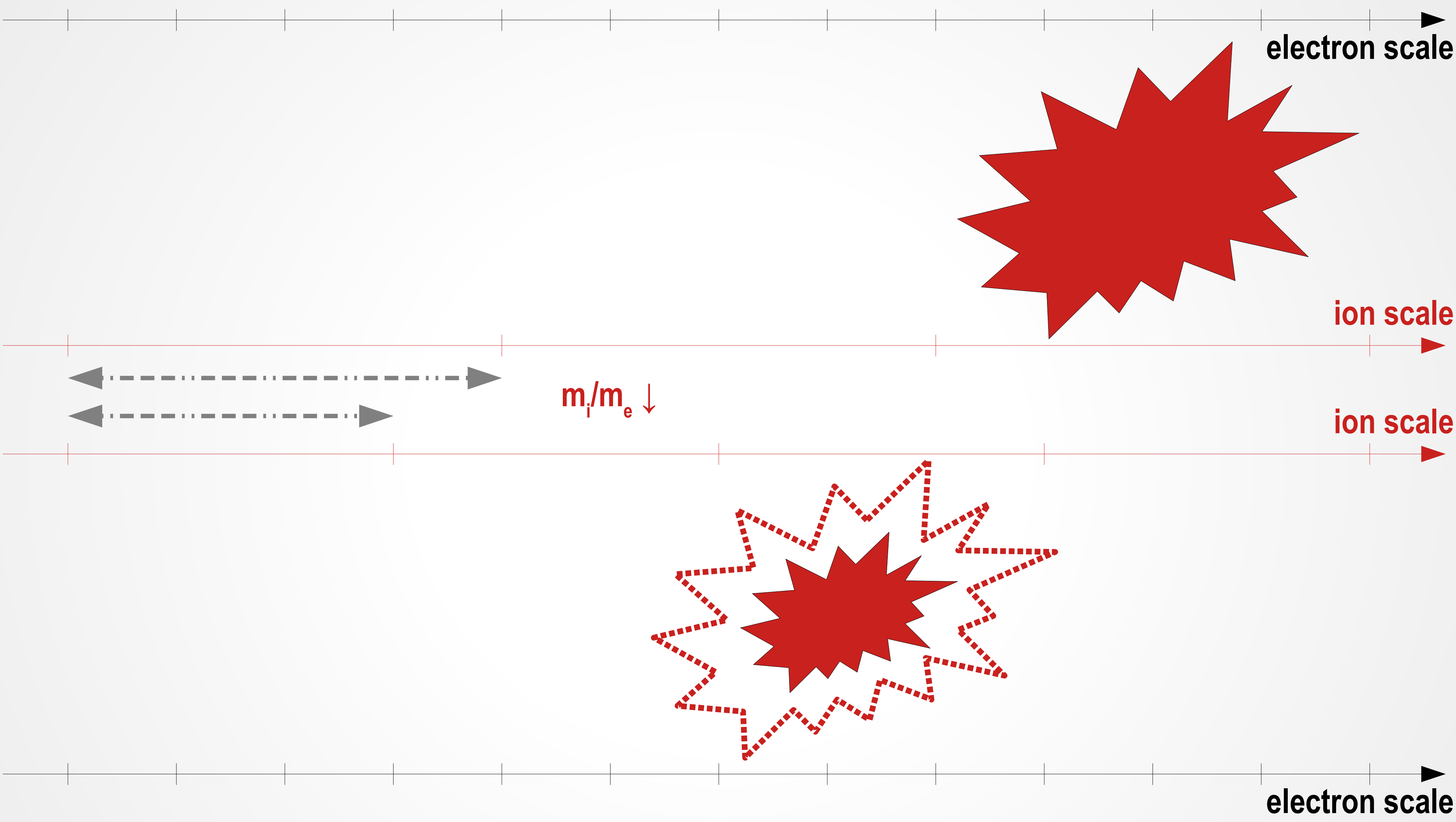
electron scale

Mass ratio



Number density ratio

While there are different particle components in the simulation system,

but $n_2 \ll n_1$, or says $\rho_2 \ll \rho_1$ ($\rho_{c,2} \ll \rho_{c,1}$) ($m_2 = m_1$, $q_2 = q_1$) .....

For instance, $n_2 / n_1 = 0.001$ ($\rho_2 / \rho_1 = 0.001$)

If for component 1, we first put 256 particles per cell, but for component 1??

Or for component 2, we first put 32 particles per cell,
but for component 32 particles per cell??

What you can do is, keep $\rho_2 / \rho_1 = 0.001$ ($\rho_{c,2} / \rho_{c,1} = 0.001$)
and the same number particles per cell for both components,

which implies $m_2 / m_1 = 0.001$ and $q_2 / q_1 = 0.001$, but still $m_2 / q_2 = m_1 / m_1$

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Same number of representatives,
but with different weight.

A numerical particle (super-particle) generally represents a group of particles......