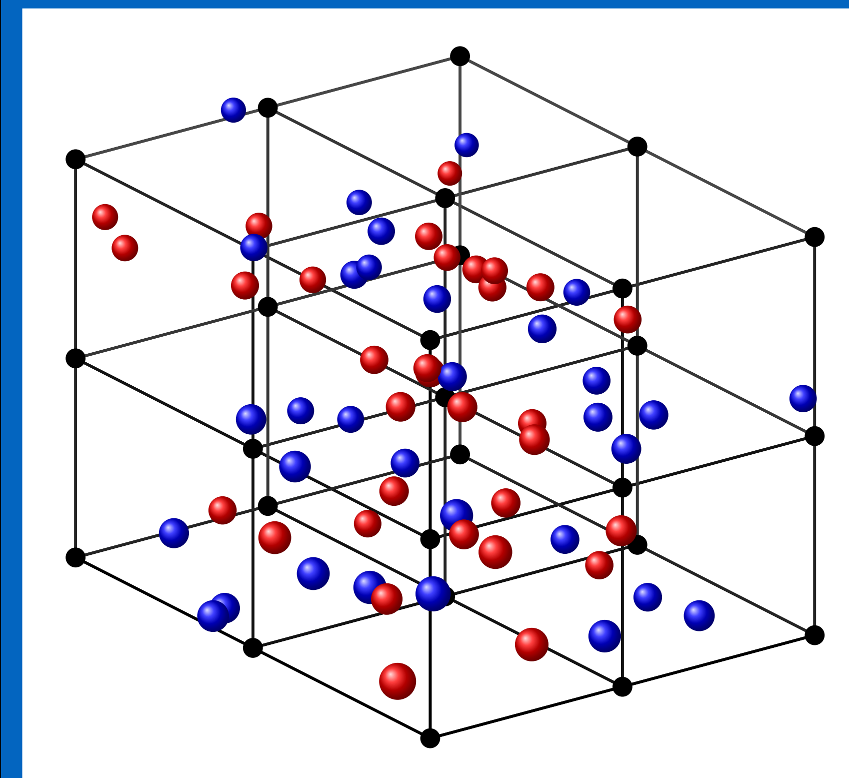
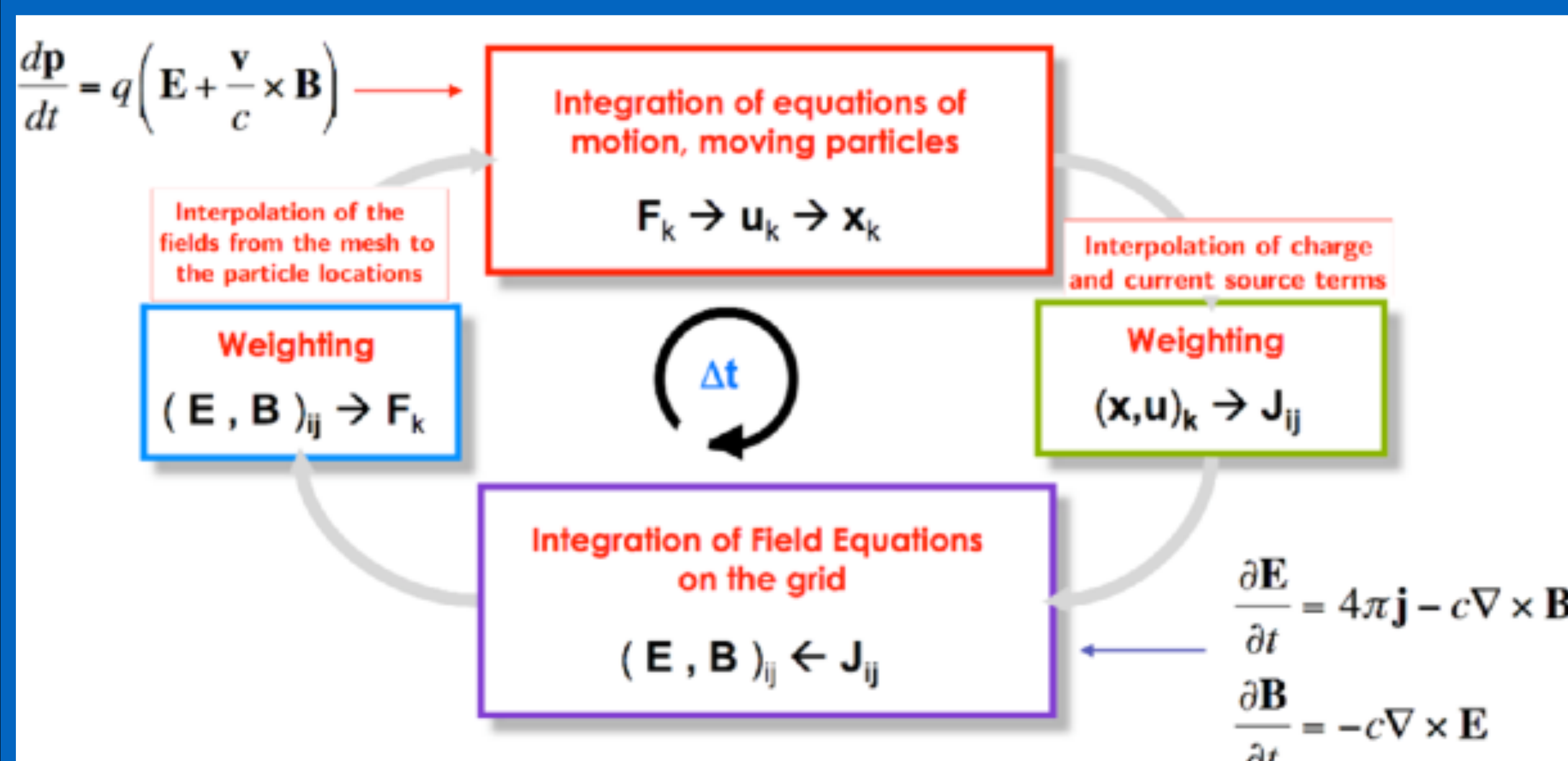
The quasi-relativistic regime is relatively unexplored

Parameters

σ_w	β_i	T_e/T_i	$\Delta\gamma_i$
0.1	0.0078125	0.1	0.000406687
0.1	0.0078125	0.3	0.000406767
0.1	0.0078125	1	0.000407051
0.1	0.03125	0.1	0.00163203
0.1	0.03125	0.3	0.00163334
0.1	0.03125	1	0.00163818
0.1	0.125	0.1	0.00661497
0.1	0.125	0.3	0.00663803
0.1	0.125	1	0.00673223
0.1	0.5	0.1	0.0280133
0.1	0.5	0.3	0.0285164
0.1	0.5	1	0.0308345
0.1	2.	0.1	0.155222
0.1	2.	0.3	0.178254
0.1	2.	1	0.394336
0.3	0.0078125	0.1	0.0012227
0.3	0.0078125	0.3	0.00122343
0.3	0.0078125	1	0.0012261
0.3	0.03125	0.1	0.00493921
0.3	0.03125	0.3	0.00495179
0.3	0.03125	1	0.00500182
0.3	0.125	0.1	0.0205981
0.3	0.125	0.3	0.0208554
0.3	0.125	1	0.022019
0.3	0.5	0.1	0.102084
0.3	0.5	0.3	0.110952
0.3	0.5	1	0.163062

Use **PiC simulation**.
Choose parameters so that inflow/ outflow electrons are **moderately** relativistic





The Vlasov equation

if they are at about the same position and share about the same velocity. Hence, we define $f(\boldsymbol{x}, \boldsymbol{v}, t)$ as the particle distribution function, which represents the number density of particles found near the point $(\boldsymbol{x}, \boldsymbol{v})$ in phase space. Specifically, the number of particles located within intervals d^3x about $\boldsymbol{x}$ and d^3v about $\boldsymbol{v}$ is given by

$$dN = f(\boldsymbol{x}, \boldsymbol{v}, t) d^3x d^3v \ . \tag{2}$$

$\boldsymbol{X} \equiv (\boldsymbol{x}, \boldsymbol{v})$ is phase space coordinates and $\dot{\boldsymbol{X}} = (\boldsymbol{v}, \boldsymbol{a})$

$$\dot{\boldsymbol{x}}_i = \boldsymbol{v}_i \ , \quad \dot{\boldsymbol{v}}_i = \boldsymbol{a}_i = \frac{q}{m}\left(\boldsymbol{E} + \frac{\boldsymbol{v}_i \times \boldsymbol{B}}{c}\right)$$

$$\frac{\partial f}{\partial t} + \nabla \cdot (f\boldsymbol{v}) + \nabla_{\boldsymbol{v}} \cdot (f\boldsymbol{a}) = 0$$

$$\frac{Df}{Dt} \equiv \left(\frac{\partial}{\partial t} + \dot{\boldsymbol{X}} \frac{\partial}{\partial \boldsymbol{X}}\right) f = 0$$

$Df/Dt = 0$ is known as *Liouville's theorem*. It states that the distribution function f is constant along particle trajectories in phase space (when $\nabla_{\boldsymbol{v}} \cdot \boldsymbol{a} = 0$).