Validity of fluid approach

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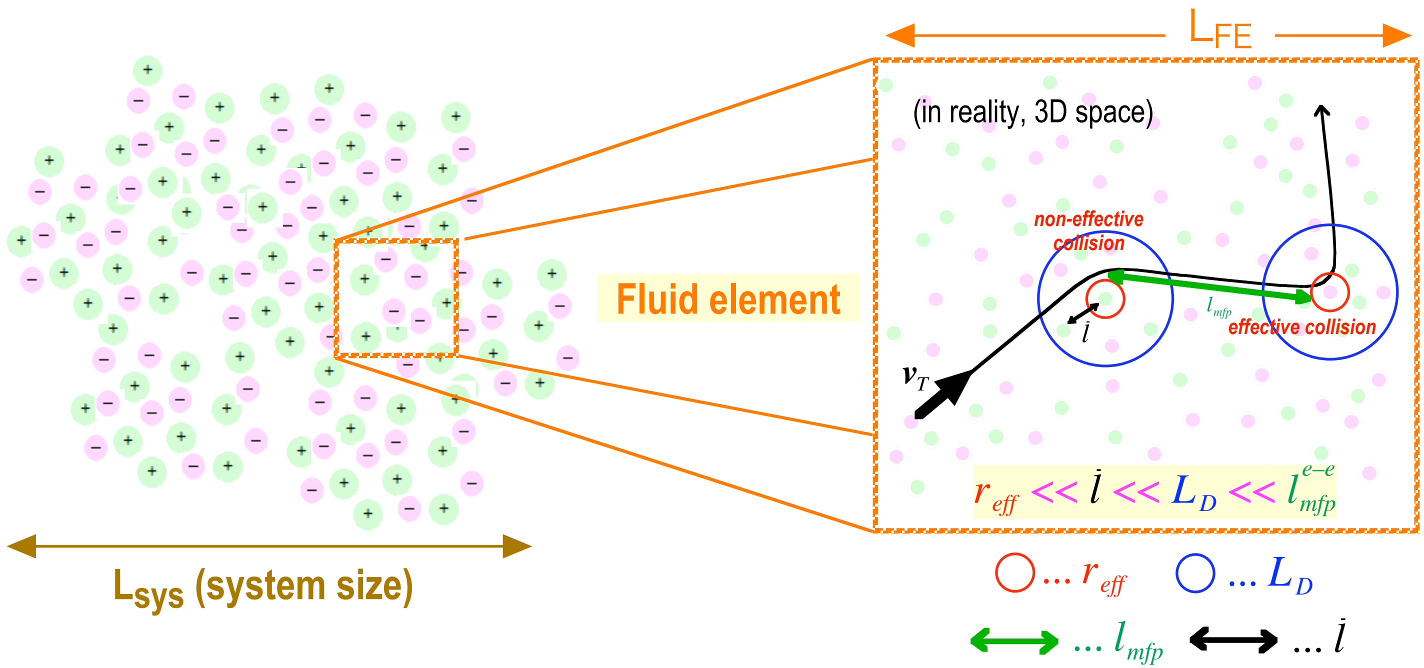
=> **mean free path** and **gyration radius** are key quantities



$l_{mfp} \ll L_{sys}$... **Fluid approach** is **appropriate.**

It makes good physical sense to introduce a fluid element whose size L_{FE} is smaller than L_{sys} but larger than l_{mfp}.
Particles inside the fluid element make a random walk with the velocity v_T. They basically stay inside the element; only part of them move in or out near the boundary of the element, which is treated by **diffusion approximation**.

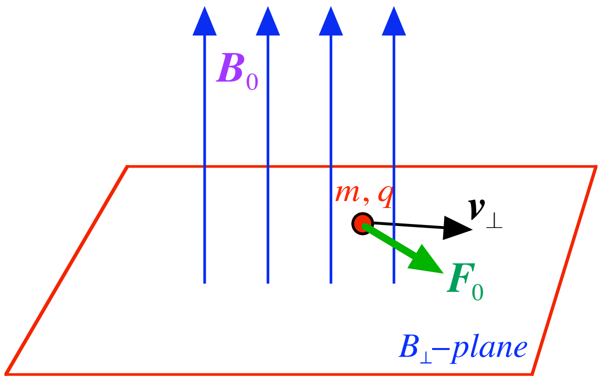
$l_{mfp} \gg L_{sys}$... **Fluid approach** is **generally inappropriate.**

However, even if collision is less frequent (**collisionless plasma**), fluid approach may be valid in $B_{\perp}$*−plane* if $r_G \ll L_{sys}$
(in $B_{//}$-direction, we may have to take a different approach).

Motion of a charged particle in $B_{\perp}$–*plane*

(Gyration & Drift)

Gyration with external force



B_0: magnetic field (uniform & constant, straight shape)

v: particle's velocity m, q: particle's mass & charge

F_0: external force (uniform & constant, in $B_\perp$–plane)

Equation of motion in $B_\perp$–plane: $m \dfrac{d\boldsymbol{v}_\perp}{dt} = q\, \boldsymbol{v}_\perp \times \boldsymbol{B}_0 + \boldsymbol{F}_0$

$\boldsymbol{v}_\perp = \boldsymbol{v}_G(t) + \boldsymbol{v}_F$

$m \dfrac{d\boldsymbol{v}_\perp}{dt} = q\, \boldsymbol{v}_\perp \times \boldsymbol{B}_0 + \boldsymbol{F}_0$

$$\begin{cases} \dfrac{d^2 \boldsymbol{v}_G(t)}{dt^2} = -\dfrac{q^2 B_0^2}{m^2}\, \boldsymbol{v}_G(t) \\ \boldsymbol{v}_F = \dfrac{\boldsymbol{F}_0 \times \boldsymbol{B}_0}{q\, B_0^2} \end{cases}$$

$q\, \boldsymbol{v}_G(t) \times \boldsymbol{B}_0$ => gyration: $\boldsymbol{v}_G(t)$

gyration angular frequency: $\omega_B \equiv \dfrac{q\, B_0}{m}$

gyration radius: $r_G = \dfrac{m\, v_\perp}{q\, B_0}$

$\boldsymbol{F}_0$ => drift: $\boldsymbol{v}_F$

$\boldsymbol{F}_0 = q\, \boldsymbol{E}_0$ => ExB drift ($\boldsymbol{v}_{E\times B} = \dfrac{\boldsymbol{E}_0 \times \boldsymbol{B}_0}{B_0^2}$)

$\boldsymbol{v}_\perp = \boldsymbol{v}_G(t)$ **(gyration)** $+\ \boldsymbol{v}_F$ **(drift)**