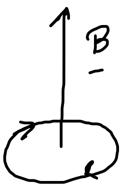
$J = \int p \, dq$ q: coordinata periodica

inv. adiabatico $p = \dfrac{\partial L}{\partial \dot{q}}$



μ é inv. adiabatico $\mu = \dfrac{m v_\perp^2}{2B}$

1) $\underset{\pi r_L^2}{\Phi(\underline{B})} = \pi r_L^2 B = \pi \dfrac{m^2 v_\perp^2}{q^2 B^{\cancel{2}}} \cancel{B} = \dfrac{2\pi m}{q^2} \dfrac{m v_\perp^2}{2B} = \dfrac{2\pi m}{q^2} \cdot \mu$

$B = 1\,T$ $\omega_L = \dfrac{qB}{m} \approx \dfrac{1.6 \cdot 10^{-19}}{1.6 \cdot 10^{-27}} \sim 10^8$ $\nu_L = \dfrac{\omega_L}{2\pi} \sim 10^7 \Rightarrow T_L \sim \mu s$

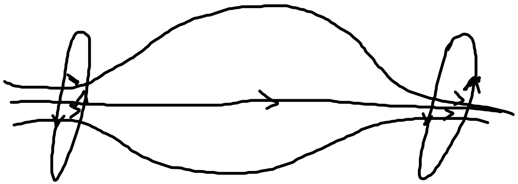
$B \uparrow$ $\Phi = \text{const} \Rightarrow r_L \downarrow$: "strizzare" il plasma

$B \downarrow$ $\Phi = \text{const} \Rightarrow r_L \uparrow$: espansione del plasma

2) Macchine a "specchio magnetico"

$$v_{\parallel} \cdot \quad m\frac{dv_{\parallel}}{dt} = -\mu \frac{\partial B}{\partial s} \cdot v_{\parallel} \quad (+F_{\parallel})$$

$$\underline{F} = -\mu\, \underline{\nabla} |\underline{B}|$$



S: coordinata lungo la linea di campo

$$v_{\parallel} = \frac{\partial s}{\partial t}$$

$$m v_{\parallel} \frac{dv_{\parallel}}{dt} = \frac{d}{dt}\left(\frac{1}{2} m v_{\parallel}^2\right) \qquad \frac{\partial B}{\partial s} \cdot \underbrace{\frac{\partial s}{\partial t}}_{v_{\parallel}} = \frac{dB}{dt}$$

$$\mu \frac{\partial B}{\partial s} v_{\parallel} = \mu \frac{dB}{dt} = \frac{d}{dt}(\mu B)$$

$$\frac{1}{2} m v_{\parallel}^2 + \mu B = \text{const} \qquad \frac{d}{dt}\left(\frac{1}{2} m v_{\parallel}^2 + \mu B\right) = 0;$$

$V(B)$

$\frac{1}{2} m v_\parallel^2 + \mu B =$

$= \frac{1}{2} m v_{\parallel 0}^2 + \frac{m v_{\perp 0}^2}{2 \cancel{B_{min}}} \cdot \cancel{B_{min}} = W_0$

0: qtà valutate dove $B = B_{min}$

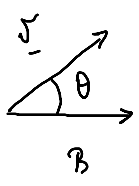
μB: potenziale efficace

moto in 1D

$E = \frac{1}{2} m v^2 + V(x)$

$v_\parallel = \sqrt{\frac{2}{m}\left[W_0 - \mu B\right]}$

μB ha valore max: μB_{max}



$v_\parallel = v \cos\theta$

$v_\perp = v \,\mathrm{sen}\,\theta$

Se $W_0 > \mu B_{max}$: $v_\parallel$ non si annulla mai

$\Rightarrow$ part. non è confinata

Se $W_0 < \mu B_{max}$: $v_\parallel = 0$ in qualche punto

moto confinato tra i punti dove $v_\parallel = 0$

$W_0 = \mu B_{max}$

$$W_0 = \mu B_{max} = \frac{m v_{\perp 0}^2}{2 B_{min}} B_{max}$$

θ: angolo di pitch

$$\frac{1}{\cancel{2}} m v_0^2 = \frac{\cancel{m} v_0^2 \operatorname{sen}^2\theta \, B_{max}}{\cancel{2} B_{min}}$$

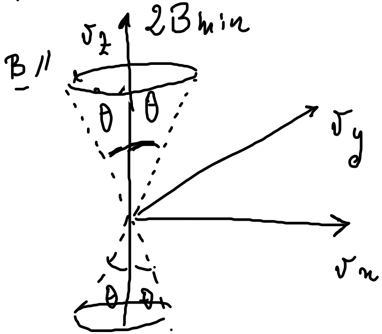
$$\operatorname{sen}^2\theta = \frac{B_{min}}{B_{max}} \; ; \; \operatorname{sen}\theta_{cr} = \sqrt{\frac{B_{min}}{B_{max}}}$$

$\theta_0 < \theta_{cr}$: particella non confinata

$$F = -\mu \frac{\partial B}{\partial s} \qquad \mu = \frac{m v_{\perp 0}^2}{2 B_{min}}$$

$v_0 \sim v_{\parallel 0}$ sarà difficilmente confinata

$\theta > \theta_{cr}$: " confinata



Cono di perdita

fuori dal cono: $\theta_{cr} < \theta < \pi - \theta_{cr}$

$0 < \varphi < 2\pi$

$0 < v < +\infty$

$f(\underline{v})$ è Maxwelliana

$$d^3\underline{v} = v^2\, dv\, \mathrm{sen}\theta\, d\theta\, d\varphi$$

$\hat{\text{L}}$ coord. sferiche

$$f = \frac{\#\text{particelle fuori dal cono}}{\#\text{particelle totali}} = \frac{\int_{\theta_{cr}}^{\pi-\theta_{cr}} d\theta\, \mathrm{sen}\theta \int_0^{2\pi} d\varphi \int_0^{+\infty} dv\, v^2 f_M(v)}{\int f_M(\underline{v})\, d^3\underline{v}} =$$

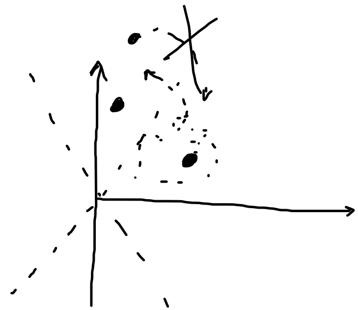
$$= \frac{\int_{\theta_{cr}}^{\pi-\theta_{cr}} d\theta\, \mathrm{sen}\theta \cancel{\int_0^{2\pi} d\varphi} \cancel{\int_0^{+\infty} dv\, v^2} f_M(v)}{\int_0^{\pi} d\theta\, \mathrm{sen}\theta \cancel{\int_0^{2\pi} d\varphi} \cancel{\int_0^{+\infty} dv\, v^2} f_M(v)} = \frac{-\cos\theta \Big|_{\theta_{cr}}^{\pi-\theta_{cr}}}{-\cos\theta \Big|_0^{\pi}}$$

$$= \frac{-\left[-\cos\theta_{cr} - \cos\theta_{cr}\right]}{2} = \cos\theta_{cr} = \sqrt{1-\mathrm{sen}^2\theta_{cr}}$$

$$= \sqrt{1 - \frac{B_{min}}{B_{max}}}$$

Supponiamo $\frac{B_{min}}{B_{max}} = \frac{1}{2}$ $\mathcal{J} \simeq 70\%$

2 problemi → instabilità
→ collisioni



$T \sim keV$

$T_{coll} \sim ms$

$v = \left(\frac{2 k_B T}{m_{ione}}\right)^{\frac{1}{2}} \simeq 4 \cdot 10^5 \, m/s$

$L \sim 1 \, m$ $t_{percorso} \sim \frac{L}{v} \sim \mu s$