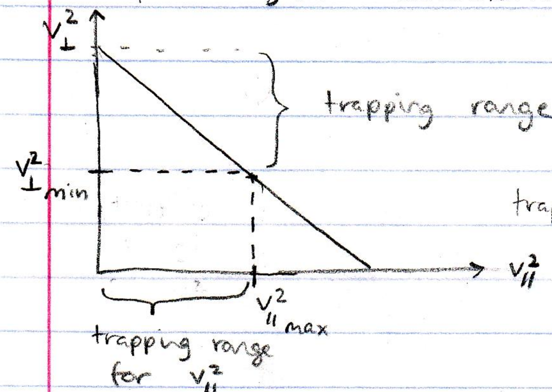
Open Magnetic Confinement



mirror ratio: $\dfrac{B_{max}}{B_{min}} = R_M$

trapping domain only depends on mirror ratio.

trapping domain:

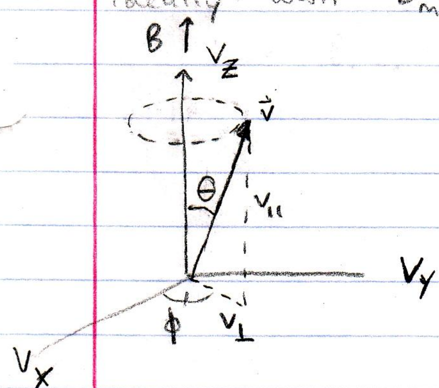
$$\frac{v_{\parallel\,max}^2}{v_{\perp\,min}^2} < \frac{B_{max}}{B_{min}} - 1$$

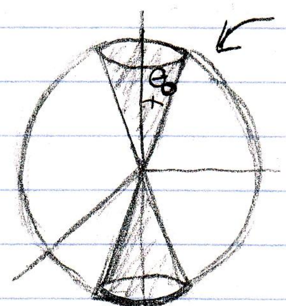
loss domain > (mirror ratio) − 1

$$\frac{v_{\parallel\,max}^2}{v_{\perp\,min}^2} > \frac{B_{max}}{B_{min}} - 1$$

good mirror ratio ~ 3, or 4

ideally: want B_{min} to be large enough for pressure balance





shaded region is the loss cone

loss cone angle: θ_0

$$\theta_0 = \arcsin\sqrt{\frac{B_{min}}{B_{max}}}$$

probability of an ion scattering into the loss cone is given by the solid angle

loss fraction: $$f_{loss} = \frac{\int^{\text{double cone}} f(v)\, d^3v}{\int_0^\infty f(v)\, d^3v} \Rightarrow 1 - \cos\theta_0$$

therefore $\cos\theta_0$ is the trapped fraction.

$$f_{trap} = \cos\theta_0 = \sqrt{1 - \frac{B_{min}}{B_{max}}} = \sqrt{1 - \frac{1}{R_M}}$$

Note: [redacted] non-equilibrium distribution in velocity space.

☆: particles prefer minimum energy state loss cone instability: / due to lack of particles in the loss cone direction, $f(\vec{v})$ is not isotropic, i.e. non-equilibrium (Maxwellian) RF is generated anomalously in plasma to try to fill loss → increase loss rate

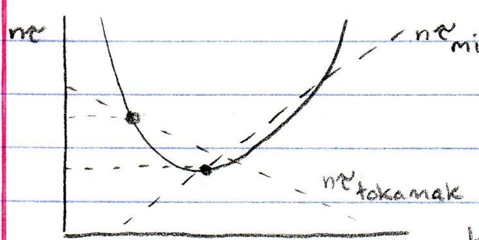
In mirror configuration, both fluid & kinetic instabilities are solved.

$$\text{(Eqn 9.41)} \quad \tau_{ii} = \frac{1}{N_i \langle \sigma_s v_r \rangle} \propto \frac{A^{1/2} (kT_i)^{3/2}}{N_i q_i^4}$$ ion-ion collision time

$$\tau_M = \frac{1}{N_i \langle \sigma_s v_r \rangle \cdot f_{\text{loss cone}}} = \tau_{ii} \cdot f_{\text{loss}}^{-1} = \tau_{ii} \cdot (1 - f_{\text{trap}})^{-1}$$

$$\tau_M = \tau_{ii} \cdot \left(1 - \sqrt{1 - \frac{1}{R_M}}\right)^{-1}$$

Mirror confinement time increases as mirror ratio increases.



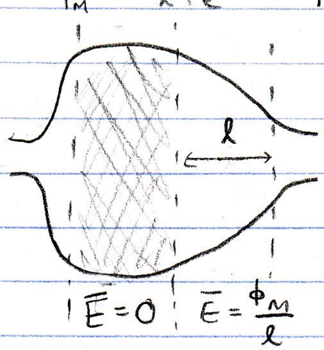
$$n\tau_M = \frac{n \, \tau_{ii}}{1 - \sqrt{1 - \frac{1}{R_M}}} \qquad \tau_{ii} = \frac{k' \, kT^{3/2}}{n}$$

$$\tau_M < \tau_{\text{tokamak}}$$

can see it is not as efficient compared to the closed magnetic field

Electrons: scatter at a faster rate & scatter into the loss cone before ions do. This results in a plasma potential ϕ_M

$\phi_M \sim kT_e \sim 100$ keV



ions are magnetically confined

electrons are electrostatically confined

4/20

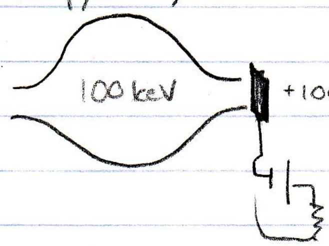
How can we get advanced / alternate mirrors ?

- Bumpy torus

loss cones lead into loss cones of another set

trap electrons ~~in~~ a ring

(Elmo Bumpy Torus)



- tandem mirror