opravа cvičení
laserová fúze $E \sim 10\ keV$ $n \sim 10^{26}\ cm^{-3}$

Coulombický logaritmus $\Lambda_c = \frac{\lambda_D}{b_{90}}$
vs plazmatický parametr Λ?

$$\Lambda = 4\pi n \lambda_D^3 \quad (3 N_D)$$

$$= 4\pi n \left(\frac{\varepsilon_0 k_B T}{q_0^2 n}\right)^{3/2} = 4\pi \frac{1}{\sqrt{n}} \left(\frac{\varepsilon_0 k_B T}{q_0^2}\right)^{3/2}$$

$$\Lambda_c = \frac{\lambda_D}{b_{90}} = \sqrt{\frac{\varepsilon_0 k_B T}{q_0^2 n}} \; \frac{4\pi\varepsilon_0 \, m g^2}{q_0^2} \quad m g^2 \sim 3 k_B T \text{ (ve stř. hodnotě)}$$

$$\Lambda_c = \frac{4\pi \varepsilon_0^{3/2}\, 3 (k_B T)^{3/2}}{q^3 \sqrt{n}} = 3\Lambda = 9 N_D$$

prostředí, $\Lambda < 1$?
iontové krystaly $T \sim mK$
$k_B T \sim \mu eV$
$n \sim 10^9\ cm^{-3}$

Poznámka k Λ
používáme λ_D s parametry elektronů
elektrony stíní pohyblivé částice

ZTRÁTA HYBNOSTI V COUL. SR.

$$\Delta \vec{p}_1 = \mu (\vec{g}_{12}' - \vec{g}_{12})$$

nechť
$v_2 = 0 \Rightarrow v_1 = g_{12}$
$\vec{v}_1 \parallel \hat{x}$

$$\Delta p_{1x} = \mu (g_{12x}' - g_{12x})$$

el. srážka: $g_{12}' = g_{12}$
$g_{12x}' = g_{12x} \cos\chi = v_1 \cos\chi$

$$\Delta p_{1x} = \mu v_1 (\cos\chi - 1) =$$

$$= -\mu v_1 (1 - \cos\chi) =$$

$$= -p_{1x} \frac{m_2}{m_1 + m_2} (1 - \cos\chi)$$

pro $m_1 \gg m_2$ ztráta hybnosti malá

aproximace pro malé úhly

$$\simeq -p_{1x} \frac{m_2}{m_1 + m_2} \left(\cancel{1} - \cancel{1} + \frac{\chi^2}{2}\right)$$

coulombické sr.
$\cot\chi \simeq \frac{1 - \frac{\chi^2}{2} + \dots}{\chi - \dots} \simeq 1/\chi$

$$\frac{\chi}{2} \sim \frac{b_{90}}{b}$$

$$\Delta p_{1x} \simeq -p_{1x} \frac{m_2}{m_1 + m_2}\, 2 \frac{b_{90}^2}{b^2}$$

$$\frac{dp_{1x}}{dl} = n_2 \int_{b_{min}}^{b_{max}} \Delta p_{1x}\, 2\pi b \, db =$$

$$= n_2 (-p_{1x}) \frac{m_2}{m_1 + m_2} 4\pi b_{90}^2 \underbrace{\int_{b_{min}}^{b_{max}} \frac{1}{b}\, db}_{\ln \Lambda_c}$$

na jednotku času:

$$\frac{dp_{1x}}{dt} = v_1 \frac{dp_{1x}}{dl} \equiv \underbrace{-\nu_p\, p_{1x}}_{\text{definice } \nu_p}$$

$$\nu_p = -\frac{v_1}{p_{1x}} \frac{dp_{1x}}{dl}$$

$$\nu_p = +\frac{v_1}{\cancel{p_{1x}}} n_2 \cancel{p_{1x}} \frac{m_2}{m_1 + m_2} 4\pi b_{90}^2 \ln \Lambda_c =$$

$$= n_2 v_1 \underbrace{\frac{m_2}{m_1 + m_2} 4\pi b_{90}^2 \ln \Lambda_c}_{\sigma_p}$$

$$= n_2 v_1 \underbrace{\left(\frac{q_1 q_2}{4\pi\varepsilon_0}\right)^2 \cdot 4\pi \frac{m_1 + m_2}{m_1^2 m_2 v_1^4} \ln \Lambda_c}_{\sigma_p}$$

porovnejme ν_E a ν_p

$$\frac{\nu_E}{\nu_p} = 2 \frac{1}{m_1 \cancel{m_2}} \Big/ \frac{m_1 + m_2}{m_1^2 \cancel{m_2}} = 2 \frac{m_1}{m_1 + m_2}$$

e-i srážky : $m_1 \ll m_2$, $\nu_E \ll \nu_p$

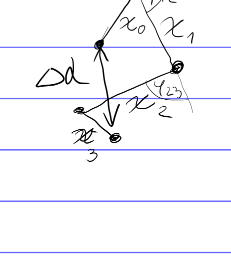
e-e, i-i : $m_1 = m_2$; $\nu_E = \nu_p$

i-e $m_1 \gg m_2$; $\nu_E \simeq 2\nu_p$

ROZPTYL POD MALÝMI ÚHLY

pro $m_1 \ll m_2$, $\nu_E \ll \nu_p$
$v_1' \simeq v_1$
coulombické srážky s malým úhlem
rozptylu $\chi \simeq 2 b_{90}/b$

výsledek sekvence srážek
- sekvence náhodných rotací $\vec{v}$



$$\overline{(\vec{\chi}_0 + \vec{\chi}_1)^2} = \overline{\chi_0^2} + \overline{\chi_1^2} + \overline{2\cos\varphi_{01}\chi_0\chi_1}$$

$$= \overline{\chi_0^2} + \overline{\chi_1^2} + 2\, \underbrace{\overline{\cos\varphi_{01}}}_{0} \cdot \overline{\chi_0 \chi_1}$$

$$= \overline{\chi_0^2} + \overline{\chi_1^2}$$

$$\overline{\Delta\alpha^2} = \sum \overline{\chi^2} = \left| \begin{matrix} \text{na vzdálenost} \\ L \end{matrix} \right| = L n_2 \int_{b_{min}}^{b_{max}} \chi^2\, 2\pi b\, db$$

$$= L n_2\, 8\pi b_{90}^2 \ln \Lambda_c$$

na jak dlouho dojde k výchylce $\overline{\Delta\alpha^2} = 1$?

$$1 = L n_2 \underbrace{8\pi b_{90}^2 \ln \Lambda_c}_{\sigma_\Sigma \text{ pro } \overline{\Delta\alpha^2} = 1}$$

$\sigma_\Sigma = 2\sigma_p$ $(m_1 \ll m_2)$

srovnejme s $\sigma_{90} = \pi b_{90}^2$

$$\to \sigma_\Sigma = \underbrace{8 \ln \Lambda}_{\sim \text{ desítky}} \sigma_{90}$$