Note for electron-positron plasma

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I. ENERGY DENSITY RATIO BETWEEN ELECTRON/POSITRON AND BARYONS

Considering the energy density between nonrealtivistc $e^{\pm}$ and baryon, it can be written as

$$\frac{\rho_e+\rho_{\bar{e}}}{\rho_p+\rho_\alpha}=\frac{m_e(n_e+n_{\bar{e}})}{m_pn_p+m_\alpha n_\alpha}=\frac{m_e(n_e+n_{\bar{e}})}{n_B(m_pX_p+m_\alpha X_\alpha)}=\left(\frac{n_e+n_{\bar{e}}}{n_B}\right)\left(\frac{m_e}{m_pX_p+m_\alpha X_\alpha}\right) \tag{1}$$

where from particle data group $X_p=n_p/n_B$ and $X_\alpha=n_\alpha/n_B$ are given by

$$X_p=0.878,\qquad X_\alpha=0.245 \tag{2}$$

and masses are given by

$$m_e=0.511\,\mathrm{MeV},\qquad m_p=938.272\,\mathrm{MeV},\qquad m_\alpha=2m_p+2m_n=3755.67\,\mathrm{MeV} \tag{3}$$

In Fig.(1) we plot the energy density ratio Eq.(1) as a function of temperature $10\,\mathrm{keV}\leqslant T\leqslant 200\,\mathrm{keV}$. It shows that the energy density of electron and positron is dominated until $T=30.2$ keV, i.e., we have $\rho_e\gg\rho_B$. After $T=30.2$ keV, we have $\rho_e\ll\rho_B$ and ratio becomes constant when is around $T=20$keV because of the positron annihilation and charge neutrality.

To estimate the energy density ratio for the low temperature limit $T\ll 20$ keV, we can consider that all positrons disappear because of the annihilation. Then the energy density ratio becomes:

$$\frac{\rho_e+\rho_{\bar{e}}}{\rho_p+\rho_\alpha}=\left(\frac{n_e}{n_B}\right)\left(\frac{m_e}{m_pX_p+m_\alpha X_\alpha}\right)=\left(\frac{n_p}{n_B}\right)\left(\frac{m_e}{m_pX_p+m_\alpha X_\alpha}\right) \tag{4}$$

$$=X_p\left(\frac{m_e}{m_pX_p+m_\alpha X_\alpha}\right)\approx 2.5\times10^{-4} \tag{5}$$

where we use the charge neutrality $n_e=n_p$ to replace the electron density by proton density and we can calculate the ratio by giving the X_p and X_α from observation.

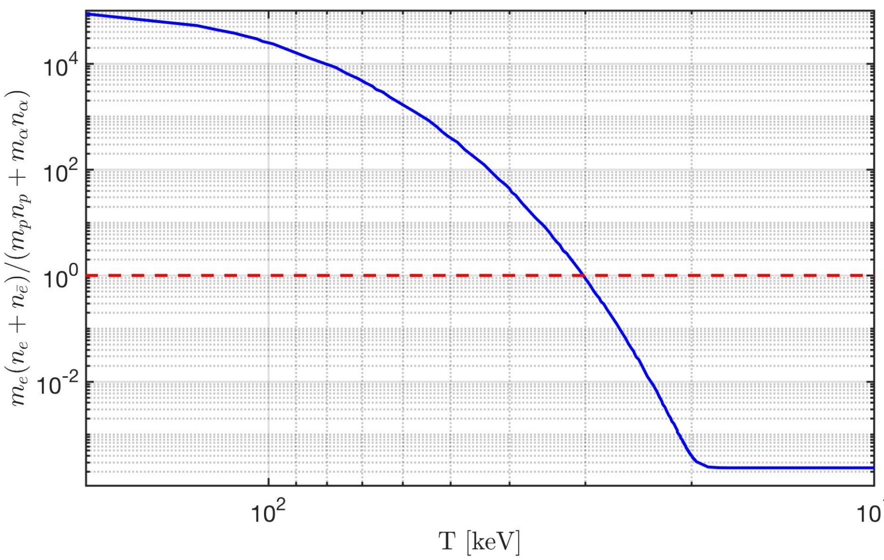

FIG. 1: The energy density ratio Eq.(1) as a function of temperature $10\,\mathrm{keV} \leqslant T \leqslant 200\,\mathrm{keV}$. It shows that the energy density of electron and positron is dominated until $T = 30.2$ keV, i.e., we have $\rho_e \gg \rho_B$.