beam-gas scattering

two effects: (1) lifetime limited by nuclear interactions & proton loss

$$\frac{1}{\tau} \approx nc\sigma_{nucl}$$

(2) emittance growth due to multiple Coulomb scattering

$$\frac{d\left(\gamma\varepsilon_{x,y}\right)}{dt} = \beta_{x,y}\gamma\left(\frac{13.6\,\mathrm{MeV}}{\beta c\gamma}\right)^2 \frac{cnm_{gas}}{X_0}$$

Table 5.5: Nuclear scattering cross sections, the implied maximum allowed densities, and the accompanying emittance growth at injection for various gas species.

molecule	σ [barn] at 7 TeV	n [m^{-3}] at 7 TeV for $\tau_{\mathrm{nucl}} = 100$ h	equiv. gas pressure at 300 K [ntorr]	τ_ϵ [h] at 450 GeV for $\tau_{\mathrm{nucl}} = 100$ h
H_2	0.078	1.2×10^{15}	37.8	17.0
He	0.133	6.9×10^{14}	21.7	12.5
CH_4	0.511	1.8×10^{14}	5.6	7.6
H_2O	0.510	1.8×10^{14}	5.7	9.5
CO	0.751	1.2×10^{14}	3.8	7.5
CO_2	1.171	7.9×10^{13}	2.5	5.0

from LHC design report

also calculated by B. Jeanneret

gas density for lifetime of 100 h (at inj. or top)

corresponding emittance growth time at injection

open issues / plans: (1) heat load & cryogenic limit

(2) effect of elastic nuclear interactions on emittance

(3) halo generation & tails using Lebedev/Nagaitsev approach