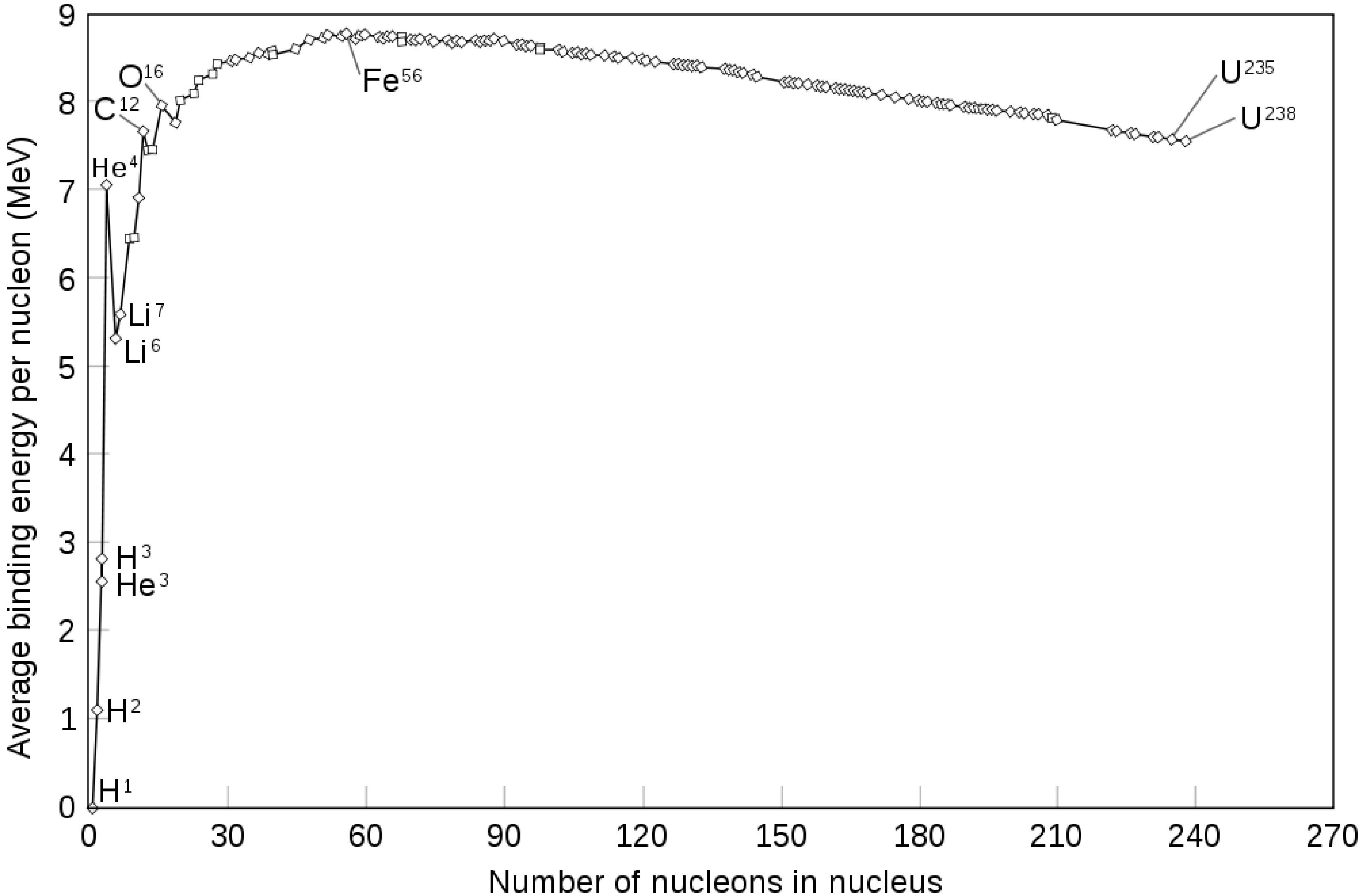
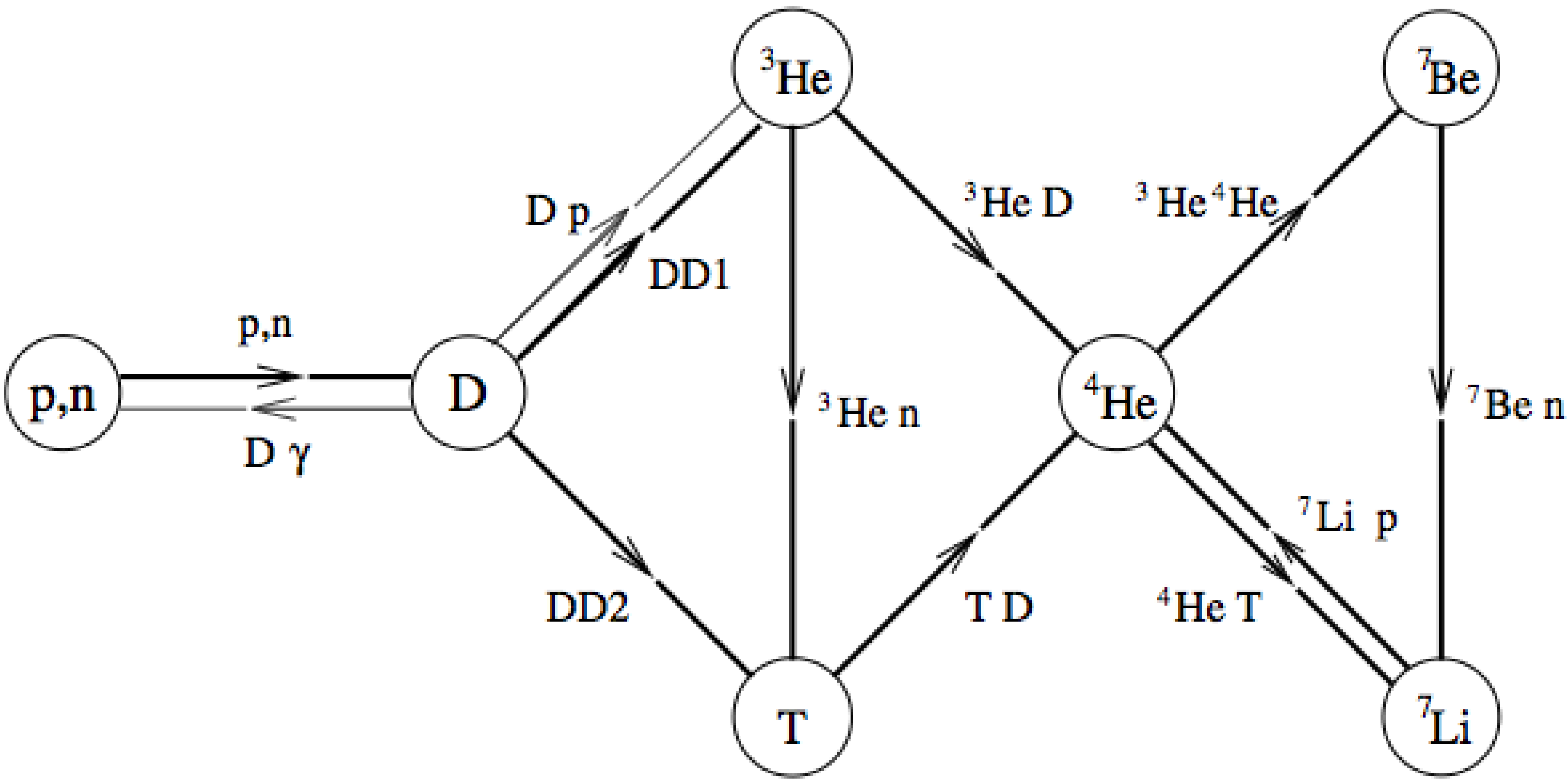
Binding energy



- To produce chemical elements one needs to pass through “deuterium bottleneck” $p + n \leftrightarrow D + \gamma$

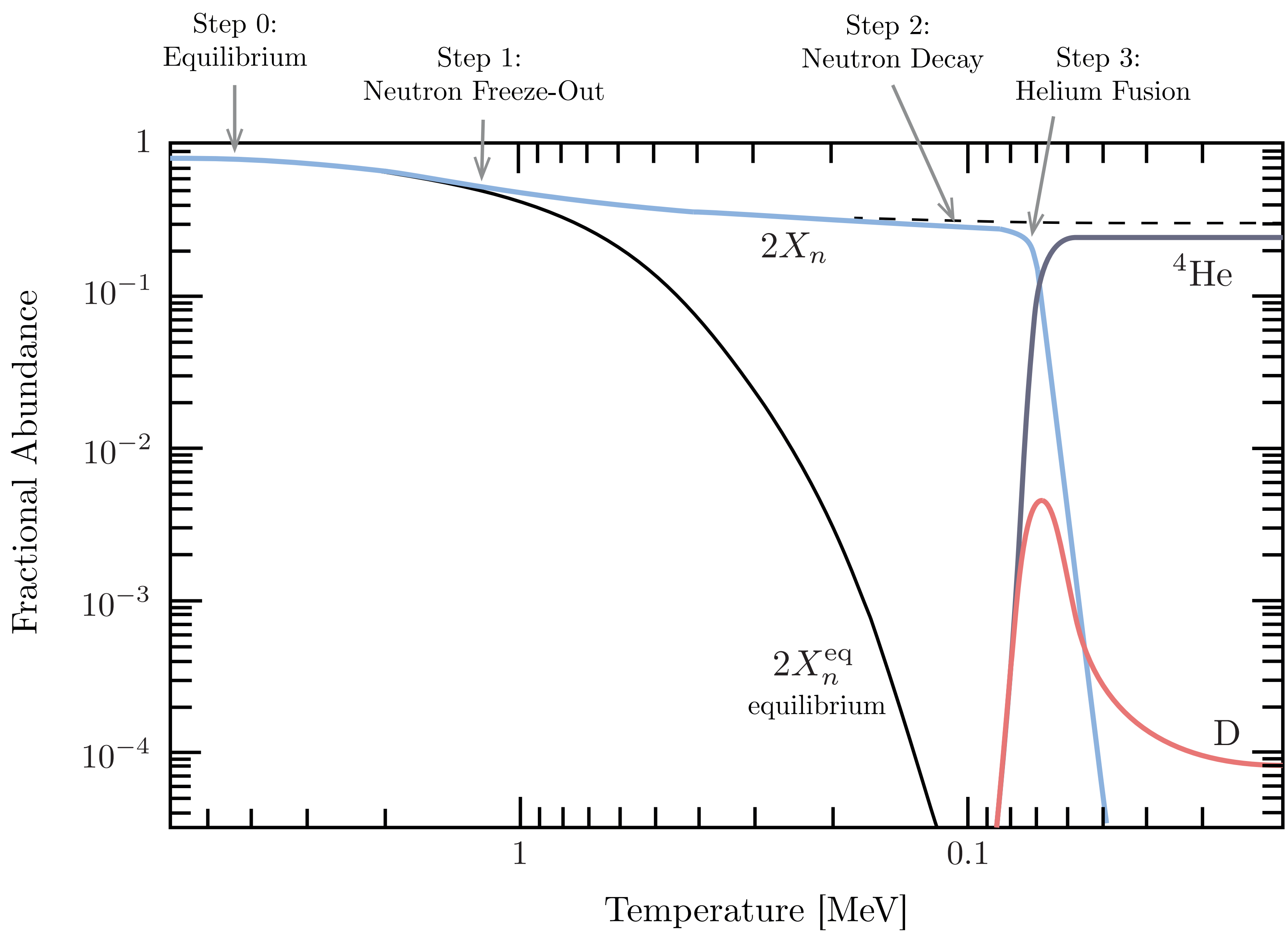


- We saw that for each baryon there were $\sim 10^{10}$ photons.
- Binding energy of deuterium is $E_D = 2.2$ MeV (or $T_D = 2.5\times 10^{10}$ K).
- At $T = E_D$ 85% of all photons have $E > T_D$ $\Rightarrow$ any deuterim nucleus will be quickly photo-disassociated via $D + \gamma \to p + n$
- Production of deuterium becomes efficient when temperature drops so that the number of photons with $E > E_D$ will be $\sim 10^{-10}$

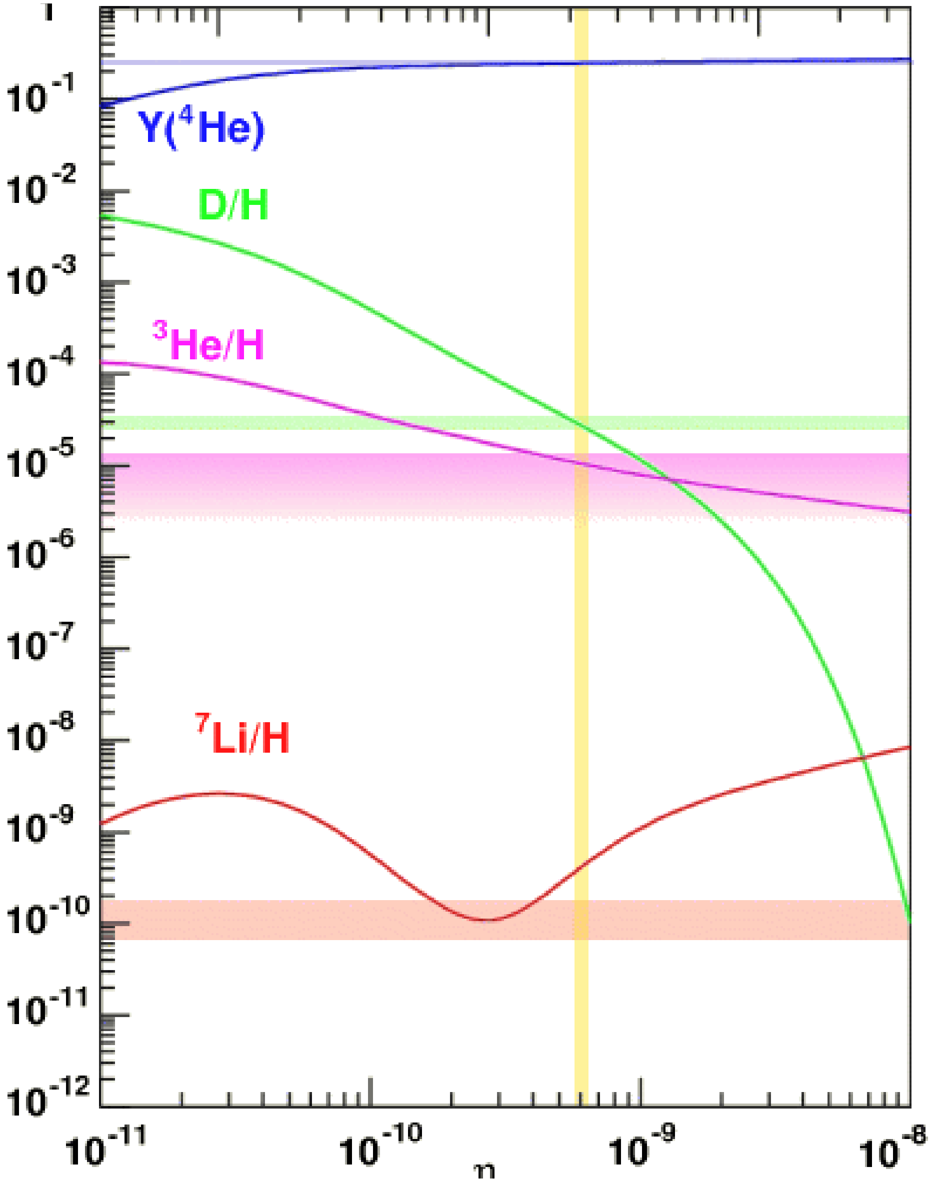
$$\frac{n_\gamma(E > E_D)}{n_{\gamma_{tot}}} \sim \eta_B \Longrightarrow \eta_B \left(\frac{2.5 T_{BBN}}{m_p}\right)^{\frac{3}{2}} e^{\frac{E_D}{T_{BBN}}} \sim 1 \qquad (1)$$

$$T_{BBN} \approx 70\,\mathrm{keV} \quad \text{and} \quad t_{BBN} = \frac{M^*_{Pl}}{2T^2_{BBN}} \approx 120s$$

Neutron abundance



BBN predictions confirmed



- Curves – theoretical predictions of Big Bang nucleosynthesis
- Horizontal stripes – values that follow from observations.
- Golden stripe – measured value of η from CMB observations!

Dependence on number of neutrinos

N_ν	g_*	$\frac{n_n}{n_p}$	Y_p
1.	2.45421	0.148321	0.258
2.	2.90843	0.15189	0.263
3.	3.36264	0.15477	0.268
4.	3.81686	0.157159	0.271
5.	4.27107	0.159185	0.274
6.	4.72529	0.160931	0.277

Measurements of Y_p have error bars ± 0.008