

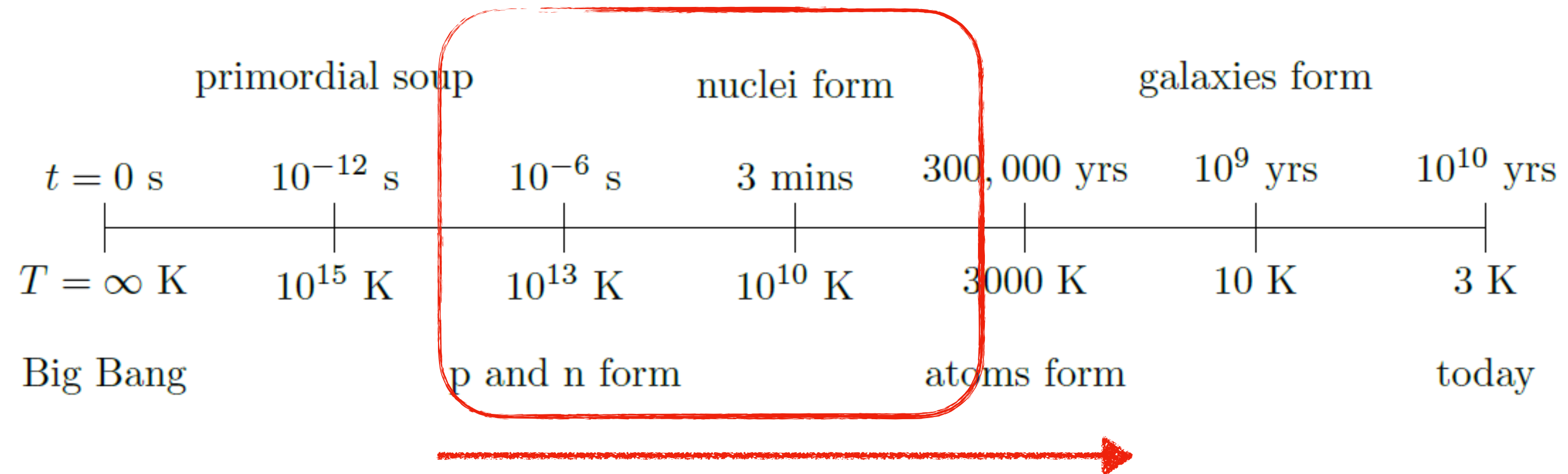
Early Dark Energy During Big Bang Nucleosynthesis

Based on 2407.03508

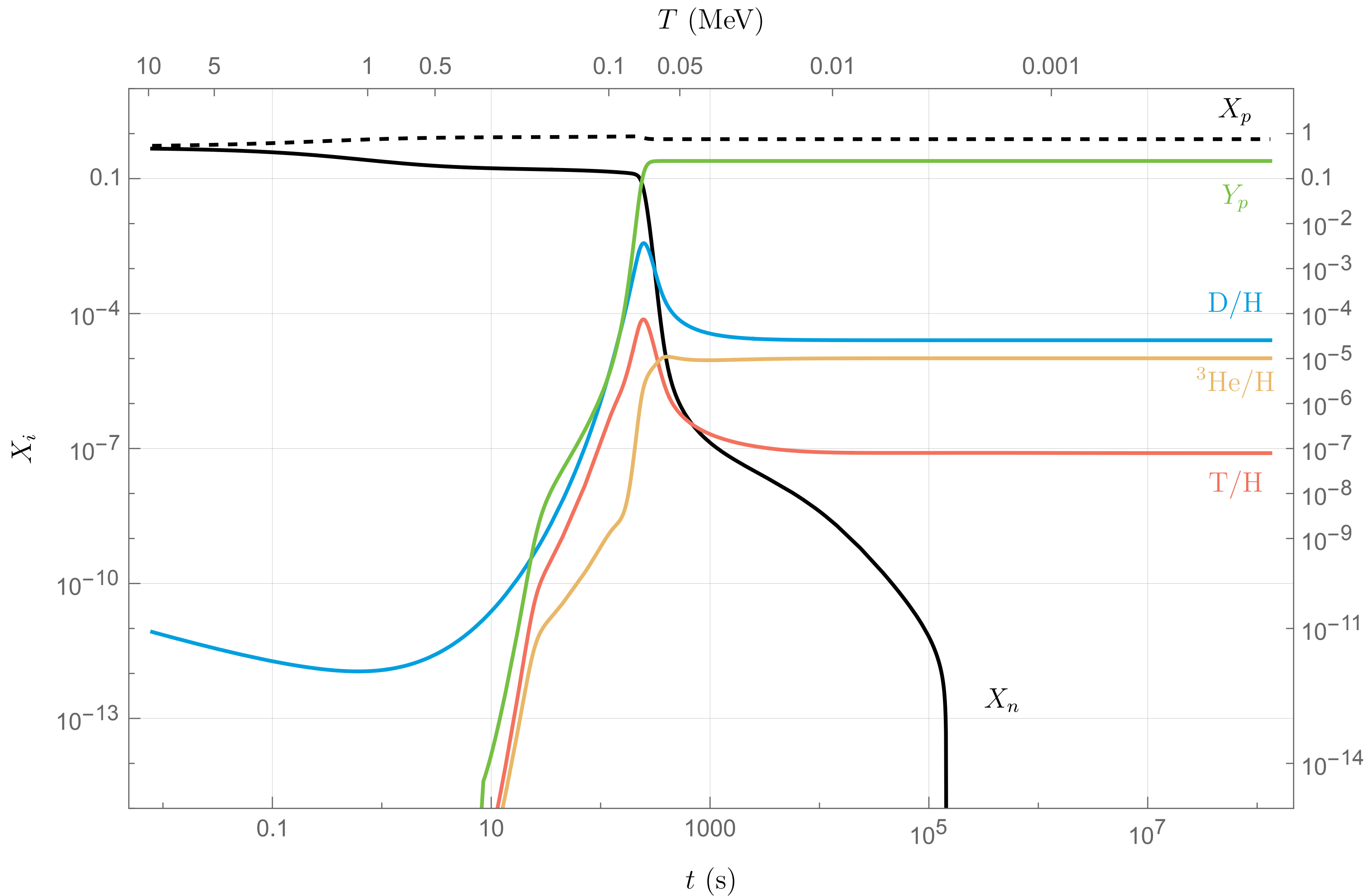
Dark Interactions 2024

Afif Omar (he/him), Oct 2024
aomar@triumf.ca

Standard Big Bang Nucleosynthesis



Standard Big Bang Nucleosynthesis



Galaxies form

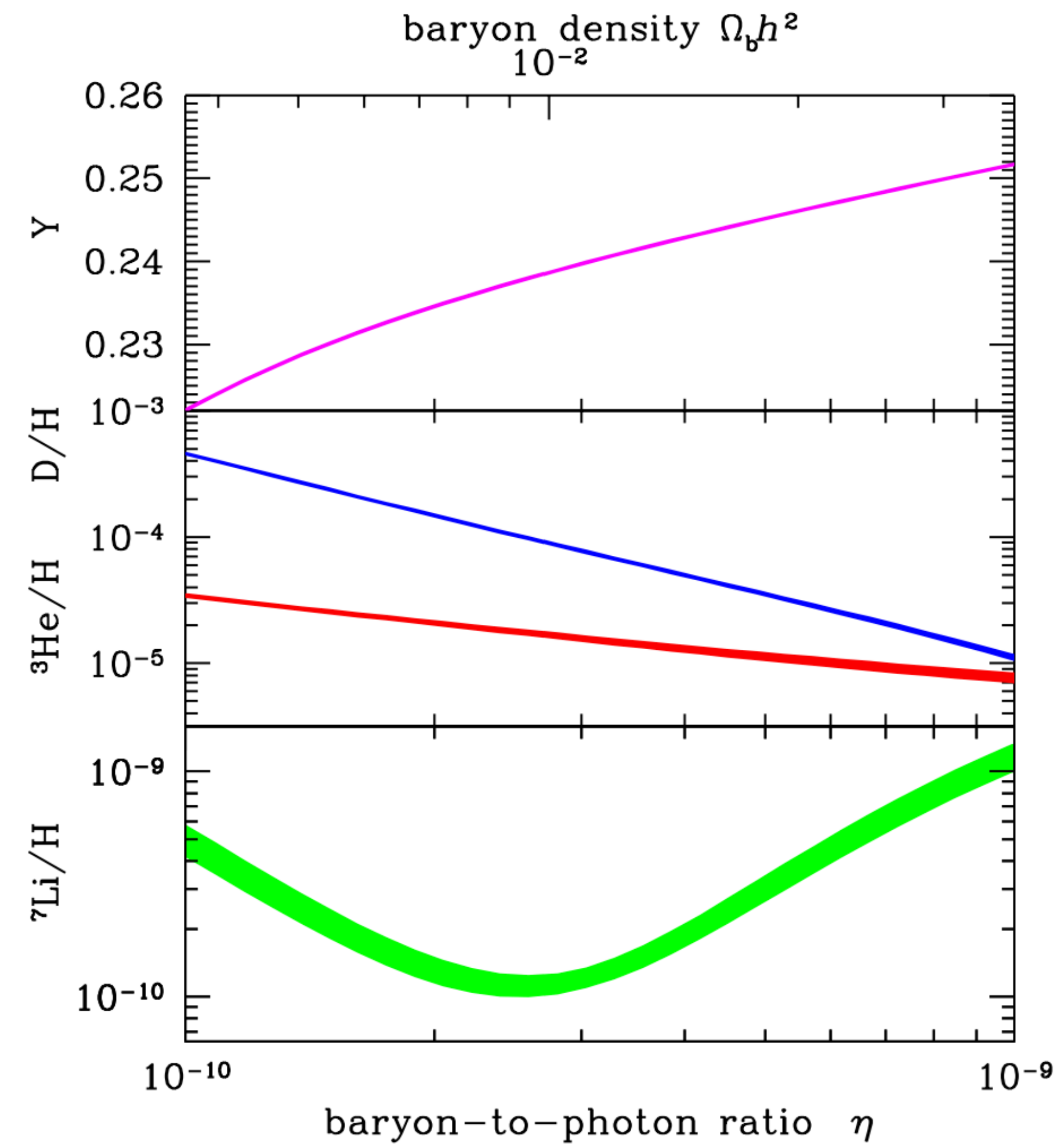
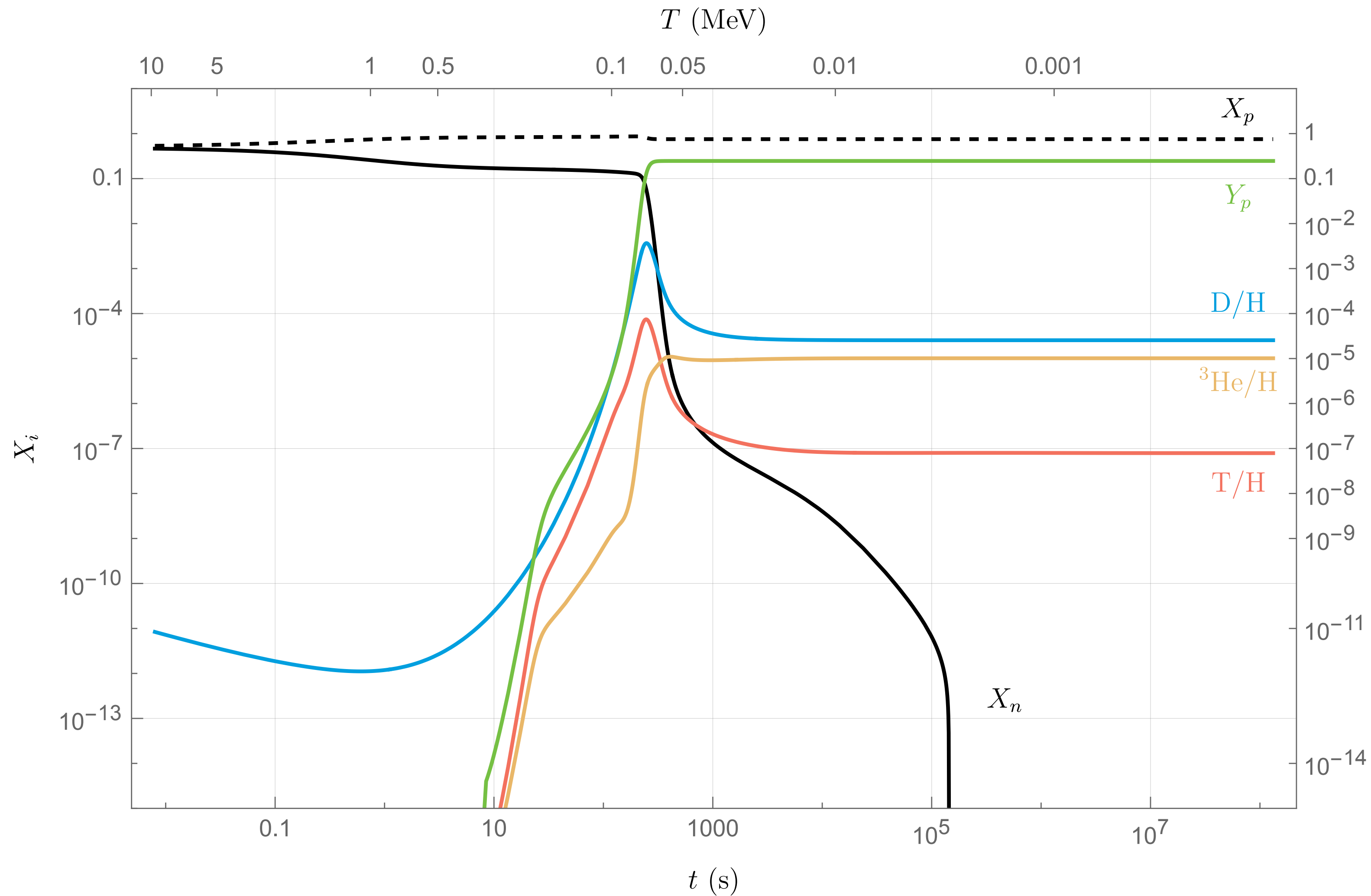
10^9 yrs 10^{10} yrs

10 K

3 K

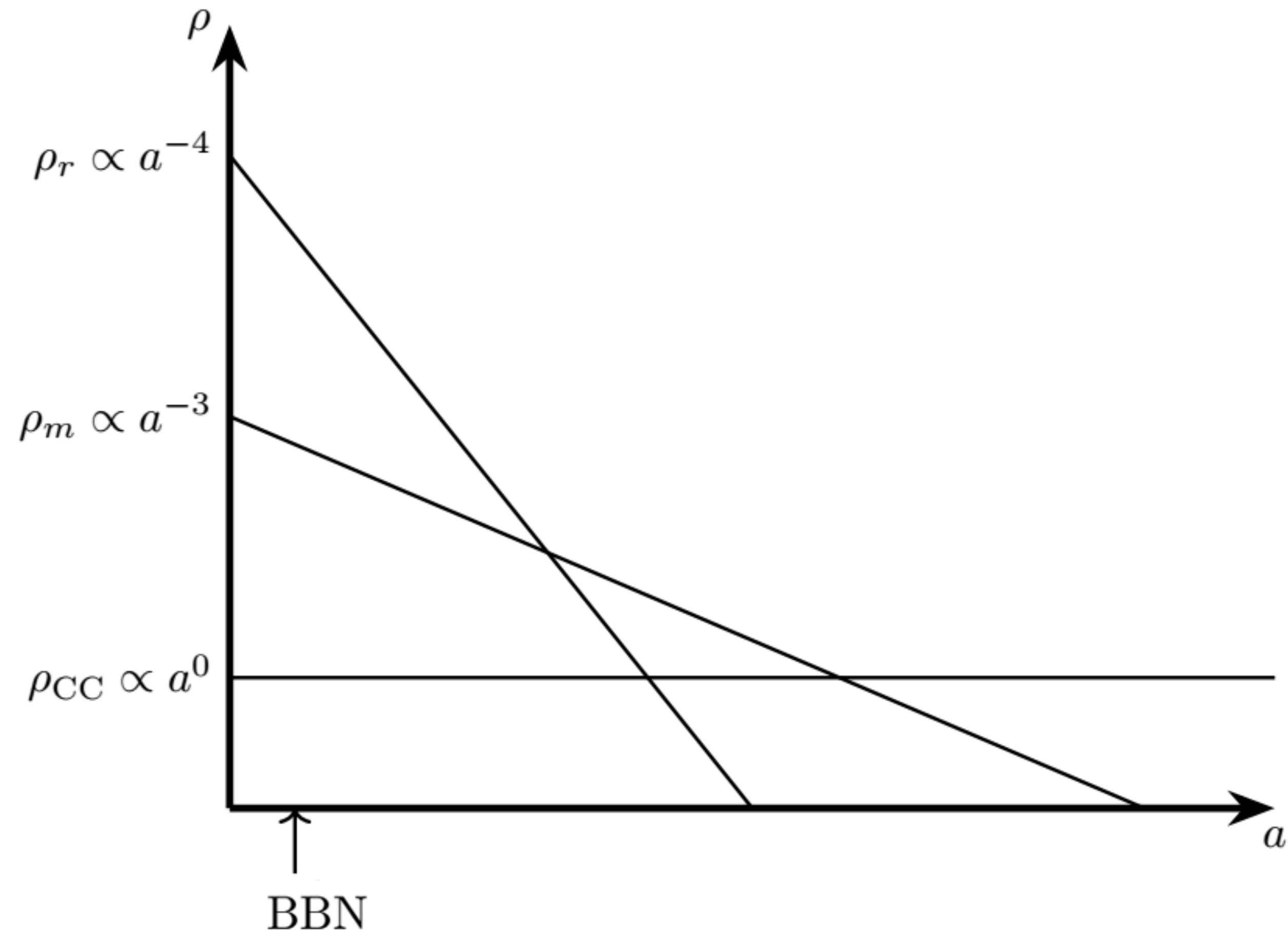
today

Standard Big Bang Nucleosynthesis

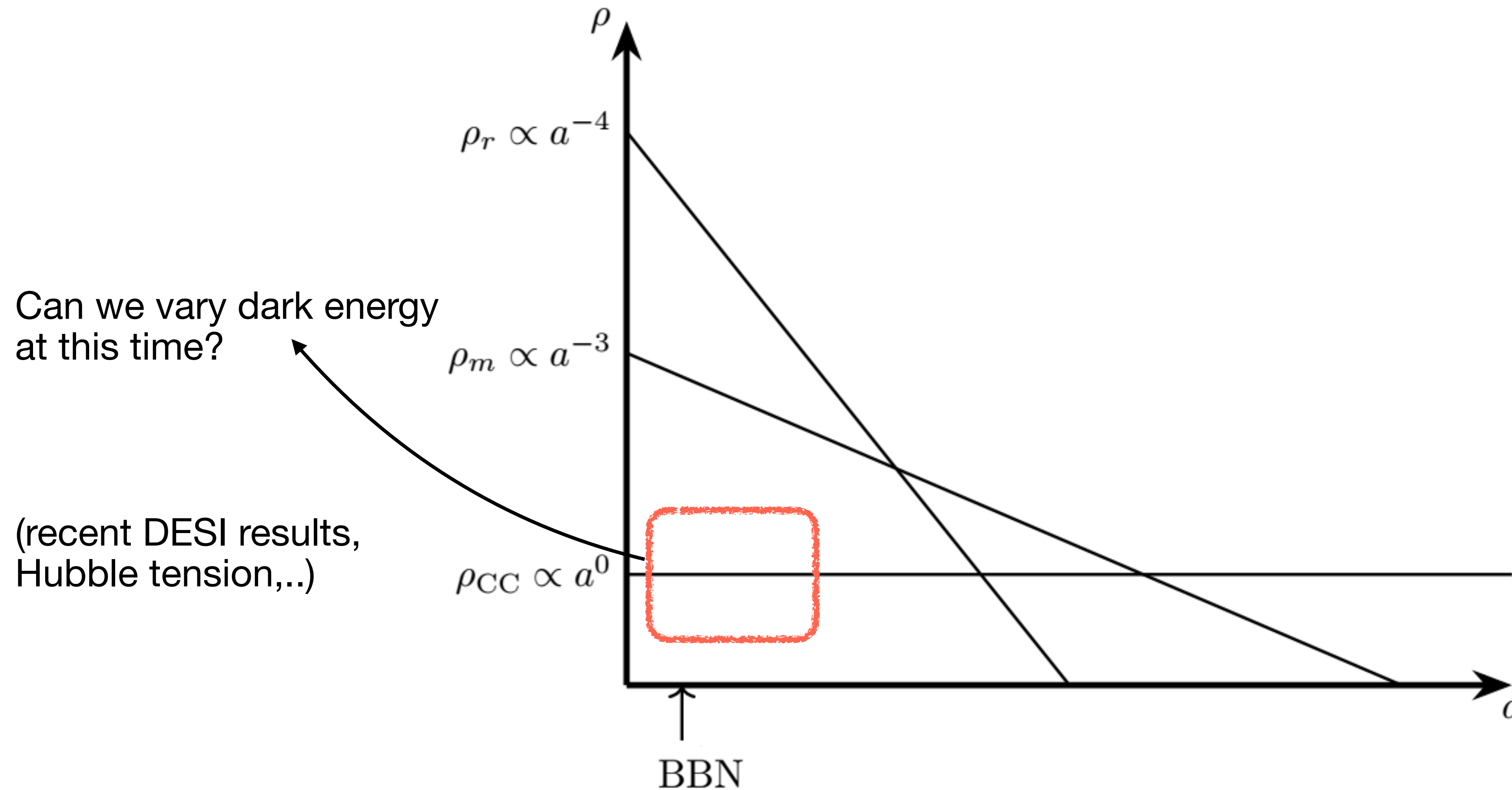


[Cyburt et al, 2016]

Introducing EDE

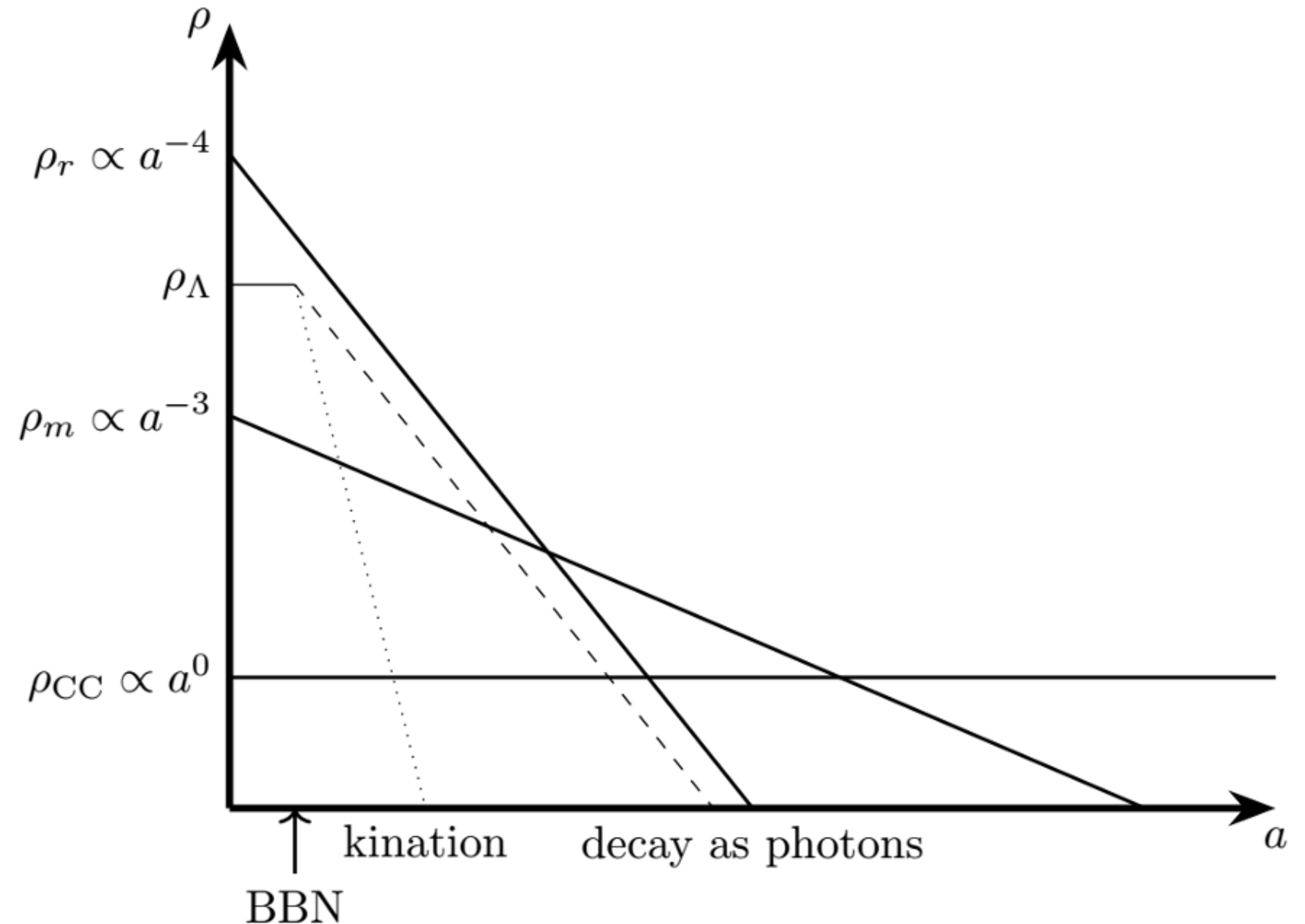


Introducing EDE

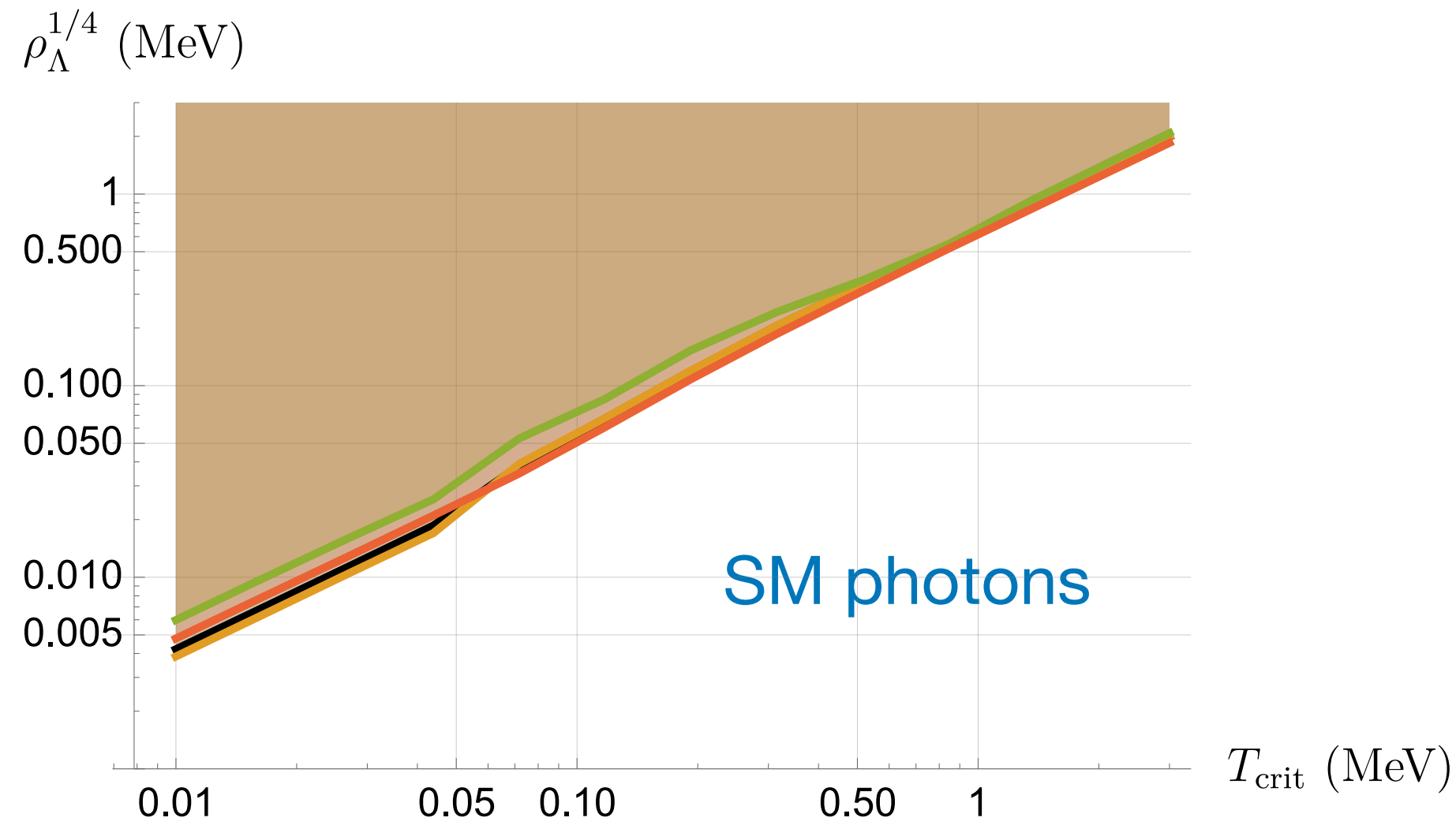


Introducing EDE

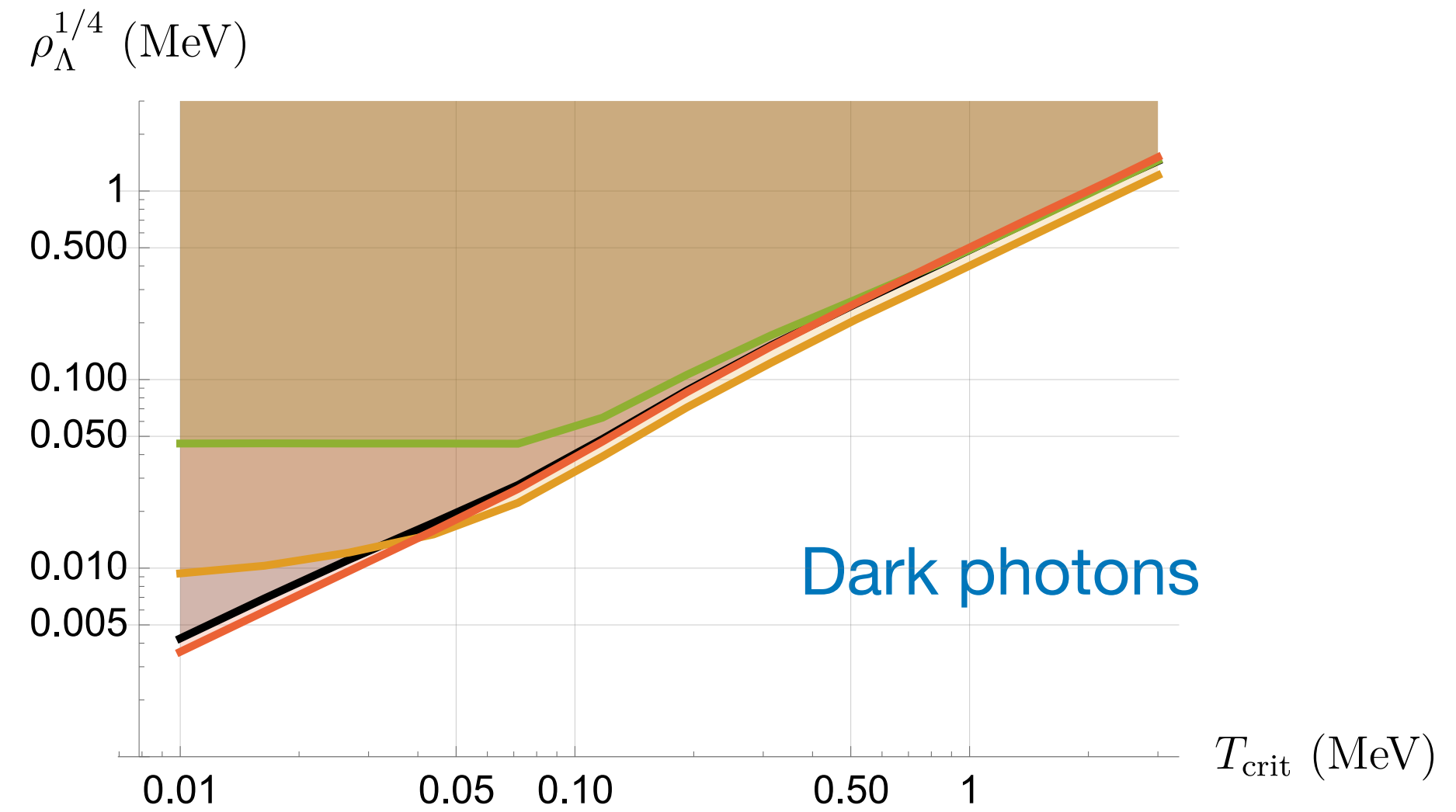
- The parameters of the theory are
 - The initial amount of EDE ρ_Λ
 - The temperature when it starts decaying T_{crit}
 - The type of decay mode (photons, dark radiation, or kination).



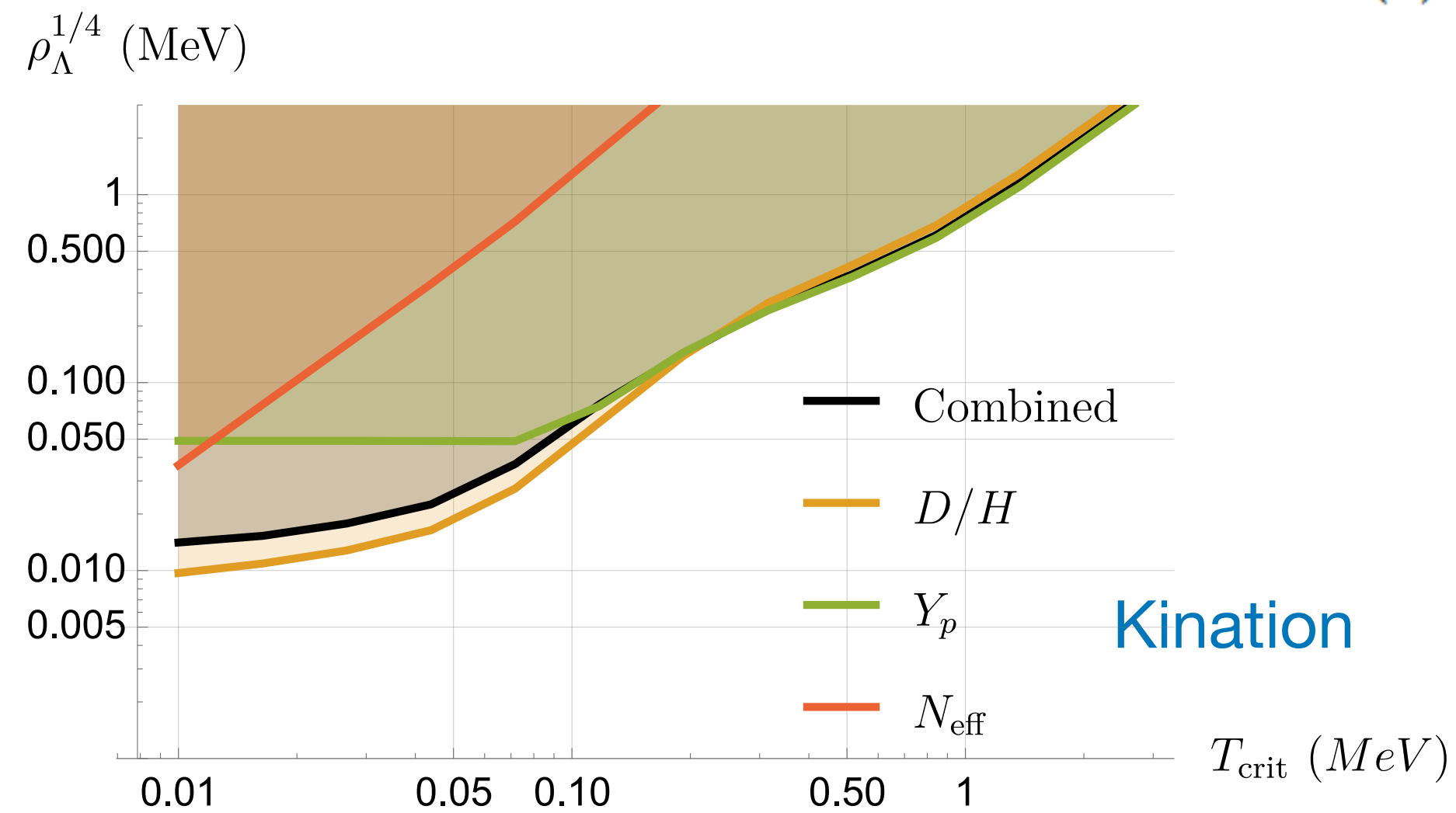
The EDE parameter space



(a)



(b)

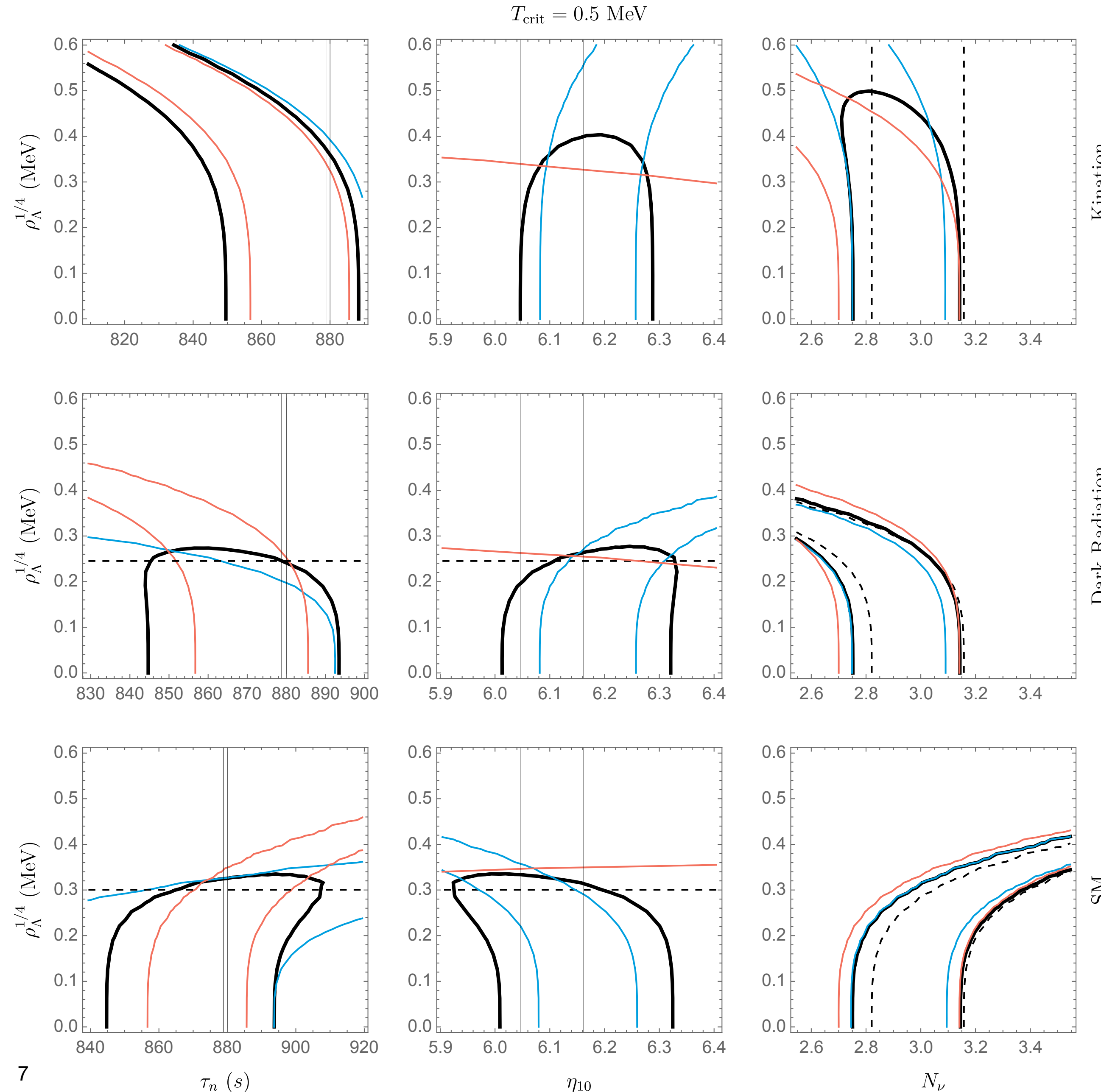


(c)

[McKeen, AO, 2407.03508]

Varying the other BBN parameters

$T_{\text{crit}} = 0.5 \text{ MeV}$

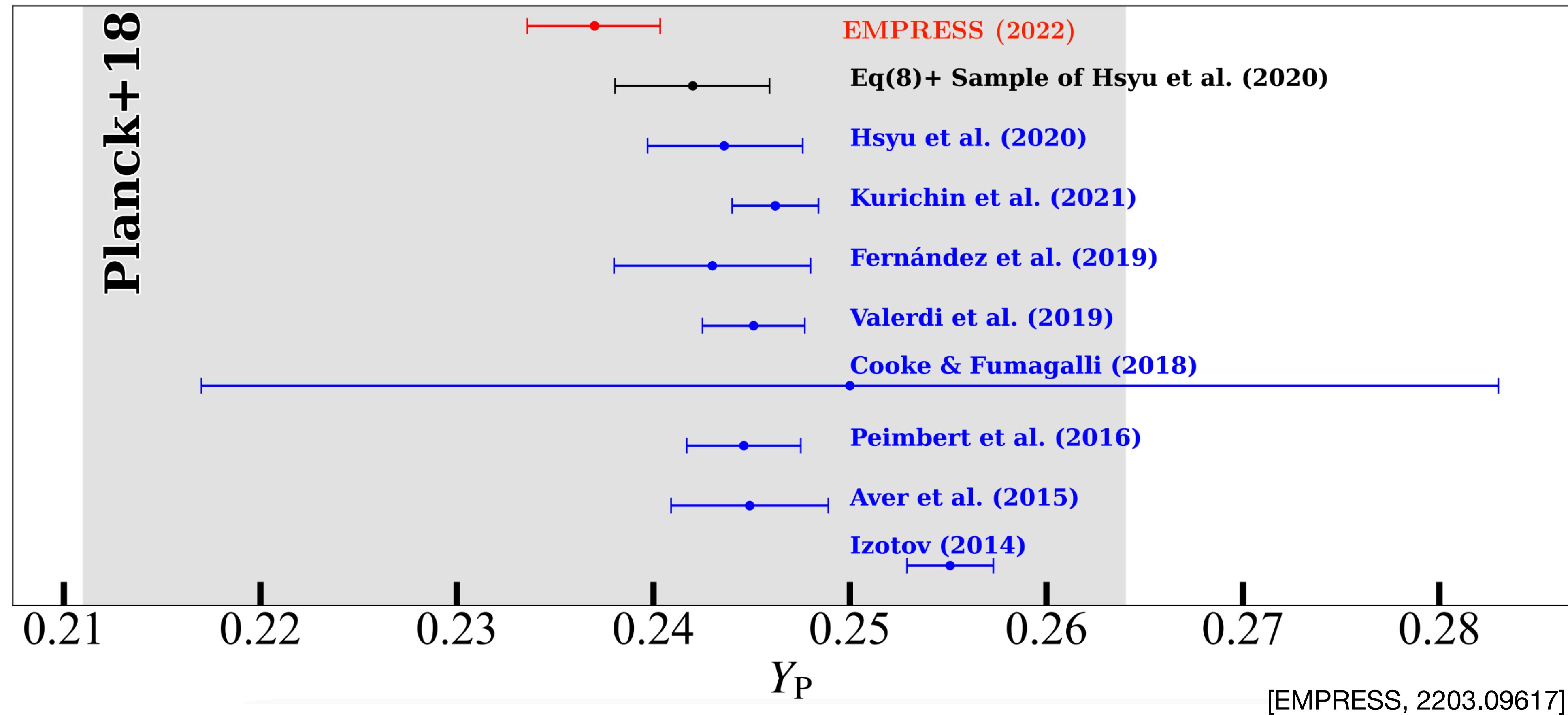


[McKeen, AO, 2407.03508]

Afif Omar - TRIUMF/UVic

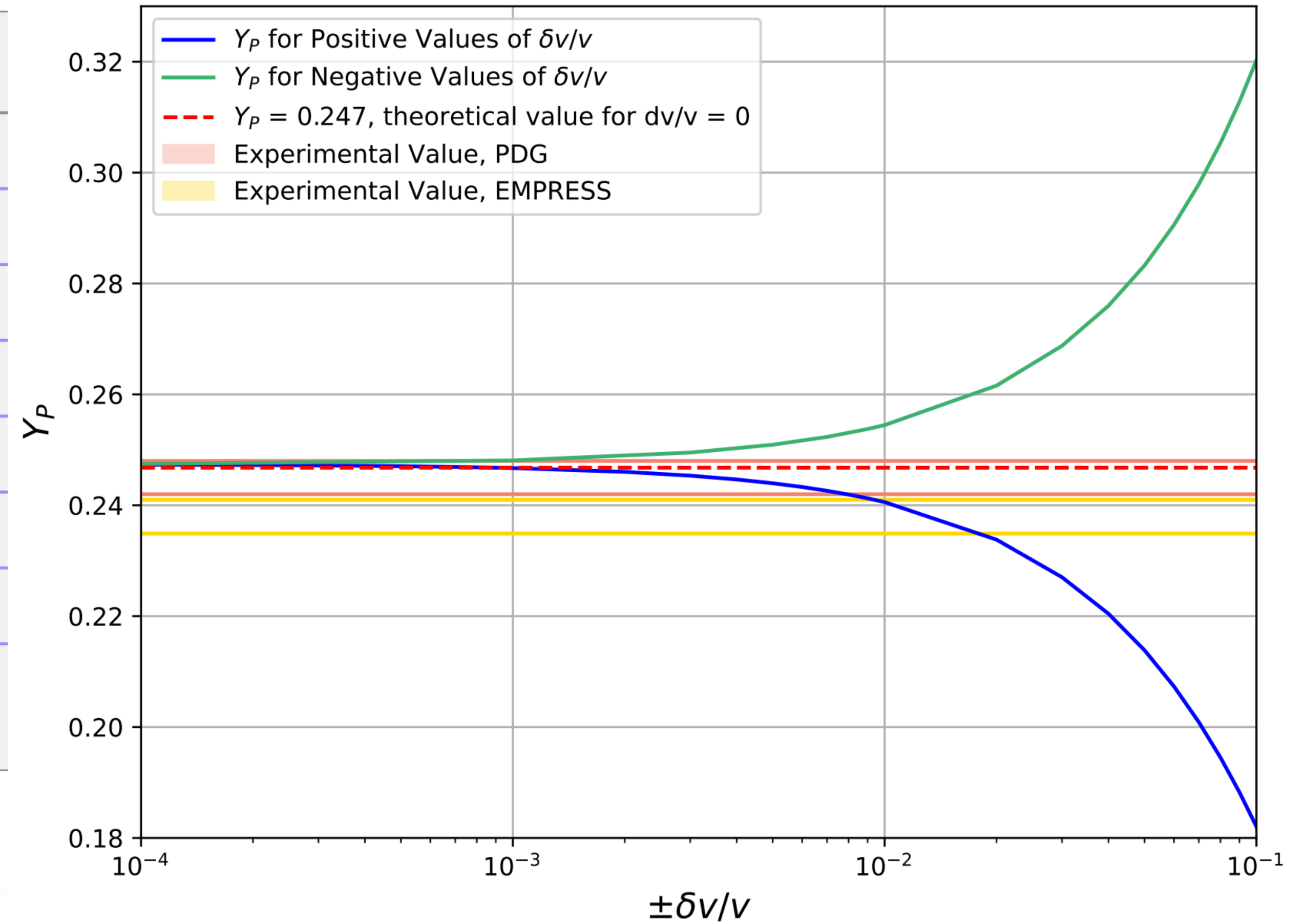
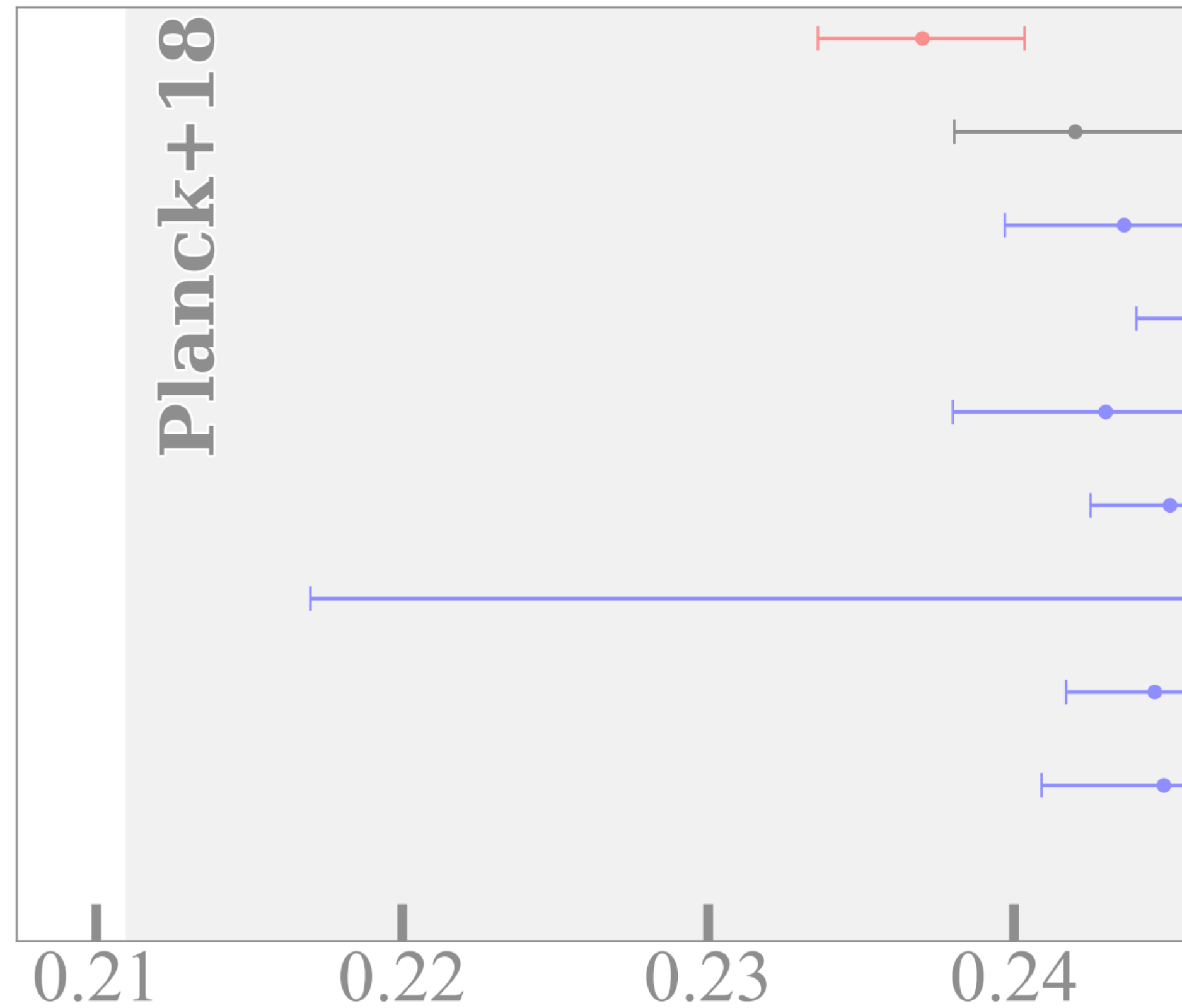
Lower primordial helium fraction?

Can this be explained by new physics?



Lower primordial helium fraction?

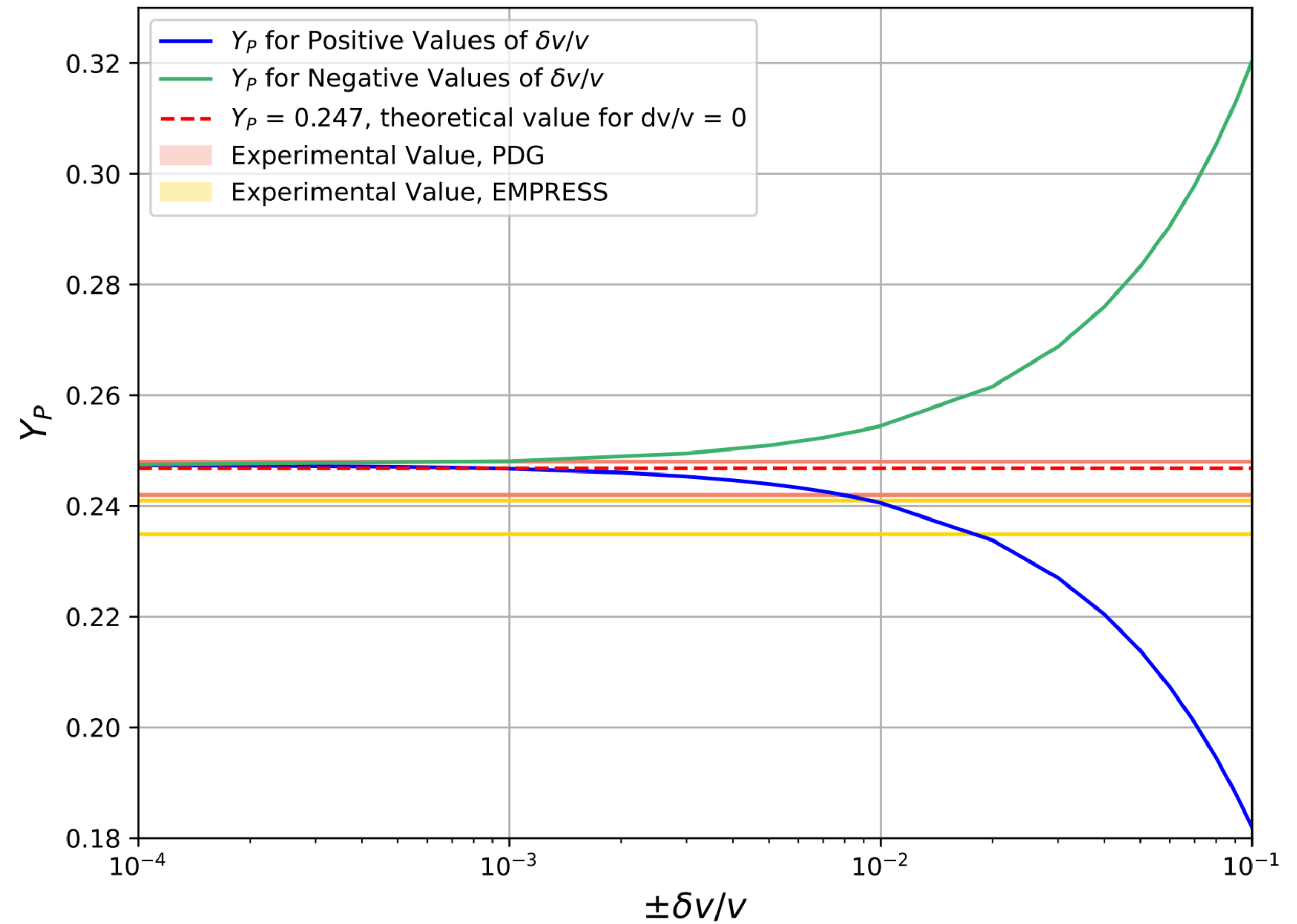
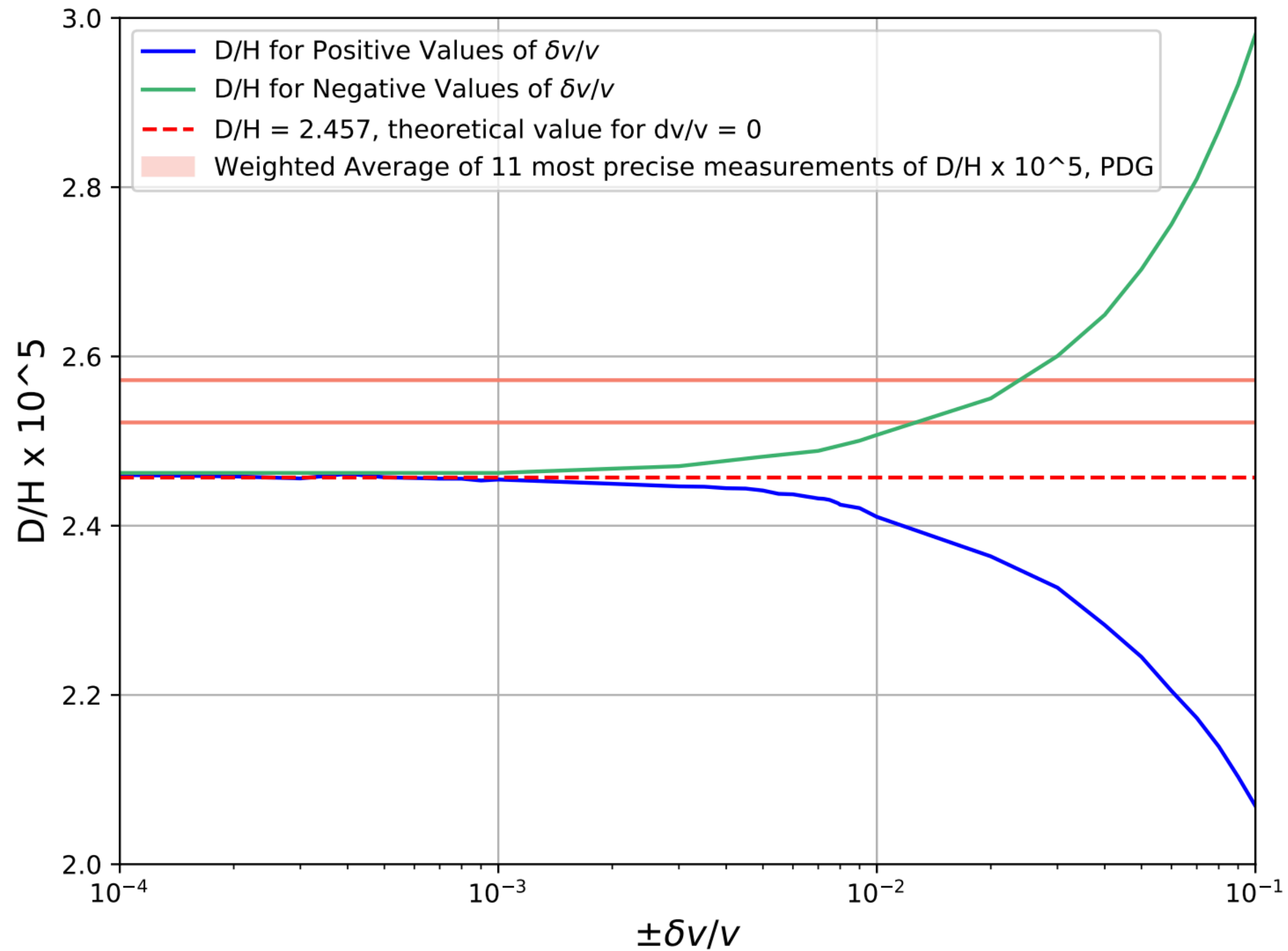
Can this be explained by new physics?



[Burns, Keus, Sher, and Tait , 2402.08626]

Lower primordial helium fraction?

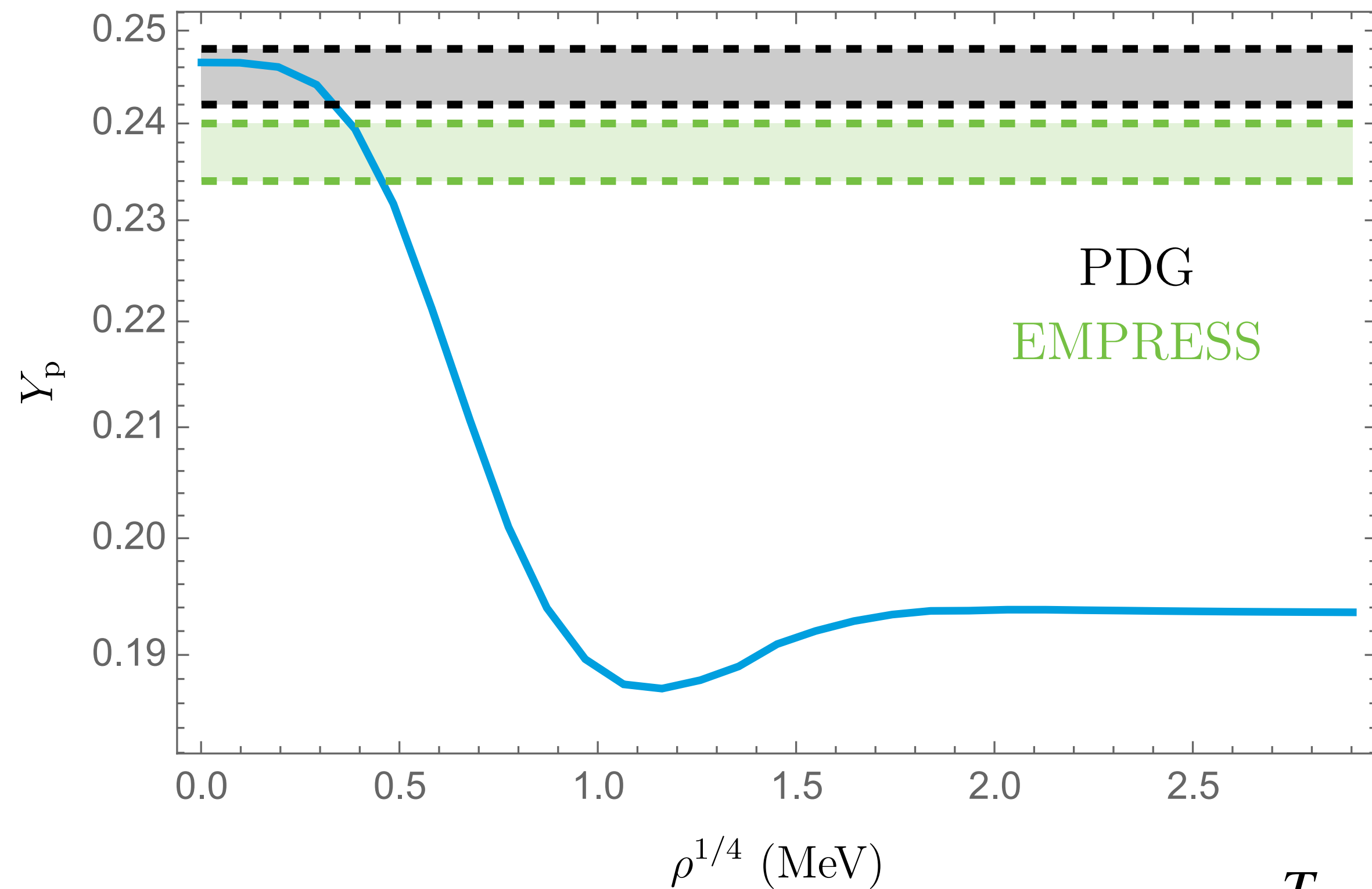
Can this be explained by new physics?



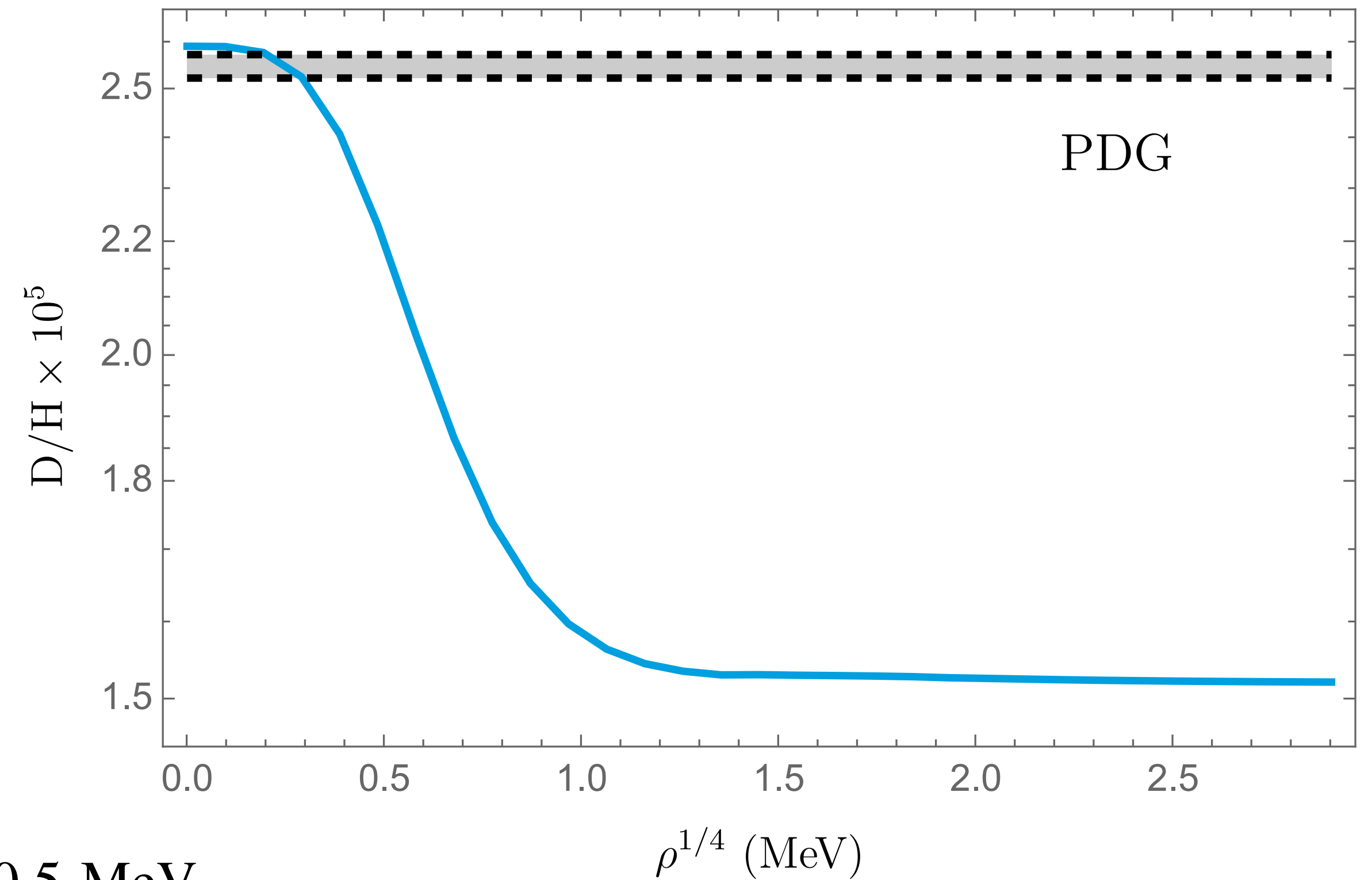
[Burns, Keus, Sher, and Tait , 2402.08626]

Lower primordial helium fraction?

Can EDE explain the EMPRESS results?



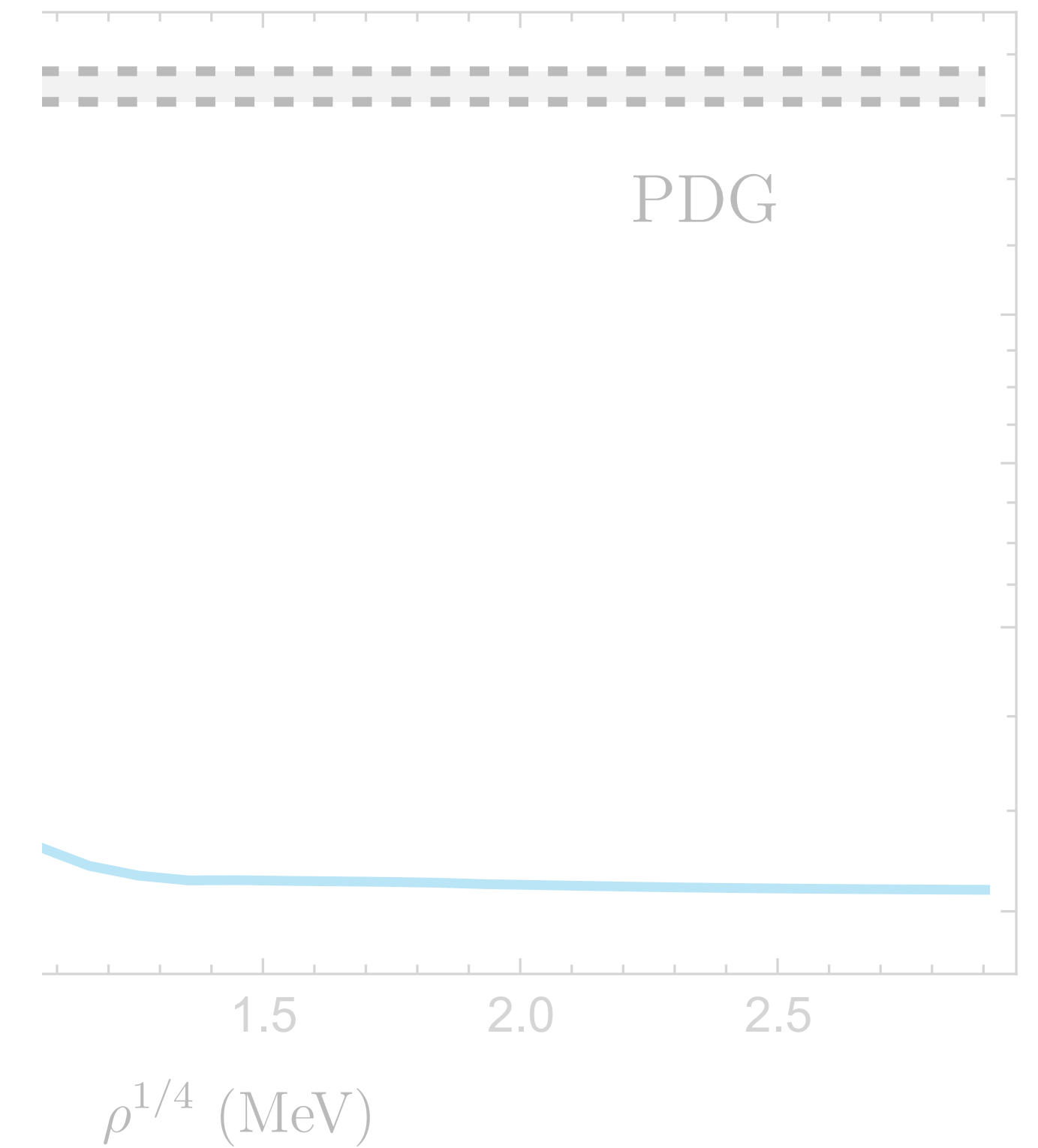
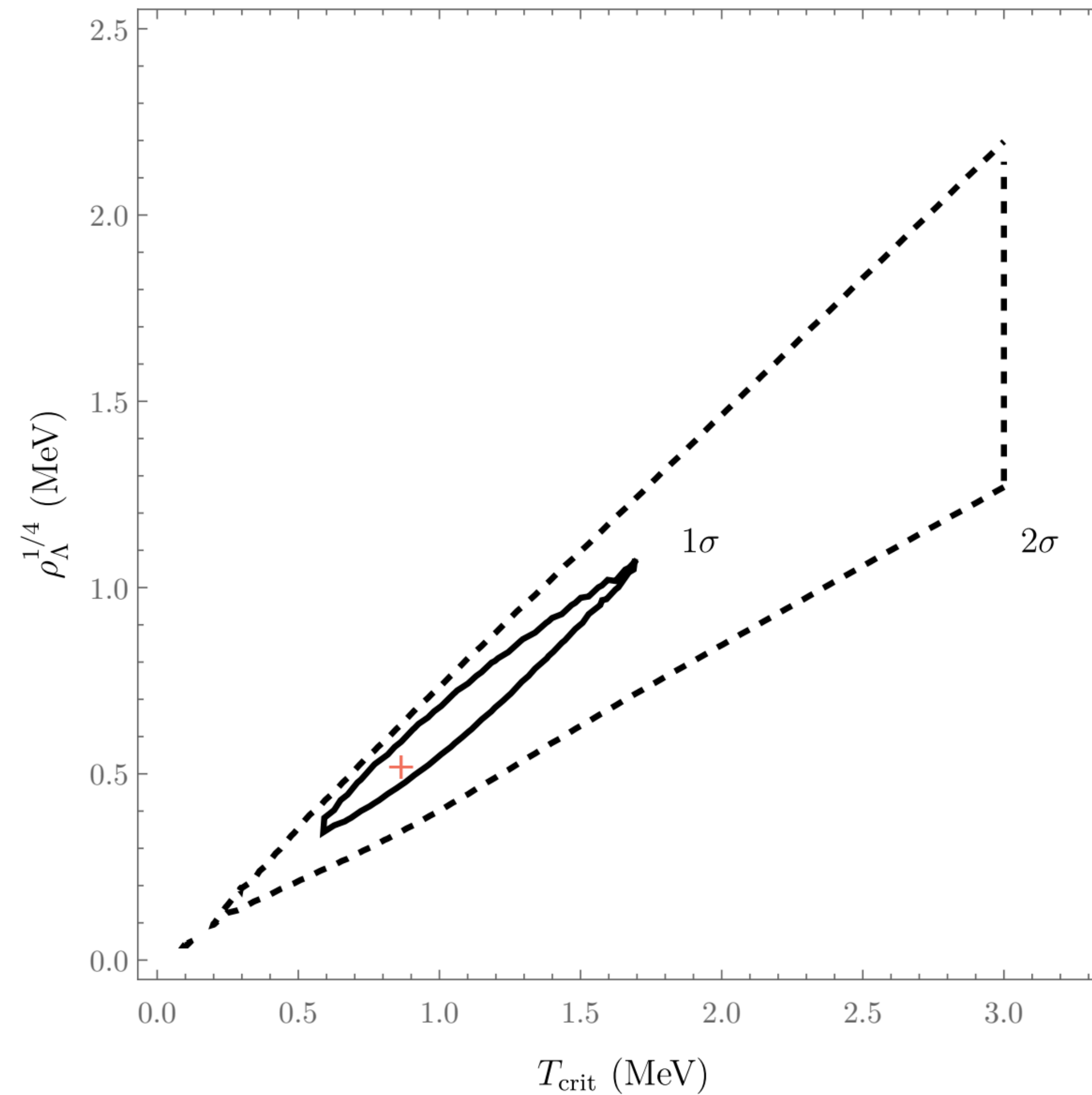
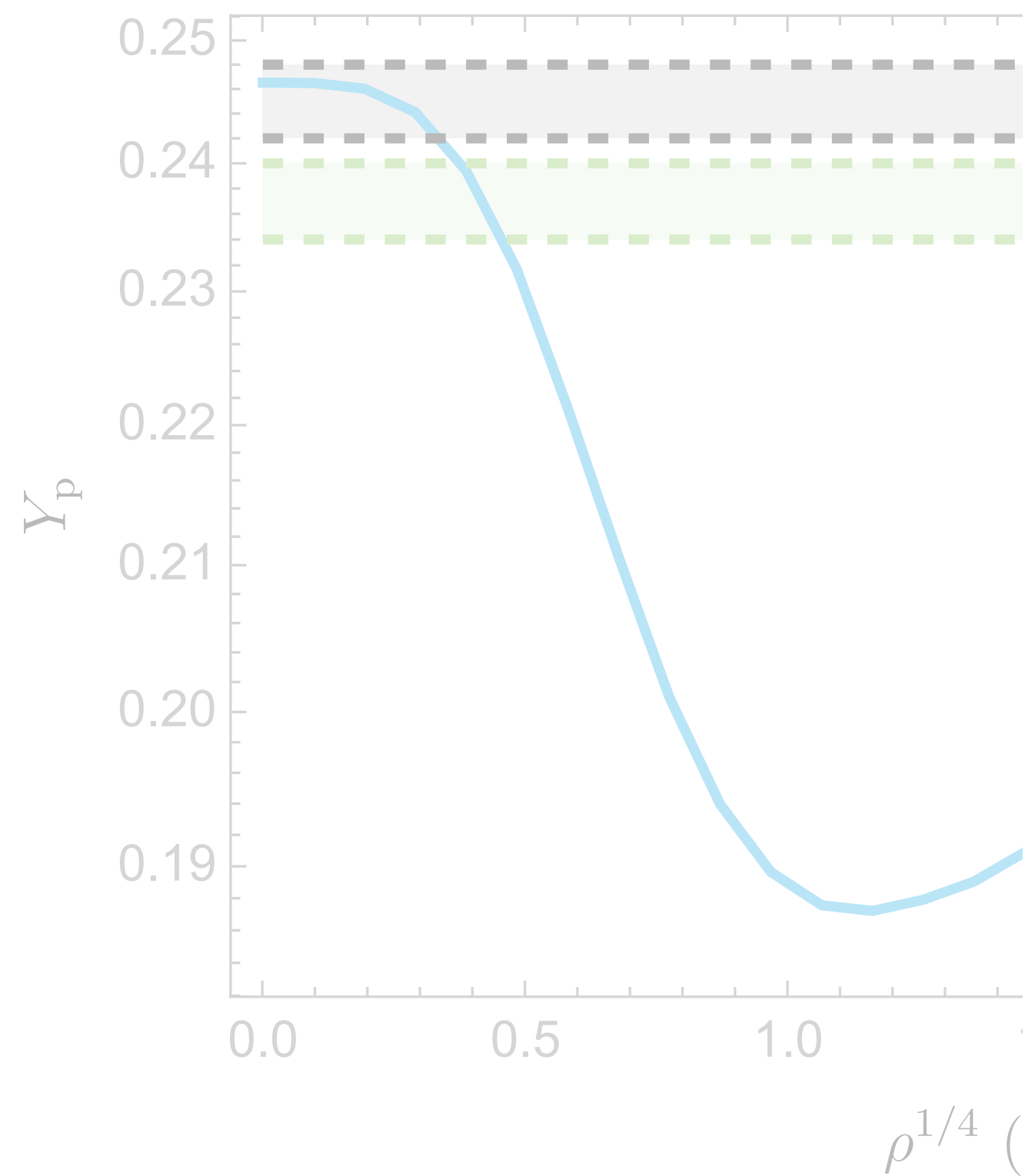
$T_{\text{crit}} = 0.5$ MeV



[McKeen, AO, 2407.03508]

Lower primordial helium fraction?

Can EDE explain the EMPRESS results?



[McKeen, AO, 2407.03508]

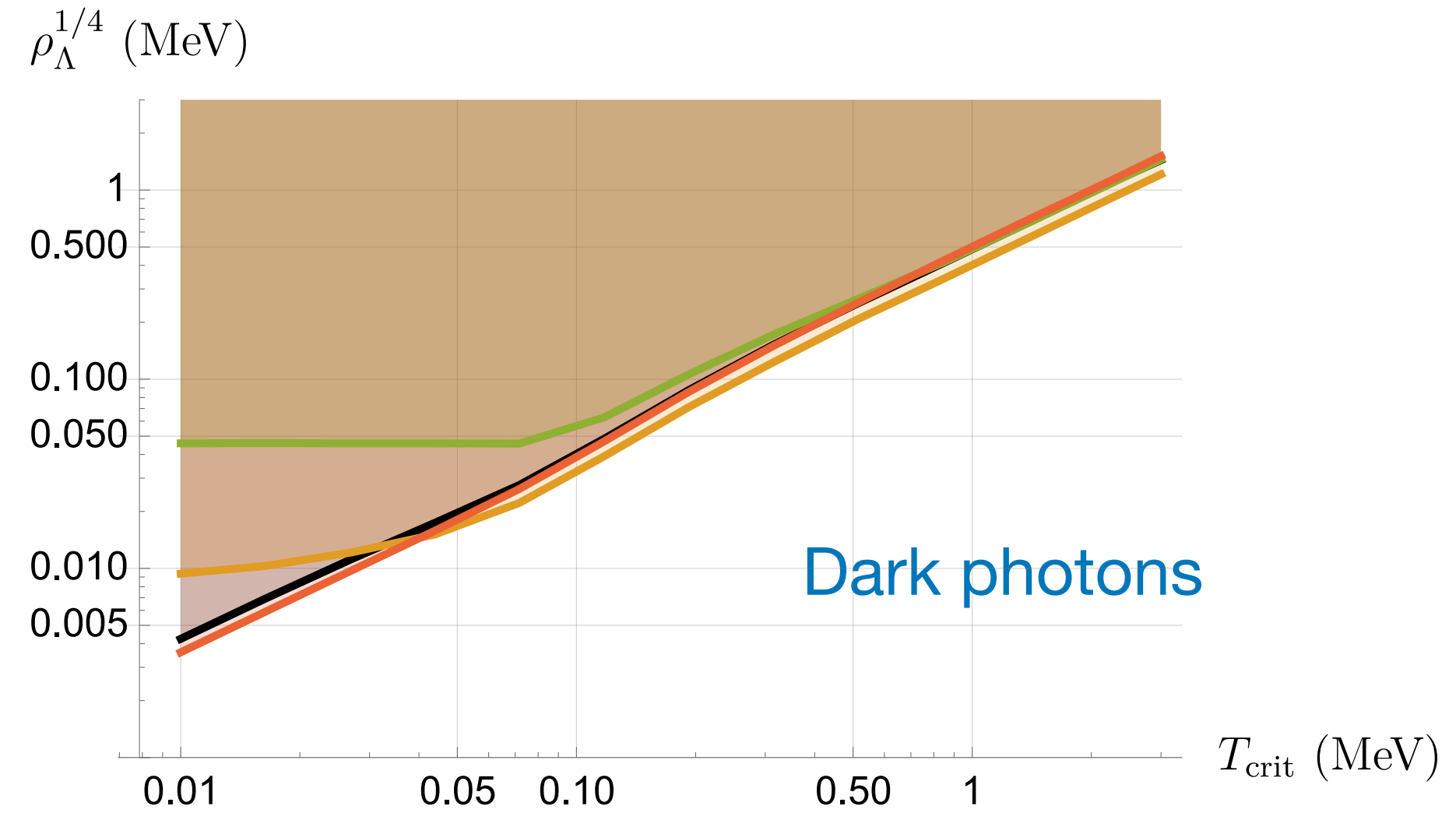
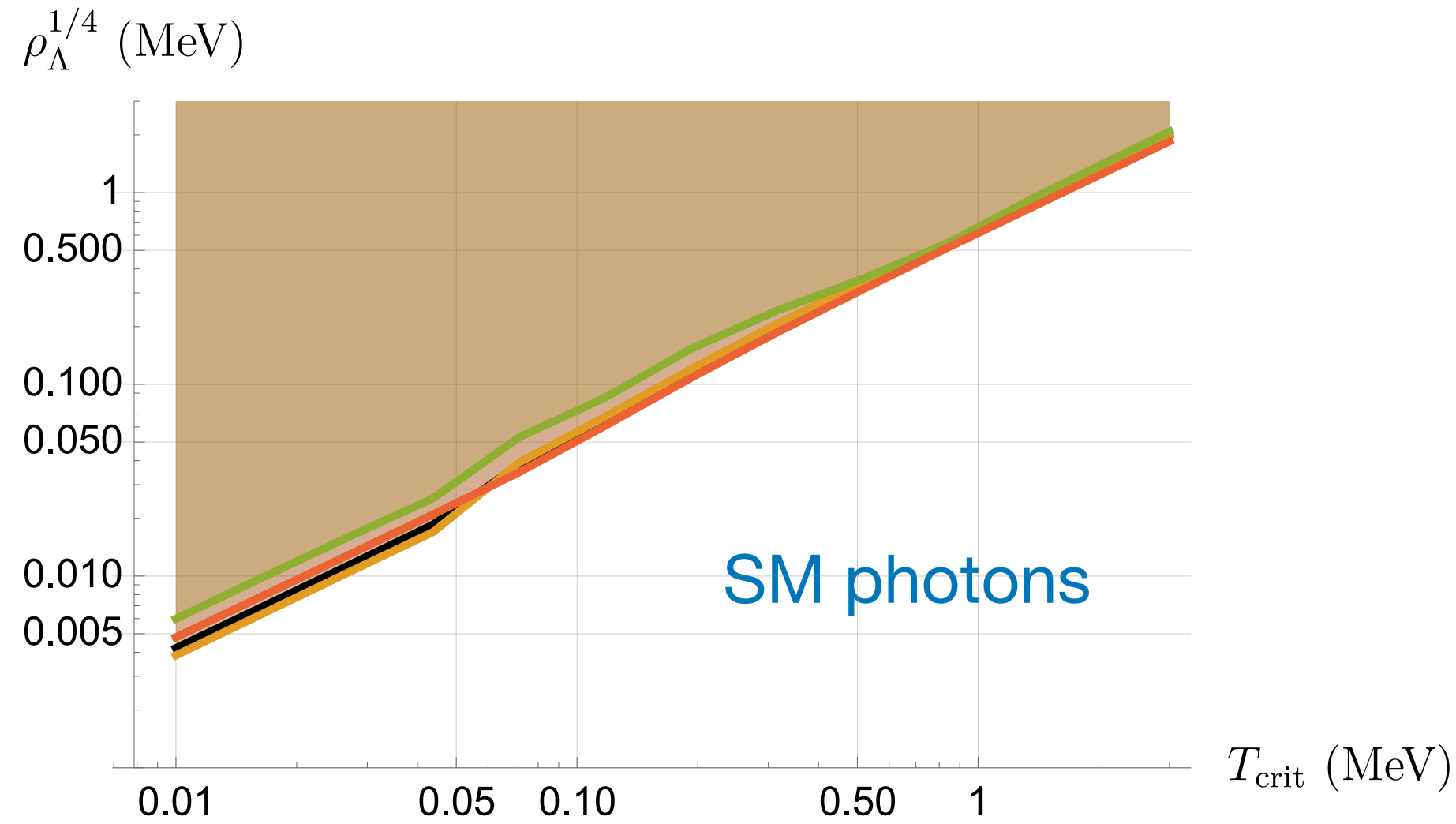
Key Takeaways

- BBN is a good test of new physics as it's essentially parameter-free.
- Introducing an EDE component alters the expansion rate of the universe which in turns alters the outcomes of BBN.
- Altered BBN outcomes set limits on the input parameters of EDE, namely ρ_Λ and T_{crit} .
- Fixing one parameter, one could explore varying other typically-fixed BBN parameters (like τ_n , η_b , and N_ν).
- Low Helium abundance results from EMPRESS could be explained by EDE, although it does make the Deuterium prediction worse.

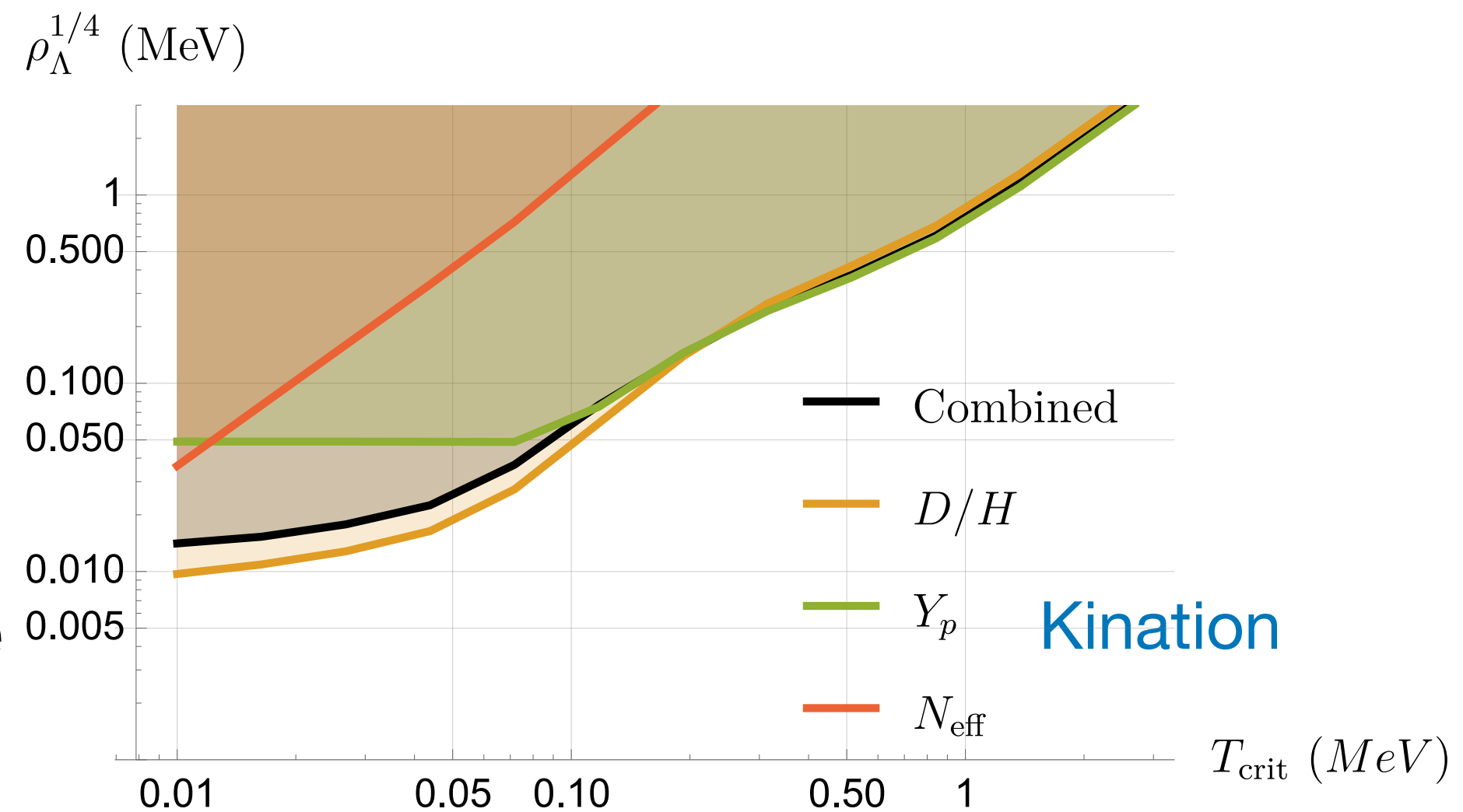
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Backup Slides

The EDE parameter space



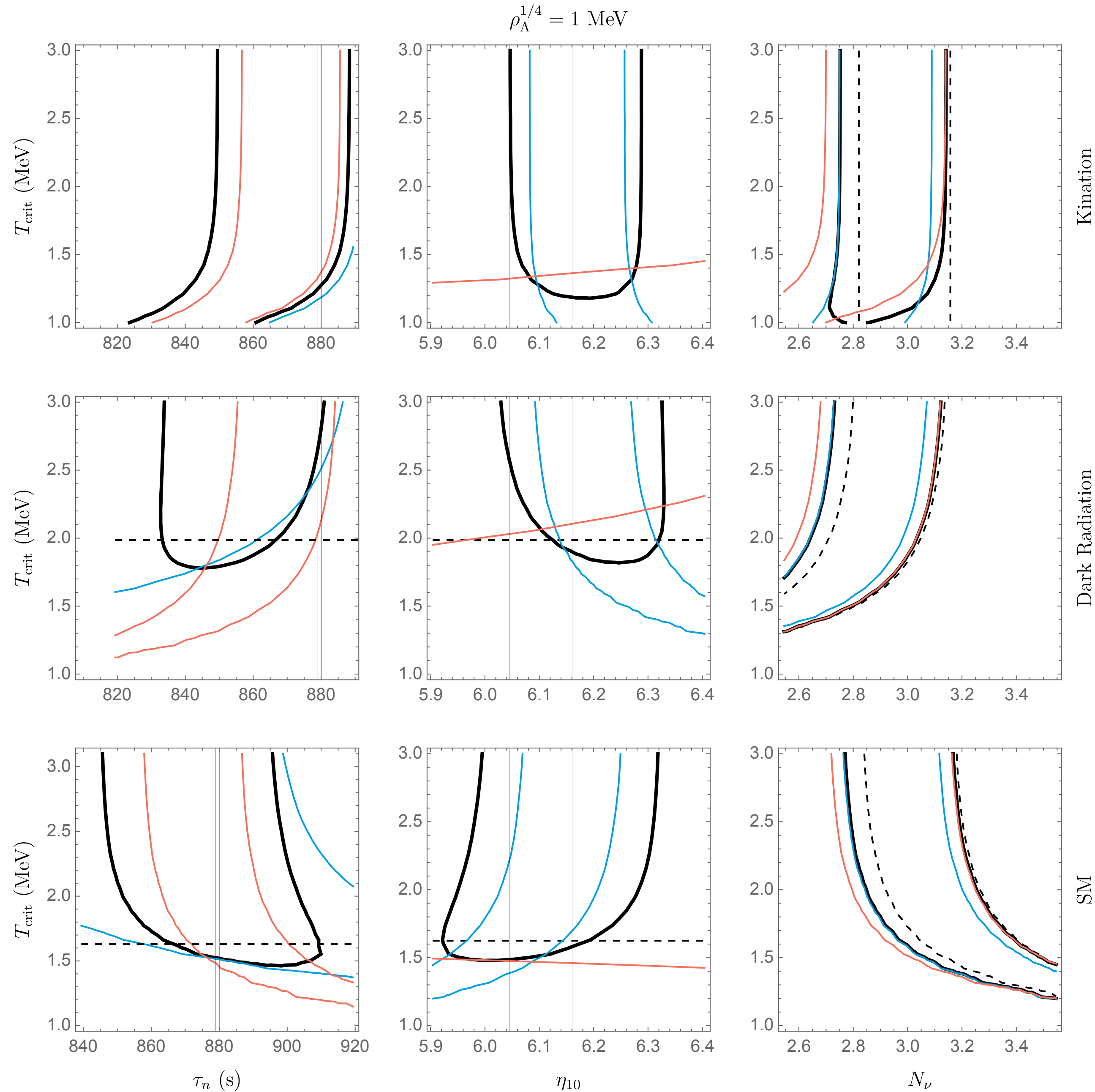
Limits plateau due to reaching end of BBN, thus the limits are on the amount extra DE allowed, regardless of BBN. This doesn't happen in SM case because η_b is forced to stay high before the decay so BBN is altered even if T_{crit} is low



Limits on N_{eff} come from the CMB

[McKeen, AO, 2407.03508]

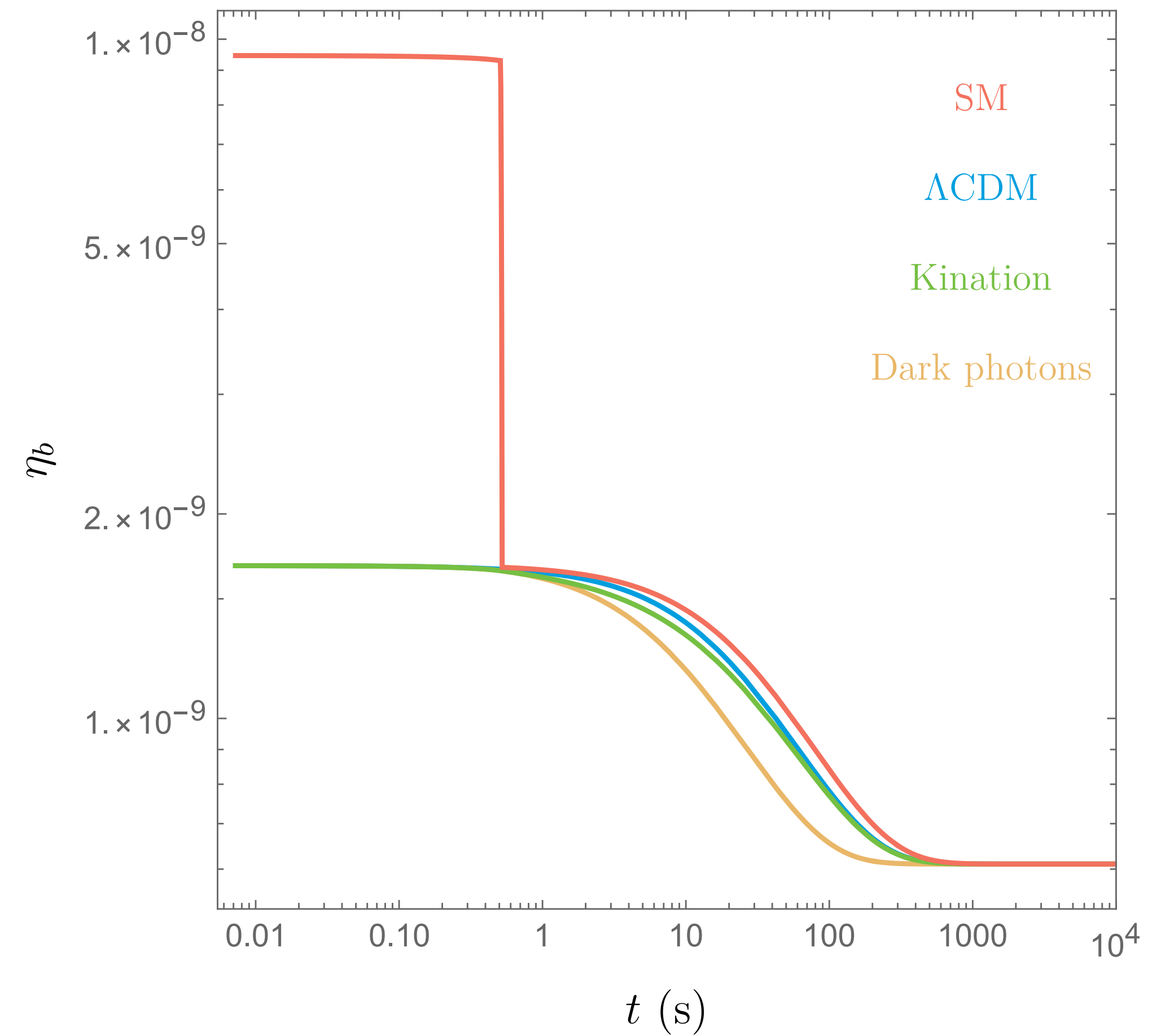
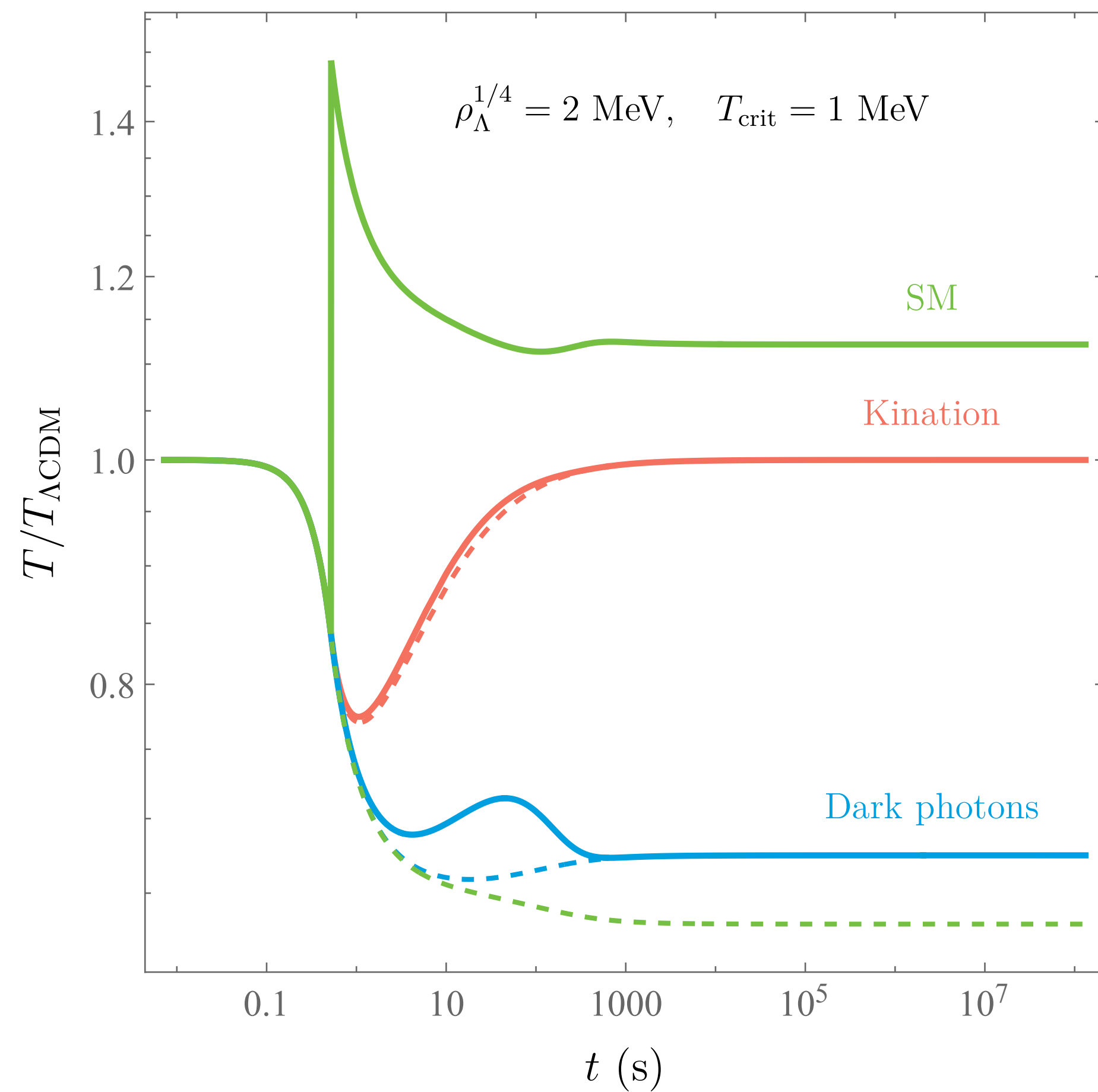
Varying the other BBN parameters



$$\rho_{\Lambda}^{1/4} = 1 \text{ MeV}$$

[David McKeen, AO, in prep]

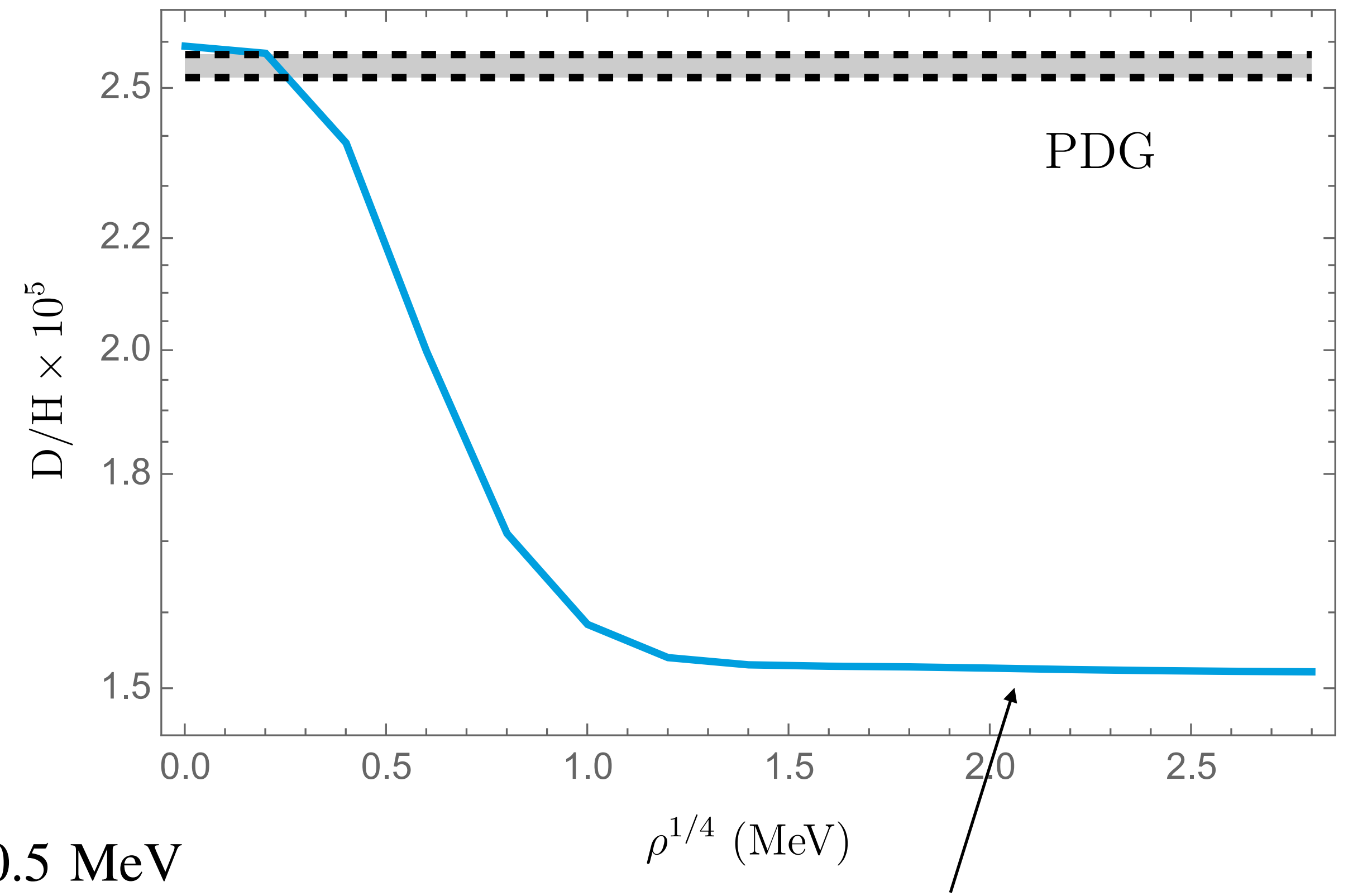
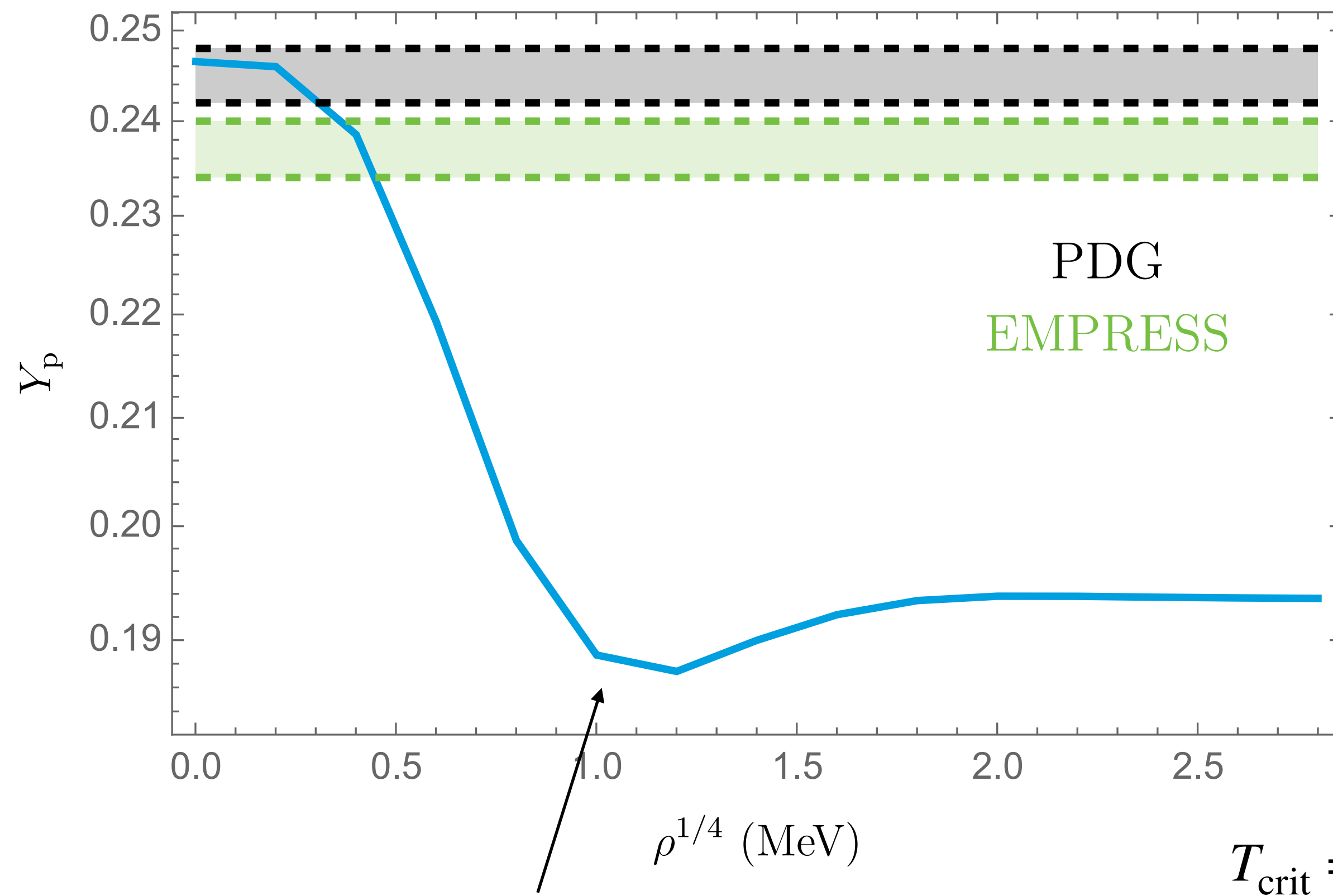
Effect of entropy injections



Even in SM case, there's rapid cooling before energy dumping

Lower primordial helium fraction?

Can EDE explain the EMPRESS results?



This kink and the plateau are a result of the rapid cooling before reheating