

computational methods for astroparticle propagation

# class 2: particle interactions and decays

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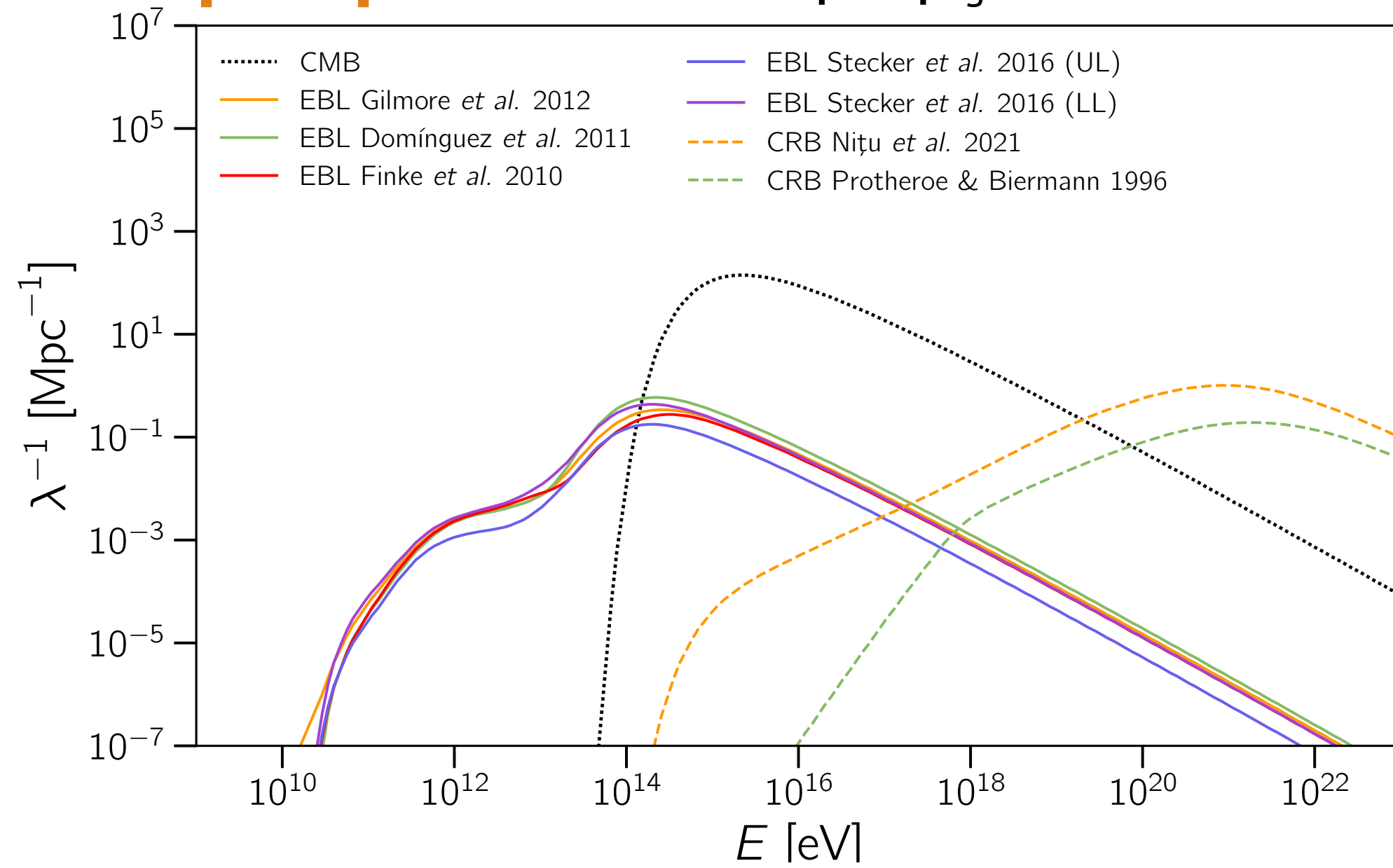
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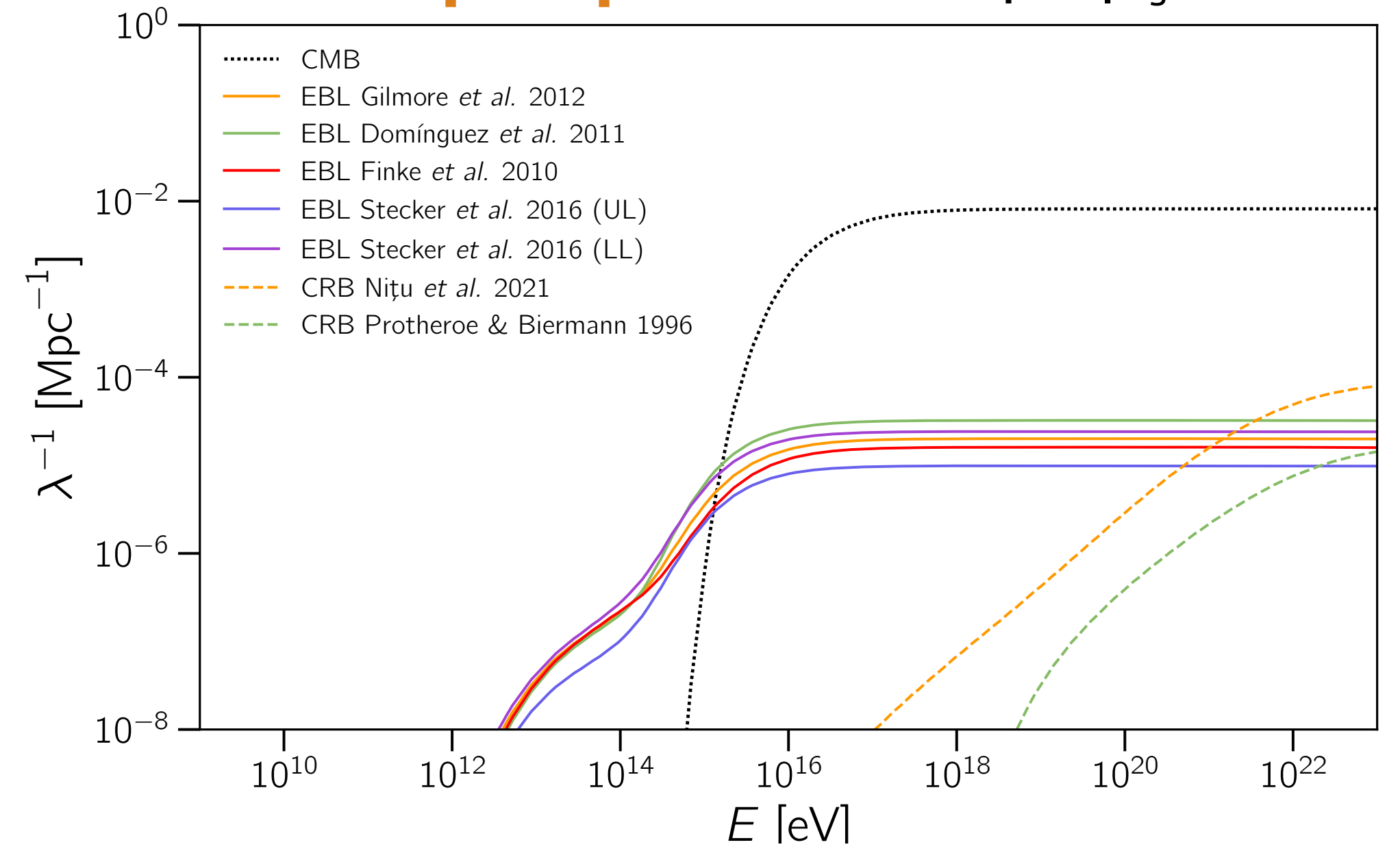
IFSC-USP  
2023

# gamma rays: mean free paths

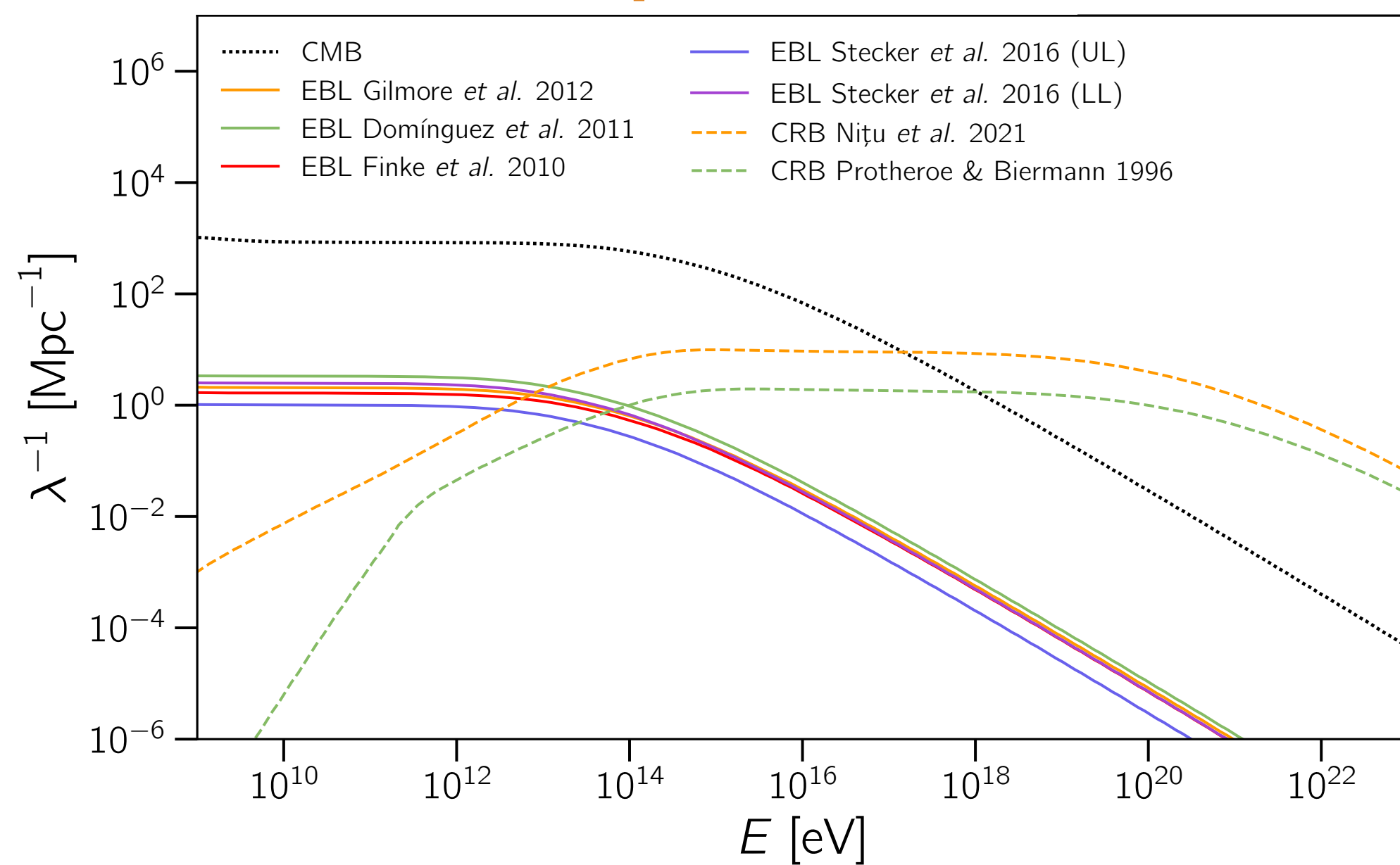
## pair production $\gamma + \gamma_{bg} \rightarrow e^- + e^+$



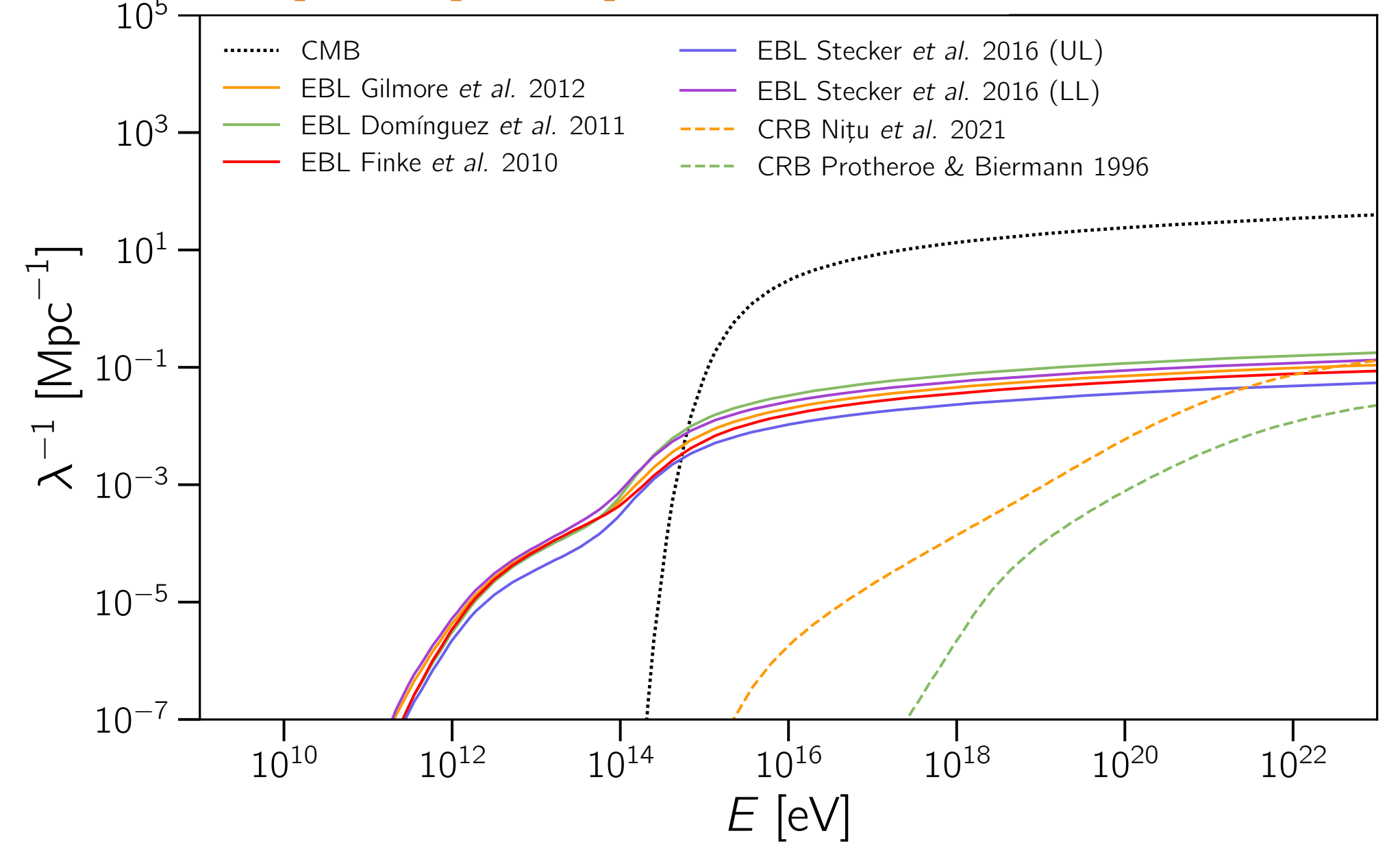
## double pair production $\gamma + \gamma_{bg} \rightarrow e^- + e^+ + e^- + e^+$



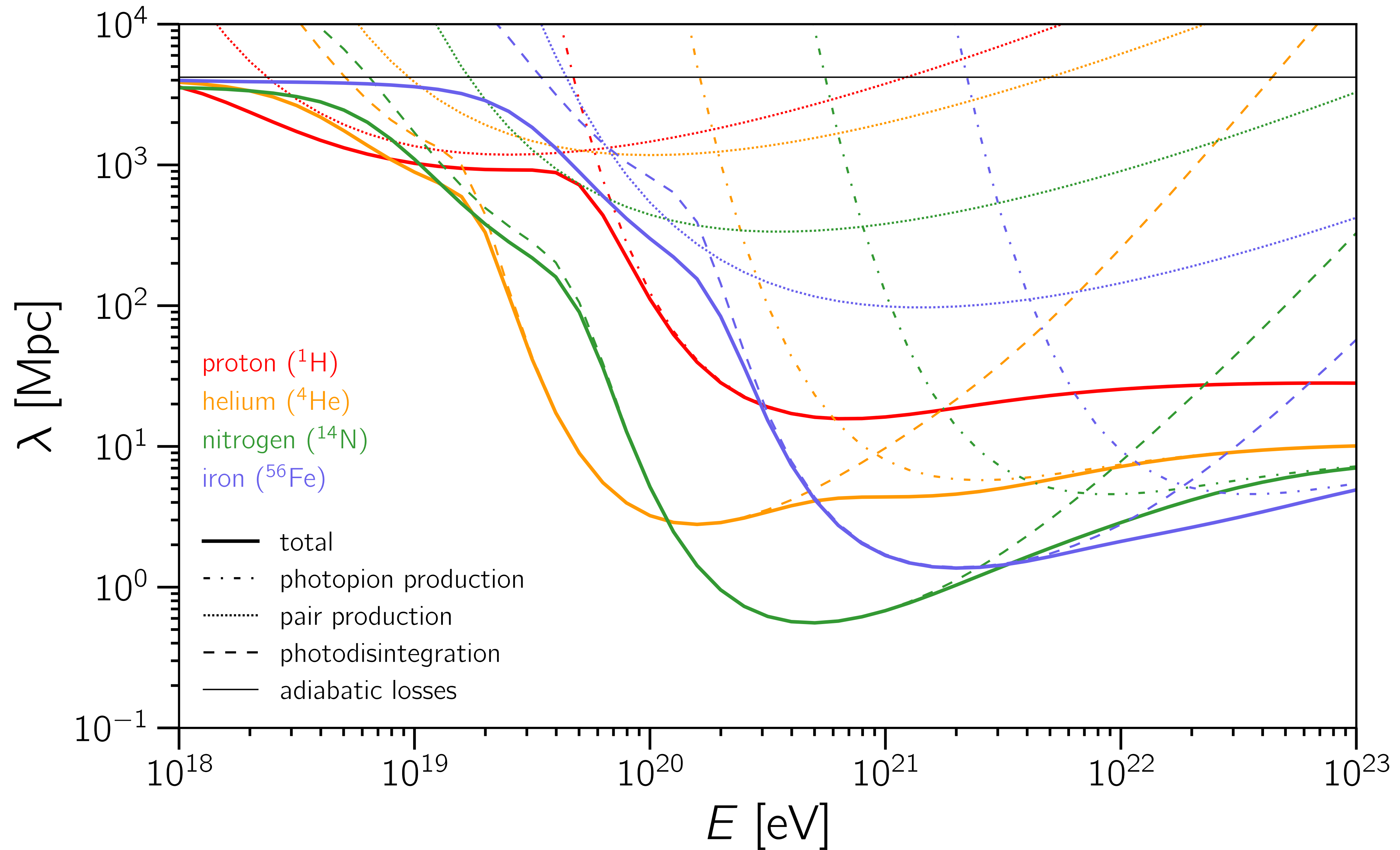
## inverse Compton $e^\pm + \gamma_{bg} \rightarrow e^\pm + \gamma$

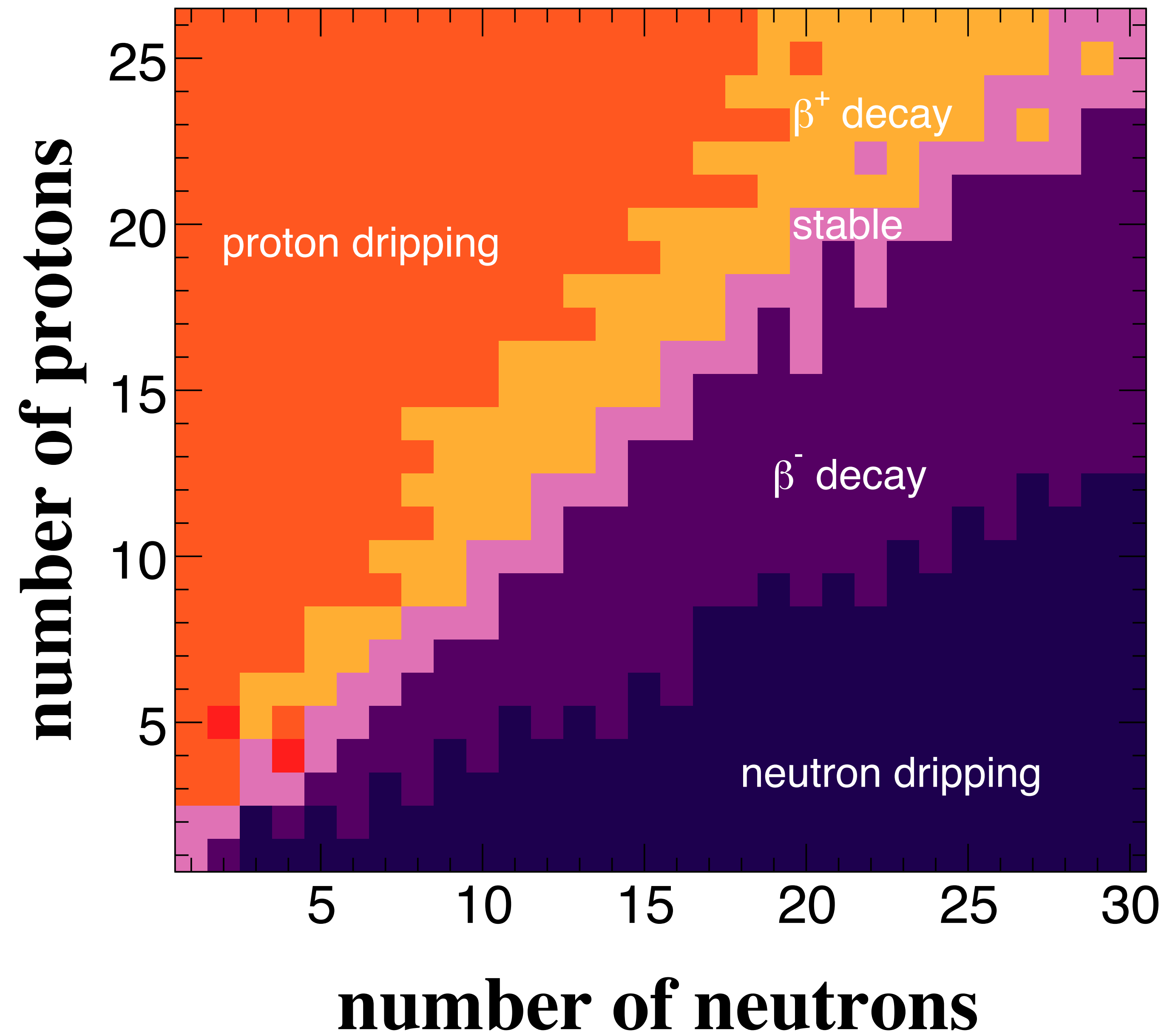


## triplet pair production $e^\pm + \gamma_{bg} \rightarrow e^\pm + e^- + e^+$

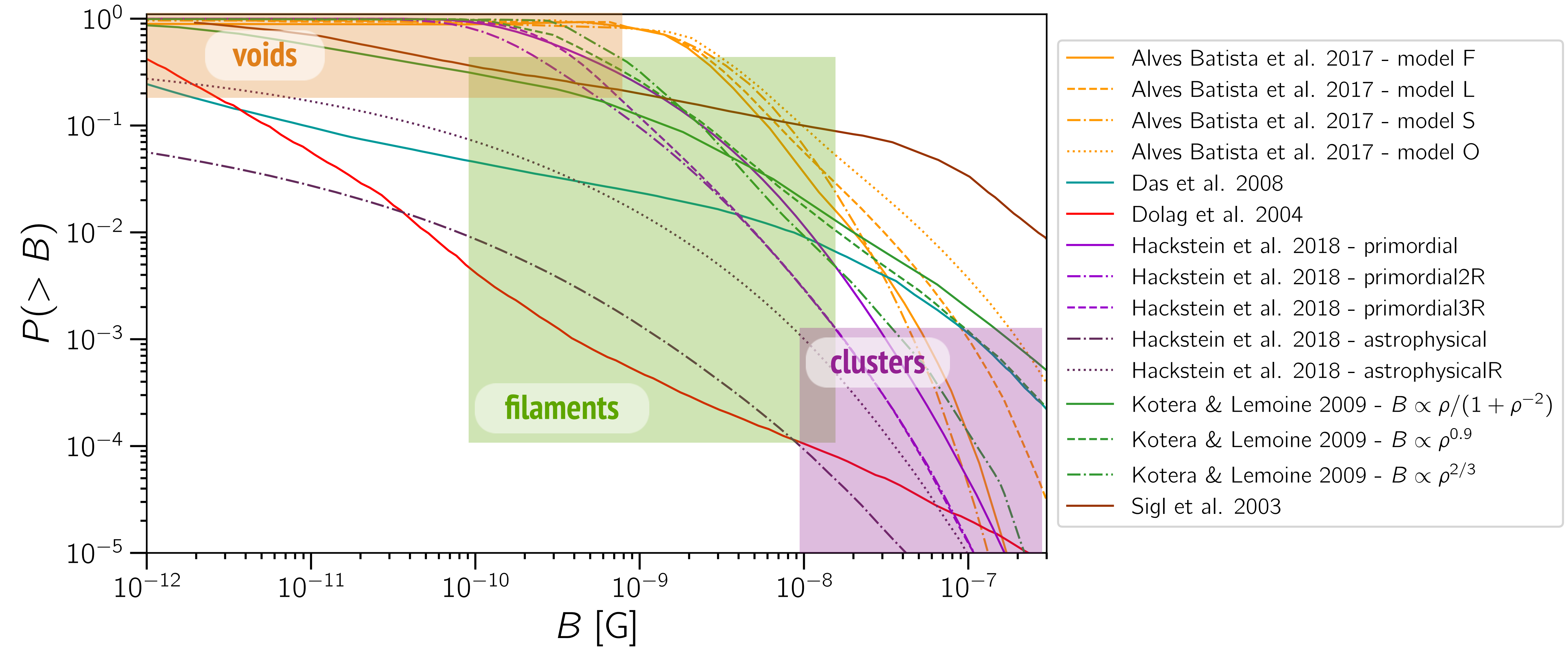


# UHECRs: mean free paths





# magnetic fields in the large-scale structure of the universe



# intergalactic magnetic fields: constraints

