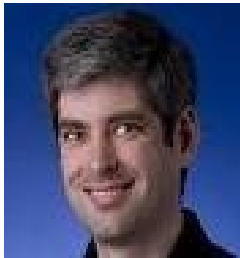


# What Percentage of Cosmic Rays are Expected to be Photons? ( $>10^{18}$ eV)



Dan Hooper



Subir Sarkar



Paolo Coppi

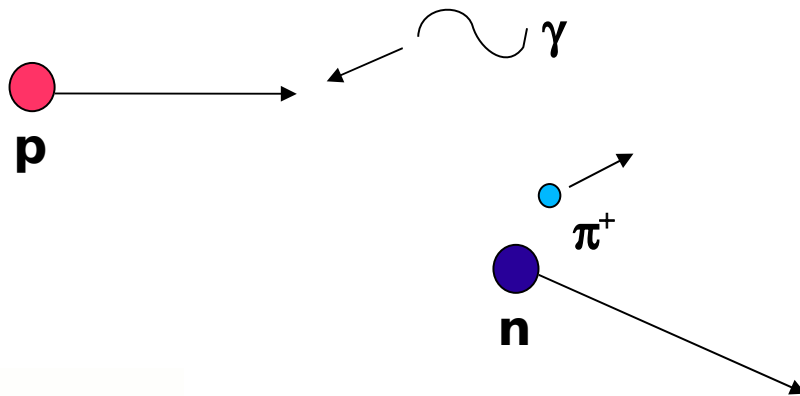
# Outline

- cosmic ray proton interactions and their secondary products
- the difficulties for a high energy photon in the universe
- which has the tougher time, protons or photons?
- the photon/proton ratio expected at Earth

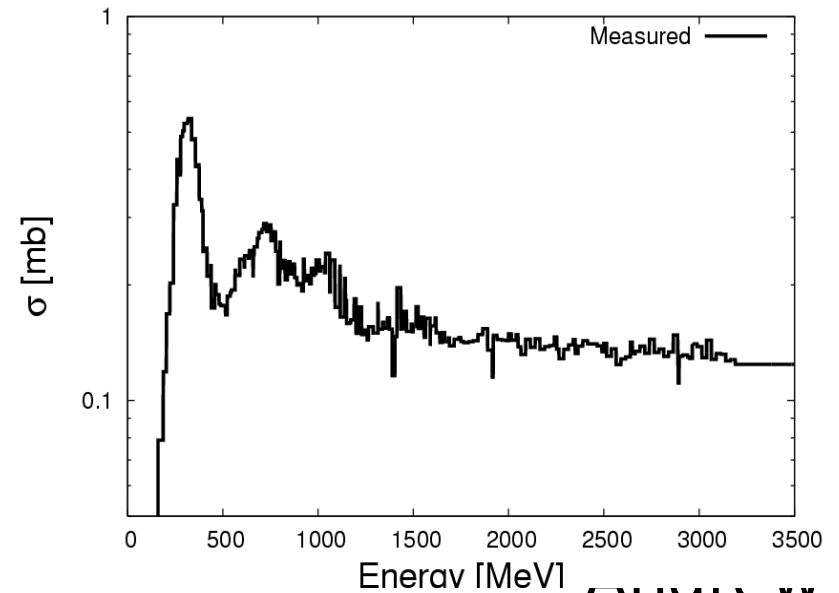
# Why any Cosmic Rays should be Photons?

Charged Pion production interaction with CMB  $\gamma$

For  $E_{\text{proton}} > 10^{19.6}$   
eV



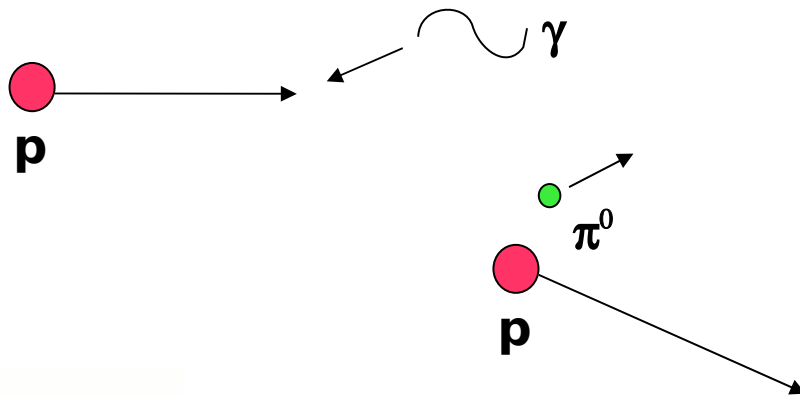
(photon energy in proton frame)



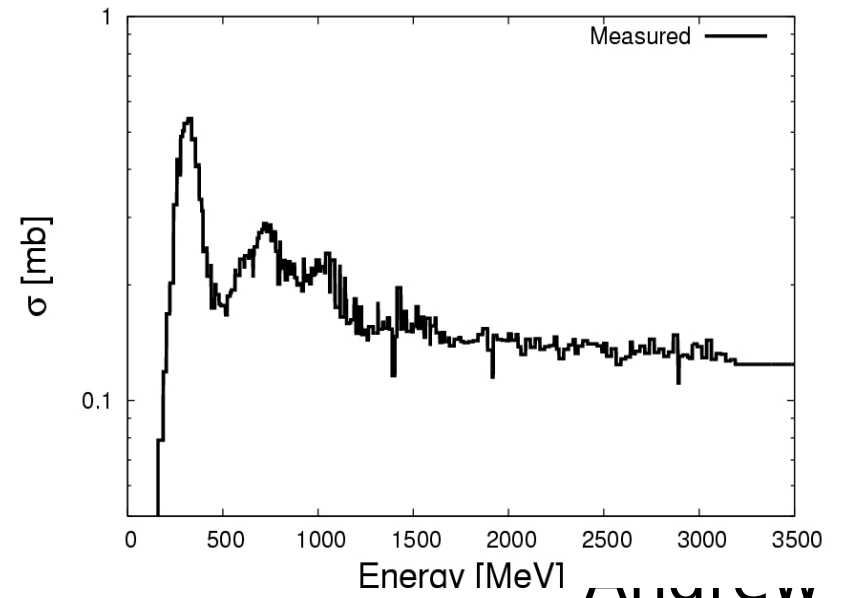
# Why any Cosmic Rays should be Photons?

Neutral Pion production interaction with CMB  $\gamma$

For  $E_{\text{proton}} > 10^{19.6}$   
eV

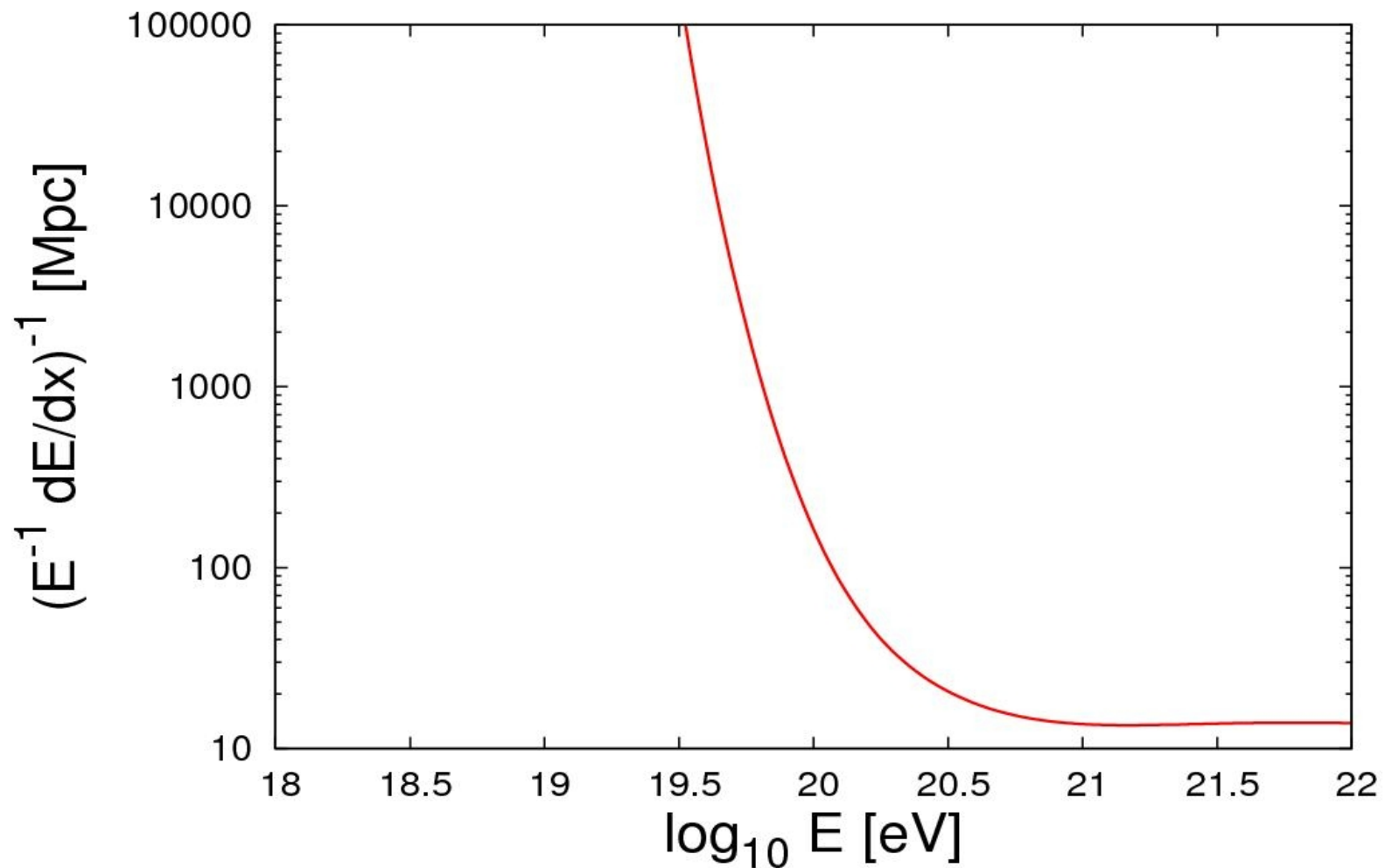


(photon energy in proton frame)

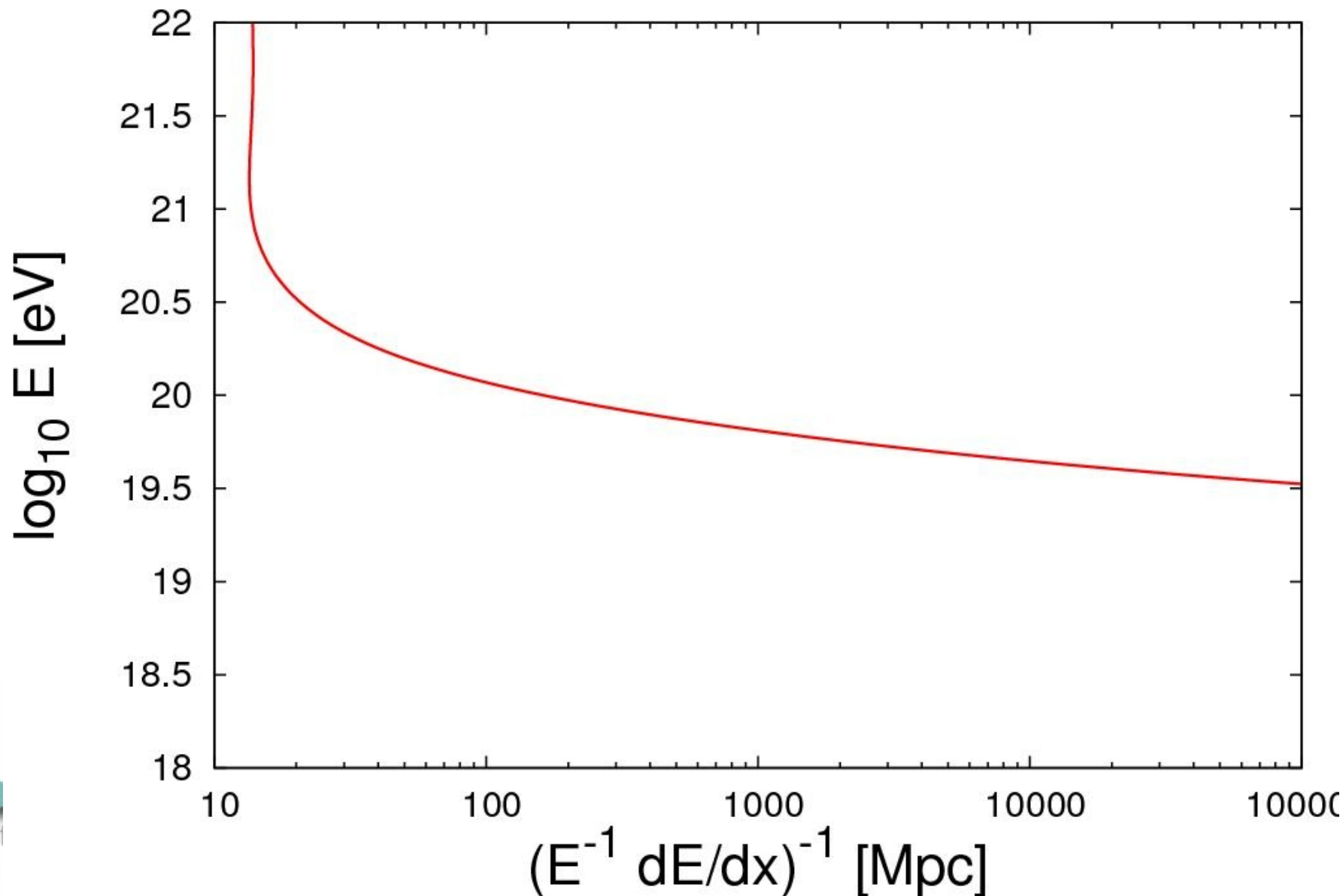


# Proton (Cosmic Ray)- Photon (CMB) Interaction Lengths

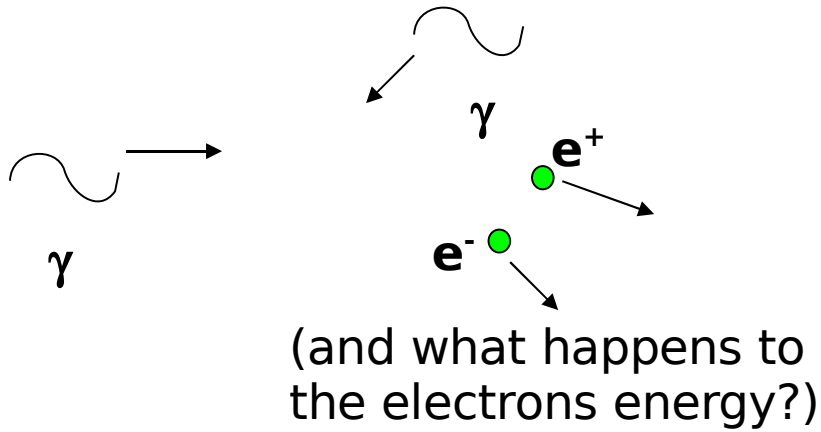
$$R = \frac{m_p^2 c^4}{2E^2} \int_0^\infty d\epsilon \frac{n(\epsilon)}{\epsilon^2} \int_0^{2E\epsilon/m_p c^2} d\epsilon' \epsilon' \sigma_{p\gamma}(\epsilon') K_p \quad (\text{where } R \text{ is the energy loss rate})$$



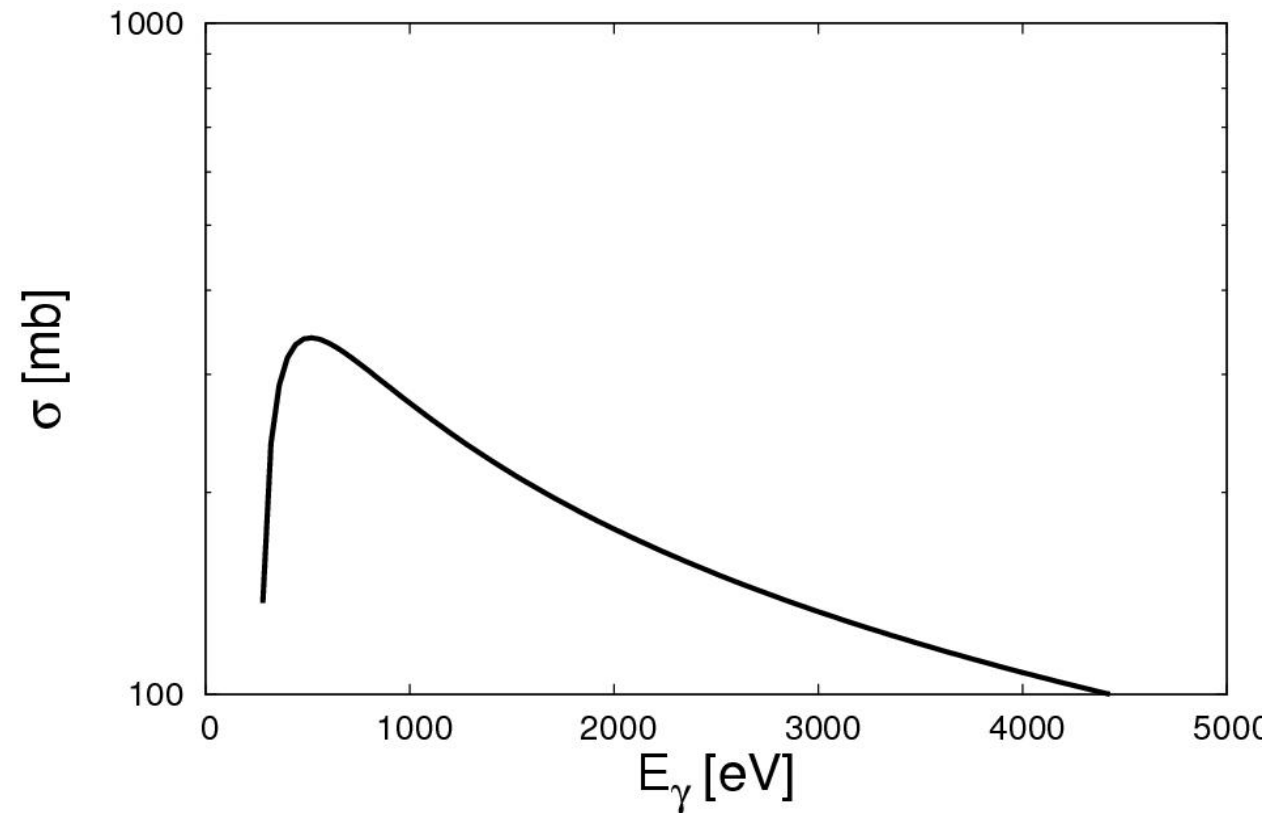
# Proton (Cosmic Ray)- Photon (CMB) Interaction Lengths



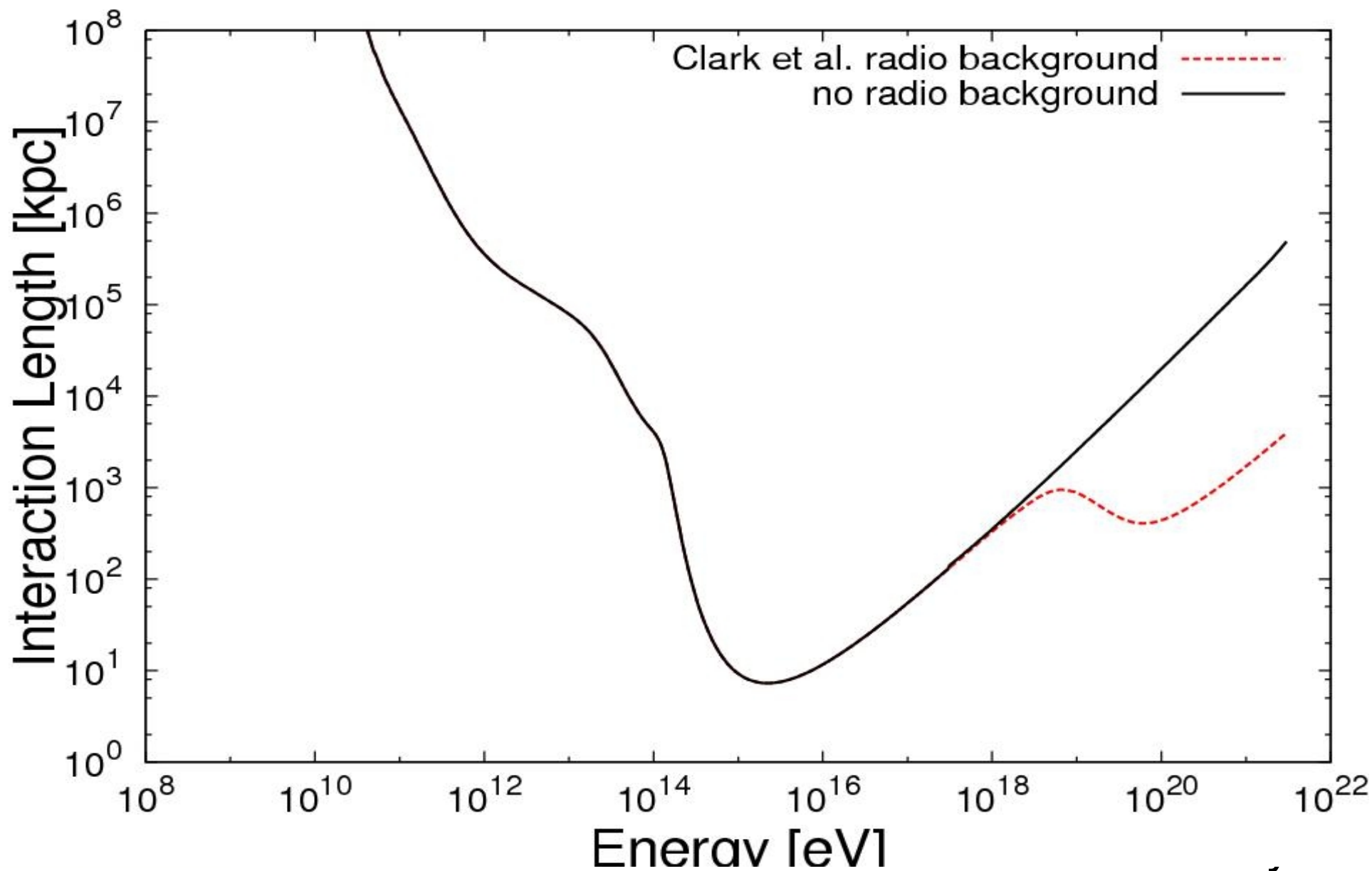
# Why aren't most Cosmic Rays Photons above $10^{19.6}$ eV?



(photon energy in lab frame- for a GeV photon)

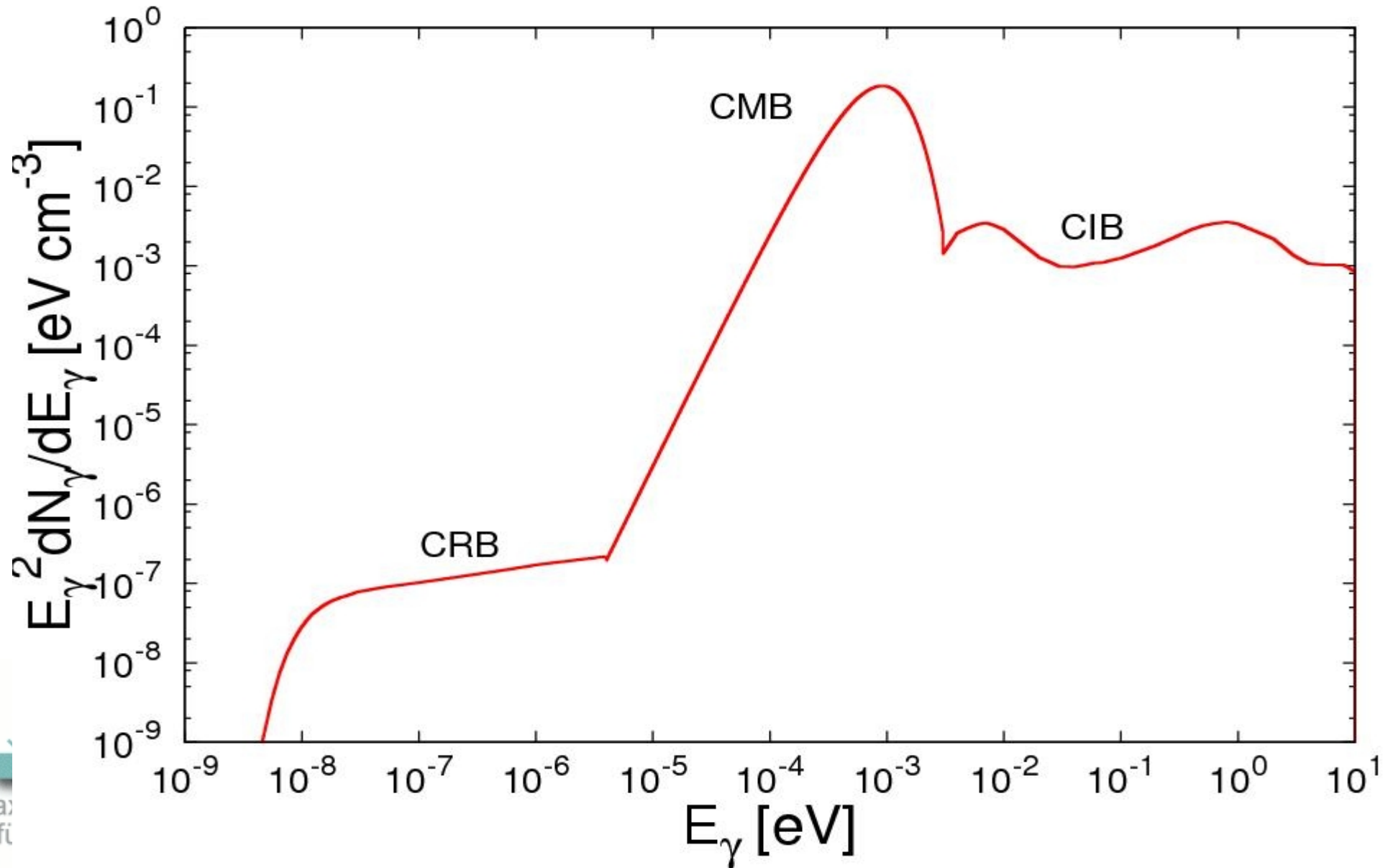


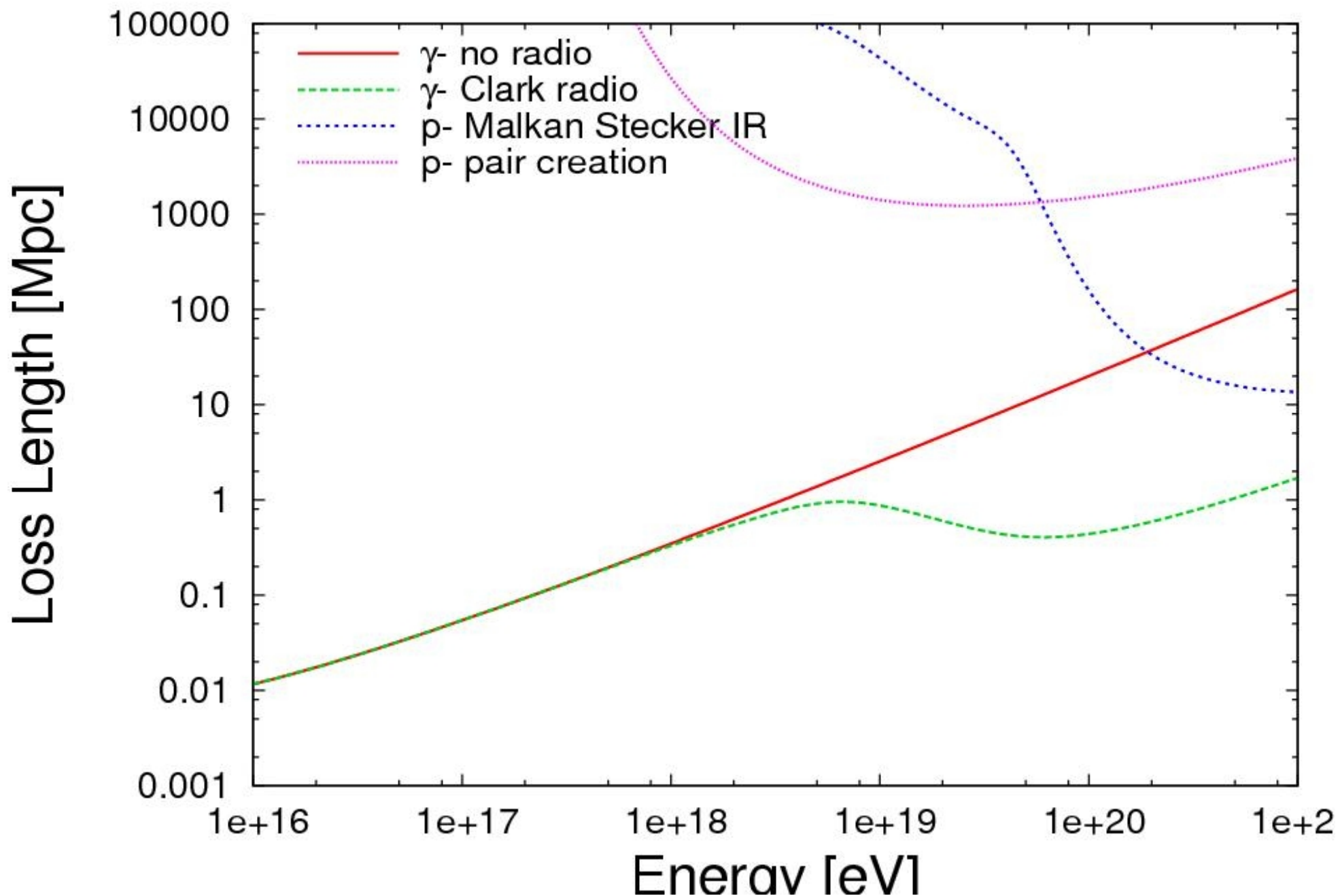
# Photon (Cosmic Ray)- Photon (CMB) Interaction Lengths

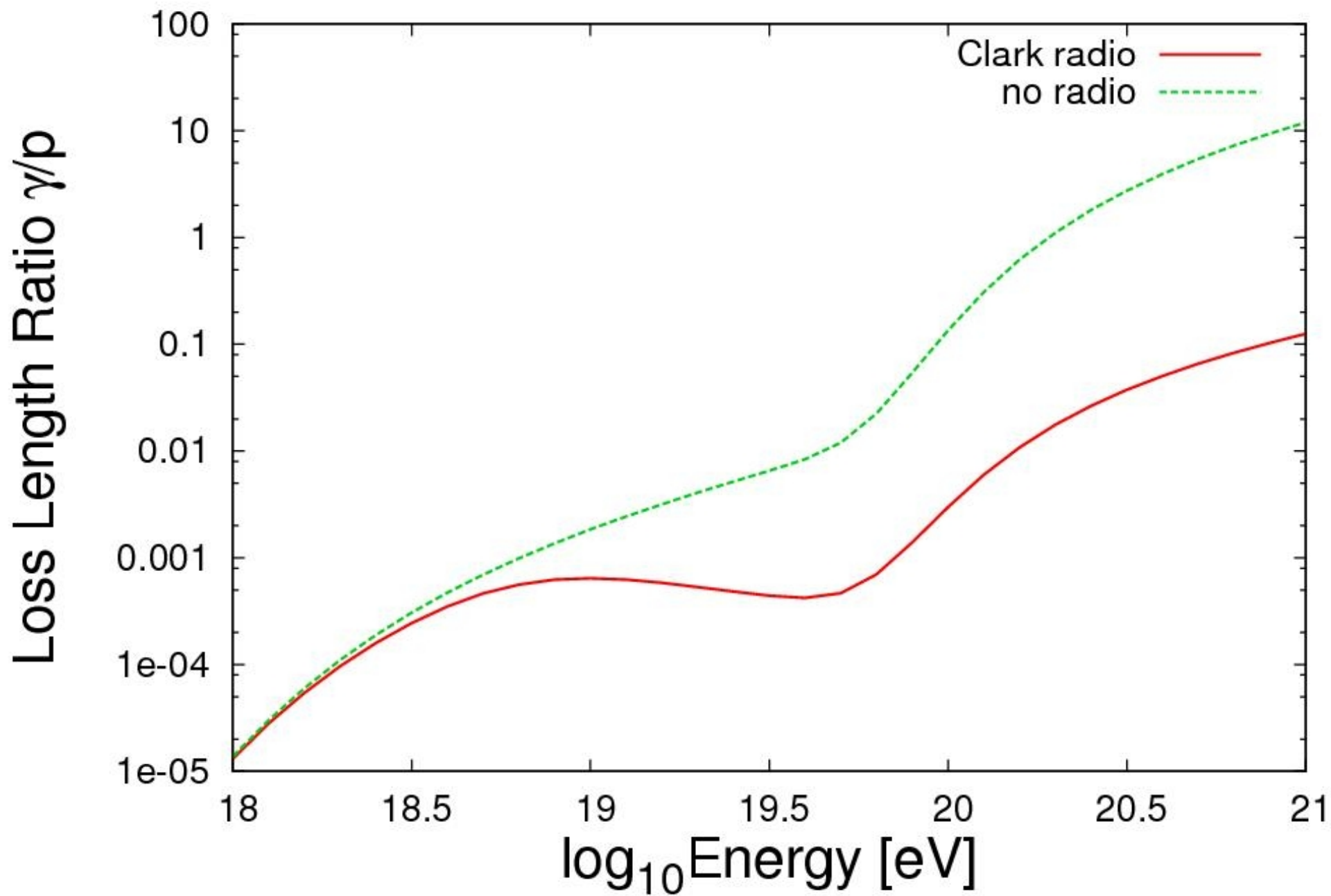


# Uncertainties in the Radio Background

(the spanner in the works)







# So....what Percentage of Cosmic Rays are Photons then?

