Dose Build-Up effect and Secondary Particles in Proton Therapy

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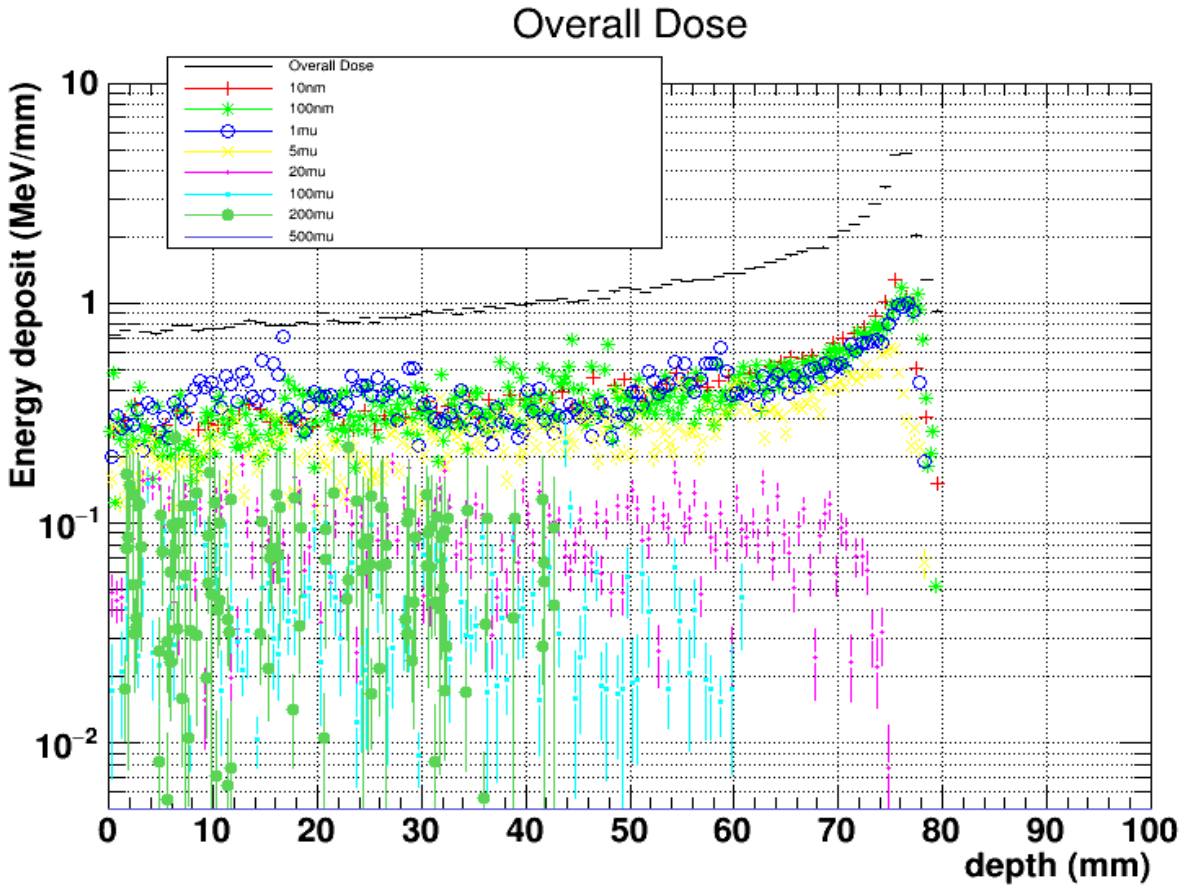
Remember electron dose contribution for different range cuts



This is because there is a “safety threshold” for ionisation in Geant4: E_th = 990 eV
Geant4 might not accurately simulate energies below that threshold

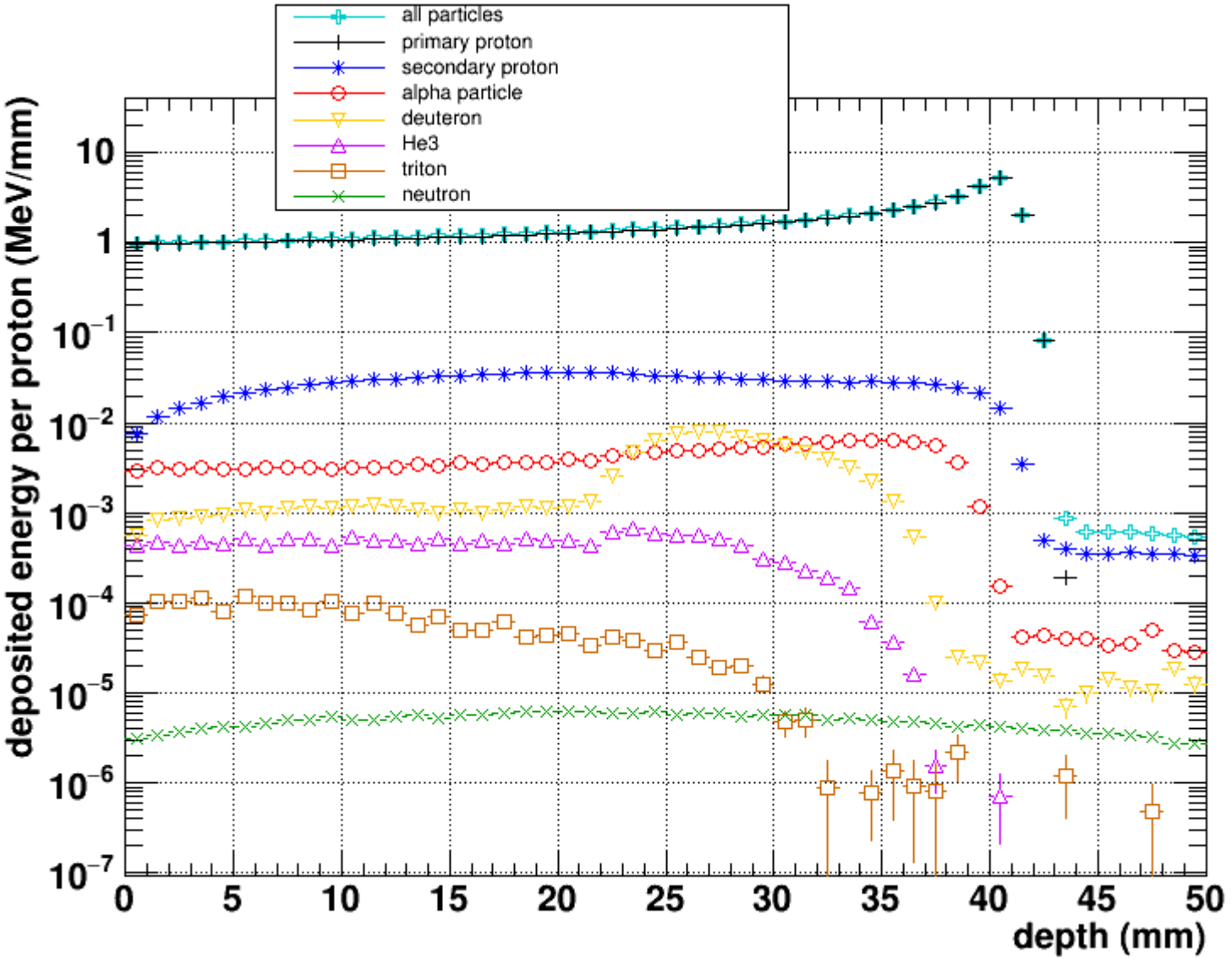
Fun facts about Geant4

- “Deposited energy” ignores energy of secondary particles
- “Energy loss” records energy of tracked particle and its secondaries BUT in the place where they are produced! (not where the secondaries deposit their energy)
- “Range cut”: Only secondaries which are expected to travel further then the range cut will be tracked BUT this theoretically only applies to secondary electrons, positron, gammas and protons.
- To be more clear: exotic secondaries as neutrons will always be produced and tracked, independently from the range cut.
- However, I didn't see an influence of the range cut on the number of secondary protons
- There is a “safety energy threshold” for the production of secondary particles of 990eV since otherwise Geant4 models might fail.

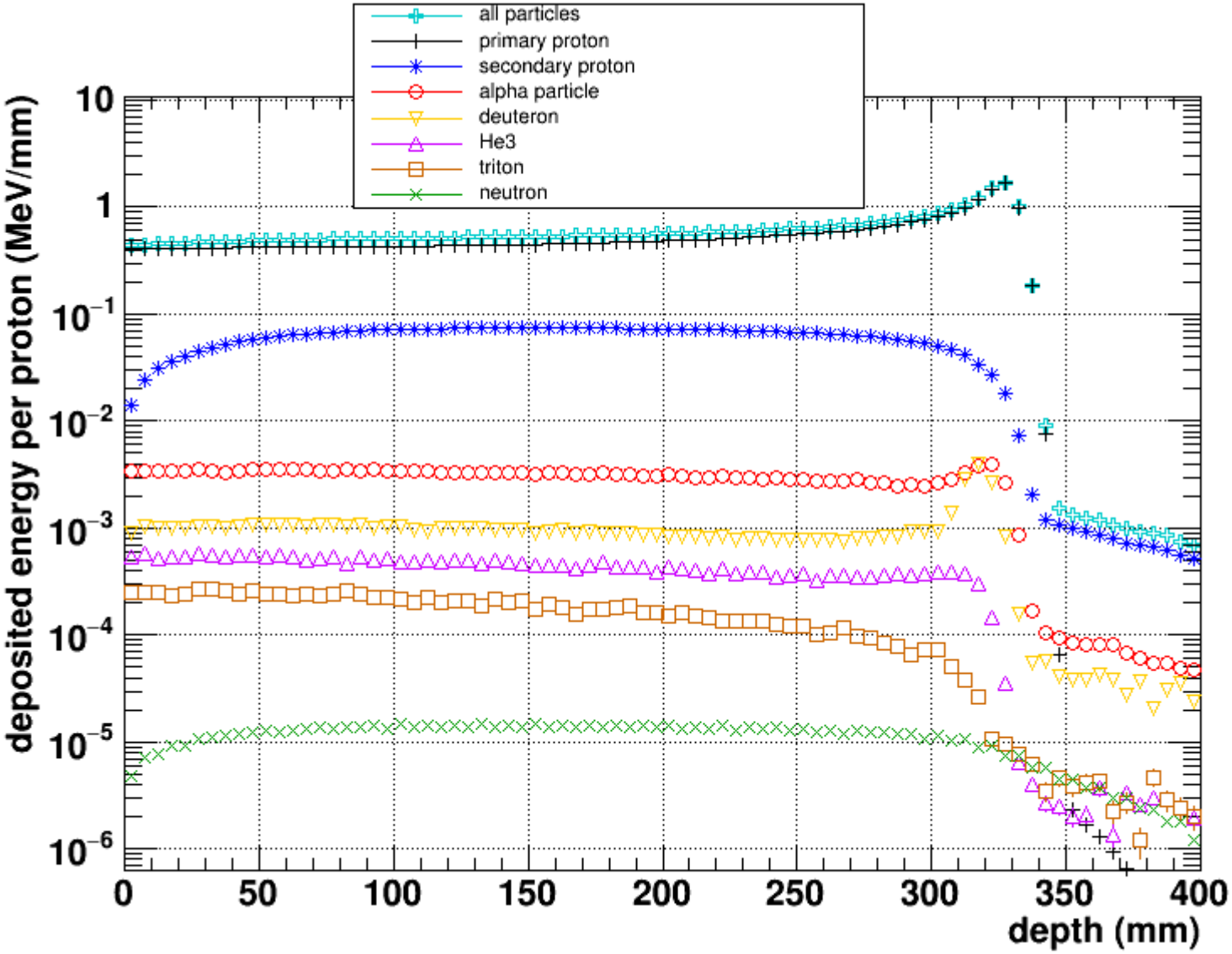
What I have simulated/calculated

- Deposited energy
- Energy loss
- Secondary particle production (location of production)
- Secondary particle production + kinetic energy (2D)
- Secondary particle density (path of flight)
- LET (dEdx)
- LET-corrected deposited energy
- LET-corrected energy loss

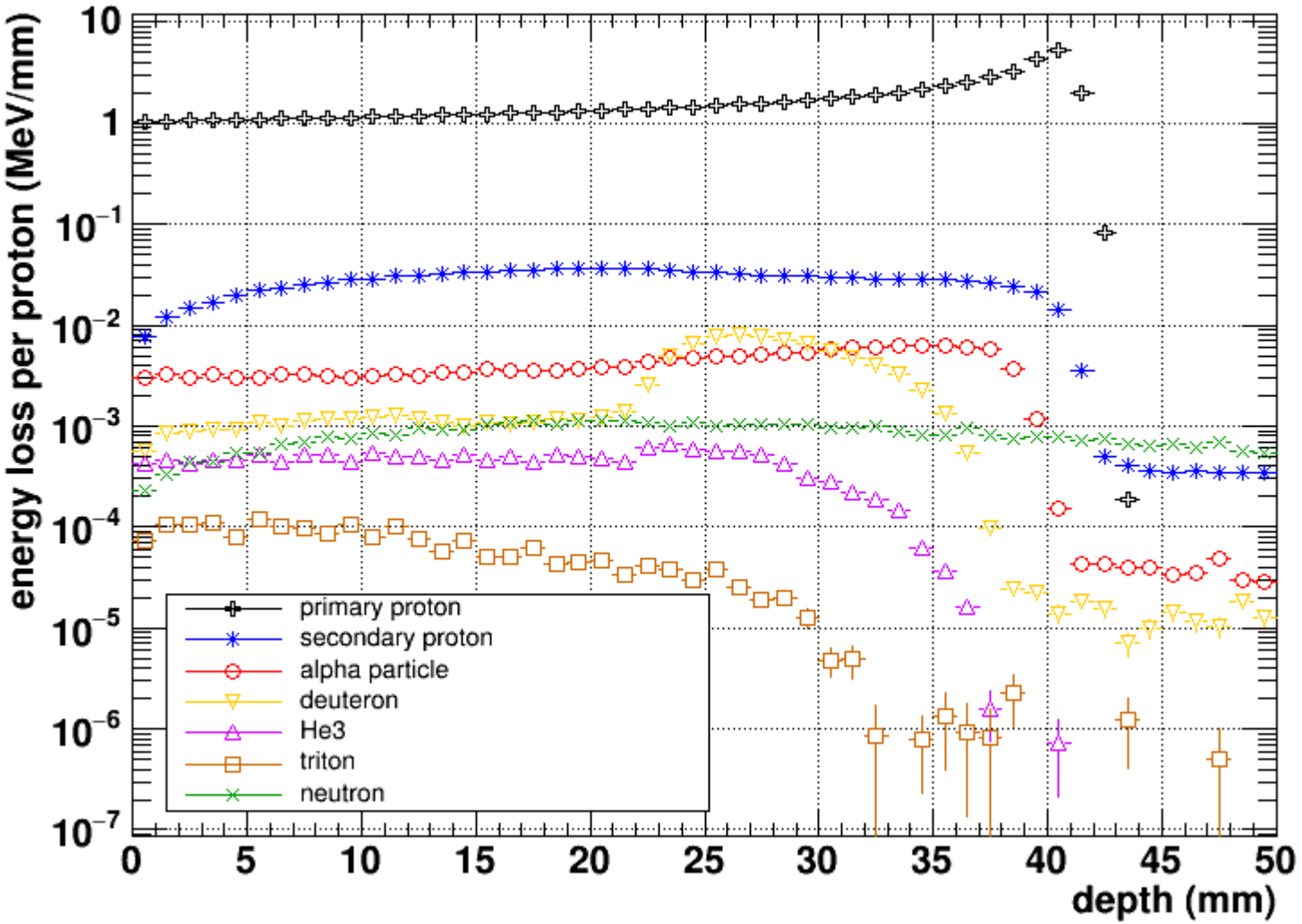
Deposited energy at 70MeV



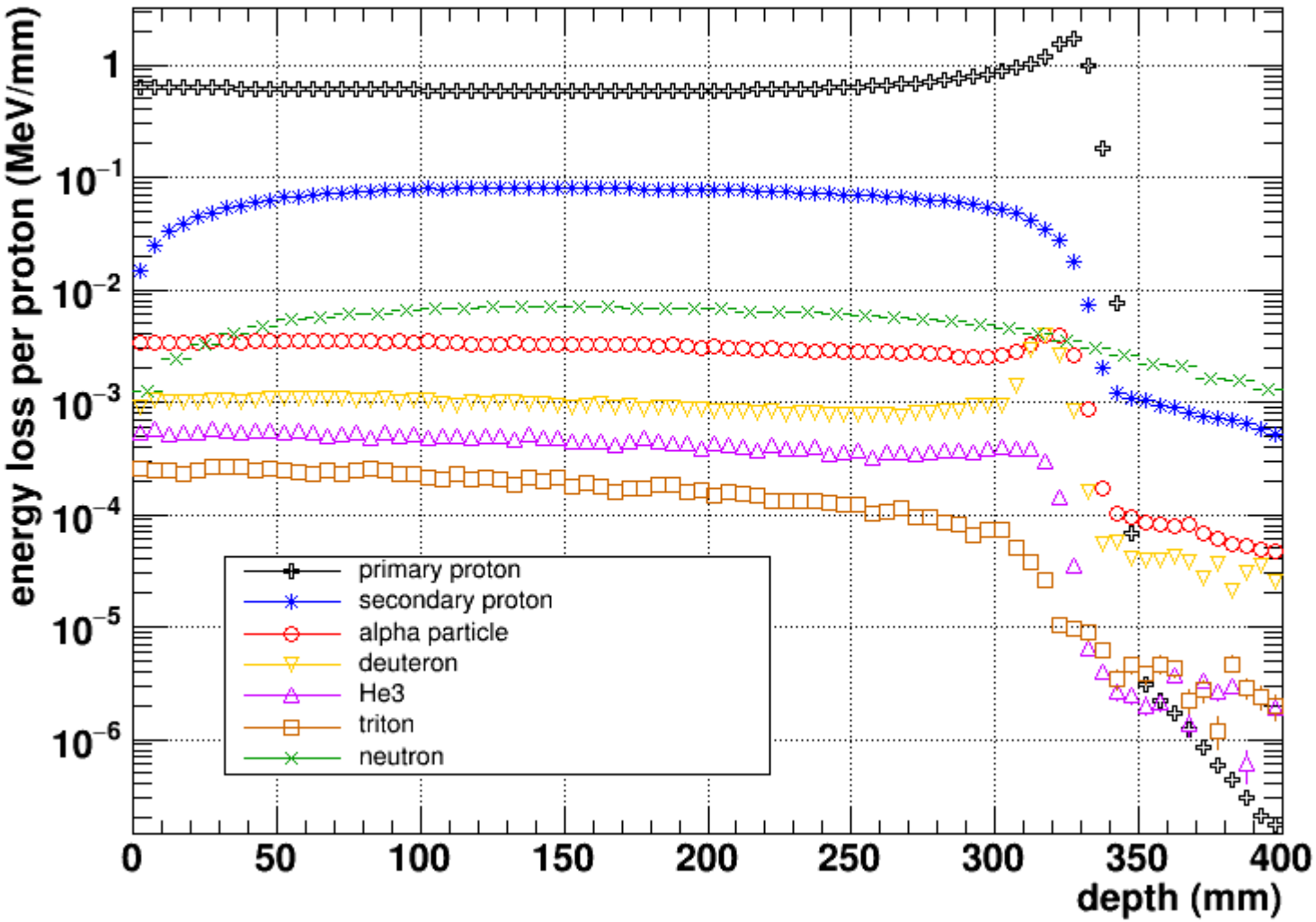
Deposited energy at 230MeV



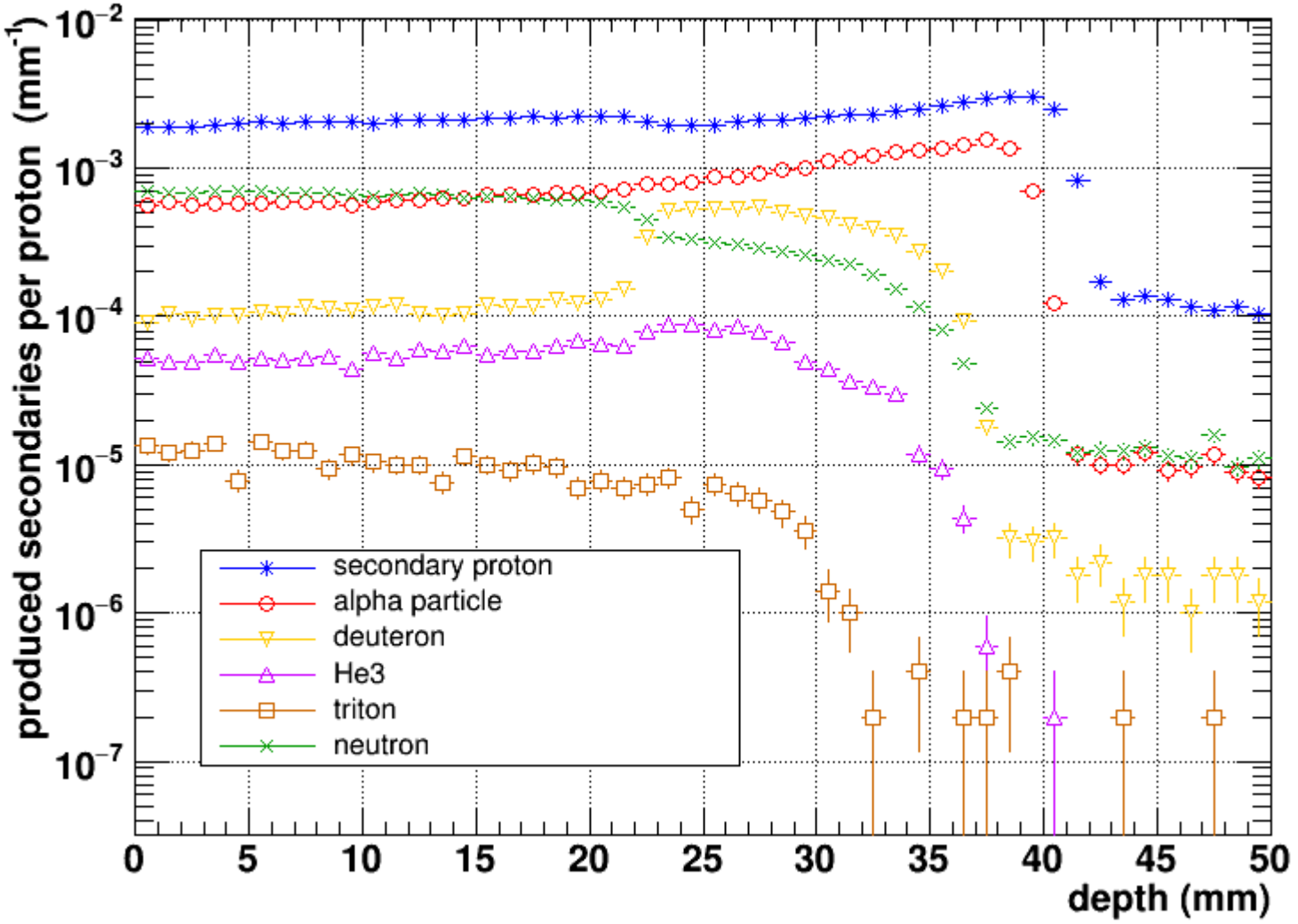
Energy loss at 70MeV



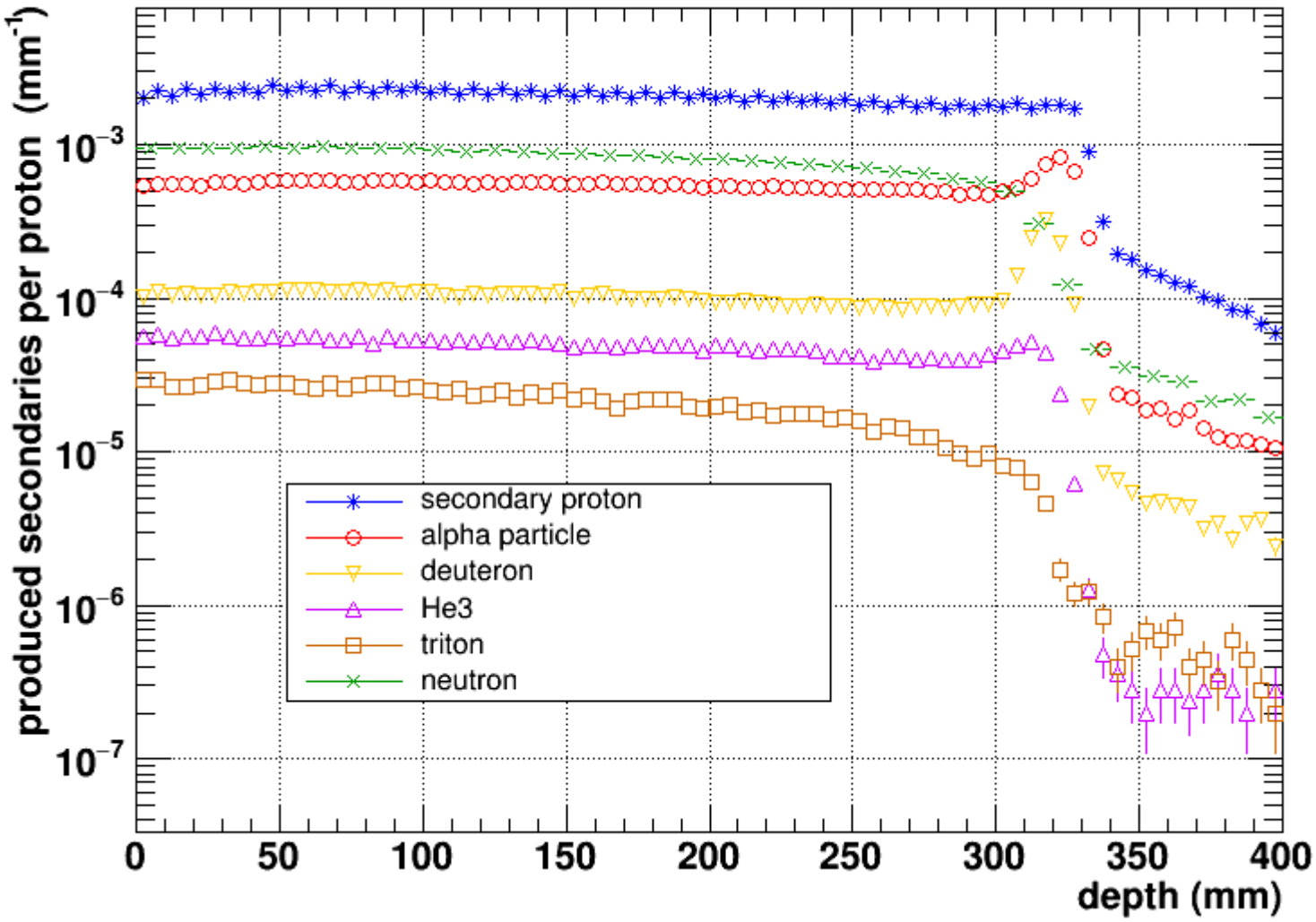
Energy loss at 230MeV



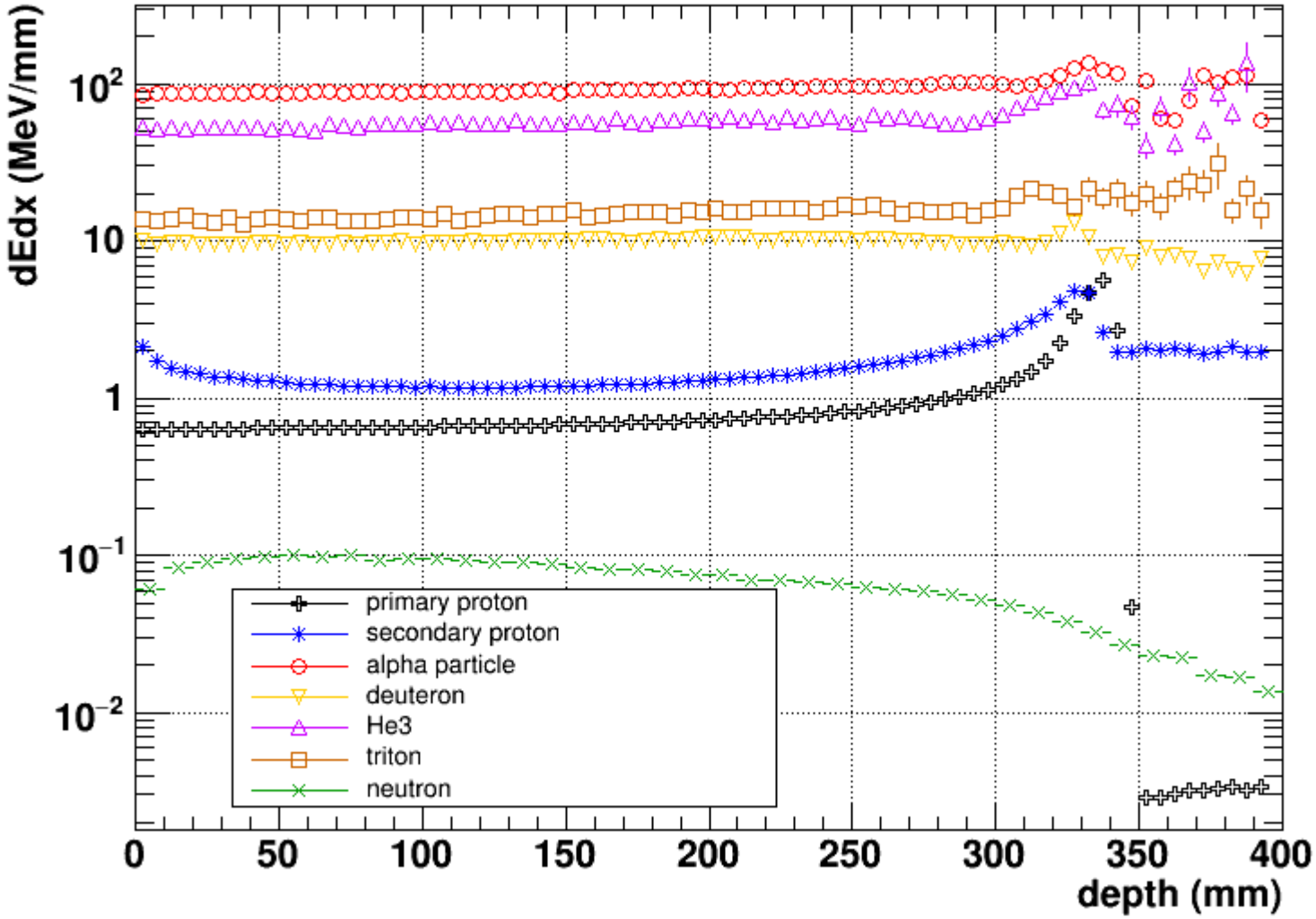
Secondary particle production 70MeV



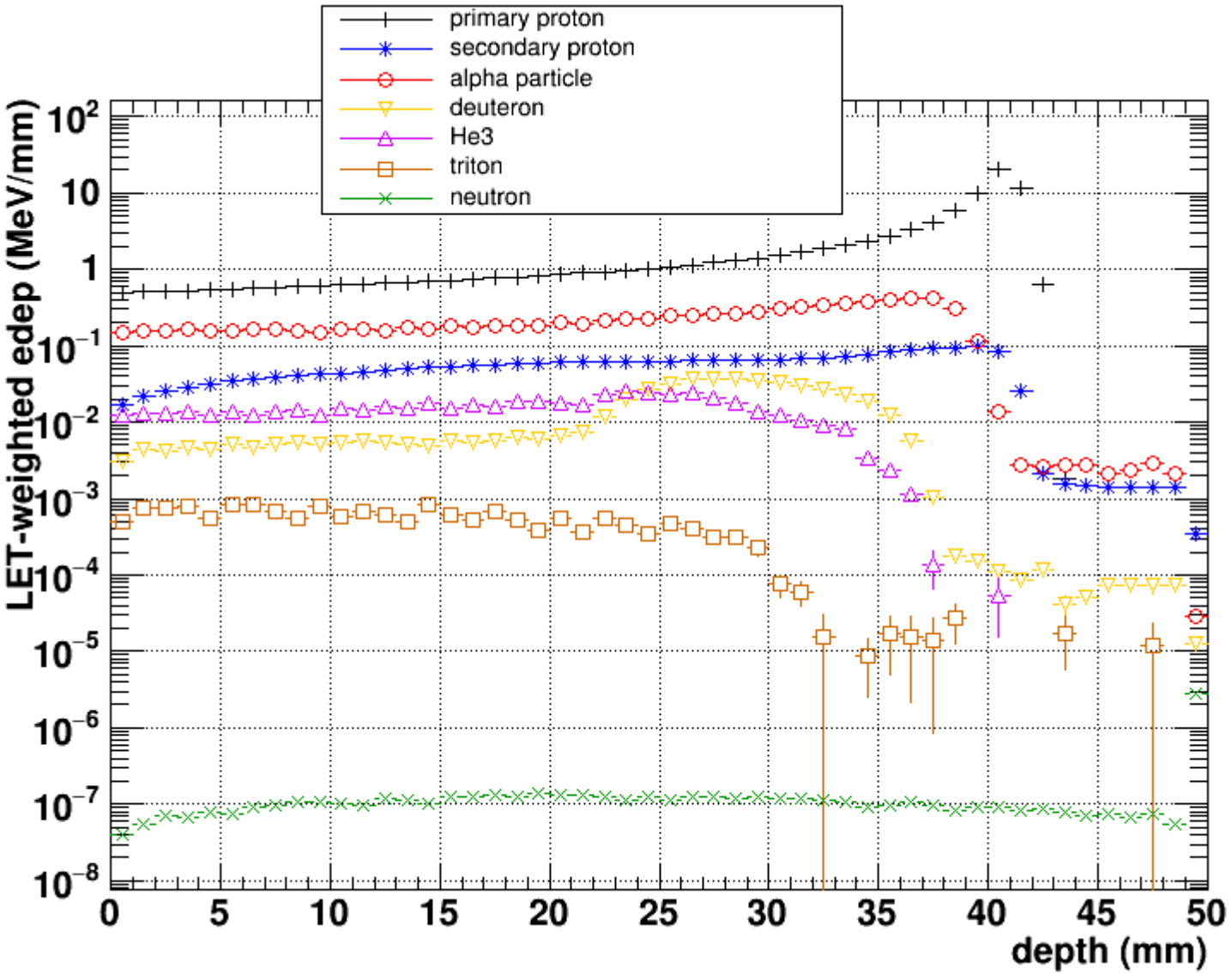
Secondary particle production 230MeV



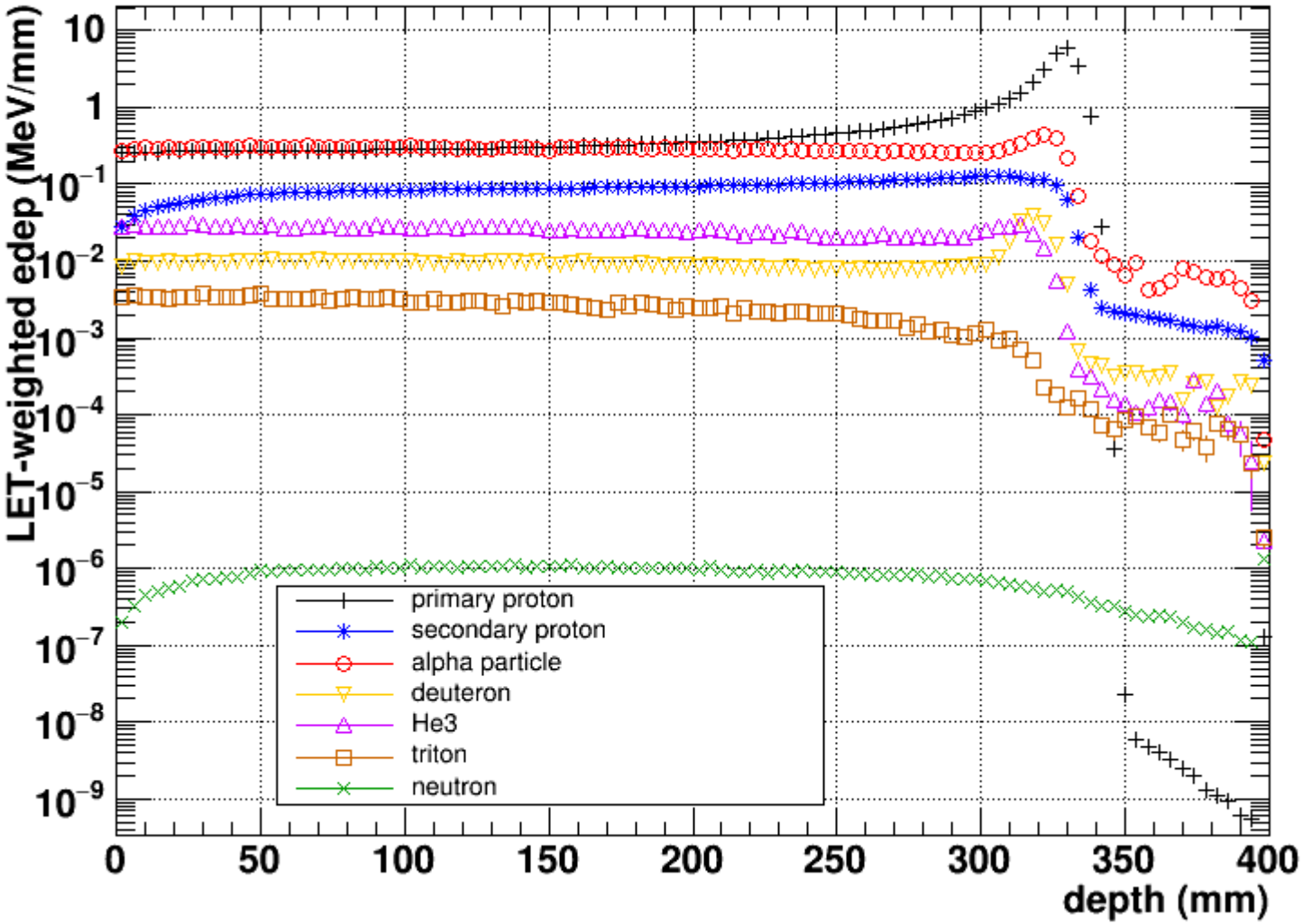
LET (dEdx) at 230MeV



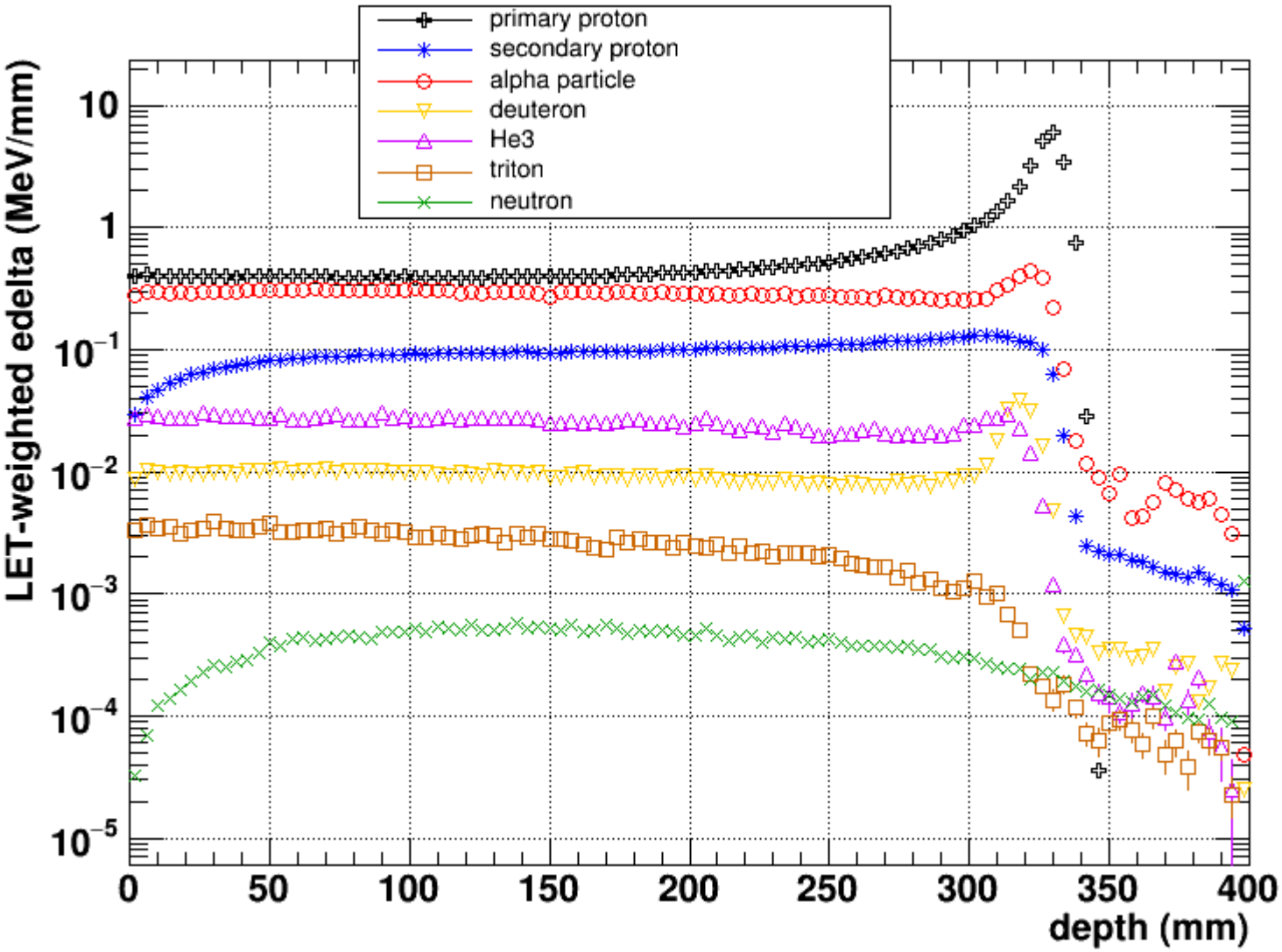
LET-weighted deposited energy 70MeV



LET-weighted deposited energy 230MeV

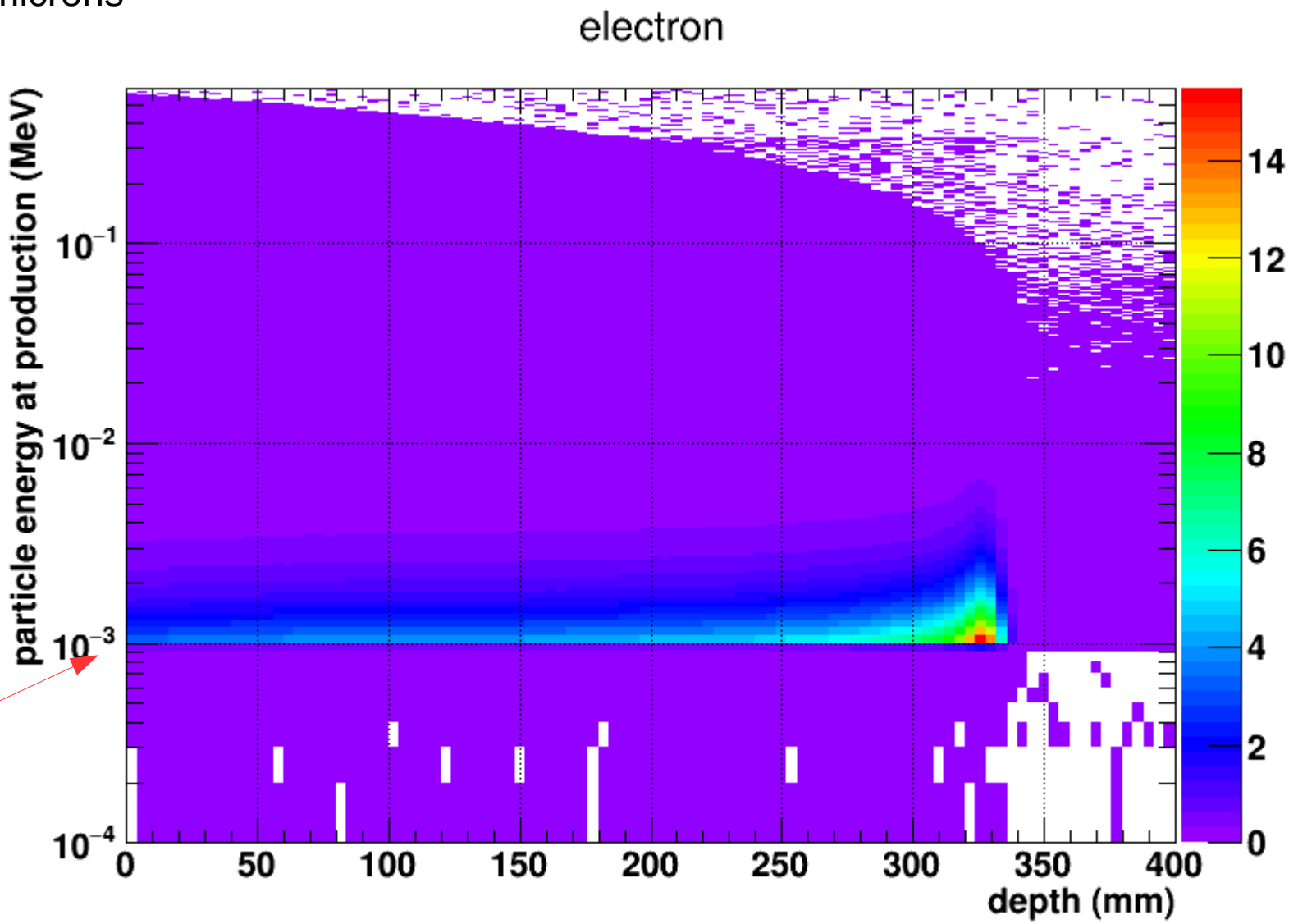


LET-weighted energy loss 230MeV



Electron production at 230MeV with ionization

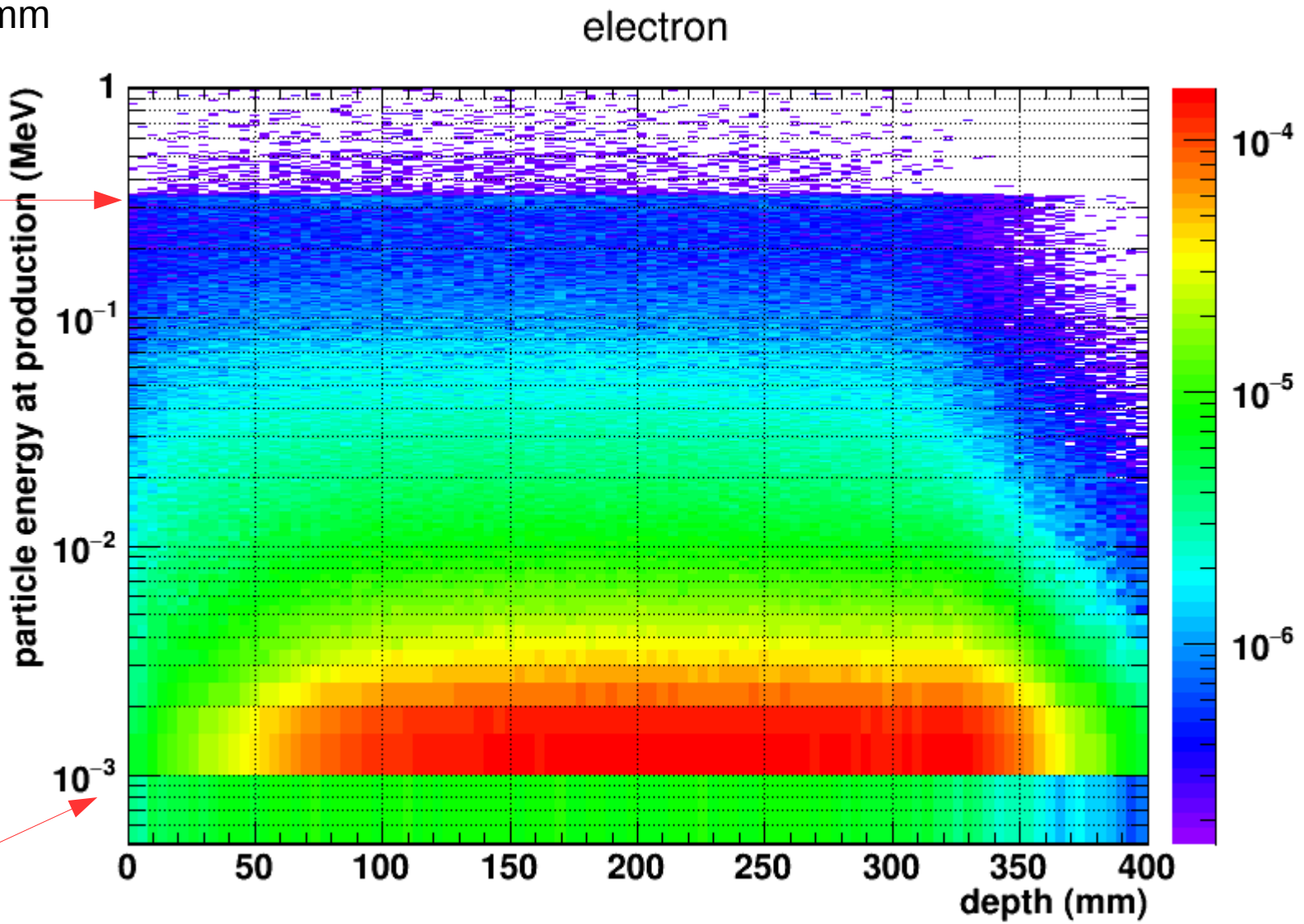
Range cut = 2 microns



990eV safety threshold

Electron production at 230MeV without ionization

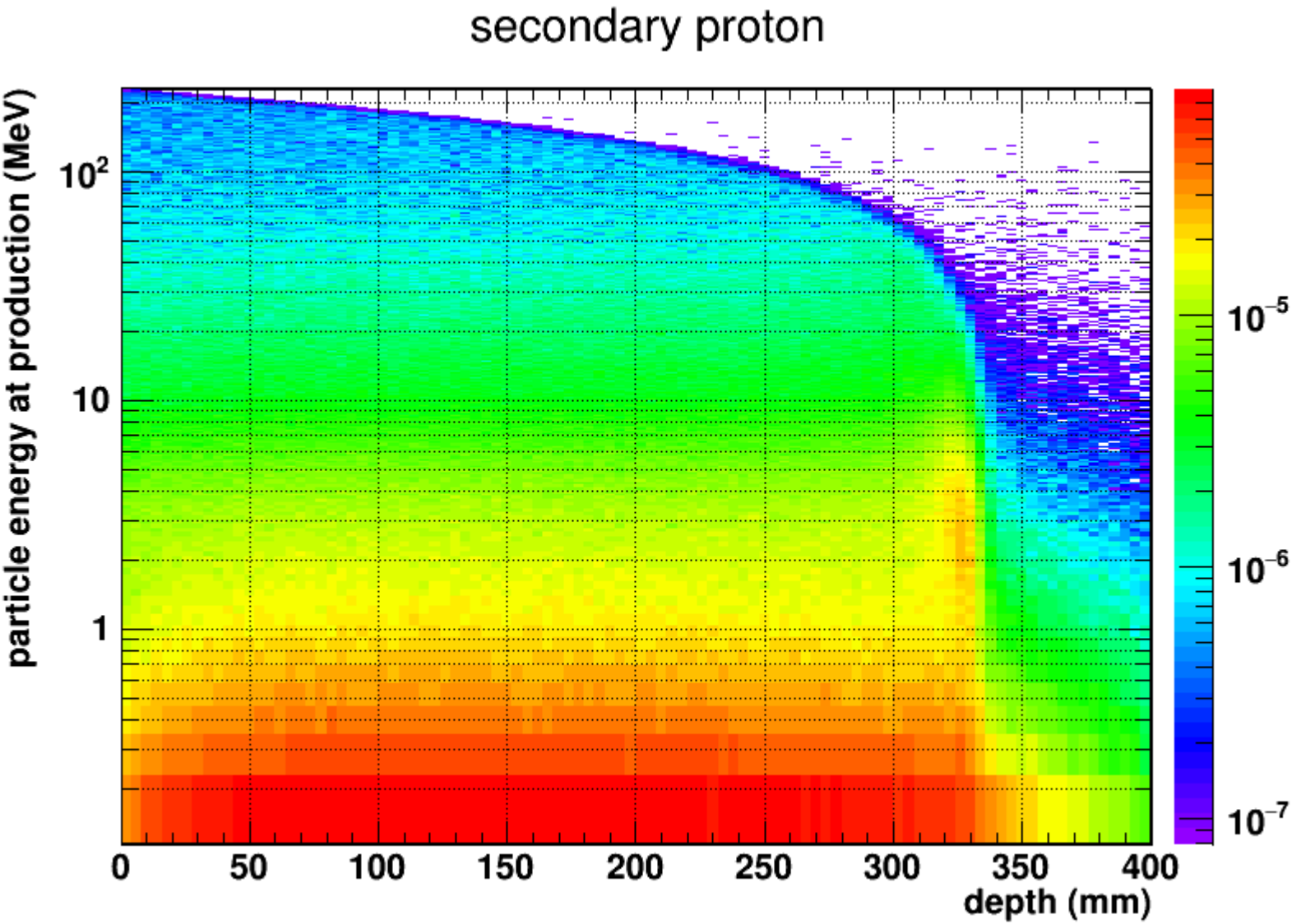
Range cut = 2 mm



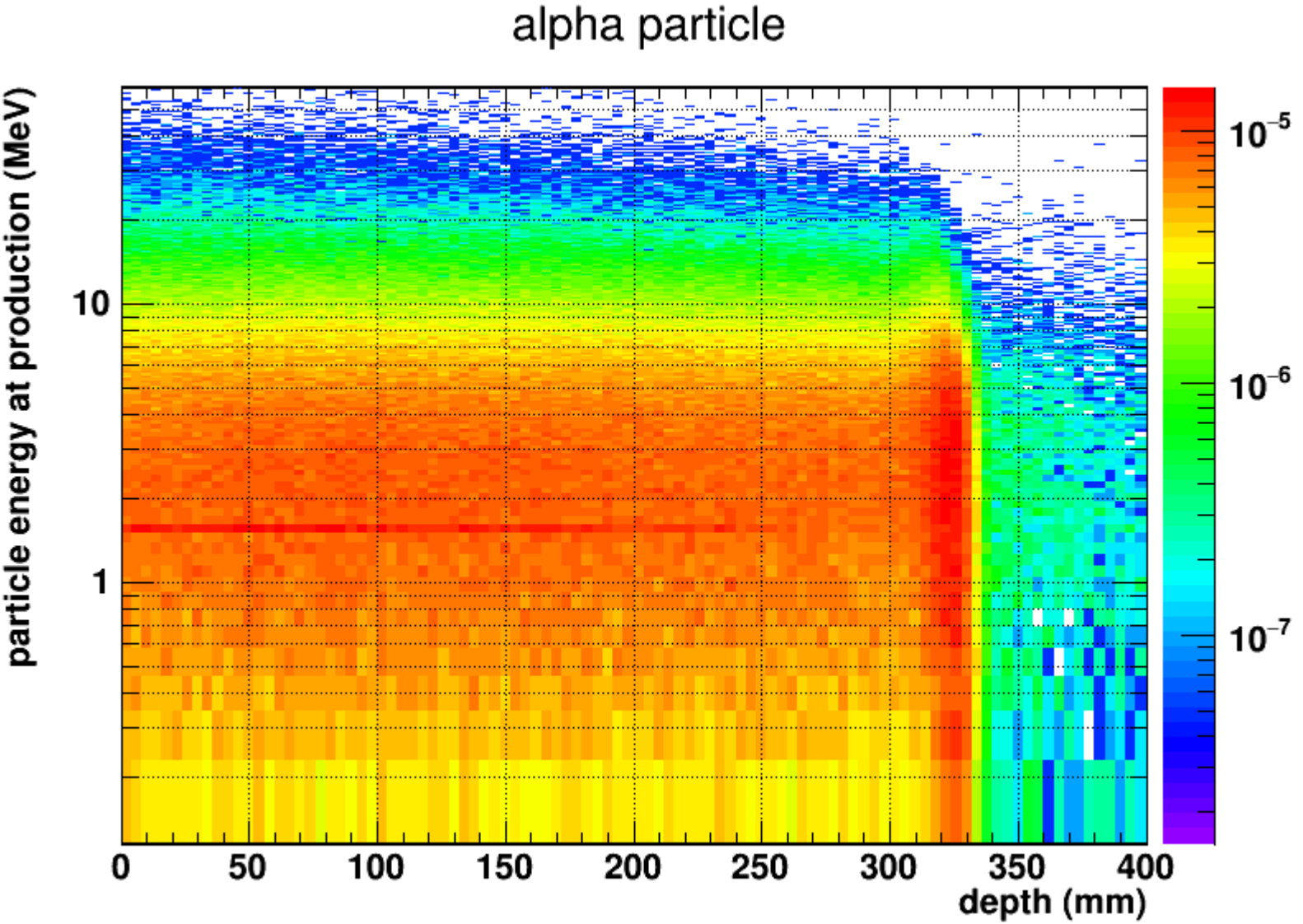
Compton edge of 511keV gammas

990eV safety threshold

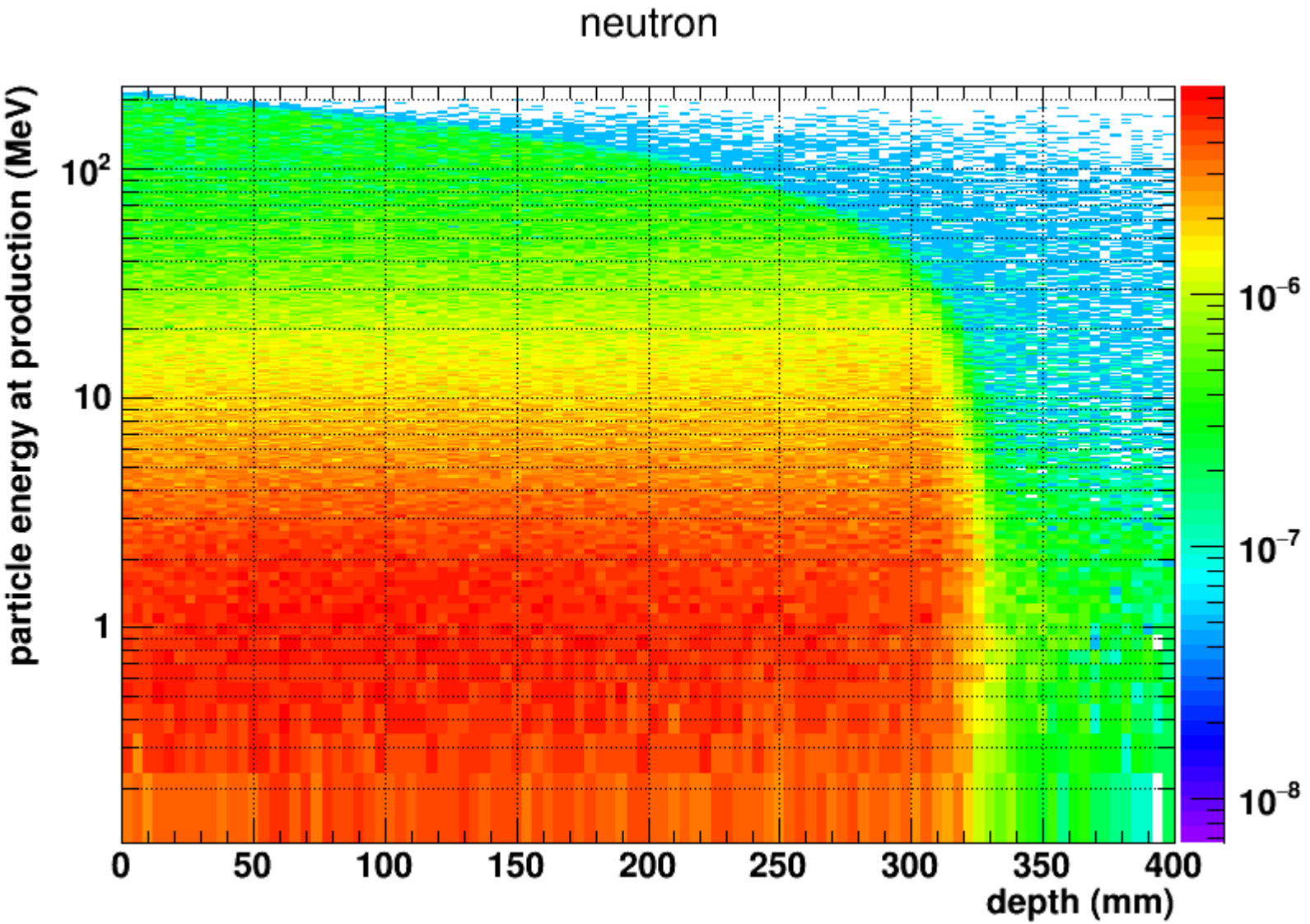
Secondary protons at 230MeV



Alpha particles at 230MeV

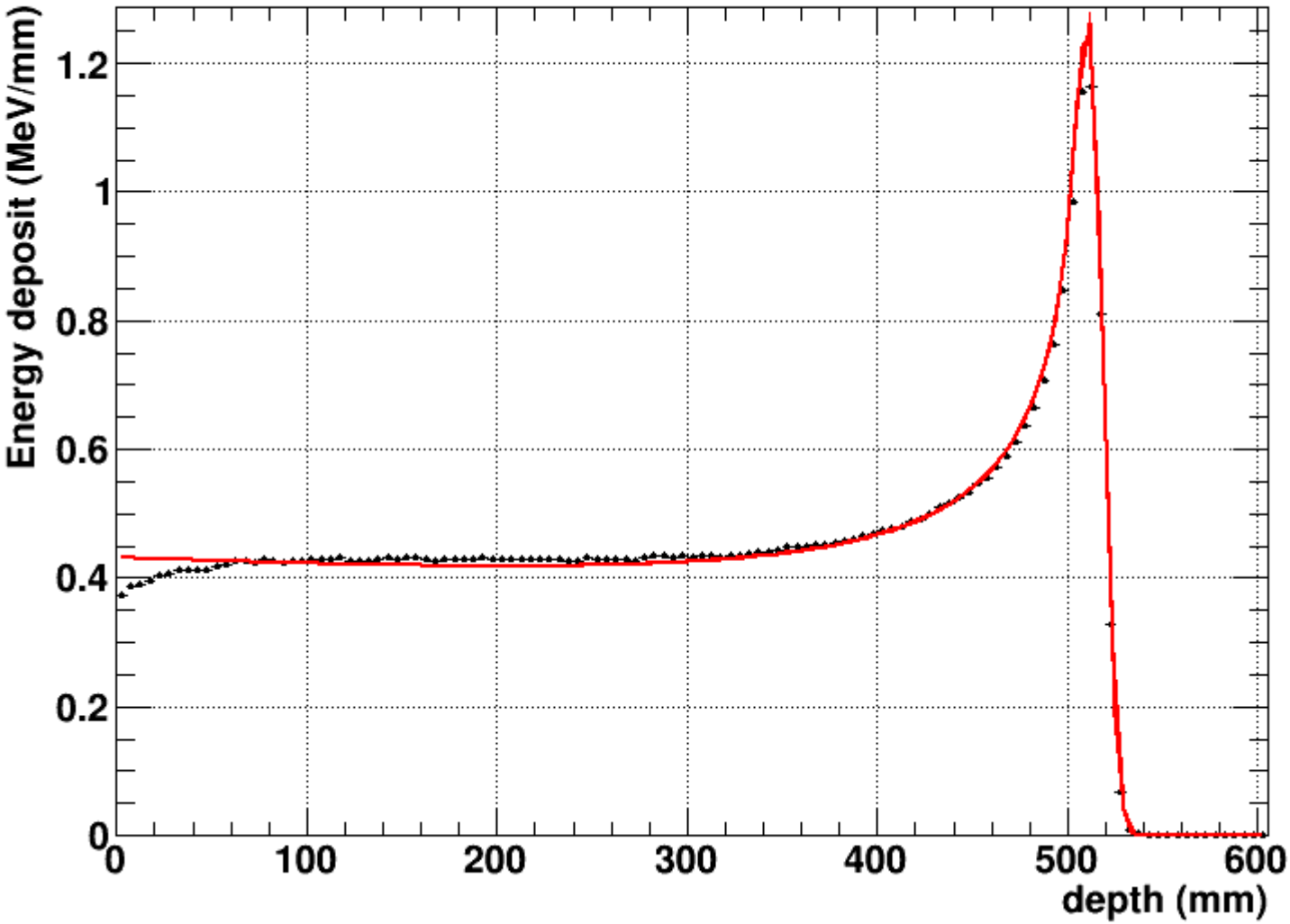


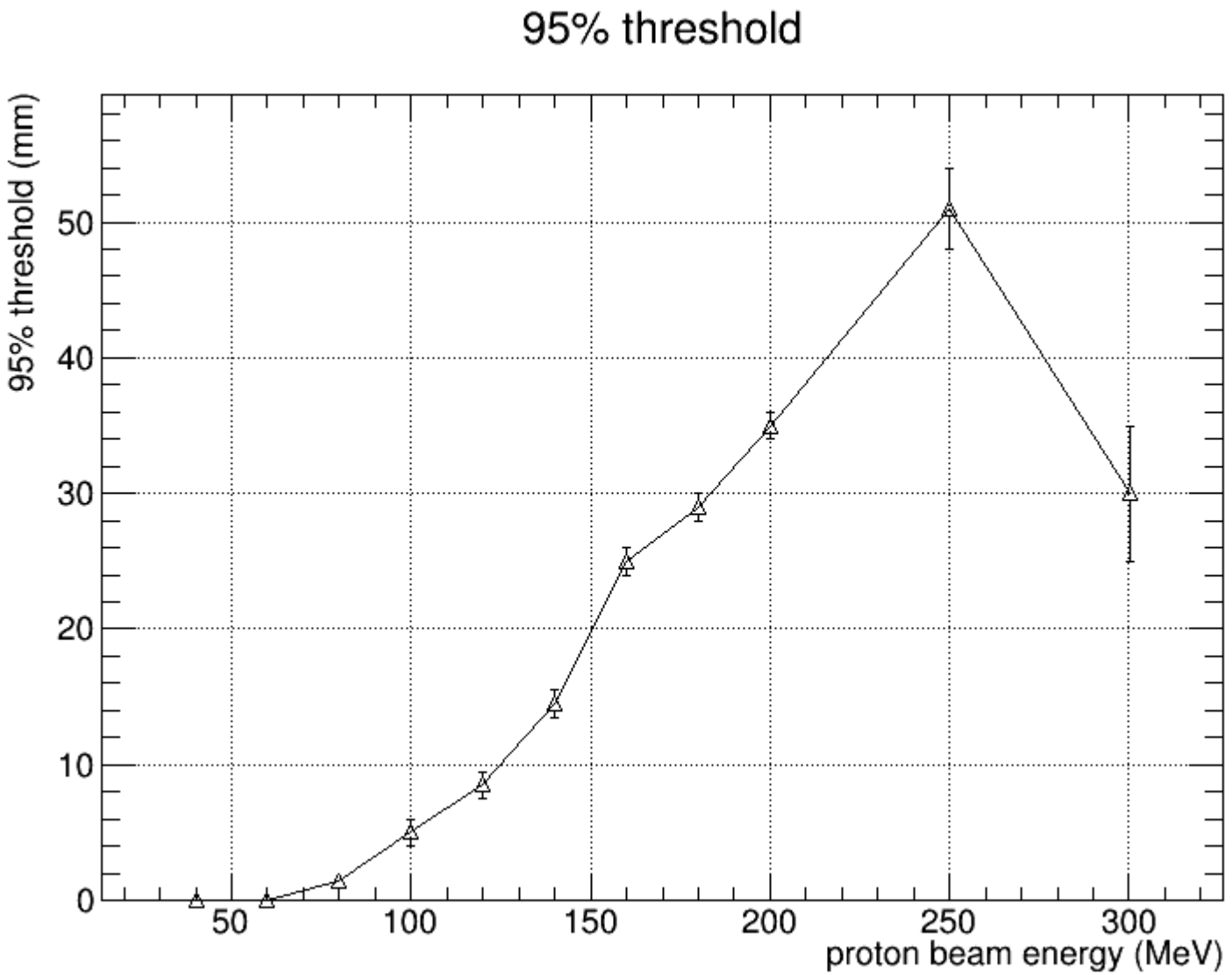
Neutrons at 230MeV



Bragg fit at 300MeV

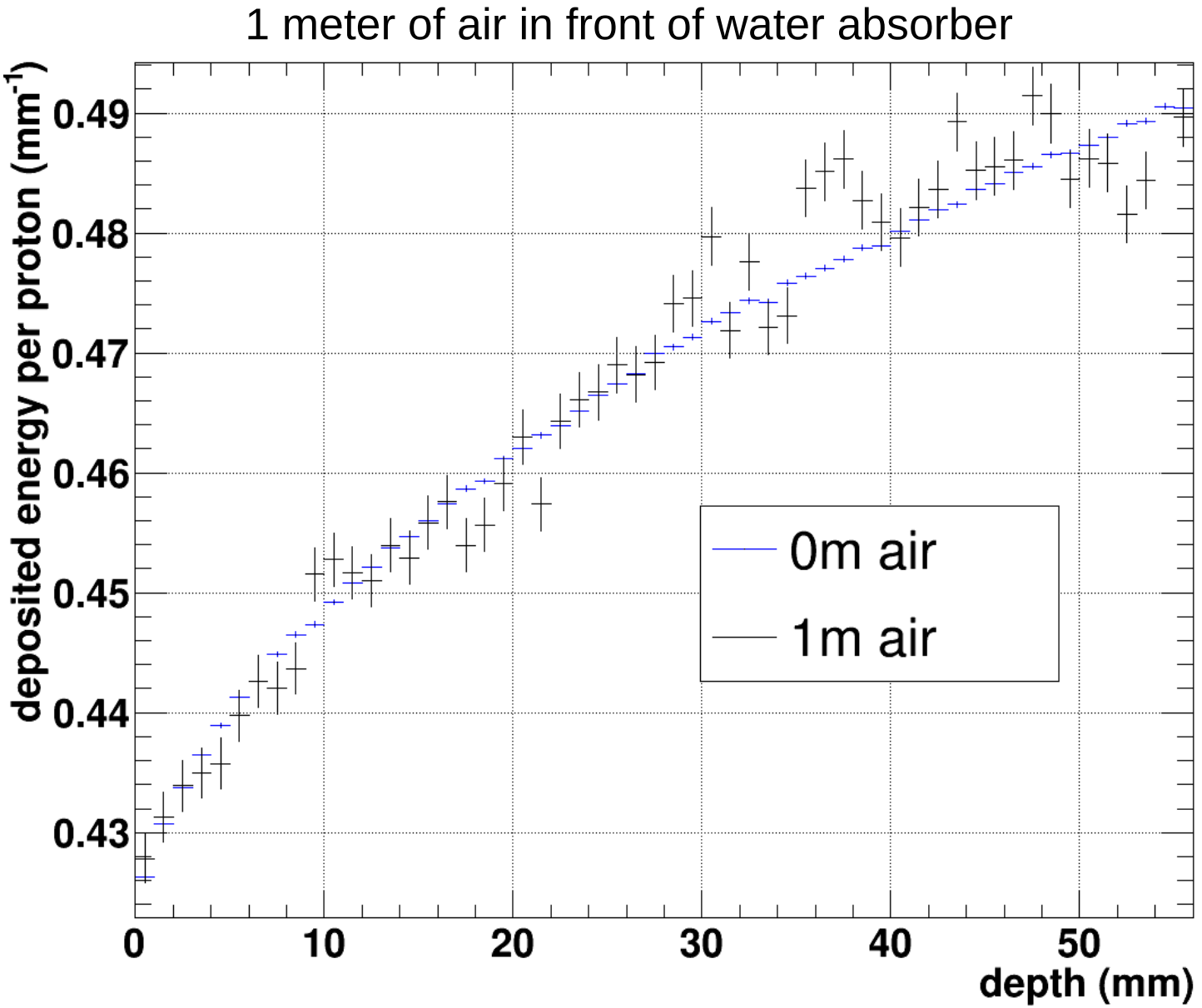
Idea: determine distance at which dose reaches 95% of dose





“where dose reaches 95% of predicted dose”
Predicted dose: define as the y-axis intersection of the fitted Bragg curve

Nuclear buildup with air



Electronic buildup with air

1 meter of air in front of water absorber