Dose Build-Up effect in Proton Therapy and Secondary Particles

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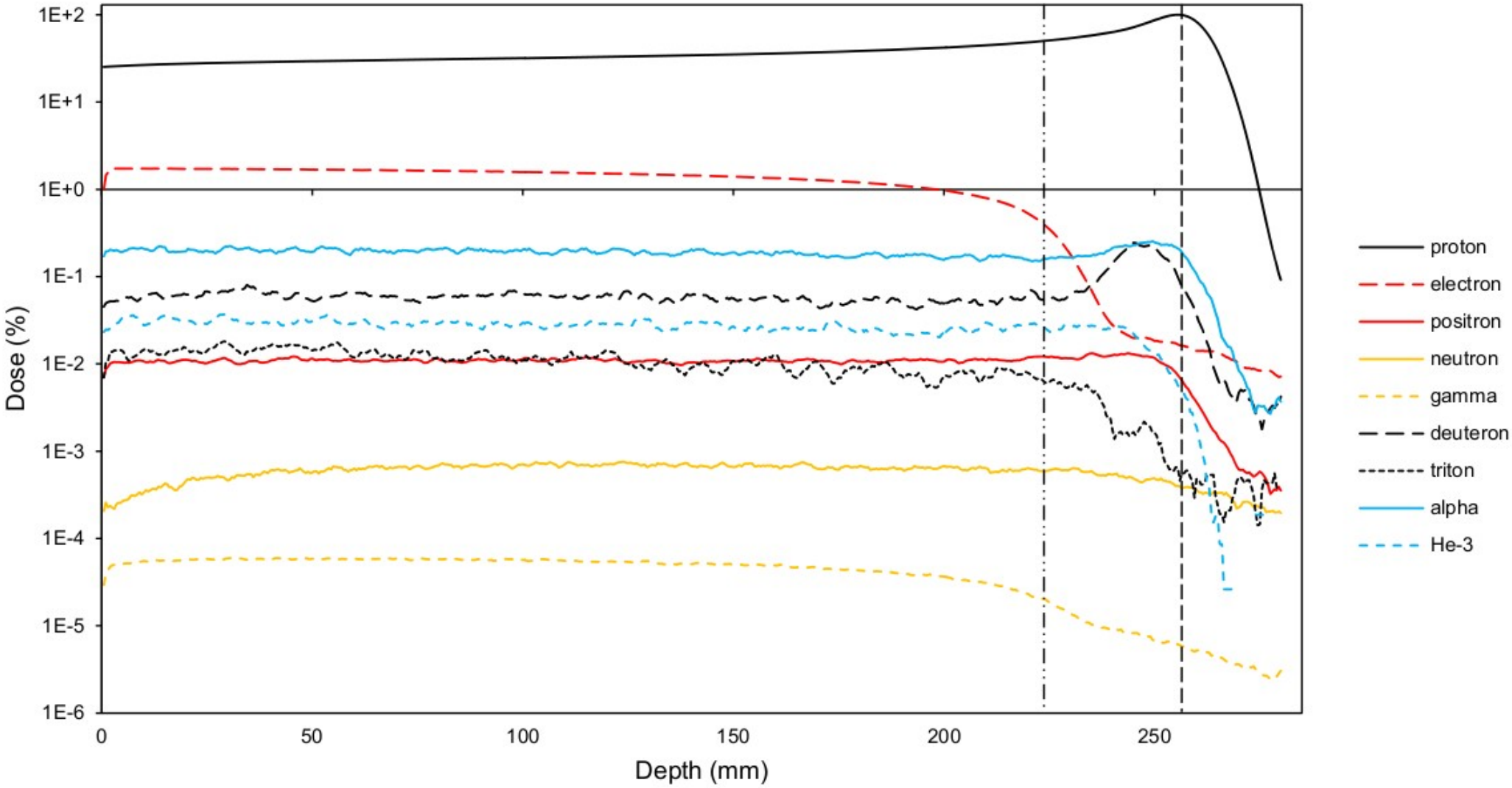
Secondary Particles

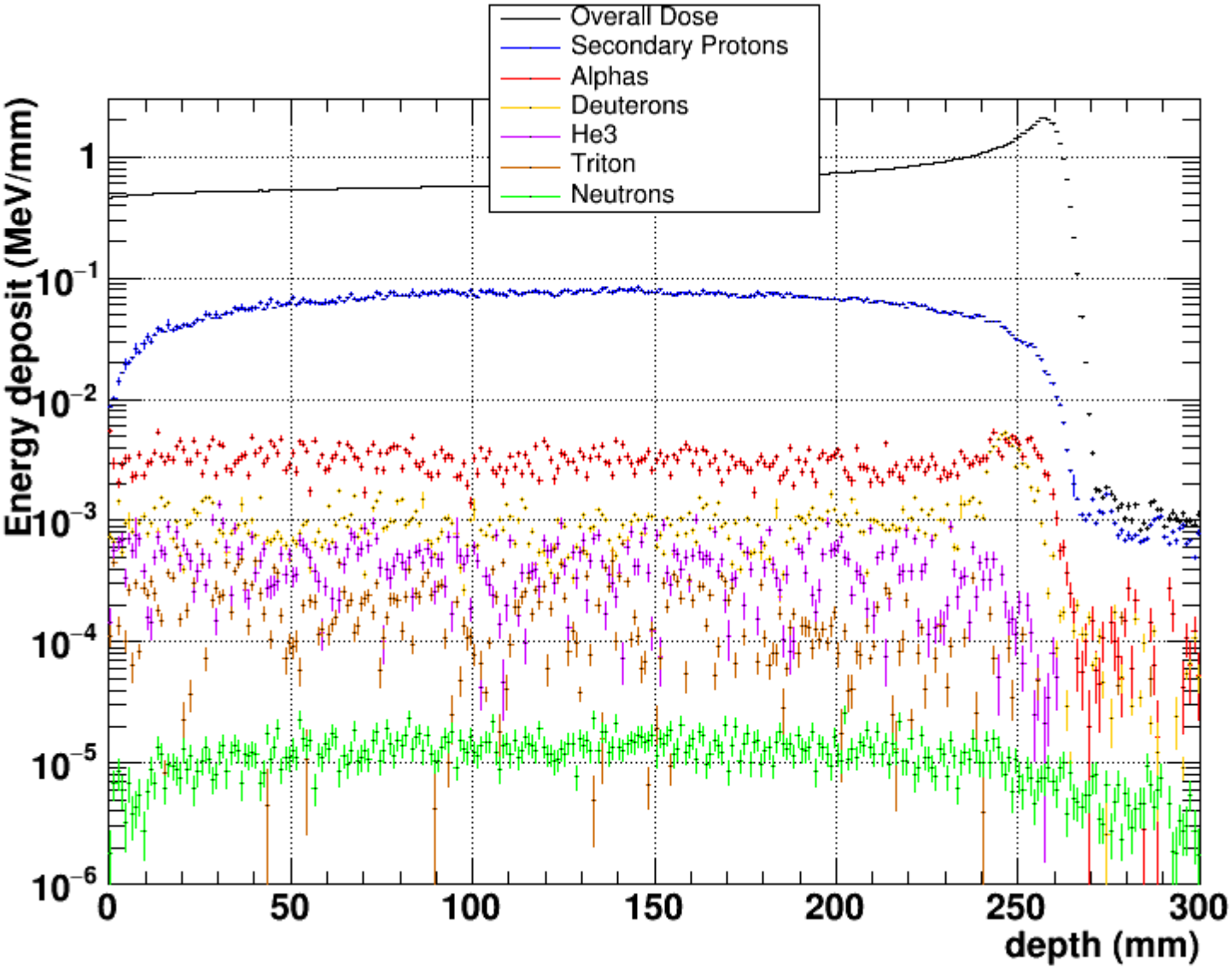
- Difficulties:
  - Range cut determines which secondaries are produced
  - GetTotalEnergyDeposit() doesn't include energy from secondary particles
- Solution: GetDeltaEnergy() returns energy lost in step. This means some energy loss is double-counted. However, as long as all relevant secondaries are produced (range cut small enough), this gives the desired quantity.
- Issues:
  - Positrons not included in simulation yet
  - Secondary protons may be recoiling atoms, deflected beam protons or coming from spallation of oxygen nuclei
  - Is there a meaningful way to define deposited energy by electrons?
  - Is the used range cut of 0.02mm small enough?

200MeV proton beam on water phantom (Ben)



Range cut unknown. Probably = 0.2mm

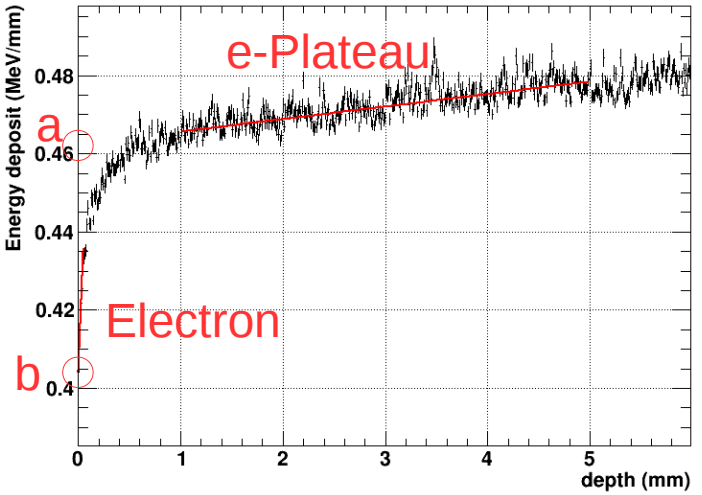
200MeV proton beam on water phantom



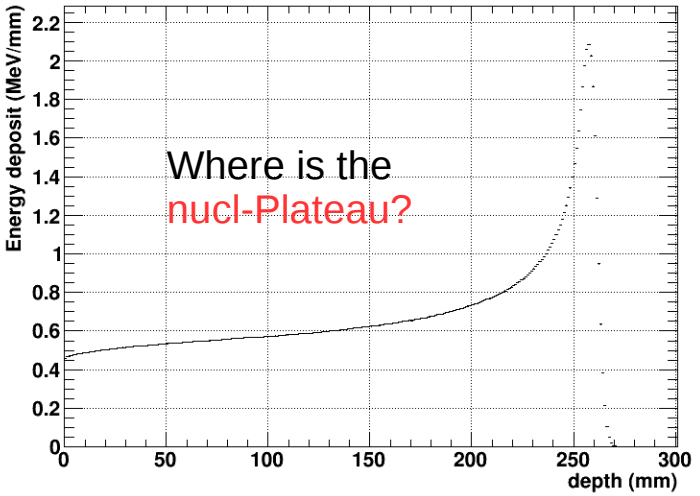
Range cut = 0.02mm

Buildup Effect

- Electronic buildup observed and defined the same way as last week
- BU = (a-b)/a

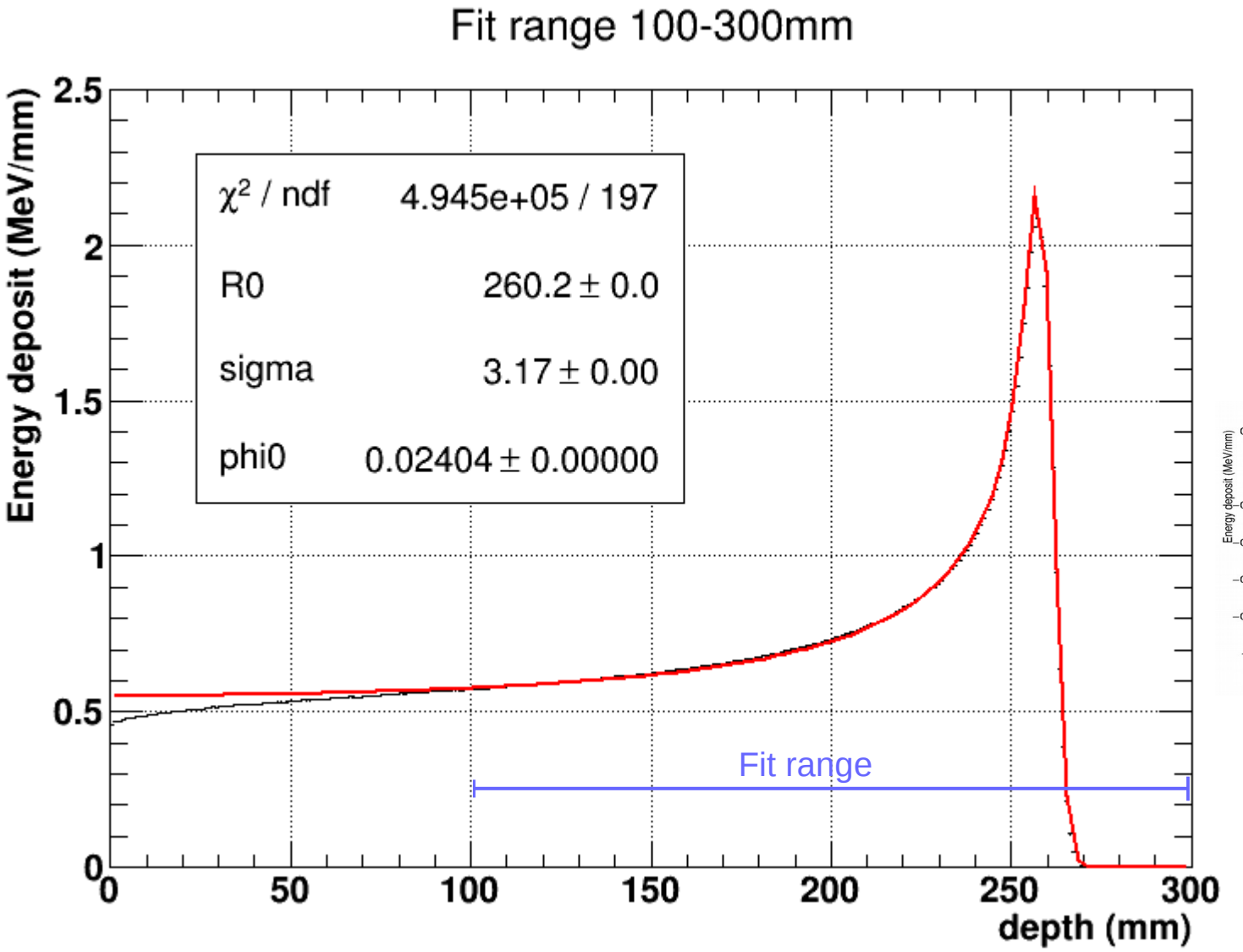


- Nuclear build-up more difficult to define since no nucl-Plateau is easily identified
- Nuclear BU happens on such a large scale that dEdx-raise interferes

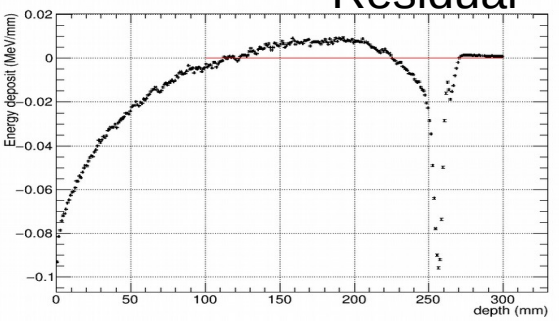


Nuclear and total buildup

- Idea: Use nice Bragg-curve fit to estimate dose without any buildup effect (Plateau)

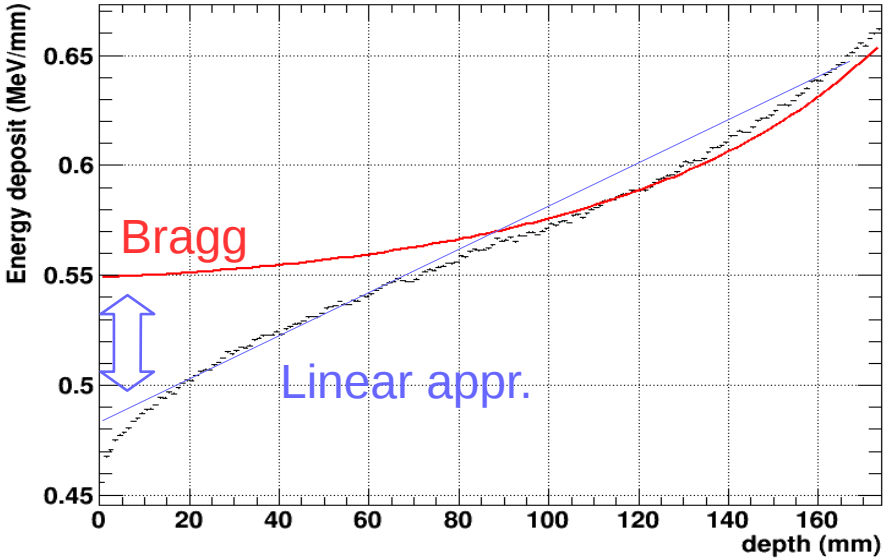


Residual



Nuclear and total buildup

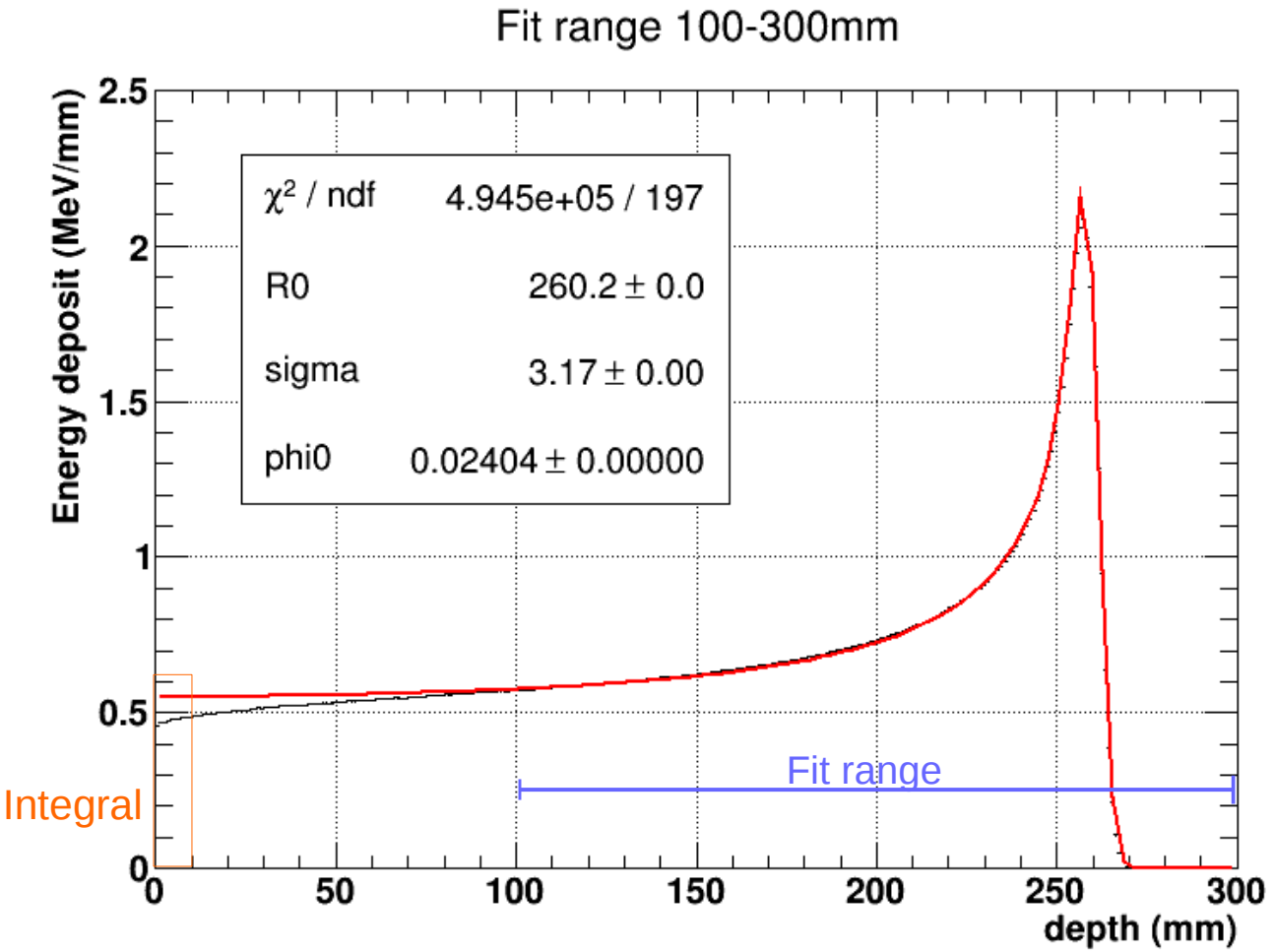
- Comparison Bragg-fit to linear Plateau approximation:



- Differentiate between
  - Total (Bragg to Electron)
  - Electron (e-Plateau to Electron)
  - Nuclear (Bragg to Plateau)

Buildup

200MeV
On water
phantom

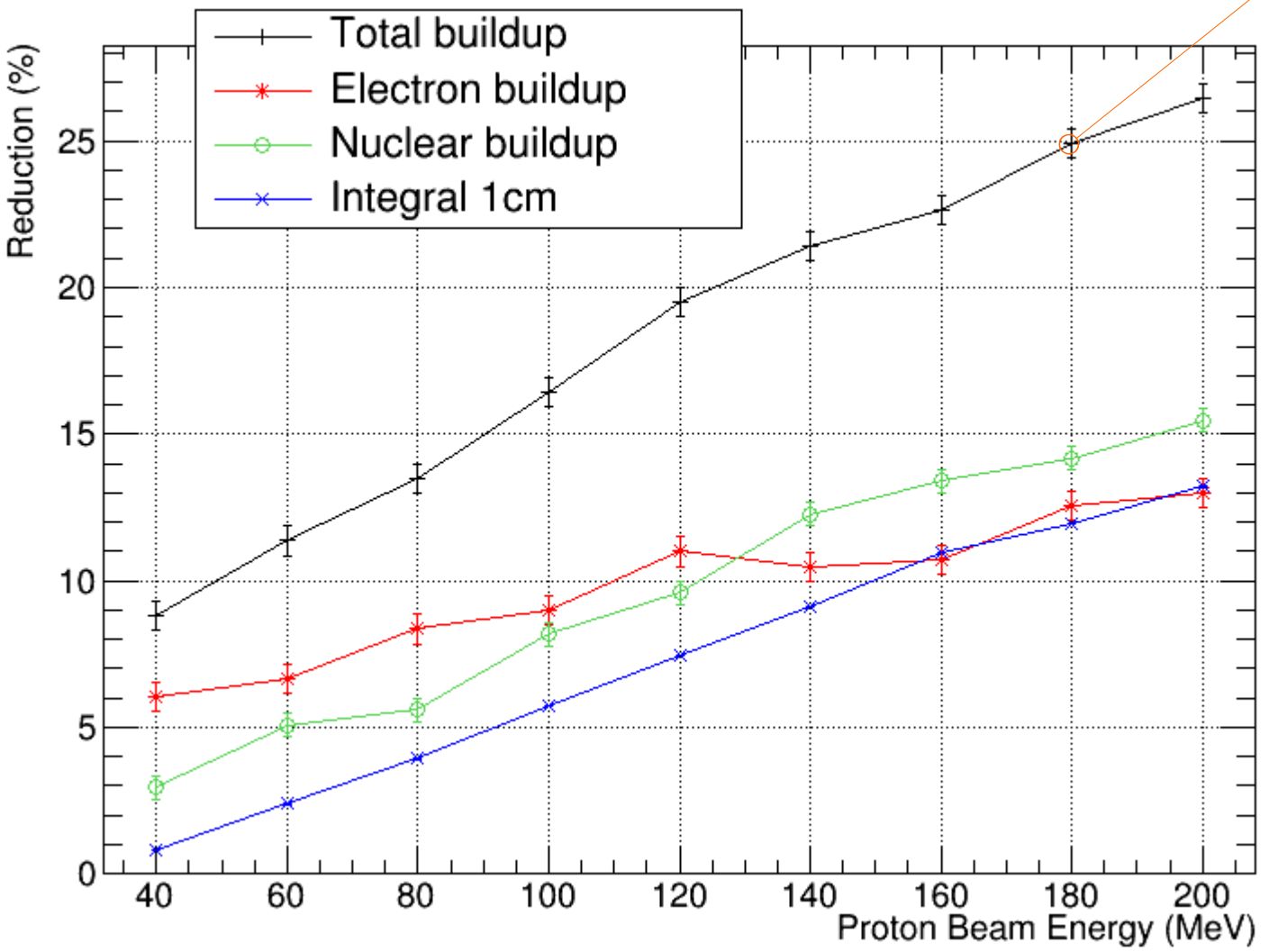


Buildup Quantisation:

Total: **26%**
Electron: **13%**
Nuclear: **16%**

Reduction of dose in 1 cm depth is about **13%**
(ratio of dose integrals fit/simulation)

Buildup vs. Energy



Error bars from fit-range variation