Hadronic containment in a Liquid Argon test beam

Pawel Guzowski

University of Manchester

Outline

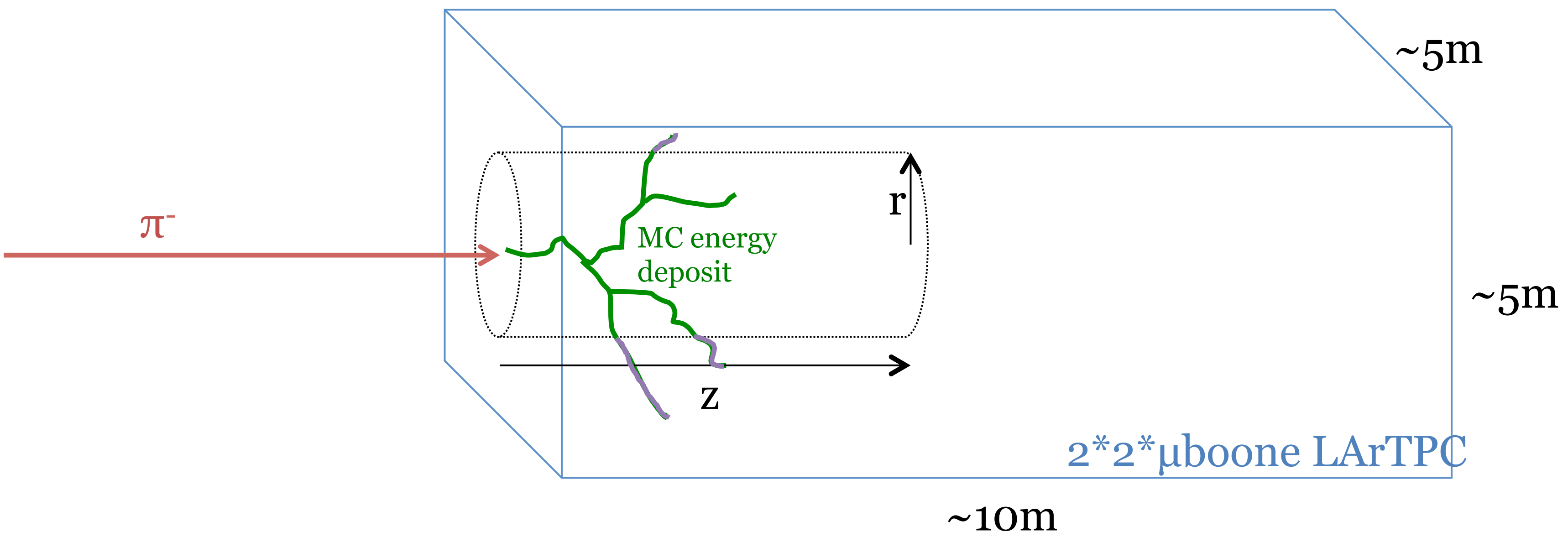
- Definition of containment
- Treatment of neutrons
- Pion containment
- Proton containment
- π^0 containment

Introduction

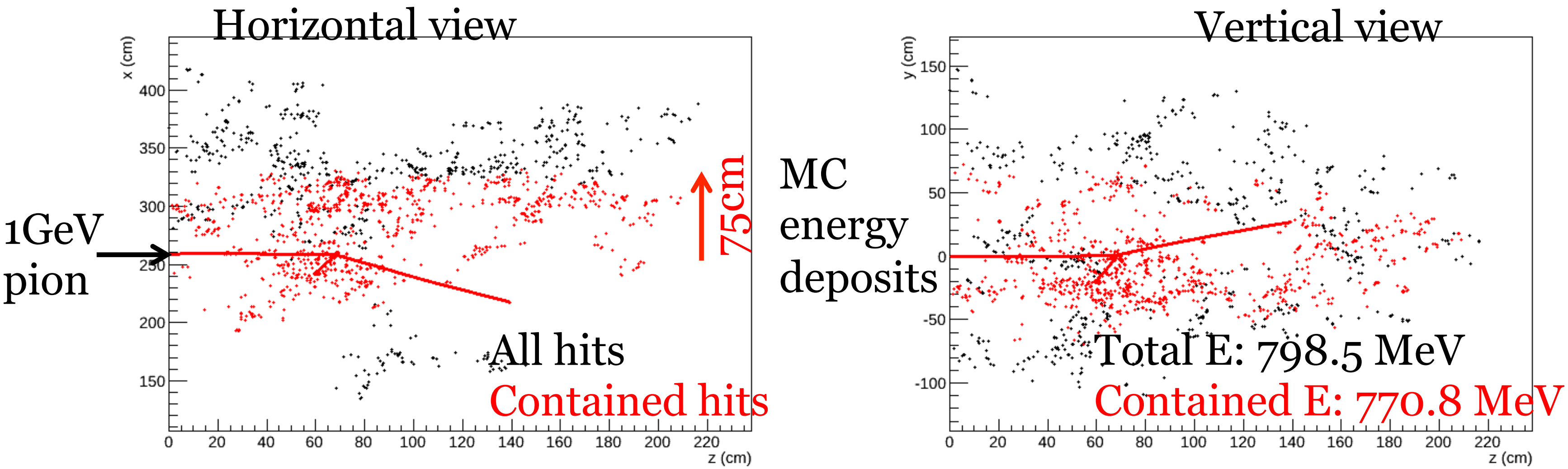
- Presented here is a study I performed for the LArIAT Phase 2 proposal
- This study was performed >3 years ago
  - Apologies if my memory is a bit hazy
- The goal was to study hadronic containment, to influence the design of the detector, specifically the dimensions required
- The study was performed with LarSoft version "S2012.05.09"

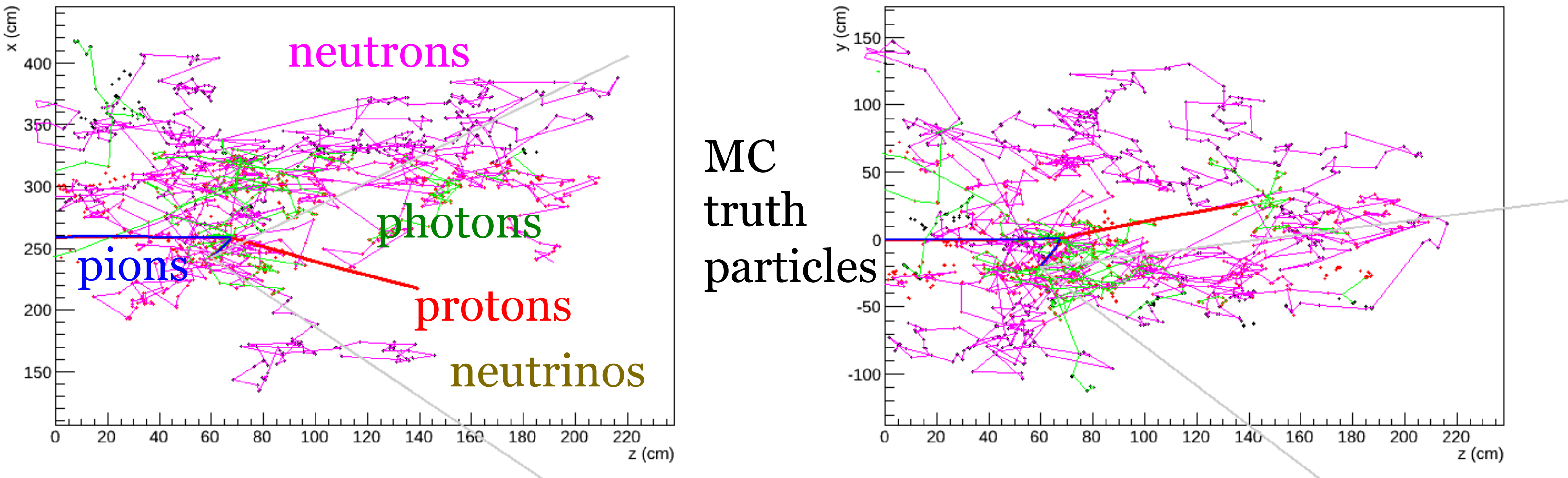
Quantifying containment

- Fire hadrons at an expanded microboone detector simulation (double width & double height)
- Determine what fraction of total energy deposit is contained inside cylinder (r,z) around particle axis
  - Numerically: (Sum of energy in cylinder) / (Total energy in whole detector)



Relatively poor containment due to neutrons

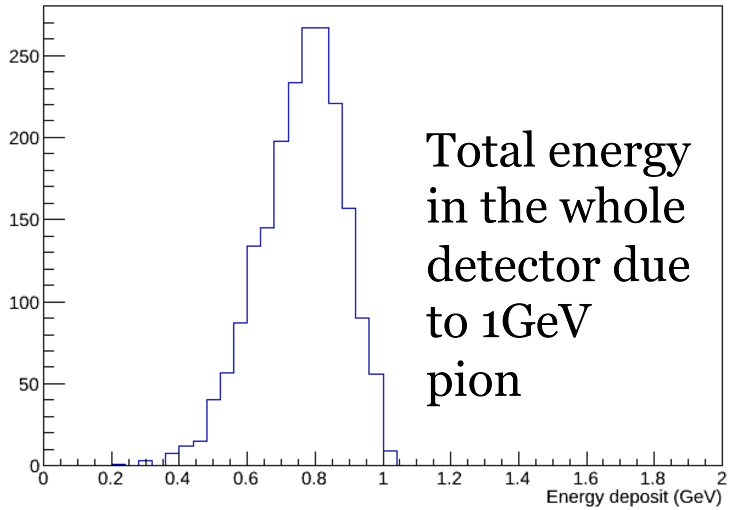


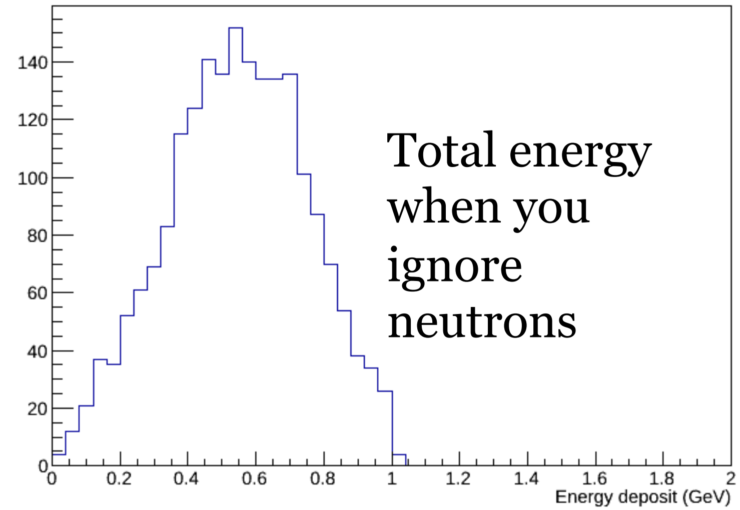


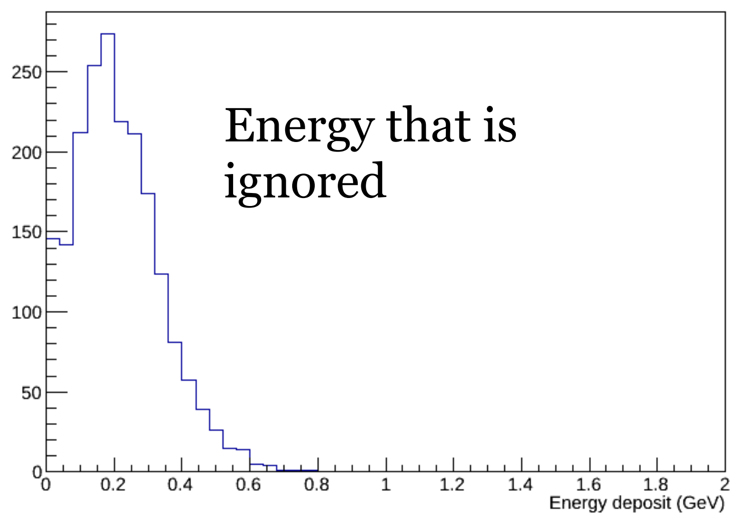
Strategy for neutrons

- Three strategies available for dealing with neutrons
  1. Ignore them completely
  2. Have a KE cut
  3. Have a time cut
  4. Noise floor – not simulated
- Probably a combination of 2&3 is the best

Ignoring neutrons

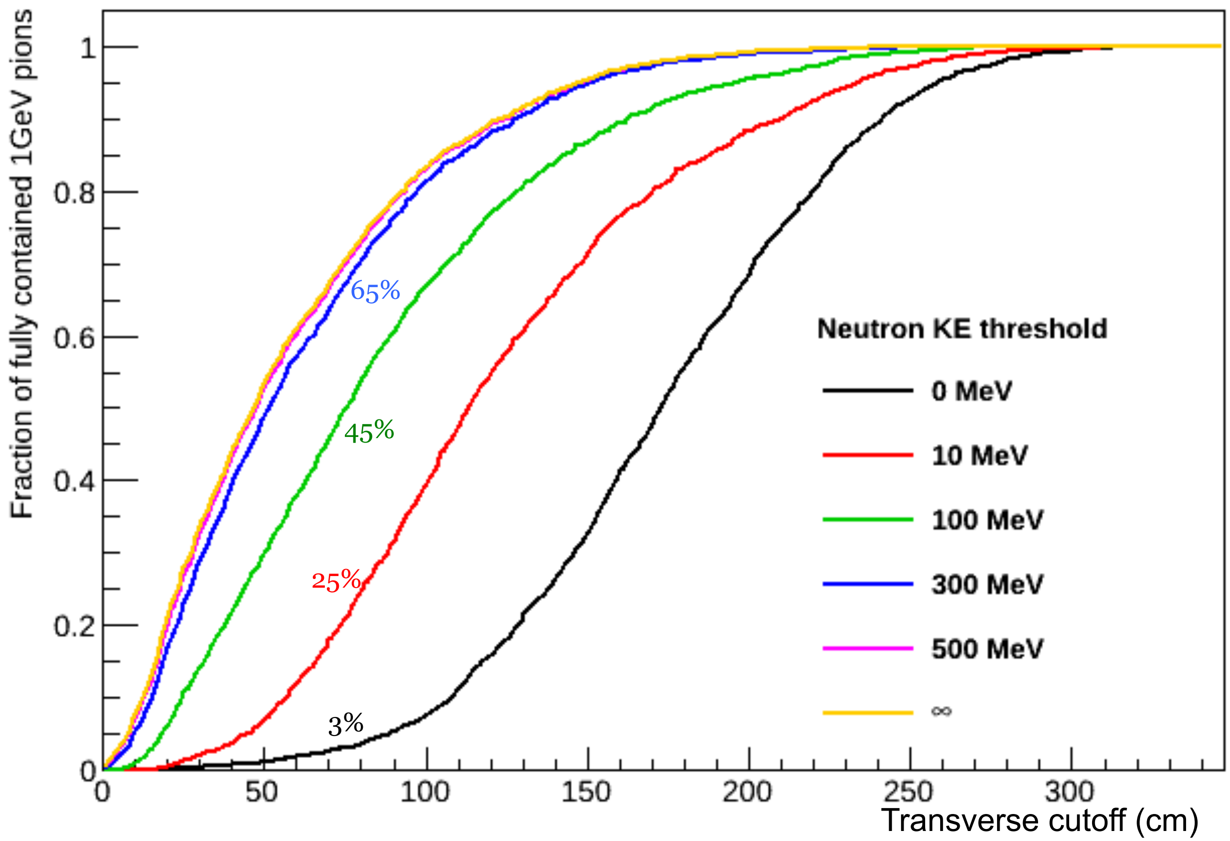






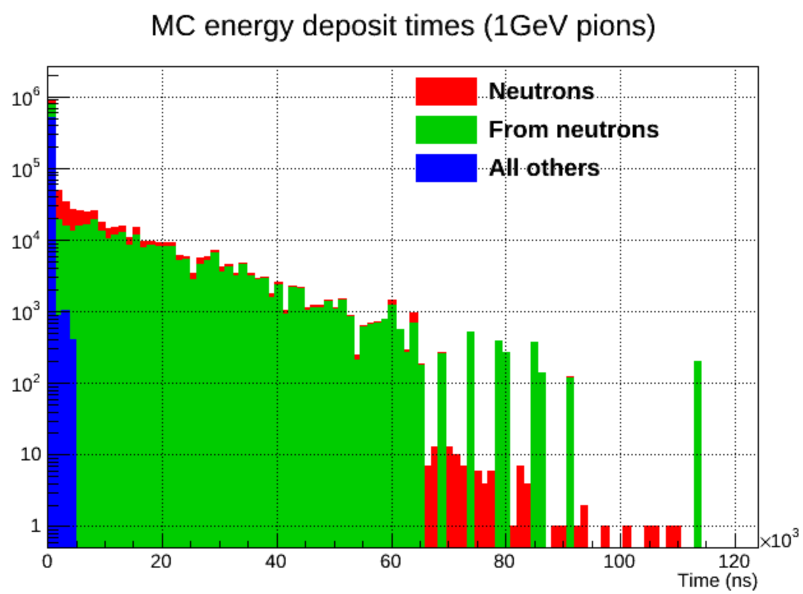
Neutron KE cuts

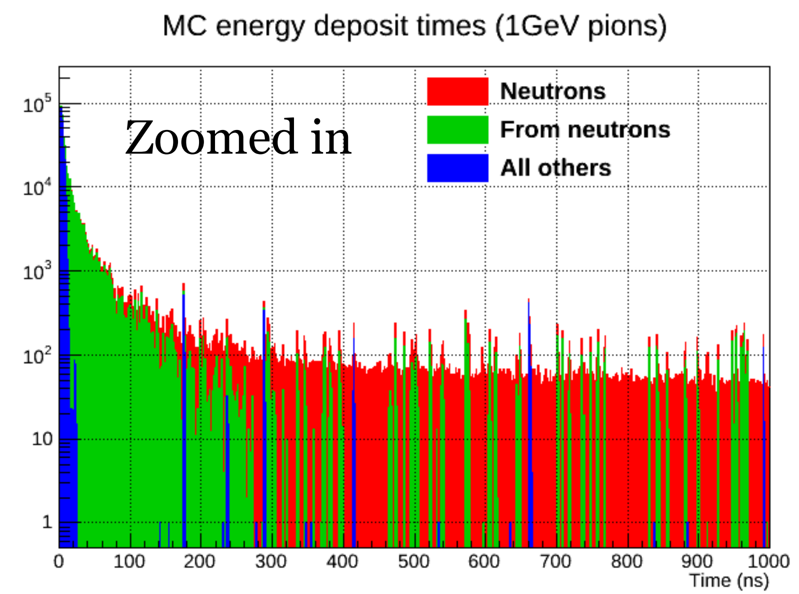
- Ignore hits produced by neutrons below KE thresh



Neutron time cuts

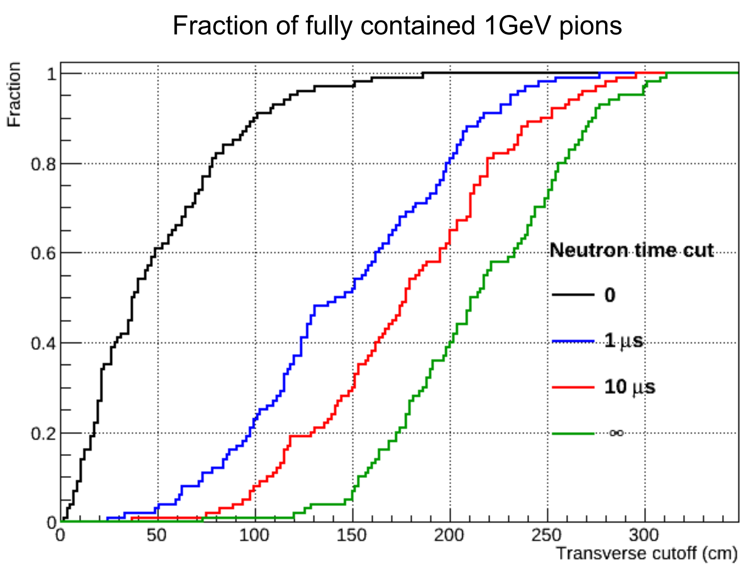
- Geant4 has a default neutron tracking time cut of 10μs
- However neutron times extend up to 120μs

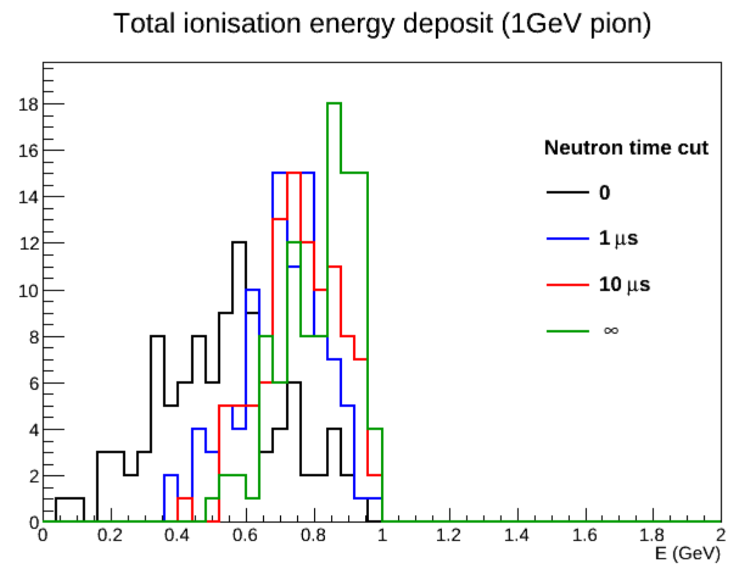




Effects of time cut

- Ignore hits produced by neutrons after time thresh





(Apologies for poor statistics, as these had to be regenerated after altering GEANT4)

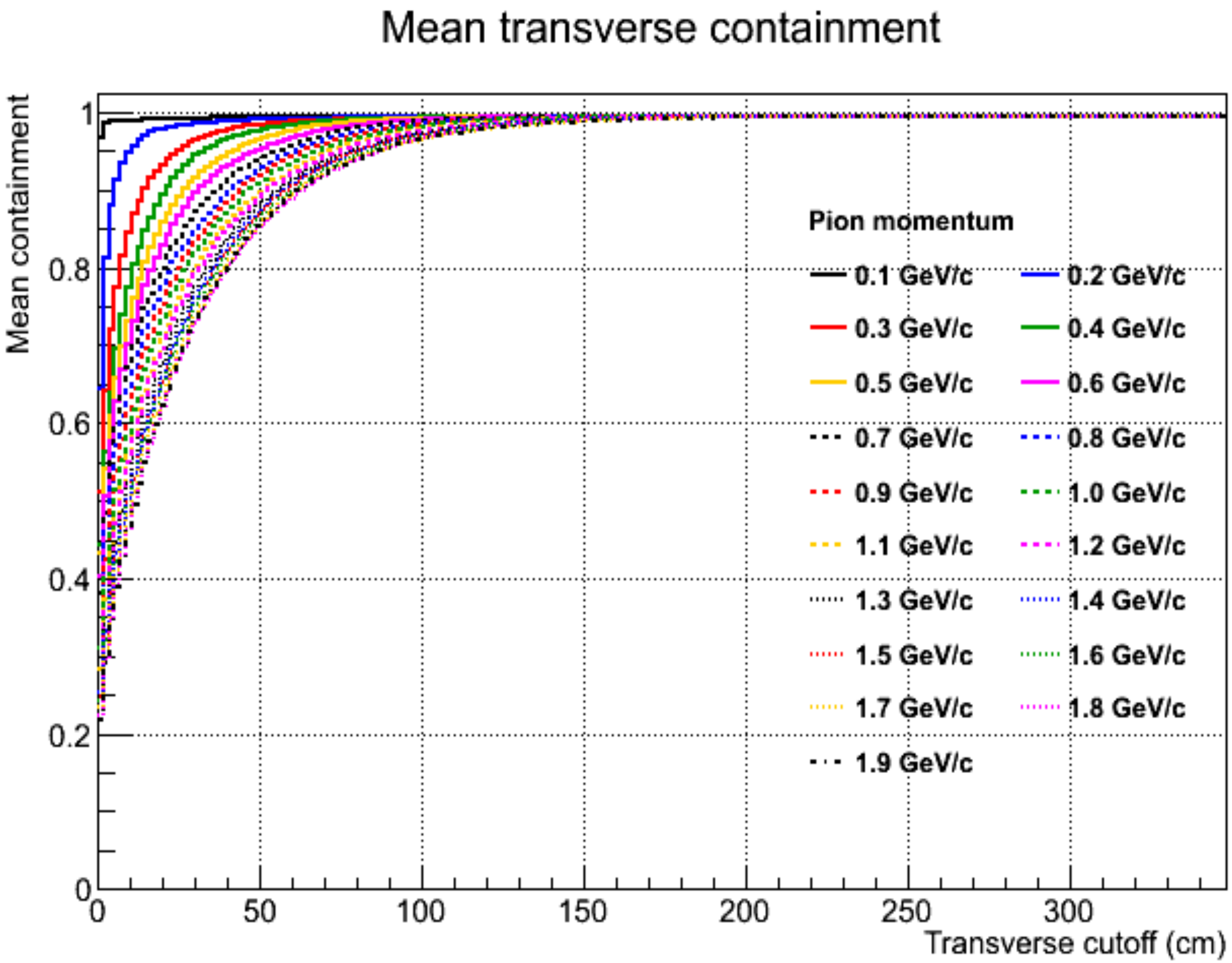
Handling neutrons

- These neutron hits are in theory reconstructable.
  - Without a good handle on t_o, how much use are they?
- Do you really want these neutron hits to be a significant input to deciding the size of the detector?
- Remainder of the plots in this presentation are with neutrons hits removed.

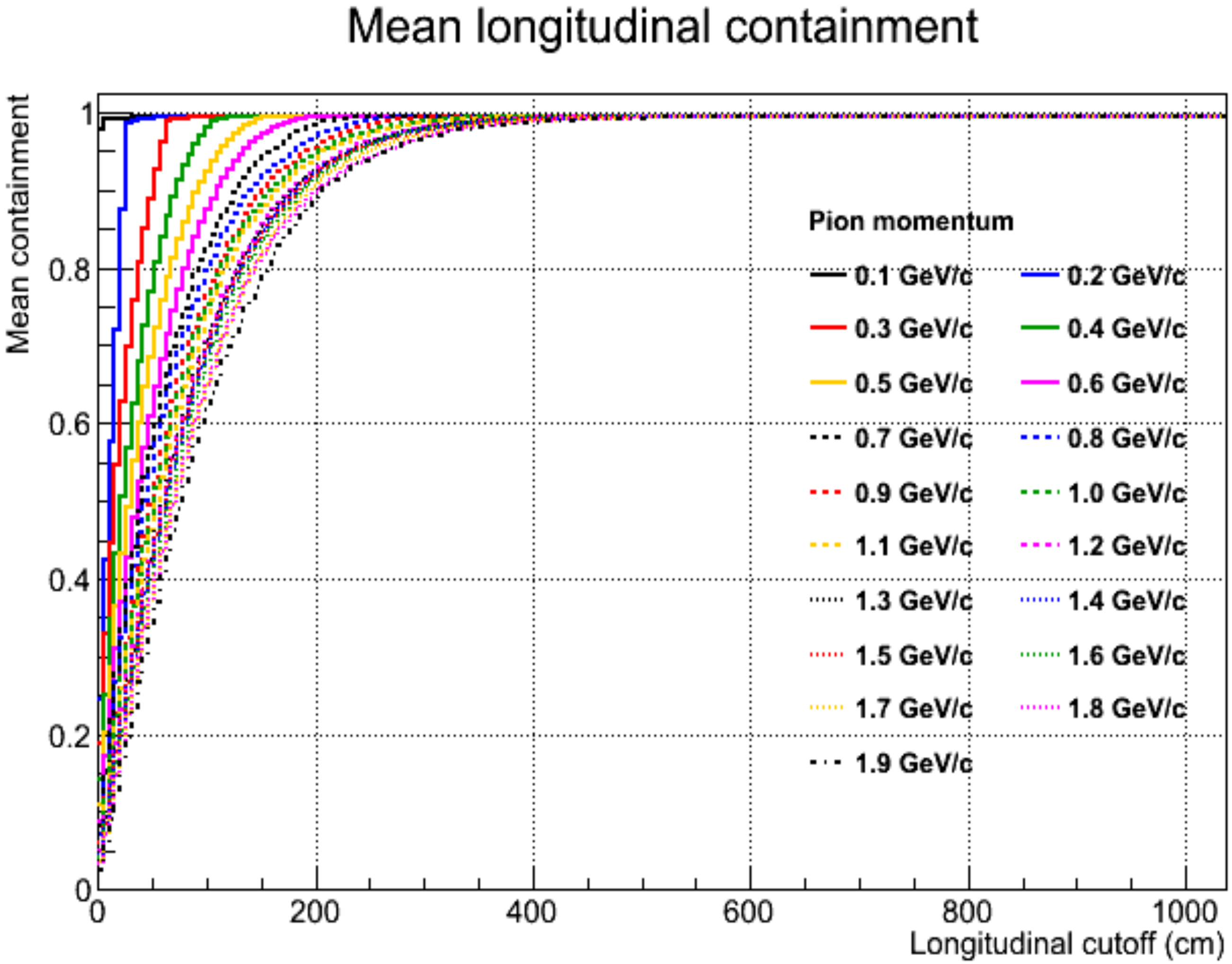
Pions

- 0—2 GeV/c momentum range
- These plots ignore neutrons
  - Neutron-inclusive plots in backups for comparison
  - But for quick reference, at 75cm radius:
    - ~5% fully contained 1 GeV/c pions
    - ~85% mean containment for 1GeV/c pions

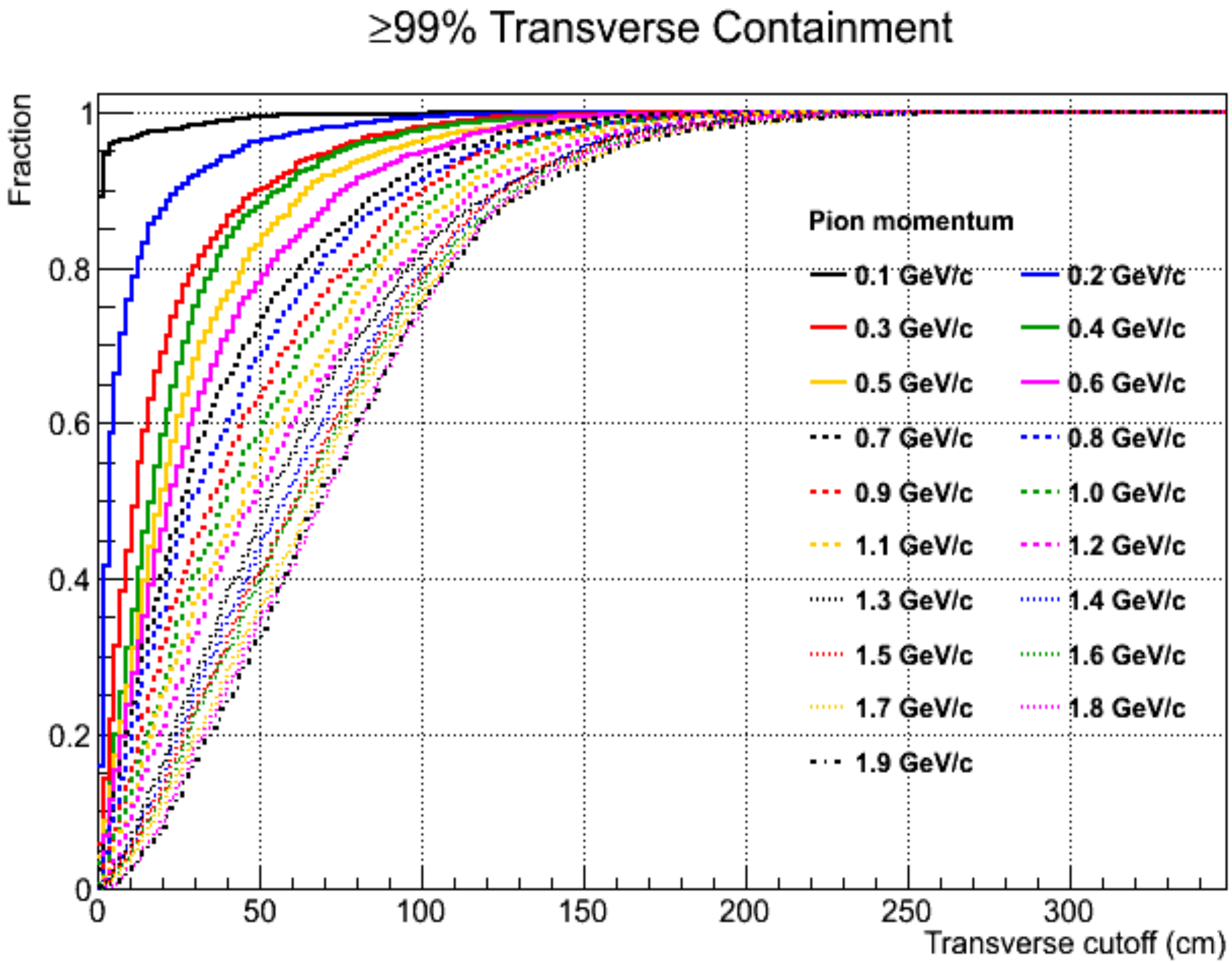
Pion containment



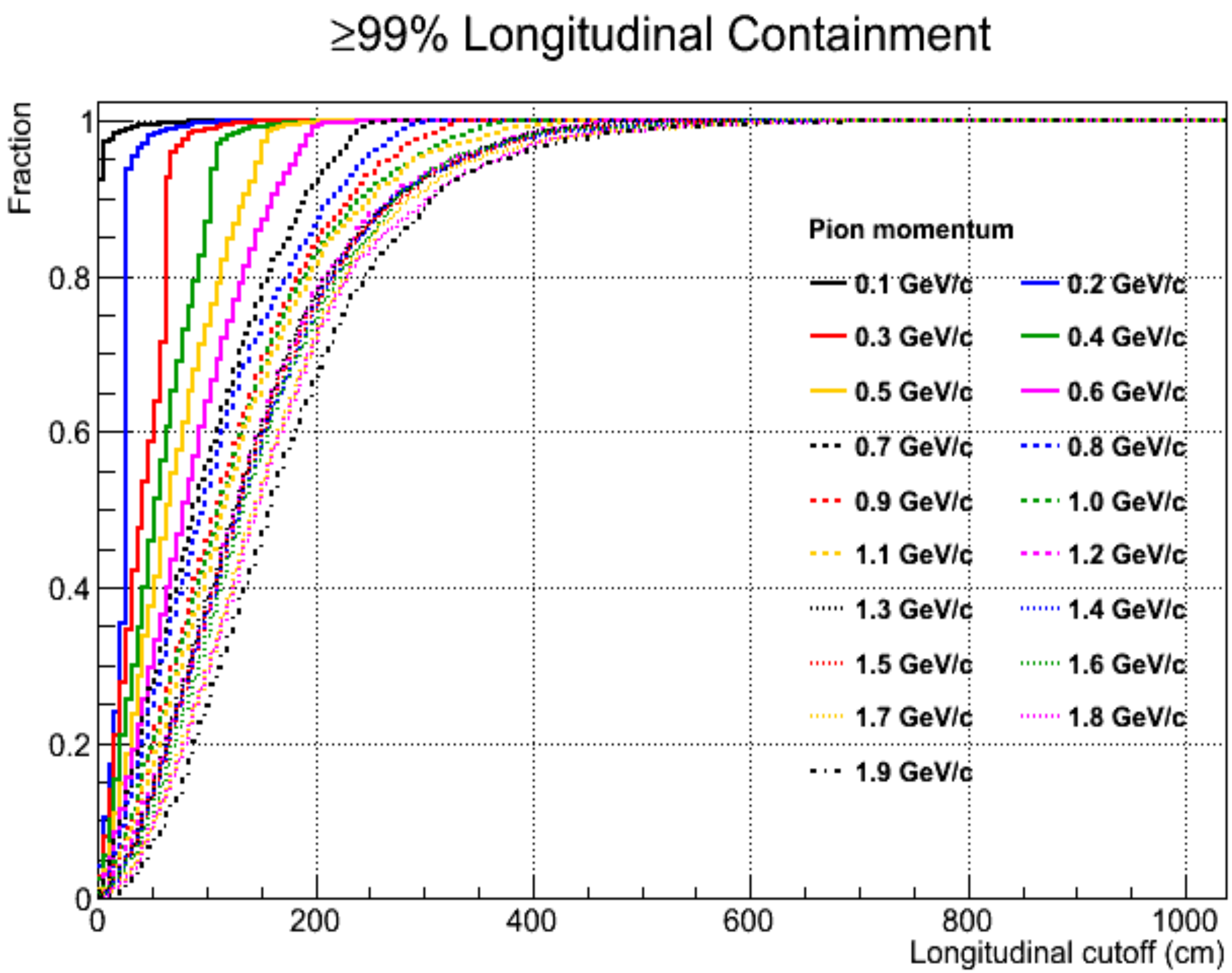
Pion containment



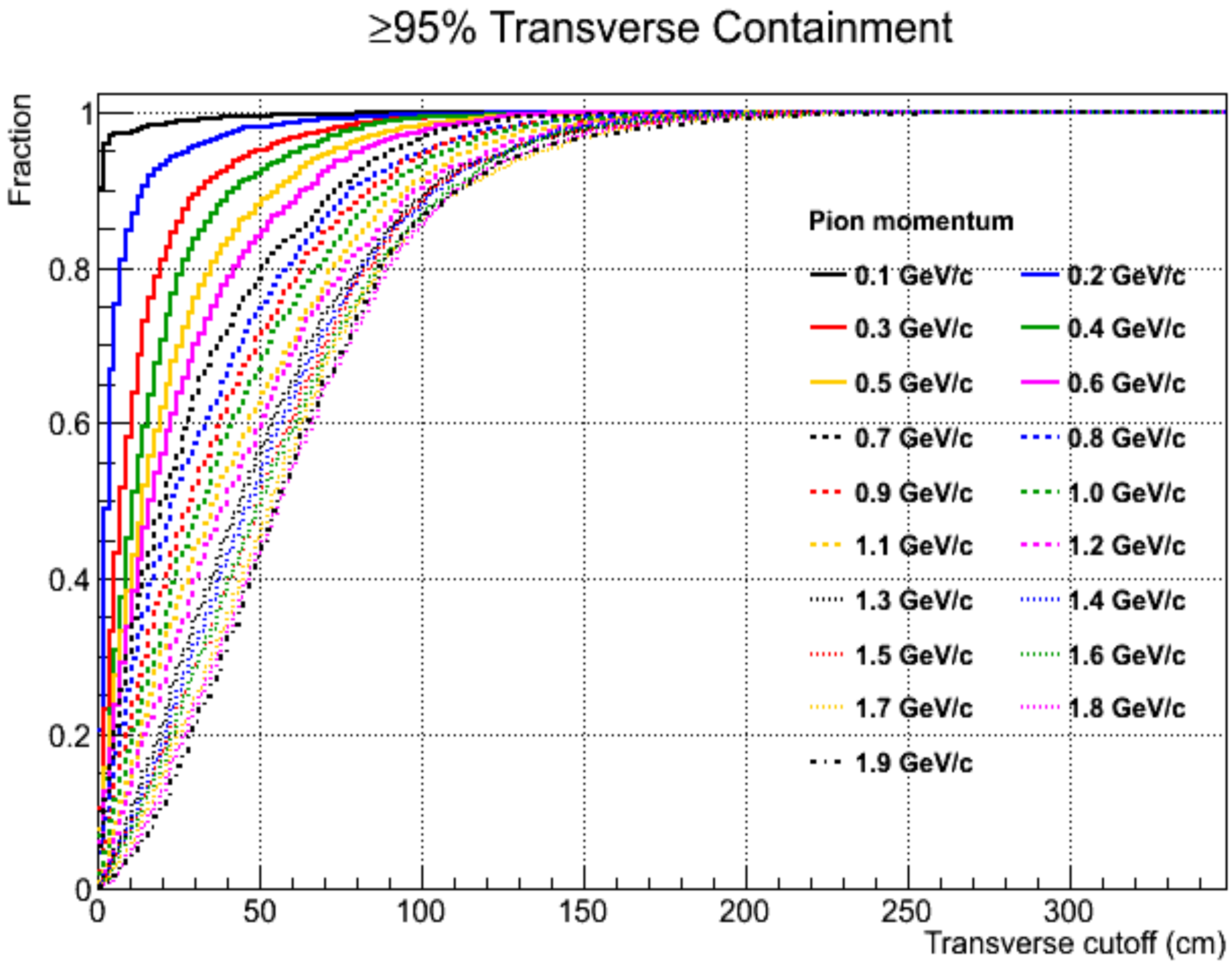
Pion containment



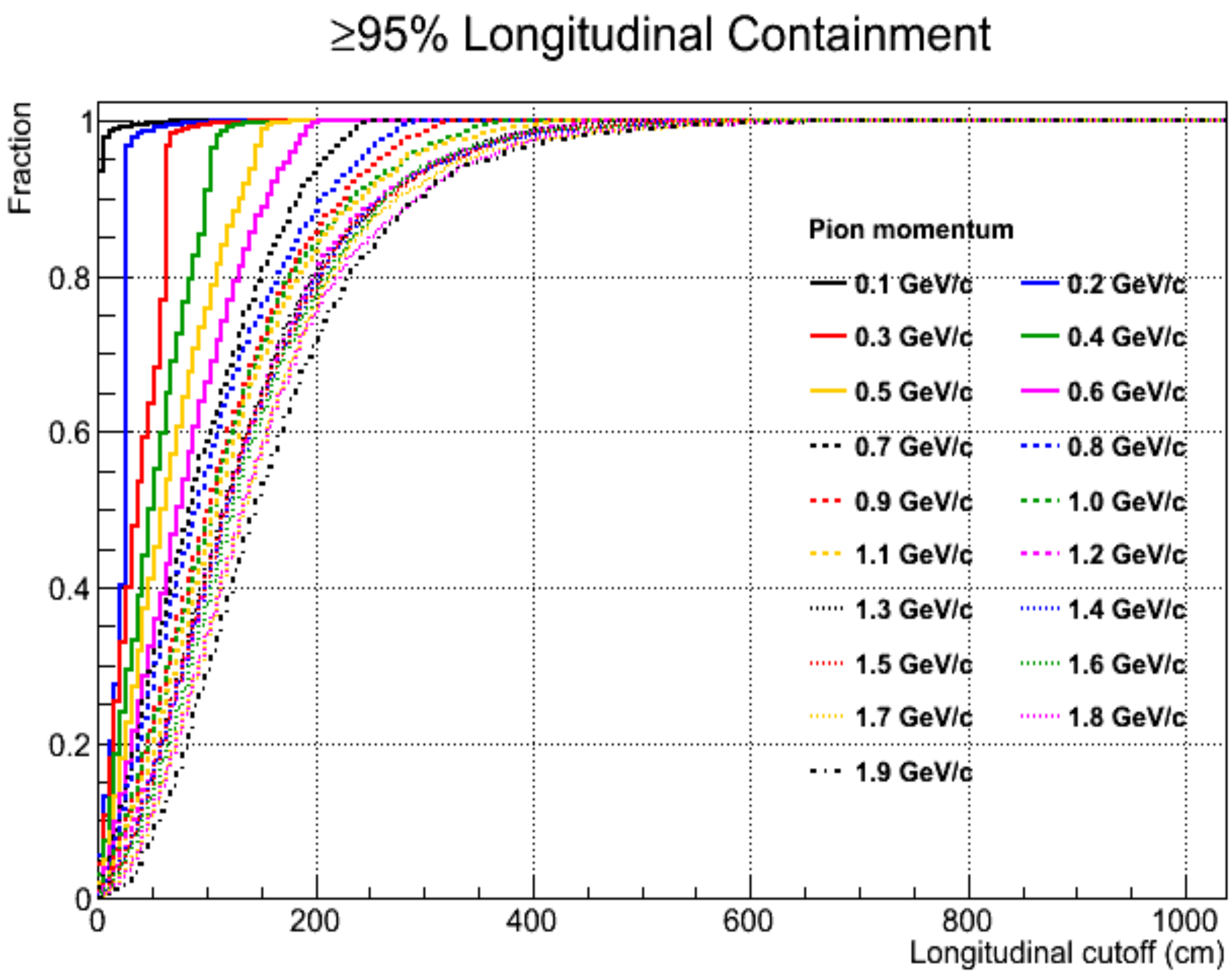
Pion containment



Pion containment



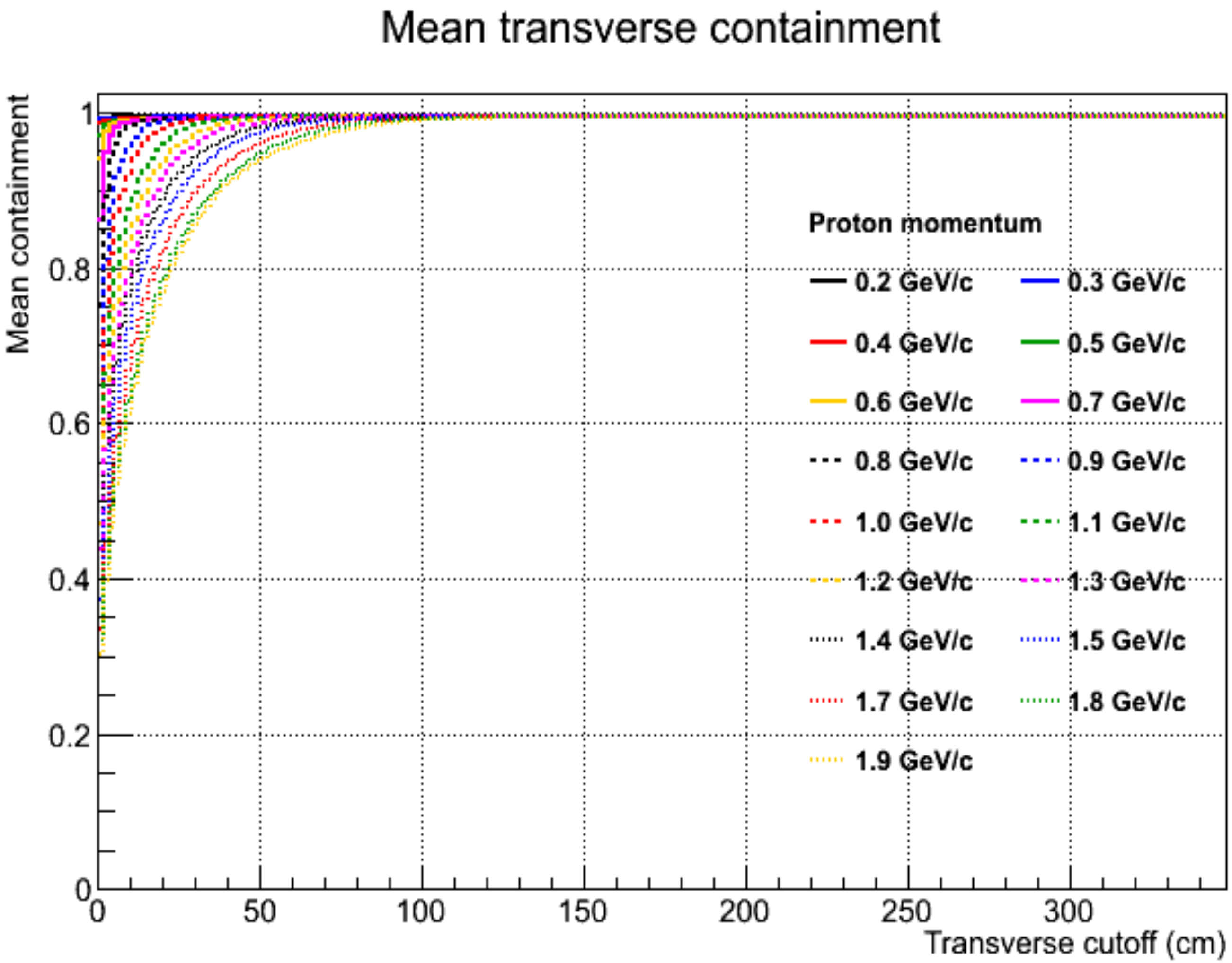
Pion containment



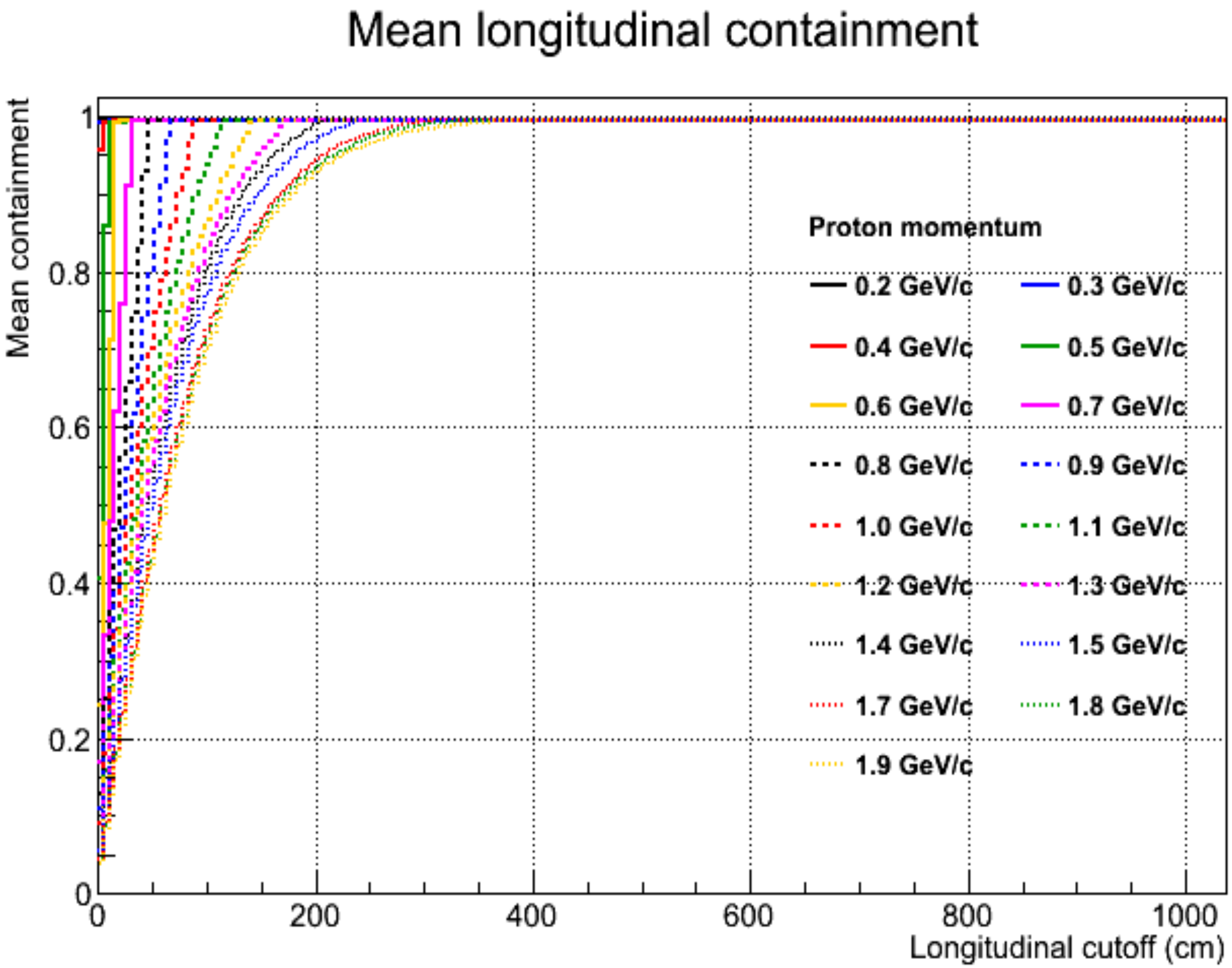
Protons

- 0—2 GeV/c momentum range
- These plots ignore neutrons
  - Neutron-inclusive plots in backups for comparison
  - But for quick reference, at 75cm radius:
    - ~50% fully contained 1 GeV/c protons
    - ~95% mean containment for 1GeV/c protons

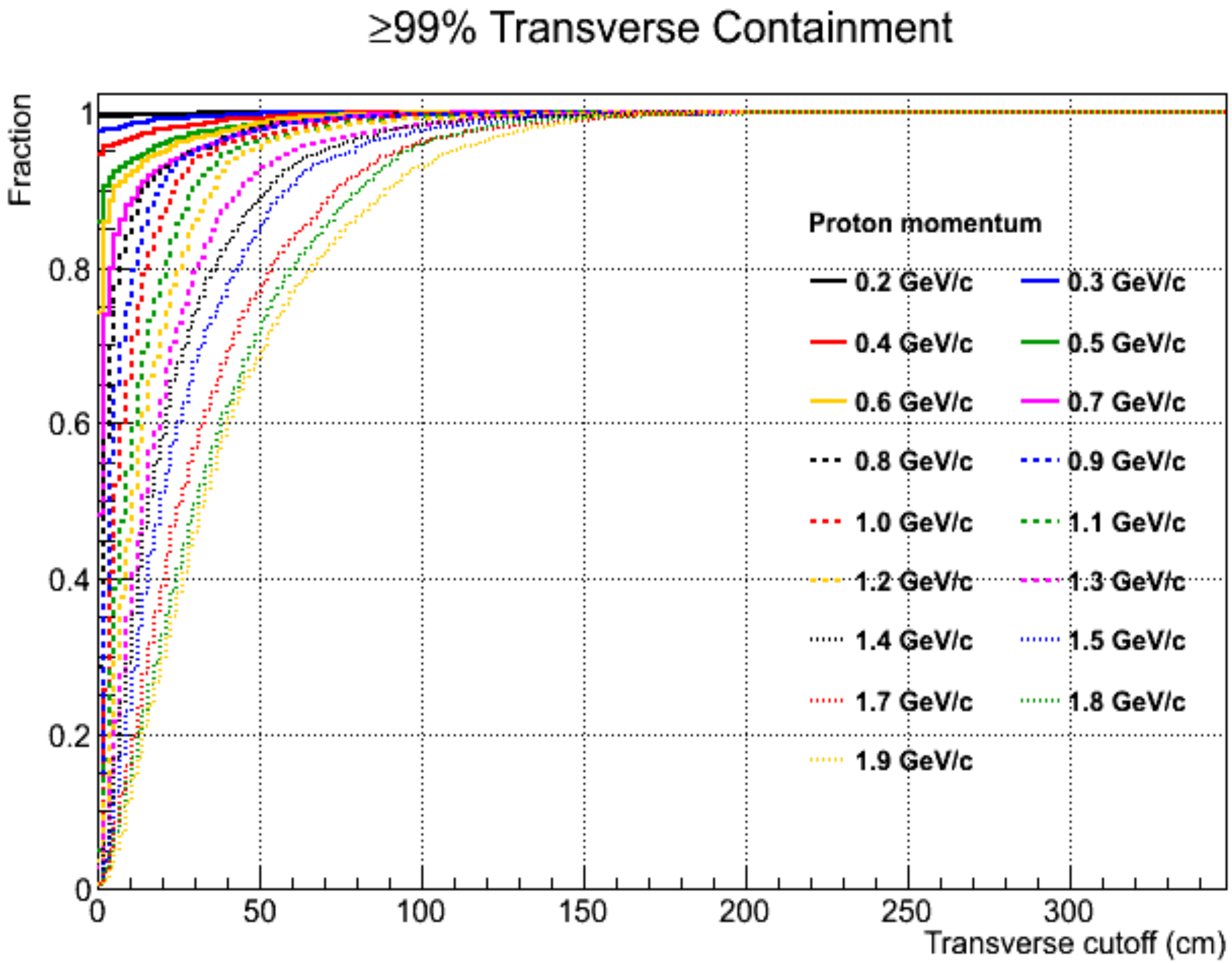
Proton containment



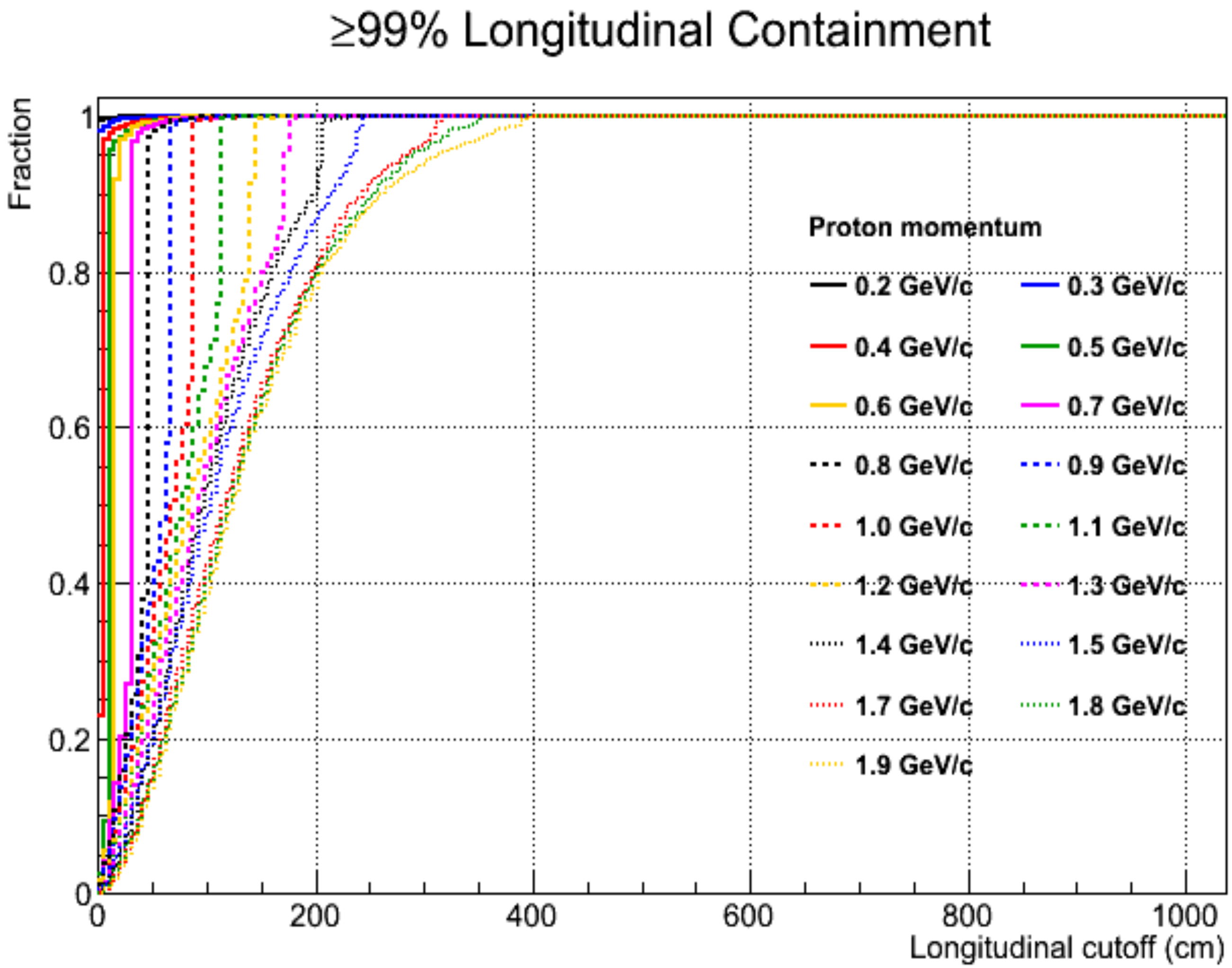
Proton containment



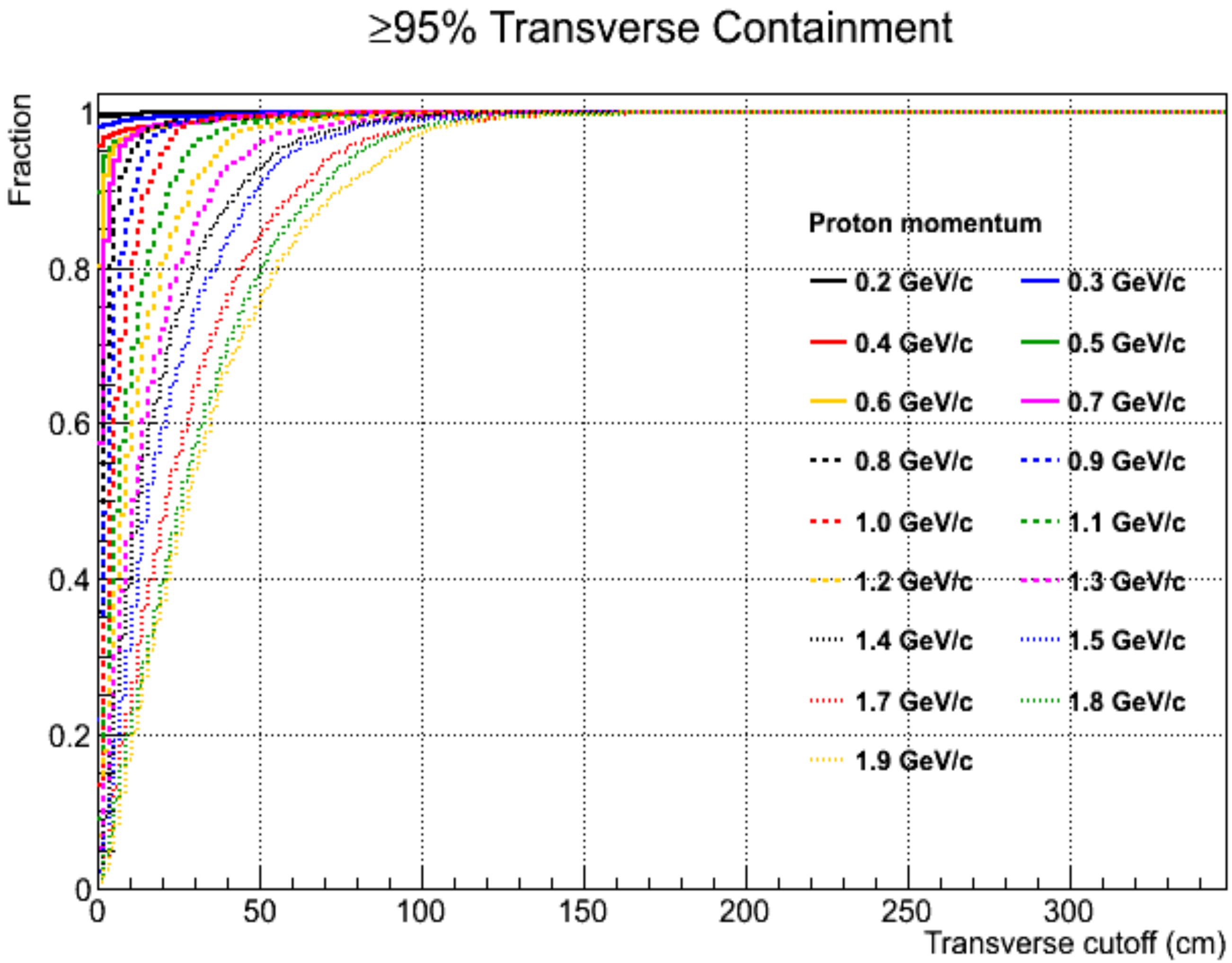
Proton containment



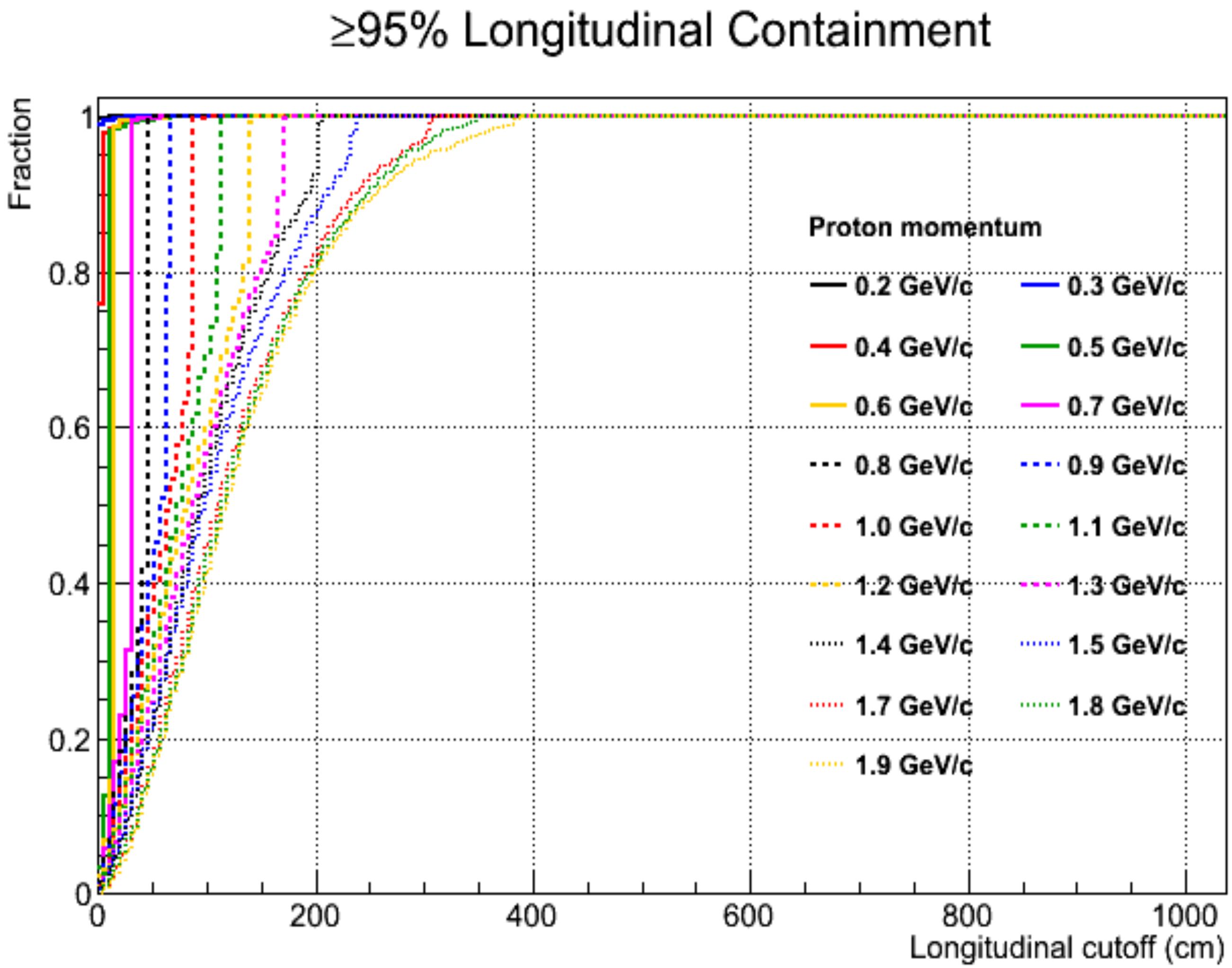
Proton containment



Proton containment



Proton containment

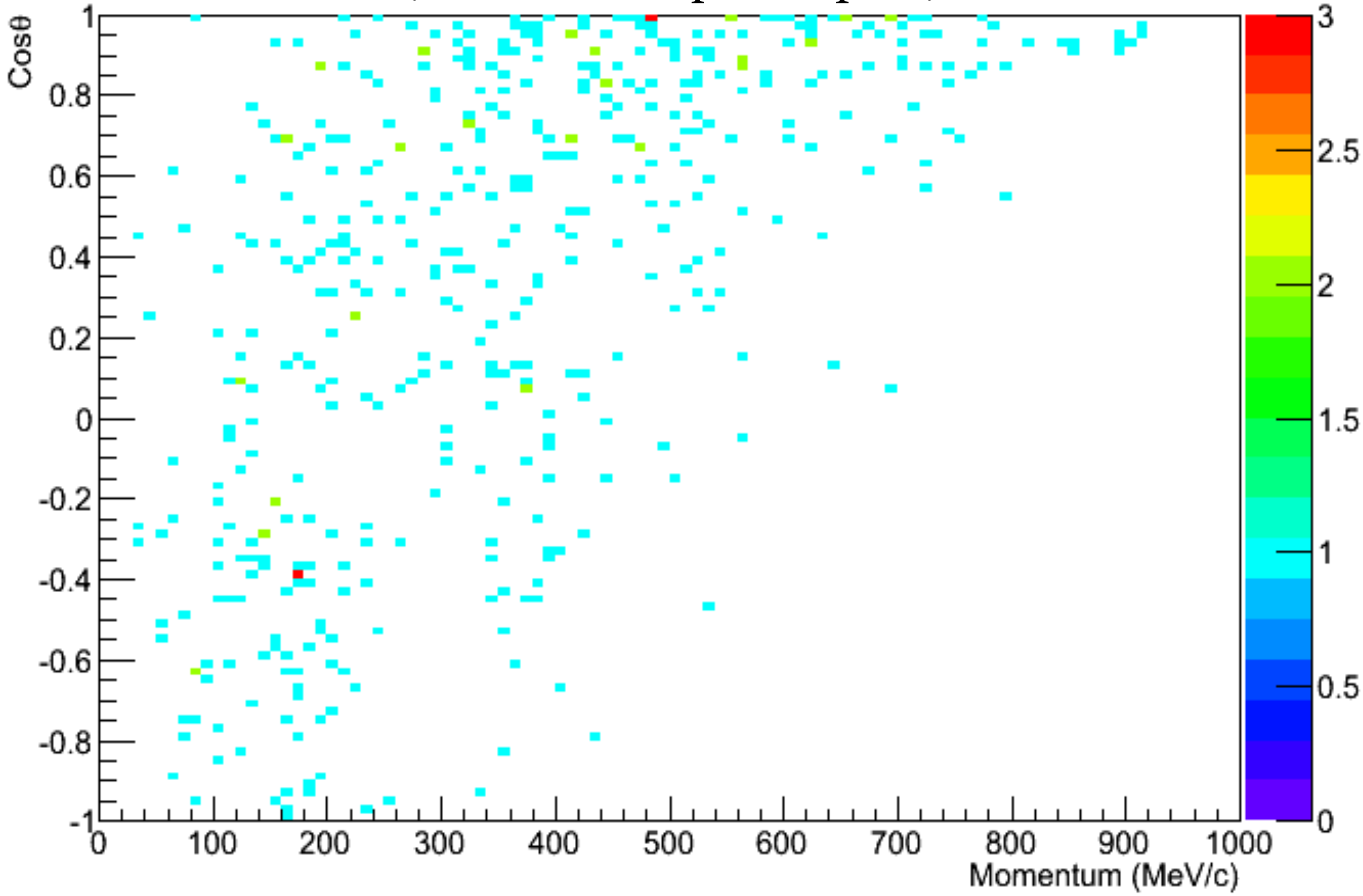


Secondary π^0s

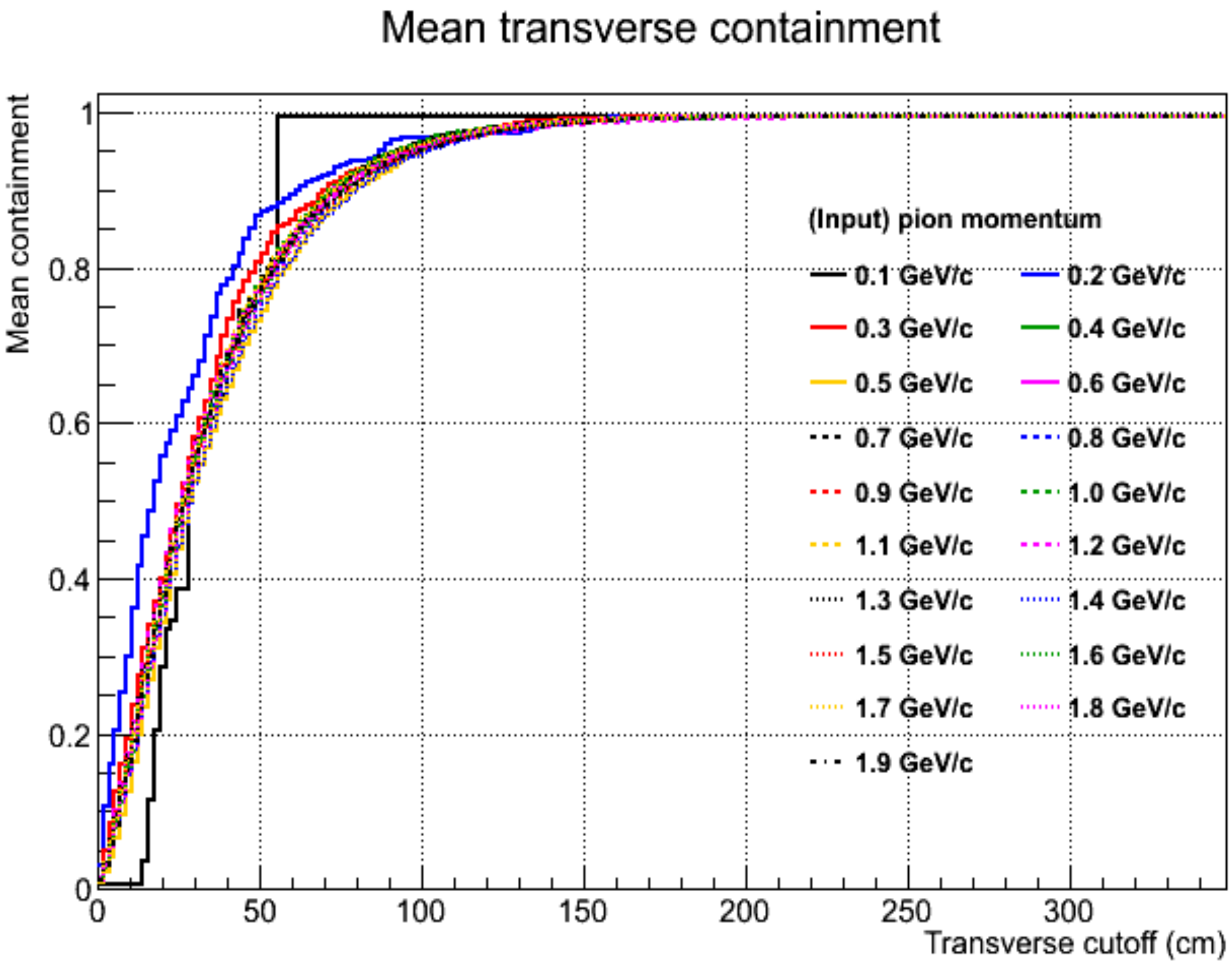
- Following the removal of neutrons from the event, the next most significant effect limiting the containment of hadrons is the production of secondary π^0s
- If these decay transversely, the photons are rarely fully contained within ~75cm.

Secondary π^0 kinematics

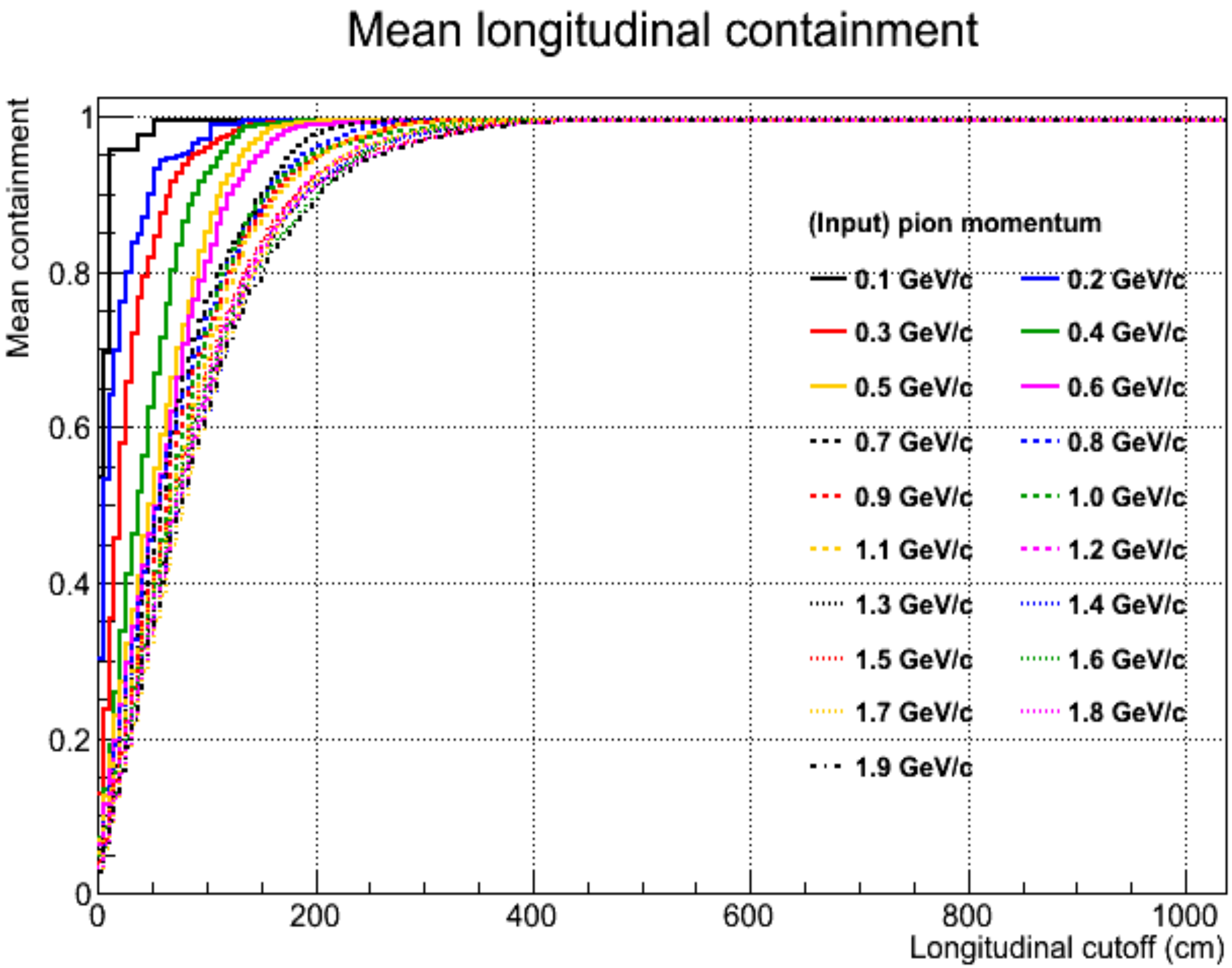
(From a 1GeV parent pion)



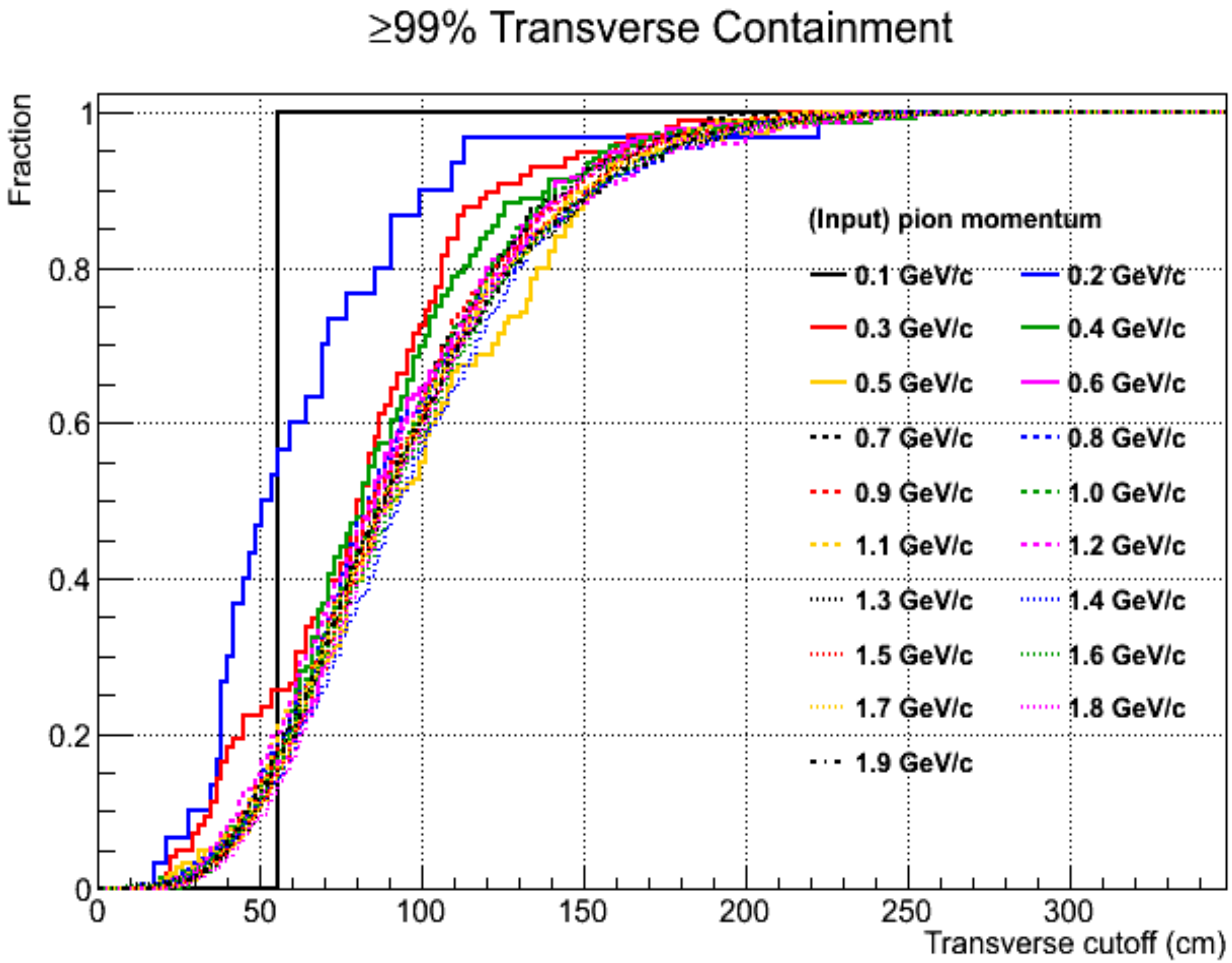
π^0 containment



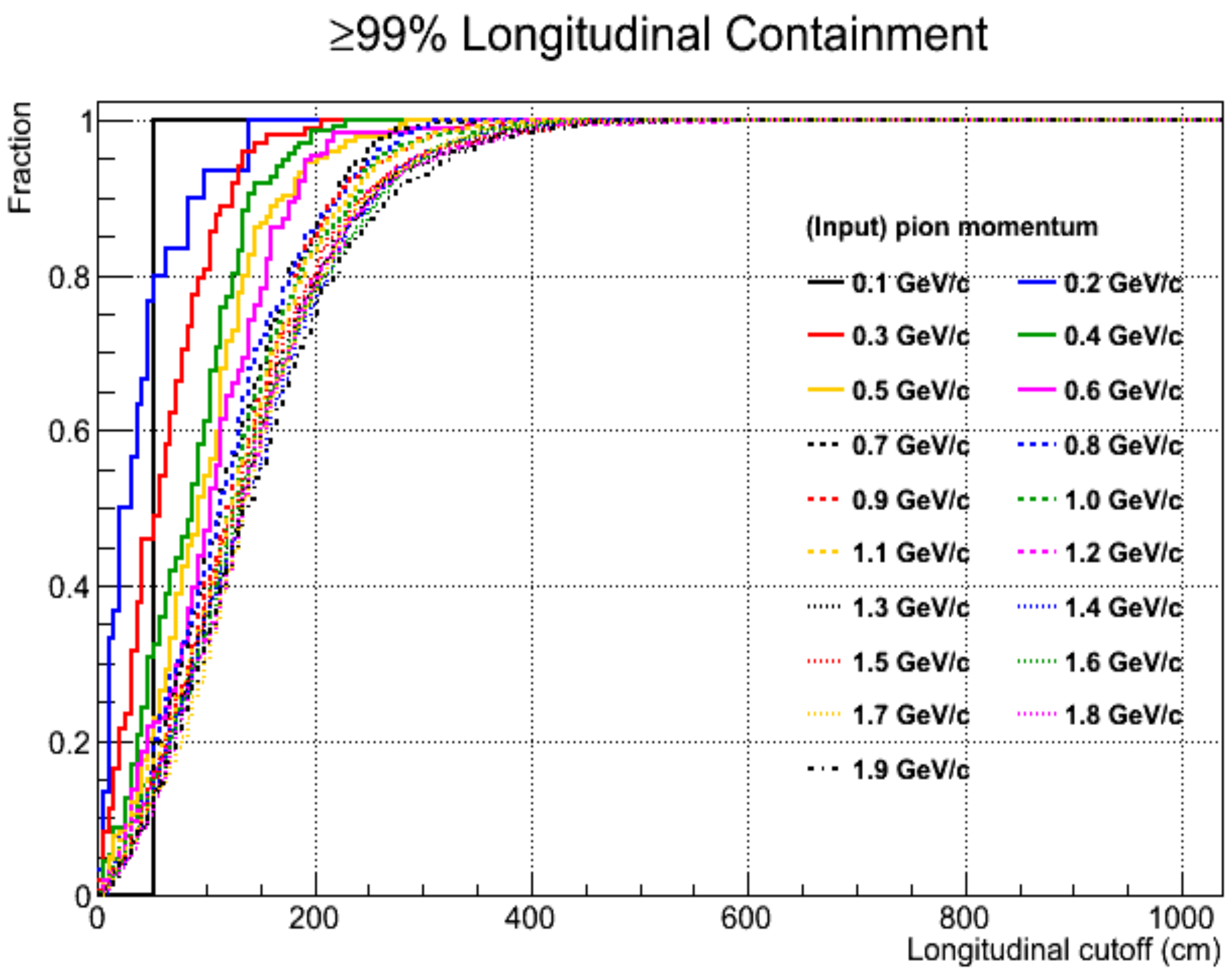
π⁰ containment



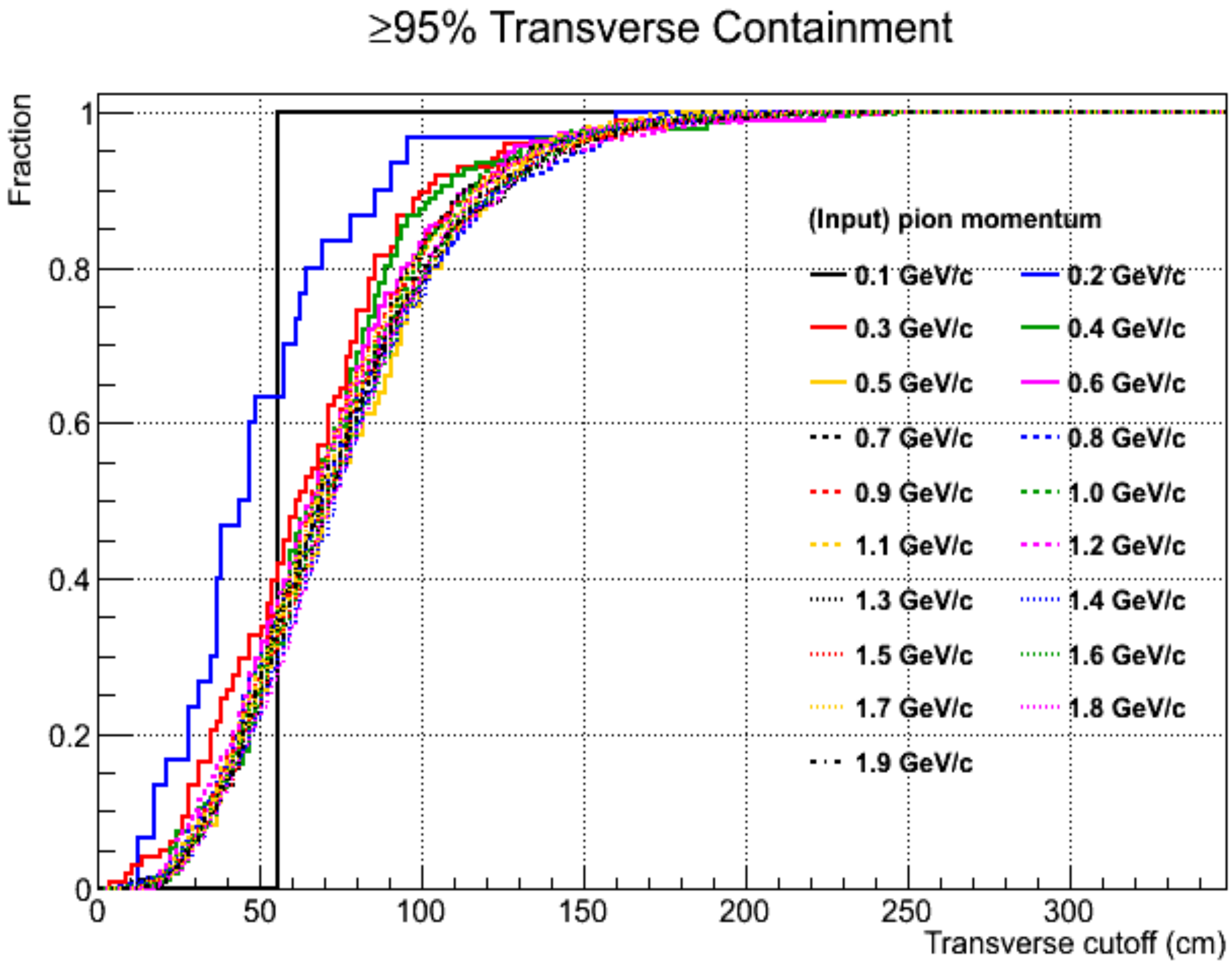
π^0 containment



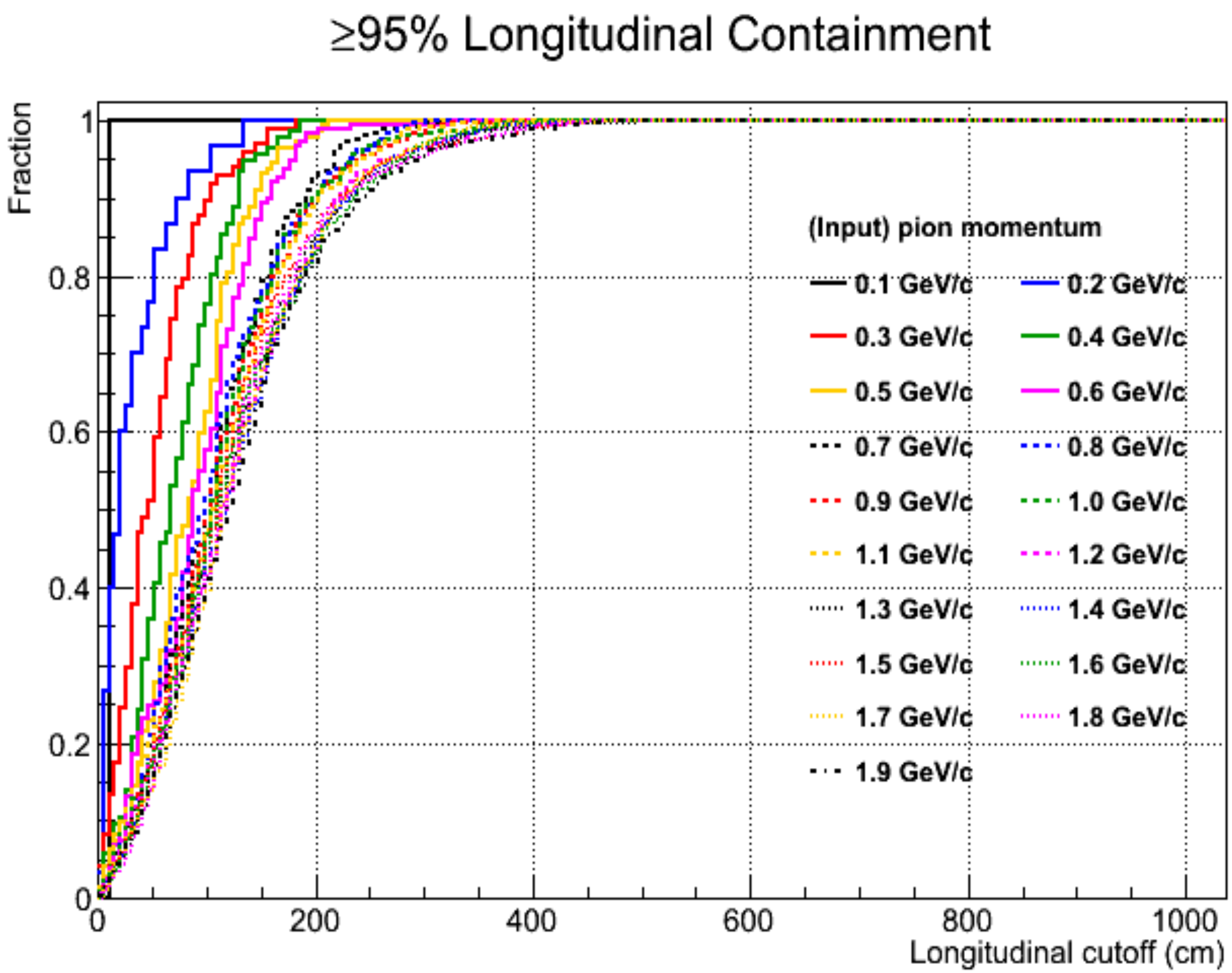
π⁰ containment



π^0 containment



π^0 containment



Summary

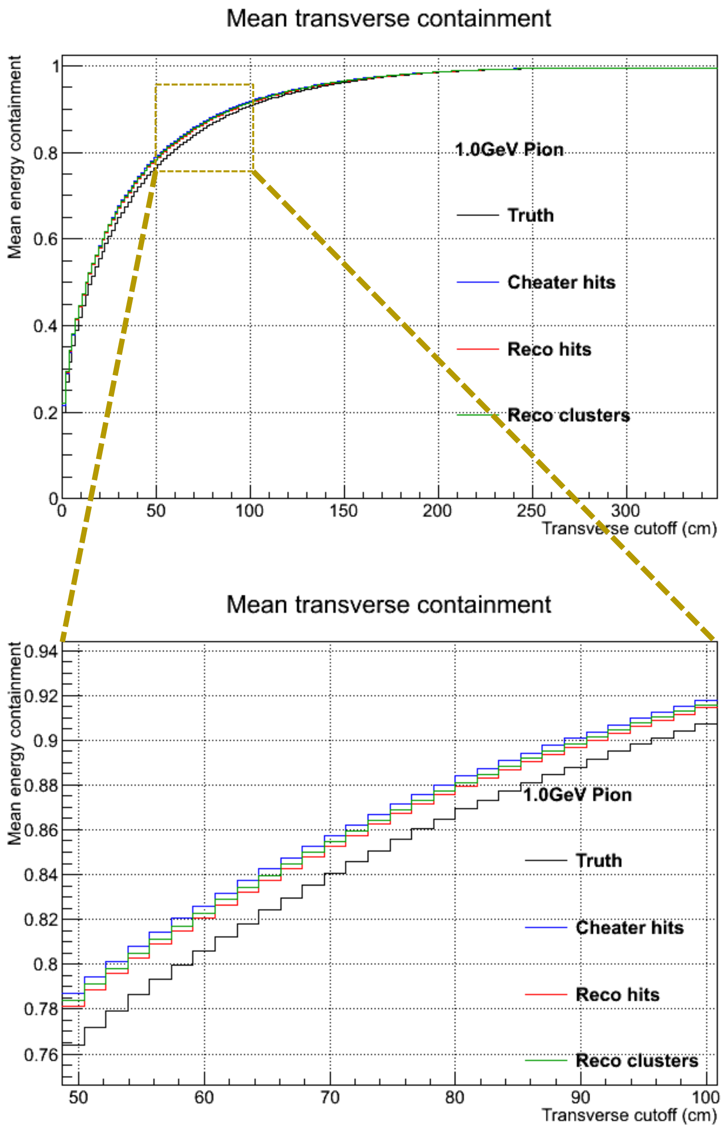
- These plots will hopefully be a good start for understanding the containment of hadronic showers in protoDUNE
- Containment is limited by pions, protons and secondary π^0s (when neutrons are ignored)
- Muons, electrons etc are relatively well contained, compared to these

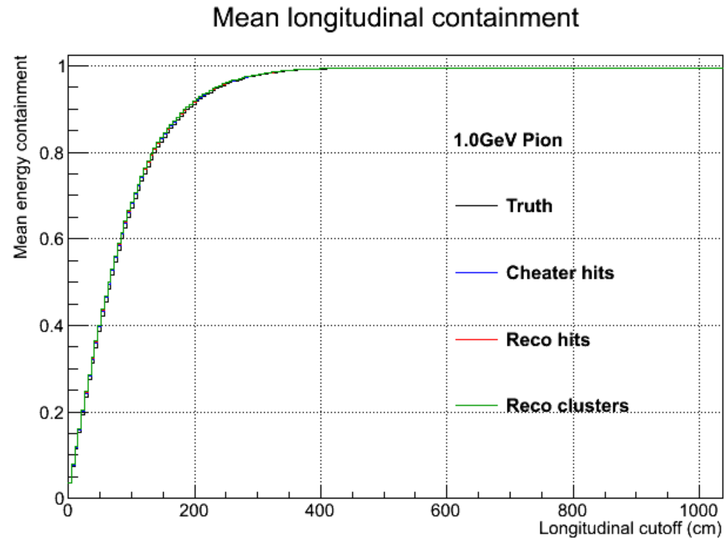
BACKUPS

Effects of reconstruction on containment

- Using reconstruction information to refine containment studies
  - Only use those energy deposits that end up in
    - Cheater hits
      - Uses MC truth
    - Reconstructed hits
      - Gaussian hit finder
    - Reconstructed clusters
      - DB scan

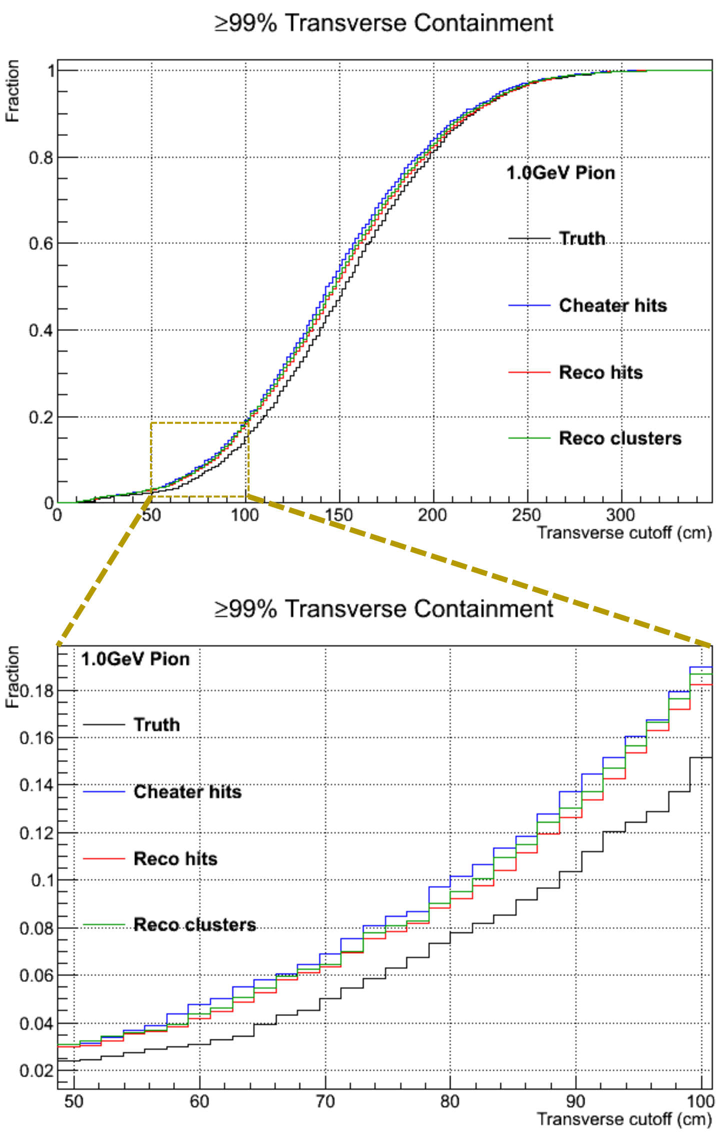
Mean containment

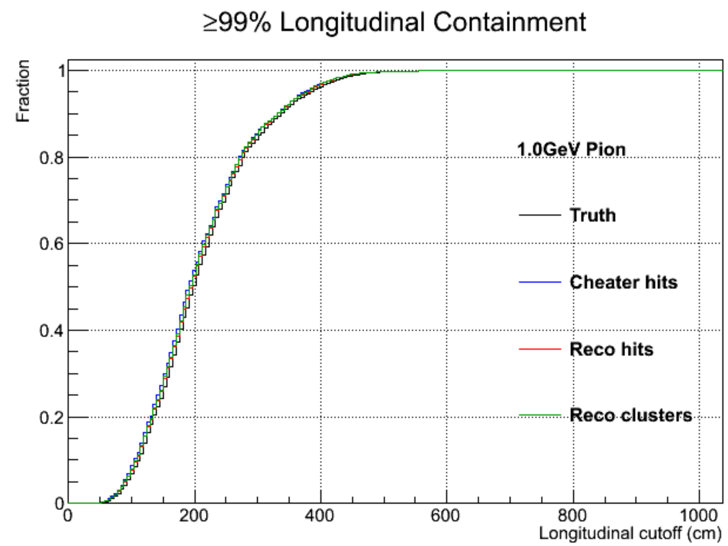




- Using reconstruction info doesn't add much to the containment study

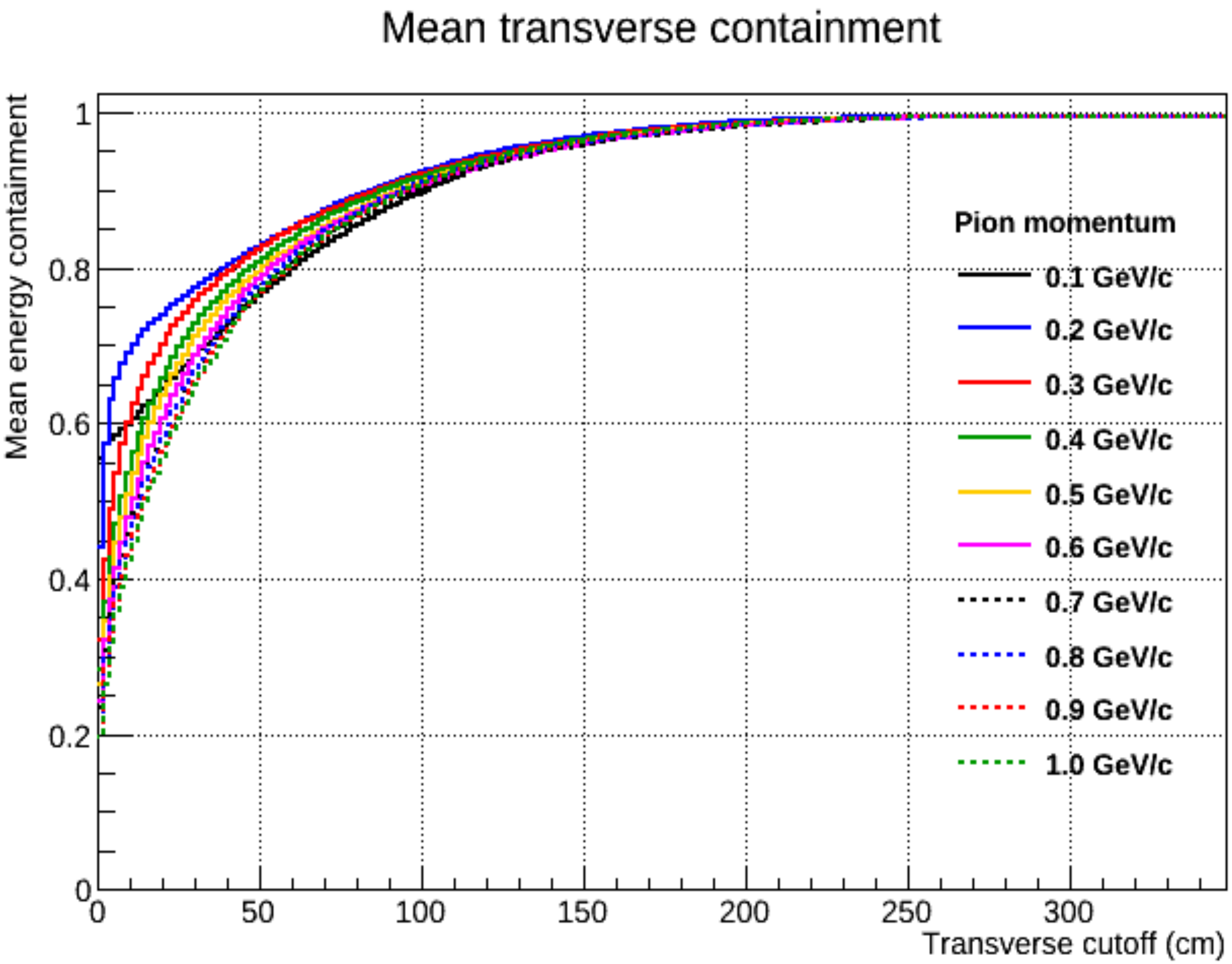
Full containment



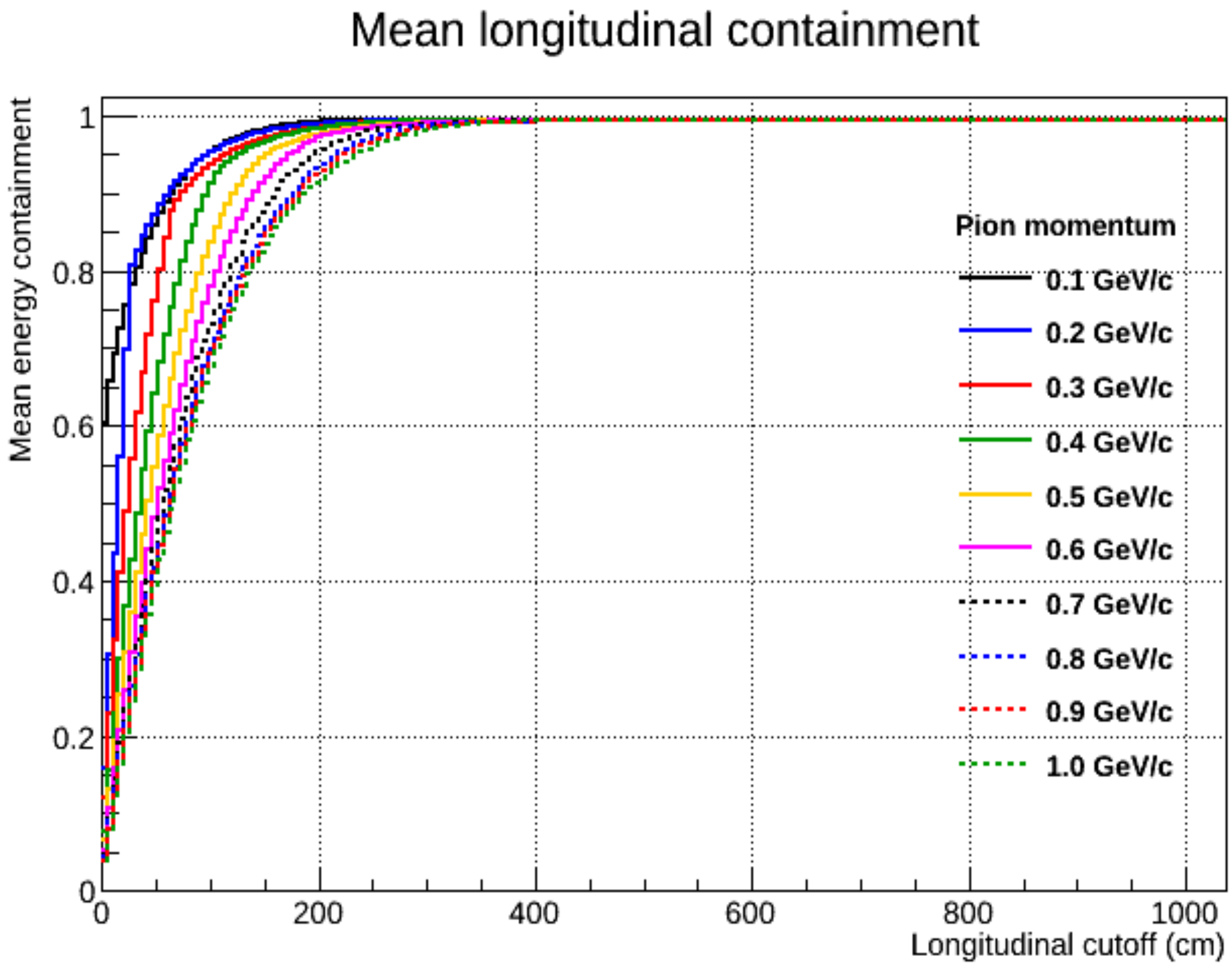


- Using reconstruction info doesn’t add much to the containment study

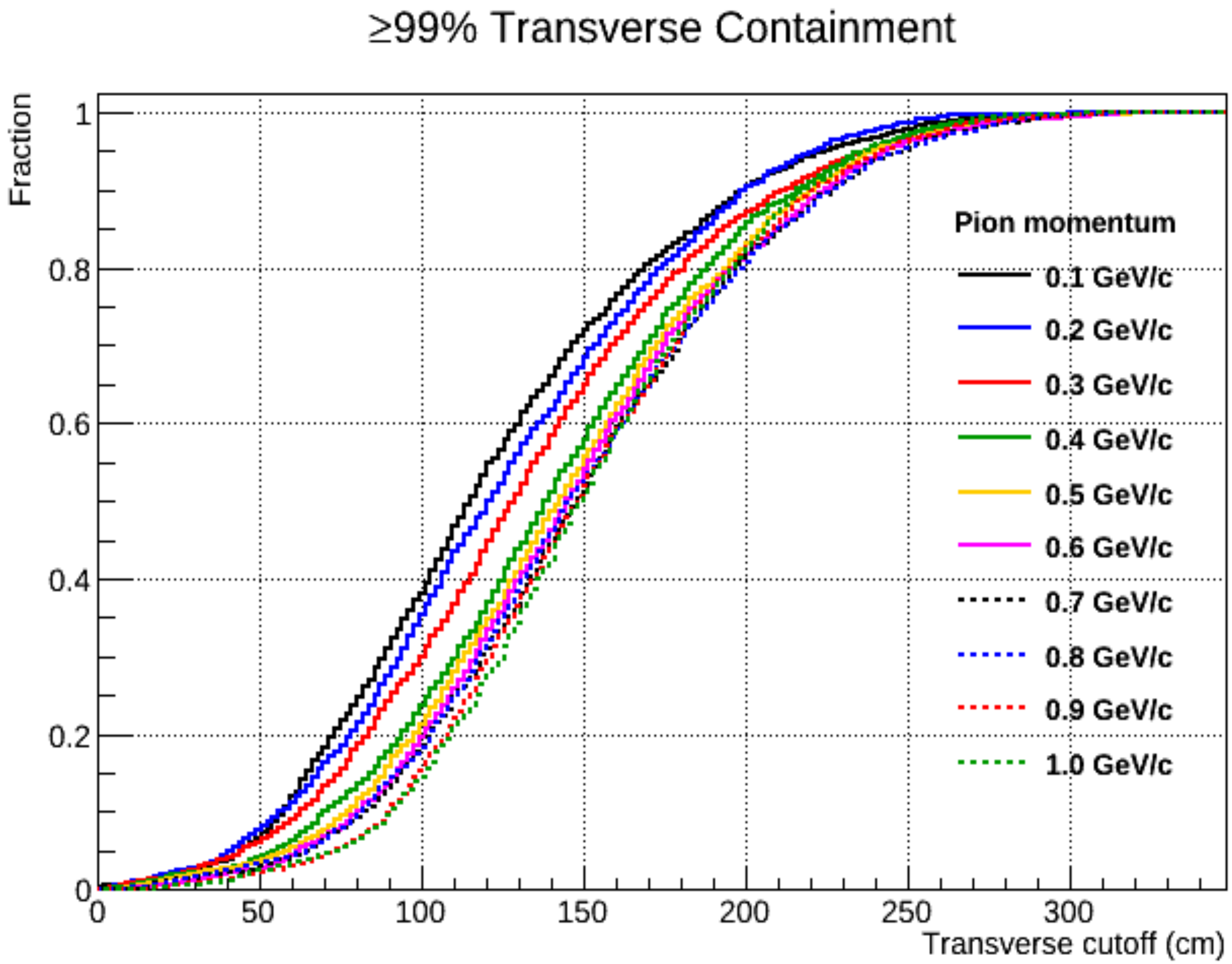
Pion containment (inc neutrons)



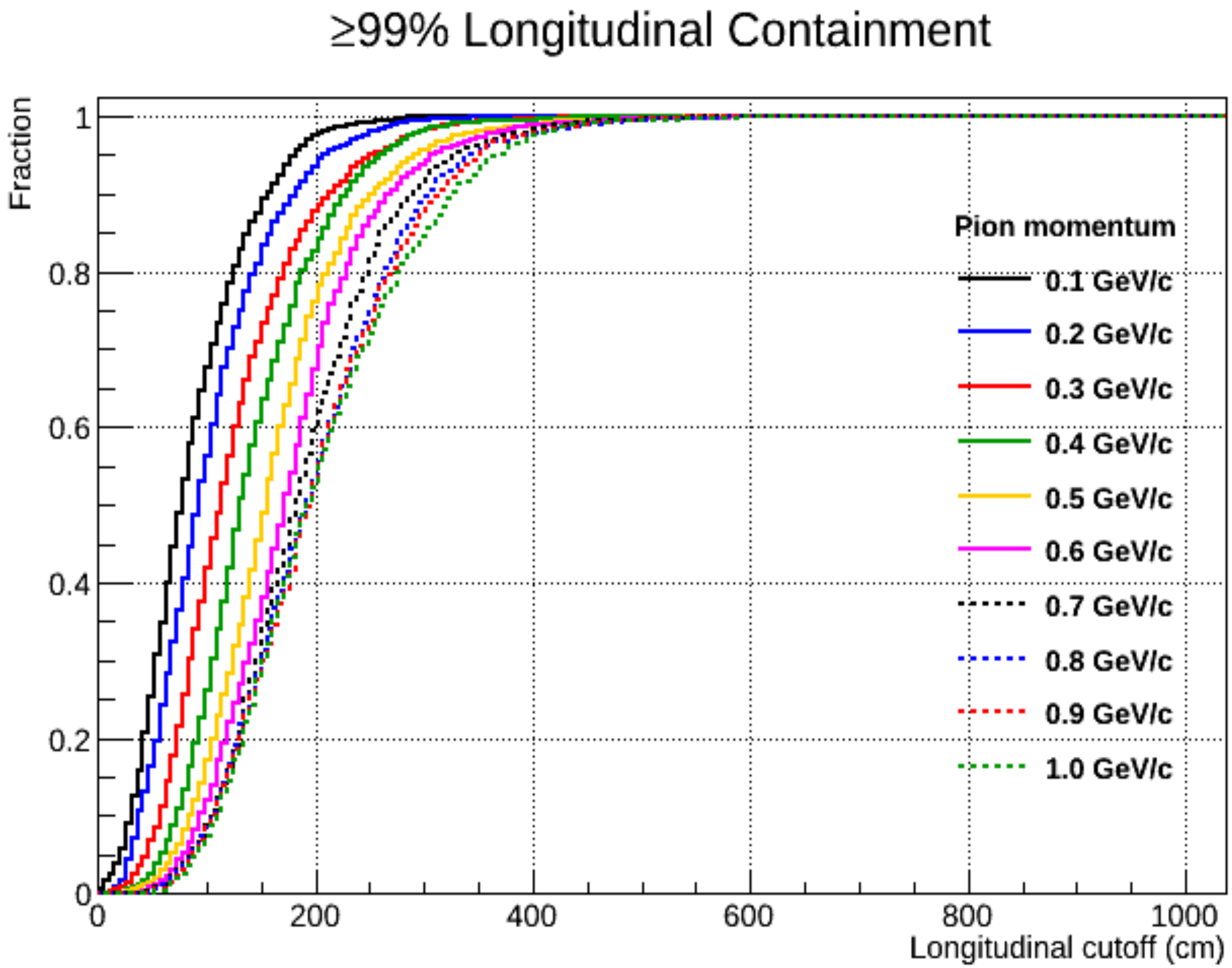
Pion containment (inc neutrons)



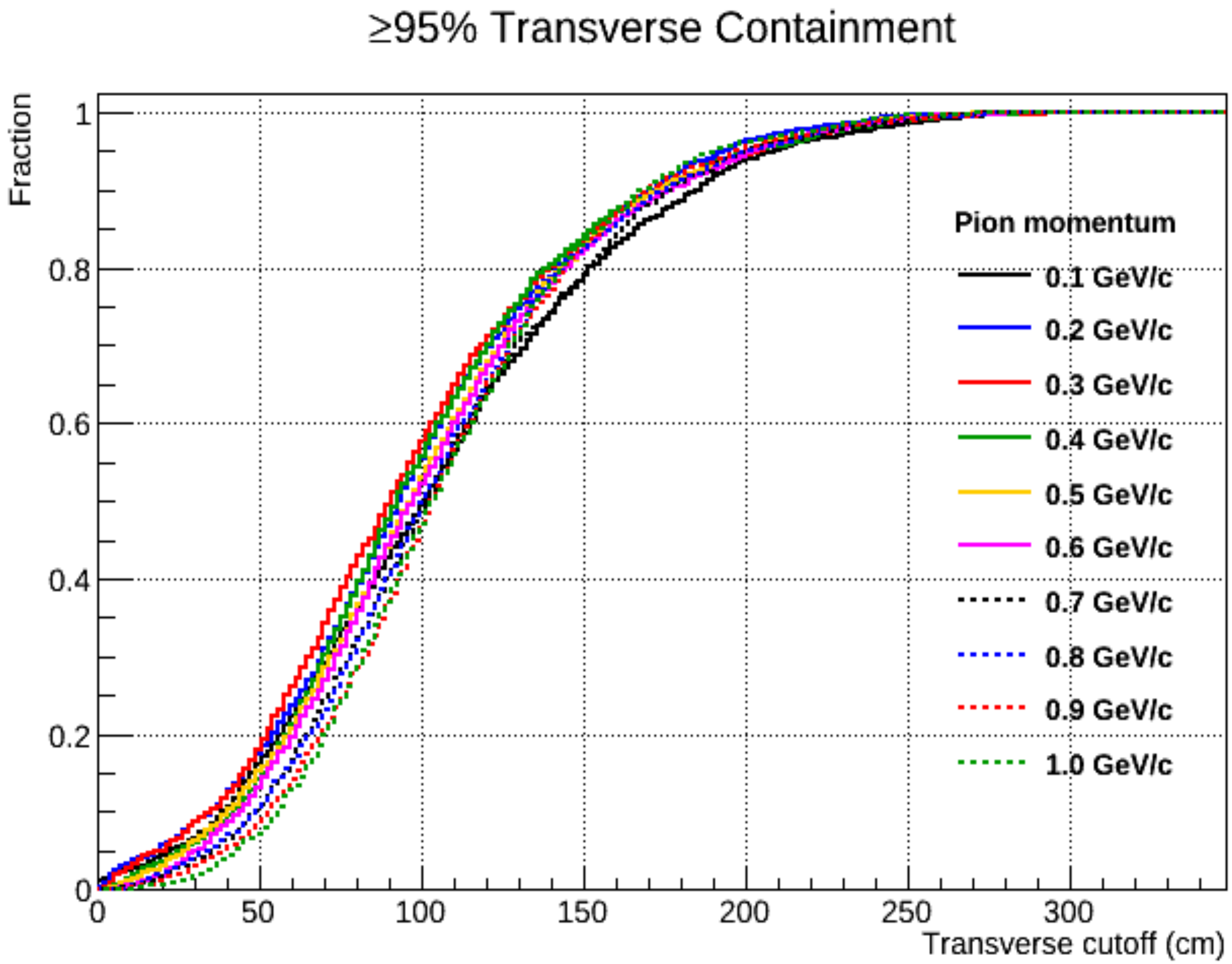
Pion containment (inc neutrons)



Pion containment (inc neutrons)



Pion containment (inc neutrons)



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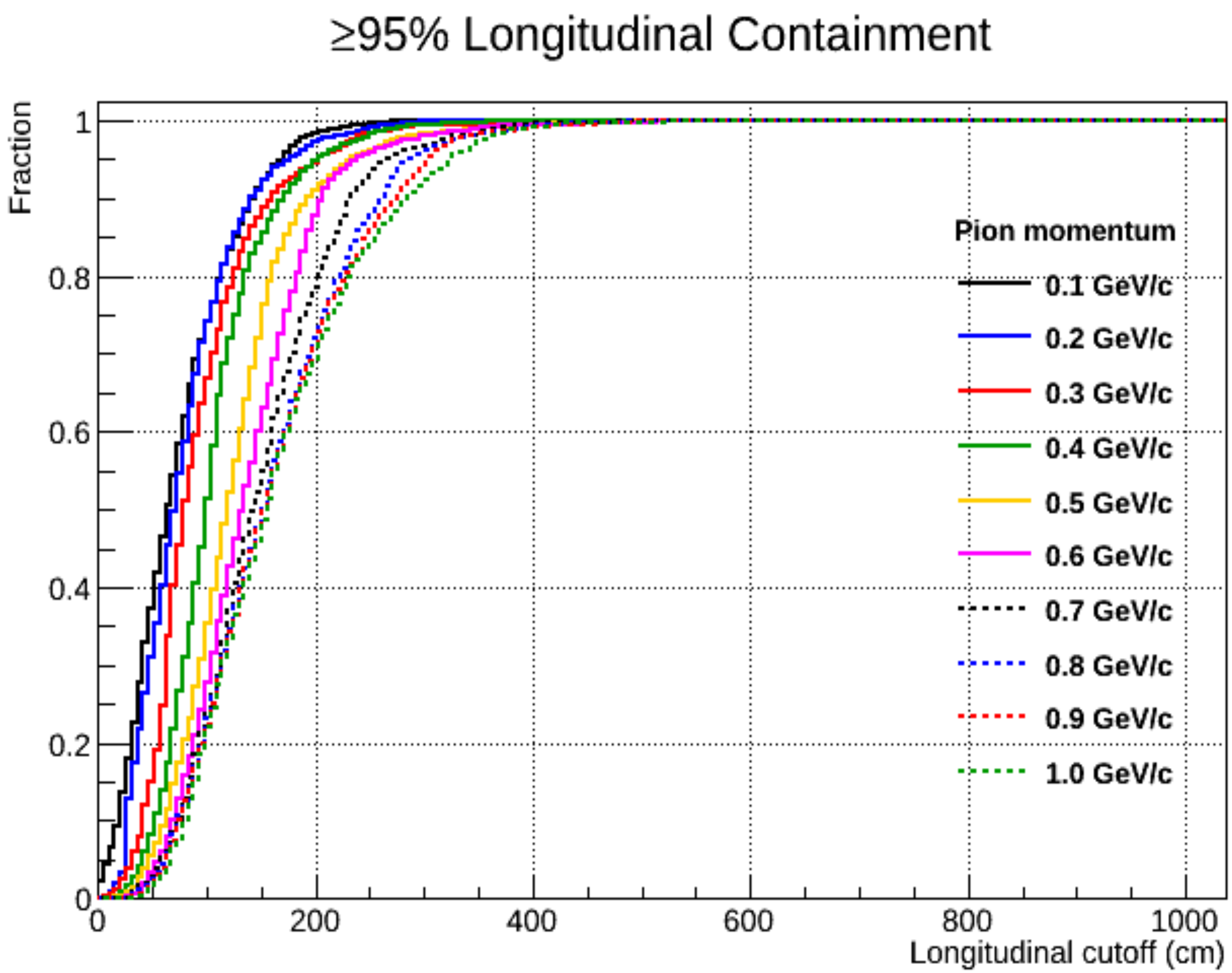
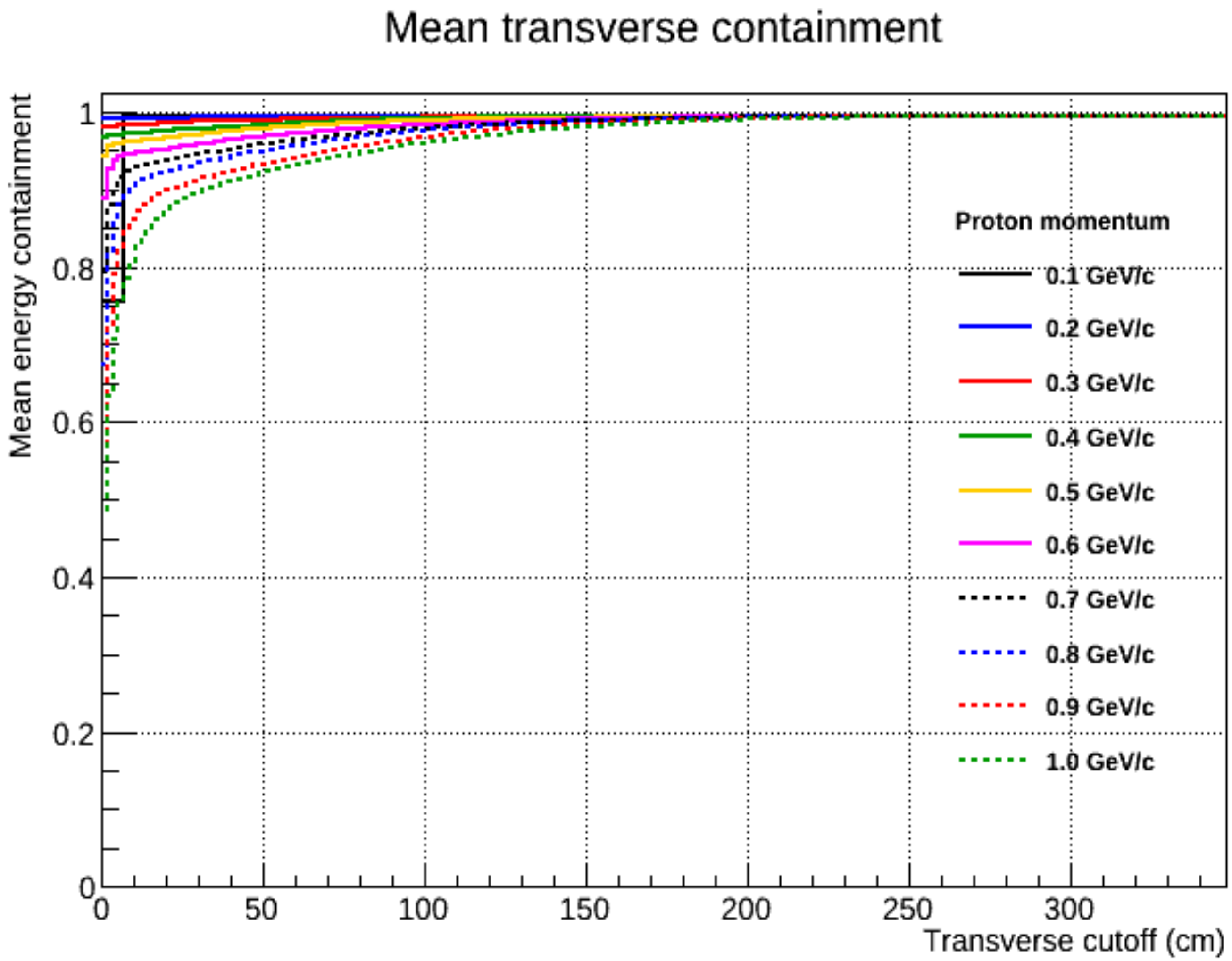


Proton containment (inc neutrons)



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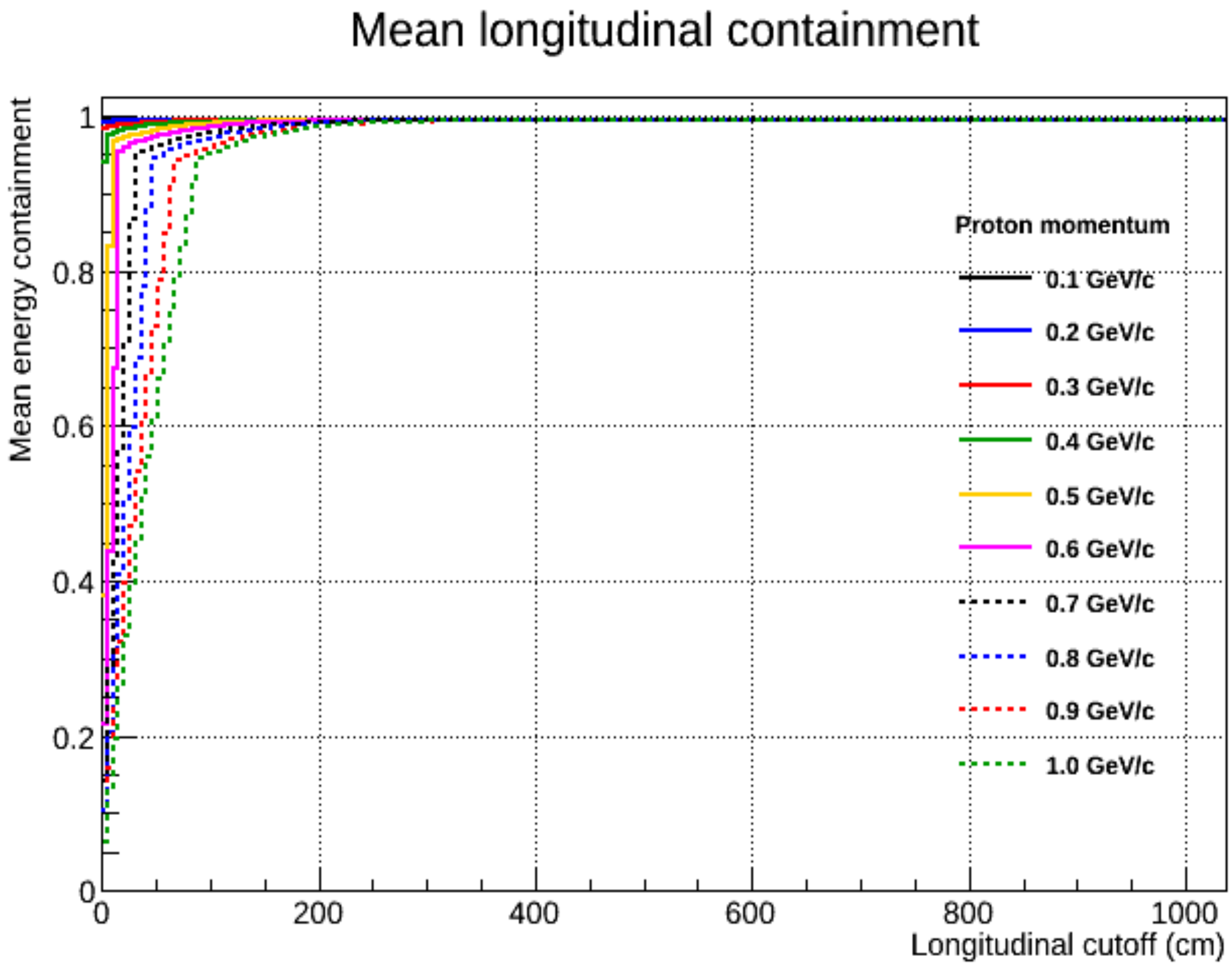

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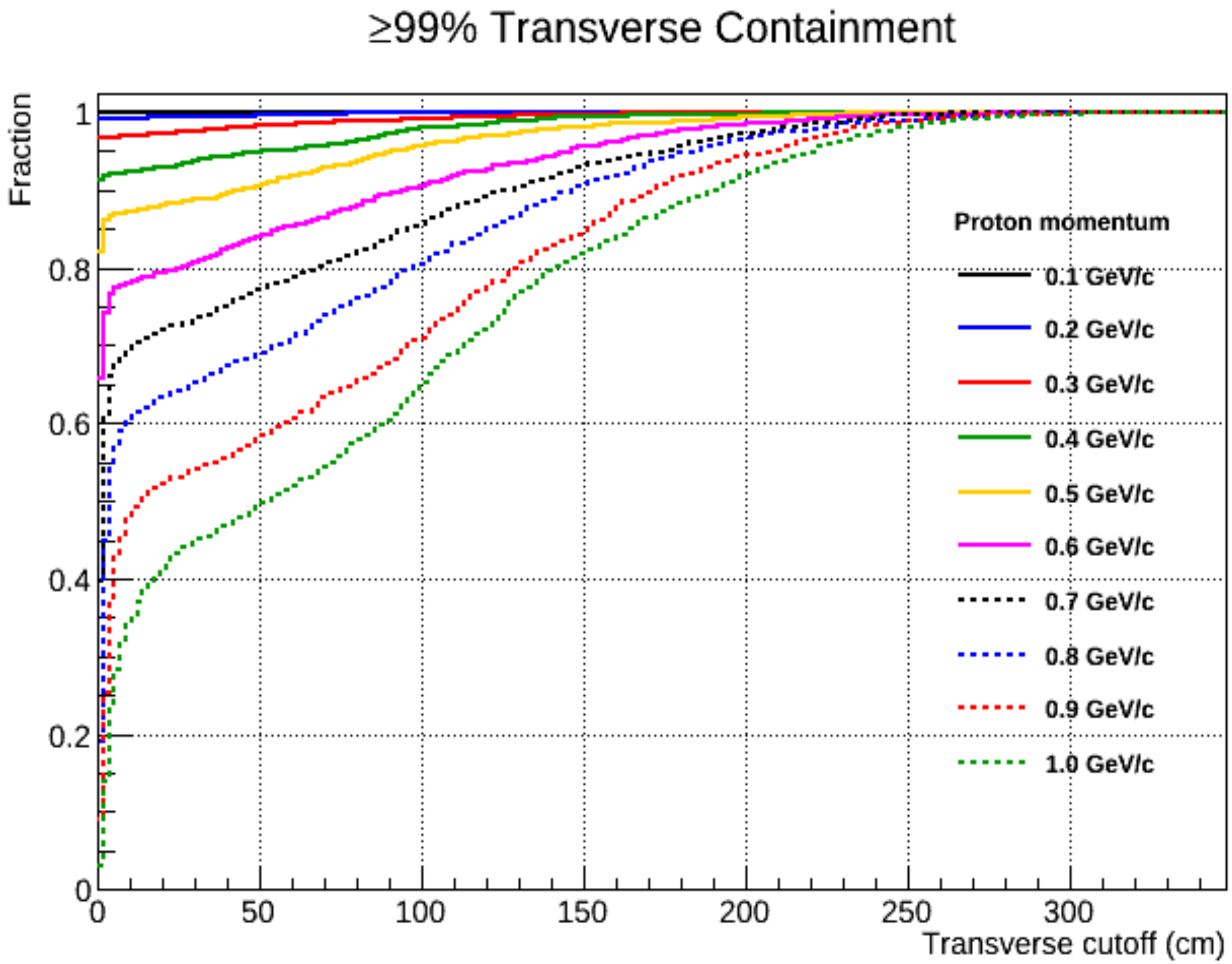

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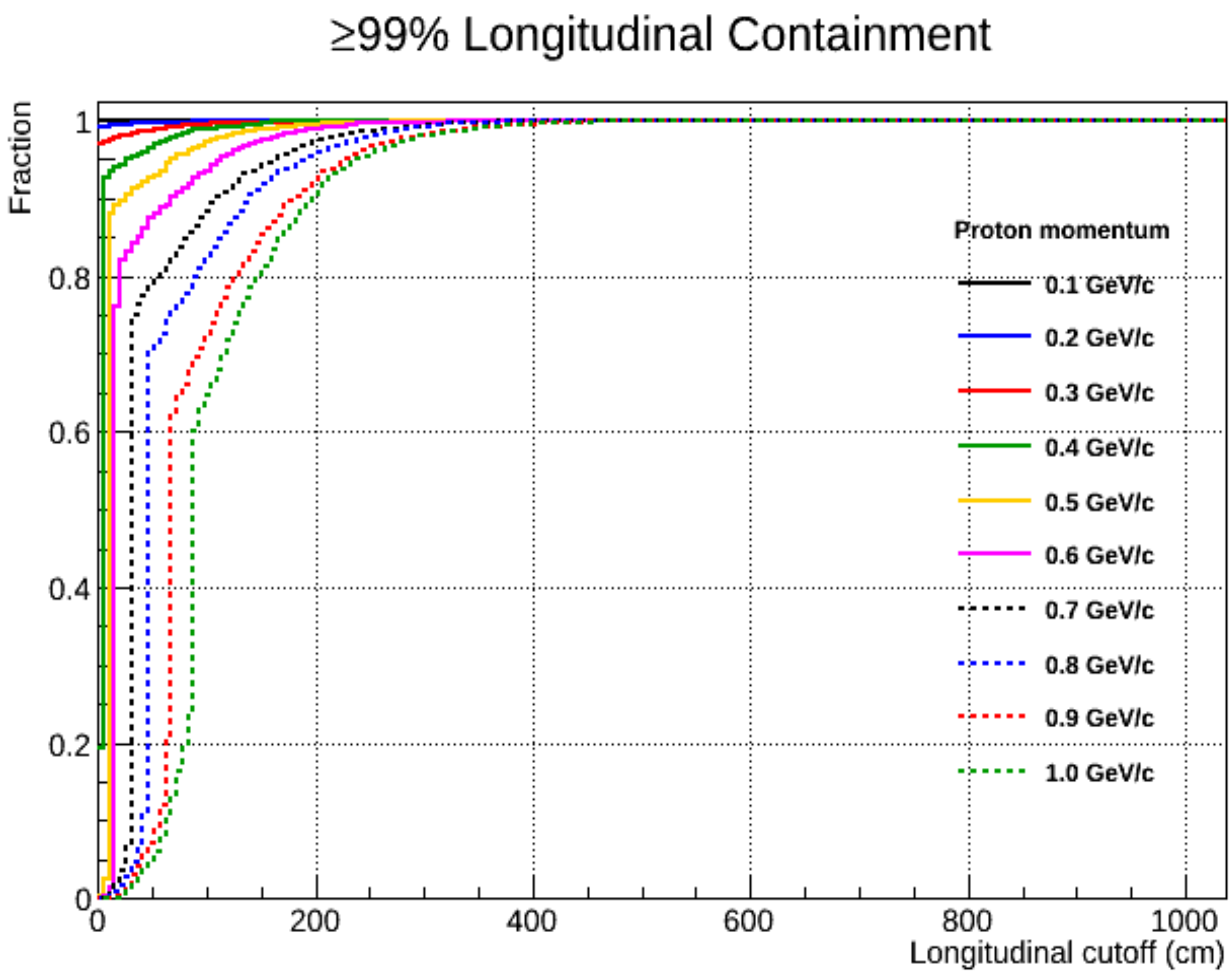

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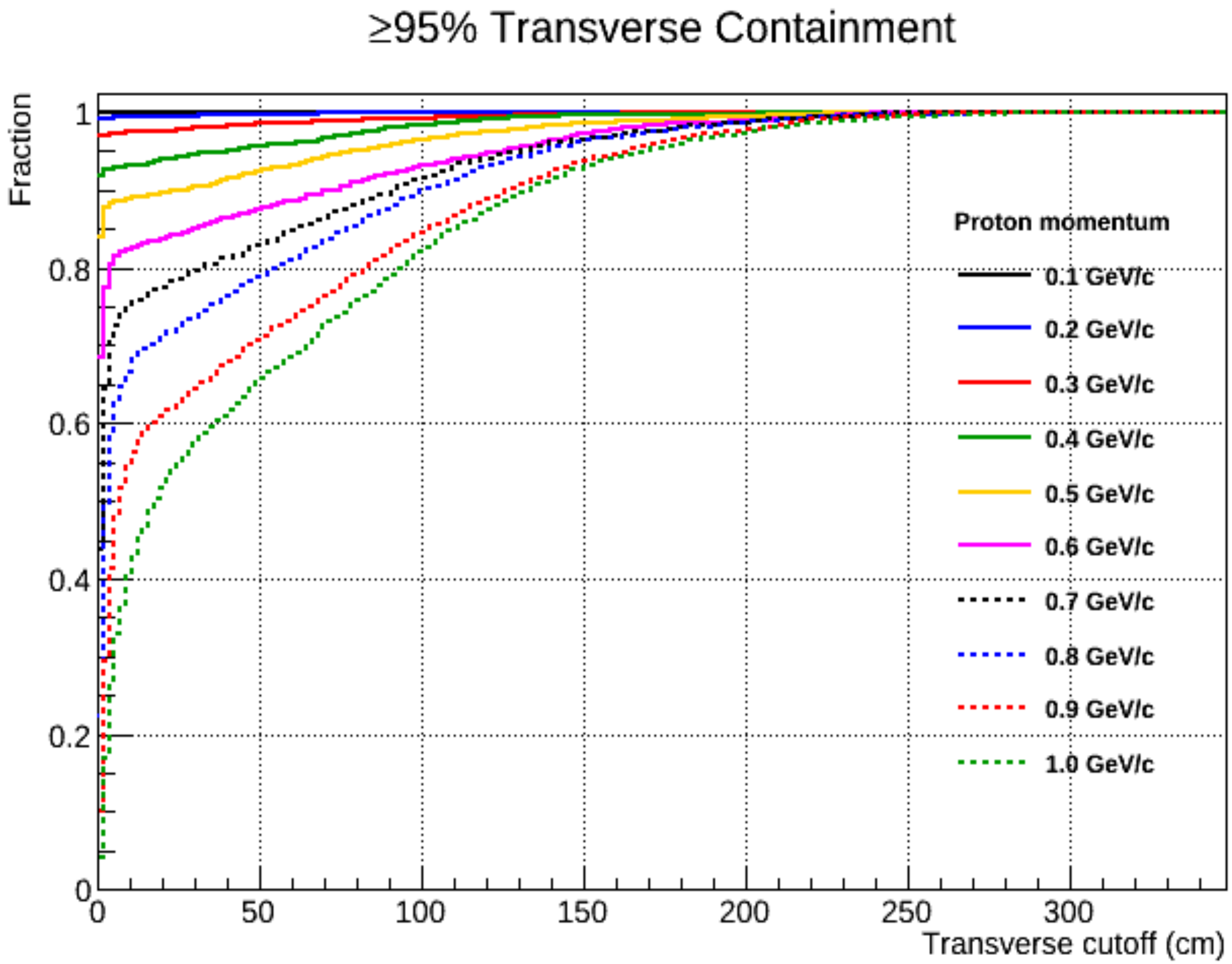

Proton containment (inc neutrons)