LBNF target studies: graphite core density & Δz gaps

John Back
University of Warwick

07 Dec 2023

DUNE-doc-29702

Introduction

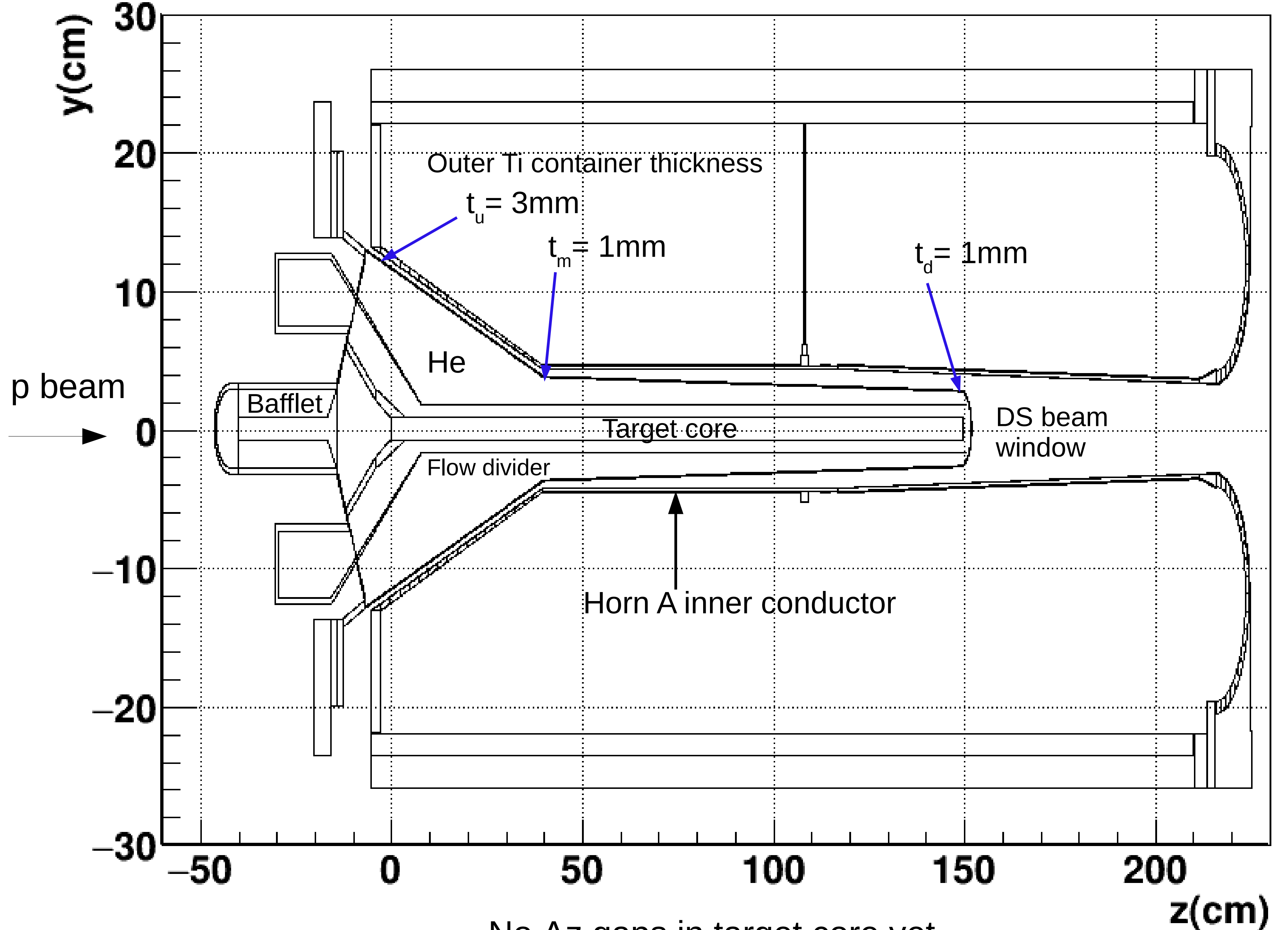
- LBNF graphite cantilevered target neutrino flux & energy deposition studies
  - Changing **graphite core density**: **1.74 to 1.94 g/cm^3** in **0.02 g/cm^3** steps
  - Introducing small **Δz gaps** between graphite core sections (for thermal expansion)

- G4LBNF simulations: **graphite target, 3 focusing horns (A, B, C), hadron absorber etc.**
  - **Cantilevered target**, double-cone Ti support structure with He cooling
  - Proton beam: **120 GeV, 1.2 MW**; QGSP_BERT hadronic model
  - **Target core:** r = 8 mm, **L = 1.5 m** (minimum) & **1.8 m** (aspiration)
  - Bafflet graphite density fixed at 1.78 g/cc (POCO); Horn currents I = 300 kA

- FLUKA (CERN v4-3.4) energy deposition simulations: **graphite target & horn A**

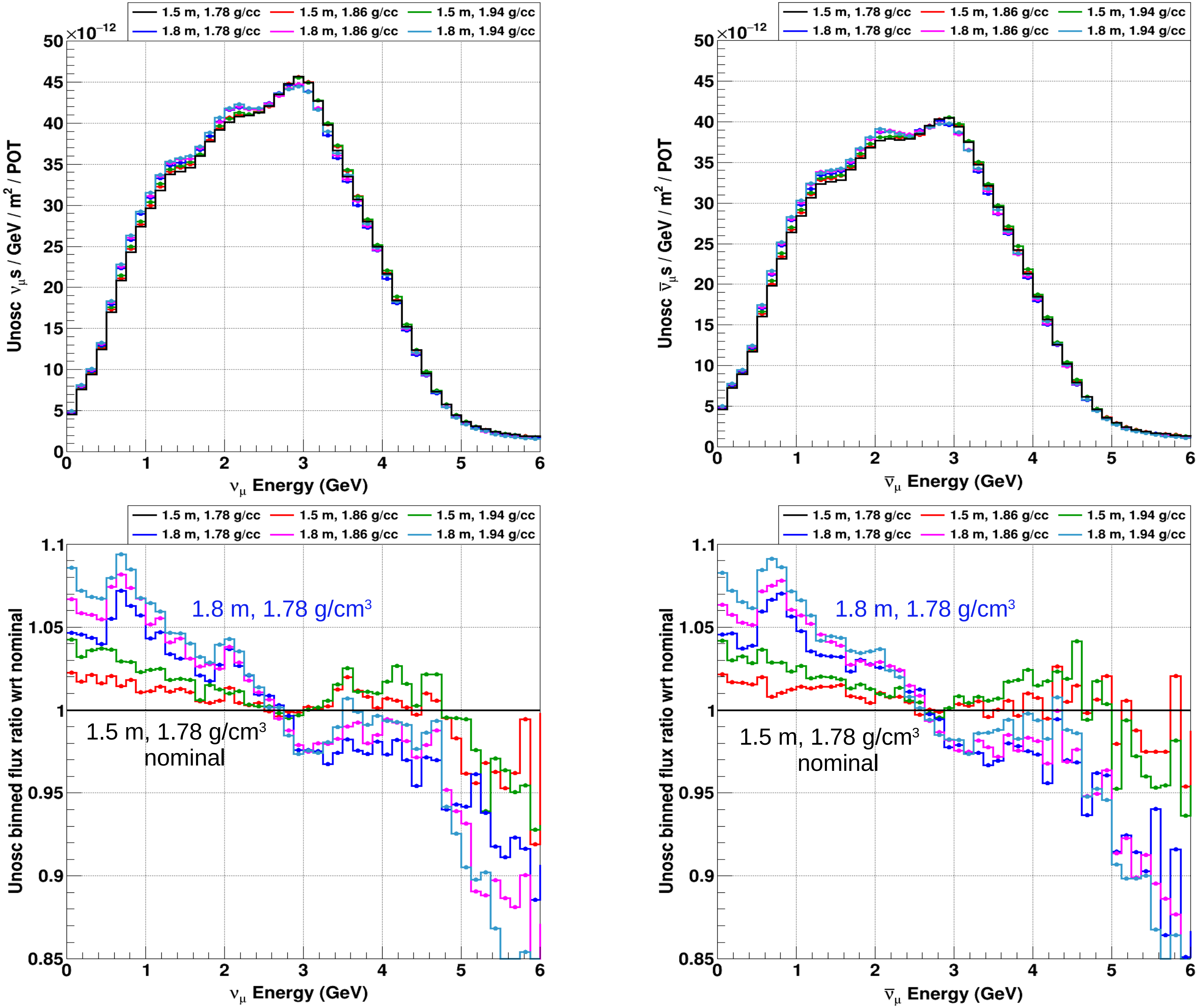
- Plots of **unoscillated ν signal & bkgnd fluxes** extrapolated to far detector
- Plots of **CP sensitivity & exposure** (run time x far detector 40 kt mass)
  - GLoBES, NuFit 4.0 parameters, normal neutrino mass ordering
  - No beam power staging from 1.2 MW to 2.4 MW

G4LBNF geometry: target & horn A

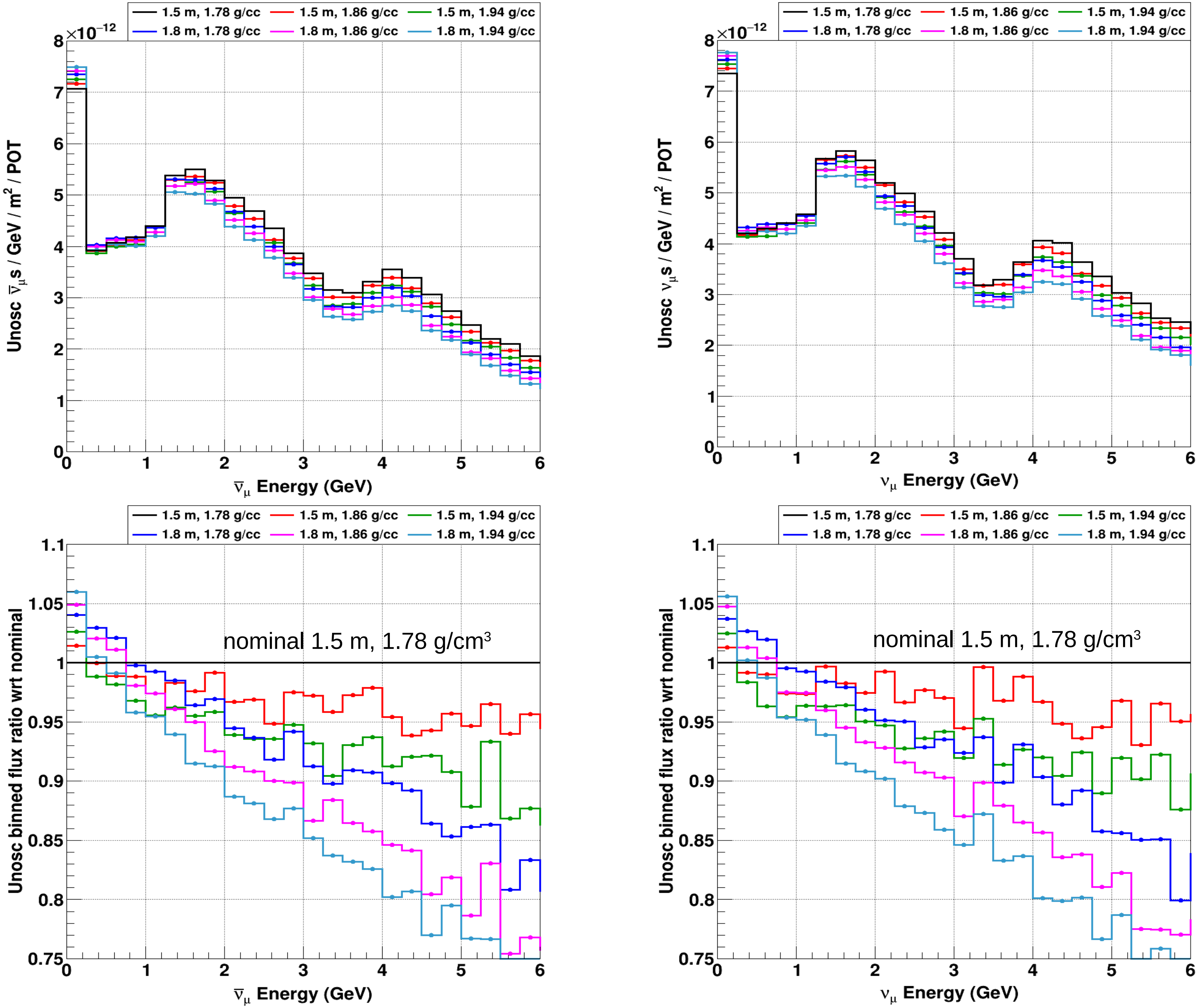


No Δz gaps in target core yet

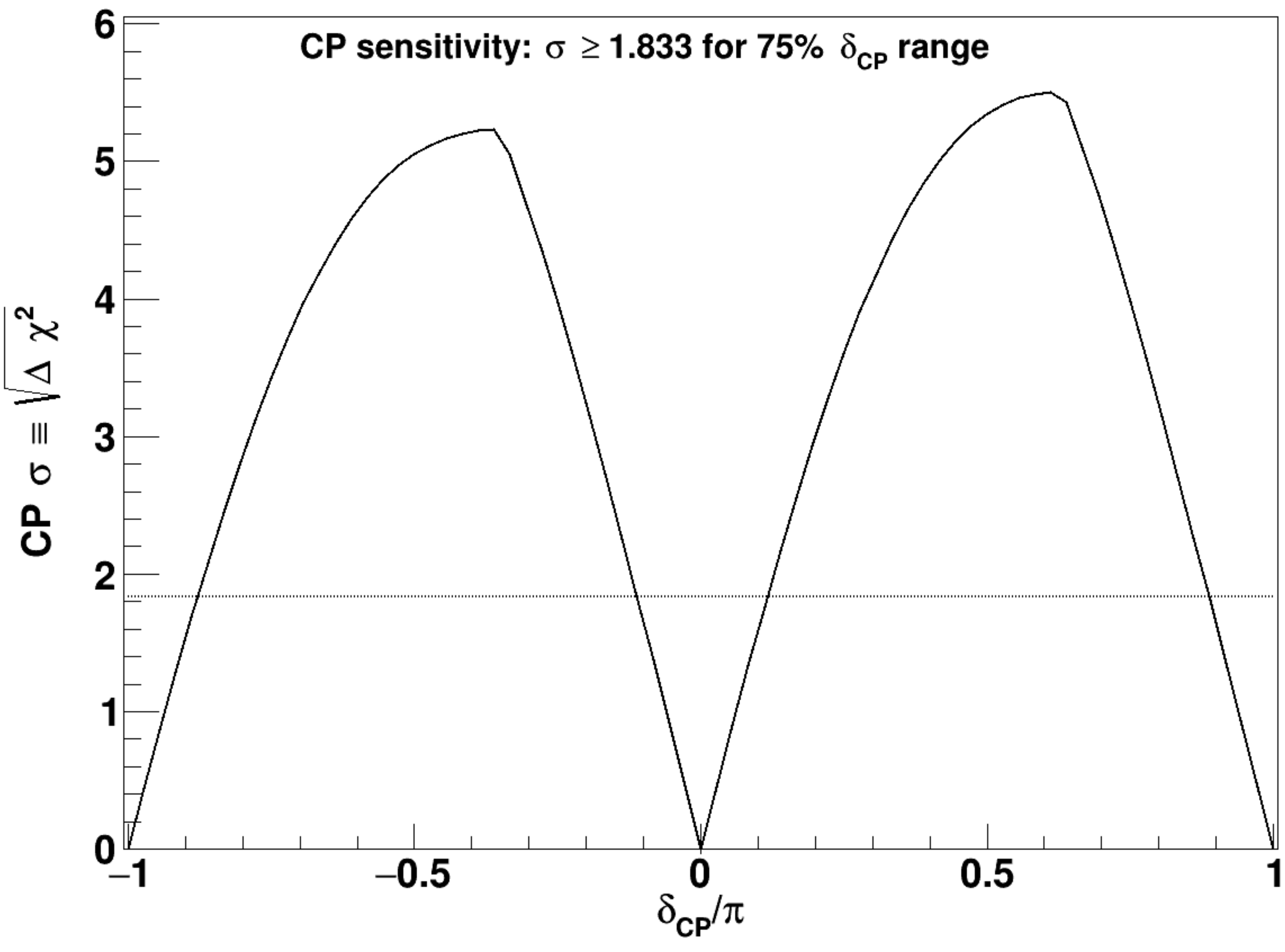
Neutrino signal mode: ν_μ (left) & anti-ν_μ (right)



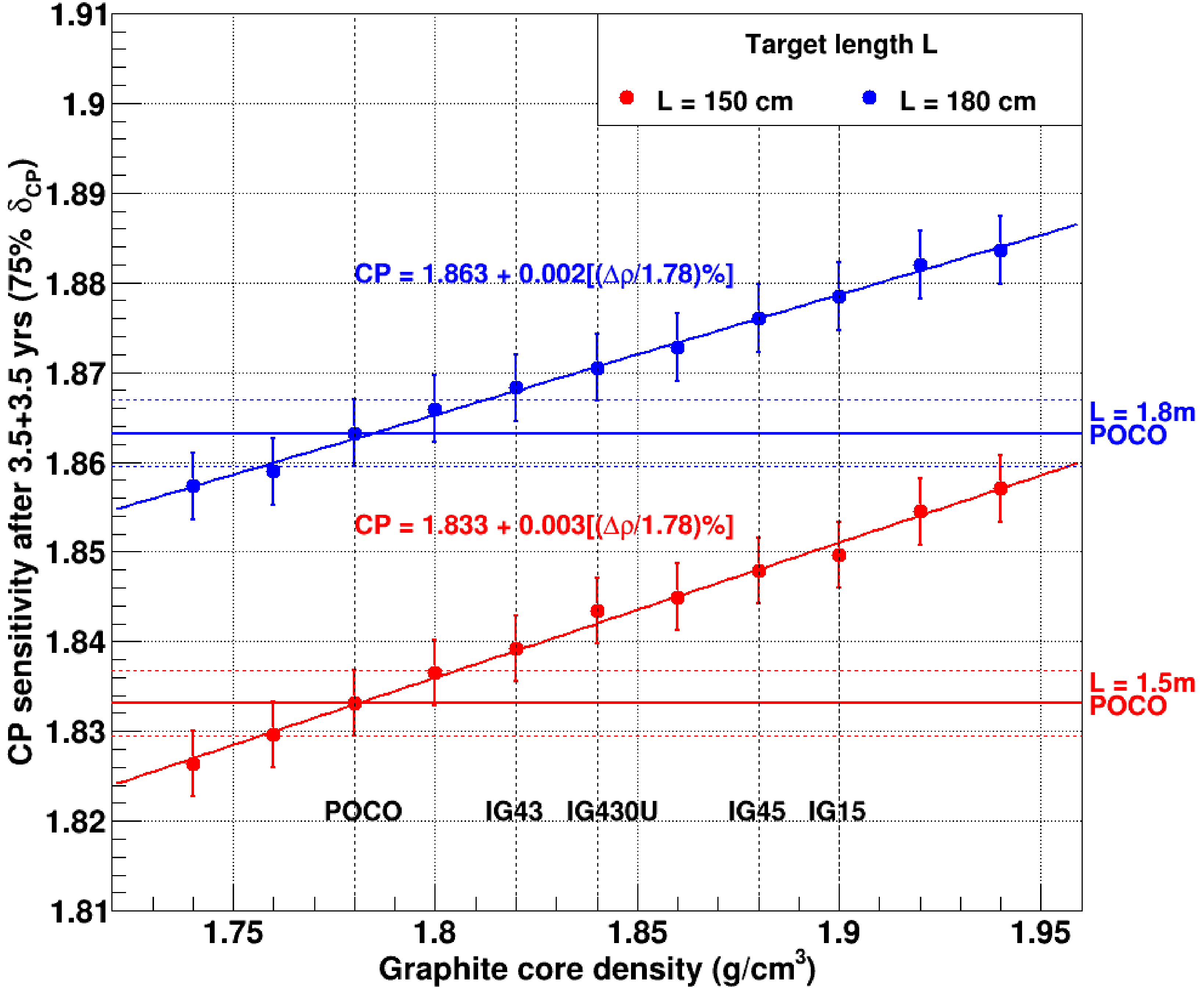
Neutrino wrong sign background: anti-ν_μ (left) & ν_μ (right)



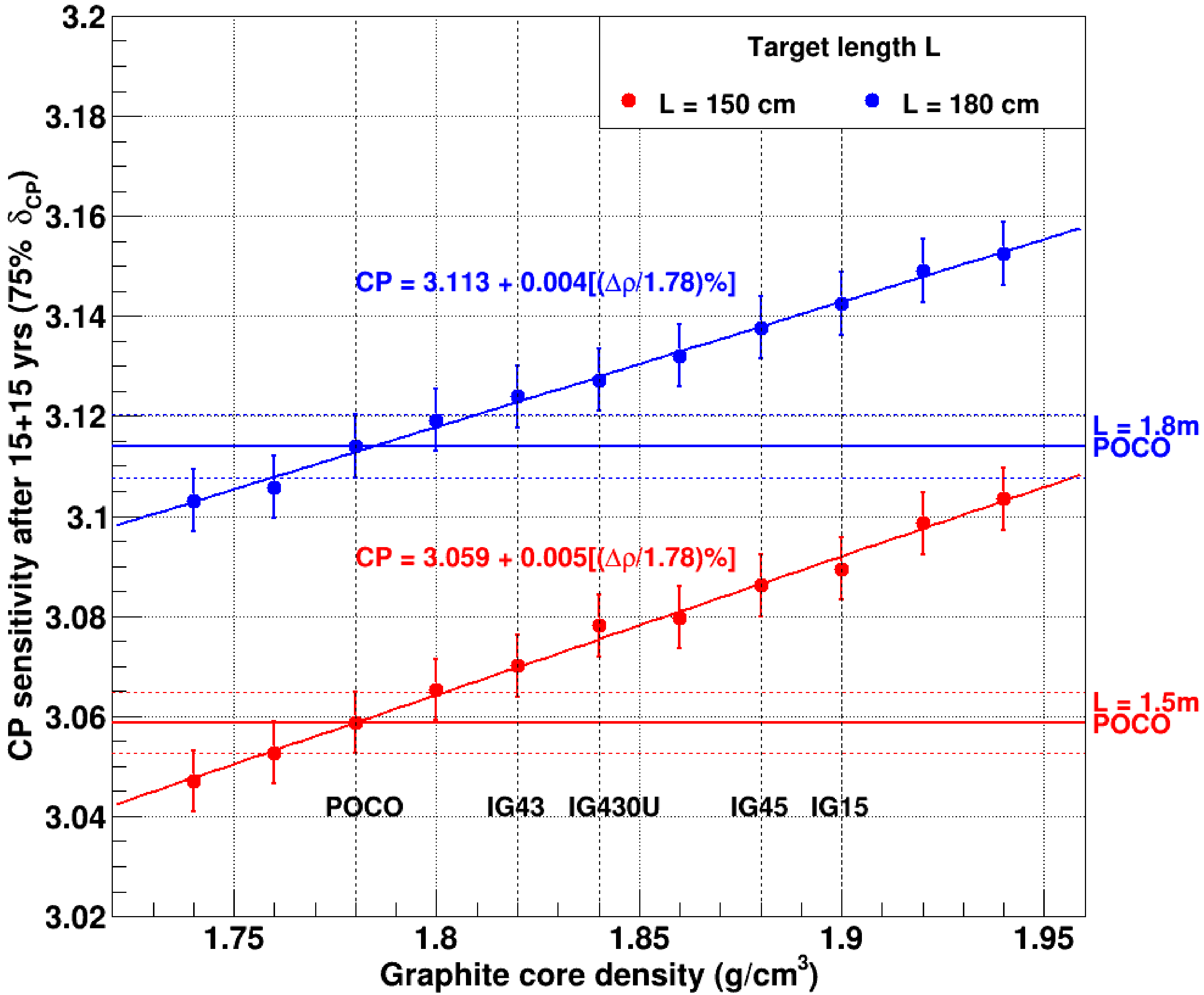
CP sensitivity for L = 1.5 m, ρ = 1.78 g/cm^3 (POCO)
3.5 ν + 3.5 anti-ν run years, 1.2 MW, 1.1x10^{21} POT/year



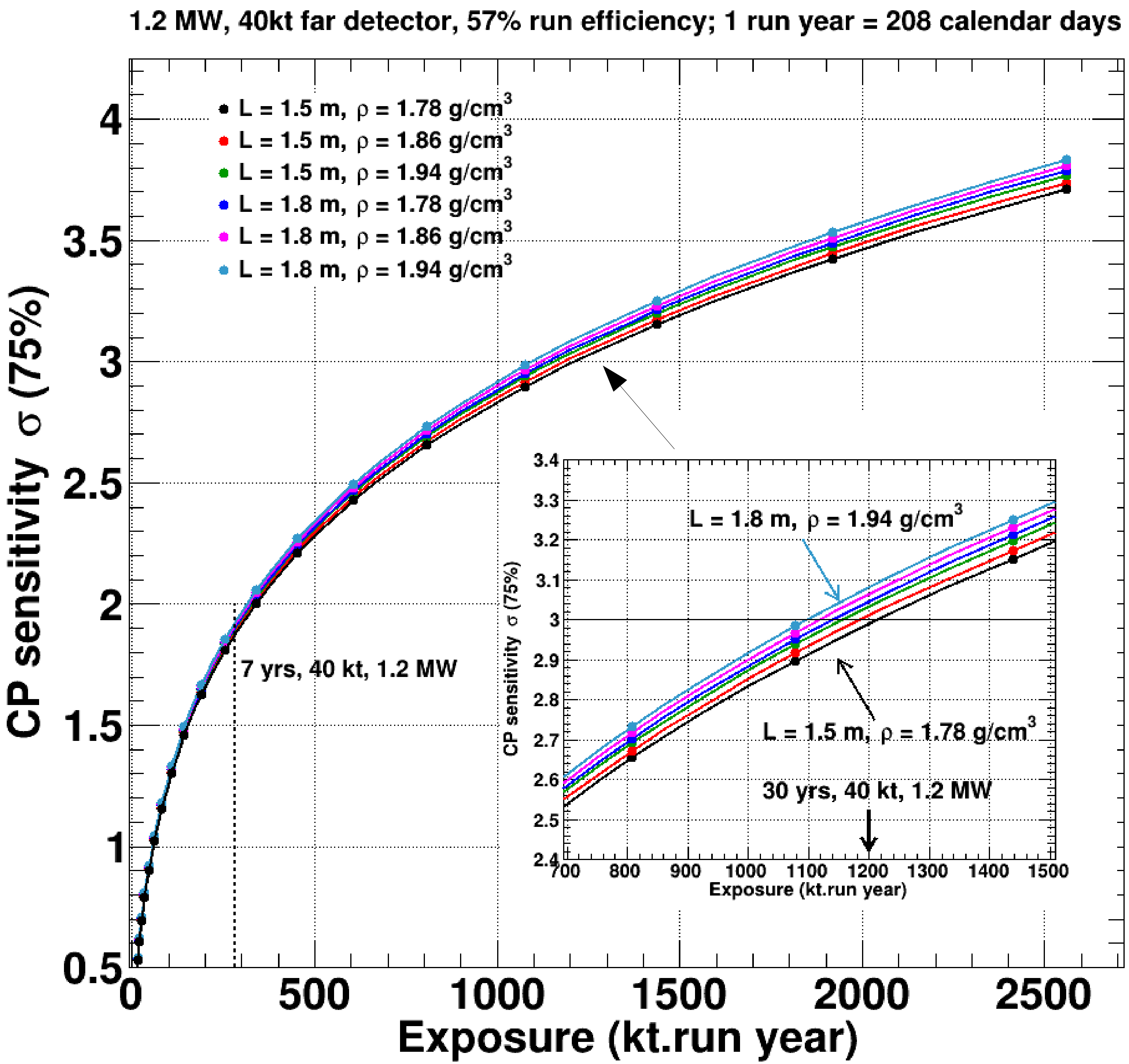
CP sensitivities: 75% δ_{CP} range, **3.5+3.5 run yrs**, 1.2 MW



CP sensitivities: 75% δ_{CP} range, **15+15 run yrs**, 1.2 MW

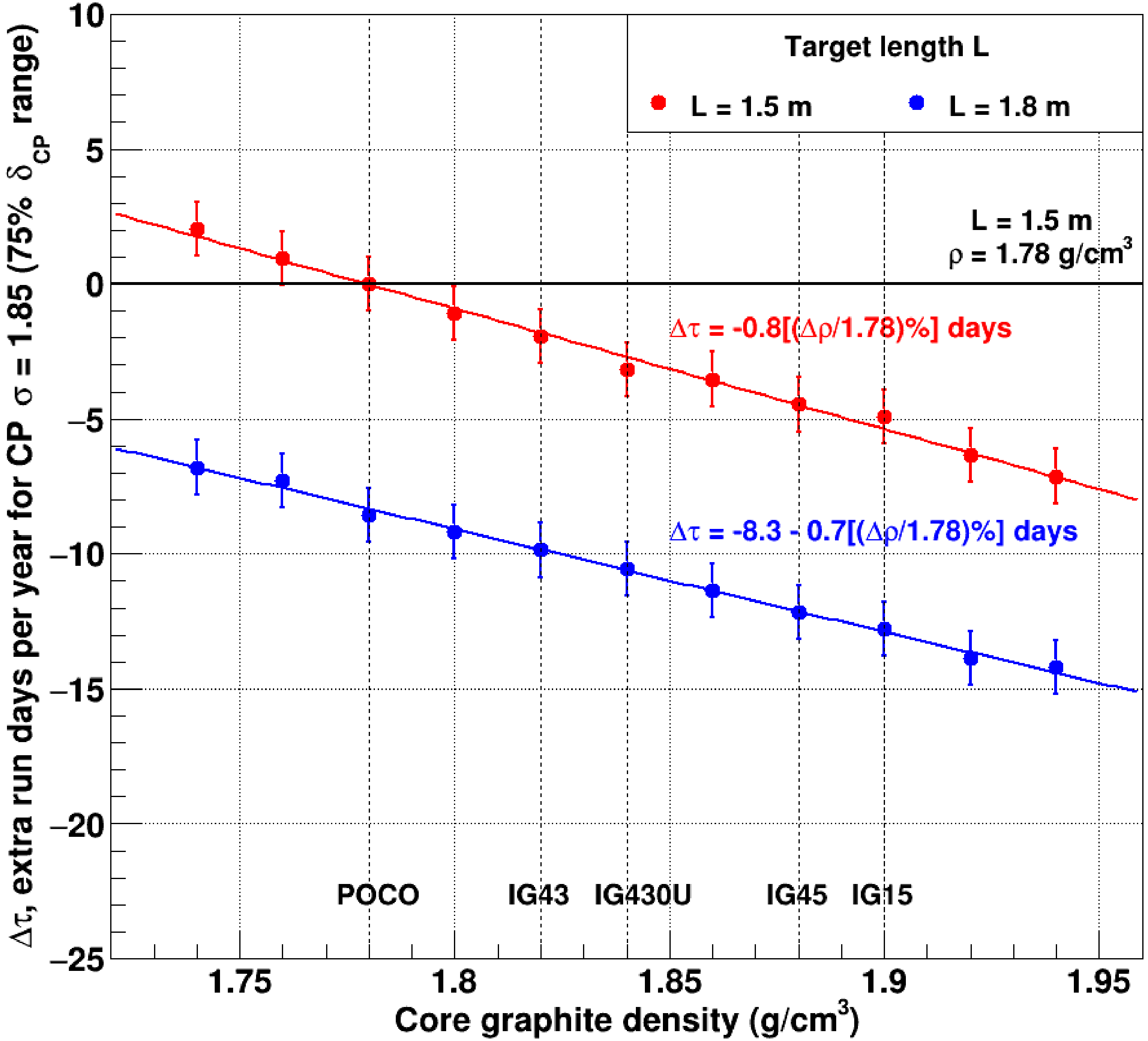


CP sensitivity vs exposure



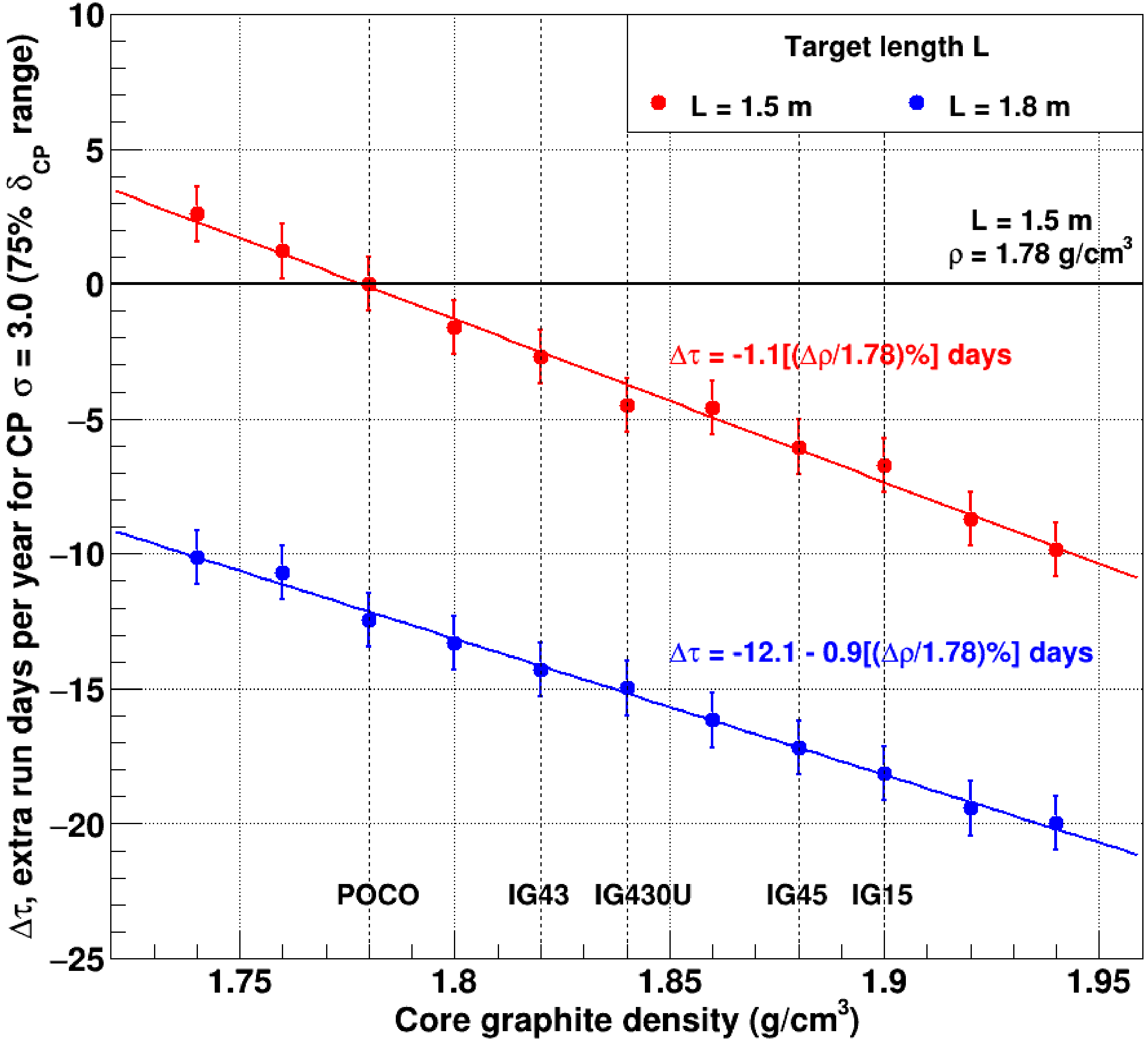
detector mass (40 kt) x run time

Extra run days per year to match **L = 1.5 m**, CP σ **= 1.85**



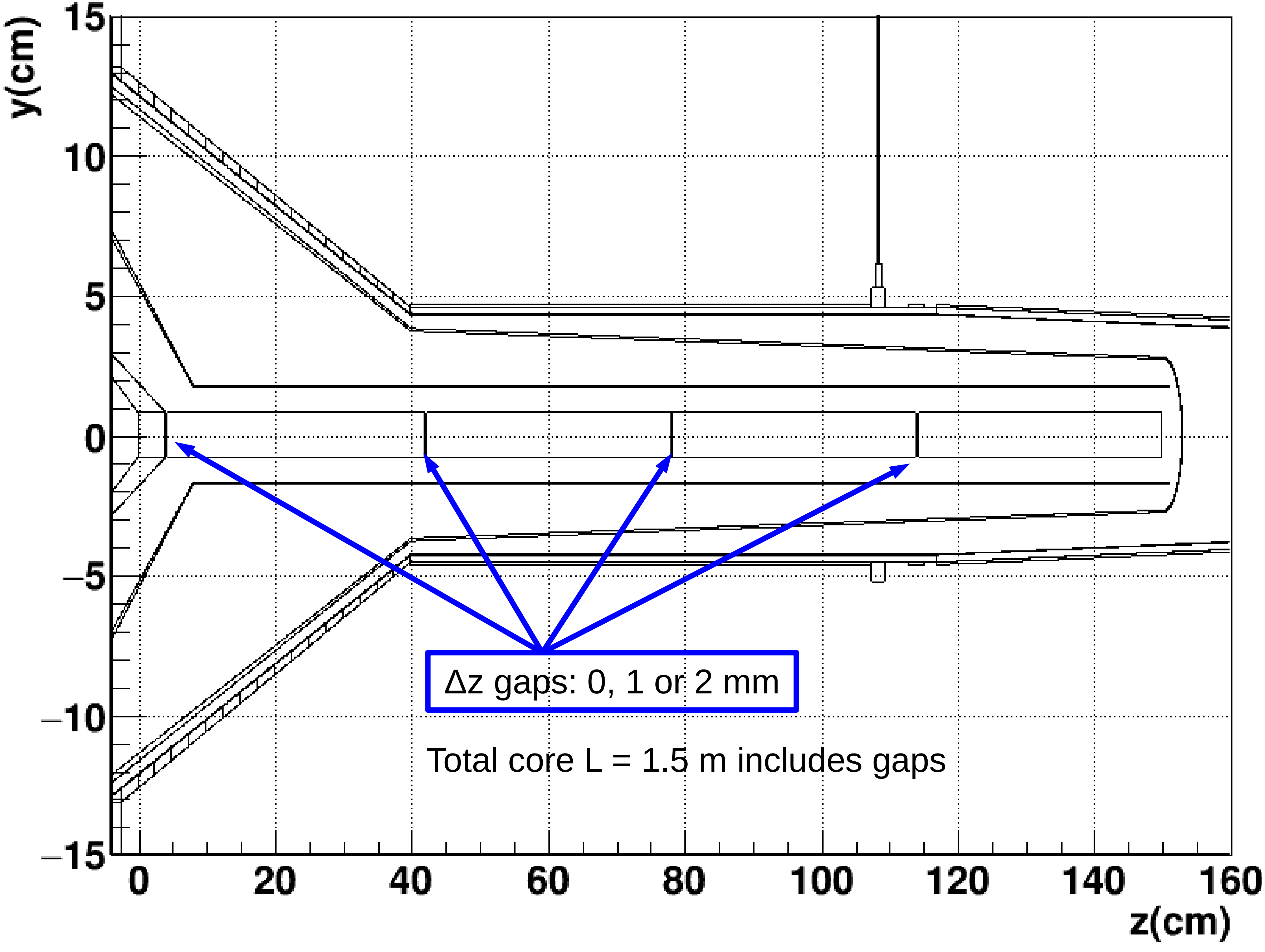
$\Delta\tau$ extra days/yr = fractional exposure change x 208 days; same **40 kt** far detector mass, 1.2 MW

Extra run days per year to match **L = 1.5 m**, CP **σ = 3.0**

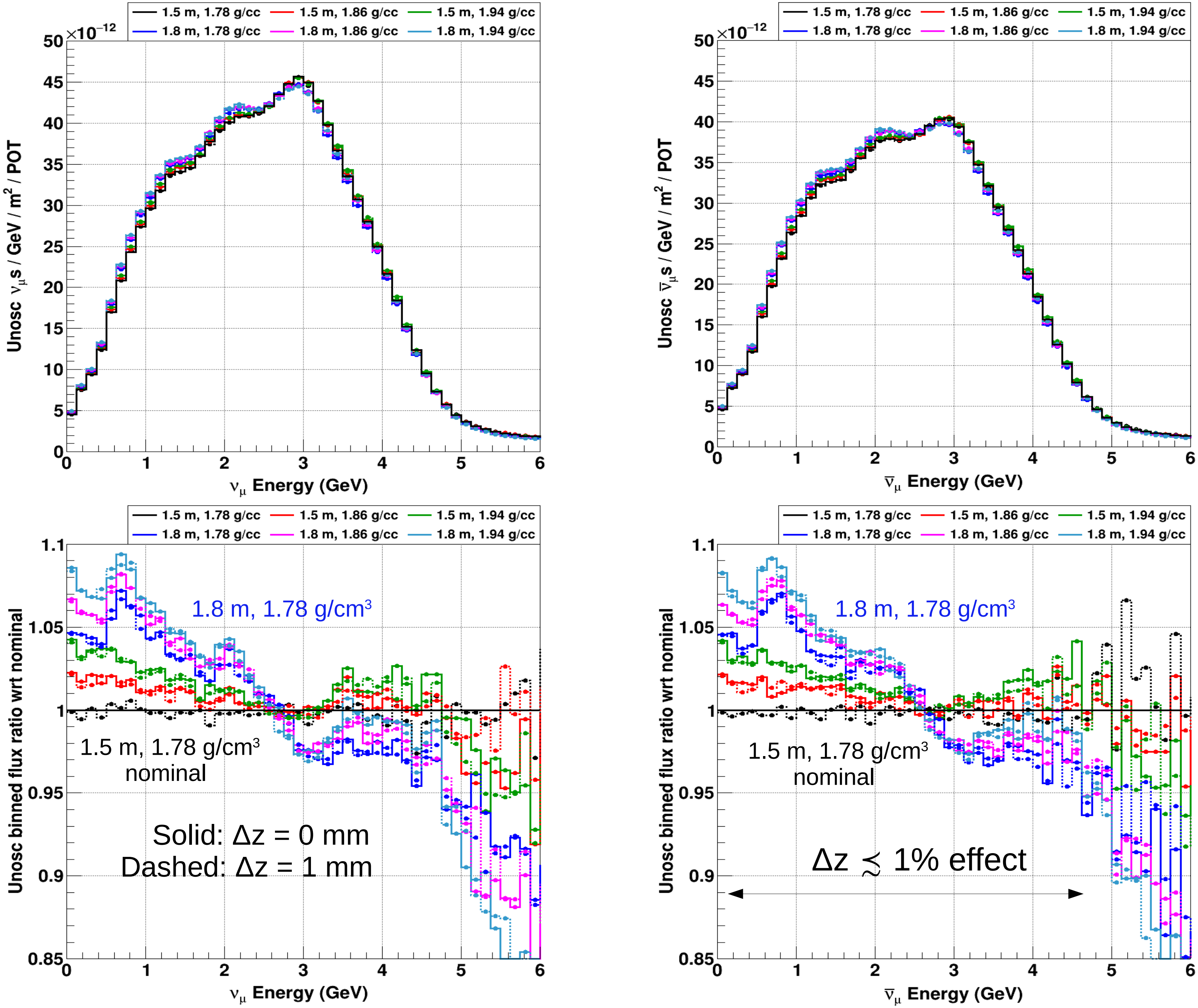


Δτ extra days/yr = fractional exposure change x 208 days; same **40 kt** far detector mass, 1.2 MW

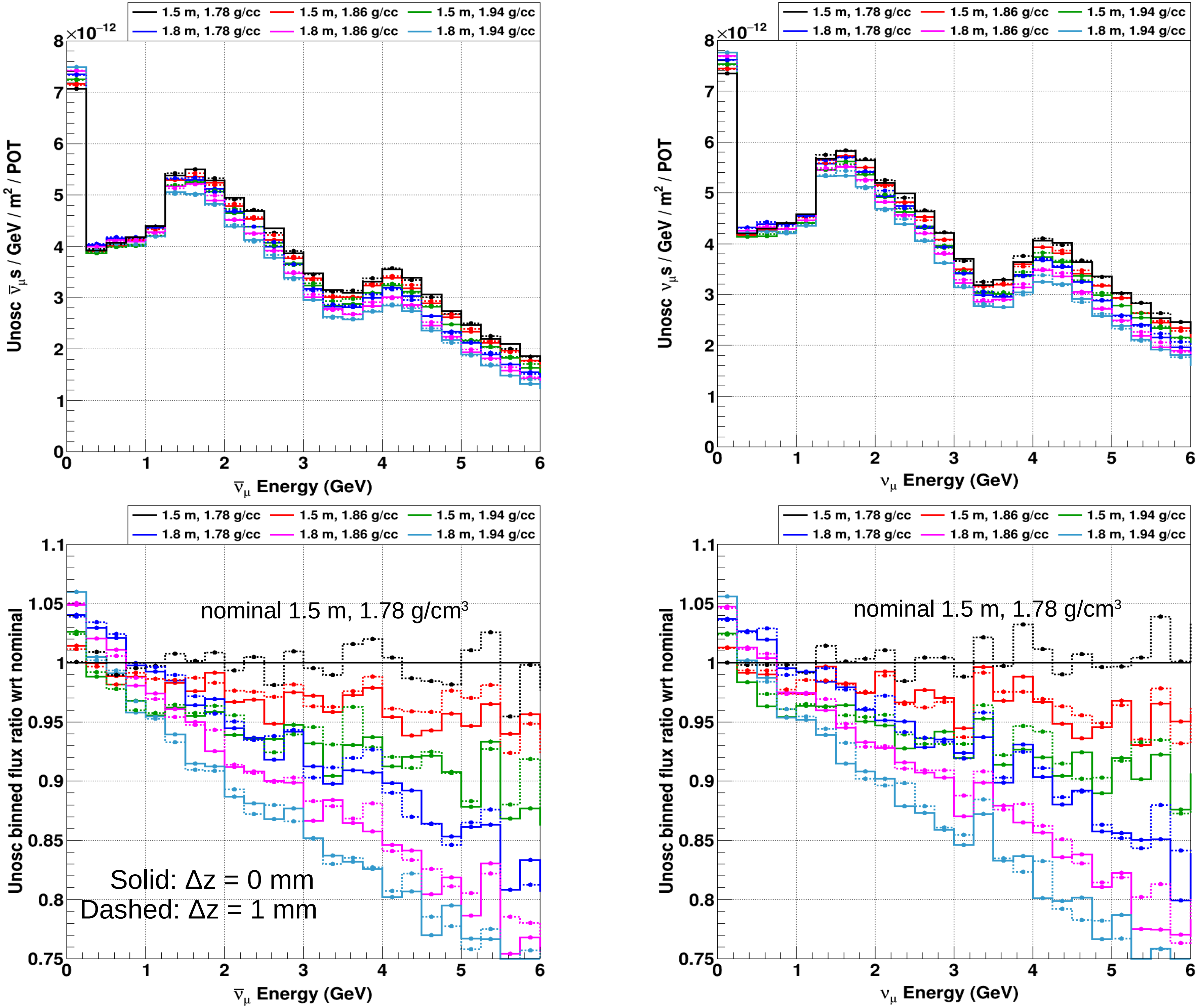
Graphite core: 4 sections with Δz gaps



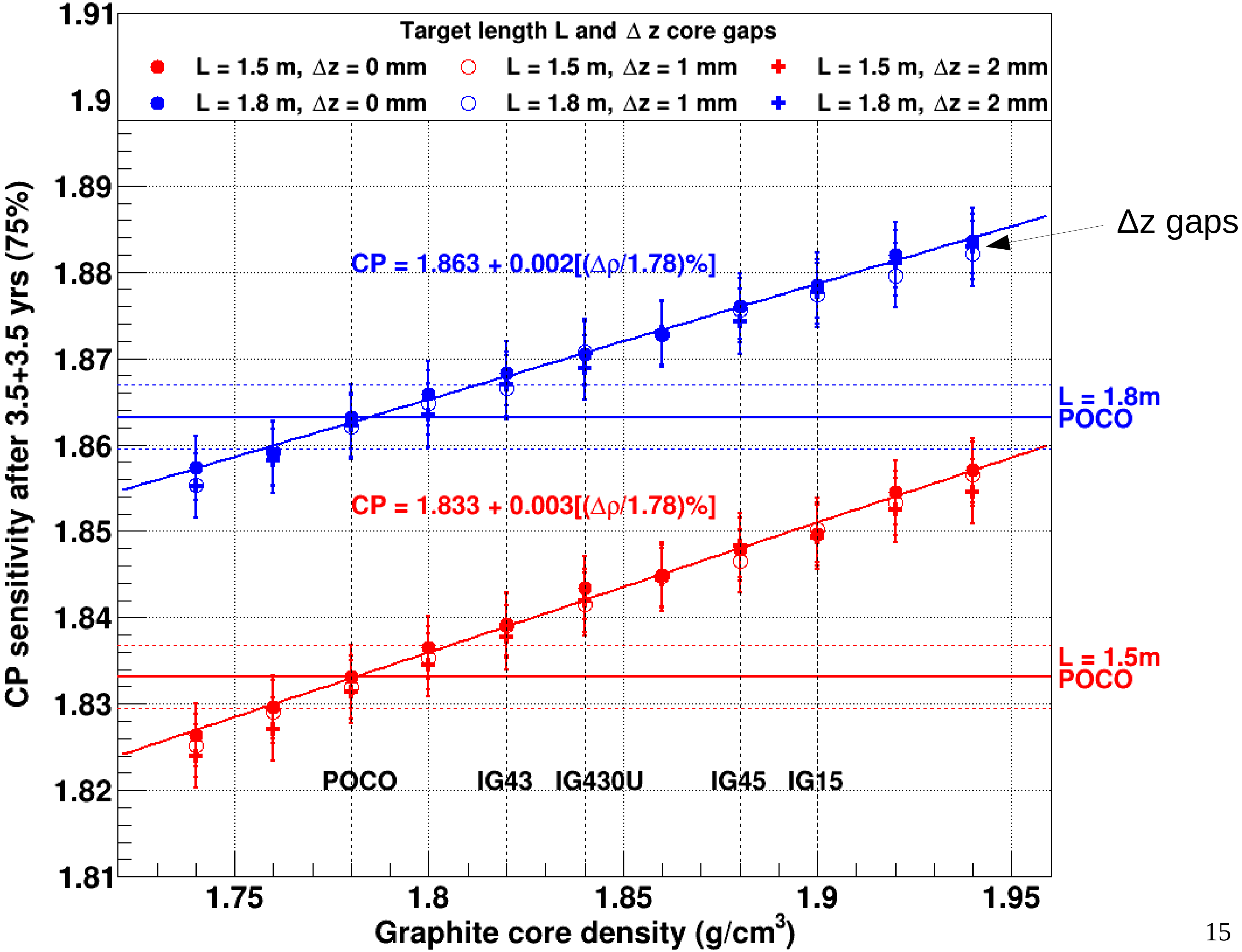
Neutrino signal mode: ν_μ (left) & anti-ν_μ (right)



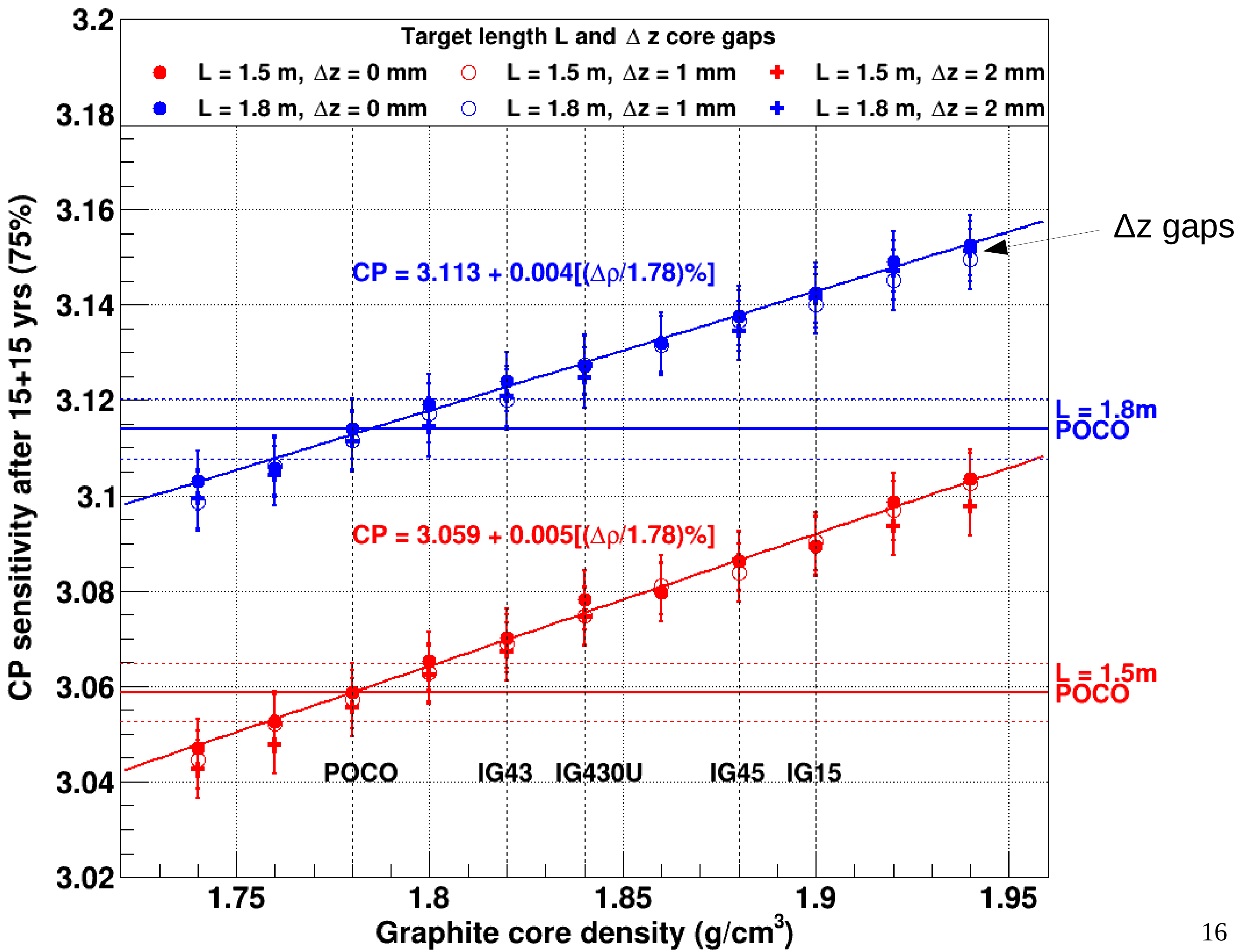
Neutrino wrong sign background: anti-ν_μ (left) & ν_μ (right)



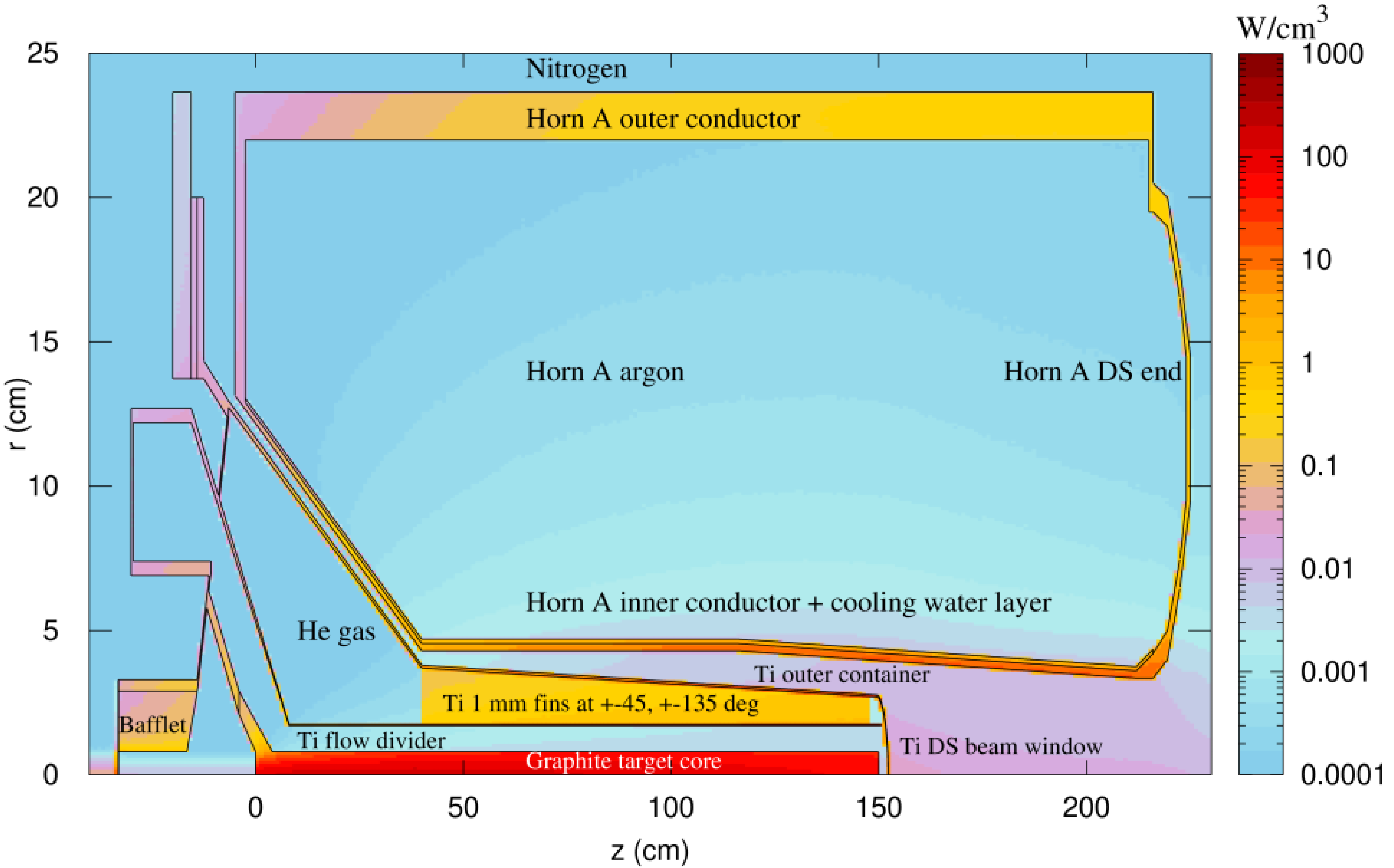
CP sensitivities: 75% δ_{CP} range, **3.5+3.5 run yrs**, 1.2 MW



CP sensitivities: 75% δ_{CP} range, **15+15 run yrs**, 1.2 MW

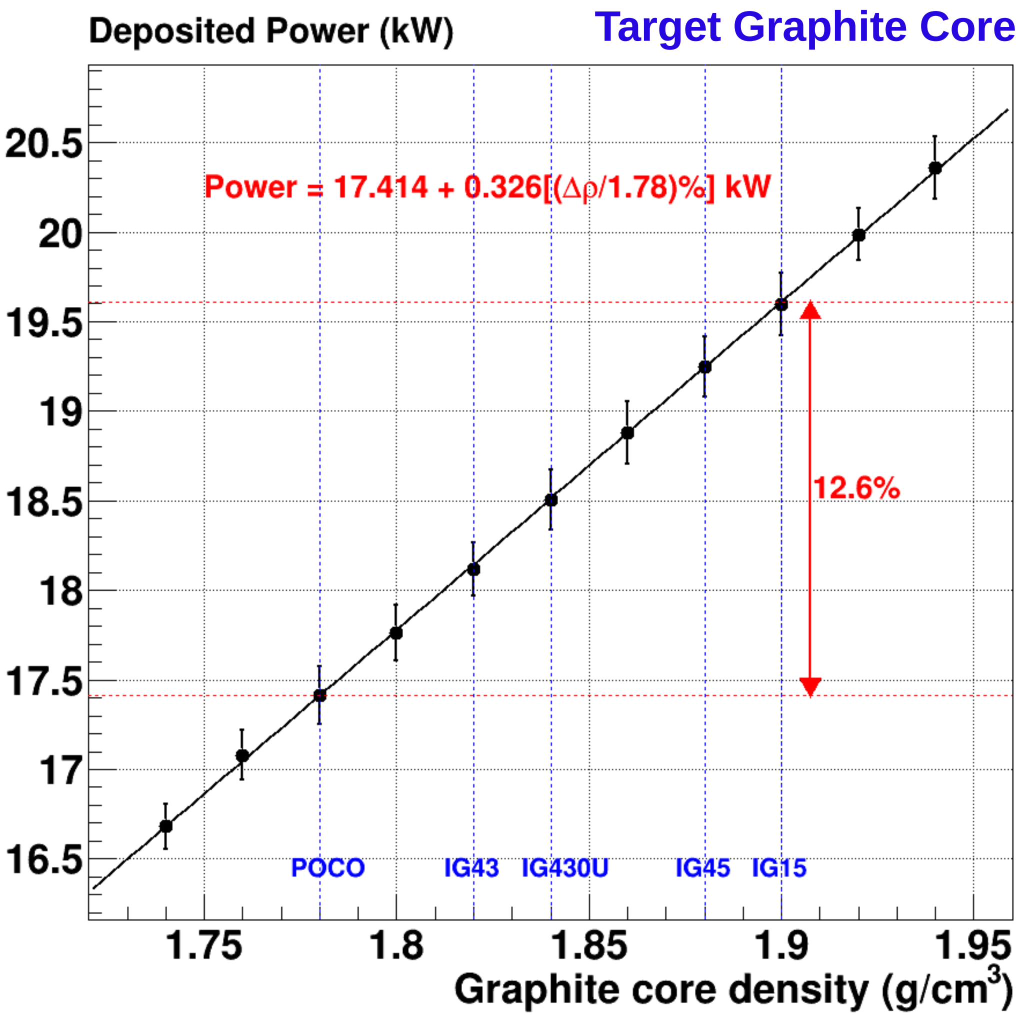


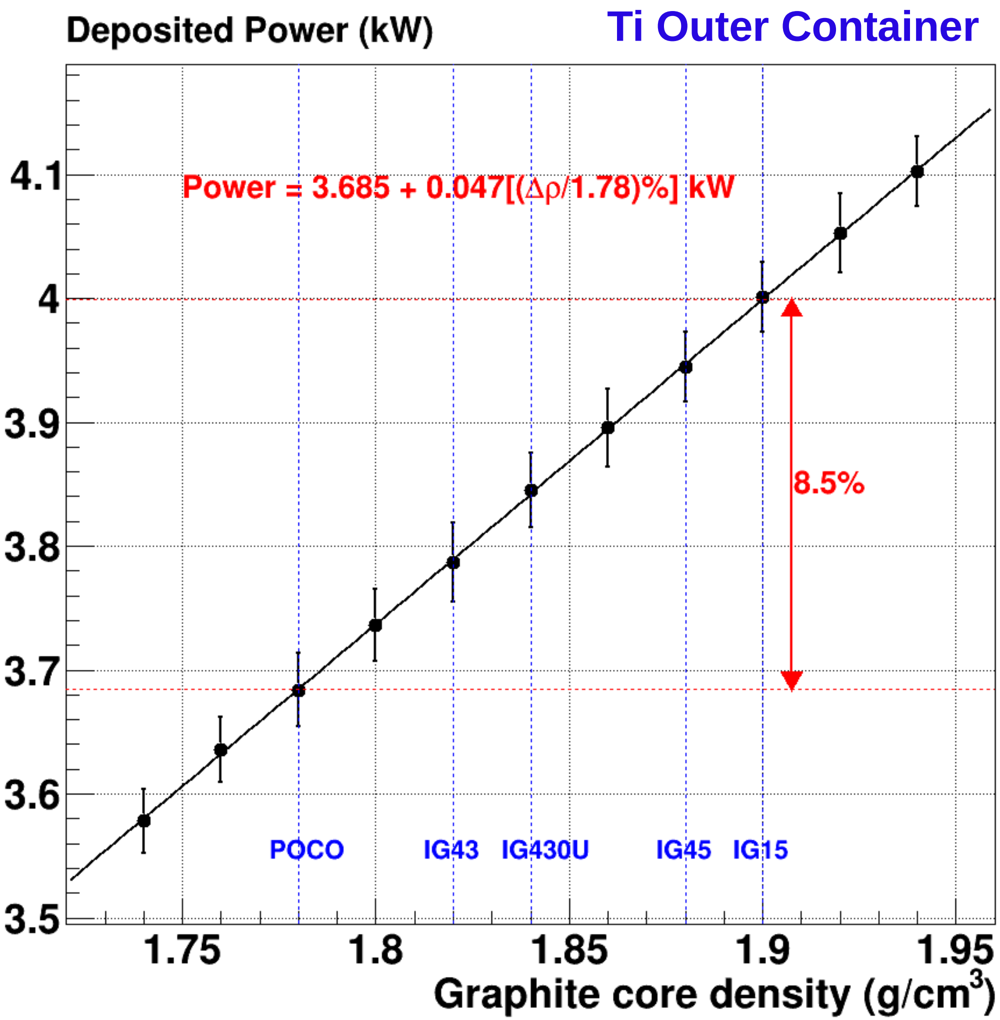
FLUKA power deposition: target & horn A



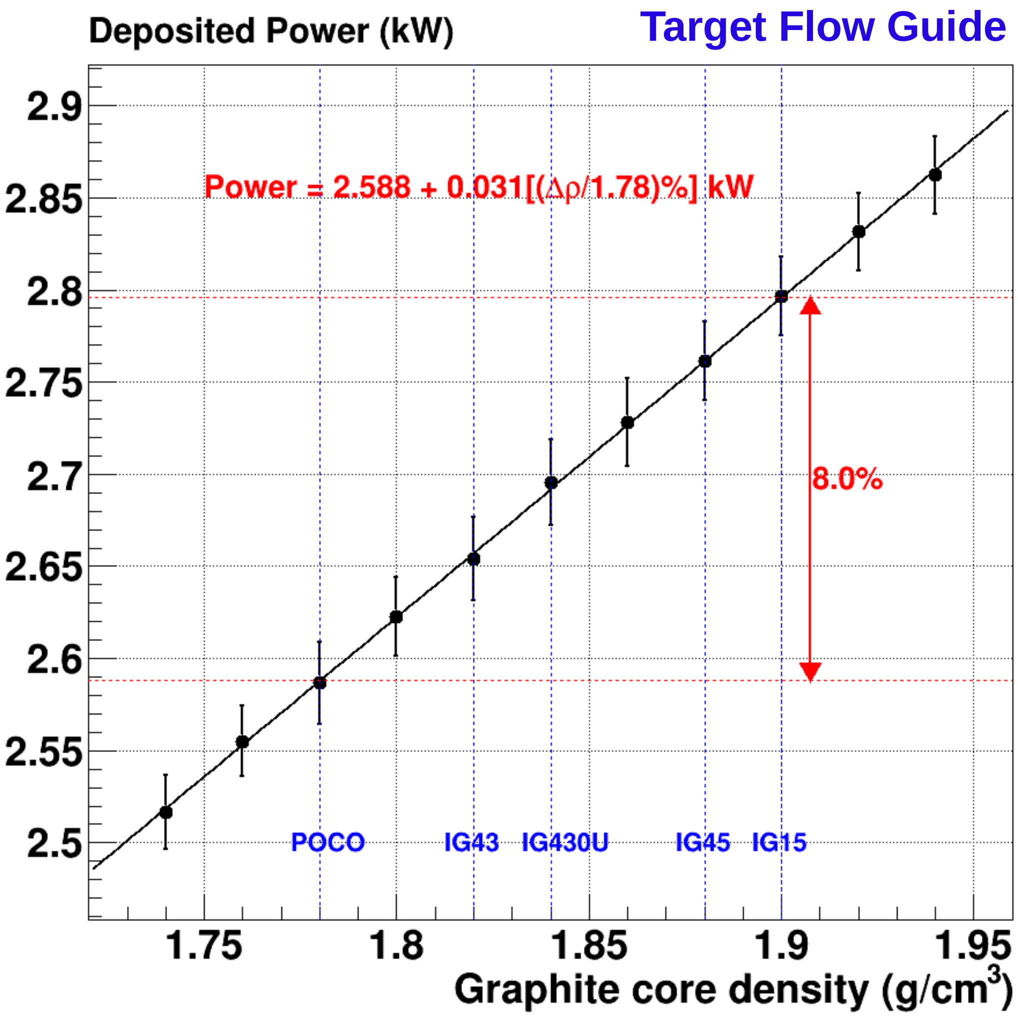
No Δz gaps in target core. Beam Power = 1.2 MW

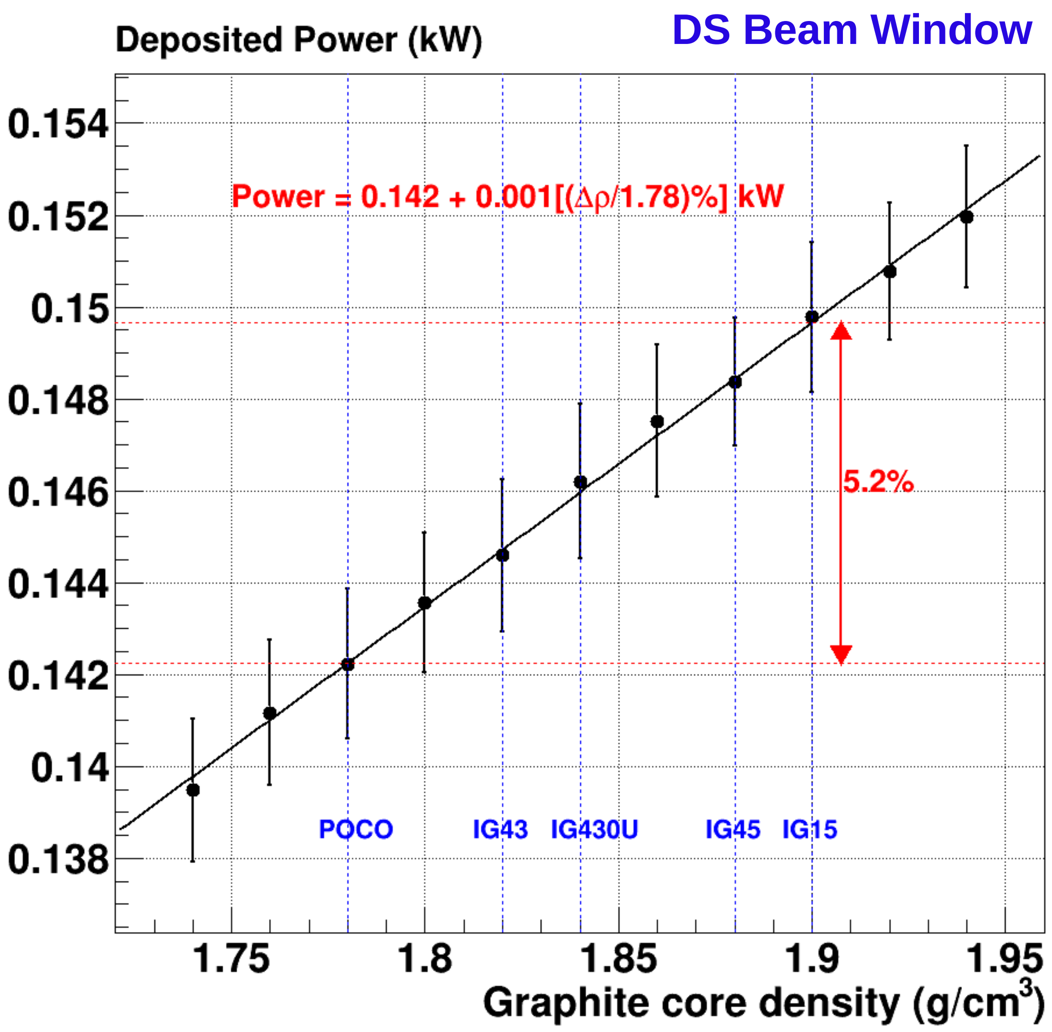
Deposited power: target core & outer container



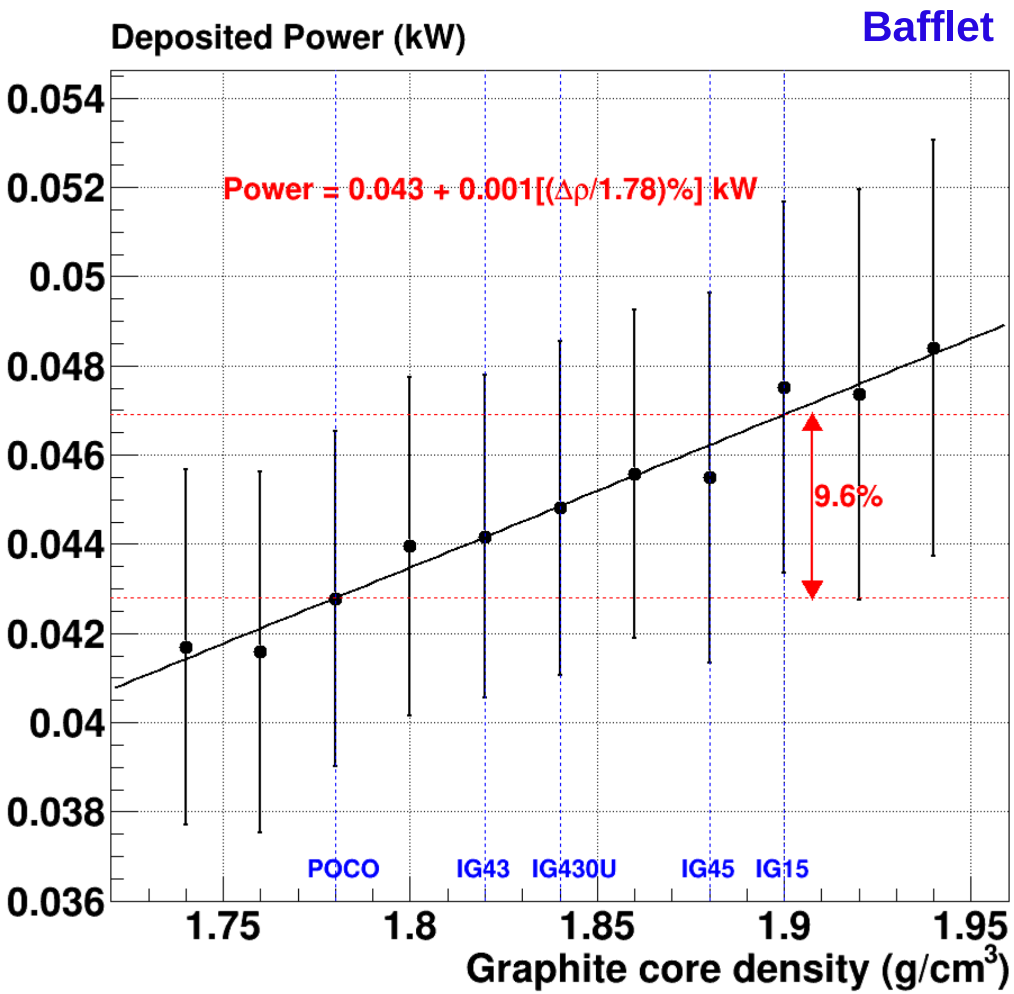


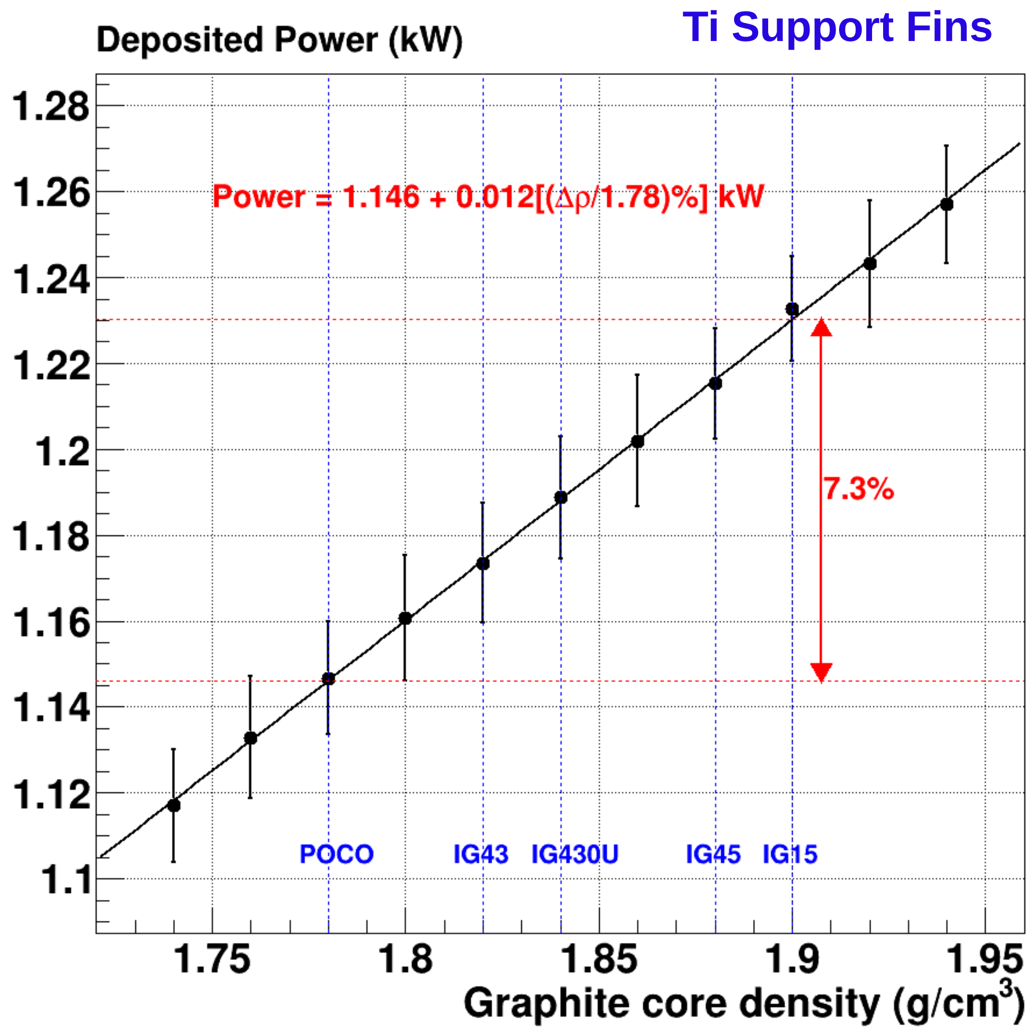
Deposited power: flow guide & DS beam window



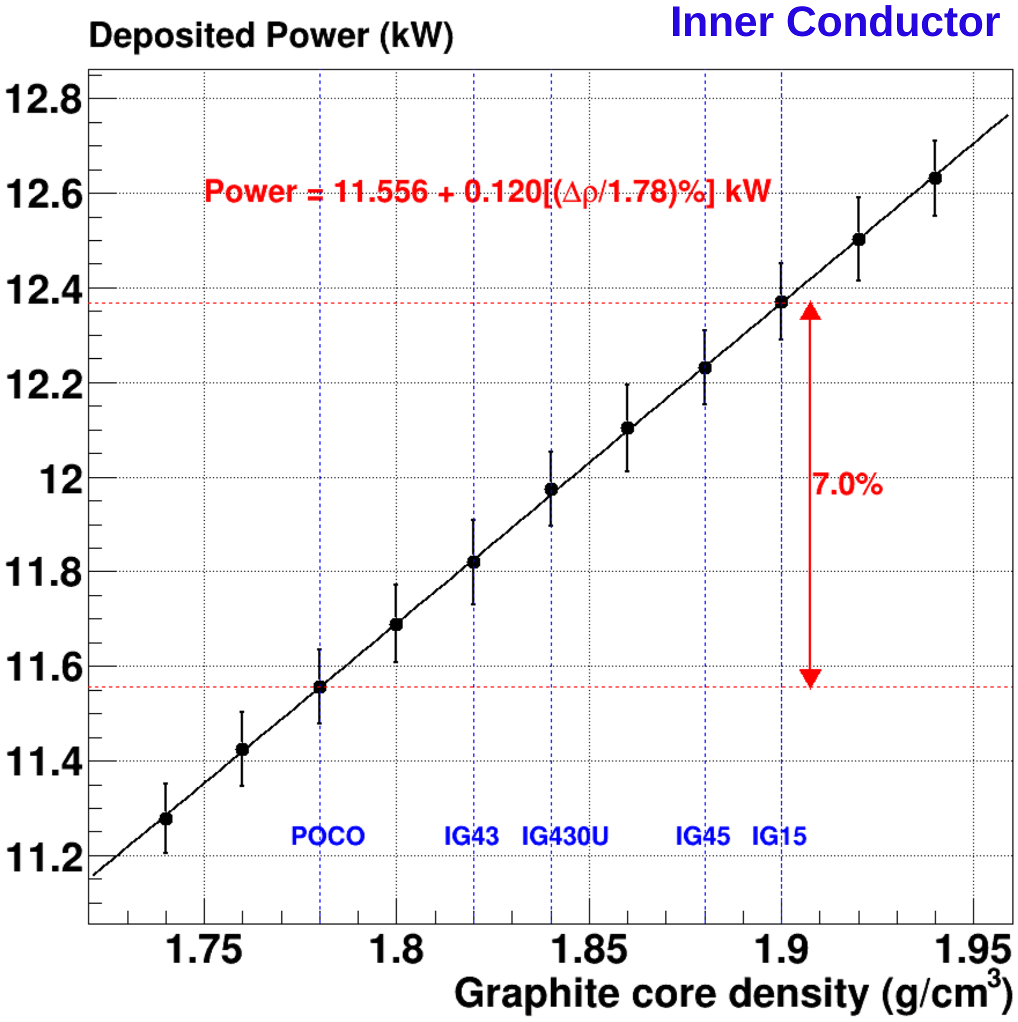


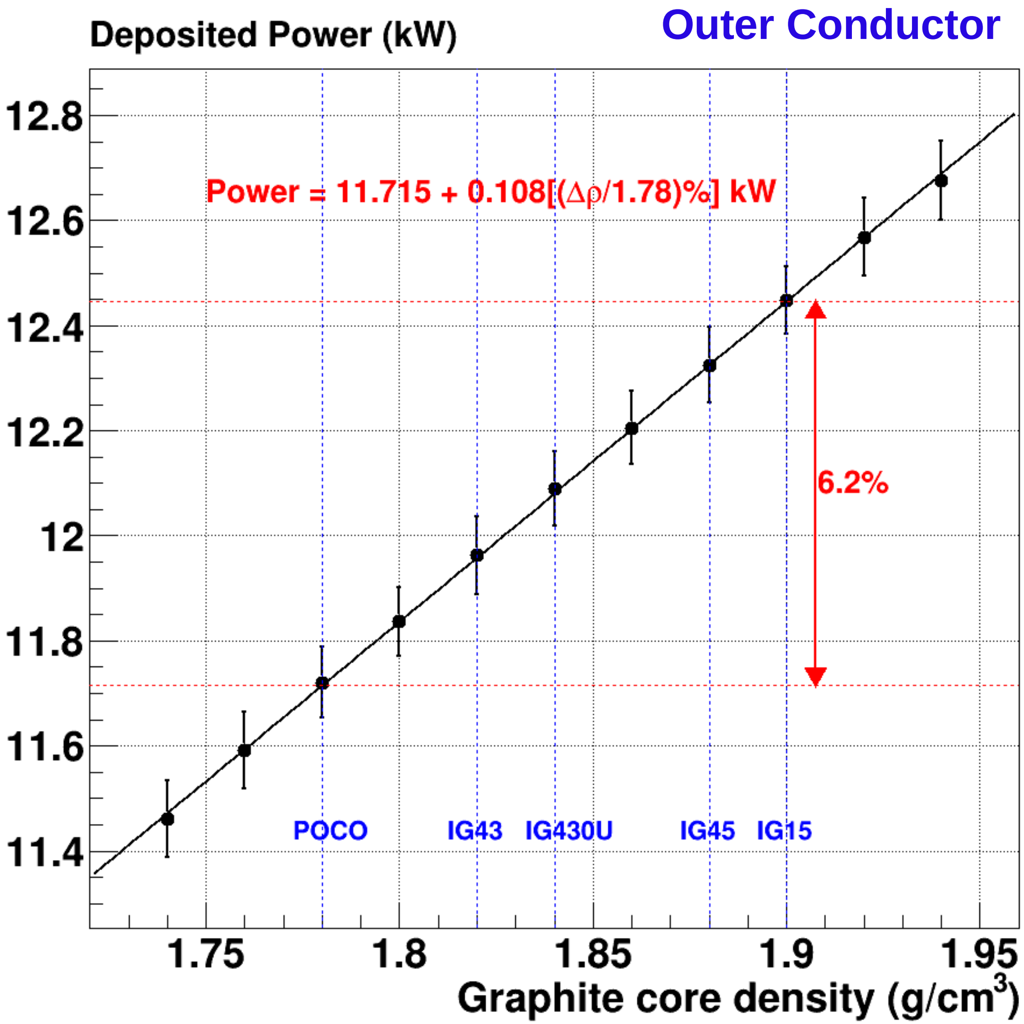
Deposited power: bafflet & target support fins



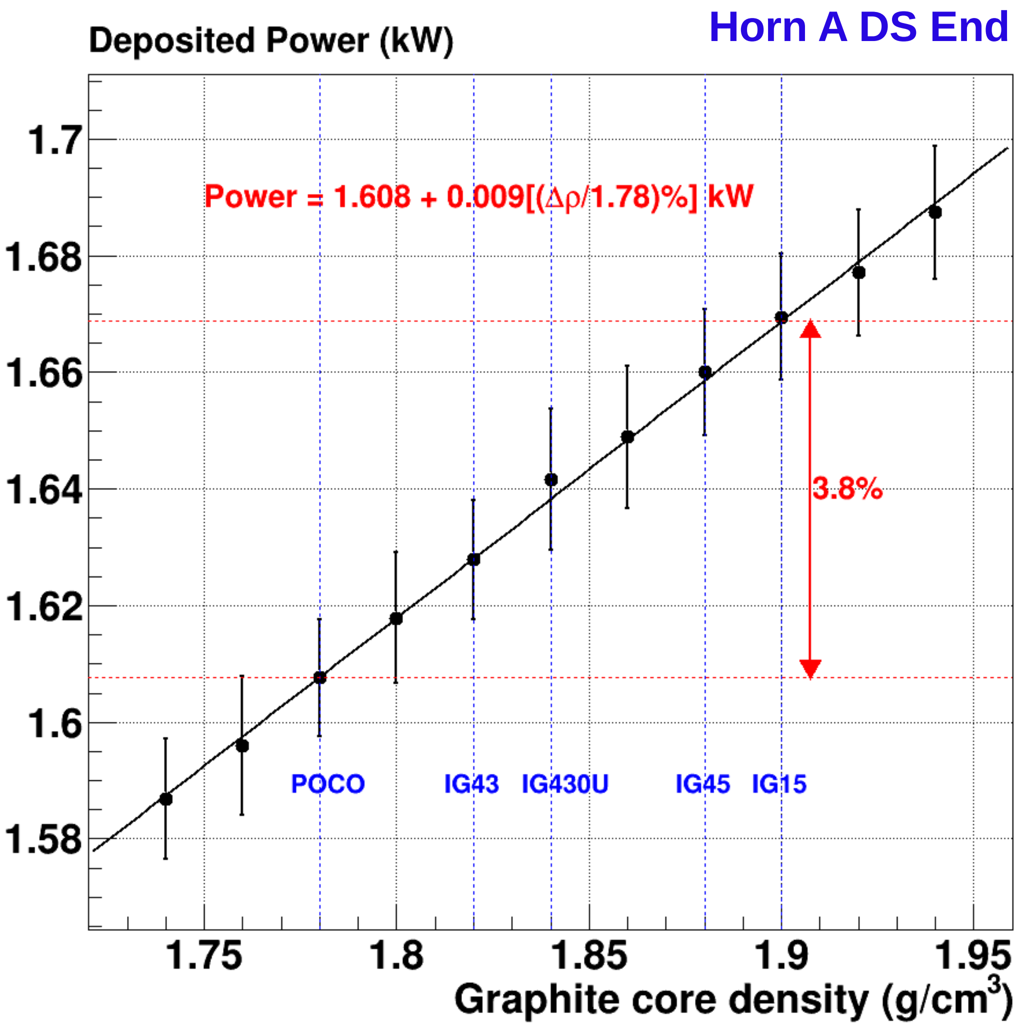


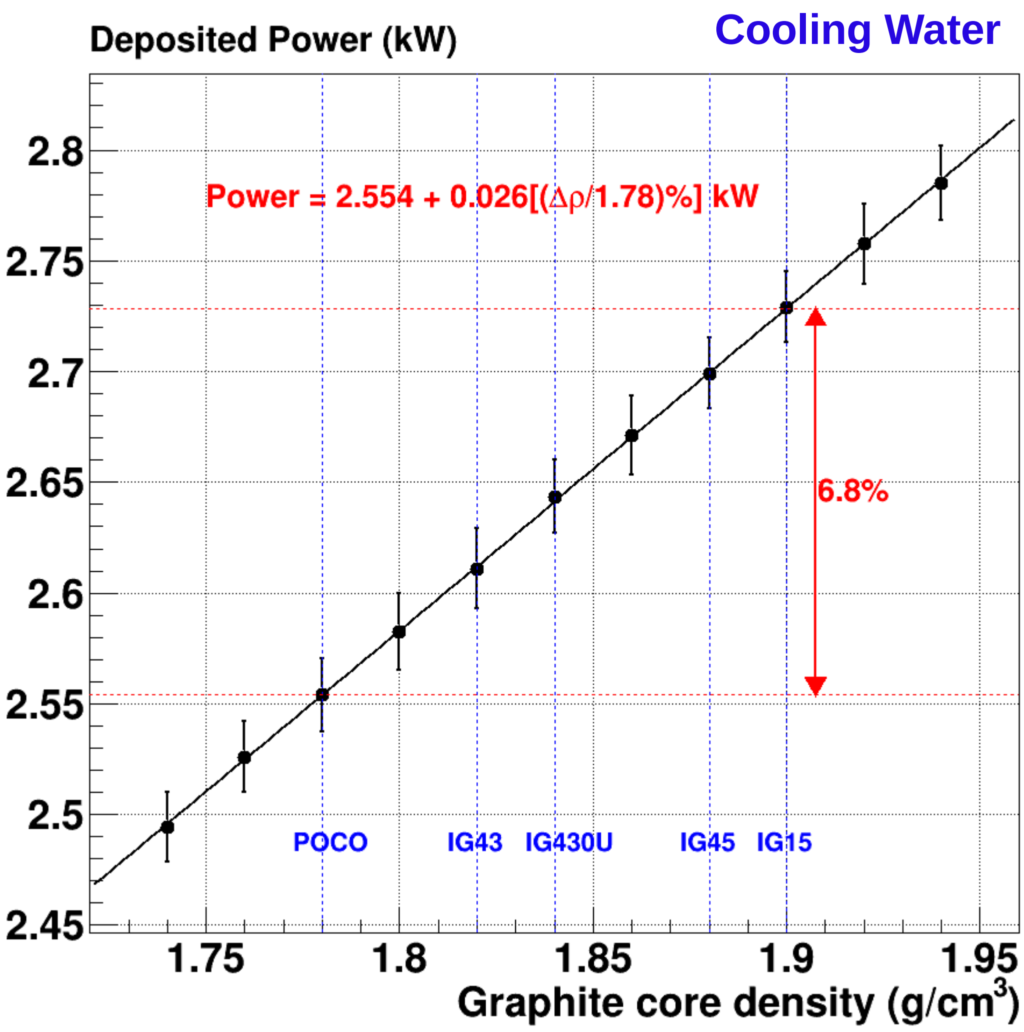
Deposited power: horn A inner & outer conductors





Deposited power: horn A downstream end & water





Summary

- Physics impact of LBNF target **core graphite density** & **Δz gaps**

- Higher graphite densities increase neutrino flux
  - **High density L = 1.5 m approaches low density L = 1.8 m**
  - More low energy neutrinos (especially for 2nd osc max)
  - Reduced wrong-sign backgrounds for E_ν > 0.5 GeV

- Small Δz gaps between 4 graphite core sections
  - ~±1% changes in ν flux, no significant changes in CP sensitivity
  - OK to have Δz = 1 mm to allow for thermal expansion

- Energy deposition scales linearly with core graphite density