Bafflet Optimization for LBNF with the RAL Target

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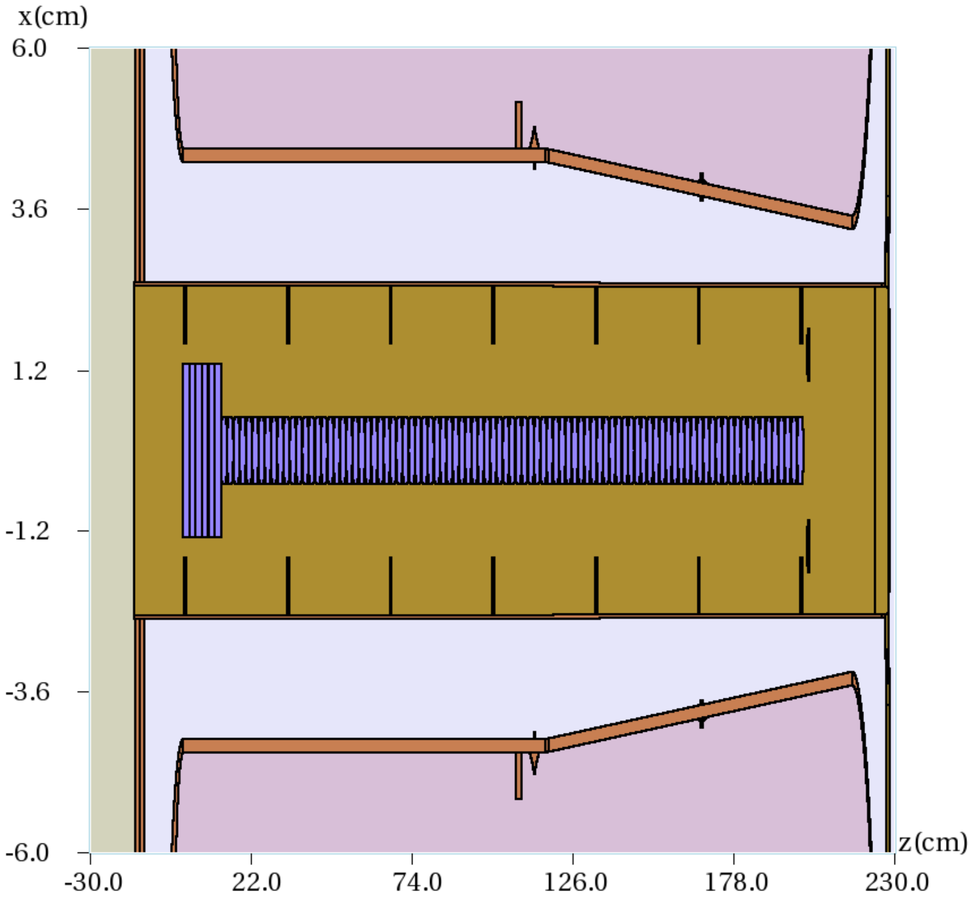
Introduction

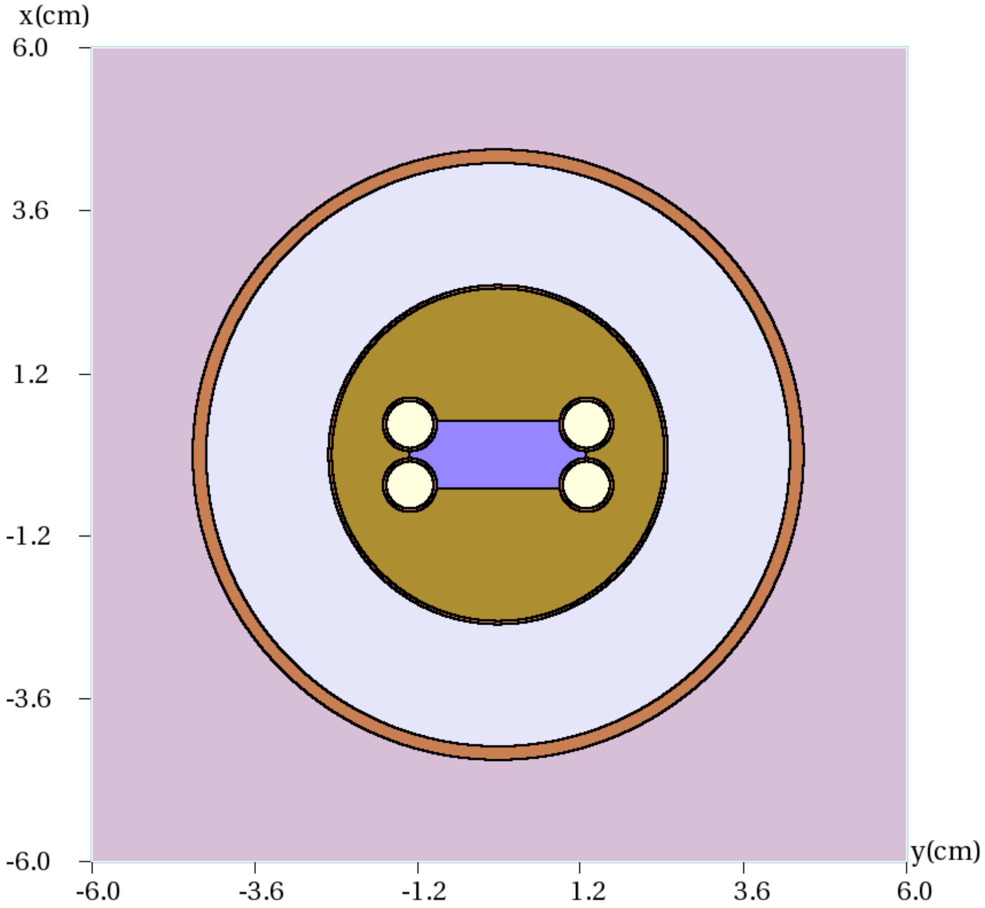
RAL design is considered for the LBNF target

Our experience with MARS15 studies of energy deposition in the LBNF Hadron Absorber (HA) for the reference and optimized designs show that the peak energy deposition density in HA core is strongly dependent on the target configuration details

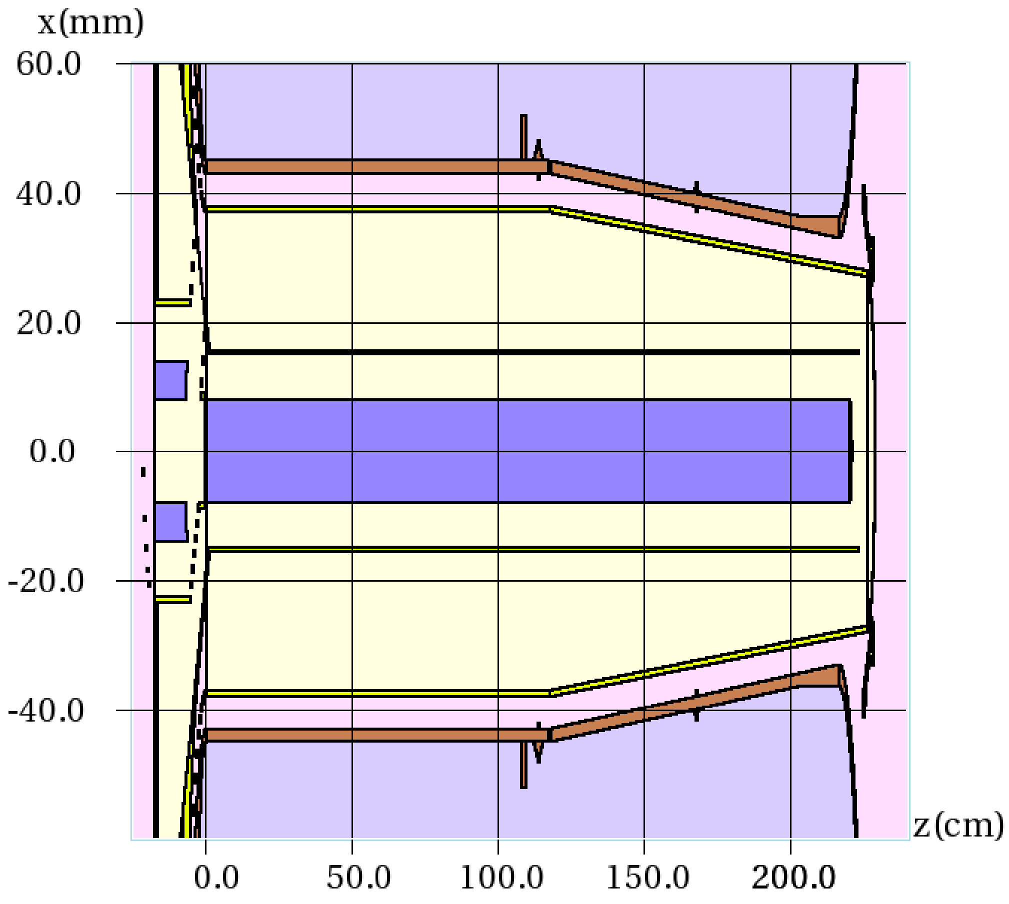
The prime goal of this study is the peak energy deposition in the Hadron Absorber for the RAL design target compared to the original NuMI-type target

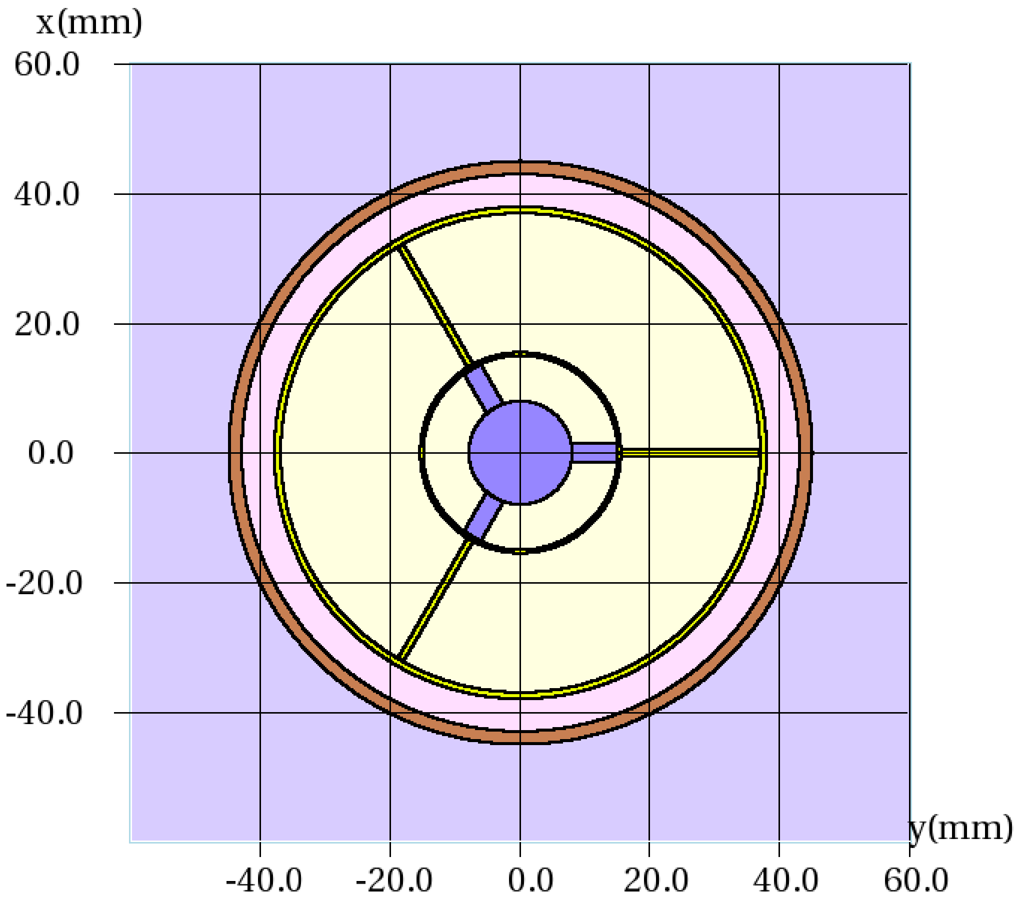
”Optimized” design –NuMI-type target, σ_{beam}=0.17 cm
93 1x2.6x2 cm graphite fins + 1.3 cm radius x 12 cm bafflet



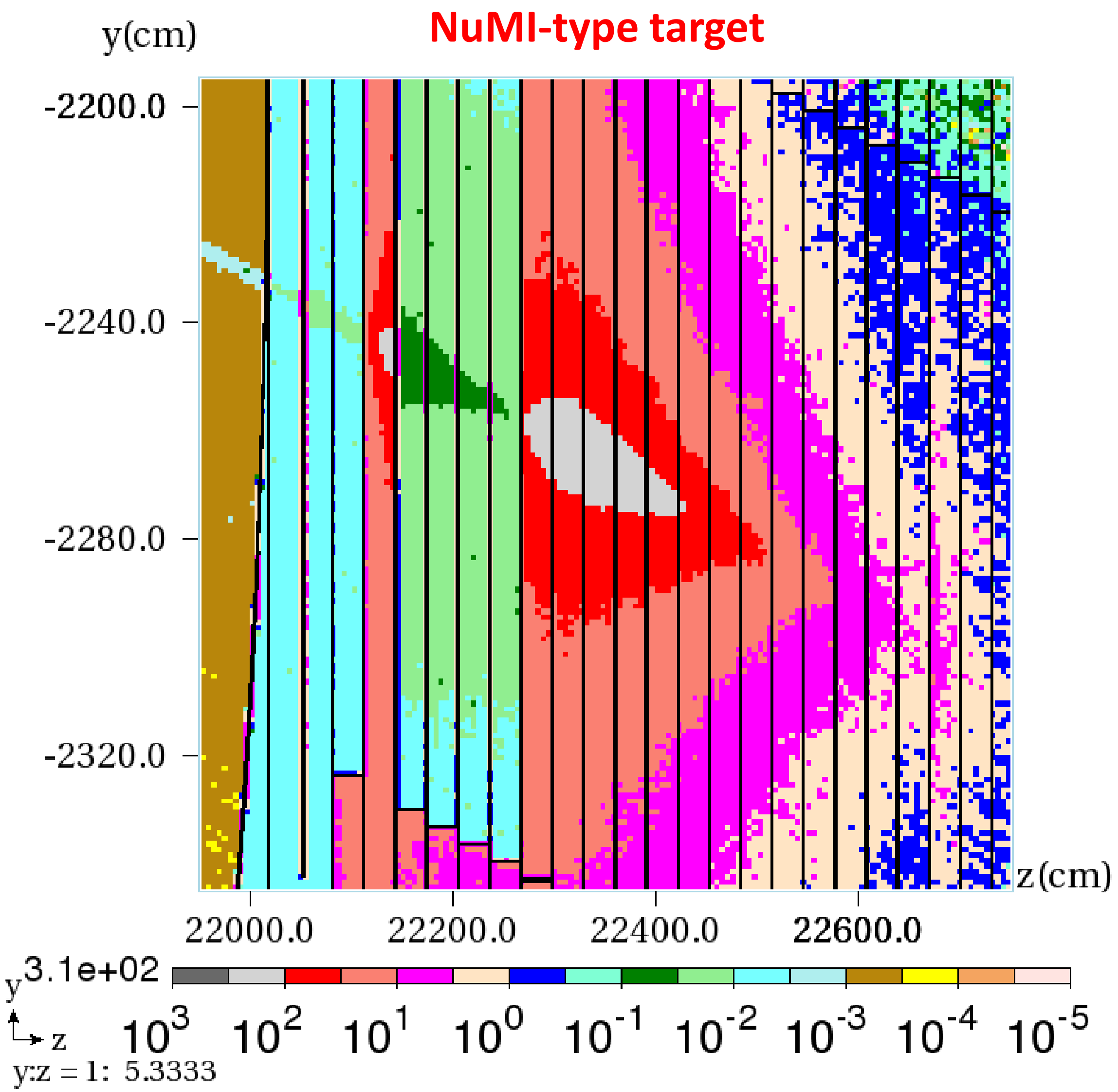


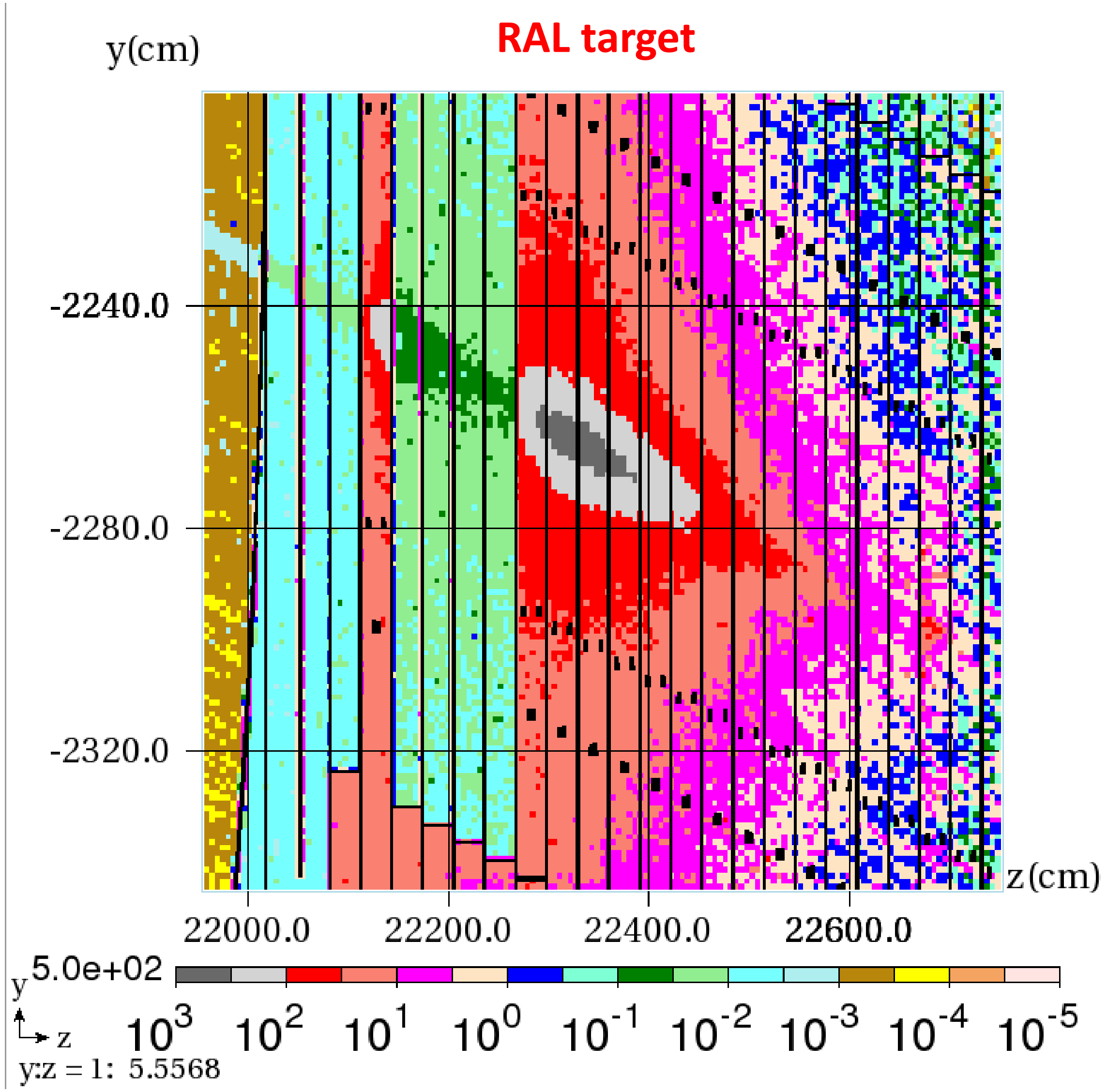
RAL target, σ_{beam}=0.267 cm
0.8 cm target radius, 220 cm target length + 10-12 cm bafflet





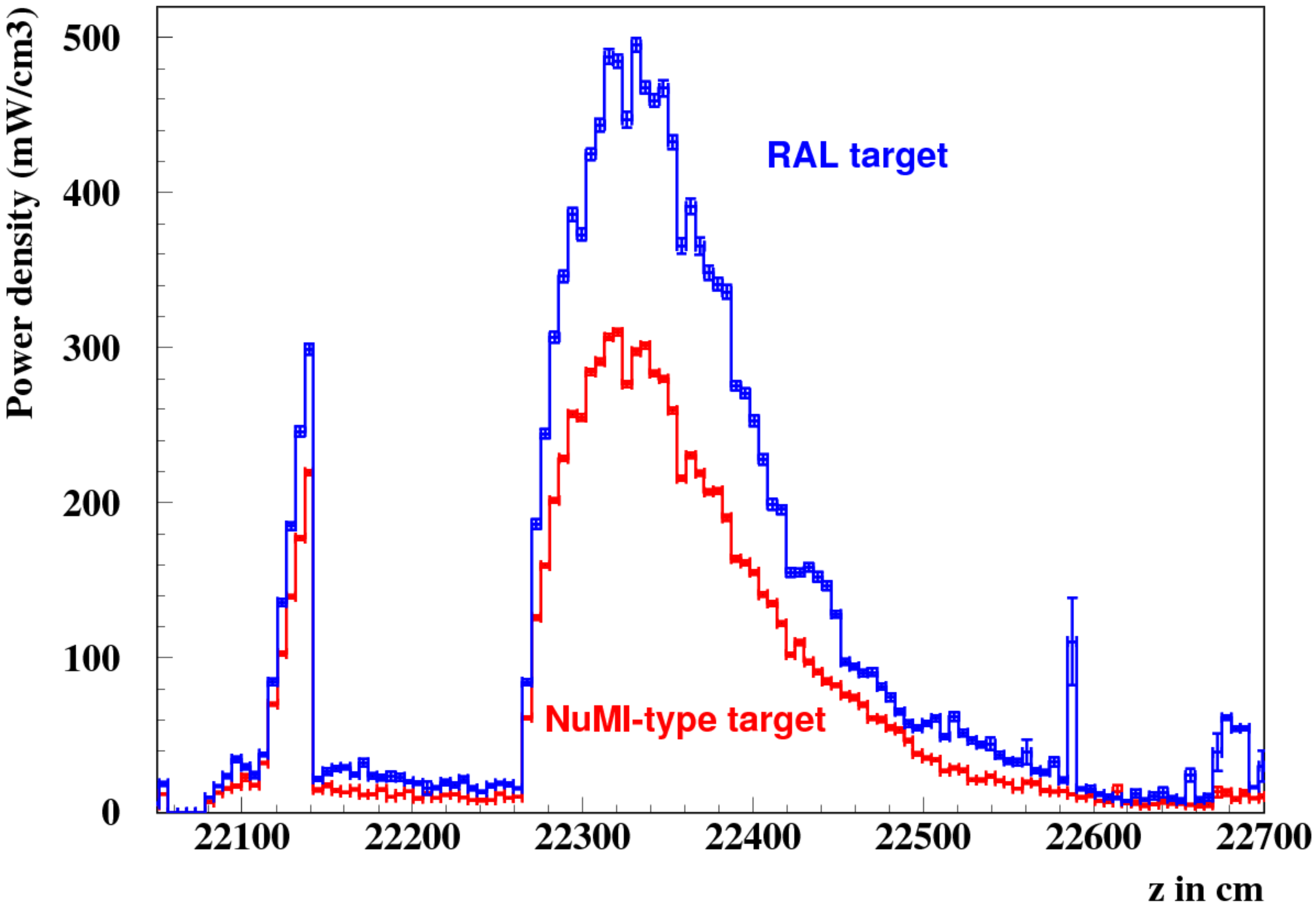
Energy Deposition density (mW/cm^3) in Uniform Hadron Absorber: NuMI-Type Target *vs* RAL target (1x1x5cm^3 bin)





Peak energy deposition density is ~60% higher for RAL target

Energy Deposition Density (mW/cm^3) in Uniform Hadron Absorber: NuMI-Type Target *vs* RAL target



Allowed temperatures in aluminum core of Hadron Absorber are < 100 C.

MARS-ANSYS calculation with NuMI-type target predicts that maximal temperature in UHA is 35 degree C for 10 degree water.

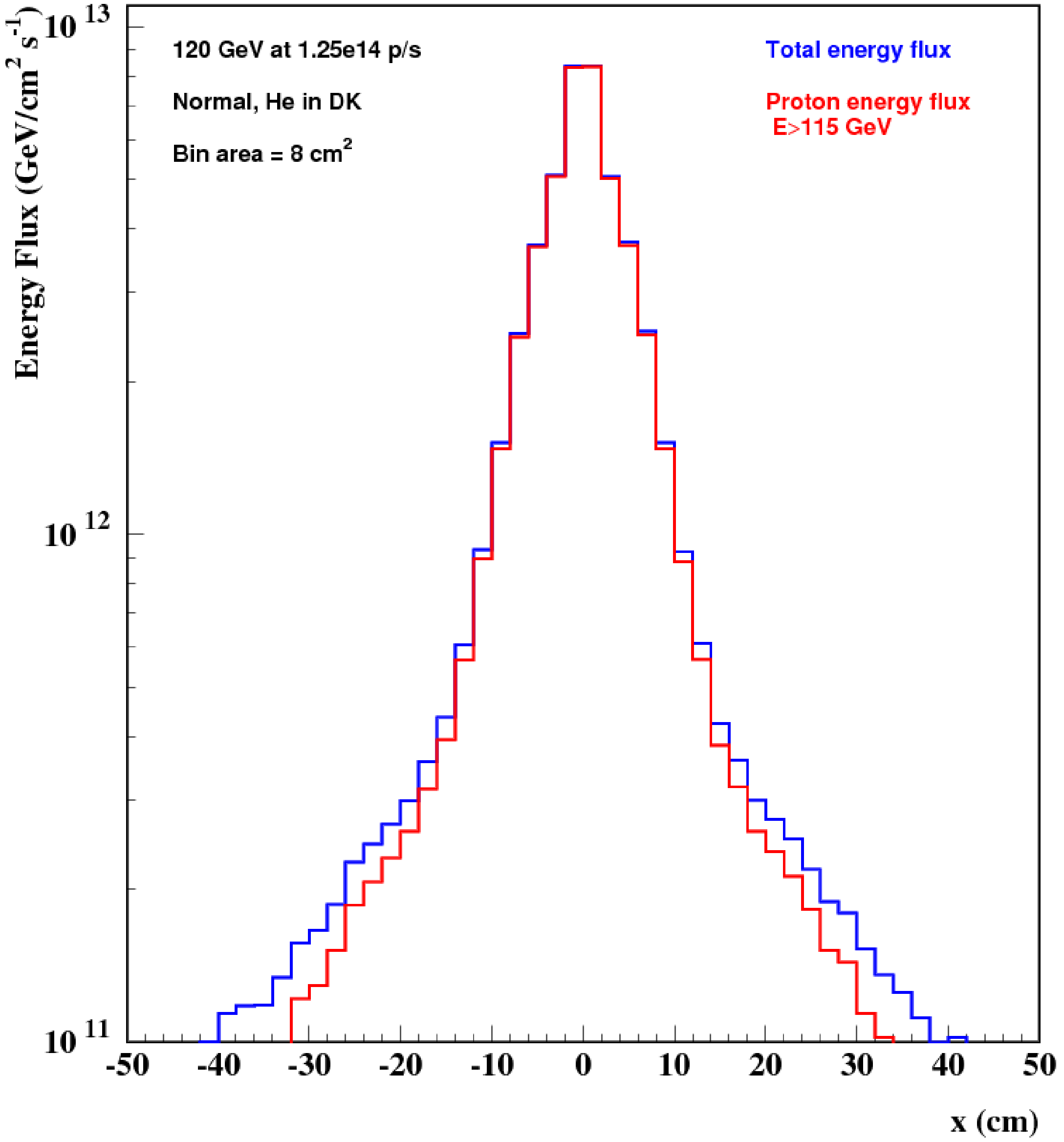
Maximal temperature could reach ~60 degree C for RAL target.

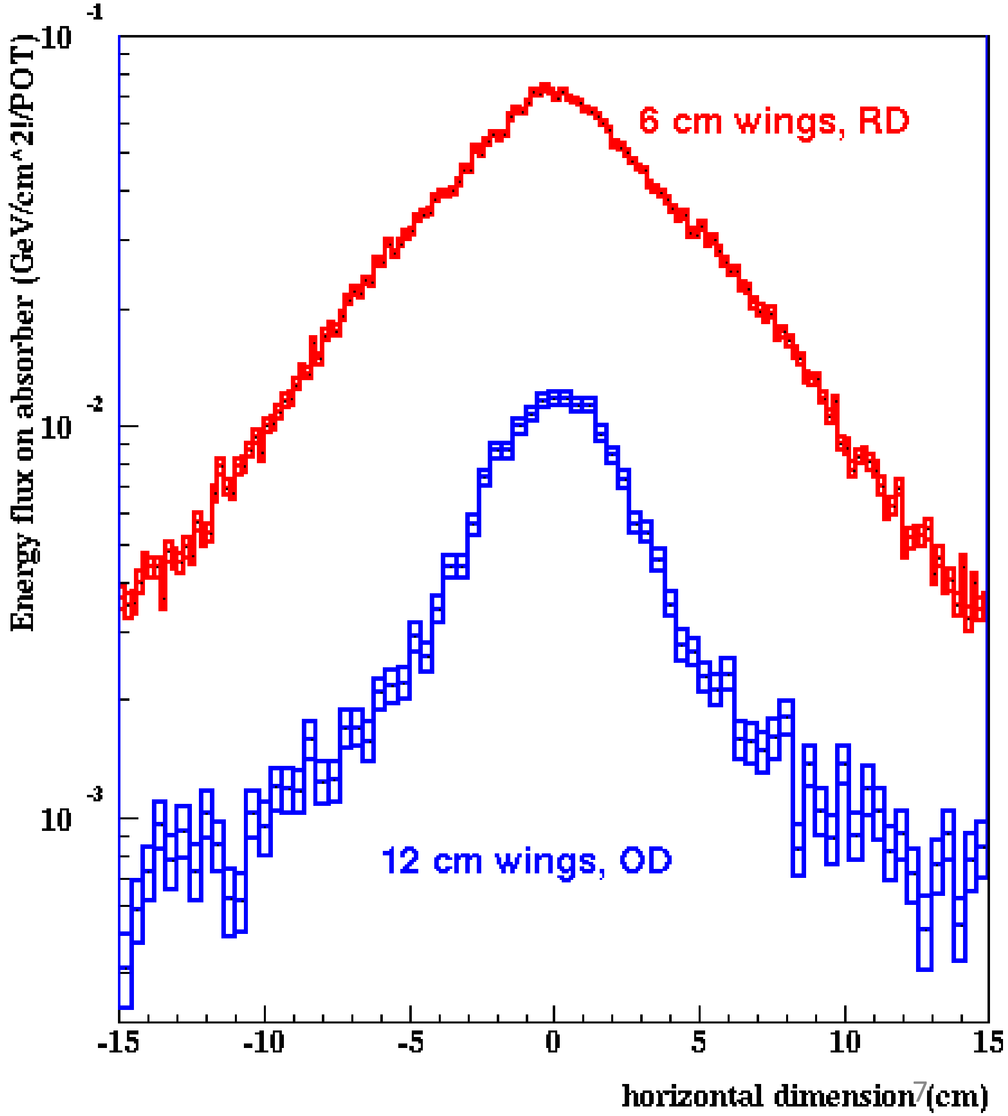
What is origin of peak energy deposition rise?

Could we reduce it to previous level?

Energy deposition peak is driven by fast protons missing target. It is significantly reduced by adding bafflet ("wings").

NuMI-type target

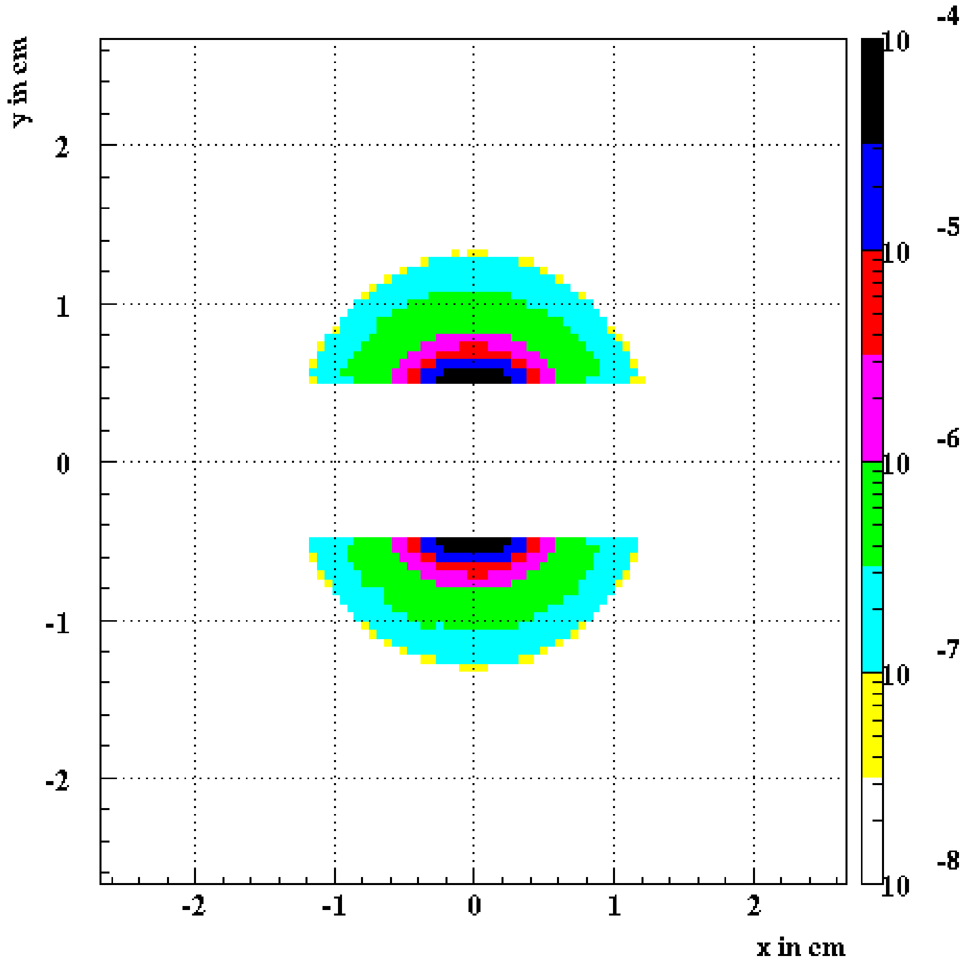


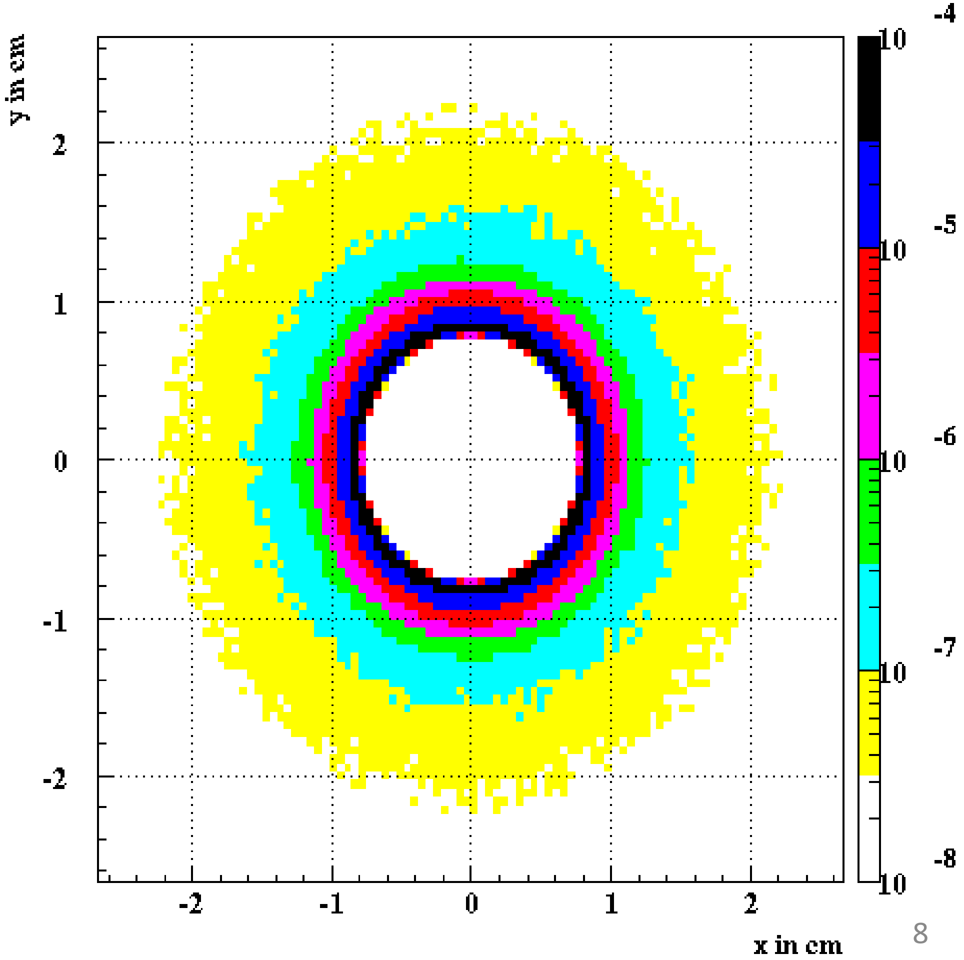


A fraction of primary proton beam missing target: about 3 times more protons miss RAL target

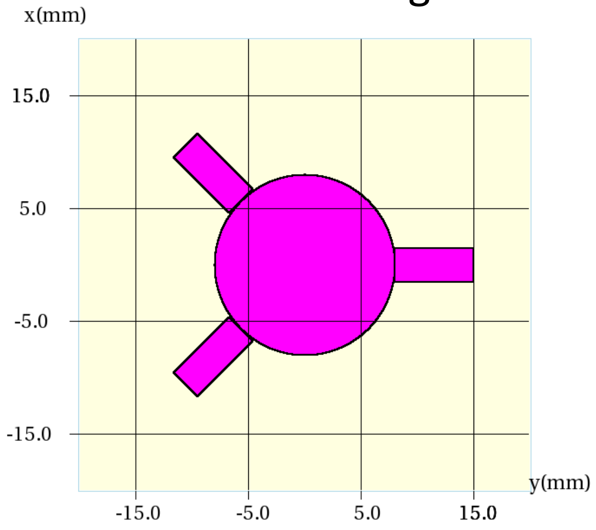
NuMI target = 0.39%
beam sigma =0.17 cm

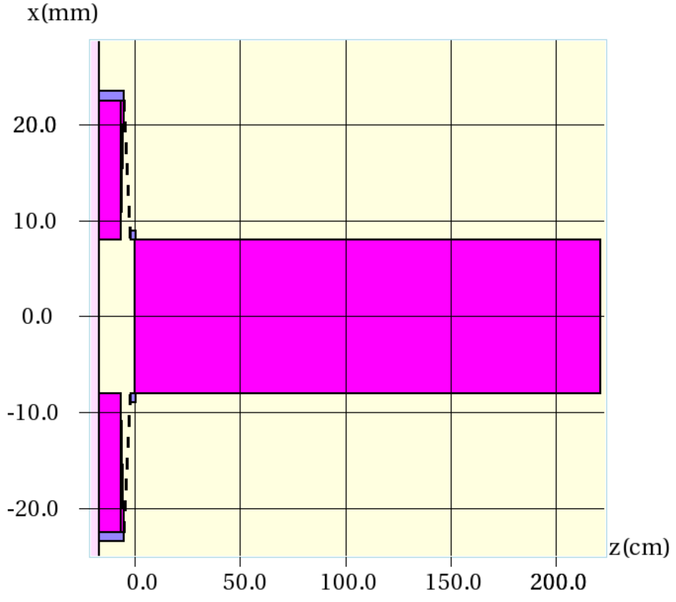
RAL target = $\exp(-r^2/2\sigma^2)$ = 1.1%
beam sigma = 0.267 cm



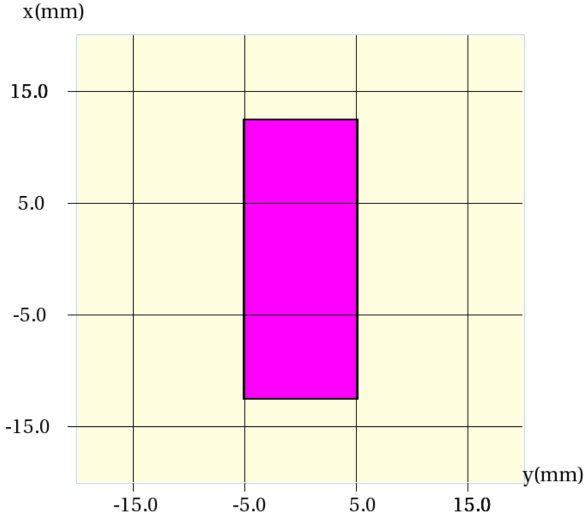


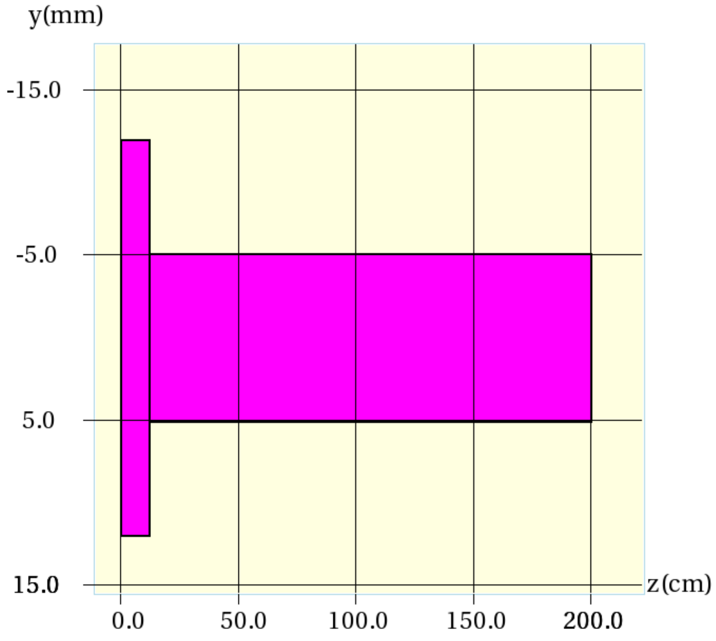
SMMC: RAL target





SMMC: NuMI type target





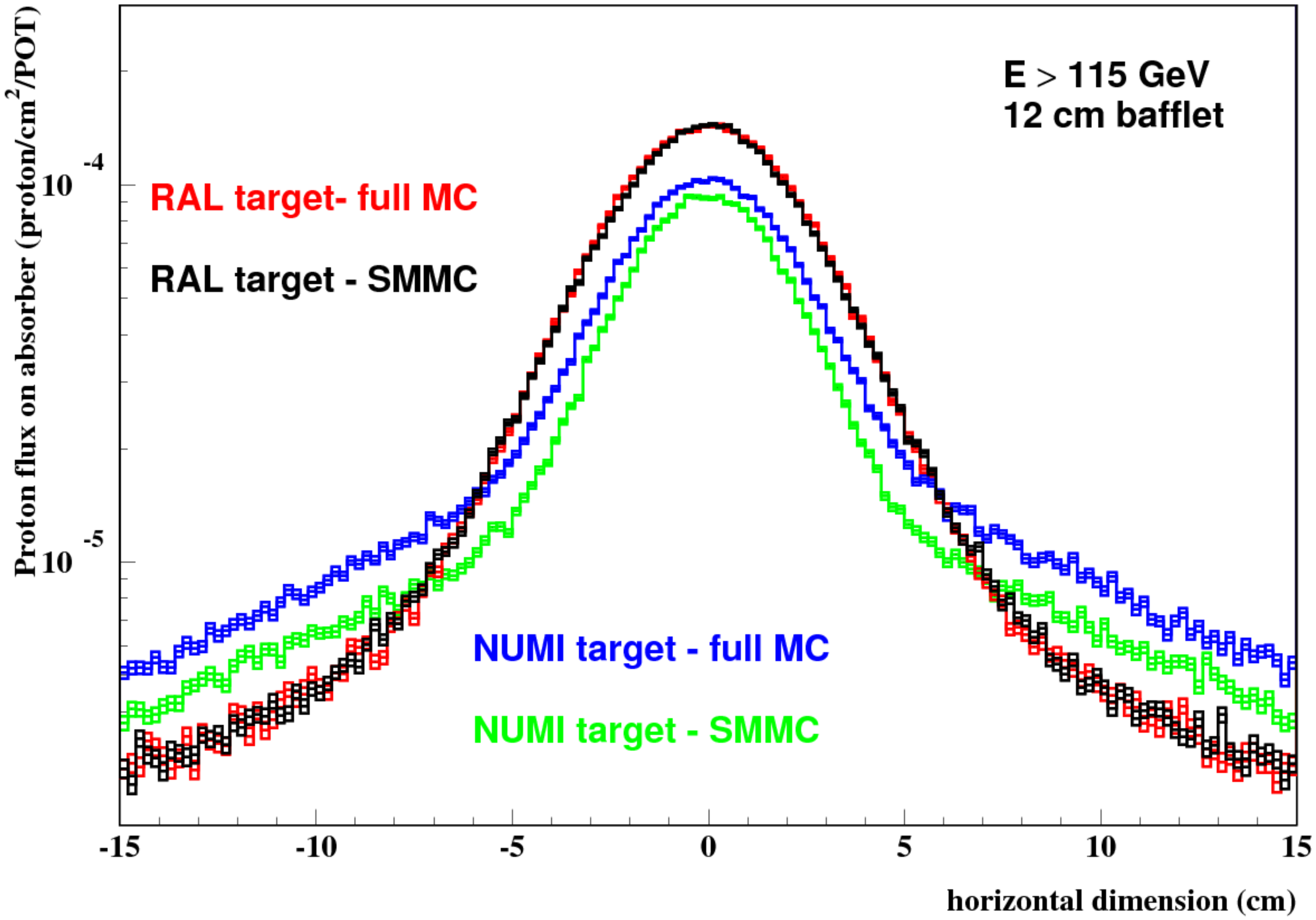
To check full MARS15 results, a simplified MARS Monte Carlo (SMMC) calculations were performed. SMMC geometry includes baffle, target, target support, beam windows and decay pipe. No magnetic field

Primary proton beam transverse distribution is the same as in full Monte Carlo.

All physical processes are taken into account.

Cutoff energy = 115 GeV

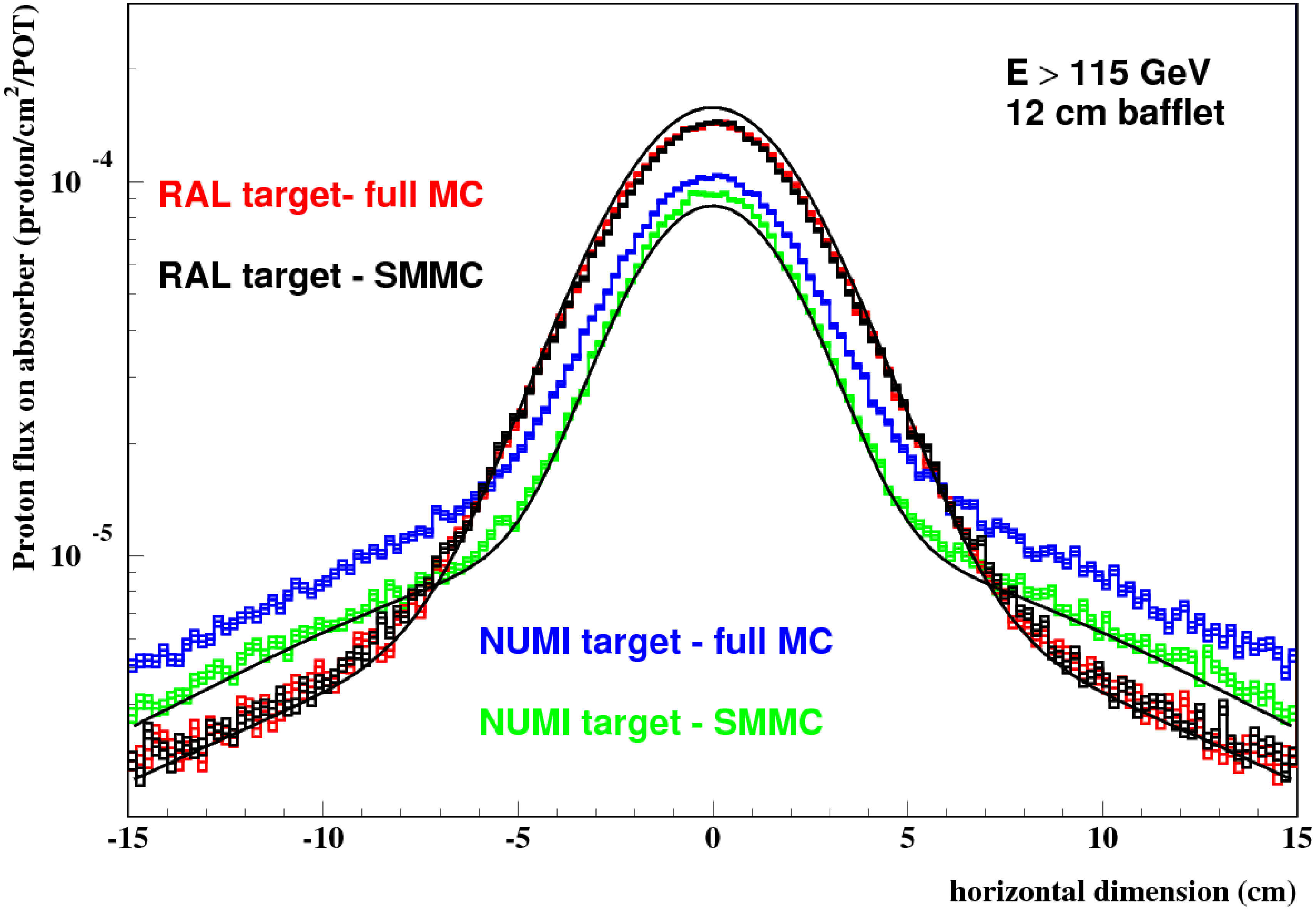
Proton flux at entrance to hadron absorber. Maximal flux is about 40% higher for RAL target



Full MC and SMMC agree well for RAL target because all near beam elements description is very similar in both models.

SMMC flux for NuMI-type target is slightly smaller than full MC flux because in SMMC model target is simple graphite parallelepiped, it described as 93 fins with complicated form in full MC. So “optical length” of full MC target is smaller than SMMC target length.

Proton flux at entrance to hadron absorber. Monte Carlo and analytical calculations.



High energy proton flux at Hadron Absorber entrance could be also calculated analytically (lbne-docdb-10013)

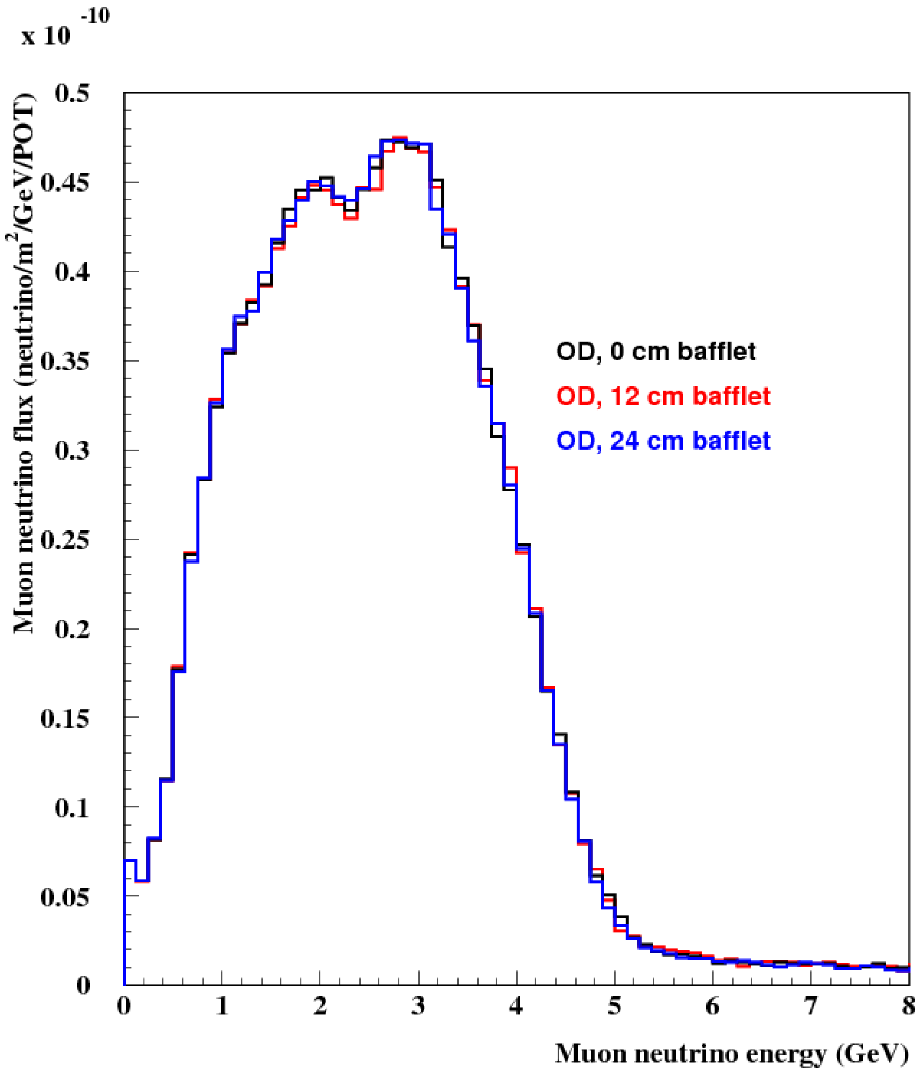
Such calculation agrees well with RAL target simulation (full and SMMC).

Analytical calculation underestimates NUMI full Monte Carlo, because this target consists of fins with complicated geometry which do not included to simple analytical model. But analytical estimates agree well with SMMC which is based on target with simple geometry.

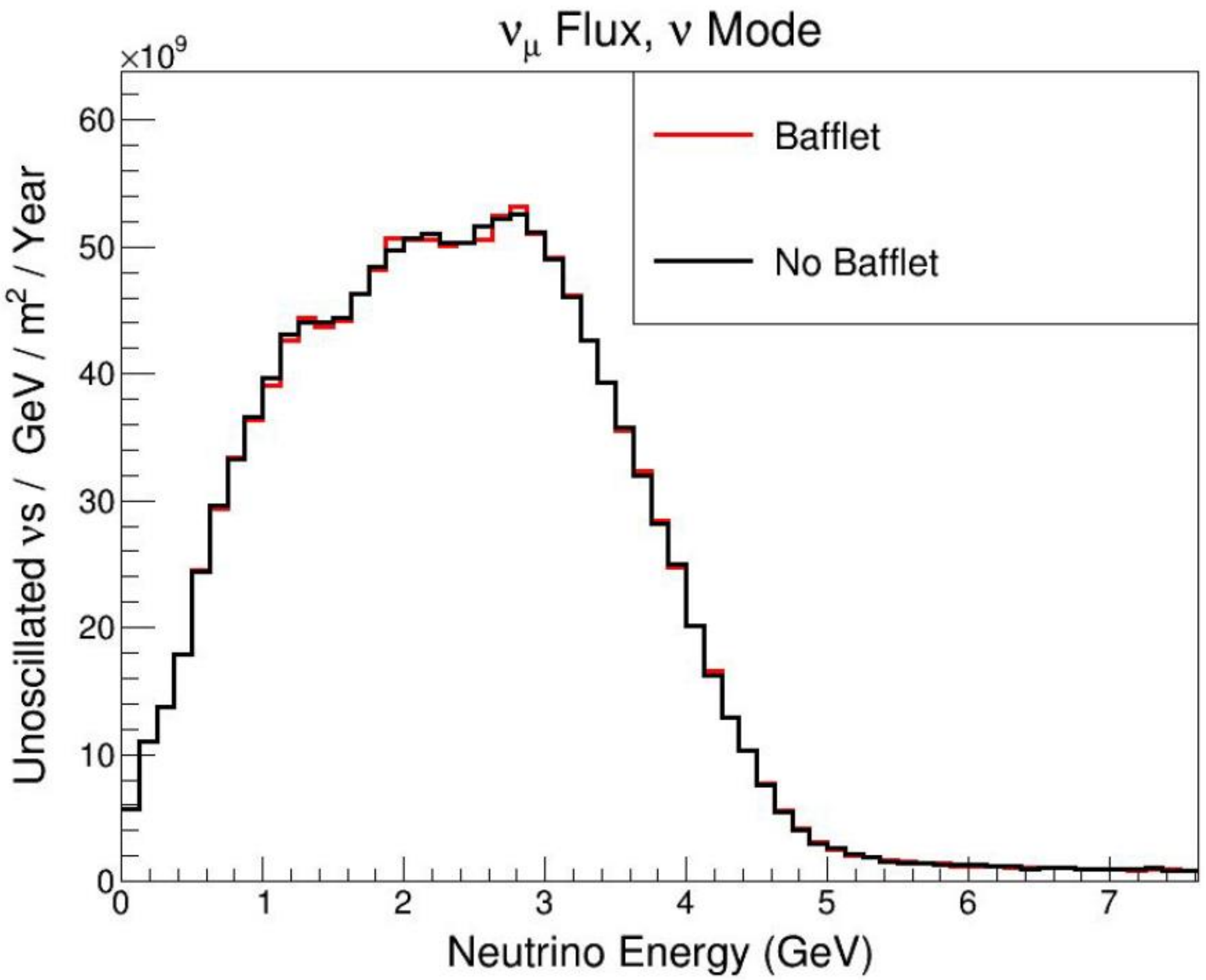
Close agreement of analytical model, simple and full Monte Carlo simulation confirms reliability of obtained results.

How long bafflet could be:
No impact on neutrino spectra – bafflet length up to 24 cm?

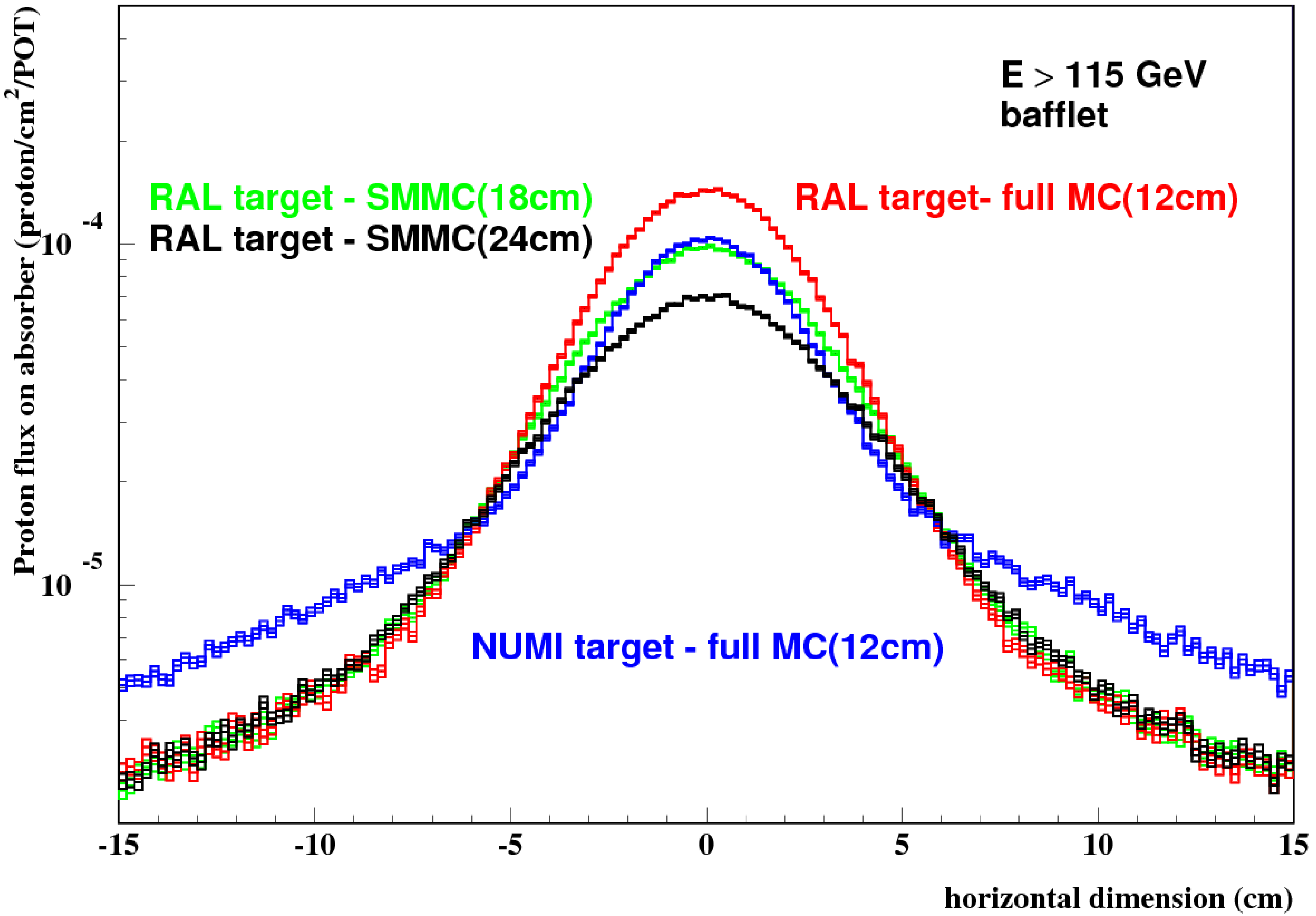
MARS simulation –NuMI-type target



G4LBNF simulation – RAL target, 12 cm bafflet

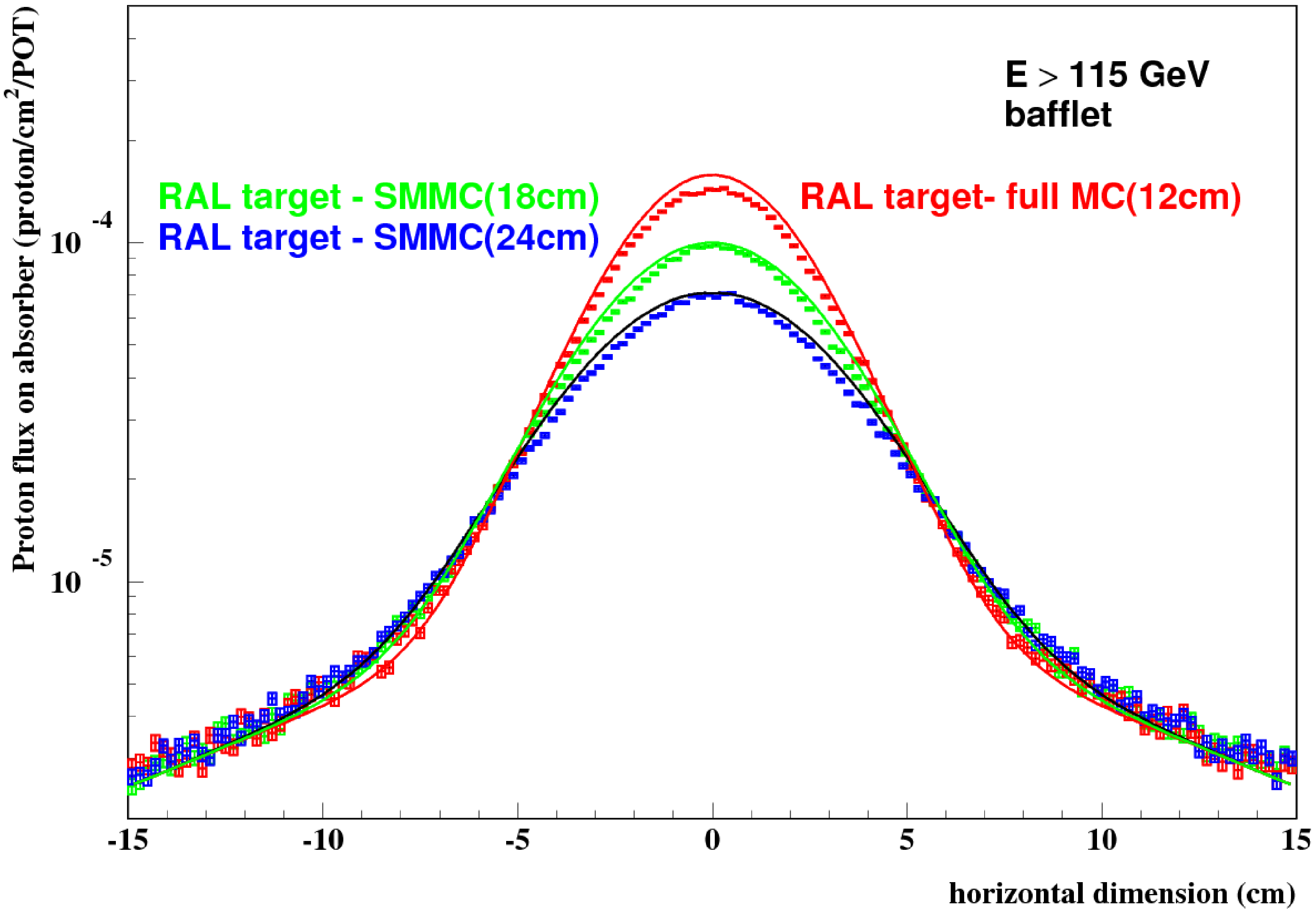


Impact of bafflet length on proton flux at HA entrance



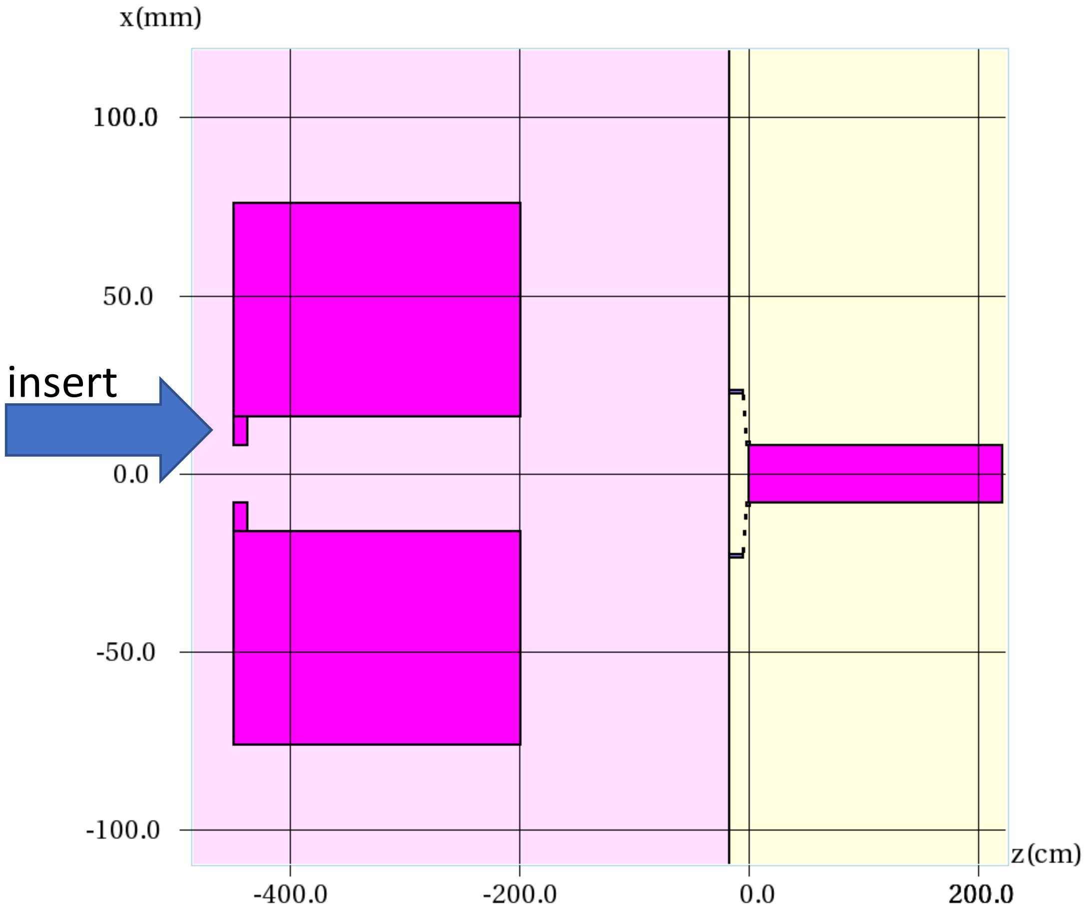
Increase of bafflet length from 12 to 18 cm reduces high energy proton flux at Hadron Absorber entrance to NuMI-type target case level. Further increase from 18 to 24 cm creates ~50% safety margin

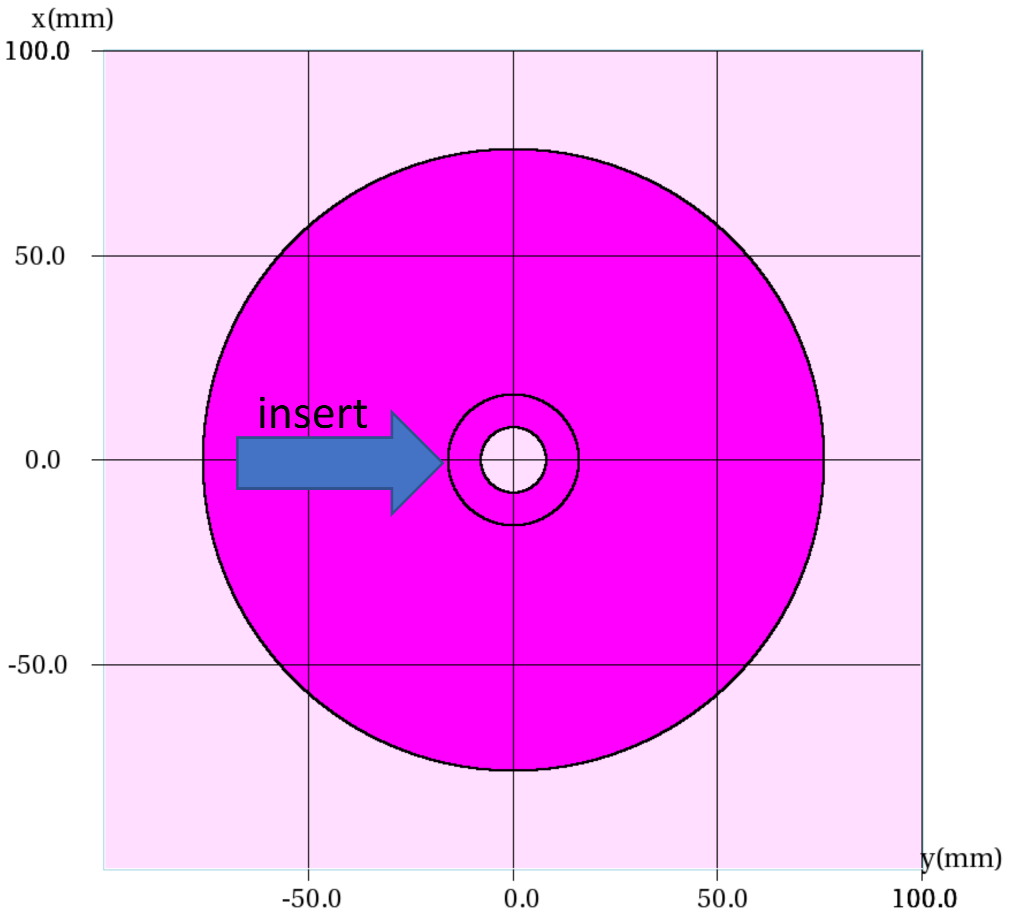
Impact of bafflet length on proton flux at HA entrance . Analytical calculations and Monte Carlo simulations.



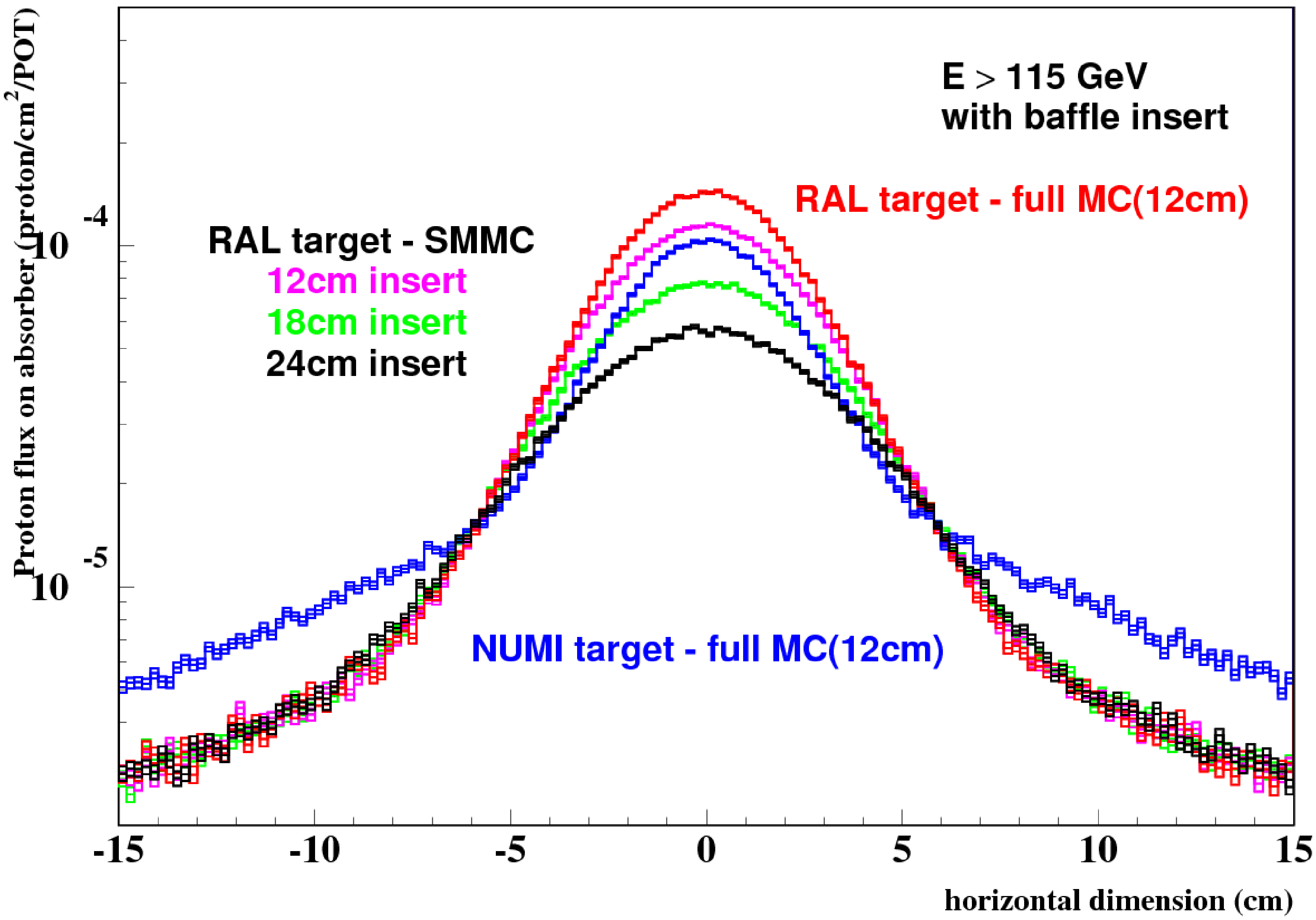
Analytical calculations predict decreasing proton flux with increasing of bafflet length in agreement with Monte Carlo simulation.

Insert to baffle instead of bafflet?
Inner radius same as target radius, length < 24 cm





Insert length impact on proton flux at HA entrance

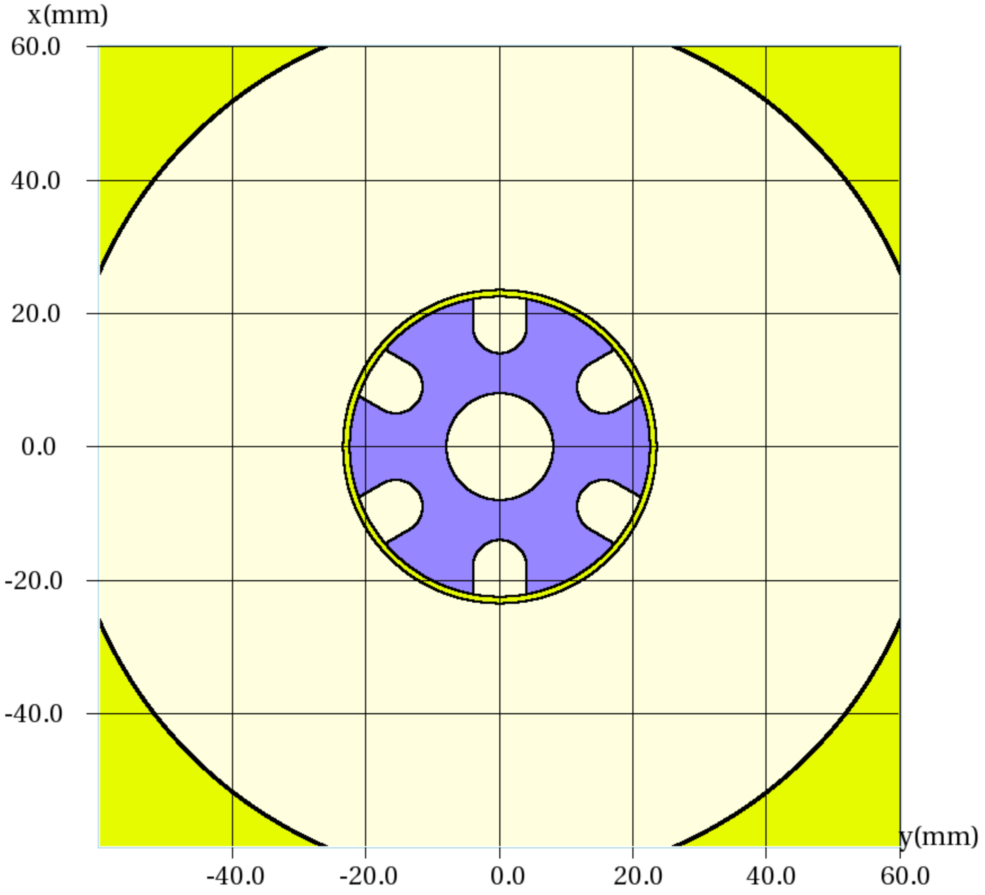


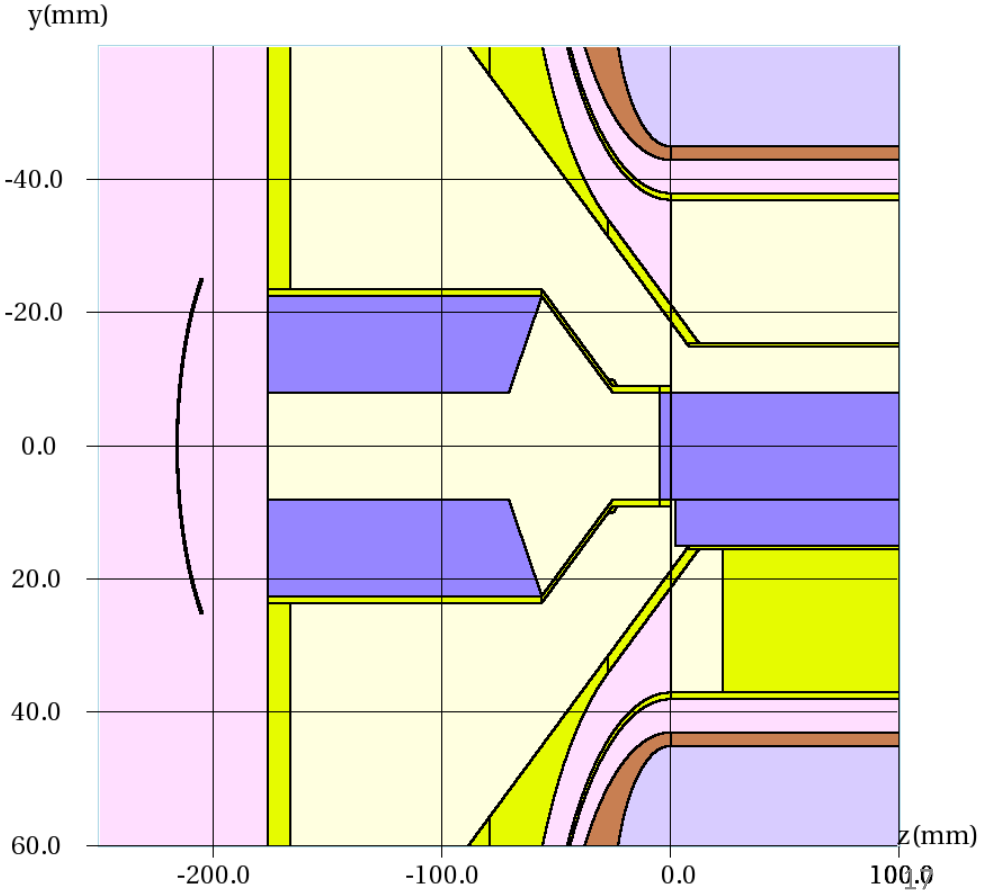
12 cm insert to baffle instead of bafflet before target could reduce high energy proton flux at hadron absorber to NuMI-type target case level.

About 0.3% of beam proton will create pions in such insert (same amount as in current bafflet), but most of secondary pion produced in insert will be captured in baffle before neutrino production decay. Note, that G4LBNF simulation predicts negligible muon neutrino production from 12 cm bafflet.

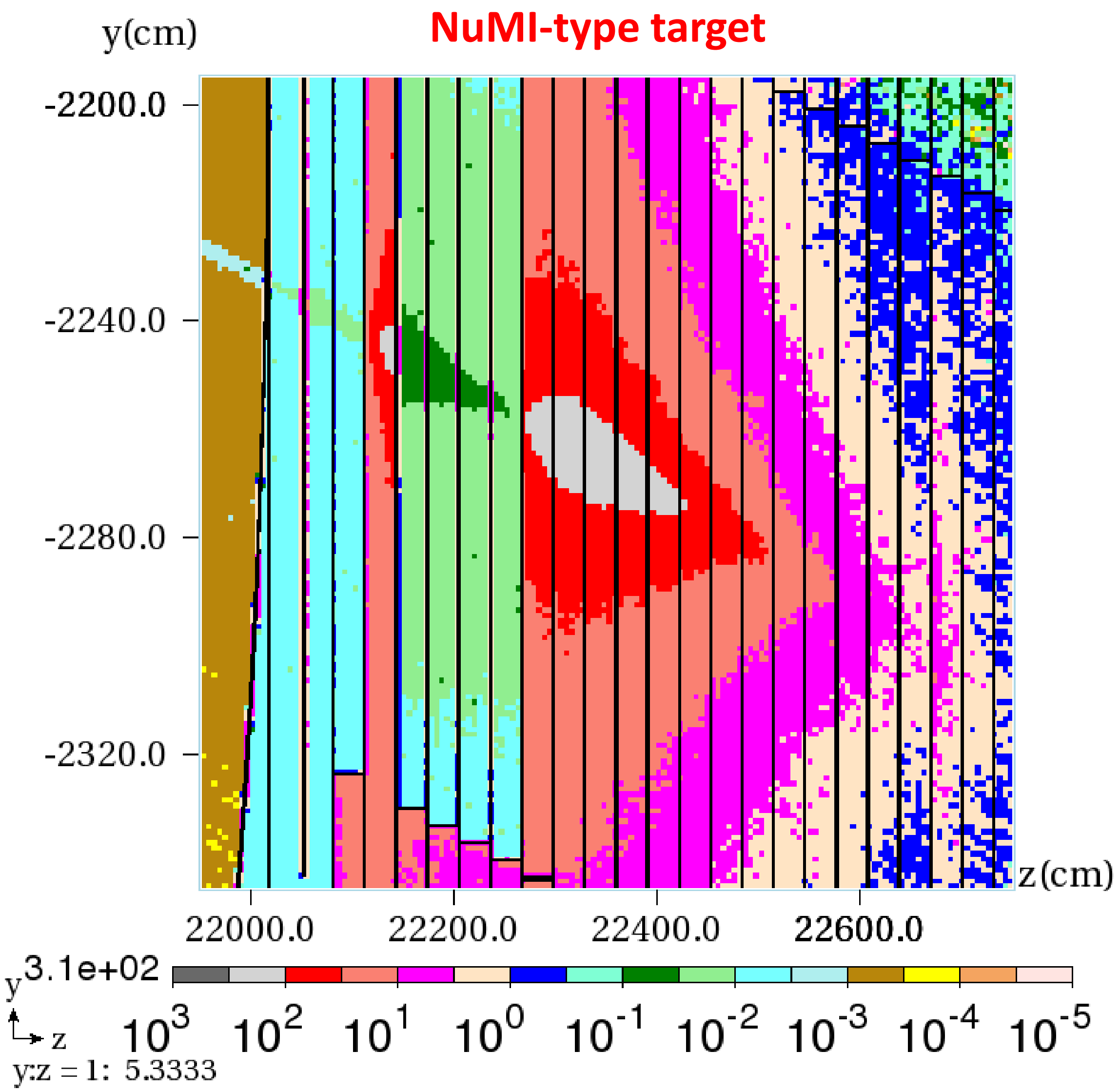
Why insert to baffle is more efficient then bafflet?

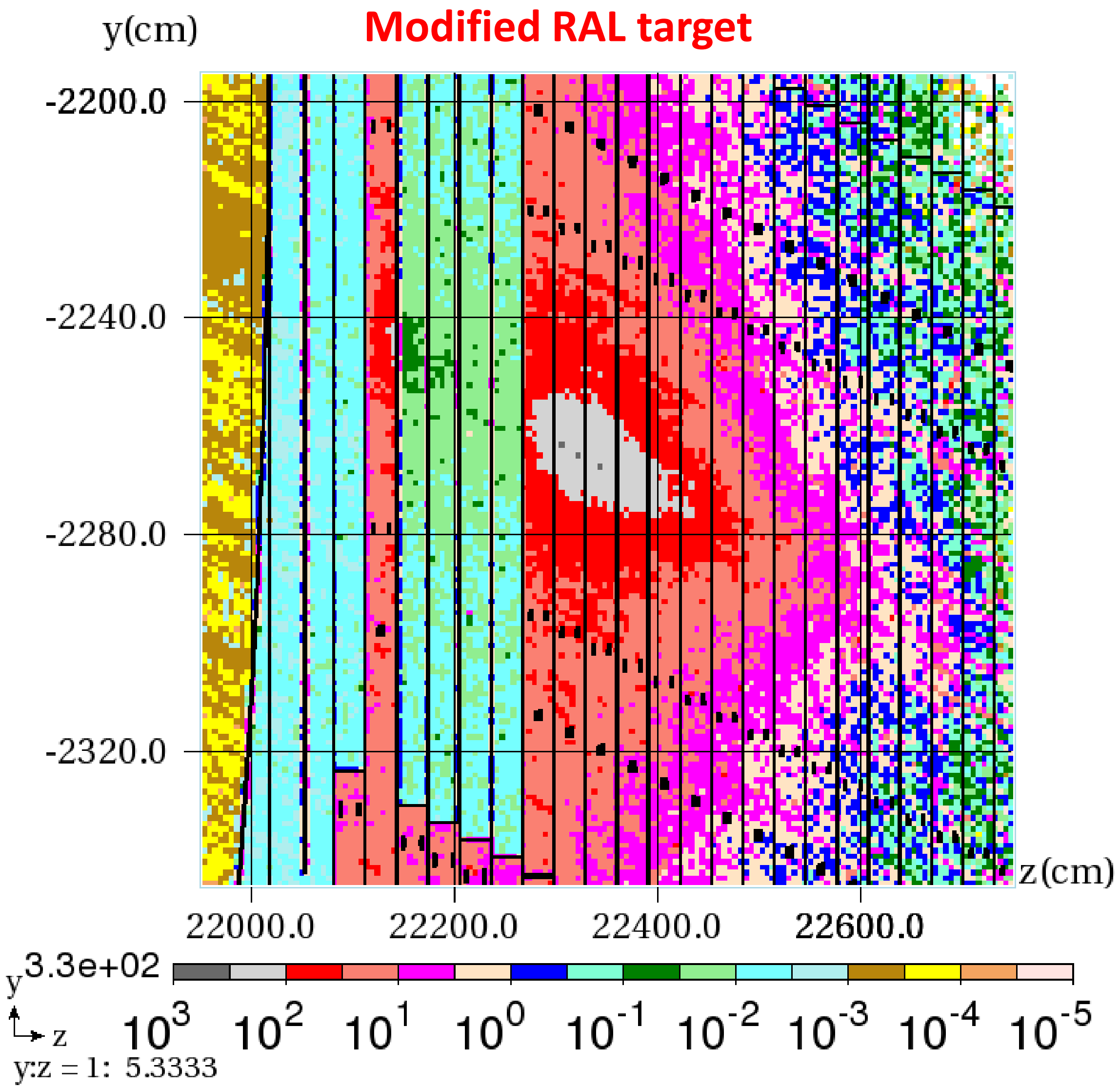
Effective length of bafflet is ~14% shorter than length of insert
Effective radius of bafflet is ~14% smaller than insert radius
Distance between bafflet and HA is slightly smaller than distance between insert and HA





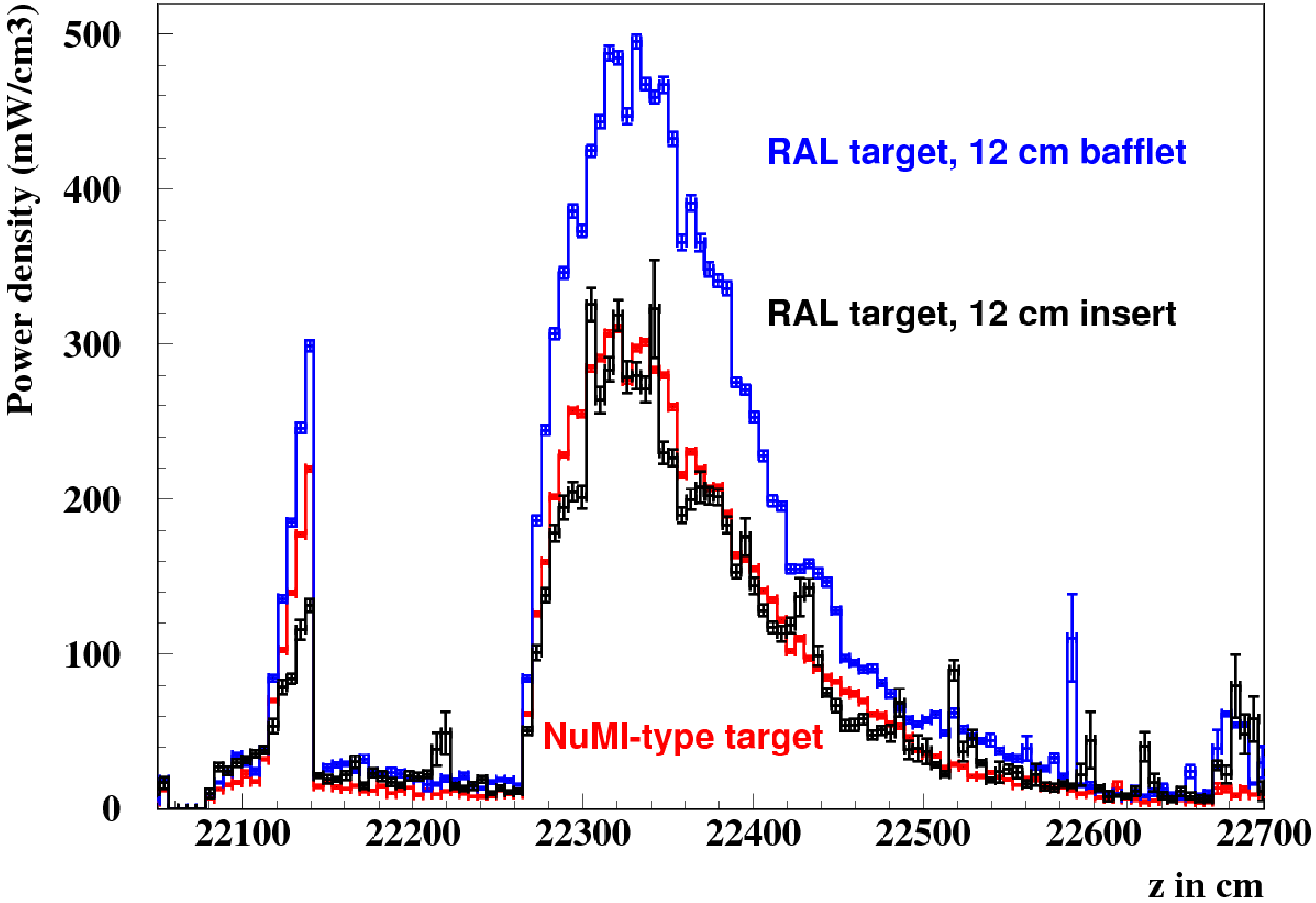
Energy Deposition Density (mW/cm^3) in Uniform Hadron Absorber: NuMI-Type Target *vs* modified RAL target (12cm insert instead bafflet)



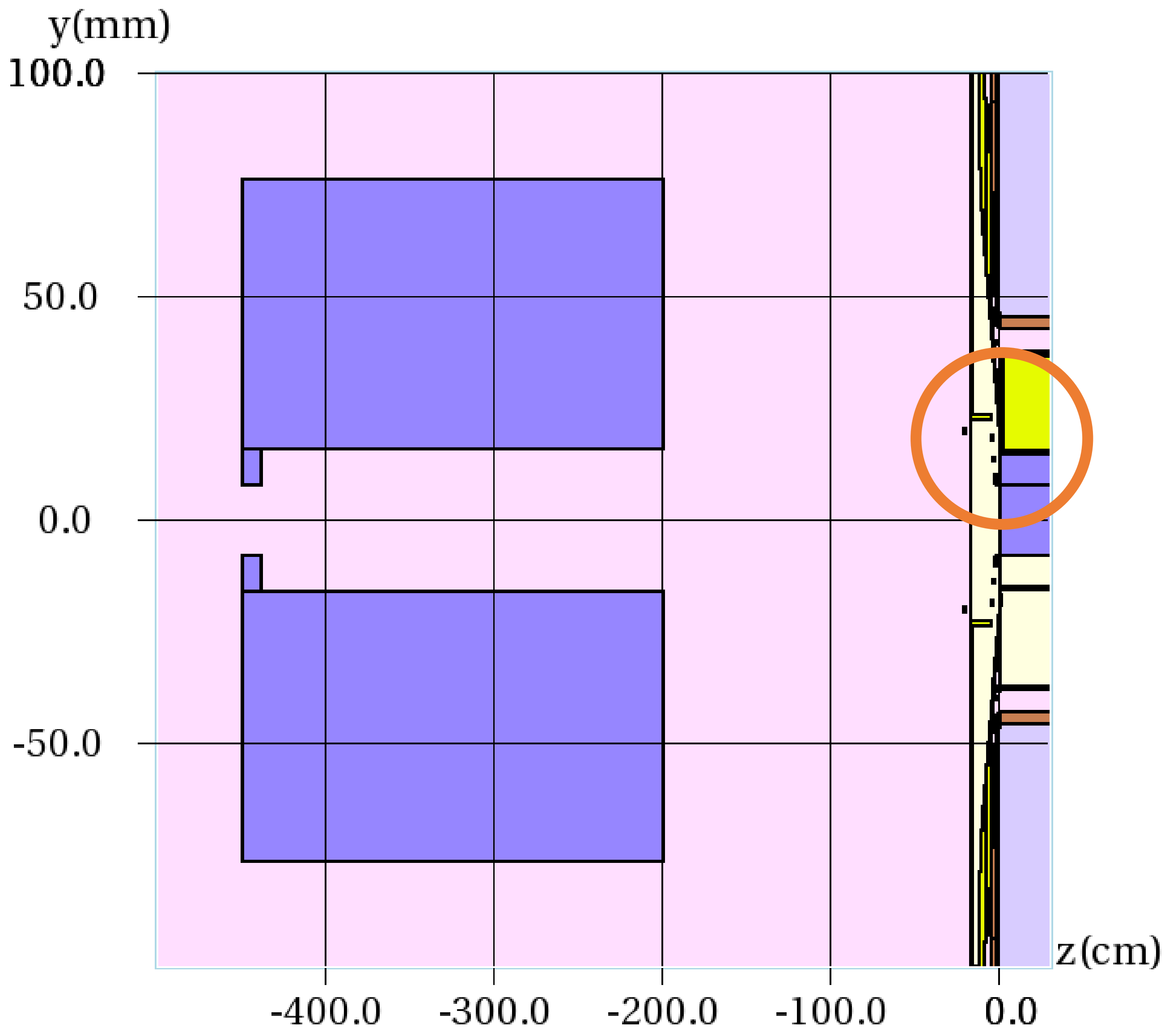


Peak energy deposition densities are close for both targets

Energy Deposition Density (mW/cm^3) in Uniform Hadron Absorber: NuMI-Type Target *vs* two designs of RAL target

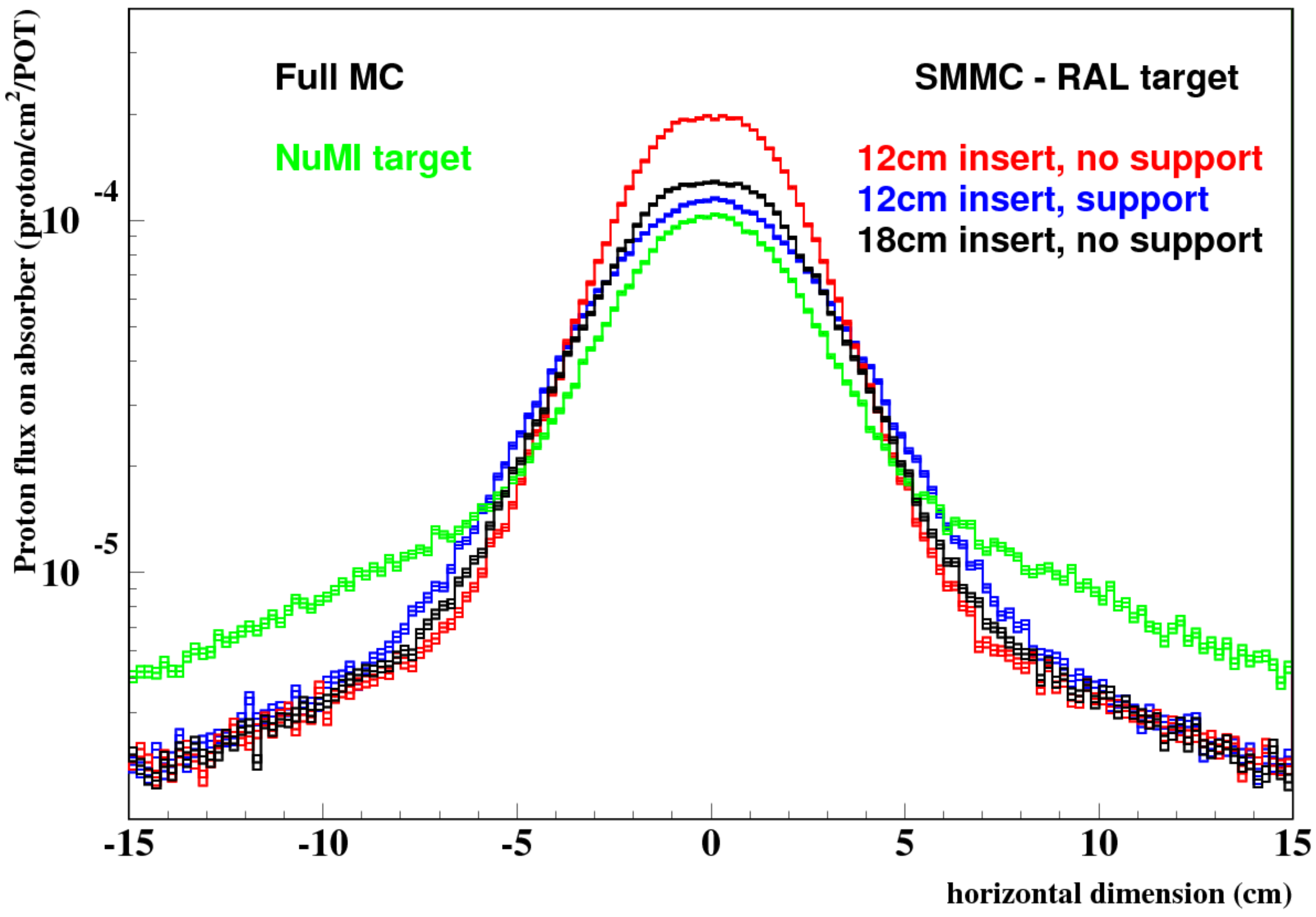


12 cm insert in baffle instead 12 cm bafflet



Do we need support if bafflet is removed

Removing bafflet support



Titanium support of bafflet at US end of target is not thin. If we move bafflet from target to baffle, we do not need this support. But if we remove the support, proton flux on HA rises on ~70%. So, we need longer insert in this case. It looks like 18 cm insert is long enough to reduce peak energy deposition density to NuMI-type target case level.

Conclusions

- The RAL target has no material outside the R=3σ contrary to the NuMI-type fin-target. Therefore, more primary beam protons miss the target. As a result, the peak energy deposition density in the Hadron Absorber is ~60% higher for the RAL target

- High energy proton flux simulation using full MARS15 LBNF model agrees well with simplified Monte Carlo model taking into account only objects within few cm around beam direction and analytical calculation

- Peak energy deposition can be reduced with the RAL target to the NuMI-type target case level by increasing the bafflet length from 12 to 18 cm

- Similar result can be achieved with the RAL target by removing the near target bafflet and adding a 12-cm graphite insert at the US end of the baffle. If we could remove bafflet support also, insert length should be ~18 cm.