Energy Deposition in Optimized Target/Horns with a Glance at Absorber

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DUNE Beam Interface/Optimization/Simulation Meeting

Fermilab

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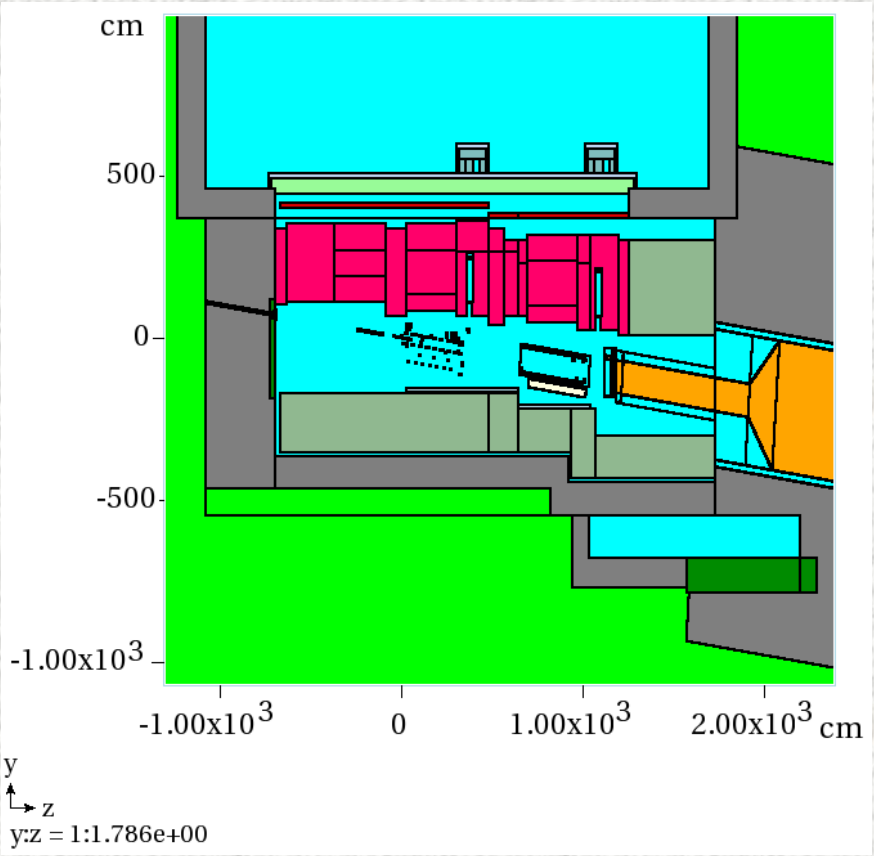
Outline

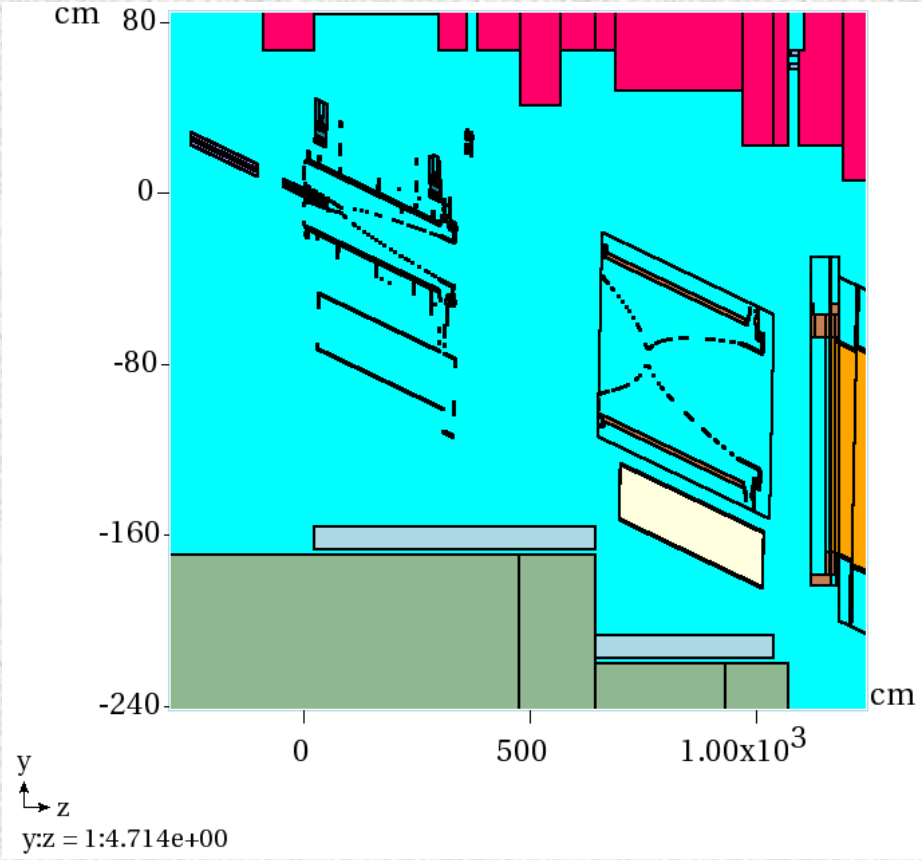
- MARS Model: Baseline (Nominal), Optimized and Test (B=0)
- Energy Deposition, Fluxes and DPA
- Impact on Hadron Absorber

Building and optimizing MARS model of all the components in the LBNF primary and neutrino beamlines from Main Injector to Near Detector:

NM, Y. Eidelman, I. Rakhno, D. Reitzner, S. Striganov, I. Tropin

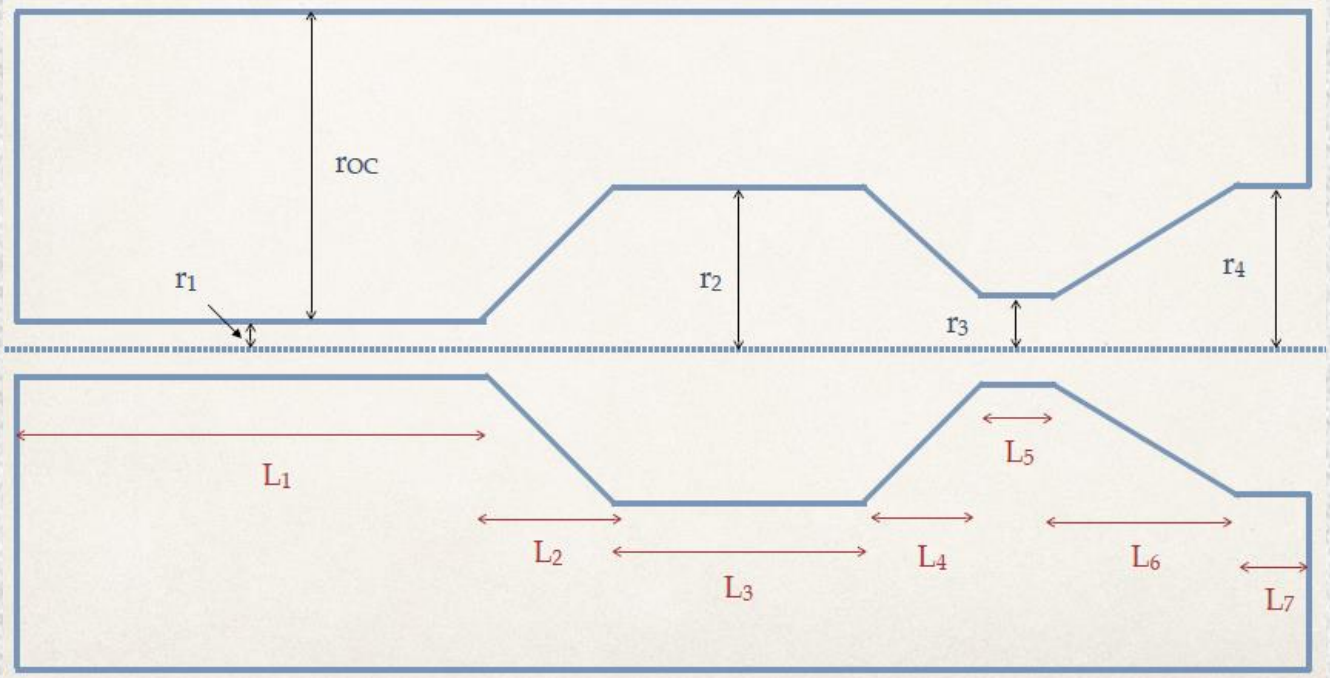
LBNF Target Station in Baseline MARS15 Model





NuMI-like target (2λ) and horns

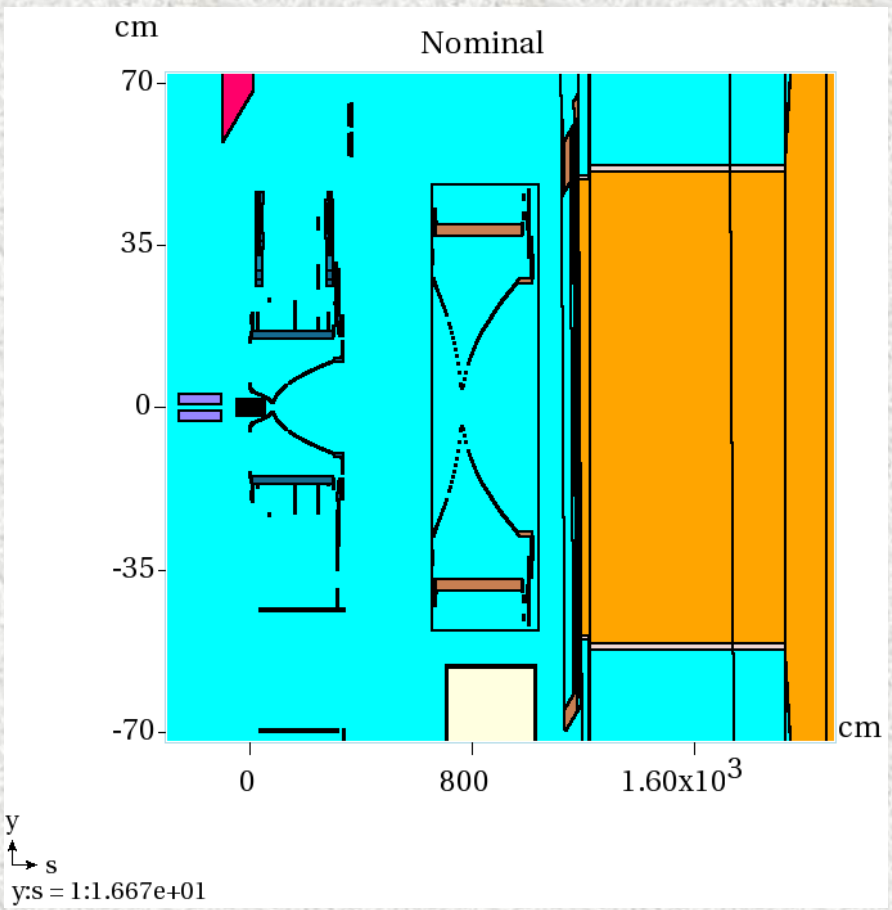
Optimized Target and Horns

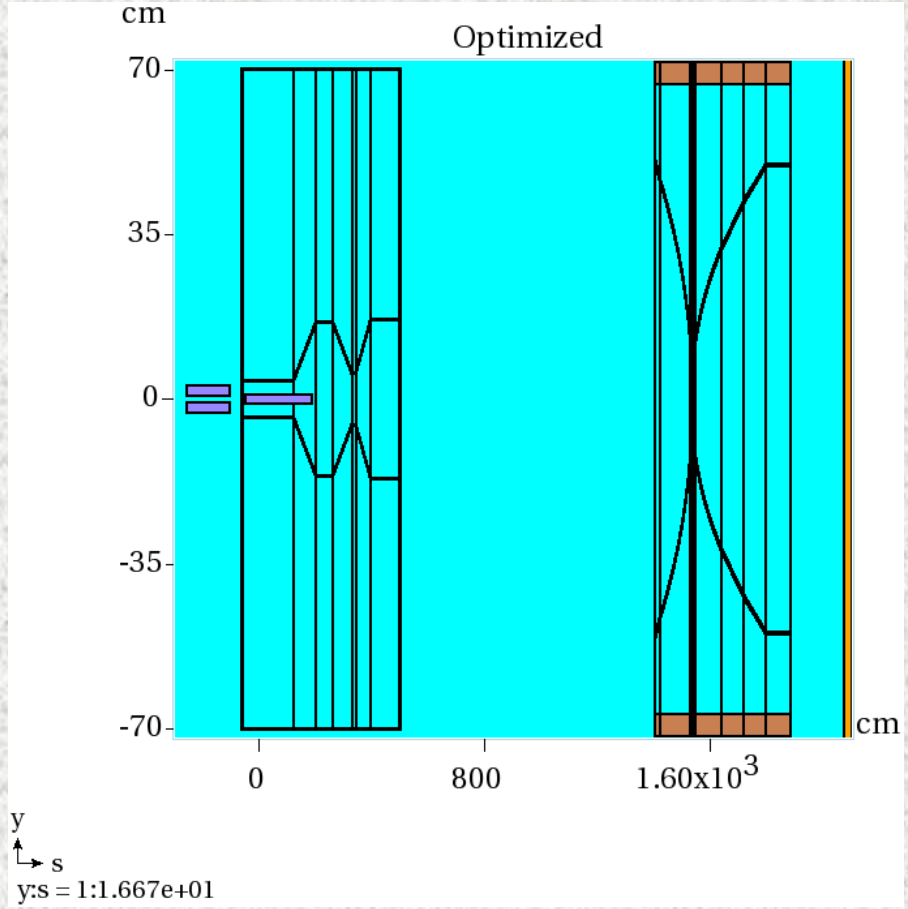


Laura Fields, DUNE DocDb #56, Sept. 1, 2015

Target: Graphite (1.8gcc), solid block for now,
abs(x)=4.75mm, abs(y)=10mm, L=237cm (5λ), z_0 = -50cm.
Horn1: z_0 = -59.4cm

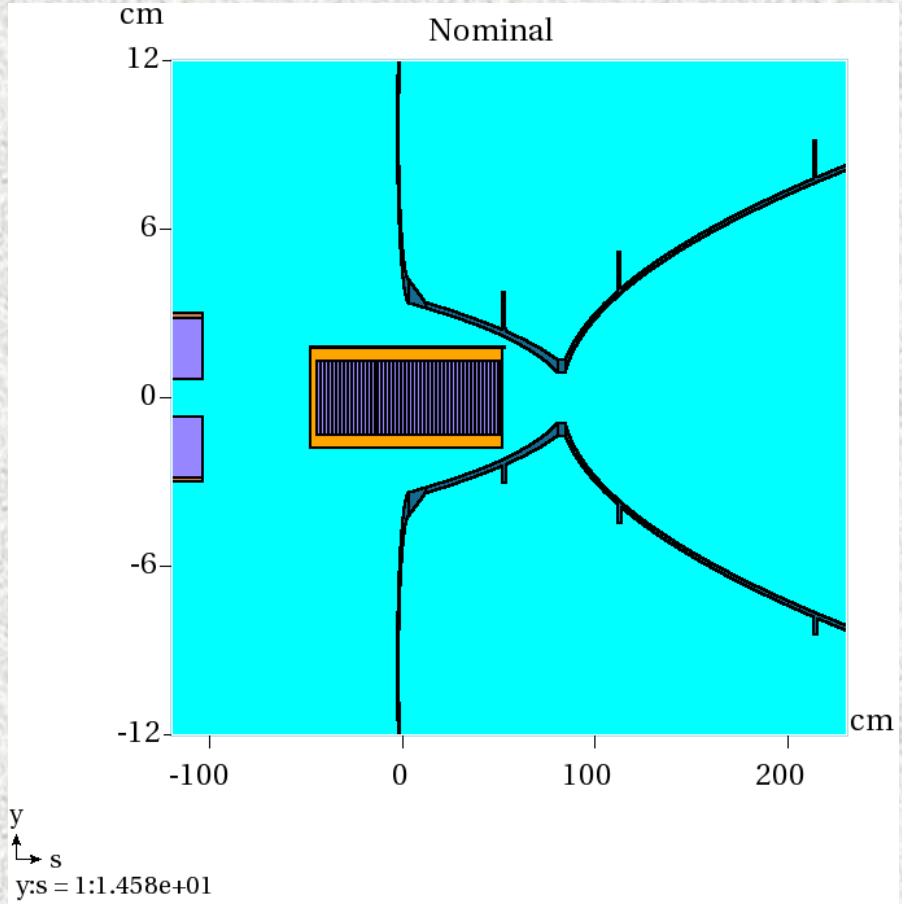
Baseline and Optimized (1)

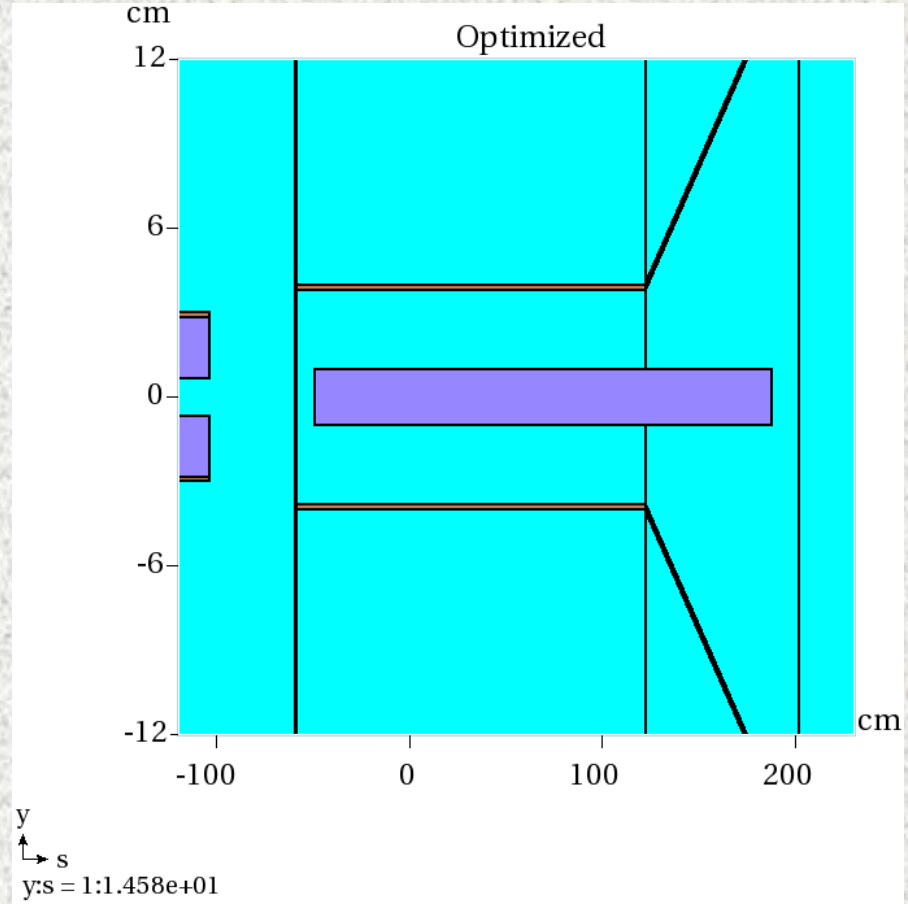




Proton beam coordinate system

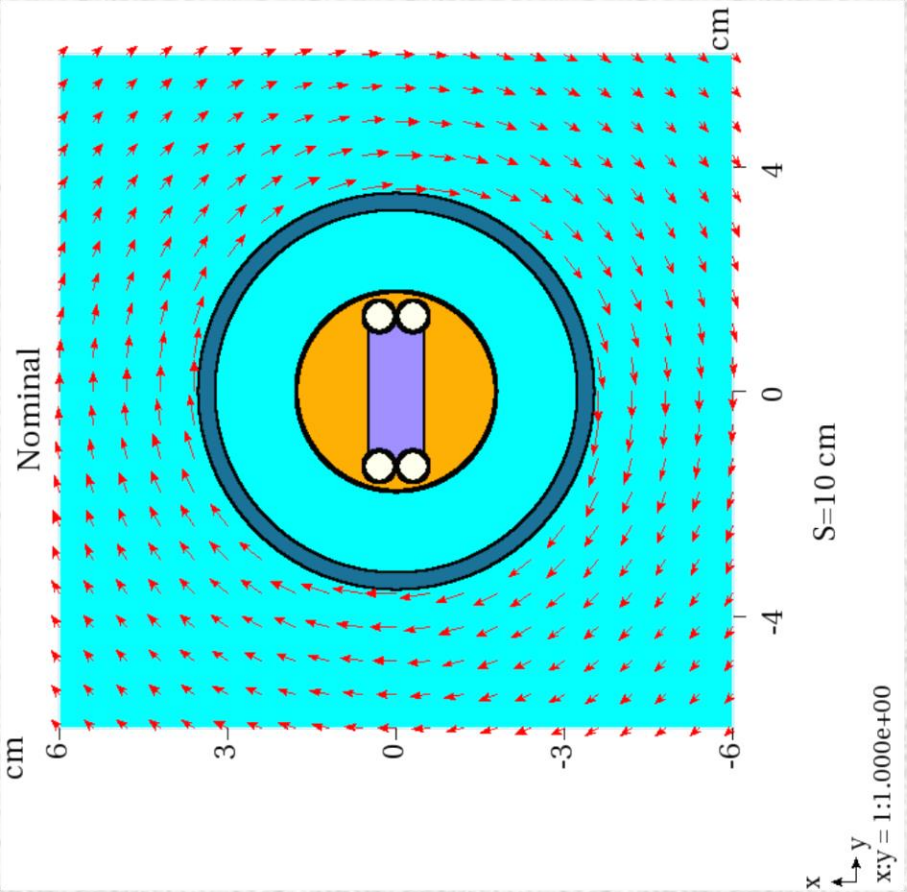
Baseline and Optimized (2)

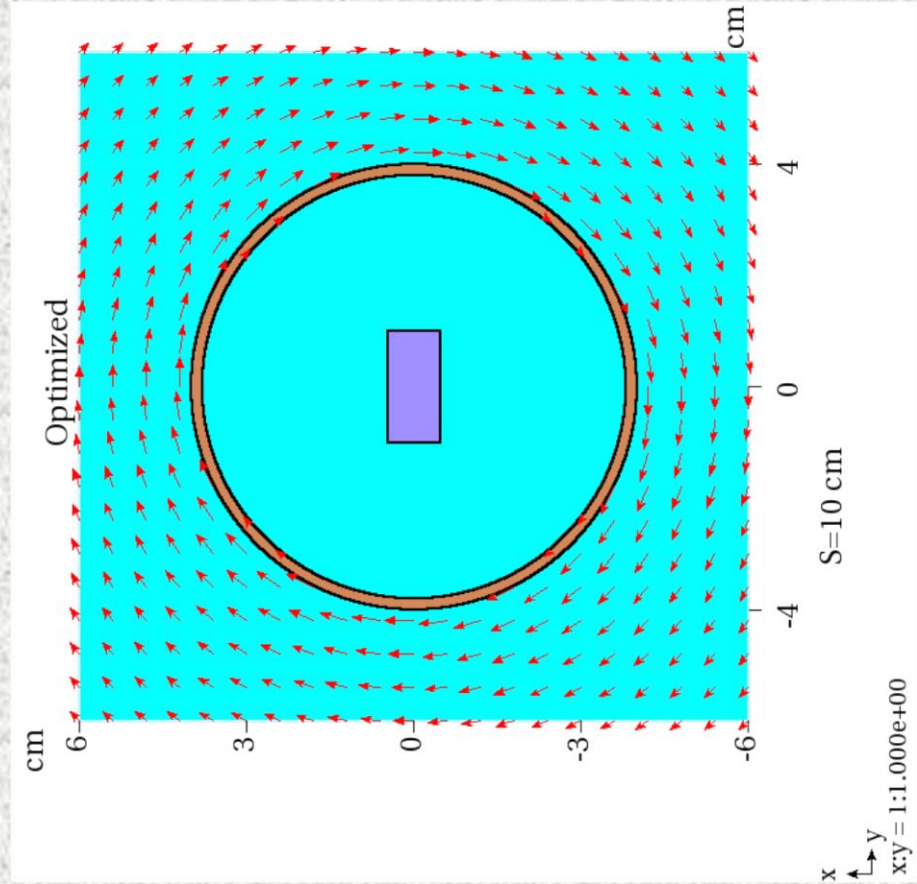




Proton beam coordinate system

Baseline and Optimized (3)





Proton beam coordinate system

Scenarios & Beam Parameters in MARS15 Simulations

$\varepsilon_{95} = 20\pi$ mm-mrad, $N_p = 1.5\times10^{14}$ ppp

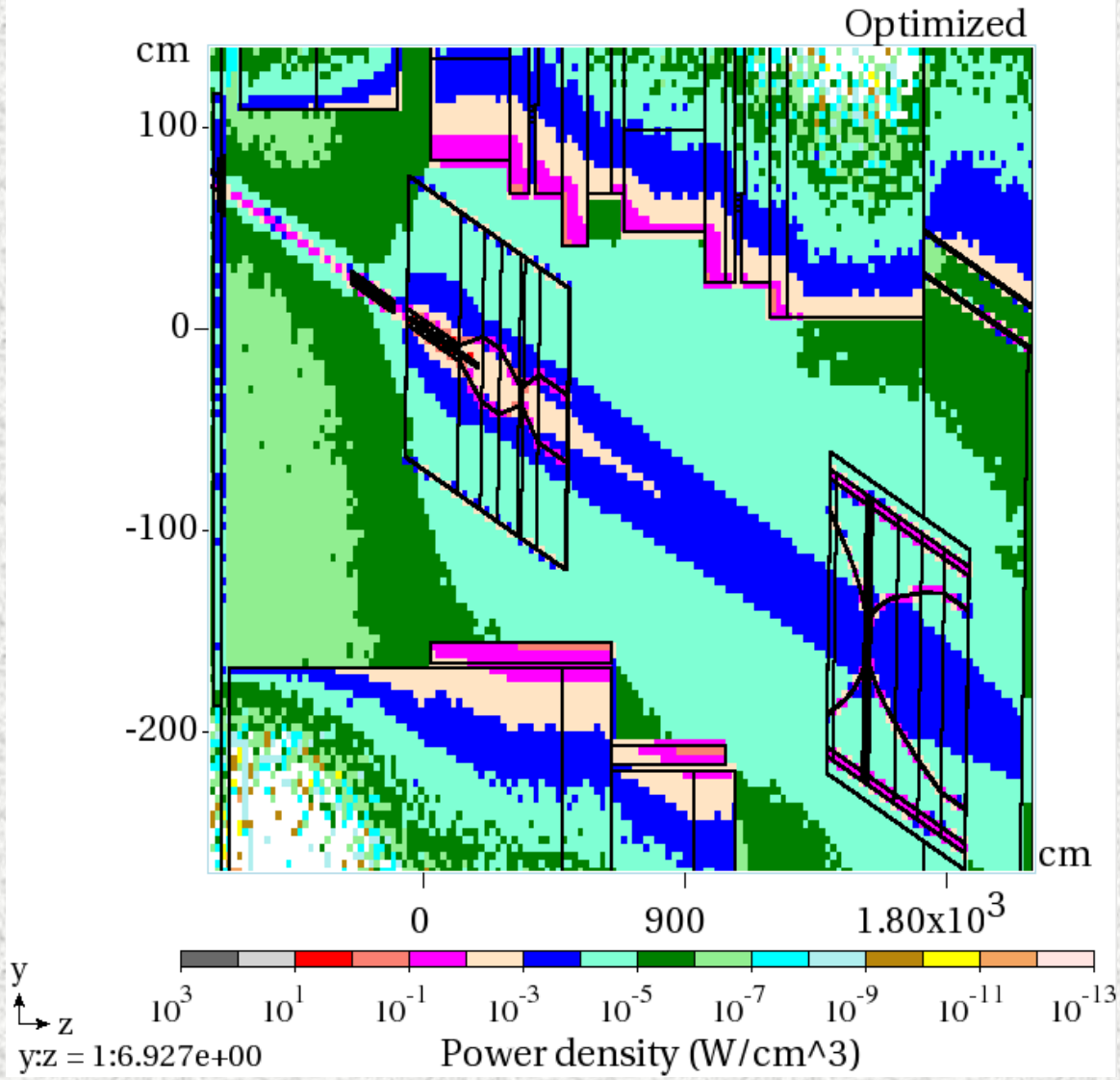
Beam starts at z = -7.3 m from MC0, tilt = 0.101074

Scenario	E_p (GeV)	P (MW) Q (MJ)	σ_0 (mm) at MC0	β_0 (m) at MC0	Cycle (s)	$\times 10^{14}$
Normal	**120**	**2.40 MW**	**1.7**	**110.8837**	**1.2**	**1.25 p/s**
No-target accident*	120	2.88 MJ	2.4	221.03	1.2	1.5 ppp
Off-axis accident**	120	2.88 MJ	2.4	221.03	1.2	1.5 ppp
Normal	60	2.06 MW	1.7	55.44	0.7	2.14 p/s

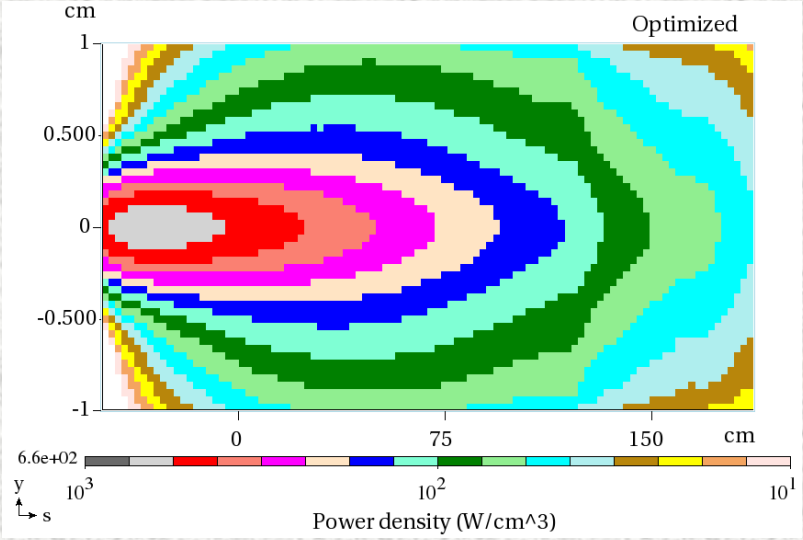
*) On-axis

**) Beam points to absorber cooling water pipes

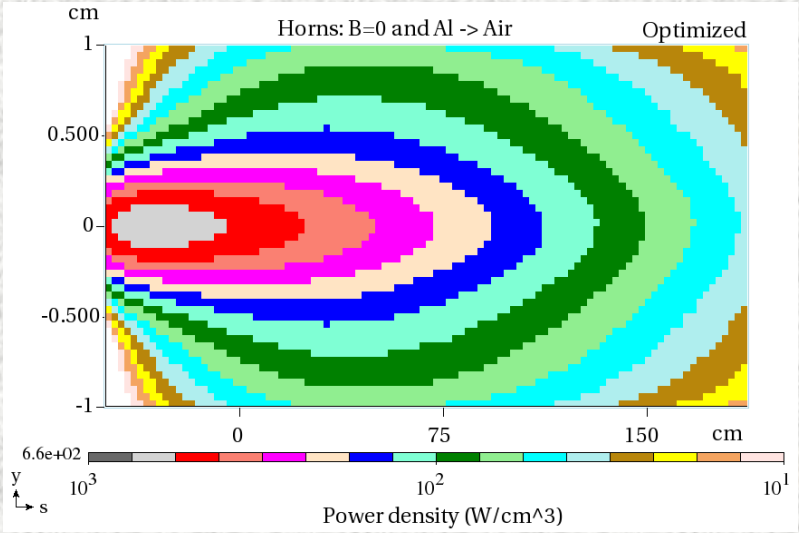
Power Density Profiles in Target Station



Power Deposition in Optimized Target: Density and Total in Graphite Only



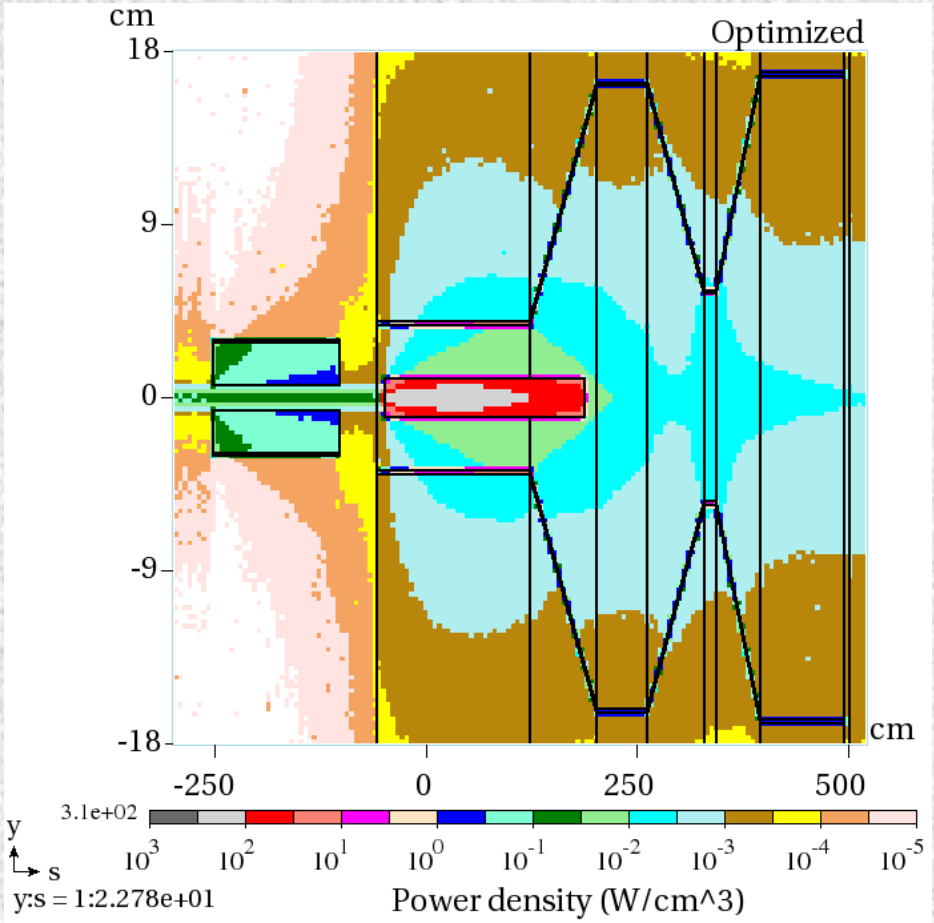
P_0 = 45.02 kW
Compare to 22.4 kW baseline



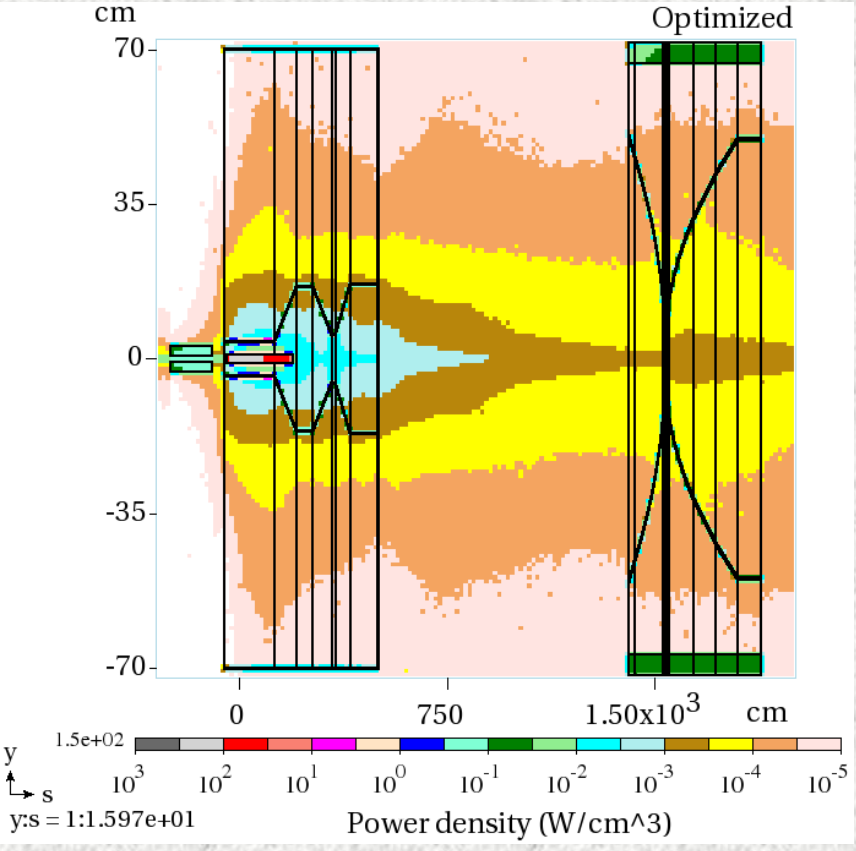
Test: Impact of Horn1 field and Material -> B=0 and Al -> Air

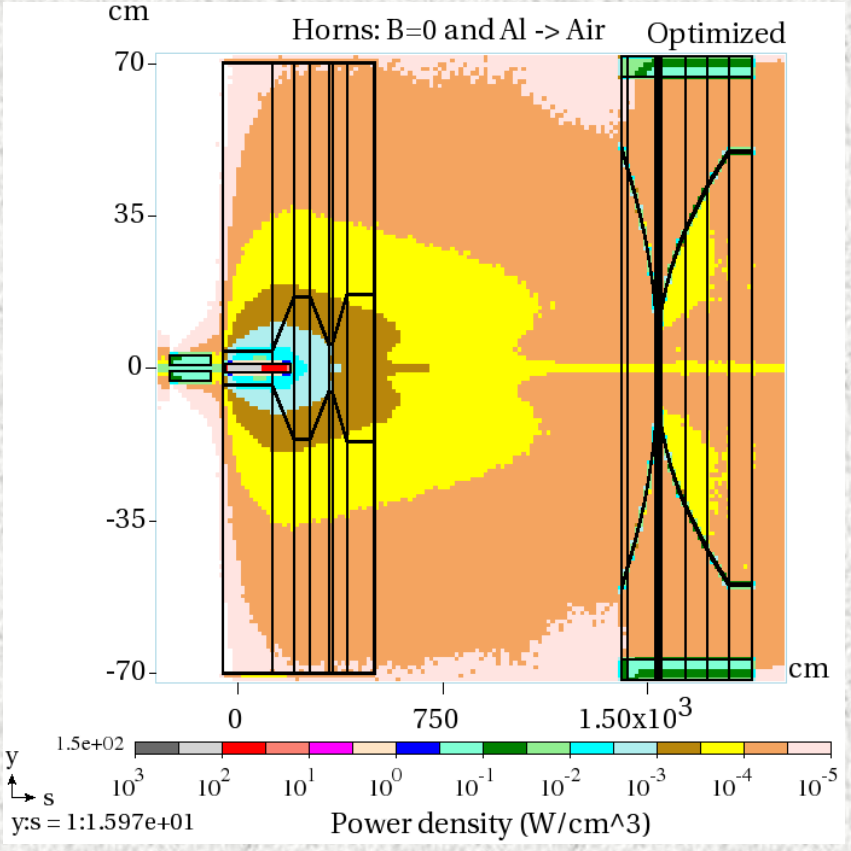
P_{0T} = 44.10 kW,
just 2% less than P_0

Zooming out…

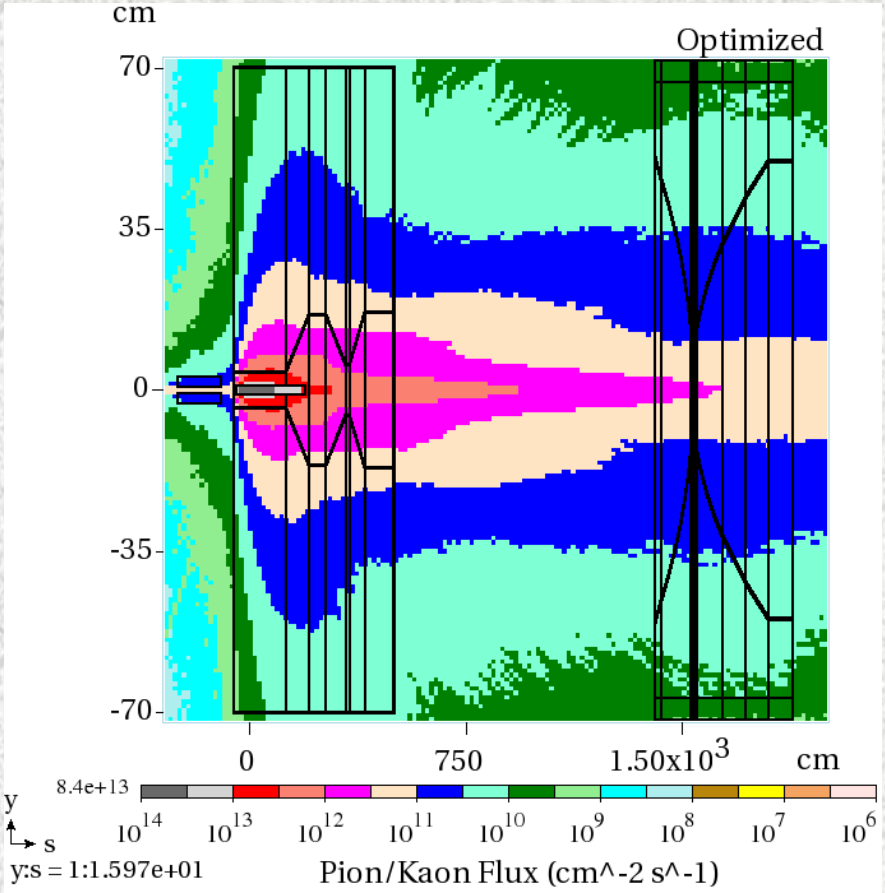

cm
Optimized
18
9
0
-9
-18
cm
-250
0
250
500
3.1e+02
y
s
10^{3} 10^{2} 10^{1} 10^{0} 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5}
y:s = 1:2.278e+01
Power density (W/cm^3)

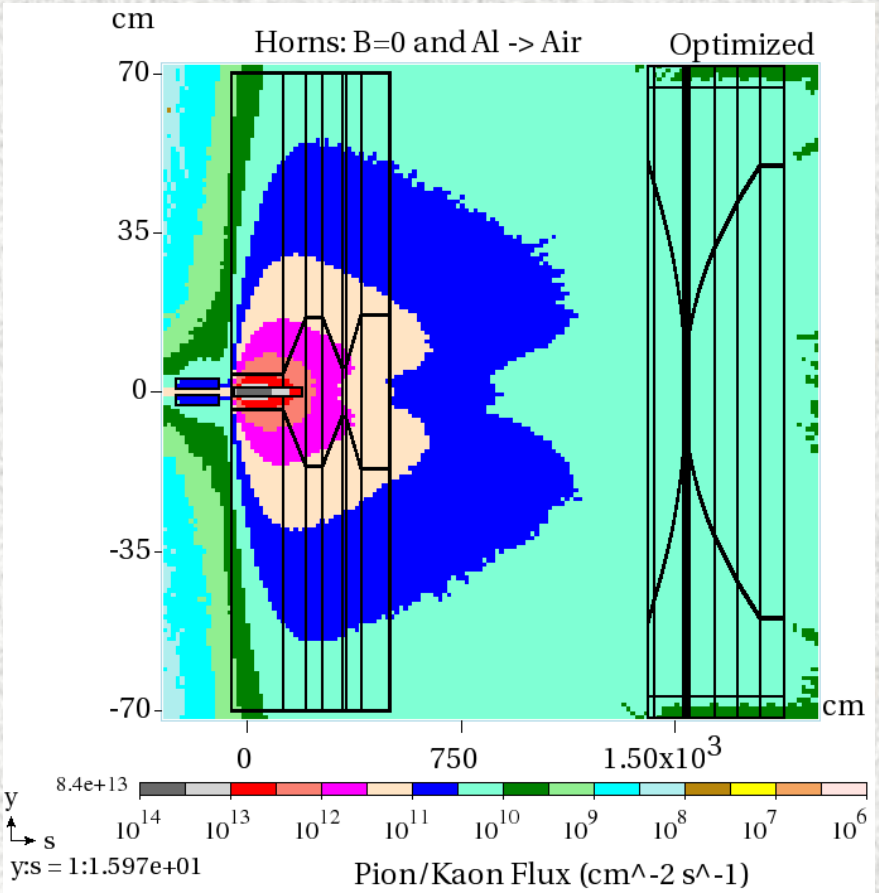
Power Density



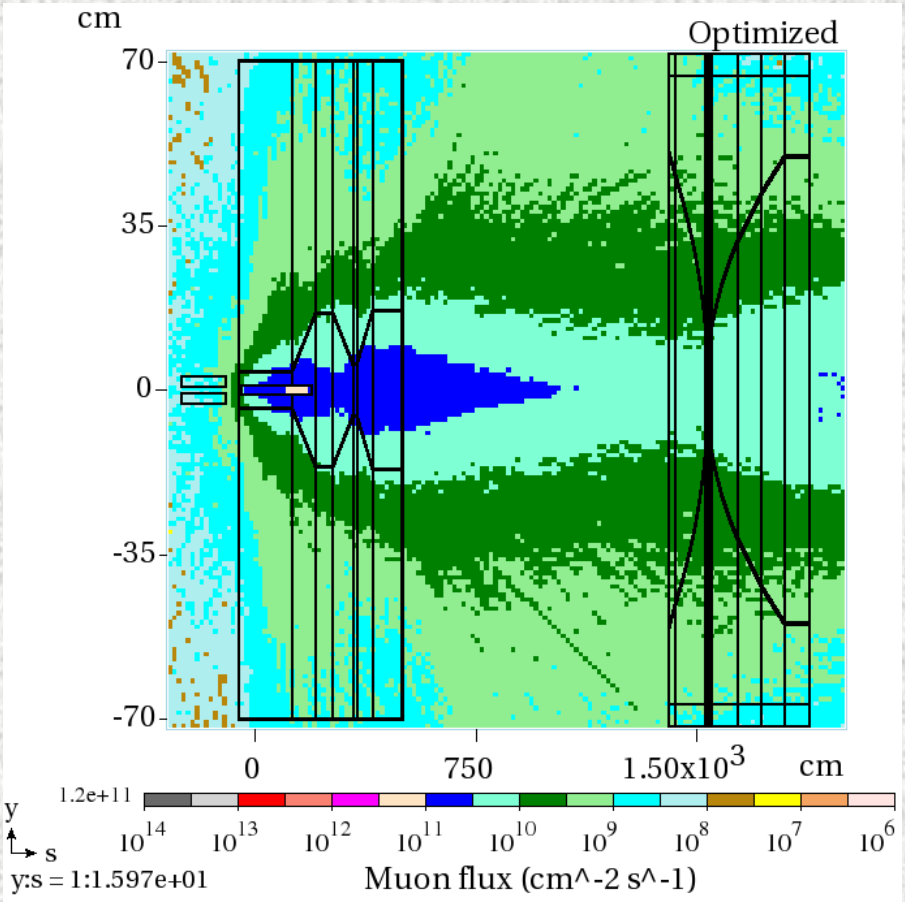


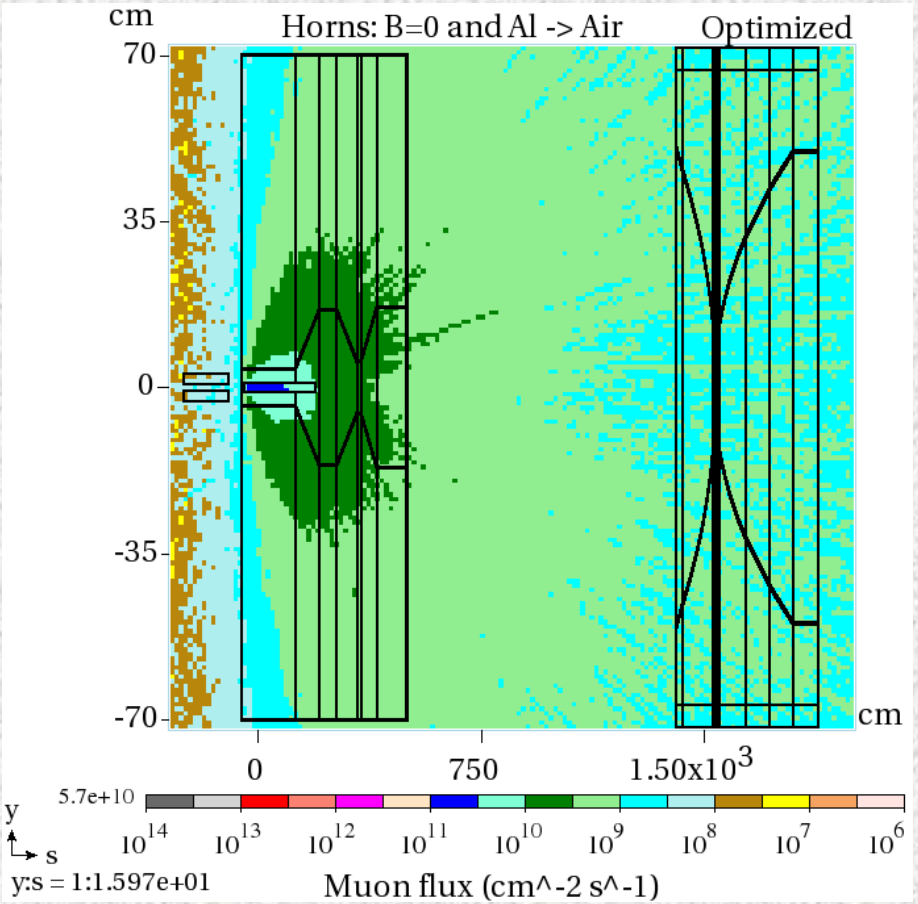
$\pi^{\pm}$ + $K^{\pm}$ Fluxes



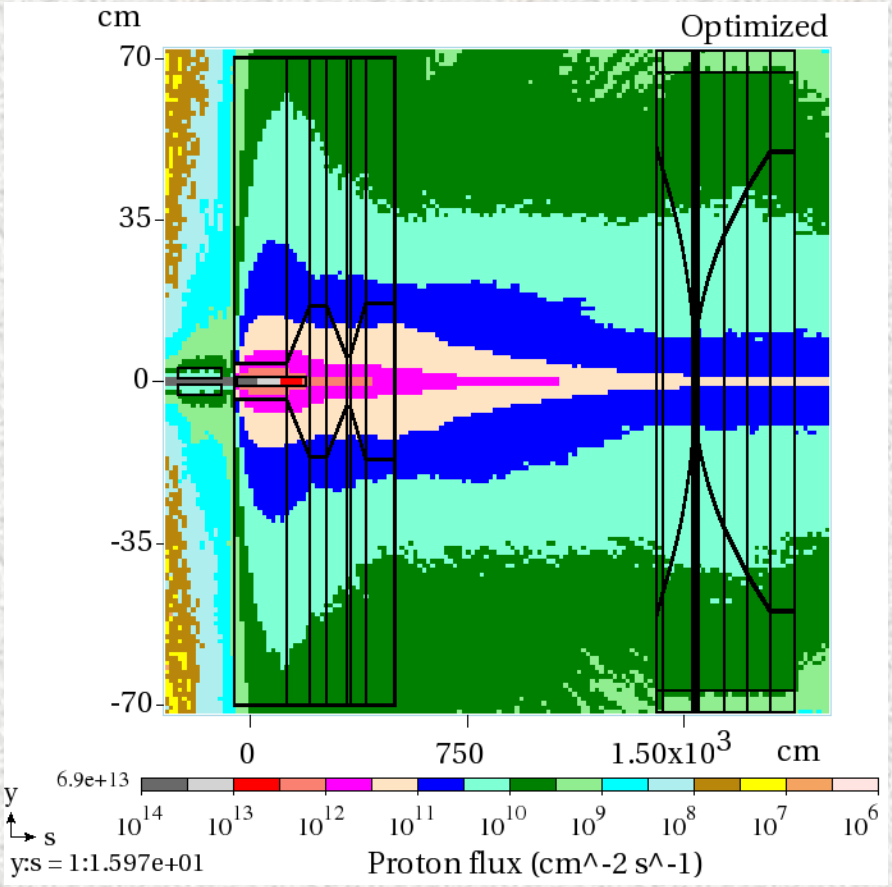


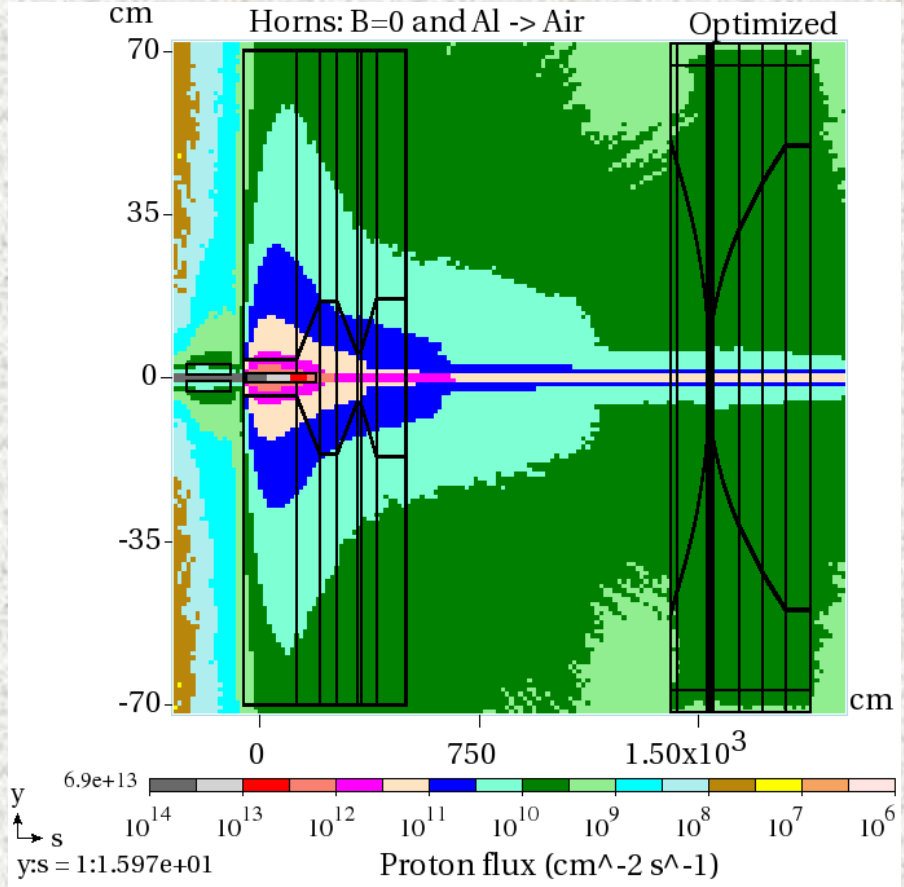
μ± Fluxes


cm
Optimized
70
35
0
-35
-70
0
750
1.50x10^3
cm
1.2e+11
10^14 10^13 10^12 10^11 10^10 10^9 10^8 10^7 10^6
y
s
y:s = 1:1.597e+01
Muon flux (cm^-2 s^-1)

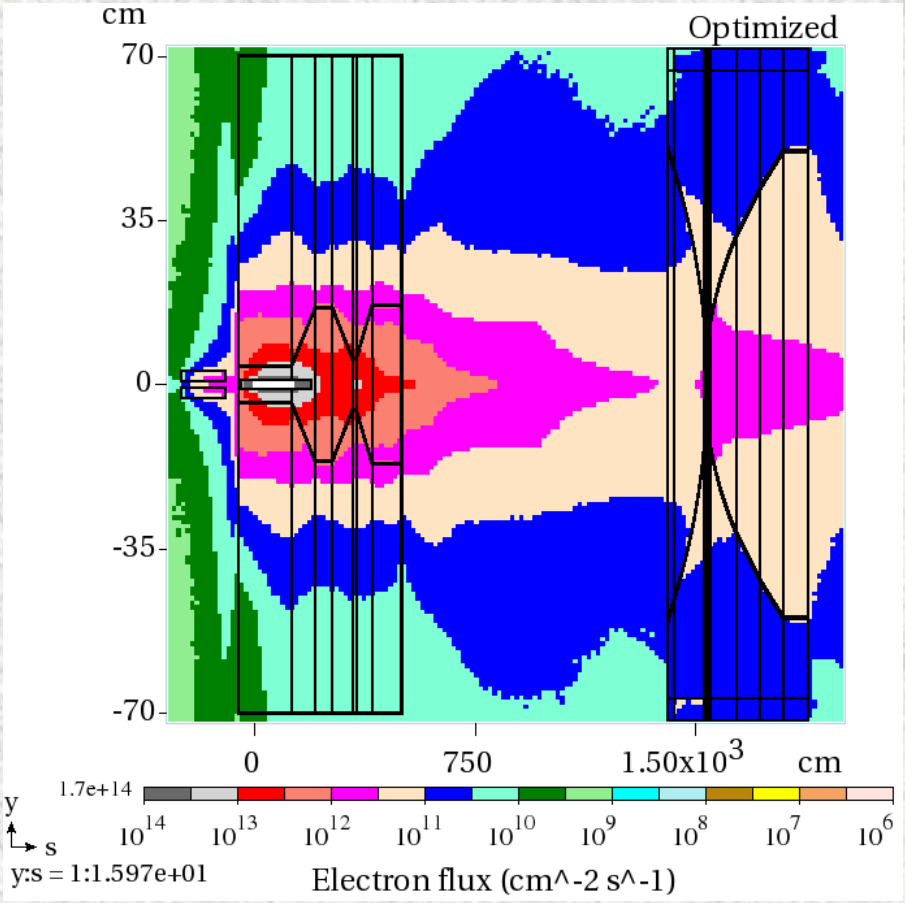

cm
Horns: B=0 and Al -> Air
Optimized
70
35
0
-35
-70
cm
0
750
1.50x10^3
5.7e+10
10^14 10^13 10^12 10^11 10^10 10^9 10^8 10^7 10^6
y
s
y:s = 1:1.597e+01
Muon flux (cm^-2 s^-1)

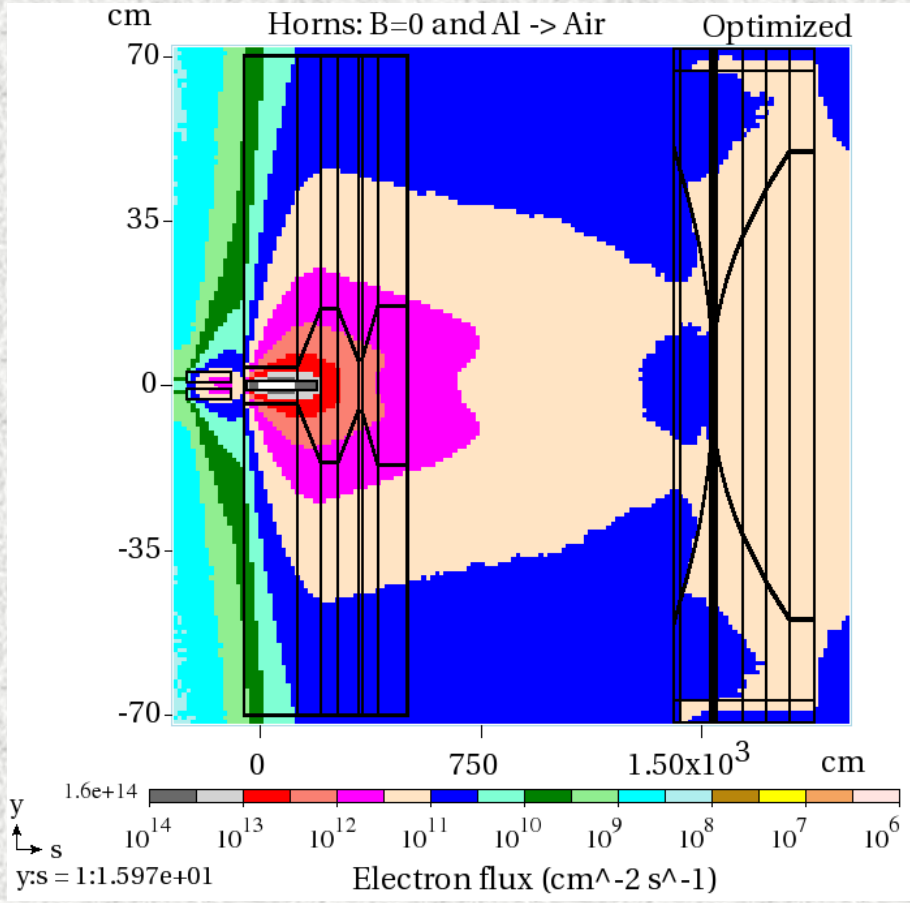
Proton Fluxes



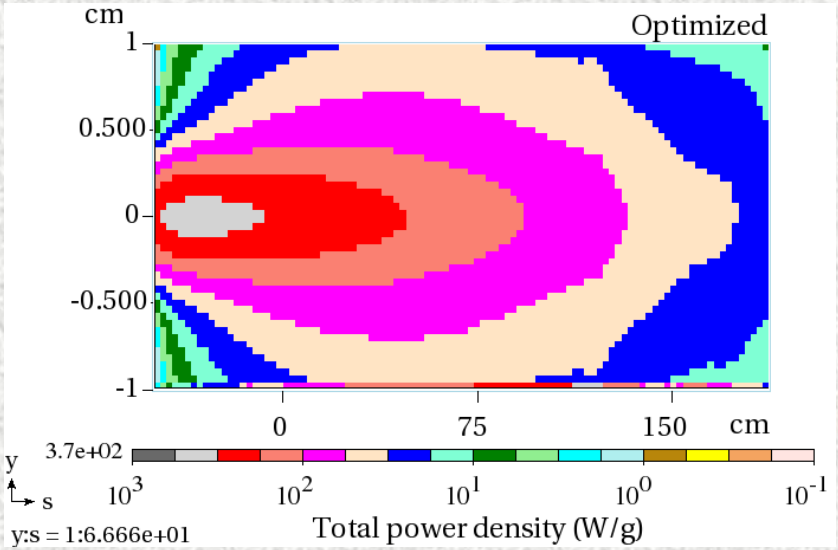


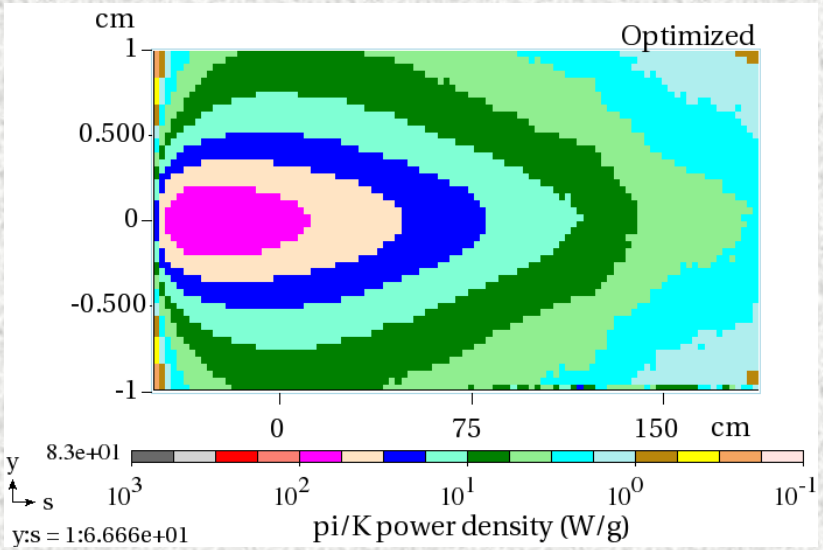
$e^{\pm}$ Fluxes

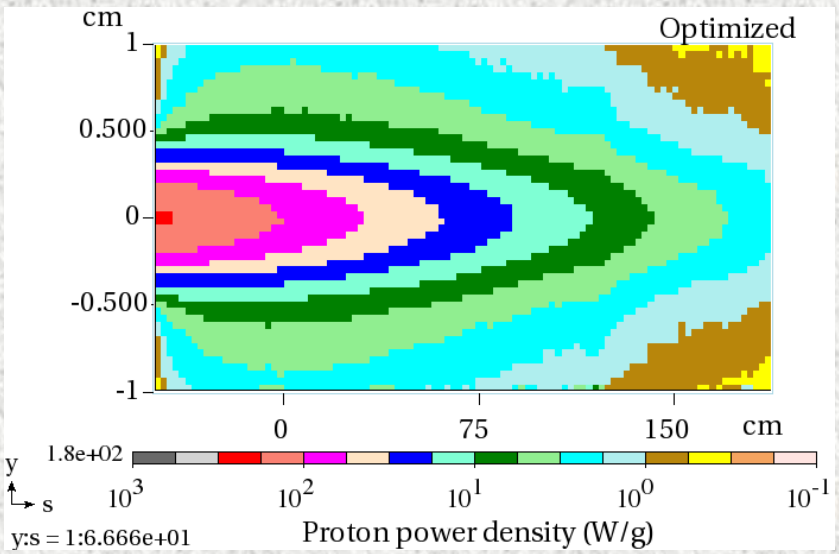

cm
Optimized
70
35
0
-35
-70
0
750
1.50x10^3
cm
1.7e+14
10^14 10^13 10^12 10^11 10^10 10^9 10^8 10^7 10^6
y
s
y:s = 1:1.597e+01
Electron flux (cm^-2 s^-1)

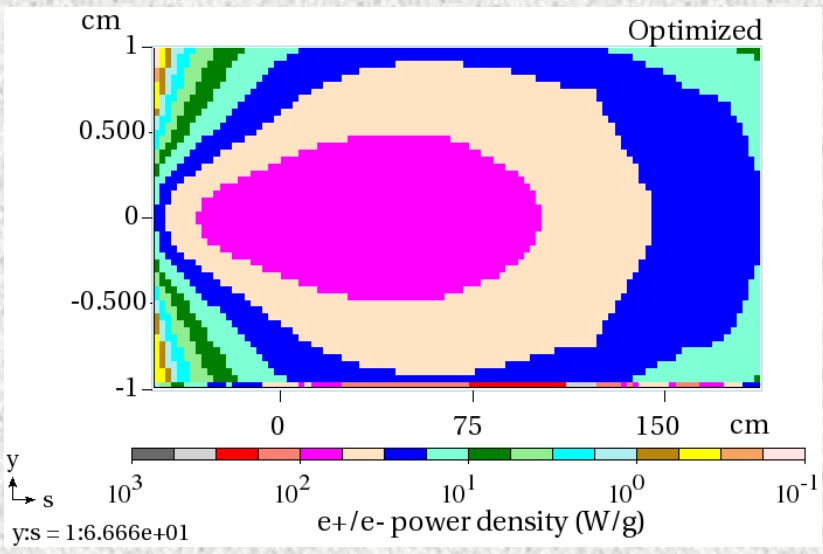

cm
Horns: B=0 and Al -> Air
Optimized
70
35
0
-35
-70
0
750
1.50x10^3
cm
1.6e+14
10^14 10^13 10^12 10^11 10^10 10^9 10^8 10^7 10^6
y
s
y:s = 1:1.597e+01
Electron flux (cm^-2 s^-1)

Power Density Contributors in Target

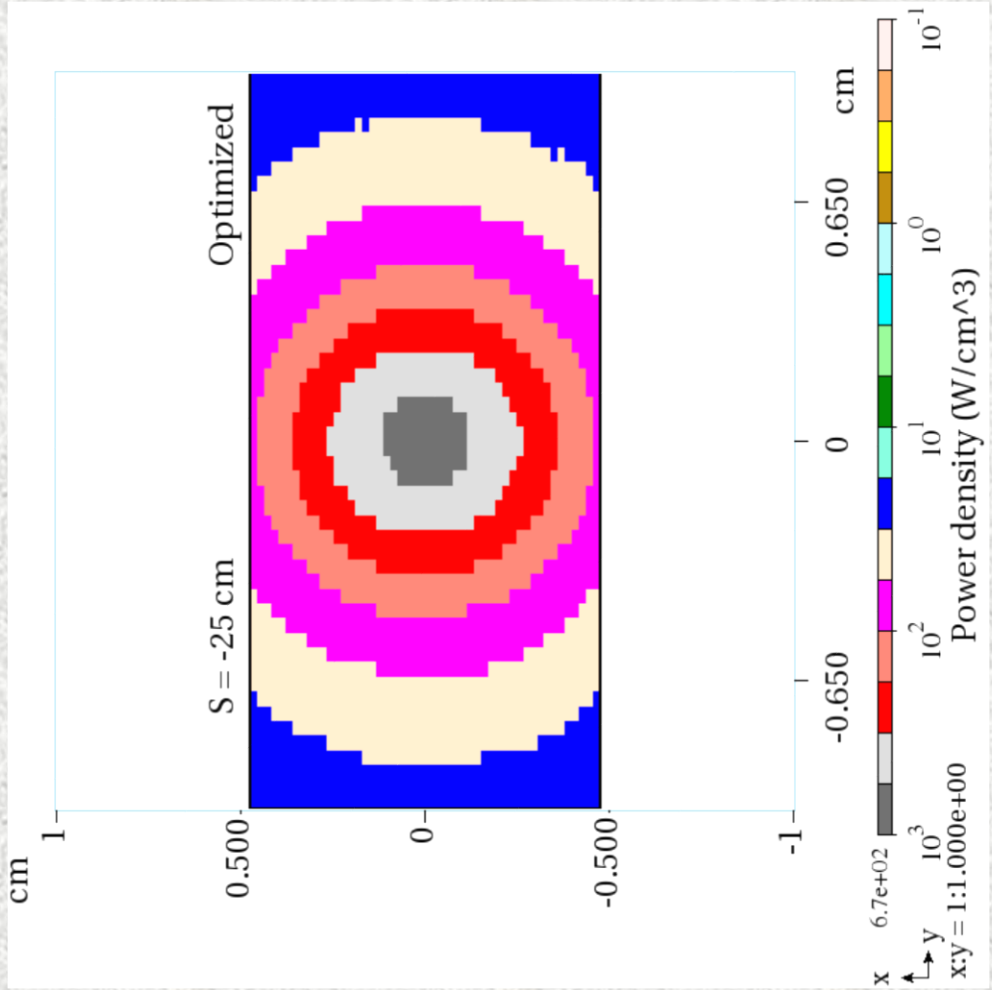




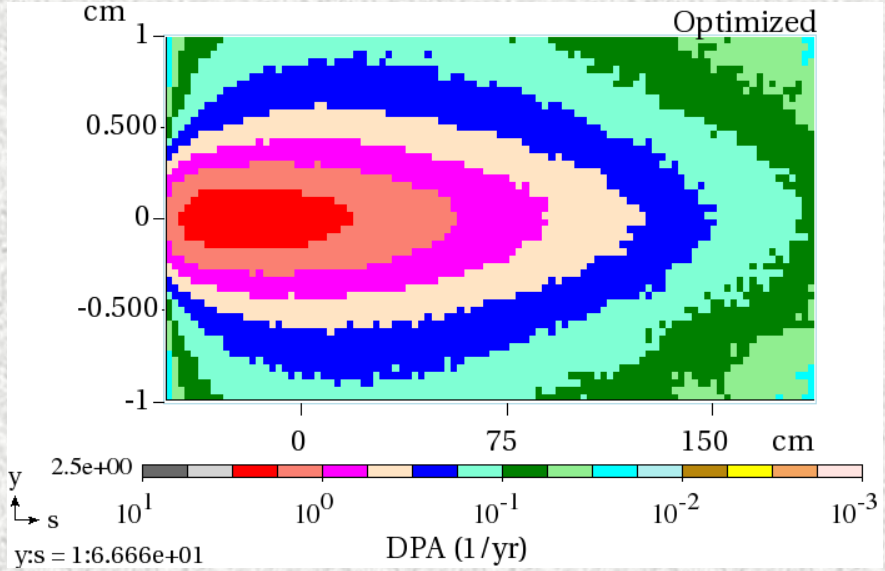


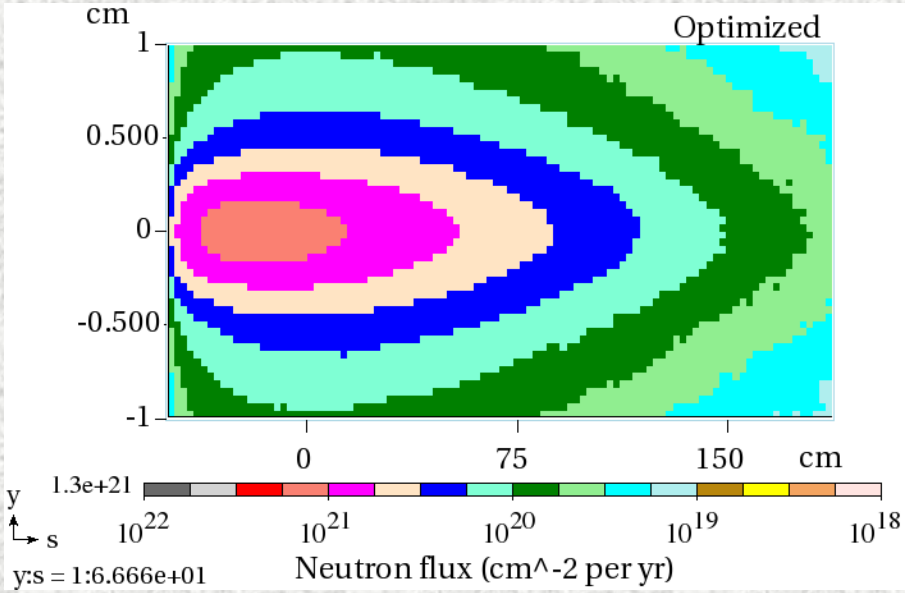


Power Density Lateral Profile at Shower Maximum

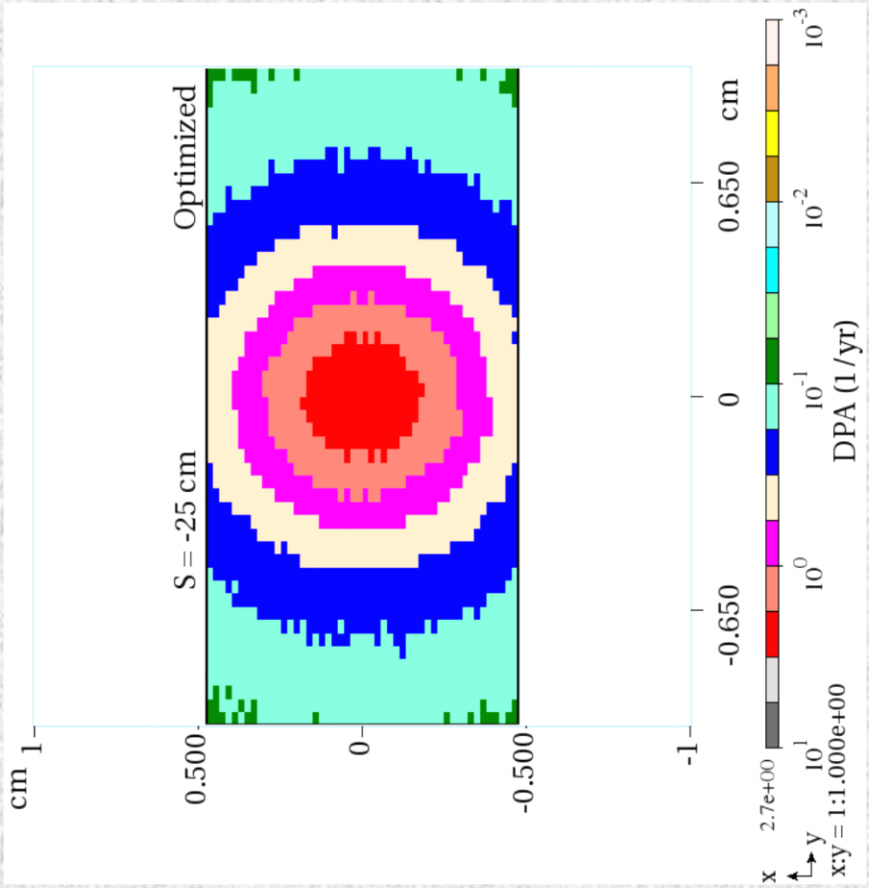


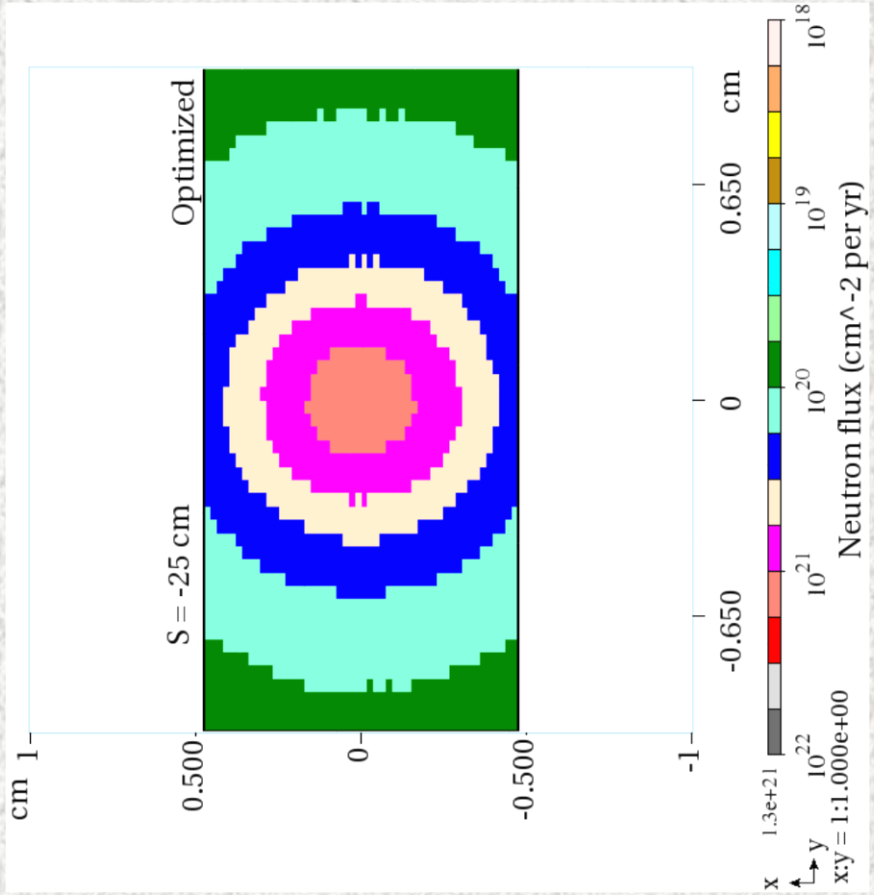
RadDam and Target Lifetime: DPA and Neutron Flux (1)





RadDam and Target Lifetime: DPA and Neutron Flux (2)

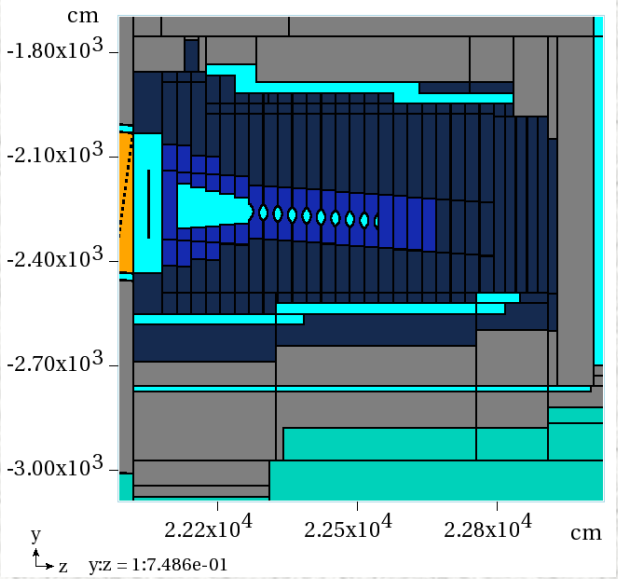


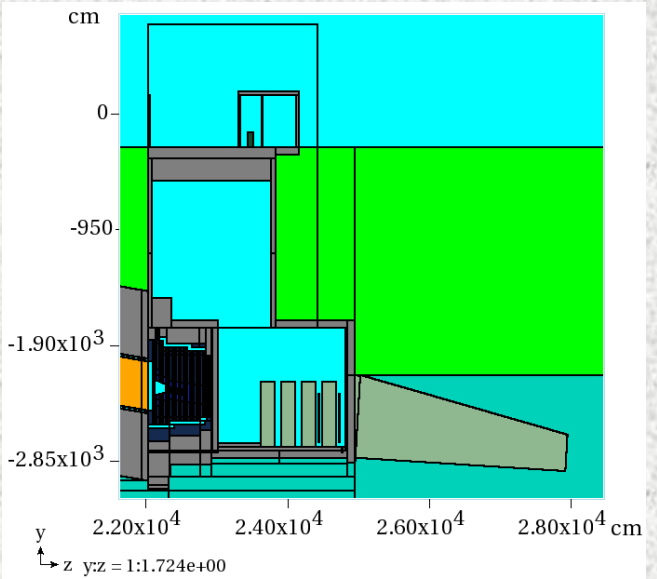


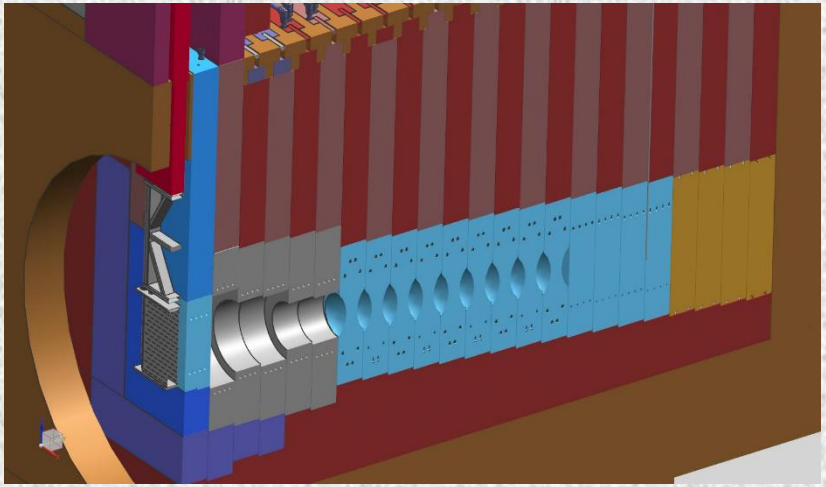
Peak: 2.7 DPA and 1.3e21 n/cm2 per 1.5e7 s/yr

Compare to a 0.2 to 0.7 limit (BLIP & NuMI): enlarge beam on target

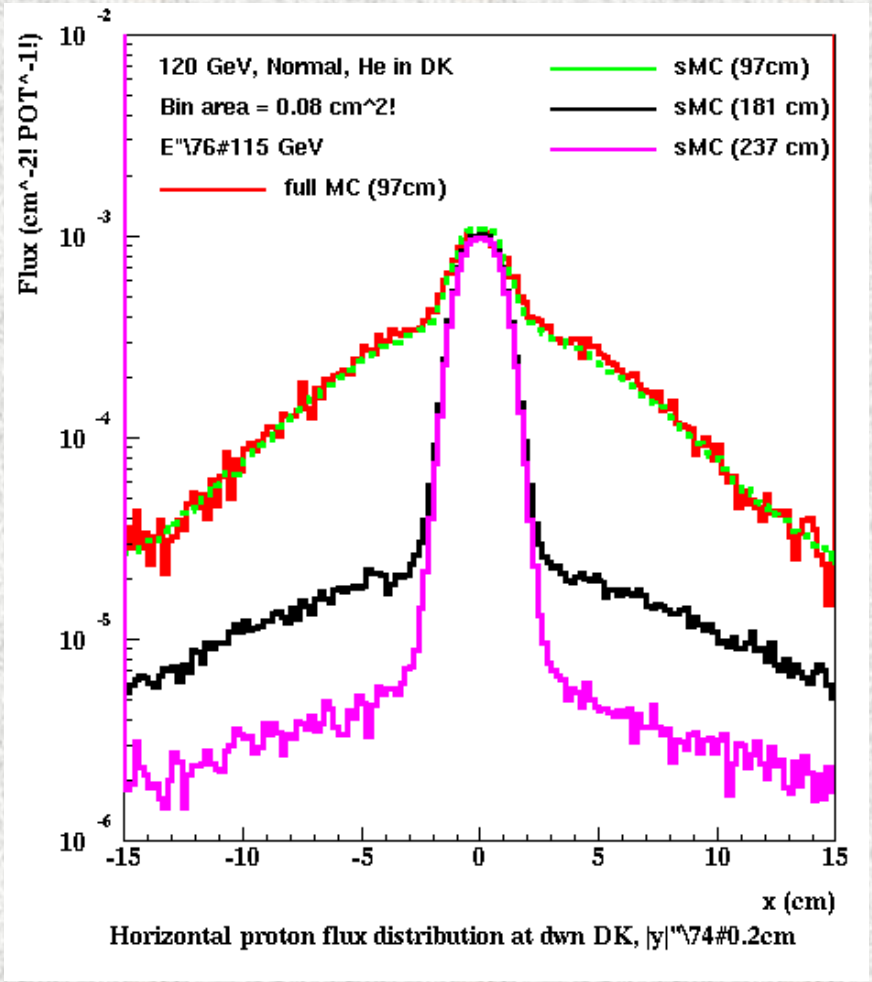
Absorber: Optimized MARS15 Model

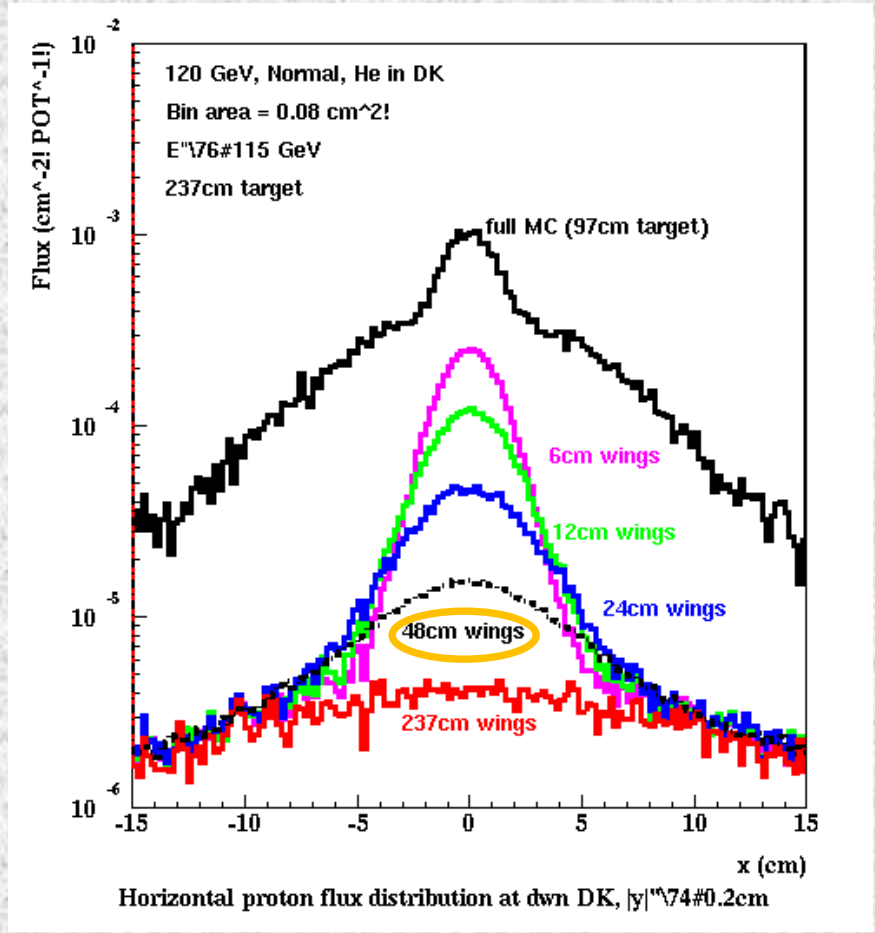






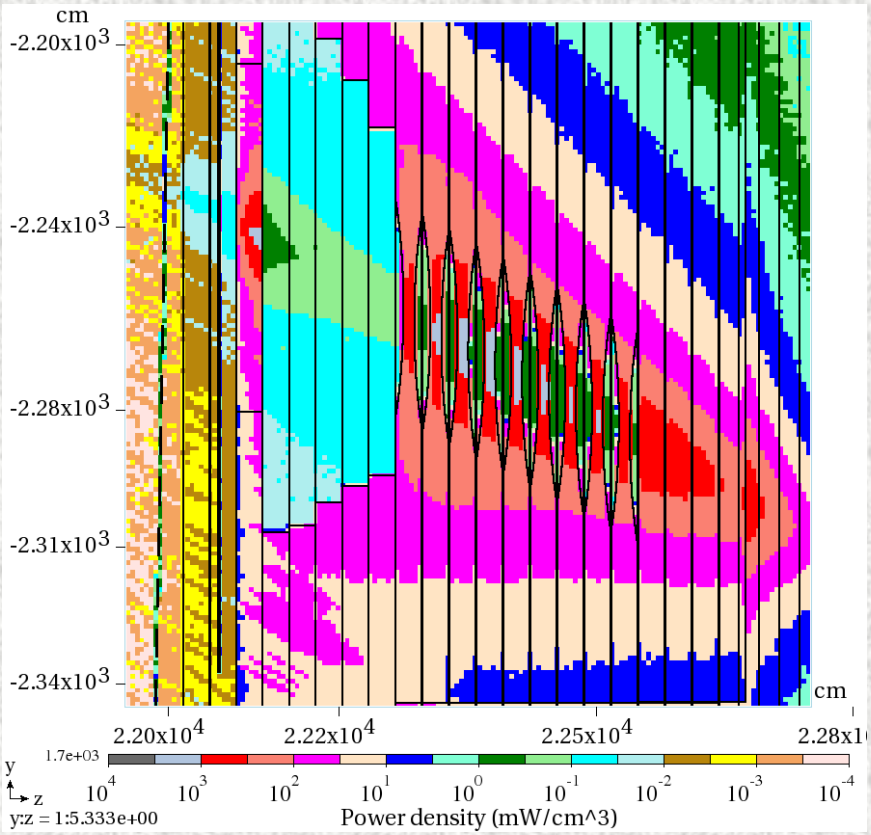
Longer target: up to 20-fold reduction of pedestal
Longer wings decrease peak: 100 times for 48-cm wings



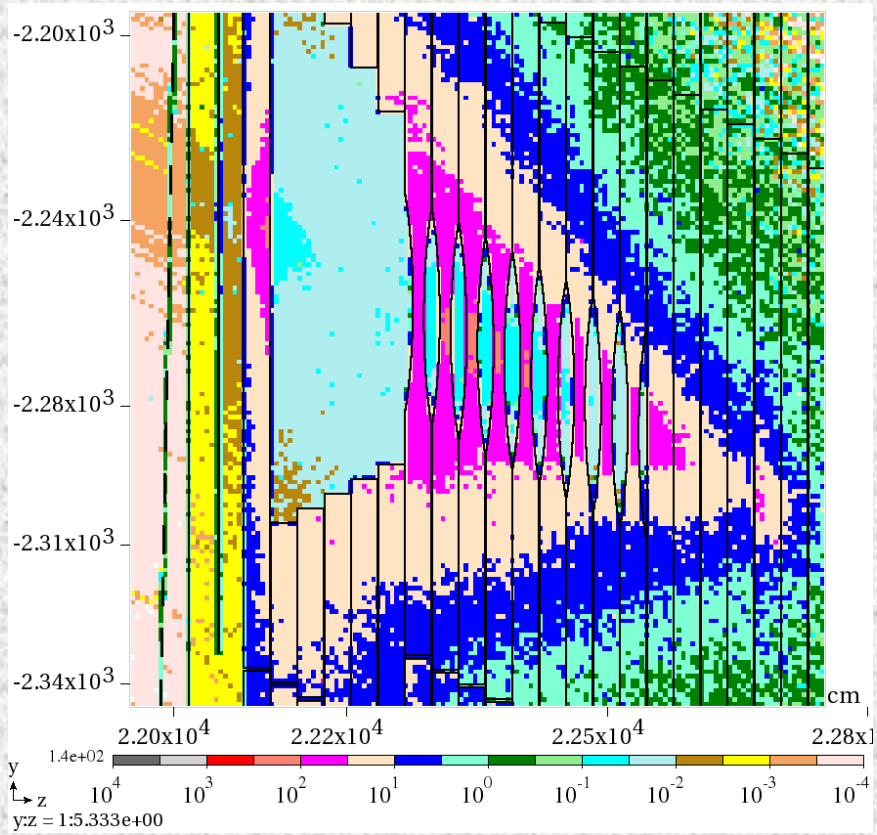


Energy Deposition (mW/cm3) y-z Profile: 1x1x5.33 cm bin

Baseline NuMI style



Optimized with 42cm wings



Peak energy deposition density is about 12 times lower for optimized target with 42-cm long wings

Power on absorber for 2.4 MW beam

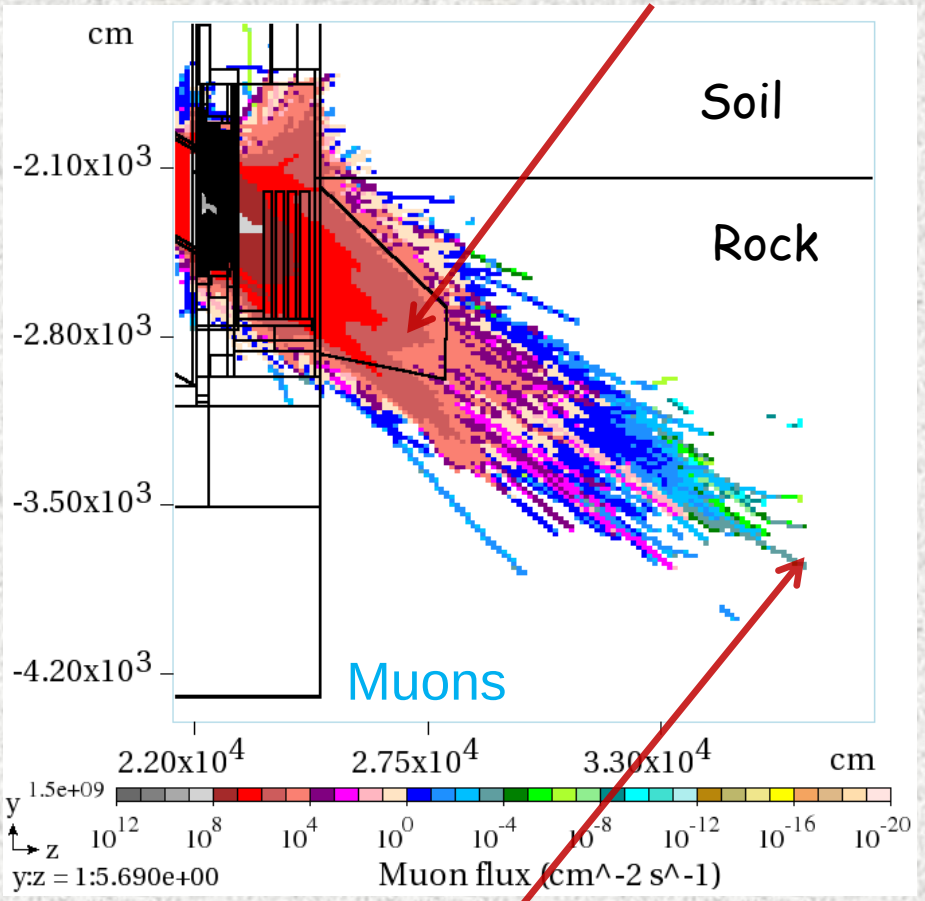
x*y	Baseline	Baseline +12cm wings	Optimized	Optimized +48cm wings
cm^2	kW	kW	kW	kW
6*6	107	46	16	6.6
12*12	196	86	25	16
32*32	350	159	71	62
300*300	760	726	392	382

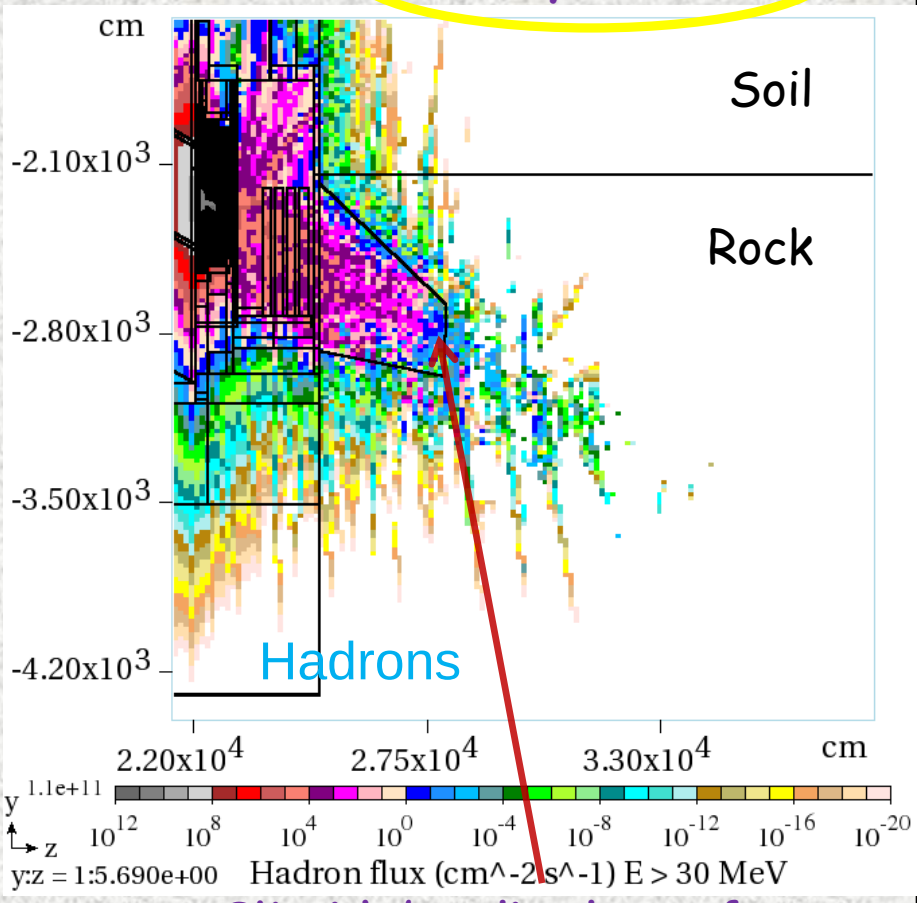
Baseline total heat dissipation in absorber: 741.7 kW

Muon/Hadron Fluxes (cm^{-2} s^{-1}) with Steel Kern

30-m steel kern: R_1=3.5m, R_2=1.5m

July 2015





July: Z=365m, S=118m

ND: L=459m, Z=456.7 m

OK with baseline kern after further model refinement