LBNF/RAL Target Options Physics Comparisons

John Back

University of Warwick

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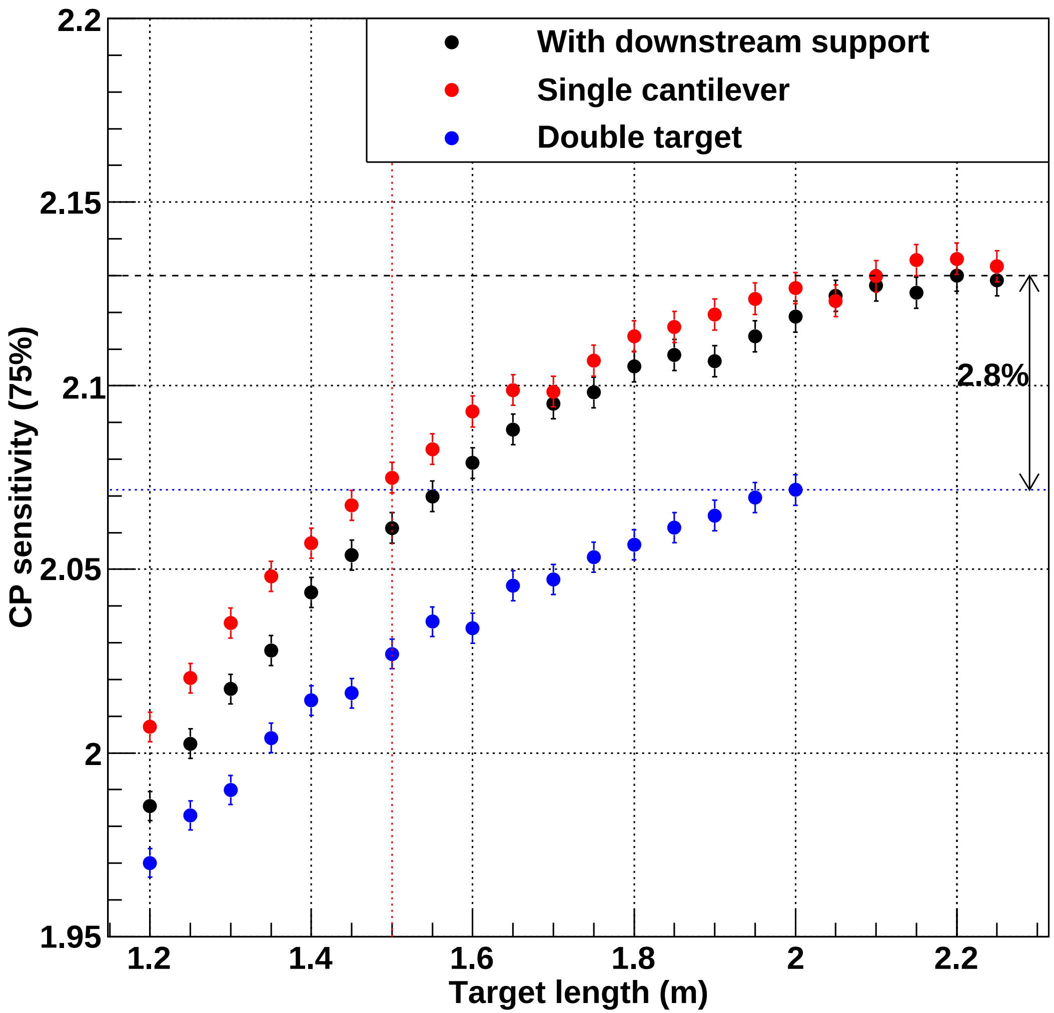
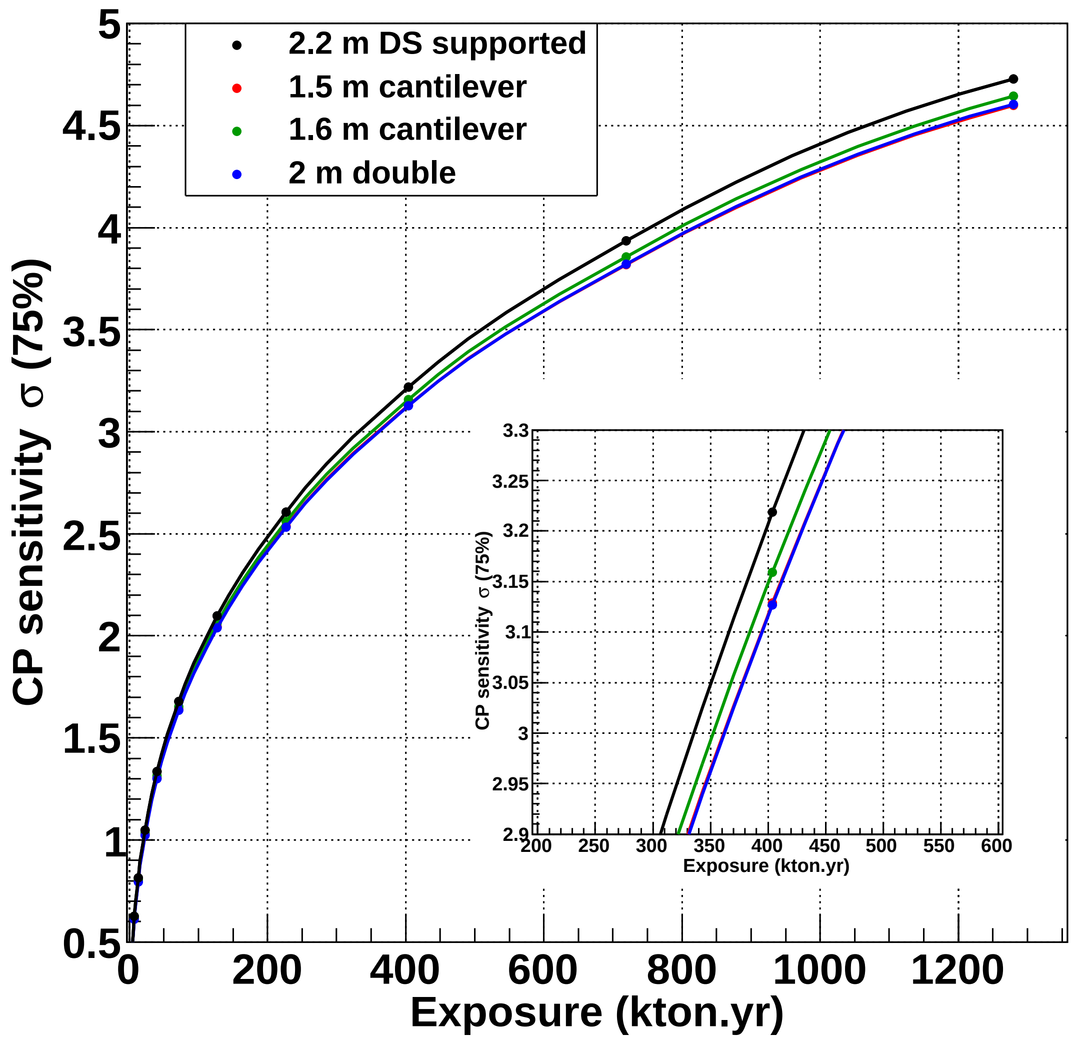
Introduction

- Comparing physics performance of 3 RAL cylindrical graphite target options:
  - 2.2 m long with downstream (DS) support
  - Shorter 1.5 m, cantilevered
  - Double target, 2 $\times$ 1 m with DS support
- Using Geant4 (G4LBNF) to study ν CP sensitivity & fluxes
  - Varying target length to see trends; $r = 8$ mm and variable r
  - Proton beam energy fixed at 120 GeV; $\sigma = r/3$; total power = 1.2 MW
  - GLoBES with TDR settings/parameters: 3.5+3.5 years, 40kton detector
- Fluka (2011.2x.6) energy deposition study
  - (a) double target 2 $\times$ 1 m and (b) single cantilevered target 1.5 m
  - geometry includes Horn 1 & its $\underline{B}$ field from G4LBNF
  - 120 GeV proton beam, $r = 3\sigma_r = 8$ mm
  - Beam power = 1.2 MW, POT = 7.5×10^{13}/pulse (1.2 s)

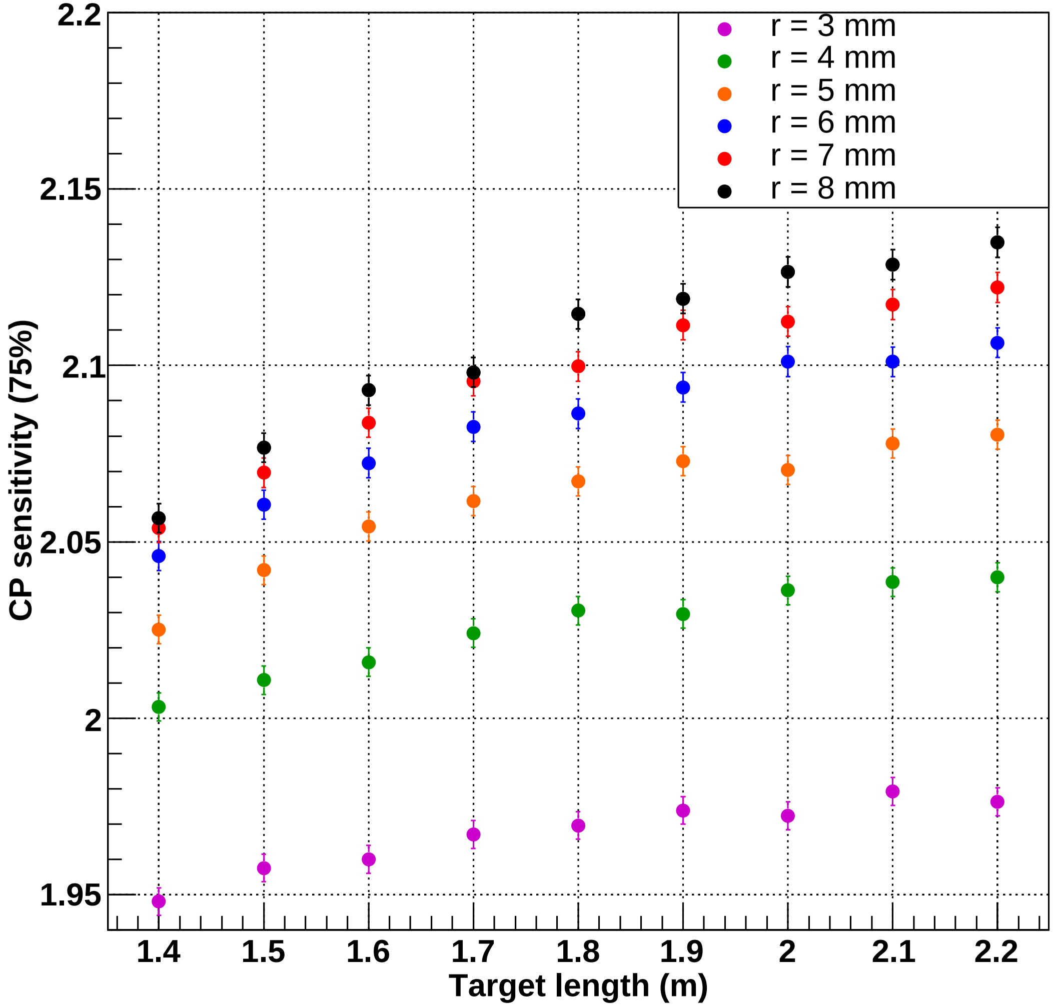
CP Sensitivities ($r = 8\,\text{mm}$)

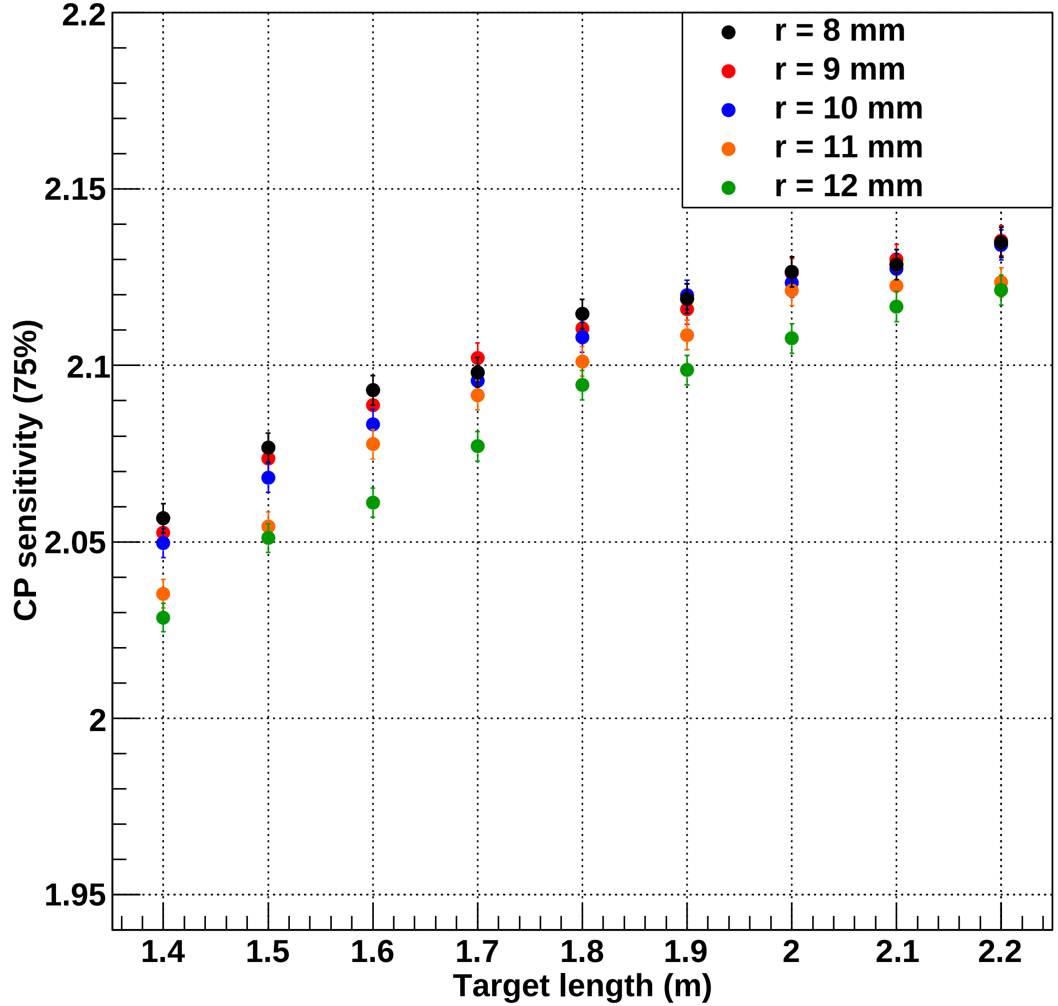




3σ exposure increase: double target 8.2% (30 days/yr)
1.5 m cantilever 8.2% (30 days/yr)
1.6 m cantilever 5.4% (20 days/yr)

Cantilevered target CP sensitivities, varying $r = 3\sigma$

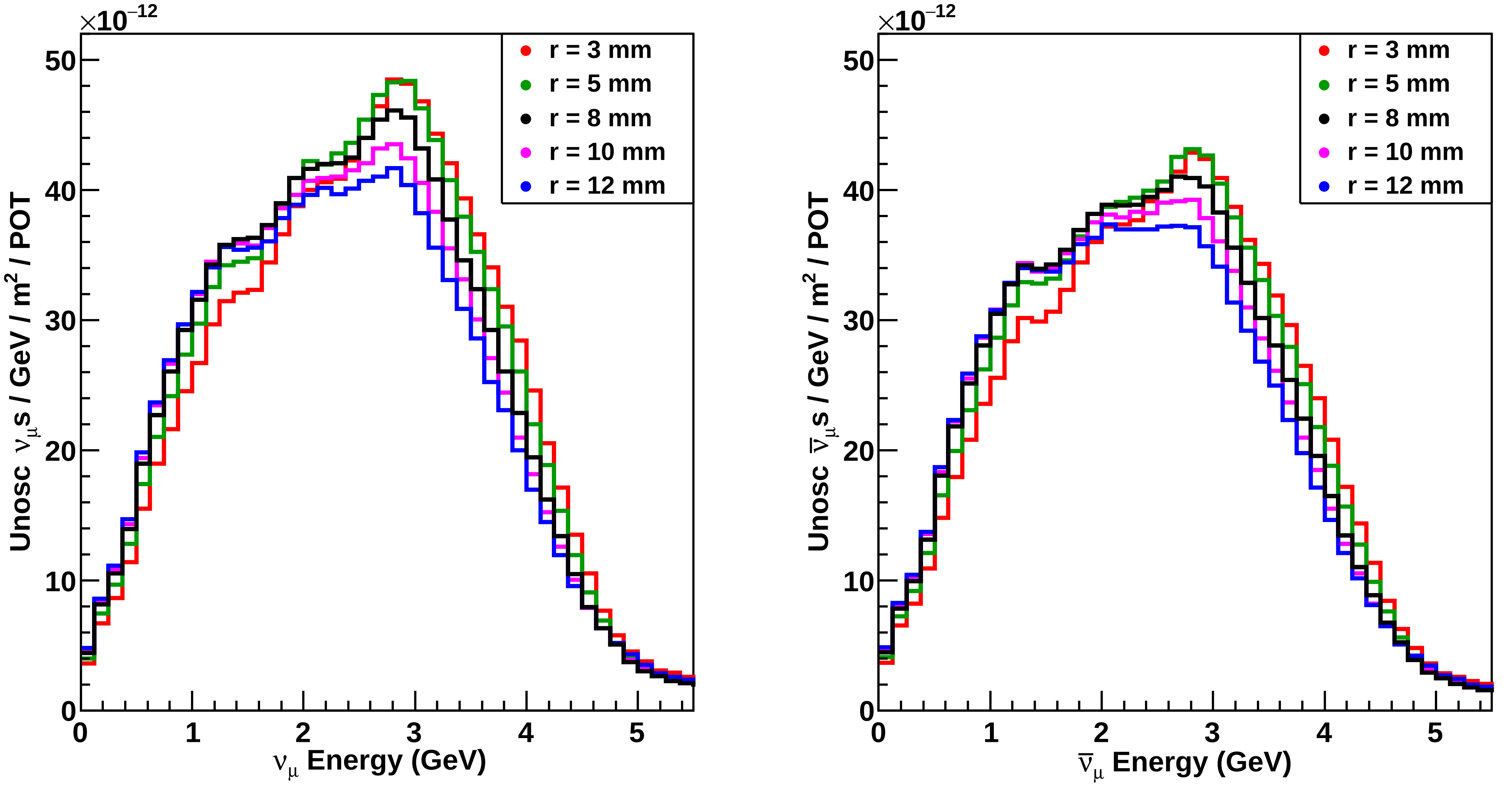




Smaller r gives more higher energy neutrinos, not good for CP sensitivity

Optimal r is around 8 mm

Neutrino far detector fluxes for 1.5 m cantilevered target

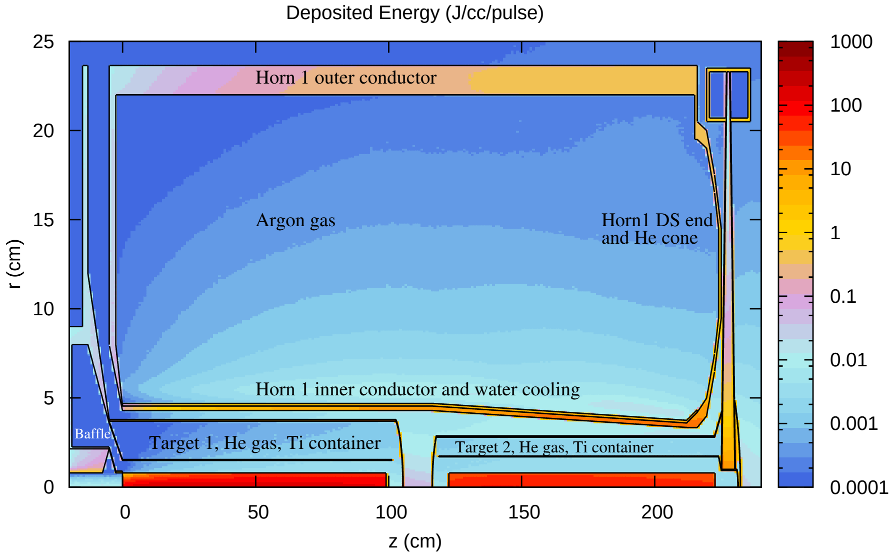


Smaller r: reduced (larger) neutrino flux below (above) 2.5 GeV

$r = 3$ mm has 9% less ν below (13% more ν above) 2.5 GeV compared to $r = 8$ mm

Double target all regions E density: J/cc/pulse

B Field



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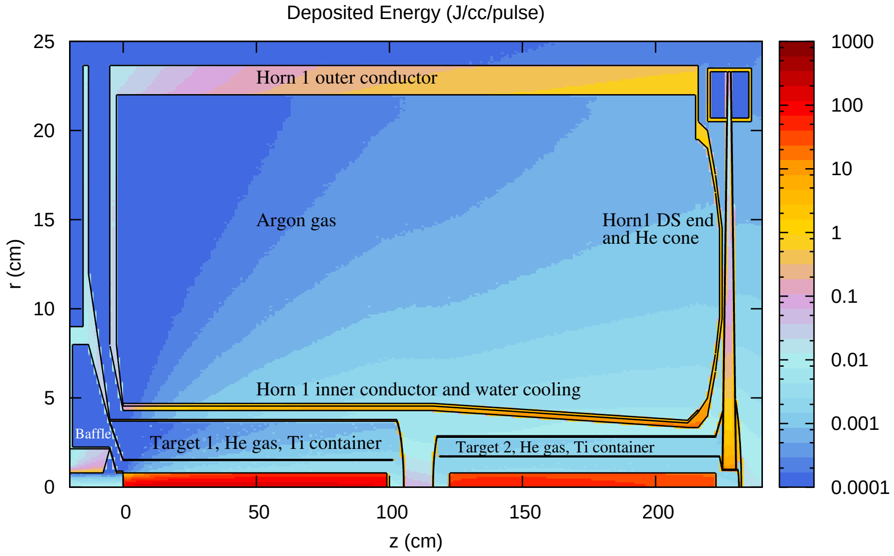
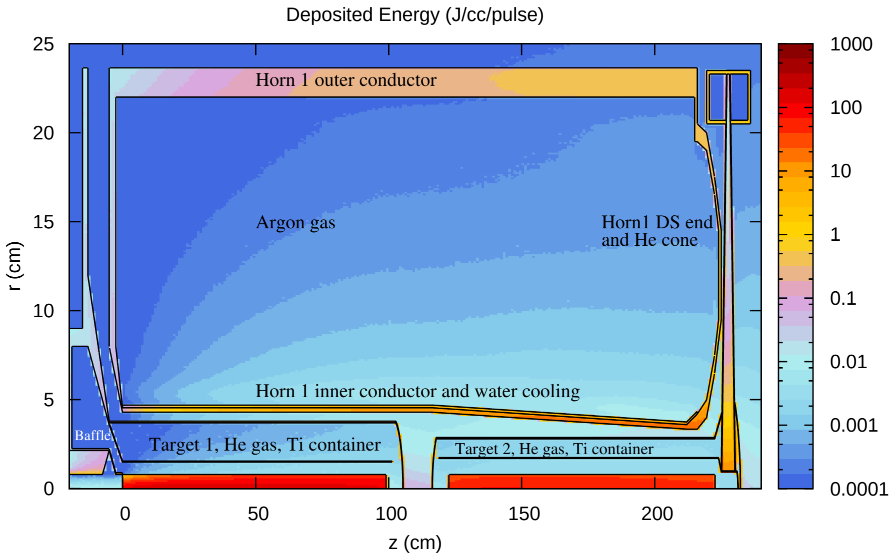
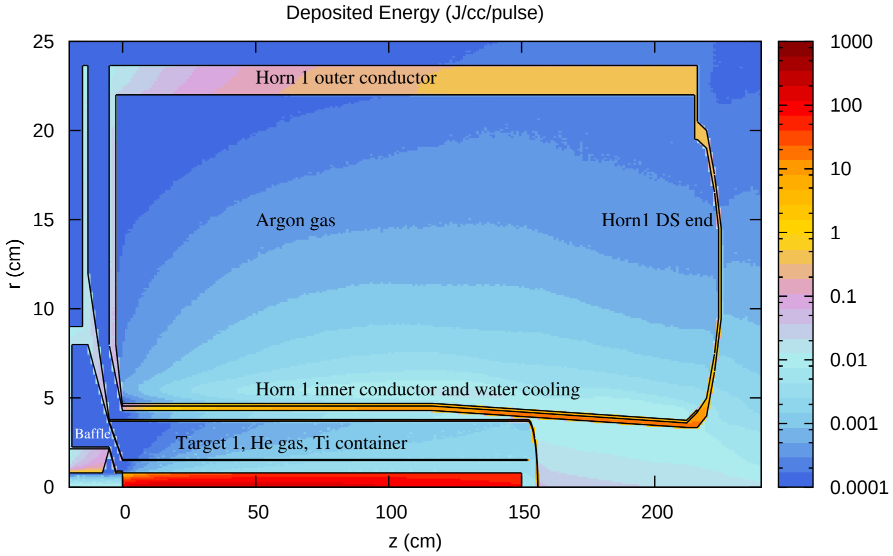




Reversed field

1.5 m target all regions E density: J/cc/pulse

B Field



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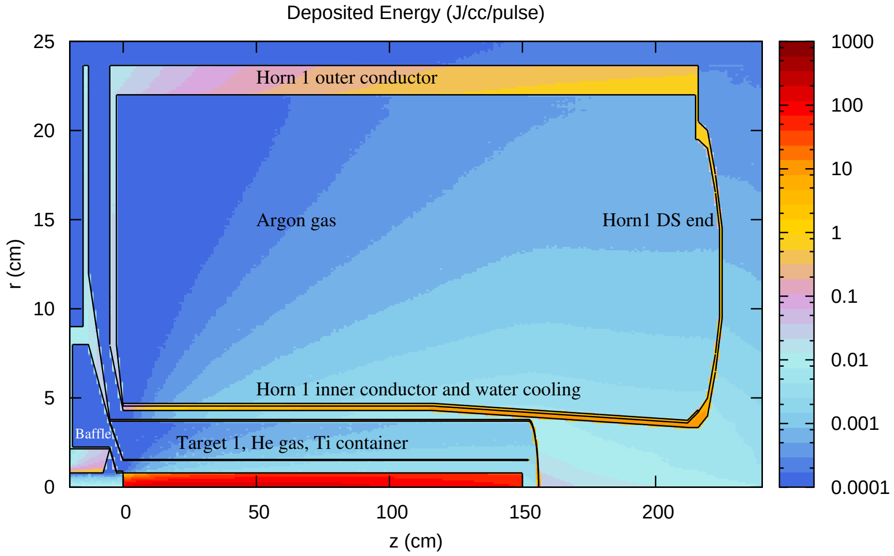
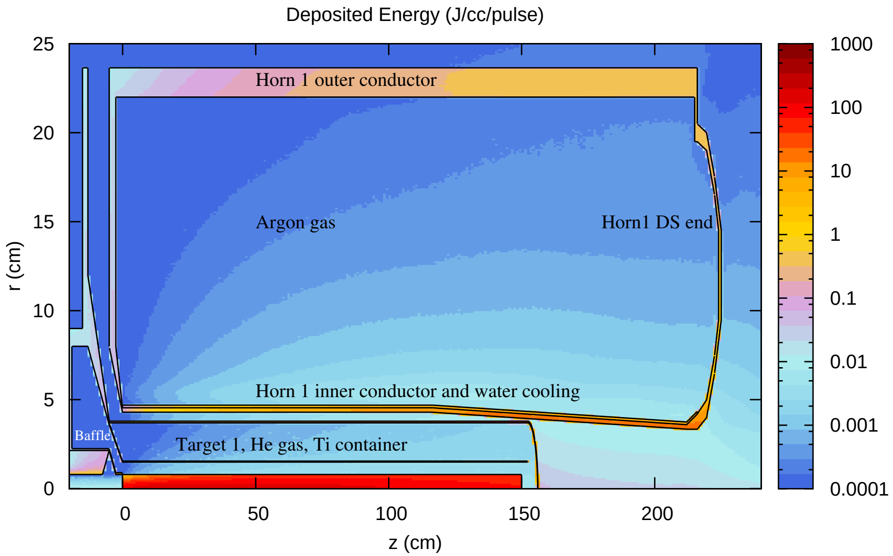
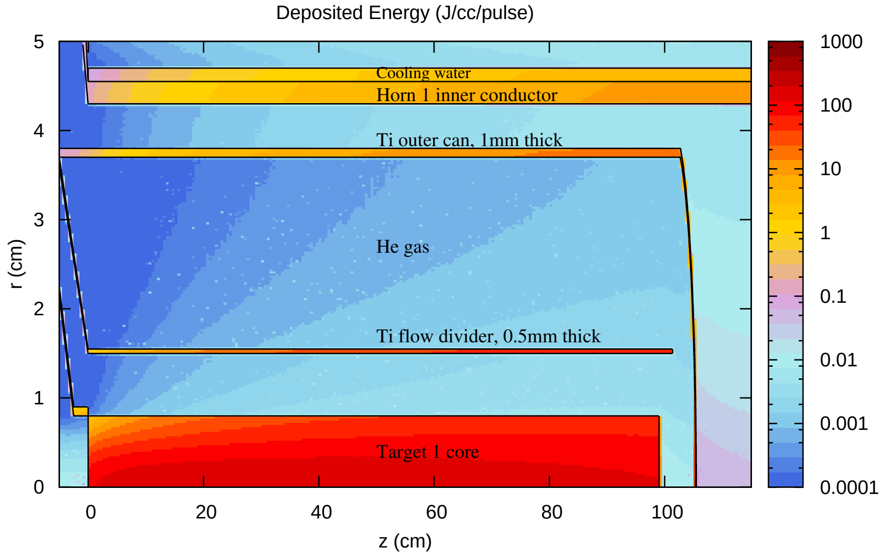


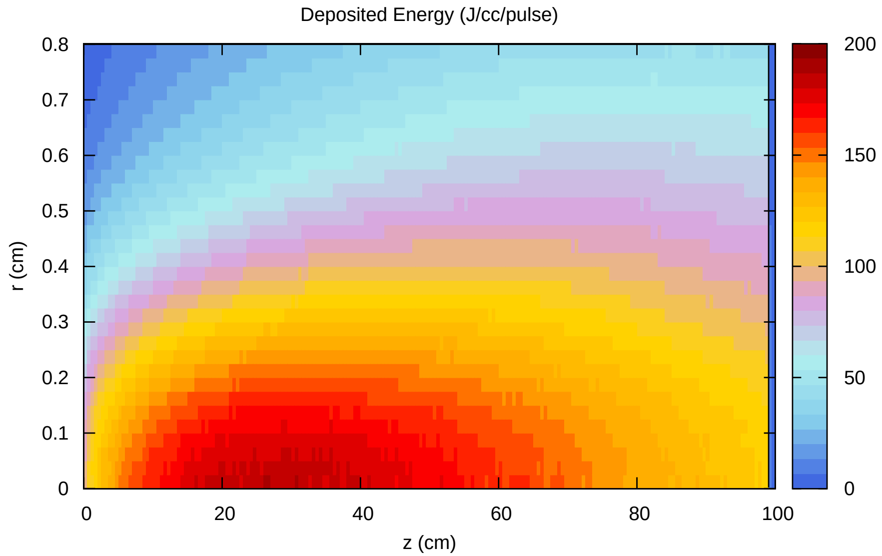


Reversed field

Double Target 1 E densities: J/cc/pulse

B Field





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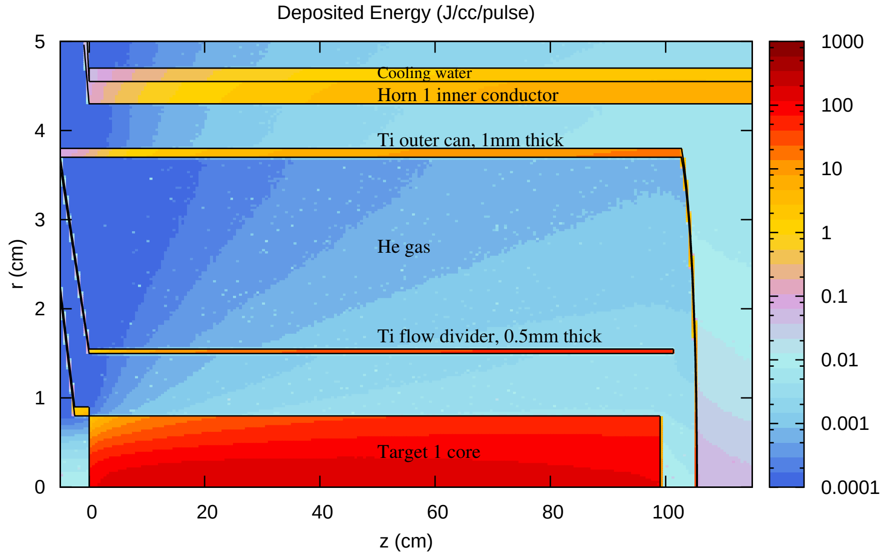
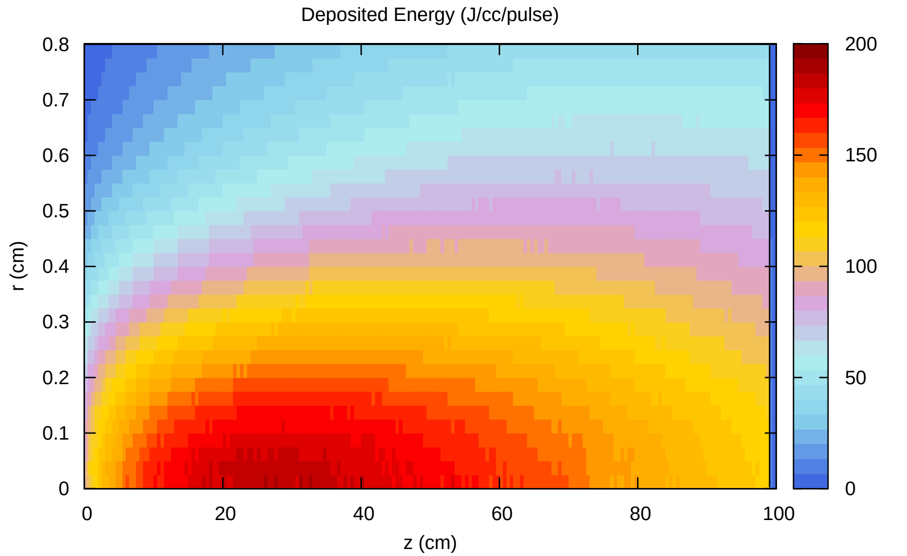
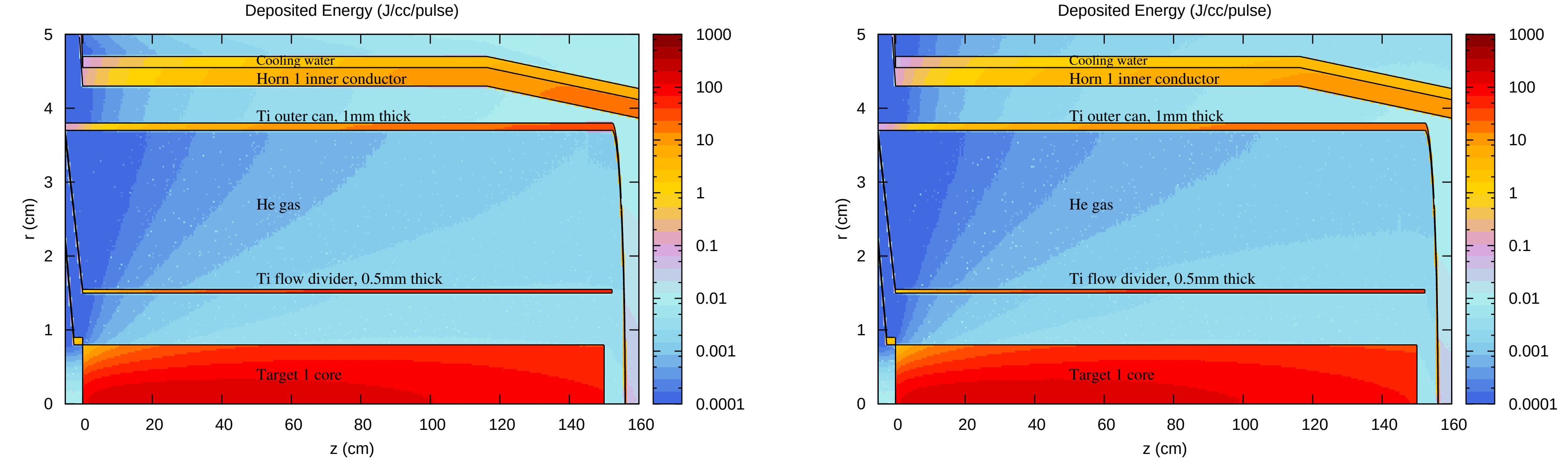


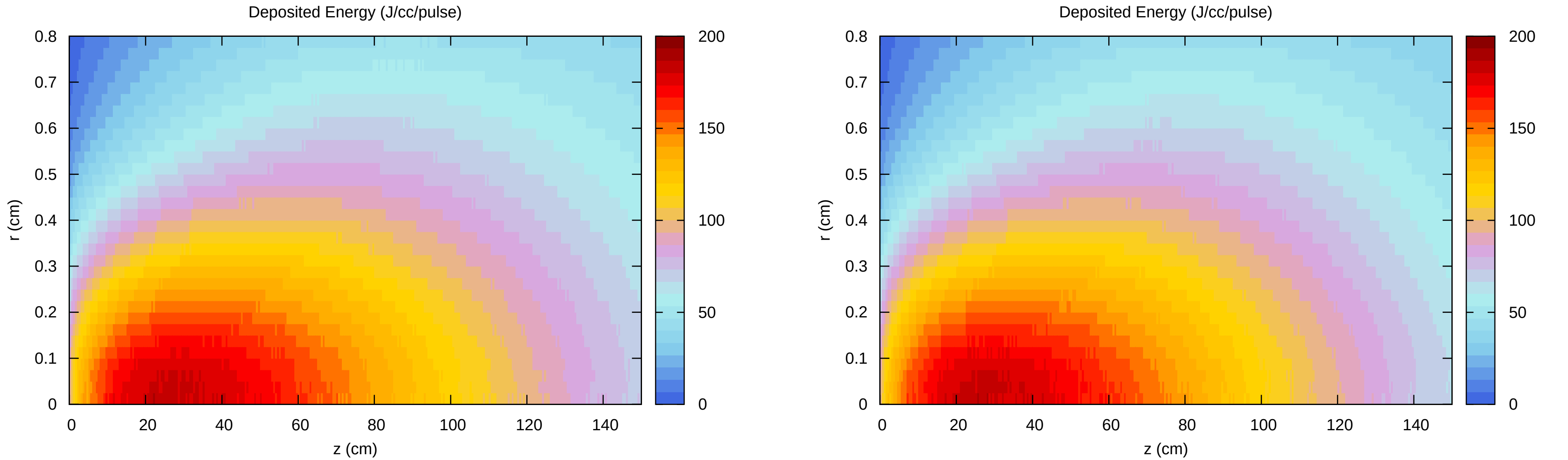


Single 1.5 m Target E densities: J/cc/pulse

B Field

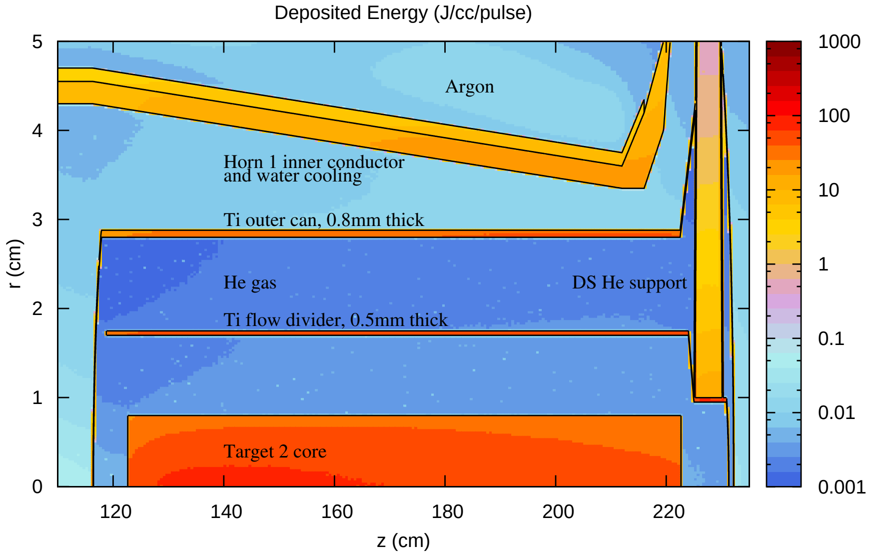
No Field

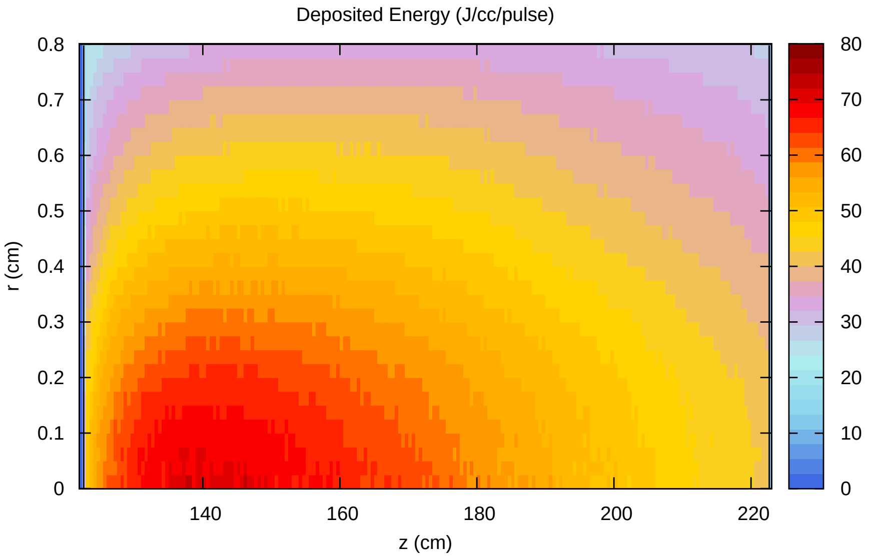




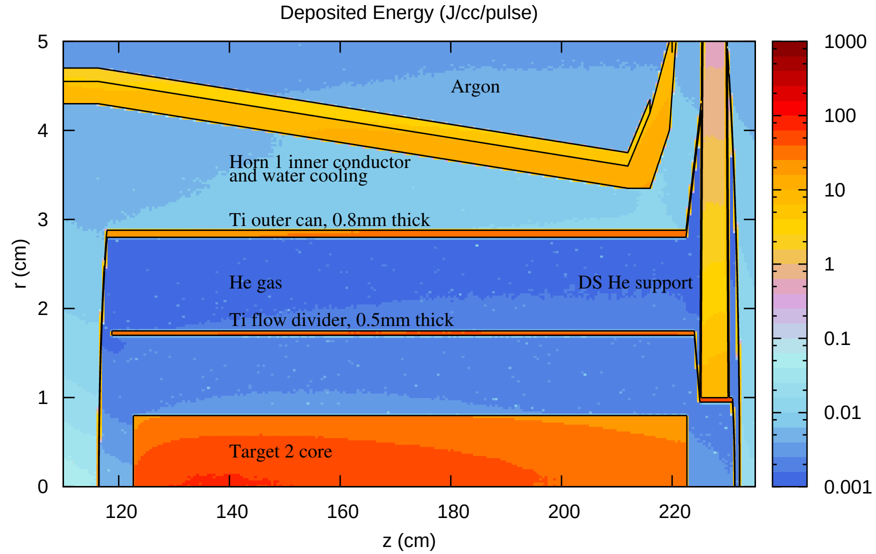
Double Target 2 E densities: J/cc/pulse

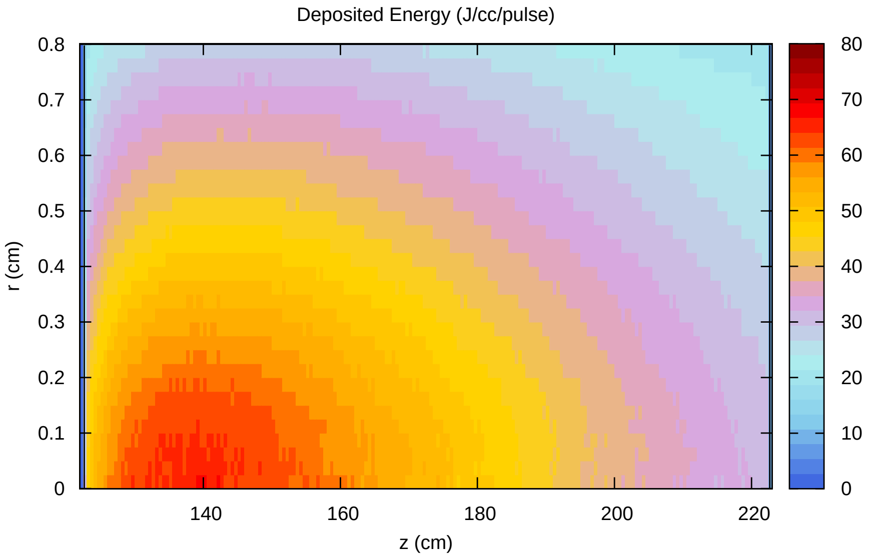
B Field





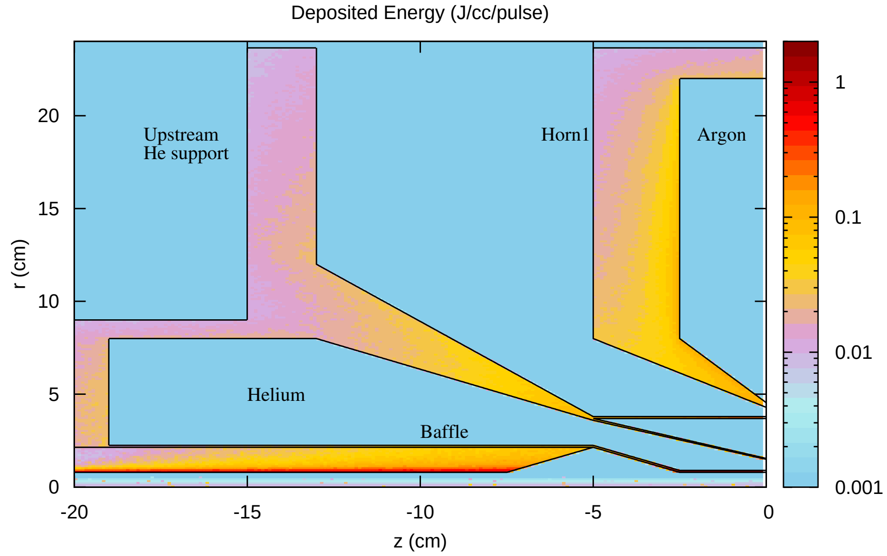
No Field

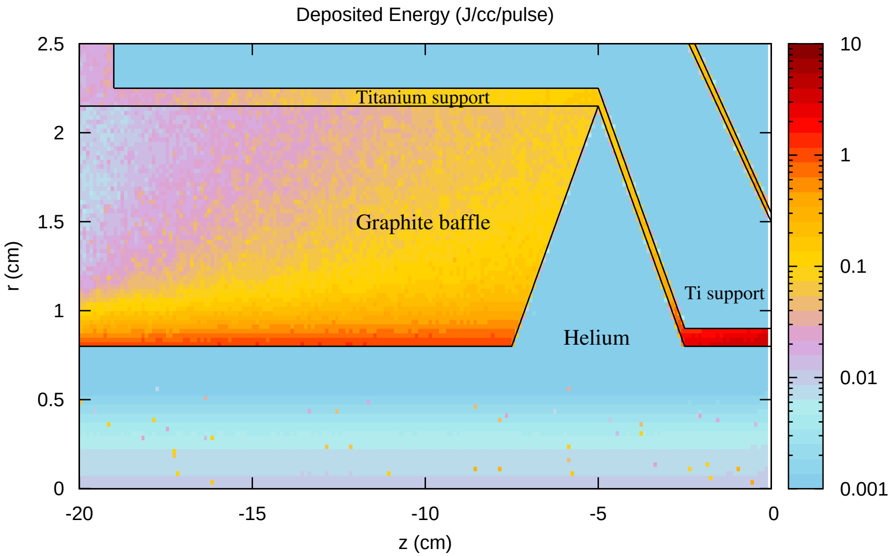




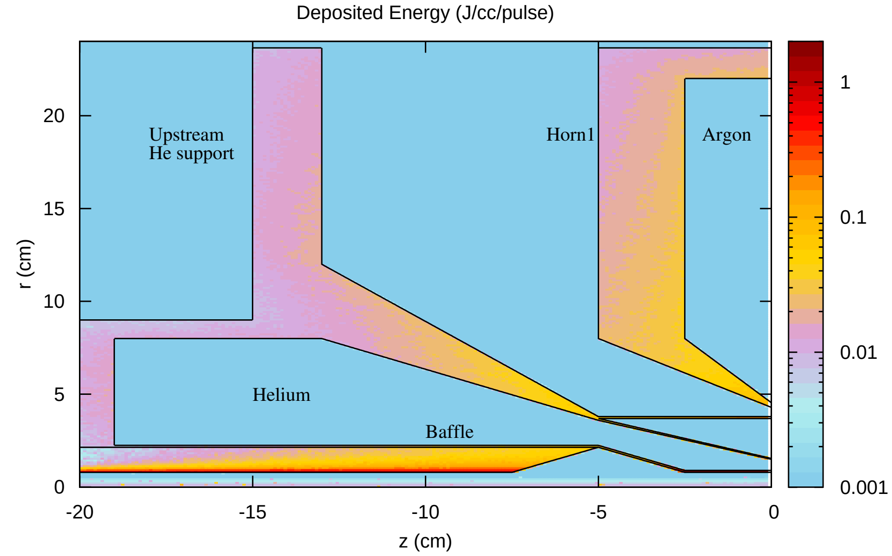
Upstream Baffle & start of Horn1 (2 targets): J/cc/pulse

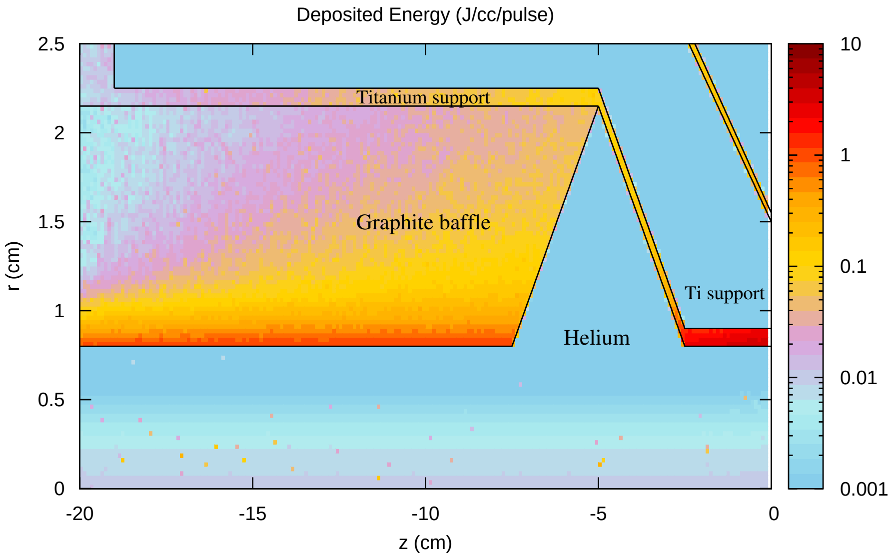
B Field





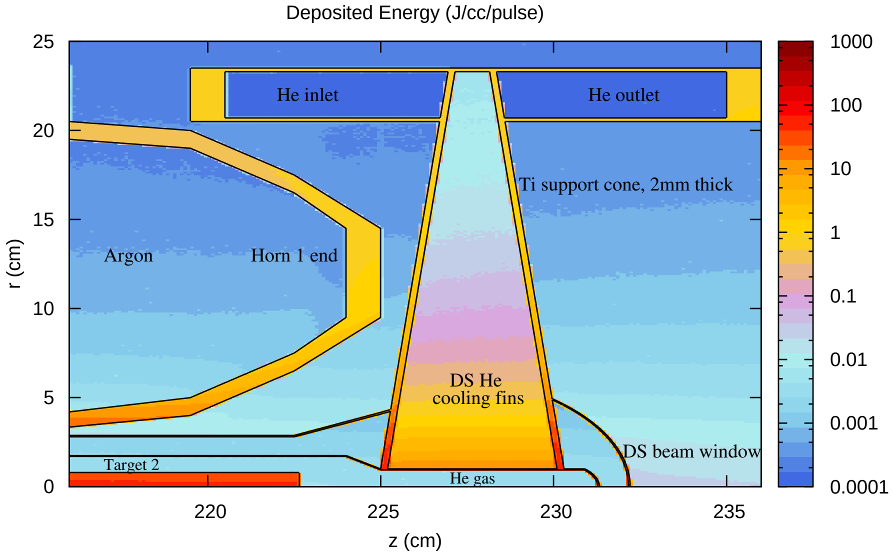
No Field



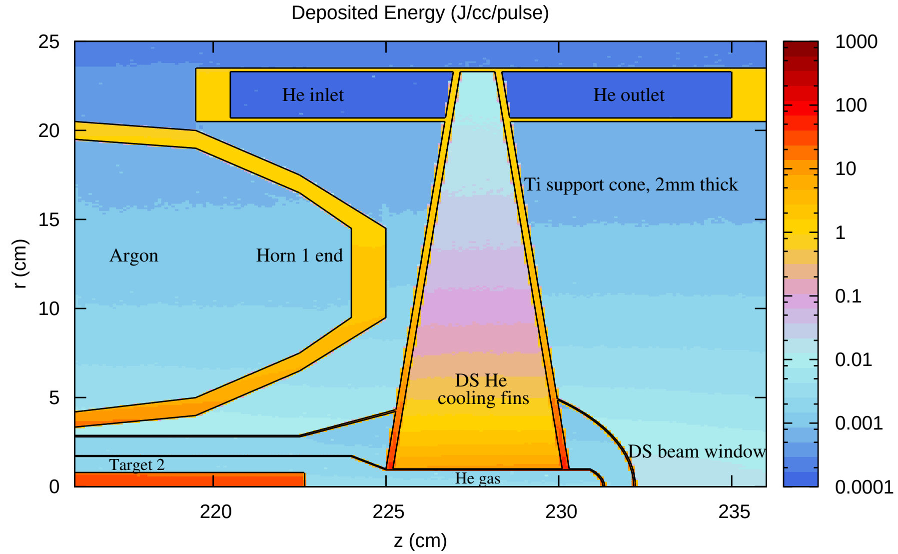


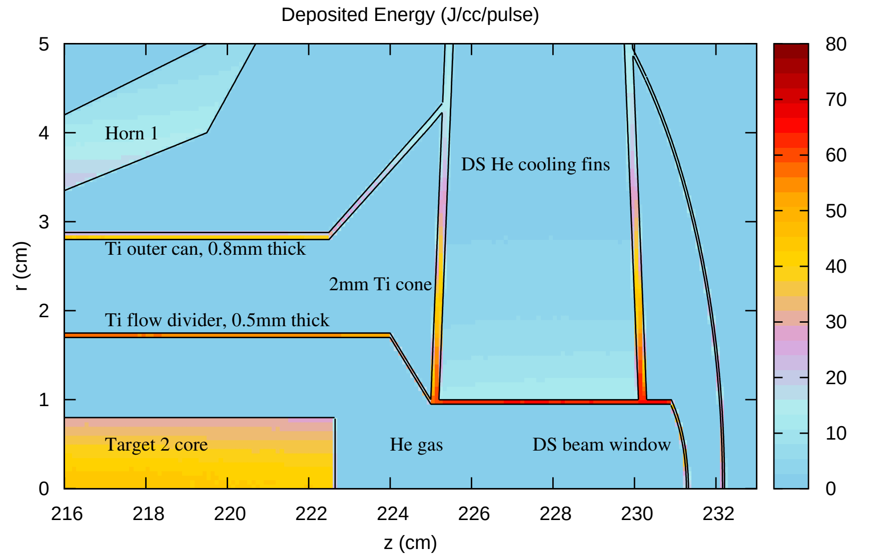
Double targets downstream He cone: J/cc/pulse

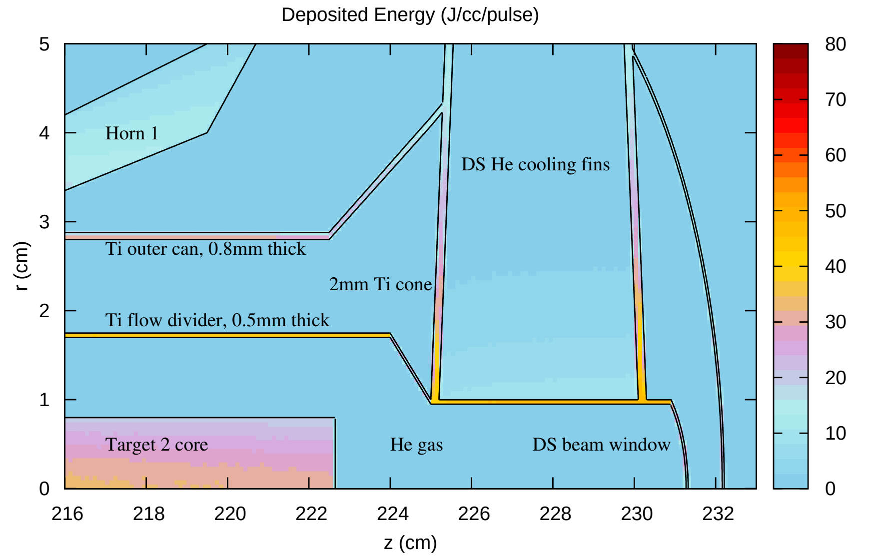
B Field



No Field







Total Regional Deposited Power (kW)

Region	2x1 m Double Target			1.5 m Single Target		
	Field	Neg Field	No Field	Field	Neg Field	No Field
Target 1 graphite core	11.88	11.90	11.79	17.30	17.31	16.91
Target 2 graphite core	7.17	7.35	5.94	–	–	–
Target 1 flow tube	1.30	1.32	1.26	2.57	2.60	2.38
Target 2 flow tube	2.58	2.71	1.96	–	–	–
Target 1 outer container	1.93	2.00	1.71	4.39	4.62	3.60
Target 2 outer container	4.48	4.81	3.38	–	–	–
US graphite baffle	0.01	0.01	0.01	0.01	0.01	0.01
US He cooling support	0.06	0.07	0.05	0.06	0.07	0.05
Horn 1 outer conductor	11.23	10.73	14.23	11.49	10.98	14.70
Horn 1 inner conductor	11.30	11.71	8.28	11.11	11.69	8.08
Horn 1 curved DS end	2.11	2.05	3.05	1.81	1.80	2.43
Horn 1 water cooling	2.70	2.67	1.81	2.71	2.73	1.80
DS He cone support (Ti)	1.70	1.71	2.06	–	–	–
He cone fins 1,2 (horiz)	0.29	0.29	0.26	–	–	–
He cone fins 3,4 (60 deg)	0.29	0.29	0.26	–	–	–
He cone fins 5,6 (120 deg)	0.29	0.29	0.26	–	–	–
Outer DS He flow tubes	1.00	0.96	1.43	–	–	–
DS Ti beam window	0.12	0.12	0.10	–	–	–

Deposited power uncertainties ≈ 1 to 2%; DS = downstream, US = upstream

Single target outer container 1 end bulb = DS beam window

Approx max energy densities (J/cc/pulse)

Region	2x1 m Double Target			1.5 m Single Target		
	Field	Neg Field	No Field	Field	Neg Field	No Field
Target 1 graphite core	188.1	186.4	188.4	187.9	186.7	189.1
Target 2 graphite core	73.6	72.3	67.2	–	–	–
Target 1 flow tube	57.7	58.7	54.6	66.4	69.3	58.3
Target 2 flow tube	64.9	66.4	47.0	–	–	–
Target 1 outer container	34.1	34.7	34.5	30.7	33.1	22.2
Target 2 outer container	43.7	48.2	30.7	–	–	–
US graphite baffle	1.2	1.2	1.1	1.2	1.2	1.1
US He cooling support	0.1	0.1	0.1	0.1	0.1	0.1
Horn 1 outer conductor	0.5	0.4	1.0	0.4	0.4	0.9
Horn 1 inner conductor	20.5	22.5	16.2	15.0	16.7	10.4
Horn 1 curved DS end	19.9	21.7	15.9	14.2	15.8	10.4
Horn 1 water cooling	15.2	15.8	10.1	7.3	7.9	4.3
DS He cone support (Ti)	59.9	62.0	41.4	–	–	–
He cone fins 1,2 (horiz)	68.0	70.0	53.0	–	–	–
He cone fins 3,4 (60 deg)	68.0	70.0	53.0	–	–	–
He cone fins 5,6 (120 deg)	68.0	70.0	53.0	–	–	–
Outer DS He flow tubes	0.9	0.8	1.5	–	–	–
DS Ti beam window	65.0	66.3	47.5	–	–	–

Upper limit for cooling $\sim$ 1000 J/cc/pulse

Summary

- Shown physics performance of the 3 RAL target options
  - 2.2 m DS-supported performance is best
  - 1.5 m cantilever has same performance as 2 m double target
  - $r = 8$ mm target size looks optimal
- Fluka energy deposition for 1.5 m cantilever and 2 m double target
  - Results given to RAL target group for further study
  - No B field increases energy deposition at outer radii
  - Need to also look at DS-supported 2.2 m target
- Important consideration is target reliability
  - Overall performance = physics $\times$ reliability
  - Reliability includes lifetime, remote handling procedures, ...

Horn 1 Magnetic Field (Tesla)