MC/NF TARGET SHIELDING STUDIES.

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Energy deposition from MARS, MARS+MCNP codes.

STANDARD (STUDY II) GEOMETRY.

STANDARD SHIELDING (80%WC+20% H_2O).

4MW proton beam.

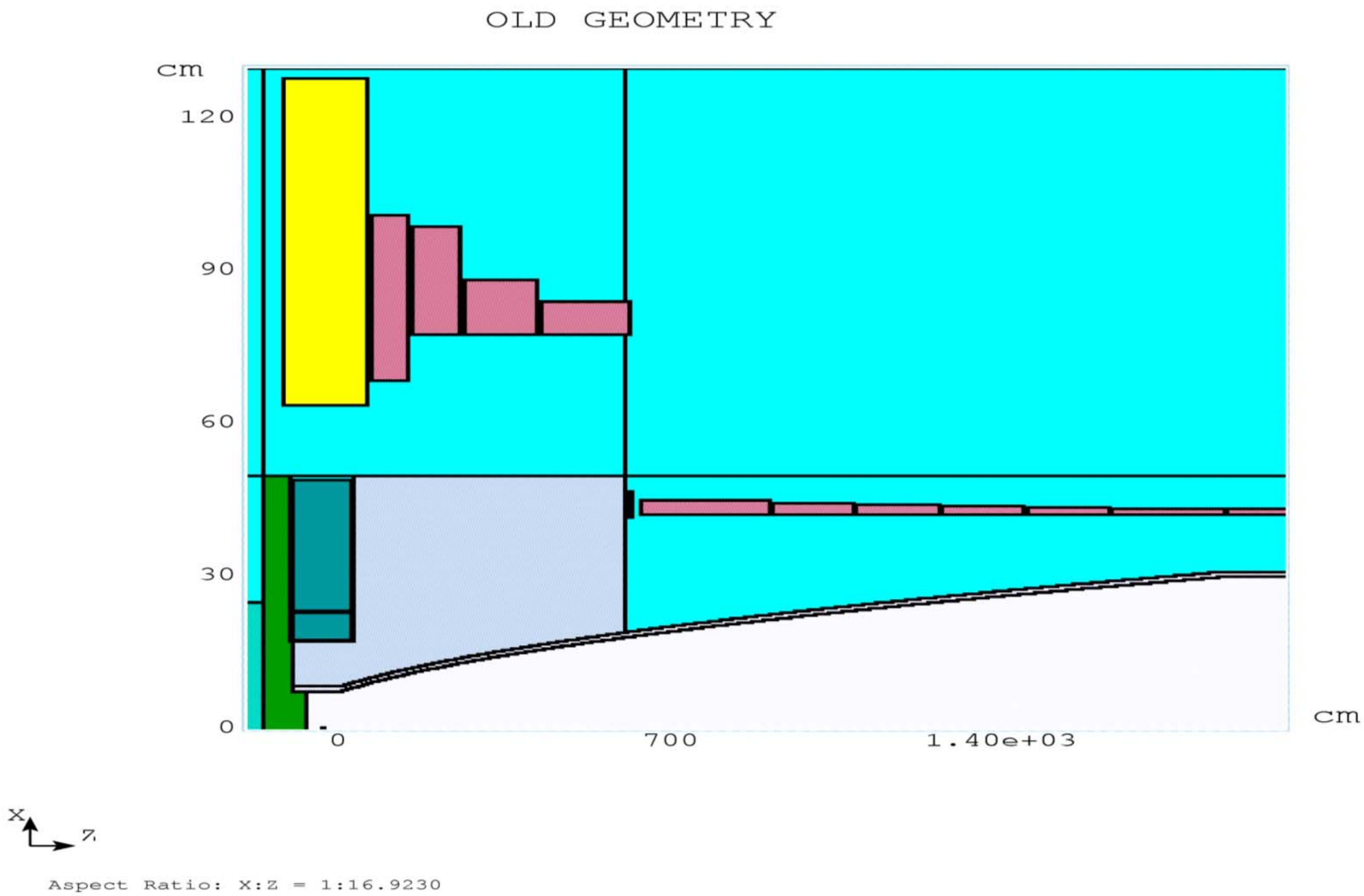
Initially E=24 GeV,

GAUSSIAN PROFILE: $\sigma_x=\sigma_y=0.15$ **cm.**

Now E=8 GeV,

GAUSSIAN PROFILE: $\sigma_x=\sigma_y=0.12$ **cm.**

STANDARD (STUDY II) SOLENOID GEOMETRY, 13 NiTi+Cu+... SC



SC#1 -120<z<57.8 cm R_{in}=63.3 cm R_{out}=127.8 cm
SC#2 67.8<z<140.7 cm R_{in}=68.6 cm R_{out}=101.1 cm
SC#6-13 632.5<z<218.7 cm R_{in}=42.2 cm R_{out}=45.1-->43.4 cm (TOTAL # SC=13)

DEPOSITED ENERGY WITH 24 GeV AND 8 GeV BEAM (MARS, MARS+MCNP).

Table 0.1:

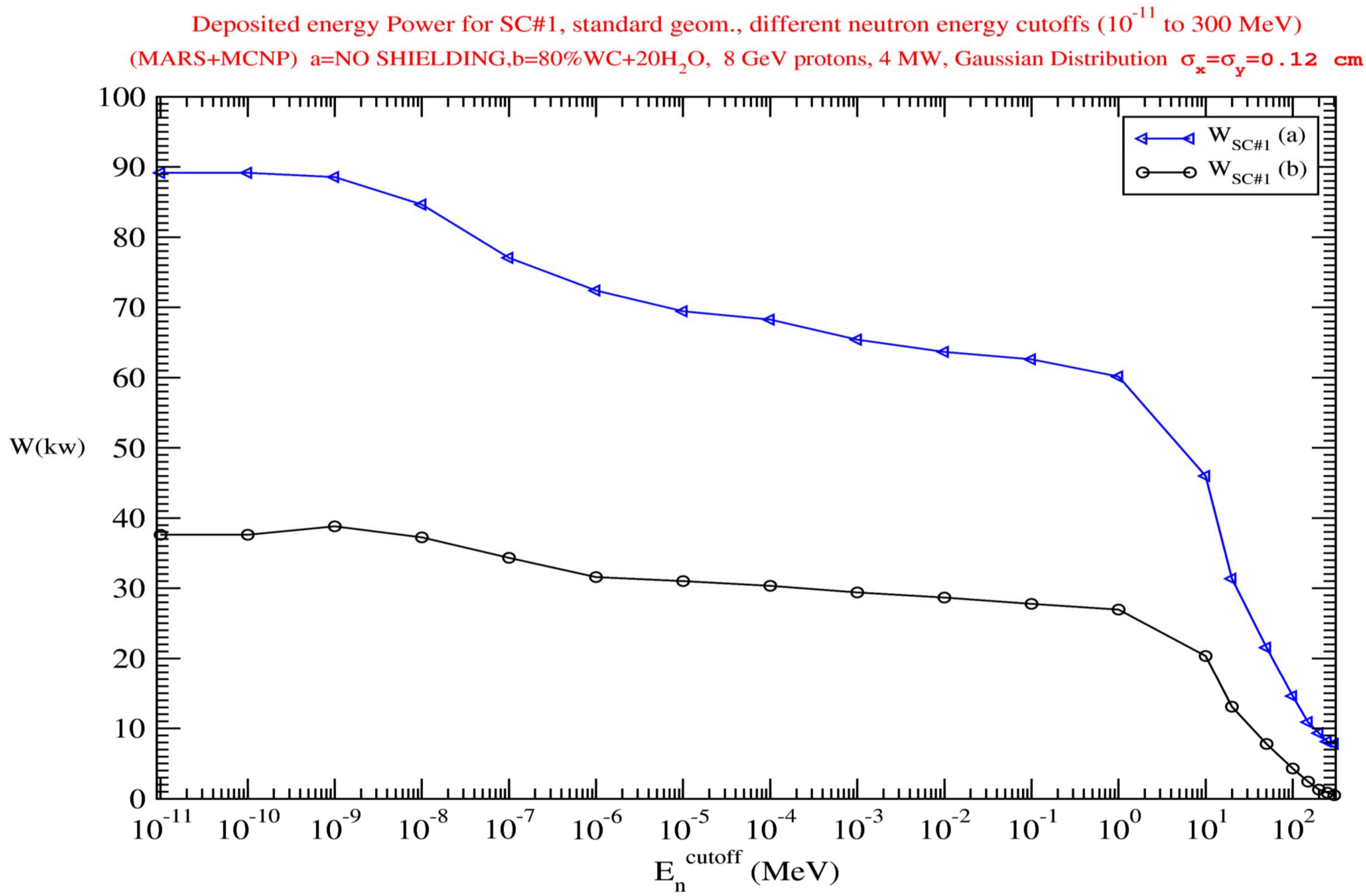
N_p=100,000 , STANDARD GEOMETRY,13 SC COILS
SOLENOID MATERIALS: SC#1-13=SCON (NiTi+Cu+..)
E_p=24 GeV, 4 MW BEAM, Gaussian Distr., $\sigma_x=\sigma_y$=0.15 cm
a= MARS $E_n \geq$0.1 MeV (DEFAULT)
b= MARS+MCNP $E_n \geq 10^{-11}$ MeV
E_p=8 GeV, 4 MW BEAM, Gaussian Distr., $\sigma_x=\sigma_y$=0.12 cm
c= MARS $E_n \geq$0.1 MeV (DEFAULT)
d= MARS+MCNP $E_n \geq 10^{-11}$ MeV

Table 0.2: POWER OF DEPOSITED ENERGY IN kW, DW/W %=$((W_x\text{-}W_a)/W_a)$ x100 where x=b,c,d.

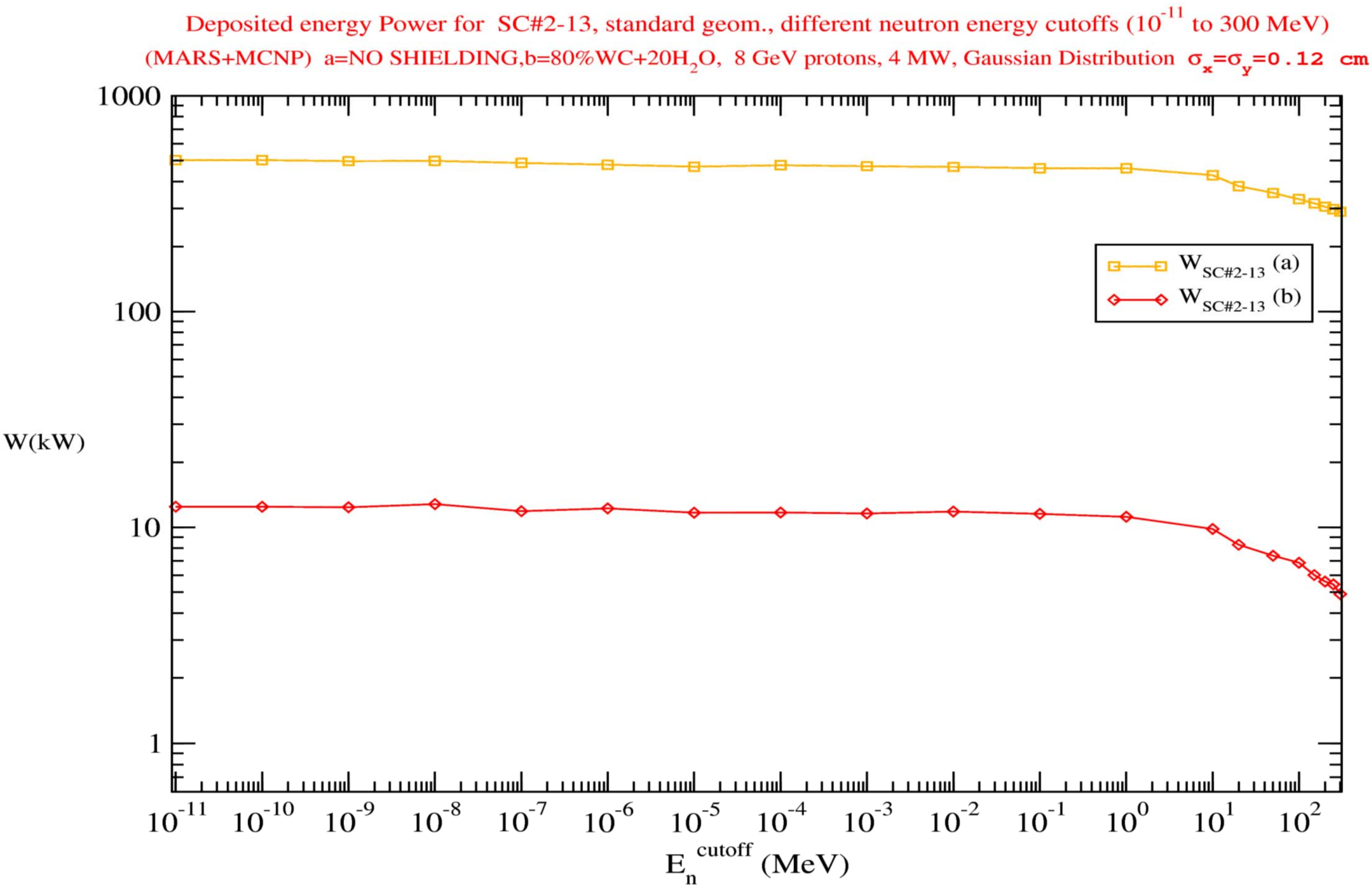
		SC#1	%	SC#2-13	%	Total	%
24 GeV	a	14.28	–	14.90	–	29.18	–
	b	22.06	+54.48	16.30	+9.40	38.36	+31.50
8 GeV	c	24.97	+74.86	11.84	-20.54	36.81	+26.15
	d	37.62	+163.45	12.46	-16.38	50.08	+71.62

From 24 GeV to 8 GeV, and from a more detail treatment of low energy neutrons:
from ~14 kW to ~38 kW power in SC1 and from ~29 kW to 50 kW in total power.

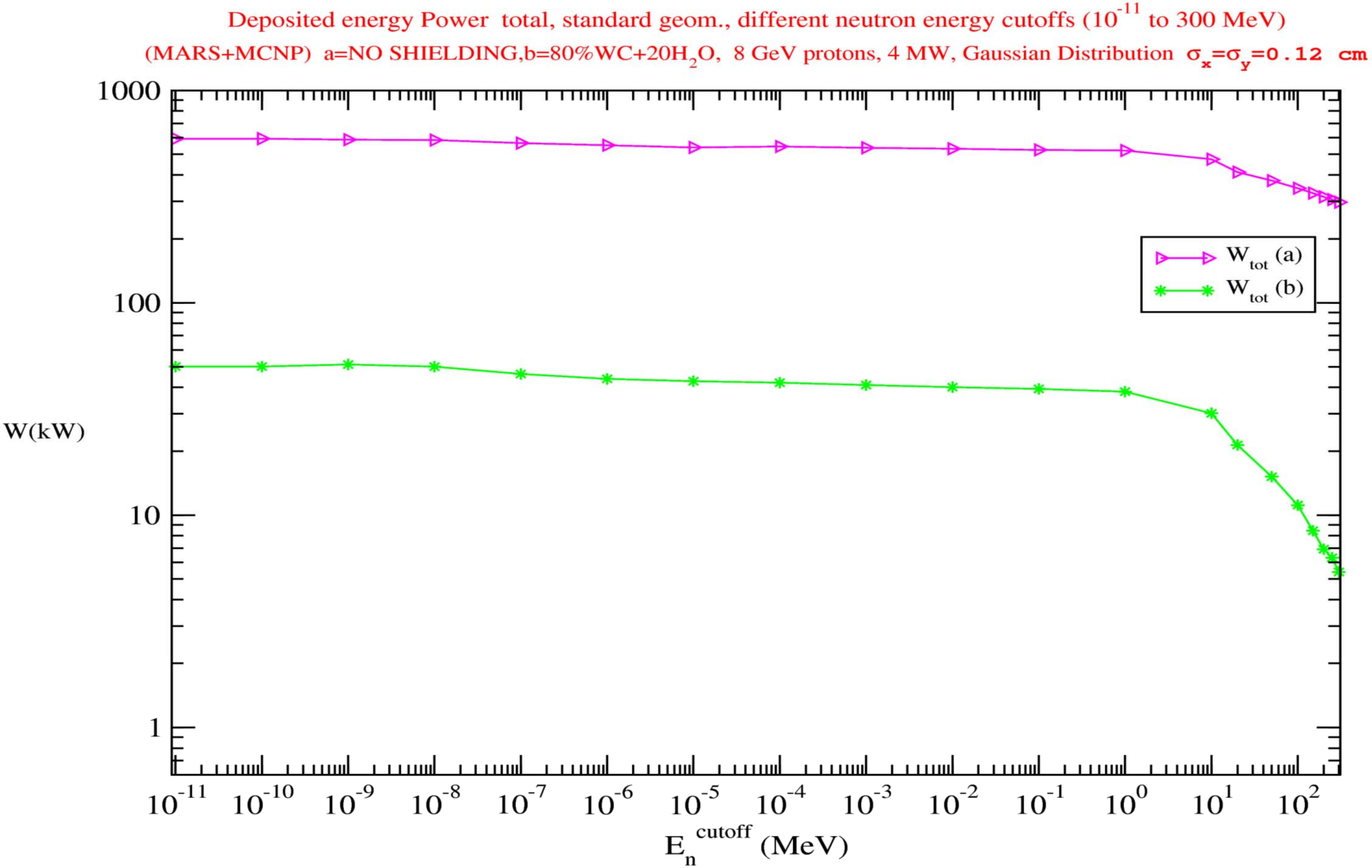
OFF/ON SHIELDING, DIFFERENT NEUTRON ENERGY CUTOFFS.



OFF/ON SHIELDING, DIFFERENT NEUTRON ENERGY CUTOFFS.

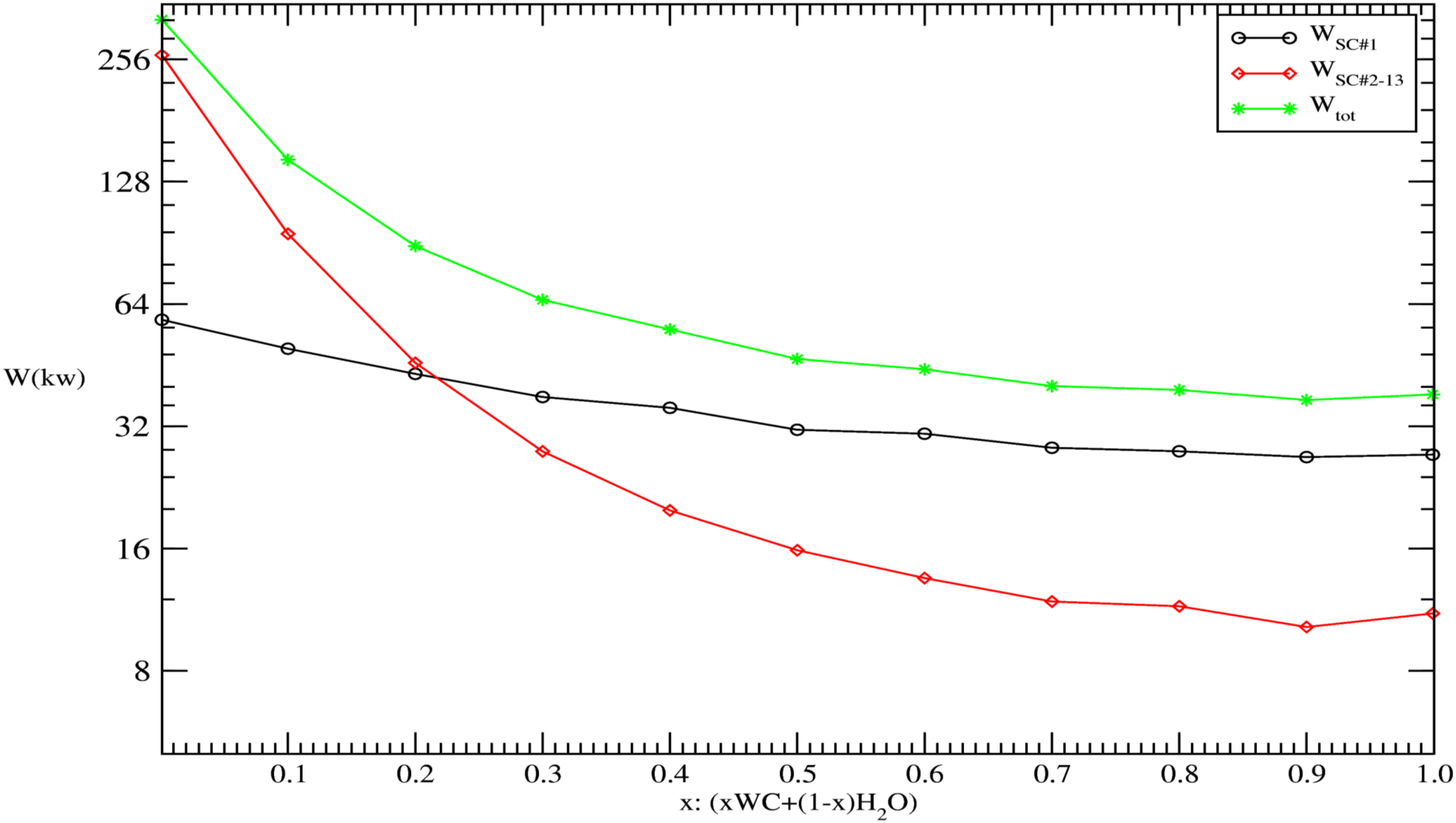


OFF/ON SHIELDING, DIFFERENT NEUTRON ENERGY CUTOFFS.

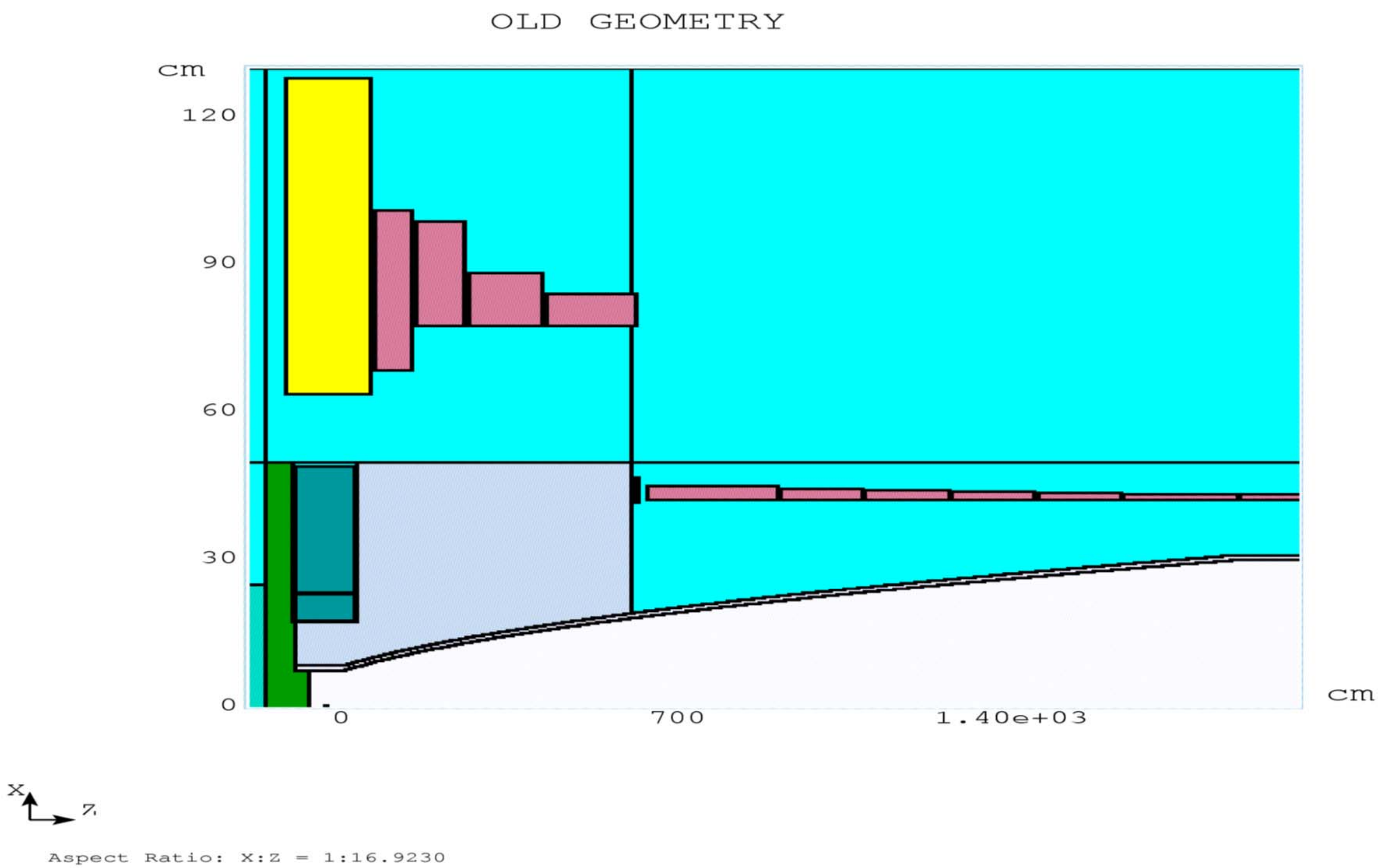


High energy neutrons are a problem even with shielding material.

Deposited energy Power for SC#1, SC#2-13 and total, standard geom., different shielding compositions.
(MARS+MCNP), x WC+(1-x) H_2O shielding, 8 GeV protons, 4 MW, Gaussian Distribution $\sigma_x=\sigma_y=0.12$ cm



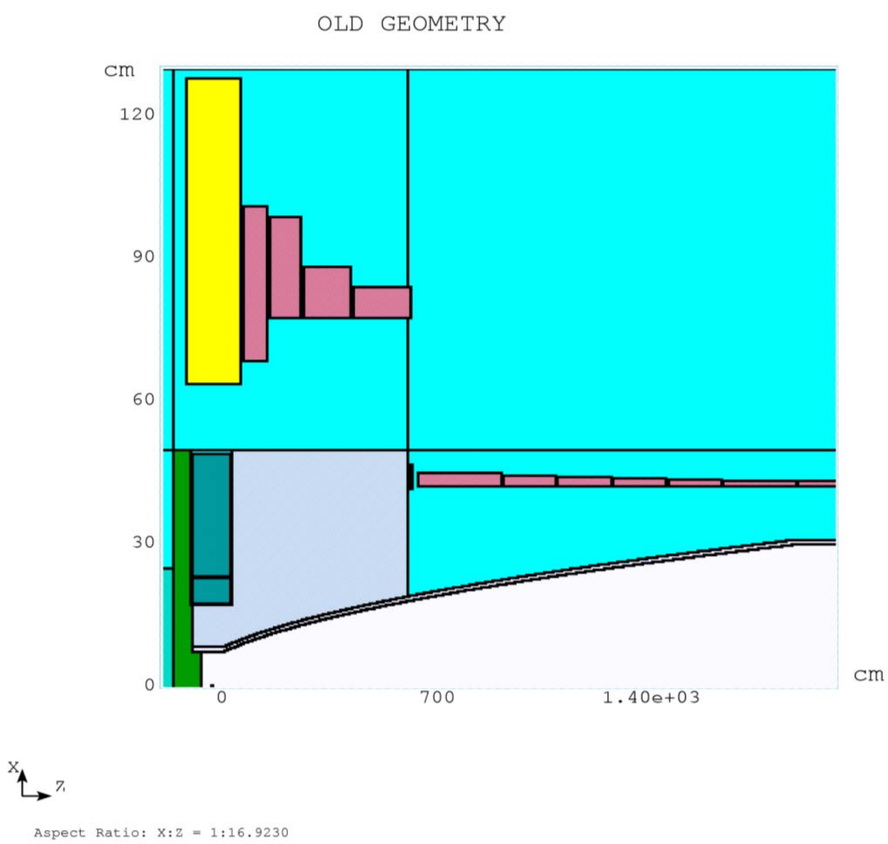
Within shielding thickness restrictions, best effect is achieved by maximizing content in high Z material. For WC beads and H_2O, from random sphere packing analysis x~0.63.

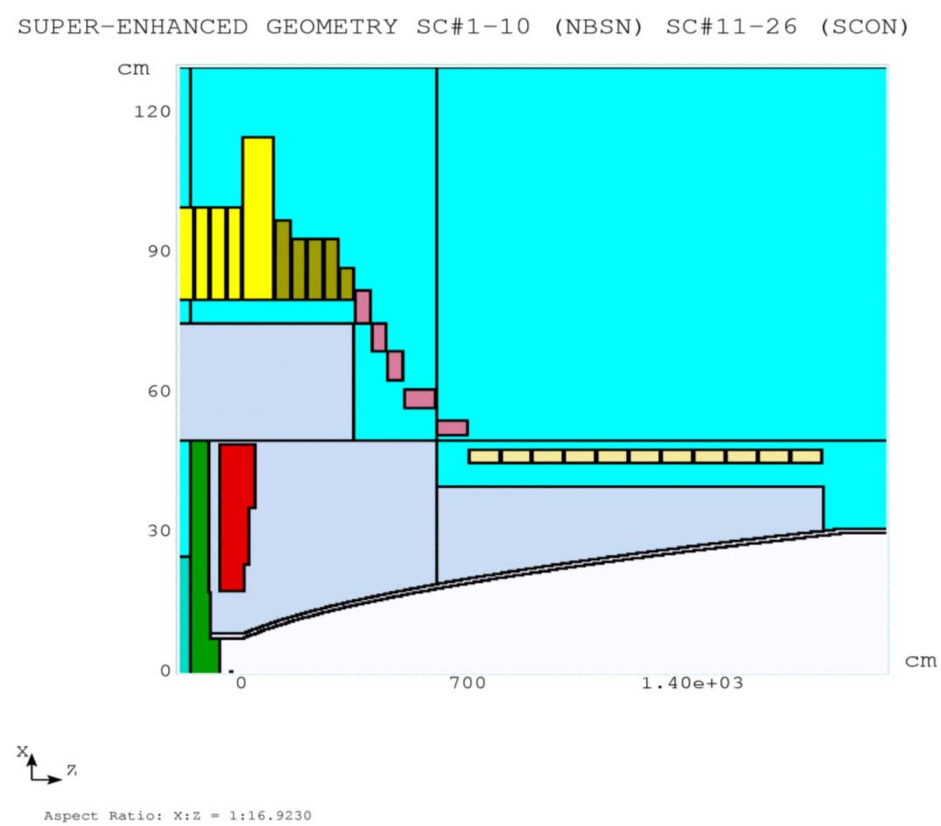


REPLACING RESISTIVE MAGNET WITH SHIELDING MATERIAL (80%WC+20% H_2O) REDUCES DEPOSITED ENERGY IN SC1 FROM ~28 kW TO ~10 kW (A FACTOR OF ~3).

STANDARD (OLD) VS. IDS80 (NEW) SOLENOID GEOMETRY

(IDS80 WITH 60%WC+40% H_2O SHIELDING)





From 63.3 cm (SC#1) to 80 cm (SC#1-10) inner radius for solenoids around target area: more space for shielding.

MARS+MCNP (DEFAULT NEUTRON ENERGY CUTOFF 0.1 MeV)

Study II, standard case, first solenoid (NiTi+Cu+...) and with 80%WC+20% H_2O shielding-------->

Enhanced shielding case (IDS80), first group of solenoids (SC#1-5) (Ni +...) and with 60%WC+40% H_2O shielding:

28 kW --------> 2 kW

CONCLUSIONS.

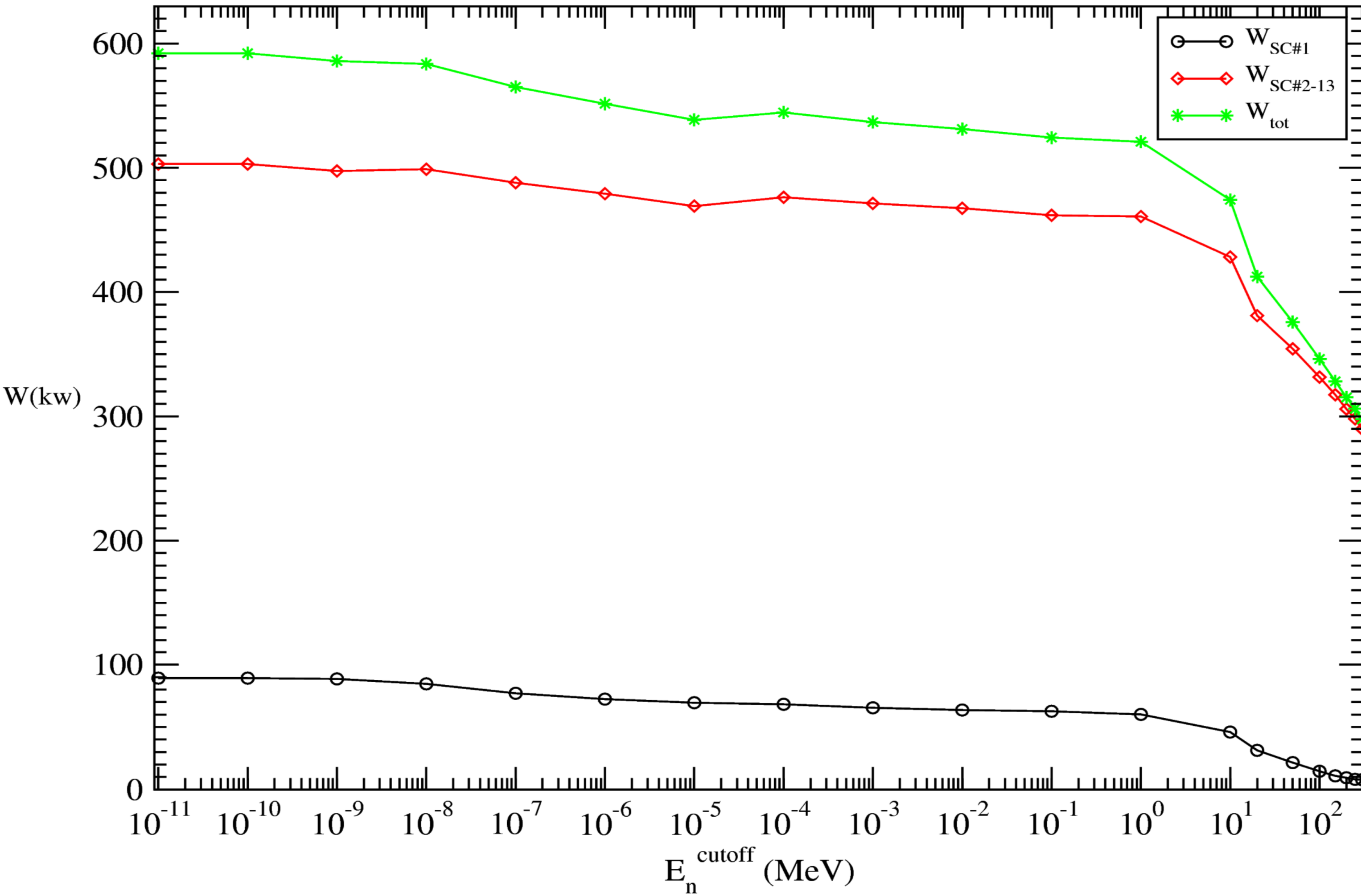
- Low energy neutrons require detail study provided by MCNP.
- High energy neutrons are a problem even with the shielding material.
- Resistive coil significantly reduces the ability for shielding SC1.
- High Z material required and as much as possible.
- Additional space for shielding material necessary for solenoids especially around target area.

BACKUP SLIDES

NO SHIELDING, DIFFERENT NEUTRON ENERGY CUTOFFS.

	$E_n \geq E_i$(MeV)	SC#1	%	SC#2-13	%	Total	%
1	$1\ 10^{-11}$	89.15	–	503.00	–	592.15	–
2	$1\ 10^{-10}$	89.15	0	503.00	0	592.15	0
3	$1\ 10^{-9}$	88.55	-0.67	497.40	-1.11	585.90	-1.06
4	$1\ 10^{-8}$	84.64	-5.06	498.90	-0.82	583.55	-1.45
5	$1\ 10^{-7}$	77.05	-13.57	488.00	-2.98	565.05	-4.58
6	$1\ 10^{-6}$	72.40	-18.79	479.15	-4.74	551.55	-6.85
7	$1\ 10^{-5}$	69.45	-22.10	469.15	-6.73	538.60	-9.04
8	$1\ 10^{-4}$	68.25	-23.44	476.25	-5.32	544.50	-8.05
9	$1\ 10^{-3}$	65.40	-26.64	471.35	-6.29	536.75	-9.36
10	$1\ 10^{-2}$	63.65	-28.60	467.50	-7.06	531.15	-10.30
11*	$1\ 10^{-1}$	62.60	-29.78	461.75	-8.20	524.35	-11.45
12	$1\ 10^{0}$	60.15	-32.53	460.80	-8.39	520.95	-12.02
13	$1\ 10^{+1}$	45.98	-48.42	428.25	-14.86	474.23	-19.91
14*	$2\ 10^{+1}$	31.35	-64.83	381.10	-24.23	412.45	-30.35
15	$5\ 10^{+1}$	21.54	-75.84	354.30	-29.56	375.84	-36.53
16	$10\ 10^{+1}$	14.60	-83.62	331.60	-34.08	346.20	-41.54
17	$15\ 10^{+1}$	10.89	-87.78	317.30	-36.92	328.19	-44.58
18	$20\ 10^{+1}$	9.33	-89.53	305.90	-39.18	315.23	-46.77
19	$25\ 10^{+1}$	8.13	-90.88	298.00	-40.76	306.13	-48.30
20	$30\ 10^{+1}$	7.81	-91.24	289.80	-42.39	297.61	-49.74

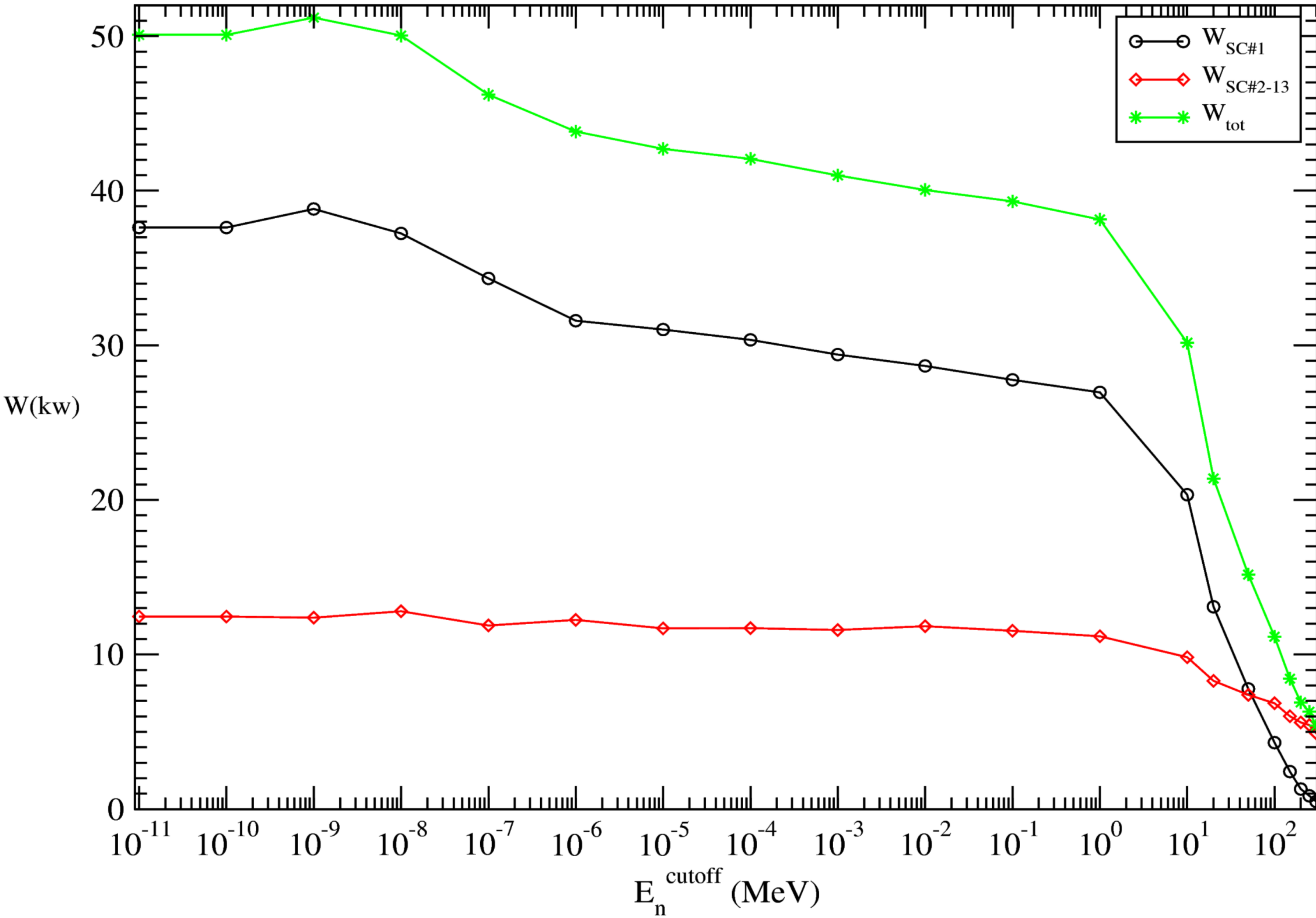
Deposited energy Power for SC#1, SC#2-13 and total, standard geom., different neutron energy cutoffs (10^{-11} to 300 MeV)
(MARS+MCNP) NO SHIELDING, 8 GeV protons, 4 MW, Gaussian Distribution $\sigma_x=\sigma_y=0.12$ cm

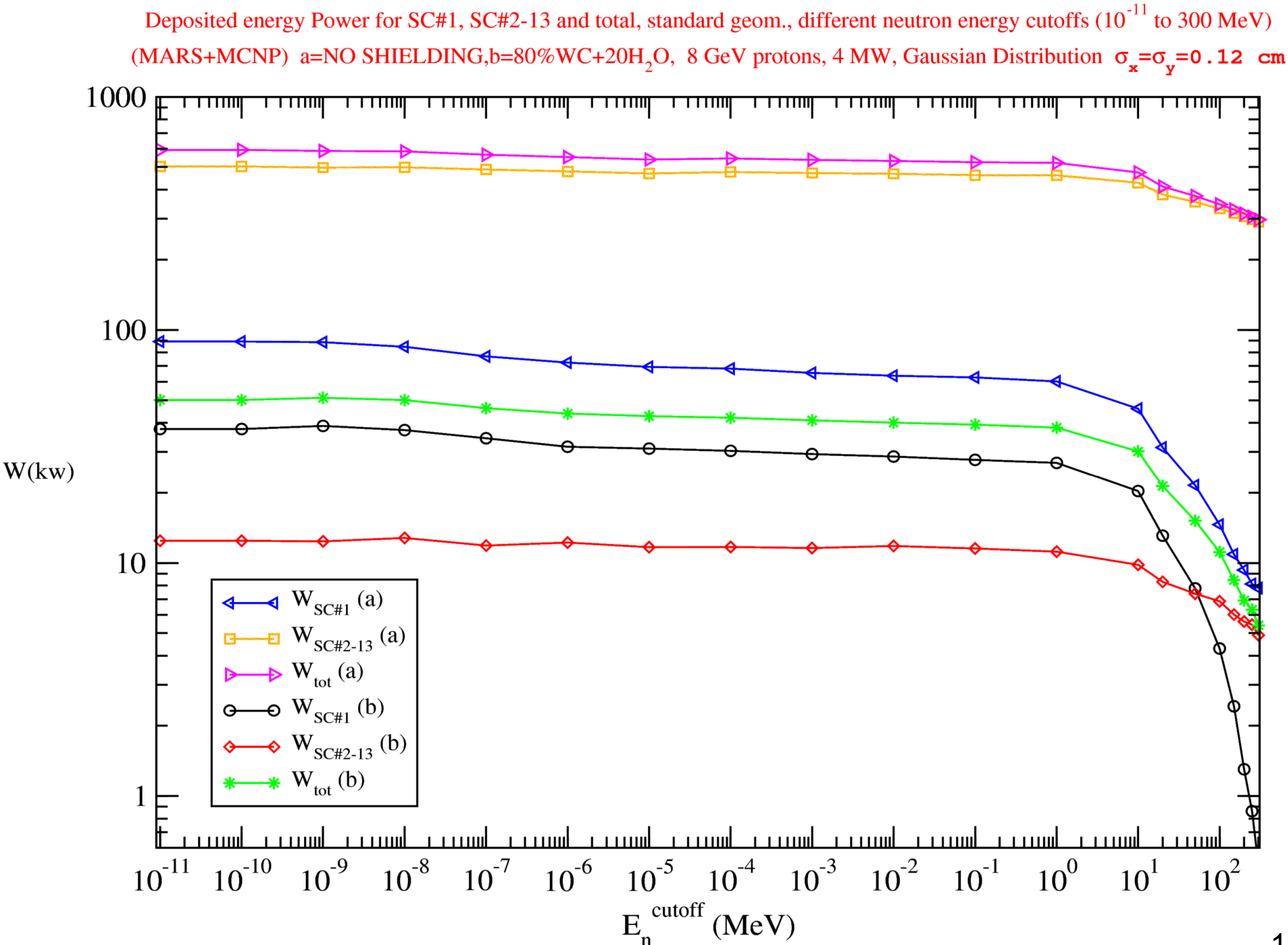


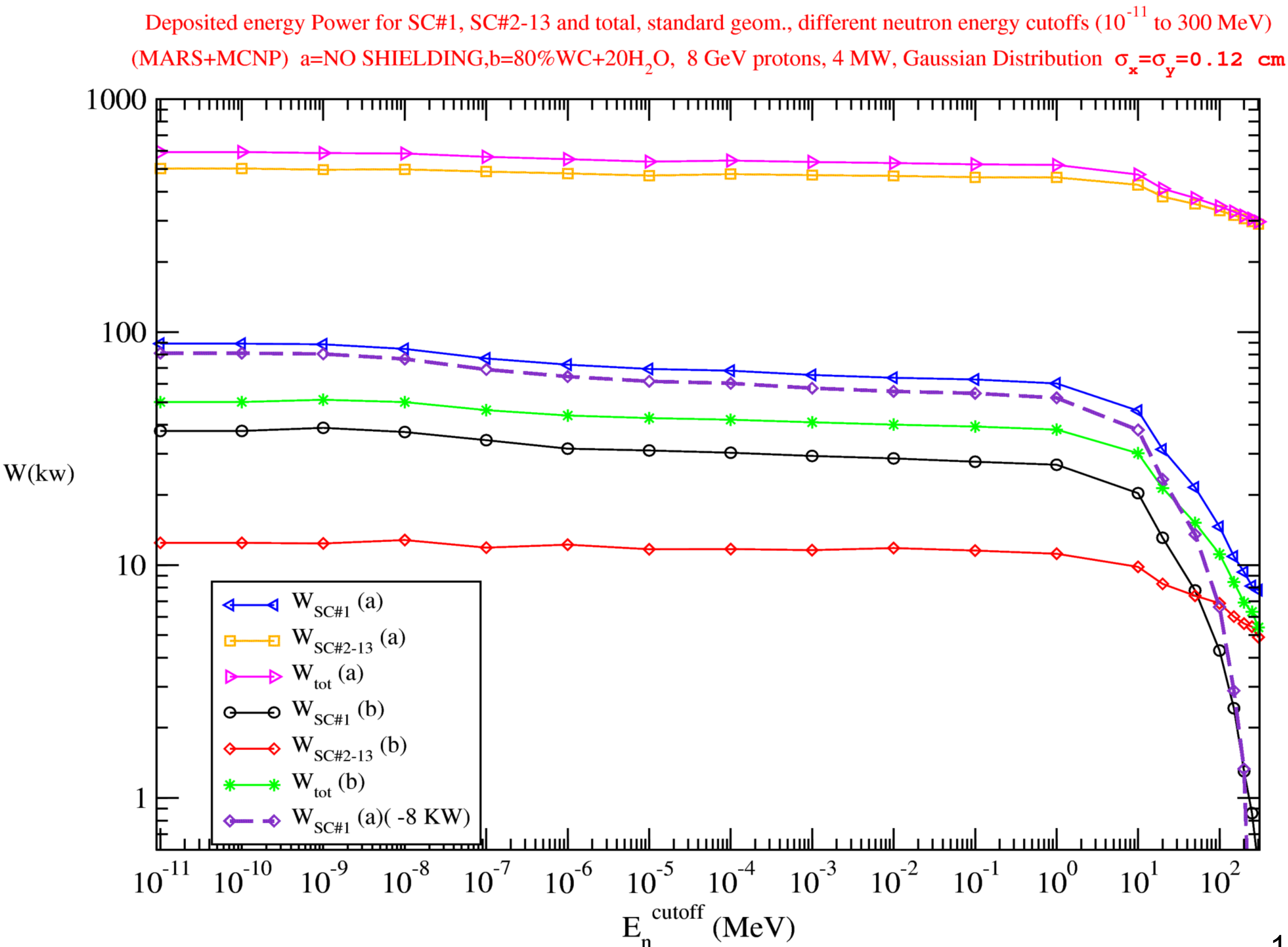
80%WC+20%H_2O SHIELDING,
DIFFERENT NEUTRON ENERGY CUTOFFS.

	$E_n \geq E_i$(MeV)	SC#1	%	SC#2-13	%	Total	%
1	$1\ 10^{-11}$	37.62	–	12.46	–	50.08	–
2	$1\ 10^{-10}$	37.62	0	12.46	0	50.08	0
3	$1\ 10^{-9}$	38.82	+3.19	12.38	-0.64	51.20	+2.23
4	$1\ 10^{-8}$	37.24	-1.01	12.80	+2.73	50.04	-0.08
5	$1\ 10^{-7}$	34.33	-8.75	11.88	-4.65	46.21	-7.72
6	$1\ 10^{-6}$	31.59	-16.03	12.24	-1.77	43.83	-12.48
7	$1\ 10^{-5}$	31.02	-17.54	11.69	-6.17	42.71	-14.71
8	$1\ 10^{-4}$	30.35	-19.32	11.71	-6.02	42.06	-16.01
9	$1\ 10^{-3}$	29.40	-21.85	11.59	-6.98	40.99	-18.15
10	$1\ 10^{-2}$	28.67	-23.79	11.83	-5.06	40.05	-20.03
11*	$1\ 10^{-1}$	27.77	-26.18	11.54	-7.38	39.31	-21.51
12	$1\ 10^{0}$	26.96	-28.34	11.18	-10.27	38.14	-23.84
13	$1\ 10^{+1}$	20.34	-45.93	9.83	-21.11	30.17	-39.76
14*	$2\ 10^{+1}$	13.09	-65.20	8.30	-33.39	21.39	-57.29
15	$5\ 10^{+1}$	7.78	-79.31	7.39	-40.69	15.17	-69.71
16	$10\ 10^{+1}$	4.30	-88.57	6.85	-45.02	11.15	-77.74
17	$15\ 10^{+1}$	2.43	-93.54	6.01	-51.77	8.44	-83.15
18	$20\ 10^{+1}$	1.30	-96.54	5.61	-54.98	6.91	-86.20
19	$25\ 10^{+1}$	0.86	-97.71	5.44	-46.34	6.30	-87.42
20	$30\ 10^{+1}$	0.50	-98.67	4.90	-60.67	5.40	-89.22

Deposited energy Power for SC#1, SC#2-13 and total, standard geom., different neutron energy cutoffs (10^{-11} to 300 MeV)
(MARS+MCNP) 80% WC+20% H_2O shielding, 8 GeV protons, 4 MW, Gaussian Distribution $\sigma_x=\sigma_y=0.12$ cm




Deposited energy Power for SC#1, SC#2-13 and total, standard geom., different neutron energy cutoffs (10^{-11} to 300 MeV)
(MARS+MCNP) a=NO SHIELDING,b=80%WC+20H_2O, 8 GeV protons, 4 MW, Gaussian Distribution $\sigma_x=\sigma_y=0.12$ cm
W(kw)
E_n^{cutoff} (MeV)
$W_{SC\#1}$ (a)
$W_{SC\#2-13}$ (a)
W_{tot} (a)
$W_{SC\#1}$ (b)
$W_{SC\#2-13}$ (b)
W_{tot} (b)


Deposited energy Power for SC#1, SC#2-13 and total, standard geom., different neutron energy cutoffs (10^{-11} to 300 MeV)
(MARS+MCNP) a=NO SHIELDING,b=80%WC+20H_2O, 8 GeV protons, 4 MW, Gaussian Distribution $\sigma_x=\sigma_y$=0.12 cm
W(kw)
E_n^{cutoff} (MeV)
$W_{SC\#1}$ (a)
$W_{SC\#2-13}$ (a)
W_{tot} (a)
$W_{SC\#1}$ (b)
$W_{SC\#2-13}$ (b)
W_{tot} (b)
$W_{SC\#1}$ (a)(-8 KW)

ENERGY DEPOSITED FOR DIFFERENT COMPOSITIONS OF THE SHIELDING (x WC+(1-x) H_2O)

	SHIELDING	ρ(g/cc)	G1	%	G2	%	Total	%
1	0.1% WC+99.9% H_2O	1.0148	58.50	–	262.30	–	320.80	–
2	10% WC+90% H_2O	2.48	49.67		95.20		144.87	
3	20% WC+80% H_2O	3.96	43.06		45.84		88.90	
4	30% WC+70% H_2O	5.44	37.78		27.75		65.53	
5	40% WC+60% H_2O	6.92	35.53		19.87		55.40	
6	50% WC+50% H_2O	8.4	31.38		15.85		46.85	
7	60% WC+40% H_2O	9.88	30.67		13.54		44.21	
8	70% WC+30% H_2O	11.36	28.34		11.85		40.19	
9	80% WC+20% H_2O	12.84	27.77		11.54		39.31	
10	90% WC+10% H_2O	14.32	26.88		10.26		37.14	
11	99.9% WC+0.1% H_2O	15.79	27.25		11.08		38.33	
1C	0.1% WC+99.9% H_2O	1.0148	31.90	–	221.70	–	253.60	–
2C	10% WC+90% H_2O	2.48	25.35		71.10		96.45	
3C	20% WC+80% H_2O	3.96	21.48		31.46		52.94	
4C	30% WC+70% H_2O	5.44	18.77		18.80		37.57	
5C	40% WC+60% H_2O	6.92	17.02		13.79		30.80	
6C	50% WC+50% H_2O	8.4	15.21		10.62		25.83	
7C	60% WC+40% H_2O	9.88	14.10		9.58		23.68	
8C	70% WC+30% H_2O	11.36	13.26		8.98		22.24	
9C	80% WC+20% H_2O	12.84	13.09		8.30		21.39	
10C	90% WC+10% H_2O	14.32	12.45		8.14		20.58	
11C	99.9% WC+0.1% H_2O	15.79	11.95		7.94		19.89	

DEPOSITED ENERGY BY REMOVING THE MAGNETIC FIELD, USING TWO WAYS: (4=F, B≠0) (4=T, B=0)

Table 0.4: (10/23/2010)

YES/NO MAGNETIC FIELD (SET 4=F OR B=(0,0)) (****)
N_p=100,000 , STANDARD GEOMETRY,13 SC COILS, 2 SC groups:G1=1, G2=2-13
STANDARD SHIELDING WITH: 80% WC+20% H_2O, MARS+MCNP
SOLENOID MATERIALS: SC#1-13=SCON (NiTi+Cu+..)
E_p=8 GeV, 4 MW BEAM, $\sigma_x=\sigma_y$=0.12 cm Gaussian distr.
a= $E_n \geq$0.1 MeV (DEFAULT)
b= $E_n \geq$20 MeV
c=B FIELD OFF(SET PARAM. 4=F IN THE .INP FILE), $E_n \geq$0.1 MeV (DEFAULT)
d=B FIELD OFF(SET PARAM. 4=F IN THE .INP FILE), $E_n \geq$20 MeV
e=B FIELD OFF(SET B=0, 4=T IN THE .INP FILE), $E_n \geq$0.1 MeV (DEFAULT)
f=B FIELD OFF(SET B=0, 4=T IN THE .INP FILE), $E_n \geq$ 20 MeV

Table 0.5: POWER OF DEPOSITED ENERGY IN KW, DW/W %=((W_x-W_a)/W_a) x100 where x=b,c,e, in d and f are the percentage differences with c and e correspondingly (10/23/2010)

	G1	%	G2	%	Total	%
a	27.77	–	11.54	–	39.31	–
b	13.09	-52.86	8.30	-28.08	21.39	-45.59
c	23.27	-16.20	12.63	+9.45	35.90	-8.67
d	11.06	-52.47	8.88	-29.69	19.94	-44.46
e	22.03	-20.67	12.42	+7.63	34.45	-12.36
f	10.87	-50.66	8.61	-30.68	19.48	-43.45

DEPOSITED ENERGY WHEN RESISITIVE COIL IS REPLACED BY SHIELDING MATERIAL.

Table 0.10: (10/18/2010)

REPLACING RC WITH 80% WC+20% H_2O (****)
N_p=100,000 , STANDARD GEOMETRY,13 SC COILS, 2 SC groups:G1=1, G2=2-13
STANDARD SHIELDING WITH: 80% WC+20% H_2O, MARS+MCNP
SOLENOID MATERIALS: SC#1-13=SCON (NiTi+Cu+..)
E_p=8 GeV, 4 MW BEAM, σ_x=σ_y=0.12 cm Gaussian distr.
a= E_n $\geq$0.1 MeV (DEFAULT)
b= E_n $\geq$20 MeV
c=REPLACING RC WITH 80% WC+20% H_2O, E_n $\geq$0.1 MeV (DEFAULT)
d=REPLACING RC WITH 80% WC+20% H_2O, E_n $\geq$20 MeV

Table 0.11: POWER OF DEPOSITED ENERGY IN KW, DW/W %=((W_x-W_a)/W_a) x100 where x=b,c, in d the percentage difference is with c. (10/18/2010)

	G1	%	G2	%	Total	%
a	27.77	–	11.54	–	39.31	–
b	13.09	-52.86	8.30	-28.08	21.39	-45.59
c	9.83	-64.60	10.45	-9.45	20.28	-48.41
d	4.41	-58.28	7.97	-23.73	12.38	-38.95

DEPOSITED ENERGY WITH 24 GeV BEAM.

Table 0.6: (10/26/2010)

E_p=24 GeV, 4 MW BEAM, σ_x=σ_y=0.15 cm Gaussian distr.(****)
N_p=100,000 , STANDARD GEOMETRY,13 SC COILS, 2 SC groups:G1=1, G2=2-13
SOLENOID MATERIALS: SC#1-13=SCON (NiTi+Cu+..)
a= MARS E_n ≥0.1 MeV (DEFAULT)
b= MARS $E_n \geq 10^{-11}$ MeV
c= MARS+MCNP E_n ≥0.1 MeV (DEFAULT)
d= MARS+MCNP $E_n \geq 10^{-11}$ MeV

Table 0.7: POWER OF DEPOSITED ENERGY IN KW, DW/W %=((W_x-W_a)/W_a) x100 where x=b,c,e, in d is the percentage difference with c. (10/26/2010)

	G1	%	G2	%	Total	%
a	14.28	–	14.90	–	29.18	–
b	15.92	+11.48	14.99	+0.60	30.91	+5.95
c	15.45	+8.19	14.68	-1.48	30.13	+3.26
d	22.06	+42.78	16.30	+8.99	38.36	+27.31