Energy deposition studies in IR7 and absorbers

Collimation
Meeting
29-10-2004

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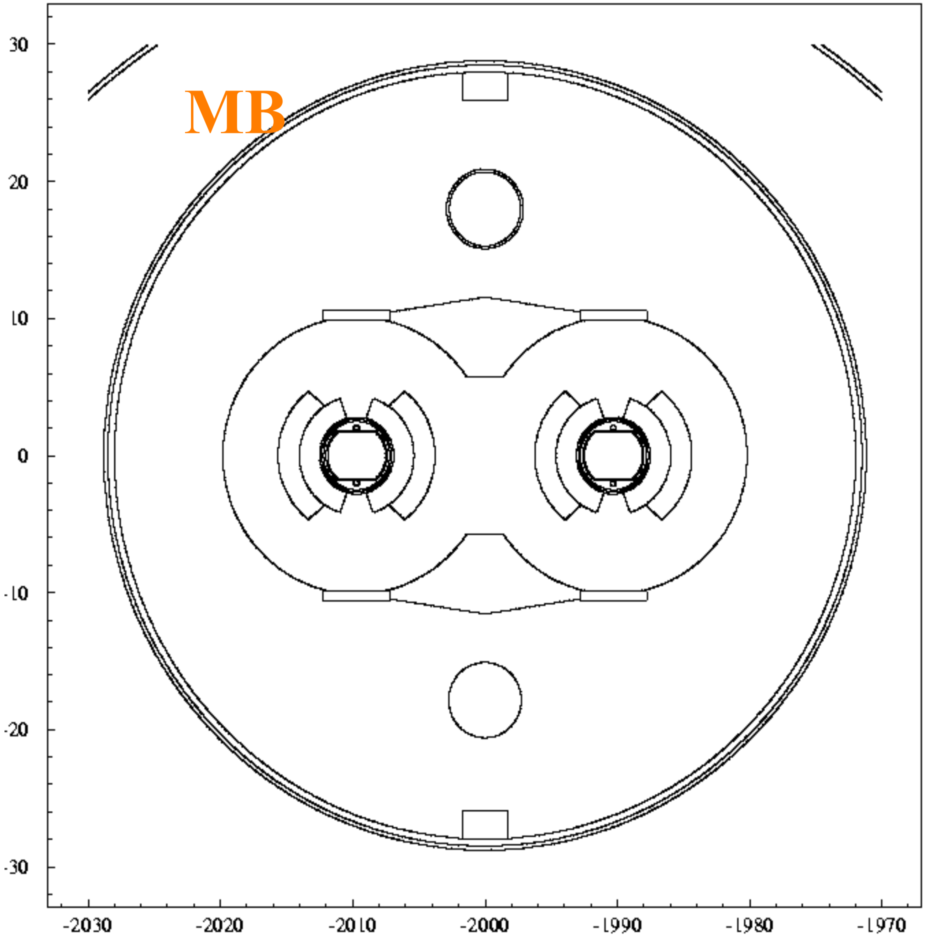
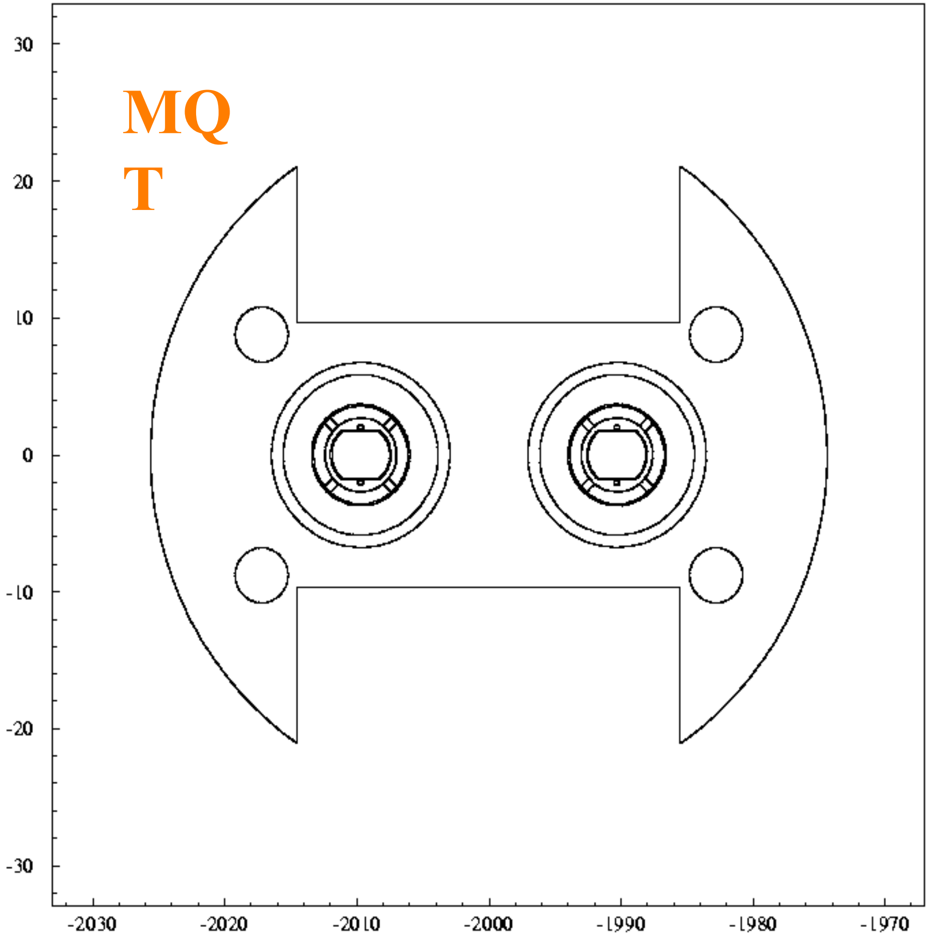
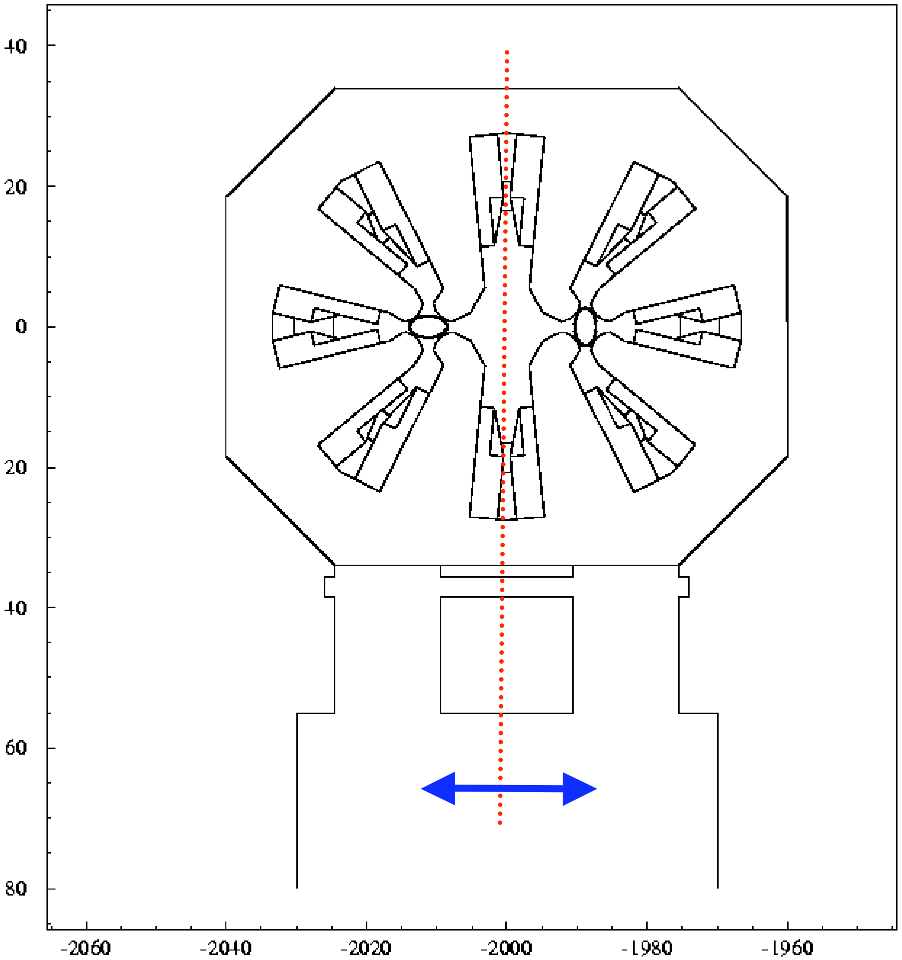
Prototypes

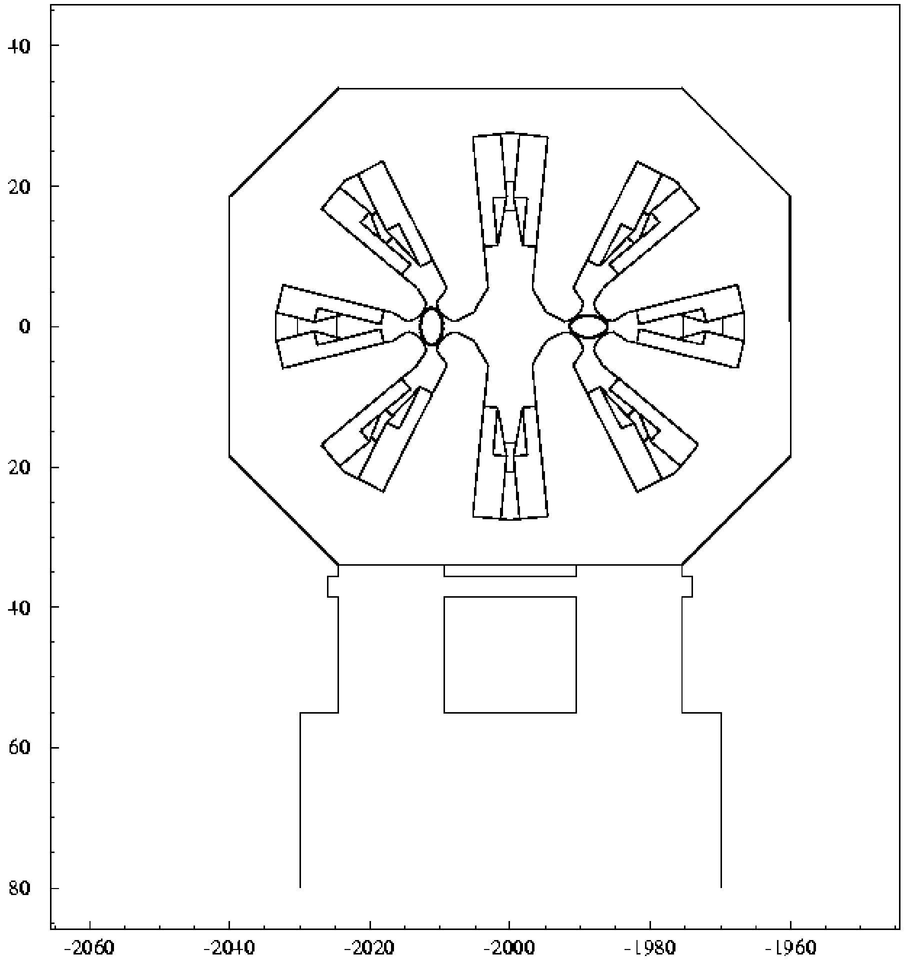
Collimators, dipoles, quadrupoles, sextupoles, multipoles



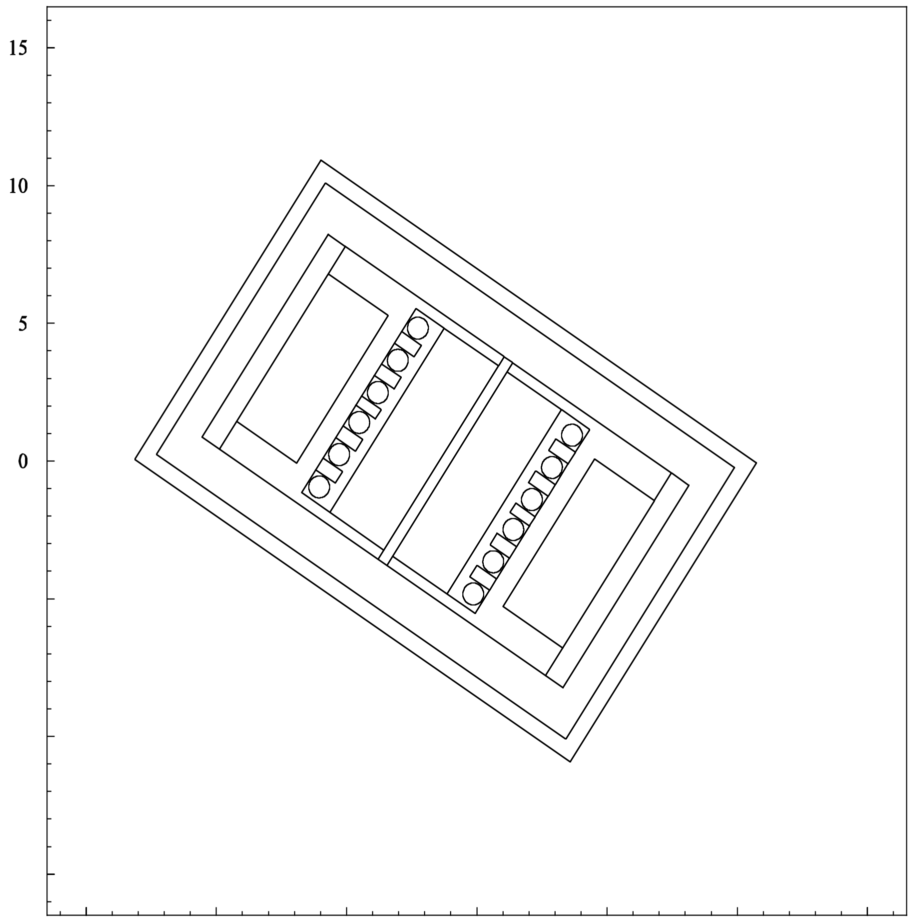


Reflection: MQW
Vertical and Horizontal





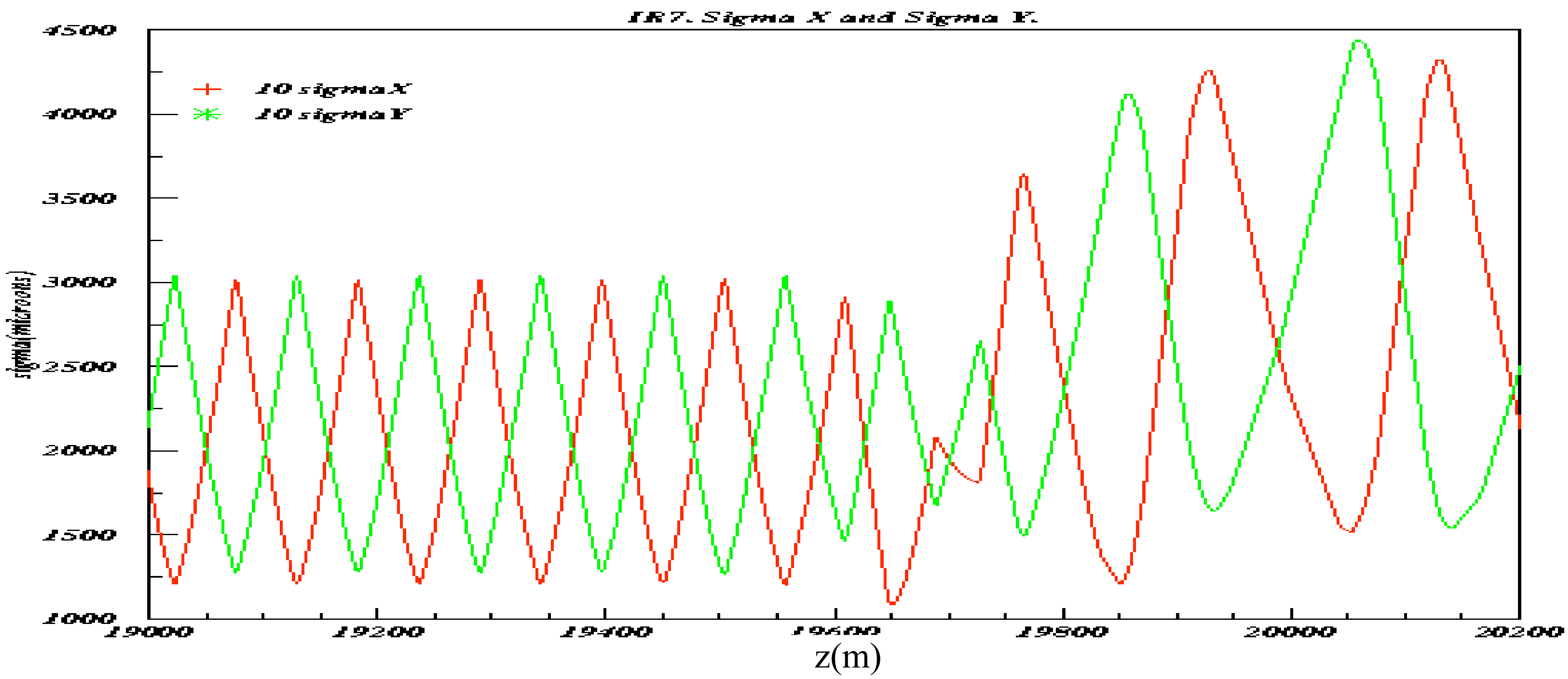
Rotation and run-time corrections:
Primary and secondary collimators

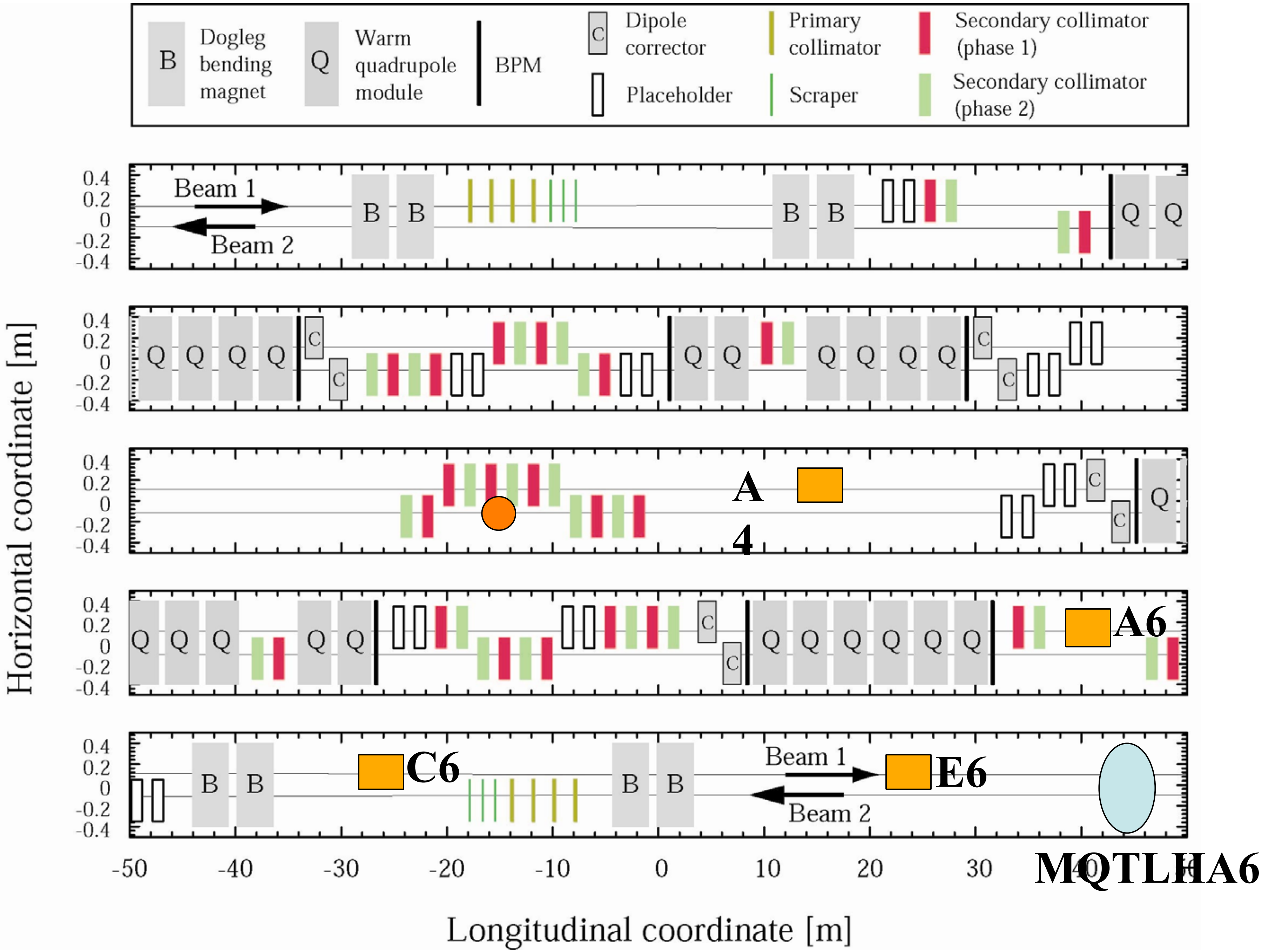


- Rotation around the beam direction and the vertical axis
- Jaw material (carbon, metal)
- Collimation gap and misalignment (run-time)

Absorber geometry

Like secondary collimator, with Cu jaws and 10 sigma half width





B Dogleg bending magnet
Q Warm quadrupole module
BPM
C Dipole corrector
Placeholder
Primary collimator
Scraper
Secondary collimator (phase 1)
Secondary collimator (phase 2)
Beam 1
Beam 2
A
4
A6
C6
E6
MQTLHA6
Horizontal coordinate [m]
Longitudinal coordinate [m]

Special techniques and physics options

- Biasing techniques (“Russian roulette”, splitting, leading particle biasing and region importance)
- Energy cutoff by region
- Electromagnetic cascade
- Particles to be tracked

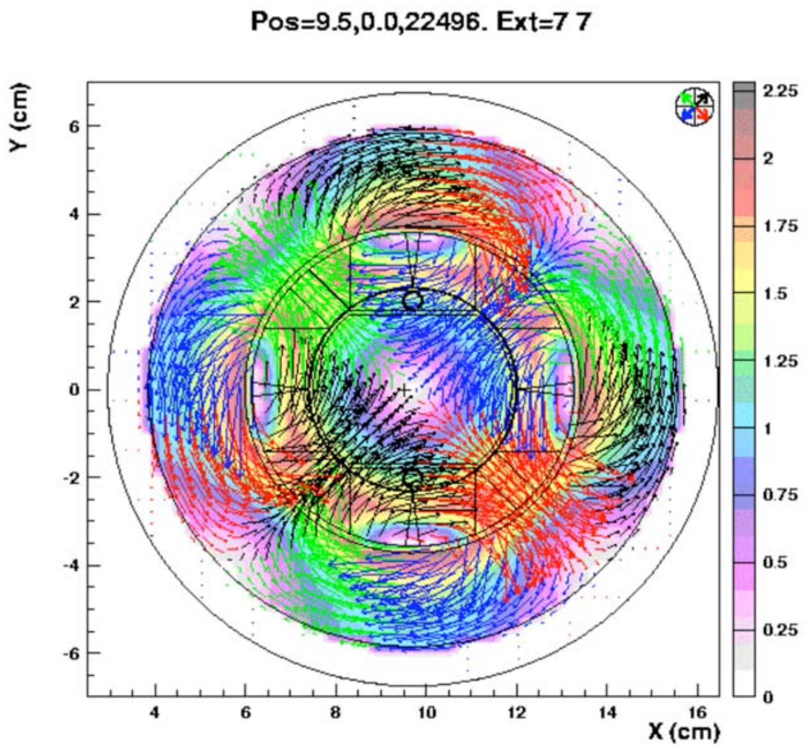
The CPU time to track one primary proton was reduced from 120 s to 1.6 s

Validation

- Trajectory of primary protons along the tunnel (magnetic field fine-tuning)
- 4 _ horizontal and vertical beam (consistency half-gaps / beta functions)
- H, V and S losses simulated separately and together (source consistency)
- Flange design (C. Rathjen)

Validation

- Magnets (Tortschanoff, R Wolf,R. Ostojic)
- Beta function (S. Redaelli
- Losses in TCP (R. Assmann)
- Tunnel (R. Valbuena)



Analysis

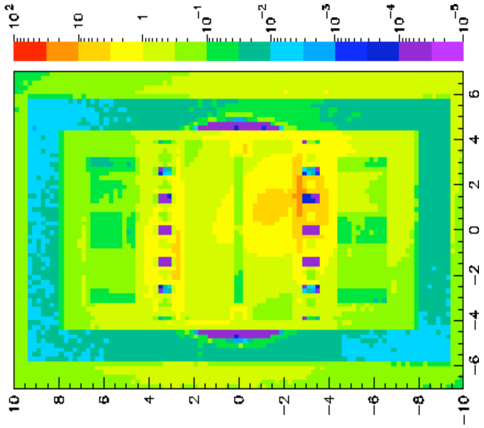
Energy deposition (Cartesian, cylindrical binning and by region)

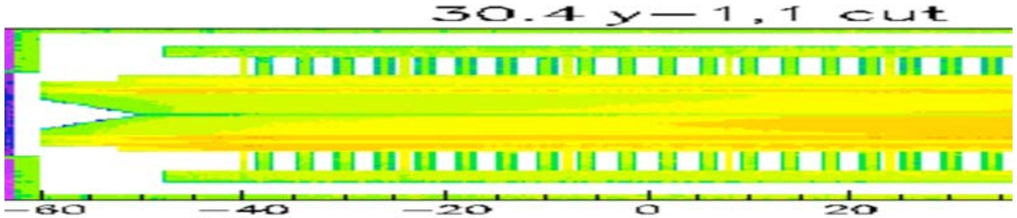
Star density

- MCNPX (Geometry plots, 2D)
- Povray (Geometry plots, 3D)
- EnLattice (Average and statistical error)
- Flukaplot (Plots of energy distribution)
- Results.sh (To create a table with results from all scenarios)

Analysis can be performed by region, eg. collimator TCSG.A6.L7

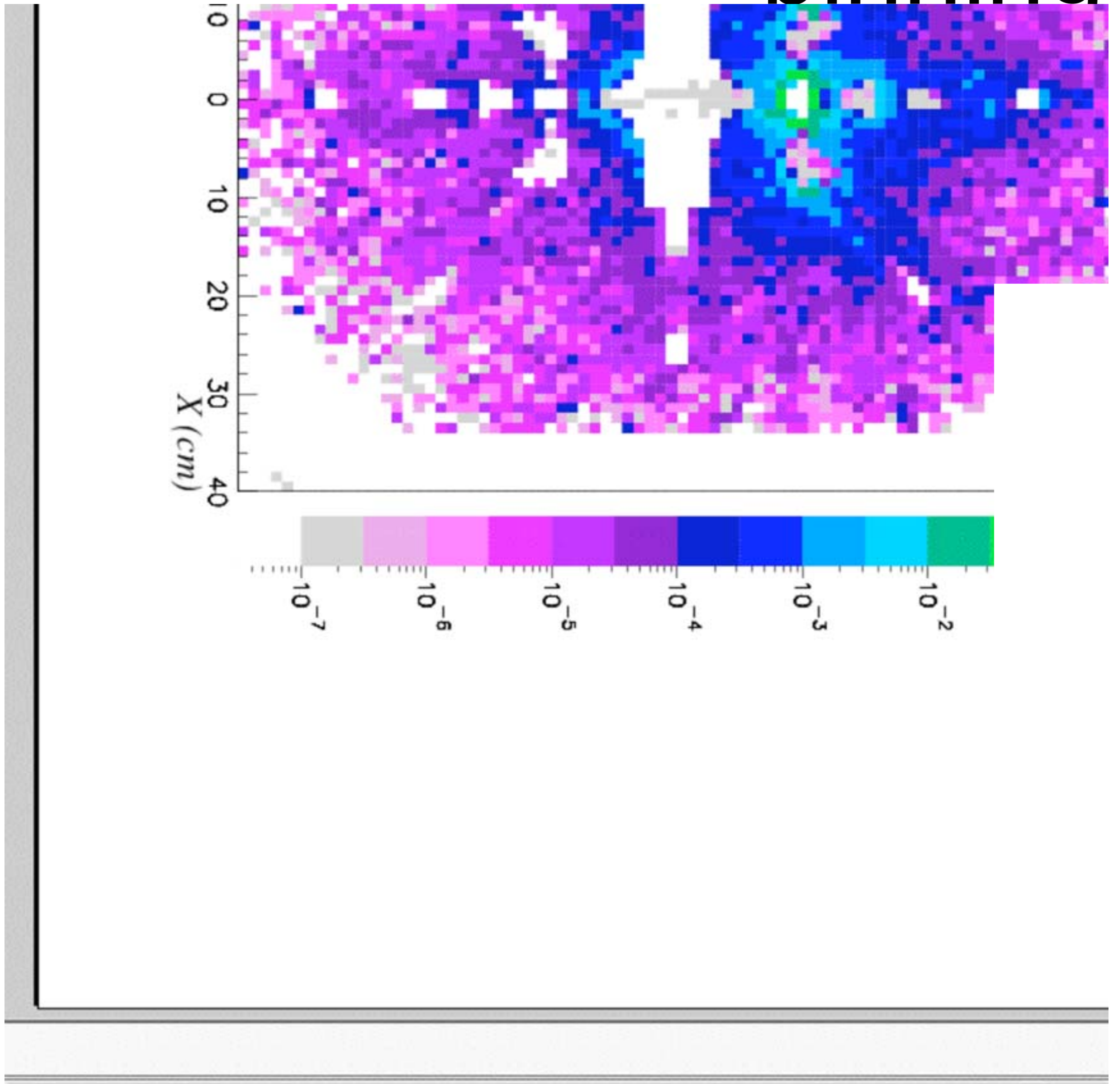
Region	W
entr:344	0.98
exit:345	9.18
cups:347	75.97
box:348	726.35
clSR:350	87.44
clSL:351	125.2
plaR:352	355.21
plaL:353	70.64
scaR:354	129.74
jawR:355	412.31
scaL:356	52.1
jawL:357	611.33
CuJR:358	225.48
CuJL:359	854.42
claR:360	124.11
claL:361	1478.78
vclR:362	4168.6
vclL:363	691.55





Region	W
sprR:364	667.01
sprL:365	1094.88
piJR:366	193.12
piJL:367	389.75
CusR:368	11.87
CusL:369	1292.21
ho1R:370	0.07
ho2R:371	2817.07
ho3R:372	1151.7
ho4R:373	2382.4
ho5R:374	648.73
ho1L:375	1335.47
ho4L:378	85.8
ho5L:379	159.51
shaR:380	44.69
shaL:381	109.54
Total:	**22583.5**

Energy distribution with Cartesian binning



Cross-sectional front view of a warm quadrupole

Total energy deposition in MQWAE5L:

38.5 kW

Beam loss scenario

Assumed loss scenario (0.2 h) for all calculations :

- The number of primaries lost in LHC is 4×10^{11} p/s.
- 90 % of losses in LHC take place in the TCP of IR7 section

Four loss scenarios have been studied:

- losses concentrated in the horizontal TCP (horizontal losses)
- losses concentrated in the vertical TCP (vertical losses)
- losses concentrated in the skew TCP (vertical losses)
- losses distributed over the three TCP (full losses)

Optimization scheme

Simulations are run for:

4 loss scenarios (Hori, Vert, Skew and full)

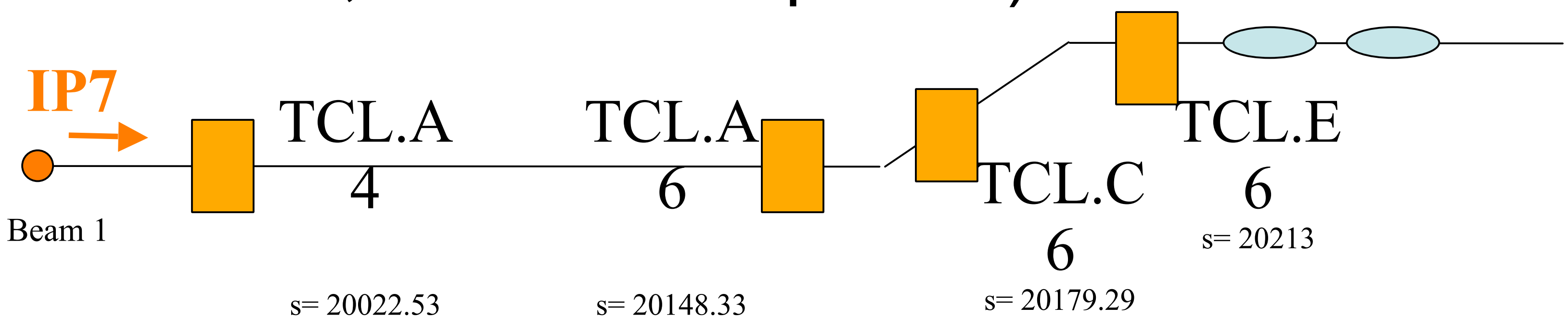
4 possible locations (A4, A6, C6 and E6)

2 absorber orientation (Vert and Hori)

→ 32 possible 1-TCL configurations

(80 possible 2-TCL configurations)

- CPU time: 12 hours per set (5000 protons per simulation, 5 simulation per set)



Systematic check-up

- Well defined loss scenario and TCL
- Consistent position and half-gap
- CPU time per run
- Jaw orientation and beta function

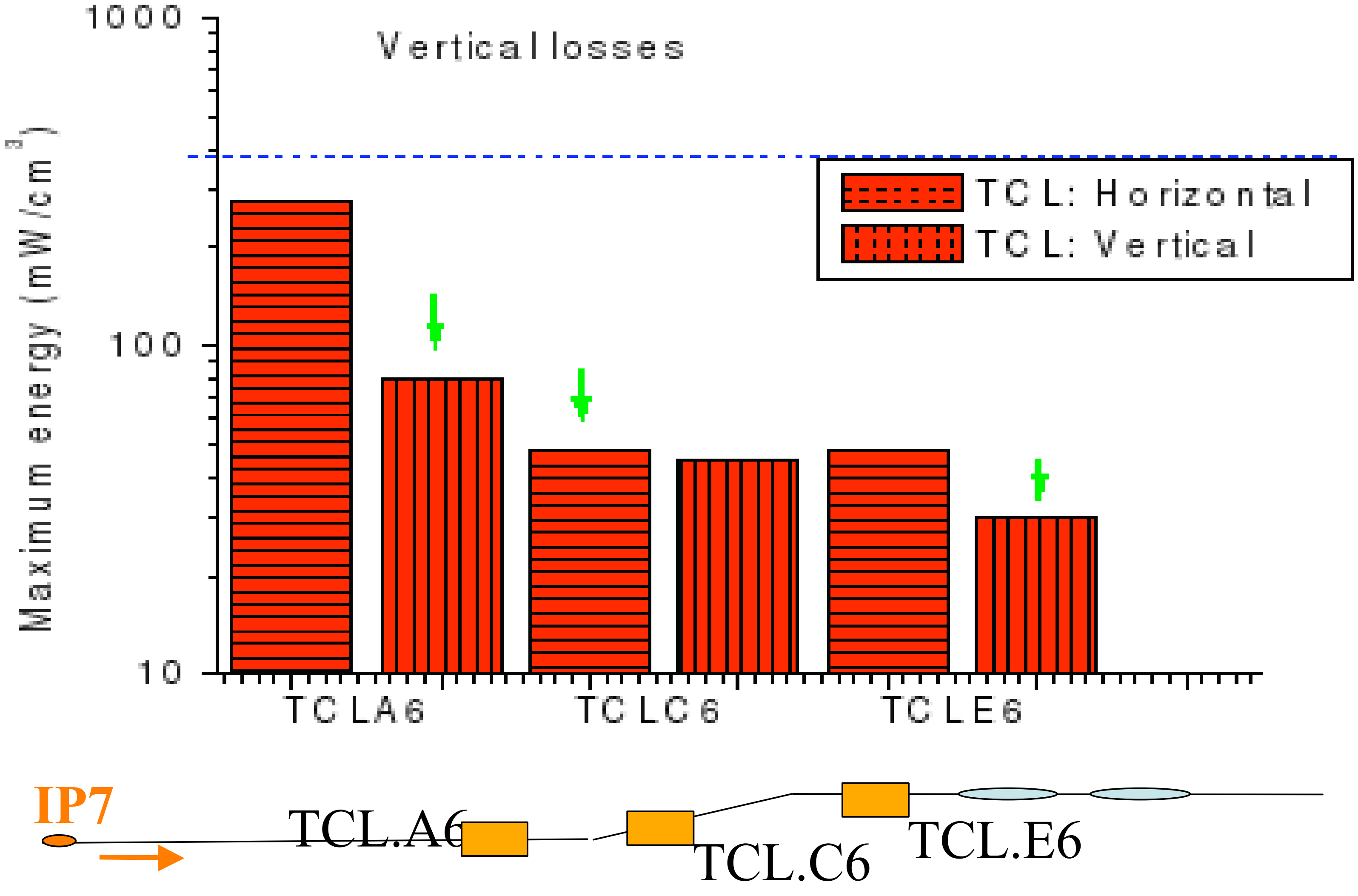
Automated table filling with energy deposition for a single absorber.

250 simulations, 25 CPU days

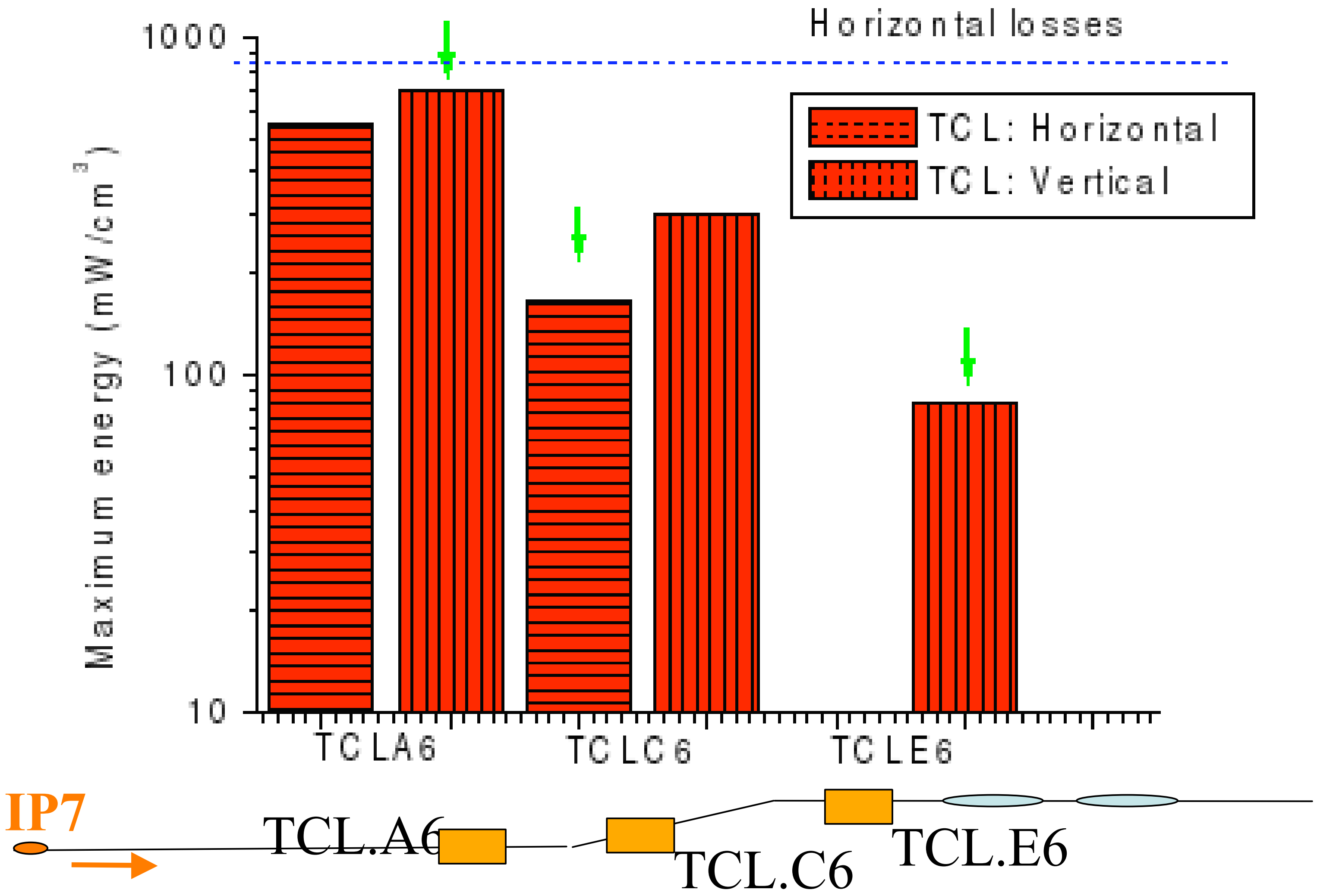
Absorb	Ns	$COIL_{tot}$ (W)	$COIL_{den}$ (mW/cm3)	MQ_{tot} (W)	TCL (W)
vert					
NoTCL	20	64.03	330.215	201.94	0
err%		20.00	28.0	11.39	0
TCLA4v	15	48.62	626.244	169.97	2515.34
err%		21.00	37.6	9.95	3.91
TCLA6h	10	27.23	277.176	133.20	860.00
err%		41.00	85.2	23.59	10.10
TCLA6v	20	4.71	74.940	10.17	1981.37
err%		52.00	79.0	28.64	5.14
TCLC6h	10	5.39	48.349	12.62	854.03
err%		46.00	95.6	32.17	12.64
TCLC6v	20	3.05	45.800	7.20	1137.42
err%		39.00	49.9	21.18	9.71
TCLE6h	6	17.50	48.317	65.80	1068.14
err%		47.00	54.1	28.08	20.07
TCLE6v	15	3.89	31.226	11.56	1017.02
err%		33.00	37.7	15.26	17.45

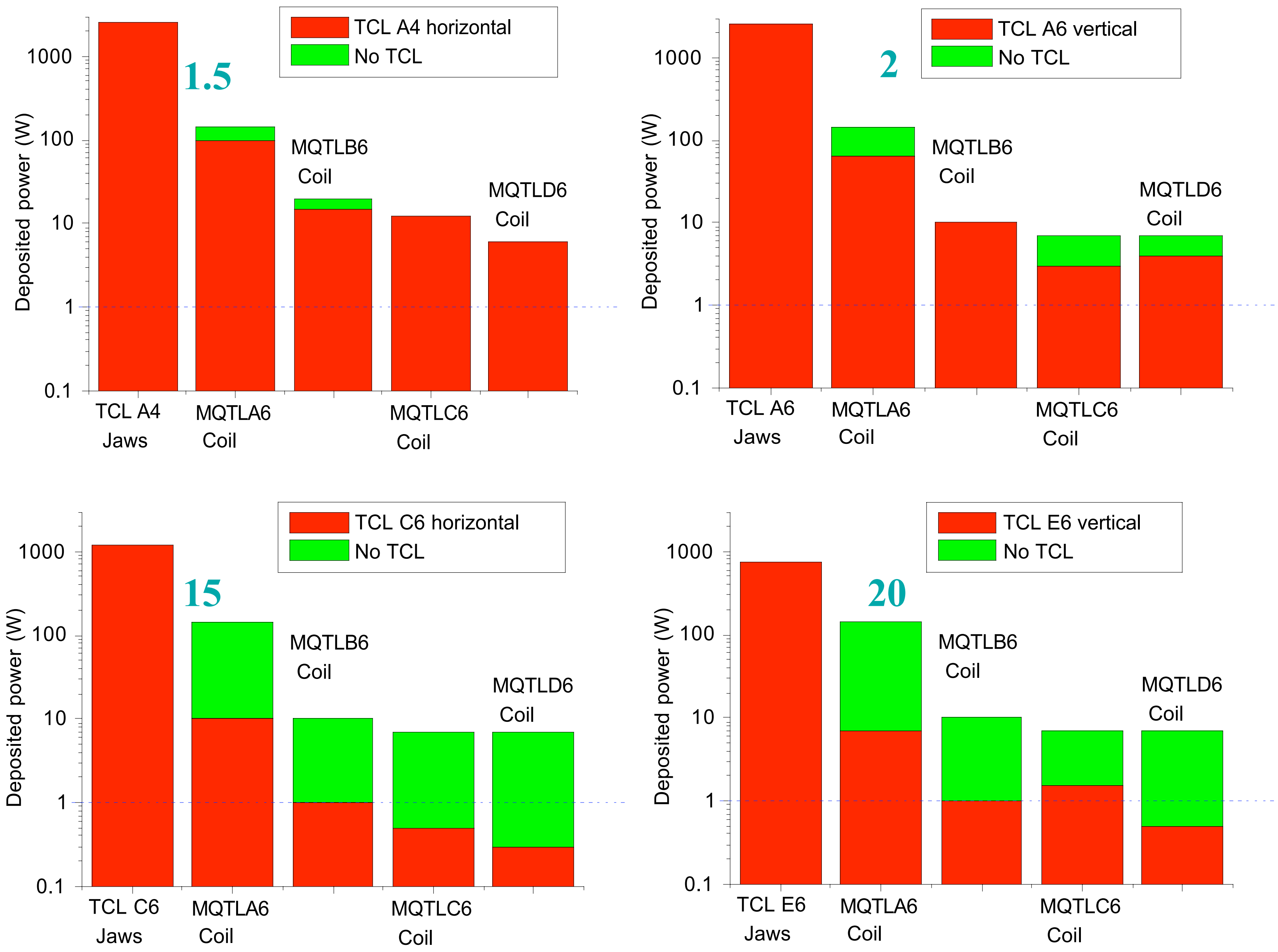
Absorb	Ns	$COIL_{tot}$ (W)	$COIL_{den}$ (mW/cm3)	MQ_{tot} (W)	TCL (W)
hori					
NoTCL	20	142.10	848.125	396.48	0
err%		13.00	27.9	7.25	0
TCLA4h	10	97.29	1196.577	314.77	3273.48
err%		23.00	57.1	11.59	5.43
TCLA6h	15	95.94	547.627	285.69	2116.38
err%		23.00	45.8	14.11	4.09
TCLA6v	10	62.18	700.980	147.27	3333.66
err%		39.00	47.5	23.28	4.36
TCLC6h	20	9.69	166.982	21.14	1679.45
err%		49.00	73.2	26.68	4.73
TCLC6v	10	31.23	295.989	60.54	1793.23
err%		54.00	60.8	32.70	11.11
TCLE6h	10	27.27	709.016	75.91	928.53
err%		32.00	43.7	25.54	12.63
TCLE6v	10	7.17	82.933	30.66	996.87
err%		20.00	34.8	27.66	11.31
skew					
TCLA6h	6	38.22	1004.774	173.22	390.93
err%		51.00	96.5	37.69	9.35
TCLC6h	5	1.26	16.248	3.02	563.61
err%		49.00	58.0	26.01	21.28
TCLE6h	4	1.17	64.416	4.08	392.67
err%		48.00	86.0	32.04	41.14
full					
NoTCL	10	85.73	539.627	244.48	0
err%		40.00	60.5	18.23	0

Max. heat density on MQTLHA6 coil



MQTLHA6


Horizontal losses
1000
100
10
Maximum energy (mW/cm3)
TCL: Horizontal
TCL: Vertical
TCLA6
TCLC6
TCLE6
IP7
TCL.A6
TCL.C6
TCL.E6



TCL A4 horizontal
No TCL
1.5
Deposited power (W)
1000
100
10
1
0.1
MQTLB6
Coil
MQTLD6
Coil
TCL A4
Jaws
MQTLA6
Coil
MQTLC6
Coil
TCL A6 vertical
No TCL
2
Deposited power (W)
1000
100
10
1
0.1
MQTLB6
Coil
MQTLD6
Coil
TCL A6
Jaws
MQTLA6
Coil
MQTLC6
Coil
TCL C6 horizontal
No TCL
15
Deposited power (W)
1000
100
10
1
0.1
MQTLB6
Coil
MQTLD6
Coil
TCL C6
Jaws
MQTLA6
Coil
MQTLC6
Coil
TCL E6 vertical
No TCL
20
Deposited power (W)
1000
100
10
1
0.1
MQTLB6
Coil
MQTLD6
Coil
TCL E6
Jaws
MQTLA6
Coil
MQTLC6
Coil

Two absorbers

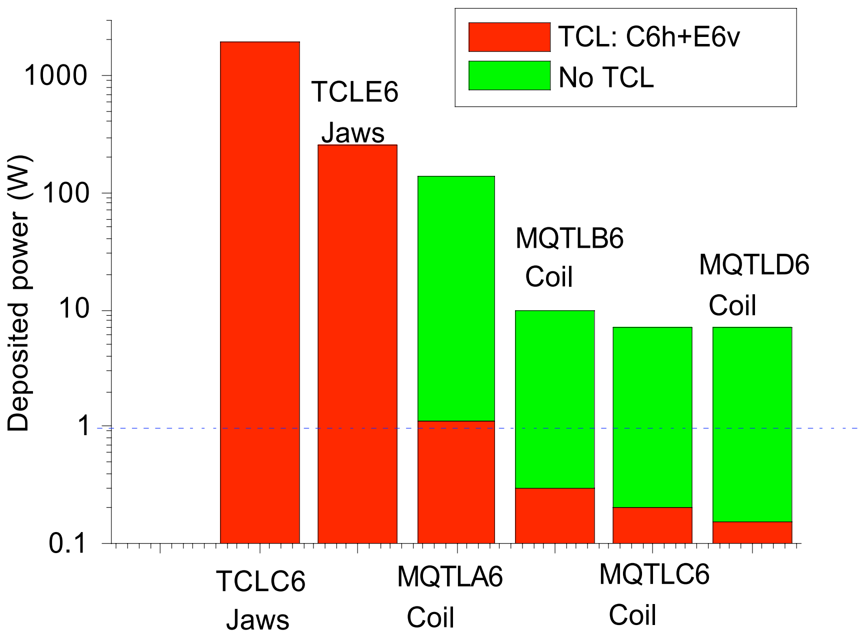
170 Simulations, 18 CPU days

Absorb	Ns	COIL$_{tot}$ (W)	COIL$_{den}$ (mW/cm3)	MQ$_{tot}$ (W)	1stTCL (W)	2ndTCL (W)
vert						
TCLA6vC6h	10	0.03	0.645	0.05	1979.65	210.74
err%		71.00	99.0	42.70	10.33	19.29
TCLA6vC6v	15	5.34	27.907	12.37	2197.87	193.40
err%		66.00	88.7	34.14	6.48	15.32
hori						
TCLA6vC6h	15	5.30	87.149	18.95	3218.39	622.79
err%		97.00	99.0	46.45	5.59	9.76
TCLC6hE6v	86	0.69	3.975	3.15	2078.00	321.68
err%		29.00	75.2	14.11	3.40	9.30
skew						
full						
TCLA6vC6h	28	0.16	0.744	0.72	2085.63	325.12
err%		60.00	99.0	29.67	4.82	9.37
TCLC6hE6v	20	0.94	7.369	4.05	1225.19	278.35
err%		50.00	95.0	26.59	9.52	28.33

Three absorbers

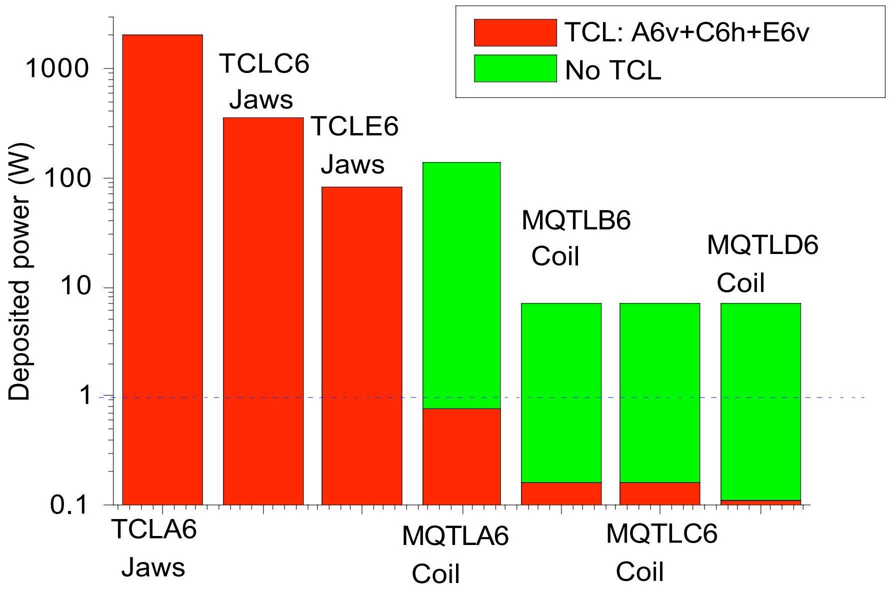
600 Simulations, 60 CPU days

		W	mW/cm^3	W	W	W	W
Absorb	**Ns**	**$COIL_{tot}$**	**$COIL_{den}$**	**MQ_{tot}**	**$1^{st}TCL$**	**$2^{nd}TCL$**	**$3^{rd}TCL$**
vert							
hori							
TCLA6vC6hE6v256		0.76	2.256	2.77	2368.91	428.60	79.29
err%		31.00	48.7	15.89	2.26	4.80	13.60
skew							
full							
TCLA6vC6hE6v342		0.42	1.331	1.46	2167.72	371.46	58.65
err%		27.00	59.2	13.83	1.90	4.51	14.61



Two absorbers in C6, E6

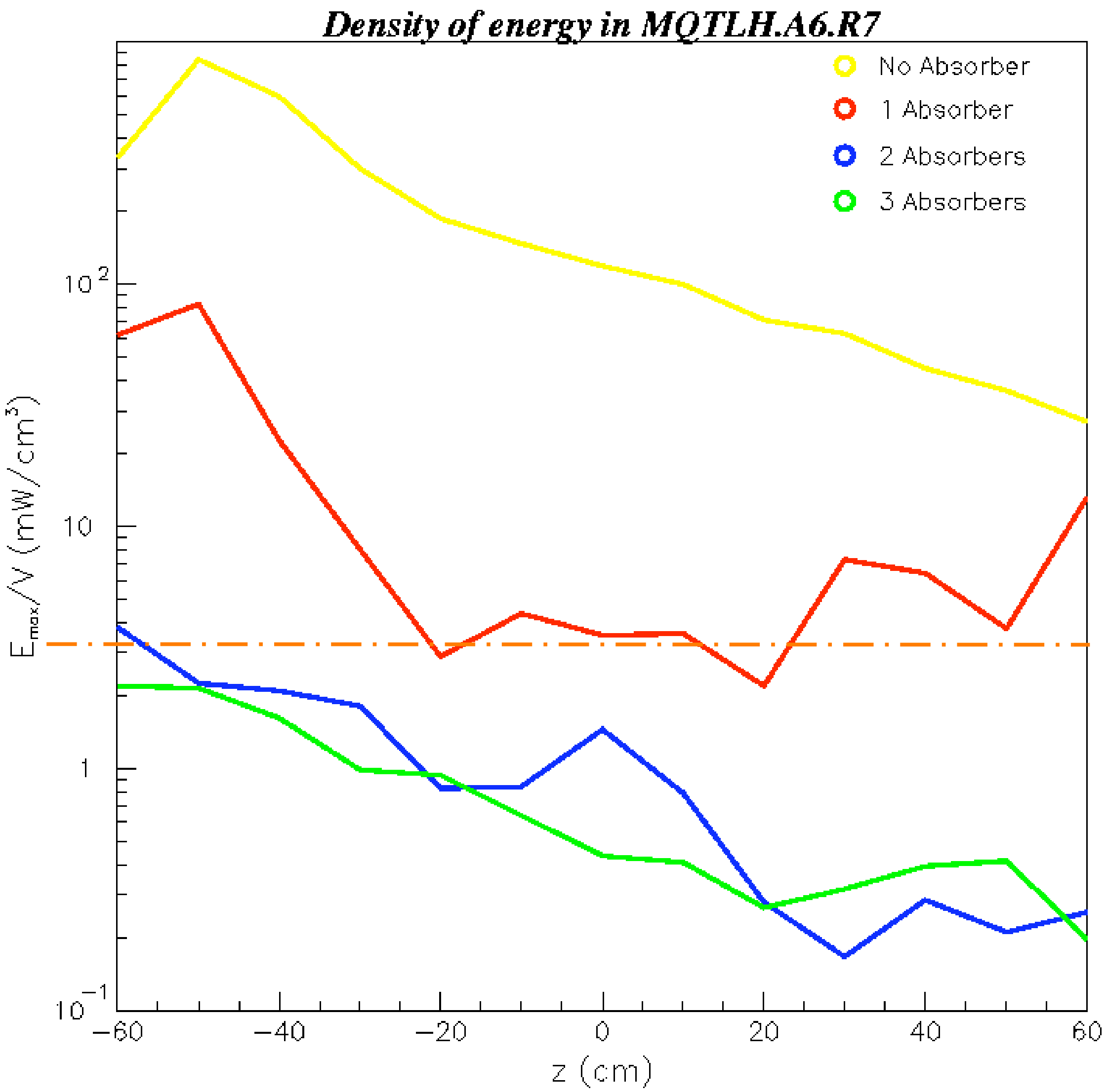
3-5 mW/cmc



Three absorbers in A6, C6, E6

1-3 mW/cmc

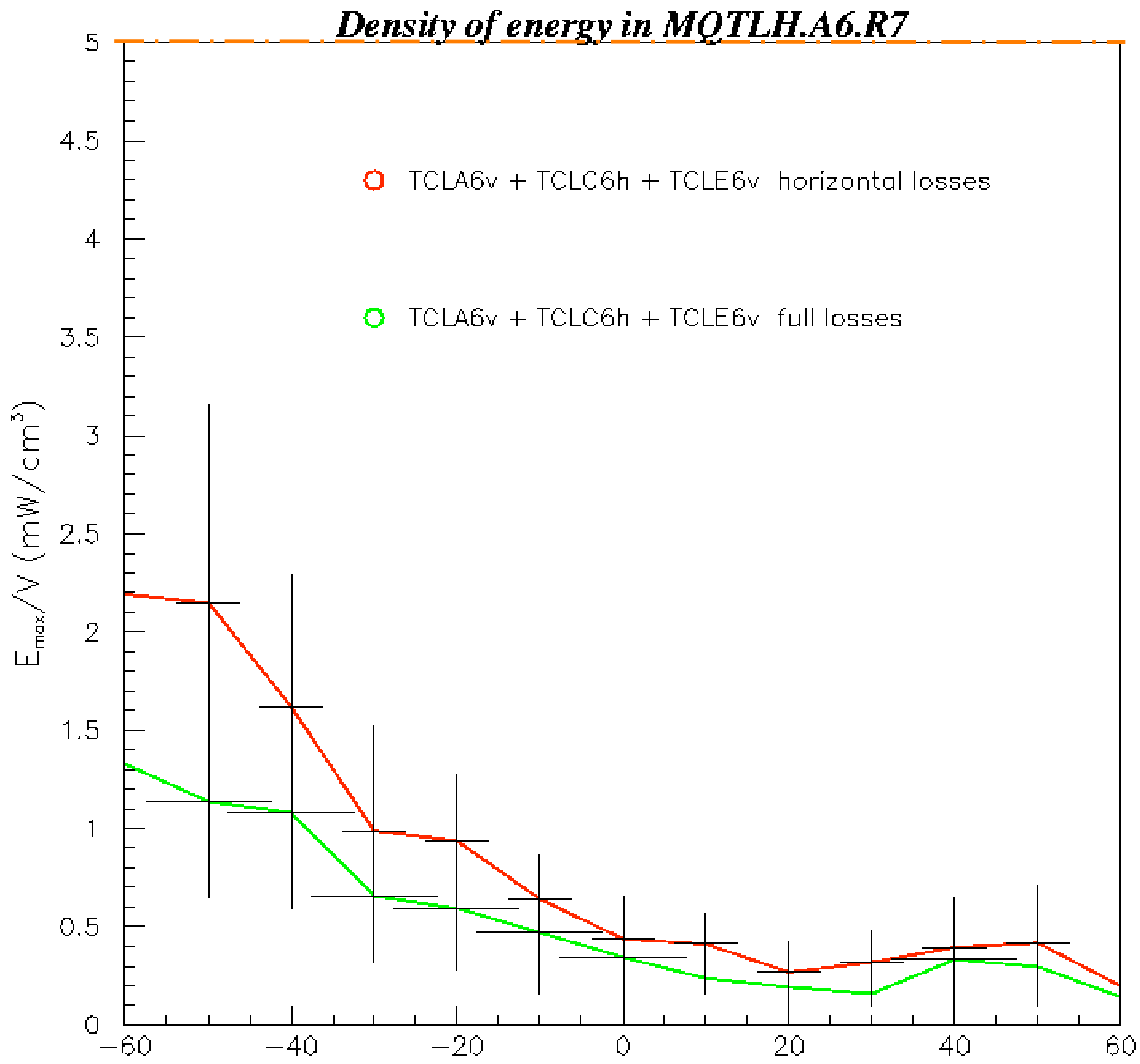
Maximum energy deposition



Highest value of energy deposition in 1 cm thick slices

The dashed line corresponds to 5 mW/cmc

Maximum energy deposition



Highest value of energy deposition in 1 cm thick slices

The dashed line corresponds to 5 mW/cmc

Conclusions

- Four possible locations for absorbers (A4, A6, C6, E6)
- Absorbers in C6 and E6 are the most effective ones
- The worst scenario consists in all losses concentrated in the horizontal TCP
- Results suggest that three absorbers per beam should be enough to avoid quenching in the first MQTL
- Further investigation may suggest more effective combinations of absorbers
- We will also investigate energy deposition in cold dipoles