LHC COLLIMATION WORKING GROUP

29 October 2004

PASSIVE ABSORBERS FOR THE MOMENTUM CLEANING INSERTION

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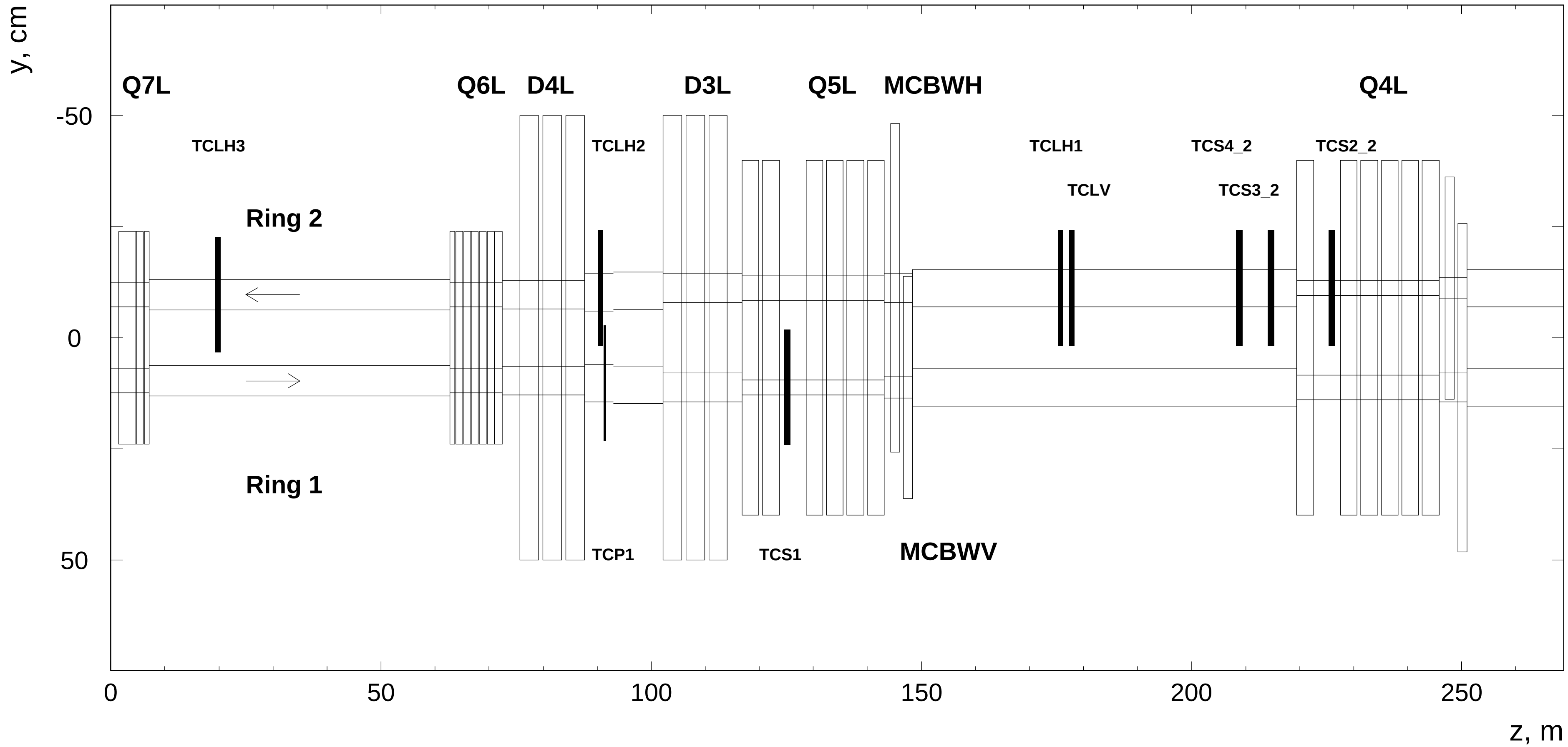
Historical background

- 2001 – Cascade simulation studies for momentum cleaning insertion of LHC (LHC Project Note 263)
- 2002 – Power deposition in superconducting magnets of the momentum cleaning insertion (LHC Project Note 286)
- 2002 – Towards a shielding design for the momentum cleaning insertion of the LHC (LHC Project Note 297)
- 2002 - Radiological studies of the momentum cleaning insertion (Technical Note, TIS-RP/TN/2002-024)
- 2002-2003 – BLM signal studies for the momentum cleaning insertion
- 2003 – Irradiation of electronic components in the dispersion suppressor of the LHC IR3 (LHC Project Note 331)

A model of momentum cleaning insertion

Layout of one half of the momentum cleaning section



A model of momentum cleaning insertion

- New layout and optics version V6.5
- New collimator design
- n_1=12.5 and n_2=14.0
- New design of the warm corrector magnets
- New apertures and beam pipes design
- 28 elements in consideration: cold and warm magnets, DBFA, flanges, bellows, vacuum pumps, BPM, BLM et al.

Simulation details

- STRUCT code is used to prepare a map of primary inelastic interactions in the collimator jaws (900000 protons)
- Hadron and electromagnetic cascades development is simulated using the Monte-Carlo code MARS.
- The geometry starts at the end of DS.3L and ends up at the entrance of the DS.3R.
- Dipole fields and quad gradients in the apertures of D3, D4, Q4, Q5, Q6 and Q7, magnetic lengths of their modules and the drift spaces between the module in a full accordance with the optics version 6.5.
- An individual cascade starts from the inelastic nuclear interaction of a proton inside one of the collimator jaws.

Simulation details

- 3 Setups:
  - no TCL, L_{TCP} = 20cm
  - TCLV + 3TCLH, L_{TCP} = 60cm
  - TCLV + 3TCLH + PasAbs, L_{TCP} = 60cm

Collimator	No TCLs				TCLV+3TCLH			
	Length (cm)	skew angle (mrad)	radius (cm)	relative rate	Length (cm)	skew angle (mrad)	radius (cm)	relative rate
TCP1	20	0.00000	0.3240	0.461	60	0.00000	0.3240	0.685
TCS1	100	0.00000	0.2330	0.044	100	0.00000	0.2330	0.028
TCS2	100	0.00000	0.1610	0.335	100	0.00000	0.1610	0.190
TCS3	100	0.15813	0.2060	0.095	100	0.15813	0.2060	0.057
TCS4	100	-0.18605	0.2310	0.065	100	-0.18605	0.2310	0.040
TCLV					100	1.57080	0.3000	
TCLH1					100	0.00000	0.5000	
TCLH2					100	0.00000	0.5000	
TCSH3					100	0.00000	0.3250	

Maximal doses without passive absorbers

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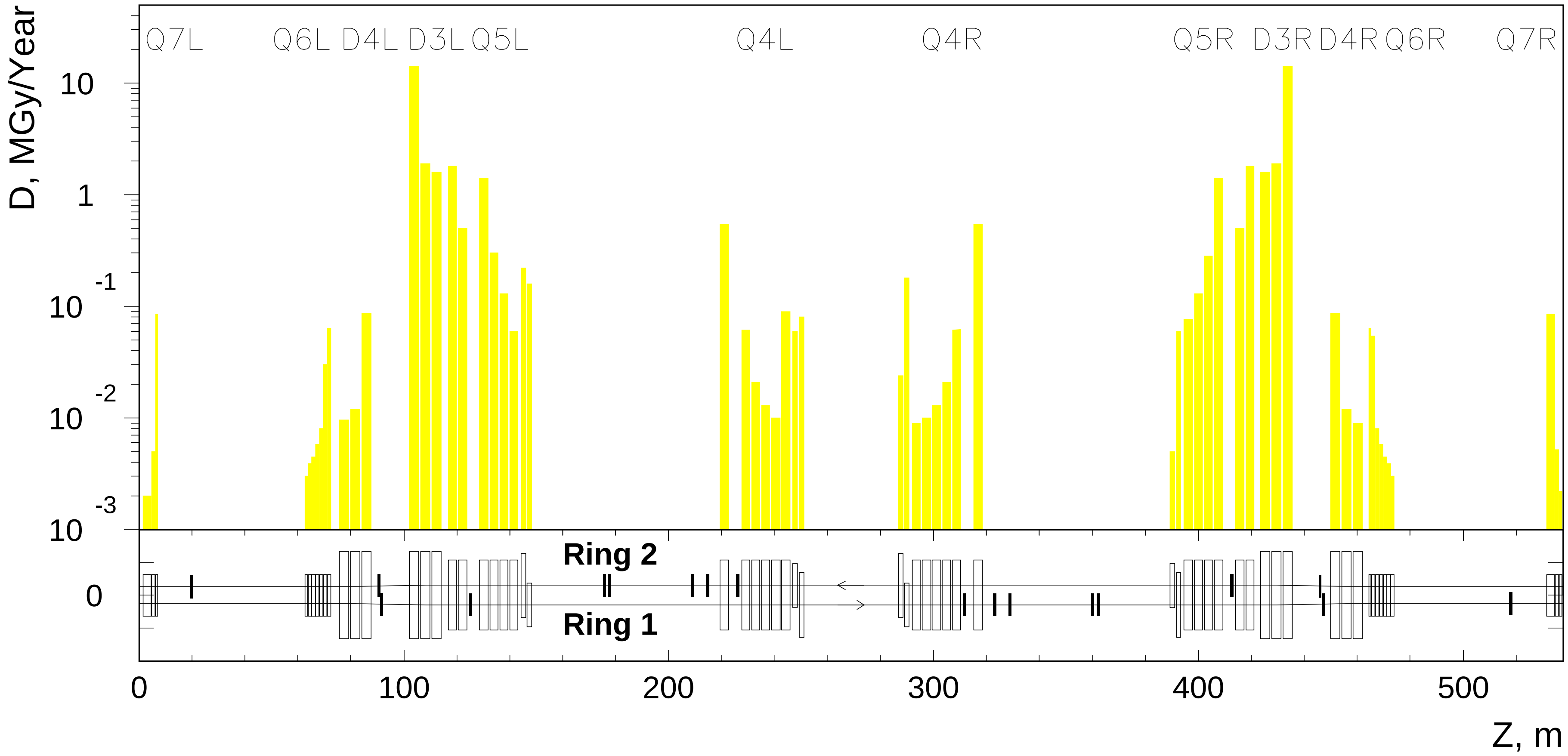

Doses to coils without passive absorbers

Absorbed dose in MGy is normalized to 10^{16} inelastic proton interactions per year.

Elements	Setup		Elements	Setup	
	no TCLs	TCLV+3TCLH		No TCLs	TCLV+3TCLH
MBW.F4	0.08	0.0093	MQWA.E4	0.90	0.54
MBW.E4	0.09	0.0110	MQWA.D4	0.066	0.061
MBW.D4	0.80	0.086	MQWA.C4	0.035	0.021
MBW.C3	6.00	14.0	MQWB.4	0.013	0.013
MBW.B3	1.20	1.90	MQWA.B4	0.011	0.010
MBW.A3	1.00	1.60	MQWA.A4	0.011	0.009
MQWA.E5	1.20	1.80	MCBWH.Q5L	0.22	0.22
MQWA.D5	0.34	0.48	MCBWV.Q5L	0.14	0.16
MQWA.C5	1.20	1.40	MCBWV.Q4L	0.013	0.012
MQWB.5	0.26	0.28	MCBWH.Q4L	0.087	0.081
MQWA.B5	0.12	0.13	MCBWH.Q4R	0.024	0.024
MQWA.A5	0.28	0.076	MCBWV.Q4R	0.18	0.18
MCBWV.Q5R	1.20	0.005	MCBWH.Q5R	1.50	0.06

Maximal dose loads in D3

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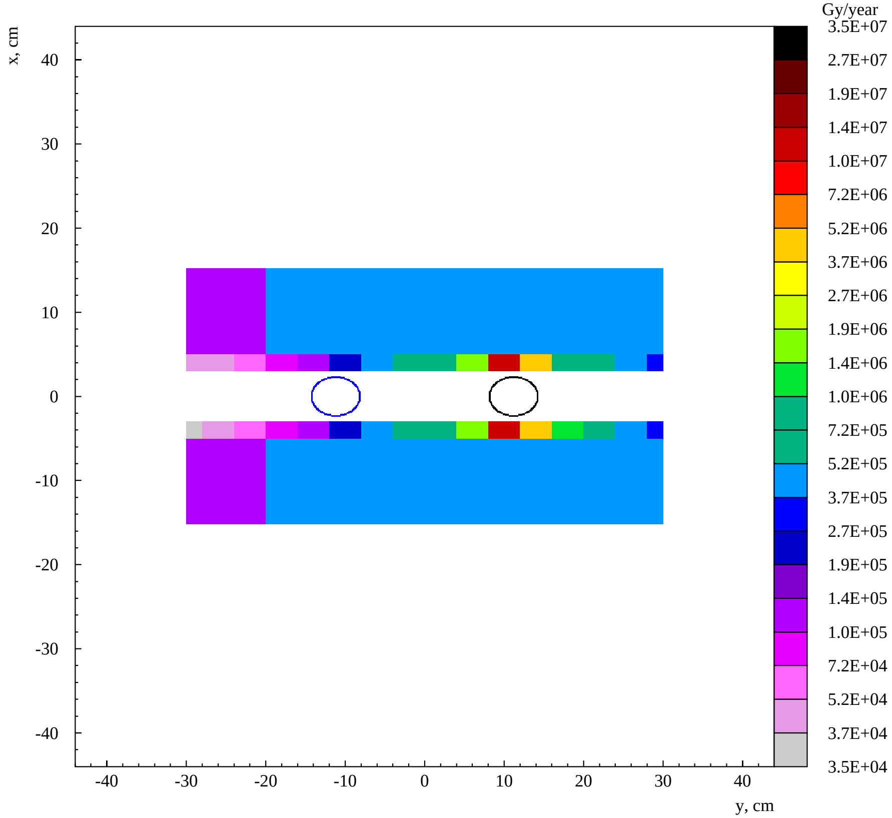
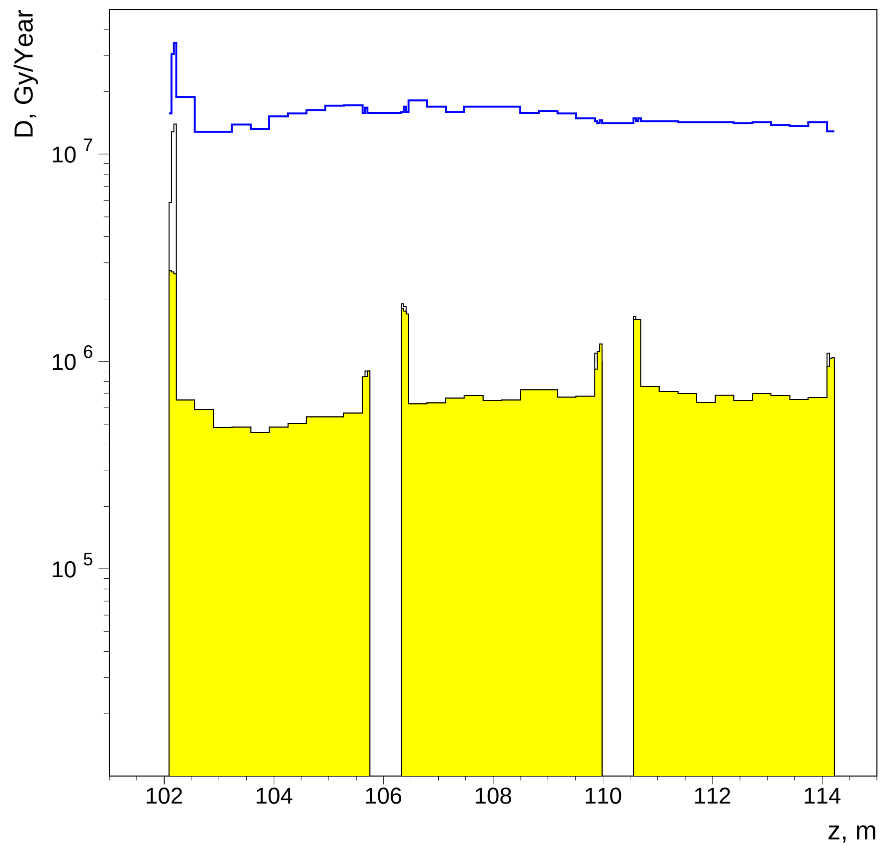
Annual dose in bare coils



Annual dose in the D3. Blue line - absorbed dose in beam pipe, solid clear histogram - dose in coils without PasAbs, yellow histogram - dose in coils with PasAbs



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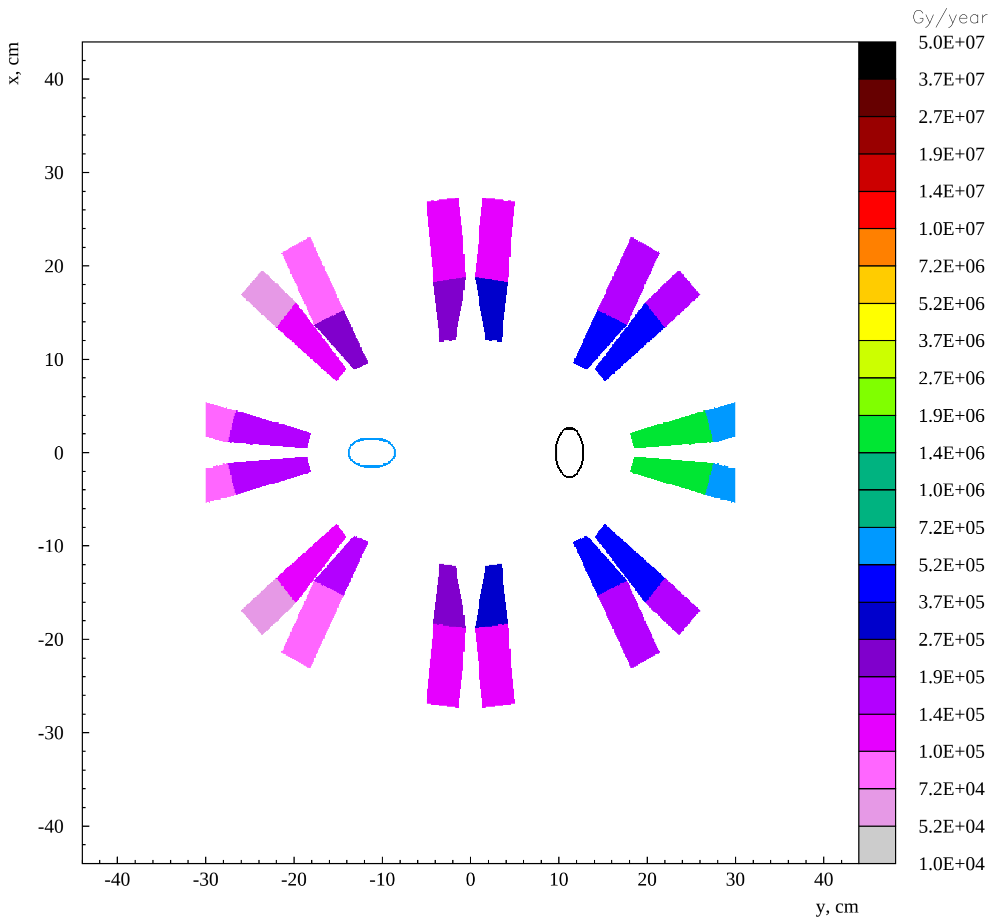
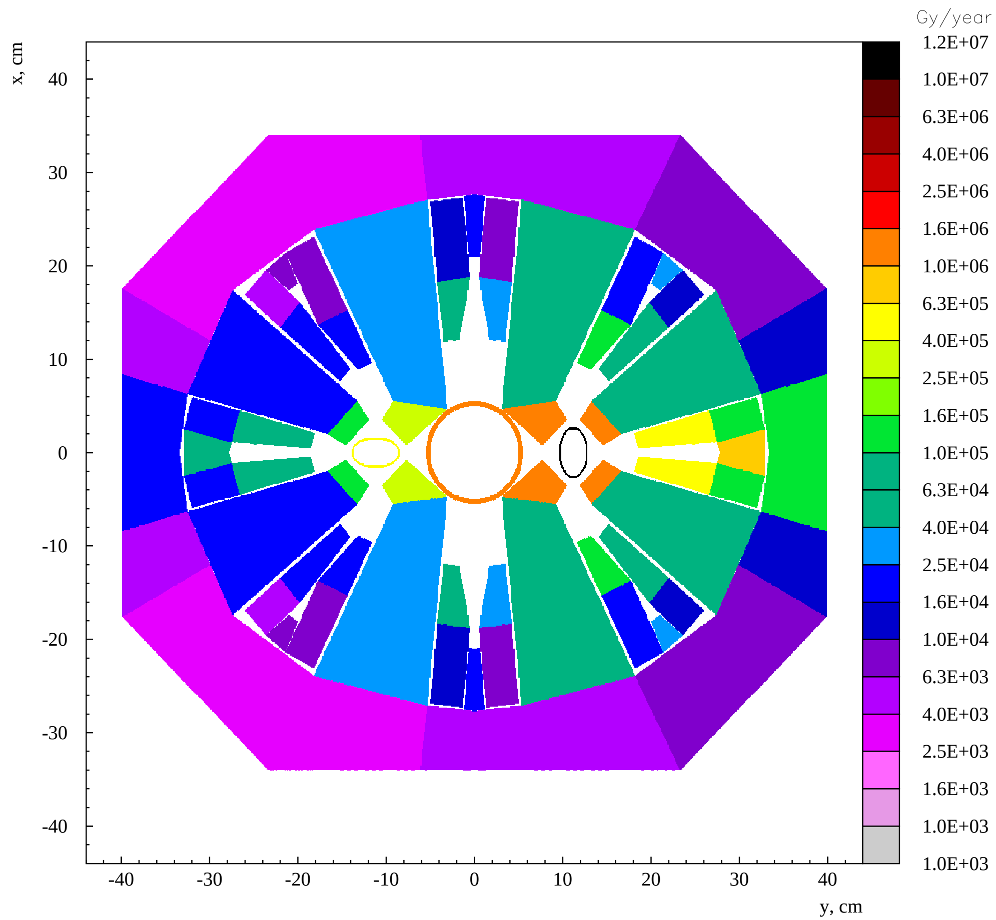
Doses in the MQWA.E5L

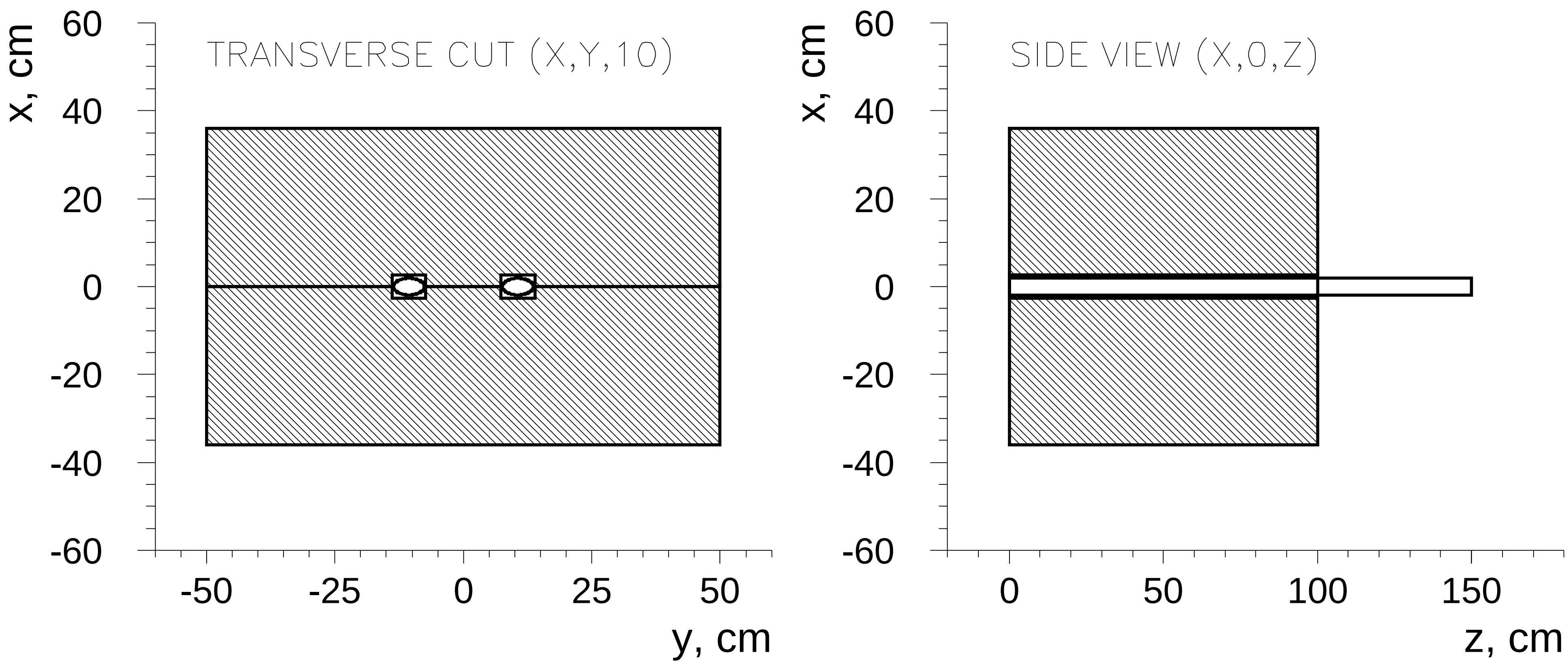
Annual dose in bare coils



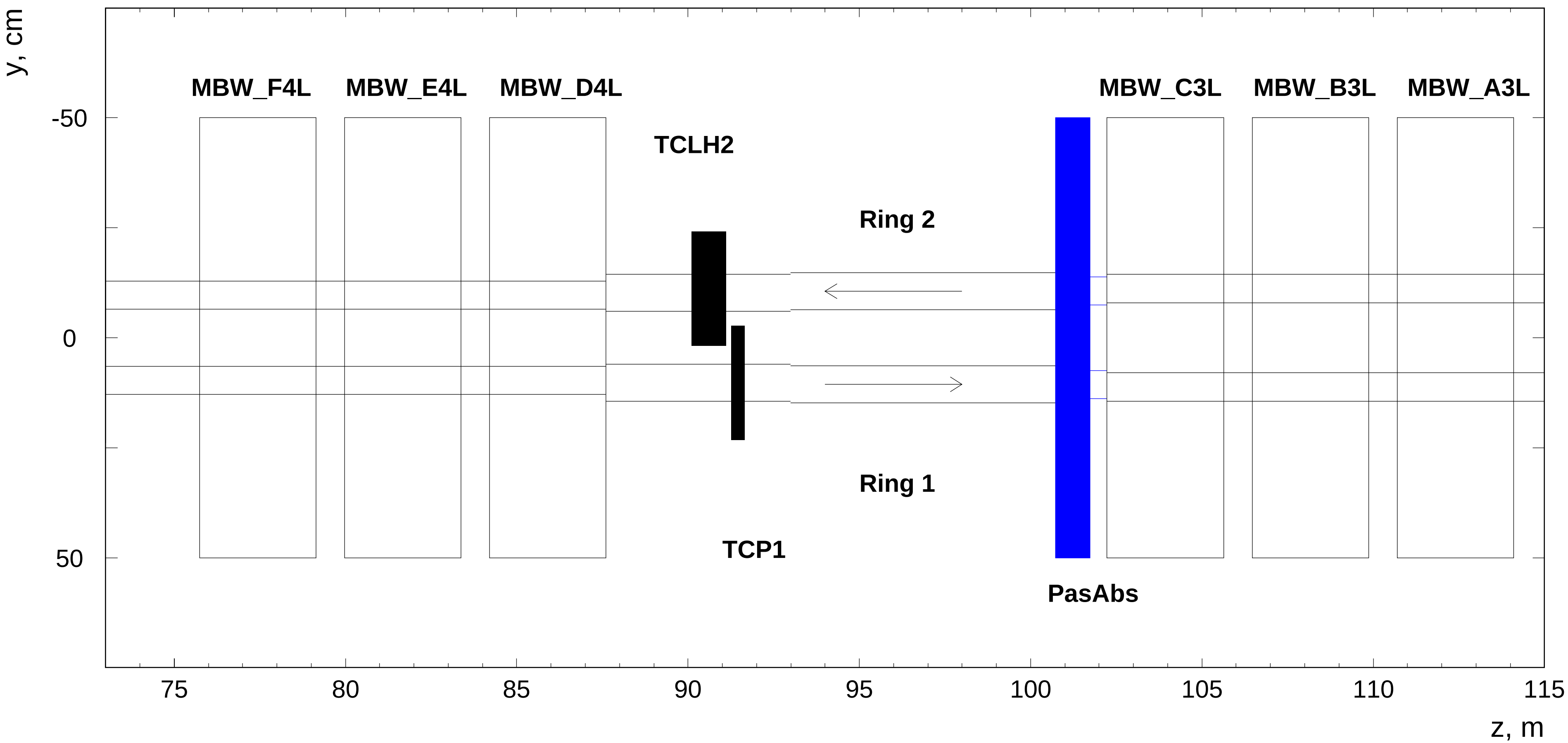
Annual dose in the MQW



Passive Absorber design



Location of passive absorbers



Doses to coils with passive absorbers

Absorbed dose in MGy is normalized to 10^{16} inelastic proton interactions per year

Elements	Setup		Elements	Setup	
	4TCLs	4TCLs+PasAbs		4TCLs	4TCLs+PasAbs
MBW.F4	0.0093	0.0096	MQWA.E4	0.54	0.54
MBW.E4	0.011	0.012	MQWA.D4	0.061	0.059
MBW.D4	0.086	0.086	MQWA.C4	0.021	0.021
MBW.C3	14.00	2.70	MQWB.4	0.013	0.013
MBW.B3	1.90	1.80	MQWA.B4	0.010	0.010
MBW.A3	1.60	1.60	MQWA.A4	0.009	0.009
MQWA.E5	1.80	1.60	MCBWH.Q5L	0.22	0.20
MQWA.D5	0.48	0.47	MCBWV.Q5L	0.16	0.14
MQWA.C5	1.40	1.40	MCBWV.Q4L	0.012	0.012
MQWB.5	0.28	0.28	MCBWH.Q4L	0.081	0.081
MQWA.B5	0.13	0.12	MCBWH.Q4R	0.024	0.022
MQWA.A5	0.076	0.073	MCBWV.Q4R	0.18	0.18
MCBWV.Q5R	0.005	0.005	MCBWH.Q5R	0.06	0.06

Energy deposition in the collimators

The energy deposition corresponds to one proton lost in the collimators of one ring. Power deposition corresponds to a peak loss rate of $3 \cdot 10^9$ protons/s at collision energy

Collimator	*no TCLs* Energy [GeV/proton] jaws	*no TCLs* tank	*TCLs+PasAbs* jaws	*TCLs+PasAbs* tank	**Power [W]**
TCP1	1.5	2.1	15.3	22.0	10.6
TCS1	59.2	94.3	80.0	122.0	58.6
TCS2	26.2	36.6	16.0	22.4	10.8
TCS3	98.3	125.0	58.1	73.8	35.4
TCS4	213.0	272.0	126.0	162.0	77.8
TCLV			397.0	431.0	206.9
TCLH1			69.0	83.0	39.8
TCLH2			46.3	49.3	23.7
TCLH3			17.2	28.1	13.5
All	398.2	530.0	824.9	993.6	477.0

Power deposition in details

Power deposition corresponds to a peak loss rate of $3 \cdot 10^9$ protons/s at collision energy

Collimator	**Unit**	*Elements*				
		flange$_{up}$	bpipe$_{up}$	tank	bpipe$_{dn}$	flange$_{dn}$
TCP1	W·cm^{-3}	1.2·10^{-6}	3.0·10^{-6}		6.0·10^{-3}	3.4·10^{-3}
	W	3.2·10^{-4}	1.8·10^{-4}	10.6	0.37	0.9
TCS1	W·cm^{-3}	6.7·10^{-3}	1.2·10^{-2}		1.3·10^{-2}	5.5·10^{-3}
	W	1.75	0.73	58.6	0.79	1.43
TCS2	W·cm^{-3}	2.2·10^{-5}	3.5·10^{-5}		4.1·10^{-3}	1.9·10^{-3}
	W	5.7·10^{-3}	2.1·10^{-3}	10.8	0.25	0.5
TCS3	W·cm^{-3}	4.2·10^{-4}	1.6·10^{-3}		1.1·10^{-2}	3.8·10^{-3}
	W	0.11	0.099	35.4	0.71	1.0
TCS4	W·cm^{-3}	2.4·10^{-3}	1.9·10^{-2}		2.1·10^{-2}	6.0·10^{-3}
	W	0.62	0.55	77.8	1.3	1.57

Power deposition in the TCS4

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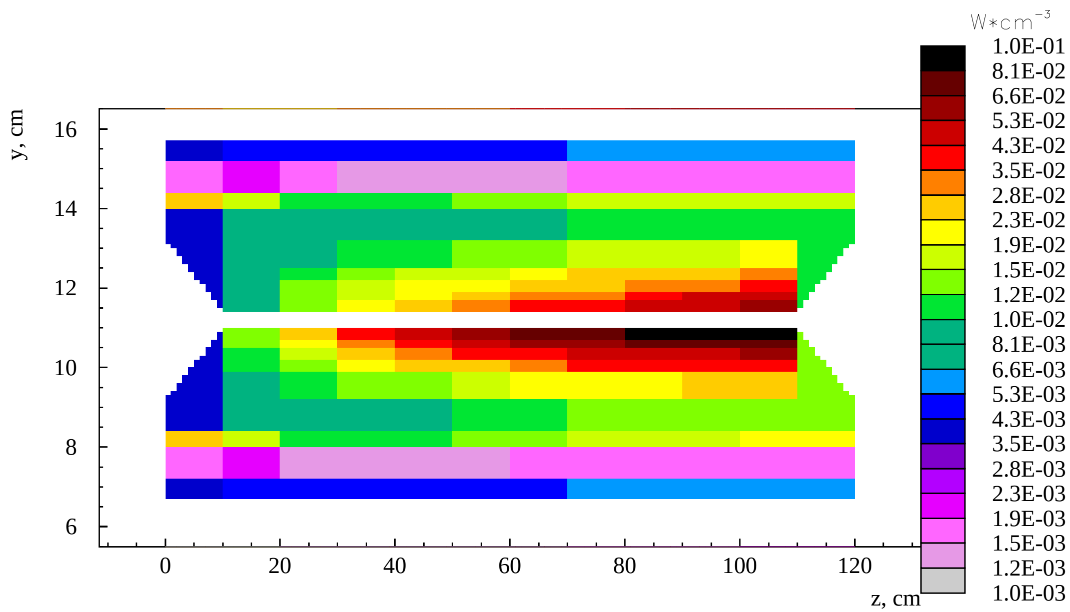
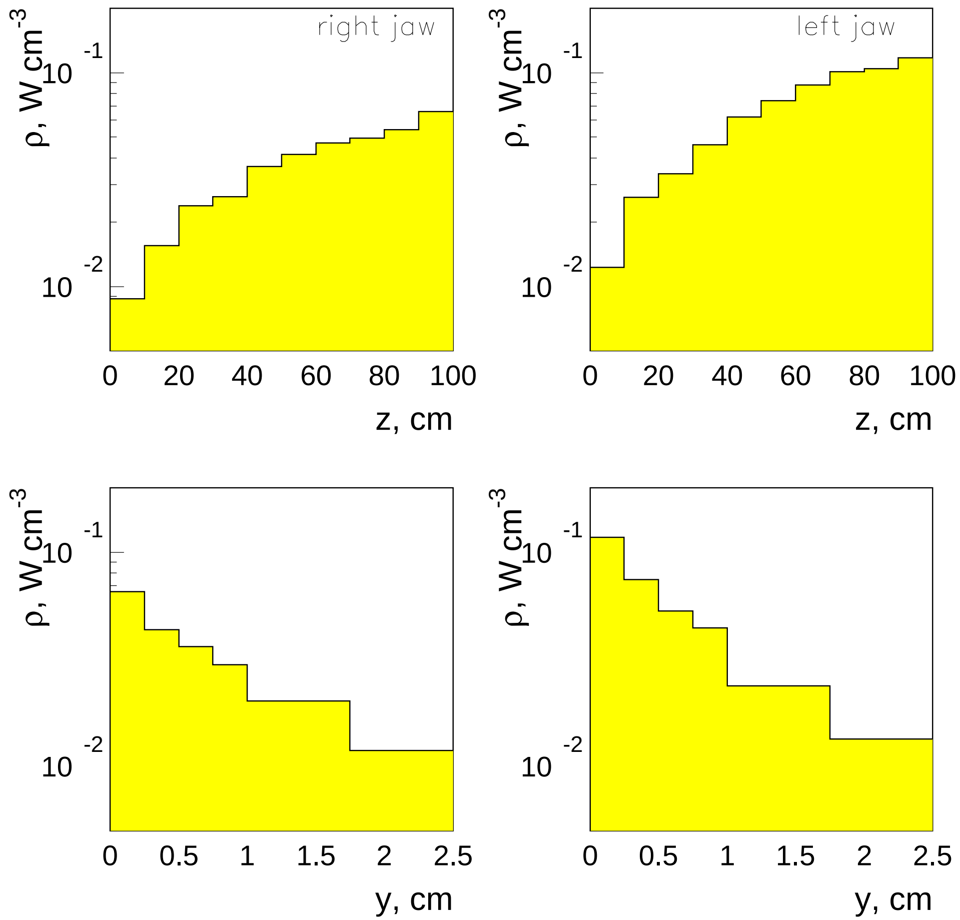
Power deposition density $p(0, y, z)$ corresponds to a peak loss rate of $3 \cdot 10^9$ protons/s at collision energy

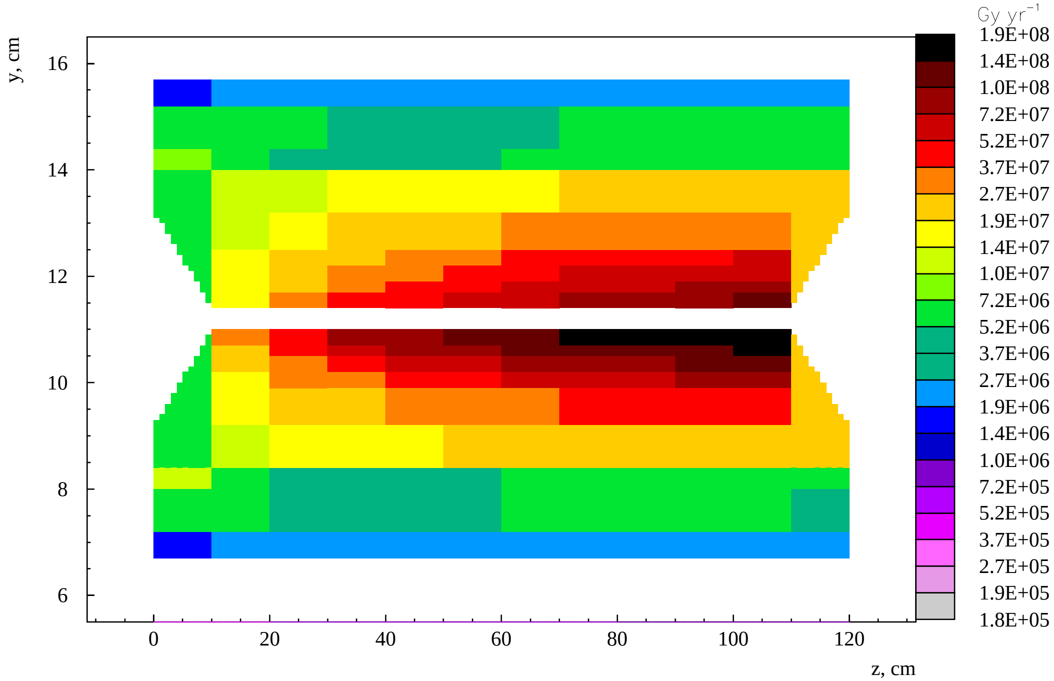


Power deposition density in jaws corresponds to a peak loss rate of $3 \cdot 10^9$ protons/s at collision energy

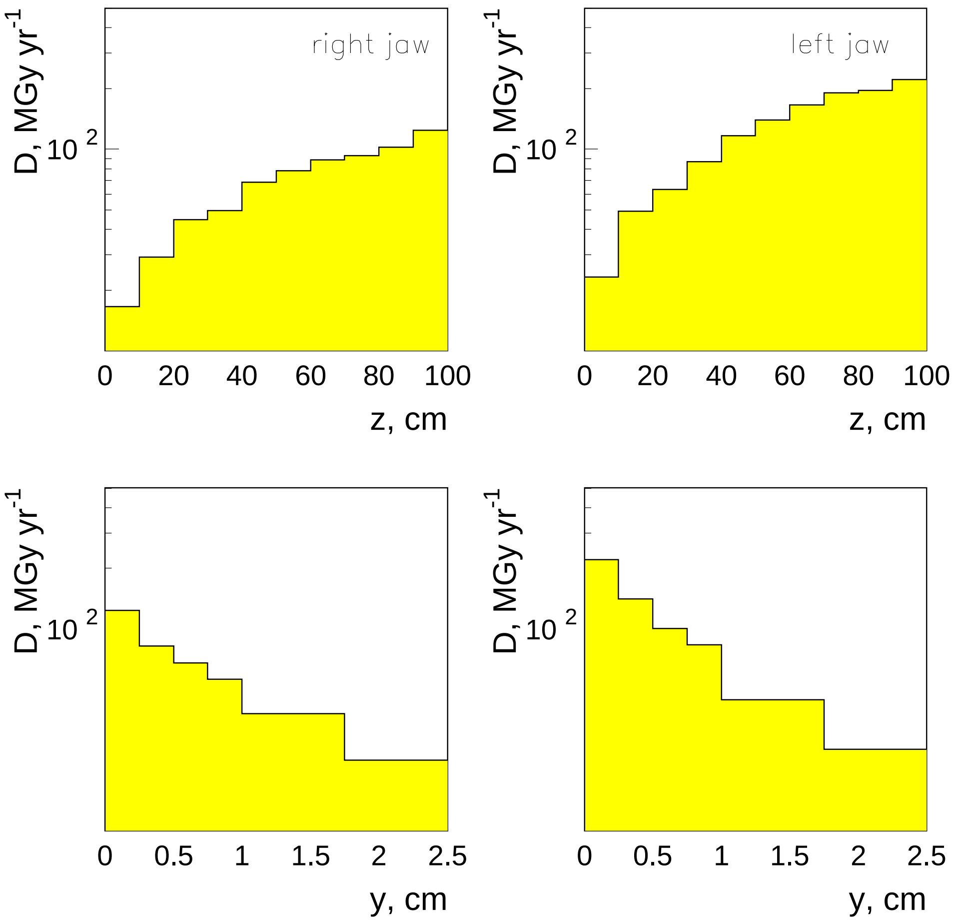


Absorbed dose in the TCS4

Absorbed dose $D(0, y, z)$ (Gy yr^{-1}) corresponds to 10^{16} 7 TeV protons lost in momentum cleaning collimators of each Ring



Absorbed dose (MGy yr^{-1}) corresponds to 10^{16} 7 TeV protons lost in momentum cleaning collimators of each Ring



Power deposition in the TCLV

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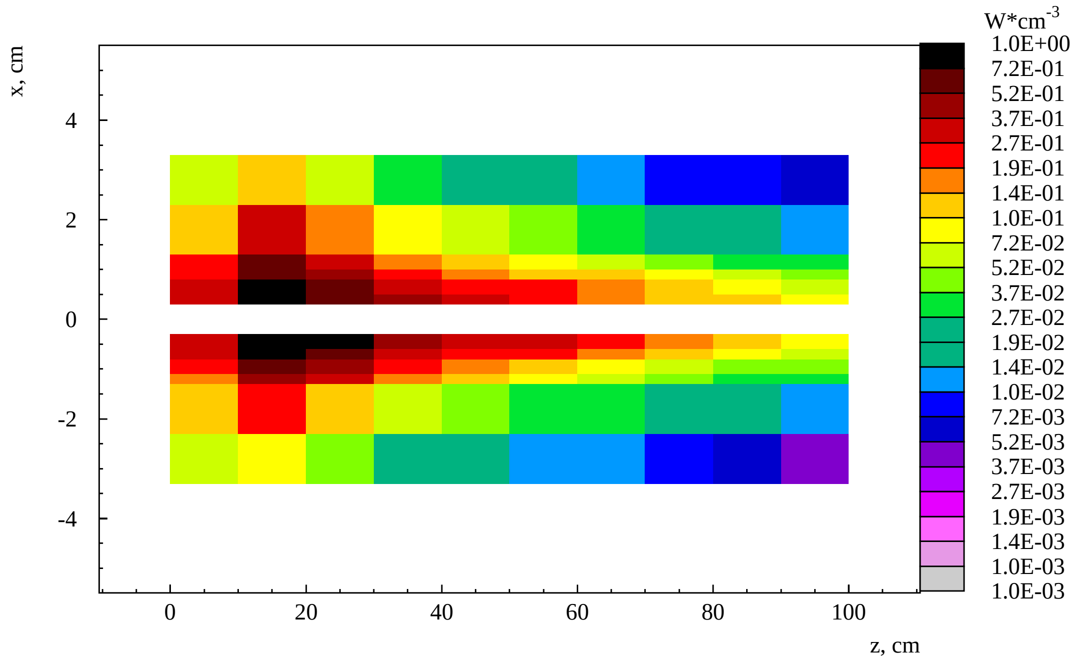
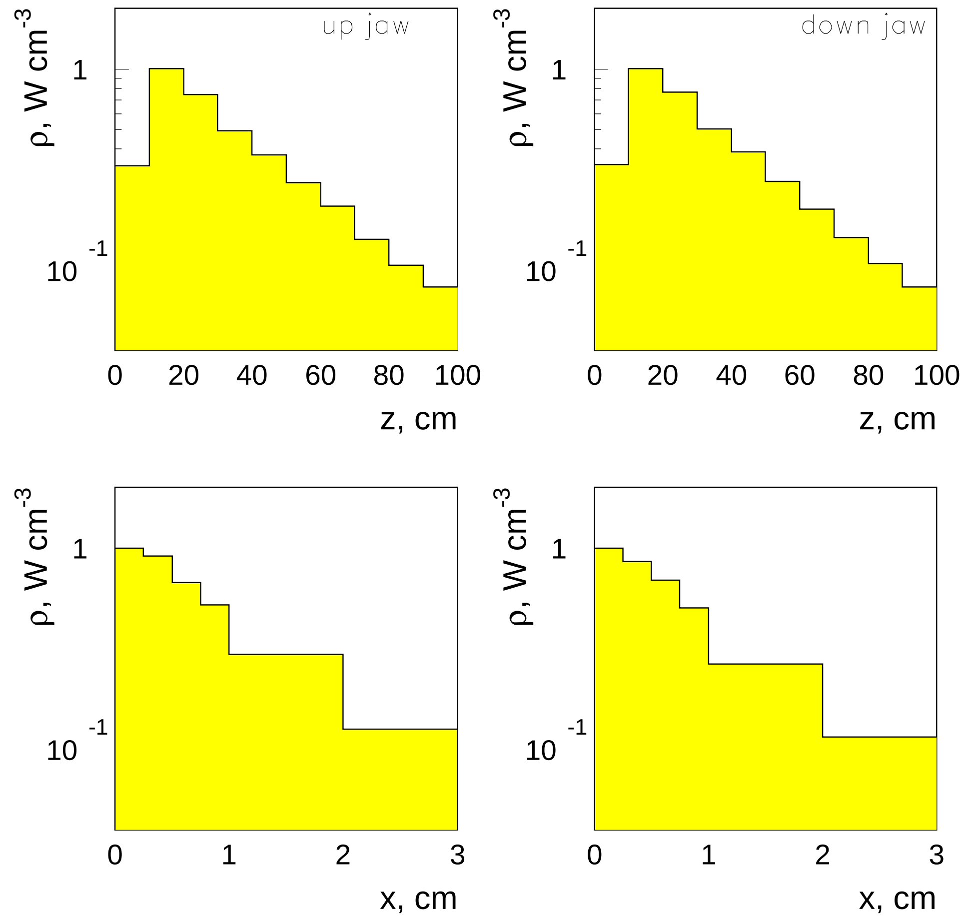
Power deposition density $p(x, 11.2, z)$ corresponds to a peak loss rate of $3 \cdot 10^9$ protons/s at collision energy



Power deposition density in jaws corresponds to a peak loss rate of $3 \cdot 10^9$ protons/s at collision energy



Absorbed dose in the TCLV

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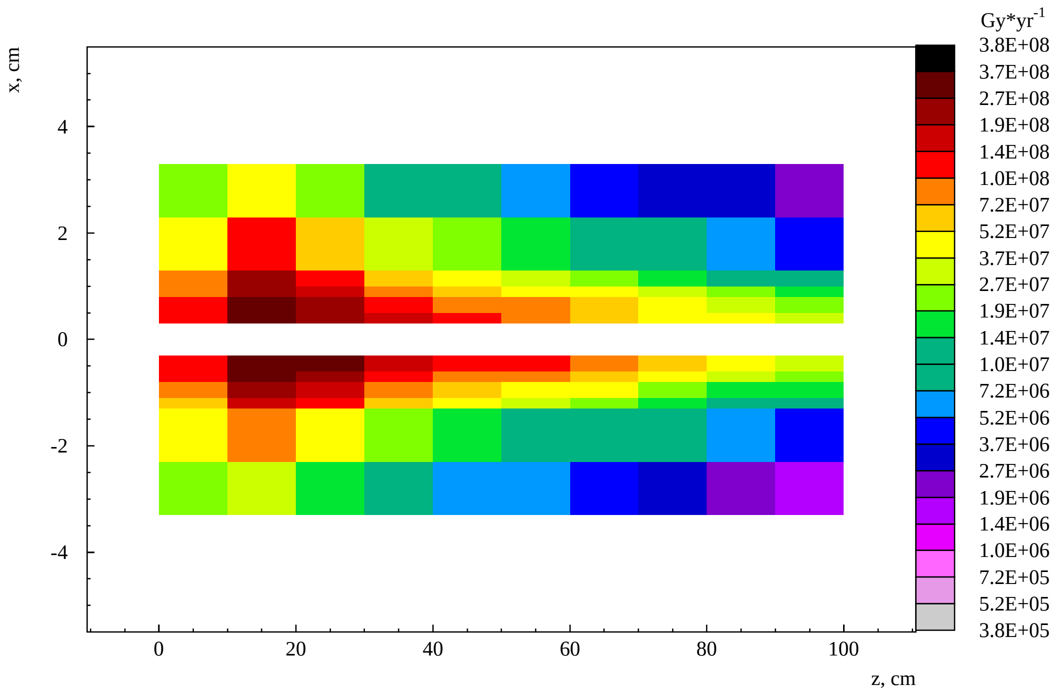
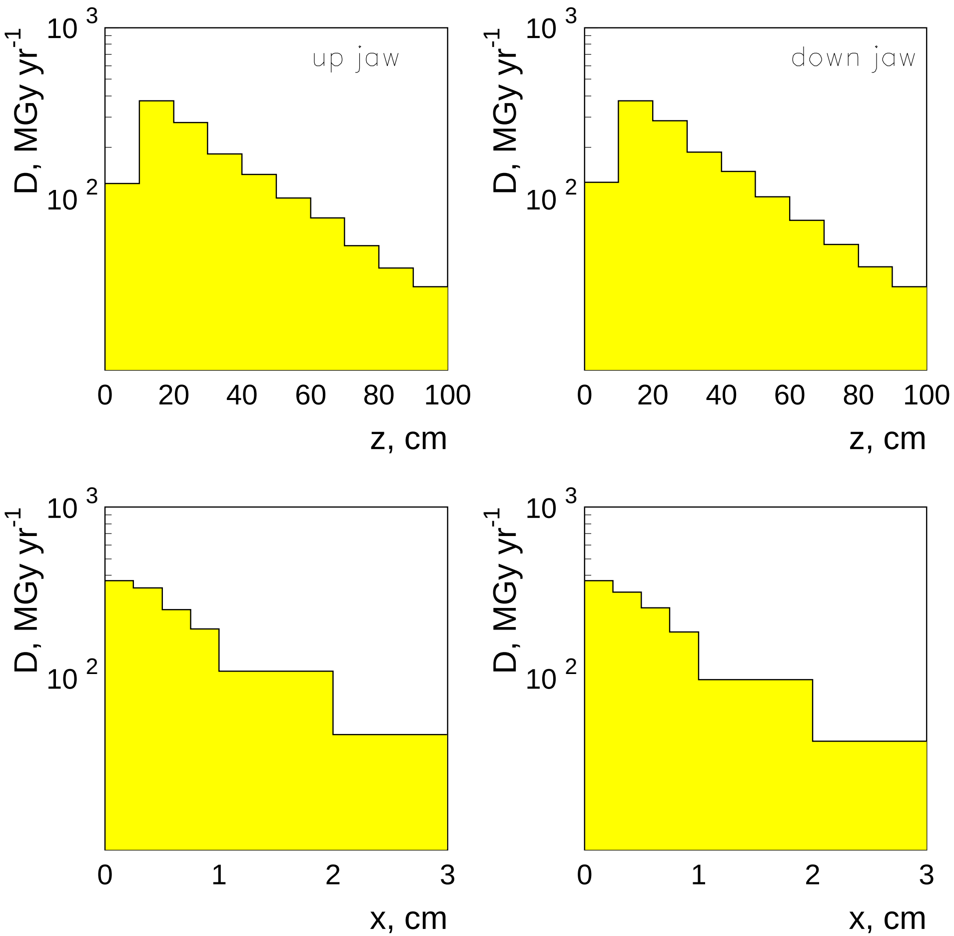
Absorbed dose $D(x, 11.2, z)$ (Gy yr^{-1}) corresponds to 10^{16} 7 TeV protons lost in momentum cleaning collimators of each Ring.



Absorbed dose (MGy yr^{-1}) corresponds to 10^{16} 7 TeV protons lost in momentum cleaning collimators of each Ring.



Power deposition in beam pipes

Power deposition corresponds to a peak loss rate of $3 \cdot 10^9$ protons/s at collision energy

Elements	Power, W	Elements	Power, W	Elements	Power, W
MBW.F4L	< 0.0001	MQWB. 5L	18.5	MQWA.A5R	0.2
MBW.E4L	< 0.0001	MQWA.B5L	11.0	MQWA.B5R	0.2
MBW.D4L	< 0.0001	MQWA.A5L	10.2	MQWB. 5R	0.3
MBW.C3L	60.0	MQWA.E4L	4.7	MQWA.C5R	0.4
MBW.B3L	55.0	MQWA.D4L	1.5	MQWA.D5R	0.4
MBW.A3L	46.0	MQWA.C4L	1.1	MQWA.E5R	0.5
MBW.A3R	0.13	MQWB. 4L	0.9	MCBWV.Q5L	1.5
MBW.B3R	0.25	MQWA.B4L	0.8	MCBWH.Q5L	1.3
MBW.C3R	0.42	MQWA.A4L	0.8	MCBWV.Q4L	0.2
MBW.D4R	0.3	MQWA.A4R	0.7	MCBWH.Q4L	0.14
MBW.E4R	0.14	MQWA.B4R	0.3	MCBWV.Q4R	0.27
MBW.F4R	0.13	MQWB. 4R	0.2	MCBWH.Q4R	0.3
MQWA.E5L	40.0	MQWA.C4R	0.2	MCBWV.Q5R	0.05
MQWA.D5L	30.0	MQWA.D4R	0.2	MCBWH.Q5R	0.05
MQWA.C5L	37.0	MQWA.E4R	23.0		

Power deposition in beam pipes

- Beam pipes in long drifts:
  - TCP1-PasAbs – 64.4 W
  - MCBWH.Q5L-TCS4.2 – 20 W
  - TCS4-TCLV – 65.2 W
- Elliptical beam pipes between MBW modules:
  - MBW.C3L-MBW.B3L – 9 W
  - MBW.A3L-BPMW.B5L – 21 W
- Elliptical beam pipes between MQW and MCBW modules:
  - MQWA.D5L-TCS1 – 7 W
  - TCS1-MQWA.C5L – 9 W

Summary

- Passive Absorbers are necessary to protect coils of dipoles MBW
- Without Passive Absorbers doses (hottest element MBW.C3L - 14 MGy/year) to coils of D3 are dangerously close to the maximum allowed dose of 50 MGy
- Passive absorbers for D3 modules allow to reduce doses to coils in 5 times, up to 2.7 MGy.
- Total power dissipated in active absorbers (TCL) is 1.5 times higher than in TCP and TCSs. Power dissipated in TCLV (max of all TCLs) is equal to 206.9 W, in TCS4 (max of all TCSs) – 77.8 W.