CERN

MBW-MQW in the LHC

Considerations on expected life and available options

Presented by P. Fessia

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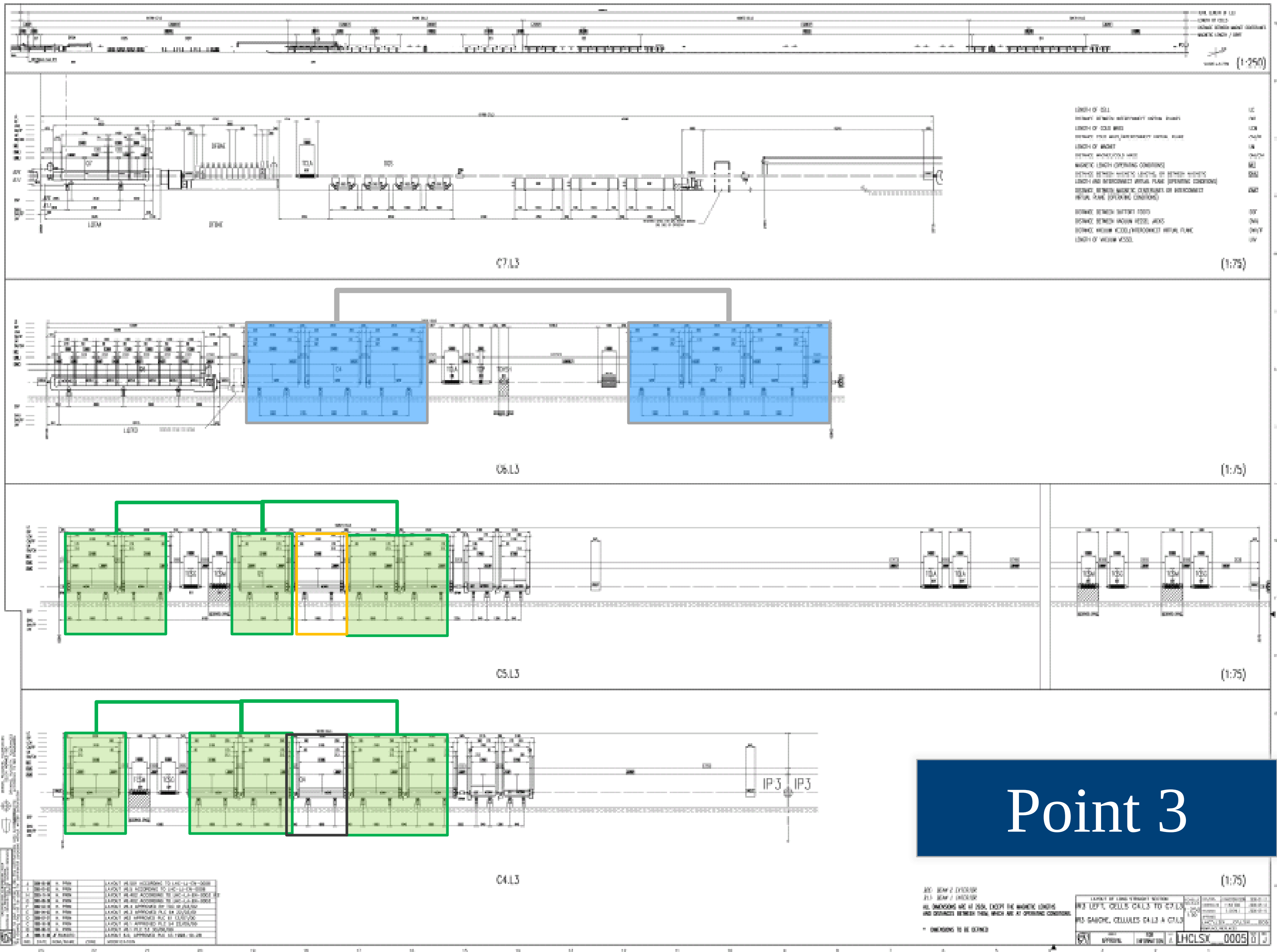
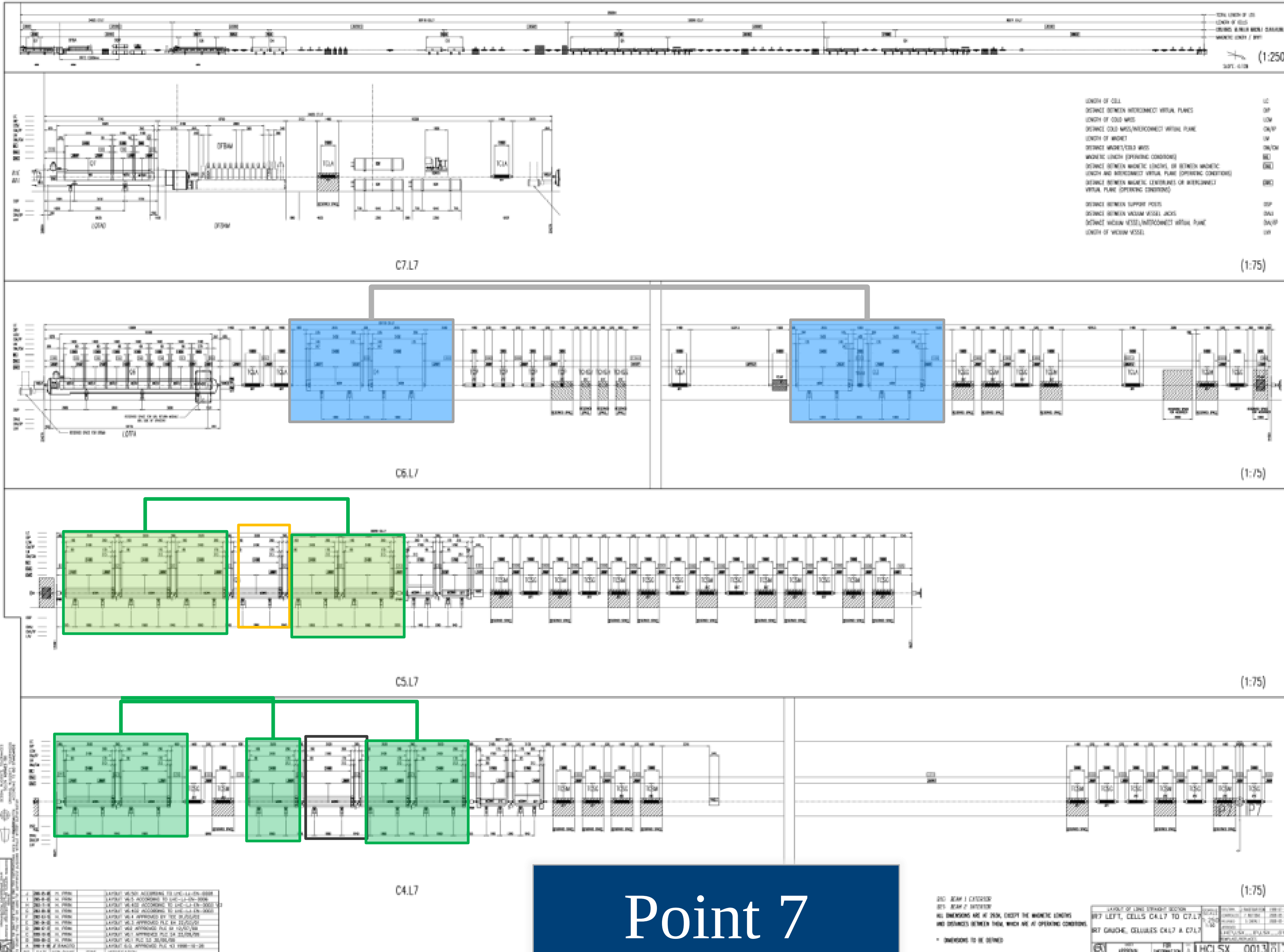
Magnetic Measurement team: M. Buzio

Summary

- The magnets and their circuits
- The expected dose
- Magnet radiation resistance
- Protective actions
  - Shielding
  - Optics changes
- The present “final” picture
- Next steps


(1:250)
C7.L3
(1:75)
C6.L3
(1:75)
C5.L3
(1:75)
IP3
IP3
Point 3
C4.L3
(1:75)
LHCLSX__0005



Point 7

MQW point 7 and 3

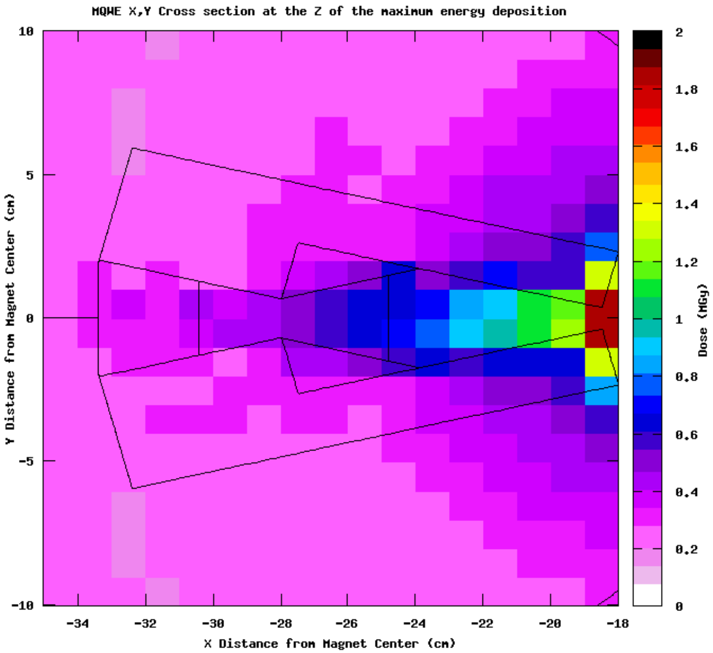
Characteristics	RQ4. LR7	RQ5. LR7	RQT4 .L7	RQT5 .L7	RQT4 .R7	RQT5 .R7	RQ4. LR3	RQ5. LR3	RQT4 .L3	RQT5.L 3	RQT4.R 3	RQT5.R3
I ultimate (from layout database) [A]	**810**	**810**	**600**	**600**	**600**	**600**	**810**	**810**	**600**	**600**	**600**	**600**
Voltage I ultimate [V]	381	383	29	31	27	29	451	452	38	34	42	39
I 7 TeV (Fidel report) [A]	**598**	**610**	**151**	**17**	**151**	**17**	**561**	**593**	**313**	**441**	**313**	**441**
Voltage I 7 TeV [V]	282	289	8	2	8	2	313	331	20	31	22	29
Number magnet in series in circuit	10	10	1	1	1	1	10	10	1	1	1	1
Turn/magnet	171											
Estimated ultimate inter-turn voltage [V]	0.22	0.22	0.17	0.18	0.16	0.17	0.26	0.26	0.22	0.2	0.25	0.23
Estimated inter-turn voltage at 7 TeV [V]	0.16	0.17	0.05	0.01	0.05	0.01	0.18	0.19	0.12	0.18	0.13	0.17
Estimated inter layer voltage	Same as inter turn											
Insulation thickness inter turn	2X(2X0.25) mm=1 mm glass tape											
Circuit energy ultimate [Kj]	154	164	9	9	9	9	154	164	9	9	9	9
Circuit energy 7 TeV [Kj]	84	93	0.6	0.01	0.6	0.01	74	88	2.5	5	2.5	5
Ground insulation	1X(2X0.25) mm+3X(2X0.25)=2 mm											
Resin used	EPN1138 42%+ GY 6004 42% + CY 221 16% + HY 905 100 %+ 30ml DY 073											
Dielectric resin	> 20 kV/mm											

MBW point 7 and 3

Characteristics	RD34.LR7	RD34.LR3
I ultimate [A] (layout database)	**810**	**810**
Voltage I ultimate [V]	440	700
I 7 TeV (Fidel report)	**643**	**643**
Voltage I 7 TeV	350	556
Number magnet in series in circuit	8	12
Turn/magnet	84	
Estimated ultimate inter-turn voltage [V]	0.65	0.7
Estimated inter-turn voltage 7 TeV [V]	0.52	0.55
Estimated ultimate inter layer voltage [V]	9.2	9.7
Estimated inter layer voltage 7 TeV [V]	7.2	7.8
Circuit energy ultimate [Kj]	472	793
Circuit energy 7 TeV [Kj]	297	500
Insulation inter turn [mm]	2X(2X0.15)=0.6 glass tape	
Insulation inter layer [mm]	2X(2X0.15)+2X(2X0.15)+1(glass cloth) =1.6 glass tape	
Ground insulation	2X(2X0.15)+(0.15X6)=1.8 glass tape	
Resin used	EPC-1: resin ED-16 100 Hardener MA 2.28 □ K Plasticizer MGF-9 20 TEa accelerant 0.5	

DOSE ESTIMATION

nap



Dose (MGy)

Dose (MGy)

Normalization: 1.15 10 p (30-50 fb).

Computations with E 6.5 TeV relaxed collimator settings

Relationship dose vs. luminosity and point 7 vs. point 3

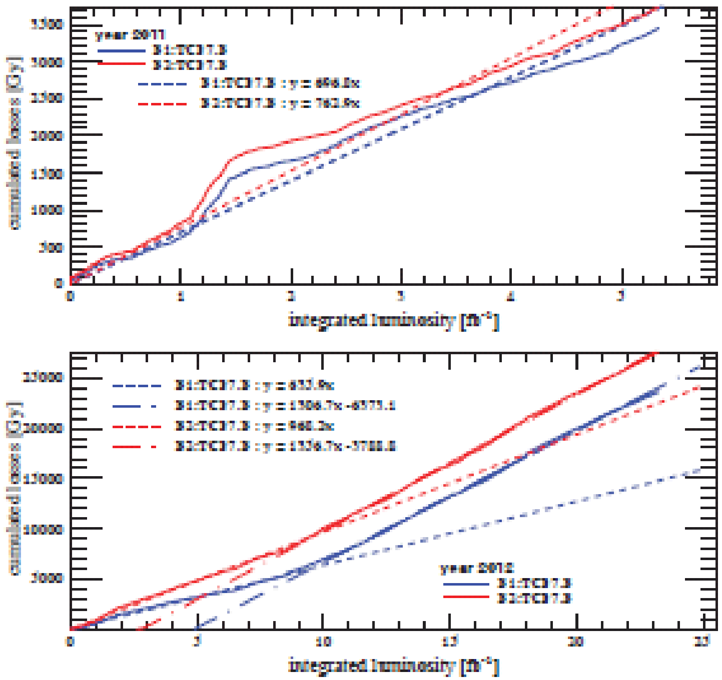


Figure 2: Cumulated losses at the BLM located dov stream the primary skew collimator in IR7 during 2((top) and 2012 (bottom) as a function of the LHC del ered integrated luminosity to ATLAS.

2

Table 2: Result from the linear fit to the cumulated losses during each fill in 2011 and 2012 as a function of the LHC delivered integrated luminosity to ATLAS.

Fit results (slope) [Gy fb]	IR7		IR3	
	B1	**B2**	**B1**	**B2**
2011	696.8	762.9	196.7	115.1
2012 before TS2	635.9	968.2	26.8	12.6
2012 after TS2	1306.7	1356.7	54.7	30.1

Worst P3 196.7/(697+196.7)=0.23

Worst P1357/(1357+30)=0.97

ESTIMATE OF WARM MAGNETS LIFETIME IN THE BETATRON AND MOMENTUM CLEANING INSERTIONS OF THE LHC

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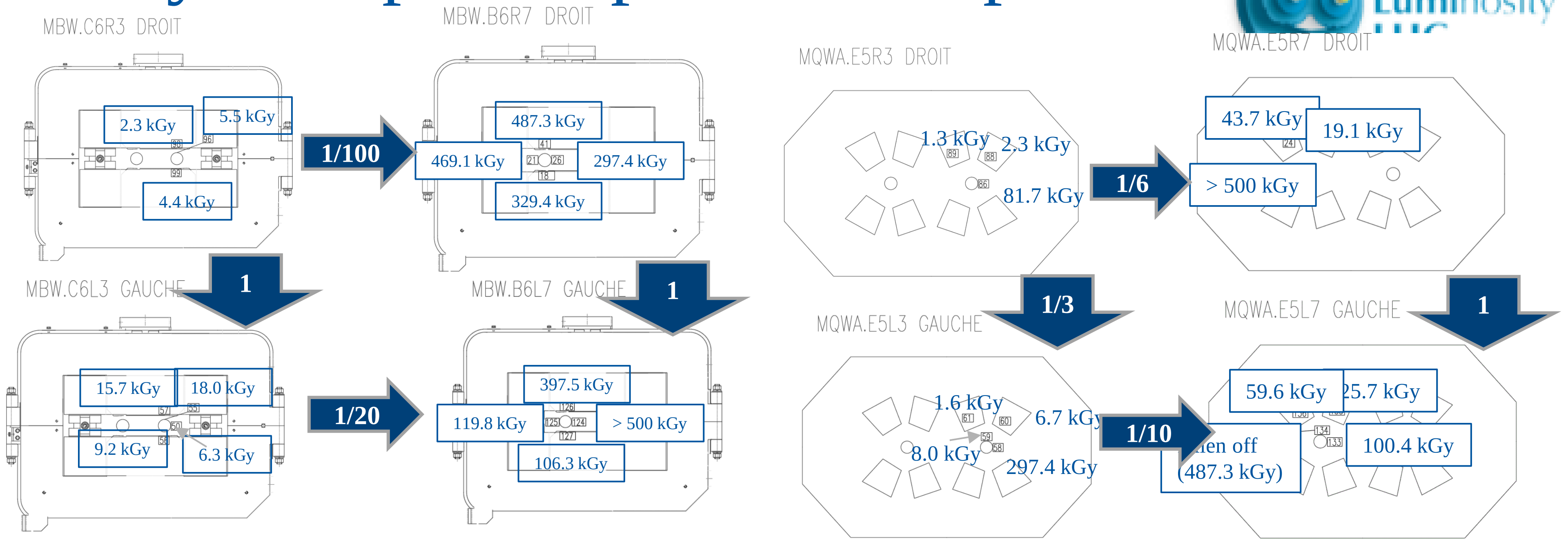
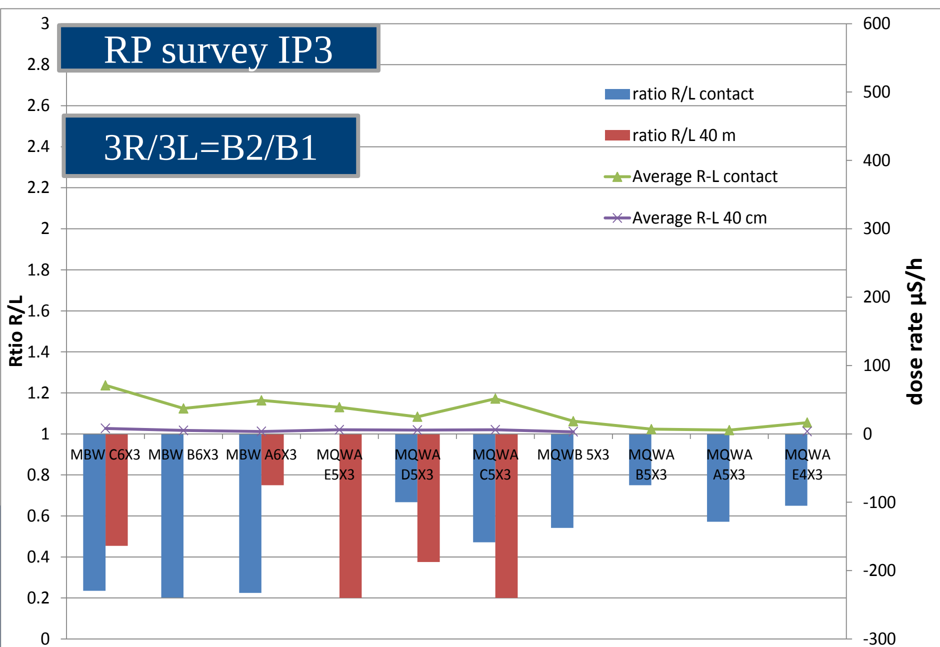
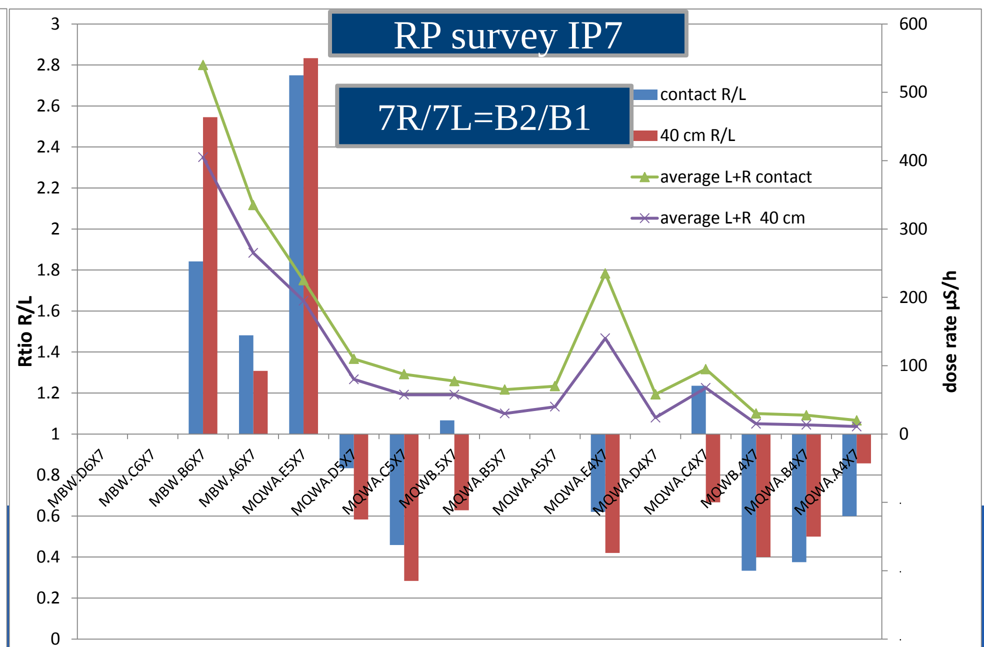
Analysis exp. data point 3 and point 7







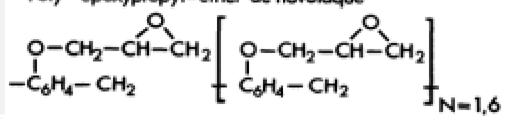
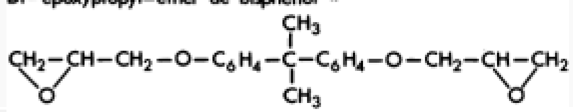
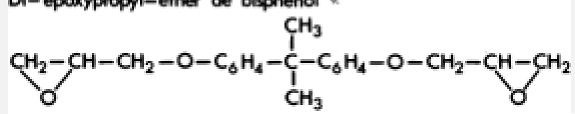
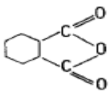
Dose evaluation process for each point

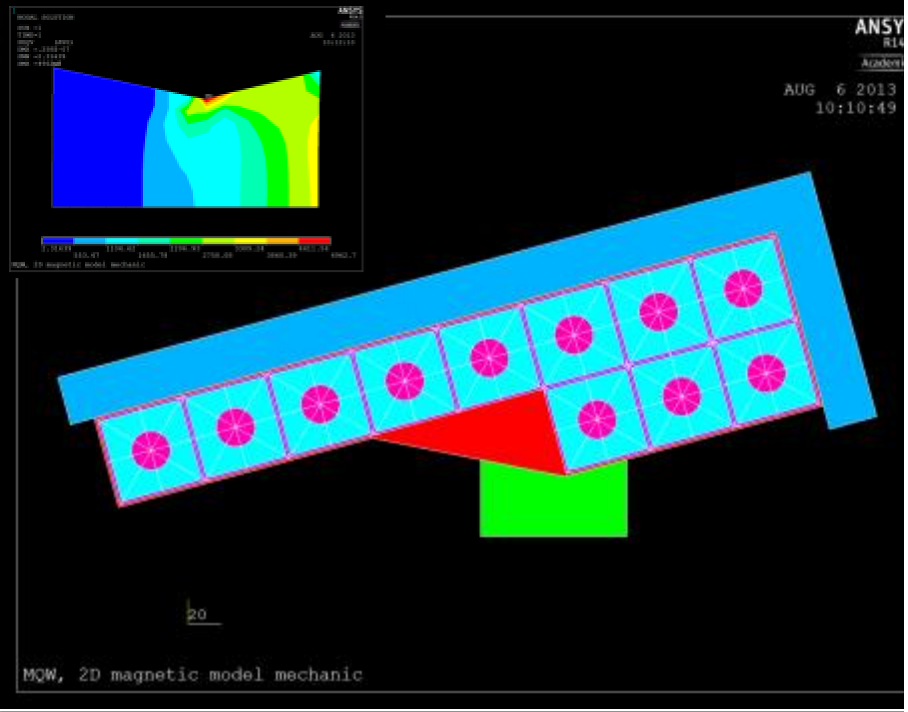
IP 3	Process	IP 7
	Fluka model results with 1.15 10^{16} p lost **per interaction point** E 7 TeV.	
1	Scale to the dosimeter readings as benchmark (TS2)	1
150 fb^{-1} ->3 350 fb^{-1} -> 7 3000 fb^{-1} ->60	Scale to the LS1, LS2 LS3 and HL-LHC integrated luminosity	150 fb^{-1} ->3 350 fb^{-1} -> 7 3000 fb^{-1} ->60
2	Scale to the increase slope dose/luminosity after TS2	2
0.23	Normalise to a total losses (adding the 2 points) of 1.15 10^{16}	0.98->1
L=1 R=0.5	Scale to the Left and Right using RP survey	L=1 R= (0.4->2)

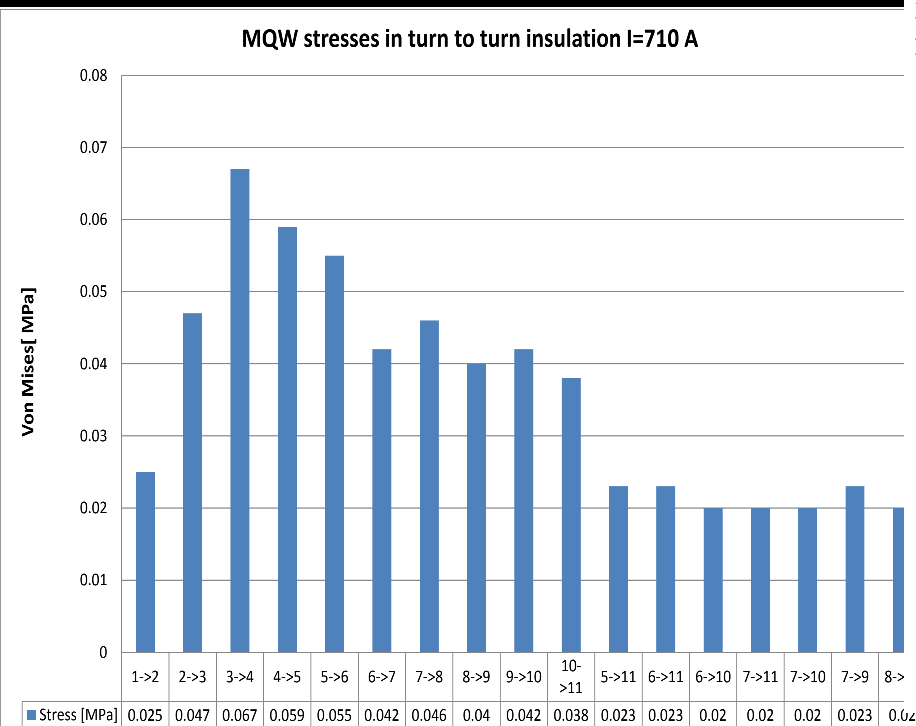
MAGNET RADIATION RESISTANCE ESTIMATION

MQW coil resins

Resin used					
component	EPN1138	GY 6004	CY 221	HY 905	30ml DY 073
ppw	50	50	20	120	0.03

EPN 1138	Novolac 
GY 6004	DGEBA 
CY 221	DGEBA 
HY 905	HY 905 (CIBA-GEIGY) Acid anhydride hardener, liquid, modified Hexahydrophthalic anhydride (see HT 907) HT 907 (CIBA-GEIGY) Acid anhydride hardener, solid, unmodified Hexahydrophthalic anhydride  HPA
DY 073	flexibilizer





CERN 98–01/A3/E

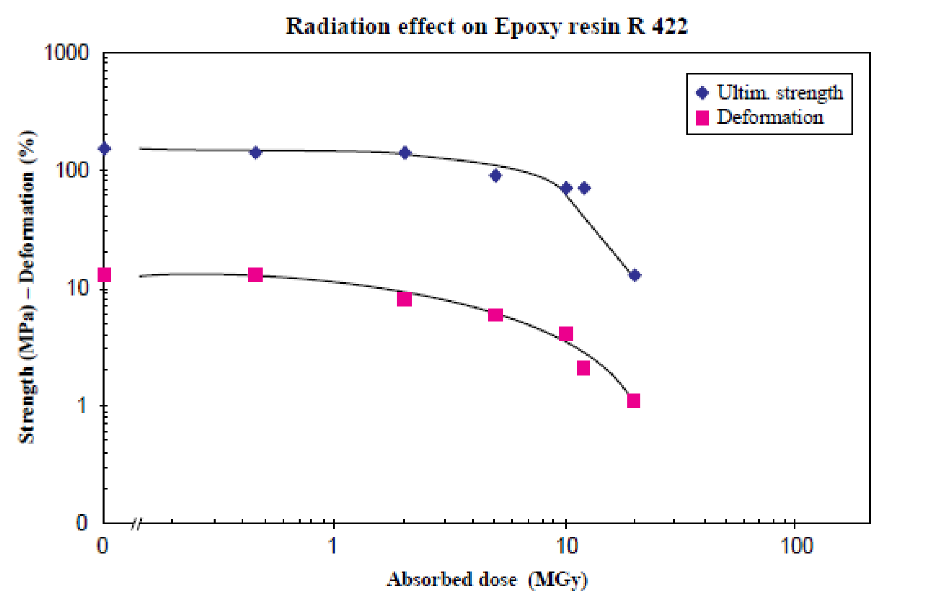
Material:	**Epoxy resin**	TIS No. **R 422**
Type	**MY 745 (50) + EPN 1138 (50) + CY 221 (20) + HY 905 (120) + DY 073 (0.3)**	
Supplier:	**Ciba-Geigy**	UL 94: n.m.
Remarks:	used for the ISR dipoles	LOI:

Radiation test results according to IEC Standard 544 (and ISO 178)

Dose rate (kGy/h)	Dose (MGy)	Ultim. strength (MPa)	Deformation ε (%)	Modulus (GPa)
0	0	153±3	13.1±1.9	3.80±0.03
0.2	0.5	142±1	12.9±0.3	3.50±0.02
0.2	2.0	140±1	7.9±0.3	3.50±0.02
180	5	93±2	6.1±0.3	4.00±0.03
180	10	73±3	4.2±0.2	4.10±0.04
0.5	12	71±6	2.1±0.2	3.7±0.1
180	20	13±1	1.1±0.1	3.40±0.04

Radiation index (RI) = 6.9 if strength is the critical property

Radiation index (RI) = 6.6 if deformation is the critical property



EPN 1138

No.	Material and Supplier	Dose (Gy)	Ultimate flex. strength S (N/mm²)	Deflexion at break D (mm)	Modulus of elasticity M (N/mm²)
89	EPN 1138(50) + MY 745(50) + + CY 221(20) + HY 905(120) + + DY 063(0.3)	0	131.5 ± 24.5	9.3 ± 3.2	$3.55 \pm 0.15 \times 10^3$
	24 h 120 °C	6×10^6	92.2 ± 6.9	4.6 ± 0.3	$3.75 \pm 0.13 \times 10^3$
	Type ISR	1×10^7	68.7 ± 22.6	3.5 ± 1.2	$3.56 \pm 0.07 \times 10^3$
		2×10^7	62.8 ± 13.7	3.0 ± 0.7	$3.88 \pm 0.08 \times 10^3$
	ALSTHOM	6×10^7	6.9 ± 0.3	0.7 ± 0.1	$1.90 \pm 0.24 \times 10^3$
123	EPN 1138(50) + MY 745(50) + + HY 905(103) + XB 2687(0.25)	0	118.7 ± 21.6	8.4 ± 3.1	$3.30 \pm 0.05 \times 10^3$
	24 h 120 °C	5×10^6	114.8 ± 21.6	9.8 ± 3.4	$3.34 \pm 0.12 \times 10^3$
		1×10^7	78.5 ± 8.8	4.3 ± 0.4	$3.45 \pm 0.13 \times 10^3$
	ALSTHOM	2×10^7	53.0 ± 6.9	2.8 ± 0.3	$3.51 \pm 0.06 \times 10^3$
203	EPN 1138(100) + HY 906(95) + + DY 062(0.5)	0	130.5 ± 19.6	8.7 ± 2.2	$3.52 \pm 0.05 \times 10^3$
	2.5 h 80 °C + 12 h 160 °C	5×10^6	115.8 ± 19.6	7.1 ± 1.8	$3.88 \pm 0.17 \times 10^3$
	CIBA-GEIGY	1×10^7	122.6 ± 7.8	7.2 ± 0.7	$3.95 \pm 0.04 \times 10^3$
297	EPN 1138(50) + MY 745(50) + + CY 221(20) + HY 905(120) + + XB 2687(0.3)	0	124.2 ± 24.5	12.4 ± 3.7	$3.73 \pm 0.25 \times 10^3$
	24 h 120 °C	5×10^6	91.9 ± 8.8	6.4 ± 0.6	$3.80 \pm 0.13 \times 10^3$
		1×10^7	68.9 ± 11.8	4.5 ± 0.9	$4.01 \pm 0.09 \times 10^3$
		2.5×10^7	13.7 ± 0.3	1.2 ± 0.4	$3.26 \pm 0.04 \times 10^3$
	CIBA-GEIGY	5×10^7	2.1 ± 0.0	0.7 ± 0.0	$5.27 \pm 0.00 \times 10^2$

CY 222 (similar to CY221)

No.	Material and Supplier	Dose (Gy)	Ultimate flex. strength S (N/mm²)	Deflexion at break D (mm)	Modulus of elasticity M (N/mm²)
103 (a)	CY 222 + HY 920	0	too flexible for testing		
	(Pure resin)	5×10^6			
		1×10^7			
		3×10^7	15.7 ± 2.0	5.4 ± 3.6	$8.04 \pm 1.32 \times 10^2$
	BBC Baden	5×10^7	12.8 ± 1.0	1.4 ± 0.3	$1.66 \pm 0.13 \times 10^3$

MY745 replaced by GY6004

No.	Material and Supplier	Dose (Gy)	Ultimate flex. strength S (N/mm²)	Deflexion at break D (mm)	Modulus of elasticity M (N/mm²)
240 (a)	MY 745(100) + HY 906(90) + + XB 2687(1.5) 12 h 125 °C CIBA-GEIGY	0	118.8 ± 10.0	6.5 ± 0.8	$3.64 \pm 0.07 \times 10^3$
298	MY 745(100) + HY 906(90) + + XB 2687(1.5)	0	100.4 ± 37.3	8.3 ± 4.0	$3.68 \pm 0.04 \times 10^3$
	5 h 110 °C + 16 h 125 °C	5×10^6	118.8 ± 32.4	11.2 ± 4.1	$3.65 \pm 0.12 \times 10^3$
		1×10^7	100.0 ± 44.1	7.0 ± 3.5	$4.08 \pm 0.10 \times 10^3$
		2.5×10^7	48.1 ± 17.7	2.9 ± 1.1	$4.20 \pm 0.21 \times 10^3$
	CIBA-GEIGY	5×10^7	13.7 ± 2.9	1.2 ± 0.4	$3.42 \pm 0.00 \times 10^3$
299	MY 745(100) + HY 906(90) + + XB 2687(1.5)	0	107.7 ± 20.6	7.9 ± 2.0	$3.84 \pm 0.15 \times 10^3$
	24 h 125 °C	5×10^6	114.9 ± 34.3	9.3 ± 3.3	$3.76 \pm 0.12 \times 10^3$
		1×10^7	68.7 ± 21.6	4.4 ± 1.3	$4.02 \pm 0.16 \times 10^3$
		2.5×10^7	36.3 ± 8.8	2.2 ± 0.5	$4.25 \pm 0.24 \times 10^3$
	CIBA-GEIGY	5×10^7	8.8 ± 1.96	0.6 ± 0.2	$3.21 \pm 0.00 \times 10^3$

Filler contribution

Resins	Hardeners	Additives	Filler	Composition (p.p.)	Fig	Dose for 50% flex. (MGy)	Dose Range (MGy)
DGEBA	MDA		Papier	100-27-200	5.14	1.3	1 - 2
DGEBA	MDA		Silice	100-27-200	5.14	10	10 - 15
DGEBA	MDA		Silice	100-27-200	5.18	11.4	
DGEBA	MDA		Silice (5 micron)	100-27-20	5.16	14.8	
DGEBA	MDA		Silice (20 micron)	100-27-20	5.16	14.8	
DGEBA	MDA		Silice (40 micron)	100-27-20	5.16	14.6	
DGEBA	MDA		Silice (40 micron)	100-27-200	5.17	12.1	
DGEBA	HPA	BDMA	Silice (40 micron)	100-80-2-200	5.17	<10	<10
DGEBA	MDA		Aérosil + Sulphate de Barium	100-27-2-150	5.14	15.8	15
DGEBA	MDA		Magnésie	100-27-120	5.14	18	18
DGEBA	MDA		Graphite	100-27-60	4.6	26.8	25 - 30
DGEBA	MDA		Graphite	100-27-60	5.14	30.5	
(DGEBA	MDA		Alumine	100-27-220	4.7	23.5)	**20 - 50**
DGEBA	MDA		Alumine	100-27-220	5.14	51.7	
DGEBA	MDA		Alumine	100-27-100	5.15	20.6	
DGEBA	MDA		Alumine	100-27-220	5.15	42.5	
DGEBA	**MDA**		**Fibre de verre**	**100-27-50**	**5.19**	**82**	**80 - 100**
DGEBA	**MDA**		**Fibre de verre**	**100-27-60**	**5.18**	**100**	
EPN	**MDA**		**Fibre de verre**	**100-29-50**	**5.19**	**>100**	**>100**
TGMD	**MDA**		**Fibre de silice**	**100-41-50**	**5.20**	**>100**	**>100**
TGMD	**DADPS**		**Fibre de silice**	**100-40-50**	**5.20**	**>100**	

2 Categories of fillers:
1. Powder fillers
2. Glass/Silice fibers

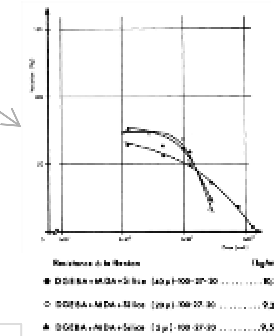
Paper [cellulose $(C_6H_{10}O_5)_n$]
→ Strong decrease of radio-resistance

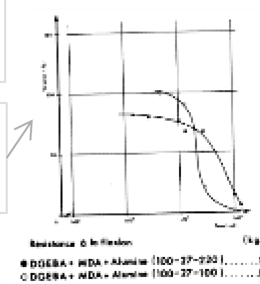
The bigger the powder, the more radio-resistant

Hardener choice not influenced by filler

High r.-resistance for Graphite and Alumina

The more fillers, the more radio-resistant





Best Radio-Resistant materials are obtain with Glass/**Silice** (influence of boron) fibers and aromatic resins (**Novolac** and **glycidyl-amine**)

Legend

Resin
- Linear aliphatic
- Cycloaliphatic
- Aromatic

Hardener
- Aliphatic Amine
- Aromatic Amine
- Alicyclic Anhydride
- Aromatic Anhydride

EPN 1138 with filler

CIBA-GEIGY	DOW	SHELL
EPN 1138	DEN 438	EPIKOTE (EP) 154
EPN 1139	DEN 431	

No.	Material and Supplier	Dose (Gy)	Ultimate flex. strength S (N/mm^2)	Deflexion at break D (mm)	Modulus of elasticity M (N/mm^2)
89	EPN 1138(50) + MY 745(50) + + CY 221(20) + HY 905(120) + + DY 063(0.3) 24 h 120 °C Type ISR ALSTHOM	0	131.5 ± 24.5	9.3 ± 3.2	$3.55 \pm 0.15 \times 10^3$
		6×10^6	92.2 ± 6.9	4.6 ± 0.3	$3.75 \pm 0.13 \times 10^3$
		1×10^7	68.7 ± 22.6	3.5 ± 1.2	$3.56 \pm 0.07 \times 10^3$
		2×10^7	62.8 ± 13.7	3.0 ± 0.7	$3.88 \pm 0.08 \times 10^3$
		6×10^7	6.9 ± 0.3	0.7 ± 0.1	$1.90 \pm 0.24 \times 10^3$
94	EPIKOTE 154 + MNA + glass tape MICAFIL	0	441.4 ± 18.6	5.5 ± 0.6	$1.85 \pm 0.10 \times 10^4$
		5×10^6	394.4 ± 12.7	5.2 ± 0.5	$1.77 \pm 0.06 \times 10^4$
		1×10^7	270.8 ± 44.2	3.6 ± 0.9	$1.82 \pm 0.10 \times 10^4$
		2×10^7	308.0 ± 21.6	4.1 ± 0.3	$1.85 \pm 0.11 \times 10^4$
		5×10^7	234.5 ± 3.9	3.0 ± 0.2	$1.95 \pm 0.16 \times 10^4$

CY 222 (similar to CY221) with filler

No.	Material and Supplier	Dose (Gy)	Ultimate flex. strength S (N/mm^2)	Deflexion at break D (mm)	Modulus of elasticity M (N/mm^2)
103 (a)	CY 222 + HY 920 (Pure resin) BBC Baden	0	too flexible for testing		
		5×10^6			
		1×10^7			
		3×10^7	15.7 ± 2.0	5.4 ± 3.6	$8.04 \pm 1.32 \times 10^2$
		5×10^7	12.8 ± 1.0	1.4 ± 0.3	$1.66 \pm 0.13 \times 10^3$
104	CY 222 + HY 920 + 70% glass (cut ‖ to fibre) BBC Baden	0	88.3 ± 8.8		$6.87 \pm 1.31 \times 10^3$
		1×10^7	114.8 ± 4.9		$1.02 \pm 0.09 \times 10^4$
		3×10^7	89.3 ± 6.9		$8.34 \pm 0.46 \times 10^3$
		6×10^7	69.7 ± 3.9		$8.44 \pm 0.50 \times 10^3$
		1×10^8	61.8 ± 6.9	3.8 ± 3.5	$6.07 \pm 2.45 \times 10^3$

MY745 replaced by GY6004 with filler

No.	Material and Supplier	Dose (Gy)	Ultimate flex. strength S	Deflexion at break D	Modulus of elasticity M
232					
240 (a)					
298					
299	24 h 125 °C CIBA-GEIGY	1×10^7	68.7 ± 21.6	4.4 ± 1.3	$4.02 \pm 0.16 \times 10^3$
		2.5×10^7	36.3 ± 8.8	2.2 ± 0.5	$4.25 \pm 0.24 \times 10^3$
		5×10^7	8.8 ± 1.96	0.6 ± 0.2	$3.21 \pm 0.00 \times 10^3$

Other DGBA with filler

No.	Material and Supplier	Dose (Gy)	Ultimate flex. strength S (N/mm^2)	Deflexion at break D (mm)	Modulus of elasticity M (N/mm^2)
					$\times 10^3$
					$\times 10^3$
					$\times 10^3$
					$\times 10^3$
					$\times 10^3$
					$\times 10^4$
					$\times 10^4$
					$\times 10^4$
					$\times 10^4$
176	Magnet coil resin Orlitherm® reinforced with glass woven tape type 2 with a special silane finish 12 h 165 °C BBC Baden	0	450.3 ± 24.5	5.2 ± 0.3	$1.64 \pm 0.07 \times 10^4$
		1×10^7	419.9 ± 18.6	5.0 ± 0.1	$1.62 \pm 0.05 \times 10^4$
		5×10^7	387.5 ± 55.9	5.2 ± 0.5	$1.61 \pm 0.01 \times 10^4$
		1×10^8	281.5 ± 28.5	4.9 ± 0.3	$1.44 \pm 0.01 \times 10^4$

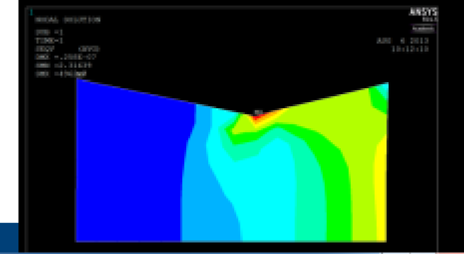
MQW

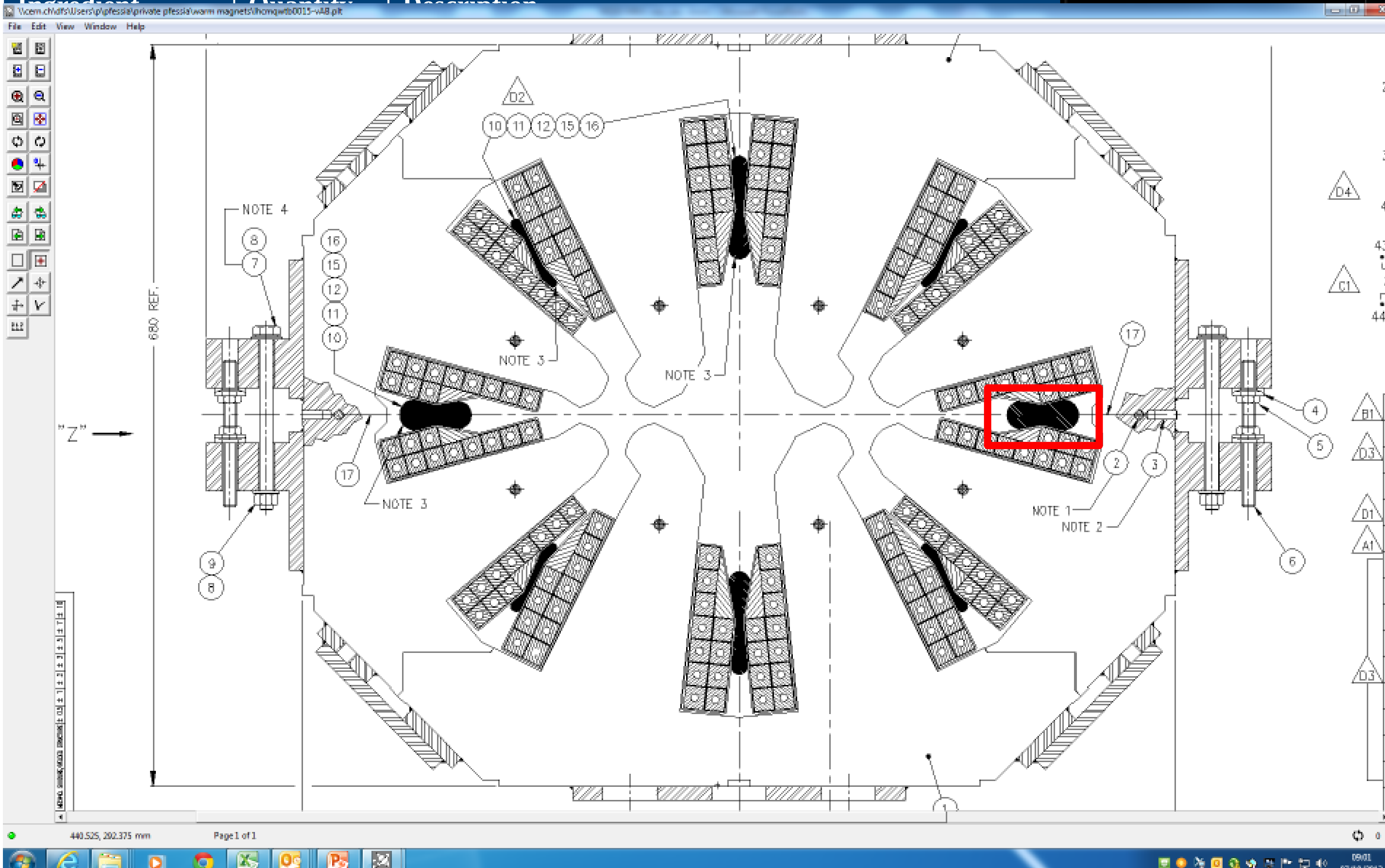
- The pure resin mix used shall keep substantial mechanical properties at least till 15-20 MGy
- Presence of glass fibre shall increase the substantial mechanical properties at least to 40-50 MGy

Spacers resins

- Composition
  - HD polyethylene pipes filled with

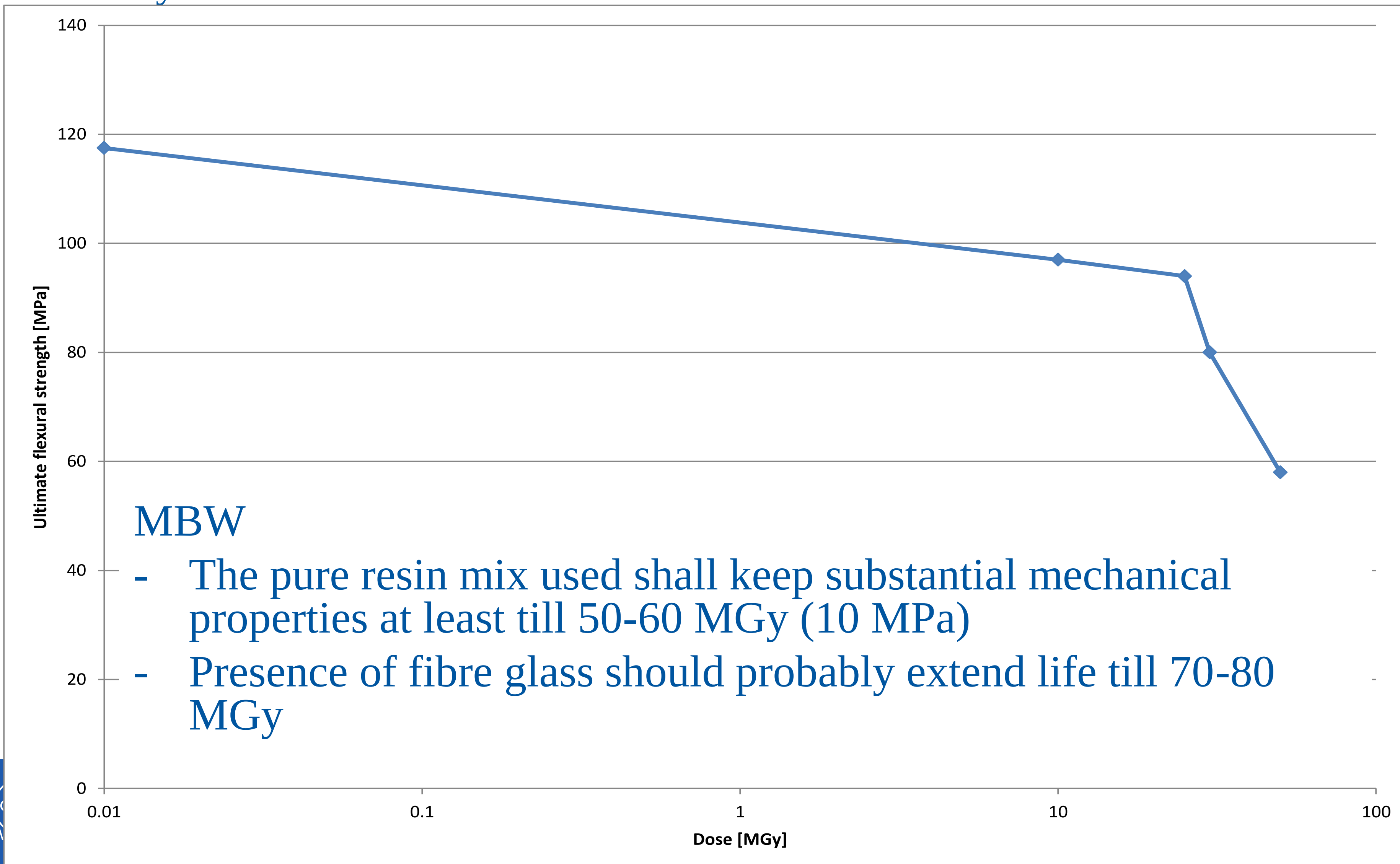
Ingredient	Quantity	Description





MBW BINP used resin.

We looked at molecule and there is good indication that it should radiation hard as witnessed by the tests and we assume stresses of the order of 10 MPa



MBW

- The pure resin mix used shall keep substantial mechanical properties at least till 50-60 MGy (10 MPa)
- Presence of fibre glass should probably extend life till 70-80 MGy

Point 3 and 7 coil magnet damage estimation

High Luminosity LHC

IP 3	Dose [MGy] for integrated luminosity 150 fb^-1		Dose [MGy] for integrated luminosityy350 fb^-1		Dose [MGy] for integrated luminosity3000 fb^-1	
	R	L	R	L	R	L
MQWA.A4	0.0	0.1	0.1	0.2	1.0	1.9
MQWA.B4	0.1	0.1	0.1	0.2	1.0	2.1
MQWB.4	0.1	0.1	0.1	0.3	1.1	2.2
MQWA.C4	0.1	0.1	0.2	0.3	1.4	2.8
MQWA.D4	0.2	0.3	0.4	0.8	3.5	6.9
MQWA.E4	0.9	1.7	2.0	4.0	17	35
MQWA.A5	0.6	1.1	1.3	2.6	11	22
MQWA.B5	0.7	1.4	1.6	3.2	14	28
MQWB.5	1.7	3.3	3.9	7.7	33	66
MQWA.C5	3.9	7.7	9.0	18	77	155
MQWA.D5	0.9	1.9	2.2	4.3	19	37
MQWA.E5	1.7	3.5	4.0	8.1	35	69
MBW.A6	1.0	2.0	2.3	4.6	20	40
MBW.B6	1.2	2.3	2.7	5.4	23	46
MBW.C6	1.6	3.3	3.8	7.6	33	65

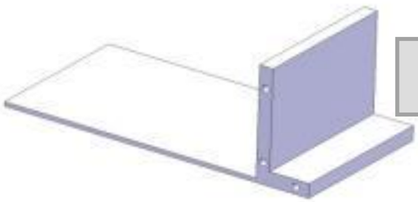
IP 7	Dose [MGy] for integrated luminosity 150 fb^-1		Dose [MGy] for integrated luminosityy350 fb^-1		Dose [MGy] for integrated luminosity3000 fb^-1	
	R	L	R	L	R	L
MQWA.A4	0.4	0.5	0.9	1.2	7.4	11
MQWA.B4	0.3	0.8	0.7	1.9	6.4	16
MQWB.4	0.5	1.3	1.2	2.9	10	25
MQWA.C4	4.0	4.0	9.3	9.3	80	80
MQWA.D4	2.7	2.7	6.2	6.2	53	53
MQWA.E4	5.0	10	12	23	100	199
MQWA.A5	2.6	2.6	6.1	6.1	52	52
MQWA.B5	3.5	3.5	8.1	8.1	69	69
MQWB.5	4.1	4.1	9.5	9.5	81	81
MQWA.C5	1.9	4.9	4.5	11	39	97
MQWA.D5	4.2	6.0	10	14	84	120
MQWA.E5	37	12	86	29	738	246
MBW.A6	23	17	54	39	465	332
MBW.B6	37	19	87	43	745	372

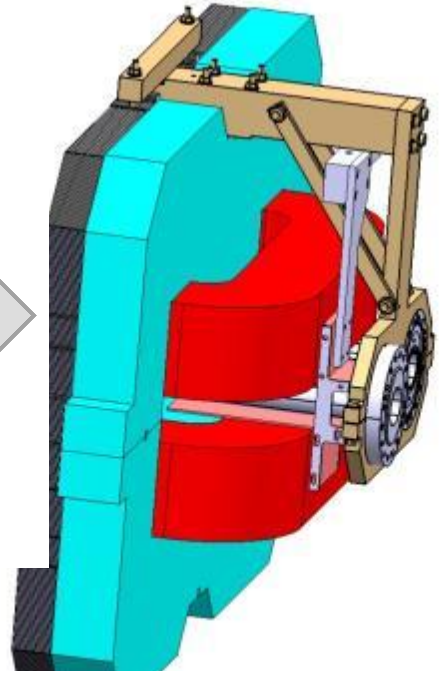
MQW	MBW
From 10 to 20 MGy	From 40 to 60 MGy
From 20 to 50 MGy	From 60 to 80 Mgy
Larger than 50 MGy	Larger than 80 MGy

CERN

PROTECTIVE ACTIONS

Screen design

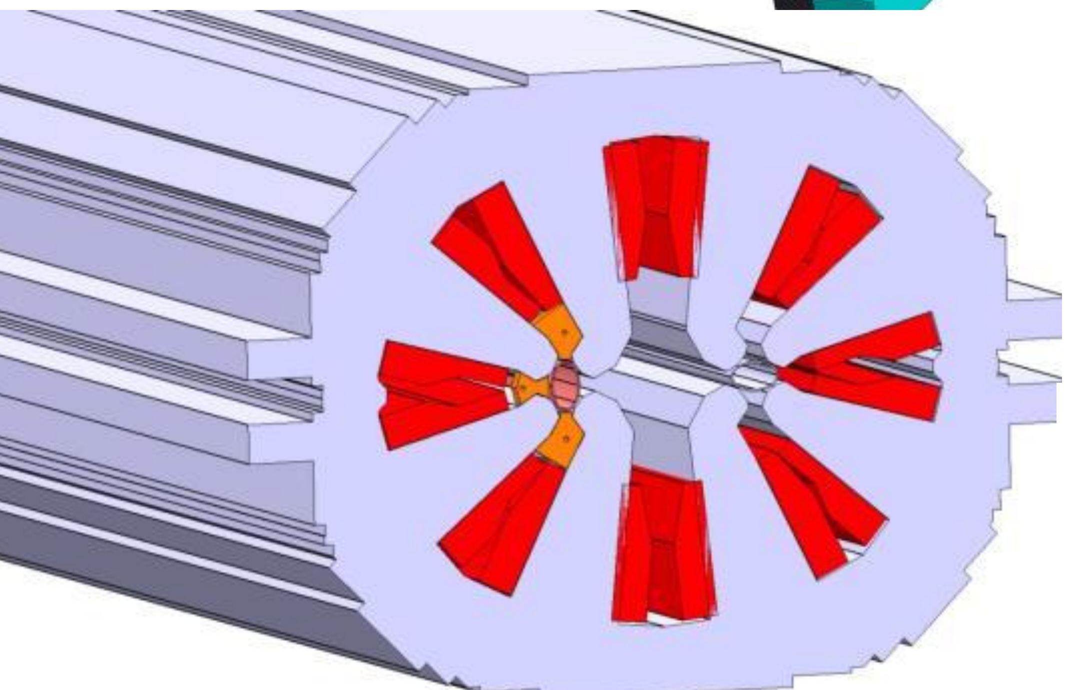


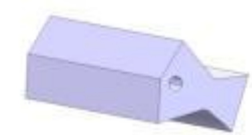


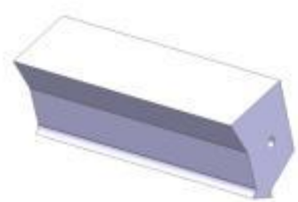
- For max effectiveness we have to target the higher possible density candidate therefore W, or better the alloys for machining

	Inermet IT180
Nominal density	18
W content %	95
Balance	Ni,Cu
E-modulus	360 GPa

- Material staging along the MQW magnet length under study

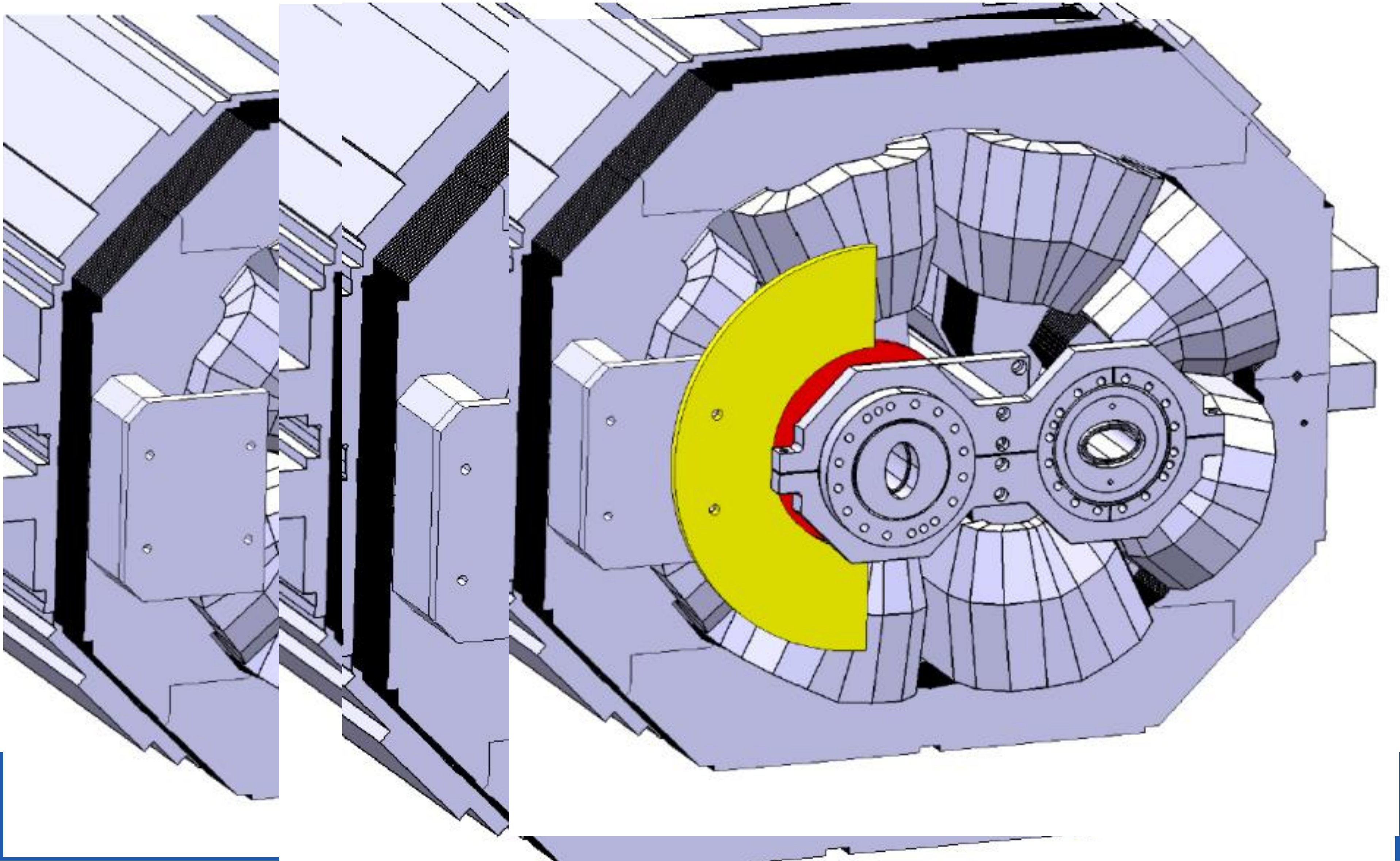






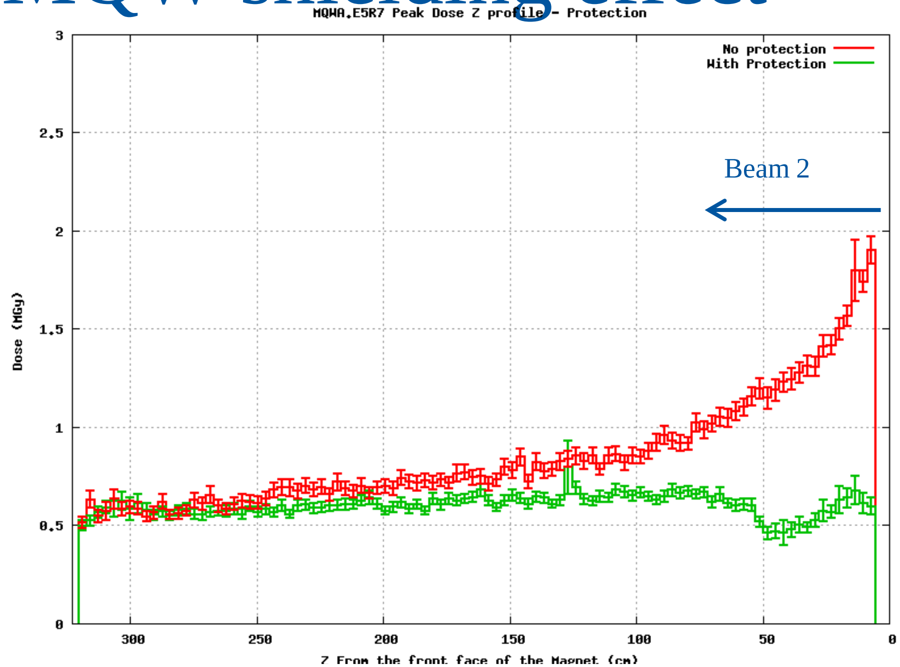
Inserts 5 cm long
We cannot insert longer pieces because of the vacuum pipes flanges

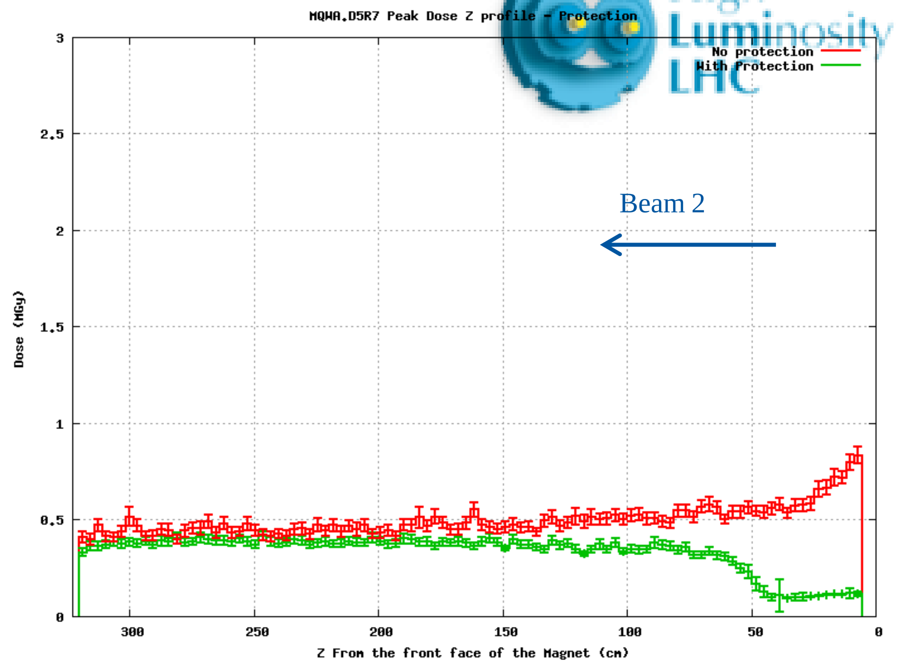
MQW II

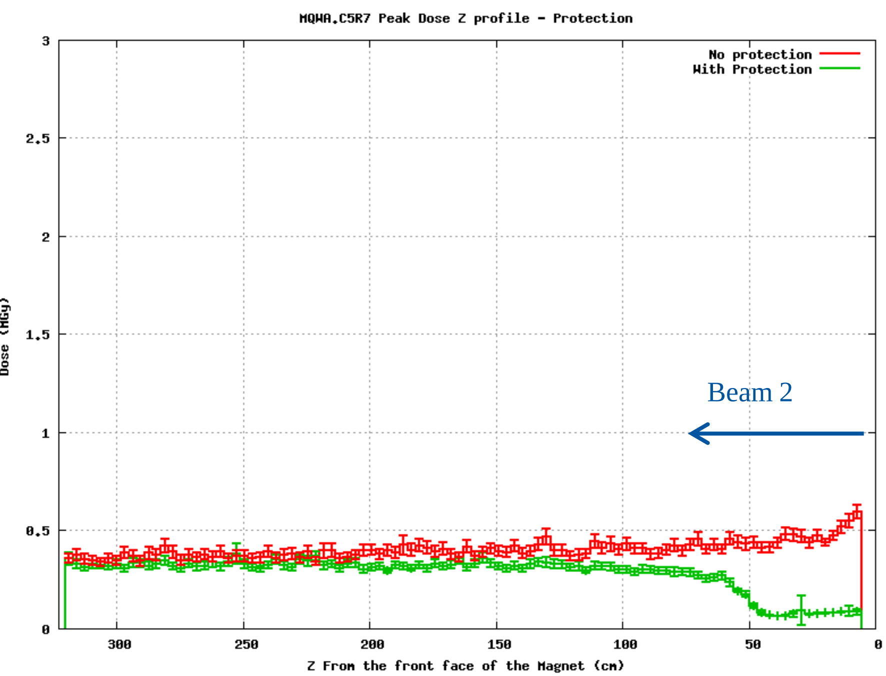


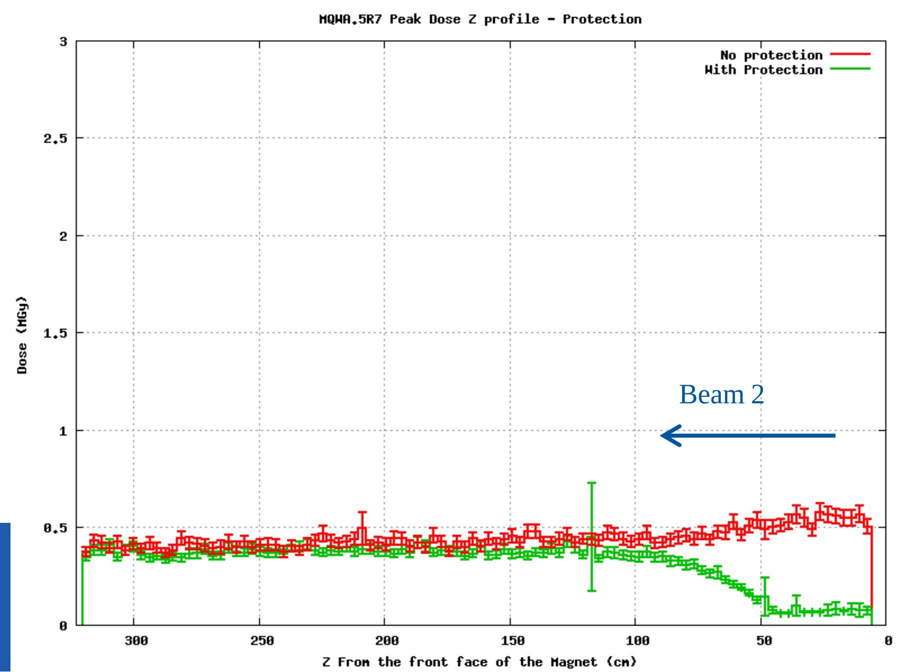
MQW shielding effect

Normalization: 1.15 10^{16} p (50 fb^{-1})

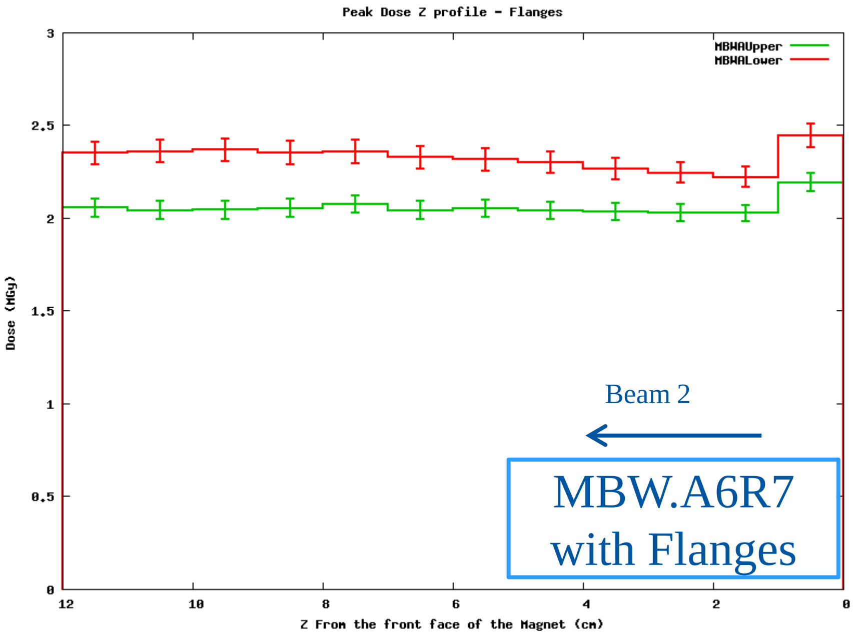


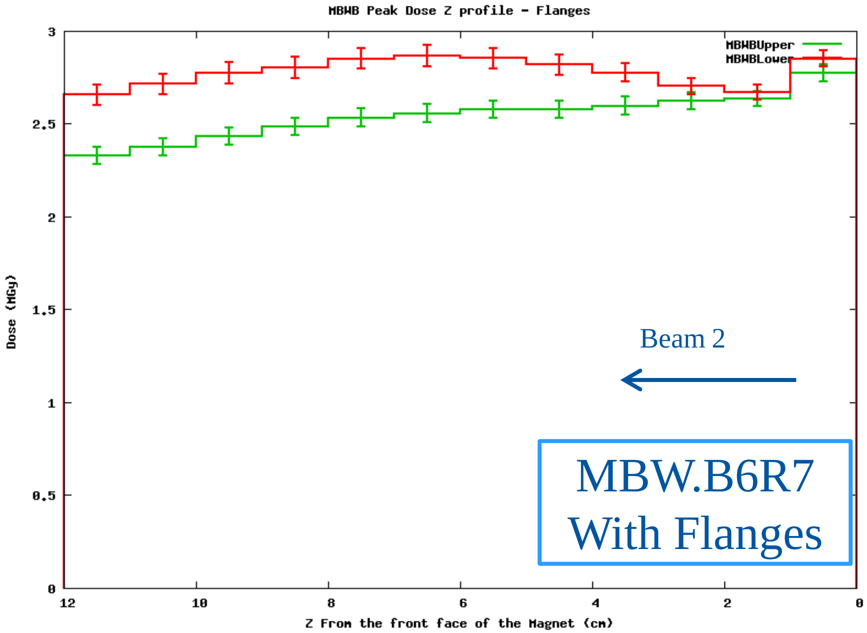


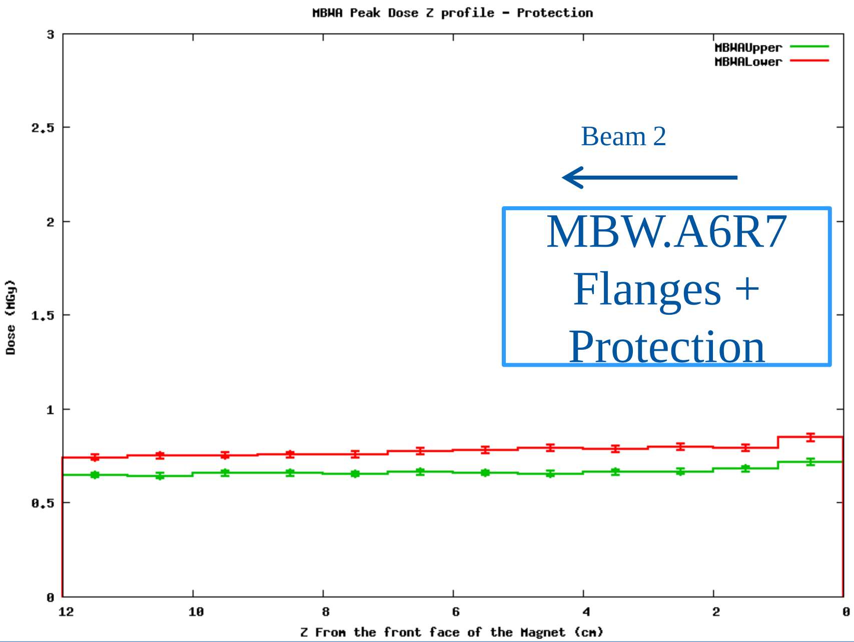


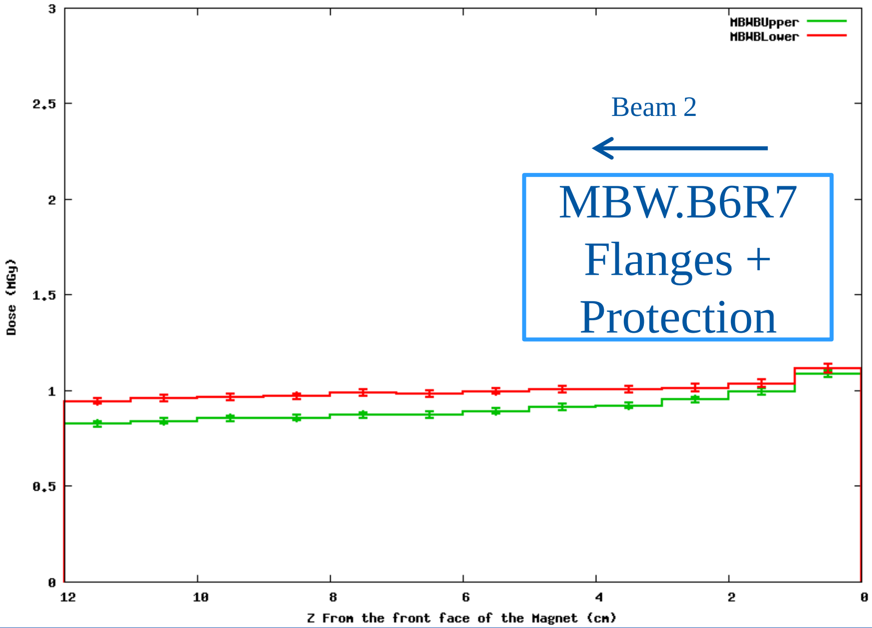


MBWA - MBWB Peak Dose profile

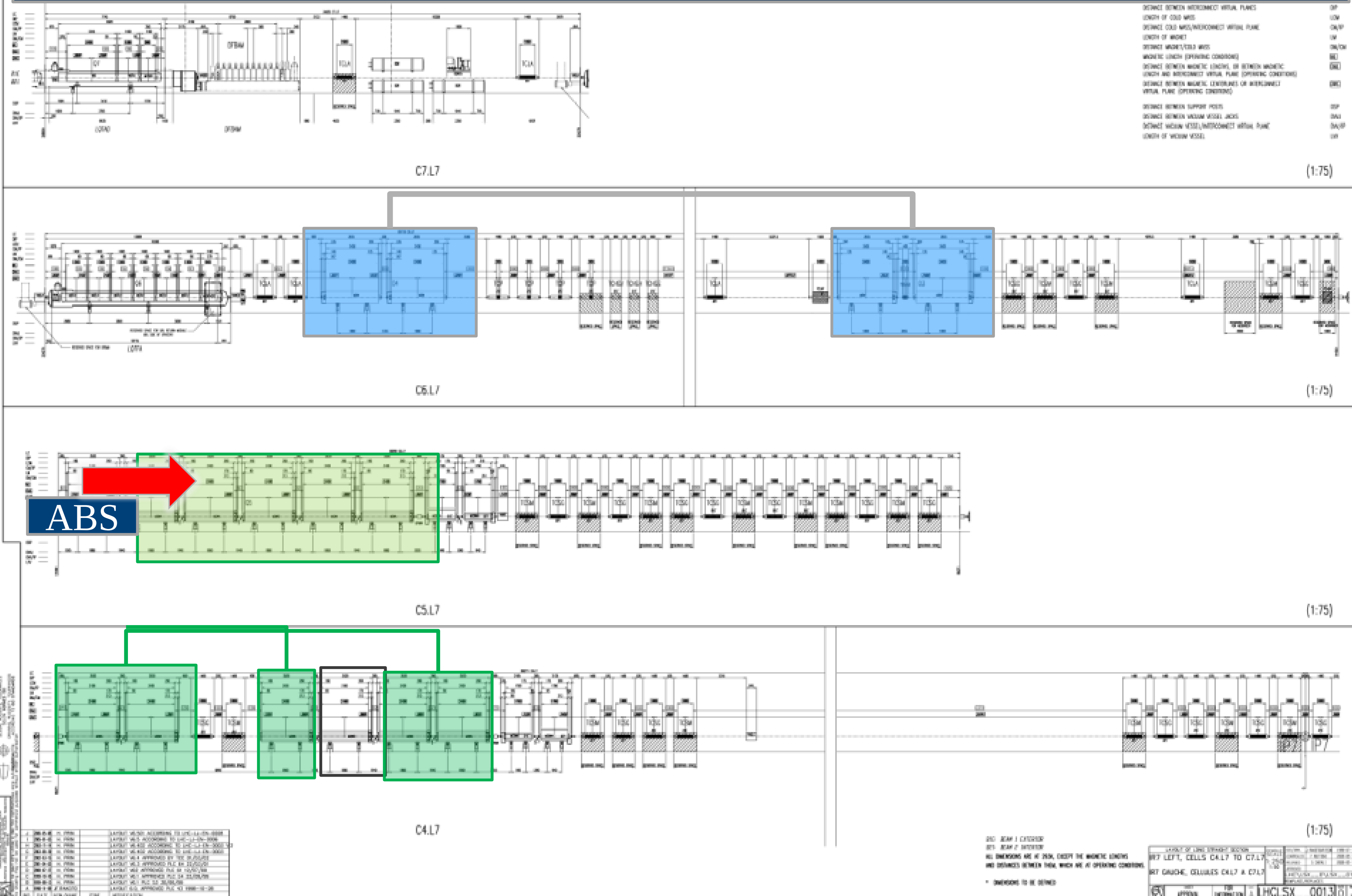








Optic change proposal point 7 discussed and agreed as possible with M. Giovannozzi (it needs verification)



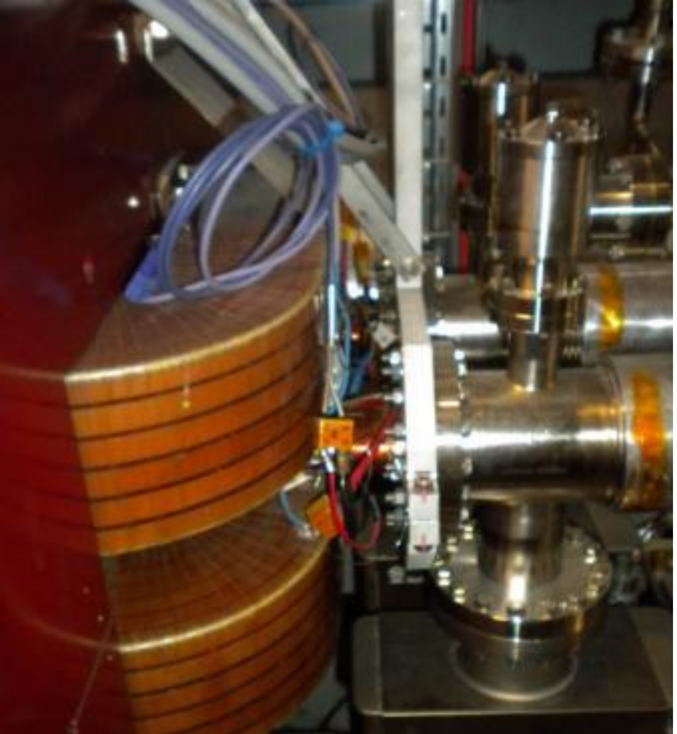
Magnet damage with shielding point 3 and 7, W shielding peak dose scaling

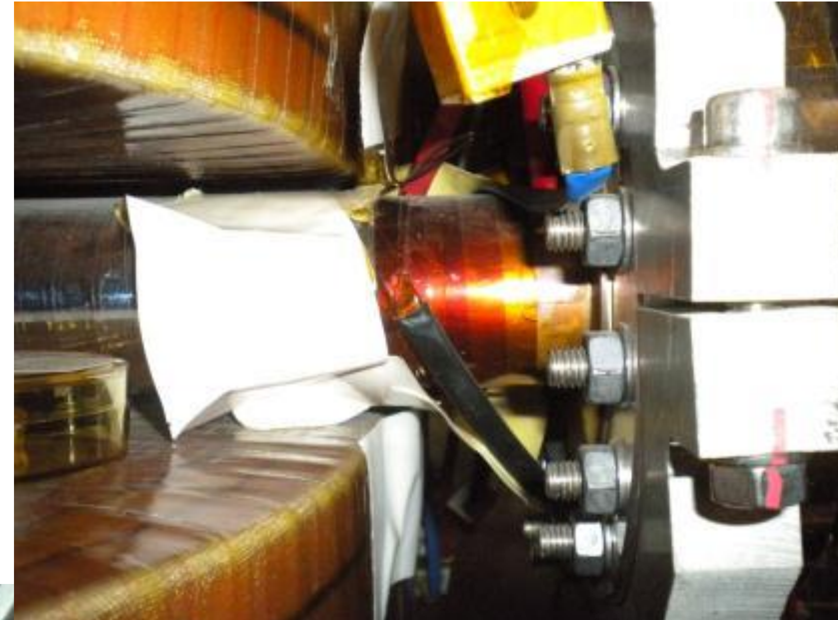
IP 3	Action LS1		Dose [MGy] for integrated luminosity 150 fb^-1		Action LS2		Dose [MGy] for integrated luminosity 350 fb^-1		Action LS3		Dose [MGy] for integrated luminosity 3000 fb^-1		Action during HL-LHC exploitation	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L
MQWA.A4			0.0	0.1			0.1	0.2			1.0	1.9		
MQWA.B4			0.1	0.1			0.1	0.2			1.0	2.1		
MQWB.4			0.1	0.1			0.1	0.3			1.1	2.2		
MQWA.C4			0.1	0.1			0.2	0.3			1.4	2.8		
MQWA.D4			0.2	0.3			0.4	0.8			3.5	6.9		
MQWA.E4			0.9	1.7	S	S	**1.2**	**2.5**			**6.3**	**12**		
MQWA.A5			0.6	1.1	S	S	**0.8**	**1.6**			**4.0**	**7.5**		
MQWA.B5			0.7	1.4	S	S	**1.0**	**2.0**			**5.1**	**9.4**		
MQWB.5			1.7	3.3	S	S	**2.4**	**4.8**			**12**	**23**		
MQWA.C5			3.9	7.7	S	S	**5.6**	**11**			**29**	**53**		
MQWA.D5			0.9	1.9	S	S	**1.3**	**2.7**			**6.8**	**13**		
MQWA.E5			1.7	3.5	S	S	**2.5**	**5.0**			**13**	**24**		
MBW.A6			1.0	2.0	S	S	**1.4**	**2.9**			**7.3**	**14**		
MBW.B6			1.2	2.3	S	S	**1.7**	**3.3**			**8.4**	**16**		
MBW.C6			1.6	3.3	S	S	**2.3**	**4.7**			**12**	**3**		

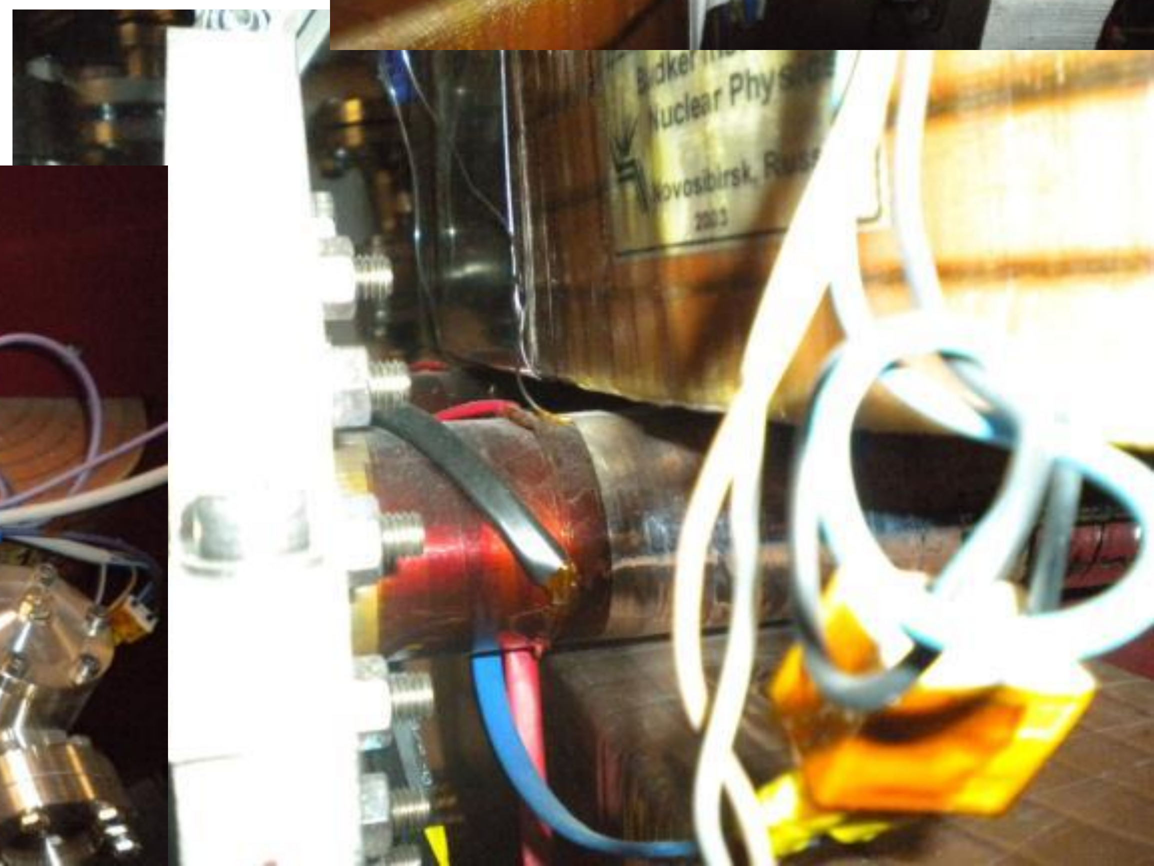
IP 7	Action LS1		Dose [MGy] for integrated luminosity 150 fb^-1		Action LS2		Dose [MGy] for integrated luminosityy350 fb^-1		Action LS3		Dose [MGy] for integrated luminosity3000 fb^-1		Action during HL-LHC exploitation	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L
MQWA.A4			0.4	0.5			0.9	1.2			7.4	10.6		
MQWA.B4			0.3	0.8			0.7	1.9			6.4	16.0		
MQWB.4			0.5	1.3		S	1.2	**1.8**			10.1	**9.3**		
MQWA.C4			4.0	4.0	S	S	**5.8**	**5.8**			**29.3**	**29.3**		
MQWA.D4			2.7	2.7	S	S	**3.8**	**3.8**			**19.5**	**19.5**		
MQWA.E4	S	S	6	10	D	D	7.2	15			36	74		R
MQWA.A5			2.6	2.6	S	S	**3.7**	**3.7**			**19.0**	**19.0**		
MQWA.B5			3.5	3.5	S	S	**5.0**	**5.0**			**25.4**	**25.4**		
MQWB.5			4.1	4.1	S	S	**5.9**	**5.9**			**29.7**	**29.7**		
MQWA.C5			1.9	4.9	S	S	**2.8**	**7.0**			**14.2**	**35.6**		
MQWA.D5			4.2	6.0	S	S	**6.1**	**8.6**			**30.7**	**43.9**		
MQWA.E5	S	S	37	12	Remove		54	18			271	90		
MBW.A6	S	S	23	17	D	D	32	24			169	122	R	R
MBW.B6	S	S	37	19			54	28			275	137	R	R

	7R	7L
MQWA.E4		1800 fb^-1
MBW.B6	1500 fb^-1	2400 fb^-1
MBW.A6	1000 fb^-1	2000 fb^-1

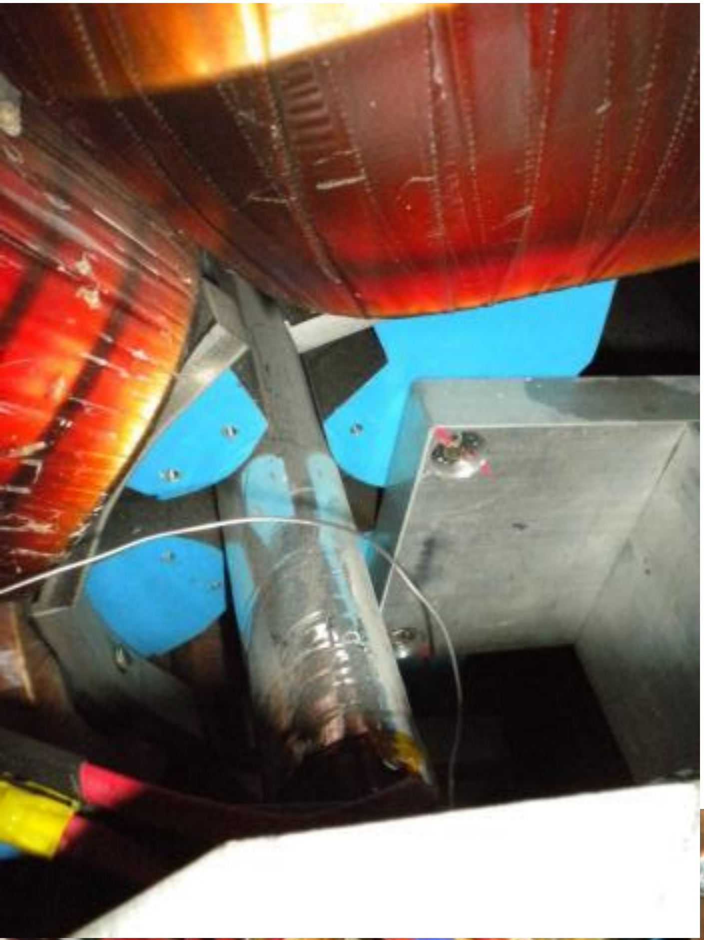
MBW

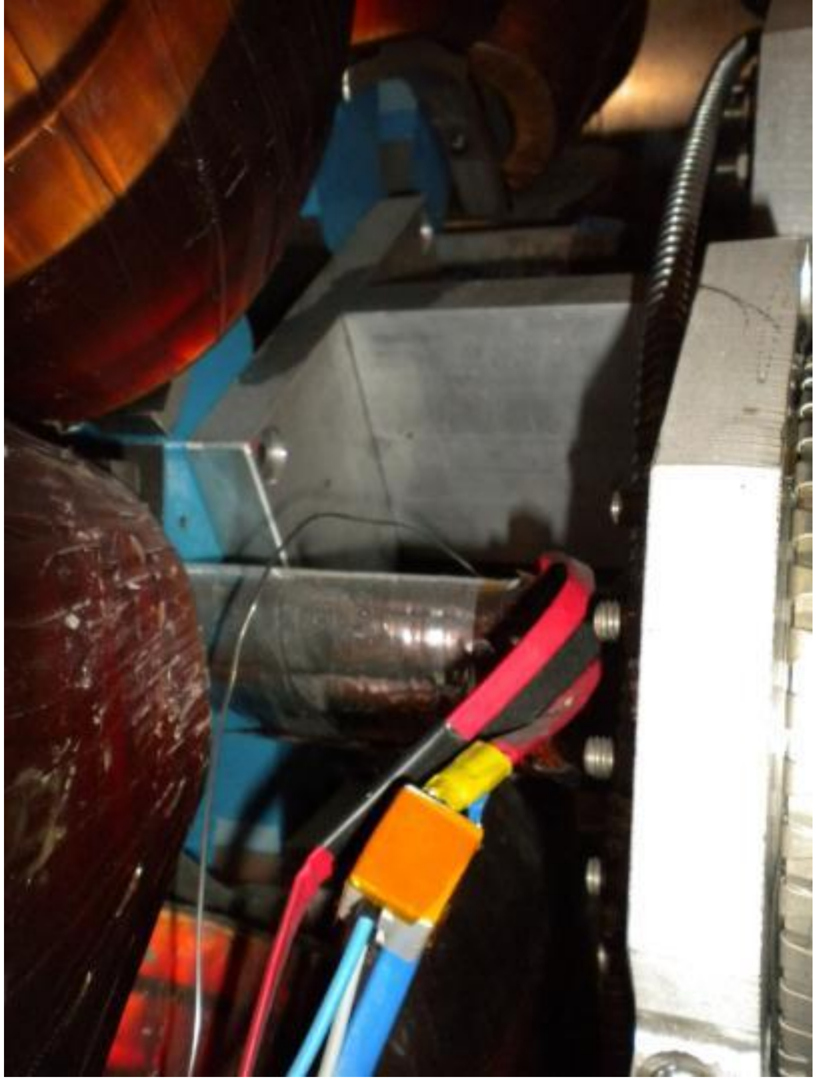




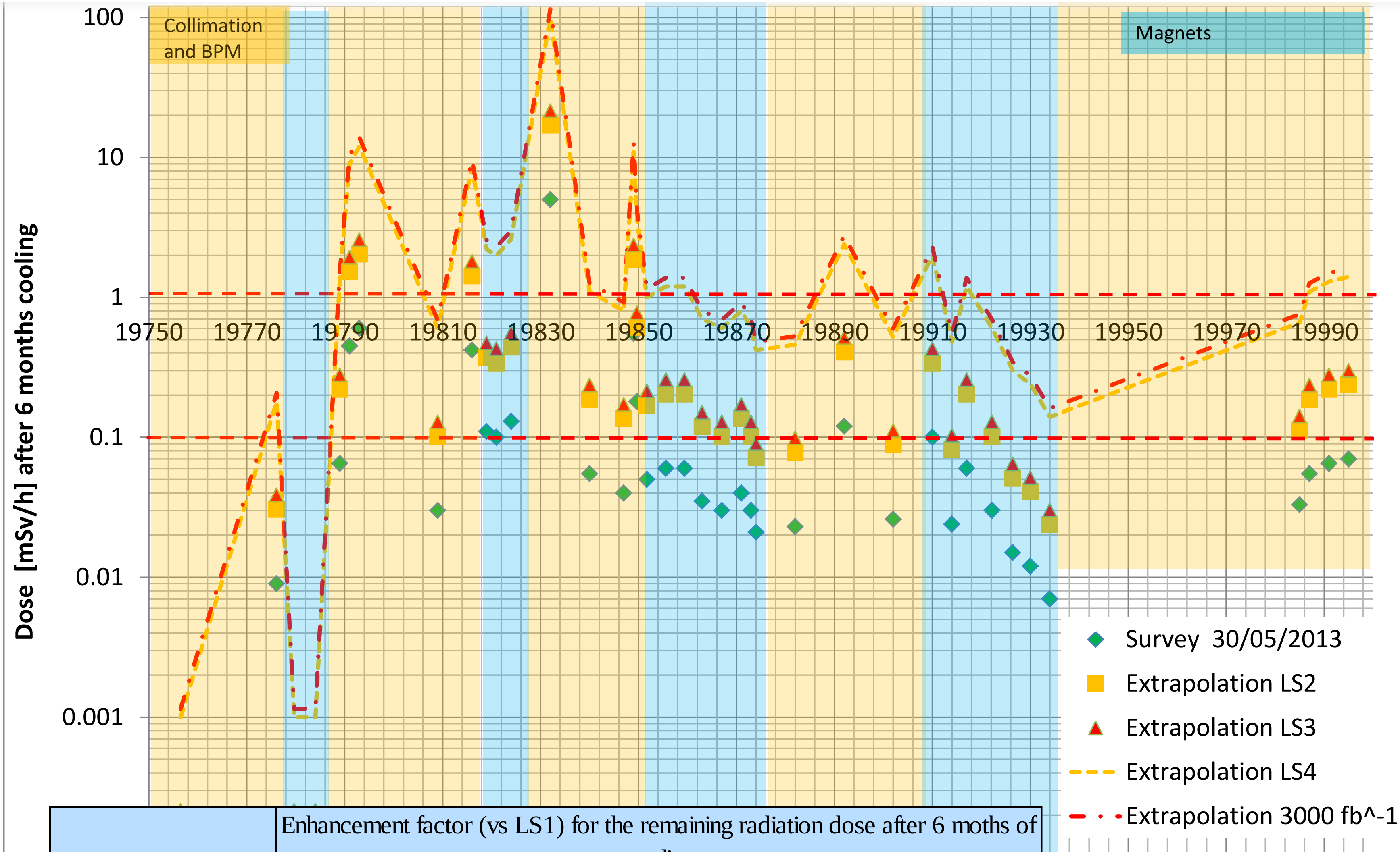


MQW





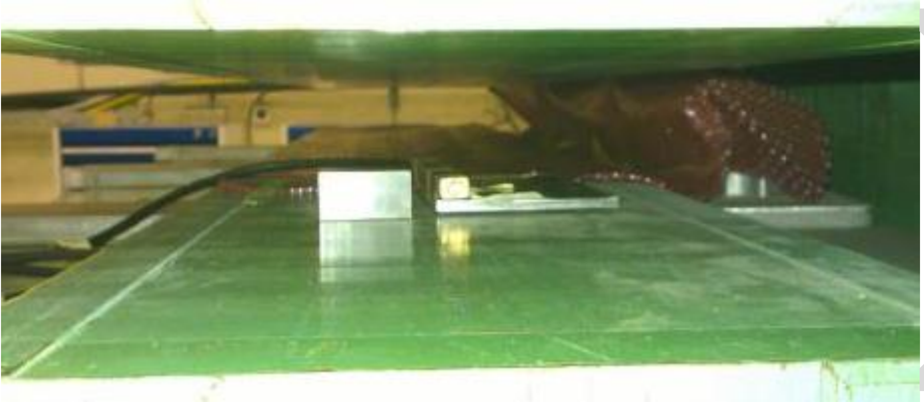
POINT 7 residual dose at 40 cm after 6 months of cooling

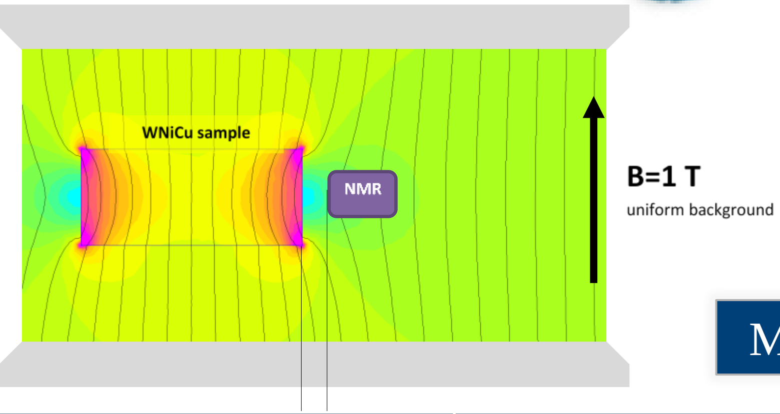


	Enhancement factor (vs LS1) for the remaining radiation dose after 6 moths of cooling
LS2	3.4
LS3	4.3
LS4	20
3000 fb^-1 in 2035	23

[S. Roesler, C. Adorisio]

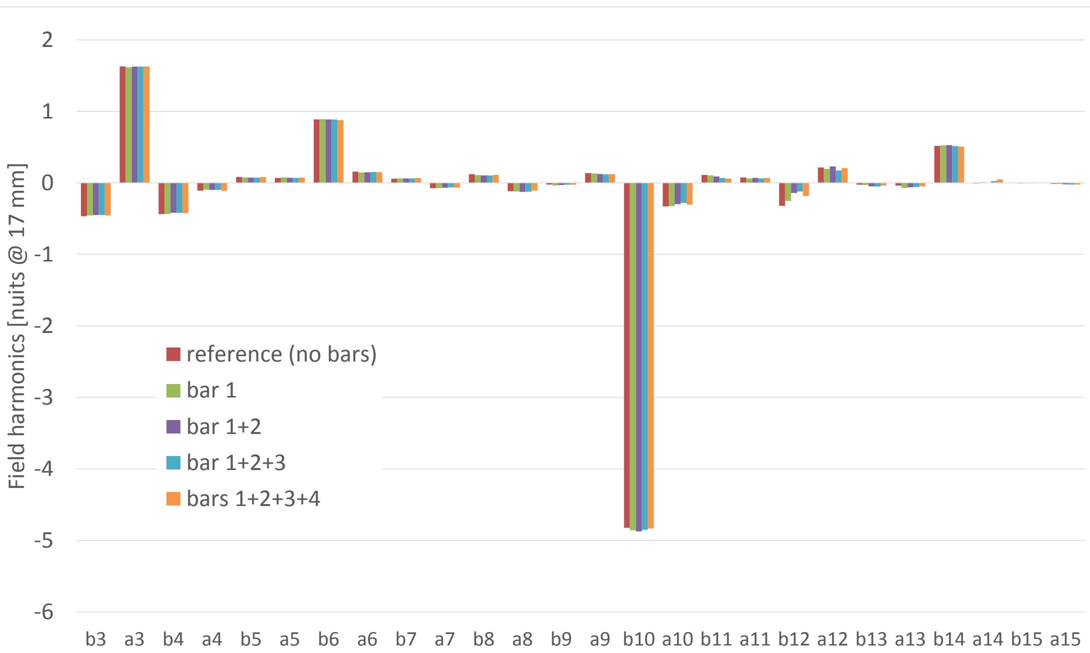
W alloy magnetic properties (95% W, 3.5% Ni, 1.5 % Cu)





M. Buzio

B background [T]	B with sample [T]	Relative B drop [T/kA]	Susceptibility [-]
0.999874	0.999862	$-1.2\cdot10^{-5}$	$5.2\cdot10^{-5}$



Conclusion I

- The proposed screen allow reducing of a factor 3 the dose and limit the number of magnet at risk or surely damaged, see previous slides. <u>Hp. to achieve the same reduction factor on the spacers</u>
- The change of the optic in point 7 installing a long absorber is key to complete the protection
- The lifetime of these units could be affected by the environmental condition of point 7 not discussed here

Conclusion II: actions

- The proposed shielding campaign has start in LS1 for effectiveness and ALARA
- *<u>Very high dose dosimeter shall be installed systematically in point 3 and 7 to better benchmark computations and check symmetry effect</u>*
- *<u>A campaign of irradiation of resins shall be performed with the real used resins and the relevant fillers in order to real know when the magnet will reach damage level</u>*
- *<u>For HL LHC 4 MBW shall be reassembled with saddle type heads. This will solve the issue without needing special development</u>*
- **We suggest that we launch the program to build a NC magnet with extremely high radiation resistance (>300 MGy). It is and it will be more and more needed and today we do not have it in our capabilities and it will be key for future target areas development**
- We need to check
  - For HL-LHC the MBW radiation dose along the straight part of the coil
  - The level of accumulated dose of the MBXW units
  - If any protection can be added to on the beam line for the MQWA.E4 in point 7 R and 7 L

END

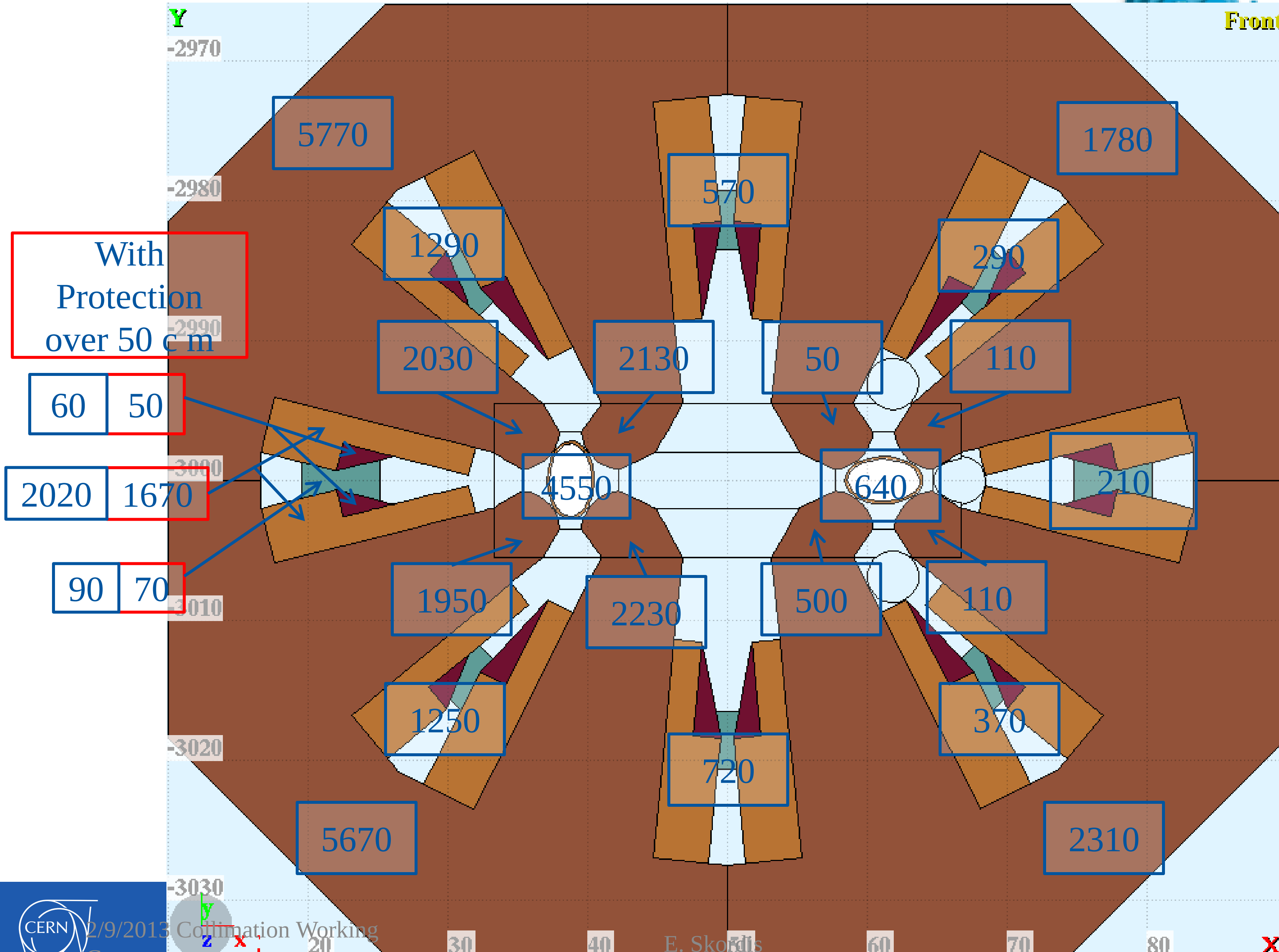
POWER DEPOSITION

Power deposition

	MQW		MBW	
Ultimate current	810	A	820	A
Electrical dissipated power ultimate current	25	kW	41	kW
Delta T measured ultimate current on cooling water	16	C	30	C
New operational current	620	A	650	A
New dissipated electrical power operational current	15	kW	26	kW
Worst dissipated power due to radiation losses (including dissimetry and new loss rate)	3	kW	4	kW
New total power to be dissipated (Pel+Prad+Pconv)	19	kW	30	kW
New Delta T necessary to evacuate the power	12	C	22	C
New magnet working temperature	38	C	48	C

Remark
Due to small lifetime (load case 1h) we do not take into account the coefficient 2linked to the ratio losses/luminosity nor the discrepancy B1/B2 (L/R)

MQWA.E Energy Deposition on various elements



Values are in pJoule/proton lost in the collimators

Peak power adiabatic (wrong) approximation in shielding

	MQW shielding		MQW beam pipe		MBW shielding	
Env Temp	50	C	50	C	50	C
Integral proton energy lost	1012	pJ/proton	4550	pJ/proton	256	pJ/proton
symmetry, loss rate and 7 TeV factor	1.0775		1.0775		1.0775	
Proton losses	9.00E+10	proton/s	9.00E+10	proton/s	9.00E+10	proton/s
Loss time	3600	s	3600	s	3600	s
Total integral power	98	W	441	W	25	W
Assumed ratio Pmax/Pmin along magnet	4		4		1	
Adiabatic Delta T Pmax	170	C	750	C	224	C
Adiabatic Delta T Pmin	43	C	190	C		

Baking vacuum chamber
T->230 C
Necessary 4 KW to get to the temperature along several hours

Different epoxy

High Luminosity LHC

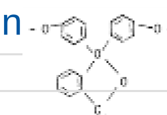
Resins	Hardeners	Additives	Composition (p.p.)	Mix Temp (°C)	Viscosity (cPs)	Service life (mn)	Fig	Dose for 50% flex. (MGy)	Dose Range (MGy)
EDBAH	MA						5.4	1.4	1 - 3
EDBAH	MA	BDMA	100-105-0.2	80	45	>180	5.1	1.6	
BECP	MA						5.4	2.5	
BECP	MA	BDMA	100-110-0.2	80	40	>180	5.1	2.3	
ECC	MA		100-72	80	20	>240	5.5	1.8	1 - 6
VCD	MA	BDMA	100-160-05	60	20	>180	5.4	3.7	
DADD	MA		100-65	80	180	>240	5.4	5.5	
DGEBA + EDGDP	TETA		100-20-12	25			5.21	1.3	1 - 2
DGEBA	TETA	DBP	83-9-17	50	500	few	5.22	1.2	
DGEBA	DADPS		100-35	130	60	180	4.2	5.1	5 - 15
DGEBA + EDGDP	MDA		100-20-30	80			5.21	8.2	
DGEBA	MDA		100-27	80	100	50	5.9	13.0	
DGEBA	MPDA		100-14.5	65	200	30	5.7	23.5	**23**
DGEBA	AF		100-40	100	150	30	5.26	45.2	**45**
DGEBA	DDSA	BDMA	100-130-1	80	70	120	5.2	4.2	5 - 15
DGEBA	NMA	BDMA	100-80-1	80	80	120	5.2	5.9	
DGEBA	MA		100-100	60	69	>1440	5.23	7.1	
DGEBA	MA	BDMA					5.1	12.0	
DGEBA	MA	BDMA + Po. Gl.	100-100-0.1-10	60	65	300	5.23	12.1	
DGEBA	AP		100-70	120	26	180	5.2	13.0	
DGPP	DADPS		100-28	130			5.6	8.2	5 - 15
DGPP	MA		100-135	120			5.3	13.0	
EDTC	MDA		100-20	80		40	5.9	10.0	
TGTPE	DADPS		100-34	125	>20000		5.6	12.1	
TGTPE	MA	BDMA	100-100-0.2	125	>15000		5.3	10.6	
EPN	DADPS		100-35	100		30	5.6	23.5	**20 - 40**
EPN	MDA		100-29	100		35	5.10	37.2	
EPN	HPA	BDMA	100-76-1	80		40	5.10	13.0	**10 - 20**
EPN	MA	BDMA	100-105-0.5	80		100	5.3+5.25	15.0	
EPN	NMA	BDMA	100-85-1	100		80	5.10	20.6	
TGMD	DADPS		100-40	80		50	5.6	20.6	**10 - 25**
TGMD	MA	BDMA	100-136-0.5	60		30	5.3	11.4	
TGMD	NMA	BDMA	100-110-1	80	500	20	5.8	18.0	
TGPAP	NMA		100-137	80	<20		5.8	23.5	
DGA	MPDA		100-20	25		120-420	5.7	23.5	**20 - 30**
DGA	NMA		100-115	25	5 - 20	30-5760	5.8	28.6	

Aromatic >
Cycloaliphatic >
Linear Aliphatic

Aliphatic amine harderner → poor radio-resistance

Aromatic amine hardener >
Anhydride hardener

H: Too high local concentration of benzene may induce steric hin... disturbation



Good radio-resistance even if Cl (tendence to capture n_{th})

Novolac: HIGH Radio-resistance

- Large nb of epoxy groups
  → Density + rigidity

Glycidyl-amine: HIGH R.-resistance

- Quaternary carbon
  → weakness
- Ether group (R-O-R') → Repl. by amina
  → weakness

Legend

Resin
- Linear aliphatic
- Cycloaliphatic
- Aromatic

Hardener
- Aliphatic Amine
- Aromatic Amine
- Alicyclic Anhydride
- Aromatic Anhydride

E. Fornasiere

INSTALLATION ISSUES, PLANNING AND COSTS

Installation/planning/risks

High Luminosity LHC

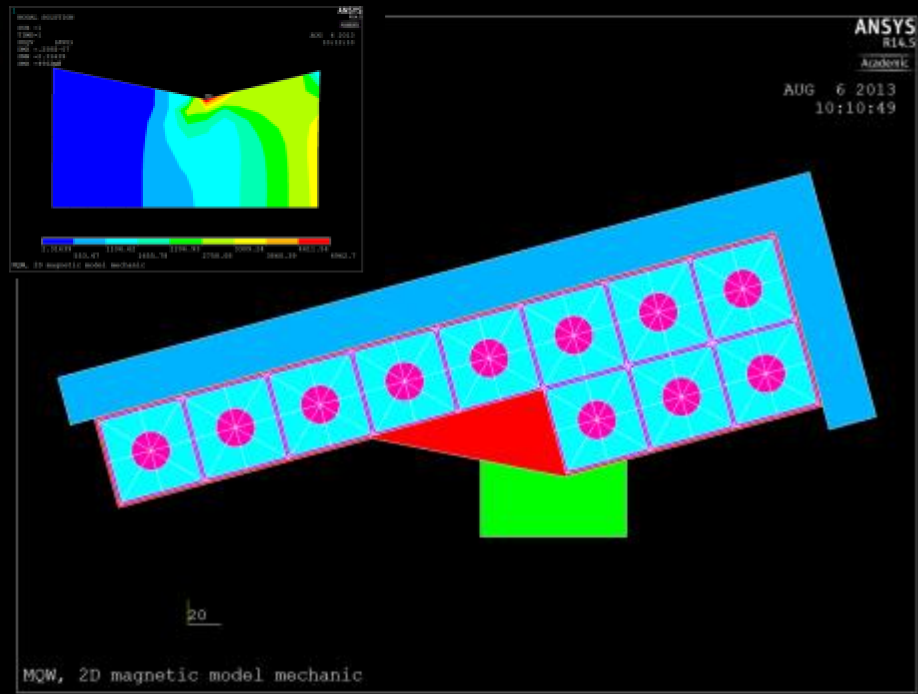
- To reduce radiation aging, the intervention, on most exposed magnets, shall performed in LS1 (also for ALARA reasons). The initial foreseen modus operandi (directly on the magnet in the tunnel) is not feasible because of the interference with the backing equipment. Due to the limited number of vacuum chambers available and also field quality sorting, it is better to modify the magnets presently installed in LHC and replace them in the same slot. It will help in saving non radioactive spares.
- The backing strips power wiring and the related thermocouples need to be rewired. VSC (N. Zelko) performed test and it looks feasible. Possible back up strategy with screen modification is available
- Vacuum sector impacted
  - A6L7 no bake out yet because of the door project
  - B5L7: no bake out yet because of UA9 project
  - A4L7: no bake out yet because of UA9 project
  - A4R7: no bake out yet because of UA9 project
  - **B5R7: already baked out**
  - A6R7 no bake out yet because of door project
- Possible planning sequence
  - 25/10 go or no go decisions (full, partial, nothing)
  - From the 28/10 magnet of L7 can go out to UX65 for buffer storage
  - From R7 can go out from the 11/11 to UX65 for buffer storage
  - Possible co activity with the fibre optic worksite in week 45 (4/11 to 8/11) and 49 (2/12 to 6/12)
  - 02/12 start of modification in the NormaLaP (867)
  - 03/02/2014: start of reinstallation
  - 01/03/2014 we need to have completed re-installation

Risks	Solutions/Consequences
Screens not available on time	Install steel screen or re-install without screen
W-Ni-Cu alloy cause no acceptable field distortion	Install reduce effectiveness copper or steel screens
Difficult installation on MBW	Possibility to machine the shielding to ease installation and close the hole with W tap
Damage of backing strip	One magnet not backed out

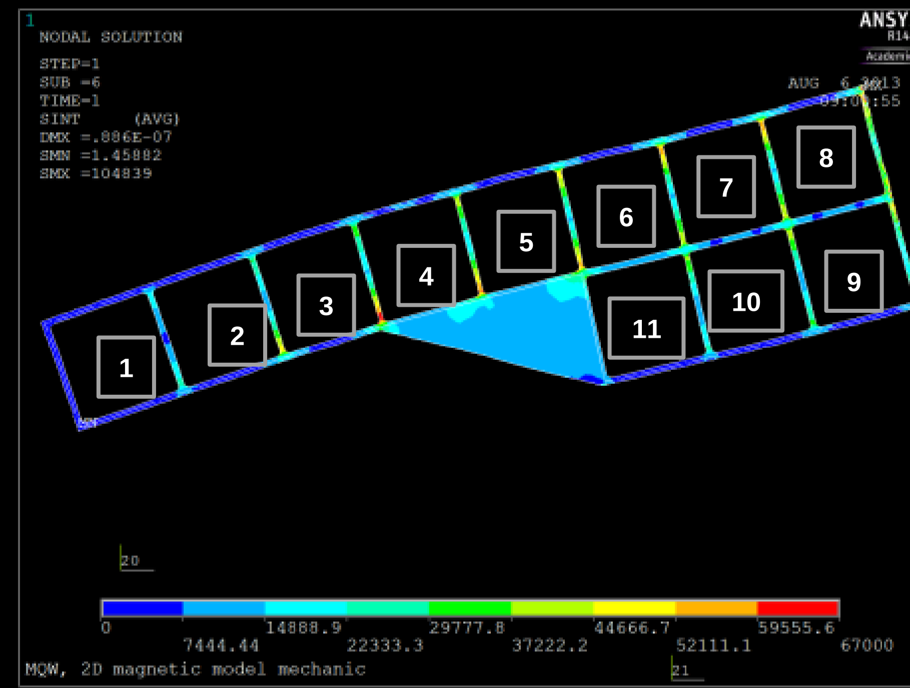
Magnetic qualification of Innermet 180

- 1st measurement provided by M. Buzio indicate a μ_r<=1.00002
- 2nd series of measurement with Innermet 180 inserts in a reference quadrupole to be performed this week
- 3rd computations on the 2D MQW cross section of the MQW being performed by Per Hagen (TE-MSC-MDT) with a μ_r=1.00005
- Measurement of a spare magnet with and without shielding foreseen (but it will come late)

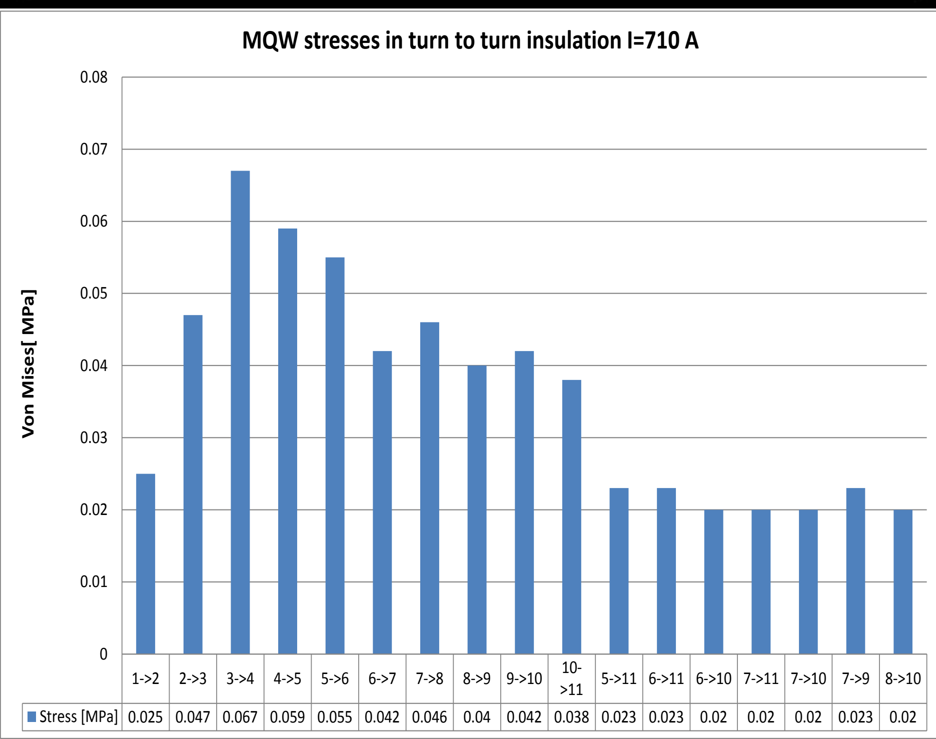
LONG VERSION



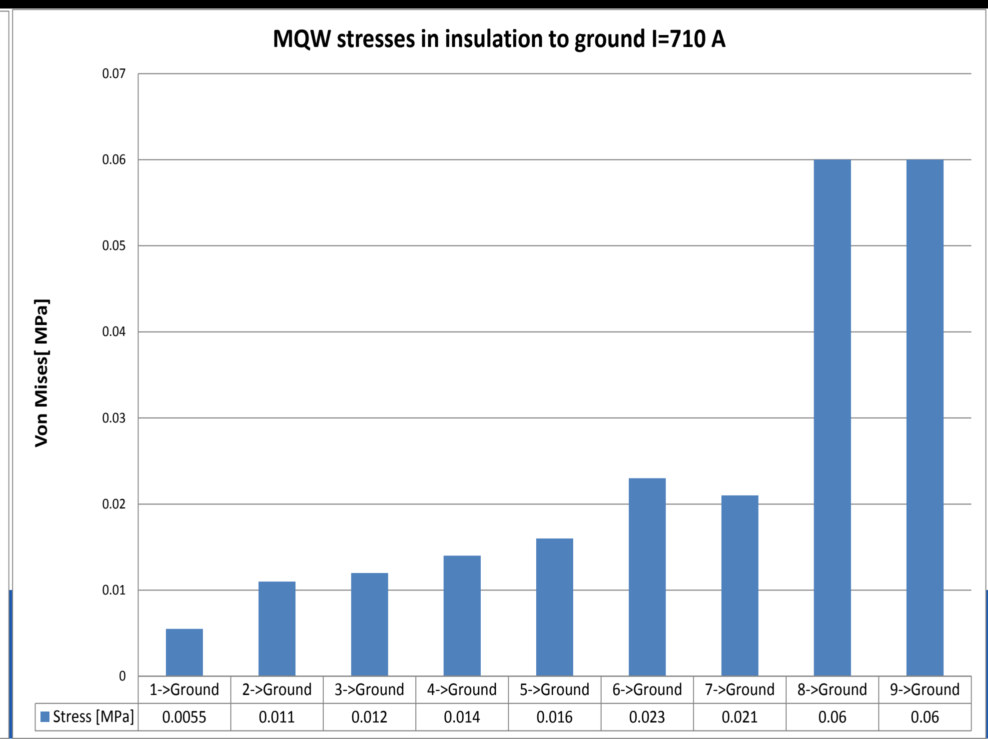
ANSYS
R14.5
Academic
AUG 6 2013
10:10:49
MQW, 2D magnetic model mechanic



ANSYS
R14.5
Academic
NODAL SOLUTION
STEP=1
SUB =6
TIME=1
SINT (AVG)
DMX =.886E-07
SMN =1.45882
SMX =104839
1
2
3
4
5
6
7
8
9
10
11
0
7444.44
14888.9
22333.3
29777.8
37222.2
44666.7
52111.1
59555.6
67000
MQW, 2D magnetic model mechanic



MQW stresses in turn to turn insulation I=710 A
Von Mises[MPa]
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1->2 | 2->3 | 3->4 | 4->5 | 5->6 | 6->7 | 7->8 | 8->9 | 9->10 | 10->11 | 5->11 | 6->11 | 6->10 | 7->11 | 7->10 | 7->9 | 8->10
Stress [MPa] | 0.025 | 0.047 | 0.067 | 0.059 | 0.055 | 0.042 | 0.046 | 0.04 | 0.042 | 0.038 | 0.023 | 0.023 | 0.02 | 0.02 | 0.02 | 0.023 | 0.02



MQW stresses in insulation to ground I=710 A
Von Mises[MPa]
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1->Ground | 2->Ground | 3->Ground | 4->Ground | 5->Ground | 6->Ground | 7->Ground | 8->Ground | 9->Ground
Stress [MPa] | 0.0055 | 0.011 | 0.012 | 0.014 | 0.016 | 0.023 | 0.021 | 0.06 | 0.06

Material:	**Epoxy resin**	TIS No. **R 422**
Type	**MY 745 (50) + EPN 1138 (50) + CY 221 (20) + HY 905 (120) + DY 073 (0.3)**	
Supplier:	**Ciba-Geigy**	UL 94: n.m.
Remarks:	used for the ISR dipoles	LOI:

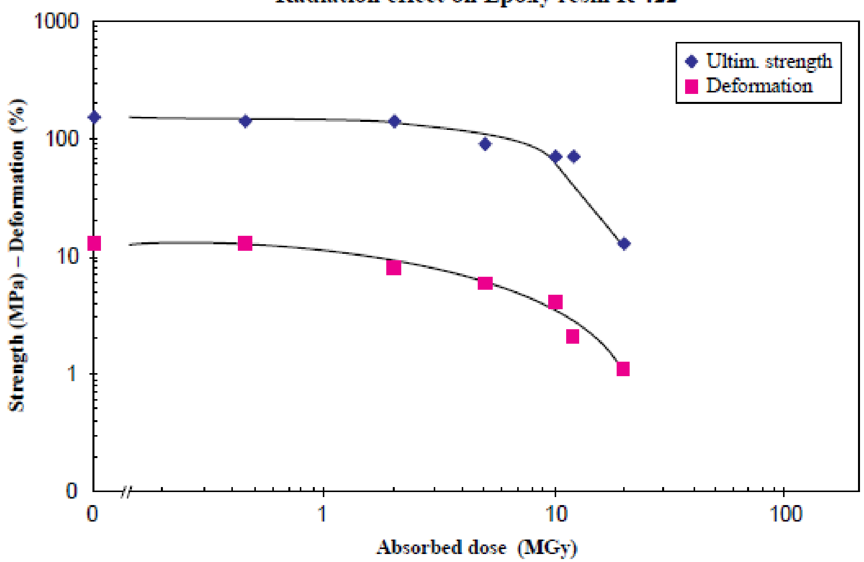
Radiation test results according to IEC Standard 544 (and ISO 178)

Dose rate (kGy/h)	Dose (MGy)	Ultim. strength (MPa)	Deformation ε (%)	Modulus (GPa)
0	0	153±3	13.1±1.9	3.80±0.03
0.2	0.5	142±1	12.9±0.3	3.50±0.02
0.2	2.0	140±1	7.9±0.3	3.50±0.02
180	5	93±2	6.1±0.3	4.00±0.03
180	10	73±3	4.2±0.2	4.10±0.04
0.5	12	71±6	2.1±0.2	3.7±0.1
180	20	13±1	1.1±0.1	3.40±0.04

Radiation index (RI) = 6.9 if strength is the critical property

Radiation index (RI) = 6.6 if deformation is the critical property

Radiation effect on Epoxy resin R 422



Material:	**Epoxy resin**	TIS No. **R 422**
Type	**MY 745 (50) + EPN 1138 (50) +** CY 221 (20) + HY 905 (120) + DY 073 (0.3)	
Supplier:	**Ciba-Geigy**	UL 94: n.m.
Remarks:	used for the ISR dipoles	LOI:

Radiation test results according to IEC Standard 544 (and ISO 178)

Dose	Mechanical test results at RT			Mechanical test results at 77 K		
(MGy)	Strength (MPa)	Deformation ε (%)	Modulus (GPa)	Strength (MPa)	Deformation ε (%)	Modulus (GPa)
0	152.6 ± 3.0	13.1 ± 1.9	3.8 ± 0.03	344 ± 19	3.5 ± 0.5	6.7 ± 0.9
5	93.0 ± 2.0	6.1 ± 0.3	4.0 ± 0.03			
10	73.0 ± 3.0	4.2 ± 0.2	4.1 ± 0.04			
14				191 ± 13	3.5 ± 0.3	5.3 ± 0.2
20	13.0 ± 1.0	1.1 ± 0.1	3.4 ± 0.04			
35				124 ± 44	2.0 ± 0.1	6.1 ± 0.7
119				18 ± 5.0	0.7 ± 0.2	2.8 ± 1.0
RI =	6.9	6.6	> 7.3	> 7.3	7.7	7.7

Radiation effect on epoxy resin R 422

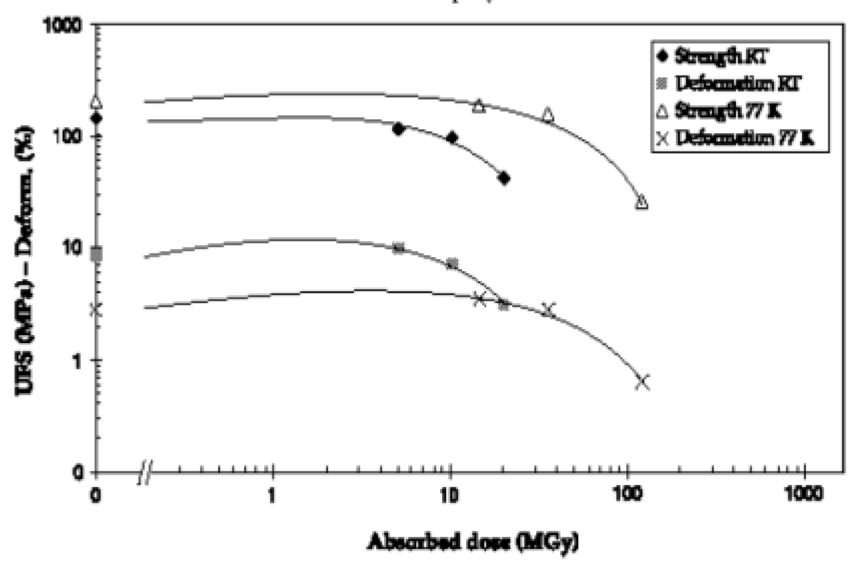
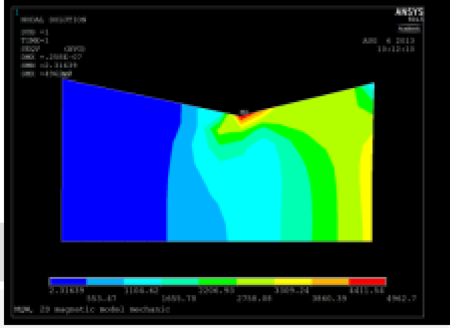


Fig. 18: Araldite MY 745 + EPN 1138 R 422

Spacers resins

- Composition
  - HD polyethylene pipes filled with



Ingredient	Quantity	Description
EPON 826	22 kg	Low viscosity, liquid bisphenol A based epoxy resin.
RP 1500	3kg	Tetramine hardener
MIN-SIL 120 F	17 kg	Fused silica particles 50% diameter smaller than 0.044 mm

ARALDITE F

CY205

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No.	Material and Supplier	Dose (Gy)	Ultimate flex. strength S (N/mm²)	Deflexion at break D (mm)	Modulus of elasticity M (N/mm²)
97	Magnet coil resin Orlitherm® (Base: DGEBA + MNA + + other components)	0	97.1 ± 16.7	5.8 ± 1.7	$3.53 \pm 0.11 \times 10^3$
		5.6×10^6	64.7 ± 10.8	3.6 ± 0.6	$3.51 \pm 0.06 \times 10^3$
		1.1×10^7	52.9 ± 14.7	3.0 ± 0.8	$3.55 \pm 0.13 \times 10^3$
		2.2×10^7	39.2 ± 6.8	2.0 ± 0.4	$3.75 \pm 0.15 \times 10^3$
	BBC Baden	5.6×10^7	7.9 ± 1.0	1.0 ± 0.1	$2.26 \pm 0.21 \times 10^3$
99	Magnet coil resin Orlitherm® reinforced with fibre-silanized woven glass tape type 1 and mica-paper tape	0	224.6 ± 11.7	5.0 ± 0.5	$2.96 \pm 0.74 \times 10^4$
		1.1×10^7	191.3 ± 2.9	5.2 ± 0.4	$7.99 \pm 0.54 \times 10^3$
		3.1×10^7	130.4 ± 5.9	4.6 ± 0.5	$8.00 \pm 0.50 \times 10^3$
		6.3×10^7	84.4 ± 14.7	3.9 ± 0.5	$5.85 \pm 0.49 \times 10^3$
	BBC Baden	1.0×10^8	54.9 ± 1.9	3.2 ± 0.2	$4.59 \pm 1.01 \times 10^3$
131	ARALDITE F(100) + MNA(80) + + DMNA(0.5) + filler	0	312.9 ± 2.9	9.0 ± 0.3	$1.57 \pm 0.05 \times 10^4$
		1×10^7	287.4 ± 11.8	8.9 ± 0.1	$1.45 \pm 0.02 \times 10^4$
		2×10^7	301.2 ± 8.8	10.2 ± 0.3	$1.51 \pm 0.02 \times 10^4$
	Rutherford Workshop	5×10^7	222.7 ± 2.9	9.8 ± 0.4	$1.09 \pm 0.05 \times 10^4$
132	ARALDITE F + MNA + filler	0	436.5 ± 55.9	6.8 ± 0.8	$2.42 \pm 0.07 \times 10^4$
		5×10^6	392.4 ± 28.5	6.3 ± 0.5	$2.24 \pm 0.13 \times 10^4$
		1×10^7	402.2 ± 54.0	6.8 ± 1.0	$2.19 \pm 0.22 \times 10^4$
		2×10^7	365.9 ± 53.0	6.4 ± 0.6	$2.35 \pm 0.22 \times 10^4$
	LINTOTT	5×10^7	230.5 ± 17.7	5.1 ± 0.8	$1.74 \pm 0.08 \times 10^4$
149	CY 205(100) + HY 964(130) + + DY 040(20) + DY 064(0.5) 40 h 75 °C	0	71.6 ± 0.98	8.4 ± 0.4	$2.12 \pm 0.05 \times 10^3$
		5×10^6	49.6 ± 30.4	6.2 ± 5.3	$2.14 \pm 0.05 \times 10^3$
		1×10^7	56.9 ± 3.9	5.2 ± 0.5	$2.18 \pm 0.01 \times 10^3$
	CIBA-GEIGY	3×10^7	samples broken after irradiation		
150	CY 205(100) + HY 964(130) + + DY 040(20) + DY 064(0.5) + + Silica 40 h 75 °C	0	83.4 ± 2.9	2.4 ± 0.3	$8.36 \pm 0.37 \times 10^3$
		5×10^6	56.9 ± 4.9	1.1 ± 0.1	$9.98 \pm 0.39 \times 10^3$
		1×10^7	42.2 ± 3.9	0.9 ± 0.1	$9.40 \pm 0.29 \times 10^3$
	CIBA-GEIGY	3×10^7	samples broken after irradiation		

Assume a limit of 20 MGy

No.	Material and Supplier	Dose (Gy)	Ultimate flex. strength S (N/mm²)	Deflexion at break D (mm)	Modulus of elasticity M (N/mm²)
320	ARALDITE D + HY 956 (Cured at ambient temp.)	0	92.2 ± 12.8	5.9 ± 1.6	$2.78 \pm 0.05 \times 10^3$
		2×10^6	46.1 ± 31.4	2.2 ± 1.7	$2.82 \pm 0.27 \times 10^3$
		6×10^6	23.5 ± 10.8	1.1 ± 0.6	$2.44 \pm 0.38 \times 10^3$
		2×10^7	samples broken after irradiation		
	+)	2×10^6	69.7 ± 32.4	3.7 ± 2.3	$2.78 \pm 0.09 \times 10^3$
		6×10^6	11.8 ± 3.9	0.6 ± 0.2	$2.33 \pm 0.12 \times 10^3$
	SIN	2×10^7	samples broken after irradiation		
321	ARALDITE D + HY 956 filled with cotton (Cured at ambient temp.)	0	91.2 ± 3.9	5.3 ± 1.1	$3.82 \pm 0.09 \times 10^3$
		2×10^6	21.6 ± 3.9	1.1 ± 0.3	$2.84 \pm 0.06 \times 10^3$
		6×10^6	22.6 ± 3.9	1.3 ± 0.4	$2.25 \pm 0.32 \times 10^3$
		2×10^7	samples broken after irradiation		
	+)	2×10^6	36.3 ± 9.8	2.1 ± 0.8	$2.52 \pm 0.41 \times 10^3$
		6×10^6	26.5 ± 9.8	1.4 ± 0.5	$2.75 \pm 0.34 \times 10^3$
	SIN	2×10^7	1.9 ± 0.0	0.4 ± 0.1	$5.20 \pm 1.84 \times 10^2$

311	CY 205(100) + HY 906(80) + + DY 061(0.5) + Silica	0	96.1 ± 2.9	1.6 ± 0.0	$9.28 \pm 0.09 \times 10^3$
		5×10^6	67.7 ± 1.96	1.4 ± 0.1	$9.15 \pm 0.17 \times 10^3$
		1×10^7	64.5 ± 3.9	1.3 ± 0.1	$9.16 \pm 0.16 \times 10^3$
	CIBA-GEIGY	5×10^7	30.6 ± 0.98	0.6 ± 0.0	$7.48 \pm 0.34 \times 10^3$
312	CY 205(100) + HY 906(80) + + DY 061(0.5)	0	64.9 ± 5.9	3.0 ± 0.2	$3.35 \pm 0.07 \times 10^3$
		5×10^6	68.7 ± 5.9	2.9 ± 0.3	$3.67 \pm 0.04 \times 10^3$
		1×10^7	50.0 ± 2.9	2.0 ± 0.1	$3.81 \pm 0.08 \times 10^3$
	CIBA-GEIGY	2.5×10^7	32.6 ± 7.8	1.3 ± 0.3	$3.93 \pm 0.13 \times 10^3$

169	CY 205(100) + HY 905(100) + + DY 040(10) + Silica(400) + + DY 061(1)	0	51.0 ± 3.9	1.4 ± 0.1	$1.02 \pm 0.02 \times 10^4$
		5×10^6	50.0 ± 2.0	1.3 ± 0.0	$1.27 \pm 0.25 \times 10^4$
		1×10^7	29.4 ± 2.0	0.9 ± 0.1	$1.10 \pm 0.07 \times 10^4$
	CIBA-GEIGY	5×10^7	27.8 ± 4.9	1.1 ± 0.1	$8.13 \pm 1.20 \times 10^3$

Magnet damage with shielding point 3 and 7, W shielding peak dose scaling

IP 3	*Action LS1*		*Dose [MGy] for integrated luminosity 150 fb^-1*		*Action LS2*		*Dose [MGy] for integrated luminosity 350 fb^-1*		*Action LS3*		*Dose [MGy] for integrated luminosity 3000 fb^-1*		*Action during HL-LHC exploitation*	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L
MQWA.A4			0.0	0.1			0.1	0.2			1.0	1.9		
MQWA.B4			0.1	0.1			0.1	0.2			1.0	2.1		
MQWB.4			0.1	0.1			0.1	0.3			1.1	2.2		
MQWA.C4			0.1	0.1			0.2	0.3			1.4	2.8		
MQWA.D4			0.2	0.3			0.4	0.8			3.5	6.9		
MQWA.E4			0.9	1.7	S	S	1.2	2.5	S	S	6.3	12		
MQWA.A5			0.6	1.1	S	S	0.8	1.6	S	S	4.0	7.5		
MQWA.B5			0.7	1.4	S	S	1.0	2.0	S	S	5.1	9.4		
MQWB.5			1.7	3.3	S	S	2.4	4.8	S	S	12	23		
MQWA.C5			3.9	7.7	S	S	5.6	11	S	S	29	53		
MQWA.D5			0.9	1.9	S	S	1.3	2.7	S	S	6.8	13		
MQWA.E5			1.7	3.5	S	S	2.5	5.0	S	S	13	24		
MBW.A6			1.0	2.0	S	S	1.4	2.9	S	S	7.3	14		
MBW.B6			1.2	2.3	S	S	1.7	3.3	S	S	8.4	16		
MBW.C6			1.6	3.3	S	S	2.3	4.7	S	S	12	3		

IP 7	*Action LS1*		*Dose [MGy] for integrated luminosity 150 fb^-1*		*Action LS2*		*Dose [MGy] for integrated luminosityy350 fb^-1*		*Action LS3*		*Dose [MGy] for integrated luminosity3000 fb^-1*		*Action during HL-LHC exploitation*	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L
MQWA.A4			0.4	0.5			0.9	1.2			7.4	11		
MQWA.B4			0.3	0.8			0.7	1.9			6.4	16		
MQWB.4			0.5	1.3		S	1.2	1.8		S	10.1	9		
MQWA.C4			4.0	4.0	S	S	5.8	5.8	S	S	30	30		
MQWA.D4			2.7	2.7	S	S	3.8	3.8	S	S	20	20		
MQWA.E4			5.0	10.0	S	S	7.2	14	S	S	37	73		R
MQWA.A5			2.6	2.6	S	S	3.7	3.7	S	S	19	19		
MQWA.B5			3.5	3.5	S	S	5.0	5.0	S	S	25	25		
MQWB.5			4.1	4.1	S	S	5.9	5.9	S	S	30	30		
MQWA.C5			1.9	4.9	S	S	2.8	7.0	S	S	14	36		
MQWA.D5	S	S	1.4	2.0	done	done	3.3	4.7	done	done	27.9	39.9		
MQWA.E5	S	S	12	4.1	Remove									
MBW.A6	S	S	7.8	5.5	done	done	18	13	done	done	155	111	R	R
MBW.B6	S	S	12	6.2	done	done	30	14	done	done	248	124	R	R

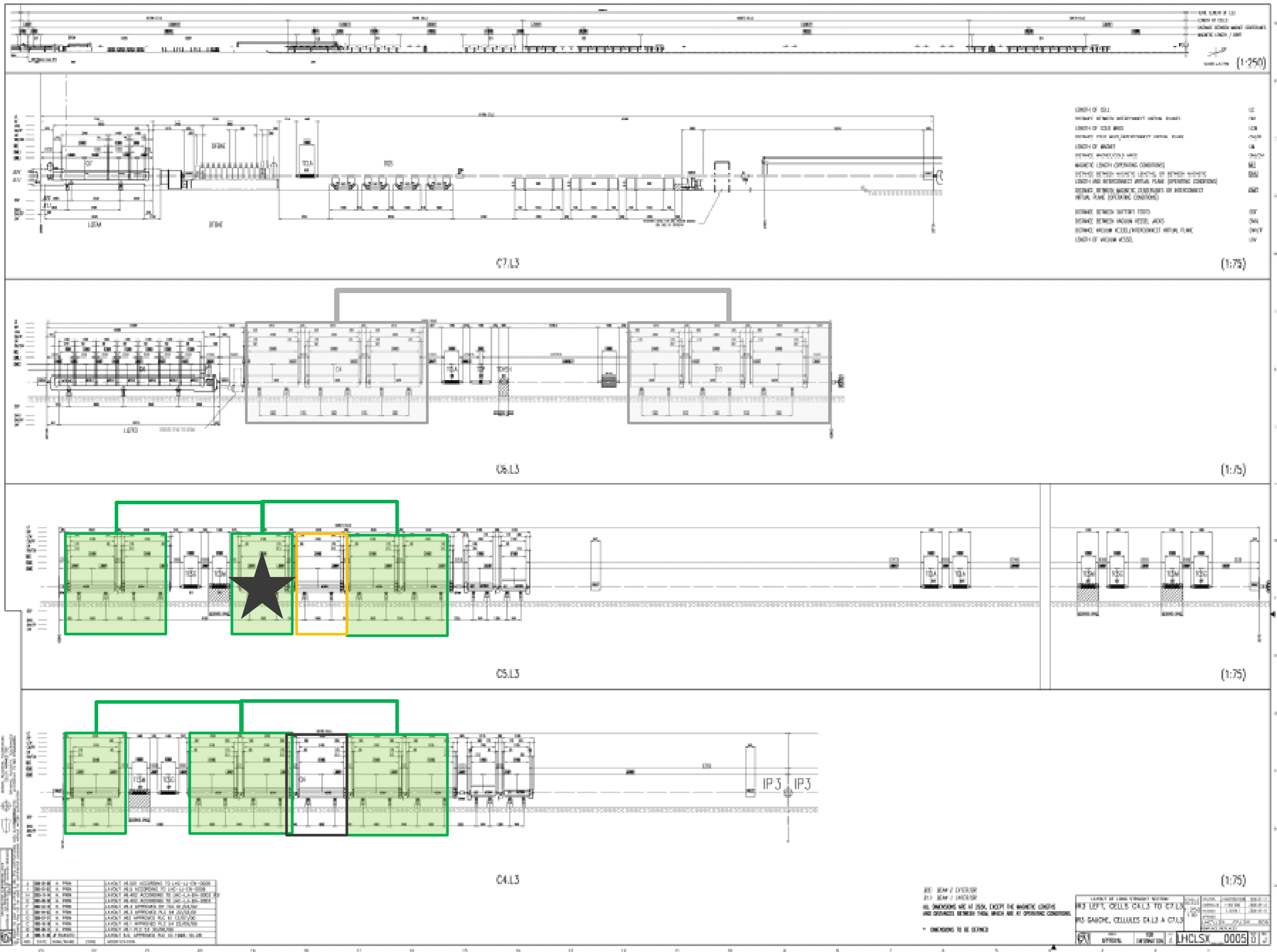
Limit reached in	7R	7L
MQWA.E4		1500 fb^-1
MBW.B6	1500 fb^-1	2400 fb^-1
MBW.A6	1000 fb^-1	2000 fb^-1

MQW Shielding strategy

Bring the coil below 50 MGy, trying to get uniform and below that level (useless to have points at 10 MGy if your peak is at 50 MGy)

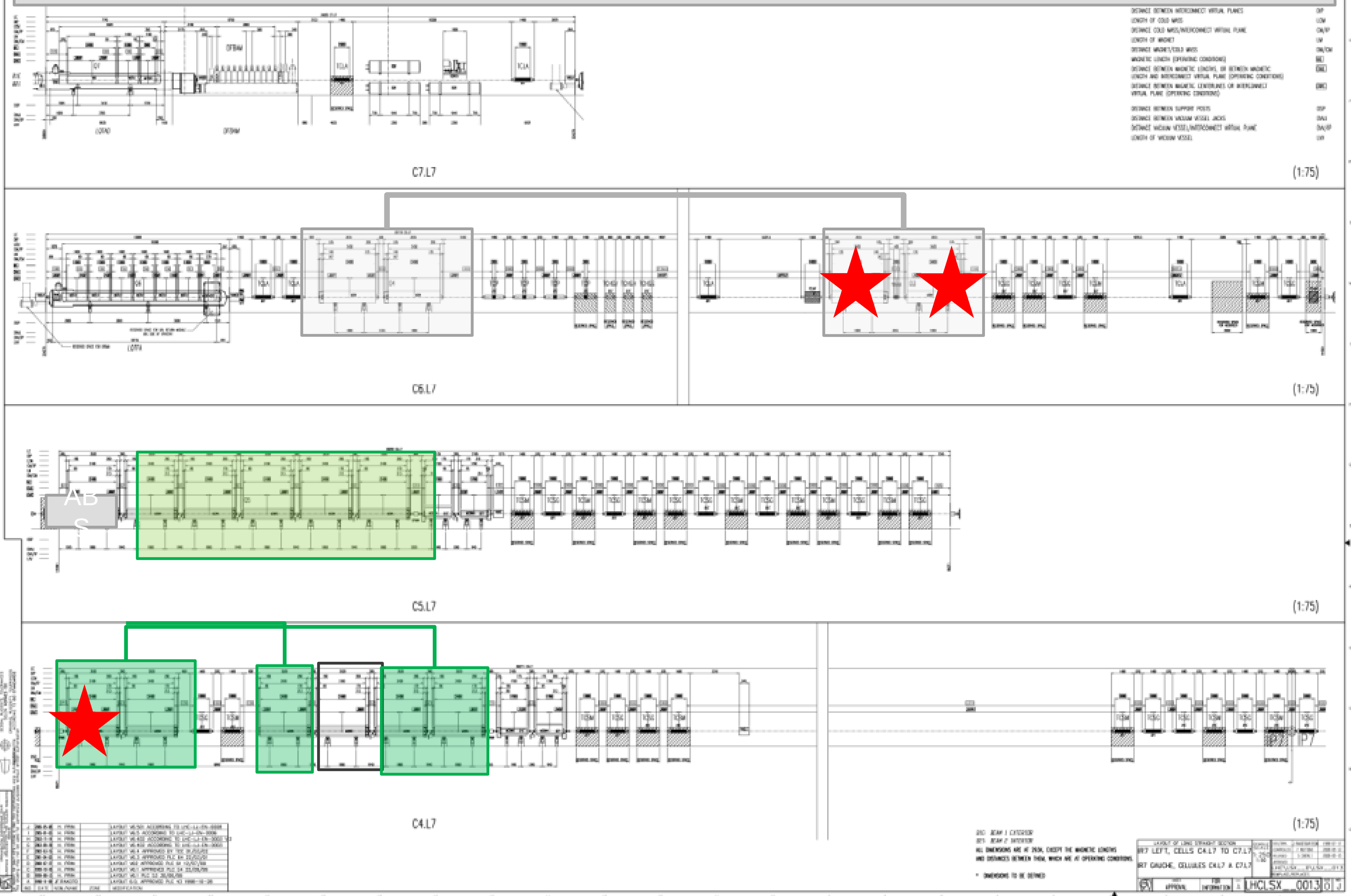
IP 3	*Peak dose reduction factor to reach 3000 fb^-1*		*Shielding strategy*	
	R	**L**	W	Steel/Copper/Bronze
MQWA.A4				
MQWA.B4				
MQWB.4				
MQWA.C4				
MQWA.D4				
MQWA.E4	Not needed	Not needed		50 cm
MQWA.A5	Not needed	Not needed		50 cm
MQWA.B5	Not needed	Not needed		50 cm
MQWB.5	Not needed	1.4	50 cm	rest of length
MQWA.C5	1.7	3.3	100 cm	rest of length
MQWA.D5	Not needed	Not needed		50 cm
MQWA.E5	Not needed	1.5	50 cm	rest of length

IP 7	*Peak dose reduction factor to reach 3000 fb^-1*		*Shielding strategy*	
	R	**L**	W	Steel/Copper/Bronze
MQWA.A4	Not needed	Not needed		
MQWA.B4	Not needed	Not needed		
MQWB.4	Not needed	Not needed	none	full length
MQWA.C4	1.6	1.6	50 cm	rest of length
MQWA.D4	1.1	1.1	none	full length
MQWA.E4	2.0	4.0	100 cm	rest of length
MQWA.A5	1.0	1.0	none	full length
MQWA.B5	1.4	1.4	none	full length
MQWB.5	1.6	1.6	50 cm	rest of length
MQWA.C5	Not needed	1.9	50 cm	rest of length
MQWA.D5	1.7	2.4	100 cm	rest of length
MQWA.E5	14.8	4.9	100 cm	rest of length



(1:250)
C7.L3
(1:75)
C6.L3
(1:75)
C5.L3
(1:75)
C4.L3
(1:75)
IP3
IP3
R3 LEFT, CELLS C4.L3 TO C7.L3
R3 GAUCHE, CELLULES C4.L3 A C7.L3
LHCLSX__0005

Optic change proposal point 7 discussed and agreed as possible with M. Giovannozzi (it needs verification)



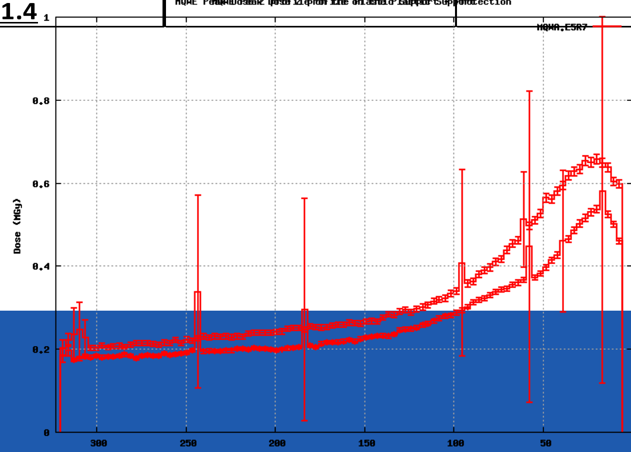
Estimated MQW spacer damage with screens

(extrapolated red. factor 3)

IP 7	Dose [Mgy] for integrated luminosity 150 fb^-1		Dose [Mgy] for integrated luminosityy350 fb^-1		Dose [Mgy] for integrated luminosity3000 fb^-1	
	R	L	R	L	R	L
MQWA.A4	0.1	0.2	0.3	0.4	2.5	3.5
MQWA.B4	0.1	0.3	0.2	0.6	2.1	5.3
MQWB.4	0.2	0.4	0.4	1.0	3.4	8.4
MQWA.C4	1.3	1.3	3.1	3.1	26.6	26.6
MQWA.D4	0.9	0.9	2.1	2.1	17.7	17.7
MQWA.E4	1.7	3.3	3.9	7.8	33.2	66.5
MQWA.A5	0.9	0.9	2.0	2.0	17.3	17.3
MQWA.B5	1.2	1.2	2.7	2.7	23.1	23.1
MQWB.5	1.4	1.4	3.2	3.2	27.0	27.0
MQWA.C5	0.6	1.6	1.5	3.8	12.9	32.4
MQWA.D5	1.4	2.0	3.3	4.7	27.9	39.9
MQWA.E5	12.3	4.1	28.7	9.6	246.0	82.0

IP 7	Dose [Mgy] for integrated luminosity 150 fb^-1		Dose [Mgy] for integrated luminosityy350 fb^-1		Dose [Mgy] for integrated luminosity3000 fb^-1	
	R	L	R	L	R	L
MQWA.A4	0.1	0.2	0.3	0.4	2.5	3.5
MQWA.B4	0.1	0.3	0.2	0.6	2.1	5.3
MQWB.4	0.2	0.4	0.4	**0.6**	3.4	**3.1**
MQWA.C4	1.3	1.3	**1.9**	**1.9**	**9.8**	**9.8**
MQWA.D4	0.9	0.9	**1.3**	**1.3**	**6.5**	**6.5**
MQWA.E4	1.7	3.3	**2.4**	**4.8**	**12.2**	**24.4**
MQWA.A5	0.9	0.9	**1.2**	**1.2**	**6.3**	**6.3**
MQWA.B5	1.2	1.2	**1.7**	**1.7**	**8.5**	**8.5**
MQWB.5	1.4	1.4	**2.0**	**2.0**	**9.9**	**9.9**
MQWA.C5	0.6	1.6	**0.9**	**2.3**	**4.7**	**11.9**
MQWA.D5	**0.5**	**0.7**	**1.1**	**1.6**	**9.3**	**13.3**
MQWA.E5	**4.1**	**1.4**				

Need to modify screen design



LONG VERSION

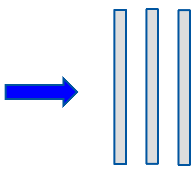
The doses

MEASUREMENTS VS EXPECTATIONS

(different collimation settings and before change of slope losses vs. luminosity)

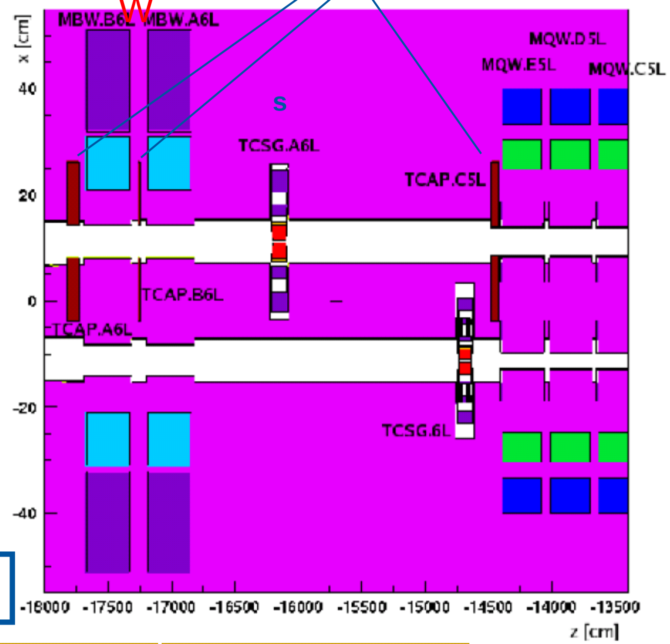
beam 1

v h s



TCP.D C B 6L7.B1

MB W TCAP MQW



IP7

assuming a horizontal

	7 TeV	3.5 TeV
magnet	peak dose [MGy]	
MBW.B6L7	3.3	1.7
MQWA.E5L7	0.9	0.3

for ***intermediate*** *collimator settings*

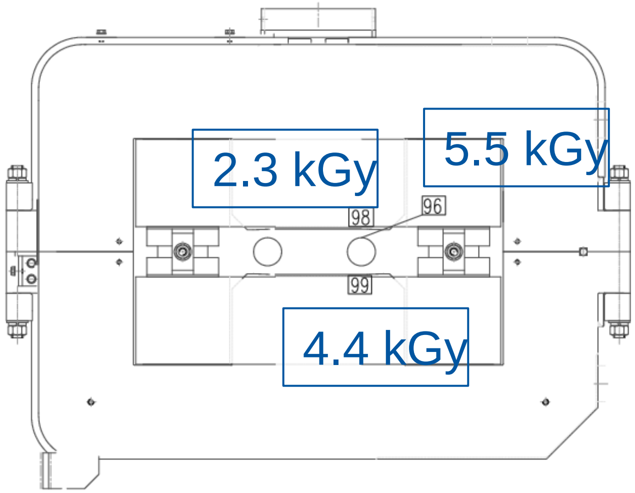
for **1.15 10^16** lost protons per beam

taking for 4 TeV
with **tight** settings

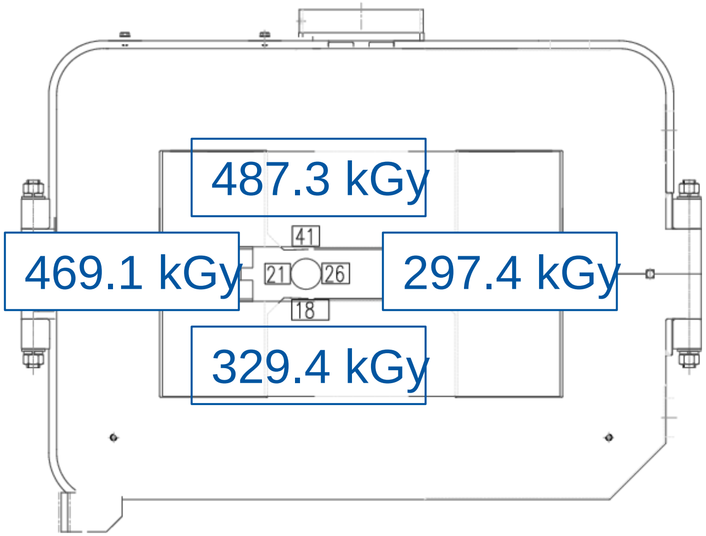
2	one would get by	250kGy	100-400 kGy
0.5	normalizing to **1.4 10^15** beam 1 protons lost in P7	60 kGy	measured 60 kGy

Point 3 vs. point 7

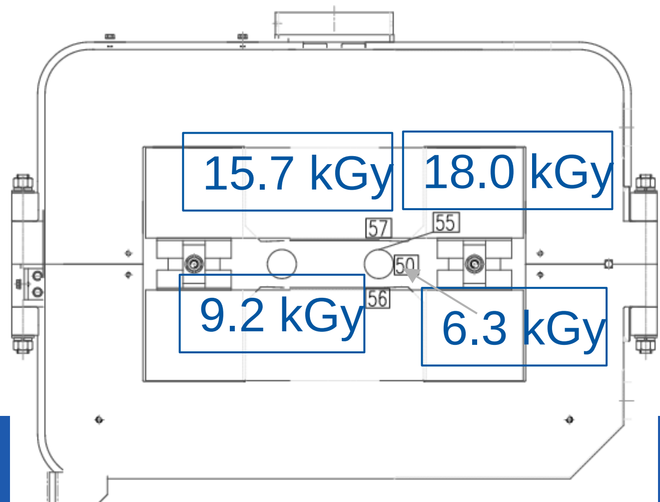
MBW.C6R3 DROIT



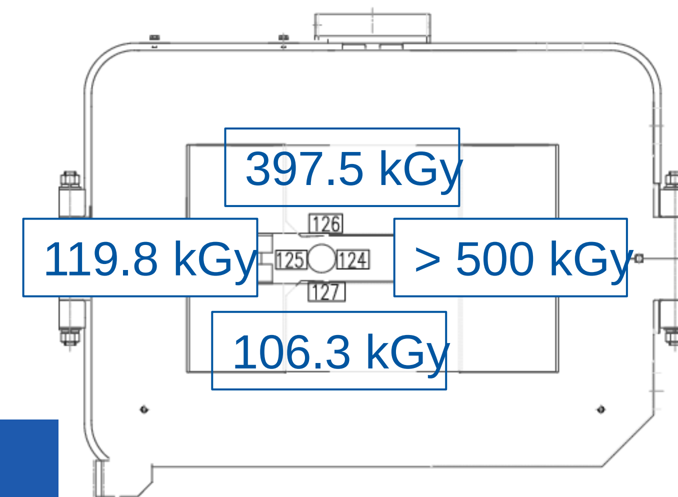
MBW.B6R7 DROIT



MBW.C6L3 GAUCHE

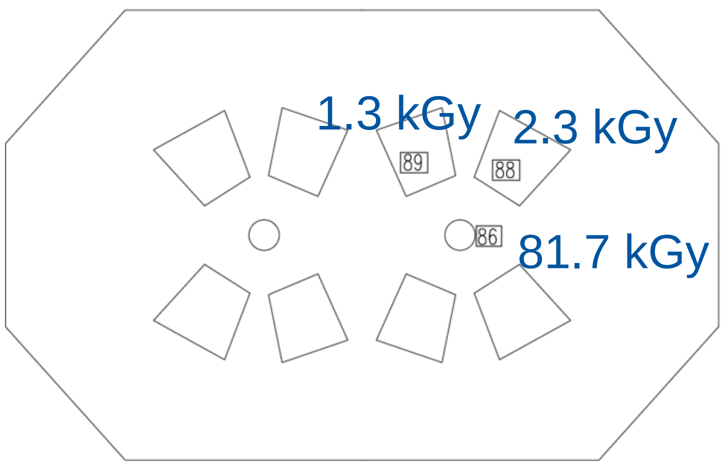


MBW.B6L7 GAUCHE

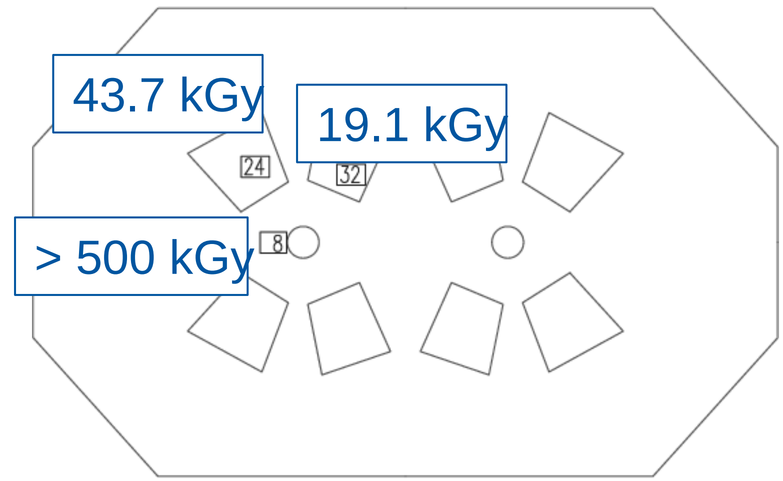


Point 3 vs. point 7

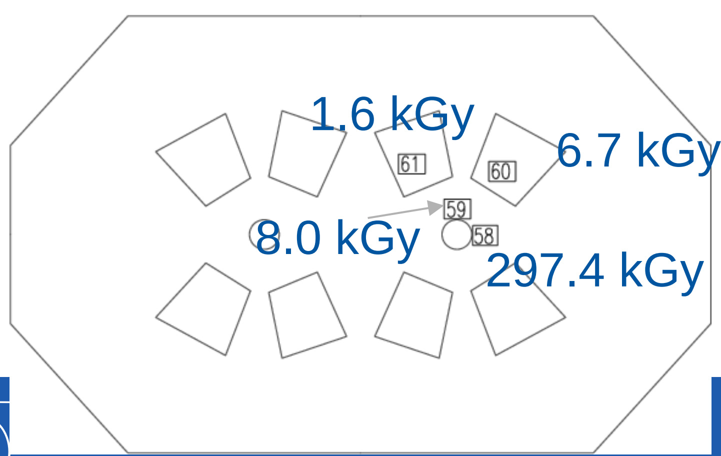
MQWA.E5R3 DROIT



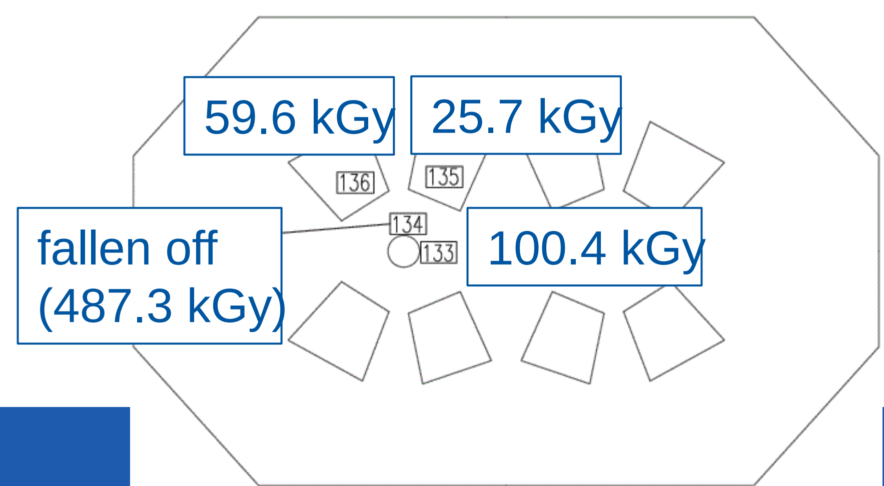
MQWA.E5R7 DROIT



MQWA.E5L3 GAUCHE



MQWA.E5L7 GAUCHE

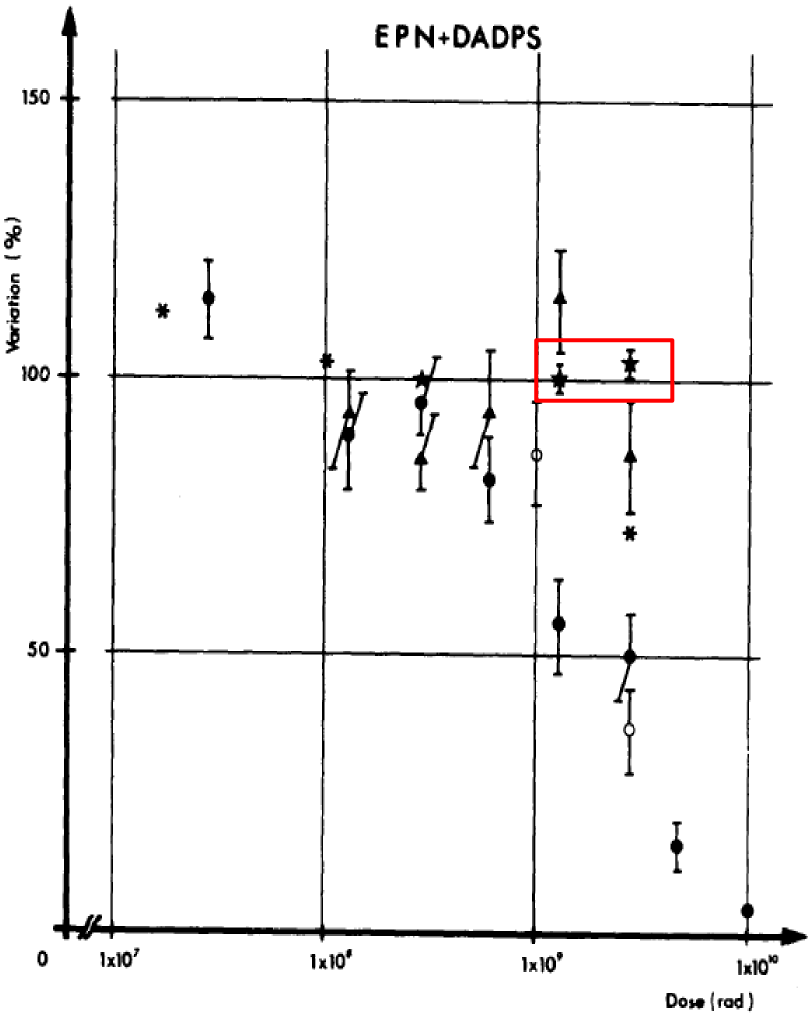


Estimated dose point 3 and point 7

IP 3	Dose [Mgy] for integrated luminosity 150 fb^-1		Dose [Mgy] for integrated luminosityy350 fb^-1		Dose [Mgy] for integrated luminosity3000 fb^-1	
	R	L	R	L	R	L
MQWA.A4	0.1	0.1	0.1	0.2	1.0	2.1
MQWA.B4	0.1	0.1	0.1	0.3	1.1	2.2
MQWB.4	0.1	0.1	0.1	0.3	1.2	2.4
MQWA.C4	0.1	0.1	0.2	0.3	1.5	3.0
MQWA.D4	0.2	0.4	0.4	0.9	3.7	7.4
MQWA.E4	0.9	1.9	2.2	4.3	18.6	37.2
MQWA.A5	0.6	1.2	1.4	2.8	11.9	23.8
MQWA.B5	0.7	1.5	1.7	3.5	14.9	29.7
MQWB.5	1.8	3.6	4.2	8.3	35.7	71.3
MQWA.C5	4.2	8.3	9.7	19.4	83.2	166.4
MQWA.D5	1.0	2.0	2.3	4.7	20.1	40.1
MQWA.E5	1.9	3.7	4.3	8.7	37.2	74.3
MBW.A6	1.1	2.1	2.5	5.0	21.4	42.7
MBW.B6	1.2	2.5	2.9	5.8	24.8	49.6
MBW.C6	1.8	3.5	4.1	8.2	35.0	70.1

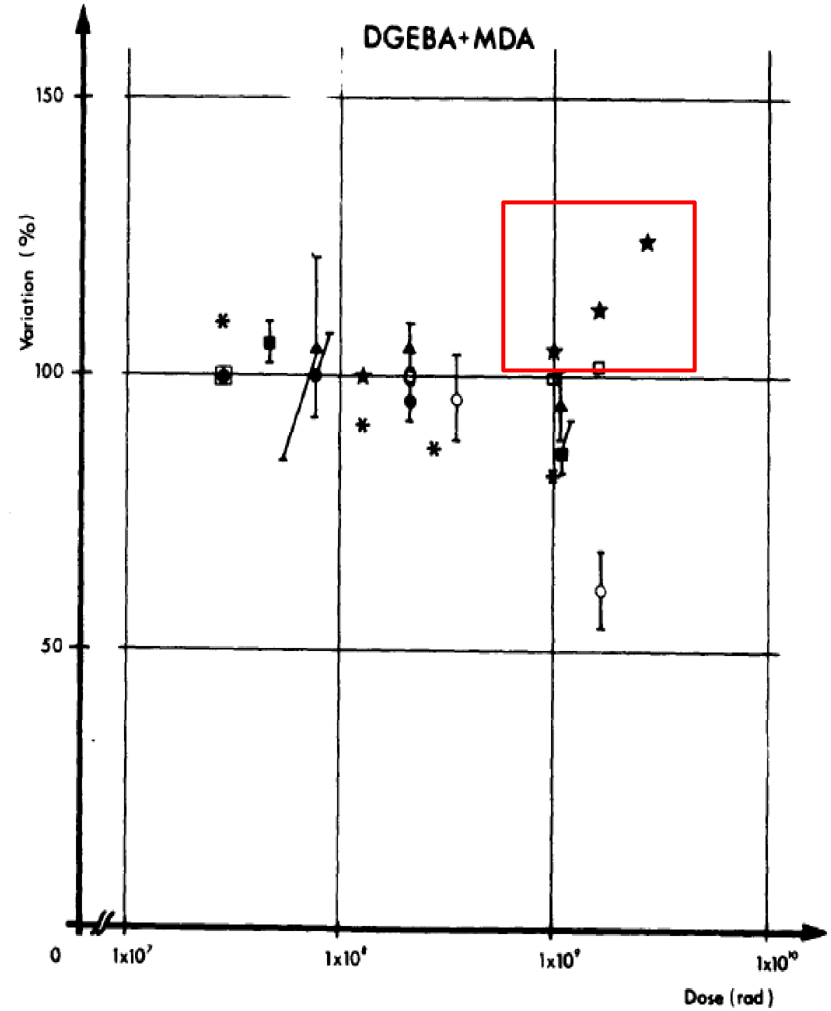
IP 7	Dose [Mgy] for integrated luminosity 150 fb^-1		Dose [Mgy] for integrated luminosityy350 fb^-1		Dose [Mgy] for integrated luminosity3000 fb^-1	
	R	L	R	L	R	L
MQWA.A4	0.4	0.5	0.9	1.2	7.4	10.6
MQWA.B4	0.3	0.8	0.7	1.9	6.4	16.0
MQWB.4	0.5	1.3	1.2	2.9	10.1	25.3
MQWA.C4	4.0	4.0	9.3	9.3	79.8	79.8
MQWA.D4	2.7	2.7	6.2	6.2	53.2	53.2
MQWA.E4	5.0	10.0	11.6	23.3	99.7	199.5
MQWA.A5	2.6	2.6	6.1	6.1	51.9	51.9
MQWA.B5	3.5	3.5	8.1	8.1	69.2	69.2
MQWB.5	4.1	4.1	9.5	9.5	81.1	81.1
MQWA.C5	1.9	4.9	4.5	11.3	38.8	97.1
MQWA.D5	4.2	6.0	9.8	14.0	83.8	119.7
MQWA.E5	36.9	12.3	86.1	28.7	738.1	246.0
MBW.B67	23.3	16.6	54.3	38.8	465.5	332.5
MBW.A67	37.2	18.6	86.9	43.4	744.8	372.4

Magnet lifetime



Modifications des propriétés mécaniques du EPN+DADPS
en fonction des doses absorbées

● 1 - Résistance à la flexion	14,5	kg/mm²
○ 2 - Résistance à la traction	9,1	kg/mm²
▲ 3 - Module d'élasticité	245	kg/mm²
△ 4 - Allongement à la rupture		mm
■ 5 - Résistance au choc		kg-m/cm²
□ 6 - Dureté		
★ 7 - Absorption d'eau - 25 °C , 4 jours	0,5	%
✱ 8 - Point de fléchissement à la chaleur	216	°C



Modifications des propriétés mécaniques du DGEBA+MDA
en fonction des doses absorbées

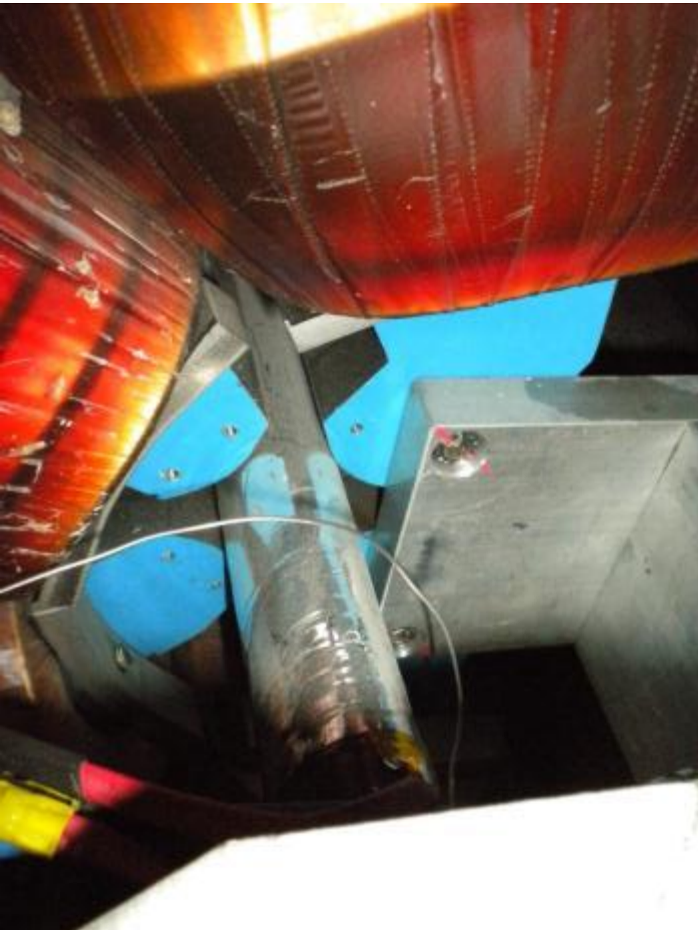
● 1 - Résistance à la flexion	17	kg/mm²
○ 2 - Résistance à la traction	7,2	kg/mm²
▲ 3 - Module d'élasticité	325	kg/mm²
△ 4 - Allongement à la rupture		mm
■ 5 - Résistance au choc	25	kg-m/cm²
□ 6 - Dureté	86	Shore D
★ 7 - Absorption d'eau - 25 °C , 4 jours	0,6	%
✱ 8 - Point de fléchissement à la chaleur	158	°C

POWER DEPOSITION

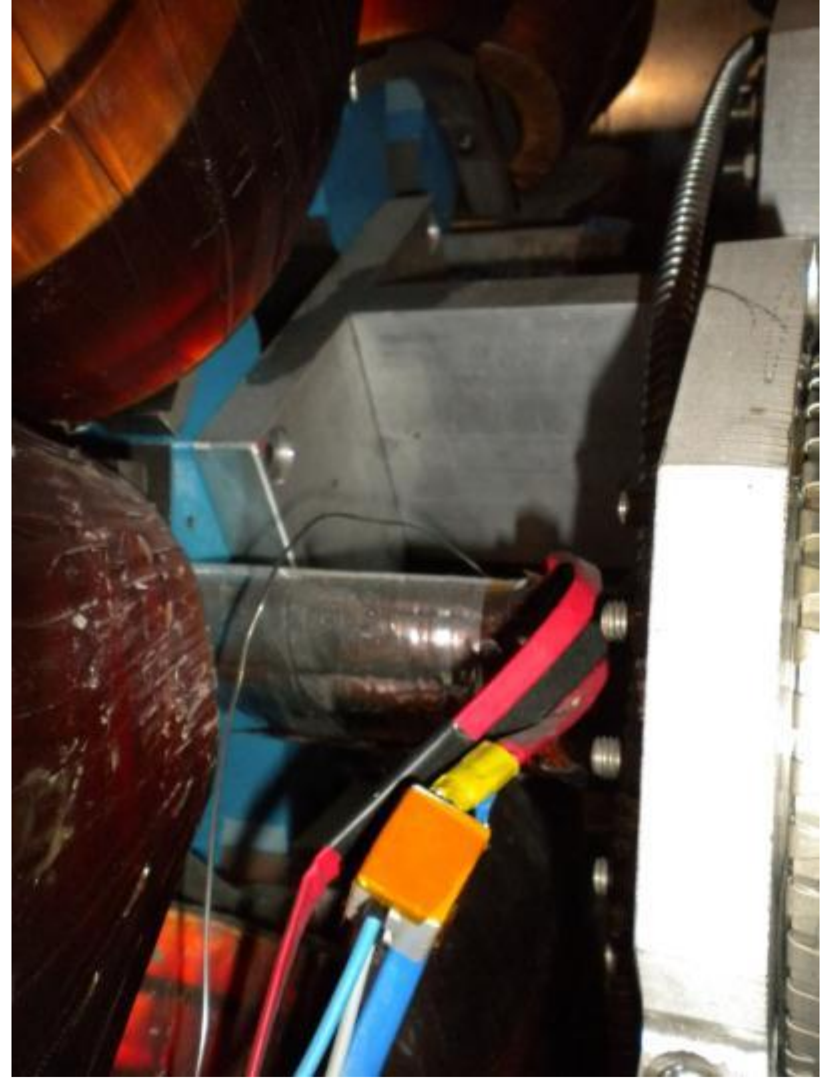
Power deposition

	MQW		MBW	
Ultimate current	810	A	820	A
Electrical dissipated power ultimate current	25	kW	41	kW
Delta T measured ultimate current on cooling water	16	C	30	C
New operational current	620	A	650	A
New dissipated electrical power operational current	15	kW	26	kW
Worst dissipated power due to radiation losses (including dissimetry and new loss rate)	3	kW	4	kW
New total power to be dissipated (Pel+Prad+Pconv)	19	kW	30	kW
New Delta T necessary to evacuate the power	12	C	22	C
New magnet working temperature	38	C	48	C

Remark
Due to small lifetime (load case 1h) we do not take into account the coefficient 2linked to the ratio losses/luminosity nor the discrepancy B1/B2 (L/R)

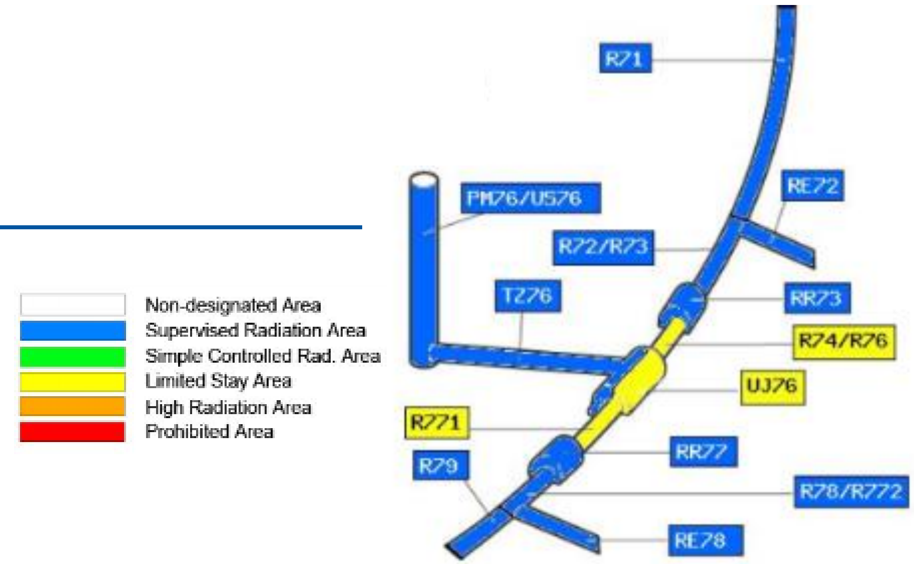


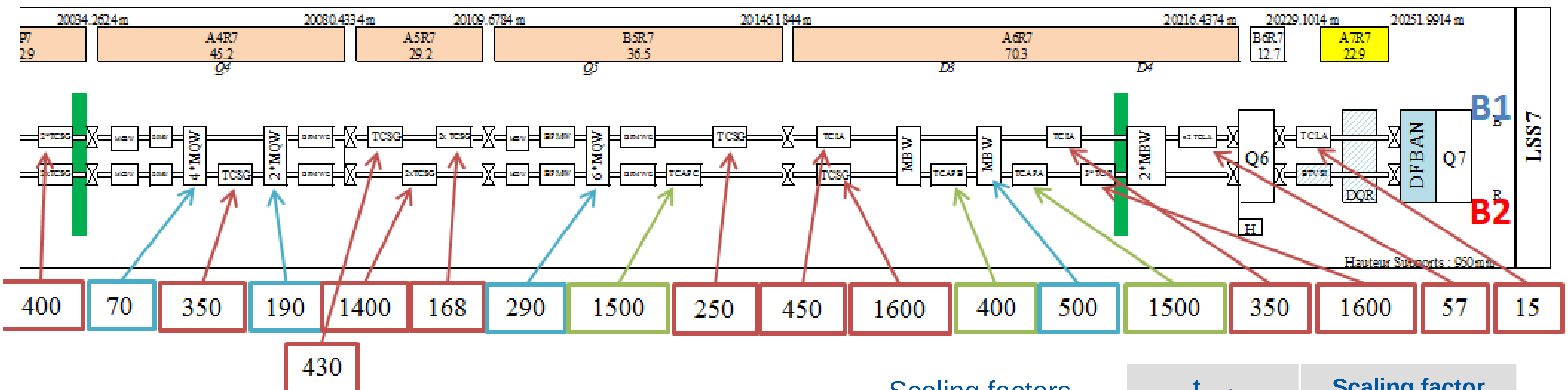

3
R5



LHC Point 7

Ambient dose equivalent rates in µSv/h at 40cm measured on Dec 20, 2012
(last “good” fill on Dec 5, i.e. cooling time >1week)





collimators
magnets
absorbers

Scaling factors based on generic Studies for IR7:

t_{cool}	Scaling factor
One hour	1.4
One day	1.0
One week	0.73
One month	0.45
4 months	0.20

Table 1

Technical application, composition, curing conditions, and short survey on properties of the tested impregnation systems based on ARALDITE® and ARACAST® epoxy resins

Type	1	2 and 2a	3	4	5
Technical application CERN	Vacuum impregnation of ISR magnet coils	Vacuum impregnation of SPS magnet coils	Comparative systems		
			Standard 1	Standard 2	Hydantoin
Composition: a)					
- Epoxy resins	EPN 1138 Araldite MY 745 Araldite CY 221	Araldite MY 745	Araldite CY 205= Araldite F	Araldite CY 205 = Araldite F	Aracast CY 362
- Hardener	HY 905	HY 906	HY 905	HY 906	HY 905
- Accelerator	XB 2687	XB 2687	DY 061	DY 064	XB 2687
Parts per weight of the components	50:50:20:120:0.3	100:90:1.5	100:100:1	100:80:1	100:120:1.5
Curing conditions for test specimen	24 h/120 °C	Type 2: 5 h/110 °C + 16 h/125 °C Type 2a: 24 h/150 °C	8 h/80 °C + 8 h/130 °C	24 h/150 °C	12 h/90 °C + 18 h/140 °C
Processing properties b)	Medium viscosity, very good long pot-life, long gel-time.	Medium viscosity, long pot-life, medium gel-time.	Medium viscosity, short pot-life, short gel-time.	Medium viscosity, short pot-life, short gel-time.	Low viscosity, long pot-life, short gel-time.
Mechanical and thermo-mechanical properties b)	Good flexibility, medium heat distortion temperature respectively glass transition temperature (medium cross-linking grade).	Good flexibility, higher transition temperature than type 1 (higher cross-linking grade). Type 2a: less flexible and higher glass transition temperature.	Good flexibility, medium glass transition temperature (medium cross-linking grade).	Medium flexibility, high glass transition temperature (high cross-linking grade).	Medium heat distortion temperature respectively glass transition temperature (medium cross-linking grade).
Electrical properties b)	Medium tracking resistance.	Good properties as a function of temperature.	Very good tracking resistance.	Good dielectrical properties as a function of temperature.	Very good tracking resistance.

a) For more details see Table 2; b) For more details see Table 3.

ARALDITE® and ARACAST® are trade names of Ciba-Geigy epoxy resins.

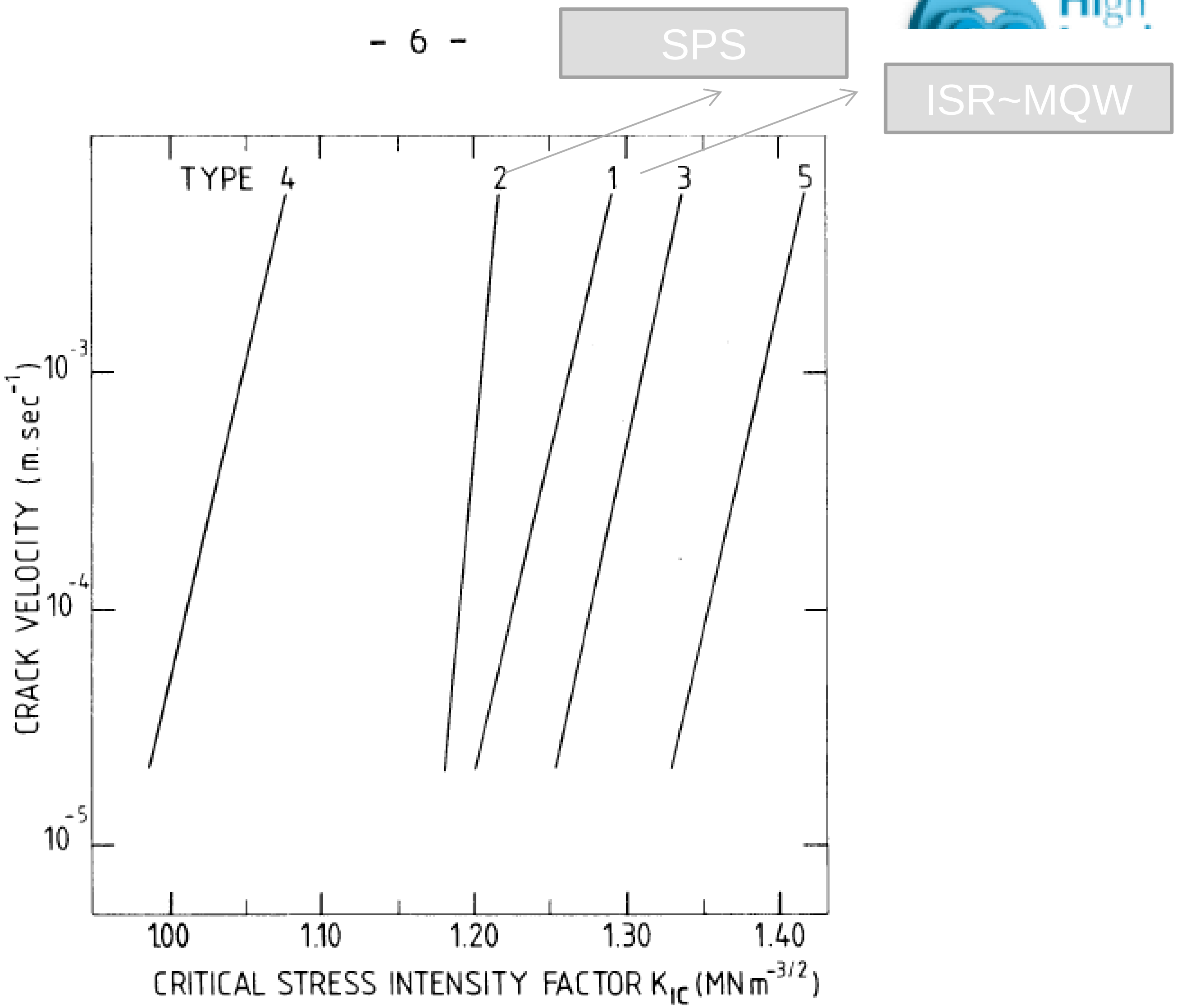
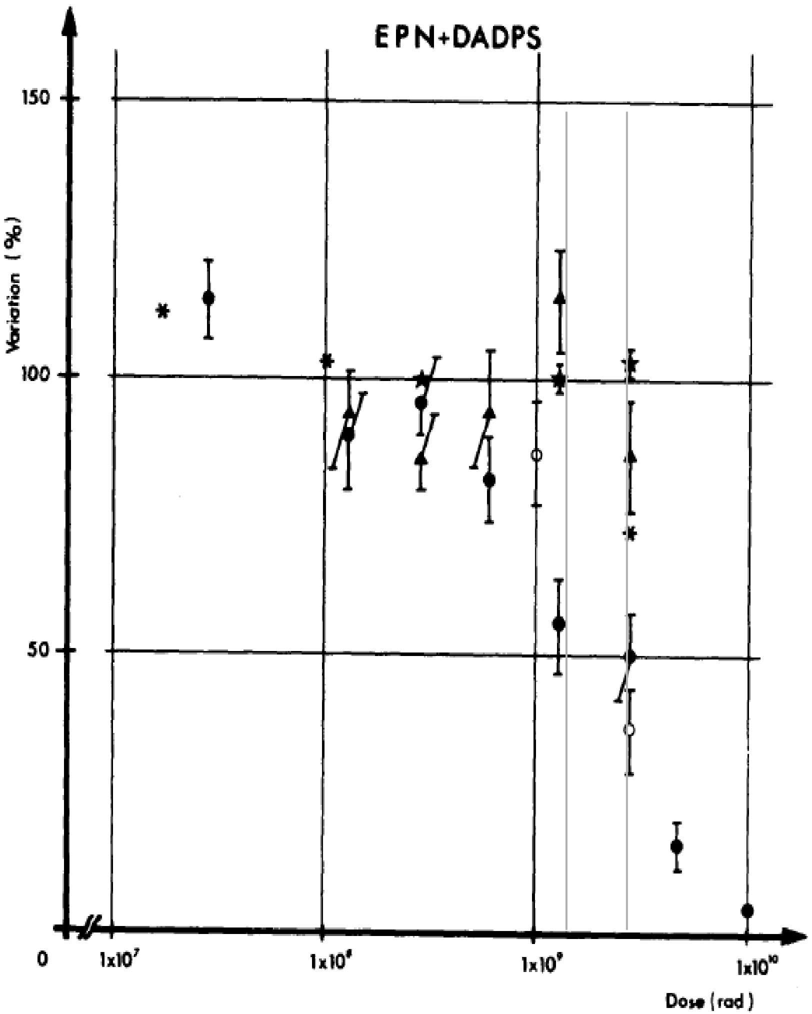
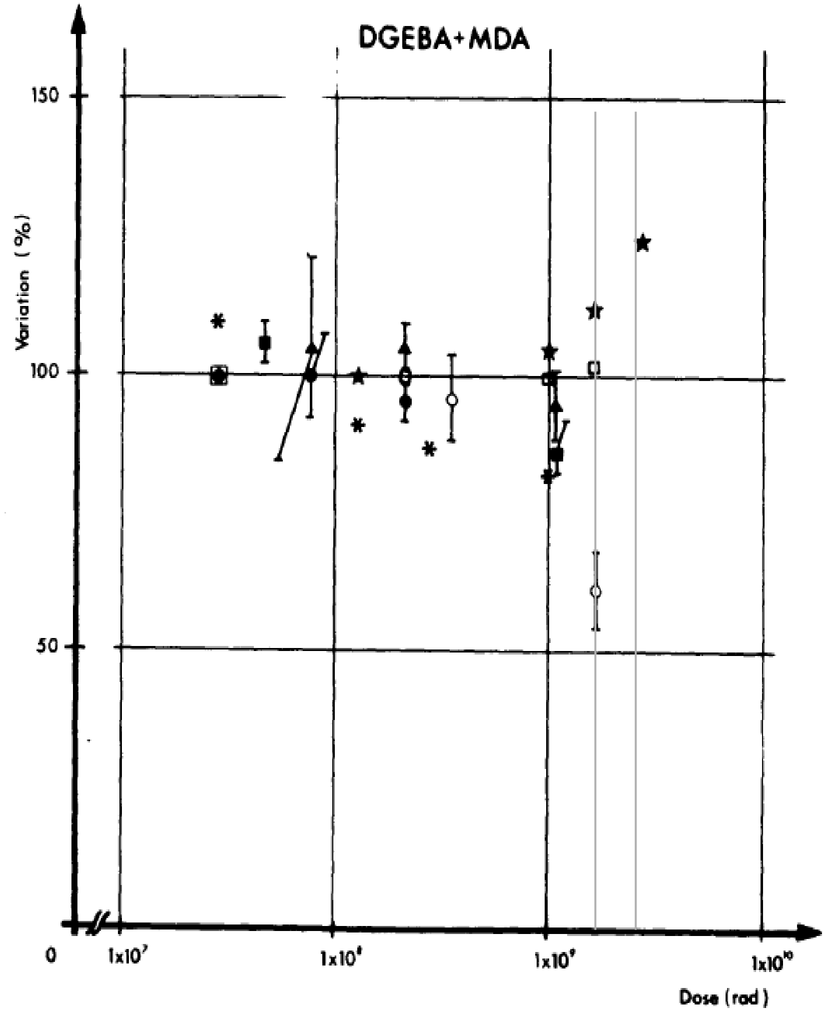


Fig. 4 Crack velocity as a function of critical stress intensity factor



Modifications des propriétés mécaniques du EPN+DADPS
en fonction des doses absorbées

● 1 - Résistance à la flexion	14,5	kg/mm²
○ 2 - Résistance à la traction	9,1	kg/mm²
▲ 3 - Module d'élasticité	245	kg/mm²
△ 4 - Allongement à la rupture		mm
■ 5 - Résistance au choc		kg-m/cm²
□ 6 - Dureté		
★ 7 - Absorption d'eau - 25 °C, 4 jours	0,5	%
✱ 8 - Point de fléchissement à la chaleur	216	°C



Modifications des propriétés mécaniques du DGEBA+MDA
en fonction des doses absorbées

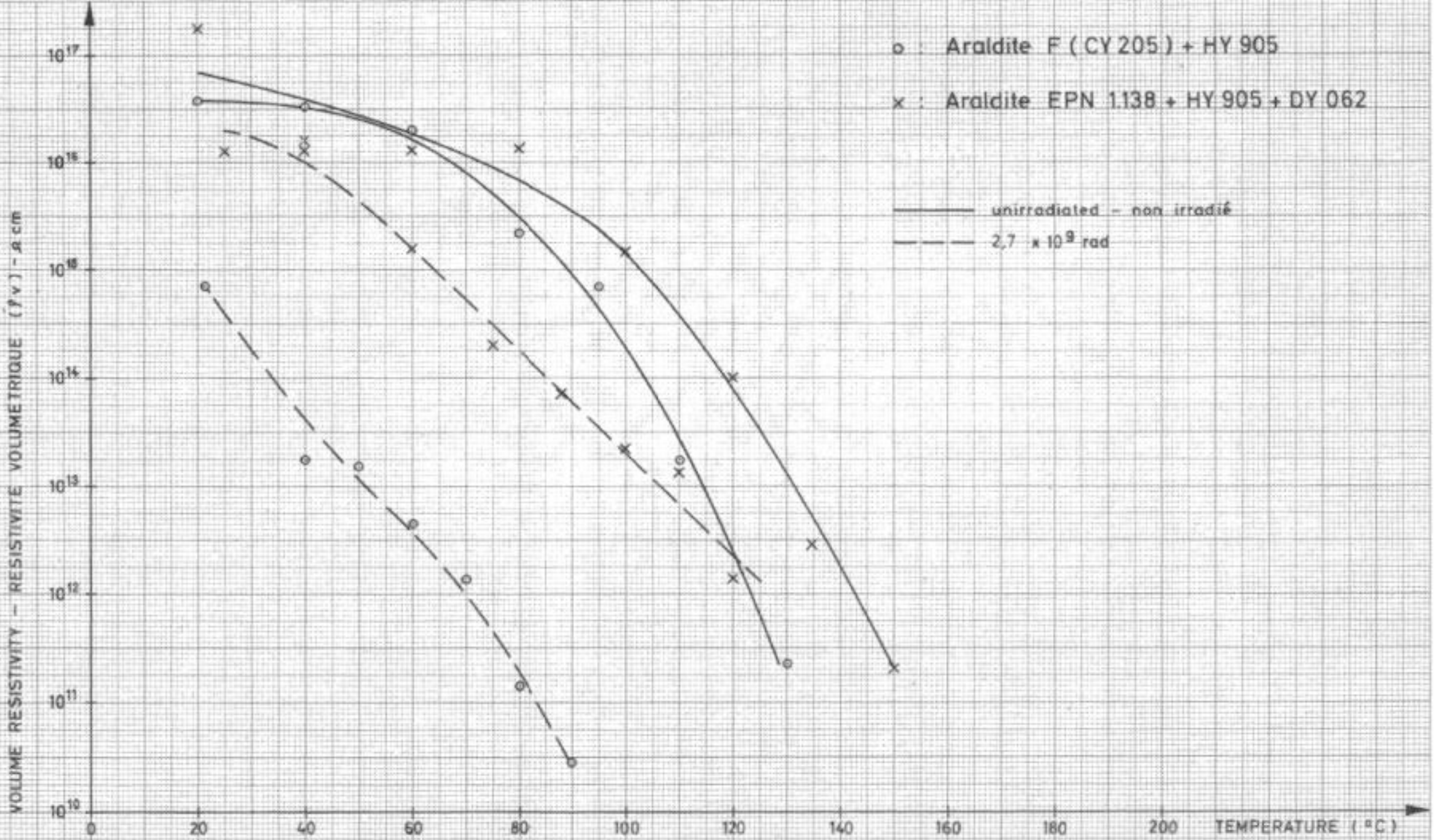
● 1 - Résistance à la flexion	17	kg/mm²
○ 2 - Résistance à la traction	7,2	kg/mm²
▲ 3 - Module d'élasticité	325	kg/mm²
△ 4 - Allongement à la rupture		mm
■ 5 - Résistance au choc	25	kg-m/cm²
□ 6 - Dureté	86	Shore D
★ 7 - Absorption d'eau - 25 °C, 4 jours	0,6	%
✱ 8 - Point de fléchissement à la chaleur	158	°C

Table III.1e

Effect of nuclear radiation on the dielectric strength of epoxy resins

Resin composition	Dielectric strength (kV/mm) versus dose (rad)						
	0	2.3×10^8	5.6×10^8	6.8×10^8	1.2×10^9	1.2×10^9	2.7×10^9
1) Araldite F + MDA	21.2 ± 0.8				17.7 ± 0.8(83.5)		16.1 ± 0.8(76)
2) Araldite F + DADPS	21.4 "				18.5 " (86.5)		17.5 " (82)
3) Araldite F + MA	19.0 "				18.2 " (96)		17.8 " (93.5)
4) Araldite B + AP	18.1 "				17.4 " (96)		14.5 " (80)
5) Araldite F + DPA + TETA	19.6 "	19.5 ± 0.8(100)		16.5 ± 0.8(84)	0		
6) EPN + MA + BDMA	22.5 "		21.0 ± 0.8(93.5)			20.0 ± 0.8(89)	
7) EPN + MDA	19.1 "		20.0 " (105)			18.5 " (97)	
8) TGMD + MA + BDMA	20.1 "		18.7 " (93.5)			18.0 " (90)	
9) TGMD + MDA	23.4 "		23.3 " (100)			25.2 " (108)	

The values in brackets represent the percentage of the initial value.

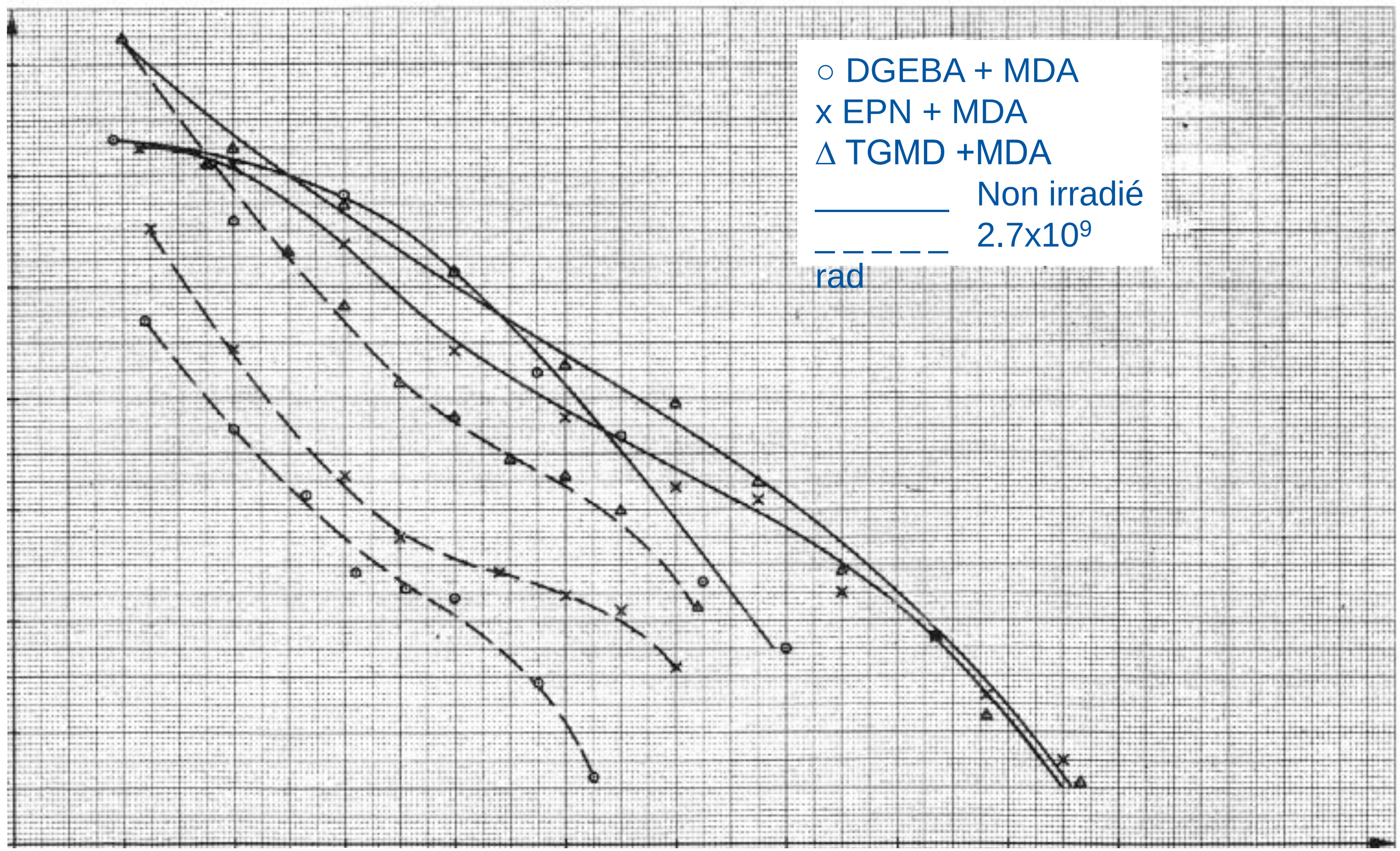


VOLUME RESISTIVITY VS TEMPERATURE FOR IRRADIATED EPOXY RESINS CURED WITH HY 905

RESISTIVITE VOLUMETRIQUE VS TEMPERATURE POUR DES RESINES EPOXYDES IRRADIEES DURCIE AVEC HY 905

Fig. 11

Electrical Properties Changes 2



ρ = ~10^{16} Ω·cm @RT

T ↑ => ρ ↓

High mechanical radio-resistance → High electrical resistance (mechanical degradation occurs first)

Example of low mechanical-resistance system: DGEBA-DBP-TETA → ρ = ~10^{13} Ω·cm @RT for 6.8x10^8 rad

DGEBA considerations

4.1 Pure resin combinations (Table 2 and Figs. 1 to 6)

The radiation resistance of composite insulating materials depends primarily on the binding material, in particular in cases where the other components are inorganic, e.g. glass tape, mica, etc. For this reason pure resins that are generally used as binding materials were included in this study. On the other hand, not too much importance should be attributed to these results since the radiation resistance may be considerably improved by the reinforcing materials.

Comparing the results and taking the half-value dose for flexural strength after irradiation as the parameter, the following radiation resistance was found:

- No. 338, epoxy resin + isocyanate — up to 1×10^8 Gy
- No. 348, epoxy resin: DGEBA + anhydride + other components — up to 3×10^7 Gy
- No. 336, epoxy resin: DGEBA + anhydride + other components — up to 1×10^7 Gy
- No. 337, silicone resin — up to 1×10^7 Gy
- No. 369, silicone resin — up to 1×10^7 Gy
- No. 368, epoxy resin: DGEBA + anhydride + other components — up to 3×10^6 Gy

4

No.	Material Type Supplier Remarks	Dose (Gy)	Flex. strength at max. load S (MPa)	Deflexion at max. load D (mm)	Modulus of elasticity M (GPa)	RI IEC 544-4 at 10^5 Gy/h
336	Solventless epoxy resin	0.0	85.0 ± 3.0	4.6 ± 0.1	3.36 ± 0.02	7.3
	(Base: DGEBA + anhydride hardener + other components)	3.0×10^5	90.6 ± 7.5	4.6 ± 0.1	3.54 ± 0.09	
	Micadur resin	1.0×10^6	94.4 ± 6.0	5.2 ± 0.3	3.47 ± 0.11	
	BBC, Baden	3.0×10^6	84.2 ± 6.0	4.6 ± 0.6	3.41 ± 0.16	
	HV machine insulation application	1.0×10^7	75.0 ± 6.1	4.0 ± 0.4	3.46 ± 0.06	
		3.0×10^7	31.4 ± 0.0	2.9 ± 0.0	1.93 ± 0.0	
		1.0×10^8	6.4 ± 2.5	0.8 ± 0.3	1.00 ± 0.32	

PROPOSALS I

	Traction test	Flexural test	Leakage current in air humid	Dielectric in air humid	Leakage current in air humid after 1 month in water	Dielectric in air humid after 1 month in water
0 MGy	Y	Y	(Y)	Y	(Y)	Y
10 Mgy		Y	(Y)	Y	(Y)	Y
20 Mgy	Y	Y	(Y)	Y	(Y)	Y
40 Mgy	Y	Y	(Y)	Y	(Y)	Y
50 MGy			(Y)	Y	(Y)	Y
60 MGy	Y	Y	(Y)	Y	(Y)	Y
70 MG	Y	Y	(Y)	Y	(Y)	Y

Wafer 1 and 2 mm thickness resin and glass fibre

PROPOSALS II

	Shear test	Leakage current in air humid	Dielectric in air humid	Leakage current in air humid after 1 month in water	Dielectric in air humid after 1 month in water
0 MGy	Y	(Y)	Y	(Y)	Y
10 Mgy		(Y)	Y	(Y)	Y
20 Mgy	Y	(Y)	Y	(Y)	Y
40 Mgy	Y	(Y)	Y	(Y)	Y
50 MGy		(Y)	Y	(Y)	Y
60 MGy	Y	(Y)	Y	(Y)	Y
70 M					

Insulated cables, 2 resins, 3 samples