



# **Follow-up on heat loads and cooling capacity estimations**

*(for WP2-WP9 discussion)*

Daniel Berkowitz (TE-CRG)

On behalf of HL-LHC / WP9 / Heat Load Working Group

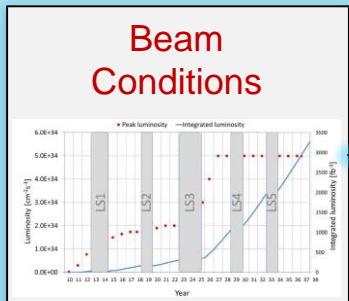
CERN, 9 November 2016

# Outline

1. Methodology for heat load estimation (quick recapitulation)
2. Reasons to update heat load data
3. Proposed update of heat load data (for sync.rad., image current & e-cloud)
4. Interface between WP2 & WP9 (communication of heat load data)

# Methodology for heat load estimations

## EDMS 1719021 v0.2



## EDMS 1610791 v0.3

**Heat load data**

Heat Load Type	Heat Loads on Sector 4.5 (W)				
	40-50 K	4.5-20 K	4.5 K	1.8 K	3.4 K
Heat-In leaks	1200	361	18.77	520.4	-
Resistive heating	58.50	16.58	0.544	283.4	-
Synchrotron radiation	-	872	0.0628	1.822	-
Image current	-	0.022	0.0628	2.794	-
Longitudinal impedance	-	-	-	-	-
Photo-electron	-	294	1.101	2483	-
Photo gas ionization	-	-	-	-	-
Secondary particle losses	-	1.473	3.96	225.5	-
Heat-In leaks	382.0	5	-	50	-
Resistive heating	-	-	-	2.34	-

Recollected from official sources:

- HLWG 2000
- LHC Design Report
- LHC Project Note 140
- ...

**Theoretical values!**  
Measured values to be considered at a later stage.

**Reference heat loads**  
(for „LHC nominal“)

## Scaling laws (equations)

Scaling factors for:

- Heat-in leaks
- Resistive heating
- Synchrotron radiation
- Image current
- ...

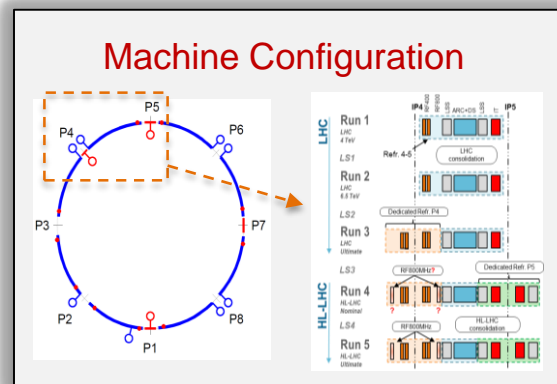
scale up

„scaled“ heat loads

sum all

**Total heat load on Sector**

Values w/o contingency



Total heat loads are defined by

- Beam conditions
- Machine configurations

# Reasons to update heat load data

EDMS 1610791 v0.3

Heat Load Type		Heat Load on Sector 45 (W)					
		30-25 K	4.5-20 K	4.5 K	1.8 K	3.4 K	20-20 K
Magnets	Heat in leads	170.30	301	18.37	238.4	-	-
	Resonator heating	30.50	16.38	8.544	233.4	-	-
	Quadrupole radiation	-	93	0.0436	1.822	-	-
	Quadrupole current	-	102	0.0054	2.764	-	-
	Longitudinal impedance	-	-	-	-	-	-
	Diode electron	-	286	1.101	2483	-	-
	Beam gas scattering	-	1.473	3.596	232.5	-	-
	Secondary particle losses	-	-	-	-	-	-
	Heat in leads	302.5	5	-	50	-	-
	Resonator heating	-	-	-	2.24	-	-

Recollected from official sources:

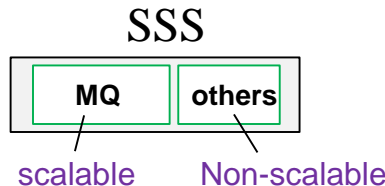
- HLWG 2000
- LHC Design Report
- LHC Project Note 140
- ...

Identified points to be refined (after discussions with G.Iadarola for WP2)

- Design Report (ch.11 *cryogenics*) vs **calculated** by WP2 (see G.Iadarola summary)
  - Image Current: 180 vs **115** mW/m/beam (DR includes 30mW/m/beam for BPM bellows)
  - Synchr. Rad.: consistent within 4% (175 vs **173** mW/m/beam)
  - Electron cloud: **new WP2 calculations** should be used instead.

■ Precision of scaling laws

- Some heat loads are not *scalable*



Estimated as main impact:  
-36% of IC values  
(-700W/sector@4.5-20K)

- SAMs are approximated using MQs. However,
  - SAMs present no synchr. rad.
  - The „drift“ part differs between SAMs

Calculation-based values (SR, IC & e-cloud) can be provided by WP2. A tool is available and can generate calculated values for all magnets at any set of beam-parameters.

# Proposed update of WP9 Input Data

## Heat Load Studies v.2 (concluded)

**EDMS 1610791 v0.3**

Heat Load Data

Recollected from official sources:

- HLWG 2000
- LHC Design Report
- LHC Project Note 140

**EDMS 1719021 v0.1**

**Preliminary**  
Beam Parameters /  
Scaling Laws

**WP2 Input**

## Heat Load Studies v.3 (new version)

**EDMS 1610791 v0.4**

Heat Load Data

Recollected from official sources

- HLWG 2000
- LHC Design Report
- LHC Project Note 140

**EDMS 1719021 v0.3**

Beam Parameters /  
Scaling Laws

Source of input data

Heat Load Mechanism	Scaling Factor
Heat-In leaks	X
Resistive heating	X
Synchr. Rad.	X
Image Current	X
Photo-el. Effect	X
Beam Scattering	X
Sec. particle losses	X

From DR for LHCn

Source of input data

Heat Load Mechanism	Scalingg Factor	Calc.
Heat-In leaks	X	
Resistive heating	X	
Synchr. Rad.		X
Image Current		X
Photo-el. Effect		X
Beam Scattering	X	
Sec. particle losses	X	

From DR for LHCn

Provided by WP2

tbd (DR for now)

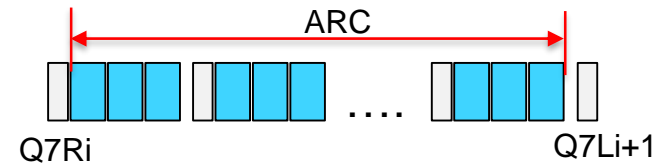
Scaling Factors will be provided, but are for information only.

# Matching the heat load tables between WP2 & WP9

WP2 report on heat loads (CERN-ACC-2016-0112) (for IRs only)

Name	Length	Field config.	Chamber	Impedance (T_BS=20 K)	e-cloud (SEY=1.3/1.1)	Total (SEY=1.3/1.1)
Q6R2	12.0 m		BSMQ_1	9.1 W	191.7/0.8 W	200.8/9.9 W
MQML.6R2.B1	4.8 m	quad	BSMQ_1	3.7 W	111.9 W/0.2 W	
MQM.6R2.B1	3.4 m	quad	BSMQ_1	2.6 W	79.3 W/0.1 W	
MCBCH.6R2.B1	0.9 m	dip	BSMQ_1	0.7 W	0.1 W/0.1 W	
Drifts	2.9 m	drift	BSMQ_1	2.0 W	0.5 W/0.5 W	

- WP2 report is a very good basis. Tables for the other operational scenarios needed.
- *Twin-document* for ARCs needed.
  - ARC will be defined as „magnet string from first to last dipole“



ARC will be treated as a single element

- Discretization would introduce errors for synchr. radiation.
- Average values for the estimation of standard half cells.

Q6R2 (12.0 m)

Values used for analysis

For information only, since averaged value.

Source	Total (2 beams) [W]	Av. Power density [mW/m/beam]
Synchrotron Radiation	0.0	0.0
Image Current	9.1	379.2
Electron cloud	191.7	7987.5
<b>Total</b>	<b>200.8</b>	<b>8366.67</b>

RAW data will be exchanged as .csv file (comma-separated values)