Heat load review
Methodology

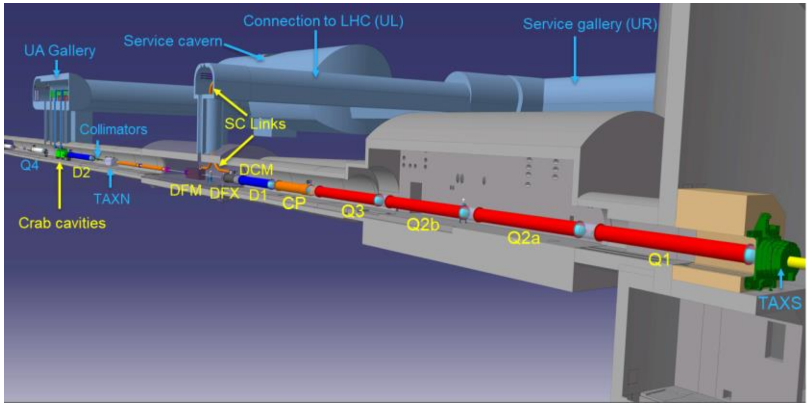
P. Zijm, V. Gahier and S. Claudet on behalf of WP9

https://indico.cern.ch/event/1019569/
EDMS 2560556
CERN, 27/04/2021

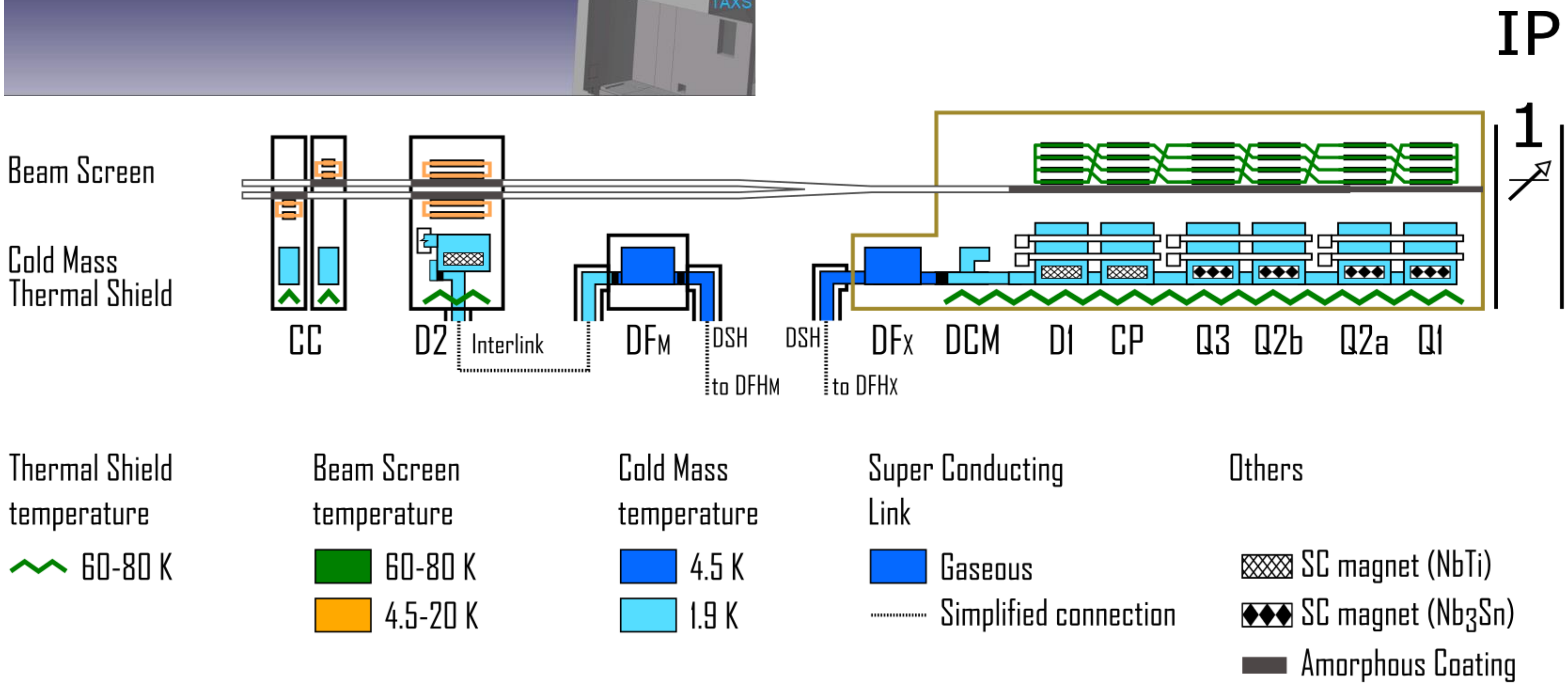
Content

- Introduction and Terminology
  - Hilumi machine configuration
  - Heat load classification and deposition
  - Design coefficients
- Hilumi heat load methodology
  - Static
  - Dynamic
  - Heat load database
- Conclusions
- Overview

Hilumi Machine configuration P1/P5



The **variety** of Users/ Components required a **homogeneous and systematic methodology** to guide towards the design of Refrigerator.



Machine configuration mirrored around Interaction Point (IP)

Breakdown of heat load by type

Determining refrigerator capacity

- Static
  - Heat-In leaks
- Resistive
- Beam Induced
  - Synchrotron radiation
    - Marginal for HL-LHC
  - Image current
  - Electron cloud
  - Beam Scattering
    - Only if degradation of vacuum
- Collision induced
- Radio frequency induced (Crab cavities)

Dynamic heat loads

Not determining

- Cooldown
- Magnet induced
  - Ramp-up / ramp-down
  - Magnet Quench
- Pulse induced

Heat load mechanisms

Static → **occurs at any time** with the same magnitude

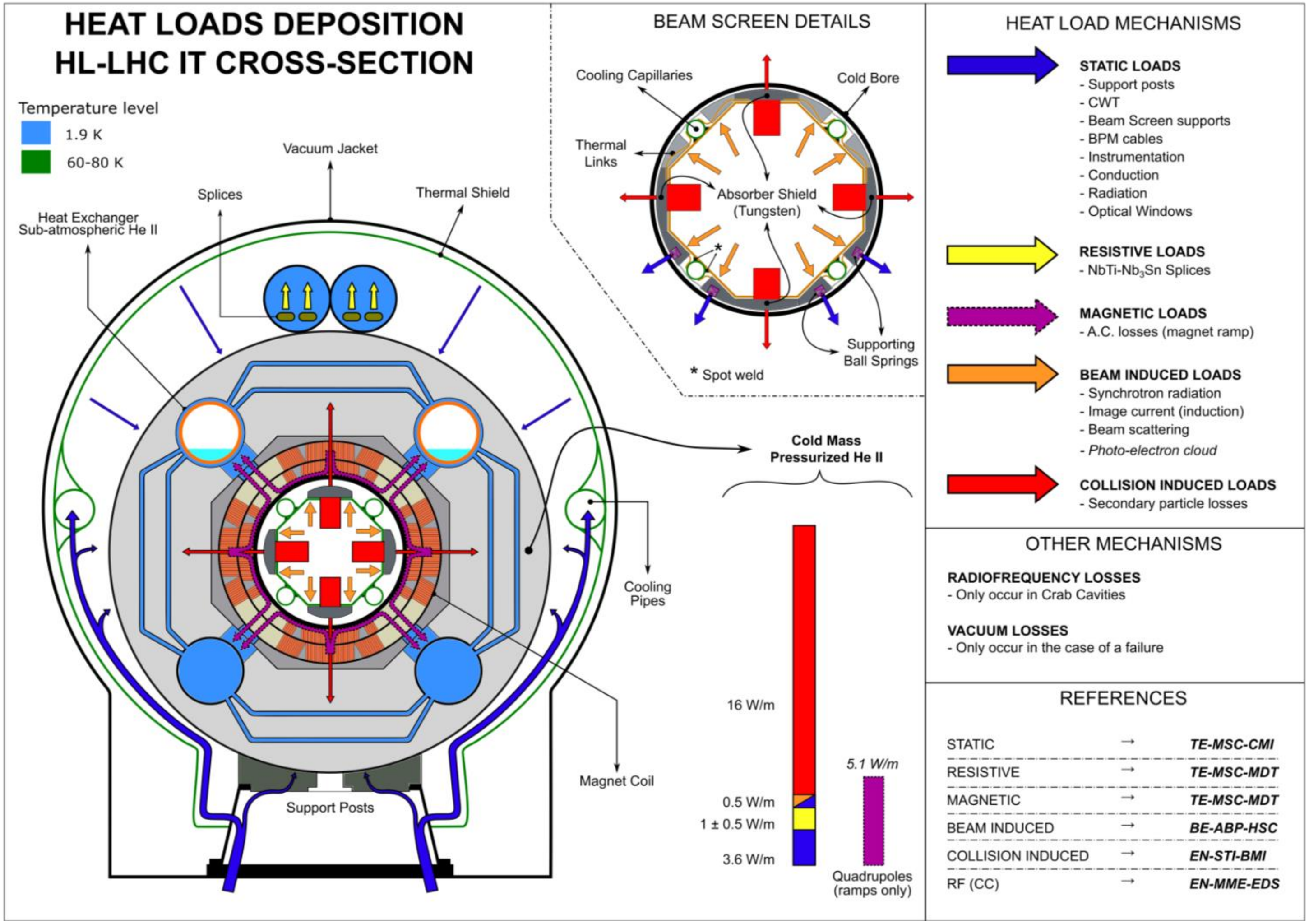
Magnetic (AC losses) → occurs only during current **ramp-up** and **ramp-down**
Specific load 5.1 W/m Magnetic length at cold → 31.1 m

Resistive → goes with the square of current intensity in splice
Splices resistance → 1 nΩ Local powering current leads

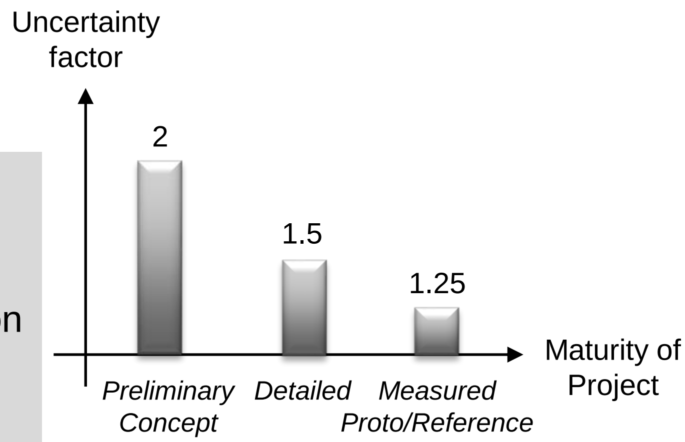
Beam induced→ occurs as long as the **beam is circulating**
Assumed linear with injection → 17 min Beam dump assumed instantaneous

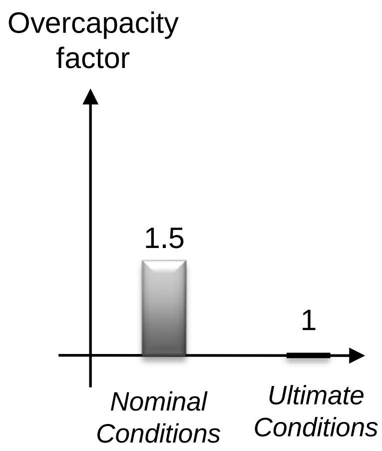
Collision induced→ suddenly occurs when particles collide
Initial regime: instantaneous Time to max collisions: tbd.

Hilumi heat deposition
Magnet schematic - cross view



Terminology and heat loads margins definition





Name & Definition

Static heat load: Q_{static}
Raw static heat load from calculation or measurement without contingency.

Dynamic heat load: $Q_{dynamic}$
Raw dynamic heat load from calculation or simulation without contingency.

Design heat load: Q_{design}
Heat load including uncertainty and overcapacity margin

Installed local cooling capacity :
Capacity that is installed at the user interface

Uncertainty factor (F_{un})
Evolved during the project lifetime. On **static heat loads** only.
To cover:

- uncertainty in the design (material, installation…)
- Engineering change
- Tolerances
- Room for growth

Uncertainty factor evolves with maturity of design.

Overcapacity factor (F_{ov})
On static + dynamic.

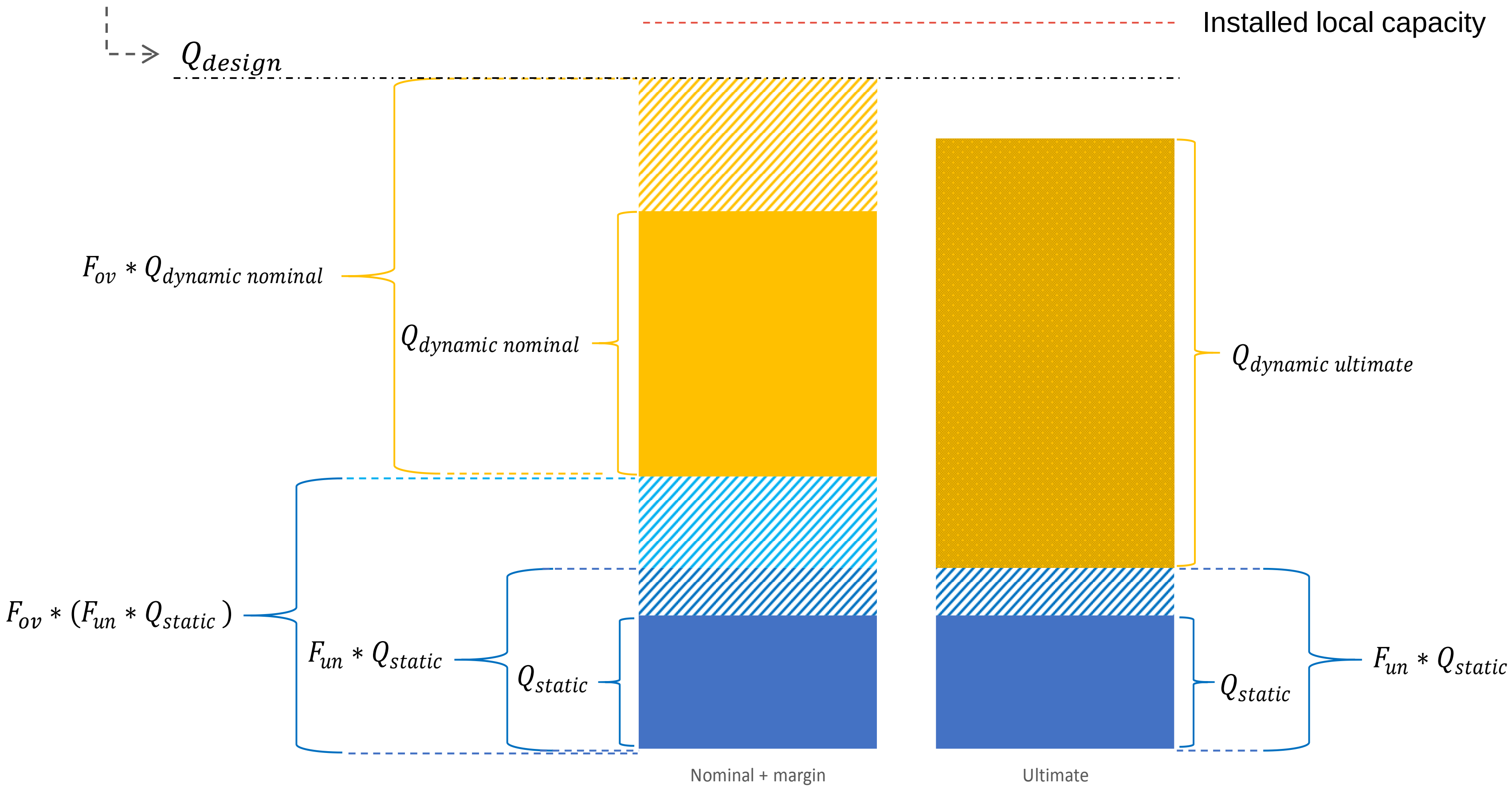
To ensure nominal performance by covering the risk; for example reduced performance, uncertainty due to modelling.

No margin taken on Ultimate Conditions.

Design heat load (Local)

General approach *"inspired from LHC project note 140"* :

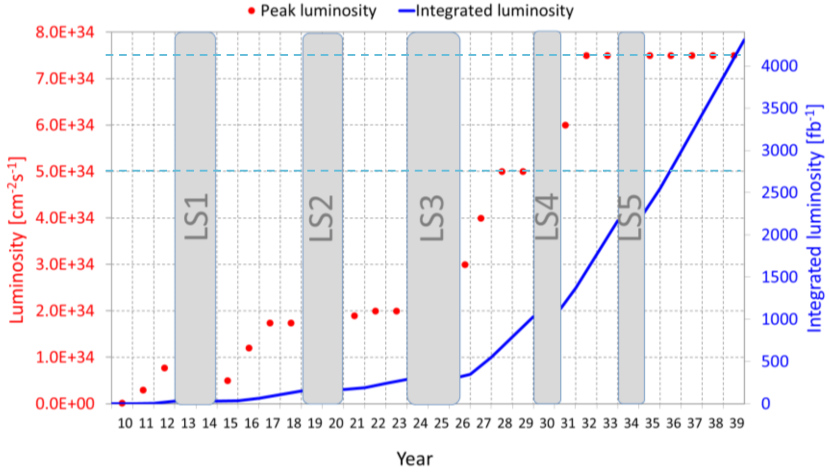
$$Q_{design} = Max\left[\ F_{ov} * \left(F_{un} * Q_{static} + Q_{dynamic\ nominal}\right)\ ;\ F_{un} * Q_{static} + Q_{dynamic\ ultimate}\ \right]$$



**graph not to scale*

Dynamic Operational parameters
From Nominal to Ultimate dynamic heat loads

- **Nominal** conditions as well as **Ultimate Luminosity and Ultimate energy** are considered for the **heat load review**



	Luminosity	Energy
Nominal	5 L0	7 TeV
Ultimate	7.5 L0	7.5 TeV

* L0 = 10^{34} Hz/cm^2

- Dynamic heat loads are provided by WP2 (beam induced heat loads) and by WP10 (collision induced) for given beam parameters and Luminosity. → **Scaling factors** were required for resistive and collision induced heat loads.
- The change in beam induced heat loads between Ultimate and Nominal conditions is assumed negligible.

	Luminosity	Energy
Resistive	-	E^2
Collision	L	15% from 7→ 7.5 TeV

	Scaling factor
Resistive	1.15
Beam induced	1.00
Collision	1.72

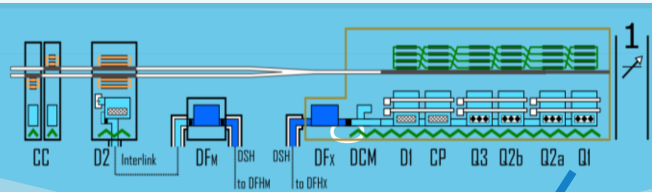
Content

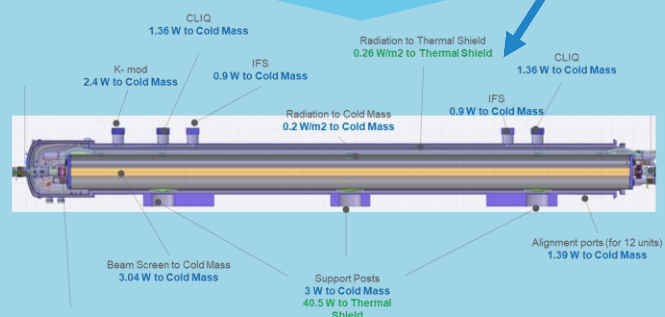
- Introduction term..
  - Hilumi machine configuration
  - Heat load classification and deposition
  - Design coefficients
- Hilumi heat load assessment methodology
  - Static
  - Dynamic
  - Heat load database
- Conclusions
- Overview

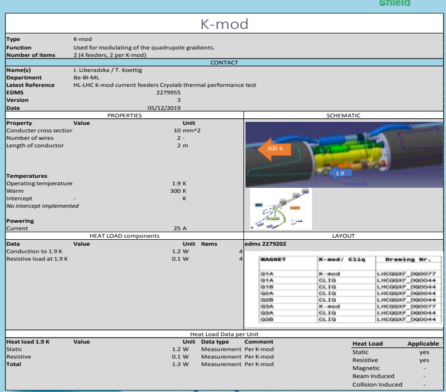
Hilumi static heat load methodology

Q_{static} heat load

Approach for each Temperature level







K-mod

Type	K-mod
Function	Used for modulating of the quadrupole gradients.
Number of items	2 (4 feeders, 2 per K-mod)

CONTACT

Name(s)	J. Liberadzka / T. Koettig
Department	Be-BI-ML
Latest Reference	HL-LHC K-mod current feeders Cryolab thermal performance test
EDMS	2279955
Version	3
Date	05/12/2019

PROPERTIES

Property	Value	Unit
Conducter cross sectior	10	mm^2
Number of wires	2	-
Length of conductor	2	m
Temperatures		
Operating temperature	1.9	K
Warm	300	K
Intercept	-	K
No intercept implemented		
Powering		
Current	25	A

SCHEMATIC

300 K
1.9

HEAT LOAD components

Data	Value	Unit	Items
Conduction to 1.9 K	1.2	W	4
Resistive load at 1.9 K	0.1	W	4

LAYOUT

edms 2279202

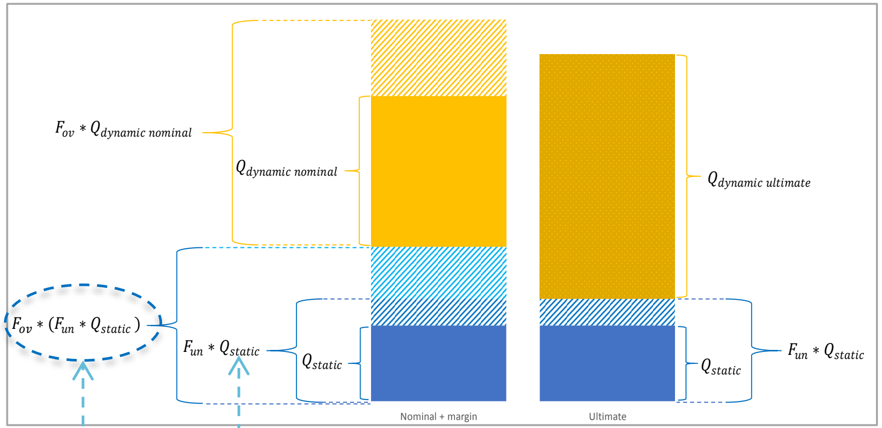
MAGNET	K-mod/ Cliq	Drawing Nr.
Q1A	K-mod	LHCQQXF_DQ0077
Q1A	CLIQ	LHCQQXF_DQ0044
Q1B	CLIQ	LHCQQXF_DQ0044
Q2A	CLIQ	LHCQQXF_DQ0044
Q2B	CLIQ	LHCQQXF_DQ0044
Q3A	K-mod	LHCQQXF_DQ0077
Q3A	CLIQ	LHCQQXF_DQ0044
Q3B	CLIQ	LHCQQXF_DQ0044

Heat Load Data per Unit

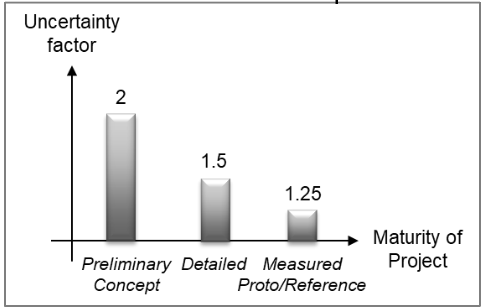
Heat load 1.9 K	Value	Unit	Data type	Comment
Static	1.2	W	Measurement	Per K-mod
Resistive	0.1	W	Measurement	Per K-mod
Total	1.3	W	Measurement	Per K-mod

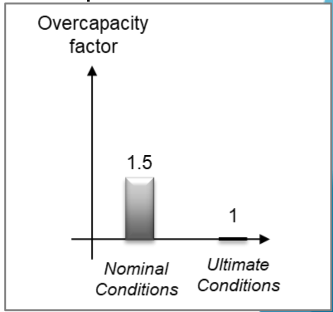
Heat Load	Applicable
Static	yes
Resistive	yes
Magnetic	-
Beam Induced	-
Collision Induced	-

- Documentation
  - Edms
  - Indico
- Review
- Communication



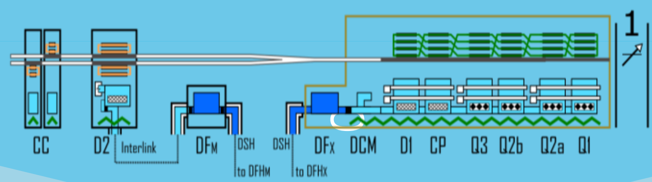
Uncertainty factor according to the design maturity level → $F_{un} * Q_{static}$ → $F_{ov} * (F_{un} * Q_{static})$

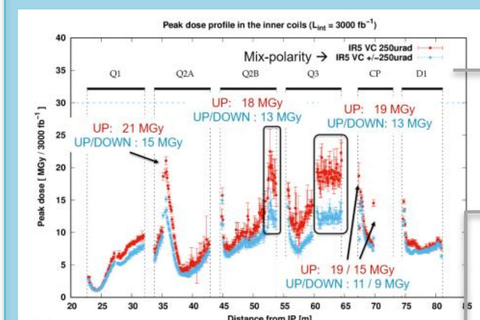




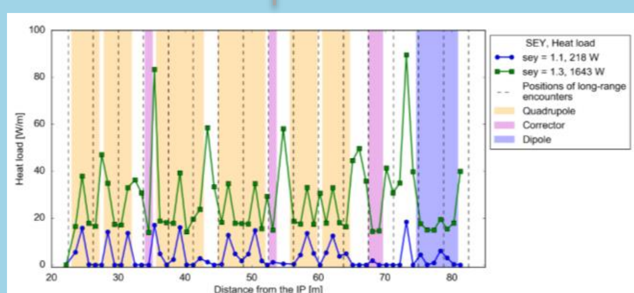
Hilumi dynamic heat load methodology

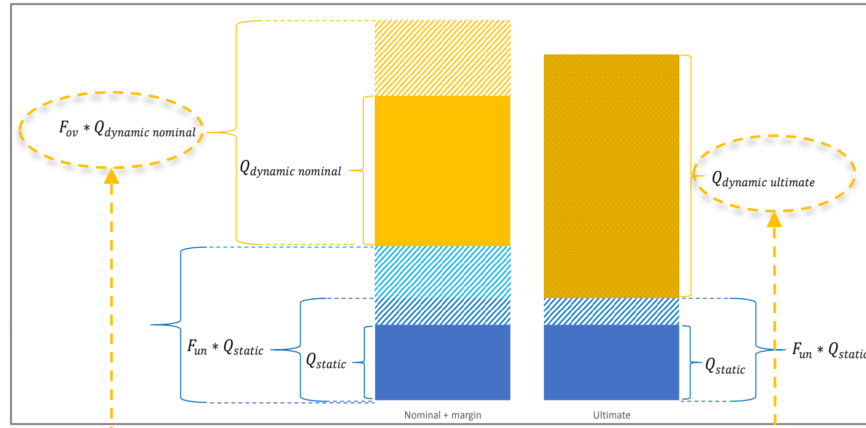
$Q_{dynamic}$ heat load





- WP10
  - Collision induced
    - FLUKA Simulation
- WP2
  - Beam induced
    - PyEcloud simulation for electron cloud
    - Analytical for impedance

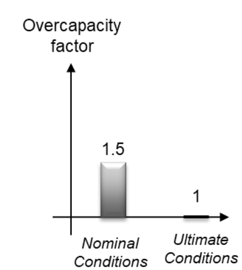




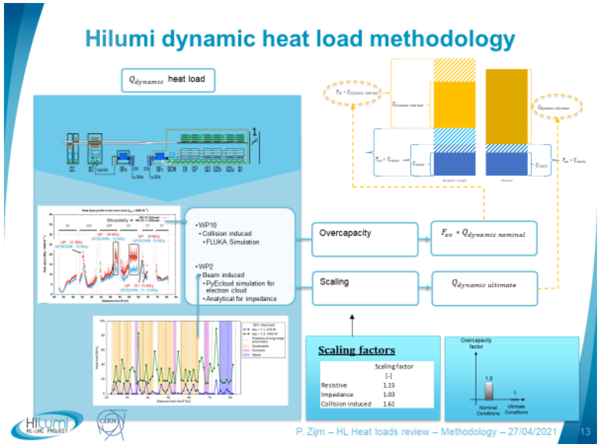
Overcapacity → $F_{ov} * Q_{dynamic\ nominal}$

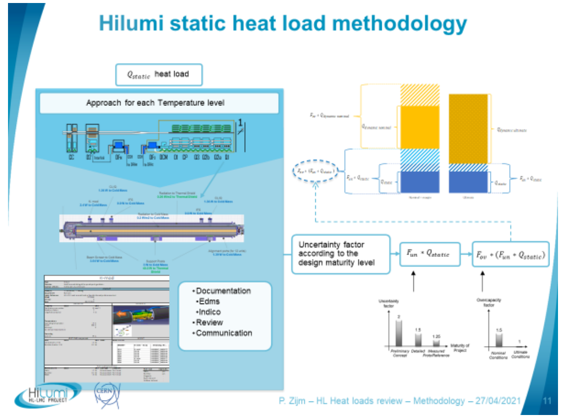
Scaling → $Q_{dynamic\ ultimate}$

	Scaling factor
Resistive	1.15
Beam induced	1.00
Collision	1.72



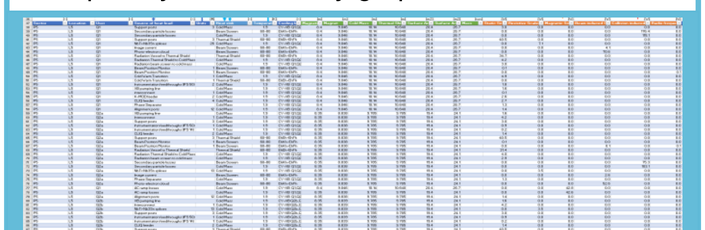
Heat load repository





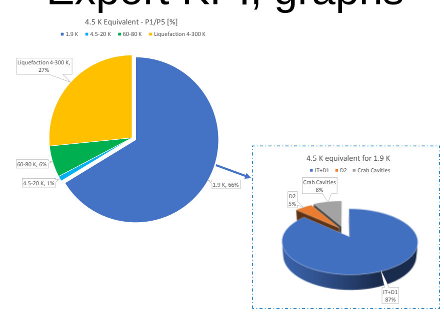
Heat load database

- ~168 rows of data and ~40 columns
- Ordered by Sector-location-User
- Contains raw and scaled heat load data
- Temperature levels per source and heat sink
- References, reference date, EDMS
- Capability to extract any graph or table



Heat load repository

- Central database containing information
- Tool to Track design evolution
- Export KPI, graphs



Conclusions

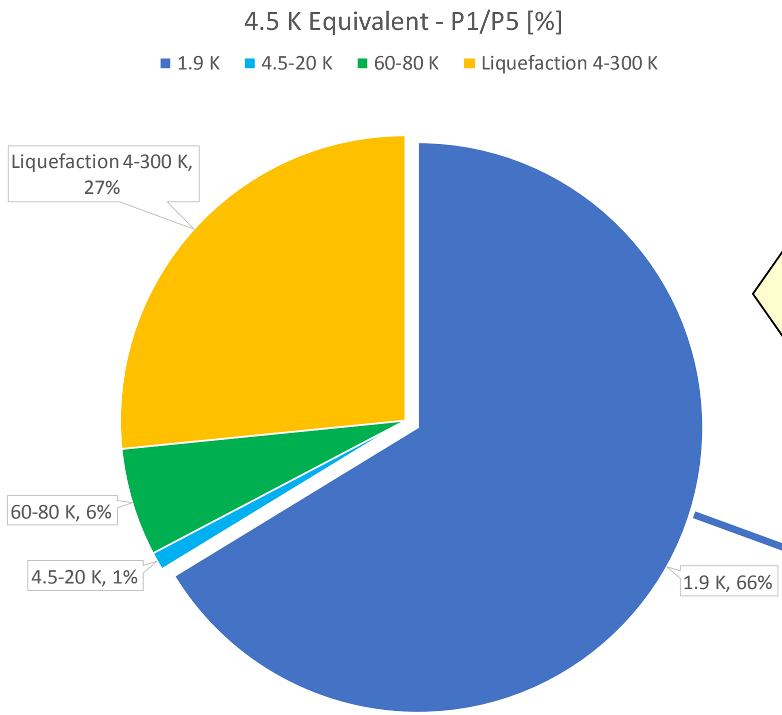
- Methodology to define the design heat loads for each user has been applied.
  - Static heat loads
    - Exhaustive breakdown approach performed
  - Dynamic heat loads
    - Beam/Collision induced heat loads provided by WP2/WP10 Simulations
  - Systematic approach to margin uncertainty/ overcapacity

- Solid repository compiling all inputs to validate heat loads and temperature levels for each user.

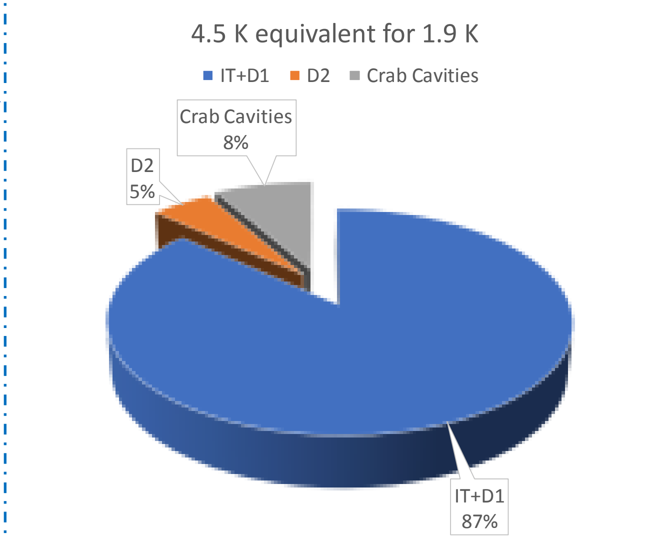
Thanks for your time and attention

Global overview of heat loads
(4.5 K equivalent)

In addition to the methodology an introduction to the users to come



1.9 K temperature level accounts for 2/3 of the total load.
Main focus in today's approach.



Thanks for your time and answers