MEBT dump

Thermo-mechanical analysis

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Preliminary consideration

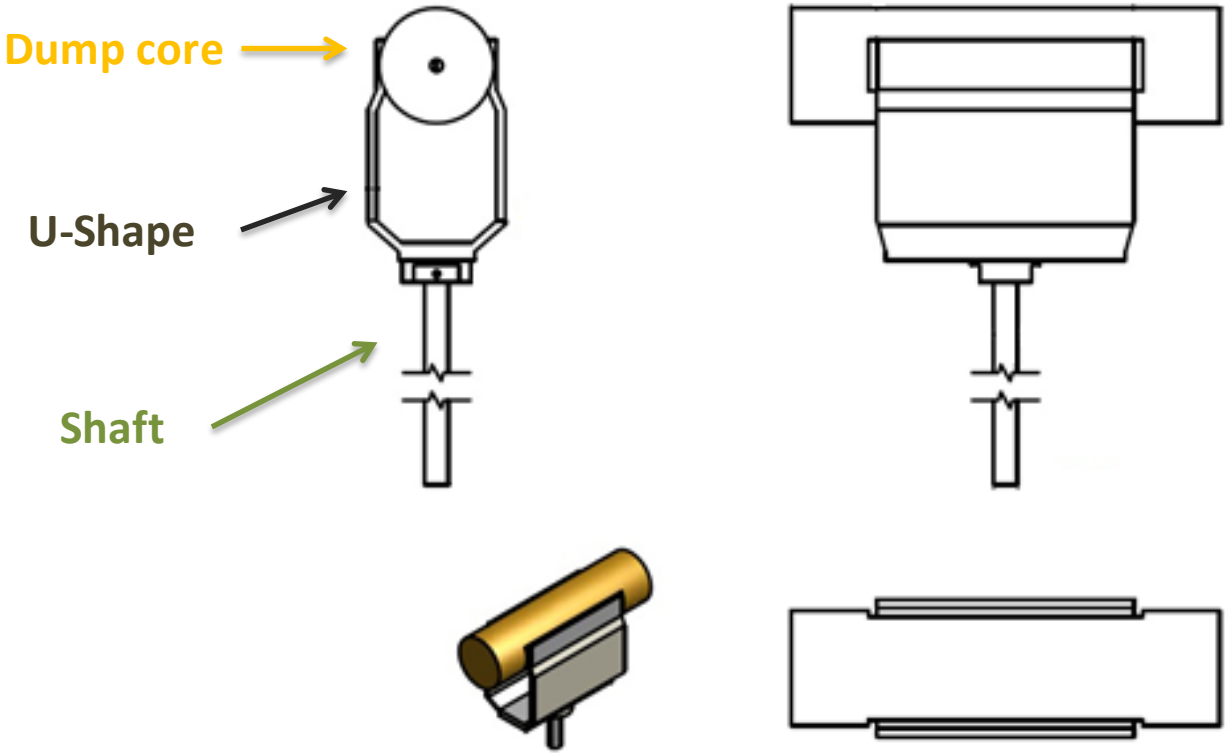
- The MEBT dump is located in the injection line (7 MeV)

Beam Parameters, proton beam		
Current:	0,8	*mA*
Pulse-time:	500	*µs*
Frequency:	2	*Hz*
Pulse-period:	0,5	*s*
Np:	2,5E+12	-
Power beam:	5,6	*W*

- The study focus on the three part of the MEBT dump:

  - The dump core
  - The U-shape part
  - The shaft

Preliminary design



Design as from K. Asvestas

Material configuration

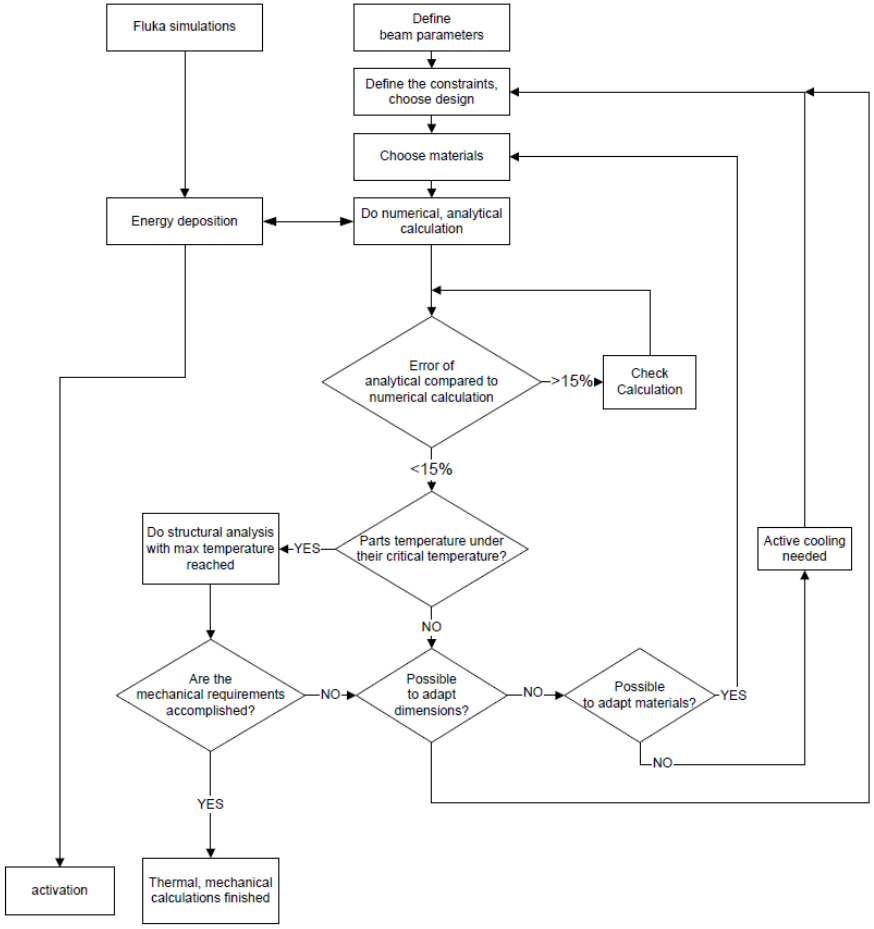
- Initial material configuration:
  - Dump core: Tungsten
  - U-Shape: Aluminium
  - Shaft: Stainless Steel
- Alternative configuration:
  - Dump core: Tungsten
  - U-Shape and Shaft: All Aluminium/ All copper/ All Stainless Steel

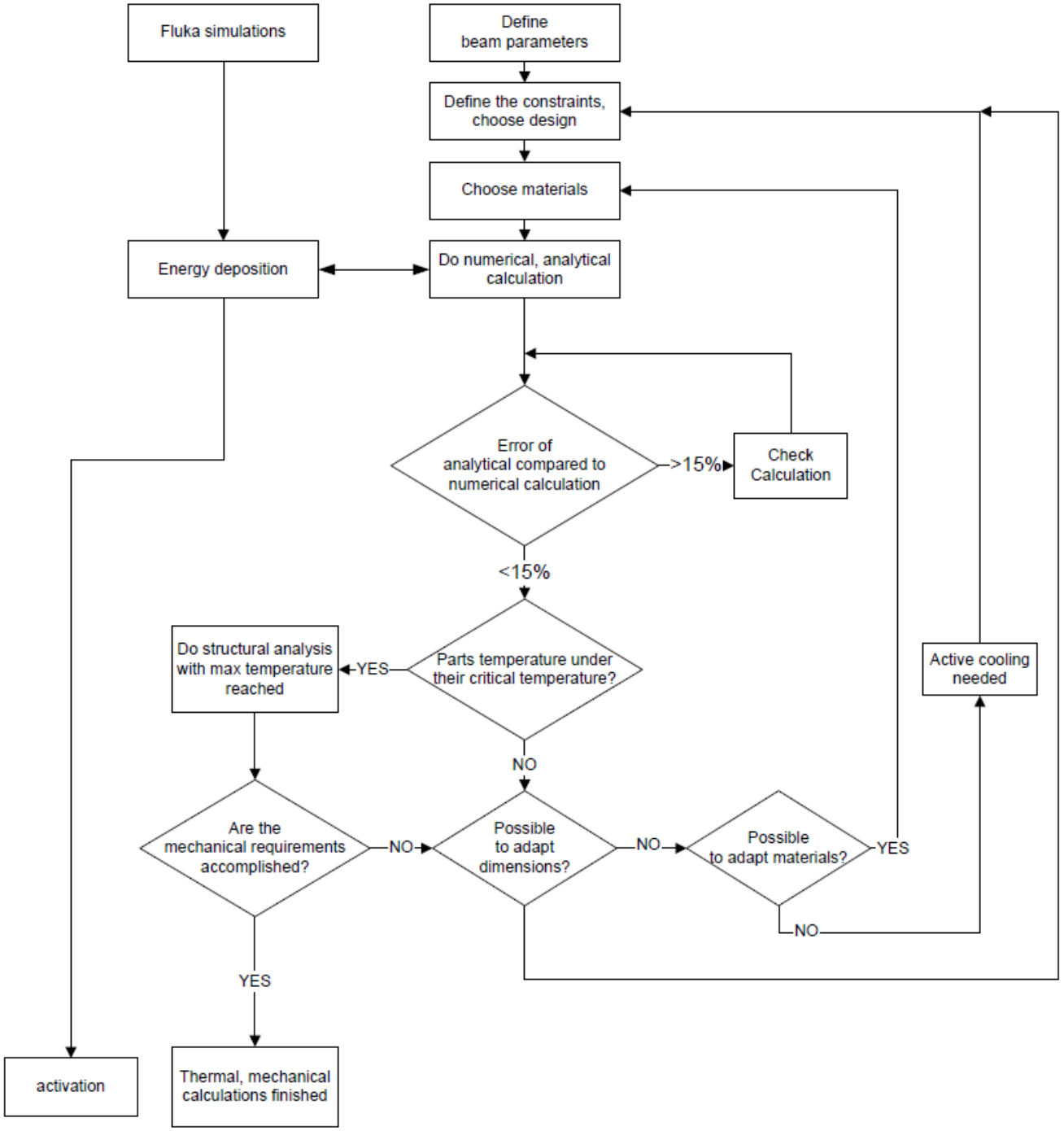
Material Properties

		Tungsten	Aluminium	Stainless Steel	Copper
Density	*ρ (kg/m3)*	19 299	2 770	7 750	8940
Thermal expansion coefficient	*λ (˚C-1)*	4.48E-06	2.30E-05	1.70E-05	1.74E-05
Young's modulus	*E (Mpa)*	3.99E+05	7.10E+04	1.93E+05	1.00E+05
Poisson's ratio	*v (-)*	0.28	0.33	0.31	0.34
Thermal conductivity	*k (W/m.˚C)*	173	149	15.2	387
Specific heat capacity	*Cp (J/kg.˚C)*	132	875	480	383
Emissivity	*ε (-)*	0.04	0.2	0.54	0.03
Melting point	*Tm (°C)*	3410	660	1750	1050
Maximum service temperature	*Tc (°C)*	**927**	**160**	**300**	**300**

Note: *the emissivity values are taken for not surface treated material (oxidation/polishing/…) and have to be checked after final choice and configuration of the material*

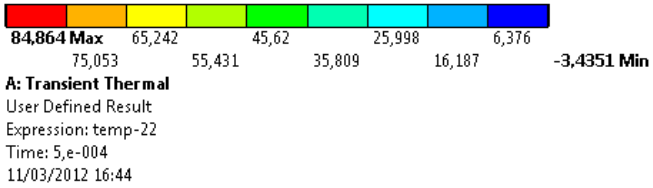
Methodology of analysis




Fluka simulations
Define beam parameters
Define the constraints, choose design
Choose materials
Energy deposition
Do numerical, analytical calculation
Error of analytical compared to numerical calculation
>15%
Check Calculation
<15%
Do structural analysis with max temperature reached
YES
Parts temperature under their critical temperature?
Active cooling needed
NO
Are the mechanical requirements accomplished?
NO
Possible to adapt dimensions?
NO
Possible to adapt materials?
YES
NO
YES
activation
Thermal, mechanical calculations finished

One pulse analysis

- Increase of temperature for one-pulse

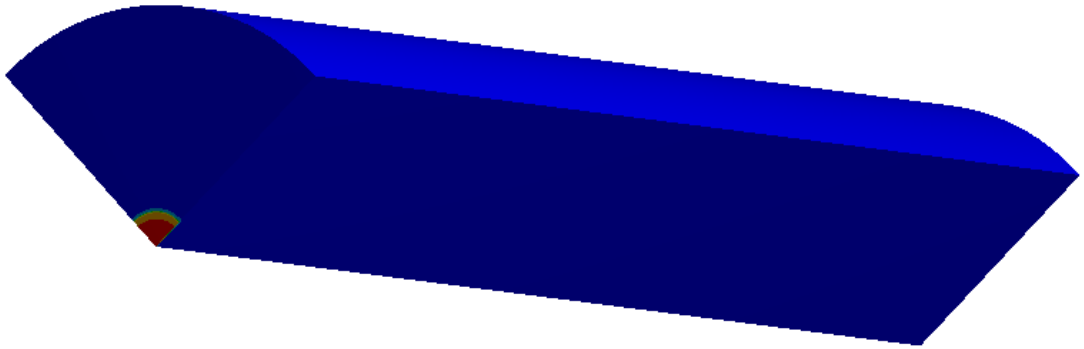


ANSYS 14.0

ΔT Max = 84,9 °C

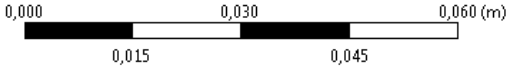
ΔT Max analytical = 85 °C

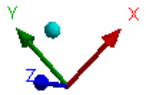
Melting point = 3410 °C



Note: *no Fluka simulation were used for all the thermal analysis.*

¼ of the geometry





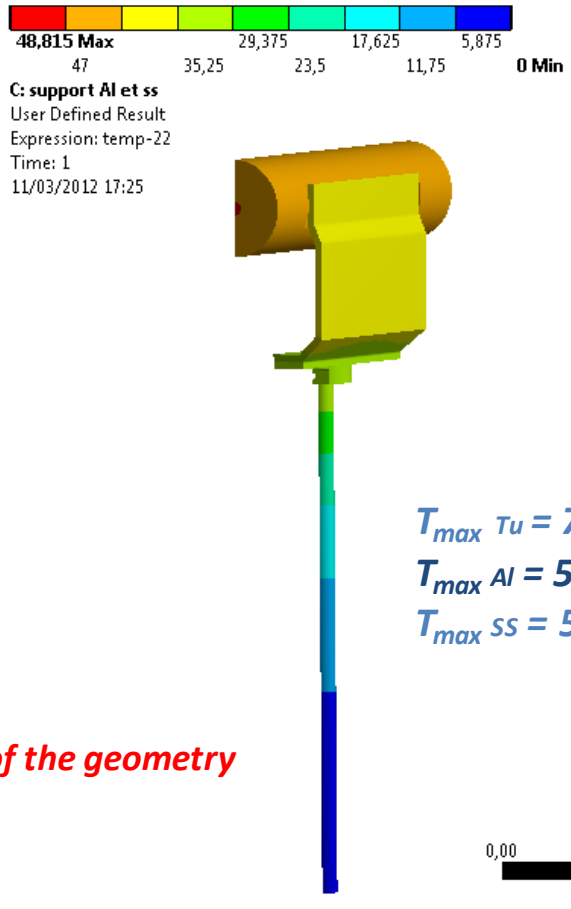
Steady State analysis

- Evaluation of TCC:
  - Between the Shaft and the U-Shape, the contact is considered as perfect
    - TCC = 10 000 W/m^{2}K
  - Between the Dump core and the U-Shape: pressure of contact estimated at about 11 Mpa
    - The TCC between two surfaces depends on the pressure of contact and the material properties

	S.S/Tu	Al/Tu	Cu/Al
TCC	2240	62	35900

Steady State analysis

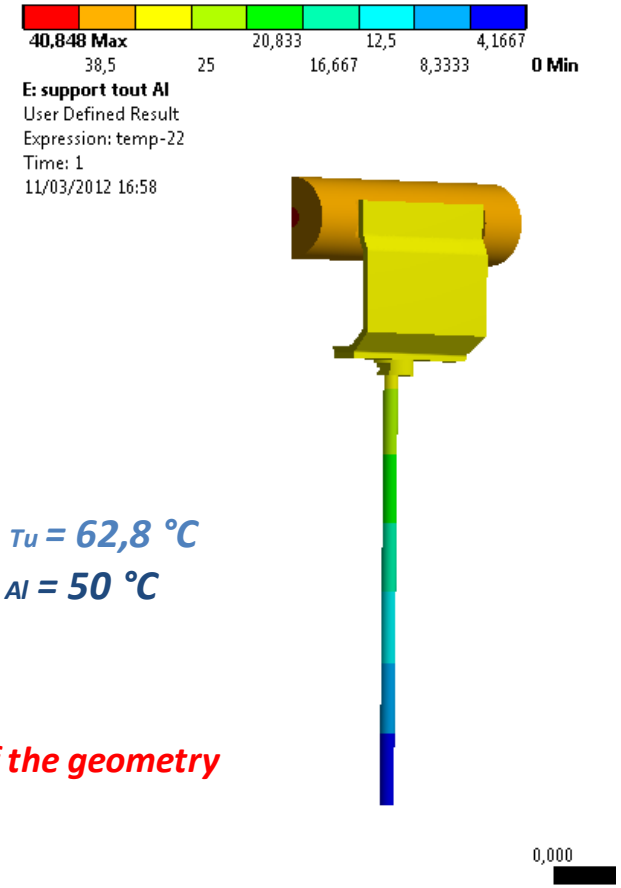
U-Shape : Aluminium
Shaft : S. Steel



$T_{max\ Tu} = 70{,}8\ °C$
$T_{max\ Al} = 58\ °C$
$T_{max\ SS} = 56\ °C$

half of the geometry

U-Shape : Aluminium
Shaft : Aluminium

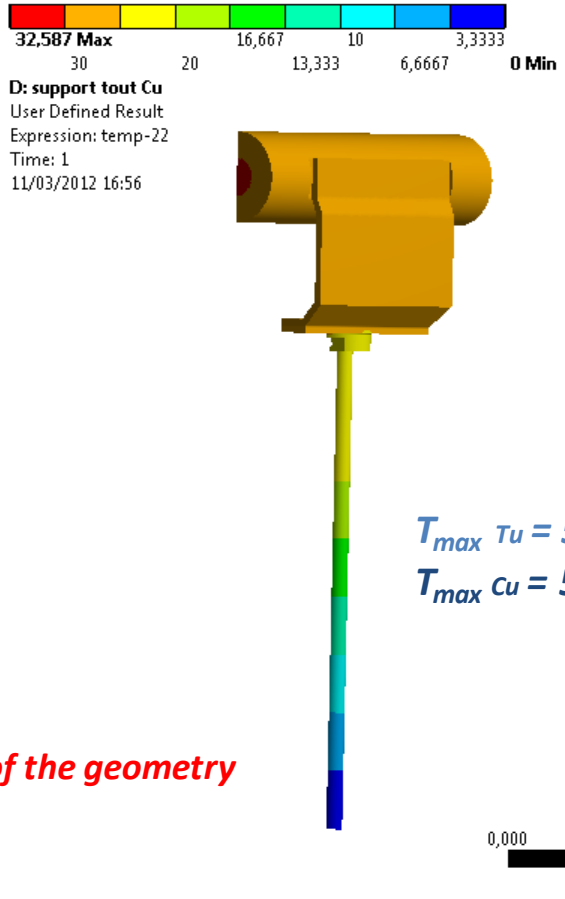


$T_{max\ Tu} = 62{,}8\ °C$
$T_{max\ Al} = 50\ °C$

half of the geometry

Steady State analysis

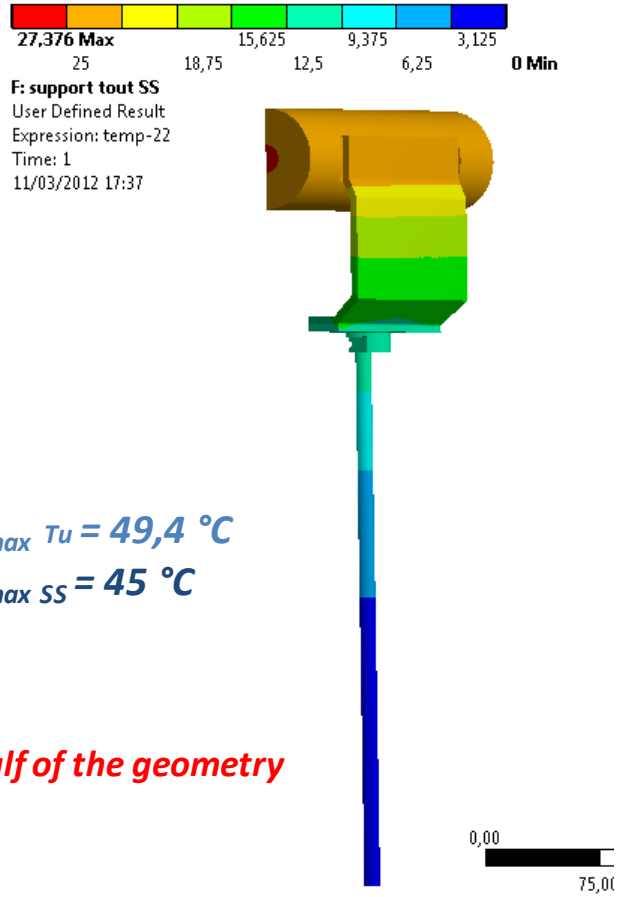
U-Shape : Copper
Shaft : Copper



$T_{max\ Tu} = 54{,}6\ °C$
$T_{max\ Cu} = 51\ °C$

half of the geometry

U-Shape : S. Steel
Shaft : S. Steel

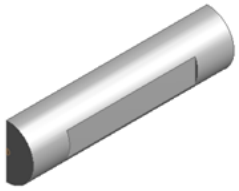
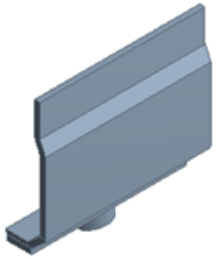


$T_{max\ Tu} = 49{,}4\ °C$
$T_{max\ SS} = 45\ °C$

half of the geometry

Steady State analysis

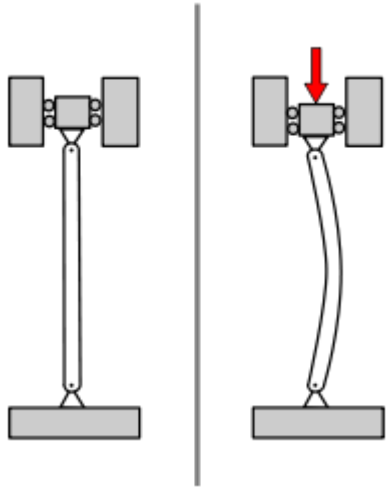
- Summarize of results

		Dump Core	U-Shape	Shaft
Config. Number				
1	***Material***	Tungsten	Aluminium	S.Steel
	Temp. Maxi	70,8 + 85 = 155,8 °C	58 °C	56 °C
2	***Material***	Tungsten	Aluminium	Aluminium
	Temp. Maxi	62,8 + 85 = 147,9 °C	50 °C	Same material
3	***Material***	Tungsten	Copper	Copper
	Temp. Maxi	54,6 + 85 = 139,8 °C	51 °C	Same material
4	***Material***	Tungsten	S.Steel	S.Steel
	Temp. Maxi	49,4 + 85 = 134,4 °C	45 °C	Same material

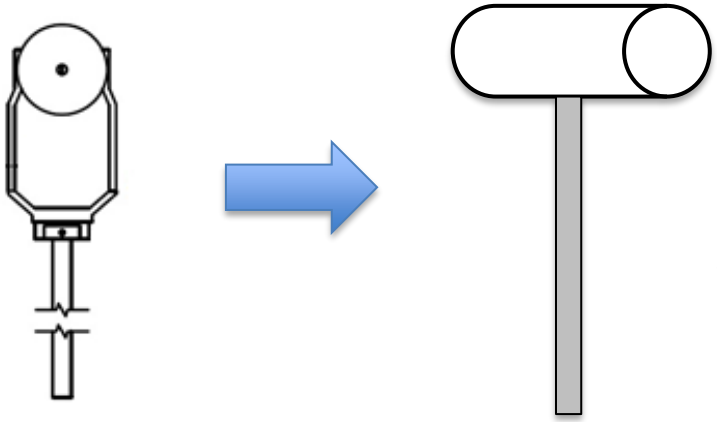
Reminder:

	Tungsten	**Aluminium**	**Copper**	**S. Steel**
Service temp.	927 °C	160 °C	300 °C	300 °C

Buckling analysis



- Considering the geometry: risk of buckling



σ due to proper weigh of the set "dump core + U-shape" = 1,1 MPa

	S.S	Al	Cu
$\sigma_{adm.}$ *(Mpa)*	326	120	169

Best material choice : ***Stainless Steel***

Conclusion for MEBT dump

- The best material choice is to have the U-Shape and the Shaft with the same material. The **Stainless Steel** seems to be a good candidate.
- The **emissivity** value of the material will have to be checked with the supplier since it can have a significant impact on the results.
- To ensure a good heat evacuation, the **contact** between the dump core and the U-Shape has to be properly ensured.
- Considering the increase of temperature, the thermal stresses are not an issue. However, it is advised to use a **spring washer** to partially limit a part of the stresses due to the thermal expansion.

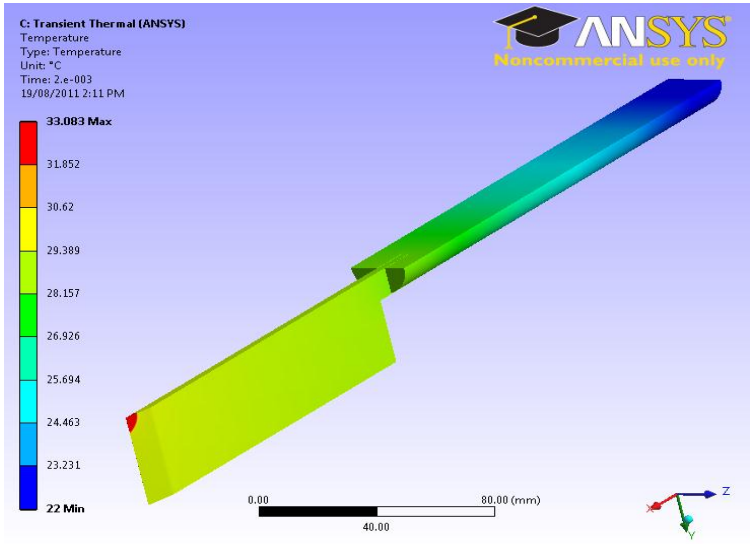
Other devices

- The others devices of the facility:
  - The Scarpers: *located in the Synchrotron*
  - The internal beam Dumps: *located in the Synchrotron*
  - The chopper dump: *located in the extraction line*
  - The Beam Stopper: *located in the extraction line*
  - The EX dump: *located in the extraction line*

Thermal behavior

- The scrapers: ***Aluminium*** core, ***Stainless Steel*** shaft

1 Pulse:

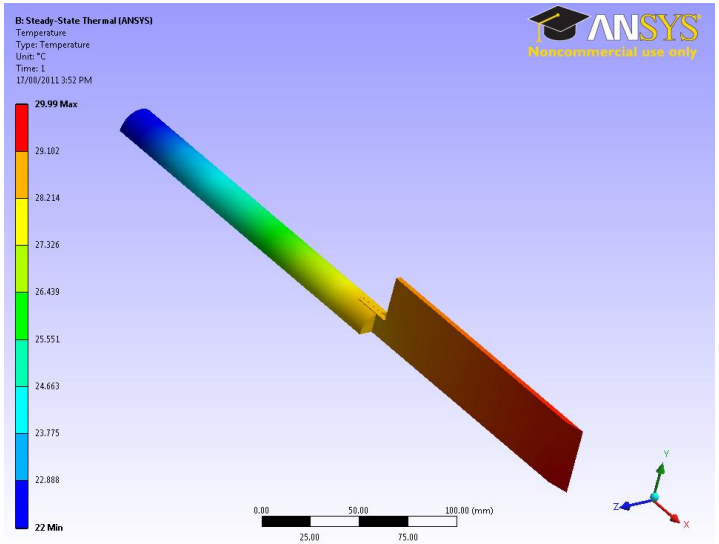


$T_{max\ Al} = 33{,}1\ °C$

$T_{max.\ use\ Al} = 160\ °C$

NB: results from K. Asvestas

Steady State:



$T_{max\ Al} = 30\ °C$

$T_{max.\ use\ Al} = 160\ °C$

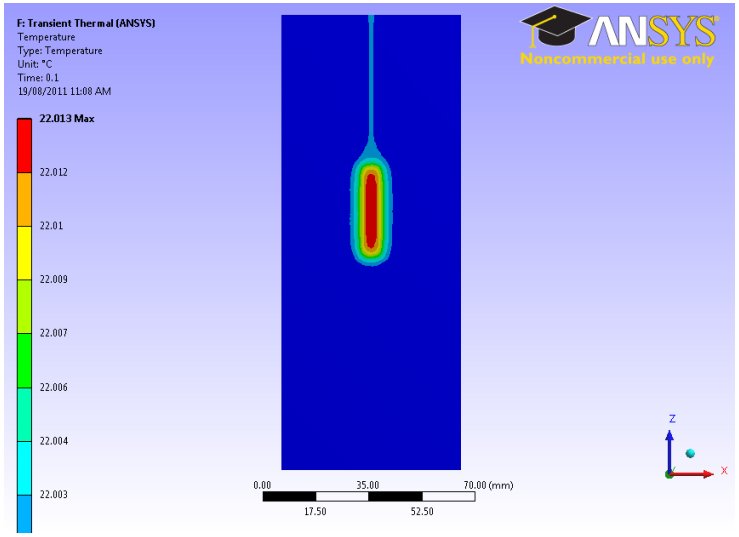
$T_{max\ Total} = 63{,}1\ °C$

The contact between the two parts is assumed perfect.

Thermal behavior

- The Chopper dump: Core in ***graphite***, external part in ***Tungsten, metallic*** support

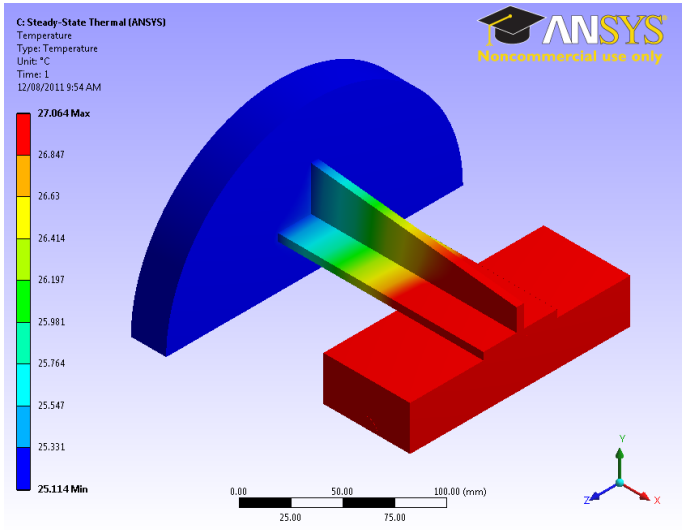
1 Pulse:



$T_{max\ Gr} = 22{,}1\ °C$

$T_{max.\ use\ Gr} = 3800\ °C$

Steady State:



$T_{max\ Gr} = 27{,}1\ °C$

$T_{max.\ use\ Gr} = 3800\ °C$

$T_{max\ Total} = 49{,}2\ °C$

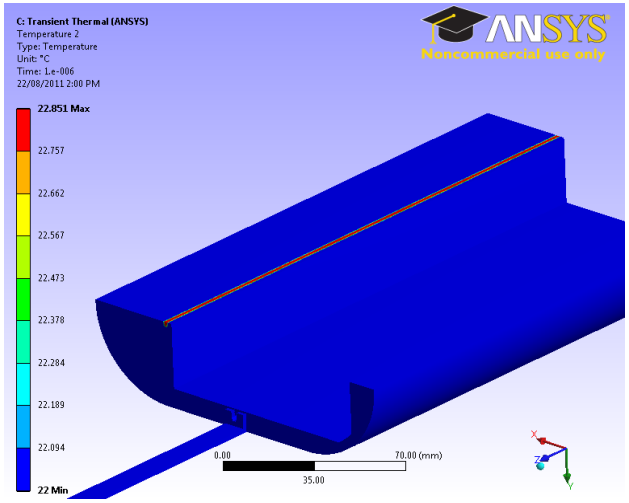
NB: results from K. Asvestas

The contact between the two parts is assumed perfect.

Thermal behavior

- The Internal dump: core in ***Tungsten, metallic*** spacers

1 Pulse:

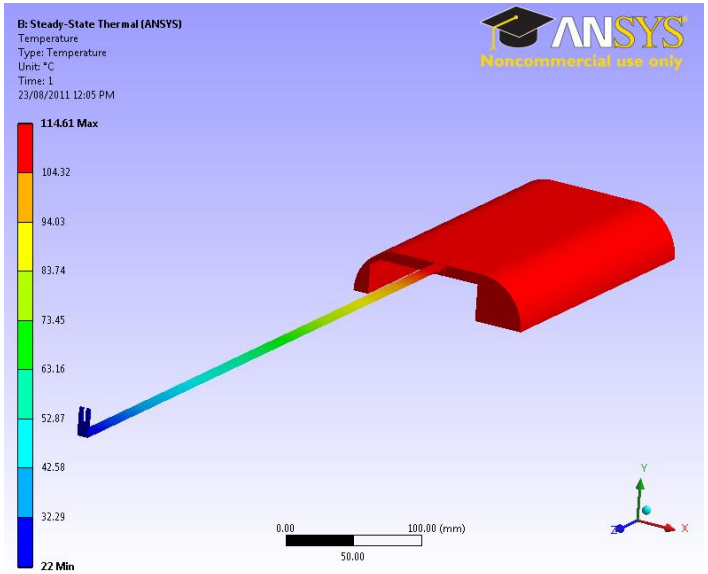


$T_{max\ Tu} = 22{,}9\ °C$

$T_{max.\ use\ Tu} = 927\ °C$

NB: results from K. Asvestas

Steady State:



$T_{max\ Tu} = 115{,}5\ °C$

$T_{max.\ use\ Tu} = 927\ °C$

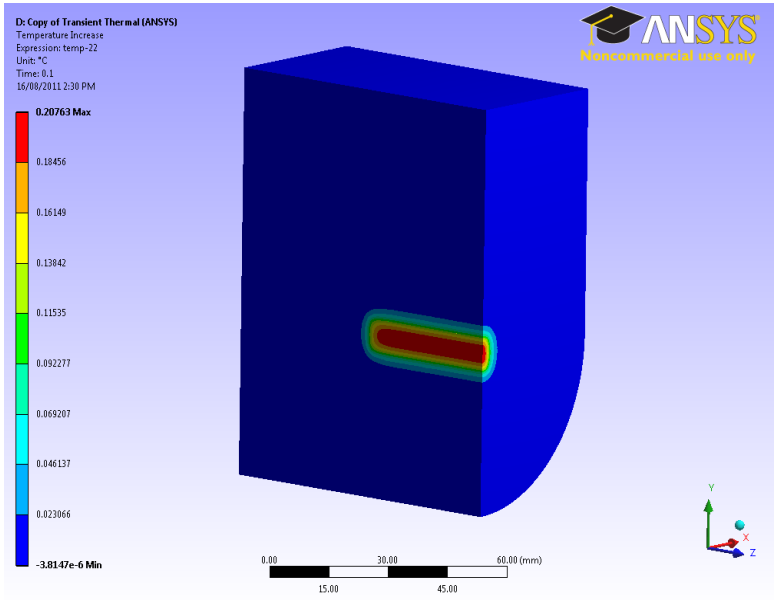
$T_{max\ Total} = 138{,}4\ °C$

The contact between the two parts is assumed perfect.

Thermal behavior

- The Beam Stopper: ***Tungsten***

1 Pulse:



$T_{max\ Tu} = 22{,}2\ °C$

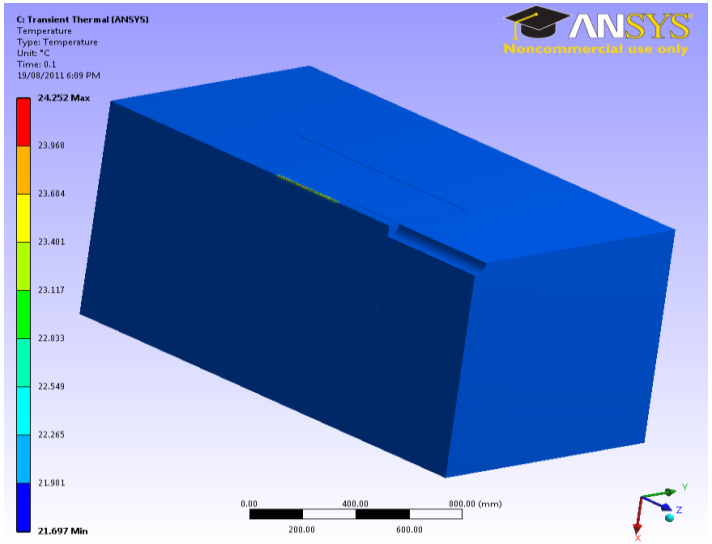
$T_{max.\ use\ Tu} = 927\ °C$

NB: results from K. Asvestas

Thermal behavior

- The Ex dump: Core in ***graphite***, second part in ***Iron***

1 Pulse:

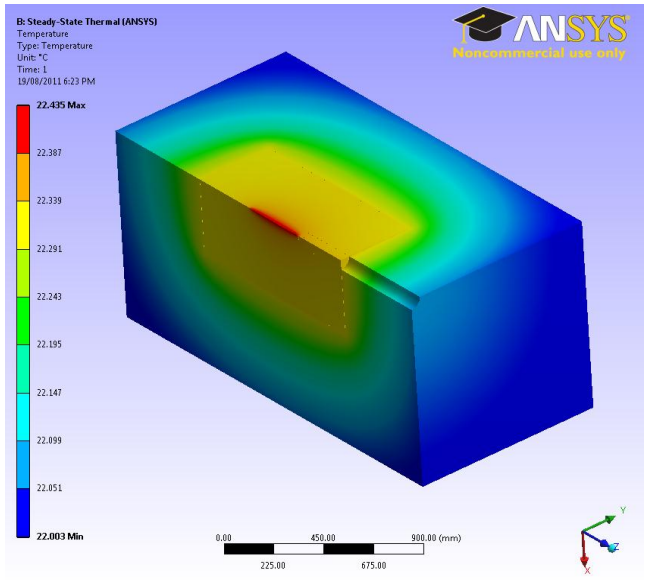


$T_{max\ Ir} = 24{,}2\ °C$

$T_{max.\ use\ Ir} = 1530\ °C$

NB: results from K. Asvestas

Steady State:



$T_{max\ Ir} = 22{,}5\ °C$

$T_{max.\ use\ Ir} = 1530\ °C$

$T_{max\ Total} = 46{,}7\ °C$

The contact between the three parts are assumed perfect.

Summarize of results

	Temp. Maxi	Service Temp.	Safety Factor	Detailed study needed
Scrapers	63,1	160	***2,5***	✓
Chopper dump	49,2	3800	***77,2***	
Internal Dump	138,4	927	***6,7***	✓
Beam Stopper	22,2	927	***41,8***	
Ex Dump	46,7	1530	***32,8***	

- **Next step:** the pre-calculation already performed **may be sufficient**. However, it is advised to study more carefully the **Scrapers** and the **Internal dump**.

Thank you for your attention.