PSB Upgrade
LIU Project

Internal H0/H- dump

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On behalf of EN/STI

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LIU Project

Outline

- Loading cases
- Methods of fixation
- Space & layout
- FOMS
- Choice of material(s)
- Electrical behavior
- Preliminary analyses :
  - Instantaneous DT
  - Steady operation
  - Transient to steady operation
- Does the dump need active cooling ?
- Conclusions

Loading cases

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Table 1 - main machine parameters for H^0/H^- beam dump definition.

Ion species		H^-/H^0
Beam energy (kinetic)	MeV	160
Max. repetition rate	Hz	1.11
Max. Beam pulse length (useful beam)	μs	400
Injection turns		4 x 100
Beam head/tail length	μs	<60/20
Peak LINAC current	mA	40
RFQ peak current	mA	70
Average LINAC current	mA	0.018
Max. beam power	kW	2.8
Max Nbr. of particles per beam pulse		1.0×10^{14}

EDMS 963395

Three loading case (following stripping efficiency):

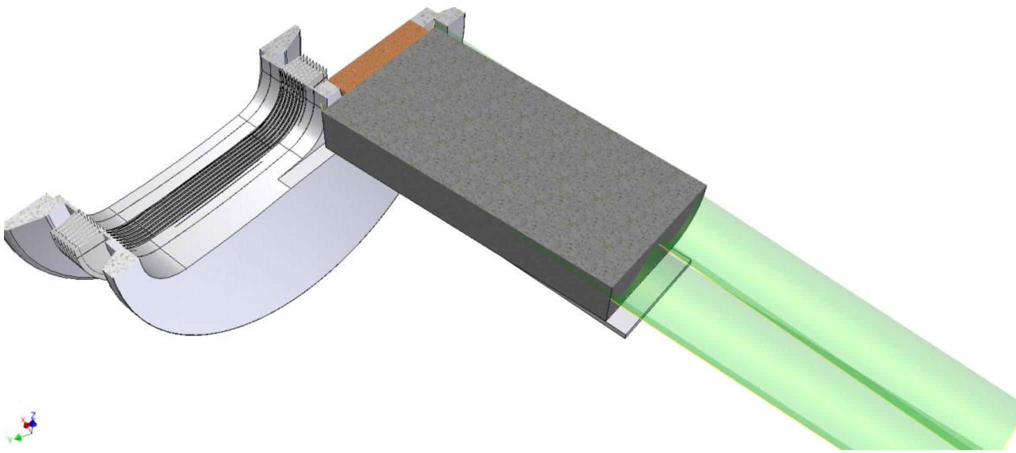
Operation:

- (1) e = 98% (foil operational) --› Steady-state, 2% all H0, 0.8mA
- (2) e = 90% (foil degraded) --› Steady-state, 10% all H0 , 4mA, 8h max
- (3) e = 0% (foil accident) --› Transient 1/4 Linac4 pulse, 40mA, 100% H- (interlock after 1 pulse)

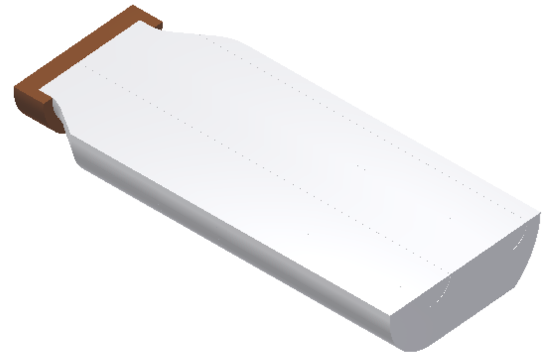
4/4 Linac4 Beam loading case (foil accident + distributor failure) --› not considered

Methods of fixation

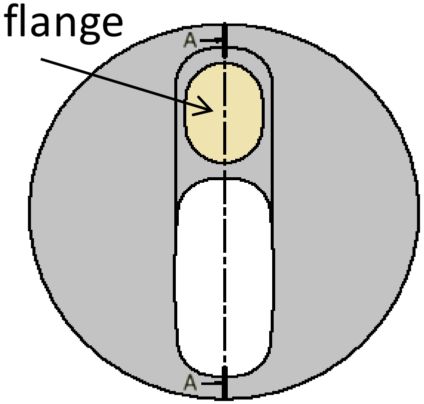
- ***Metallization + Brazing***



- ***Shrinking***



Copper part inserted into Steel flange

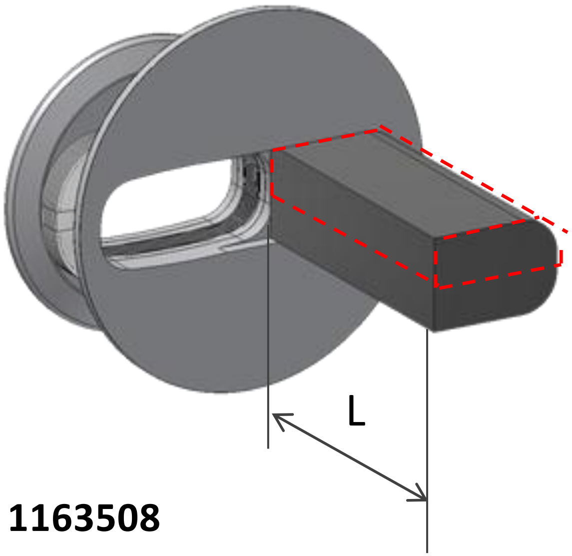


For both solution:

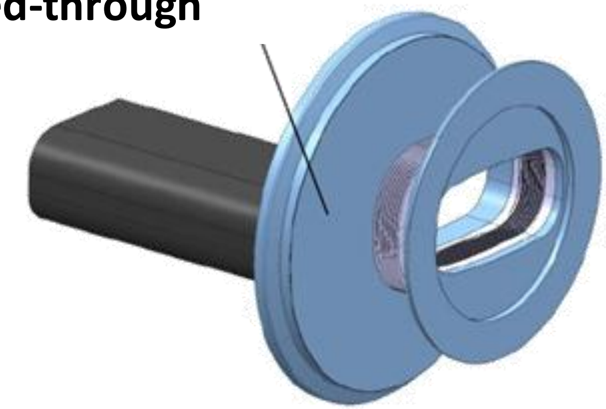
- Metallic part inserted into Steel flange

Space & layout

Area to be modified for the cooling/bake-out of the dump, possibly **no feed-through**



EDMS 1163508



- The flange has to be adapted to the assembly / fixation / cooling needs of the dump

- The instrumentation has to be fixed on the dump (front face)
- The dump is one-piece with the flange (ALARA, quick exchange / disassembly)

FOMS

To be minimized

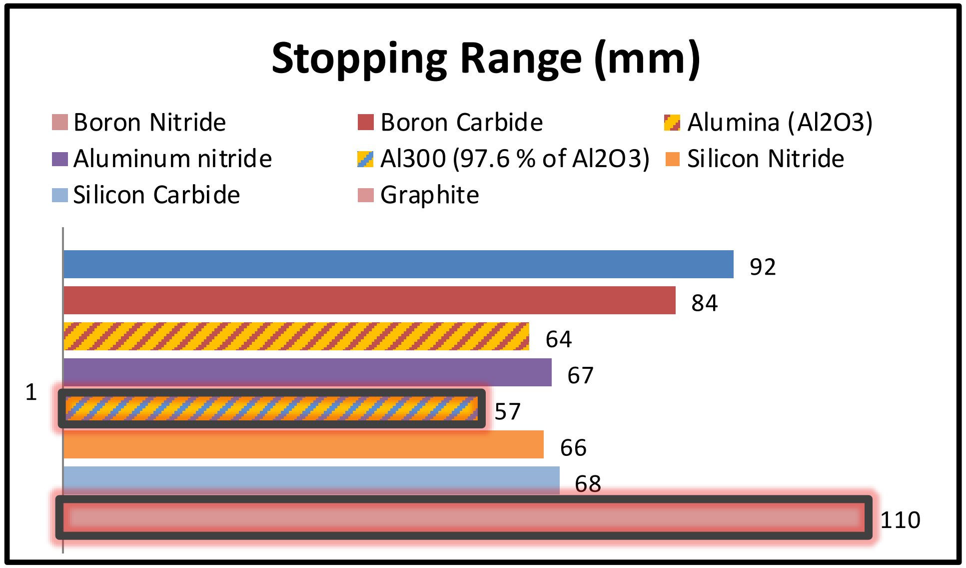
- Thermal: $FOM_1 = \frac{T_{100\,\%\,beam}}{T_{service\,maxi.}} < 1$
- Structural: $FOM_2 = \frac{Z*E(Pa)*\alpha(K^{-1})}{A*Yield(Pa)*Cp} < 1$
- RP (simplified): $FOM_3 = Z$ ↘
- Vacuum: $FOM_4 = porosity$ ↘

ON/OFF

- Electrical Conductivity: $< \sigma_{Graphite}$ **but not too small**
- Weld-ability: depend on method of fixation

⇒ ***Ceramic material*** *(8 material identified)*

Choice of material(s)



Graphite:

Good thermal behavior

BUT

Vacuum pb + fixation pb

Al300:

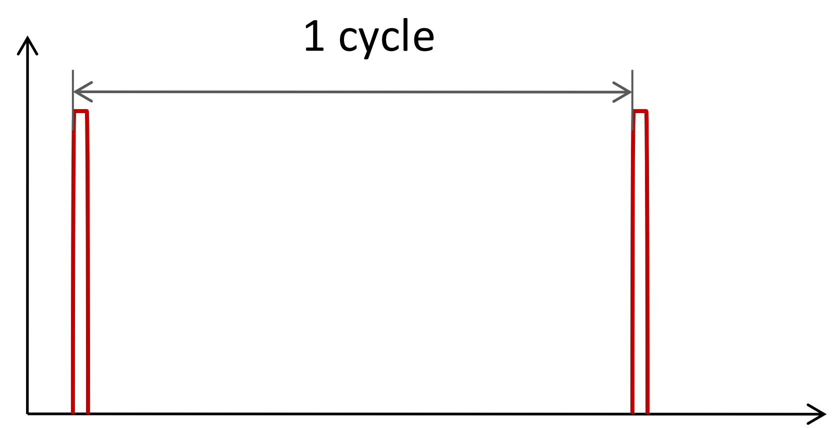
Possible to be brazed to a metallic part + good thermal and structural behavior

BUT

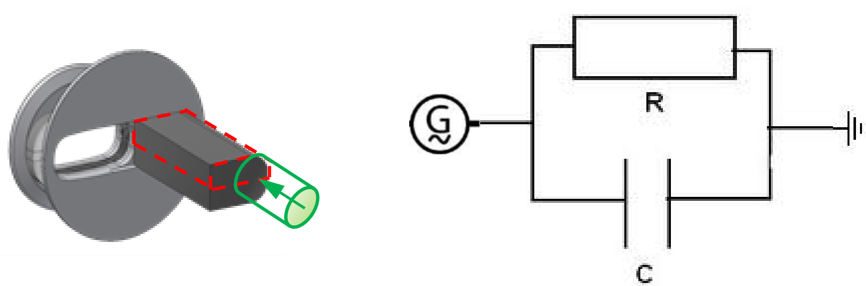
Bad Electrical behavior (risk of highly charging)

Electrical behavior (1)

Conservative approximated model to define the electrical behavior of material → the full charge of the beam is deposited in the material during the charge.



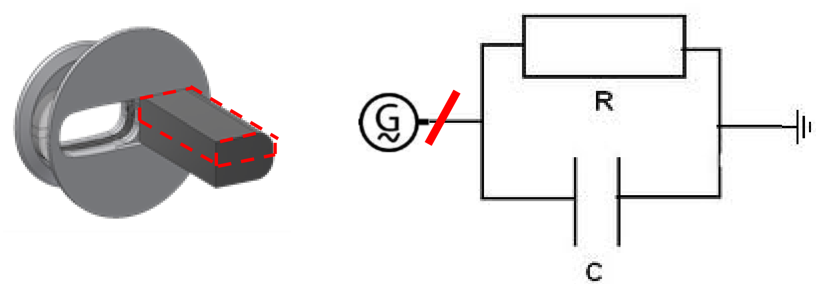
Beam → Charge: parallel RC model



$$V(t) = I_b(t) \cdot \left(\frac{\boldsymbol{C}}{t} + \frac{1}{\boldsymbol{R}}\right)^{-1}$$

$t = pulse\ length$

NO Beam → Discharge: series RC model



$$V(t) = V_C(t) = V_{initial} \cdot exp\left(-\frac{t}{\boldsymbol{RC}}\right)$$

$t = cycle\ length$

Electrical behavior (2)

In reality, some charges escape from the dump while the "charging" phase

→ Fluka simulation were done to assess the % of escaping charges.

	Graphite	Al300	SiC	
Total Charge, full beam (V)	1.07e-7	22500	1.98	← End of pulse
% escaping (Fluka)	5.23	0.28	0.79	
Charge accumulated (Fluka) (V)	1.01e-7	22400	1.96	← End of pulse
Charge after Discharge (V)	0	22200	0	← End of full cycle

At the end of the cycle, the accumulated charge should be *as low as possible* -> $\boldsymbol{FOM_5 = RC}$

Al300 cannot be used for the dump

- does the chamber risk to be charged too?

SiC is the current material choice

- can be brazed to a metallic part (few companies contacted)

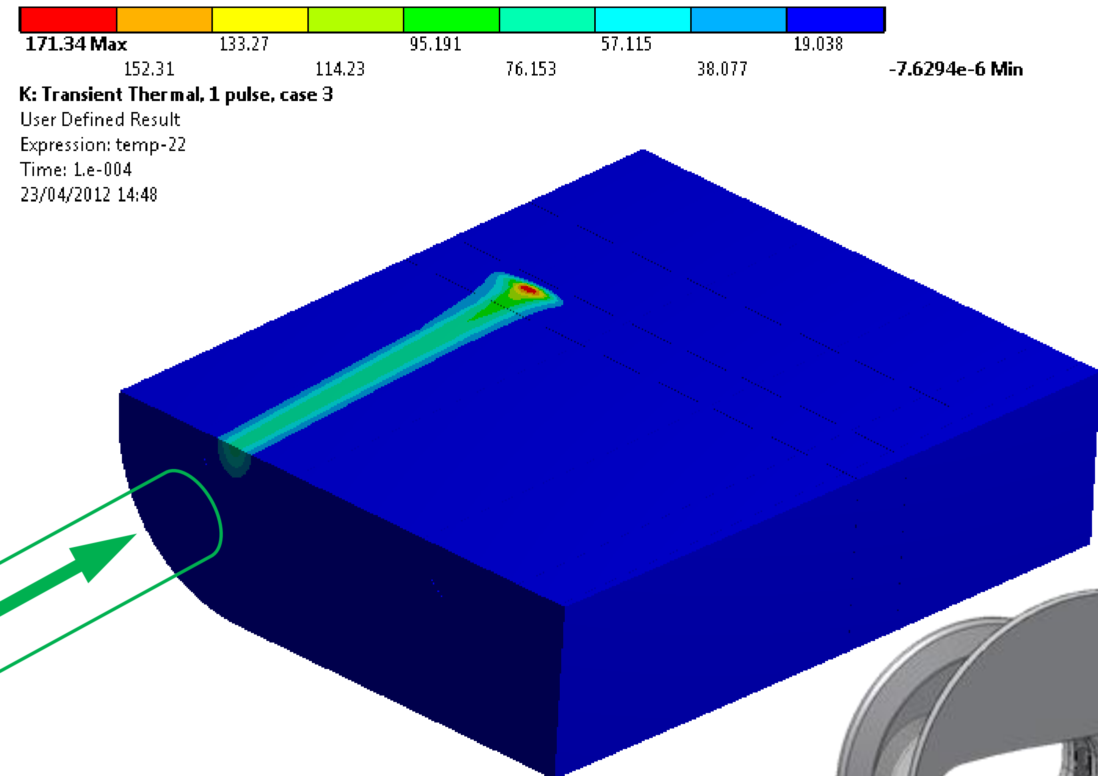
- respect all FOMs

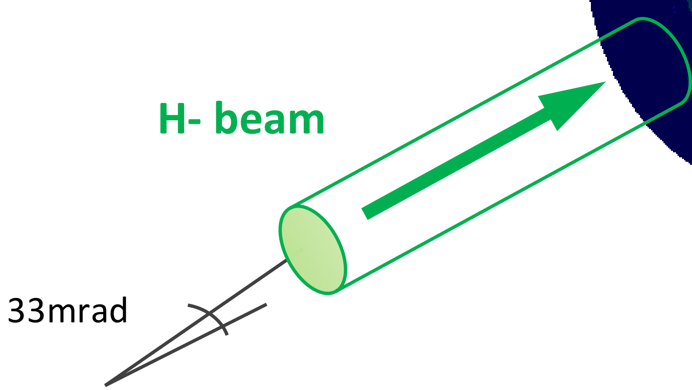
*Results for the loading case 2: 10 % of the beam, H0 beam, only **1 cycle** considered.*

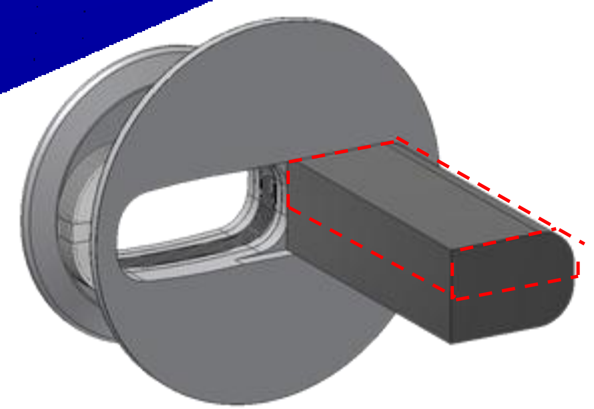
Instantaneous ΔT – SiC

Case 3

Half dump BOTTOM view, T due to 1/4 Linac4 pulse (3)



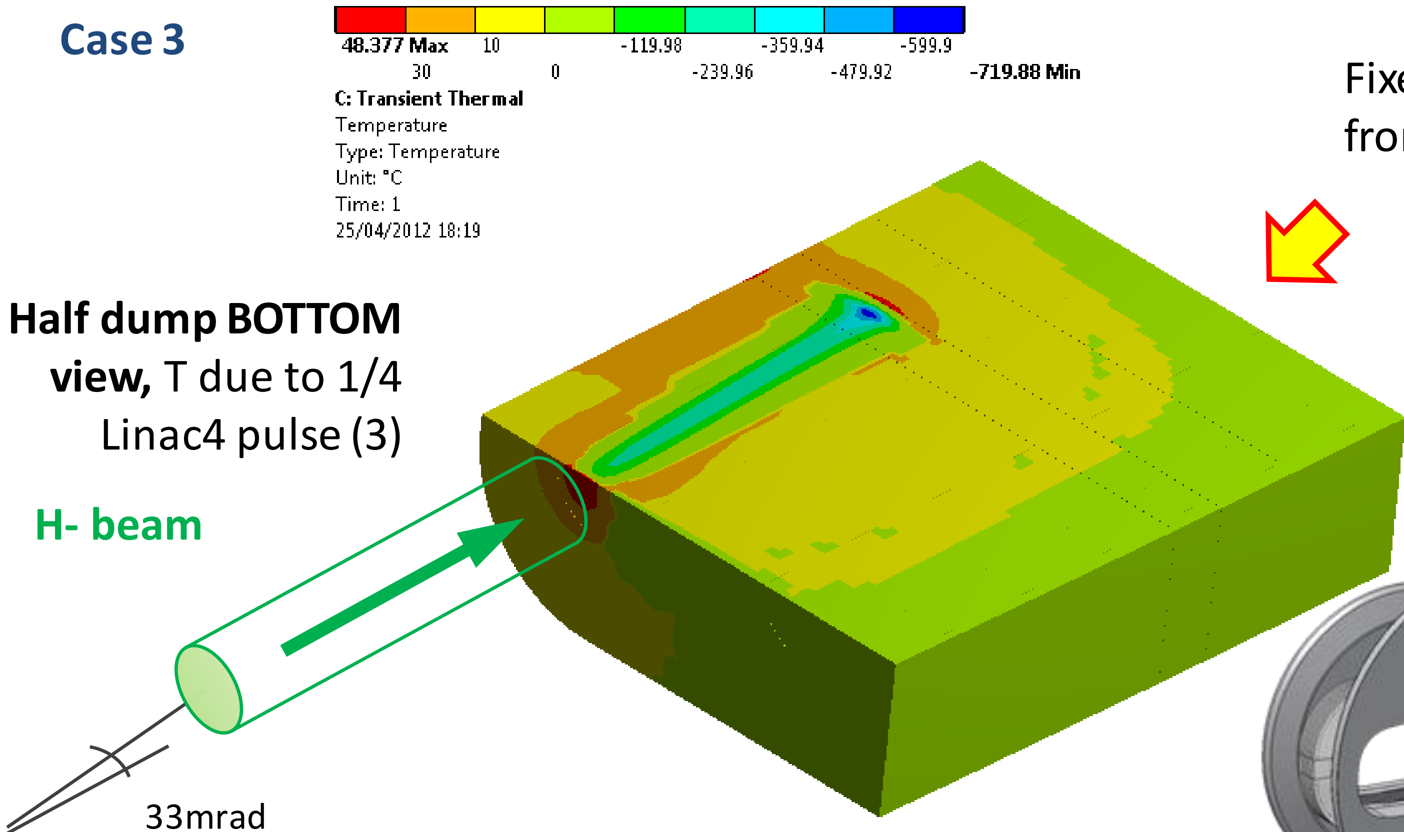




Maximum Service Temperature = 1900 °C

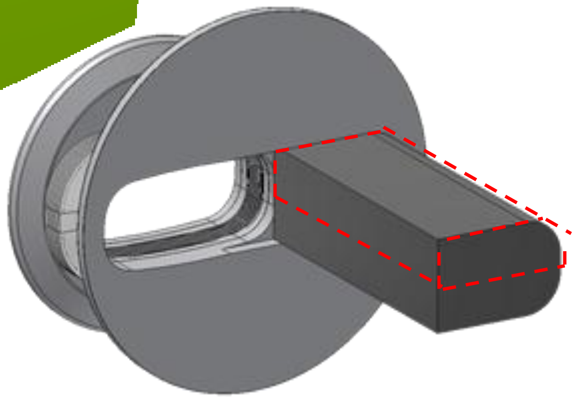
Instantaneous eq. Stassi – SiC

Case 3



Half dump BOTTOM view, T due to 1/4 Linac4 pulse (3)

H- beam



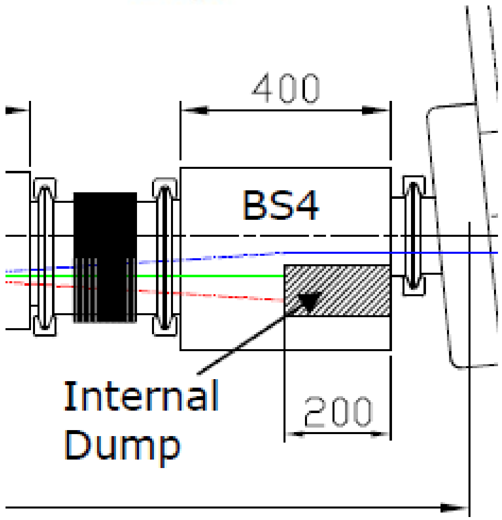
Static Limit in tension: 390 Mpa

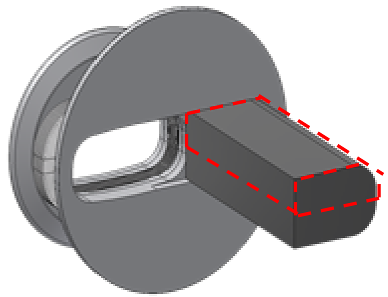
Static Limit in compression: 3900 Mpa

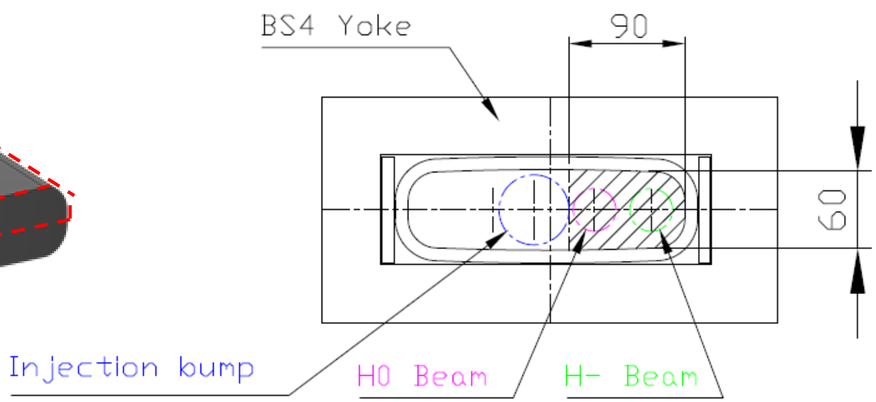
Safety factor $_{tension}$: 7.9

Safety factor $_{compression}$: 5.1

Steady operation – SiC (1)



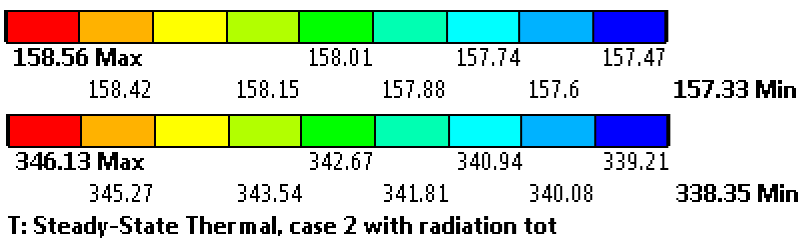




In Steady State operation, if NO active cooling:

- inter radiation between external surface of dump core and internal surface of ceramic chamber → *considered in ANSYS simulation*
- inter radiation between external surface of ceramic chamber and internal surface of magnet → *considered as radiation with Ambient for chamber*
- conduction between dump/inserted piece and Stainless Steel connecting flange → *flange not considered for theses simulations*

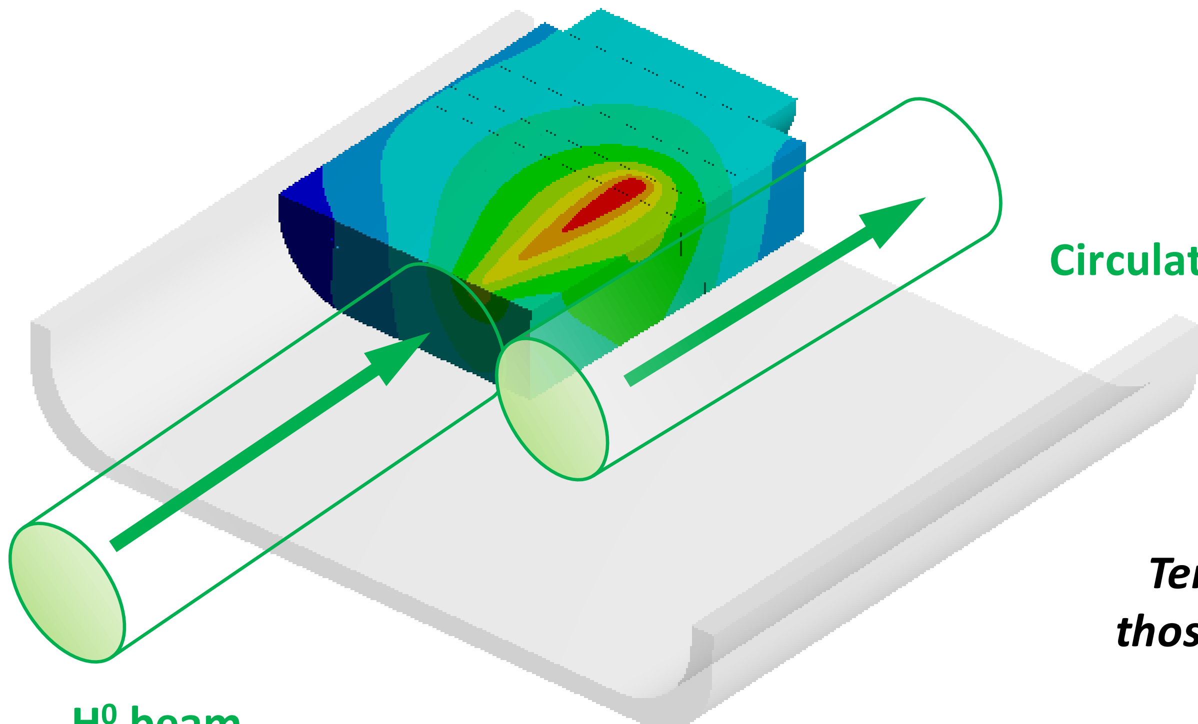
Steady operation – SiC (2)



Case 1

Case 2

Half dump BOTTOM view, T due to steady-state operation

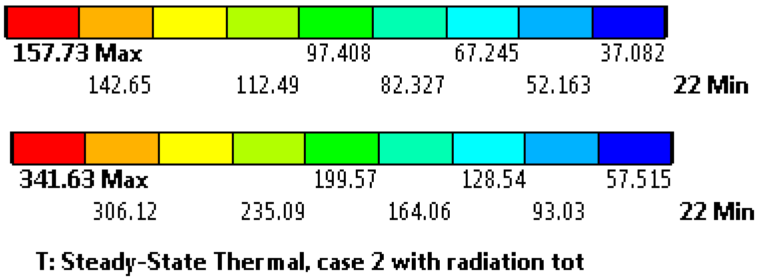


Circulating H+ beam

H^0 beam

Temperature similar to those reached with Al300.

Steady operation – SiC (3)



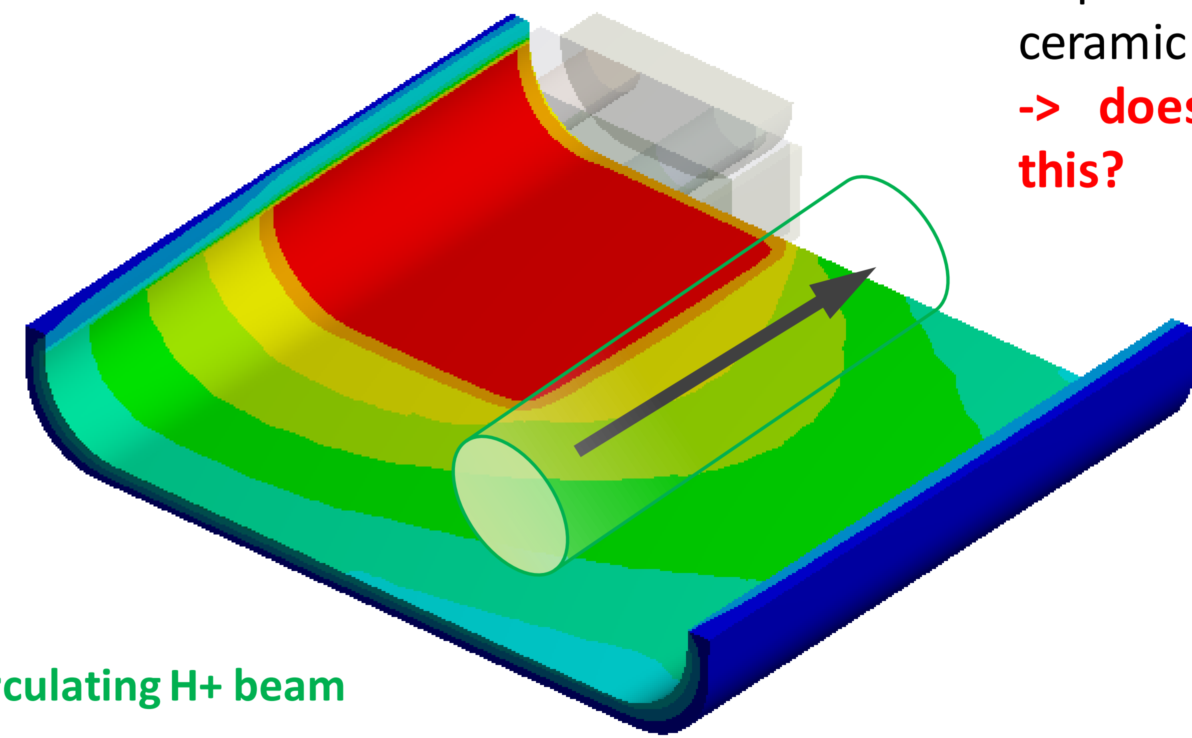
Case 1

Case 2

Half dump BOTTOM view, T due to steady-state operation

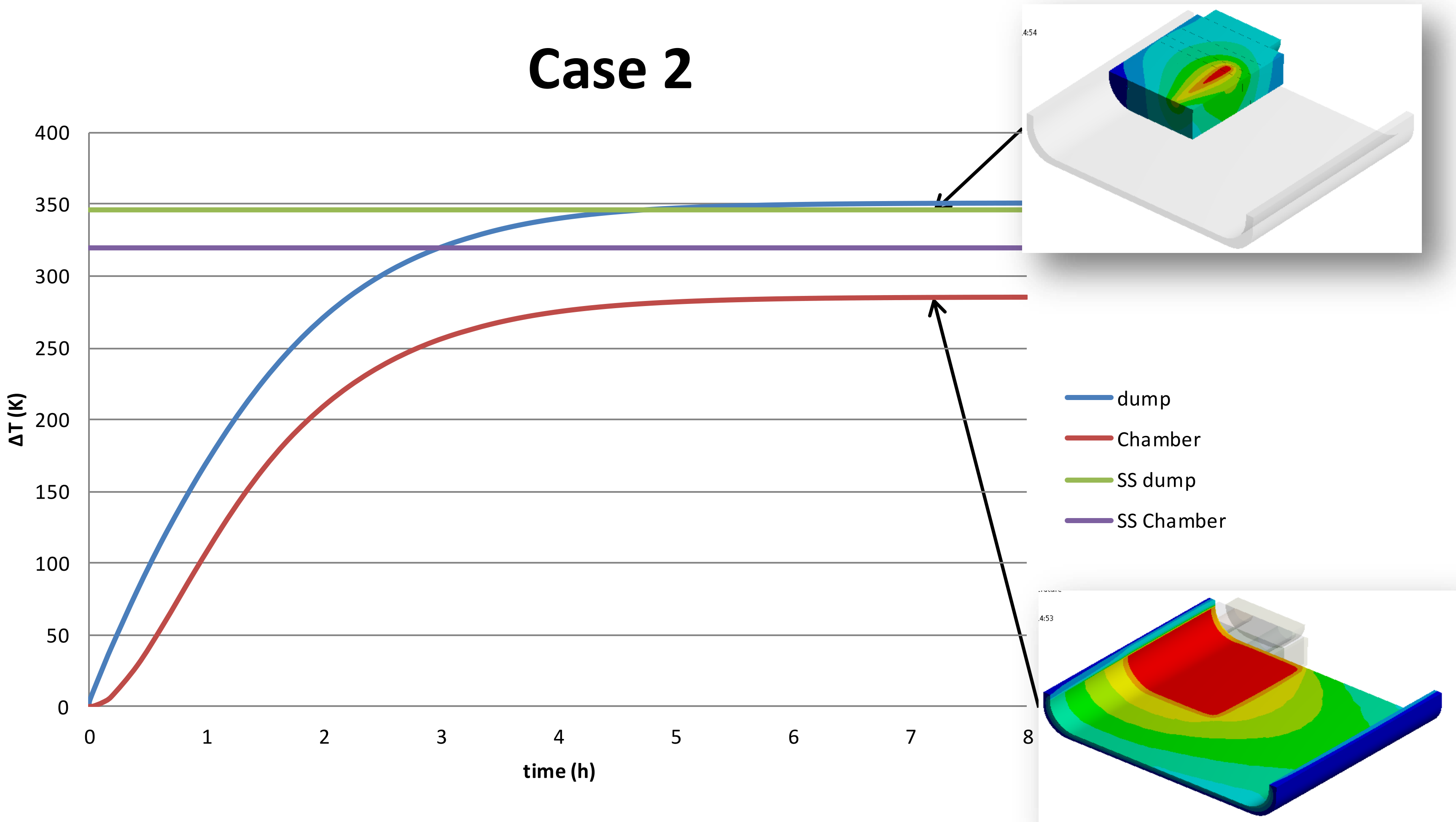
Important gradient of T on ceramic chamber

-> does the chamber allow this?



Circulating H+ beam

Transient to steady operation



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Does it need active cooling?

- Need to define the **maximum temperature** and **gradient of temperature** allowed on **ceramic chamber**
- Need to define the **maximum temperature** allowed on connecting **flange**

	Active cooling	NO Active cooling
Installation	X	√
Steady State T	√	X
Stresses	√	X
Maintenance	X	√
Activation water	X	√
Complexity	X	√

Bad on ceramic chamber and vacuum flange but acceptable for dump core itself.

Conclusions

- An active cooling would significantly reduce the temperature field on dump core, ceramic chamber and connecting flange BUT
  - It requires a more complex geometry,
  - It requires a water flow -> water activation problem
  - More complicated for the maintenance

Need to clearly assess the temperature limit on component closed to the dump core.

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Thank You