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Thermal Simulations method for rotated target

M.Michel[1], B.Aubert[2], A.Fournier[3], C.Barthedejean[1], F.Launay[4], F.Nunio[5], M.Krauth[6]

1) GANIL, 14076 Caen, France, 2) CESTA, 33114 Le Barp, France, 3) CENBG, 33175 Gradignan, France
4) IPN ORSAY ,91400 Orsay, France 5) IRFU/SIS, 91191 Saclay, France 6) IPHC, 67067 Strasbourg, France

Abstract

At GANIL laboratory, the temperature of rotating targets irradiated with intense heavy ions has to be known with accuracy which is essential for the safety and success of experiments.

3 methods to simulate the temperature of a rotated target are shown :

- Analytical
- Simplified FEA (FEA= Finite Element Analysis)
- Global FEA

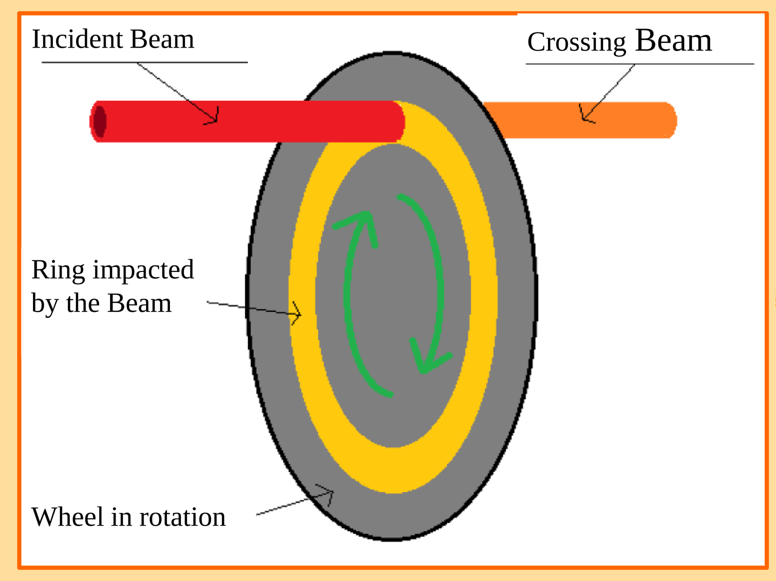
Conclusions

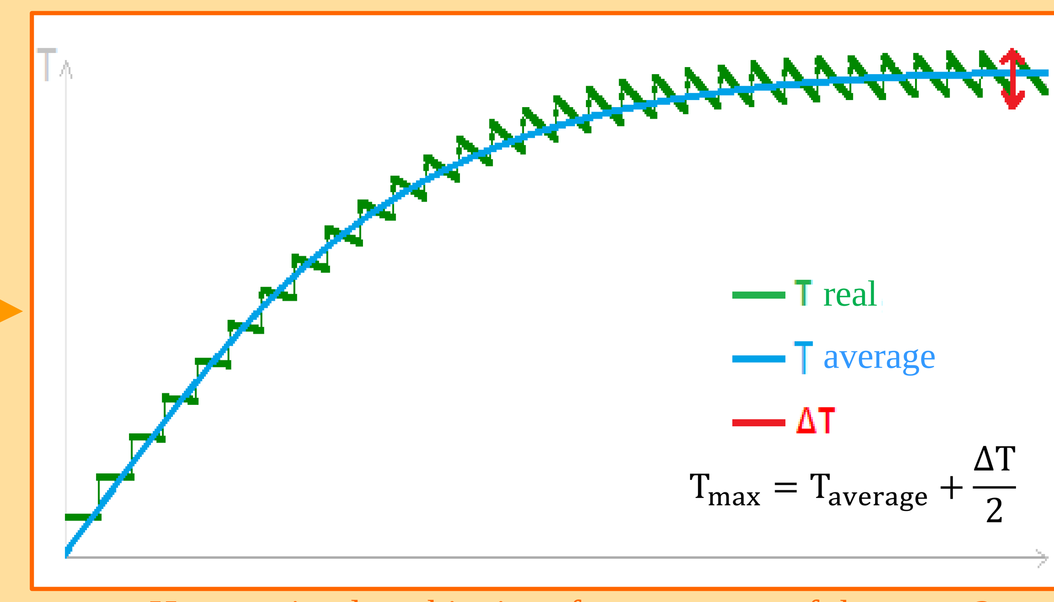
The thickness of the target and the thermal conductivity is important for the accuracy of the results.
Uncertainty due to :
- emissivity value,
- simplifications ,
- FEA method with very thick target (~1µm)

⇒ Require to use safety margin (50% at GANIL).

The global method is the more reliable but requires long calculation processing time with a good computer.

Challenge of the thermal rotated wheel simulations





How to simulate this rise of temperature of the target?

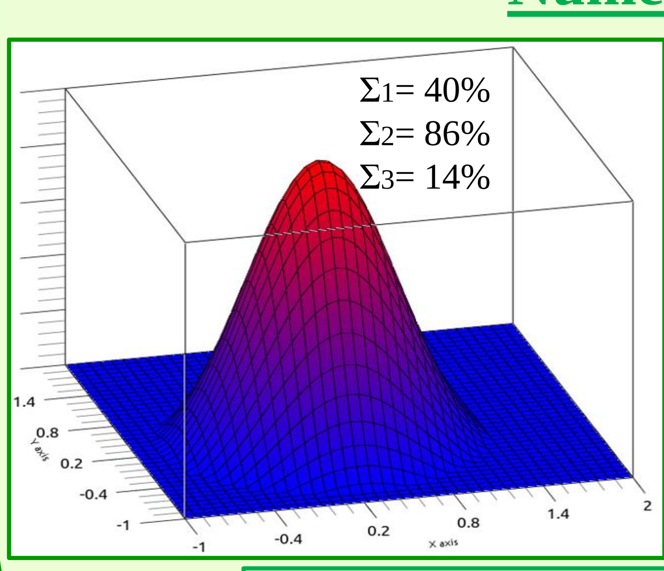
Full target

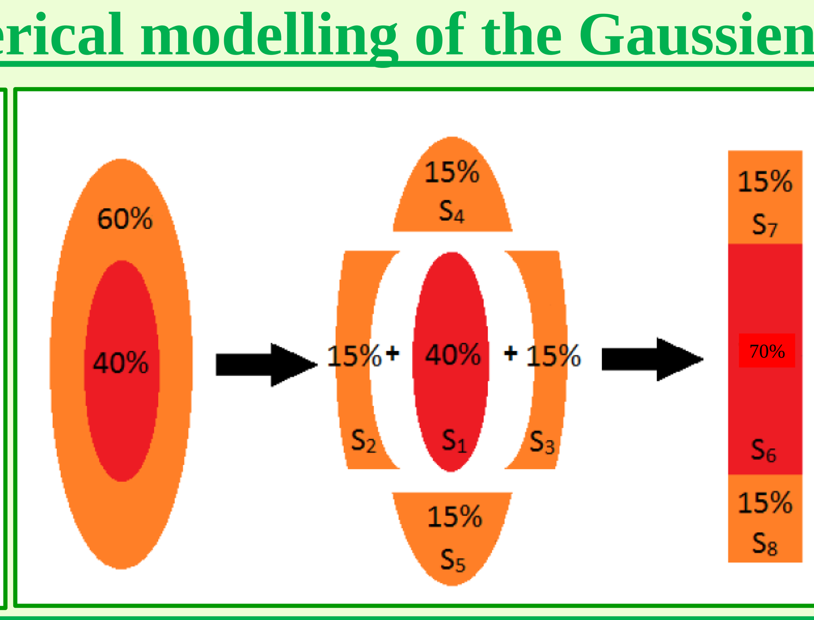
Portion target

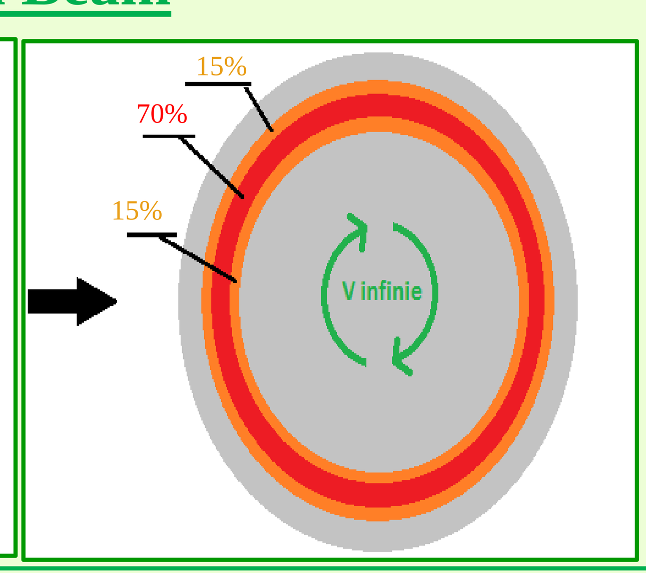
Difficult to measure temperature → simulations → Decrease safety margin → More accurate

Analytical method

Numerical modelling of the Gaussien Beam







$T_{average}$ and ΔT are calculated independently

$$T_{average} = \sqrt[4]{\frac{0{,}7 \times Power}{2 \times S_{ring} \times \varepsilon \times \sigma} + T^4_{ambient}}$$

ε emissivity of the 2 faces
σ Stefan-Boltzmann constant

$$T_{max} = T_{average} + \frac{\Delta T}{2}$$

$$\Delta T = \frac{P \times \Delta t}{m \times \text{Heat capacity}}$$

m : mass of the volum hit by the beam
Δt : time during the spot hit the target

+ Quicly, easy to run

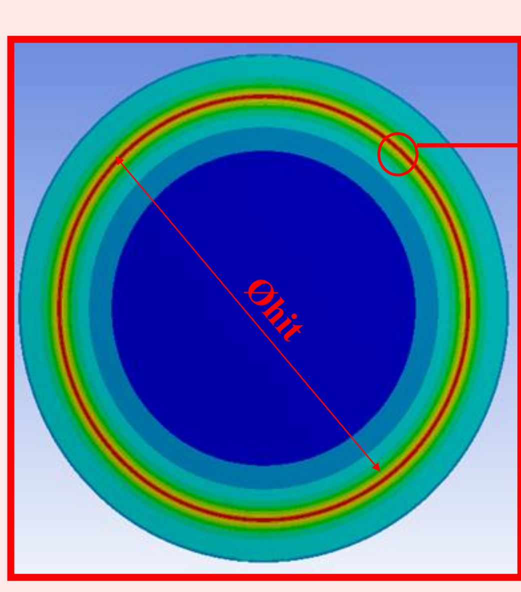
− Conductivity is not considered and rotation speed is considered as infinite

Simplified FEA method

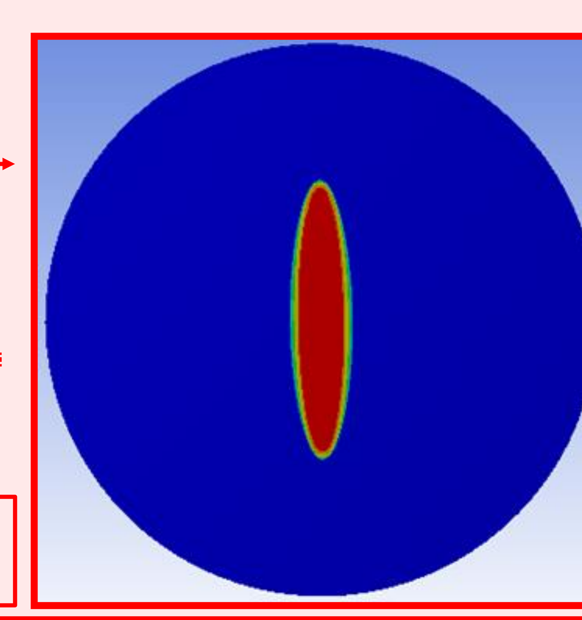
$T_{average}$ → steady state simulation with the same simplified Gaussien beam

ΔT → transient simulation with : $\Delta t = \frac{4 \times \sigma\ gaussien}{\pi \times \text{Ø}hit \times \frac{speed}{60}}$

Same philosophy than analytical method, but with FEA method computer.
Main Interest : the conductivity is taken into account



→ $T_{average}$ → $T_{max} = T_{average} + \frac{\Delta T}{2}$ ← ΔT ←

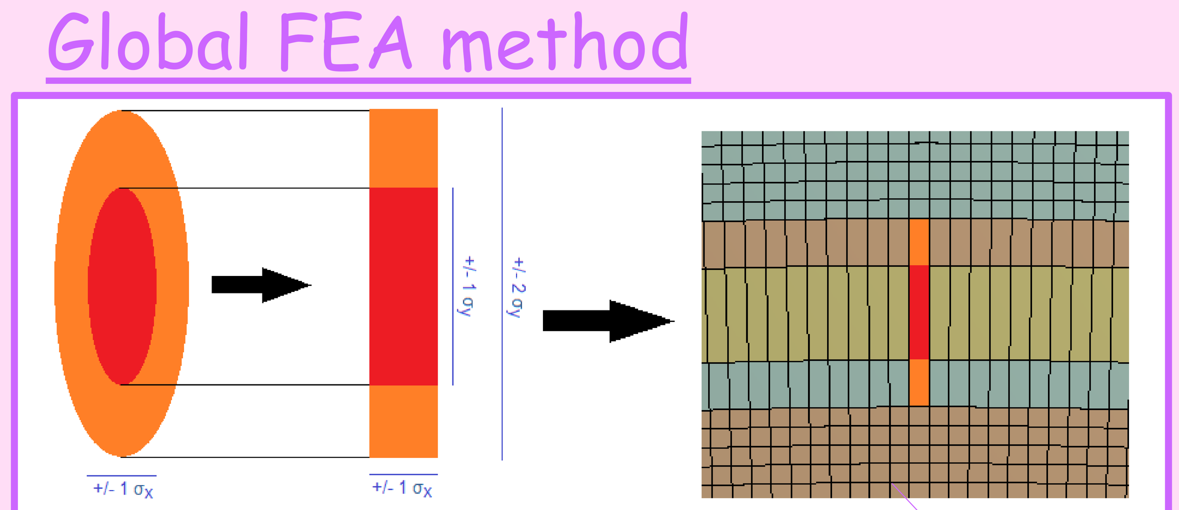


+ Quick with computer, conductivity taken into account

− Rotation speed considered as infrite

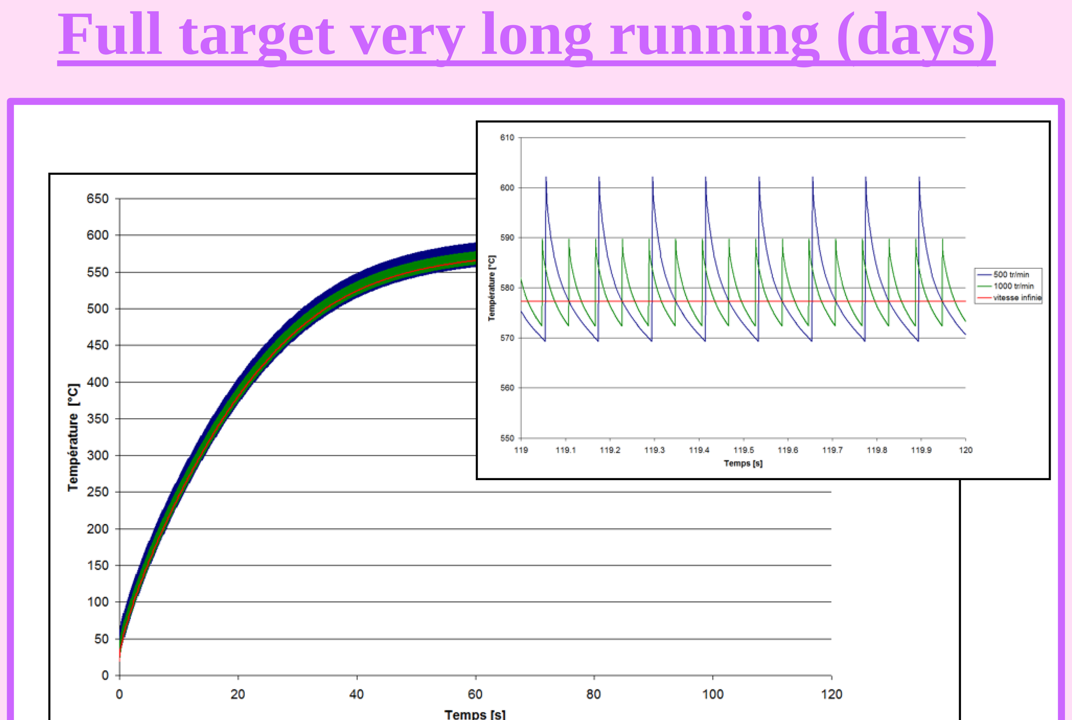
Global FEA method

Steady state simulation. The calculation step depends on the rotation speed, the elements are loaded one by one.



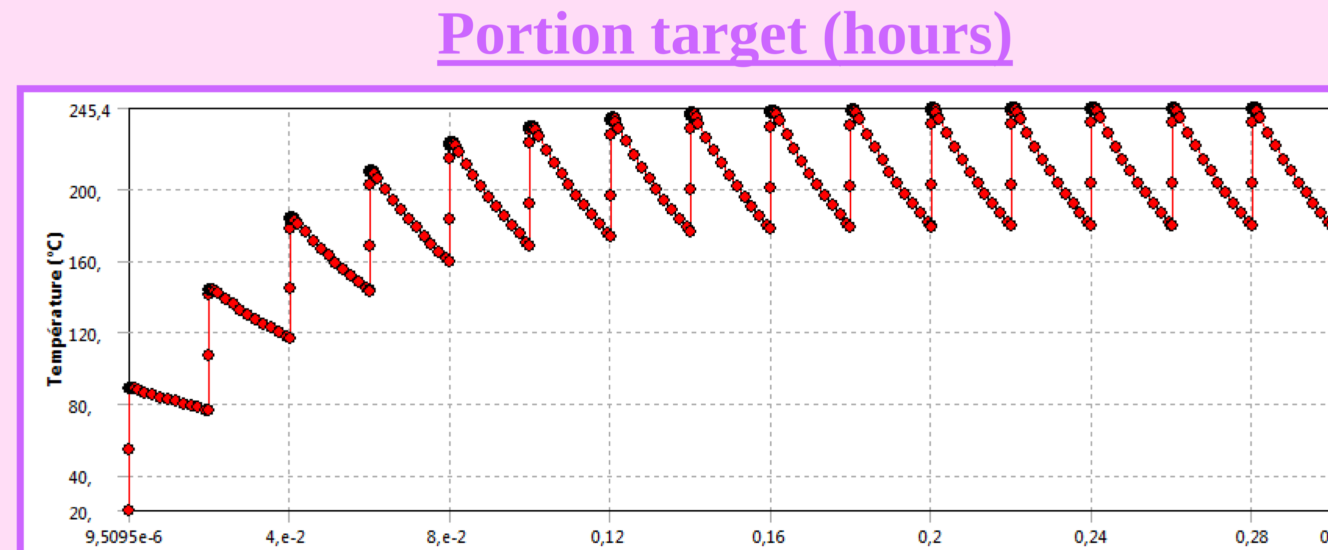
Mapping Meshing depends on Beam size σx

Full target very long running (days)



Exemple : temperature depending on the rotational speed for a full target

Portion target (hours)



Exemple temperature for a portion target (we see the cooling between 2 rounds)

+ Taken into account of the rotational speed and conduction

− Quite difficult to run and long processings calculation time