Development for Fe, Ni, Co ion production at SPIRAL1

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GANIL

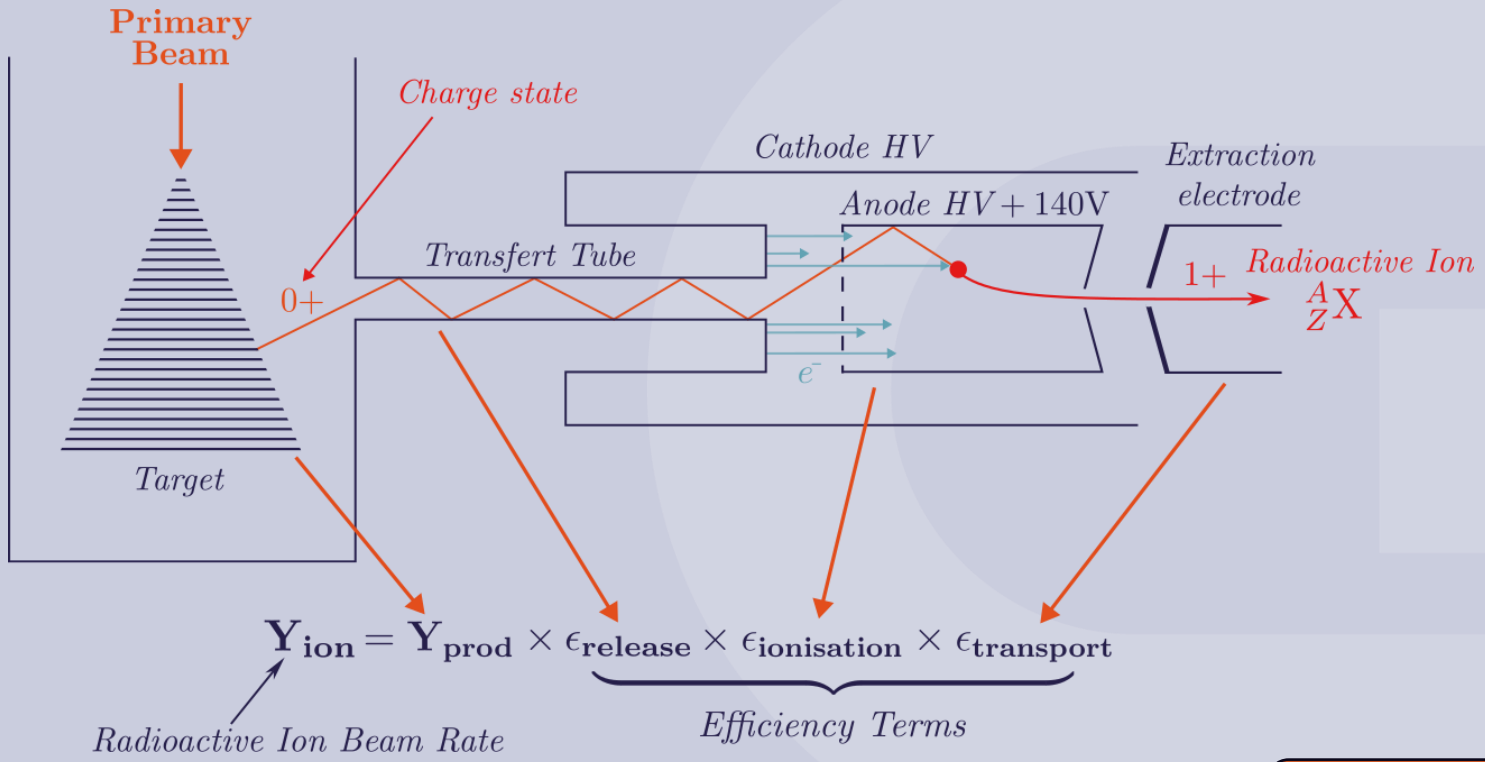
- Principle of the FEBIAD TISS
- Analysis of the production test of July
- Thermal simulation of the TISS
- Design optimization
- Hall D experiment model

Principle of the FEBIAD TISS cavity

Ideal primary beam : ^{58}Ni / 600W / 74,5 MeV

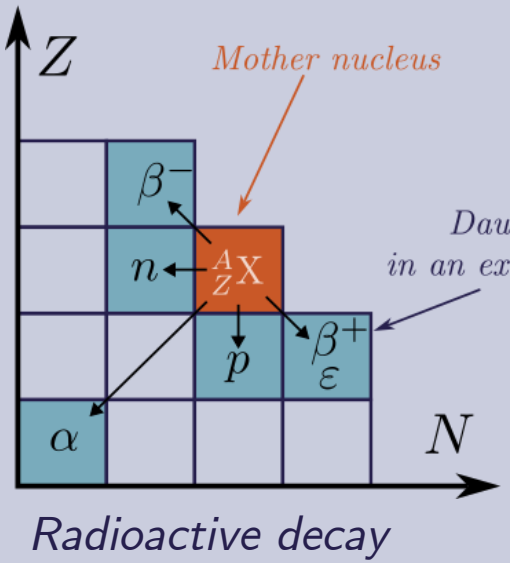
1. Fragmentation
2. Diffusion
3. Effusion
4. Ionization
5. Transport
6. Mass separation

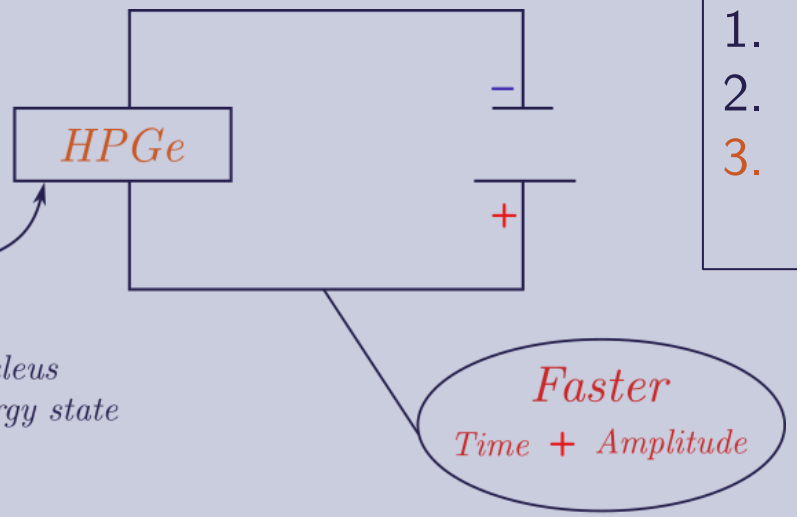
→ Identification Station



Data analysis of the production test of Fe, Ni, Co

➔Producing iron-like ion beams : ^{57}Ni, ^{56}Ni, ^{55}Co, etc...



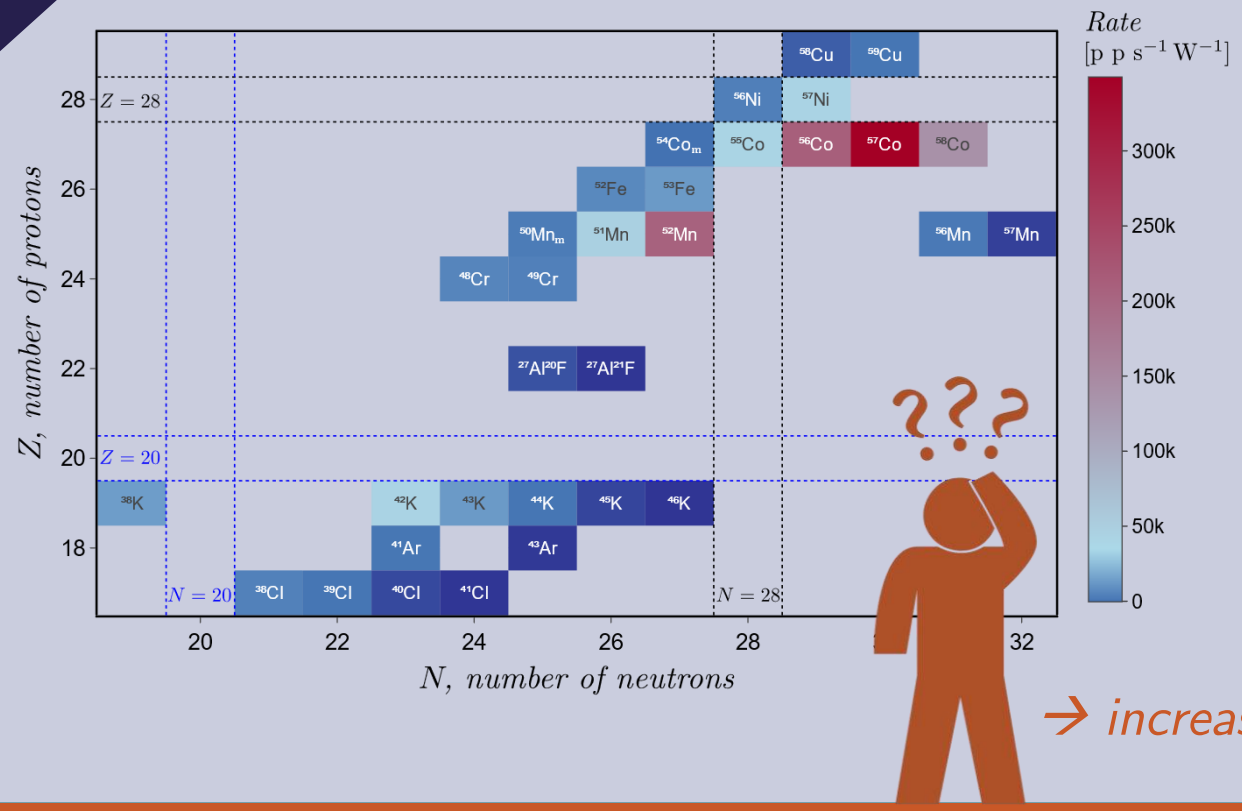


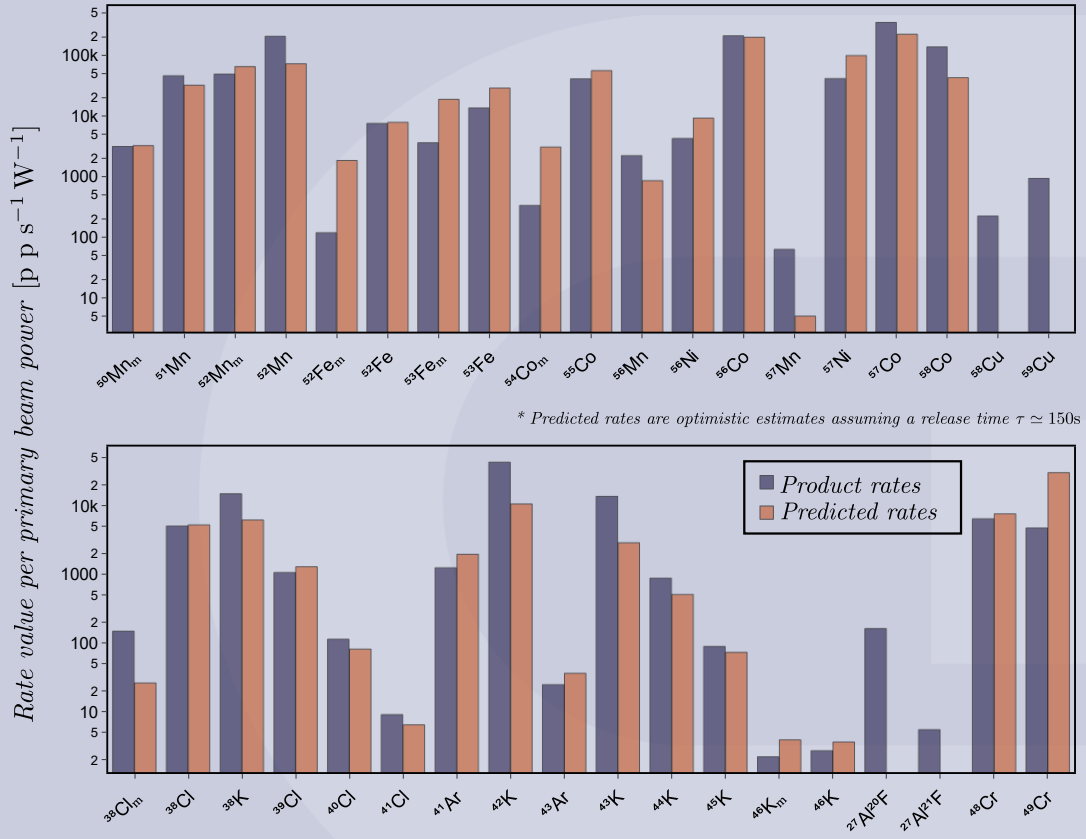
1. Photopeak γ → E_γ *and* I_γ *probability*
2. Nuclear decay count fitted
3. Contaminant correction
   → Rate calculation Y_{ion} [p p/s]

HPGe detector signal ∝ Gamma ray energy E_γ [eV]

Analysis results

- ✓ ^{56}Ni
- ✓ *Results ≈ Predicted*





→ *increase the production rate ?*

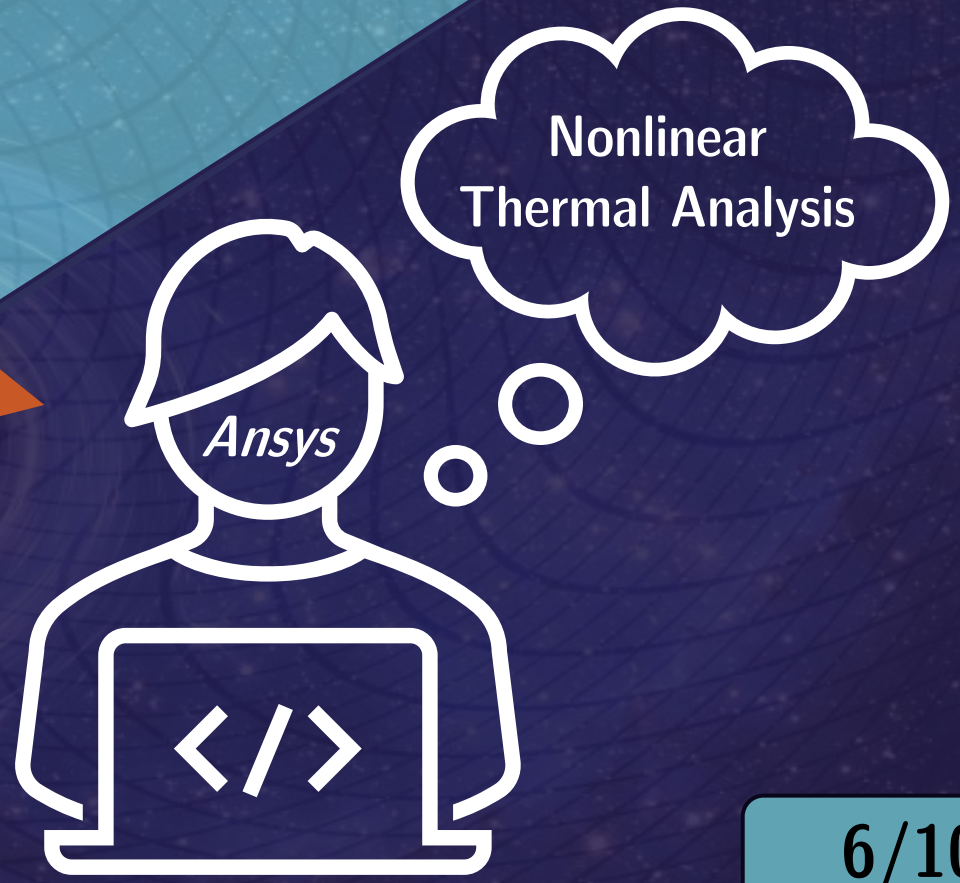
Design optimization ?

- Diffusion
- Effusion ⟹ T° dependent !
- Ionization

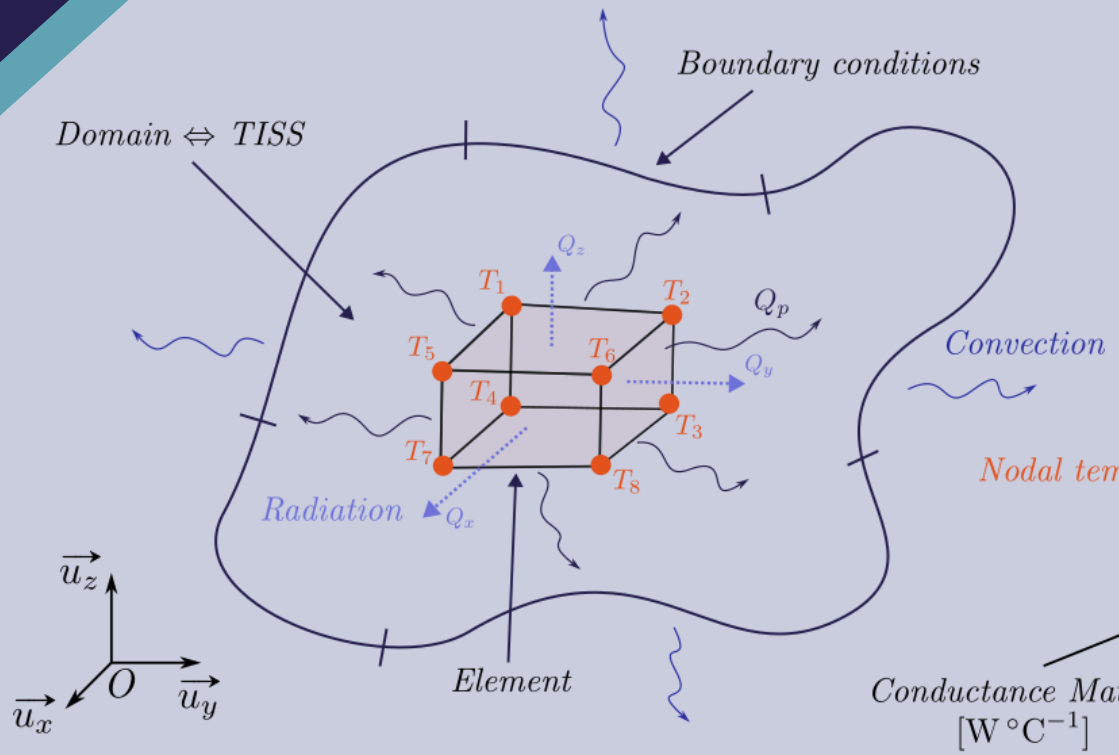
We need high and homogeneous temperatures
→ optimization with thermal simulation

Material properties :

- $\rho(T)$ *electrical resistivity* $[\Omega/\,\mathrm{m}]$
- $k(T)$ *thermal conductivity* $[\mathrm{W/m°C}]$
- $\varepsilon(T)$ *total emissivity*



Ansys : thermal simulation with finite element model



→ *Boundary Conditions :*

Temperature constraints,
Radiation, Cooling of the vacuum chamber

→ *Thermal loads :*

Power distribution of the primary beam,
Heating power of the anode and the Target Oven

$$[K] \begin{Bmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \\ T_5 \\ T_6 \\ T_7 \\ T_8 \end{Bmatrix} = \underbrace{\begin{Bmatrix} Q_x \\ Q_y \\ Q_z \end{Bmatrix} + \{Q_p\}}_{\text{Thermal loads}}$$

Nodal temperatures

Heat flow through the surfaces

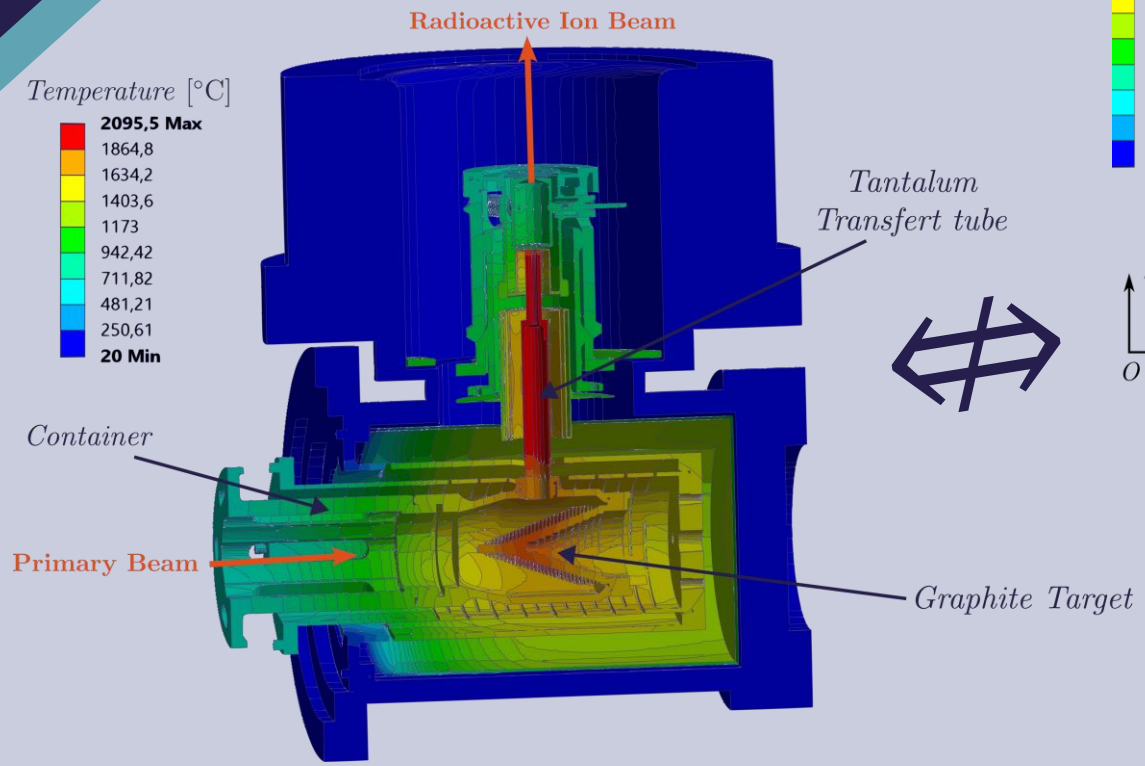
Internal Heat generation

Conductance Matrice [W °C^{-1}]

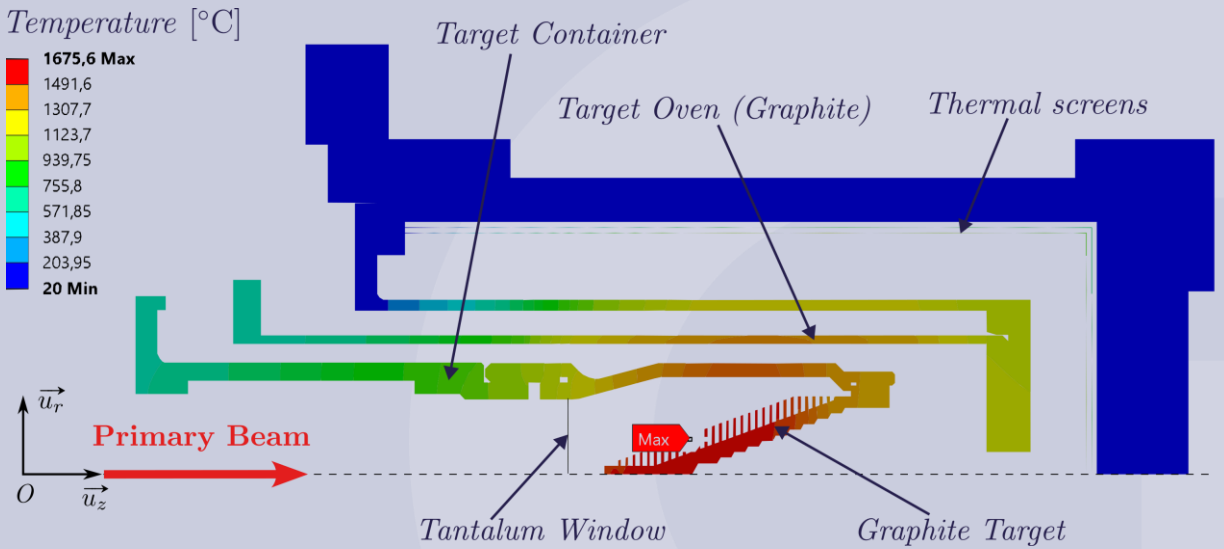
→ *Heat flow convergence managed by Ansys solver*

Which models for design optimization ?

3D model



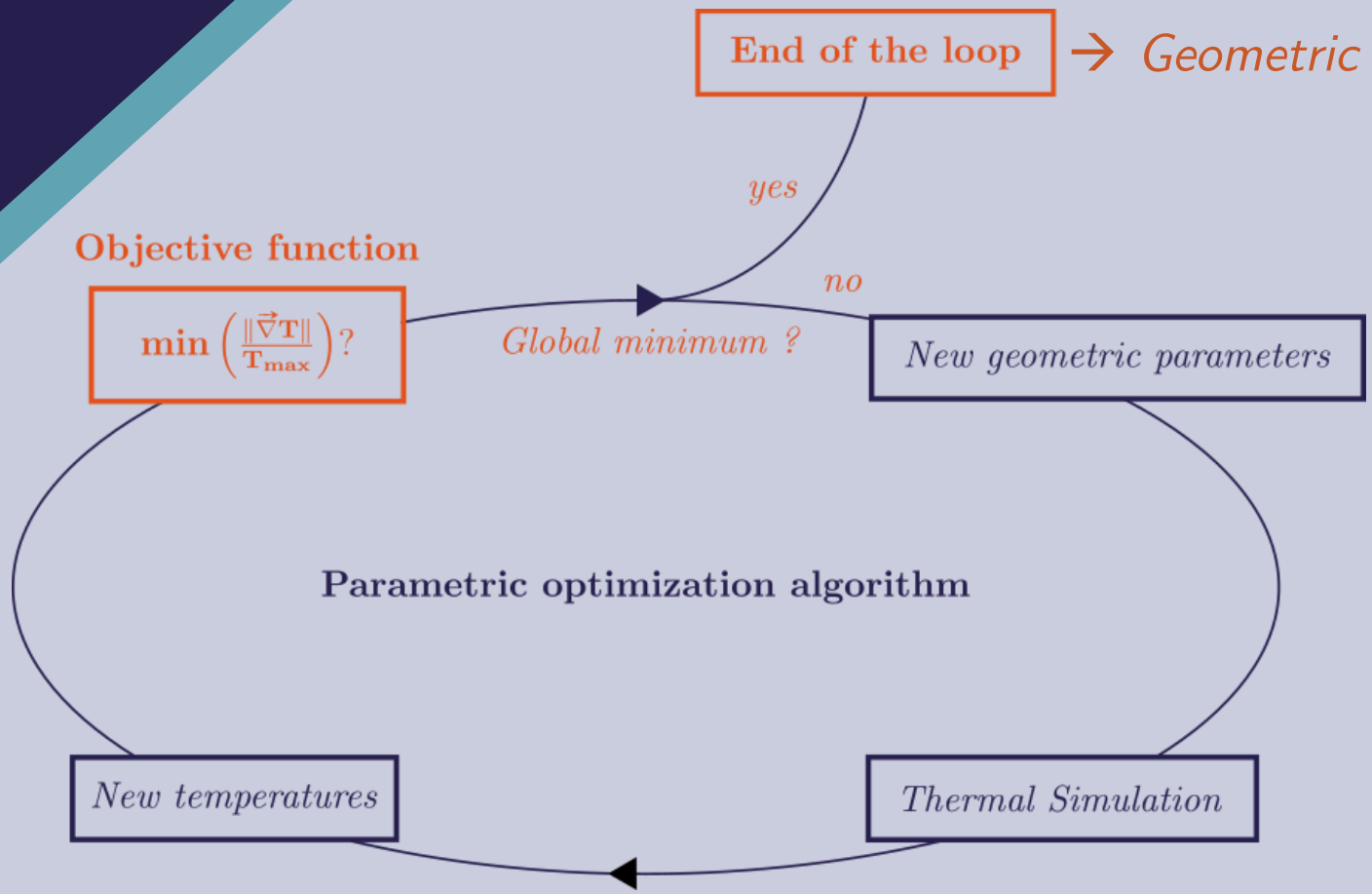
Axisymmetric model



- ✓ *Quick geometric changes*
- ✓ *Quick calculations*
- × *Cathode heating power ≈ 1500 W*

→ *Suitable for automated optimization*

Multi-parameters optimization



→ *Geometric optimum for the target*

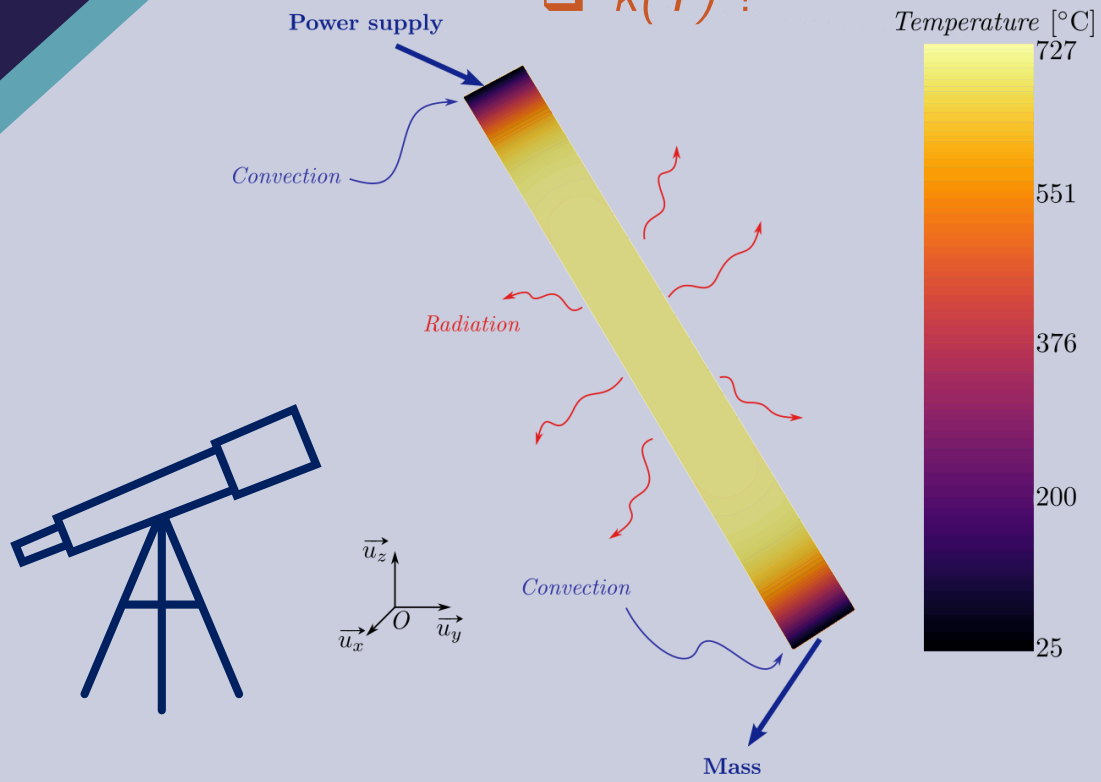
✓ *Parametric geometry with pyMAPDL !*

Minimization of temperature gradient :

- *Gradient based algorithm ?*
- *Parallel computing ?*

Minimization example : Hall D set up model

✓ $\rho(T)$
✓ $\varepsilon(T)$
❑ $k(T)$?



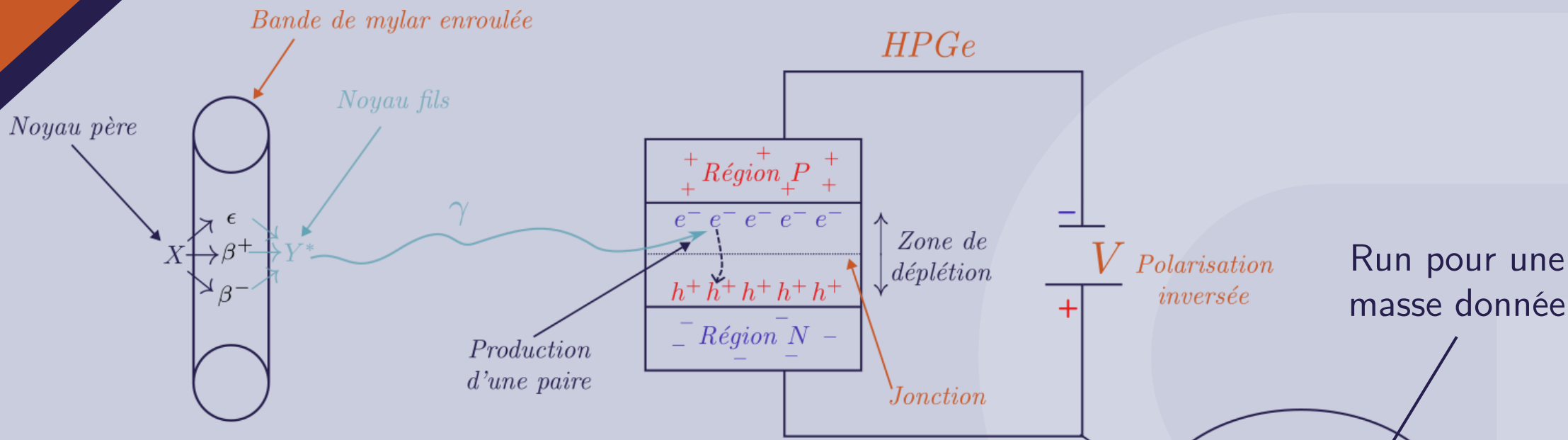
→ *Retrieve the thermal conductivity k(T) thanks to experimental measures :*

$$\chi^2 = \sum_{i=1}^{N} \frac{\left(T_i^{meas} - T_i^{model}(k)\right)^2}{\varepsilon_i^2}$$

- T_i^{meas} *the temperature of the measure i,*
- $T_i^{model}(k)$ *depending on the k parameter,*
- ε_i *the uncertainty of the measure i*

Conclusion

Détection des raies γ à l'IBE



Désintégrations radioactives

$$\begin{cases} {}^{A}_{Z}X \xrightarrow{\beta^-} {}^{A}_{Z+1}Y^* + e^- + \overline{\nu}_{e^-} \\ {}^{A}_{Z}X \xrightarrow{\beta^+} {}^{A}_{Z-1}Y^* + e^+ + \nu_{e^-} \\ {}^{A}_{Z}X + e^- \xrightarrow{\epsilon} {}^{A}_{Z-1}Y^* + \nu_{e^-} \end{cases}$$

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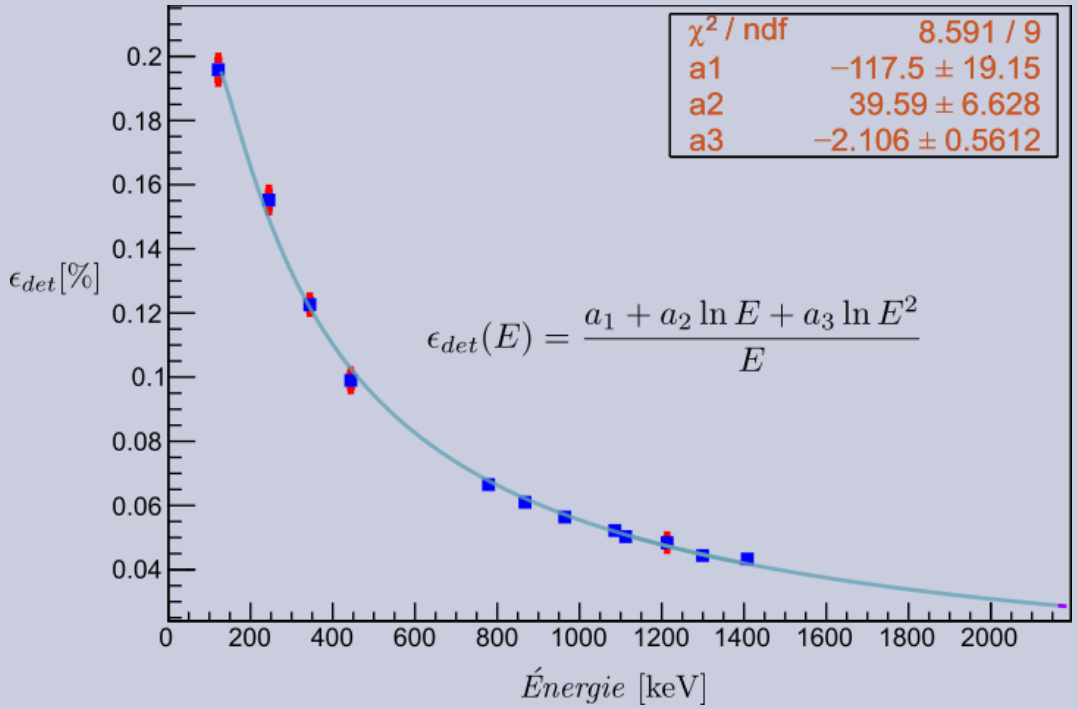
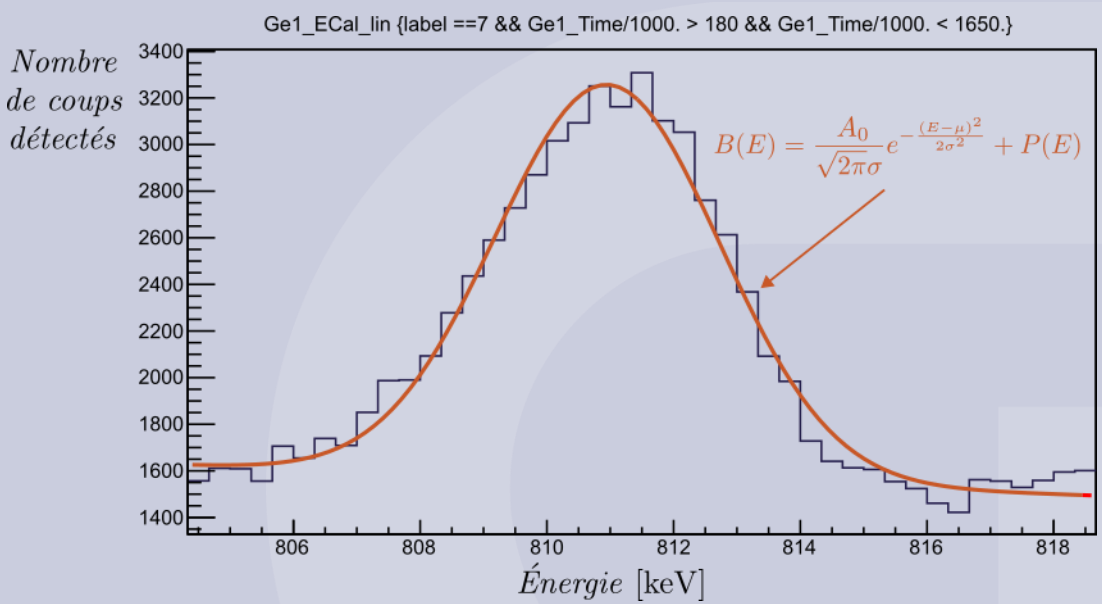
Calibration et ajustement

Calibration du signal s *en énergie*

$E(s) = (4{,}07 \times 10^{-2})s + 1{,}21$ → *Root*

Ajustement de l'efficacité en fonction de l'énergie

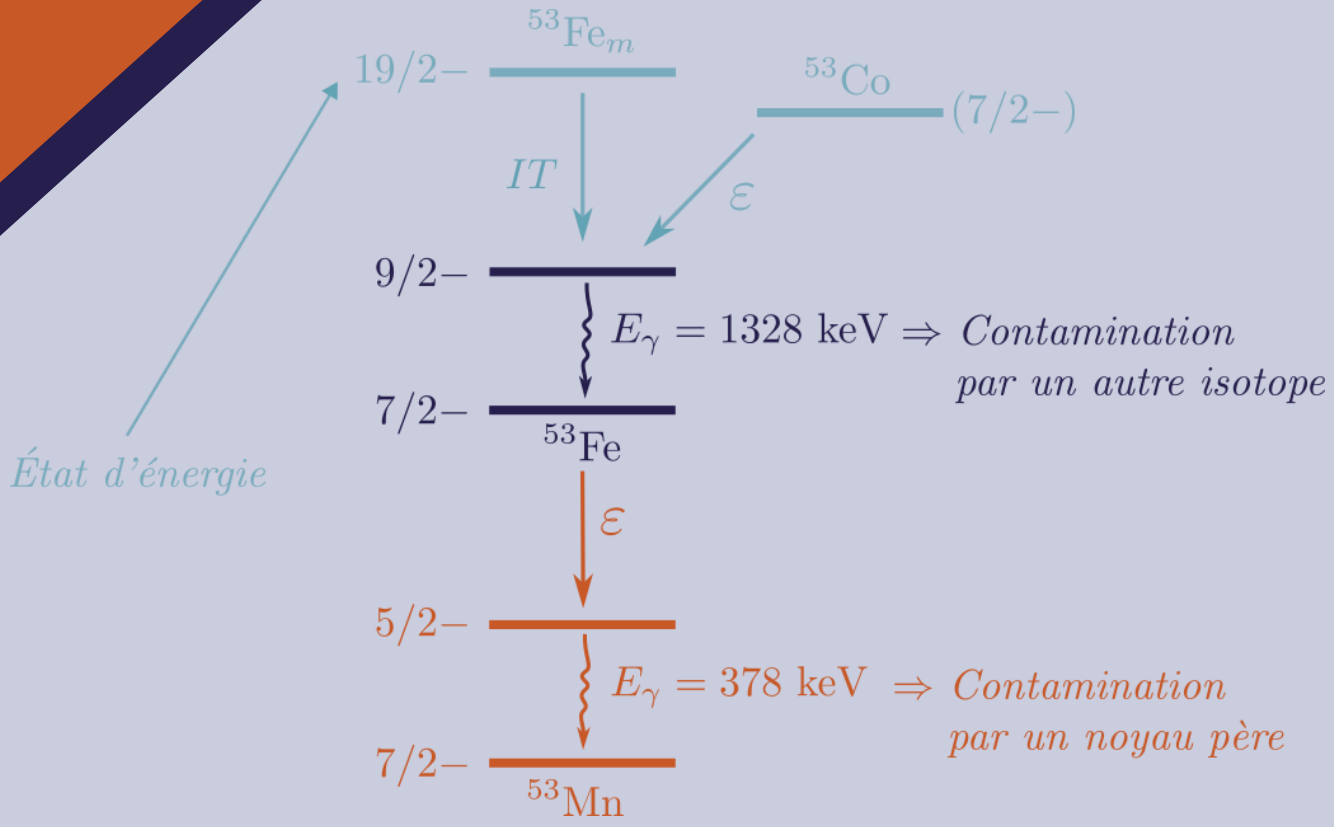




Ajustement d'un pic d'énergie d'une raie γ

→ *taux produit sur bande* Y_{ion} [p p/s] *?*

Protocole et analyse



1. Run faisceau primaire / ECS stable
2. Raie γ → E_γ *et probabilité* I_γ
3. *Ajustements coups détectés*
4. Contamination ? *Population chambre ?*
5. Correction des coups réels
6. Efficacité $\epsilon_{det}(E_\gamma, distance)$

→ Y_{ion}

Résultats

Isotopes	$T_{1/2}$ [s]	Run	Puissance faisceau [W]	Taux prédits [p p s^{-1} W^{-1}]	Y_{ion} [p p s^{-1} W^{-1}]
^{57}Ni	128160	A57-2	630 ± 90	$9,91 \times 10^4$	$(4,1 \pm 0,6) \times 10^4$
^{56}Ni	525398, 4	A56-2	500 ± 120	$9,25 \times 10^3$	$(4,3 \pm 0,7) \times 10^3$
^{55}Co	63108	A55-6	570 ± 110	$5,57 \times 10^4$	$(4,1 \pm 0,8) \times 10^4$
^{53}Fe$_m$	510, 6	A53-4	570 ± 70	$1,88 \times 10^4$	$(3,6 \pm 0,6) \times 10^3$
^{53}Fe	152, 4	A53-4	570 ± 70	$2,89 \times 10^4$	$(1,4 \pm 0,2) \times 10^4$

Taux de production pour un faisceau ^{58}Ni *de* 74,5 MeV/A

- ✓ ^{56}Ni *à des taux suffisants*
- ✓ *de nombreux autres isotopes produits*
- × *Problème étude machine et moins bon taux*

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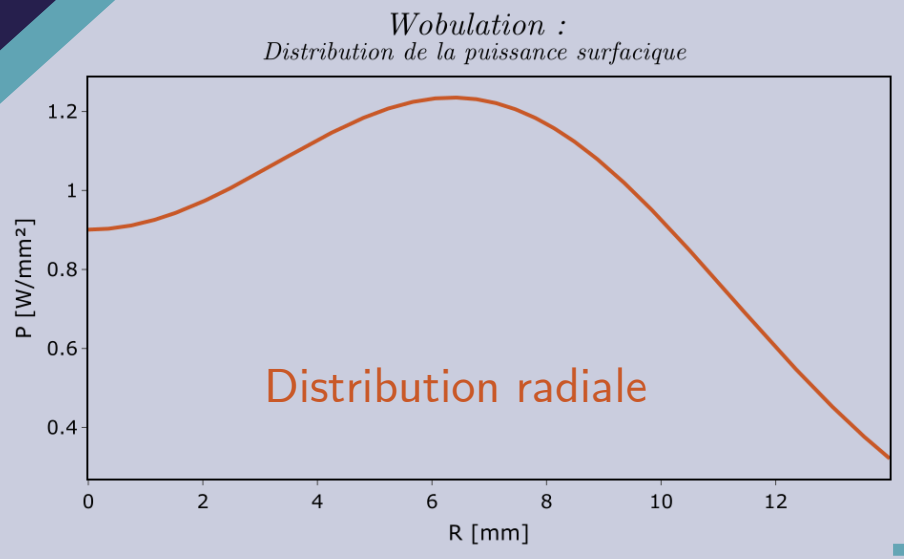
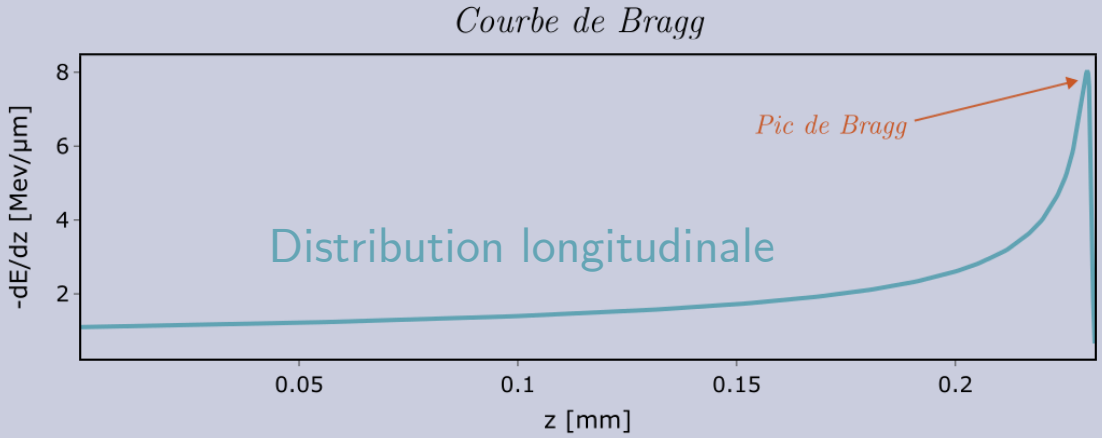
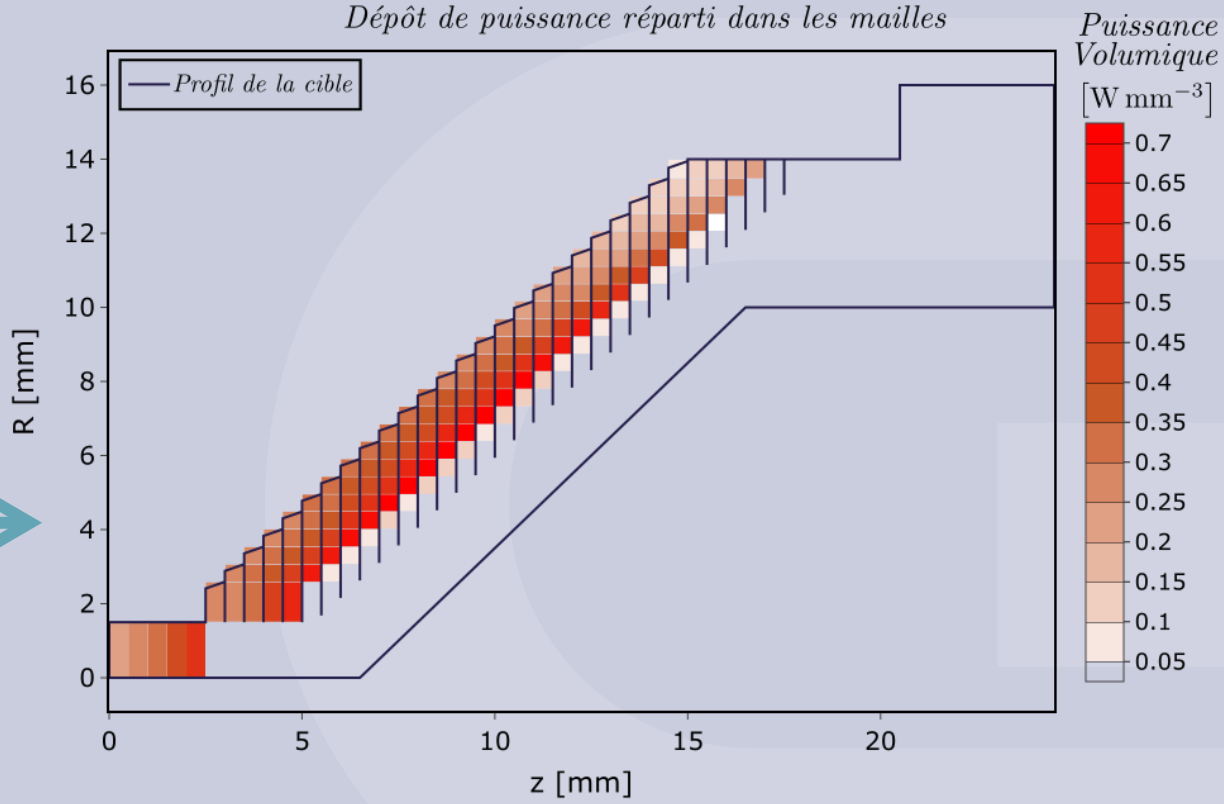
Répartition de la puissance dans la cible

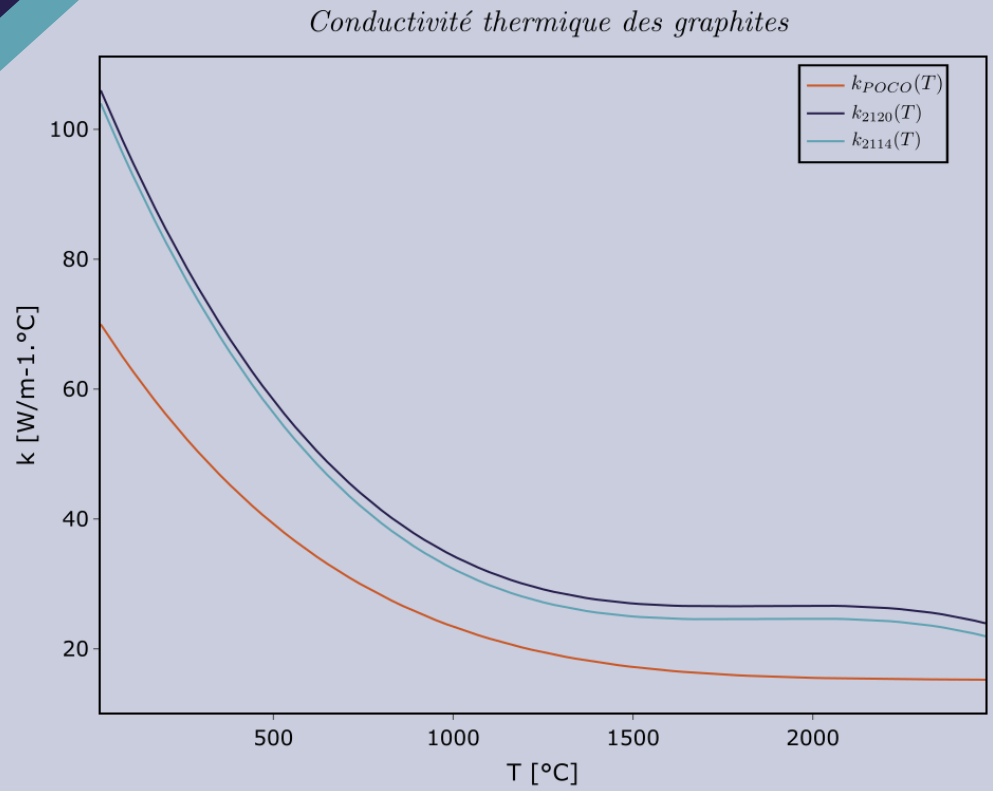


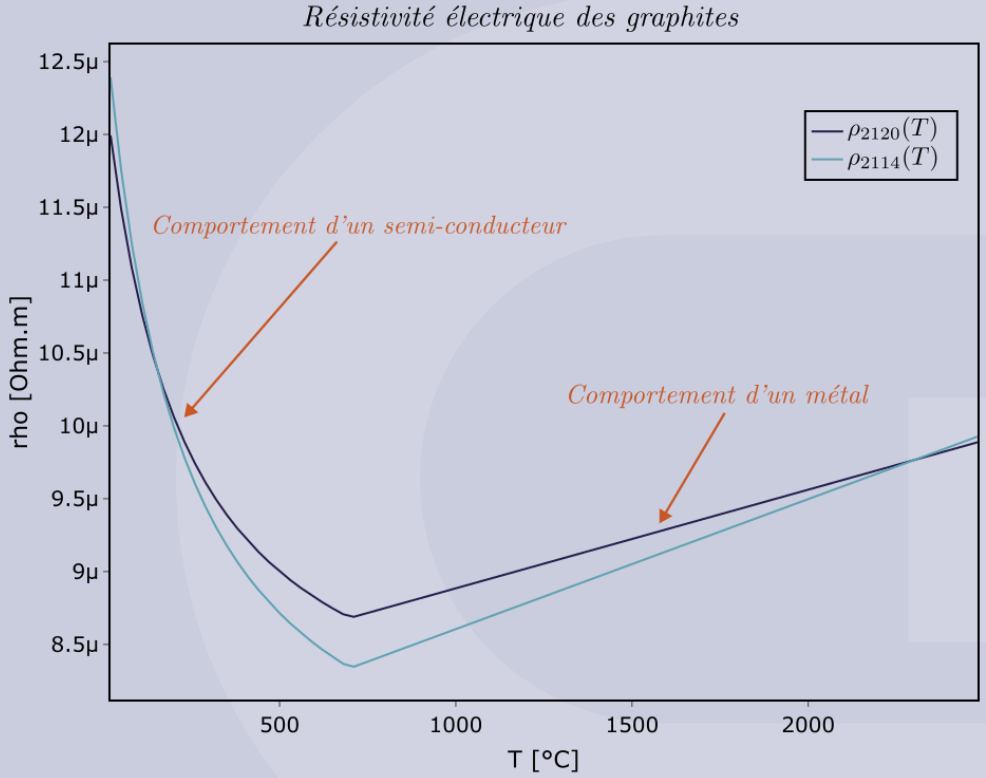




600 W wobulé et déposé dans la cible

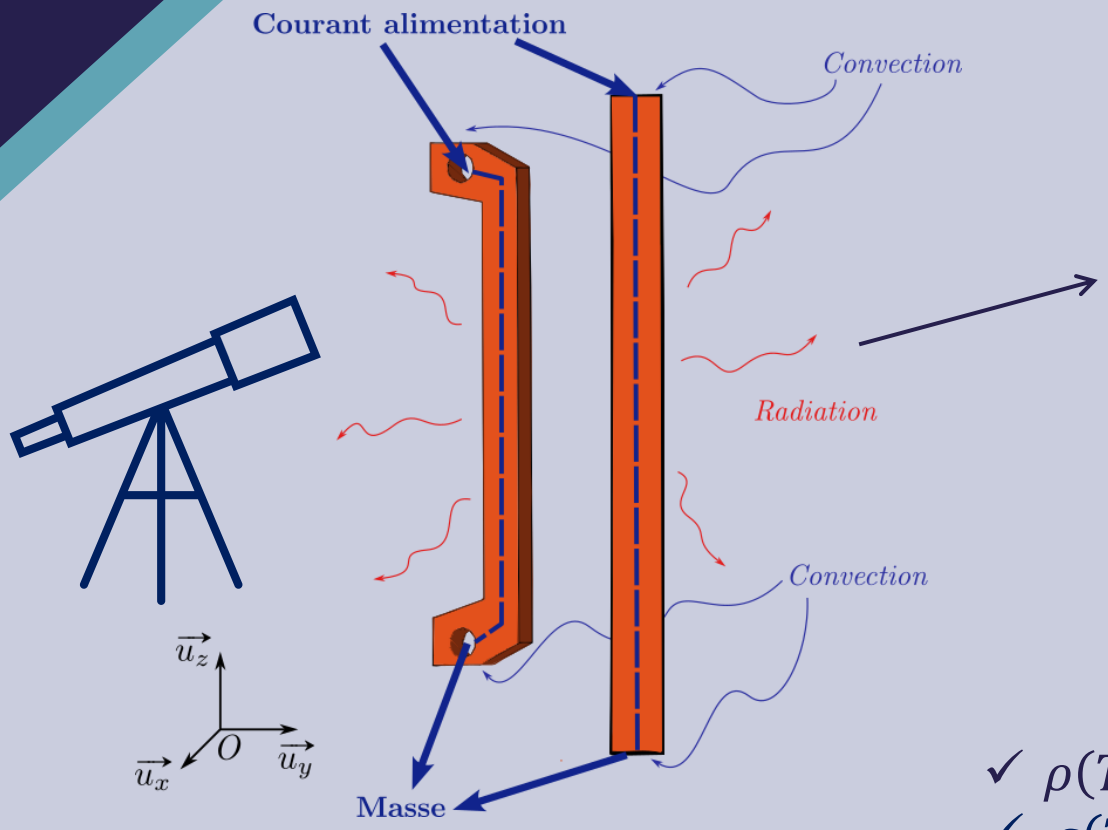
Spécificité des graphites et effet Joule



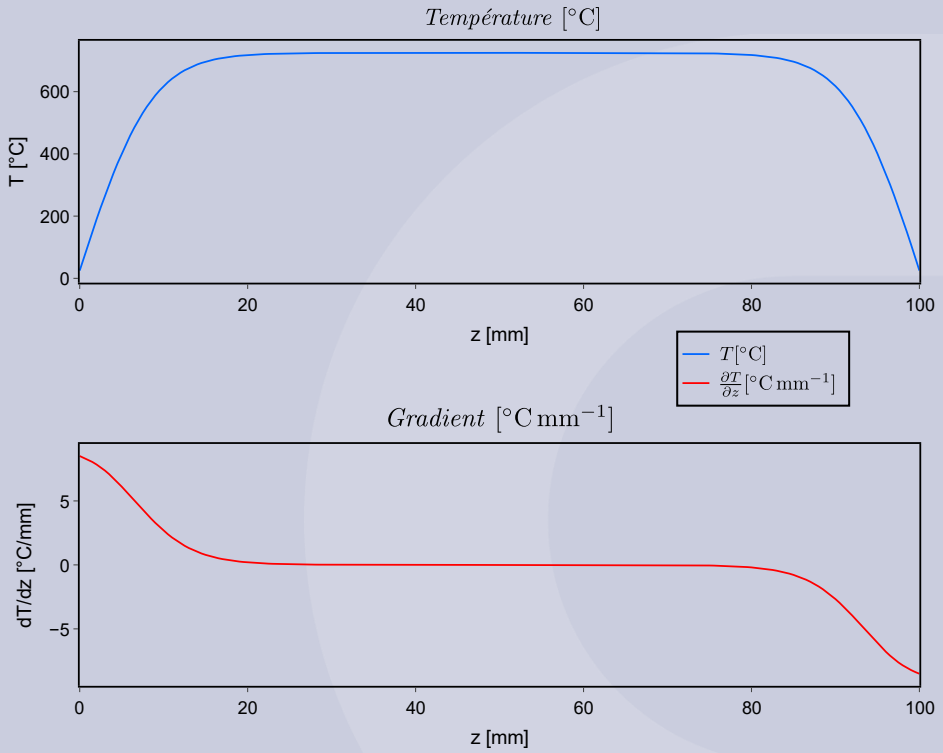


Effet Joule [W/m^3] : $q_{pj} = \rho(T)J^2$,
avec J la densité surfacique de courant [A/m^2].

Principe de la manipulation du hall D



Simulation des échantillons



- ✓ $\rho(T)$ *la résistivité électrique* [Ω/ m]
- ✓ $\varepsilon(T)$ *l'émissivité*
- ❑ $k(T)$ *la conductivité thermique* [W/m°C] ?

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