# Development of a Thermal Response Model for Profile Monitors and Benchmarking to CERN LINAC4 Experiments

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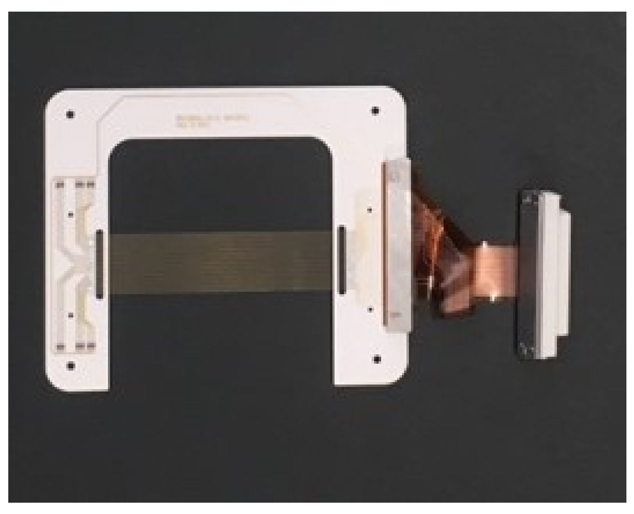
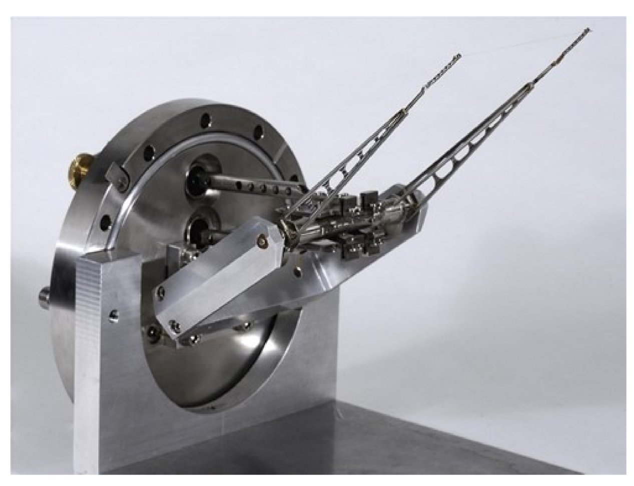
## ABSTRACT

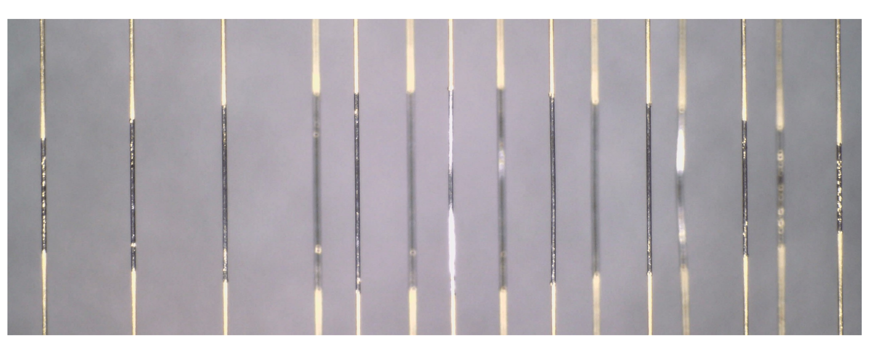
The operation of wire grids and wire scanners as beam profile monitors, both in terms of measurement accuracy and wire integrity, can be heavily affected by the thermal response of the wires to the energy deposited by the charged particles. A comprehensive model to describe such interaction has been implemented including beam induced heating, all relevant cooling processes and the various phenomena contributing to the wire signal such as secondary emission and H- electron scattering. The output from this model gives a prediction of the wire signal and temperature evolution under different beam conditions. The model has been applied to the wire grids of the CERN LINAC4 160 MeV H- beam and compared to experimental measurements. This successful benchmarking allowed the model to be used to review the beam power limits for operating wire grids in LINAC4.

## Wire Grid Systems

- A SEM grid consists of thin ribbons or wires, the signal produced by each of them is proportional to the number of particles reaching the wire.
- Wire scanners consists in a single wire that is moved through the beam.
  - Slow wire scanners: Every beam pulse there is an acquisition.
  - Fast Wire scanners: The beam profile can be obtained by controlling the wire position and measuring the secondary particle shower.







## Model Benchmarking and Results

For model bench-marking, the simulated results were compared with experimental temperature measurements. The temperature of the wires was measured indirectly by means of thermionic emission process. The measurements presented here were performed with one of the wire grids located at 160 MeV LINAC4 section.

The simulations do not include neither a variable beam intensity during the pulse (e.g. the modulations from the source) nor the intensity 'holes' due to the chopper settings. Despite this, the model successfully reproduces the measured signals. The agreement in terms of wire signal versus beam current is well within 10%

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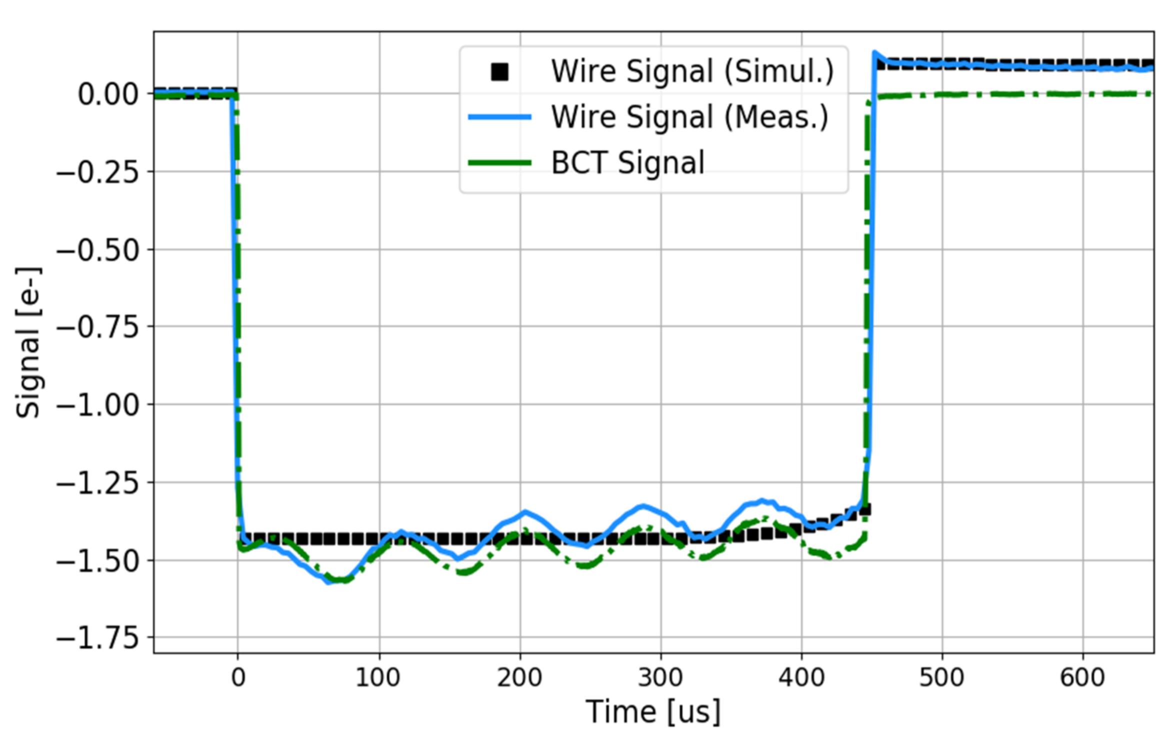
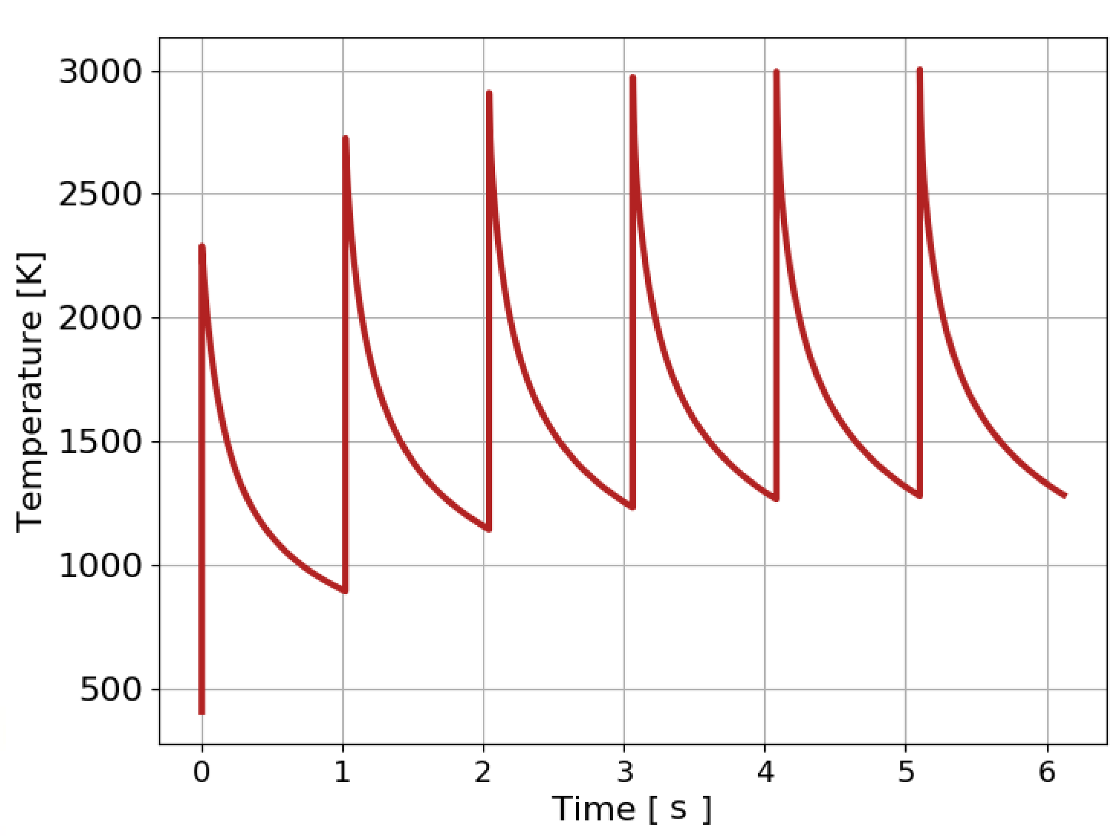



## Simulation Model

### Intensity Model:

The charge generated in the wire per incident particle can be summarized by the following equitation:

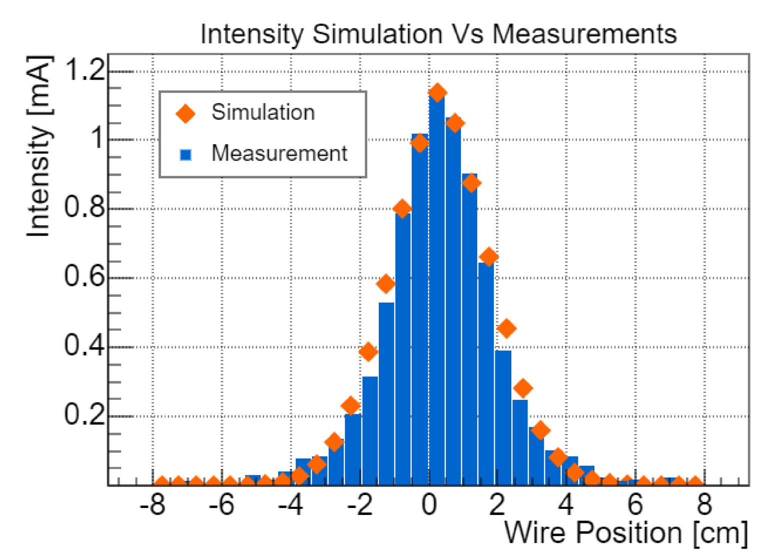
$$Q\left(\frac{e}{Proj}\right) = Q_{dep} + Q_{SE} + Q_{th}$$

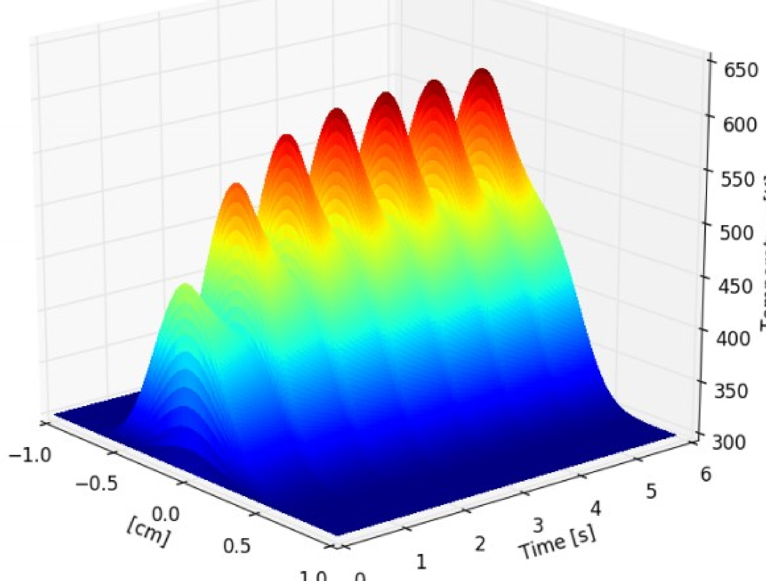
The term $Q_{dep}$ refers to the charge generated in the wire due to charge deposition of the incident particle.. $Q_{SE}$ refers to the charge generated due to the effect of secondary particle emission. $Q_{th}$ refers to charge generated due to thermionic emission.

### Thermal Model:

During operation, the beam of particles deposits some energy on the wire material, which is translated into a temperature increase ($\Delta T_{Ht}$). For this model, the considered cooling mechanisms were Radiative Cooling ($\Delta T_{Rd}$), Thermionic Cooling ($\Delta T_{Th}$), Conductive Cooling ($\Delta T_{Con}$) and Sublimation cooling ($\Delta T_{Sub}$). The temperature variation of the wires for each time step can be written as follows

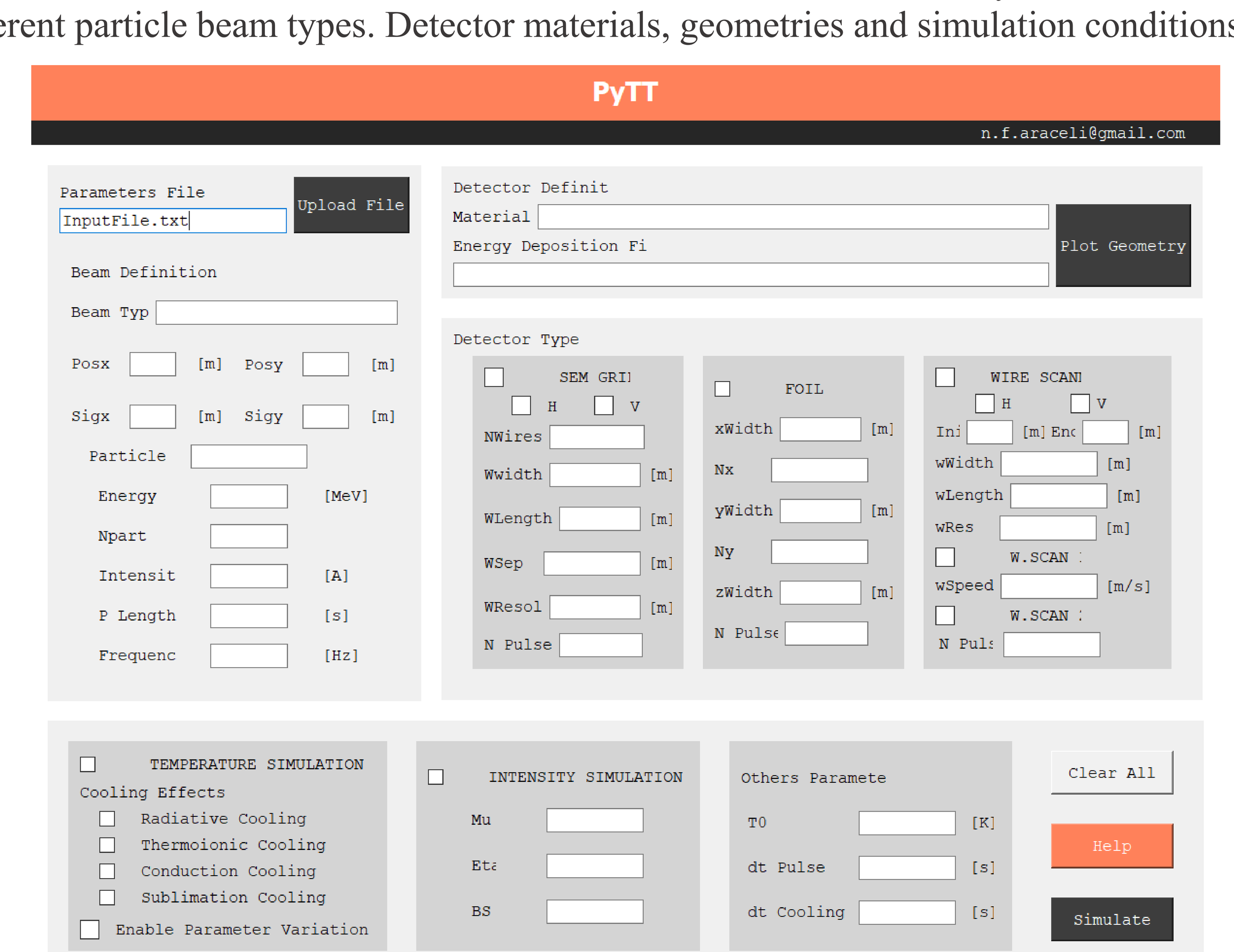
$$\Delta T_{Tot} = \Delta T_{Ht} - \Delta T_{Rd} - \Delta T_{Th} - \Delta T_{Con} - \Delta T_{Sub}$$




### Simulation Code:

Simulation code can be launched via terminal or with a user friendly interface. It includes different particle beam types. Detector materials, geometries and simulation conditions.

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## Model Applicability: LINAC4 power limits.

LINAC4 beam power limits were calculated, to minimize the risk of overheating and damaging the tungsten wires. The temperature limit set for tungsten wires at LINAC4 was 1400 K due to the gold coating of the wires.