Università degli Studi di Padova – Dipartimento di Ingegneria Industriale

Corso di Laurea in Ingegneria Dell'Energia

Relazione per la prova finale

«Negative Ion Beam profile estimation on STRIKE calorimeter by means of Newton's Method »

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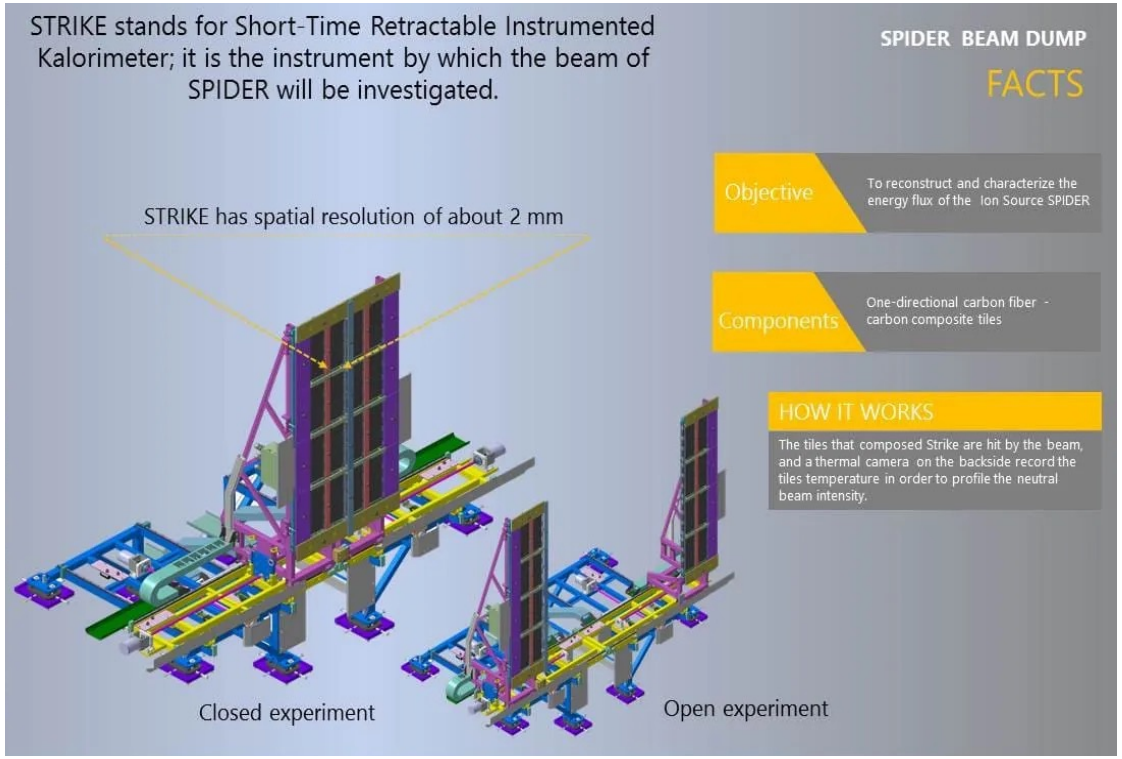
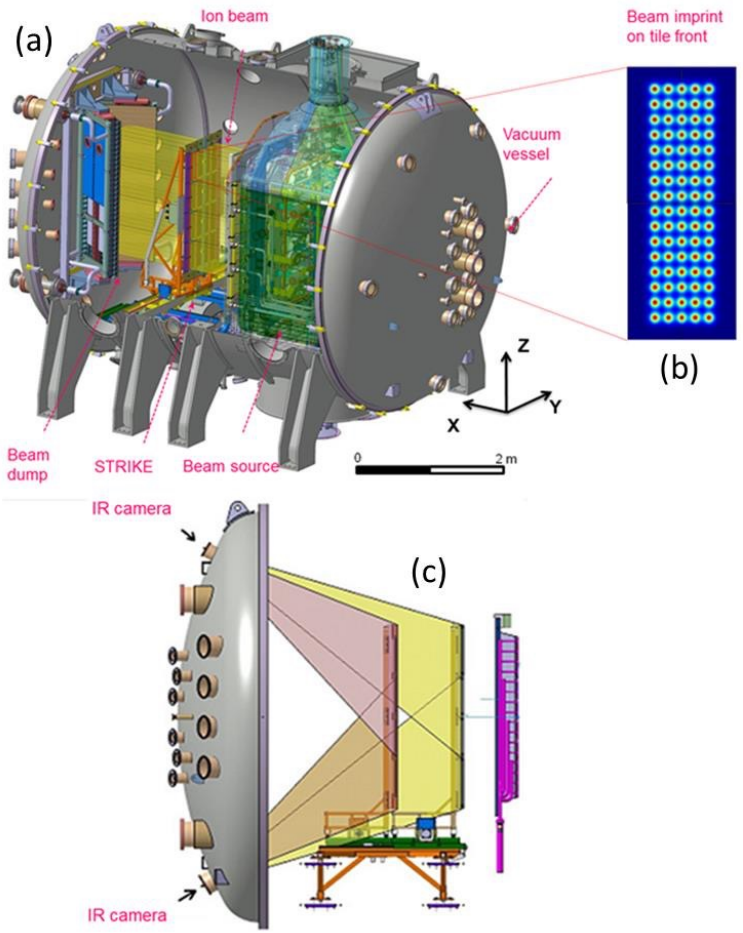
INTRODUCTION

- What is Spider?

  Spider is a negative ion source prototype to heat plasma on ITER, a fusion reactor located in Cadarache, France.
  It products negative ions beams of Deuterium and Hydrogen with a current density of respectively: 258 A/m^{2}e 355 A/m^2

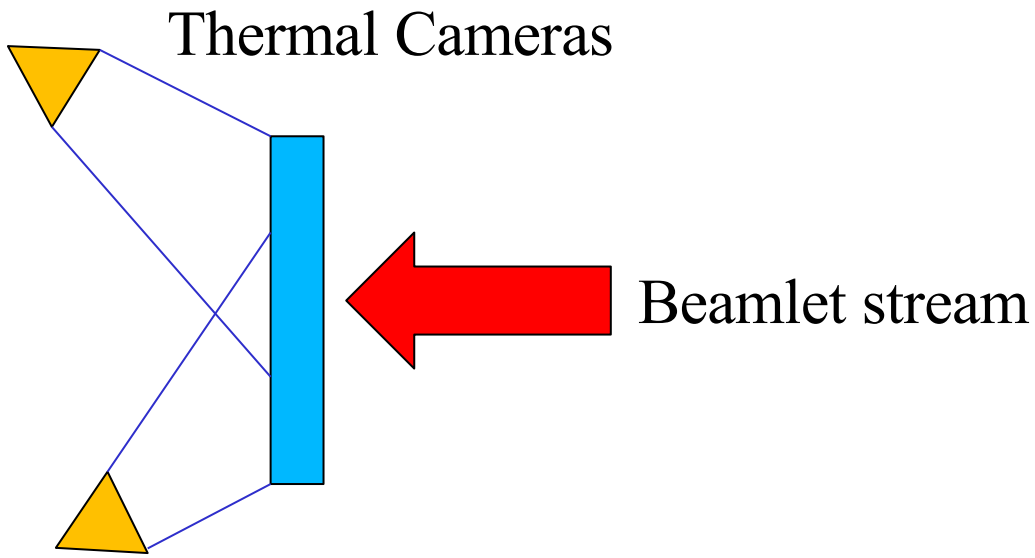




- What is STRIKE?

STRIKE is a calorimeter and the main diagnostic system on Spider, designed to characterize the negative ion beam in terms of uniformity and divergence.
16 one way graphite tiles.

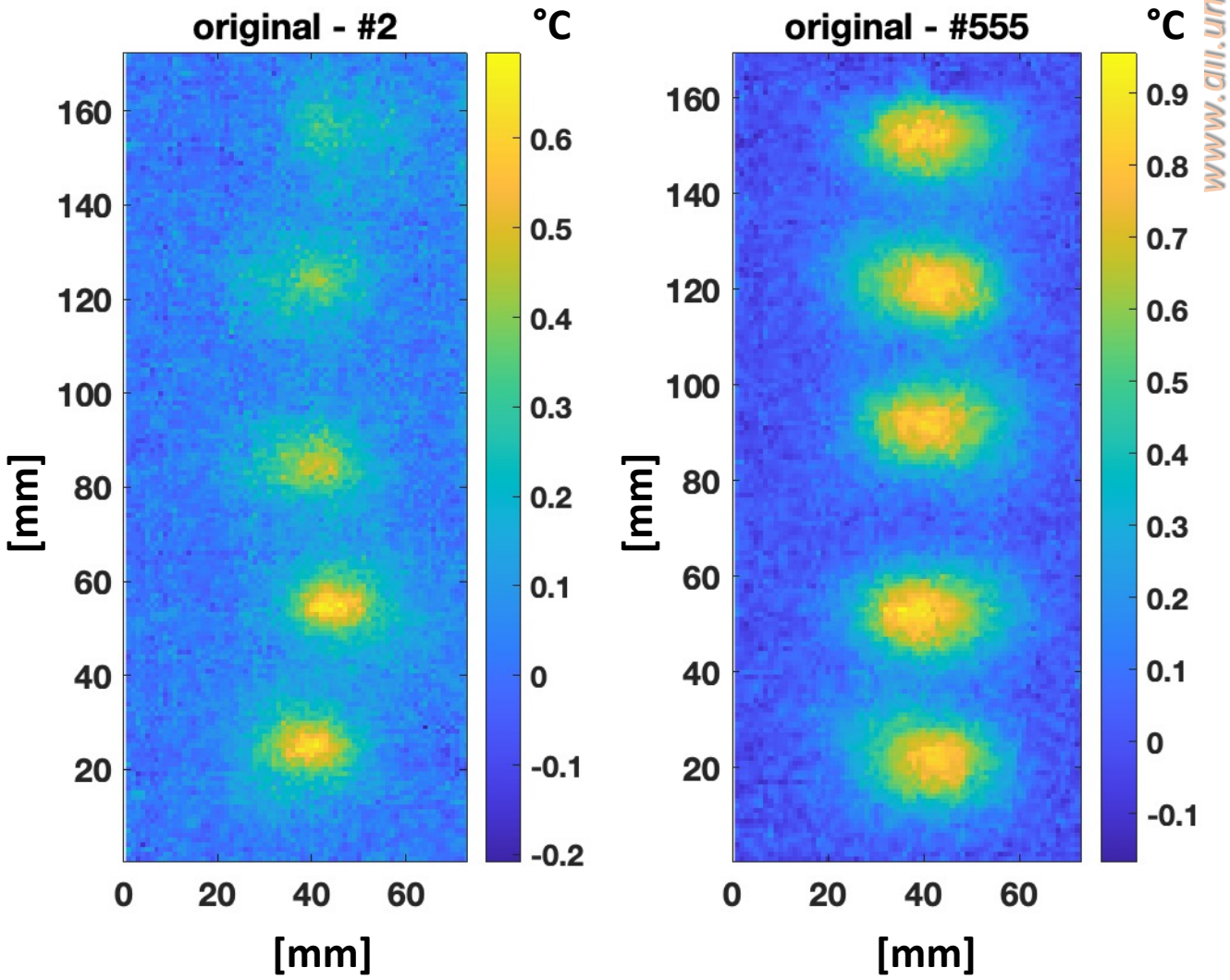
PROJECT OBJECTIVES



- $T = \sum_i \sum_s A_s e^{-\frac{1}{2}((\frac{x_i - x_s}{\sigma x_s})^2 + (\frac{y_i - y_s}{\sigma y_s})^2)}$

  $i = pixel\ number;$
  $s = beamlet\ number$

- **Project objective**: to provide a tool that can be used during experimental sessions to derive the meaning parameters of the beamlets very quickly



DATABASE AND PARTS OF THE CODE

- Two database types: Synthetic and Experimental Images – 573 images for both;

  - **Method Steps:**

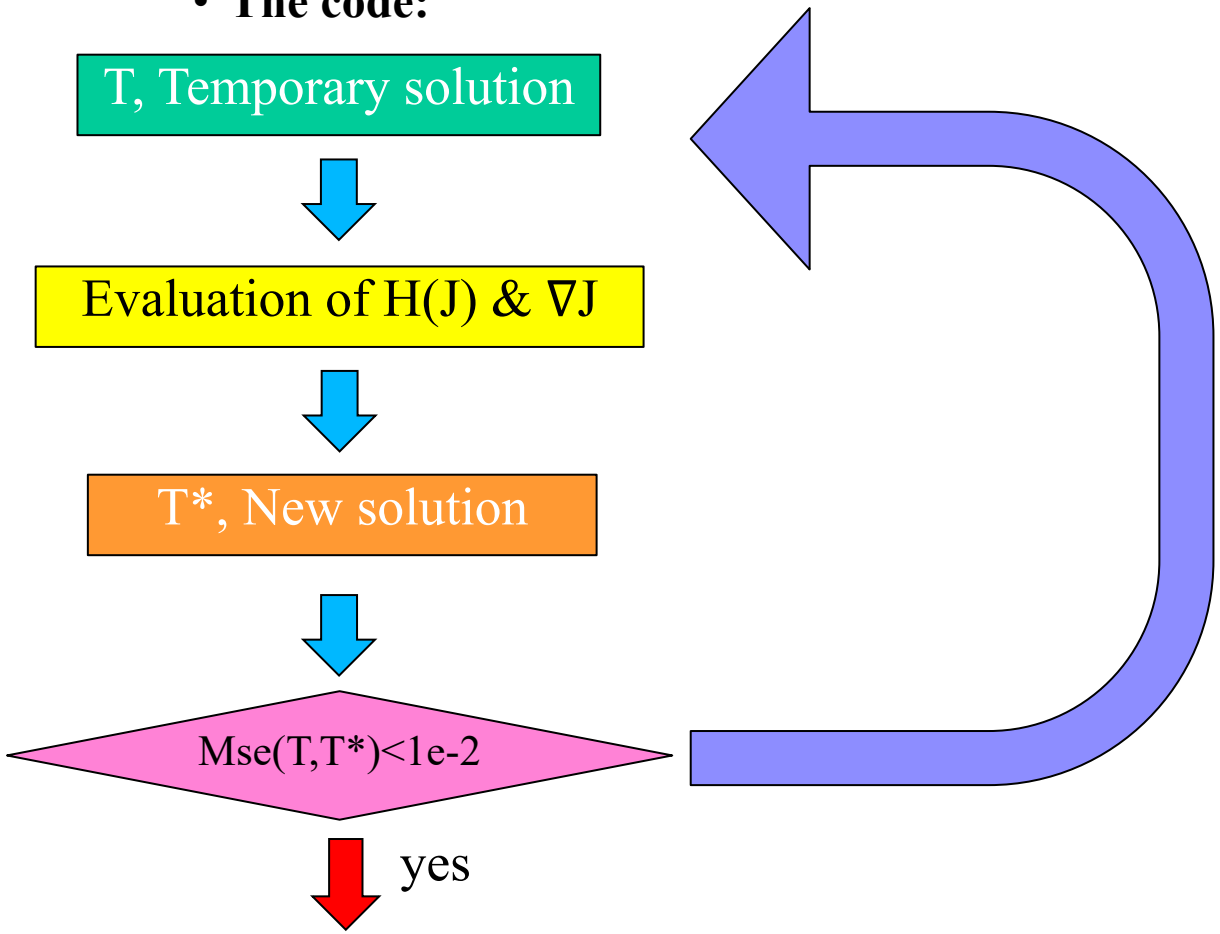
$$J = \frac{1}{2N}\sum_{N}(T - T^*)^2$$

…If $\begin{cases} J'(A, x, y, \sigma_x, \sigma_y) = 0 \\ J''(A, x, y, \sigma_x, \sigma_y) > 0 \end{cases}$; $H(P^*) \geq 0$

$\Longrightarrow P^*$

Otherwise:
$T(k+1) = T(k) + \alpha^* \delta(H(J), \nabla(J))$

  - **The code:**



SYNTHETIC DATA

- esc if mse(T,T*)<1e-2;
- α=0,005
- except for image n°546

- Mean Error Reconstruction:

  →Amplitude=0.91%

  →x_0=9.5e-04%

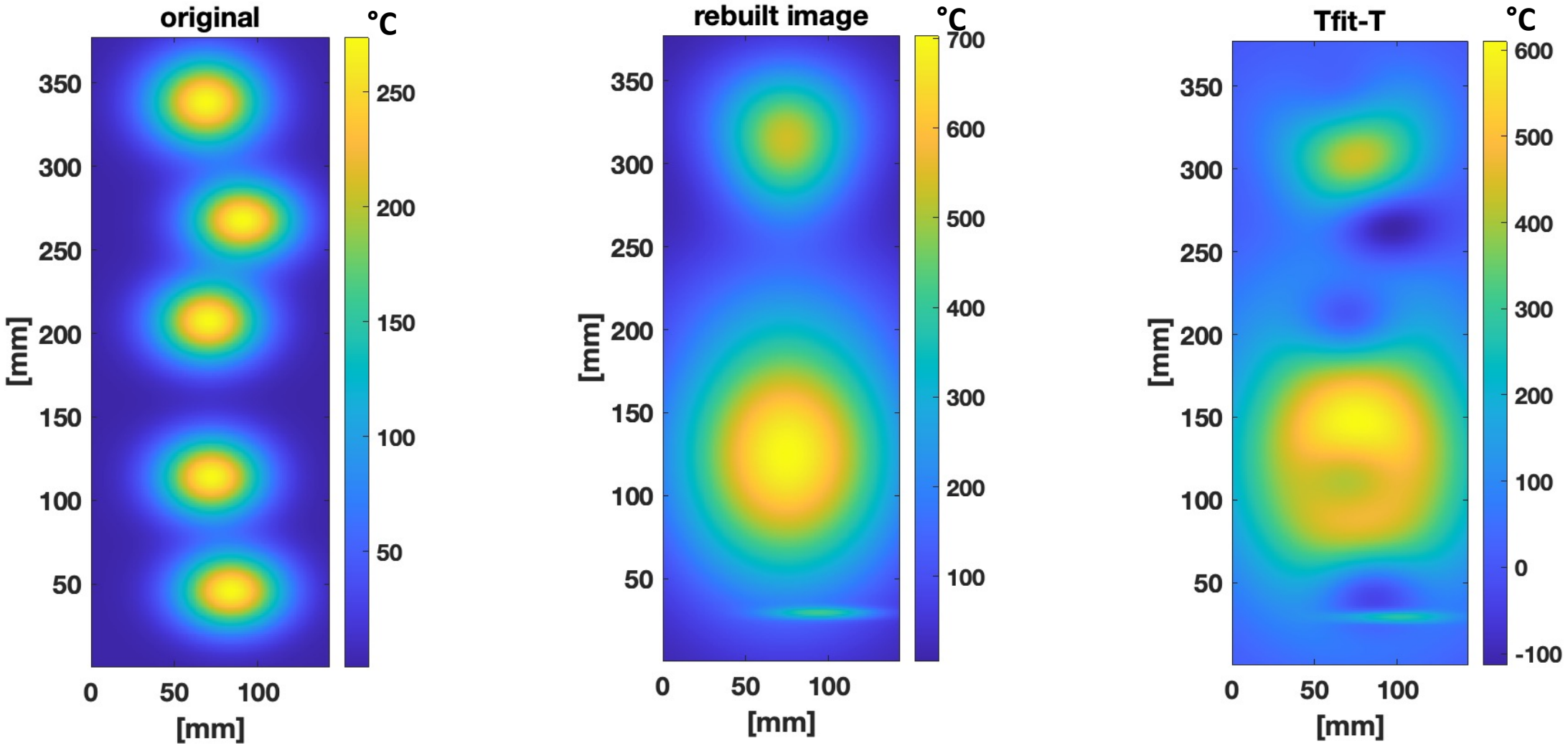
  →y_0=0.0011%

  →σ_x= 0.0103%

  → σ_y= 3.82%

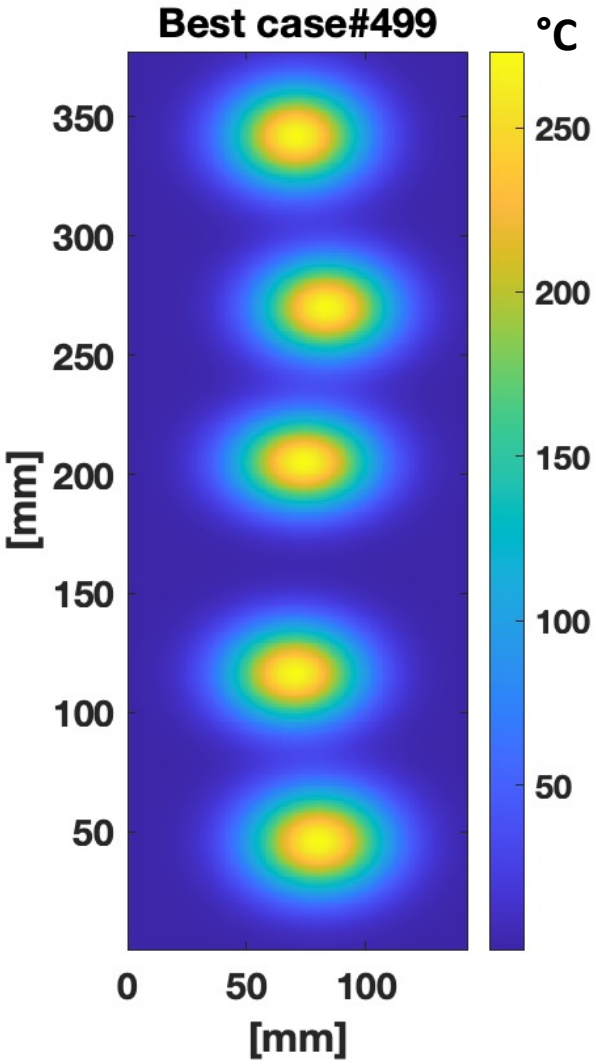
SYNTHETIC DATA

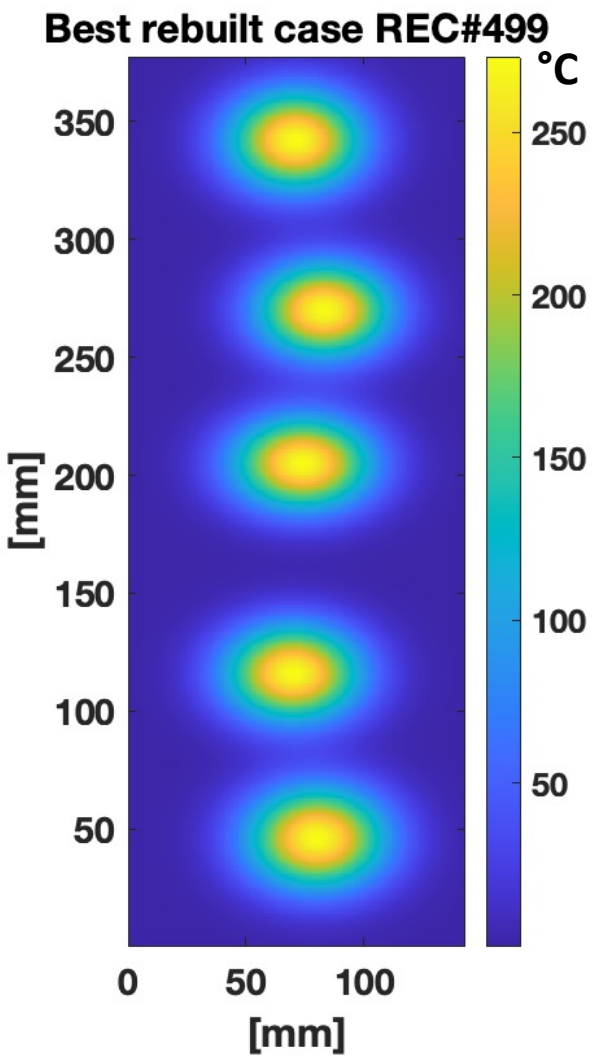
Worst Image: n°546

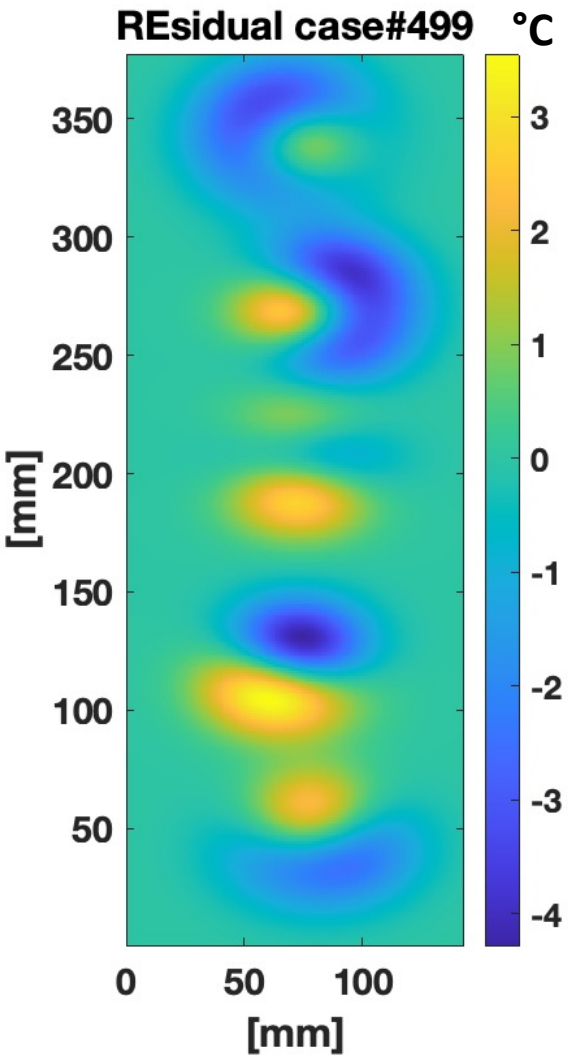


SYNTHETIC DATA

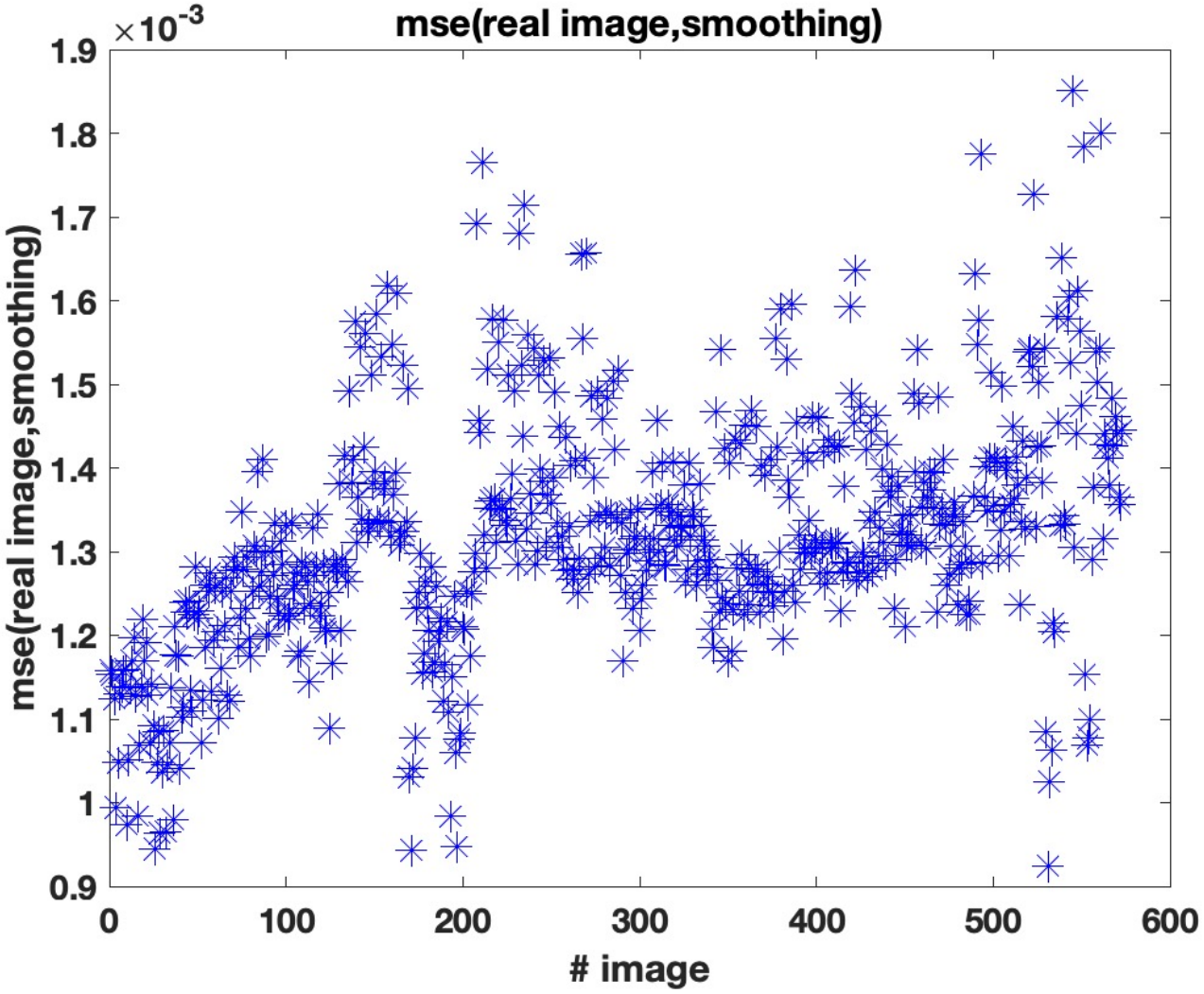
Best Image: n°499







EXPERIMENTAL DATA



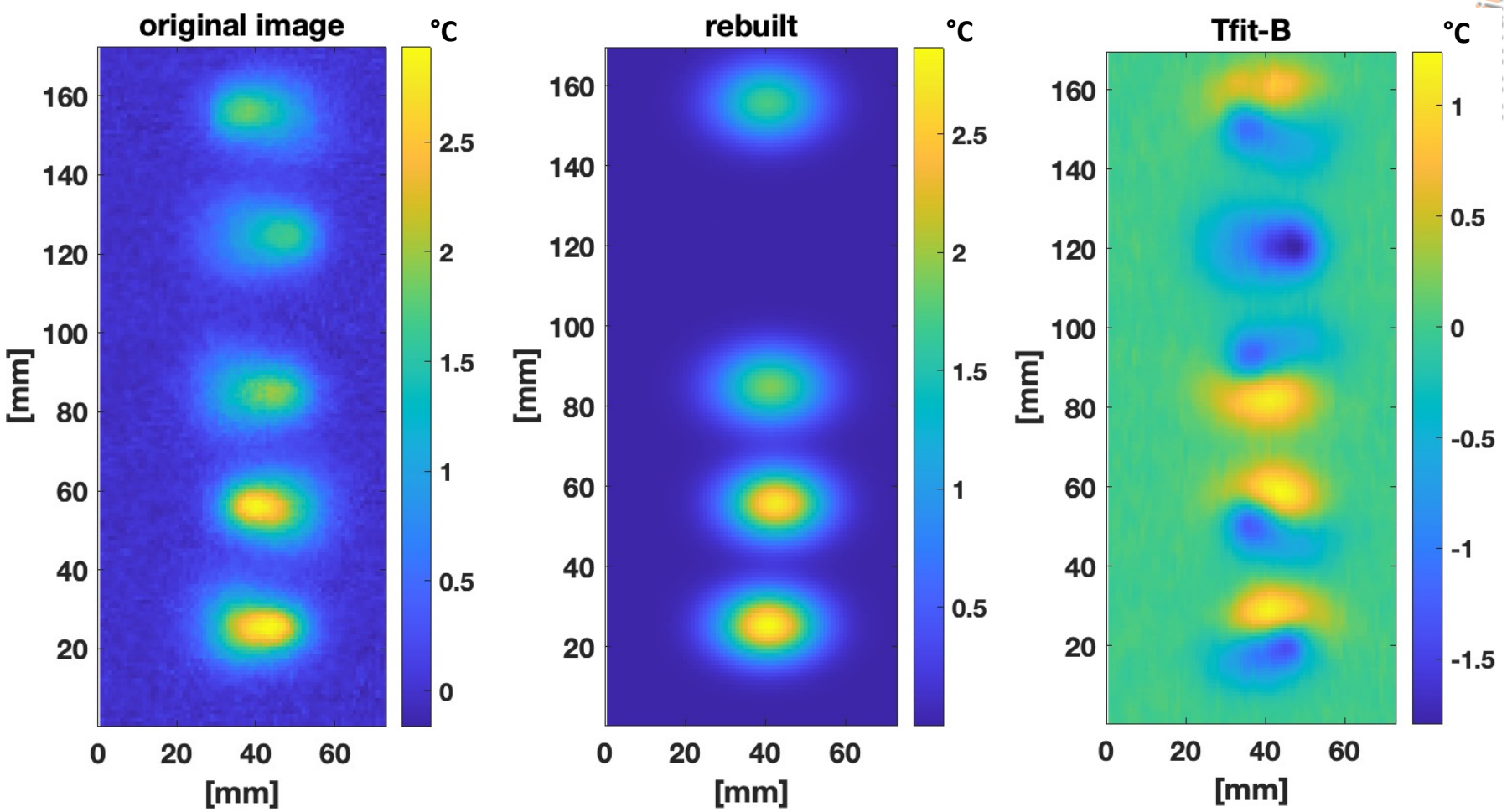
$$MSE = \frac{1}{N}\sum_{N}(RealImage - Smooth)^2$$

MAX Mean Squared Error between real image and smoothing: < 0.002%

EXPERIMENTAL DATA

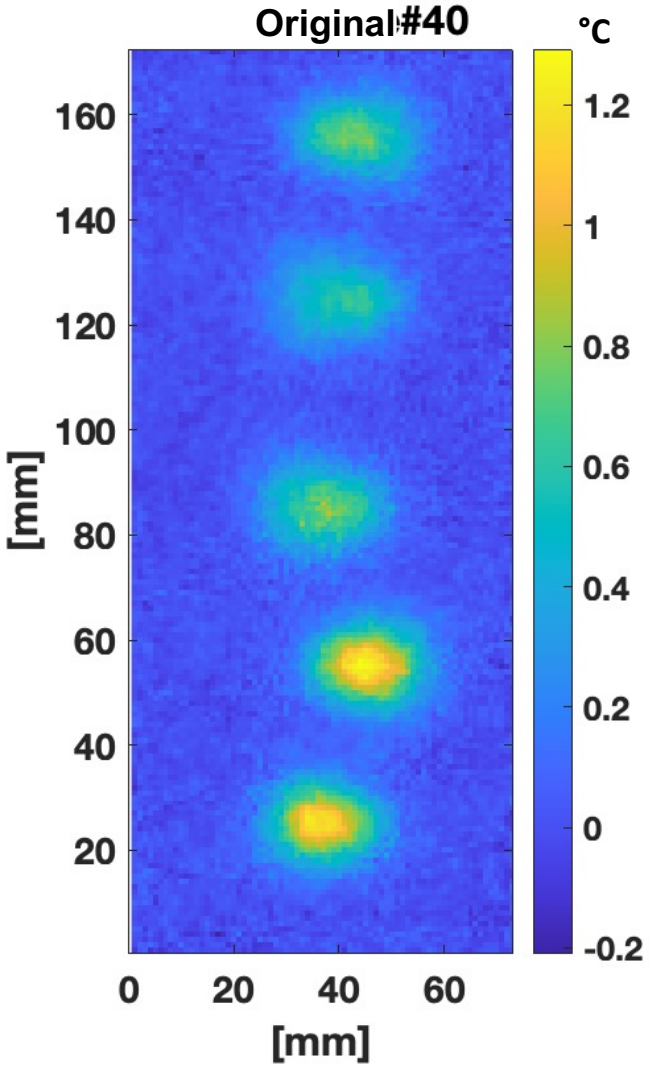
- Esc with mse(T,T*)<1e-3;
- Found optimal α=1,5 for the majority of experimental images;
- Solution didn't converge (NaN): α=0,01;
- Negative Amplitude or sigmas: α=0,01;
- for images n°107 and 293: α=1;
- 3 single images: α= 0,009 for n°89 and 265; α=0,011 for n°435;

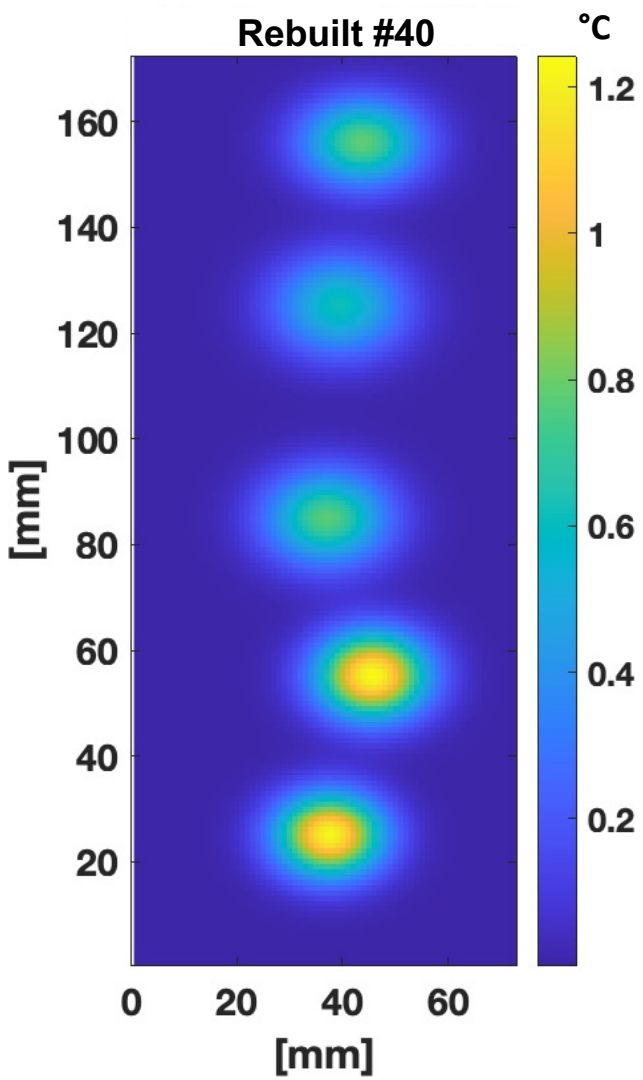
Worst Image: n°565

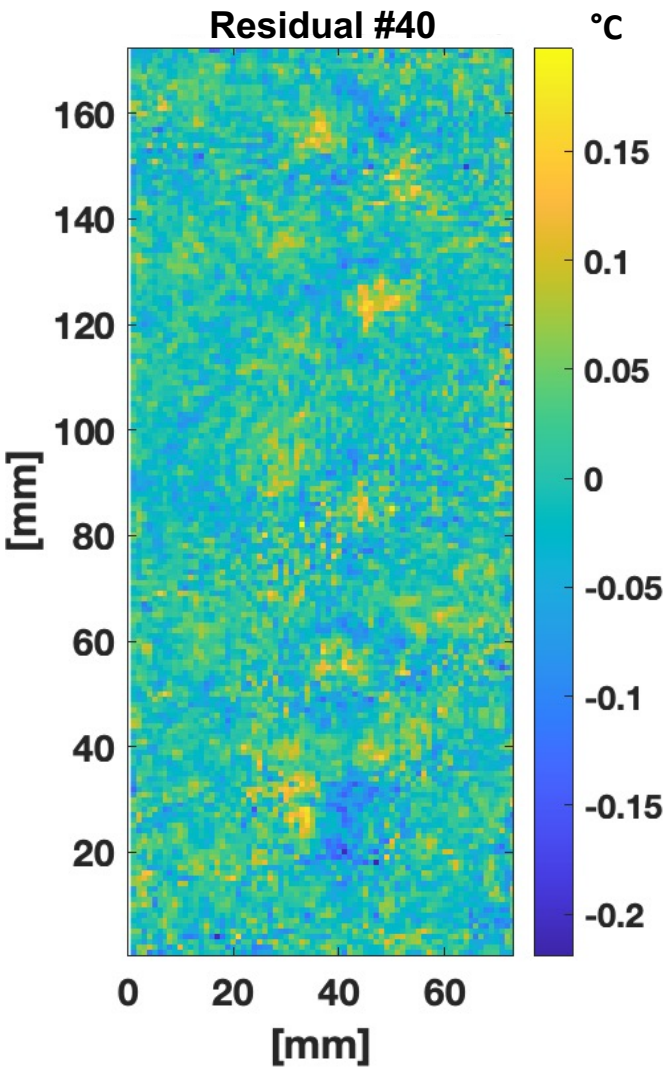


EXPERIMENTAL DATA

Best Image: n°40

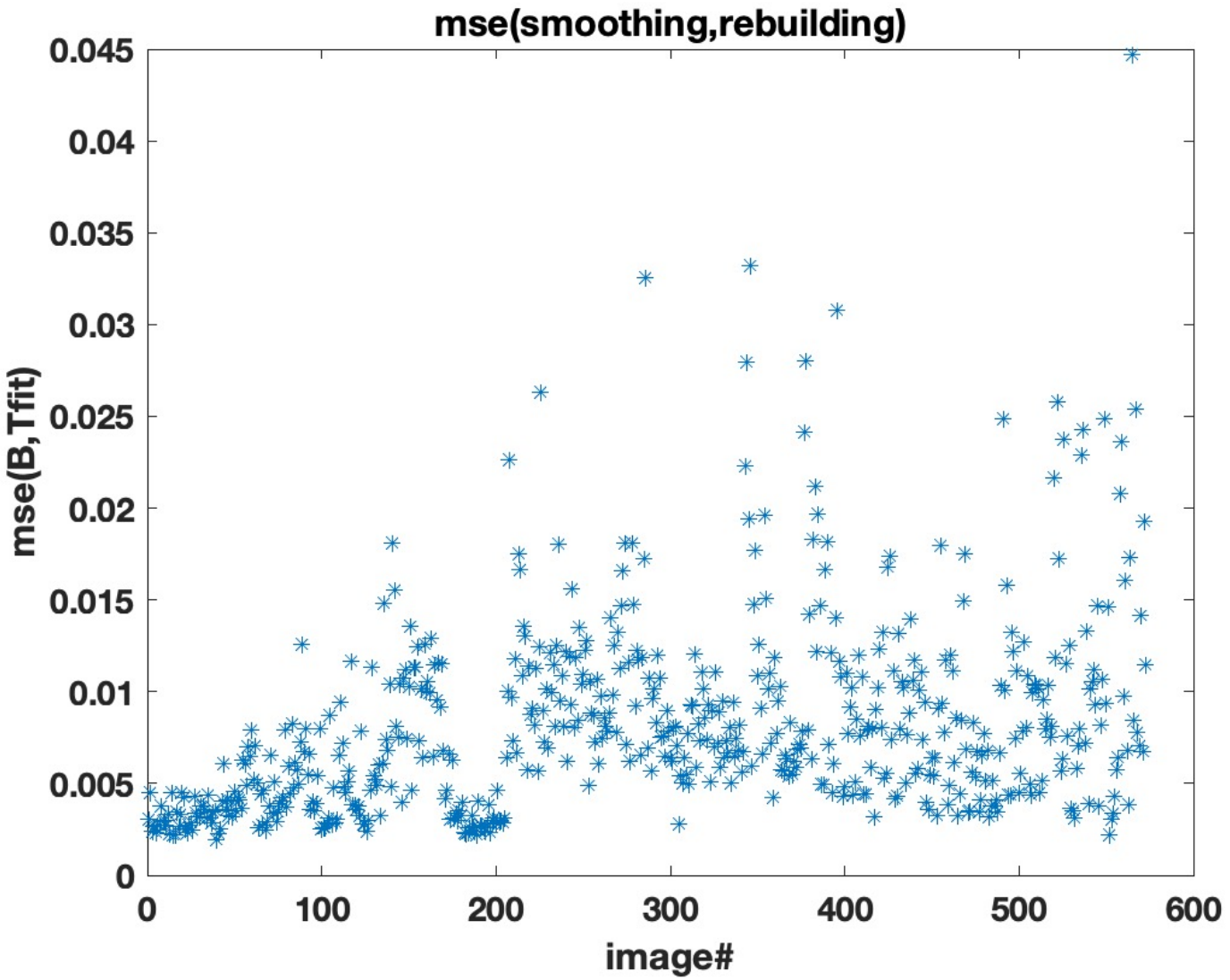






RESULTS – MEAN SQUARED ERROR

Mean Squared Error between RealImage_smooth and RecImage



$$MSE = \frac{1}{N}\sum_{N}(RealImage' - Fit)^2$$

RealImage'= Smooth(Realimage)

CONCLUSIONI

PRONS AND CONS OF NEWOTON'S METHOD:

✓ The regularization of the solution is more precise with this method

- The progress of the intermediate solution should be optimized depending on the context (depending on the type of image)
- It's probable that the advancement variable method is not the most suitable one that fits to our case

x The convergence of the method is very sensitive to the goodness of the initial solution;

FUTURE PERSPECTIVES:

- Tested an even more customizable method, such as the Machine Learning optimization method
- Development and testing of regularization methods of the solution
- Tile test with 80 beamlets (from 25 to 400 parameters)