



Dictionary-based protoacoustic imaging for proton range verification

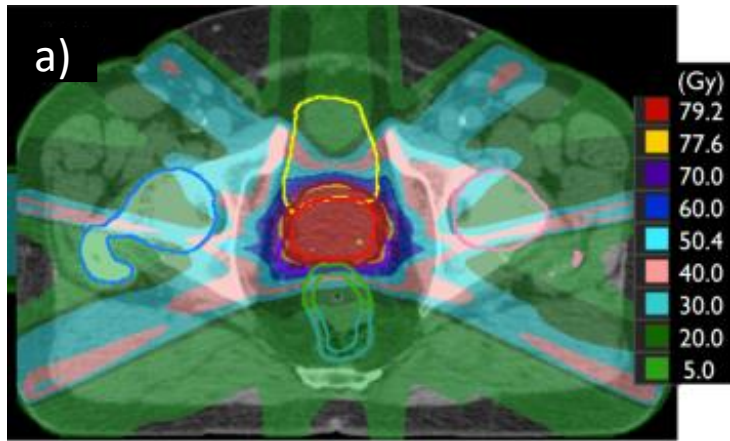
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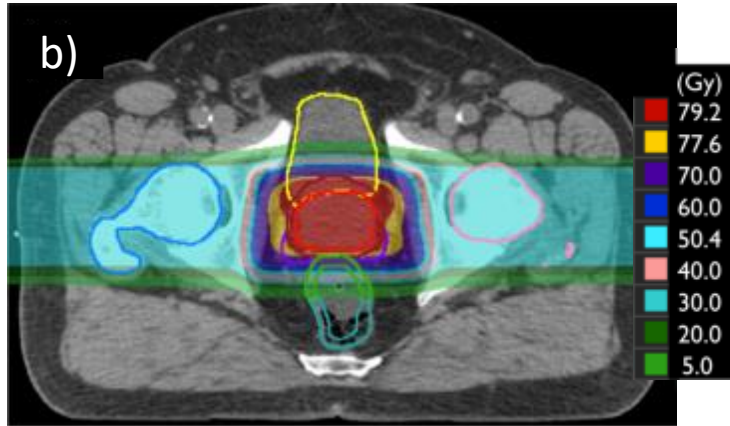
Instituto de Investigación Sanitaria del Hospital Clínico San Carlos (IdISSC)



Protontherapy



Photon Dose Distribution

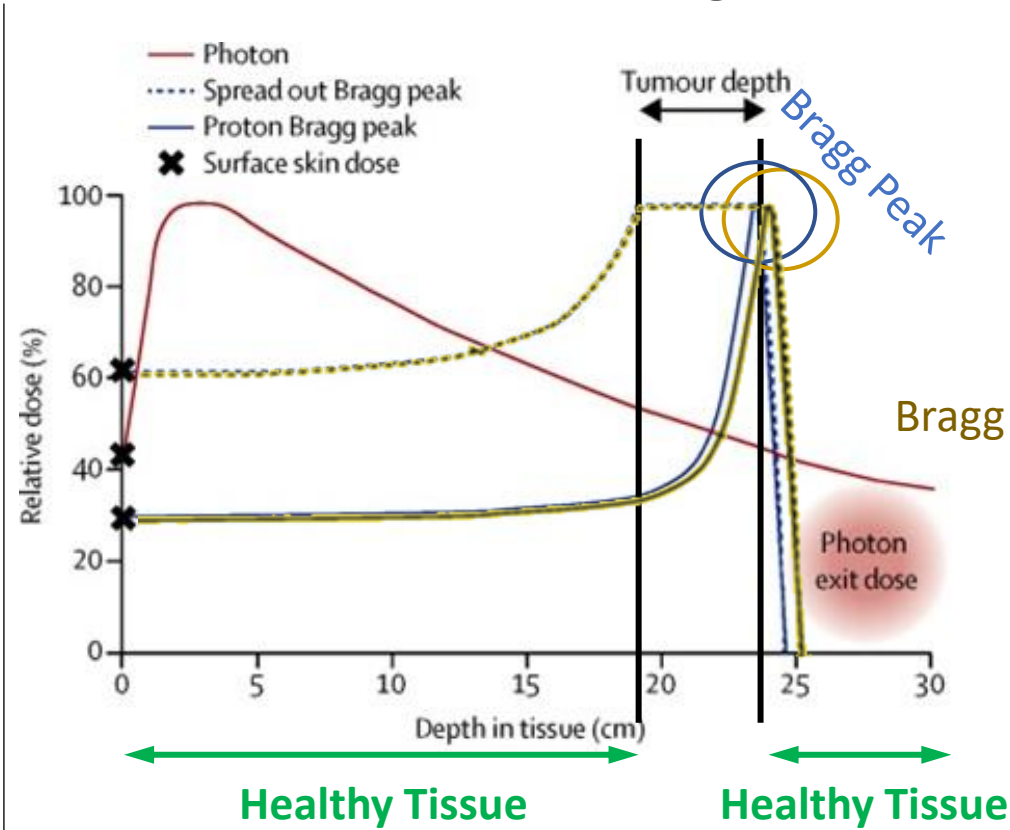


Proton Dose Distribution

Benefits:

- More conformal dose distribution
- Lower dose in healthy tissue

Problem: Proton Range Uncertainty



ERROR

Bragg Peak in Healthy Tissue

**Solution:
Proton Range
Verification**

In Vivo Proton Range Verification Techniques

- **Nuclear activation techniques: PET and prompt gamma imaging** → Measurement of secondary photons

- Alternative technique: **Protoacoustics**

Radio-induced Thermoacoustic Effect



Advantages

- Less bulky equipment
- More cost-effective

Disadvantages

High computational cost of image reconstruction

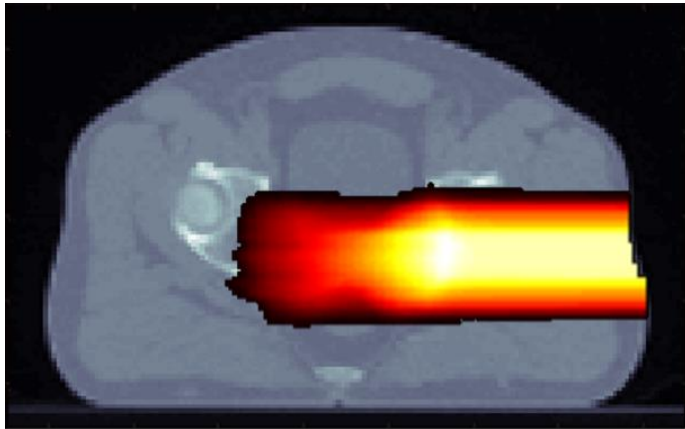


Make difficult the *in vivo* implementation

Novel Approach: Protoacoustic Dictionary

Workflow for Dictionary Construction

Treatment Plan



- Thousands of pencil beams
- Personalized for each patient
- Available at least one day before the treatment session

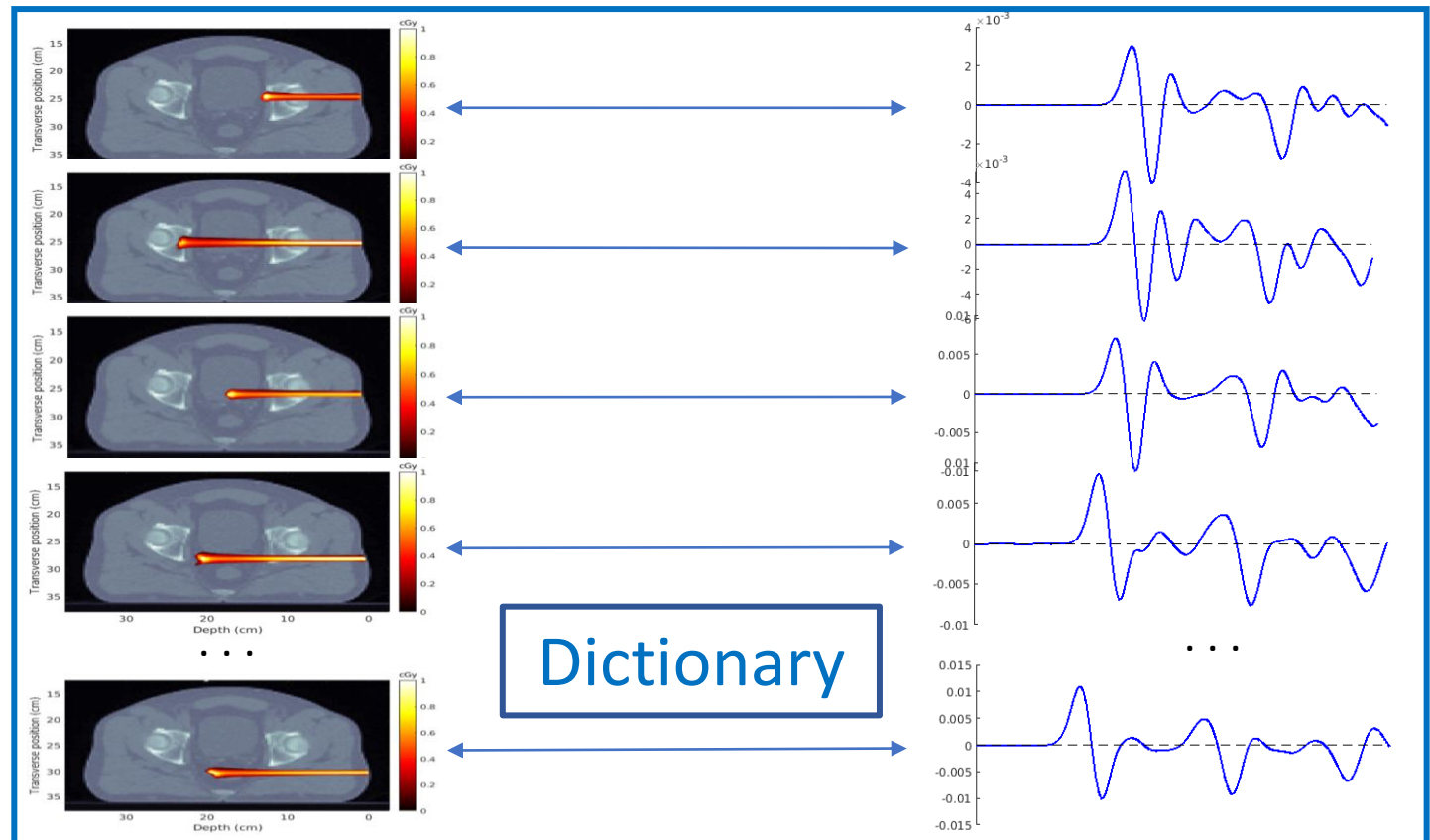
A priori Information

- Energy and pencil beam position
- Density
- Speed of sound

Acoustic Simulation

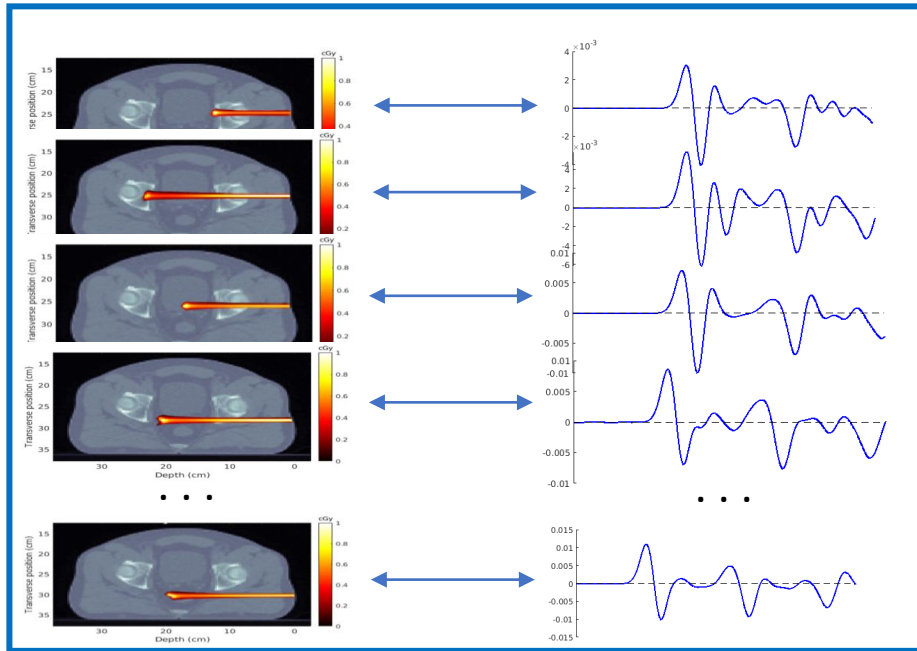


<http://www.k-wave.org/>



Dictionary-based Proton Range Verification

Pre-Computation

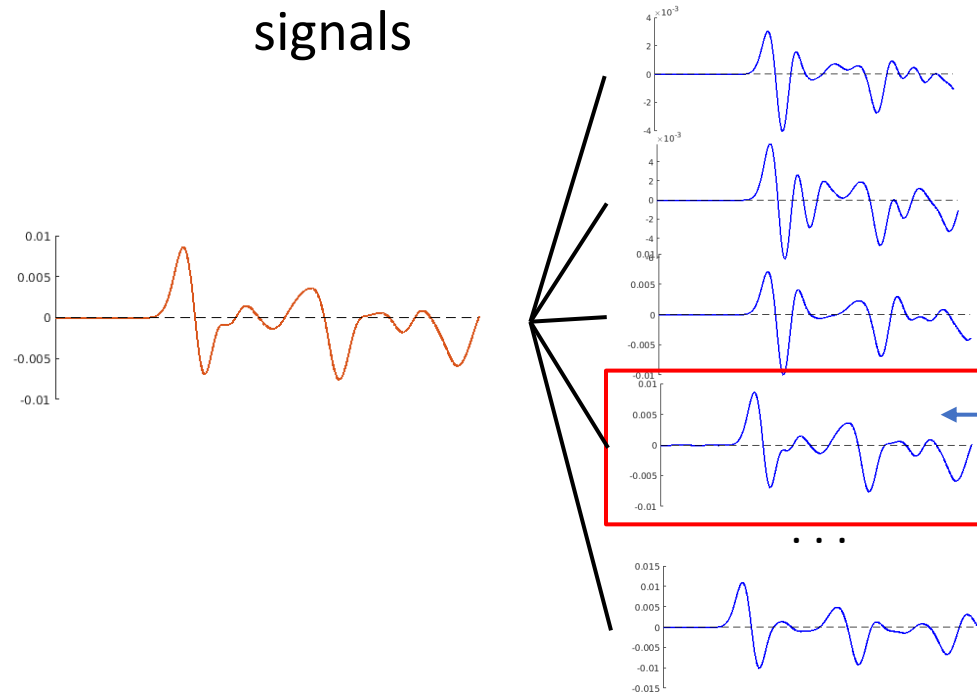


Individualized Dictionary

500 pencil beams ~ 100 min

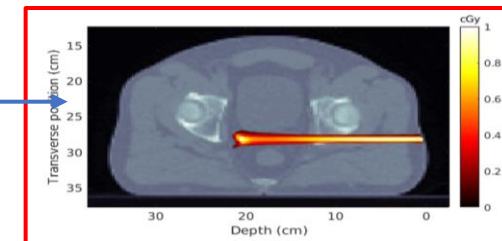
Real Time

Similarity
Measured vs Dictionary
signals



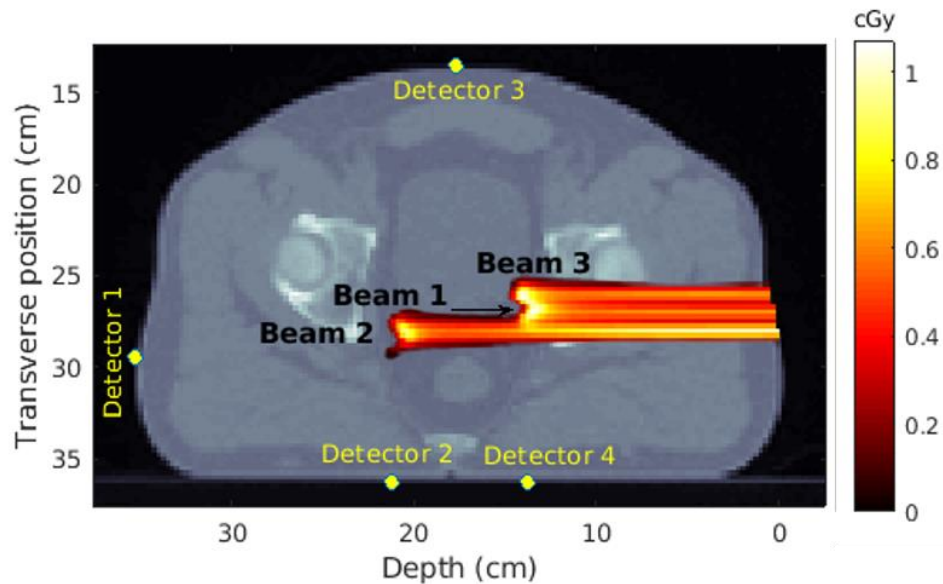
In-house developed
algorithm based on
L1 norm (100 ms)

Most probable
Bragg peak (BP)
position



Application: Detection of Deviations from Protontherapy Plan. SETUP

Simulation Setup

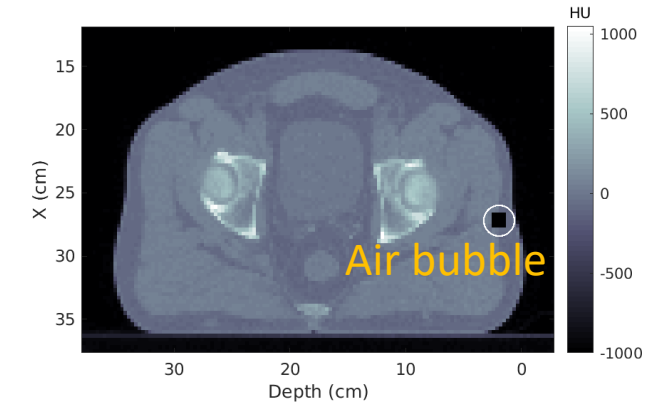


- Treatment plan for **prostate** tumor
- **4** ideal **detectors**
- Dictionary for axial **central slice**
- **GPU** k-Wave simulation (~ 90 min in NVIDIA GeForce RTX 2080)
- **Noise** added

Robustness Evaluation

Changes from the original plan:

1. Air bubble
2. Weight gain
3. 1 mm Shift in patient position
4. 3.5 % error in HU to relative stopping power conversion

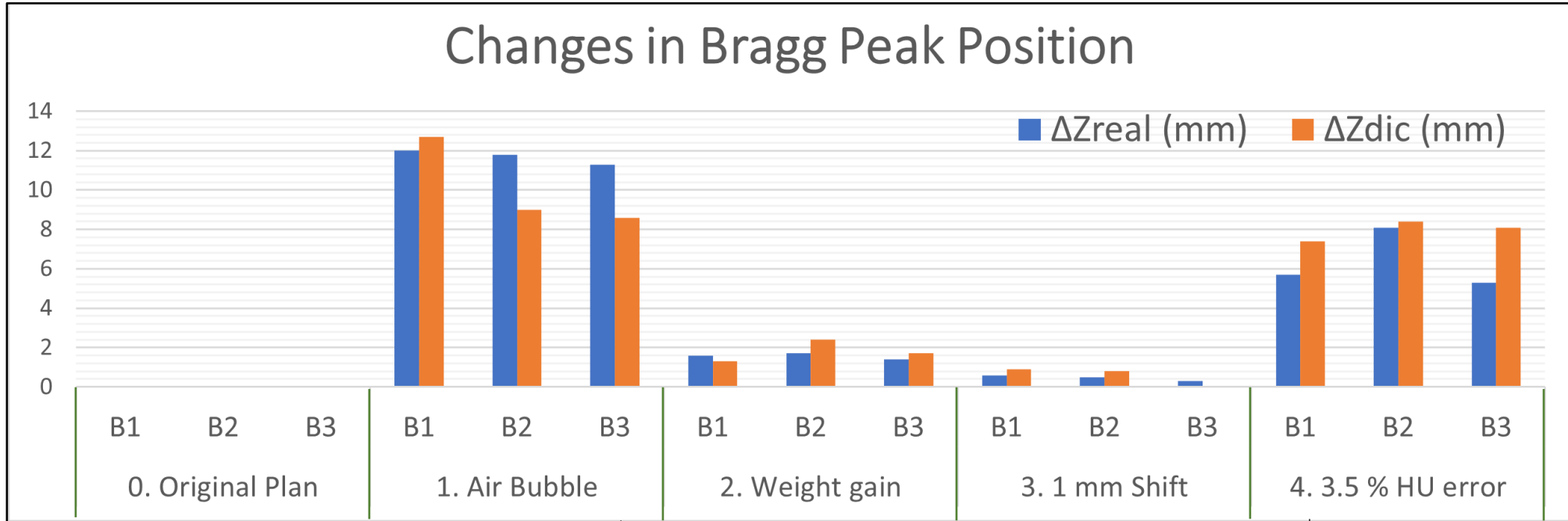


ΔZ_{real} Real change in BP position

VS

ΔZ_{dic} Change detected in BP position

Application: Detection of Deviations from Protontherapy Plan. RESULTS



Biggest changes caused by **air bubble** and **HU** conversion error

The **dictionary** method **detects** the **deviations** in all cases

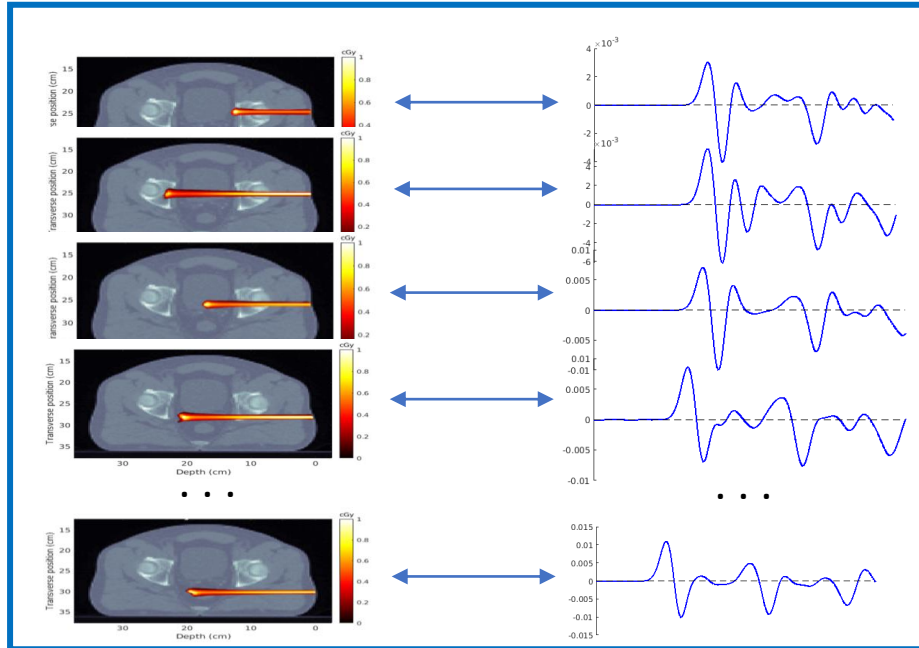


It could **alert** of **errors**

1.1 mm Average Accuracy (<0.7 %)

Conclusions & Next Steps

- Novel approach for proton range verification based on a protoacoustic dictionary.
- A proof-of-concept study demonstrated the feasibility of implementation of the proposed method.
- Experimental measurements would be useful to improve the simulation.
- Experiments in proton facilities to test the method in a real scenario.
- Paper sent to *Photoacoustics Journal*: *Dictionary-based protoacoustic imaging for proton range verification*. PACS-D-20-00082R1, submitted.



Thank you!

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Sociedad
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