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Automated Proton Treatment Planning and Beam Angle Selection Using Bayesian Optimization

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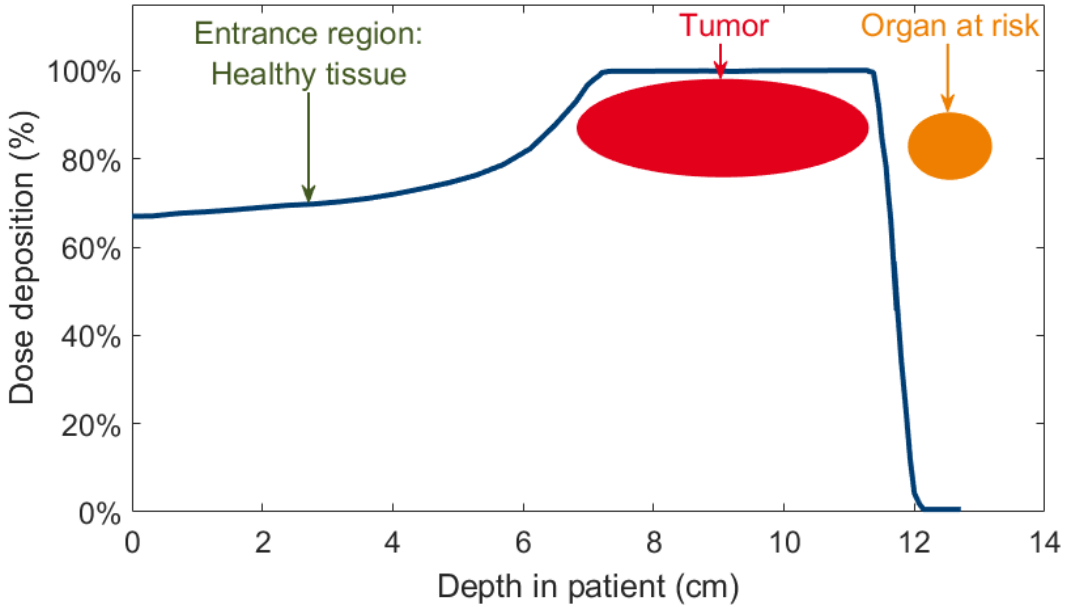
Motivation

- Beam angle optimization is important in proton therapy
- Non-convex problem
- Solution:

  Bayesian optimization



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Bayesian optimization

- Does **not** need a function expression for the objective function to be minimized
- Only few function evaluations needed to find minimum → reduced time consumption

Input:
Few initial function evaluations →

→ **Output:**
Best estimate of function minimum

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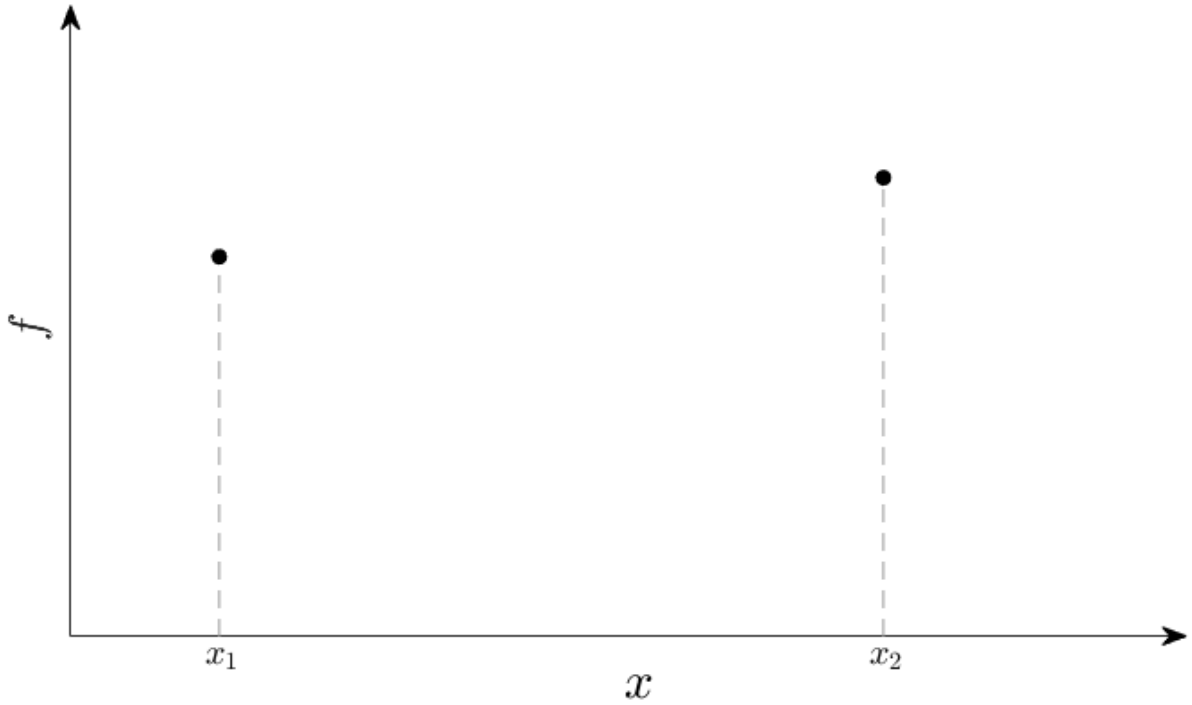
Bayesian optimization



Evaluated points

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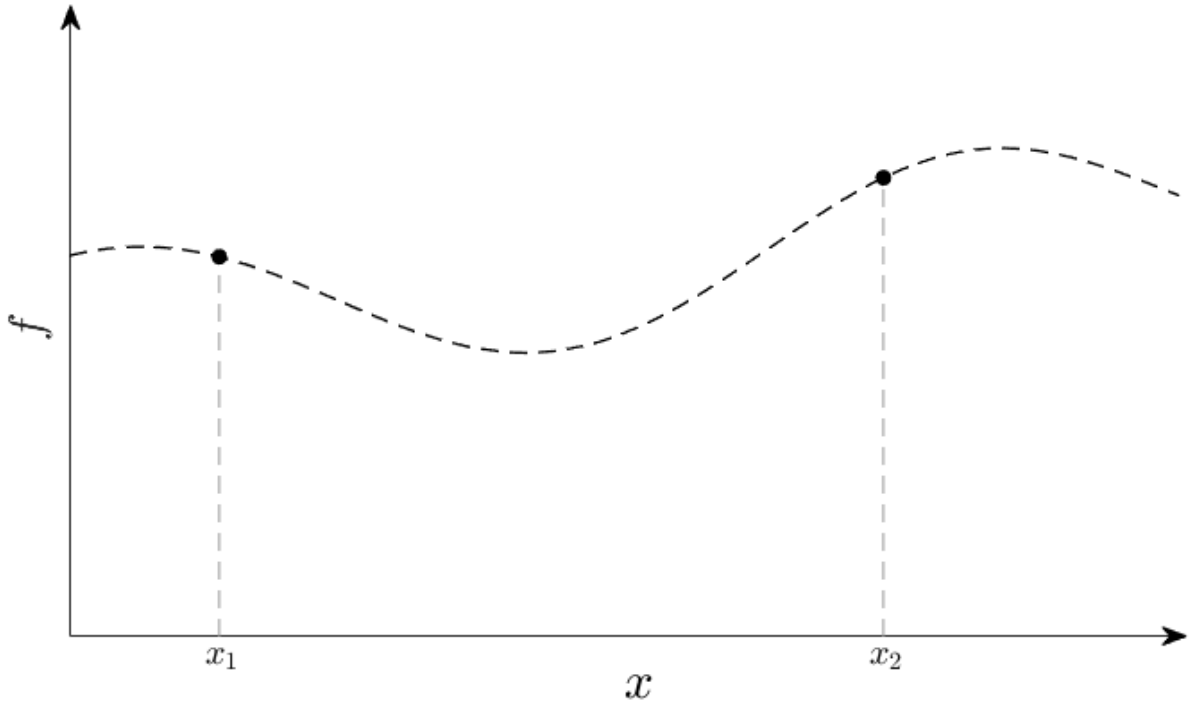
Bayesian optimization



Evaluated points

True (unknown) objective function

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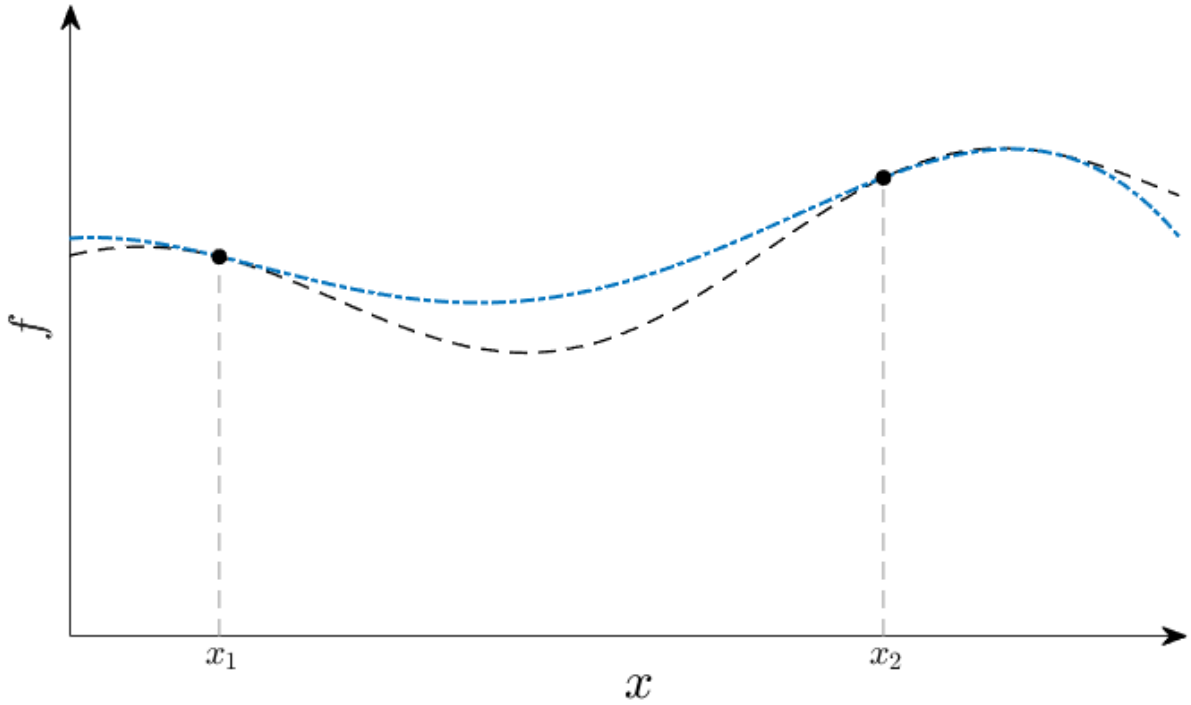
Bayesian optimization



Evaluated points

True (unknown) objective function

Estimated objective function

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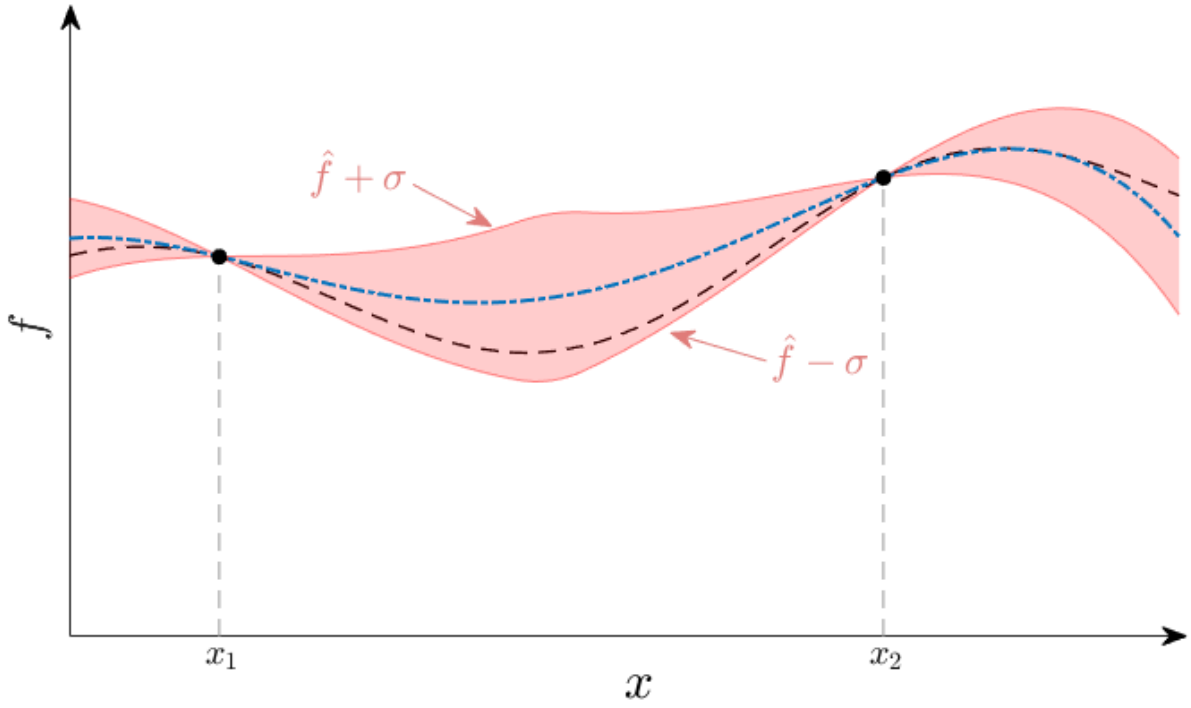
Bayesian optimization



Evaluated points
True (unknown) objective function
Estimated objective function
Uncertainty band

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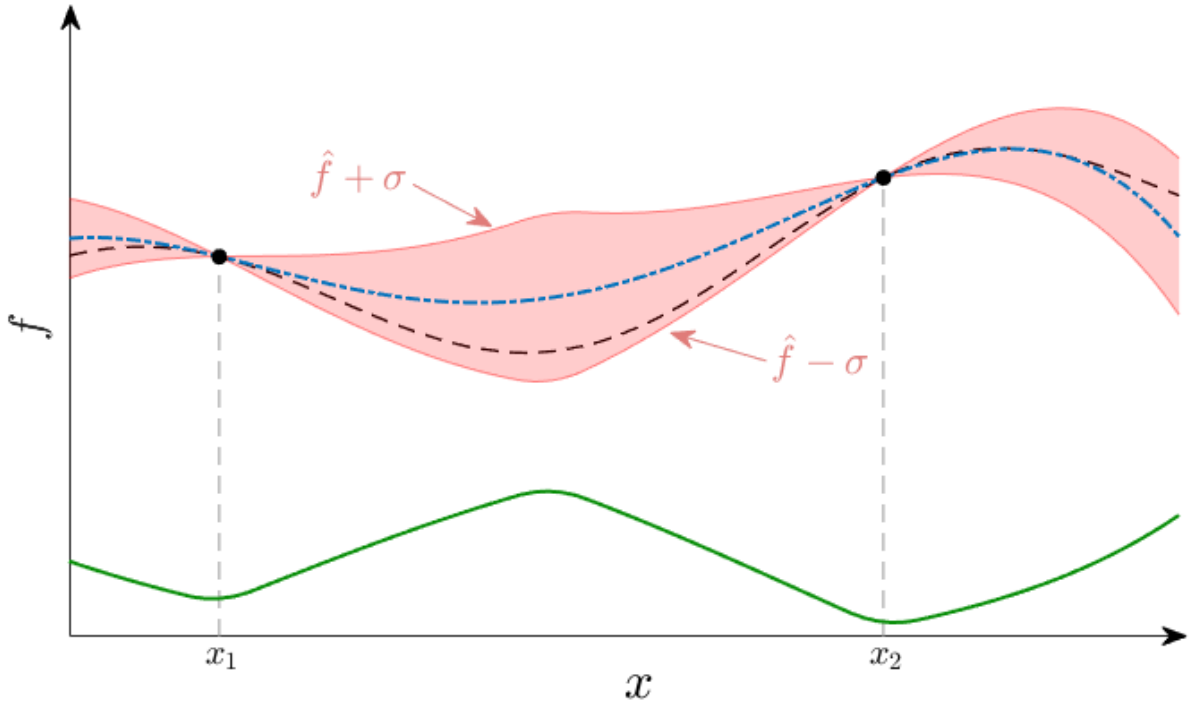
Bayesian optimization



- Evaluated points
- True (unknown) objective function
- Estimated objective function
- Uncertainty band
- Acquisition function

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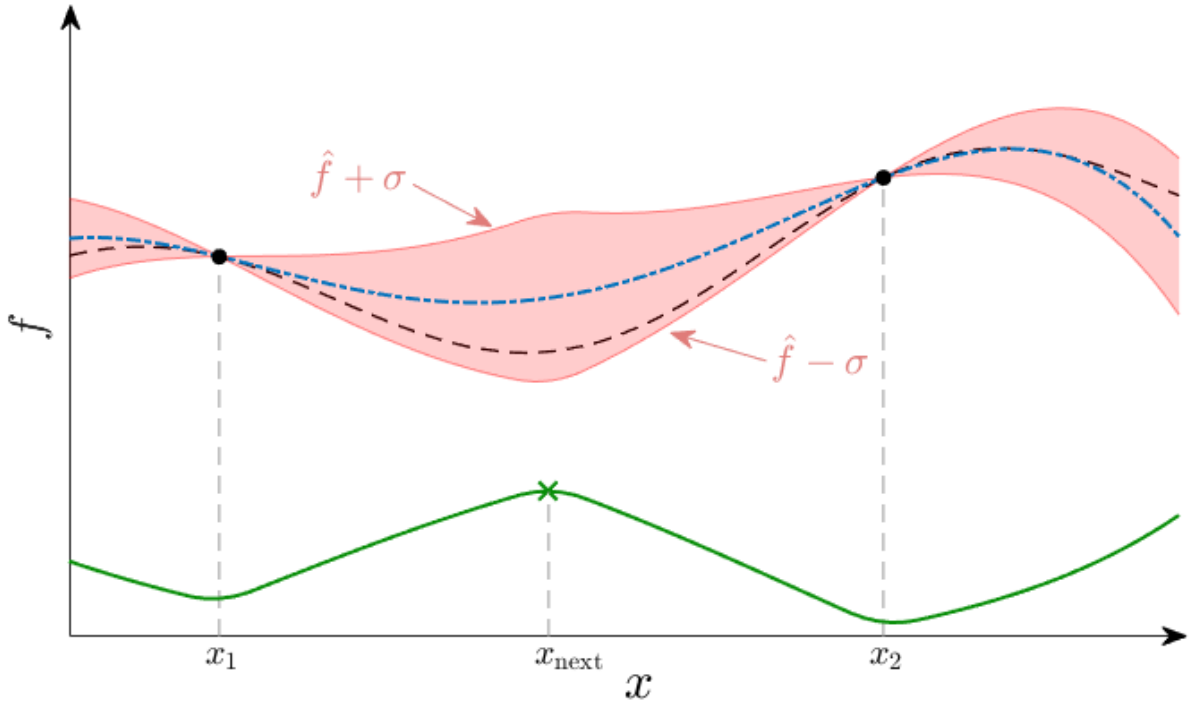
Bayesian optimization



- Evaluated points
- True (unknown) objective function
- Estimated objective function
- Uncertainty band
- Acquisition function
- Maximum of acquisition function

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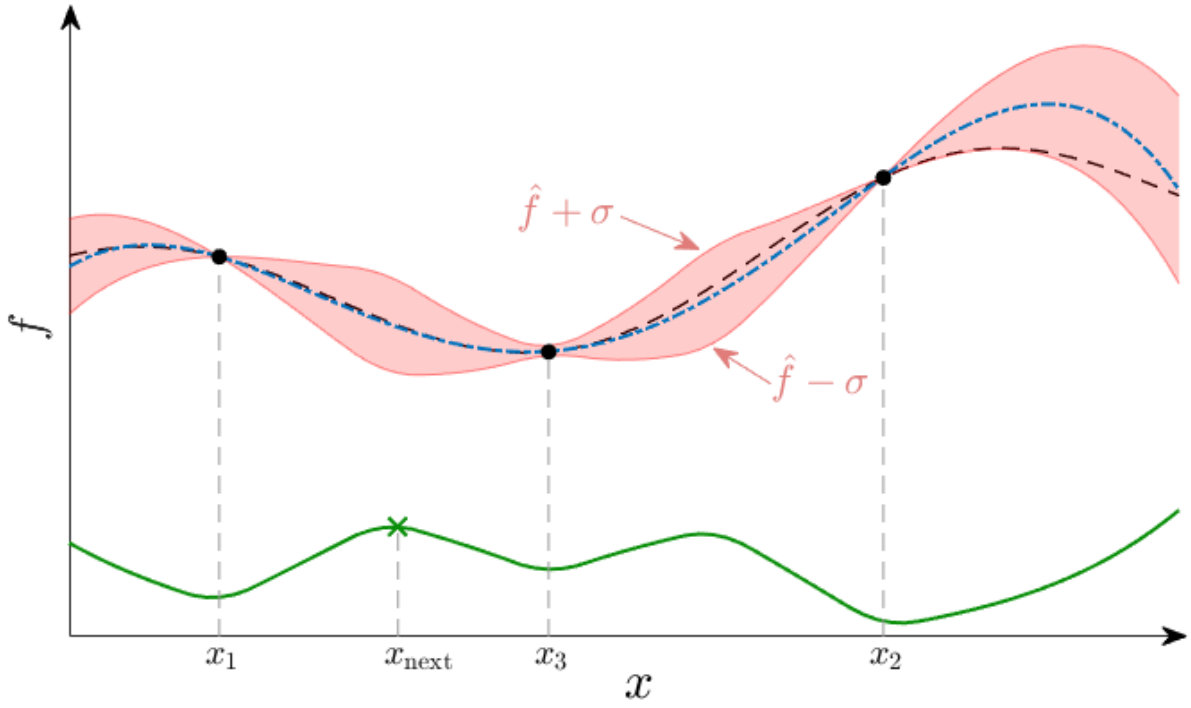
Bayesian optimization



- Evaluated points
- True (unknown) objective function
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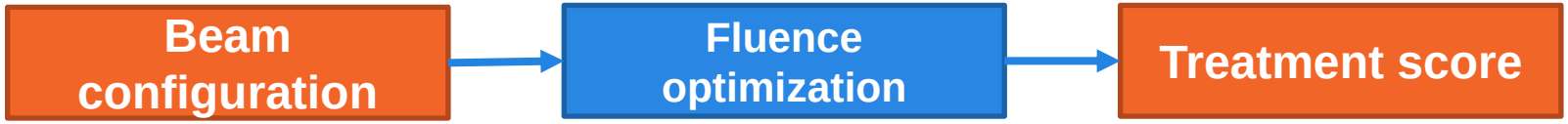
Beam angle optimization



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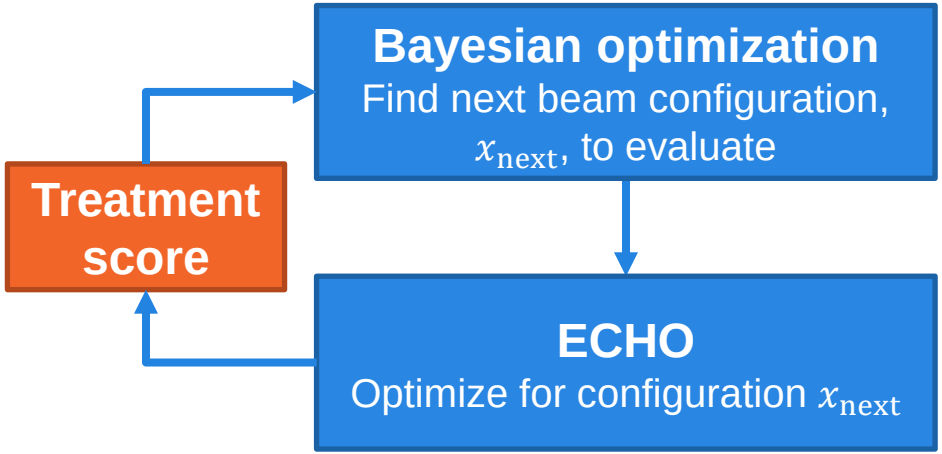
Beam angle optimization

- Automated fluence optimizer: **E**xpedited **C**onstrained **H**ierarchical **O**ptimization (**ECHO**)[1]
- Bayesian optimization
- Treatment score function
  - Dosimetric indices



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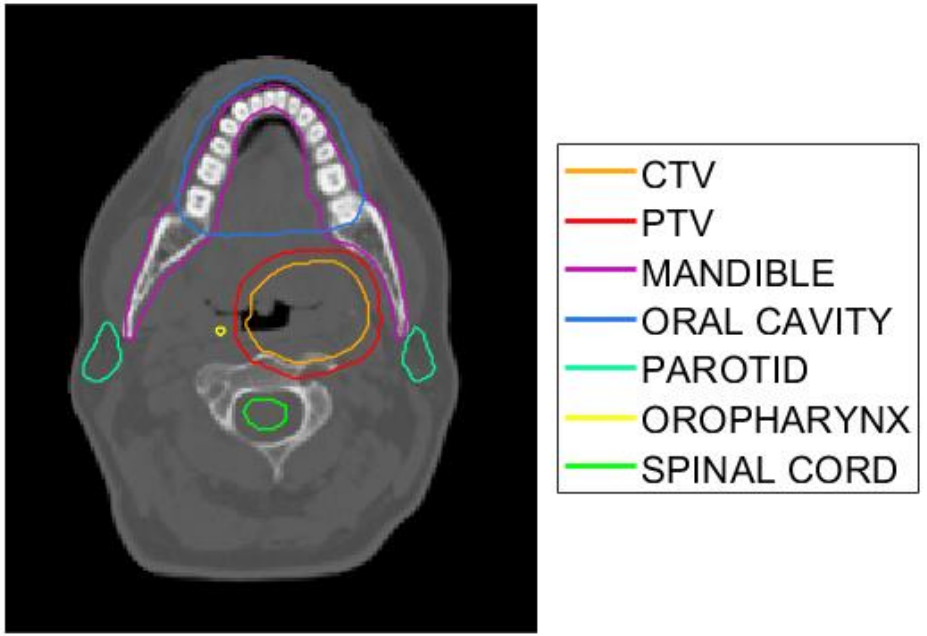
[1] Zarepisheh *et al.*, Med Phys (2019)

Materials and methods

- Five head and neck patients
- Two co-planar beams
  - 558 beam configuration candidates
- Ground truth configuration (lowest treatment score)
- Manual beam configuration selection



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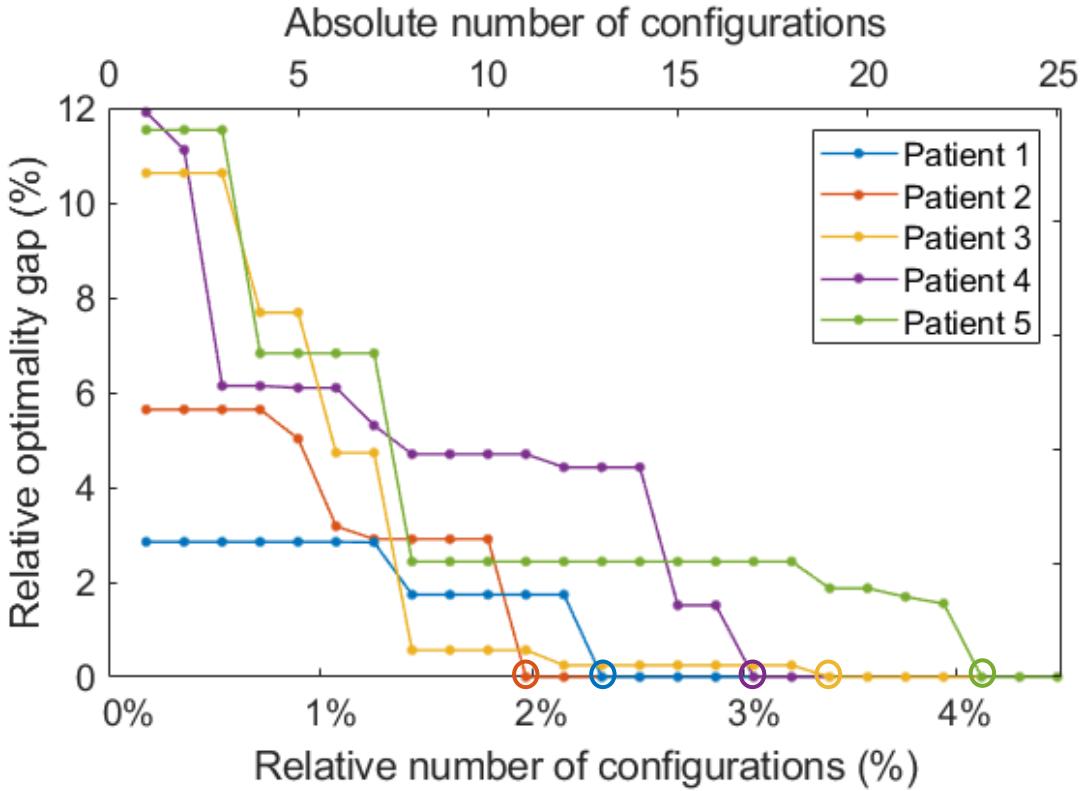
Results – Convergence



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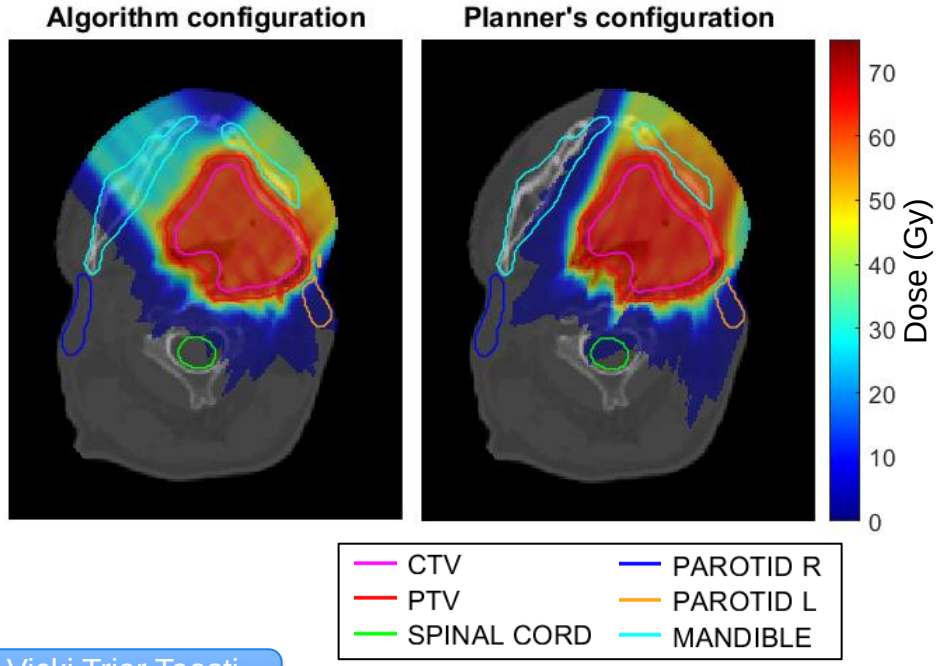
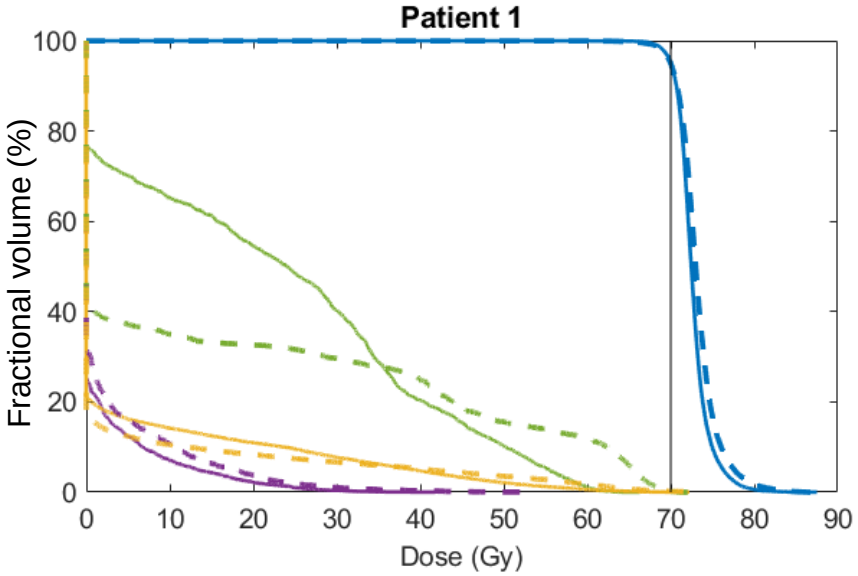
Results – Dose distribution

Beam configurations:

(40°,320°) (20°,60°)





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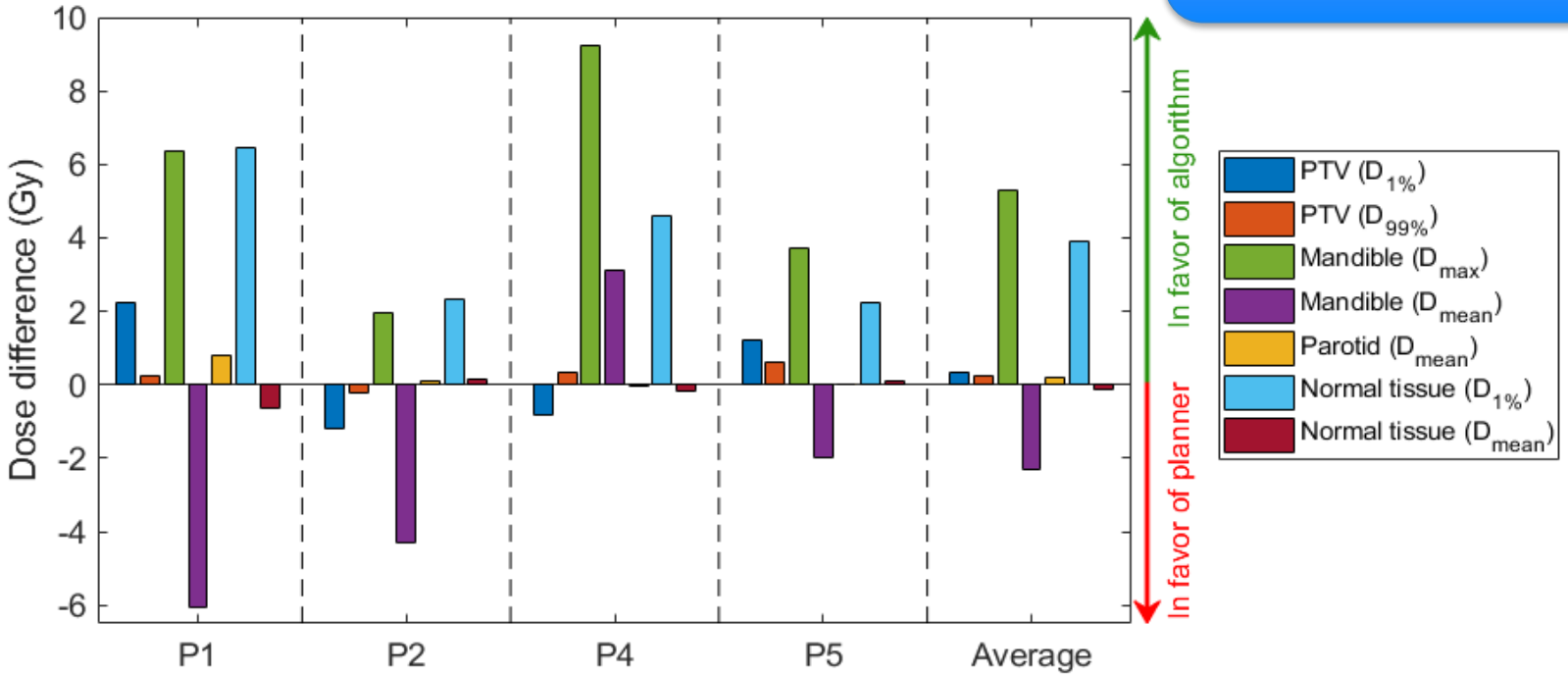
Results - Dosimetric indices

Aim: To automate the treatment plan process



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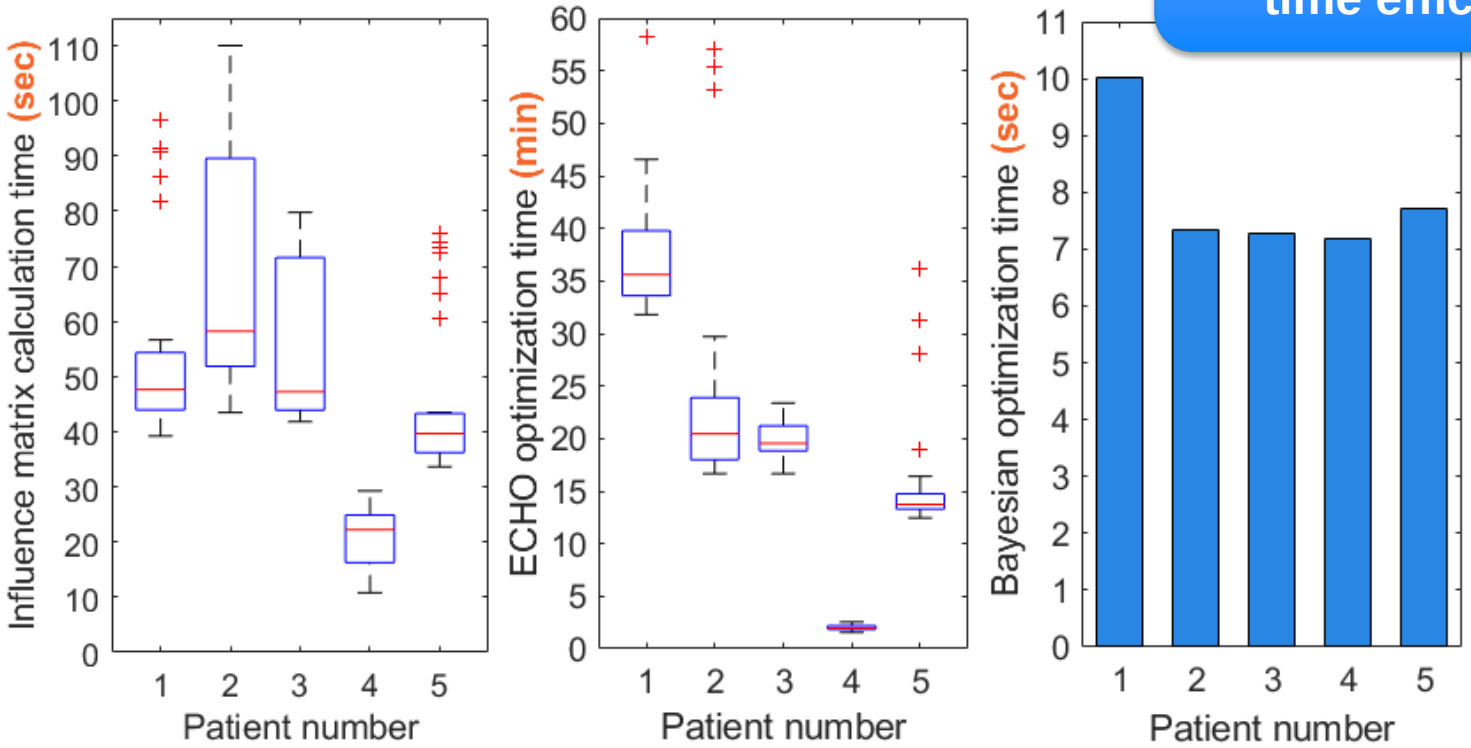
Results - Timing

Bayesian optimization is very time efficient!



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Summary

- Beam angle optimization for proton therapy
- Bayesian optimization
  - At most 4% of the configuration needed to be evaluated
  - Time efficient
- Flexible framework
  - Any metric can be included
  - Any fluence optimizer can be used
    - ✓ Constrained optimization
- **Future:** Include robustness

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Thank you very much for your attention

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