# Distributed and Scalable Optimization for Robust Proton Treatment Planning

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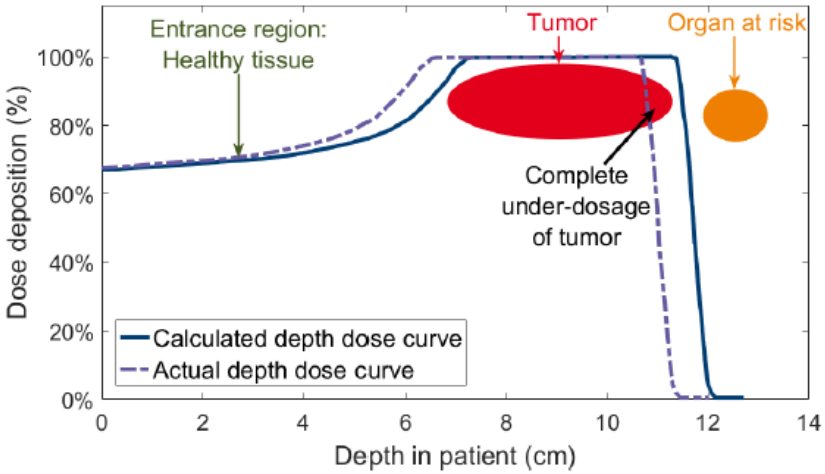
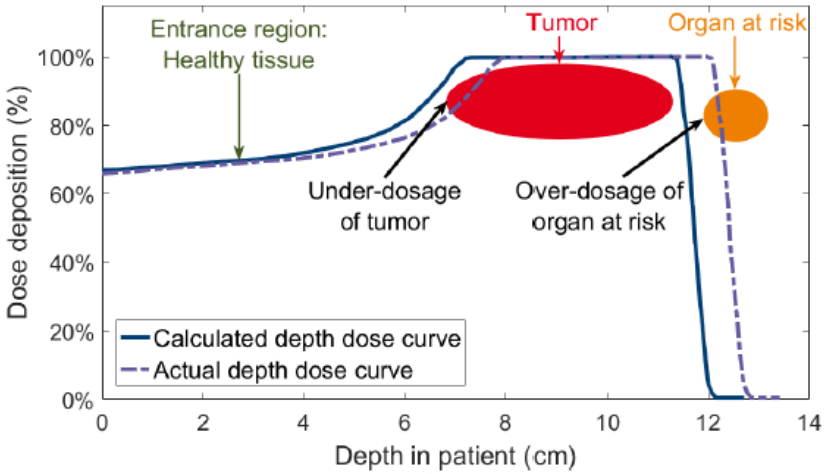
AAPM Annual Meeting
July 10–14, 2022

# Robust Proton Therapy



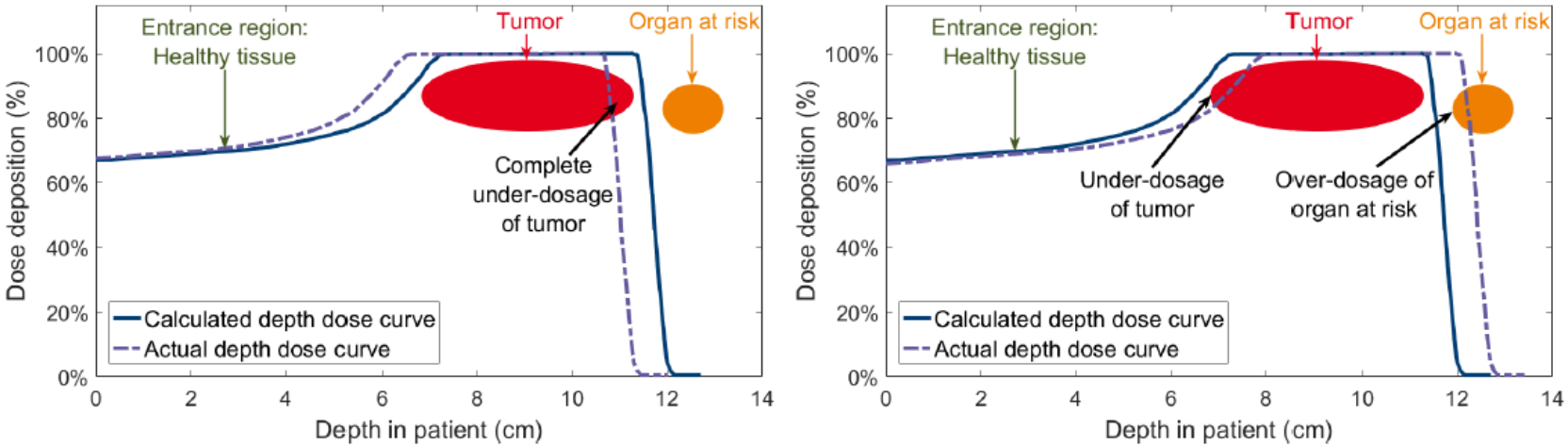

**(a)** Range over-estimation




**(b)** Range under-estimation

- Proton plans susceptible to uncertainties

# Robust Proton Therapy




- Proton plans susceptible to uncertainties
- Robust optimization desensitizes the plans to uncertainties
- Main steps:
  1. Identify errors/uncertainties
  2. Simulate dose distribution in each uncertainty scenario
  3. Optimize for all possible scenarios

# Motivation

- Downsides:
  1. Computationally expensive and slow
  2. Problem size grows as number of scenarios increases
  3. Less parameter tuning $\Rightarrow$ potential plan sub-optimality

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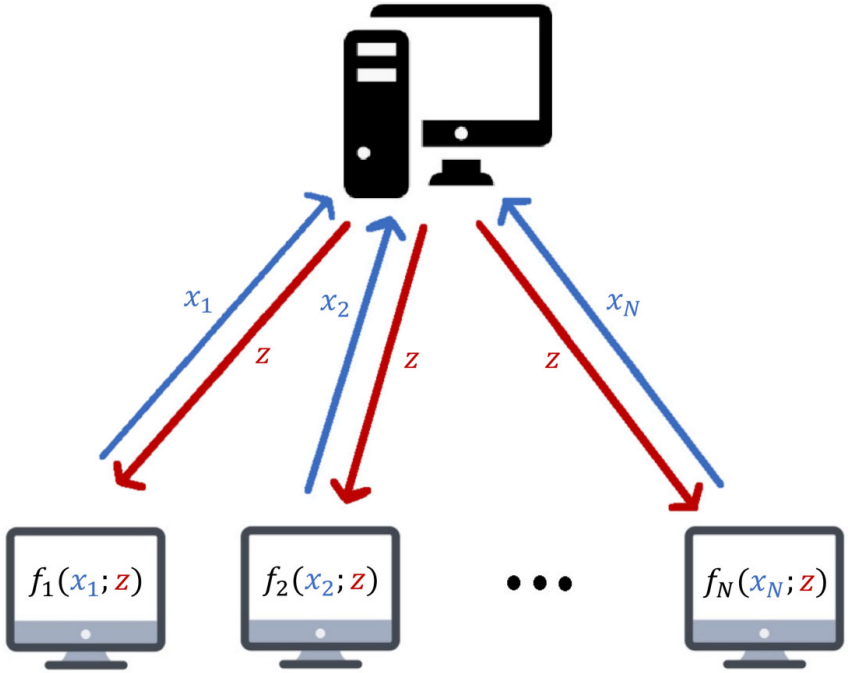
- Solution: fast and scalable **distributed optimization**

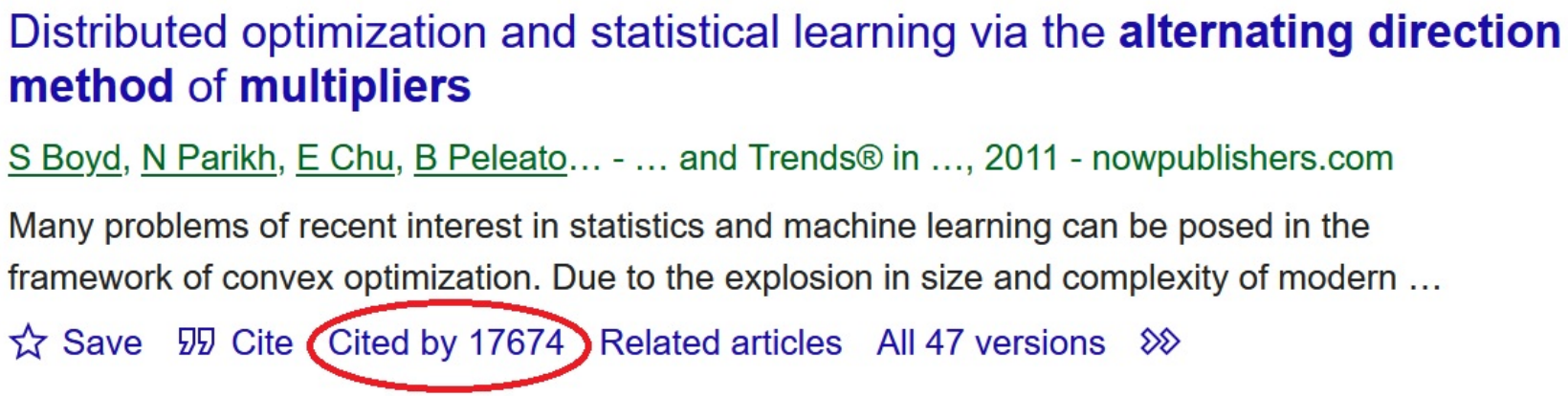
# Distributed Optimization




- Multiple agents collaborate to solve optimization problem
- Each agent handles part of the problem
- Fast, memory efficient, scales well with size of data

# Alternating Direction Method of Multipliers (ADMM)

- Distributed optimization method dating back to 1970's
- Recently gained attention in machine learning & data science



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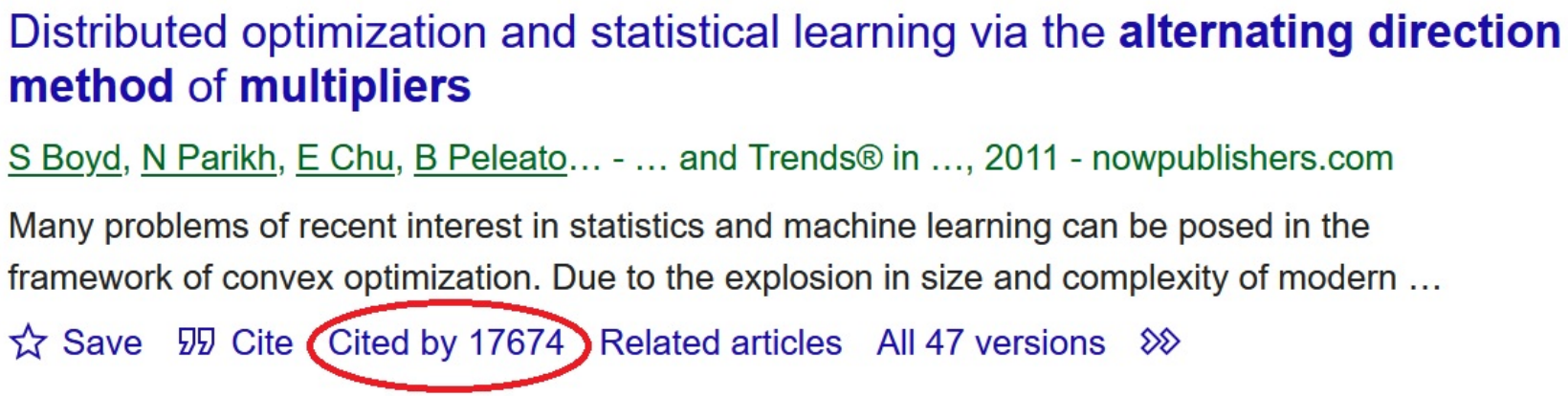
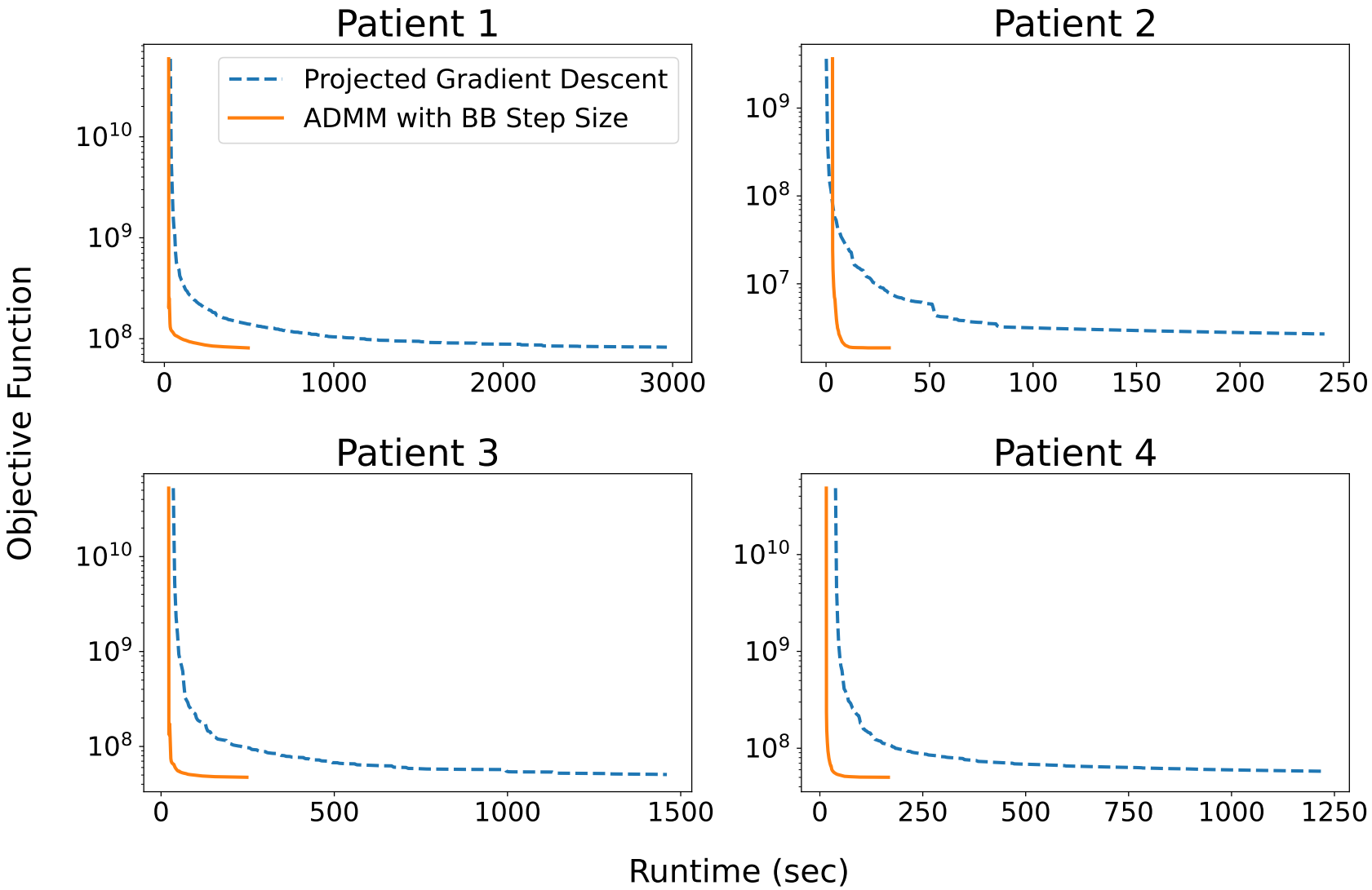
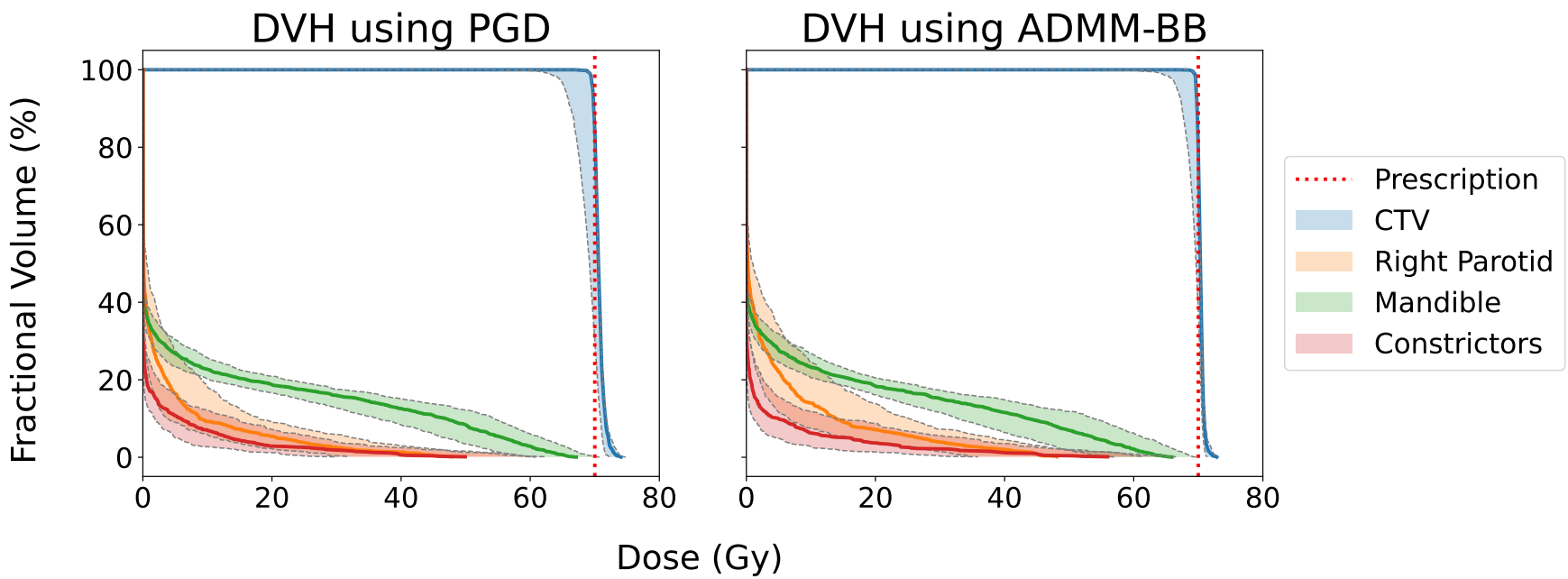



- **Key points**:
  - Split the problem into simpler subproblems
  - Solve each subproblem with a separate agent (CPU, GPU)

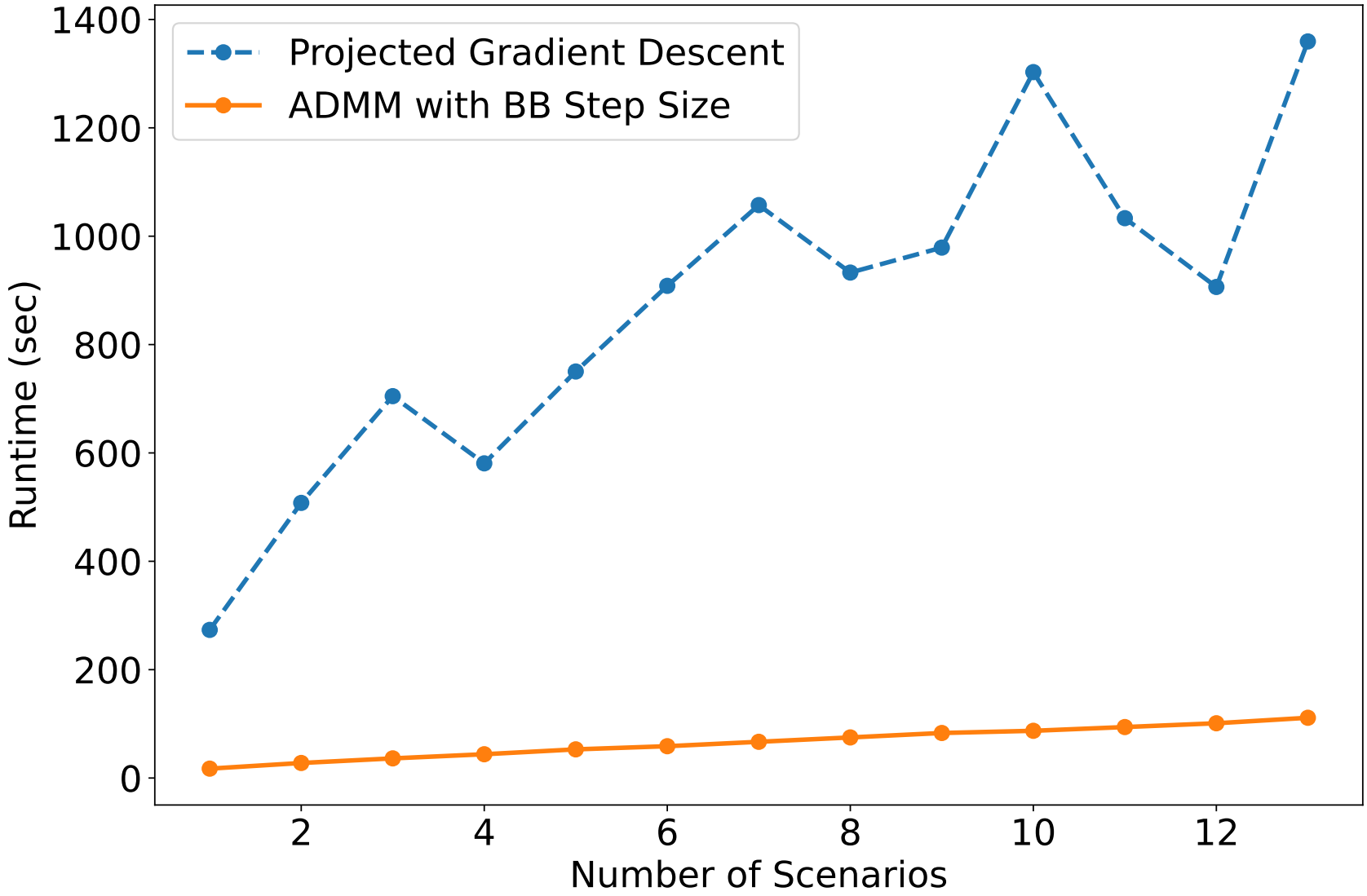
# Objective Value vs. Algorithm Runtime



# Dose-Volume Histogram (DVH) Bands



# Algorithm Runtime vs. Number of Scenarios



# Conclusion

- Robust optimization used in clinic, but suffers from slow speed and high computational overhead
- ADMM splits optimization problem so workload can be distributed efficiently across multiple CPU cores/threads
- Results in shorter planning time and improved plan quality
- Future work: implement ADMM in the cloud

**A. Fu**, V. T. Taasti, M. Zarepisheh. “Distributed and Scalable Optimization for Robust Proton Treatment Planning.” *Medical Physics*. Under minor revision, June 2022.