Improvement in Plan Quality and Reduction in Treatment Time Through Beam Angle Optimization and Field Co-Optimization

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2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

INTRODUCTION

Intensity Modulated Neutron Therapy (IMNT) is valuable for radioresistant head & neck (H&N) tumors due to the high LET of neutrons [1], but there are **practical delivery constraints** in the current delivery workflow**:**

1) Low Output Rates (~55 MU/min) require long beam-on times
2) Manual gantry and couch rotations (~3-5 min/field)
3) Mandatory wait times before entering the vault (~1-2 min) for neutron activation concerns, mostly (n,2n) reactions with ^{12}C and ^{16}O
4) The vault floor must open to allow gantry rotation for posterior field delivery

In our standard of care (SOC) planning approach, initial and boost treatment fields are independently optimized with manual beam angle selection, which may be operationally inefficient and dosimetrically suboptimal.

This study investigates the potential of **beam angle optimization (BAO) with field co-optimization (FCO)** to improve plan quality and facilitate delivery of a simultaneous integrated boost while reducing treatment times for complex H&N cancers.

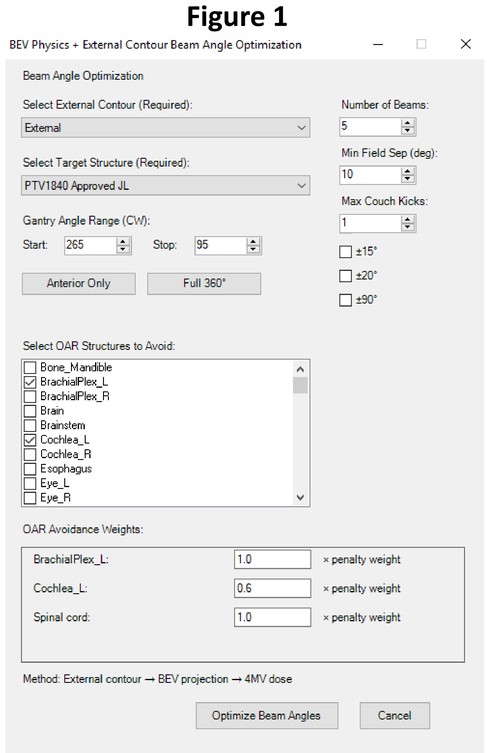
METHODS AND MATERIALS

We developed a Beam Angle Optimizer (BAO) as a **Raystation-based Python script**. An example GUI is displayed in Figure 1.

It performs **fast heuristic optimization with a < 5 min runtime**. It creates a representation of each structure (external, target, and selected OARs) in each beam's eye view. It simulates PDD curves starting from the external contour, while calculating radiological depth of the target and OARs. Integrating under the neutron PDD curve along the central axis of each candidate beam, it **evaluates path quality** (high target dose, low OAR dose).

Five representative H&N cancer treatment plans were retrospectively replanned with the BAO-FCO approach. Figure 2 shows one case planned with BAO-FCO.

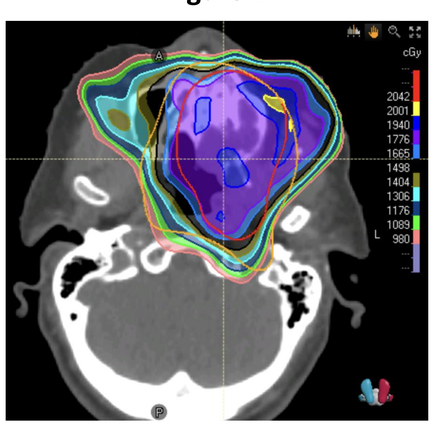
Figure 1



The following scenarios were investigated:

Scenario	Goal
12-field BAO vs. SOC	Improve plan quality
9-field BAO	Reduce total number of treatment fields
Anterior-only beams	Avoid vault floor opening
Limited couch kicks	Reduce setup time

Figure 2



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RESULTS

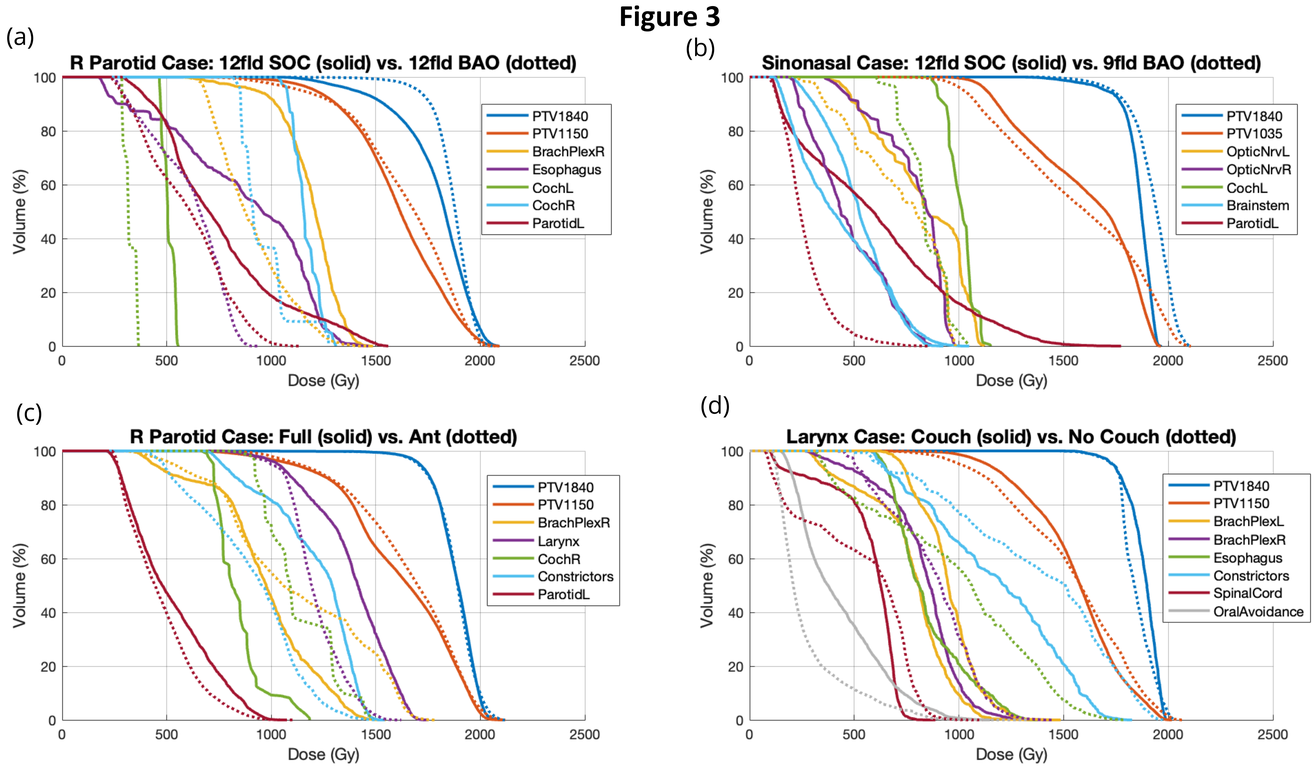
Result #1: Optimizing the same number of fields and objectives as the SOC plans, BAO with co-optimization achieves a **2.9% improvement** in high-risk target V95 while **significantly sparing OARs** (parotids, cochlea, mandible, oral cavity, temporal lobes, spinal cord, optic nerves), as shown in Figure 3a. The planning efficiency is improved by replacing an independently optimized boost with a simultaneous integrated boost (SIB).

Result #2: Reducing the number of BAO fields from 12 to 9 fields still achieves **improvements in high-risk target V95 by 1.4%,** and spares OARs (parotids, cochlea, mandible, oral cavity, temporal lobes, optic nerves, optic chiasm) as seen in Figure 3b. **Delivery efficiency is improved by at least 30%**.

Result #3: It is **possible to achieve clinically acceptable plan quality** for a parotid case with bilateral involvement with **anterior-only fields** to avoid opening the vault floor and to avoid treating through the couch. This is compared to a plan using the entire 360-degree gantry space, using the same number of fields, as shown in Figure 3c.

Result #4: Clinically acceptable plan quality is achievable with ZERO couch kicks due to smoother junctions between beams. The comparison with a plan with MANY couch kicks for a larynx case with bilateral neck involvement is shown in Figure 3d. For these cases, we can **safely recommend using at most ONE couch kick** to improve dose distributions while significantly reducing treatment delivery time.

Figure 3



CONCLUSIONS

This work shows that beam angle optimization (BAO) with field co-optimization (FCO) can substantially improve both plan quality and delivery efficiency for high-LET IMNT in complex head and neck cancers, despite strict operational constraints. By reducing field count and intelligently constraining beam angles, the approach significantly lowers OAR doses while improving high-risk target coverage compared to standard-of-care (SOC) planning. Critically, these gains translate into shorter treatment times and a projected increase in IMNT patient throughput, amplifying the clinical impact beyond dosimetry alone.

BAO-FCO could increase the capacity of our facility to treat IMNT patients by >30-40% through more efficient delivery.

REFERENCES

[1] Viscariello N, et al. Comparisons of 3-Dimensional Conformal and Intensity-Modulated Neutron Therapy for Head and Neck Cancers. Int J Part Ther. 2021 Sept 14;8(2):51-61. doi: 10.14338/IJPT-20-00059.1