Proton PBS Head and Neck Treatment Planning: Making the Complex Commonplace

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Inova Schar Cancer Institute

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About this session:

- A time capsule — a free, shareable resource capturing the best of what we know today in static field PBS HN planning
- **Who this is for — Everyone!**
  - Large academic centers, community-based programs, single-room facilities, and centers not yet online
  - The performance gap in PBS HN is not about equipment — it is closeable with the right practices
- **How to use this deck**
  - On-stage: the guided tour — key concepts with clinical depth
  - Download: the full resource — supplemental slides and notes with added detail
  - Share freely

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Disclaimer

- The techniques presented here were developed and refined using the RayStation treatment planning system. RayStation users should be able to directly test and implement these practices as appropriate for their clinical environment.
- While not every technical detail will be reproducible in other proton treatment planning systems, many of the underlying concepts and strategies are broadly applicable and offer value regardless of platform.

Scope & Applicability

- This presentation focuses on Bilateral HN cases with SIB prescriptions
  - The most common and representative scenario in PBS proton HN planning.
- We recognize that other case types present their own unique challenges and may require specialized approaches not covered here, including:
  - Nasopharyngeal carcinoma
  - Cases involving skin or scalp target volumes
  - Unilateral head and neck treatments
  - And many other site-specific variations
- That said, much of the planning philosophy, technique, and efficiency strategy discussed in this presentation transfers directly to these cases and can serve as a strong foundation for approaching them.

Roadmap:

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Why PBS Protons for Head & Neck?

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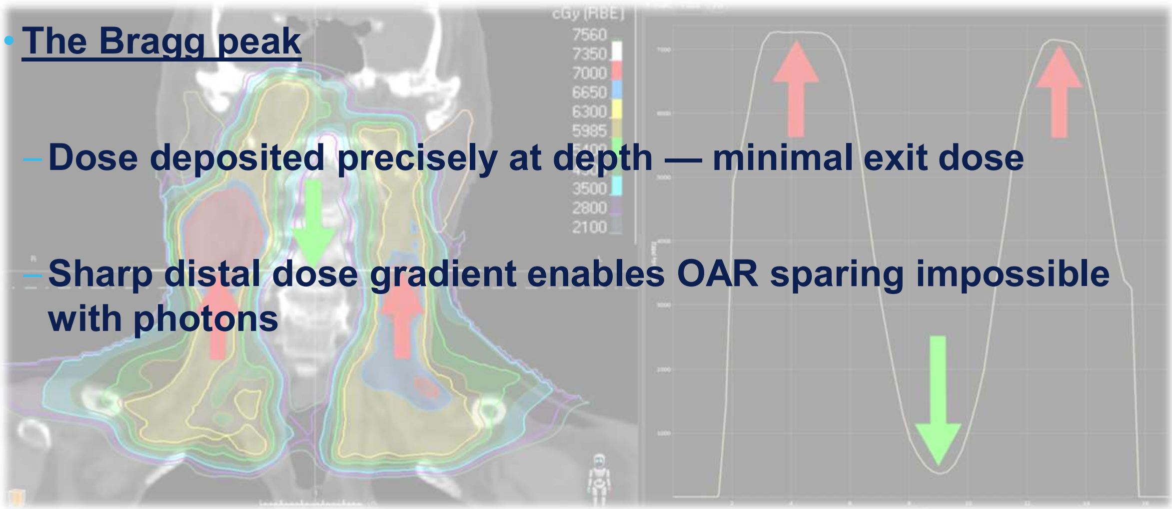
HN cancer and the proton advantage



- **The Bragg peak**
  - **Dose deposited precisely at depth — minimal exit dose**
  - **Sharp distal dose gradient enables OAR sparing impossible with photons**

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Level I Evidence: IMPT vs. IMRT

- **Proton versus photon radiotherapy for patients with oropharyngeal cancer in the USA: a multicentre, randomised, open-label, non-inferiority phase 3 trial**

- Frank SJ, Busse PM, Lee JJ, Rosenthal DI, Hernandez M, Swanson DM, Garden AS, Gunn GB, Patel SH, Snider JW, Ma DJ, Molitoris JK, Lee NY, Parvathaneni U, McDonald MW, Kalman NS, Lin A, Mohammed N, Henson C, Hyde C, Bajaj GK, Katz SR, Dagan R, Morrison WH, Reddy JP, Fuller CD, Shah SJ, Phan J, Chronowski GM, Mayo L, Sturgis EM, Ferrarotto R, Zhu XR, Zhang X, Wang L, Hutcheson KA, El-Naggar AK, Moreno AC, Lee A, Spiotto MT, Gross ND, Lai SY, Liao JJ, Paly J, Liao Z, Foote RL; University of Texas MD Anderson Cancer Center Clinical Trial Consortium. Proton versus photon radiotherapy for patients with oropharyngeal cancer in the USA: a multicentre, randomised, open-label, non-inferiority phase 3 trial. Lancet. 2026 Jan 10;407(10524):174-184. doi: 10.1016/S0140-6736(25)01962-2. Epub 2025 Dec 11. PMID: 41391462; PMCID: PMC12812248.

Phase 3 RCT: IMPT vs IMRT for Oropharyngeal Cancer

Frank et al. — The Lancet 2026 | NCT01893307

STUDY DESIGN & RIGOR

- **21 U.S. Cancer Centers**
  NCI-credentialed for both modalities (IROC QA)
- **440 Patients Enrolled**
  Oct 2013 – May 2022 | Median follow-up 3.2 yrs
- **1:1 Randomization**
  Stratified by HPV/p16, smoking, induction chemo
- **70 Gy / 33 Fx**
  Primary tumor + bilateral neck; all received systemic Rx
- **Non-Inferiority Design**
  9% margin for 3-yr PFS; O'Brien–Fleming interim
- **ITT + Per-Protocol**
  Both populations analyzed; crossovers pre-specified
- **95% HPV+ / p16+**
  91% male, stages III–IV; 80%+ had N2–N3 disease

EFFICACY OUTCOMES

Progression-Free Survival (Primary Endpoint)

IMPT 81.3%
IMRT 76.2%

HR 0.88 | p=0.005 → Non-Inferiority MET ✓

Overall Survival (Secondary Endpoint)

IMPT 90.9%
IMRT 81.0%

HR 0.58 | p=0.045 → 42% reduction in hazard of death

Disease Control at 5 Years (Per-Protocol)

Local recurrence:	2.9% vs 5.6%	*p=0.474*
Regional recurrence:	3.4% vs 3.2%	*p=0.860*
Distant metastasis:	9.1% vs 8.9%	*p=0.897*

TOXICITY: IMPT ADVANTAGE

Toxicity	IMRT	IMPT
Lymphopenia (Gr 3/4)	89%	76%
Dysphagia (Gr 3)	49%	34%
Xerostomia (Gr 3)	45%	33%
Weight Loss (Gr 3)	55%	46%

G-Tube Dependence at 60 Days

IMRT: 40.2% **IMPT: 26.8%**

33% relative reduction | p=0.018
0 IMPT patients G-tube dependent at 1 year

Treatment-Related & Post-Progression Deaths

Tx-related deaths: IMRT 6 vs IMPT 3
Post-progression deaths: IMRT 18 vs IMPT 9

"IMPT is a new standard-of-care treatment option for patients with oropharyngeal cancer." ***— Frank et al., Lancet 2026***

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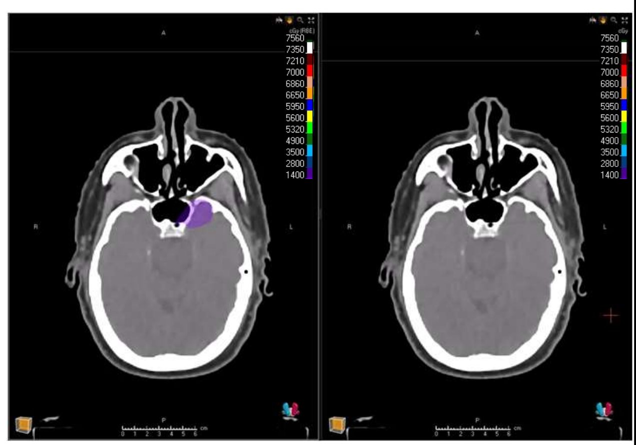
Proton Photon Comparison

- The clinical benefit is real and proven in the literature.
- Demonstrated meaningful differences in salivary function, xerostomia, and dysphagia outcomes
- The challenge is consistent, reproducible delivery of high-quality plans



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The Core Imperative

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The Core Imperative

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Our Patients -- First and Always

Obtaining and Defining Excellence in Patient Care

Our Team

Supplying the infrastructure, processes, and tools that support the total success of our team

Standardized Cases are Solved: Typical bilateral HN optimization solutions are now highly reproducible and trending toward efficient.

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The Core Imperative

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- **Unprecedented Planning Complexity** : Relatively, typical bilateral HN are moderate to simple complexity in the current comprehensive proton clinical
  - **The New Clinical Reality**: Patients now present with highly complex histories requiring re-treatment.
  - **Prior Radiation Challenges**: Managing multiple overlapping historical courses of radiation therapy (RT).
    - **Advanced Dosimetry Demands**: Requires extensive dose grid manipulation and custom plan preparation.
    - **Complex Multi-Regimen Tracking**: Merging physical dose, EQD2, and BED summations across past and current treatments.
    - **Tailored Beam Geometry**: Demanding non-standard, non-templated field arrangements and plan solutions.
    - **High-Stakes Collaboration**: Forcing highly iterative, time consuming, feedback loops between Dosimetry and Physicians to balance complex trade-offs.
- **The Imperative**: We must streamline typical bilateral HN SIB PBS workflows to free up critical clinical time and manpower for these highly complex, data-heavy cases.

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INOVA PROTON

H&N CLINIC

- 2025 Annual Data
  - All disease sites
  - Pediatric services
  - Expedited palliative proton
  - Mixed modality solutions

Comprehensive Cancer Center

H&N Caseload: Volume & Planning Complexity

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2025 Clinical Year | Inova Schar Cancer Institute – Proton Program

329	92	28%	490	141
Unique Patients	H&N Patients	of Patient Population	Total Plans	H&N Plans

H&N PATIENT PROFILE (N = 92)

- No revision | 56 pts | 61% | 63 plans
- Revision plans | 36 pts | 39% | 42 plans

REVISION TIER BREAKDOWN

- 1 revision — 30 pts (77% of revision pts)
- 2+ revisions — 6 pts (23% of revision pts)

PLANNING WORKLOAD DRIVERS

- **28.8%** **of all plans are H&N** — 141 of 490 total plans
- **29.8%** **of H&N plans are revisions** — 42 of 141 H&N plans
- **39.1%** **of H&N pts require replanning** — 36 of 92 H&N patients

Each H&N case also requires: 20–30+ OAR contours · Weekly QACTs · VMAT backup plan

Inova Schar Cancer Institute | Proton Therapy Program | 2025 Annual Data

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The Challenge

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Bilateral HN with SIB represents one of the most demanding scenarios in radiation treatment planning:

Large, complex, and irregularly shaped target volumes	Added complexity from SIB dose level management	Overlapping and immediately adjacent organs at risk	Densely packed anatomy with minimal spatial separation	Potential for severe treatment-related side effects

This combination demands a large number of OAR dose constraints — many of which are difficult to achieve simultaneously.

The result is a planning environment where trade-offs between target coverage and OAR sparing are not just possible but expected.

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H&N PBS: Resource-Intensive

The case for a smarter system

COST

H&N demands more of everything

- Most contouring-heavy site in the PBS clinic
- Most optimization cycles & clinical judgment
- Highest adaptive replanning burden
- Steepest learning curve for new dosimetrists

RISK

Without a system, the Return On Investment breaks down

- Plans that underdeliver on proton's clinical promise
- Quality that varies by planner
- Preventable failures triggering avoidable adaptations

SOLUTION

Not fewer H&N cases — a smarter system

- Standardize the low, medium, and some high - judgment decisions
- Compress planning time without sacrificing quality
- Scale quality independent of who's at the console

The goal: a planning framework that delivers consistent, high-quality H&N proton plans — every time.

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2 | Cost–Value

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Unfinished Business

Why these gains are not being captured

Centers without time to focus on efficiency and research cannot pursue these gains independently

The research pipeline is not oriented toward practical clinical application

Knowledge is siloed — what works at one center does not automatically, or possibly ever, reach another

Our work is focused on closing that gap

Enormous efficiency and quality gains remain available in static-field, constant-RBE PBS HN — right now.

Static-field PBS HN is not disappearing for a considerable time

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The Strategic Framework

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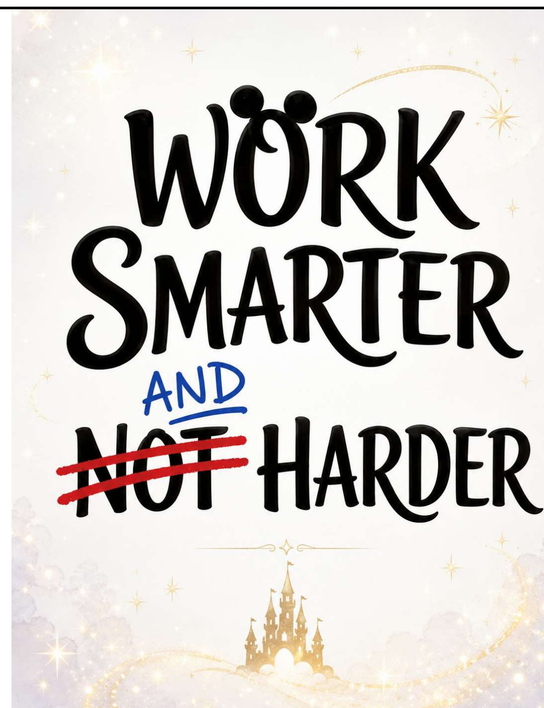
Mindset:

Both, not either/or

2 | The Strategic Framework



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The Value Equation

Cost Benefit Analysis Formula

$$\text{Net Present Value (NPV)} = \sum \text{Present Value of Future Benefits} - \sum \text{Present Value of Future Costs}$$

$$\text{Benefit Cost Ratio} = \frac{\sum \text{Present Value of Future Benefits}}{\sum \text{Present Value of Future Costs}}$$

2 | The Strategic Framework

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The Value Equation

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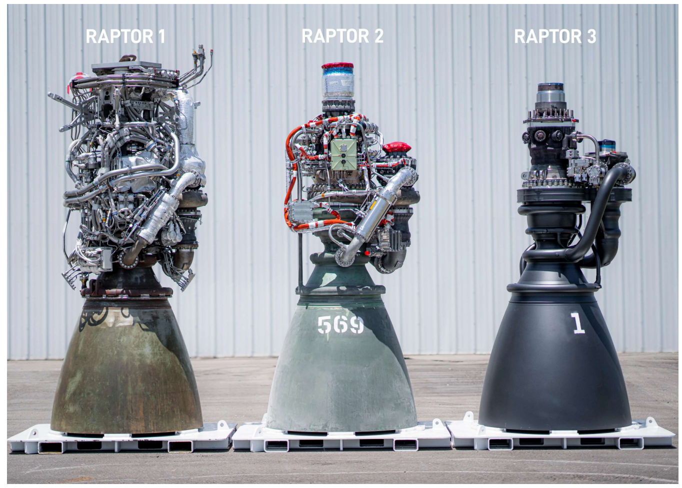
One good workflow × many patients × many planners

- Build once → harvest across every plan, every planner
- Quality: consistent starting points, higher floor across the team
- Speed: faster iteration, more optimization cycles per session
- Scale: new planners reach competency on an established framework

Automation doesn't replace clinical judgment — it gives judgment the space to operate



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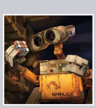
Standardization

Establishing uniform baseline specifications across all processes and outputs.

Eliminates ad-hoc variance to ensure predictable, high-quality execution at every layer.

Class Solutions

Shifts focus from isolated fixes to unified architectures that resolve entire categories of problems simultaneously



Reusability

- Engineering assets intentionally for seamless integration into future revision cycles

- Maximizes historical effort and reduces friction

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Execution:

From framework to workflow

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From framework to workflow

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Standardization ▪ Class Solutions ▪ Reusability – guiding every decision

Image Prep → Plan Creation → Field Arrangement → Optimization → Plan QA → Adaptive

Adaptive durability woven throughout

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Image Preparation & ROI Strategy

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Image Prep: Where plan quality is set

The principle

- Image preparation is where plan quality is won or lost — before the optimizer ever runs
- The optimizer cannot compensate for poor upstream structure work
- Garbage in, garbage out — this is as true for PBS H&N as anywhere in treatment planning

Our design criteria for every step in Image Prep

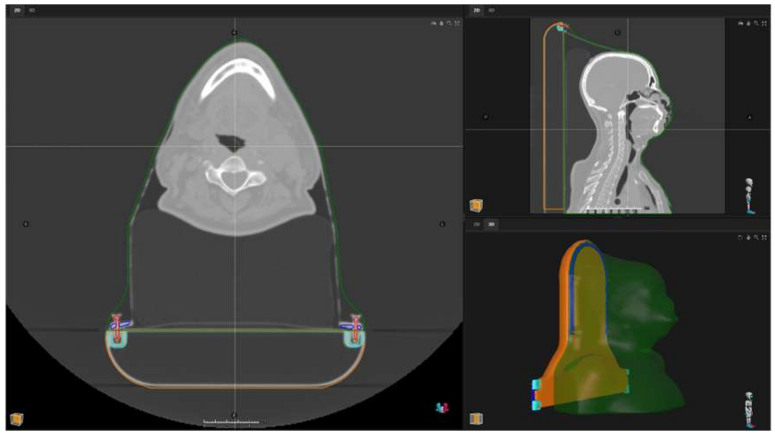
- Clinically excellent: structures reflect clinical intent precisely
- Adaptive-friendly: every step is designed to be reusable at adaptation time
- Script-compatible: every action can be automated or semi-automated

External

- Standardized
- Script generated
- Requires single crop on coronal plane (‘Couch Removal’)
- Includes patient anatomy and immobilization devices

Virtual Couch

- Standardized
- Template based



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Clean CTV/PTV Architecture

Structures Drive Optimization

1 Non-Overlapping CTVs

Overlapping CTVs create competing objectives the optimizer cannot fully resolve — forcing trade-offs that should have been resolved structurally.

Every minute spent fighting optimization conflicts is a minute the ROI architecture cost you.

2 No Missing Voxels

Dose is delivered where contours exist.
Gaps in coverage trace directly back to gaps in structure.
Especially critical at SIB dose-level junctions.
Valuable in robust evaluation.

OptiPTVCTVCreator Script

Automated CTV/PTV generation from clinical contours

Non-overlap by design

Enforces non-overlapping CTV geometry at generation — eliminates structural conflict at its source.

Consistent margin application

Identical margin logic applied across all planners — no planner-to-planner variability in PTV expansion.

Adaptive-friendly

Runs on adaptive CT with the same logic. Replanning always starts from a clean, structured baseline.

Direct optimization feed

Output populates the optimization ROI library directly — no manual cleanup or restructuring step required.

Inova Schar Cancer Institute | H&N PBS Planning | OptiPTVCTVCreator

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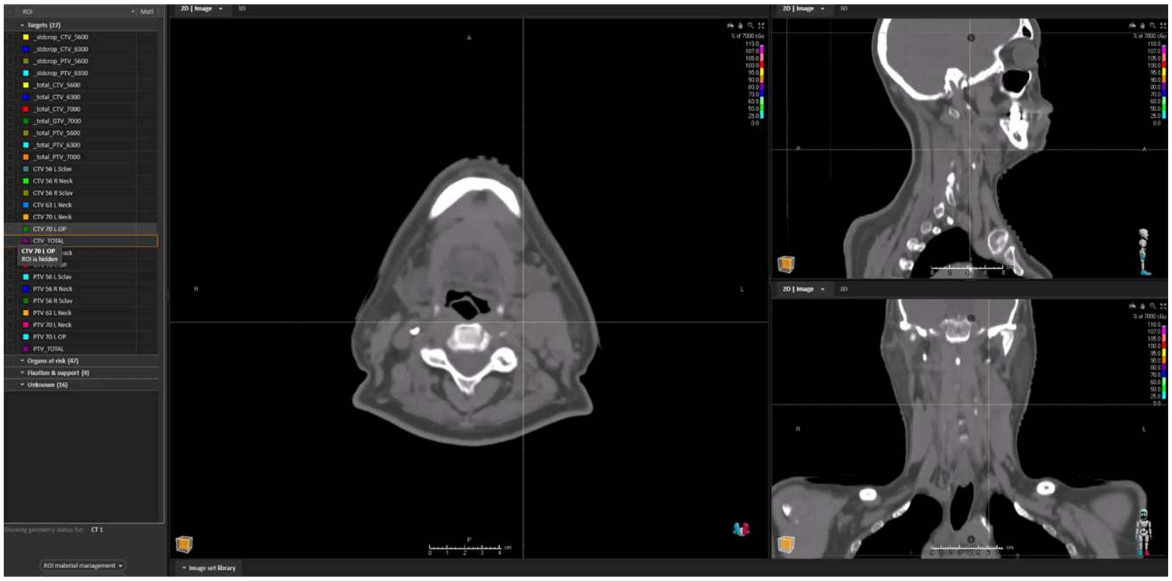
3 | Image Prep – Non-Overlapping Target Structures



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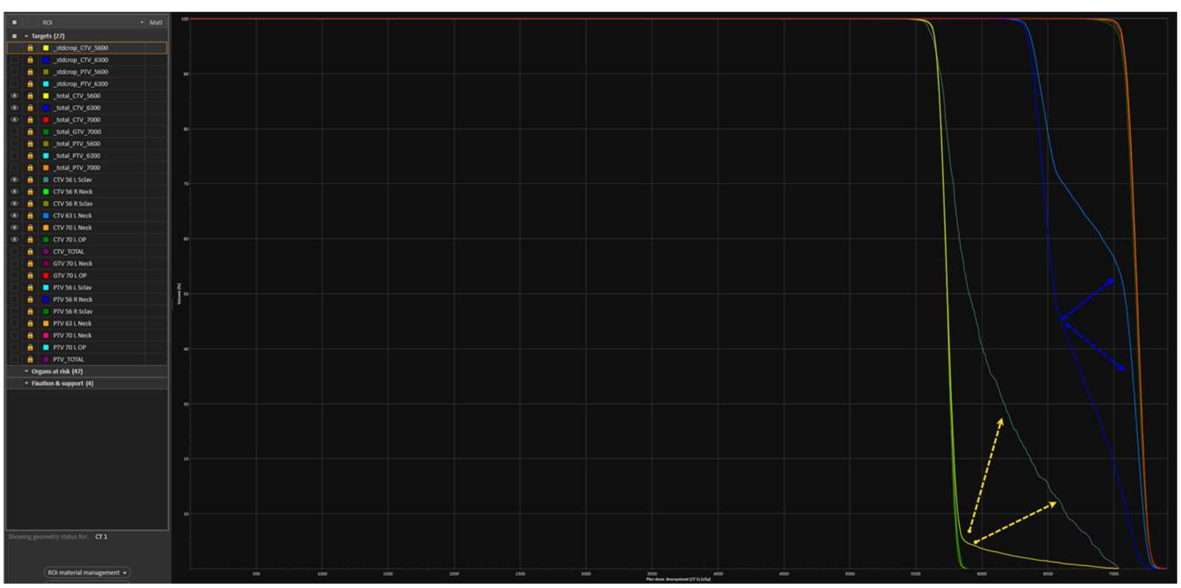
3 | Image Prep – Non-Overlapping Target Structures – DVH Visualization



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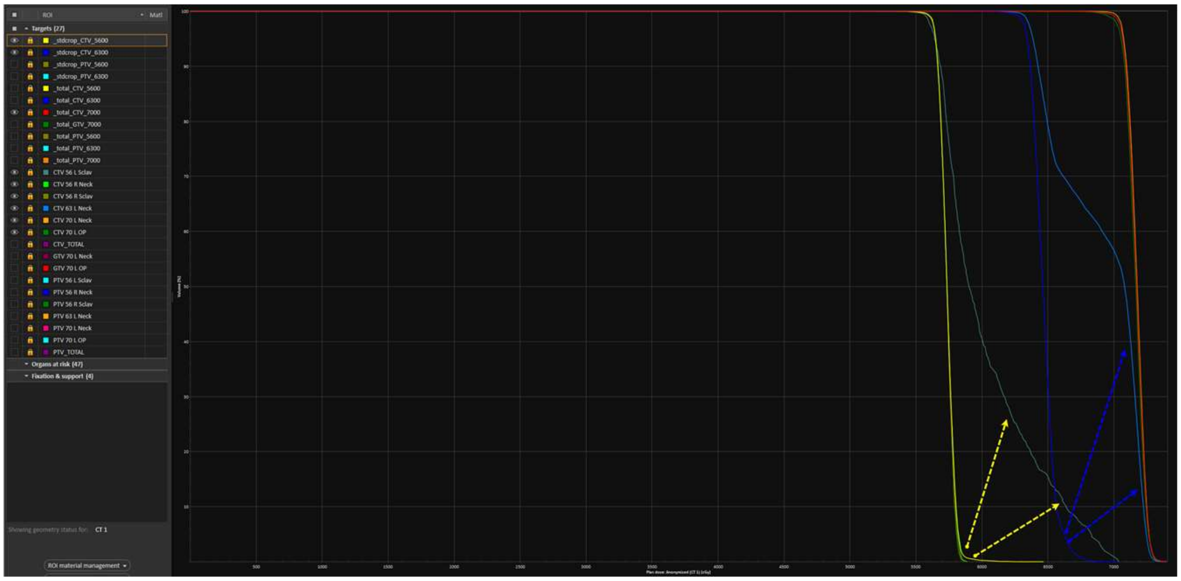
3 | Image Prep – Non-Overlapping Target Structures + Margin



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controlMax ROIs

Optimization ROI | One per CTV dose level

Purpose: Used to control max dose both nominally and robust across multiple dose levels in plans utilizing SIB technique. Clean, non-overlapping region per dose level — eliminating conflicting dose instructions in optimization, across SIB target volumes.

1 EXPAND
CTV union +2 cm all directions

2 CLIP
Intersect with body contour

3 CROP
Subtract each higher-dose CTV (with dose-scaled margin)

Crop Margin: margin (cm) = (dose gap (Gy) ÷ 10) + 0.2

2 Gy→4 mm
5 Gy→7 mm
10 Gy→12 mm

Step 1a — Highest Level
Union of all CTVs at this dose level, expanded +2 cm. No subtraction — this is the terminal step.

Step 1b — Lower Levels
Same expansion, but higher-dose CTV union is immediately subtracted with zero margin in this pass.

Step 2 — Body Clip
Intersect with External ROI. Removes any expansion that breaches the skin surface. Skipped if no External exists.

Step 3 — Iterative Crop
Each higher-dose CTV is subtracted one-by-one. Margin scales with dose gap — bigger gap, bigger buffer.

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3 | Image Prep – Max Dose Control Structures and Rings

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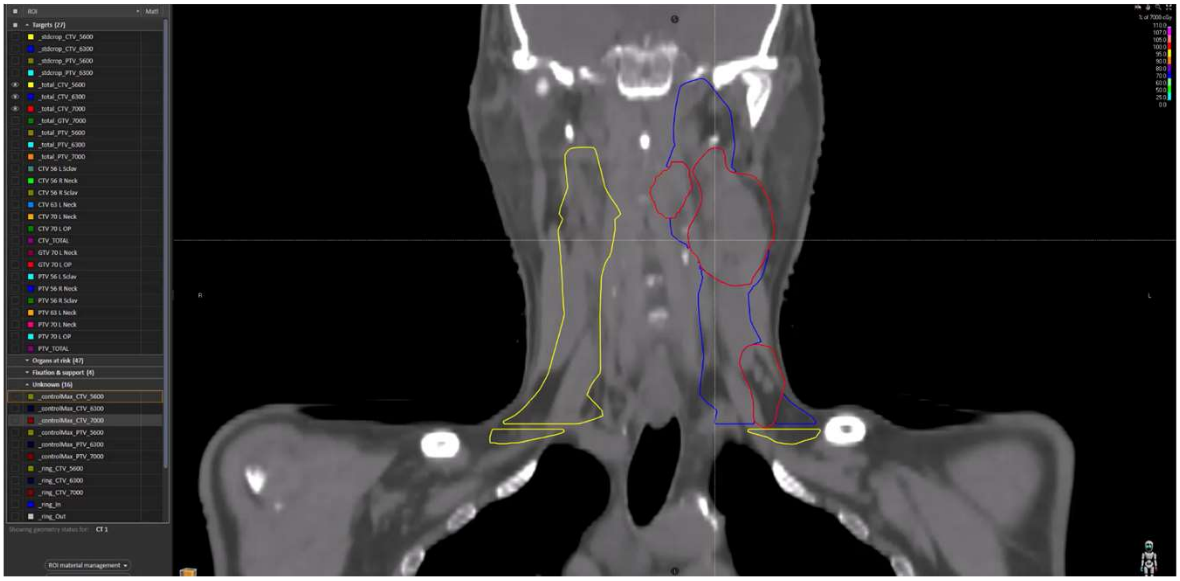

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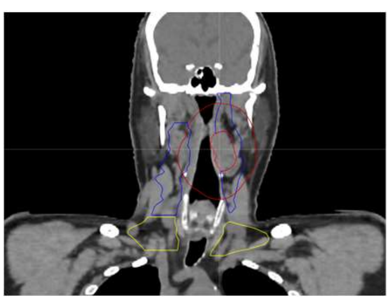
controlMax ROIs:



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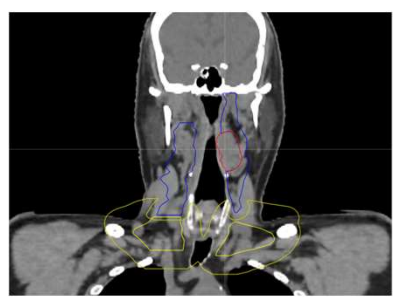
_controlMax_CTV_6300



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Comprehensive OAR Template

H&N PBS Planning — Standard Structure Set

UNIVERSAL — Present on every H&N case

Salivary	Parotid L/R · Submandibular L/R · Oral Cavity
CNS / Spine	Brainstem · Spinal Cord · SpinalCord_PRV05
Visual	Eye L/R · Lens L/R · OpticNrv L/R · OpticChiasm
Auditory	Cochlea L/R
Aerodigestive	Larynx · PharynxConst · Esophagus · Trachea
Other	Mandible · Mandible-PTV · Thyroid · Glottis

SITE-SPECIFIC — Added per clinical indication

Brachial Plexus	Lower neck targets · Prior RT cases
Carotid Arteries	Prior RT cases
Temporal Lobes	Nasopharynx · Skull base targets
Pituitary / Hypothalamus	Skull base targets

RayStation Structure Set

Missing OARs = Missed Optimization Opportunities

The optimizer cannot protect what it cannot see. DFO objectives, NTO, and dose rings can partially compensate — but diluted focus over absent volumes cannot be fully recovered.

Inova Schar Cancer Institute | H&N PBS Planning | Standard OAR Template

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Standard Target ROI Color Scheme

Small investment. Large compounding returns.

THE SYSTEM — SIB Dose Tier Mapping

1	**1st — Highest dose SIB level**
2	**2nd — dose SIB level**
3	**3rd — Elective / prophylactic target**
4	**4th — dose SIB level**
5	**5th — dose SIB level**

Isodose line colors are standardized to match — reinforcing the same visual language in dose review.

WHY IT COMPOUNDS WITH TEAM SIZE

Instant orientation

Any planner new to a case knows exactly what they are looking at within seconds.

Frictionless handoffs

Second checks and plan reviews require minimum orientation time.

Faster chart rounds

Every team member shares the same visual language — no re-explanation needed.

Accelerated training

The color coding is a cognitive scaffold. New planners build fluency faster.

CONSISTENCY ENABLES AUTOMATION

Color System

Standardized conventions applied consistently to every patient, every planner, every plan.

↓

Scripting Library

Scripts expect structures with predictable values.

The naming-color system and the scripting library reinforce each other.

Inova Schar Cancer Institute | H&N PBS Planning | Standard ROI Color Scheme

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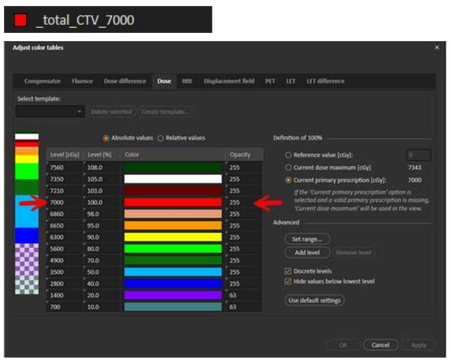
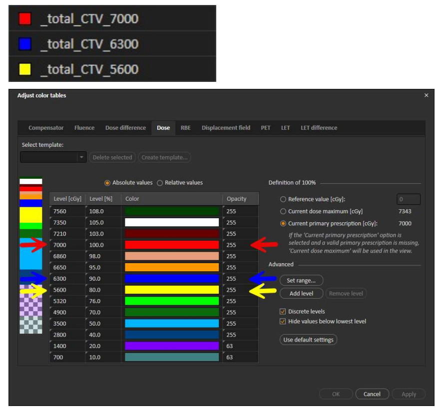
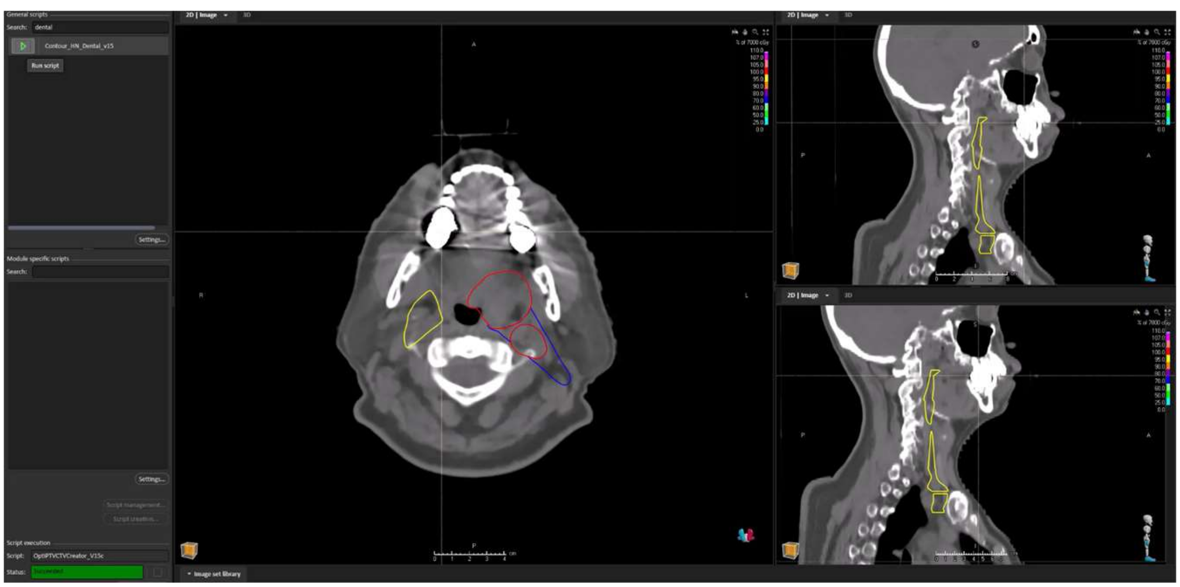
Color coding examples:

Single Dose Level Plan



Multi-Dose Level Plan





Field Arrangement

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The Max Single-Field Contribution Rule

MFO Field Weighting | H&N PBS Planning

HARD CONSTRAINT

No single field > **70%** of prescribed dose to any target voxel

Up to ~72% accepted when final dose calc / scale-normalization post-optimization is the cause

What the Rule Forces

- Every target voxel covered by ≥2 independent beams
- No single beam path is load-bearing for coverage
- Inherent robustness: if one beam is perturbed, coverage is maintained by the others
- Shapes every field arrangement decision that follows

Why It Matters for PBS H&N

- H&N anatomy is highly variable — within treatment and between patients
- Single-field dominance creates plans fragile to anatomy change
- End-of-range uncertainty: a dominant field places its Bragg peak dose entirely at risk if tissue density shifts
- Distributing dose across fields reduces the consequence of any one beam's range error

Adaptive Planning Benefit

- Plans built with this rule are more durable between fractions
- Moderate anatomy change is less likely to trigger a replan
- Reduces adaptive burden: fewer replans = reduced resource and patient load
- When replan is needed, multi-field baseline makes the new plan easier to construct robustly

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Anatomy Drives Field Decision

Field Arrangement | H&N PBS Planning

IMMOBILIZATION Setup quality directly determines robustness settings and available field angles — **plan for the reproducibility you actually have — not the ideal.**

Oral Cavity & Mandible

Tongue mobility: anterior fields may deliver unpredictable dose if not carefully designed and/or mitigated
Mandible mobility: limits certain inferior field angles
Anterior fields: valuable for anterior targets but require careful evaluation

Posterior Neck

Cord proximity: limits posterior oblique depth and energy range options
Target depth: affects energy layer selection and delivery time

Shoulders

Primary limitation for low neck and supraclavicular fields

Couch angles and positioning can help — but have limits

Symmetric positioning is worth the setup time investment

Dental Implants & Hardware

Required avoidance: beam paths through dense metal generate artifacts and unpredictable dose
Standardized strategy: define the geometry, use blocking structures, document the decision

Prior RT Cases

Near case-by-case field selection based on prior dose distribution and MD goals

Couch kicks, modified angles, and additional OAR considerations (brachial plexus, carotids)

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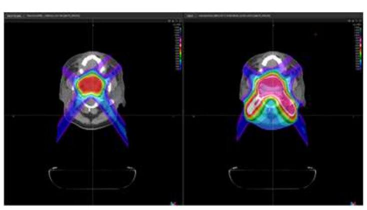
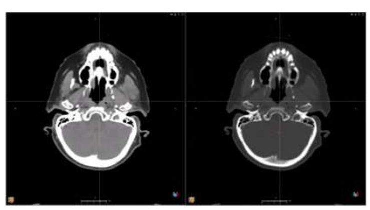
4 | Field Arrangement – Neck Folds

Anatomy Challenges and Considerations



Prior Radiation



Dental Implants and Hardware

Neck Folds

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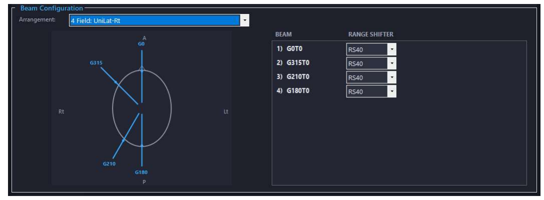
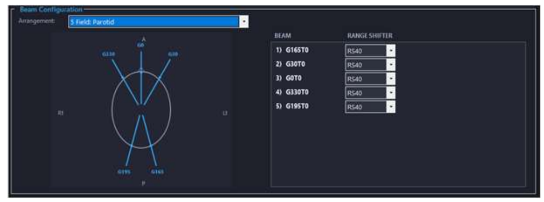
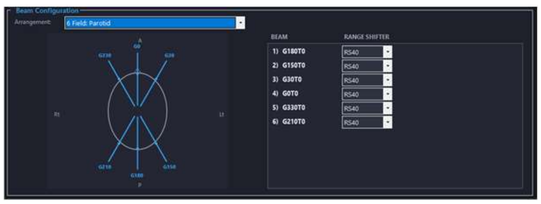
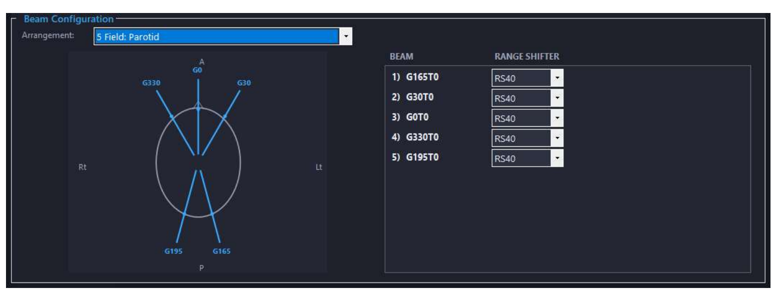






Default 5-field arrangement

- **Standard configuration**
  - Two posterior obliques + two anterior obliques AP.
  - Posterior obliques: primary coverage of posterior neck and bilateral nodal volumes
  - Anterior obliques: anterior neck coverage with parotid and oral cavity sparing
- **Angle selection principles**
  - Narrow vs. wider posterior obliques: OAR trade-offs between cord, contralateral structures, and posterior neck targets
  - Narrow vs. wider anterior obliques: dental, parotid, oral cavity dose considerations



When to deviate from the default

- **6-field indications**
  - Nasopharynx / sinus: vertex field addition for superior target coverage at skull base
  - Significant dental burden: modified angles to reduce implant interference across multiple fields
  - High-dose targets adjacent to or overlapping parotids: additional angle for sparing
  - Bilateral neck nodes with high-dose CTVs in the lower neck: modified geometry for cord and esophagus
  - High density materials, implanted devices, mandating atypical arrangements
- **Prior RT cases**
  - Almost case-by-case evaluation based on MD goals and prior dose distribution
  - Couch kicks: when and how much -- per case decisions
  - The goal: maximum utilization of non-overlapping beam paths while respecting anatomy

Plan Creation

4 | Plan Creation

Setting up for excellence from the start

Standardized naming conventions

Consistent field names, beam set names, and plan names across all H&N cases

Template-based plan creation

Scripted plan setup: beam configuration, field angles, and initial optimization structure populated automatically

Reduces setup time and ensures every plan starts from the same foundation

Adaptive-ready from the start

Plan structure, naming, and settings choices made at creation time affect how smoothly the adaptive plan will run

Beneficial for data mining - research

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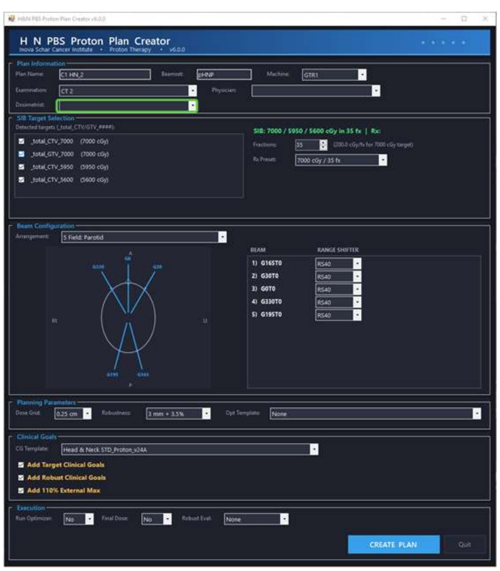
4 | Plan Creation script



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4 | Plan Creation script

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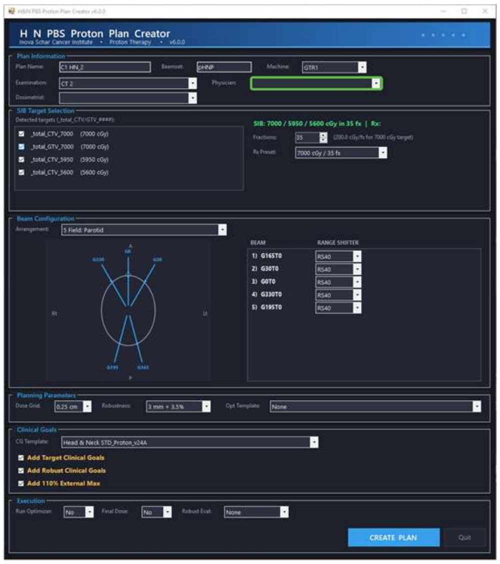

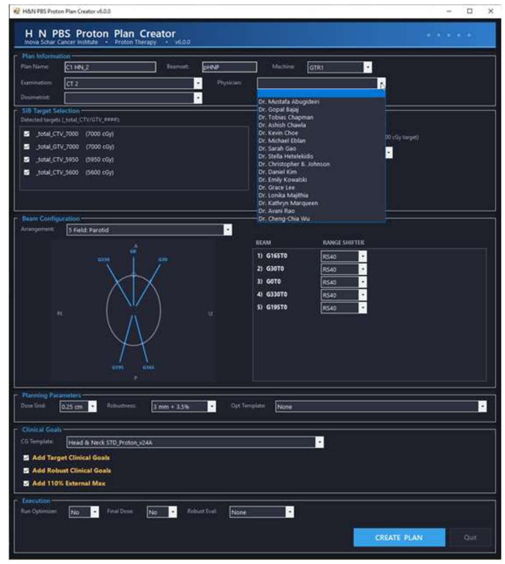

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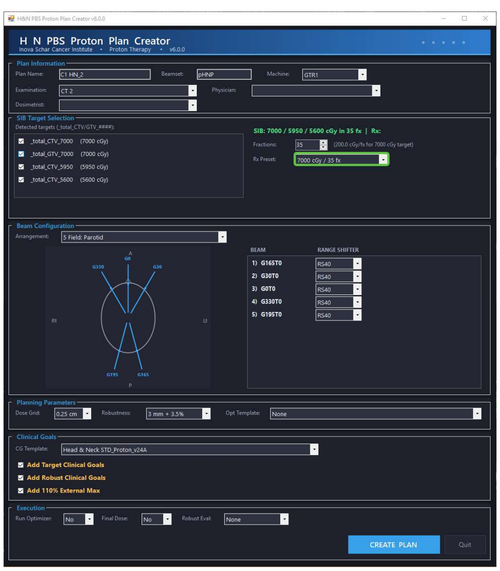

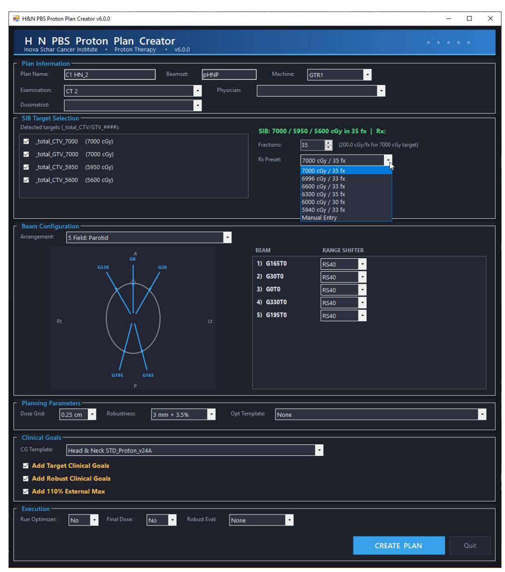

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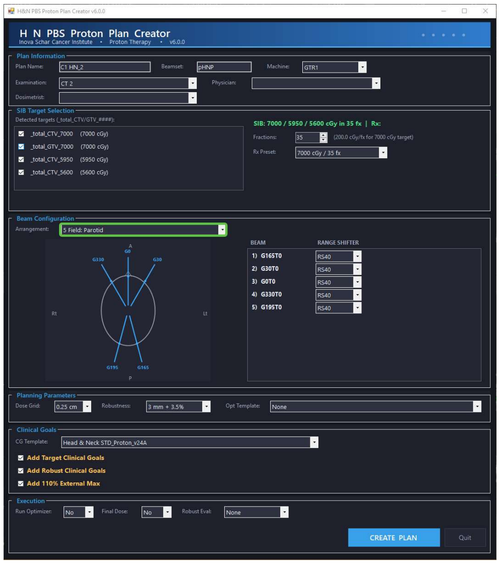

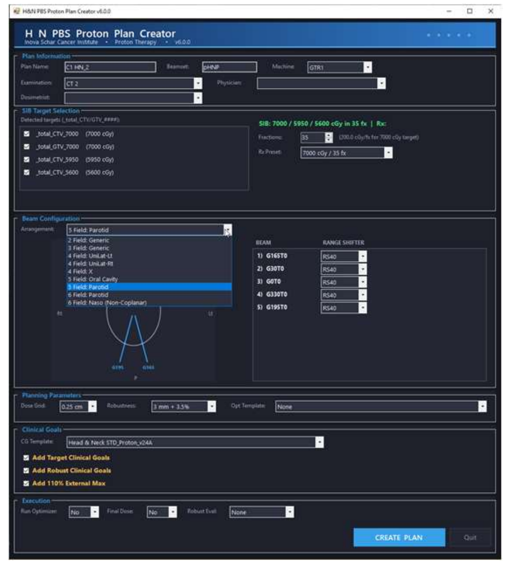

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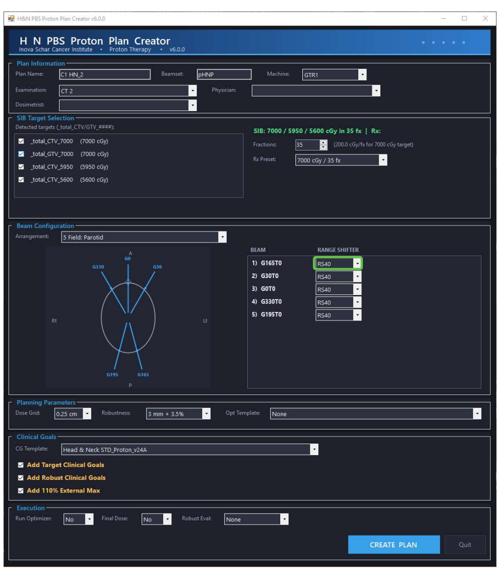

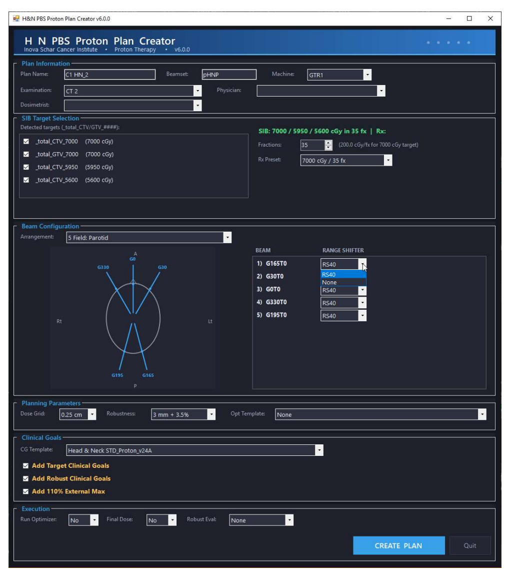

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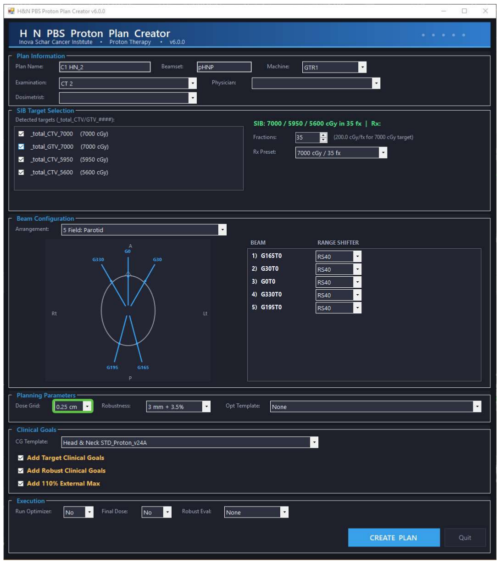

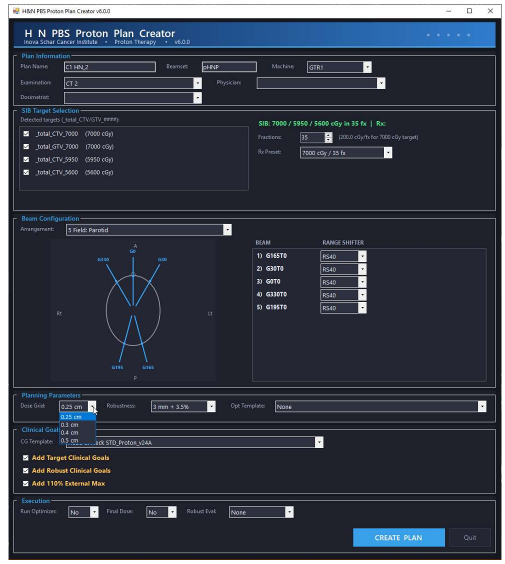

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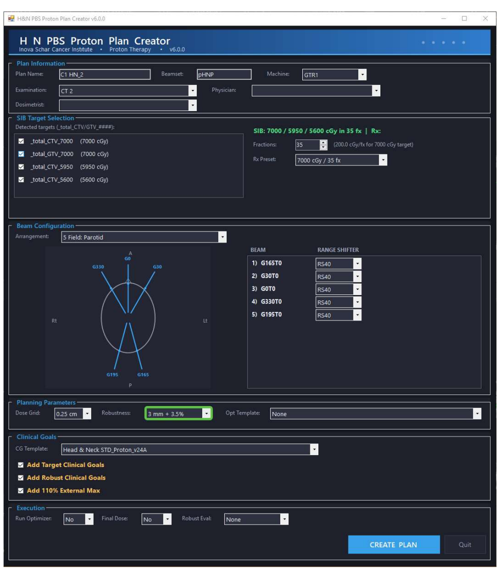

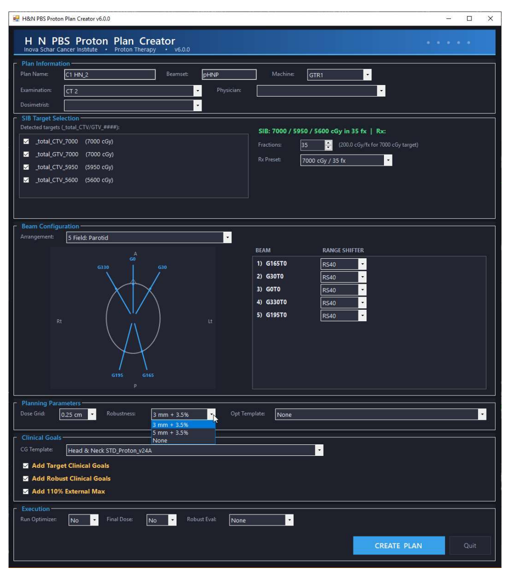

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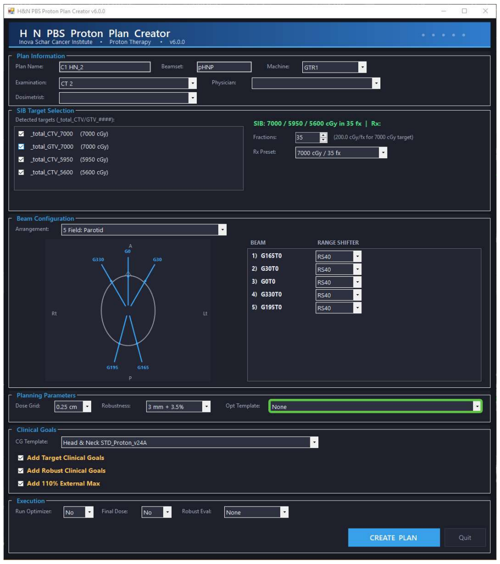

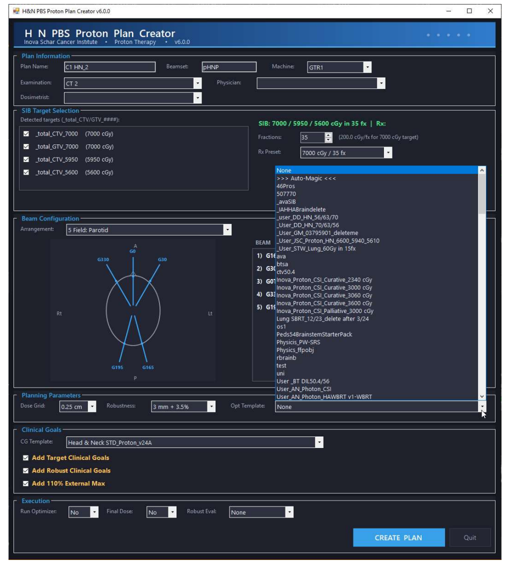

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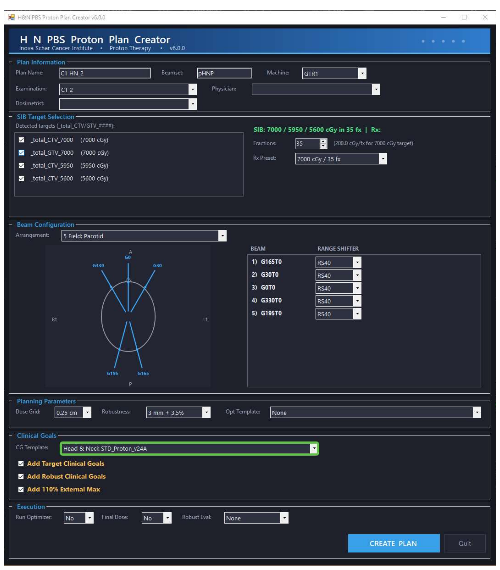

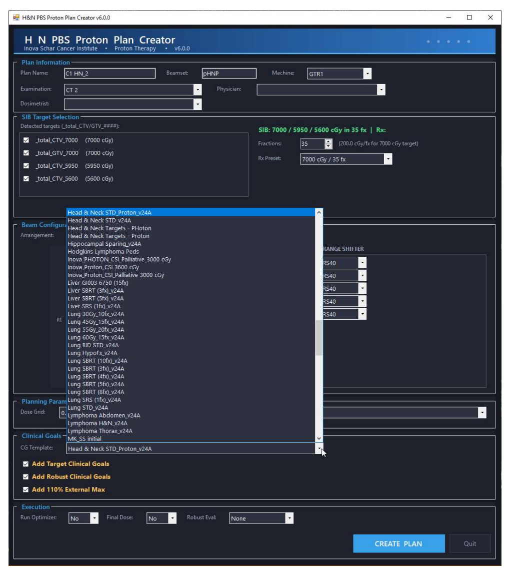

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4 | Plan Creation script

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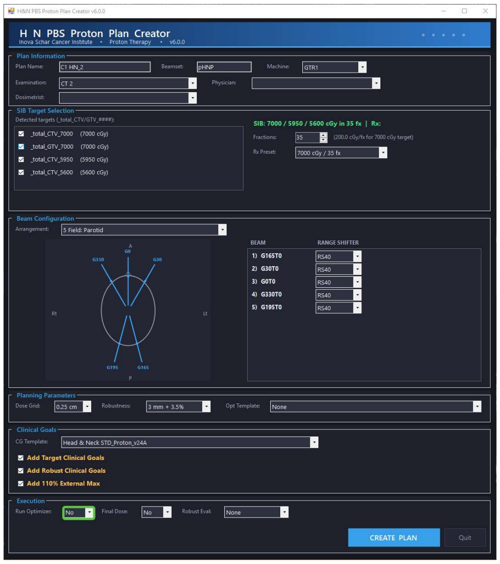

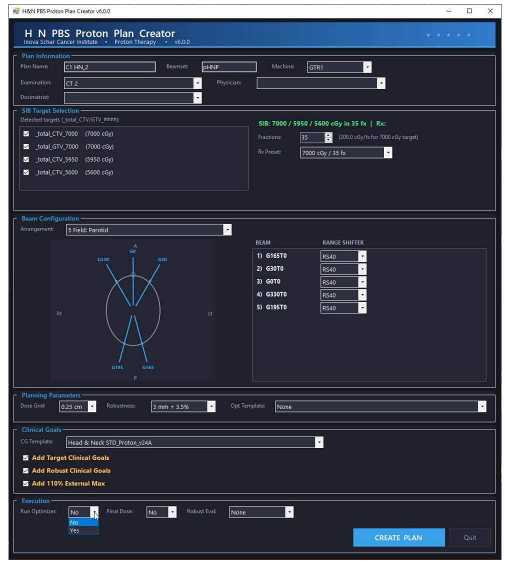

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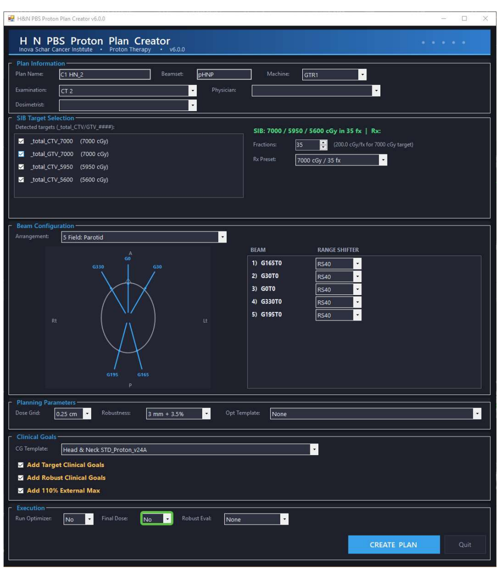

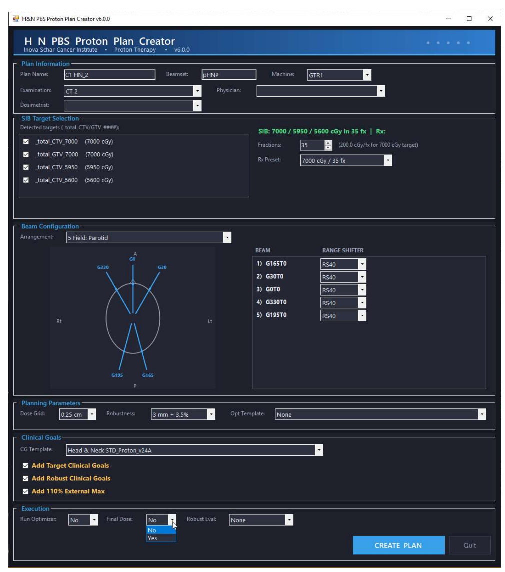

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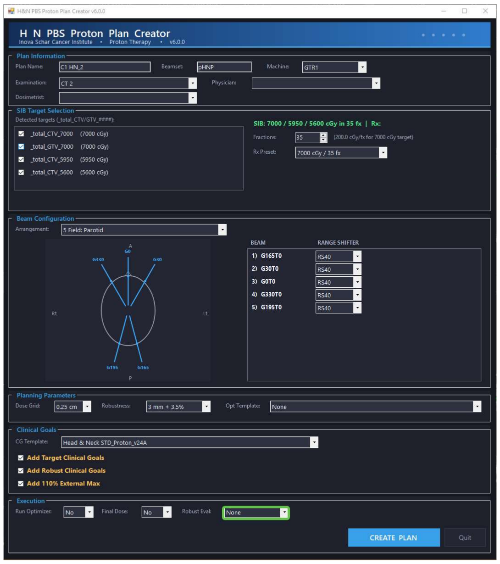

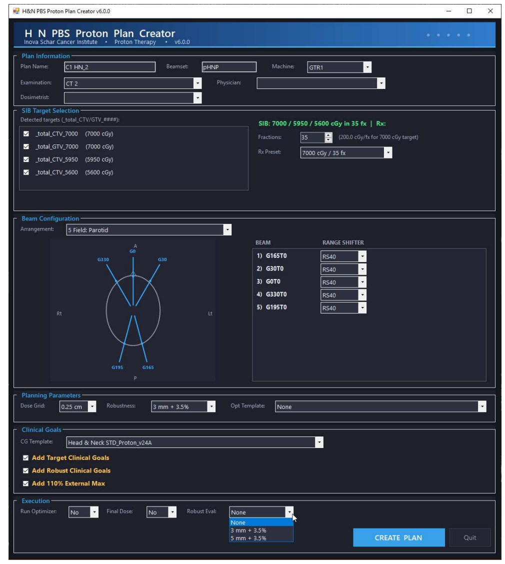

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Optimization

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Optimization: section guide

- **6a | Spot blocking & spot assignment**
  - Where the spots go and why we define it before optimization starts
- **6b | Settings & beam computation**
  - Layer spacing, spot spacing, machine characteristics, iterative vs. sequential strategy
- **6c | Optimization philosophy**
  - The pressure valve — robust optimization as a design decision
- **6d | Robust Max per SIB Level**
  - Highly important for plan quality -
- **6e | Class solution optimization**
  - Reusable frameworks for consistent, efficient planning
- **6f | Case walkthrough**

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6a | Spot Blocking

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With plan is created and fields placed: Where do the spots go?

Our answer: Blocking structures

This is not a workaround for complex cases

It is a foundational element of our standard workflow

- Photon planning: MLC shapes define the beam — the dose conforms to the aperture
- PBS planning: there is no aperture — spots are placed individually, and their placement is a planning decision
- The naive approach: let the optimizer place spots wherever it wants, within the field boundary
- The problem: the optimizer will use this freedom in ways that may not align with clinical intent

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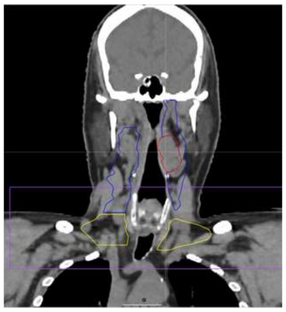
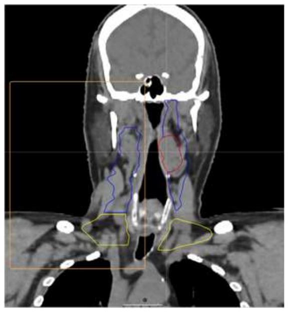
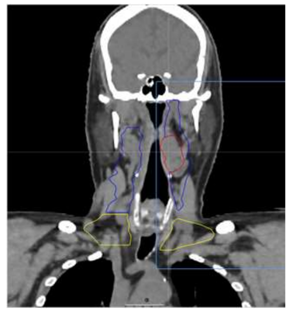
Field Specific Spot Blocking ROIs



Posterior Field(s)



Left Anterior Oblique



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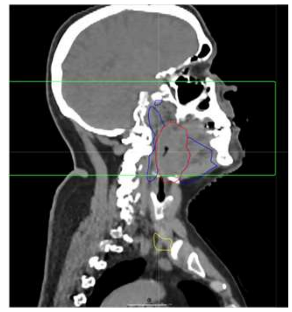
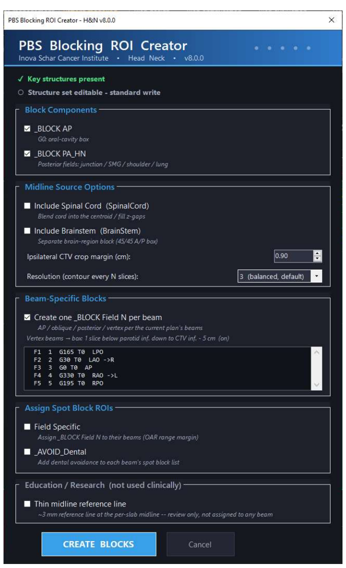


Anterior Field(s)

Field Specific Spot Blocking ROIs



Settings & Beam Computation: Upstream Decisions with Downstream Consequences

- **The Principle** Beam computation settings are locked in before optimization begins — yet they define the solution space the optimizer works within. Defaults were designed for general use, not H&N geometry. A suboptimal setting compounds silently through subsequent planning step.
- **Key Beam Computation Settings**
  - **Spot spacing** — lateral distance between pencil beam spots within an energy layer
  - **Layer spacing** — distance between energy layers in depth
- **Key Insight** H&N geometry demands tighter control at target edges and OAR interfaces than default setting provides. Beam computation settings should reflect that before a single spot weight is calculated.

Layer and Spot Spacing

- **Layer Spacing — Tighter Than Default** RayStation defines layer spacing relative to the 80%–80% Bragg peak width (1.0 = reference). The default suits simple, homogeneous targets. H&N is neither.
  - Tighter spacing gives the optimizer more Bragg peak positions in depth:
  - Sharper dose gradients at target/OAR interfaces
  - Better heterogeneity control within the target
  - More optimizer degrees of freedom distally — where H&N anatomy places its hardest OAR constraints and where wide spacing hurts most
- **Spot Spacing — Lateral Gradient Control** At cord, brainstem, and mandible interfaces, tighter spot spacing sharpens and stabilizes the lateral dose gradient.
- **Machine Specificity** Settings do not transfer from the literature or other systems without verification. Characterize your beam first; then optimize spacing values that match what your machine.
- **Our preferred settings for Inova's IBA Proteus®PLUS**
  - Relative layer = 0.6
  - Relative spot = 0.6

6c | Optimization philosophy

Robust Optimization: The Pressure Valve

- **The Concept** Robust optimization scenarios apply pressure to the system. How you release that pressure determines what the optimizer actually solves for.
  - **Too loose** — the optimizer relieves pressure by allowing dose to drift across scenarios. The nominal plan looks clean. The patient receives something different, possibly unacceptable, every fraction.
  - **Too tight** — the system fails under its own constraints. Something breaks, usually where you weren't watching.
  - **The goal** — minimum viable constraint set that keeps every scenario within clinically acceptable bounds. Not perfect. Controlled with flexibility.
- **What Breaks When You Over-Constrain** Failure is predictable — it just appears in different places:
  - Target coverage degrades in worst-case scenarios
  - Hot spots emerge in structures without robust constraints
  - OAR sparing erodes as the optimizer finds its only available release
  - Dose homogeneity breaks down at SIB level boundaries
  - The optimizer converges to an infeasible local minimum and stops improving
- **The Skill** Learning to read these failure modes is as important as learning to set the constraints. The plan that looks optimized may simply be a plan where the damage is hidden.

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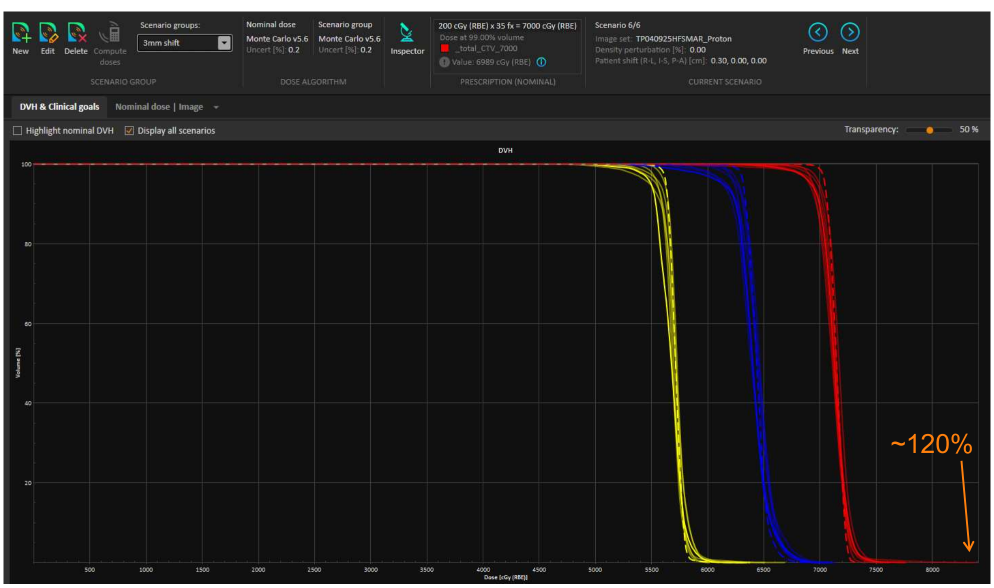
6c | No Robust Max (Rmax)



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6c | Rmax Objective 10000

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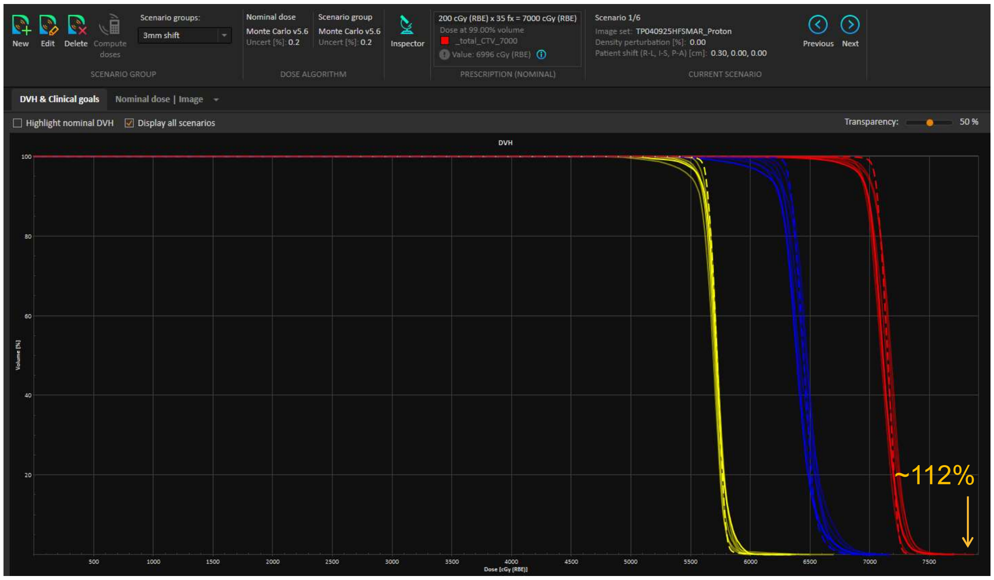

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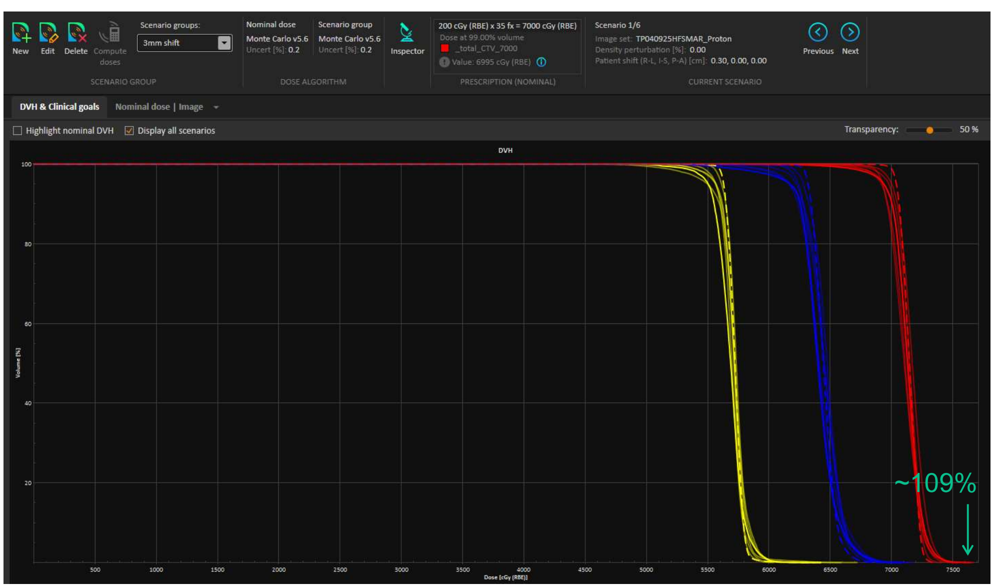
6c | Rmax Const

Inova



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Max dose robust objectives: every SIB level

- **The key practice**
  - **Max dose robust objectives are applied at every SIB dose level — not just the highest**
    - This enforces dose ceilings across all robust scenarios for each target level simultaneously
    - Without this: the optimizer satisfies the nominal max dose constraint while scenarios silently exceed it
- **Clinical implication**
  - When the optimizer is constrained robustly at every dose level, plan behavior under scenario perturbation is more predictable
- **Adaptive planning benefit**
  - Robustly constrained plans are more durable between fractions
  - Moderate anatomy change is more likely to remain within clinical tolerances without triggering a formal replan

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Auto-Class Solution

The objective set behind the H&N PBS class solution

Inova Schar Cancer Institute

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The class-solution premise

One objective set, applied to every H&N case, in priority order.

1

NON-NEGOTIABLE

Coverage

Targets must receive their prescription dose. CTV and GTV MinDvh objectives carry the heaviest target weights and drive the optimization.

2

NON-NEGOTIABLE

Robustness

Coverage must hold under 3 mm setup and 3.5% range uncertainty. Robust MinDvh and robust Max objectives sit alongside their nominal counterparts so the envelope holds across every worst-case scenario.

3

OPPORTUNISTIC — ALARA

OAR sparing

Only after coverage and robustness are protected does the class solution attempt to reduce OAR dose. Defaults are intentionally permissive so they never fight the target; the optimizer drives below threshold wherever geometry permits.

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Eight objective groups

What the class solution builds from the Rx levels, beams, and ROI list.

1 CTV / GTV Coverage
MinDvh ladder, escalating weights

2 Coverage (robust)
MinDvh under uncertainty scenarios

3 Ring Conformality
MaxDose on _ring_CTV_####

4 External DoseFallOff
Three nested tiers, body-wide gradient

5 OAR DoseFallOff
Per-OAR threshold from lookup table

6 Plan SIB Max (constraint)
103.5% absolute hotspot ceiling

7 Per-Beam Max (constraint)
68.5% single-field contribution cap

8 Robust Max (objective)
108.5% under worst-case scenarios

Inputs: target Rx levels · beam list · OAR names auto-scanned from the structure set (ROI metadata: Type = Organ AND OrganType = OrganAtRisk).

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Target coverage — the MinDvh ladder

Stacked objectives push both coverage AND uniformity at every Rx level.

CTV (per target, nominal)

Dose	Volume	Weight	Purpose
Rx × 1.000	100.00 %	350	Floor — full-volume coverage
Rx × 1.005	99.95 %	250	Tighten the toe
Rx × 1.010	99.00 %	150	Uniformity push

Three stacked MinDvh objectives at each Rx level. Reading together: every CTV voxel must be at Rx; nearly all must be 0.5% above; the bulk must be 1% above. Weights rise toward the floor so the optimizer prioritizes full coverage before chasing upper-tail uniformity.

GTV (per target, nominal)

Dose	Volume	Weight	Purpose
Rx × 1.010	100.00 %	901	Single heavy push — gross disease never undercovers

Why GTV weight = 901

A single dominant objective is intentional. The GTV is the visible disease — it should pull dose hardest, with no competing volume-uniformity tiers stealing weight. The pull is balanced against the surrounding CTV ladder so hot spots remain centered on gross disease.

SIB de-dup
When a recognized GTV shares a dose level with its CTV, only one set of ring / control-max objectives is created — but BOTH MinDvh ladders apply.

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Robustness — the parallel stack

Coverage must hold under 3 mm setup + 3.5% range, universally across all beams.

Scenario sampling
3 mm setup uncertainty · 3.5% range uncertainty · Universal mode (single setting applied to every beam — not per-beam).

Highest-Rx target (e.g. 7000 cGy)

Three robust MinDvh objectives stack on top of nominal:

Dose	Volume	Weight
Rx × 0.98	98%	98
Rx × 0.97	97%	197
Rx × 0.97	95%	**305**

Other SIB targets (e.g. 6300 / 5600 cGy)

Two robust MinDvh objectives — leaner stack:

Dose	Volume	Weight
Rx × 0.97	97%	197
Rx × 0.97	95%	**305**

GTV robust Rx × 0.98 at 98% volume, weight 98 · one objective per GTV. Mirrors the nominal GTV push under uncertainty scenarios.

Also robust Group 8 — Robust Max on each _controlMax structure (Rx × 1.085, weight 777). Hot-spot suppression under worst-case scenarios.

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Conformality — Rings + the SIB hotspot ceiling

Two control structures per Rx level shape the dose envelope and cap absolute hotspot.

OBJECTIVE

Group 3 — Ring Conformality

ROI	`_ring_CTV_####`
Type	`MaxDose`
Dose	`Rx (at the matching dose level)`
Weight	`20`

What it does

A thin shell ROI built outside each CTV by the OptiPTVCTVcreator prerequisite script. MaxDose set AT the Rx forces dose to fall immediately outside the target.

Why

Without this, the optimizer can hit MinDvh coverage by overshooting into the ring volume. The ring is the geometric tool that says: coverage ends here.

CONSTRAINT

Group 6 — Plan SIB Max (constraint)

ROI	`_controlMax_CTV_####`
Type	`MaxDose`
Dose	`Rx × 1.035 (103.5%)`
Weight	`1.0 · constraint = hard limit`

What it does

A controlMax shell ROI extending further outward. Applied as a CONSTRAINT, not an objective — the optimizer treats it as a hard ceiling.

Why

Caps absolute hotspot at 103.5% of the dose level it controls. One per unique Rx level so each SIB tier gets its own ceiling — not just the highest Rx.

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6e | OBJECTIVE & CONSTRAINT LOGIC

Inova

OAR DoseFallOff — designed not to fight

Proximity-based thresholds, radiosensitivity-tiered weights, one per OAR.

The non-conflict principle

Each OAR gets ONE DoseFallOff objective. The low-dose value is set to where the OAR can plausibly be driven without geometry making the objective fight the target.

Two key design choices

Proximity-based, not protocol-based.
Threshold reflects how close the OAR sits to the target — not its tolerance dose. ALARA emerges from the optimizer driving below threshold wherever geometry permits.

High dose = highest MinDvh dose.
Same anchor as External DFO — keeps the OAR falloff envelope consistent with the coverage goal, not the bare Rx.

OAR lookup table (excerpt)

OAR	Low dose (cGy)	Weight	Tier
BrainStem	1400	1.0	**Serial, high**
OpticChiasm	2100	1.0	**Serial, high**
SpinalCord	1400	1.0	**Serial, high**
Parotid_L / R	700	2.0	**Parallel, push**
Larynx	1400	1.0	**Parallel, std**
Cochlea_L / R	700	0.2	**Sensitive, low**
Lens_L / R	500	0.1	**Sensitive, low**
Mandible	4200	0.5	**Close, lenient**
Glnd_Submand_L / R	2800	0.1	**Close, lenient**

Distance: 1.0 cm · Atypical OARs (not in the table) get low dose 1400 cGy, weight 0.1, and applied last with user review.

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Robust Max — the 108.5% safety net

Hot-spot suppression under worst-case scenarios.

ROI	TYPE	DOSE	WEIGHT	KIND
_controlMax_CTV_####	MaxDose · Robust	Rx × 1.085 (108.5%)	777	Objective

What it controls

Layered onto the same _controlMax shell as the Plan SIB Max (Group 6) and Per-Beam Max (Group 7). Three independent dose limits act on one ROI: a 103.5% hard ceiling nominal, a 68.5% per-beam ceiling, and this 108.5% robust soft ceiling.

One per unique Rx level

SIB 7000 / 6300 / 5600 → three Robust Max objectives.

Weight is tunable

Default is a starting point; increased on subsequent runs to tighten the hot-spot envelope.

The full Auto-Class Solution inventory

Every objective, in the order applied, with its formula.

#	Group	ROI	Type	Dose / Threshold	Vol	Wt	Notes
1	CTV Coverage	Each CTV target	MinDvh	Rx × 1.010	99.00%	150	Per CTV
1	CTV Coverage	Each CTV target	MinDvh	Rx × 1.005	99.95%	250	Per CTV
1	CTV Coverage	Each CTV target	MinDvh	Rx × 1.000	100.0%	350	Per CTV
1	GTV Coverage	Each GTV target	MinDvh	Rx × 1.010	100.0%	901	Per GTV
2	CTV Robust (high)	Highest-Rx CTV	MinDvh / R	Rx × 0.98	98.00%	98	Highest Rx only
2	CTV Robust	Each CTV target	MinDvh / R	Rx × 0.97	97.00%	197	Per CTV
2	CTV Robust	Each CTV target	MinDvh / R	Rx × 0.97	95.00%	305	Per CTV
2	GTV Robust	Each GTV target	MinDvh / R	Rx × 0.98	98.00%	98	Per GTV
3	Ring Conformality	_ring_CTV_####	MaxDose	Rx (matching)	–	20	Per unique Rx
4	External DFO	External	DoseFallOff	Hi=max MinDvh → 24% maxRx @ 1.0 cm	–	0.10	
4	External DFO	External	DoseFallOff	Hi=max MinDvh → 40% maxRx @ 1.0 cm	–	0.50	
4	External DFO	External	DoseFallOff	Hi=max MinDvh → 70% maxRx @ 0.65 cm	–	1.00	
5	OAR DoseFallOff	Each standard OAR	DoseFallOff	Hi=max MinDvh → lookup low @ 1.0 cm	–	lookup	Per OAR
5	OAR DoseFallOff	Each atypical OAR	DoseFallOff	Hi=max MinDvh → 1400 cGy @ 1.0 cm	–	0.1	Applied last
6	Plan SIB Max	_controlMax_CTV_####	MaxDose / C	Rx × 1.035	–	1.0	Hard constraint
7	Per-Beam Max	_controlMax_CTV_####	MaxDose / C	Rx × 0.685	–	1.0	× beams × Rx levels
8	Robust Max	_controlMax_CTV_####	MaxDose / R	Rx × 1.085	–	777	Objective, not constraint

/ R = robust   / C = constraint   Hi = high-dose level   Wt = weight

6e | **WORKED EXAMPLE**

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SIB 7000 / 6300 / 5600 cGy, 3 fields

What the class solution actually writes to the optimization panel.

TARGETS	BEAMS	HIGHEST MINDVH	ROBUSTNESS
CTV_7000 · CTV_6300 · CTV_5600	3 (named 1, 2, 3)	7070 cGy → DFO Hi	3 mm + 3.5% · Universal

Objectives written

CTV Coverage (3 per × 3 CTVs)	9
CTV Robust (3 + 2 + 2)	7
Ring Conformality (1 per Rx)	3
External DFO (3 tiers)	3
OAR DoseFallOff (one per OAR)	n
Plan SIB Max (1 per Rx)	3
Per-Beam Max (3 beams × 3 Rx)	9
Robust Max (1 per Rx)	3
Total (excluding OARs)	**37 + n**

Objectives written for CTV_7000 (one Rx level shown)

Group	ROI	Type	Dose	Vol	Wt	Note
Cov	CTV_7000	MinDvh	7070	99.00%	150	
Cov	CTV_7000	MinDvh	7035	99.95%	250	
Cov	CTV_7000	MinDvh	7000	100.0%	350	
Rob	CTV_7000	MinDvh R	6860	98.00%	98	high-Rx 3rd tier
Rob	CTV_7000	MinDvh R	6790	97.00%	197	
Rob	CTV_7000	MinDvh R	6790	95.00%	305	
Ring	_ring_CTV_7000	MaxDose	7000	–	20	
Plan Max	_controlMax_CTV_7000	MaxDose C	7245	–	1.0	constraint
Beam Max	_controlMax_CTV_7000	MaxDose C	4795	–	1.0	× 3 beams
Rob Max	_controlMax_CTV_7000	MaxDose R	7595	–	777	objective

Same pattern repeats for CTV_6300 and CTV_5600 with their own ring, controlMax, plan-max, per-beam-max, and robust-max set. Three SIB levels → 3 full stacks of the above.

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6f | Case Walkthrough

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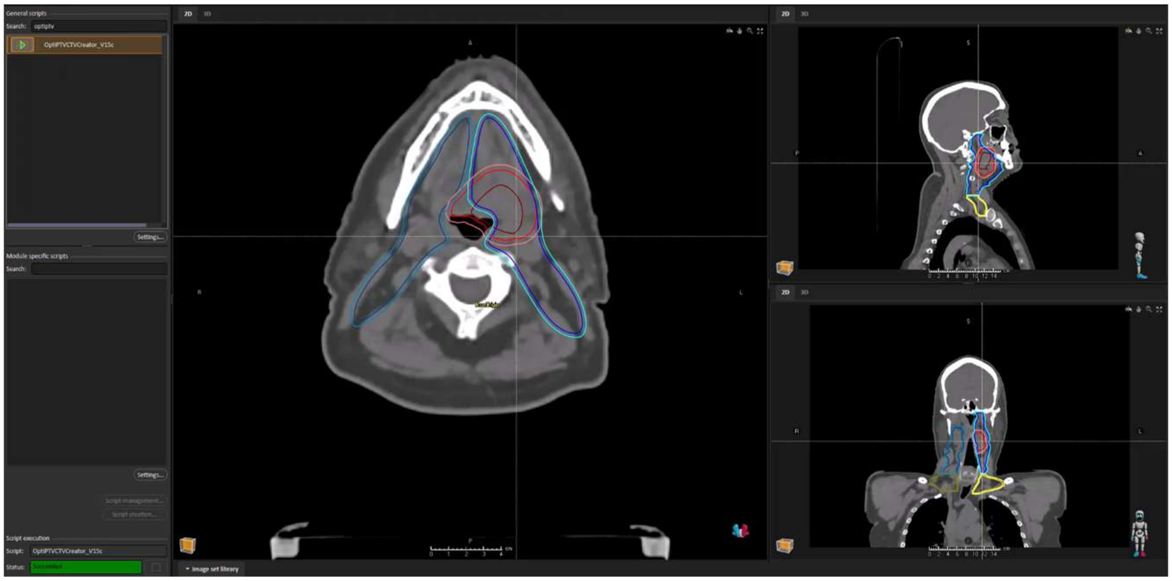
6f | Case Walkthrough – OptiPTVCTV Target Structures Creator Script



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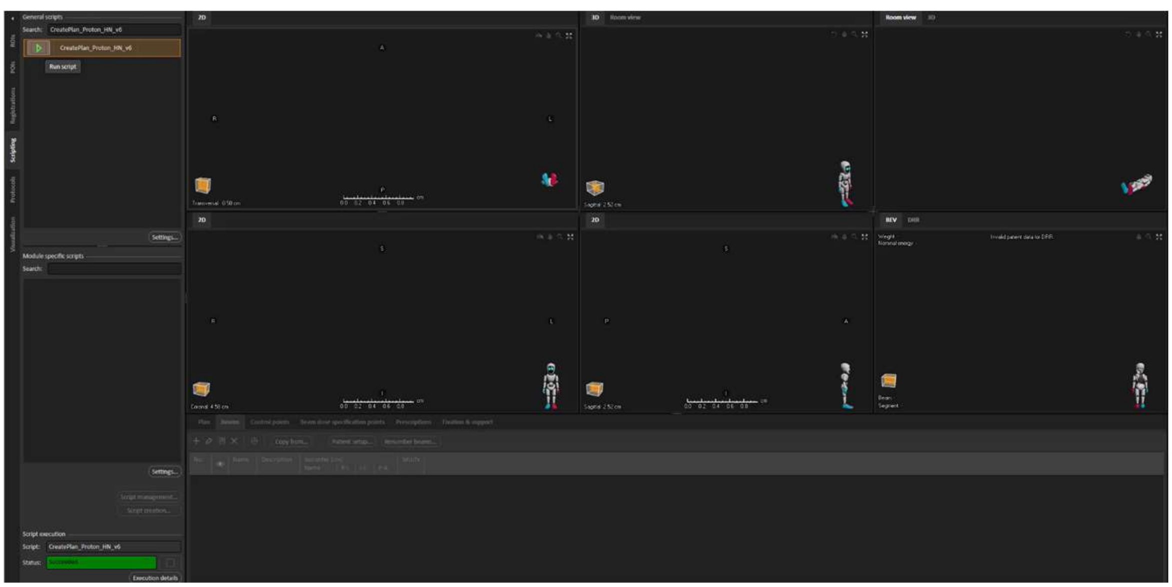
6f | Plan Creation script – PBS HN



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6f | Spot Blocking Script – ROI creation and assignment

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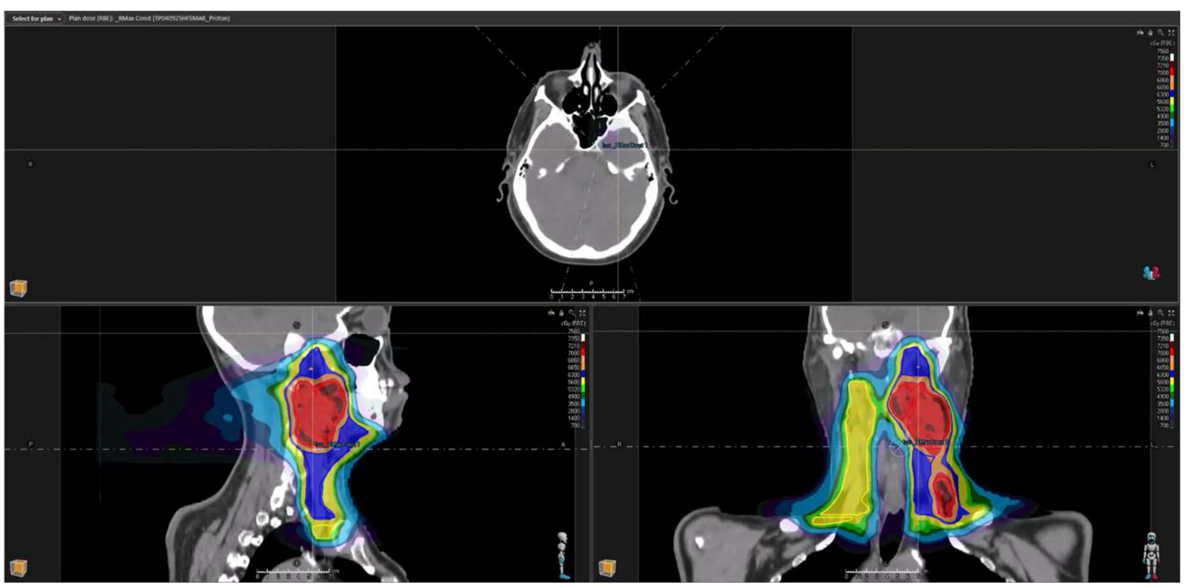
Plan Results – after a single run



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Adaptive Planning: The Payoff

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ADAPTIVE PLANNING

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The payoff

PBS H&N replans are routine — every framework choice compounds here.

Built for Fx 1. Built for Fx 30.

The standardization, templates, and scripts you've seen are not initial-plan tools. **They ARE the adaptive workflow.** The framework that produced the original plan applies — unchanged — at replan.

KEY ENABLER

Compatible with approved and partially approved RT structure sets

Scripts create derived ROIs, build new beamsets, and apply the full objective stack against the clinically-locked structure set. No re-segmentation. No parallel working copy. No rebuilding from scratch.

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WHAT THIS DELIVERS

Higher-value adaptive planning

Three returns the framework delivers under adaptive pressure.

1

SAME STANDARD, NEW ANATOMY

Dosimetric quality preserved

The adaptive plan inherits the same class solution, the same robustness envelope, the same hot-spot controls. Not a degraded copy — the original standard, applied to the new anatomy.

2

MINUTES, NOT HOURS

Fast turnaround

The planner adjusts; the framework is not rebuilt. Adaptive planning shifts from reconstruction to refinement — and replan time stops scaling with plan complexity.

3

CAPACITY PRESERVED FOR JUDGMENT

Lower dosimetry cost

Dosimetry effort is reserved for the work that actually requires clinical judgment. Adaptive volume no longer compounds linearly with replan rate.

Adaptive planning becomes refinement, not reconstruction.

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Plan Quality

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PBS-DERIVED CLINICAL GOALS

Raising the bar on OAR sparing

Retrospective review of Inova PBS H&N plans → new OAR goals calibrated to observed achievement, not photon precedent.

STRUCTURE	● ACHIEVED → ● NEW GOAL vs. ○ CURRENT	VALUES	REDUCTION
Lungs Apices *V20*		25 → **10** %	−60%
Esophagus *mean*		34 → **15** Gy	−56%
BrainStem *max 0.03cc*		54 → **32** Gy	−41%
Lips *mean*		15 → **10** Gy	−33%
Lips *max 0.03cc*		30 → **20** Gy	−33%
SpinalCord *max*		45 → **30** Gy	−33%
Glottis *mean*		30 → **22** Gy	−27%
Parotid *D50*		20 → **16** Gy	−20%
PharynxConst *mean*		54 → **44** Gy	−19%
Parotid *mean*		24 → **20** Gy	−17%
Oral Cavity *mean*		32 → **27.5** Gy	−14%
Esophagus *max 0.03cc*		45 → **40** Gy	−11%
Esophagus *max*		45 → **45** Gy	—
Glottis *max 0.03cc*		45 → **45** Gy	—

PBS plans consistently deliver OAR doses well below photon-derived goals. New goals codify that reality — and hold every future plan to it.

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PBS-DERIVED CLINICAL GOALS

Priority	ROI/POI	Clinical goal
8	BrainStem	At most 3200 cGy (RBE) dose at 0.03 cm³ volume
8	Cavity_Oral-PTV	At most 2750 cGy (RBE) average dose
8	Esophagus	At most 1500 cGy (RBE) average dose
8	Esophagus	At most 4000 cGy (RBE) dose at 0.03 cm³ volume
8	Glottis	At most 2200 cGy (RBE) average dose
8	Lips	At most 1000 cGy (RBE) average dose
8	Lips	At most 2000 cGy (RBE) dose at 0.03 cm³ volume
8	Lung Apices	At most 10.00 % volume at 2000 cGy (RBE) dose
8	Parotid_L	At most 1500 cGy (RBE) dose at 50.00 % volume
8	Parotid_L	At most 2000 cGy (RBE) average dose
8	Parotid_R	At most 1500 cGy (RBE) dose at 50.00 % volume
8	Parotid_R	At most 2000 cGy (RBE) average dose
8	PharynxConst	At most 4400 cGy (RBE) average dose
8	SpinalCord	At most 3000 cGy (RBE) dose at 0.03 cm³ volume
	3cm Column	At most 2100 cGy (RBE) average dose
	AreaPostrema	At most 3000 cGy (RBE) dose at 0.03 cm³ volume
	Brain	At most 1.00 cm³ volume at 6500 cGy (RBE) dose
	Brain	At most 6000 cGy (RBE) dose at 0.03 cm³ volume
	BrainStem	At most 1.00 cm³ volume at 6000 cGy (RBE) dose
	BrainStem	At most 3600 cGy (RBE) average dose
	BrainStem	At most 5400 cGy (RBE) dose at 0.03 cm³ volume
	Cavity_Oral-PTV	At most 2000 cGy (RBE) average dose
	Cavity_Oral-PTV	At most 3200 cGy (RBE) average dose
	Cavity_Oral-PTV	At most 6500 cGy (RBE) dose at 0.03 cm³ volume
	Cerebellum	At most 5400 cGy (RBE) dose at 0.03 cm³ volume
	Cochlea_L	At most 3500 cGy (RBE) average dose
	Cochlea_L	At most 6000 cGy (RBE) dose at 0.03 cm³ volume
	Cochlea_R	At most 3500 cGy (RBE) average dose
	Cochlea_R	At most 6000 cGy (RBE) dose at 0.03 cm³ volume
	Esophagus	At most 10.00 cm³ volume at 3500 cGy (RBE) dose
	Esophagus	At most 2000 cGy (RBE) average dose
	Esophagus	At most 3400 cGy (RBE) average dose
	Esophagus	At most 4500 cGy (RBE) dose at 0.03 cm³ volume

	Eye_L	At most 2000 cGy (RBE) average dose
	Eye_L	At most 3500 cGy (RBE) dose at 0.03 cm³ volume
	Eye_R	At most 2000 cGy (RBE) average dose
	Eye_R	At most 3500 cGy (RBE) dose at 0.03 cm³ volume
	Glnd_Lacrimal_L	At most 2000 cGy (RBE) dose at 50.00 % volume
	Glnd_Lacrimal_L	At most 2400 cGy (RBE) average dose
	Glnd_Lacrimal_R	At most 2000 cGy (RBE) dose at 50.00 % volume
	Glnd_Lacrimal_R	At most 2400 cGy (RBE) average dose
	Glnd_Submand_L	At most 2000 cGy (RBE) dose at 50.00 % volume
	Glnd_Submand_L	At most 2400 cGy (RBE) average dose
	Glnd_Submand_R	At most 2000 cGy (RBE) dose at 50.00 % volume
	Glnd_Submand_R	At most 2400 cGy (RBE) average dose
	Glottis	At most 3000 cGy (RBE) average dose
	Glottis	At most 4500 cGy (RBE) dose at 0.03 cm³ volume
	Lens_L	At most 700 cGy (RBE) dose at 0.03 cm³ volume
	Lens_R	At most 700 cGy (RBE) dose at 0.03 cm³ volume
	Lips	At most 1500 cGy (RBE) average dose
	Lips	At most 3000 cGy (RBE) dose at 0.03 cm³ volume
	Lung Apices	At most 25.00 % volume at 2000 cGy (RBE) dose
	Mandible	At most 7200 cGy (RBE) dose at 0.03 cm³ volume
	Mandible-PTV	At most 7000 cGy (RBE) dose at 0.03 cm³ volume
	OpticChiasm	At most 1.00 cm³ volume at 6000 cGy (RBE) dose
	OpticChiasm	At most 5400 cGy (RBE) dose at 0.03 cm³ volume
	OpticNrv_L	At most 1.00 cm³ volume at 6000 cGy (RBE) dose
	OpticNrv_L	At most 5400 cGy (RBE) dose at 0.03 cm³ volume
	OpticNrv_R	At most 1.00 cm³ volume at 6000 cGy (RBE) dose
	OpticNrv_R	At most 5400 cGy (RBE) dose at 0.03 cm³ volume
	Parotid_L	At most 2000 cGy (RBE) dose at 50.00 % volume
	Parotid_L	At most 2400 cGy (RBE) average dose
	Parotid_R	At most 2000 cGy (RBE) dose at 50.00 % volume
	Parotid_R	At most 2400 cGy (RBE) average dose
	PharynxConst	At most 5400 cGy (RBE) average dose
	SpinalCord	At most 4500 cGy (RBE) dose at 0.03 cm³ volume
	SpinalCord_PRV05	At most 5000 cGy (RBE) dose at 0.03 cm³ volume
	Teeth_Gingiva	At most 3000 cGy (RBE) average dose
	TemporalLobe	At most 6000 cGy (RBE) dose at 0.03 cm³ volume
	Tongue	At most 5500 cGy (RBE) average dose

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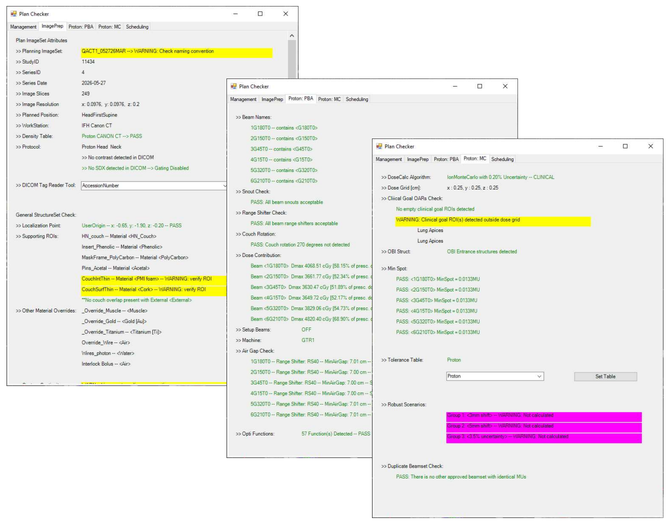
8 | Plan QA

Clinical Goals, Robust Eval, Plan Check Script

- **Plan check workflow**
  - Target coverage at every SIB level: nominal and worst-case scenario
  - Heterogeneity evaluation nominal and worst-case scenario
  - OAR dose: nominal and worst-case scenario — both matter
  - Field contribution: verify no single field exceeds 70% to any target voxel
  - Blocking structure integrity: spot maps reviewed for each field
  - Naming and structure completeness: scripted QA check



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Future Directions

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Future direction — a self-improving class solution

The current Auto-Class Solution applies fixed defaults from a lookup table. The next iteration replaces those defaults with geometry-aware logic and a built-in feedback loop from our own planning data.

- **1. Smart OAR–target spatial logic** The script evaluates the geometric relationship between each serial OAR and the target — distance, overlap, available dose gradient — and derives the appropriate low-dose threshold and weight automatically. Per-patient analysis replaces static defaults.
- **2. Auto-generated sub-target optimization structures** When a target dose level exceeds an adjacent OAR's tolerance, the script builds the protective geometry on its own: dose-graded sub-targets, CTV-minus-OAR shells, OAR-adjacent control structures. Each receives its own objective tier. The planner stops carving these by hand.
- **3. Data logging and statistical learning** Every plan logs pre-planning anatomy (volumes, distances, overlap) and post-planning dosimetric outcomes (achieved DVH points per OAR). The dataset grows with every case and drives the next generation of defaults — serial OARs tuned against max-dose patterns, parallel OARs against mean-dose distributions, and objective weights adjusted wherever the data shows consistent headroom.

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Where the field is heading

- **LET optimization**
  - LET (Linear Energy Transfer) increases as protons slow near end of range — higher LET = higher biological effectiveness per unit dose
  - Current practice: LET is not optimized — it falls where it falls based on geometry
  - The opportunity: steer high-LET regions away from brainstem, cord, and cochlea — structures most sensitive to high-LET biological effects
    - Or even remove areas of concern completely
  - For H&N planners: this is an optimization layer added on top of current physical dose optimization

- **RBE optimization**
  - Current standard: constant RBE of 1.1 across all tissue and all depths
  - Reality: RBE varies by tissue type, dose rate, LET, and fractionation
  - RBE optimization: explicitly model biological uncertainty and optimize for biological dose distribution
  - For H&N planners: changes how OAR constraints are defined and applied — understanding physical dose planning is the prerequisite

- **Proton arc therapy**
  - Continuous beam delivery over a range of gantry angles — analogous to VMAT for protons
  - Potential advantages: reduced treatment time, improved dose conformality, new optimization solution space
  - Current status: active clinical development — possible to enter routine practice within this decade

1. **Robust optimization is a design philosophy**
   Build the framework before you open the optimizer — clean CTVs, blocking structures, and ROI library first.
2. **Spot blocking is our standard practice**
   Every H&N case — not a workaround, a foundation.
3. **Max Dose Robust Control on every SIB target level**
   Too open: scenarios run wild. Unacceptable perturbed results can hide in DVHs — intentional mitigation is required.
4. **Everything was designed for adaptive planning**
   The payoff at replan time is directly proportional to the rigor of the original planning workflow.
5. **The gains are available now**
   Static-field, constant-RBE PBS H&N has significant untapped potential

Thank You

for your time
and attention

AAMD 2026

H&N PBS Planning Workflows

Inova Schar Cancer Institute
Proton Therapy Program

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Thank you

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Appendix: Supplemental Notes

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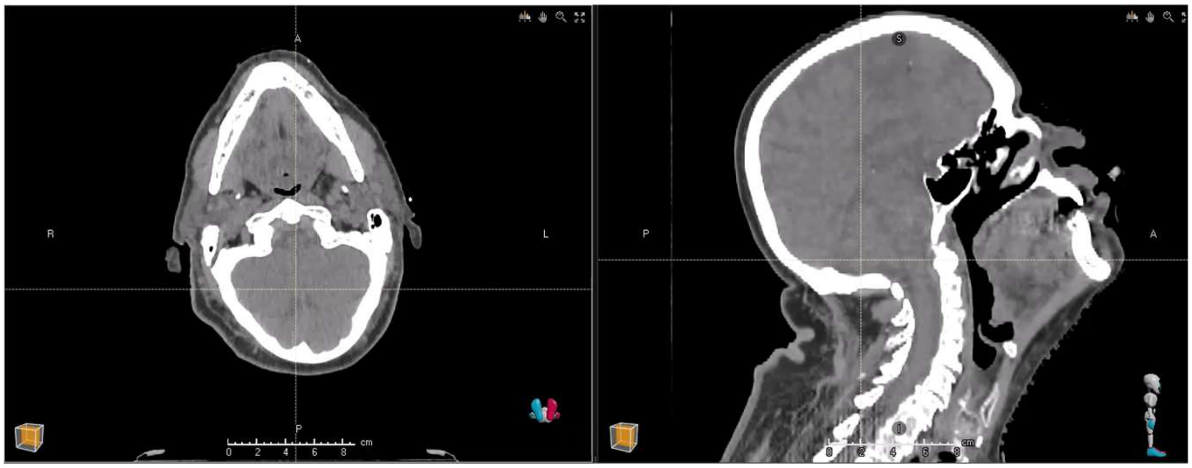
5 | Field Arrangement – Neck Folds



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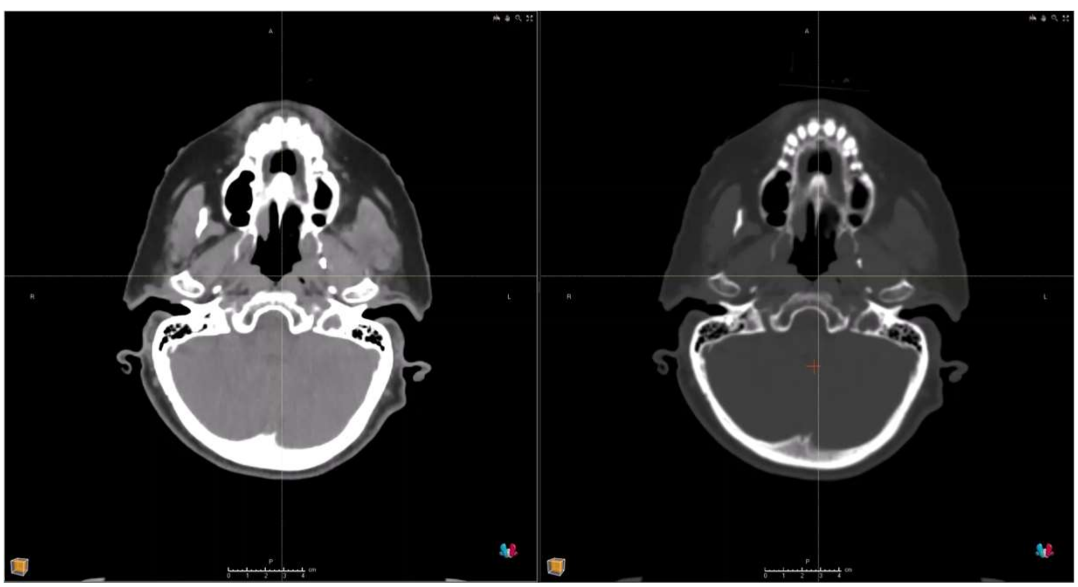
5 | Field Arrangement – hardware



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5 | Field Arrangement – prior RT

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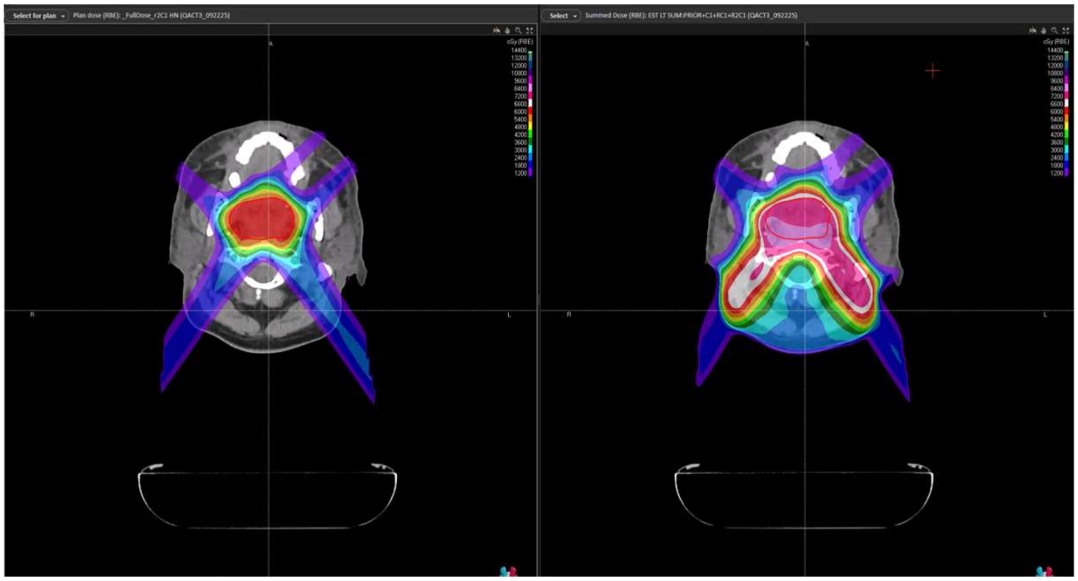

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Building H&N Blocking ROIs step-by-step manually

A treatment-planning-system–agnostic procedure

- This handout describes how to build the proton (PBS) blocking structures for a head-and-neck plan manually, using only the generic structure-editing tools that every planning system provides. No scripting is required. Wherever the automated tool would call a function, this guide substitutes the equivalent hand operation (for example, "subtract A from B" instead of opening an algebra dialog).
- The blocks are *spot-placement / range-margin avoidance* structures. They are not targets or true OARs; they tell the optimizer where **not** to place spots for a given field. Review every structure visually before optimizing.

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Generic operations used in this guide

These are the only building blocks you need. Every planning system has an equivalent; the names may differ.

- **Make a box** — create a rectangular-solid ROI of a given size (R-L × A-P × S-I) centered at a given point.
- **Bounding box / extent** — read the most superior, inferior, anterior, posterior, left, and right edges of an existing structure.
- **Expand / contract** — grow or shrink a structure by a uniform or direction-specific margin (in cm).
- **Combine (union)** — merge two or more structures into one.
- **Intersect** — keep only the overlap of two structures.
- **Subtract** — remove structure B from structure A.
- **Crop to slices** — limit a structure to a superior–inferior range.

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Getting started

- **Convention used in this guide (head-first supine):**
  - patient LEFT is screen right, patient RIGHT is screen left.
  - "Superior/inferior" refers to slice position. If your patient is setup in a different orientation, mirror left/right accordingly.

Reference measurements to take first

- Read and write down these extents before you start — every block depends on them:
  - **CTV (total) inferior slice** — the lowest slice of the total CTV.
  - **Larynx superior slice.**
  - **Oral cavity inferior slice.**
  - **Parotids inferior slice** — the lowest slice of either parotid.
  - **External (body) bounding box** — overall width, depth, and center.
  - **CT slice thickness** (e.g., 0.25 cm) — needed for "one slice" offsets.

Housekeeping

- **Naming and housekeeping**
  - Suggested names (adjust to your standard):
  - Mark every finished block as **excluded from export** and display it as filled colorwash so it is easy to review.
  - Delete all temporary/intermediate structures when finished.

Block	Suggested ROI name
Anterior block	_BLOCK AP
Posterior block	_BLOCK PA
Left-extending oblique	_BLOCK Oblique_L
Right-extending oblique	_BLOCK Oblique_R
Vertex block	_BLOCK Vertex
Brainstem block (optional)	_BLOCK Brainstem
Per-field combined block	_BLOCK Field N

_BLOCK AP

- Shadows the oral cavity for the anterior (≈ G0) field.
  - Read the oral cavity bounding box: note its center and its superior–inferior length.
  - **Make a box** centered on the oral cavity center:
    - **20 cm** left–right
    - **20 cm** anterior–posterior
    - **Superior–inferior** = the oral cavity's own S-I length (top and bottom match the oral cavity).
  - Rename it _BLOCK AP.

_BLOCK PA

- Shadows the posterior tissues for posterior/PA fields, while leaving a junction gap below the anterior block and staying clear of spared submandibular glands, the shoulders, and the lung apices.
  - **Determine the superior edge (ceiling).**
    - Start from the oral cavity inferior slice, move **0.5 cm** inferior, then move an additional **2 cm** inferior (junction gap). This is your starting ceiling.
    - For each submandibular gland you intend to **spare** (i.e., it is *not* mostly inside the CTV — see note), if its inferior edge is lower than the current ceiling, lower the ceiling to **1 cm below that gland's inferior edge.**
- **Sparing check (manual):** a submandibular gland is considered "in the target" (do not lower the ceiling for it) if roughly **75% or more** of its volume lies inside the CTV. Otherwise treat it as spared.
  - **Determine the floor (inferior edge):** CTV inferior slice **minus 5 cm**.
  - **Determine the lower clearance limit** (the block must not dip below this):
    - **1.2 cm** above the lung apices superior edge, and
    - **1 cm** above the shoulder reference superior edge (if you use one).
    - Take the **higher** of these as a lower bound. If this bound ends up above your ceiling, the block is very short — flag for review.
  - **Make a box:**
    - Left–right = External width **+ 4 cm**
    - Anterior–posterior = External depth **+ 4 cm**
    - Superior–inferior = from the ceiling (step 1) down to the floor (step 2), centered on the External center in L-R and A-P.
  - Rename it _BLOCK PA.

Building H&N Blocking ROIs step-by-step

_BLOCK Oblique_L, _BLOCK Oblique_R

- Each oblique field is blocked **contralateral** to where the beam enters, so the beam can treat its own side without the optimizer placing spots across midline. The ipsilateral CTV is carved out so spots remain available over the near-side target.
  - **Which side extends which way:**
    - **LAO** (enters patient LEFT) → block extends to patient **RIGHT**, crop the **LEFT** CTV half → _BLOCK Oblique_R.
    - **RAO** (enters patient RIGHT) → block extends to patient **LEFT**, crop the **RIGHT** CTV half → _BLOCK Oblique_L.
  - **3a. Find the per-slice midline**
  - The "midline" is the side-to-side center of the central airway/swallowing structures, slice by slice. Combine the available midline sources into one temporary structure:
    - Glottis, Larynx, Pharyngeal constrictors, Trachea, Esophagus (use whichever exist). Optionally include the spinal cord to fill gaps.
  - On each slice, the left–right center of this combined structure is your midline for that slice. (Working by hand, you can approximate this as the patient's anatomic midline through the airway; the script samples it per slice.)
  - **3b. Define the superior–inferior range**
    - **Inferior** = CTV inferior slice **minus 5 cm.**
    - **Superior** = the **lower** of:
      - Larynx superior slice **+ 1 cm**, and
      - Oral cavity inferior slice **− 3 cm**.

Building H&N Blocking ROIs step-by-step

_BLOCK Oblique_L, _BLOCK Oblique_R

  - **3c. Build one oblique (repeat mirrored for the other)**
  - Example for the **right-extending** block (used by an LAO field):
    - **Make a box** spanning the S-I range from 3b:
      - Its **medial face sits on the midline**, and it extends **20 cm toward patient RIGHT** (so it covers the right side of the neck).
      - **45 cm anterior** and **30 cm posterior** about the airway center.
    - **Carve out the ipsilateral (LEFT) CTV:**
      - Take the CTV and keep only its **LEFT half** (intersect with a half-space on the patient-left side of the midline).
      - **Expand** that left-CTV half by the crop margin — **0.9 cm** in all directions, **plus an extra 5 cm anteriorly** (this relieves the medial- anterior "hook" over the near-side target).
      - **Subtract** this expanded left-CTV from the box.
    - (Optional) If a brainstem block is in use, **combine** it into this oblique.
    - Rename _BLOCK Oblique_R.
    - For the **left-extending** block (RAO field): mirror everything — extend 20 cm toward patient LEFT, and crop the **RIGHT** CTV half.

_BLOCK_Vertex

- For a non-coplanar / couch-kicked vertex field. A single large box that shadows everything below the parotids down to the neck floor.
  - **Superior edge:** parotids inferior slice, moved **one CT slice inferior** (e.g., 0.25 cm if that is your slice thickness).
  - **Inferior edge:** CTV inferior slice **minus 5 cm** (same floor as the other blocks).
  - **Make a box** spanning that S-I range:
    - Left–right = External width **+ 4 cm**
    - Anterior–posterior = External depth **+ 4 cm**
    - Centered on the External center in L-R and A-P.
  - Rename _BLOCK Vertex.
- The box is deliberately broad so it fully shadows the cross-section beneath the parotids. If you prefer it to hug the neck, intersect it with the External contracted by a small margin, or reduce the +4 cm padding.

_BLOCK_Brainstem

- A simple symmetric box over the brainstem region.
  - Read the brainstem bounding box (center and S-I length).
  - **Make a box** centered on the brainstem:
    - Left–right = brainstem width
    - Anterior–posterior = **45 cm anterior, 45 cm posterior**
    - Superior–inferior = the brainstem's own S-I length.
  - Rename _BLOCK Brainstem. It is only combined into oblique fields, never the midline. There is an intentional gap at the oral cavity.

Assemble one block per field (_BLOCK Field N)

- For each treatment field, combine the relevant component(s) above into a single structure named for that field. Classify each field by its gantry angle (and couch, for vertex):

Field type	Approx. gantry	Component to use
Anterior (AP)	≈ 0°	_BLOCK AP
LAO (enters left)	≈ 15–75°	_BLOCK Oblique _R
RAO (enters right)	≈ 285–345°	_BLOCK Oblique _L
Posterior / PA / posterior-oblique	≈ 105–255°	_BLOCK PA
Lateral	≈ 75–105° / 255–285°	(typically none)
Vertex	any gantry with a couch kick	_BLOCK Vertex

- For each field:
  - **Combine** the component(s) above for that field's type.
  - If you use a **dental-artifact avoidance** structure, **combine** it in as well (so dental scatter regions are blocked on every field).
  - Rename _BLOCK Field N (N = field number) and assign it as that field's spot-avoidance / range-margin structure in the optimizer.

Working on an APPROVED structure set (revision planning)

- When the structure set is **approved/locked**, you usually cannot edit or delete existing approved geometry. There is a reliable manual workaround that mirrors what the automated tool does:
  - Do **not** try to delete or modify approved structures. Leave them alone.
  - Build each block in a **temporary** structure (any name; you will delete it).
  - If the destination block ROI **already exists but is empty** on this CT (no contours on the current image set), you may still **add** geometry to it — most systems permit adding geometry to an empty ROI even on an approved set. Copy/transfer the temporary structure's geometry into that empty ROI.
  - If the destination block ROI **already has contours** on this approved image set, you **cannot** overwrite it. Either:
    - Unapprove the set, clear that ROI's geometry, and rebuild; **or**
    - build under a new ROI name.
  - Delete all temporary structures when finished.
- The key idea: **adding** geometry to a new or empty ROI is allowed even on a locked set; **editing or deleting** existing approved geometry is not.

Reference: geometry parameters at a glance

Parameter	Value
CTV inferior padding (block floor)	5 cm below CTV inferior
Larynx superior margin	+1 cm
Oral-cavity gap (AP build-up)	3 cm below oral cavity inferior
Oblique wall — lateral extent	20 cm to the contralateral side
Oblique wall — anterior / posterior	45 cm / 30 cm
Ipsilateral CTV crop margin	0.9 cm (+5 cm anterior relief)
AP box	20 × 20 cm, S-I matched to oral cavity
Posterior box L-R / A-P	External + 4 cm

Parameter	Value
Posterior junction gap	2 cm below the AP block
Submandibular clearance	1 cm below a spared gland
Submandibular "in target" threshold	≥ 75% inside CTV
Shoulder clearance	1 cm above shoulder reference
Lung apices clearance	1.2 cm above lung apices
Vertex superior offset	1 CT slice below parotids inferior
Vertex box L-R / A-P	External + 4 cm
Brainstem box A-P	45 cm / 45 cm

Always review every block on the planning images before optimization. These structures shape spot placement and should be confirmed by the planner and checked at plan review.

Scripting & automation tools inventory

- **Current tools in clinical use**
  - CreateExternal
  - Remove Wires and BBs
  - Contour HN Dental
  - OptiPTVCTVCreator: automated CTV/PTV generation from clinical contours
  - Blocking structure script: automated field-specific blocking structure generation
  - Optimization class solution loader: automated objective set population
  - Plan Check QA script: automated verification of plan criteria, naming, completeness
  - Adaptive planning workflow scripts: structure transfer and plan initialization for adaptive replanning
- **How these tools were developed**
  - All tools developed in-house by the Inova Dosimetry and Physics team
  - Developed iteratively alongside clinical validation — not in isolation

