**PHILIPS**

Pinnacle³

**Proton Planning**

# Integrated proton–photon treatment planning

## Philips Pinnacle³ Proton Planning specifications

Pinnacle³ Proton Planning is designed to simplify treatment planning for proton therapy. It integrates proton planning for double scattering and uniform scanning within the conventional external beam treatment planning process. It addresses some of the major challenges faced within proton planning today.

The combination of specially designed tools and the seamless integration with existing Pinnacle³ provides an extensive range of  functionalities that offers clinicians the chance to select the appropriate treatment options for the patient and complete their work quickly through improved workflow.
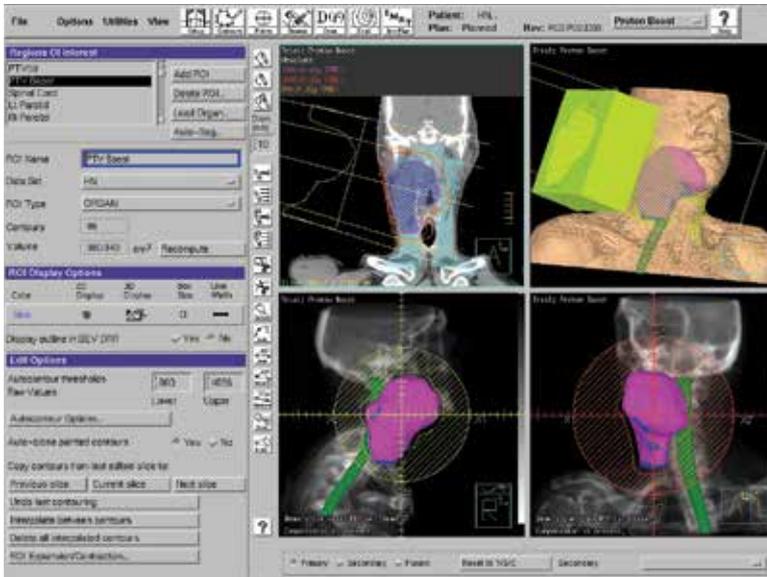
**Provide confidence for integrated photon-proton planning**
Seamless integration within the Pinnacle³ environment
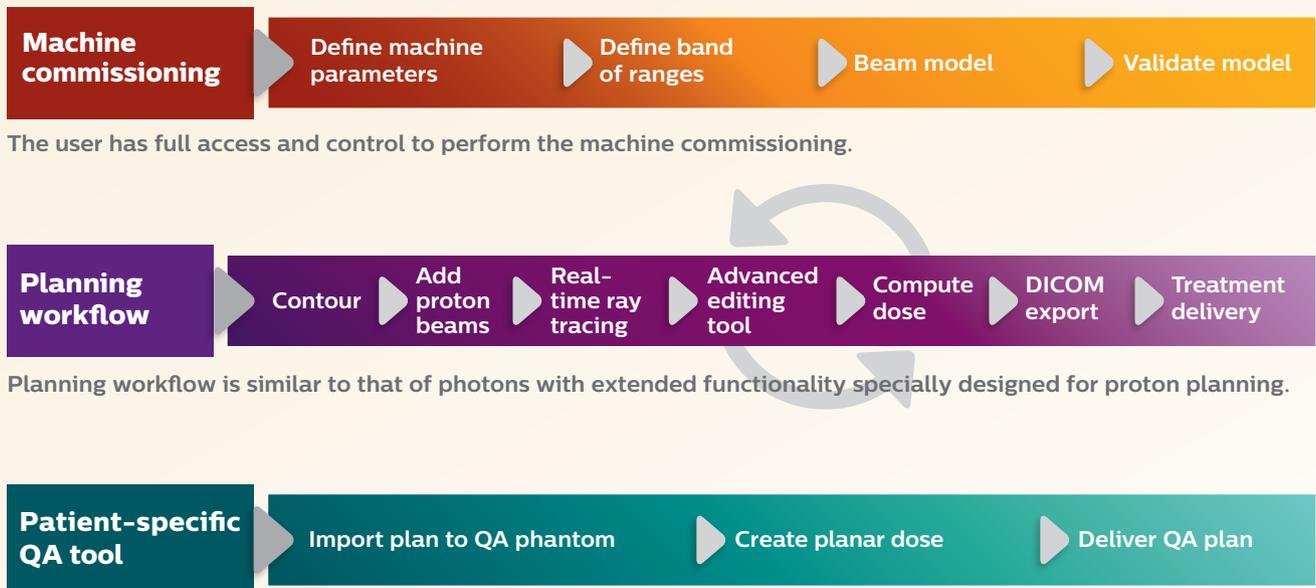
**Accelerate clinical adoption with reduced effort**
Simplified modeling and commissioning process

**Enhance daily planning**
Specially designed tools that address key workflow needs in proton planning

**Figure 1** Pinnacle³ Proton Planning.

# Pinnacle³ Proton Planning workflow

A key advantage of Pinnacle³ is that the commissioning and workflow for proton planning is similar to that of conventional external beam planning, as shown in **Figure 2**. This simplifies clinical implementation and daily use. However, specially designed tools have been introduced to enhance the functionality for proton planning.

| Machine commissioning | Define machine parameters | Define band of ranges | Beam model | Validate model |
|---|---|---|---|---|

The user has full access and control to perform the machine commissioning.

| Planning workflow | Contour | Add proton beams | Real-time ray tracing | Advanced editing tool | Compute dose | DICOM export | Treatment delivery |
|---|---|---|---|---|---|---|---|

Planning workflow is similar to that of photons with extended functionality specially designed for proton planning.

| Patient-specific QA tool | Import plan to QA phantom | Create planar dose | Deliver QA plan |
|---|---|---|---|

Integrated and automated QA process simplifies the plan verification process.

# Integrated Physics interface accelerates commissioning

Pinnacle[3]'s generalized machine model for protons requires limited information about machine components, which reduces the need for incorporating detailed information of the delivery system. This decreases the collection time for measurement data and simplifies the commissioning process.

## Customized machine modeling

For each defined band of ranges, dose model parameter values are determined separately and are modeled as a linear function of the range. This parameter linearization model produces computed profiles that agree with measurement profiles taken for beams within the range band. The ability to edit the fitting parameters lets the user customize the model and provides the tools necessary to change the fitting to achieve the best match between computed and measured profiles during machine modeling.

## Beam model parameters

The input data for modeling the delivery device includes pristine Bragg peaks, effective source size, effective source–to–axis distance, and virtual source–to–axis distance. Pinnacle[3] also provides an interface for accurate modeling of the spread out Bragg peak via measurement data entered by the user.

## Model validation and evaluation

Prior to commissioning the machine, the model's accuracy can be verified in a water phantom using the full 3D dose calculation algorithm. Quantitative comparisons of differences between computed and measured dose are displayed in graphical format to provide easy evaluation and validation of the model.

## Dose algorithm

The dose calculation algorithm uses an improved Bortfeld Bragg Peak fitting function and enhanced Multiple Coulomb Scattering based on Monte Carlo simulated data that boosts accuracy over dose algorithms that use a Water Equivalent Thickness (WET) approximation alone. The dose calculation includes all components of the delivery that are traversed along the proton beam's path including line components (range modulator wheels, degraders), beam limiting devices (apertures), patient-specific modifiers (compensators), and the patient's anatomy.
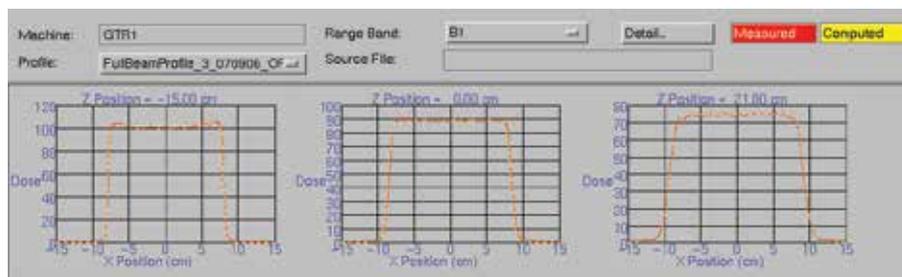


**Figure 2** Comparison of measured (red) and computed (yellow) profiles.

# Planning features that enhance daily workflow

## Real-time beam parameters computation

When the user adds a new proton beam and associates a target ROI to the beam, ray tracing activities are promptly triggered and all beam parameters, including range, modulation, aperture, and compensator, are computed automatically.

By default, the smallest snout that adequately covers the target ROI is selected. The movable snout support allows the user to easily change the air gap between the distal end of the compensator and the surface of the patient.

## Potential collision detection

If the air gap is too small, Pinnacle[3] detects a collision between the compensator and the patient or the table. Detection of collisions during this early phase of planning allows the user to correct the gantry and snout positions to avoid collisions during the treatment.

## Slab management

Pinnacle[3] knows the relationship between snout, slab thickness, and the total number of slabs available per snout. The software will automatically compute the required number of slabs based on the selected snout and range of the beam, reducing unwanted dose.

## Automatic margin selection

Longitudinal dose to the target can be adjusted by adding margins to the proximal or distal edges to account for setup and motion errors. These margins can be added either automatically or manually.

## Advanced tools for compensator

The user can manually adjust the dose distribution by changing the compensator shape using sophisticated tools, including smearing, edge processing, and distal blocking.

- In the Smearing process, a compensator pixel thickness value is re-assigned to the lowest value among its nearest neighbors within a user-specified radius (i.e., the Smear Margin). This mitigates patient motion and setup errors.
- Edge processing adjusts for dose fall-off in the beam penumbral region by automatically applying a meaningful compensator pixel value within the aperture margin so that there is adequate dose coverage to the edges of the target ROI.
- Distal blocking adds thickness to the compensator to "pull away" the dose distribution from a non-target ROI. Ray tracing determines the compensator pixels that can be thickened to pull back the dose away from the distally positioned organ at risk.
- The compensator editing tool lets the user adjust the dose distribution by changing the thickness values of a compensator so that different dose distributions can be compared easily and efficiently. The user can create the appropriate compensator for the treatment. There are many methods available for editing the compensator, including Pixel, Area, Flat, and Uniform.
- The aperture manual editing tool lets the user modify the shape of the aperture to create a more conformal dose distribution to the target ROI and minimize dose to the critical organ at risk.

**Figure 3** Compensator advanced editing tool.



**Figure 4** Proton plan with effective dose display in cGy(RBE).

## Lock compensator/aperture shape

In many re-planning cases, it is necessary to reuse existing modifiers. Locking the compensator and aperture prevents unexpected modifications during the planning process.

## Patch and Through tool

The Patch and Through technique allows the user to treat a target volume that has a "U" or "V" shape and surrounds a critical organ by splitting the target ROI into two ROIs using the Part ROI tool.

## Full plateau support

Pinnacle[3] is designed to support full plateau delivery, which extends the 100% dose level for a delivered SOBP to the patient surface in a beam's dose calculation. This functionality can be used for superficial tumors.

## Effective dose display

Dose in Pinnacle[3] is presented in terms of effective dose, which includes the Relative Biological Effect (RBE). This facilitates composite planning and visualization of dose distributions from all modalities within a single plan without the need to import multiple prescriptions.

## Multiple prescriptions

Pinnacle[3] manages multiple prescriptions for a plan in order to effectively display the composite dose without requiring plan addition or subtraction.

## Stopping power override

This feature lets the user easily override the stopping power for any ROI.

## Patient-specific QA tool

- The Compensator Printing feature enables the user to generate printouts to verify the quality of the Pinnacle[3]-generated compensators against the physical ones.
- The Print to Scale feature allows the user to print a beam's-eye view image of the aperture to compare it against the physical aperture used during treatment.
- The Copy to Phantom feature allows the user to copy the plan to one of the stored QA phantoms to verify the dose distribution.
- The Export Dose Planes or Profiles feature makes it easy to export the required planar dose information from Pinnacle[3] for comparison with measured planar dose.
- The Set-up DRR feature computes the DRRs at the different SADs to provide that the magnification is correct.

# Benefit from access to all Pinnacle³ functionalities

## Integrated photon-proton planning

The dose computation is designed to facilitate composite planning with protons, photons, electrons, and brachytherapy. Intuitive visualization tools enable side-by-side comparisons of different plans to determine the preferred treatment protocol.

## Comprehensive evaluation tools

Well-designed tools let the user monitor the dose to the target and critical structures from different plans including photons, protons, and composite plans.
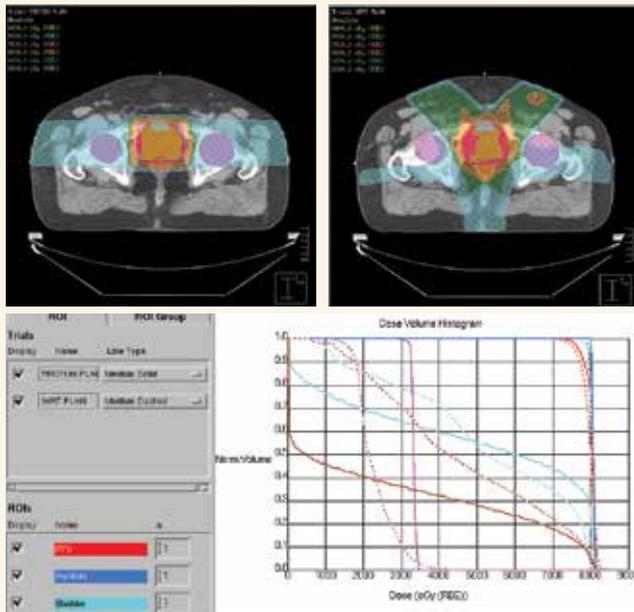
**Figure 5** Comparison between IMRT vs Proton plans.

## Automated contouring (SPICE)

Automated contouring using Auto-Segmentation with SPICE streamlines the contouring process to just a few clicks, providing consistent contours in minutes that require little or no editing.

## Re-planning (Dynamic Planning)

Fast assessment and automated re-planning tools provided by Dynamic Planning generate at-a-glance information to help monitor treatment efficacy and create new plans with limited user intervention to adjust for patient changes during treatment.

## Scripting ability

The ability to automate repetitive processes through scripting provides consistency of plan and streamlined workflow.

## Biological response evaluation

Pinnacle³ generates biological response comparisons to view radiobiological response probabilities based on biological responses for selected ROIs across multiple trials.

## Hardware compatibility

Pinnacle³ demands a high processing power. It will run on Professional and SmartEnterprise (x4170 and newer) platforms only.

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