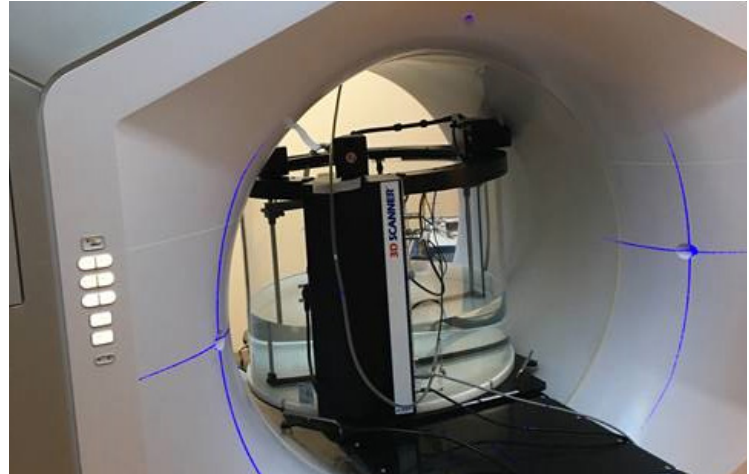


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## Introduction

Sun Nuclear's 3D SCANNER™ has been tested and validated at 3 sites with recently installed Halcyon™ Systems. In addition to these users, Varian has reviewed and confirmed the validity of the Sun Nuclear approach. The feedback after initial use from these Halcyon customer sites\* included positive reviews of the straightforward and intuitive software; excellent functionality for set up and alignment verification; and an overall robust system. This overview highlights the process of using the 3D SCANNER to acquire beam modeling data from the Varian Halcyon System.

### Highlights

- Easy Beam Model Verification and Acceptance of Halcyon System
- Couch Positioning Plate (CPP): Indexes to couch to orient and align tank
- AutoSetup™ Routine for Halcyon System for easy and fast setup
- Halcyon-specific scan support and analysis

### Requirements

- Halcyon Kit with 3D SCANNER, or
- Halcyon upgrade Kit for existing 3D SCANNER owners (contact Sun Nuclear for details)
- SNC Dosimetry™ Software version 3.6 or later

\* Used other systems for their initial Halcyon beam modeling

## Workflow

### 1. Place Couch Positioning Plate

The Couch Positioning Plate (CPP) provides a protective surface between the couch and the 3D SCANNER. Cutouts on the top surface of the CPP match the 3D SCANNER Lift Ring, and the features on the bottom surface of the CPP align with couch positions F1, H1, and H3 (see Fig. 1). The wedged design of the CPP compensates for couch sag associated with the weight of the 3D SCANNER and water.

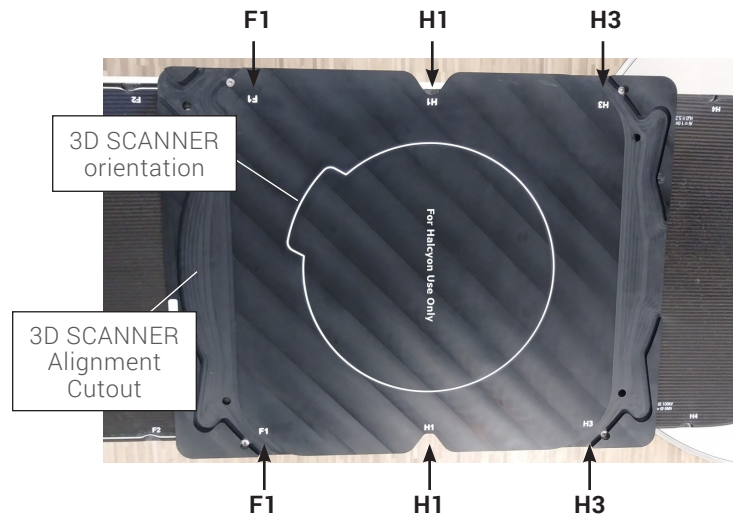


Fig. 1: Couch Positioning Plate (CPP)

### 2. Place 3D SCANNER on Couch

- Disconnect cables from the 3D SCANNER electronics enclosure.
- Lift and orient the 3D SCANNER as shown on the CPP. When the 3D SCANNER is fully seated in the CPP, its positive x axis aligns to the Halcyon's negative y axis. (see Fig. 2)



Fig. 2: 3D SCANNER placement within CPP

### 3. Install Field Detector & Reference Detector

Use a scanning detector, such as SNC125c™ or EDGE™ Detector, for AutoSetup.

- Install the Field Detector holder on the detector holder base and Field Detector in holder, as illustrated in Fig. 3a and 3b.

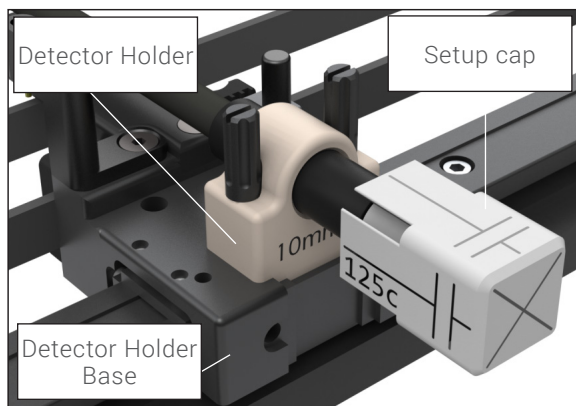


Fig. 3a: Field Detector Holder with alignment cap

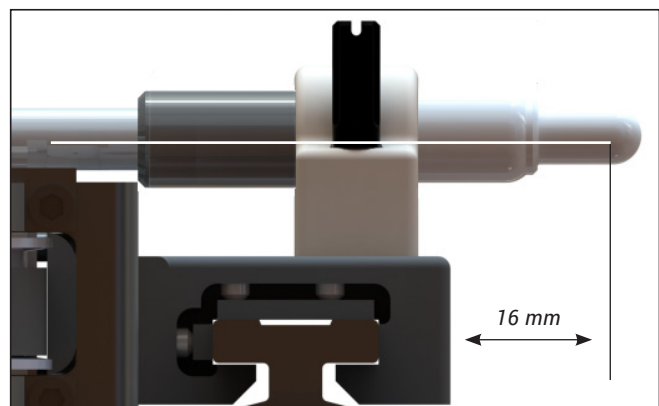


Fig. 3b: Field Detector installed

## Workflow *Continued*

- b. Install Reference Detector
  - i. Insert the detector into the reference detector holder, as illustrated in Fig 4.

### 4. Move 3D SCANNER into Bore

To prevent collision, a couch position label on the CPP provides the coordinates (LAT, LNG, and VRT) recommended when moving the couch and 3D SCANNER into the Halcyon bore. Move the couch to the position indicated on the label. (See Fig. 4.)

### 5. Fill Tank with Water

Fill the 3D SCANNER to the SSD line on the side of the water tank.

- a. Position the reference detector, avoiding penumbra or scan line.

### 6. Launch SNC Dosimetry Software

- a. Define Delivery System = Varian Halcyon

### 7. Run AutoSetup

The 3D SCANNER AutoSetup for Varian Halcyon uses a patent-pending leveling method that is based on multiple depth scans. The software analyzes the results to determine relative changes in depth at each (x,y) detector location and corrects the Z position of subsequent step-by-step profiles to keep the detector at a constant depth.

- a. Enter the AutoSetup SSD relevant to your measurements.
- b. Click Start to begin AutoSetup. Follow the on-screen prompts until all AutoSetup steps are complete. For the steps where a beam is required, set up a 10 cm x 14 cm (x,y) field. (See Fig 6.)

### 8. Scan Mode for Halcyon

Continuous and step-by-step measurements selected from the queue perform differently when a Halcyon delivery system is selected.

- Step-by-step profile measurements are performed such that the vertical motors adjust between every measurement point based on leveling results, keeping the detector motion parallel to the water surface.
- Continuous scans are performed with single axis motions and are offset from the water surface based on the leveling angle reported in AutoSetup.

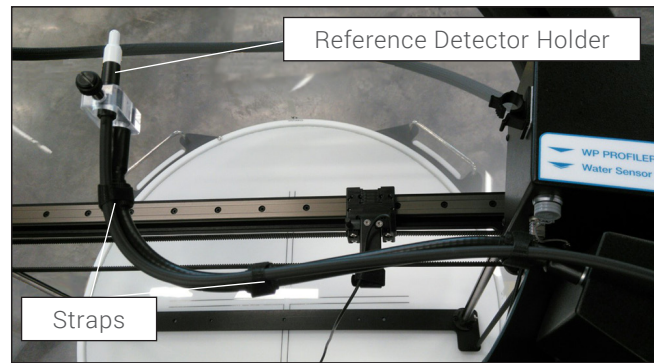


Fig. 4: Reference Detector installed

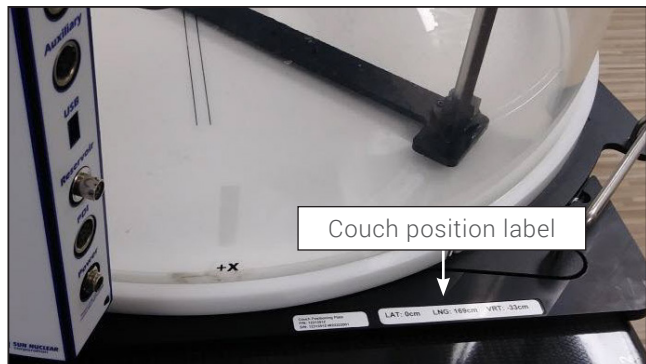


Fig. 5: Label provides LAT, LNG, and VRT coordinates

Complete?	Overridden?	Step	
✓		1. No Beam	
		Home the 3D SCANNER positions.	
		Apply voltage to detectors.	300.0 V
		Find the water surface.	8.68 cm (water surface)
		Measure the background rate	(Field) 0.2216 pA, (Reference) 0.2295
✓		2. Beam	
		Take a normalization measurement.	Currently normalized to X = 0.00 cm
		Determine the ring center.	25.16 cm
		Determine the ring angle offset relative to the Delivery S...	4.87 degrees
		Determine the 3D SCANNER hysteresis in the diameter d...	0.05 cm
✓		3. Halcyon	
		Adjust the ring center position to the central axis.	X Axis Offset = 0.02 cm and Y Axis C
		3D SCANNER level.	Leveling result: x axis offset: -0.3°; y
✓		4. Advanced	
		Set the vertical limit.	3.00 cm
		Find the ray trace angle.	

Fig. 6: Halcyon Auto setup workflow

## Workflow *Continued*

### 9. Highlighted Analysis Features

#### Halcyon Processing Layer

The 3DS Dosimetry software provides an audit trail of all data processing, identified as the Processing layer. At any time, these layers may be peeled back to reveal underlying data.

#### Analysis Parameters

The FFF profile beam edge calculation reports the positions of the inflection points at the maximum and minimum dose gradients.

Analysis parameters are displayed in the lower left of the User Interface based on the protocol selected. See examples in Fig. 8 and 9, based on IAEA 398:

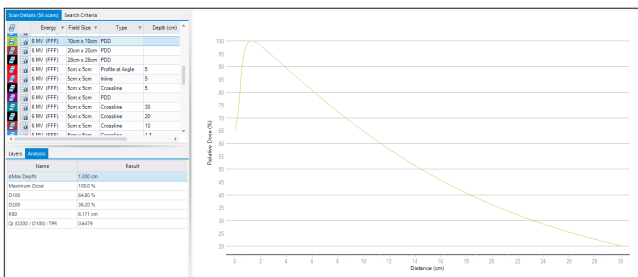


Fig. 7: 10x10 cm<sup>2</sup> PDD, d-max at 1.30 cm

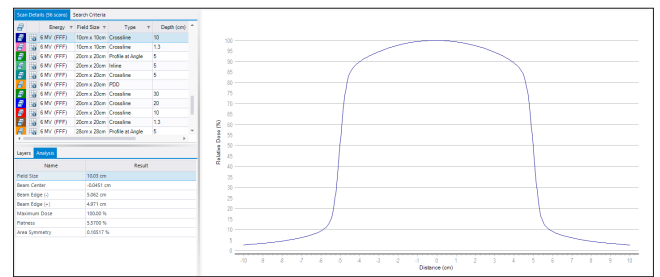


Fig. 8: 10x10 cm<sup>2</sup> profile at 10 cm depth

Measurement data closely matched the previous beam data at each test site, except in the case of inline measurements, where reference data was collected with a square tank whose detector orientation with respect to beam edge was orthogonal to the crossline measurement and consequently an inferior detector orientation for inline profiles. For example, a 10x10cm<sup>2</sup> dMax inline profile is shown in Fig 9, as measured with the 3D SCANNER (blue) and a square tank (red).

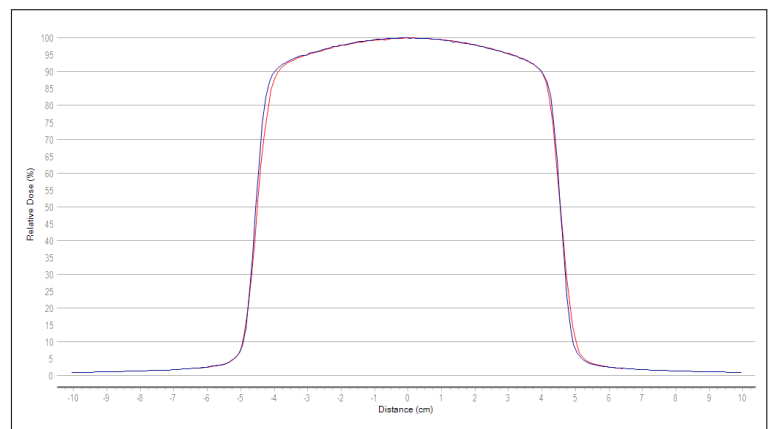
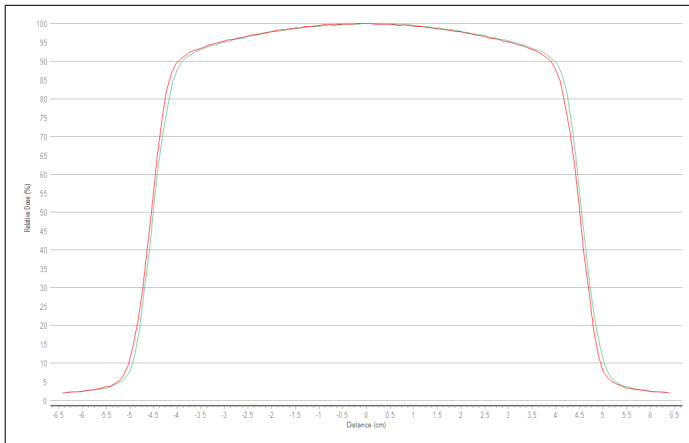


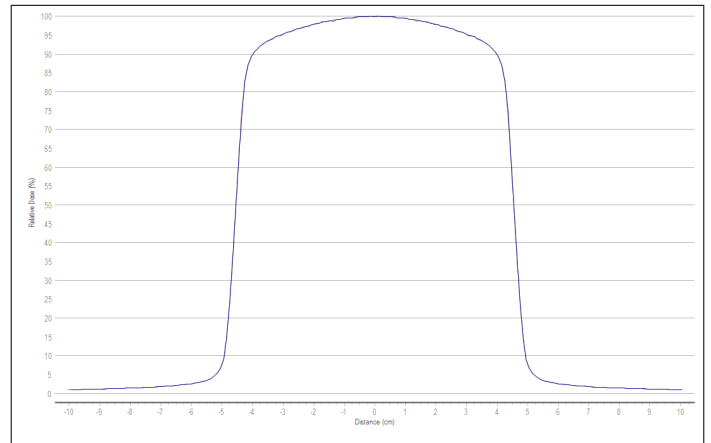
Fig. 9: Scan Comparison of 3DS (blue) and rectangular (red), illustrating consequence of detector orientation resulting from scanner construction.

## Workflow *Continued*

The in-beam and out-of-beam portions show good agreement, but the penumbra show different symmetry and sharpness. Because of the cylindrical design, the 3D SCANNER maintains consistent detector orientation between crossline and inline measurements, maintaining accurate penumbra shape by always scanning the detector in a lateral motion. Cable effect and the asymmetry of a cylindrical ionization chamber in the longitudinal direction also compromise the penumbra symmetry when scanning along that axis. This is demonstrated by mirroring each centered profile and analyzing the differences of each beam edge:



**Fig. 10: Square Tank Inline Measurement, Centered (red) and Mirrored about CAX (green)**



**Fig. 11: 3D SCANNER Inline Measurement, Centered (red) and Mirrored about CAX (blue)**

The difference is practically unresolvable.

## Conclusion

The described workflow with AutoSetup optimized for Halcyon allows for fast and accurate setup of the 3D SCANNER and characterization of the Halcyon system. The Couch Positioning Plate (CPP) eliminates the need for visual alignment of the system and makes each setup experience consistent and predictable. Measurements showed strong agreement with each site data, except in inline profiles where the 3D SCANNER advantage of consistent chamber orientation helped maintain profile symmetry and penumbra resolution. The uniqueness and accuracy of the 3D SCANNER system make it the optimal solution for Halcyon beam characterization.