Small Field Dosimetry using the Exradin W1

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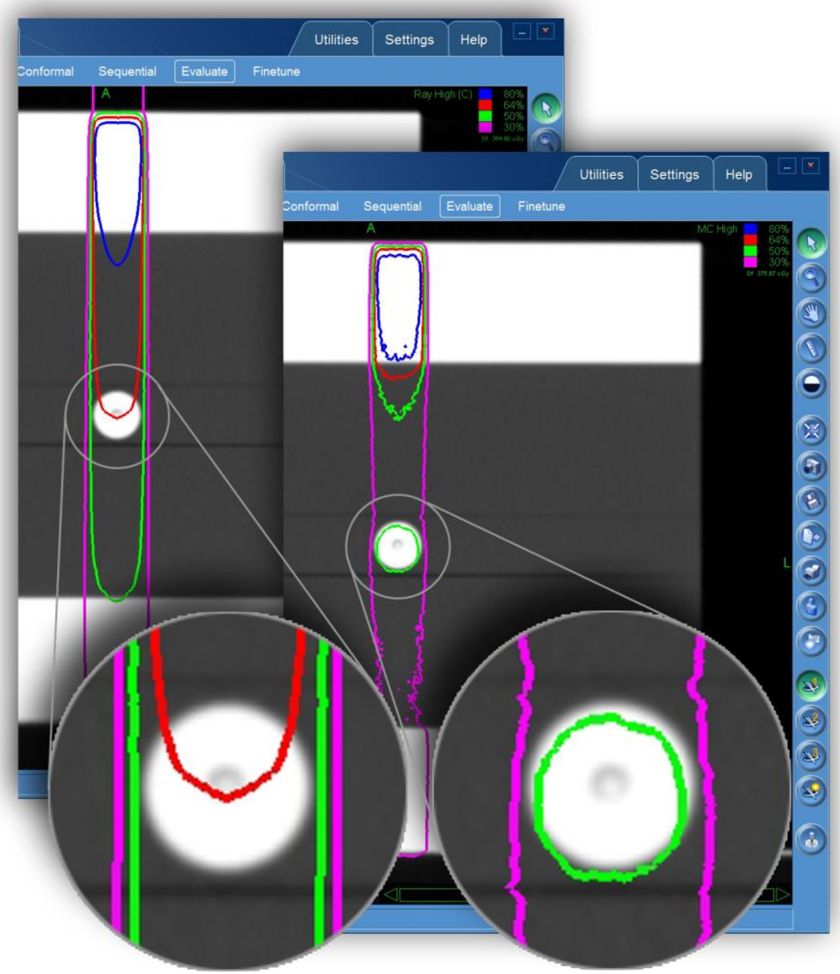
Opening Questions

- **What is the W1?**
  - **Pinpoint scintillating fiber-based detector**
- **What type of small fields?**
  - **CyberKnife circular cones**
  - **Emphasis on cones smaller than 20mm**
- **What heterogeneity environment?**
  - **New lung equivalent phantom material for SDVP**

Main Question

- **How do we verify Monte Carlo in a highly heterogeneous environment?**



Ray Trace Monte Carlo

Small Field Using Exradin W1 and SDVP Lung Phantom

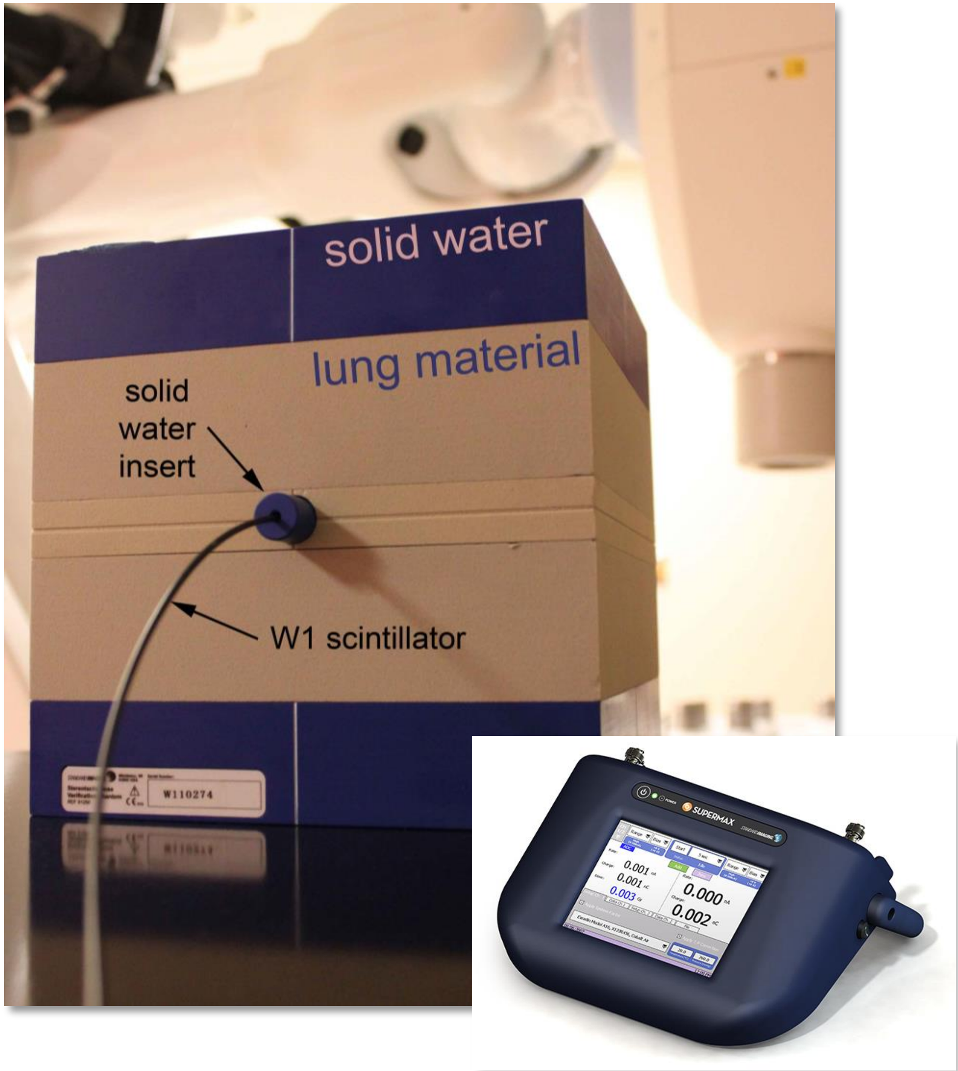
This Talk…

- **Will not address how to correlate Monte Carlo dose to clinical outcomes**

- **Will outline a straightforward, step-by-step approach to Monte Carlo dose verification using the W1 scintillator and other new tools**

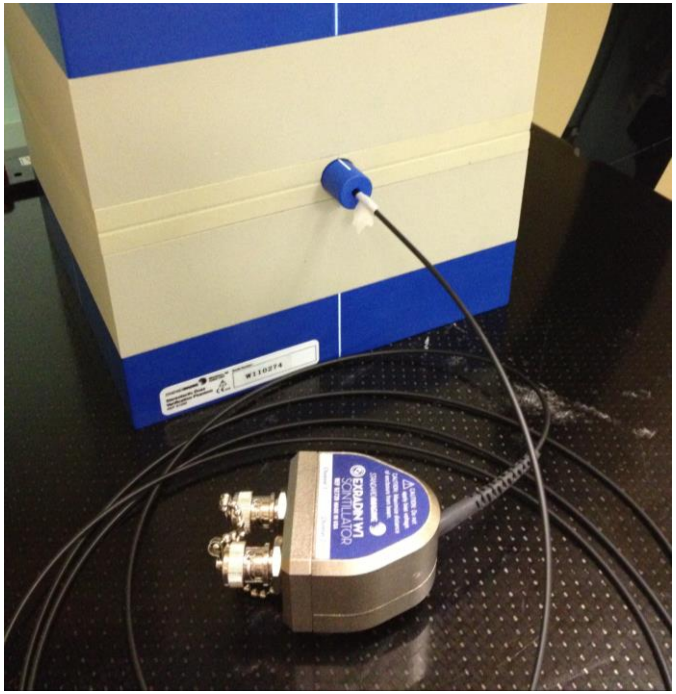
Step 1 – Define Tools

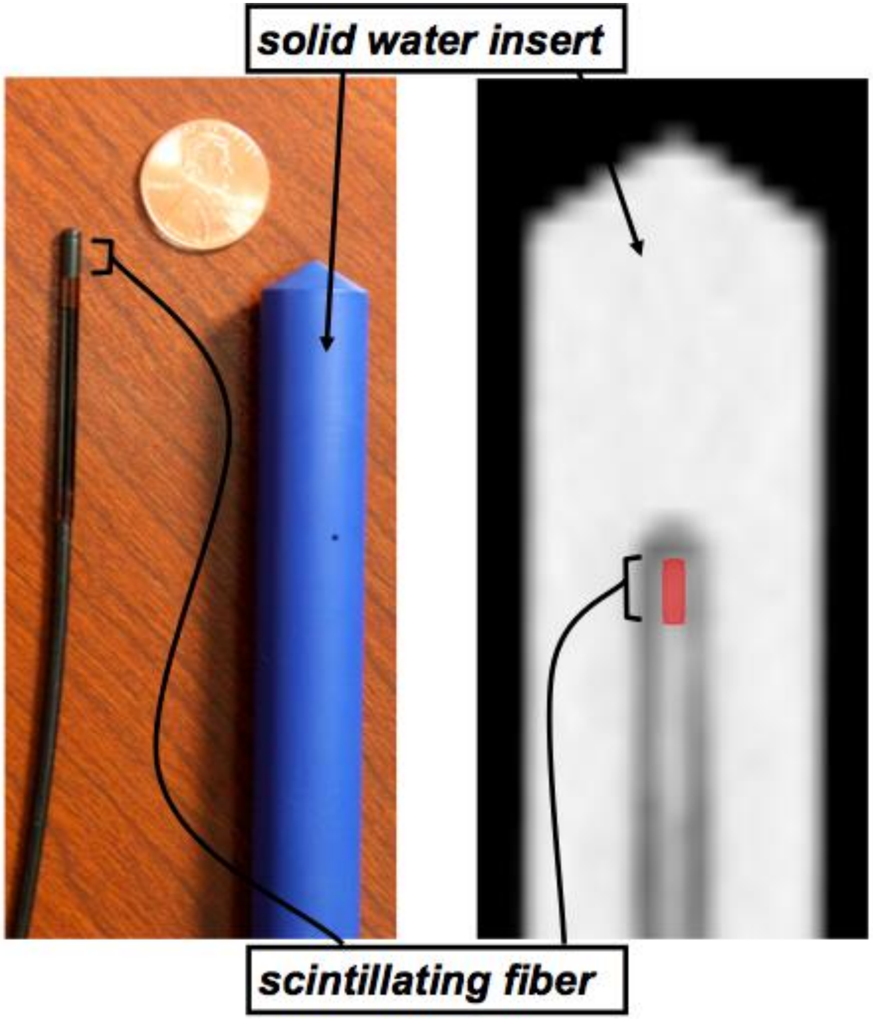
1. **W1 scintillator**
2. **Solid water insert**
3. **Lung equivalent phantom material**
4. **SuperMax electrometer**



Step 1 – Define Tools

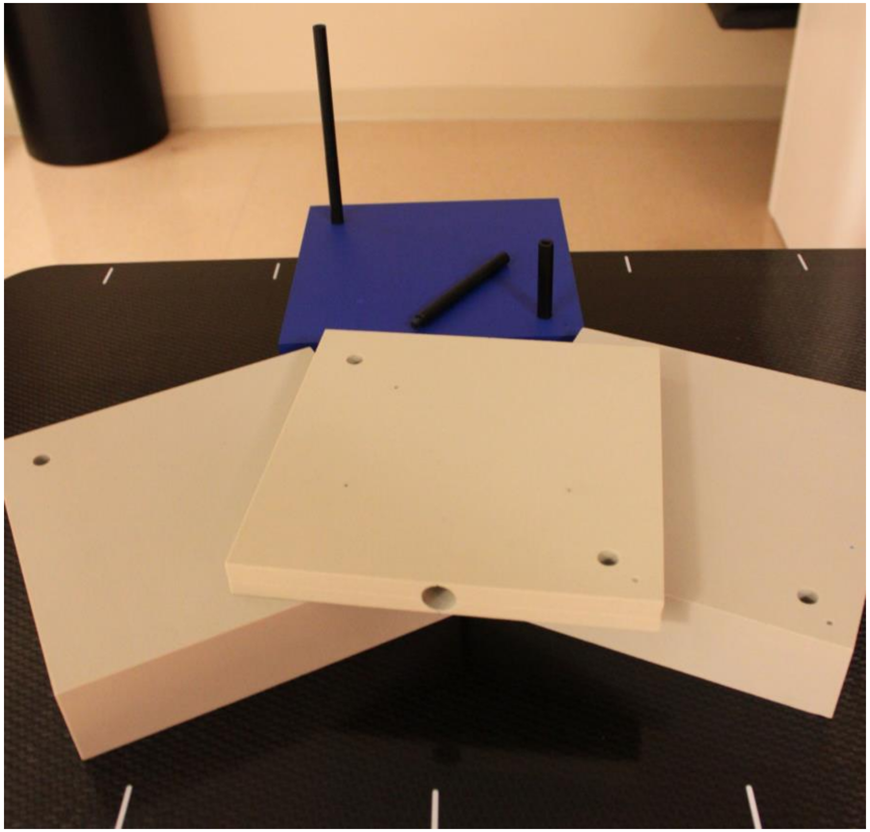
- **Exradin W1 Scintillator and solid water insert**





Step 1 – Define Tools

- Lung material phantom
  - SDVP ("Baby Blue") phantom
  - Lung equivalent phantom material
    - 0.28g/cc
    - Embedded with fiducials

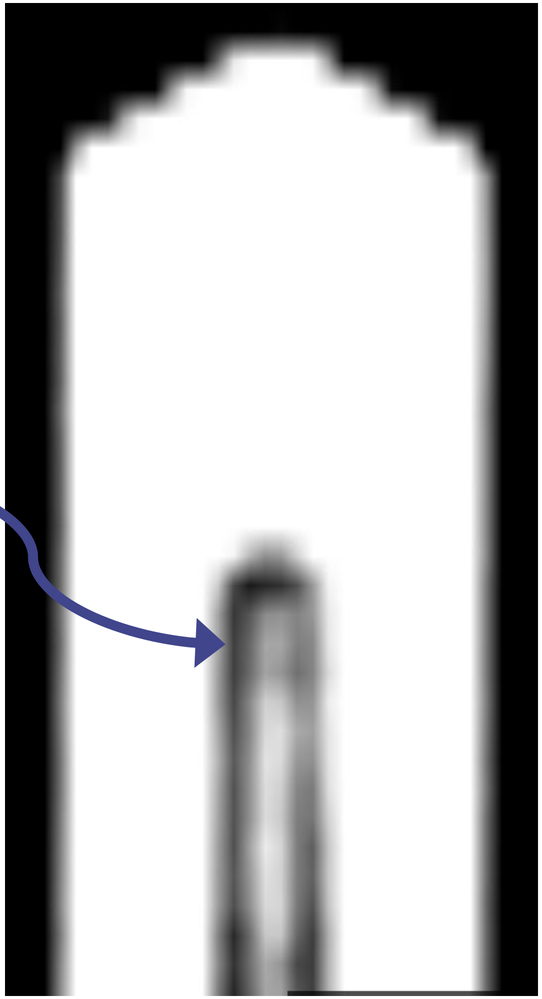


Step 1 – Define Tools

- **SuperMax electrometer**
  - **Two data ports**
  - **Needs firmware v2.0**

Step 2 – TPS Planning

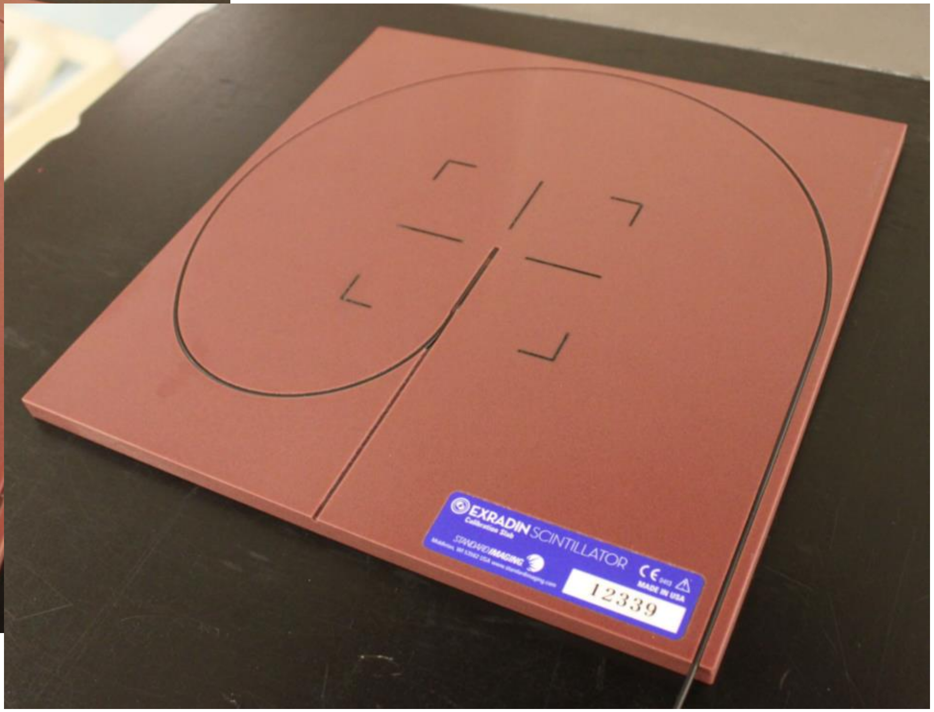
- CT phantom- smallest slice thickness
- Plan a single AP beam with 300MU
  - Most crucial: defining the 1mm x 3mm fiber
  - Monte Carlo calculated for all 12 cones to 0.5% uncertainty

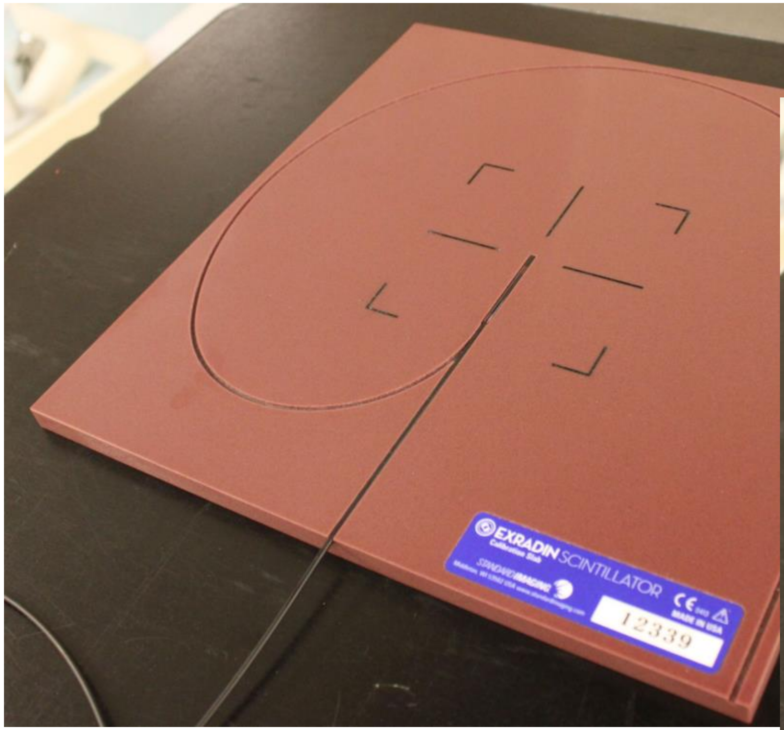


Step 3 – Preparation

- **Generate W1 correction factors**
  - **The Cherenkov Light Ratio (CLR)**
    - **Factored out due to small (pC) readings**

maximum fiber

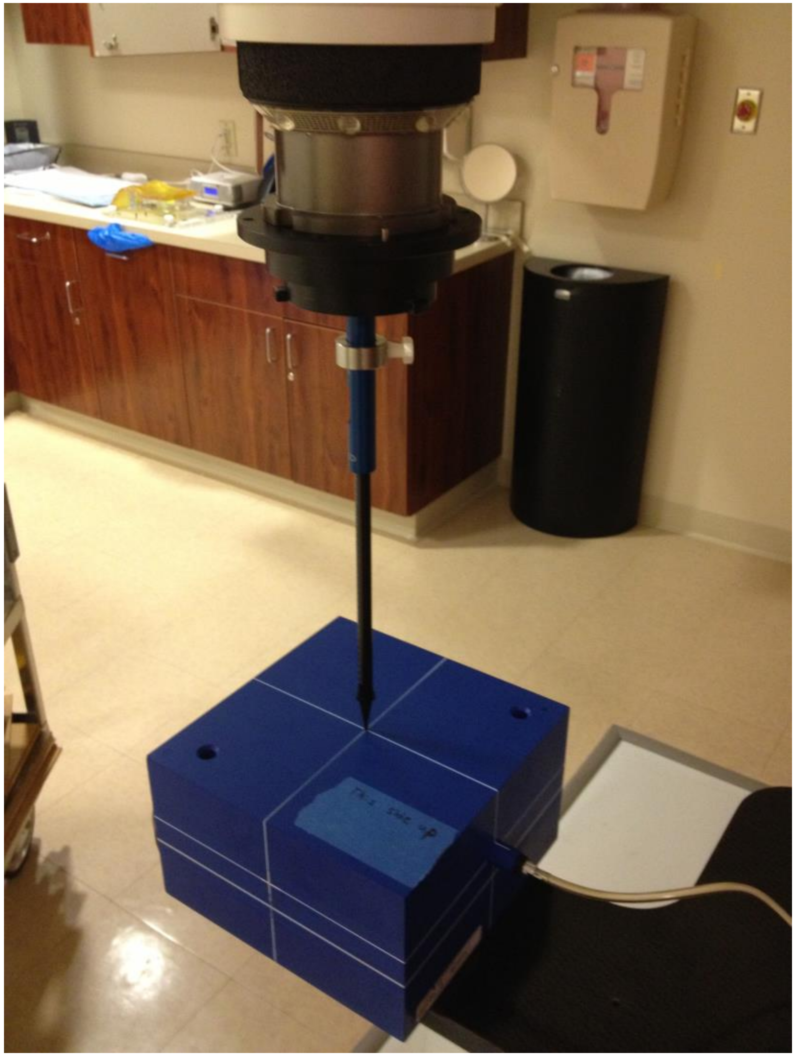




minimum fiber

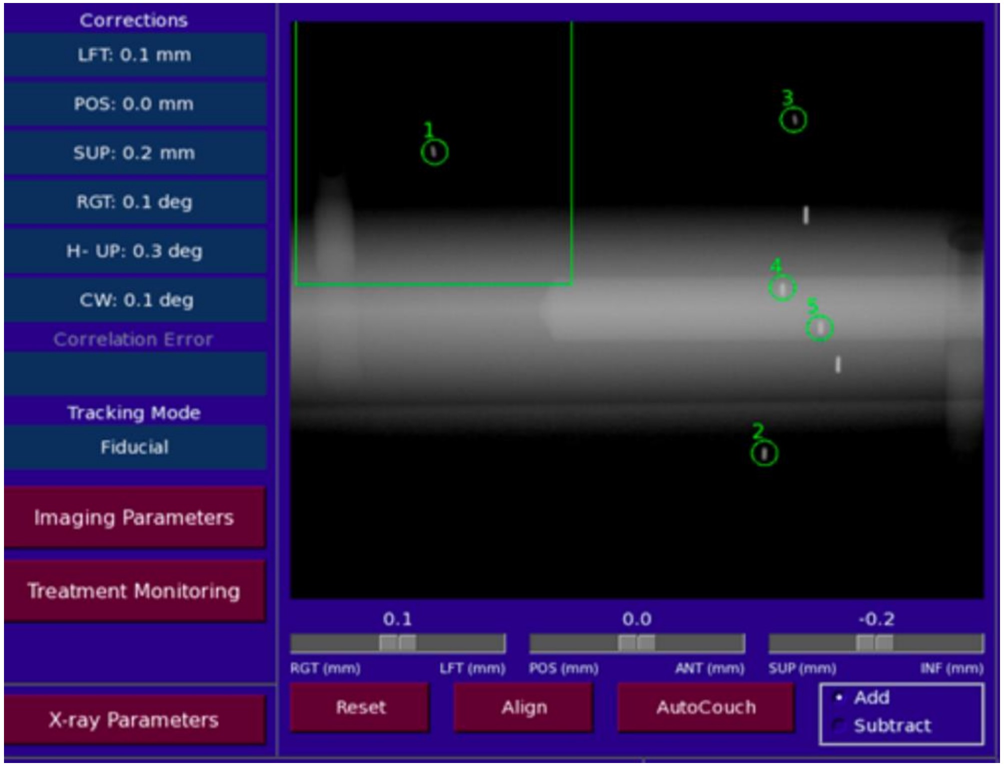
Step 4 – Measurements

- **Cross calibration with A19 in solid water immediately before taking measurements**
  - 80cm SAD
  - 60mm cone



Step 4 – Measurements

- Phantom position tracked with fiducials using orthogonal kV imagers
- Only 45 min for all 12 cones



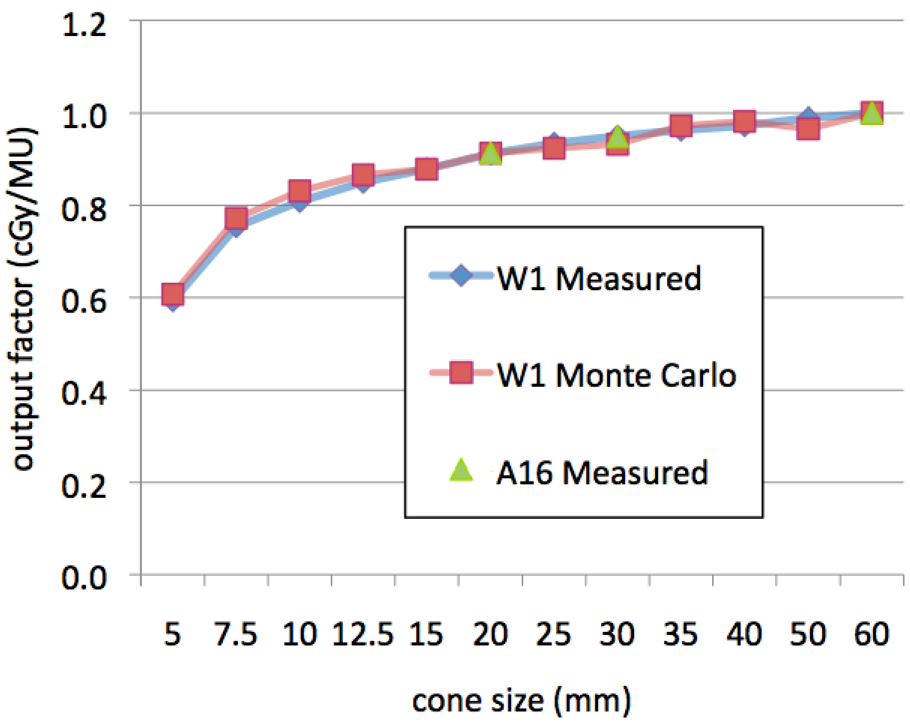
Data Analysis

- **Raw data- agreement within 3%**

detector	cone mm	rdg nC/pC	T/P cor	Gy/C	cGy	MC dose cGy	% error
A19	60	53.82	1.0298	4.998E+07	274.02		
W1	60	0.929		2.982E+12	274.02		
W1	5	0.498			146.89	150.11	**-2.14%**
	7.5	0.633			186.71	190.89	**-2.19%**
	10	0.679			200.28	205.55	**-2.56%**
	12.5	0.714			210.60	214.17	**-1.66%**
	15	0.738			217.68	217.24	**0.20%**
	20	0.766			225.94	225.80	**0.06%**
	25	0.785			231.55	228.43	**1.36%**
	30	0.798			235.38	230.59	**2.08%**
	35	0.809			238.63	240.52	**-0.79%**
	40	0.817			240.99	242.86	**-0.77%**
	50	0.831			245.12	238.84	**2.63%**
	60	0.840			247.77	247.31	**0.19%**

Data Analysis

- **Measured vs Monte Carlo Output Factors**



- A16 micro-chamber used as benchmark

Conclusion: The W1 is an effective measuring tool for verifying MC dose in a heterogeneous environment with all CK cone sizes.

Time Required

- Assuming TPS MC is commissioned
- CT scan phantom - 30 min
- Import CT, plan, and calculate for all 12 cones - 3 hours (includes calc time)
- Measuring - 2.5 hours
- Analyzing data - 2 hours

- Total = 8 hours

Thanks to:

- Jimm Grimm, Ph.D.
- Ron Berg, Ph.D.
- Indra Das, Ph.D.
- Chee-Wai Cheng, Ph.D.
- Jinyu Xue, Ph.D.

Poster

Lung Material Phantom for Small Field Monte Carlo Dose Validation

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Objective

Monte Carlo has the potential to be much more accurate than conventional effective path length algorithms, especially in a highly heterogeneous environment. Commissioning Monte Carlo beam data for clinical use within a treatment planning system (TPS) for Stereotactic Body Radiation Therapy (SBRT) should require validation both in homogeneous and in heterogeneous phantom materials. Compounding this task is the difficulty in accurately measuring small field sizes. This work outlines the use of a proprietary lung material phantom in conjunction with a new scintillation detector designed for small field measurement in order to verify the Monte Carlo dose calculated in the TPS.

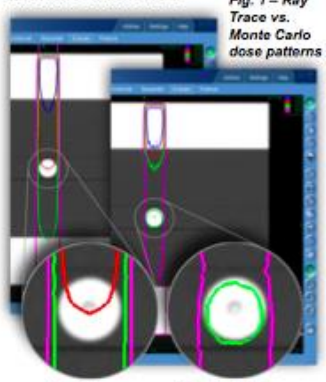


Fig. 1 – Ray Trace vs. Monte Carlo dose patterns

The figure in the bottom left shows the 20mm cone calculated with Ray Trace and Monte Carlo. The green isodose line indicates that Monte Carlo appropriately predicts dose within the solid water insert, while Ray Trace appears to treat the entire phantom homogeneously.

Materials/Methods

Fig. 2 – components of lung material phantom

The measurements were performed on a CyberKnife VSI. The Stereotactic Dose Verification Phantom (SDVP) from Standard Imaging (SI) was fitted with 12cm of lung material with a physical density of 0.28 g/cc.

The scintillating detector was placed in a 1.5 cm diameter water-equivalent insert, which was then placed in the SDVP lung phantom and CT scanned. Fiducials were embedded in both the lung material and insert for tracking purposes using 45 degree orthogonal kV imagers.

After dose cross-calibration with the SI A19 ion chamber in the basic SDVP water equivalent phantom, measurements were taken with the scintillator for all 12 cones (5mm – 60mm).

The new SI W1 pinpoint scintillator is nearly water equivalent but with careful window/leveling the 1mm diameter by 3mm long scintillating fiber was visible and was contoured in the MultiPlan TPS. The Monte Carlo calculations were executed with an uncertainty value of 0.5%.

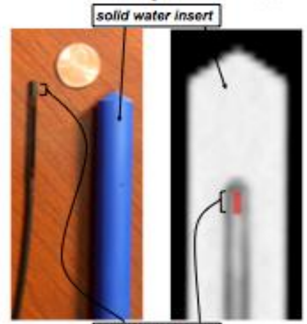
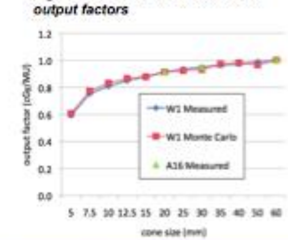


Fig. 3 – point of measurement of physical scintillator (left) and imaged scintillator within solid water insert (right)

Results

For cross-calibration to known larger field equilibrium conditions, the SI A16 ion chamber was used to re-measure the 20, 30, and 60mm cones, and the measured dose matched the Monte Carlo dose within 2% for the three collimator sizes. All 12 cones measured with the W1 scintillator matched the calculated Monte Carlo dose to within 3%.

Fig. 4 – measured vs. Monte Carlo output factors



Conclusions

The SDVP lung material inserts provide an acceptably heterogeneous environment that is well suited to testing the accuracy of Monte Carlo calculations. The W1 scintillator has an appropriately small sensitive area capable of measuring field sizes down to 5mm in diameter. The combined utilization of both pieces of equipment results in a clinically acceptable correlation of measured dose to the Monte Carlo dose calculated in the TPS for all cone sizes.

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Questions?

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