AAPM 2025
JULY 27–30 | WASHINGTON, DC
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# Quantitative 3D Surface Mapping of Cherenkov Images for Real-Time Beam Deviation Detection in Radiotherapy


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## ABSTRACT

***Purpose:*** Cherenkov images are two-dimensional projections of the surface light emissions, and lack spatial information about the radiotherapy beam delivery. We implement the first fusion of Cherenkov images and 3D patient surface meshes to quantify beam outline deviations with respect to the patient's outer anatomy and treatment plan with objective metrics. This work simplifies clinical workflow and enables implementation of automatic thresholds that enable Cherenkov-based treatment verification.

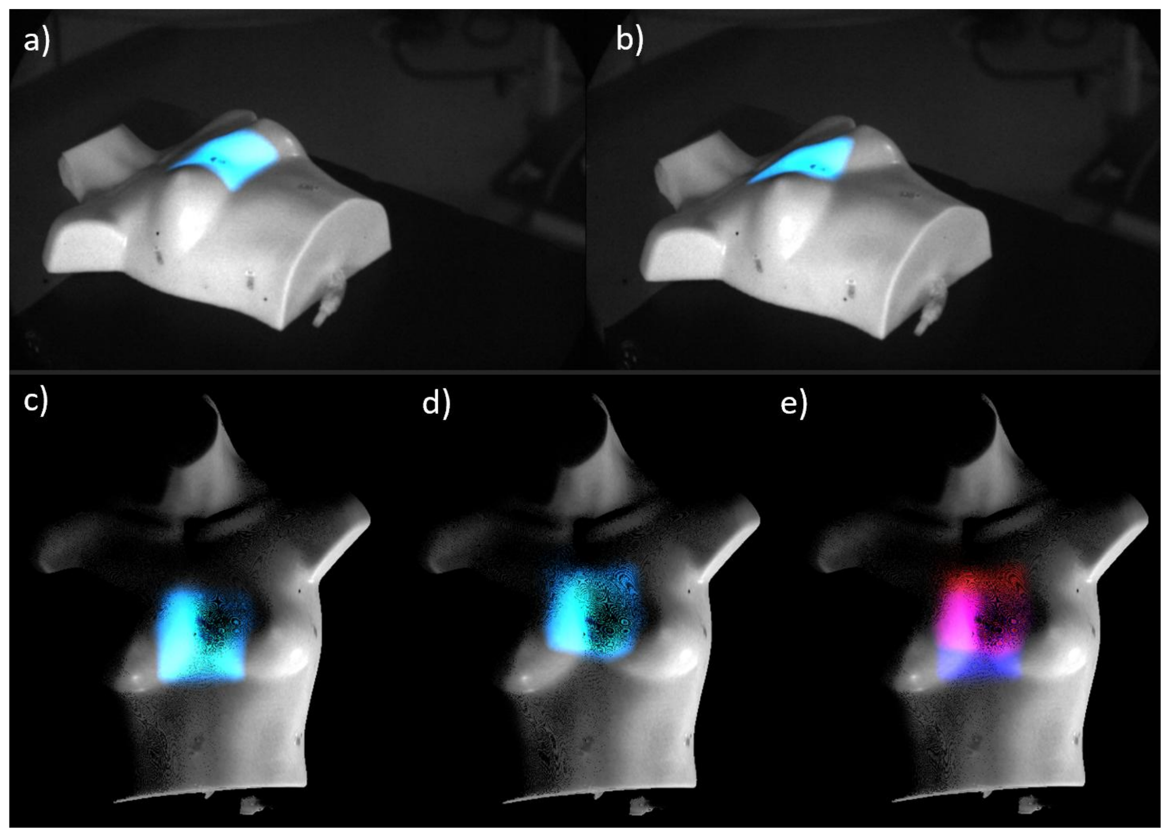
***Methods:*** Cherenkov images from multiple geometrically calibrated cameras were combined with 3D CT datasets (3D SGRT datasets will be tested in the future) to provide a novel Cherenkov surface image map on the patient. Raycasting was utilized to virtually image the Cherenkov surface map from the beam's eye view, therefore enabling spatial quantification of beam outline on the patient. Several quantitative spatial metrics were tested (DICE, Hausdorff, ICP, ICP COM, etc.) to automatically detect beam outline deviations from planned deliveries.

***Results:*** Iterative Closest Point algorithms achieve an accuracy of less than 2 mm for the at phantom and 3 mm for the anatomical Annie phantom. Setup error and camera resolution account for up to 1 mm of inaccuracy.

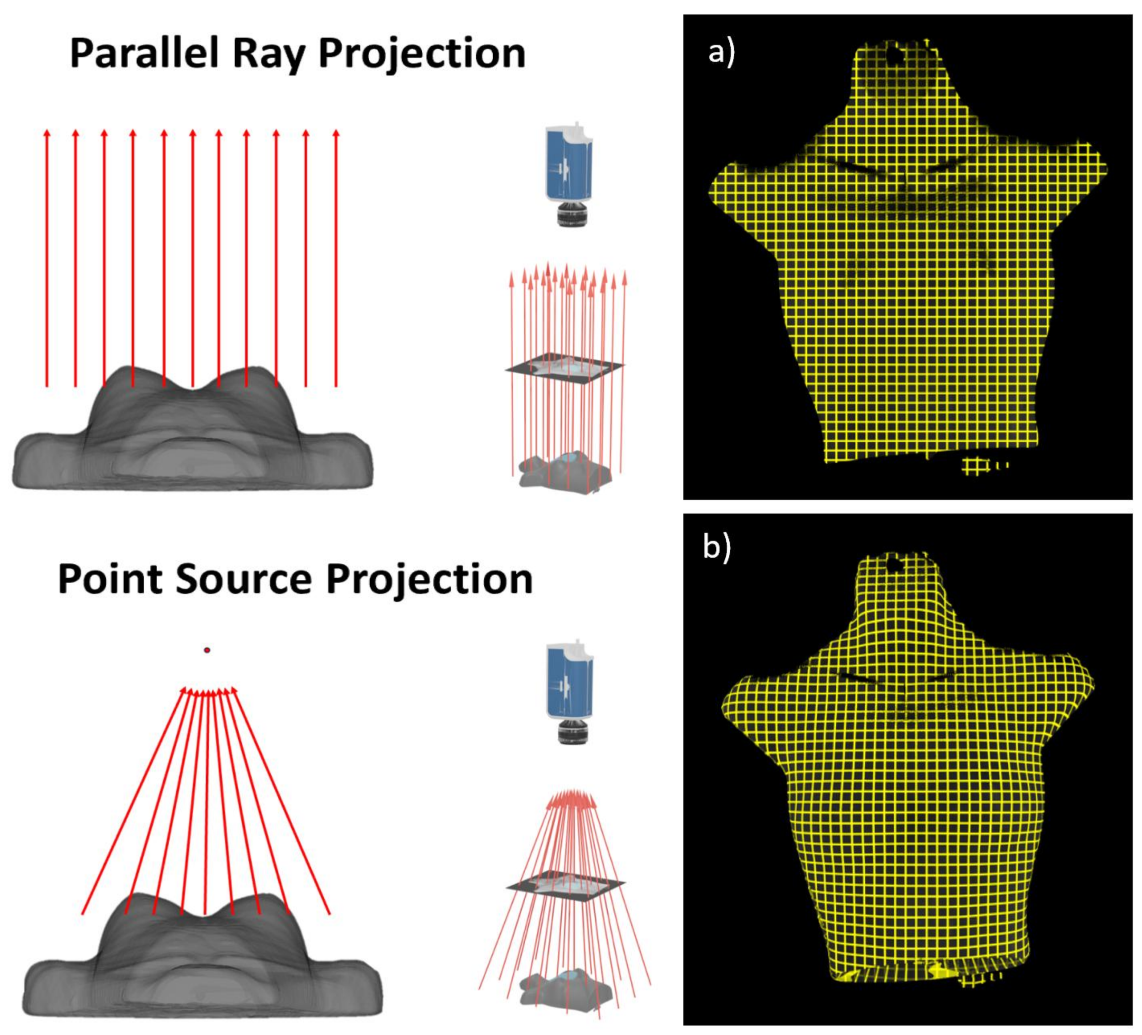
***Conclusion:*** Cherenkov surface maps can reliably detect beam deviations of 1 mm using existing Cherenkov imaging technology. Our work demonstrates the first feasible method for automatic incident detection and allows the clinical team to adapt to treatments in real time and adjust future fractions to improve patient safety and treatment efficacy


## MOTIVATION

**Cherenkov images are incredibly useful for qualitatively assessing treatment fields are delivered correctly during RT treatments. However, current Cherenkov images have no spatial coordinates, so beam deviations cannot be easily measured. This work introduces a method for registering Cherenkov images to the patient surface via raycasting projection, thereby allowing for quantitative spatial measurements of RT beams to be made on the patient's surface.**



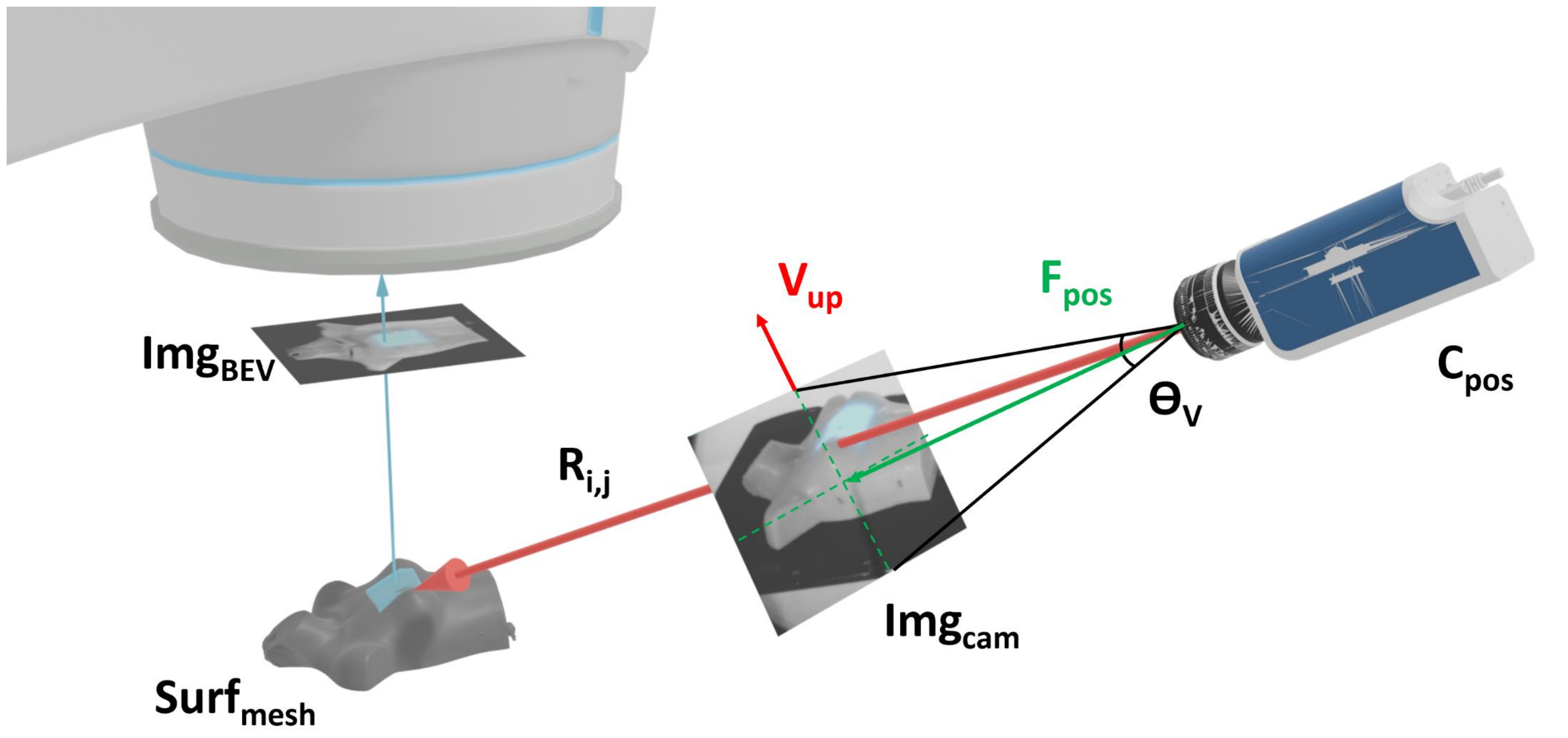

- **Two 10x10 fields on an anthropomorphic phantom. Due to oblique angle of view, therapists are not necessarily assured if the field is different or shifted. Virtual beam's eye view images c), d), e) show the fields are the same shape.**




- ***a)* Parallel ray projections preserve distance and allow for uniform spatial measurements on the images**
- ***b)* Point source projections preserve beam's eye view through MLCs**

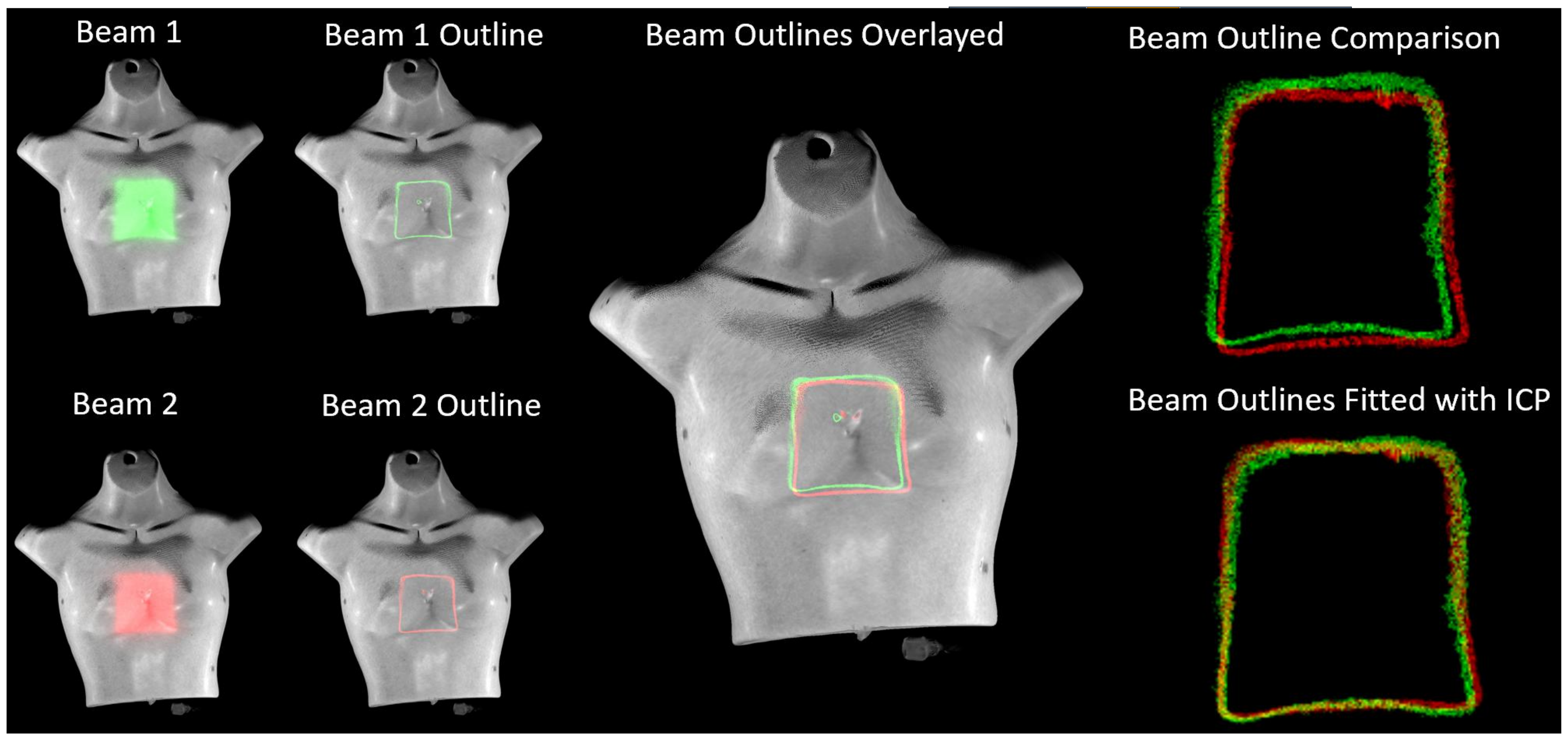
## DISCUSSION

**Future work will combine Cherenkov surface images with SGRT surfaces to generate real-time on-patient beam monitoring. Quantitative beam measurements will allow for automatic error detection and makes an important stride along the path towards optical treatment verification.**

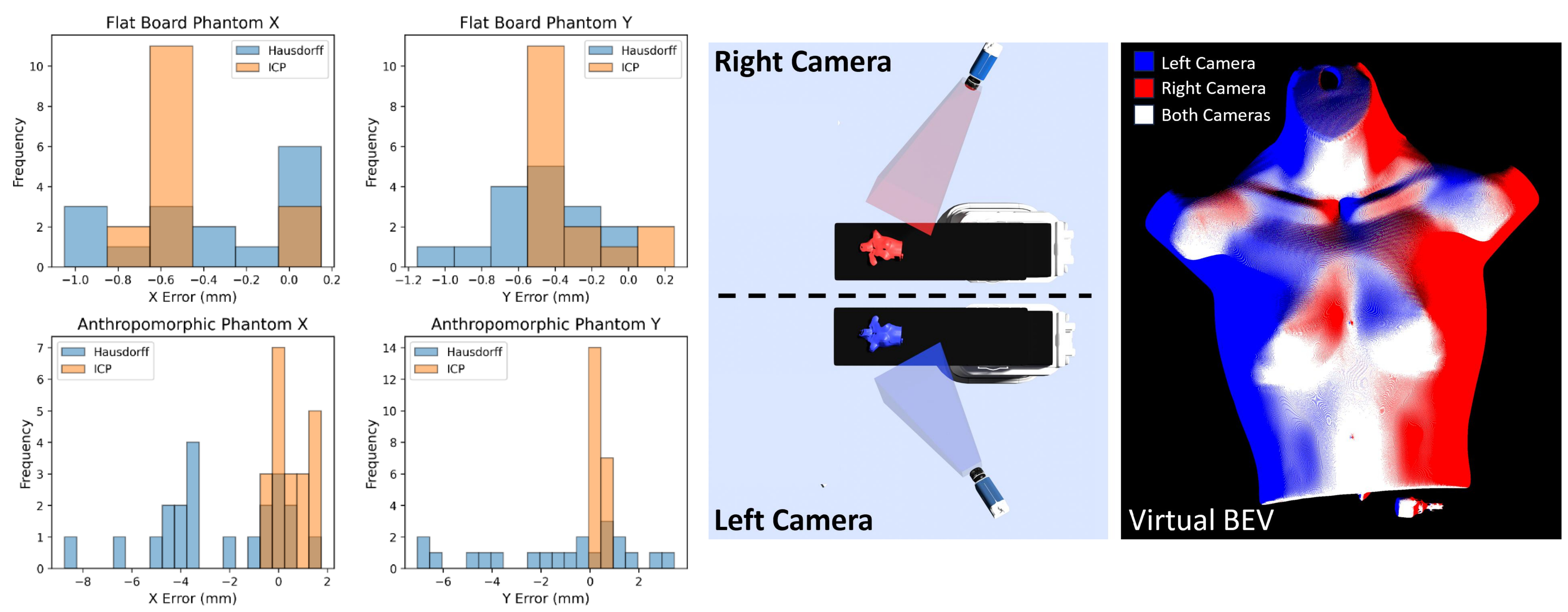



- **Camera images are projected onto CT surfaces with Cherenkov intensity overlay onto background images to produce Cherenkov surface images**
- **Cherenkov surface images are reprojected from the beam's eye view to create virtual images for spatially quantitative beam measurements**

## RESULTS




- **Beam outlines are generated for different treatment fractions and compared using two spatial distance metrics (Hausdorff distance and Iterative Closest Point)**
- **Spatial metrics show beam shift with less than 1 mm accuracy**




- **(Left) Error between simulated and detected shifts for beam outline metrics**
- **(Right) Two Cherenkov camera views combined to enhance patient surface visualization from 67% coverage (Single Camera) to 93% (Two Cameras)**

## CONTACT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