

*A new paradigm: Stereotactic Radiotherapy for Breast Cancer: **GammaPod™***

YILDIRIM D. MUTAF, PhD



UNIVERSITY of MARYLAND  
SCHOOL OF MEDICINE



# *Disclosures*

*I do not have anything to disclose.*

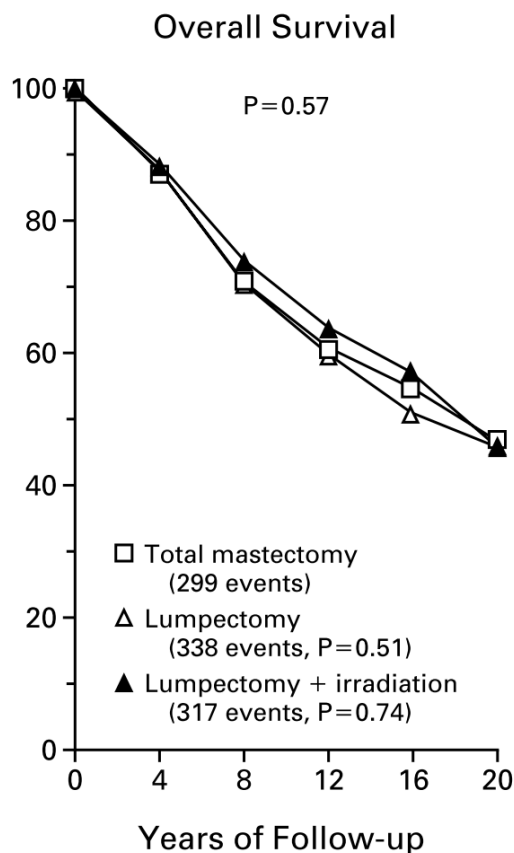


- *Clinical background*
- *Device Introduction*
  - GammaPod
  - Immobilization Device & Image Loader
- *Preliminary Performance Results*
  - Reproducibility Study
  - Post-operative and pre-operative settings
  - Dosimetric comparisons

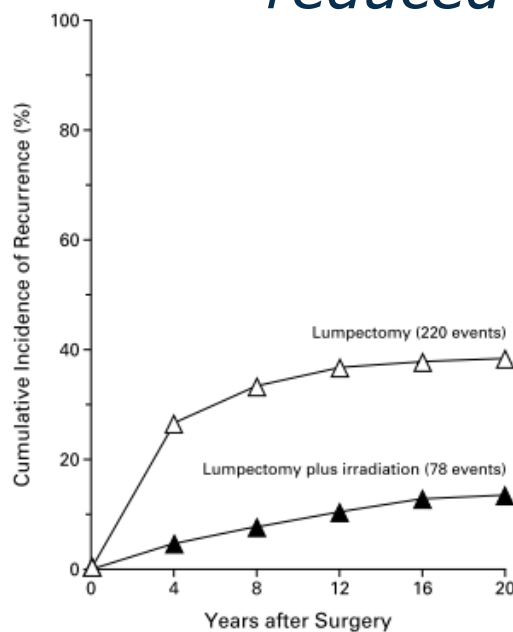


# Breast Conservation Therapy

- *BCT established as standard of practice*

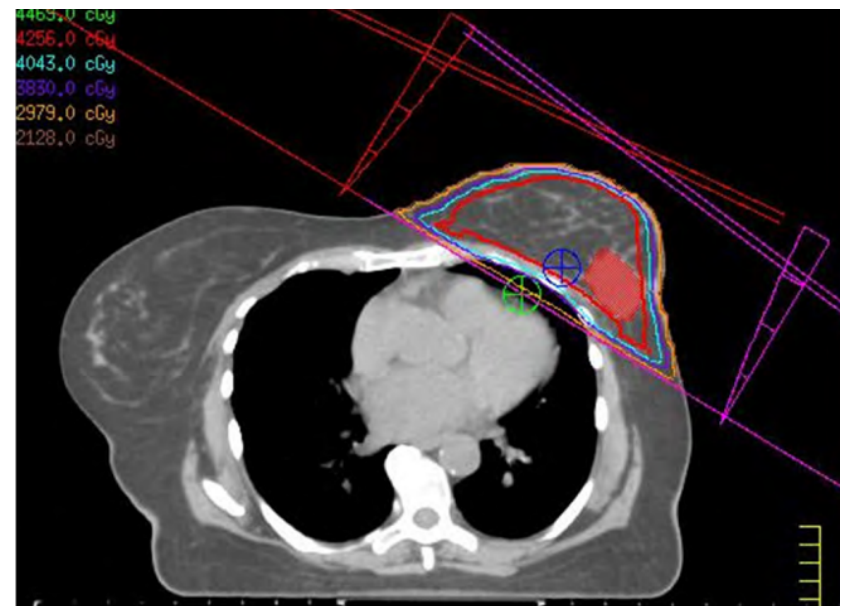
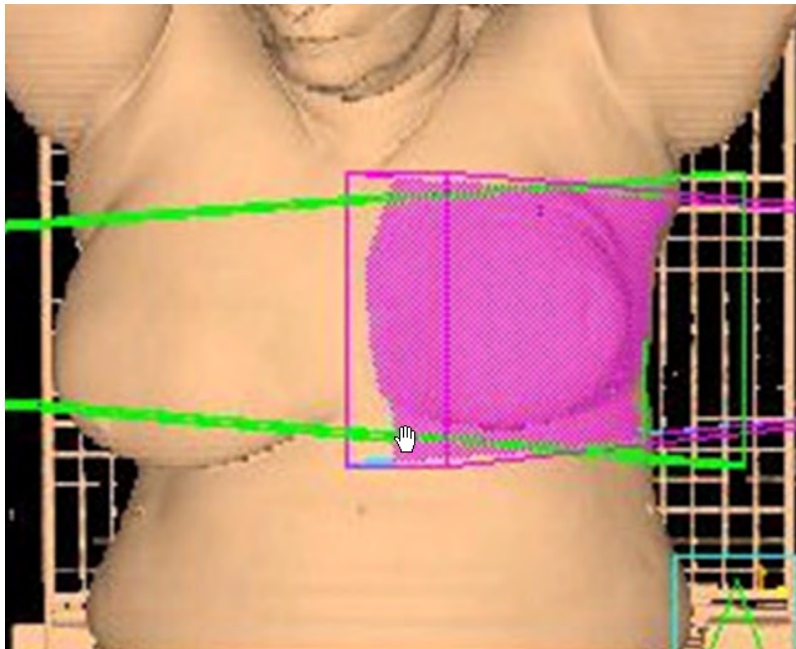


- *Comparable outcomes to mastectomy*
- *Better cosmetic results and reduced trauma*



# Whole Breast Radiotherapy

- *Whole breast RT*

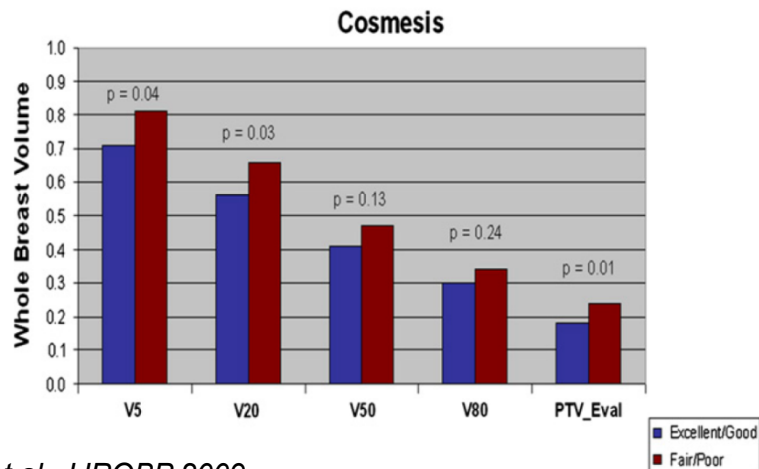
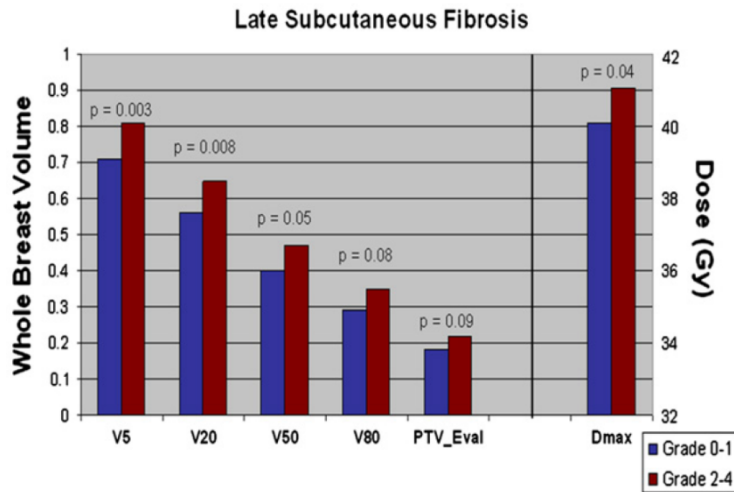


- *Simple parallel opposed tangent beams*
- *Course of 5-7 weeks*



# Breast Toxicity

- *Hepel et al. 2009*





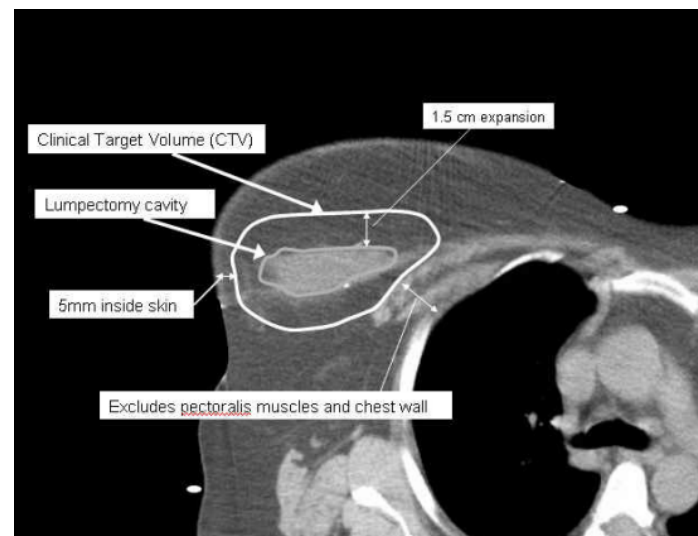
## *Extent of Tumor Involvement*

- *Pathological studies of multi-focality of the breast cancer improved understanding of disease extent...*
- *Holland et al. Cancer 1985*
  - ~ 40% disease @ >2.0 cm away from the “otherwise would-be resections” in the mastectomy specimens
- *Ohtake et al. BCRC 2000*
  - < 10% cases with disease @ >2.0 cm
- *Faverly et al. Cancer 2001*
  - Residual disease unlikely @ >1.1 cm (<8%)



# Partial Breast Irradiation

- *Several "partial breast" irradiation techniques have been devised...*
- *External beam RT*
  - IMRT & 3DCRT
- *Brachytherapy*
  - Interstitial and multi-lumen applicators
  - Balloon-based, single & multi-lumen

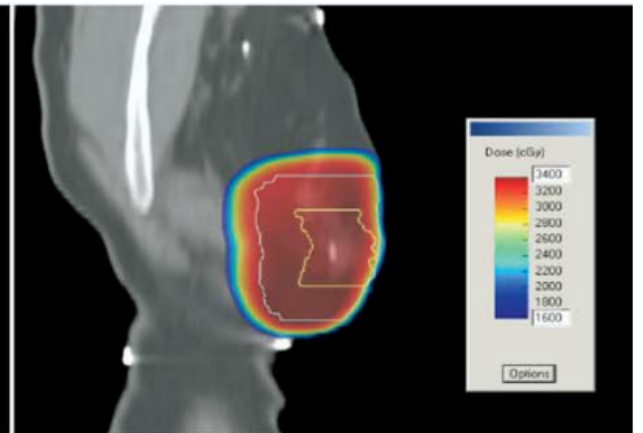
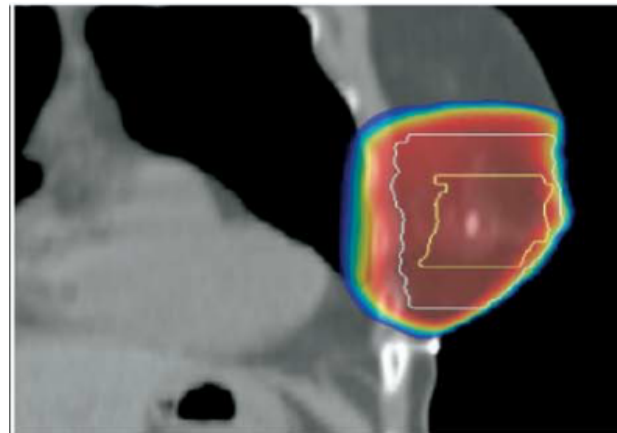
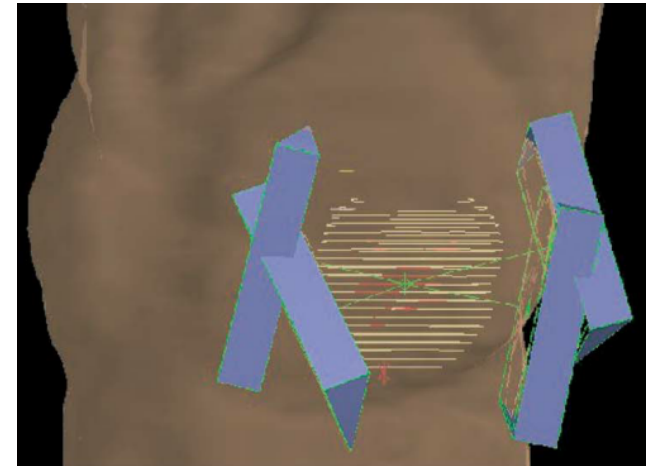
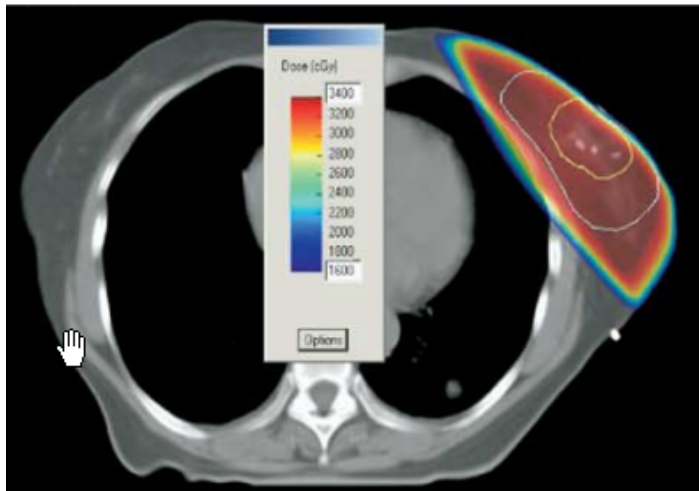






# External Beam RT

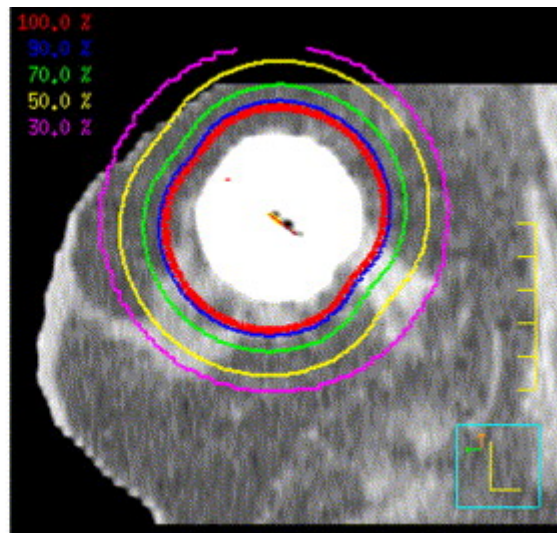
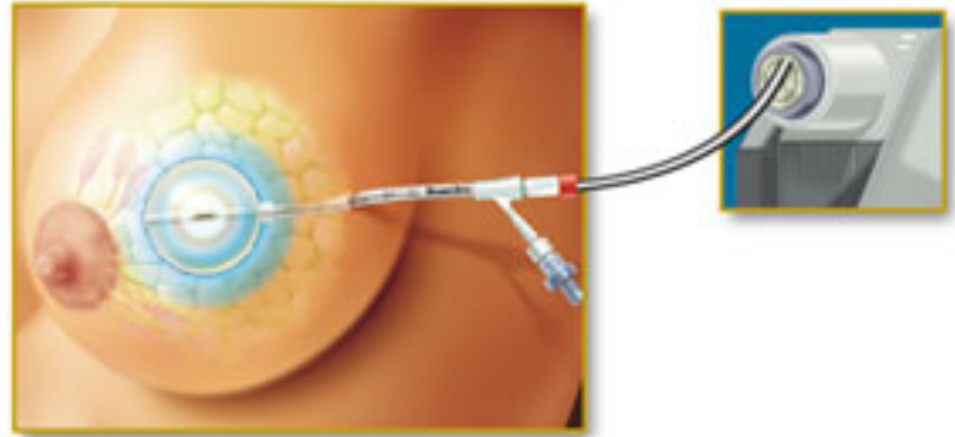
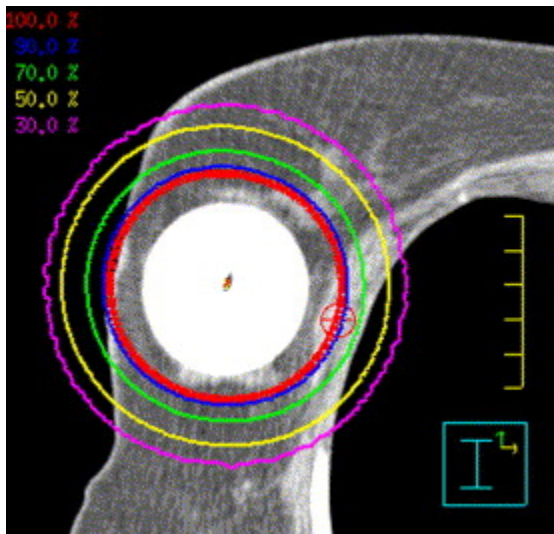
- External Beam RT





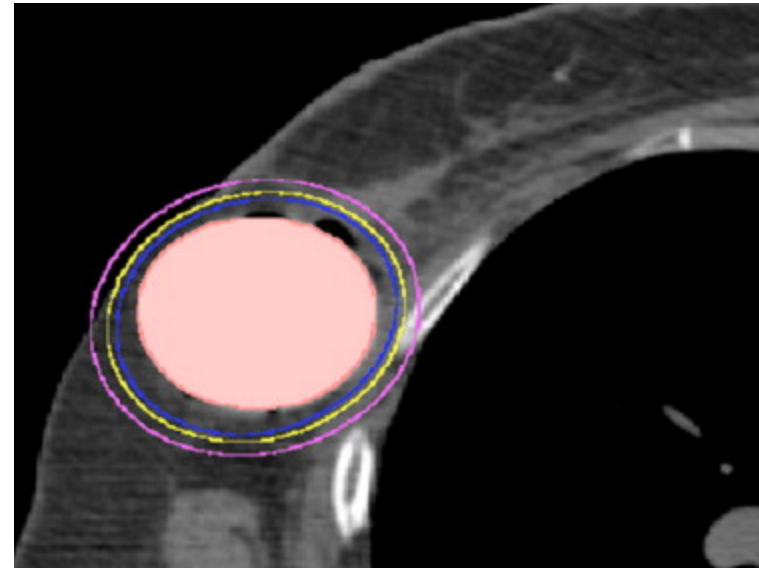
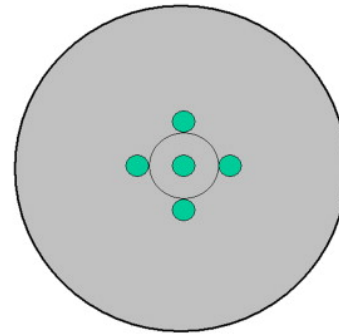
# Balloon Based

- *Mammosite*





- *Contura multi-lumen*





- *SAVI*

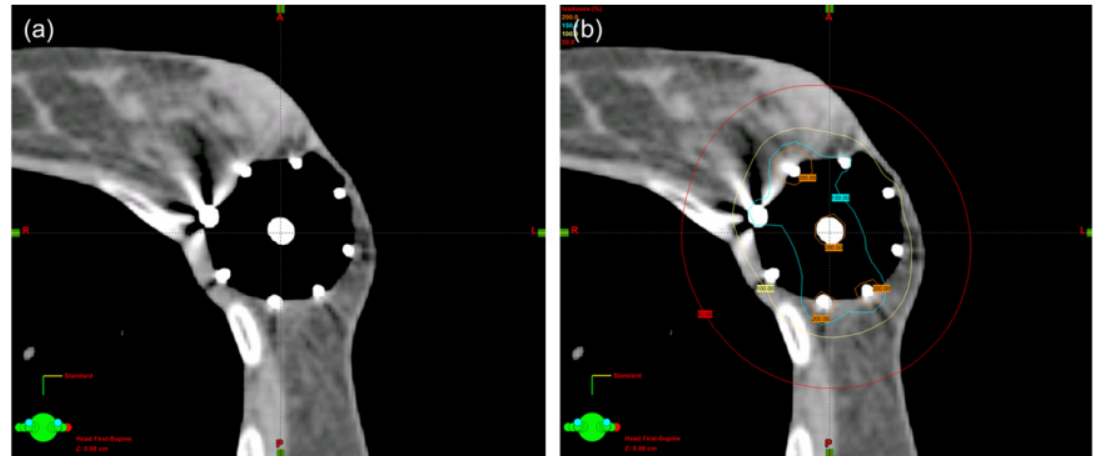
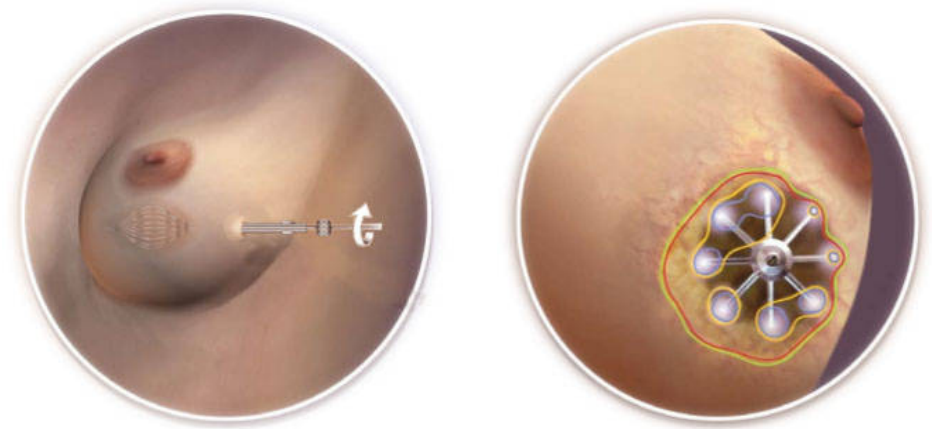


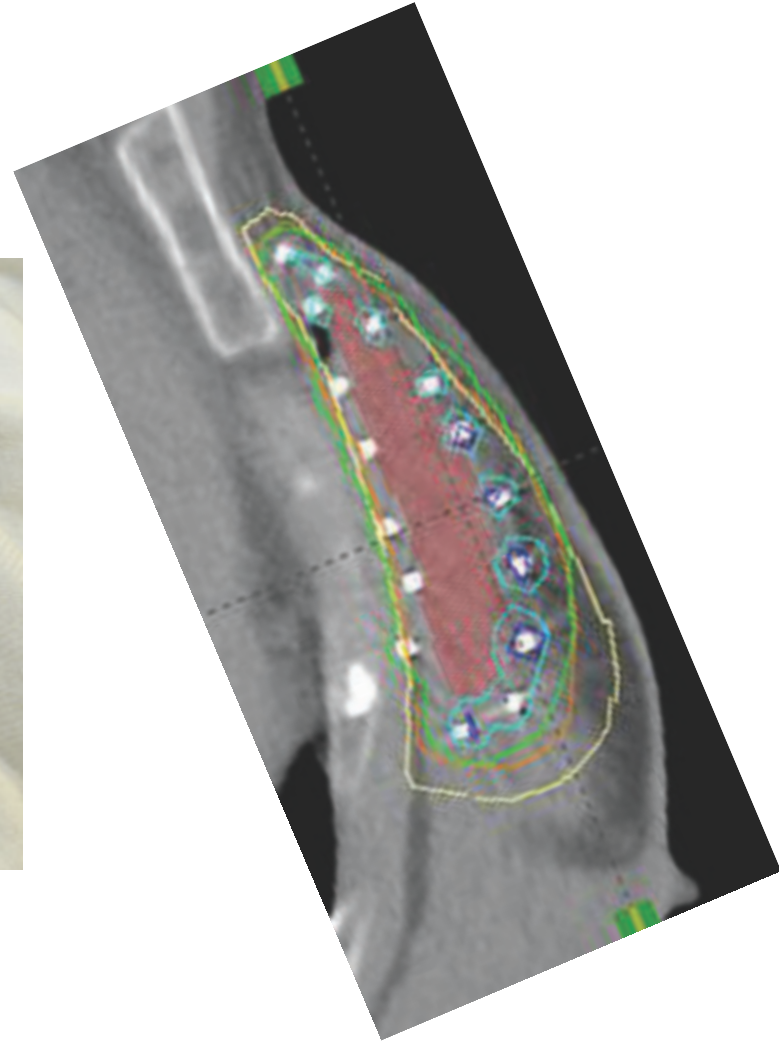
Fig. 2. Strut-Adjusted Volume Implants (SAVI) with simultaneous close proximity to (a) skin and chest wall and (b) dosimetry.





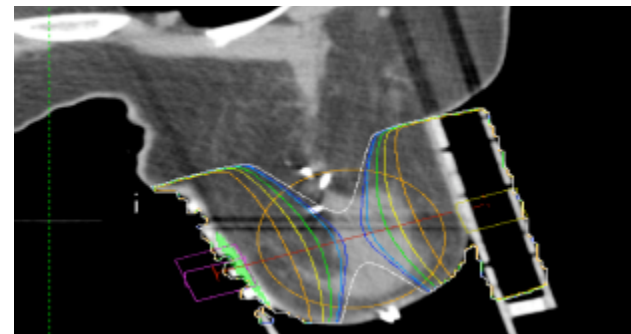
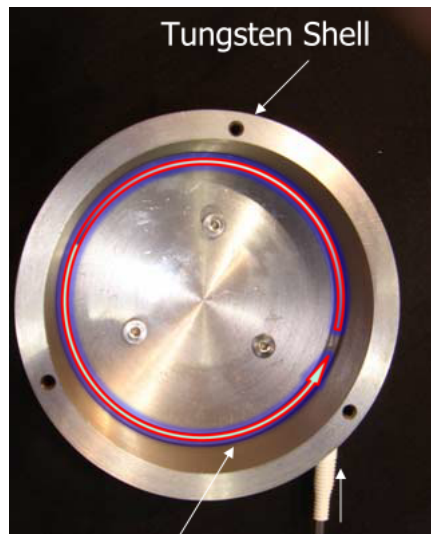
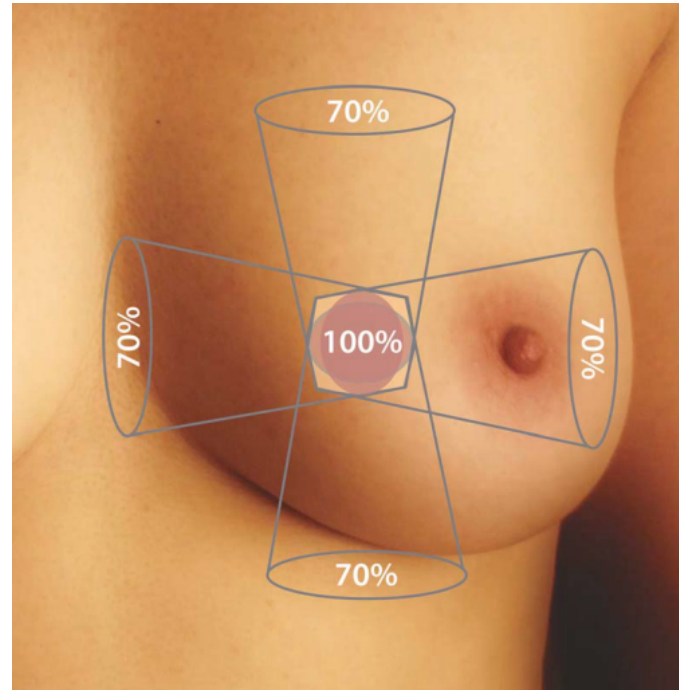
# Interstitial

- *Interstitial*





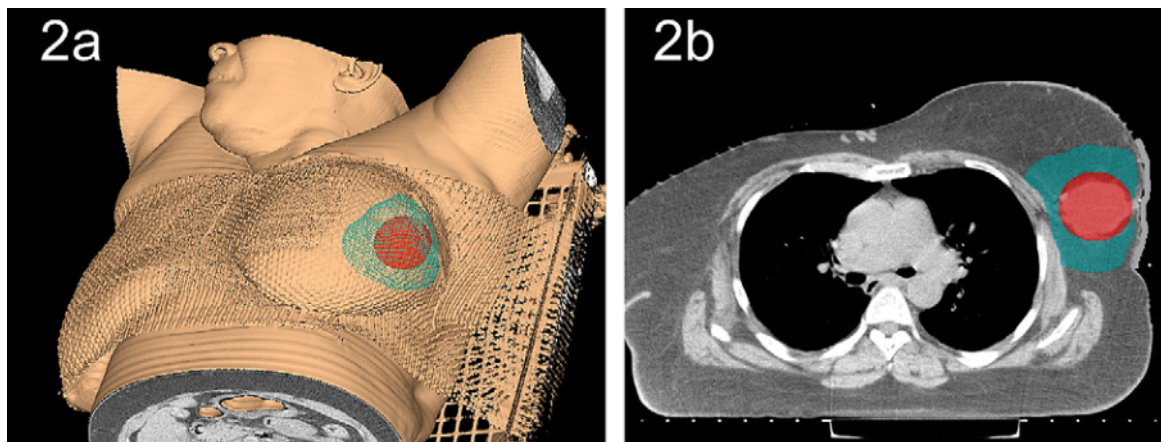
- *Accuboot*





## *Problem(s) with Standard APBI*

- *Radiation following lumpectomy results in large volumes of normal tissue treated*
  - NSABP-B39: 1.5 cm CTV & 1.0 cm PTV margin



Nichols et al., IJROBP 2010

- *Can we give RT pre-operatively?*



## *Problem(s) with Standard APBI*

- *There are also other issues with standard PBI techniques*
  - Non-conformal irradiation
    - ✓ EBRT still tangents
    - ✓ Brachytherapy dose is very heterogeneous and poor dose fall-off
  - Localization, setup, reproducibility difficulties
  - Breathing motion etc.
- *Can we improve the technology?*





# GammaPod



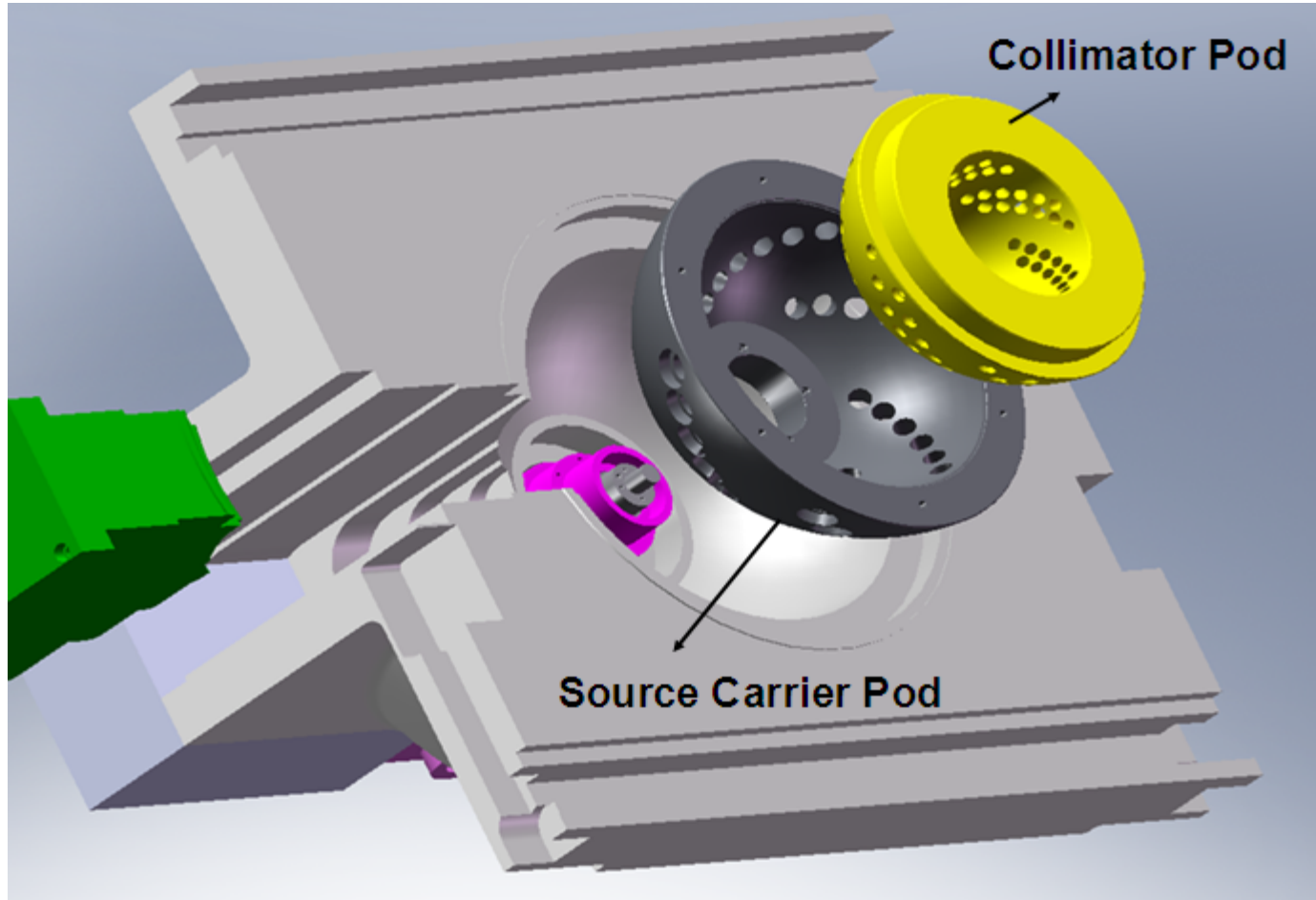


# GammaPod



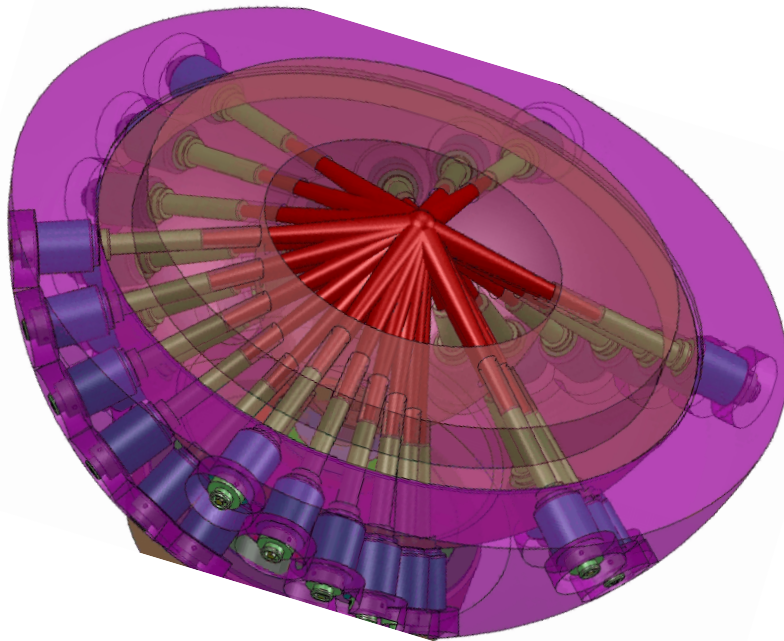


# Collimator





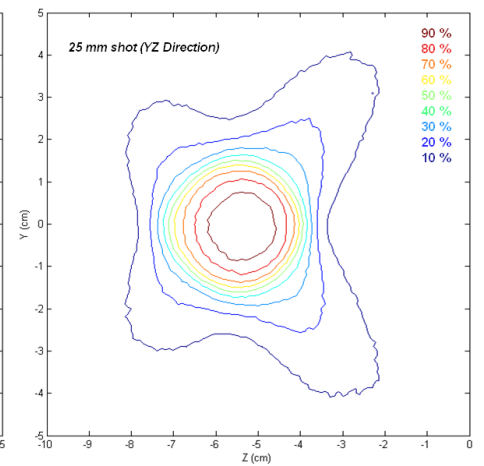
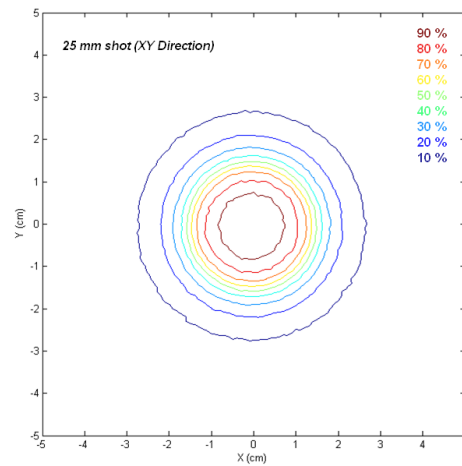
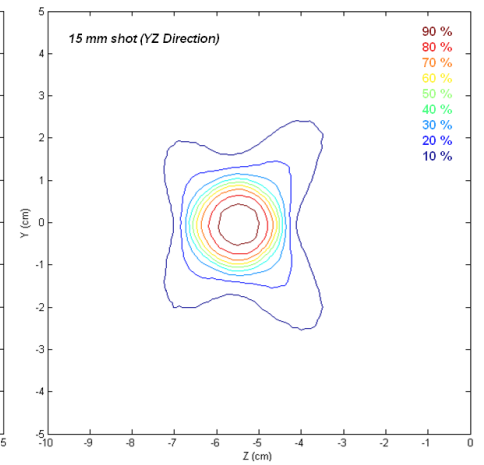
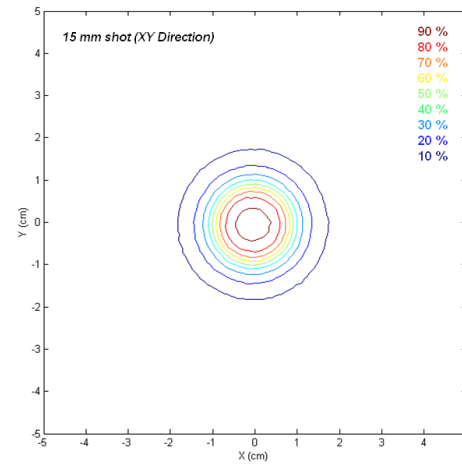
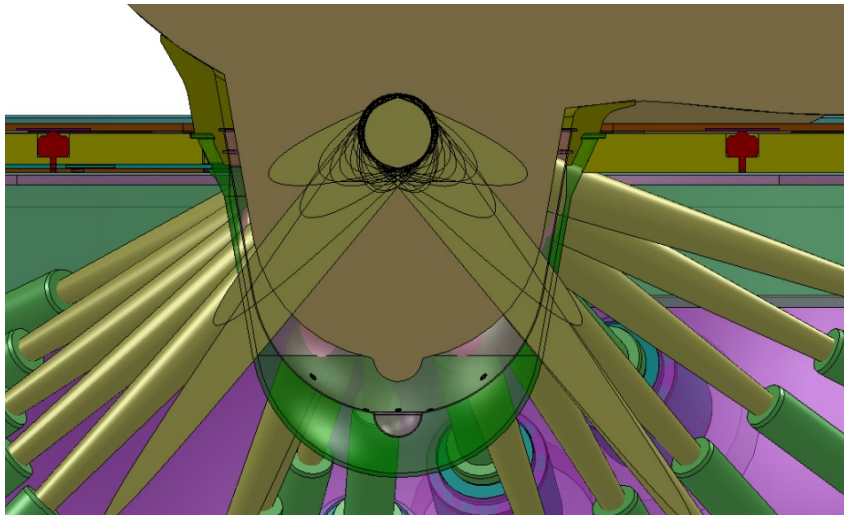
- *36 sources spaced 1 degree apart laterally and 10 degrees longitudinally*



- *2.5 cm & 1.5 cm collimator positions*
- *Source carrier & collimator rotates synchronously...*
- *Total 4400 Ci source produces ~5 Gy per minute for 2.5cm*



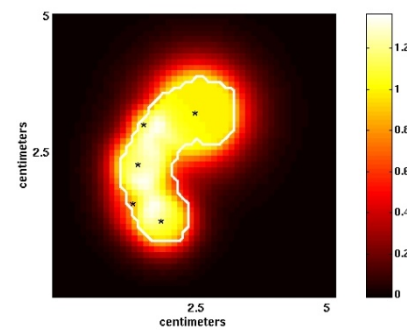
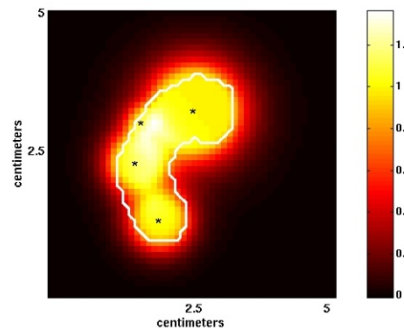
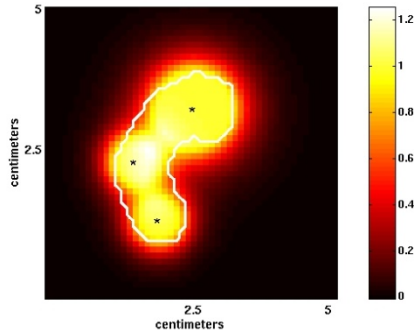
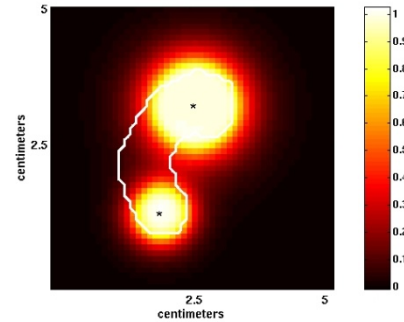
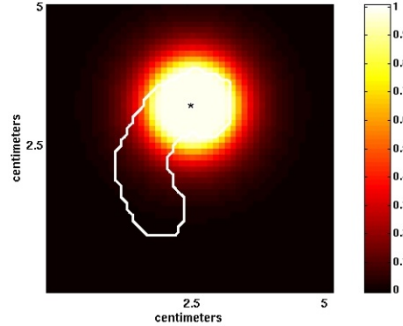
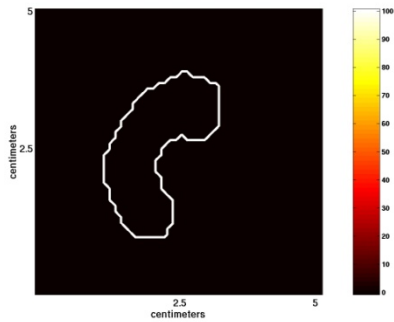
# Dose Distributions





# Static Dose Shaping

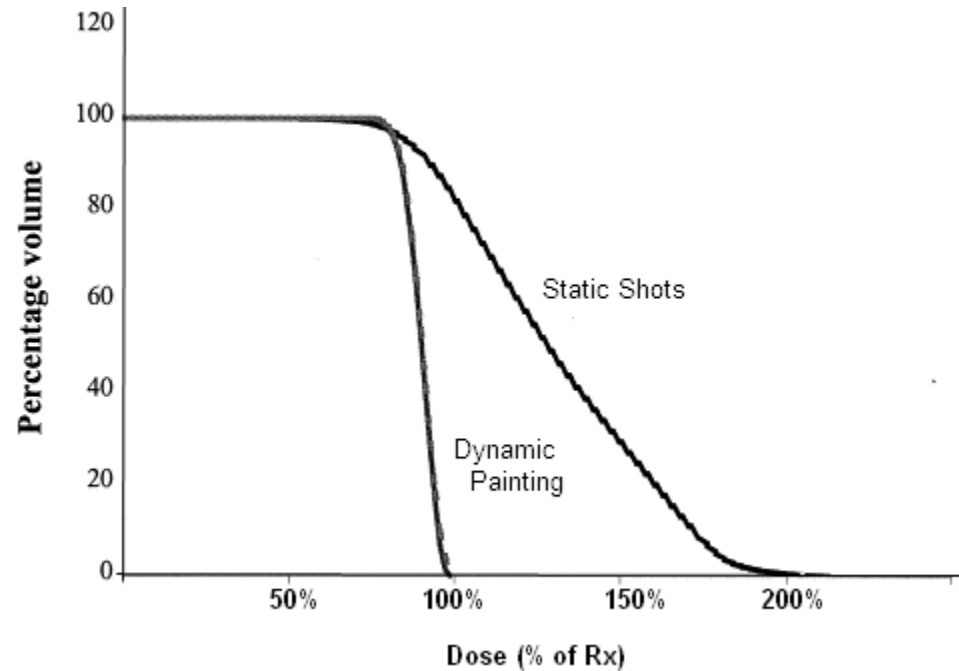
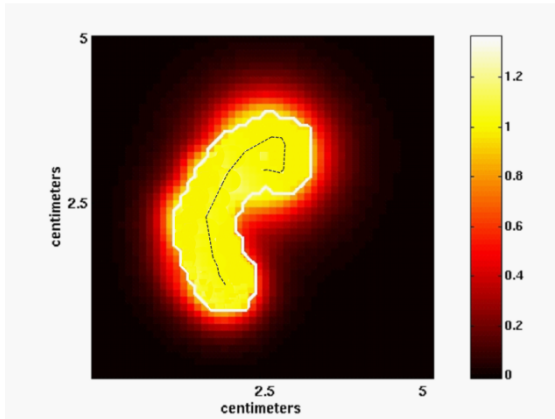
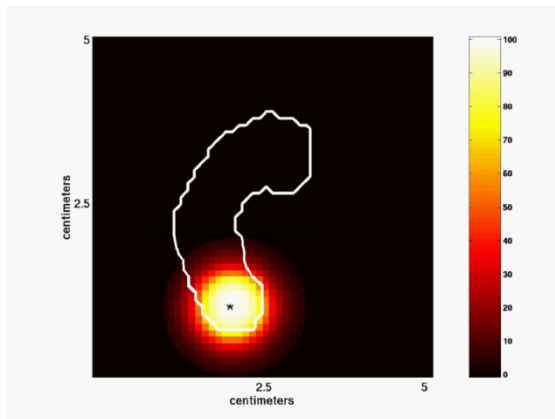
*Static ball packing of "shots" to create adequate target coverage → Gamma Knife*





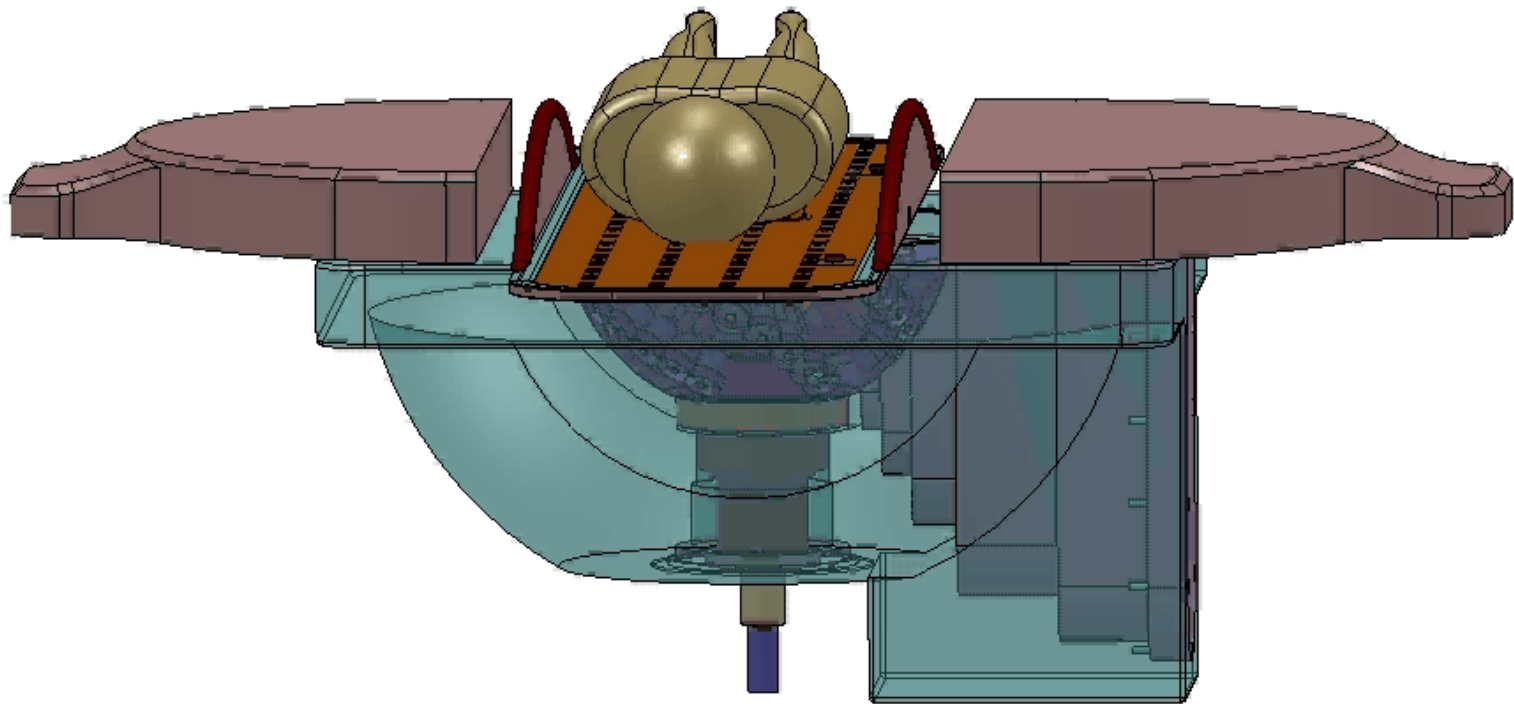
# Dynamic Dose Painting

*Dynamic dose painting allows more high dose homogeneity and differential dosing...*





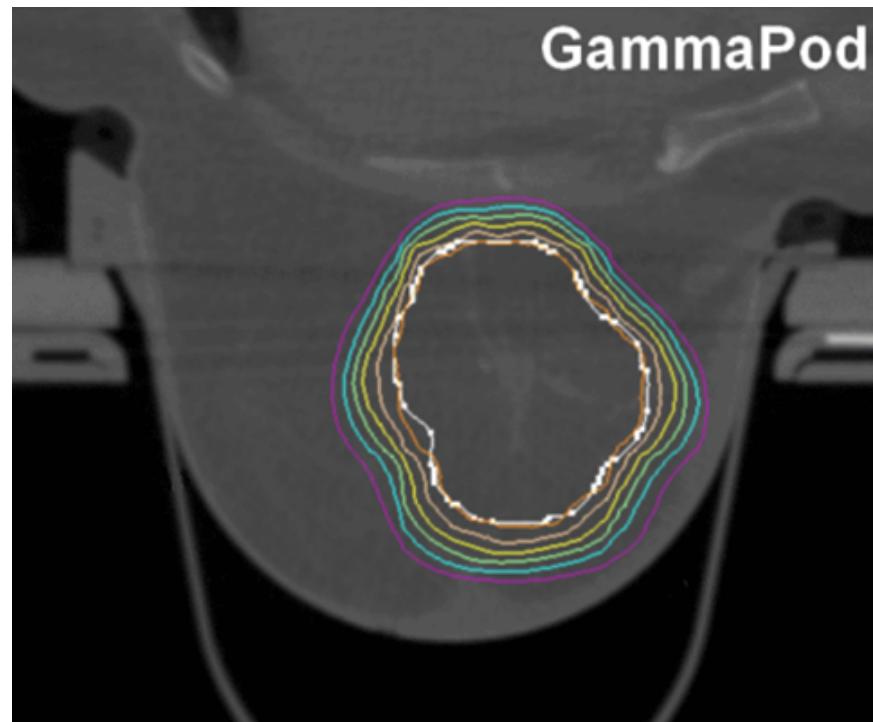
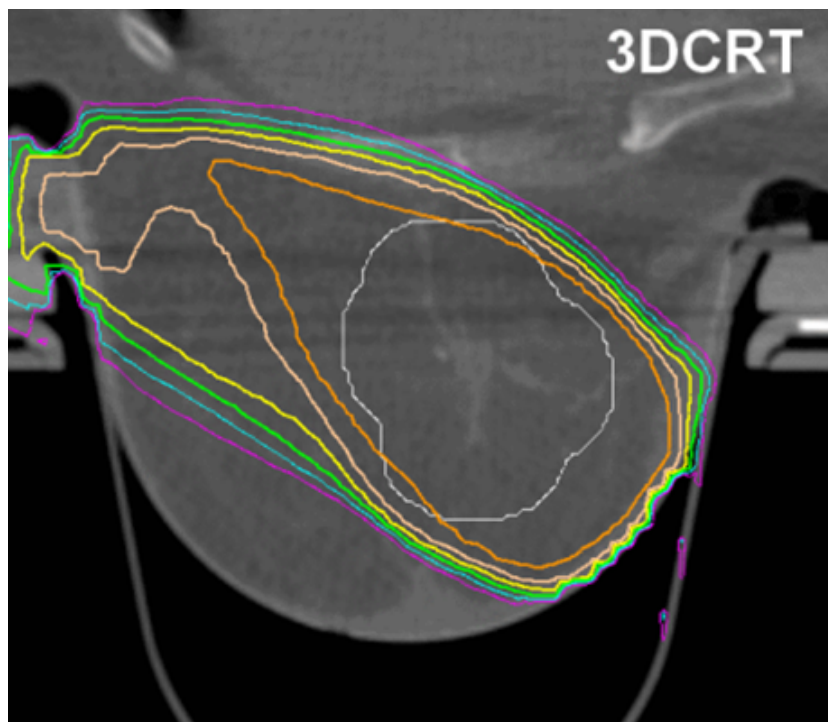
# GammaPod







# *GammaPod Dose Distribution*





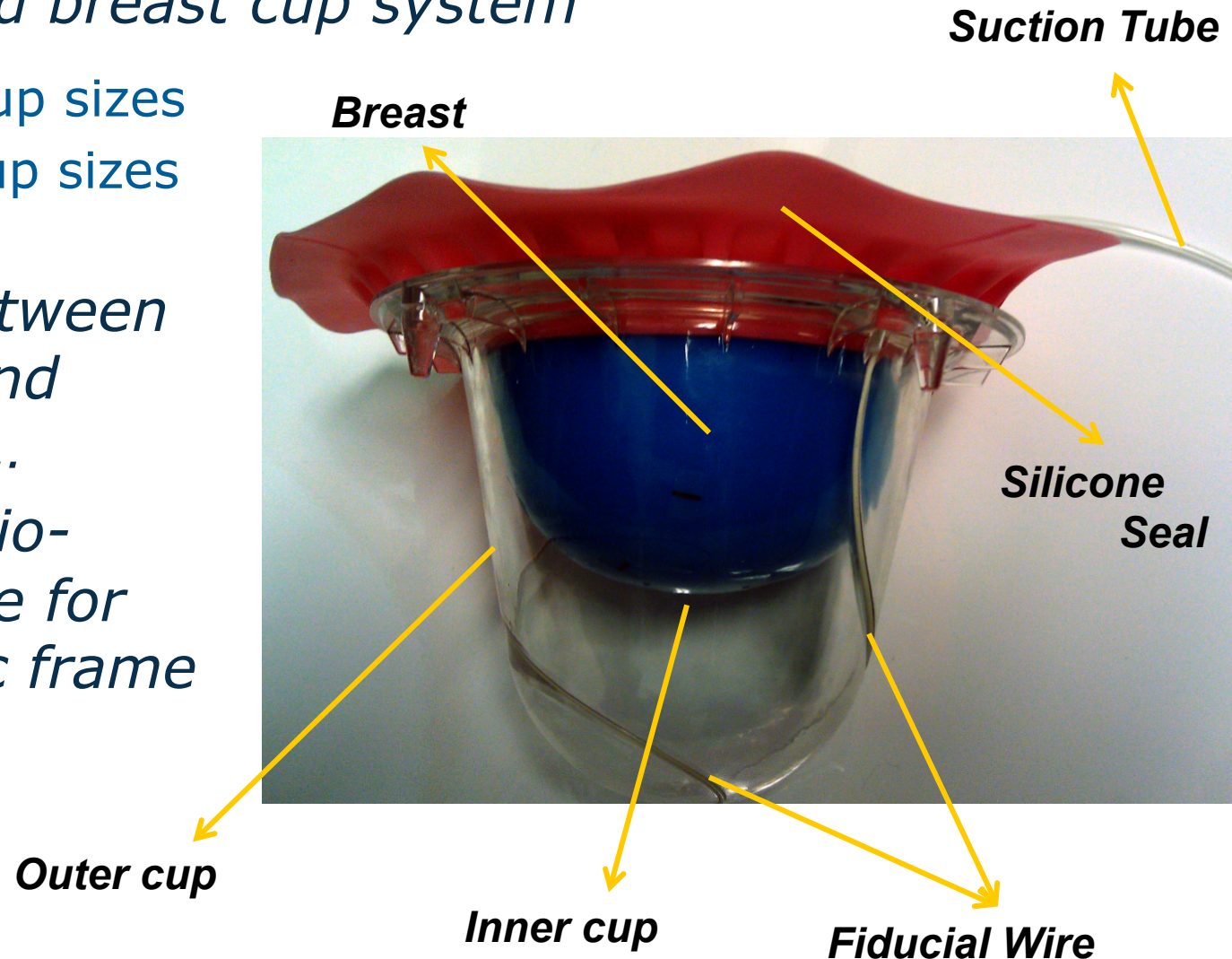
# *Stereotactic Principles*

- *Stereotactic level of targeting accuracy requires*
  - Good immobilization of anatomy
  - Improved localization
- *GammaPod Immobilization*
  - Reduced motion with prone setup
  - Breast cup with vacuum suction
  - Automatic patient loading mechanism
- *Localization*
  - Radio-opaque stereotactic frame



# GammaPod Breast Cup

- *Two-layered breast cup system*
  - 3 Outer cup sizes
  - 9 Inner cup sizes
- *Vacuum between the inner and outer cups...*
- *Built-in radio-opaque wire for stereotactic frame*



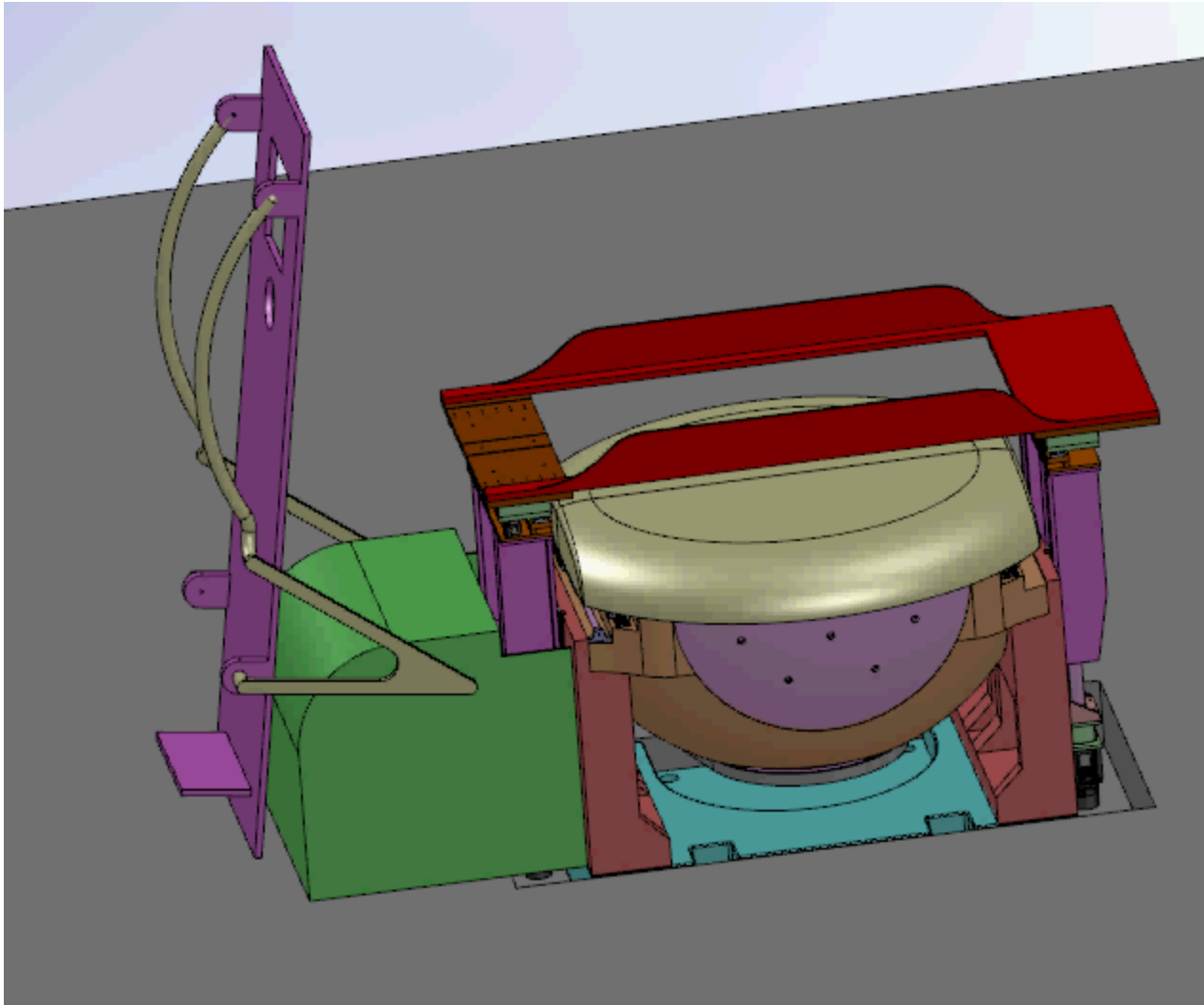


# *GammaPod Breast Cup*





# GammaPod Loader





# GammaPod Loader

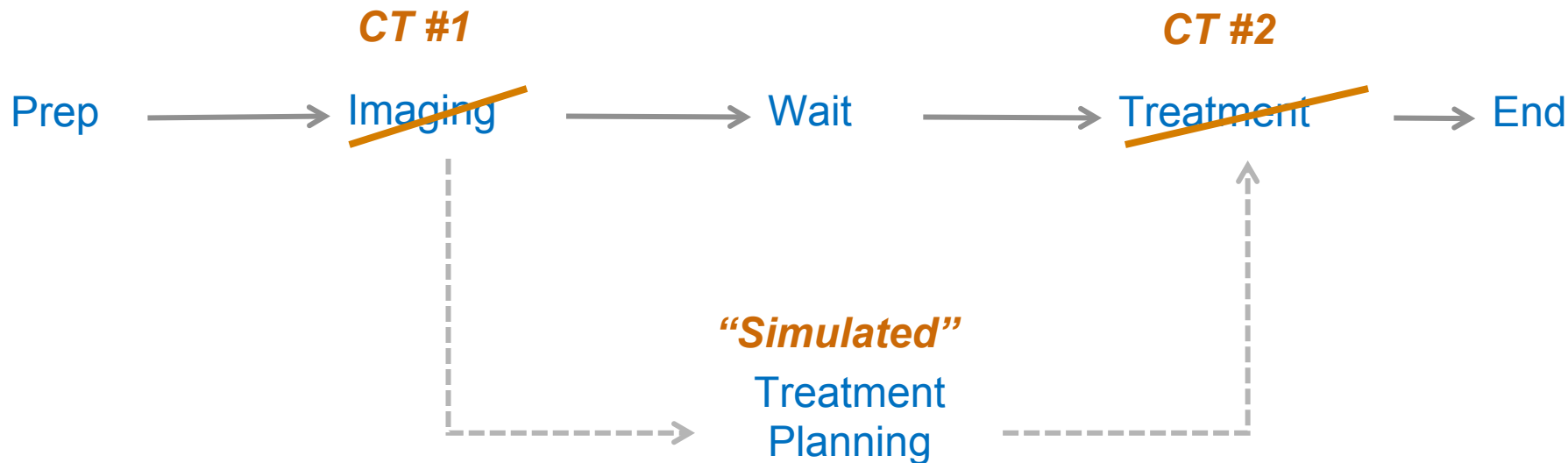
- *Improves integrity of breast immobilization between imaging and treatment sessions...*





# Study of Localization Accuracy

- *U of Maryland IRB approved Localization Accuracy and Reproducibility Study*





# *Imaging Session*







# *Imaging Session*






# Timing of the Process


**Initial Setup**

 26" [13 - 45]


**Dock & Scan**

 6" [4 - 10]

**Registration**

 3" [1 - 7]


**Contouring**


 6" [2 - 13]

**Planning & Finish**

 8" [6 - 14]

**Second Setup**

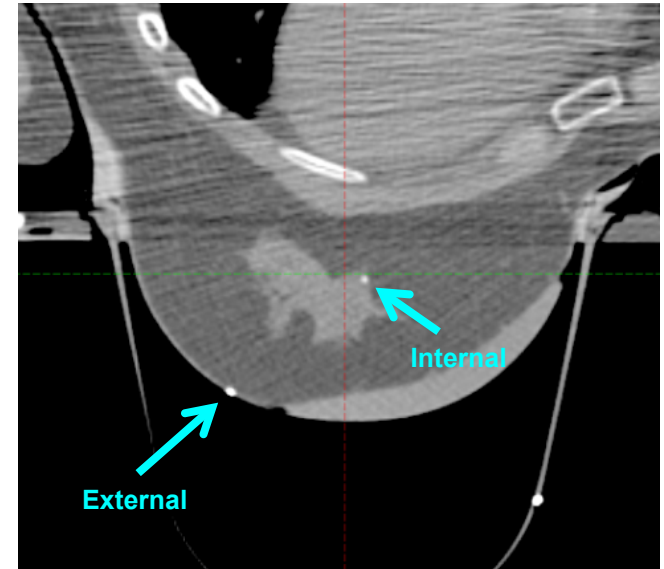
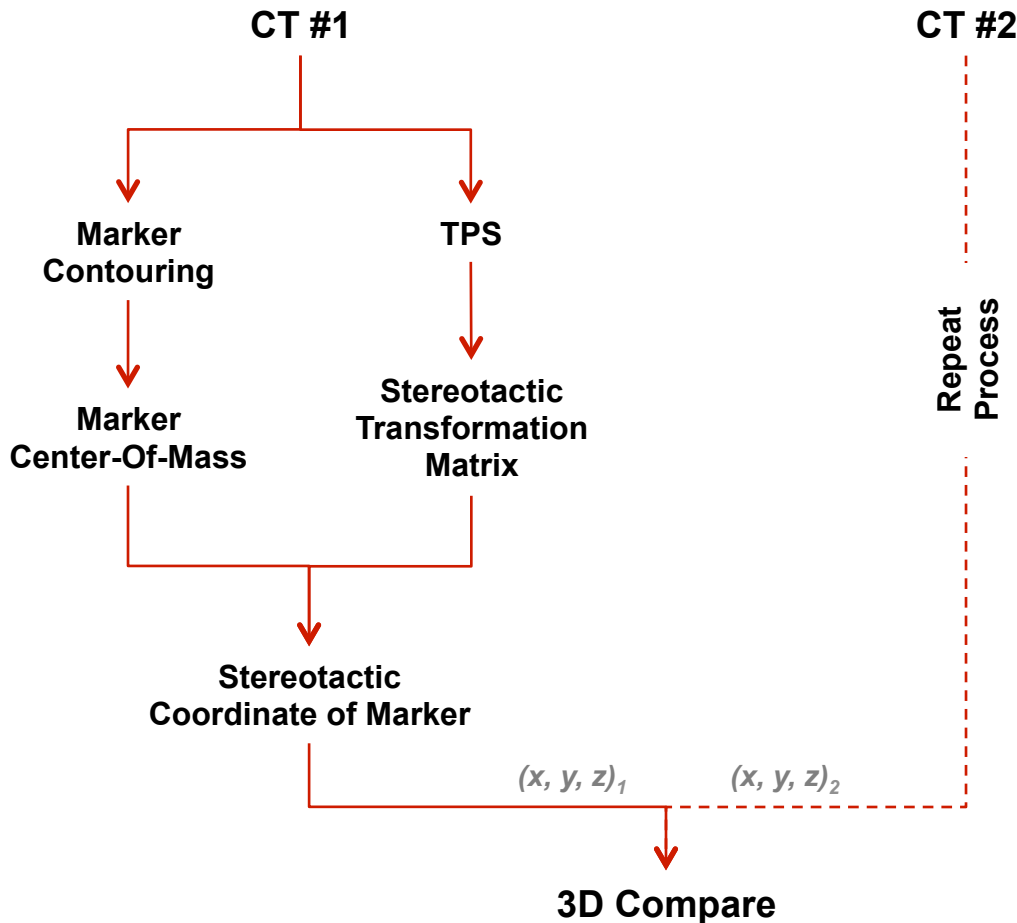
 6" [3 - 13]

  
31" [13 - 45]



# Analysis Method

- *Reproducibility of Internal and External Fiducials*



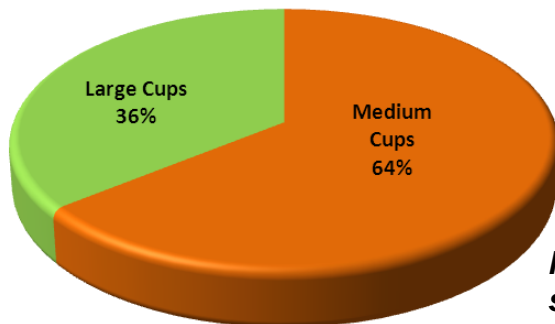
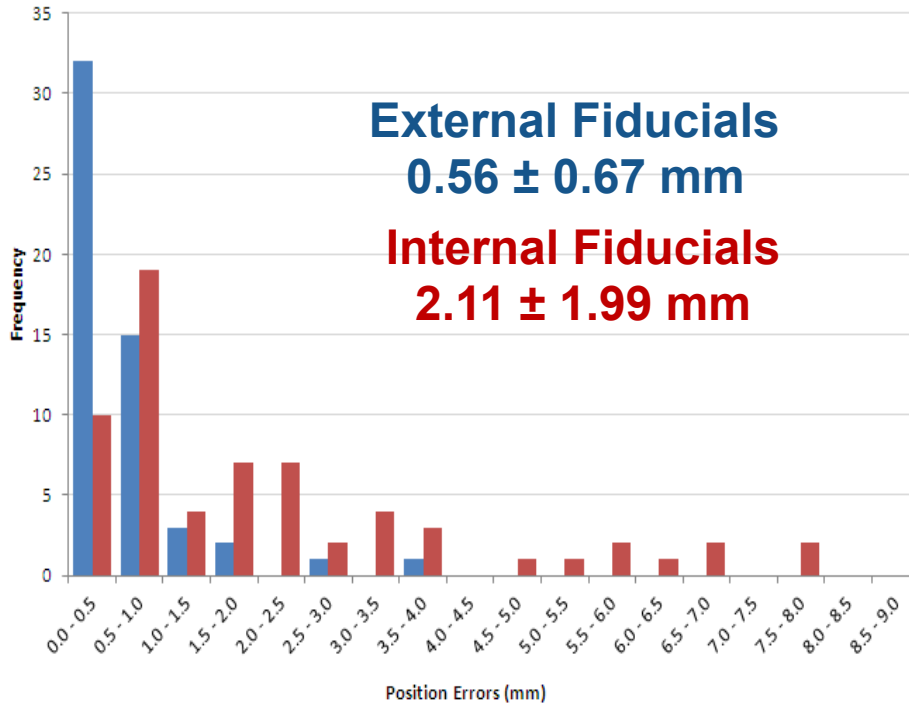


# Reproducibility Results

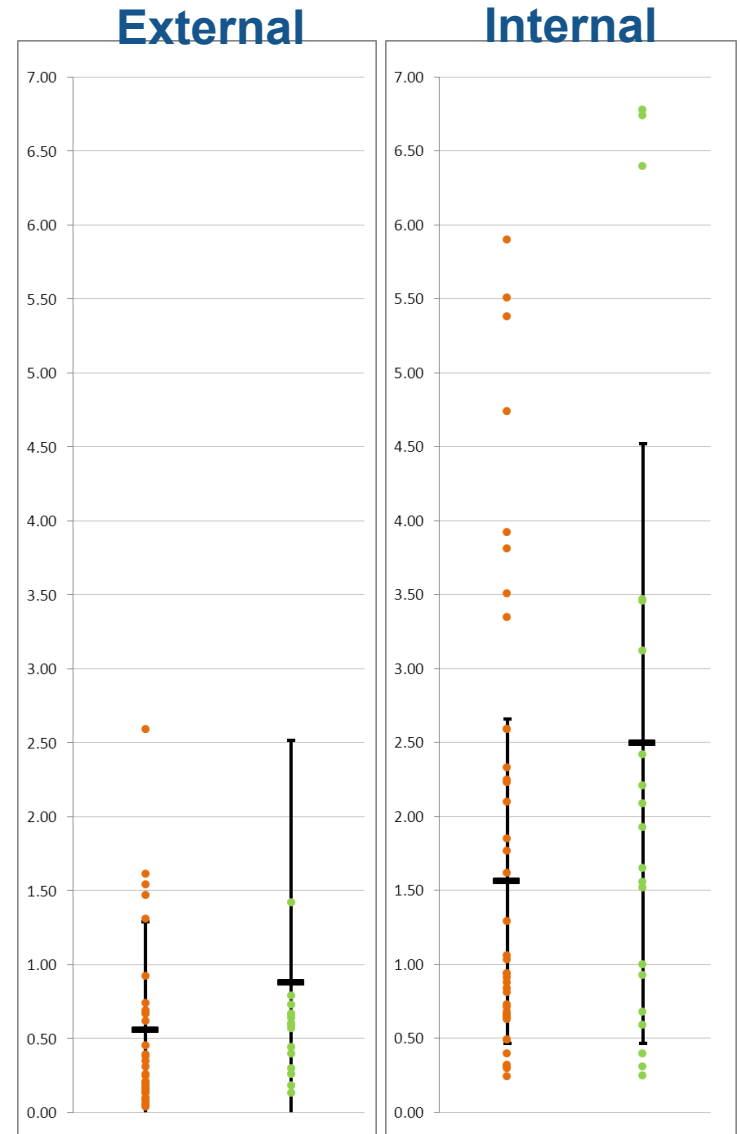
- *20 patients accrued in the study...*
  - 3 patients aborted the study due to comfort issues or setup difficulty...
  - 1 patient cancelled due to breast cup size mismatch (logistics)
  
- *16 patient scans were available for study...*
  - 5 patients had pressure related issues



# 3D Reproducibility

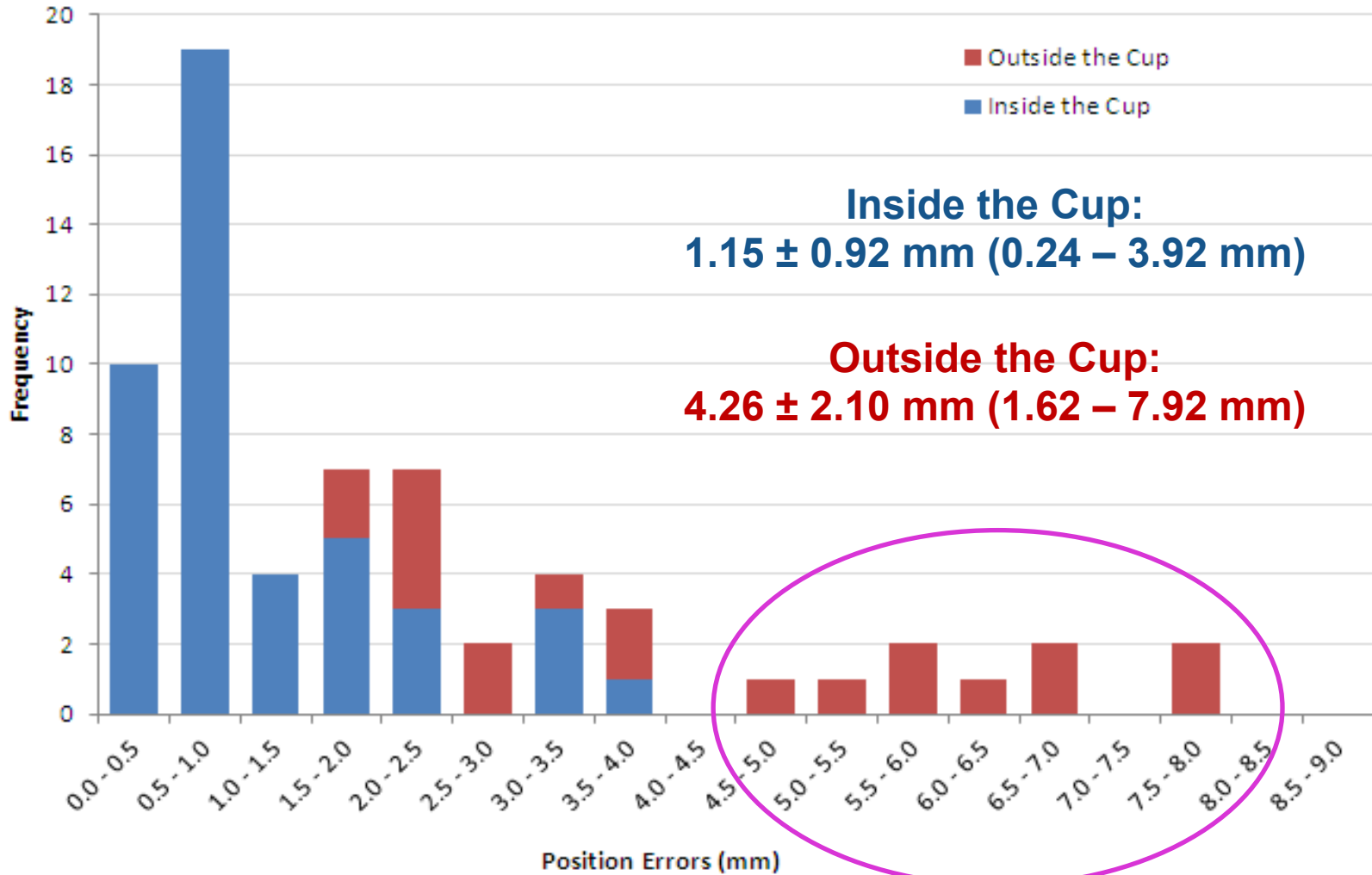


*No patient requiring  
small cup yet...*





# 3D Reproducibility

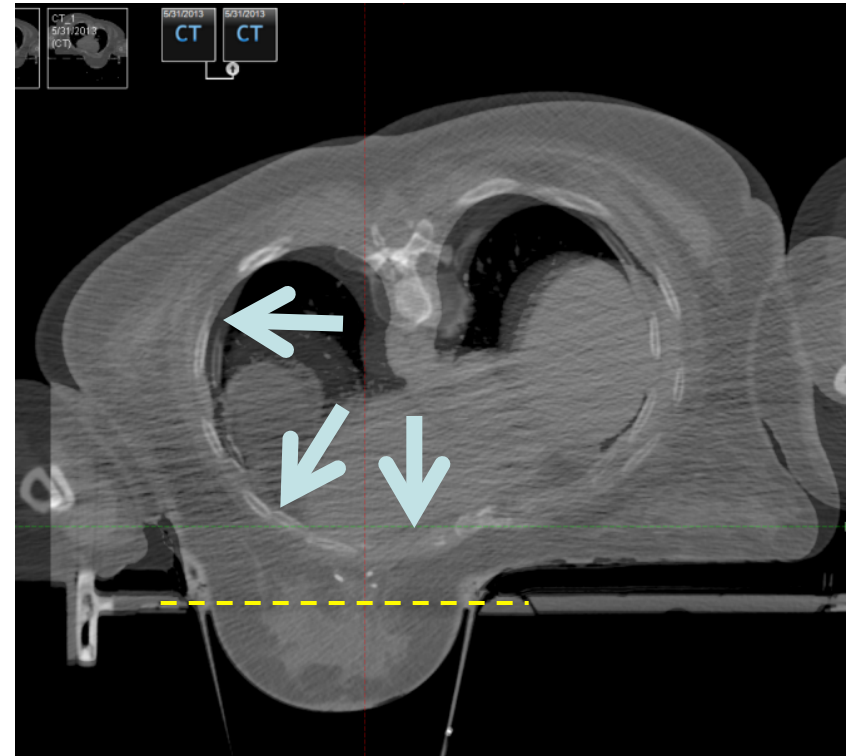
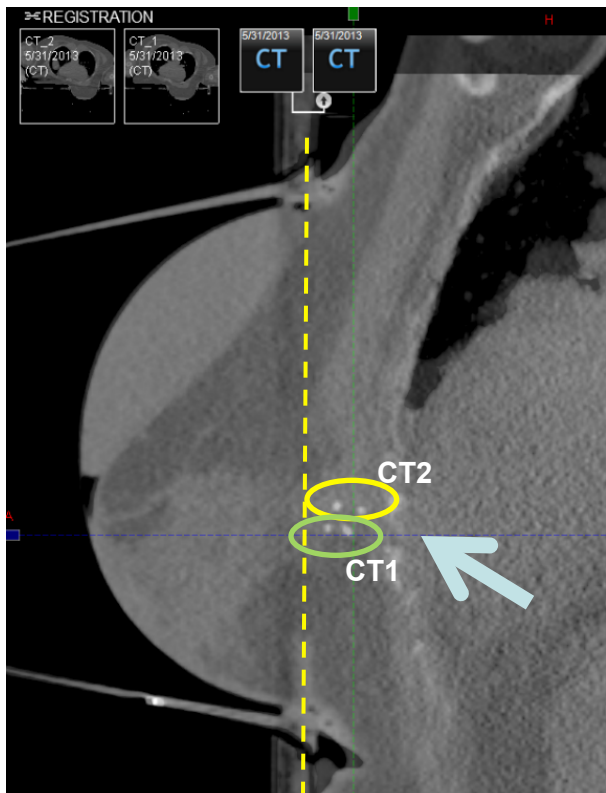




# 3D Reproducibility

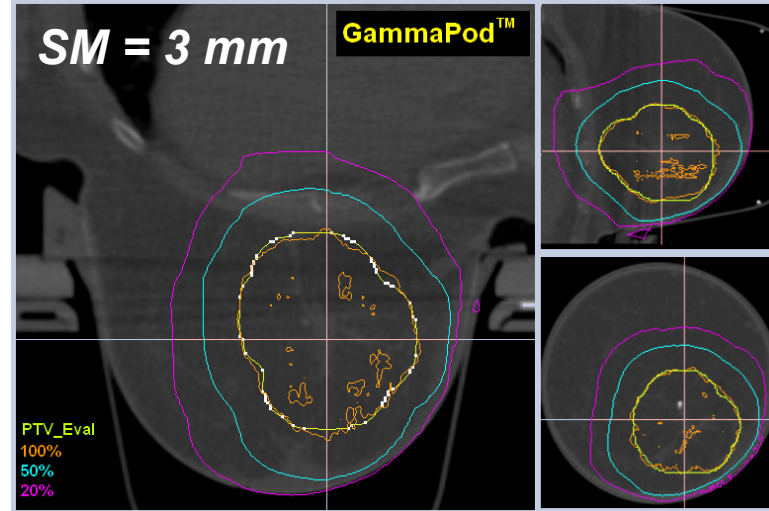
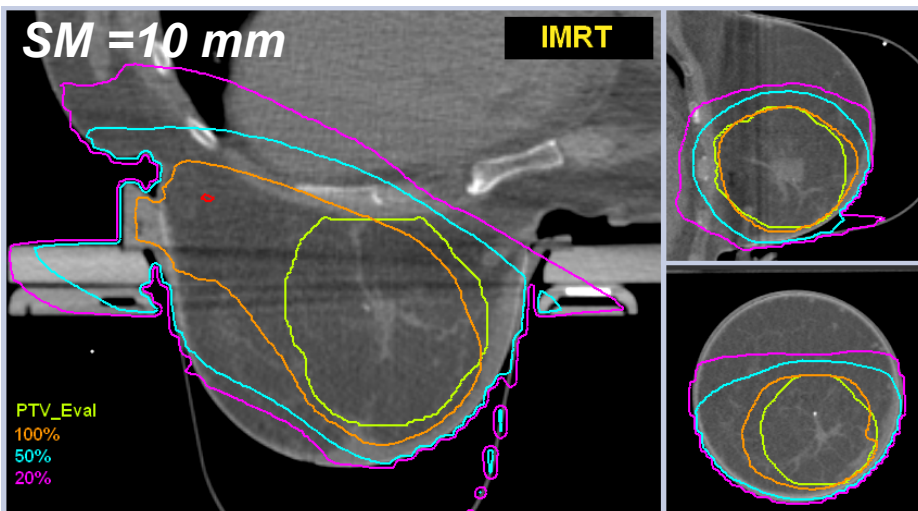
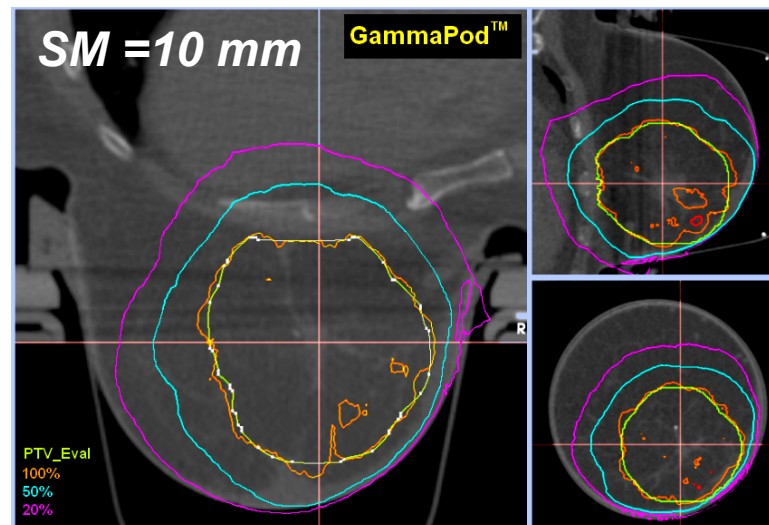
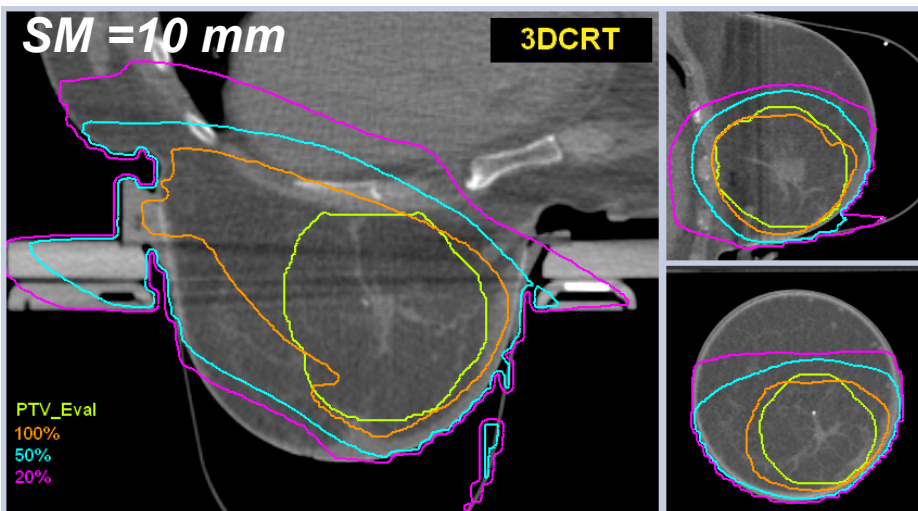
Breast cup immobilizes the tissue within the cup sufficiently...

The anatomy outside the cup (for targets close to chest-wall) is prone to general patient setup errors.





# GammaPod in Post-Op APBI



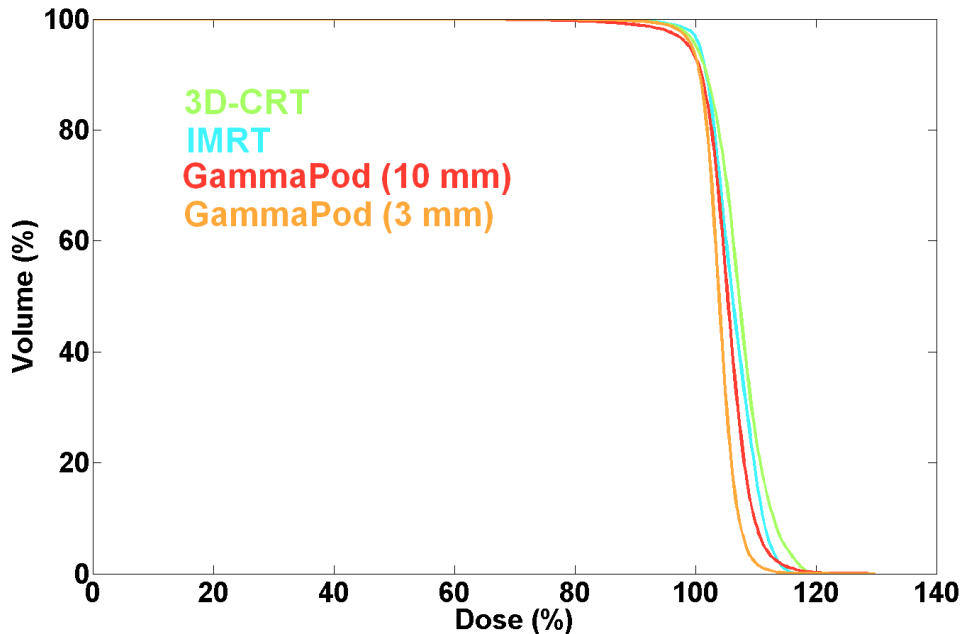




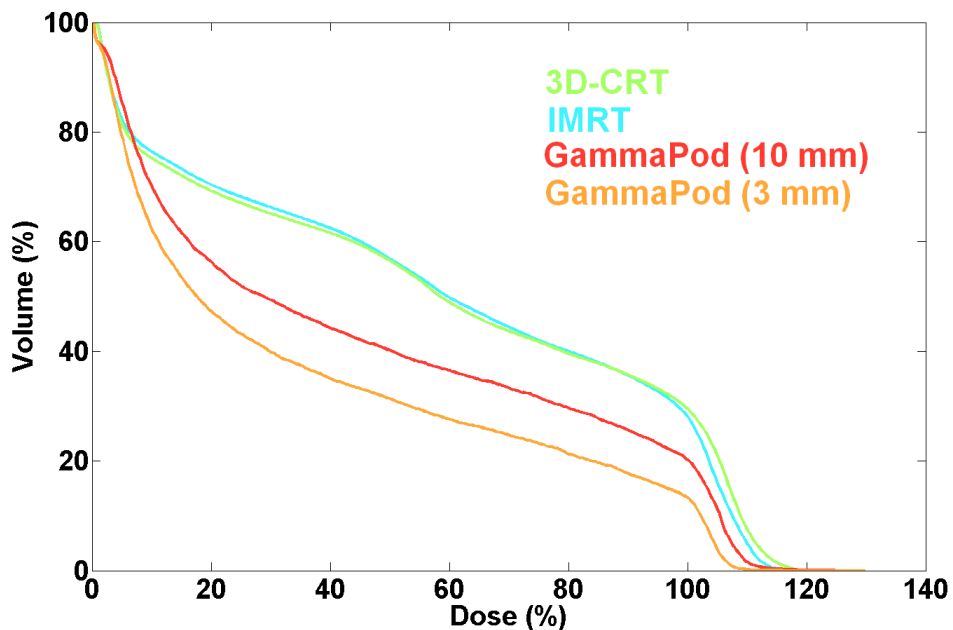
# GammaPod in Post-Op APBI

6 post-lumpectomy breast cancer patients (5 LT and 1 RT)

**PTV\_EVAL**



**Ipsi-lateral Breast**



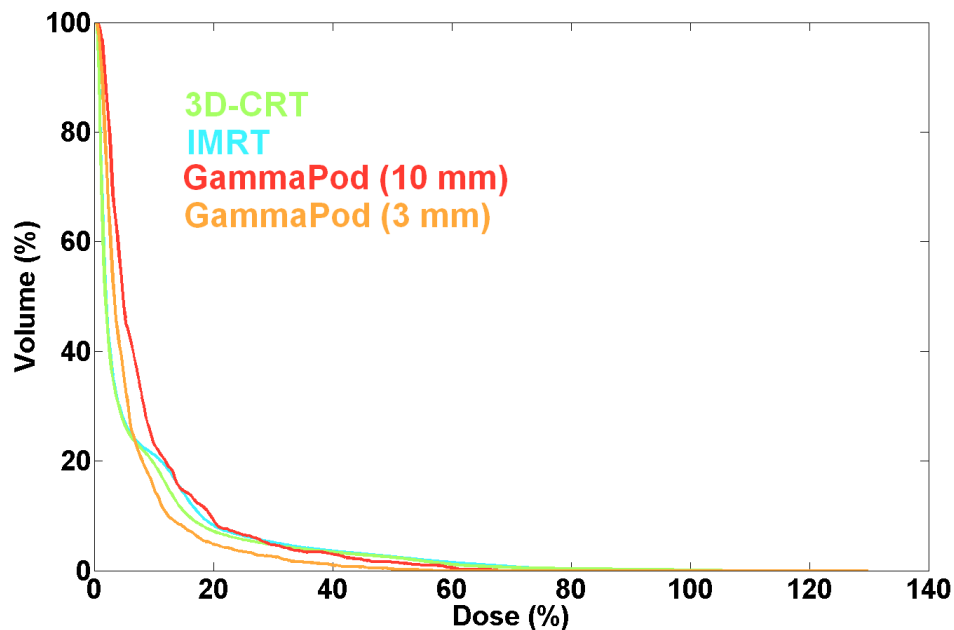
Hepel et al. → V20 less than 60%



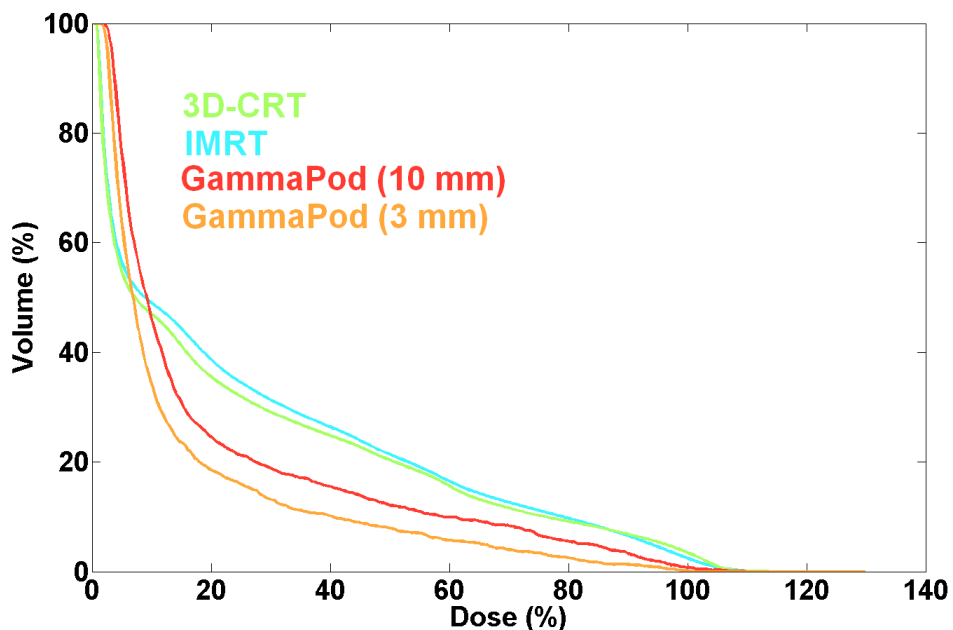
# GammaPod in Post-Op APBI

6 post-lumpectomy breast cancer patients (5 LT and 1 RT)

## Heart

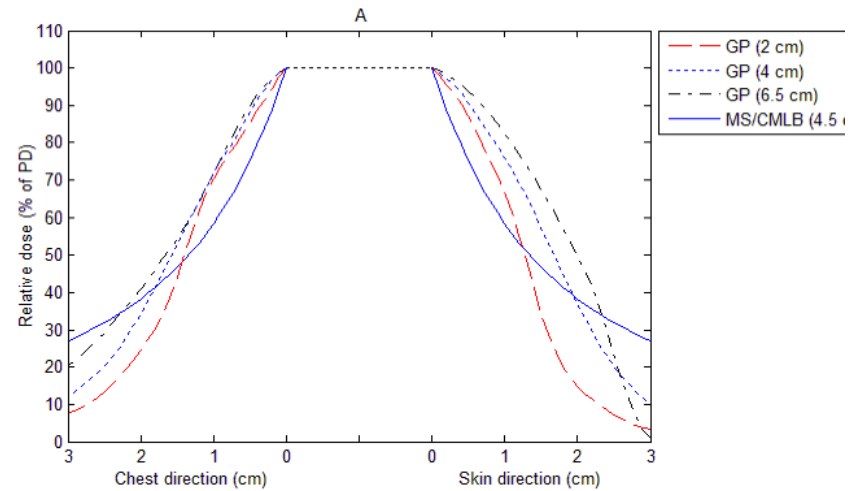
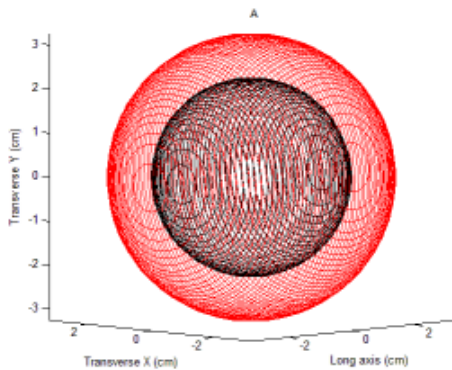
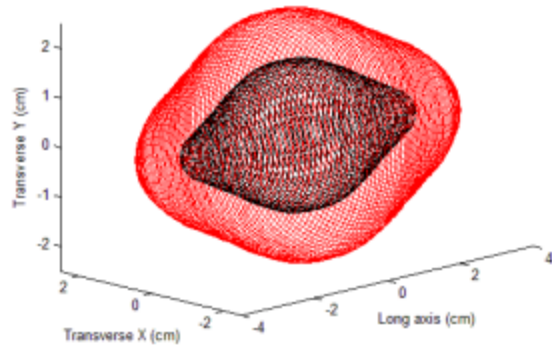
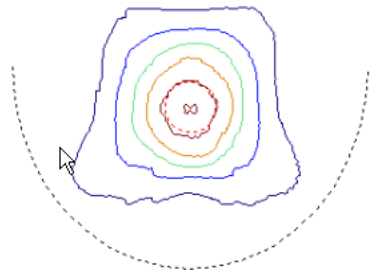


## Chest Wall





# Comparison to APBI Brachytherapy



**Table 2:** Skin doses in % of PD. Mean skin doses for the BT devices and range within parentheses. Two values for GP – skin dose when the dose is normalized to 100% of PD at the target edge and skin dose obtained from the optimization (second one within square brackets).

Skin distance (cm)	MS	CMLB	SAVI	GP 6.5 cm	GP 4 cm	GP 2 cm
1.5	75 (73-77)	75 (74-77)	71 (70-71)	13 [9]	7 [5]	9 [7]
1.0	100 (100-100)	75 (73-77)	72 (71-74)	9 [6]	10 [9]	10 [7]
0.7	122 (120-124)	79 (78-79)	72 (70-74)	20 [15]	14 [14]	12 [10]
0.5	144 (137-144)	83 (82-84)	76 (74-77)	22 [13]	21 [18]	23 [20]



# GammaPod in Pre-Op APBI

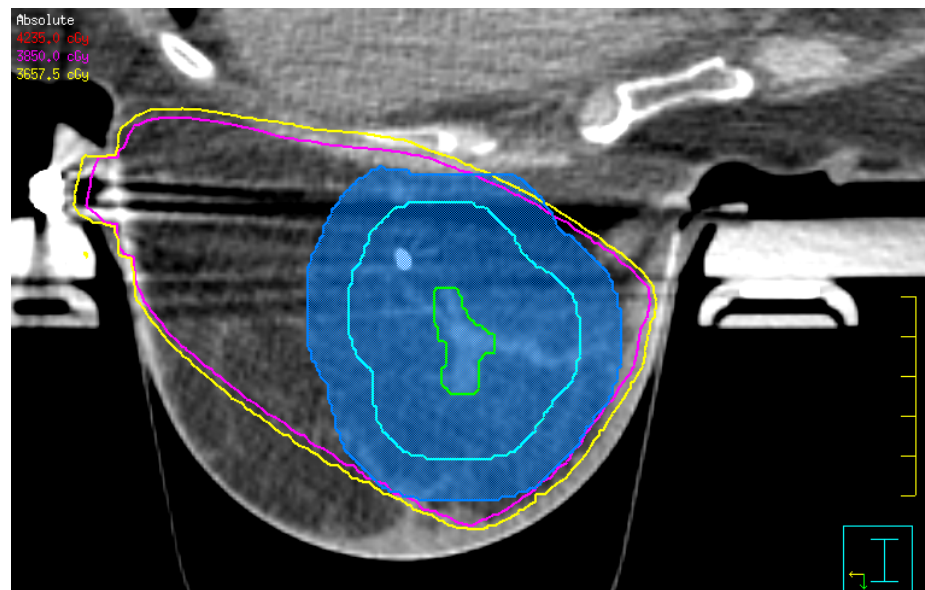
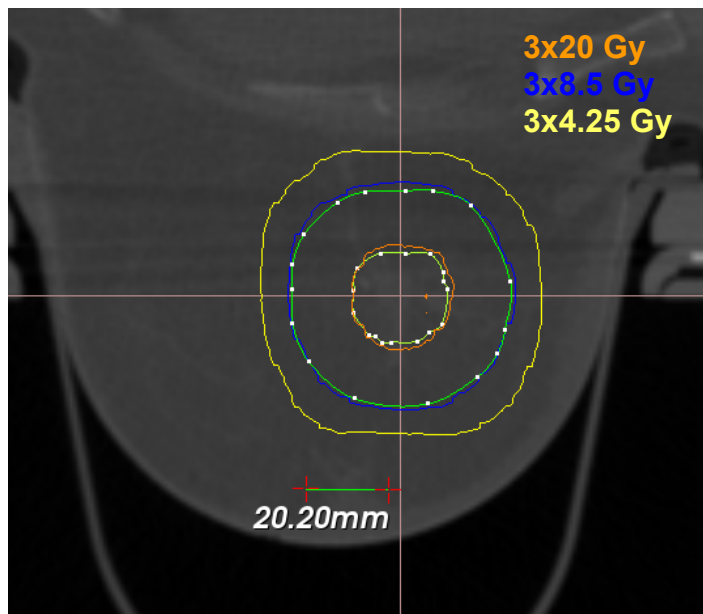
*Potentially use dose-shaping capabilities of GammaPod*

*Deliver ablative dose to the gross tumor (GTV)*

*Example: High dose e.g. 3 x 20 Gy to GTV*

*Deliver sterilizing dose to tumor extension  $\sim$  GTV + 1.5 cm*

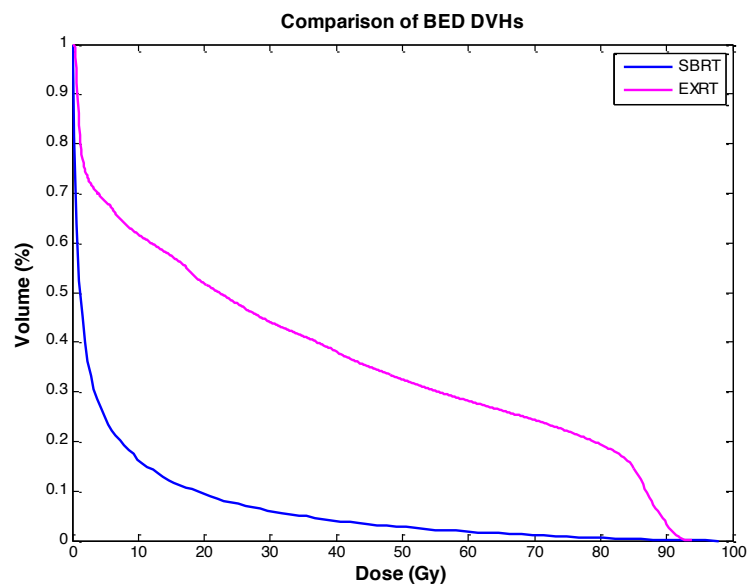
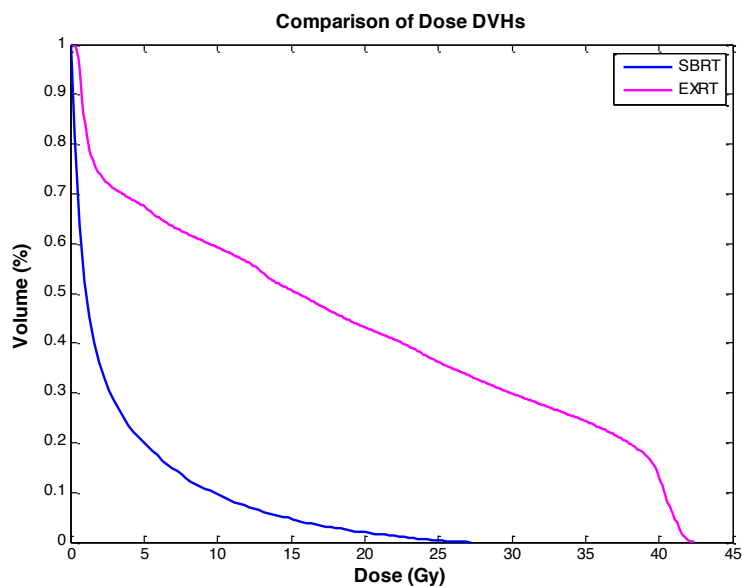
*Example: Low dose e.g. 3 x 8.5 Gy ( $\sim$ equiv. to 10x3.85 Gy)*





# GammaPod in Pre-Op APBI

- *Whole Breast Physical Dose (D) and Biologically Equivalent Dose (BED)*





## *GammaPod in Pre-Op APBI*

- *Uninvolved Breast NTCP\** (end point "moderate" fibrosis)
  - GammaPod (SBRT) = < 0.1
    - EUD (2 Gy) = 5.5 Gy
  - APBI Post-Op (EXRT) = 1.2 %
    - EUD (2 Gy) = 24.5 Gy

\* Assuming Lyman's Poisson Model with NTCP parameters from Alexander et al.

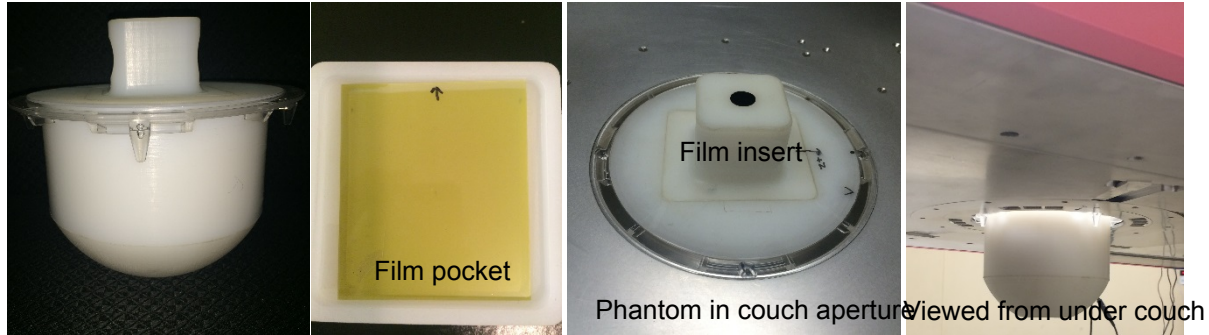


## Current Status

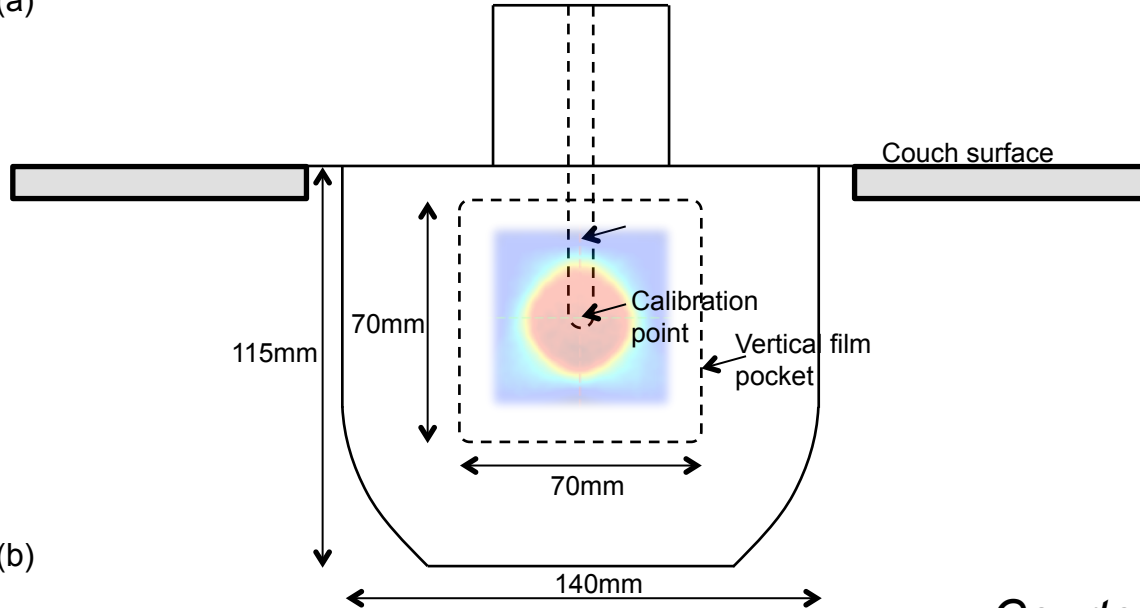
- *GammaPod was installed at U of Maryland in June 2014*
  - *Co-60 sources (2700 Ci) were installed in November 2014*
- *Preliminary dosimetry and commissioning work has started*
  - *First treatments expected in Aug 2015*
- *Studies coordinated through a consortium of 5 academic institutions*
  - **UMMS**, *UT Southwestern, Kansas, Allegheny and Ottawa*



# Commissioning Work



(a)



(b)

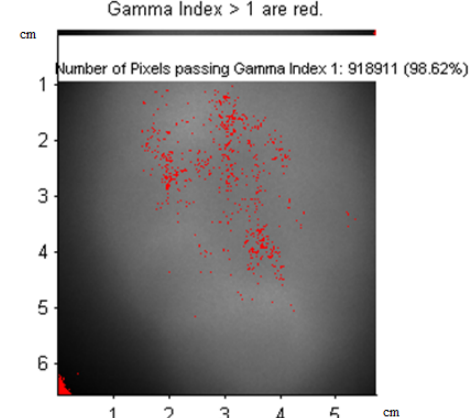
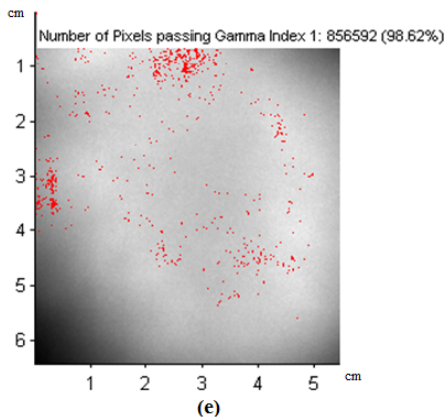
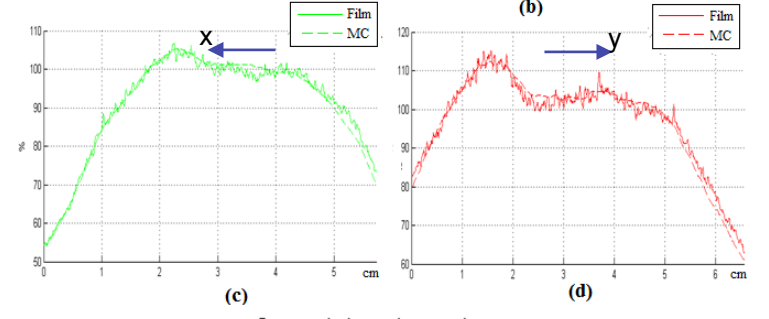
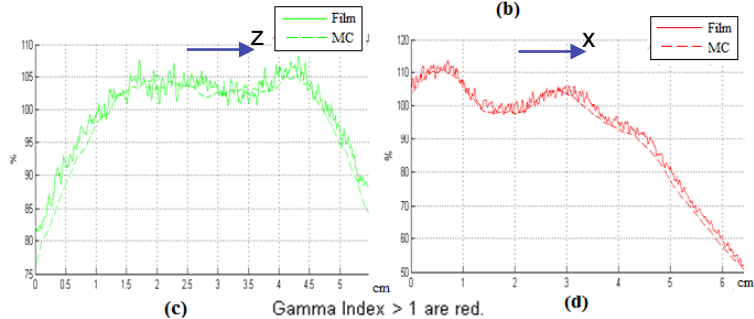
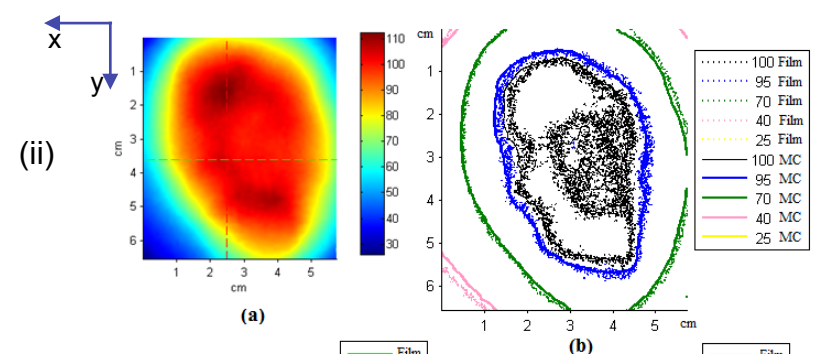
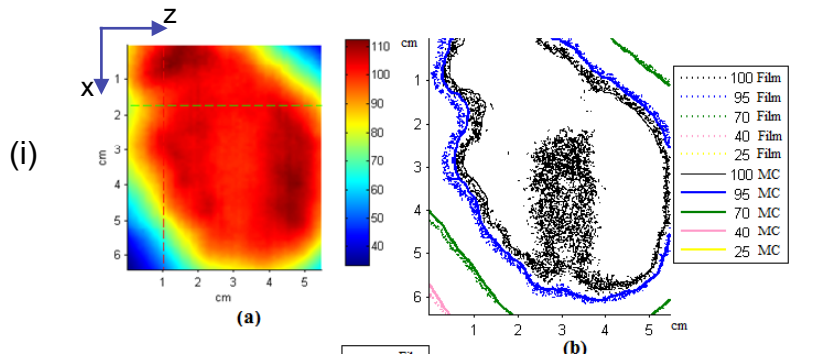
*Courtesy of P. Hoban*





# Commissioning

## Treatment Plan Measured vs Calculated Relative Dose





*Thank You!*