



Patient Alignment Technologies

PTCOG54 Educational session

San Diego – May 20, 2015

Niek Schreuder

Learning Objectives

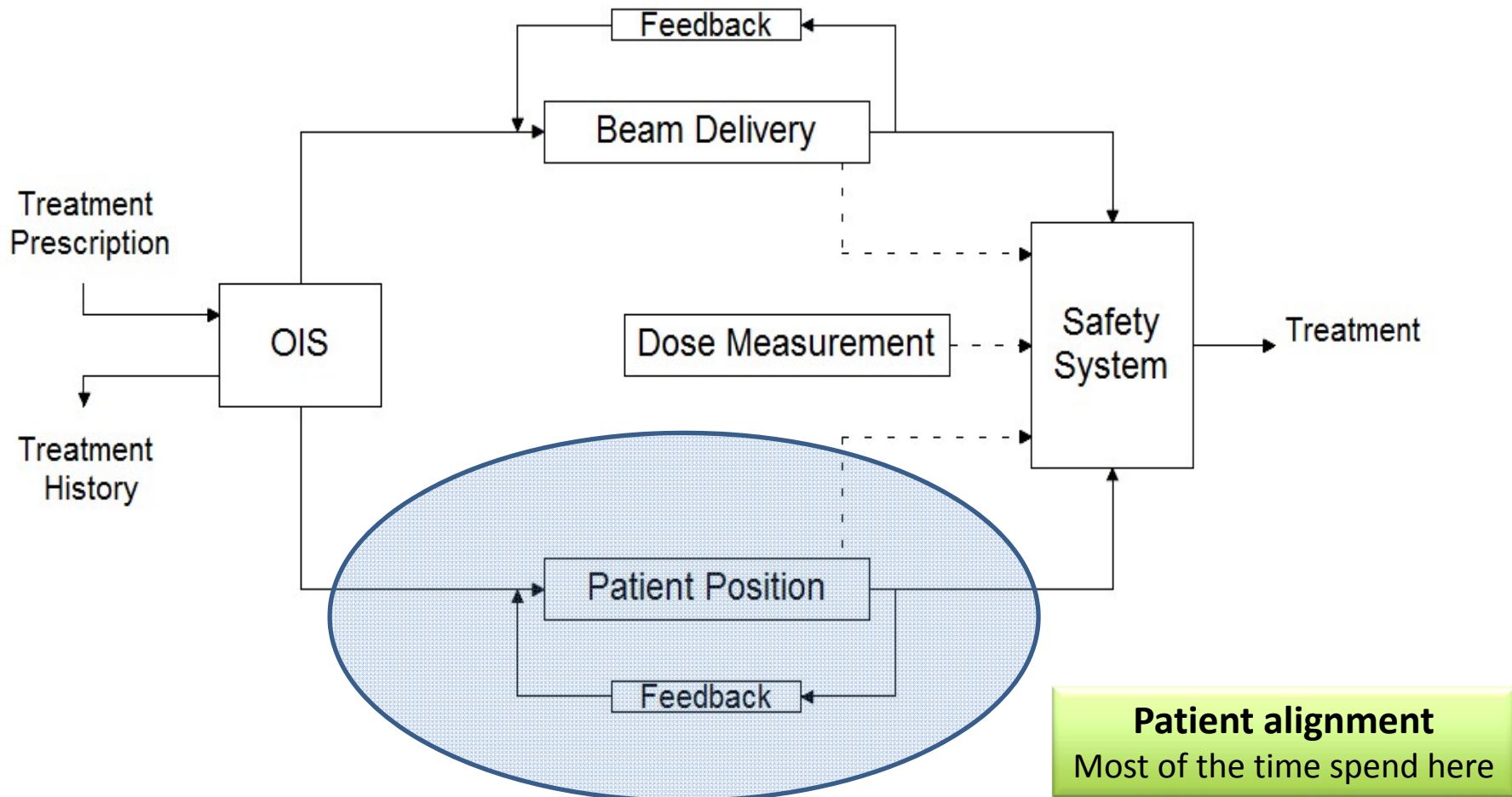
After this lecture the attendees should have

- **A better understanding of the unique challenges in Patient Alignment for Ion Therapy**
- **Knowledge about state of the art Patient Alignment Systems (PAS).**
- **Understand the needs for new thinking towards patient positioning for proton therapy.**

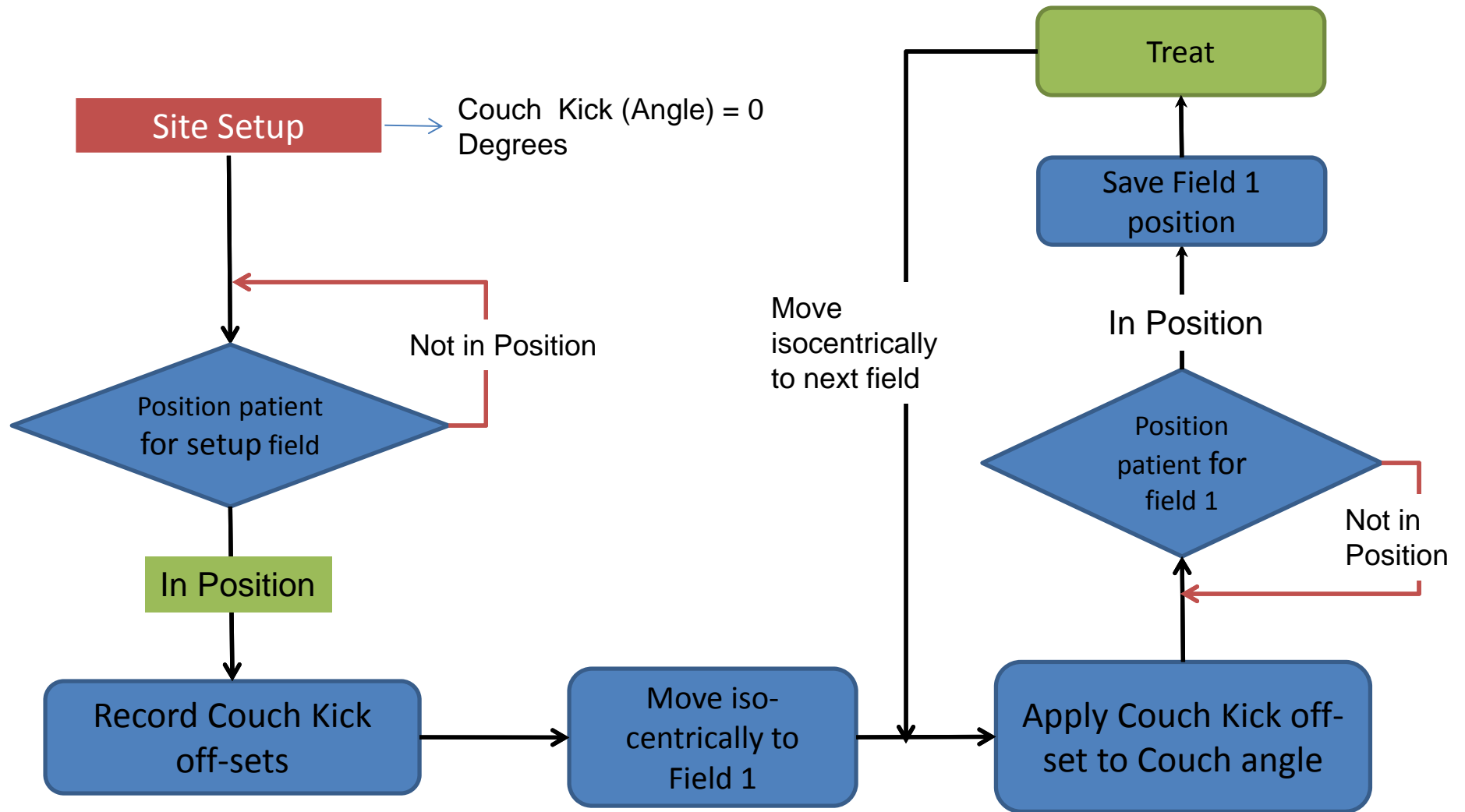
Outline

- **The Treatment Process**
- **The Current + Future Clinical Challenges**
- **Set-up Tolerances**
- **Short overview of Patient Alignment Systems (PAS)**

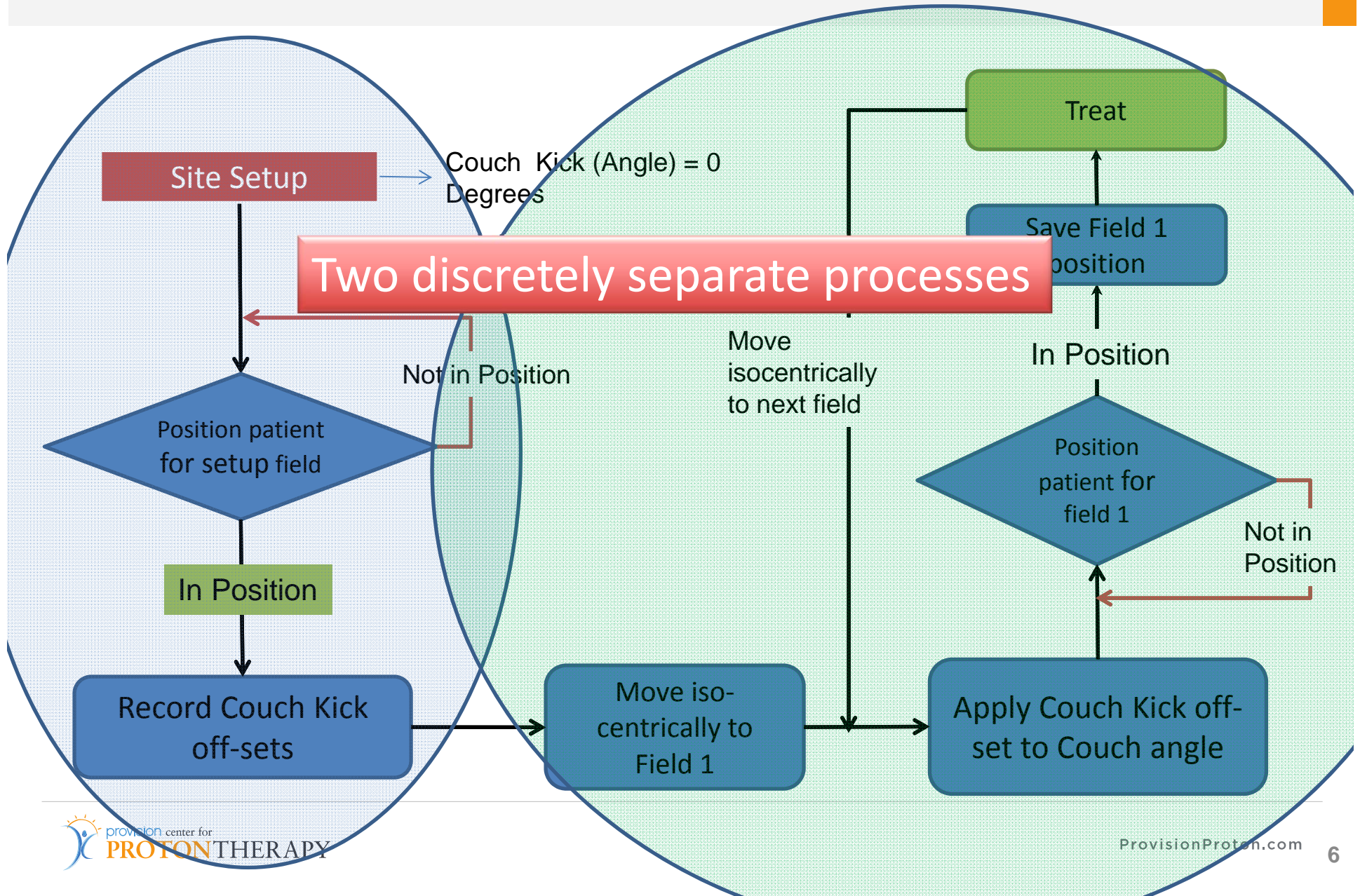
The Radiation Therapy Process – Control diagram



Patient Alignment Workflow



Patient Alignment Workflow



What is required in the Patient Alignment Process?

- **Patient Positioner**

- to move the patient accurately into position
- to keep the patient in position

3

- **Immobilization system**

- To keep the target at isocenter

1

- **Imaging + Localization System**

- to know where the target is
- to ensure the target remains in position

2

- ~~**Oncology information System**~~

- provide the information
- track and record the process

What Cancers Can Protons Treat?

Before 2012 ←

Classic indications:

Base of skull tumors

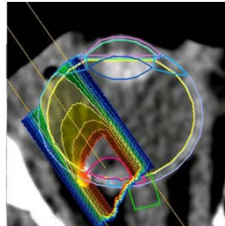
Eye (uveal) melanomas

Brain tumors

Pediatric tumors

Spinal / Para spinal tumors

Prostate cancers



→ After 2014

Pencil Beam Scanning changed the landscape

Lung

Liver

Breast

Esophagus

Pelvic tumors

Large sarcomas

Mediastinal tumors

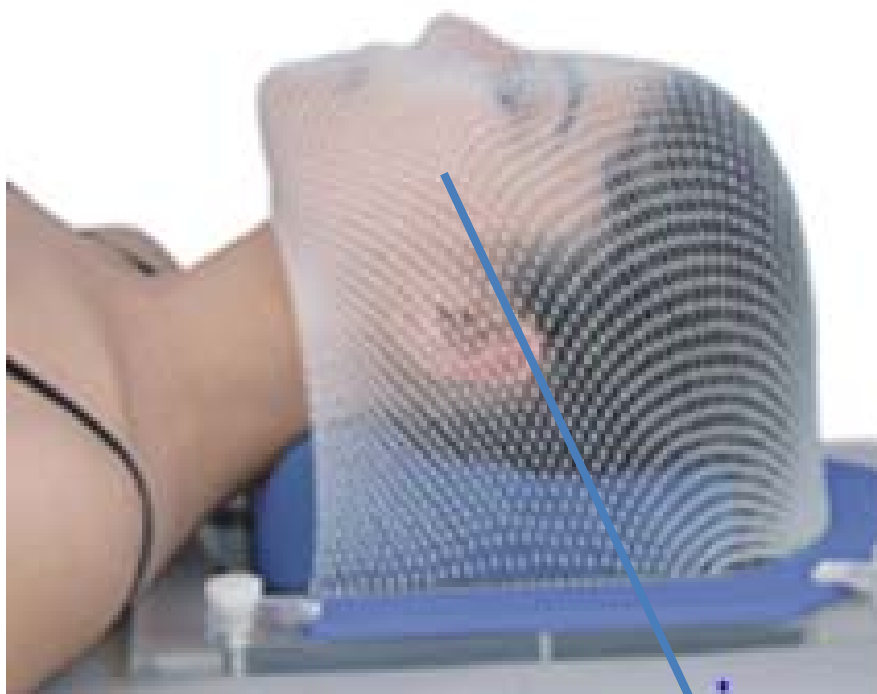
Re-irradiation of recurrent tumors



Immobilization

- **Some Paradigm shifts are required**
 - Masks
 - Positioning devices
- **Patients move during treatment**
- **Immobilization devices often provide a false sense of security**
- **Its easy to blame the PPS but did the patient perhaps move?**
- **If the patient is not comfortable he/she will move!**
- **If the treatment takes too long the patient will move**

Some Paradigm Shifts Required - Masks



Perforated Thermoplastic masks are;

- Required in X-ray therapy to preserve the skin dose
- Not very sturdy

Thermoplastic masks for IONS;

- Does not affect the skin dose
- Can be thicker and more rigid.

In ION Therapy the skin dose is not affected by the Mask

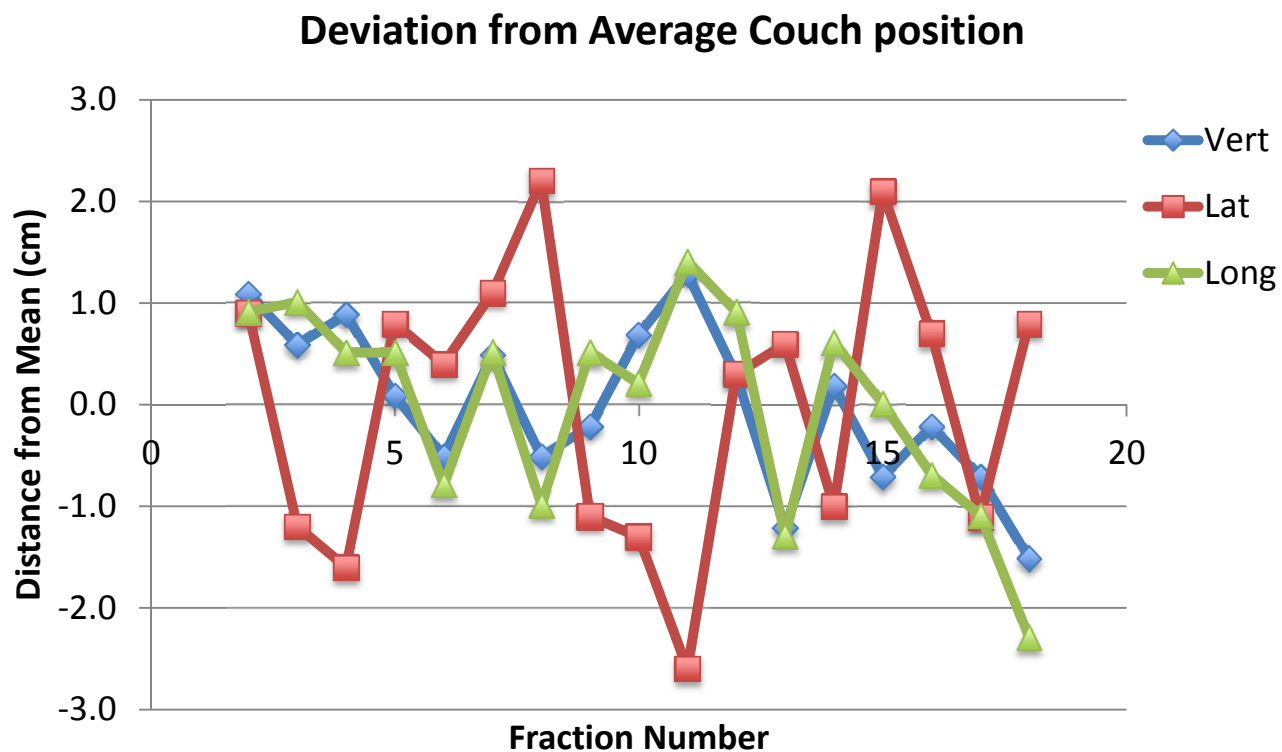
Breast Immobilization

To immobilize the breast or not to – That’s the question !



Need to preserve
the external shape
of the breast

Breast Immobilization



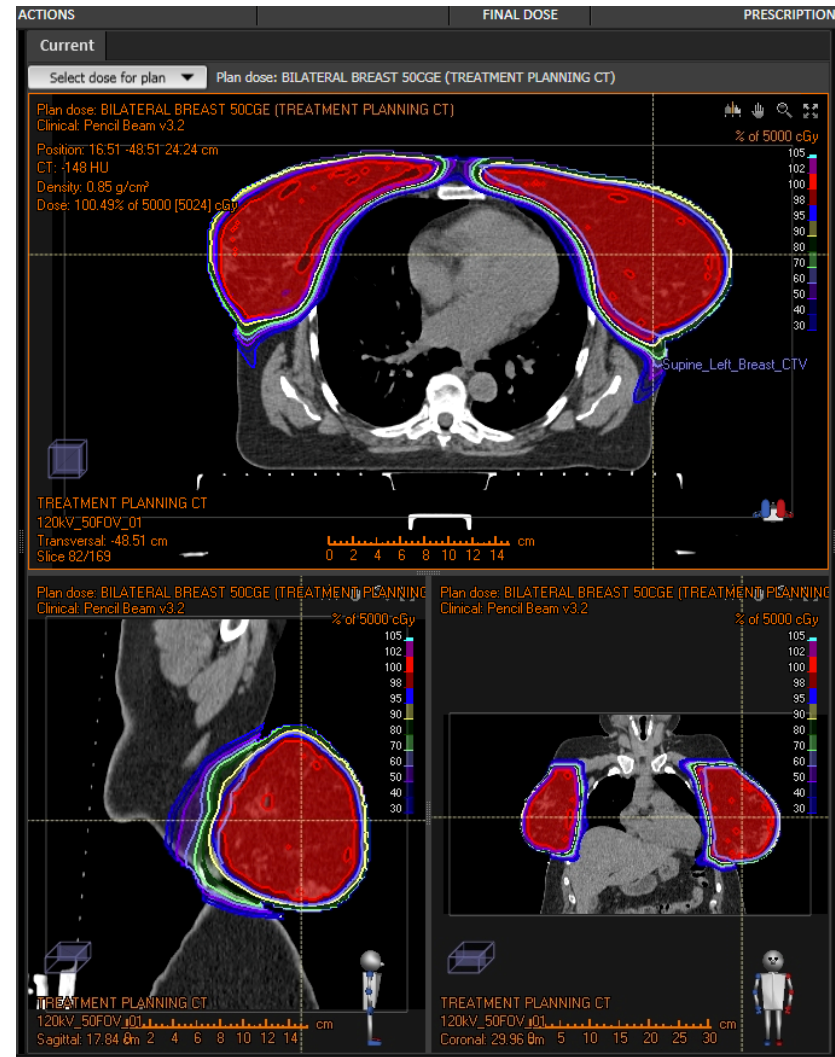
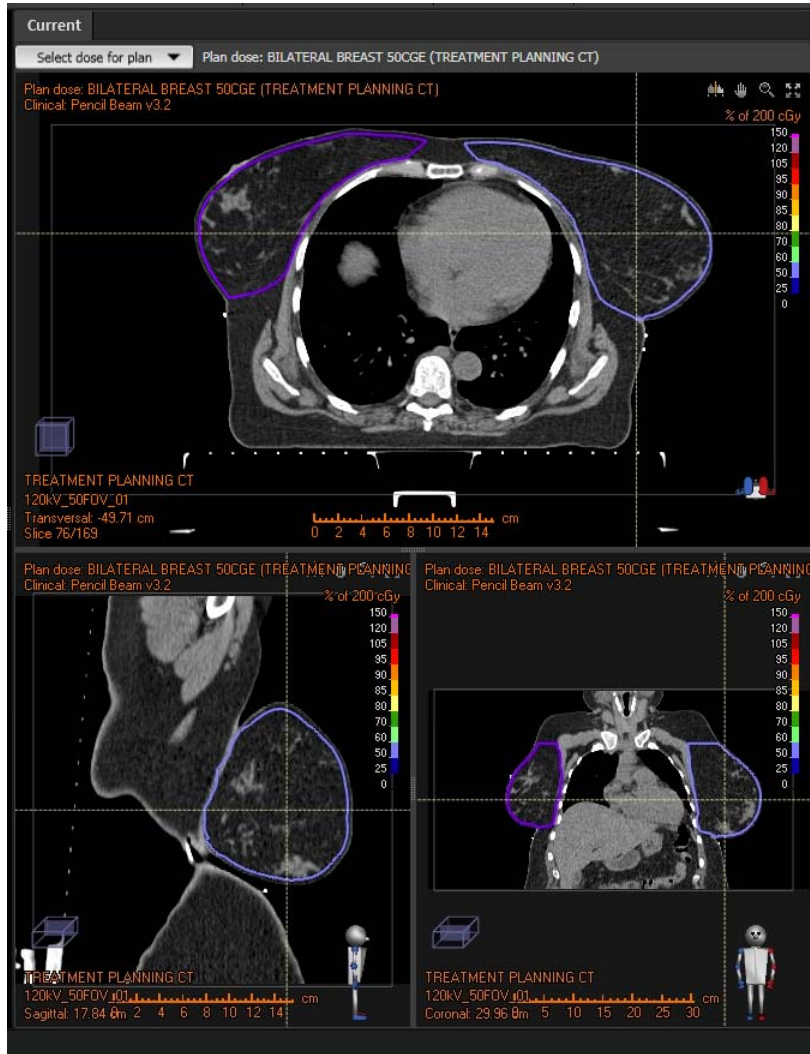
Take home message =

Don't attach the "mesh" to the table or breast board

OR

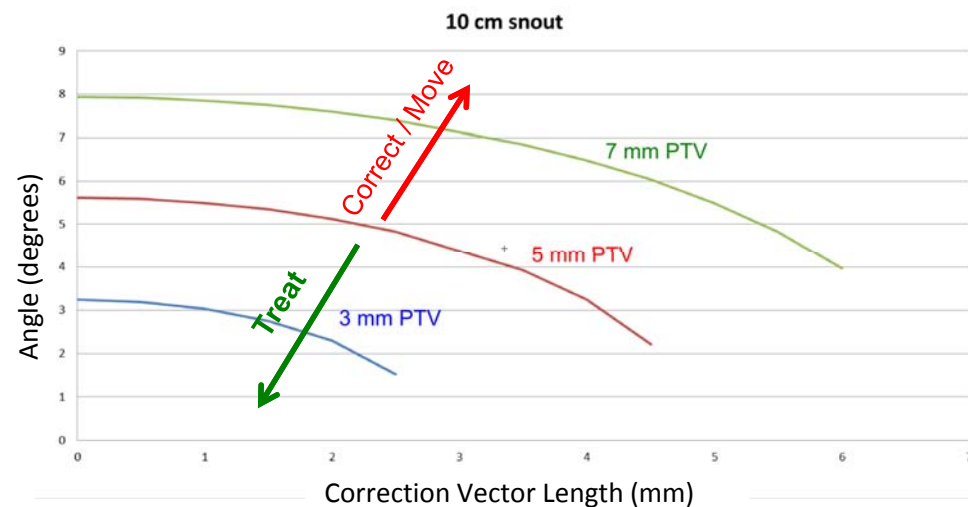
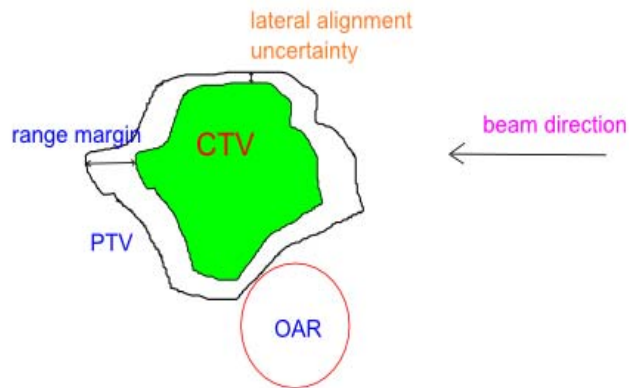
First align the patient with the table before attaching the "Mesh"

The Challenge !



Set-up Tolerances

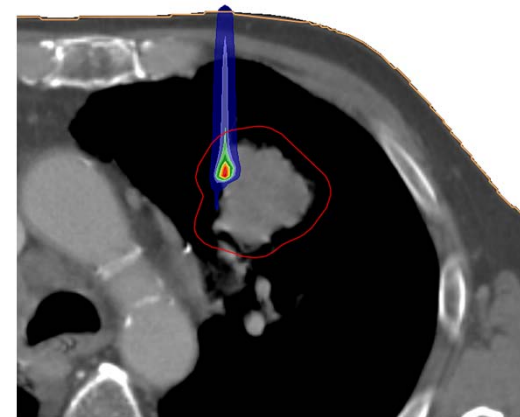
- Everything we do is done against certain tolerances
- In Ion therapy we are so brainwashed with the sharp dose gradients that we forget that the treatment plans were designed with certain tolerances in mind.
- Classically the PTV margins should drive the setup Tolerances



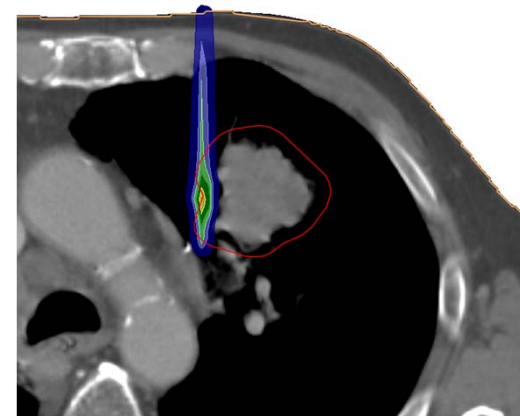
From Dennis Mah, ProCure NJ

PBS Allows for Robust Optimization

- TPS automatically calculates 21 plans
- Evaluate the uncertainties in the dose delivered by every plan.
- Give higher weights to those spots with less uncertainty and vice versa
- Instead of setting margins – specify uncertainties
- Robust optimization is also referred to as “*Inverse planning of Margins*”
- This Obviates the need for PTV’s for proton PBS plans
- **At PCPT we will use 2/3 of robust optimization parameters as the setup tolerance**

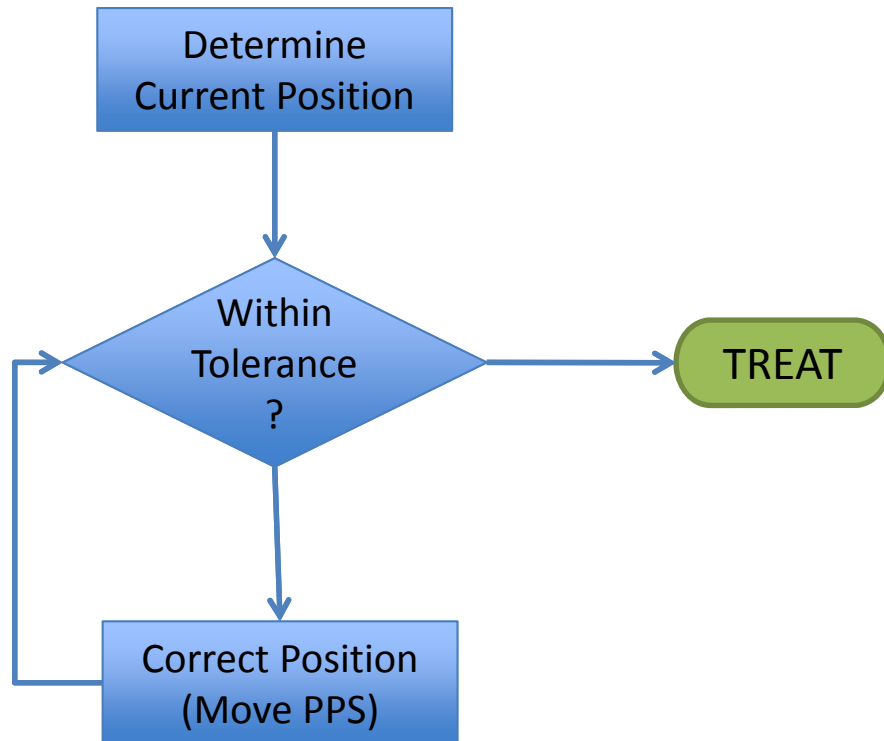


(a) Nominal setup



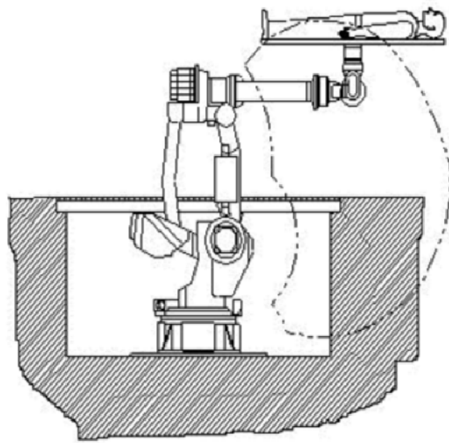
(b) Shifted setup

How should we use setup tolerances ?



- ◆ If the Physician desires, you can make the tolerances for the first iteration small
 - *Desire to be exact*
 - *Accurate.*
- ◆ Use well established tolerances for the second iteration and use them.
- ◆ If not the therapists will drop into an infinite set-up loop / downward spiral to no-where.

First + 2nd Generation: Commercially available Robots



START

CPO
1997



With Compliments from CPO



MPRI
2004



Forte 2008



Siemens 2005

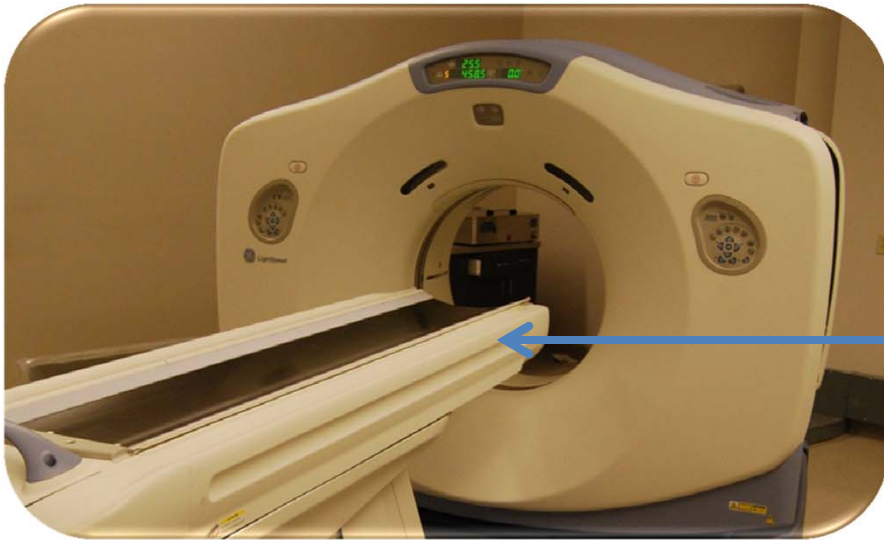


Next Steps – Robotic PPS

- **Smarter uses of the Robotic positioners**
 - Haptic motions
 - Smart trajectories
 - Vision guidance
- **Add tracking software to enlarge useable work envelopes**
- **Improved calibration methods**
- **Integrate the PPS better with PAS and Control systems**



Some Paradigm Shifts Required – Positioning Devices



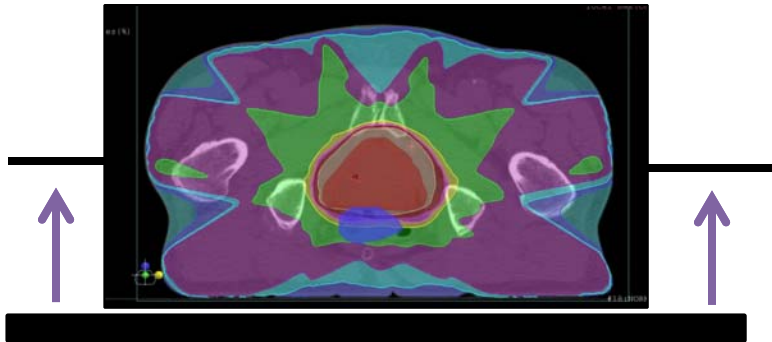
Comfortable CT Scanner top

Very Uncomfortable CT Scanner top



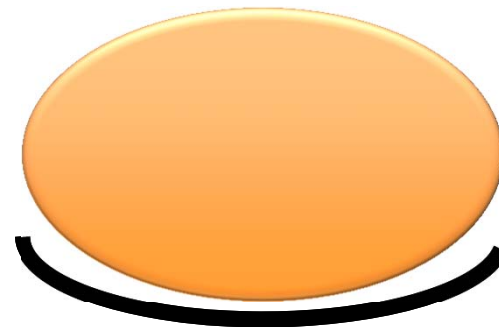
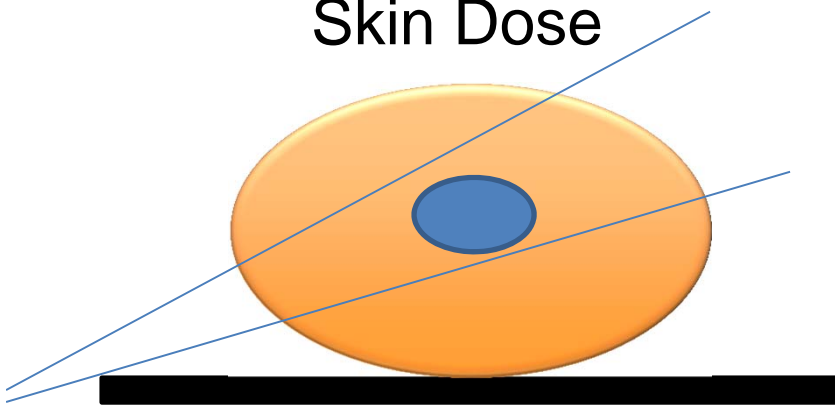
Some Paradigm Shifts Required – Positioning Devices

Roll correction



1. Neither the roll correction or skin dose is a problem for Ion therapy
2. We should not use flat table tops
3. The LLUMC Pods are probably the right answer

Skin Dose



Imaging System + Localization System

*to know where the target is
to ensure the target remains in position*

• Requirements

- Dose to the patient (*if ionizing radiation is used*)
- Resolution
- Accuracy
- Reproducibility
- Ease of use / Intuitive user interface
- Connectivity with OIS

Overview of PAS Systems

Existing PAS Systems used in Proton Therapy

Optical Tracking + Surface Recognition

~~Internal sensors~~

~~Ultra Sound~~

Planar X-Rays - everybody use this

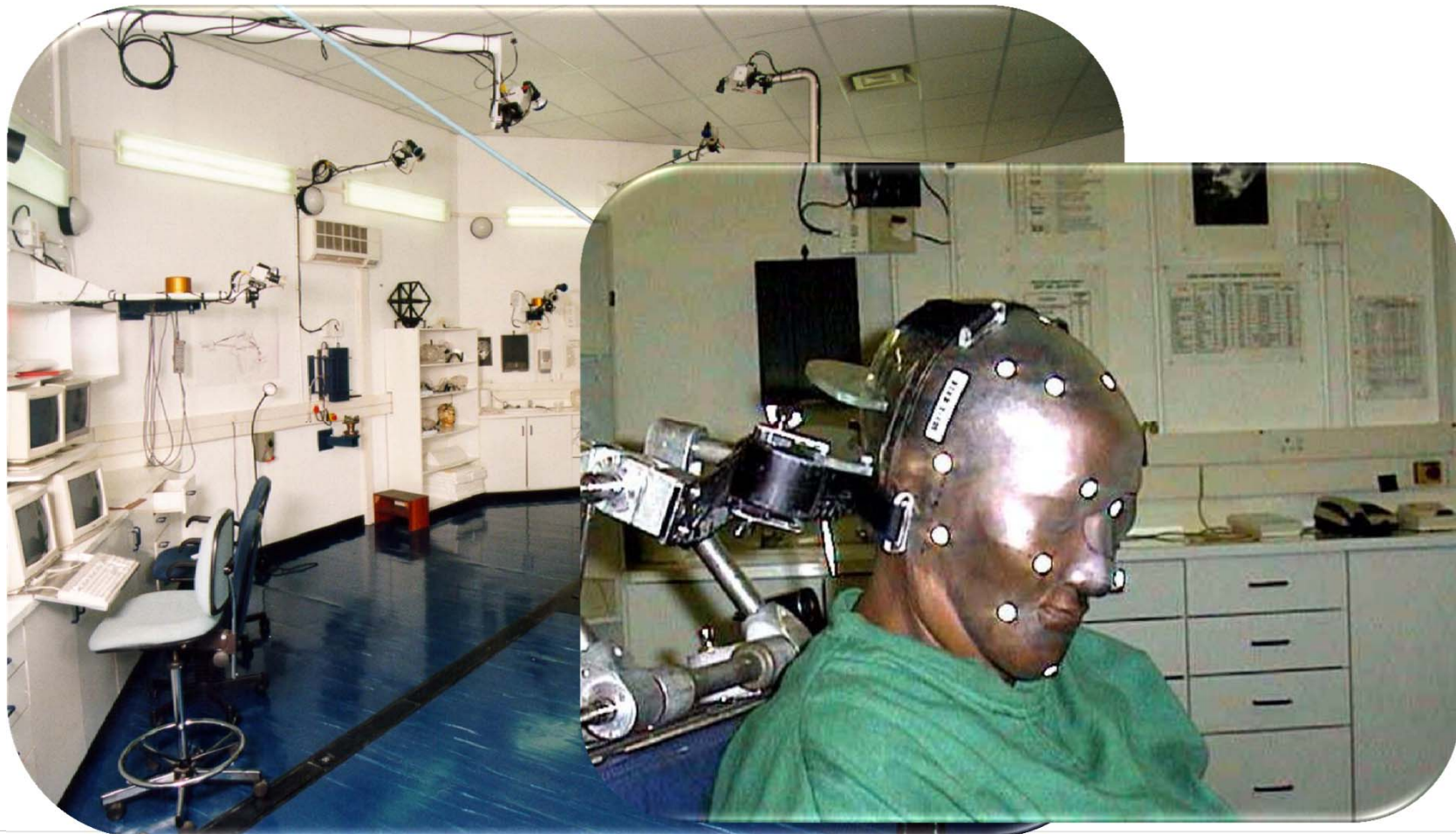
Volumetric Imaging – Some starting to use it

Proton Radiography

Proton Tomography

Overview of PAS Systems – Optical Tracking

iThemba Labs – Cape Town



Overview of PAS Systems

Orthogonal x-rays or Stereoscopic x-rays



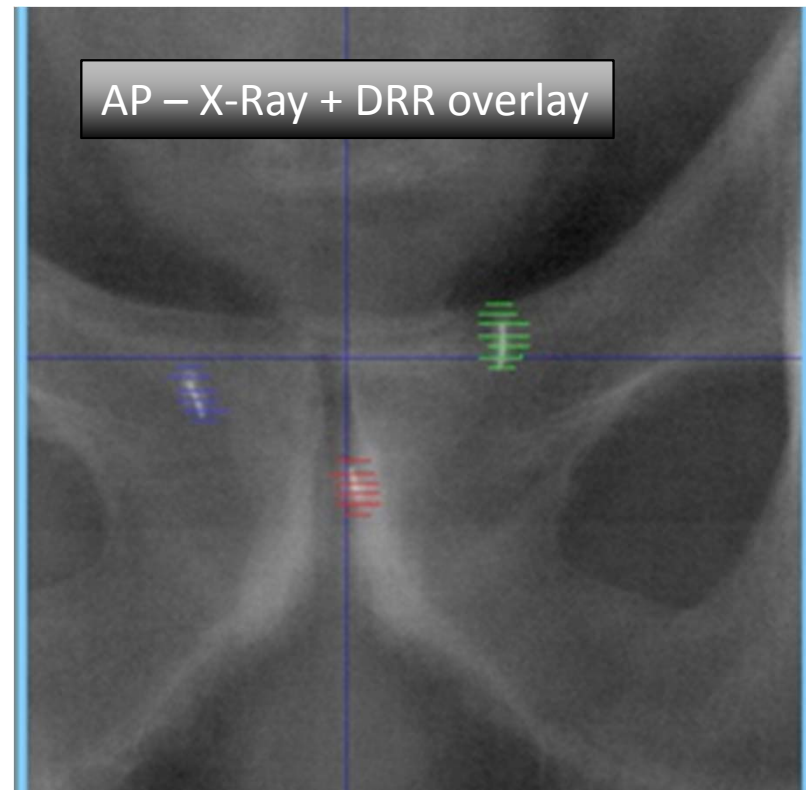
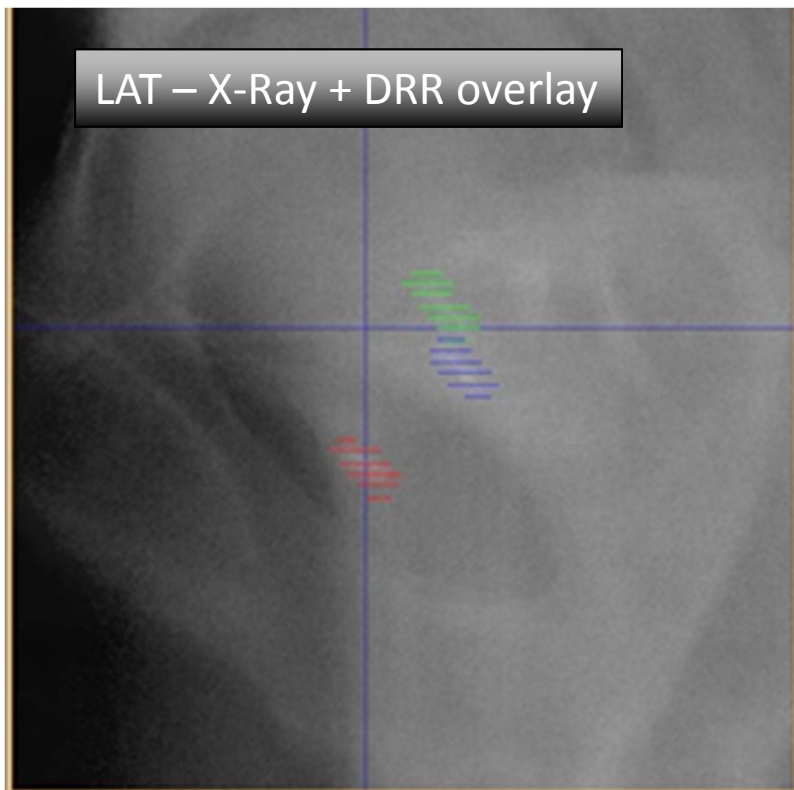
visions. innovations. solutions.

The screenshot displays the VeriSuite Advanced Treatment Mode interface. The top status bar shows: VeriSuite Advanced Treatment Mode Patient: BRAIN_JOE_IBL Study Date: October 24, 2011 Resolution: 512x512x226. The patient information panel on the left includes: Patient ID: MOS01, Name: BRAIN^JOE_IBL, Date of Birth: 19691231, Machine Name: IBL, Field: 1: SETUP. The correction settings panel includes: X-ray Images, Fusion Image (XR/DRR 0.8, Split View, DBL EXP 0.5), Correction Vector (DCM ROBO Translation [cm] 0.000, 0.000, 0.000; Rotation [°] 0.00, 0.00, 0.00), and Correction (6 DoF, Automatic, Manual, Reset, Abort, Calculate OI, Accept, RT Images). The main display area shows a 3x3 grid of images: X-ray A, Fusion Image (Split) A, DRR A (top row); X-ray C, Fusion Image (Split) C, DRR C (bottom row). The right side features a 3D visualization of a patient on a treatment table with a coordinate system and labels like '5024.6.1 IBC WITH' and '5024.6.3 Stereoscopic X-ray'. The Windows taskbar at the bottom shows the Start button, open applications (VeriSuite, Notepad), and system tray (Removable Disk, 9:46 AM).

Overview of PAS Systems – Fiducial Markers + X-rays

The use of Fiducial Markers - Prostate Grapes

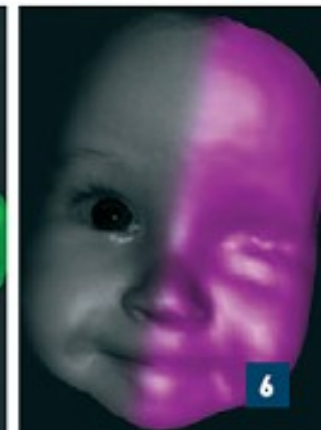
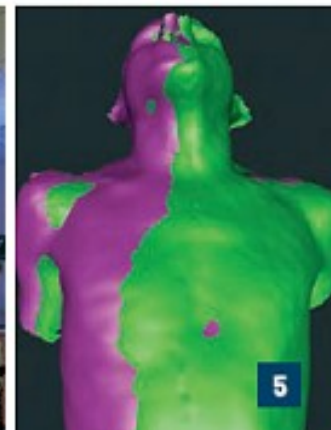
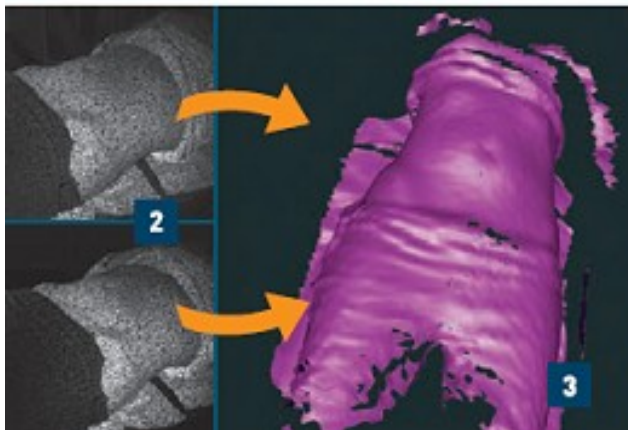
Contour individual Fiducial markers with a 2 mm margin
Place Fiducials in the “grapes” in AP and LAT images



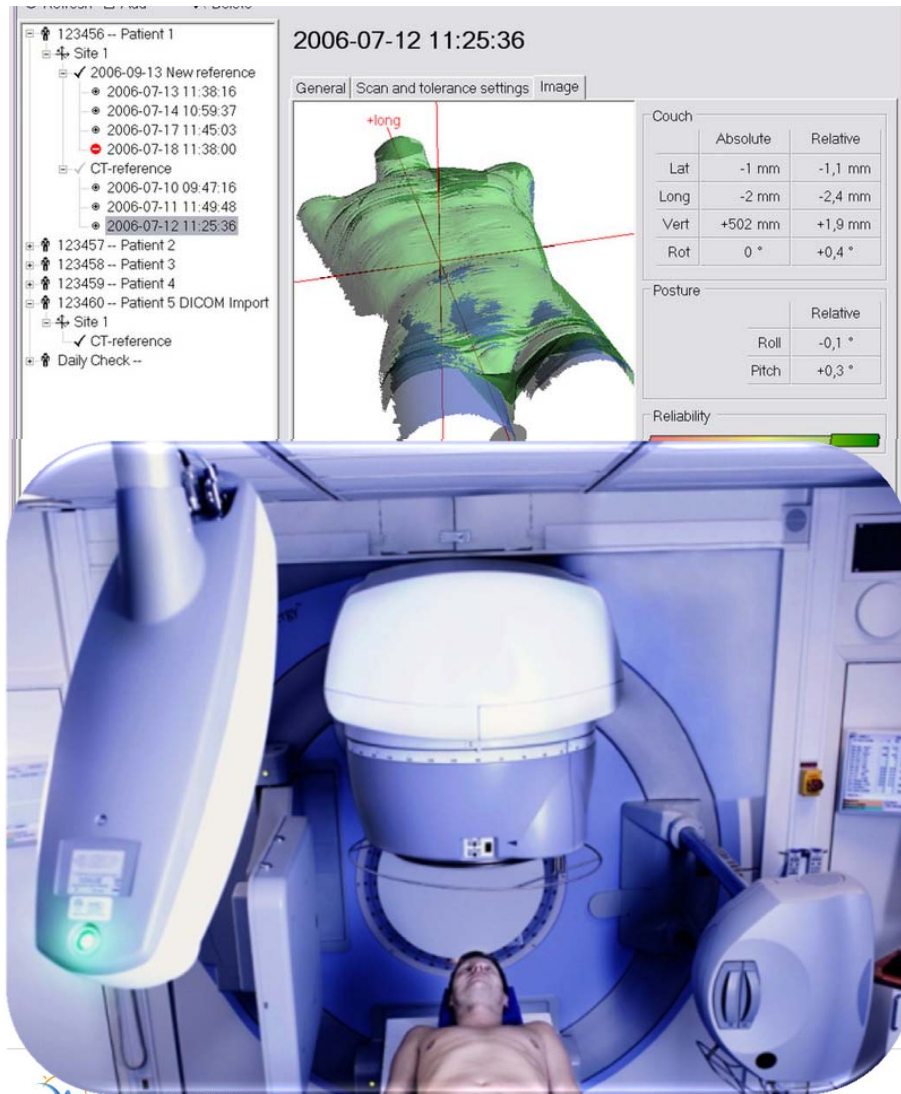
Overview of PAS Systems – Surface Recognition

visionrt

Stereo Cameras

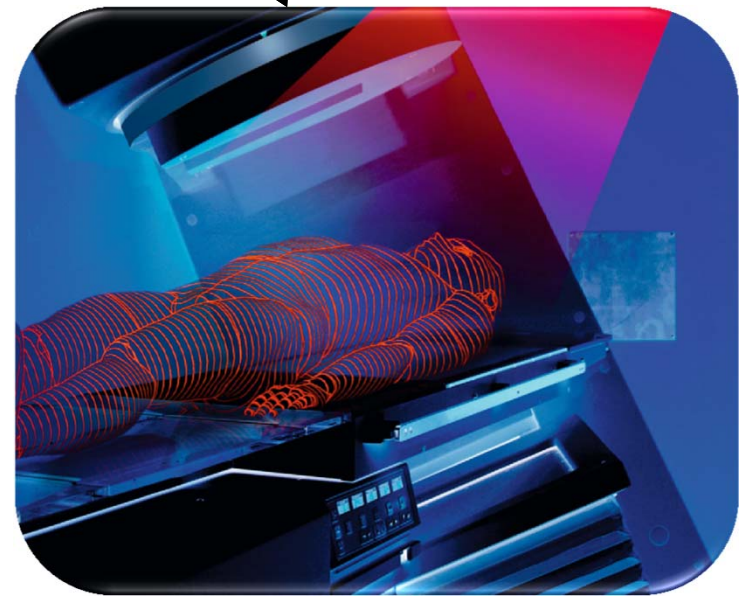


Overview of PAS Systems – Surface Recognition



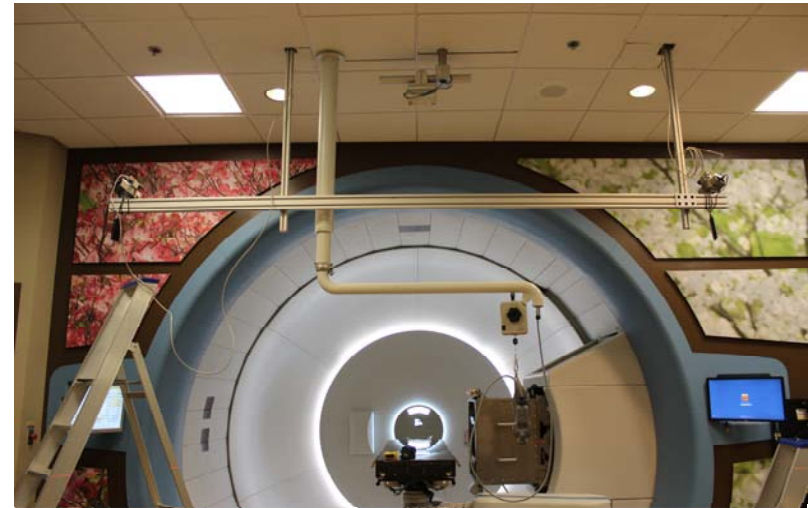
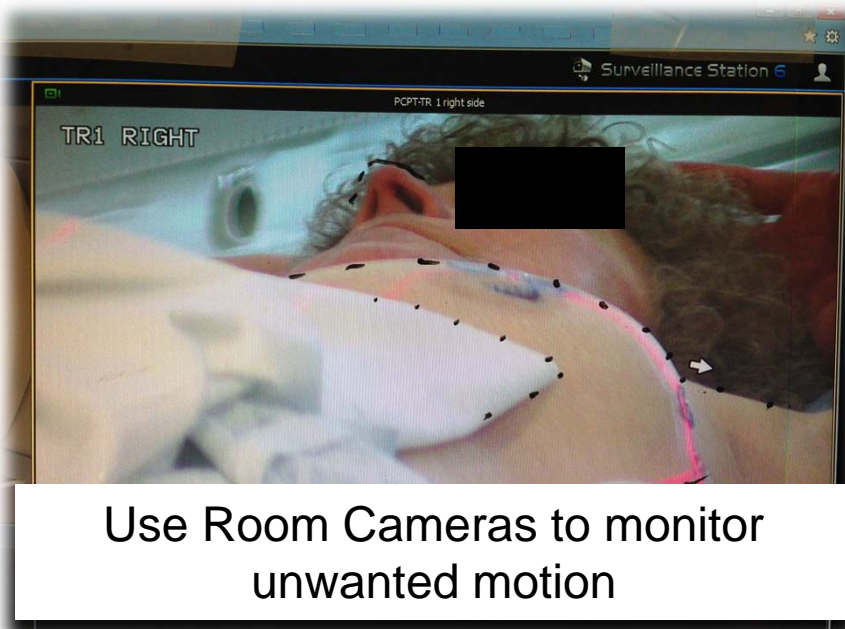
Laser Surface Scanner

**C-RAD
Galaxy – LAP Laser**



Overview of PAS Systems – Optical Tracking

Poor Man's Tracking system



Methods of Controlling Respiratory Motion

- **Breath hold / Breathing control**
 - *ABC*
 - *DIBH*
 - *Spirometers – Measuring lung Volume*
- **Gating – Japanese experience**
- **Synchronize Beam Delivery with Breathing Pattern**
- **Abdominal Compression**

Volumetric Imaging

- **In the Photon world**
 - Volumetric imaging \Leftrightarrow Cone Beam CT
 - Cone Beam CT \Leftrightarrow Image Guidance
- **In the Ion Therapy world**
 - Volumetric imaging \Leftrightarrow Soft Tissue Definition
 - Volumetric imaging \Leftrightarrow Anatomical characterization
 - › *Image quality is much more important*
 - › *CBCT only gives a partial answer*
- **One solution is to use Axial CT Scanners + MRI scanners –
*Inside or Outside the room***

Volumetric Imaging – New Developments

CBCT in the treatment Position



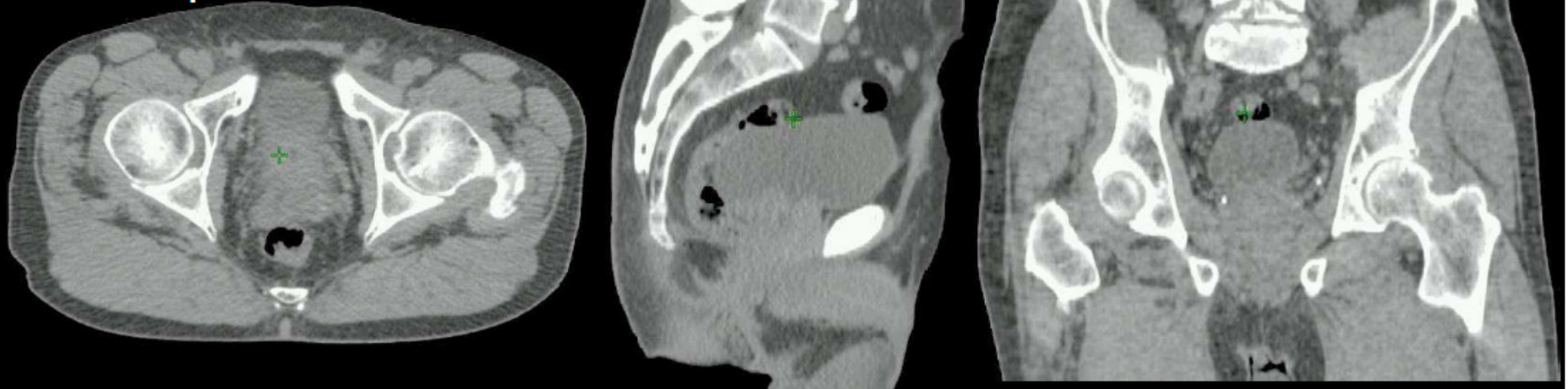
Med-Photon



ProNova

Volumetric Registration – Planning/CBCT

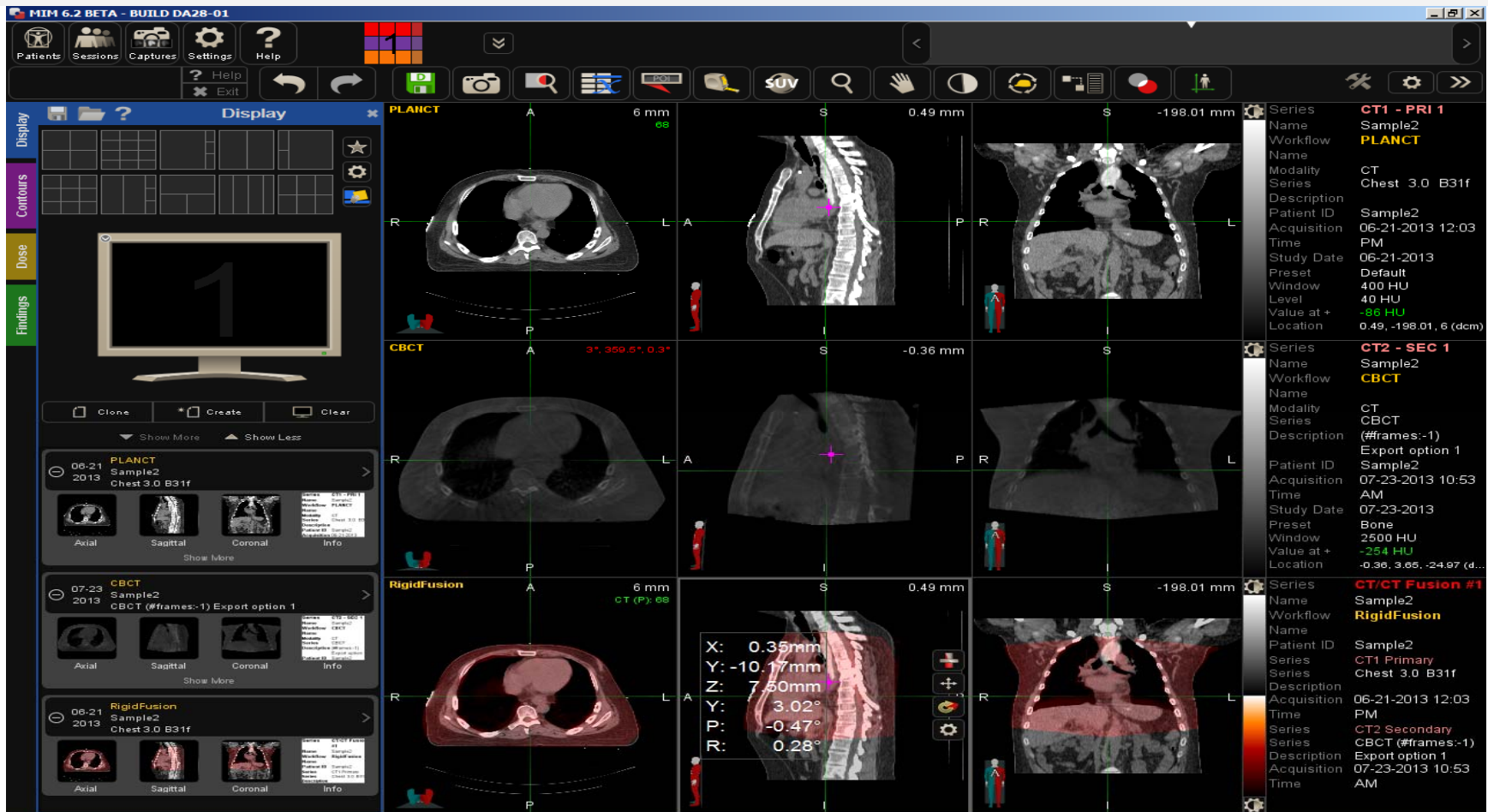
Clinical Spiral CT



CBCT



Image Registration 3D/3D (MIM)



- (Rigid) registration of CBCT image is used to establish couch shifts/rotations needed to bring planning CT dose reference point to gantry isocenter

Setup Uncertainty – Image Registration

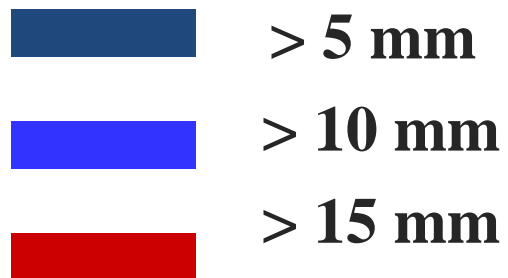
The screenshot displays a medical image registration software interface. It features several panels:

- Fusion View:** Shows a fused image of a planning CT and a CBCT. The planning CT is in blue, and the CBCT is in red. A red circle labeled 'Isocenter' is visible. Position: -36.96 -0.80 -6.95 cm. CT: -996 HU. Density: -.
- Reference View:** Shows the reference image (Planning CT). Position: -23.02 -0.80 -34.25 cm. CT: -996 HU. Density: -.
- Floating View:** Shows the floating image (CBCT 8). Position: -52.73 0.60 -12.36 cm. CT: -996 HU. Density: -.
- Image Set Library:** Lists image sets with their respective parameters:
 - CBCT 6:** TPAIAlign. Description: ***KV-IMAGES TREATMENT:48018**. Date and time: 25 Nov 2009, 10:27:26 (hr:min:sec). Protocol: XVI Synergy. Modality: CBCT. Patient position: HFS. Imaging system: XVIXP. Nr of pixels: 410 410 168. Pixel size [cm]: 0.1 0.1. Used for: Evaluation. Fraction: 6.
 - CBCT 7:** TPAIAlign. Description: ***KV-IMAGES TREATMENT:48018**. Date and time: 26 Nov 2009, 10:50:20 (hr:min:sec). Protocol: XVI Synergy. Modality: CBCT. Patient position: HFS. Imaging system: XVIXP. Nr of pixels: 410 410 168. Pixel size [cm]: 0.1 0.1. Used for: Evaluation. Fraction: 7.
 - CBCT 8:** SecondaryTPAIAlign. Description: ***KV-IMAGES TREATMENT:48018**. Date and time: 27 Nov 2009, 08:43:43 (hr:min:sec). Protocol: XVI Synergy. Modality: CBCT. Patient position: HFS. Imaging system: XVIXP. Nr of pixels: 410 410 168. Pixel size [cm]: 0.1 0.1. Used for: Evaluation. Fraction: 8.

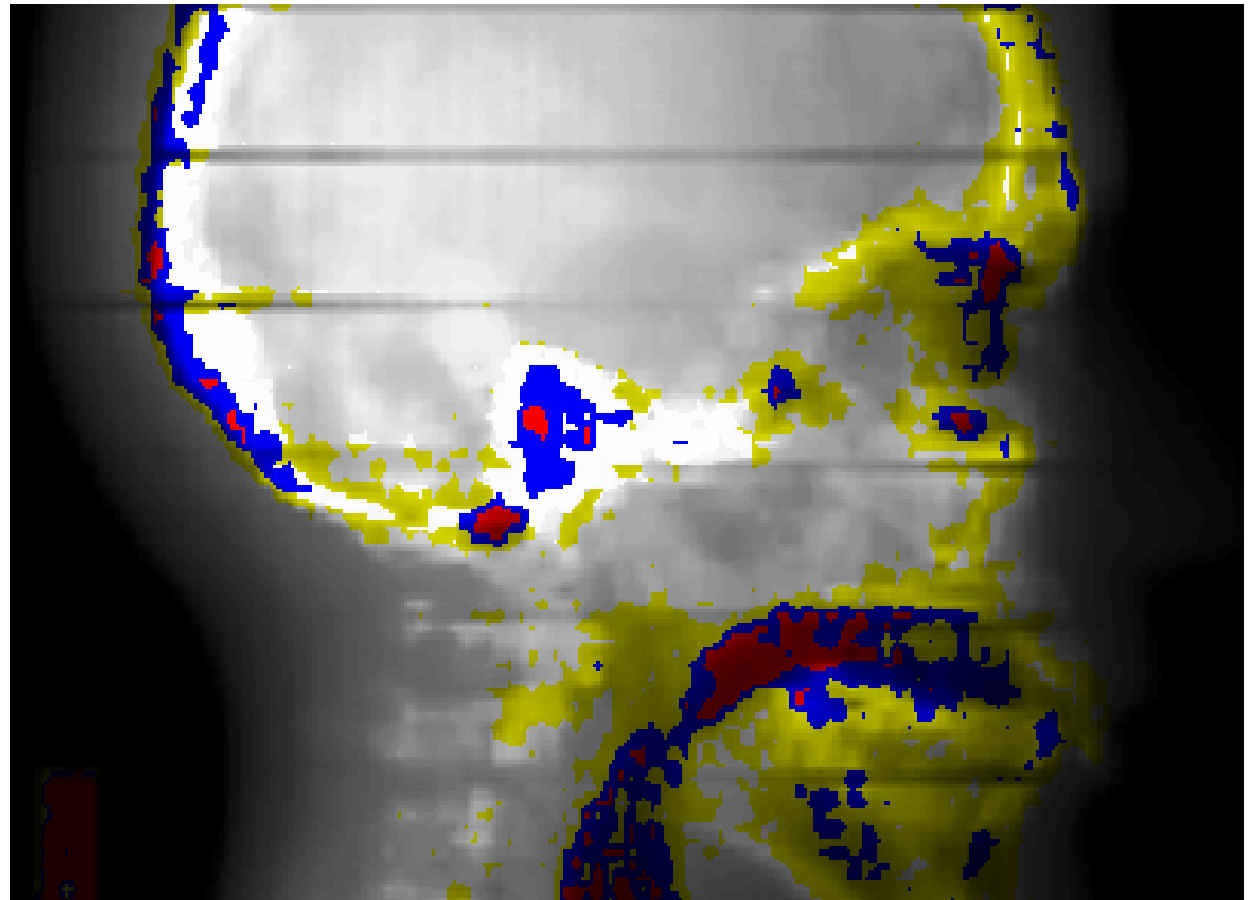
- Some TPS systems can perform deformable registration to daily CBCT – alerting user to patient presentation changes and dose mismatch

Proton Radiography → Tomography

Range Uncertainties (measured with PTR)

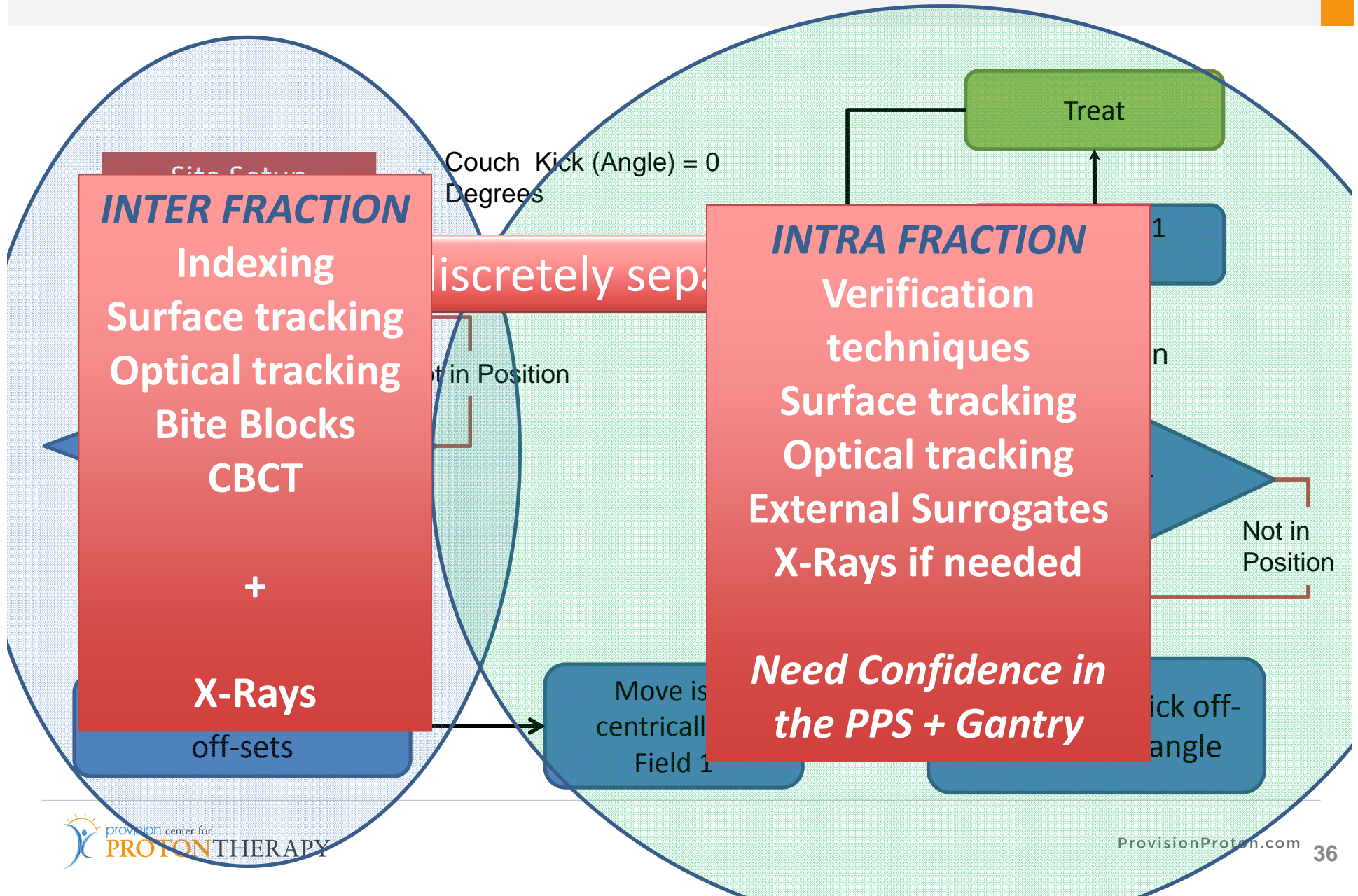


Schneider U. (1994), "Proton radiography as a tool for quality control in proton therapy,"
Med Phys. 22, 353.



Alderson Head Phantom

Patient Alignment Workflow



IGRT + Proton Therapy

- **Proton Therapy introduced Image Guided Radiation Therapy (IGRT) to the field of Radiation Therapy.**
- **Protons have always been delivered while using some sort of imaging during the setup process.**
- **However – today Ion Therapy Systems are not properly equipped with IGRT systems as compared to Photon therapy systems.**

Summary

- **Unlike photons - Immobilization devices does not impact the skin dose for ion beams.**
- **The use of disease site specific immobilization and patient positioning devices will improve patient positioning in Ion therapy.**
- **Treatment Plan design parameters must be communicated to the Treatment room aka “setup tolerances”**