provision center for PROTONTHERAPY

Patient Alignment Technologies

PTCOG54 Educational session

San Diego – May 20, 2015

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Learning Objectives

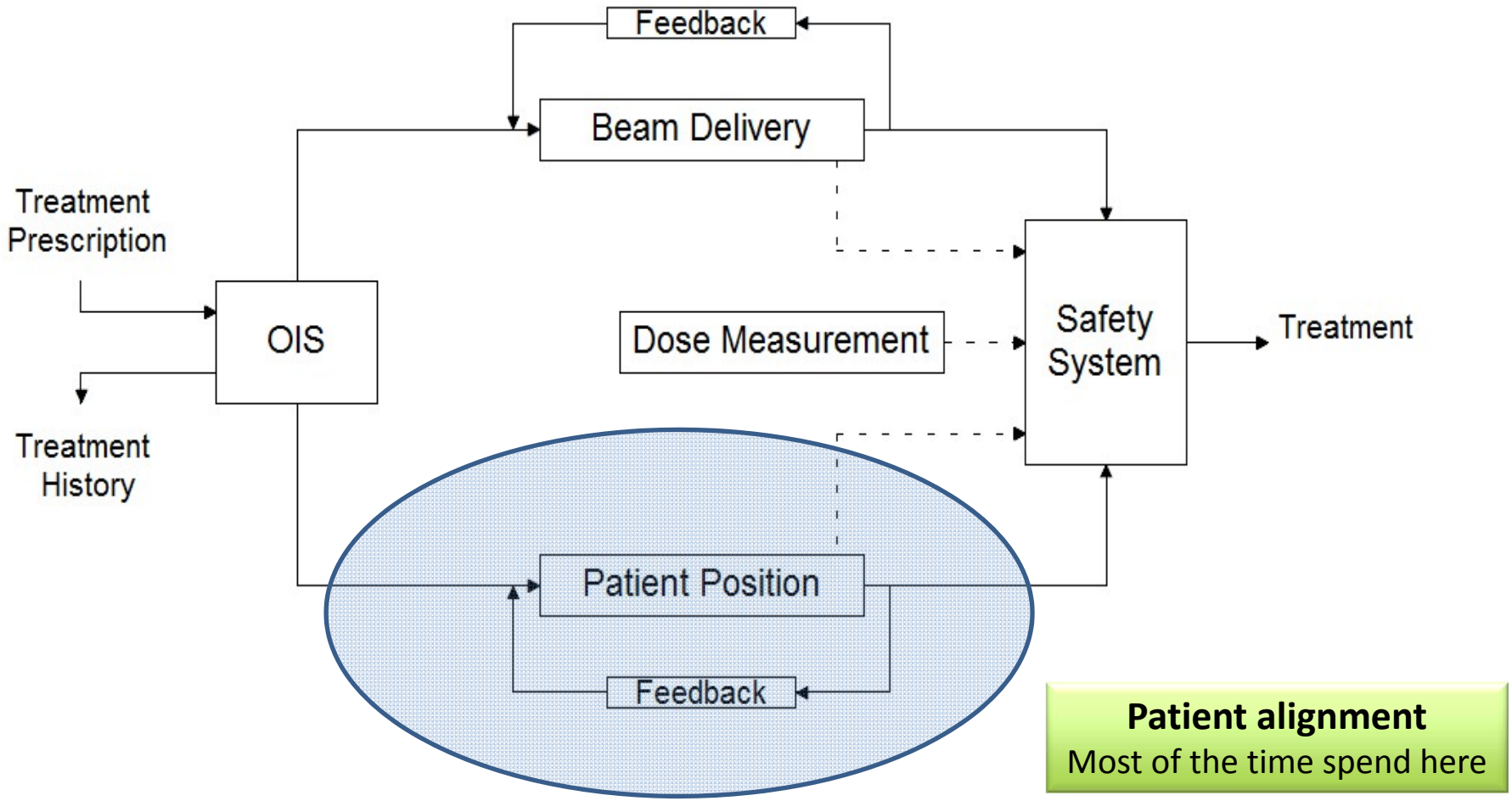
After this lecture the attendees should have

- **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.**

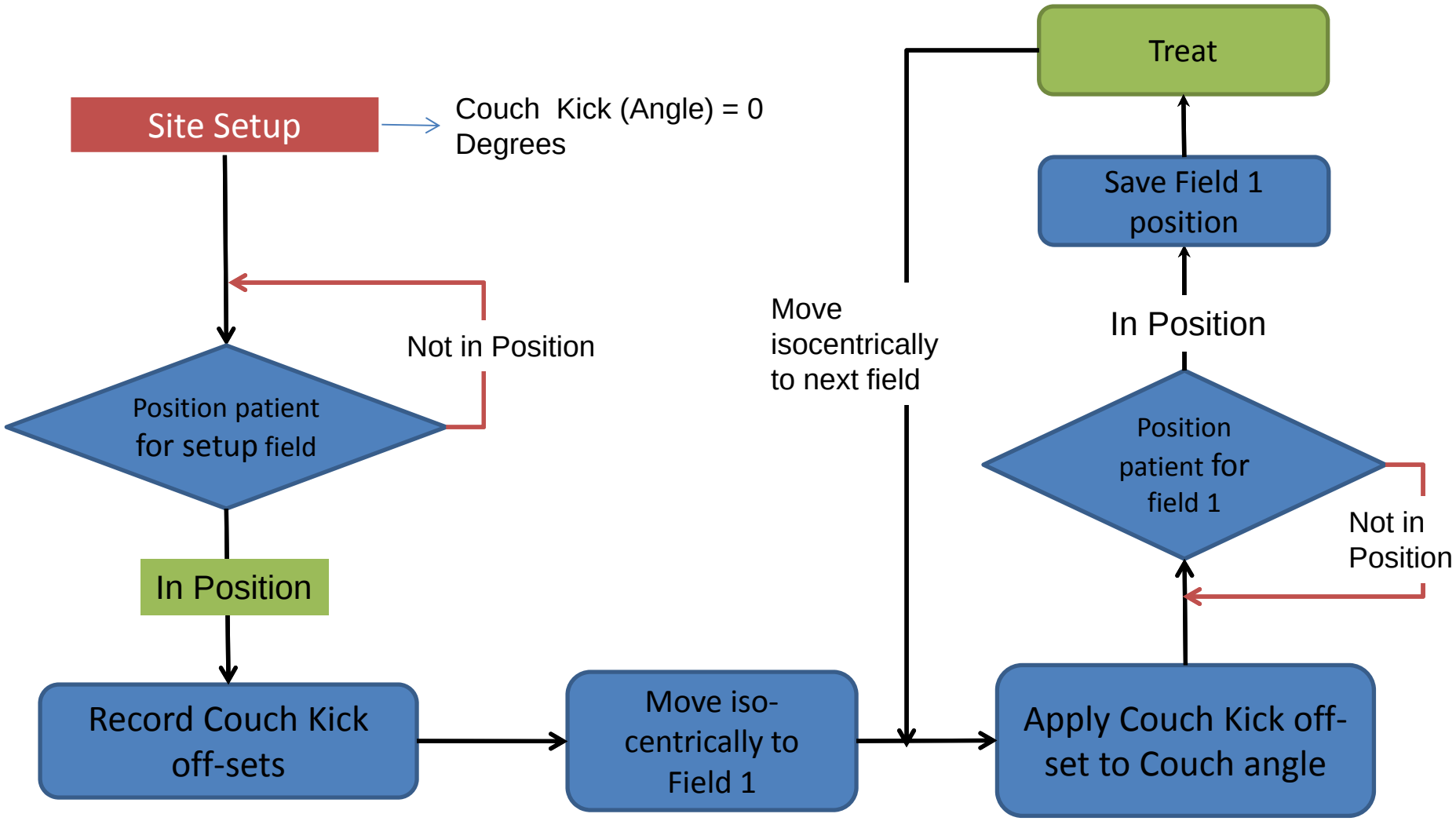
Outline

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

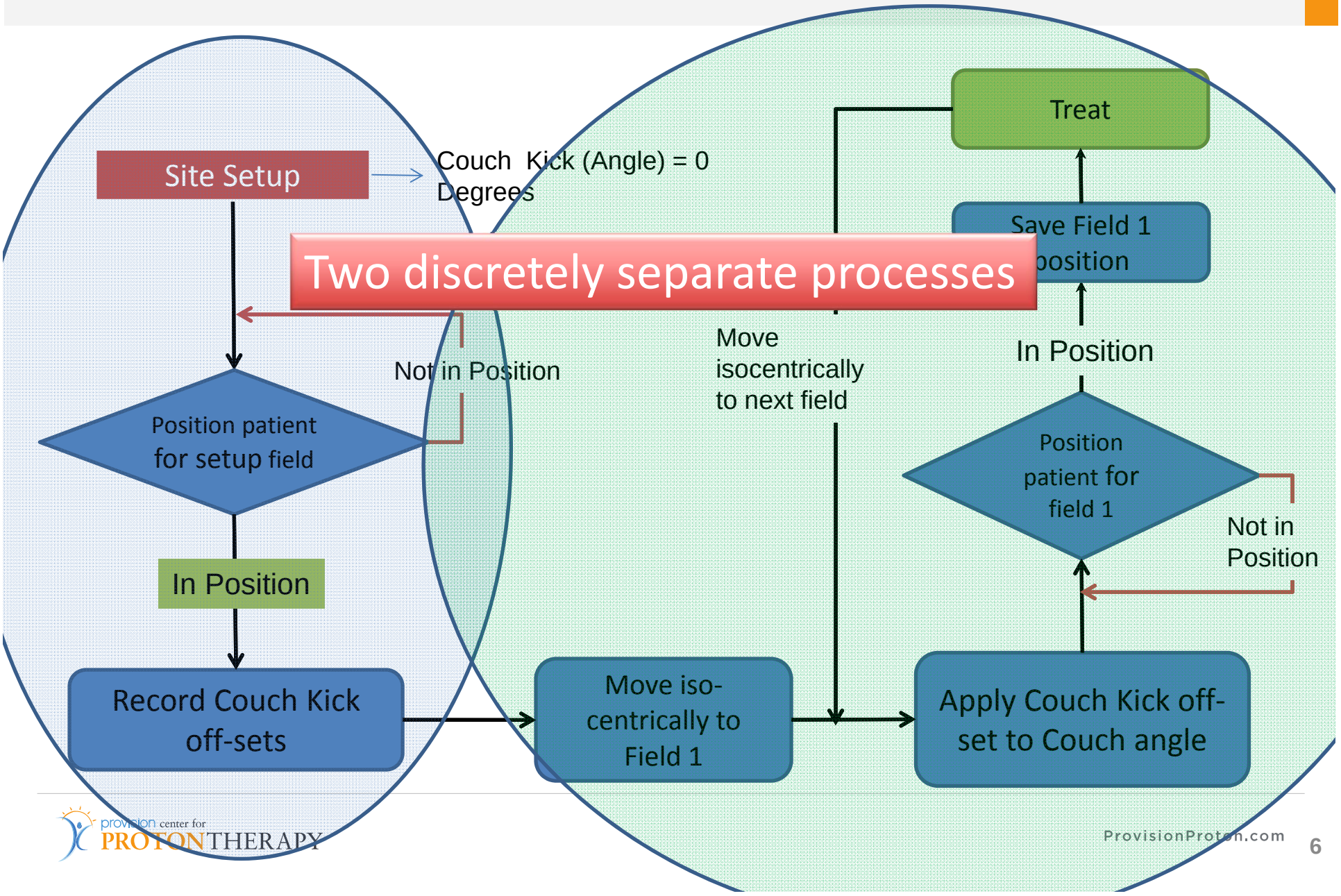
The Radiation Therapy Process – Control diagram



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

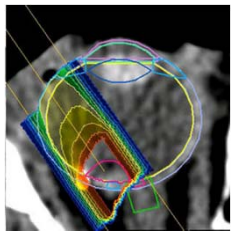
Eye (uveal) melanomas

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

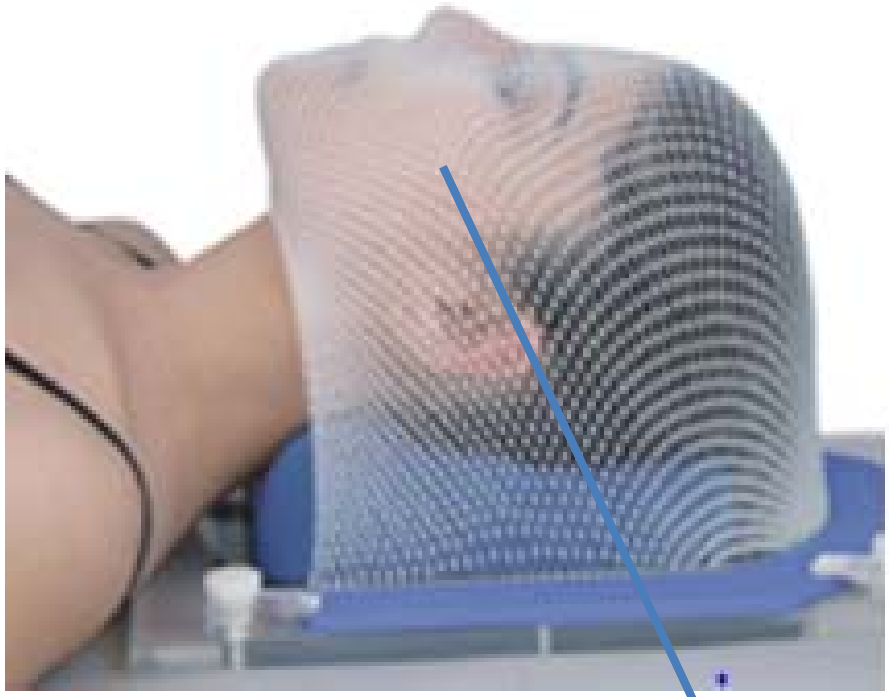
Immobilization

- **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.

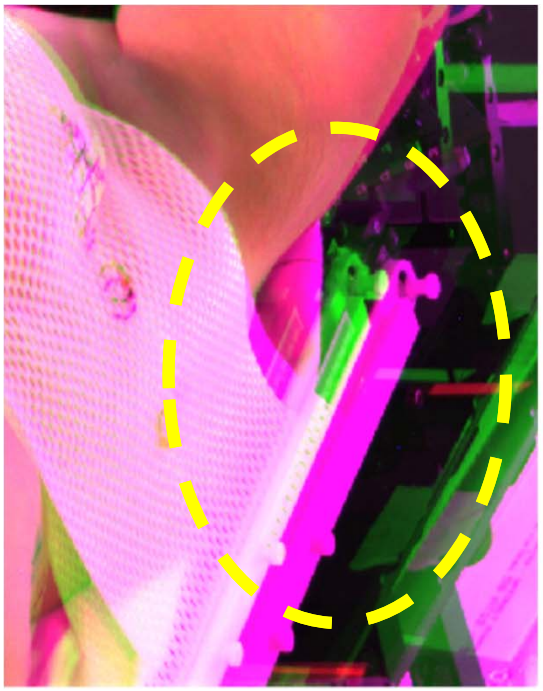
In ION Therapy the skin dose is not affected by the Mask

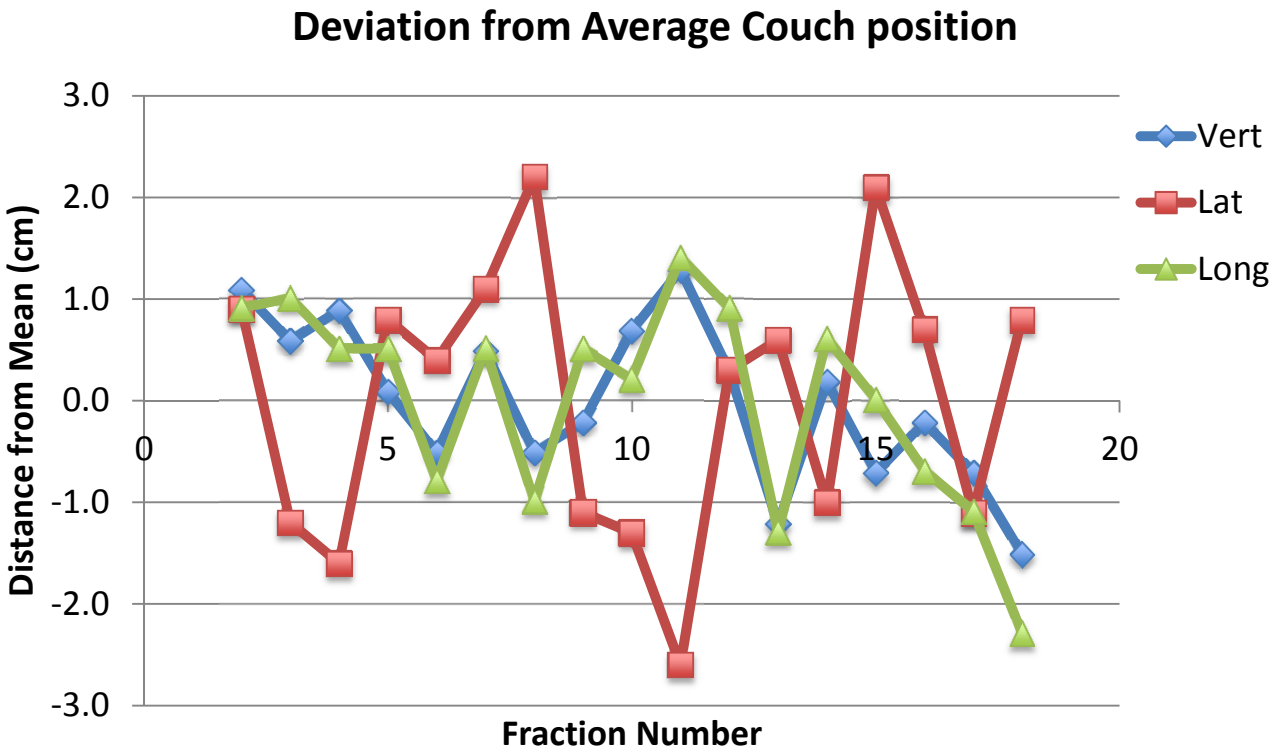
Breast Immobilization

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

Need to preserve the external shape of the breast

Breast Immobilization





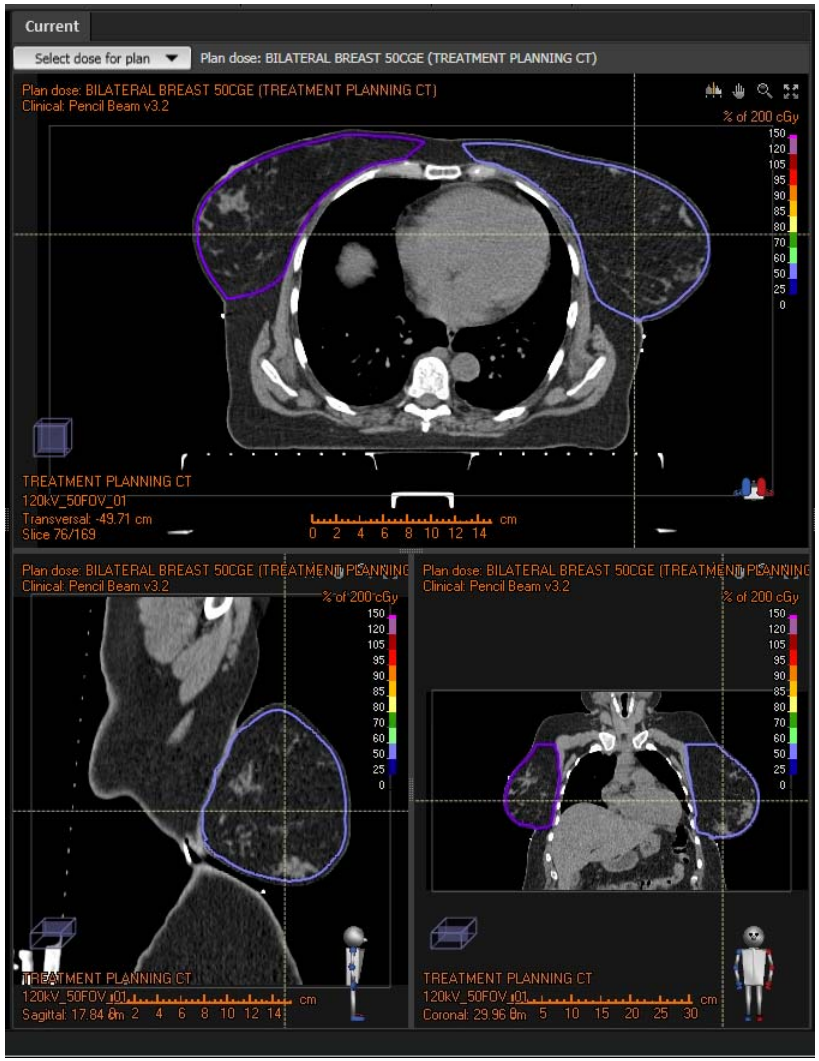
Take home message =

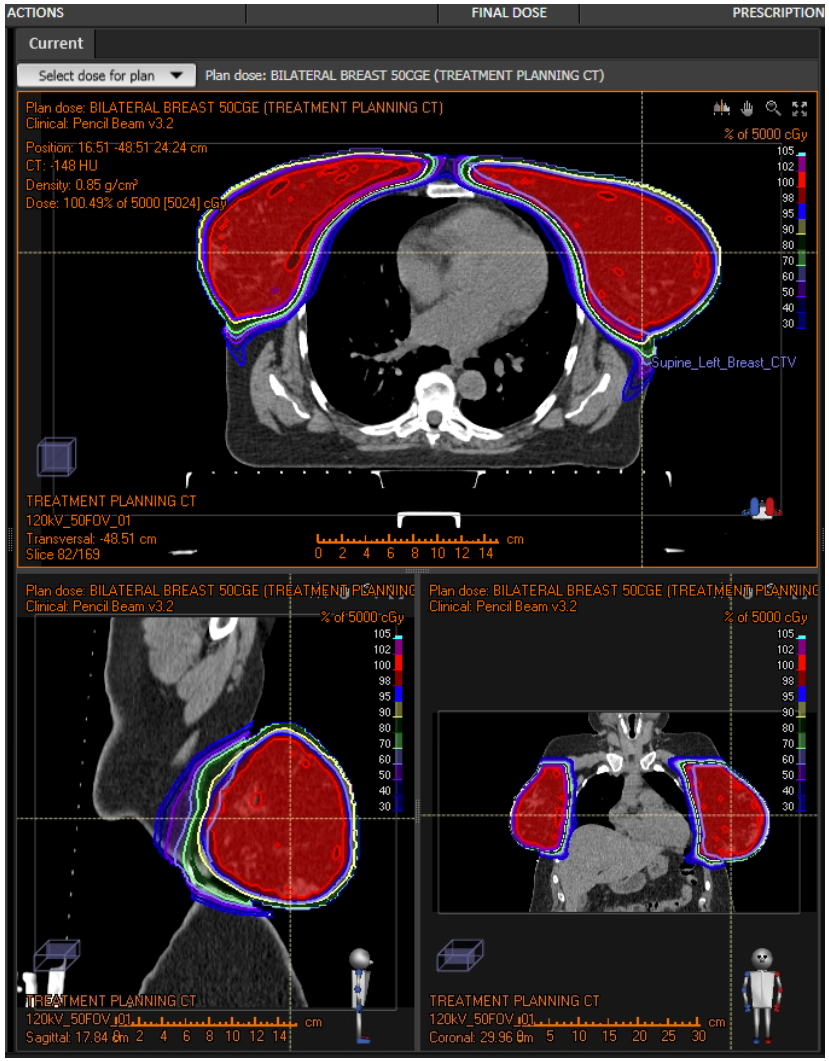
Don't attach the "mesh" to the table or breast board

OR

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

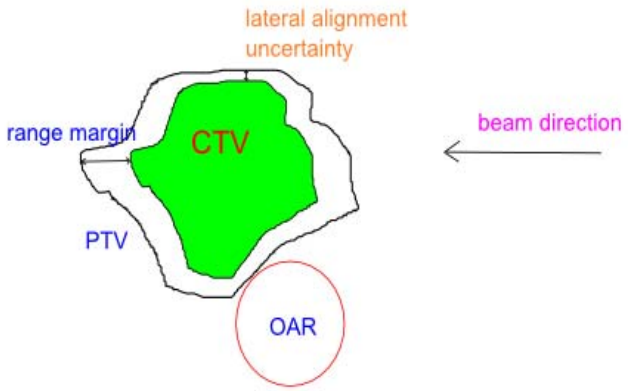
The Challenge !

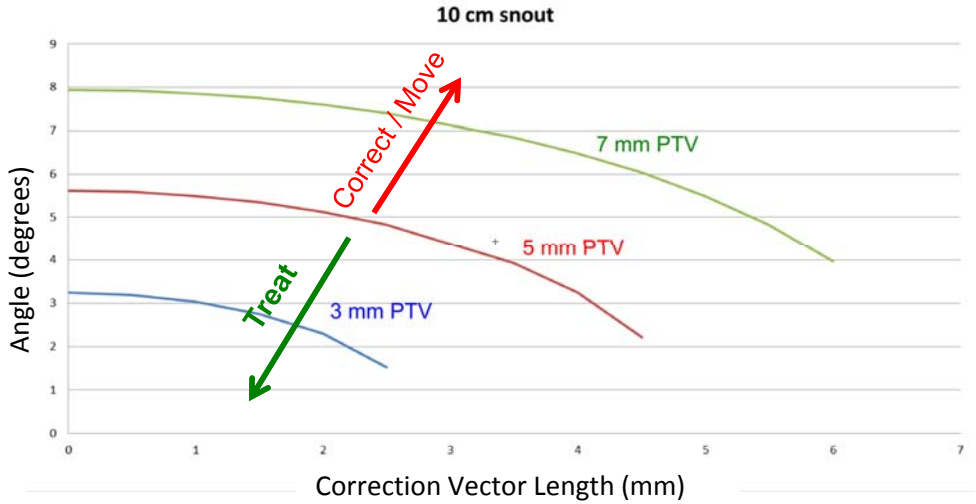




Set-up Tolerances

- **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**



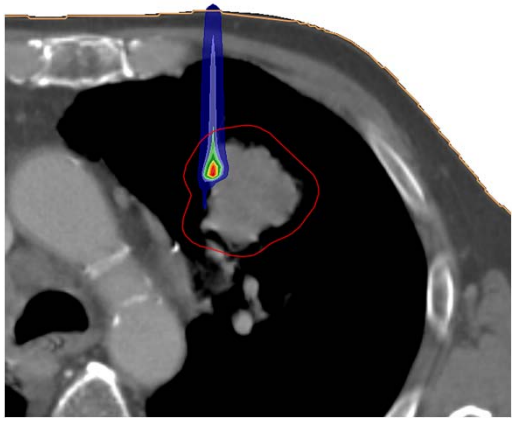


From Dennis Mah, ProCure NJ

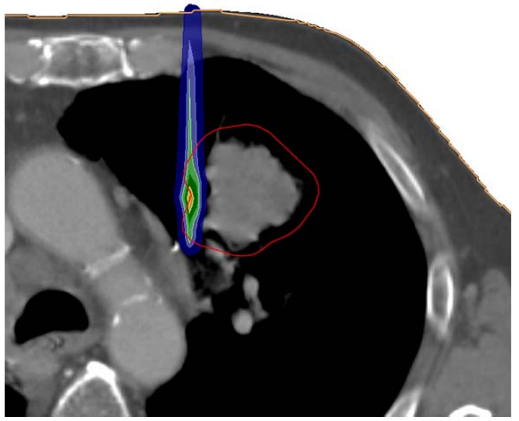
PBS Allows for Robust Optimization

- 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**

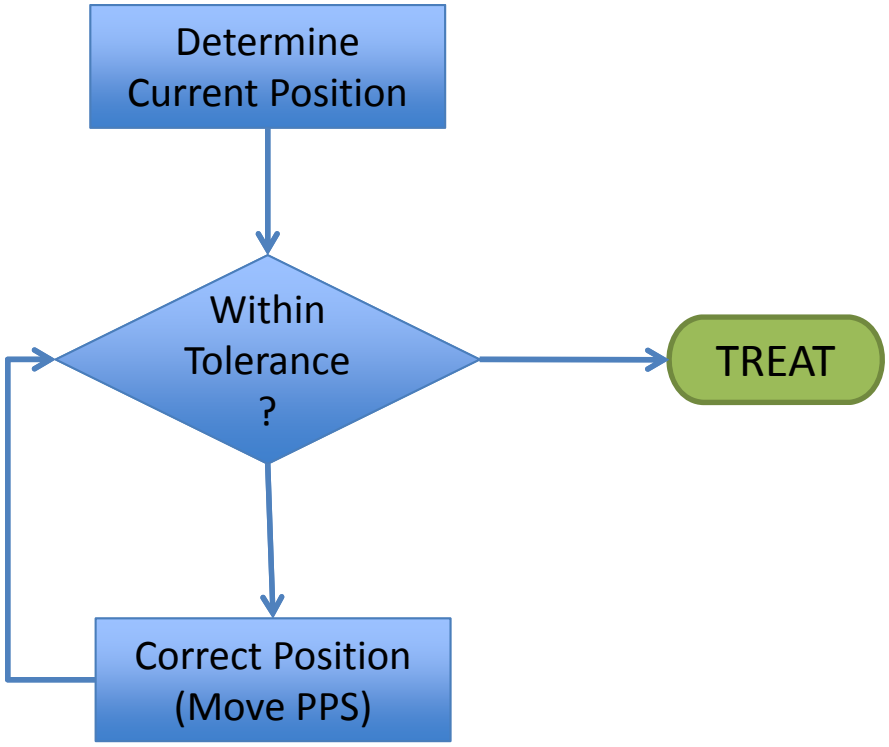


(a) Nominal setup



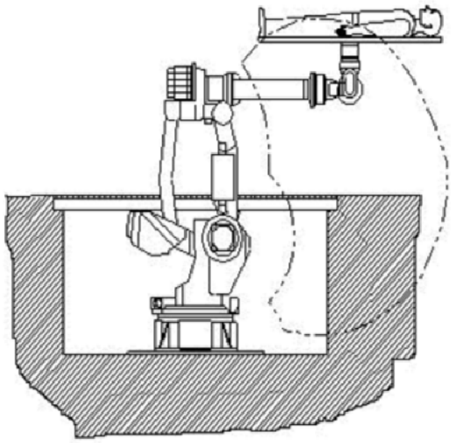
(b) Shifted setup

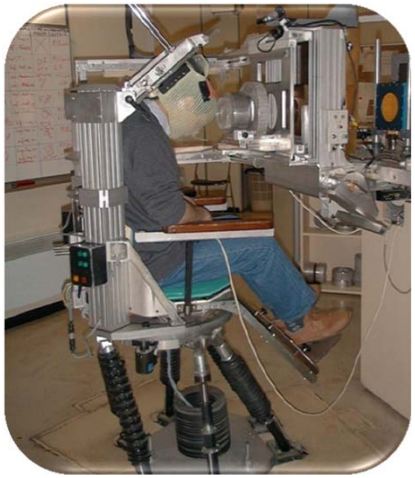
How should we use setup tolerances ?

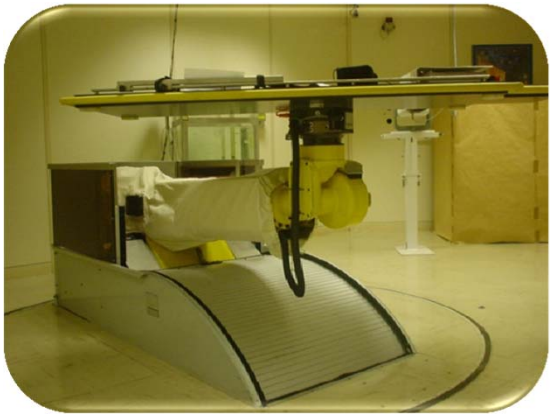


- If the Physician desires, you can make the tolerances for the first iteration small
  - → *Desire to be exact*
  - → *Accurate.*
- Use well established tolerances for the second iteration and use them.
- If not the therapists will drop into an infinite set-up loop / downward spiral to no-where.

First + 2nd Generation: Commercially available Robots







START

CPO
1997

With Compliments from CPO

MPRI
2004

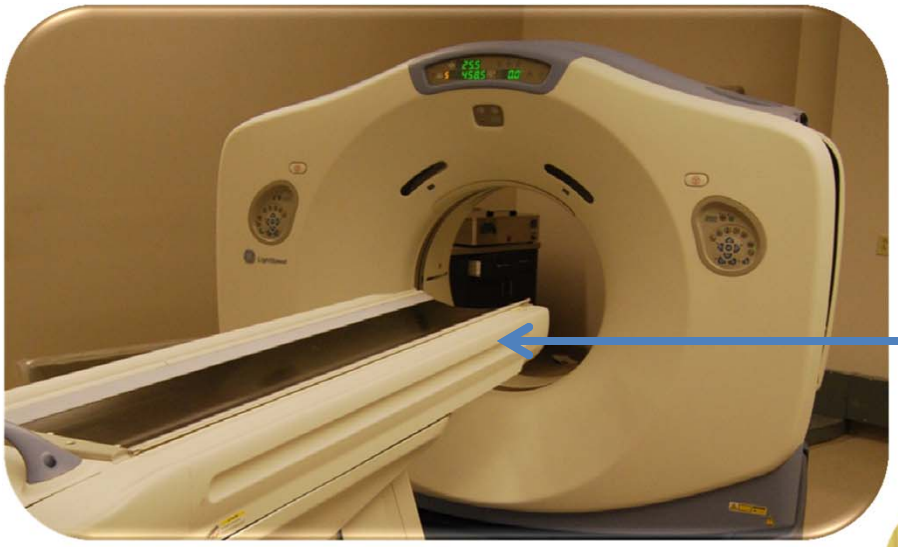
Forte 2008

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

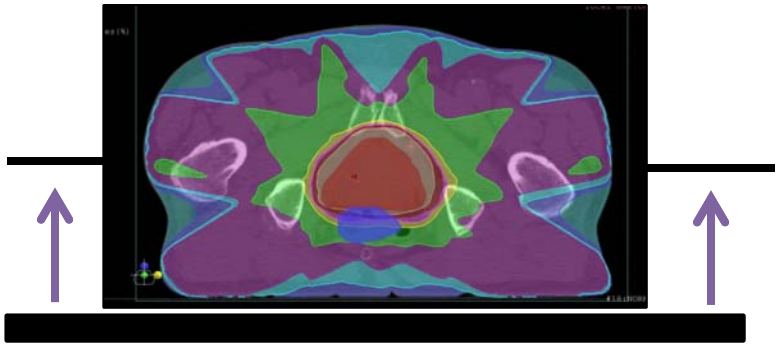


Comfortable CT Scanner top

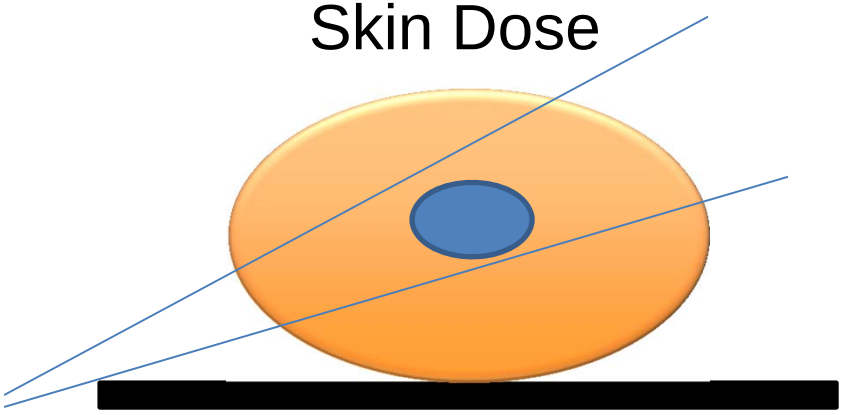
Very Uncomfortable CT Scanner top

Some Paradigm Shifts Required – Positioning Devices

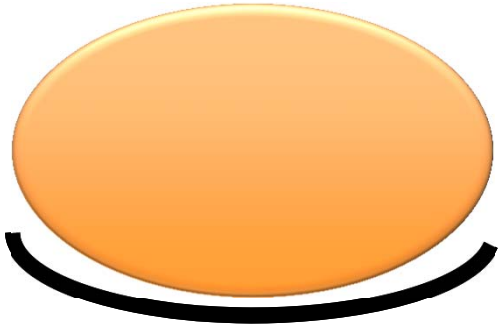
Roll correction



Skin Dose



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



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

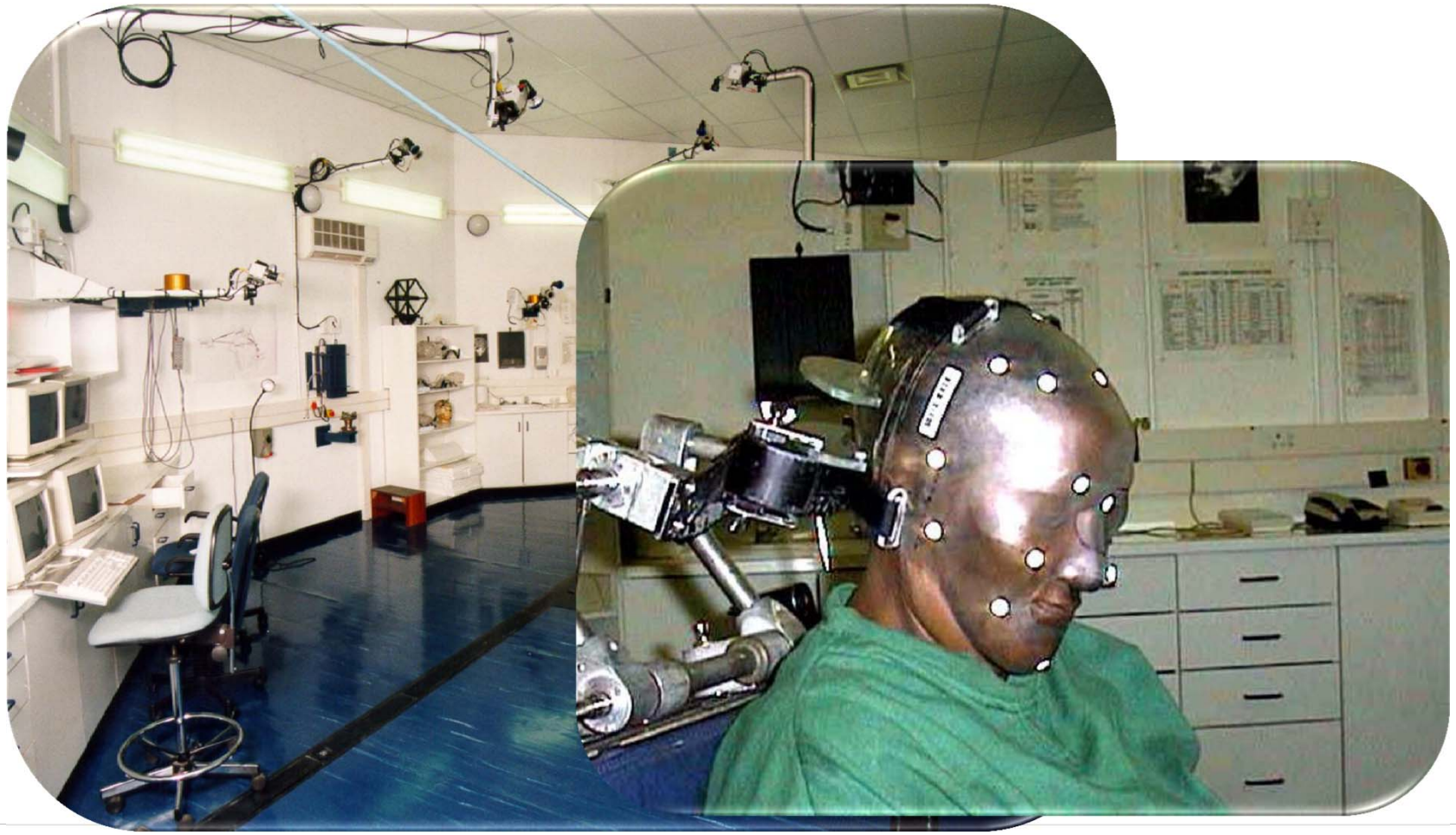
Existing PAS Systems used in Proton Therapy

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

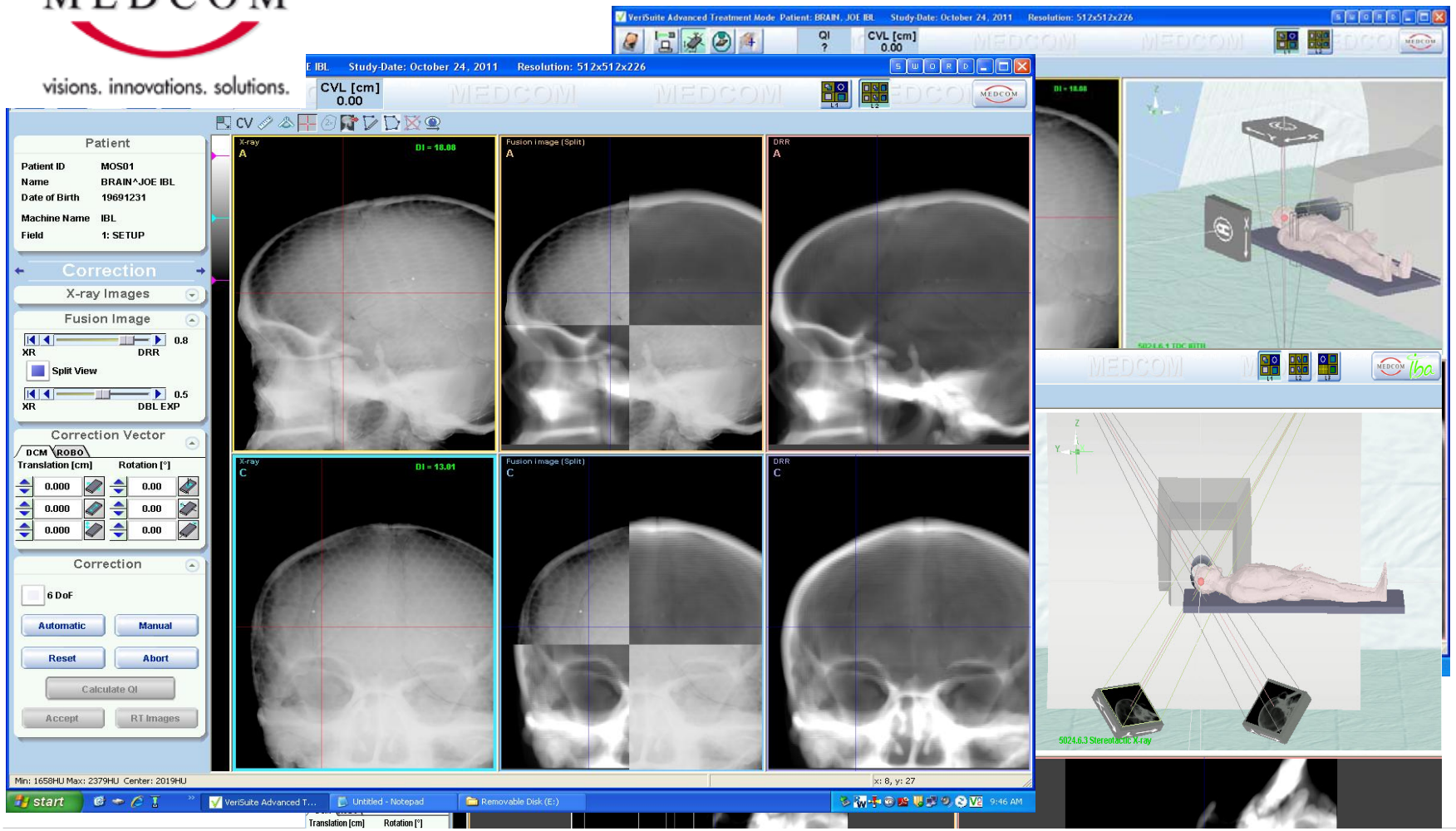


Overview of PAS Systems

MEDCOM

visions. innovations. solutions.

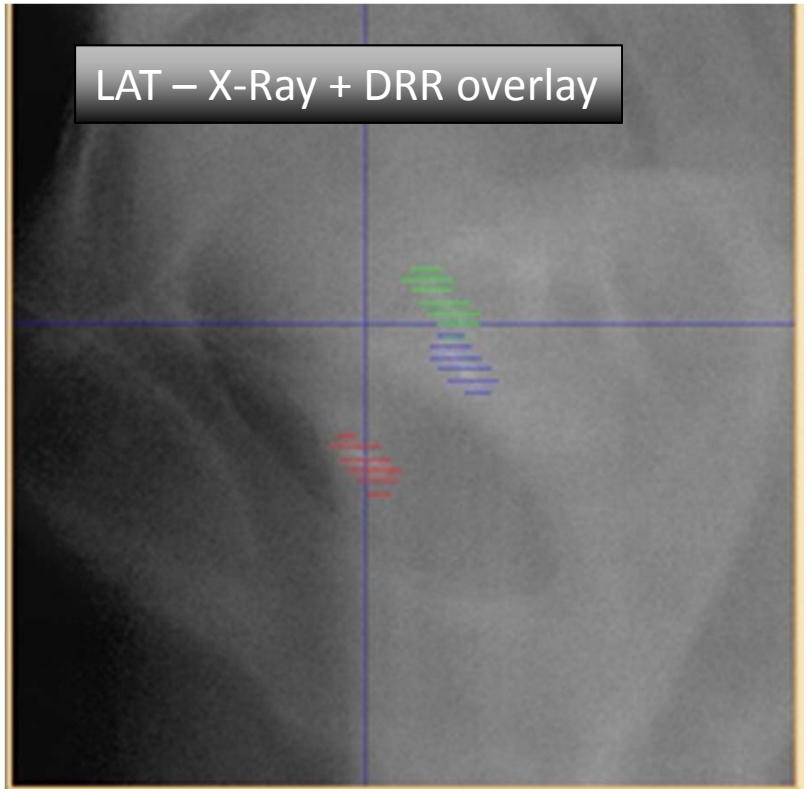
Orthogonal x-rays or Stereoscopic x-rays

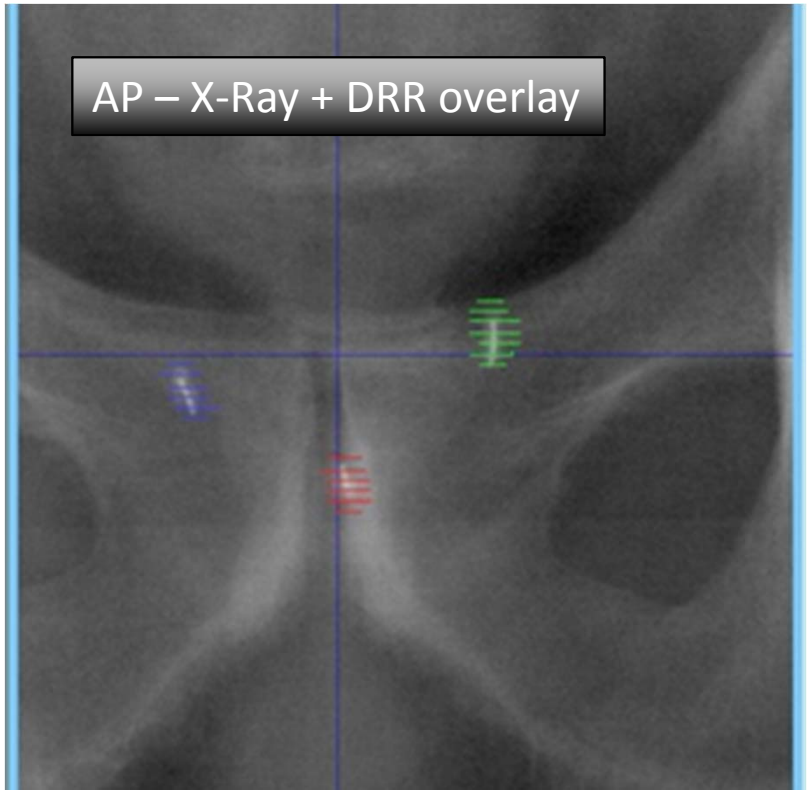


Overview of PAS Systems – Fiducial Markers + X-rays

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

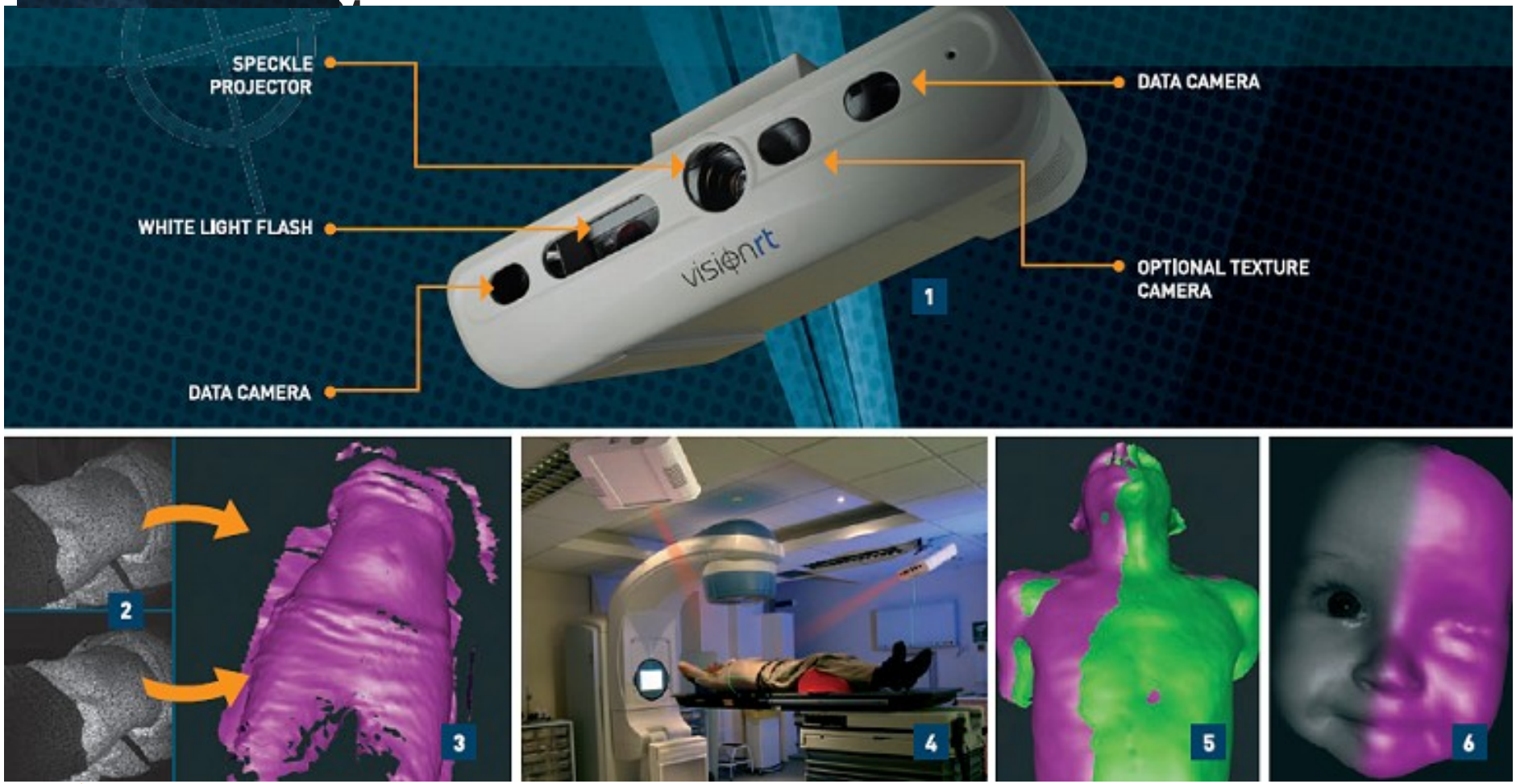




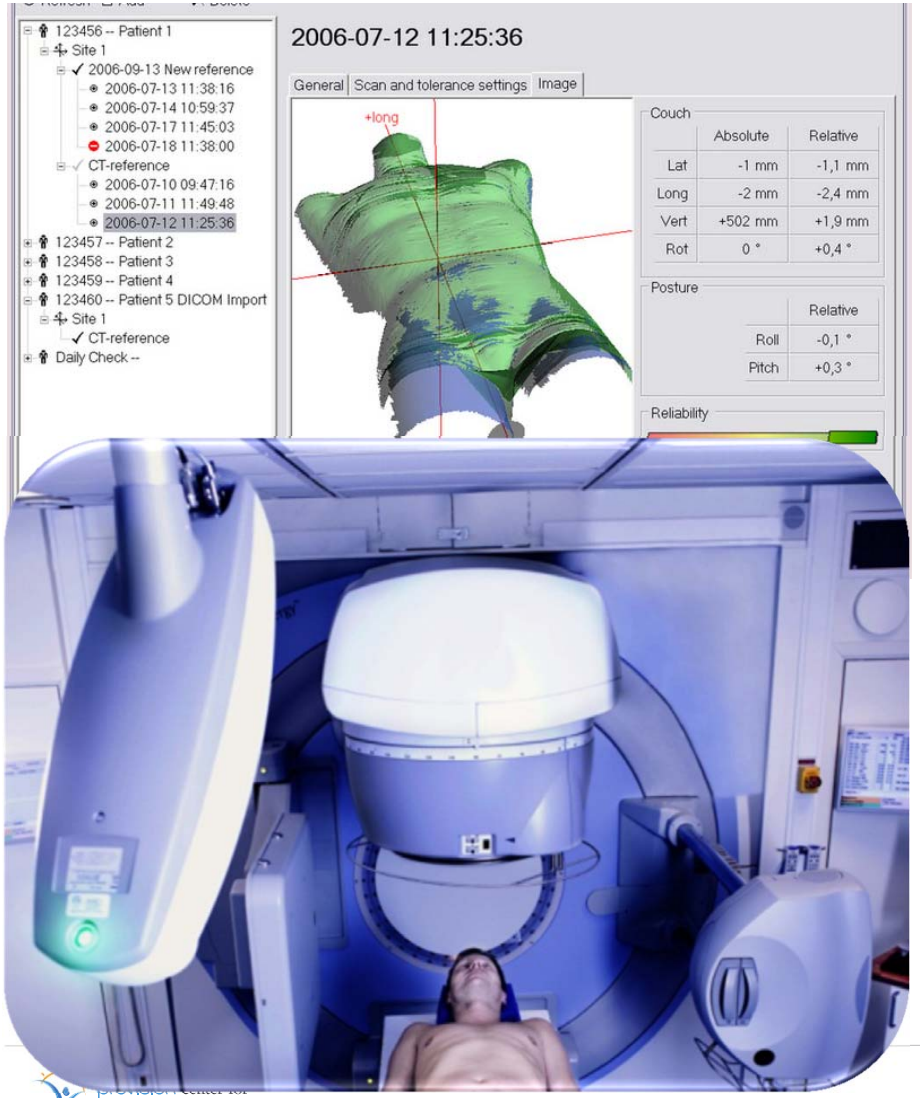
Overview of PAS Systems – Surface Recognition

visionrt

Stereo Cameras

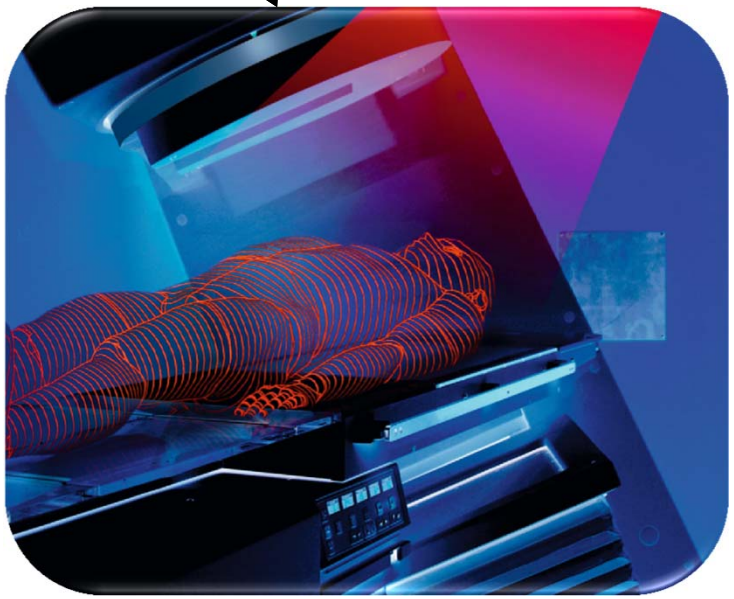


Overview of PAS Systems – Surface Recognition

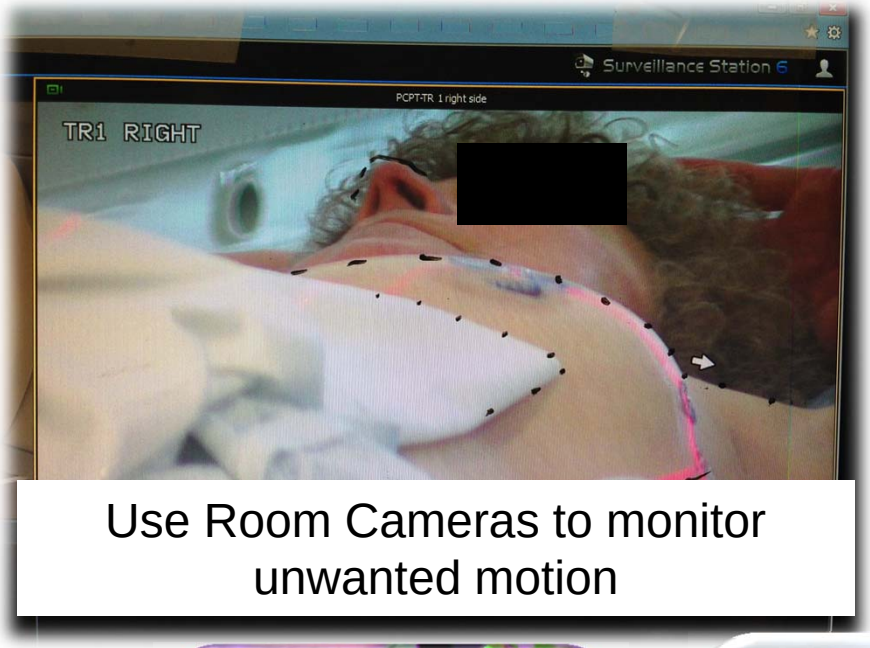


Laser Surface Scanner

C-RAD
Galaxy – LAP Laser

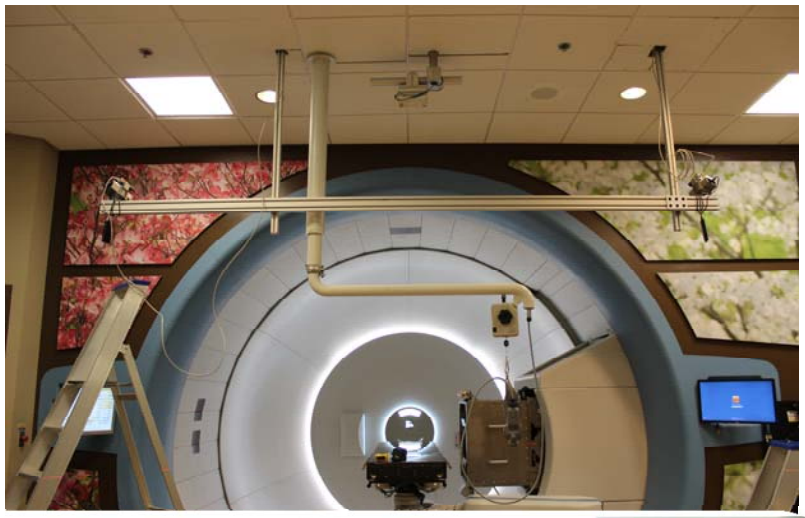


Overview of PAS Systems – Optical Tracking



Use Room Cameras to monitor unwanted motion

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 <==> Cone Beam CT
  - Cone Beam CT <==> Image Guidance
- **In the Ion Therapy world**
  - Volumetric imaging <==> Soft Tissue Definition
  - Volumetric imaging <==> 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

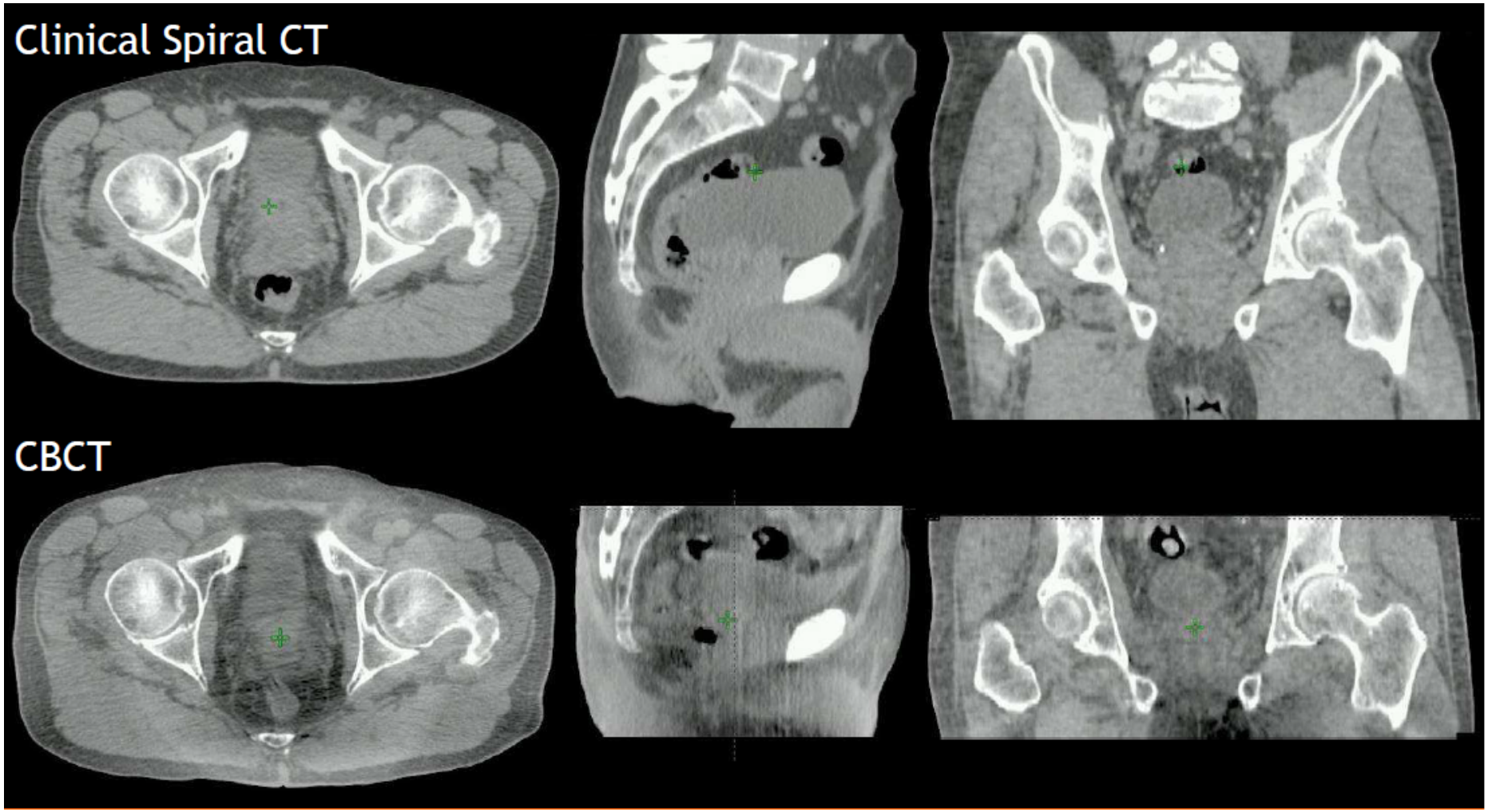
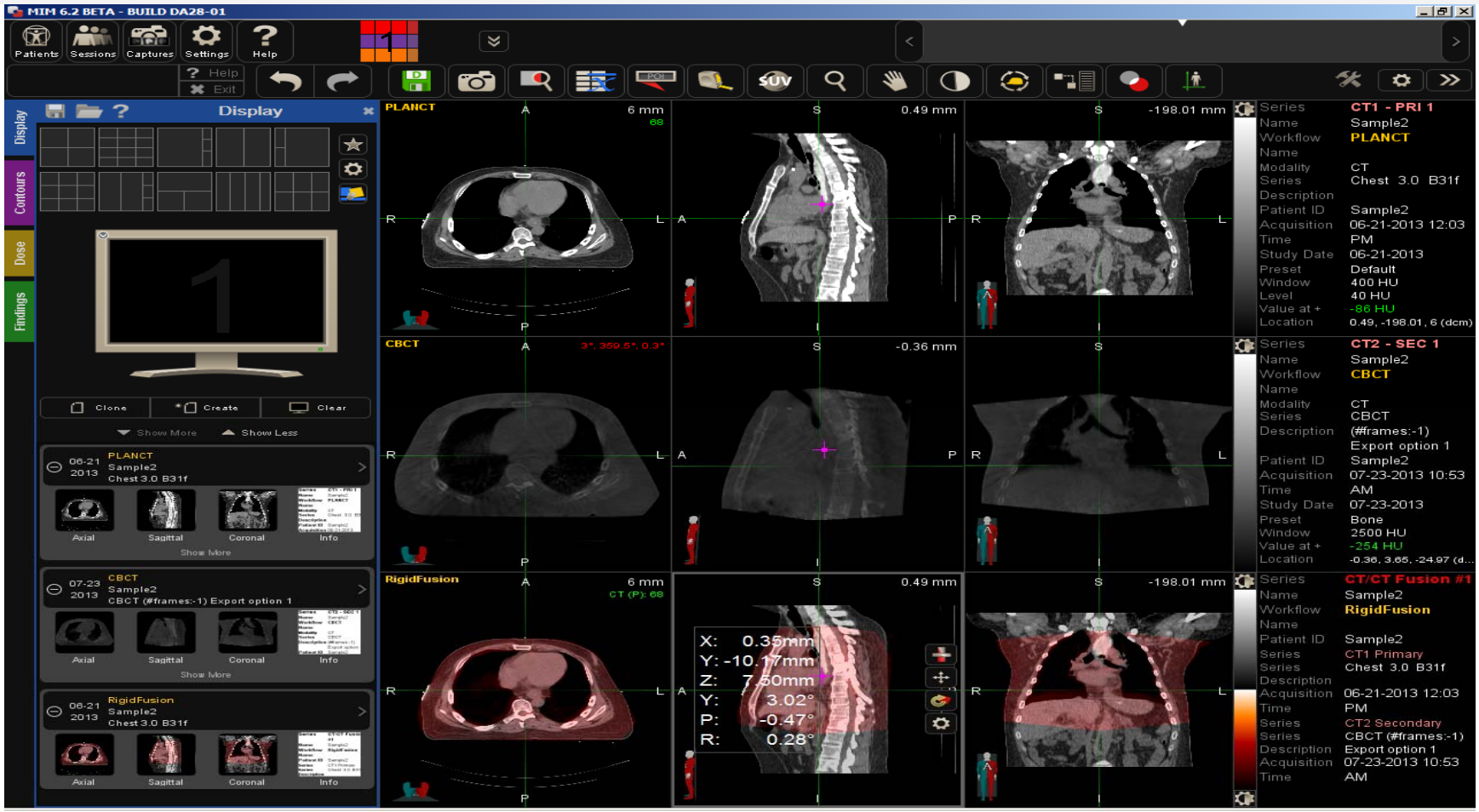


Image Registration 3D/3D (MIM)



- **(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

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

courtesy Raysearch Labs

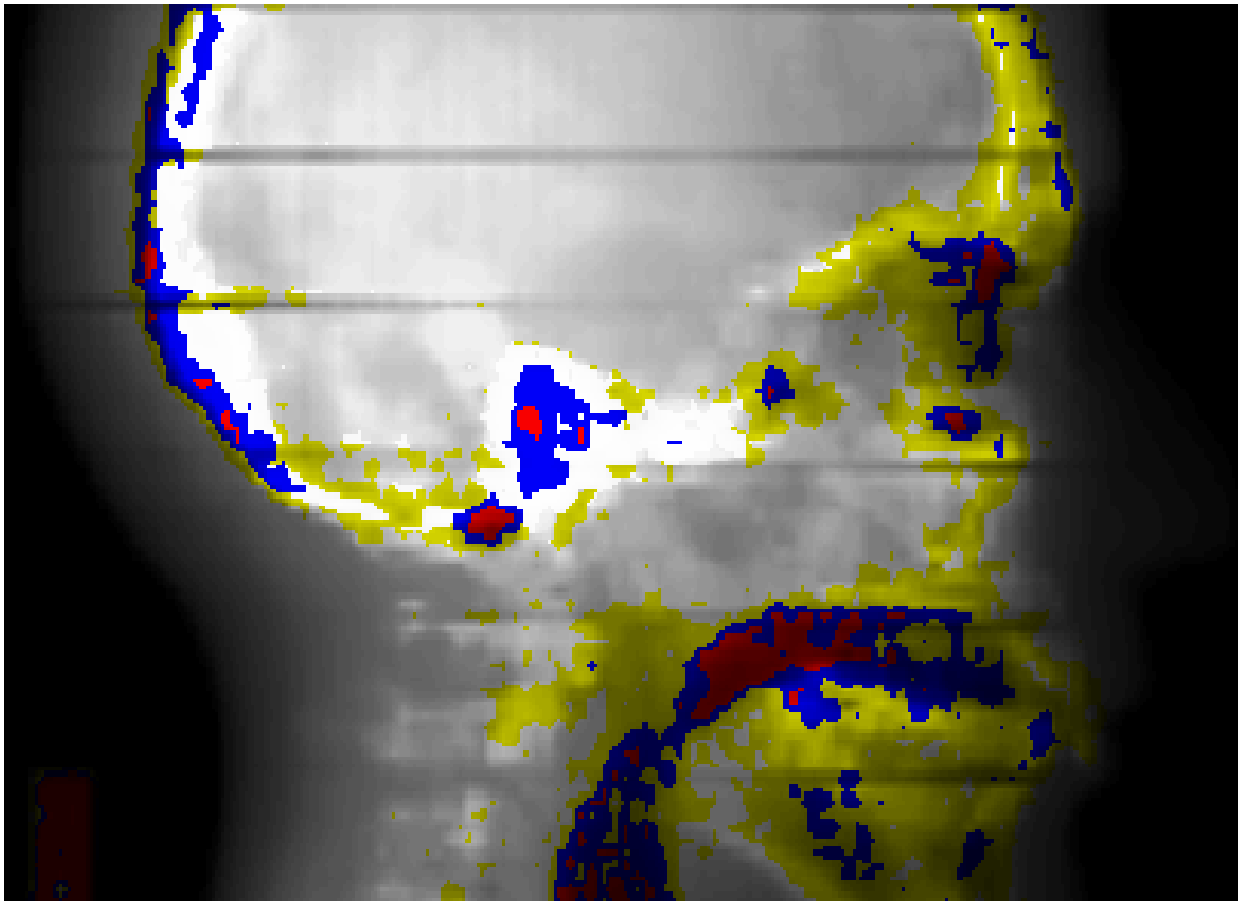
Proton Radiography → Tomography

Range Uncertainties
(measured with PTR)

> 5 mm

> 10 mm

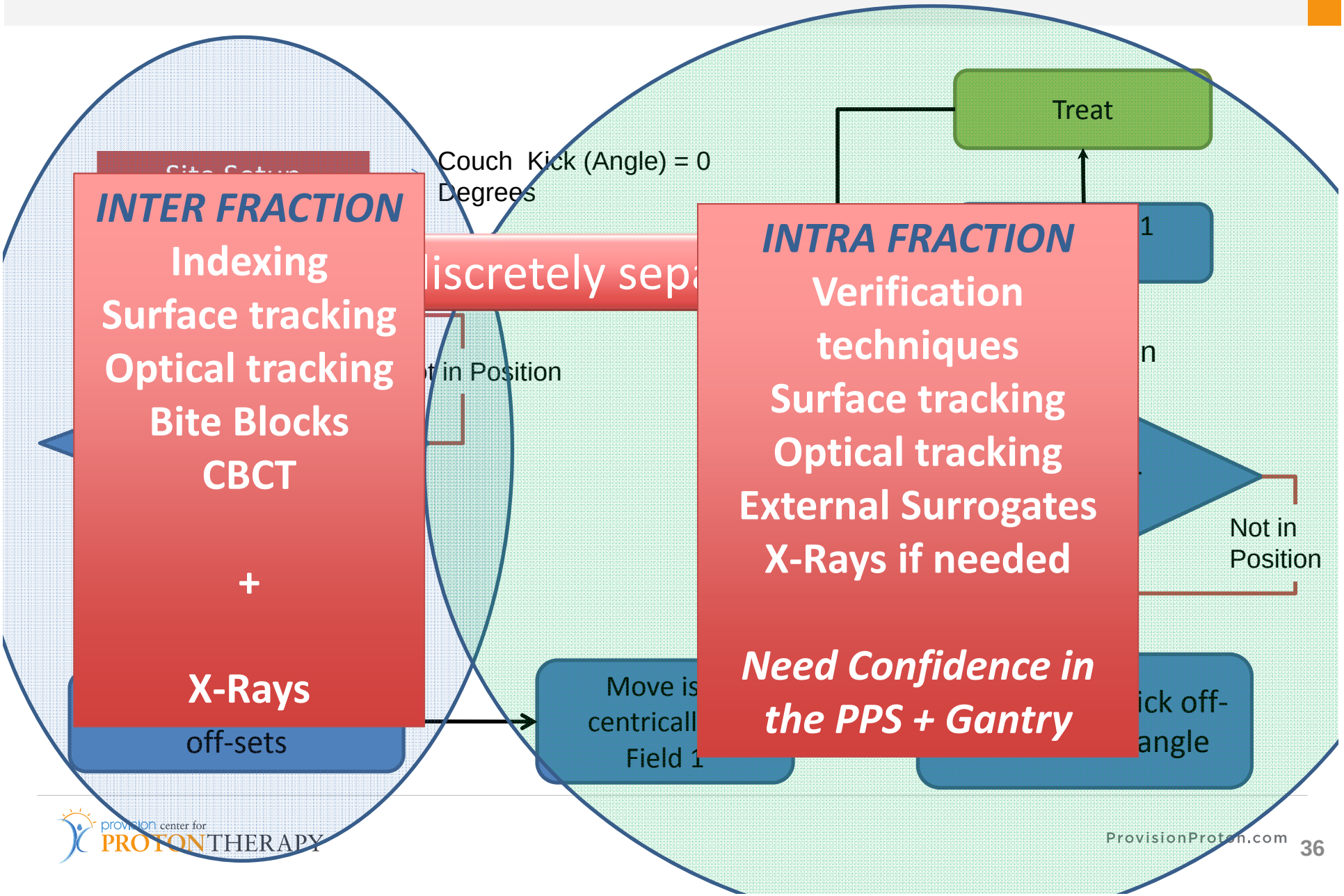
> 15 mm



Alderson Head Phantom

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

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”**