Prevention of accidents in radiotherapy

Ben Mijnheer

Prevention of accidents in radiotherapy: different aspects

Implementation of a comprehensive quality assurance programme of:

- all types of equipment used to plan and treat a patient
- all steps in the actual patient treatment
- all procedures used by the personnel involved including teaching and training

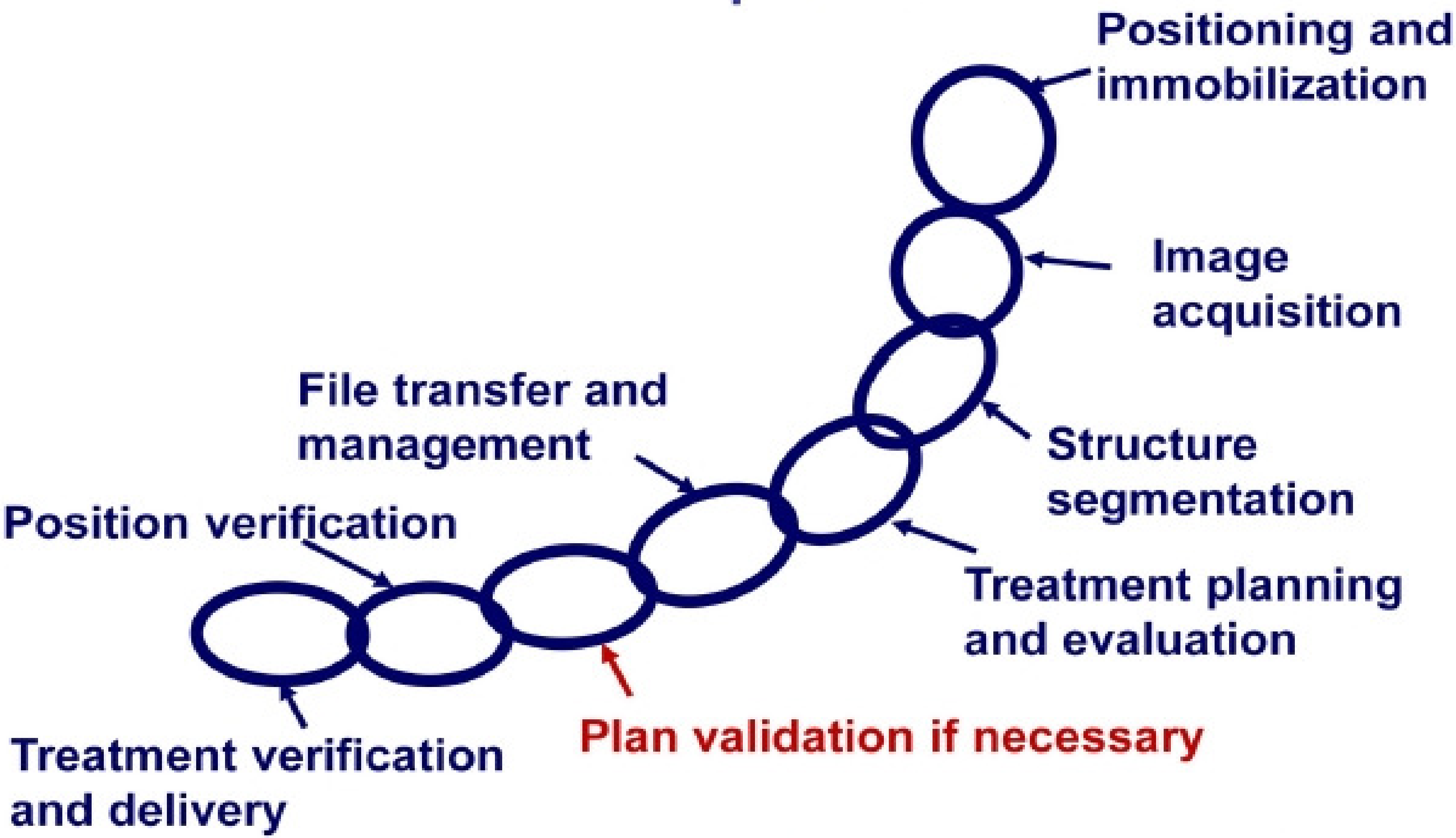


Prevention of accidents in radiotherapy: different aspects

Implementation of a comprehensive quality assurance programme of:

- all types of equipment used to plan and treat a patient

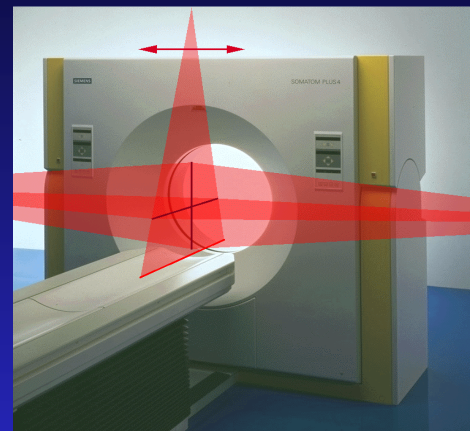
3D CRT process

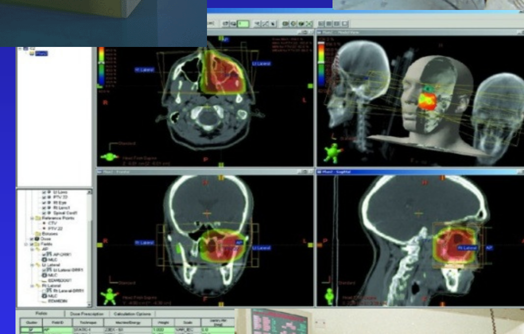
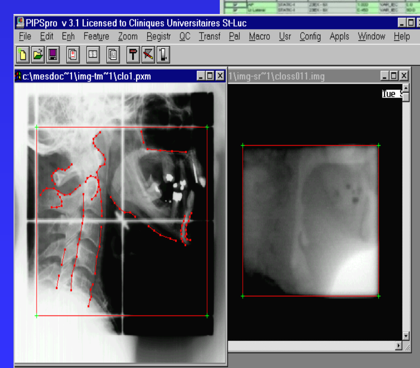


Adapted from an illustration presented by Webb, 1996

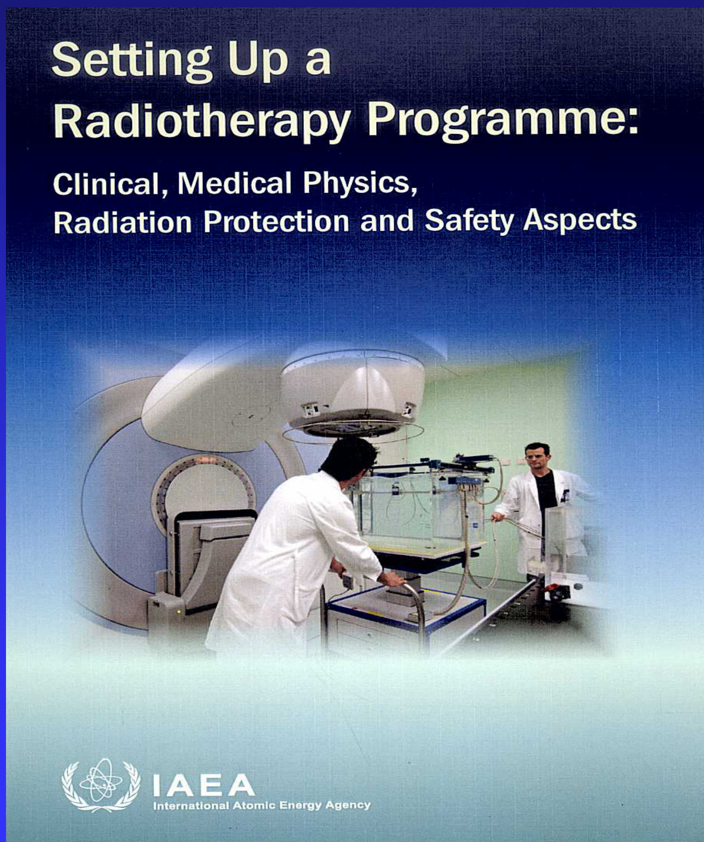
Guidance on equipment

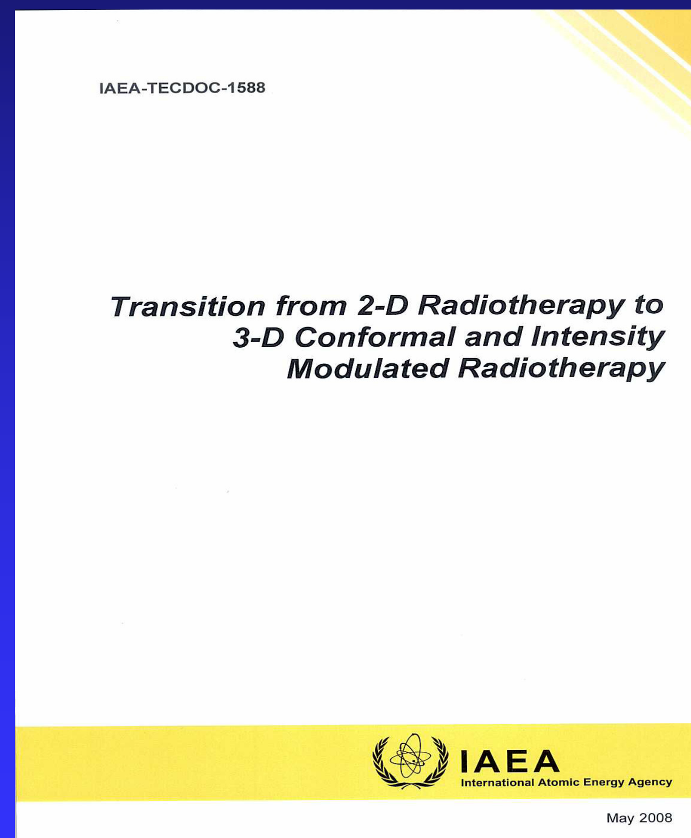
- CT, CT Simulator
- Immobilization
- Treatment Planning Systems
- Accelerators with MLC and EPID
- Networking



QA programme of the whole process: from CT to treatment - is important





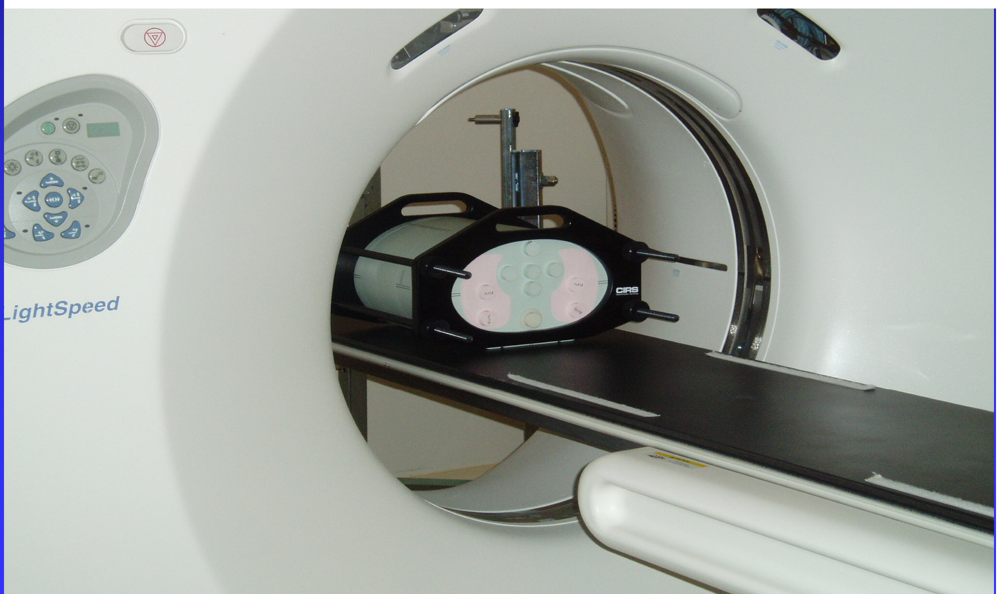
Quality control

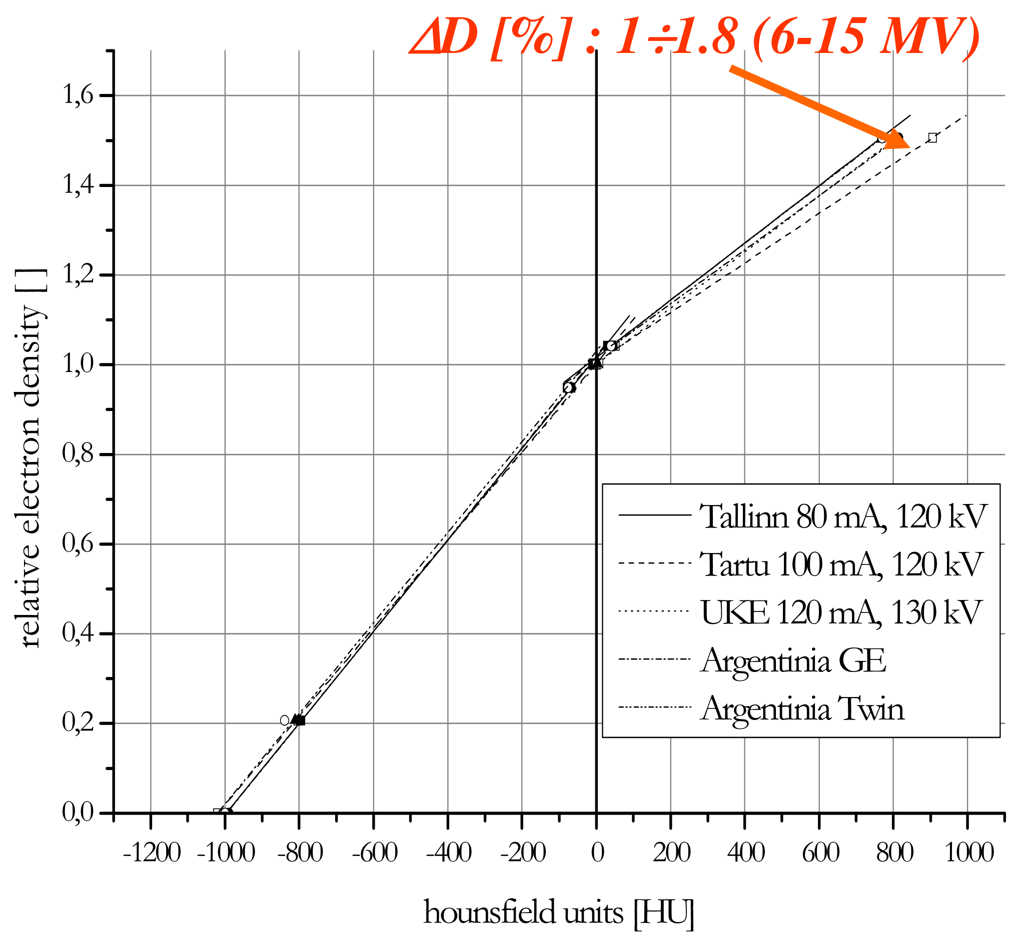
- An equipment quality control program should specify the following:
  - The **parameters** to be tested and the **tests** to be performed;
  - The **specific equipment** to be used for that;
  - The **geometry** of the tests;
  - The **frequency** of the tests;
  - The **staff group** or **individual** performing the tests, as well as the individual supervising and responsible for the standards of the tests and for actions that may be necessary if problems are identified;

Verification of HU/ED conversion

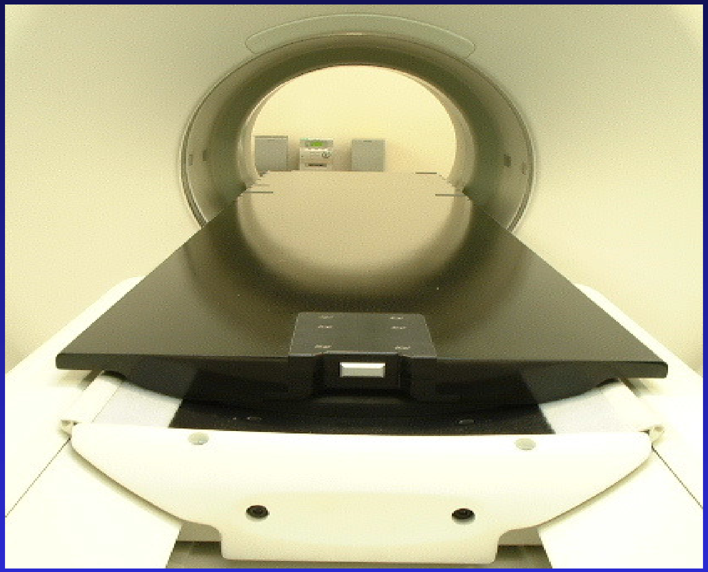
Electron Density Reference Inserts for IMRT Phantoms: Models 74-008, 74-007, & 74-

	Density	Electron density per cc x 10^{23}	Electron density relative to H_2O
H_20	1.00	3.34	1.000
Lung	0.21	0.69	0.207
Bone	1.60	5.03	1.506
Muscle	1.06	3.48	1.042
Adipose	0.96	3.17	0.949
Plastic Water® - diagnostic/ therapy range	1.04	3.35	1.003

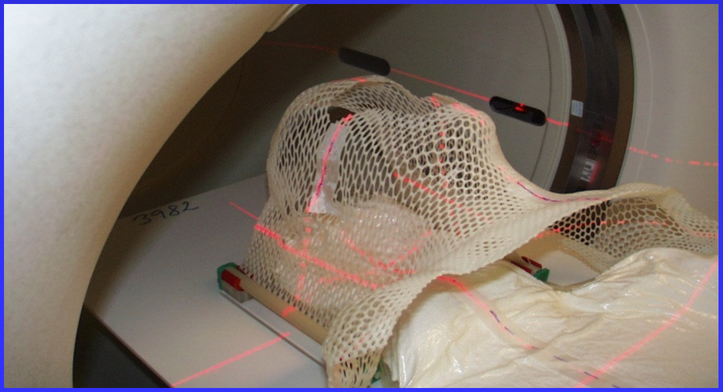




Differences
between diagnostic and therapy CT scanning



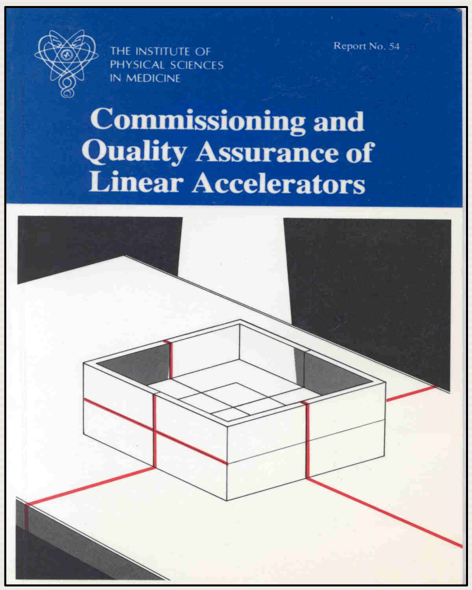
therapy CT
scanning

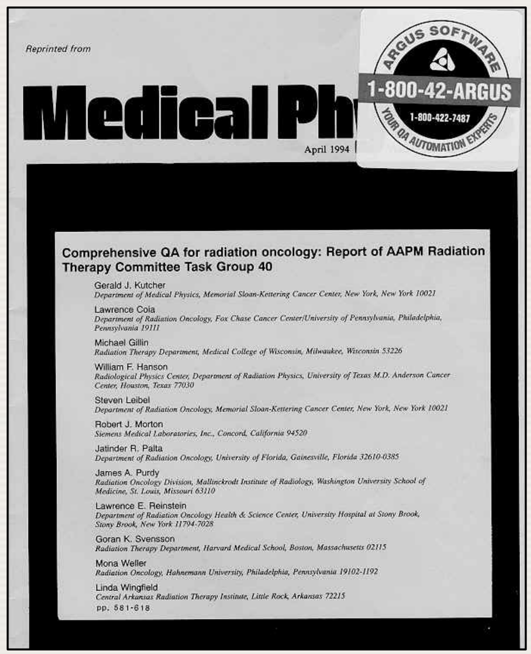


diagnostic CT
scanning

12.3 QUALITY ASSURANCE PROGRAMME FOR EQUIPMENT

- Many documents are available:





Comprehensive QA for radiation oncology: Report of AAPM Radiation Therapy Committee Task Group 40

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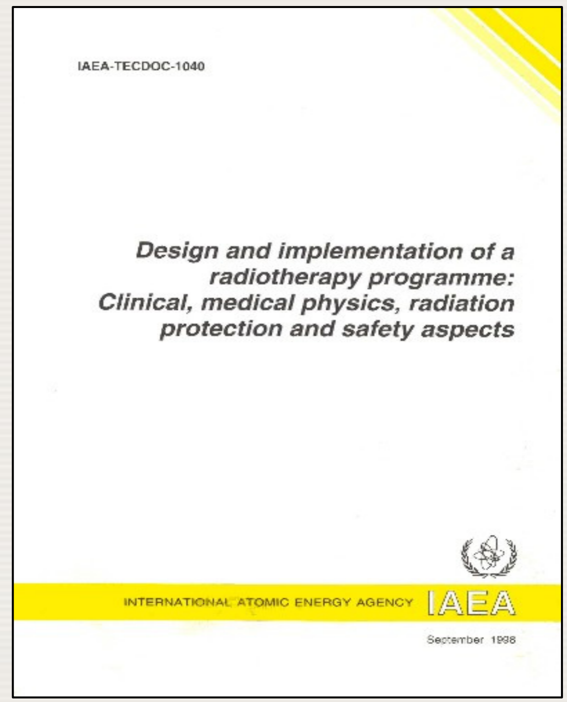
pp. 581-618




IAEA-TECDOC-1640

Specification and Acceptance Testing of Radiotherapy Treatment Planning Systems

IAEA
International Atomic Energy Agency

April 2007

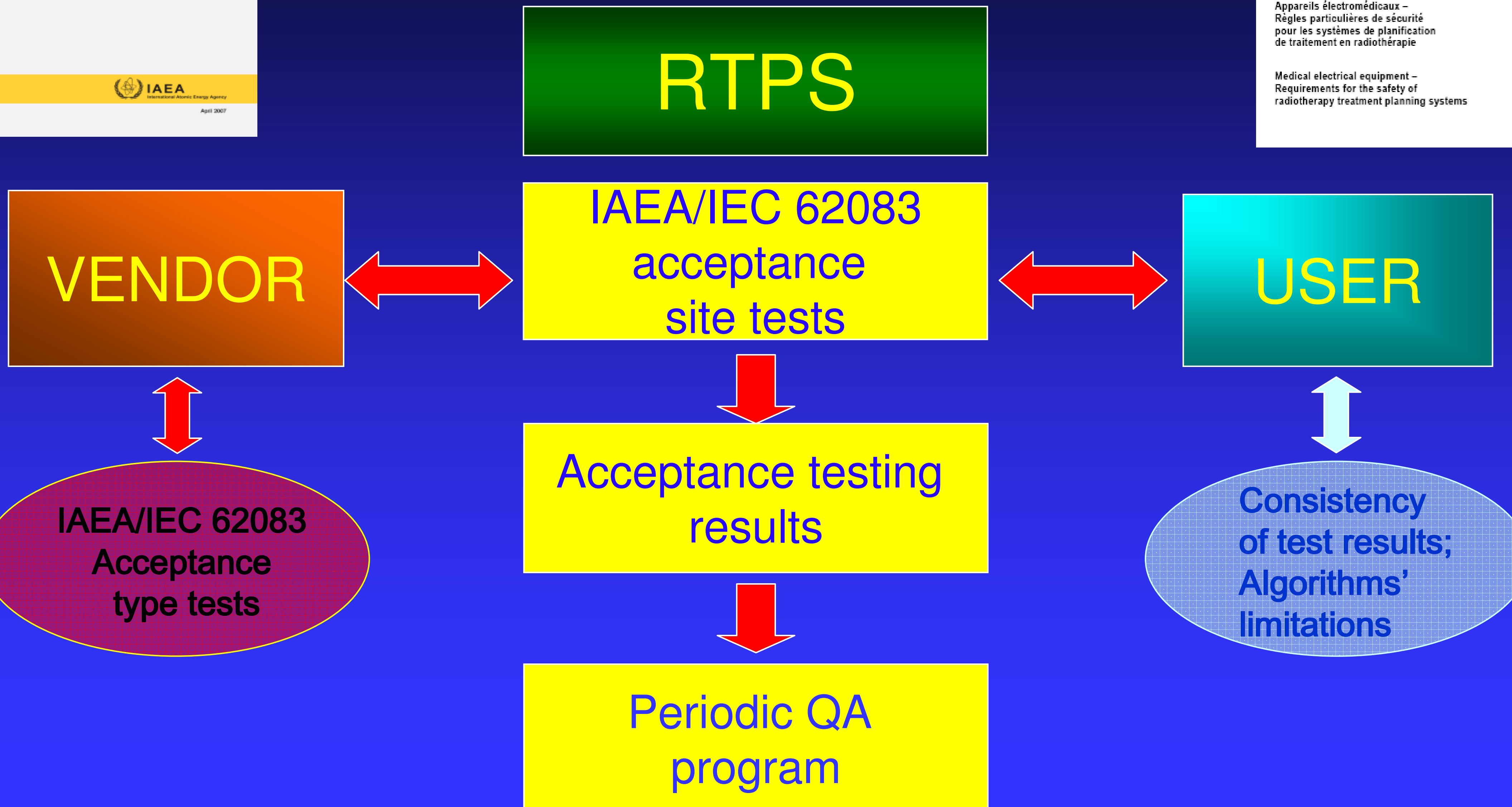
Acceptance testing and QA of a radiotherapy treatment planning system (RTPS)


NORME INTERNATIONALE
INTERNATIONAL STANDARD

CE
62083

Appareils électromédicaux –
Règles particulières de sécurité
pour les systèmes de planification
de traitement en radiothérapie

Medical electrical equipment –
Requirements for the safety of
radiotherapy treatment planning systems

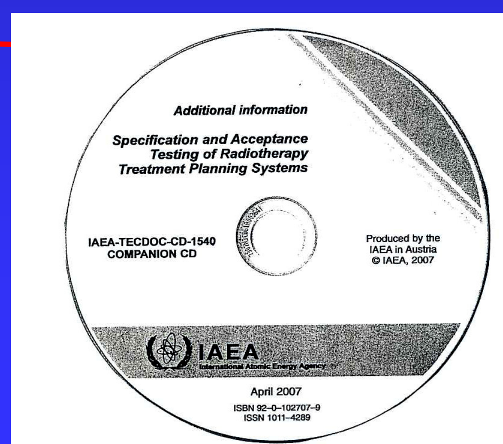


IAEA TECDOC 1540:
acceptance tests of dose calculations

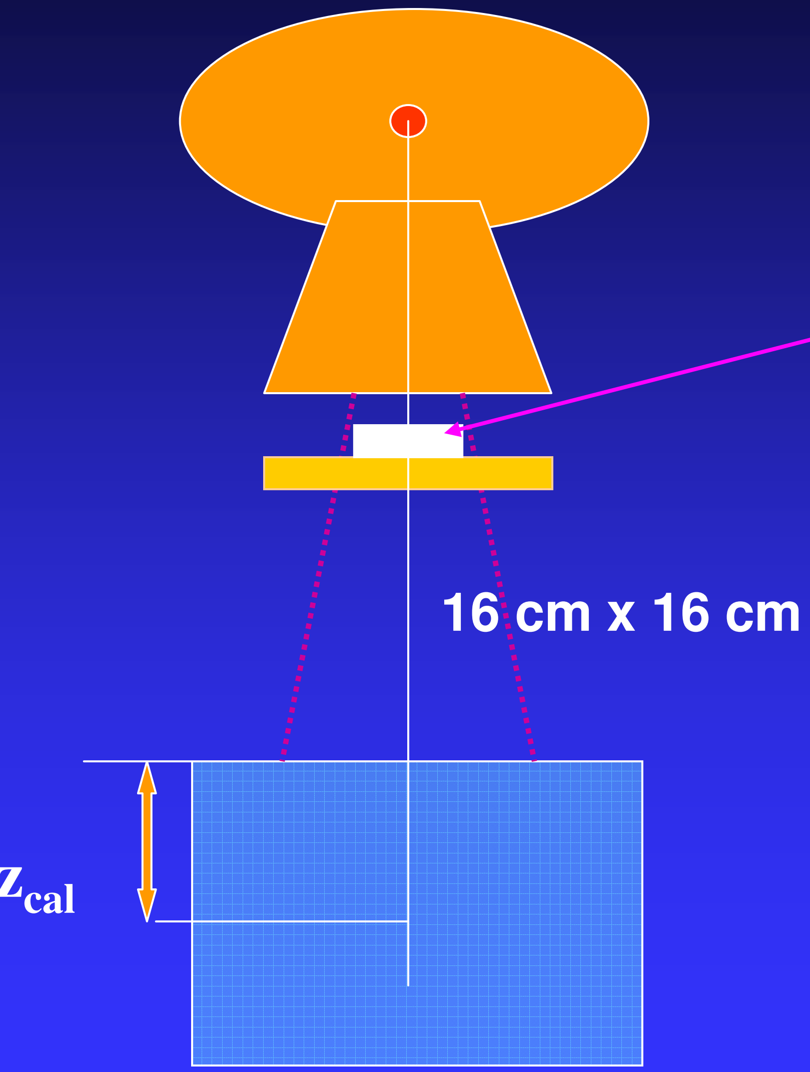
Protocol for specification and acceptance testing of Radiation Treatment Planning Systems

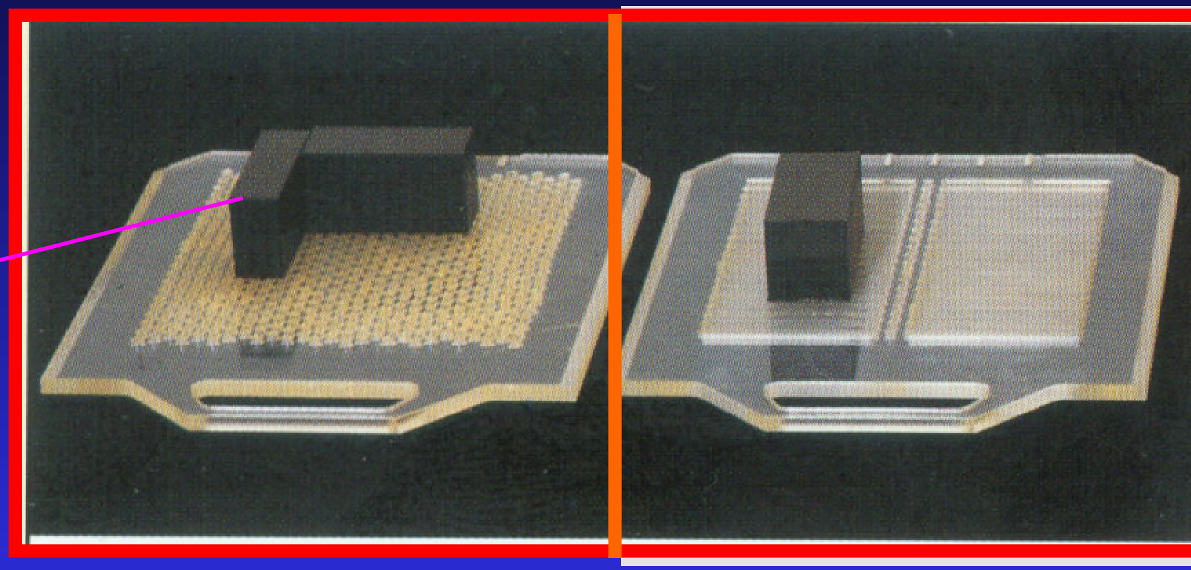
General tests

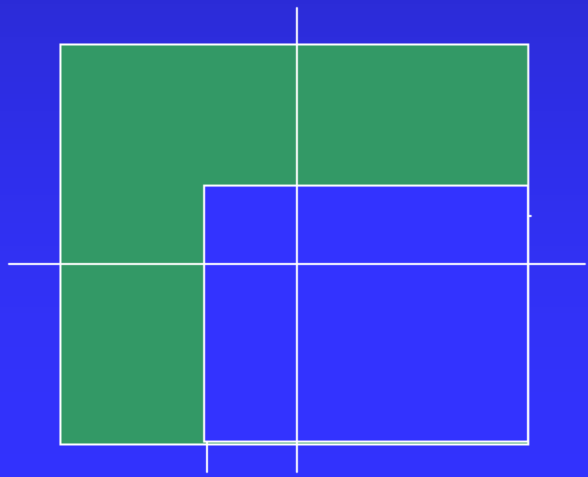
- **Data sourses**
  - **NCS package** (…enselaar and Welleweerd)
    - AAPM TG23: 6 MV, 10 MV, 18 MV
  - **IAEA/AKH Co-60 package**
    - AAPM TG 23
- **Dose calculation Type tests**
  - **Appendix A**: Tests per IEC 62083
- **Dose calculation Site tests**
  - **Appendix B**: Tests per IEC 62083 subset from Appendix A
- **Optional site tests**
  - **Appendix C**: Tests per IEC 62083 subset from Appendixes A and B

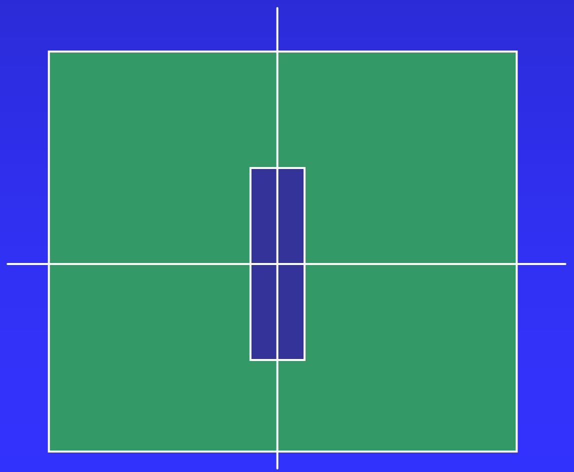


IAEA TECDOC 1540
central block and L-shaped field tests









Does your TPS know this?

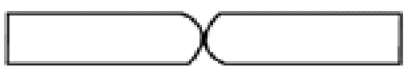
MLC Design – Leaf Ends

Non-focused (rounded) Leaf Ends

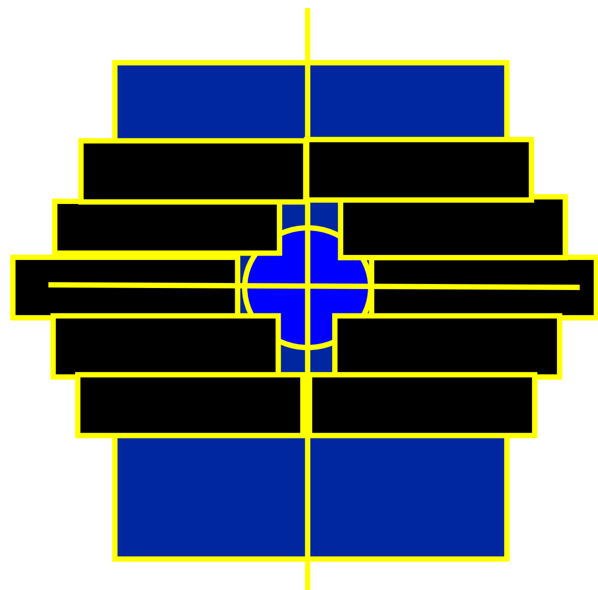
Leaf motion restricted to a single plane

In principle, penumbra is somewhat greater than for focused collimators of divergent custom blocks

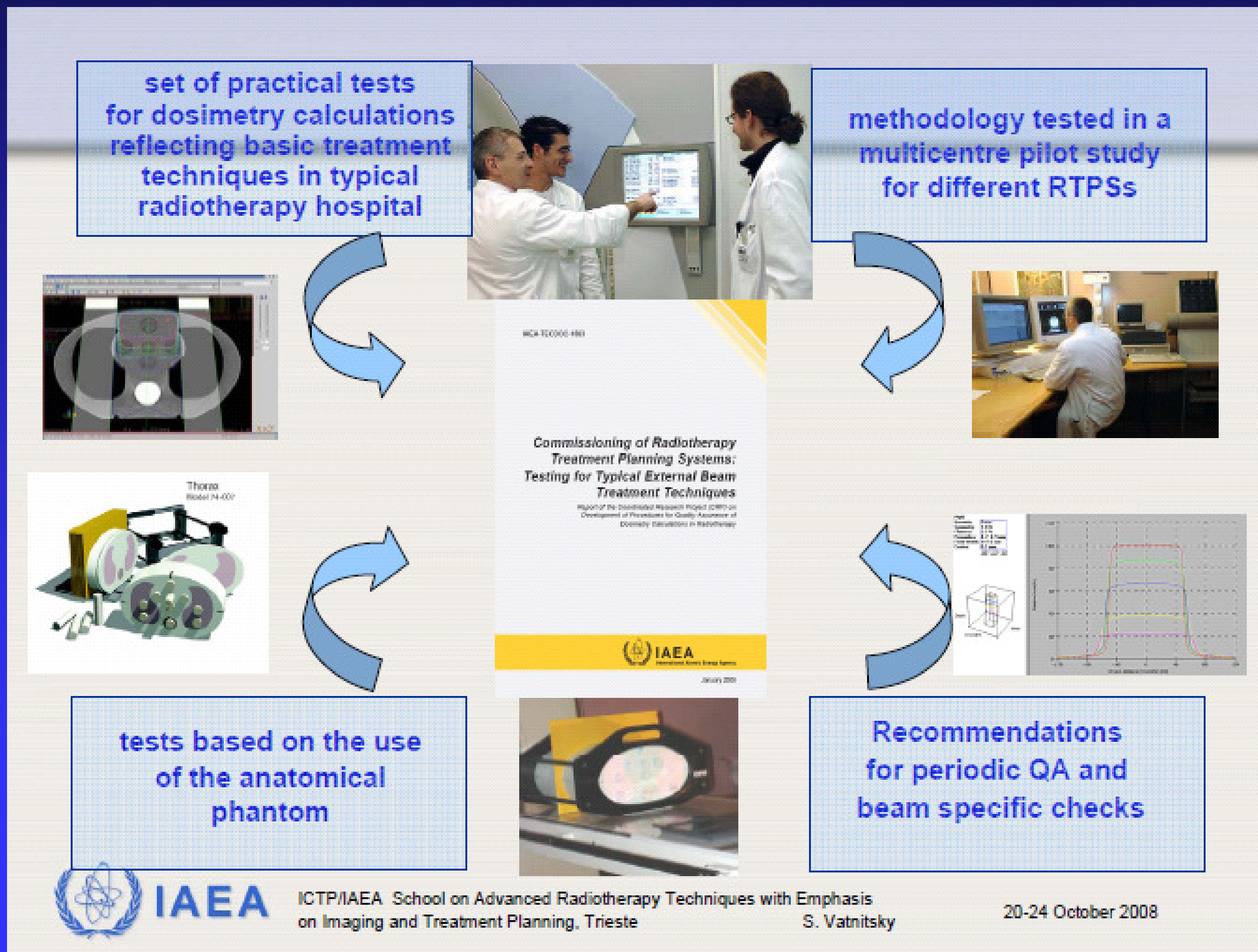
Potential for greater leaf end transmission when leaves are abutted



Both Varian and Elekta use the non-focused design



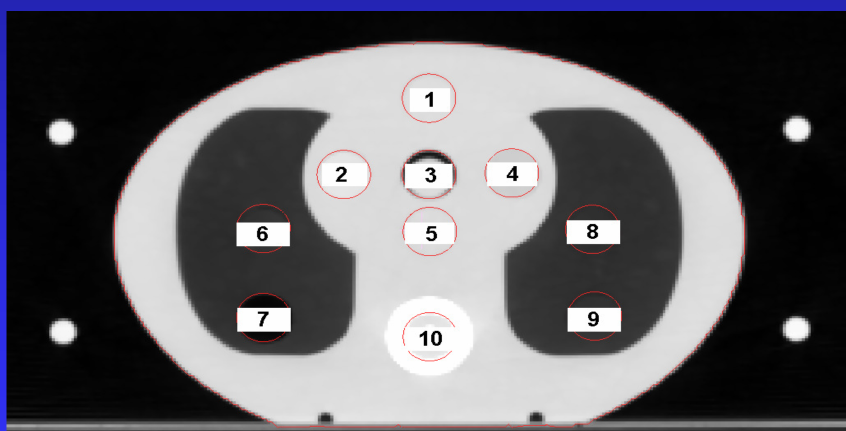
Testing of the treatment planning system



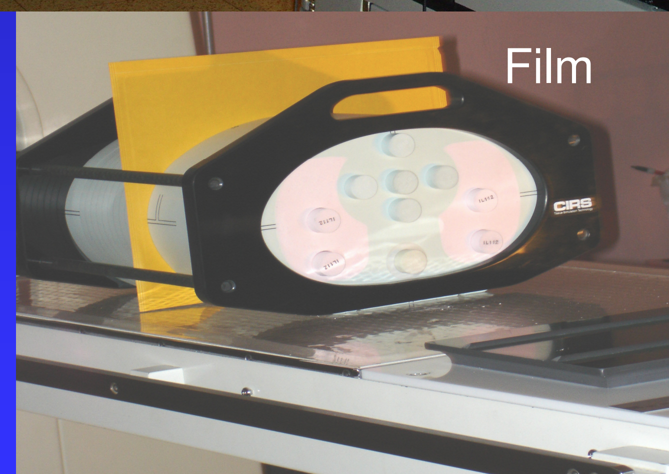
Clinical test cases

Beam arrangements for 8 test cases:

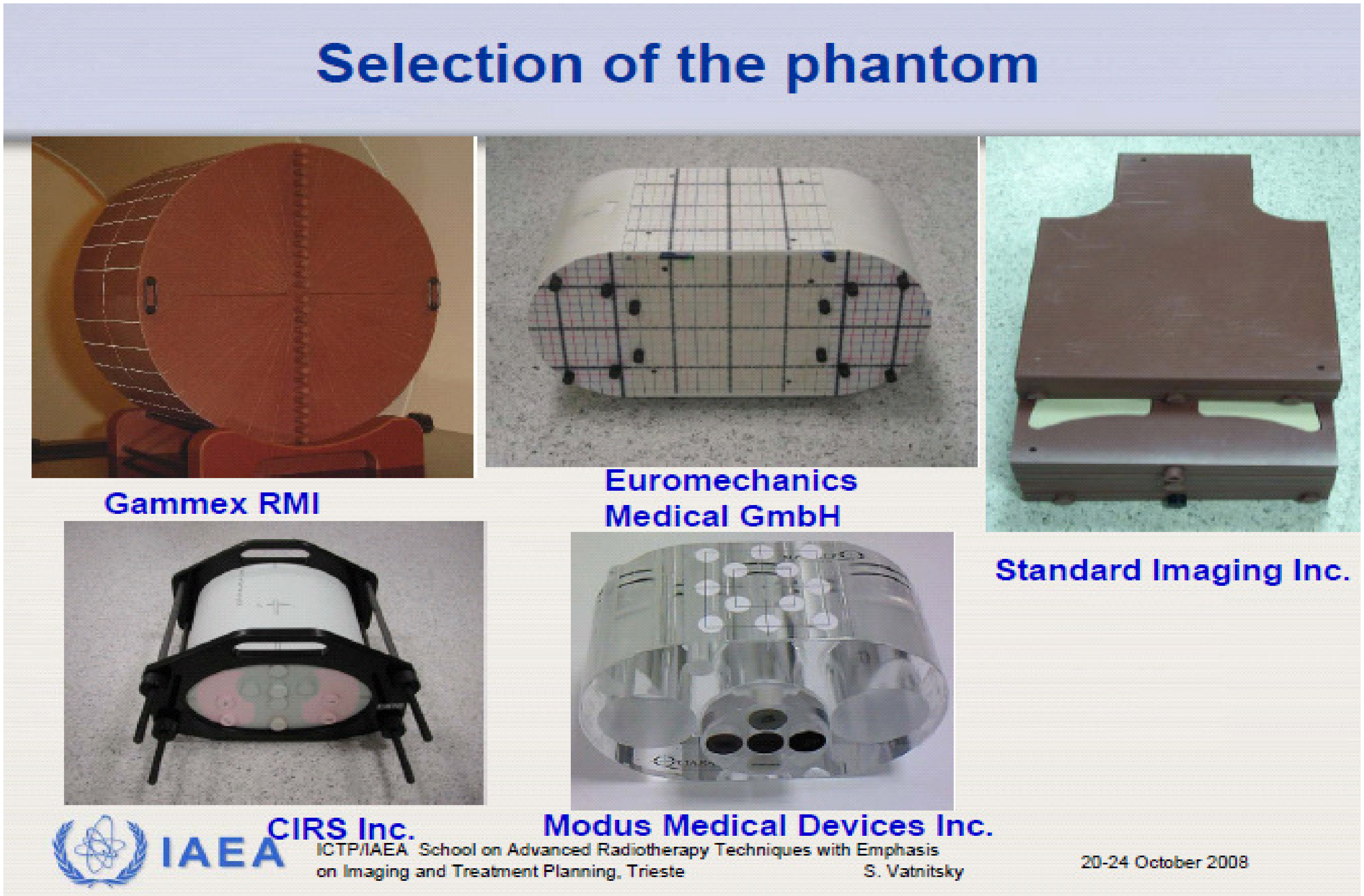
- customized blocks and wedges
- oblique incidence
- asymmetric and non-coplanar fields
- extended SSD
- multiple beam combinations



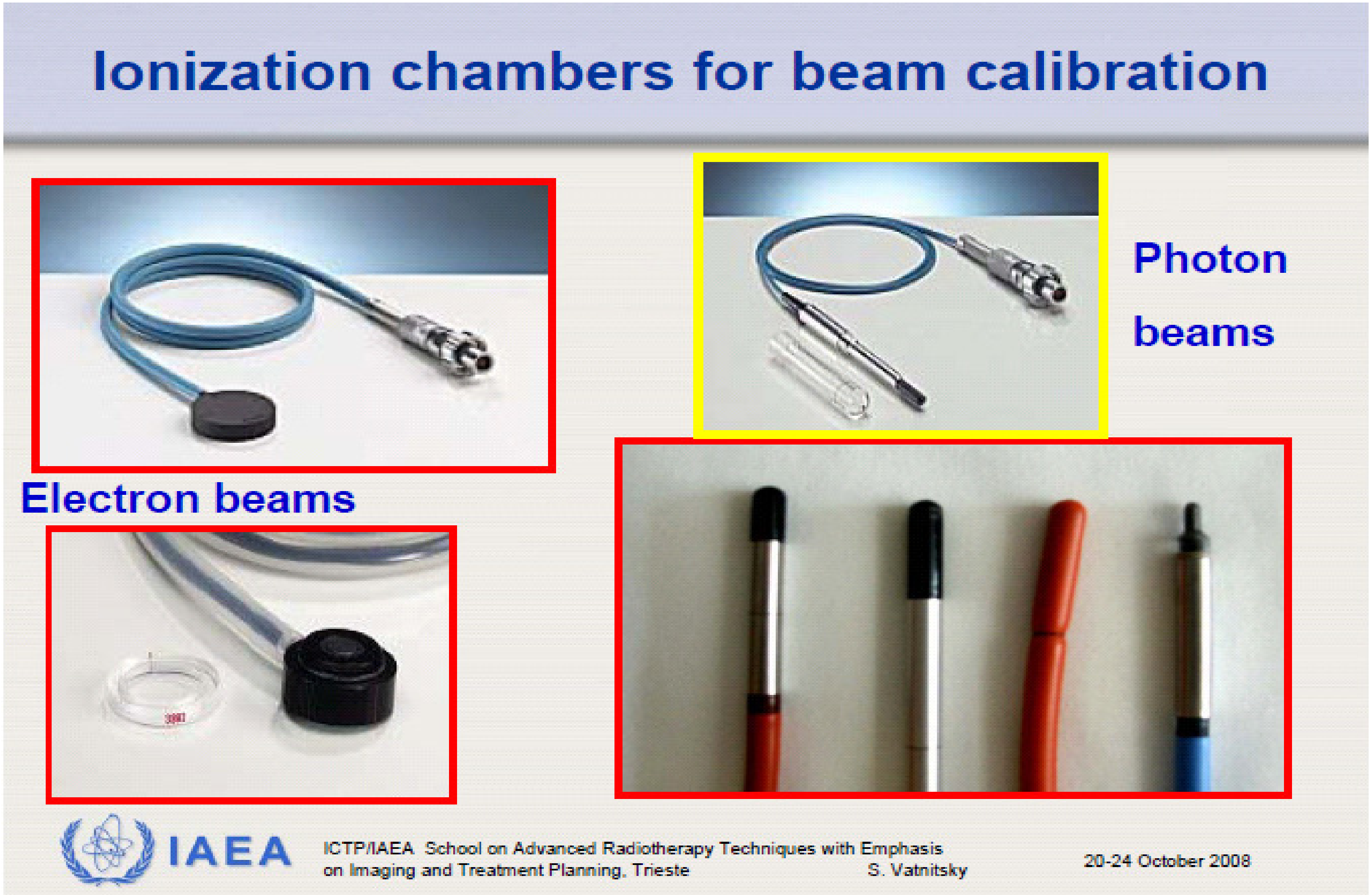
Measurement points for dose calculation verification



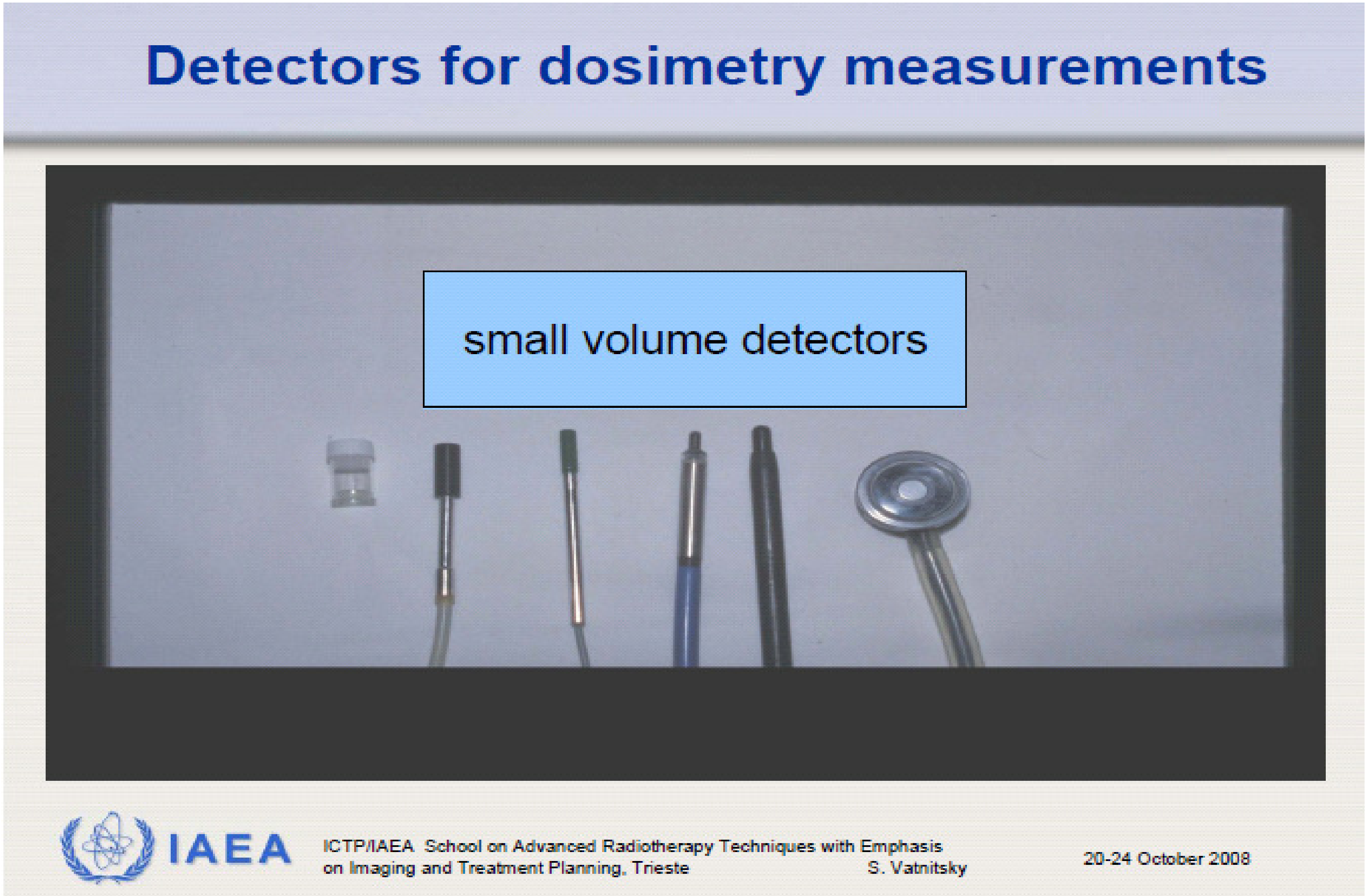
End-to-end testing



Ionization chambers



Small fields and high dose gradients

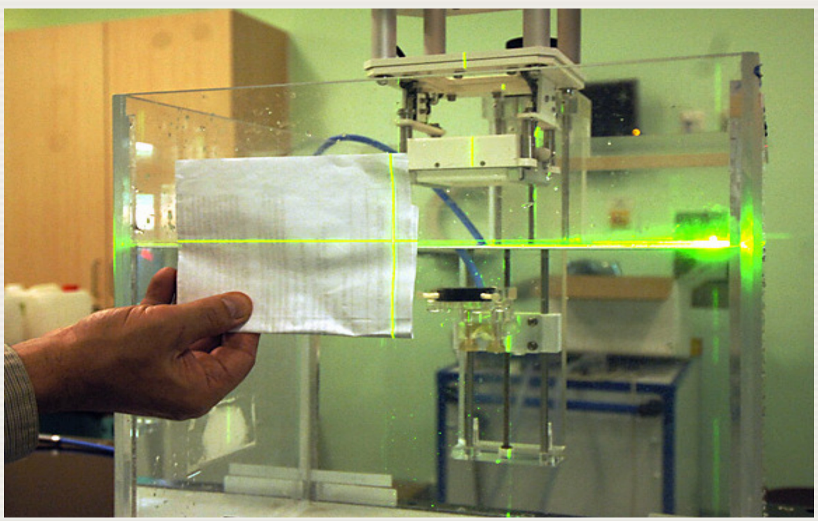


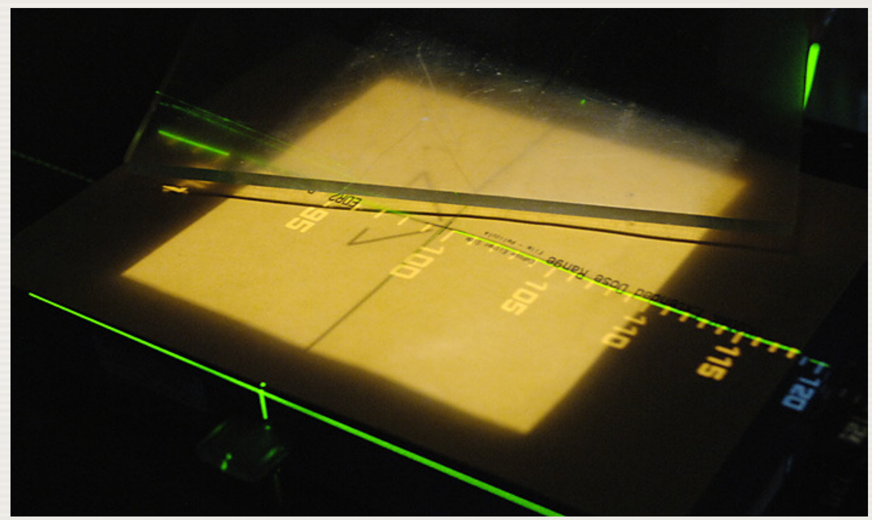
12.3.4 QA program for linear accelerators

- Typical quality assurance procedures (quality control tests) for a linac with frequencies and action levels are given in the following tables
- They are structured according daily, weekly, monthly, and annually tests

Daily Tests

Procedure or item to be tested	Action level
Lasers	2 mm
Distance indicator	2 mm





Daily Tests

Procedure or item to be tested	Action level
Audiovisual monitor	functional

12.3 QUALITY ASSURANCE PROGRAMME FOR EQUIPMENT

12.3.4 QA program for linear accelerators

Daily Tests

Procedure or item to be tested	Action level
X ray output constancy	3%
Electron output constancy	3%

Daily output checks and verification of flatness and symmetry can be done using different multi-detector devices.

Daily Tests

Procedure or item to be tested
X ray output constancy
Electron output constancy

Monthly Tests

Procedure or item to be tested	Action level
X ray output constancy	2%
Electron output constancy	2%
Backup monitor constancy	2%
X ray central axis dosimetry parameter constancy (PDD, TAR, TPR)	2%
Electron central axis dosimetry parameter constancy (PDD)	2 mm at thera-peutic depth
X ray beam flatness constancy	2%

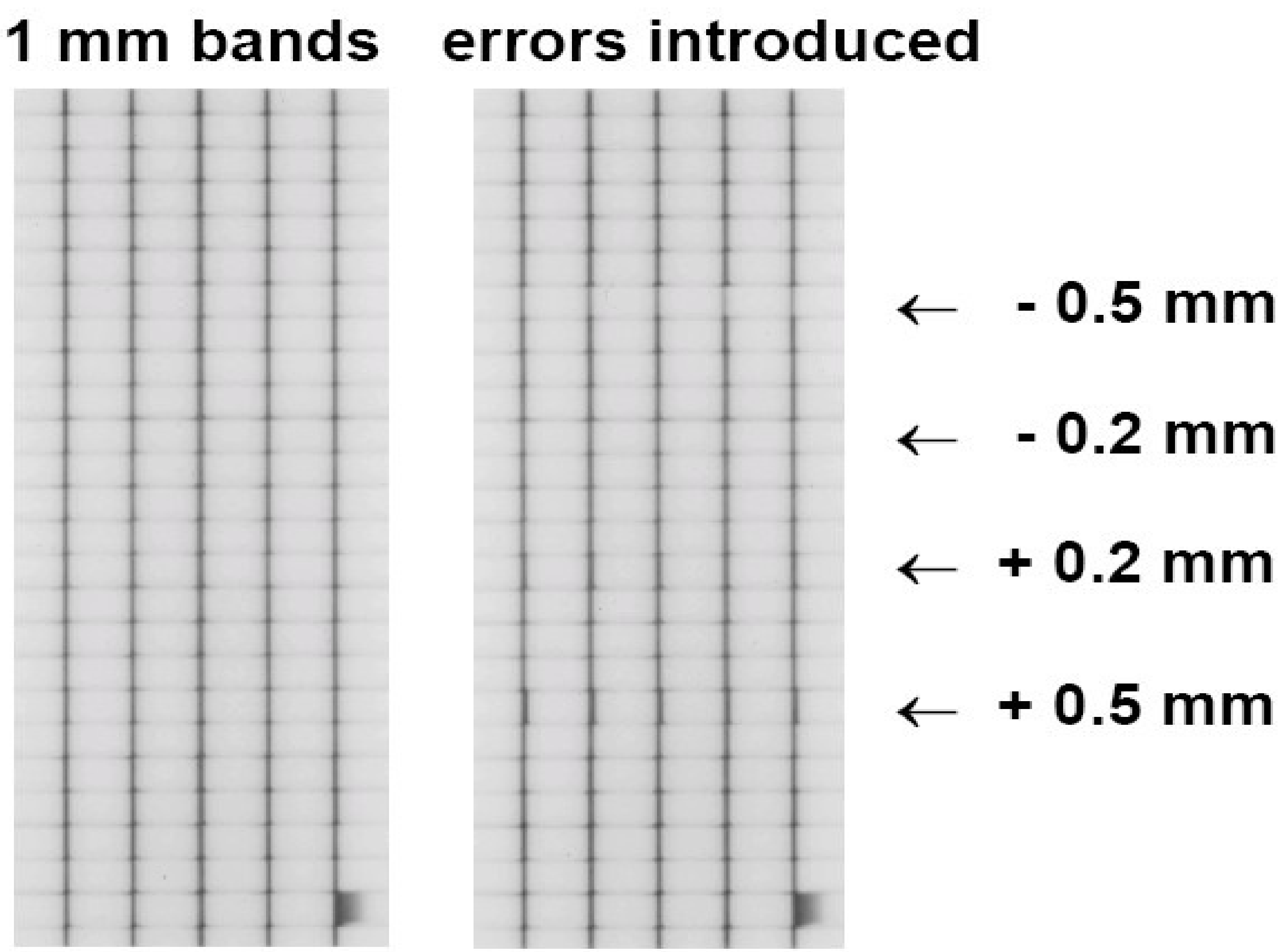
Annually Tests

Procedure or item to be tested	Action level
Wedge transmission factor constancy	2%
Monitor chamber linearity	1%
X ray output constancy with the gantry angle	2%
Electron output constancy with the gantry angle	2%
Off-axis factor constancy with the gantry angle	2%
Arc mode	manufacturer's specifications

Annually Tests (continued)

Procedure or item to be tested	Action level
Safety interlocks	functional
Collimator rotation isocenter	2 mm diameter
Gantry rotation isocenter	2 mm diameter
Table rotation isocenter	2 mm diameter
Coincidence of collimator, gantry and table axes with the isocenter	2 mm diameter
Coincidence of the radiation and mechanical isocenter	2 mm diameter

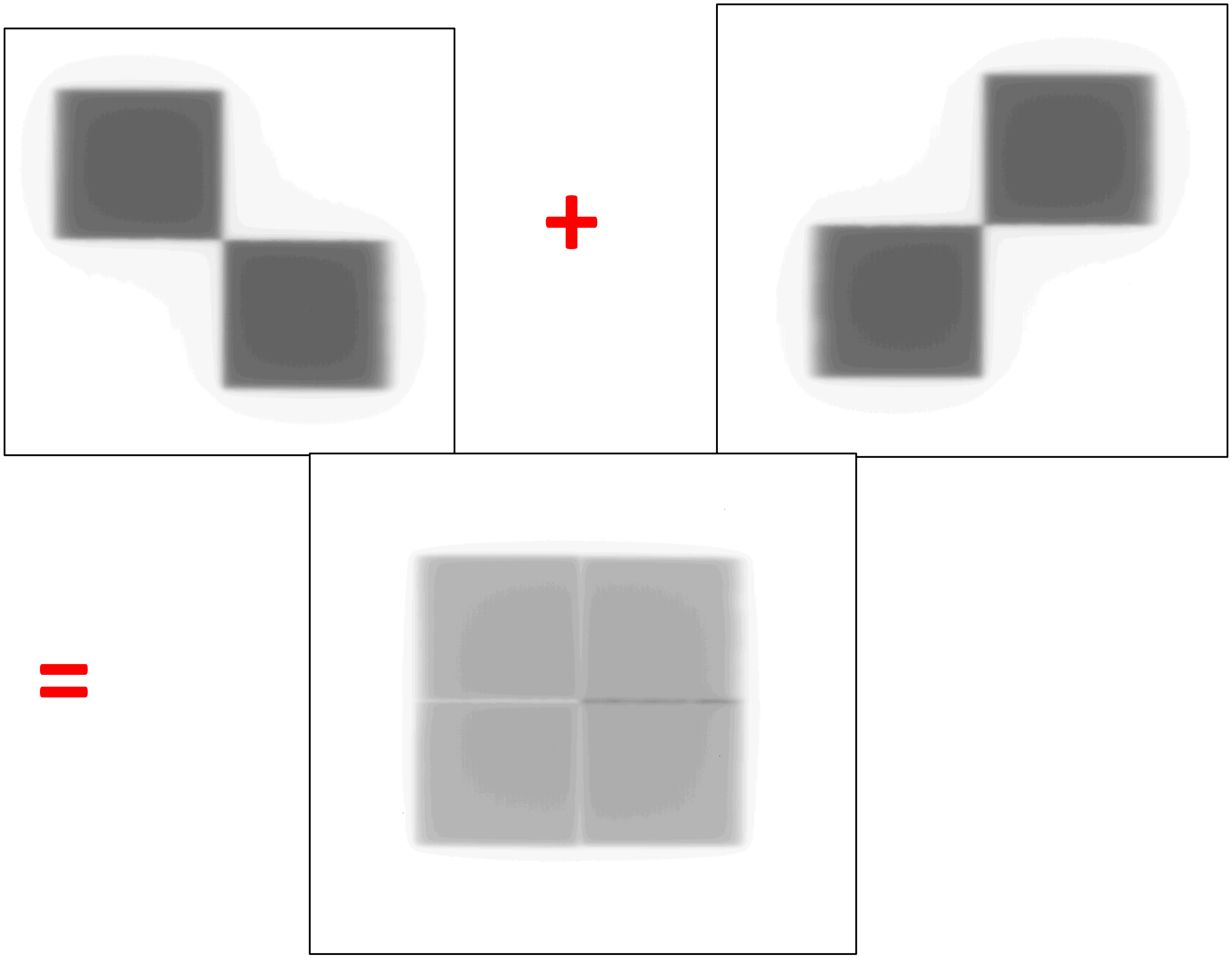
Machine-specific IMRT QA



Picket fence
Relative position

LoSasso *et al*. 2003

Machine-specific IMRT QA



Prevention of accidents in radiotherapy: different aspects

Implementation of a comprehensive quality assurance programme of:

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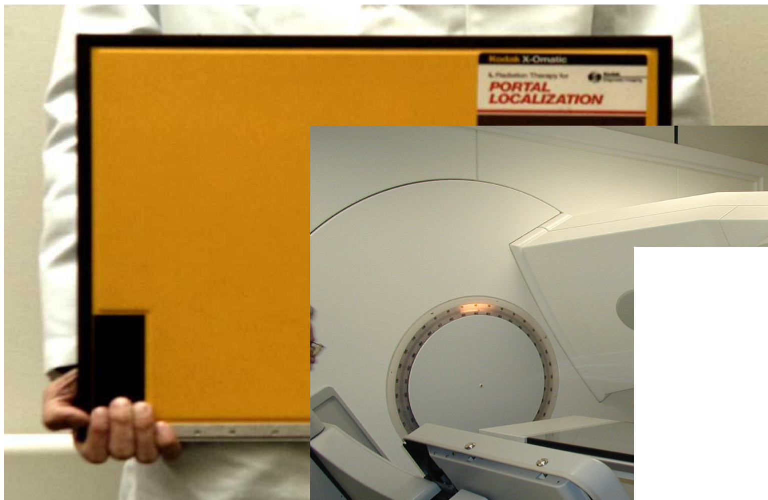
- all steps in the actual patient treatment
- all procedures used by the personnel involved including teaching and training

Treatment verification: imaging/dosimetry

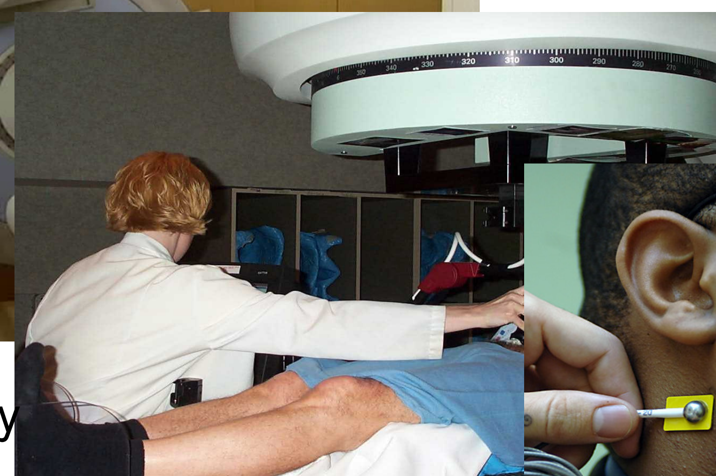


Port films

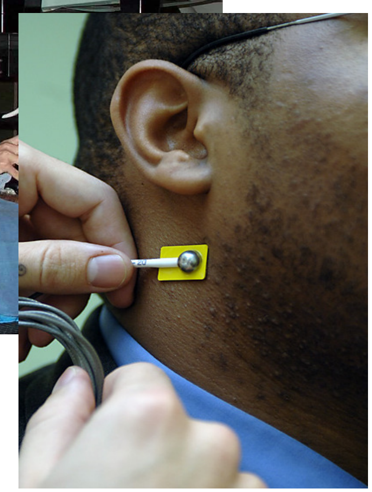
Electronic portal imaging devices (EPIDs)

Planar kilovoltage (kV) imaging

Cone-beam CT (CBCT)



Other image-guided radiation therapy (IGRT) techniques

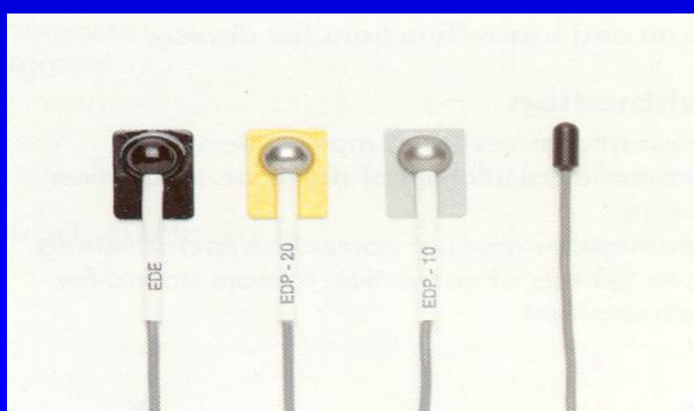


In vivo dosimetry

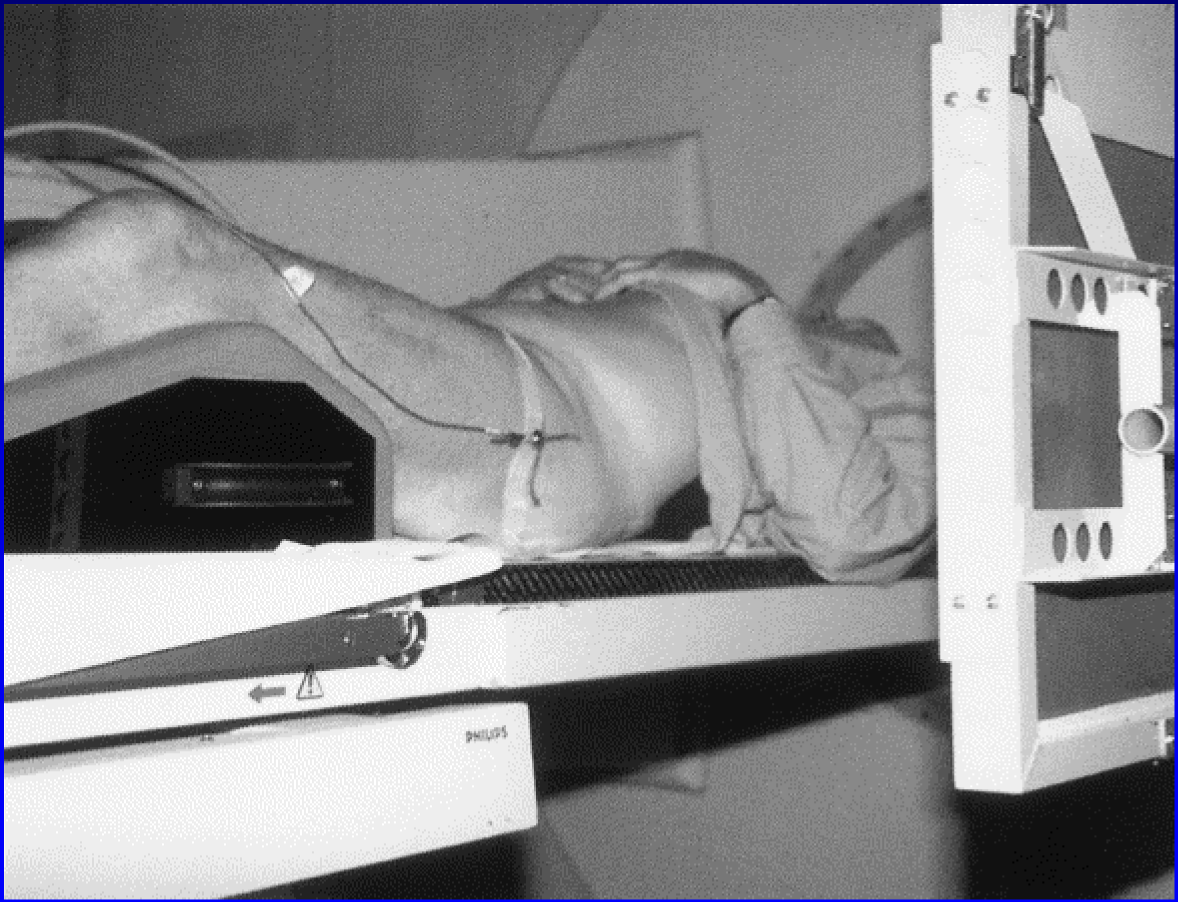
In vivo dosimetry using TLDs

In vivo dose measurement using TLD with a 2 mm stainless steel buildup cap (detail) for pelvis (left) and head-and-neck (right) sites

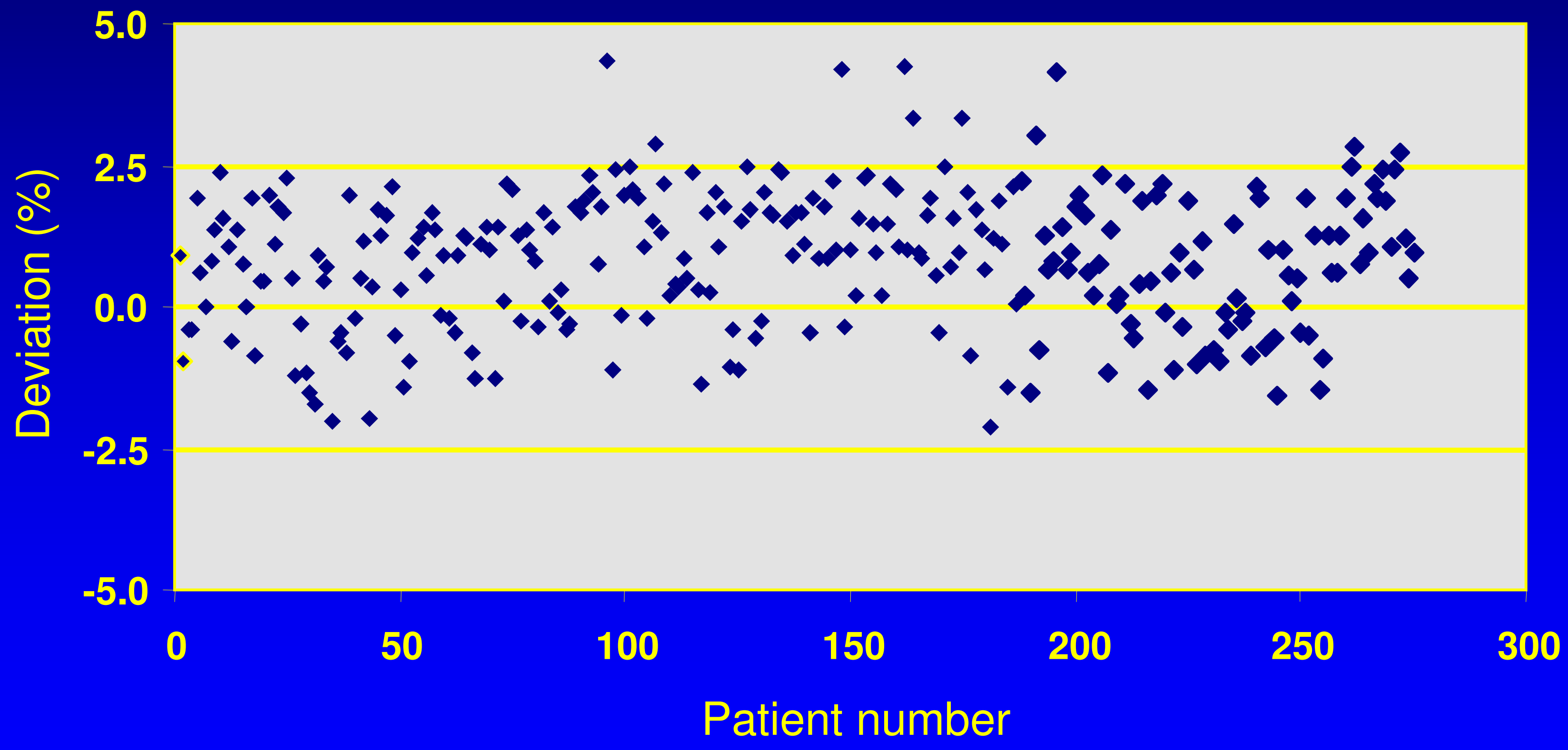
In vivo dosimetry using diodes



Prostate treatment showing patient with a diode and electronic portal imaging device



In vivo dosimetry results 3D-CRT prostate treatments



Type of errors that can be detected by *in vivo* dosimetry

- plan transfer error
- wrong SSD
- missing wedge
- wrong wedge orientation
- wrong fractionation of the total dose
- accidental plan modification
- limitations of the dose calculation algorithm
- error in entering treatment data manually into the record- and-verify system (rather than by electronic transfer)
- change in anatomy of the patient between treatment planning and dose delivery

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Portal imaging

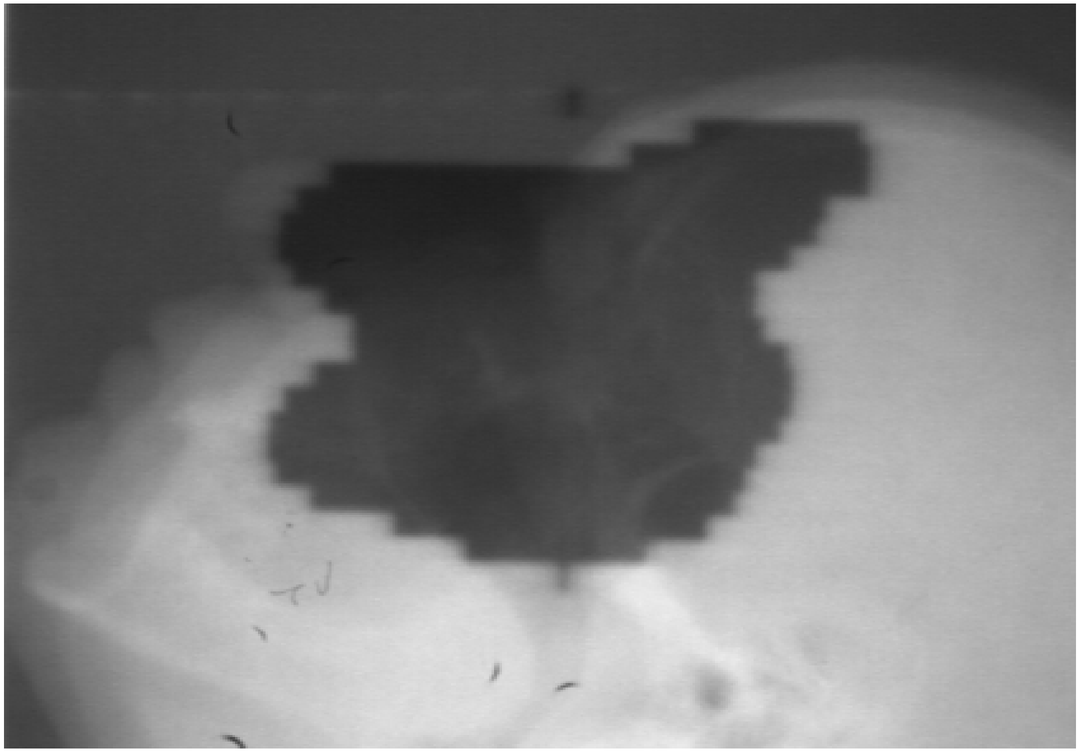
- To verify the field placement, characterized by the isocenter or another reference point, relative to anatomical structures of the patient, during the actual treatment

- To verify that the beam aperture (blocks or MLC) has been properly produced and registered

Port film device

IAEA

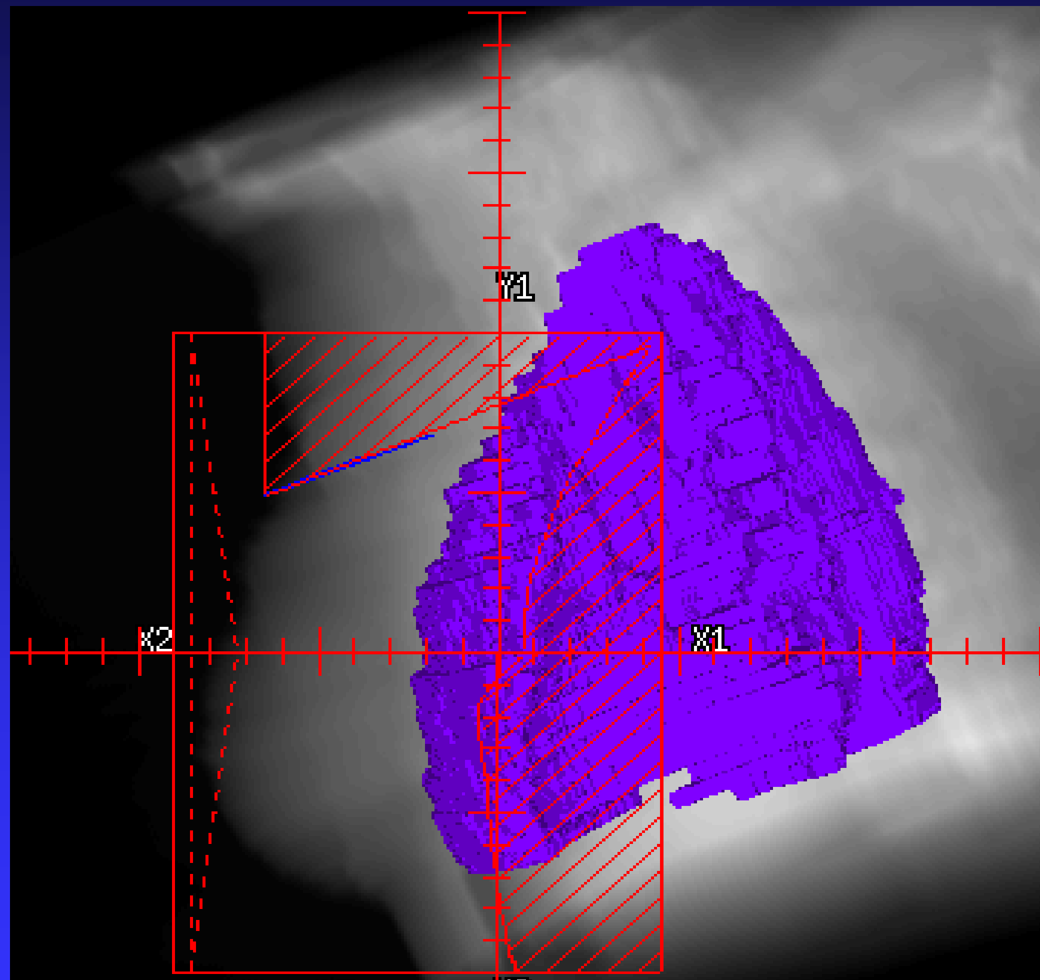
Example of portal imaging: port film



- Port film for a lateral irregular MLC field used in a treatment of the maxillary sinus

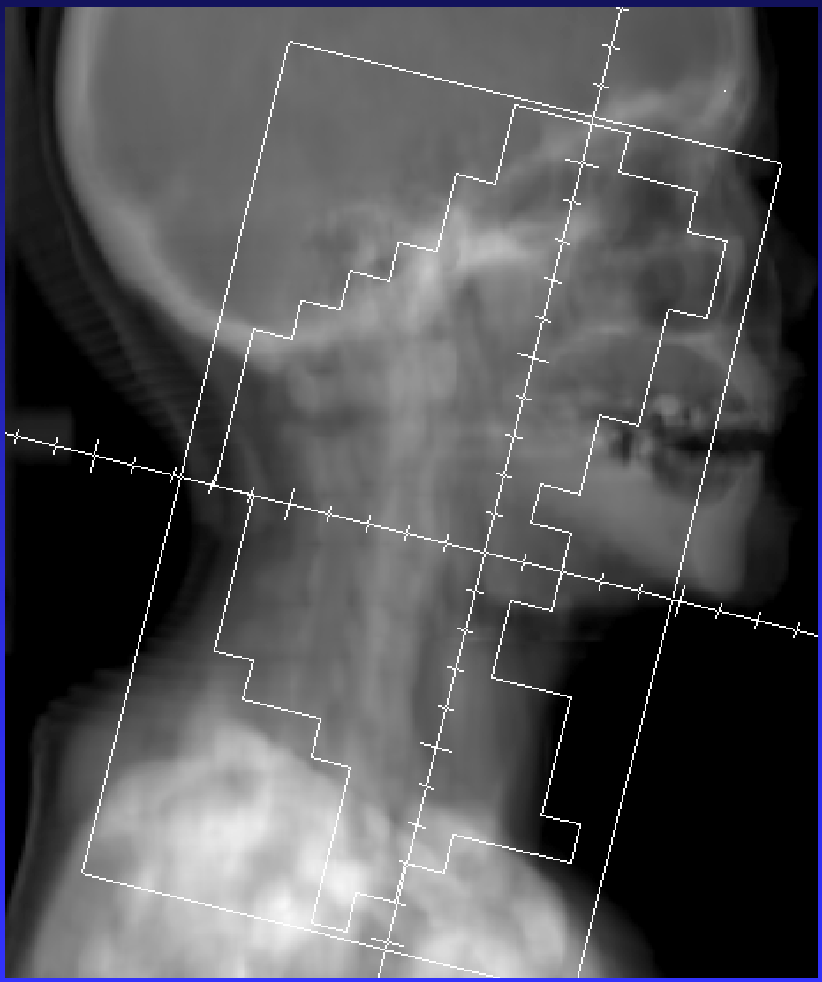
- This method allows to visualize both the treatment field and the surrounding anatomy

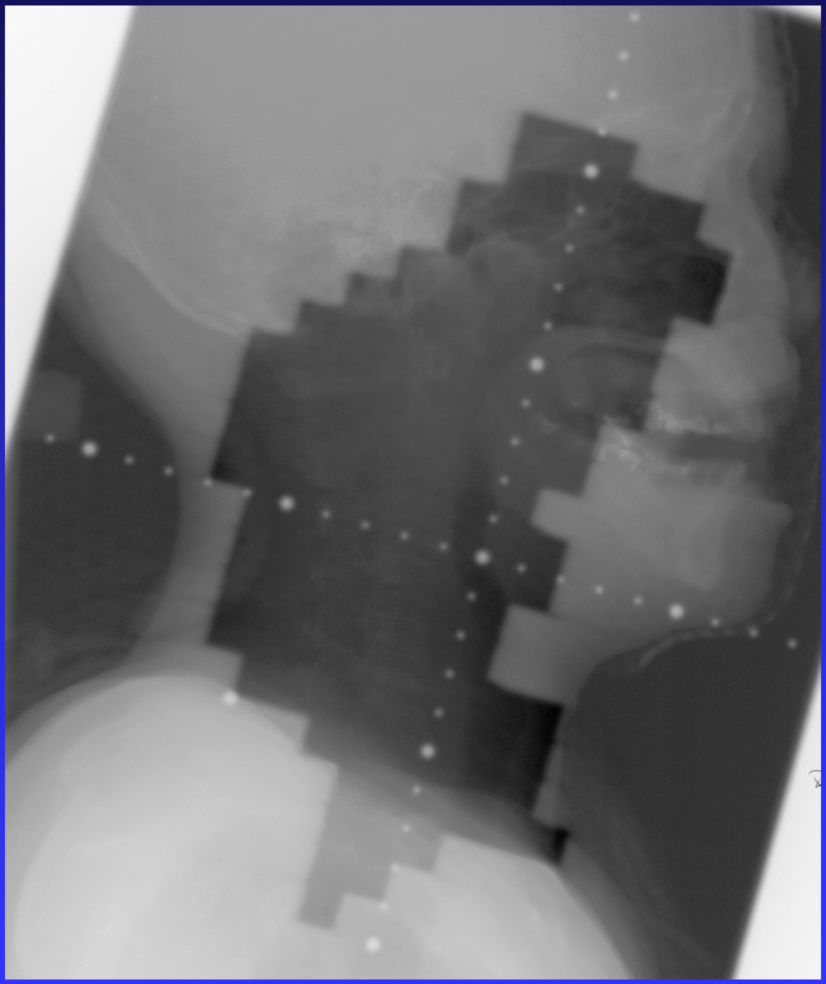
Patient setup verification



Digitally Reconstructed Radiograph (DRR) from the treatment planning system is compared with portal image

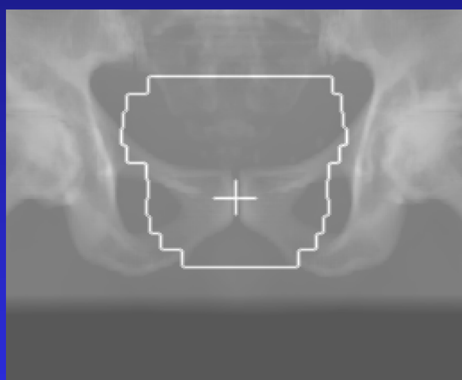
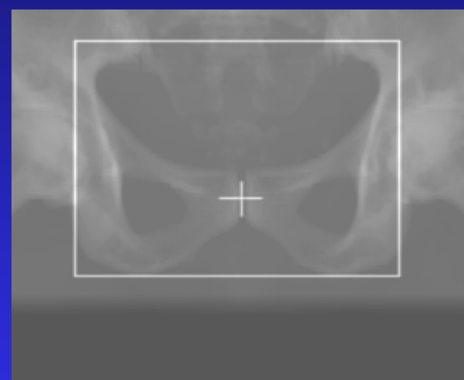
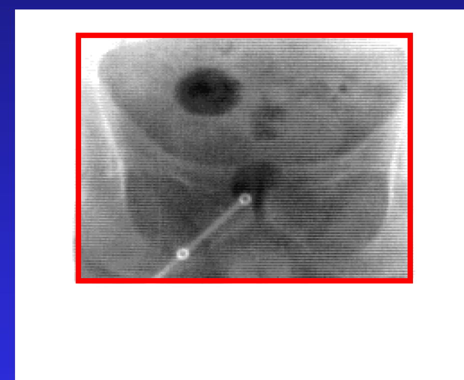
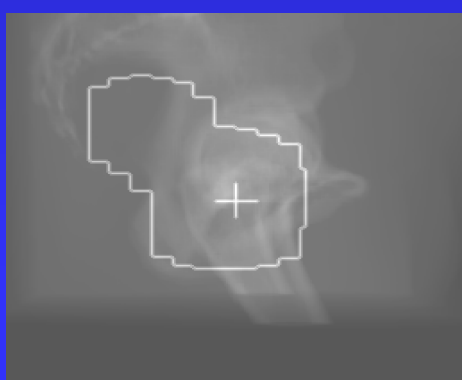
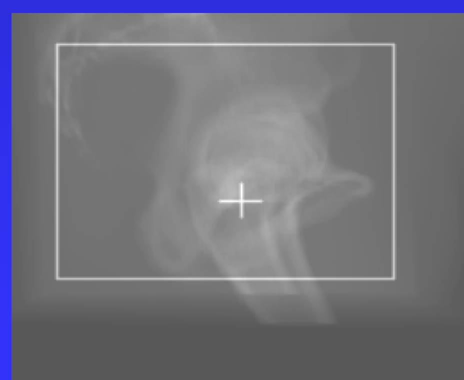
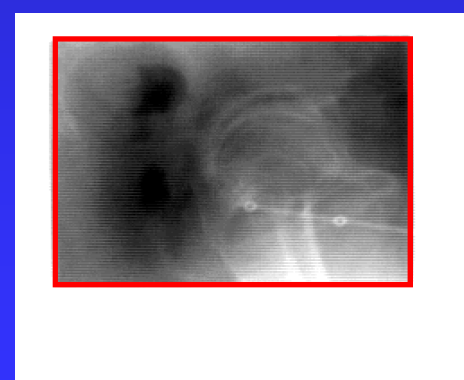
Position film verification and beam placement





Set-up verification fields

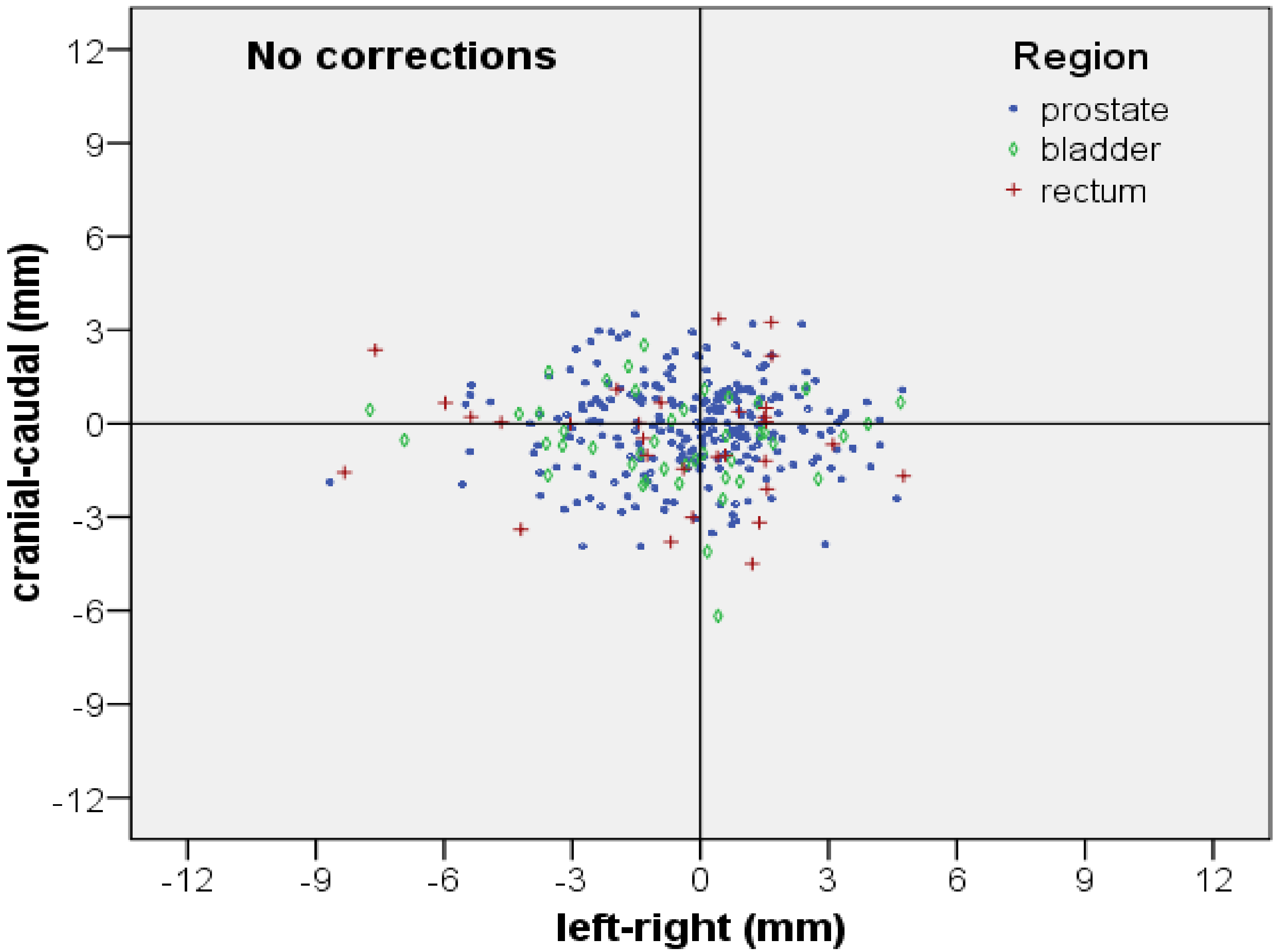
DRR treatment fields | DRR ‘EPID’ fields | EPID images

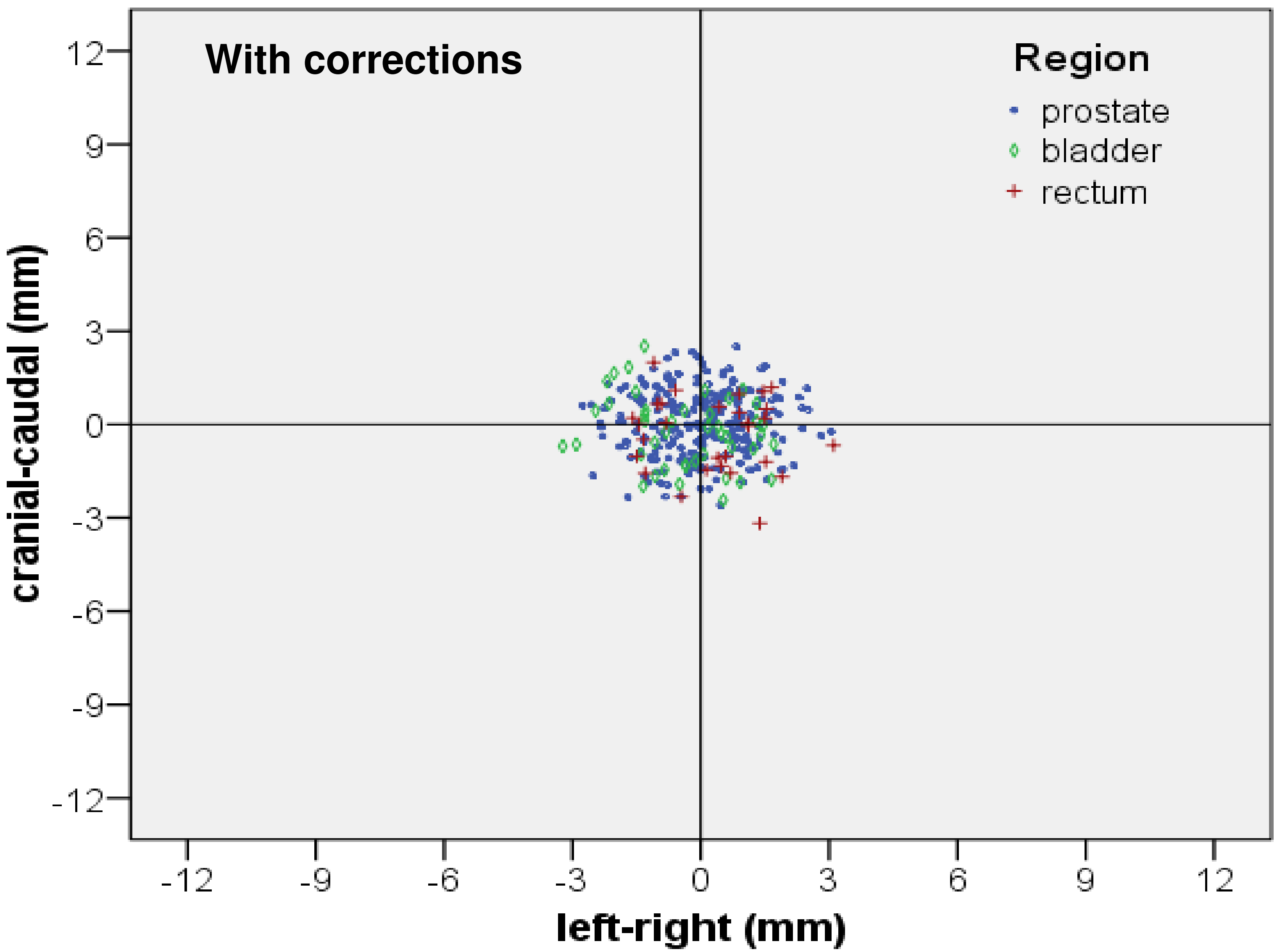
Amorphous silicon (a-Si) type of EPID

Electronic portal imaging

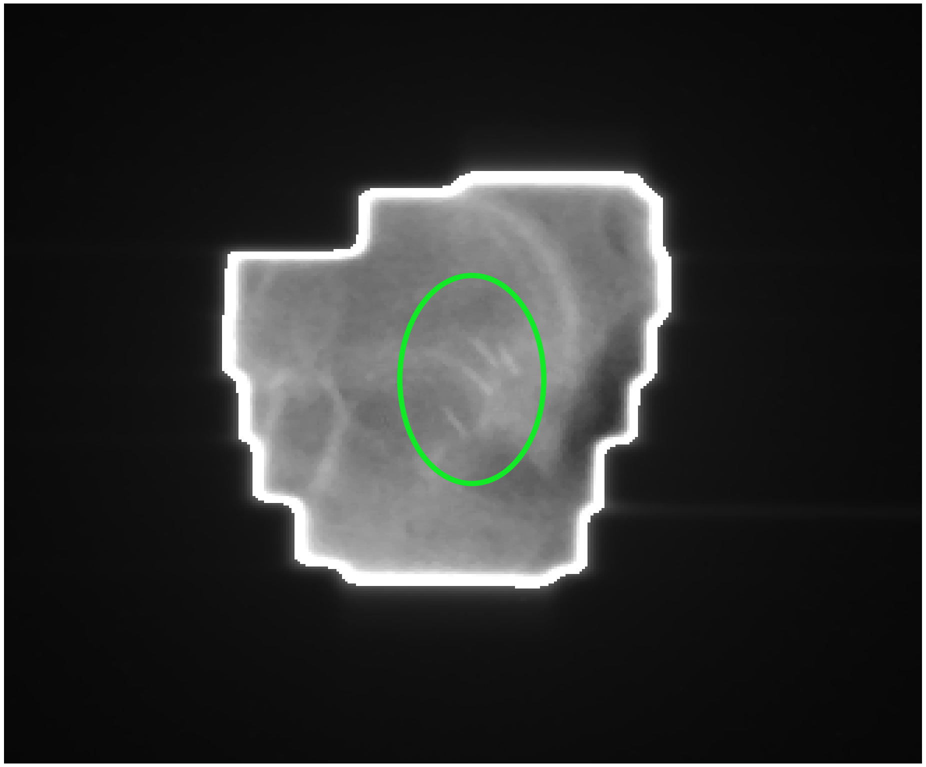
EPID setup verification at NKI-AVL



EPID setup verification at NKI-AVL

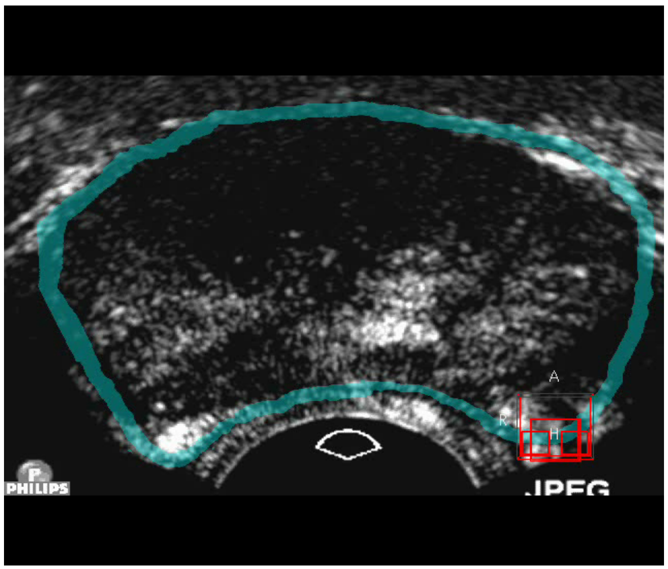


Prostate position verification using gold markers

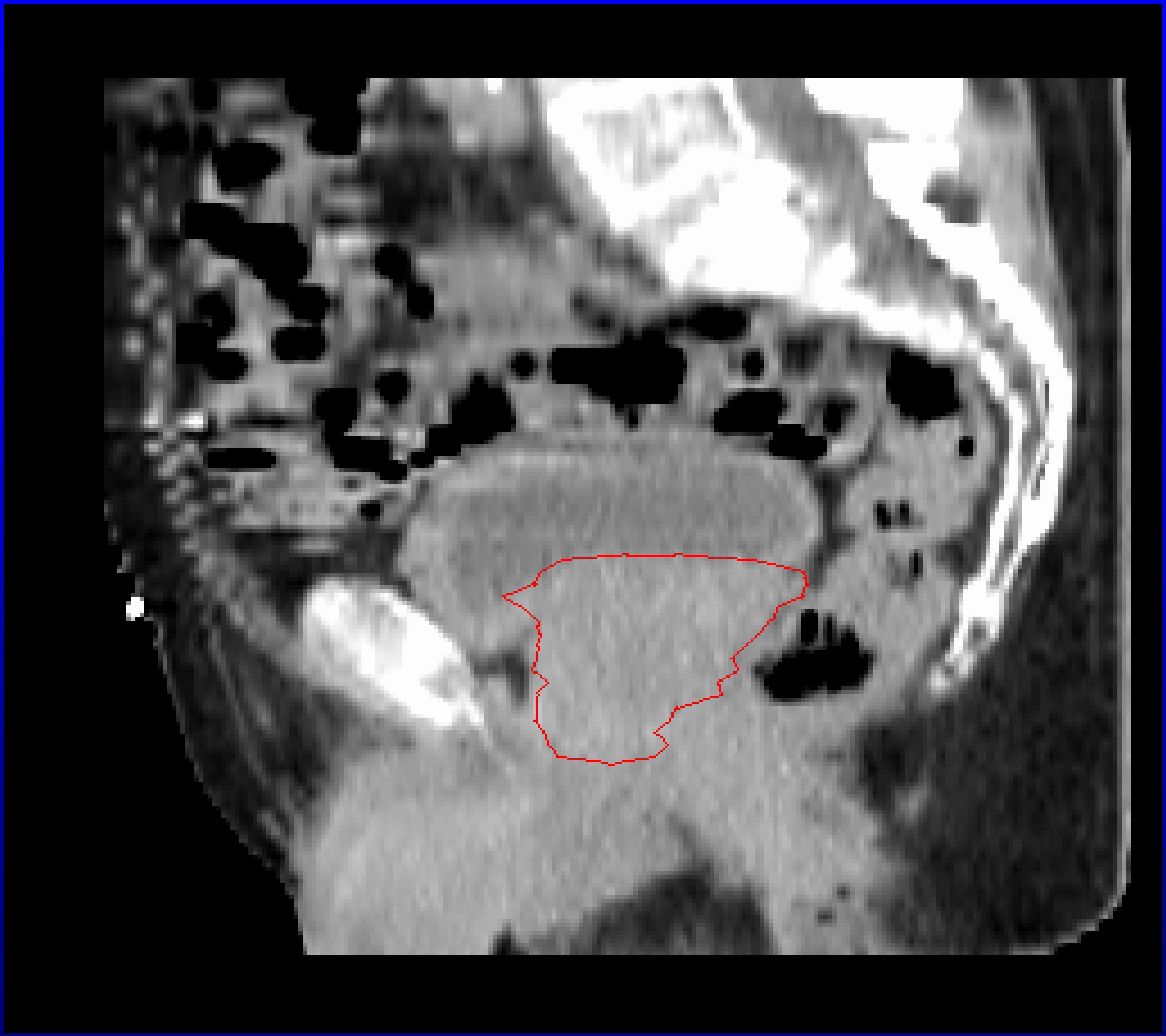


Bony anatomy vs marker position

Ultra-sound system for prostate setup verification just before treatment



Organ motion



- Compensate by irradiating a larger volume

  or

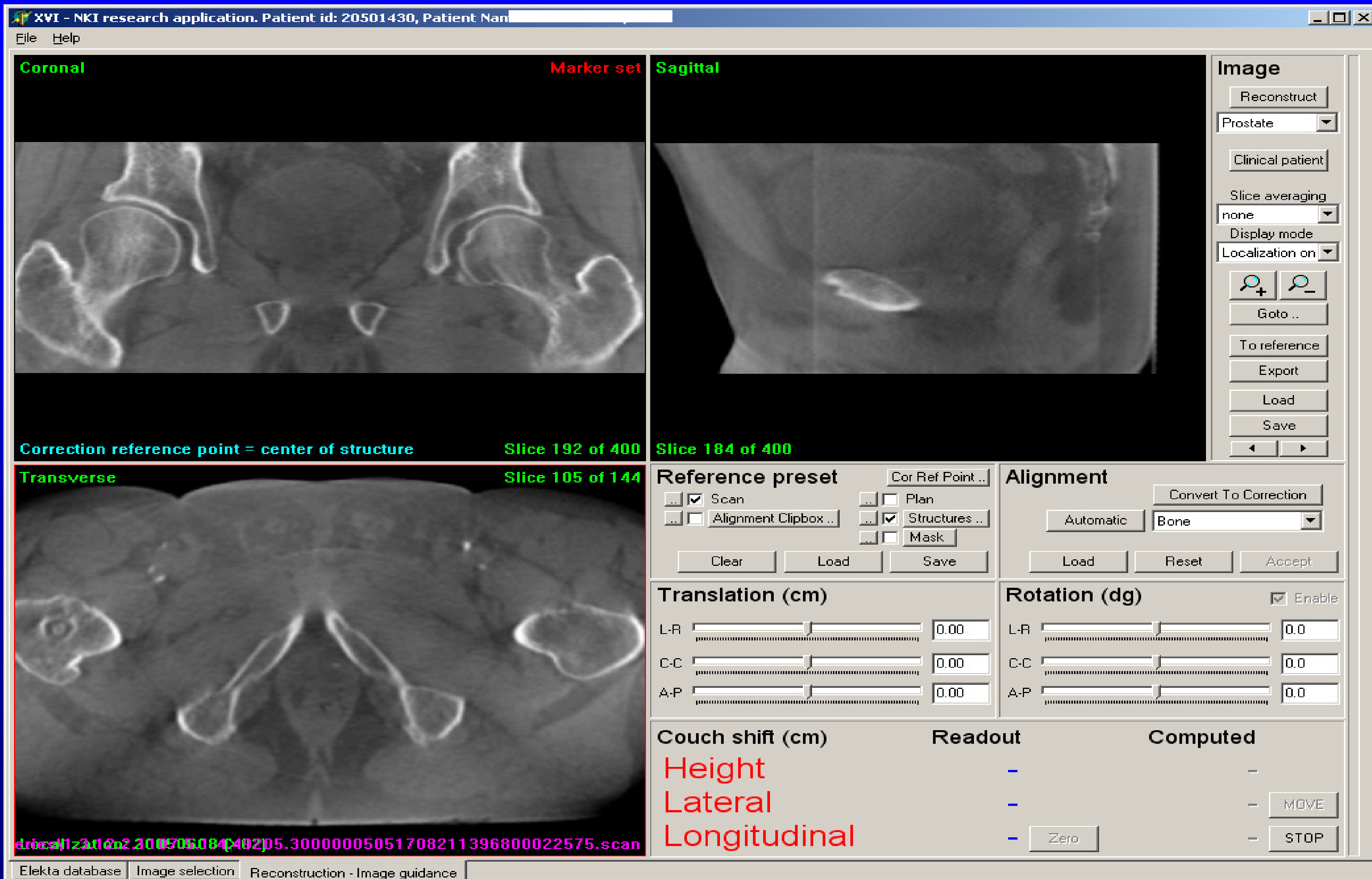
- Image-Guided RadioTherapy (IGRT)

kV cone-beam CT (CBCT) scanning

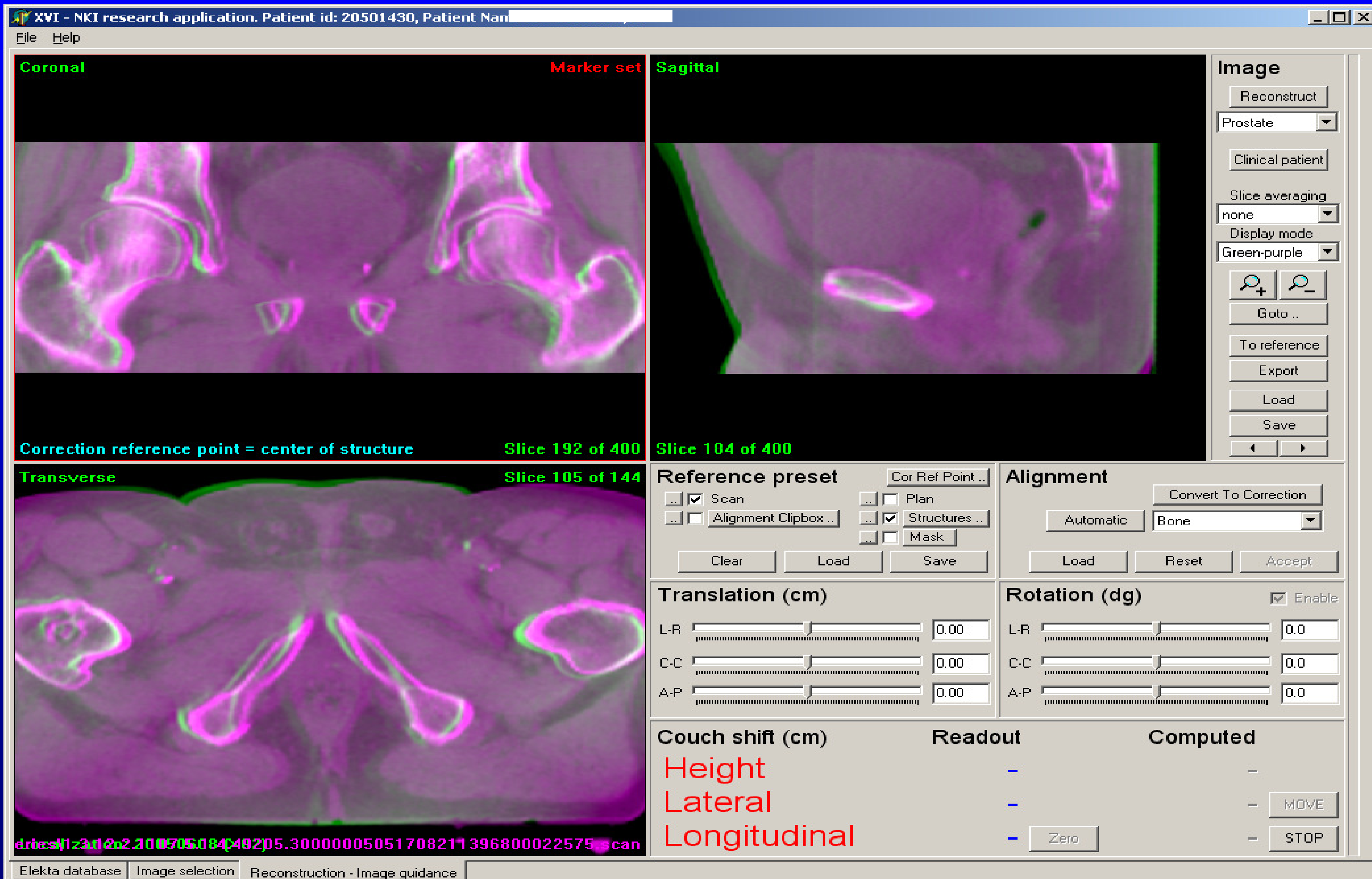
Varian OBI

Elekta Synergy XVI

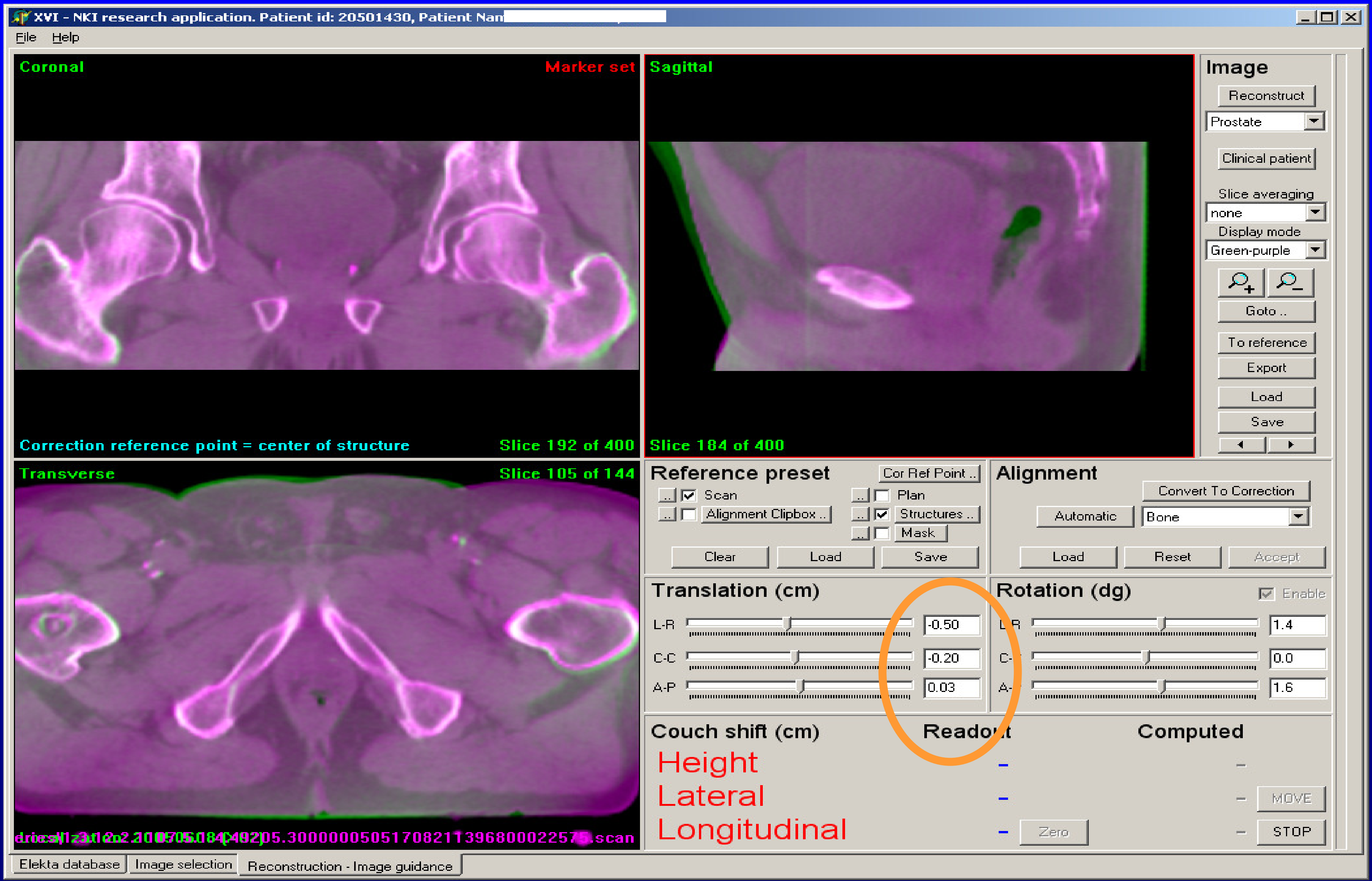
CBCT prostate cancer treatment



CBCT prostate cancer treatment

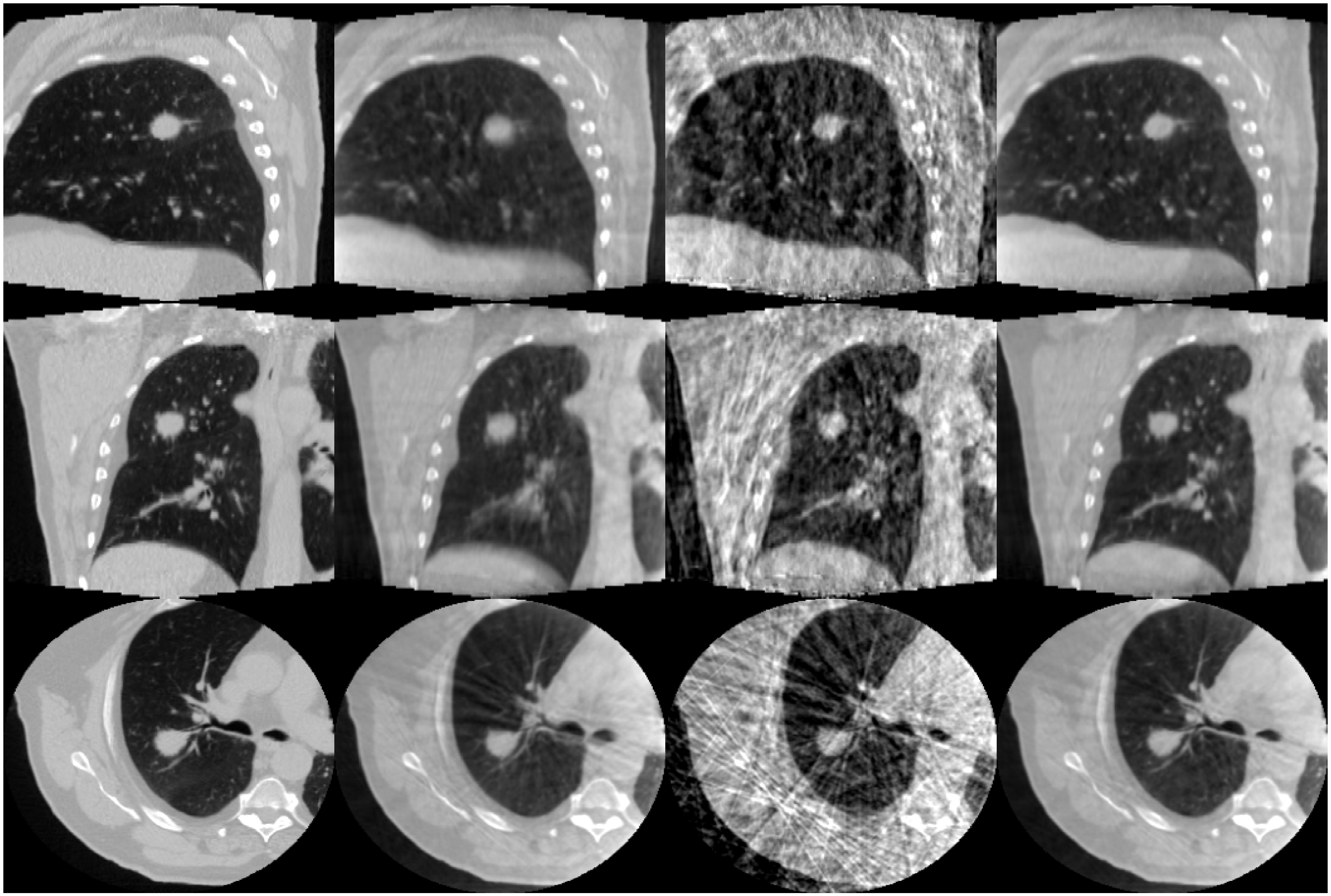


CBCT prostate cancer treatment

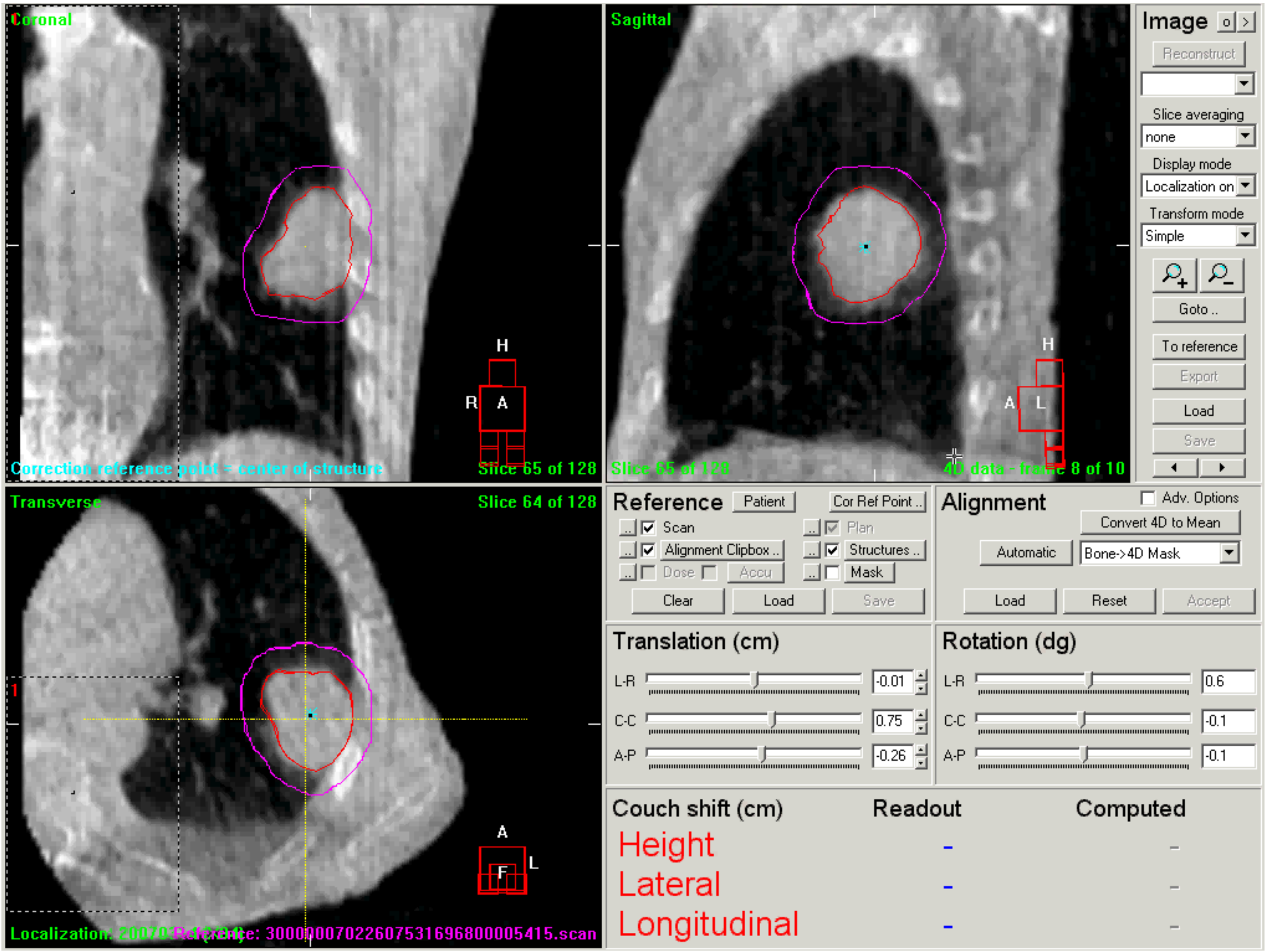


Motion compensated (MC) 4D-CBCT reconstruction

Planning 4D-CT 3D-CBCT 4D-CBCT MC 4D -CBCT

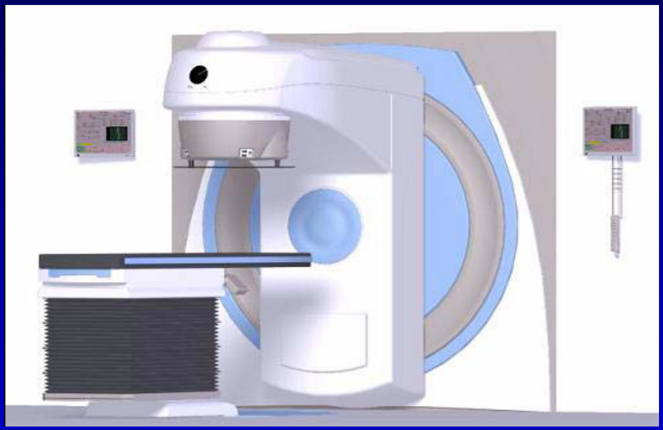


Tumour (soft tissue) match

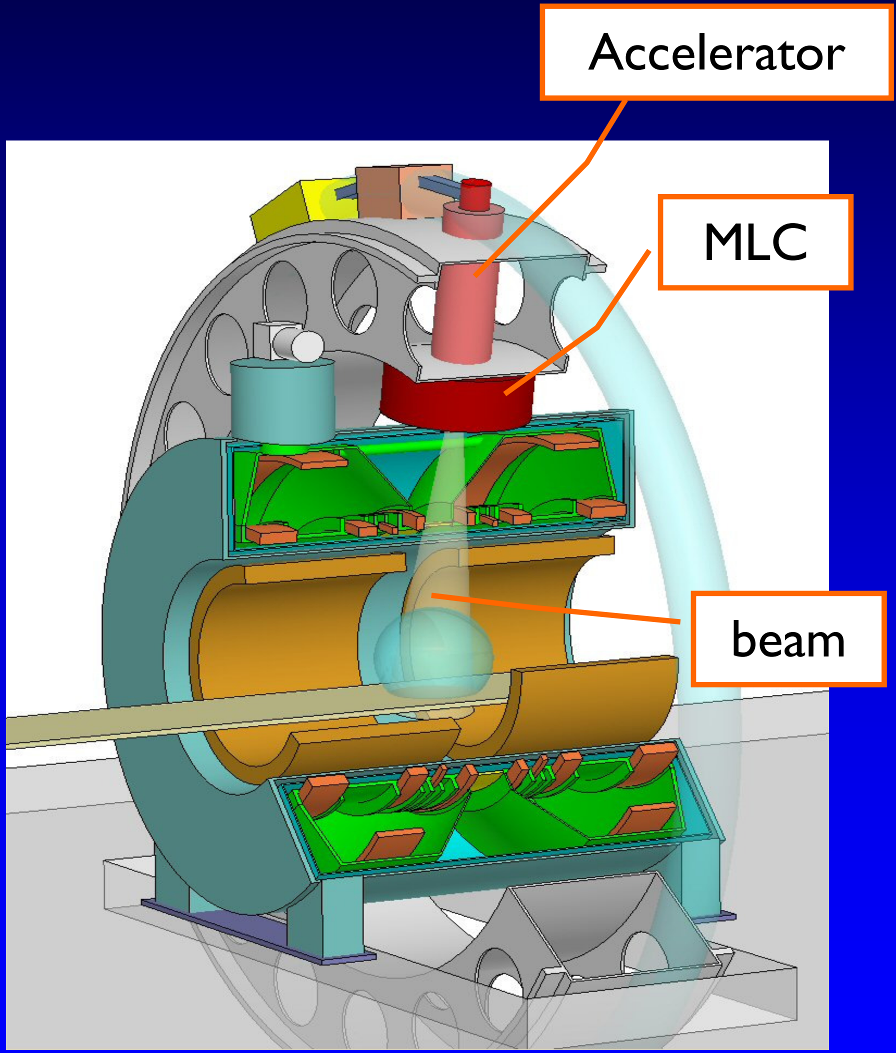


Integrating MRI functionality with external beam radiotherapy

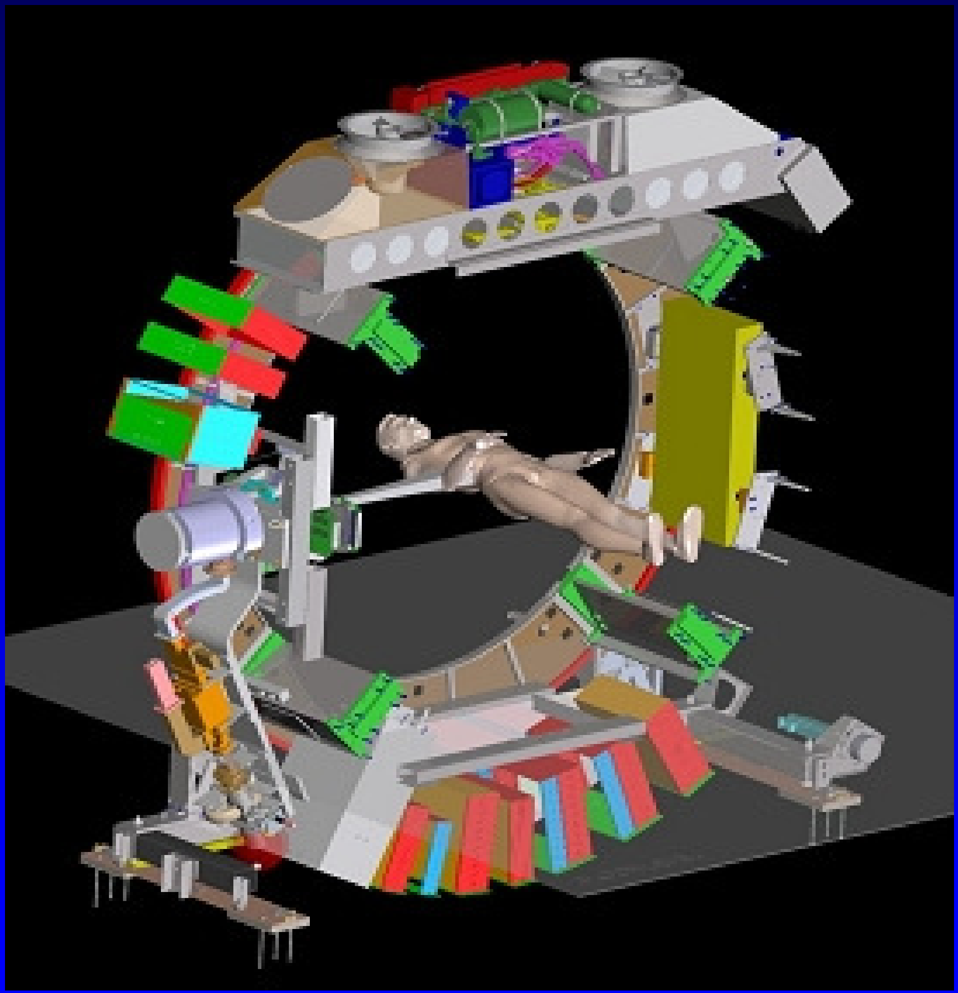
Accelerator



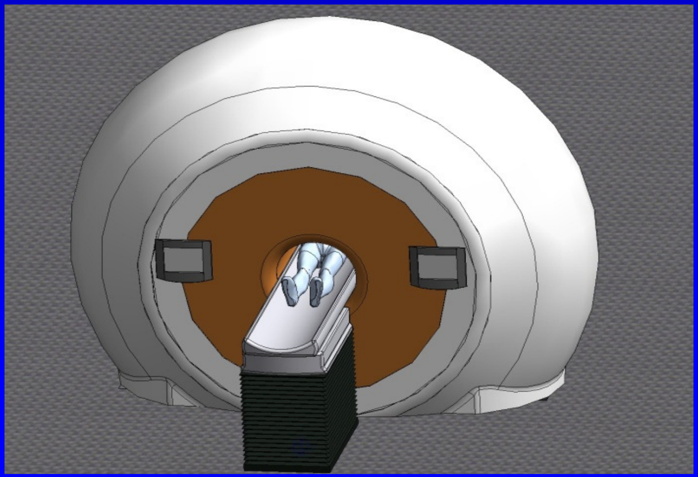
1.5 T MRI



Gantry design MRL: (MRI-Linac)



- Collaboration of UMCU Utrecht (The Netherlands) with Elekta and Philips
- System prototype: July 14, 2011
- Clinical system: “soon”



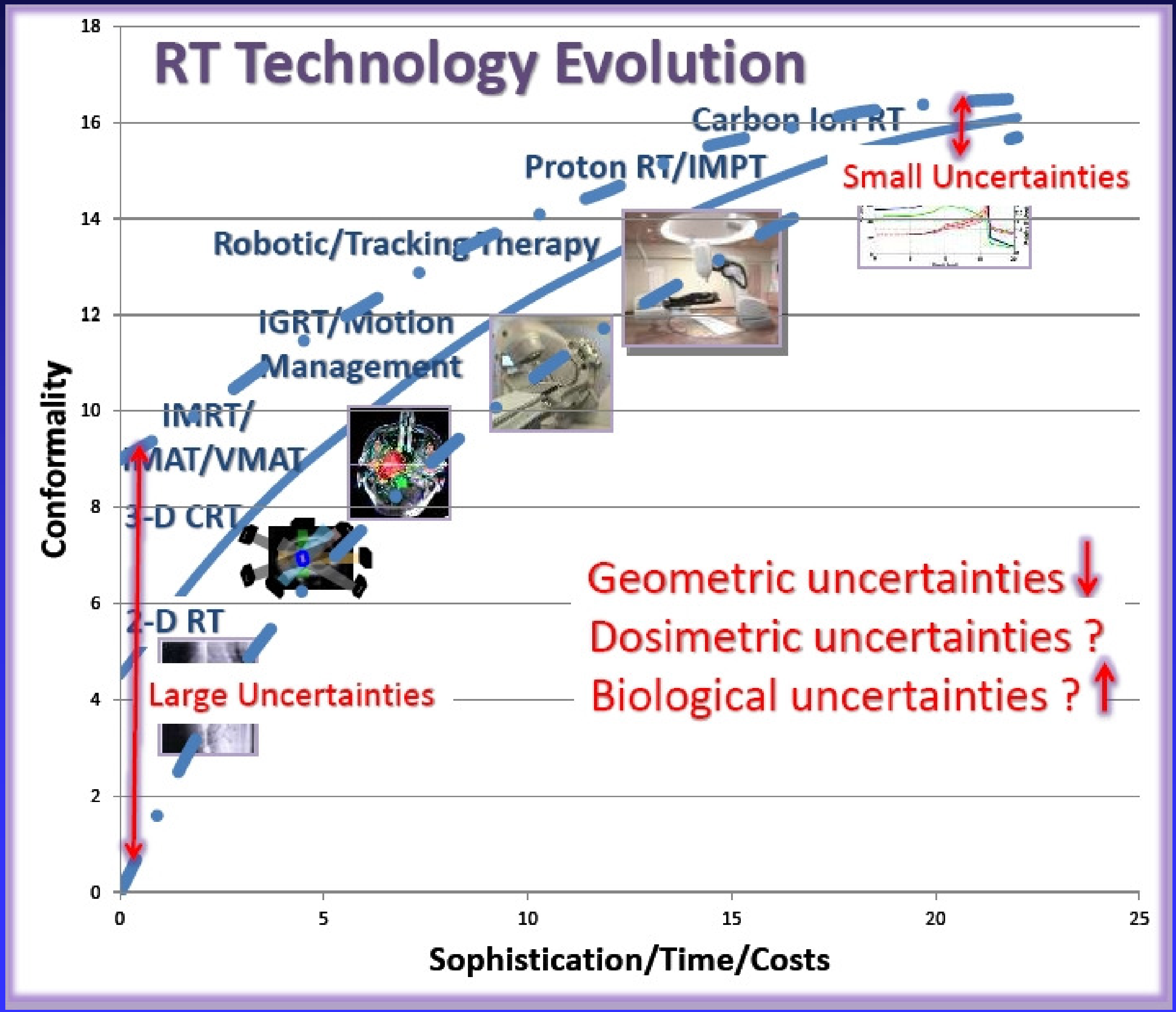
Prevention of accidents in radiotherapy: different aspects

Implementation of a comprehensive quality assurance programme of:

- all types of equipment used to plan and treat a patient
- all steps in the actual patient treatment
- all procedures used by the personnel involved including teaching and training

These personnel aspects (teaching and training) will be discussed on Friday in my lecture on “Prospective risk management” and during the group exercises

What's next in radiotherapy ?



Future developments