INDUSTRIAL DESIGN

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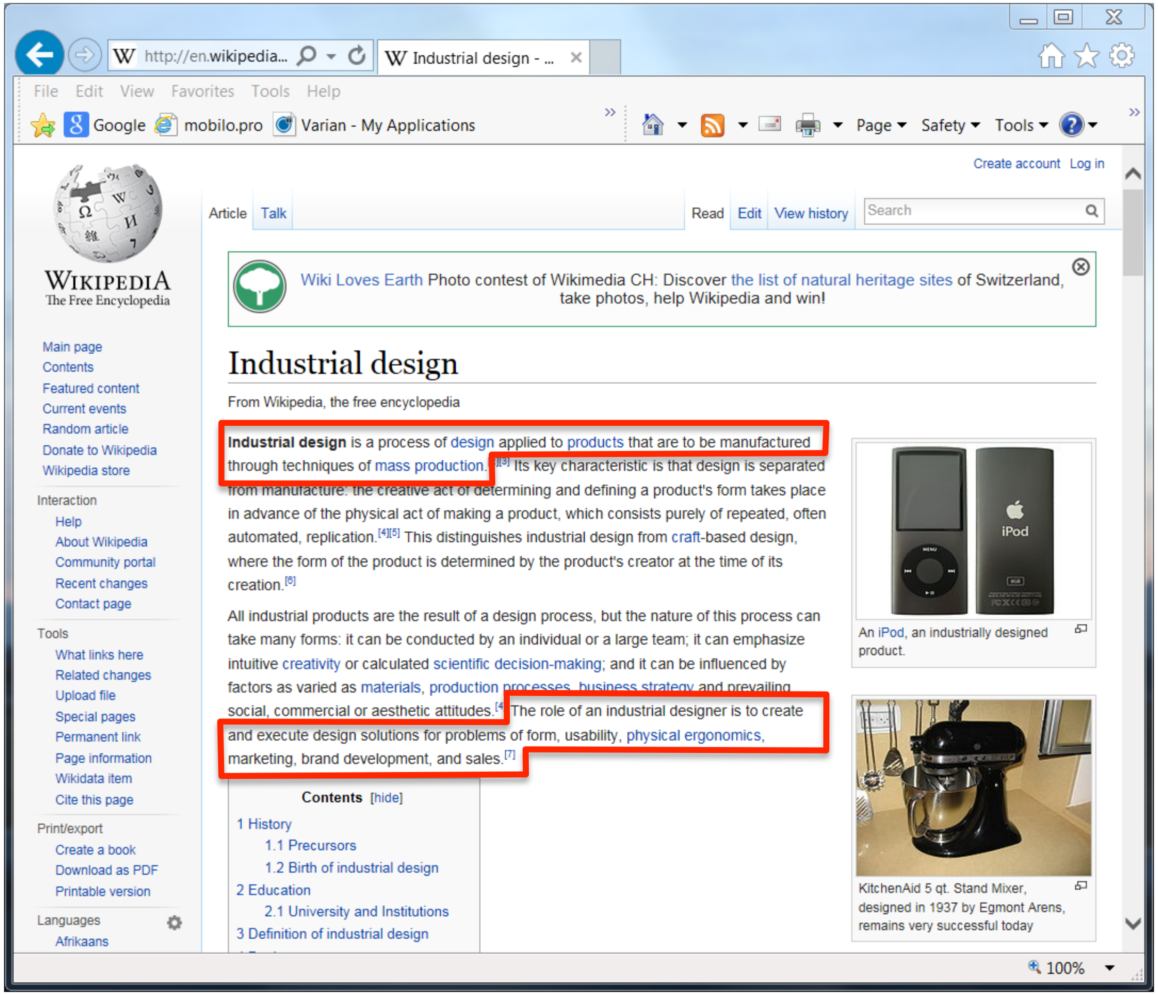
Varian Medical Systems International AG

CERN Accelerator School, May 2015

Industrial Design



New York Times Article 2010

The New York Times

HEALTH | THE RADIATION BOOM

Radiation Offers New Cures, and Ways to Do Harm

By **WALT BOGDANICH** JAN. 23, 2010

As Scott Jerome-Parks lay dying, he clung to this wish: that his fatal radiation overdose — which left him deaf, struggling to see, unable to swallow, burned, with his teeth falling out, with ulcers in his mouth and throat, nauseated, in severe pain and finally unable to breathe — be studied and talked about publicly so that others might not have to live his nightmare.

Sensing death was near, Mr. Jerome-Parks summoned his family for a final Christmas. His friends sent two buckets of sand from the beach where they had played as children so he could touch it, feel it and remember better days.

Mr. Jerome-Parks died several weeks later in 2007. He was 43.

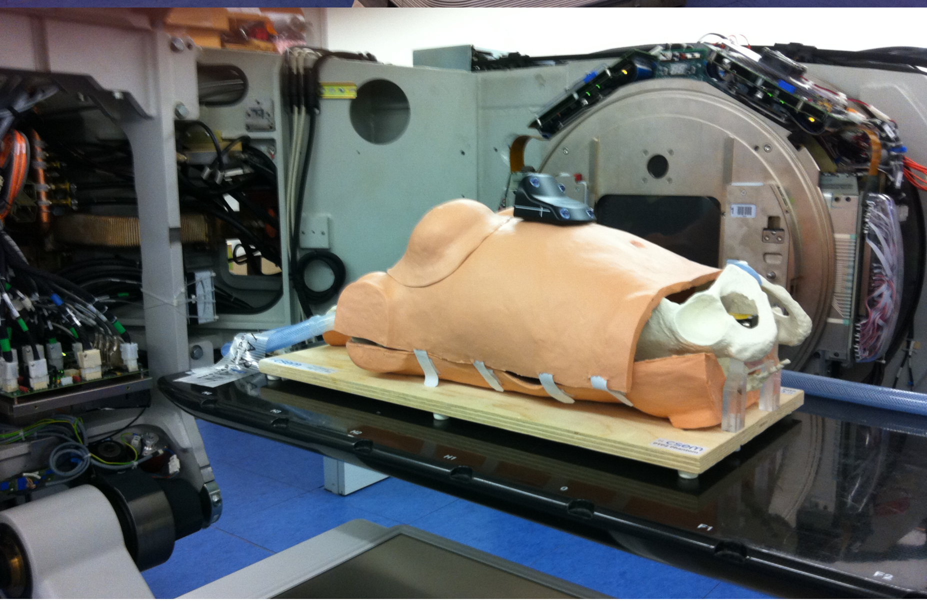
A New York City hospital treating him for tongue cancer had failed to detect a computer error that directed a linear accelerator to blast his brain stem and neck with errant beams of radiation. Not once, but on three consecutive days.

Soon after the accident, at St. Vincent's Hospital in Manhattan, state health officials cautioned hospitals to be extra careful with linear accelerators, machines that generate beams of high-energy radiation.

http://www.nytimes.com/2010/01/24/health/24radiation.html?pagewanted=1&_r=0

From Research to a Clinical Product

- There is a clear difference between a research project and a clinical product



From Research to a Clinical Product

- Before a product can be sold, must achieve market clearance
- Regulatory clearance, e.g. FDA 510(k), CE marking etc, has many complex requirements
- Safety is a fundamental component in attaining these clearances and underpins the entire design process

From Research to a Clinical Product

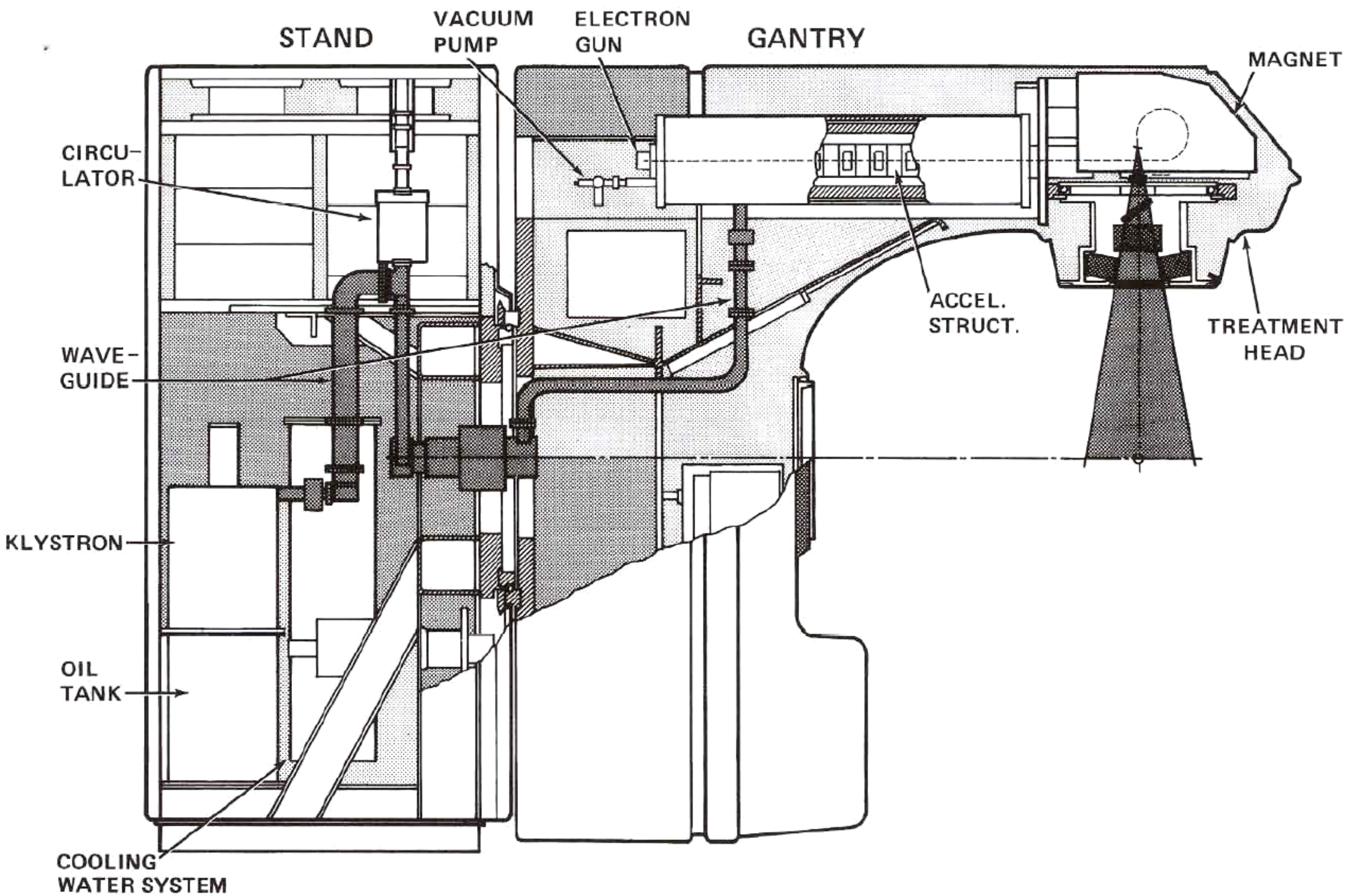
- New techniques and approaches to radiation therapy are constantly being researched and developed
- Before being realized in a clinical system, a safe, smooth, efficient implementation is needed
- In some cases, the market (or the users) is not ready for new techniques

Clinac – The Previous State of the Art

Varian High Energy Linac Fundamentals

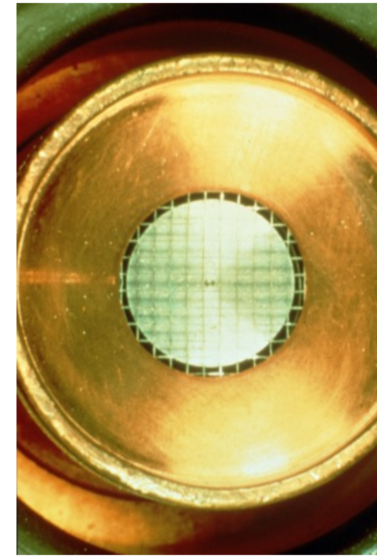
- Klystron driven
- Triode electron gun
- Standing wave guide
- 270°bending magnet
- 2 sets of independent collimators

Major Accelerator Components

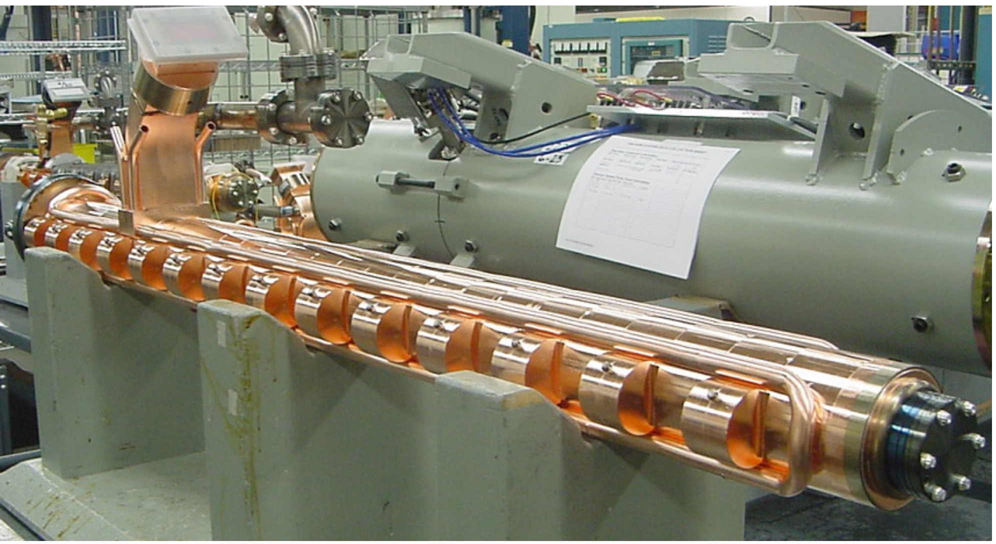


Triode Electron Gun

- Fastest beam-on and off.
- **Allows for fast "single" pulse control.**
- Fast control of electron emission (for IMRT, dynamic arc and gating)
- No dark current (using the grid)
- Filament & cathode remain hot for stable operation

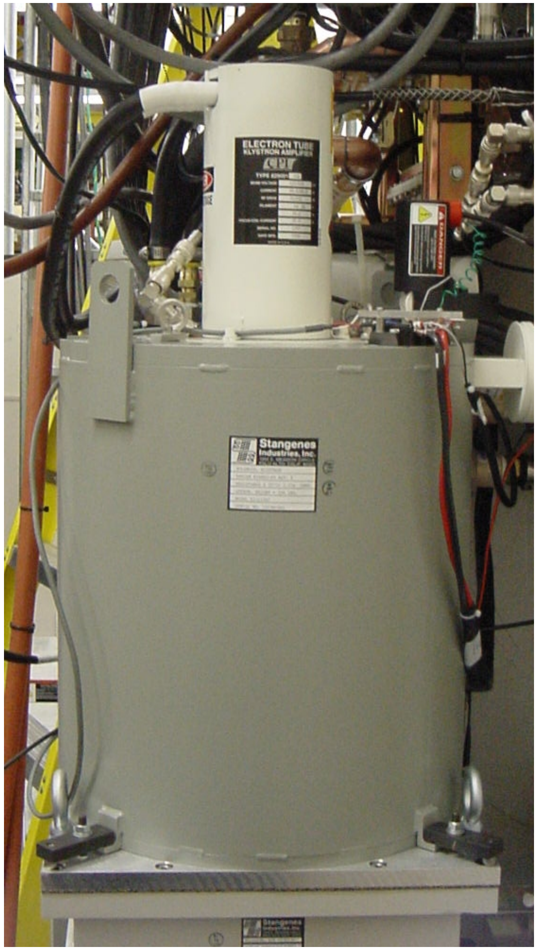


Varian's Accelerator Structure



- Standing Wave, Side-Coupled
- **Energy switch for dual energy operation**
- Shorter length (smaller accelerator footprint)
- Less sensitive to temperature changes (more stable operation)
- Small spread in electron energies
- **Very stable electron and photon beam characteristics**
- **Maximum energy depends on total length of the structure**

Microwave Amplifier - Varian's Klystron



- Lasts five times longer than a magnetron (less expensive over time, less "down-time" for the accelerator)
- Klystron-Amplifies Microwaves cleanly up to 5 Mega Watts
- RF power characteristics are independent of reflections from the accelerator

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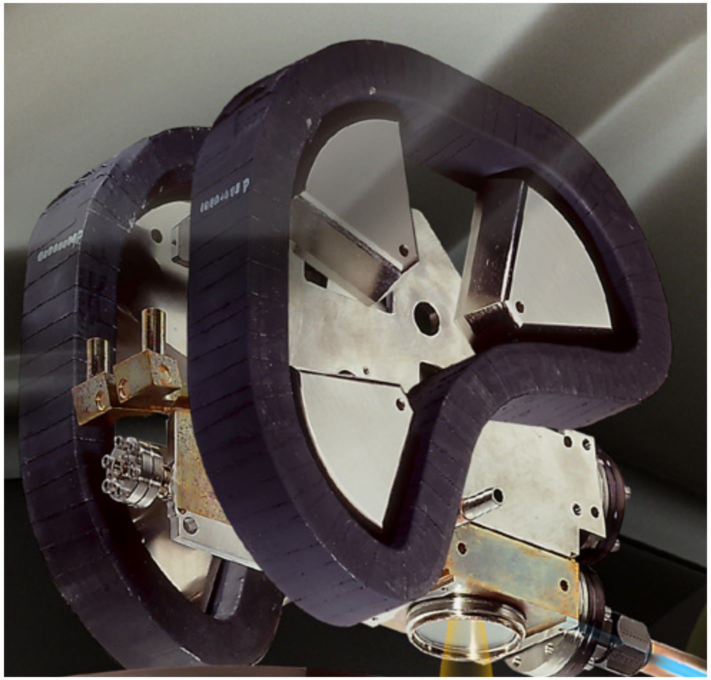
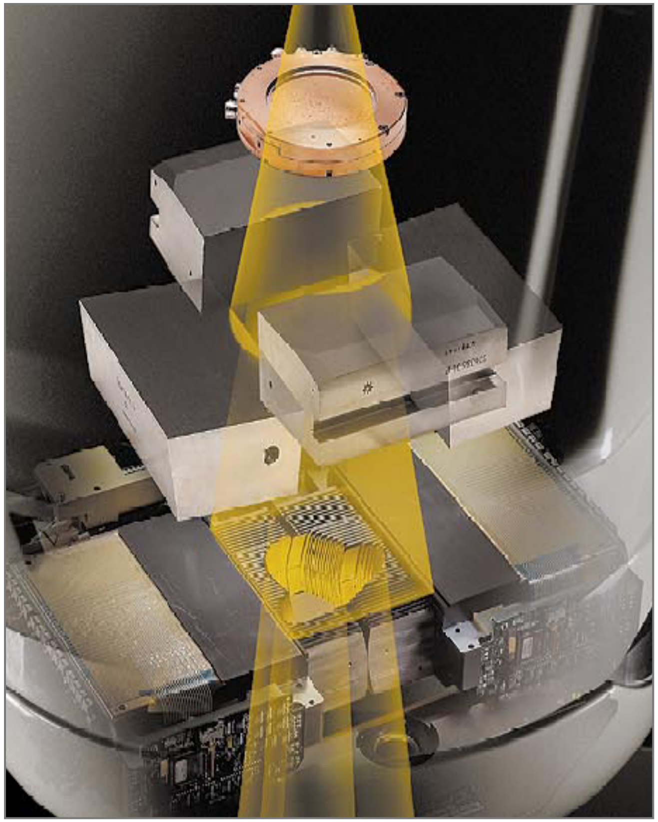
Bending Magnet



- 270-degree, 3-sector (pole), uniform pole gap, achromatic, bending magnet
- +/- 3% energy slits
- Long-term energy stability
- Direction and position independence (easy to adjust)
- Beam flatness
- Small, circular x-ray spot
  - Sharp penumbra
  - Good imaging

Beam Collimation

- Beam shape exiting treatment head is limited by 2 pairs of jaws and MLC
- Each jaw has independent drive and double read out system
- Multi leaf collimator is added below the jaws



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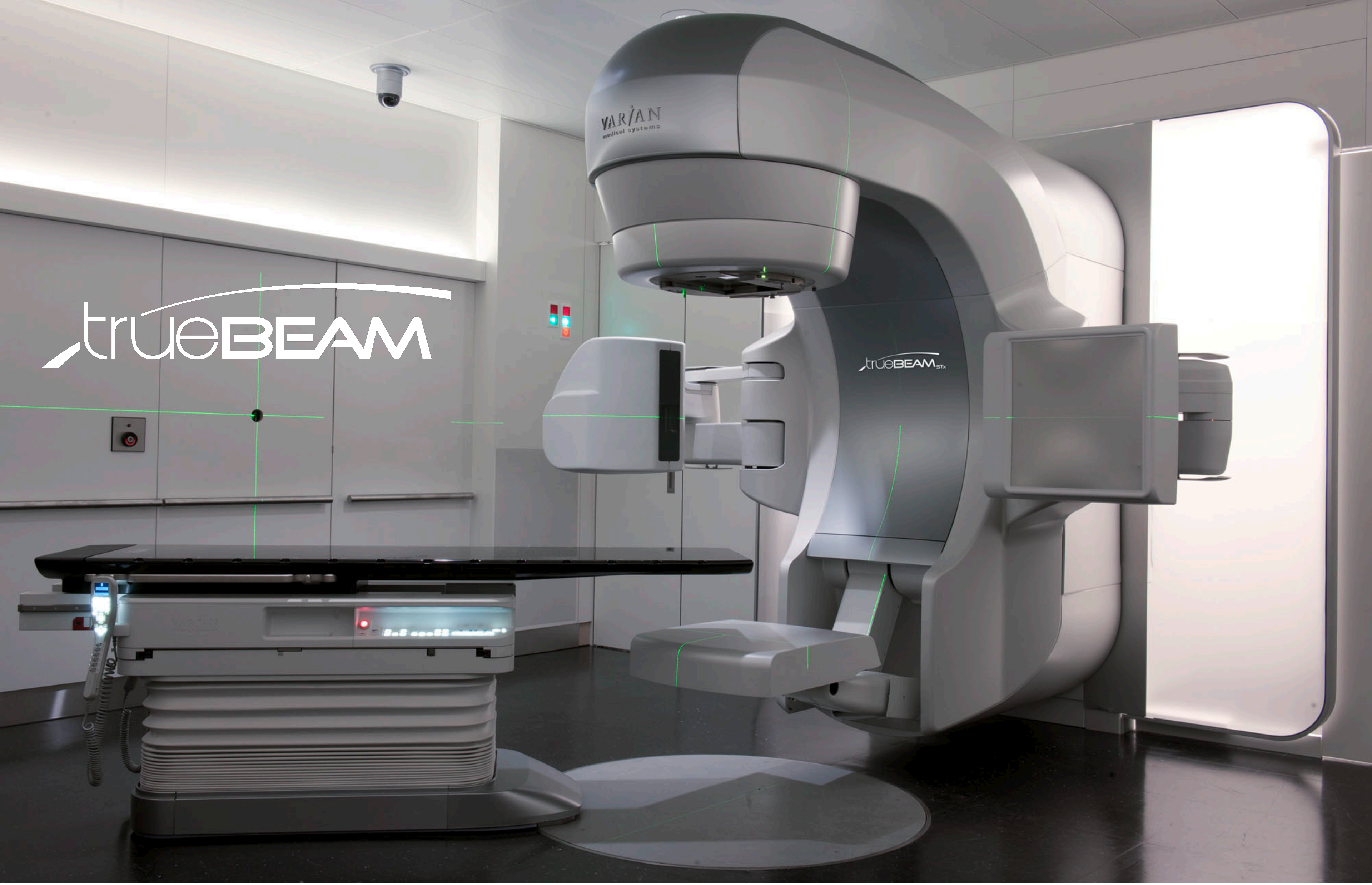
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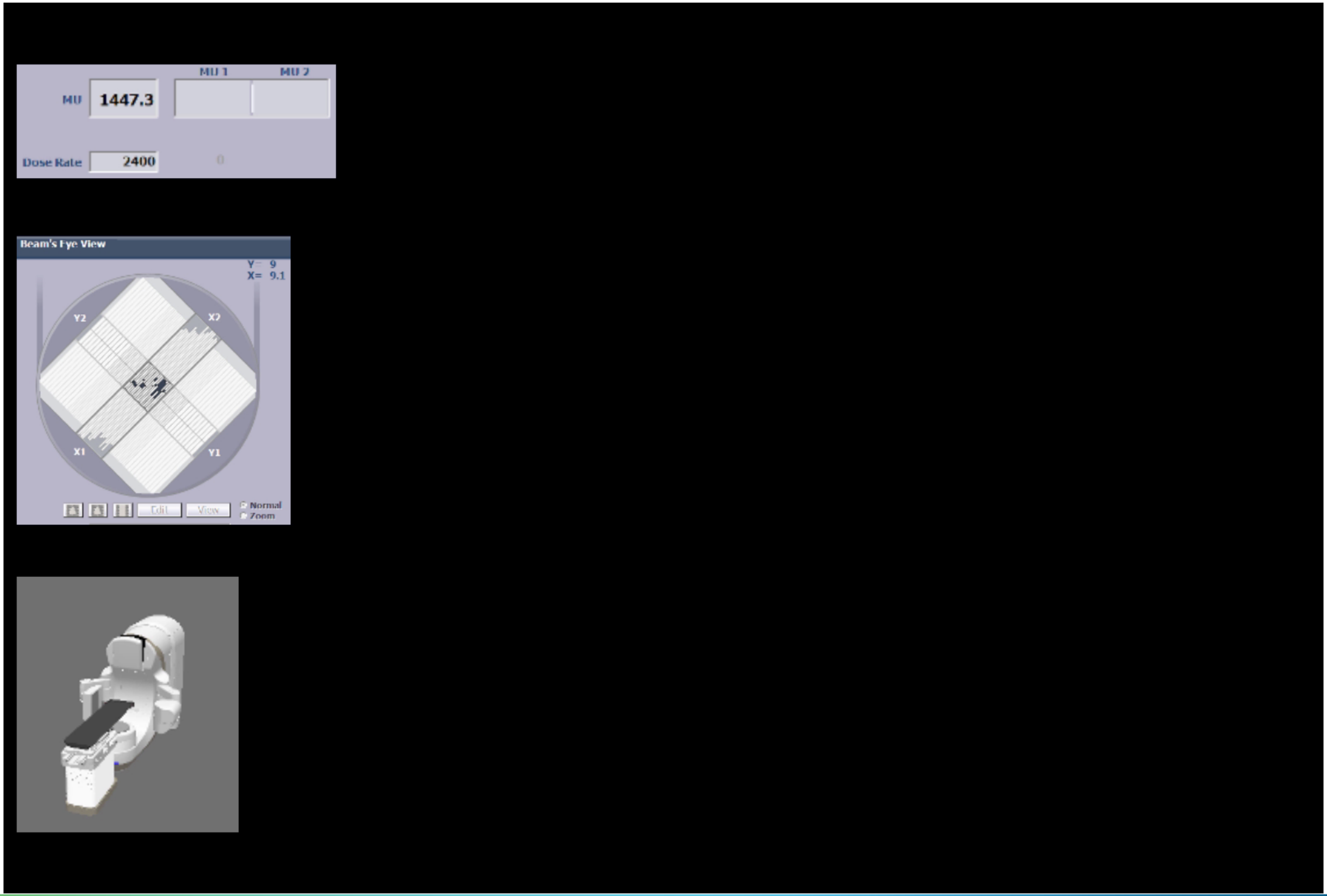
trueBEAM STx

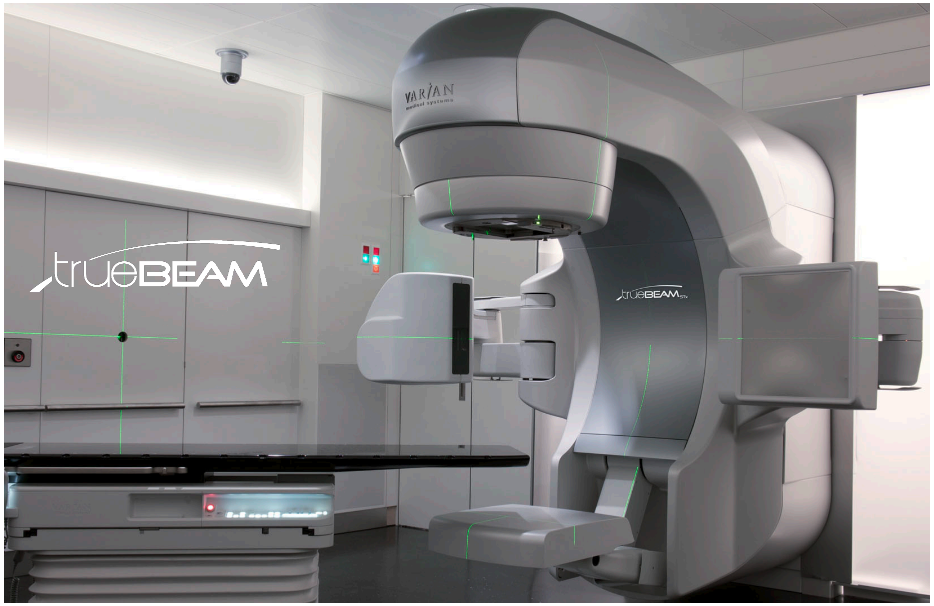
Advanced IGRT – Automatic Beam Hold



Images courtesy of VUmc

A New Platform – Introducing TrueBeam

- Launched 2010
- ~1000 clinical systems
- Complete redesign
- Built around core values:
  - Precision
  - Speed
  - Safety



TrueBeam Design Mission

- Ease of use, through an ergonomic and intuitive user experience, guided workflows and automation
- Superior imaging to increase confidence in challenging use cases
- Built in safety features to support advanced or complex techniques
- Improved serviceability
- Increased reliability
- Platform for future research and development

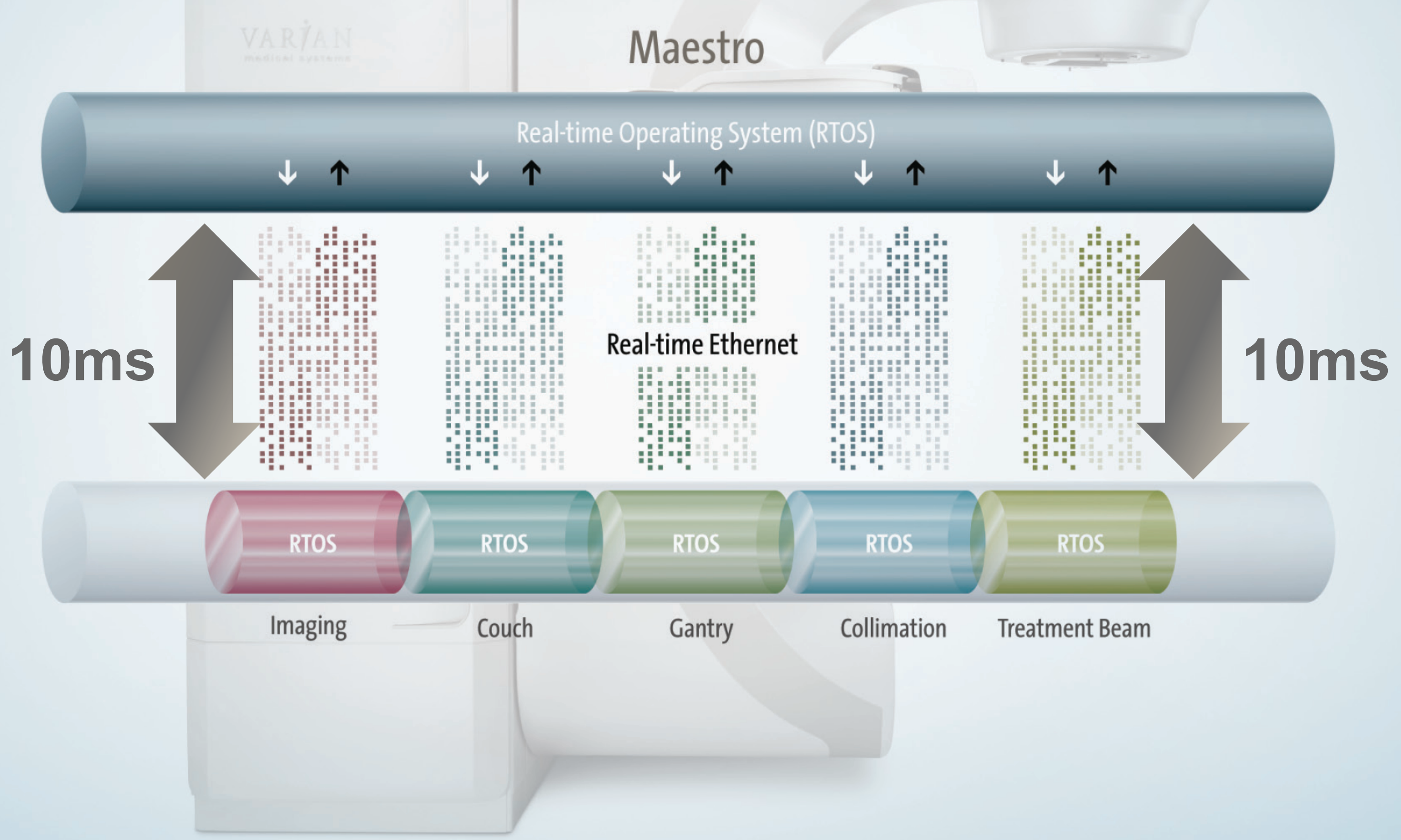
TrueBeam - Hardware

New Control System

- Fully digital
- Fully integrated
- Faster “heartbeat”

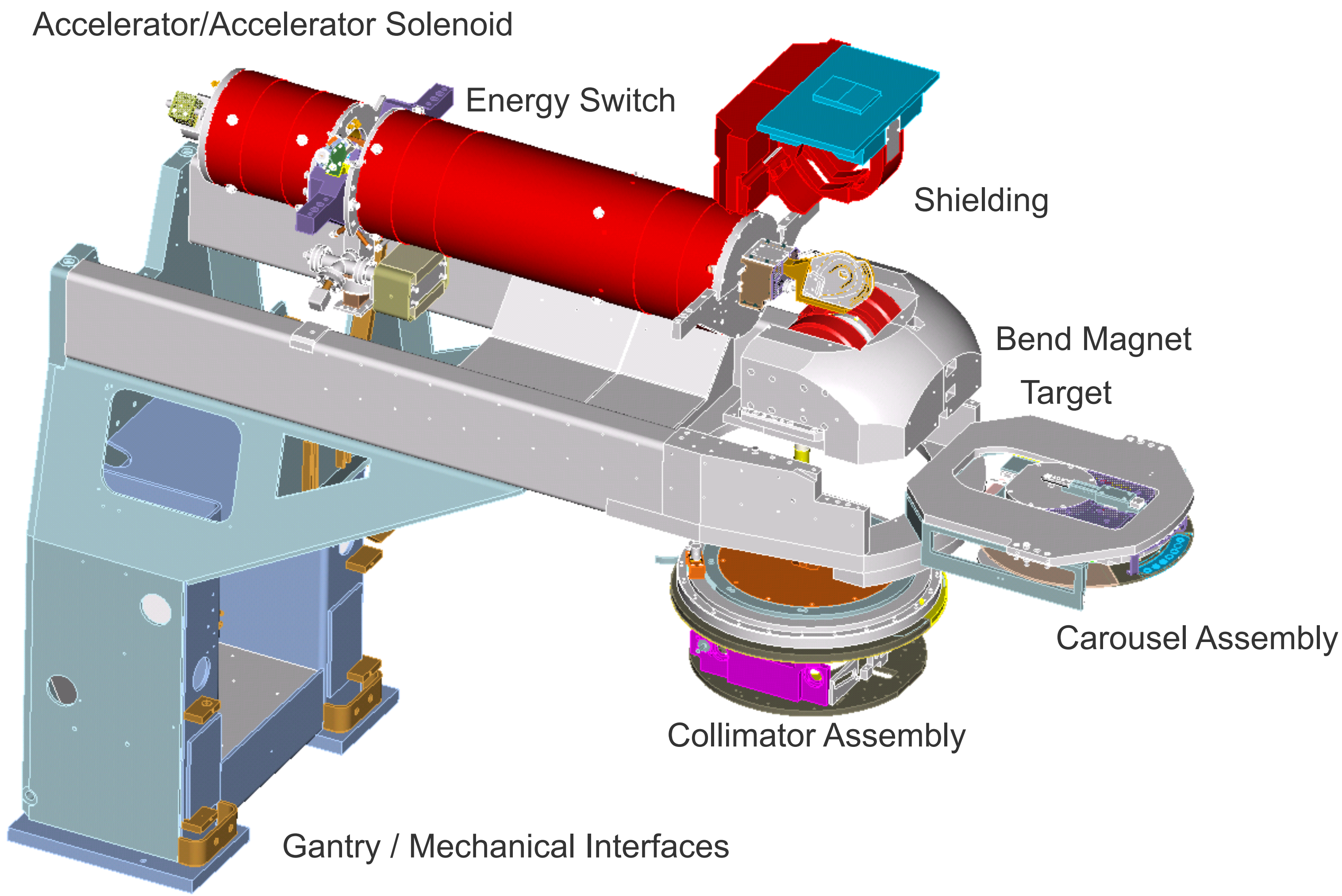
- Supervisor concept – monitors all components and compares to plan. Updates commands as required.

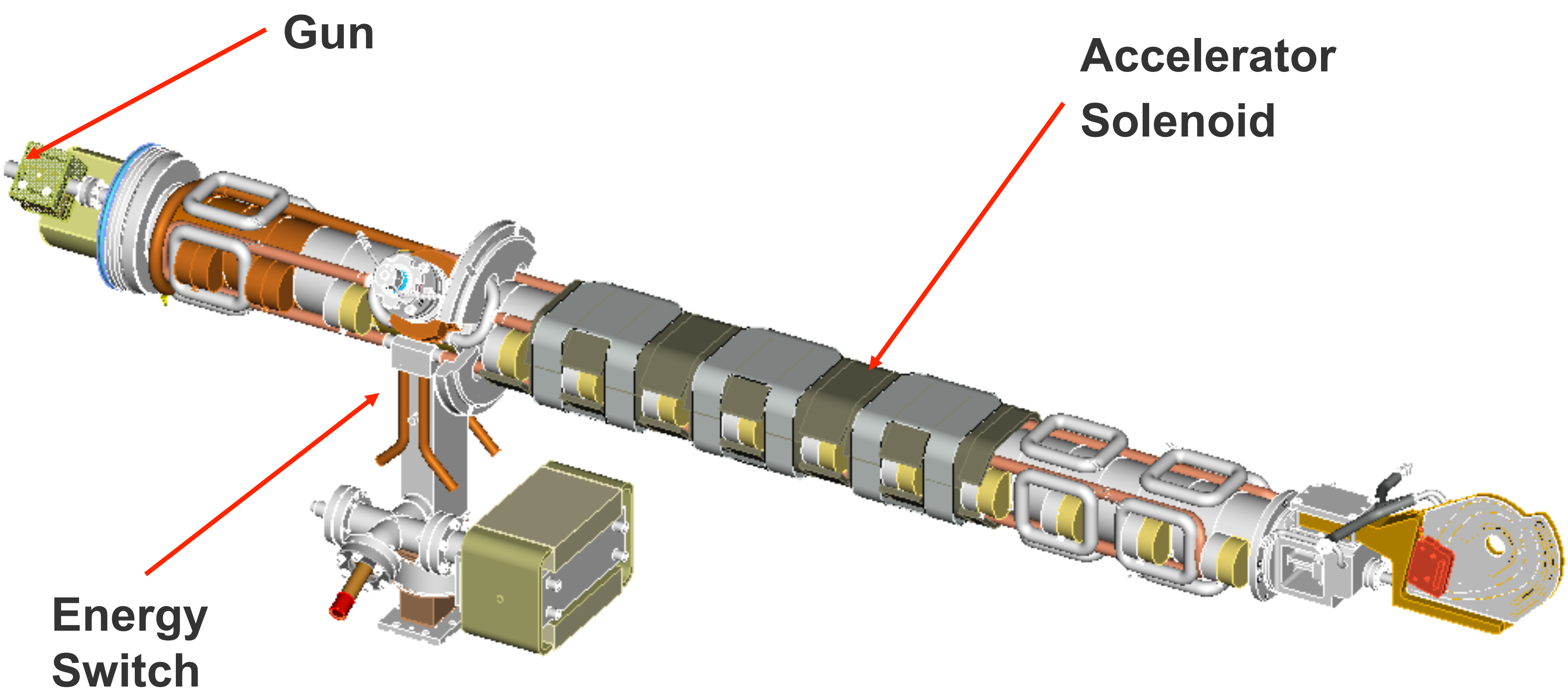
Maestro™ Control System



Redesigned Beamline Components

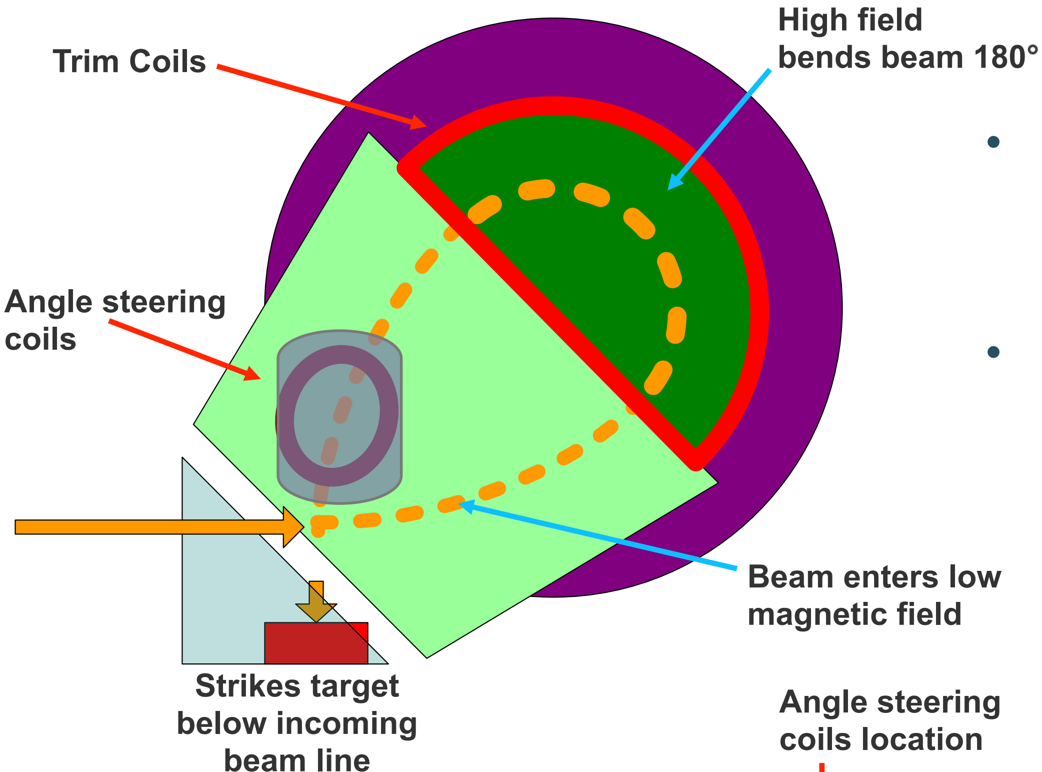
- Accelerating waveguide
- Bending magnet
- Target assembly
- New ion chamber design – additional segments to support FFF
- Revised shielding design for easier access to internal components

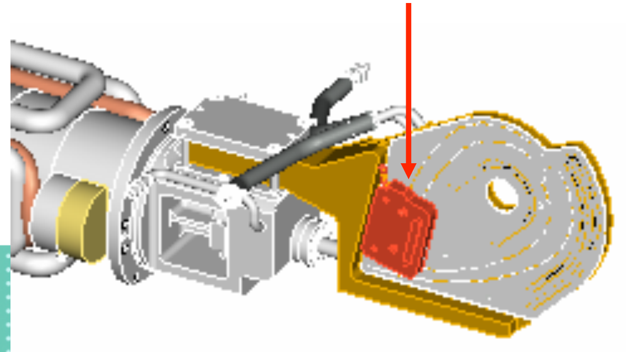

Accelerator/Accelerator Solenoid
Energy Switch
Shielding
Bend Magnet
Target
Carousel Assembly
Collimator Assembly
Gantry / Mechanical Interfaces



New “universal” wave guide and energy switch, up to 5 photon energies now possible

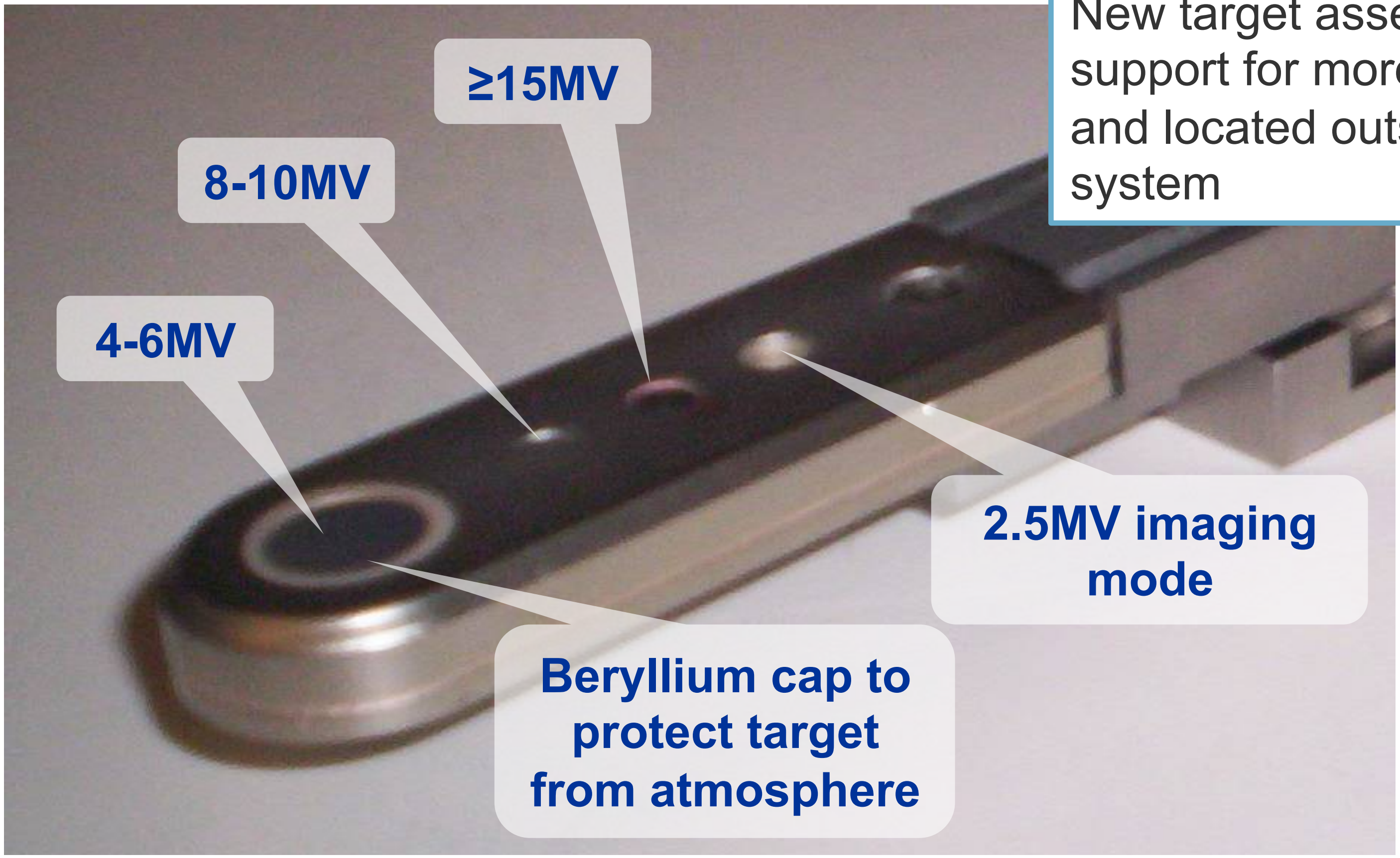
Bending Magnet





- Function
  - Bends electron beam to target by 270 º
- Features
  - Stepped pole field achromatic magnet
  - Simple design
  - Separate from orbit (vacuum) and target
  - More space bellow target
  - Easy to service

Beam Generation - Target

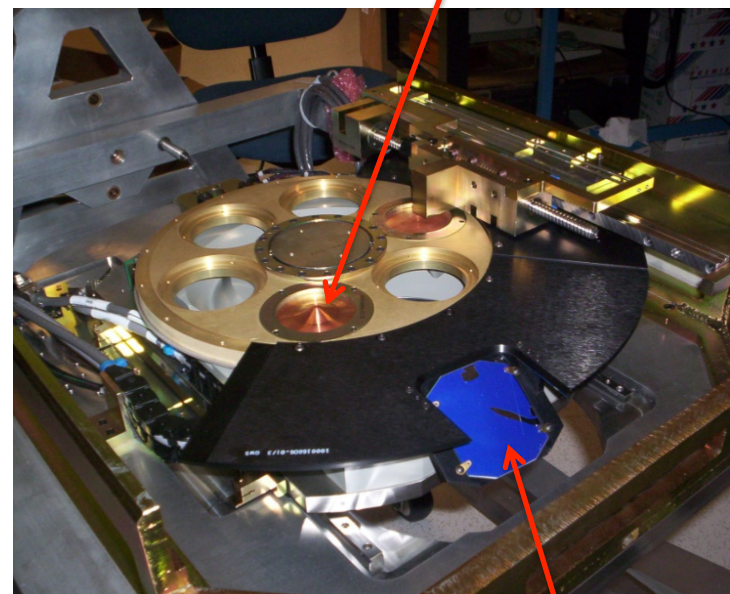


New target assembly – support for more energies and located outside vacuum system

→ **Retract target from beam for electron modes**

Beam Generation - Carousel

- Multi-Energy: 13 Carousel positions available
  - Up to 4 Flattened Photon Energies:
    - Up to 600 MU/min
  - 2 High Intensity Mode Energies:
    - 6X FFF (max 1400MU/min)
    - 10X FFF (max 2400 MU/min)
  - 8 electron energies



- Carousel rotates and translates to position required elements in beam line

TrueBeam – User Interface

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Control Console – Clinac vs TrueBeam

C-Series

TrueBeam™

User Interface

- Fewer points of contact – less distractions from looking at treatment and patient. Safer and more efficient.
- Simplified/harmonized interface – learn once, apply to all points of interaction
- Guided workflow – buttons light up to show what machine needs next
- Automation of imaging components

Harmonized User Interface

Console

Pendant

Couch

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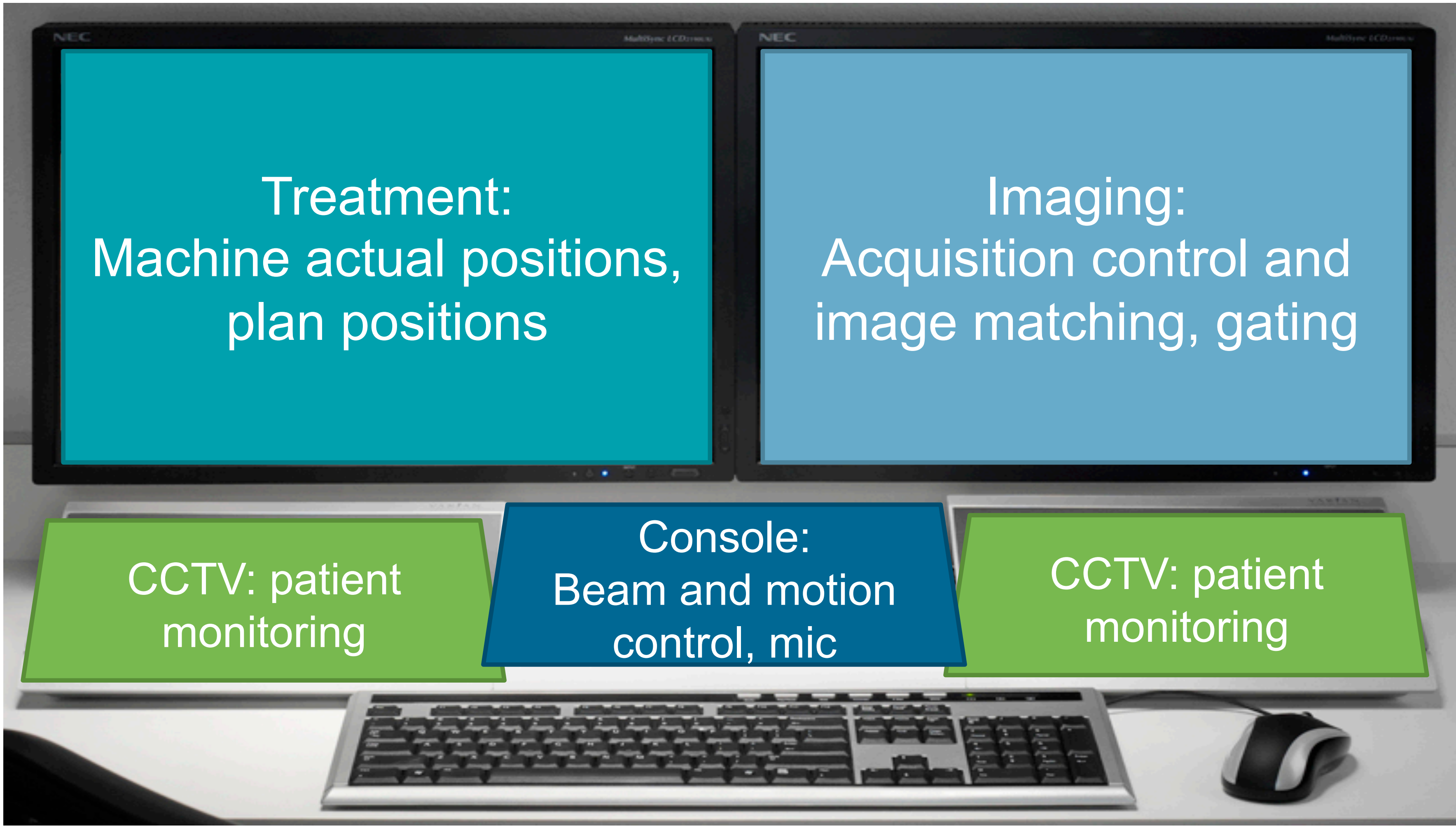
Software – Treatment Mode

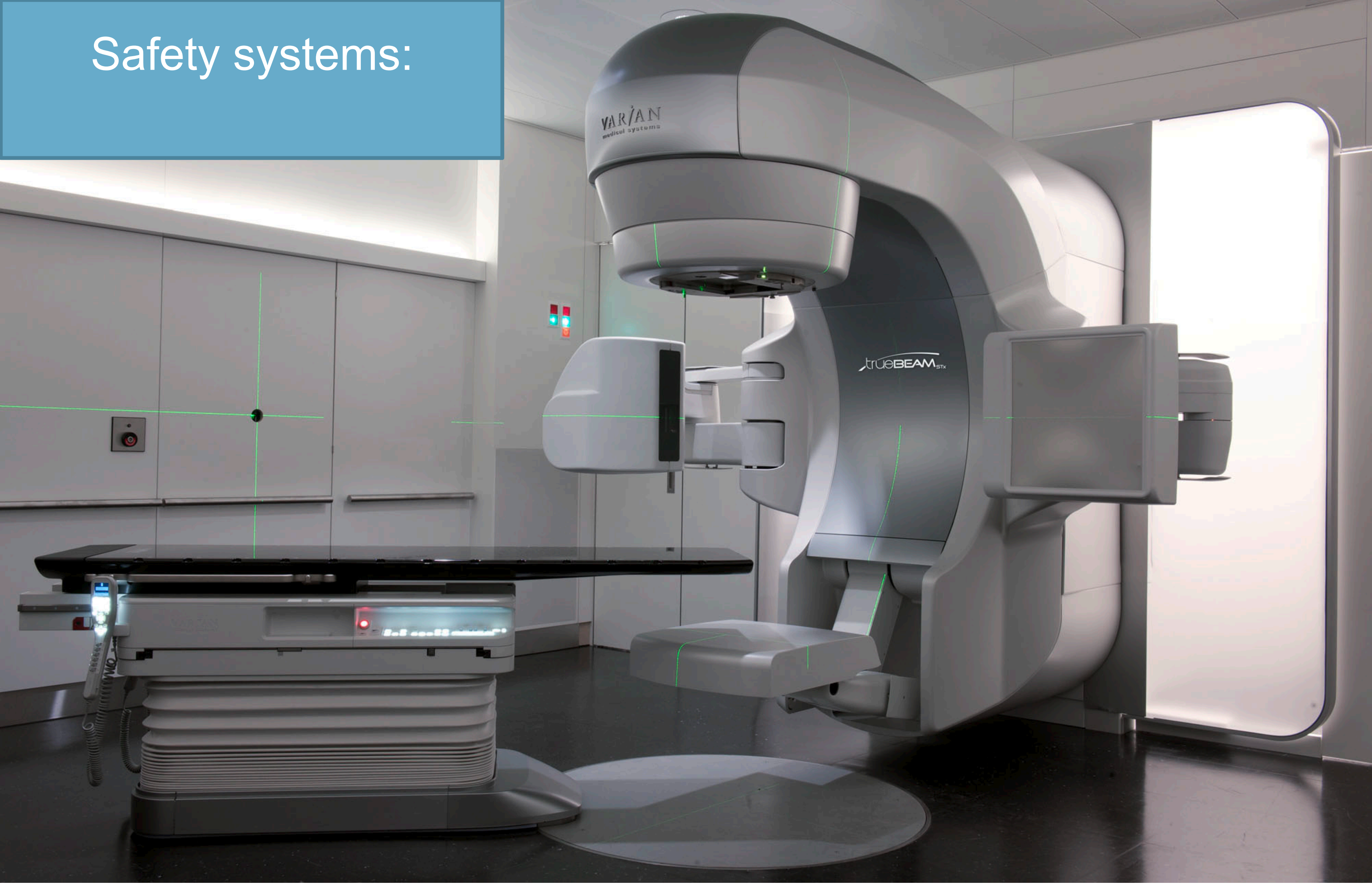
Software – Treatment Mode



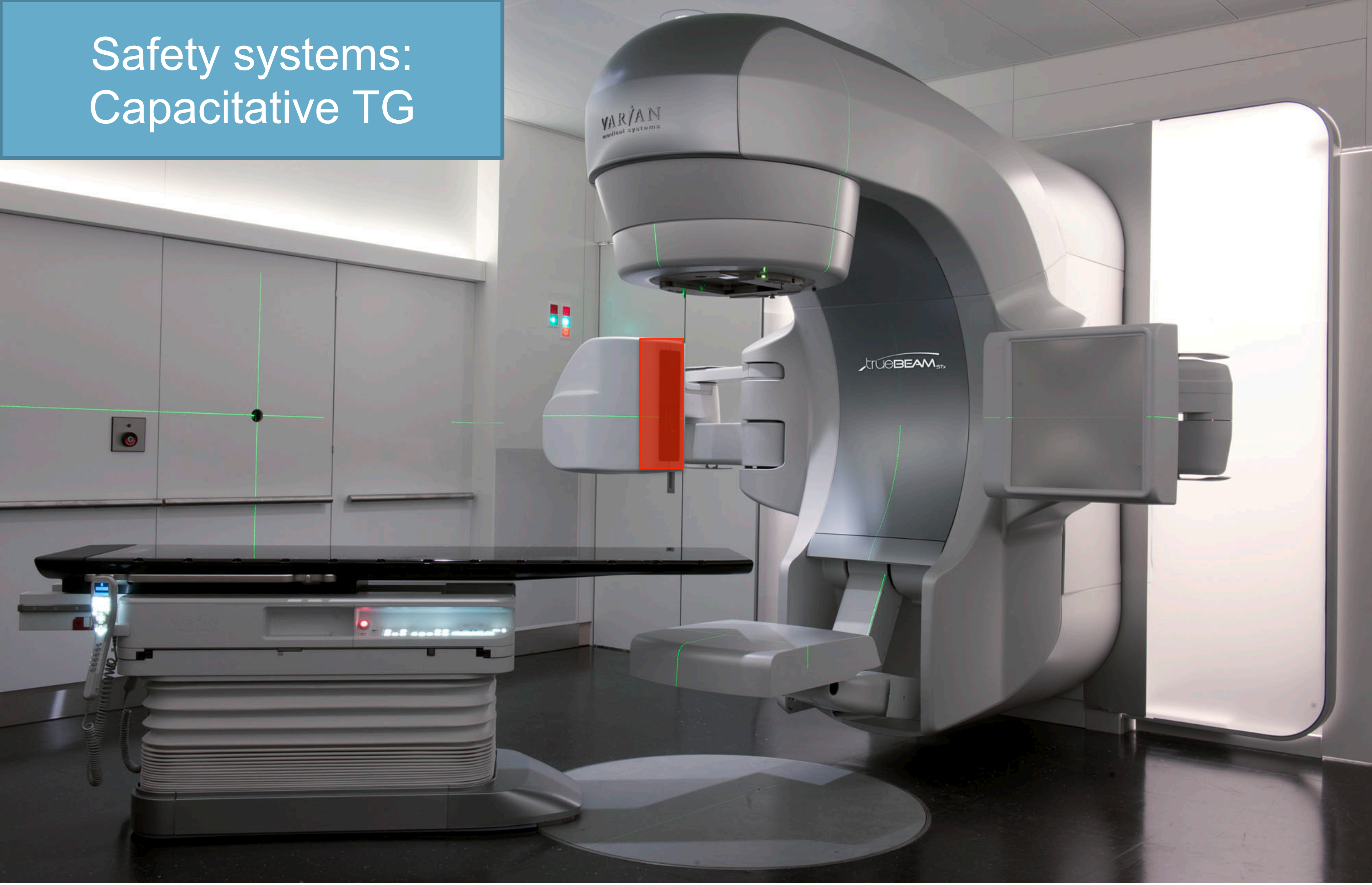
Safety

- In addition to “standard” safety features present on all medical linacs…
- Capacitative collision detection on kV source
- Laserguard to protect patient zone without contact
- Mechanical touchguards on all other moving parts
- LiveView display…
- Machine software model…

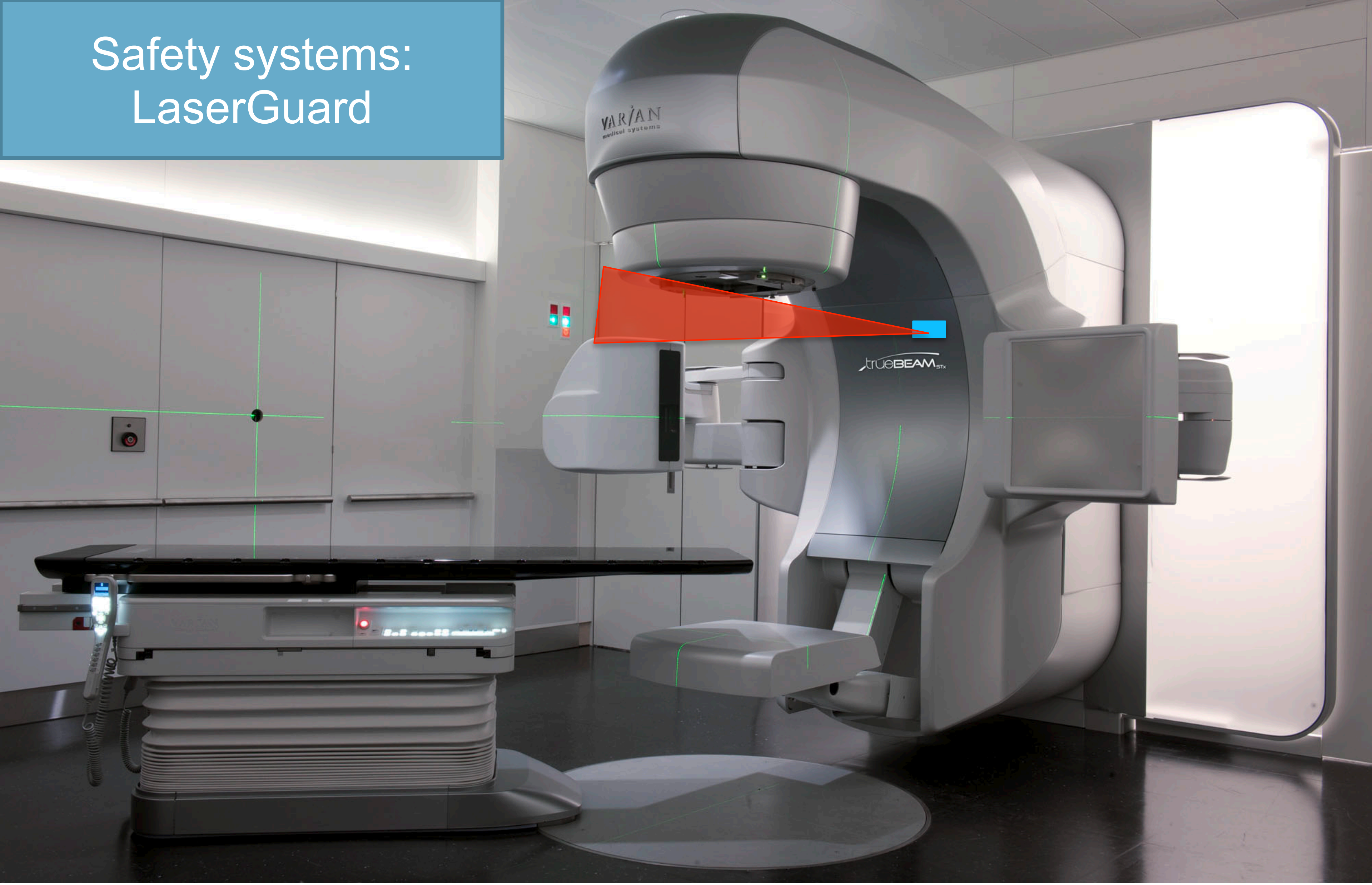
Safety systems:



Safety systems: Capacitative TG



Safety systems: LaserGuard



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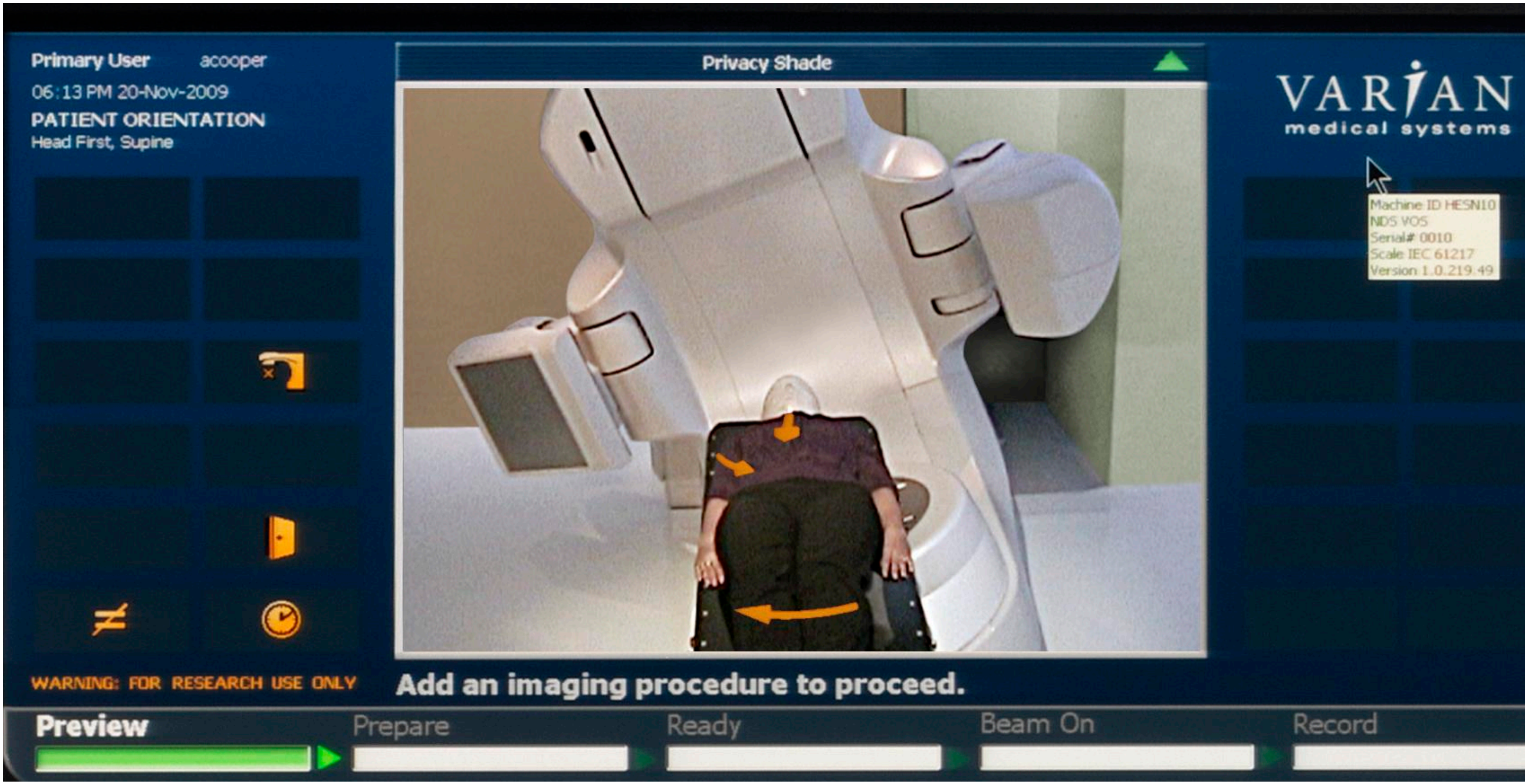
Safety systems: Mechanical TG

TrueBeam – Safety Features: LiveView



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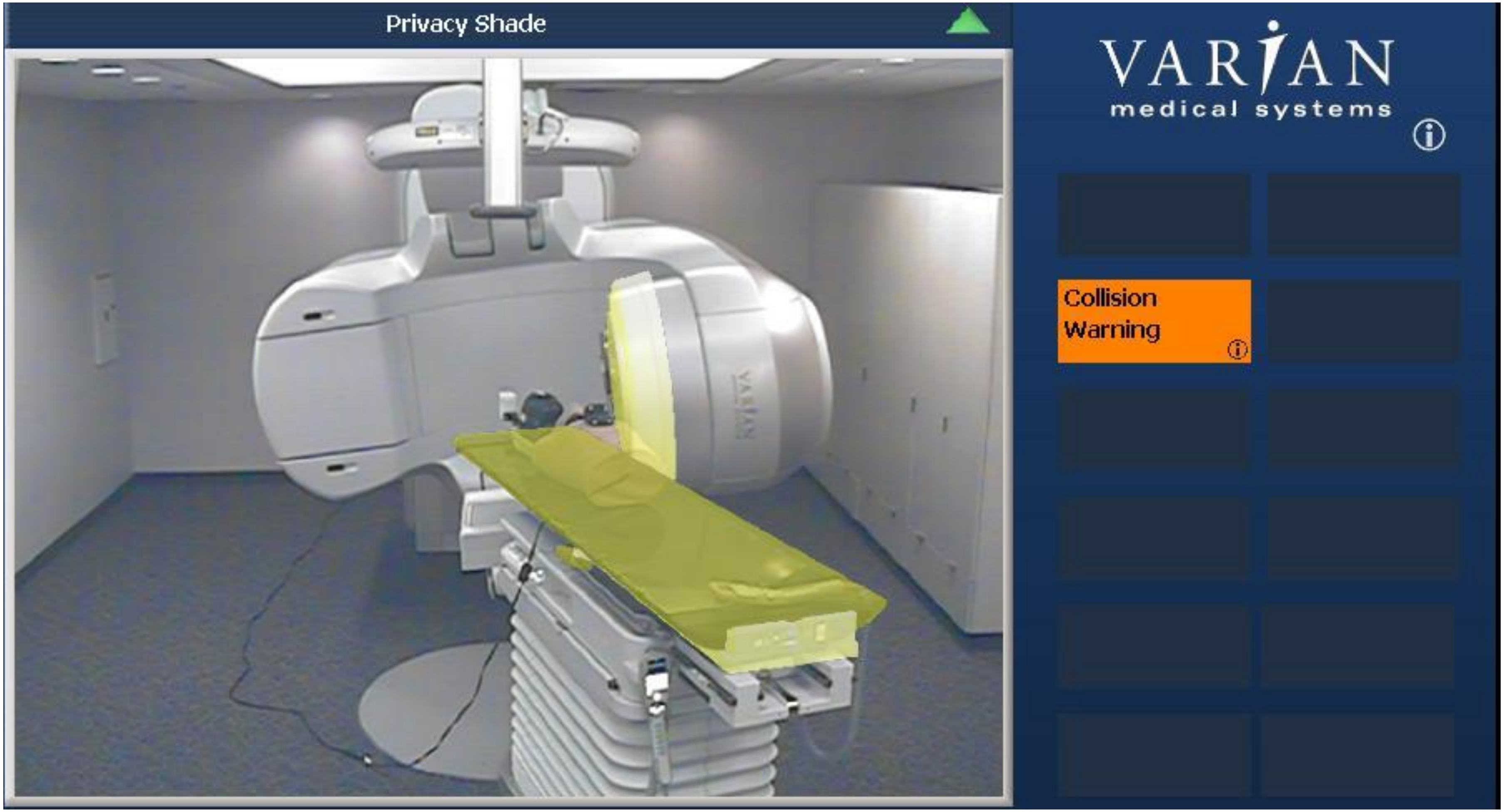
TrueBeam – Collision Avoidance Model



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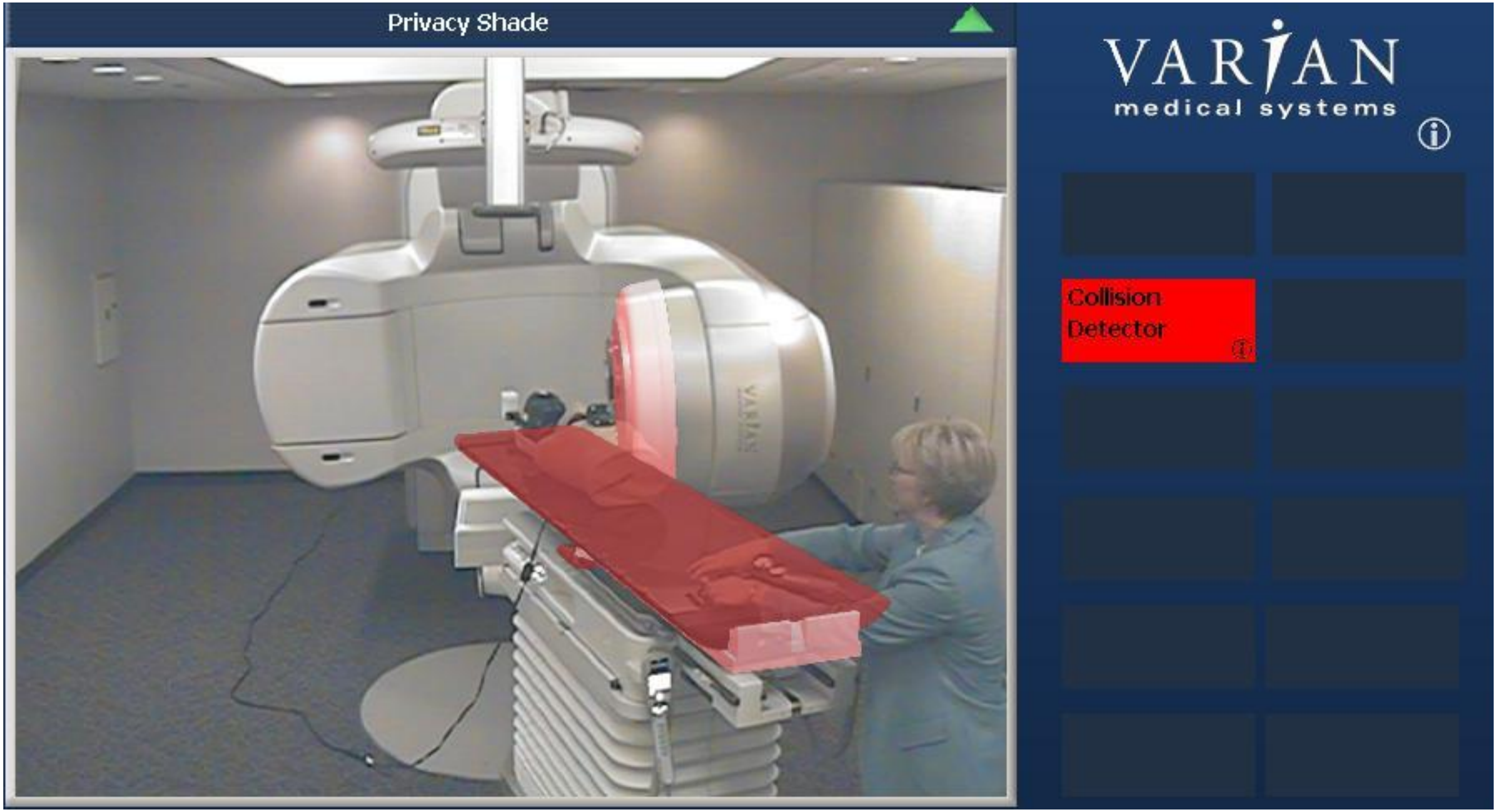
TrueBeam – Collision Avoidance Model



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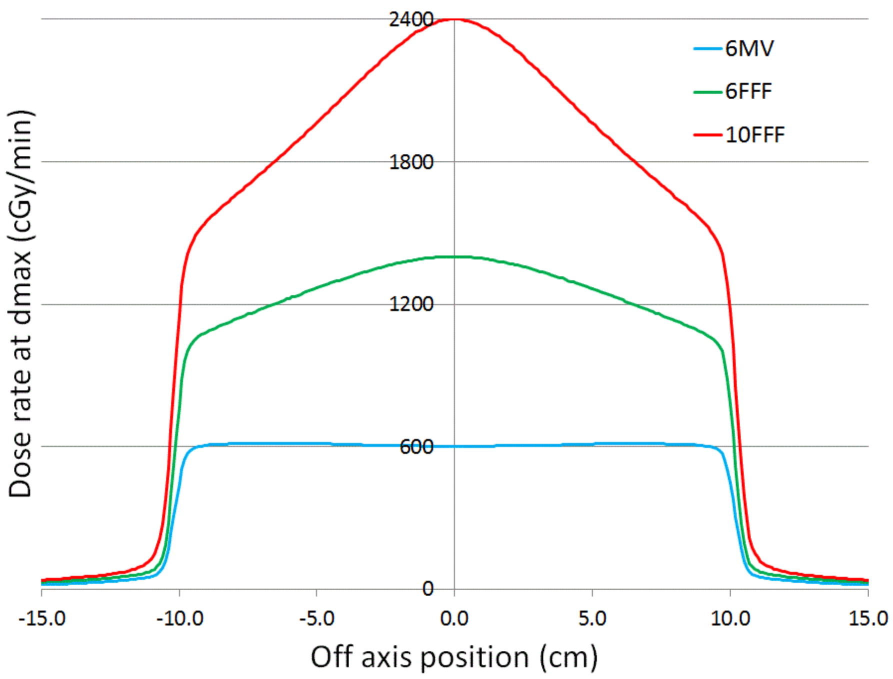
Research Applied

Flattening Filter Free (FFF) Mode

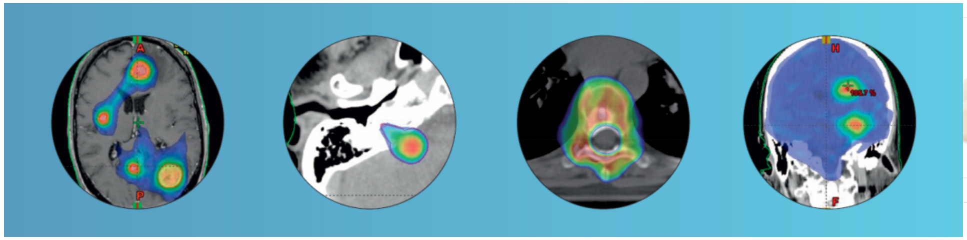
Higher dose rates, lower scatter and out of field leakage are possible by removing the flattening filter

- Gains for IMRT, RapidArc or small field SRS
- Available in clinical mode for
  6 MV → 1400 MU/min
  10 MV → 2400 MU/min

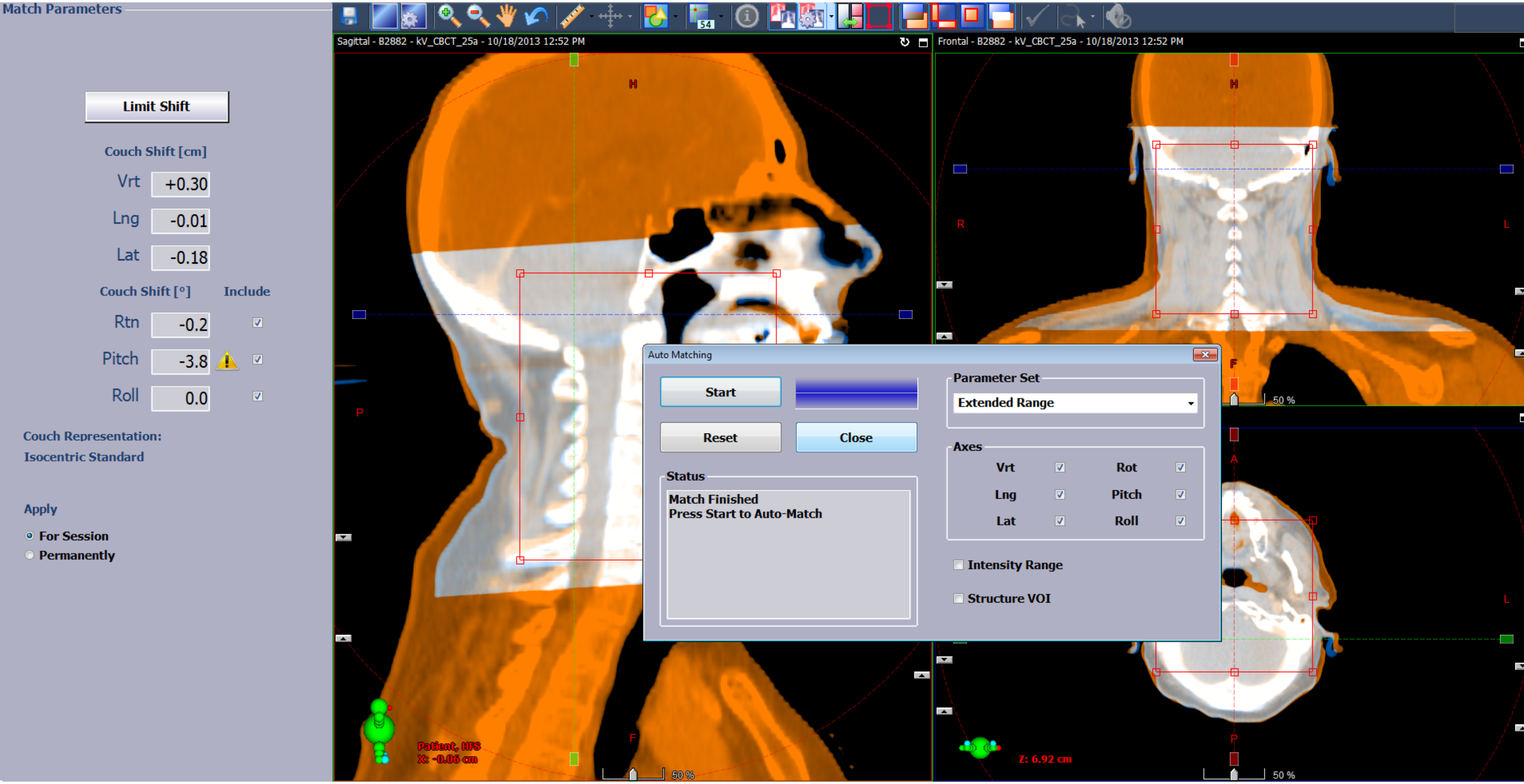


PerfectPitch™ Couch

- Increased treatment precision
- Fully integrated with TrueBeam
- Precise isocentric rotation



Matching with 6 Degrees of Freedom



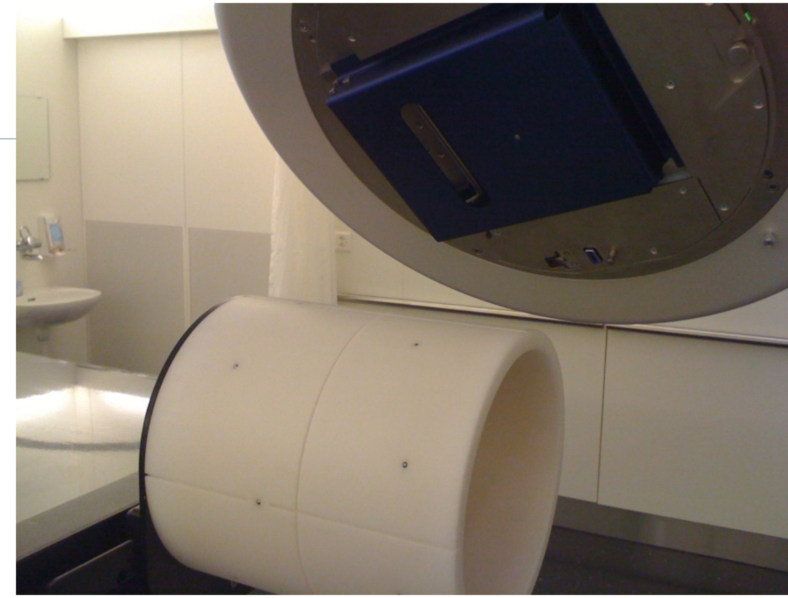
Images courtesy of The Clatterbridge Cancer Center

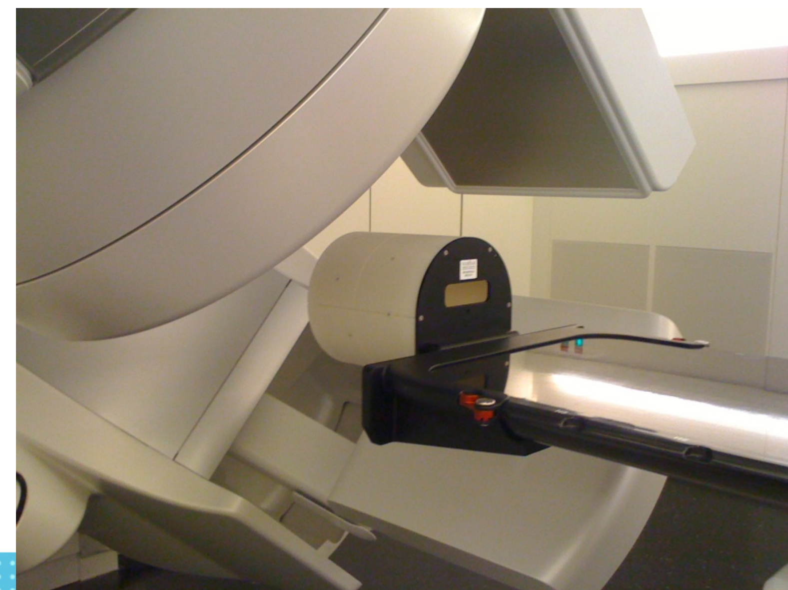
IsoCal - Phantom

- **Phantom of a known geometry with 16 BBs**
- **Transmission plate with a radio-opaque pin**

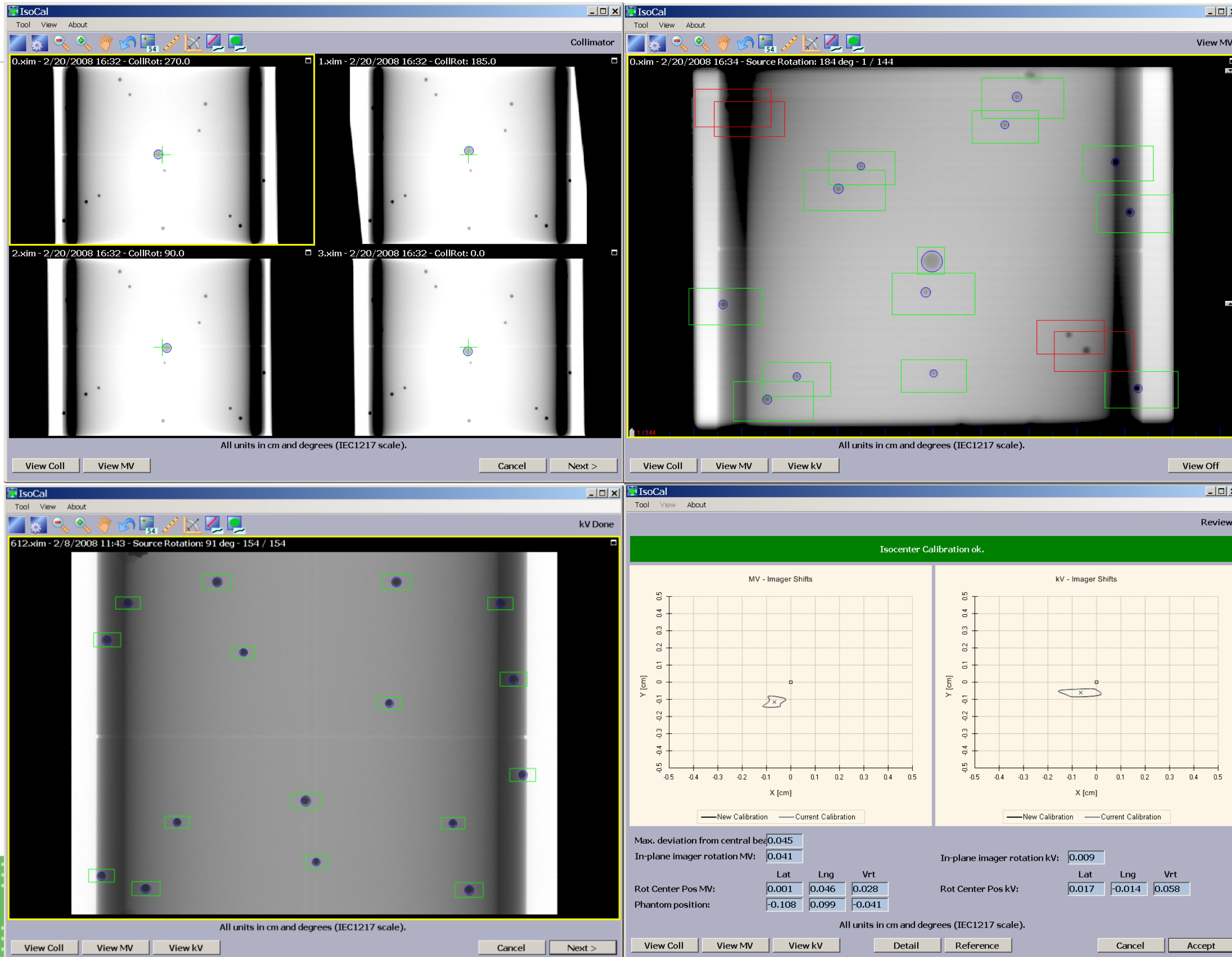
- Based on imaging of the phantom
- 4 collimator positions to find its axis
- kV and MV projections during 360° rotation around the phantom

- Algorithm finds gantry rotational axis and the position of three isocenters on it
- Isocenters projected onto imagers to determine the correction shift vectors for active arm position correction





IsoCal – sub-millimeter precise imaging



Summary

- Transition from research to design
- Consider:
  - Safety
  - Usability
  - Serviceability
  - Production cost
  - Marketability

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