Architecture of New Radiotherapy Equipment

ICTP School on Medical Physics
March 25 – April 5, 2019
Miramare, Trieste

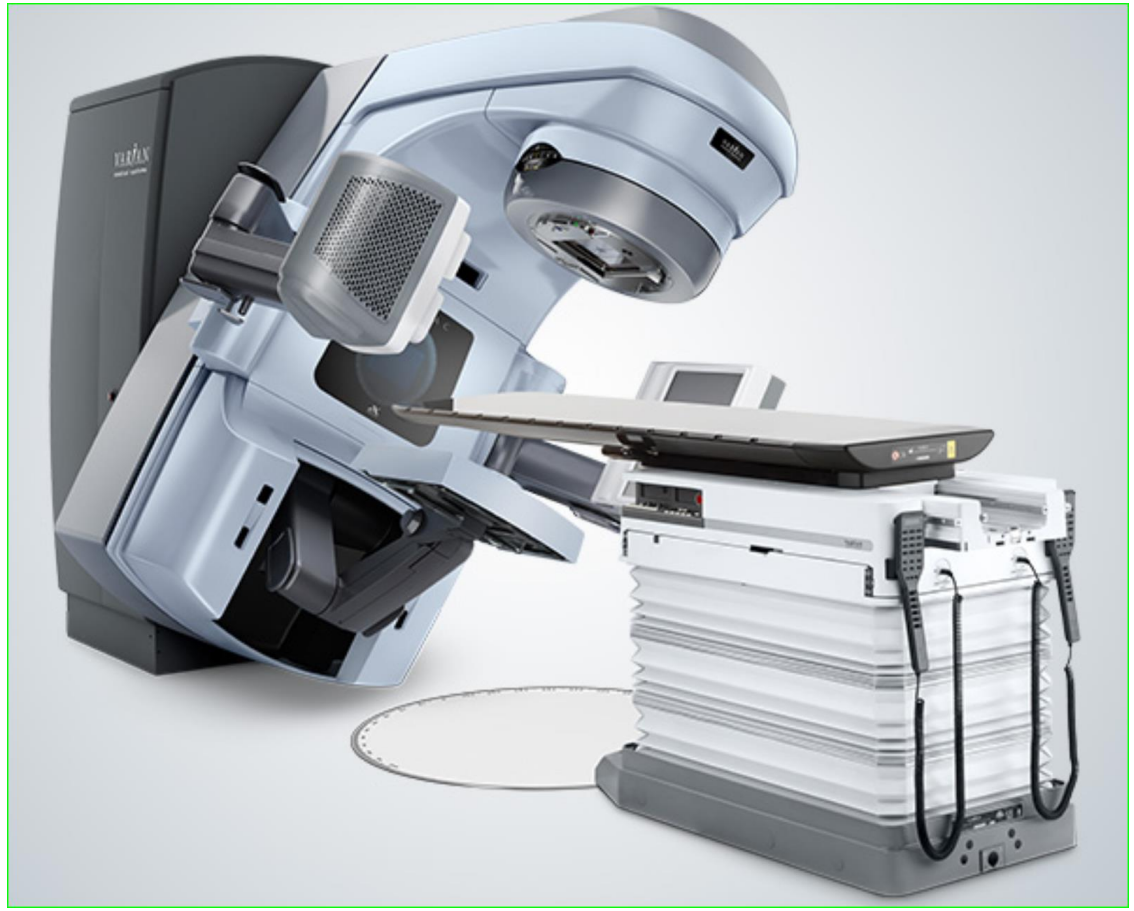
Yakov Pipman, DSc

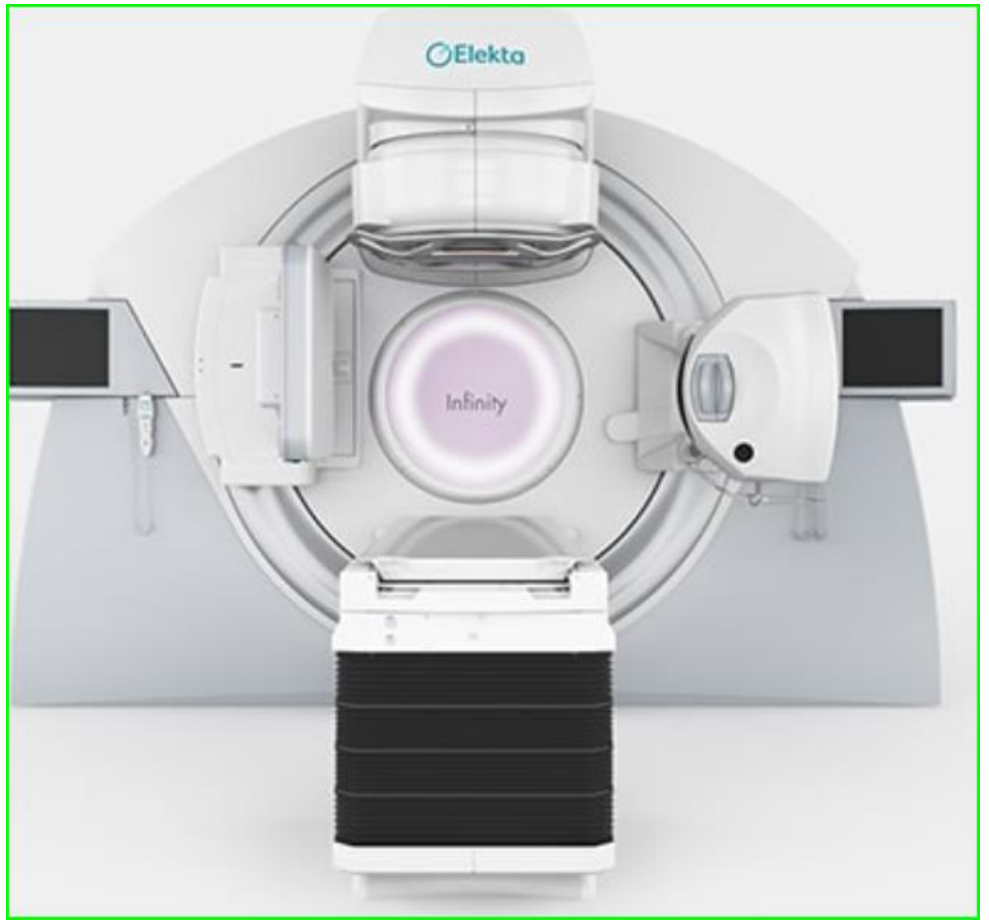
Overview

- Tomotherapy
- Brainlab
- CyberKnife
- GammaKnife
- MRIdian
- Halcyon
- New ideas

Hybrid Technologies-Imaging and Therapy

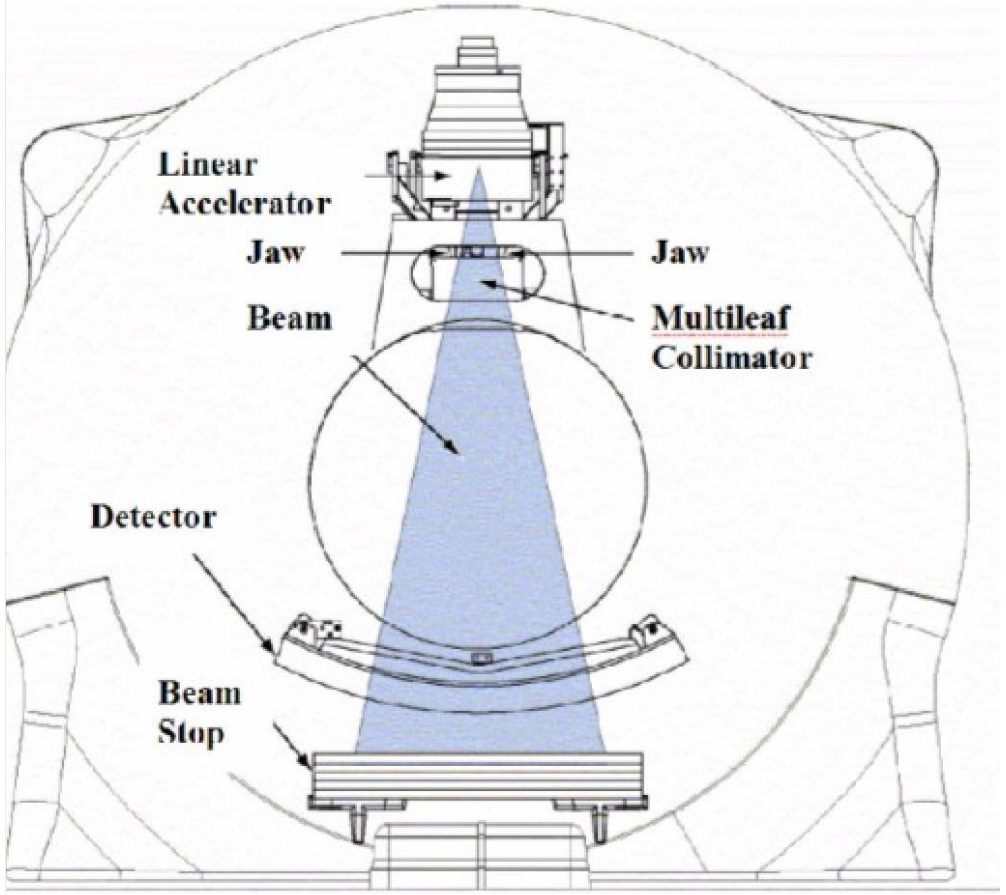
- Linac/CBCT





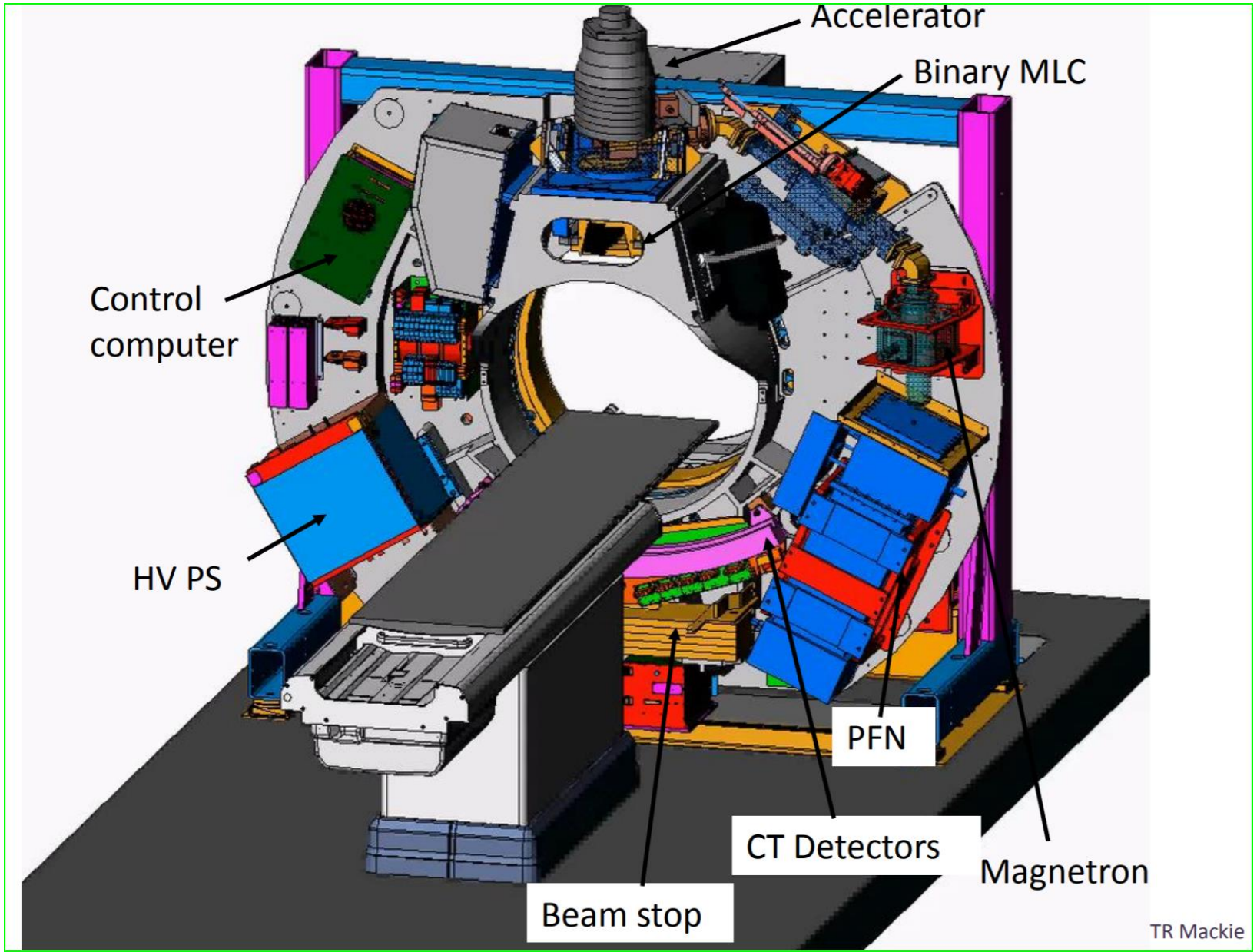
Tomotherapy (now part of Accuray)

Integrated Imaging and Therapy

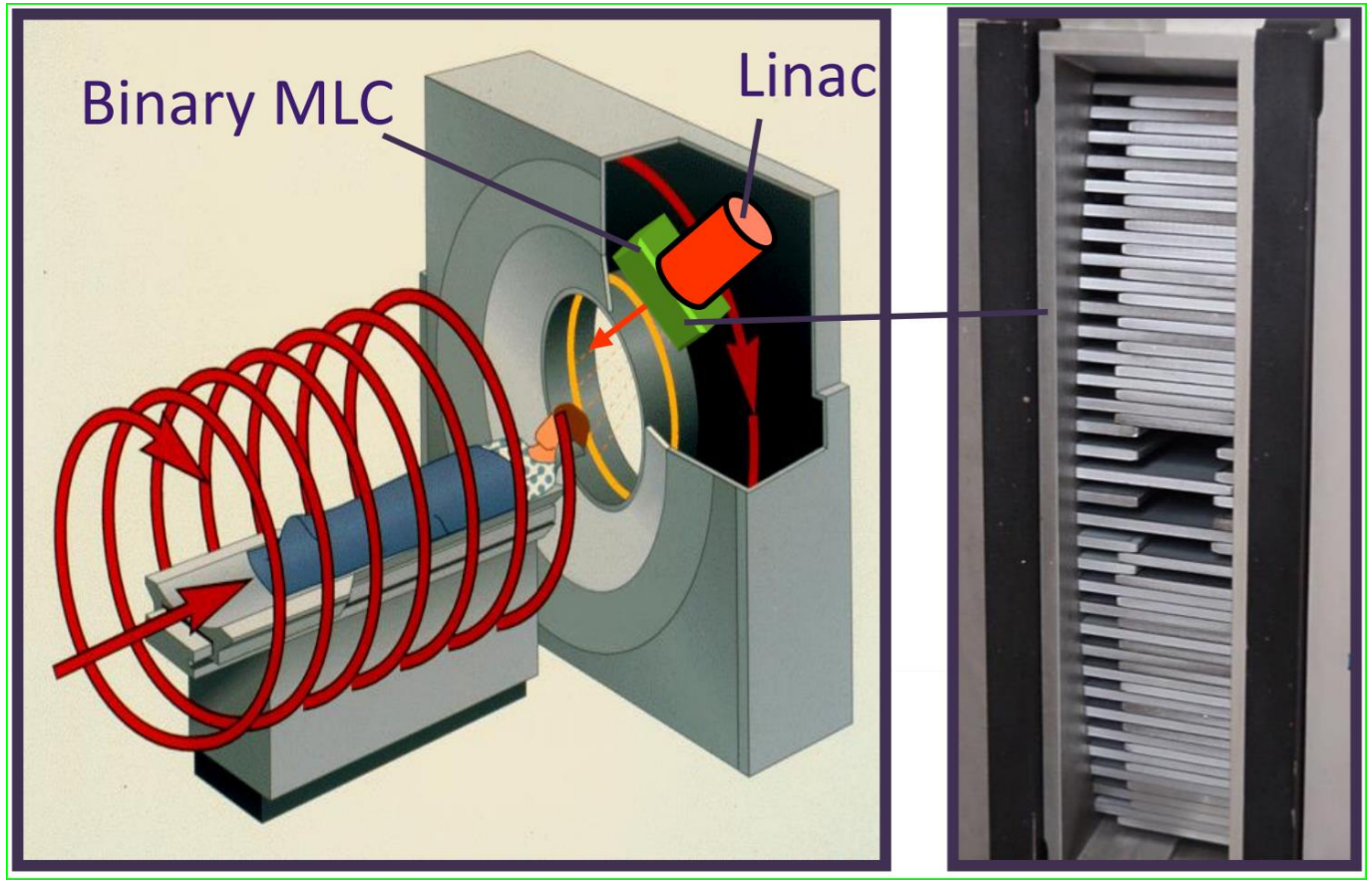


Jeswani S, Mackie TR, Aoyama H. Overview of the HI-ART TM Helical Tomotherapy System.

Tomotherapy - Components



Tomotherapy - Binary MLC

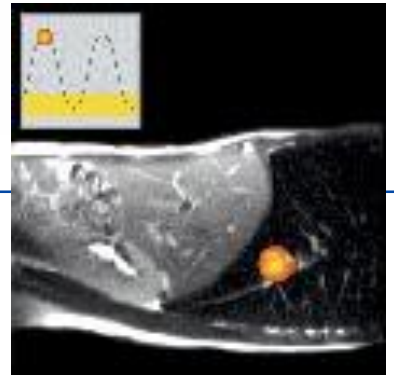


TR Mackie

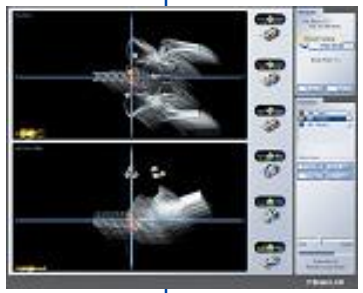
IGRT Solutions

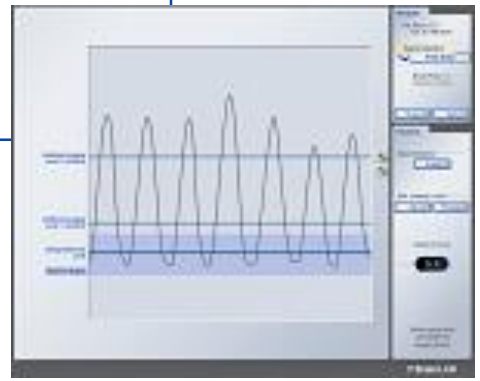
ExacTrac X-Ray 6D

Robotics



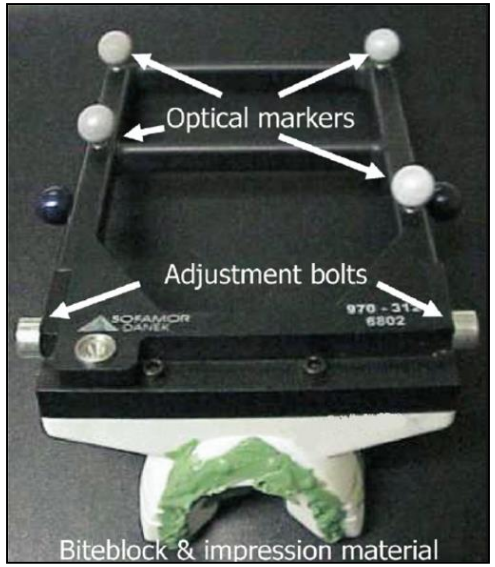
Adaptive Gating

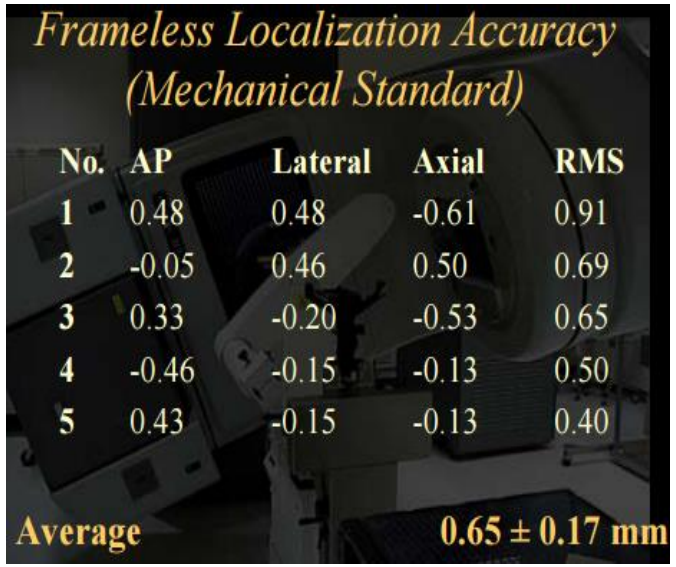


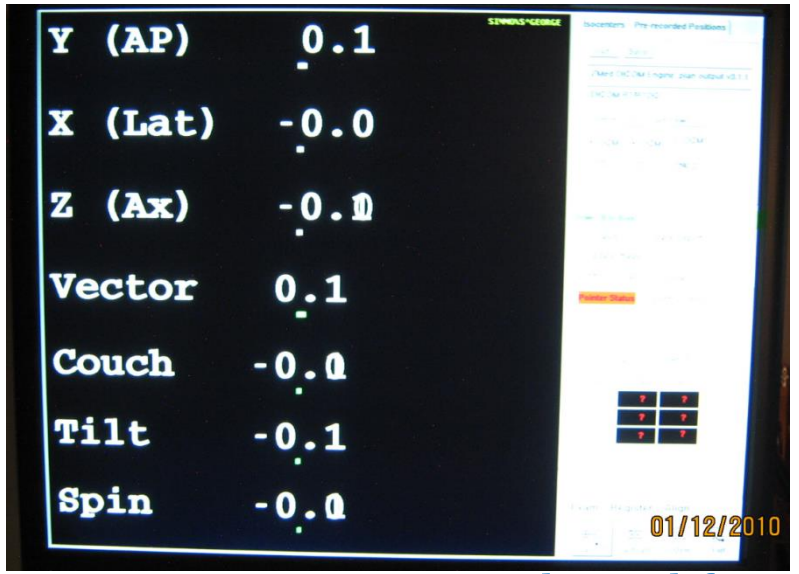


In Room Radiographic guidance

Zmed System – Frameless Immobilization/tracking







Adapted from Dr. D Roa

THE CYBERKNIFE® TREATMENT DELIVERY SYSTEM

1. Xchange® Robotic Collimator Changer
2. X-ray Imaging System
3. RoboCouch® (optional)
4. Robotic Manipulator
5. Linear Accelerator
6. InCise™ 2 Multileaf Collimator (optional)
7. Iris™ Variable Aperture Collimator
8. Synchrony® Respiratory Tracking System

CyberKnife (Accuray)

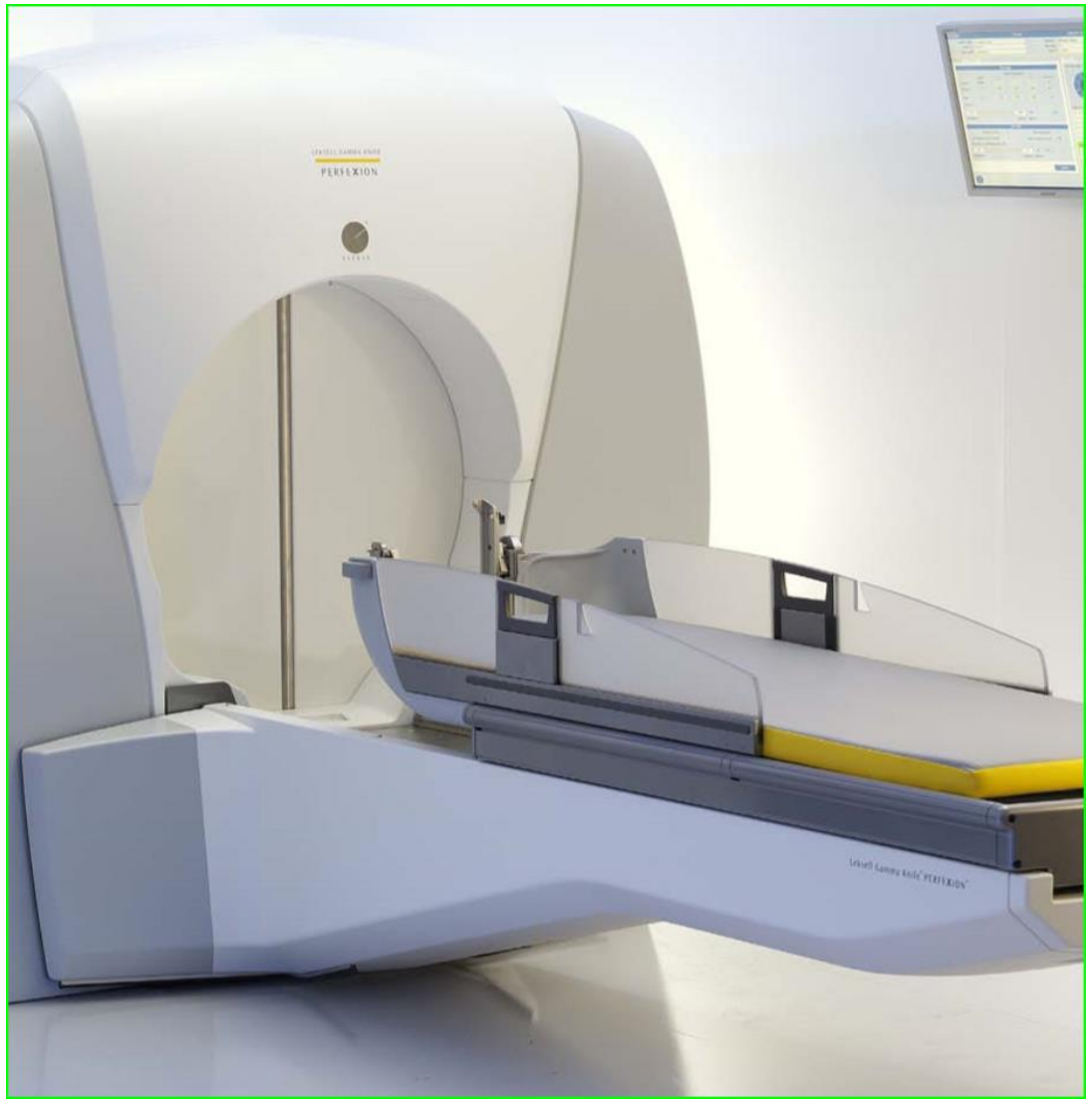
- Robotic arm -> treatment non-isocentric
- Beams re-targeted based on DRR/live image comparison
- Submillimeter accuracy with limited immobilization

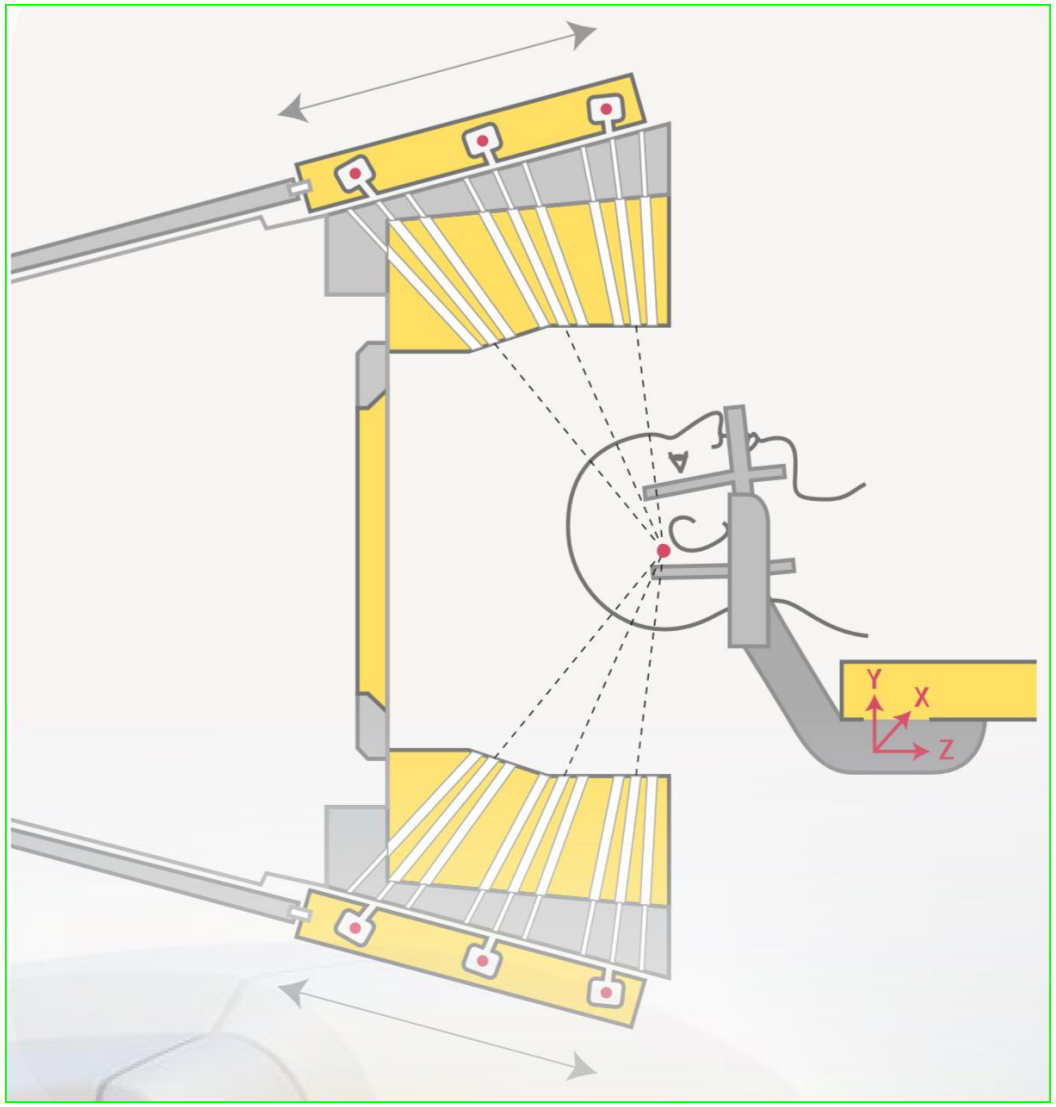
- 6 MV Beam – No flattening filter
- Dmax= 1.5cm
- 600-800 MU/min

CyberKnife (Accuray) – sub systems

- Image Guidance System
- Robotic Manipulator
- Treatment Delivery Control Console
- 12 Fixed Collimators (5mm to 60mm)
- Xchange® Robotic Collimator Changer (optional)
- Iris™ Variable Aperture Collimator
- InCise™ 2 MultiLeaf Collimator
- Standard Treatment Couch
- RoboCouch® Patient Positioning System
- Fiducial Tracking System

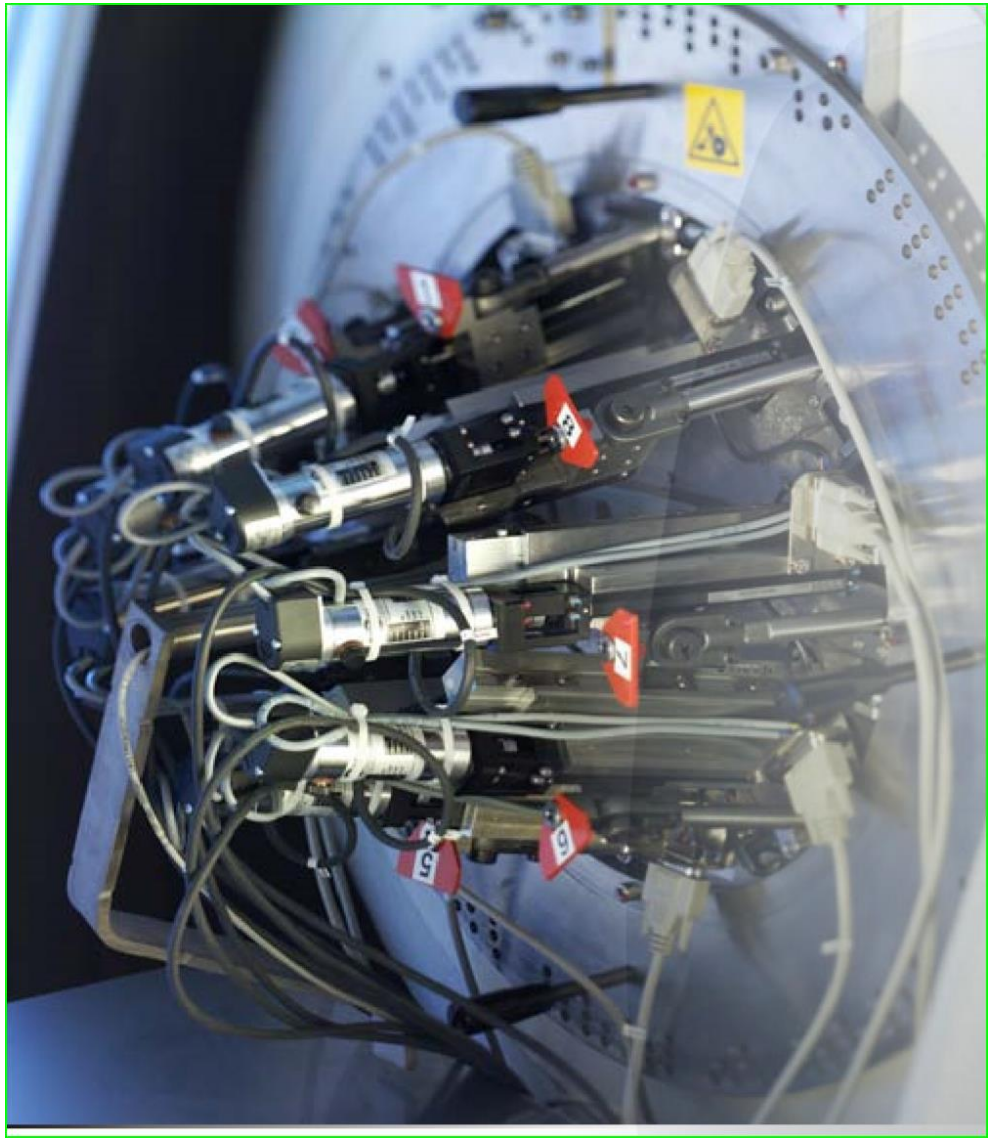
Leksell Gamma Knife® Perfexion™ (Elekta)





Gamma Knife® Perfexion™ collimators

- 192 Co-60 sources in 8 independently movable sectors on the collimator body
- 24 sources per sector
- Collimators of 4, 8 and 16 mm.
- At full loading (~6,300 Ci), dose rate > 3 Gy/min at focal point



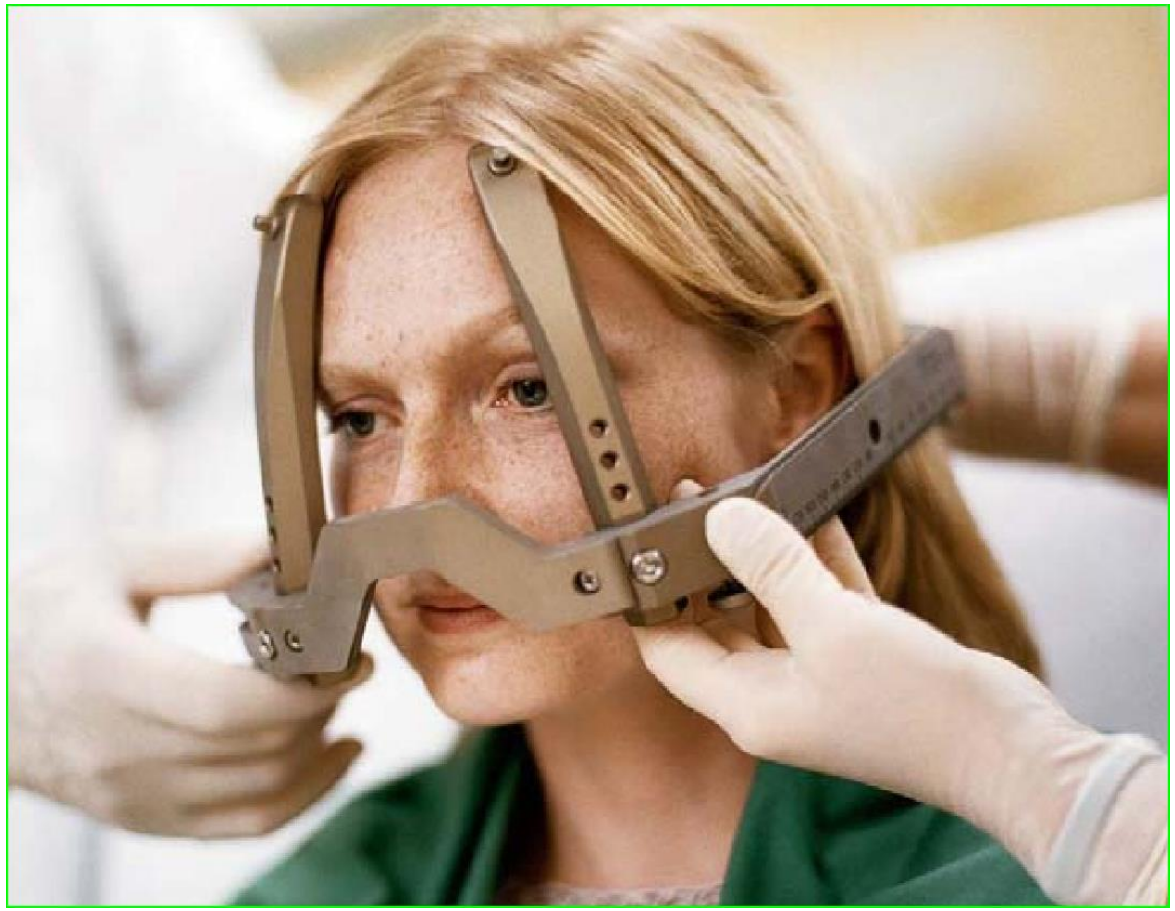
Gamma Knife® Perfexion™

- Radiological accuracy < 0.5 mm
- Position repeatability < 0.05 mm

Leksell Positioning system

Coordinate Frame for spatial reference and immobilization

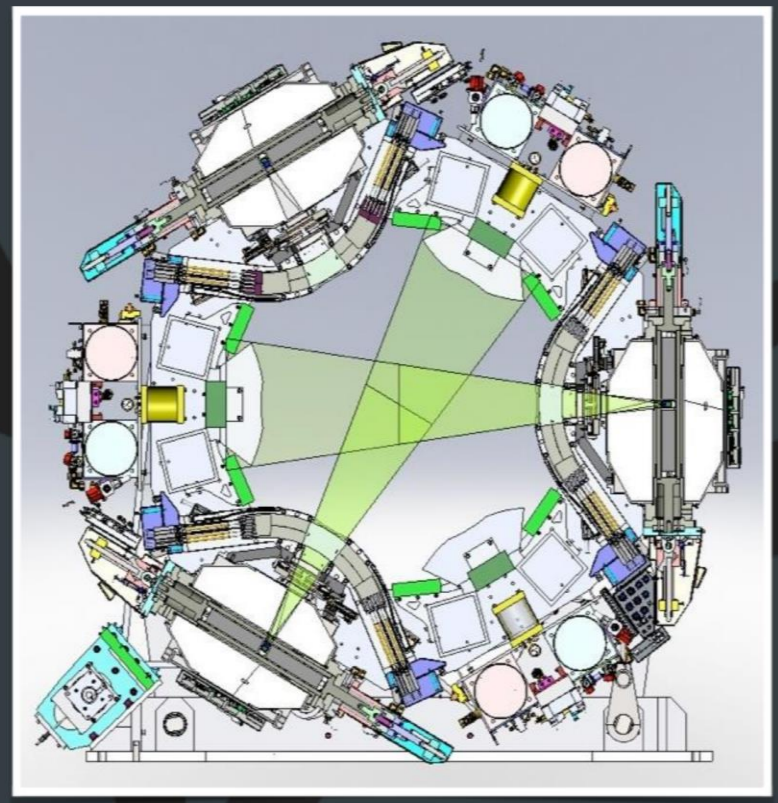
MR, CT or AI indicator boxes for reference fiducials during image acquisition



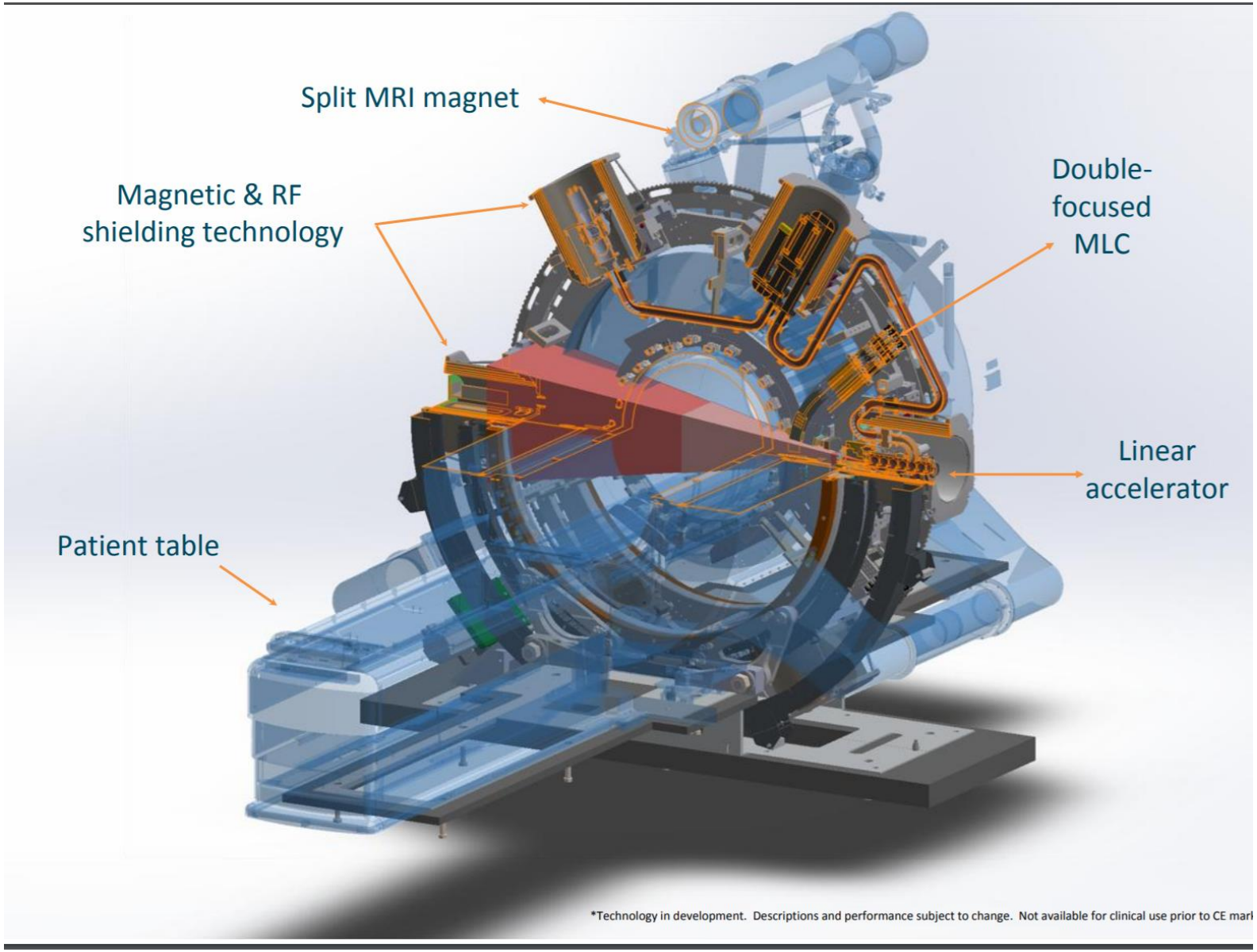
MRIdian (ViewRay)-Imaging and Therapy

MRI + 3 x Co-60

- Rotating Gantry Assembly
- 3 Independent Co60 Headed Design
  - Asynchronous Delivery
  - Mounted with 120 degree separation
  - 15,000 Ci per source
  - +-240 degree Rotation for 2 or 3 Head Operation for Maximum Reliability.
- 3 Doubly Focused MLC Systems
  - 180 MLC Leaves. 60 per Head
  - Best-in-class MLC for Reduced Penumbra & Interleaf Leakage



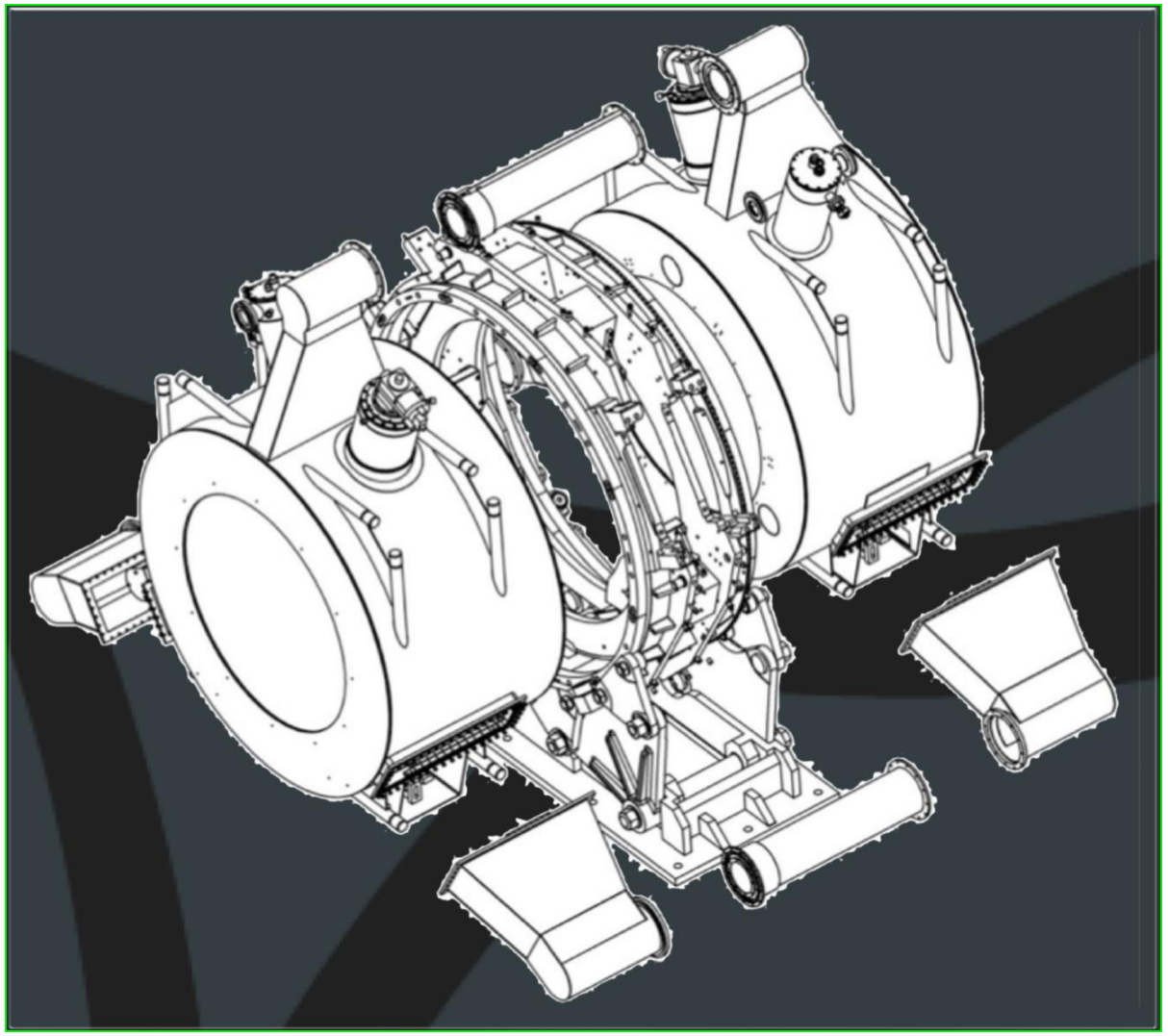
MRIdian (ViewRay)- MRI / Linac



MRIdian (ViewRay)- MRI / Linac

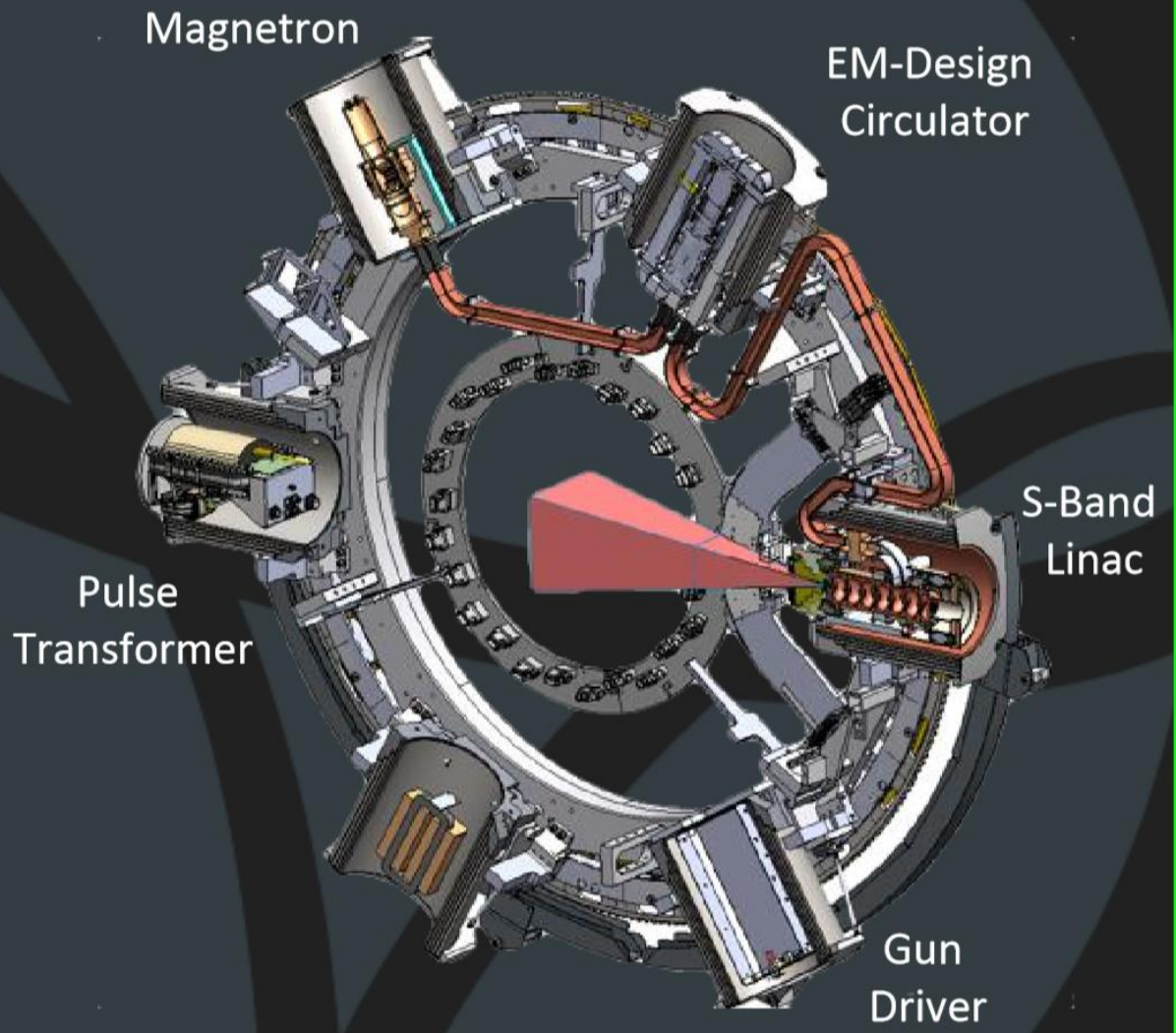
Interventional MR Imaging System

- Split 0.35T Superconducting Magnet
- Does not distort either image or dose during therapy
- 50cm Field of View
- 70cm Bore - accommodate large patients
- Fits in standard vaults.
- Pop-apart design for non-destructive rigging



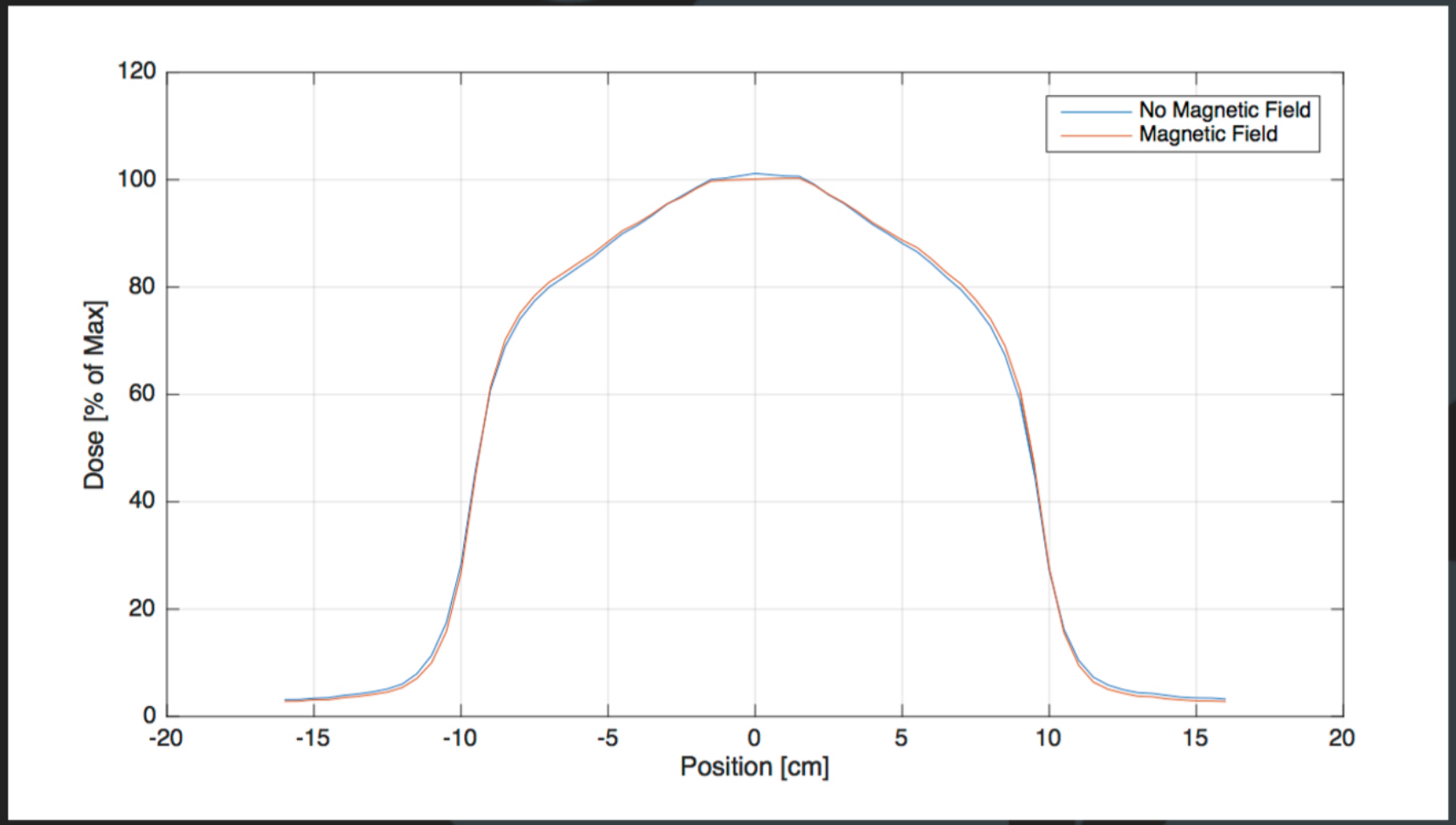
LINAC Based Radiation System*

- Compact inline S-Band 6 MV standing wave linac with side coupled cavities
  - flattening filter free
- Designed for >600 MU/min
  - IMRT, SBRT, Conformal therapies
- ±180º gantry rotation
  - 360º treatment around patient
- 5 RPM gantry rotation speed
  - Enables faster treatments



*Technology in development. Descriptions and performance subject to change. Not available for clinical use prior to CE mark

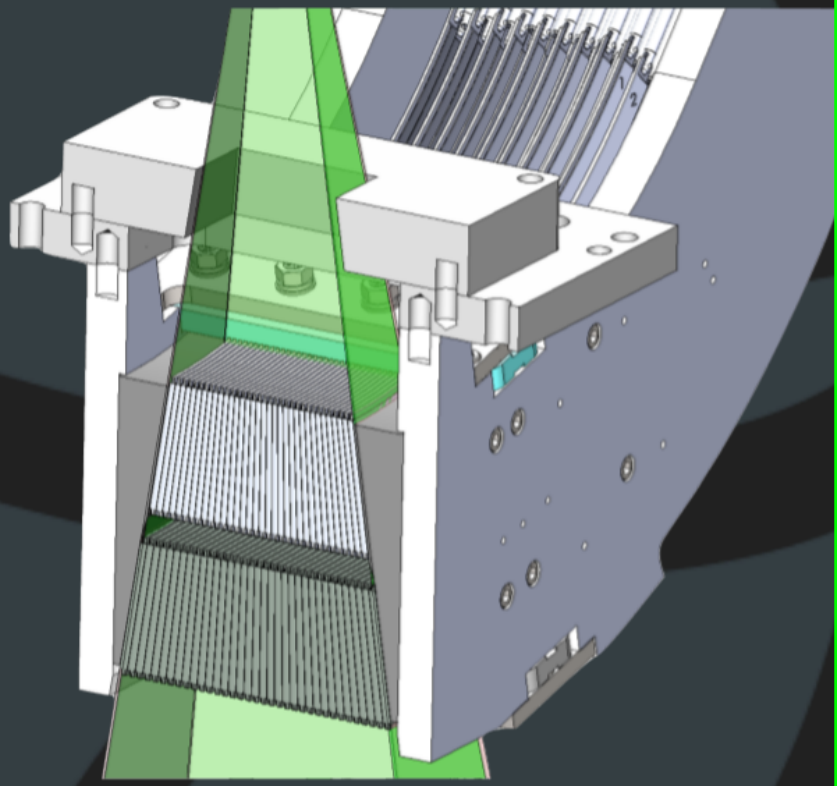
Beam Profile on MRIdian Linac* System



*Technology in development. Descriptions and performance subject to change. Not available for clinical use prior to CE mark

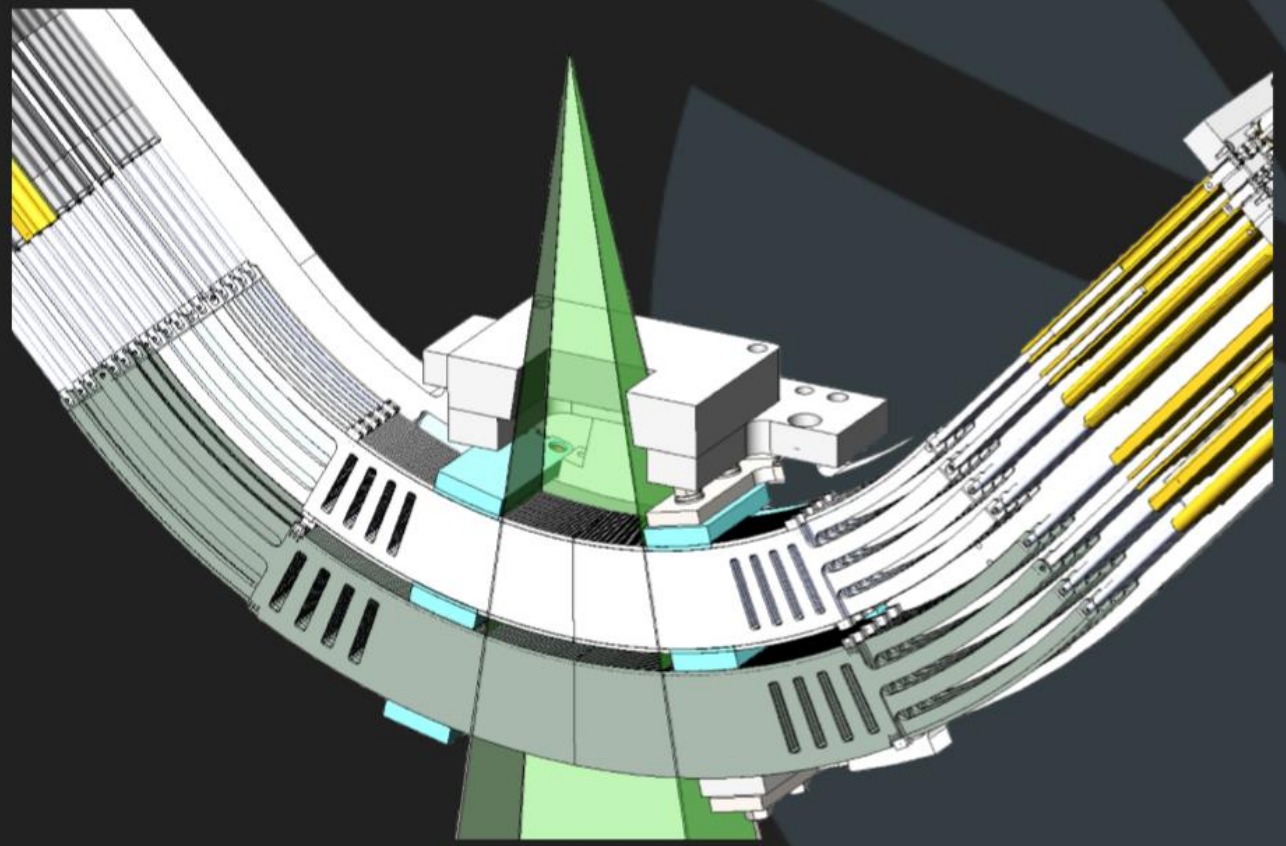
Double Stacked Double Focused MLC

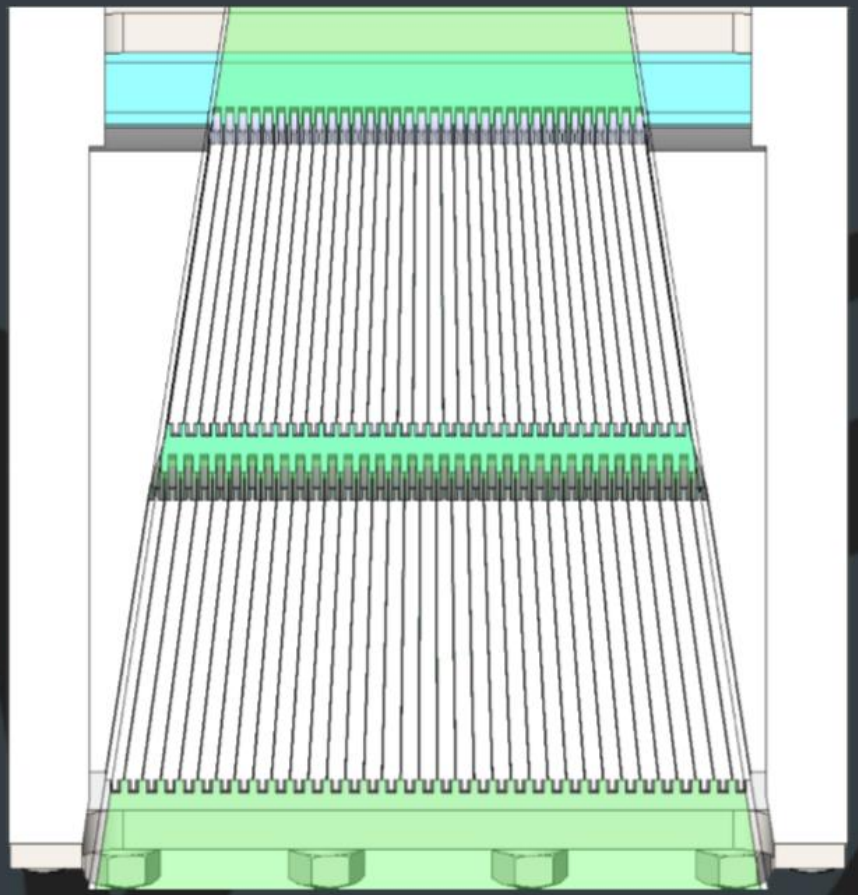
- 138 leaf Double-focus, Double-stack MLC
  - 68 leaf upper stack; 70 leaf lower stack
  - Upper stack offset by ½ leaf width
- Designed for SRS treatment
  - 2 mm x 4 mm minimum field size
- Best-in-class for reduced penumbra & interleaf leakage
  - Eliminates tongue and groove due to stack offsets
- Designed for 27cm x 27cm max field size
- Designed for 4 cm/sec leaf speed



*Technology in development. Descriptions and performance subject to change. Not available for clinical use prior to CE mark

Double Stacked Double Focused MLC Designed for SRS





*Technology in development. Descriptions and performance subject to change. Not available for clinical use prior to CE mark

Fits in Standard Treatment Room

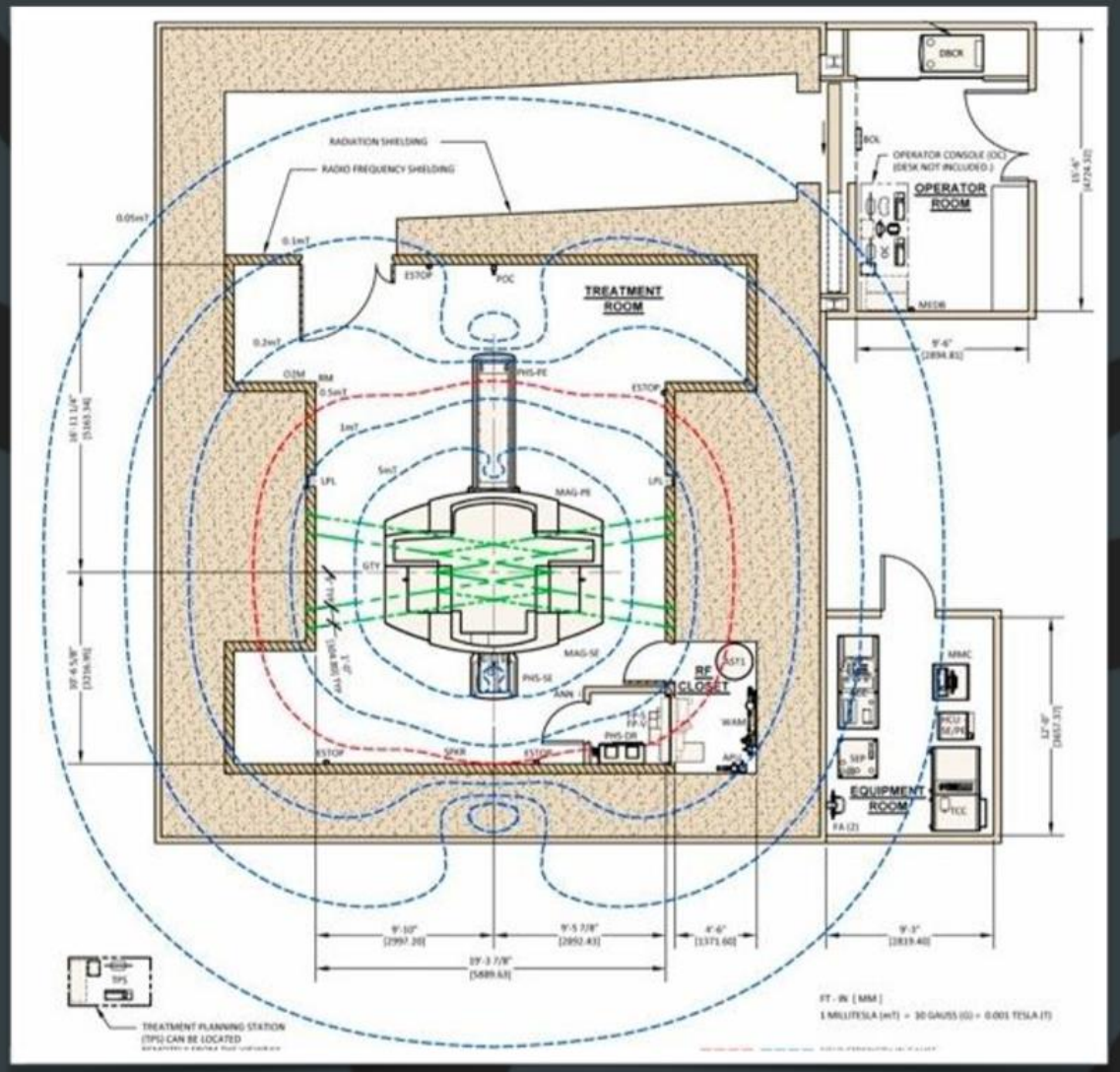
Space Requirements

Recommended Vault Size:
19’-2” (5.9 m) x 24’-8” (7.6 m)

Minimum Finished Ceiling Height:
9’-6” (2.9 m)

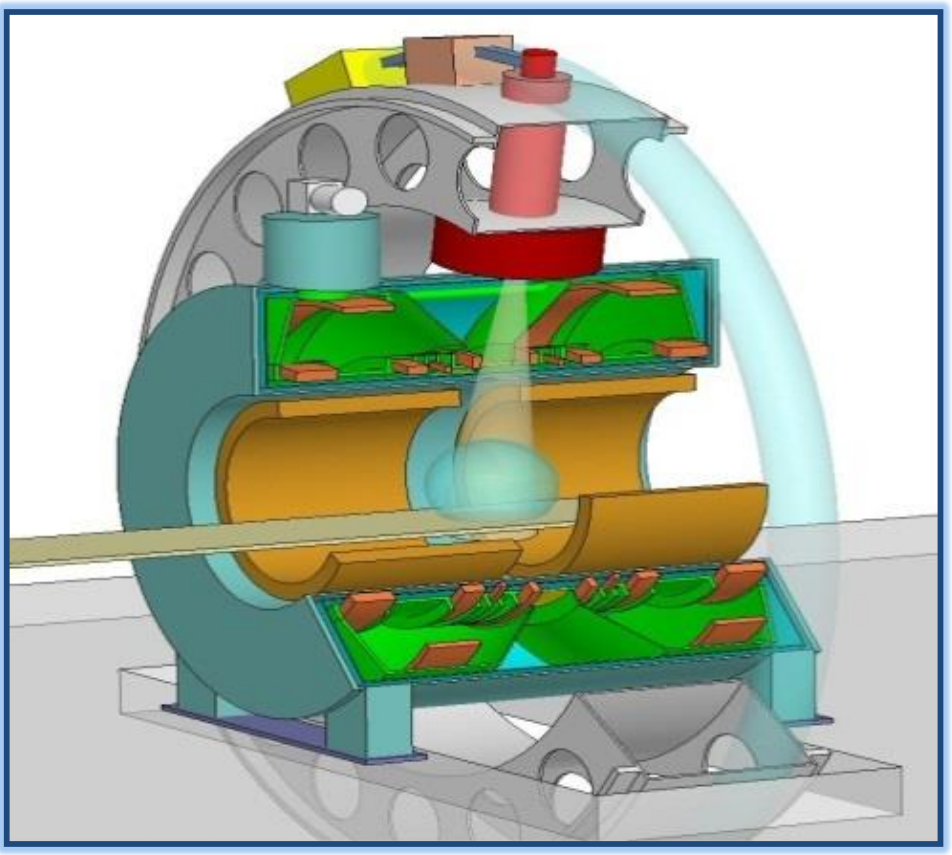
Minimum Clear Opening into Vault:
3’-11” (1.2 m) W x 6’-11” H (2.1 m)

Recommended RF Closet Size:
3’-8” (1.1 m) x 4’-0” (1.2 m)

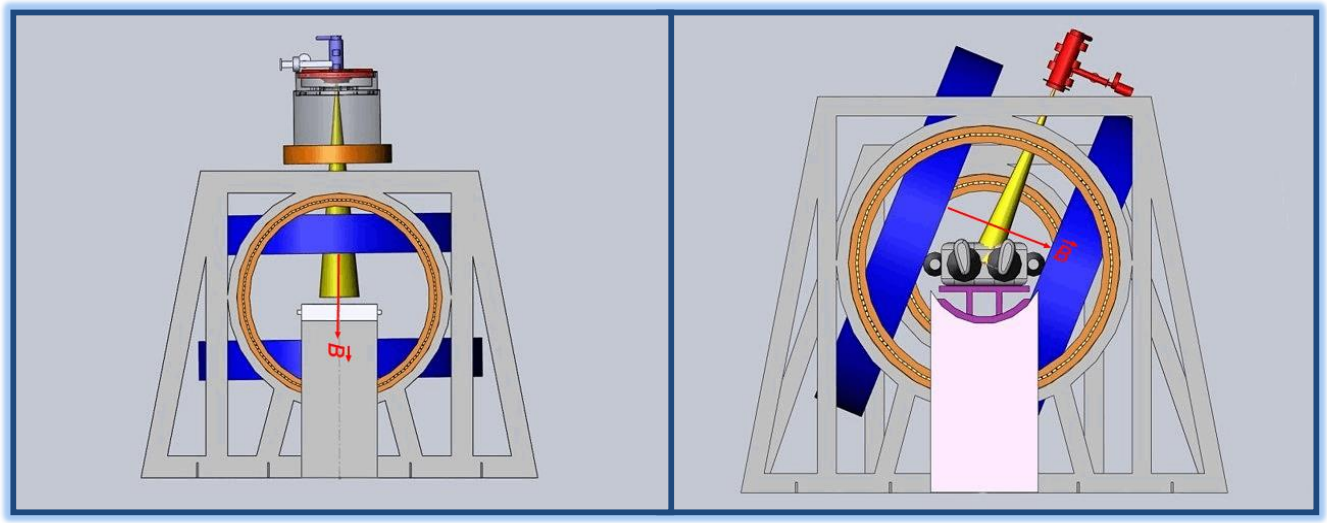


MRIdian (ViewRay)- MRI / Linac

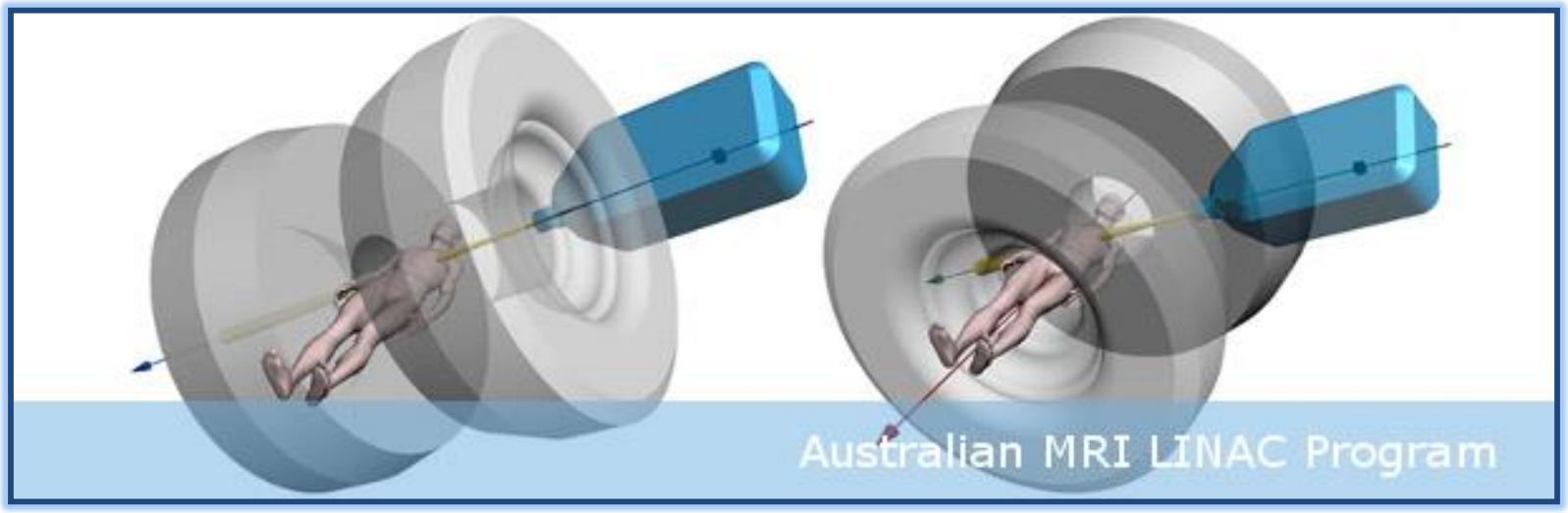
Other Linac/MRI systems



UMC Utrecht ELEKTA/Philips



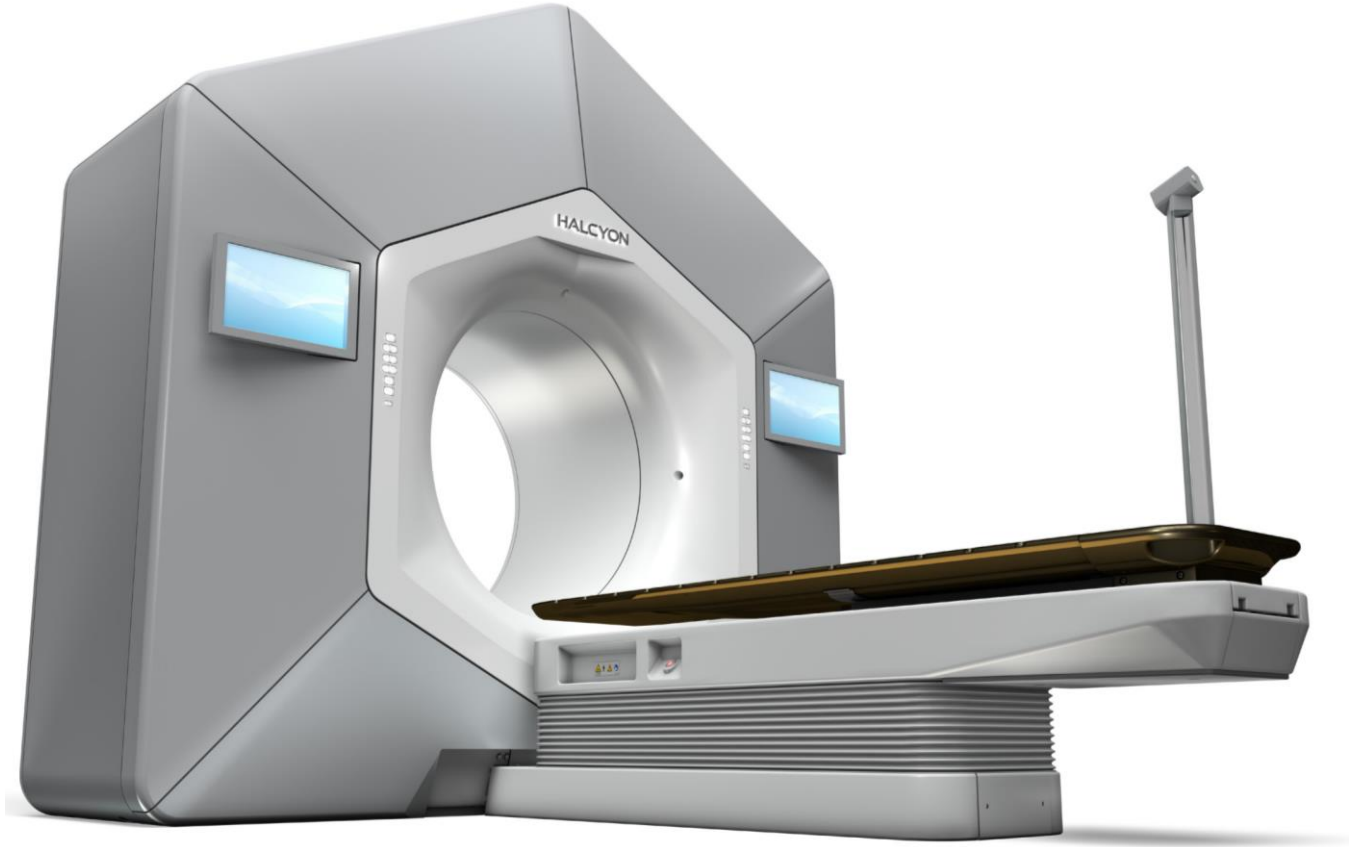
Alberta, Canada (G. Fallone)

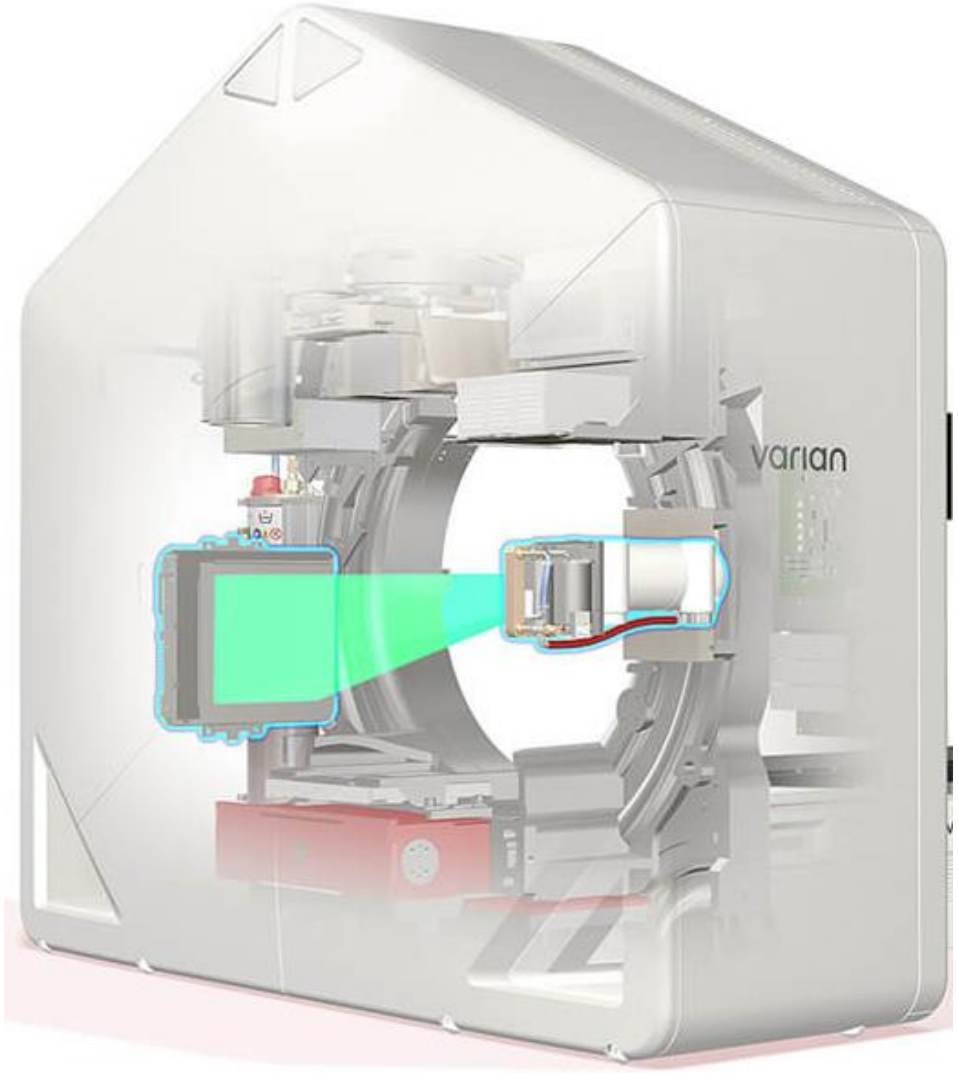


Figures from: Uwe Oelfke, Paul Keall

Halcyon

Integrated Imaging and Therapy





Halcyon – technical aspects

GANTRY	100 cm bore, linear-drive ring motor
STAND	Small footprint, no modulator cabinet, beam stopper
BEAM	6 FFF @ 800 cGy/min — Cone beam … Max field size: 28 cm x 28 cm
COLLIMATION	New, patented dual-layer MLC
IMAGING	100% IGRT, ~15 second MV CBCT — Optional kV CBCT
CONSOLE & CONTROL SYSTEM	Shared with TrueBeam™

Courtesy Paritosh Ambekar, Varian

Halcyon

Power Specifications

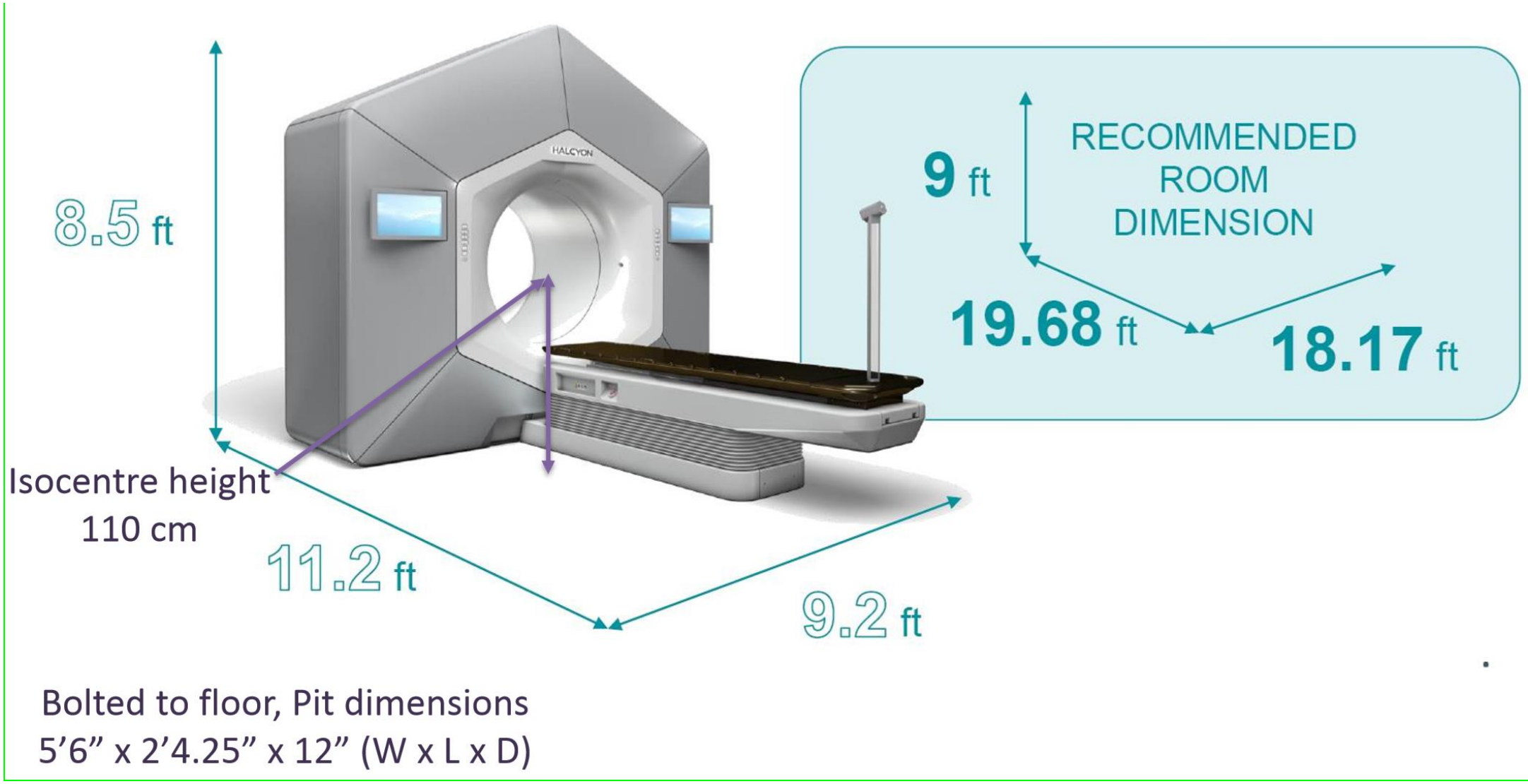
Table 9: Supported Power Configuration Specifications

Specifications	
Input Voltage for 3 Phase AC Power[1]	380 V: 50/60 HZ[2] Or 400–480 V: 50/60 HZ
Maximum Power[1]	18 kVA[2] Or 15 kVA

[1] Configuration depends on the country of use.

[2] Requires a transformer that will be included with the system.

Halcyon – technical aspects

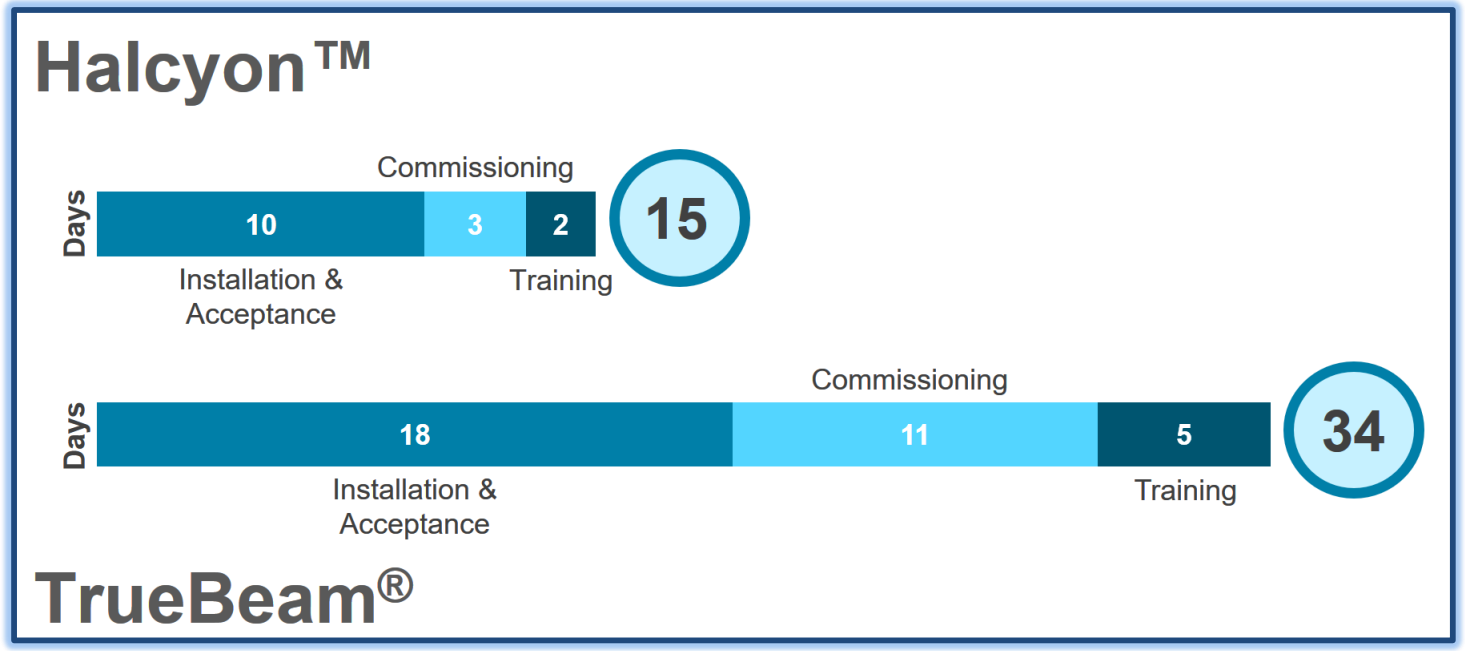


Bolted to floor, Pit dimensions
5’6” x 2’4.25” x 12” (W x L x D)

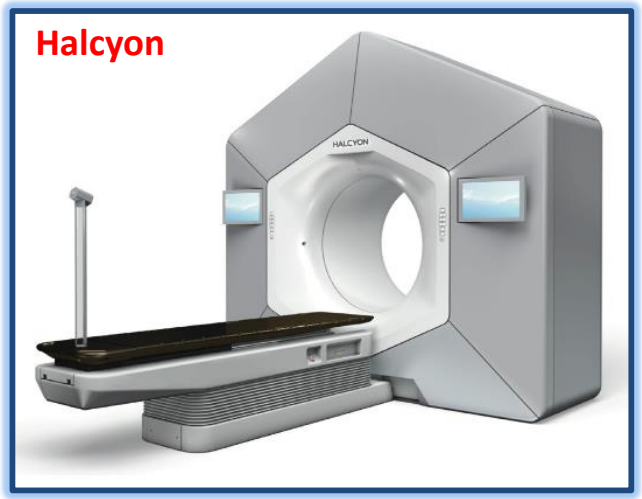
Technology advantages

- More efficient
  - VMAT, TomoTherapy, Halcyon

Example: Installation, commissioning, training



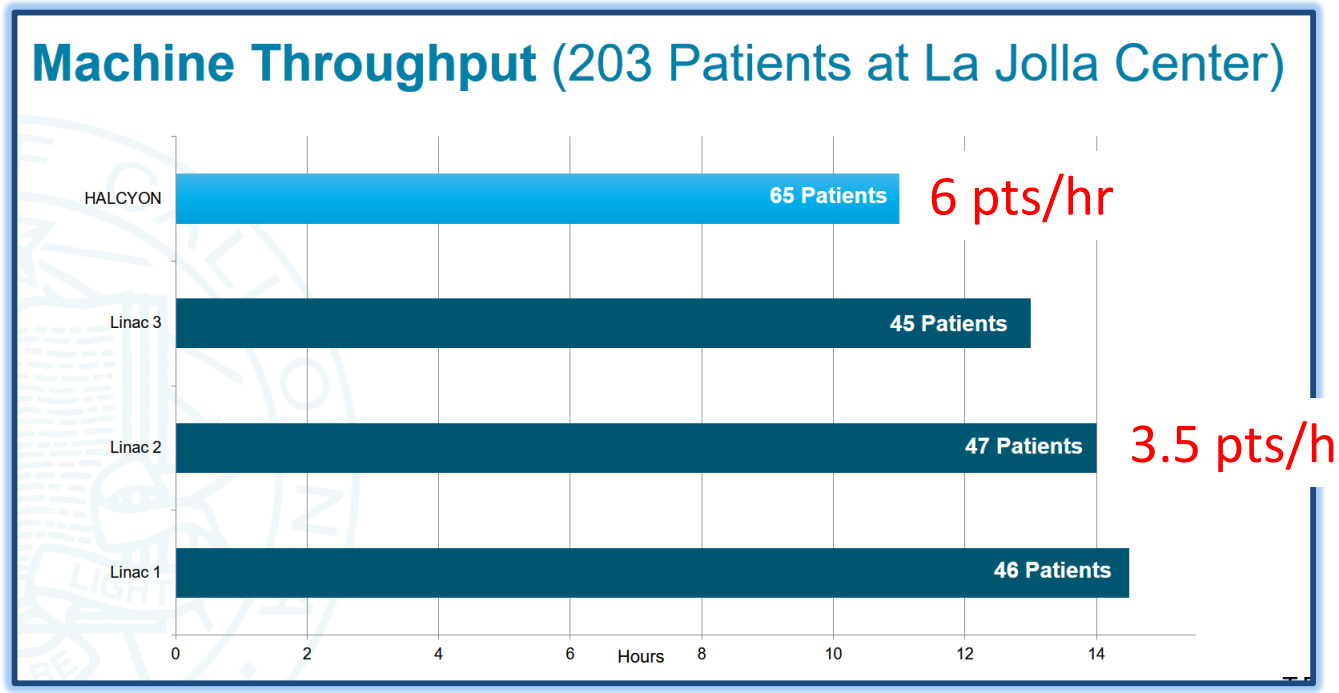
Courtesy
T.F. Atwood, UCSF
Sept 2018



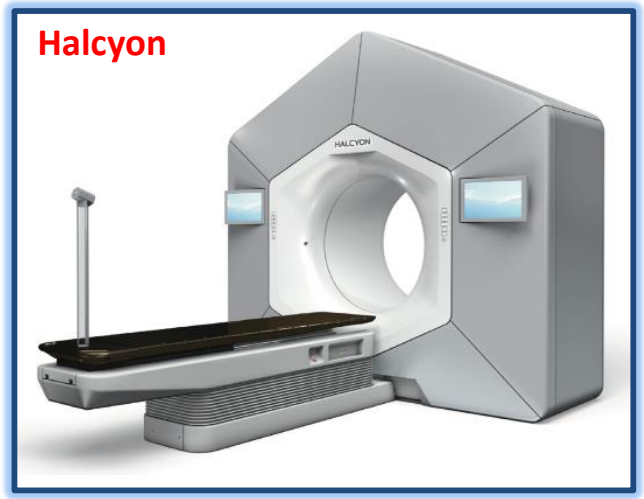
Technology advantages

- More efficient
  - IMAT, TomoTherapy, Halcyon

Example: Patient throughput



Courtesy
T.F. Atwood, UCSF
Sept 2018



Other ideas

Fixed source and Imager Move the patient.

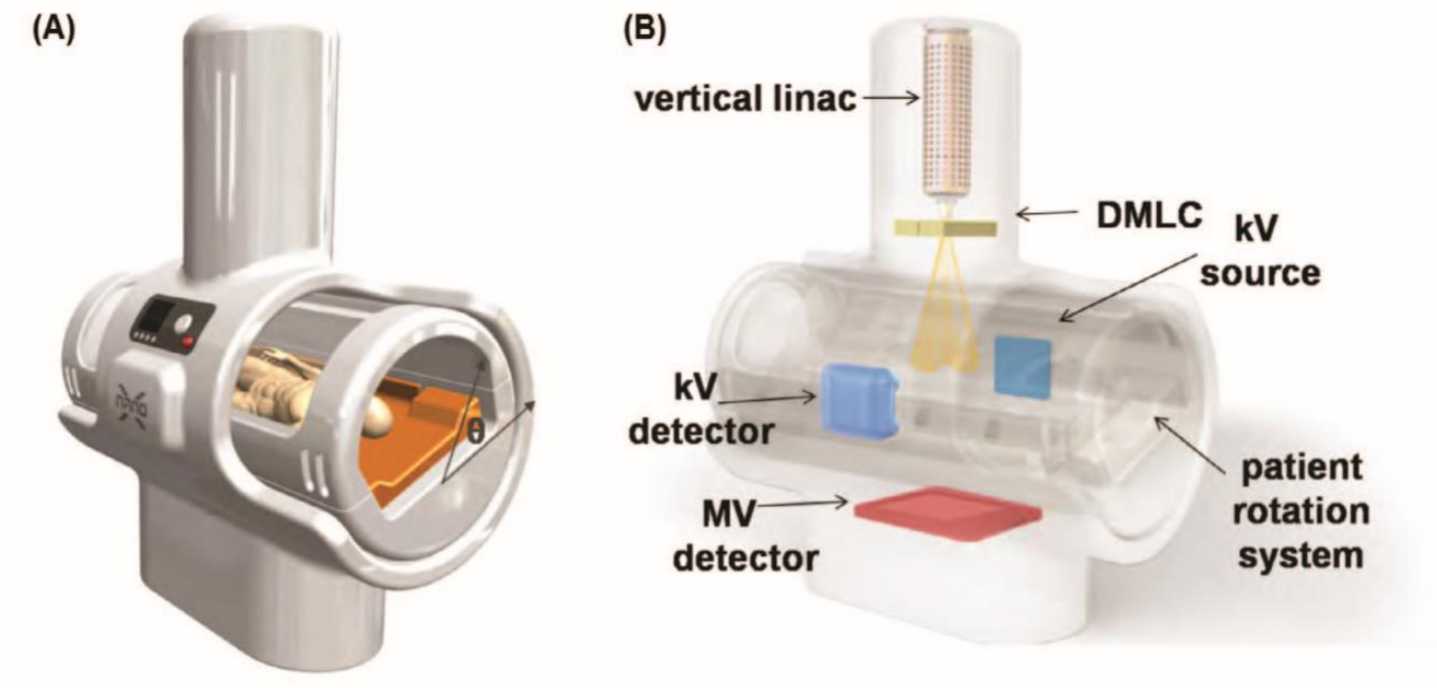


Figure 2: (**A**) Proposed Nano-X prototype design. (**B**) Schematic of the Nano-X main functional components, showing the vertical linac; DMLC for intensity modulation and real-time adaptation; kV source and detector and MV detector for image guidance; and the patient rotation system for multiple beam angle and VMAT treatments.

Other ideas

- Fixed source and Imager
- Move the patient.

physicsworld

RADIOTHERAPY RESEARCH UPDATE

Patient rotation enables fixed-beam radiotherapy system

14 Feb 2019

The prototype radiotherapy system combines a fixed vertical radiation beam with horizontal patient rotation. (Courtesy: Paul Liu)

Thank you!