# Commissioning and Radiation Safety Aspect of Image Guided Radiation Therapy System for Proton Beam Therapy

Rohidas Punde
Medical Physicist
Proton Therapy Centre
Advanced Centre for Treatment, Research And Education in Cancer, Tata Memorial Centre, Mumbai, INDIA

Joint ICTP-IAEA Workshop on Radiation Protection in Image-Guided Radiotherapy(IGRT) Trieste, Italy, 7-11 Oct 2024.

# Contents

- Background and Objective
- Methods and Materials
- Results
- Conclusions

# Background

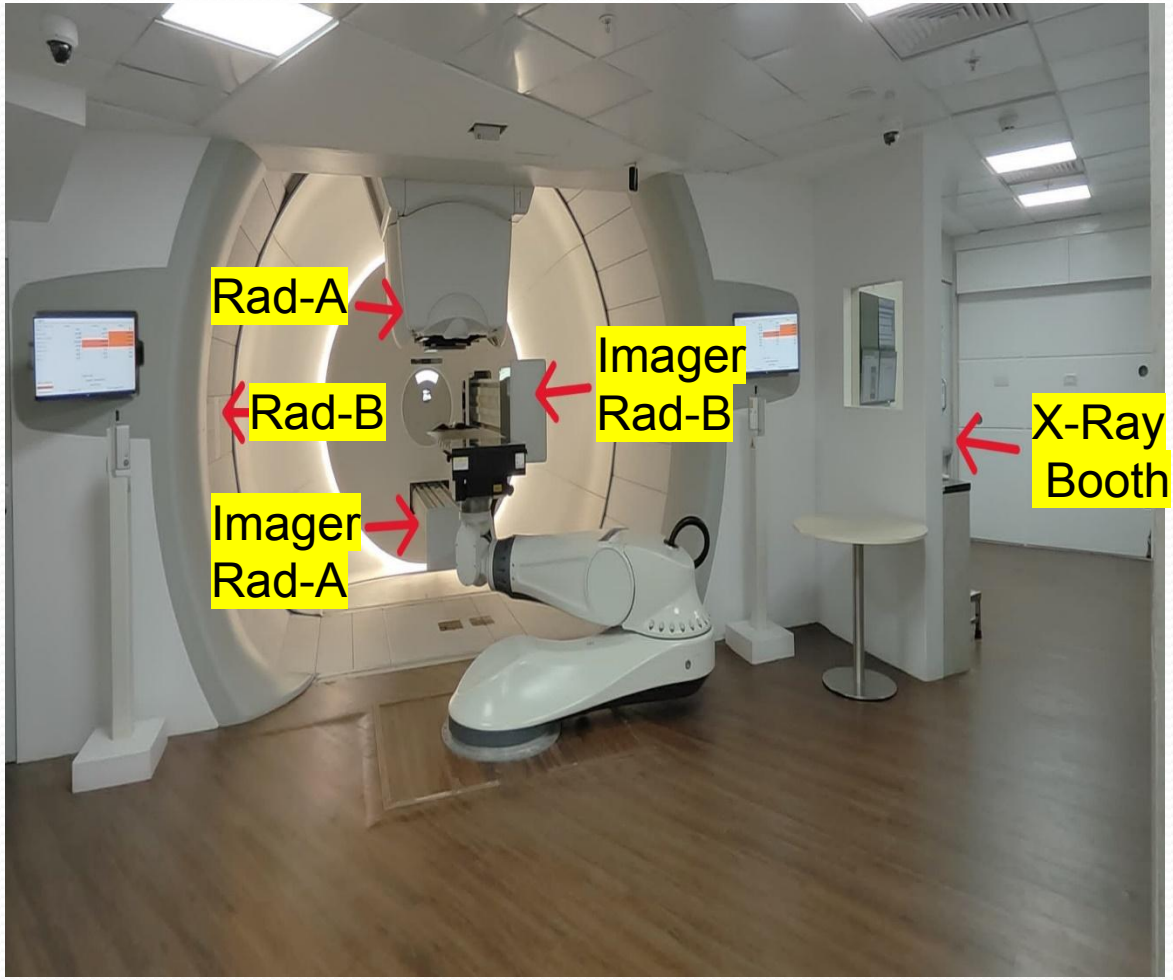
- Image-Guided Radiation Therapy (IGRT) is a crucial component in the delivery of precise and effective Radiotherapy.

- Proton therapy, a type of radiation treatment that uses protons rather than X-rays to treat cancer, benefits significantly from IGRT due to the need for high precision in targeting tumors while minimizing damage to surrounding healthy tissues.

# Objective

- To address the commissioning process of the IGRT system in proton therapy
- To evaluate the radiation safety aspects

# Methods and Materials




- Proteus Plus proton therapy Unit (IBA Belgium)
- Two X-Ray Tube- Rad A and Rad B
- Two Imager Pannel corresponding to each tube
- X-Ray Booth inside the treatment room

# Methods and Materials

**X-ray Tube and Imager details for GTR3**

| | Rad A | Rad B |
|---|---|---|
| Make | Varian Medical Systems | Varian Medical Systems |
| Model | A277 | GS2075 |
| Anode Type | Rotating Anode | Rotating Anode |
| Anode Material | Rhenium-Tungsten Molybdenum | Tungsten-Rhenium Molybdenum |
| X-Ray Tube Location | Gantry Nozzle ($0^{o}$) | Gantry Mounted (at $270^{o}$) |
| Maximum Tube Potential (kV) | 150 | 150 |
| Maximum Tube Current (mA) | 1000 | 1000 |
| Focal spot size (mm) | 0.6 – 1.0 | 0.7 x 1.2, 1.2x1.5 (Large Focal Spot used for Imaging) |
| | | |
| Imager Type | | |
| Imager Serial Number | 44S02-1402 | 172041 |
| Source to Imager Distance (mm) | 1208 | 2627 |
| FOV | 40cm x 30cm | 43cm x 43cm |
| | | |

**Rad A & Rad B : kV Planer imaging**

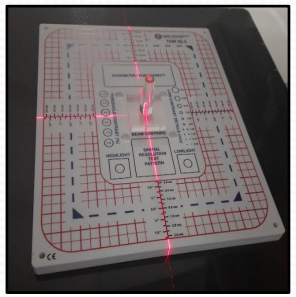
**Rad B : Volumetric kV imaging (CBCT)**

# Portal X-ray QA Test

| Sr No | Parameters | Observation | Tolerance Limit |
|---|---|---|---|
| 1 | Accuracy of kVp | Rad A = 2.4 kVp<br>Rad B = 4.8 kVp | ± 5 kVp |
| 2 | Reproducibility of kVp | Rad A = 0.44 %<br>Rad B = 0.87 % | ≤ 5% |
| 3 | Reproducibility of the Exposure time | Rad A = 2.36 %<br>Rad B = 0.69 % | ≤ 5% |
| 4 | Linearity of Exposure time | Rad A = 1.0<br>Rad B = 1.0 | Between 0.95 and 1.05 |
| 5 | High Contrast Spatial Resolution (Planer Imaging) | Rad A = 2.8 lp/mm , Rad B = 3.1 lp/mm | > 2.5 lp/mm at 70 kV |
| 6 | Low Contrast Sensitivity (Planer Imaging) | Rad A = 0.9 %<br>Rad B = 0.9 % | < 2.8% (typical <2%) |
| 7 | Stereo X-ray Correction Vectors Performance (point-based) | 0.46 mm , 0.2° | ≤ 1mm, Rotation ≤ 1° |
| 8 | Accuracy of focal spot size (f) | Rad A = 1.12 mm<br>Rad B = 1.2 mm<br>X 1.57 mm | +0.5f for f < 0.8mm, +0.4f for f between 0.8 to 1.5mm, +0.3f for f >1.5mm |

| Sr no | Parameters | Observation | Tolerance Limit |
|---|---|---|---|
| 9 | Accuracy of timer | Rad A = 3.8 %<br>Rad B = 4.4 % | 10% |
| 10 | Linearity of mA station | Rad A : CoL=0.015<br>Rad B: CoL=0.025 | CoL≤0.1 |
| 11 | Output Consistency | Rad A : CoV=0.007<br>Rad B: CoV=0.012 | CoV≤0.05 |
| 12 | Total filtration (mm of Al) of the x-ray tube | RAD A: 1.7 mm Al for kV≤ 70 kV, 4.4 mm Al for 70 < kV ≤100, 6.1 mm Al for kV >100, RAD B: 2.5 mm Al for kV≤ 70 kV, 3.8 mm Al for 70 < kV ≤100, 6.2 mm Al for kV >100 | 1.5 mm Al for kV≤ 70 kV, 2.0 mm Al for 70 < kV ≤100, 2.5 mm Al for kV >100 |

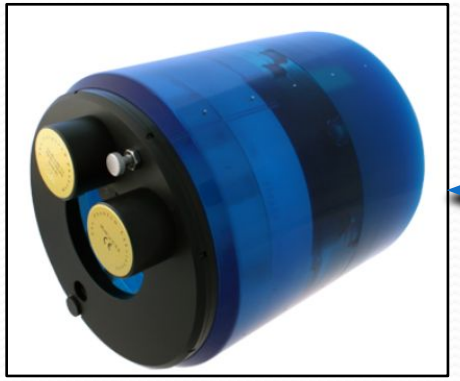
Raysafe Xi detectors



Tor IQ

# CBCT QA

| Sr no | Parameters | Observation | Tolerance Limit |
|---|---|---|---|
| 1 | Scale and Distance Accuracy (CBCT) | 0.72% | 1% |
| 2 | CT Number Accuracy (CBCT) | -35.5 HU | ± 40 HU |
| 3 | High Contrast Spatial Resolution (CBCT) | 7 lp/cm | ≥7lp/cm |
| 4 | Uniformity | 25.3 HU | ± 40 HU |
| 5 | Low contrast sensitivity (CBCT) | 9 mm | 15 mm @ 1 % |
| 6 | CBCT Correction vectors performance (Intensity -based) | Trans.= 0.5 mm Rotation = 1° | Translation ≤ 1 mm, Rotation < 1° |
| 7 | Positional/re-positional accuracy of imager | 0.41 mm | ≤ 1 mm |



CatPhantom

## Formation of IGRT QA Programme

- AAPM TG 224
- AAPM TG 179
- AAPM TG 142
- AAPM MPPG 2.b

# CBCT Preset Validation using Anthropomorphic Phantom

Total 12 CBCT presets were validated.

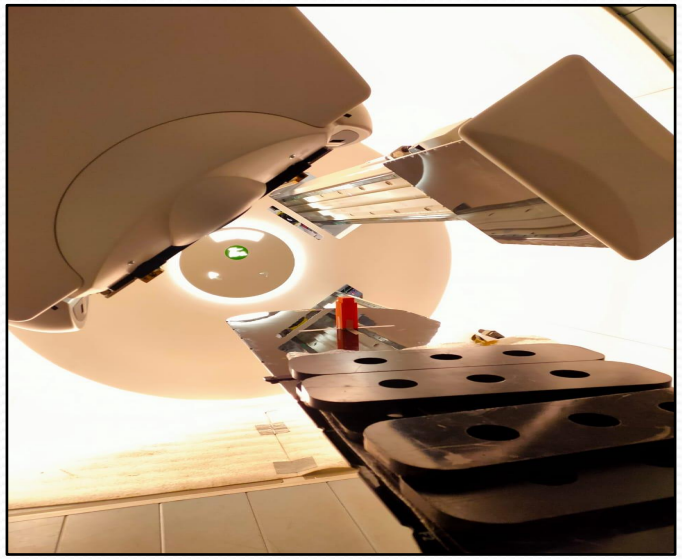
Optimization must be done between image quality and radiation dose.

# CBCT Preset/Protocol & CTDI measurement

| Sr No | Preset/Protocol Name | Tube Voltage (KVp) | Total mAs | Tube Current (mA) | FOV (cm) | Slice Width (mm) | Scan Speed | $CTDI_{vol}$ (mGy) |
|---|---|---|---|---|---|---|---|---|
| 1 | Head high contrast | 100 | 2277.5 | 250 | Small (26) | 2.5 | Low | 6.1 |
| 2 | Head Low Dose | 80 | 472 | 100 | Small (26cm) | 2.5 | High | 1.1 |
| 3 | Head & Neck | 120 | 2277.5 | 250 | Medium(35cm) | 2.5 | Low | 13.1 |
| 4 | Thorax Lung | 110 | 2915.2 | 320 | Medium(35cm) | 2.5 | Low | 14.5 |
| 5 | Thorax High Speed | 110 | 1180 | 250 | Medium(35cm) | 2.5 | High | 5.6 |
| 6 | Thorax Breast | 120 | 2277.5 | 250 | Large(50 cm) | 2.5 | Low | 10.2 |
| 7 | Abdomen High speed | 125 | 1510.4 | 320 | Medium(35cm) | 2.5 | High | 9.6 |
| 8 | Pelvis Large | 125 | 2915.2 | 320 | large(50cm) | 2.5 | Low | 15.1 |
| 9 | Pelvis Medium | 125 | 2915.2 | 320 | medium(35) | 2.5 | Low | 18.8 |
| 10 | Pediatric Medium | 90 | 590 | 125 | medium(35) | 2.5 | High | 2.2 |
| 11 | Pediatric small | 90 | 590 | 125 | small(26) | 2.5 | High | 2.1 |
| 12 | Body High Dose | 125 | 2915.2 | 320 | Medium(35cm) | 2.5 | Low | 18.9 |

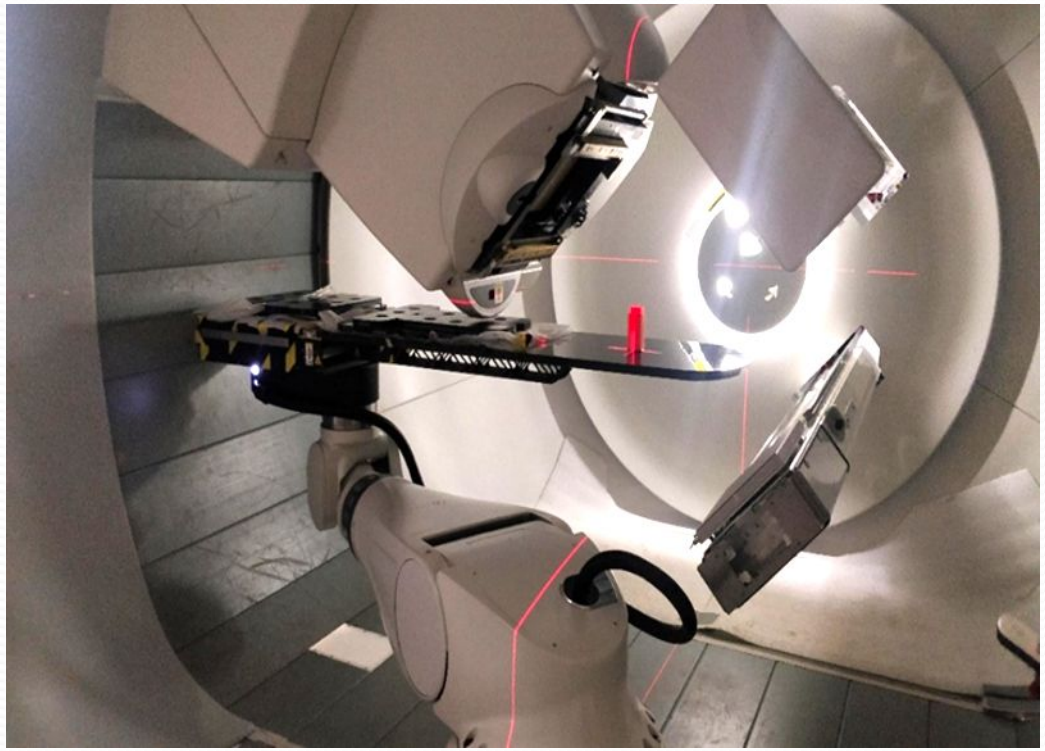
# Coincidence of Isocentre of treatment Gantry and kV Imaging system

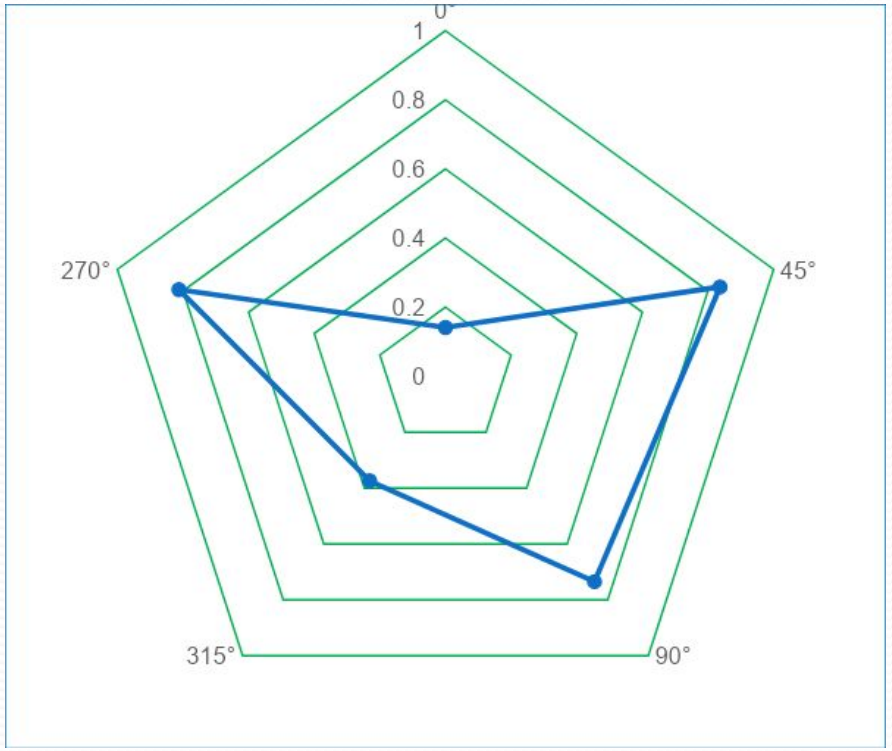
| | |
|---|---|
| Tolerance: | ≤ 2.0 mm dia |
| Setup: | BB ball placed on PPS at isocentre and orthogonal image taken at each gantry angle |
| Shift = | $\sqrt{(\Delta x2 + \Delta y2 + \Delta z2)}$ |
| | Δx,Δy and Δz are the residual error vectors along X, Y and Z-axis |




Maximum shift 0.20 mm at 225° Gantry angle

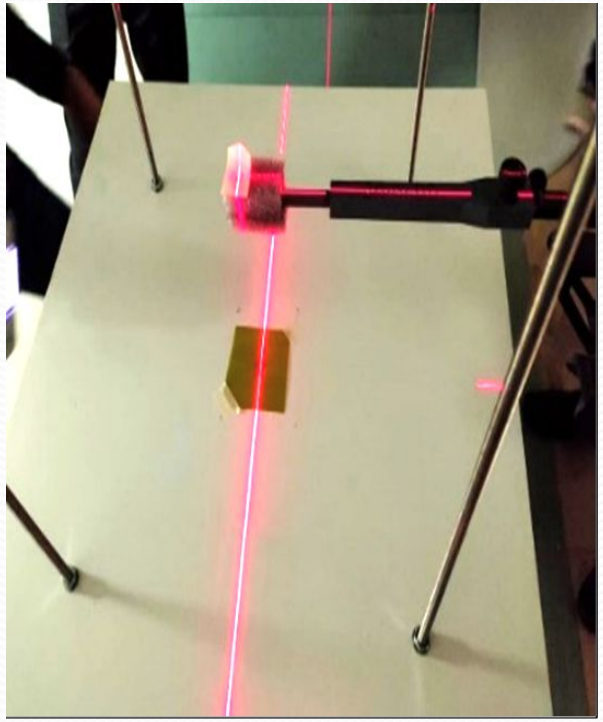
# Coincidence of isocentre of treatment Couch and kV Imaging system

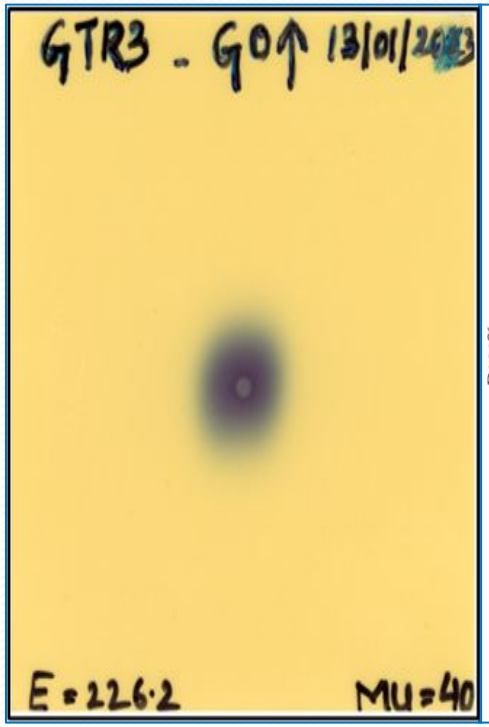


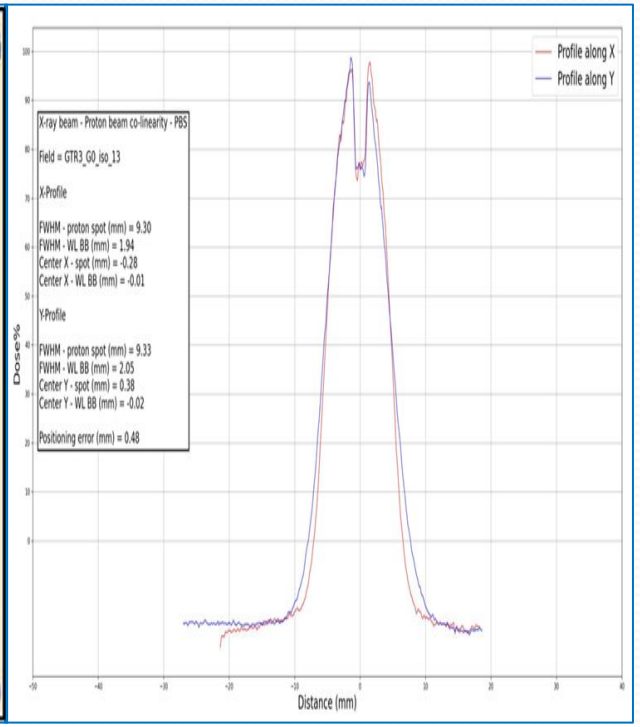


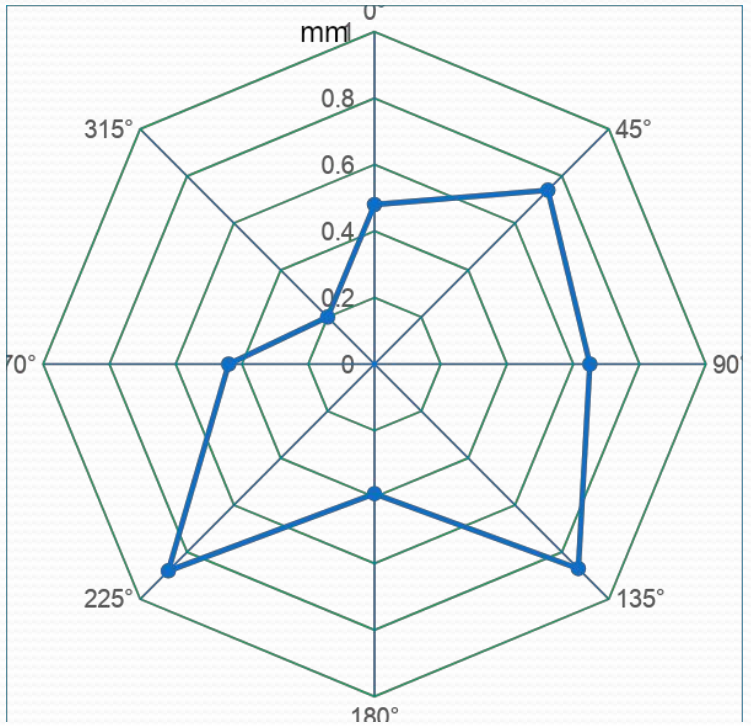

Maximum shift 0.84 mm at 45° couch angle

# Coincidence of Isocenter between *Proton Beam and KV imaging system*






Maximum shift 0.88 mm at 225° Gantry angle

# Radiation Safety Aspect:

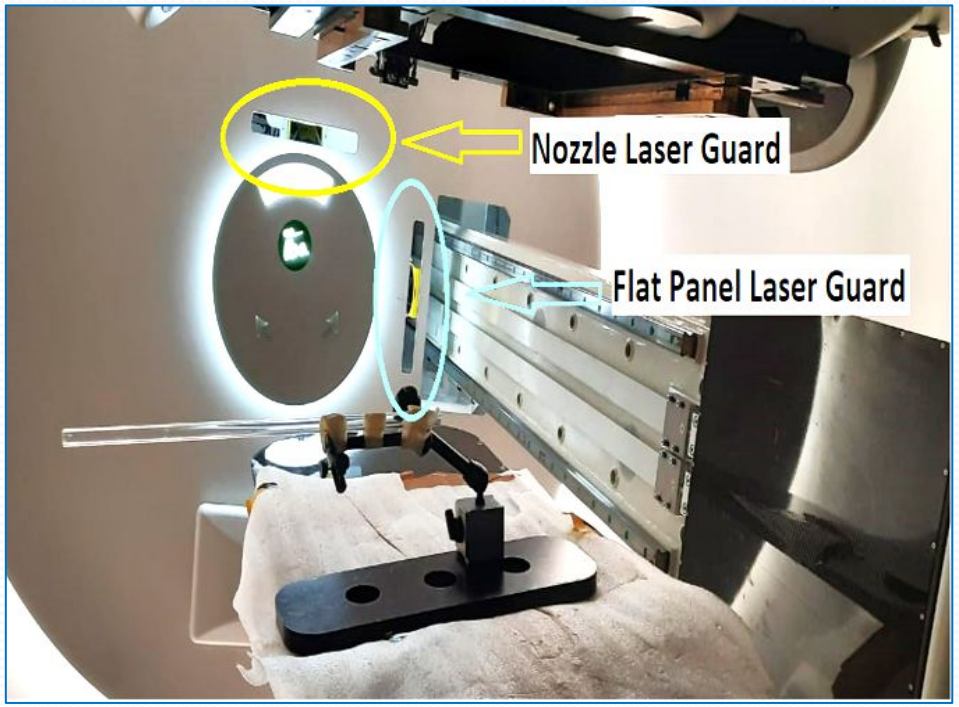

X-Ray ON Indicator Near treatment Door


X-Ray ON Indicator in Maze Wall

Maze Motion Detector

# Radiation Safety Aspect:

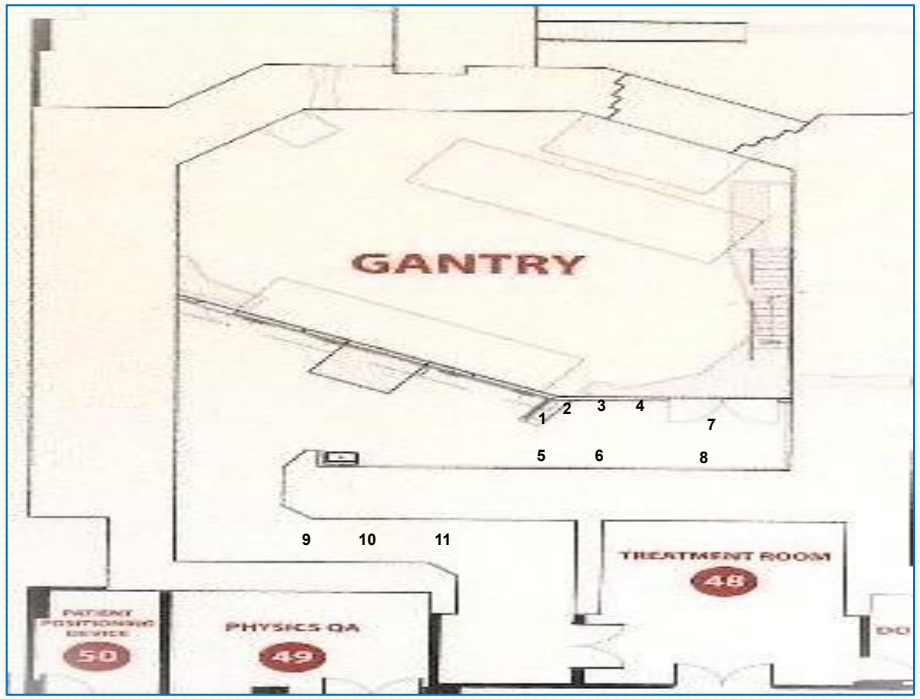

Emergency Stop buttons at both control console



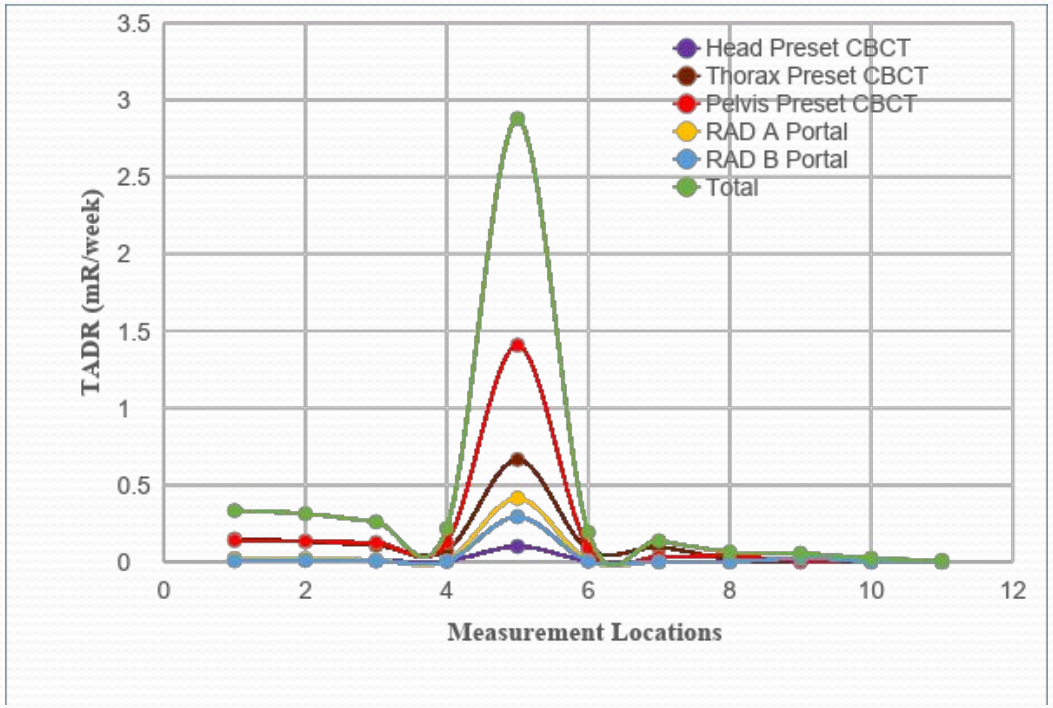

Collision Detection System

# Radiation Protection Survey:

Ion Chamber Survey Meter 451P series




Layout of gantry room with Measurement locations




The total maximum TADR was found to be 2.1 mR/Week during CBCT and 0.70 mR/Week during portal KV imaging.

# Conclusions

- The commissioning of the IGRT system in the proton therapy system was done successfully.
- While commissioning IGRT system optimization of imaging protocol must be done by minimizing the radiation dose while considering acceptable image quality.
- The extensive radiation protection survey shows the X-ray booth is safe to perform imaging inside the treatment room.
- All safety measures were taken into account before giving IGRT system for patient imaging.


# THANK YOU