Proton Therapy QA & Operations
Loma Linda University Medical Center

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LOMA LINDA UNIVERSITY
MEDICAL CENTER

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Facility Overview

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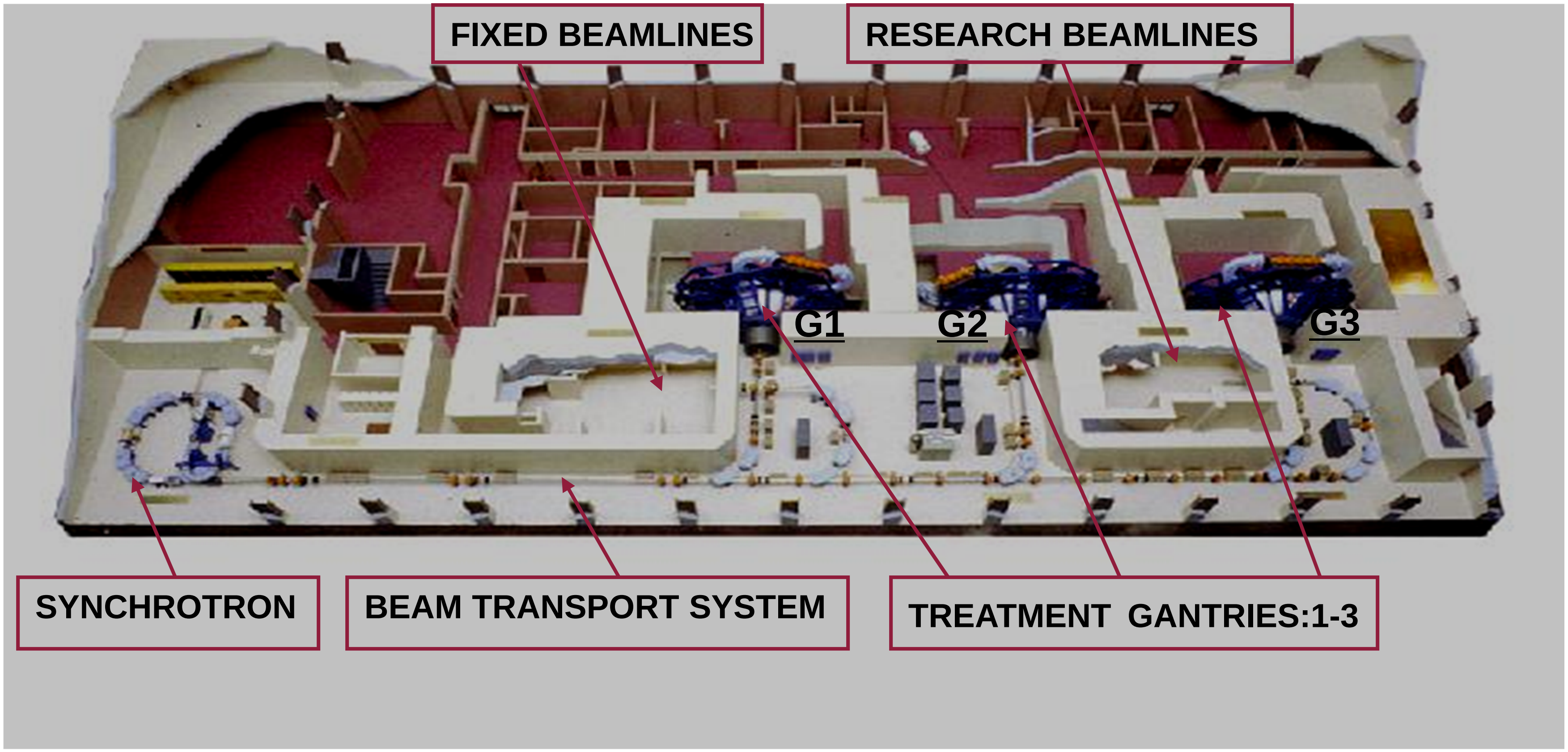
Operations

James M. Slater, MD, Proton Therapy and Research Center

World's first hospital based proton treatment facility (1990)

- Accelerator: a synchrotron
- Passive beam scattering
- Four treatment rooms, Five treatment beam lines
  - three isocentric gantries
    - one with robotic patient positioner
  - one horizontal beam line
  - one fixed eye beam line
- One research room (3 horizontal beam lines)
- Variable energy capability with energies up to 250 MeV
- Accelerator runs 6 days a week, 24 hrs. a day
- One day per week for repair and preventive maintenance
- Active beam scanning (ABS) under development

Proton Treatment Facility Layout



Typical Proton Facility Weekly Usage

MODE	HOURS	PERCENTAGE
Treatment	94	56%
Calibration	24	14%
Maintenance	12	7%
Research	10	6%
Upgrades	16	10%
Operations	5	3%
Other	7	4%
TOTAL	168	100%

Timeline of a Proton Treatment @LLUMC

Procedure	Time Needed	Time before Tx
Patient orientation & education	1-2 hours	7-10 days
Patient immobilization & imaging	15-30 min	7-10 days
Treatment planning & plan QA	1- 3 days	5-8 days
Device manufacture & calibration	1 day	1-3 days
Treatment session	15-45 min	….
Patient setup	5-10 min	…..
Alignment verification & approval	5-25 min	…..
Treatment	2-5 min	….
Room reset	2-5 min	….

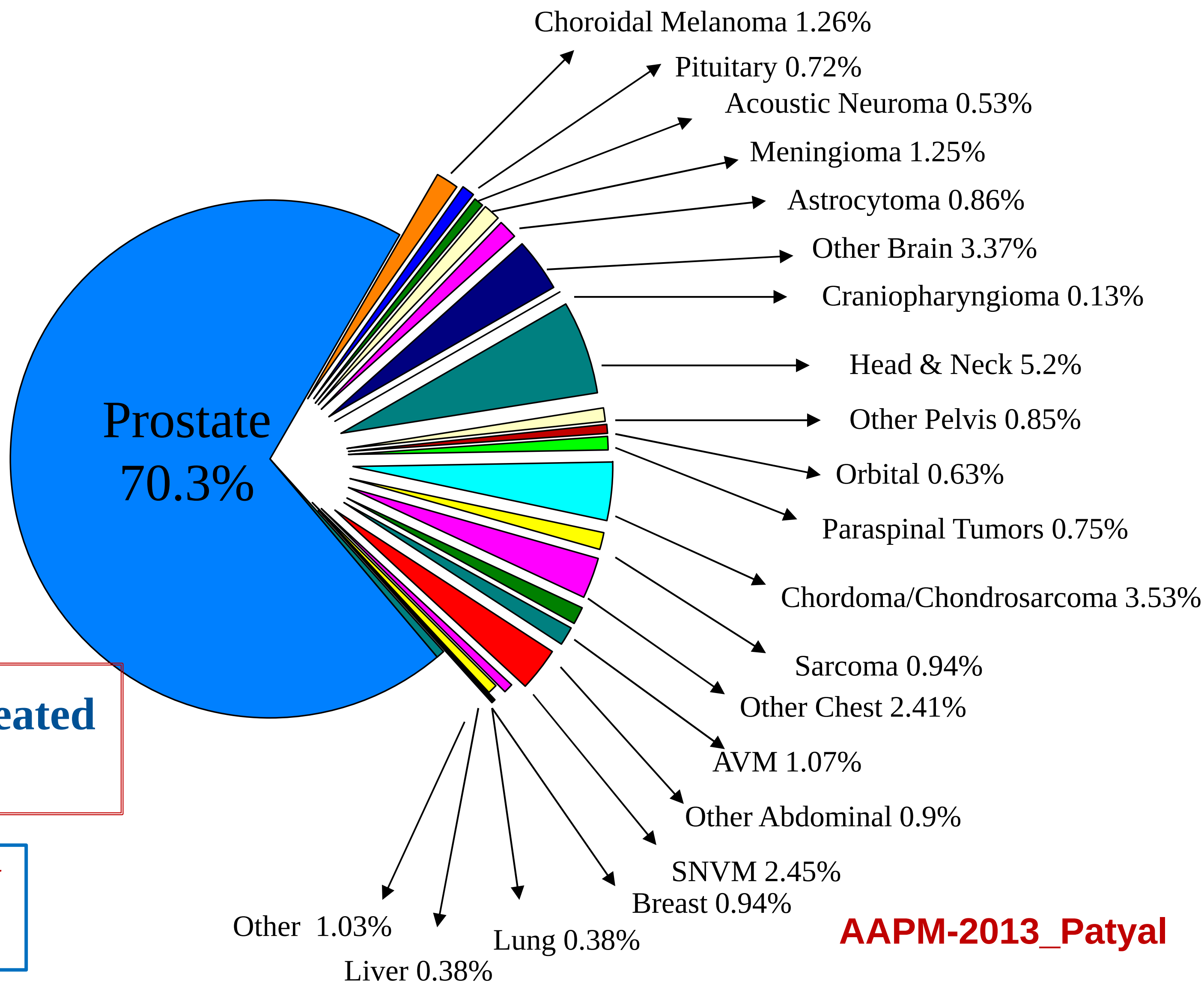
Time Requirements for Routine QA Tasks

Task	Time Needed	Comments
Simple calibration	10 min/field	5 min/additional field
Complex calibration	15-20 min/field	10 min/additional field
Problem fields	30-60 min/field	Small, odd shaped fields
Radio surgery fields	20-30 min/field	10-15 min/additional field
Eye-beam fields	45 min to 2 hours	Small mod-wheels, range
Model calibration	5-7min/field	Does not need beam
Device checks	5 min/device	Boluses and apertures
Daily QA	15 min/energy 20 min imaging sys lasers, table etc.	
Calibration checks	15-20 min/field	

Staffing

- Staff cross-trained in both x-ray and proton therapy
- 5 Ph.D. physicists, 5 M.S. physicists, 10 dosimetrists (9 physicians)
- 2 proton calibration physicists (night shift)
- 4 proton treatment rooms, 4 linear accelerators, one CT-Sim, 2 CT scanners and brachy service
- EMR: ARIA/Oncochart
- Three academic programs
- Ongoing research & development (without treatment interruption)
- Physics workload: protons to x-rays: 65:35

Patient Mix by Diagnosis (since inception)



17,288 Patients treated through 06/2013

110 patients a day (year-to-date)

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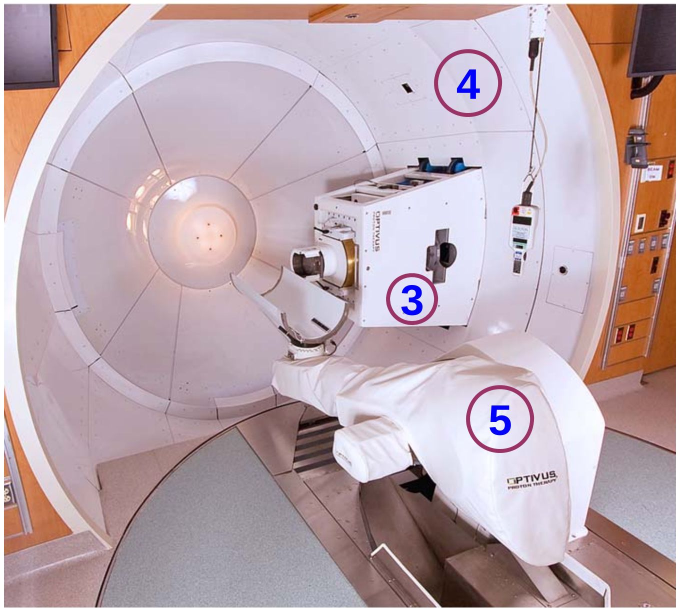
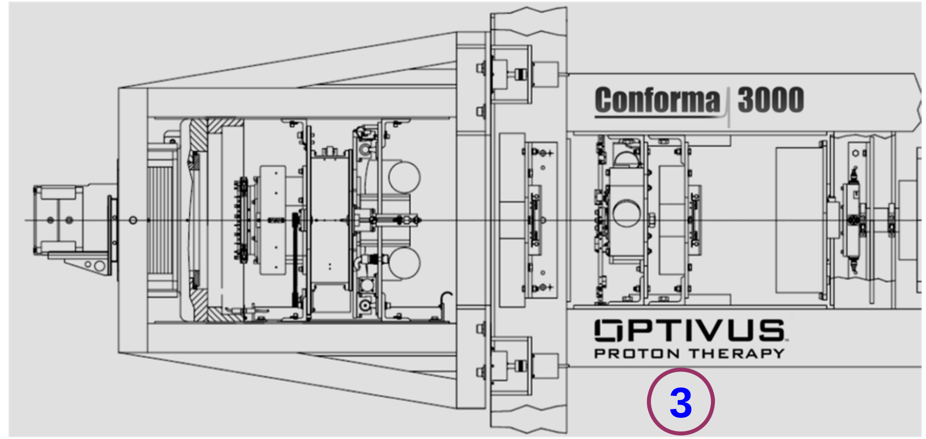
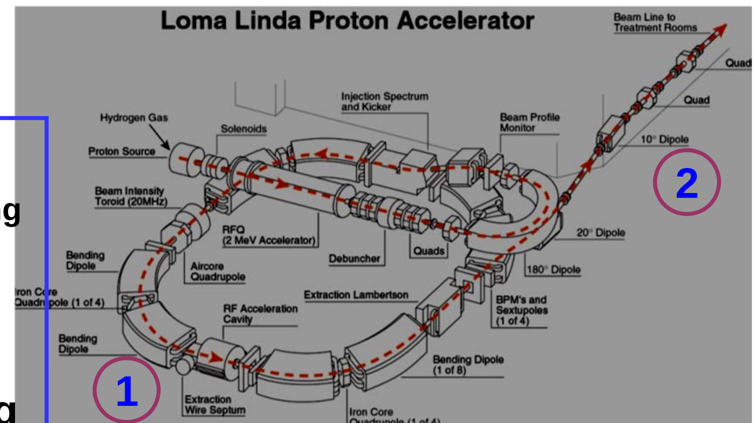
Quality Assurance

A Proton Treatment System







1 Accelerator
- Beam position monitoring
- Beam energy monitoring
- Beam current monitoring
- Beam steering

2 Beam Transport System
- Beam routing to tx rooms
- Beam profile and centering

3 Nozzle
- Beam shaping/steering
- Beam monitoring
- Dose monitoring

4 Gantry
- Beam rotation/aiming
- Imaging

5 Patient Positioner

Daily QA Checks

- Review beam delivery system logbook
- Verify integrity of the control system database for each beam-line
- Inspect treatment room (motion locks, snout extension, snout motion, range of table motions, hand pendent function etc.)
- Inspect treatment console area (indicator lamps, token key, backup monitor reset, audio-visual patient monitors
- Check localization lasers (2 mm)
- Verify modulator propeller interlock
- Verify functionality of barcode scanning system
- Check the functionality of the area radiation monitor within the room
- Run the daily DI tests
- Perform a daily QA for each energy
- Perform patient calibration for each new portal

Daily Proton Beam QA

- A procedure to standardize operating conditions for each day, each room, each energy
- Daily beam calibration performed under standard conditions for each energy
  - Isocenter at Center of modulation (6 cm mod wheel)
  - Nozzle extension
  - Standard aperture
- Detector response compared with standard calibration (Pass/Fail)
- Calibration factor used for patient portal calibration
- Also includes verification of entrance and distal dose and range verification

Daily beam calibration summary report

Daily Calibration summary Run Number: 55653
Portal ID: AB

Outcome: Finished
Standard Calibration #: 103

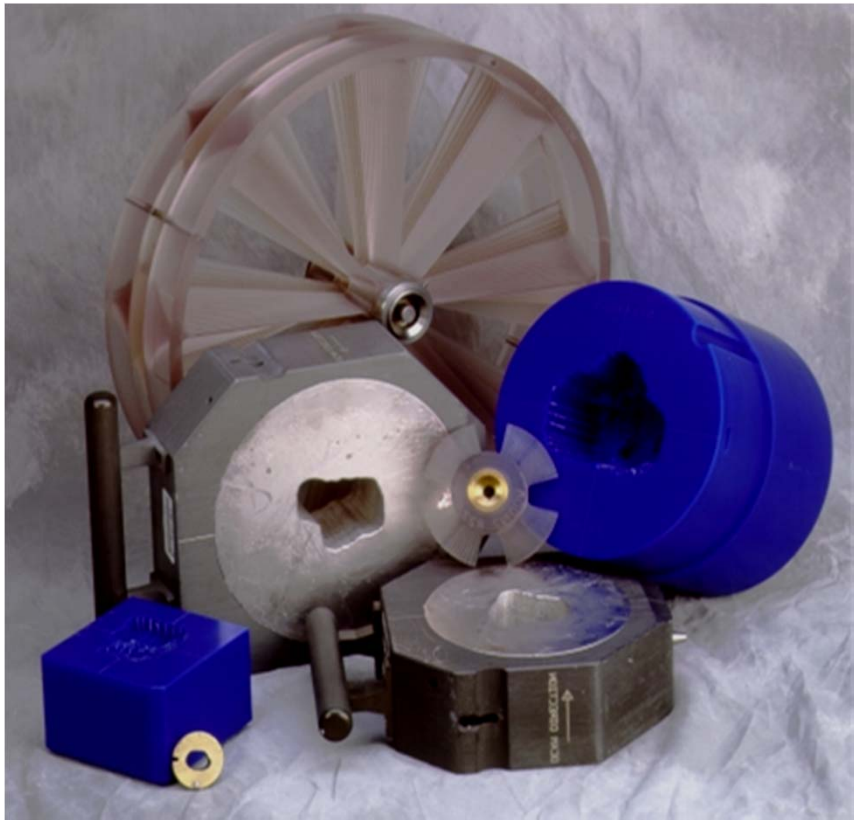
Temperature (deg C.): 19.40
Pressure (mm Hg.): 735.40
Beam Energy (Mev.: 155
Counts: 1000000
Modulator Wheel: 060
Range Shifer ID: 0
Nozzle Extension: 48.29
Target Identifier: wpc 88
Validation: VALID
Comment:
Combo detector passed daily calibration.TIC 3 detector passed daily calibration.

Sequence Number	Channel	Background Factor	Raw Counts	Corrected Counts	Monitor Units	Calibration Factor
Detector: Combo						
1	SEM	3.64	7294	6826.909	6826.91	48.4341
1	TIC 1 SF	3.14	666510	666107.062	666107.06	4725.7578
1	TIC 1 Q1	3.11	164528	164128.922	164128.92	1164.4277
1	TIC 1 Q2	1.74	155416	155192.719	155192.72	1101.0289
1	TIC 1 Q3	3.11	164893	164493.922	164493.92	1167.0172
1	TIC 1 Q4	2.69	154578	154232.812	154232.81	1094.2189
1	TIC 2 Q1	3.00	157415	157030.031	157030.03	1114.0640
1	TIC 2 Q2	3.16	158365	157959.500	157959.50	1120.6582
1	TIC 2 Q3	3.11	153664	153264.922	153264.92	1087.3521
1	TIC 2 Q4	3.11	152639	152239.922	152239.92	1080.0801
Detector: TIC 3						
1	TIC 3 CPP	3.04	3908	3517.896	3517.90	24.9580
1	Backup	0.32	19676	19634.936	19634.94	139.3018
1	TIC 3 R1	3.15	1004275	1003870.750	1003870.75	7122.0532
1	TIC 3 R2	3.25	623925	623507.938	623507.94	4423.5342
Detector: Ion Chamber						
1	0	0.00	0	1.233	140.95	114.3167

Ratios:	Numerator	Denominator	Value
TIC 1 Up/Down	59487.50	638048.38	0.09323
TIC 1 Left/Right	132487.50	638048.38	0.20764
TIC 2 Up/Down	948468.75	620494.38	1.52857
TIC 2 Left/Right	195450.00	620494.38	0.31499
TIC 3 Up/Down	-23938.28	86053.50	-0.27818
TIC 3 Left/Right	-20031.64	86731.70	-0.23096
TIC 3 R1/SEM	1003870.75	6826.91	147.04617
TIC 3 R1/TIC 3 CPP	1003870.75	3517.90	285.36108
TIC 3 R1/TIC 1 SF	1003870.75	666107.06	1.50707
TIC 1 SF/SEM	666107.06	6826.91	97.57082

Patient Specific QA: Each New Portal

- Check aperture for each new portal
- Check compensator bolus
  - Visual inspection
  - Probe plunge depths at select points against treatment planning data
- Correct barcodes for devices
- Perform patient specific calibration (model or physical)
- Do a second person check of patient calibration before the first treatment



Patient Specific QA: Portal Calibration

Physical Calibration

- Performed with portal specific energy and patient devices
- Ion chamber placed at an equivalent depth in a solid phantom
- Prescribed dose delivered and output measured
- The counts, output and calibration factors generated for the detectors are stored in a patient file
- The beam calibration performed the day of treatment is used for portal calibration
- Model calibrations used when possible
- Small fields, large air gap, thick bolus: require physical calibration

Patient physical calibration report

Data for patient set-up file:

Physical dose (cGy)	163.6
Energy (MeV)	249.5
Modulator wheel ID	80
Range shift	0
Nozzle extension	29.1
Table angle (deg)	-90
Effective f. s. at iso (cm)	5.52
Cone size (cm)	15

Data for physical calibration:

Iso to cal. pt. distance (cm)	0.0
Calibration depth (cm)	20.61
Blocks used: 35PMJA	20.657

Additional data:

Source to aperture dist. (cm)	212.1
Source to bolus dist. (cm)	218.5
Aperture pos. relative to bolus	upstrm
Optirad MU prediction	1.114

3-point bolus check:

Point location	Coordinates (x : y)	WEQ. thkness (cm)	Phys. thkness (cm)	Meas. phys. thkness (cm)
Minimum	(-0.87:-1.53)	6.67	6.80	6.80
Calibration	(0.25:0.39)	7.08	7.22	7.22
Maximum	(-1.87:-2.57)	11.53	11.75	11.76

SMGD = 7.14

Overlay checks:

Bolus
AA 01/06/2011

Aperture
AA 1/6/11

Center of modulation calculation:

Beam range (cm)	31.50
- modulation ÷ 2 (cm)	08.23 / 2
- bolus thickness cal. pt. (cm)	07.08
= COM depth (cm)	20.31

Beam range check:

Beam range (cm)	31.50
- max. treatment depth (cm)	24.83
- min. bolus thickness (cm)	06.67
= excess range (cm)	00.00

Manual calculation of backup monitor:

Backup = C_{mod} × C_{size} × C_{ISL} × *phys. dose* × K_{energy}

= 1.101 × 1.054 × 0.998 × 163.6 × 121.6776

= 23054

Physical calibration output:

Ion chamber ID	WPC 88
IC calibration factor	111.60
Temperature (°C)	19.7
Pressure (mm Hg)	734.6
Nozzle extension used	29.0
Requested dose (cGy)	163.6
Delivered dose (cGy)	163.6756
IC charge (nC)	1.4289
IC dose ($nC \times calfactor \times K_{TP}$)	163.6927
Time used (min.)	2.2
Primary TIC MU	—
Norm. primary TIC MU	—
Backup TIC MU	22848
Norm. backup TIC MU	22837
Difference w.r.t. manual calc.	0.95%

General calibration output:

Run ID			51706
Date			01/06/2011
Time			20:27
Saved?	✓	Gantry set to	—

Treatment settings: Chamber at (0.25, 0.4)

Backup setting:
= backup TIC MU × 1.1
= 25121

Bolus replaced by SMGD.

Timer setting (min):
= run time × 1.5
= 3.3

Planner	1-3-11
Calibrator	01/06/2011

Plan QA	1-6-11
Cal Check	1/7/11

Rev. 2.6, 06/20/2000

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Monthly QA

- Review daily QA records
- Verify the room secure and other interlocks
- Verify the backup dose monitor functions properly
- Check snout extension accuracy at three extensions
- Beam pause and reset functions
- Verify the integrity and alignment of the scatterers
- Verify the patient calibration system
- Emergency off switches
- Beam flatness and symmetry
- X-ray and proton beam centering
- DI calibration tests

Annual QA…

Safety Checks

- Facility shutdown switches
- Area shutdown switches
- All beam safety interlocks
  - Beam energy interlock
  - Beam centering interlock
  - Backup counter interlock
  - Modulator wheel interlock
  - Door interlock
- Room secure
- Beam on indicator
- Beam pause and resume functions
- Calibrate area radiation monitors
- Audio-visual system function
- Radiation warning signs

Mechanical Checks

- Gantry angle readout accuracy
- Patient positioner readout accuracy
- Patient positioner sag
- Snout extension readout accuracy
- Laser alignment accuracy
- Modulator wheel visual inspection
- Inspection of block and bolus doors and latches in the nozzle
- Hand pendant operation (also daily)

X-rays & Imaging Checks

- Image magnification accuracy
- kVp and mAs accuracy
- Image quality

Annual QA…

Proton Checks

- Proton vs. X-ray field centering
- Location of the effective source
- Location of the virtual source
- Linearity of dose per monitor unit for the primary channel

Proton Dosimetry Checks

- Field size dependent factors for all clinically used energies (±2%)
- Modulation factors (±2%)
- Depth dose profile
- Dose per monitor unit for the primary and all backup channels at selected gantry angles (±1%)
- Bolus gap factors
- Calibration protocol: IAEA-TRS-398 (ICRU 78)

Proton Beam Quality Checks

- Lateral field symmetry
  - energy and gantry angle
- Lateral field flatness
  - energy and gantry angle
- Lateral penumbra widths
  - energy and gantry angle
- Range uniformity (picket fence)

QA Equipment Tests

- Standard ion chambers and electrometers calibration factors
  - Current ADCL calibrations
- In house ion chambers and electrometers calibration factors
  - Periodic inter-comparisons

Summary

- Quality begins at the top! Institution leadership has to show tangible commitment to quality

- To maintain quality and to improve quality, a Quality Management Program; a written document of quality expectations, of procedures and policies, and roles and responsibilities should be developed

- To implement quality programs, the institution should make available the needed resources: personnel, tools and time

- The main purpose of a hospital based proton center is to treat patients. But to treat patients right, a thorough QA program is essential. Don't squeeze out QA time to accommodate more patients

- QA procedures and policies should be strictly followed