Facility Overview

&

Operations
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

- Fixed Beamlines
- Research Beamlines
- Synchrotron
- Beam Transport System
- Treatment Gantry 1-3
## Typical Proton Facility Weekly Usage

<table>
<thead>
<tr>
<th>MODE</th>
<th>HOURS</th>
<th>PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>94</td>
<td>56%</td>
</tr>
<tr>
<td>Calibration</td>
<td>24</td>
<td>14%</td>
</tr>
<tr>
<td>Maintenance</td>
<td>12</td>
<td>7%</td>
</tr>
<tr>
<td>Research</td>
<td>10</td>
<td>6%</td>
</tr>
<tr>
<td>Upgrades</td>
<td>16</td>
<td>10%</td>
</tr>
<tr>
<td>Operations</td>
<td>5</td>
<td>3%</td>
</tr>
<tr>
<td>Other</td>
<td>7</td>
<td>4%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>168</td>
<td>100%</td>
</tr>
</tbody>
</table>
## Timeline of a Proton Treatment @LLUMC

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Time Needed</th>
<th>Time before Tx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient orientation &amp; education</td>
<td>1-2 hours</td>
<td>7-10 days</td>
</tr>
<tr>
<td>Patient immobilization &amp; imaging</td>
<td>15-30 min</td>
<td>7-10 days</td>
</tr>
<tr>
<td>Treatment planning &amp; plan QA</td>
<td>1-3 days</td>
<td>5-8 days</td>
</tr>
<tr>
<td>Device manufacture &amp; calibration</td>
<td>1 day</td>
<td>1-3 days</td>
</tr>
<tr>
<td>Treatment session</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient setup</td>
<td>15-45 min</td>
<td></td>
</tr>
<tr>
<td>Alignment verification &amp; approval</td>
<td>5-10 min</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>5-25 min</td>
<td></td>
</tr>
<tr>
<td>Room reset</td>
<td>2-5 min</td>
<td></td>
</tr>
</tbody>
</table>

AAPM-2013_Patyal
## Time Requirements for Routine QA Tasks

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

- Prostate: 70.3%
- Choroidal Melanoma: 1.26%
- Pituitary: 0.72%
- Acoustic Neuroma: 0.53%
- Meningioma: 1.25%
- Astrocytoma: 0.86%
- Other Brain: 3.37%
- Craniopharyngioma: 0.13%
- Head & Neck: 5.2%
- Other Pelvis: 0.85%
- Orbital: 0.63%
- Paraspinal Tumors: 0.75%
- Chordoma/Chondrosarcoma: 3.53%
- Sarcoma: 0.94%
- Other Chest: 2.41%
- AVM: 1.07%
- Other Abdominal: 0.9%
- SNVM: 2.45%
- Lung: 0.38%
- Liver: 0.38%

17,288 Patients treated through 06/2013

110 patients a day (year-to-date)
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

<table>
<thead>
<tr>
<th>Detector</th>
<th>Channel</th>
<th>Background Factor</th>
<th>Raw Counts</th>
<th>Corrected Counts</th>
<th>Monitor</th>
<th>Calibration Factor</th>
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<tr>
<td>Combo</td>
<td>SEM</td>
<td></td>
<td>7294</td>
<td>6826.909</td>
<td>6826.91</td>
<td>48.4341</td>
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<tr>
<td>TIC 1 SF</td>
<td></td>
<td></td>
<td>666510</td>
<td>666107.066</td>
<td>666107.066</td>
<td>4725.7578</td>
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<tr>
<td>TIC 1 Q1</td>
<td></td>
<td></td>
<td>164520</td>
<td>164326.922</td>
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<td>TIC 1 Q2</td>
<td></td>
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<td>155436</td>
<td>155207.719</td>
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<td>1101.0289</td>
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<td>TIC 1 Q3</td>
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<td>164893</td>
<td>164493.922</td>
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<td>TIC 1 Q4</td>
<td></td>
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<td>158579</td>
<td>158322.811</td>
<td>158322.811</td>
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<td>157415</td>
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<td>157300.033</td>
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<td>153264.922</td>
<td>153264.922</td>
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<td>TIC 2 Q4</td>
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<td>152299.922</td>
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<td>TIC 3 CPP</td>
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<td>3998</td>
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<td>24.9580</td>
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<tr>
<td>Backup</td>
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<td>19668</td>
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<td>19634.936</td>
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<td>623925</td>
<td>623507.938</td>
<td>623507.94</td>
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<tr>
<td>Ion Chamber</td>
<td></td>
<td></td>
<td>1 0.00</td>
<td>1 1.233</td>
<td>114.3167</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ratio:</th>
<th>Numerator</th>
<th>Denominator</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIC 1 Up/Down</td>
<td>59427.50</td>
<td>638048.38</td>
<td>0.0939</td>
</tr>
<tr>
<td>TIC 1 Left/Right</td>
<td>132400.50</td>
<td>639048.38</td>
<td>0.20764</td>
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<tr>
<td>TIC 2 Up/Down</td>
<td>948468.75</td>
<td>620494.38</td>
<td>1.52857</td>
</tr>
<tr>
<td>TIC 2 Left/Right</td>
<td>155400.00</td>
<td>620494.38</td>
<td>0.319499</td>
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<tr>
<td>TIC 3 Up/Down</td>
<td>-23938.28</td>
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<td>-0.27818</td>
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<tr>
<td>TIC 3 Left/Right</td>
<td>-20031.64</td>
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<td>TIC 3 R1/SEM</td>
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<td>666107.06</td>
<td>1.50707</td>
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<tr>
<td>TIC 3 R1/TIC 1 CPP</td>
<td>1003870.75</td>
<td>3517.90</td>
<td>285.36108</td>
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<tr>
<td>TIC 3 R1/TIC 1 SF</td>
<td>1003870.75</td>
<td>666107.06</td>
<td>1.50707</td>
</tr>
<tr>
<td>TIC 1 SF/SEM</td>
<td>666107.06</td>
<td>6825.91</td>
<td>97.57092</td>
</tr>
</tbody>
</table>
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
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

LOMA LINDA UNIVERSITY MEDICAL CENTER

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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