Accelerator Reliability Workshop -ESRF- Grenoble – 4/02/2002

Accelerator Reliability in protontherapy
Specificities of the medical applications

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Accelerators in medicine

Diagnosis

Production of radioelements

imaging

Therapy

- Brachytherapy

- Radiotherapy
  - Protontherapy
  - Neutrontherapy

Beams production (sources or accelerators)
Role of the different treatments against solid tumours
Basis of radiotherapy

1. Multi-porting
2. Fractionation
Biological interest

Photons, electrons

neutrons

price

Heavy ions

protons

Ballistic interest
Conventional radiotherapy (photons, electrons)

- experimental stage

- Clinical trials 1940

- Industrial development 1960

- Medical service, economical entity 2000

30% of oncology

+ 5000 accelerators

Protontherapy
Neutrontherapy
Hadrontherapy

« experiments » on nuclear physics machines

4 hospital-based facilities

30 0000 patients treated (less than 0.1% of the overall)
Particularities due to the radiotherapy application (1)

• Overall time of treatment for a patient:
  32 x 2 Gy (WE excluded), about 2 months
  ⇒ Long maintenances very disturbing for the medical planning

• Beam time during a day
  - beam quality control (beam, accessories) 15 min – 1 hour (p)
  - 1 minute per treatment
  So beam is used only 10 % of the time
  ⇒ Short breakdowns manageable
Criticity of breakdowns in a radiotherapy facility

Impact on the medical planning about a disaster …

manageable

1 hour 1 day 1 week
time

criticity
Particularities due to the radiotherapy application (2)

• Safety of treatment
  – certification (IEC801.2 or specific CE)
  – The most important point: the dose monitoring control
Particularities due to the radiotherapy application (3)

The physicians point of vue:

« maintenance as transparent as possible »
In the conventional radiotherapy world

Reported from:
- L. Bély (Institut Gustave Roussy / Villejuif)
- J-Y Kristner (Institut Curie /Paris)

**Photons**
- breast-ORL: 4-6 MV
- lung: 10-15 MV
- body: 18-25 MV

**Electrons**
- superficial tumors
  - 6 - 24 MeV
A modern radiotherapy machine

- **Gantry**
- **Beamline**
  - **Target**
  - **Accelerating device (3Ghz)**
  - **Klystron or magnetron**
- **The multileaf collimator**
- **The portal imaging**
- **Source**
  - (diod or triod)
- **Ethernet connexion**
- **Software:**
  - Record & verifier
  - Patient database
Intensity Modulated Radiotherapy (IMRT)

Dynamic MultiLeaf Collimator (DMLC)
How do they manage reliability

• Historically: high level of subcontracting
  – no powerman inside hospital
  – required certification (CE)

• Importance of the call for bid
  – Technology choice
  – Company choice (only four competitive !)
  – maintenance contract negotiation (spare parts, minimum rate of availability)
How do they manage reliability

• before: tendency for full assistance

• new tendency: the shared maintenance
  – Hospital people are trained and “certified” by the company
  – Companies incite hospital to have a full stock of spare parts
  – hot line (no more telemaintenance)

80% of breakdowns are managed by hospital technicians
How do they manage reliability

• maintenance figures
  – Maintenance contract: 5% (of 2,5 M€/machine)
  – Preventive: 3 hours weekly, 2-4 full days yearly
  – the critical parts: vacuum, Multileaf Collimator, portal imaging, software

• how do they manage breakdowns
  – shift the treatment, reprogramming patient on another machine
  – beam quality control by medical physicist
  – home made logbook and database
Their general feeling about reliability

- they are company dependent
- with IMRT: no place for degraded modes
- RTT and reliability are difficult to conciliate
Neutrontherapy
CERI/ CNRS- Orléans

- Cyclotron built by THOMSON in 1974
- Variable energy: protons – deutons- alphas-hélions (0-50 MeV)
- Neutrontherapy: 35% of the activity (600h/an)
- 2000 patients treated since 1985 (prostate, sarcoma, head and neck)
- Project for BNCT (Boron Neutron Capture Therapy)
Protontherapy
Le Centre de Protonthérapie d’Orsay

- Synchro-cyclotron
  Philips 1956
  IPN/CNRS 1975
- 200 MeV protons
- Fully dedicated to medical application since 1990
- 2500 patients treated since 1991
- Uveal melanoma, chordoma, chondrosarcoma, head and neck
- Gantry project (collaboration with IPN)
How do we manage reliability
(for old nuclear machines now devoted to medical)

1. The situation

- a lonely specific machine (no scaling effect)
- an old machine
- a complex experimental machine (Research design)
  + Good knowledge of behaviour
  + robust technology
  + a good know-how community (internal, IPN, campus)

2. Actions

• Basic preventive maintenance
• automatization
• If possible renovation (and if possible simplification)
• « task force » for curative maintenance
PLC network at CPO:
a good way to command, monitor, store

- « clever » storage
- new level of sensitivity
One critical aspect at CPO: learning without doing

- The medical request: less maintenance time as possible
- Time needed to experiment, learn and prepare spare parts for specific systems

It works: don’t do anything  Learning by doing

Ex: the rotative condensator -HF (implementation of ceramic bearings 02/2002)

also specific: HF systems, ion source, electromagnetic channel
The medical specificity (CERI and CPO)

- Redundancy and spare parts, as much as possible
- Safety: tripping margins for most of the parameters, doubling the « beam off » signals
- « task force » in case of failure
- Degraded mode to reach the end of the day
- vacumm constant times criticals
- Quality control of the beam after significant failures (by medical physicists)
- Close relation with the medical staff (anticipated maintenance, management of the planning)

Look at all the details in the medicalusers.doc file
Hours of breakdowns

Treatments delayed or reported
CPO figures:
great demand for patient treatment (keep it alive)

Congratulations to the HCL/Harvard (Boston) team who has kept very reliable their synchrocyclotron since …1946!
Reliability: what should be a good organization for future accelerator (proton/hadrontherapy)

Projects proposed

<table>
<thead>
<tr>
<th>INSTITUTION</th>
<th>PLACE</th>
<th>TYPE</th>
<th>1ST</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFN-LNS, Catania</td>
<td>Italy</td>
<td>p</td>
<td></td>
<td>70 MeV; 1 room, fixed horiz. beam at MGH; 230 MeV cyclotron; 2 gantries + 2 horiz</td>
</tr>
<tr>
<td>NPTC (Harvard)</td>
<td>MA USA</td>
<td>p</td>
<td>2001</td>
<td>2 gantries; 2 horiz; 1 vert; 1 45 deg; nearing completion</td>
</tr>
<tr>
<td>Hyogo</td>
<td>Japan</td>
<td>p, ion</td>
<td>2001</td>
<td>new treatment room with beam line 30° off vertical.</td>
</tr>
<tr>
<td>NAC, Faure</td>
<td>South Africa</td>
<td>p</td>
<td>2001</td>
<td>270 MeV; 2 gantries; 2 fixed; construction complete</td>
</tr>
<tr>
<td>Tsukuba</td>
<td>Japan</td>
<td>p</td>
<td>2001</td>
<td>multipurpose accelerator; building completed mid 1998</td>
</tr>
<tr>
<td>Wakasa Bay</td>
<td>Japan</td>
<td>p</td>
<td>2002</td>
<td>72 MeV cyclotron; p; ions; +BNCT, isot prod.</td>
</tr>
<tr>
<td>Bratislava</td>
<td>Slovakia</td>
<td>p, ion</td>
<td>2003</td>
<td>C-ion from 100 MeV/u at HIRFL expand to 900 MeV/u at CSR: clin, treat, biol, research; no gantry; shifted patients</td>
</tr>
<tr>
<td>IMP, Lanzhou</td>
<td>PR China</td>
<td>C-Ar ion</td>
<td>2003</td>
<td>synchrotron; 2 gantry; 1 fixed beam rooms; 1 exp. room</td>
</tr>
<tr>
<td>Shizuoka Cancer Center</td>
<td>Japan</td>
<td>p</td>
<td>2003</td>
<td>4 gantries, 1 fixed beam, 230 MeV, scanning beams.</td>
</tr>
<tr>
<td>Rinecker, Munich</td>
<td>Germany</td>
<td>p</td>
<td>2003</td>
<td>4 treatment rooms, some with gantries.</td>
</tr>
<tr>
<td>CGMH, Northern Taiwan</td>
<td>Taiwan</td>
<td>p</td>
<td>2001</td>
<td>synchrotron; 230? MeV; 2 gantries; 1 horiz; funded.</td>
</tr>
<tr>
<td>Erlangen</td>
<td>Germany</td>
<td>p</td>
<td>2002</td>
<td>250MeV synchrotron/230MeV cyclotron; 3 gantry, 1 fixed</td>
</tr>
<tr>
<td>CNAO, Milan &amp; Pavia</td>
<td>Italy</td>
<td>p, ion</td>
<td>2004</td>
<td>4 treatment rooms, some with gantries.</td>
</tr>
<tr>
<td>Heidelberg</td>
<td>Germany</td>
<td>p, ion</td>
<td>2005</td>
<td>2 gantry; 1 ion; 1 fixed p; 1 fixed ion; 1 exp room</td>
</tr>
<tr>
<td>AUSTRON</td>
<td>Austria</td>
<td>p, ion</td>
<td></td>
<td>250 MeV synchrotron.</td>
</tr>
<tr>
<td>Beijing</td>
<td>China</td>
<td>p</td>
<td></td>
<td>cyclotron; 1 gantry; 1 fixed</td>
</tr>
<tr>
<td>Central Italy</td>
<td>Italy</td>
<td>p</td>
<td></td>
<td>upgrade using booster linear accelerator to 200 MeV?</td>
</tr>
<tr>
<td>Clatterbridge</td>
<td>England</td>
<td>p</td>
<td></td>
<td>70 MeV linac; expand to 200 MeV?</td>
</tr>
<tr>
<td>TOP project ISS Rome</td>
<td>Italy</td>
<td>p</td>
<td></td>
<td>including 320 MeV; compact, probably no gantry</td>
</tr>
<tr>
<td>3 projects in Moscow</td>
<td>Russia</td>
<td>p</td>
<td></td>
<td>60 MeV proton beam.</td>
</tr>
<tr>
<td>Krakow</td>
<td>Poland</td>
<td>p</td>
<td></td>
<td>300 MeV protons; therapy &amp; lithography</td>
</tr>
<tr>
<td>Proton Development N.A. Inc.</td>
<td>IL USA</td>
<td>p</td>
<td></td>
<td>Several systems throughout the USA</td>
</tr>
<tr>
<td>PTCA, IBA</td>
<td>USA</td>
<td>p</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Reliability: what should be a good organization for future accelerators (proton/hadrontherapy)

- No more experimental technology
- Not yet established market and technology

- Clinical orientation (routine or experimentation)
- «Quality» of the project management
- Budget, skills, certification and also …

⇒ Transition between Design/Construction and exploitation

Knowledge management - degree of innovation
Best transition (the medical point of vue)

Design/construction /Installation

Exploitation

Sub-contracted maintenance (lightest)

Call for bid

acceptance tests
Best transition (the technical point of vue)

Design/construction/Installation

exploitation

maintenance

Fixed specifications
1st example – Harper Hospital- Detroit
Superconducting cyclotron for neutron therapy
(reported from R. Maughan)

Design & construction
- collaboration with M.S.U.
- small company (Medcyc) created to assist hospital

Exploitation
- 1992: first patient treated
- 2000: 200 patient/year

- Information: they need to keep resources in the assistant company (powerman, $) in order to keep reliability
2nd example – Loma Linda University Medical Center
Synchrotron for proton therapy

Design & construction
- Loma Linda University Medical Center specifications
- Fermilab construction
- Berkeley & Harvard know-how

Exploitation
- 1990: first patient treated
- 1993: private society in charge of R&D (OPTIVUS)
- 2001: « 100 patients per day »

Information: many technical upgrades
3rd example: The Northeast ProtonTherapy Center – Boston (hospital-based)

**Design & construction**
- Massachusetts General Hospital specifications
- following the Harvard-HCL experience
- IBA design/installation

**Exploitation**
- 2001: first patient treated

Clinical application has driven the design and the implementation “fight against the NIH (not inventing here) syndrome”
4th example – Proscan - PSI-CH
Superconducting cyclotron for proton therapy

Design & construction

- following the PSI experimentation
- medical community specifications
- innovating accelerator bought to ACCEL
- own R&D team + PSI support

Exploitation

- 1st patient planned in 2005

« It’s an experimentation » (learning by doing)
How would be your dream machine?

My dream machine would be without breakdowns … without maintenance … without me!

I hate this machine!
Thanks to …. 

• The CPO team
  - J. Briaud (CERI/CNRS /Orléans)
  - L. Bély (Institut Gustave Roussy / Villejuif)
  - J-Y Kristner (Institut Curie /Paris)
  - R. Maughan (University of Pennsylvania medical center)

• ESRF

References
The technology of hadrontherapy: the context within which technical choices are made – Michael Goitein – Advances in hadrontherapy -1997 – U. Amaldi, B. Larsson and Yves Lemoigne Editors