University of Florida Proton Therapy Institute

Code of Practice for the Proton Therapy System

Acceptance testing and clinical commissioning of a Proton Therapy System

Roelf Slopsema

Definitions

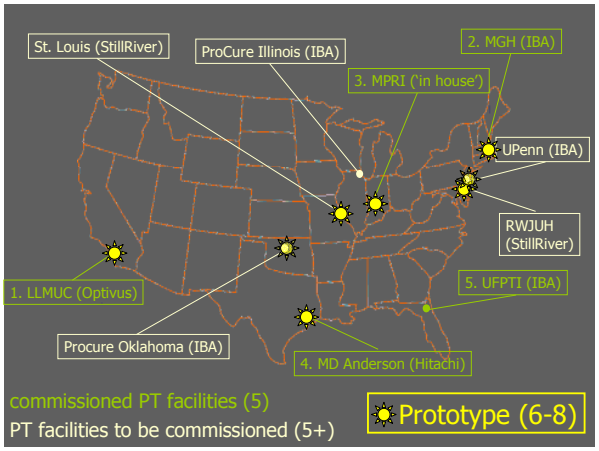
- Acceptance Testing

  '.. to determine that all applicable radiation safety standards are met or exceeded and that the machine meets or exceeds the contractual specifications.'

- Commissioning

  '....refers to the process whereby the needed machine-specific beam data are acquired and operational procedures are defined.'

AAPM code of practice for radiotherapy accelerators: Report of AAPM Radiation Therapy Task Group No. 45



commissioned PT facilities (5)

PT facilities to be commissioned (5+)

Prototype (6-8)

Accepting and commissioning PT system

"Accepting and commissioning of a prototype is not the same as for serial number 1206".

- acceptance needs to reflect maturity product
  - difference between design specifications and production specifications
  - for new developments, specifications and acceptance tests need to be defined by manufacturer and customer together
  - proton projects often bundle delivery, alignment, imaging, OIS, tx planning,... systems
- standard protocols for commissioning do not apply
  - can still provide guideline
  - up to the physicist to develop commissioning plan based on clinical requirements

Acceptance tests

- specified in the contract
- a limited set, covering random samples of the complete 'space' of delivery parameters
- describe in detail the measurement setup and the specified limits
- distinction between design specifications and installation specifications
- do not allow you to treat a single patient

Examples of PT acceptance tests

Minimum SAD:

The SAD will be measured by simultaneously irradiating two X-ray films located 1 meter apart in a square collimated beam. The source position will be obtained by geometrical reconstruction, using the x-ray film images and their relative positions. The test will be performed for 1 field configuration. The test will be deemed passed if the SAD is equal to or larger than 2 meters.

⇒ design specification

Examples of PT acceptance tests

Range accuracy:

The depth dose curve will be measured for 5 different requested ranges, including the minimum and maximum range. Measurements will be made in a water phantom. Range is defined as the water-equivalent depth of the distal 90% point of the depth dose curve along the beam axis. The test will be deemed passed if the measured range is within ±1.0mm of the specified range.

⇒ production specification

Commissioning

- Commissioning of delivery system
  - verification of dose distributions
  - mechanical alignment (gantry, couch, snout, …)
  - imaging equipment
  - commissioning of output model
- Commissioning of tx planning
  - collection of beam data
  - verification of calculation algorithm
- Commissioning of 'other systems' interfaces!
  - OIS
  - simulation equipment CT: HU-proton-stopping-power
  - milling machine apertures and range compensators
  - immobilization devices beam perturbation
- Definition of operational procedures
  - QA procedures

Ideally QA procedures based on commissioning procedures

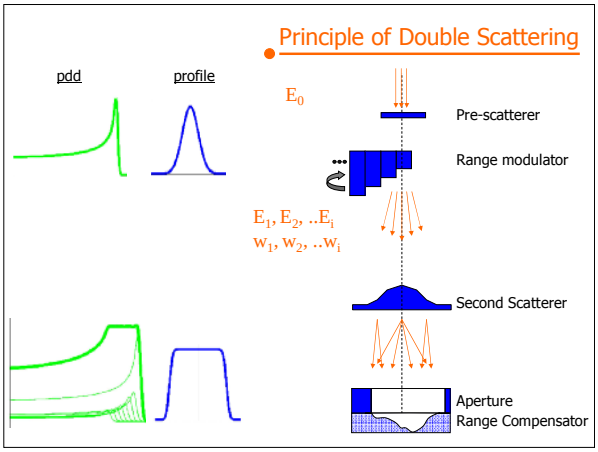
Boss

- We just bought a proton-therapy system!
- A cyclotron based system with not one, not two, but three gantries!
- We are going to treat 1500 patients a year, 16 hours a day, and for six days a week.
- There will be pediatric cases, prostates, head&neck, lung, radio-surgery…..
- We will be starting on September 1.
- *Can you commission the system for us?*

Vendor

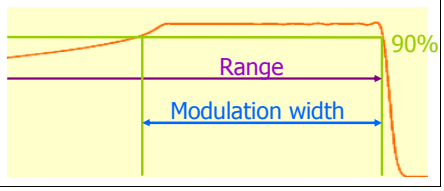
- You just bought a proton-therapy system from us. Congratulations!
- We will be ready to hand over the first room to you on June 1.
- Each room has 8 double-scattering options. Each option has three suboptions that use a different beam current modulation.

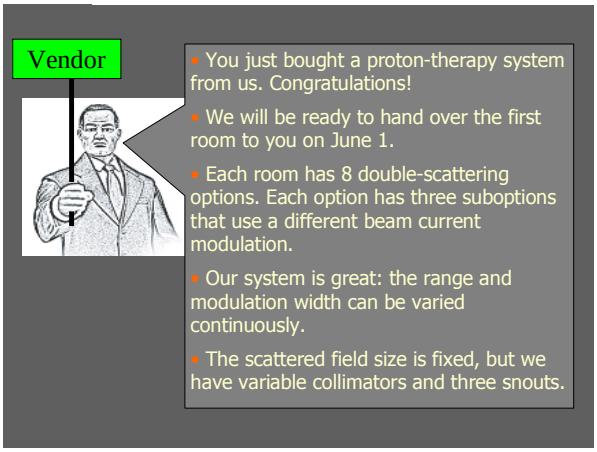
Principle of Double Scattering

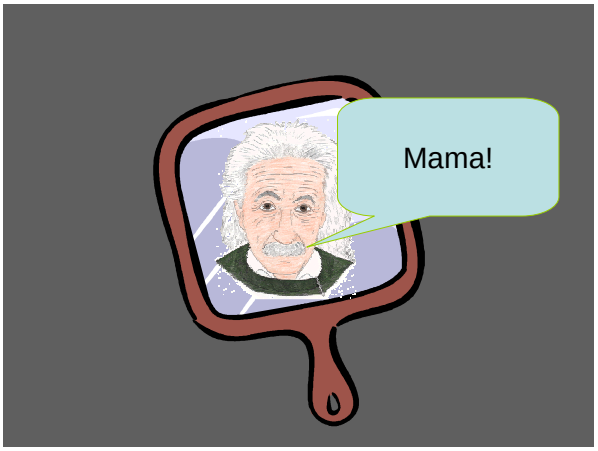


Principle of Double Scattering

- Option: combination of a range modulator and second scatterer used in a given range (energy) span
- Suboption: subspan of the option that uses its own 'beam current modulation pattern'







Determine the parameters to verify

Prescription → Equipment settings → Delivery

- range
- modulation width
- field size
- dose rat
- dose
- gantry angle
- SSD (air gap)
- snout size

For what subset of prescribed parameters do these need to be verified?

- range
- modulation width
- dose variation uniform region
- ximal region
- ofile (tilt/flatness)
- maximum field size
- lateral penumbra vs. depth
- field size vs. depth
- dose per MU
- dose rate

Depth dose | Lateral | Absolute

Defining the subset - Range

Does the range depend on……

Option	Yes
Suboption	Maybe
Modulation	No
Field size	No
Snout size	No
Gantry angle	Unlikely
Dose rate	No
Dose	No
SSD	No

Measure…

- 4 SOBP's per suboption
- 2 SOBP's for 2 gantry angles

Defining the subset – PDD uniformity

Does the pdd uniformity depend on……

Option	Yes
Suboption	Yes
Modulation	No
Field size	Yes
Snout size	Maybe
Gantry angle	Unlikely
Dose rate	Unlikely
Dose	No
SSD	Yes

Measure…

- 1 full-mod SOBP per suboption
- 2 sobp for all snouts
- 1 sobp for 2 gantry angles
- 1 sobp for 3 dose rates
- 2 sobp for varying SSD
- sobp's for small aperture size

Specification and measurement table

			Requirements to be tested	Goal	Specification
1			Range		
	a		accuracy	verify spec	< +/- 1 mm for R<8.0 g/cm2, < +/- 1.5 mm for R>8.0 g/cm2
	b		stability	verify spec	< +/- 1 mm over 2 weeks
	c		resolution	verify spec	< 1 mm
	d		maximum	verify spec	28.0 g/cm^2 for DS, 20 g/cm^2 for SS (see specs per option)
	e		minimum	verify spec	5.0 g/cm^2 for DS, 3.0 g/cm^2 for SS (see specs per option)

Specification and measurement table

			Requirements to be tested	Subset			
1			Range				
	a		accuracy	all DS options	8	min, intermediate, max range	3
	b		stability	two DS options	2	intermediate range	1
	c		resolution	two DS options	2	intermediate range plus four	5
	d		maximum	maximum system range	1	intermediate modulation	1
	e		minimum	minimum system range	1	intermediate modulation	1

						number of items
one modulation width	1		1	every gantry	3	72
one modulation width	1	10 days	10	every gantry	3	60
one modulation width	1		1	once	1	10
	1		1	every gantry	3	3
	1		1	every gantry	3	3

Specification and measurement table

Name test	Description	Result
Daily measurement DS reference field 1	Using the crs phantom measure the depth dose profile of field# 2. Measure the output at the middle of the SOBP using the electrometer. In addition time the dose delivery using a stop watch, to determine the actual dose rate in Gy/min. Repeat daily for 10 days	stability range, SOBP shape, modulation width, dose rate and output
Daily measurement DS reference field 2	Using the crs phantom measure the depth dose profile of field# 3. Measure the output at the middle of the SOBP using the electrometer. In addition time the dose delivery using a stop watch, to determine the actual dose rate in Gy/min. Repeat daily for 10 days	stability range, SOBP shape, modulation width, dose rate and output

Scheduling

- First-patient treatment versus ramp-up
  the sooner you start treating the more commissioning needs to be done in parallel to treatments
- Commissioning effort versus QA effort
  a heavy patient load prevents many QA hours and requires more commissioning (MU model)
- The expected patient mix and ranges to be commissioned
  limiting the type of treatments in a room can reduce the commissioning load
- Commissioning different rooms of the same design
  certain measurements only have to be performed for one room

Setting up a commissioning plan

1. Identify the properties that need to be verified
2. Determine the subset of equipment settings on which the property depends
3. Define the measurements required to verify the properties
4. Combine the measurements into a measurement plan
5. Schedule the measurements, taking into account
   - *desired start treatments*
   - *expected patient load*
   - *expected patient mix*

Commissioning of tx planning

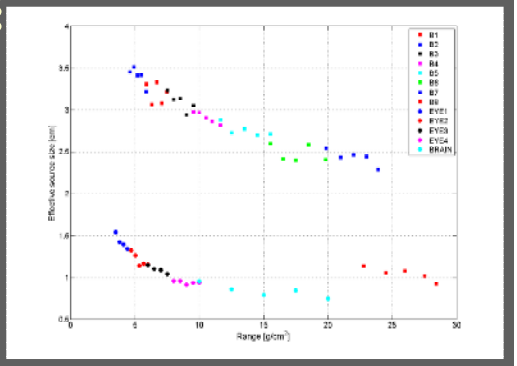
Most commercial tx planning systems are based on pencil beam algorithm.

I. Collection of beam data
   - pristine peak pdd / SOBP
   - open-field profiles Æ virtual SAD
   - half-beam profiles Æ effective source size
   - fluence along beam axis Æ effective SAD

   …for subset of energies (ranges) and nozzle settings

II. Validation dose calculation against measurement
   - water phantom
   - including inhomogeneities, oblique beams, etc…

Commissioning of tx planning



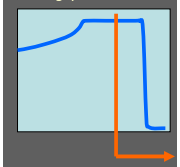
Effective source size (sigma) at 230cm nominal SAD, of IBA universal nozzle

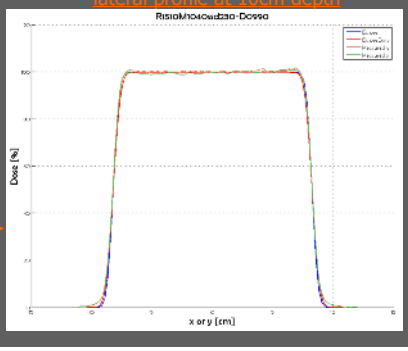
Commissioning of tx planning

comparing calculated to measured lateral profile….

lateral profile at 10cm depth

Range =15 g/cm2
Mod = 10 g/cm2
Air gap = 10cm





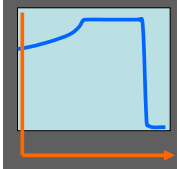
pretty good…..

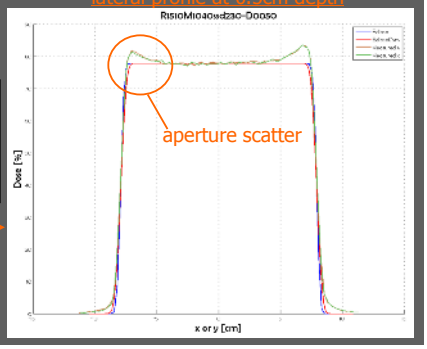
Commissioning of tx planning

comparing calculated to measured lateral profile….

lateral profile at 0.5cm depth

Range =15 g/cm2
Mod = 10 g/cm2
Air gap = 10cm

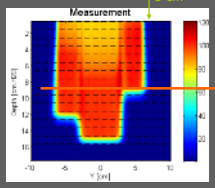




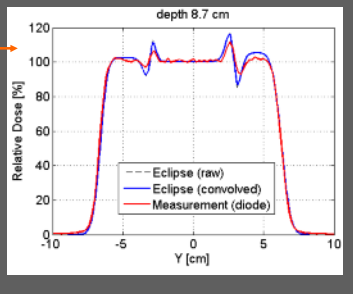
Eclipse does not model aperture scatter…..

compensator scatter

5 cm



Fluence perturbation from RC gradients, larger in tx planning than measurement

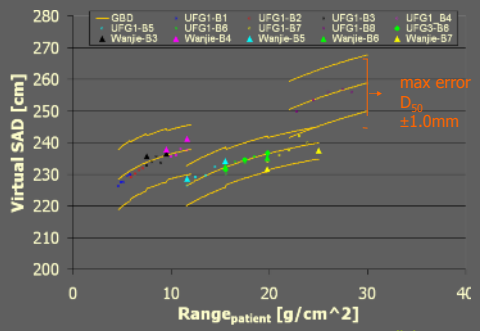


In clinical cases RC gradients smaller…

UFPTI measurement and tx planning data.

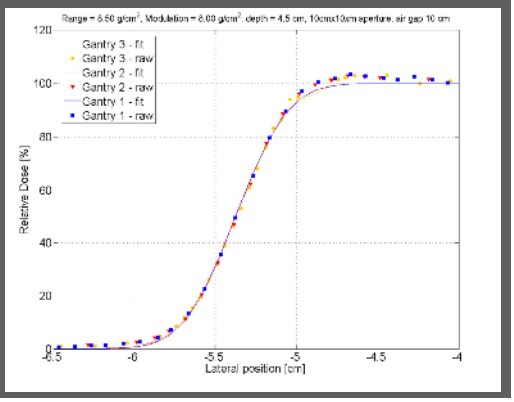
Golden Beam Data

Is it possible to use a single beam data set ('golden') to commission treatment planning for different installations of a PT system?



UFPTI project in collaboration with IBA

Golden Beam Data



Conclusion

- The limited number of proton centers and evolving technology, makes commissioning a custom job for now…
- Knowledge transfer between new and old proton centers is important in moving protons 'mainstream'
- Setting up a comprehensive commissioning plan helps to set realistic expectations and to discuss trade-offs …patient load, commissioning time, QA time,…
- Commissioning protons is fun!