UNIVERSITY of MARYLAND MEDICAL SYSTEM

Proton Planning

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Maryland Proton Treatment Center

In Memoriam of Lynn Verhey: Clinical Physicists must know and be involved in Treatment planning

Conflicts of Interest

Varian Medical: Honorarium

Why we need Physics Proton Planning ?

Help make sense out of this

Educate your colleagues !

Develop 101 lectures to clear up nomenclature mess

Delivery Techniques - The old and the new
Proton Uncertainties - Scary !
Proton planning basics – How to handle uncertainties
Site specific technology - Wow

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Who else but Physics ?

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Develop 101 lectures to clear up nomenclature mess

Delivery Techniques - The old and the new
Proton Uncertainties - Scary ! ← Drives how we plan
Proton planning basics – How to handle uncertainties
Site specific technology - Wow

This does not need to be so scary !

Range Uncertainties

First problem:

Stopping power (MeV cm^2 /g) determine how "fast" proton loses energy

CT HU to stopping power ratio calibration has 3.5% uncertainty

Translates into 3.5 % range uncertainty

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Translates into 3.5 % range uncertainty

3.5 mm at a range of 10 cm
7 mm at a range of 20 cm
} Depends on depth !

Range Uncertainties

Management (1):

Use margins = 3.5% range

Larger distal margin than proximal margin

For prostate @ 20 cm depth: margin= 7 mm

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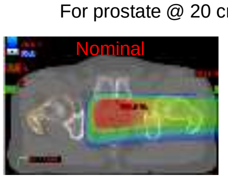

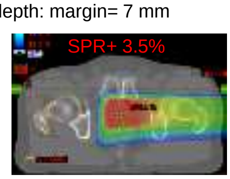

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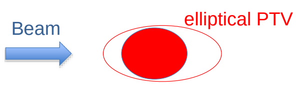

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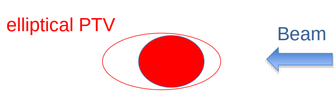

PTV ?

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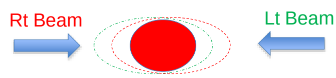


Range Uncertainties

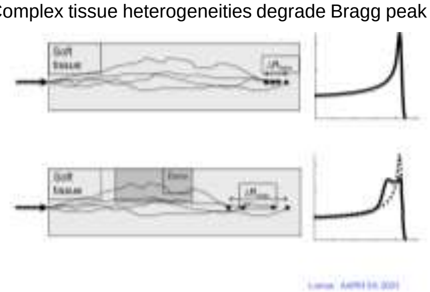
Management (2):

Do not stop beam in front of organs at risk

This is why lateral beams are used to treat prostate in proton therapy

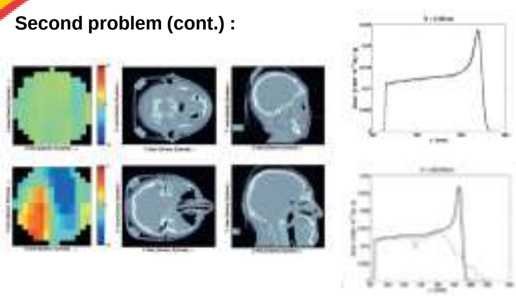
Range Uncertainties

Second problem:
Complex tissue heterogeneities degrade Bragg peak



Range Uncertainties

Second problem (cont.) :



Pflugfelder et al, Med Phys, 34 (2007), 1506

Range Uncertainties

Management:

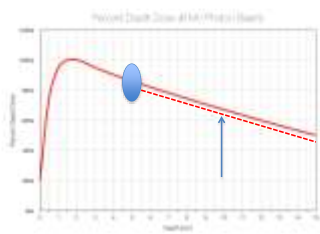
Avoid beam entrance through regions of complex heterogeneity

Even if setup is reproducible

Range Uncertainties

Third problem:
Setup error can change the dose distribution itself

Photons



Tumor at 10 cm
sees 67 % of max dose

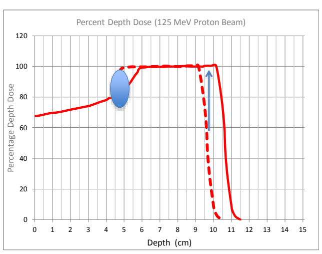
Patient roll: bone
“appears” at 5 cm depth

Add 1 cm bone
Density is twice
that of water
(1cm water => 2 cm)

Pull back PDD by an
additional 1 cm

Tumor at 10 depth still sees 64% of dose

Protons



Tumor at 10 cm
sees 100 % of max dose

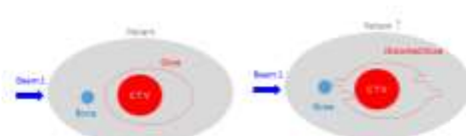
Patient roll: bone
“appears” at 5 cm depth

Add 1 cm bone
Density is twice
that of water
(1cm water => 2 cm)

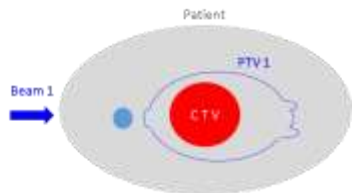
Pull back PDD by an
additional 1 cm

Tumor at 10 depth still sees 0% of dose

Dose distribution is not static

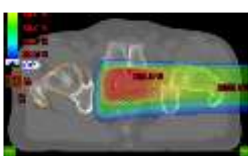


Beam specific PTV ?

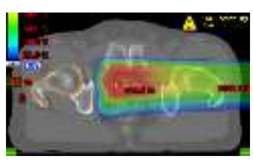


Dose distribution is not static

Nominal Plan



Patient shifted posteriorly by 5 mm



PTV ?

To ensure CTV coverage, PTV (or dose distribution) may have unintuitive shape

Traditional PTV concept is not helpful in proton planning

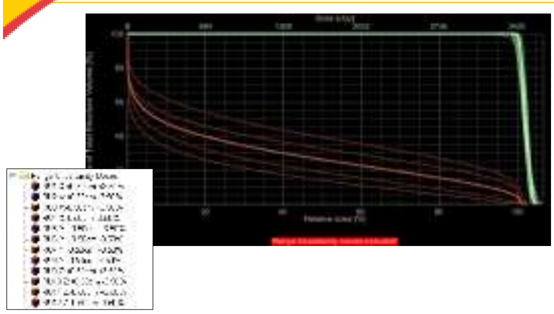
Most conformal plan may not be best plan

Robustness

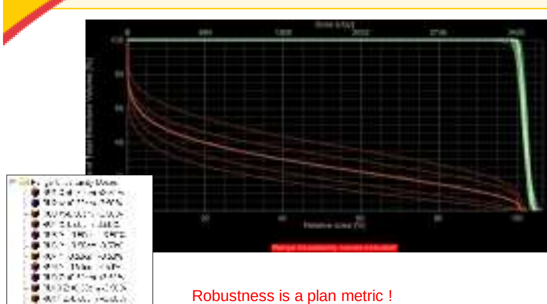
Ask

What if range is wrong by 3.5% and/or patient is setup is off

Evaluate Plan for Robustness



Evaluate Plan for Robustness



Robustness is a plan metric !
Plan robustness replaces traditional PTV concept

Robustness optimization ?

Include robustness as an objective in planning

Available in commercial treatment planning systems

Range Uncertainties

General principle to deal with all end-of-range uncertainties:

Use **multiple beams** to geographically spread out uncertainties

Be careful when ranging out into OAR

Proton planning starts at the CT scanner

Robustness, Robustness, Robustness

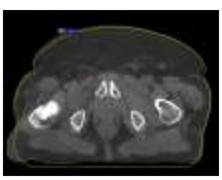
Avoid sharp edges (Devices and Patient)

Setup limitations:

CSI, avoid sharp fall off

Obese Patient

Hip implant, needed oblique beam
8 mm depth difference



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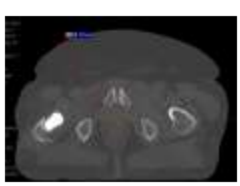


Recommended VMAT plan

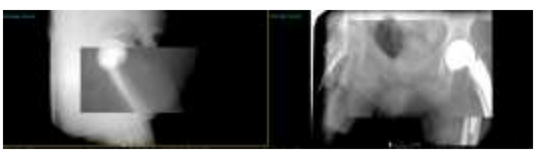
Difficult Setup

Elderly Female

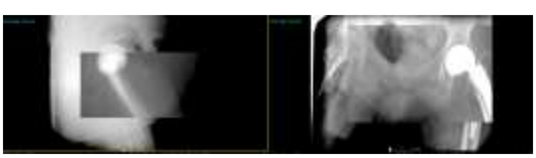
Frog-legged setup

Hip replacement

Difficult Setup



Difficult Setup



Transferred patient to Photon Clinic

Simulation

Physics and/or Dosimetry goes to CT-sim

Treatment Planning

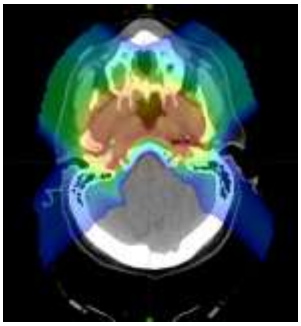
Physics reviews each treatment plan

before it is presented to Physician

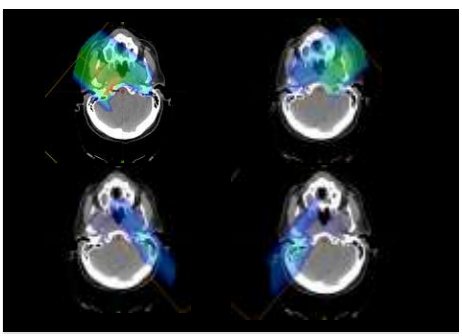
Example: MFO plan

- **M**ulti **F**ield **O**ptimization (similar to IMRT)
- In MFO plans it is not possible to control the dose contribution from each beam
- For *n* beams, dose from each beam is likely ≠ 1/*n* of dose
- Check dose from each beam manually

MFO plan (4 fields)



MFO plans (4 fields)
Field doses



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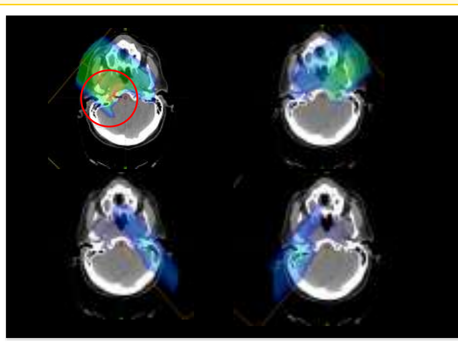

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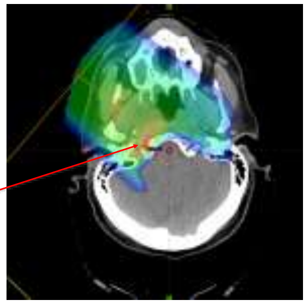

93.9% of
px dose

Lessons learned meeting

- What is working, what is not working
- Near misses
- Continue to improve process
- All of physics and dosimetry
- Time well spent

Quality treatment

- Physicians, Therapists, Dosimetry:
all need to know and understand uncertainties

- Drives how we set up and simulate patients
- Drives how we plan patients
- Drives how we evaluate plans
- Drives how we treat patients
- Drives how we monitor patients during treatment course

Physics needs to facilitate this discussion

Proton Center