IMPT – as important for proton therapy as IMRT for x-rays?

T. Bortfeld, S. Safai*, A. Trofimov,
J.A. Adams, M. Engelsman^

Massachusetts General Hospital, Boston

*Now at Paul Scherrer Institute, Villigen, Switzerland

^Now at University of Delft, The Netherlands

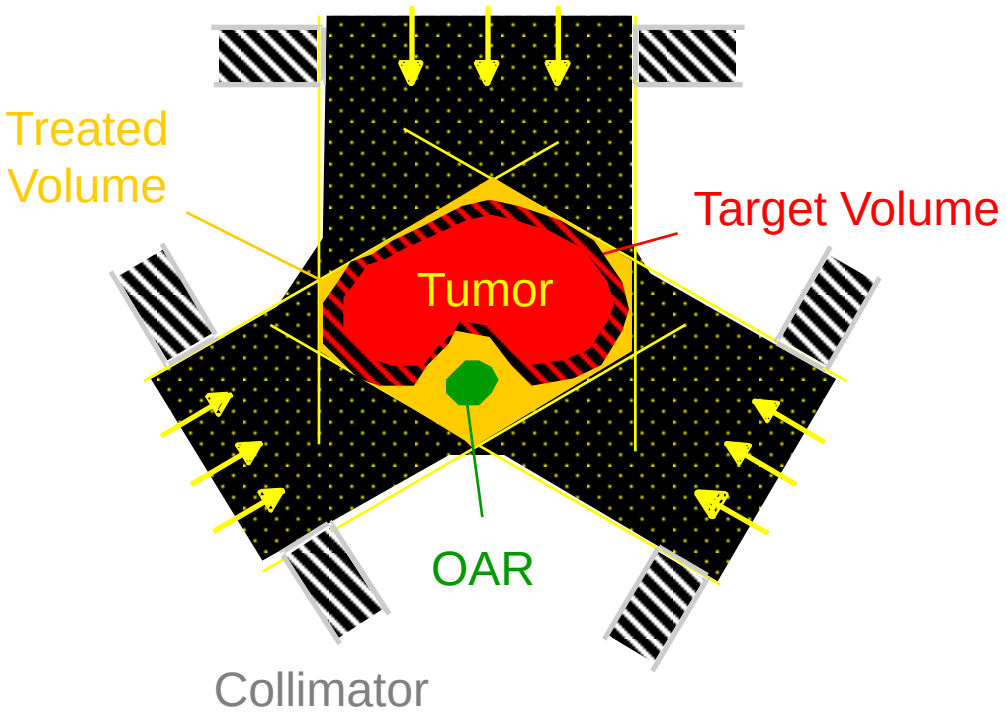
TBortfeld@hms.harvard.edu

MASSACHUSETTS GENERAL HOSPITAL
RADIATION ONCOLOGY

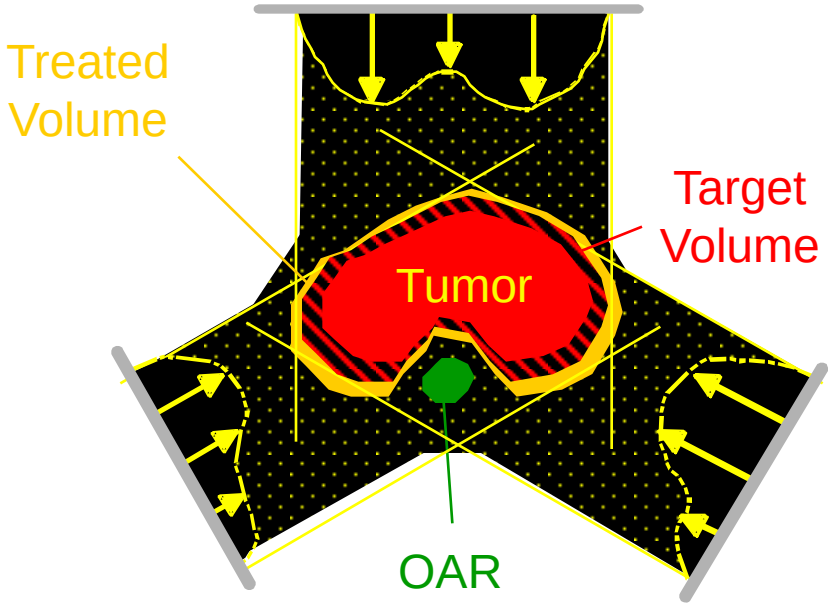
HARVARD MEDICAL SCHOOL

IMRT – concave dose distributions

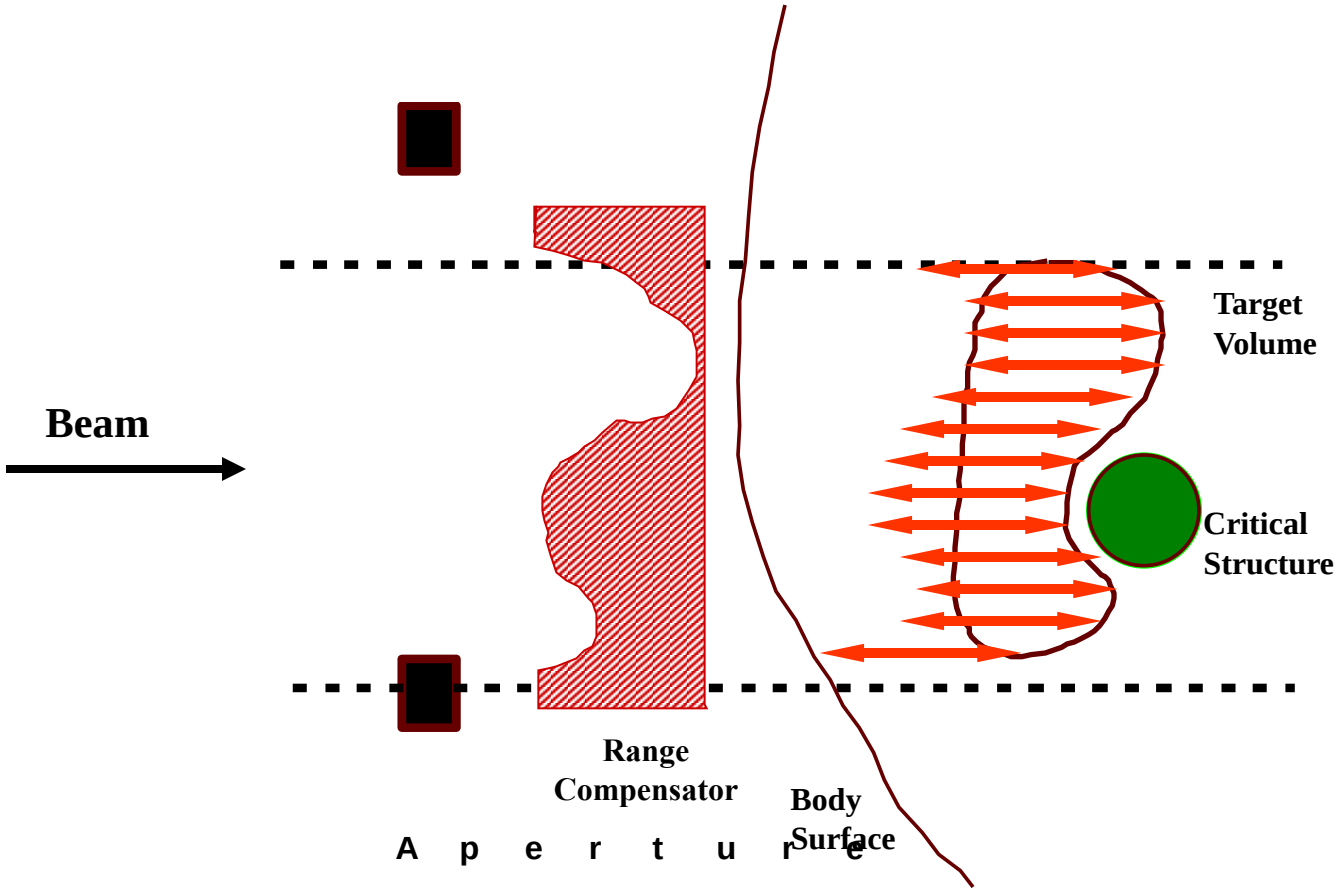
Conventional 3D conformal



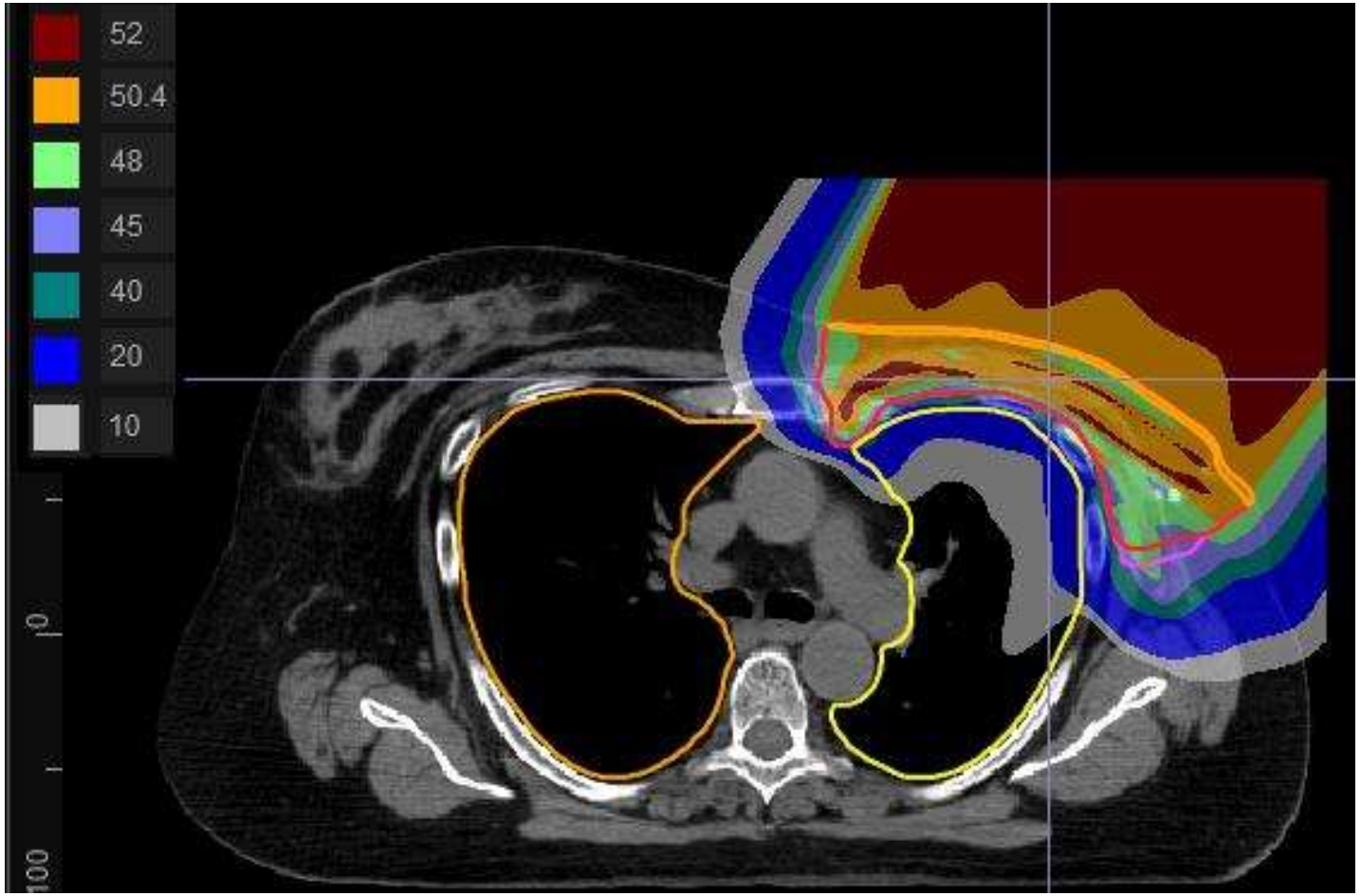
Intensity Modulation



Protons – concave dose distributions single beam, no IMRT, so what's the point?

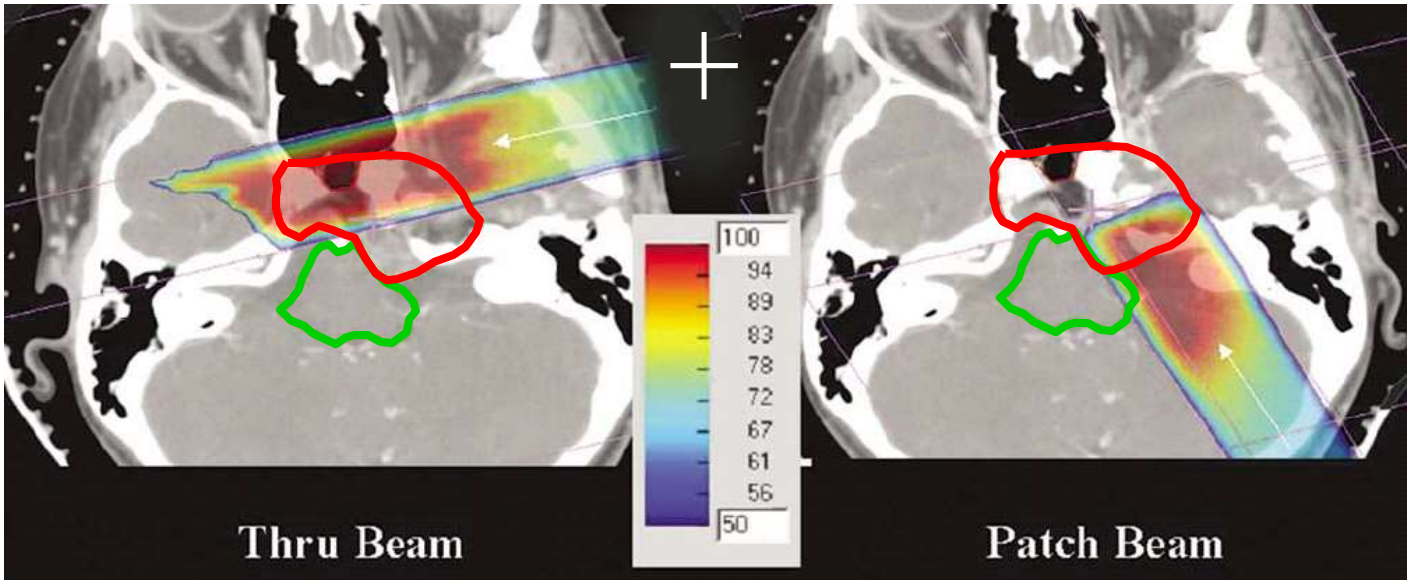


Concave dose distributions with pencil beam scanning: chest wall

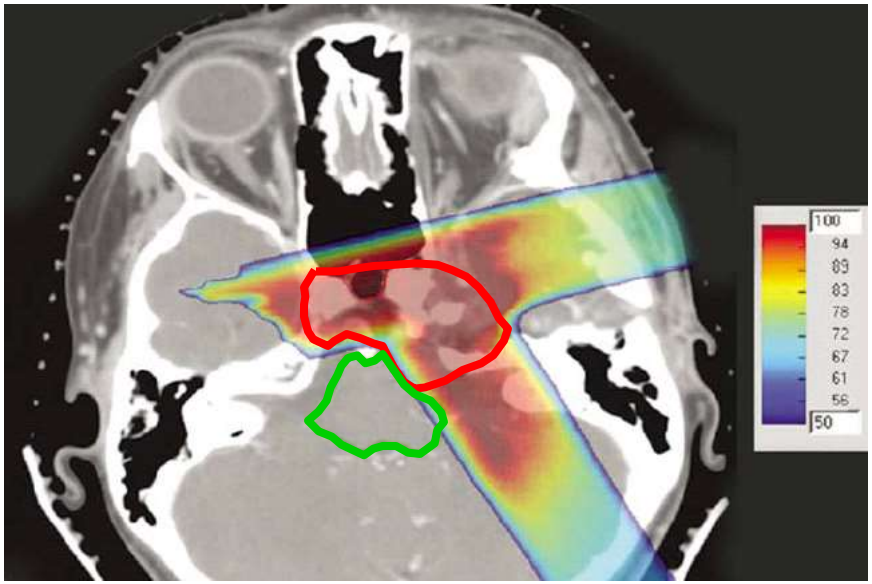


H.-M. Lu et al., MGH

Field patching

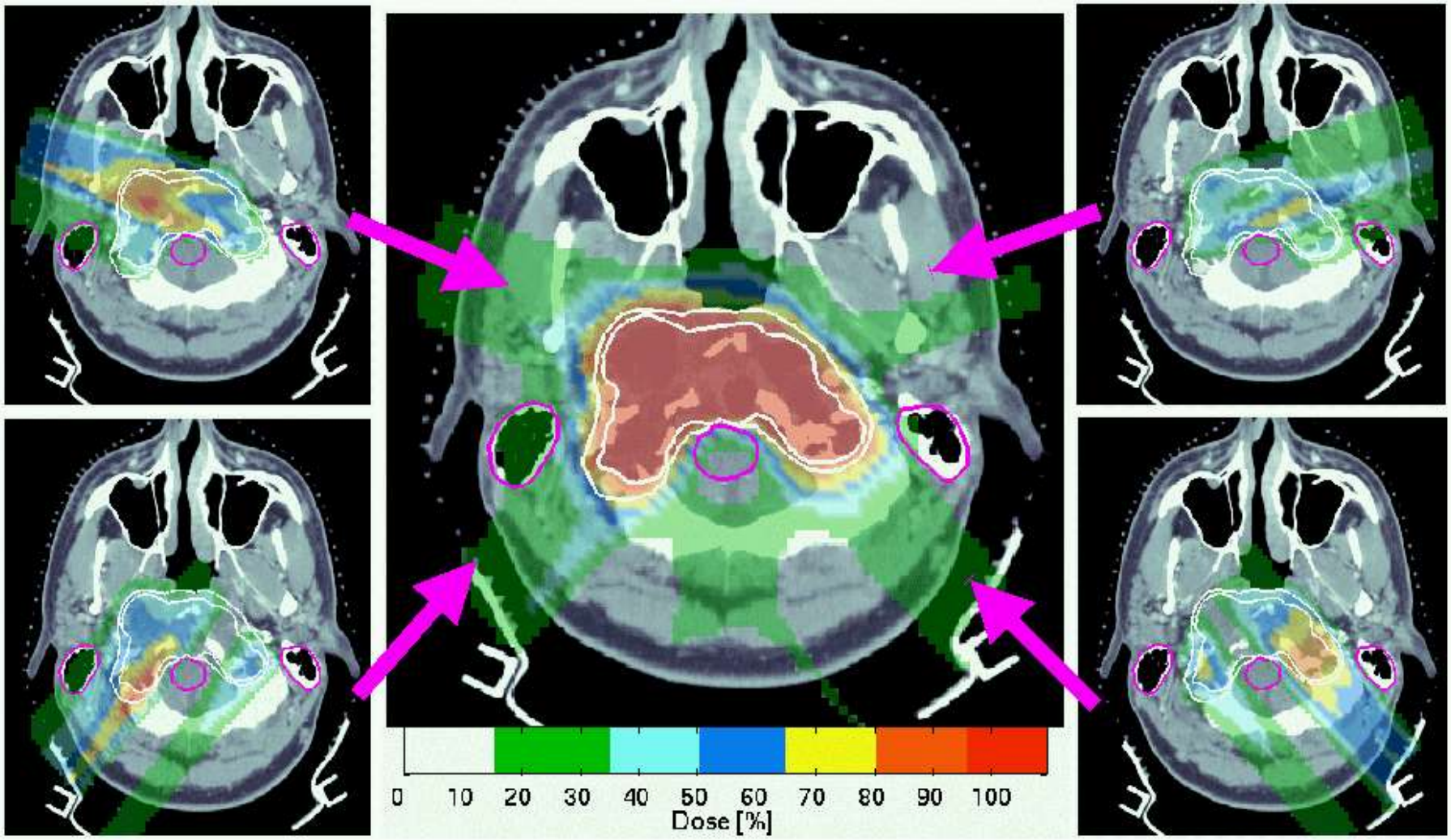


=



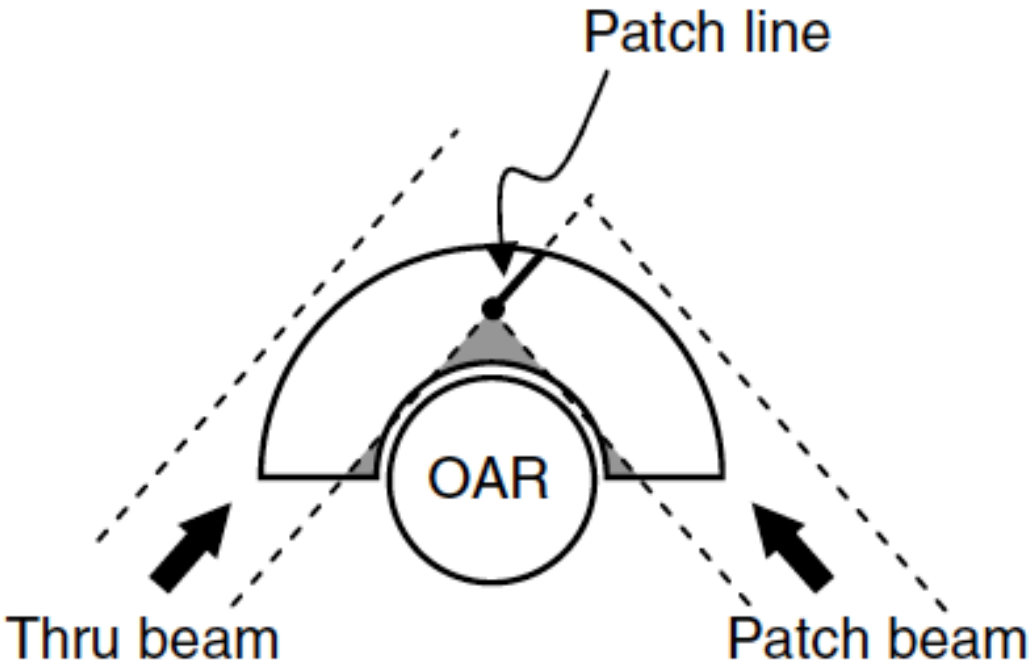
- What is the advantage of IMPT over the most sophisticated 3D conformal proton therapy (3DCPT) with patched fields?

We are talking about *multi-field* IMPT only!

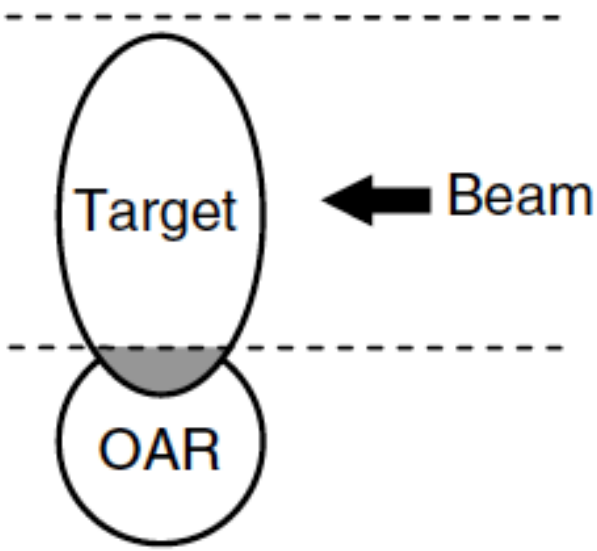


The most challenging geometric scenarios:

1. Tumor “wraps around” critical structure



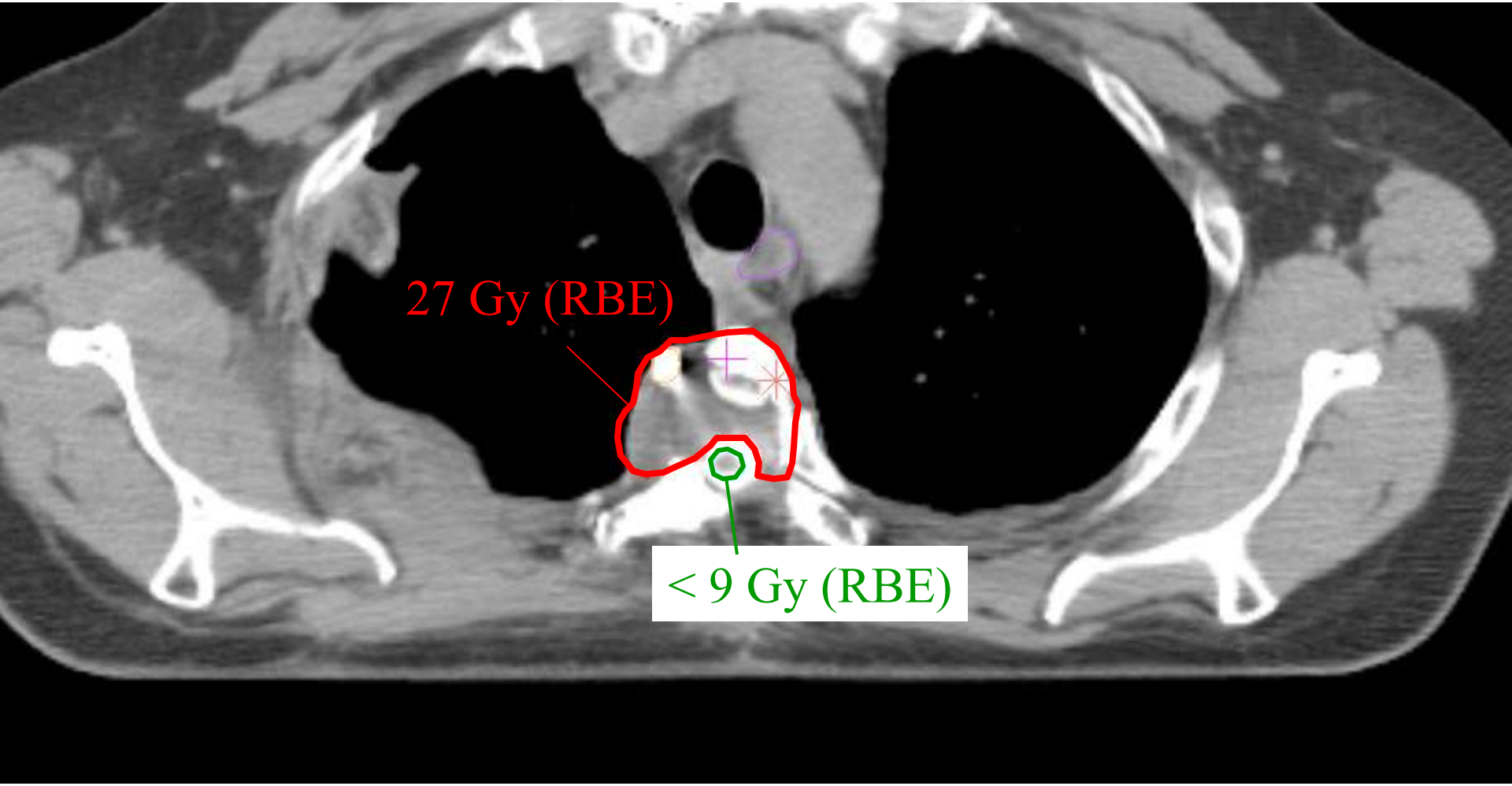
2. Critical structure “wraps around” tumor



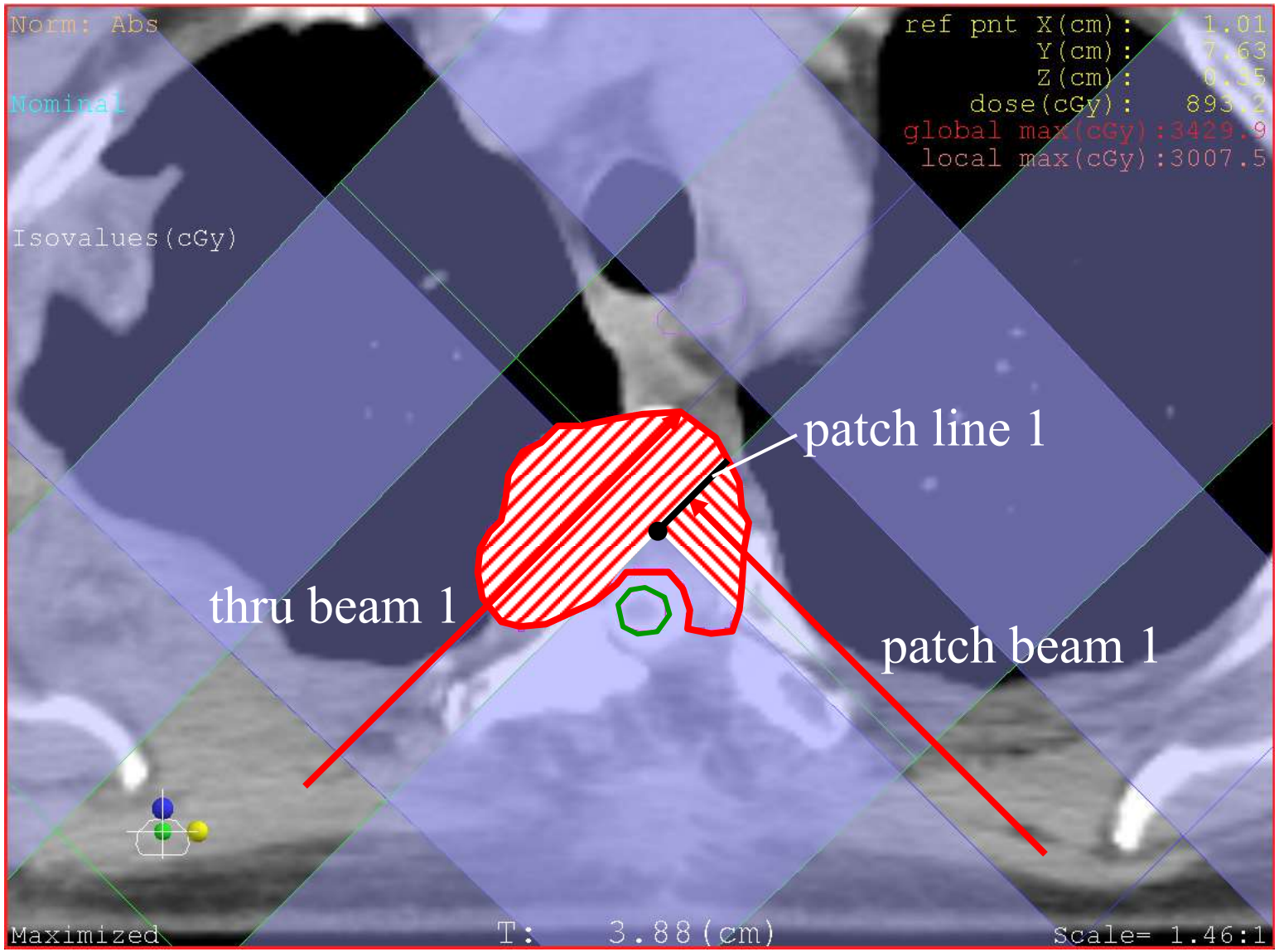
Two clinical cases representing those scenarios:

Patient	Prescribed proton dose	Fields	Patching combinations	Dose delivered with patching (% of total prescribed proton dose)	Comment
Paraspinal chondrosarcoma	27 Gy (RBE)	4	2	100%	Boost following photon therapy
Skull-base chondrosarcoma	69 Gy (RBE)	9	2	17%	Pediatric patient. Patching: boost to GTV after initial proton therapy

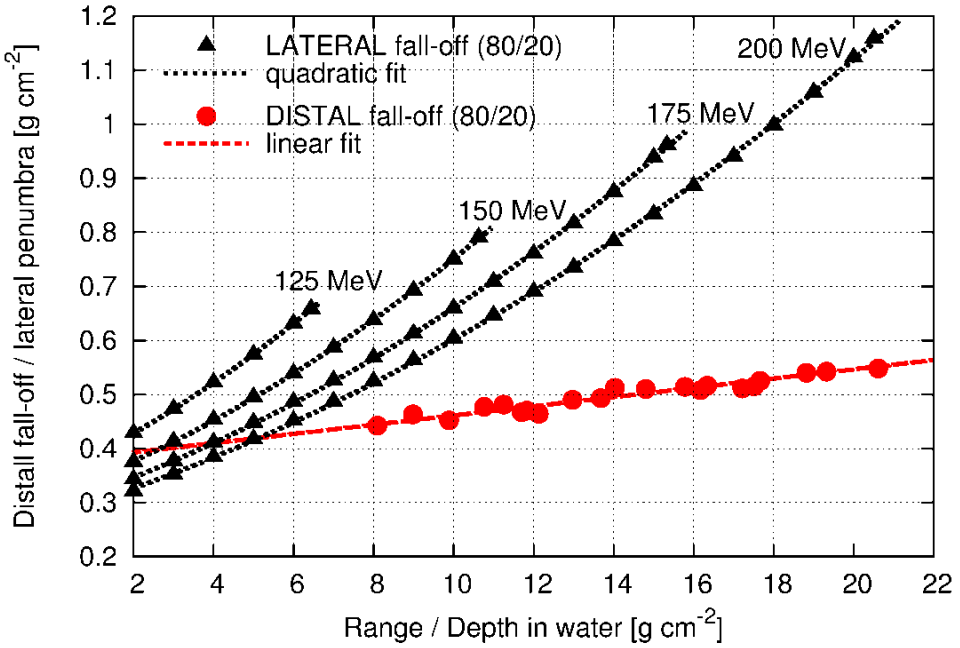
Case 1: Multiply recurrent G2 chondrosarcoma T4 (Boost after photon therapy)



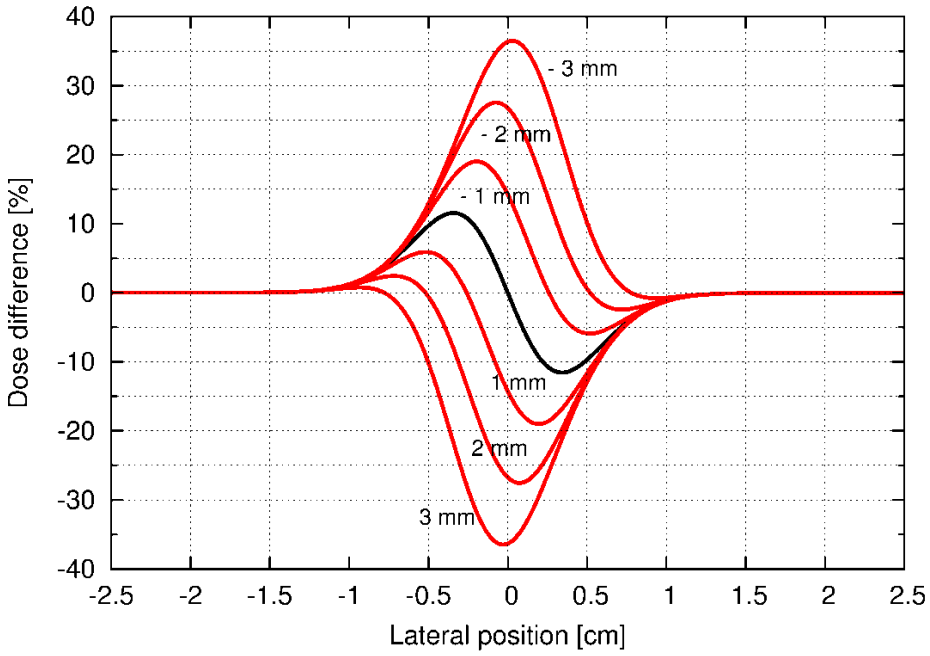
patch field combination



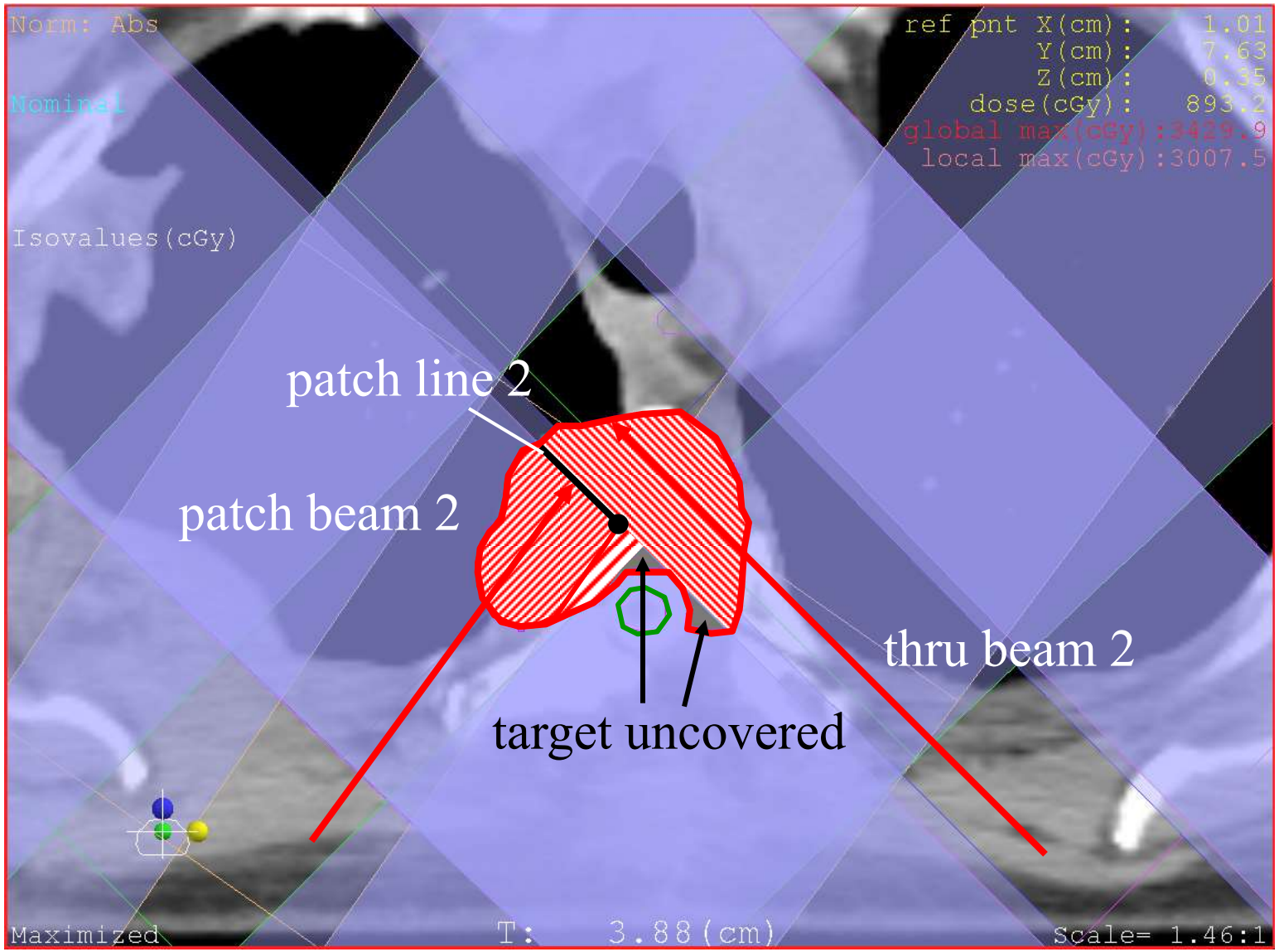
Note on the side: An issue with distal – lateral patching



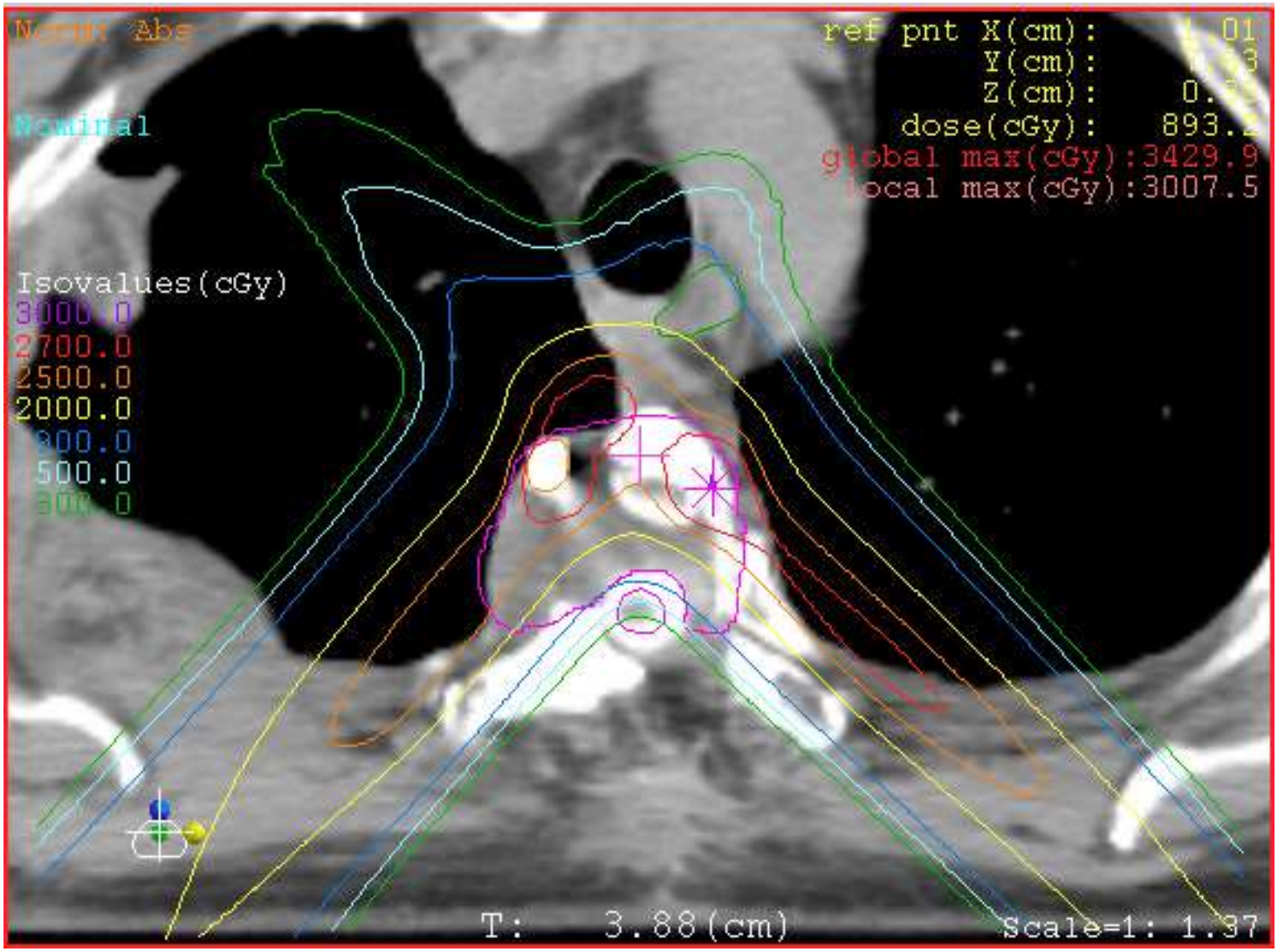
Dose difference across the junction



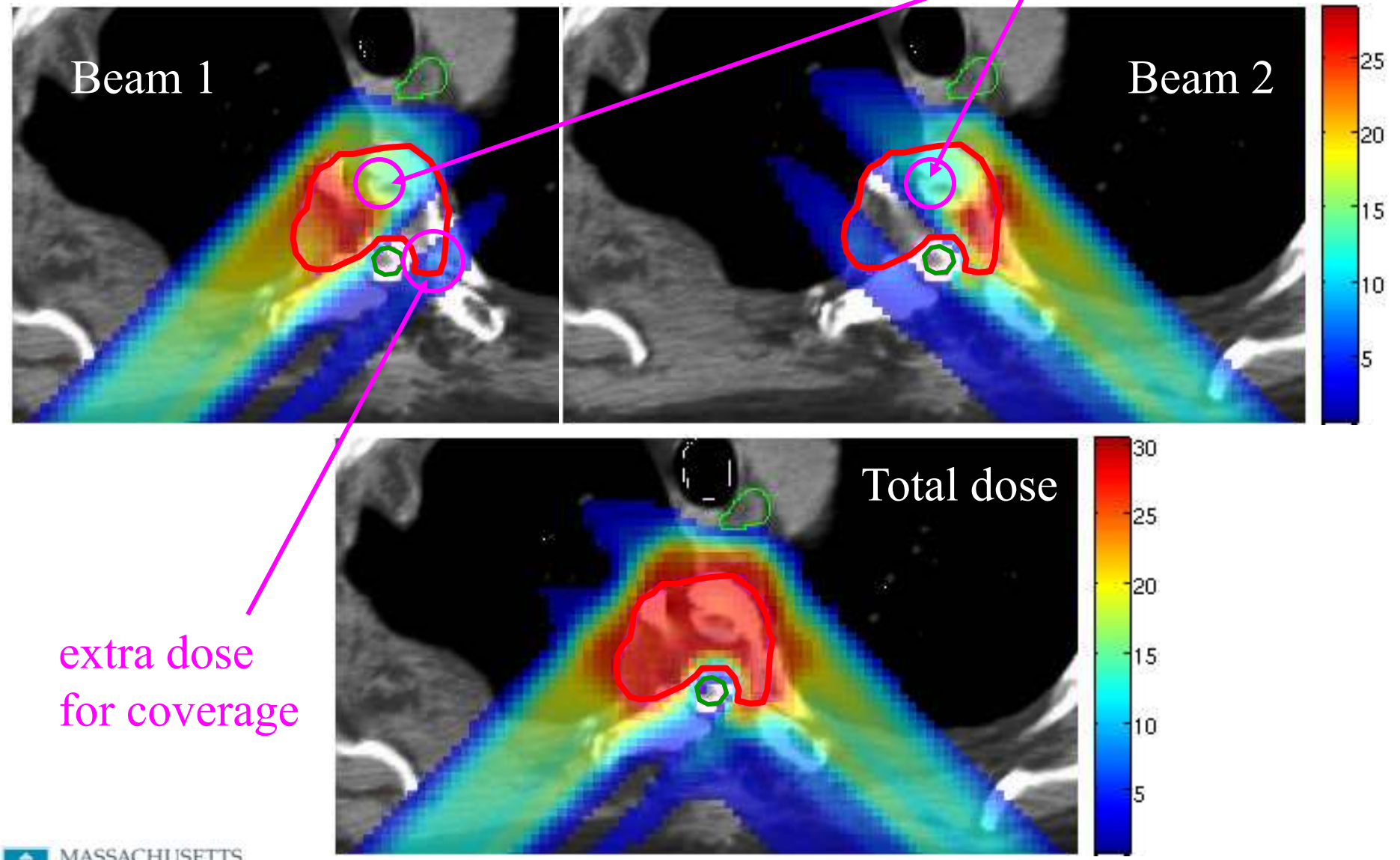
2nd patch field combination



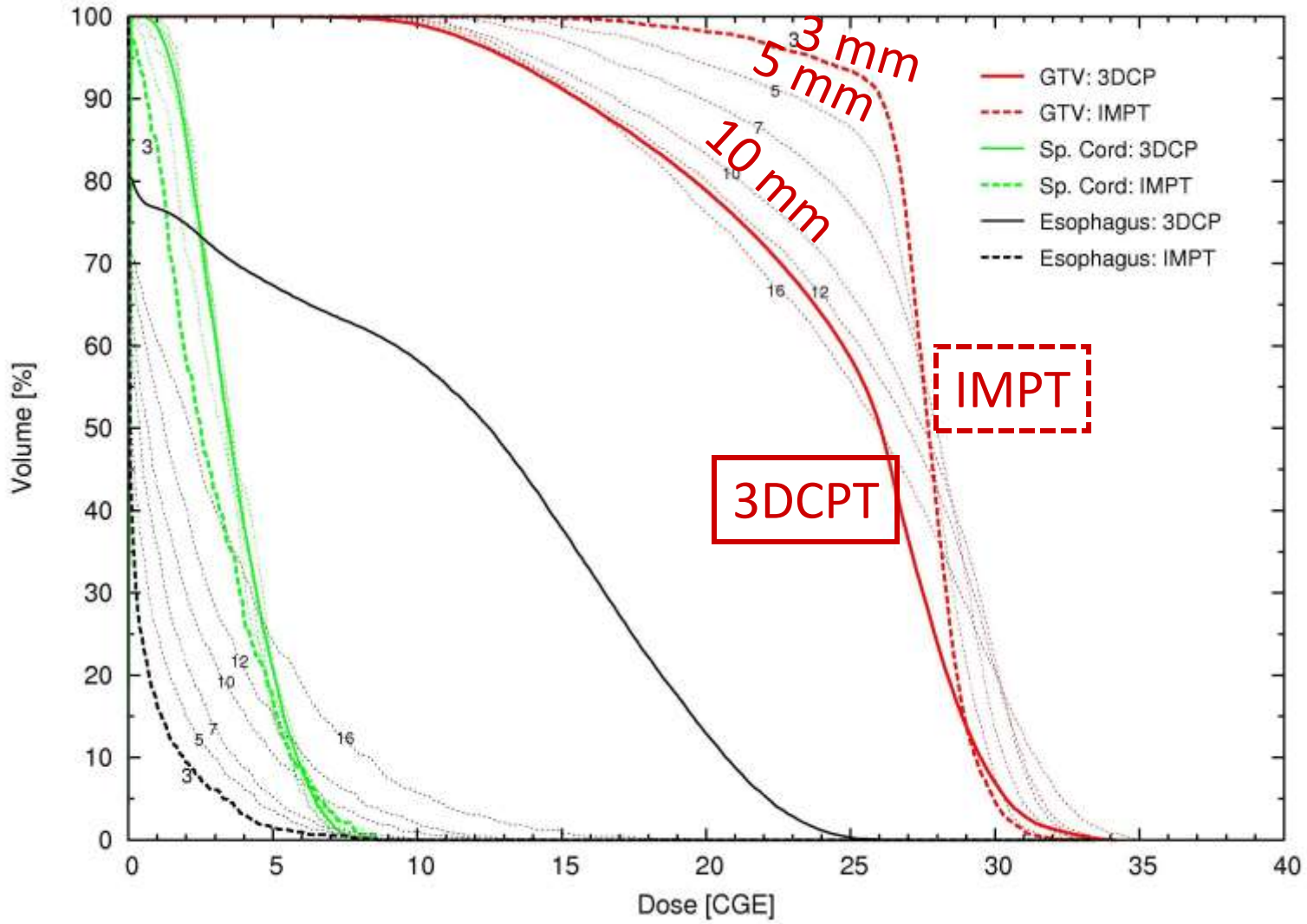
Proton plan (“3D conformal”, 3DCPT)



Same case with IMPT

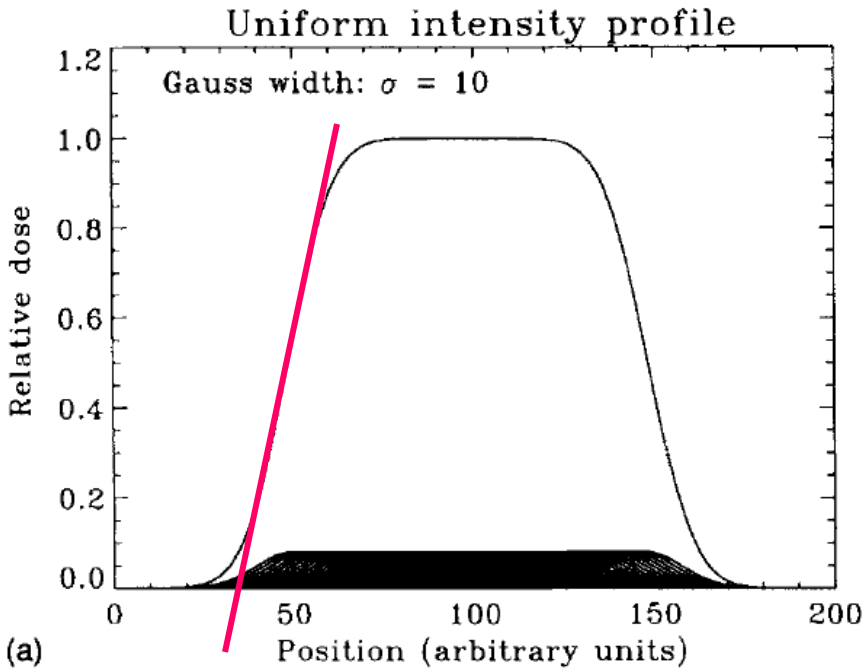


3D proton plan (3DCPT, no IM) vs. IMPT

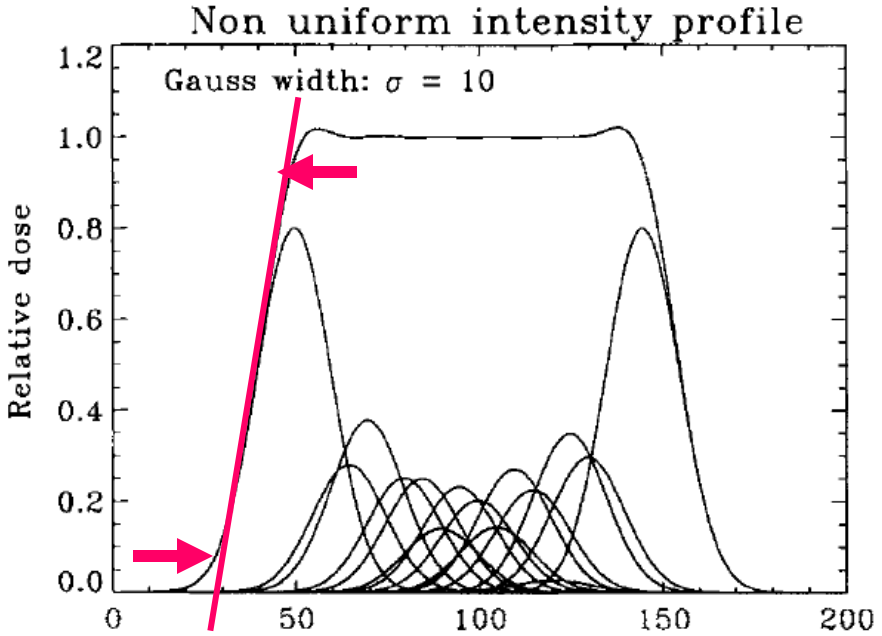


Another note on the side: Penumbra sharpening with IMPT

Passive scattering



IMPT



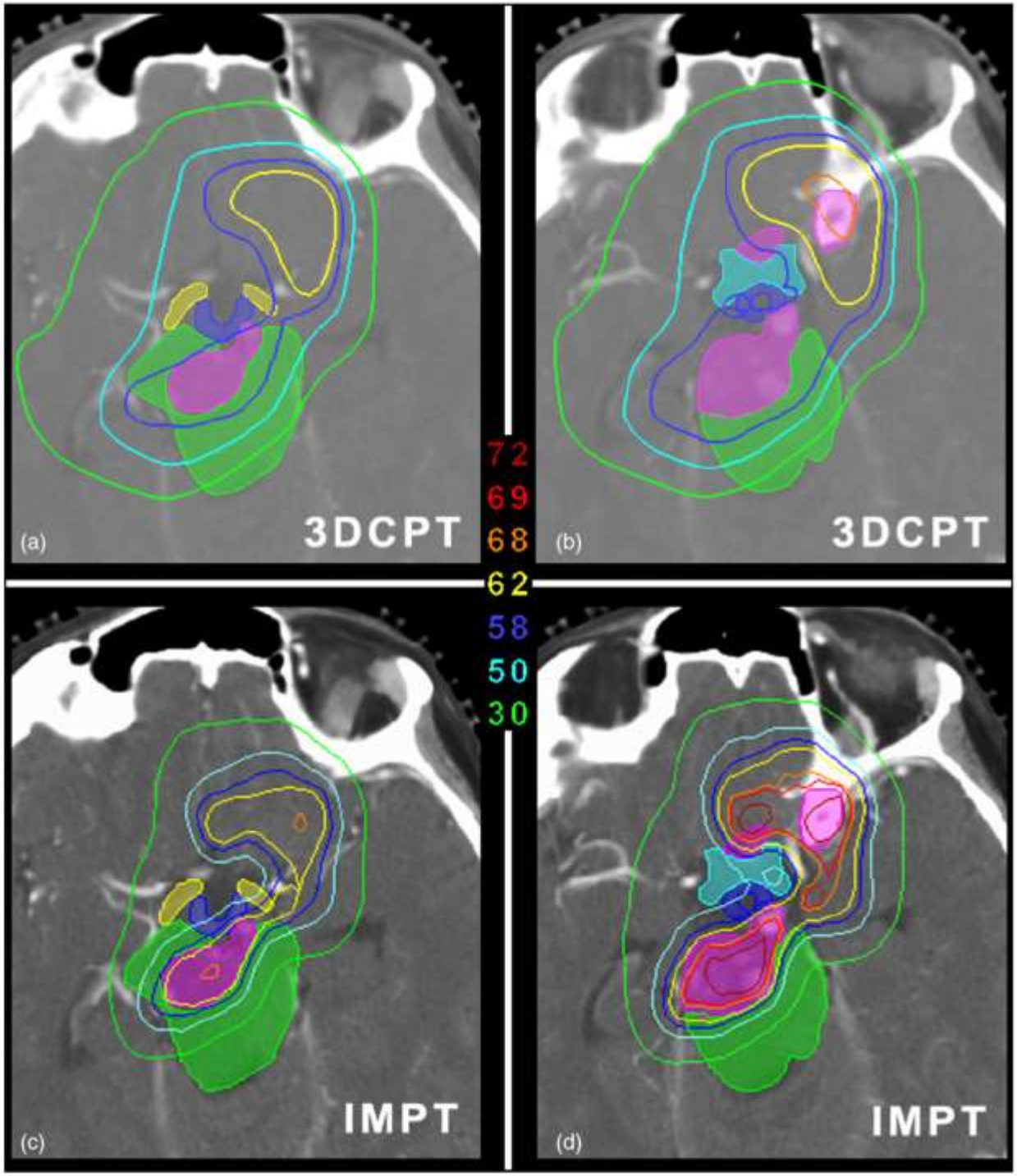
Pedroni et al., Med. Phys. **22** (1995) 37

Message 1:

- "Sharp" (narrow) pencil beams are necessary to exploit the full potential of IMPT. IMPT delivered with a broad 10 mm (sigma) pencil beam may have no benefit over 3DCPT.

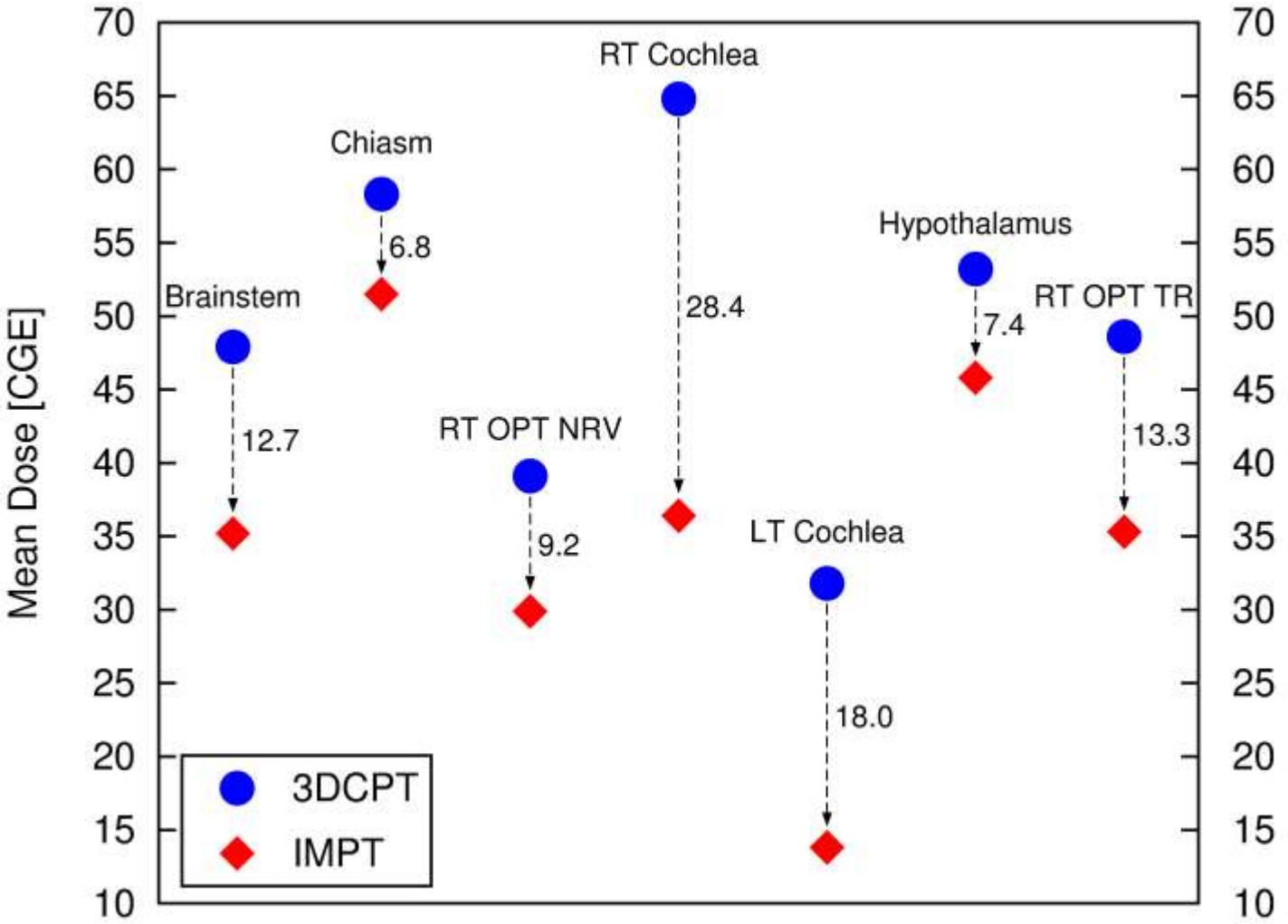
*All subsequent calculations done with 5 mm (σ) pencil beams

Case 2: skull-base chondro-sarcoma



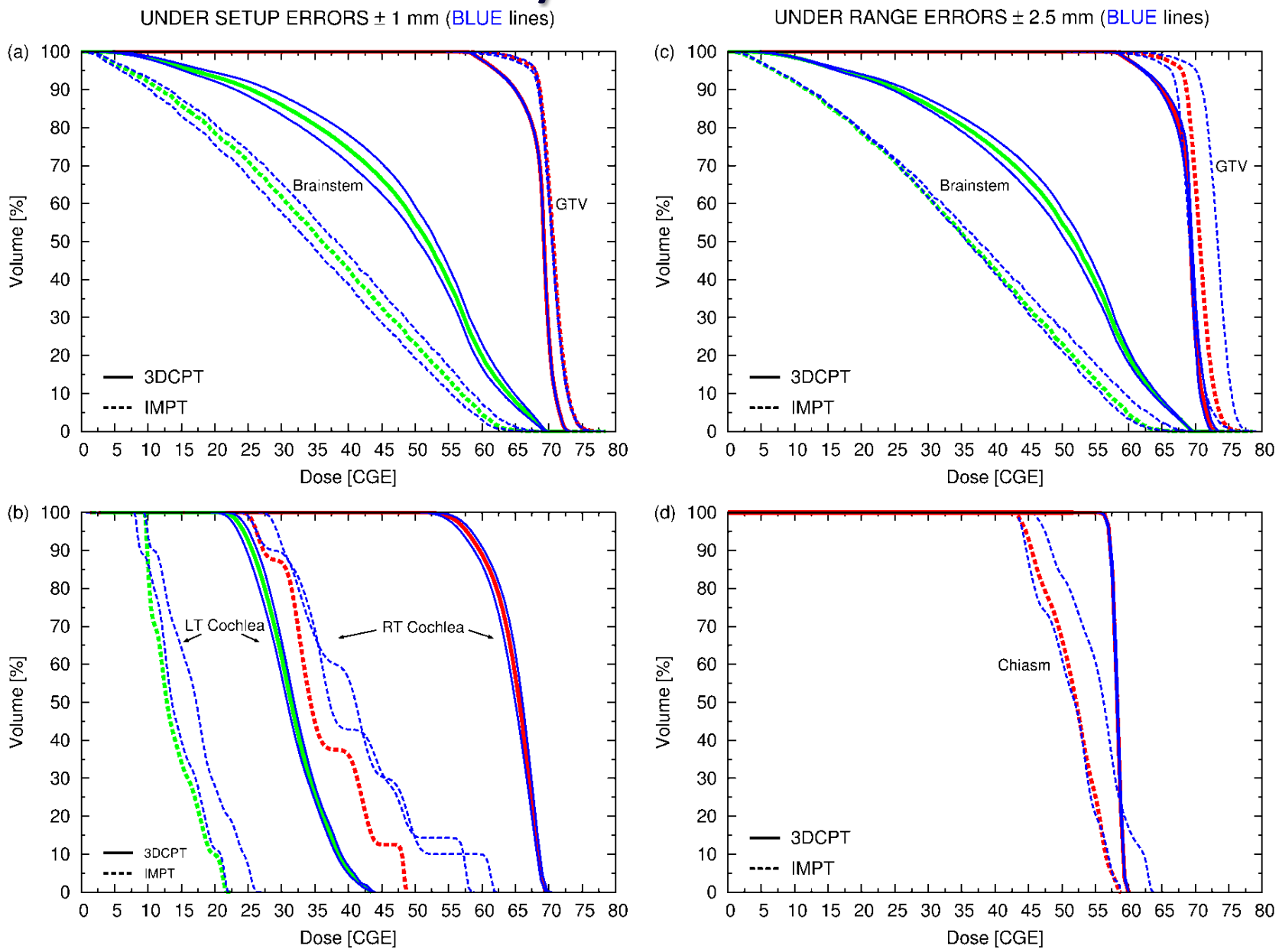
MASSACHUSETTS GENERAL HOSPITAL
RADIATION ONCOLOGY

Case 2: dose sparing 3DCPT vs. IMPT

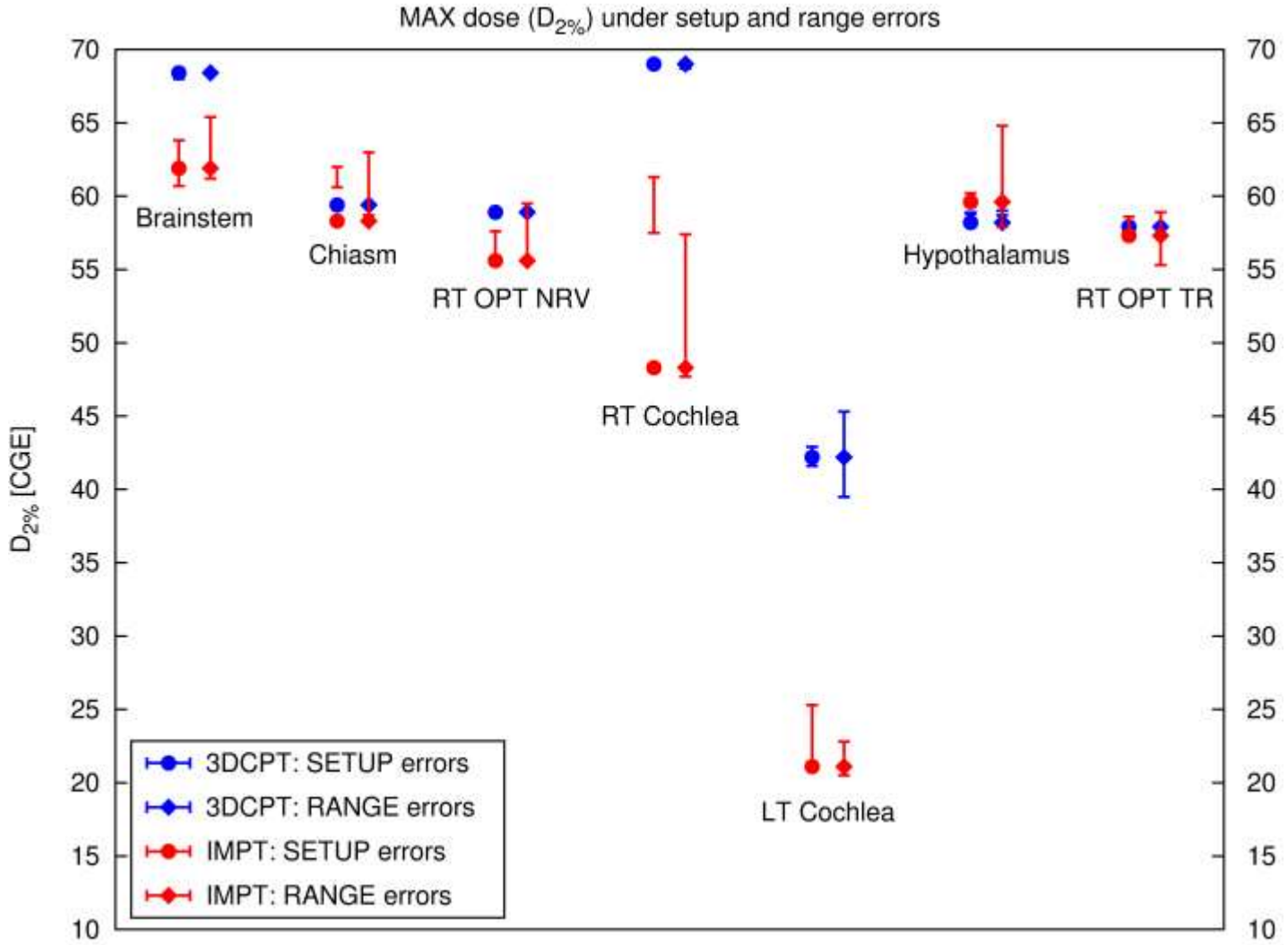


Showing the mean dose reduction through IMPT

Robustness analysis: DVH



Robustness analysis: max. dose



Message 2:

- Careful robustness analysis is essential to evaluate the merit of IMPT. It may reveal that a nominal advantage of IMPT turns into an actual disadvantage.

Future developments required to exploit the full benefit of IMPT

- Sharper pencil beams -> finer "painting" of intensity layers

- Robust optimization, ideally in combination with multi-criteria optimization to control the tradeoff between robustness and plan conformality (W. Chen et al., PMB 57:591, 2012)
- Reduced range uncertainty (e.g. through some form of in-vivo range measurement)

IMPT – as important for proton therapy as IMRT for x-rays?

- No, because:
  - Complex concave dose distributions are achievable with compensators and patching.
  - Broad "brush" pencil beams available at most centers today are limiting.
  - Tools for robust analysis and optimization are not quite mature yet.
- There is a significant *potential* advantage of IMPT – but that requires a successful completion of future developments.

More details: Safai et al., PMB August 2013

Concave dose distributions w/o IM