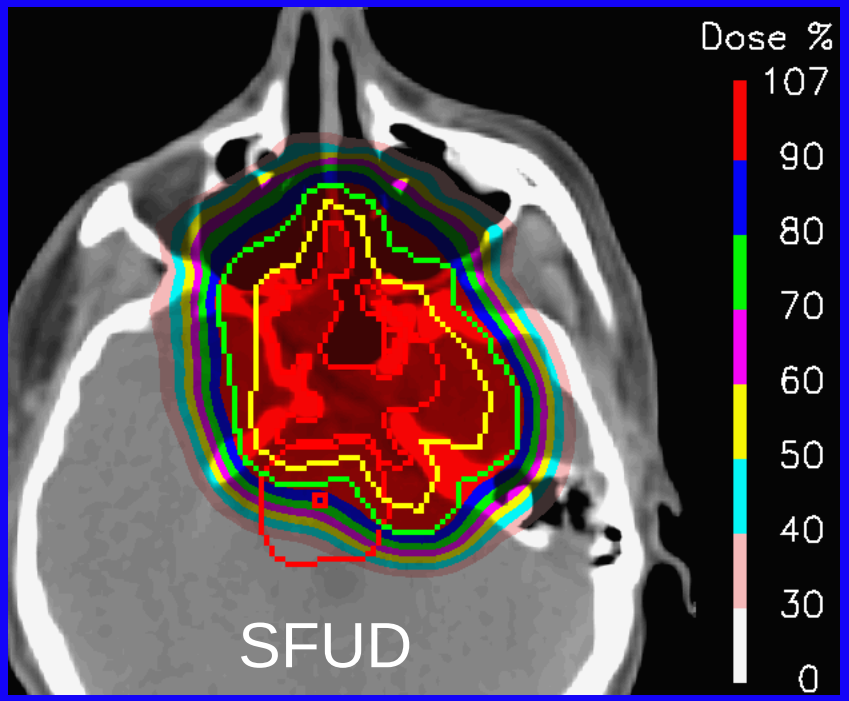
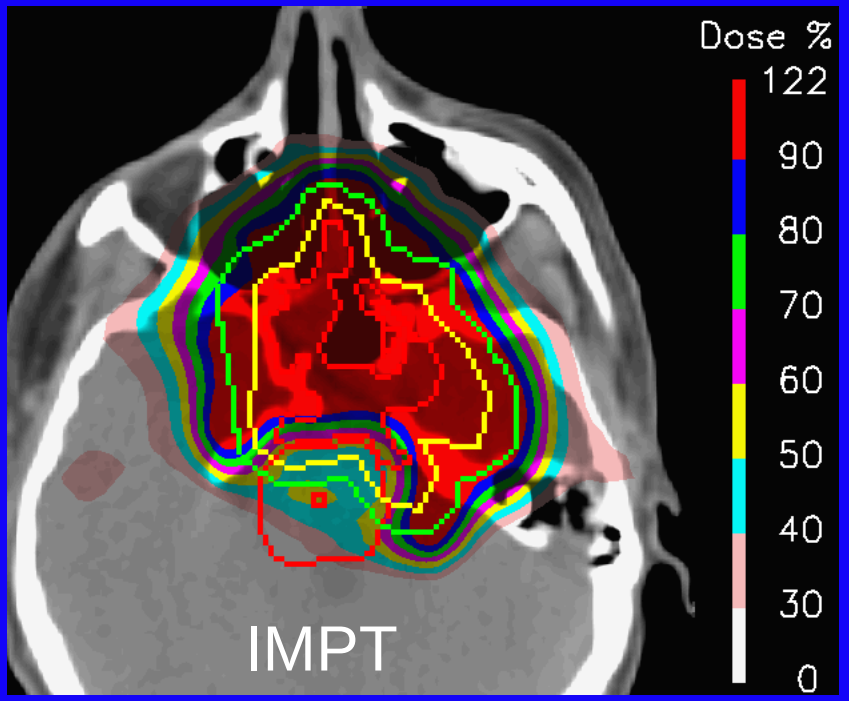
Planning with scanned beams





Tony Lomax, Centre for Proton Radiotherapy,
Paul Scherrer Institute, Switzerland

Treatment planning for scanning

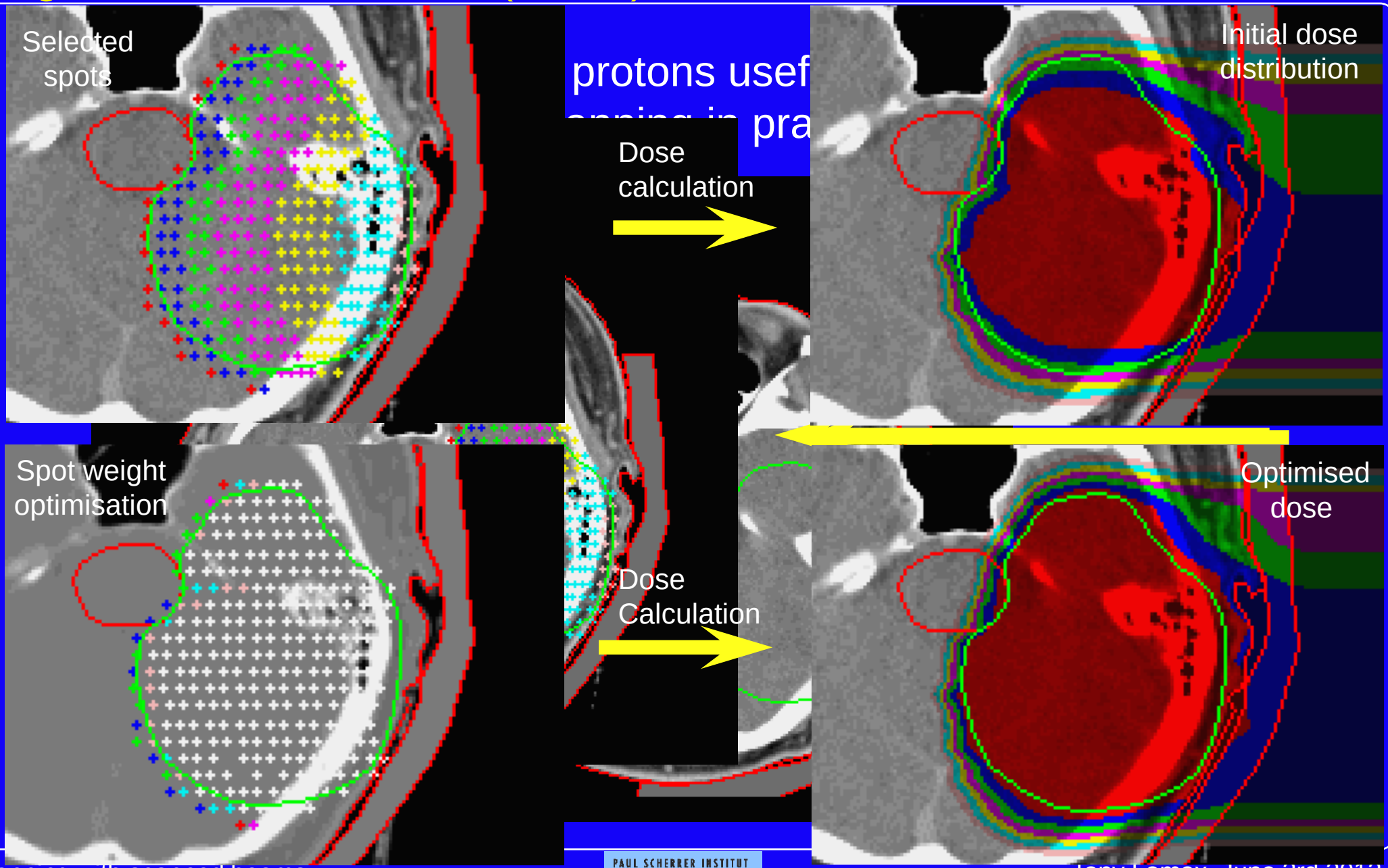
1. Single Field, Uniform Dose (SFUD)
2. Intensity Modulated Proton Therapy (IMPT)
3. Dealing with uncertainties
4. Summary

Single field, uniform dose (SFUD) planning

The combination of individually optimised fields, each of which deliver a (more or less) homogenous dose across the target volume

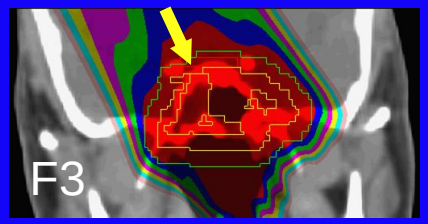
SFUD is the spot scanning equivalent of treating with ‘open’ fields.

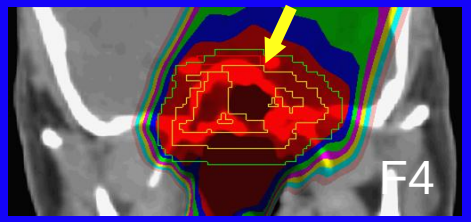
Single Field, Uniform Dose (SFUD)

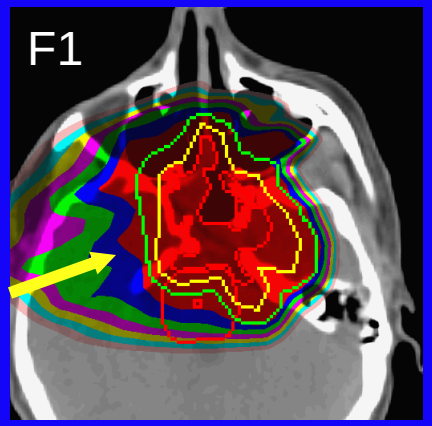


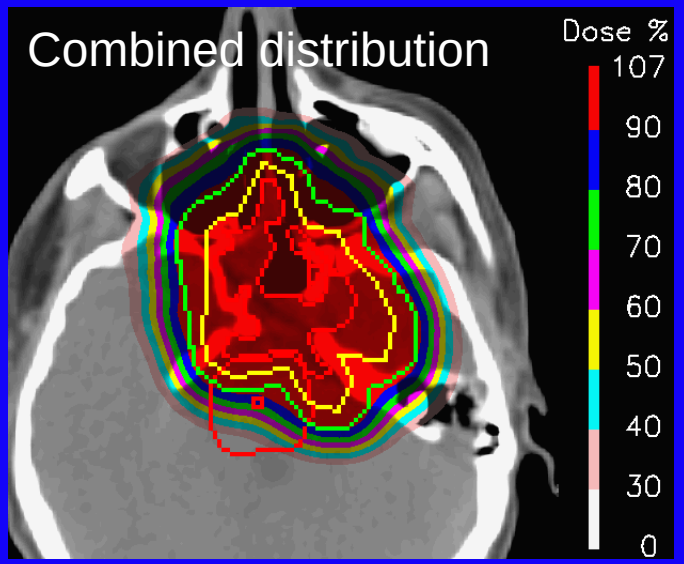
Single Field, Uniform Dose (SFUD)

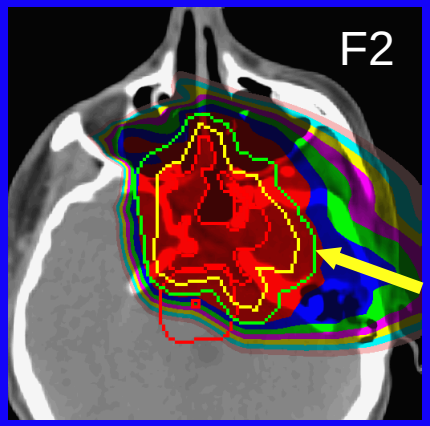
A SFUD plan consists of the addition of one or more individually optimised fields.











Note, each individual field is homogenous across the target volume

Treatment planning for scanning

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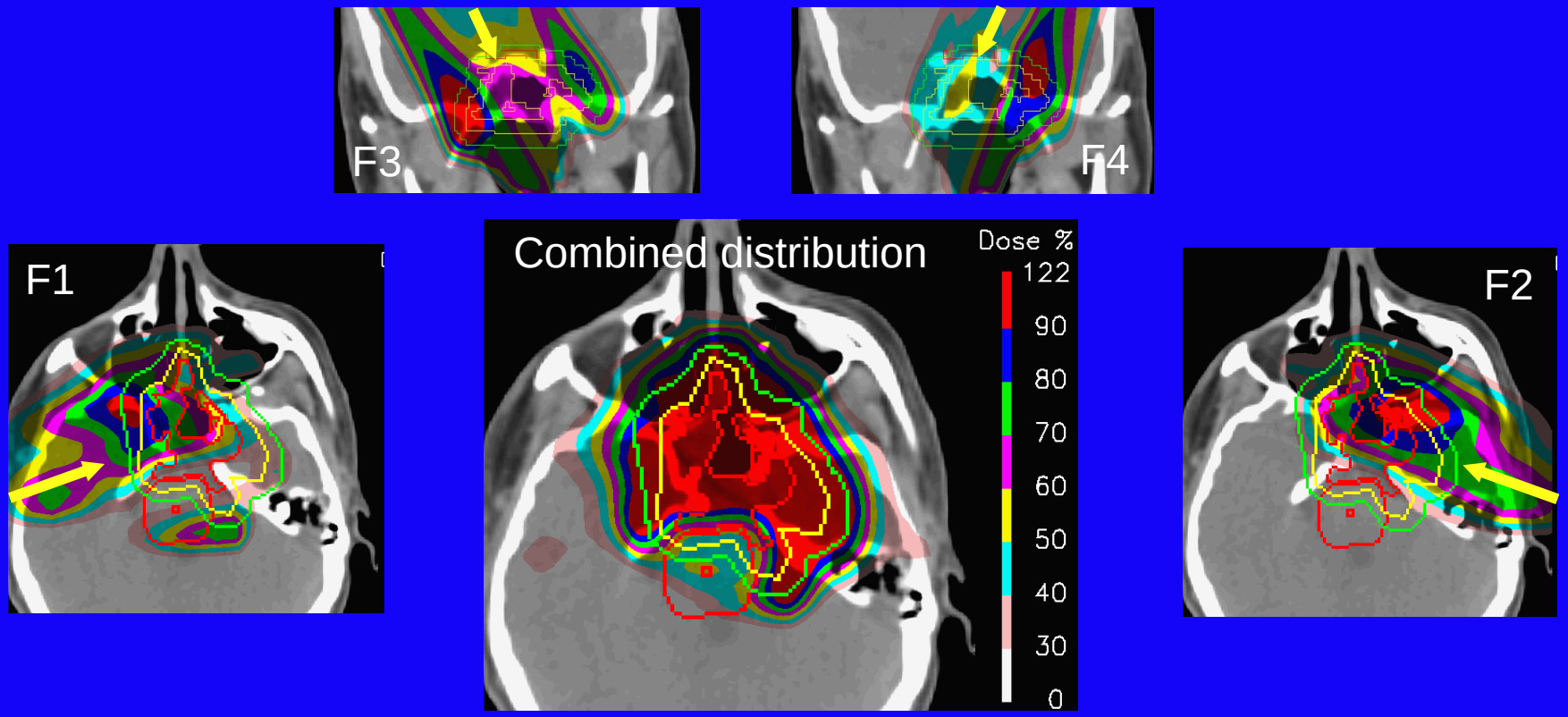
4. Summary

Intensity Modulated Proton Therapy (IMPT)

The simultaneous optimisation of all Bragg peaks from all fields (with or without additional dose constraints to neighbouring critical structures)

IMPT is the spot scanning equivalent of IMRT (and field patching for passive scattering proton therapy).

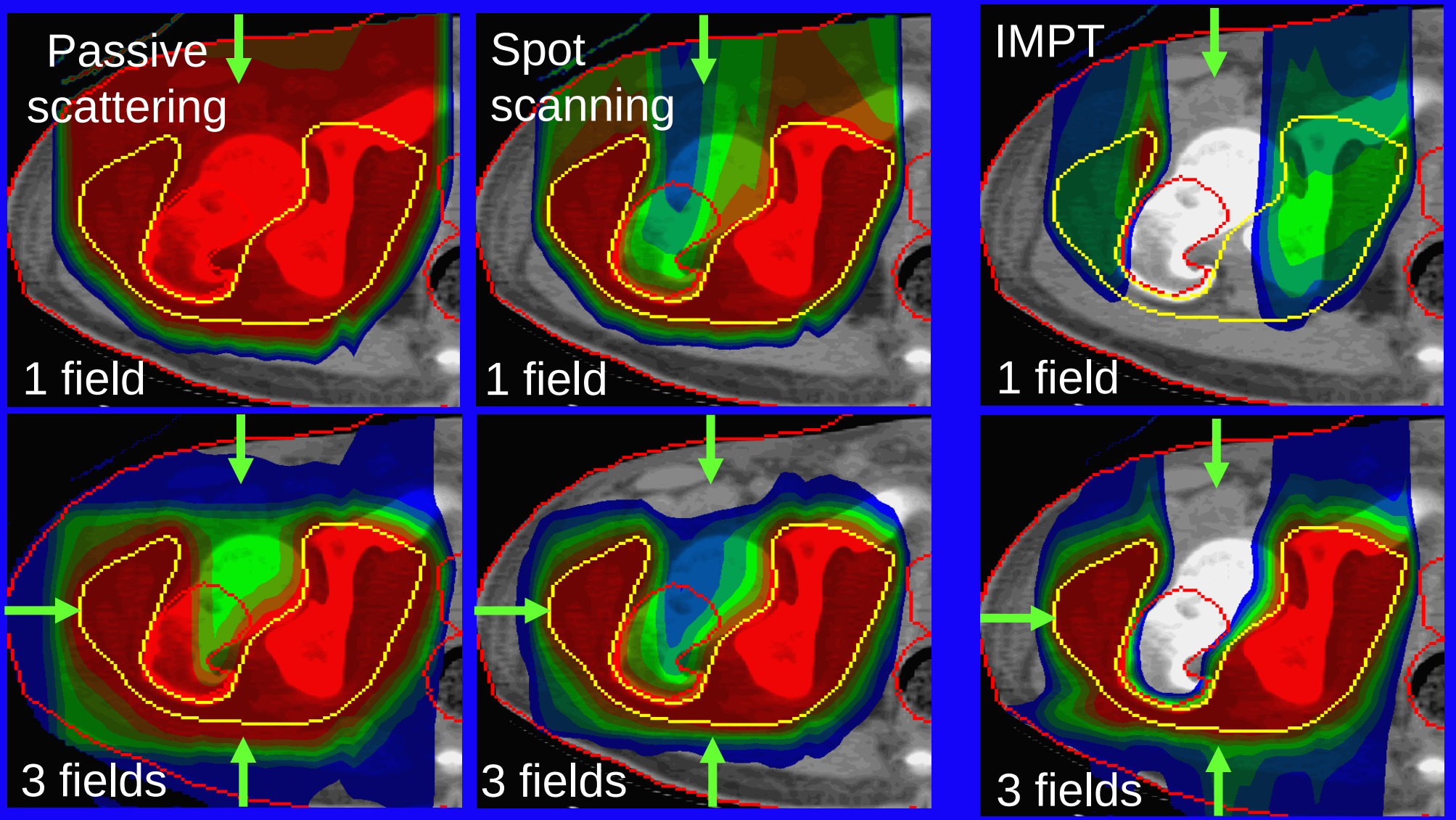
The simultaneous optimisation of all Bragg peaks from all incident beams. E.g..



Lomax 1999, PMB 44: 185-205

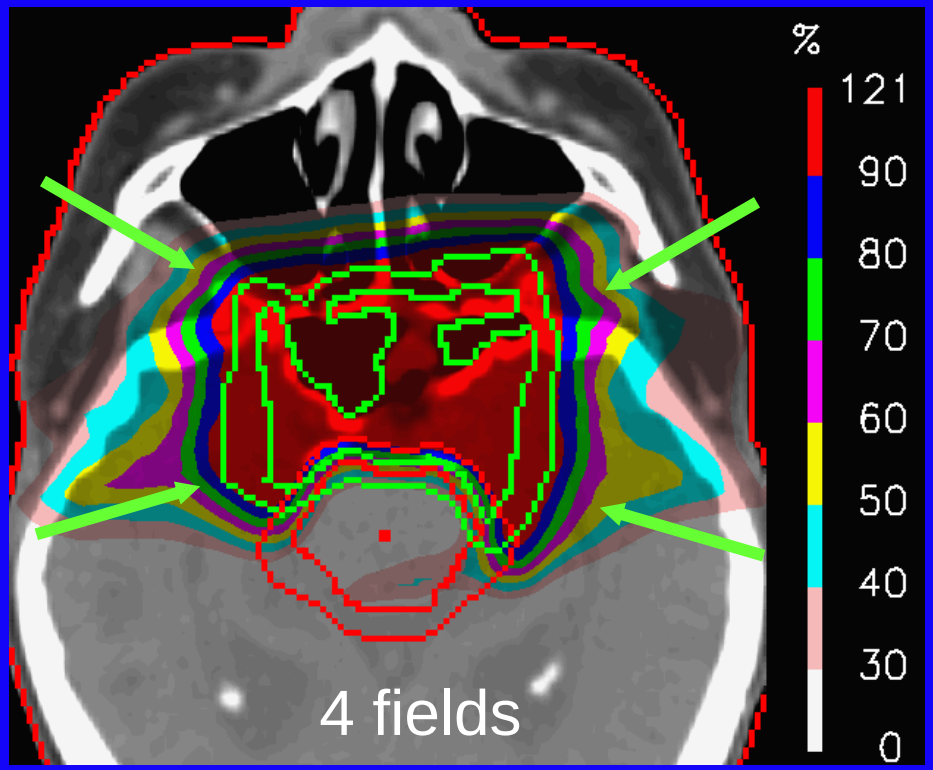
Intensity Modulated Proton Therapy (IMPT)

The three ‘orders’ of proton therapy compared

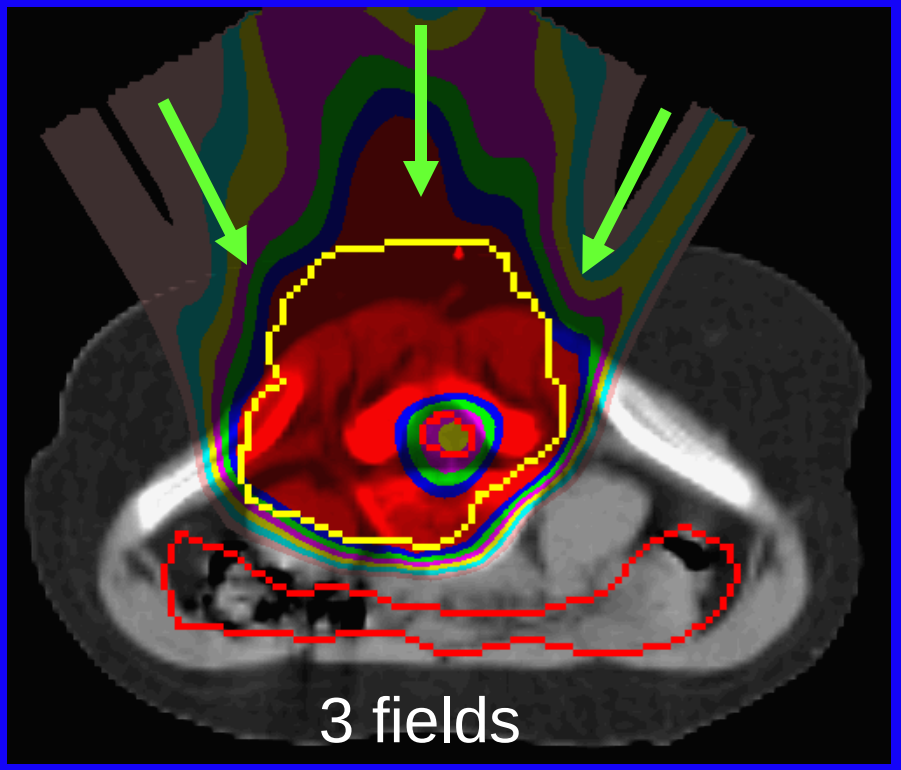


Example clinical IMPT plans delivered at PSI

Skull-base chordoma

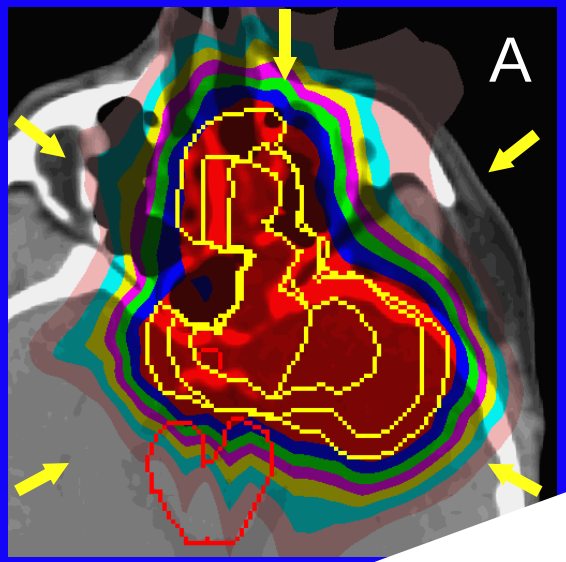


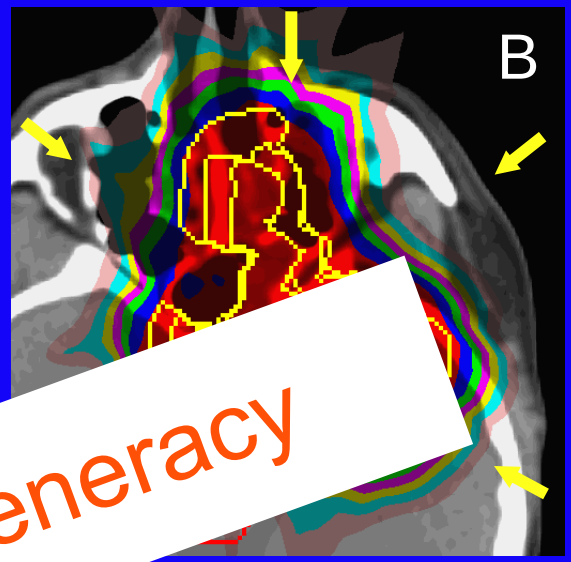
3 field IMPT plan to an 8 year old boy



There's more than one way to optimise an IMPT plan…

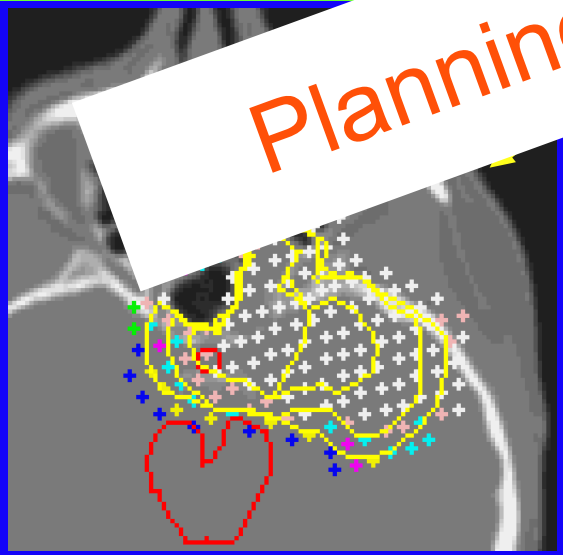
Two, 5 field IMPT dose distributions

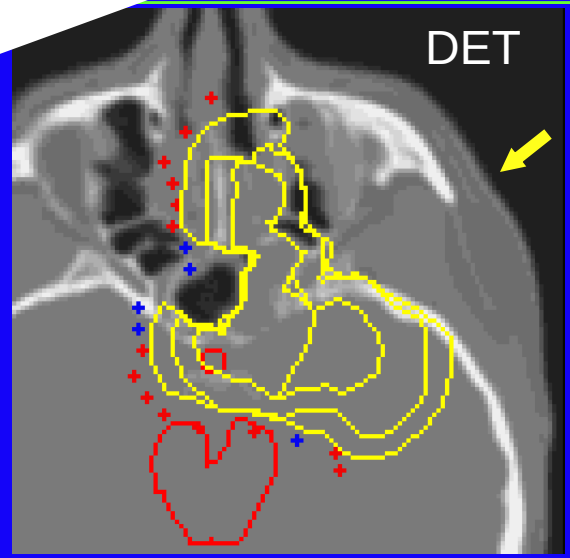




Planning degeneracy

Corresponding spot weight distributions from field 2





Treatment planning for scanning

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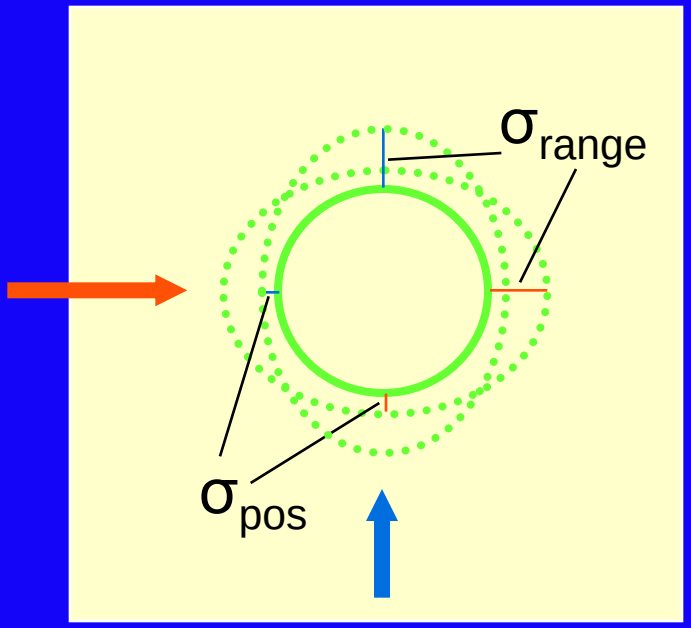
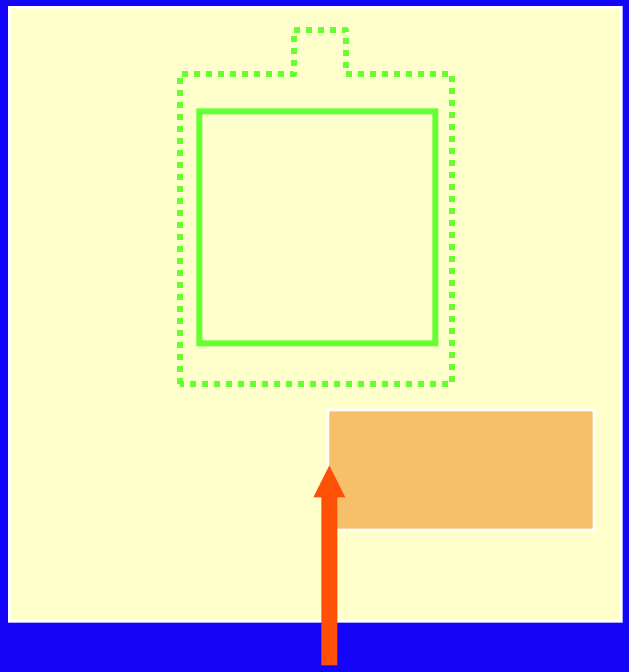
To PTV or not to PTV? – that is the question

- Definition of a PTV is conventional way of dealing with potential delivery errors
- For passive scattering protons, PTV often not used with uncertainties dealt with through expansion of apertures and smoothing and shaving of compensator
- No collimators or compensators for scanning, therefore current method is to define PTV
- Is this necessarily the best approach?

Do we need field specific PTV's?

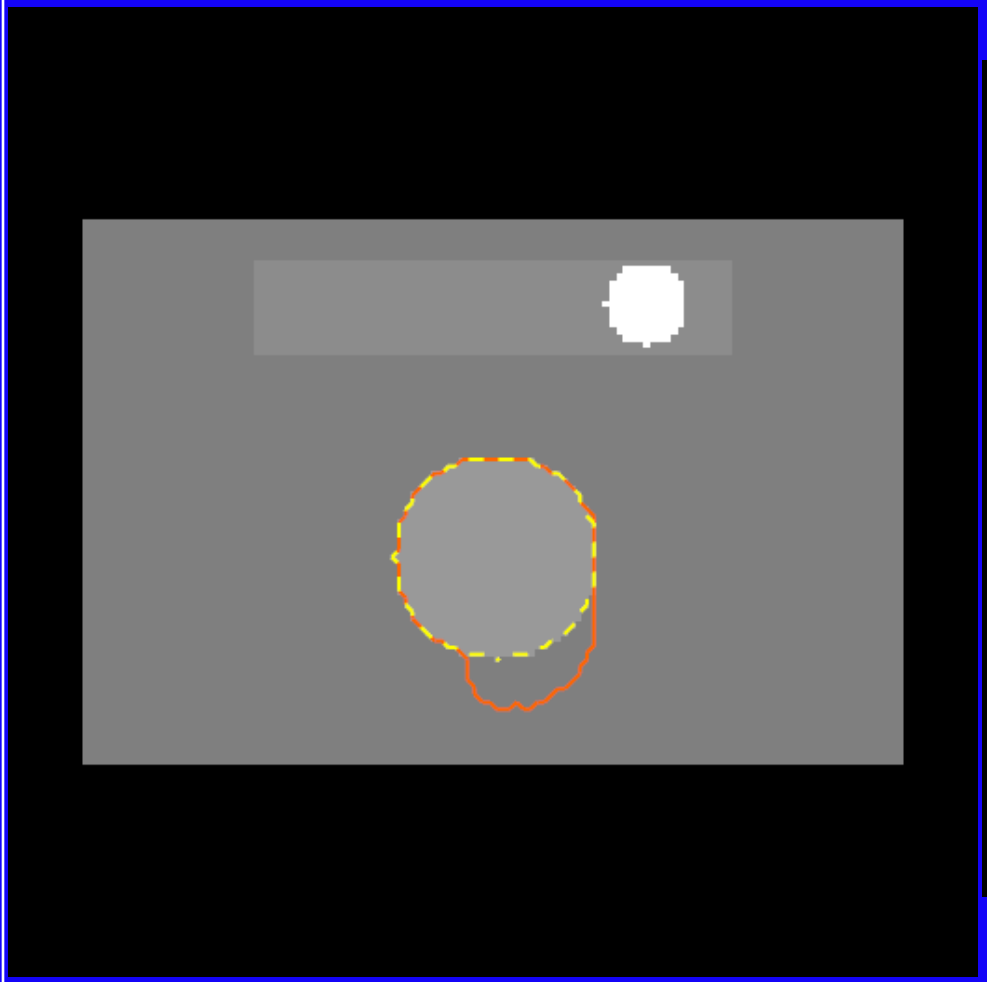


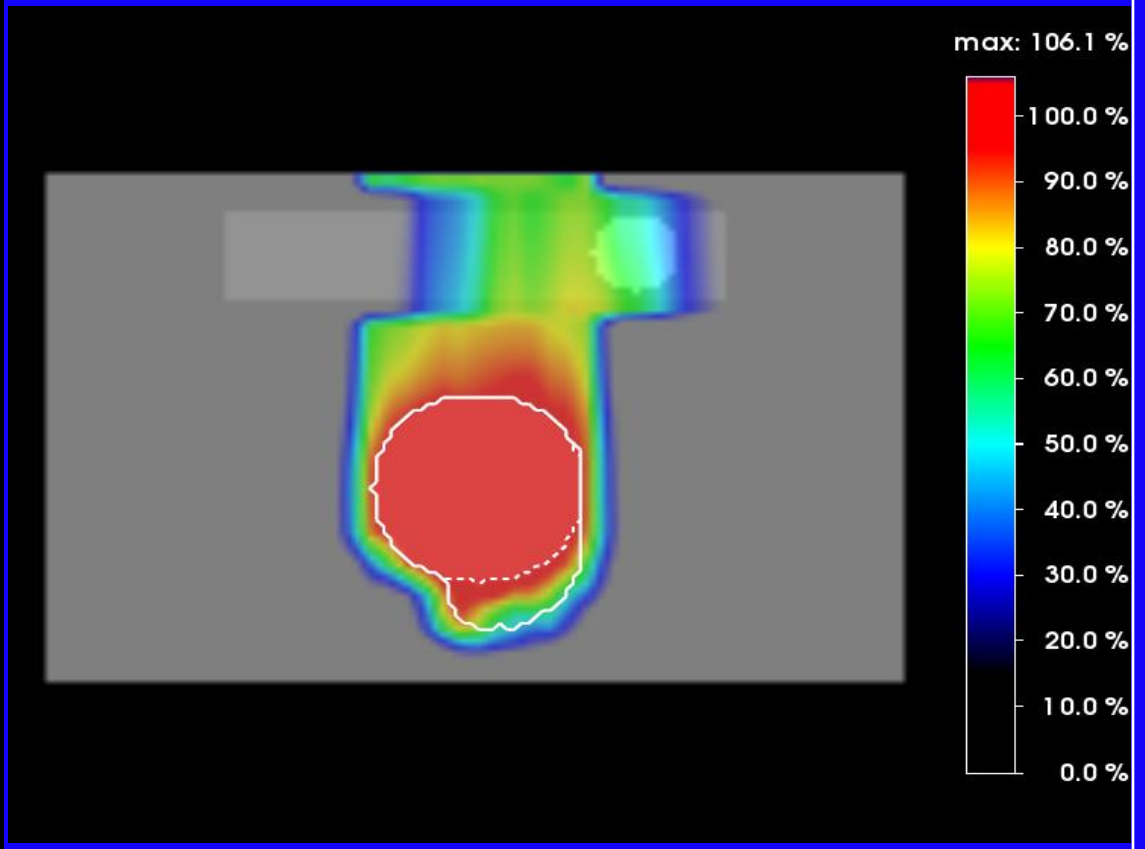
E.g. could be necessary if $\sigma_{pos} <> \sigma_{range}$



..or when passing along strong density interfaces (c.f. smearing of compensators)

Range adapted PTV's





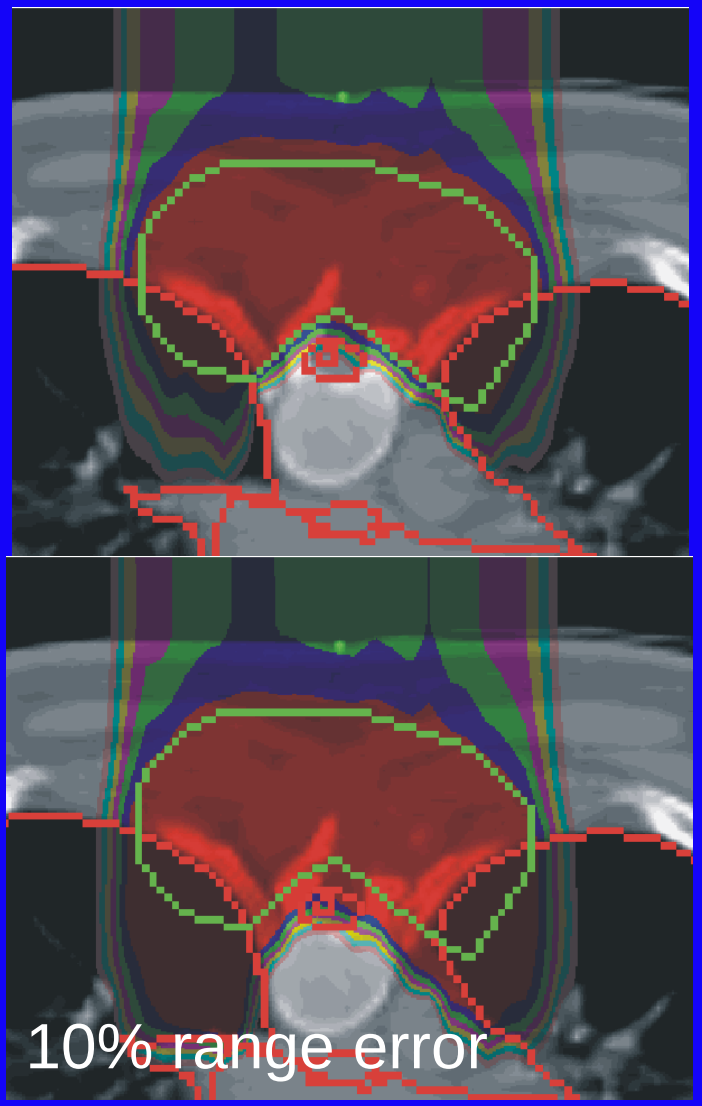
Dirk Boye, PSI

Dealing with uncertainties – range uncertainties.

The advantage of protons is that they stop.

The disadvantage of protons is that we don't always know where…

Range uncertainty will generally be systematic!



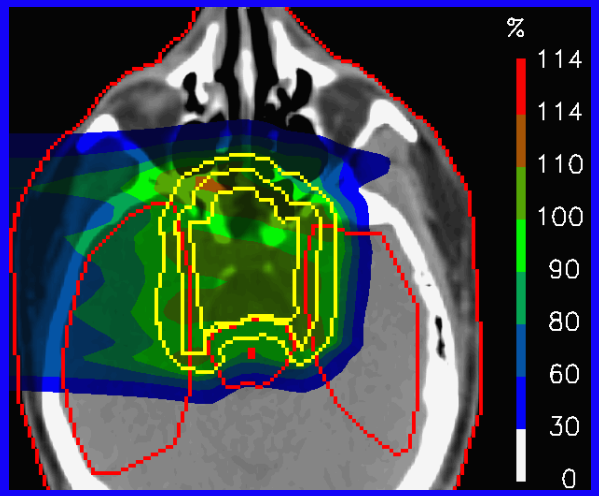
Sources of range uncertainties

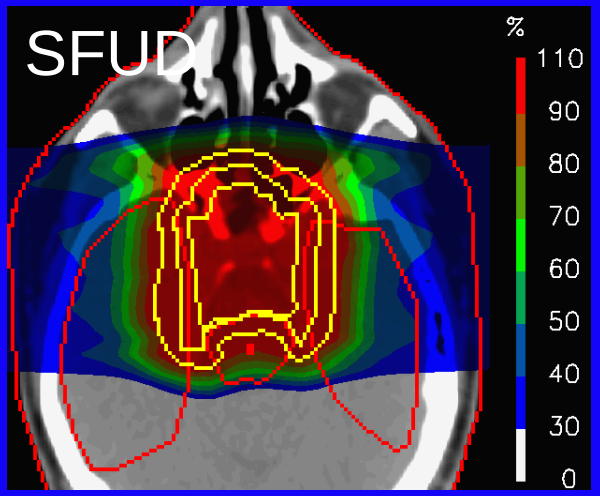
- Limitations of CT data (beam hardening, noise, resolution etc) [$\Sigma \sim \pm 1\%$]
- Uncertainty in energy dependent RBE [$\Sigma \sim +2\%$]
- Calibration of CT to stopping power [$\Sigma \sim \pm 1\text{-}2\%$]
- CT artifacts [$\Sigma \sim$ large!]
- Variations in patient anatomy [$\Sigma,\sigma \sim$ large!]

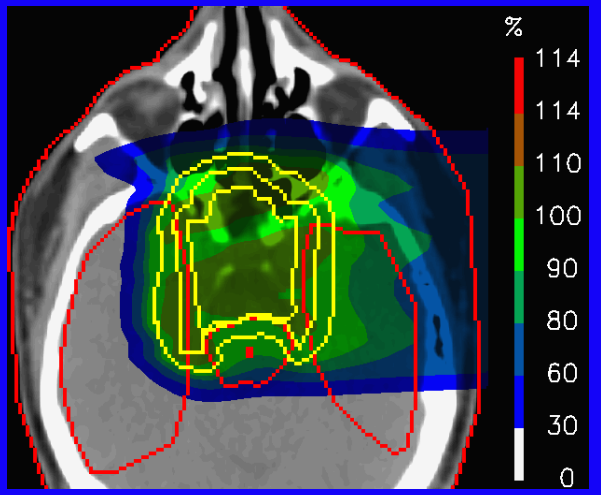
- Variations in proton beam energy [σ]
- Variations in patient positioning [σ]

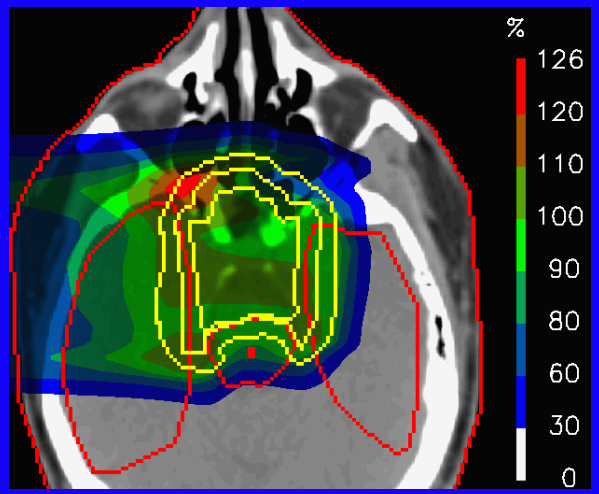
Dealing with uncertainties – range uncertainties.

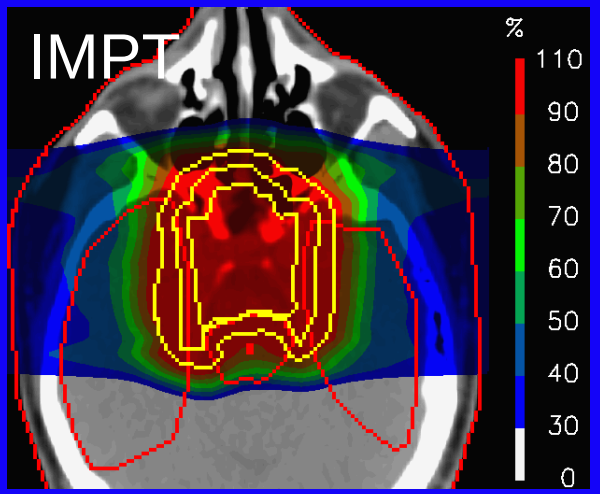
Range uncertainty for SFUD and IMPT plans

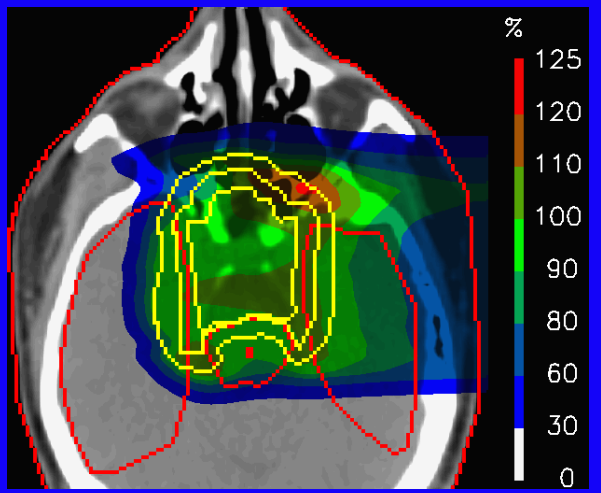








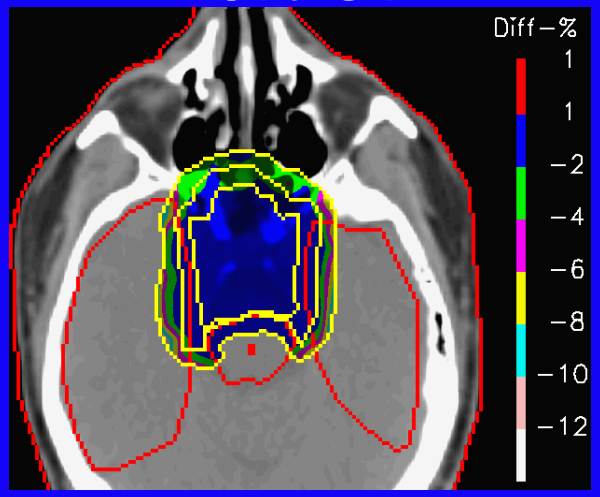


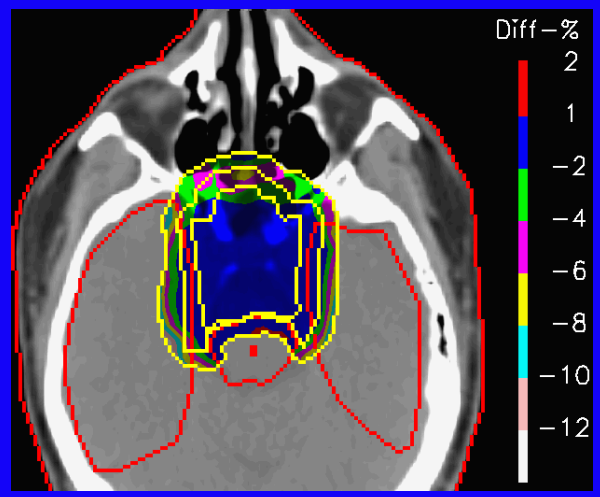


Lomax AJ (2007) in 'Proton and charged particle Radiotherapy', Lippincott, Williams and Wilkins

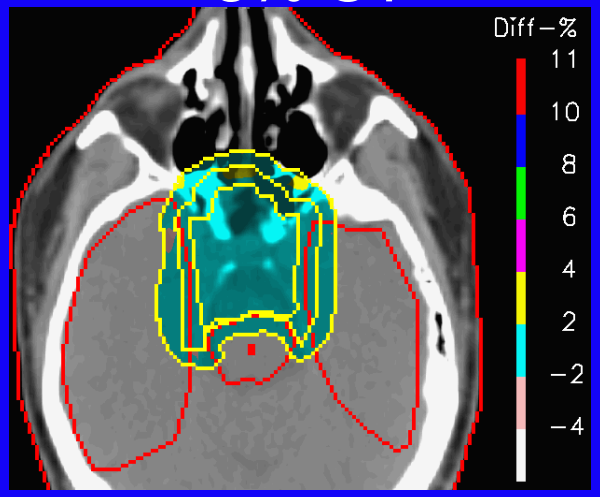
Range uncertainty for SFUD and IMPT plans

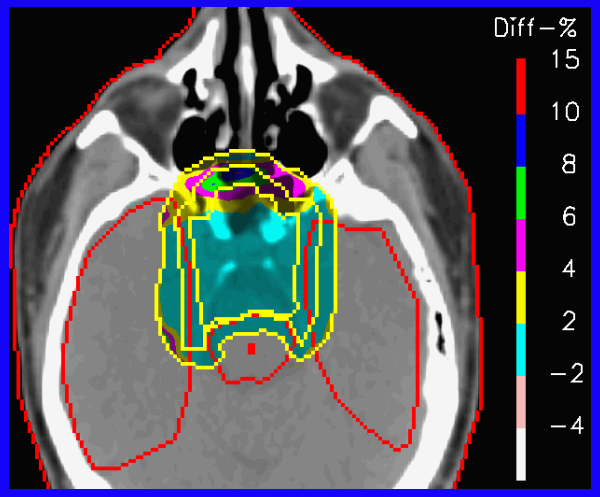
+5% CT

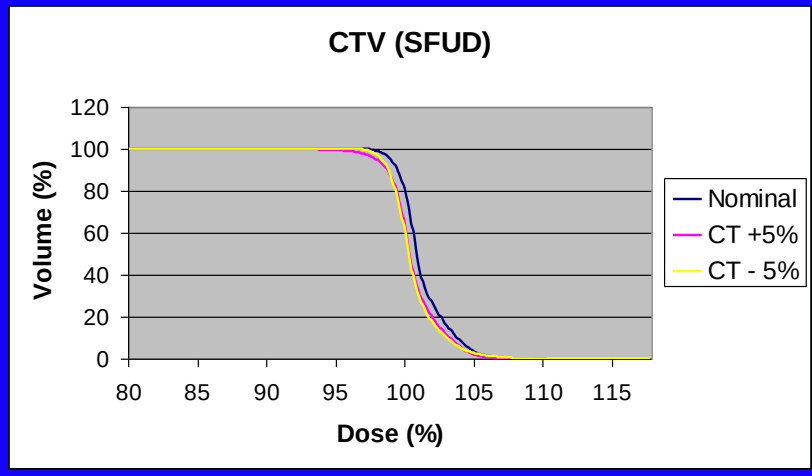


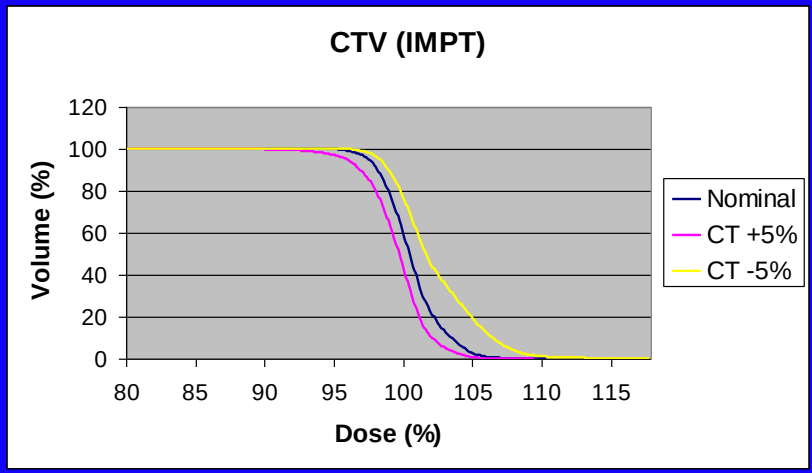


-5% CT



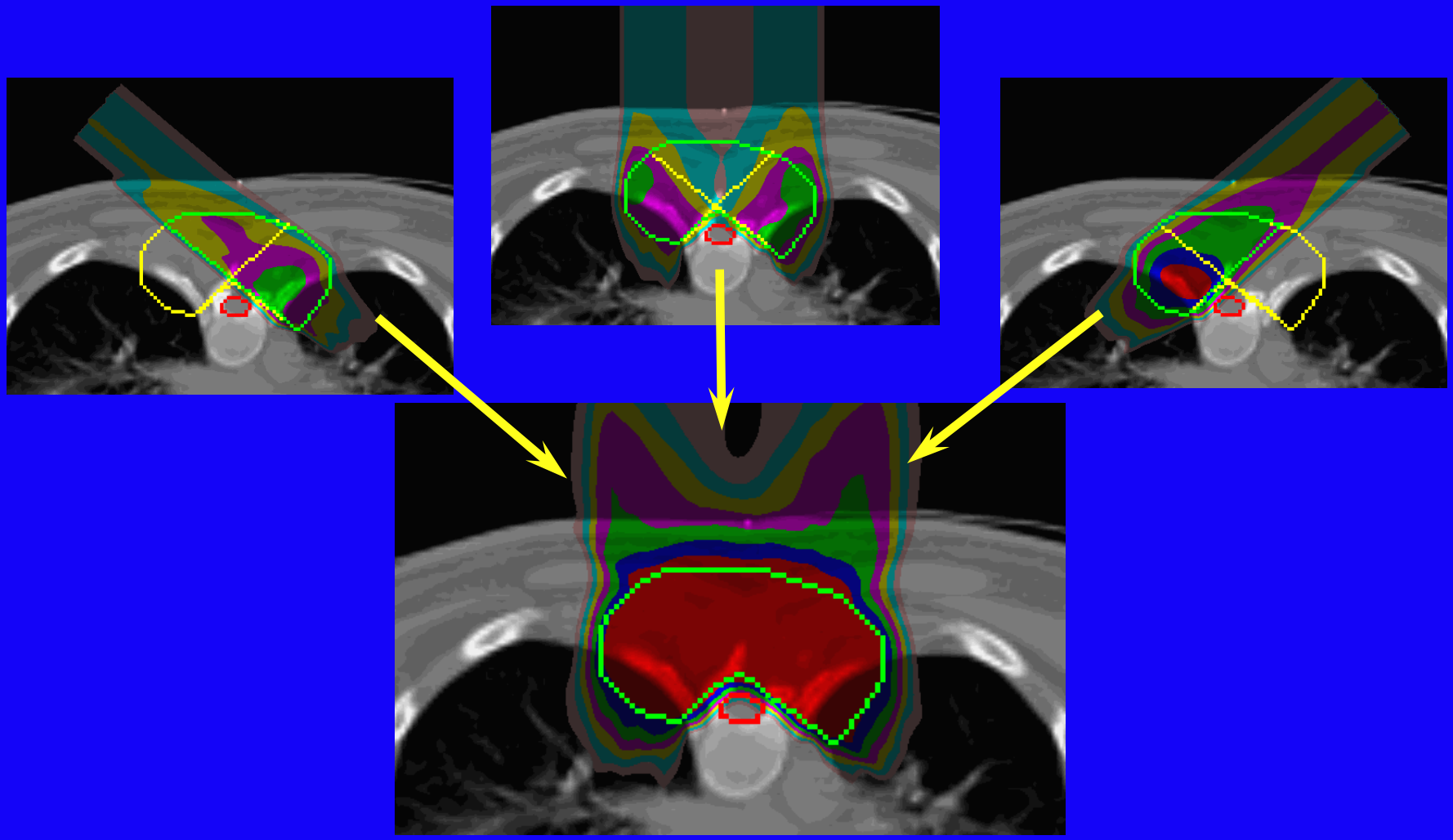






Lomax AJ (2007) in 'Proton and charged particle Radiotherapy', Lippincott, Williams and Wilkins

Dealing with range uncertainties - robust IMPT planning?



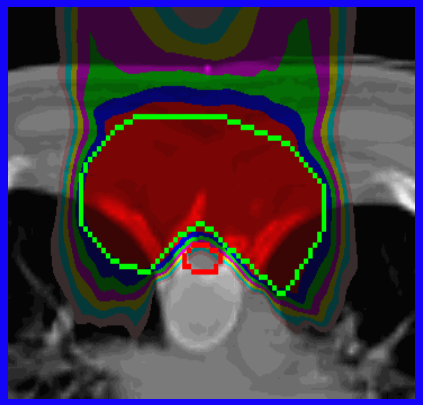
Lomax et al 2001, Med. Phys. 28:317-324

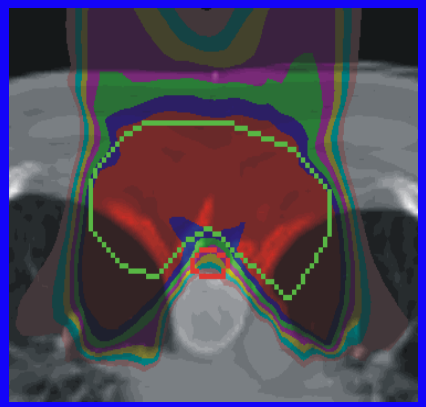
Dealing with range uncertainties - robust IMPT planning?

Nominal

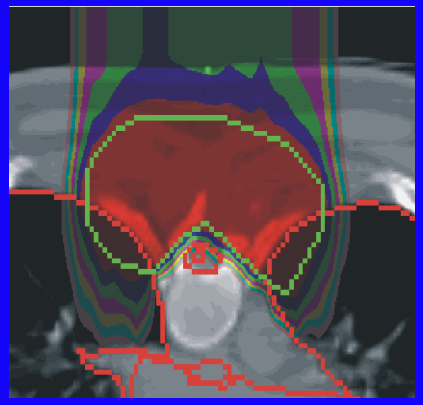
-10% CT

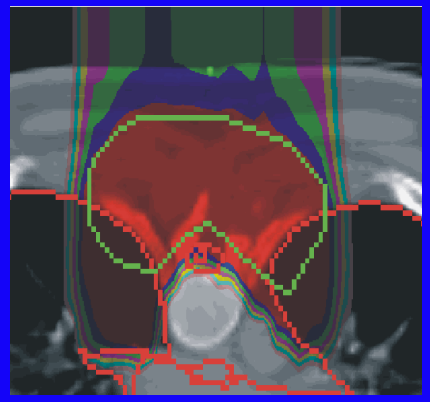
IMPT



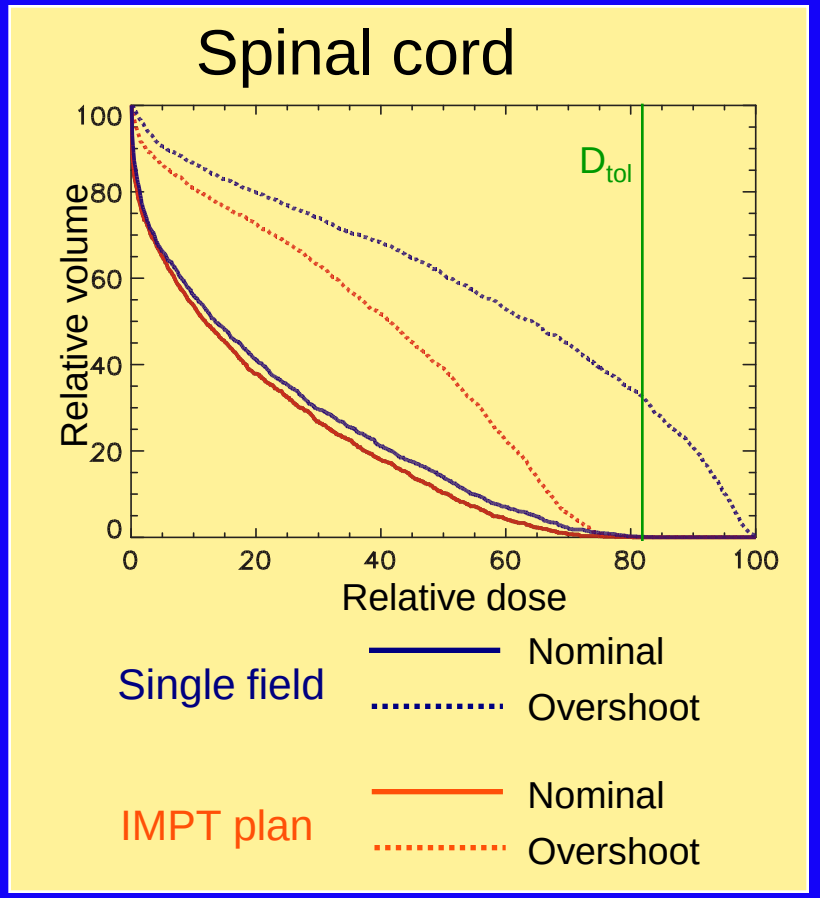


Single field



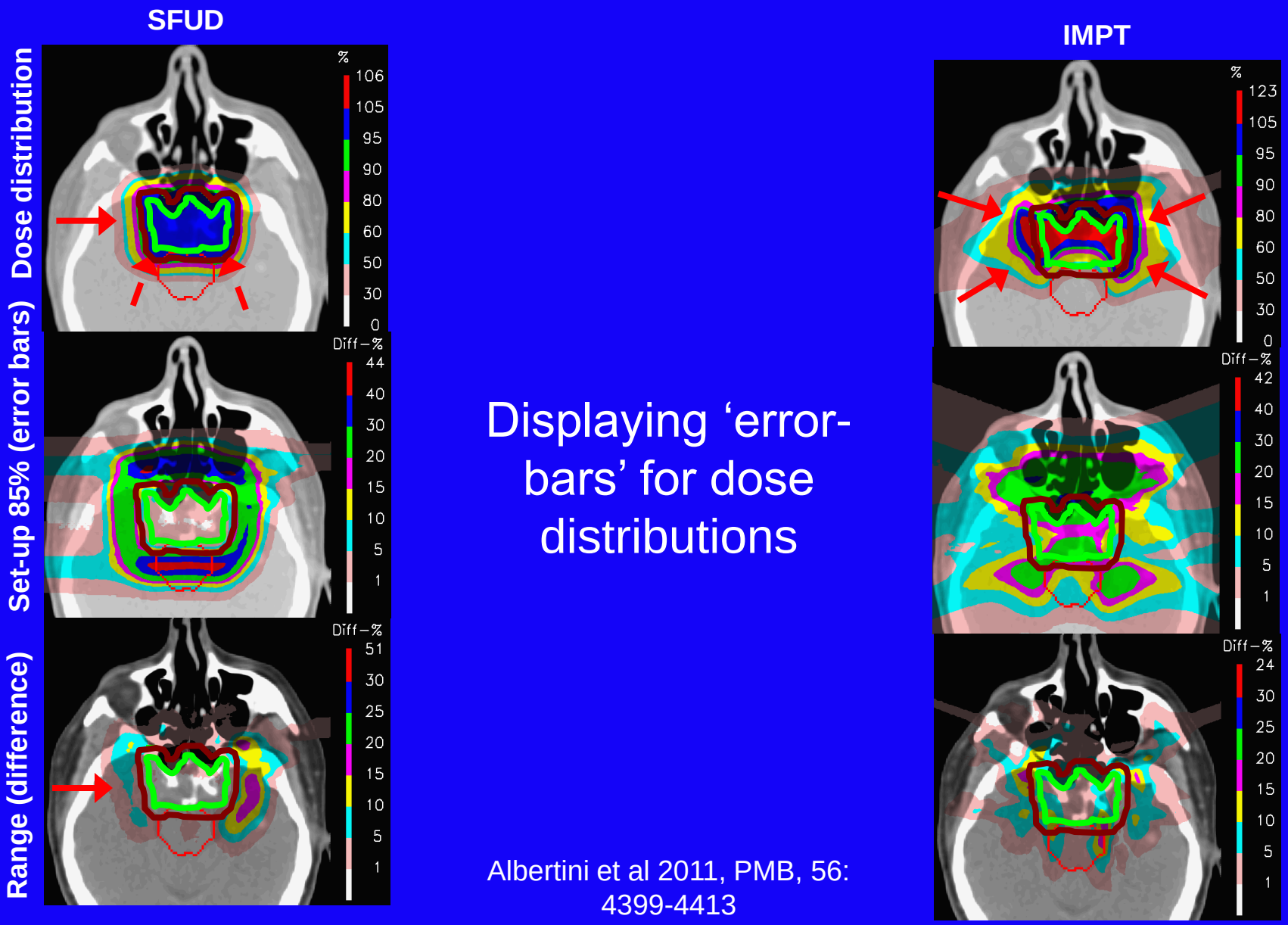


DVH analysis



Lomax et al 2001, Med. Phys. 28:317-324

Dealing with uncertainties – displaying uncertainties.



Displaying ‘error-bars’ for dose distributions

Albertini et al 2011, PMB, 56: 4399-4413

Summary

- Although many similarities with conventional therapy, there are some significant differences and issues for planning active scanned proton and IMPT plans
- Is the conventional PTV criteria still valid? Are field specific PTV's required? Do we need probabalistic planning?
- Active scanned plans (fields) have a large degeneracy – many distributions of pencil beam intensities give very similar dose distributions
- In general, spot scanned plans are more sensitive to errors than conventional photon plans and IMPT plans more sensitive than simple spot scanned plans

Don't abandon 'simple' planning techniques (e.g. SFUD)!