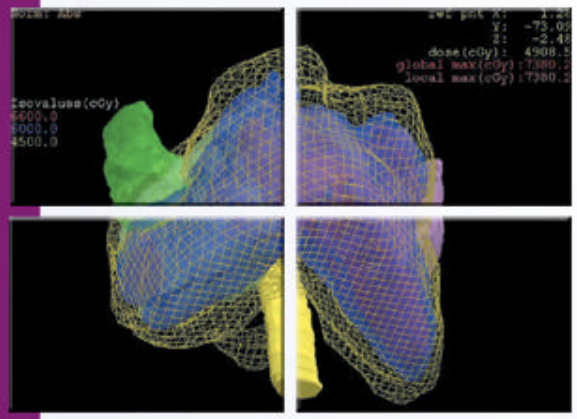
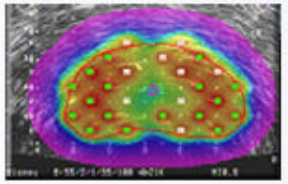
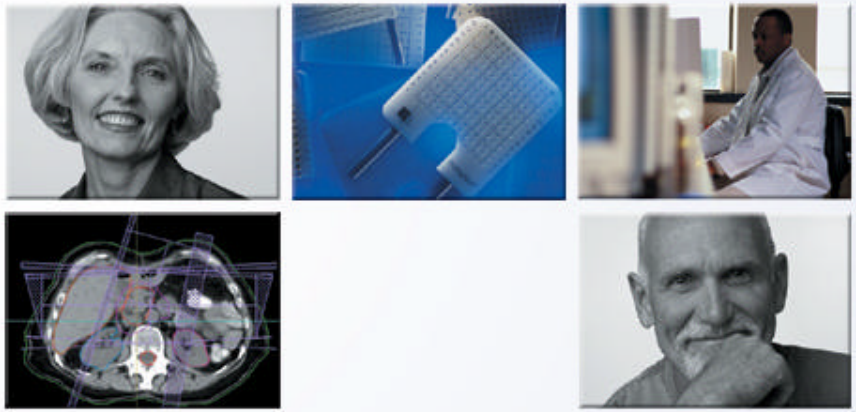
CMS®

Plan for More

Übersicht von IMRT Konzepten bei CMS





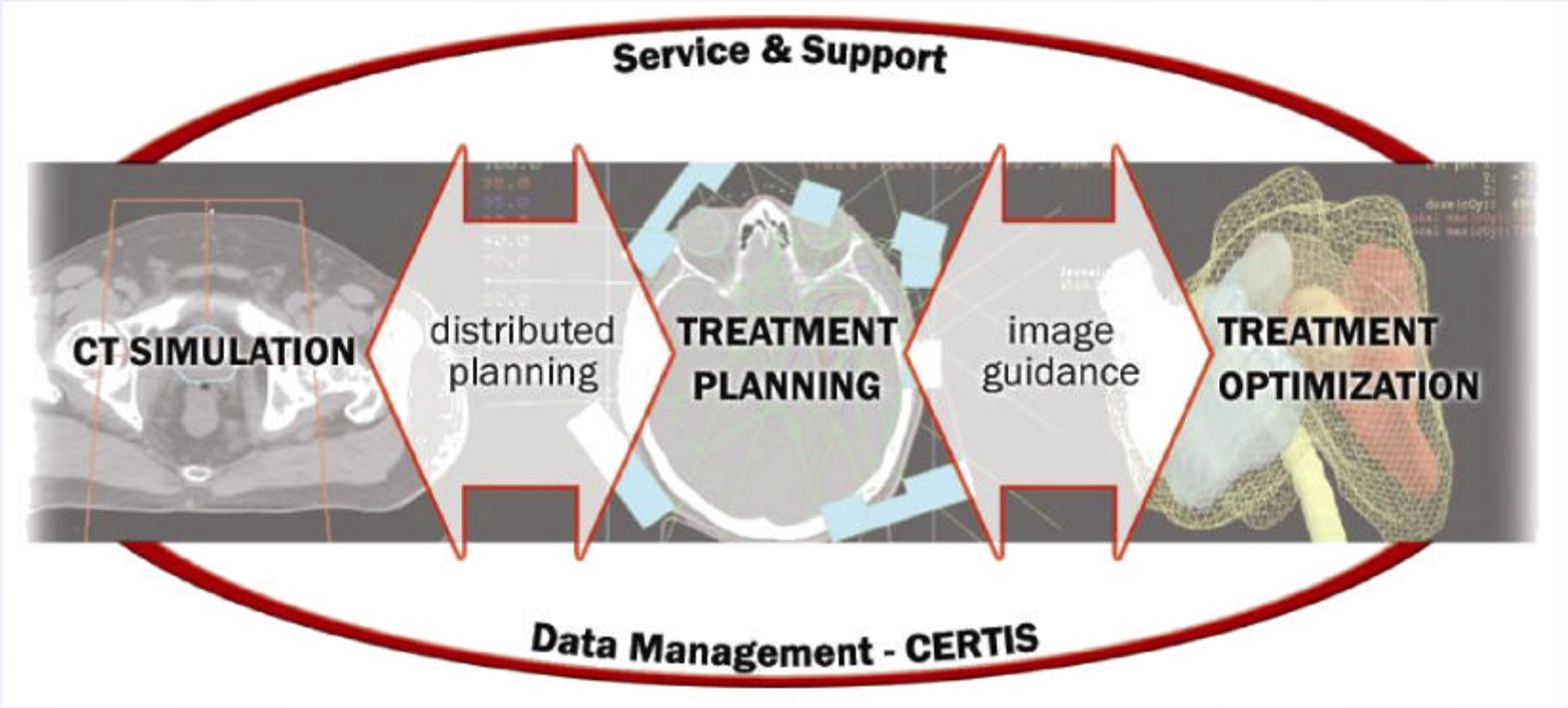


Norbert Steinhöfel

DGMP AK IMRT

19.-20.2.2002

CMS: Radiation Oncology Software



An Integrated Department – From Start to Finish

CMS provides integration from CT simulation to treatment planning to treatment optimization. Across the radiation treatment spectrum, CMS provides linkage and conveniences than can bring you value.

CMS
Plan for More

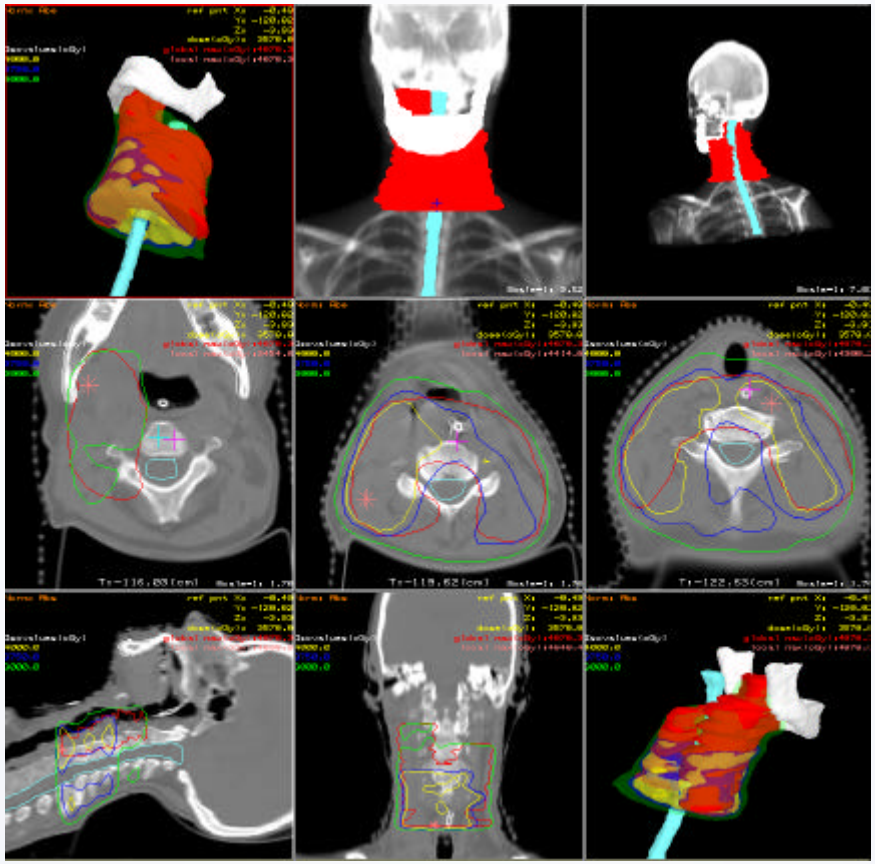
Focal: Experience the Freedom

CT Simulation. Contouring. Plan Review. Image Fusion.

Where you want, when you want it.

CMS
Plan for More

XiO® IMRT



XiO IMRT Efficency through Integration

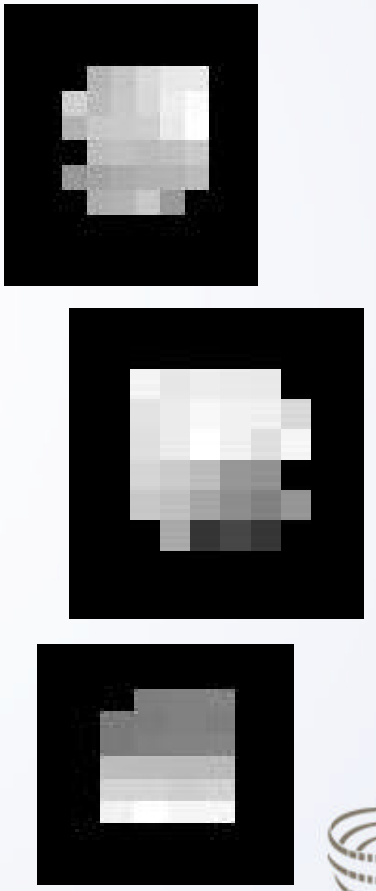
Effizienter Zugriff auf alle Planungsfunktionen zu jedem Zeitpunkt, inklusive Optimierung und IMRT

Einzellschritte Optimierungsparameter – Optimierung „inverse Planung“ – Sequenzierung sind jederzeit individuell zugänglich.

Sehr schnelle Ergebnisse!

XiO - schnelle und präzise IMRT

- Sehr schnelle Optimierung
  mit iterativem inversen Algorithmus [SIITP- Xing et al. Med Phys. 25 (1998), 1845-49]
- Echte 3D Dosisberechnung
- IMRT mit Kompensatoren
- Berücksichtigung von konventionellen Plänen – Syncrone IMRT
- DICOM-RT Export
- FDA & CE zugelassen



CMS
Plan for More

XiO IMRT QA Tools

Clinical implementation of intensity-modulated radiation therapy (IMRT) requires new quality assurance methods. The purpose of IMRT, to concentrate radiation dose into more specific and exact volumes, inherently requires stringent dose verification and patient immobilization standards. The XiO treatment planning system provides a growing set of tools to accommodate the quality assurance procedures that you may adopt.

The two main categories of tools are:

- QA dose output – the ability, for any IMRT beam, to automatically generate a dose file that represents the dose to a flat phantom at a user-defined SSD and depth.
- QA Plan – the ability to create a separate and tailored phantom plan using IMRT beams designed for an optimized patient plan.

What is IMRT optimization?

- *Mathematically:* Optimization is the search for an optimal location in a space. So?
- *For IMRT optimization*
  - the search space is defined by beamlet weights.
  - optimality is defined as a deliverable combination of beamlet weights that results in the best possible radiation dose to targets and organs at risk.
- The optimization process is iterative; that is, the beamlet weights are changed many times during the search process.
- During these iterations, cost functions are evaluated to determine how well the search is progressing.
- The optimization may or may not use cost function derivatives to determine where to search in the space.
- There may be aspects of the search which make finding a globally best location difficult (i.e. local minima)

Intro to Cost Functions – What we want

- Unambiguous specification of treatment goals
- Effective ways of expressing tradeoffs (Kompromisse) (e.g., importance weights)
- Possibility of exceeding treatment goals
- Avoidance of local minima (*i.e.,* convex cost functions)
- Cost functions that are well-suited (derivatives may not be availabe to some functions) to our chosen optimization method (*e.g.,* meaningful gradients)

- Roughly:
  - Objective is a cost function that can be violated
  - Constraint is a cost function that cannot be violated

- We talk first about objectives for XiO and then objectives and constraints for Monaco.

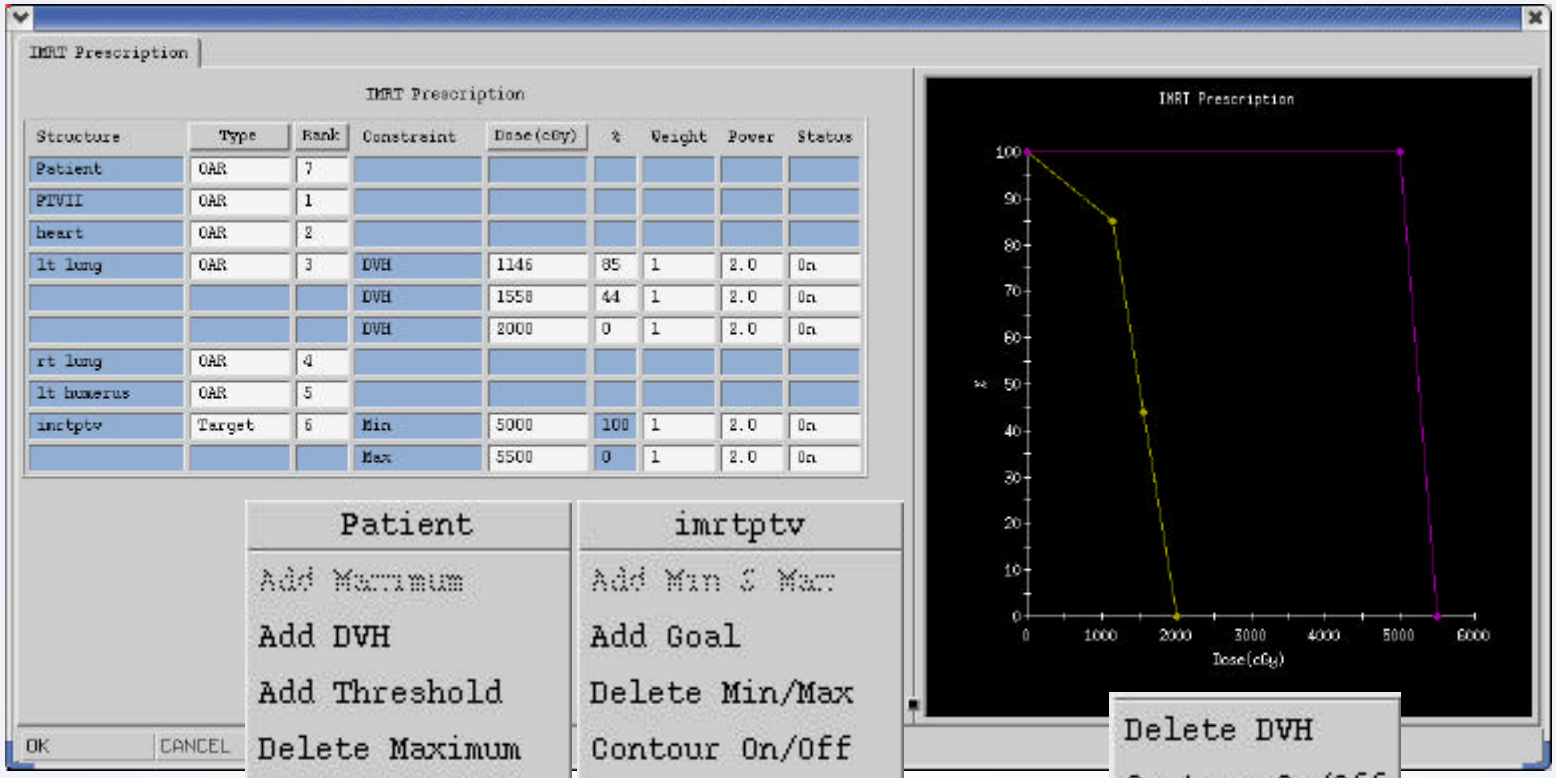
Example Prostate Case

- PTV1 – 50.4Gy, PTV2 – 78.0Gy
- PTVs should receive at least 95% of prescribed dose
- GTV should receive at least 100% of prescribed dose
- No doses less than 65Gy are acceptable in PTV2
- Limit rectum to < 20% over 65Gy and < 35% over 40Gy
- Limit bladder to < 25% over 65Gy and <50% over 40Gy
- Femoral heads <45Gy
- Penile bulb spared

PTV1: PTV2 + Seminal Vesicles

PTV2: Prostate plus an 8mm margin in all directions, except the posterior where the margin is 5mm

Dose and Dose-Volume Objectives in XiO V4.2



OPTIMIZATION OF INTENSITY-MODULATED RADIOTHERAPY PLANS BASED ON THE EQUIVALENT UNIFORM DOSE

QIUWEN WU, PH.D.,* RADHE MOHAN, PH.D.,* ANDRZEJ NIEMIERKO, PH.D.,† AND
RUPERT SCHMIDT-ULLRICH, M.D.*

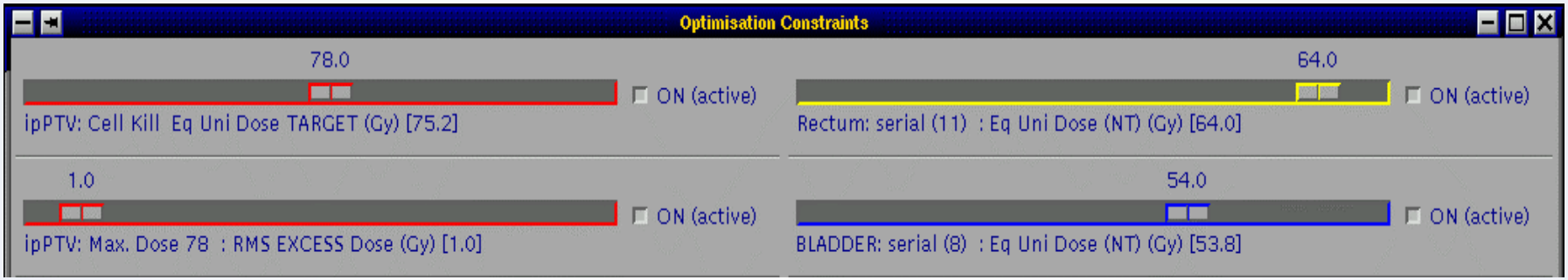
*Department of Radiation Oncology, Medical College of Virginia, Virginia Commonwealth University and McGuire Veterans Affairs
Hospital, Richmond, VA; †Department of Radiation Oncology, Massachusetts General Hospital and Harvard University, Boston, MA

The equivalent uniform dose (EUD) for tumors is defined as the biologically equivalent dose that, if given uniformly, will lead to the same cell kill in the tumor volume as the actual nonuniform dose distribution.

About DVH constrains

However, there are multiple DVHs (in fact, an infinite number of them) that could lead to an equivalent dose response for a particular organ, but optimization based on each of these DVHs would, in general, lead to different dose responses in other organs and the tumor. Only one of these DVHs will be optimum so far as other organs and the tumor are concerned. Thus, constraining the search to a single DVH for an anatomic structure may miss the overall optimum solution.

... Dose response indices may have been obstacles in their clinical use for optimization; however, many of them can be overcome with EUD-based optimization. For example, for all practical purposes, EUD is in dose domain, which makes it easier for the clinician to specify the requirements for plan optimization.

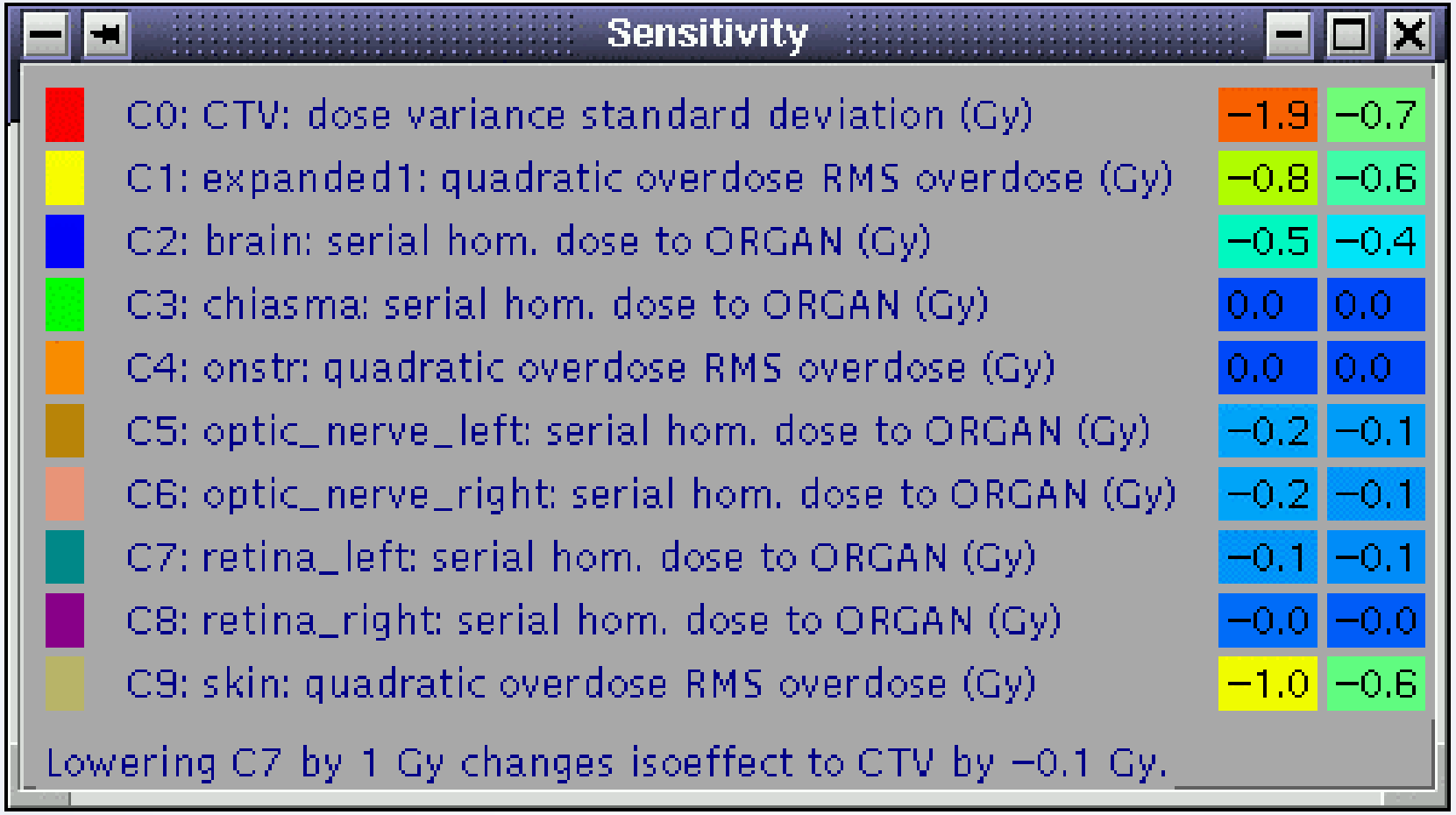


Example : Prostate

- **maxdose penalty (prescription dose)**
- **small volume effect for rectum**
- **medium volume effect for bladder**

- **Serielles *(EUDose,Typ II)* Modell:**
  starke Gewichtung hoher Dosen
- ***Maximaldosisbeschränkung***
- **Paralleles *(EUDamage,Typ I)* Modell:**
  starke Gewichtung mittlerer Dosen
- ***Dosis-Volumen-Beschränkung***

Objectives Sensitivity analysis



Assistance in strategy finding:

How do constraints affect target dose?

CMS Plan for More

Benefits

What you want is what you get.

- **Shape of DVH is determined by choice of constraints**
- **Treatment intentions are made explicit**
- **Treatment standardisation and non-interactive optimisation possible**

Scripting of dose protocols

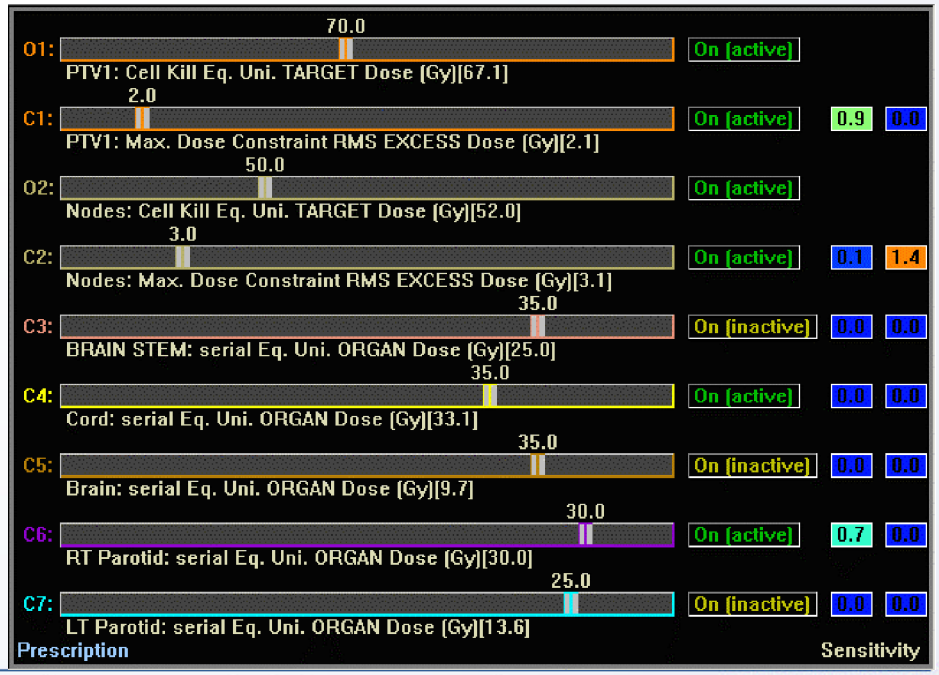
Monaco -> Hyperion

- Integrated Monte Carlo dose calculation
  - First stage optimization using pencil beams
  - Second stage optimization using MC field segments
- Lots of mixed constraints, both dosimetric and biological
- Accounts for treatment fractionation, if desired

$$D_2 \;?\; D_{total}\,\frac{1?\frac{?}{?}\frac{D_{total}}{N_{fx}}}{1?\,2Gy\frac{?}{?}}$$

Biologically Equivalent Dose (Barendsen, 1982)

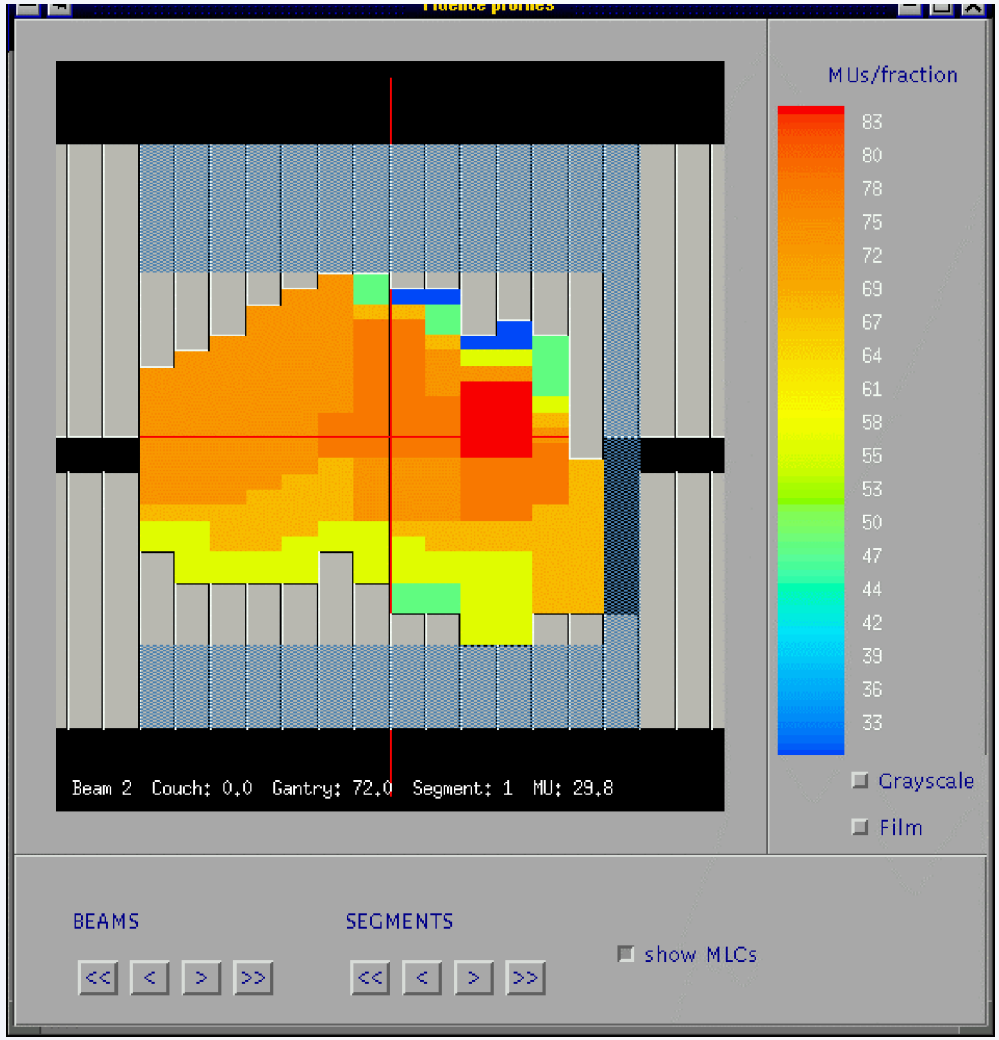
- Constrained optimization
- Importance weights are “replaced” by Lagrange multipliers
- Sensitivity analysis can be used to determine which constraints are the “hardest” to achieve.



Integrated Sequencing

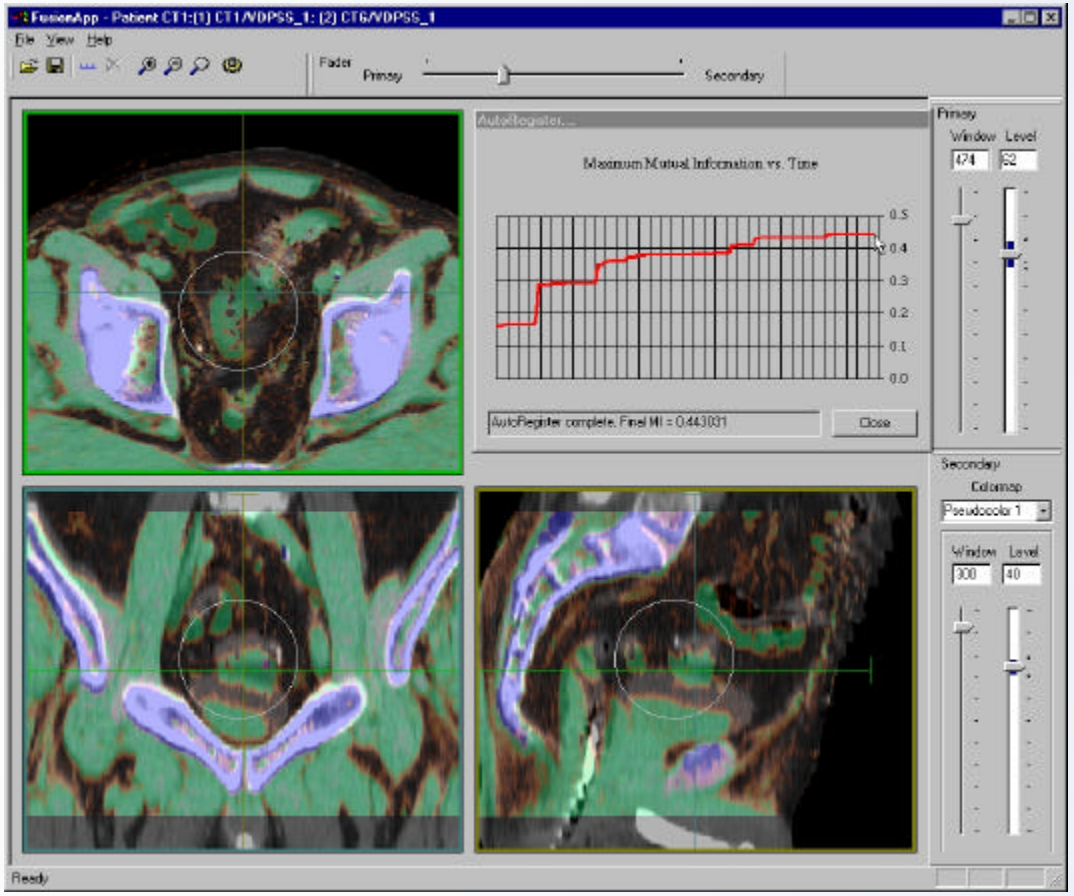
- **Dose distribution is *not degraded* by *translation* of fluence into MLC segments**
- ***Control* over the *number* of segments**
- ***Feedback* to dose objectives allows suppression of undesirable field shapes/ sizes: *Smart Sequencing***

Segment Shape Optimisation : Fewer Segments

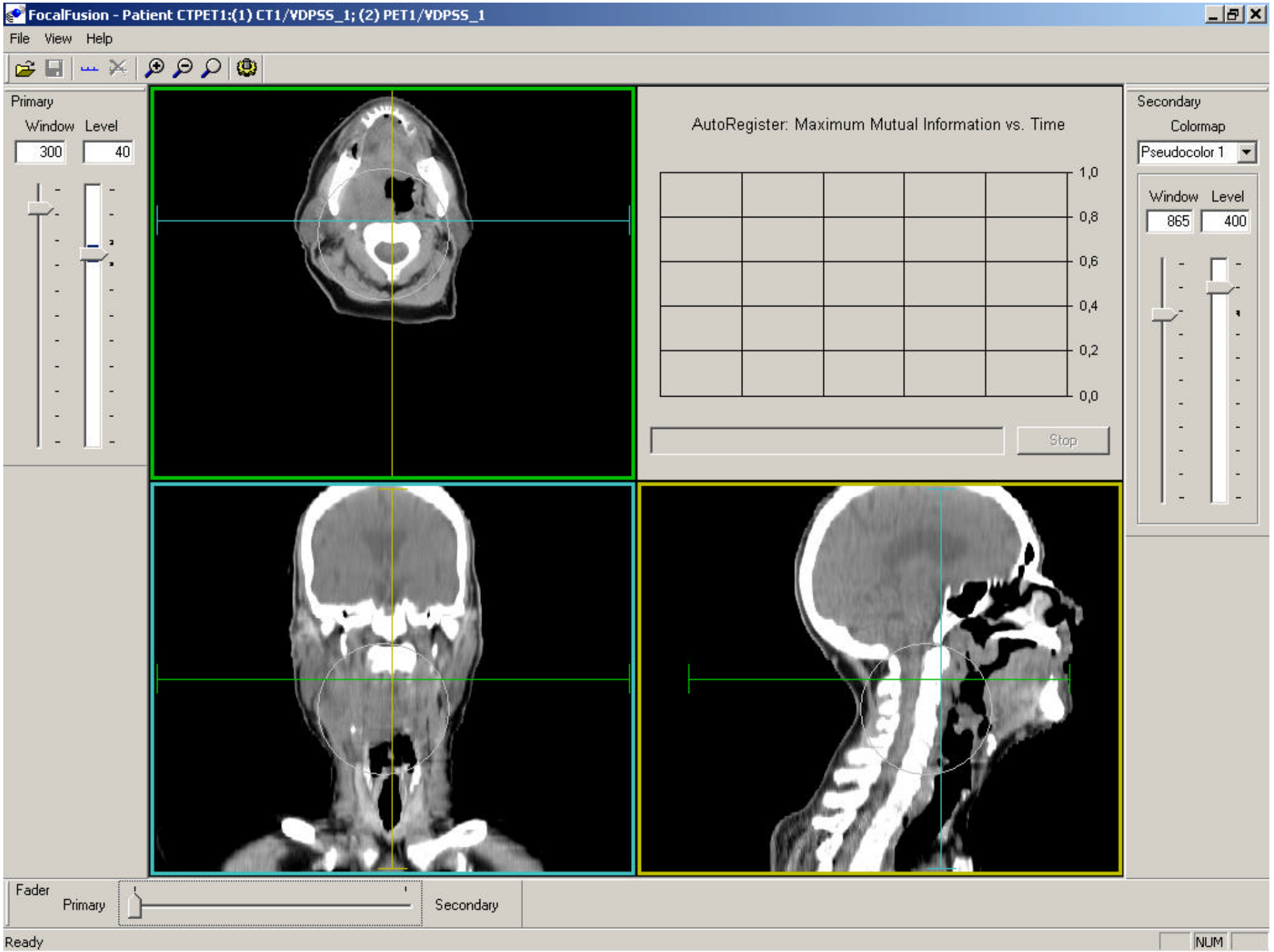


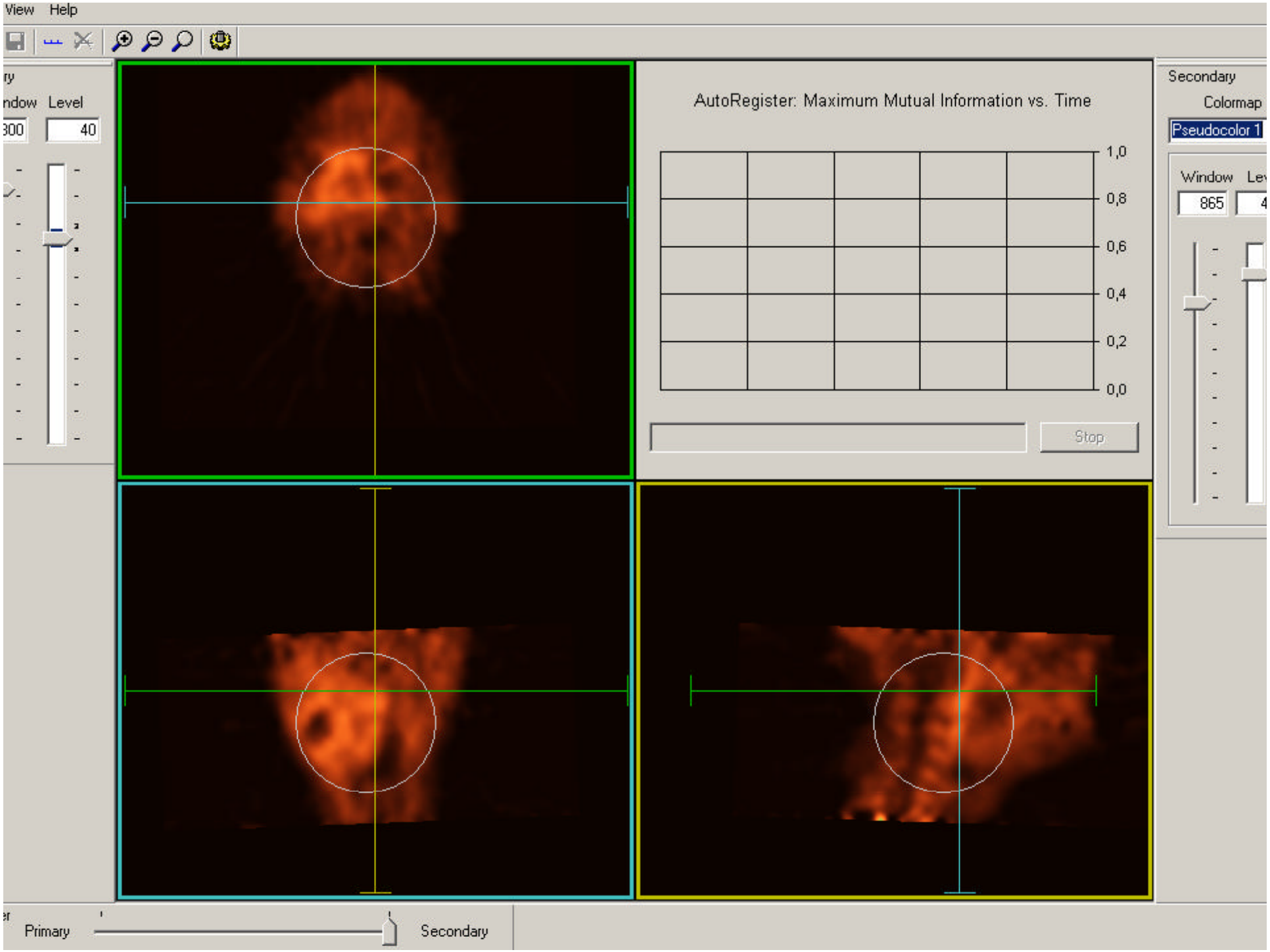
FocalFusion

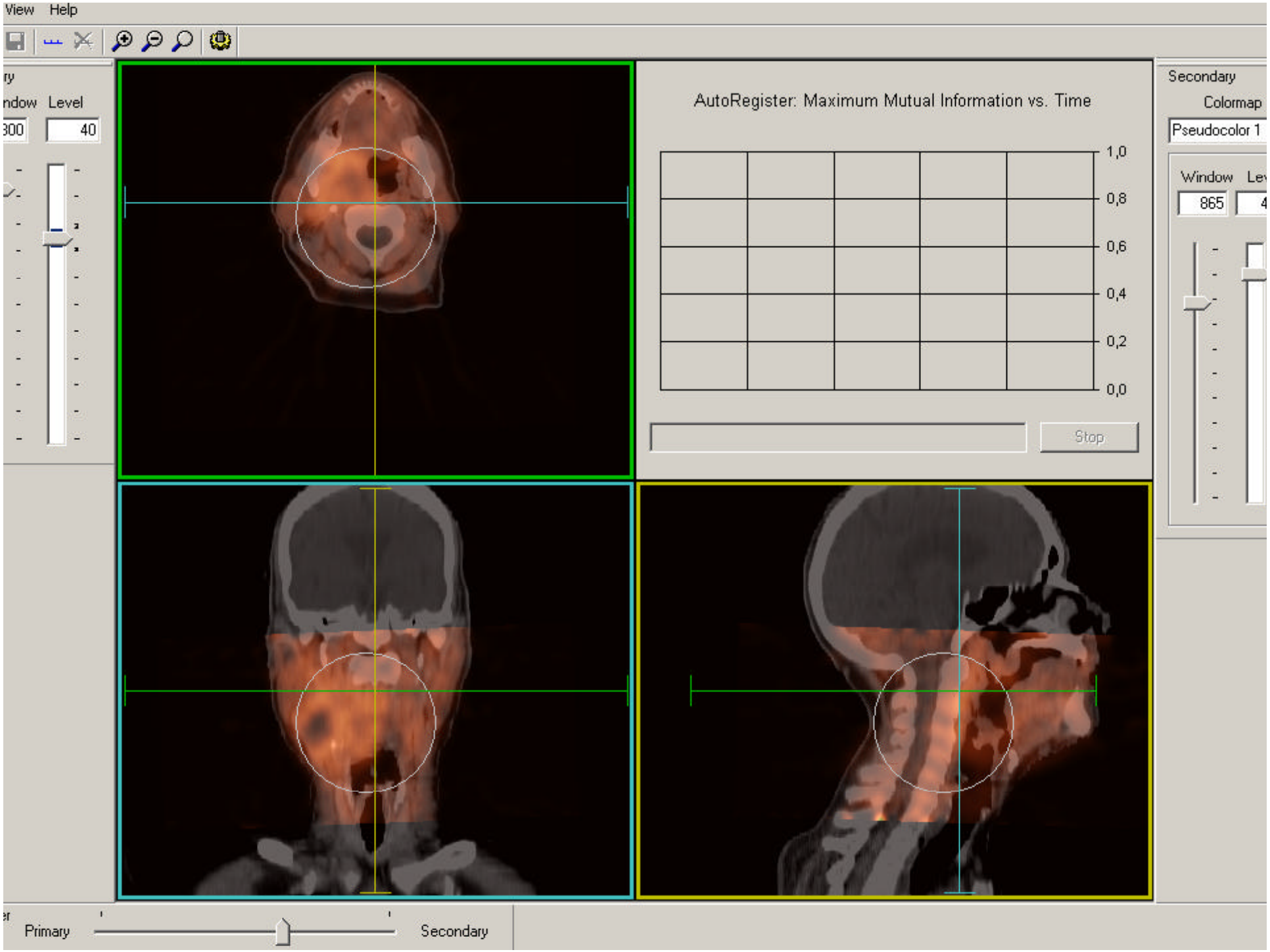
- **Automatische Bildfusion CT,MR,PET, SPECT**
- **Strukturanalyse mit Mutual Information Algorithmus**
- **Sehr schnell: weniger als 30 Sekunden**
- **Iteraktiv**
- **Manuelle Korrekturmöglichkeit**



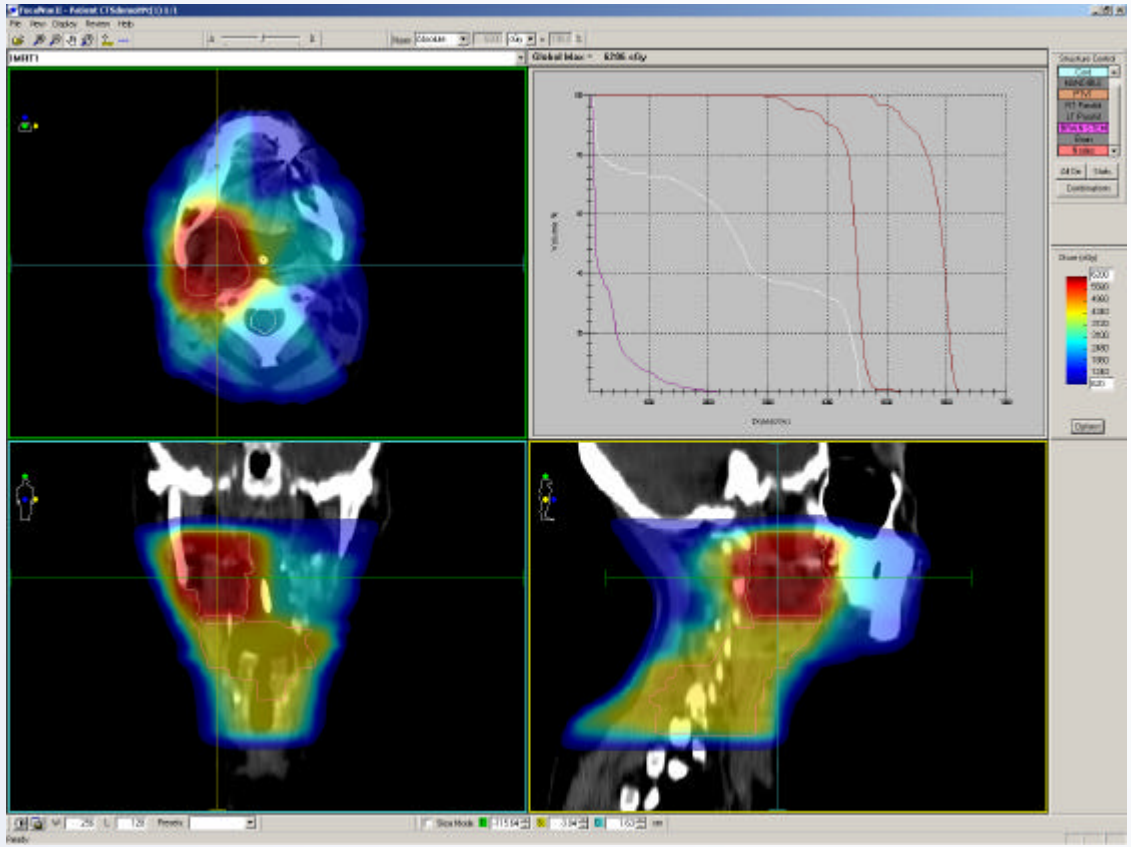
CMS Plan for More


FocalFusion - Patient CTPET1:(1) CT1/VDPSS_1; (2) PET1/VDPSS_1
File View Help
Primary
Window Level
300 40
AutoRegister: Maximum Mutual Information vs. Time
1,0
0,8
0,6
0,4
0,2
0,0
Stop
Secondary
Colormap
Pseudocolor 1
Window Level
865 400
Fader
Primary
Secondary
Ready
NUM


View Help
Level
40
AutoRegister: Maximum Mutual Information vs. Time
1,0
0,8
0,6
0,4
0,2
0,0
Stop
Secondary
Colormap
Pseudocolor 1
Window
865
Primary
Secondary


View Help
Level
40
AutoRegister: Maximum Mutual Information vs. Time
1,0
0,8
0,6
0,4
0,2
0,0
Stop
Secondary
Colormap
Pseudocolor 1
Window
865
Primary
Secondary

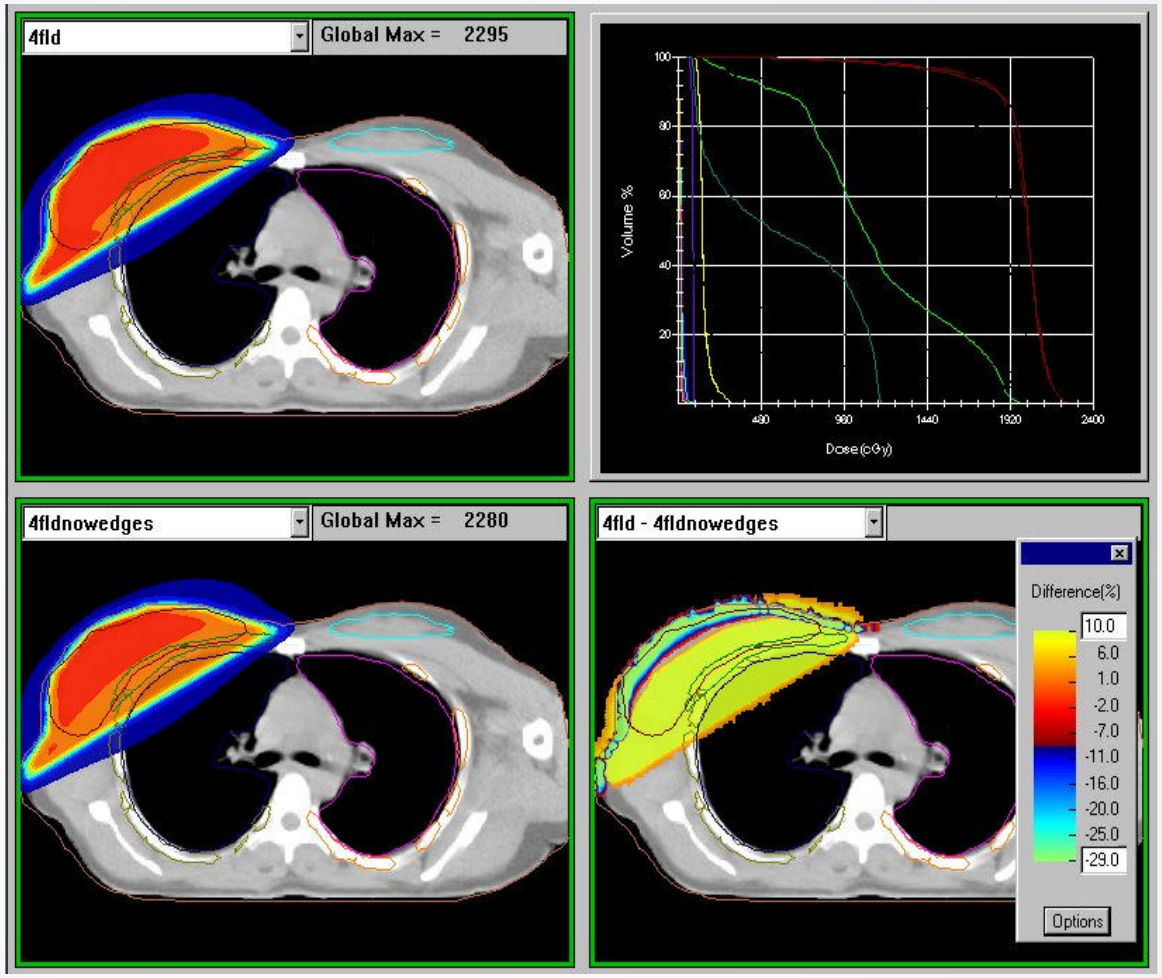
Planauswertung mit Focal



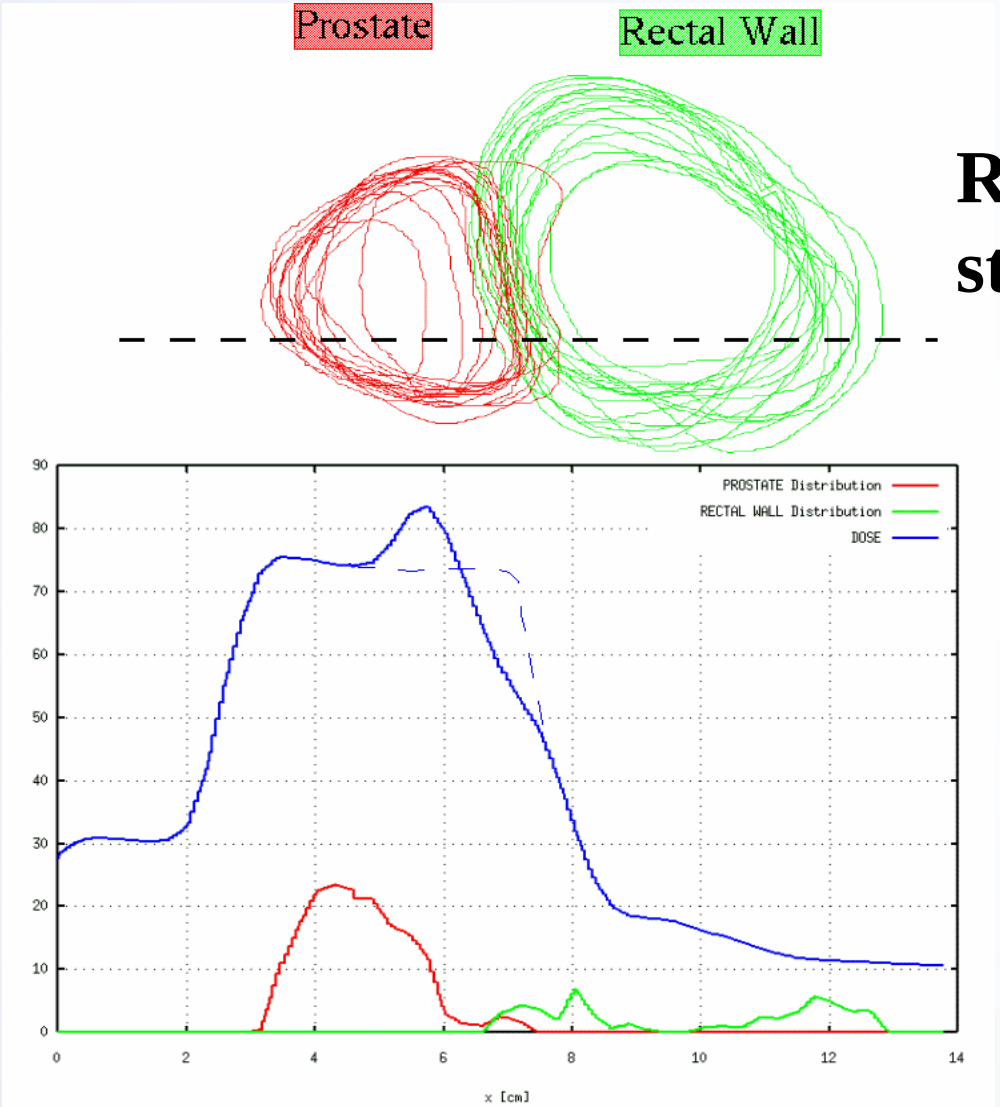
- Planauswertung
  - Dosisdarstellungen
  - Dosiscursor
  - DVH
  - Dosissubtraktion und -addition
- Planfreigabe

Plansubtraktion

Einfache und intuitive Möglichkeit Dosisunterschiede darzustellen



Organbewegung – Ergebnisse Tübingen



Result I - retrospective study

ONE 4D-plan –
15 CT images: *time-averaged compensation*

Dose profile cannot be achieved by *any* static margin

Don’t just beam. I-Beam!

Plan with Vision

CMS
Plan for More

Image Guidance – The Concept

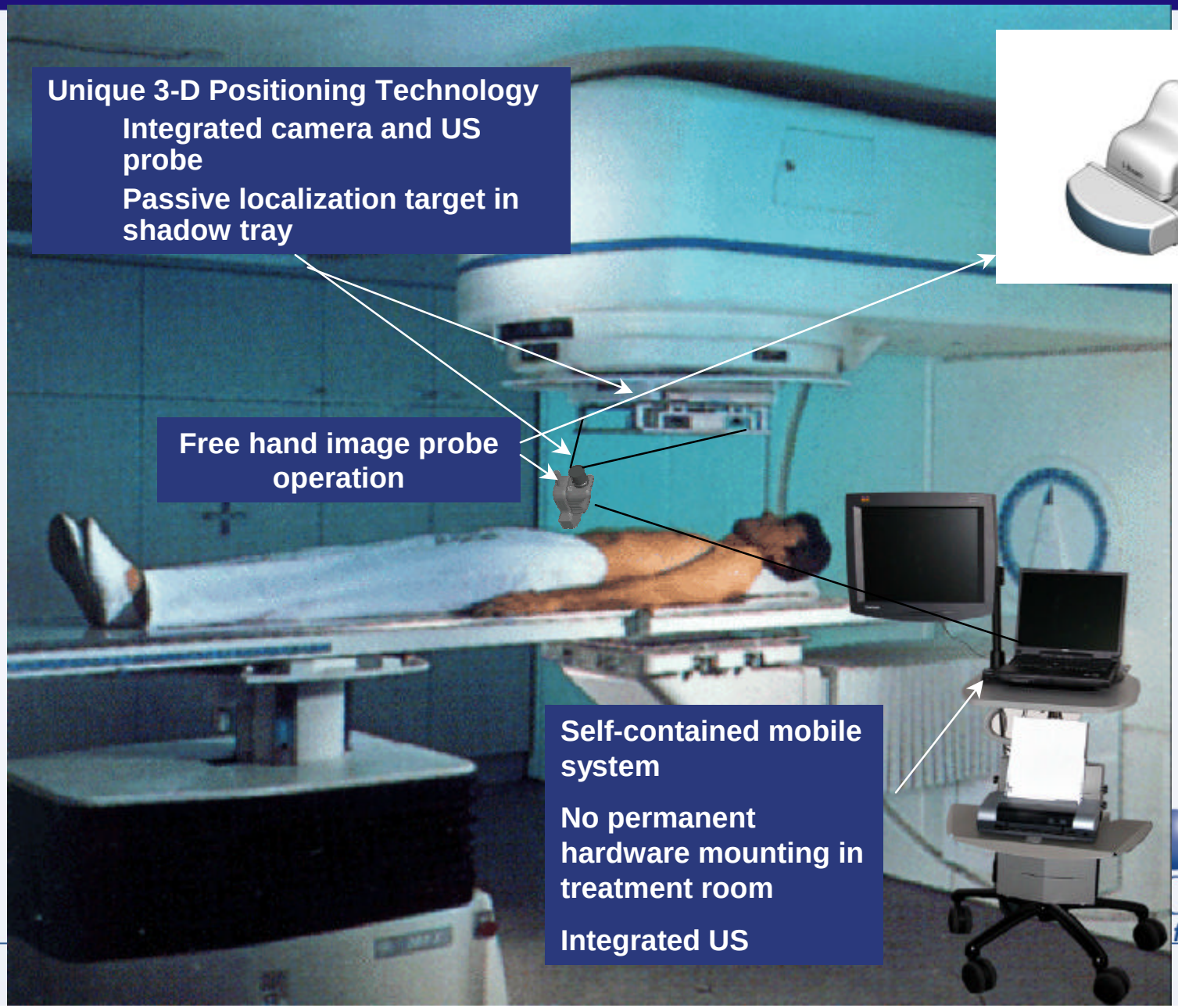
- Treatment plans are created via images that assume the targeted organ is static throughout the treatment cycle
- Organs are dynamic and can move dramatically from the original plan
  - Where you treat may not be what you truly intended
  - Treatment “margins” are typically used to account for this movement but they are assumptive
- Using “day of” images to confirm the location of targeted treatment area can enable more accurate delivery of radiation
- Ultrasound is initial image modality, however, other modalities will emerge such as EPID and cone beam CT

I-Beam™ Overview

- I-Beam is a self-contained mobile patient positioning system that uses ultrasound or other images in the treatment room to confirm the location of target organs or tumors. This localization is accomplished with an advanced target imaging tool called "CPS Technology"

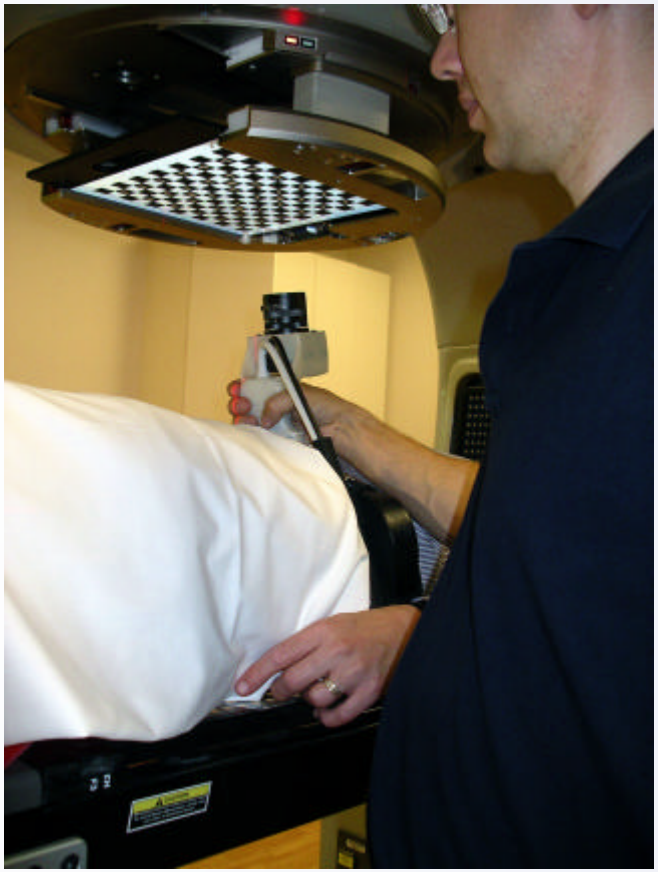
- I-Beam has received 510K clearance, CE Mark and is commercially available.

Frameless Image Registration



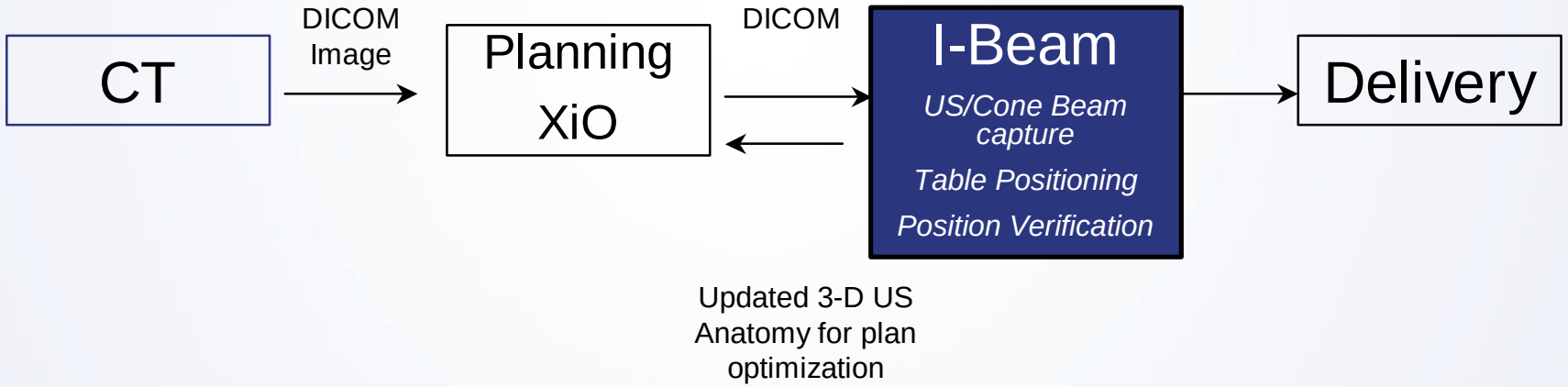
I-Beam "CPS Technology"

- Localization Target
  - No permanent installation
  - Uses wedge or block tray slot
  - Specific to accelerator type
  - Required only during the alignment mode



I-Beam Data Flow

Treatment Ultrasound Localization



Vielen Dank für Ihre Aufmerksamkeit.