

Multi-Criteria Plan Optimization (MCO)

Thomas Bortfeld

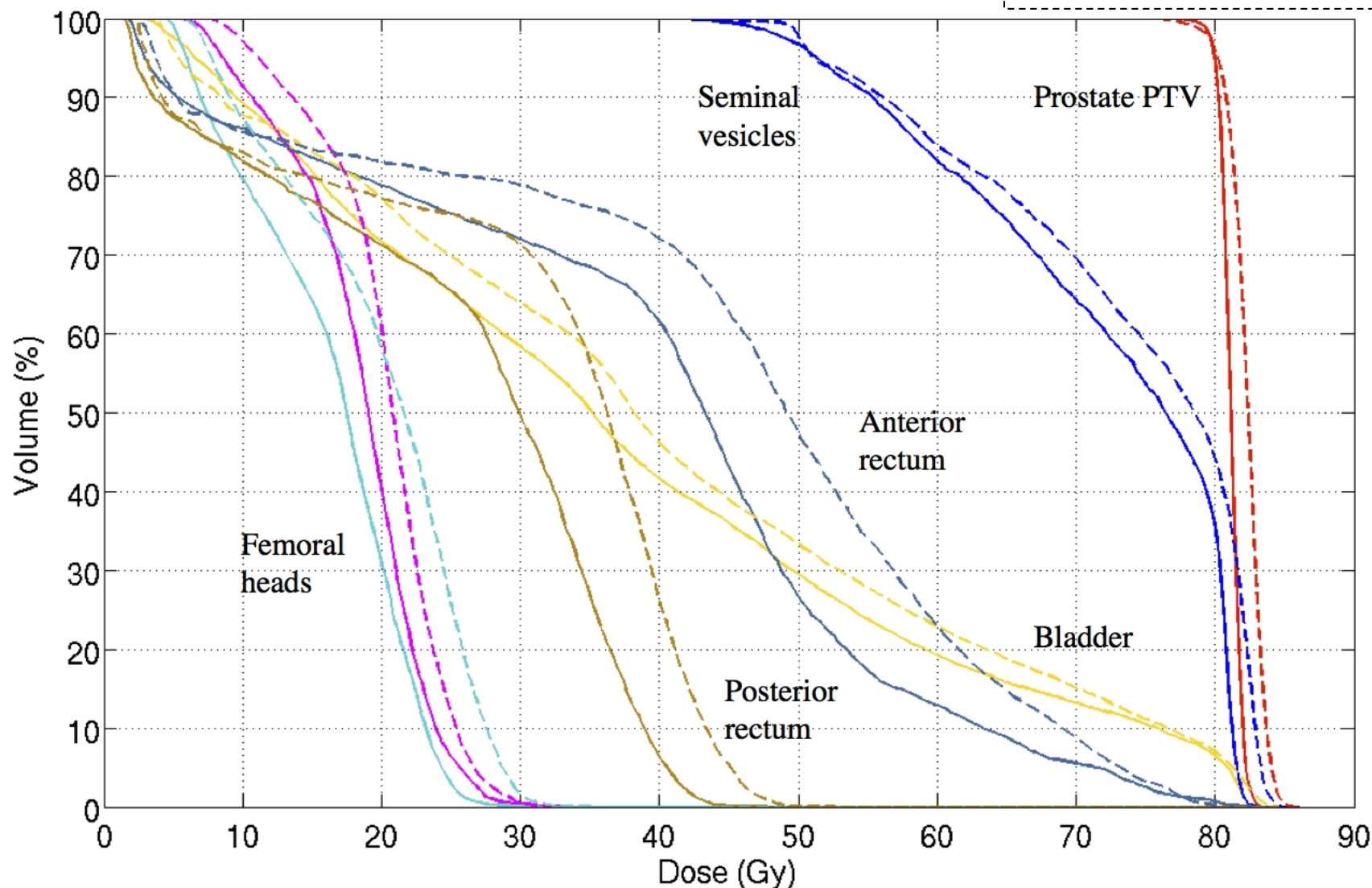
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15th Medical Physics Conference, Trabzon

Two “optimal” plans

MCO - Raystation

Corvus



Current IMRT/VMAT planning is not optimal

-----Original Message-----

From: Cornell, Mariel J.
Sent: Friday, October 26, 2007 8:21 AM
To: Hong, Theodore S., M.D.
Subject: C***

Hi,
I played around with Ms C***'s plan all day yesterday but even with relaxing the Rt Kidney restraints, the liver and stomach doses don't budge. If I push it, the PTV and CTV coverage really suffers. Are you willing to sacrifice their coverage or would you prefer to go with the plan you reviewed the other day? She's coming this afternoon for VSim.

Thanks,
Mariel

- long planning time
- not clear, which knob to turn
- tradeoffs unclear
- clinician's judgment indirect



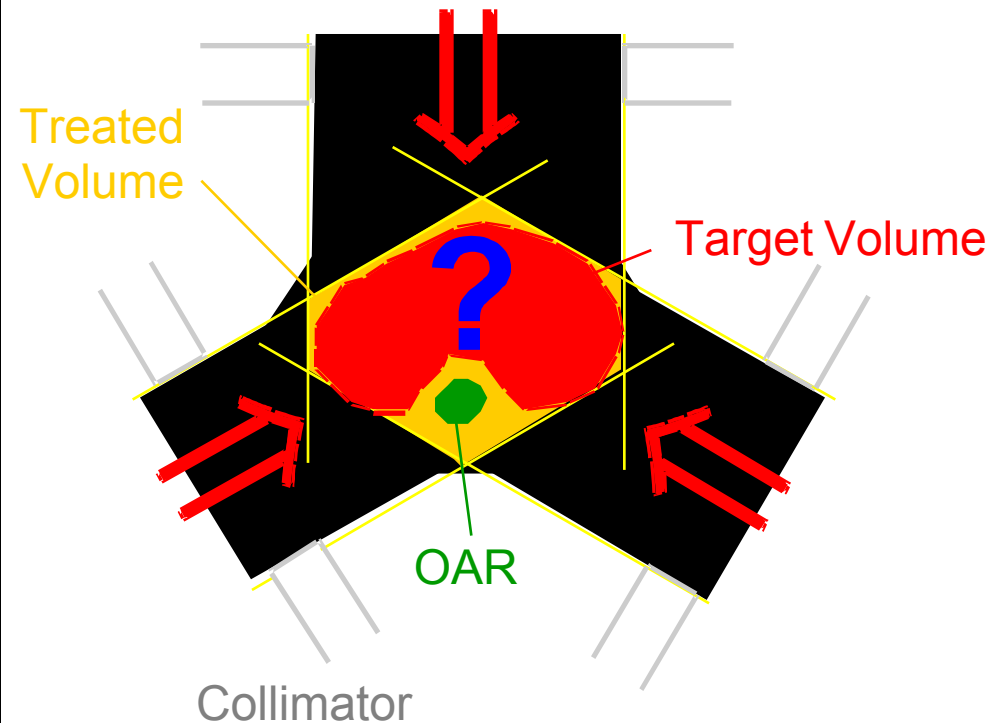
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RADIATION ONCOLOGY

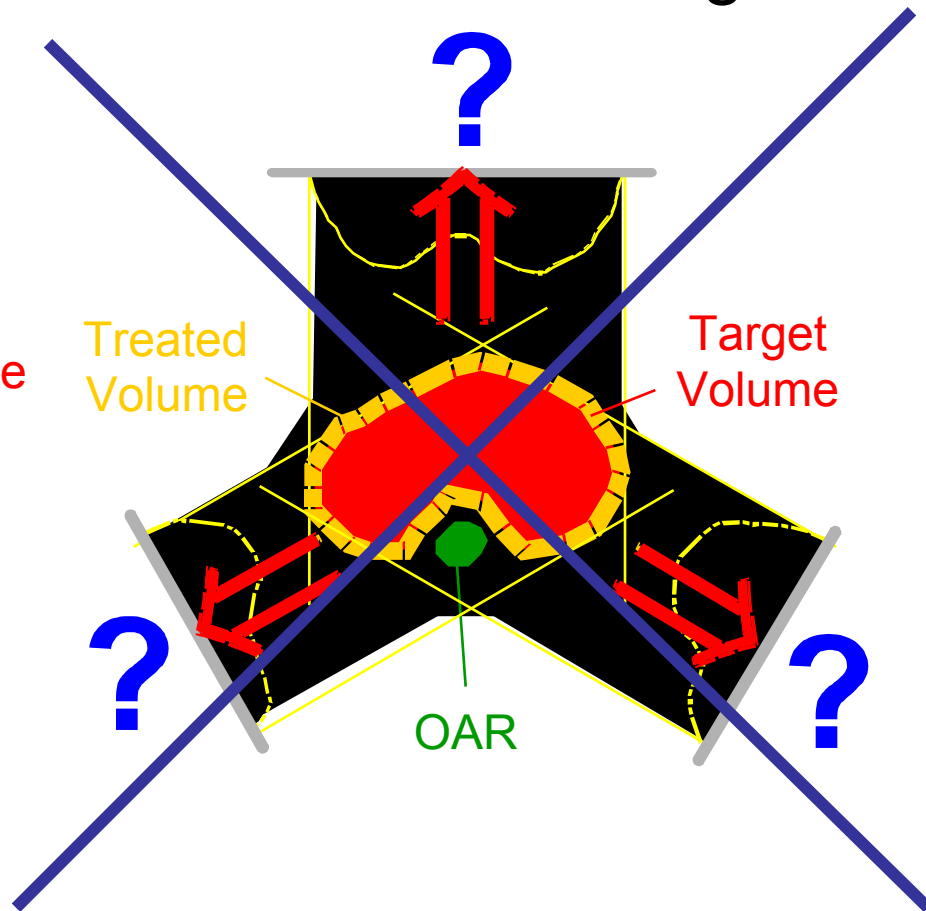
Inverse treatment planning for IMRT/VMAT

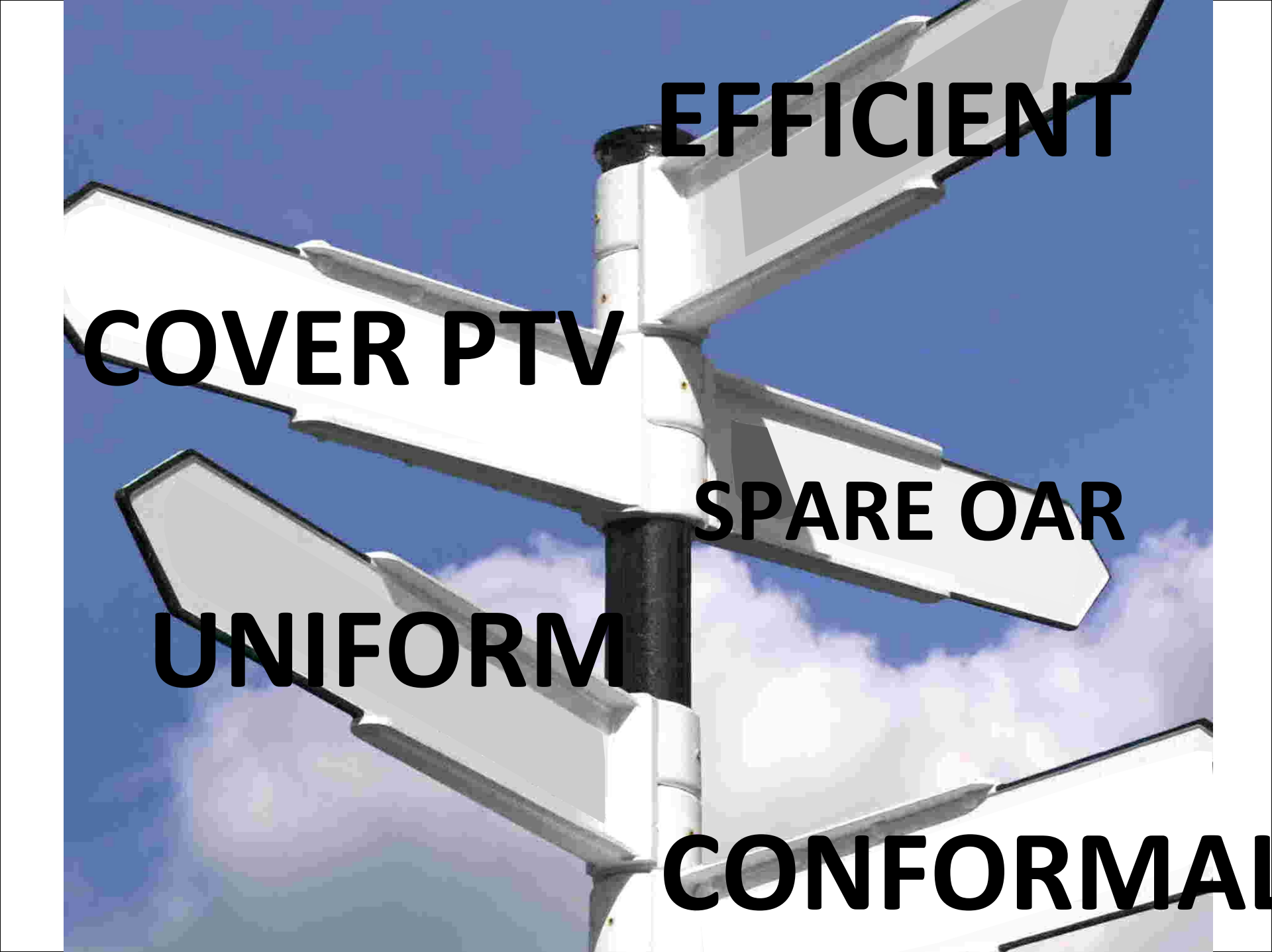
- does not really exist!

"Conventional" Planning



Inverse Planning





EFFICIENT

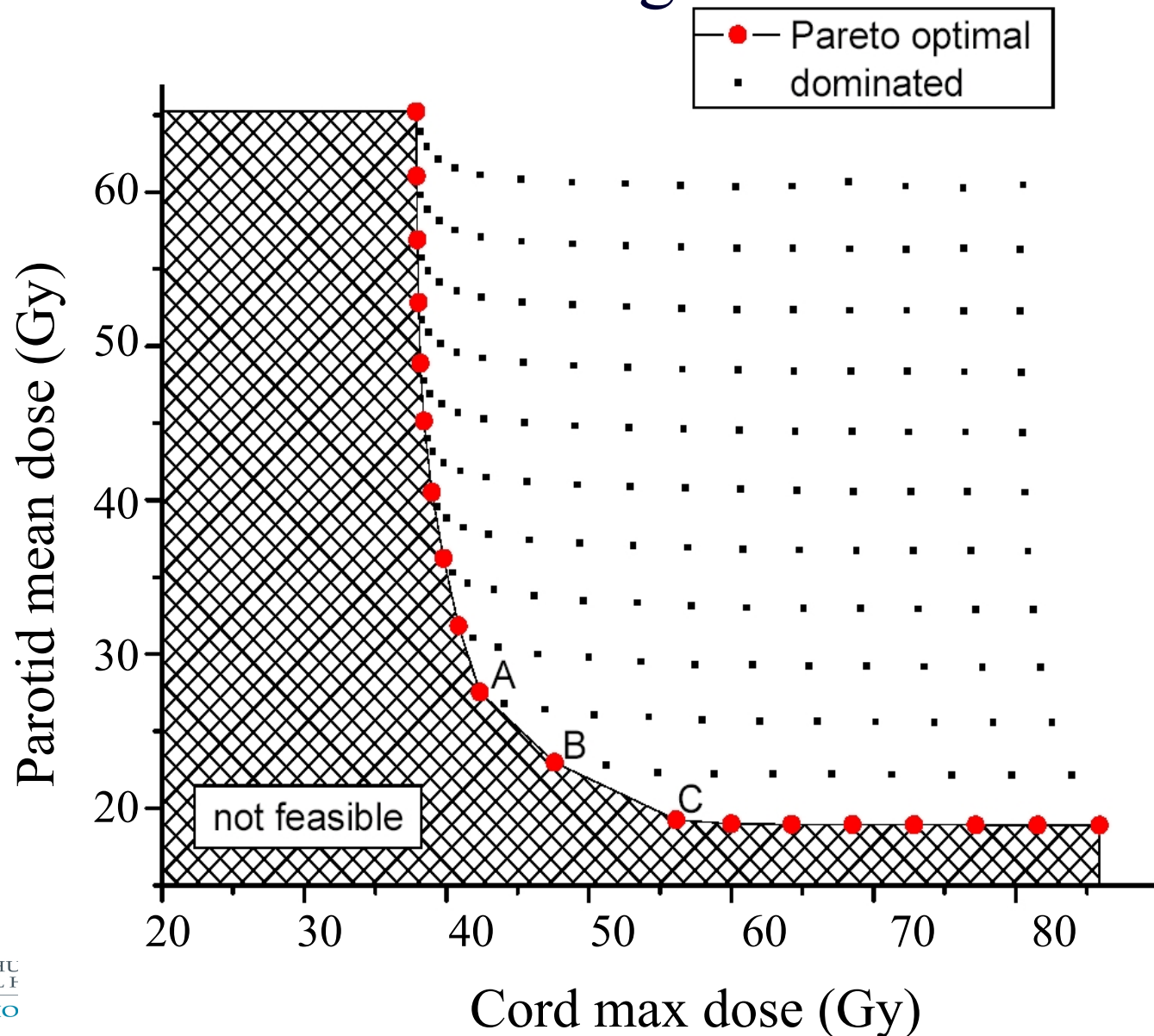
COVER PTV

SPARE OAR

UNIFORM

CONFORMAL

Solution: Pareto optimization – “cannot make one better off without making the other worse off”



Pareto Optimization

Vilfredo Pareto, born 1848 (Paris) – died 1923 (Geneva)
Industrialist, Sociologist, Economist, Philosopher
Taught in Lausanne, lived in Céligny near Geneva



Pareto chart

Pareto principle (80-20 rule)

...

Pareto-optimality, “efficient”:

“You cannot make anybody better off
without making someone else worse off”

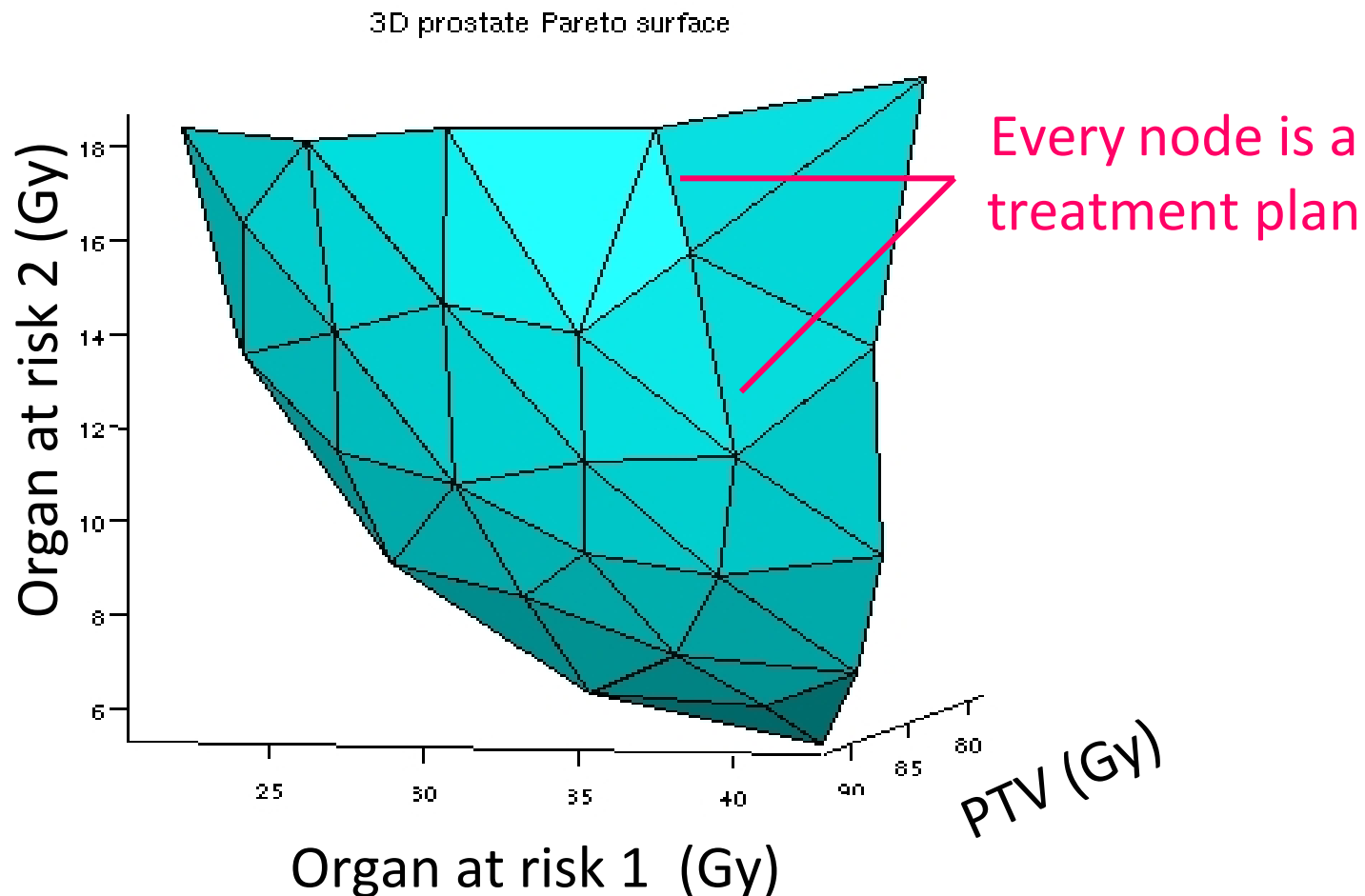


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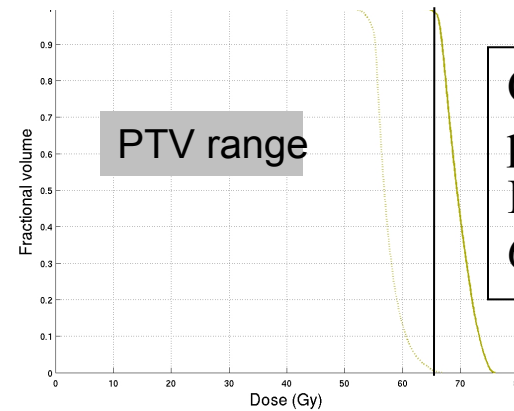
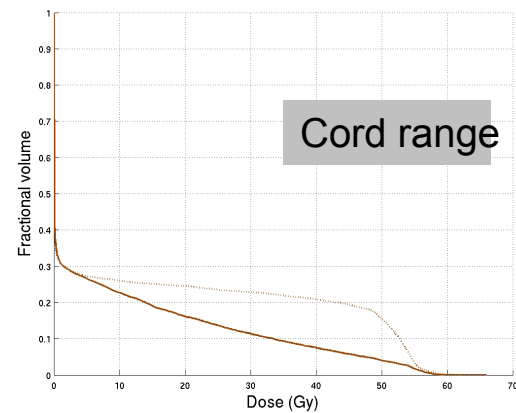
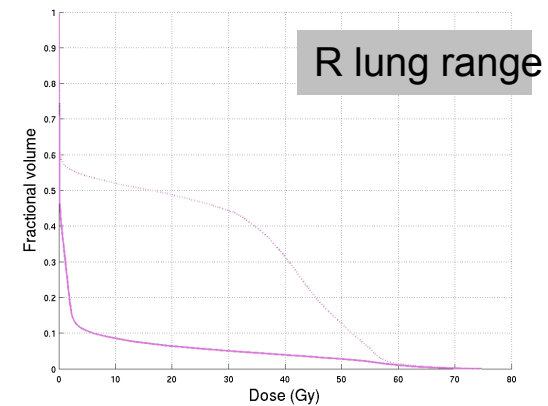
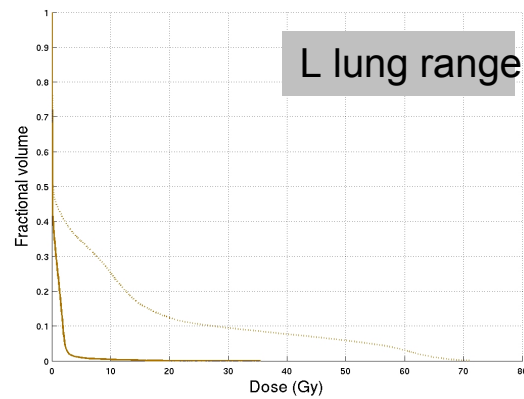
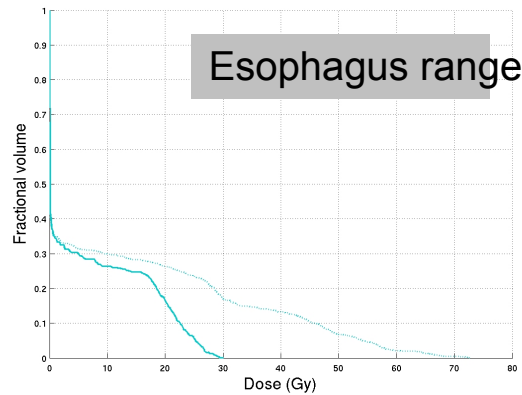
Pareto optimization – “cannot make one better off without making the other worse off”

3D Pareto surface (“frontier”), **tradeoff curve**

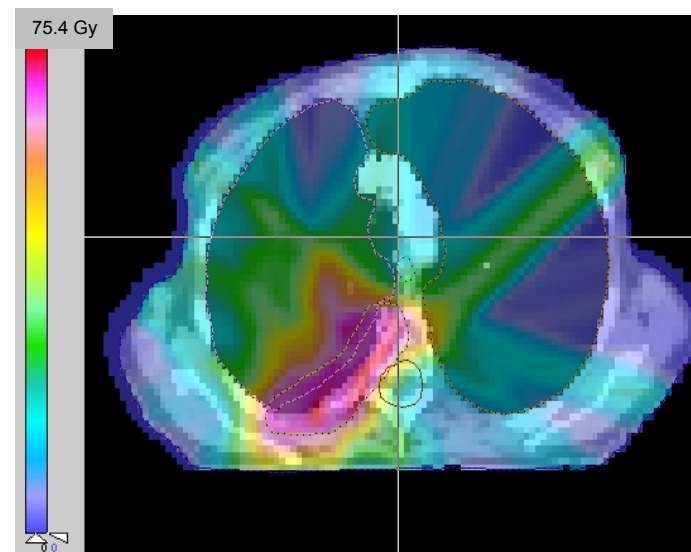
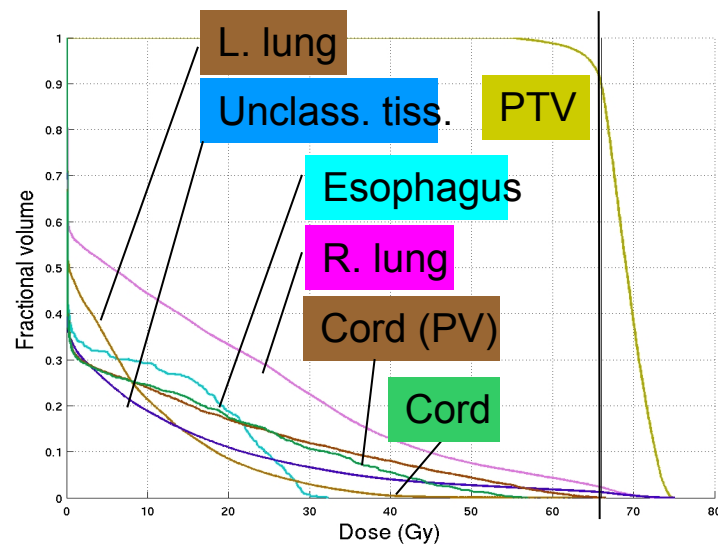


Three steps of multi-criteria Pareto IMRT optimization (MCO):





Craft et al.: "An approach for practical multi-objective IMRT"
Int J Rad Onc Biol Phys
69(5):1600-1607, 2007



1. MCO – clinical templates



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2nd step: Calculation of the Pareto surface

If the functions F_k are convex and the feasible dose space S is convex, then:

Find all Pareto optimal solutions to

$\min \{F_1(d), F_2(d), F_3(d), \dots\}$

subject to

dose vector d in set S

is equivalent to solving

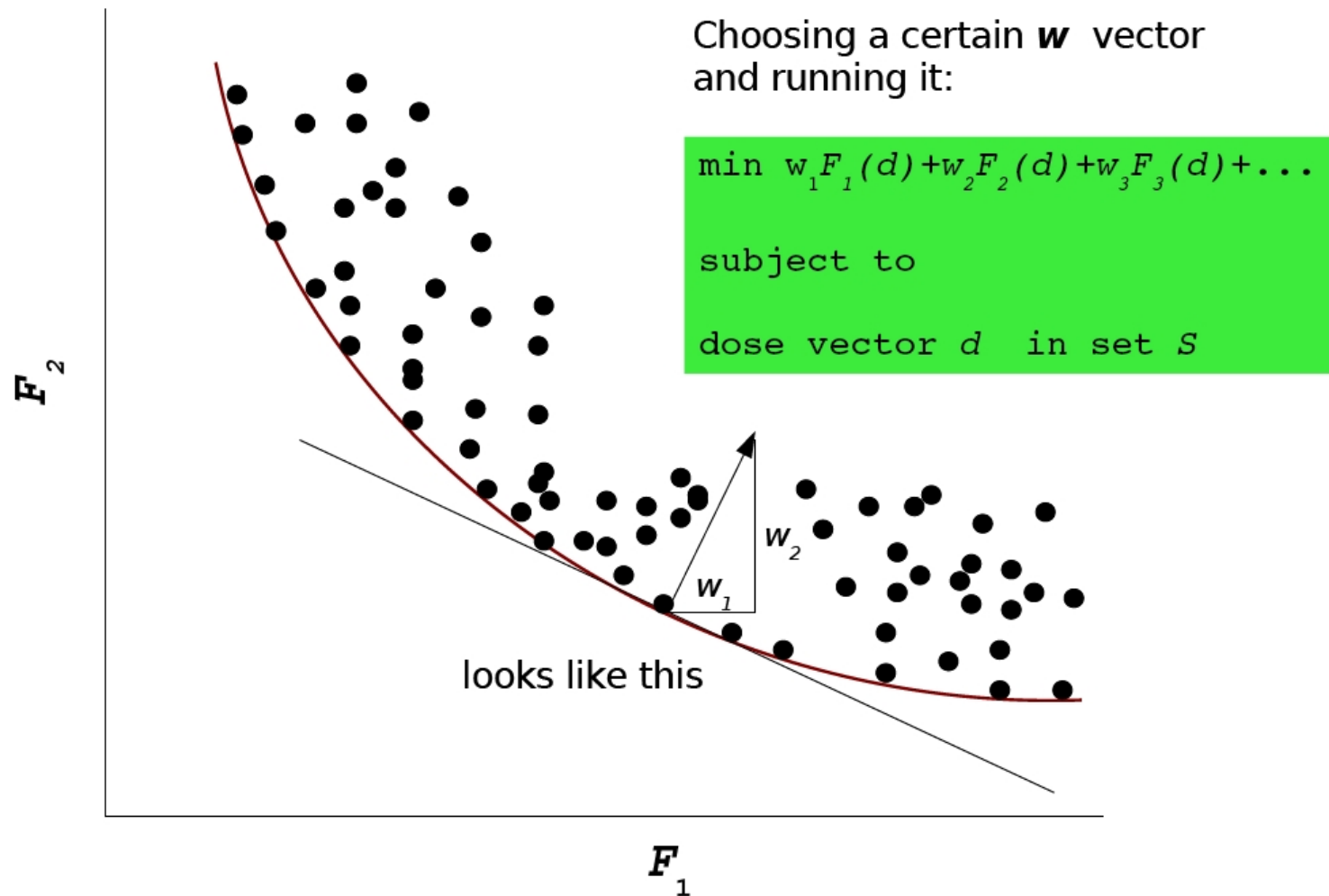
$\min w_1 F_1(d) + w_2 F_2(d) + w_3 F_3(d) + \dots$

subject to

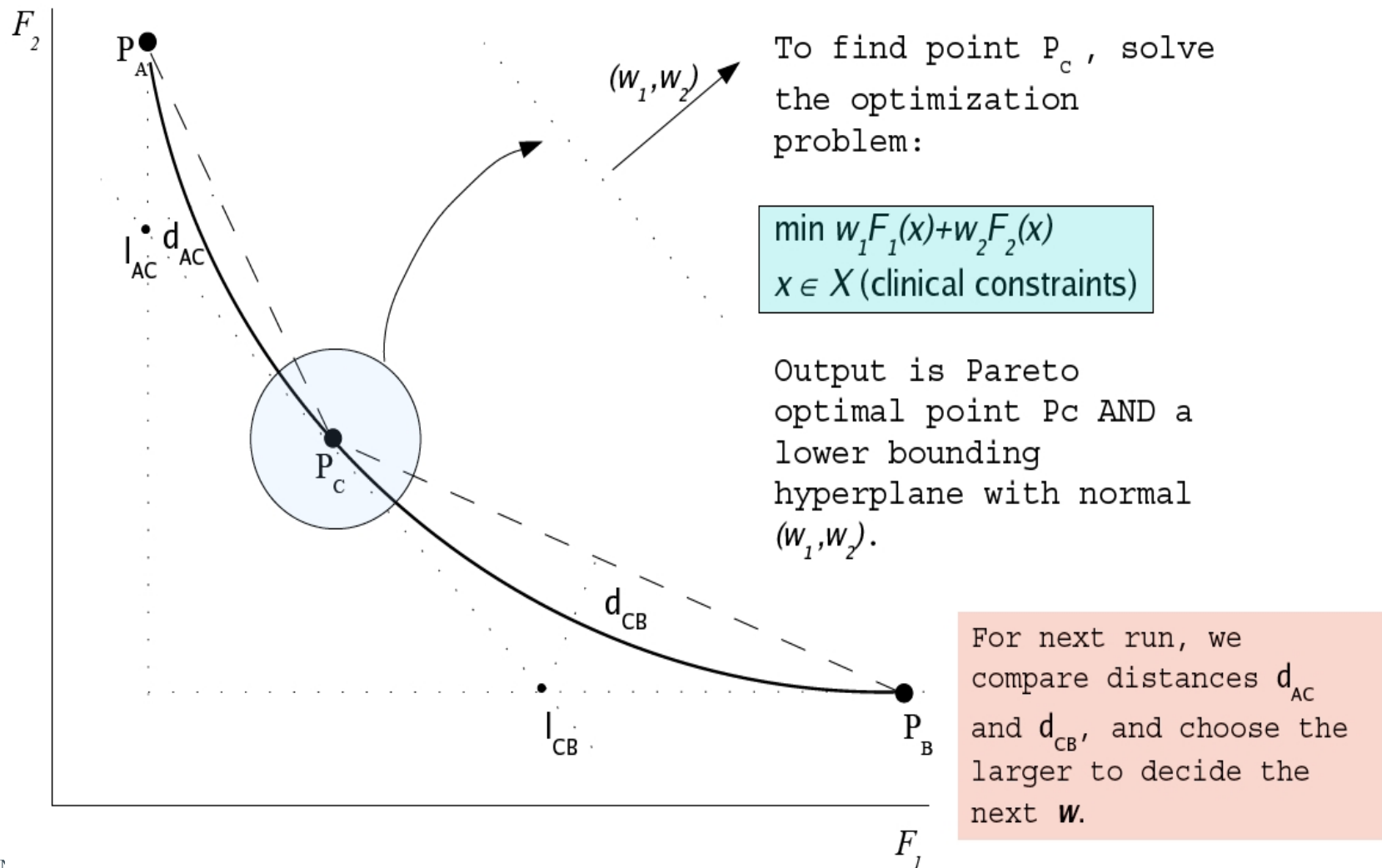
dose vector d in set S

for all possible values of w_i in $[0, 1]$.

Graphical view of finding Pareto optimal points

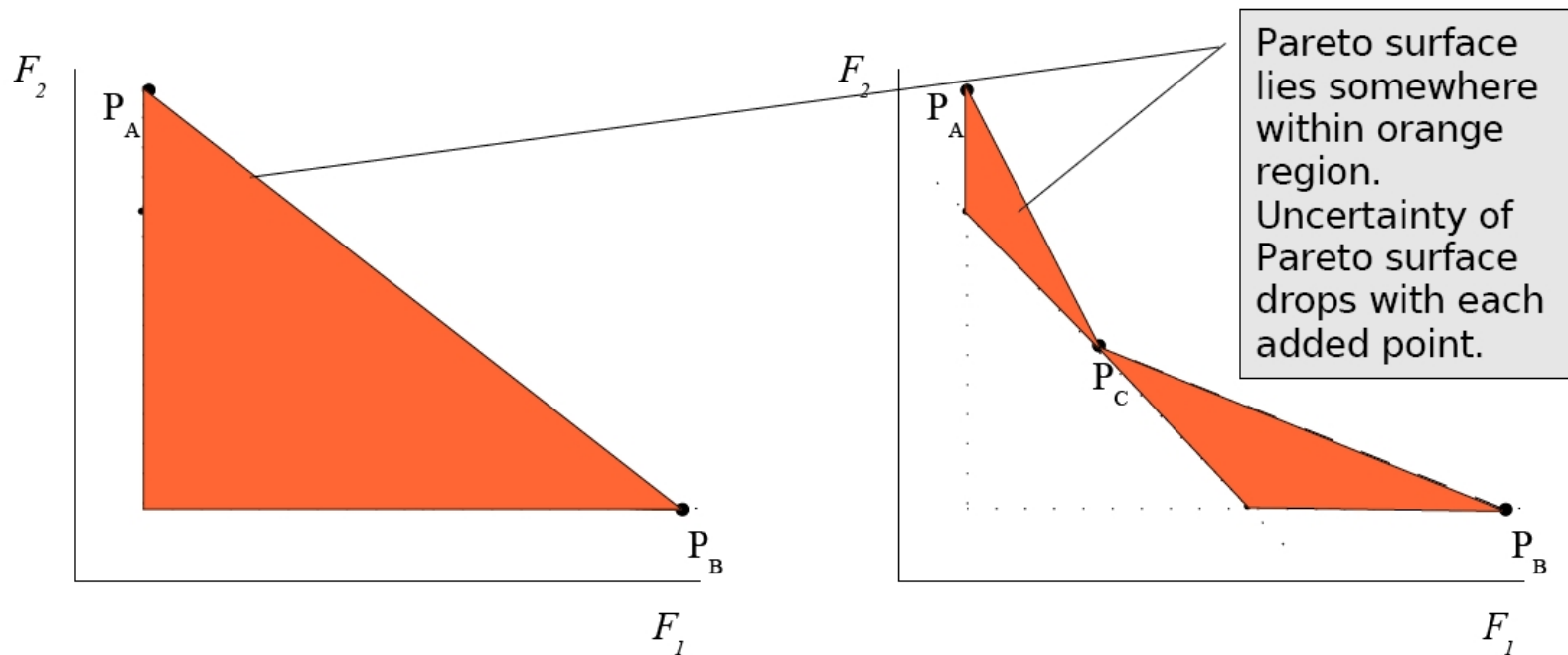


PGEN: Pareto surface generation algorithm



“Sandwiching” the Pareto surface

— Adding points to the Pareto surface —→



PGEN quickly closes the gap between the upper and lower bounds.

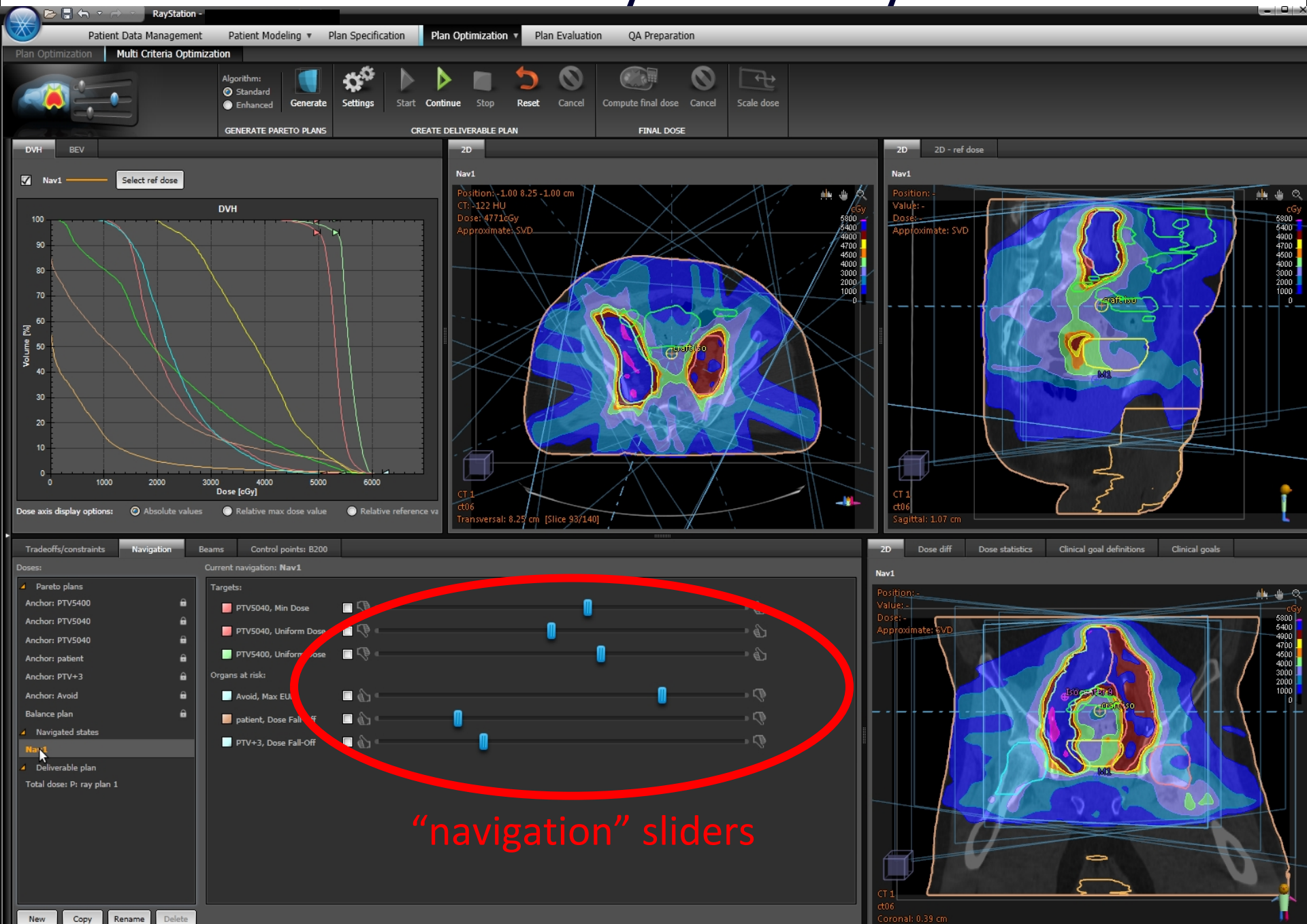
Extension to N-dimensions is possible, but not trivial!

Craft et al.: “Approximating convex Pareto...”, Med Phys 33:3399-3407, 2006
Hoffmann et al.: “... Pareto optimal IMRT”, Phys Med Biol 51:6349-6369, 2006

3rd step: Interactive navigation on Pareto frontier

- Sliders to navigate (interpolate) smoothly between the 10-30 representative plans on Pareto surface
- “Clamps” to prevent sliders to go worse than previous solution

Commercial MCO system: RayStation



The MCO promise

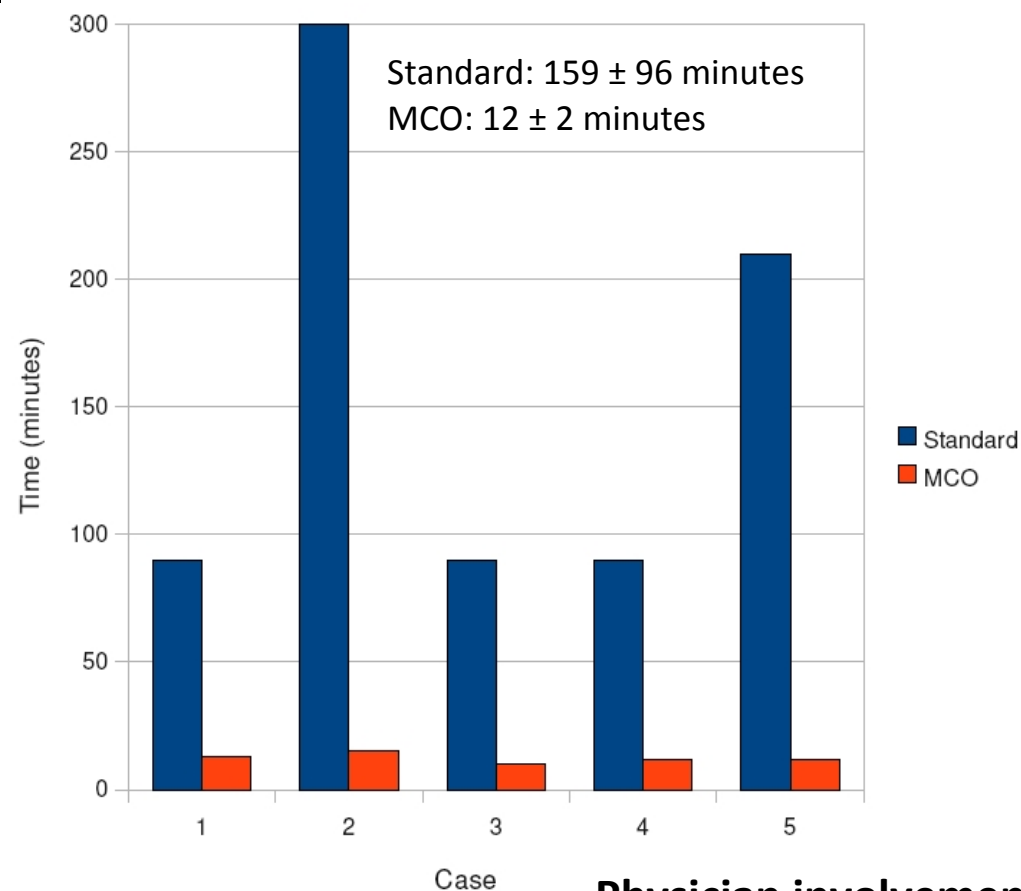


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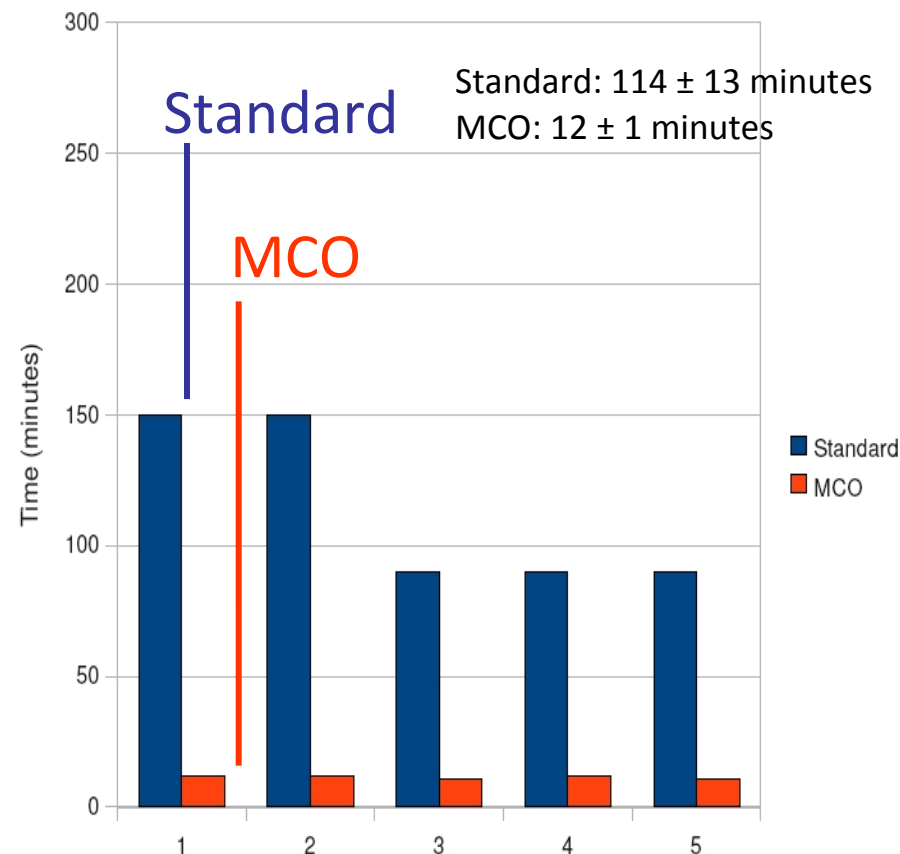
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Pre-Study

Brain cases



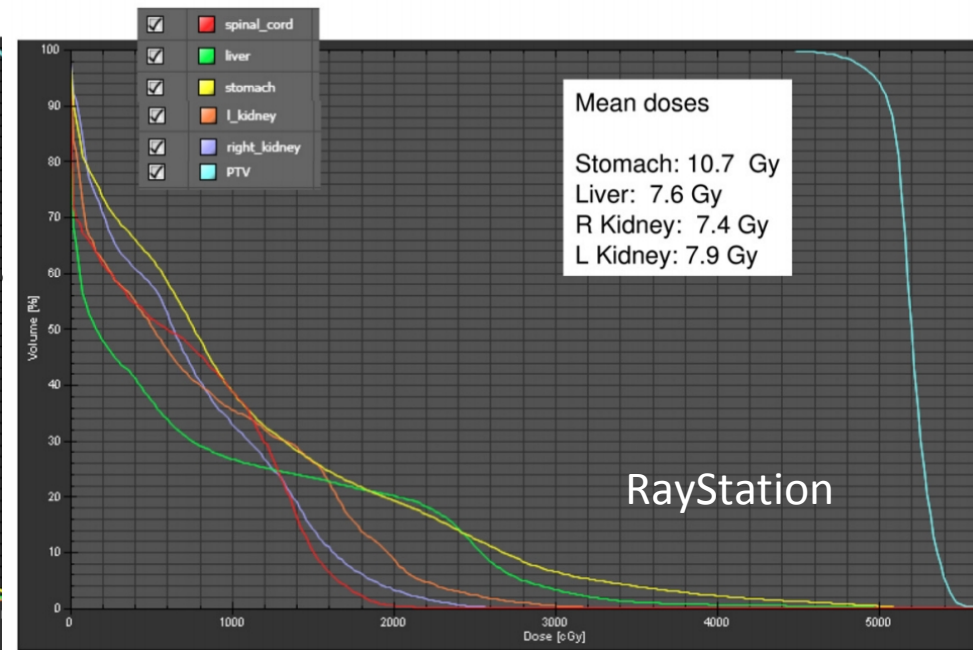
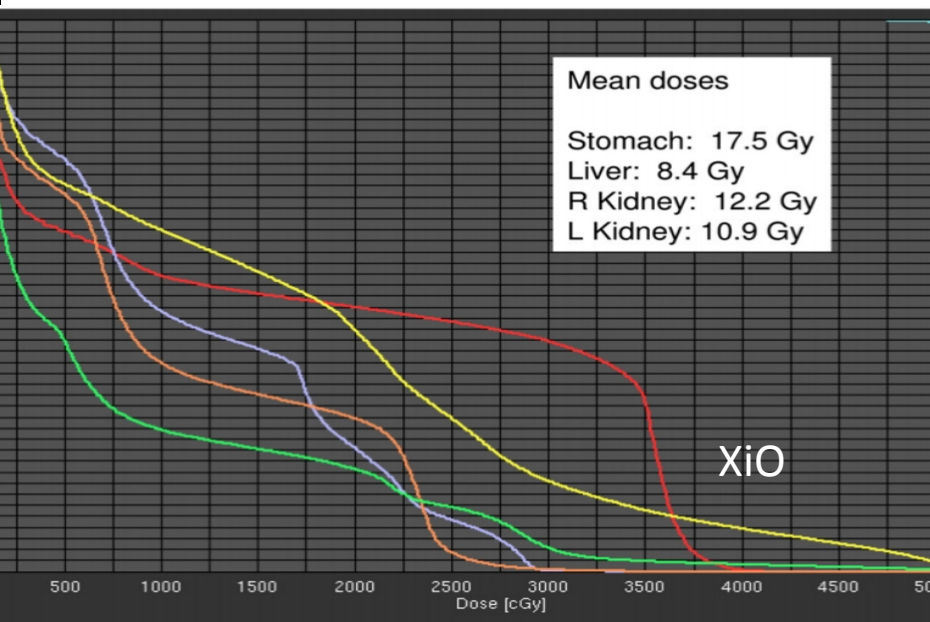
Pancreas cases



Physician involvement time increased from 5 to 10 minutes, but was deemed well worth it

Pre-Study: Brain and Pancreas – Results

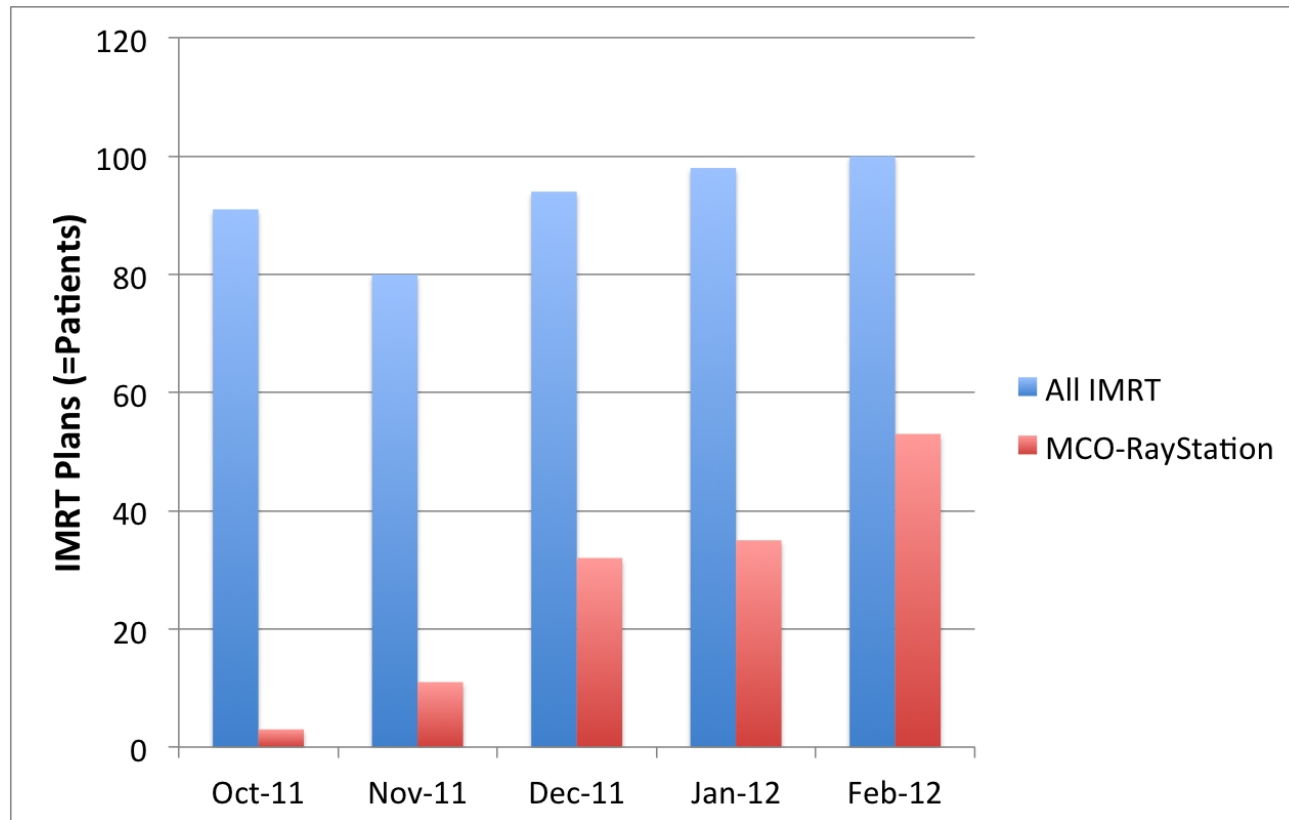
- For all cases, the physicians preferred the MCO plan to the Standard plan in a blind review weeks after initial assessments.



Craft et al., IJROBP 82(1): e83-e90, 2012

MCO – Clinical Deployment at MGH

Rapid ramping up of MCO treatments



Multi-criteria optimization @ MGH – 3.5 years, 2857 treatment plans



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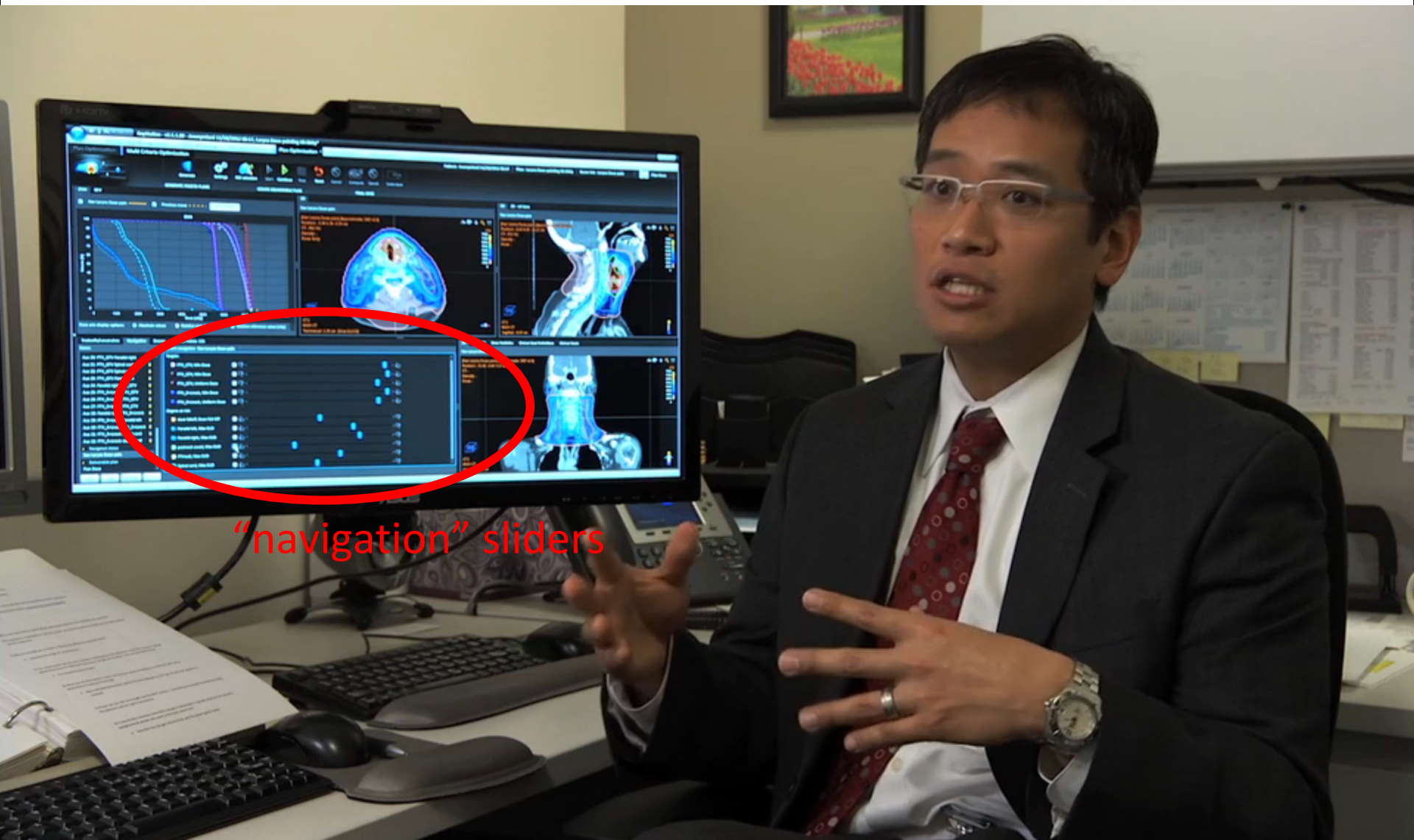
PART 2: Current developments

- MCO for protons
- MCO for VMAT
- Tradeoffs complexity – quality
- Physician planning study

Physician-driven planning study

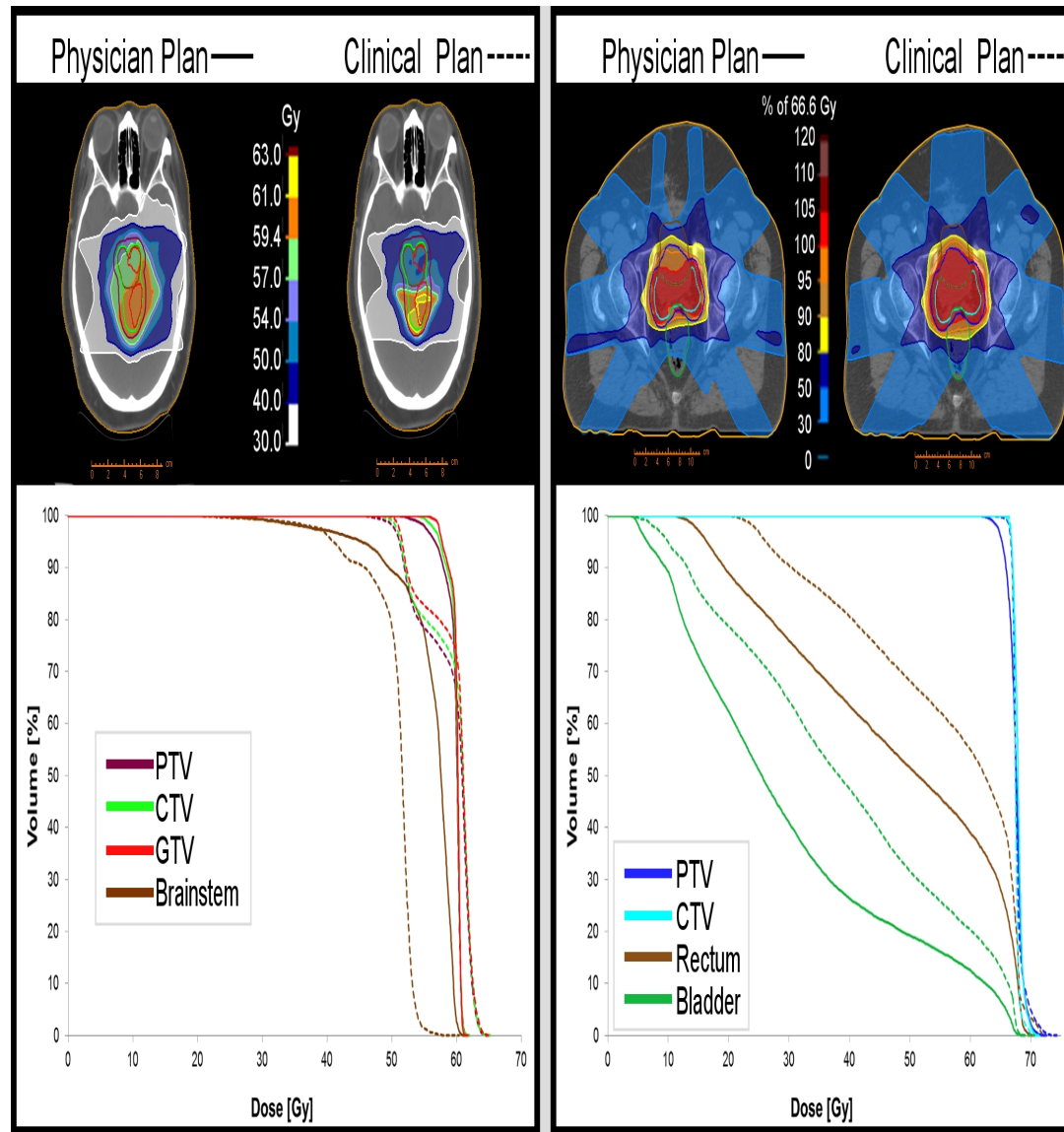
- Can physicians create treatment plans independently, using MCO?
- 22 patient cases, 10 prostate, 12 CNS
- 2 physicians participating
- Physician-driven planning was done retrospectively

RayStation Pareto optimization = multi-criteria optimization (MCO)

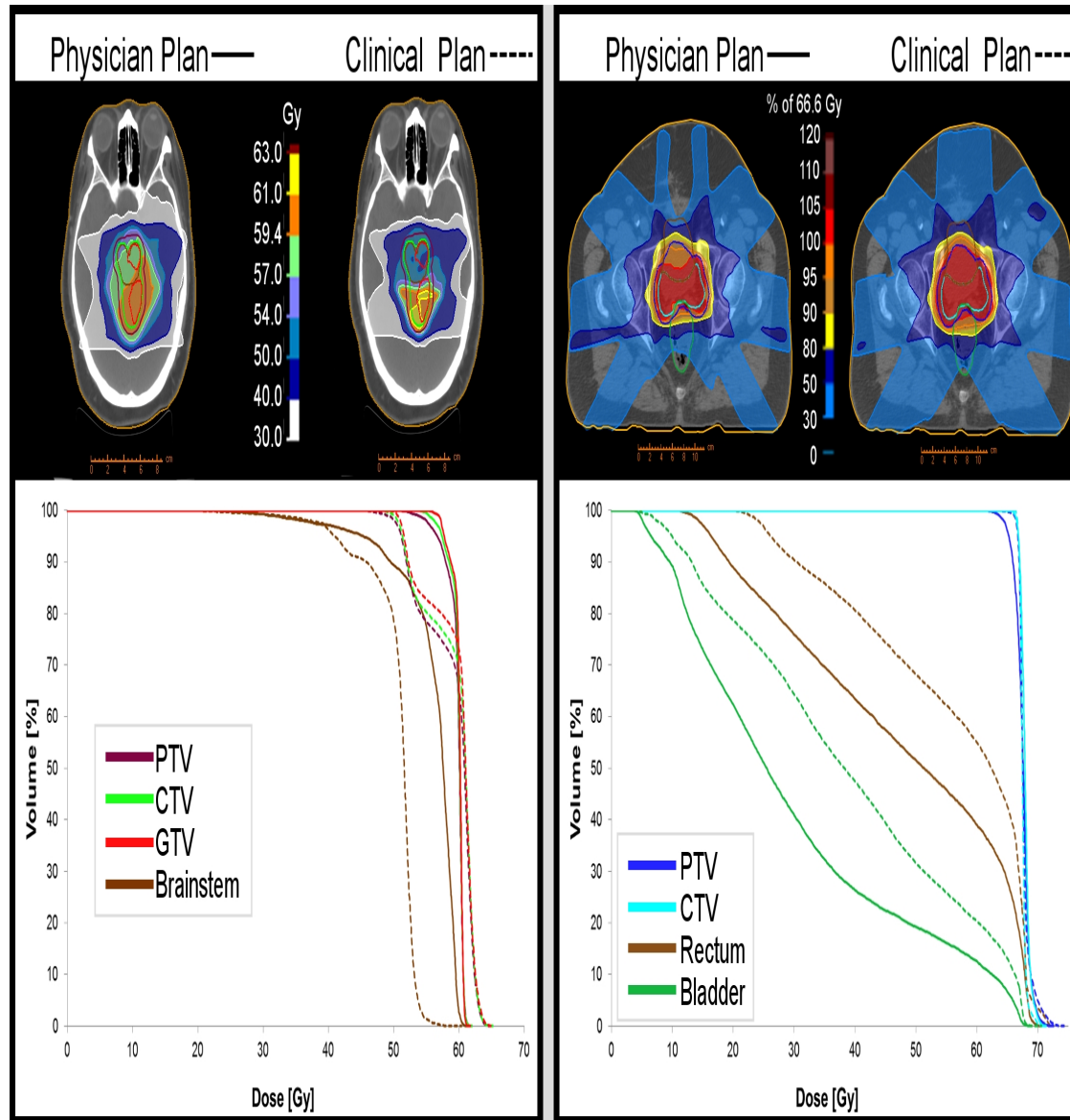


“navigation” sliders

Physician-driven planning study (CNS)



Physician-driven planning study (prostate)



Physician-driven planning study

– Results –

- All plans were approvable for clinical treatment
- No significant preference for either plan in the majority of the cases (18/22)
- There is a learning curve, physician's preference shifted towards their own plans during the course of the study
- Average planning time: 12 minutes

Multi-criteria plan optimization (MCO)

Summary:

Thanks:



- David Craft
- Helen Shih
- Ted Hong
- Jason Efstathiou
- Henning Willers

- Karl-Heinz Küfer
- Alexander Scherrer
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- Johan Löf
- Björn Hardemark
- Rasmus Bokrantz
- Albin Fredriksson

