Increasing dosimetric accuracy in optimized VMAT plans

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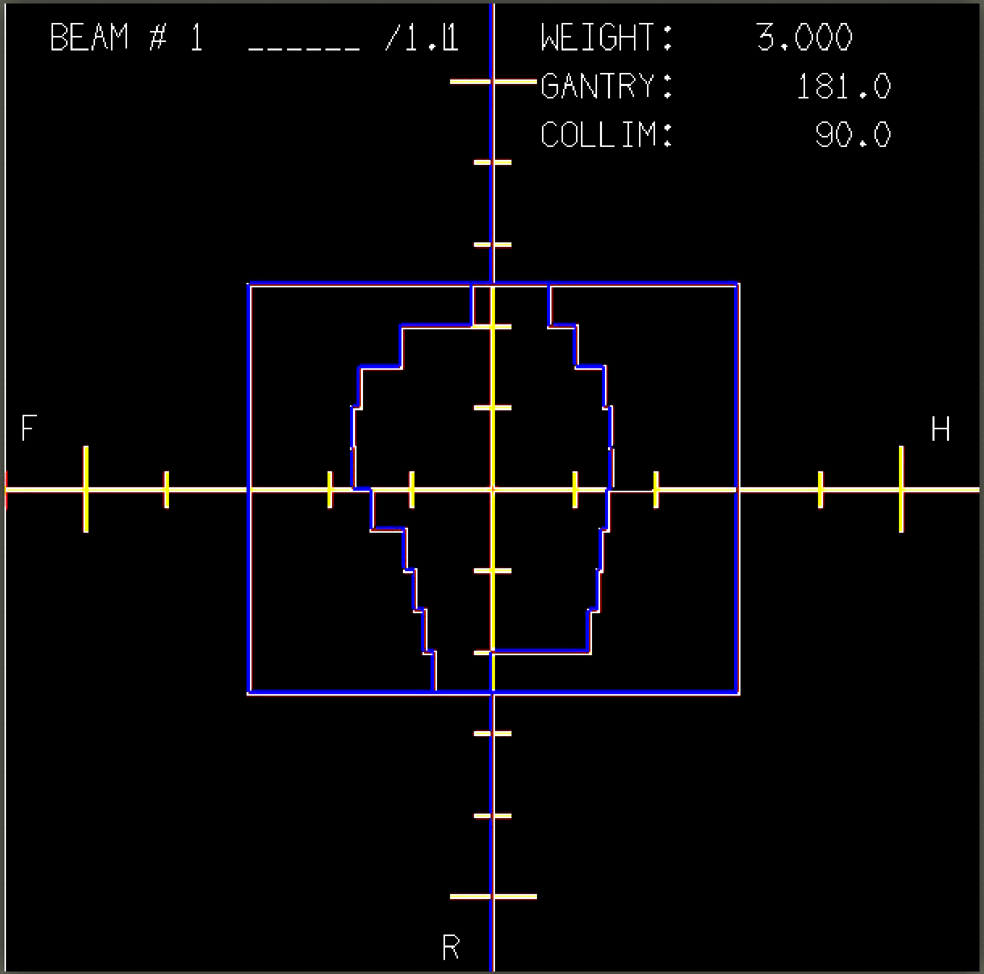
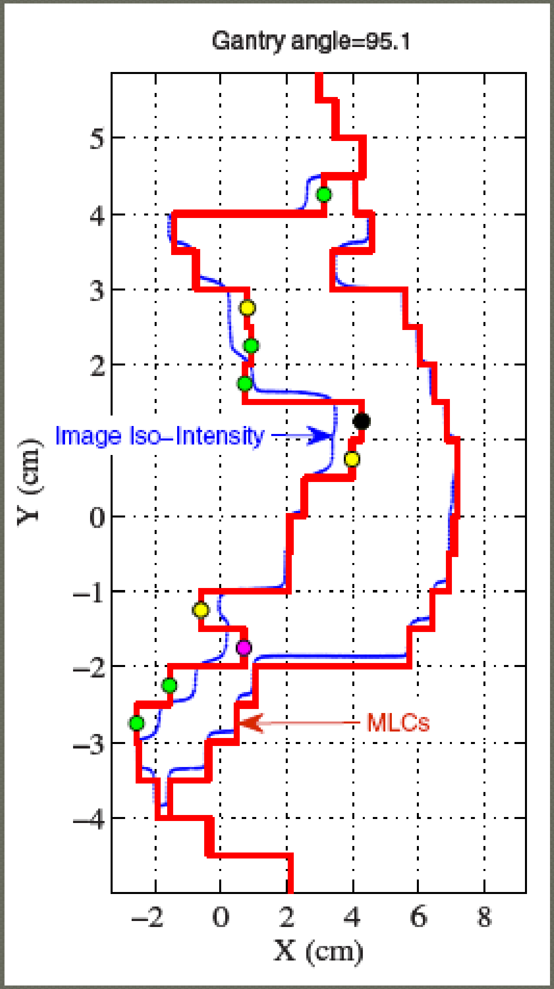
VMAT Optimization

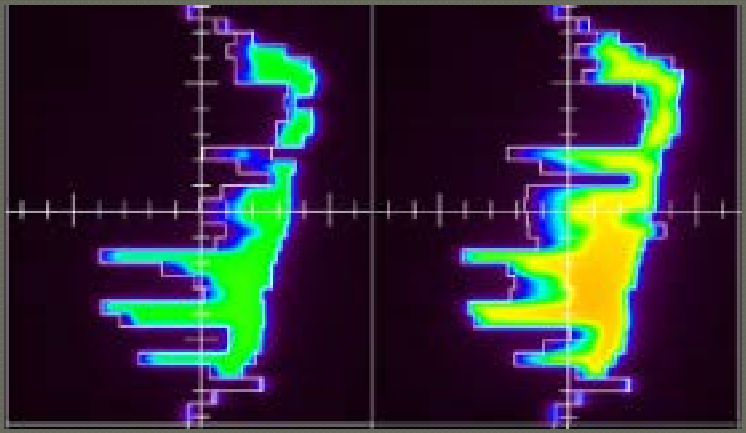
- Aperture-based optimization
- Feedback provided by cost function
- Optimization is similar to IMRT



Aperture complexity



Bakhtiari et al, *Med. Phys.* **38** (2011).



Nicolini et al., *Radiation Oncology* **3** (2008).

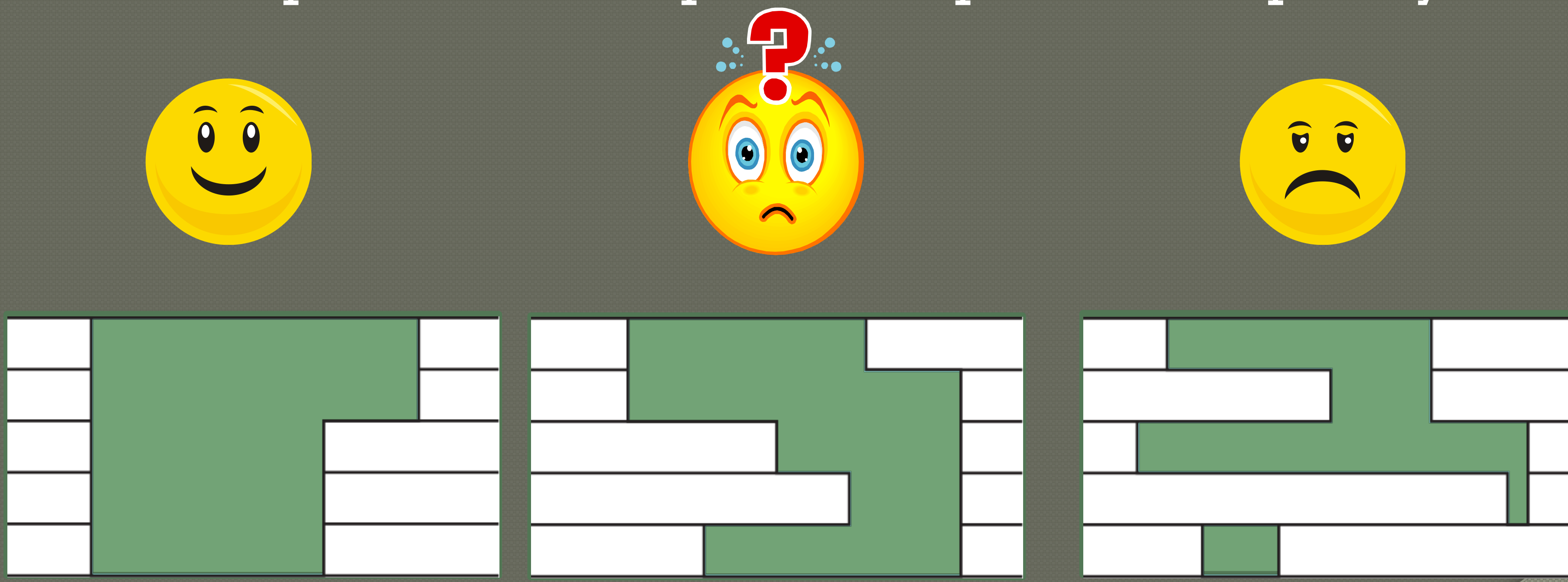
- Side-effect of inverse planning
- SmartArc errors:
  - Feygelman et al. JACMP 11, 2009.
- RapidArc errors:
  - Fogliata et al, Med. Phys. 38, 2011.
  - Nicolini et al., Med. Phys. 33, 2006.

Aperture complexity

- Complex apertures generate dose calculation
- Greater dependence on MLC leaf positioning/modeling
- Increased MU
- Greater susceptibility to motion and interplay effects
- Current solutions
  - Hand-editing of apertures
  - Constraints on area/leaf gap

Research Goals:

- Generate high quality, dosimetrically accurate VMAT plans - make it automatic
- Aperture-based feedback during optimization
- Develop a metric that quantifies aperture complexity



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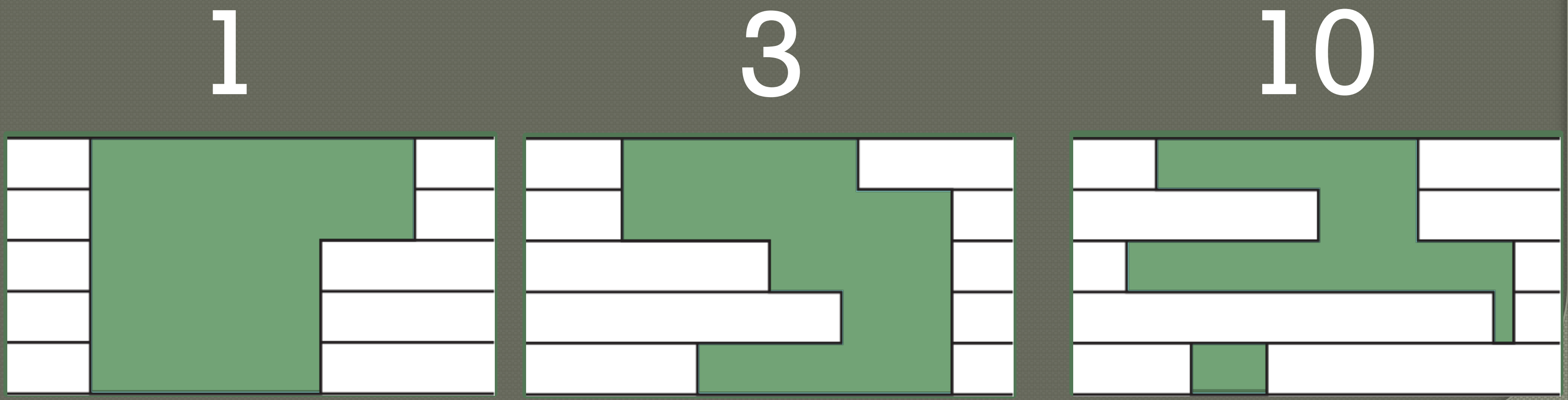
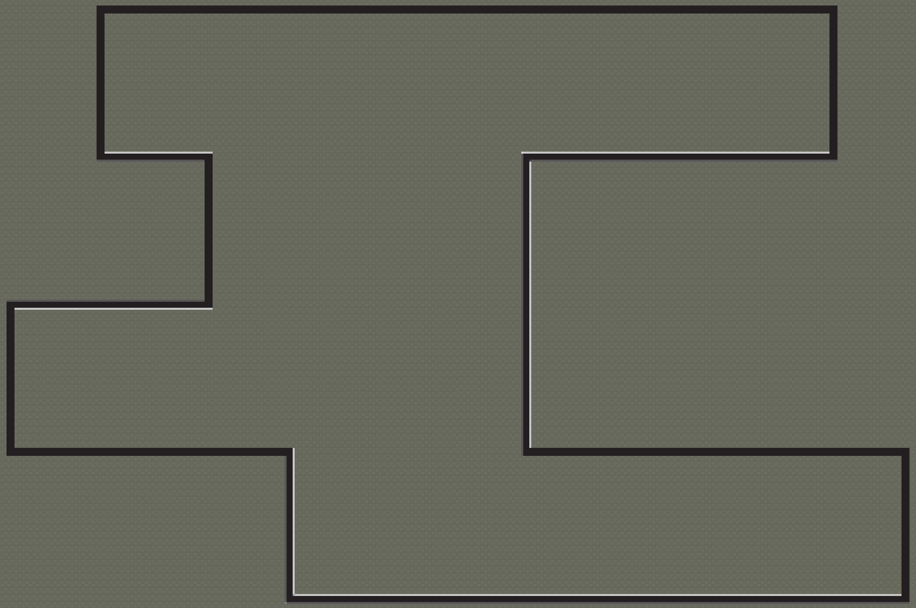


Research Goals:

- Generate high quality, dosimetrically accurate VMAT plans - make it automatic
- Aperture-based feedback during optimization
- Develop a metric that quantifies aperture complexity
- Penalize complexity during optimization

Methods: The Edge Metric

$$M = \sum_{i=1}^{N} W_i \frac{C_1 x_i + C_2 y_i}{Area}$$



- Quantify the amount of "edge"
- General form can be tailored to any algorithm
- Penalty = Metric times a weighting factor
- Add to dose related cost function with appropriate weight

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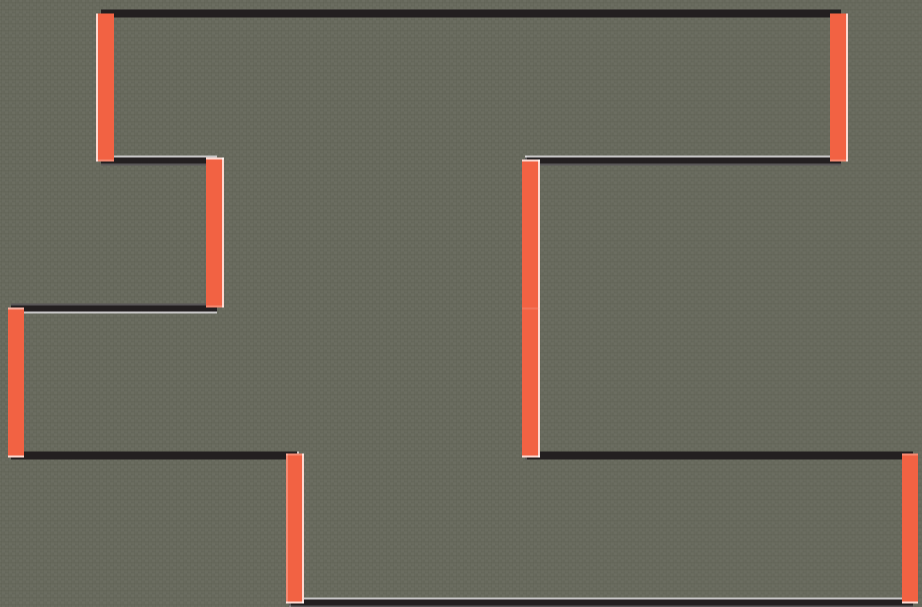

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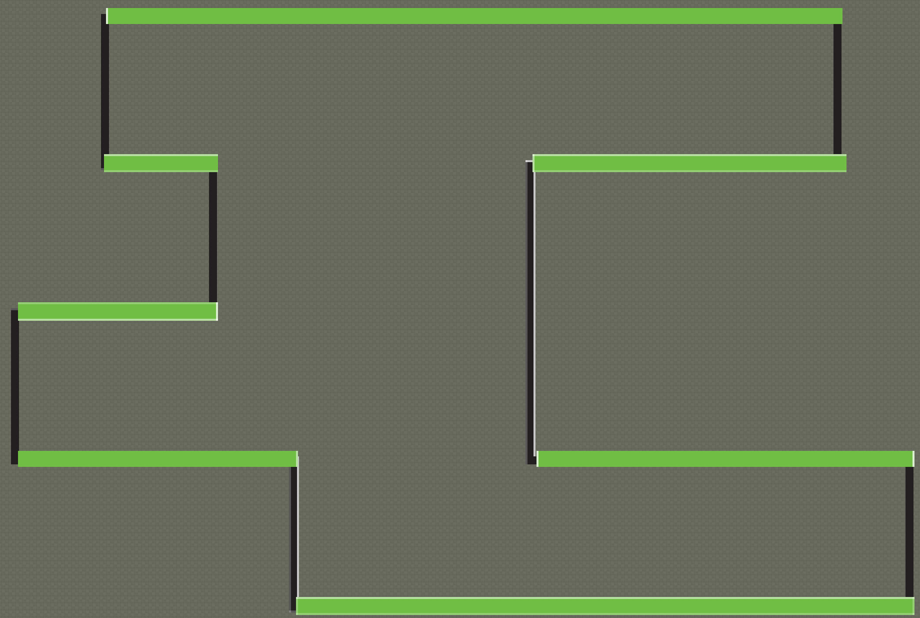

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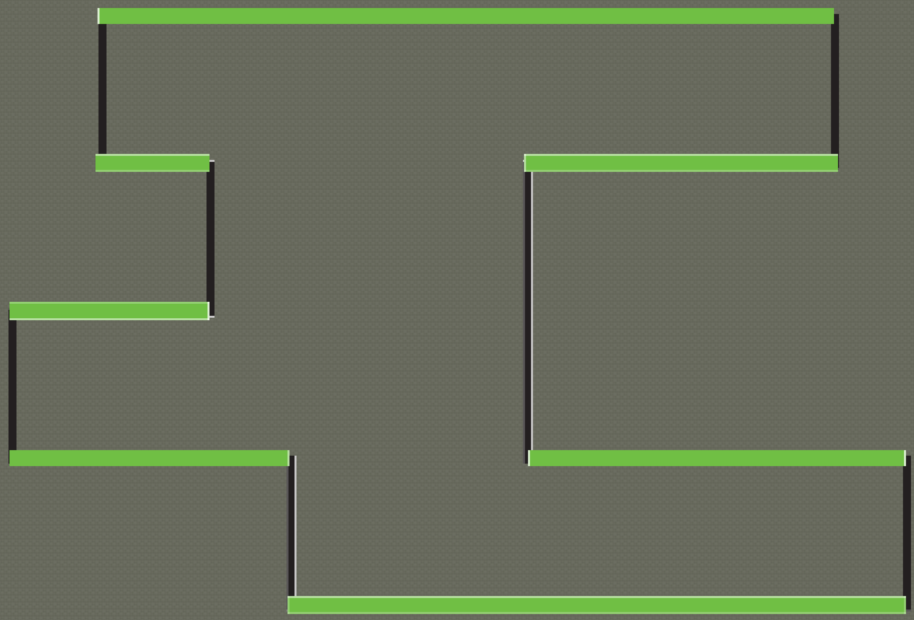

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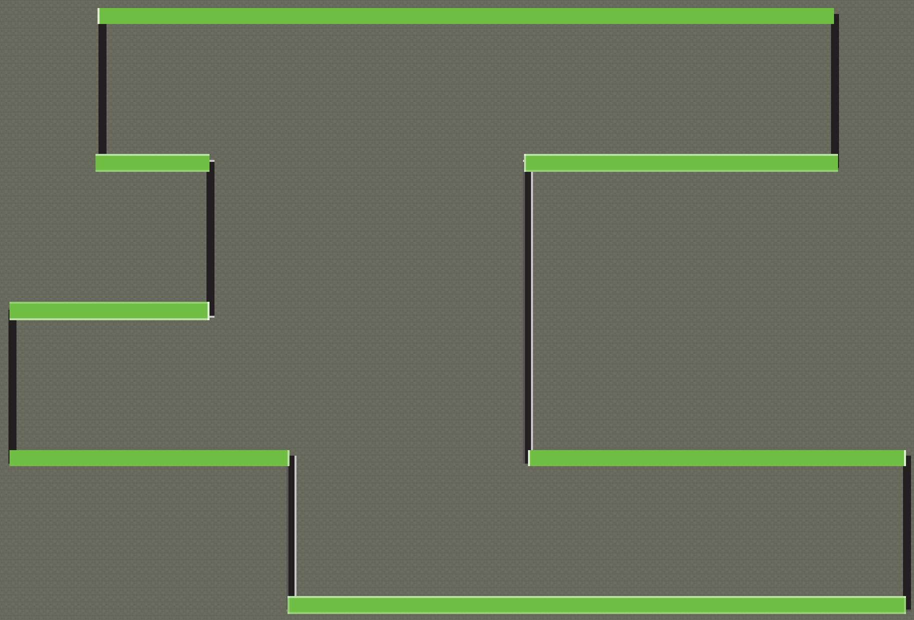
Methods: The Edge Metric

$$P = C \sum_{i=1}^{N} W_i \frac{y_i}{Area}$$



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Methods: Treatment planning and evaluation

- One paraspinal, one liver, and one brain case
  - Optimization cost functions designed based on original clinical planning goals
  - Edge penalty added during optimization at varying weights
  - UMPlan, Edge/Octree algorithm, 1mm grid size
- Evaluate aperture shapes, isodose lines, DVH curves, various metrics (mean/max dose, etc)

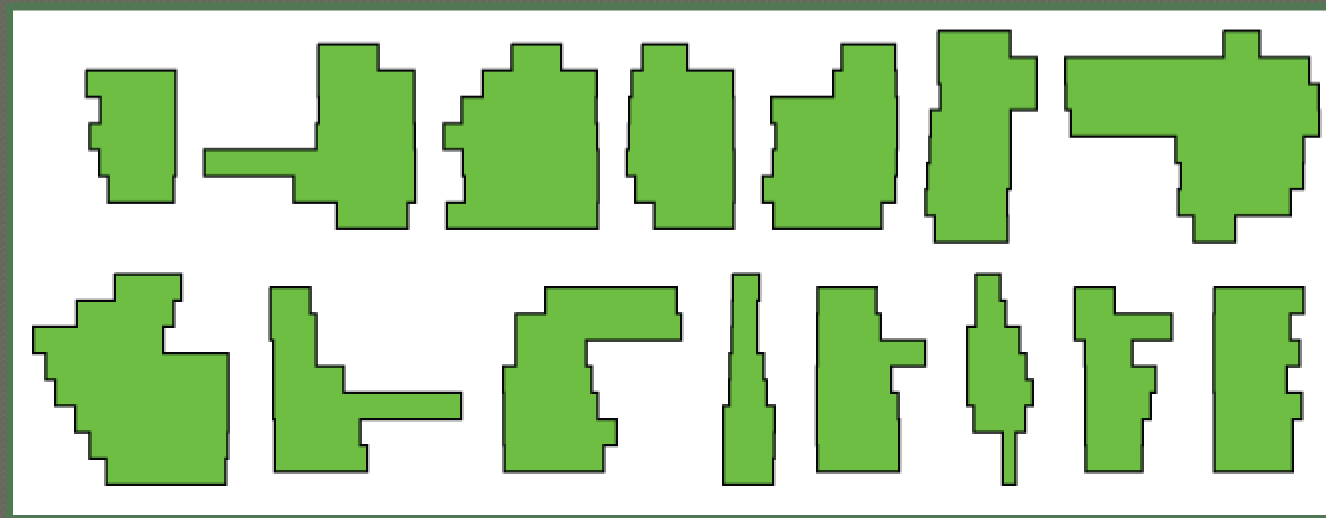
Methods: Dosimetry

- Two paraspinal plans: without and with penalty
  - 15 apertures from each plan, individual and composite
  - Solid water phantom
  - Scanned 96dpi without color correction
  - Triple-channel non-uniformity correction and image registration in Matlab
- Comparison Methods
  - Analyzed pixel by pixel for pixels with at least 10% of maximum dose
  - Gradient compensation for composites
  - Scored based on % of pixels with deviation > threshold

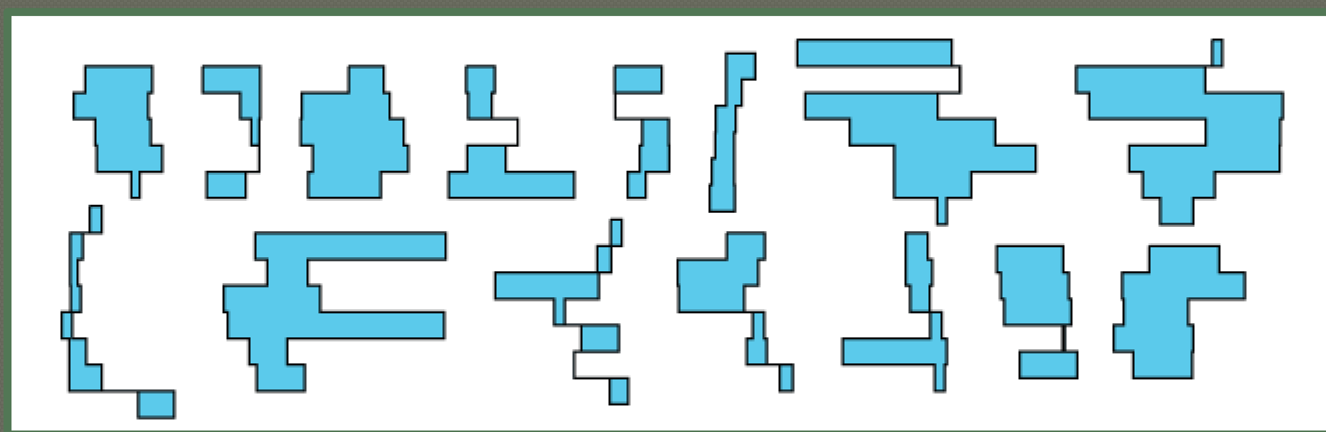
Micke et al., *Med. Phys*. 2011

Results: Paraspinal aperture design

With edge penalty (3.1%)

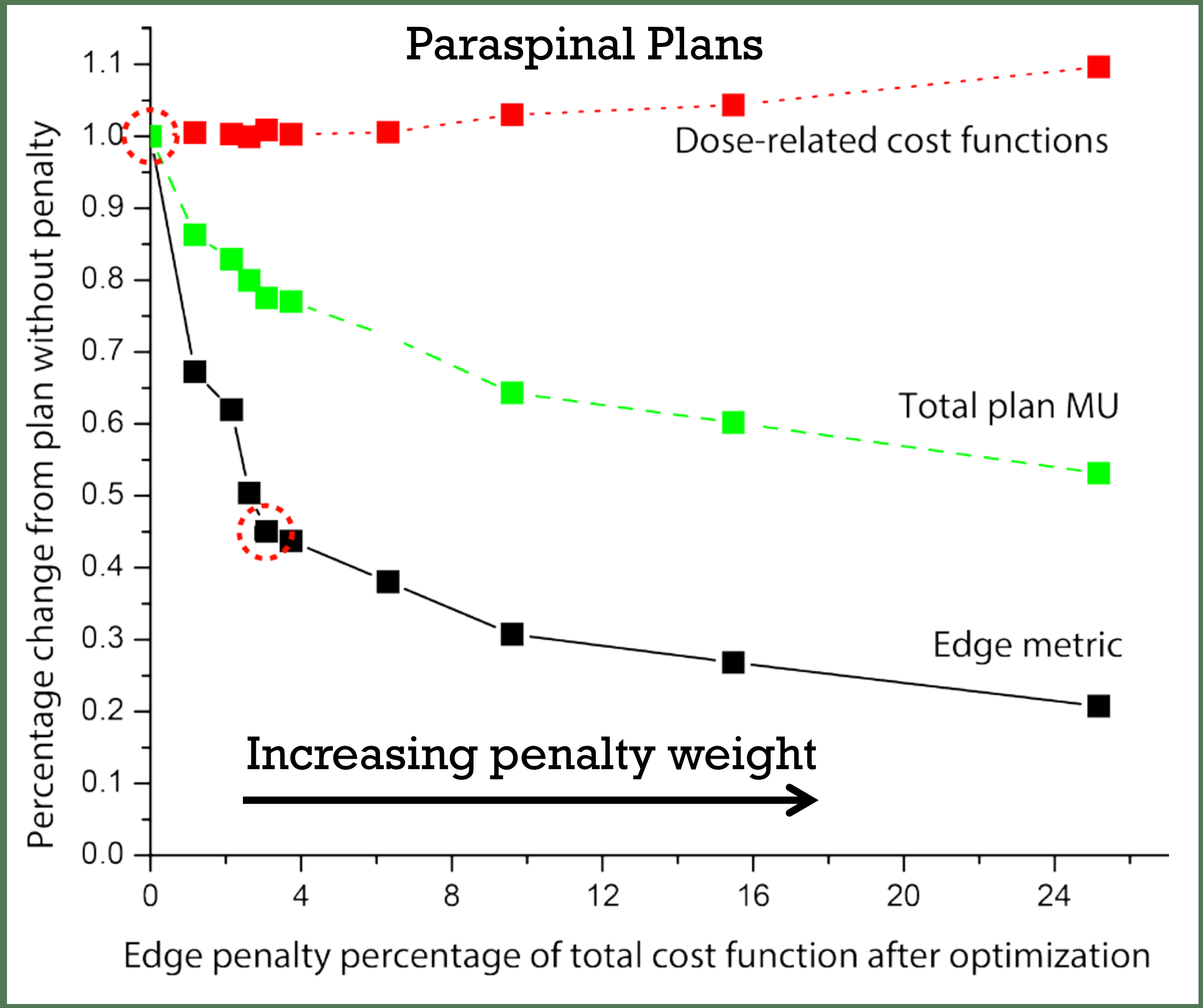


Without edge penalty



5 cm

Results: Edge metric and plan quality



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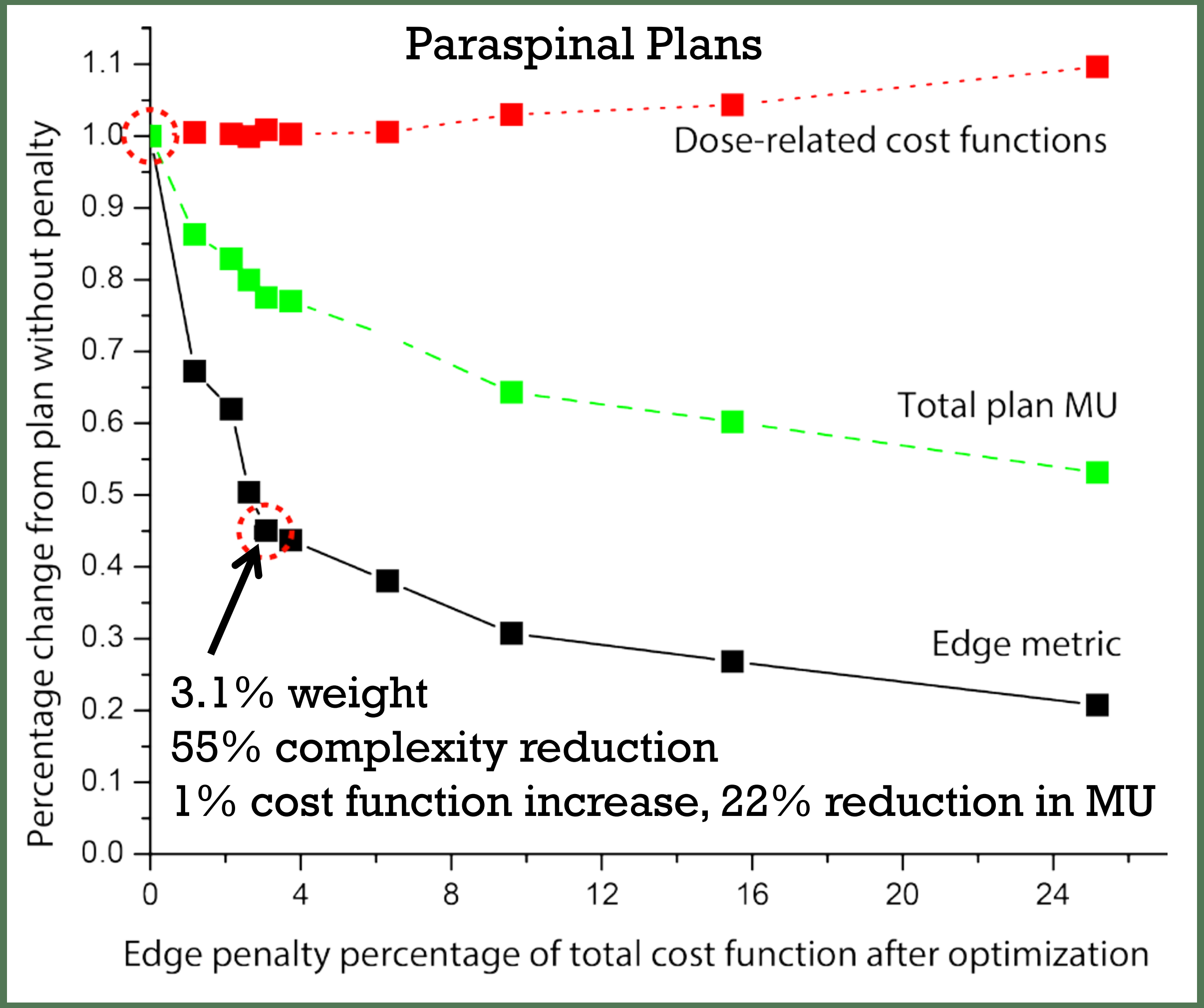
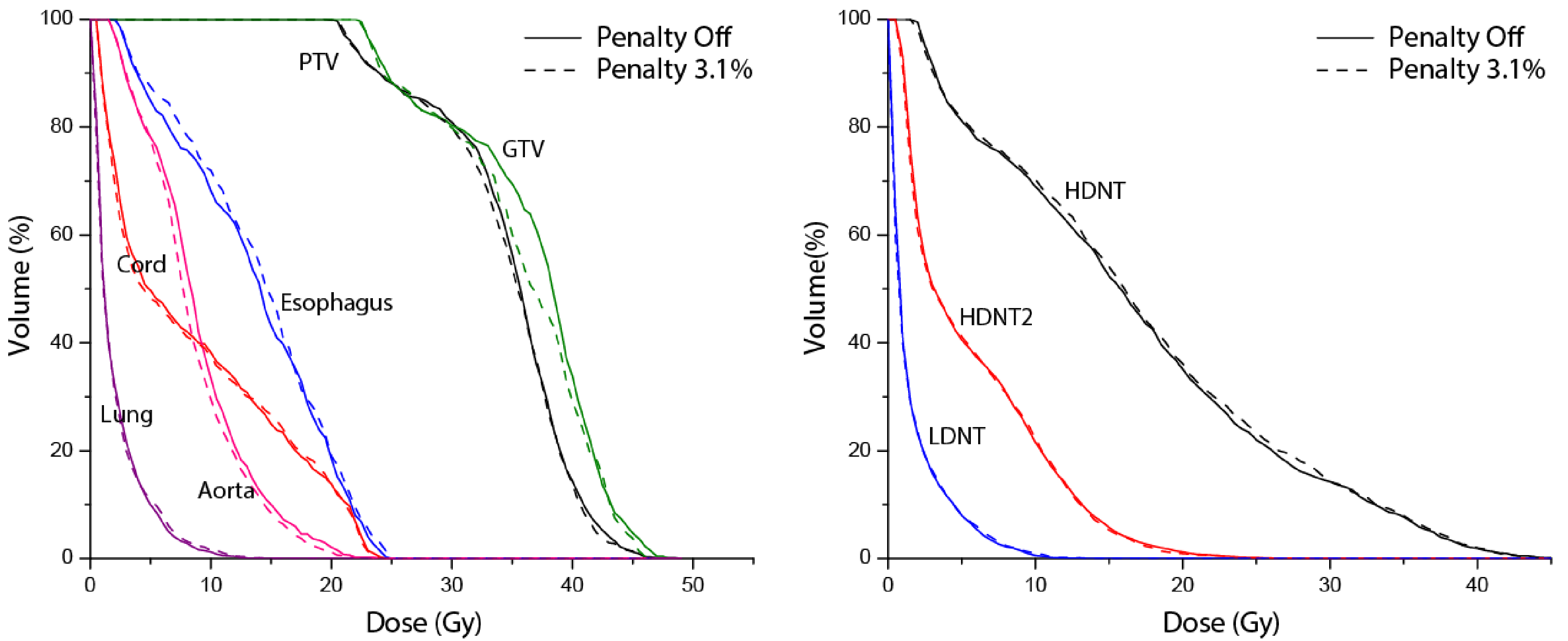
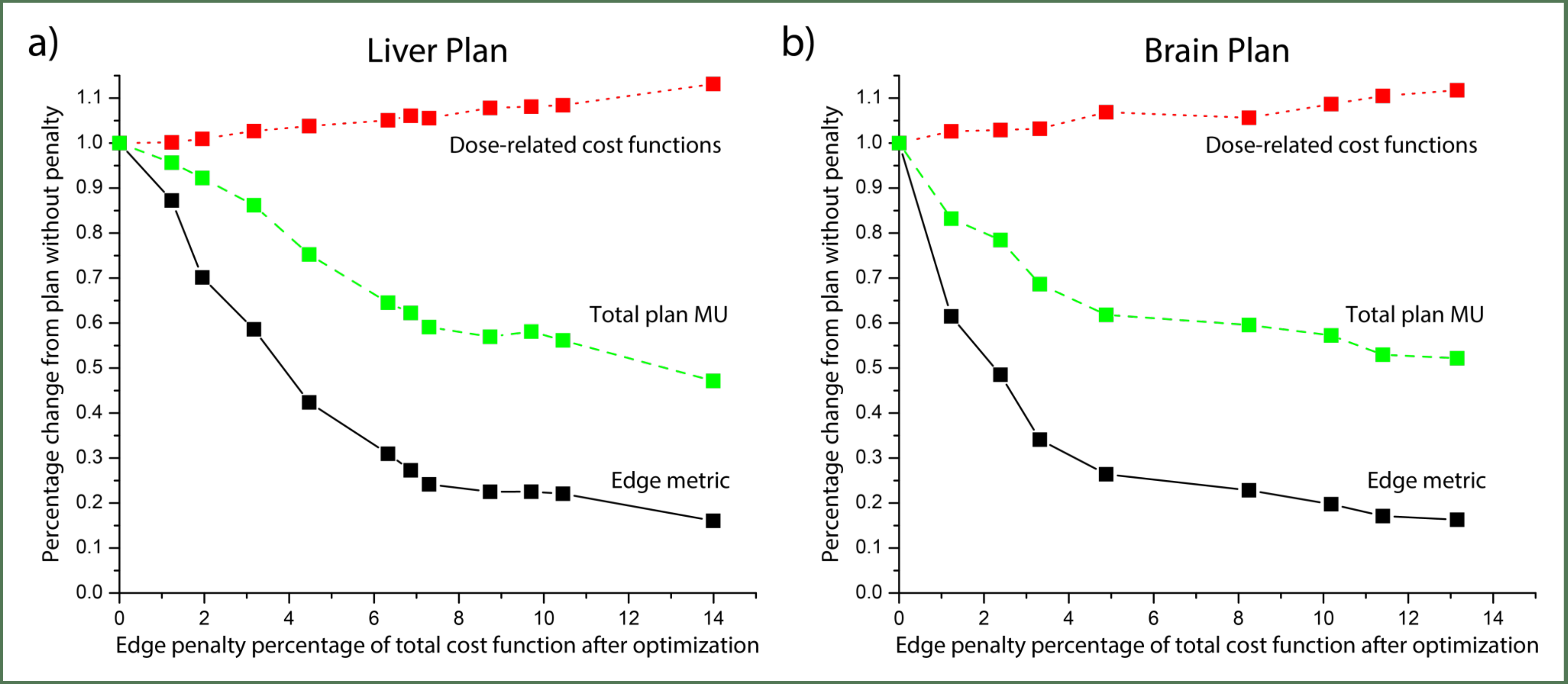


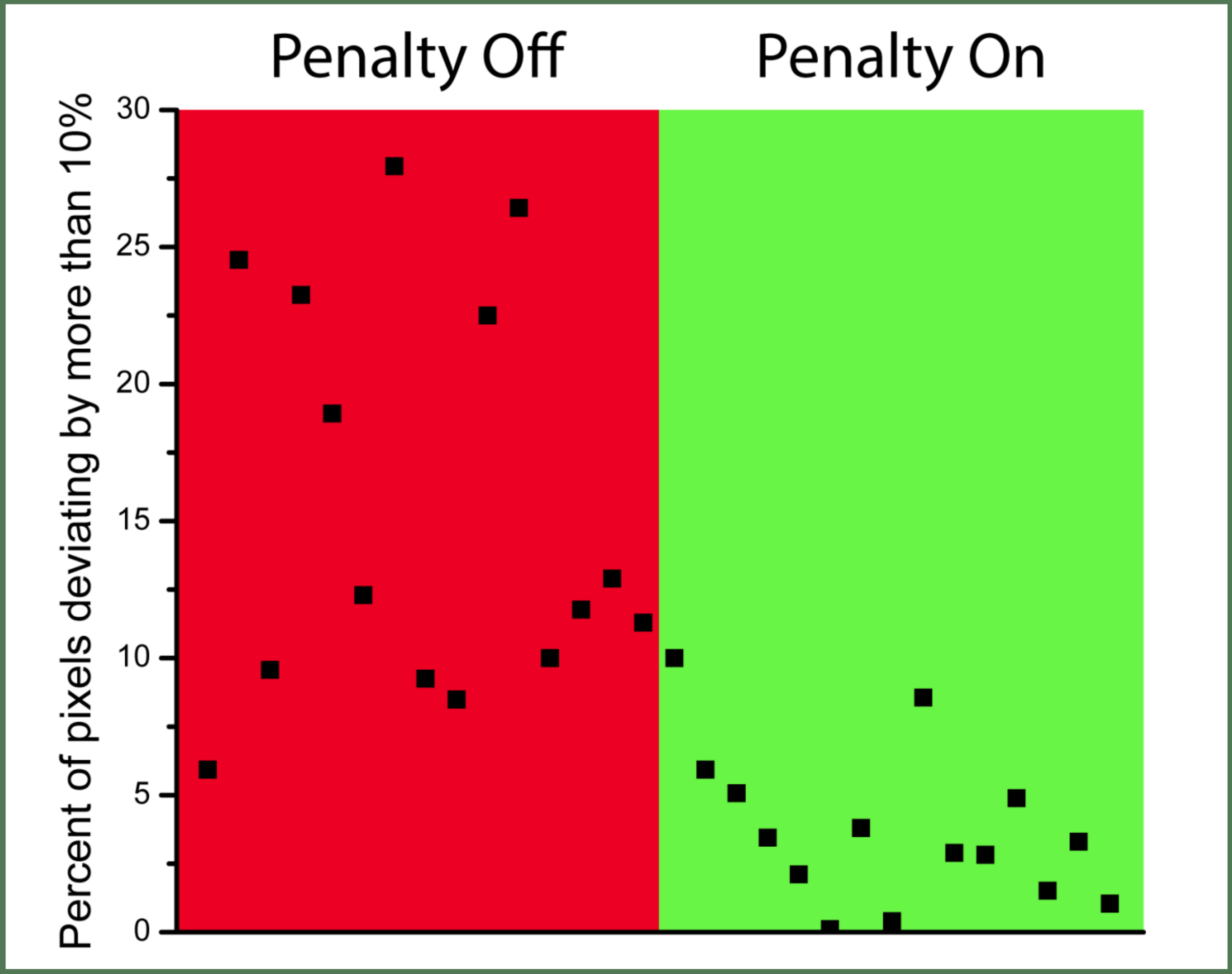
Results: Plan DVH's



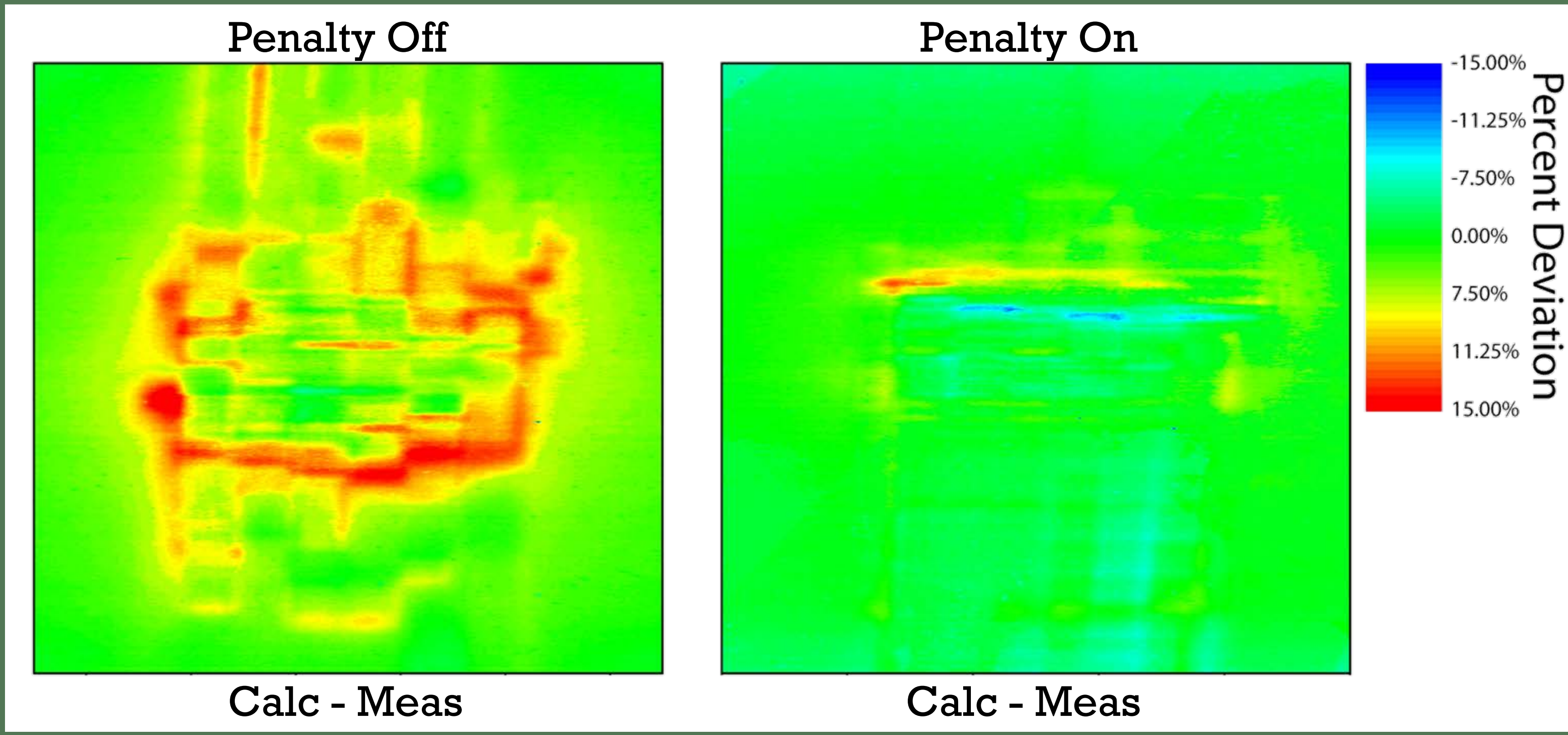
Results: Liver and Brain



Results: Individual aperture dosimetric accuracy



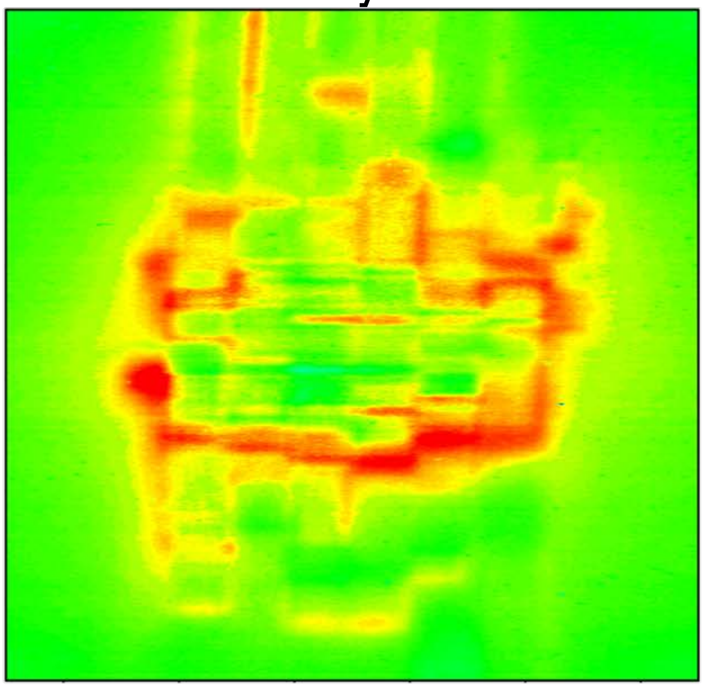
Results: Composite dosimetric accuracy



Moran et al. JACMP, 6(2) 2005

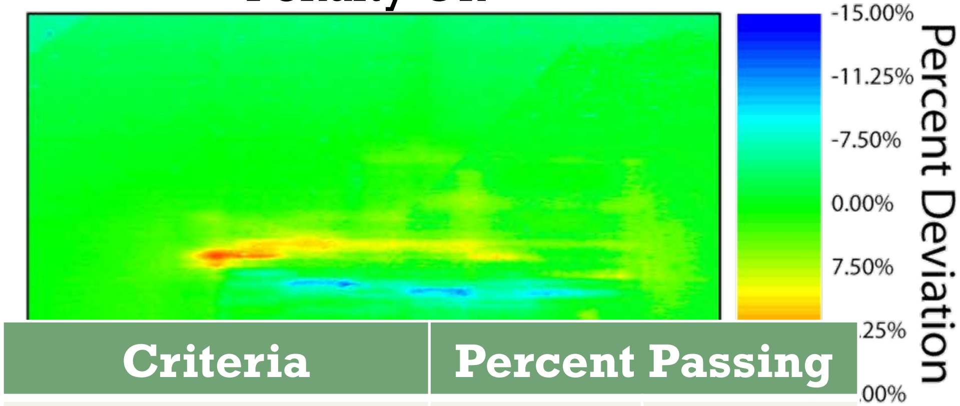
Results: Composite dosimetric accuracy

Penalty Off



Calc - Meas

Penalty On



Criteria	Percent Passing	
	Penalty Off	Penalty On
5% threshold	52%	96%
3%/1mm gamma	79.5%	95.4%
3%/1mm gradient comp*	83.3%	96.2%

Moran et al. JACMP, 6(2) 2005

Conclusions and Future Work

- Edge penalty is easy to implement and can dramatically improve dosimetric accuracy
- Minimal affect on optimized dose distributions
- Can tailor to dose calculation algorithm/planning system
- Works for a variety of treatment sites – try for other geometries

Acknowledgements - Thanks

- GLC-AAPM
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- Jean Moran
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