Bringing Automation to Proton Clinics

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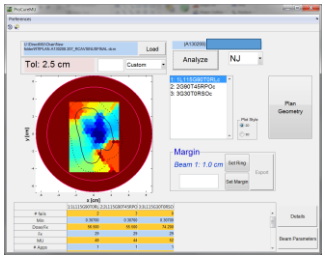
Overview

- Proton plan checks
  - Passive: MU, compensator and other checks
  - PBS: robustness, max/min MU/spot, range shifter consistency, layer/volume repainting
- Automated collision detection
  - Gantry model
  - Auto correction on snout extension
  - Challenges
- PBS Commissioning
- Some new developments

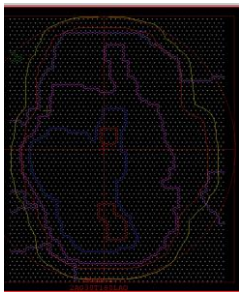
MU, App/Comp Check

- Ensure compensators meet clinical protocols, e.g. ridge height
- Review aperture boundary within snout opening
- Ensure manufacturability by checking min and max height
- Avoid "islands" that might break off
- Center-specific beam data
- Calculate MU!

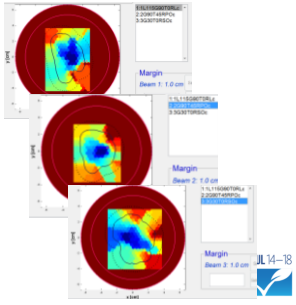


Compensator Visualization

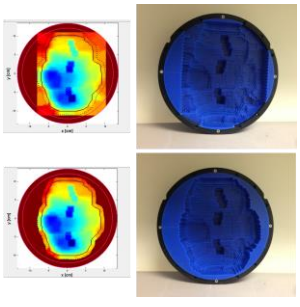
XiO TPS



ProCureMU



Compensator Fabrication



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Additional plan check items

- Field name reflects geometry, i.e. G330T90SAO
- Max and Min MU/Spot for PBS
- Beam/couch angle within the useable range
- Range Shifter is identical for all beams
- Dose grid less than 3mm

- (Limited to plan DICOM files only)

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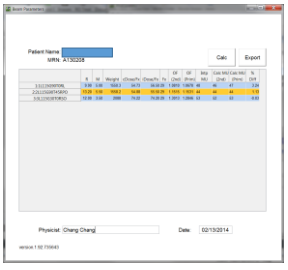
MU determination

- XiO allows user to specify a scaling factor "Weight"
- Dose to water phantom is obtained either from a QA plan, or by calculating the Track File Factor
- Output factor is measured at commissioning, relative to the calibration condition, R16/M10 for ProCure
- Depth dependent Field Size Factor is measured at commissioing
- $MU = \frac{Weight \times TFF}{OF \times FSF}$
- Measurement is only needed for small fields, esp if off-axis



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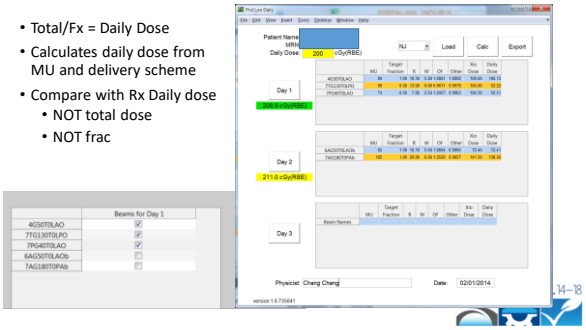
MU Second Check

- Total/Fx = Daily Dose
- Calculates daily dose from MU and delivery scheme
- Compare with Rx Daily dose
  - NOT total dose
  - NOT frac



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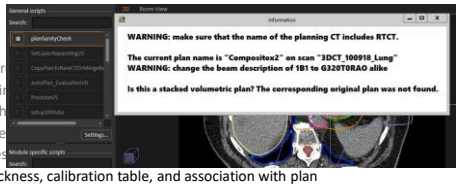
Additional plan check items



- Field name r
- Max and Mi
- Beam/couch
- Range Shifte
- Dose grid les
- CT: slice thickness, calibration table, and association with plan
- Range shifter is appropriate given field WET
- Treatment table is present or not with posterior beams
- Dose grid extent encompasses target, OAR and beam
- Dose calculation engine (Monte Carlo or Analytic)
- Layer repainting is properly set for lung and liver cases
- Specific contours exist for each treatment site
- Air gap is reasonable

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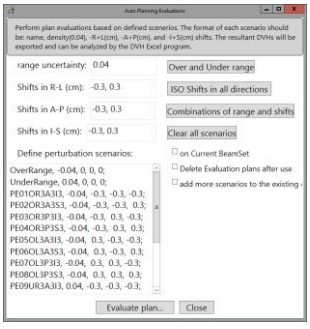
Automated plan robustness



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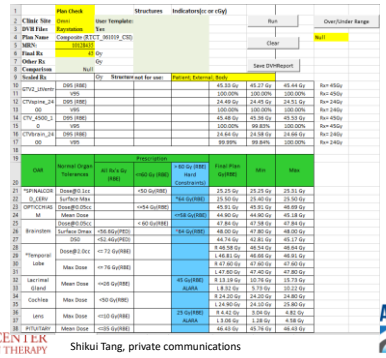
Auto robustness evaluation



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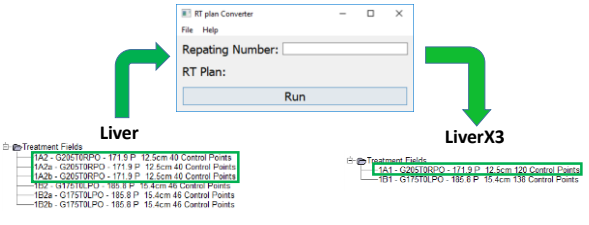
Stacked volumetric repainting

- Plan with $r \times N$ fractions (r is the # of volume repainting, N is the actual # of fractions)
- Deliver each fields r times each day
  - Standard workflow
  - Tedious and time consuming to send each field r times



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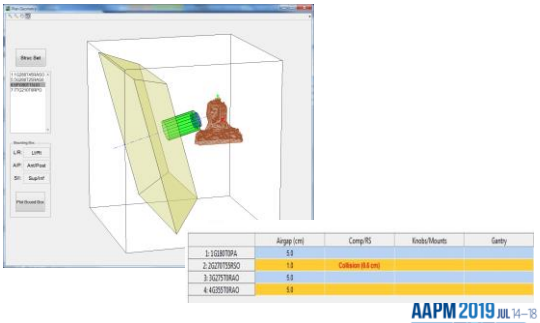
Auto collision detection



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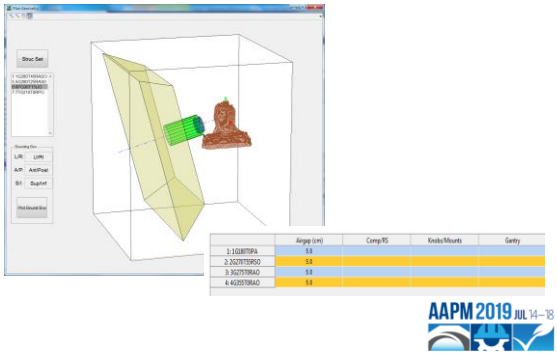
Collision averted



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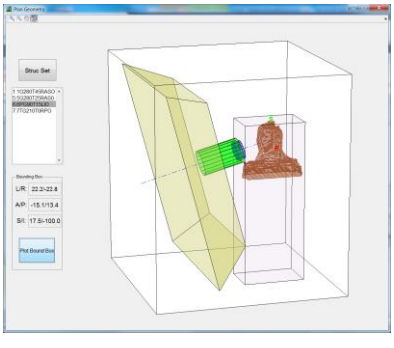
Collision prevention



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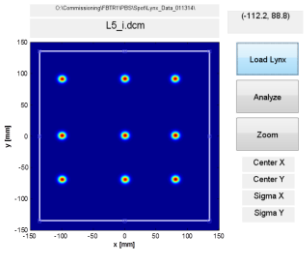
PBS Spot Size and Location

- Measurements
  - ISO, ISO+15cm, ISO-15cm
  - 18 energies
- Spot divergence
  - $\sigma_{x,y}(z)$
  - Potentially $\sigma_{x,y,\theta}(x,y,z)$
- SAD/Spot location
  - $\mu_{x,y}(z)$



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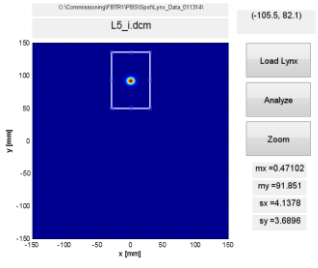
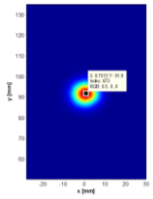
PBS spot size/location analysis





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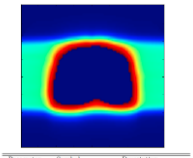
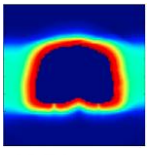
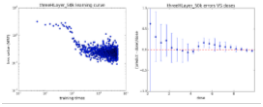
ML prostate plan





Parameter	Symbol	Description
1	V_{CTV}	CTV volume (mm^3)
2	r_{CTV}	Distance from CTV (mm)
3	$r_{Bladder}$	Distance from bladder
4	r_{FemurL}	Distance from left femur
5	r_{FemurR}	Distance from right femur
6	$r_{Sigmoid}$	Distance from sigmoid
7	r_{Rectum}	Distance from rectum
8	ϕ	Azimuthal angle (isocenter)
9	θ	Elevation angle (isocenter)



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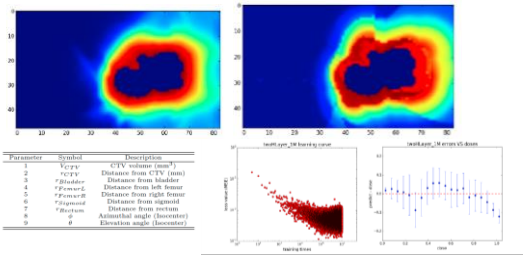
ML brain plan



Parameter	Symbol	Description
1	V_{CTV}	CTV volume (mm^3)
2	r_{CTV}	Distance from CTV (mm)
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5	$r_{Femur-R}$	Distance from right femur
6	$r_{Sigmoid}$	Distance from sigmoid
7	r_{Rectum}	Distance from rectum
8	θ	Azimuthal angle (locentor)
9	θ	Elevation angle (locentor)

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Thank you!

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