Modulated arc therapy for TBI

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Objectives

- Describe the two widely used TBI delivery techniques
- Describe how MLCs in an arcing gantry may be used to create a uniform craniocaudal profile for TBI

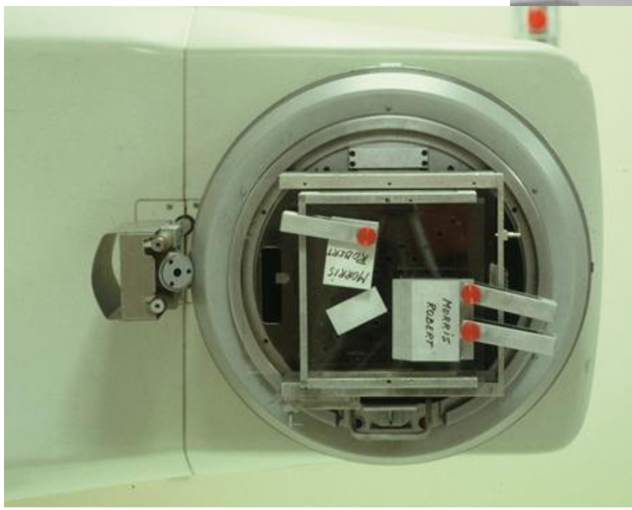
Modified Standing Technique

Concerns

- Patient fatigue
- Incompatible with pediatric cases that require anesthesia support
- Requires large vault

Photo credit: Khan, F *The Physics of Radiation Therapy, 4th ed.*

Bilateral Technique

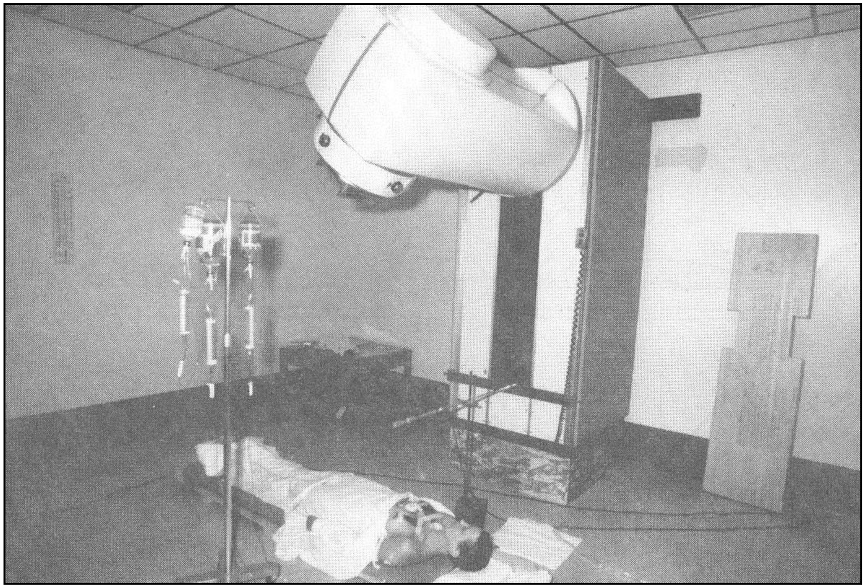


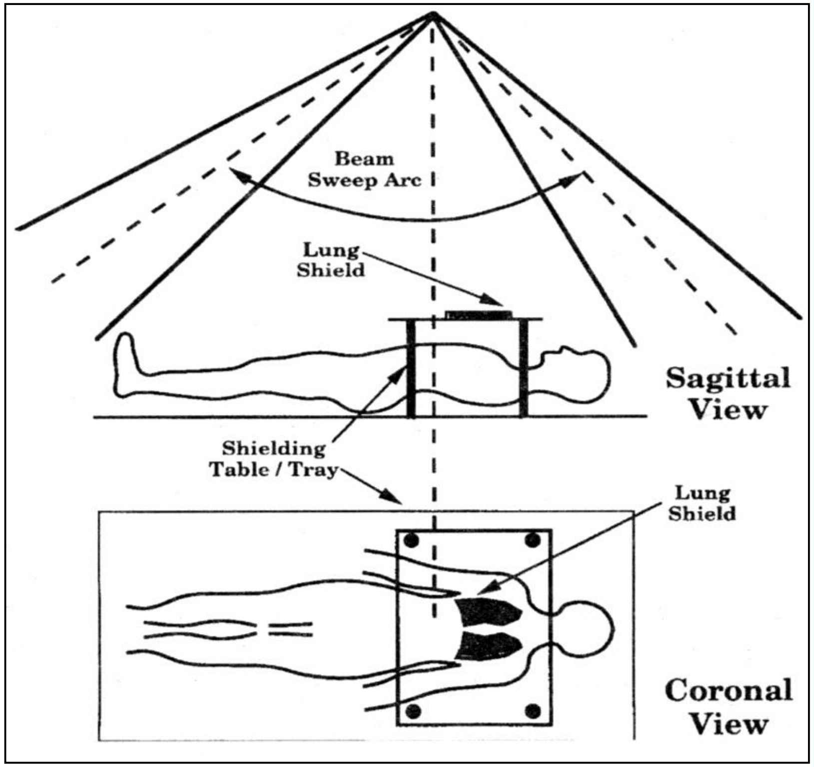
Concerns

- Dose homogeneity
- Requires large vault

Photo credit: Khan, F *The Physics of Radiation Therapy, 4th ed.*

“Sweeping Beam” Technique



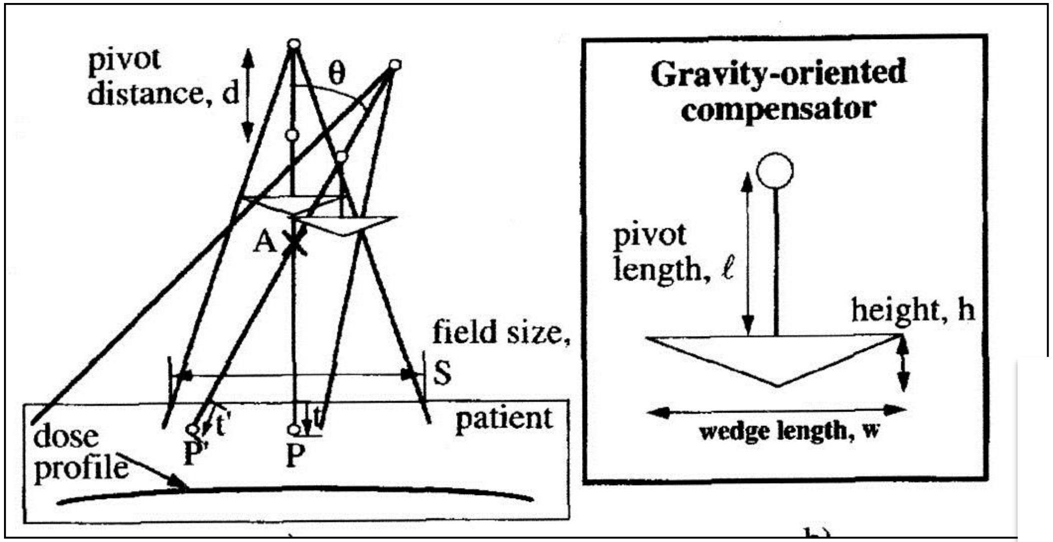


Concerns

- Dose homogeneity
    - Patient thickness
    - $1/r^2$ effect

Photo credits: Van Dyk, J. (ed) *The Modern Technology of Radiation Oncology*, Medical Physics Publishing, 1999, p646-7

Gravity-oriented compensator



Changing What's Possible

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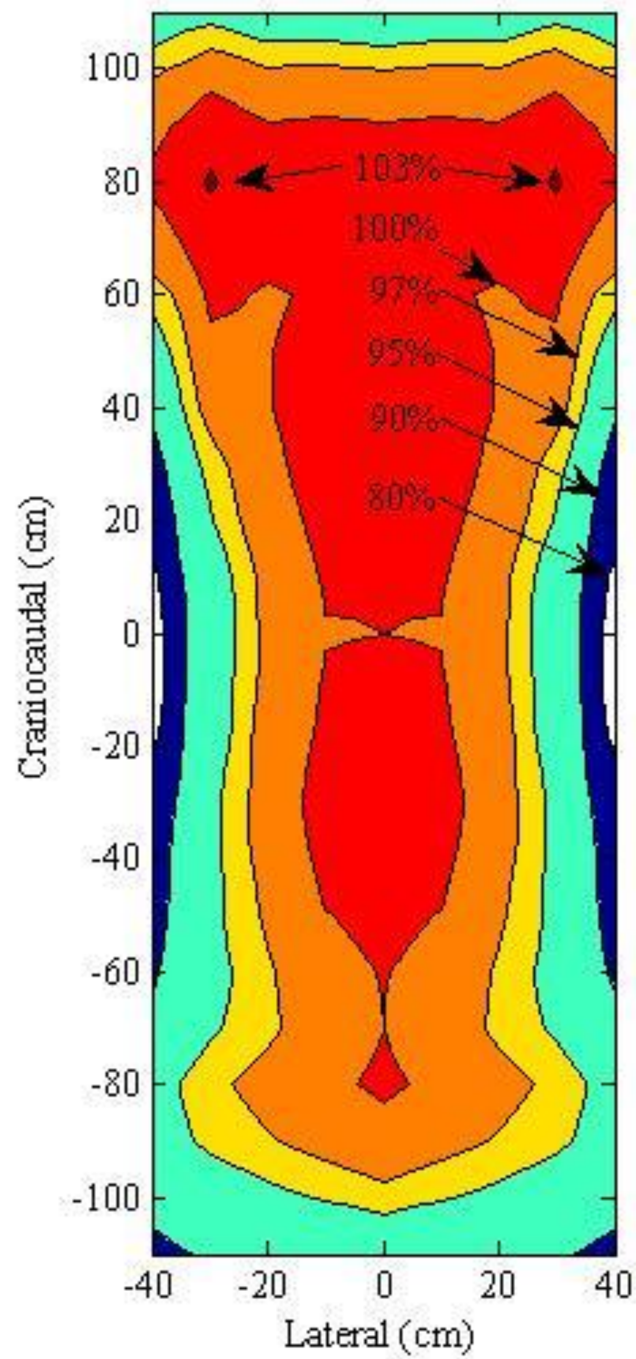
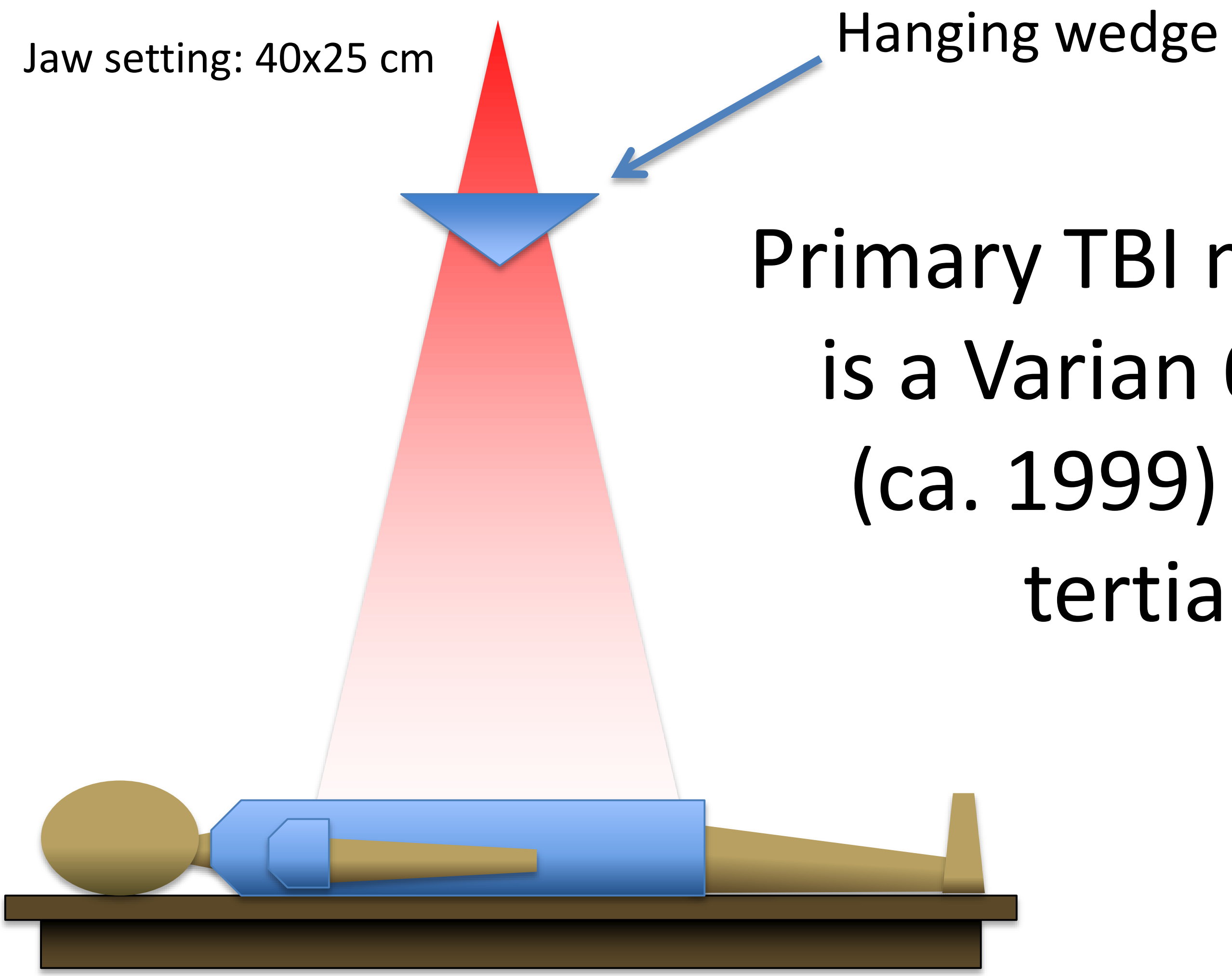
Schematic diagram from Chui, CS et al. *Total Body Irradiation with an arc and a gravity-oriented compensator*, IJROBP, 39(5) 1997, pp1191-5

Effective treatment area of TBI field

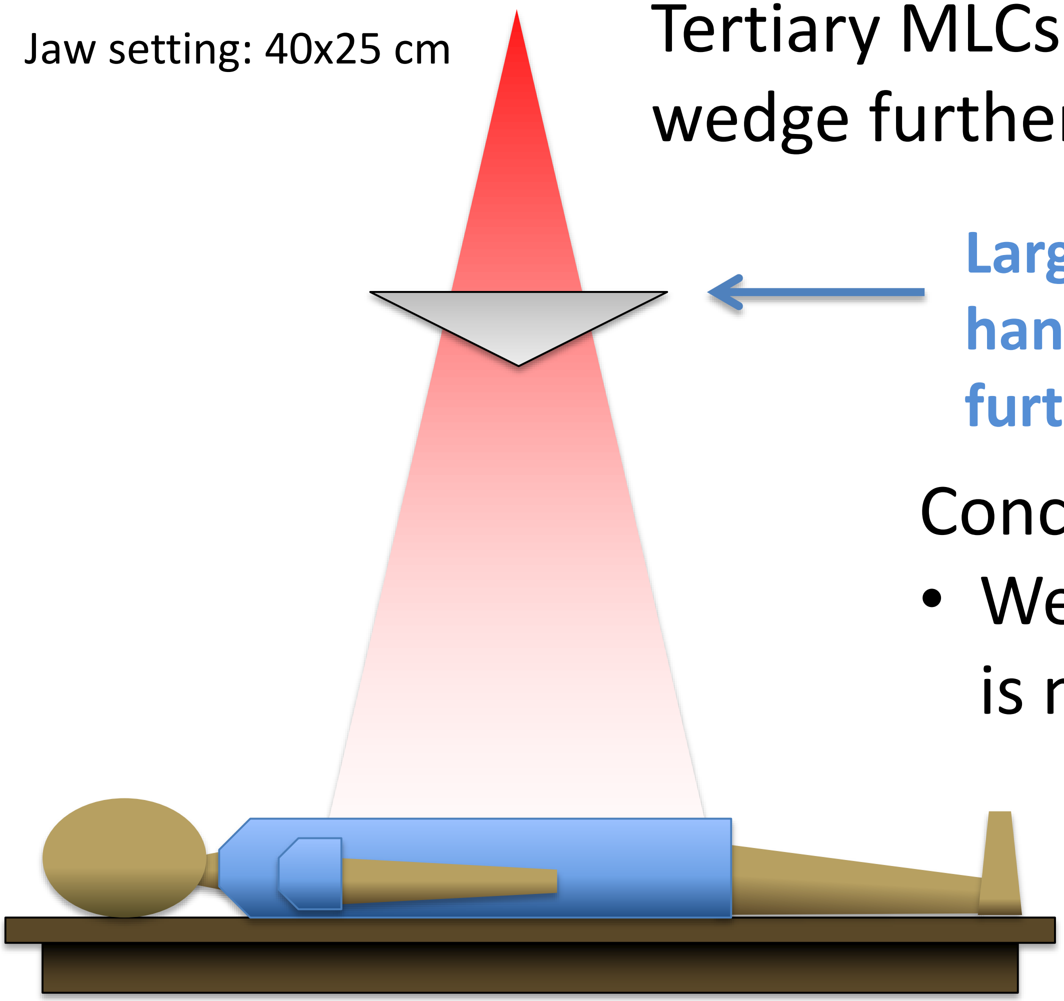




Primary TBI machine is a Varian 600 C/D (ca. 1999) with no tertiary MLCs

Tertiary MLCs move hanging wedge further from source.

Jaw setting: 40x25 cm



Larger (heavier) hanging wedge located further from source

Concern:

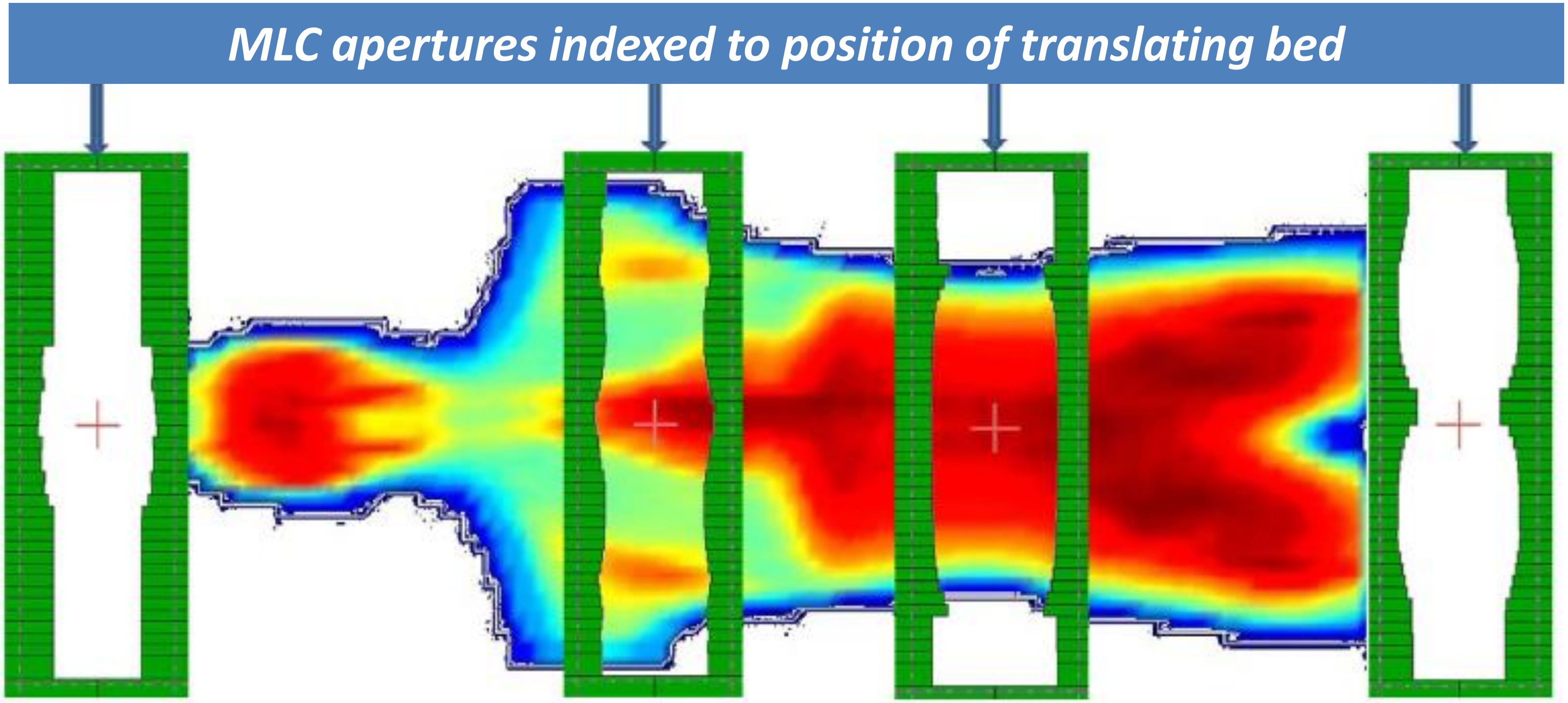
- Weight of wedge is now 35 lbs.

How can our sweeping-gantry technique be used on a machine with tertiary MLCs?

Reduce the field size...

.... Unacceptable.

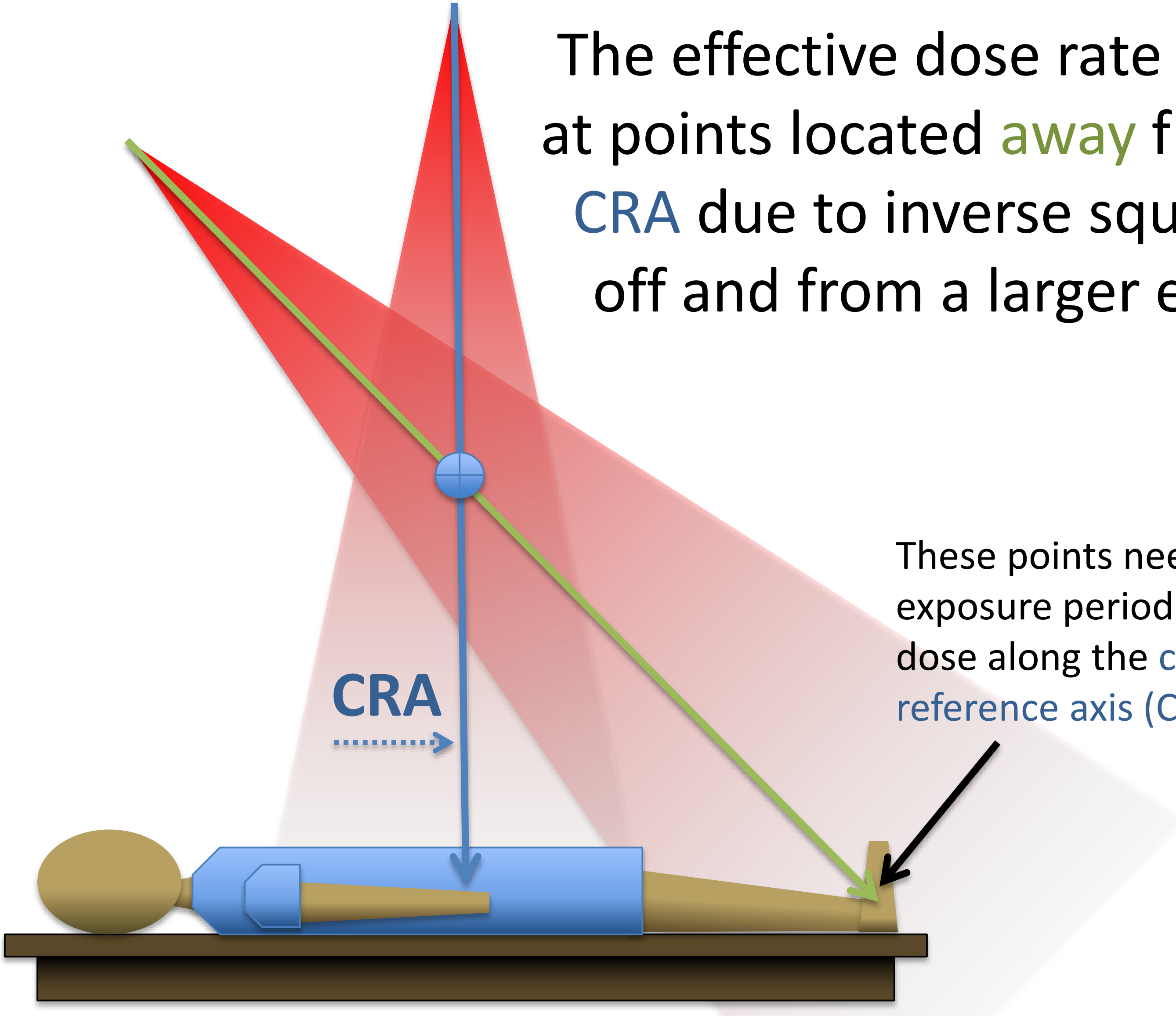
Intensity modulated TBI with MLCs



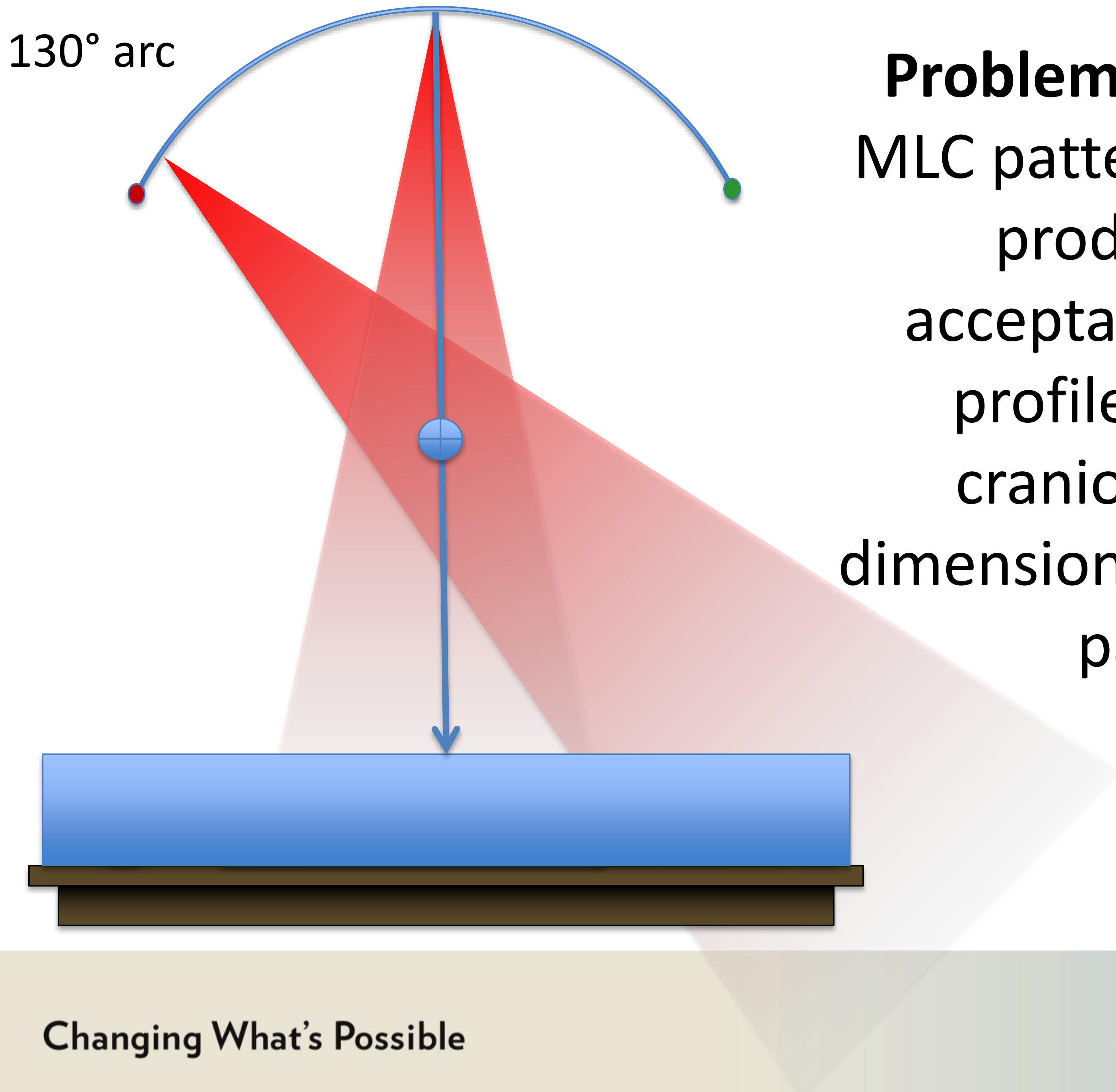
Whole body CT → Optimize dose via field width parameter → Import MLCs into TPS → Calculate dose on CT

Figure 3 from Hussain A., et al *Total body irradiation dose optimization based on radiological depth* , J Appl Clin Med Phys, 13(3), 2012

The effective dose rate is lower at points located away from the CRA due to inverse square fall-off and from a larger effective depth.

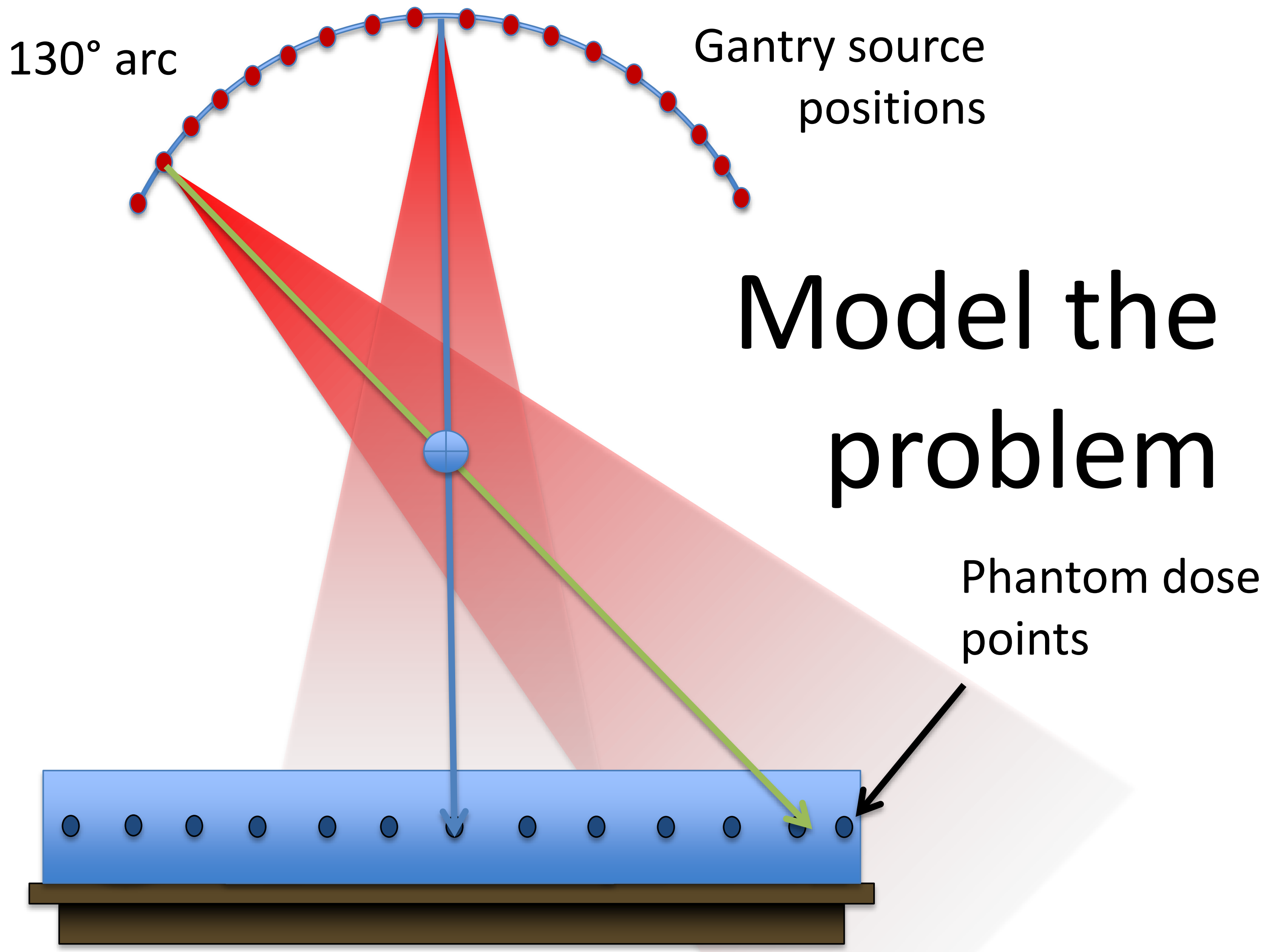


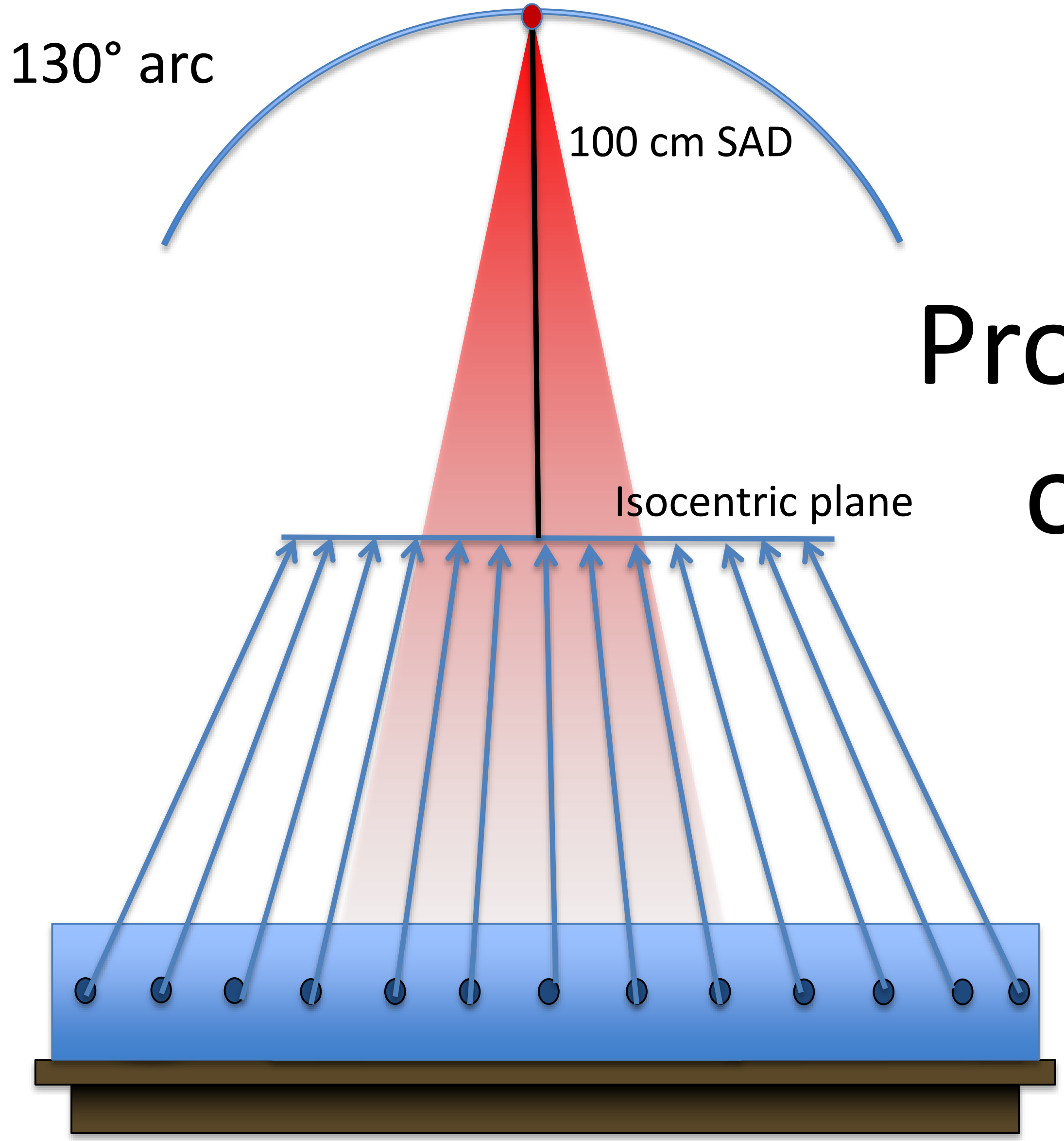
These points need a longer exposure period to match the dose along the central reference axis (CRA).



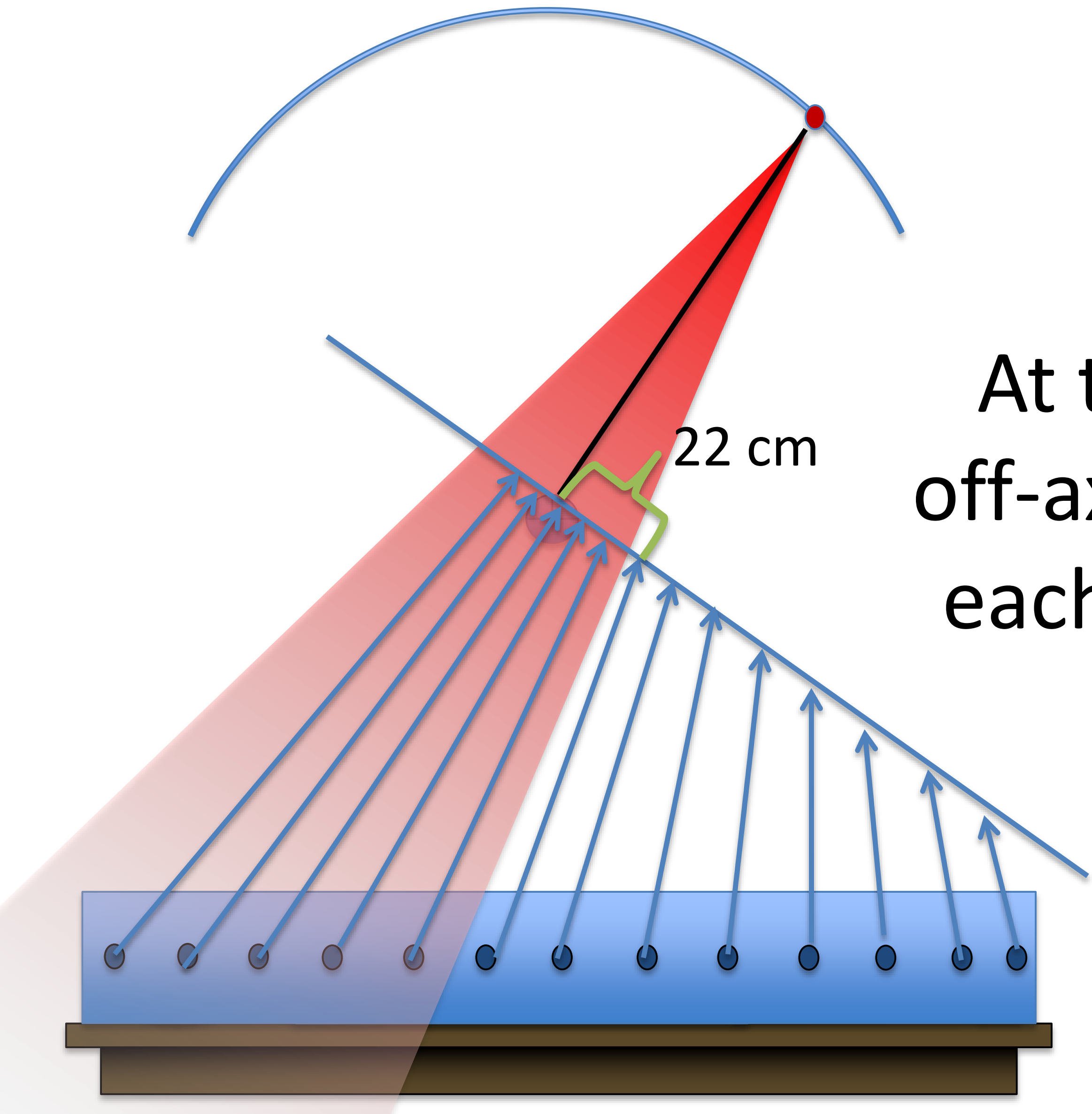
Problem: What MLC pattern will produce an acceptably flat profile in the craniocaudal dimension of the patient?

Model the problem

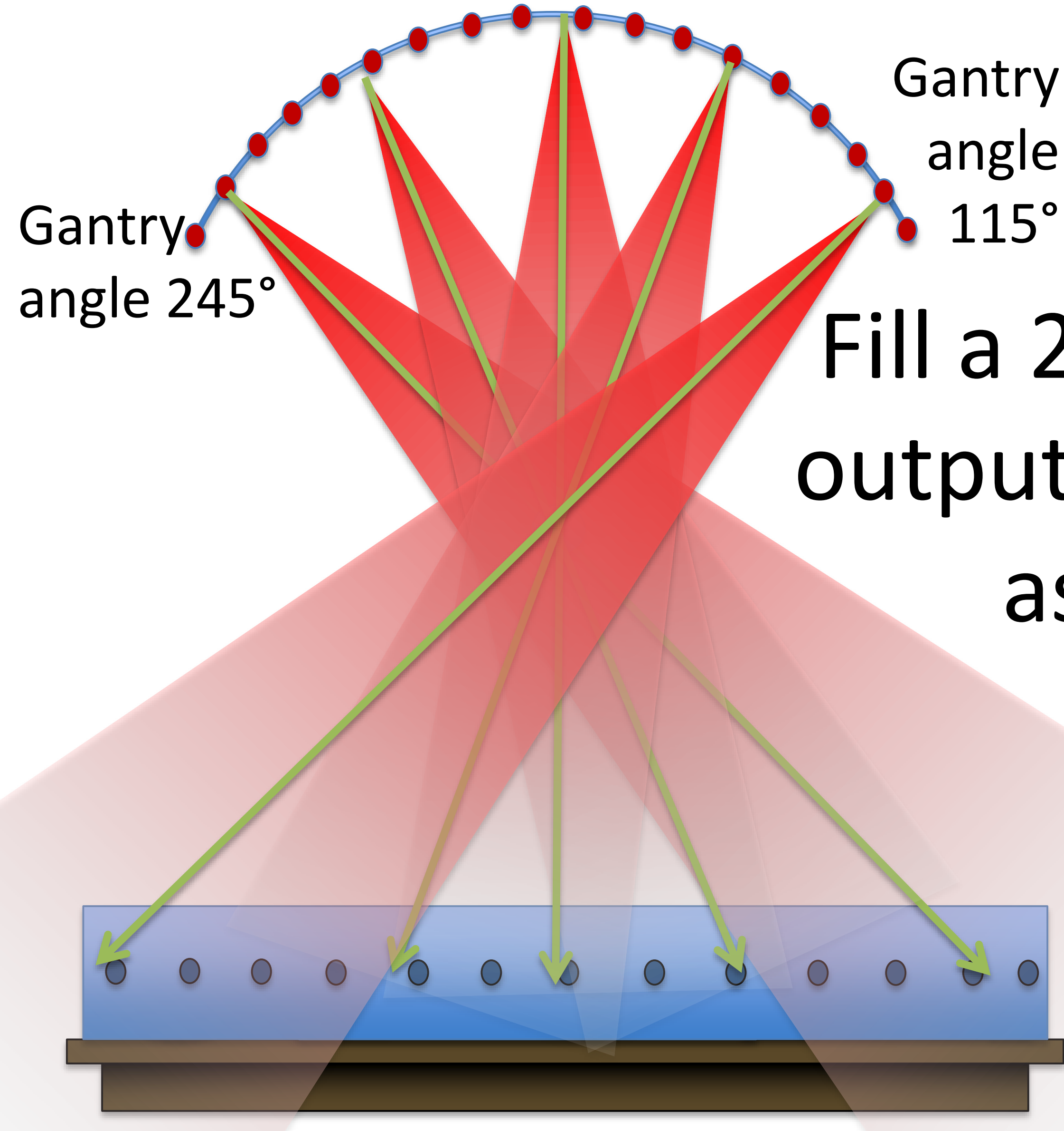




Project a relative output at each dose point

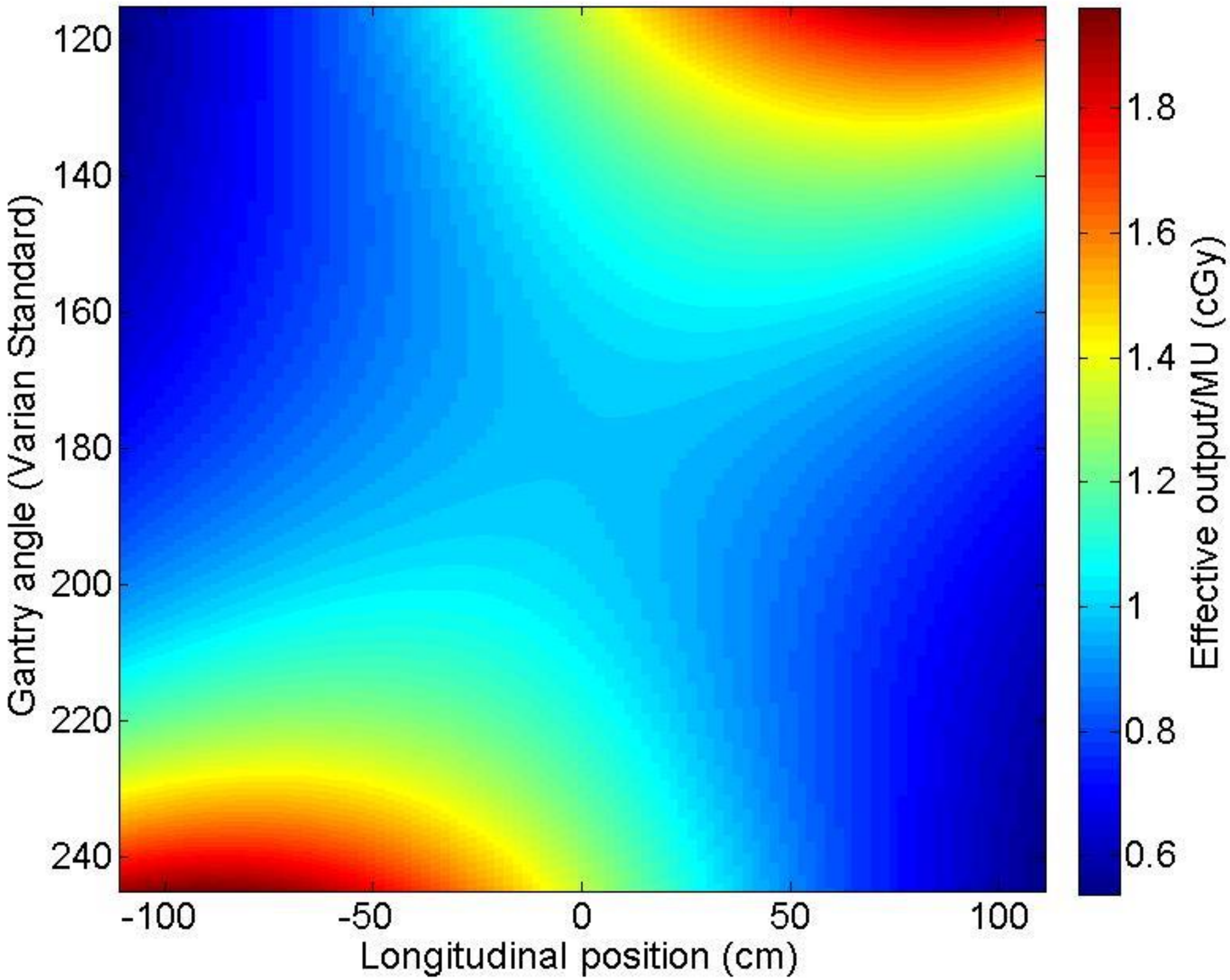


At this plane, the off-axis distance of each dose point is easily known.



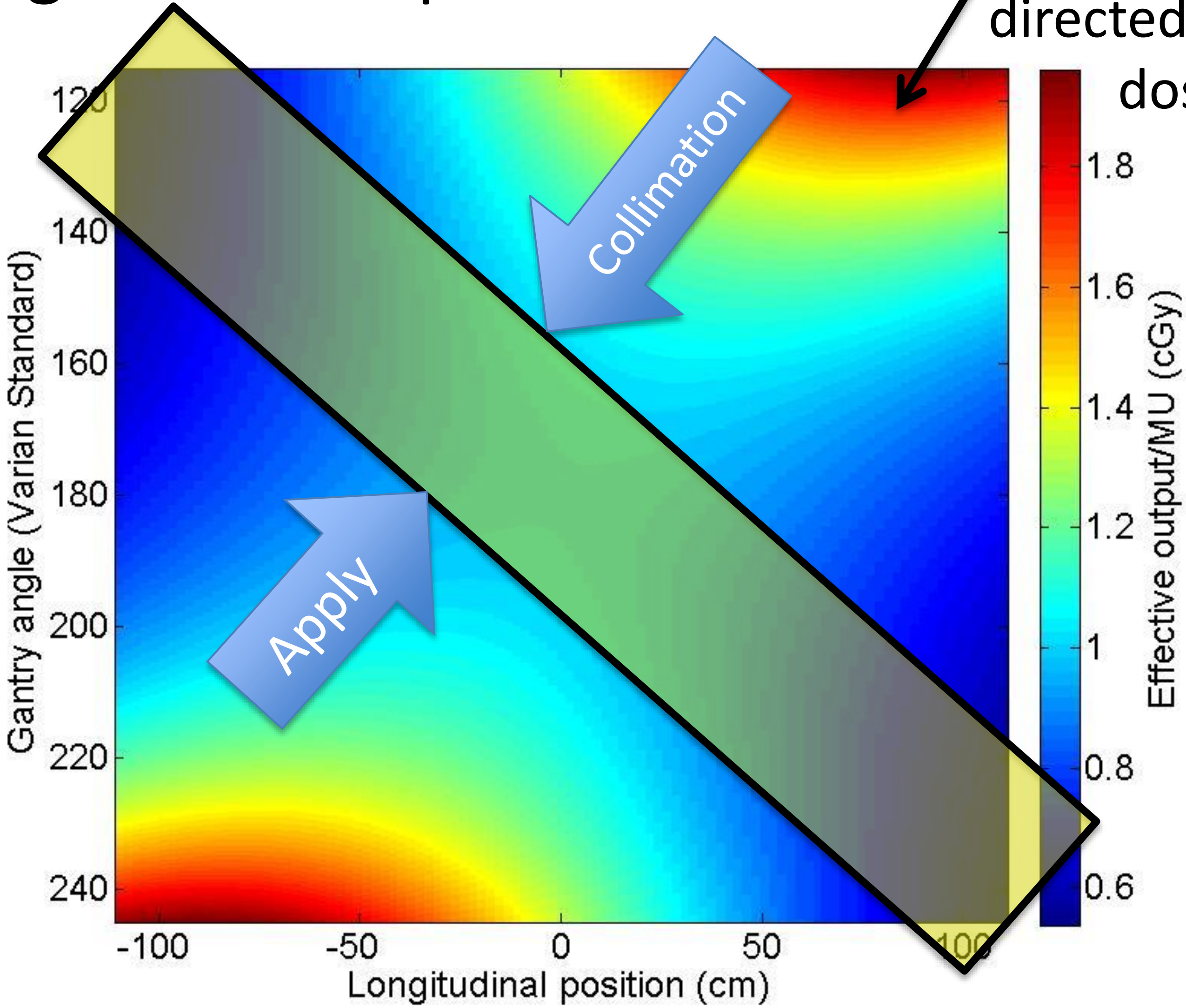
Fill a 2D matrix with output at each point as a function of gantry angle

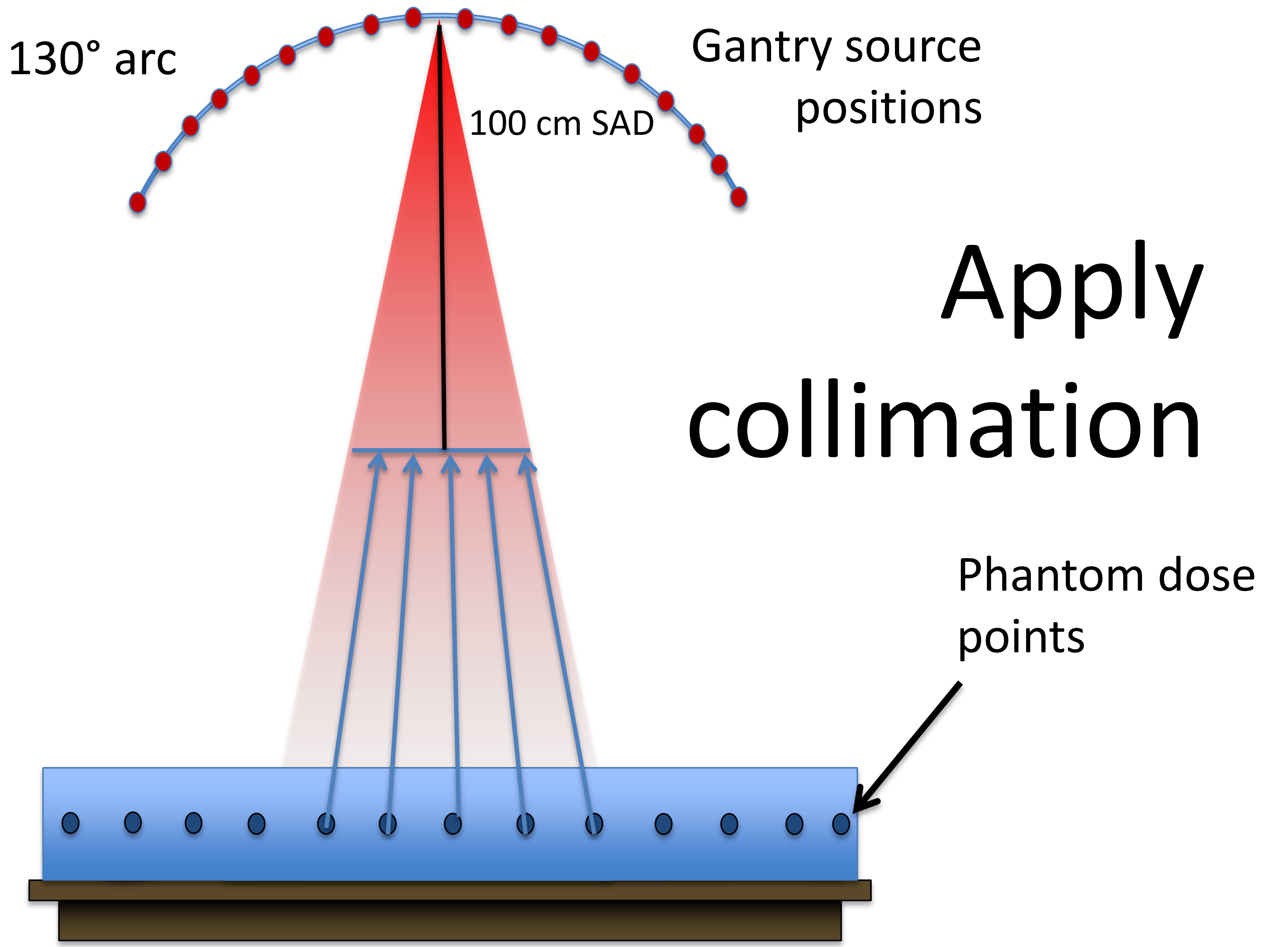
Gantry angle vs. dose point position



Gantry angle vs. dose point position

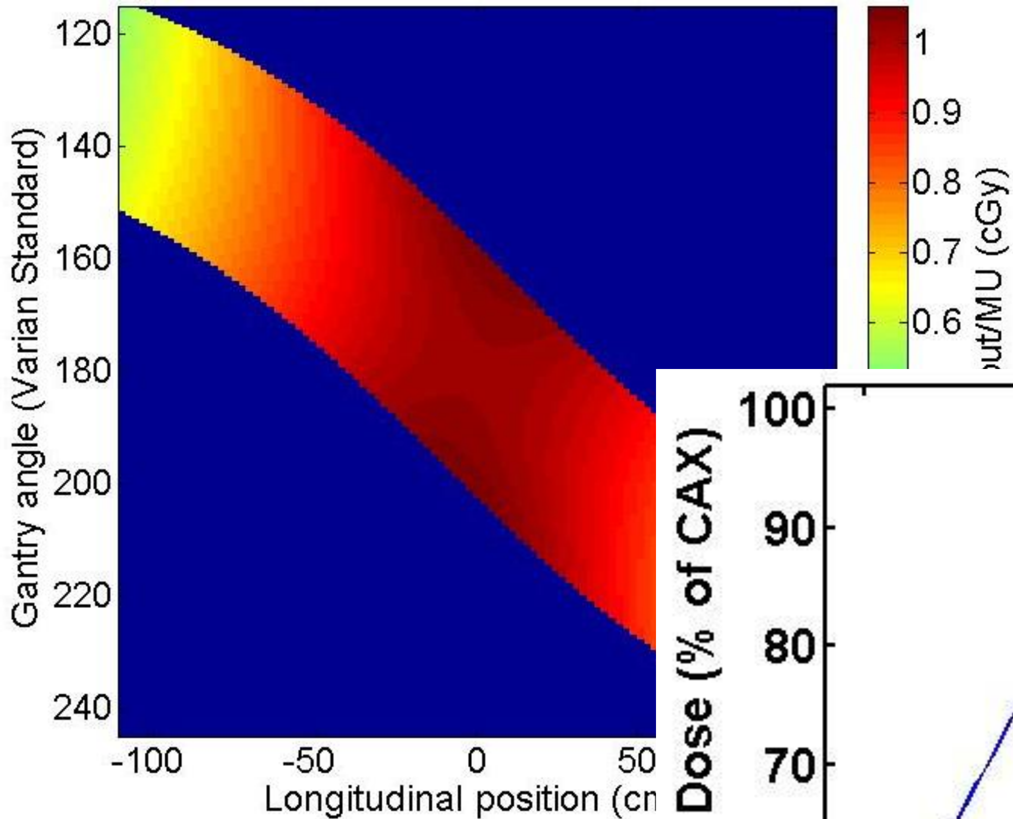
Gantry not directed at these dose points

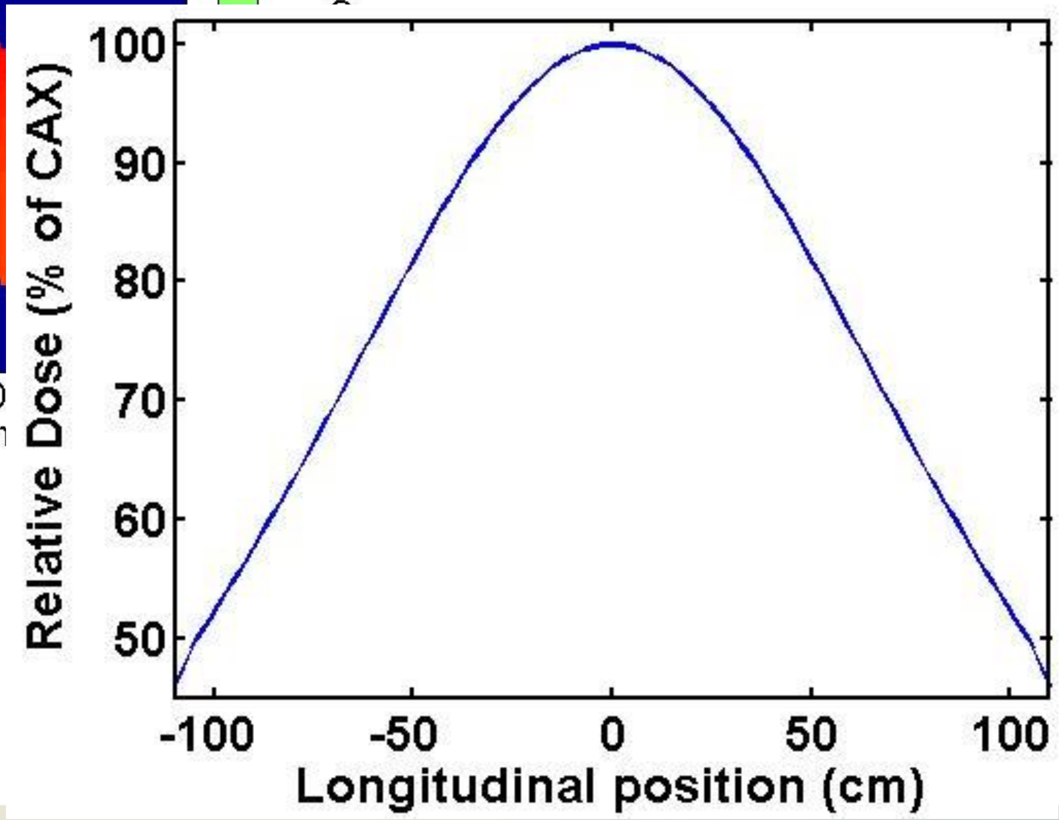




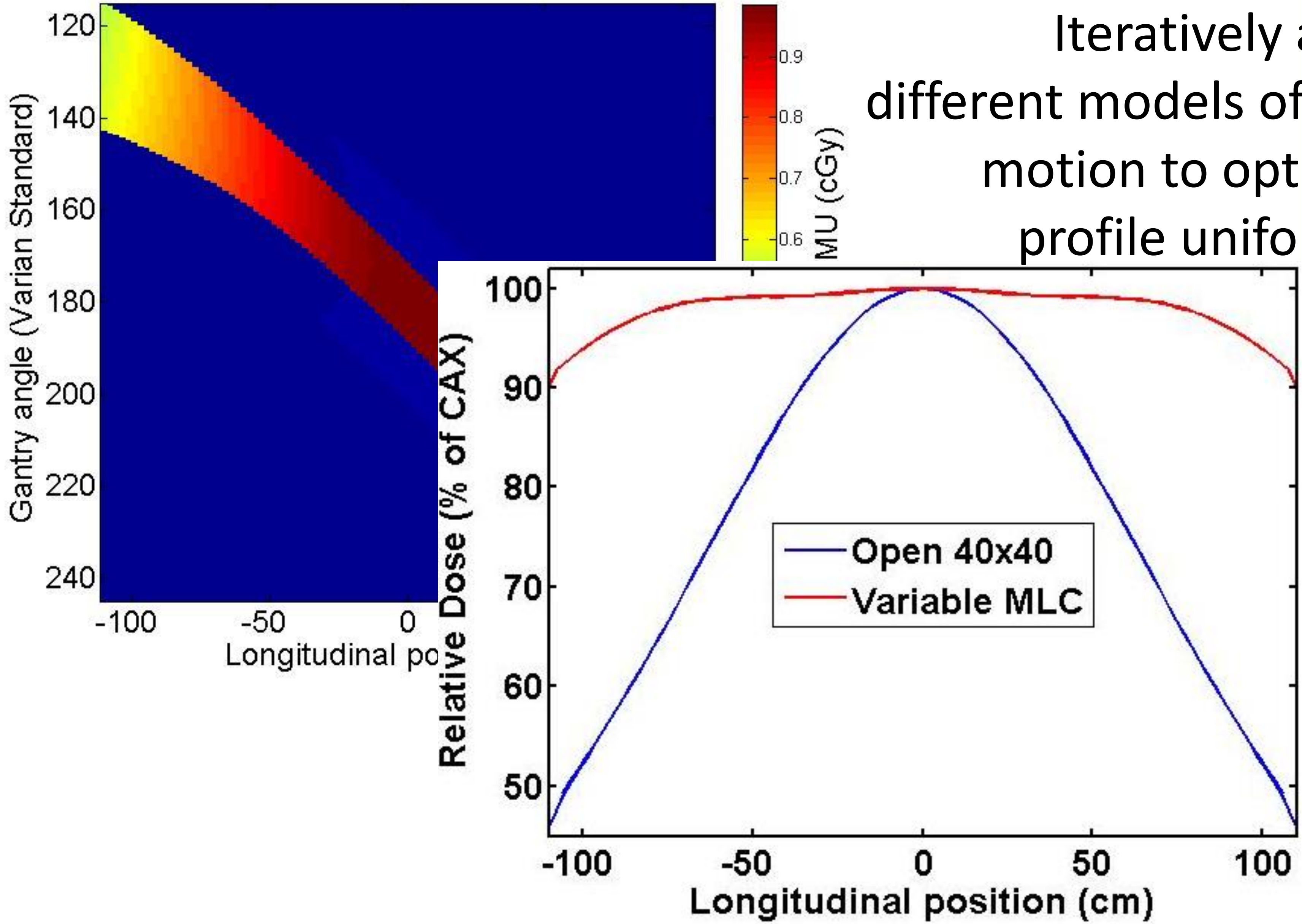
Apply collimation

40x40 cm^2 baseline is too non-uniform

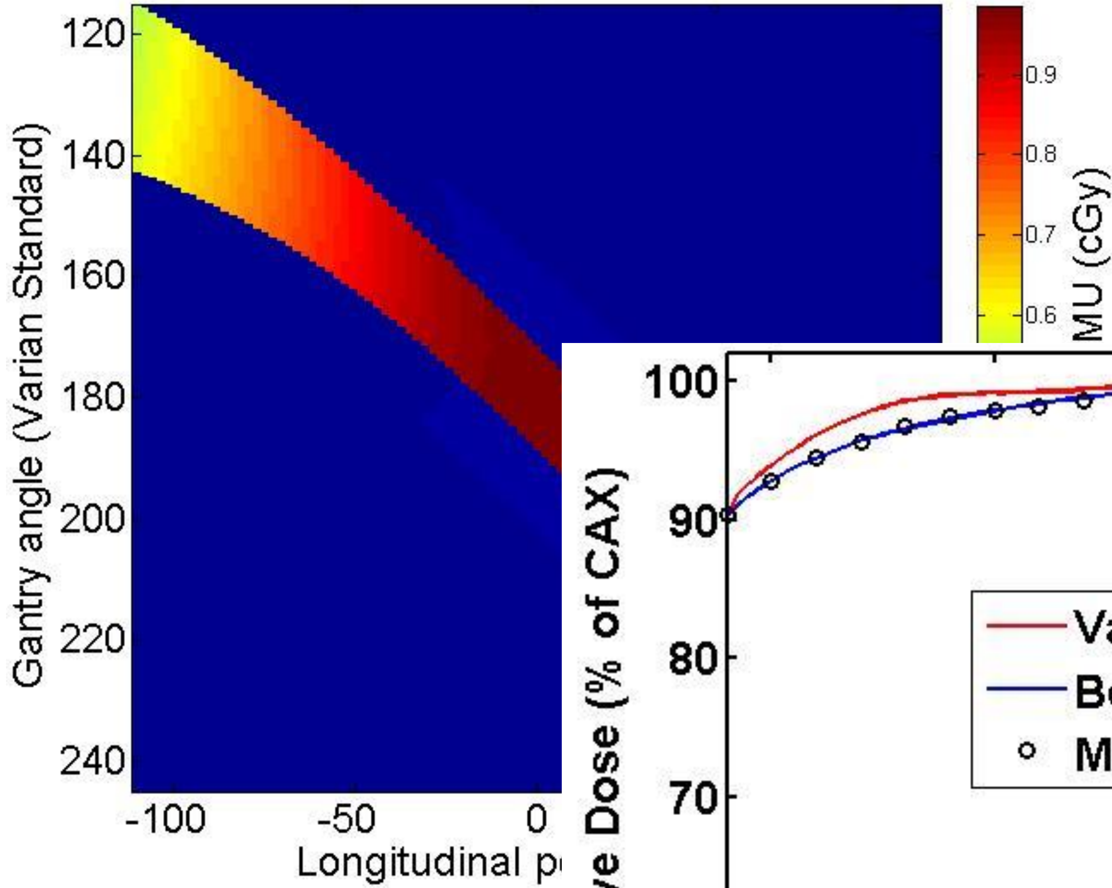


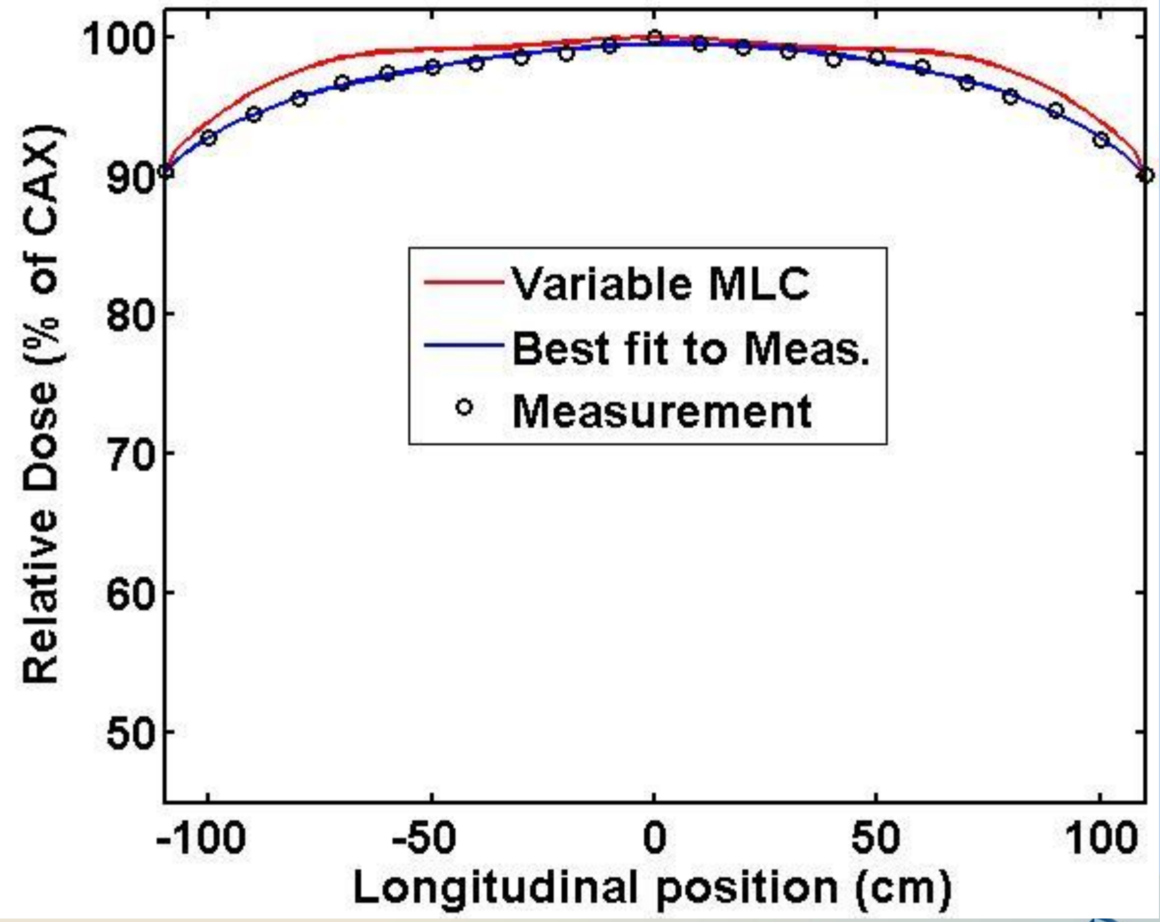


Iteratively apply different models of MLC motion to optimize profile uniformity

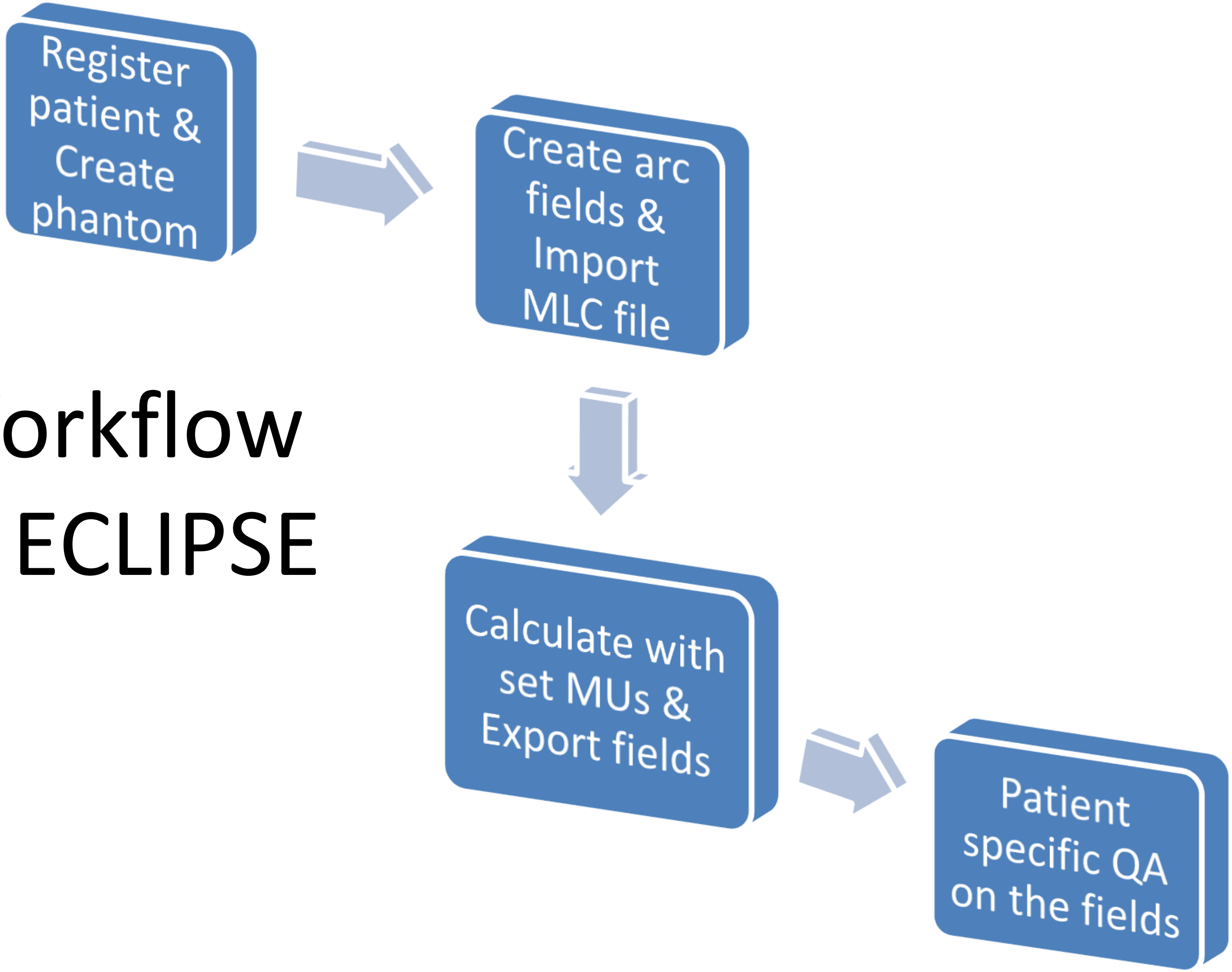


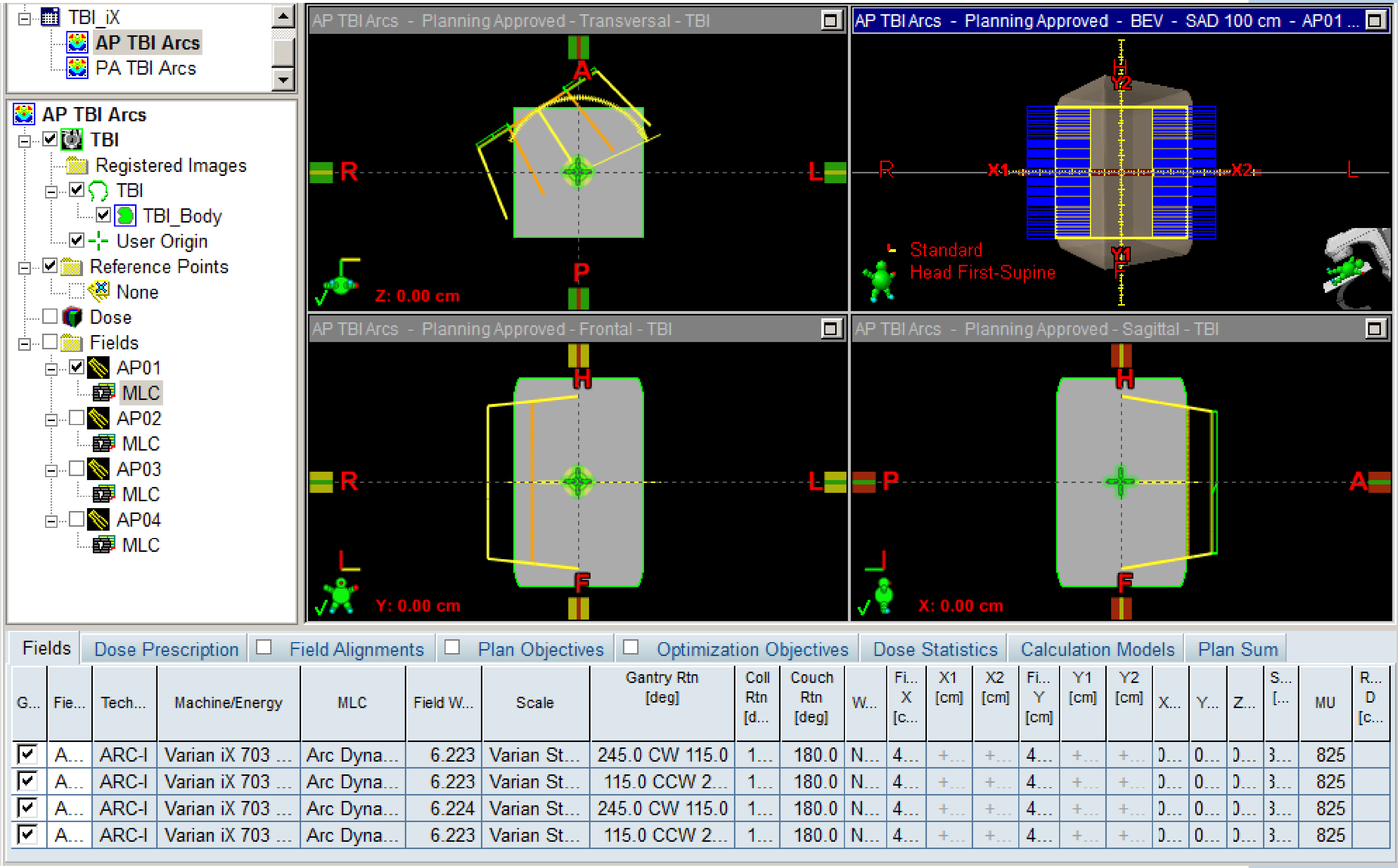
Iteratively apply different models of MLC motion to optimize profile uniformity





Workflow in ECLIPSE




TBI_iX
AP TBI Arcs
PA TBI Arcs
AP TBI Arcs
TBI
Registered Images
TBI
TBI_Body
User Origin
Reference Points
None
Dose
Fields
AP01
MLC
AP02
MLC
AP03
MLC
AP04
MLC
AP TBI Arcs - Planning Approved - Transversal - TBI
Z: 0.00 cm
AP TBI Arcs - Planning Approved - BEV - SAD 100 cm - AP01 ...
Standard
Head First-Supine
AP TBI Arcs - Planning Approved - Frontal - TBI
Y: 0.00 cm
AP TBI Arcs - Planning Approved - Sagittal - TBI
X: 0.00 cm
Fields
Dose Prescription
Field Alignments
Plan Objectives
Optimization Objectives
Dose Statistics
Calculation Models
Plan Sum
G... | Fie... | Tech... | Machine/Energy | MLC | Field W... | Scale | Gantry Rtn [deg] | Coll Rtn [d... | Couch Rtn [deg] | W... | Fi... X [c... | X1 [cm] | X2 [cm] | Fi... Y [cm] | Y1 [cm] | Y2 [cm] | X... | Y... | Z... | S... [... | MU | R... D [c...
A... | ARC-I | Varian iX 703 ... | Arc Dyna... | 6.223 | Varian St... | 245.0 CW 115.0 | 1... | 180.0 | N... | 4... | +... | +... | 4... | +... | +... | 0... | 0... | 0... | 3... | 825
A... | ARC-I | Varian iX 703 ... | Arc Dyna... | 6.223 | Varian St... | 115.0 CCW 2... | 1... | 180.0 | N... | 4... | +... | +... | 4... | +... | +... | 0... | 0... | 0... | 3... | 825
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Benefits of MLC approach

- Safer
  - No risk of dropping heavy Tx device on patient
  - Interlocked
- Reliable
  - Less dependent on physical integrity of wedge
- Potential for further development
  - Patient specific profiles

Summary

- A simple model of rotational dose delivery was helpful in selecting a dynamic MLC pattern for TBI

- Rotational dose delivery is a feasible technique for TBI in a small vault