Initial Steps in the Clinical Commissioning of a Proton Cranial Spinal Treatment Technique

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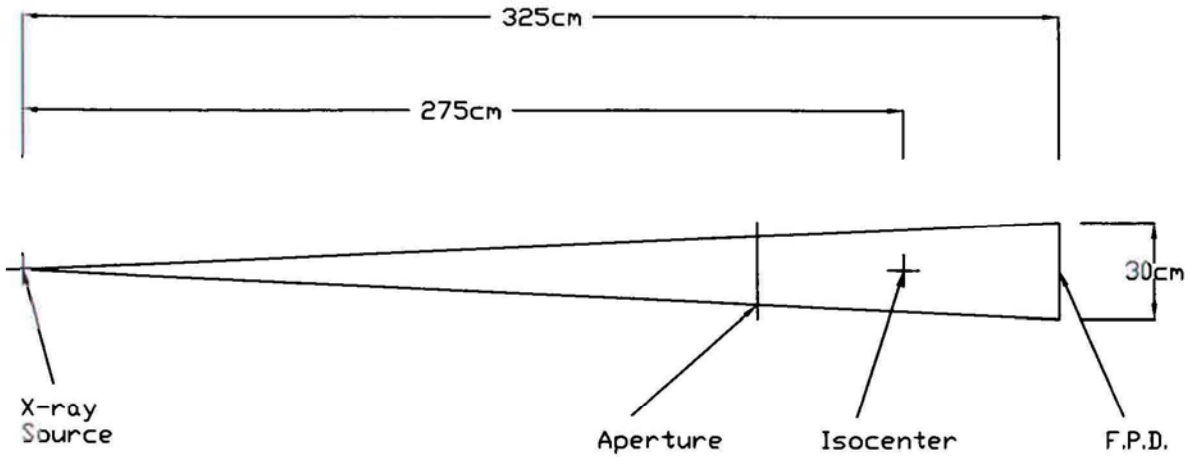
Challenges in Proton Cranial Spinal Treatments

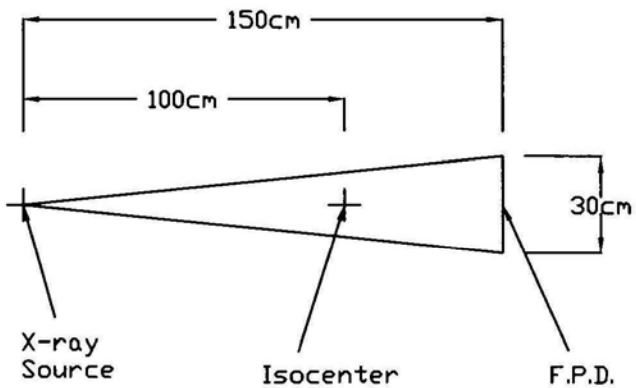
- Distances are different in the proton world as compared to the photon world.
- The nominal TSD is 270 cm. The RMW (and thus the light field and the x-ray tube) is at a distance of approximately 300 cm.
- The snout-isocenter distance is adjustable between 0 and 45 cm.
- There is an increased dose near the surface at the edges of the field due to scattering from the apertures.

X-Ray Geometries



Nozzle X-Ray

Figure A. X-Ray System (Nozzle)



Cage X-Ray

On gantry, 90 degrees from nozzle

Figure B. X-Ray System (Cage)

Challenges in Proton Cranial Spinal Treatments

- Abutting posterior spinal fields. This should be a relatively easy problem. The couch can be programmed to move very precisely. The location of the junction can be imaged, provided that the field is completely detected by the FPD.
- Abutting lateral oblique cranial fields with posterior spinal fields. This is a harder problem in that the cranial fields will be delivered using lateral oblique gantry angles and the posterior field will be at a gantry angle of zero.

Challenges in Proton Cranial Spinal Treatments

- The nozzle contains a field defining light, which has a filament of length 3 to 4 mm. There is no specification regarding the coincidence between the light and the radiation field.
- The light field can be a valuable guide in setting up the patient to the approximate treatment position, although the final position will be confirmed with x-ray images.

Challenges in Proton Cranial Spinal Treatments

- Imaging the borders of the field, given the 30 cm length in the flat panel detector
  - The flat panel detector is located approximately 50 cm from isocenter. The maximum field size at isocenter than can be imaged by the FPD is approximately 25.2 cm.
  - The field size is defined by the location of the snout, which for this work is 30 cm upstream from isocenter. The maximum aperture opening is approximately 22 cm.

Measurement Techniques

- ERD2 film. A characteristic curve has been established for each proton beam energy.
- A pin point ion chamber, PTW TN31006, with a 1 mm radius was also used.
- TLD 100 in hand loaded, sealed packets. A TLD calibration curve has been established for each proton beam energy.

Comparison of Ion Chamber versus Film

- Penumbra (80%-20%) and width (50%) measurements were made in air at the same source to measurement distance using the pin point chamber and film.
- The agreement was within 1 mm for the three different distances studied for both the penumbra and the beam width.

Initial Light and Radiation Field Measurements

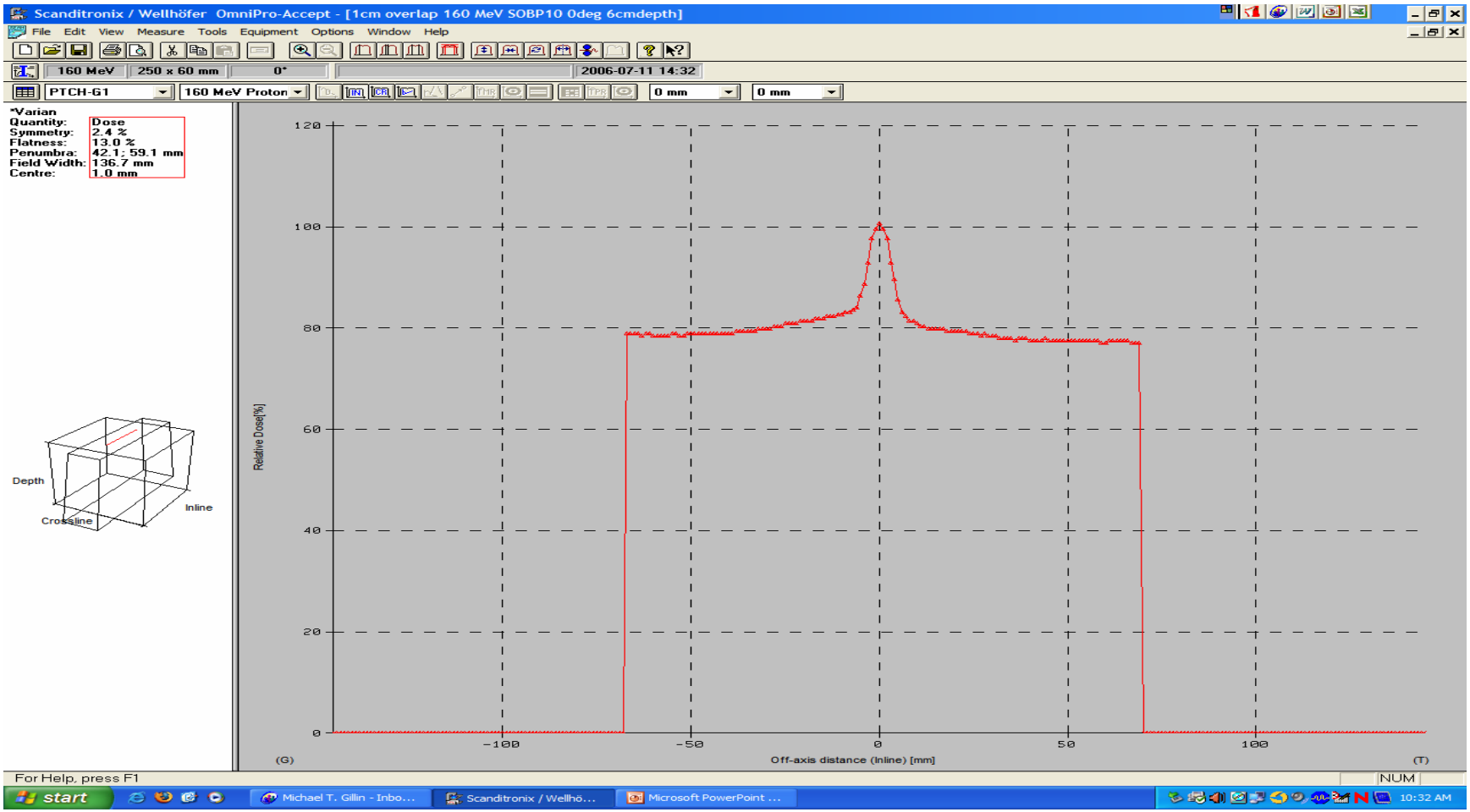
- Measurements were made using EDR2 film with the light field outlined on the film. In addition, the film was pricked at a distance far from the radiation to indicate the extent of the light field.
- The measurements indicated that the light field is coincident with and larger than the proton field by 1 to 2 mm with the gantry at zero degrees.

Spinal field abutment measurements

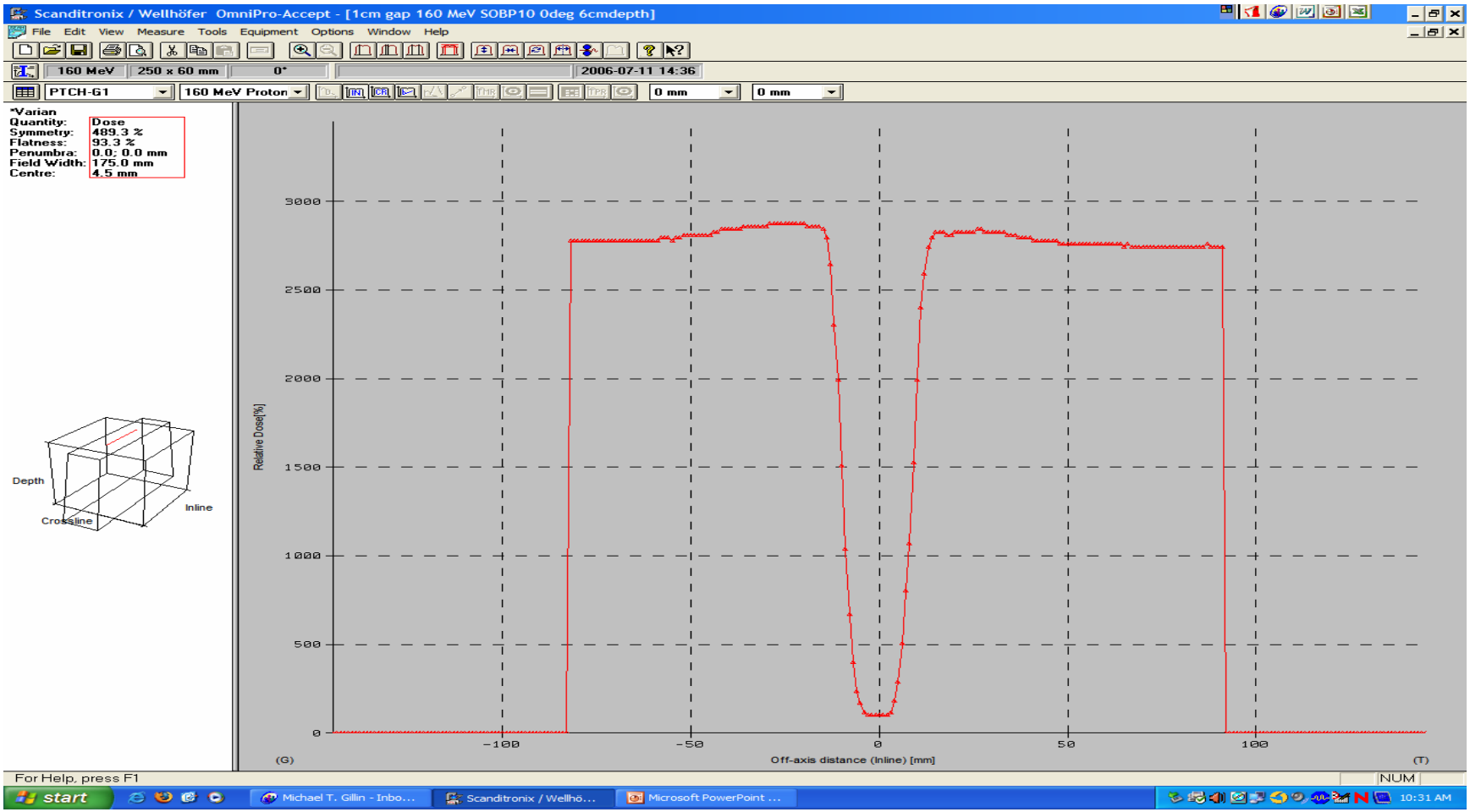
- Film was placed at 6 cm depth in a solid water phantom. Measurement conditions: 160 MeV protons, SOBP width 10 cm, snout at 30 cm, 264 cm TSD.
- Various light field gaps were defined at the surface and the result dose distribution was measured.
- Under the conditions defined above, a gap in the light fields of approximately 4 mm would result in a $\pm$ 10% dose distribution through the region in the gap.

Film at 6 cm Depth in Solid Water
Snout at 30 cm

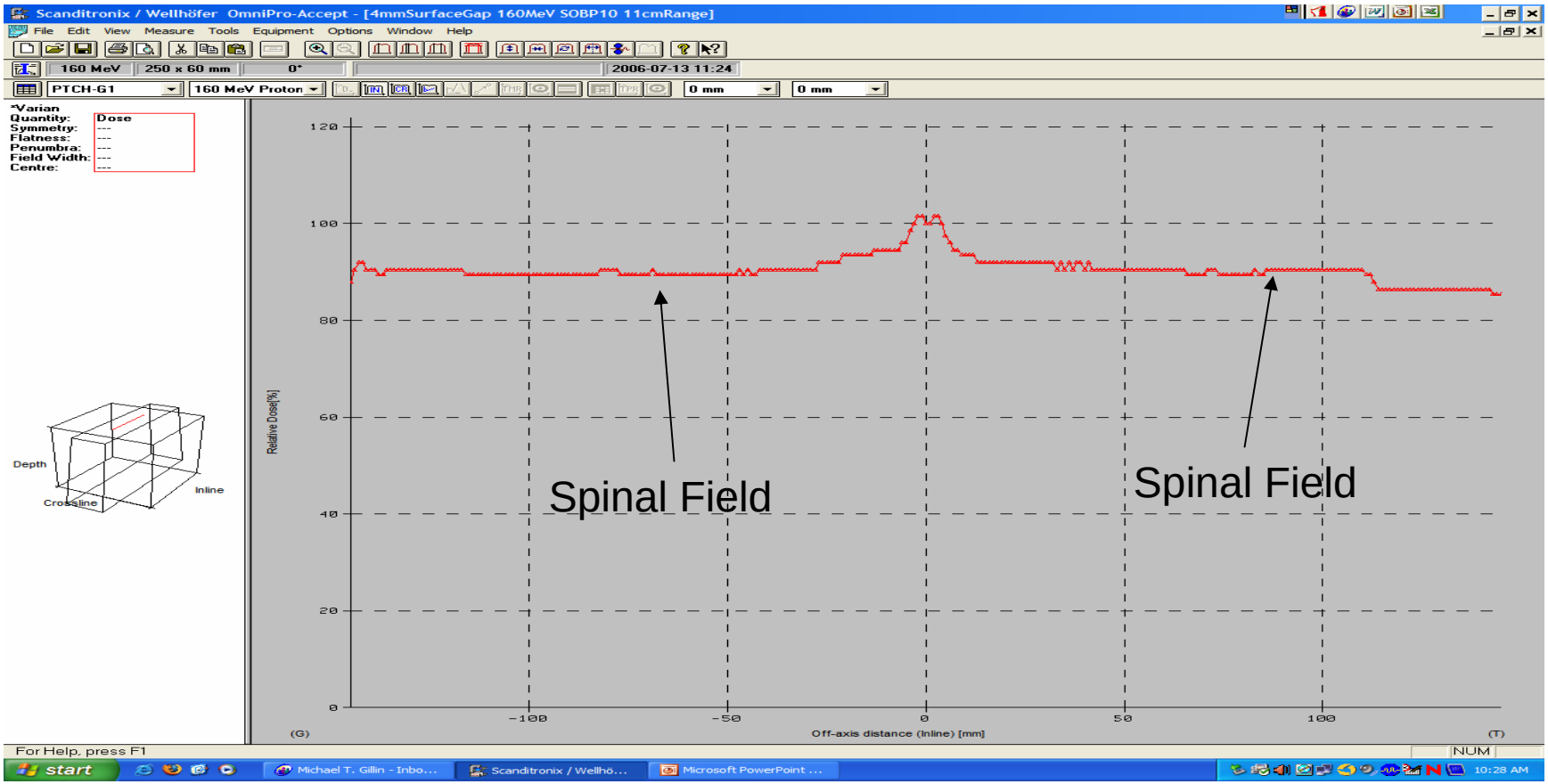
Spinal Fields Coronal Plane 6 cm 10 mm Overlap on Surface



Spinal Fields Coronal Plane 6 cm 10 mm Gap on Surface



Spinal Fields
Coronal Plane 6 cm Depth
4 mm Light Field Gap on Surface



Spinal field abutment measurements

- The 4 mm gap means that there is approximately a 6 mm gap in the proton fields.
- The classic gap equation, which assumes that the 50% radiation decrement line is coincident with the edge of the light field, results in a 6 mm gap.

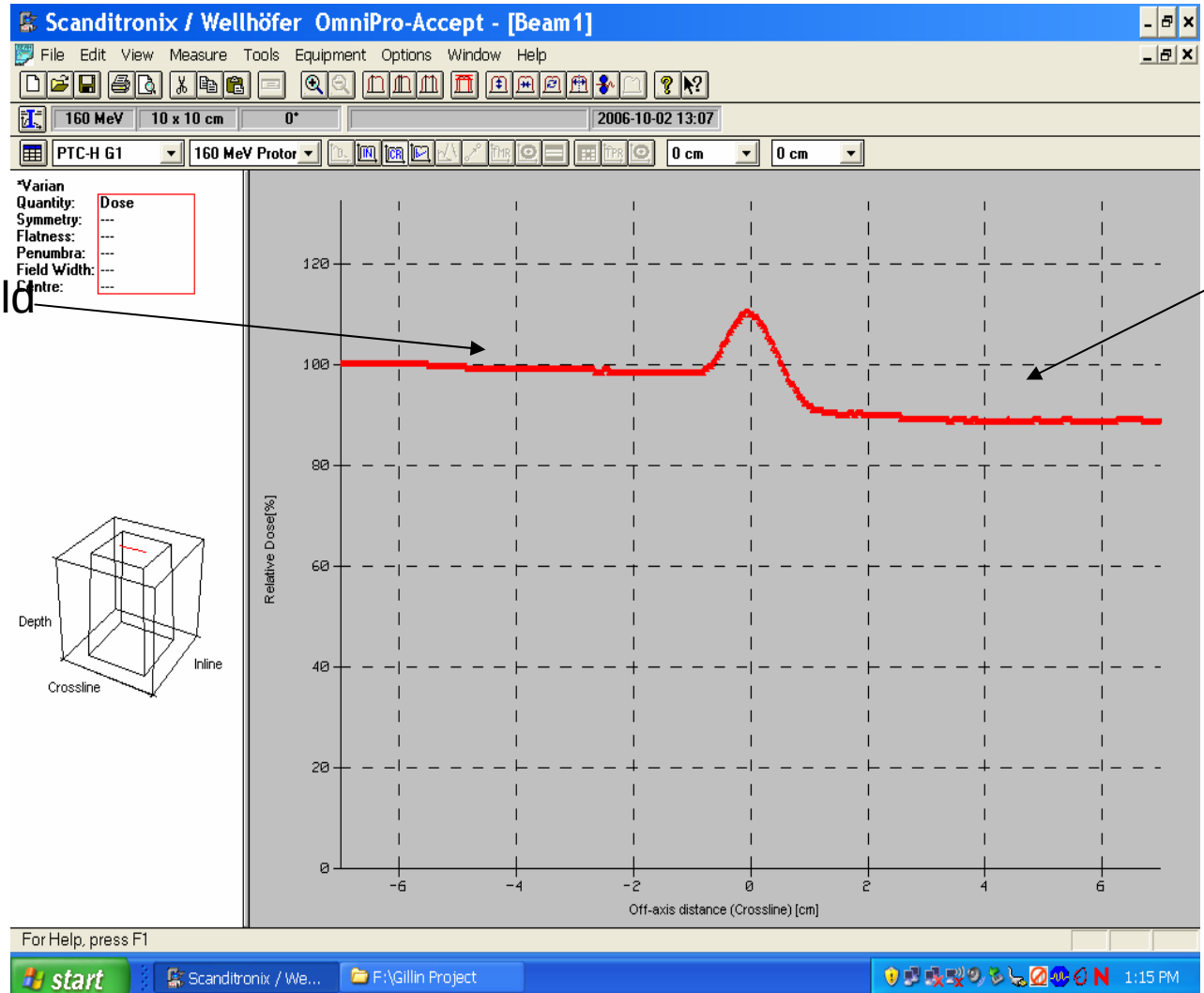
Gap between Cranial and Spinal Fields

- What is the desired dose distribution in the region of the gap between the cranial and spinal fields, especially in light of the fact that this junction will change each week?
- This work is driven by depth of measurement in Rando phantom in slice 8 and 9. This depth from the posterior surface is approximately 5 cm.

Cranial-spinal gap

- The light field gap is defined following a well established procedure, namely:
  - After the apertures and RMW have been loaded, the gantry is rotated to zero degrees and the snout extended to 30 cm.
  - The couch is adjusted to place the lower border of the cranial field at the desired location. The location of the couch in the Y direction is noted to insure that the allowed motion is sufficient to move the couch in the +Y direction to treat the spinal field(s).
  - The gantry is then rotated to the treatment gantry angles and the treatment delivered.
  - The aperture and the RMW is changed and the gantry is rotated back to zero, the snout is placed in the defined extension (30 cm), and the couch location changed to define the appropriate gap between the cranial and the spinal fields.

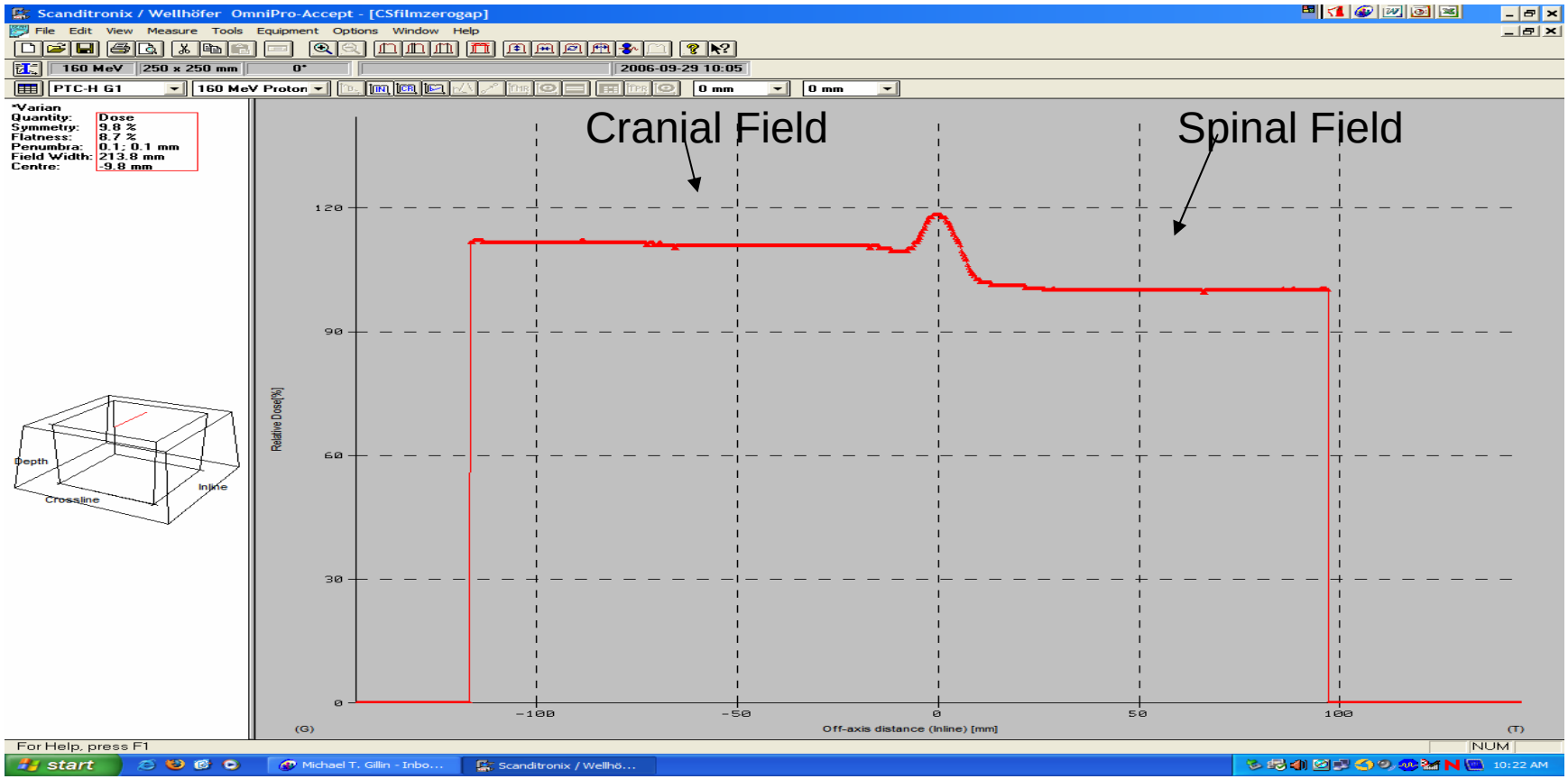
Film in sold water, 6 cm depth, coronal plane, Cranial Fields 60 and 300 degrees, spinal field 0 degrees



Cranial field

Spinal field

Film in Coronal Plane
at 6 cm Depth
Light Field: Zero Gap on posterior surface of Rando

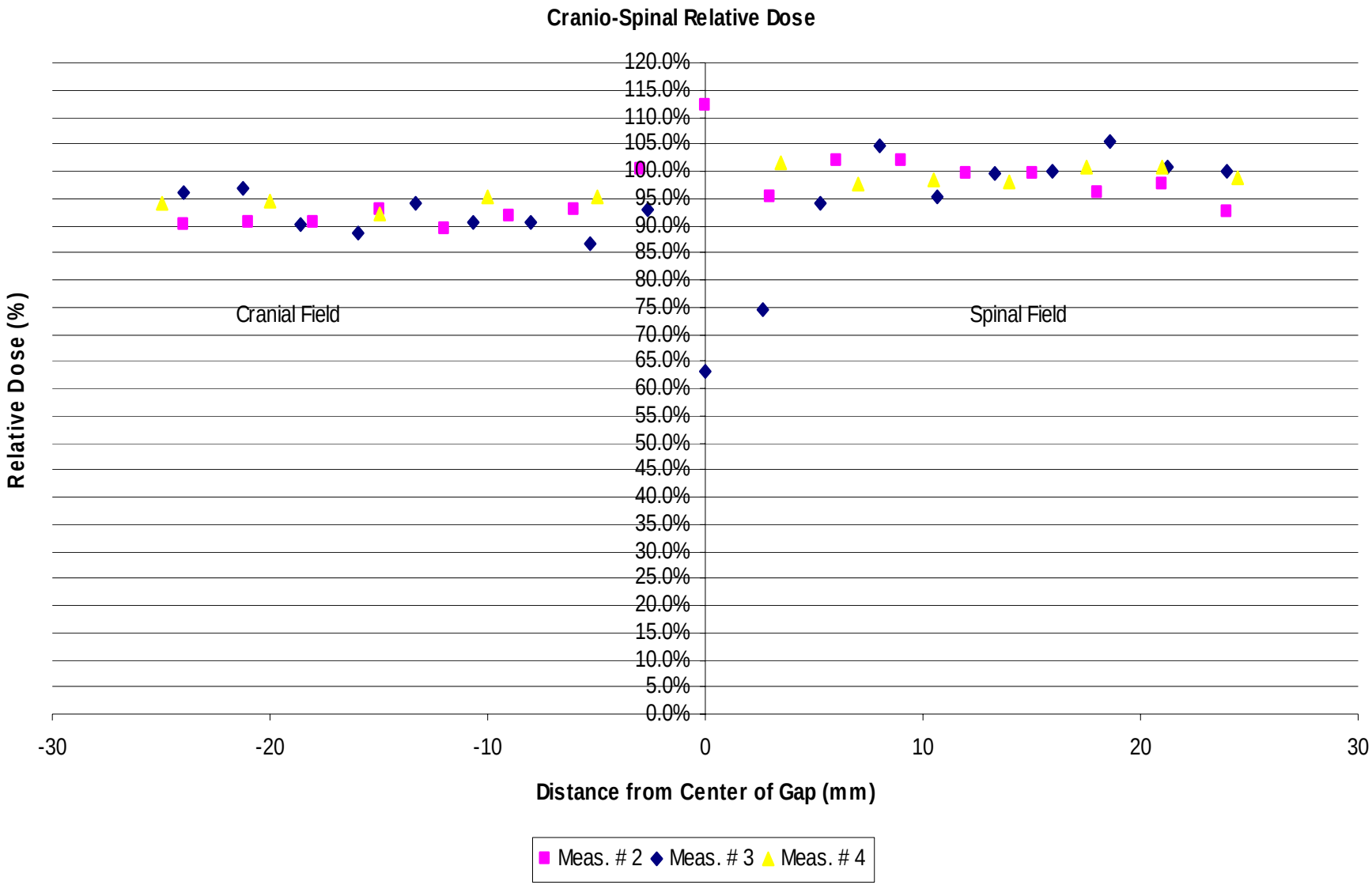


TLD

- Anderson has a long history of packaging TLD for specific use in 1 cm by 1 cm packets.
- TLD packets were folded and forced into the cylindrical 5 mm diameter holes in the Rando phantom. Approximately 7 such packets could be placed in one slice of the phantom, which comes in 25.4 mm lengths.

TLD in Rando

- Three separate measurements have been performed which used zero light field gap on the posterior surface of Rando between the cranial and spinal fields.
- Cranial fields: 200 MeV, 14 cm SOBP
- Spinal field: 160 MeV, 8 cm SOBP
- These measurements indicate that the gap region of high dose gradient is approximately 5 mm.


Cranio-Spinal Relative Dose
Relative Dose (%)
120.0%
115.0%
110.0%
105.0%
100.0%
95.0%
90.0%
85.0%
80.0%
75.0%
70.0%
65.0%
60.0%
55.0%
50.0%
45.0%
40.0%
35.0%
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
Cranial Field
Spinal Field
-30
-20
-10
0
10
20
30
Distance from Center of Gap (mm)
Meas. # 2
Meas. # 3
Meas. # 4

Summary

- Initial work has begun in defining the challenges associated with cranial spinal treatments.
- Observations:
  - The flat panel detector will limit the size of the spinal fields to a length of approximately 20 cm.
  - The correct treatment of cranial and spinal fields in Rando is very dependent upon the proper sequence of multiple steps.
  - The light field can be a useful tool in the initial patient setup. Final confirmation will be with x-rays.