Clinical Commissioning of Eclipse Treatment Planning System for Protons at PTCH

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Objective

- Review our experience in collecting the required proton beam input data for Eclipse Treatment Planning System
- Compare the measured versus calculated dose distributions in a simple water phantom

Methods and Materials

- Eclipse treatment planning system requires a limited number of both in-phantom and in-air measurements for passively modulated proton beam
- Eclipse uses a Gaussian pencil beam model for dose calculation
- The knowledge of depth dose curve and proton fluence is needed for calculation of dose in patient

Measurements in water

Pristine Bragg Peaks (PBP)-PDD of unmodulated beam

Methods and Materials

Measurements in air

Z-fluence - open field longitudinal profiles

Effective source position is derived by fitting the fluence to inverse square law

Open field transverse profiles to determine field sizes at different distances

Virtual source position is derived from measured beam divergence

Half-blocked field transverse profiles

The effective size of the proton source is calculated using the penumbra width of the half-blocked field

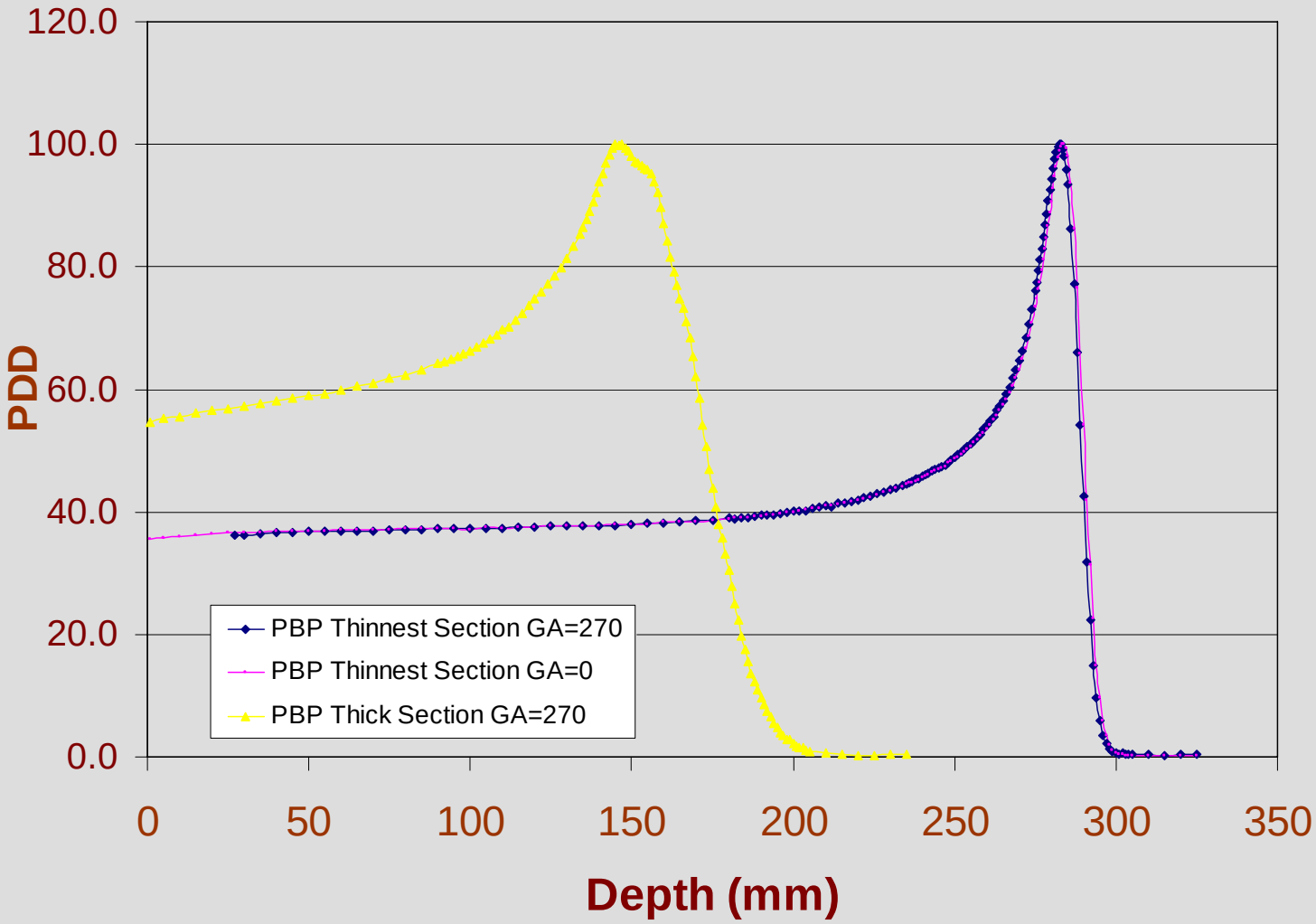
Measurements

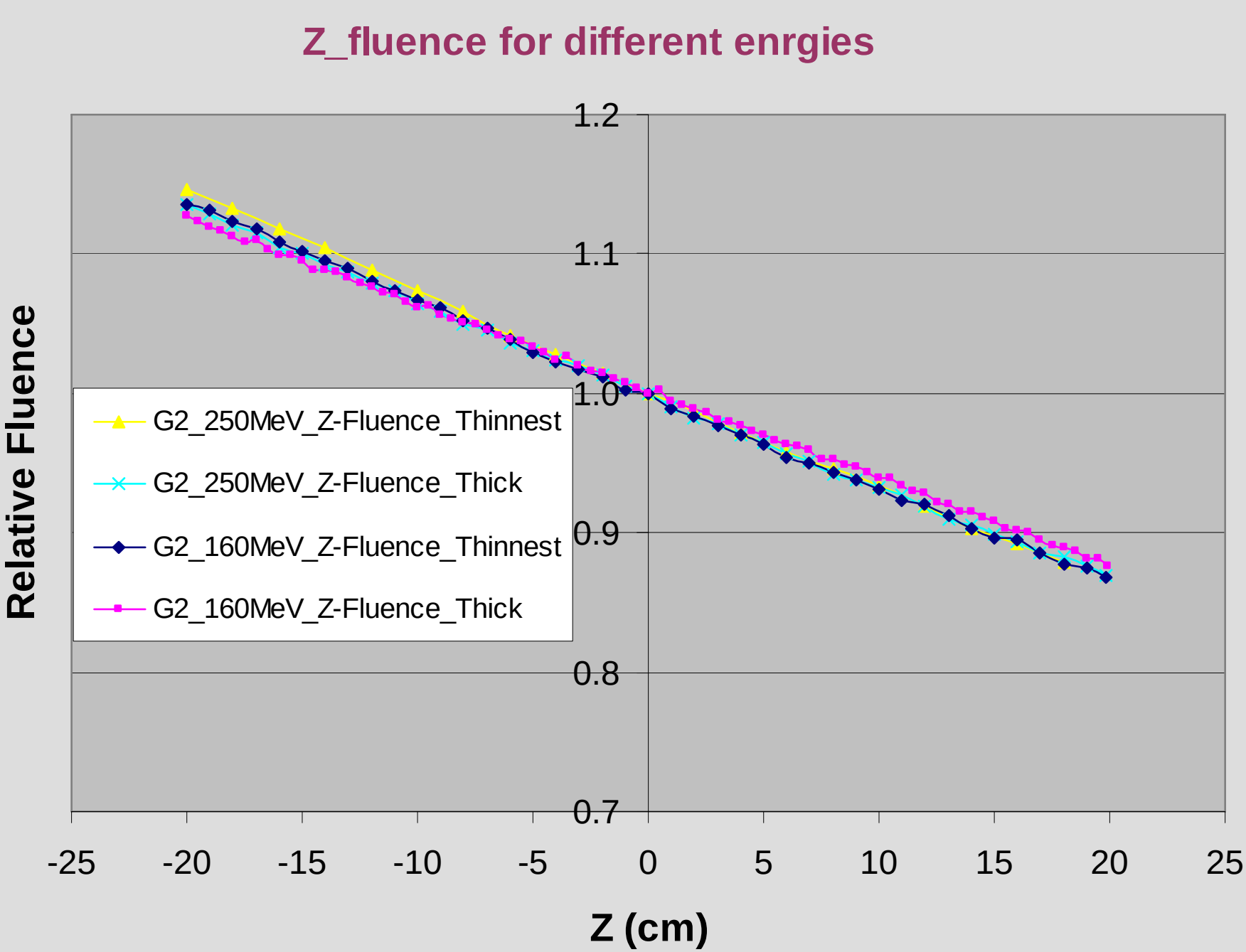
Eclipse requires measurements at the thinnest and a thick section of the stationary RMW

PBP and Z-fluence

- PTW MP3 Scanning system
- Advanced Markus Chamber
- Point by point integration of charge for 4 seconds
- Minimum five points of measurement for Z-fluence including isocenter
- Used fixed MU for Z-fluence measurements for fixed gantry room

Pristine Brag Peaks, 250 MeV Proton Beam at PTCH




Z_fluence for different enrgies
Relative Fluence
1.2
1.1
1.0
0.9
0.8
0.7
-25
-20
-15
-10
-5
0
5
10
15
20
25
Z (cm)
G2_250MeV_Z-Fluence_Thinnest
G2_250MeV_Z-Fluence_Thick
G2_160MeV_Z-Fluence_Thinnest
G2_160MeV_Z-Fluence_Thick

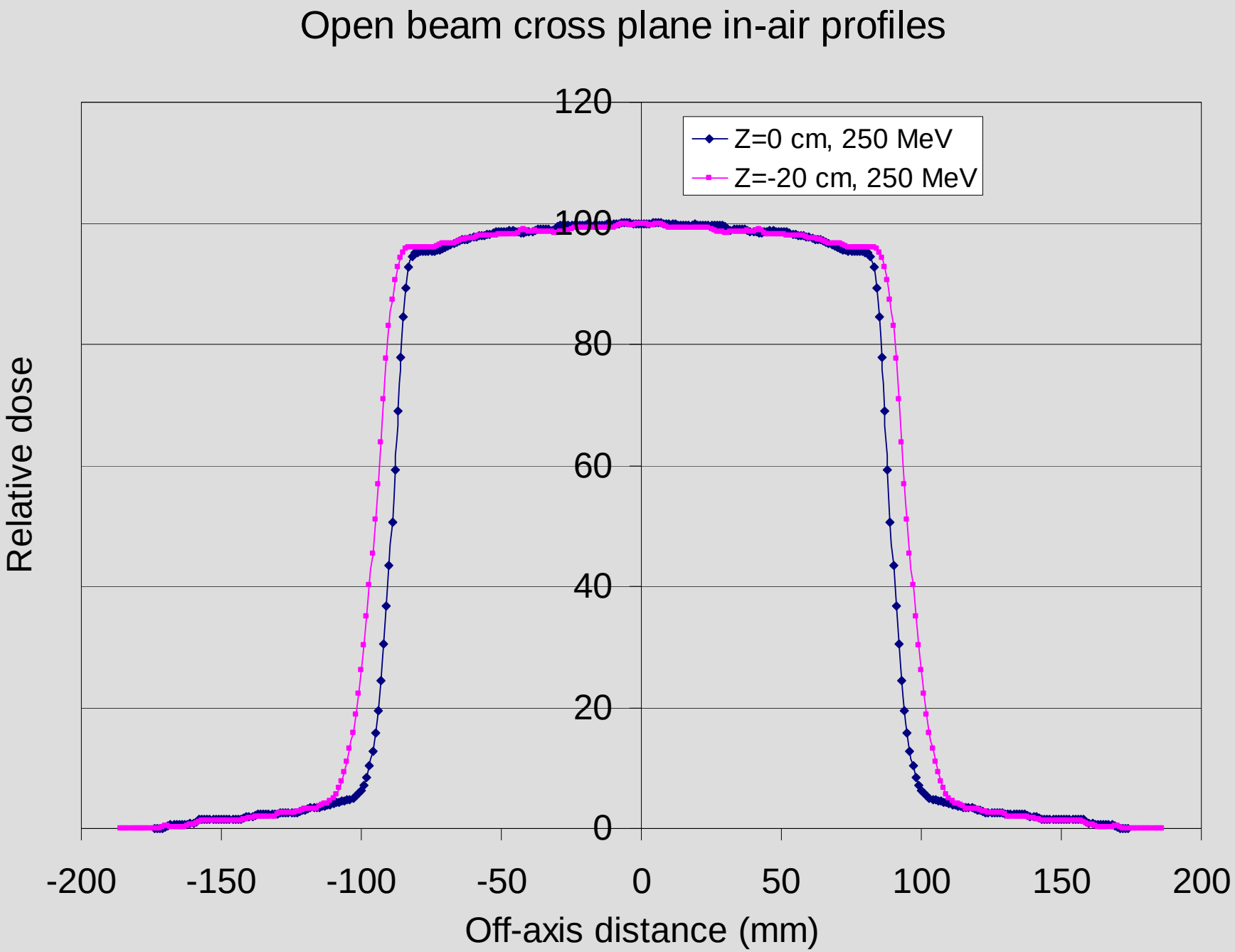
In-air transverse profiles

- Kodak EDR2 films were used to measure the cross beam profiles in air
- The film was read using a Vidar scanner and was analyzed with Scanditronix OnmiPro software
- Good agreement between pin-point chamber and film measurement validated the accuracy of the film dosimetry

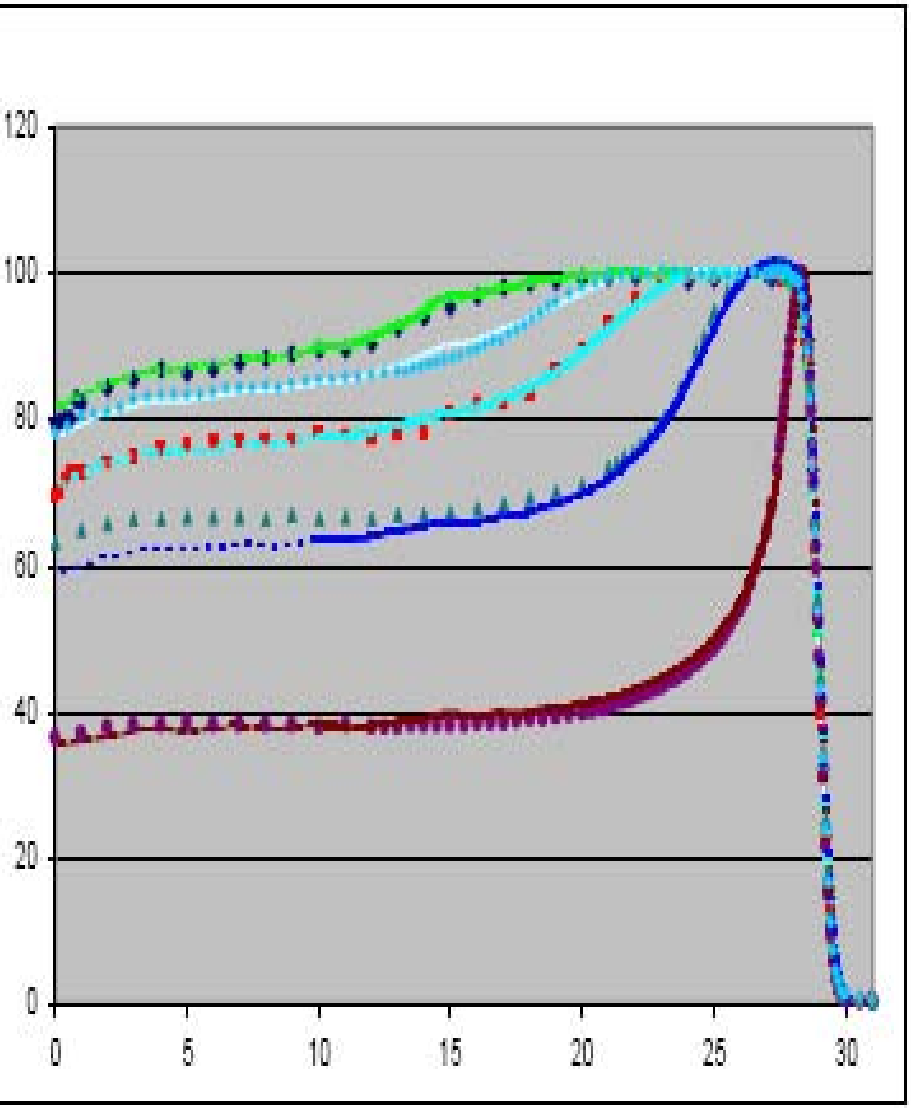
Film vs Ion Chamber

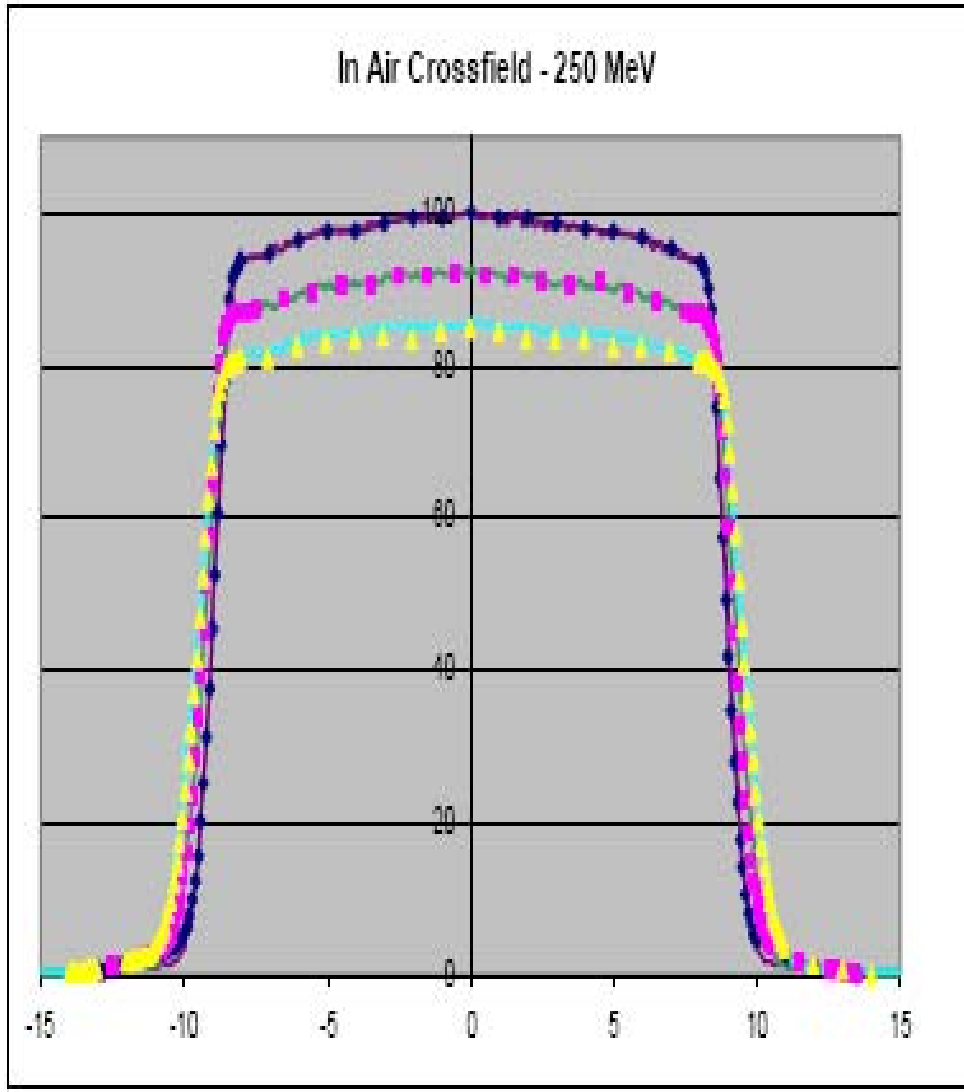
SSD, Penumbra and width are in cm

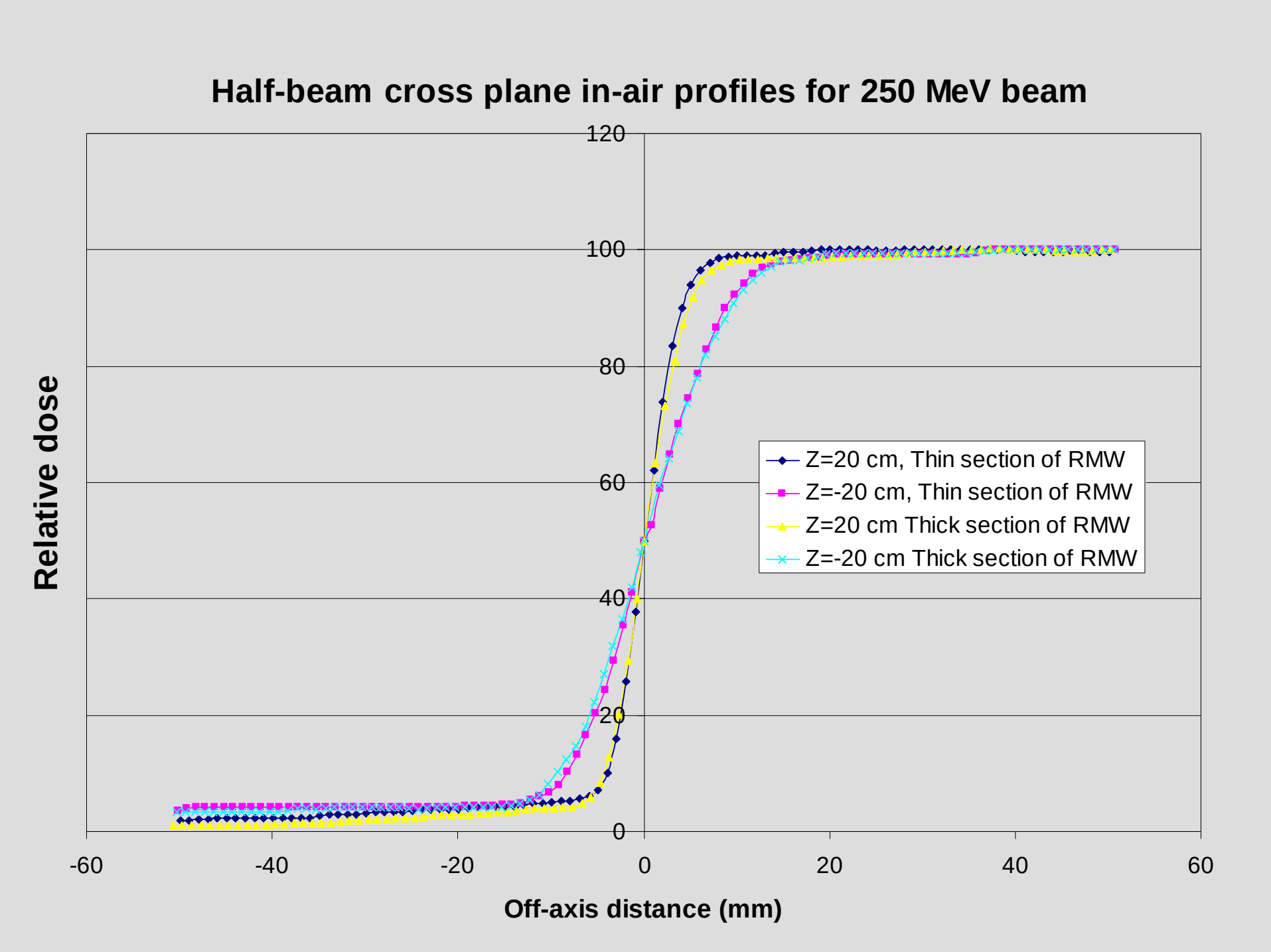
FILM	MU	SSD	Dose	Pen. Left	Pen. Right	Width 50%
	200	288	172.3	1.31	1.17	19.09
	200	270	198.0	0.97	0.88	17.97
	200	250	229.3	0.55	0.5	16.69
				Penumbra 80%-20%		
ION CHAMBER	MU	SSD	Dose	Left	Right	Width 50%
		288		1.24	1.19	19.04
		270		0.97	0.92	17.92
		250		0.59	0.57	16.63
				Penumbra 80%-20%		
DEVIATIONS	MU	SSD	Dose	Left	Right	Width 50%
		288		0.07	-0.02	0.05
		270		0.00	-0.04	0.05
		250		-0.04	-0.07	0.06


Open beam cross plane in-air profiles
Z=0 cm, 250 MeV
Z=-20 cm, 250 MeV
Relative dose
120
100
80
60
40
20
0
-200
-150
-100
-50
0
50
100
150
200
Off-axis distance (mm)

Symbols = measurements
Solid lines = Monte Carlo



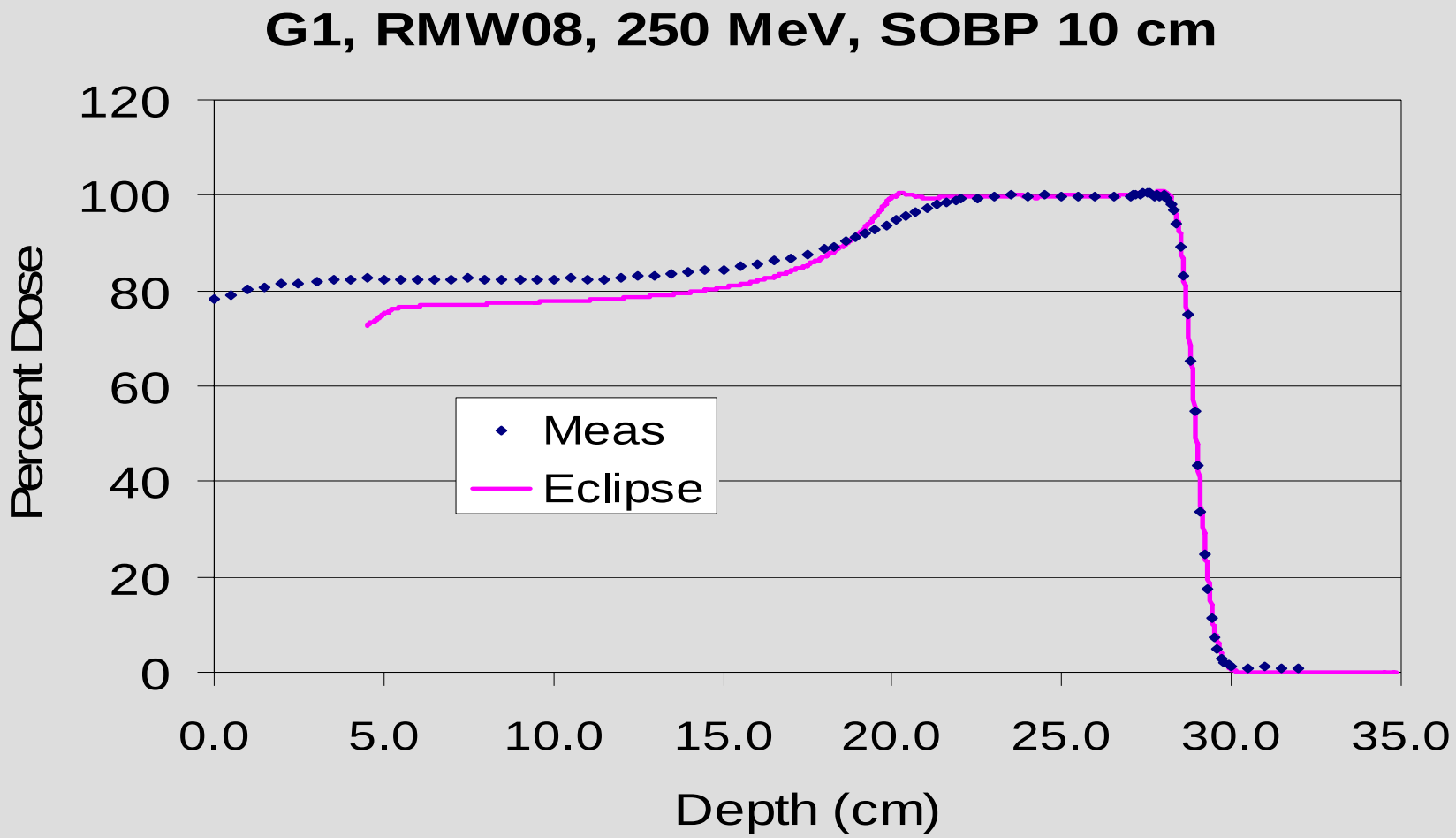


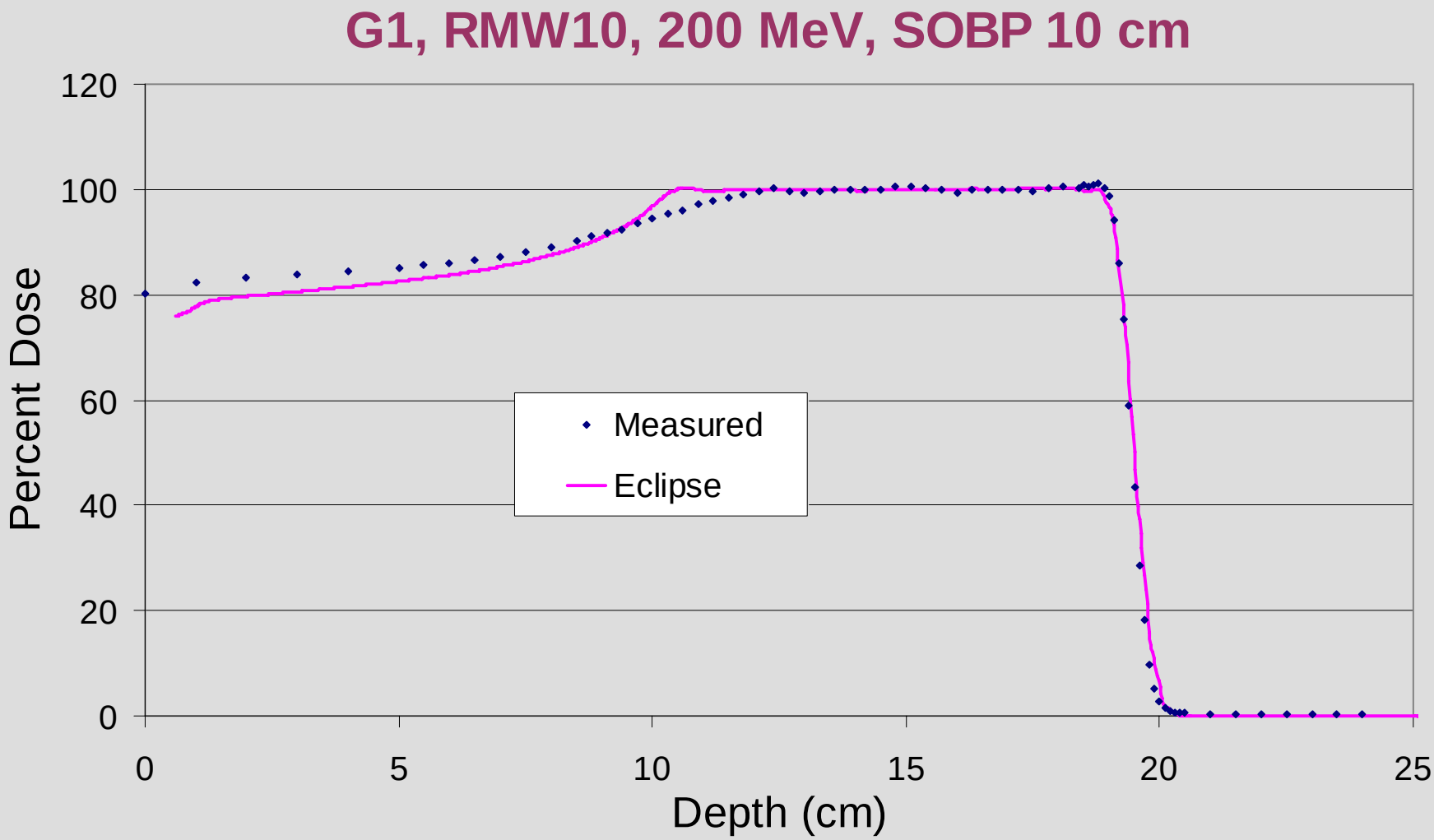

Half-beam cross plane in-air profiles for 250 MeV beam
Relative dose
120
100
80
60
40
20
0
-60
-40
-20
0
20
40
60
Off-axis distance (mm)
Z=20 cm, Thin section of RMW
Z=-20 cm, Thin section of RMW
Z=20 cm Thick section of RMW
Z=-20 cm Thick section of RMW

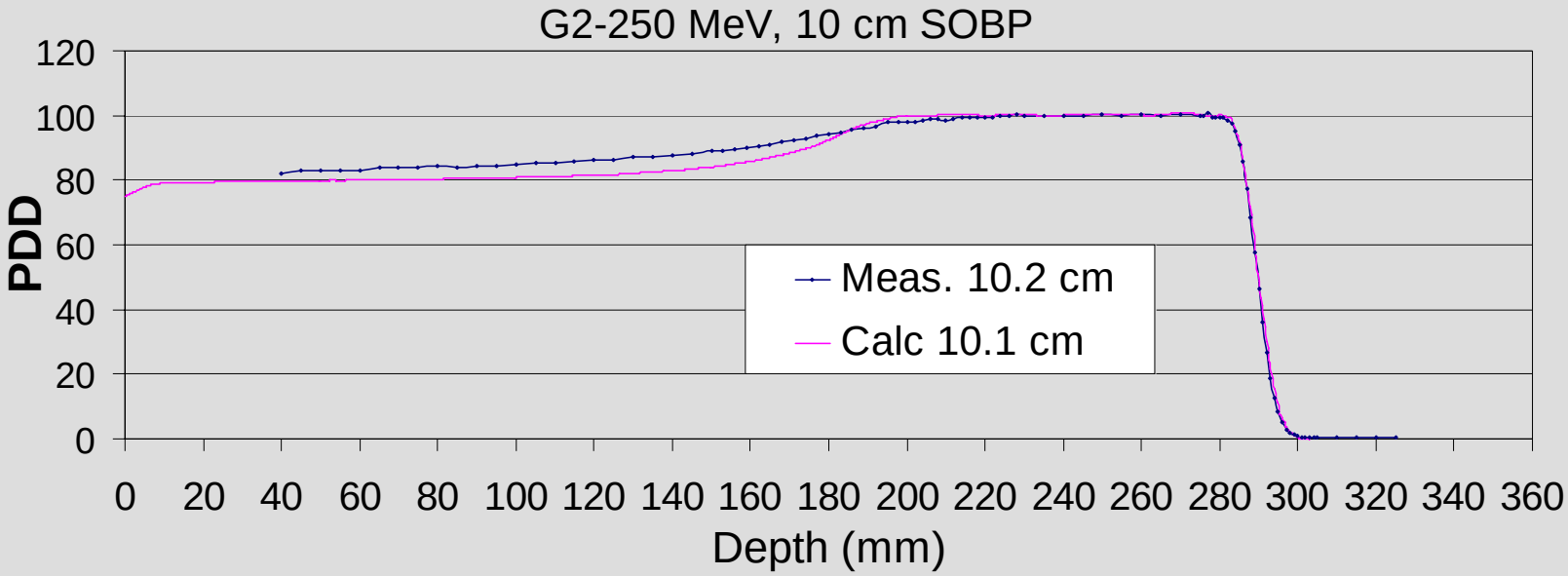
Materials and Methods

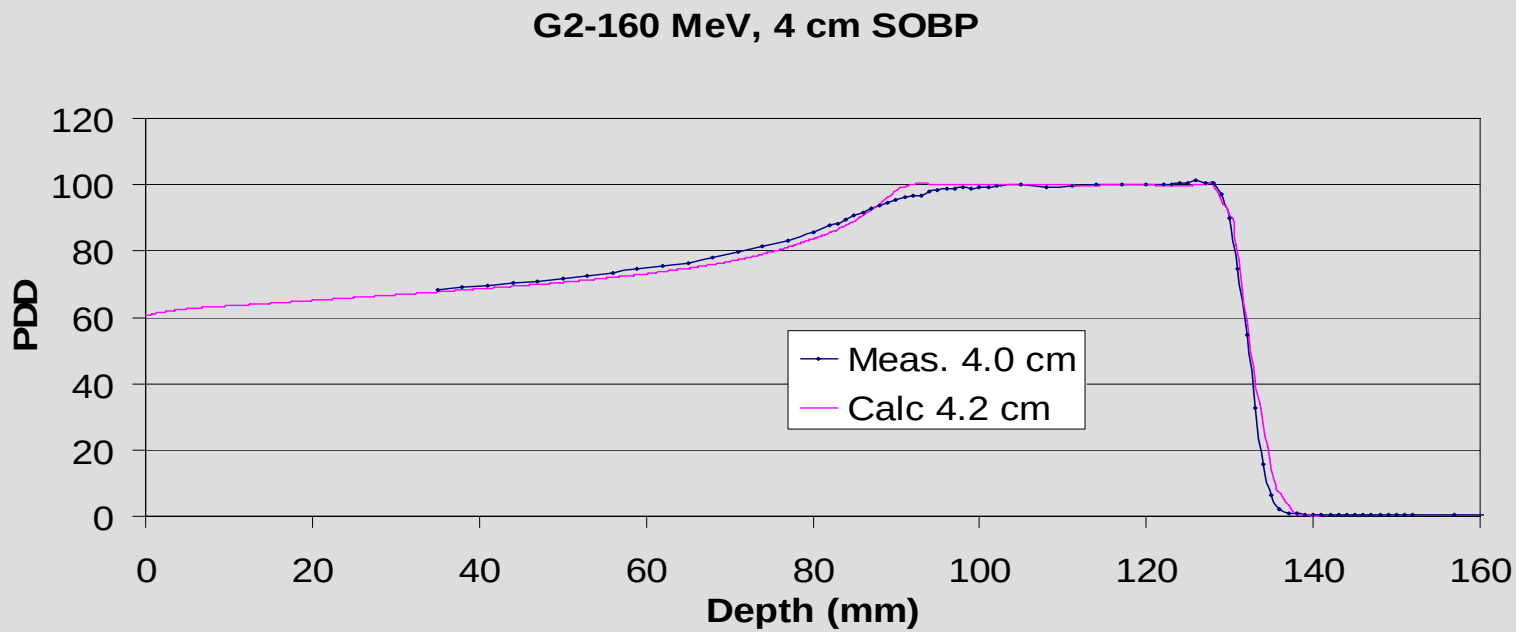
- A total of ten measurements are required for each option. These ten measurements could be completed in approximately ten hours.
- Measured data were converted into the required W2CAD format and were entered into the Eclipse Treatment Planning system.
- After a complete set of data was entered for each option, dose calculations were performed in a water phantom to test the accuracy of the beam modeling in Eclipse

Results-SOBP

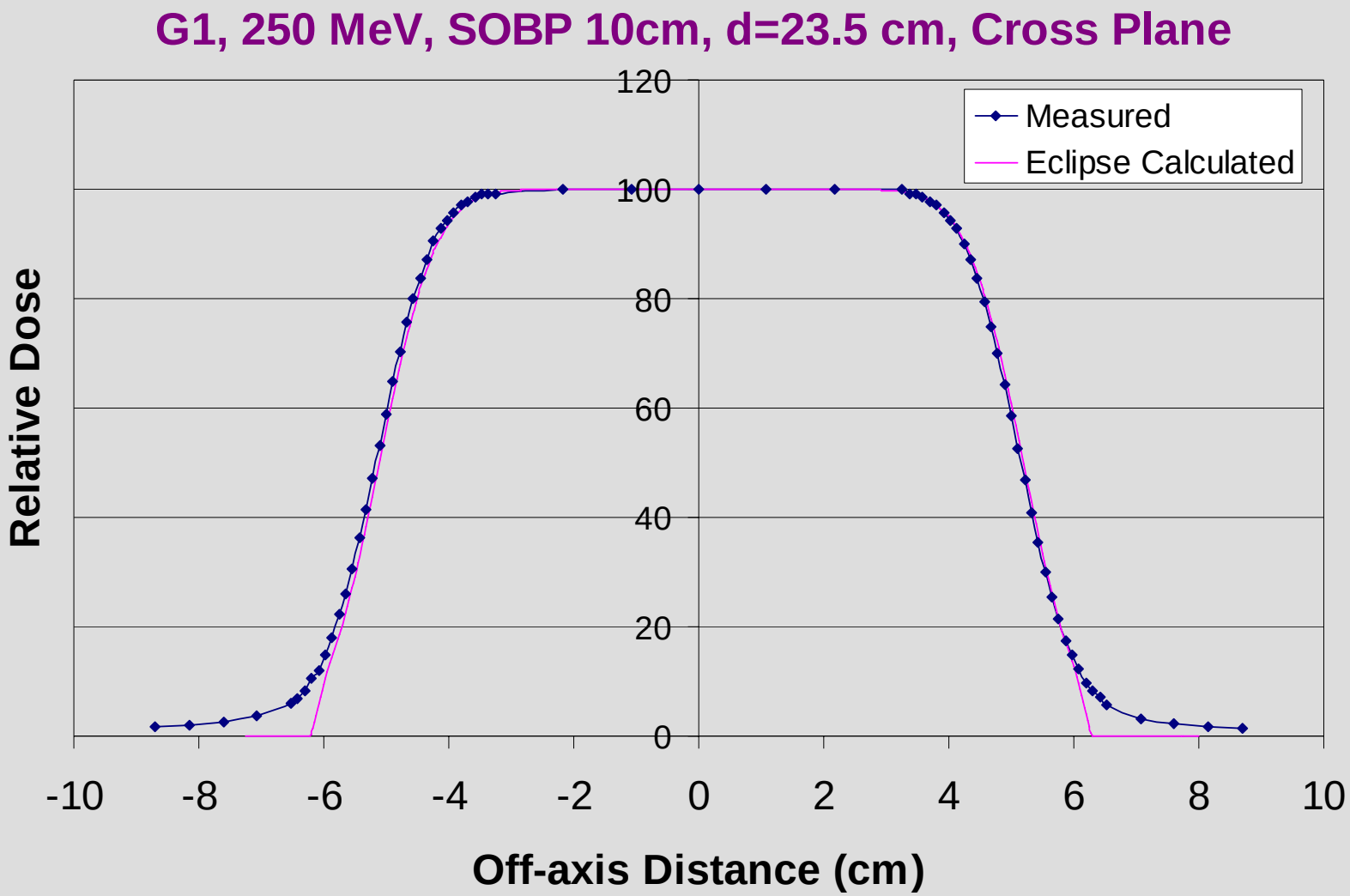



G1, RMW10, 200 MeV, SOBP 10 cm
Percent Dose
120
100
80
60
40
20
0
0
5
10
15
20
25
Depth (cm)
Measured
Eclipse

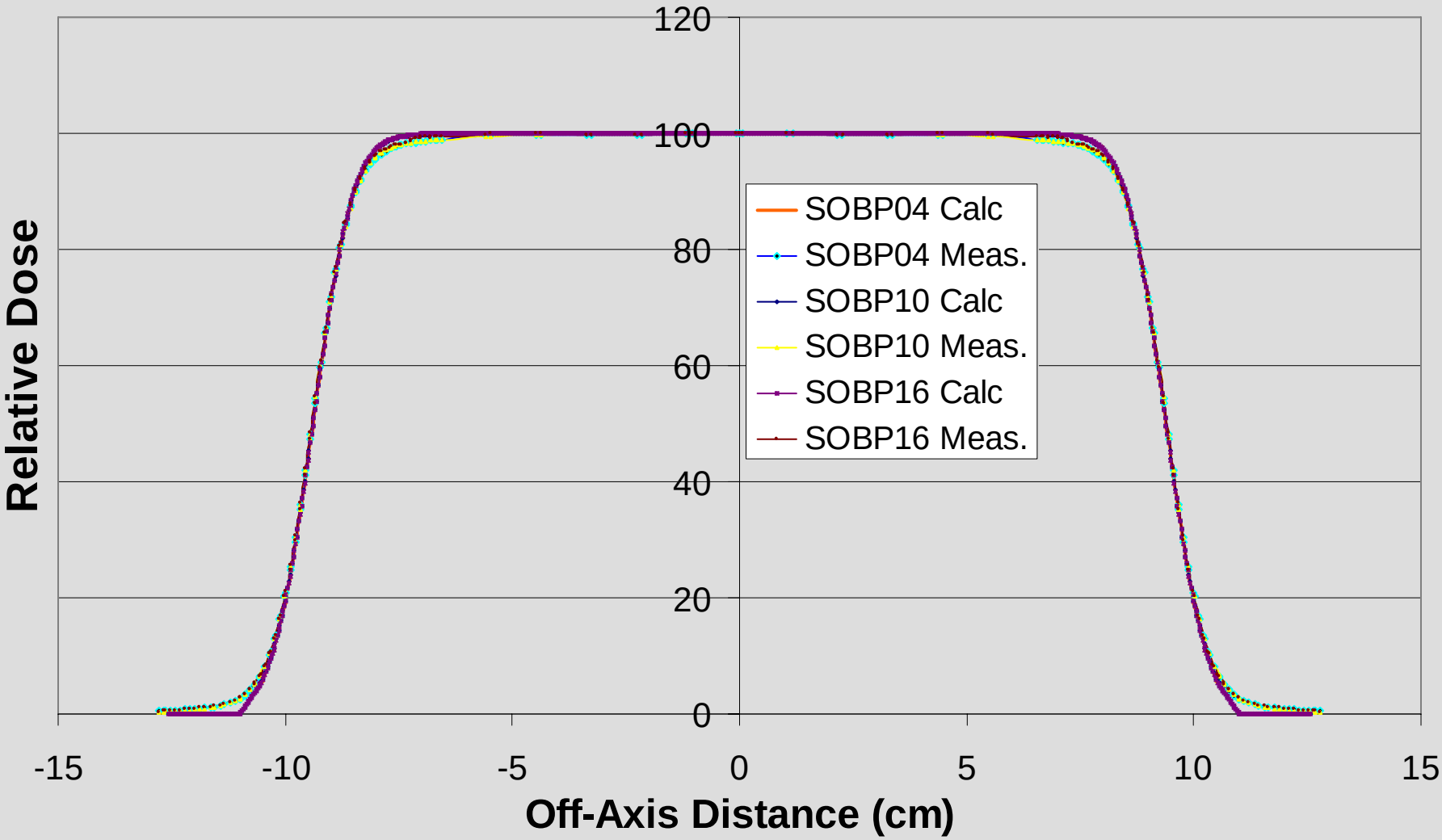

G2-250 MeV, 10 cm SOBP
PDD
120
100
80
60
40
20
0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
Depth (mm)
Meas. 10.2 cm
Calc 10.1 cm


G2-160 MeV, 4 cm SOBP
PDD
120
100
80
60
40
20
0
0 20 40 60 80 100 120 140 160
Depth (mm)
Meas. 4.0 cm
Calc 4.2 cm

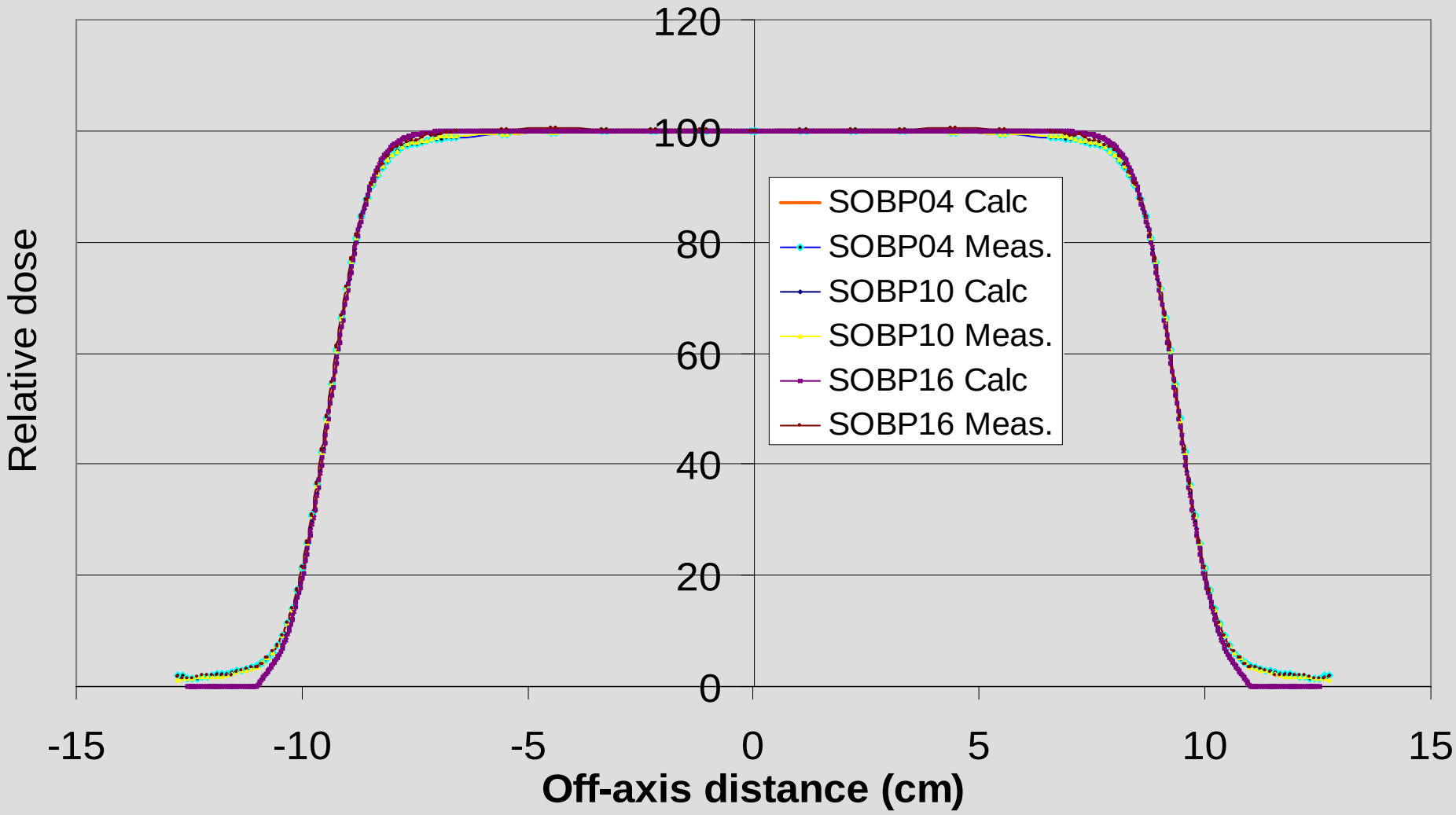
Results-Profile



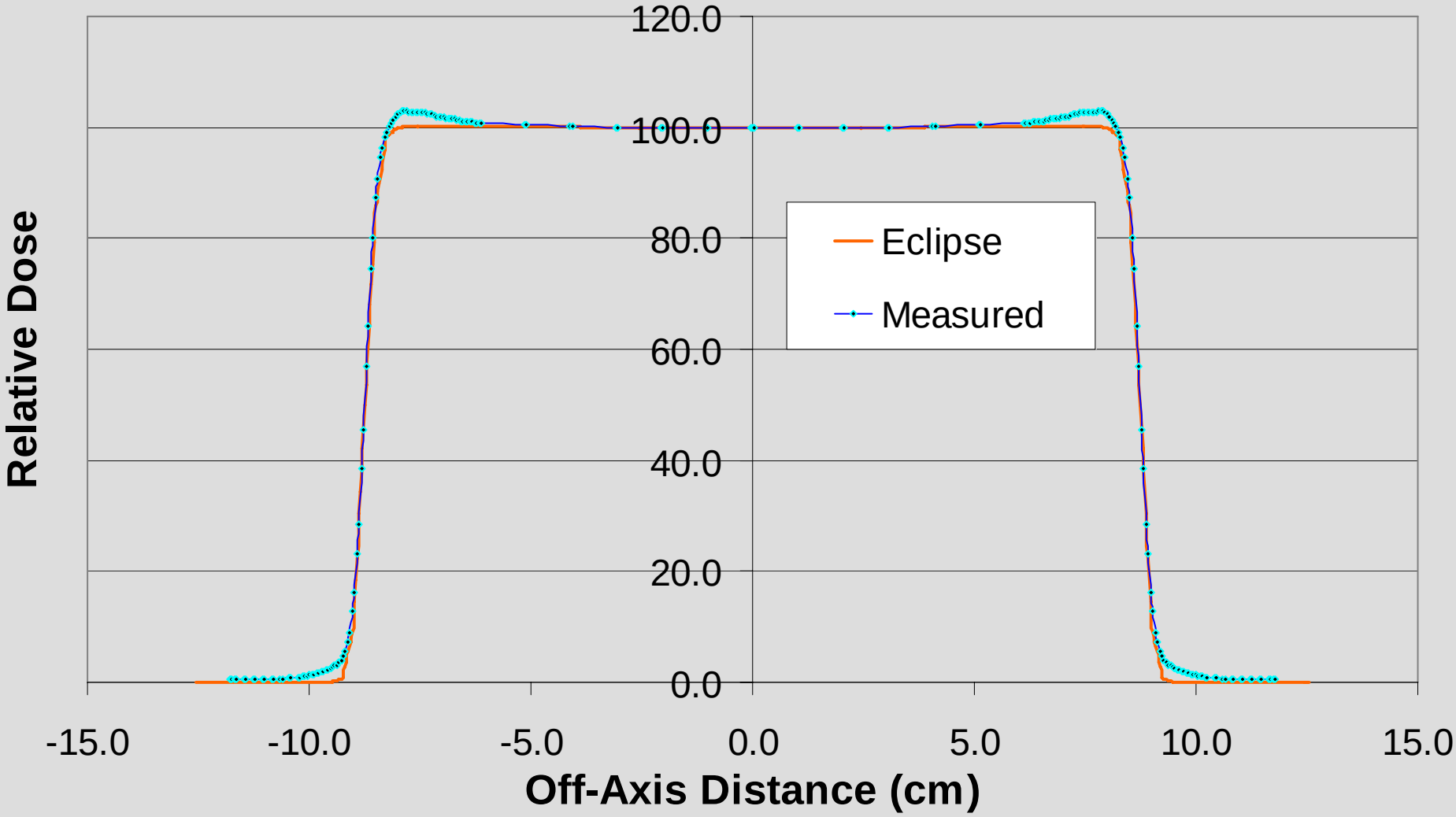
G2, RMW 91, 250 MeV, d= 23.3 cm, Cross Plane

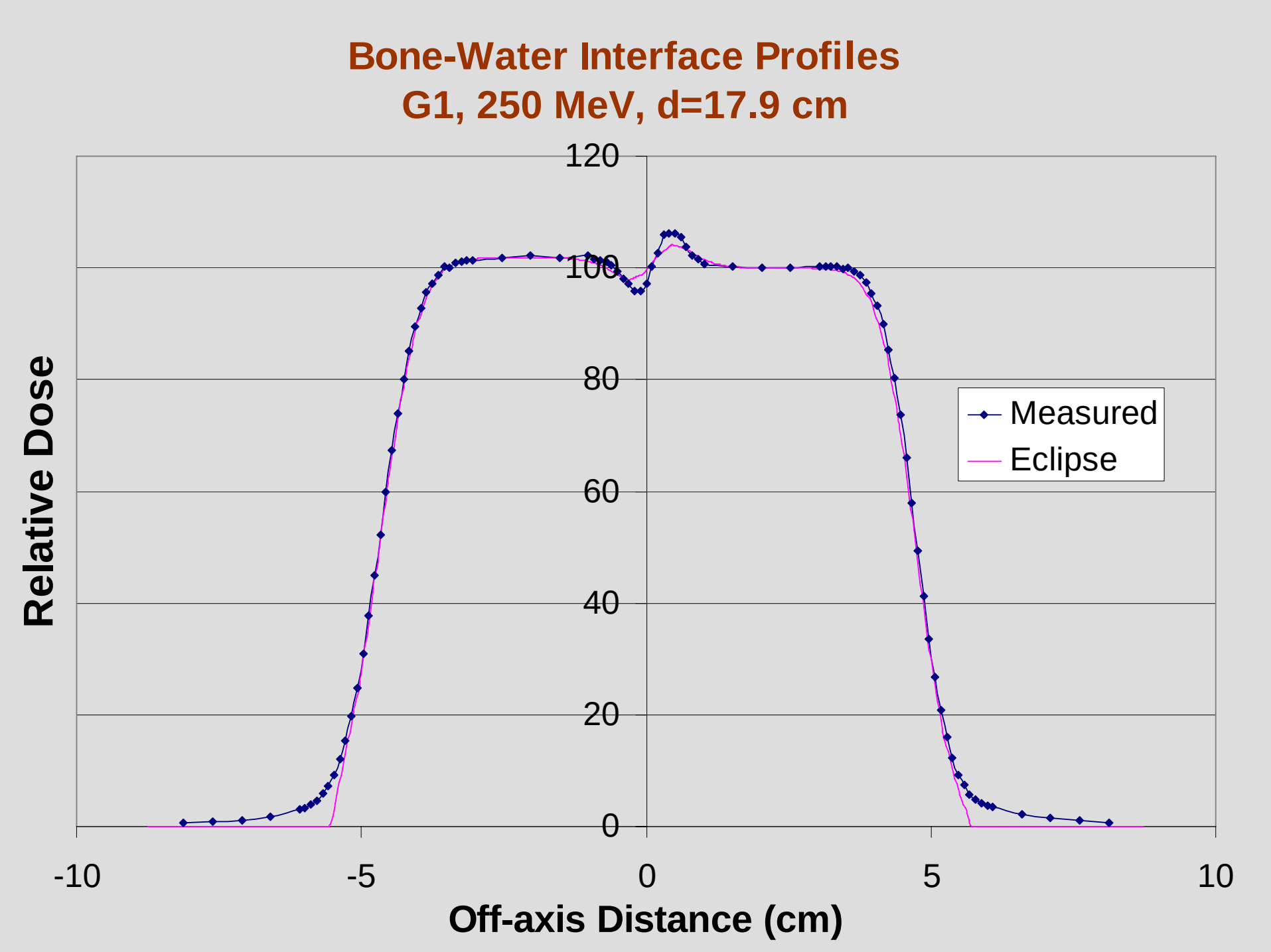


G2, RMW 91, 250 MeV, d=23.3 cm, In Plane



G2, RMW 76, 160 MeV, SOBP 4 cm, d=6 cm, Cross Plane




Bone-Water Interface Profiles
G1, 250 MeV, d=17.9 cm
Relative Dose
120
100
80
60
40
20
0
-10
-5
0
5
10
Off-axis Distance (cm)
Measured
Eclipse

Summary

- Good agreement was found between the distal portion of the measured and calculated spread out Bragg Peaks (SOBP)
- The agreement in the proximal portion is not as good as the distal portion
- May be due to simplified assumption of single step illumination by the proton beam instead of multiple steps of RMW
- This issue will be addressed in newer versions of Eclipse.

Summary

- Agreements with the profile measurements are good within the edges of the beam
- Rapid dose fall-off beyond 20% dose level
- May be due to inadequate modeling of angular confusion of protons
- Eclipse calculated profiles in a bone phantom-water heterogeneous medium agrees well with the measurement

Conclusion

- Eclipse input data can be acquired within a reasonable time period
- Pencil-beam model of Eclipse calculates the dose distribution for protons fairly accurately, but needs further improvement
- Work is in progress to test further the accuracy of Eclipse model in heterogeneous media

Thank you for your attention

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Angular confusion and divergence

"All beam-line elements introduce a certain angular confusion to the beam. The total effect of this confusion can be measured as the shape of the penumbra behind a half-blocked beam.

Angular Confusion describes the range of directions (about some mean angle) which protons passing through any given point may have.

Angular divergence measures the variation in that mean angle over a plane perpendicular to the beam's central axis." From Eclipse Planning Reference Guide for Proton Algorithm

- Only angular divergence leads to sharp and magnified image
- Only Angular confusion leads to fuzzy unmagnified image