

# Proton Therapy: Computational Problems and Proposed Benchmarks

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*Making Cancer History™*

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# Proton Therapy Calculations: Tools & History

- 1946 *Wilson proposes proton therapy*
- 1954 *Tobias et al treat patients w/ 340 MeV p at LBL*
- 1970s Three dimensional imaging (Computed Tomography)  
3-D broad beam dose algorithms
- 1990s Pencil beam dose algorithms for treatment planning  
Monte Carlo used to study neutron shielding
- 2000s Treatment planning dose algorithms (PB, MC, SN?)  
Patient neutron exposures (MC)  
Commissioning studies (MC)  
*D/MU* predictions (MC, analytical semi-empirical)
- 2005 24 proton centers (4 in USA)  
~40,000 patients treated in total

# Review of Proton Therapy Computational Literature

- Examined > 300 proton therapy papers
- > 86 proton Monte Carlo papers
- 21 include potential benchmark data
- Majority deal with nozzle modeling and proton absorbed dose in patient
- Wide variety of applications including nozzle design, code intercomparisons, dosimetry correction factors, RBE, etc.

# Proposed Benchmark #1: Neutron Shielding



Potentially huge  
cost savings to  
society  
(~700k per facility)

Some experimental  
data is available in  
the literature

Challenging  
benchmark!!!

# The Moyer Model for Slab Shielding

SHIELDING OF PROTON ACCELERATORS: A COMPARISON BETWEEN THE MOYER MODEL AND MONTE CARLO CALCULATIONS

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$$H(z) = H_0 \left( \frac{E}{E_0} \right)^{\alpha} e^{-\beta\theta} \frac{\exp(-d/(\lambda_H \sin \theta))}{r^2}$$

Production

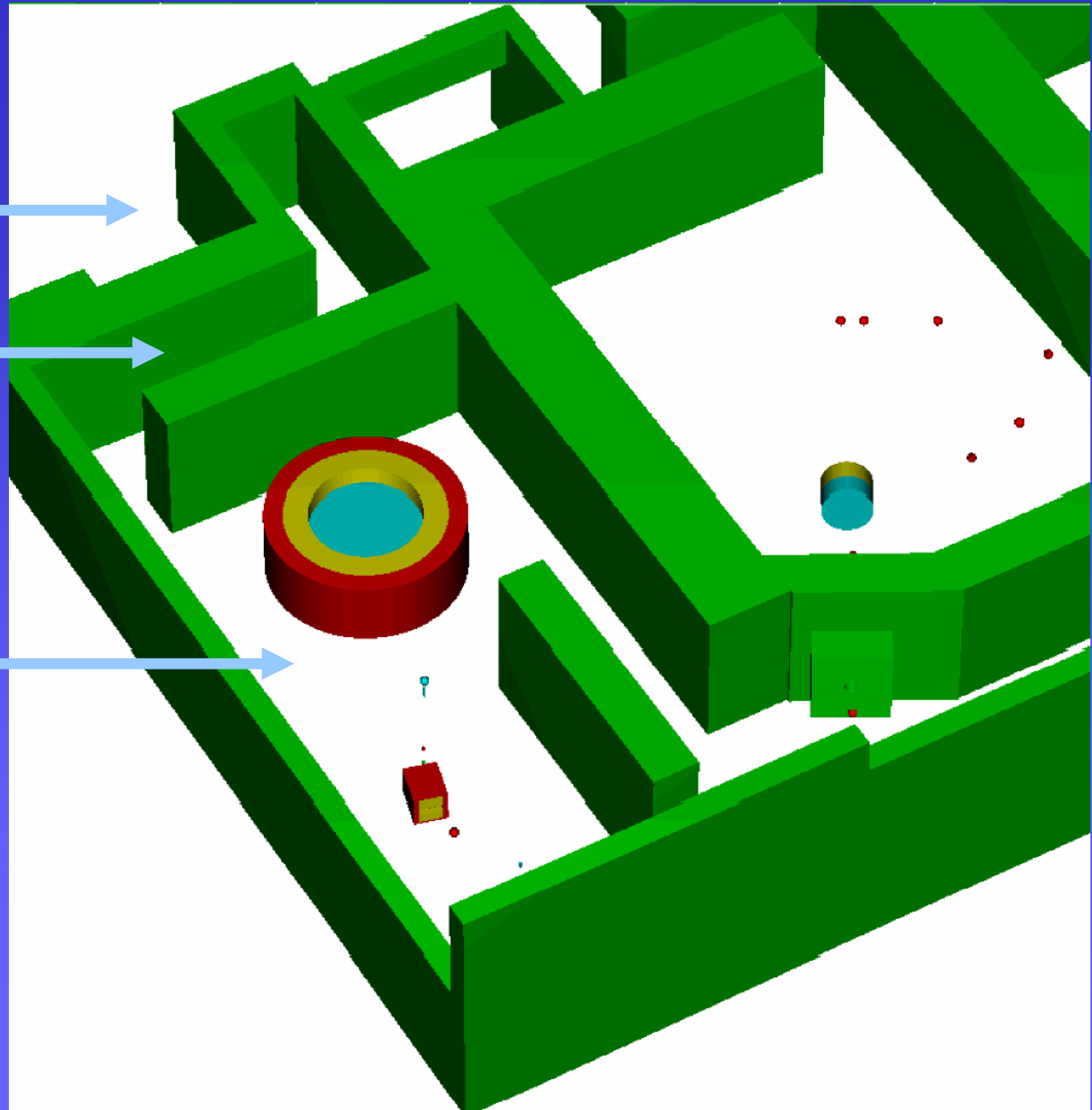
Angular  
Distribution

Attenuation,  
Inverse Square

Control  
Room

Maze

Cyclotron  
Vault



$H_a$

$H_{MC}$

# Predicted/Measured

$H_m$

$H_m$

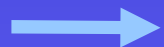
63

1.1



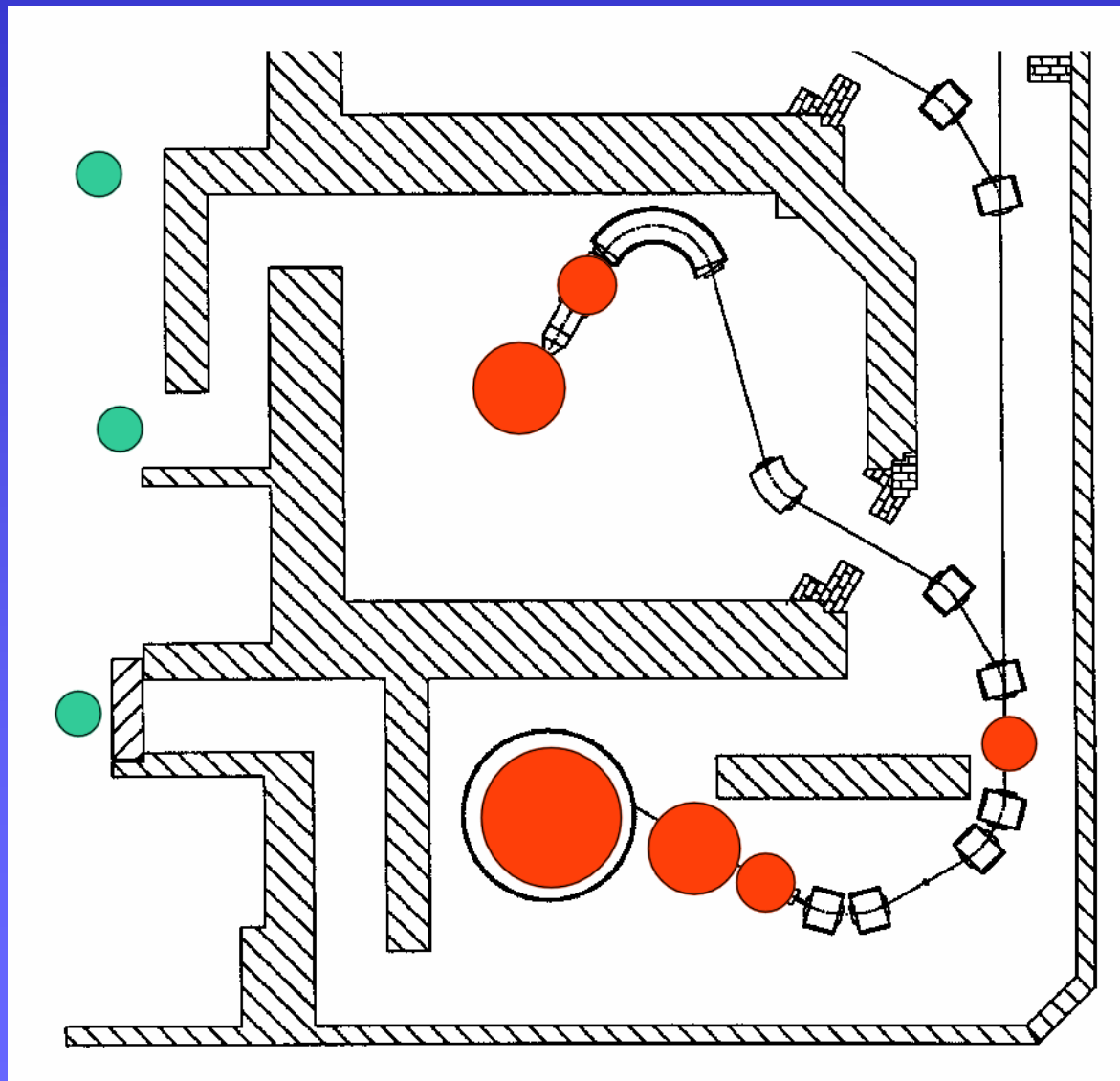
0.9

1.3

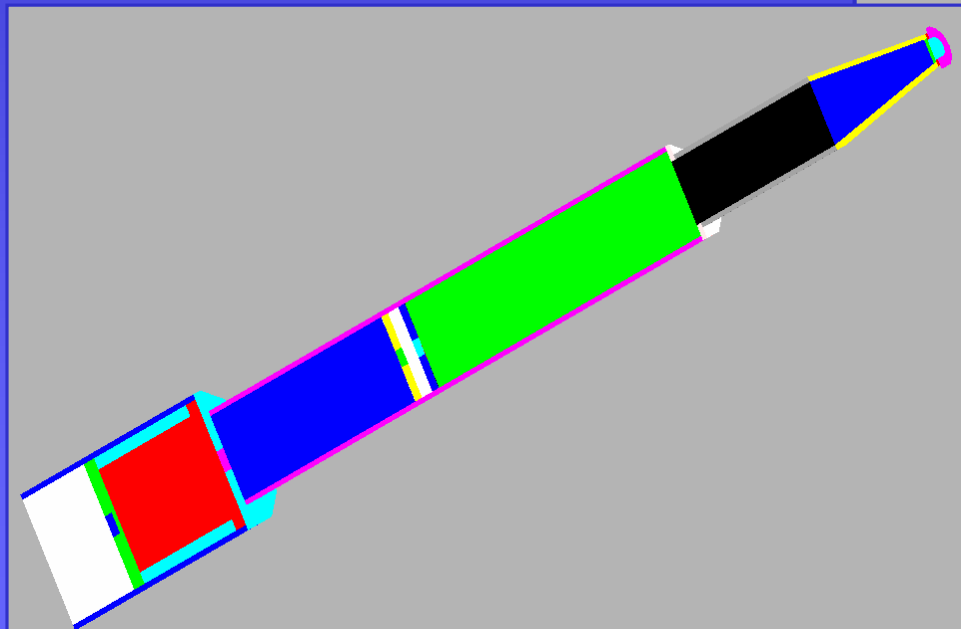
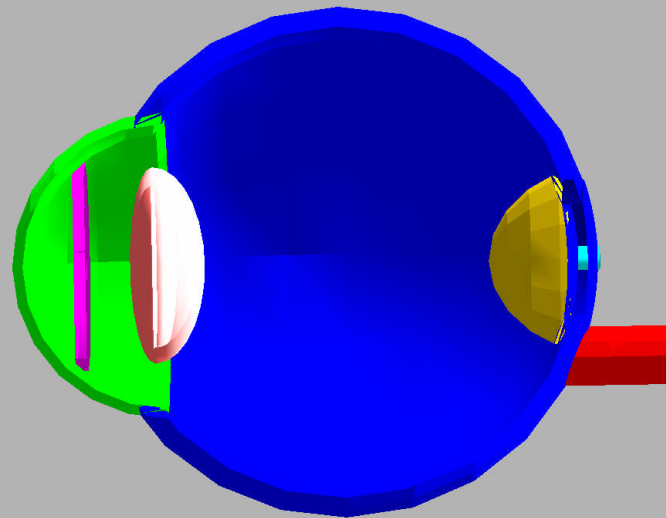


100

7.1



# Proposed Benchmark #2: Ocular Proton Therapy



Relatively simple yet  
clinically realistic and  
very informative.

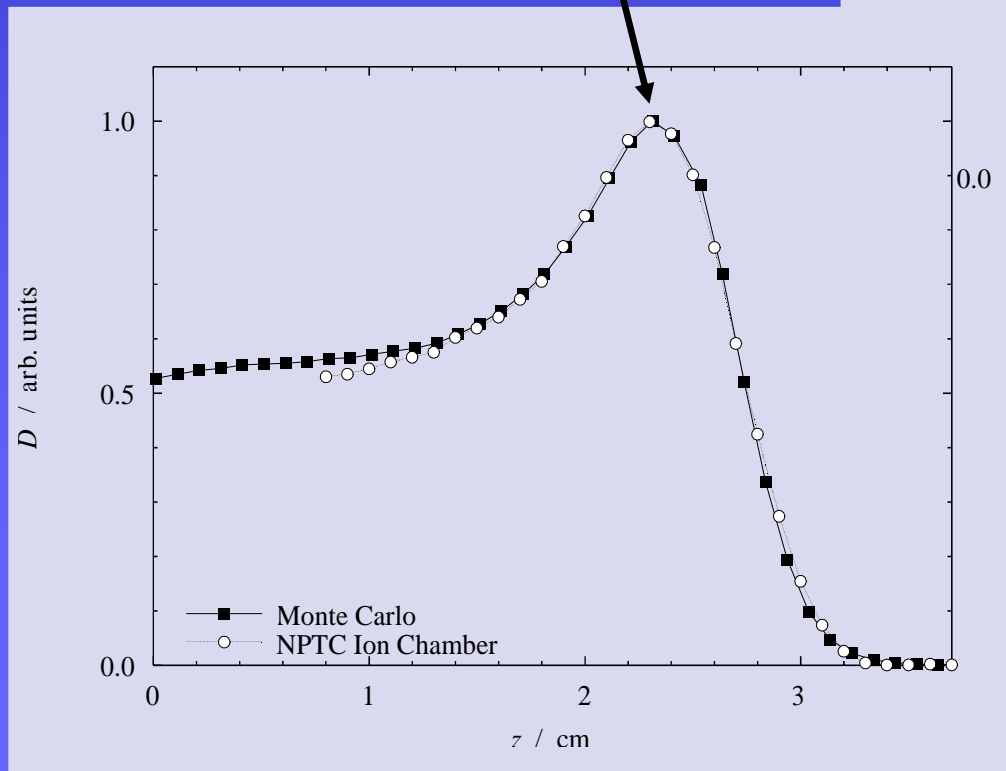
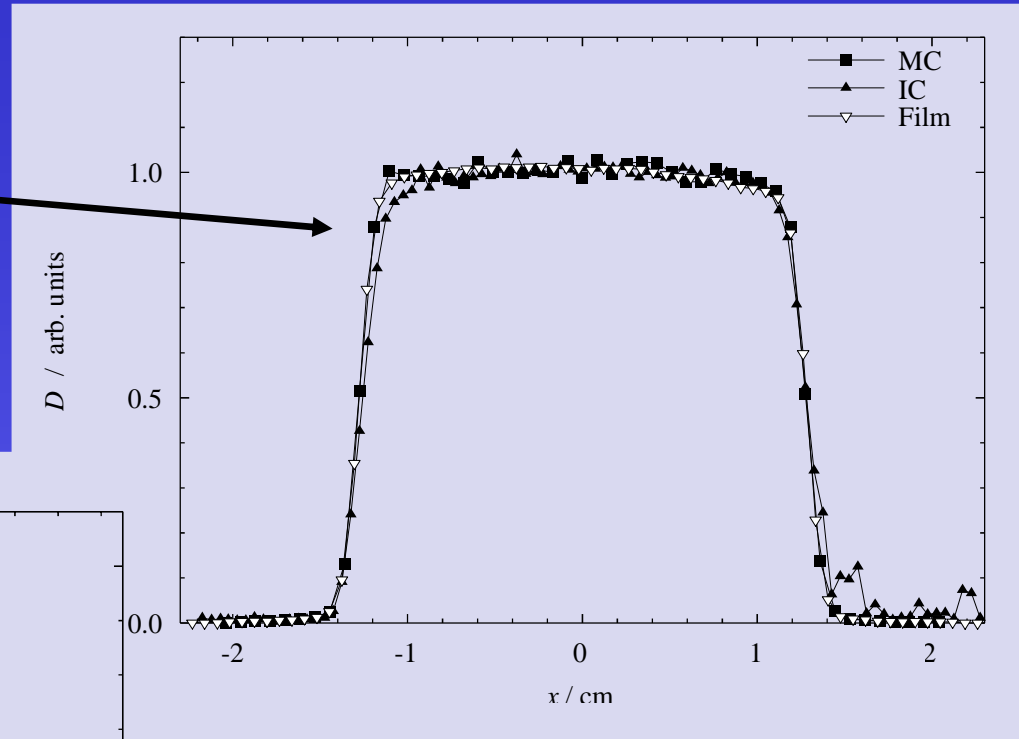
Precedent: Quados  
Problem P3 by Augusteo.



# Absorbed Dose:

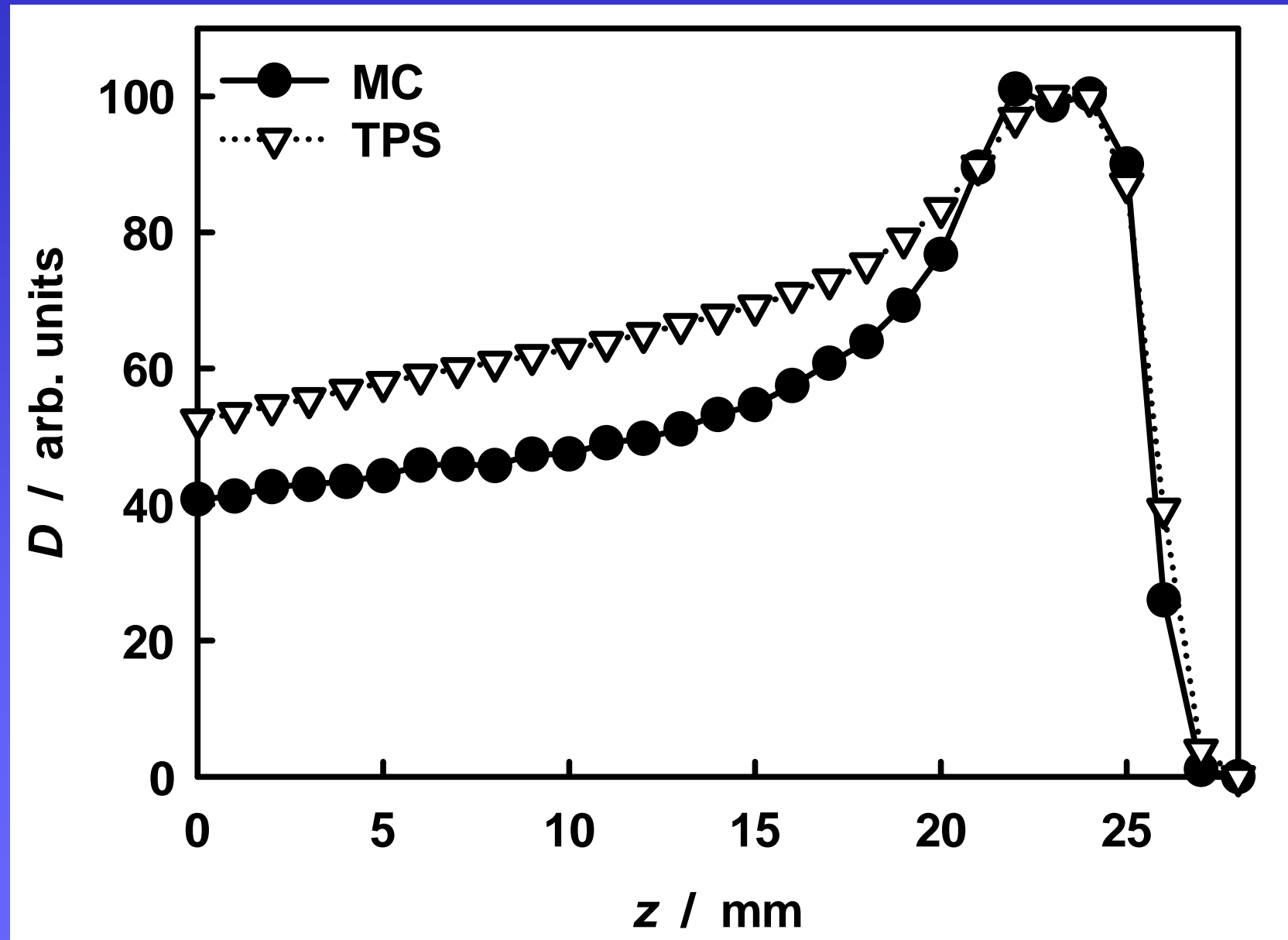
Cross Field

CAX PDD



+ Neutron Dose Equivalent

# Comparison of MC vs. Broad Beam



# Why Benchmarks Now?

- Urgent need for better predictive tools
- Overcome barriers to adoption
  - Accuracy: Would you use this on your child?
  - Speed: Is this fast enough for routine use?
  - Cost/Difficulty: Can a small clinical validate it?
- New predictive tools can reduce cost of proton therapy
  - ~ \$30k/d of delay just before startup
  - 5 weeks of pre-clinical commissioning = \$1M

# Challenges

- Proprietary designs (therapy equipment, shielding)
- Balancing simplicity vs. clinical realism
- Designing the benchmarks to reveal weakest regimes
- Packaging (publications, sample data sets, etc.)
- Resources
  - Time & money (grant?)
  - Beam time
  - Computation time (ORNL?)