Out-of-field Dose Reconstruction for Proton Therapy and Measurement of Secondary Neutron Dose
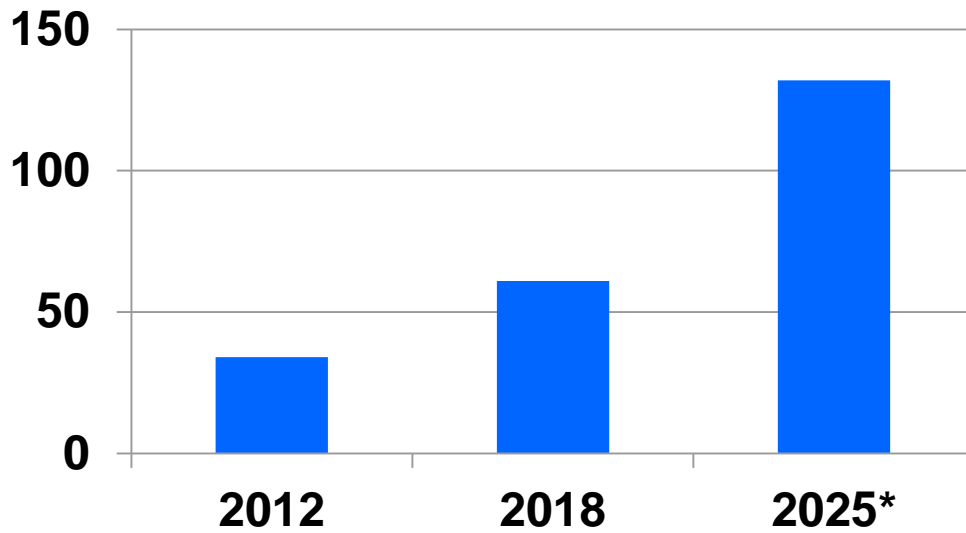
Yeon Soo Yeom

2019 CIRMS Meeting – Session I: Medical Applications
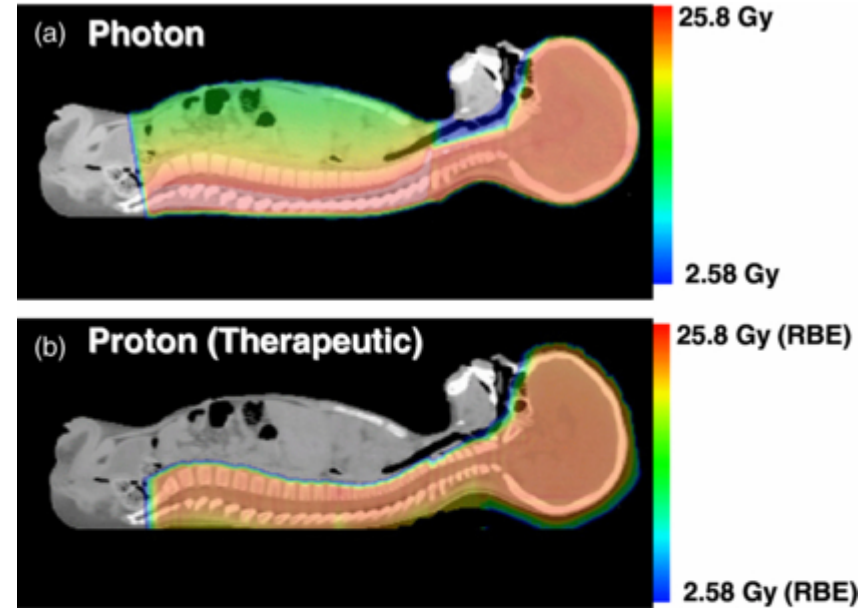
8th April 2019

NIH **NATIONAL CANCER INSTITUTE**

Late-Effects of Pediatric Proton Therapy?

Number of Proton Centers Worldwide

(a) Photon — 25.8 Gy / 2.58 Gy

(b) Proton (Therapeutic) — 25.8 Gy (RBE) / 2.58 Gy (RBE)

*projected based on construction plans

Zhang et al, *Physics in Medicine and Biology* (2013)

COMMENTARY

# A Clarion Call for Large-Scale Collaborative Studies of Pediatric Proton Therapy

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Wolfgang Dörr, MD,[§] Daphne Hass-Kogan, MD,[‖]
Johannes A. Langendijk, MD,[¶] Anita Mahajan, MD,[#]
Wayne Newhauser, PhD,** Andrea Ottolenghi, PhD,[††]
Cecile Ronckers, PhD,[‡‡] Reinhard Schulte, MD,[§§] Linda Walsh, ScD,[‖‖]
Torunn I. Yock, MD,[¶¶] and Ruth A. Kleinerman, PhD*

Proton Therapy Dosimetry Consortium

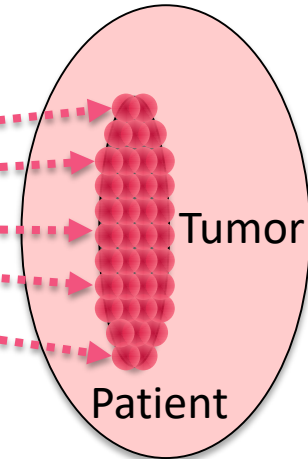# Monte Carlo (MC) Pencil Beam Scanning (PBS) Model

MC Modeling for PBS System

Proton beam

Nozzle

(QUAD, ICs, SMX, SMY, …)

Tumor

Patient

MC PBS model

TOPAS
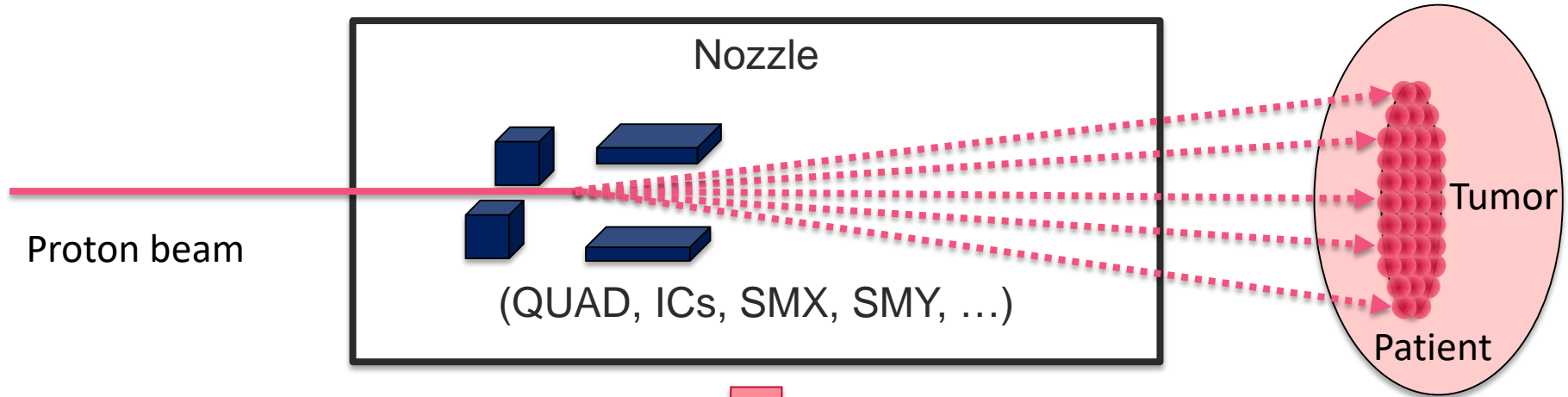
Mean energy (E_0)
Energy spread (σ_E)
Spot size (σ_x, σ_y)
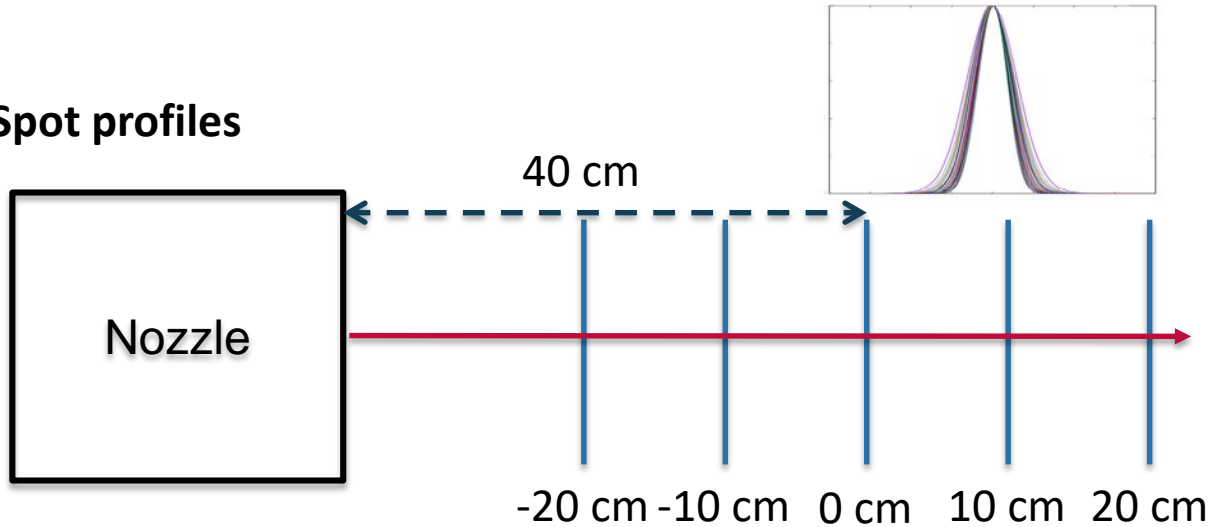Divergence (σ_θ, σ_ϕ)

By matching beam commissioning data of a proton center

Tumor

Patient

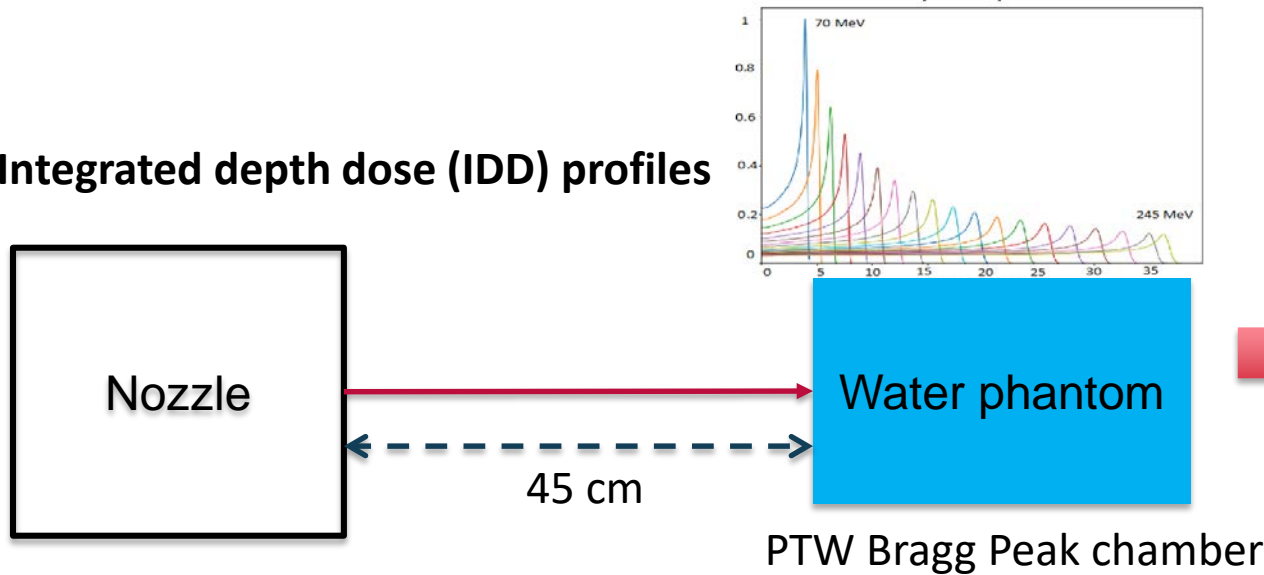# Beam Commissioning Data of Maryland Proton Treatment Center (MPTC)

Spot profiles

40 cm

Nozzle

-20 cm -10 cm 0 cm 10 cm 20 cm

Beam optical properties

Spot size (σ_x, σ_y)
Divergence (σ_θ, σ_ϕ)

Integrated depth dose (IDD) profiles

70 MeV

245 MeV

Nozzle

Water phantom

45 cm

PTW Bragg Peak chamber

Beam energy properties

Mean energy (E_0)
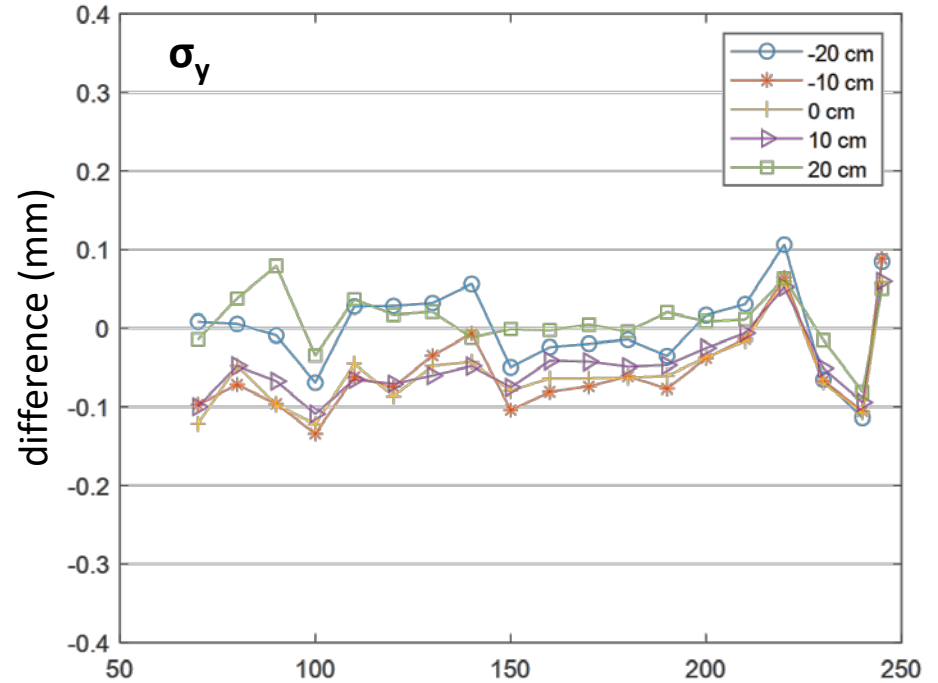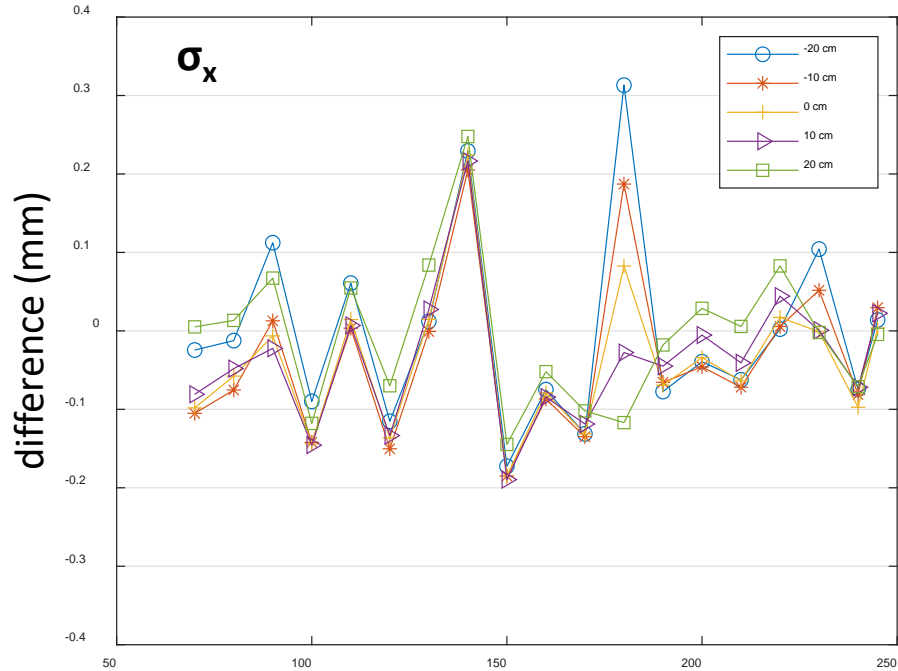Energy spread (σ_E)

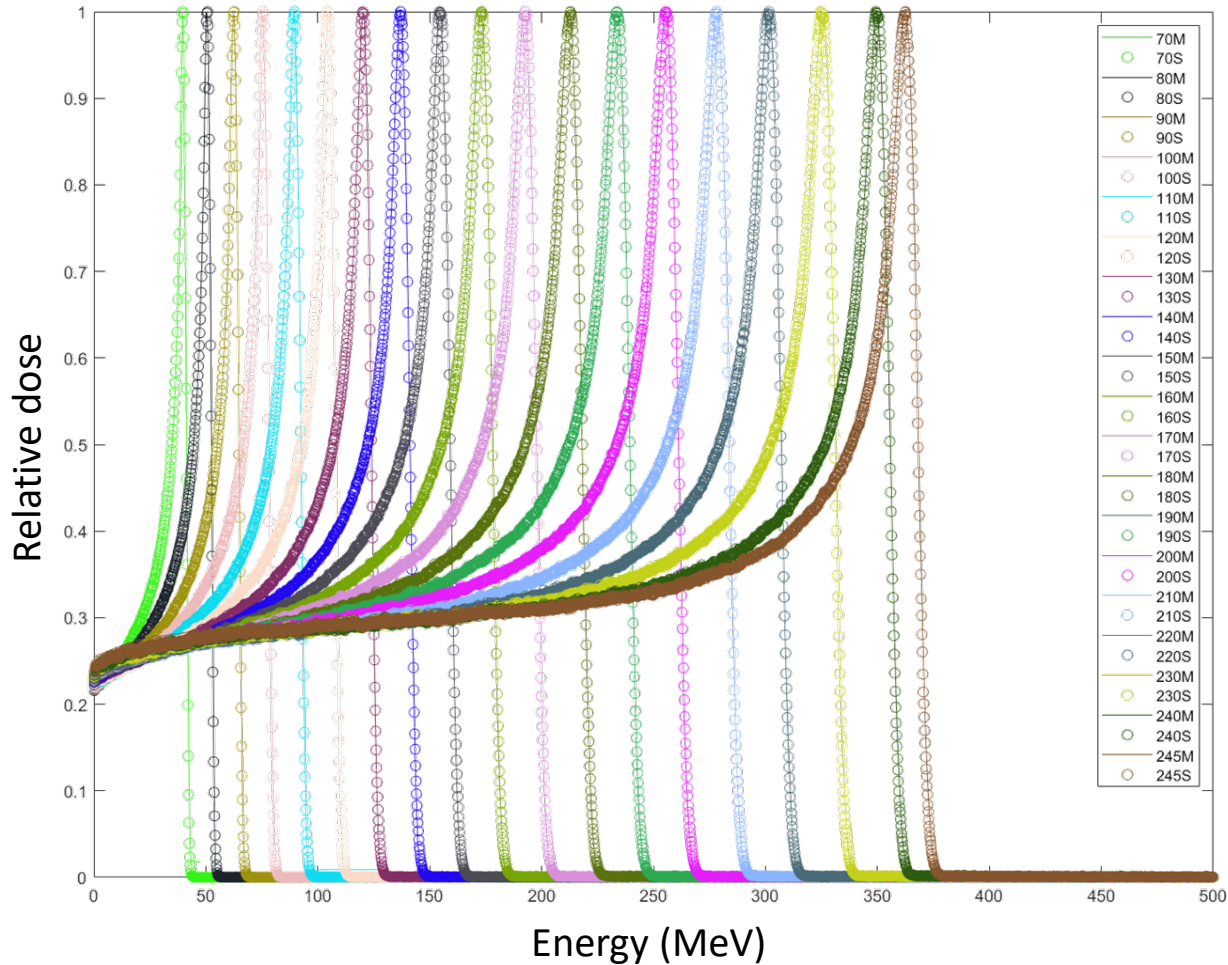# Automatic MC Beam Modeling Program
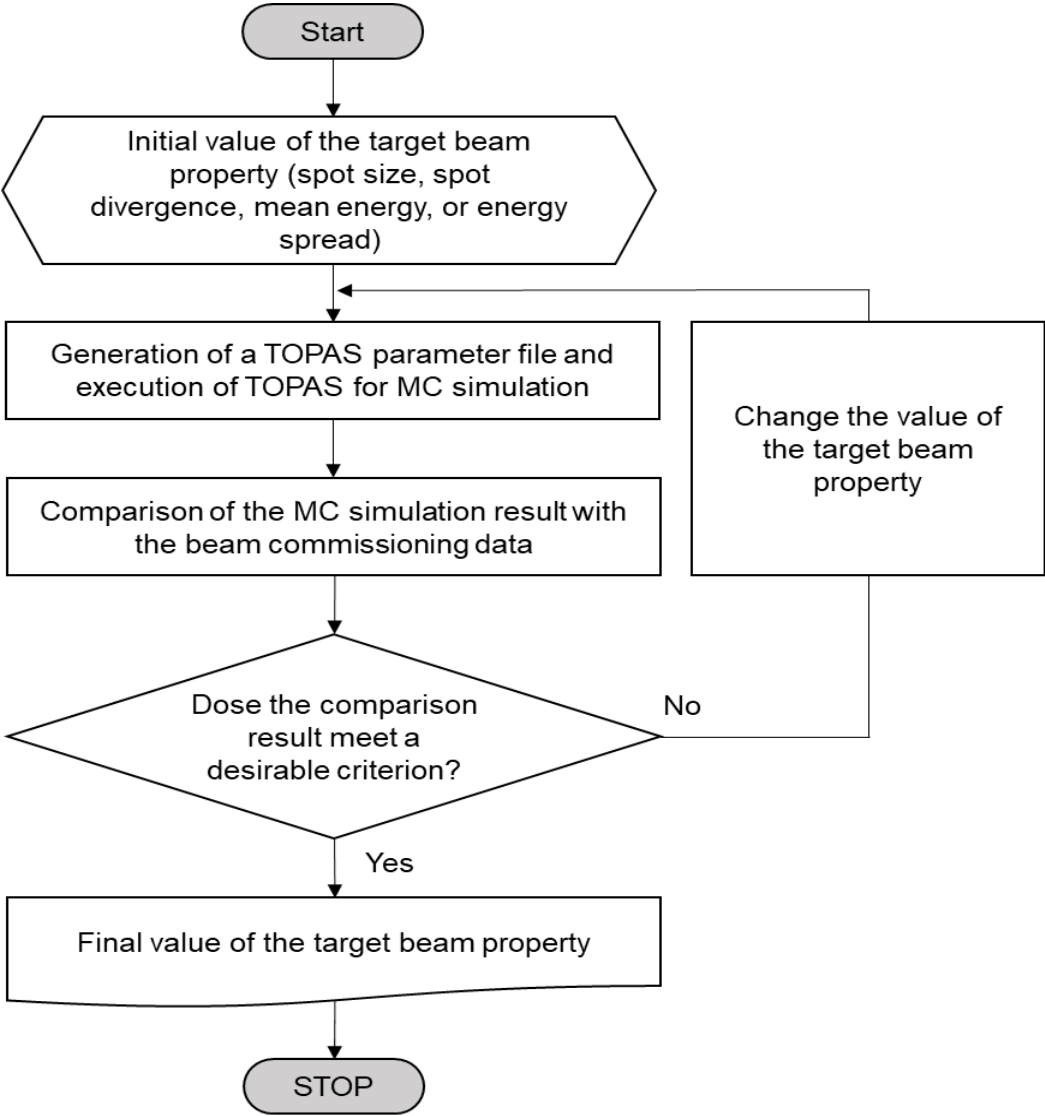
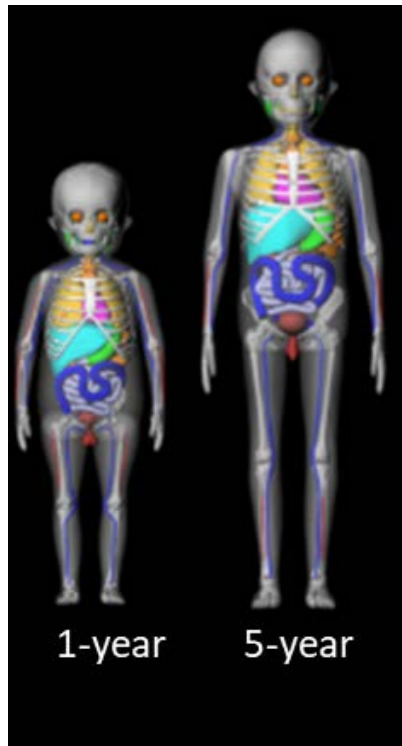# MC Simulation vs Commissioning Data – Spot Sizes

Difference = simulation - measurement

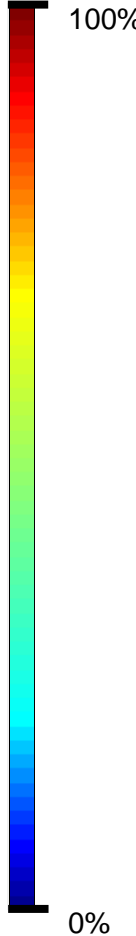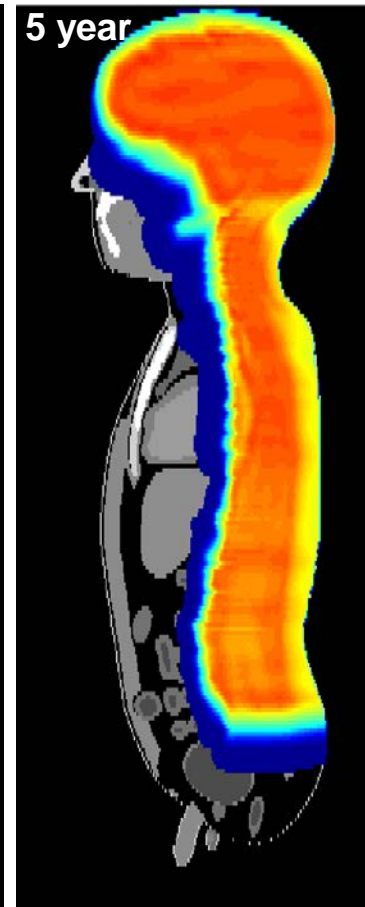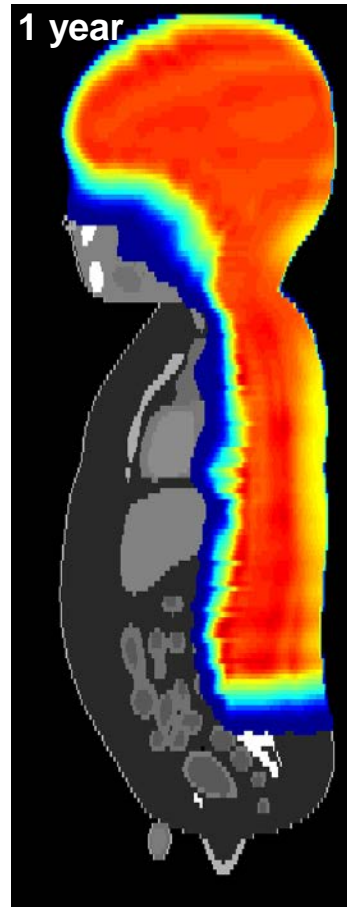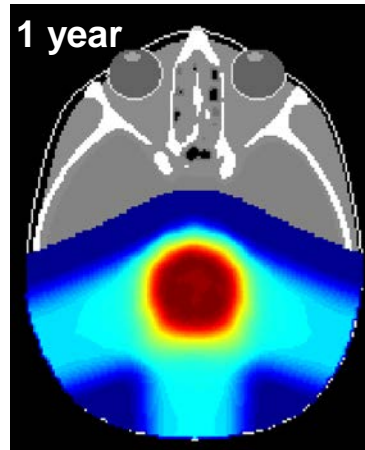# MC Simulation vs Commissioning Data – IDDs

MeV	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	245
ϵ_{mean} (%)	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Proton Irradiations

NCI computational phantoms
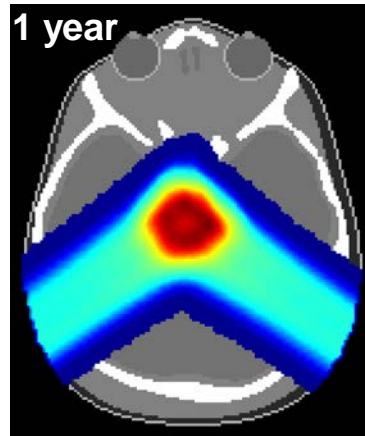
Created by Treatment Planning System of MPTC

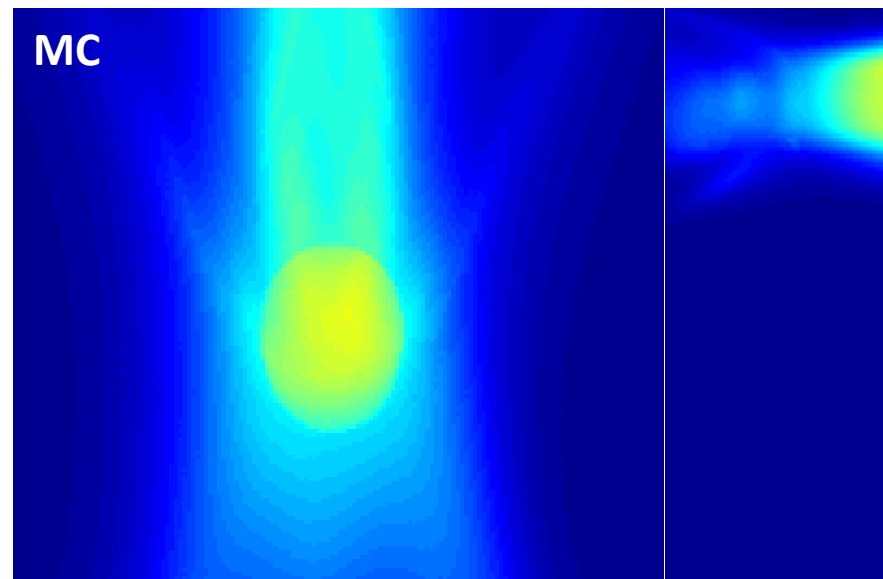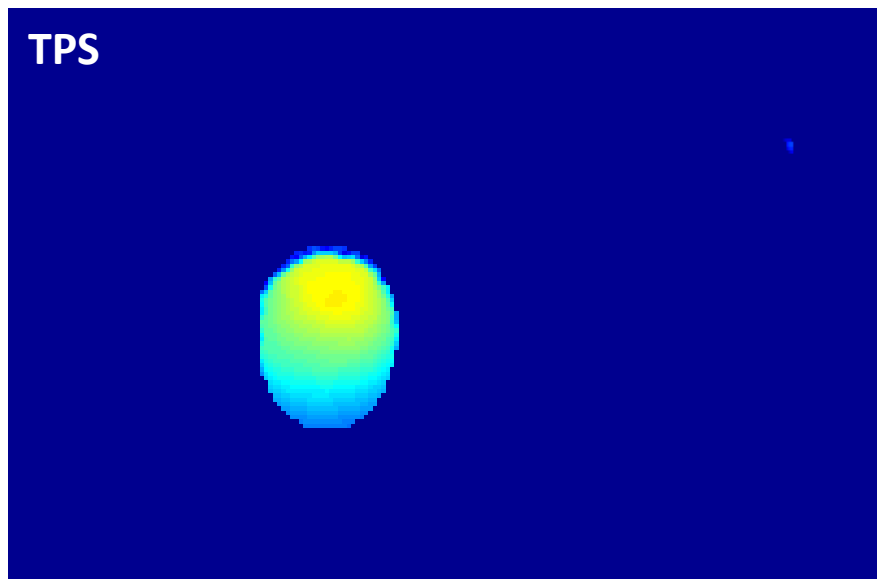# Dose Distributions (TPS vs MC)

5 year – intracranial irradiation

TPS

MC

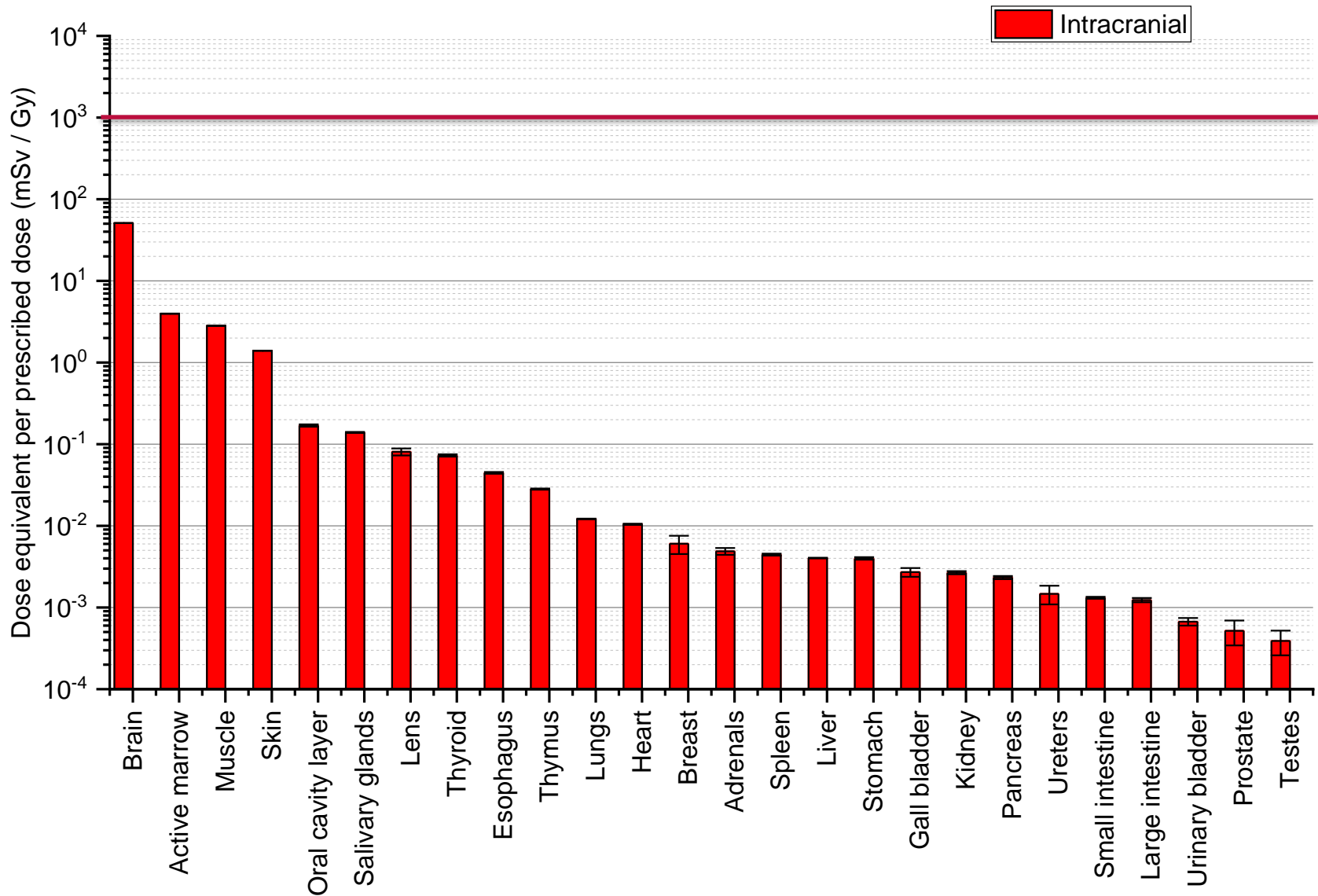**Gamma index passing rate (3 mm, 3%): 99%**

Dose Distributions (TPS vs MC)

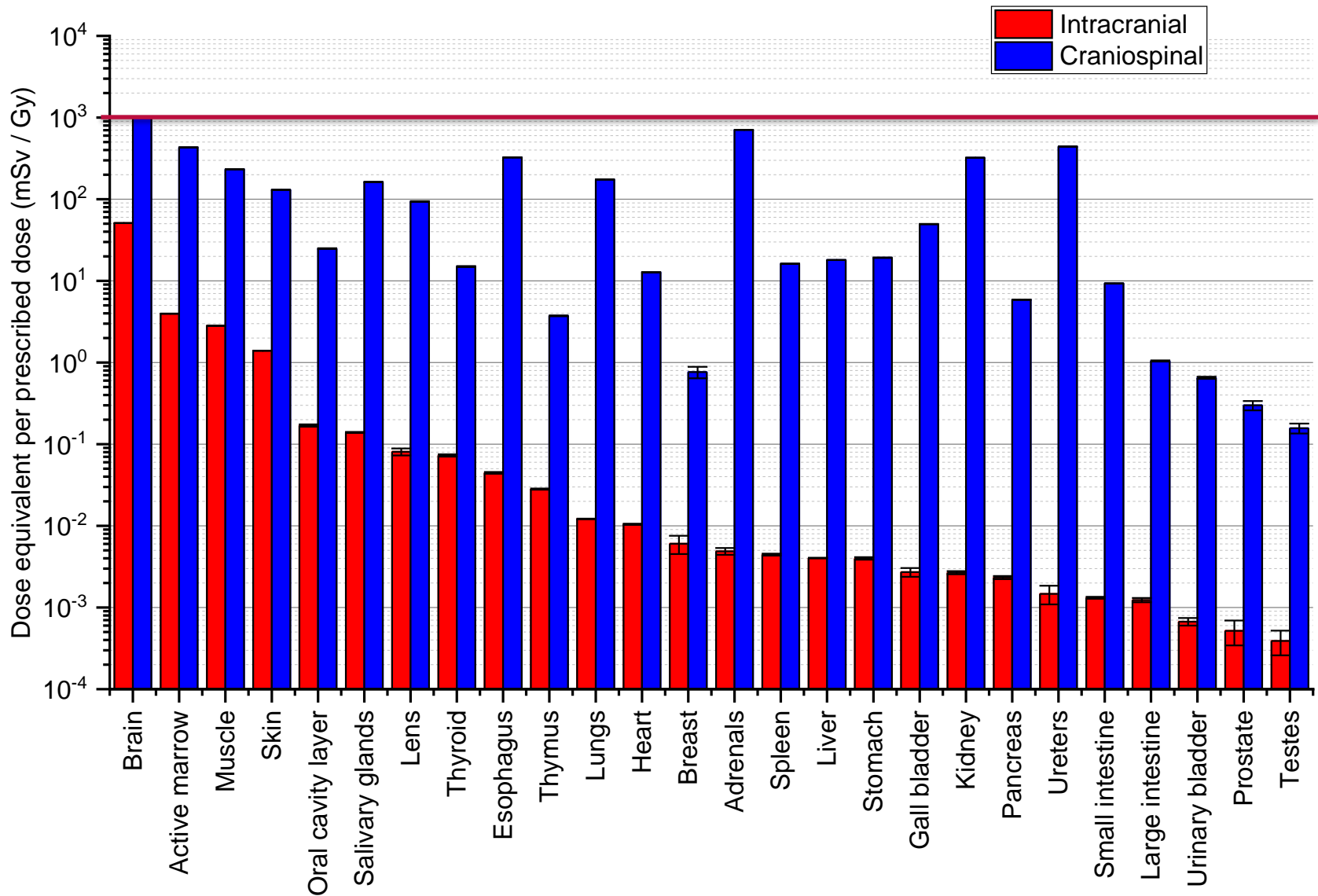**1 year - craniospinal irradiation**

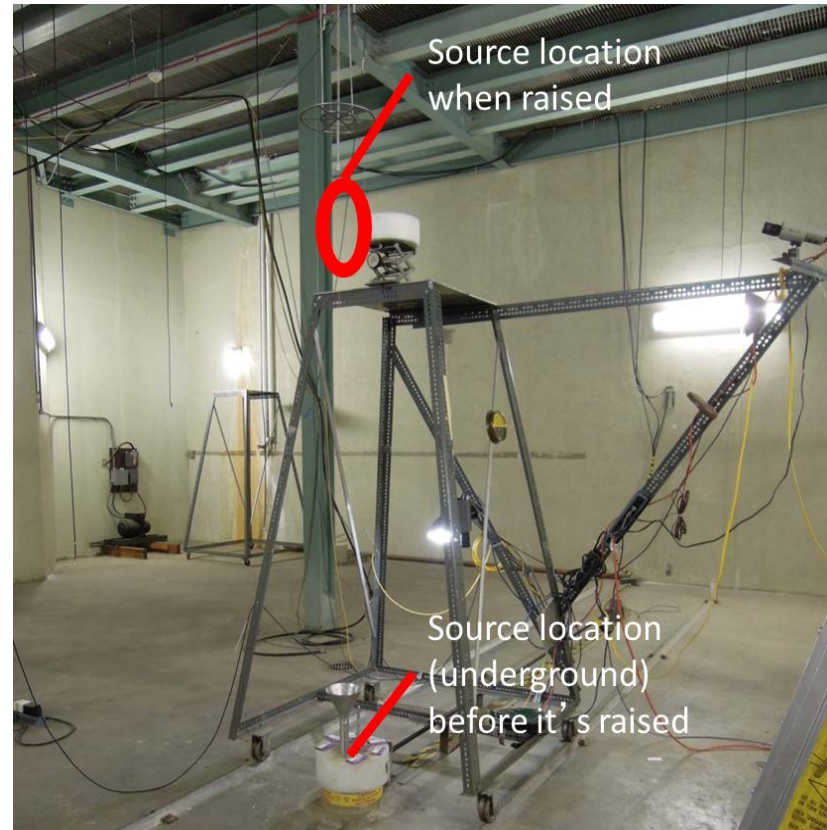**Gamma index passing rate (3 mm, 3%): 98%**

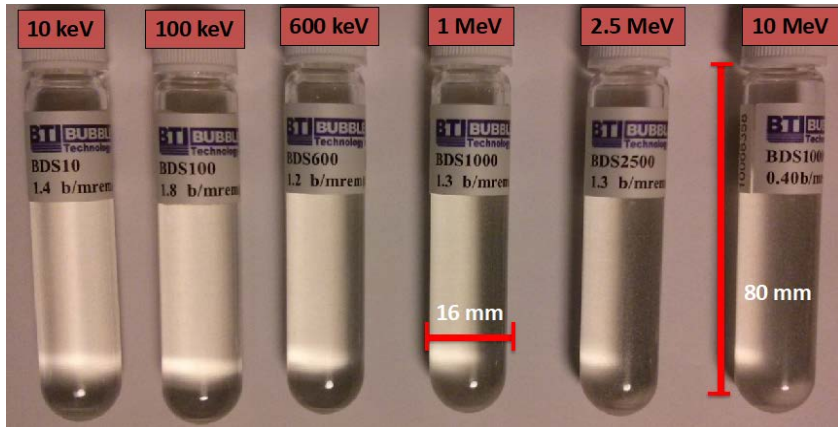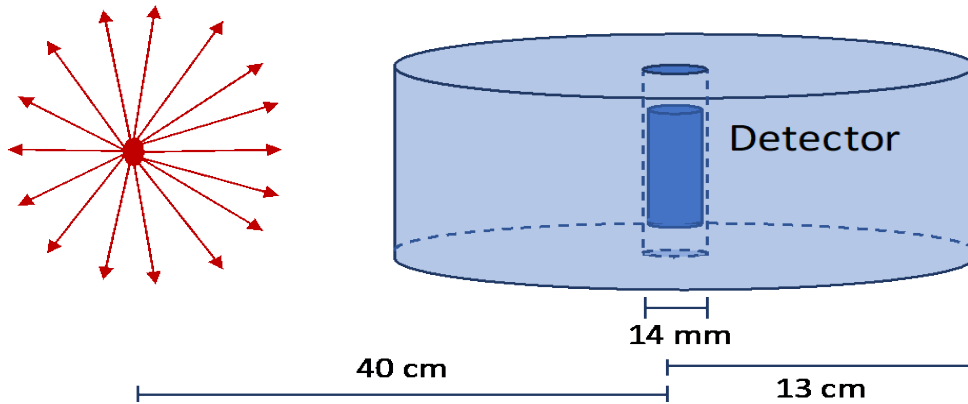# Organ Doses – 1 year

Organic Doses – 1 year
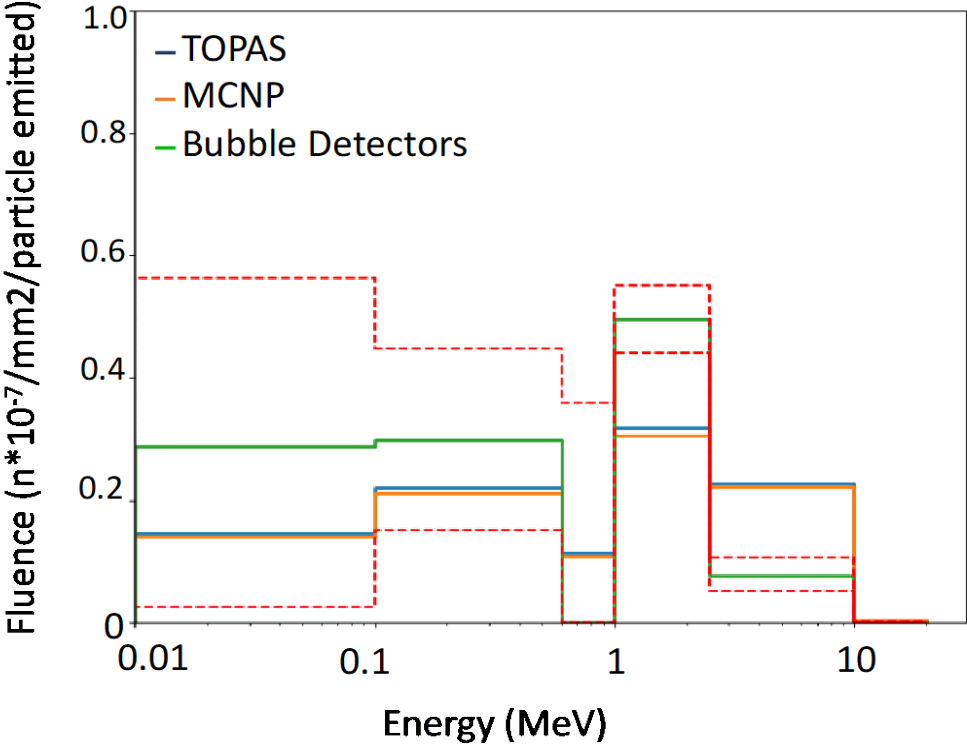
Secondary Neutron Measurement to Validate MC Model

Neutron Spectrum Measurement at NIST

Neutron Source: Cf-252
(Mean energy: 2.1 MeV)

Polyethylene phantom

Detector

14 mm

40 cm

13 cm

10 keV 100 keV 600 keV 1 MeV 2.5 MeV 10 MeV

BDS10 1.4 b/mrem
BDS100 1.8 b/mrem
BDS600 1.2 b/mrem
BDS1000 1.3 b/mrem
BDS2500 1.3 b/mrem
BDS1000 0.40b/m

16 mm

80 mm

Source location when raised

Source location (underground) before it's raised

Measurement vs MC Simulations
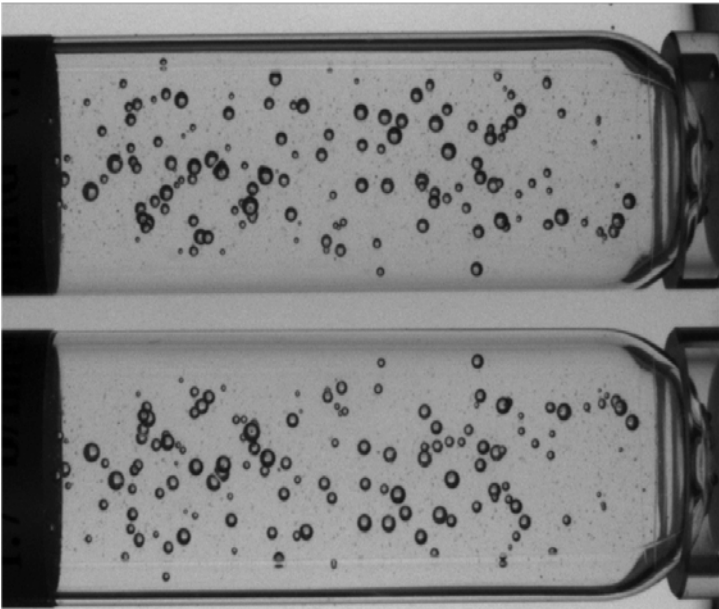
Neutron Dose Measurement at MPTC (Future Plan)

WENDI-2 neutron detector
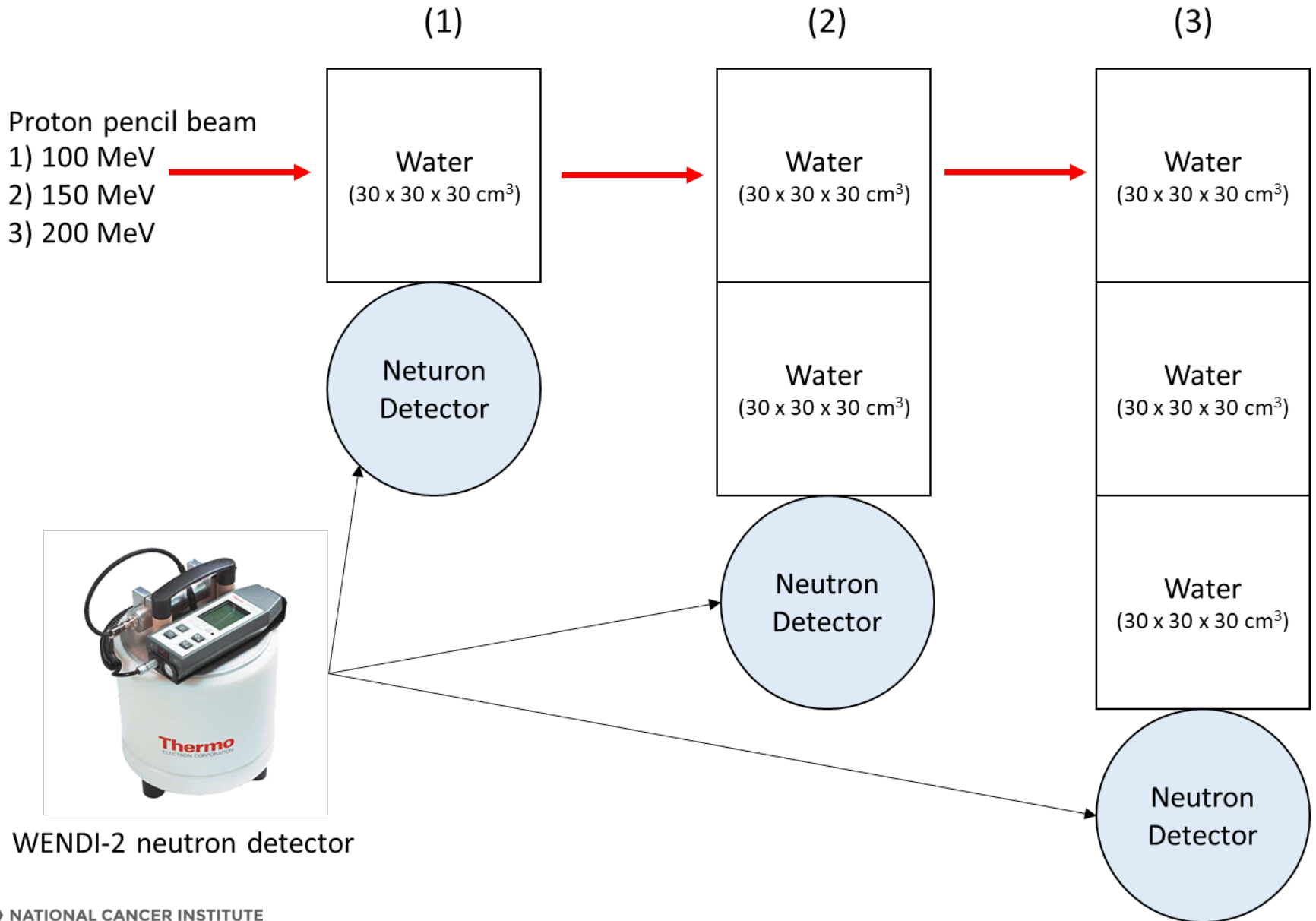
Summary

- The MC PBS model was developed for dose reconstruction of proton patients for epidemiological studies of late effects.

  - Dose reconstruction for Pediatric Proton/Photon Consortium Registry (PPCR)

- Experimental measurement of out-of-field dose (i.e., secondary neutron dose) is critical to validate the MC model

  - Collaboration work with experts in neutron measurement field and supports by proton centers (e.g., beam times)

Thank you!