Commissioning of Treatment Beam

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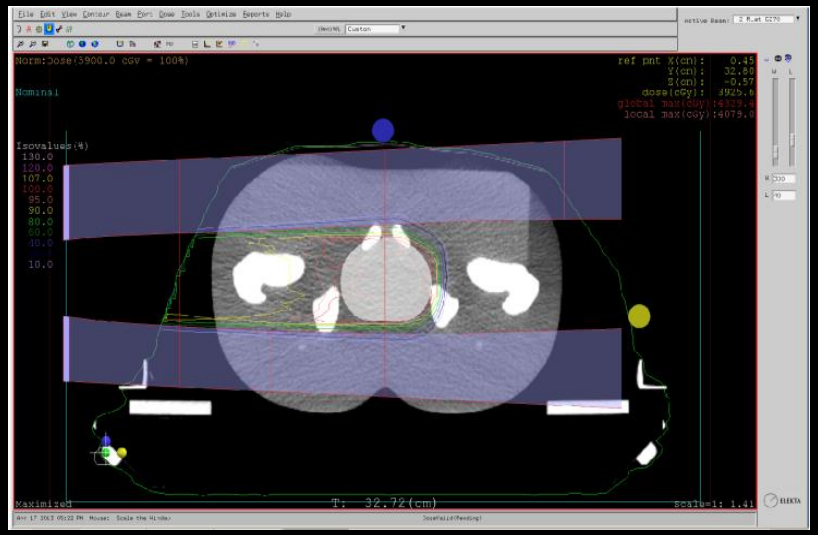
Westdeutsches Protonentherapiezentrum Essen gGmbH (WPE)

1. Treatment planning is computer simulated
2. Patient is represented by CT images
3. Treatment machine is represented by beam model



1. **WPE started the 1st treatment May 29th, 2013**
2. **Uniform Scanning (US) mode**
3. **Mosaiq as RV system**
4. **CMS XiO as treatment planning system**

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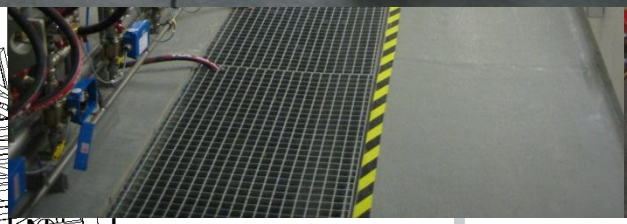
230 MeV Cyclotron

Fixed Horizontal and Eye Beamlines

PBS Nozzle



Universal Nozzle

PBS Nozzle

Gantry 1-3

WPE Essen

Uniform Scanning (1)

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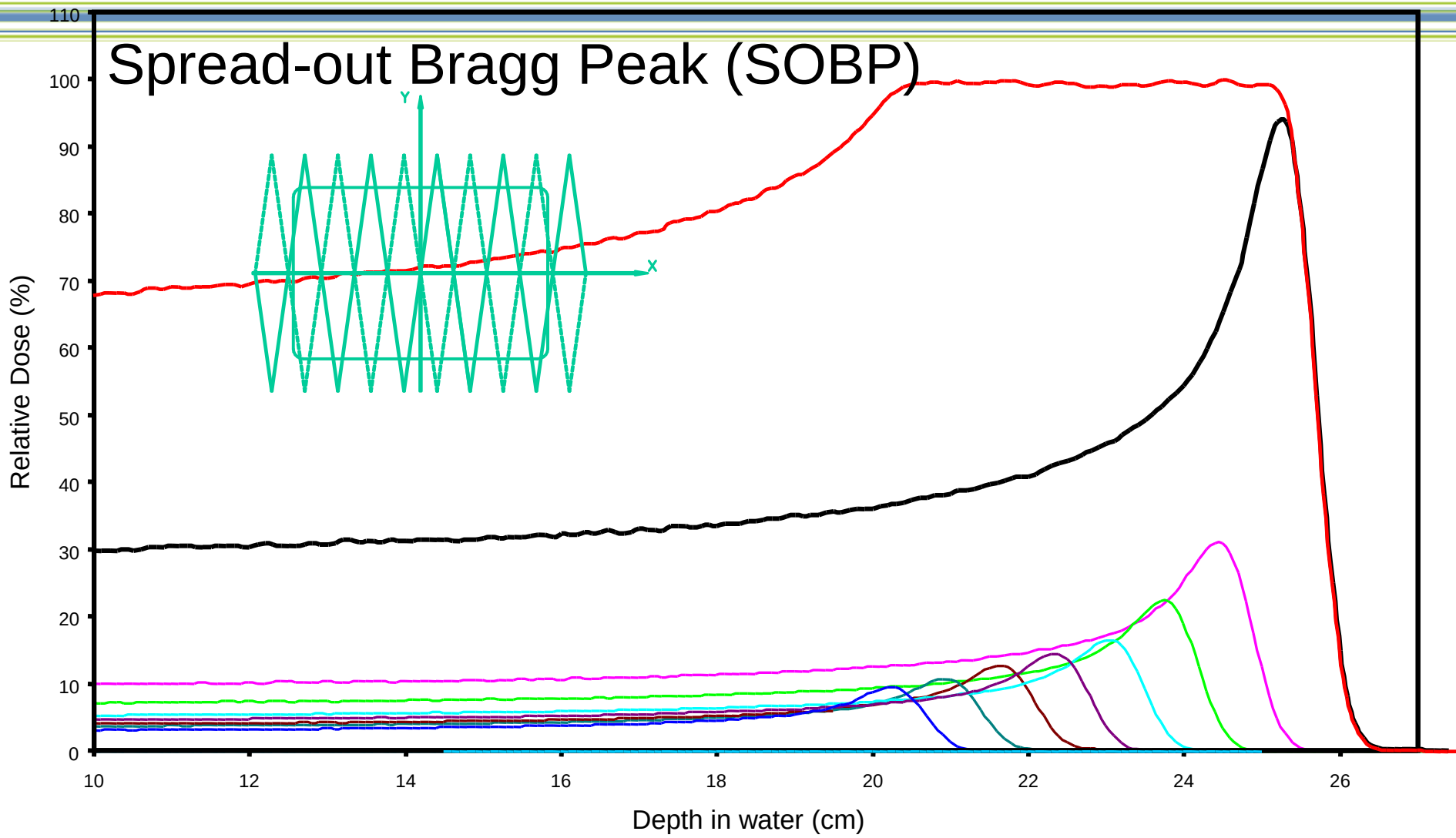

Uniform Scanning (2)

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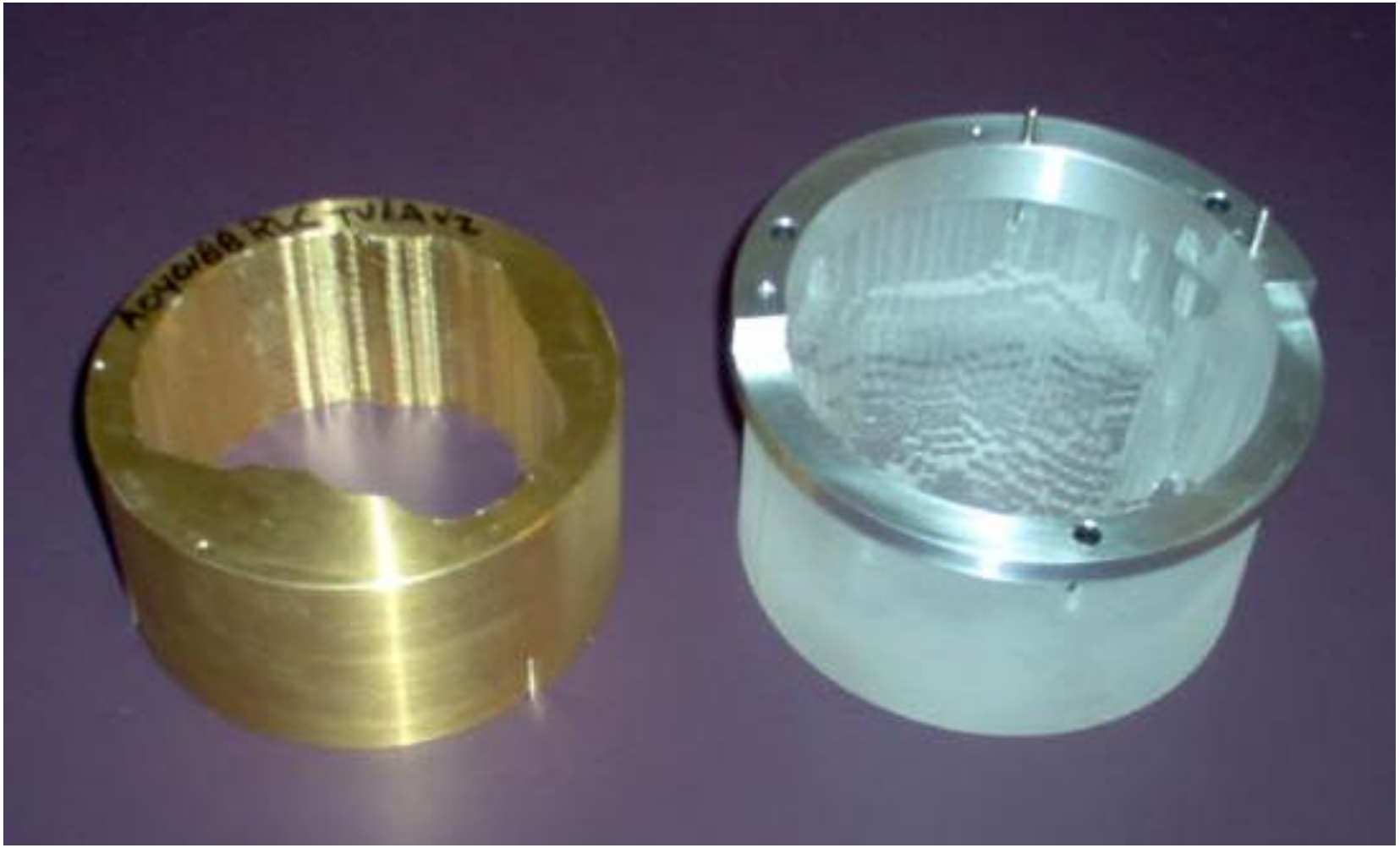

Uniform Scanning Beam Model in XiO (1)

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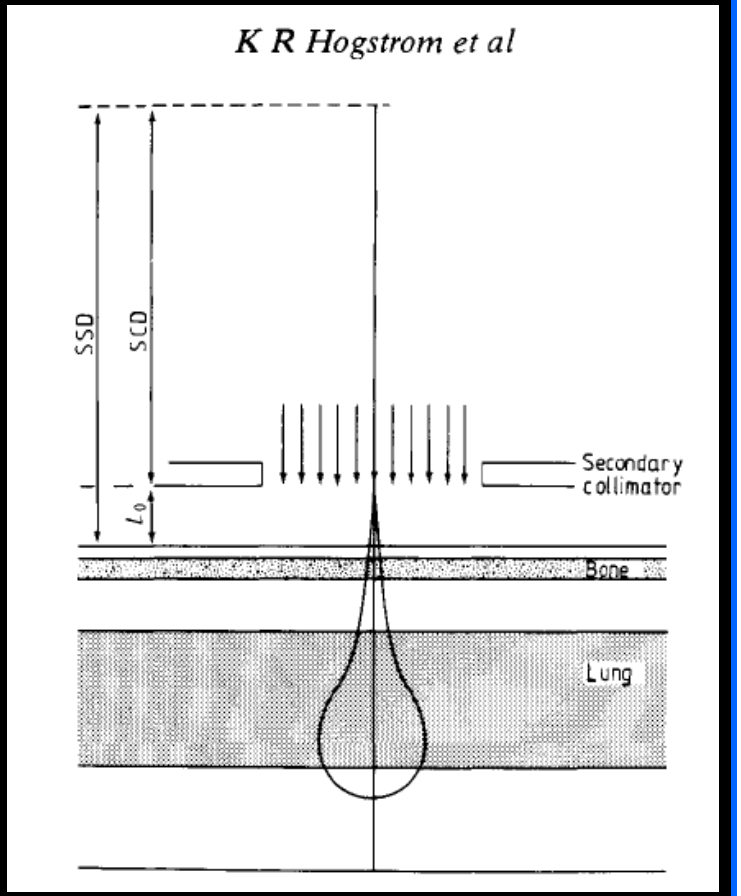
XiO uses Pencil Beam Alogrithm for US & DS (L. Heng et al, Phys. Med. Biol. 41 (1996) 1305-1330)

$$D(x,y,z) = \int\int dx'dy'\Psi_0(x',y')\frac{C(x',y',z)}{2\pi[\sigma_{tot}(x',y',z)]^2}\exp\left(-\frac{(x'-x)^2+(y'-y)^2}{2[\sigma_{tot}(x',y',z)]^2}\right)$$

$$\sigma_{tot} = \left[\sigma_{size}^2\left(\frac{z_p - z_{bld}}{z_{bld}}\right)^2 + \sigma_{srm}^2 + \sigma_{pt}^2\right]^{1/2}$$



Uniform Scanning Beam Model in XiO (2)

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1. **Proton Source →** σ_{size}
   - **ESAD**
   - **Size**
   - **VSAD**
2. **Beam Characteristic**
   - **Pristine Layers →** $C(z') = \mathrm{DD}(d_{eff}) \left(\frac{\mathrm{ssd}_0 + d_{eff}}{z'} \right)^2$
   - **SOBP ->**
   - **Cross Profiles →** σ_{pt}
3. **Relative Stopping Power (RSP) →** σ_{srm} σ_{pt}

Multi-Layer Ion Chamber (MLIC)

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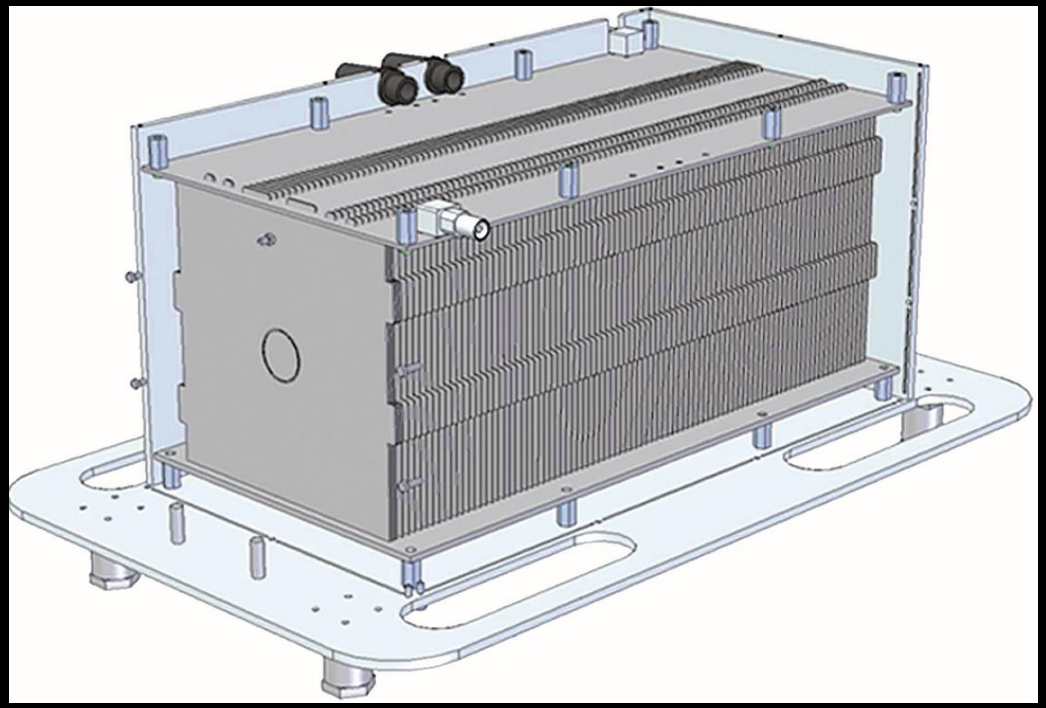
- 180 independent vented plane parallel chambers
- 33 cm WET
- 2 mm detector spacing, 2.5 cm in diameter
- +- 0.5 mm accuracy
- Ideal for US & PBS



Lynx 2D

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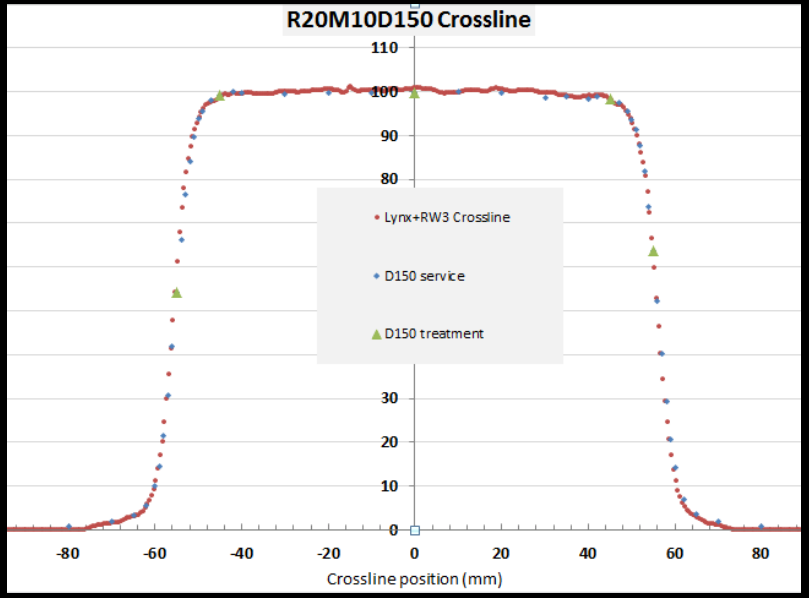
- Particles fluence
- LET dependence
- Comparison with ionization chamber
- Good for measurement of field size (50%-50%) and penumbra (80% - 20%)



Effective Sourse to Axis Distance (ESAD)

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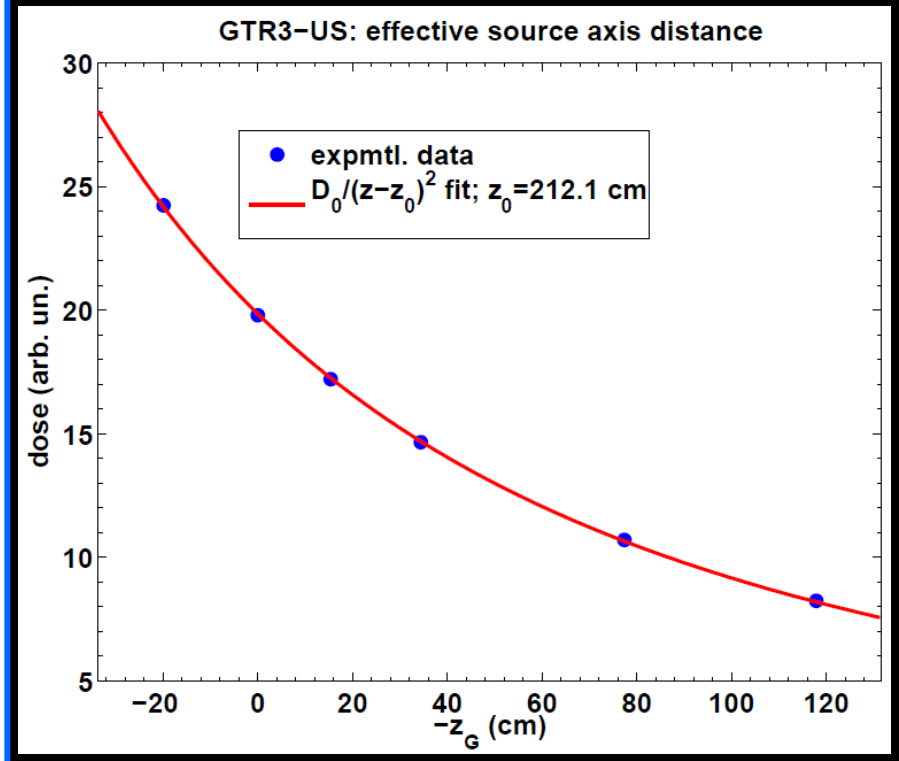
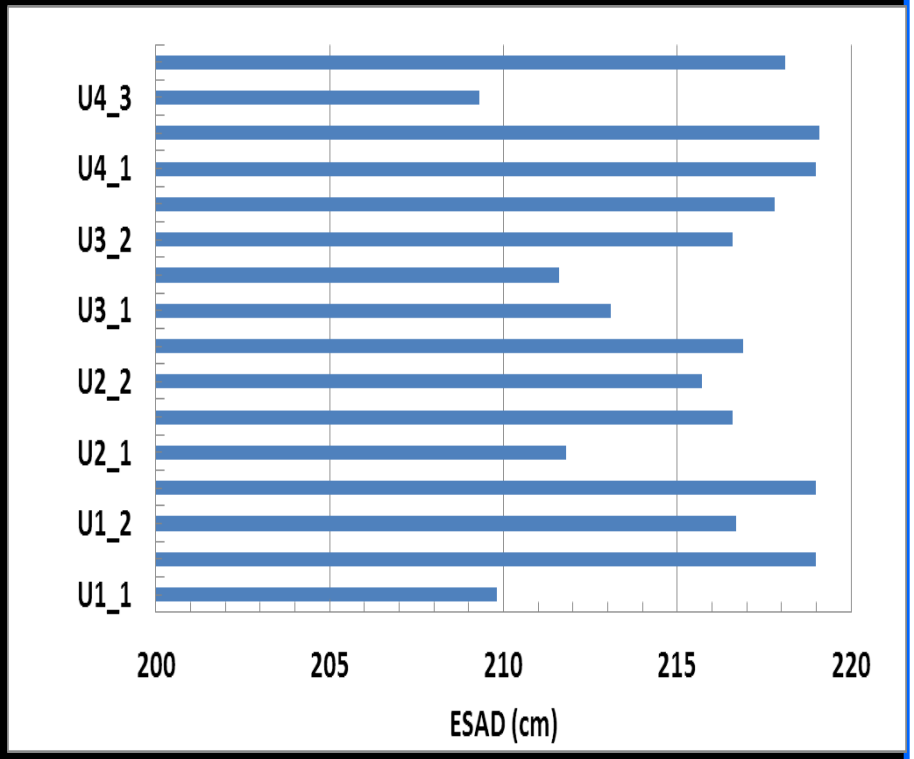
1. Ion chamber in air
2. Inverse-Square-Law fit
3. Depended on range (mean ESAD = 212 cm)





Source Size

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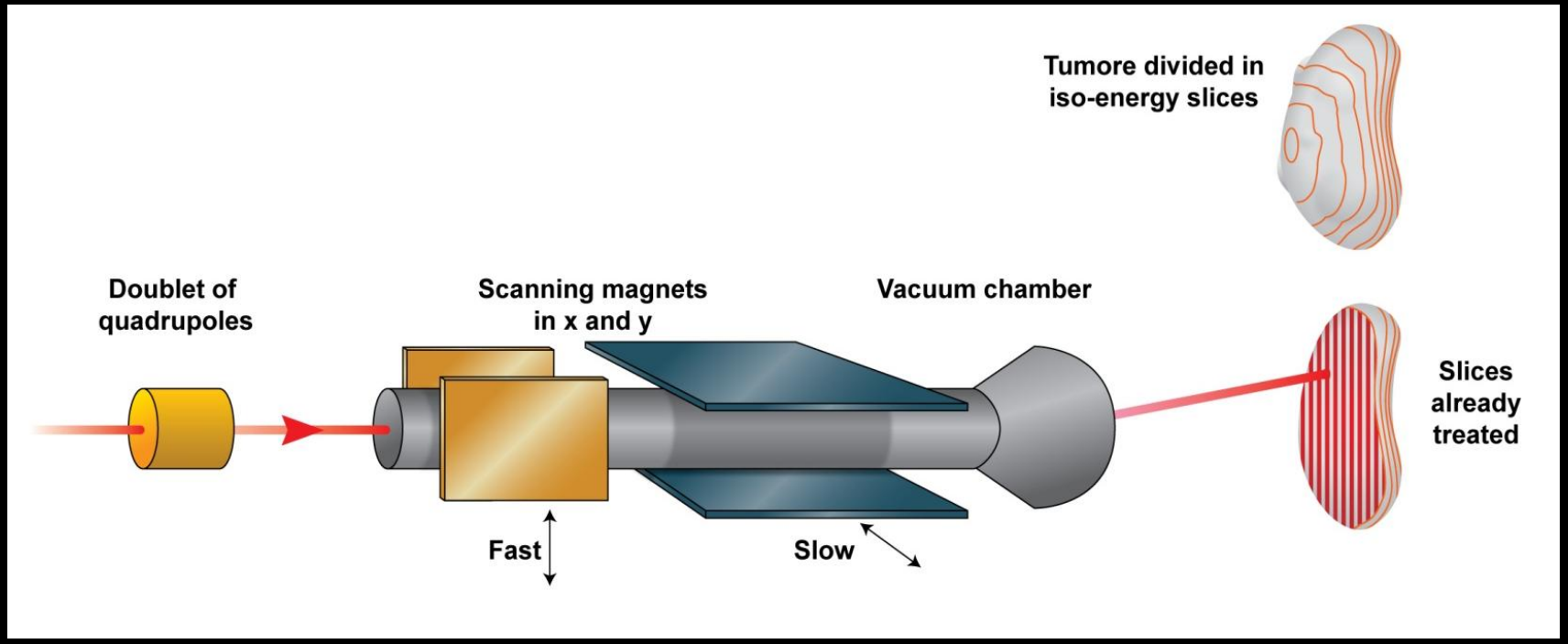
1. Penumbra (80%-20%) measurement
2. Use source size to reproduce measured lateral penumbra
3. 10cm X 10cm aperture
4. Air gap 10cm
5. 12 ranges (5 g/cm2 to 31 g/cm2)
6. Effective source radias 1.0-1.5 cm

VSAD

1. Field Size (50%-50%) measurement in air
2. VSAD = 231 cm
3. HSAD = 197 cm



Pristine Layers

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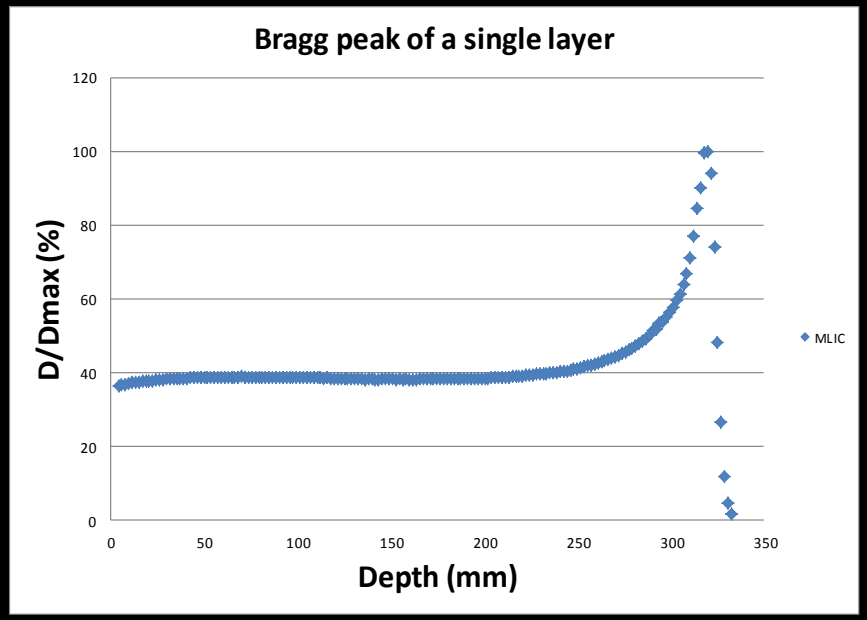
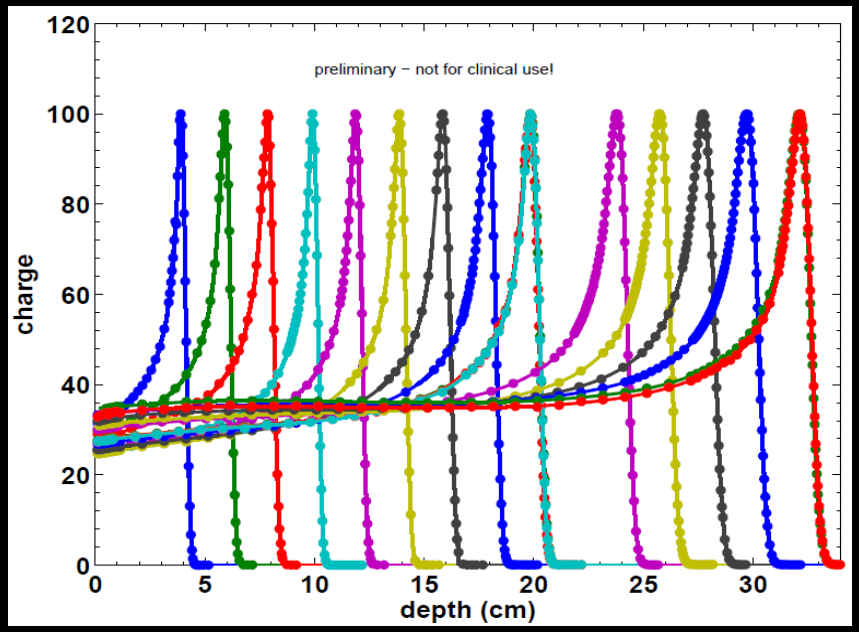
1. Range from 4.00 g/cm2 to 32.32 g/cm2
2. ~0.6 g/cm2 between layers





Cross Profiles

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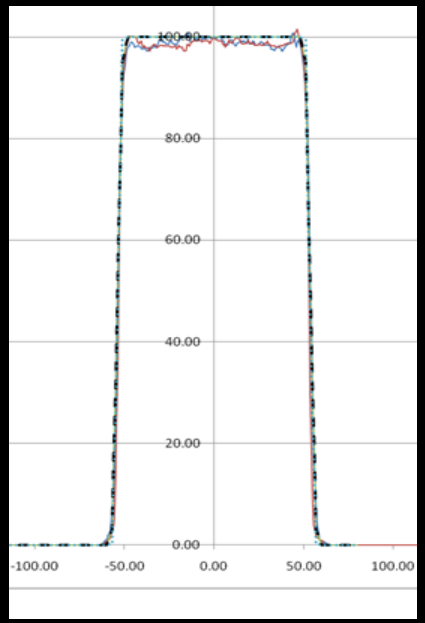
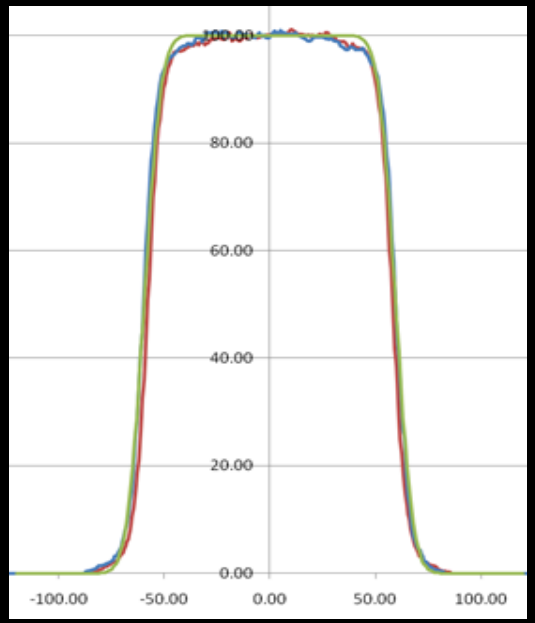
1. Lyns 2D (validated by ion chamber & EBT2)
2. 10cm X 10cm aperturen
3. 10cm air gap
4. At Isocenter & center of SOBP

R = ~5 cm



R = ~28 cm



Beam Model Validation

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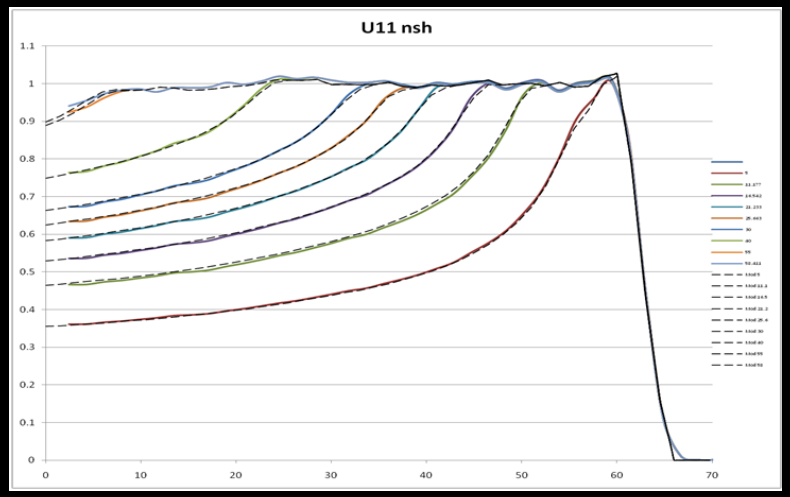
1. In Water Tank
   - Ranges & Modulations
   - Cross Profiles
2. Anthromorphic Phantom
   - Ion chamber measurement
   - Film measurement

Ranges & Modulations

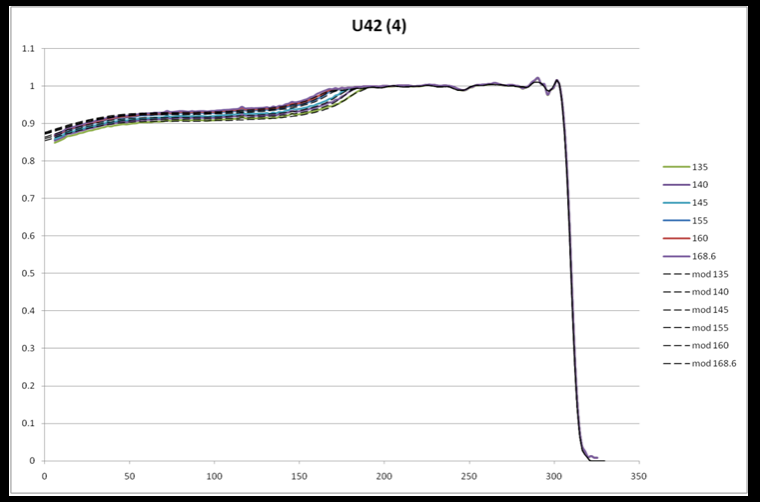
Westdeutsches Protonentherapiezentrum Essen gGmbH

1. Validation of PDDs
2. Range from 6.05 g/cm2 to 32.32 g/cm2
3. Range offs < 0.1 g/cm2
4. Modulation offs < 0.3 g/cm2

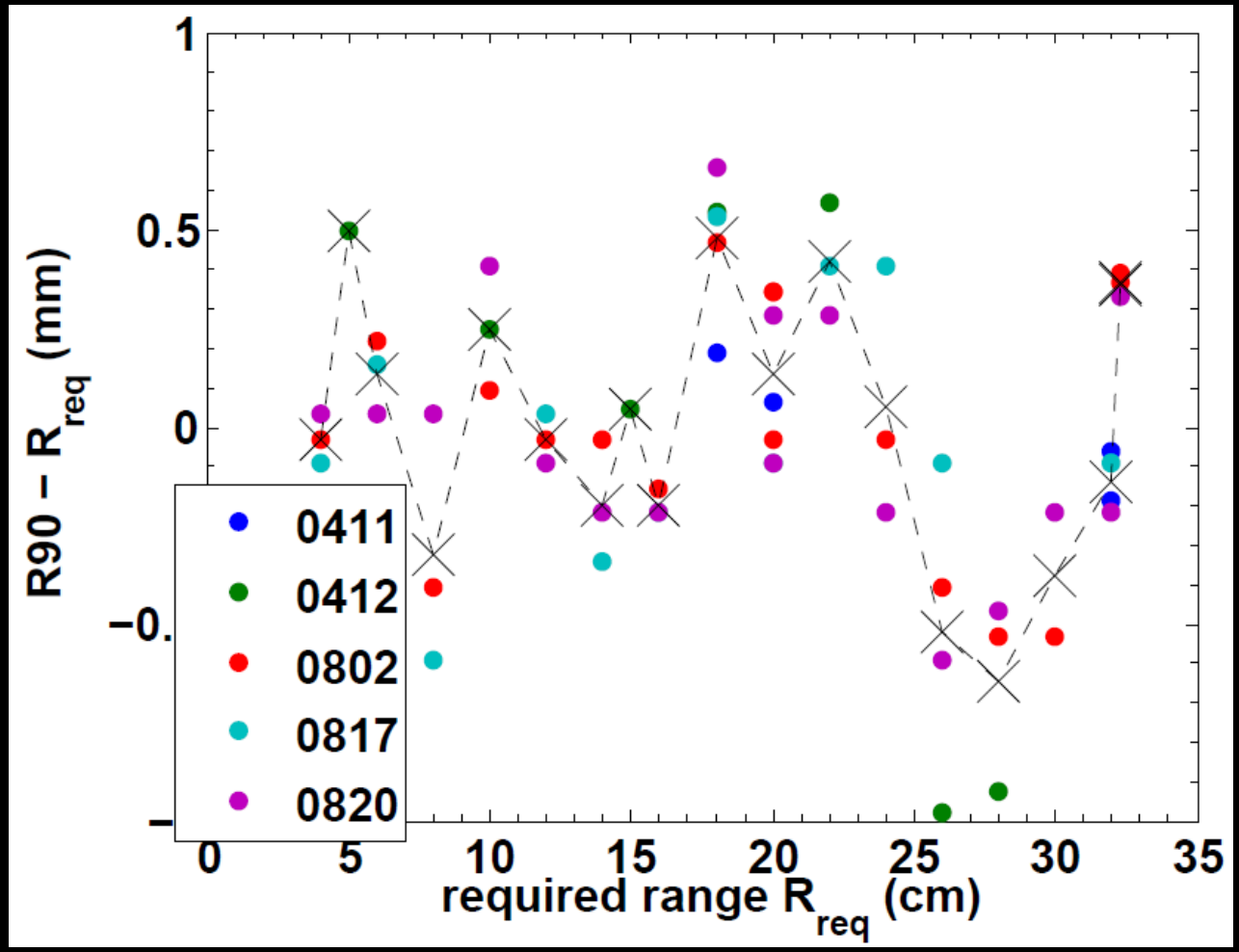
R = 6.5 cm



R = 6.5 cm



Ranges Accuracy



Cross Profiles in Solid Water Phantom

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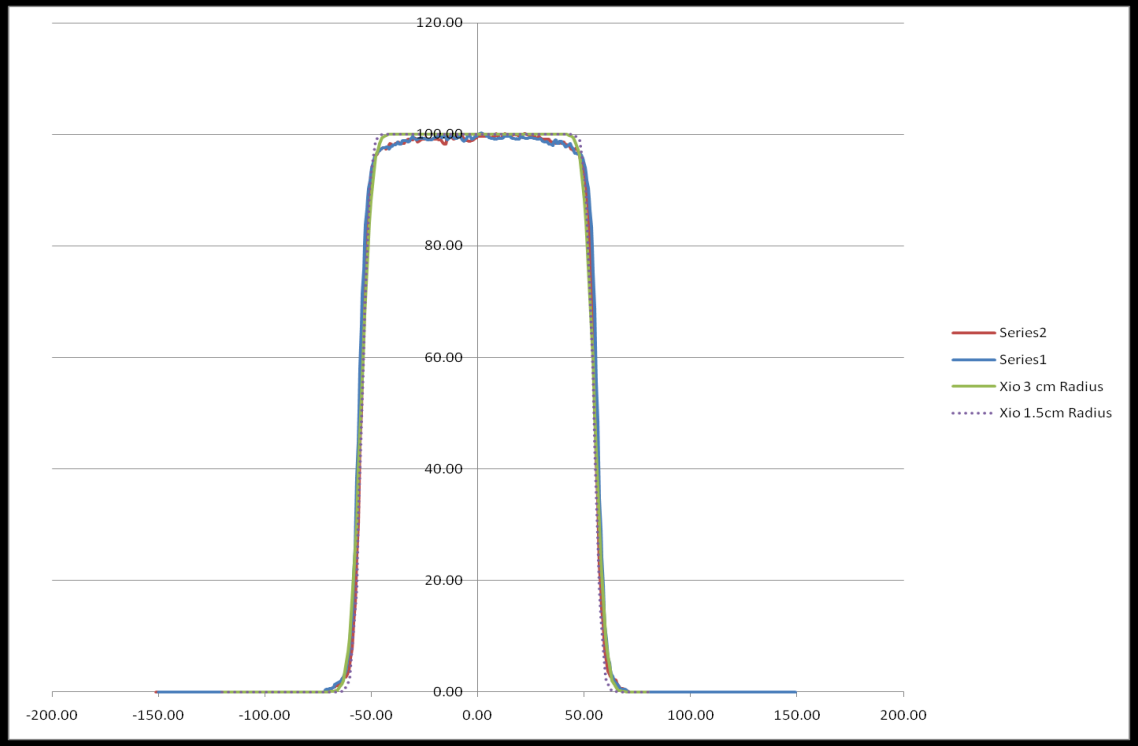
1. > 50 Comparisons
2. Field Size < 0.2 g/cm2
3. Penumbra < 0.2 g/cm2 (~90%)



Measurement in Anthropomorphic Phantom (1)

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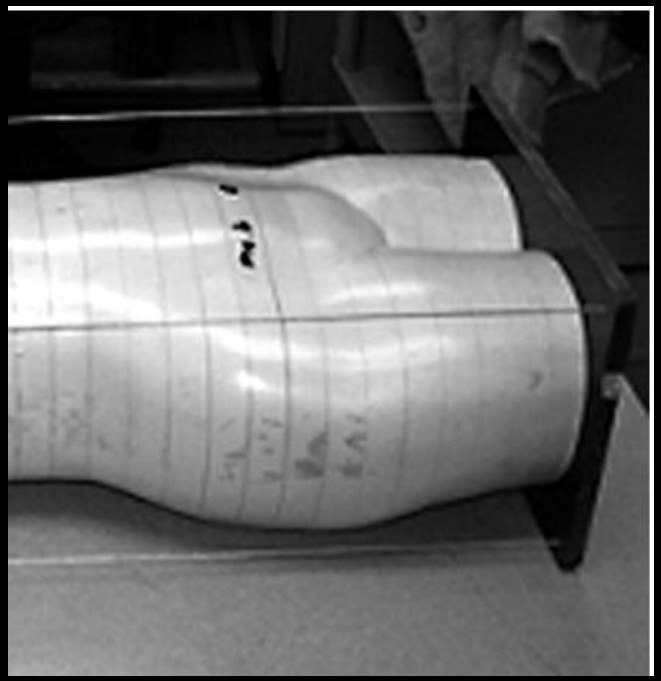
1. Two lateral fields irradiated 4 CGE in total
2. Water tank measurement determine MU #s
3. T1 chamber in the center of prostate
4. Measured dose is 1% higher than dose from TPS



Measurement in Anthropomorphic Phantom (2) -1

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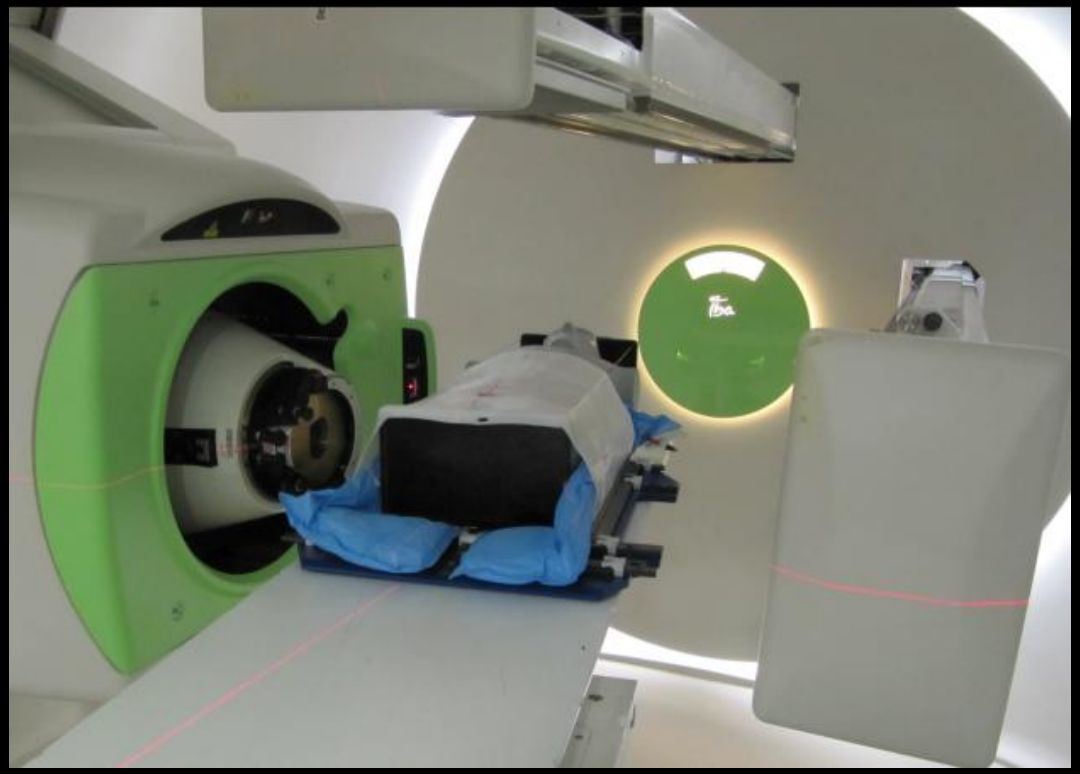
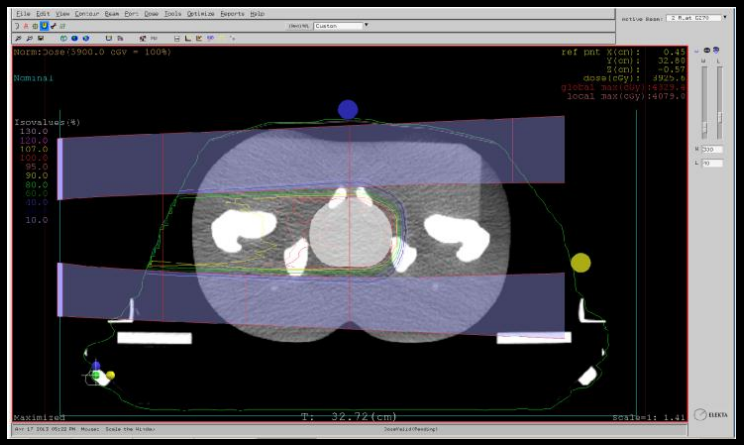
Film Measurement setup

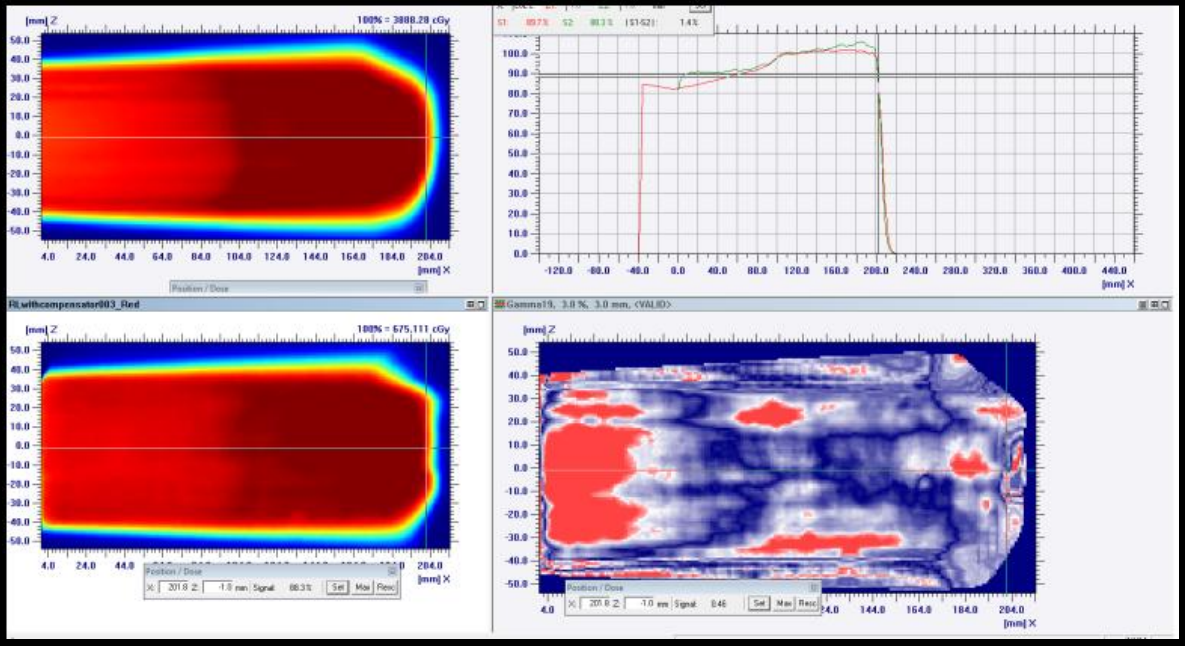
- EBT2 film sanwiched between phantom slabs
- 5 degree couch table rotation



Measurement in Anthropomorphic Phantom (2) -2

Westdeutsches Protonentherapiezentrum Essen gGmbH





Recap

Westdeutsches Protonentherapiezentrum Essen gGmbH

1. Proton Source
   - ESAD
   - Size
   - VSAD
2. Beam Characteristic
   - Pristine Layers
   - Cross Profiles
3. Relative Stopping Power (RSP)

CT Calibration Curve

Westdeutsches Protonentherapiezentrum Essen gGmbH

1. Relative Stopping Power (RSP) for US mode
2. Conver HU to RSP by CT calibration curve
3. Two methods to obtain CT calibration curve
    - Tissue Substitude
    - Stochiometric

Tissue Substitute

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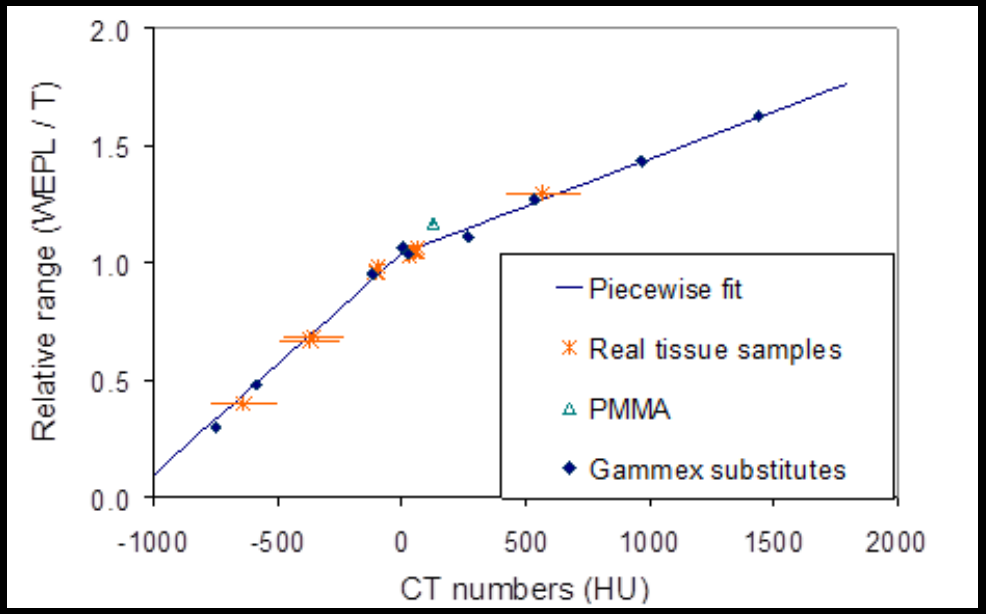
1. RMI tissue substitues & RMI 467 phantom
2. CT measurement by insert sustitue into phantom
3. Bethe-Bloch formula to calculate RSP

$$\rho_s = \rho_e\{\log[2m_e c^2\beta^2/I_m(1-\beta^2)] - \beta^2\}/\{\log[2m_e c^2\beta^2/I_{water}(1-\beta^2)] - \beta^2\} = \rho_e K$$



Validation of CT calibration curves

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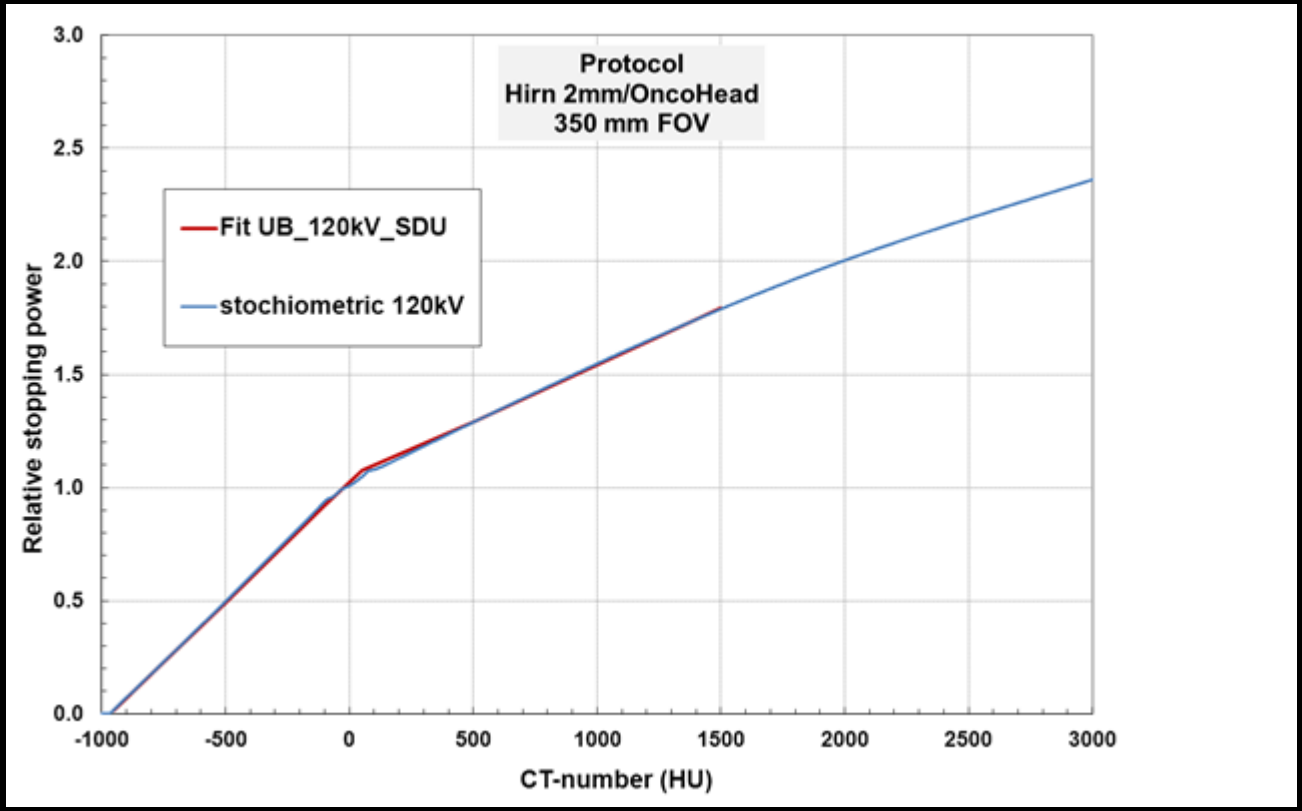
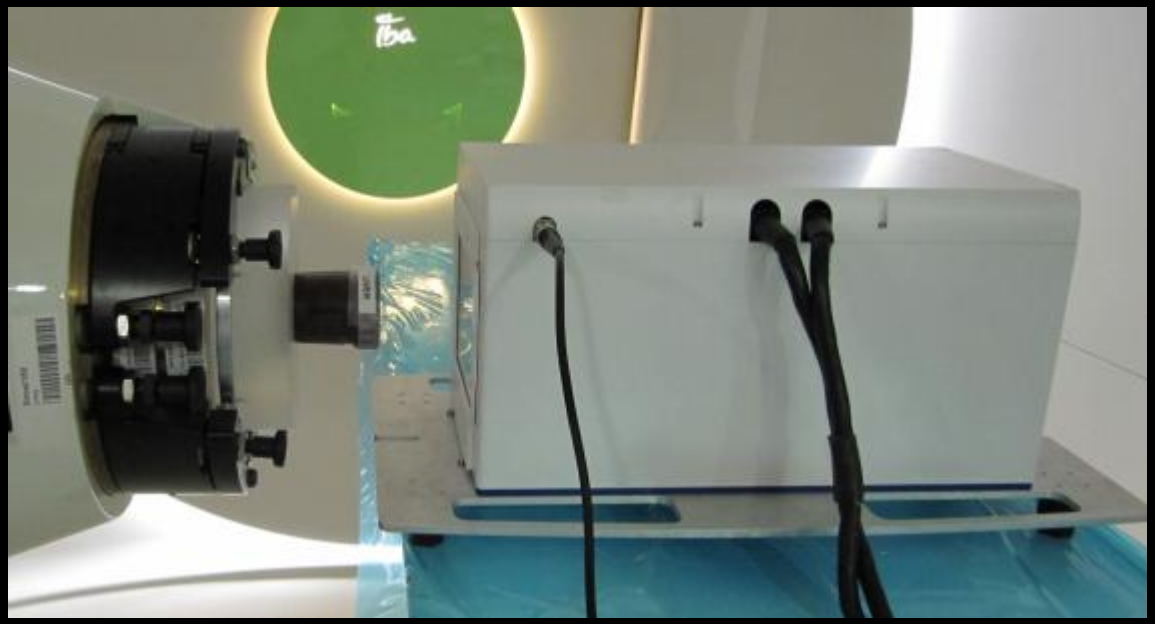
1. By Stoichiometric curve
2. By slab materials measurement
3. By animal tissues measurement

Validated Stoichiometric curve

Westdeutsches Protonentherapiezentrum Essen gGmbH



By anamal tissues measuremen



Tissue	WET (mm)	Diff from XiO (mm)	Diff (%)
brain1	71,3	-1,38	1.9
brain2	69,9	-3,10	4.4
fat1	63,3	1,28	2.0
fat2	64,3	3,30	5.1
liver	72,2	-2,42	3.4
lung1	36,6	0,78	2.1
lung2	38,7	1,32	3.4

Validated by slab meaterials measurement

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Calib. Curve	XiO (cm)	measured (cm)	diff(cm)
CTB120	2.79	2.65	0.14
CTB140	2.76	2.65	0.11
CTUB120	2.75	2.65	0.1

Validated by anthropomorphic phantom

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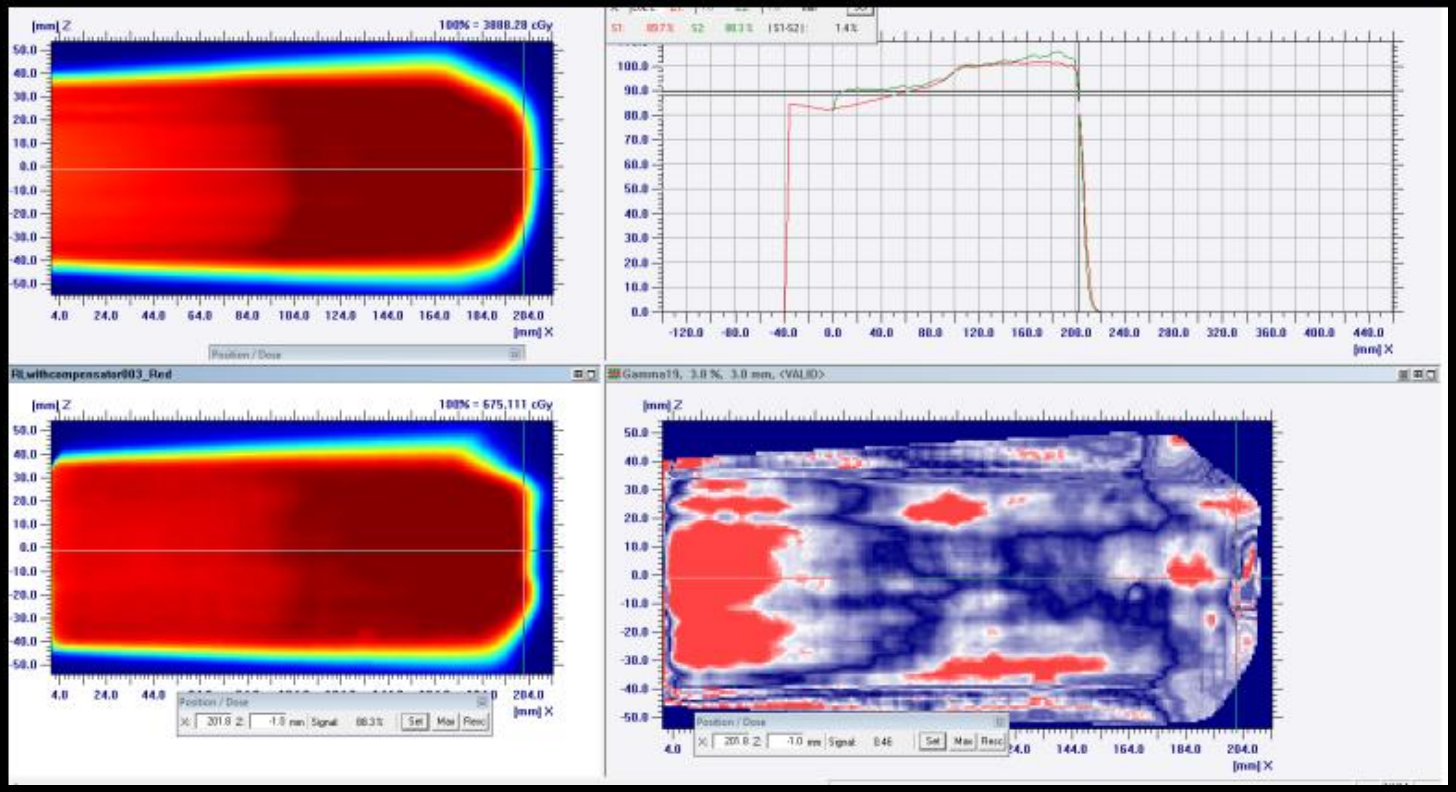

Recap

1. Treatment Beam Model
   - Obtain / Analysis data build beam model
   - Validate beam model by measurements
     - Phantom measurement
     - Anthropomorphic phantom
2. CT Calibration Curve
   - Obtain the curve by tissue substitute method
   - Validation by
     - Stoichiometric method
     - Slab material measurement
     - Animal tissue measurement
     - Anthropomophic phantom measurement

Thank You

Vielen Dank

谢谢