Computational dosimetry in Boron Neutron Capture Therapy (BNCT).

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BNCT TERAPIA POR CAPTURA NEUTRONICA EN BORO
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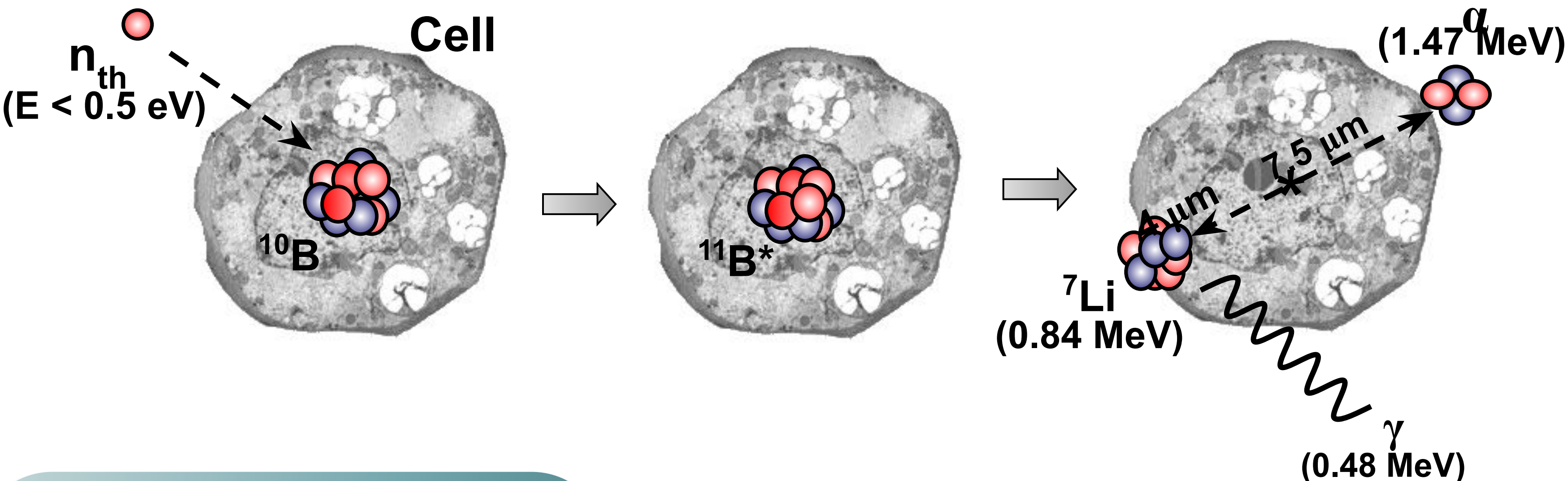
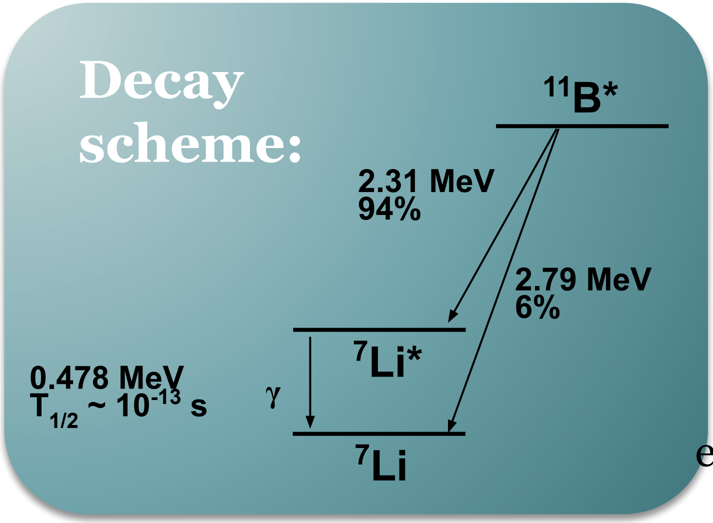
The BNCT Reaction: $^{10}B(n,\alpha)^{7}Li$





Releases an average of 2.79 MeV per neutron capture.

Products: highly ionizing
initial LET values in tissue, 180 to 370 keV/µm
lose their energy over distances less than 10 µm

Boron-10: large cross section of 3839 barns at 0.0253 eV

high natural isotopic abundance of 19.8%.

Contributions to the dose in BNCT

Main components :

- From products of $^{10}B(n,\alpha)^{7}Li$ reaction **(Boron dose: D_b)**
- From products of $^{14}N(n,p)^{14}C$ reaction **(Thermal neutron dose: D_{th})**
- From recoil nuclei, mostly elastic collisions with hydrogen nuclei $^{1}H(n,n')^{1}H$ **(Fast neutron dose: D_f)**
- From photons of the beam and neutron capture reaction in hydrogen $^{1}H(n,\gamma)^{2}H$ **(Photon dose: D_g)**

Total absorbed dose: $D = D_b + D_{th} + D_f + D_g$ in Grays [Gy = J•kg^{-1}]

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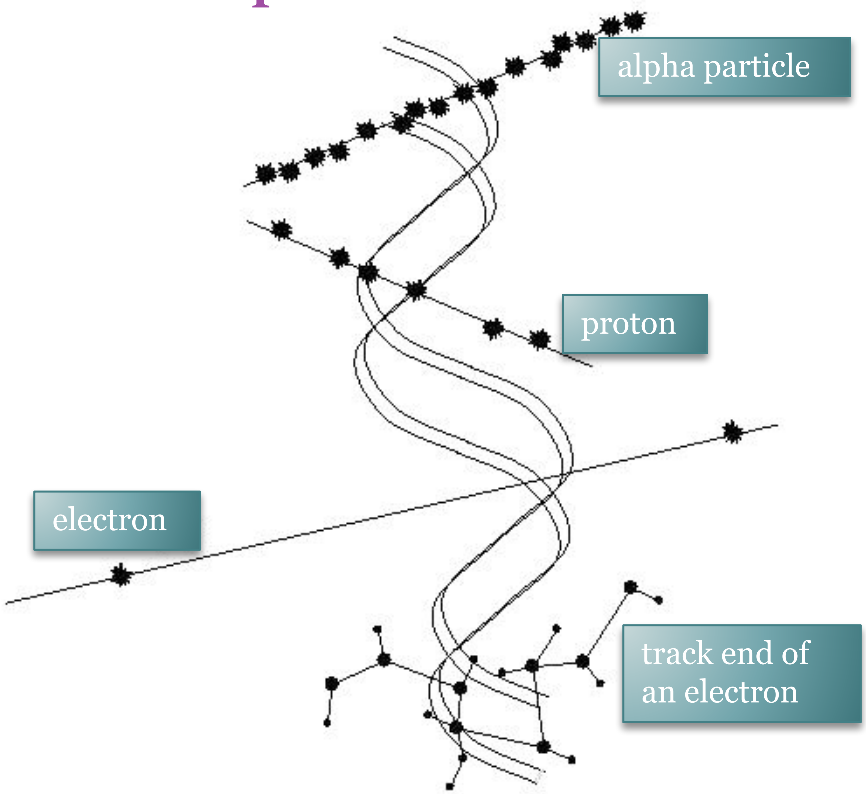
Contributions to the dose in BNCT

Ionization pattern for:



Adapted from "*Damage pattern as a function of radiation quality and other factors*;" C R Acad Sci III. 1999;322(2-3):89-101.

Different products with different ionization patterns cause different biological effect for the same absorbed dose.

Four dose components with different radiation transport characteristic conform **a complex radiation dose field**

- Deterministic transport methods:
  Too many approximations
- Statistical simulation methods:
  High accuracy (MCNP code!)

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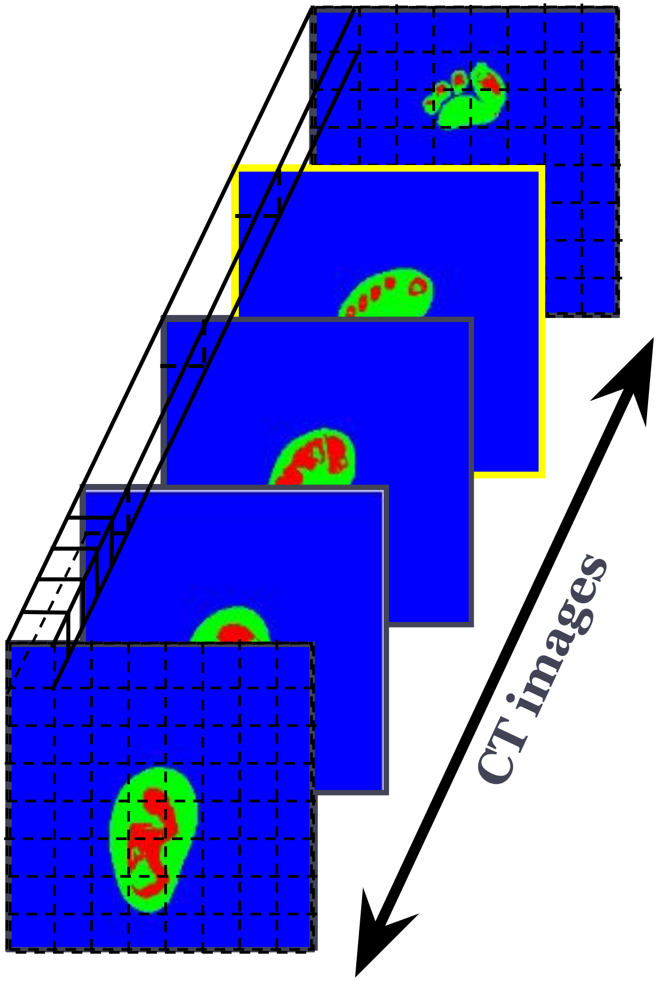
Treatment planning:

Neutron Capture Therapy Plan (NCTPlan v. 2.0)

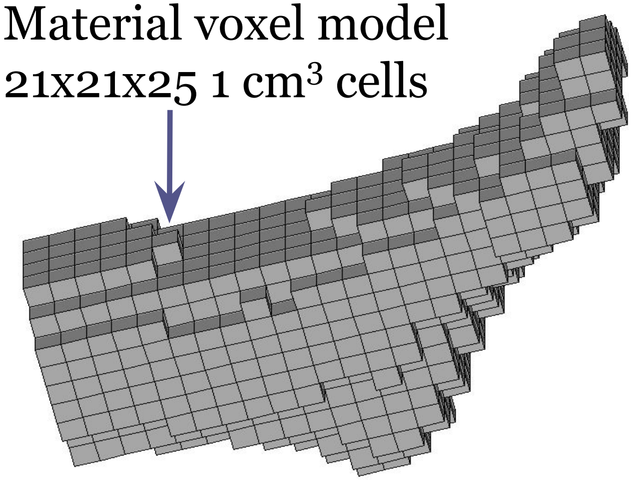
- Software:
  - developed by the joint collaboration between CNEA & Harvard-MIT
  - written in Microsoft Visual Basic
  - runs under Windows operative system
- Program structure
  - includes multiple windows for patient modeling and dose analysis and displays
  - directly creates MNCP input desks (UF: L. Provenzano & N. Mojsiejczuk)
- Clinical protocols including NCTPlan
  - Harvard-MIT, RO1 Peripheral Melanoma and R21 GBM and Intracranial Melanoma Metastases (USA)
  - CNEA, Peripheral Melanoma (Argentina)

Treatment planning: Voxel model



- Image segmentation: air ( ), normal and tumor tissues ( ), and bone ( )

- Image partitioning: each primary material is rounded off to the nearest 20% volume increment.



Lower part of the leg and foot

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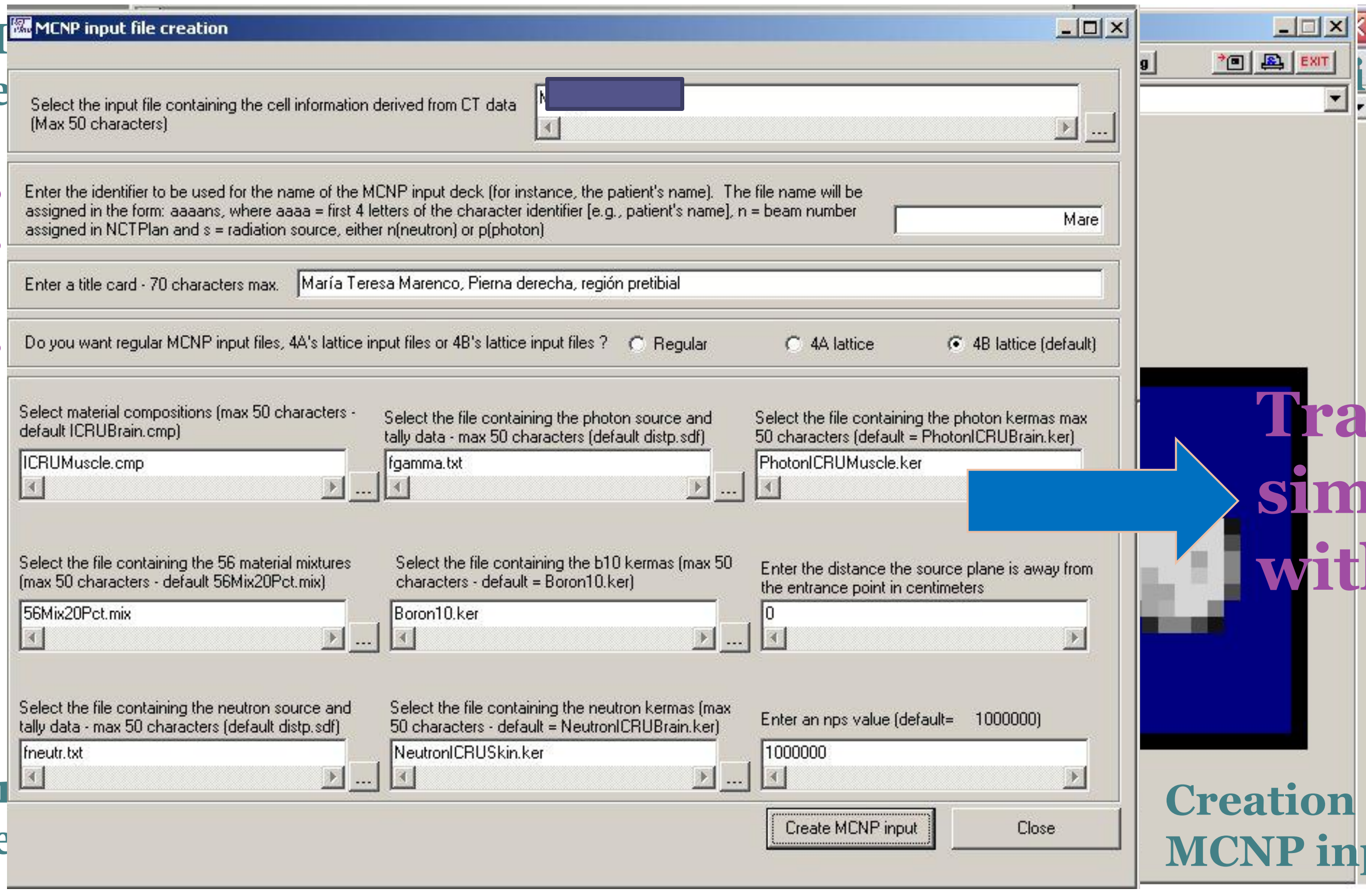
Treatment planning: dose calculations



Transport simulation with MCNP

Creation of the MCNP input file

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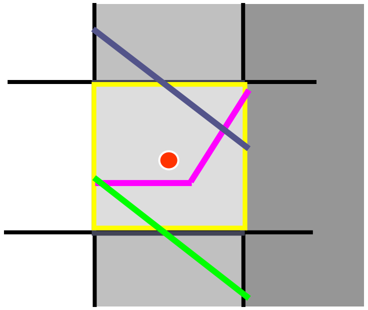
Treatment planning: dose calculations (cont.)



Tallies in MCNP:

Estimates of the average neutron/photon fluence in each cell (F4), assign the average value to the center of the 1 cm^3 voxel

To compute doses:

$$K = \int \Phi(E)\, k(E)\, dE$$

Φ(E): energy-dependent fluence,
k(E): fluence-to-kerma coefficients; account for the initial kinetic energy for all those primary charged particles released by uncharged particles (ICRU 1999).

Assumption: charged particle equilibrium (CPE) conditions are satisfied everywhere in the geometry.
Under this assumption, dose is approximated by KERMA.

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Treatment planning: dose calculations

- Geometry model: air, muscle, bone (ICRU 44)
- Normal tissue doses: specified for OAR (skin kerma factors)
- RBE & CBE weighting factors

  Photon dose: 1

  Thermal & fast neutron dose: 3

  Boron dose: 2.5 (normal skin)

  3.8 (tumor)

- ^{10}B concentration ratios

  Normal T-to-blood: 1.0

  Skin-to-blood : 1.5

  Tumor-to-blood: 3.5

  (C_{blood} = 15 ppm)

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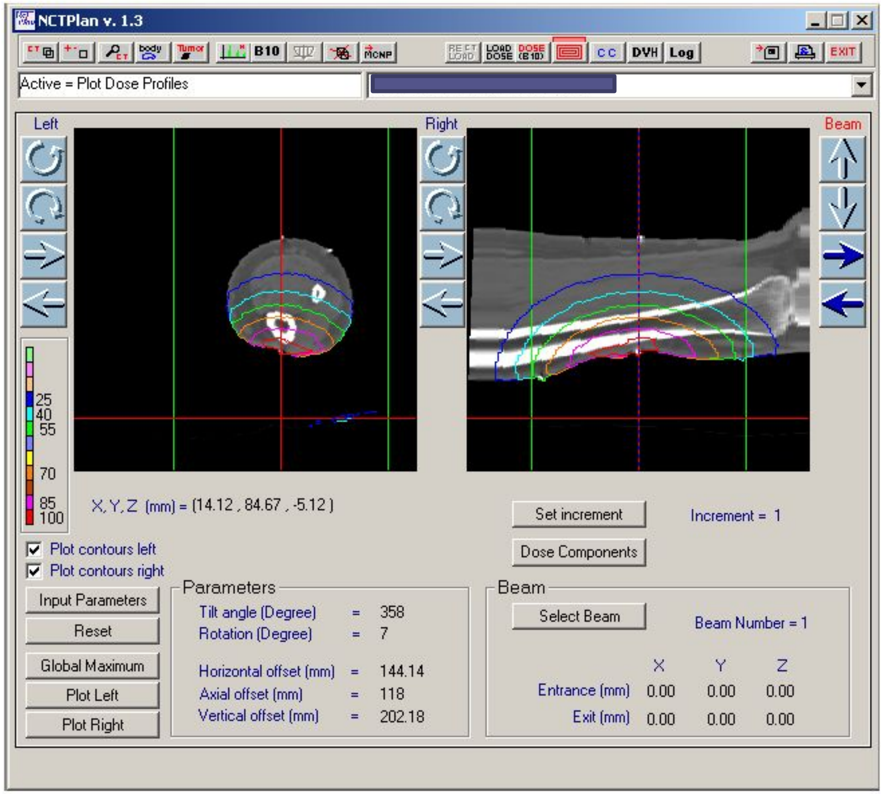
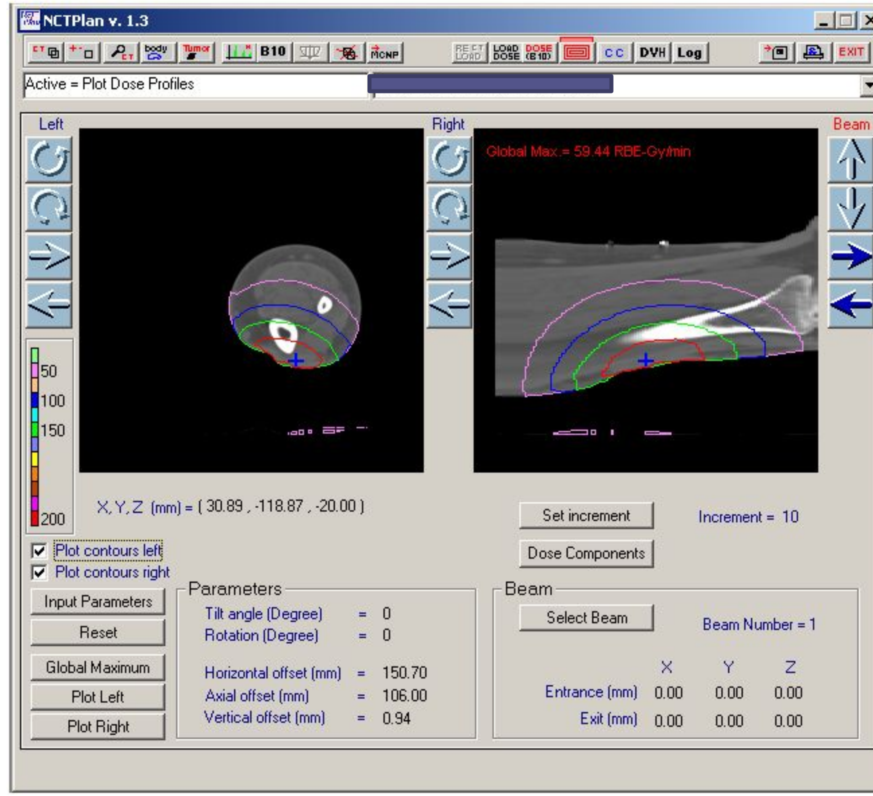
Treatment planning: dosimetry analysis





Dose distributions inside the anatomy: dose iso-curves for normal tissues and tumors.

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Treatment planning in Argentina

Particularities:

- Multiple "visible" lesions
- Fixed particle source

Steps:

1. Physicians established the treatment target area.
2. Search for the "best" patient positioning
3. Setting the skin marks for repositioning and TP
4. Performed the CT study

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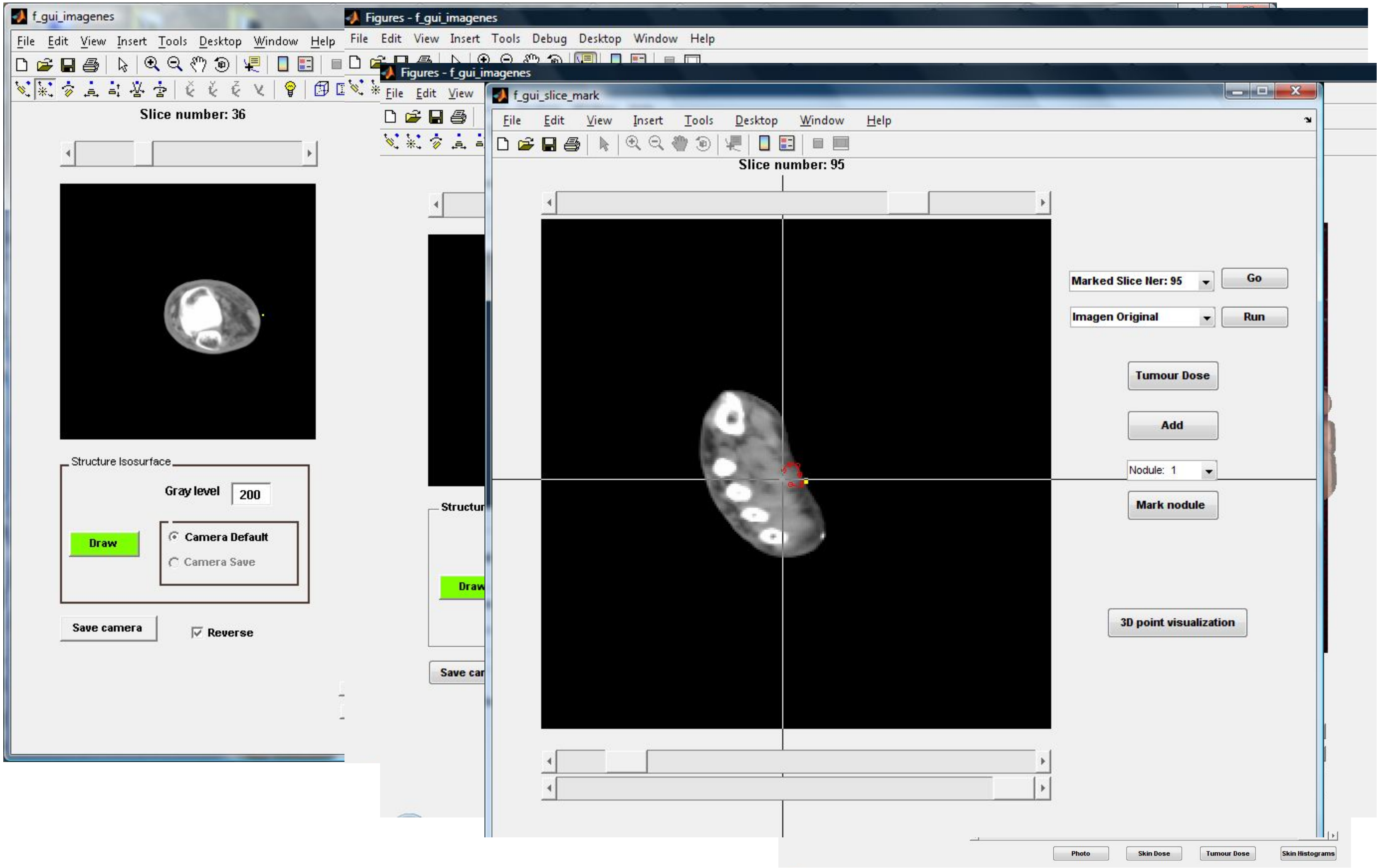
Treatment planning: 3D representations, **Sphere**

Tesis MSc. S. Gossio



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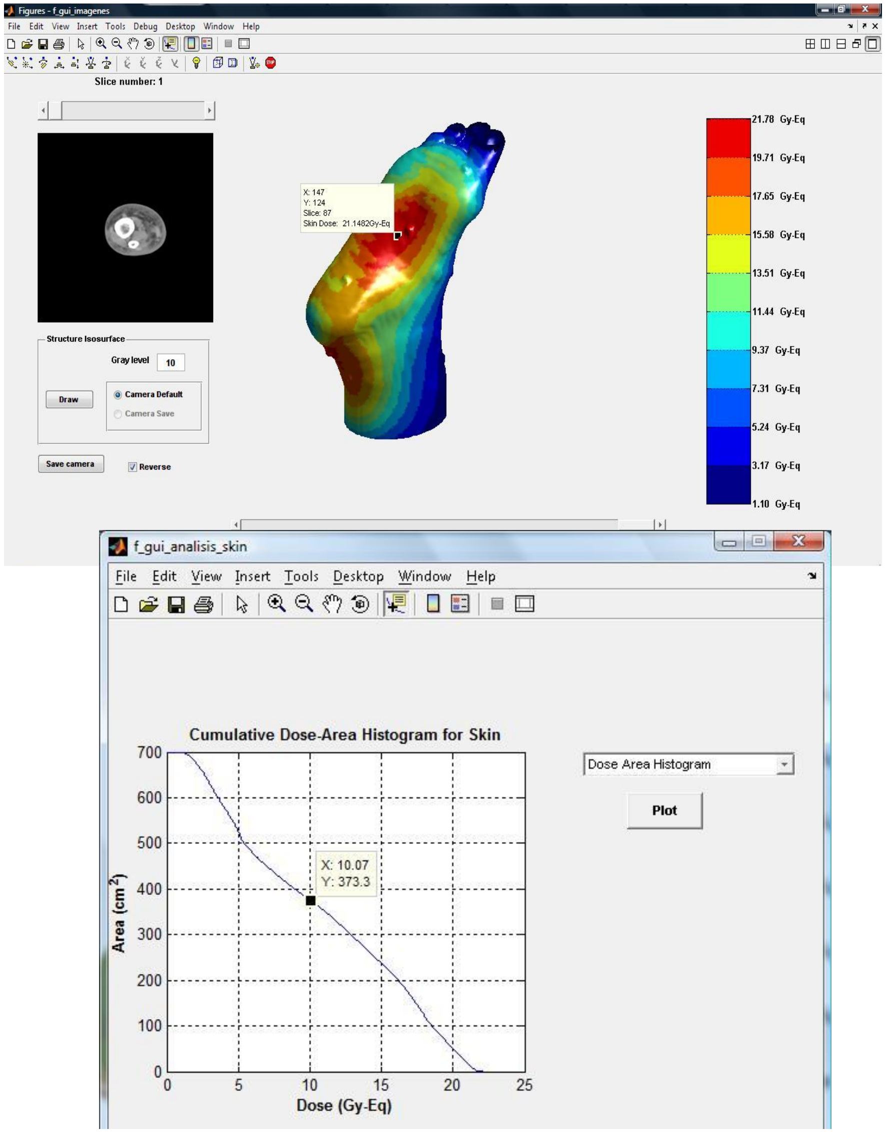
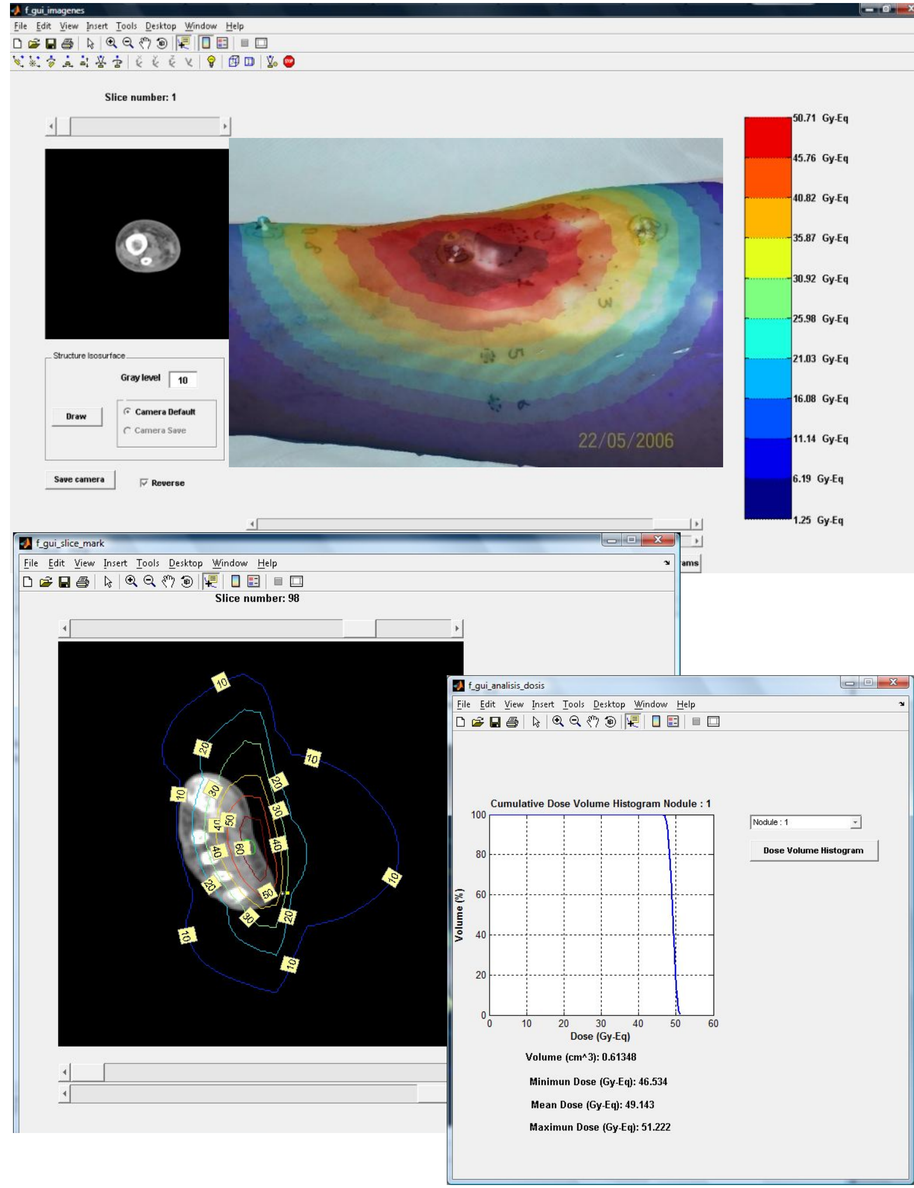
Skin



Tumors



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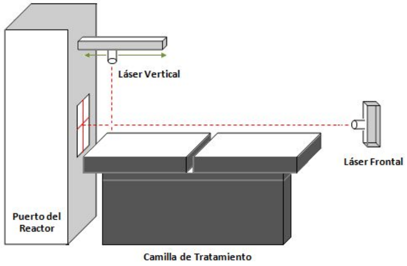
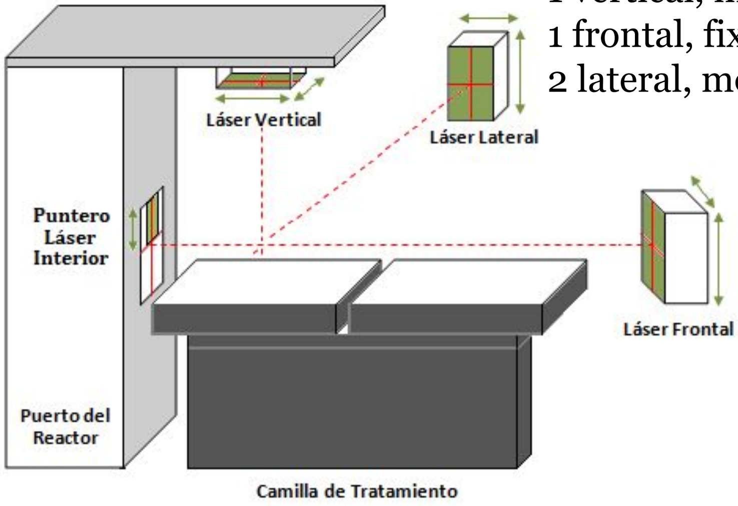
U. Favaloro: Victoria Gutierrez & Leandro Monzón

Lasers system

External

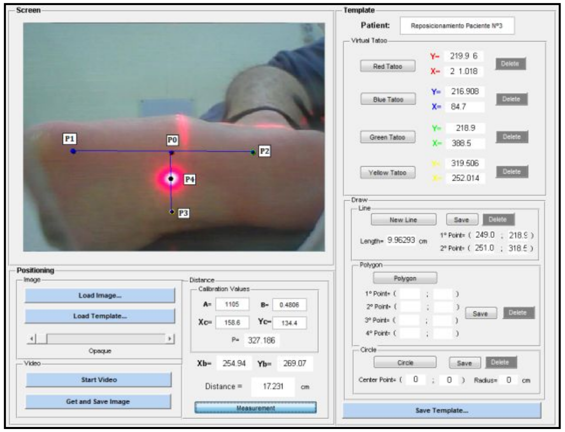


1 vertical, movile (1 dir)
1 frontal, fixed



1 vertical, movile (2 dirs)
1 frontal, fixed
2 lateral, movile (1 dir)

Internal



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Formación de RRHH:

- GRADO: Tesis de Licenciatura en Cs. Físicas (UBA)/Proyecto Final de la Carrera Ingeniería en Física Médica (U. Favaloro)

2007-2008 José Bertotti – Julio Marín
2008-2009 Rubén Farías.
2008-2010 María Silvia Soto
2009-2010 Esteban Boggio

2010-2011 Victoria Gutiérrez – Leandro Monzón
2011-2012 Natanael Mojsiejczuk
2011-2012 Lucas Provenzano
2012-2013 Agustina Razetti

- POSGRADO: Maestría en Física Médica (UBA)

2007-2009 Sebastián Gossio

- POSGRADO: Doctorado (UNSAM)

2009-2014 María Silvia Herrera
2010-2015 Rubén Farías
2012-pres. Mario Gadán
2013-pres. Lucas Provenzano
2016-pres. Sebastián Gossio

- INVESTIGADORES:

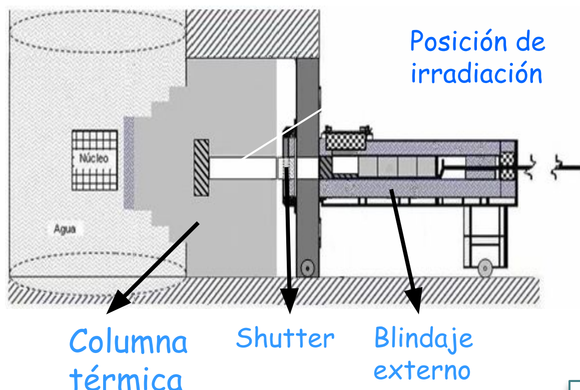
2012-2013 Agustina Portu (Beca posdoctoral)
2013-pres. Agustina Portu (Investigador Asistente CONICET)

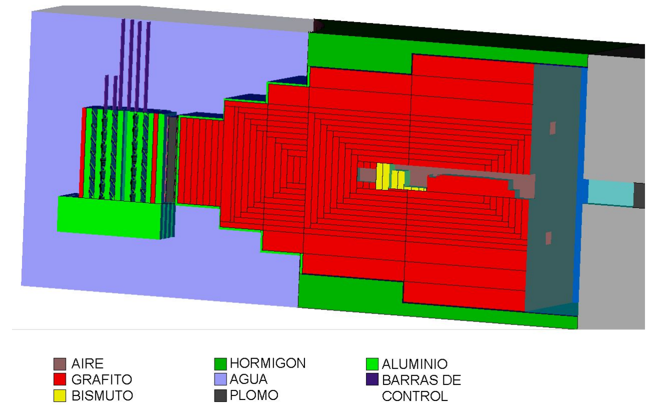
Dosimetría 3D computacional

Modelo completo de la facilidad central de columna térmica del reactor RA-3 (FCCT)

Rubén Farías

Silva Bortolussi

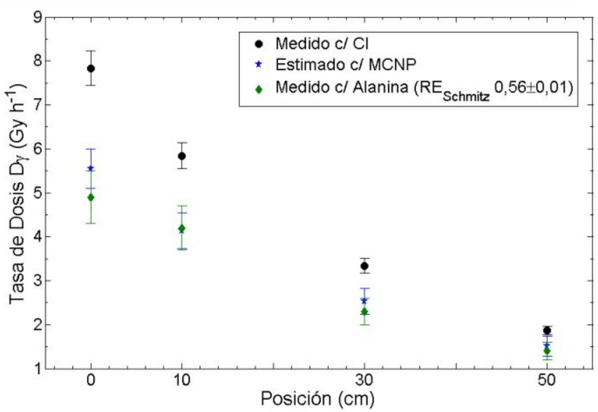




Representación 3D del modelo MCNP de la FCCT

Caracterización gamma de la cavidad de la FCCT

Alanina



Applied Radiation and Isotopes 69 (2011) 1924–1927

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/apradiso

ELSEVIER

Simulation of the neutron flux in the irradiation facility at RA-3 reactor

S. Bortolussi [a,b,*], J.M. Pinto [d], S.I. Thorp [c], R.O. Farias [f], M.S. Soto [g], M. Sztejnberg [c], E.C.C. Pozzi [d,e], S.J. Gonzalez [c,f], M.A. Gadan [a,c], A.N. Bellino [d], J. Quintana [d], S. Altieri [a,b], M. Miller [c]

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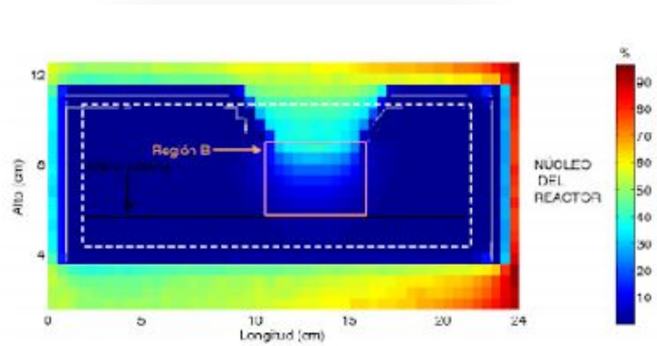
Rubén Farías

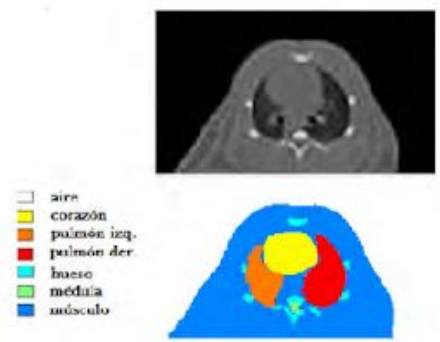
Dosimetría 3D computacional

Irradiaciones de órganos y de pequeños animales.

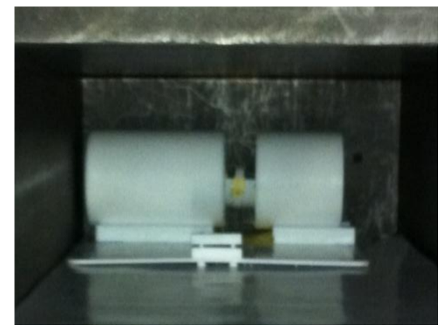
Factibilidad de BNCT para metástasis pulmonares experimentales (CNEA & U. Pavia)

Silva Bortolussi

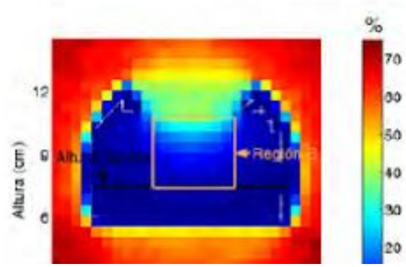




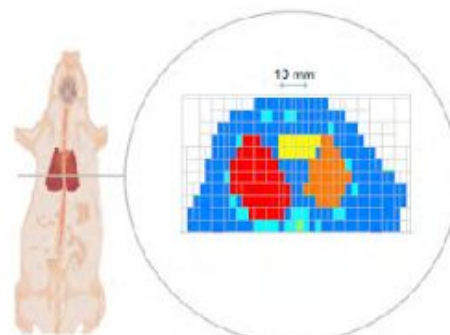
Proyecto final UF: A. Razetti

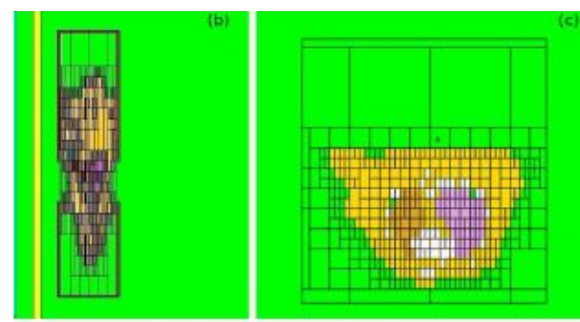


Tesis MSc. UP: M. Garioni



Eficacia terapéutica de BNCT
Proyecto final UF: A. Serrano





Modelos 3D animales: método MultiCell
Tesis Doctoral UNSAM: R. Farías

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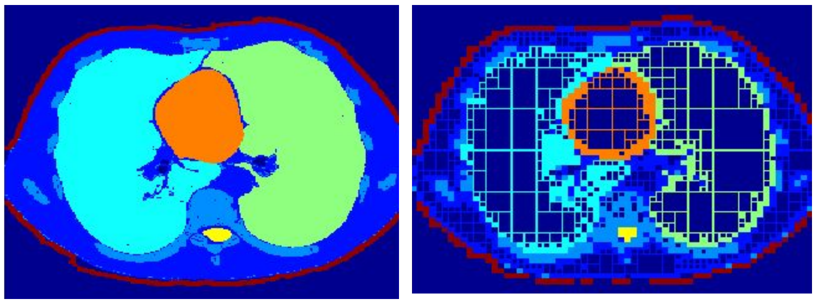
Rubén Farías

Dosimetría 3D computacional

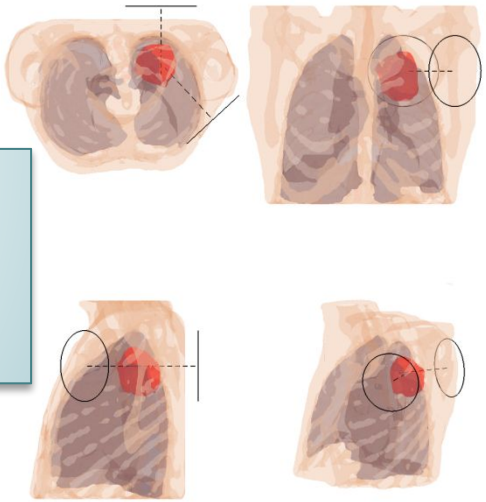
BNCT in – situ para el tratamiento de cáncer de pulmón (CNEA & U. Pavia)

Silva Bortolussi

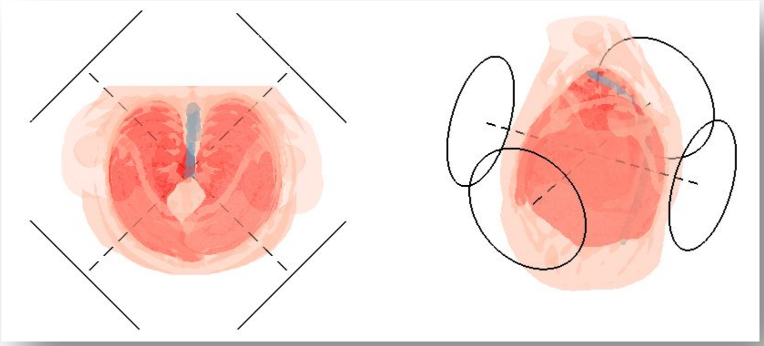


Recurrent malignancy after standard RT

Massive localized volume



Metástasis pulmonares difusas (Lesiones nodulares múltiples)



Physica Medica 30 (2014) 888–897

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journal homepage: http://www.physicamedica.com

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Original paper

Exploring Boron Neutron Capture Therapy for non-small cell lung cancer

Rubén O. Farías [a, b], Silva Bortolussi [c, d], Pablo R. Menéndez [e], Sara J. González [a, b, *]

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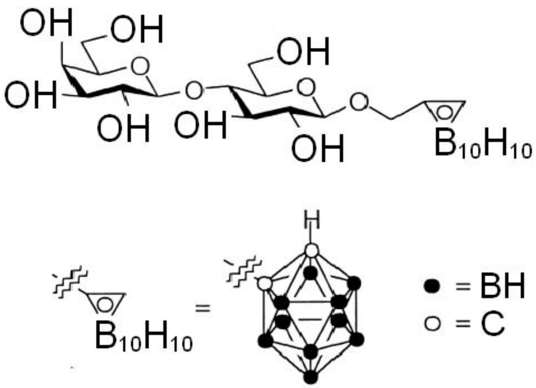
Mario Gadán

Estudios de BNCT en cáncer de mama

Luigi Panza

Encapsulamiento de compuestos borados en liposomas.



LCOB

Carboranos
Compuestos polihédricos con 10 átomos de boro por molécula

β-lactosil o-closocarborano (LCOB)
Especial interés para su aplicación en BNCT.

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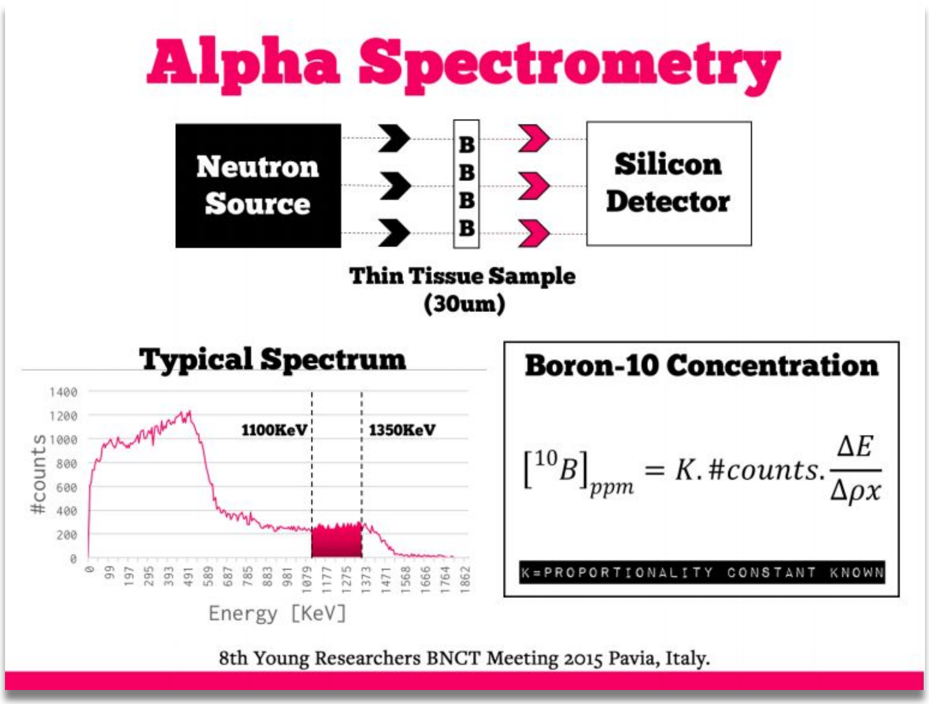
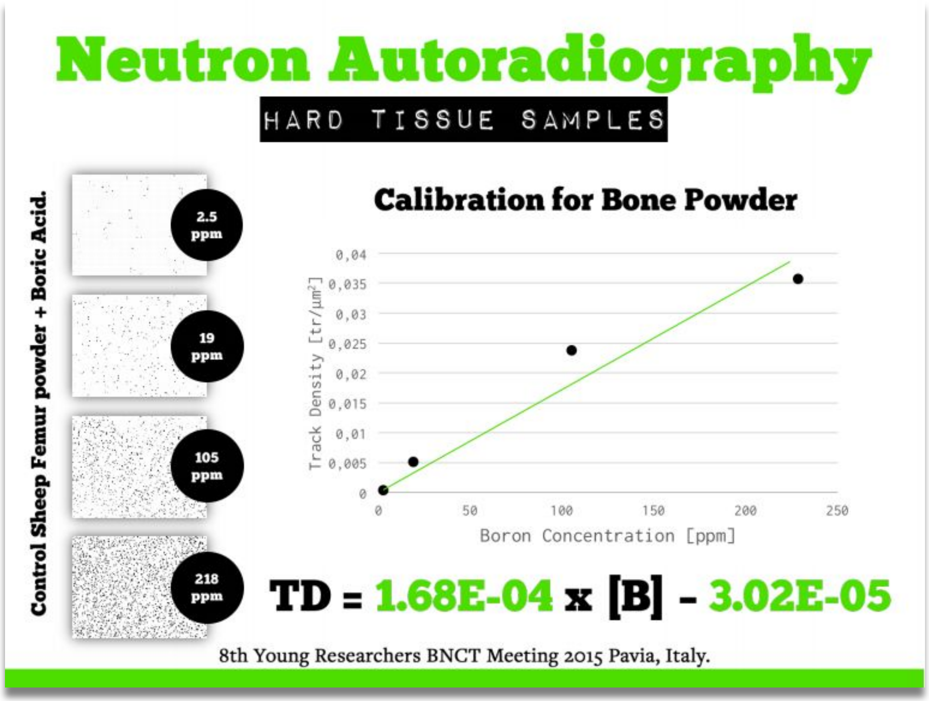
Lucas Provenzano

Extensión de técnicas de detección de boro en tejidos duros

Silva Bortolussi





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Sara González

Investigación y formación de RRHH en BNCT

Silva Bortolussi

- Dirección conjunta de L. Provenzano (becario doctoral CONICET)
  - ❑ Técnicas de detección de boro en tejidos duros: alfaespectrometría & autorradiografía neutrónica
  - ❑ Evaluación del reactor RA-6 para tratamientos de cabeza y cuello
- Estudios de BNCT en osteosarcoma
  - ❑ Evaluación de haces
  - ❑ Potencialidad de tratamiento
- Estudios de BNCT ex situ en pulmón sano de oveja
- Modelo teórico de cálculo de dosis en BNCT
  - ❑ Ensayos de sobrevida celular (líneas celulares de osteosarcoma, cabeza y cuello)
  - ❑ Aplicación del modelo a casos clínicos de BNCT
- S. Bortolussi & S. Altieri, colaboradores de subsidios PICT y PIP

Saverio Altieri

¡Muchas gracias!
Grazie mille!

Silva y Lucas siguindo atentamente los monitores durante el tratamiento de BNCT (reinicio de los tratamientos clínicos en Bariloche, Octubre 2015).

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