



Simulation Activities at IBA

23/11/2016 – 14th MCnet Workshop - CERN



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Outline



□ IBA in short:

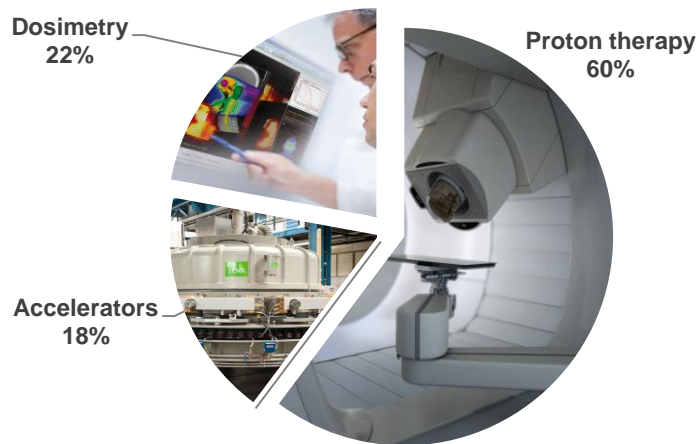
- RadioPharma solutions
- Industrial accelerators
- Dosimetry products
- Proton therapy

□ Current research activities:

- Health Physics
- Accelerator Physics
- Medical Physics

IBA in short

- Company formed in 1986 as spin-off of UCL and based in Louvain-La-Neuve (LLN), Belgium
- Employs ~ 1,000 people worldwide, ~500 based at LLN headquarters.
- Number one provider of integrated proton therapy solutions
 - More compact and targeted radiotherapy applications
- Synergistic businesses in dosimetry, medical and industrial accelerators





QUALITY ASSURANCE & GMP



^{18}F -
+ other
radioisotopes



^{18}F FDG
+ other
compounds



Quality
control &
sterility
tests



MRI/PET
OR PET/CT



Injection &
Diagnostic

IBA CYCLOTRONS FAMILY : GLOBAL COVERAGE



3 MeV

11 MeV

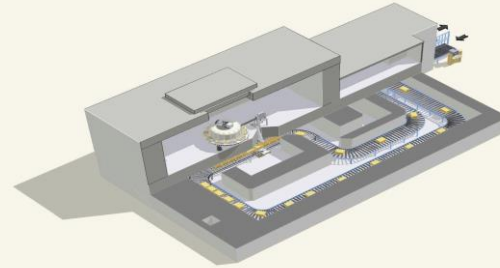
18MeV

30MeV

70MeV

IBA Industrial Accelerators

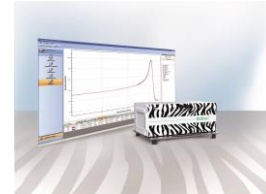
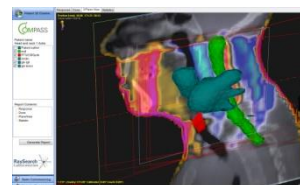
- Electron beams 3 to 10 MeV
- Beam power 35 kW to 700 kW (7 MeV/100 mA)
- E-beam or X-ray treatment modes
- Applications:
 - Medical device sterilization
 - Food pasteurization
 - Advanced material manufacturing (cables, tires, ...)
- Installed base > 200 units



IBA DOSIMETRY PRODUCTS

Radiation Therapy

Linac commissioning and quality assurance of machine and patient plan, for safer patient treatments.



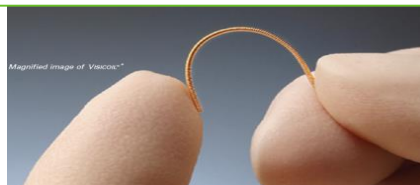
Medical Imaging

Full solution provider in quality control in diagnostics imaging, for better diagnosis.



Image Markers

Clear tumor localization, for higher targeting accuracy.



Proton Therapy

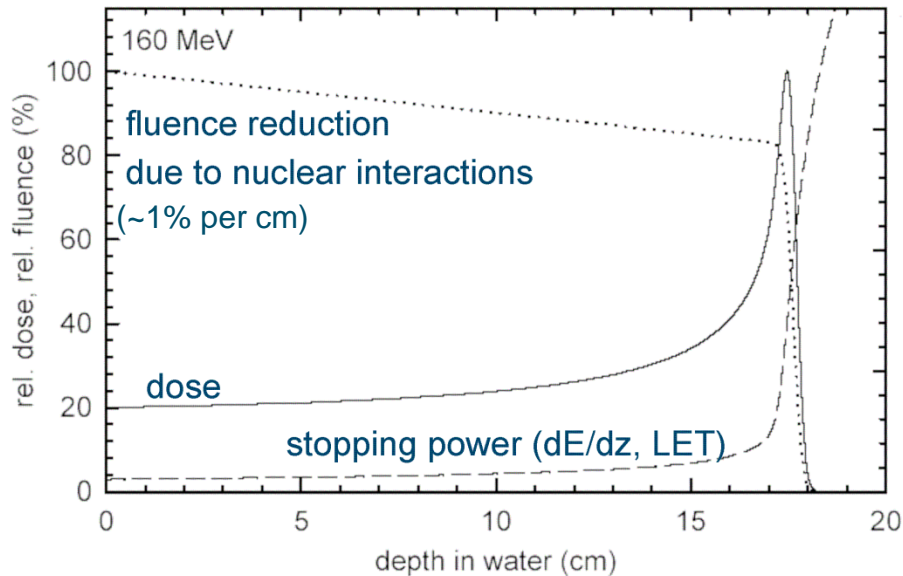
Next generation in targeted cancer treatment



Proton Depth-Dose Curve



Bragg peak:
stopping power $\frac{dE}{dz} = -4\pi n \frac{Z_{\text{eff}}^2 e^4}{m_e v^2} \left\{ \ln \frac{2m_e v^2}{I(1-(v/c)^2)} - (v/c)^2 \right\}$



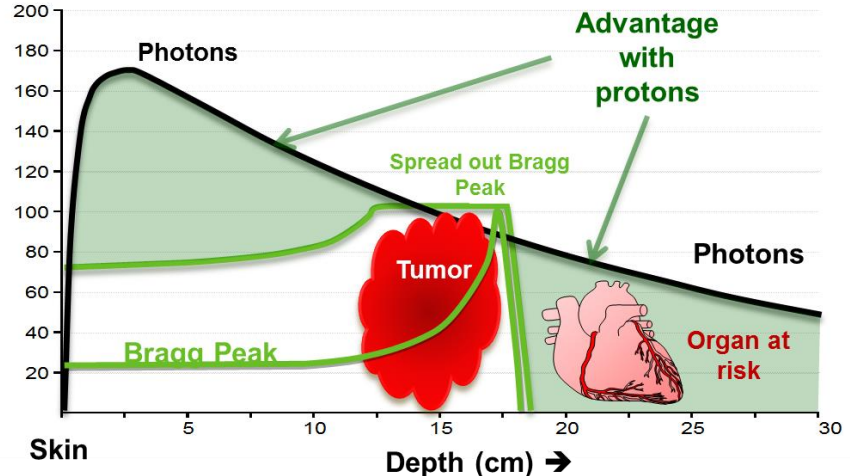
Proton therapy vs. conventional radiotherapy

Case studies for efficacy and toxicity

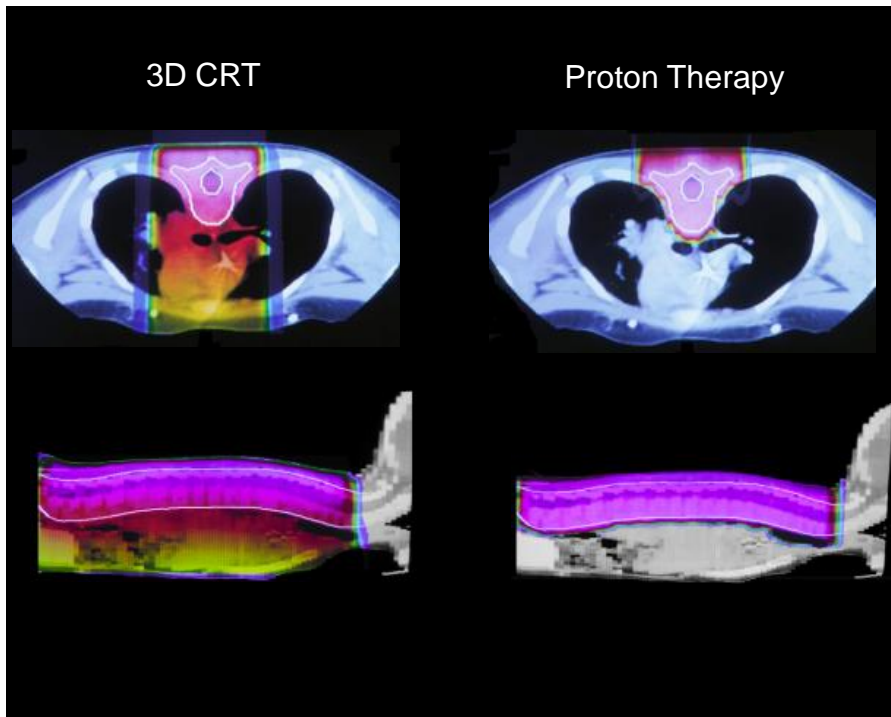
Protons have a superior dose distribution

- Protons:
 - Deliver their maximum energy within a precisely controlled range
 - Deposit a high and conformal dose
 - Deposit very little entry dose
 - Deposit no exit dose
- Up to 50% reduced risk of radiation-induced secondary cancer
- Much lower risks of adverse effects (toxicity, side effects, abnormal growth)

➔ Better quality of life during and after treatment



Clinical examples : pediatric medulloblastoma



Side Effects	Photons	Protons
Restrictive Lung Disease	60%	0%
Reduced exercise capability	75%	0%
Abnormal EKGs	31%	0%
Growth abnormality	100%	20%
IQ drop of 10 points at 6 yrs	28.5%	1.6%
Risk of IQ score < 90	25%	15%

“Proton beam therapy has become a standard of care for pediatric cancers...”

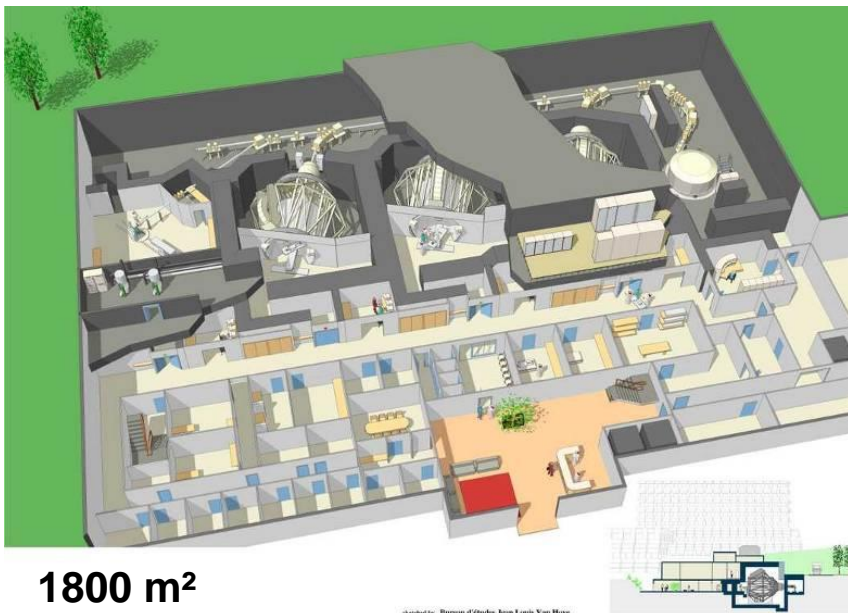
(*)

(*) Presentation Dr. Jay S. Loeffler, NPTC/MGH, ASTRO 2001

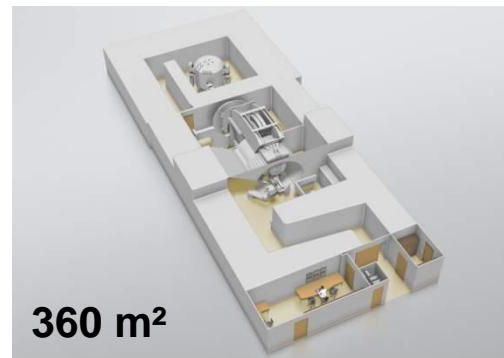
Clinical outcome and affordable

Multi-room to single-room solutions

Proteus[®]PLUS



Proteus[®]ONE*



***Proteus[®]ONE features PBS, Cone Beam CT and Compact gantry.**

Global adoption of IBA Proton Therapy

26 IBA reference centers - 25,000 patients treated



NORTH AMERICA NETWORK

4
score



CDH PROTON THERAPY CENTER, A PROCURE CENTER
Warrenville, IL, USA
Treating since 2010

5
score



UNIVERSITY OF PENNSYLVANIA HEALTH SYSTEM ROBERTS PROTON THERAPY CENTER
Philadelphia, PA, USA
Treating since 2009

5
score



HAMPTON UNIVERSITY PROTON THERAPY INSTITUTE
Hampton, VA, USA
Treating since 2010

3
score



THE PROTON THERAPY CENTER LLC (TPTC) PROVISION HEALTHCARE
Knoxville, TN, USA
Opening in 2014

1
score



WILLIS-KNIGHTON CANCER CENTER
Shreveport, LA, USA
Opening in 2014

4
score



PROCORE PROTON THERAPY CENTER IN OKLAHOMA CITY
Oklahoma City, OK, USA
Treating since 2009

3
score



MASSACHUSETTS GENERAL HOSPITAL BURR PROTON THERAPY CENTER
Boston, MA, USA
Treating since 2001

4
score



SCCA PROTON THERAPY A PROCURE CENTER
Seattle, WA, USA
Opening in 2013

4
score



PROCORE PROTON THERAPY CENTER
Somerset, NJ, USA
Treating since 2012

4
score



UNIVERSITY OF FLORIDA PROTON THERAPY INSTITUTE
Jacksonville, FL, USA
Treating since 2006

3
score



TEXAS CENTER FOR PROTON THERAPY
Dallas, TX, USA
Opening in 2015

2
score



INDIANA UNIVERSITY HEALTH PROTON THERAPY CENTER
Bloomington, IN, USA
Treating since 2004



EUROPE NETWORK

4
score



WESTDEUTSCHES PROTONTHERAPIEZENTRUM ESSEN (WPE)
Essen, Germany
Treating since 2013

2
score



AGENZIA PROVINCIALE PER LA PROTONTERAPIA (ATREP)
Trento, Italy
Opening in 2013

1
score



CENTRE ANTOINE LACASSAGNE
Nice, France
Opening in 2014

2
score



BRONOWICE CYCLOTRON CENTER
Kraków, Poland
Opening in 2013

4
score



FEDERAL HIGH-TECH MEDICAL CENTER
Dmitriygrad, Russia, Europe
Opening in 2013

4
score



PROTON THERAPY CENTER CZECH S.R.O.
Prague, Czech Republic
Treating since 2012

2
score



CENTRE DE PROTONTHÉRAPIE DE L'INSTITUT CURIE
Paris (Orsay), France
Treating since 2009

2
score



SKANDIONKLINIKEN
Uppsala, Sweden
Opening in 2013

1
score



UNIVERSITÄTSKLINIKUM CARL GUSTAV CARUS
Dresden, Germany
Opening in 2014



ASIA NETWORK

1
score



NATIONAL CANCER CENTER
Ilsan, Korea
Treating since 2007

3
score



APOLLO PROTON THERAPY CENTER
Chennai, India
Opening in 2015

2
score



WANJIE PROTON THERAPY CENTER
Zibo, China
Treating since 2004

1
score



CHC TAIPEI PROTON THERAPY CENTER
Taipei, Taiwan
Opening in 2015

3
score



NATIONAL CANCER CENTER
Kashiwa, Japan
Treating since 1998



● Proteus®PLUS

● Proteus®ONE

THIS MAP HAS BEEN LAST UPDATED IN AUGUST 2013.



Monte Carlo Simulations at IBA (1)



- **IBA core business deals with the use of particle accelerators for medical/industrial applications**
 - **MC transport codes are essential tools in many activities**
 - Radiation protection studies (shielding design, activation);
 - Accelerator physics (beam losses, beam line modeling);
 - Evaluation of radiation damages to electronic devices;
 - Medical physics:
 - On-line monitoring of proton beam range inside patient (Prompt gamma, PET emission)
 - Study of secondary neutron doses delivered to patient during treatment

Monte Carlo Simulations at IBA (2)



□ Major used codes:

- **MCNPX (Monte Carlo N-Particle eXtended) / MCNP6**
 - Developed by Los Alamos National Lab. for Nuclear Physics
 - Transport of e^- , γ , n, h, light ions, heavy ions, μ , baryons, mesons (π , K, D).
- **PHITS (Particle and Heavy Ion Transport code System)**
 - Developed by JAEA, RIKEN for accelerator design, medical physics and cosmic-ray research
 - Transport of e^- , γ , neutrons, protons, light ions, heavy ions
- **GEANT4 (TOPAS)**
 - Developed by CERN, SLAC and other HEP Labs.
 - Transport of particles for energies from 250 eV to 1 TeV.

Radiation Protection Studies in Proton Therapy



Neutrons and photons are produced at various locations along beam path when protons hit matter

Energy Selection System (ESS)

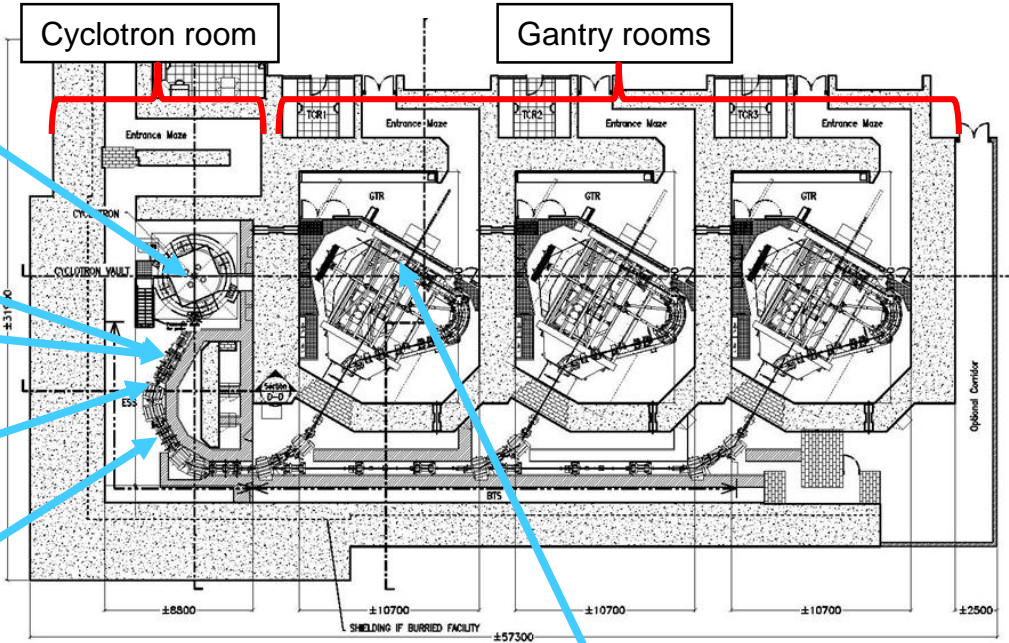
Cyclotron (230 MeV on Cu/Fe)

Degrader (230 MeV on C)

Collimator (70-230 MeV on Ta)

Divergence slits (70-230 MeV on Ni)

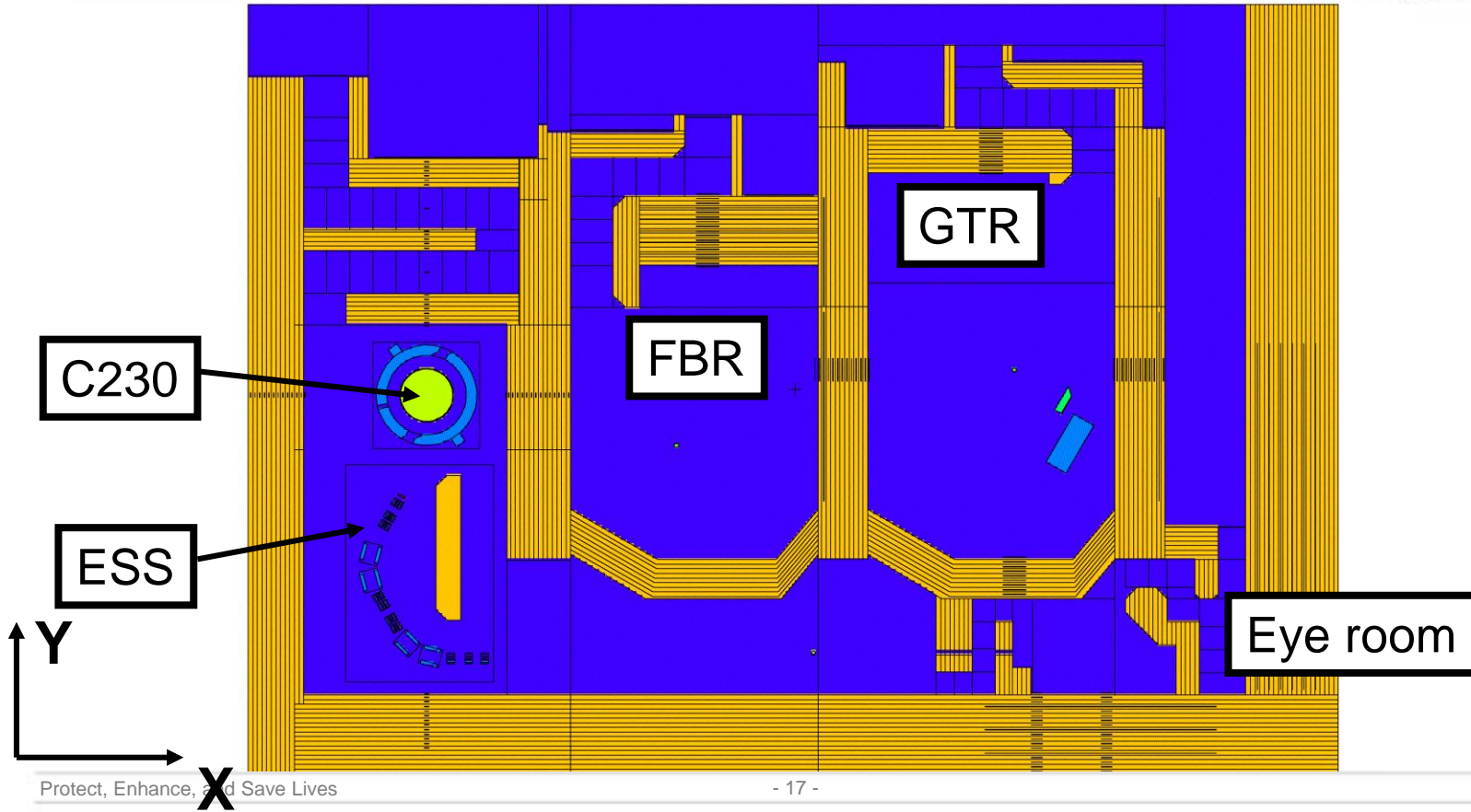
Momentum slit (70-230 MeV on Ni)



Patient (70-230 MeV on Tissue)

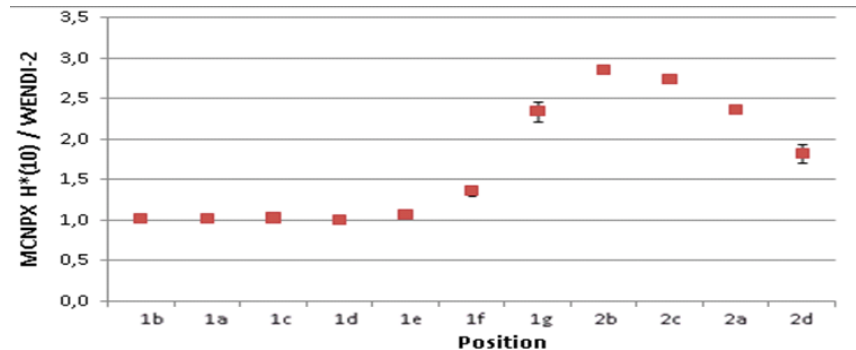
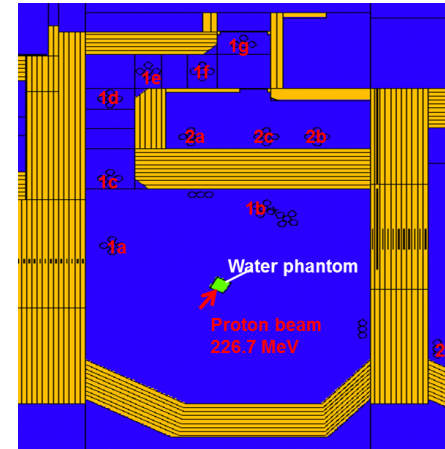


ProteusPLUS Modelling with MCNPX



Radiation Protection Studies in Proton Therapy

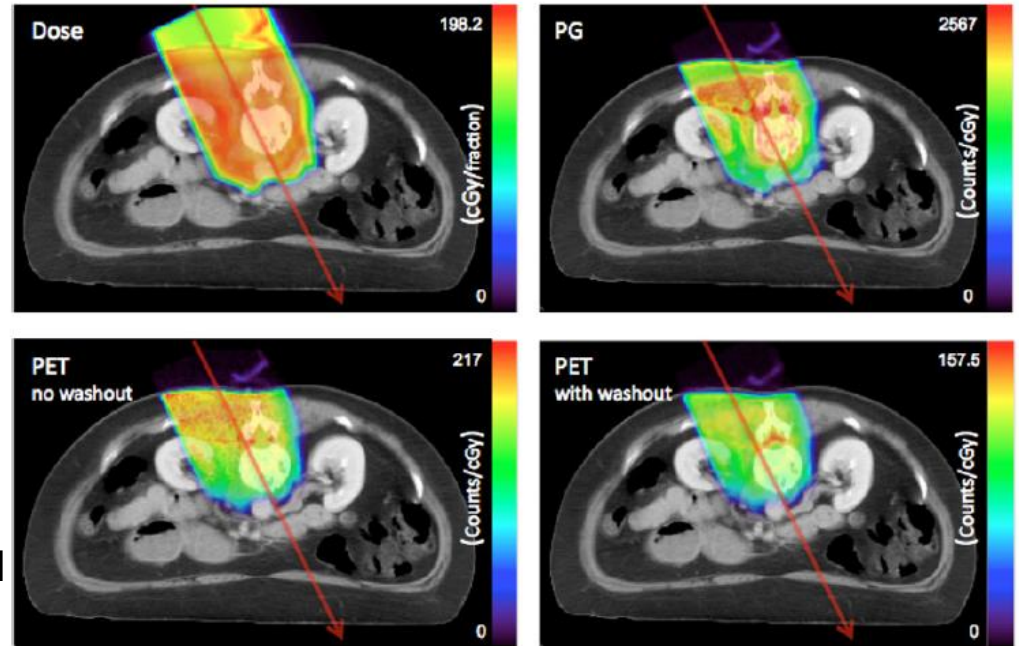
- Shielding studies:
 - Shielding optimization using MC tools;
 - Understanding of Data-MC discrepancies obtained behind thick shielding walls.
- Activation studies:
 - Simulation of activation processes to improve decommissioning activities (concrete, equipment).
 - Study of environmental impact (air, water, ground activation).



Proton Range Monitoring inside Patient



- To improve PT precision, we need to better monitor the proton range inside the patient:
 - Production of PET isotopes in patient:
 - ^{11}C ($T_{1/2} = 20.39$ min)
 - ^{15}O ($T_{1/2} = 2.03$ min)
 - ^{13}N ($T_{1/2} = 9.97$ min)
 - ^{30}P ($T_{1/2} = 2.50$ min)
 - ^{38}K ($T_{1/2} = 7.63$ min)
 - Production of prompt γ by excited nuclei along the beam path.
- A lot of MC studies to study the feasibility of these two techniques.



M. Moteabbed et al., PMB 56 (2011) 1063.

PET Isotope Production



- This method heavily rely upon MC simulations to predict the β^+ activity distribution inside the patient and compare to PET-CT measurements.
- Recent comparison of ^{11}C and ^{15}O production in water and PMMA using 4 MC codes: GEANT4, FLUKA, MCNPX, PHITS.

IOP PUBLISHING PHYSICS IN MEDICINE AND BIOLOGY
Phys. Med. Biol. 57 (2012) 1659–1673 doi:10.1088/0031-9155/57/6/1659

Monte Carlo calculations of positron emitter yields in proton radiotherapy

E Seravalli¹, C Robert^{2,9}, J Bauer^{3,9}, F Stichelbaut^{4,9}, C Kurz^{3,9},
J Smeets⁵, C Van Ngoc Ty⁶, D R Schaart⁷, I Buvat², K Parodi³
and F Verhaegen^{1,8,10}

¹ Department of Radiation Oncology (MAASTRO), University Medical Centre Maastricht, Maastricht, The Netherlands

² IMNC—UMR 8165 CNRS, Universités Paris 7 et Paris 11, Bât 440, Orsay, France

³ Heidelberg Ion Beam Therapy Centre and Department of Radiation Oncology, Heidelberg University, Clinic, Heidelberg, Germany

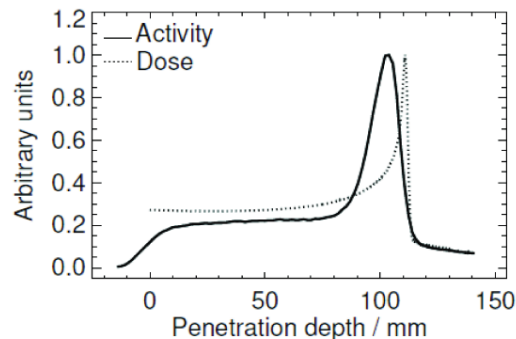
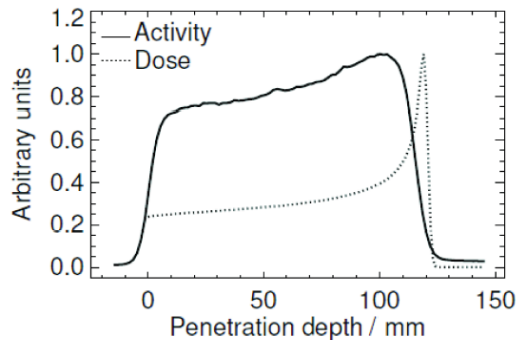
⁴ IBA, Louvain-la-Neuve, Belgium

⁵ Service de Métrologie Nucléaire, Université Libre de Bruxelles

⁶ CEA-SHFJ, Orsay, France

⁷ Delft University of Technology, Delft, The Netherlands

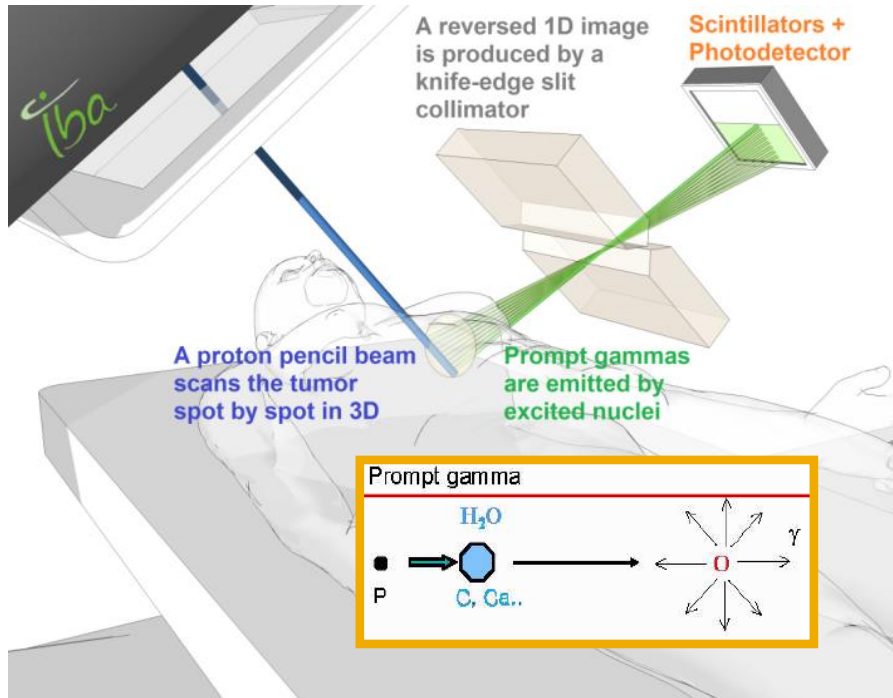
⁸ Department of Oncology, McGill University, Montréal, Québec H3G 1A4, Canada



K. Parodi thesis, 2004.



Slit Camera Concept for Proton Therapy



- Measurement of the position at which the proton beam stops in the patient **in PBS mode**
- Real-time verification with an **accuracy < 5 mm** for a selection of critical spots
- Points of attention: simplicity, low-dose sensitivity, cost effectiveness



Thank You



Frédéric Stichelbaut, Ph.D.



Domain Expert, IBA Fellow



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