DOSIMETRIA DI FASCI DI IONI

A SCANSIONE PER ADROTERAPIA

M. Ciocca

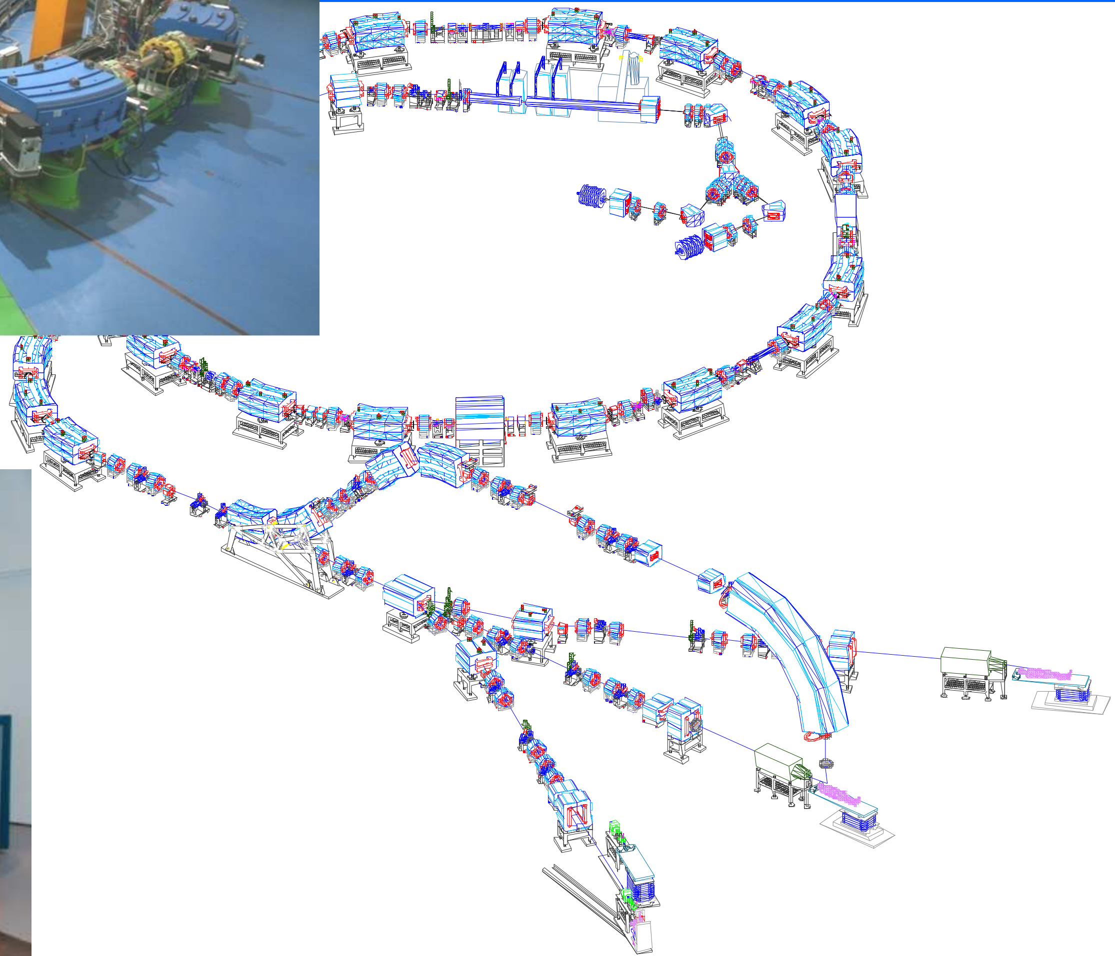
Unità di Fisica Medica, Fondazione CNAO, Pavia

CNAO

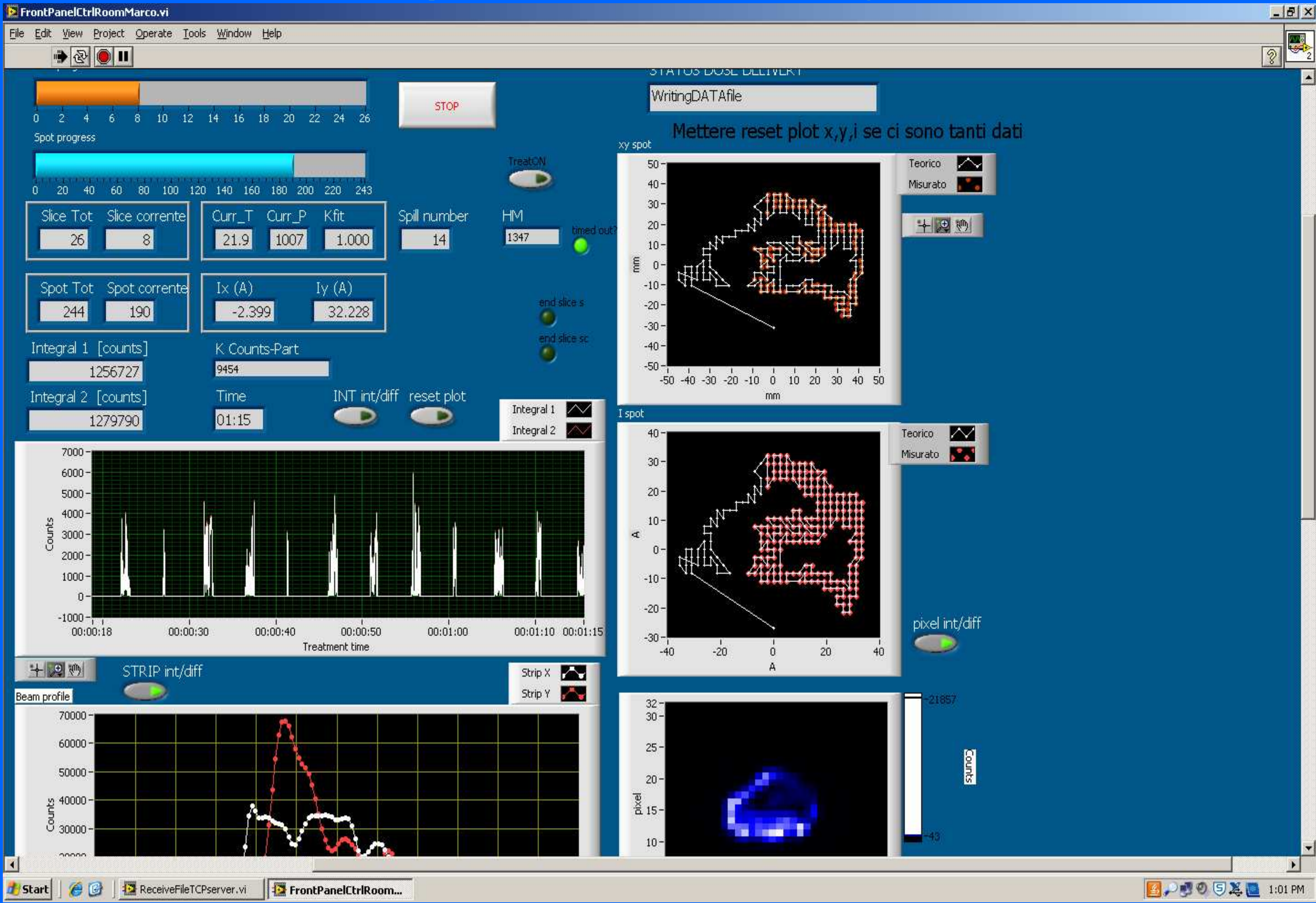
Typical layout for a proton-therapy facility:
cyclotron, 2 fixed-beam lines, 2 rooms with
gantry, 1 experimental room

CNAO

Synchrotron-based facility

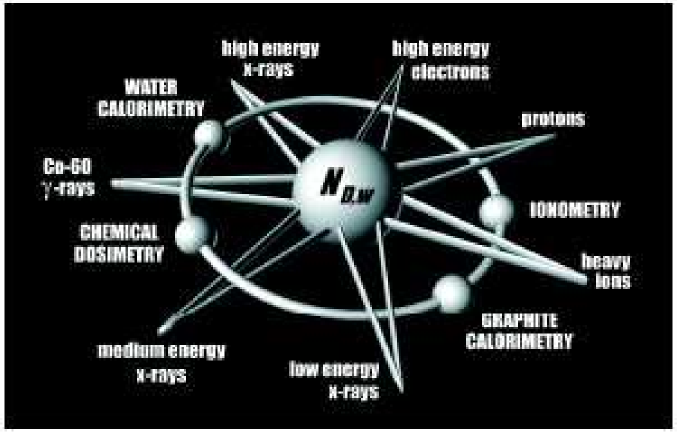


3-D active system: energy variation + pencil beam scanning



IAEA TRS-398

Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry based on Standards of Absorbed Dose to Water



Pedro Andreo, Dosimetry and Medical Radiation Physics Section, IAEA
David T Burns, Bureau International des Poids et Mesures (BIPM)
Klaus Hohlfeld, Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany
M Saiful Huq, Thomas Jefferson University, Philadelphia, USA
Tatsuaki Kanai, National Institute of Radiological Sciences (NIRS), Chiba, Japan
Fedele Laitano, Ente per le Nuove Tecnologie L'Energia e L'Ambiente (ENEA), Rome, Italy
Vere Smyth, National Radiation Laboratory (NRL), Christchurch, New Zealand
Stefaan Vynckier, Catholic University of Louvain (UCL), Brussels, Belgium

PUBLISHED BY THE IAEA ON BEHALF OF IAEA, WHO, PAHO, AND ESTRO

INTERNATIONAL ATOMIC ENERGY AGENCY IAEA
21 May 2001 (V.10A)

ISTITUTO SUPERIORE DI SANITÀ

RAPPORTI ISTISAN 21|12

ISSN: 1123-3117 (cartaceo) • 2384-8936 (online)

Raccomandazioni per l'impiego della radioterapia con fasci di protoni

M. Amichetti, M. Ciocca, E. Cisbani, M. Curzel, C. De Angelis, M. Durante, G. Esposito, M. Ferrarini, R. Orecchia, E. Orlandi, L. Raffaele, A. Rosi, M. Schwarz, C. Spatola, M.A. Tabocchini, S. Tampellini, F. Valvo, S. Vennarini

TECNOLOGIE E SALUTE

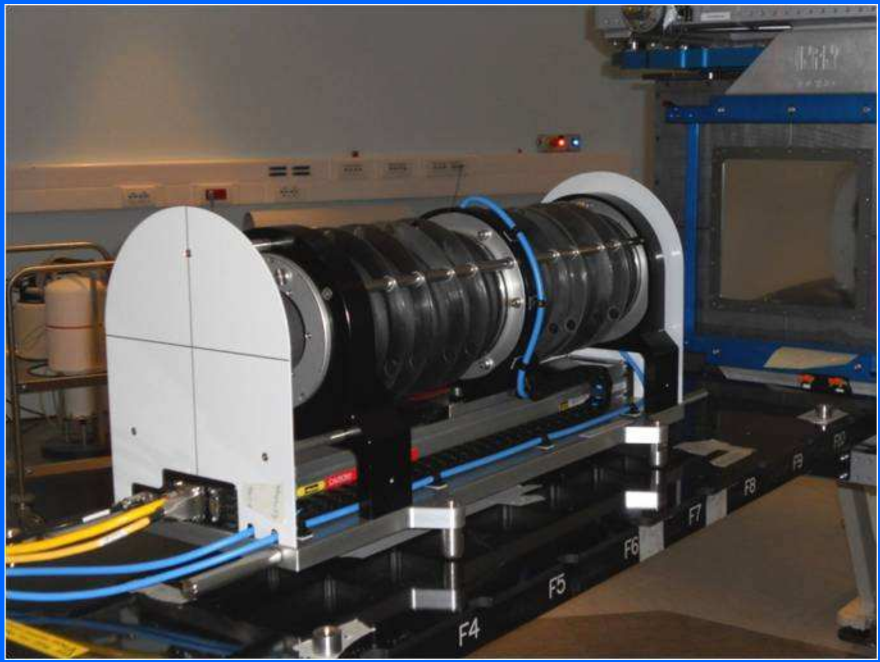
Dose to water under non-ref. conditions

Physics basic beam data acquired:

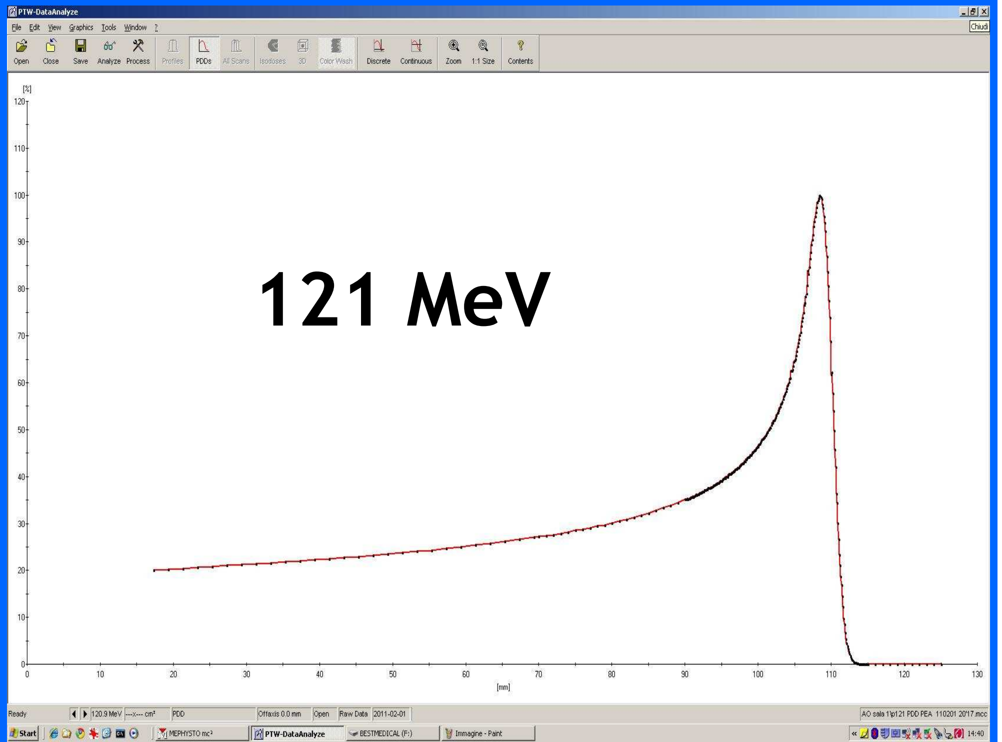
- experimentally
- Monte Carlo simulation (FLUKA or Geant4 codes)

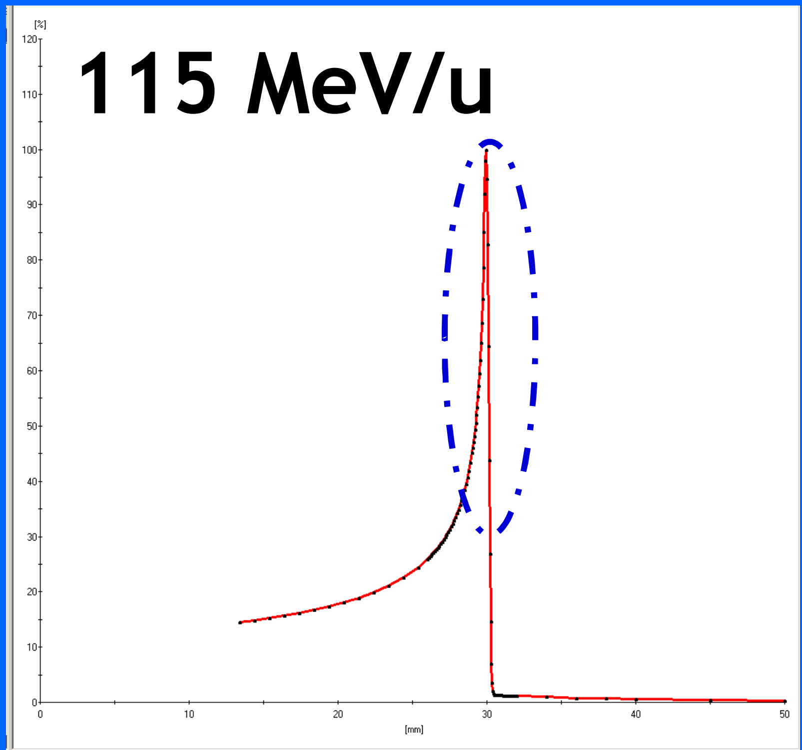
Experimental data

Lat-integrated Depth Dose Distributions (mono-en. pencil beams)

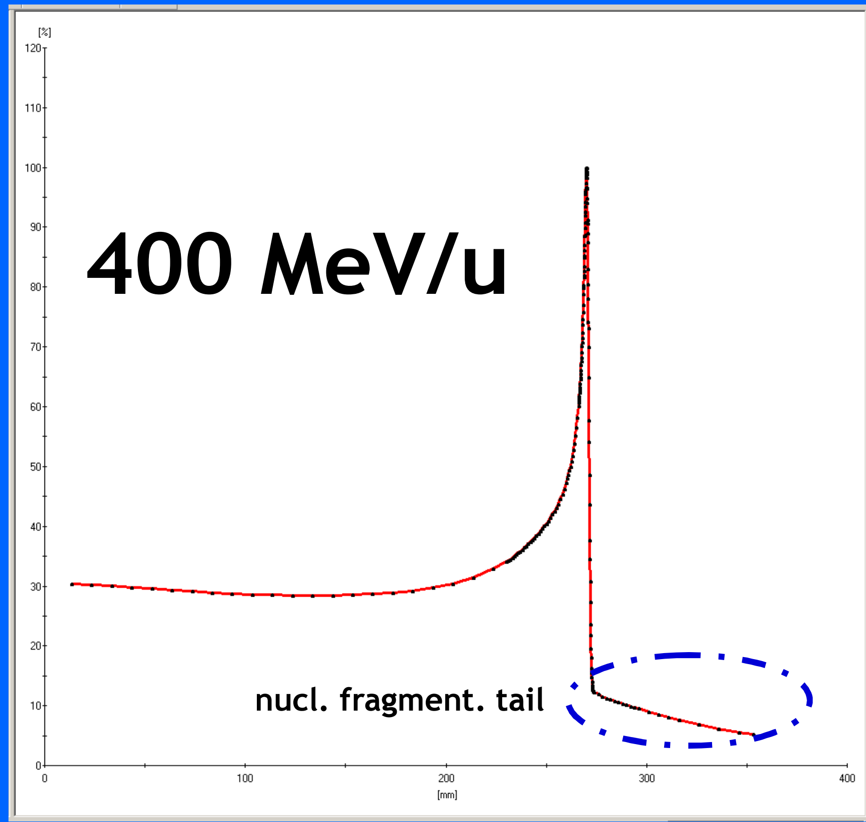


Peakfinder water column

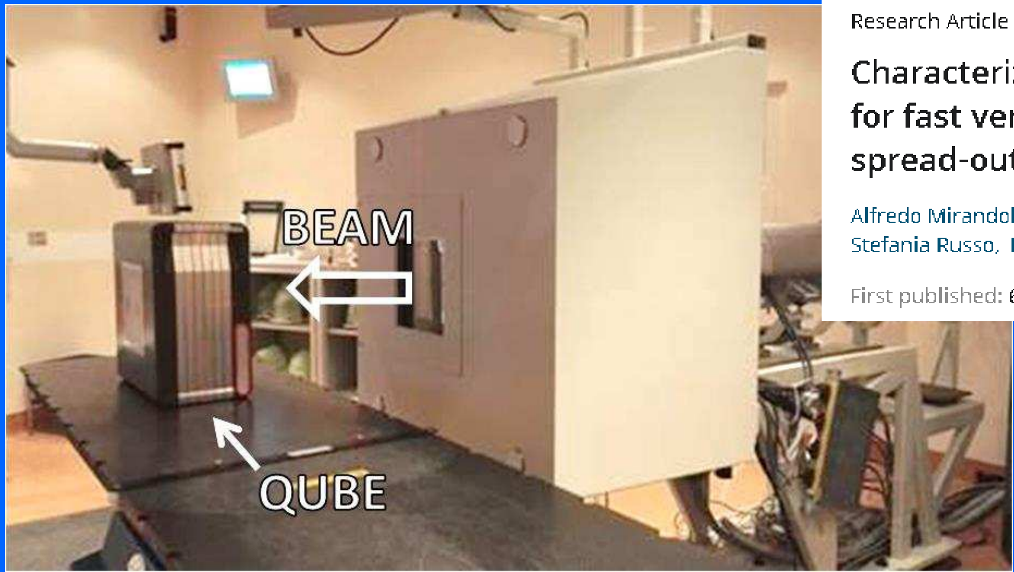




115 MeV/u
[%]
[mm]



400 MeV/u
nucl. fragment. tail
[%]
[mm]



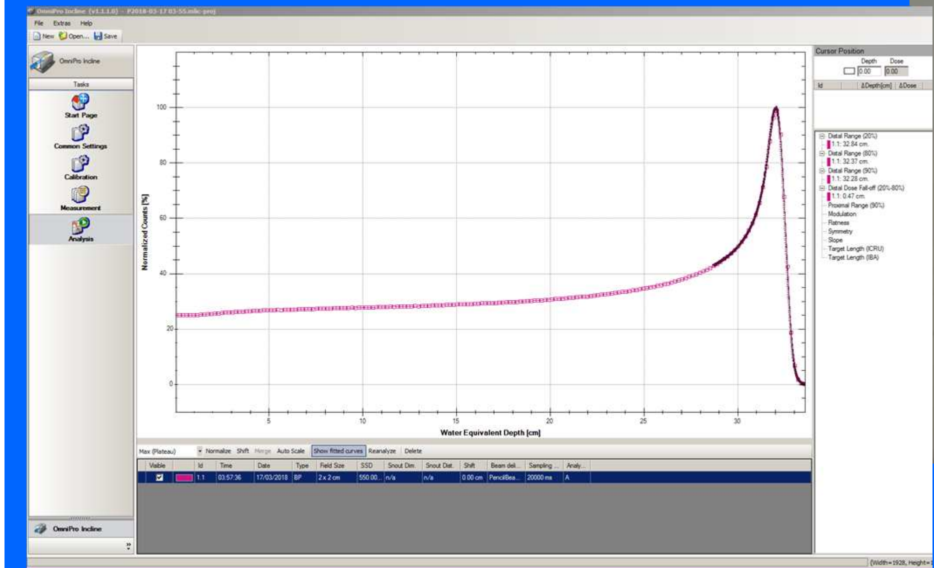
Medical Physics
The International Journal of Medical Physics Research and Practice

Research Article

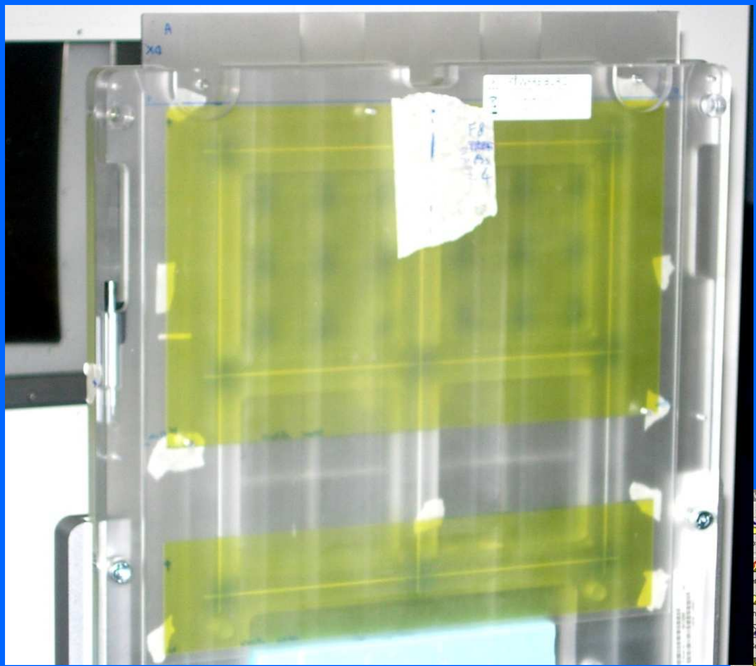
Characterization of a multilayer ionization chamber prototype for fast verification of relative depth ionization curves and spread-out-Bragg-peaks in light ion beam therapy

Alfredo Mirandola, Giuseppe Magro, Marco Lavagno, Andrea Mairani, Silvia Molinelli, Stefania Russo, Edoardo Mastella, Alessandro Vai, Davide Maestri, Vanessa La Rosa, Mario Ciocca

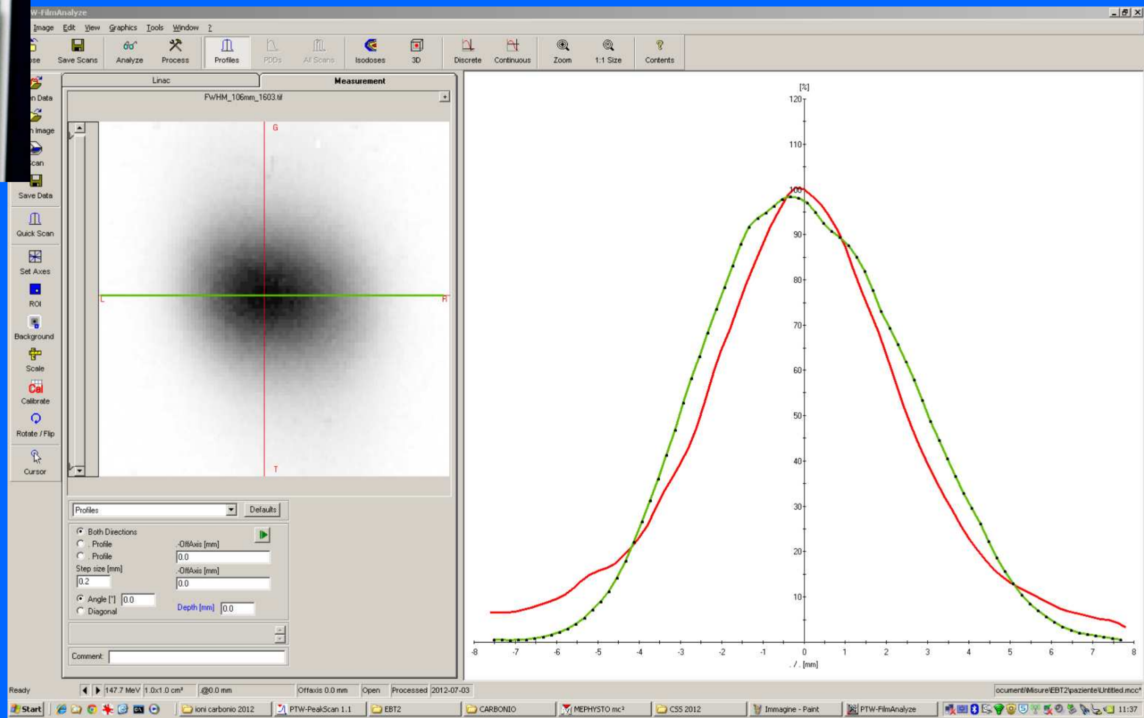
First published: 6 April 2018 | https://doi.org/10.1002/mp.12866

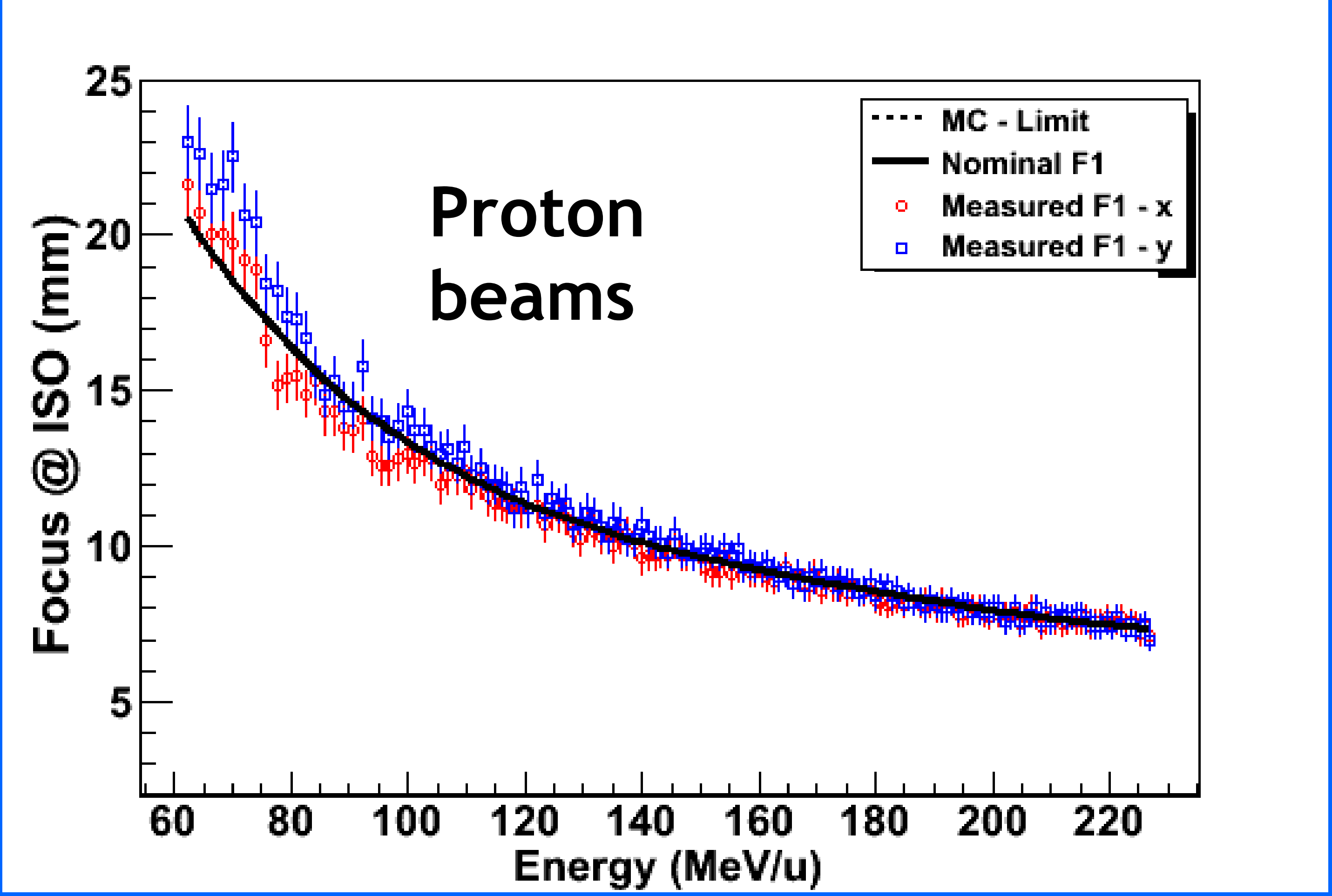


Transversal dose profiles in air

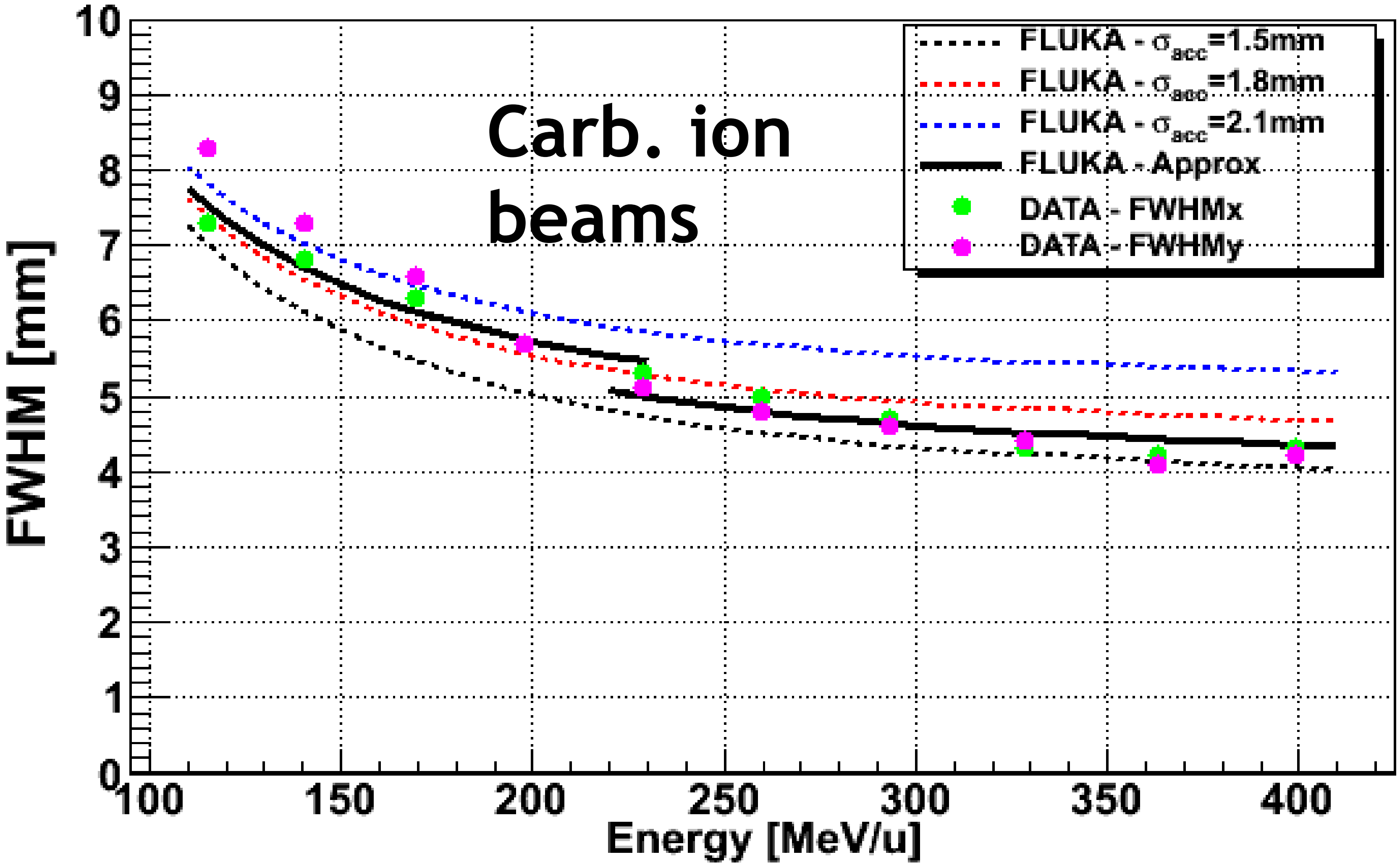


EBT3 radiochromic films





Proton beams
MC - Limit
Nominal F1
Measured F1 - x
Measured F1 - y
Focus @ ISO (mm)
Energy (MeV/u)
25
20
15
10
5
60
80
100
120
140
160
180
200
220



Carb. ion beams
FLUKA - σacc=1.5mm
FLUKA - σacc=1.8mm
FLUKA - σacc=2.1mm
FLUKA - Approx
DATA - FWHMx
DATA - FWHMy
FWHM [mm]
Energy [MeV/u]
0
1
2
3
4
5
6
7
8
9
10
100
150
200
250
300
350
400

Physica Medica 34 (2017) 48–54

Contents lists available at ScienceDirect

Physica Medica

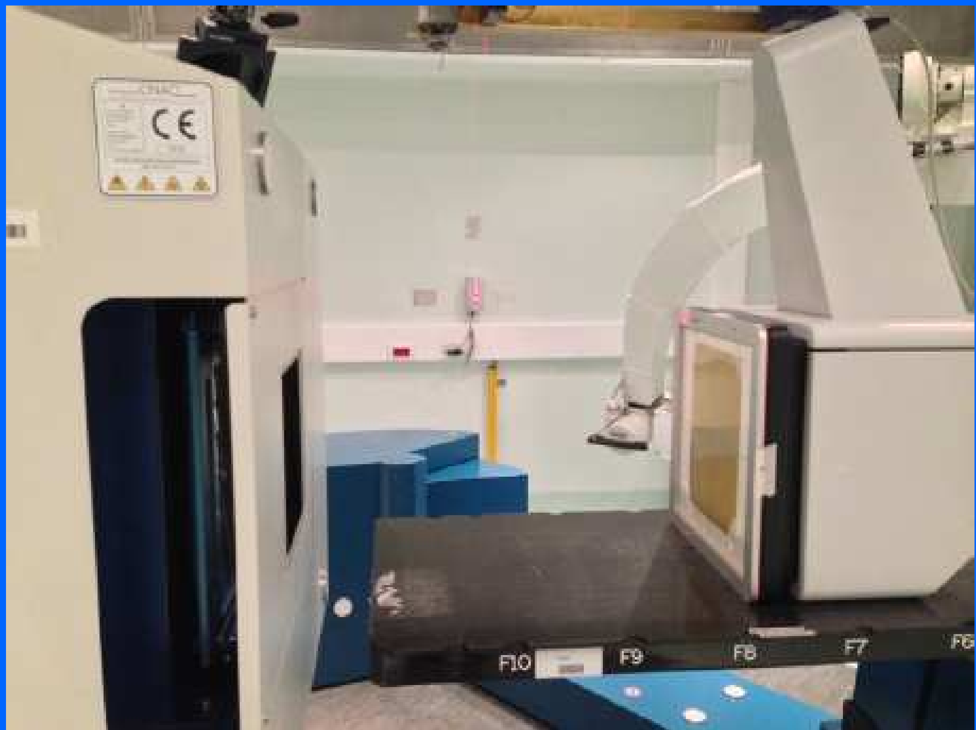
journal homepage: http://www.physicamedica.com

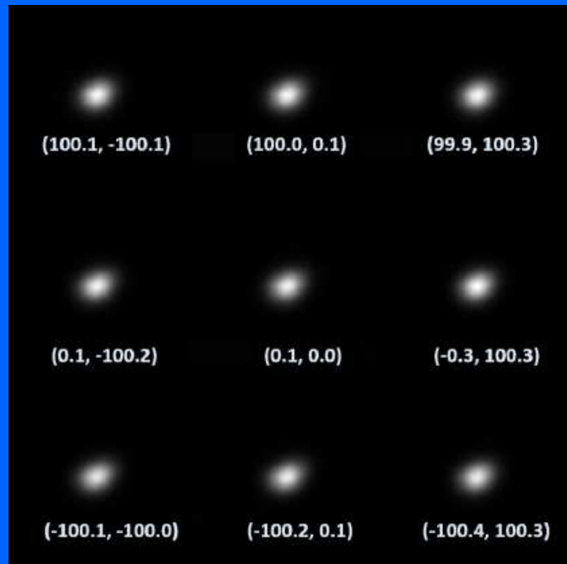
Original paper

Characterization of a commercial scintillation detector for 2-D dosimetry in scanned proton and carbon ion beams

S. Russo [a,*], A. Mirandola [a], S. Molinelli [a], E. Mastella [a], A. Vai [a], G. Magro [a], A. Mairani [a,b], D. Boi [c], M. Donetti [a,d], M. Ciocca [a]

[a] Fondazione CNAO, Pavia, Italy
[b] HIT – Heidelberg Ion Beam Therapy Center, Heidelberg, Germany
[c] Department of Physics, Università degli Studi di Cagliari, Cagliari, Italy
[d] Istituto Nazionale di Fisica Nucleare, Section of Torino, Torino, Italy





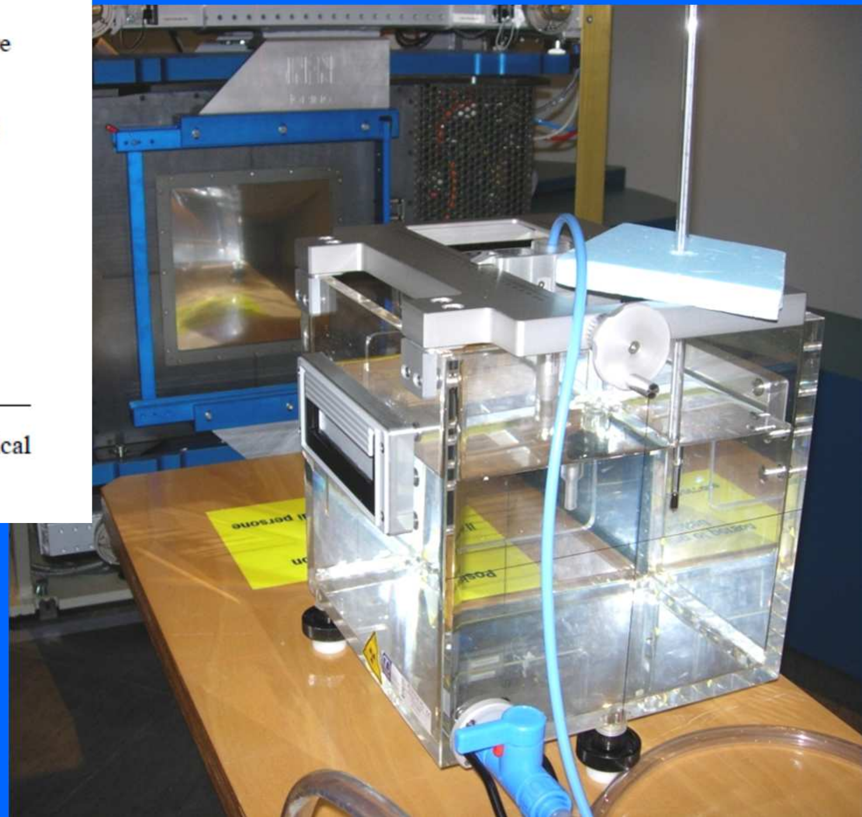
Dose to water under ref. conditions

TABLE 30. REFERENCE CONDITIONS FOR THE DETERMINATION OF ABSORBED DOSE IN PROTON BEAMS

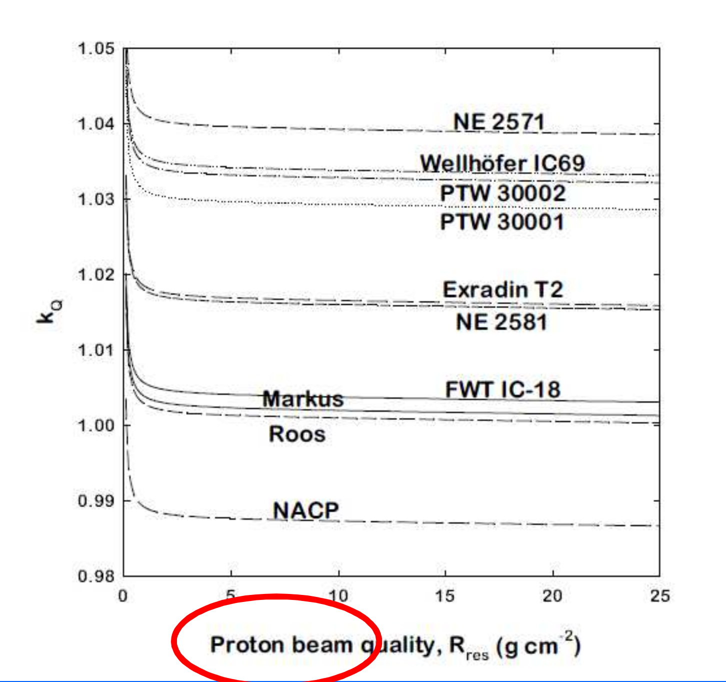
Influence quantity	Reference value or reference characteristics
Phantom material	Water
Chamber type	For $R_{res} \geq 0.5$ g/cm^2, cylindrical and plane parallel For $R_{res} < 0.5$ g/cm^2, plane parallel
Measurement depth z_{ref}	Middle of the SOBP[a]
Reference point of the chamber	For plane-parallel chambers, on the inner surface of the window at its centre For cylindrical chambers, on the central axis at the centre of the cavity volume
Position of the reference point of the chamber	For plane-parallel and cylindrical chambers, at the point of measurement depth z_{ref}
SSD	Clinical treatment distance
Field size at the phantom surface	10 cm × 10 cm, or that used for normalization of the output factors whichever is larger. For small field applications (i.e. eye treatments), 10 cm × 10 cm or the largest field clinically available

[a] The reference depth can be chosen in the 'plateau region', at a depth of 3 g/cm^2, for clinical applications with a monoenergetic proton beam (e.g. for plateau irradiations).

$$D_{w,Q} = M_Q N_{D,w,Q_0} k_{Q,Q_0}$$



IAEA TRS 398 (2000)



Ioni carbonio: dipende solo dalla camera, non da qualità fascio (current lack of experimental data!)

TABLE 11.II. CALCULATED VALUES OF k_Q FOR HEAVY-ION BEAMS, FOR VARIOUS CYLINDRICAL AND PLANE-PARALLEL IONIZATION CHAMBERS

Ionization chamber type [a]	k_Q
Cylindrical chambers	
Capintec PR-05P mini	1.045
Capintec PR-05 mini	1.045
Capintec PR-06C/G Farmer	1.037

TABLE 10.IV. ESTIMATED RELATIVE STANDARD UNCERTAINTY [a] OF $D_{w,Q}$ AT THE REFERENCE DEPTH IN WATER AND FOR A CLINICAL PROTON BEAM, BASED ON A CHAMBER CALIBRATION IN ^{60}Co GAMMA RADIATION

Physical quantity or procedure	Relative standard uncertainty (%)	
User chamber type:	cylindrical	plane-parallel
Step 1: Standards Laboratory	*SSDL* [b]	*SSDL* [b]
$N_{D,w}$ calibration of secondary standard at PSDL	0.5	0.5
Long term stability of secondary standard	0.1	0.1
$N_{D,w}$ calibration of the user dosimeter at the standards laboratory	0.4	0.4
Combined uncertainty in Step 1	*0.6*	*0.6*
Step 2: User proton beam		
Long-term stability of user dosimeter	0.3	0.4
Establishment of reference conditions	0.4	0.4
Dosimeter reading M_Q relative to beam monitor	0.6	0.6
Correction for influence quantities k_i	0.4	0.5
Beam quality correction, k_Q	1.7	2.0
Combined uncertainty in Step 2	*1.9*	*2.2*
Combined standard uncertainty in $D_{w,Q}$ (Steps 1 + 2)	**2.0**	**2.3**

(vs 1.5% photons)

TABLE 11.III. ESTIMATED RELATIVE STANDARD UNCERTAINTY [a] OF $D_{w,Q}$ AT THE REFERENCE DEPTH IN WATER AND FOR A CLINICAL HEAVY-ION BEAM, BASED ON A CHAMBER CALIBRATION IN ^{60}Co GAMMA RADIATION

Physical quantity or procedure	Relative standard uncertainty (%)	
User chamber type:	cylindrical	plane-parallel
Step 1: Standards Laboratory	*SSDL* [b]	*SSDL* [b]
$N_{D,w}$ calibration of secondary standard at PSDL	0.5	0.5
Long term stability of secondary standard	0.1	0.1
$N_{D,w}$ calibration of the user dosimeter at the standard laboratory	0.4	0.4
Combined uncertainty in Step 1	*0.6*	*0.6*
Step 2: User heavy-ion beam		
Long-term stability of user dosimeter	0.3	0.4
Establishment of reference conditions	0.4	0.6
Dosimeter reading M_Q relative to beam monitor	0.6	0.6
Correction for influence quantities k_i	0.4	0.5
Beam quality correction, k_Q	2.8	3.2
Combined uncertainty in Step 2	*2.9*	*3.0*
Combined standard uncertainty in $D_{w,Q}$ (Steps 1 + 2)	**3.0**	**3.4**

Phys. Med. Biol. **64** (2019) 095010 (13pp) https://doi.org/10.1088/1361-6560/ab0db4

Physics in Medicine & Biology

IPEM Institute of Physics and Engineering in Medicine

PAPER

Determination of ion recombination and polarity effect correction factors for a plane-parallel ionization Bragg peak chamber under proton and carbon ion pencil beams

A Mirandola[1,3], G Magro[1], D Maestri[1], A Mairani[1,2], E Mastella[1], S Molinelli[1], S Russo[1], A Vai[1] and M Ciocca[1]

[1] Centro Nazionale di Adroterapia Oncologica (CNAO Foundation), I-27100 Pavia, Italy

[2] Heidelberg Ion Beam Therapy Center (HIT), DE-69120 Heidelberg, Germany

Recombination correction factors were LET and energy dependent, ranging from 1.000 to 1.040 (±0.5%) for carbon ions, while nearly negligible for protons. Moreover, no corrections need to be applied due to polarity effect being <0.5% along the whole IDDs for both particle types. IDD^ks showed a better agreement than uncorrected curves when compared to MC, with a reduction of the mean absolute variation from 1.2% to 0.9%.

Phys. Med. Biol. 66 (2021) 145012 https://doi.org/10.1088/1361-6560/ac0d0d

Physics in Medicine & Biology

IPEM Institute of Physics and Engineering in Medicine

PAPER

Water calorimetry-based k_Q factors for Farmer-type ionization chambers in the SOBP of a carbon-ion beam

Kim Marina Holm[1,2,3,4], Oliver Jäkel[2,3,5] and Achim Krauss[1]

Abstract

The dosimetry of carbon-ion beams based on calibrated ionization chambers (ICs) still shows a significantly higher uncertainty compared to high-energy photon beams, a fact influenced mainly by the uncertainty of the correction factor for the beam quality k_Q. Due to a lack of experimental data, k_Q factors in carbon-ion beams used today are based on theoretical calculations whose standard uncertainty is three times higher than that of photon beams. To reduce their uncertainty, in this work, k_Q factors for two ICs were determined experimentally by means of water calorimetry for the spread-out Bragg peak of a carbon-ion beam, these factors are presented here for the first time. To this end, the absorbed dose to water in the ^{12}C-SOBP is measured using the water calorimeter developed at Physikalisch-Technische Bundesanstalt, allowing a direct calibration of the ICs used (PTW 30013 and IBA FC65G) and thereby an experimental determination of the chamber-specific k_Q factors. Based on a detailed characterization of the irradiation field, correction factors for several effects that influence calorimetric and ionometric measurements were determined. Their contribution to an overall uncertainty budget of the final k_Q factors was determined, leading to a standard uncertainty for k_Q of 0.69%, which means a reduction by a factor of three compared to the theoretically calculated values. The experimentally determined values were expressed in accordance with TRS-398 and DIN 6801-1 and compared to the values given there. A maximum deviation of 2.3% was found between the experiment and the literature.

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

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

Correction method of measured images of absorbed dose for quenching effects due to relatively high LET

G. Gambarini[a,b,*], D. Bettega[a,b], G. Camoni[a], M. Felisi[a], A. Gebbia[a], E. Massari[a], V. Regazzoni[a,b], I. Veronese[a,b], D. Giove[a,b], A. Mirandola[c], M. Ciocca[c]

[a] *Department of Physics, Università degli Studi di Milano, 20133 Milano, Italy*
[b] *National Institute of Nuclear Physics, Section of Milan, Milano, Italy*
[c] *Medical Physics Unit, Centro Nazionale di Adroterapia Oncologica (CNAO), Pavia, Italy*

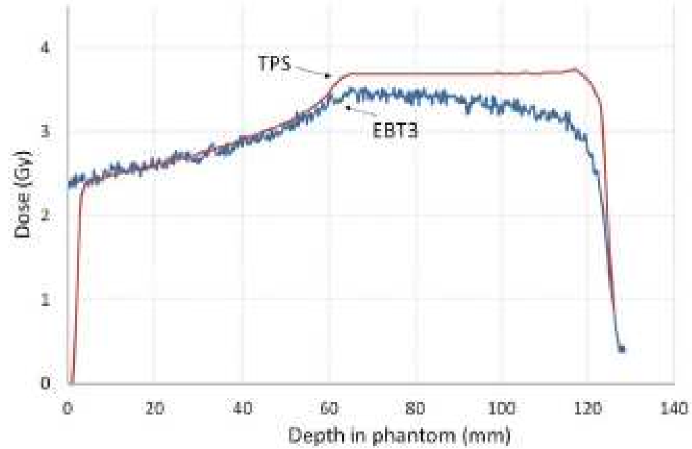


Fig. 5. Central dose profile in RW3 extracted from a dose image achieved with an EBT3 film and profile calculated by the Syngo TPS.

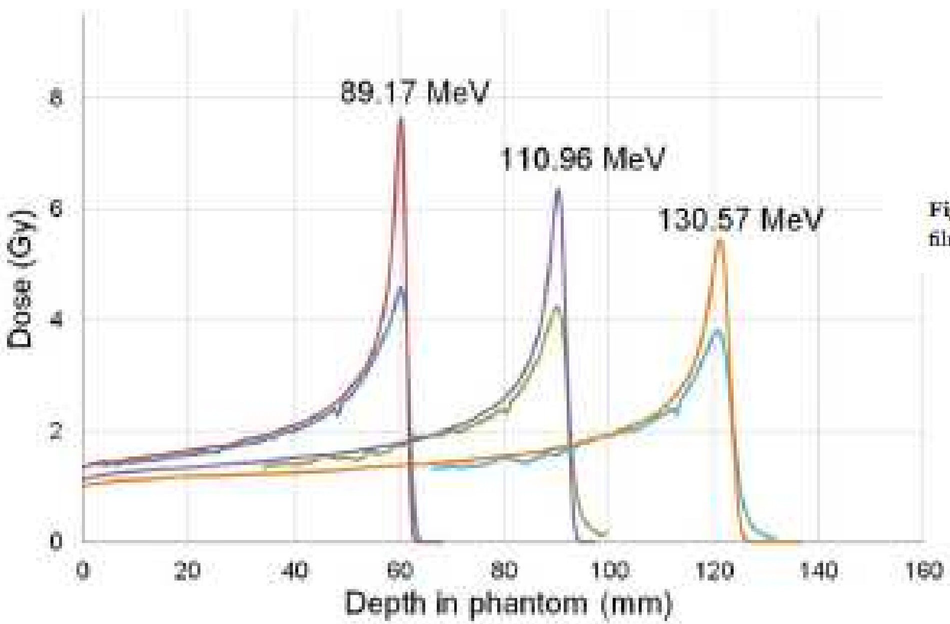


Fig. 3. Central depth-dose profiles measured with EBT3 films (lower profiles) and calculated by Monte Carlo simulations (higher profiles).

Nuclear Inst. and Methods in Physics Research, A 891 (2018) 125–132

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

ELSEVIER

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

Dosimetric characterization of a silicon diode detector in cyclotron-based passively scattered and synchrotron-based scanning clinical proton beams

Luigi Raffaele[a], Mario Ciocca[b], Alfredo Mirandola[b], Sofia Spampinato[c,*], G.A. Pablo Cirrone[a]

[a] Laboratori Nazionali del SUD, INFN, via S. Sofia 62 95123 Catania, Italy
[b] Medical Physics Unit, Fondazione CNAO, strada Campeggi 53, 27100 Pavia, Italy
[c] Scuola di Specializzazione in Fisica Medica, Dipartimento di Scienze Mediche, Chirurgiche e Tecnologie Avanzate "G.F. Ingrassia", Scuola Facoltà di Medicina, Università degli Studi di Catania, Via Santa Sofia 78, Catania, 95123, Italy

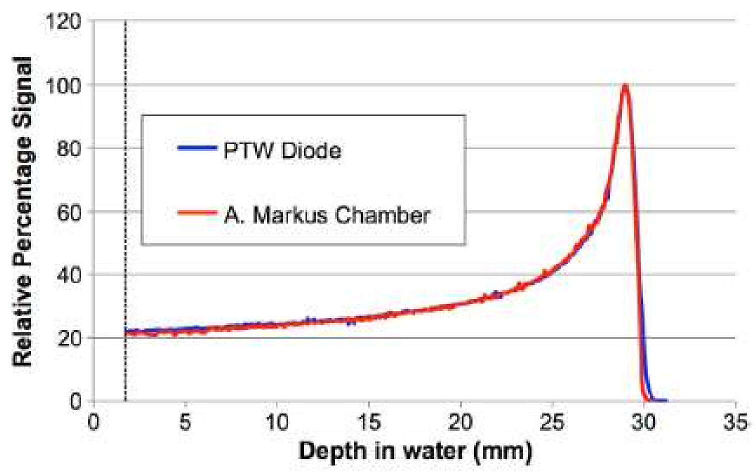


Fig. 5. Bragg peak curves measured by the diode and the Advanced Markus ionization chamber for the 62 MeV unmodulated proton beam.

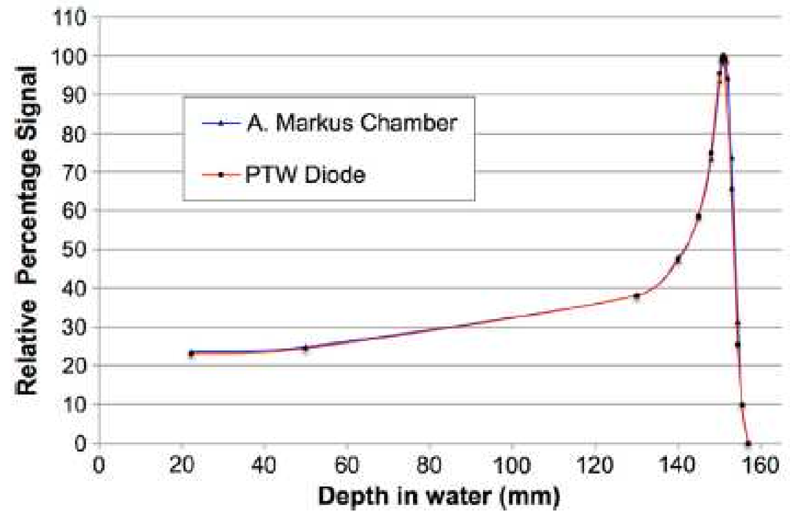


Fig. 12. Bragg peak curves measured by the diode and the Advanced Markus ionization chamber in the 149 MeV scanning proton beam.

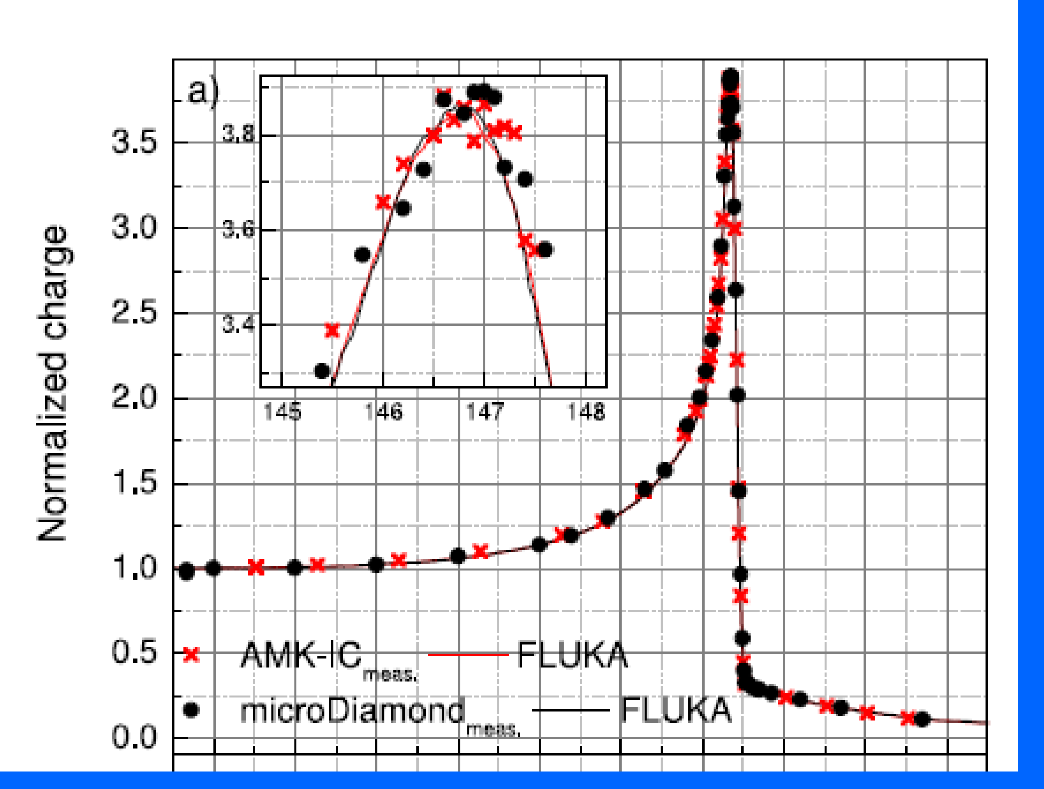
Dosimetric characterization of a microDiamond detector in clinical scanned carbon ion beams

Marco Marinelli, G. Prestopino,[a] C. Verona, and G. Verona-Rinati
INFN—Dipartimento di Ingegneria Industriale, Università di Roma "Tor Vergata," Via del Politecnico 1, Roma 00133, Italy

M. Ciocca, A. Mirandola, and A. Mairani
Fondazione CNAO, Strada Campeggi 53, Pavia 27100, Italy

L. Raffaele
INFN—Laboratori Nazionali del Sud, Via S. Sofia 62, Catania 95123, Italy and Fondazione CNAO, Strada Campeggi 53, Pavia 27100, Italy

G. Magro
INFN—Dipartimento di Fisica, Università degli Studi di Pavia, Via U. Bassi 6, Pavia 27100, Italy and Fondazione CNAO, Strada Campeggi 53, Pavia 27100, Italy



A GEMPix-based integrated system for measurements of 3D dose distributions in water for carbon ion scanning beam radiotherapy

Johannes Leidner[a)]
CERN, 1211 Geneva 23, Switzerland
Physics Institute 3B, RWTH Aachen University, 52074 Aachen, Germany

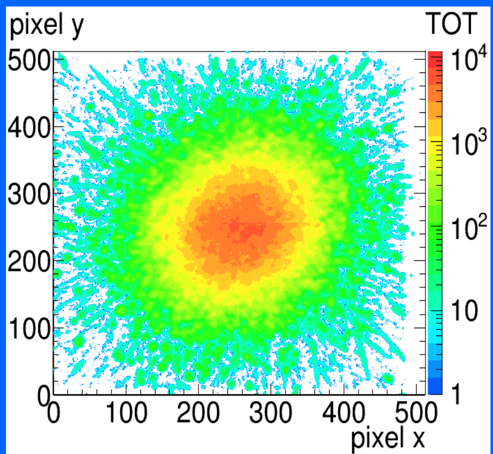
Mario Ciocca
Fondazione CNAO, 27100 Pavia, Italy

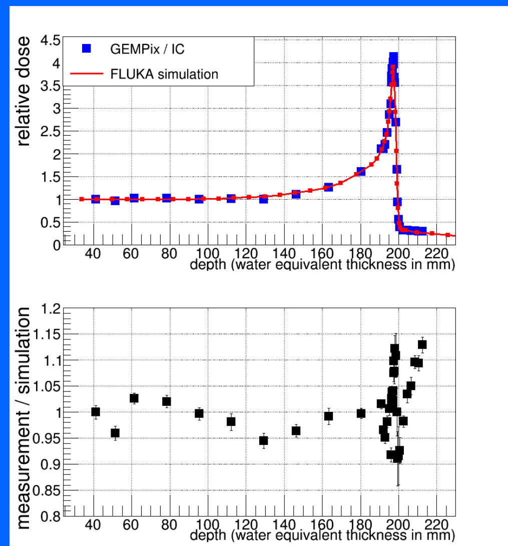
Andrea Mairani
Fondazione CNAO, 27100 Pavia, Italy
HIT, 69120 Heidelberg, Germany

Fabrizio Murtas
CERN, 1211 Geneva 23, Switzerland
INFN-LNF, 00044 Frascati, Italy

Marco Silari
CERN, 1211 Geneva 23, Switzerland

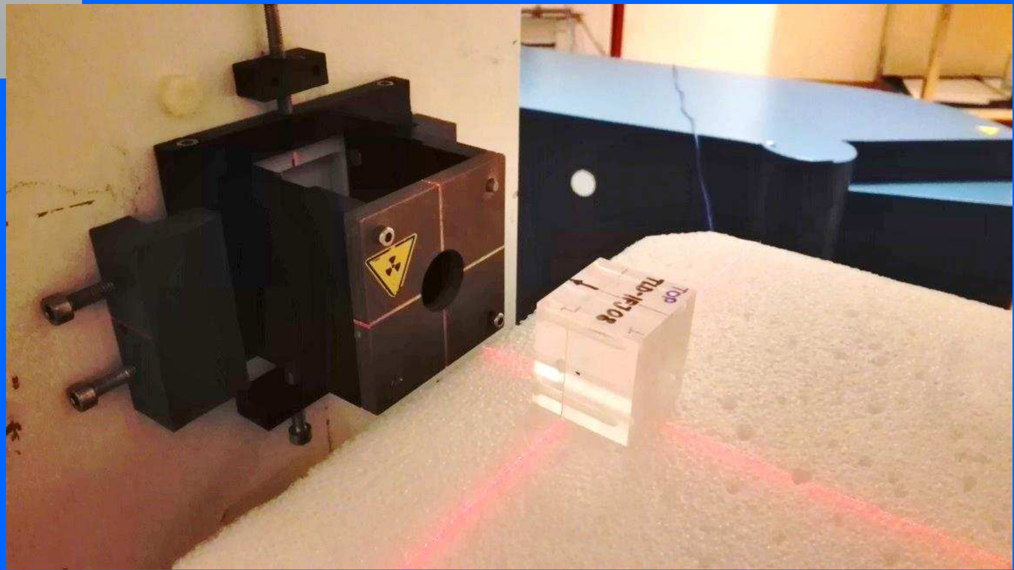
Med. Phys. 47 (6), June 2020





Mailed dosimetry intercomparison for ocular proton RT facilities (IFJ PAN, Cracovia, PL)

TLD, alanine,
Gafchromic film



End-to-end test: IMRT and protons

Background and purpose: In the next few years the number of facilities providing ion beam therapy with scanning beams will increase. An auditing process based on an end-to-end test (including CT imaging, planning and dose delivery) could help new ion therapy centres to validate their entire logistic chain of radiation delivery. An end-to-end procedure was designed and tested in both scanned proton and carbon ion beams, which may also serve as a dosimetric credentialing procedure for clinical trials in the future. The developed procedure is focused only on physical dose delivery and the validation of the biological dose is out of scope of the current work.

IROC™ IMAGING AND RADIATION ONCOLOGY CORE
Global Leaders in Clinical Trial Quality Assurance

MD Anderson

IROC Houston Quality Assurance Center

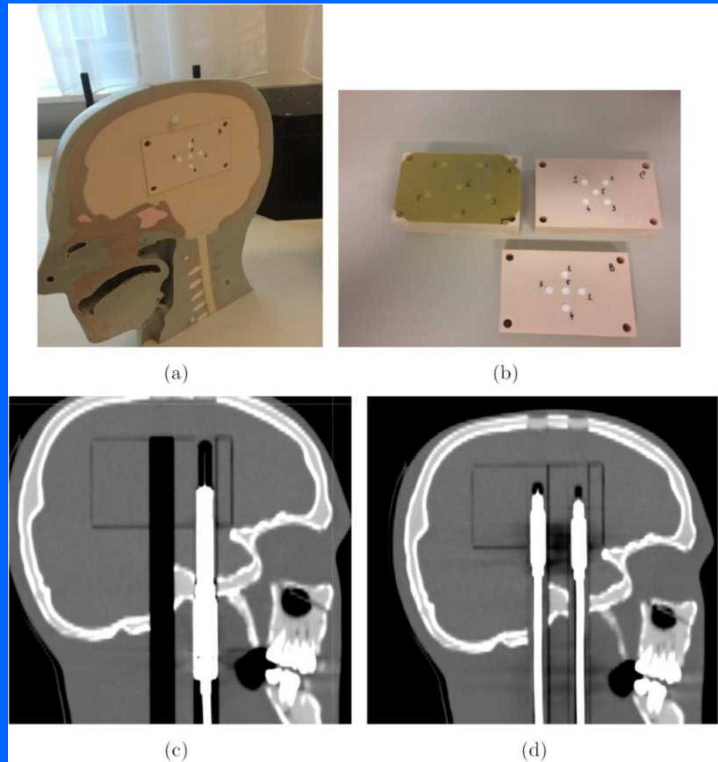
Physics in Medicine & Biology
IPEM Institute of Physics and Engineering in Medicine

PAPER

End-to-end tests using alanine dosimetry in scanned proton beams

A Carlino[1,3], C Gouldstone[2], G Kragl[1], E Traneus[4], M Marrale[3], S Vatnitsky[1], M Stock[1] and H Palmans[1,2]

1 EBG MedAustron GmbH, Marie Curie-Straße 5, A-2700 Wiener Neustadt, Austria
2 National Physical Laboratory, Hampton Road, TW11 0LW Teddington, United Kingdom
3 Department of Physics and Chemistry, University of Palermo, Viale delle Scienze, Edificio 18, 90128 Palermo, Italy
4 RaySearch Laboratories AB, Sveavägen 44, PO Box 3297, Stockholm, Sweden



Campo misto di radiazioni e dip. risposta rivelatori solidi da E, LET (quenching effect): correzioni sino al 3.5% con simulazioni Monte Carlo

Radiotherapy and Oncology 108 (2013) 99–106

Contents lists available at SciVerse ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

ELSEVIER

Dosimetry

Dosimetry auditing procedure with alanine dosimeters for light ion beam therapy

Alexander Ableitinger[a,*], Stanislav Vatnitsky[a], Rochus Herrmann[d,e], Niels Bassler[d,e], Hugo Palm
Peter Sharpe[f], Swantje Ecker[h], Naved Chaudhri[h], Oliver Jäkel[g,h], Dietmar Georg[b,c]

Currently the Radiological Physics Center (RPC) is auditing proton facilities following a procedure based on OSLDs and TLDs [36]. However, these detectors used by RPC for dosimetry measurements may not provide suitable accuracy for scanned carbon beams as the LET dependence for TL detectors requires serious effort in understanding and evaluation of correction factors [37,38].

Contrary to TLDs, where the correction factors for scanning carbon beams are not yet established, the presented results for the alanine dosimeters, based on specific corrections, show an excellent match with the prescribed dose and the Farmer chamber measurements. Hence, the relative effectiveness calculated by MC simulations seems to be validated for the different detector positions. Furthermore the uncertainty levels for the alanine dosimeters are nearly the same as for Farmer chambers.

The Italian National Centre for Oncological Hadrontherapy (CNAO) has been treating patients since 2011 with carbon-ion beams using the active-scanning modality. In such irradiation modality, the beam spot, which scans the treatment area, is characterised by very high particle-fluence rates (more than $10^5\,s^{-1}\,mm^{-2}$). Moreover, the Bragg-peak is only ~1 mm-FWHM. Commercial tissue-equivalent proportional counters (TEPC), like the Far West Technologies LET-½, are large, hence they have limited capability to measure at high counting fluence rates. In this study we have used two home-made detectors, a mini-TEPC 0.81 mm^2 in sensitive area and a silicon telescope 0.125 mm^2 in sensitive area, to perform microdosimetric measurements in the therapeutic carbon-ion beam of CNAO. A monoenergetic carbon-ion beam of 189.5 ± 0.3 MeV/u scanning a $3 \times 3\,cm^2$ area has been used. Spectral differences are visible in the low *y*-value region, but the mean microdosimetric values, measured with the two detectors, result to be pretty consistent, as well as the microdosimetric spectra in the high *y*-value region.

Radiation Protection Dosimetry (2018), Vol. 180, No. 1–4, pp. 157–161 doi:10.1093/rpd/ncx217
Advance Access publication 26 October 2017

MICRODOSIMETRIC STUDY AT THE CNAO ACTIVE-SCANNING CARBON-ION BEAM

P. Colautti[1,*], V. Conte[1], A. Selva[1], S. Chiriotti[2], A. Pola[3,4], D. Bortot[3,4], A. Fazzi[3,4], S. Agosteo[3,4] and M. Ciocca[5]
[1]INFN Laboratori Nazionali di Legnaro, Viale dell'Università 2, 35020 Legnaro, Italy
[2]Belgian Nuclear Research Centre, SCK•CEN, Boeretang 200, 2400 Mol, Belgium
[3]Politecnico di Milano, Dipartimento di Energia, via La Masa 34, 20156 Milano, Italy
[4]INFN, Sezione di Milano, via Celoria 16, 20133 Milano, Italy
[5]Fondazione CNAO, Strada Campeggi 53, 27100 Pavia, Italy

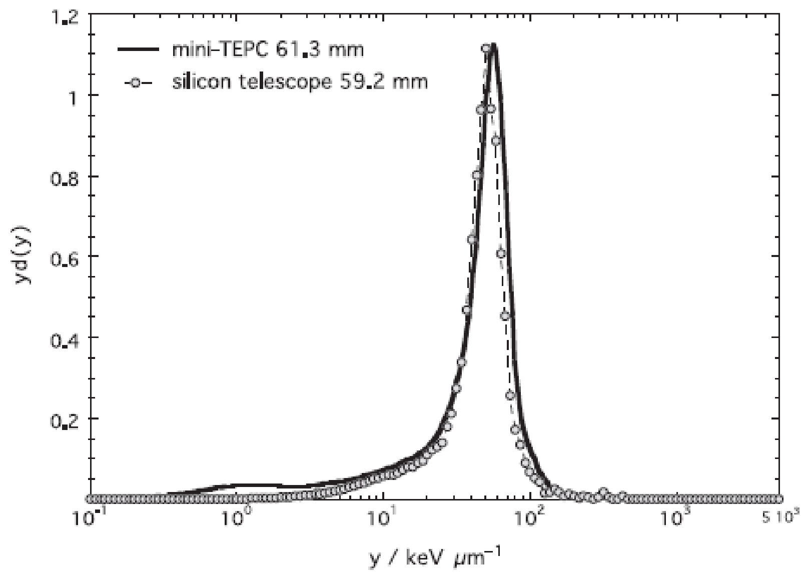


Figure 2. Microdosimetric spectra upstream of the proximal Bragg peak rise.

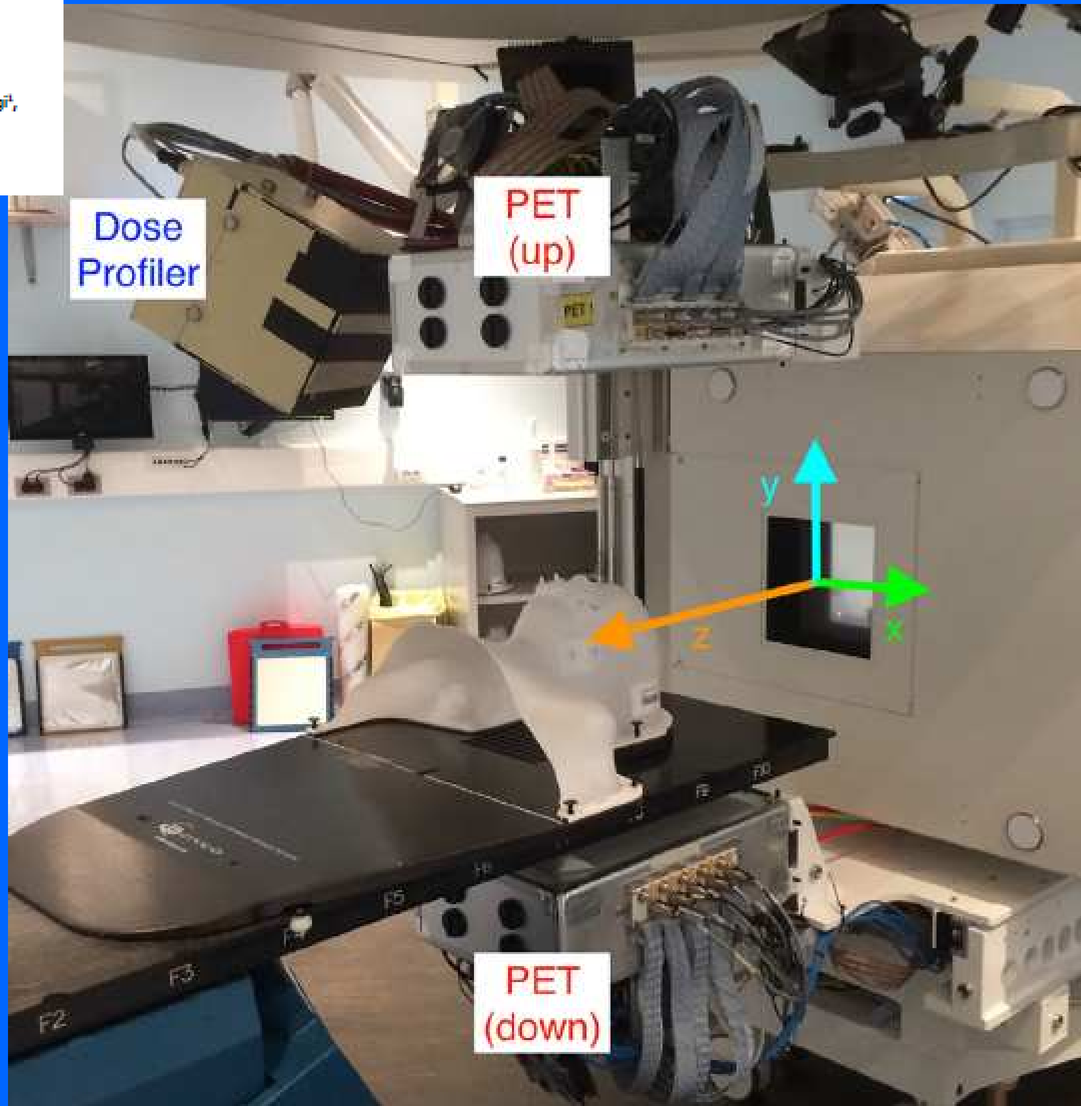
scientific reports

OPEN

Inter-fractional monitoring of $_{12}$C ions treatments: results from a clinical trial at the CNAO facility

M. Fischetti[1,3], G. Baroni[15], G. Battistoni[4], G. Bisogni[7,8], P. Cerello[10], M. Ciocca[11], P. De Maria[16], M. De Simoni[2,3], B. Di Lullo[1], M. Donetti[11], Y. Dong[4,8], A. Embriaco[13], V. Ferrero[10], E. Fiorina[10,11], G. Franciosini[2,3], F. Galante[1], A. Kraan[7], C. Luongo[7,14], M. Magi[1], C. Mancini-Terracciano[2,3], M. Marafini[3,5], E. Malekzadeh[11], I. Mattei[4], E. Mazzoni[7], R. Mirabelli[2,3,5], A. Mirandola[11], M. Morrocchi[7,8], S. Muraro[4], V. Patera[1,3,5], F. Pennazio[10], A. Schiavi[1,3], A. Sciubba[1,3,5], E. Solfaroli Camillocci[2,3,12], G. Sportelli[7,8], S. Tampellini[11], M. Toppi[1,4,12], G. Traini[3,5], S. M. Valle[4], B. Vischioni[11], V. Vitolo[11] & A. Sarti[1,3,5]

In-vivo range monitoring



frontiers in Oncology

ORIGINAL RESEARCH
published: 10 June 2021
doi: 10.3389/fonc.2021.601784

Monitoring Carbon Ion Beams Transverse Position Detecting Charged Secondary Fragments: Results From Patient Treatment Performed at CNAO

OPEN ACCESS

Edited by:
Timothy Dean Malouff,
Mayo Clinic Florida,
United States

Reviewed by:
Dalong Pang,
Georgetown University,
United States
Tomohiro Yamashita,
Kobe University, Japan

***Correspondence:**
Giacomo Traini
giacomo.traini@roma1.infn.it

Marco Toppi[1,2], Guido Baroni[3], Giuseppe Battistoni[4], Maria Giuseppina Bisogni[5,6], Piergiorgio Cerello[7], Mario Ciocca[8], Patrizia De Maria[9], Micol De Simoni[10,11], Marco Donetti[8], Yunsheng Dong[4,12], Alessia Embriaco[13], Veronica Ferrero[7], Elisa Fiorina[7,8], Marta Fischetti[1,11], Gaia Franciosini[10,13], Aafke Christine Kraan[6], Carmela Luongo[13,14], Etesam Malekzadeh[8], Marco Magi[1], Carlo Mancini-Terracciano[10,11], Michela Marafini[11,15], Ilaria Mattei[4], Enrico Mazzoni[6], Riccardo Mirabelli[10,11,15], Alfredo Mirandola[8], Matteo Morrocchi[5,6], Silvia Muraro[4], Vincenzo Patera[1,11,15], Francesco Pennazio[7], Angelo Schiavi[1,11], Adalberto Sciubba[1,2,15], Elena Solfaroli-Camillocci[9,10,11], Giancarlo Sportelli[5,6], Sara Tampellini[8], Giacomo Traini[11,15], Serena Marta Valle[4], Barbara Vischioni[8], Viviana Vitolo[8] and Alessio Sarti[1,11,15]*