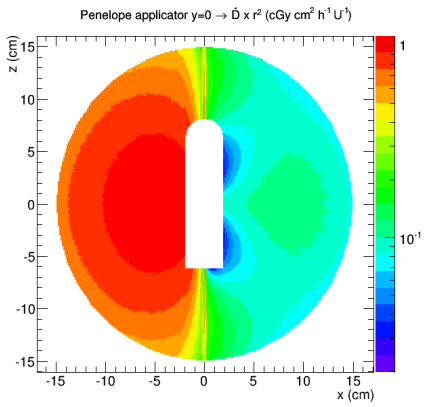
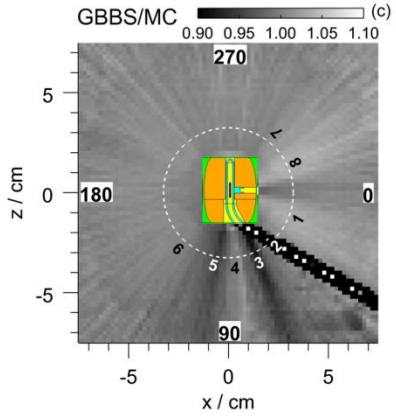
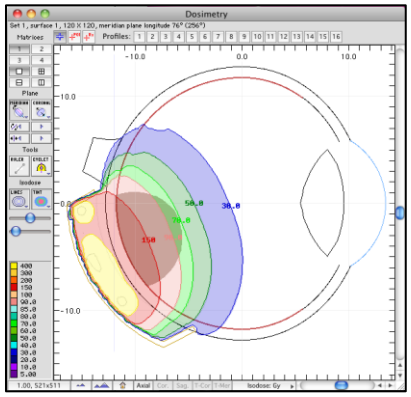
Research and Relevance of Brachytherapy Dose Calculation Advancements:

Current status of the benchmark cases with plans for availability to the medical physics community







F. Ballester PhD
University of Valencia, Spain

VNIVERSITAT DE VALÈNCIA

Disclosure

Research support to the University of Valencia provided by:

- Elekta-Nucletron BV
- Eckert & Ziegler BEBIG

Learning objectives

Present

- *work in progress* of the AAPM-ESTRO-ABG Working Group developing well-defined test cases for commissioning of model-based dose calculation algorithms (MBDCA) as recommended by TG-186

- plans to enlarge the RPC registry where 3D dose distributions will be available for medical physics comunity for commissioning and QA

Contents

- TG-186 commissioning recomendations
- MBDCA-WG road map
- Generic:
  - HDR Ir-192 source model
  - shielded cylindrical applicator
- DICOM water sphere test cases
- Conclusions

TG-186

Report of the Task Group 186 on model-based dose calculation methods in brachytherapy beyond the TG-43 formalism: Current status and recommendations for clinical implementation

Med. Phys. 39 (9), September 2012

Luc Beaulieu[a)]
Département de Radio-Oncologie et Centre de Recherche en Cancérologie de l'Université Laval, Centre Hospitalier Universitaire de Québec, Québec, Québec G1R 2J6, Canada and Département de Physique, de Génie Physique et d'Optique, Université Laval, Québec, Québec G1R 2J6, Canada

Åsa Carlsson Tedgren
Department of Medical and Health Sciences (IMH), Radiation Physics, Faculty of Health Sciences, Linköping University, SE-581 85 Linköping, Sweden and Swedish Radiation Safety Authority, SE-171 16 Stockholm, Sweden

Jean-François Carrier
Département de radio-oncologie, CRCHUM, Centre hospitalier de l'Université de Montréal, Montréal, Québec H2L 4M1, Canada and Département de physique, Université de Montréal, Montréal, Québec H3C 3J7, Canada

Stephen D. Davis
Department of Medical Physics, University of Wisconsin-Madison, Madison, Wisconsin 53705 and Department of Medical Physics, McGill University Health Centre, Montréal, Québec H3G 1A4, Canada

Firas Mourtada
Radiation Oncology, Christiana Care Health System, Helen F. Graham Cancer Center, Newark, Delaware 19899

Mark J. Rivard
Department of Radiation Oncology, Tufts University School of Medicine, Boston, Massachusetts 02111

Rowan M. Thomson
Carleton Laboratory for Radiotherapy Physics, Department of Physics, Carleton University, Ottawa, Ontario K1S 5B6, Canada

Frank Verhaegen
Department of Radiation Oncology (MAASTRO), GROW, School for Oncology and Developmental Biology, Maastricht University Medical Center, Maastricht 6201 BN, The Netherlands and Department of Medical Physics, McGill University Health Centre, Montréal, Québec H3G 1A4, Canada

Todd A. Wareing
Transpire Inc., 6659 Kimball Drive, Suite D-404, Gig Harbor, Washington 98335

Jeffrey F. Williamson
Department of Radiation Oncology, Virginia Commonwealth University, Richmond, Virginia 23298

- Provides
  - Guidance to early MBDCA adopters
  - Recommendations

TG-186

Key features identified:

- Introduction of MBDCA into clinic places hard tasks to properly commission new features of these algorithms
- At this time, the only “safe” approach possible is for each user to model and compare the same test cases in both the MBDCA TPS and a well-validated MC code
- Exploring MBDCA limitations is an important undertaking among early adopters, and must be expanded to various tumors sites and treatment geometries

TG-186

Key features identified:

- A method and infrastructure that go beyond the current TG-43 validation are required
- Test cases would be available in DICOM-RT that facilitates comparisons
- Creation of a Registry where validated test case plans would be made available via the web
- What, how, and where these test cases could be accessed?
- This could be accomplished through expansion of the joint AAPM/RPC Brachytherapy Source Registry

Working Group on Model-Based Dose Calculations Algorithms in Brachytherapy

ESTRO
EUROPEAN SOCIETY FOR RADIOTHERAPY & ONCOLOGY

Australasian Brachytherapy Group

Charges

- Develop a limited number (~ 5) of well-defined test case plans and perform MBDCA dose calculations and comparisons.
- Housing reference plans/data in the Registry.
- Propose well-defined prerequisites for test case plans to be submitted to the Registry.
- Develop a review process for evaluation as new reference data meeting the prerequisites.
- Engage the vendors to promote uniformity of practice

MBDCA-WG road map

Phase I

- To prepare 5 DICOM based test cases using a virtual ^{192}Ir source and a virtual applicator in cooperation with the vendors, with the aim to:
  - Validate the accuracy of MBDCA dosimetry
  - Confirm the feasibility of the TG-186 commissioning flowchart
  - Involve the vendors to preserve global uniformity of practice and to render tools necessary for the smooth transition to MBDCA dosimetry available
  - Inform/educate the community through publication of results and the availability of the test cases via a RPC/ESTRO/ABG hosted registry

MBDCA-WG road map

Phase II

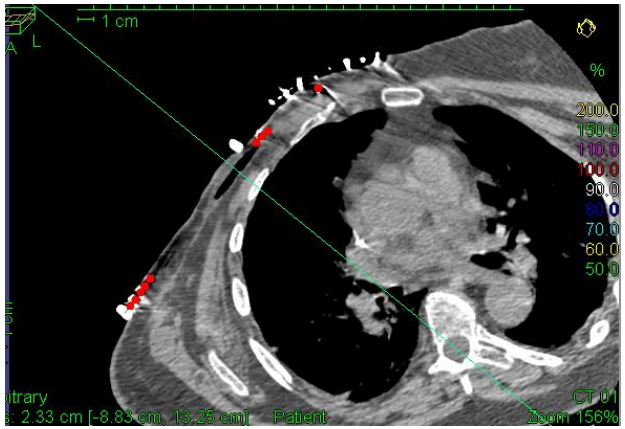
- Maintaining the registry, reviewing and uploading submitted test cases and extending it to low energy brachytherapy, aimed to:
  - The gradual compilation of cases for the thorough acceptance testing of MBDCA based treatment planning systems
  - The notification to users for potential limitations of MBDCA based treatment planning systems
  - The accumulation of dosimetry data that could be useful for reviewing brachytherapy practice in the light of the advent of MBDCAs

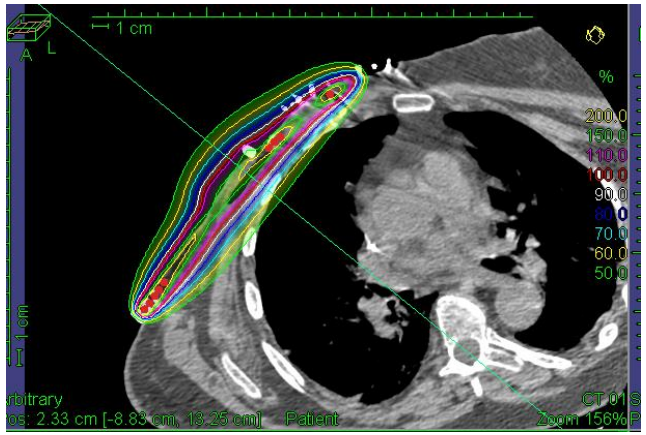
What should be tested?

- Applicators, sources and devices (TG-186 section IV.B.1.e)
- TG-186 recommendations:
  - It is responsability of the user
  - TPS vendors should provide analitical modelling schemes and visualization tools
  - The manufacturers should disclose their geometries and material
  - Prior to accepting a device it must also be verified by an independent investigator

Current clinical scenario

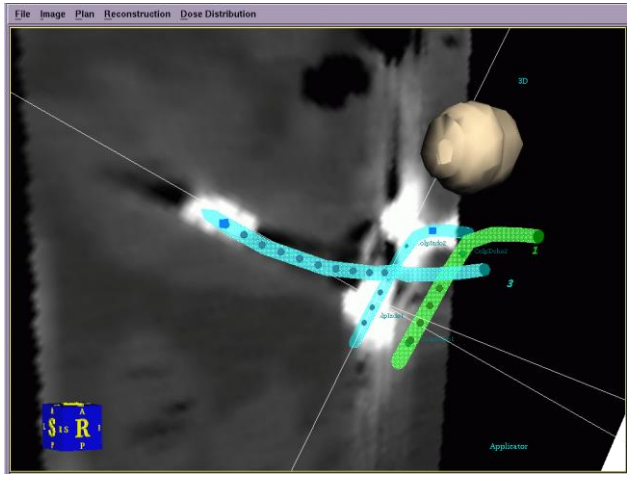
- MBDCA TPS available for HDR Ir-192 only
- Physis effects taken into account for MBDCA-based TPS and its significance in HDR:
  - Scatter default





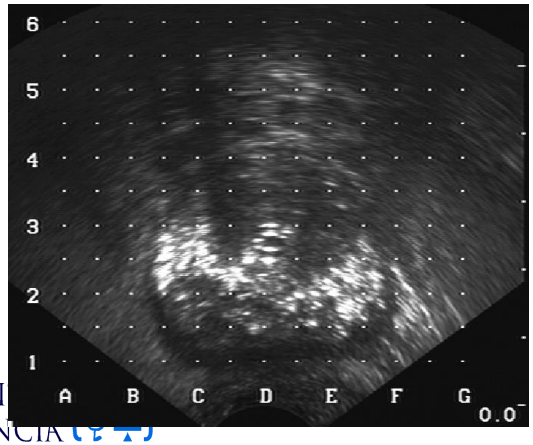
Current clinical scenario

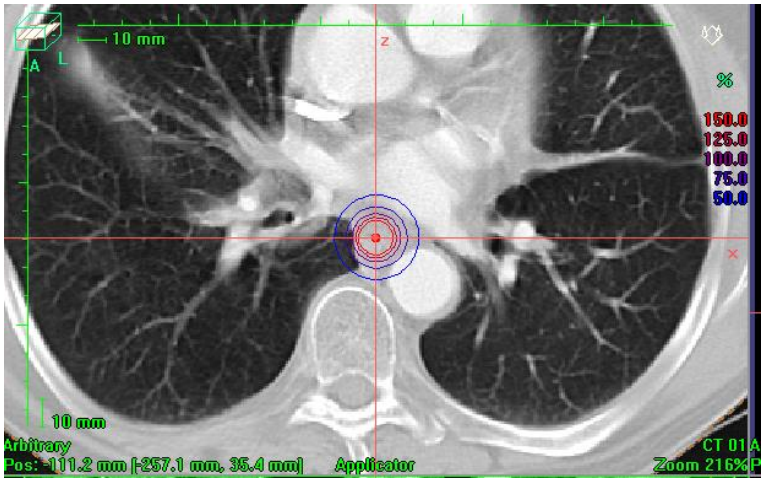
- MBDCA TPS available for HDR Ir-192 only
- Physis effects taken into account for MBDCA-based TPS and its significance in HDR:
  - Scatter default
  - Shielding



Current clinical scenario

- MBDCA TPS available for HDR Ir-192 only
- Physis effects taken into account for MBDCA-based TPS and its significance in HDR:
  - Scatter default
  - Shielding
  - Tissular Heterogeneity





TG-186

Report of the Task Group 186 on model-based dose calculation methods in brachytherapy beyond the TG-43 formalism: Current status and recommendations for clinical implementation

Luc Beaulieu[a)]
Département de Radio-Oncologie et Centre de Recherche en Cancérologie de l'Université Laval, Centre Hospitalier Universitaire de Québec, Québec, Québec G1R 2J6, Canada and Département de Physique, de Génie Physique et d'Optique, Université Laval, Québec, Québec G1R 2J6, Canada

Åsa Carlsson Tedgren
Department of Medical and Health Sciences (IMH), Radiation Physics, Faculty of Health Sciences, Linköping University, SE-581 85 Linköping, Sweden and Swedish Radiation Safety Authority, SE-171 16 Stockholm, Sweden

Jean-François Carrier
Département de radio-oncologie, CRCHUM, Centre hospitalier de l'Université de Montréal, Montréal, Québec H2L 4M1, Canada and Département de physique, Université de Montréal, Montréal, Québec H3C 3J7, Canada

Stephen D. Davis
Department of Medical Physics, University of Wisconsin-Madison, Madison, Wisconsin 53705 and Department of Medical Physics, McGill University Health Centre, Montréal, Québec H3G 1A4, Canada

Firas Mourtada
Radiation Oncology, Christiana Care Health System, Helen F. Graham Cancer Center, Newark, Delaware 19899

Mark J. Rivard
Department of Radiation Oncology, Tufts University School of Medicine, Boston, Massachusetts 02111

Rowan M. Thomson
Carleton Laboratory for Radiotherapy Physics, Department of Physics, Carleton University, Ottawa, Ontario K1S 5B6, Canada

Frank Verhaegen
Department of Radiation Oncology (MAASTRO), GROW, School for Oncology and Developmental Biology, Maastricht University Medical Center, Maastricht 6201 BN, The Netherlands and Department of Medical Physics, McGill University Health Centre, Montréal, Québec H3G 1A4, Canada

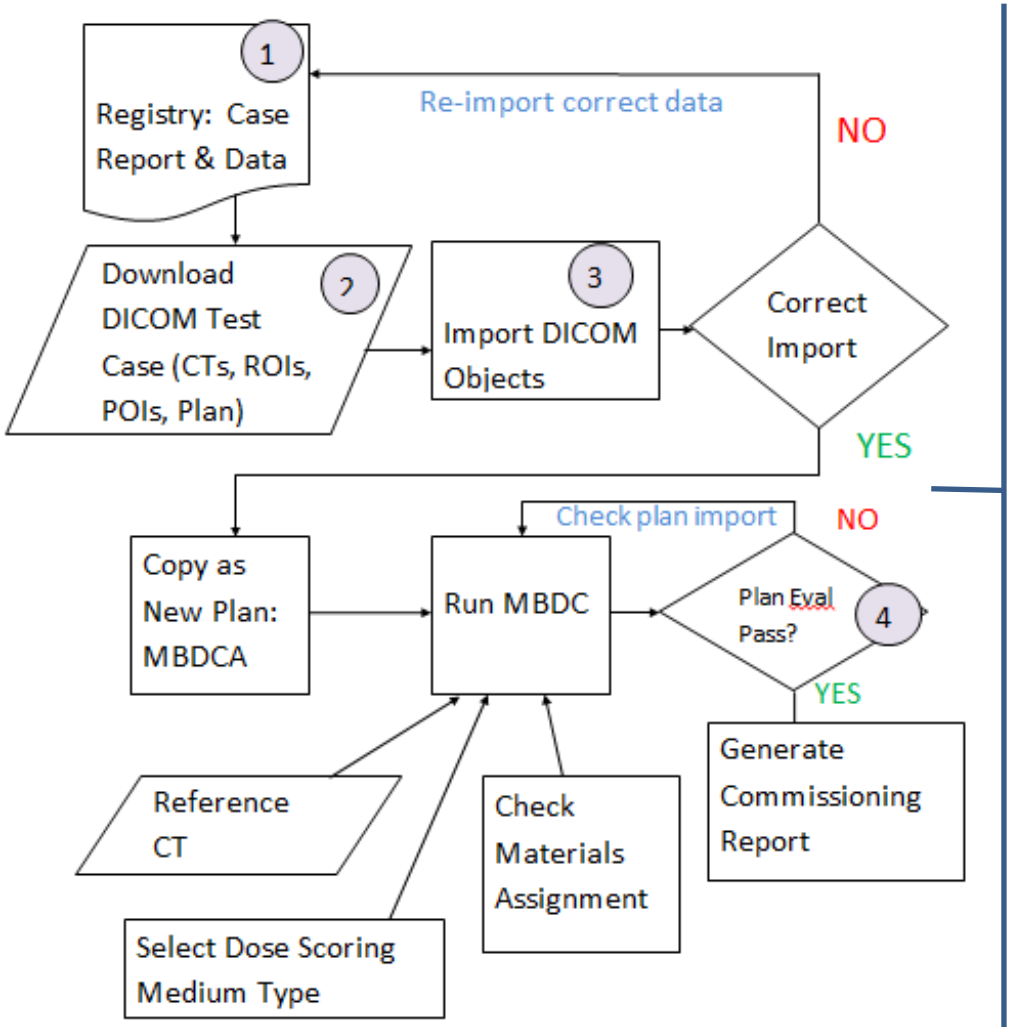
Todd A. Wareing
Transpire Inc., 6659 Kimball Drive, Suite D-404, Gig Harbor, Washington 98335

Jeffrey F. Williamson
Department of Radiation Oncology, Virginia Commonwealth University, Richmond, Virginia 23298

Med. Phys. 39 (9), September 2012

- MBDCA commissioning:
  - level 1: MBDCA should fall back to TG-43 data in well controlled conditions (all water)
  - level 2: MBDCA should take into account material heterogeneities and scatter conditions

Commissioning Flowchart



Abridged flowchart for MBDCA software commissioning (adapted from TG-186)

WG goals:

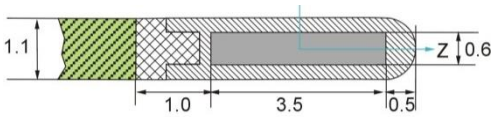
- To design a generic source
- To design a generic shielded cylindrical vaginal applicator
- To confirm the feasibility of the TG-186 commissioning flowchart
- To generate the first plan/data for the registry

MBDCA HDR ^{192}Ir source model

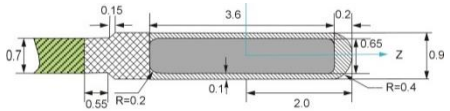
- HDR Ir-192 sources

L = 3.5 mm

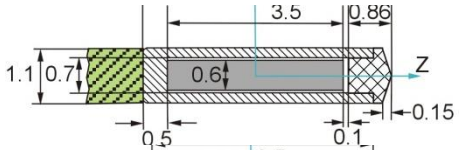
mHDR-v1



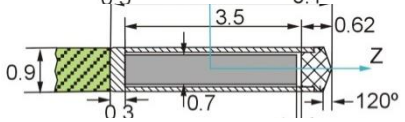
mHDR-v2



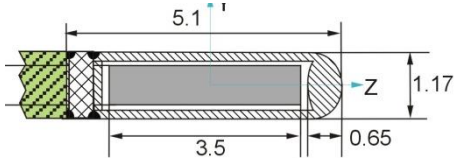
12i



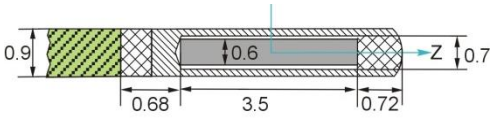
Plus



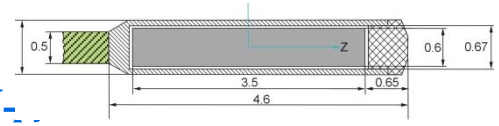
M-19



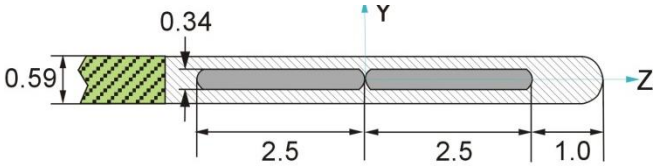
Ir2.A85-2



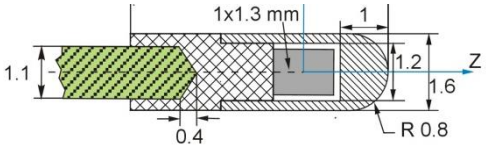
Flexisource



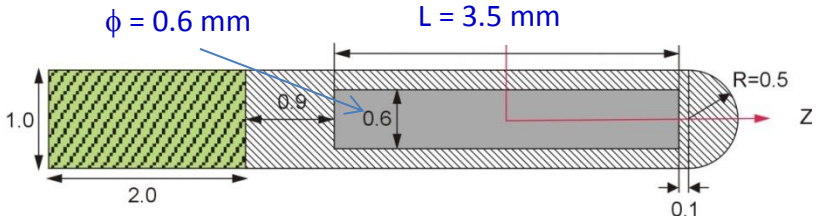
VS2000



Buchler

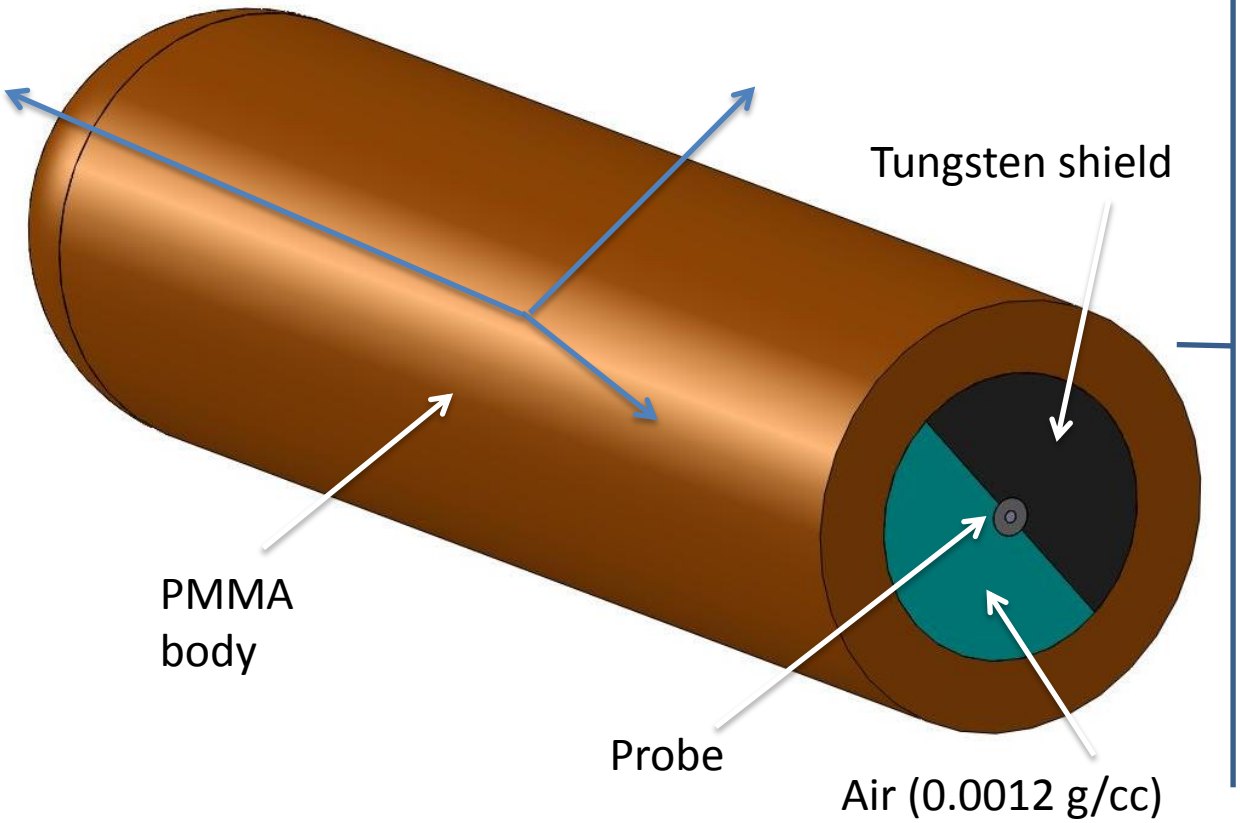


Generic HDR ^{192}Ir source MBDCA model



MBDCA applicator

- Shielded vaginal applicator with cylindrical symmetry



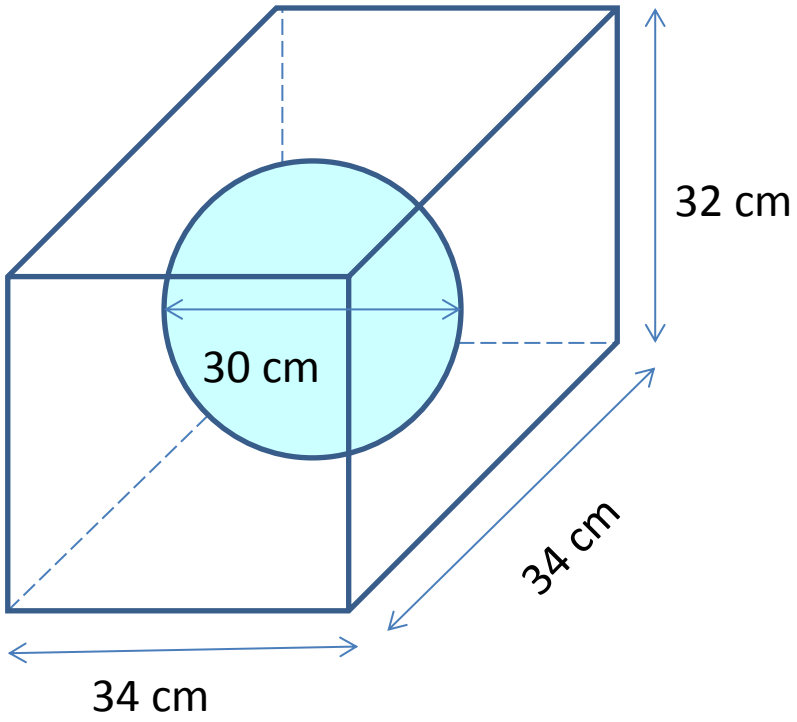
Rationale

- simple
- provide evidence of
  - ✓ transmission
  - ✓ partial scatter
  - ✓ heterogeneity

DICOM tests: source center

- DICOM water sphere in air

256 x 256 x 241 cubic voxels



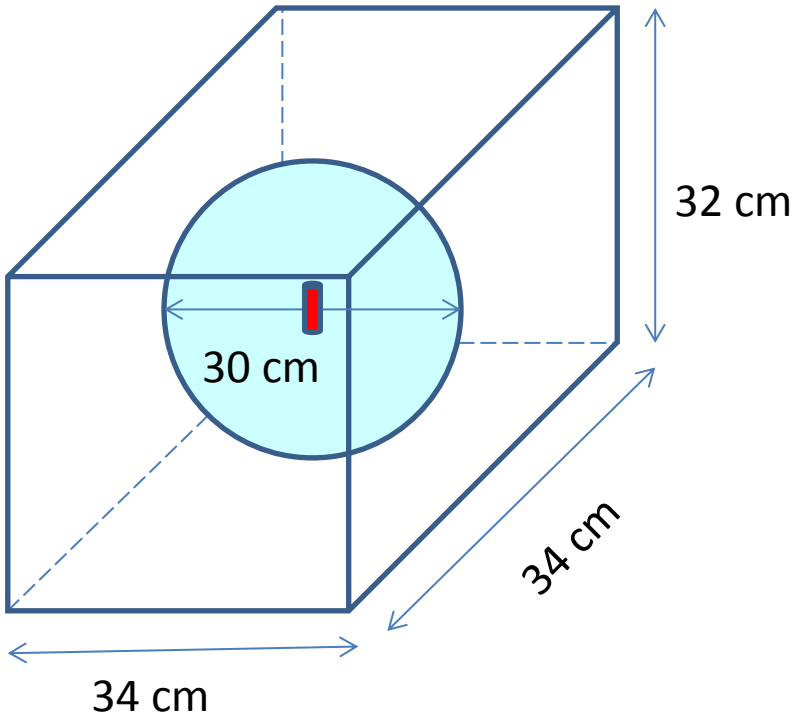
Computational model

- The model has been distributed to vendors
- Its import to vendor treatment planning systems has been checked
- an exercise has been performed to ensure the capability of exporting test RT dose data in the dicom image coordinate system.

DICOM tests: source center

- DICOM water sphere in air

256 x 256 x 241 cubic voxels



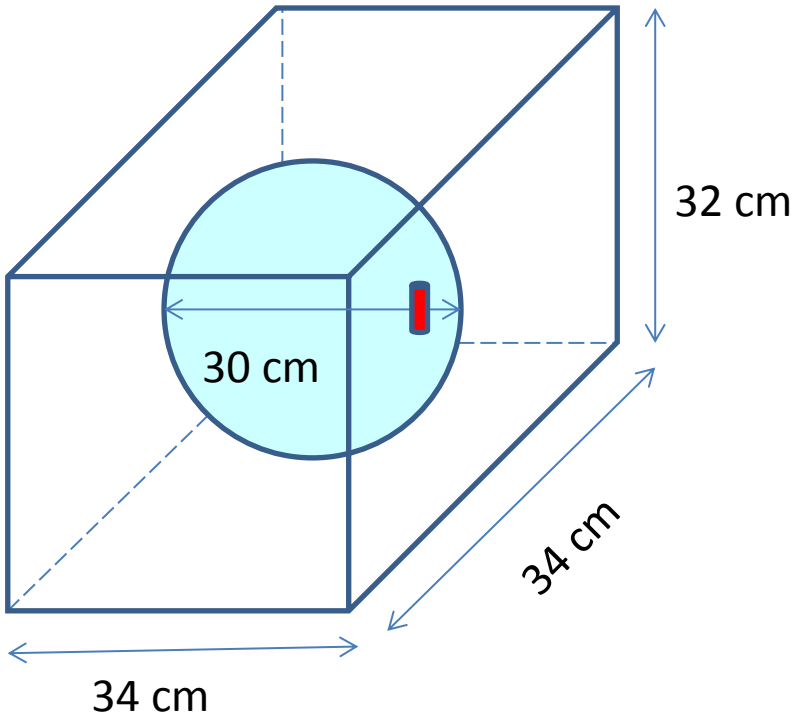
Plan:

- source at center of water sphere

DICOM tests: source displaced

- DICOM water sphere in air

256 x 256 x 241 cubic voxels



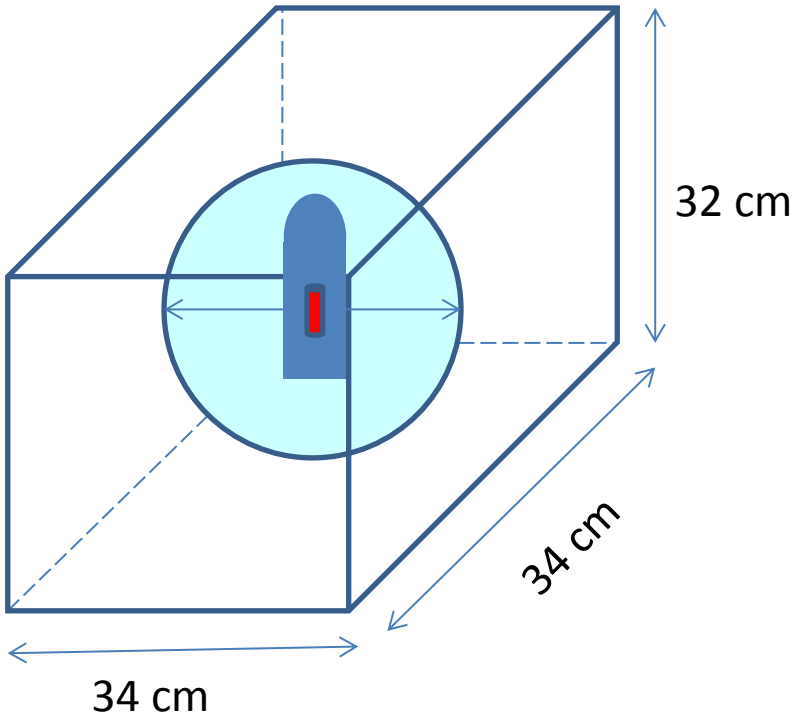
Plan:

- source at center of water sphere
- source displaced at 12.75 cm

DICOM tests: applicator

- DICOM water sphere in air

256 x 256 x 241 cubic voxels



Plan:

- source at center of water sphere
- source displaced at 12.75 cm
- source at the center of the cylindrical part of the applicator at the center of the water sphere

$$D_{w,w}$$

DICOM tests: MBDCA algorithms

General purpose Monte Carlo codes:

- BrachyDose (EGSnrs)
- Geant4
- MCNP5 v1.6
- MCNP6 beta2
- Penelope2011

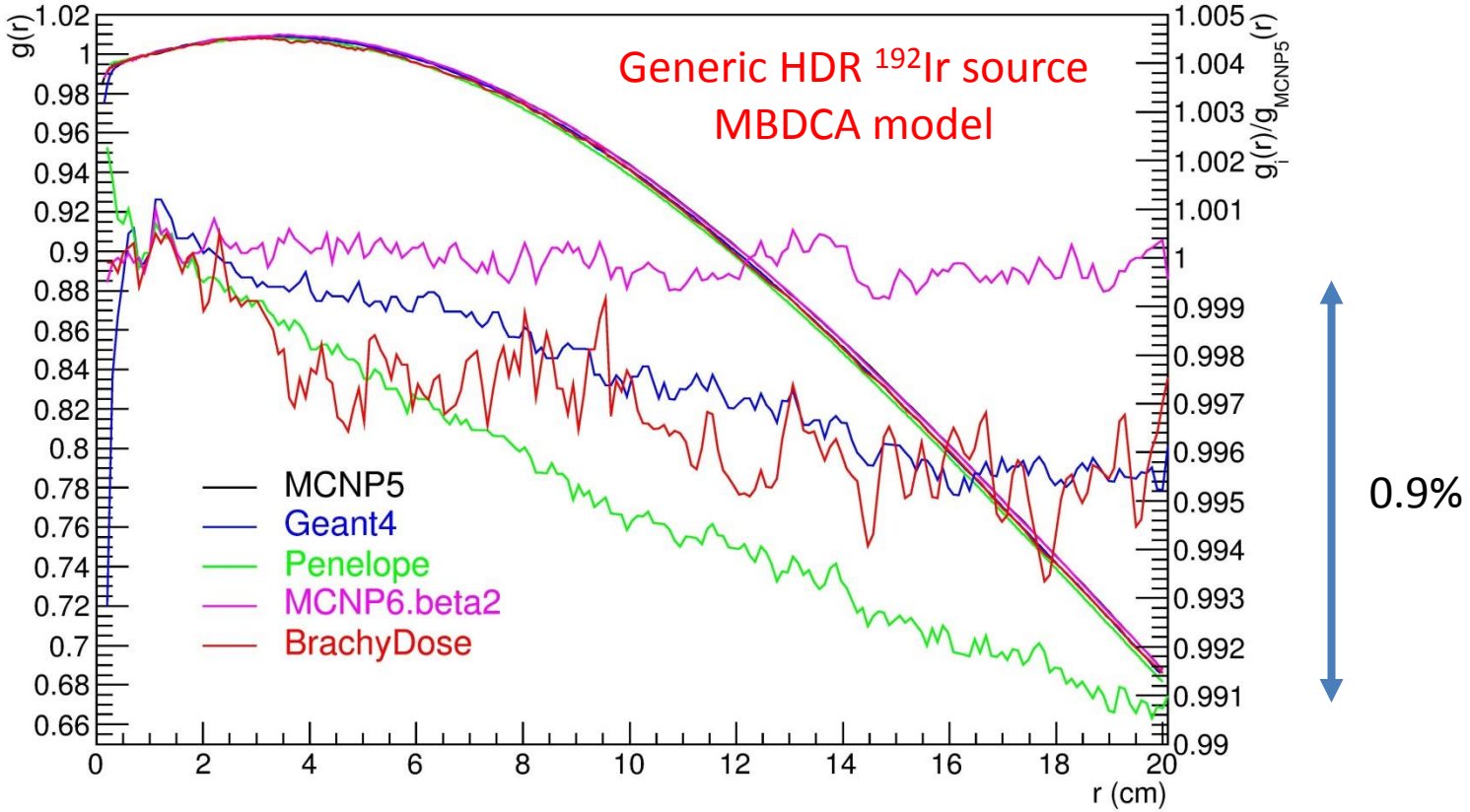
Specific algorithms for BT:

- BRACHYVISION (Acuros)
- Collapse-Cone superposition/convolution method (to be implemented in OncentraBrachy)

MBDCA HDR ^{192}Ir source model: TG-43 data

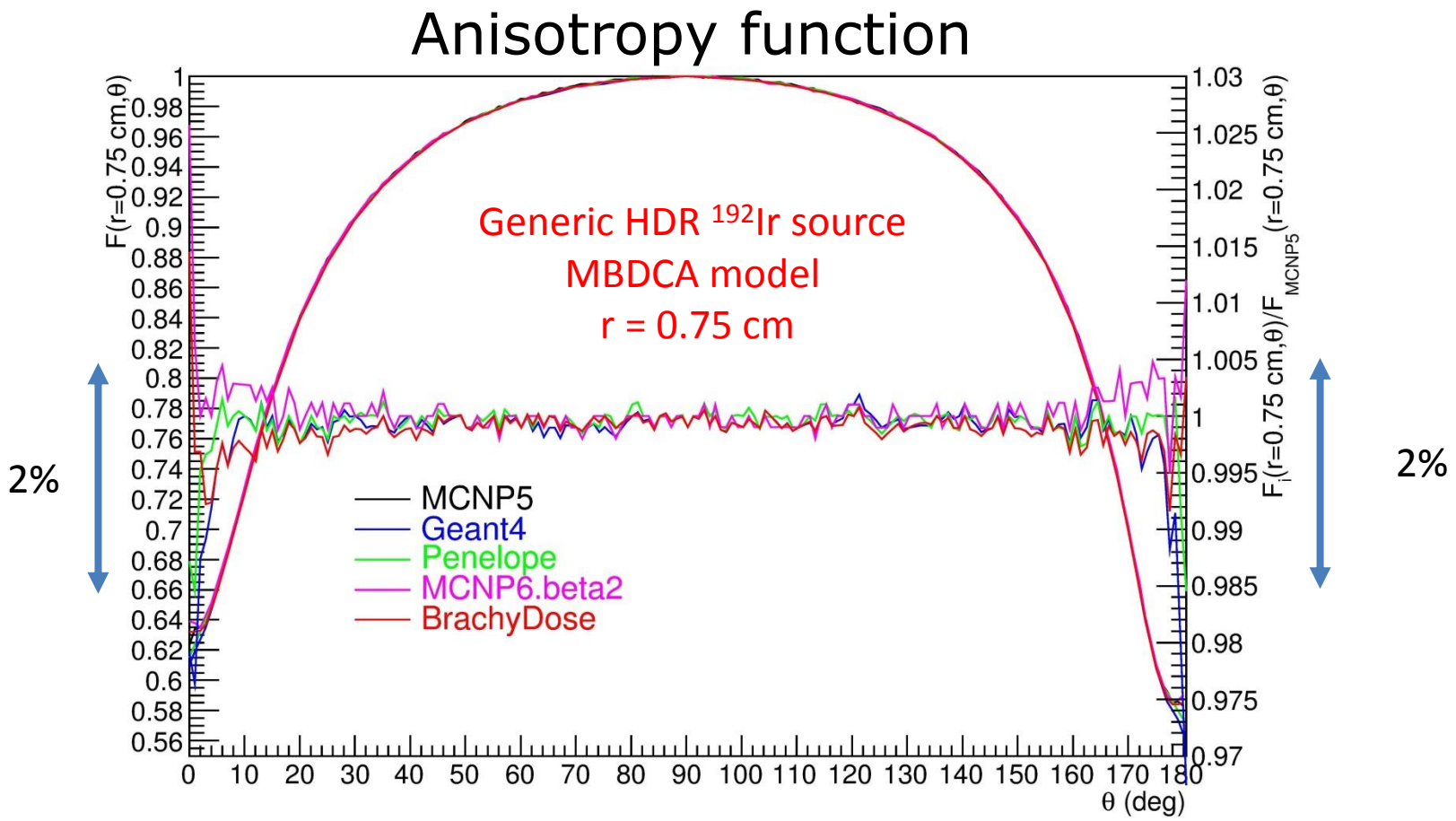
R = 40 cm water sphere Λ = 1.1107 ± 0.0004 cGy/(h U)

Radial dose function



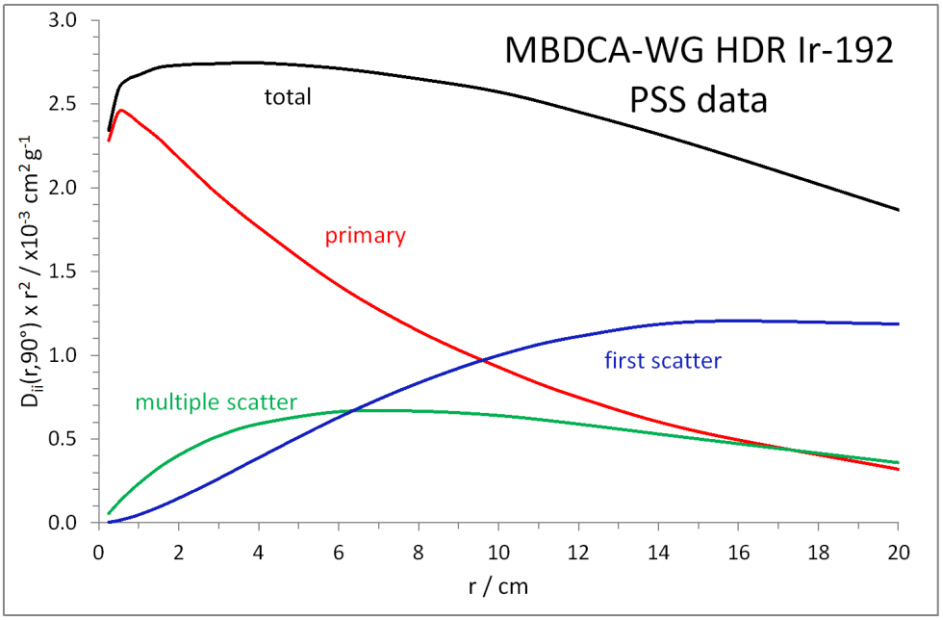
MBDCA HDR ^{192}Ir source model: TG-43 data

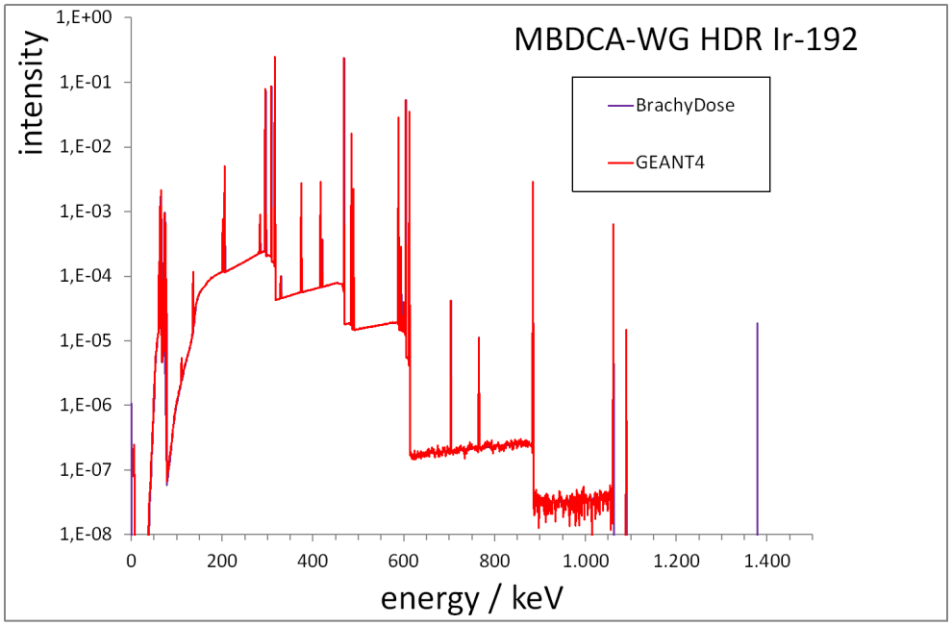
R = 40 cm water sphere



MBDCA HDR ^{192}Ir source model: PSS data

R = 40 cm water sphere

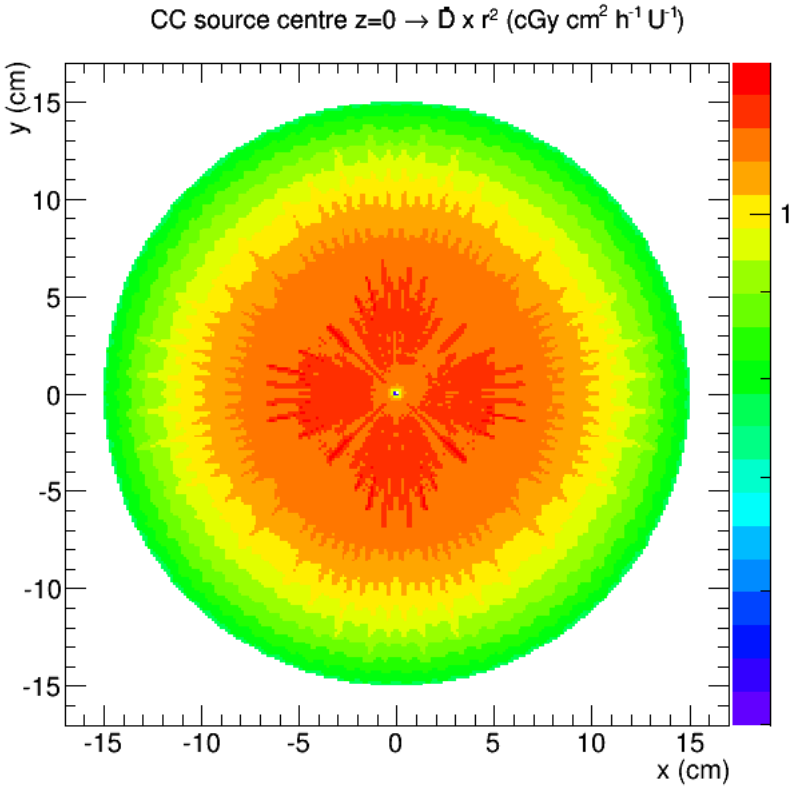


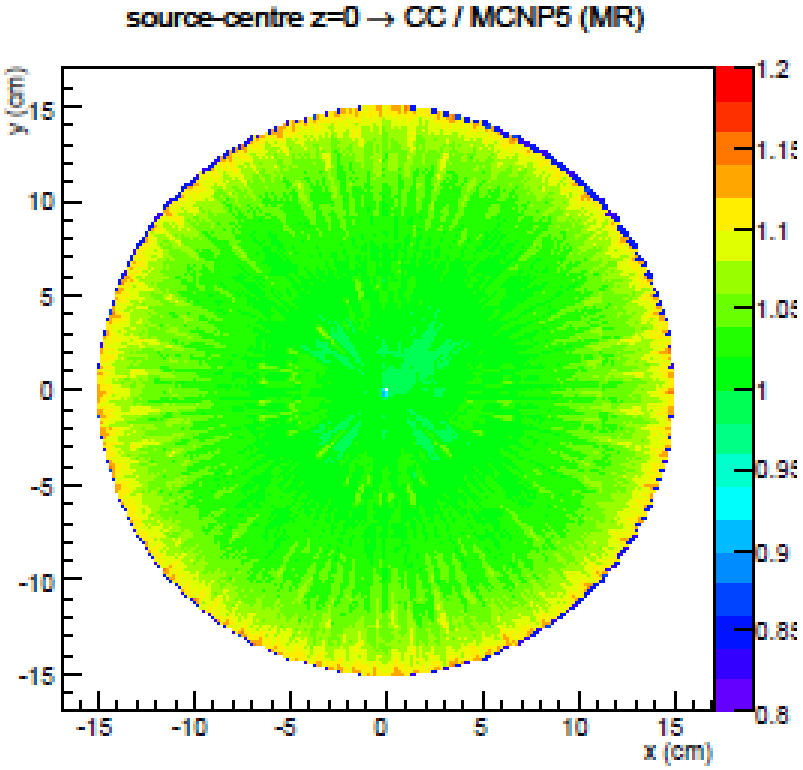


Collapse-Cone

DICOM sphere water tests: source centred

CCC *vs*. MCNP5

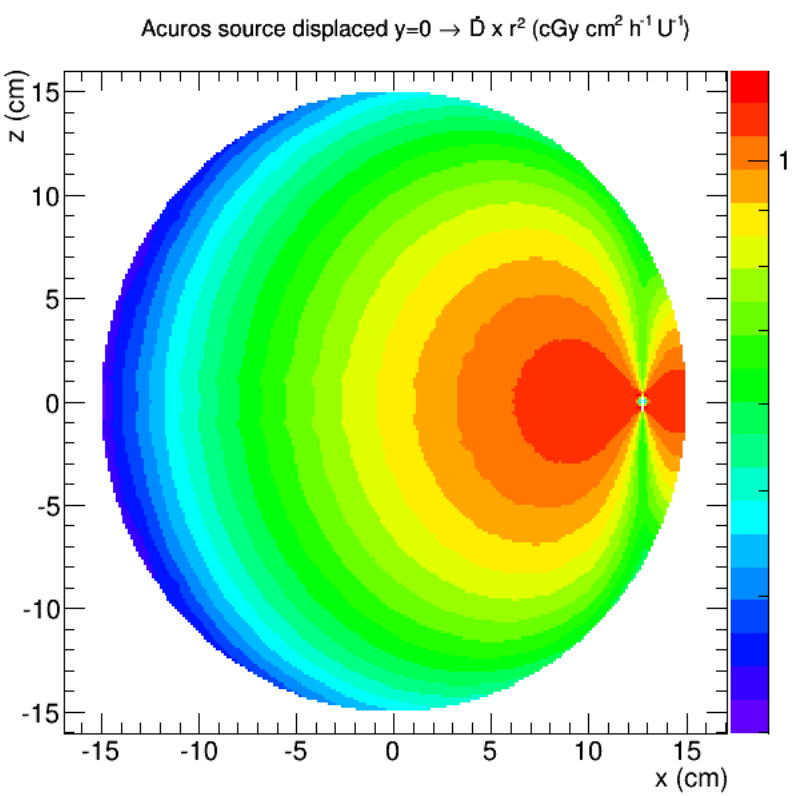


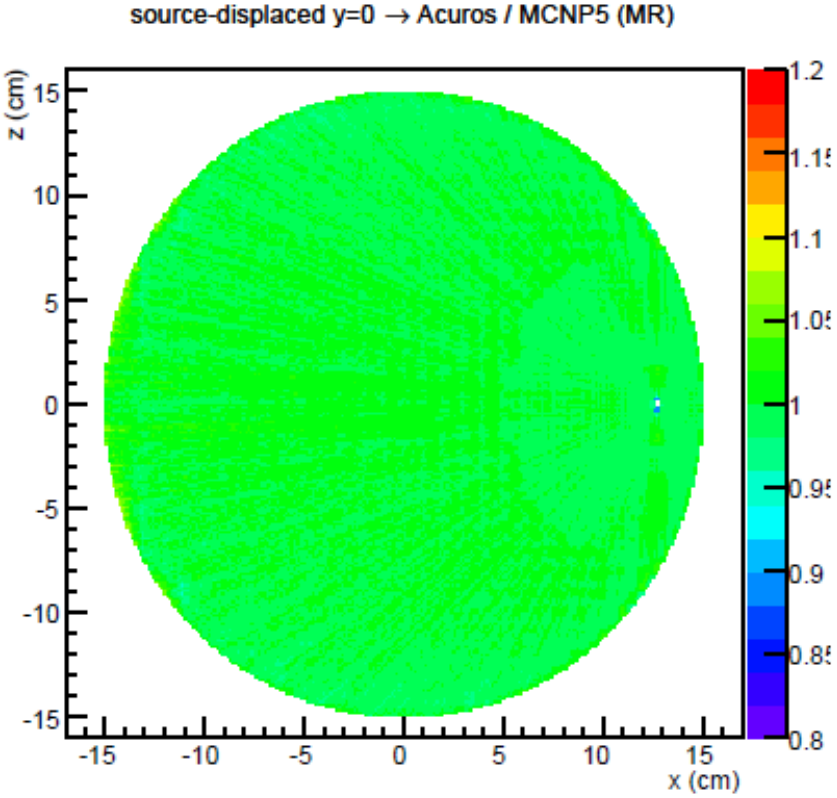


BRACHYVISION

DICOM sphere water tests: source displaced

BrachyVision *vs*. MCNP5

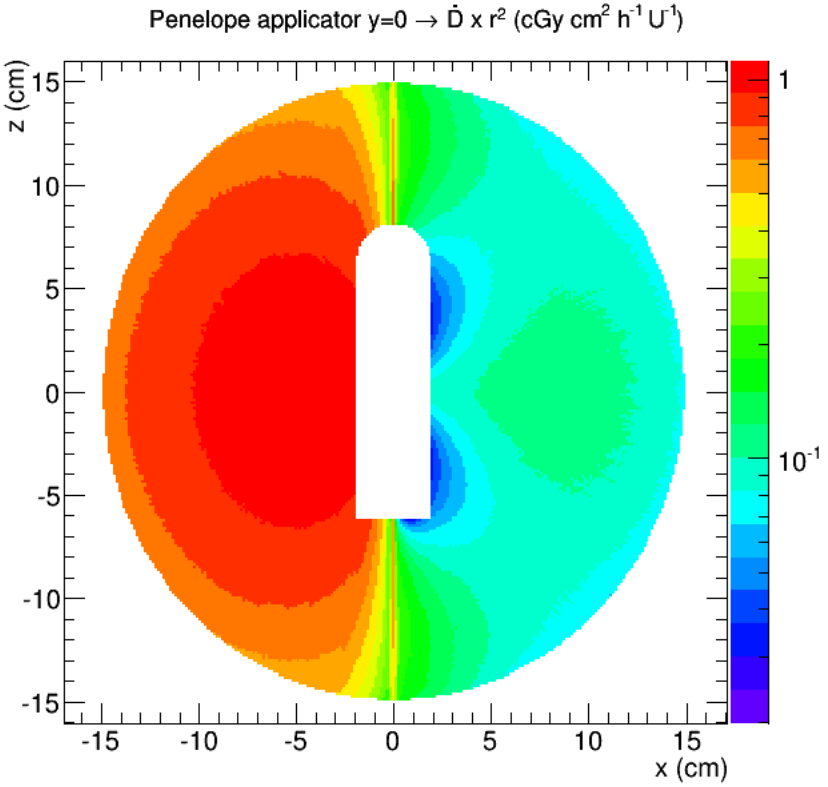


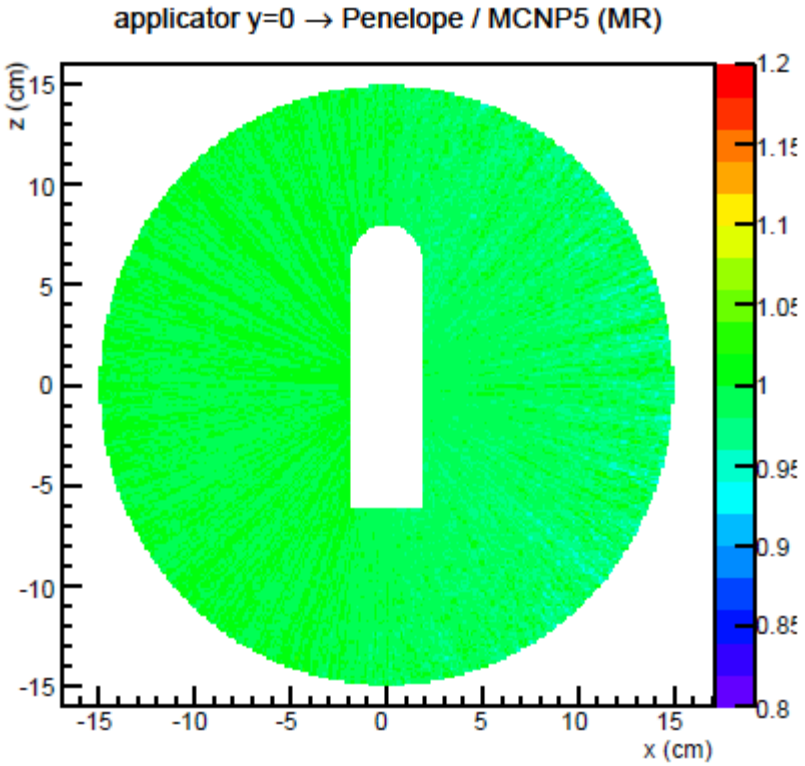


Monte Carlo results

DICOM sphere water tests: applicator

Penelope2008 *vs*. MCNP5





Conclusions

- Deterministic radiation transport algorithms are being tested for
  - HDR Ir-192 source in TG-43 conditions
  - HDR Ir-192 source in bounded conditions
  - Shielded applicator in water
- Good agreement of the TPS based on MBDCAs with Monte Carlo was obtained

Acknowledgements

MBDCA WG members

Luc Beaulieu, Chair
Å. Carlsson Tedgren
A. Haworth
G. S. Ibbott
F. Mourtada
P. Papagiannis
M.J. Rivard
F.A. Siebert
R. S. Sloboda
R.M. Thomson
F. Verhaegen

Valencia University Group

Javier Vijande, PhD
José Pérez-Calatayud, PhD
Cristian Candela-Juan, MSc
Domingo Granero, PhD

VNIVERSITAT DE VALÈNCIA

ERESA GRUPO MÉDICO

La Fe Hospital Universitari i Politècnic