Computational benchmarks - proposal -

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Increased importance of computer modeling

- High accuracy of all the steps in imaging-therapy chain is required
  - Increased role of computer simulations in medical physics (e.g., small field dosimetry)
  - Increased technological complexity (e.g., IGRT – integration of imaging and therapy)
- Further increase in treatment complexity expected
  - Treatment adaptation
  - Multi-modality imaging in treatment planning and treatment evaluation

Accuracy of treatment will depend more and more on the accuracy of computer modeling in both, imaging as well as treatment delivery !

Specific Aims

- Development of rigorous benchmarking procedures
- Compilation of the existing benchmarks
- Design of new benchmarks
- Code verification on the benchmarks

Development of rigorous benchmarking procedures

- Detailed description of the benchmark
  - Overview of the experiment
  - Experimental configuration
  - Description of material data
  - Supplemental experimental measurements
- Evaluation of experimental data
  - Experimental uncertainties
  - Material uncertainties

Development of rigorous benchmarking procedures

- Benchmark specifications
  - Description of the model
  - Dimensions
  - Material data
  - Environmental data
  - Experimental and benchmark-model values
- Results of sample calculations
- Computer code inputs

Compilation of existing benchmarks

- Classified according to their medical physics applications (can be more than one):
  - Radiation therapy (RT)
  - Imaging (IM)
  - Nuclear medicine (NM)
  - Health physics (HP)
- Some examples:
  - dose distribution on a heterogeneous phantom (RT)
  - CT density phantom (IM)
  - internal dosimetry (NM)
  - MIRD phantoms (HP)
  - dose distributions on the IGRT system (IM-RT)
  - photo-nuclear production during radiation therapy (RT-HP)

Compilation of existing benchmarks

- Classified according to their nature (can be more than one) :
  - **Theoretical benchmarks (THE):** testing consistency of the codes
  - **Clinical benchmarks (CLI):** testing clinical – real world – problems
  - **Experimental benchmarks (EXP):** (testing basic input parameters in the codes like cross sections)
- Some examples:
  - pencil beam voxel calculation (THE)
  - electron beam backscattering (CLI)
  - thick-target bremsstrahlung production measurements (EXP)
  - heterogeneous phantom dose calculations (THE) if supported by experiments (THE-EXP)

Microsoft Excel - LitList.xls

Medical Physics Computational Benchmarks - Candidates

	Author(s)	Reference	Title	Codes	Subject matter	Classif.
1	Bogner, Scherer et al.	Strahlenther. Onkol. 2004; 180:3405-350	Verification of IMRT: Techniques and Problems	XVMC/VEF	Investigation of diff. radiographic films and dose probes for their suitability	THE+EXP
2	Bohm et al.	Med. Phys. 30(4), April 2003	Brachytherapy dosimetrry of125I and 103Pd sources using an updated cross section library for the MCNP transport code	MCNP/MCNPX +improv. cr. sec. lib.	MC benchm. of brachytherapy single source character. with new cr. sec. lib.	CLI+THE
3	Borg, Kawrakow, Rogers, Seuntj.	Conf. Proc. of 22nd EMBS Jul. 23-28 2000	Experimental verification of EGSnrc MC calculated ion chamber response in low energy photon beams	EGSnrc	Experim. verification - comparison of calc. & meas. response of ionization chamber	THE+EXP
4	Carrasco et al.	Med. Phys. 31(10), October 2004	Comparison of dose calc. algorithms in phantoms with lung equivalent heterogenities under conditions of lat. electronic disequilib.	PENELOPE	PDD benchmark meas. with lung phantom TLDs, ion chamber, MC- & TPS-simulations	THE+EXP
5	Carrier et al.	Med. Phys. 31(3), March 2004	Validation of GEANT4, an object-oriented MC toolkit, for simulations in medical physics	GEANT4 comp. to MCNP, EGS, EGSnrc	Comp. of GEANT4 with other codes and simulation data of multilayer phantom	THE
6	Chetty, Bielajew et al.	Phys. Med. Biol. 47(2002) 1837-51	Exp. Validation of the DPM MC code using minimally scattered electron beams in heterogeneous media	DPM + MCNP4B modelling	(Elec.) Benchm. against meas. PDDs & ion chamber meas. in homo- & heterog. media	EXP
7	Chetty, Bielajew et al.	Med. Phys. 30(4), April 2003	Photon beam relative dose validation of the DPM MC code in lung-equivalent media	DPM + BEAM modelling	(Phot.) Validation at 6 and 15MV in heterogeneous media (lung phantom)	EXP
8	Chibani & Li	Med. Phys. 29(5), May 2002	MC dose calculations in homogeneous media and at interfaces: A comparison between GEPTS, EGSnrc and measurements	GEPTS comp. to EGSnrc, MCNP	Comp. with other codes, simul. & meas. in homo- & heterog. media / at inerfacaces	THE+EXP
9	Chibani & Li	Med. Phys. 30(1), January 2003	IVBTMC, a Monte carlo dose calculation tool for intravascular brachytherapy	IVBTMC (based on EGSnrc)	Verification against other codes (EGSnrc & MCNP) and exp. using radio-chromic films	THE+EXP
10	Chow et al.	Med. Phys. 30(10), October 2003	Comparison of dose calculation algorithms with Monte Carlo methods for photon arcs	MC, PBeamKernel, CCC, EGS/DOSXYZ	calc. of 3D dose distrib. In different phantoms; TPS and IC measurements	THE+EXP
11	Cygler, Ding et al.	Med. Phys. 31(1), January 2004	Evaluation of the first commercial MC dose calculation engine for electron beam treatment planning	VMC++ (Kawrakow)	Calc. vs. meas. data in homo- & heterogen. phantoms at diff. SSDs and gantry angles	THE+EXP
12	Ding	Med. Phys. 29(11), November 2002	Dose discrepancies between Monte Carlo calculations and measurements in the buildup region for a high-energy photon beam	EGS4/DOSXYZ EGSnrc/DOSRZnrc	Calculations vs. IC-measurements of DD	THE+EXP
13	Doucet, Olivares et al.	Phys. Med. Biol. 48(2003) 2339-2354	Comparison of measured and MC calc. dose distributions in inhomogeneous phantoms in clinical electron beams	XVMC & EGSnrc	Irradiation with 9 and 15 MeV beams, TLD measurements in solid water phantoms	THE+EXP
14	Faddegon & Rogers	Nuc.Instr.Meth.Phys. A327 (1993) 556-565	Comparison of thick-target bremsstrahlung calculations by EGS4/Presta and ITS 2.1	EGS/Presta ITS Version 2.1	Calc. of spectral distr. without meas. in 10-20 MeV beams of Be, Al and Pb targets	THE
15	Faddegon, Ross & Rogers	Med. Phys. 18(4), Jul./Aug. 1991	Angular distribution of bremsstrahlung from 15MeV electrons incident on thick targets of Be, Al and Pb	EGS4	Measurements vs. calculation of bremsstrahlung spectra at certain angles	THE+EXP
16	Flampouri, Verhaegen et al.	Phys. Med. Biol. 47(2002) 3331-49	Optimization of accelerator target and detector for portal imaging using MC simulation and experiment	EGS4/BEAM	Sim. & experim. of image contrast to max. image quality - test diff. hardw. combos	THE+EXP
17	Fragoso, Nahum, Verh. et al.	Med. Phy. 30(6), June 2003	Incorporation of a combinatorial geometry package and improved scoring capabilities in the EGSnrc MC Code system	GenUC (generic EGSnrc user code)	Incorporation/Implementation of GenUC and benchmarking against EGSnrc DOSRZnrc	THE

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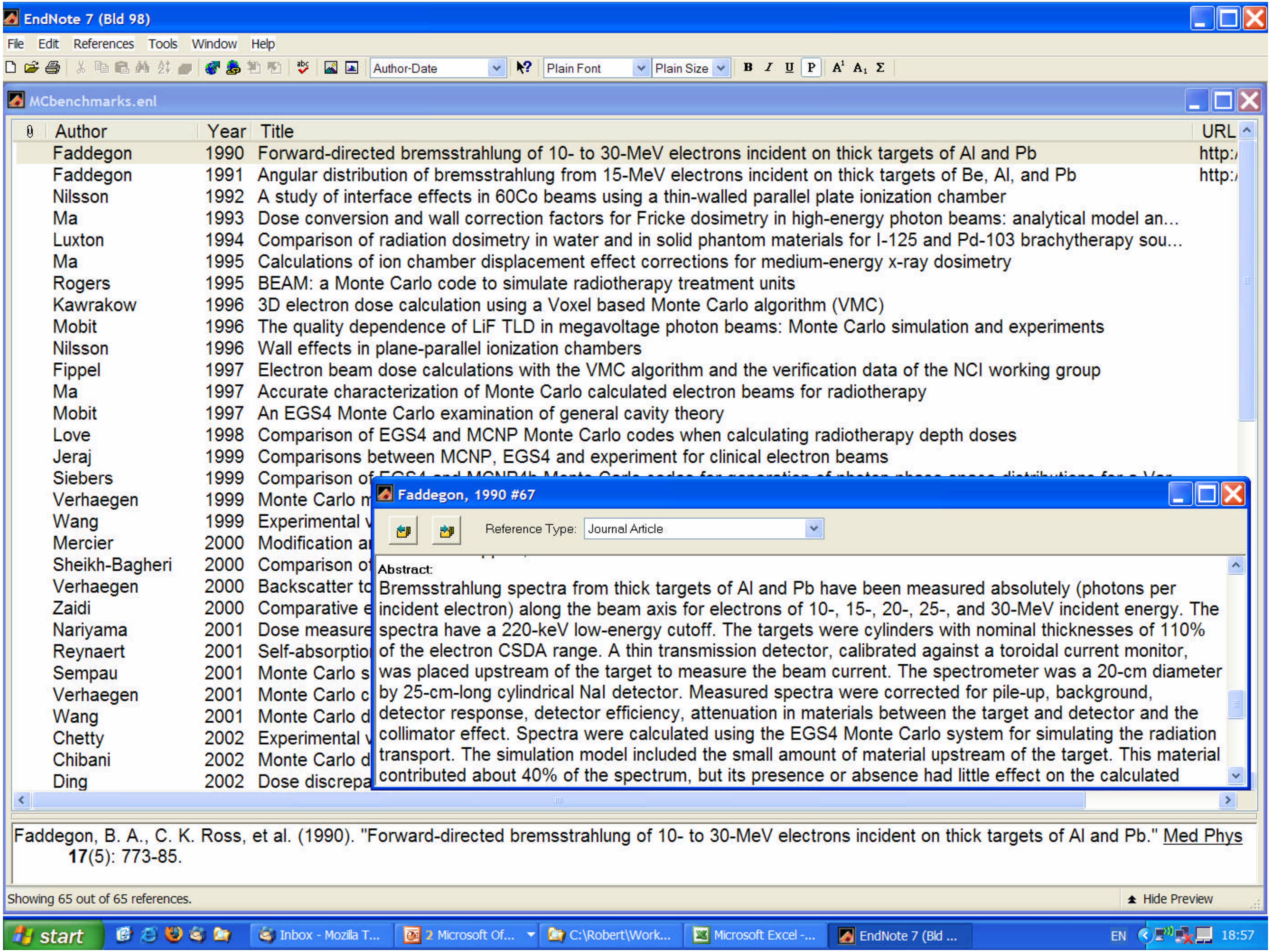
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Faddegon 1990 Forward-directed bremsstrahlung of 10- to 30-MeV electrons incident on thick targets of Al and Pb http:/
Faddegon 1991 Angular distribution of bremsstrahlung from 15-MeV electrons incident on thick targets of Be, Al, and Pb http:/
Nilsson 1992 A study of interface effects in 60Co beams using a thin-walled parallel plate ionization chamber
Ma 1993 Dose conversion and wall correction factors for Fricke dosimetry in high-energy photon beams: analytical model an...
Luxton 1994 Comparison of radiation dosimetry in water and in solid phantom materials for I-125 and Pd-103 brachytherapy sou...
Ma 1995 Calculations of ion chamber displacement effect corrections for medium-energy x-ray dosimetry
Rogers 1995 BEAM: a Monte Carlo code to simulate radiotherapy treatment units
Kawrakow 1996 3D electron dose calculation using a Voxel based Monte Carlo algorithm (VMC)
Mobit 1996 The quality dependence of LiF TLD in megavoltage photon beams: Monte Carlo simulation and experiments
Nilsson 1996 Wall effects in plane-parallel ionization chambers
Fippel 1997 Electron beam dose calculations with the VMC algorithm and the verification data of the NCI working group
Ma 1997 Accurate characterization of Monte Carlo calculated electron beams for radiotherapy
Mobit 1997 An EGS4 Monte Carlo examination of general cavity theory
Love 1998 Comparison of EGS4 and MCNP Monte Carlo codes when calculating radiotherapy depth doses
Jeraj 1999 Comparisons between MCNP, EGS4 and experiment for clinical electron beams
Siebers 1999 Comparison of
Verhaegen 1999 Monte Carlo m
Wang 1999 Experimental
Mercier 2000 Modification a
Sheikh-Bagheri 2000 Comparison o
Verhaegen 2000 Backscatter to
Zaidi 2000 Comparative e
Nariyama 2001 Dose measure
Reynaert 2001 Self-absorptio
Sempau 2001 Monte Carlo s
Verhaegen 2001 Monte Carlo c
Wang 2001 Monte Carlo d
Chetty 2002 Experimental
Chibani 2002 Monte Carlo d
Ding 2002 Dose discrepa
Faddegon, 1990 #67
Reference Type: Journal Article
Abstract:
Bremsstrahlung spectra from thick targets of Al and Pb have been measured absolutely (photons per incident electron) along the beam axis for electrons of 10-, 15-, 20-, 25-, and 30-MeV incident energy. The spectra have a 220-keV low-energy cutoff. The targets were cylinders with nominal thicknesses of 110% of the electron CSDA range. A thin transmission detector, calibrated against a toroidal current monitor, was placed upstream of the target to measure the beam current. The spectrometer was a 20-cm diameter by 25-cm-long cylindrical NaI detector. Measured spectra were corrected for pile-up, background, detector response, detector efficiency, attenuation in materials between the target and detector and the collimator effect. Spectra were calculated using the EGS4 Monte Carlo system for simulating the radiation transport. The simulation model included the small amount of material upstream of the target. This material contributed about 40% of the spectrum, but its presence or absence had little effect on the calculated
Faddegon, B. A., C. K. Ross, et al. (1990). "Forward-directed bremsstrahlung of 10- to 30-MeV electrons incident on thick targets of Al and Pb." Med Phys 17(5): 773-85.
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Design of new benchmarks

- **Testing transport mechanics of the codes:**
  - modeling of electron transport in optically thin regions
  - modeling in highly heterogeneous materials
- **Testing transport parameters of the codes:**
  - pencil beam calculations in different materials
  - bremsstrahlung differential cross sections
  - electron backscattering calculations
  - ionization chamber measurements
  - detector simulations

Design of new benchmarks

- **Preparation of the representative clinical benchmarks:**
  - external beam radiation therapy
  - brachytherapy
  - internal dosimetry
  - shielding problems
- **Imaging benchmarks:**
  - image reconstruction
  - multi-imaging modality phantoms, especially CT, PET

Code verification

- All of the computational benchmarks will be modeled with at least one of the code (typically MCNP(X) or EGSnrc)
- Verification with as many as possible codes
- Involvement of large general (medical) physics community
- National and international effort
- Agreements have been achieved with the main code developers (input code verification)
- Depository of code inputs

The most needed areas (after a short brainstorming with Wayne)

- Experiments, experiments, experiments
- Patient dosimetry
  - CT-to-code geometry conversion
  - Interface dosimetry
  - Non-tissue-like materials (high Z)

Next steps

- Grant application
- Connection with other national/international efforts
- Identify active participants
- Do the job!