View From University Research

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Overview

- The University Perspective – LSU
- Deterministic transport computations
  - Photon production spectrum in LINAC
  - External beam dose delivery
- Direct prostate dosimetry computations
  - Based on PET/CT image data
- Micro dosimetry computations
  - Cellular and DNA scales

University Perspective - LSU

- MEDP and HP programs
  - MEDP: first year on campus, second year at clinic
  - HP: mostly academic training, some at clinic
- Initially from Nuclear Eng background
  - MEDP since '83 but substantially revised in '98
  - Strong foundation in transport computations
  - MEDP curriculum is undergoing accreditation
- Currently three faculties, cooperating with adjuncts at local cancer clinic
  - Focus on therapy rather than imaging
  - Mix of computational and experimental projects
  - Radiobiology research in cooperation with Biology dp

Deterministic Computations

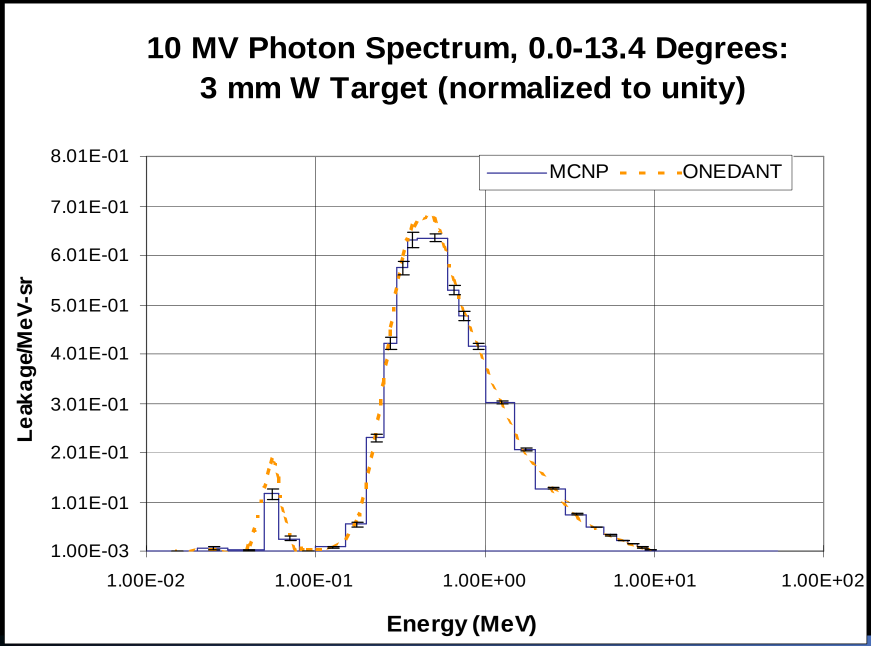
- The role of deterministic methods when MC is the “gold standard”
  - New treatment modalities with complex geometries
  - Details of dose distribution require many tally sites and long running times
  - Deterministic is a rigorous approach
    - It can provide detailed phase-space
    - Can be superior alternative to MC, especially for optimization problems
    - But, limited ability in complex geometries
- Two projects in this field

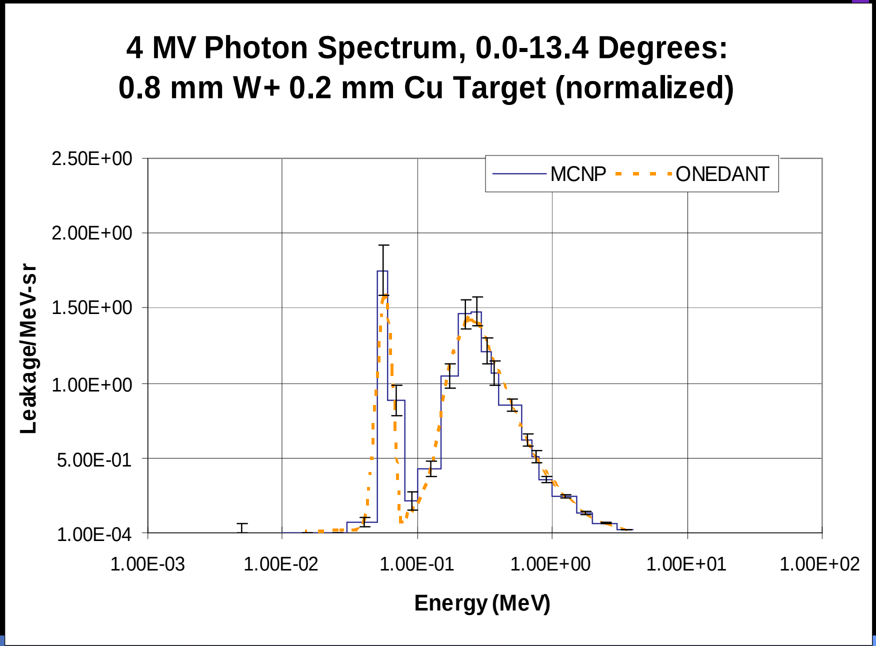
Coupled Electron-Photon Transport for Photon Production in LINAC Targets

- Electron beam incident on targets
  - Different electron energies and target materials
- Coupled electron-photon cross sections generated with CEPXS
- Target modeled as 1D slab with ONEDANT discrete ordinates code
  - Energy and angular distributions compared with MCNP coupled electron-photon results
- Results used as input to further 3D comps.

LINAC Target - conclusions

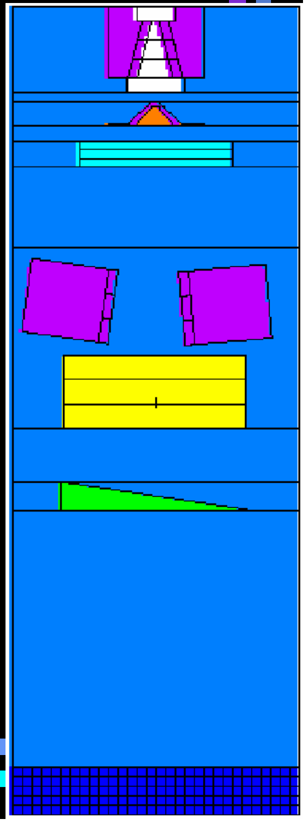
- Good agreement with MCNP within the primary collimator interval of 13.4 deg
- ONEDANT overestimates the peak source strength for the thickest target due to 1D
- Running time: 2 min vs 2-36 hrs





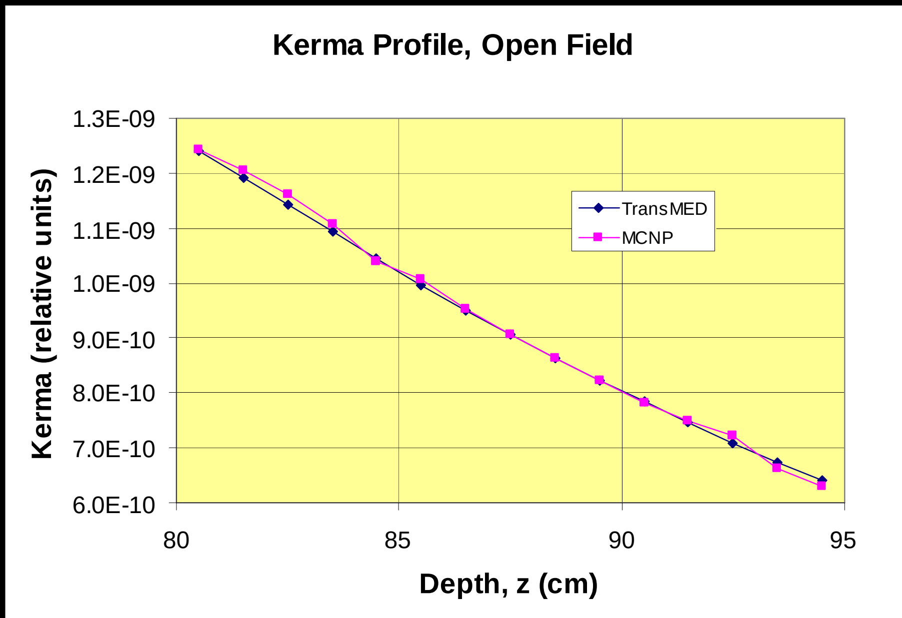
TransMED: Code for Photon transport

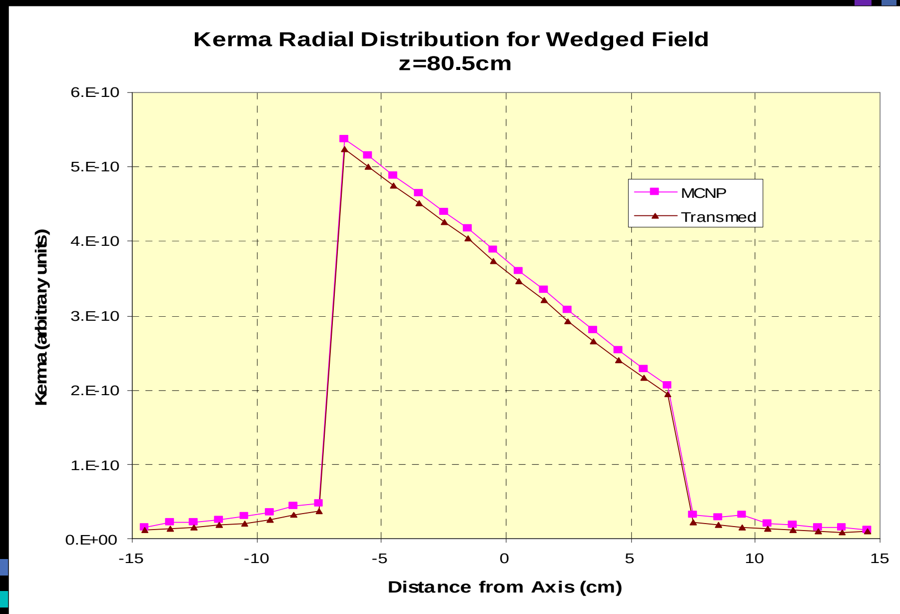
- Developed by TransWare from reactor physics code
- 3D method of characteristics in gen. geometry
- Uses MC combinatorial geometry routines for ray tracing & geometry input
- LSU's work:
  - improved 1st - and 2nd-collision-source calc.
  - added analytical calc of Klein-Nishina scatter kernel
  - developed routines to
    - set up LINAC geometry
    - patient anatomy XS from CT image files



Future Areas of TransMED Development

- Improved execution time
  - More efficient ray-tracing algorithm
  - Optimize memory & I/O management
  - Simultaneous solution for multiple beam cases
  - Parallel computation on dedicated cluster
- Addition of electron transport





Direct Prostate Seed Dosimetry

- Current limitations in seed dosimetry:
  - Brachytherapy seed localization
  - Dose computations using point-source approximation in homogeneous medium
  - Aggregate error in dose reconstruction ~ 15%
- New Method: Embedded positron emitter
  - Annihilation event distribution is imaged by PET
  - Patient tissue XS determined from CT
  - Annihilation dose is computed and linked to therapeutic dose
  - Green's function approach with precalculated kernels
  - Dose may be overlaid on anatomical image in minutes

Those perfect seeds…

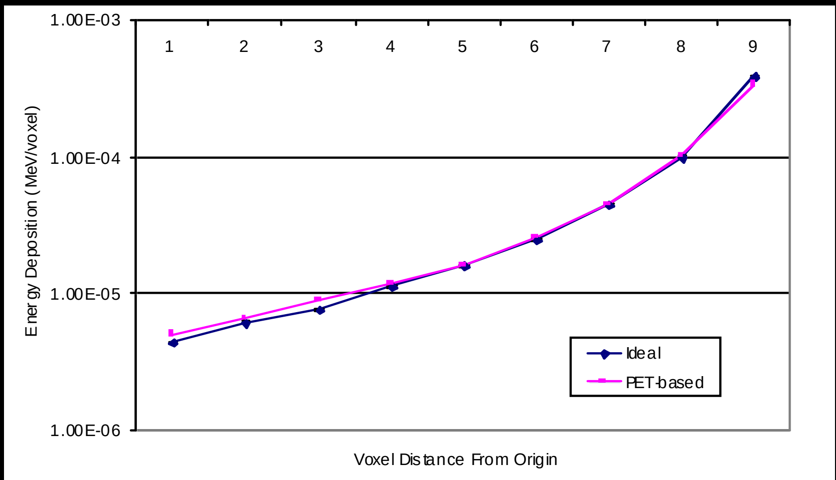
- Non-trivial number crushed or bent
- Non-standard and asymmetric dose distribution about these seeds

I-125 seed

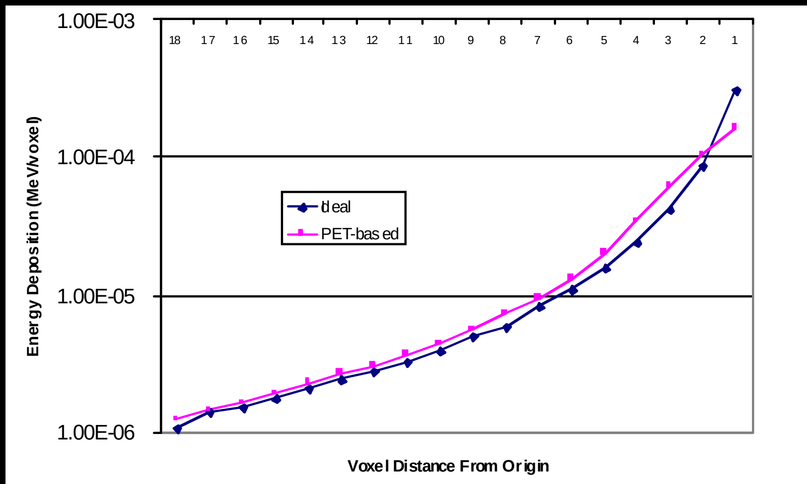
Pd-103 seed

Ideal vs PET-based dose computations

- Best agreement is in 2D acquisition due to
  - reduced out-of-plane activity
  - Increased FOV in 3D results in more false counts
- Worst discrepancy is at the seed
- Mean discrepancy when MC uncertainty is accounted for is 4%
- Problem: Current PET acquisition protocol cannot take advantage of eliminated range blurring



MCNP-calculated energy deposition in x direction based on 2D acquisition of two seeds. MC uncertainty is ~5%



MCNP-calculated energy deposition in x direction based on 3D acquisition of two seeds. MC uncertainty is ~5%

Micro- & Nano-Dosimetry Computations

- Observed chromosome changes vary with different LET of radiation (in quality, not in quantity)
  - Charged particle disequilibrium may induce secondary cancer formation (heritable translocations)
- Computation of DNA damage is limited by poor understanding of electron transport and charge exchange at the eV level
  - Event-based vs condensed history (kurbuc, moca, pits)
  - Some track structure quantities are known for vapor
  - XS are based on classical Coulomb trajectory comp.
  - No XS data for biologically important materials
- Research need in experimental XS and realistic code implementation

Thank You