AE9/AP9 Effects Kernels

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Outline

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Background

- AE9/AP9 natively provides confidence levels on differential or integral flux
- Users want more:
  - *It is conservative to compute the 95th % confidence level radiation effect from a 95th percentile spectrum: assumes all energies are at 95th % level simultaneously*
  - *Users want other radiation effects that have become de facto standards*
- Precomputed kernels convert flux-energy spectrum into linear radiation effects
- Kernels allow use of AE9/AP9 statistical machinery to compute effects at every time step or for every scenario, as needed, before computing confidence levels – removes unneeded conservatism
- Kernels allow AE9/AP9 to compute several radiation effects:
  - *Dose vs depth*
  - *Displacement damage due to protons*
  - *Single Event Effects due to protons*
  - *Charging current behind shielding*
- Kernels are “fast” to allow calculation of worst case transients by converting every spectrum to its effects
- User can provide their own kernels for custom shielding, materials

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Formulation

- A linear radiation effect converts a flux spectrum *j(E)* into an effect *y*, which may depend on shielding depth or another independent parameter (*d*):
  - $y(d) = \int j(E)G(E;d)dE$
  - $G(E;d)$ *is the Greens function or (impulse) response function*
- Numerically, we can represent this as a discrete sum:
  - $y(d_k) = \sum_i j(E_i)G(E_i;d_k)\Delta E_i = \sum_i j(E_i)A_{ik}$
  - $\underline{\underline{A}}$ *is the kernel matrix*
- We capture the kernel matrix, the input grid, the output grid, and other metadata in an XML text file
- AE9/AP9 will ship with a library of XML kernel files and an XML library for converting between shielding materials using g/cm^2 equivalence
- AE9/AP9 will also be able to read user-supplied XML kernel files that comply with the AE9/AP9 kernel format (ATR-2015-02436)

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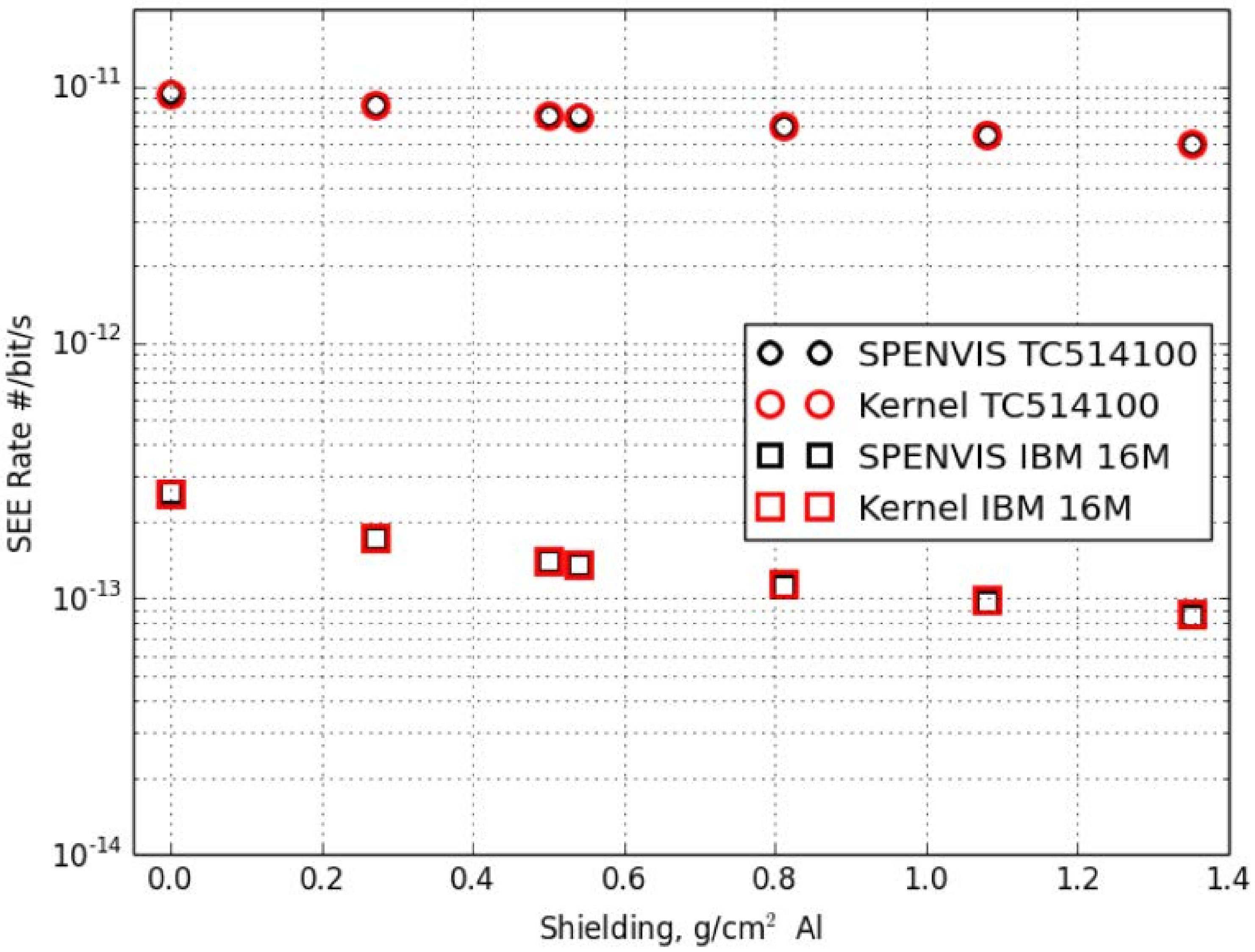
Single Event Effects

- We can use a kernel to compute the proton SEE rate behind different amounts of shielding (TOR-2015-02707)
- Use the continuous slowing down approximation to define the degraded spectrum behind known amount of Al shielding
- Apply user-defined Weibull or Bendel SEE cross section to compute SEE rate from degraded spectrum
- A utility program takes user-supplied cross section parameters and energy/shielding grids and produces a kernel XML file



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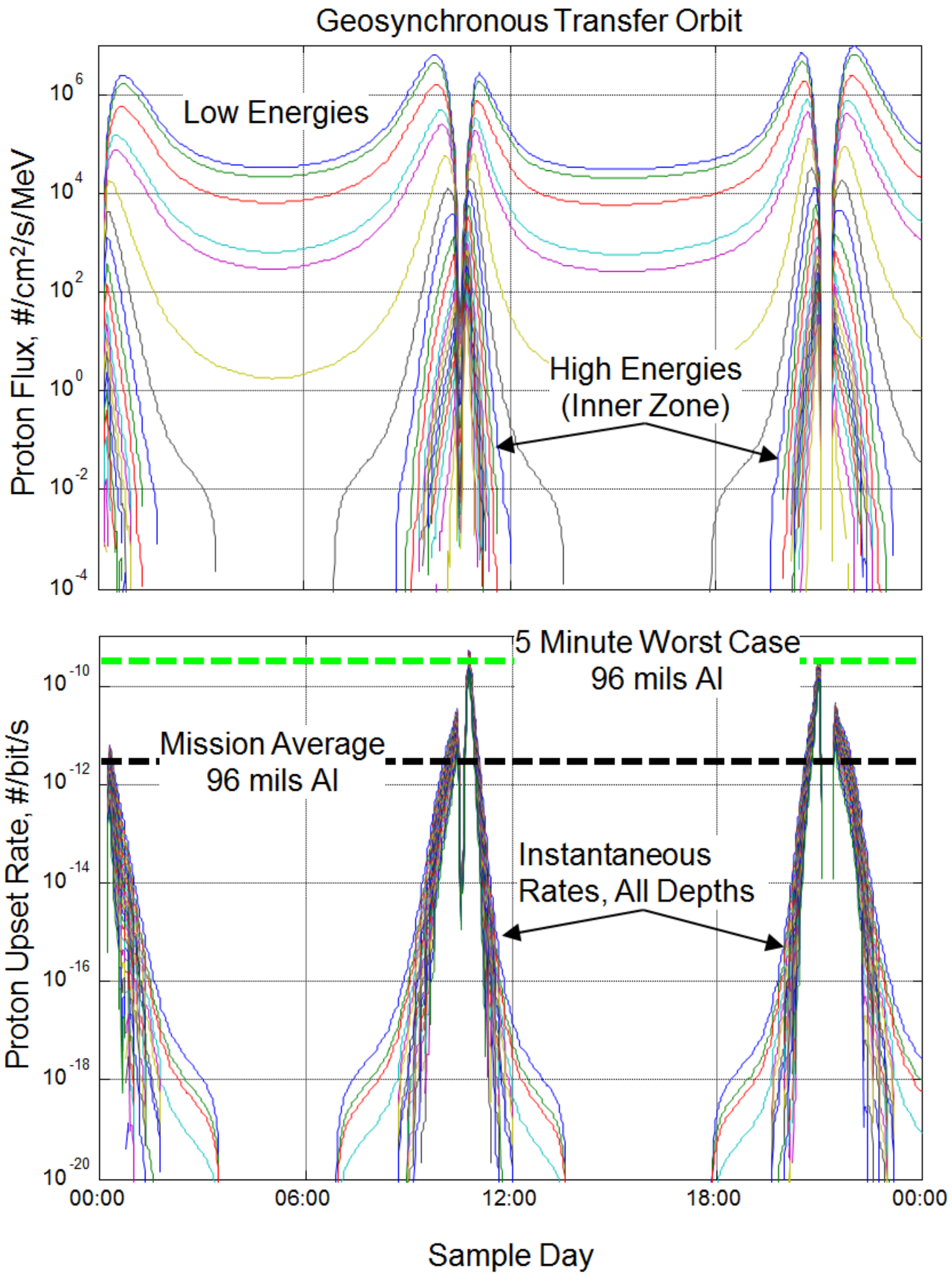
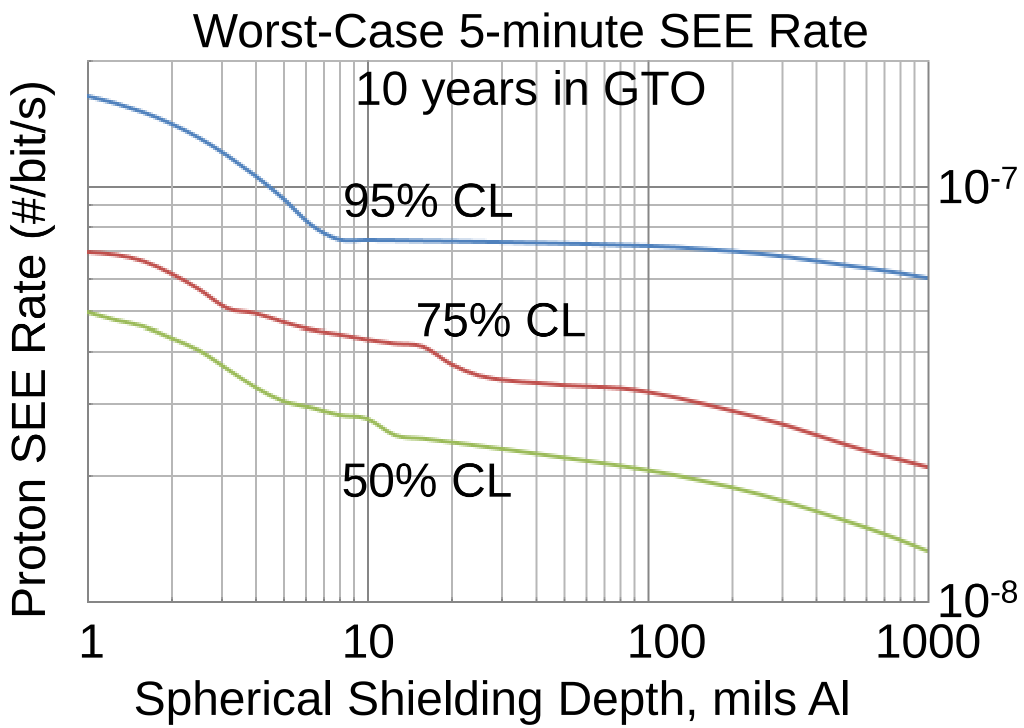
Single Event Effects



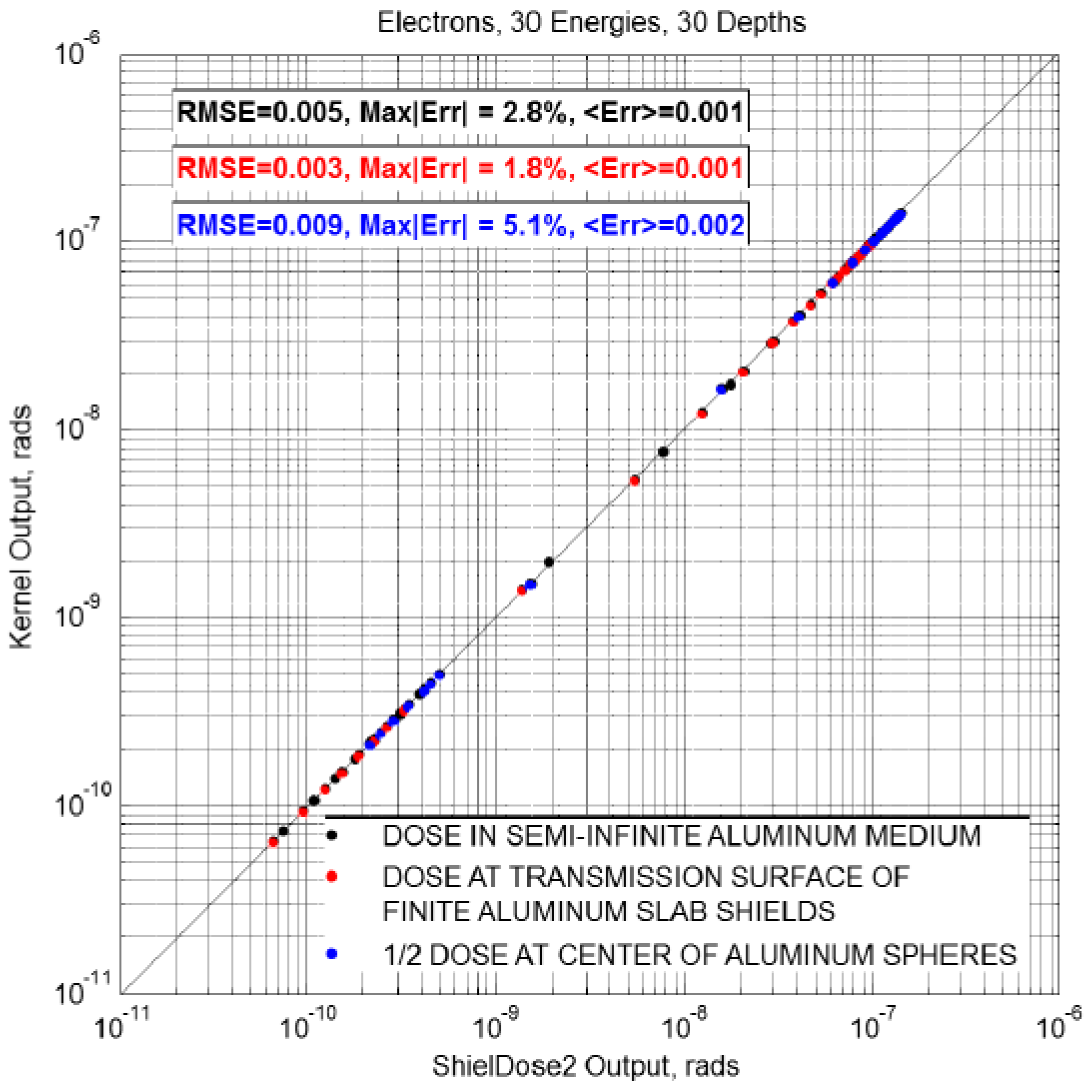
- Using the kernel, AE9/AP9 can convert every proton spectrum along the user's trajectory into a proton SEE rate
- Do this for every time step to compute max SEE rate for a single scenario
- Do this for multiple scenarios to compute confidence levels on max SEE rate



Kernels from Third-Party Apps

- Third party applications, like ShieldDose2, may not supply the Green's function to users
- It is possible to extract the Green's function by probing the application (ATR-2016-01756)
  - $y(d_k) = \sum_i j(E_i) A_{ik}$
  - $A_{ik} = \frac{\partial y(d_k)}{\partial j(E_i)} = G(E_i; d_k)\Delta E_i$
- Run the third party application multiple times*, perturbing the flux at a different energy grid point each time; each run produces on row of $\underline{\underline{A}}$, which is what you need for the kernel

- *Sometimes, as with ShielDose2, you have to be careful with how you do your perturbations to avoid complications from nonlinear interpolation inside the third party application



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Summary

- Kernels provide AE9/AP9 a means to compute *linear* radiation effects from flux-energy spectra
- Kernels allow calculation of correct confidence levels from scenarios
- Kernels satisfy user desire for more radiation effects outputs
- Kernels are just XML text files containing the transform matrix, input/output grids, and other metadata
- AE9/AP9 will ship with several “standard” kernels:
  - *Dose vs depth for 4 typical Al shielding geometries on Si and GaAs targets*
  - *Proton displacement damage vs depth for spherical Al shielding on Si and GaAs targets*
  - *Proton SEE rate vs depth for spherical shielding for a “typical” part*
  - *Utility to generate proton SEE kernels for user-defined parts (Bendel or Weibull parameters)*
  - *Internal charging current emerging from a hemispherical Al or Cu shield*
- Users can supply their own kernel XML files at run-time to account for custom shielding geometry, shielding materials, target material, and other linear effects
- Kernels can be generated from analytical approximations, Monte Carlo nuclear effects calculations (e.g, GEANT4), or by probing existing third-party applications

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