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VARSKIN Air Gaps and Covers

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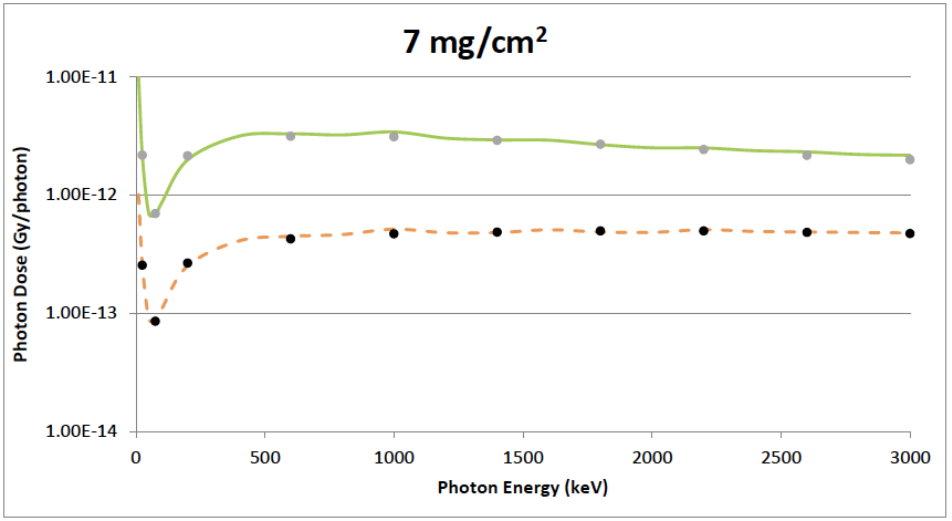
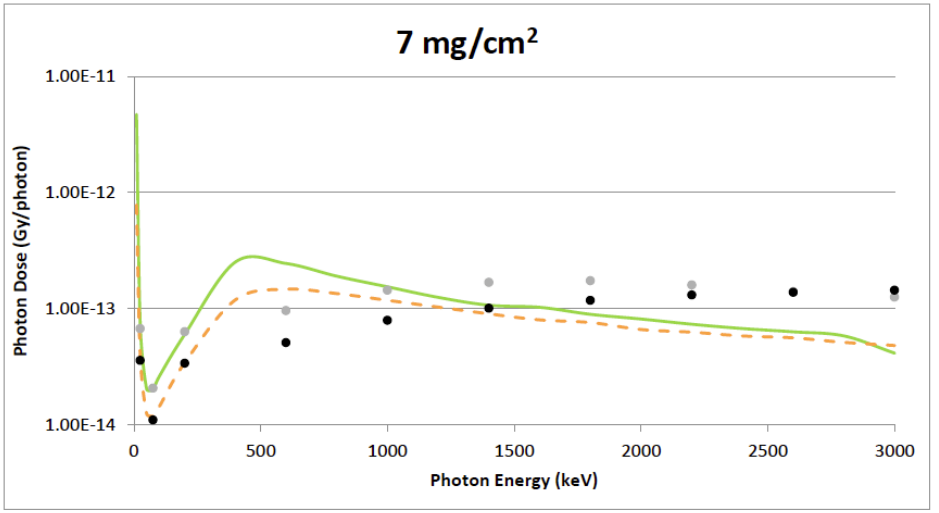
The Issue

- Adding an air gap and/or cover creates disagreements between the photon dose calculations for MCNP and VARSKIN.

No Cover or Air Gap



Air Gap and Cover



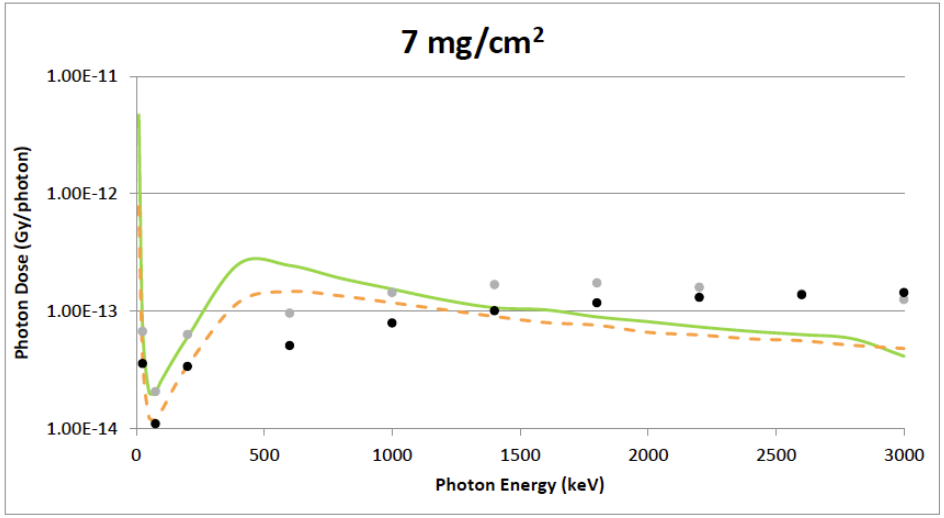
Dots: VARSKIN
Lines: MCNP

Green: 1 cm^2 Dose Averaging Area
Orange: 10 cm^2 Dose Averaging Area

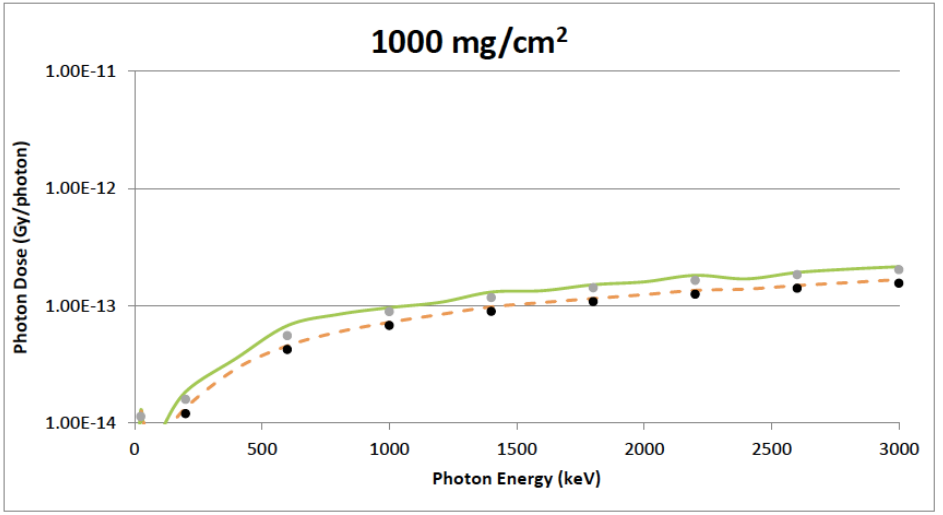
How Depth Affects the Problem

- MCNP and VARSKIN have poor agreement at the shallow depth with airgap or cover(s).
- Thought to be due to lack of charged particle buildup consideration in covers.

Air Gap and Cover, 0.007 cm depth



Air Gap and Cover, 1 cm depth



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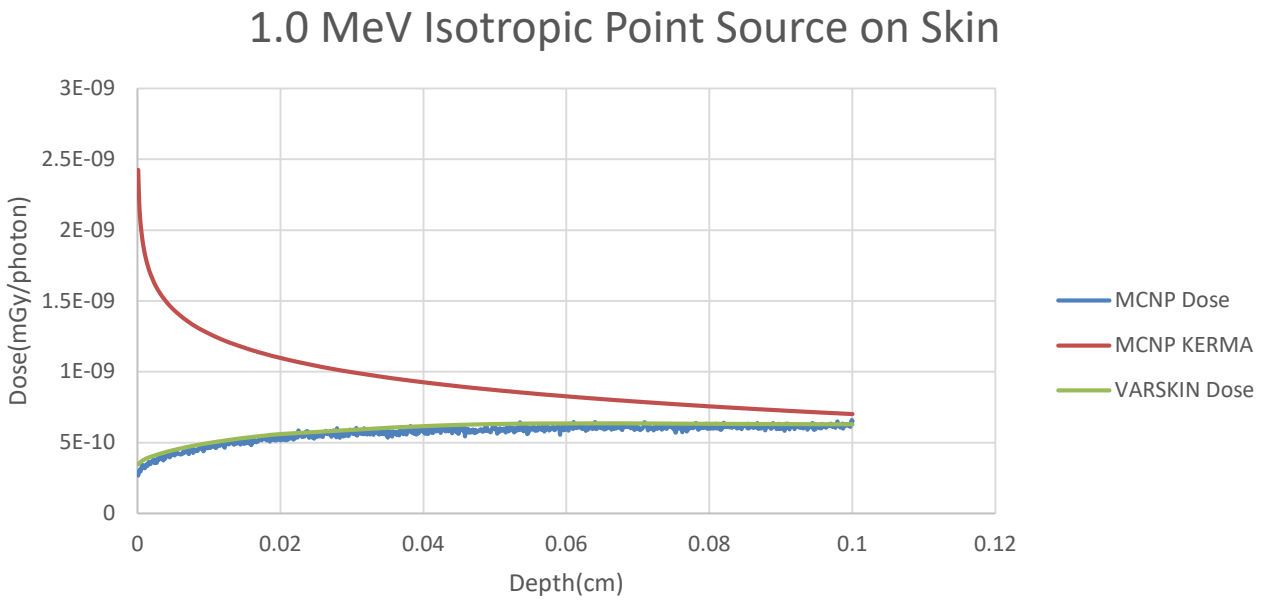
Charged Particle (CP) Buildup

- For photon radiation, the dose delivered depends on the secondary electrons released from ionization.
- Electrons deliver dose throughout a significant range of depths into the skin, leaving the surface of the skin with very little dose.



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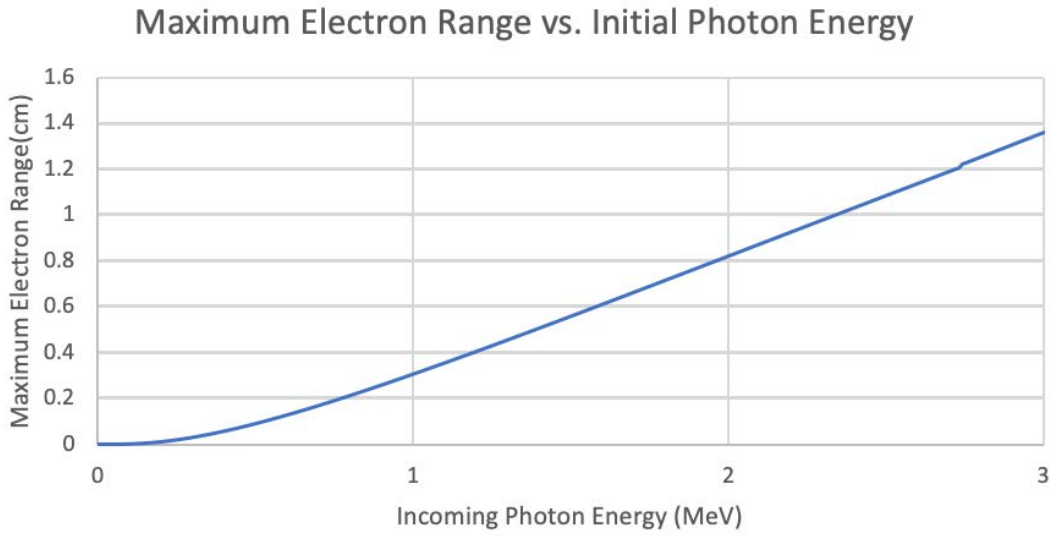
Charged Particle (CP) Buildup

- When Dose≈KERMA, Charged Particle Equilibrium (CPE) has been reached.
- High energy photons require more depth to reach CPE
- CPE depth is approximately the range of the maximum energy Compton scatter electron.

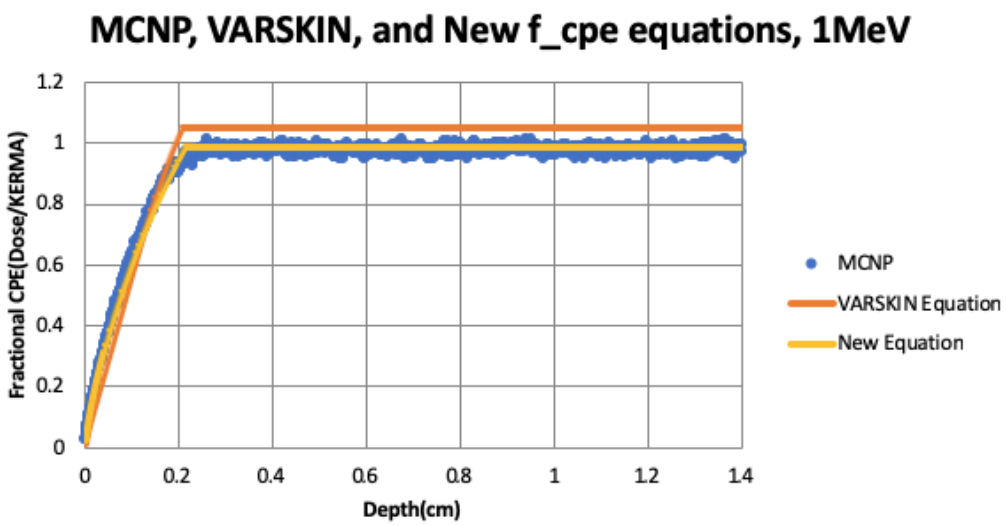
$$E_{e,\,max}=E_p\left(\frac{2Ep}{m_e c^2+2Ep}\right)$$

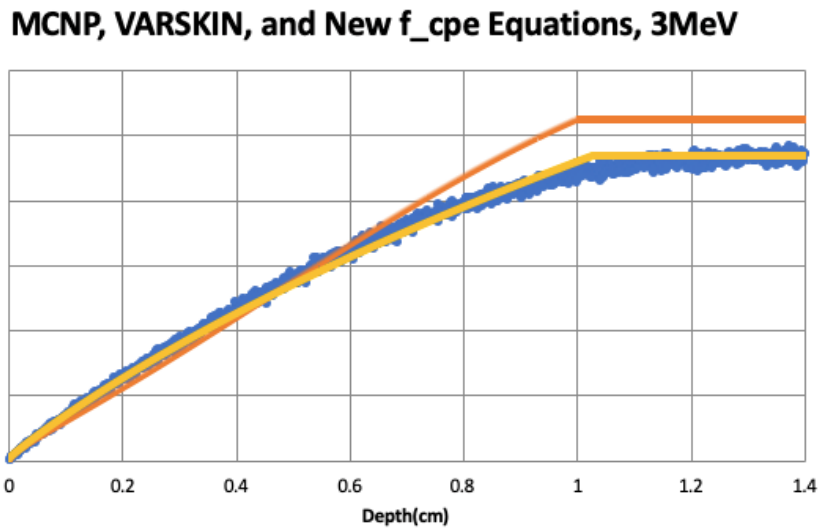
E_p = Incoming Photon Energy



Fractional CPE (f_{cpe})

- The ratio of the energy delivered by electrons (Dose) to the energy delivered by photons (KERMA) is f_{cpe}.
- MCNP was used to find an empirical equation for f_{cpe}.
- The F6 tally was used for KERMA and the *F8 tally was used for dose.
- An improved equation for f_{cpe} will be added to VARSKIN 7.





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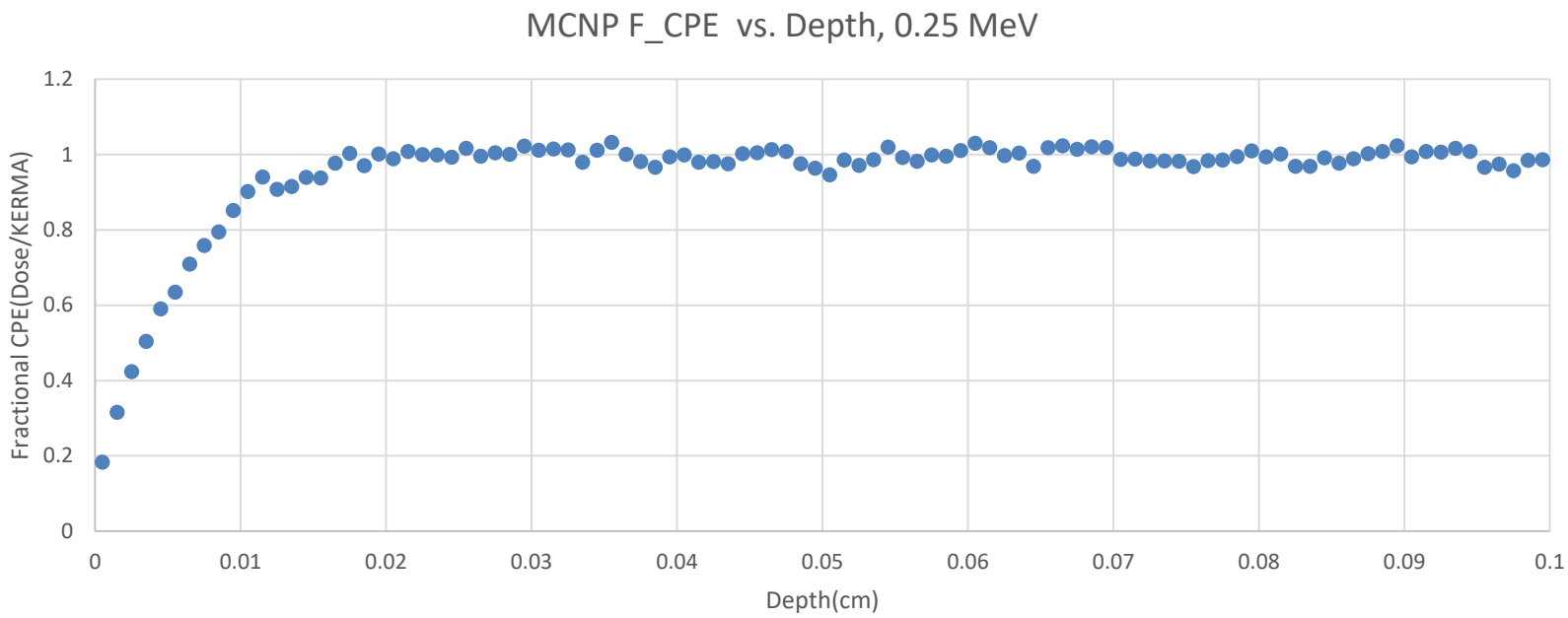
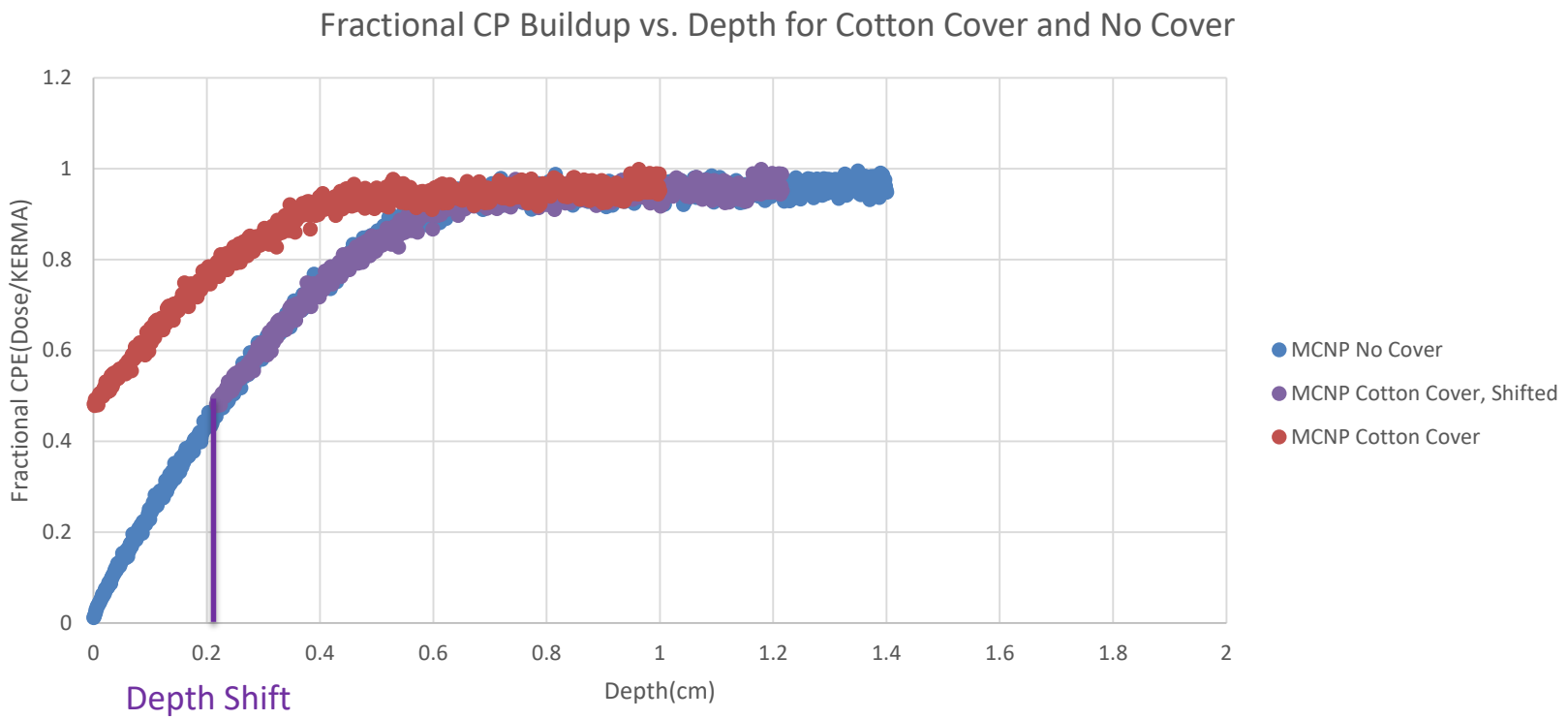
Does f_{cpe} Need to be Accounted for in Covers?

- 0.25 MeV photon buildup length in skin: ~0.02 cm (20 mg/cm^2)
- Cotton Glove Thickness: 0.03 cm
- With a cotton glove, CPE has been reached at the surface of the skin, but VARSKIN's f_{cpe} value will be 0.



Adjusting f_{cpe} for Covers

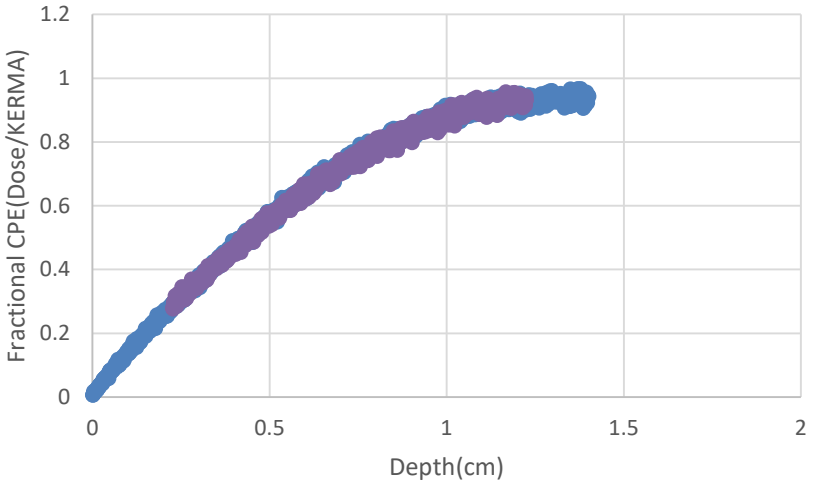
- Using MCNP simulations, we find the effective skin depth added by the cover.
- Minimize loss between cover data and non-cover data to find depth shift.



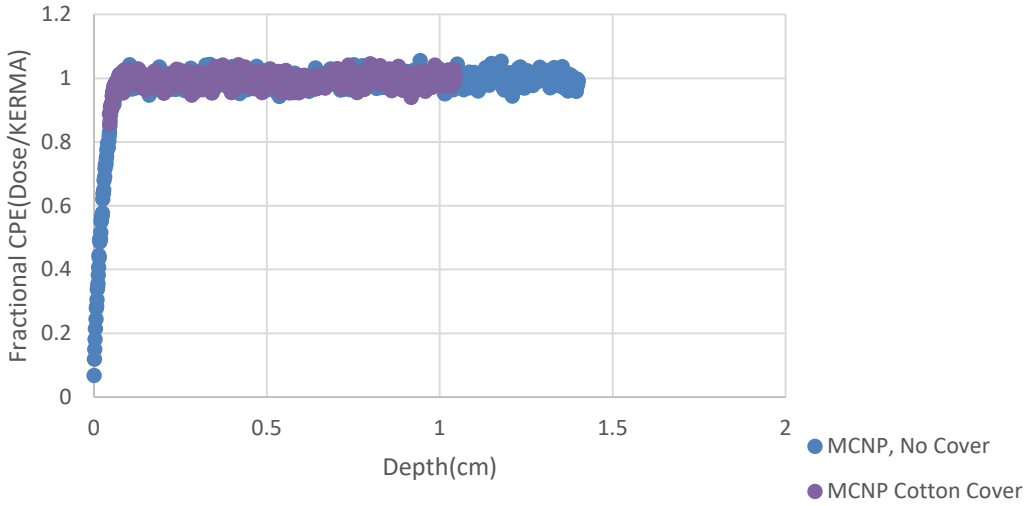
Cotton Cover Charged Particle Buildup

- The skin depth shift divided by cover thickness is a constant conversion factor between the cover material and skin.
- Effective skin density thickness over cotton density thickness is shown to be effectively independent of photon energy.

Fractional CP Buildup vs. Depth for Cotton Cover and No Cover, 3MeV



Fractional CP Buildup vs. Depth for Cotton Cover and No Cover, 0.5MeV



Cotton Density Thickness: 240 mg/cm^2
Effective Skin Thickness: 225 mg/cm^2
Skin Depth/Cotton Depth : 0.9375

Cotton Density Thickness: 48 mg/cm^2
Effective Skin Thickness: 44 mg/cm^2
Skin Depth/Cotton Depth : 0.917

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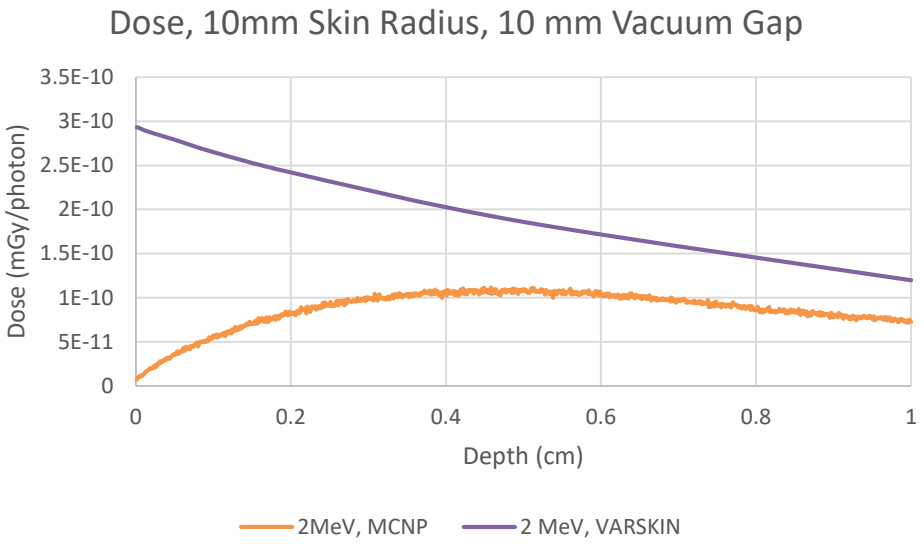
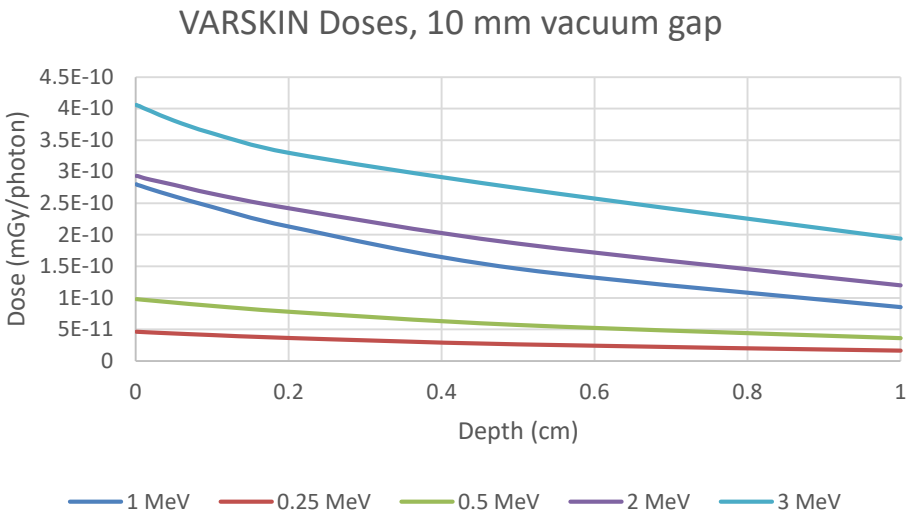
VARSKIN cover materials

- Only cover density can be currently entered into VARSKIN, not material composition.
- For photon attenuation purposes, if ρ ≤ 1.25$\frac{g}{cm^3}$, the material is assumed to be latex, otherwise it is assumed to be cotton.
  - This assumption is valid as attenuation mainly depends on density thickness.
  - The assumption of material composition based on density removes the need for large tables of attenuation coefficients.
  - The same method of finding a material composition based on density will be used for photon charged particle buildup

VARSKIN 7 Bug Fix: Depth Overestimation

- When covers were present, there was a miscalculation that overestimated skin depth for use in the f_{cpe} equation.
- VARSKIN incorrectly thought that CPE was reached, resulting in no buildup.





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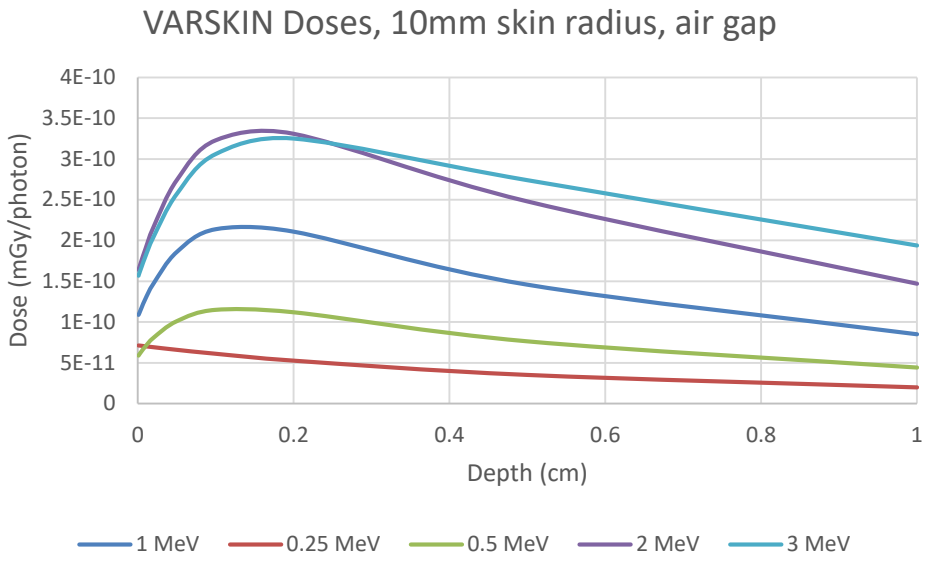
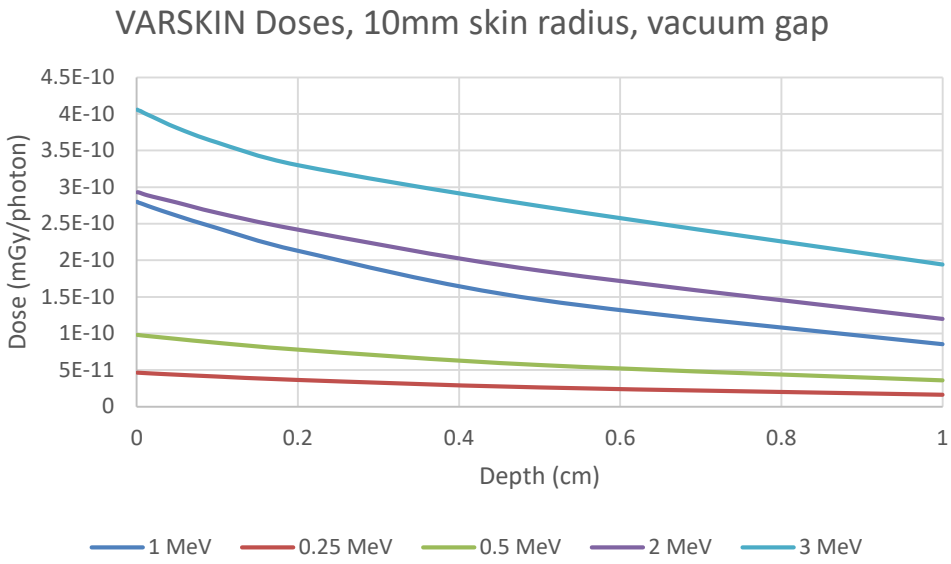
VARSKIN 7 Bug Fix: Air Gap

- The difference in dose between an air gap and a vacuum gap should be small
- With an air gap, the off-axis angle was overestimated, causing lower dose at lower angles that could have been mistaken for CP buildup.

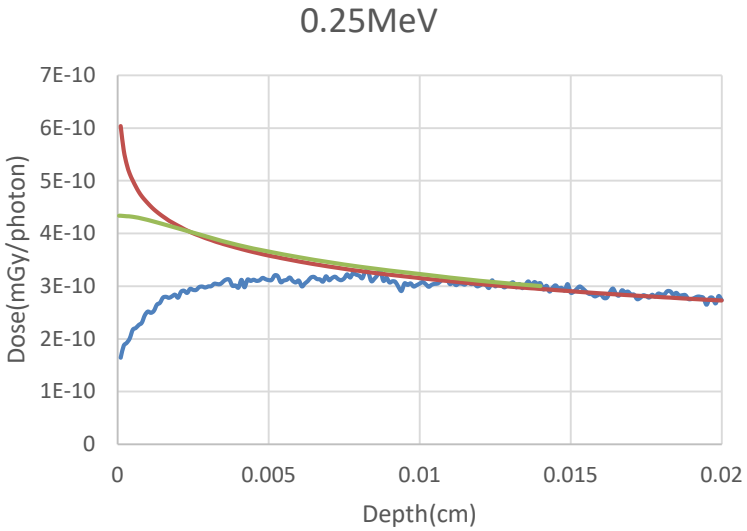


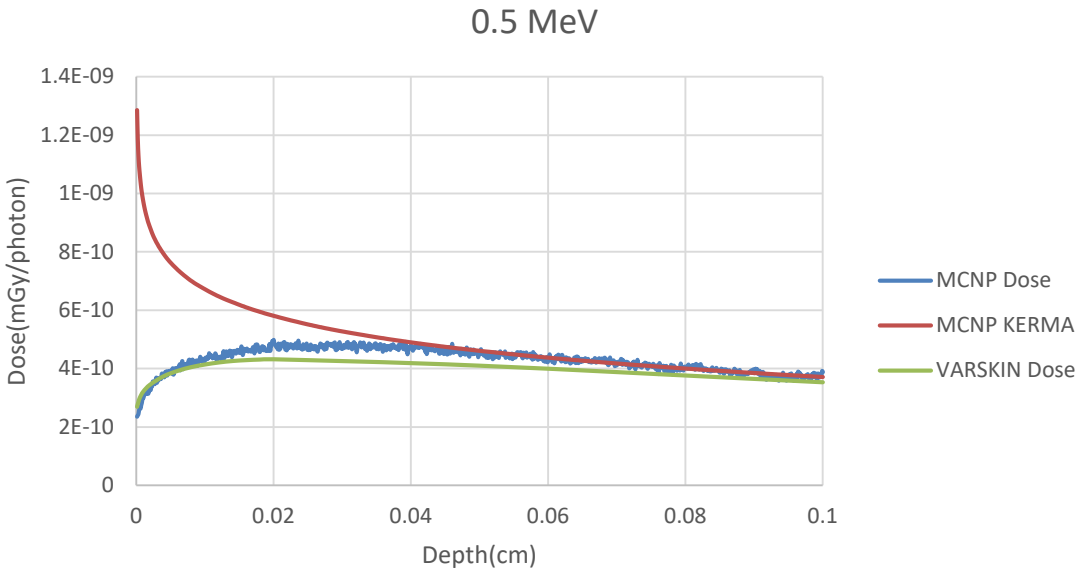


VARSKIN 7 Bug Fix: Low Energy Off-Axis Factor

- Off-Axis factor currently not applied below 0.3 MeV
- Dose, however, is inaccurate at shallow depths when the photon energy is less than 0.3 MeV.

VARSKIN and MCNP dose with no covers and an isotropic point source:





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