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Eye Dosimetry Using VARSKIN

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-- and –

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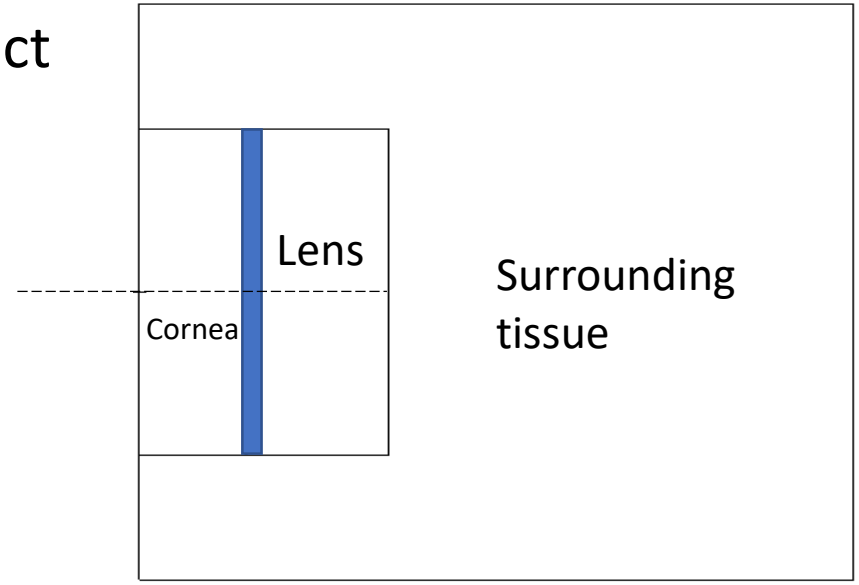
Eye Dosimetry with VARSKIN?

- VARSKIN originally intended for estimating shallow dose from skin contamination to show compliance with US Regulation 10 CFR 20.1201
  - 10 CFR 20 limit (1991) of 150 mSv/yr from ICRP 26
- ICRP 118 (2012) guidance for the dose limit to the lens
  - 20 mSv/yr averaged over 5 consecutive years, not to exceed 50 mSv in any single year
  - change indicated by higher incidence at lower dose over longer follow-up times
  - data imply that the “injury … is caused by single-hit irreparable-type events”
- Some users have turned to VARSKIN for eye dosimetry of beta emitters
- In its current state (V6.1), how well does VARSKIN estimate lens dose?

Eye Dosimetry

- We compared VARSKIN 6.1 to Monte Carlo simulation (MCNP6)
- Using a simplified eye model with cornea, lens, and surrounding tissue all assumed to be of unit density
  - to be closest to VARSKIN assumptions
- Point sources located along centerline from contact to 20 cm
- Dose estimated per incident electron
  - to normalize for geometry
  - cross-sectional area of 1 cm^2 with 20 μm thickness, centered at a depth of 3 mm



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VARSKIN 6.1 Geometry without Eye Protection

Varskin 6.1

File Help Language

Source Geometry

- Point
- Sphere
- Disk
- Slab
- Cylinder

Special Options

- Exclude Photon Dose
- Exclude Electron Dose
- Perform Volume Averaging
- Offset Particle Model

Skin Averaging Area

1.00E+00 cm²

Exposure Time

1.00E+00 sec

Radionuclide Library [Zeff]

F-18 [7.42] 38
Ho-166 [7.42] 107
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I-131 [7.42] 107
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Nd-140 [7.42] 107D
Pr-144 [7.42] 107
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Pr-144m [7.42] 38
Re-186 [7.42] 38
XX-MeV [7.42] 38
Yb-166 [7.42] 107D

Activity Units: Bq

Select | Add | Remove

Selected Radionuclides

XX-MeV [7.42] 38: 1.00E+00 Bq

Edit | Remove | Remove All

Irradiation Geometry

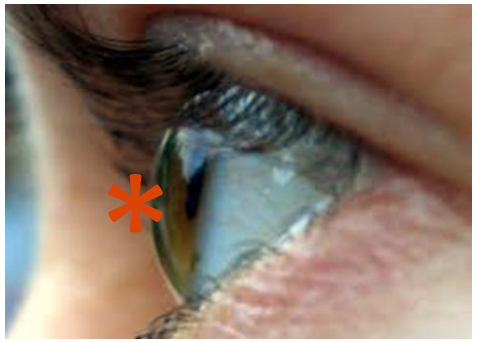
Skin Thickness or Skin Density Thickness	3.00E+02	mg/cm²
Air Gap Thickness	1.00E+00	cm
Cover Thickness	0.00E+00	mm
Cover Density	0.00E+00	g/cm³

Multiple Cover Calculator

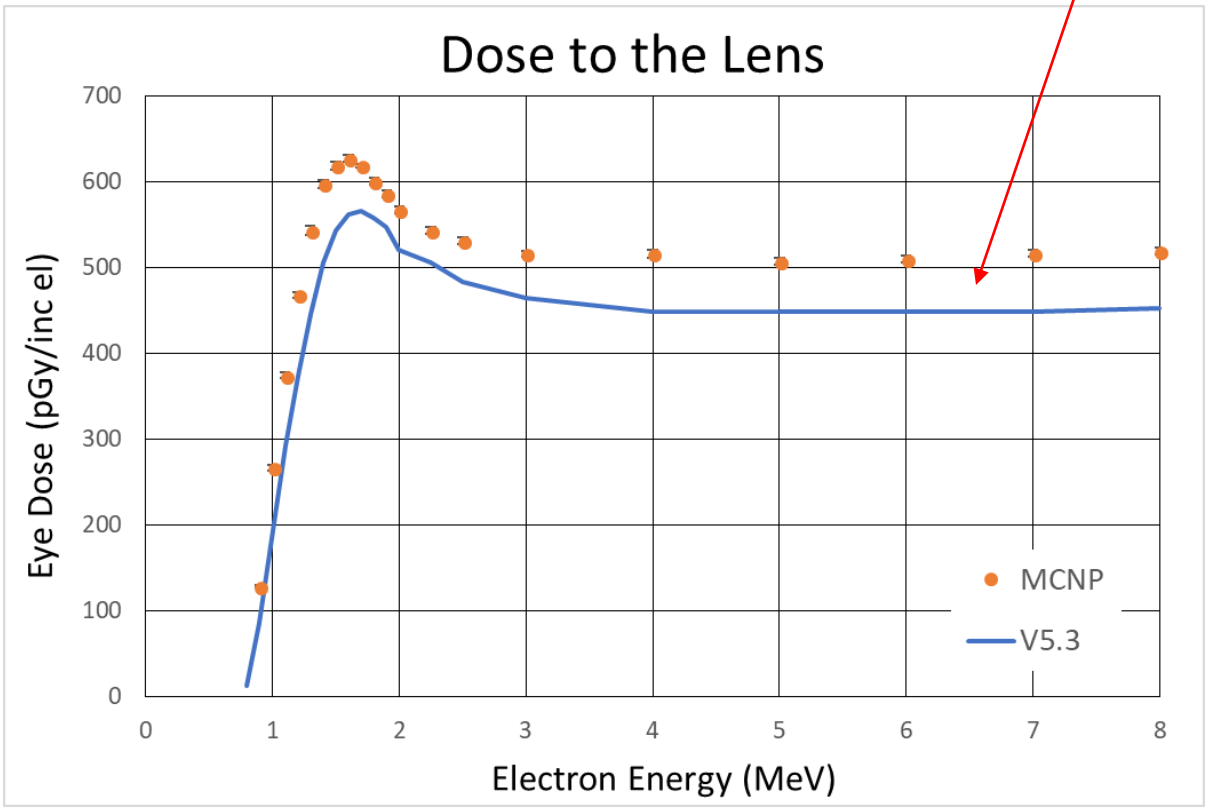
VARSKIN

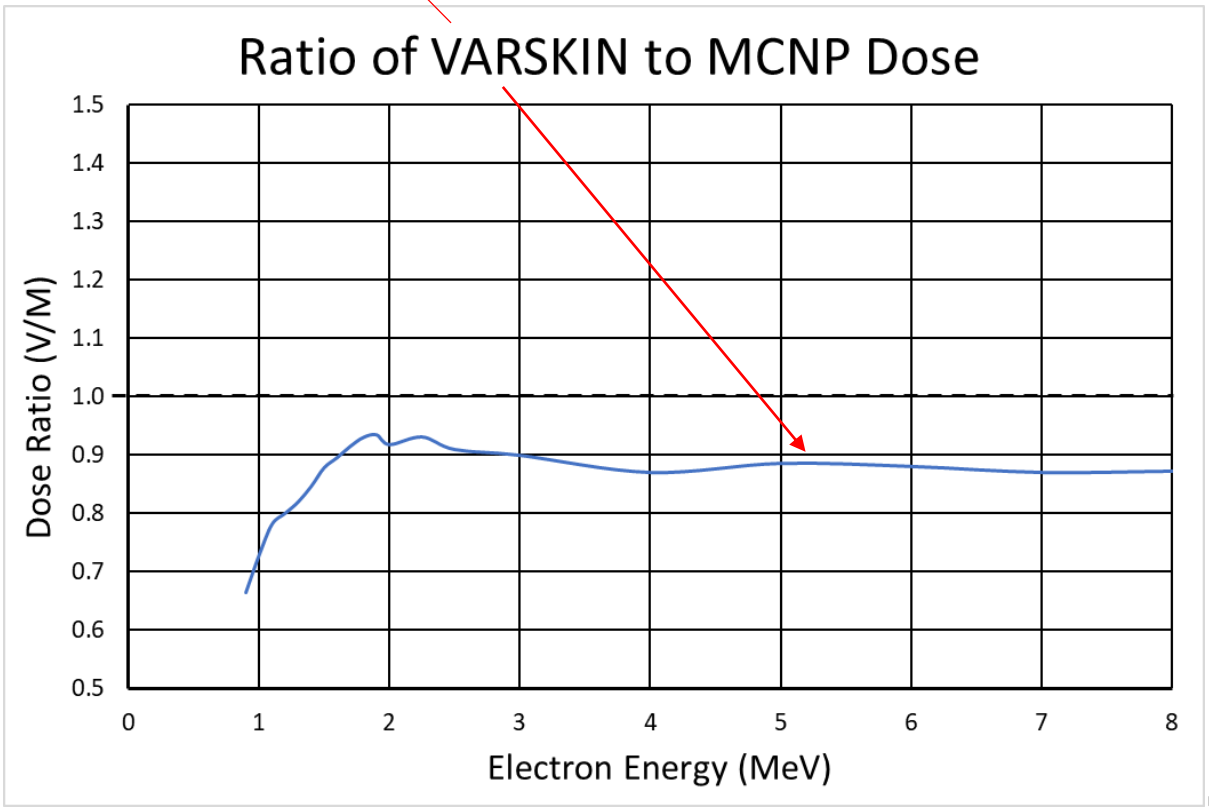
Calculate Doses

Source on Contact



VARSKIN underestimates by at least 10%





- All results are normalized for geometry to show dose per electron incident on the eyeball
- Normalized VARSKIN results are consistent, whereas MCNP results are indicative of different patterns of energy loss during electron transport

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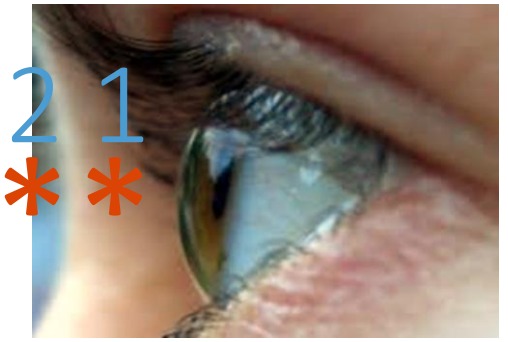

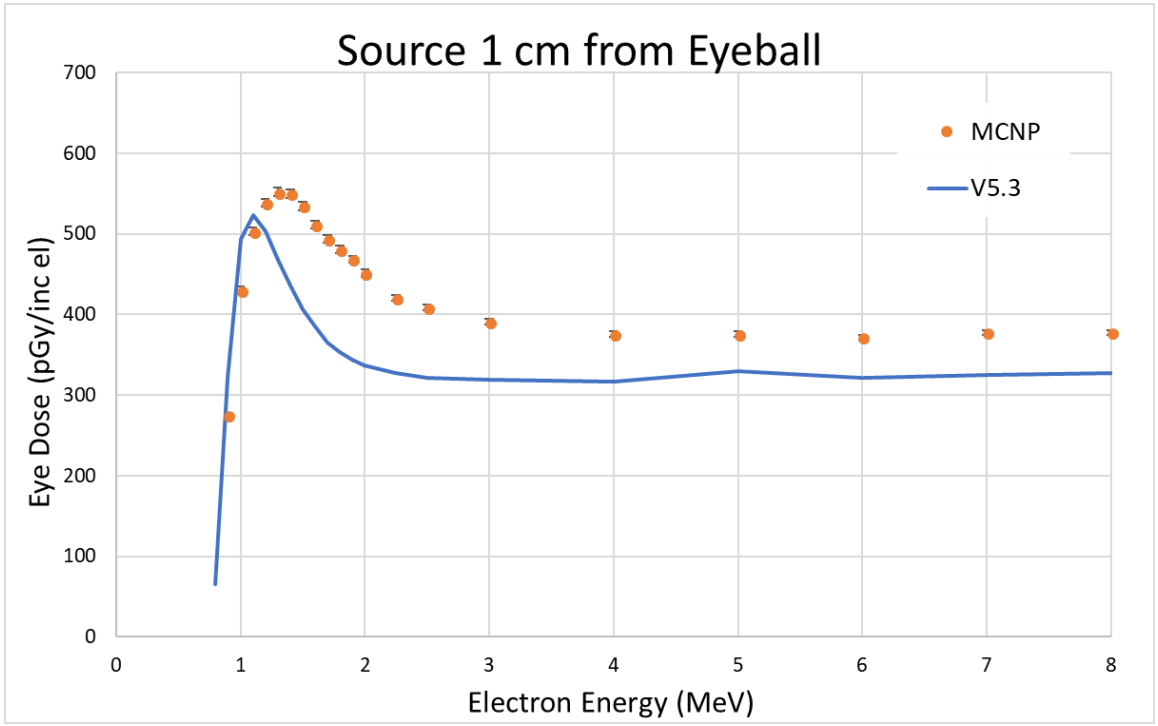

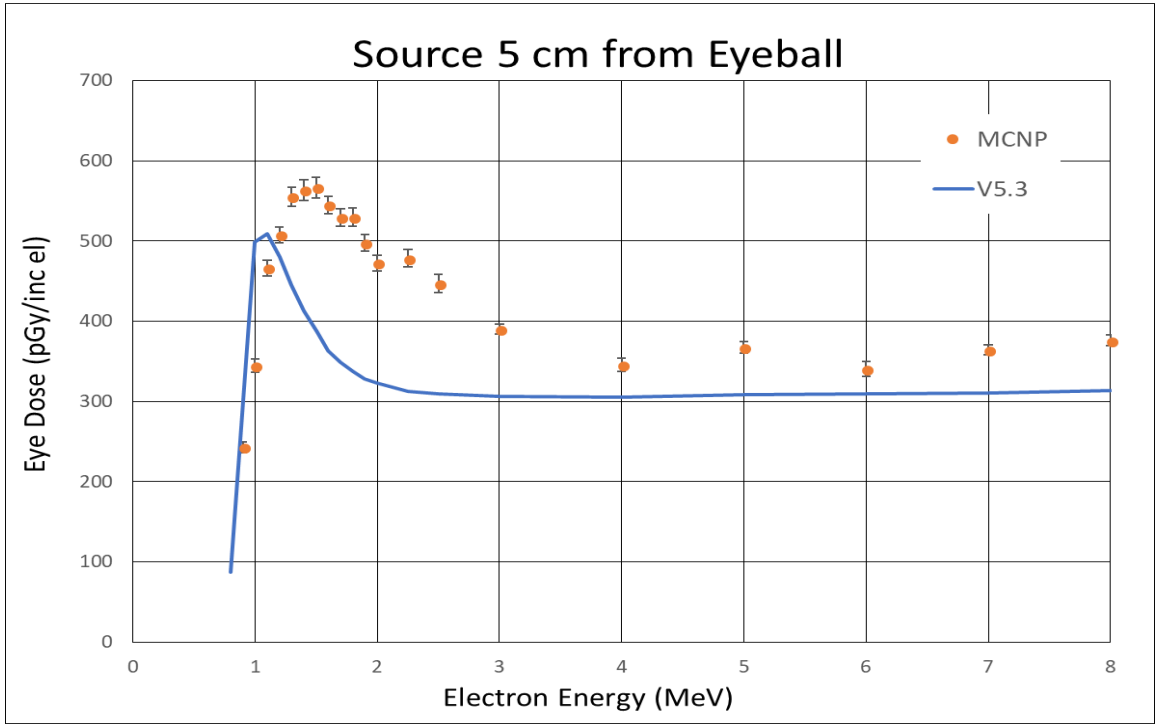

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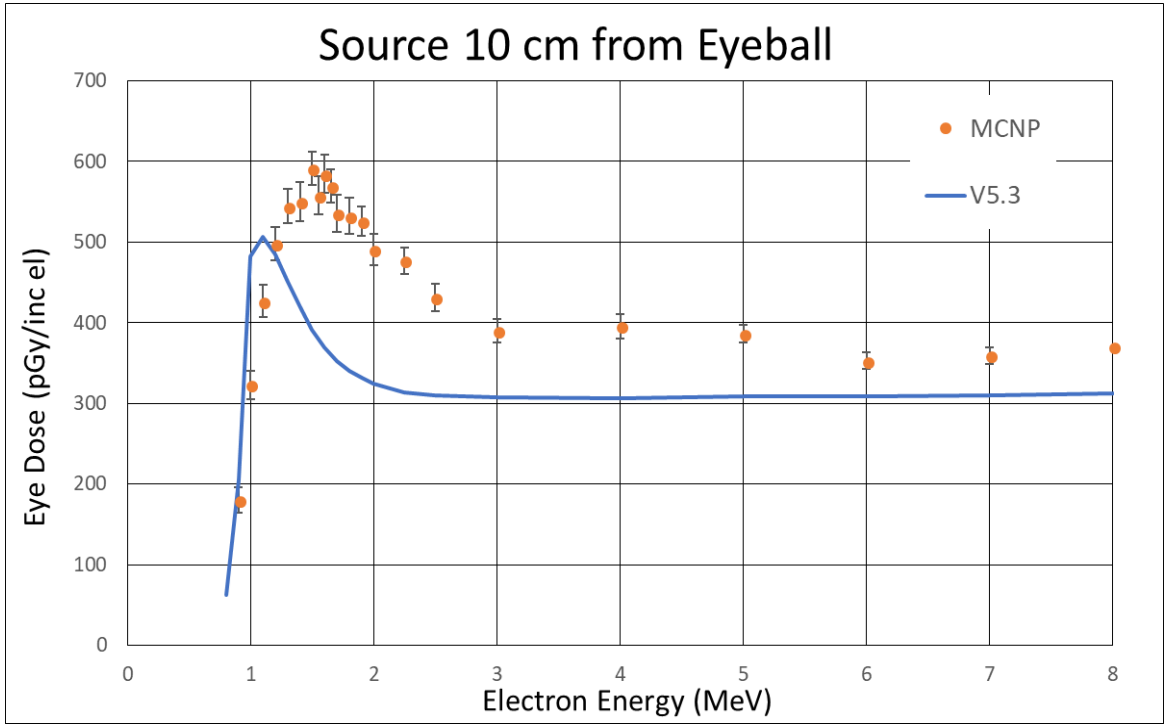
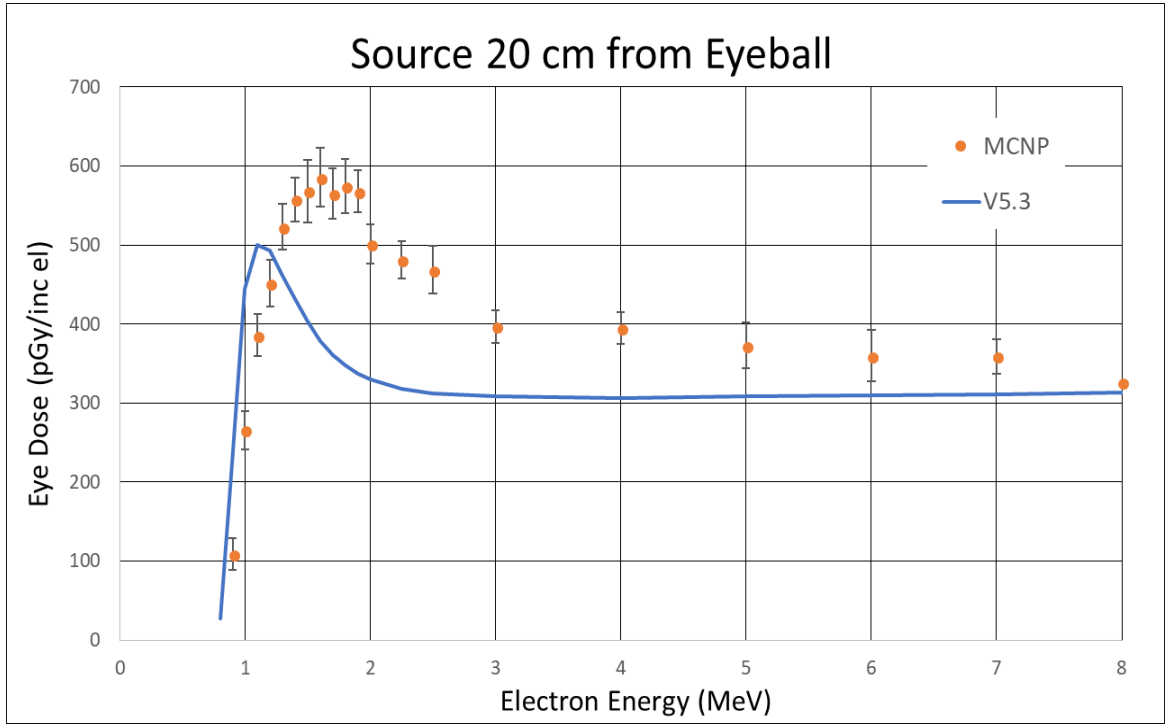
- MCNP accounts for scattered paths; VARSKIN uses CSDA assumption





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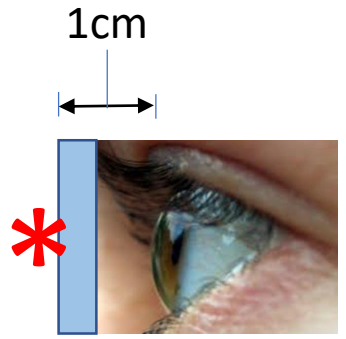
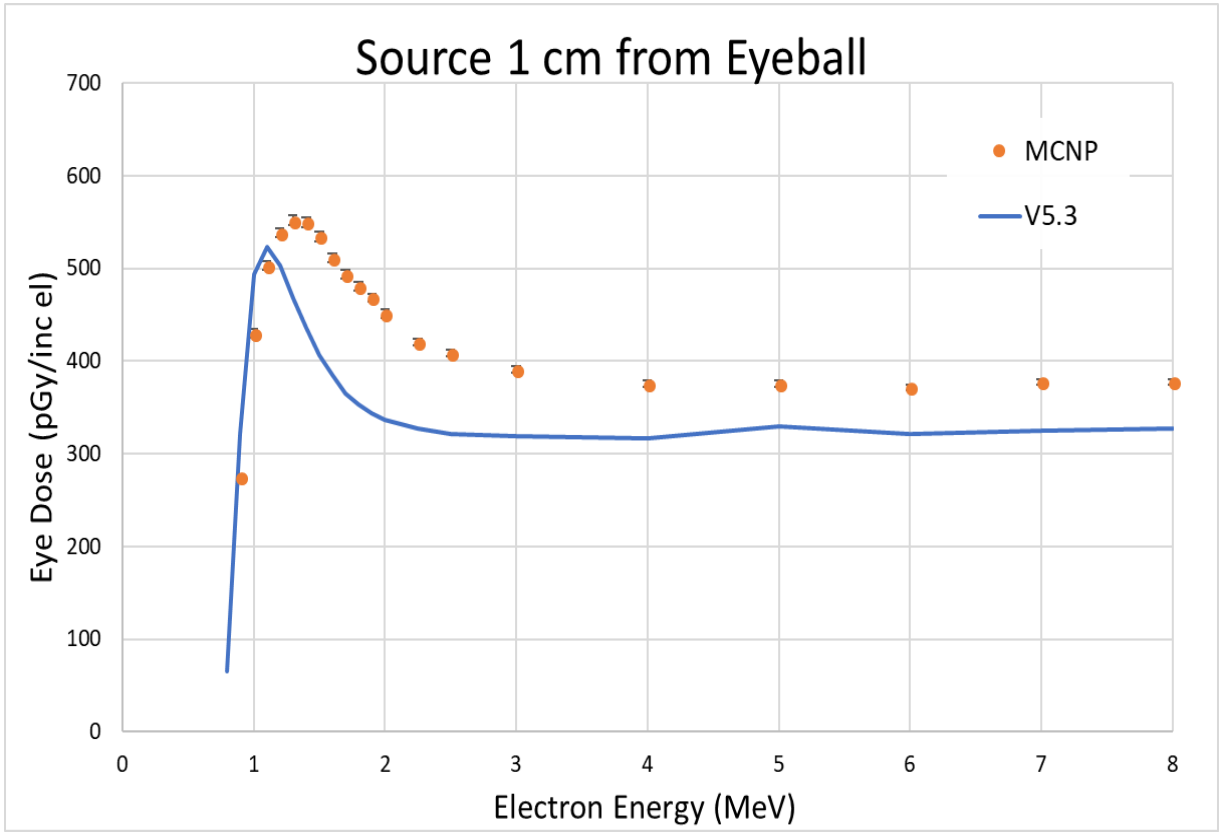
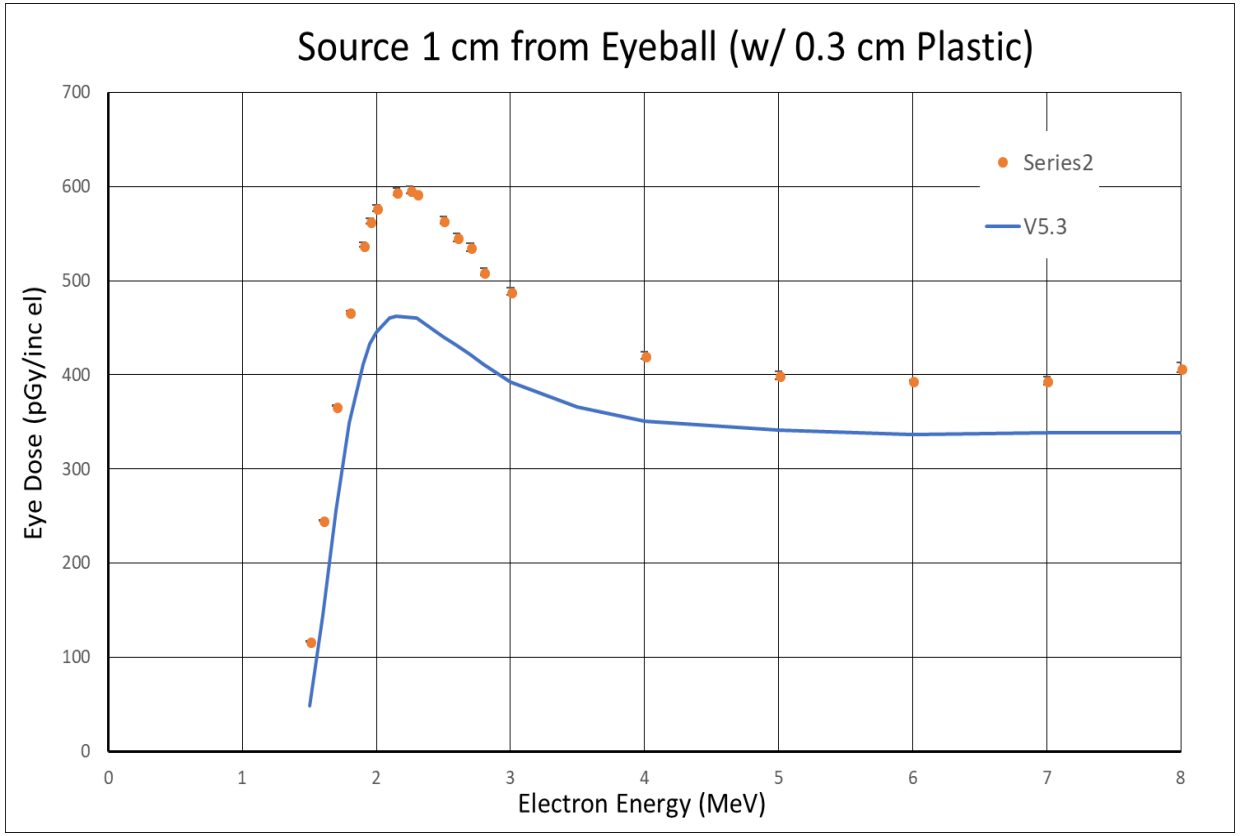
1 cm Gap with Plastic







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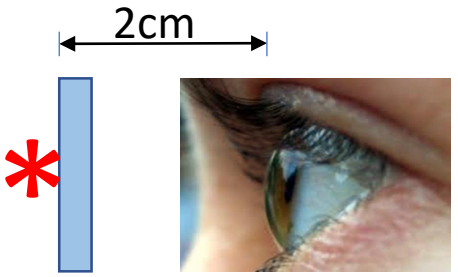
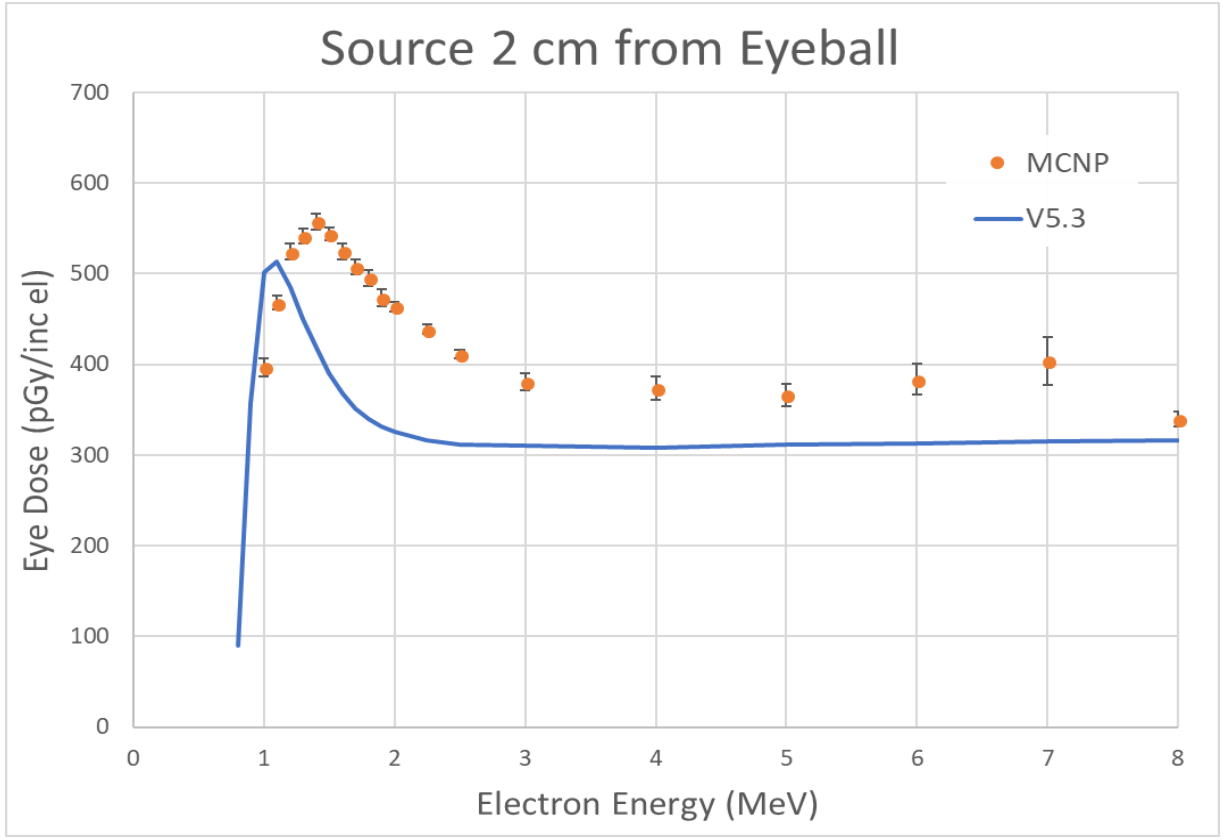
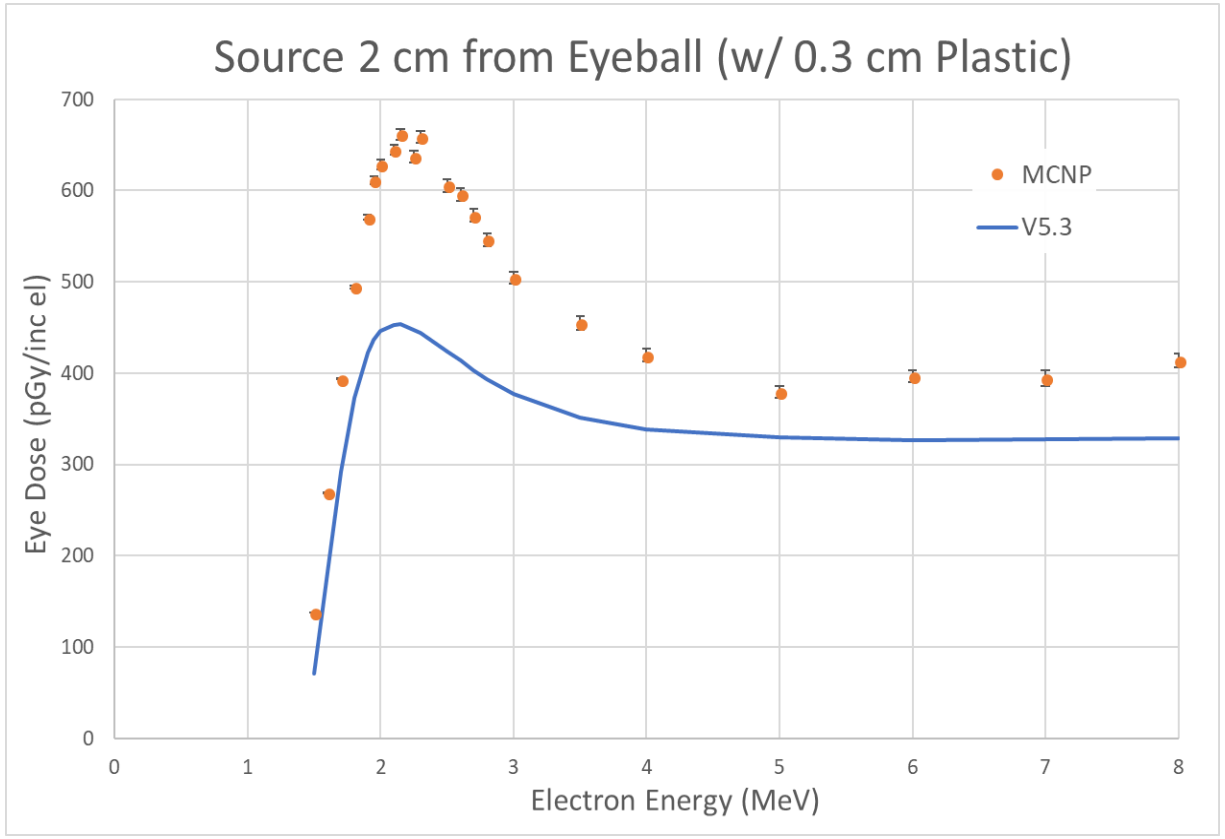
2 cm Gap with Plastic

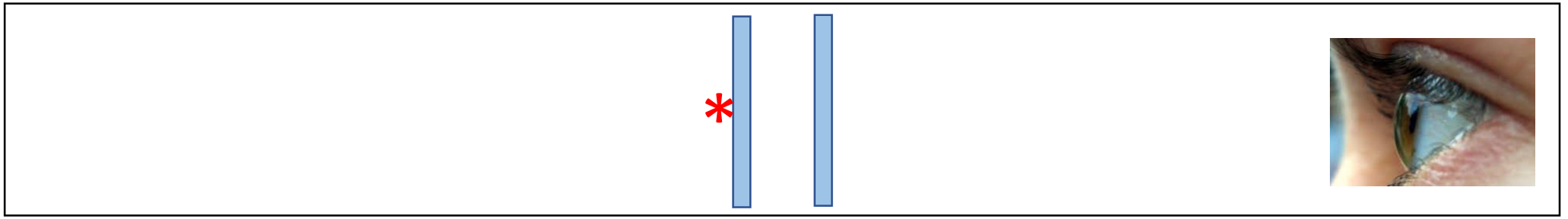




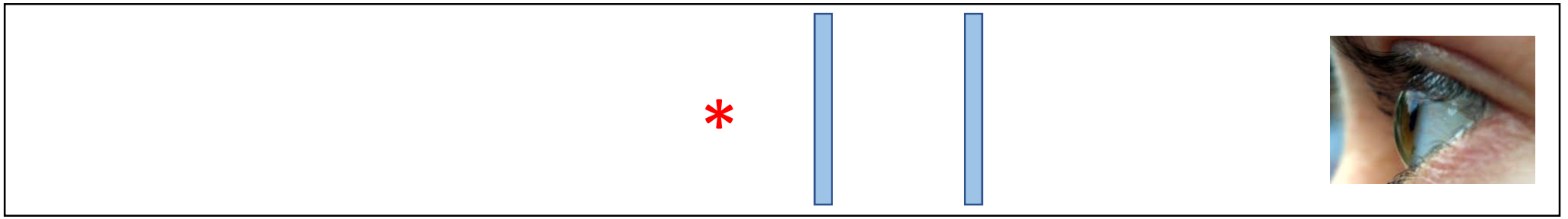


Effects of Shield Placement

Scenario 1

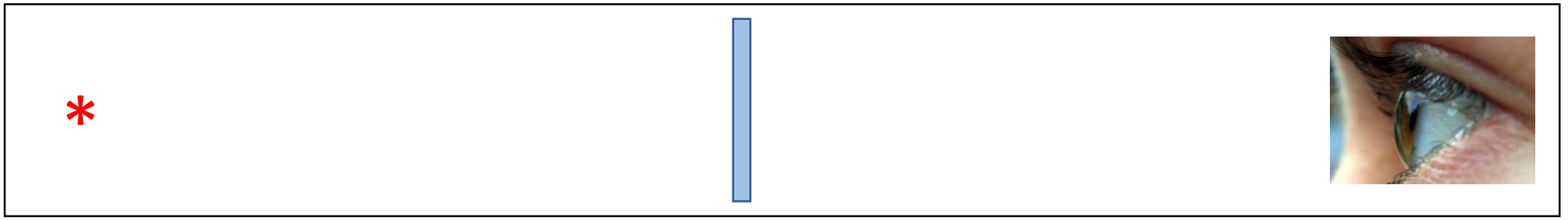


Scenario 2



Scenario 3

Scenario 4



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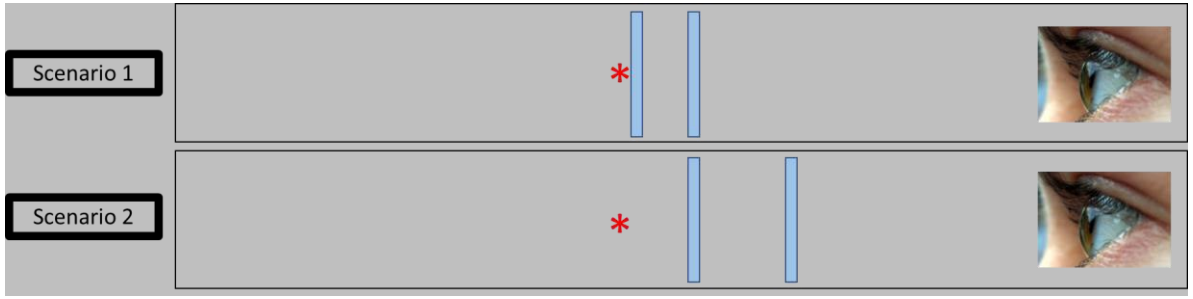
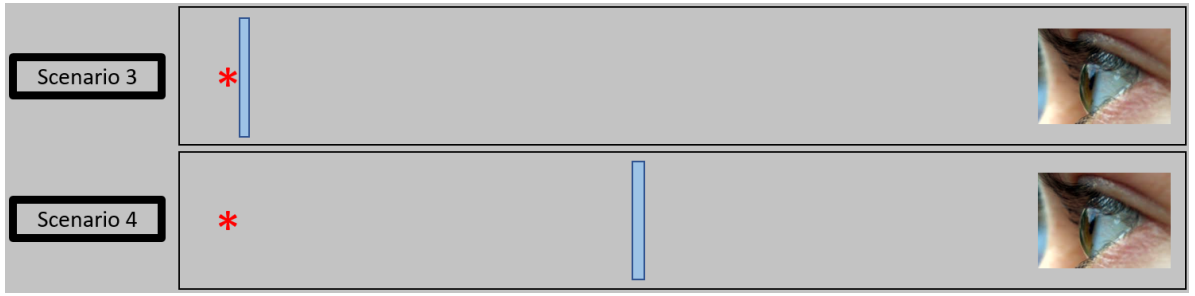
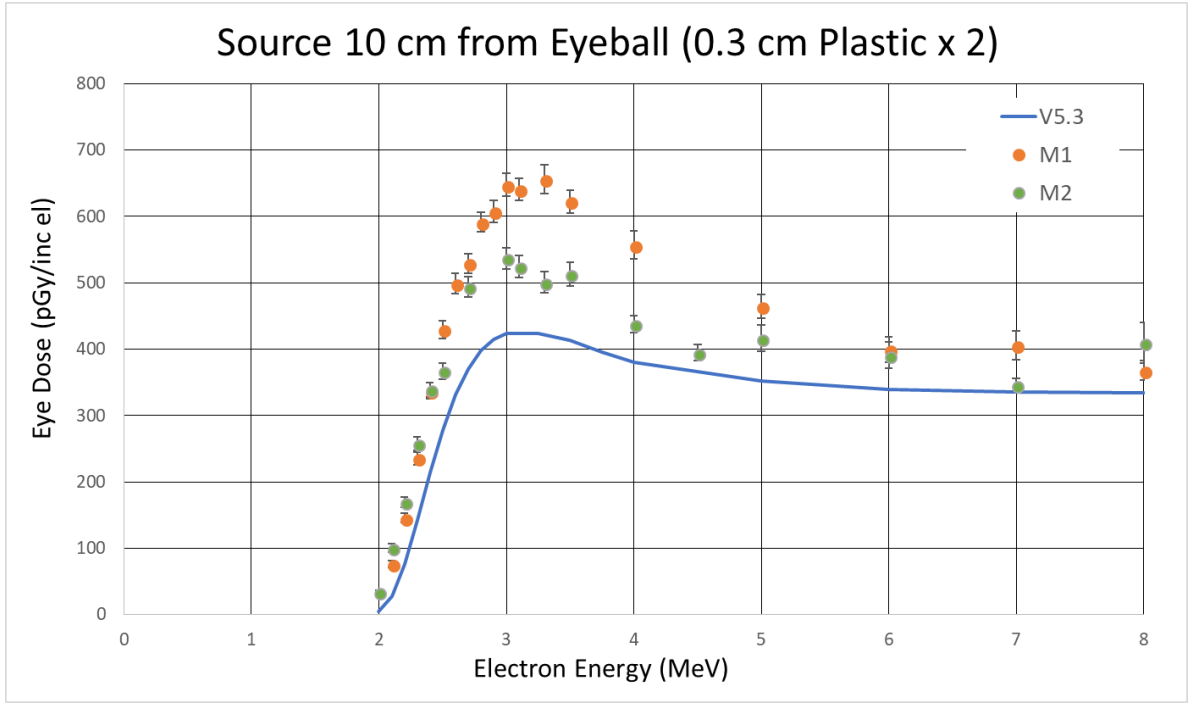
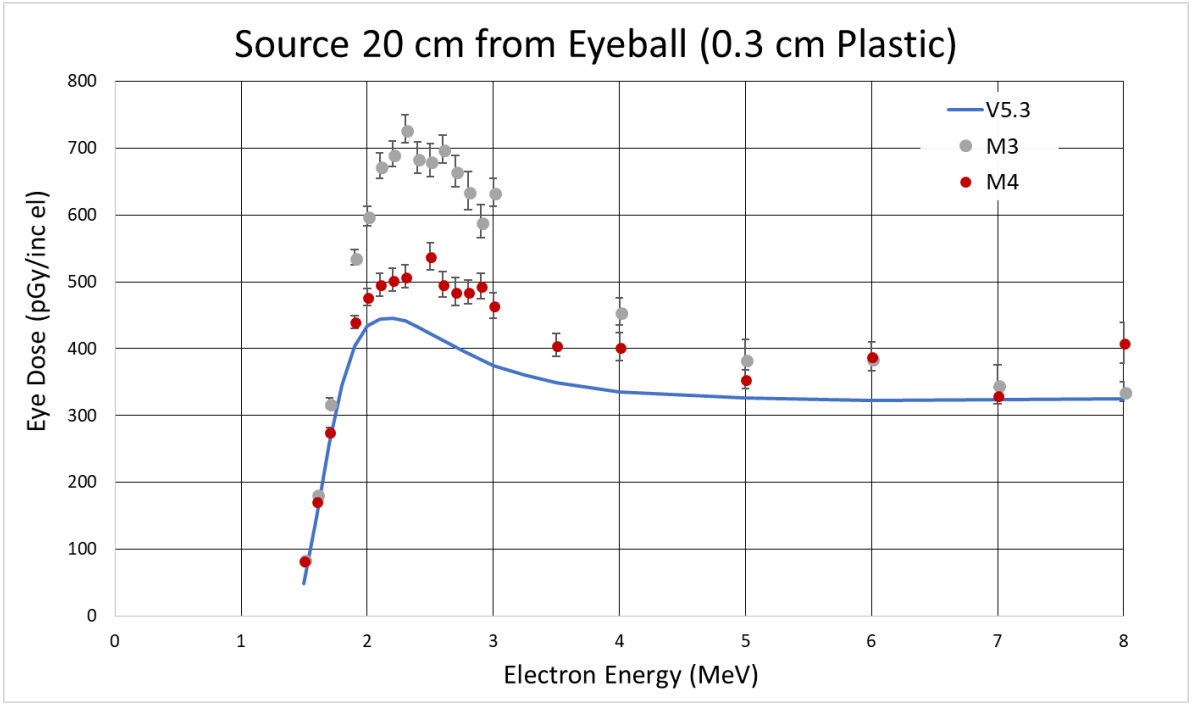
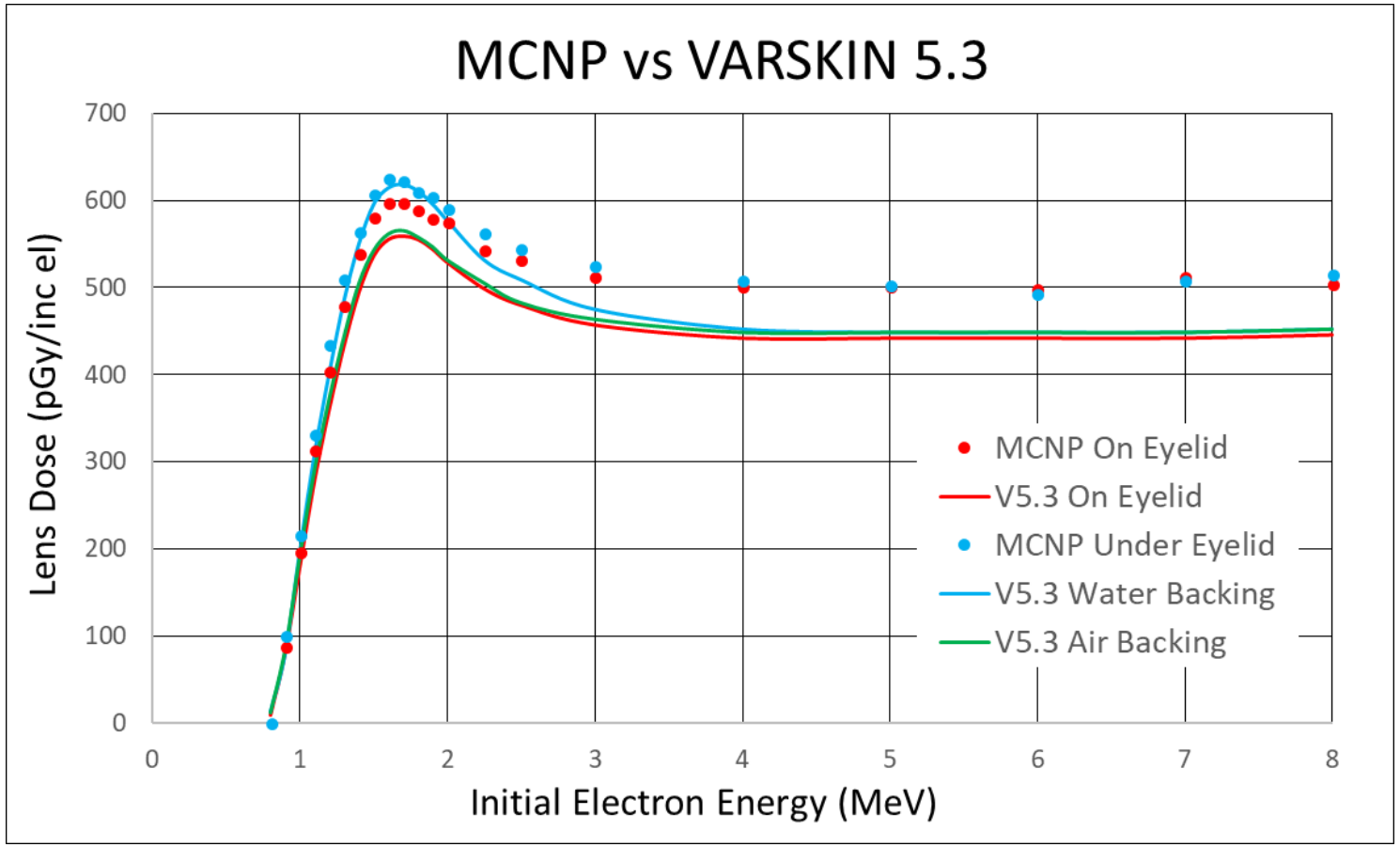








Modeling the Eyelid



- Eyelid assumed to be 0.3 mm thick
- Two scenarios:
  - on the exterior of the closed eyelid
  - on the interior of the closed eyelid
- VARSKIN cannot model a source under a closed eyelid
- The best we can do is to alter the backscatter material, either air or water

Conclusion/Recommendations

- How to accurately predict eye dose?
  - modification to the models for energy-loss in air and cover materials, and the ability to model greater separation distances
- While accurate for shallow depth, VARSKIN in its current iteration underpredicts most scenarios of eye dosimetry
- Monte Carlo considers bremsstrahlung and tortuous path
- VARSKIN considers energy conservation and CSDA range
- On contact, both show upturn at high energy; both show similar shape; VARSKIN underestimates MCNP by 10%
- With air gap, VARSKIN demonstrates no energy shift
- VARSKIN structure provides a good foundation for eye dosimetry implementation, but careful modeling is necessary

1868
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