DEVELOPMENT OF A DETERMINISTIC EYE DOSIMETRY MODEL

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GOALS OF CURRENT RESEARCH

- To describe a comprehensive eye dosimetry model
  - Particle Type
    - Photons
    - Electrons
  - Size and Orientation
    - Beam (Vacuum/Air)
    - Point
    - Planar (Contamination on eyewear)
  - Shielding
    - Leaded glass
    - Regular eyewear
  - Energy
    - Monoenergetic photons and electrons
    - Energy Distribution (beta decay)
    - Multiple photopeaks (^{60}Co, ^{192}Ir, etc.)

CONVERTING LIGHT INTO SIGHT

- Light enters the eye, refracted by the cornea
- Refracted light directed to the pupil
- The lens then directs the light to the nerve cells in the back of the eye
  - Cones and Rods
- Nerve cells send signal through the optic nerve to the brain

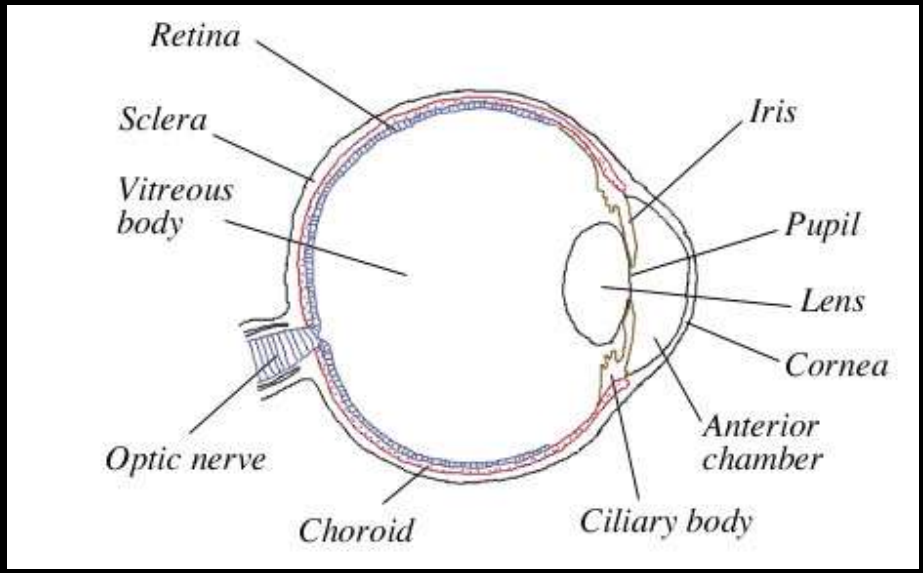


Image: http://www.ratbehavior.org/Eyes.htm

ACCOMMODATION IN THE LENS

- Accommodation: changes in lens shape from contractions of the ciliary muscle
- Dark-focus, or Resting Point of Accommodation, is about 67 cm
  - Measured with lasers in darkness

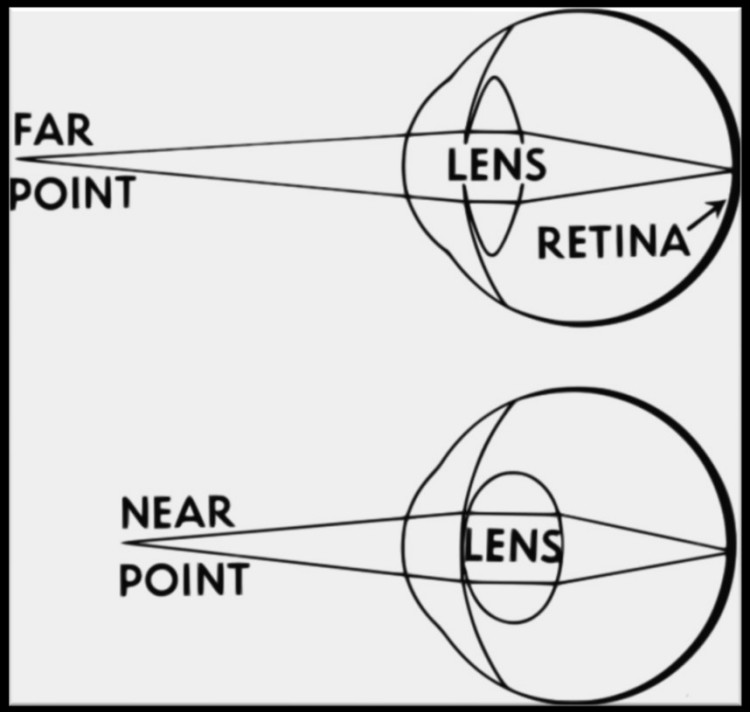


Image: https://en.wikipedia.org/wiki/Accommodation_(eye)#/media/File:Accommodation_(PSF).svg

ANATOMY OF THE LENS

- Lens epithelium is divided into four zones
  - Germinative Zone
    - Primary site of the mitotic activity
  - Transitional Zone
    - Differentiating progeny of GZ
  - Meridional Rows
    - Non-mitotic cells which queue into orderly columns
  - Central zone
    - Non-mitotic
- Structure important for transparency
- No mechanism for removal of dead/damaged cells

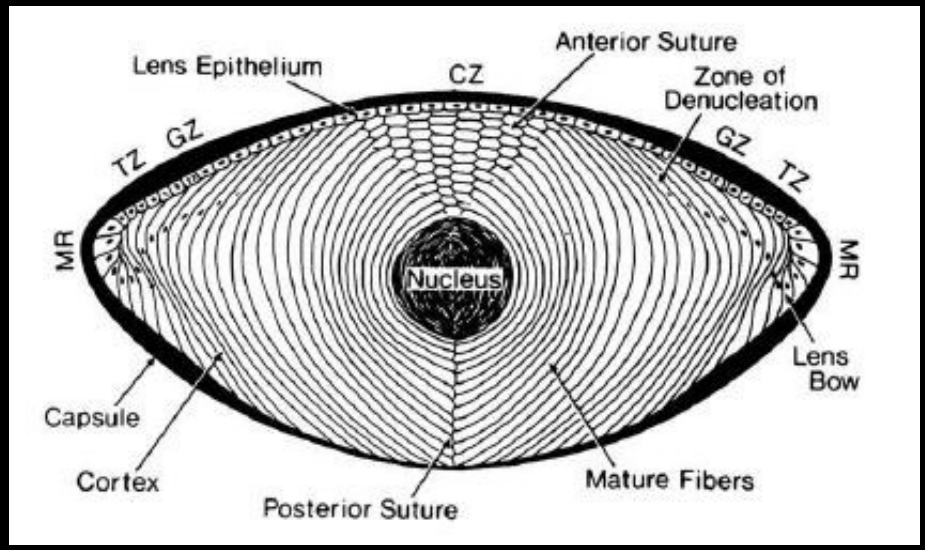


Image: Merriam and Worgul 1983

WHAT IS A CATARACT?

- Cataractogenisis: lens becomes opaque due to built-up damage

- Risk Factors
  - Aging
  - Diabetes
  - Excessive sunlight
  - Smoking
  - Obesity
  - High blood pressure
  - UV and Ionizing Radiation

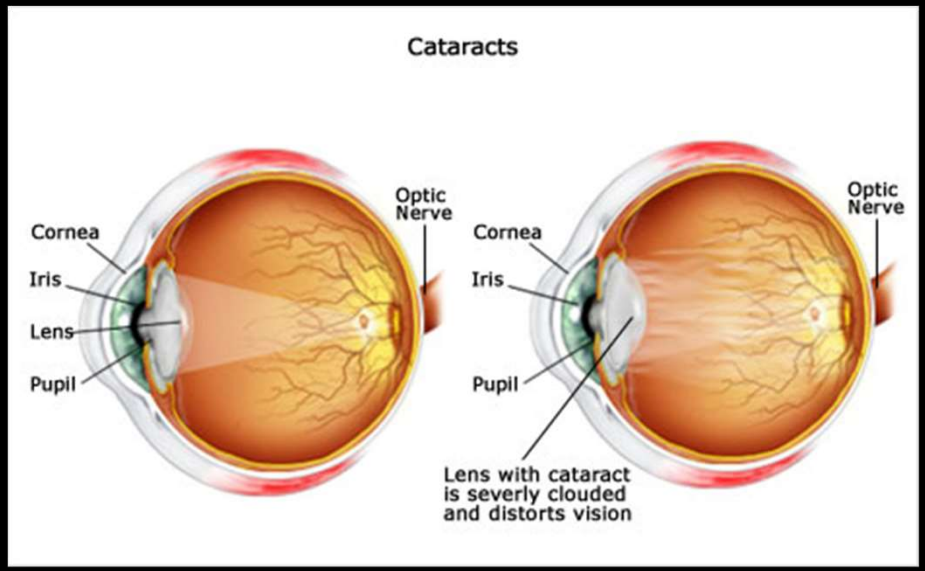


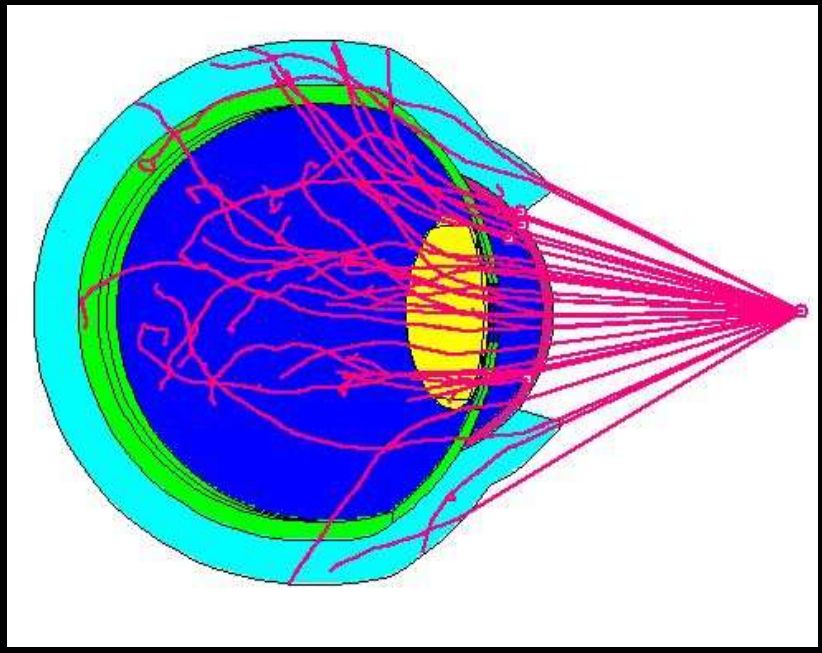
Image: Merriam and Worgul 1983

RADIATION INDUCED CATARACTS

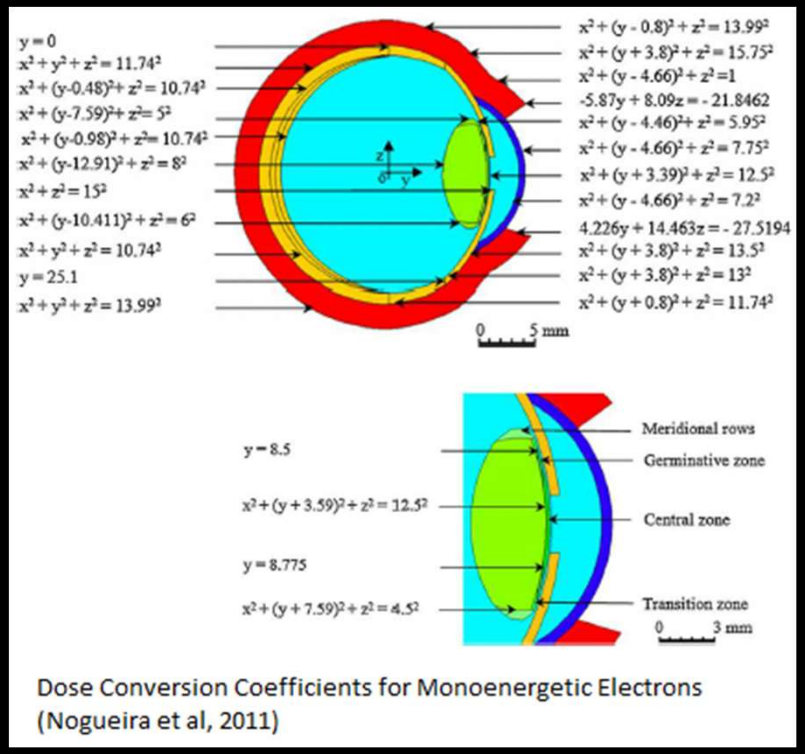
- Dividing cells limited to pre-equatorial region of epithelium are sensitive
  - Cataracts form at posterior pole of lens
- Generally considered deterministic effect
  - 2 Gy acute
  - 5-8 Gy fractionated
- NRC limit: 15 rem (150 mSv)
  - ICRP recently lowered recommendation to 20 mSv

MONTE CARLO METHODS

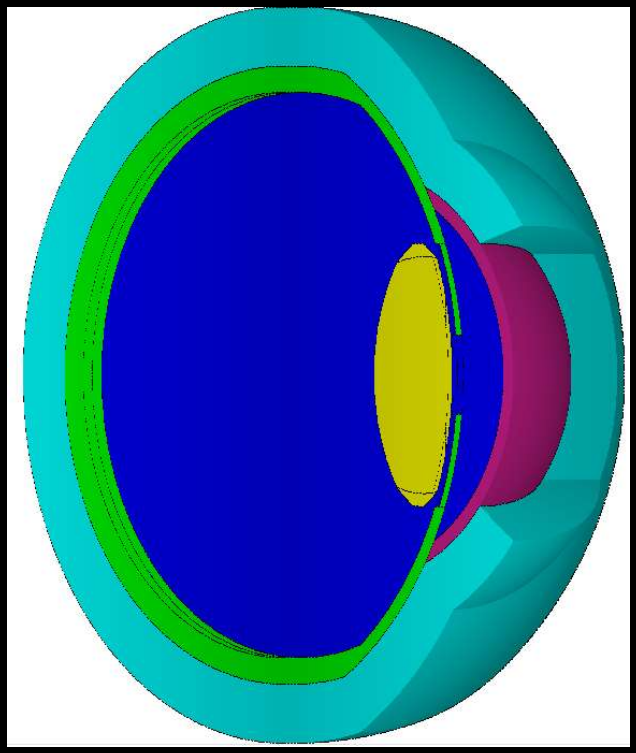
- "Random walk" physics simulator
- Gold standard in particle transport
  - MCNP6, EGS, GEANT, etc.
- Pros
  - Customizable geometries
  - Multiple particle transport
  - Multiple energy
- Cons
  - Time intensive
  - Steep learning curve
  - Output files difficult to decode



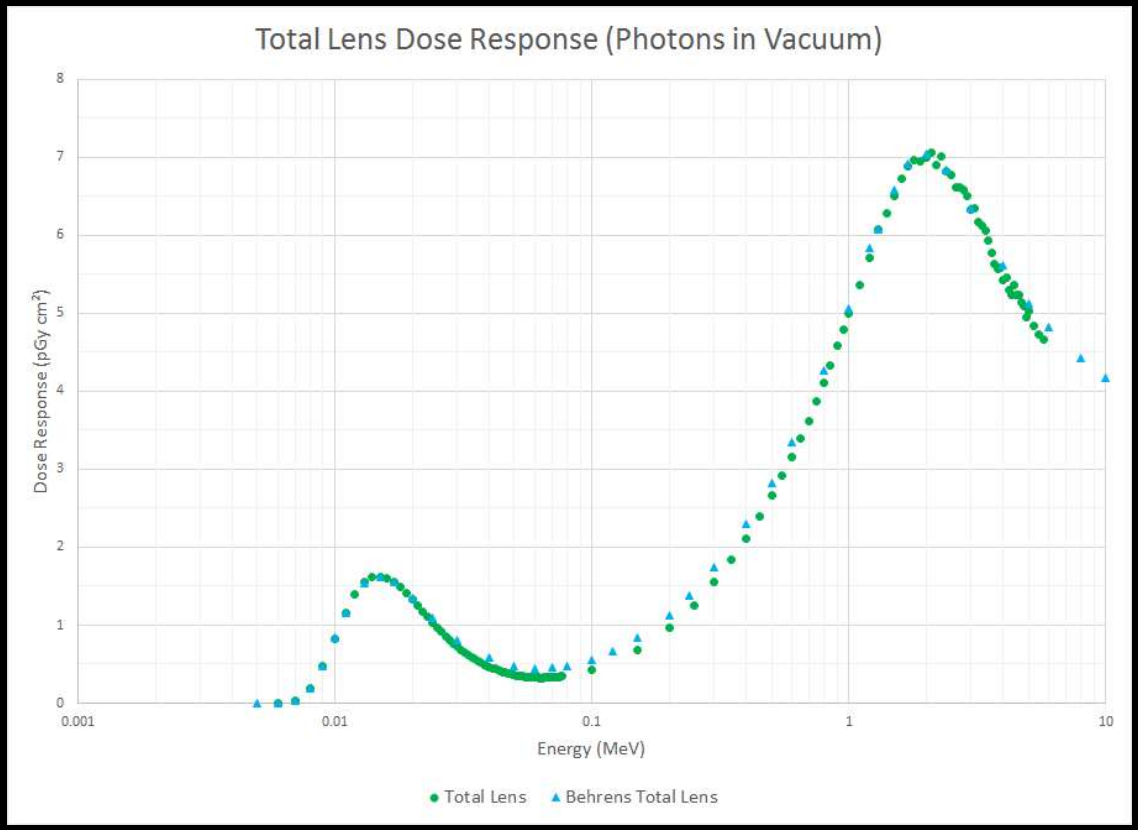
MODELLING THE EYE



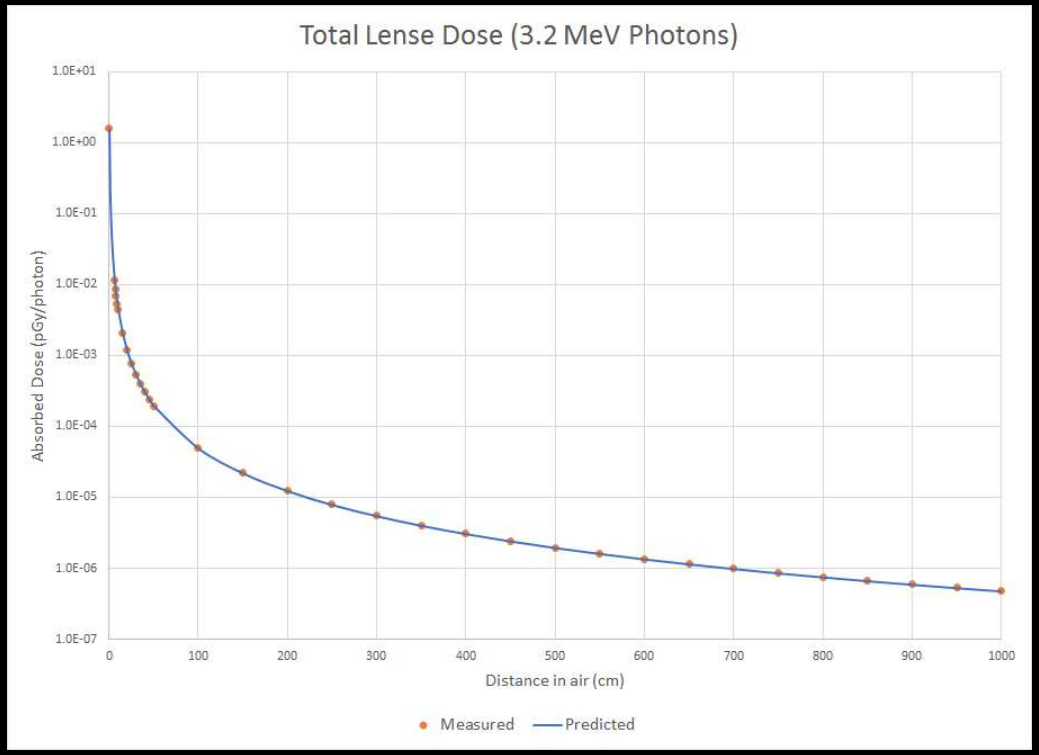
Dose Conversion Coefficients for Monoenergetic Electrons
(Nogueira et al, 2011)



PHOTON BEAM IN A VACUUM



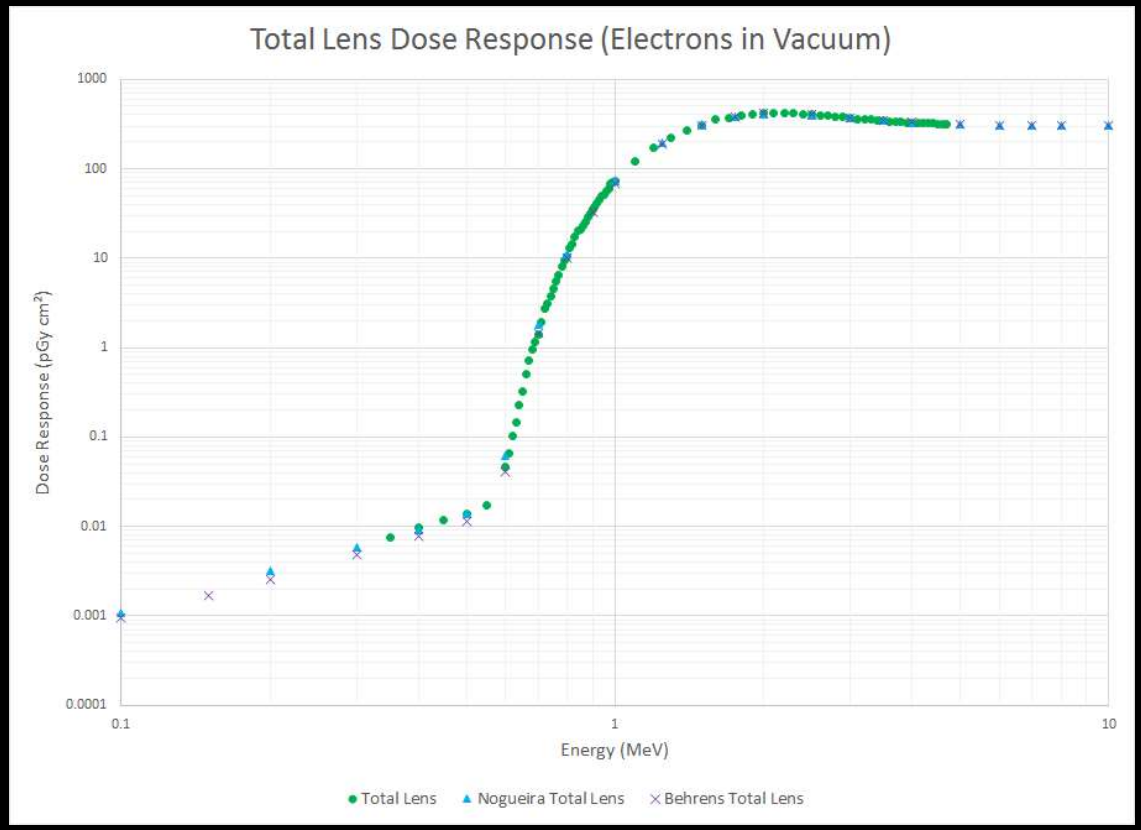
PHOTON POINT SOURCE IN AIR



- Monoenergetic point source
- Attenuation factors included
  - Geometric ($1/r^2$)
  - Shielding (tissue and air)
- Parameters are energy dependent

$$D = \frac{A}{(x+r)^2}\exp[-bx]$$

ELECTRON BEAM IN A VACUUM



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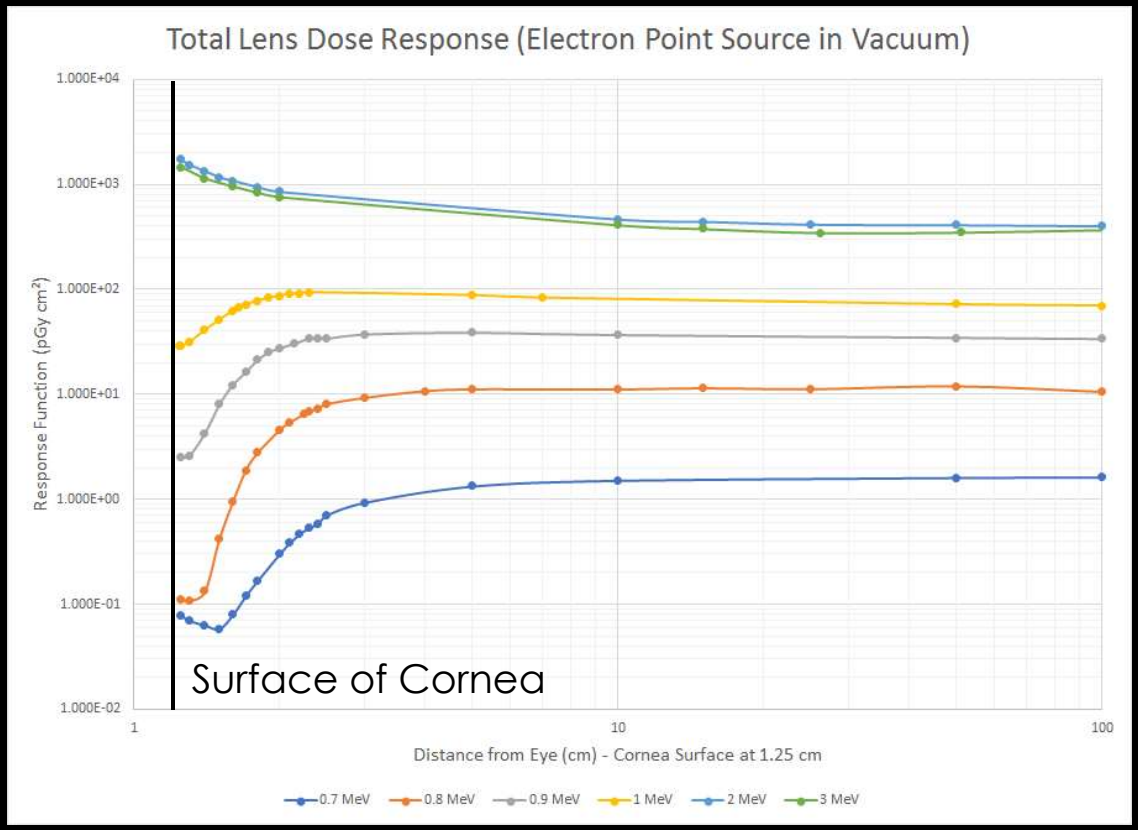
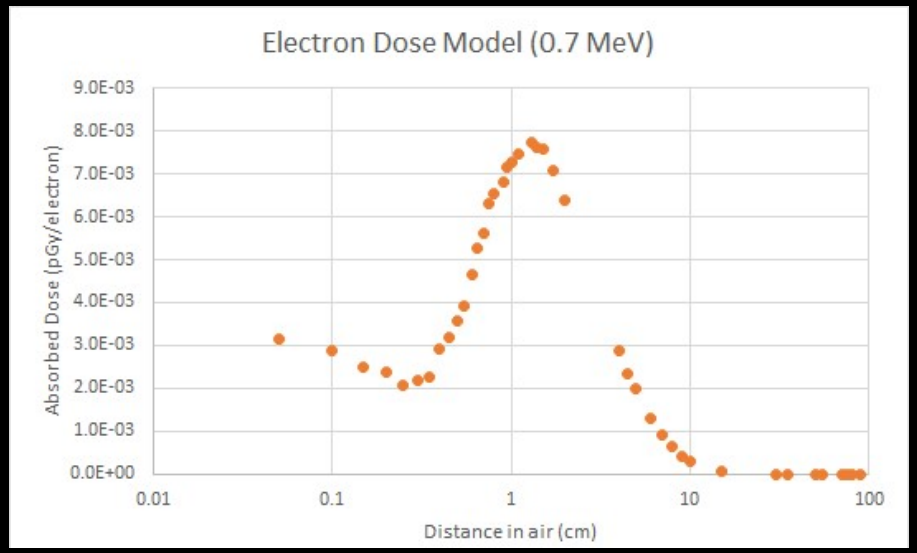
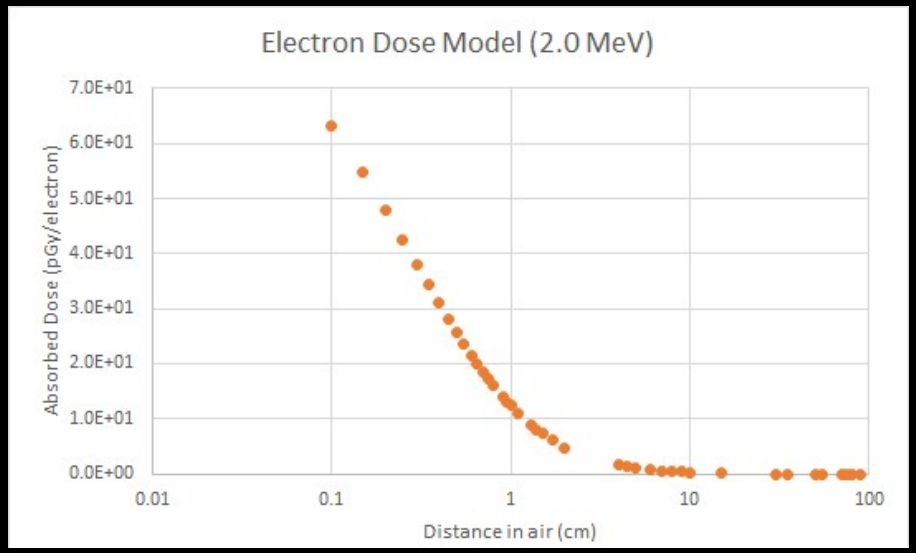


ELECTRON POINT SOURCE IN AIR





POTENTIAL FUTURE RESEARCH

- To expand the comprehensive model to include
  - Particle Type
    - Neutrons
    - Positrons
    - Protons
    - Alphas
    - Heavy Charged Particles/Fission Fragments
  - Size and Orientation
    - Line
    - Volume
    - Secondary scatter
  - Shielding
    - Suspended plastic
    - Additional configurations and materials

QUESTIONS??