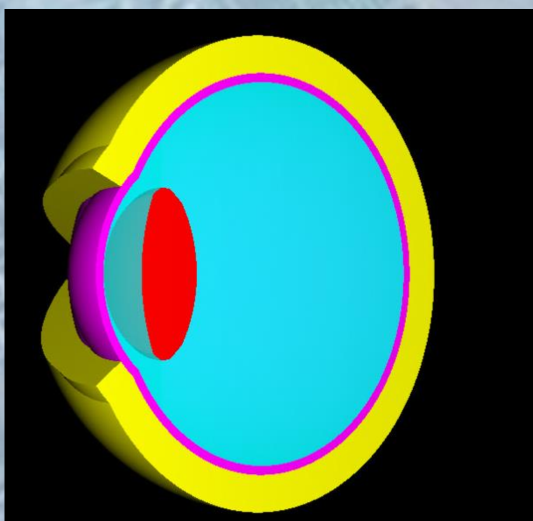
Funding

Bundesministerium für Wirtschaft und Technologie

INS INNOVATION MIT NORMEN UND STANDARDS



TS7e.3

Monitoring the eye lens

Rolf Behrens

Physikalisch-Technische Bundesanstalt

PTB

Introduction

- April 2011: ICRP
  Limit of H_{lens}: 150 mSv → 20 mSv per year
  ➔ Protecting and monitoring may be necessary!

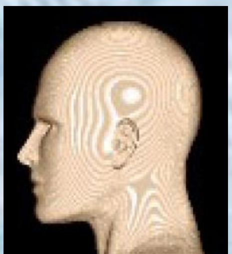
- Main question:
  Which quantity / kind of dosemeter is suitable?
  $H_p(0.07)$, $H_p(3)$ or $H_p(10)$?

  $H_p(3)$ should work well, BUT:
  not used in the past,
  only few dosemeters available.

- Method:
  Compare indication of ideal dosemeters and H_{lens},
  i.e. compare conversion coefficients for $H_p(d)$ and H_{lens}

Data base

Operational quantity (Dose equivalent) **?** **>** **Organ dose to the lens** (Equivalent dose)



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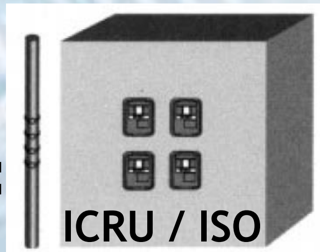
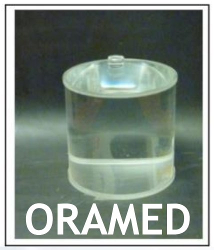
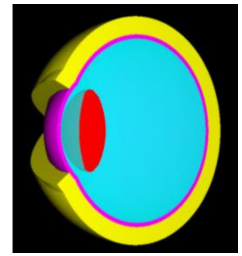
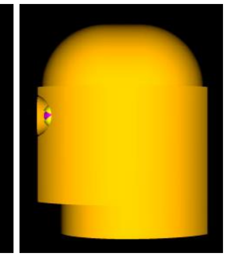
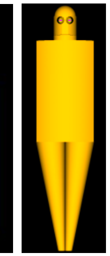




$h_{p\Phi}(d;E)$ | $h_{lens\,\Phi}(E)$







Radiation	Quantity	Data source	Quantity	Data source
Electrons	$H_p(0.07)_{slab}$ $H_p(3)_{slab}$ $H_p(10)_{slab}$ $H_p(3)_{cyl}$	} ICRP74 + ICRU57 Ferarri and Gualdrini	H_{lens}	ICRP116 (Rev. ICRP74); Behrens
Photons	$H_p(0.07)_{slab}$ $H_p(10)_{slab}$ $H_p(0.07)_{rod}$ $H_p(3)_{slab}$ $H_p(3)_{cyl}$	} ICRP74 + ICRU57 Grosswendt Till et al. Vanhavere et al.	H_{lens}	ICRP116 (Rev. ICRP74); Behrens and Dietze

Data base

Organ dose to the lens

M. W. CHARLES
and
NICHOLAS BROWN

Biology

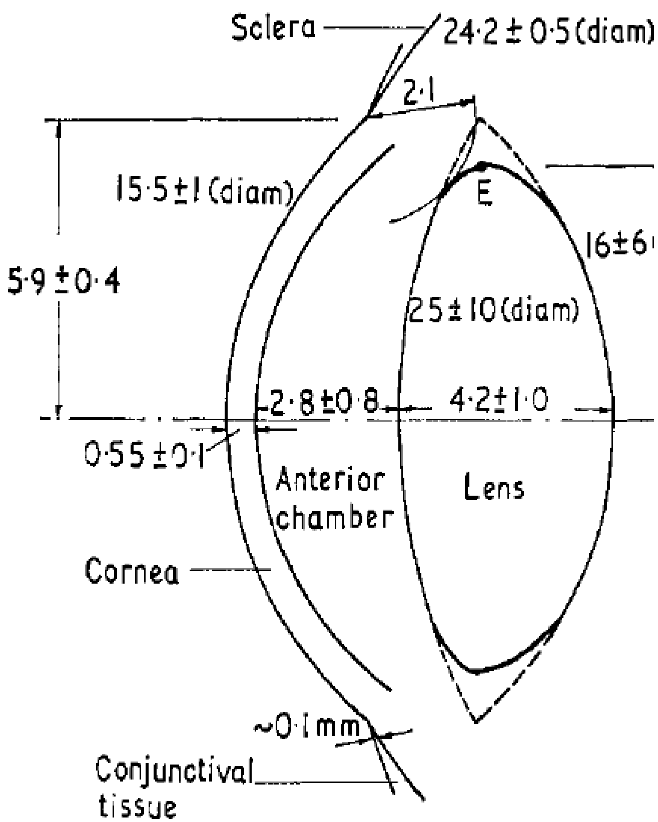
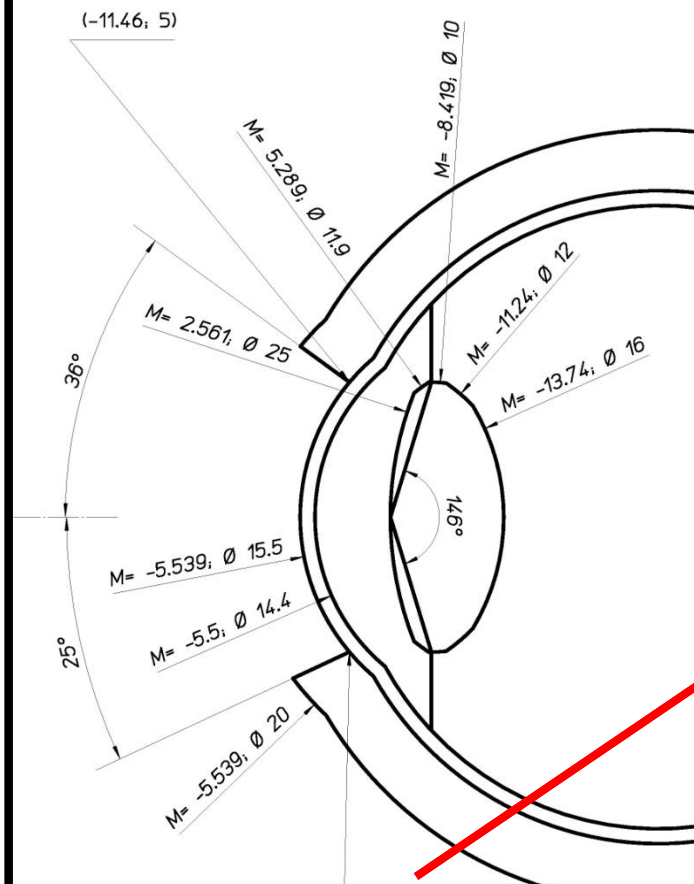
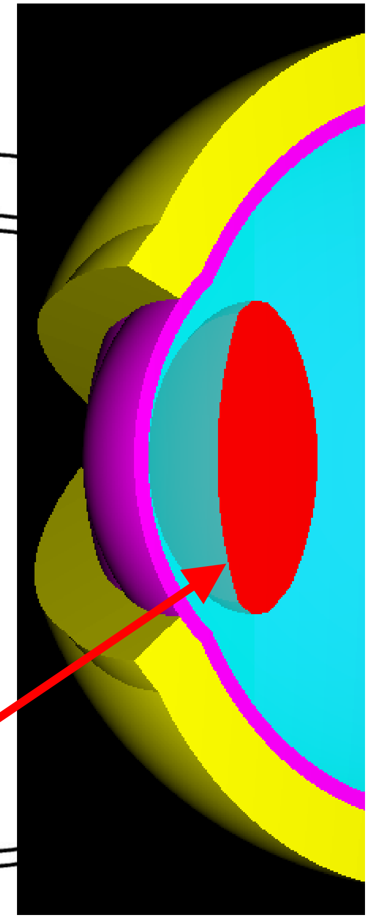


Fig. 8. Mean ocular dimensions for the unaccomm
represent the limits found in a normal adult

Simulation





Complete lens: ***ICRP state of art***

Data base

Organ dose to the lens

M. W. CHARLES
and
NICHOLAS BROWN

Biology

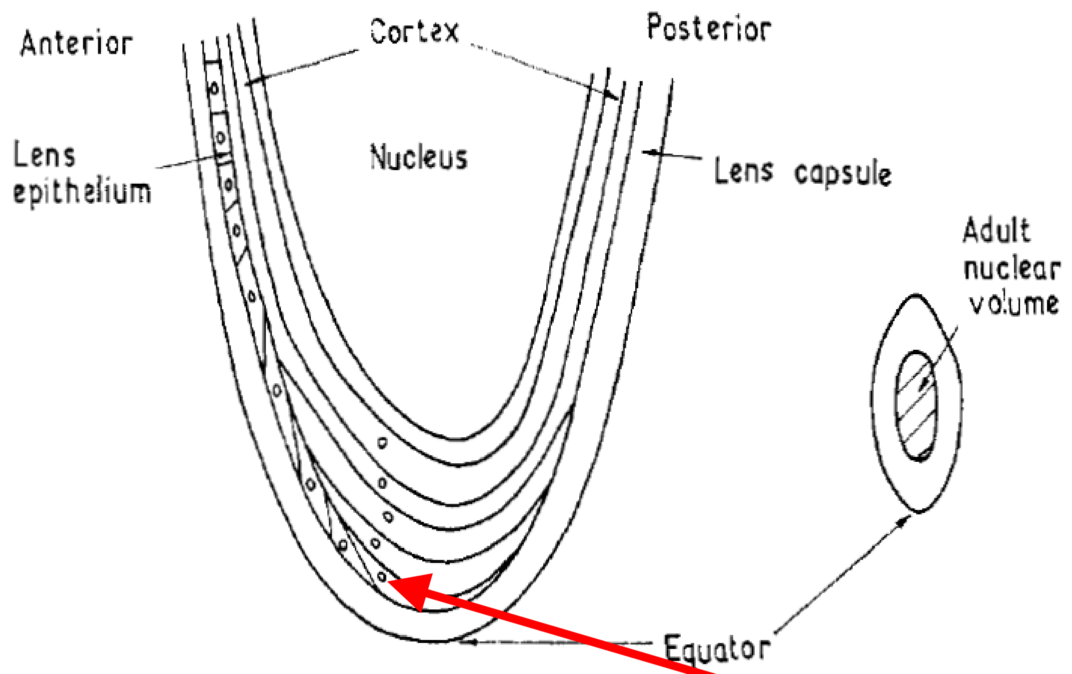
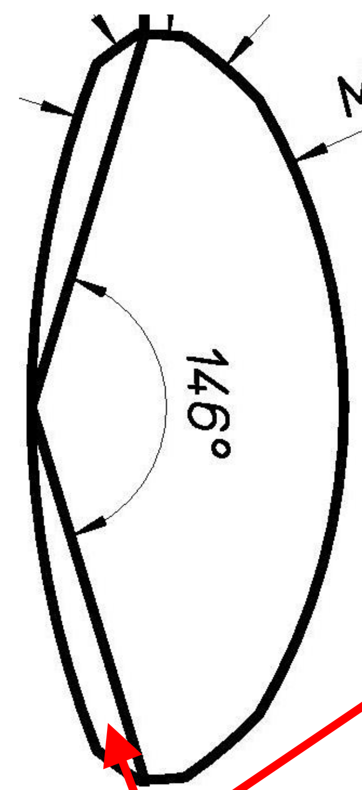
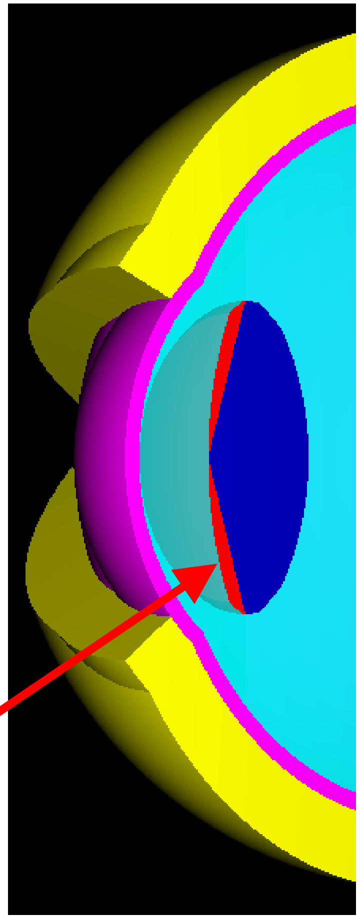


Fig. 2. Transverse section of the lens.

Simulation



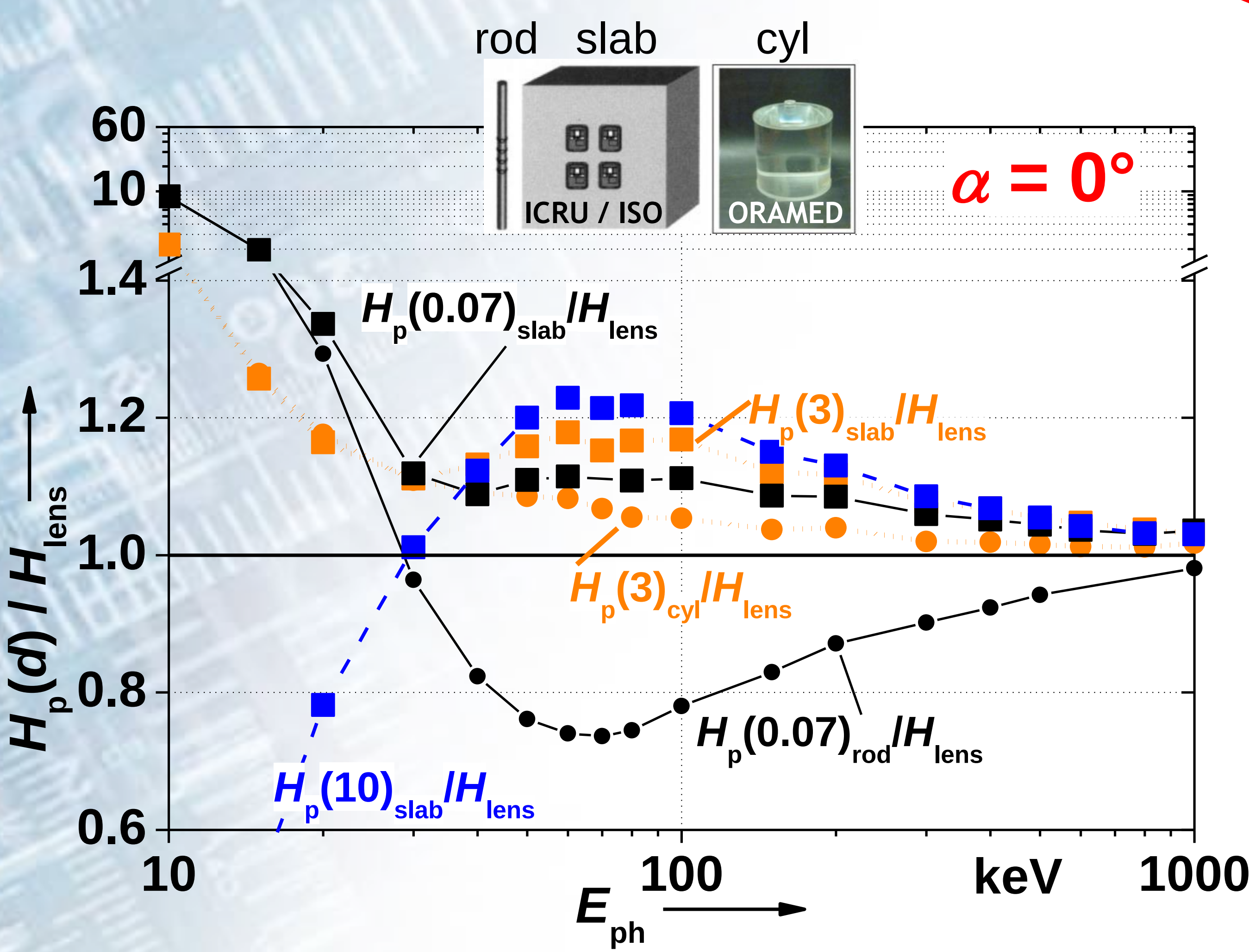


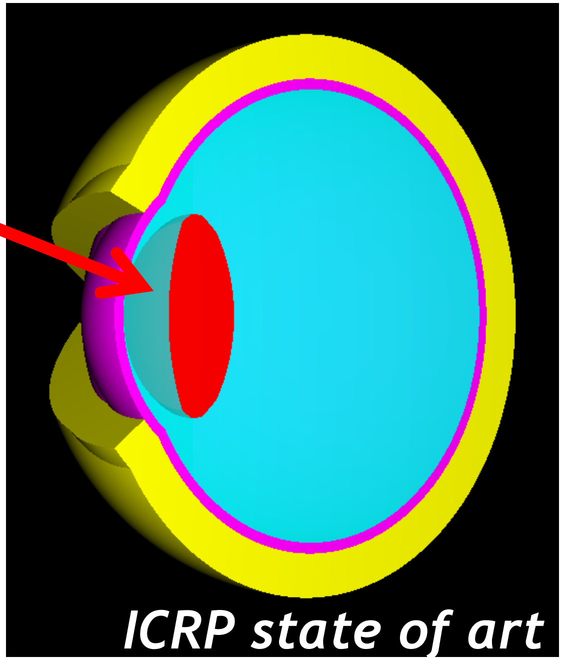
R. Behrens et al. in Phys. Med. Biol. (PMB):
PMB 54 (2009) 4069 + PMB 55 (2010) 3937,
PMB 56 (2011) 415 and PMB 57 (2012) submitted

Sensitive cells: *In ICRP discussion*

Photon radiation:

$H_p(d)$ / H_{lens} (based on complete lens)



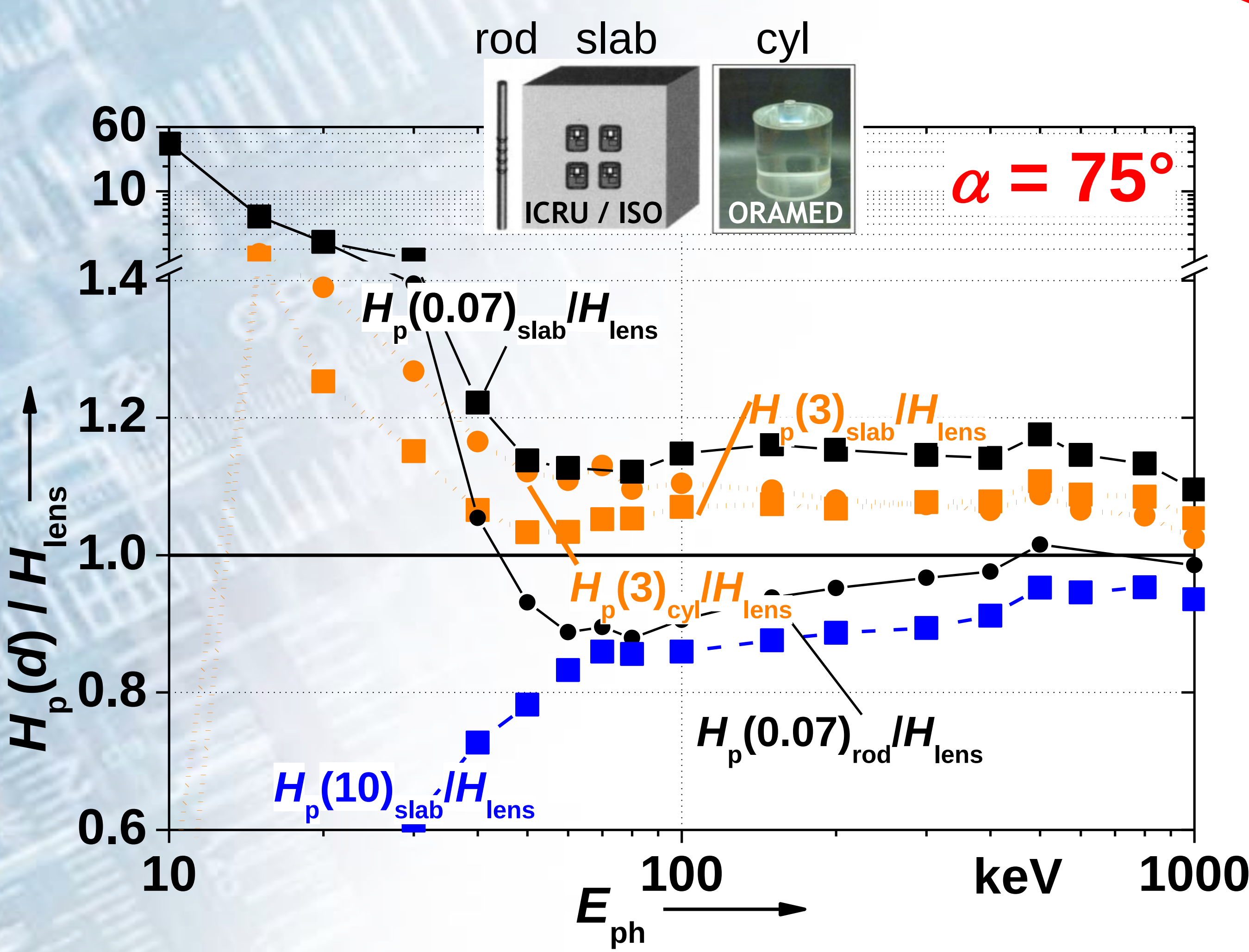


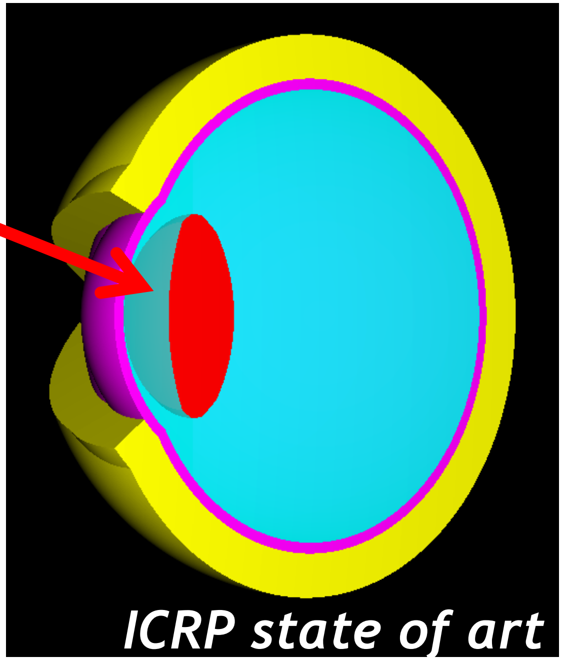
Conservative

Not conservative

Photon radiation:

$H_p(d)$ / H_{lens} (based on complete lens)



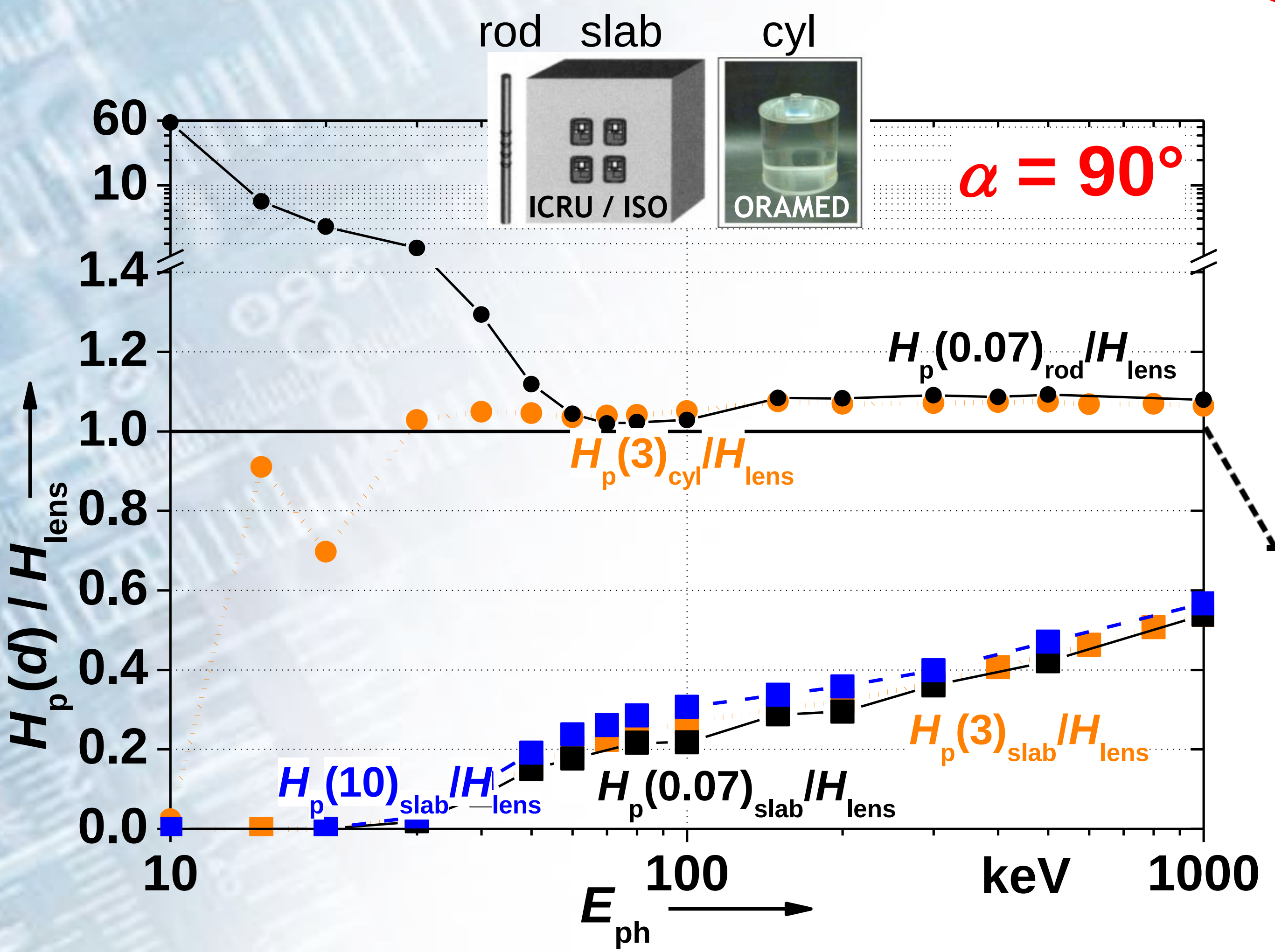


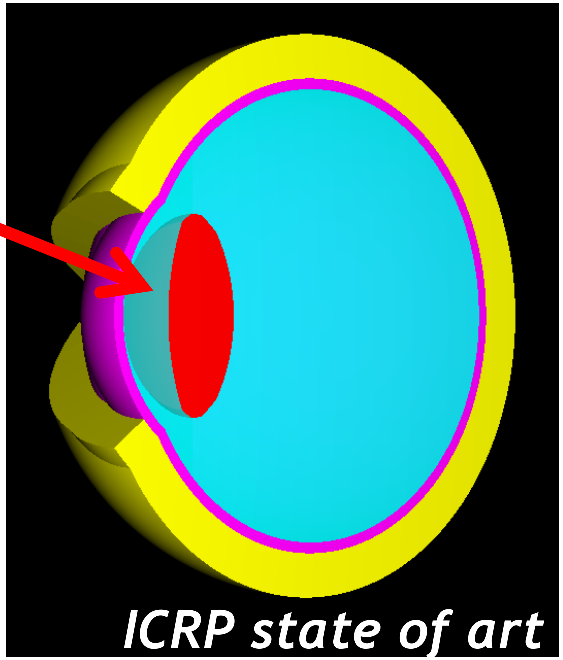
Conservative

Not conservative

Photon radiation:

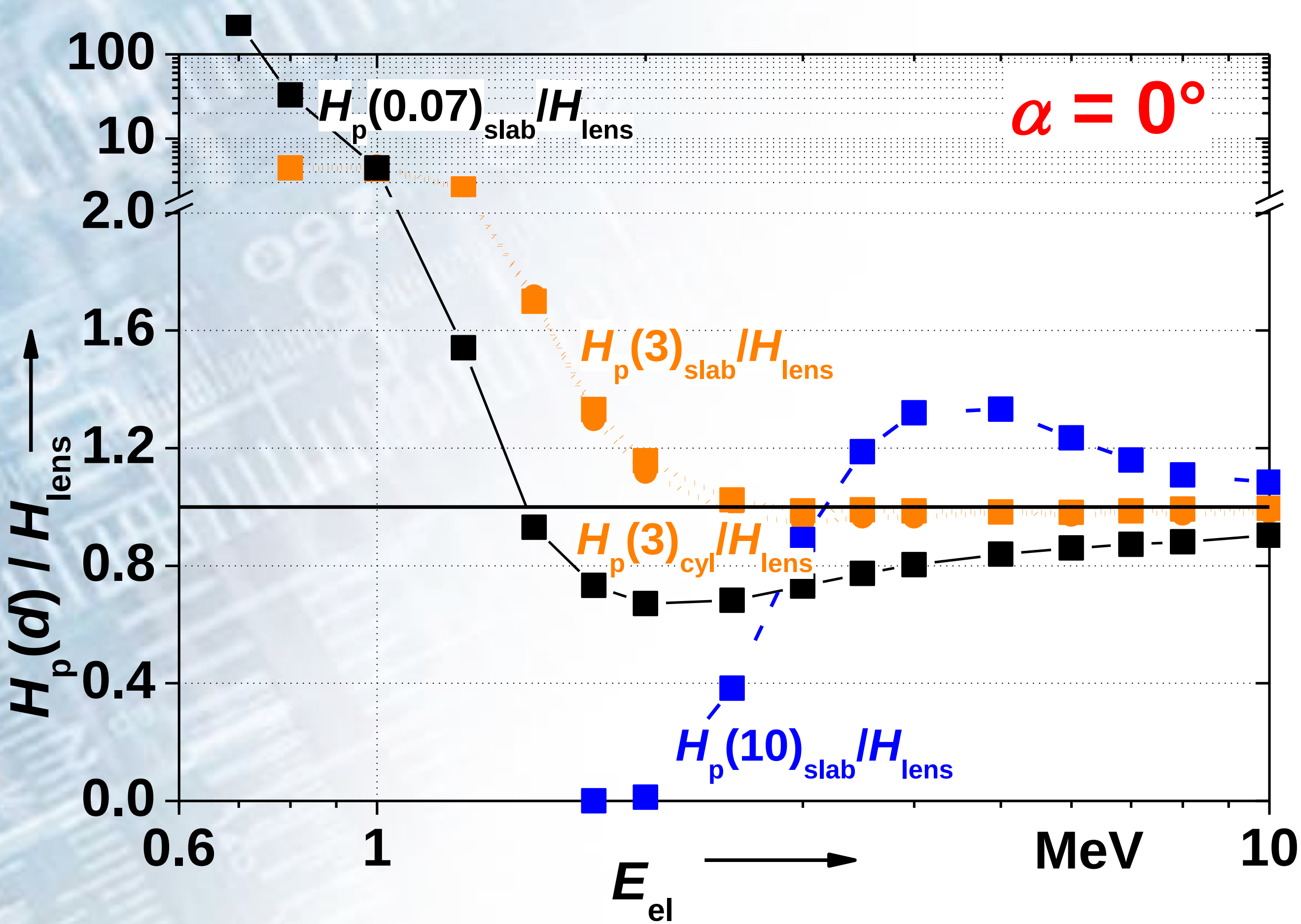
$H_p(d)$ / H_{lens} (based on complete lens)

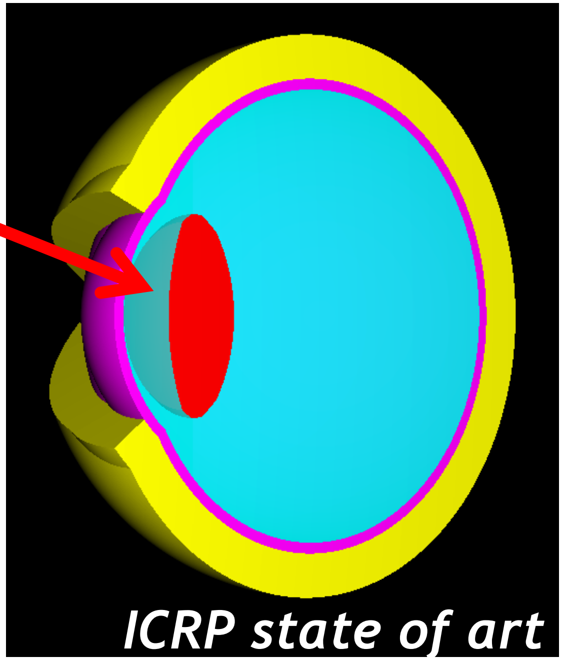




Electron radiation:

$H_p(d)$ / H_{lens} (based on complete lens)



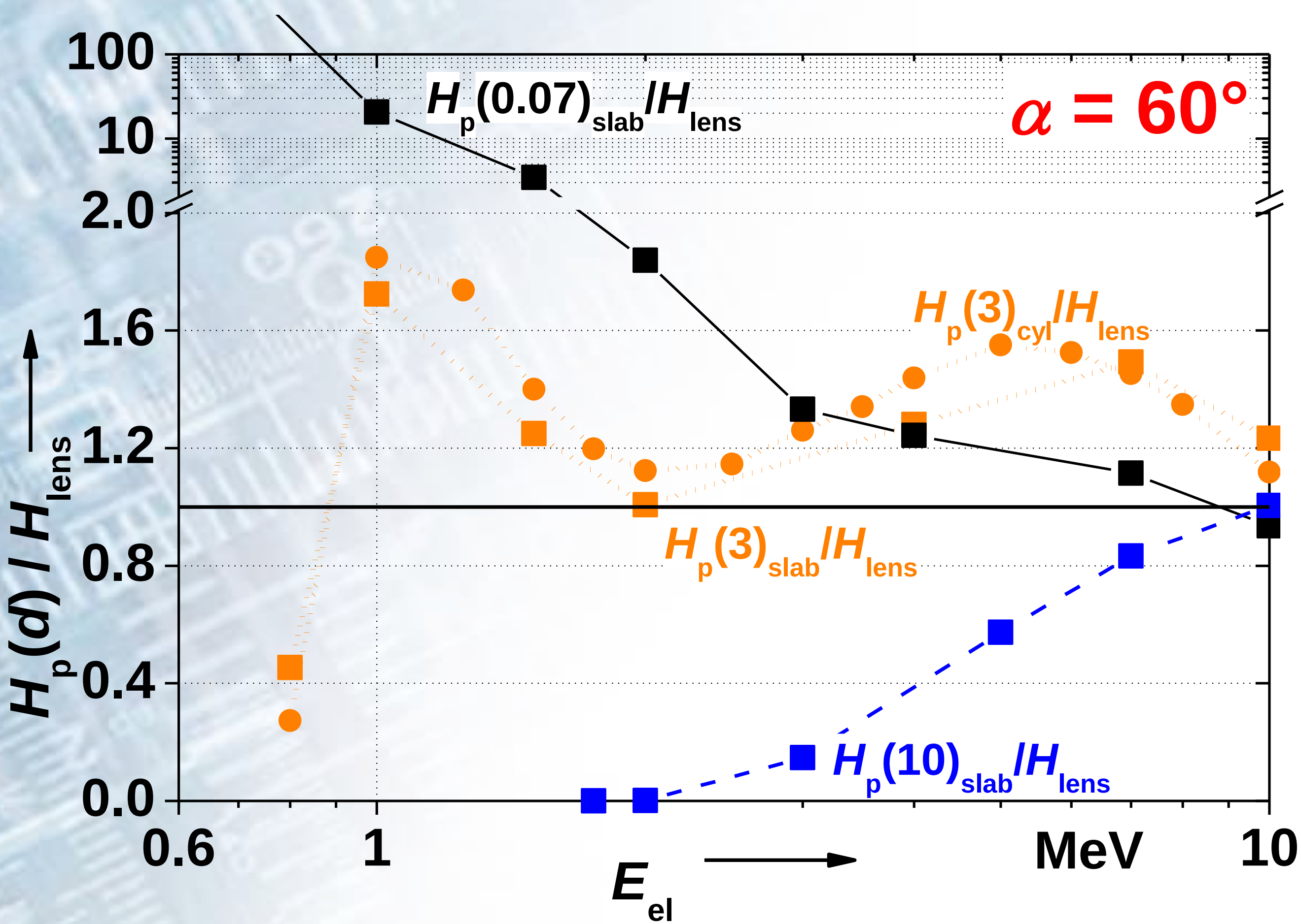


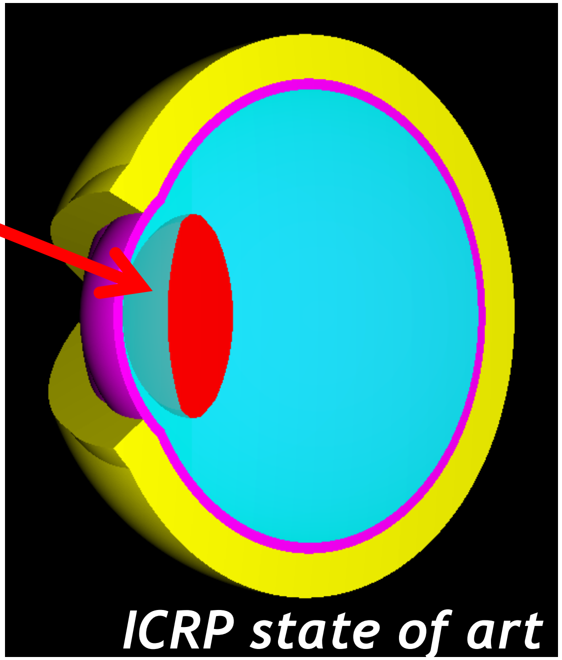
Conservative

Not conservative

Electron radiation:

$H_p(d)$ / H_{lens} (based on complete lens)



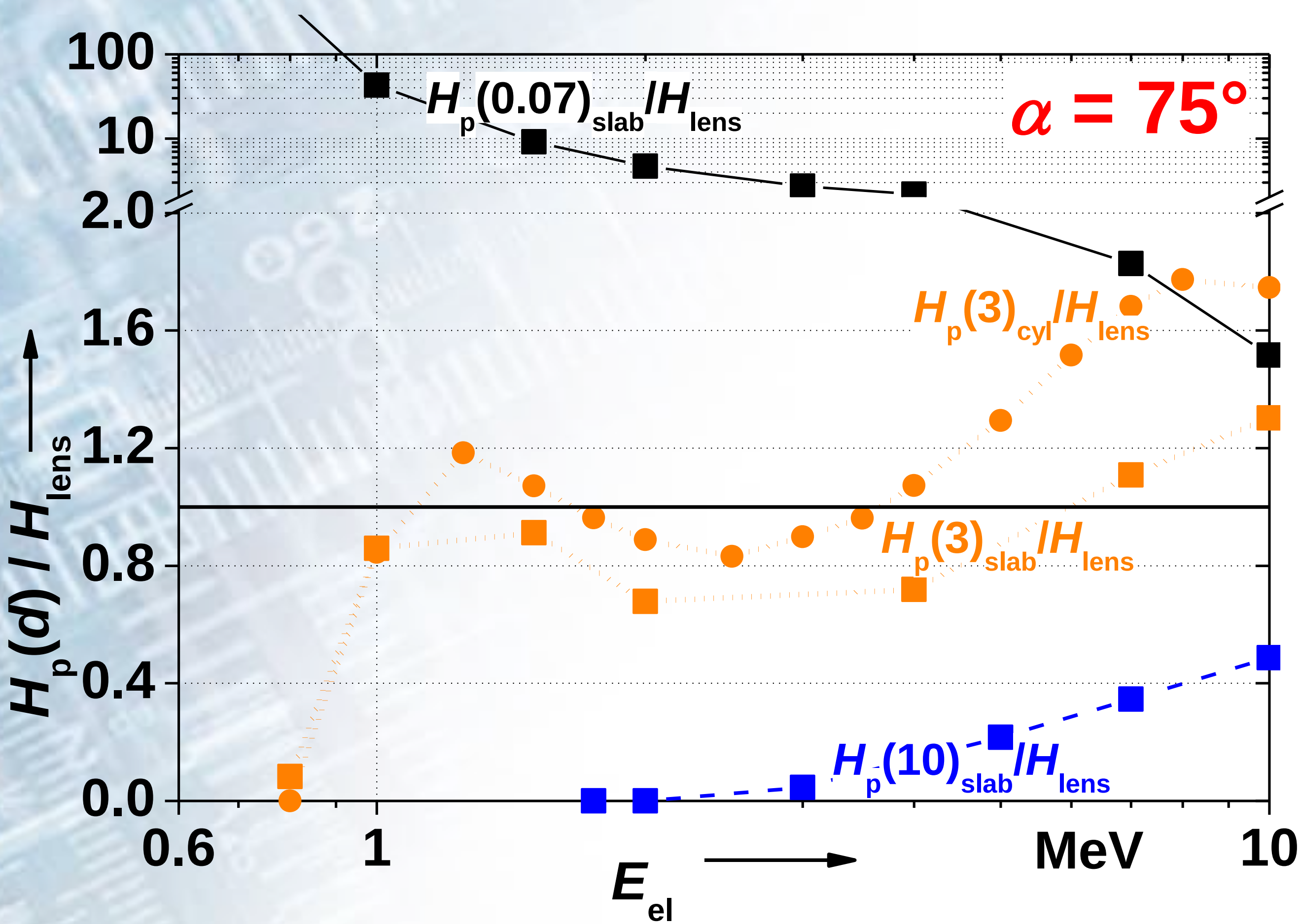


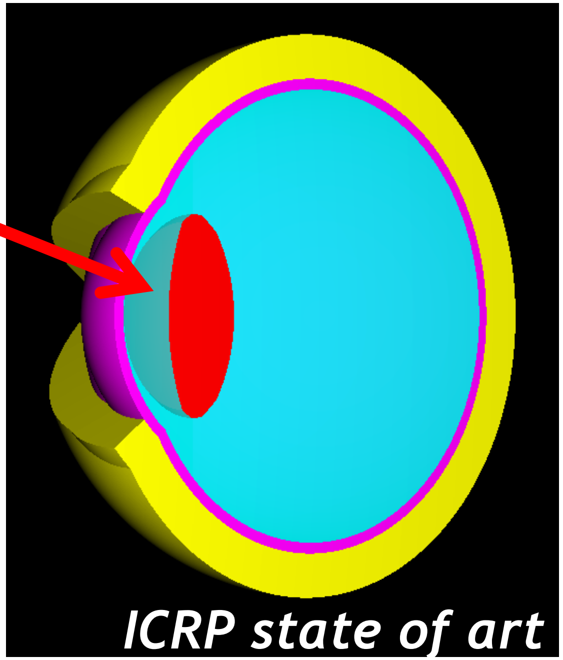
Conservative

Not conservative

Electron radiation:

$H_p(d)$ / H_{lens} (based on complete lens)



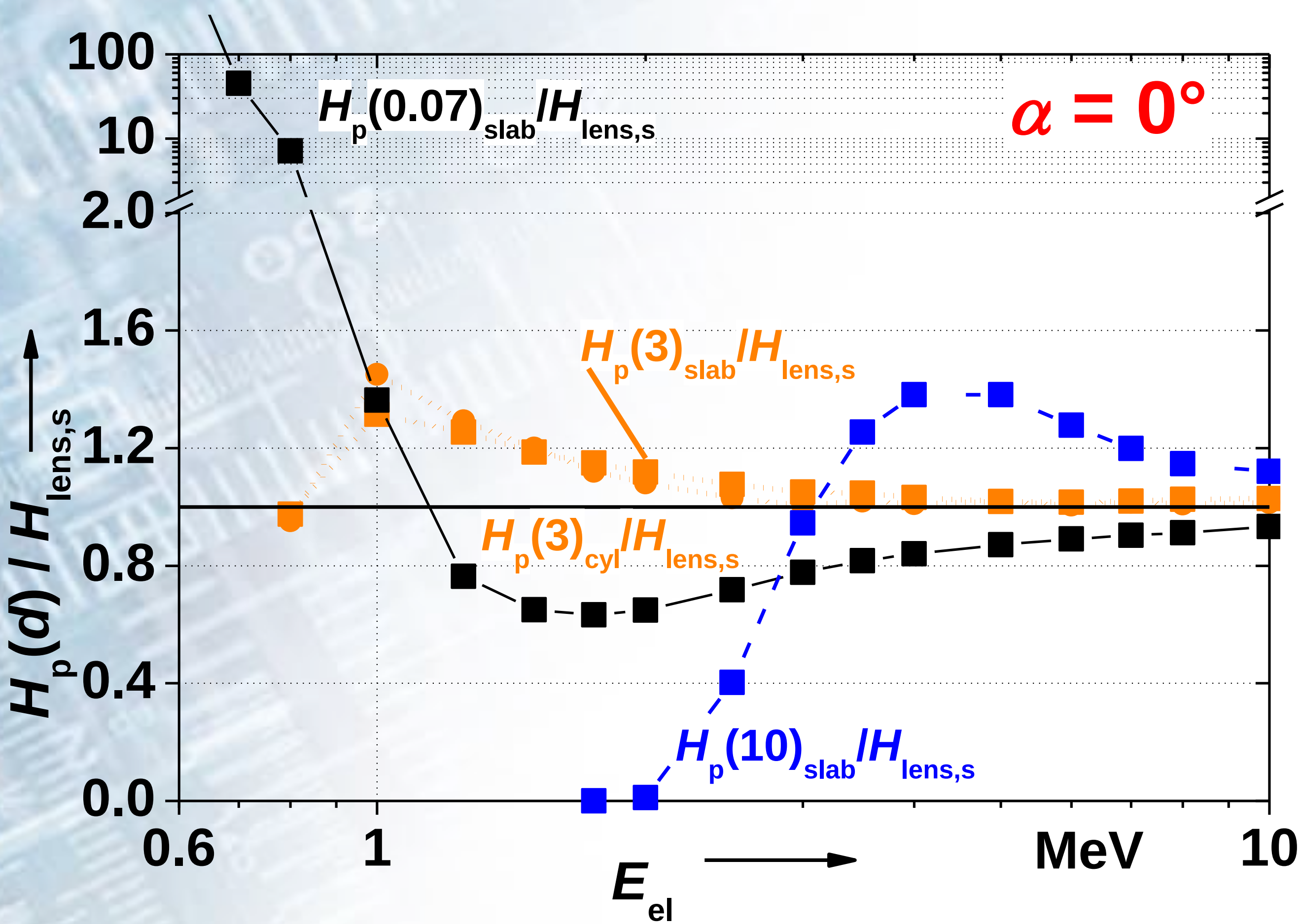


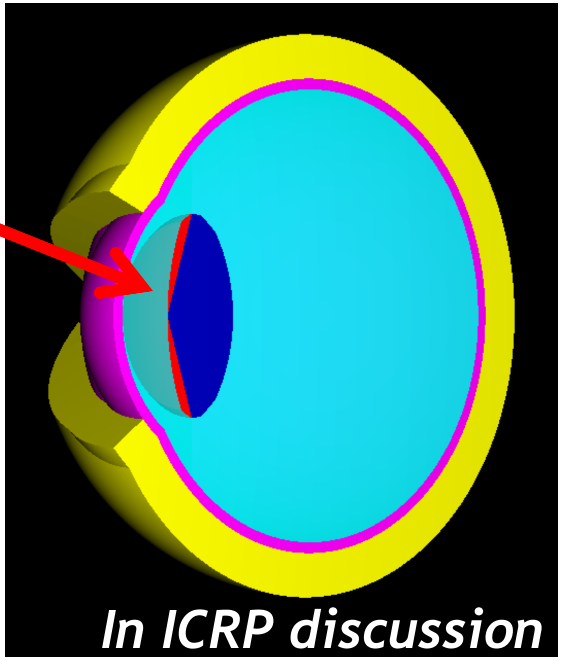
Conservative

Not conservative

Electron radiation:

$H_p(d)$ / $H_{lens,s}$ (based on sensitive cells)



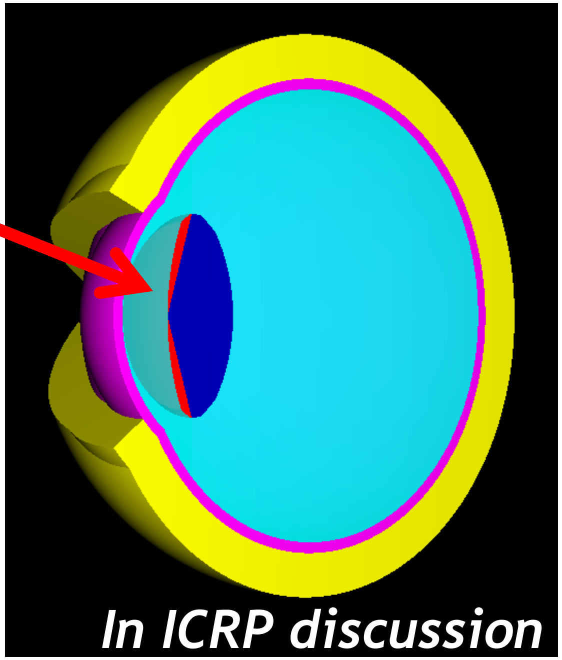


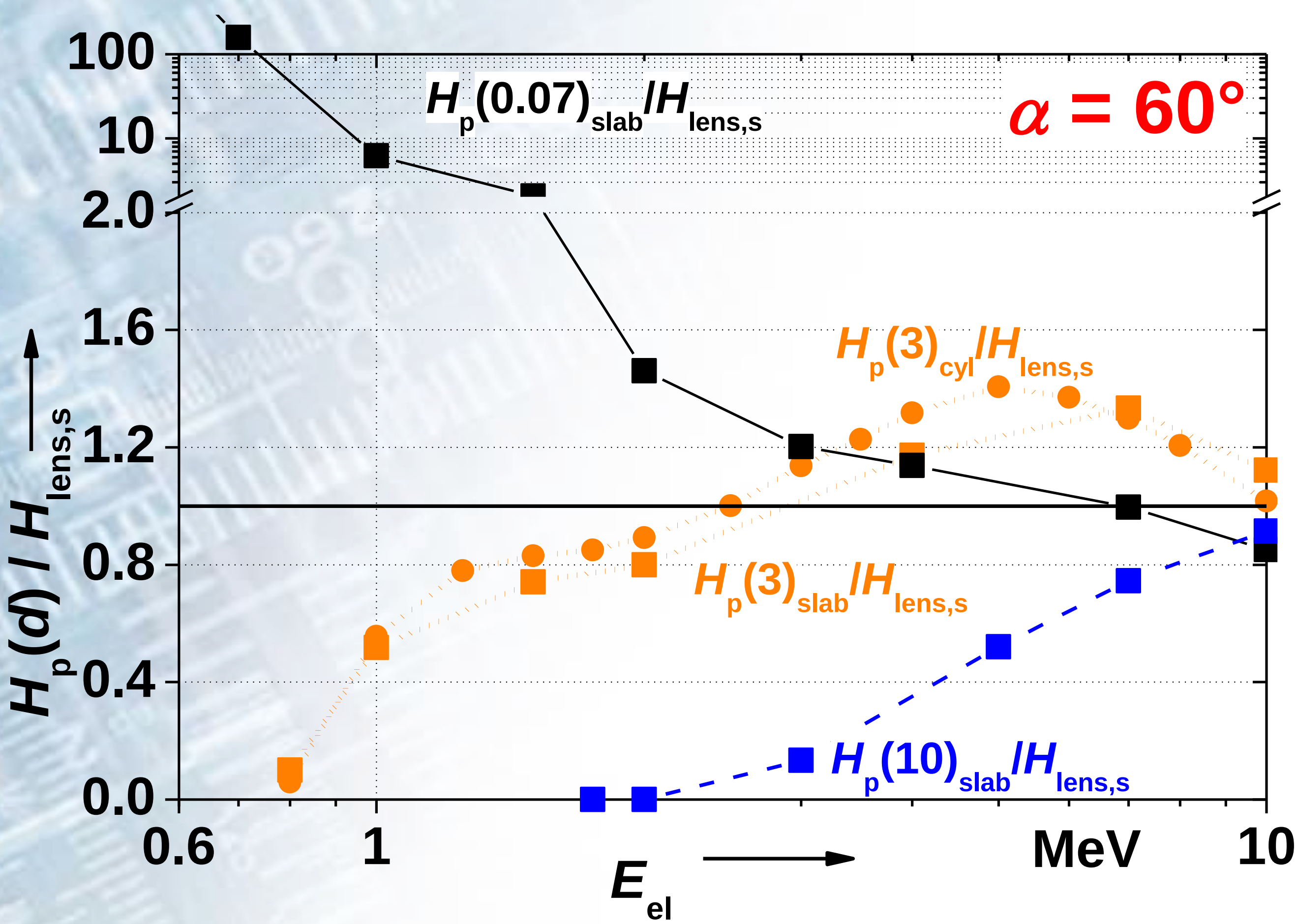
Conservative

Not conservative

Electron radiation:

$H_p(d)$ / $H_{lens,s}$ (based on sensitive cells)



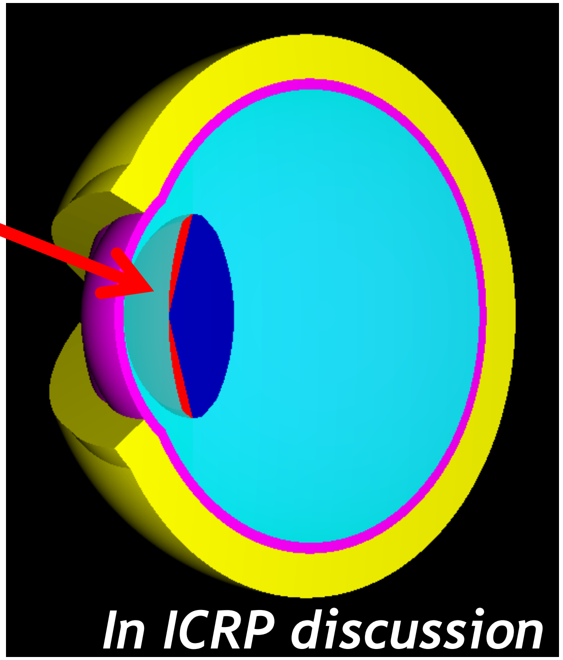


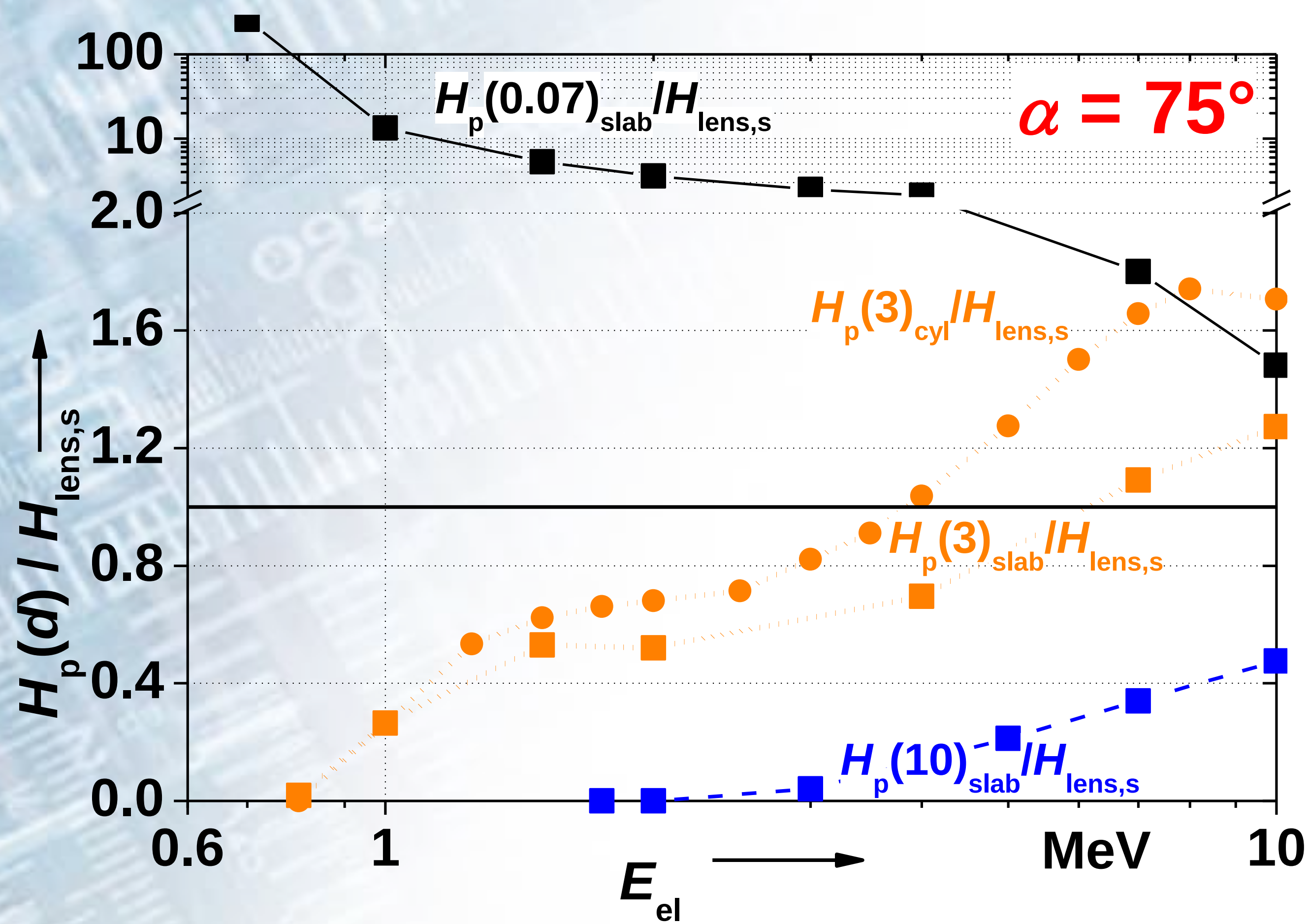
Conservative

Not conservative

Electron radiation:

$H_p(d)$ / $H_{lens,s}$ (based on sensitive part)



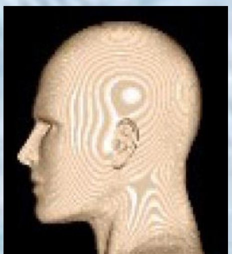


Conservative

Not conservative

Conclusions - equal for realistic radiation fields

Operational quantity (Dose equivalent) **? >** **Organ dose to the lens** (Equivalent dose)



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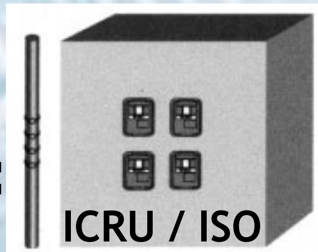
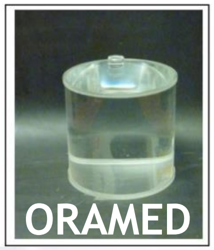
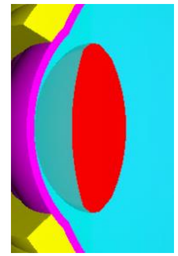
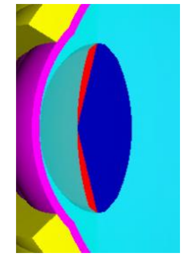




ICRP state of art:
Complete lens:
H_{lens}



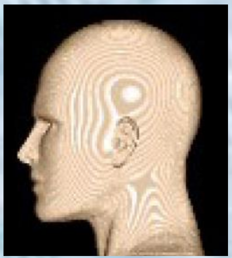
In ICRP discussion:
Sensitive cells :
$H_{lens,s}$



Radiation	Quantity	Good to estimate H_{lens}?	Good to estimate $H_{lens,s}$?
Photons	$H_p(0.07)_{rod}$ $H_p(10)_{slab}$	} Underestimating	As for H_{lens}
	$H_p(0.07)_{slab}$ $H_p(3)_{slab}$	} Up to 75° appropriate	
	$H_p(3)_{cyl}$	Up to 90° appropriate	
Electrons	$H_p(0.07)_{slab}$	Extrem. overestimating	Extremely overestimating
	$H_p(3)_{slab}$ $H_p(3)_{cyl}$	} Up to 60° appropriate	Underestimating, $H_p(d<3)$ necessary?
	$H_p(10)_{slab}$	Underestimating	Underestimating

Conclusions - equal for realistic radiation fields

Operational quantity (Dose equivalent)	? >	Organ dose to the lens (Equivalent dose)



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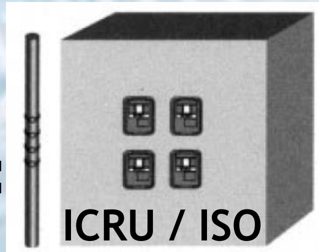
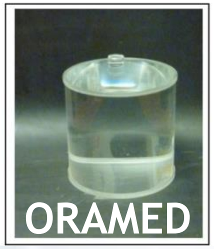
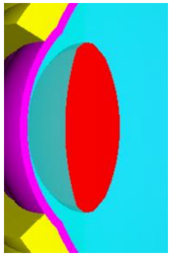
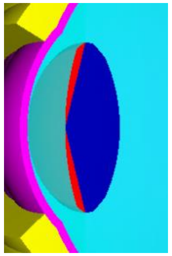




ICRP state of art:
Complete lens:
H_{lens}



In ICRP discussion:
Sensitive cells :
$H_{lens,s}$

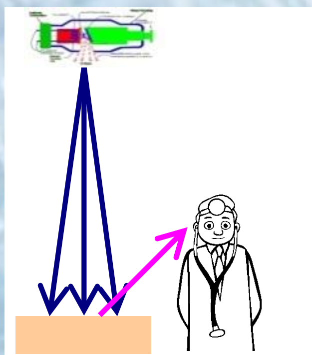


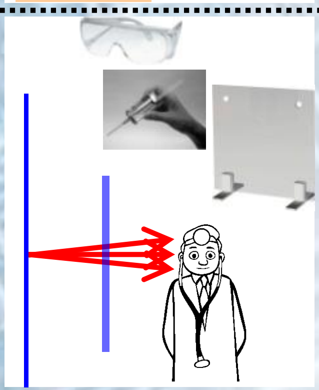
Radiation	Quantity	Good to estimate H_{lens}?	Good to estimate $H_{lens,s}$?
Photons	$H_p(0.07)_{rod}$ $H_p(10)_{slab}$ $H_p(0.07)_{slab}$ $H_p(3)_{slab}$ $H_p(3)_{cyl}$	} Underestimating	As for H_{lens}
Electrons	$H_p(0.07)_{slab}$ $H_p(3)_{slab}$ $H_p(3)_{cyl}$ $H_p(10)_{slab}$		Extremely overestimating Underestimating, $H_p(d<3)$ necessary? Underestimating

P02.247 in hall 4, this afternoon

Same conclusions for realistic radiation fields

$H_p(0.07)_{rod}$, i.e. ring dosemeters worn near the eye, suitable for photons?





Radiation field	$H_p(0.07)_{rod}$ / H_{lens}	$H_p(0.07)_{slab}$ / H_{lens}	$H_p(3)_{slab}$ / H_{lens}	$H_p(10)_{slab}$ / H_{lens}
Photons < 30 keV	0.9 – 5	1.1 – 5	0.6 – 1	0.01 – 0.9
Photons > 30 keV	0.8 – 0.9	≈ 1.1	1 – 1.2	0.9 – 1.2
Electrons < 0.6 MeV and photons	1 – 100	1 – 100	≈ 1	see above
Electrons < 0.6 MeV and photon	1 – 500	1 – 500	≈ 1	$2x10^{-4}$ – 1

$H_p(0.07)_{slab}$ is ONLY adequate for photon radiation.

$H_p(3)$ is NECESSARY for beta radiation.

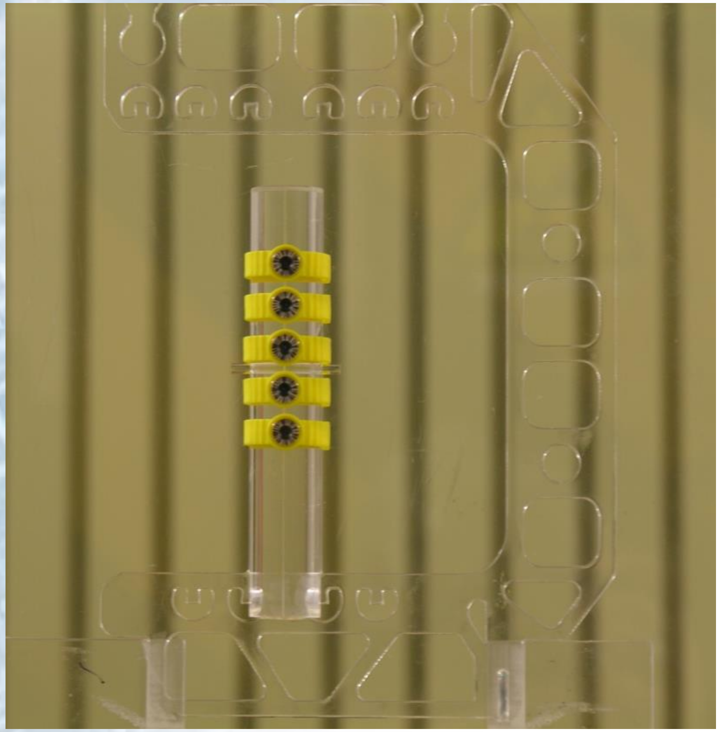
$H_p(10)$ is NOT adequate!

R. Behrens and G. Dietze:
Phys. Med. Biol. 55 (2010) 4047-4062 and
Phys. Med. Biol. 56 (2011) 511

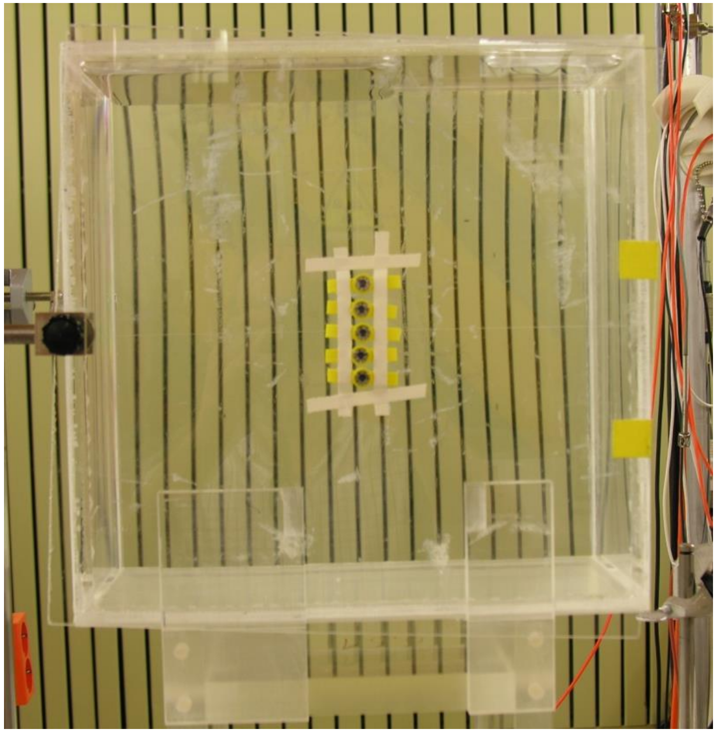
Extremity dosemeters suitable for the eye lens?

Are extremity dosemeters (for $H_p(0.07)$) appropriate?
Is a calibration on a rod phantom (as usual) appropriate?

Rod phantom



Slab phantom



R. Behrens et al.:
Rad. Prot. Dosim. 148 (2012) 139-142

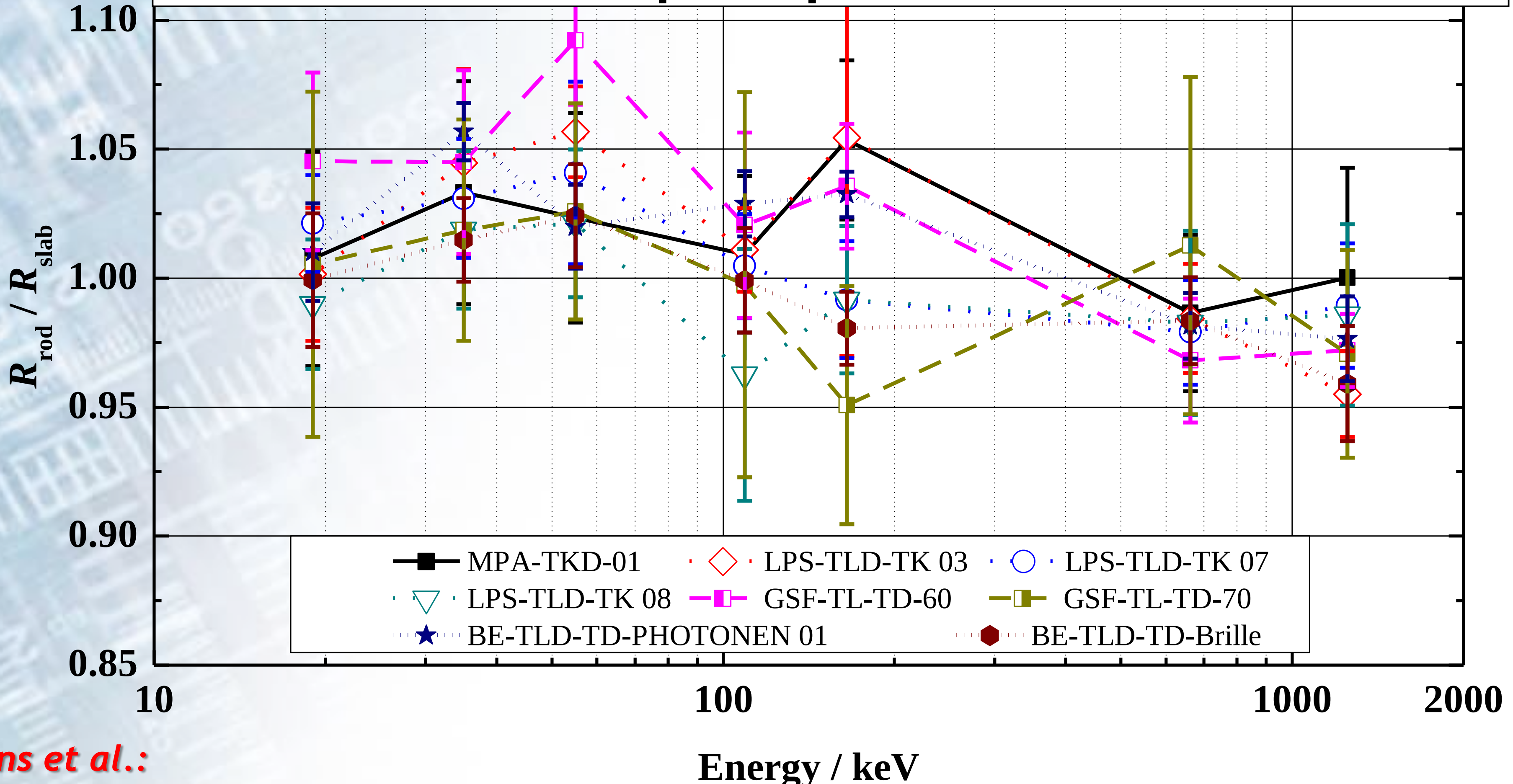
Extremity dosemeters suitable for the eye lens?

MPA-TKD-01	MPA Dortmund	
LPS TLD-TK 03	LPS Berlin	
LPS TLD-TK 07	LPS Berlin	
LPS TLD-TK 08	LPS Berlin	
GSF-TL-TD-60	HZM München	
GSF-TL-TD-70	HZM München	
BE-TLD-TD-PHOTONEN 01	Senats-verwaltung Berlin	
BE-TLD-TD-Brille	Senats-verwaltung Berlin	

R. Behrens et al.:
Rad. Prot. Dosim. 148 (2012) 139-142

Extremity dosemeters suitable for the eye lens?

Extremity dosemeters (for $H_p(0.07)$) estimate the lens dose in pure photon radiation fields!



R. Behrens et al.: Rad. Prot. Dosim. 148 (2012) 139-142

Practice: Choice of dosemeters

Whole body dosemeters measure $H_p(10)$:

- must be worn on the trunk (far from the eyes);
- underestimate the lens dose (too thick cover)
- under the lead apron if in use;

➔ danger for your eyes!

Extremity dosemeters measure $H_p(0.07)$:

- must be worn "facing" the beam / source;
- can be worn near the eye, then it
- correctly estimate the lens dose in photon fields but
- overestimates the lens dose in beta fields (too thin cover)

➔ your work may be changed although not necessary!

Eye dosemeters measure $H_p(3)$:

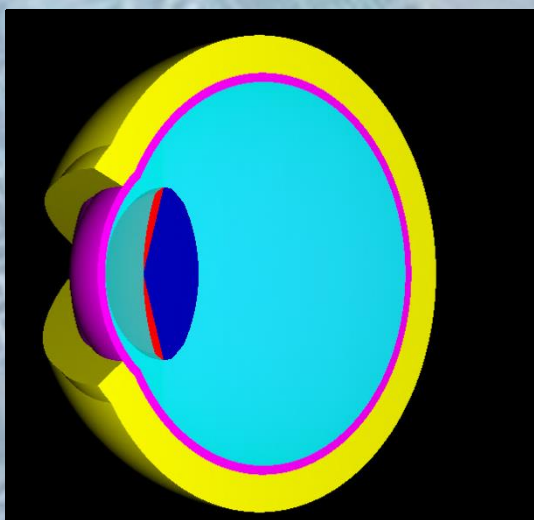
- must be worn "facing" the beam / source;
- must be worn near the eye;
- is the only type of dosemeter that correctly estimate H_{lens} (not $H_{lens,s}$) in beta and photon fields!

Funding

Bundesministerium für Wirtschaft und Technologie

INS INNOVATION MIT NORMEN UND STANDARDS

Thank you – Questions?



TS7e.3

Monitoring the eye lens

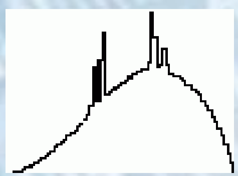
Rolf Behrens

Physikalisch-Technische Bundesanstalt

PTB

Irradiations and type tests in $H_p(3)$

Photon spectra:



- Conversion coefficients for K_a ➔ $H_p(3)_{slab}$:
  Rad. Prot. Dosim. 147, 373 (2011)
- Conversion coefficients for K_a ➔ $H_p(3)_{cyl}$:
  Rad. Prot. Dosim. doi:10.1093/rpd/ncs032 (2012)

Beta radiation:

- Extension to the Beta Secondary Standard BSS 2: Incl. conversion factors for $H_p(0.07)$ ➔ $H_p(3)$:
  J. Instrum. 6, P11007 (2011)
- Available for old instruments via SW update

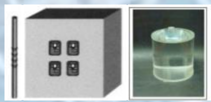
Details: Poster P02.247 in hall 4, this afternoon

ICE 62387:

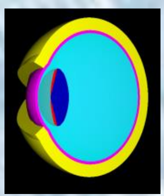
IEC

- Passive dosimetry systems (Final draft FIDS 2012) $H_p(3)$ implemented for both photons and betas

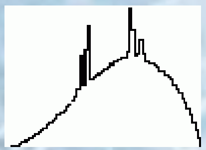
Literature



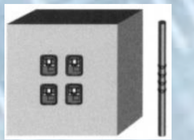
- Monitoring the eye lens: Which dose quantity is adequate?
  Phys. Med. Biol. 55, 4047 (2010) and Phys. Med. Biol. 56, 511 (2011)



- Conversion coefficients for mono-energetic electrons: $\Phi \rightarrow H_{eye}$:
  Phys. Med. Biol. 54, 4069 (2009) and Phys. Med. Biol. 55, 3937 (2010)
- Conversion coefficients for mono-energetic photons: $\Phi \rightarrow H_{eye}$:
  Phys. Med. Biol. 56, 415 (2011)



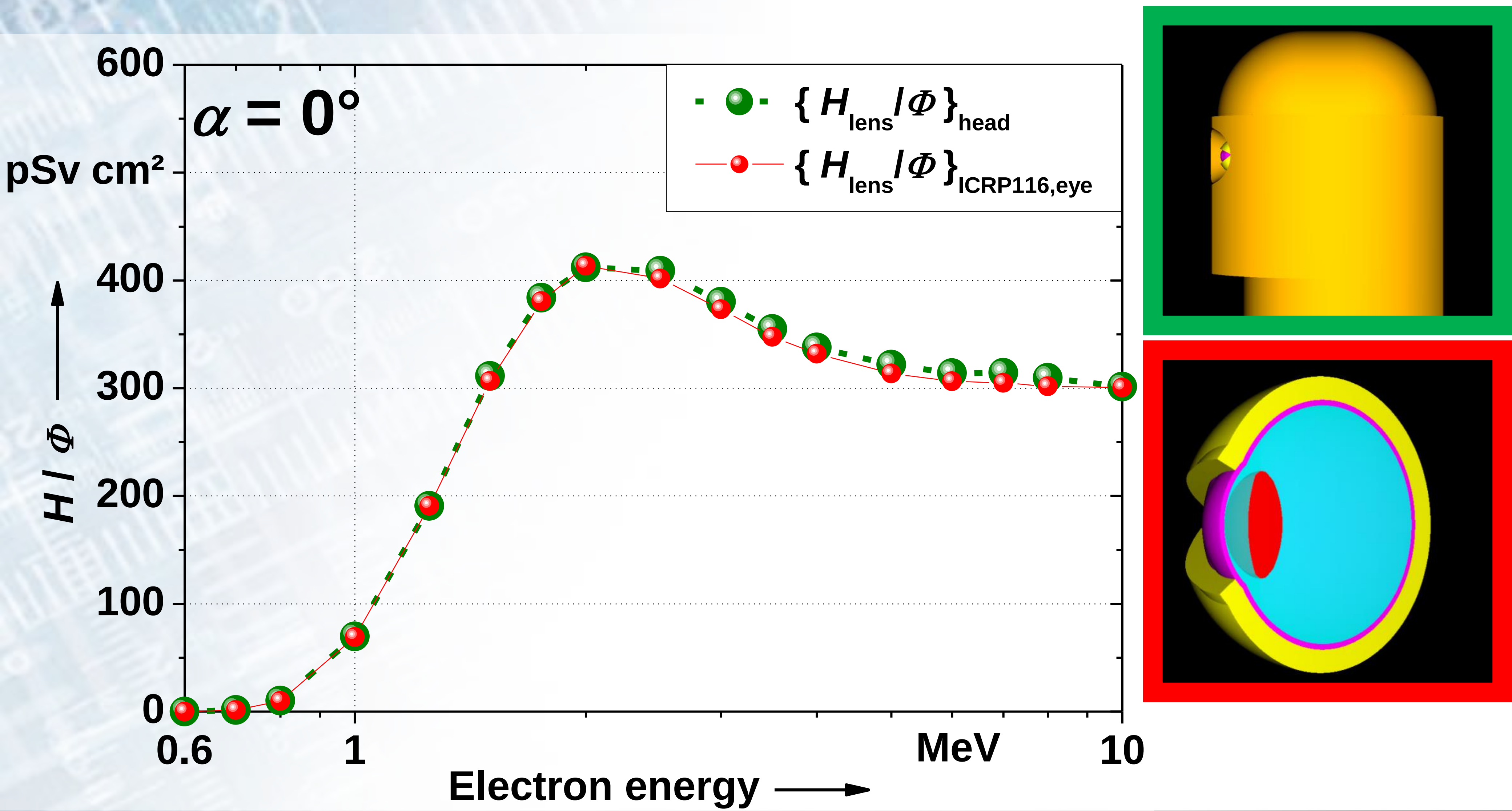
- Conversion coefficients for photon spectra: $K_a \rightarrow H_p(3)_{slab}$:
  Rad. Prot. Dosim. 147, 373 (2011)
- Conversion coefficients for photon spectra: $K_a \rightarrow H_p(3)_{cyl}$:
  Rad. Prot. Dosim. doi:10.1093/rpd/ncs032 (2012)



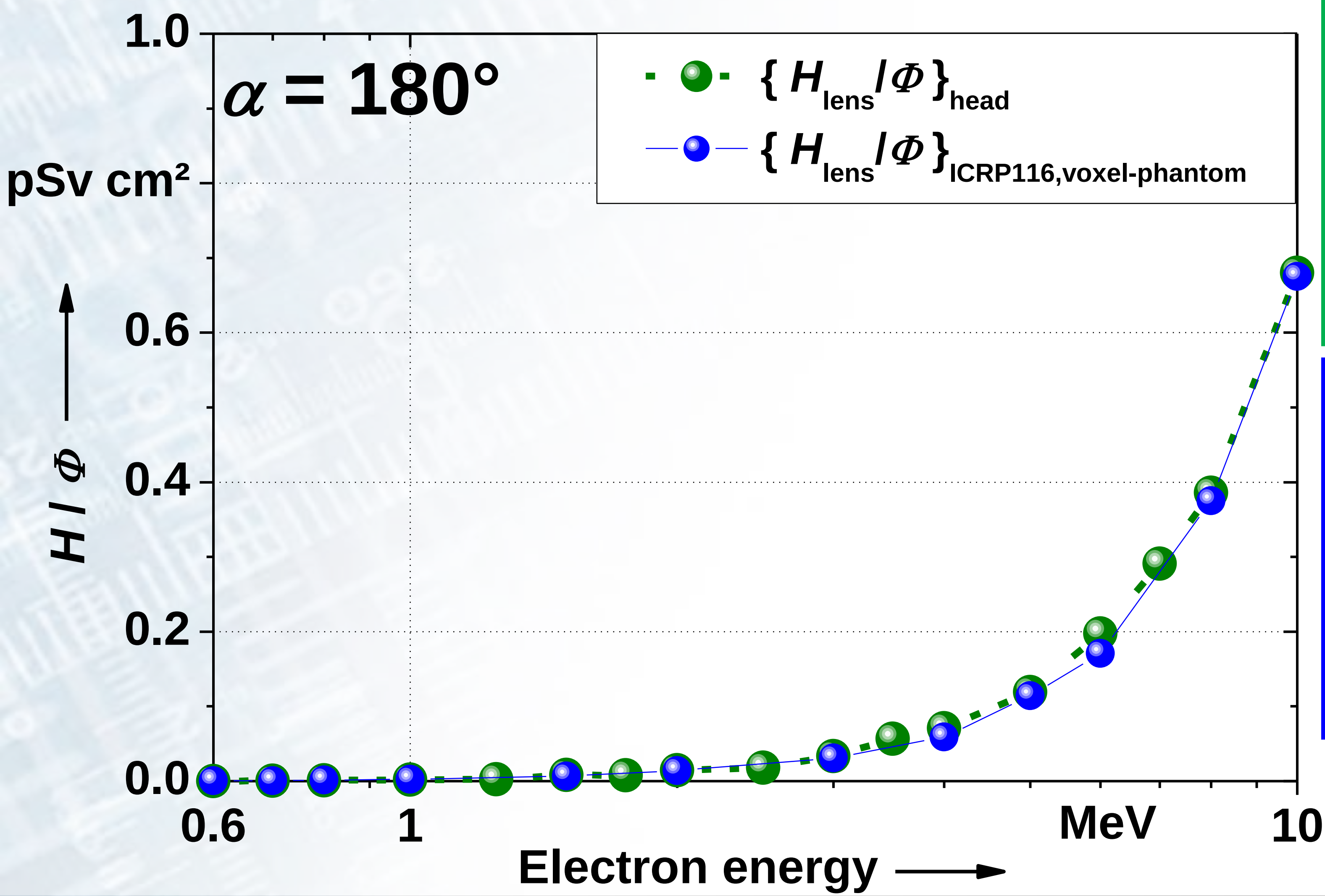
- $H_p(0.07)$ photon dosemeters: Calibration on a rod vs. a slab phantom:
  Rad. Prot. Dosim. 148 (2012) 139-142

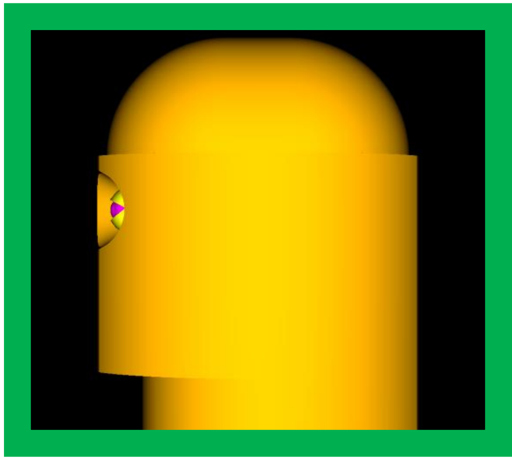
- Extensions to the Beta Secondary Standard BSS 2:
  J. Instrum. 6, P11007 (2011) and Erratum and Addendum

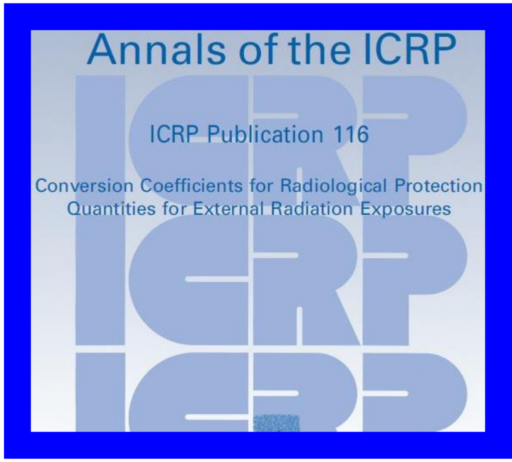
Electron radiation



Electron radiation





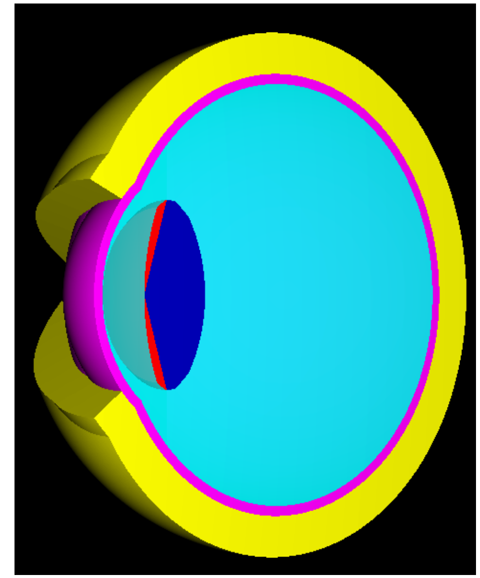


Total lens ↔ significant volume

ANNEX F. SPECIAL CONSIDERATIONS FOR ASSESSING ABSORBED DOSE IN THE LENS OF THE EYE

(F2) The annual dose limit for the lens of the eye is given in terms of the equivalent dose, H_T, and by definition this value is based on the mean absorbed dose, $D_{T,R}$, averaged over the volume of the lens. Although ICRP Committee 1 will continue to evaluate the location of the stem cells associated with cataract induction, the dosimetric assessments of this annex support the continued use of the mean absorbed dose for the lens of the eye.

(F3) However, it is well known that there are strong differences in sensitivity to ionising radiation exposure with respect to cataract induction among the tissues of the lens of the eye (Charles and Brown, 1975). Even as early as 1955, ICRP stated in its first general recommendations (ICRP, 1955): 'When the spatial distribution of radiation in the organ is very non-uniform, an average of the physical dose is not necessarily indicative of the potential damage to the organ in its relation to the normal physiological functions of the body as a whole. Therefore, in such cases it is necessary to consider a local volume within the organ in which the dose is highest. This may be called the significant volume. . . For the lens of the eye the significant volume is that in which the cell nuclei are located.' This motivated several groups to look deeper into the issue of the dose to a sensitive cell population within the lens, especially for radiations with low penetrability that have steep dose gradients inside the lens of the eye, such as electrons (Behrens et al., 2009, 2010; Behrens and Dietze, 2010, 2011a; Nogueira et al., 2011) and low-energy photons (Behrens and Dietze, 2011b). Recently, the issue of lens dosimetry for neutrons has been under investigation (Manger et al., 2011).



Data base

Organ dose to the lens

PHYS. MED. BIOL., 1975, VOL. 20, NO. 2, 202–218. © 1975

Dimensions of the Human Eye Relevant to Radiation Protection

M. W. CHARLES, PH.D.

Central Electricity Generating Board, Berkeley Nuclear Laboratories, Berkeley, Gloucestershire

and

NICHOLAS BROWN, F.R.C.S.

Institute of Ophthalmology, Judd Street, London

Data base

Organ dose to the lens

M. W. CHARLES
and
NICHOLAS BROWN

Biology

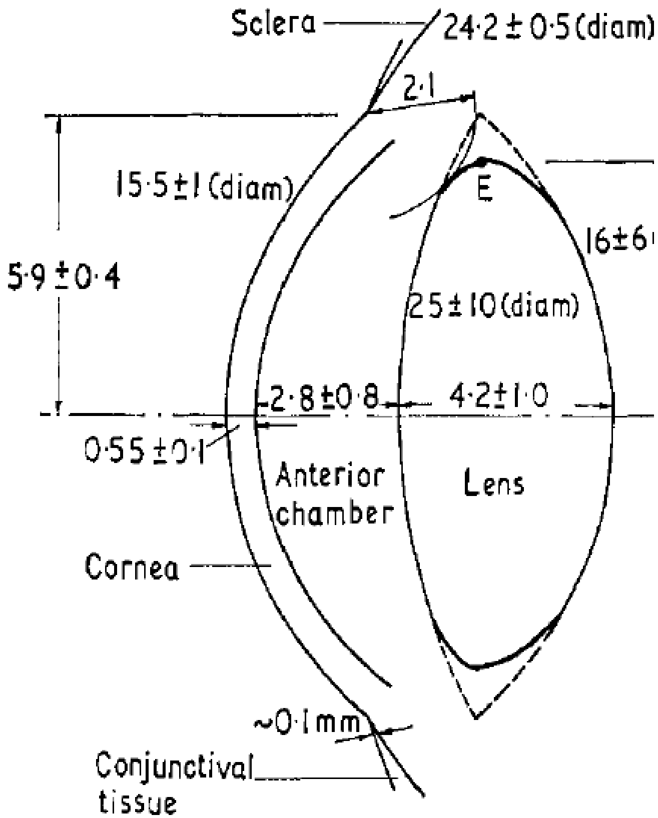
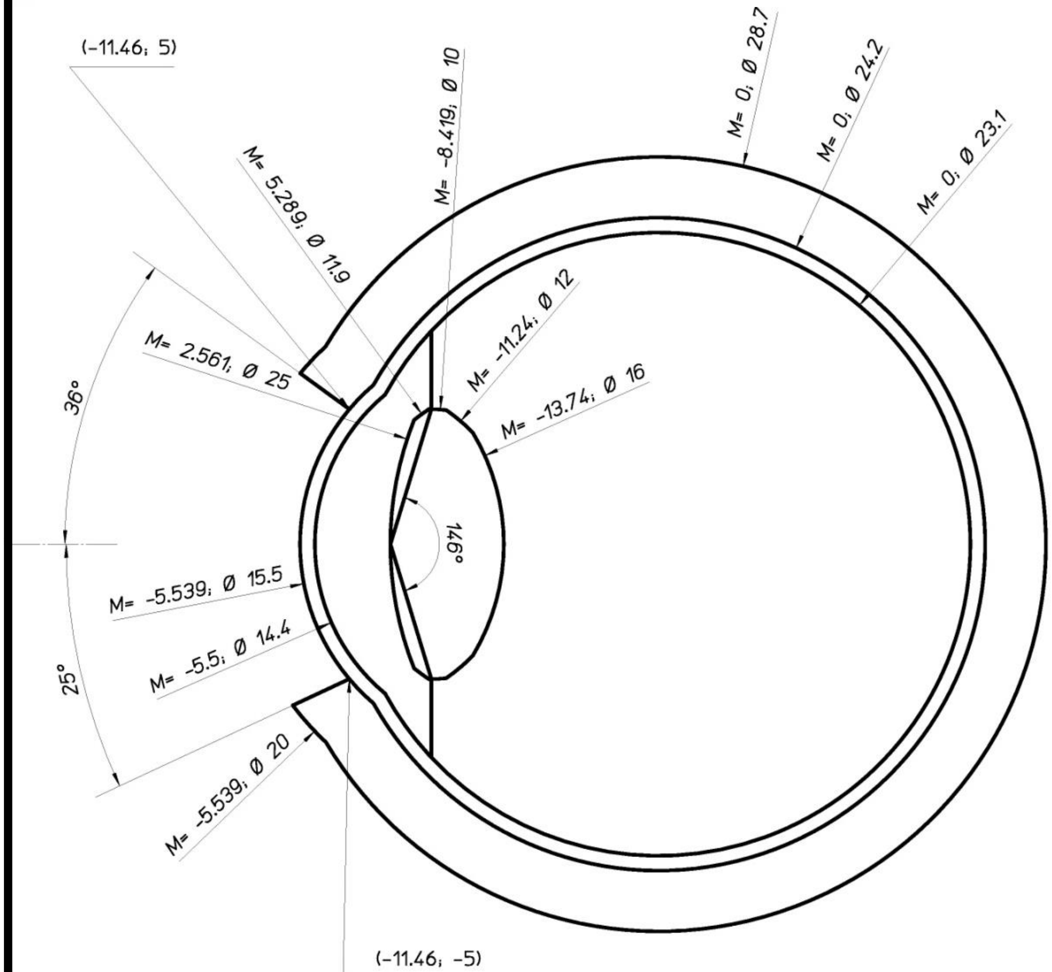


Fig. 8. Mean ocular dimensions for the unaccommo
represent the limits found in a normal adult

Simulation



Data base

Organ dose to the lens

M. W. CHARLES
and
NICHOLAS BROWN

Biology

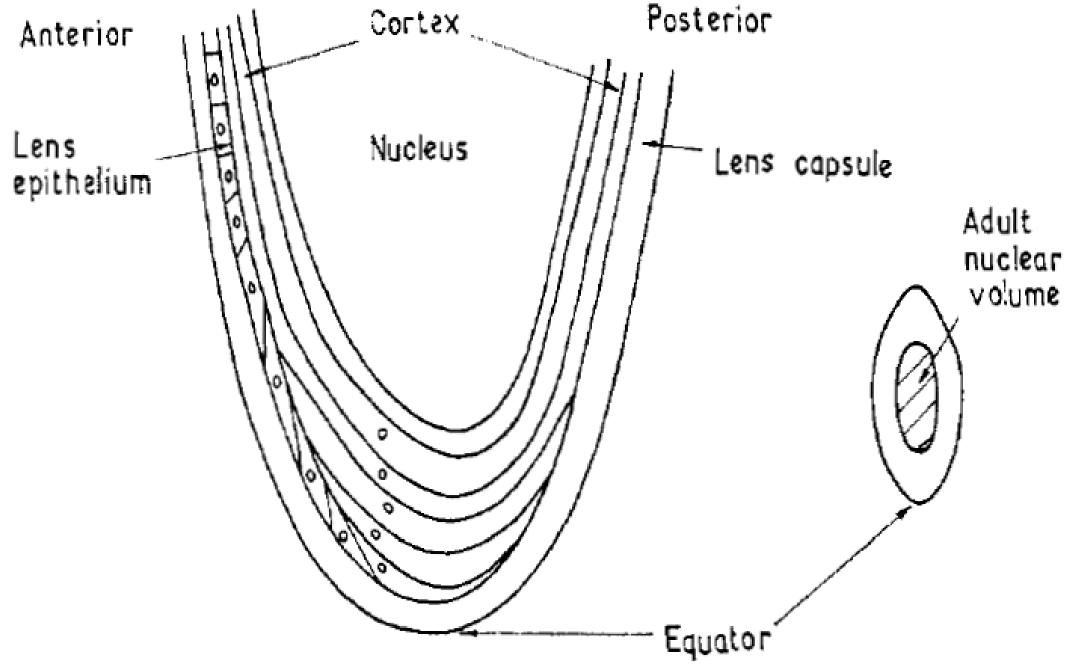
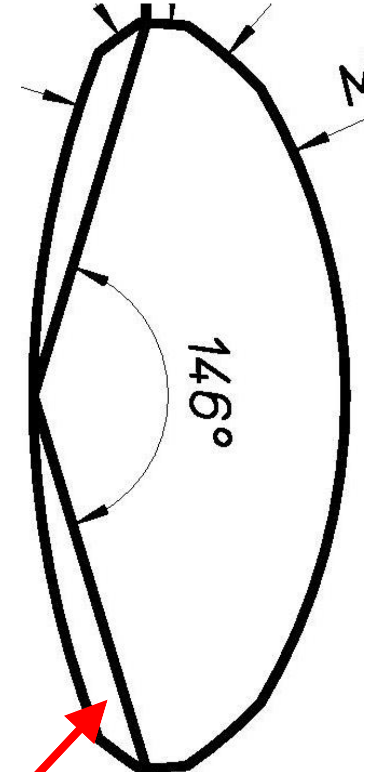


Fig. 2. Transverse section of the lens.

Simulation



Significant volume

R. Behrens et al. in Phys. Med. Biol. (PMB):
PMB 54 (2009) 4069 + PMB 55 (2010) 3937,
PMB 56 (2011) 415 and PMB 57 (2012) submitted

Data base

Organ dose to the lens

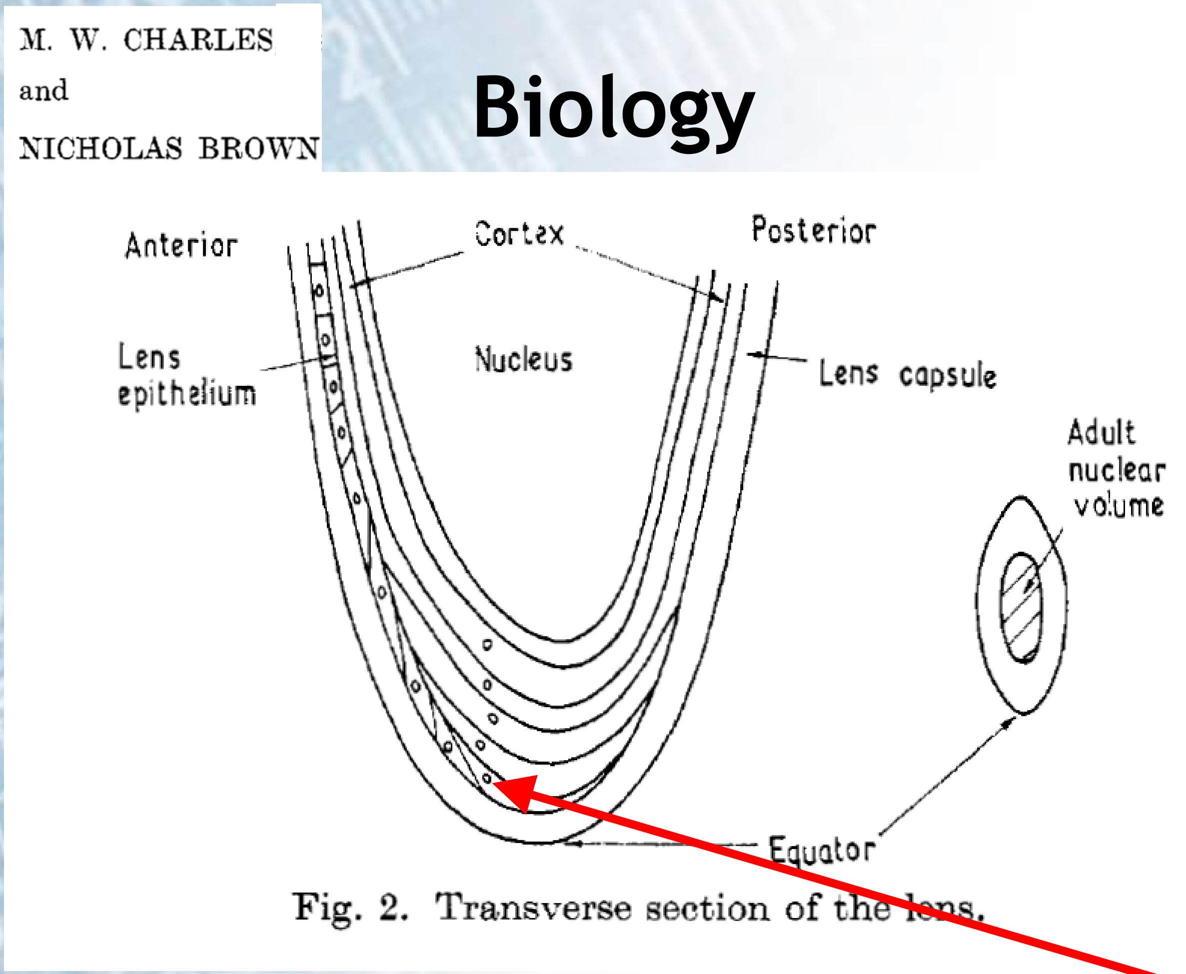
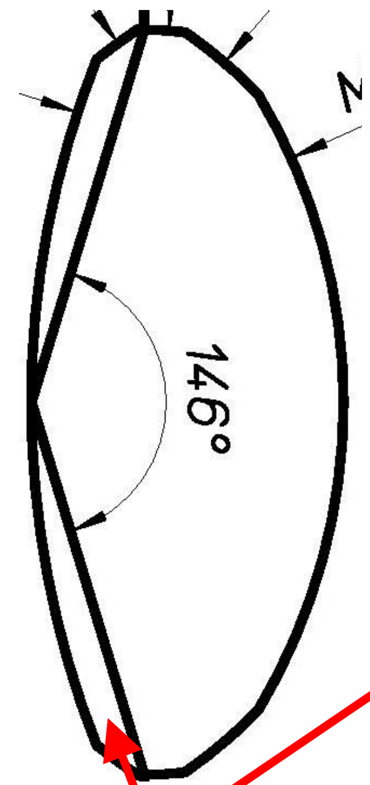
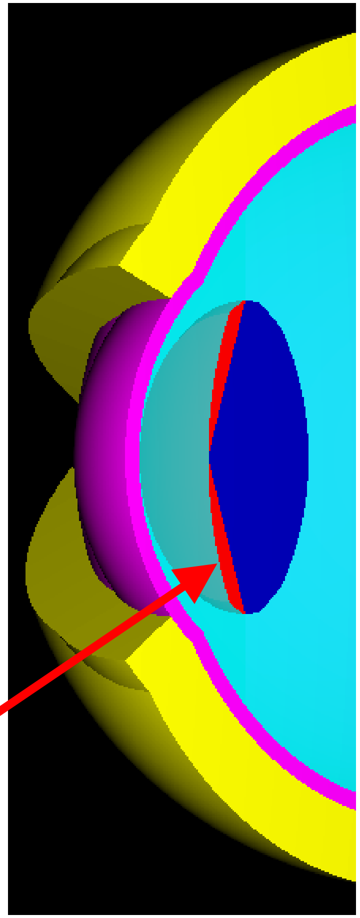


Fig. 2. Transverse section of the lens.

Biology

Simulation





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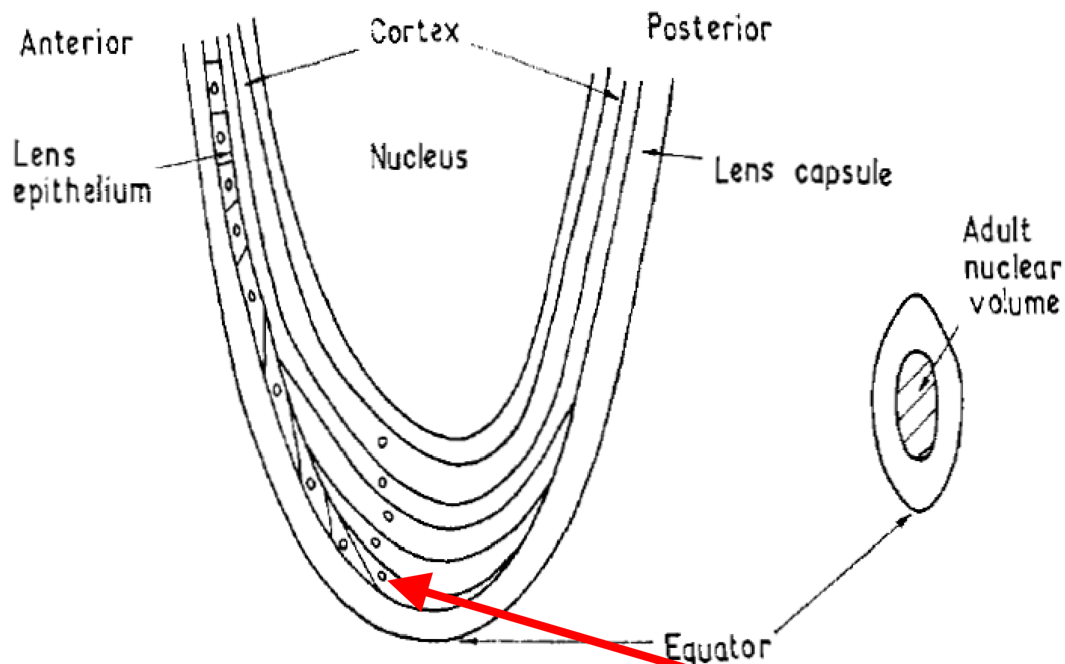
Sensitive cells: *In ICRP discussion*

Data base

Organ dose to the lens

M. W. CHARLES
and
NICHOLAS BROWN

Biology



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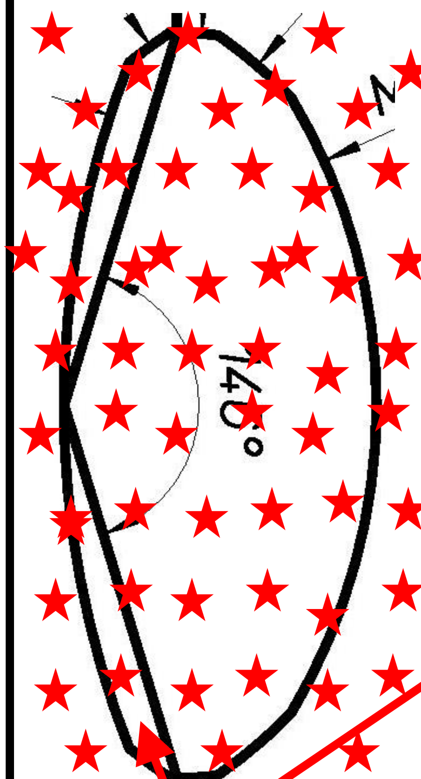
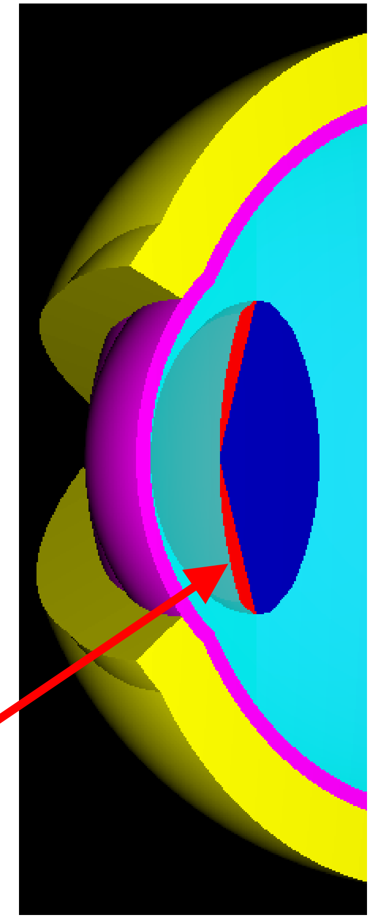
Simulation





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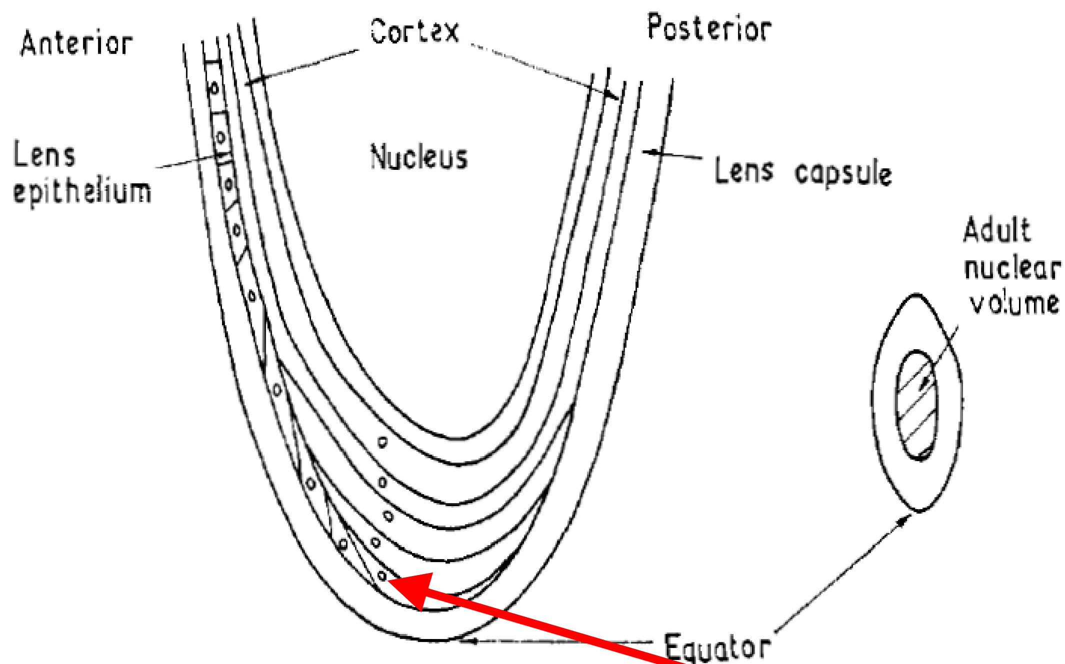

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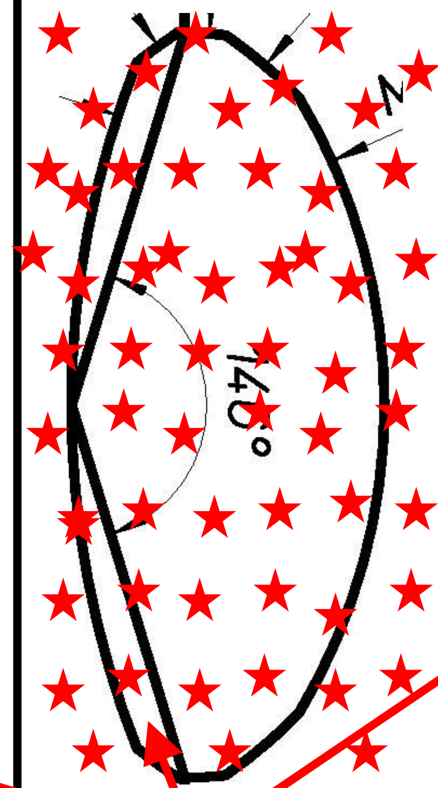
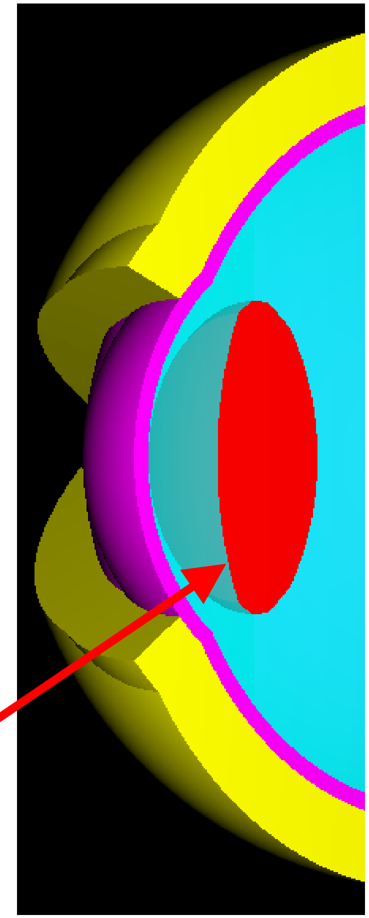




R. Behrens et al. in Phys. Med. Biol. (PMB):
PMB 54 (2009) 4069 + PMB 55 (2010) 3937,
PMB 56 (2011) 415 and PMB 57 (2012) submitted

Complete lens: *ICRP state of art*

Data base

Organ dose to the lens

Biology

M. W. CHARLES
and
NICHOLAS BROWN

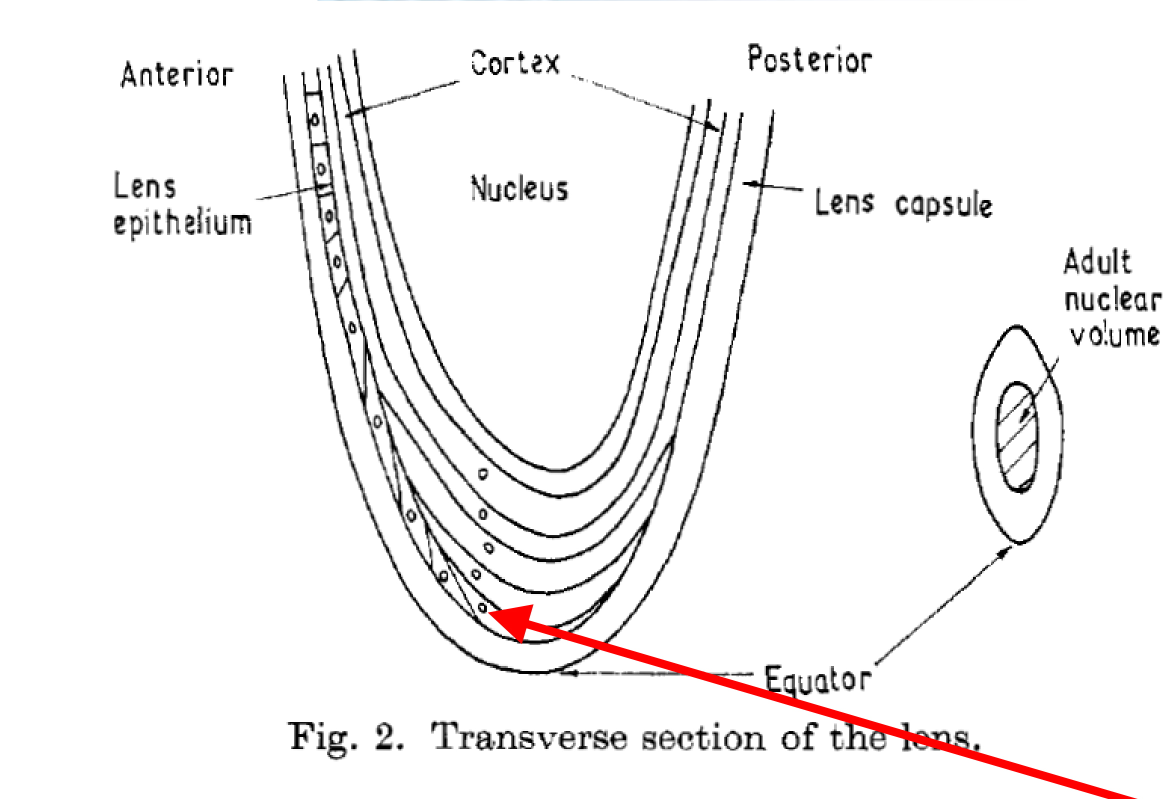
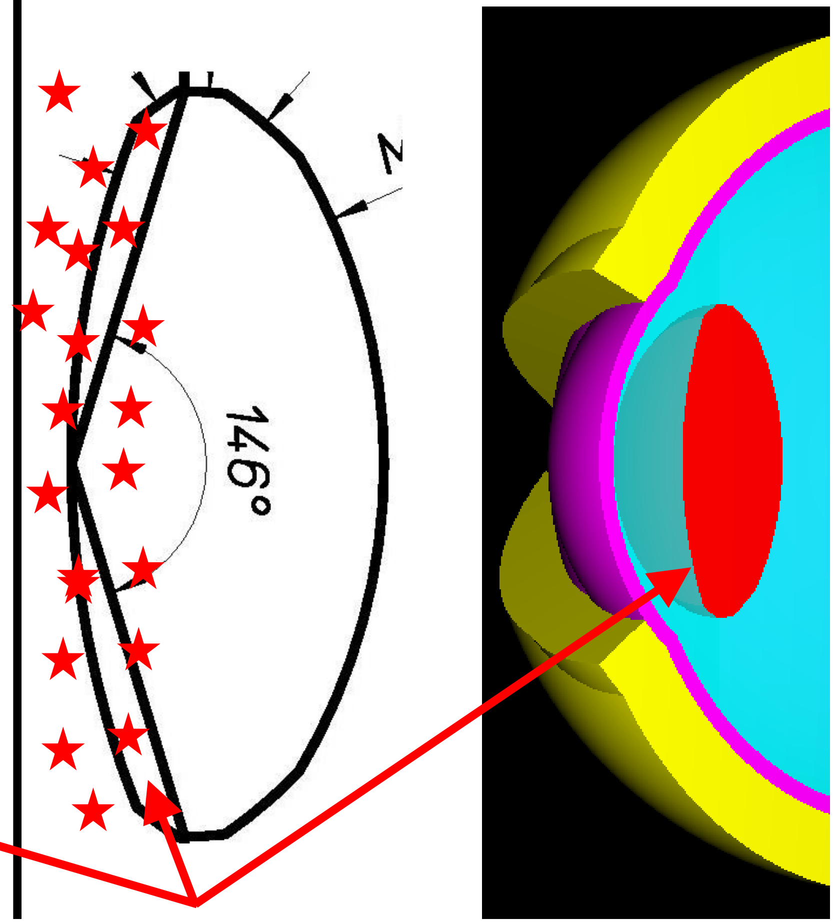


Fig. 2. Transverse section of the lens.

Simulation



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Complete lens: *ICRP state of art*

Data base

Organ dose to the lens

M. W. CHARLES
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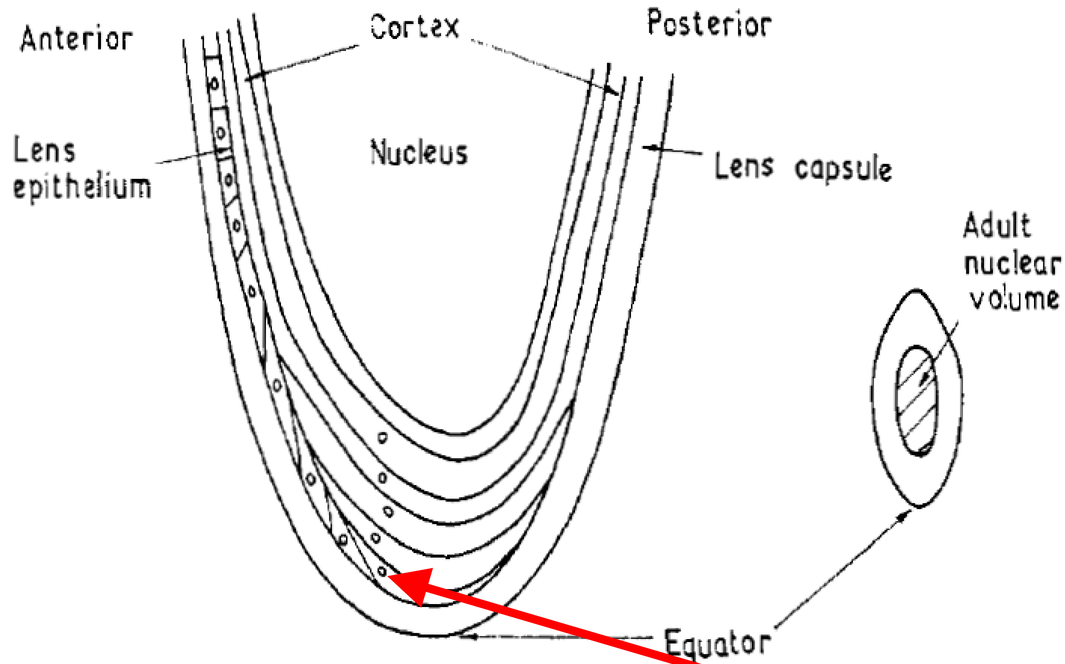

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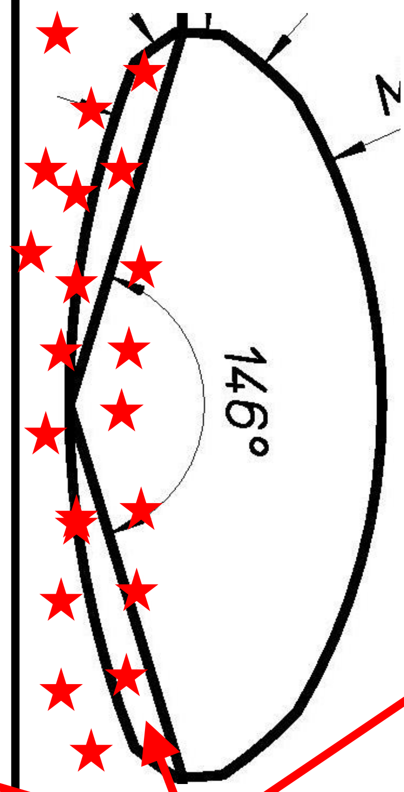

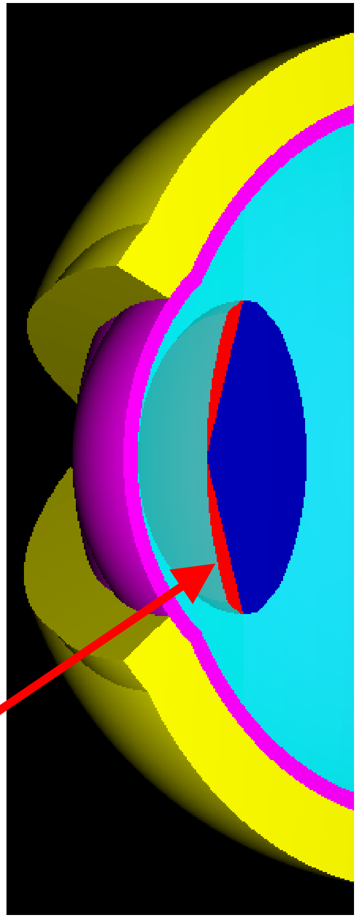

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PMB 54 (2009) 4069 + PMB 55 (2010) 3937,
PMB 56 (2011) 415 and PMB 57 (2012) submitted

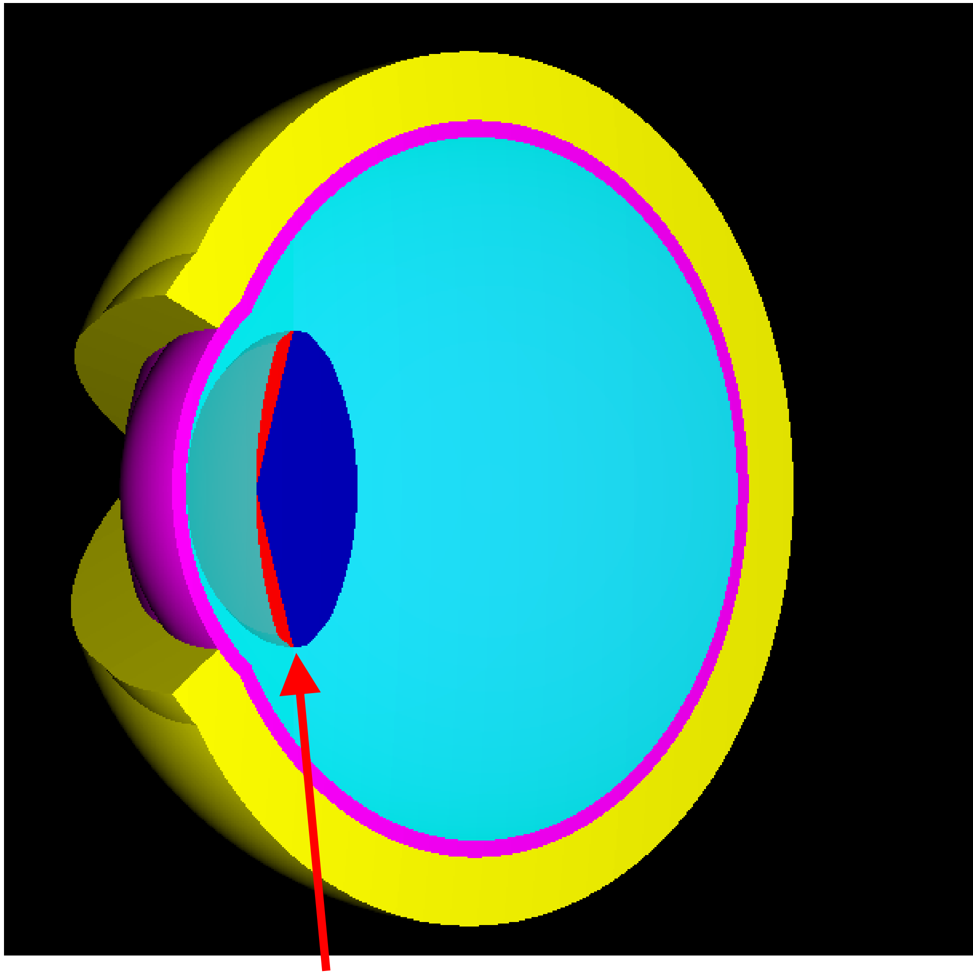
Sensitive cells: *In ICRP discussion*

Data base

Organ dose to the lens

Implementation in simulation program EGSnrc:

- Mathematical model
- Small volumes possible
- No problems with finite voxel sizes
- Correct calculation of H_{lens}



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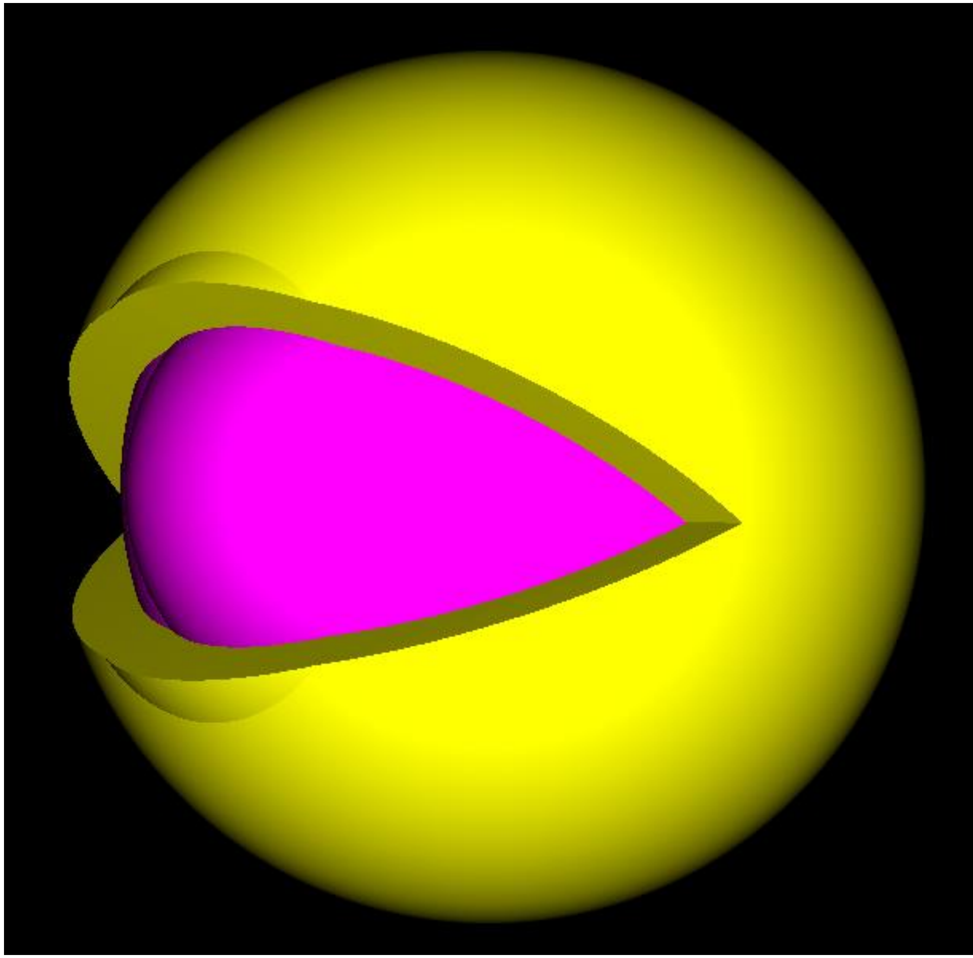

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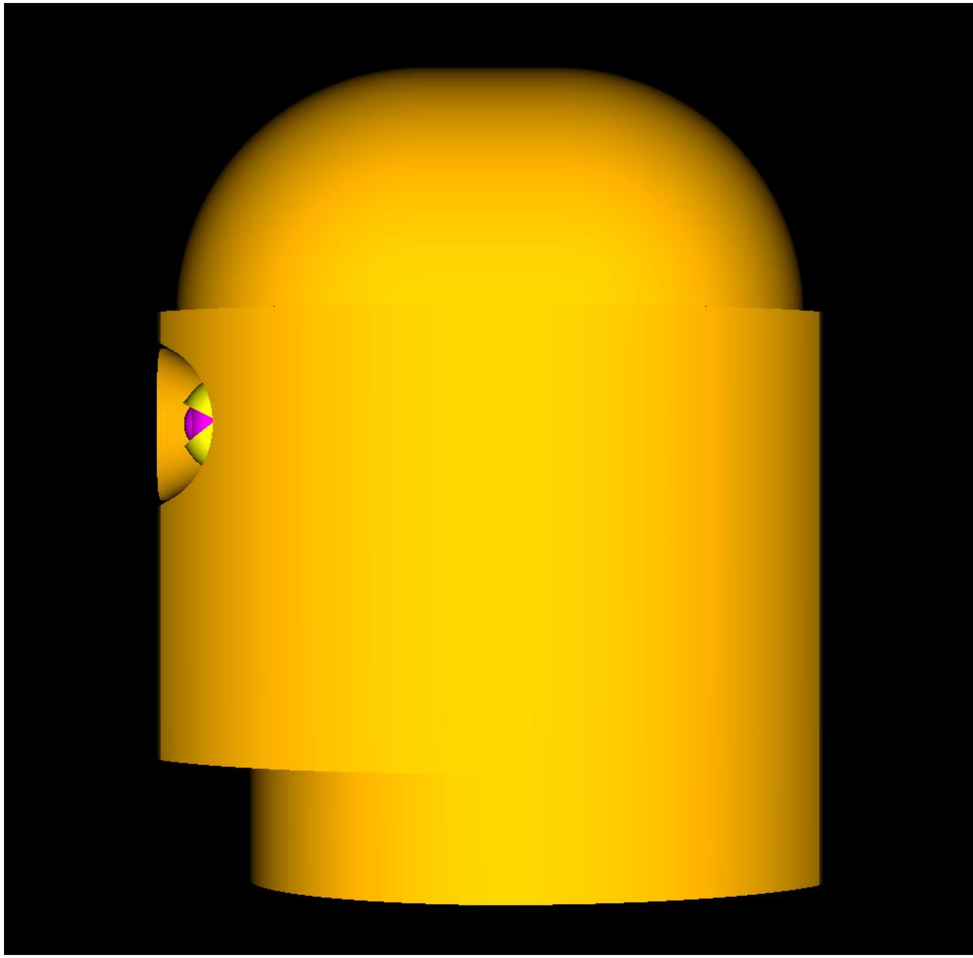

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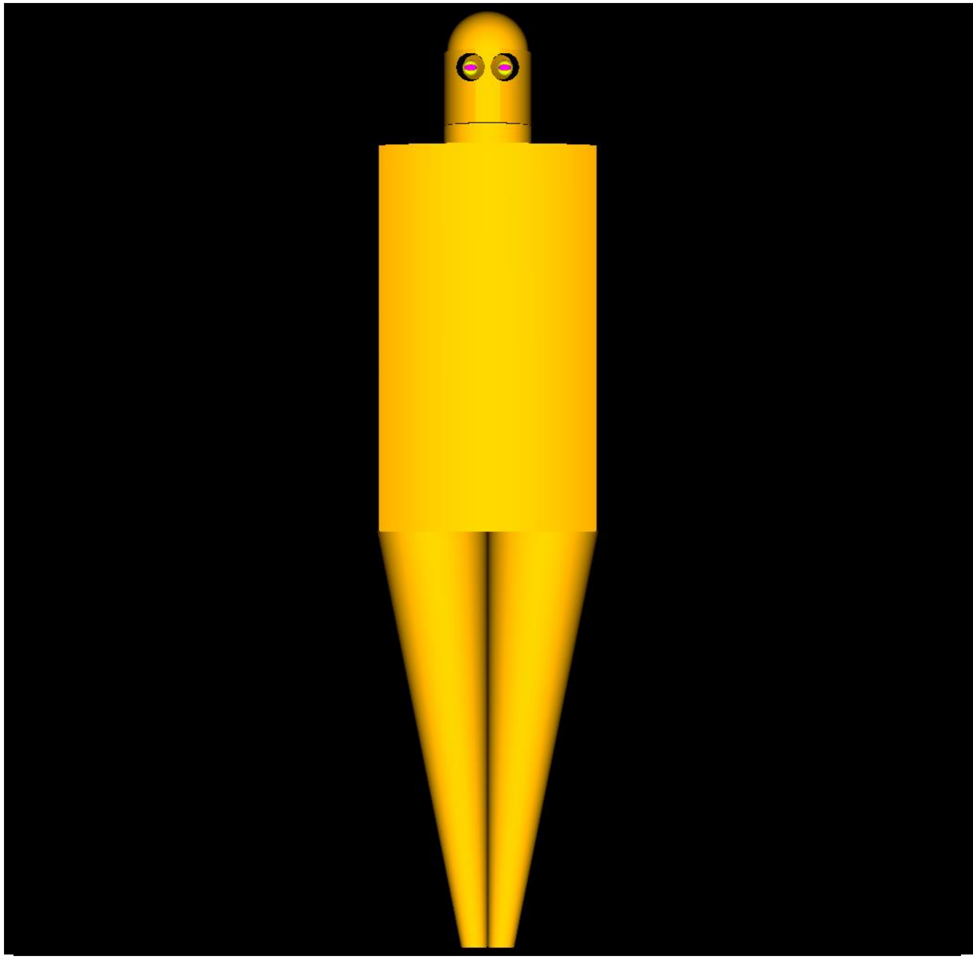

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