EYE LENS DOSIMETRY: TASK2 WITHIN THE ORAMED PROJECT

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WP2 FLOW DIAGRAM

Finding a simple phantom easy and cheap to build for better estimating the H_T(eye lens) limiting quantity.

Theoretical phase of the WP2 study ($H_p(3)$ for photons)

Behrens presentation

This presentation

Establishing a clear calibration and type test protocol in terms of $H_p(3)$ for photons

Designing and fabricating a dosemeter prototype optimized to respond in terms of $H_p(3)$ for photons

Bordy presentation

Bilski presentation

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GENERAL FRAMEWORK

Motivation:

A-Evidence of higher incidence of cataracts for the same radiation doses (discussion on the nature: deterministic or stochastic or both)

B-Poor quality of the existing mathematical model of the eye as treated in ADAM and EVA

C-Careful investigation on new H_T(eye lens) values for electrons and photons by Behrens and Dietze, using a very detailed eye model (presentation in this Workshop by Behrens)

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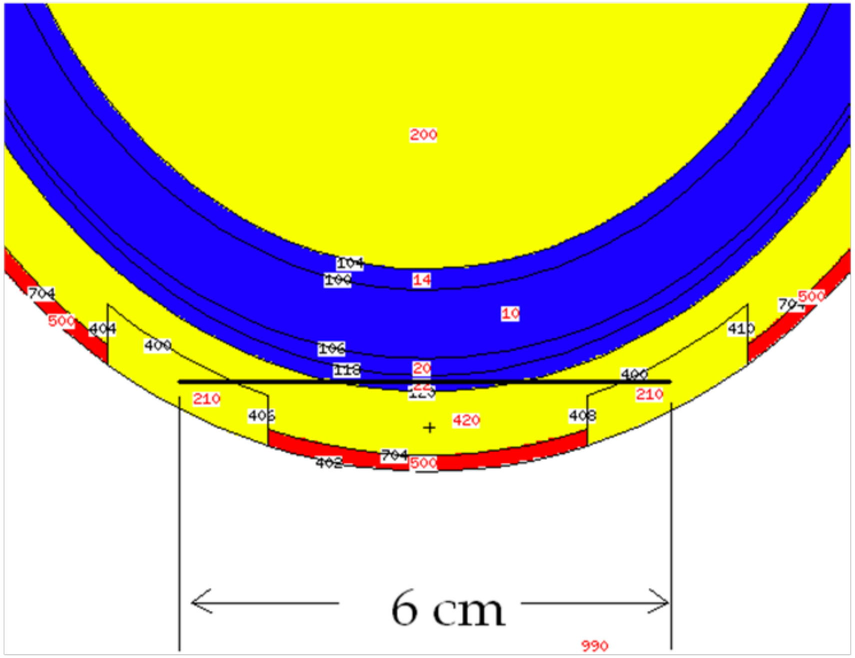
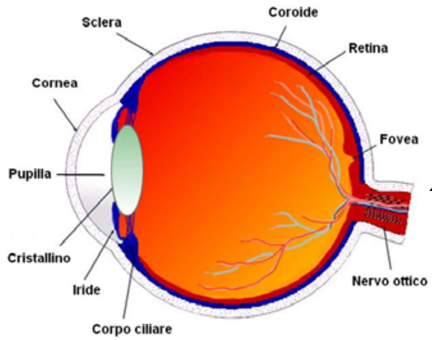
Limiting quantity study (see Behrens presentation)

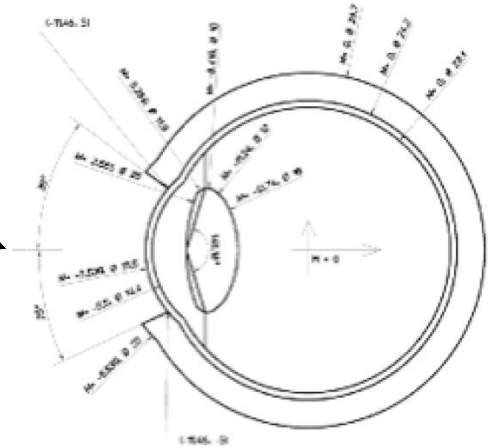
A-Poor quality of the existing mathematical model of the eye as treated in ADAM and EVA. The eyes are two cylindrical sectors with **no non-radiosensitive** layer on top of the lens (contradiction with eye lens typical depth of 3 mm as stated by ICRU): dose over-estimation at low energies (e.g. electrons with E<800 keV). (The ADAM head is an elliptical cylinder with major axis of about 20 cm (forehead to back) and minor axis about 15 cm (temple-temple))



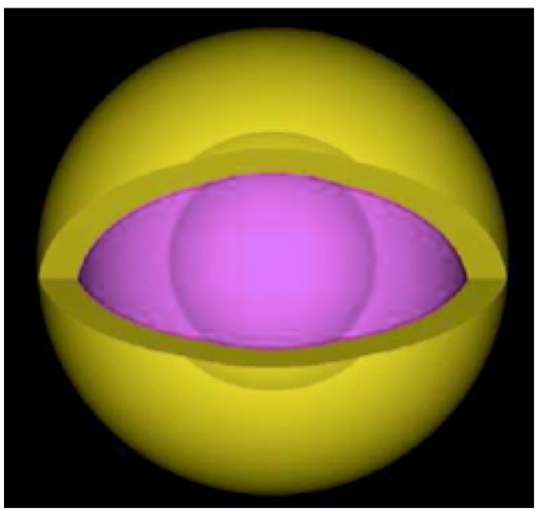
Innovative approach by Behrens, Dietze and Zankl
This workshop R. Behrens :DOSE CONVERSION COEFFICIENTS FOR PHOTON EXPOSURE OF THE HUMAN EYE LENS



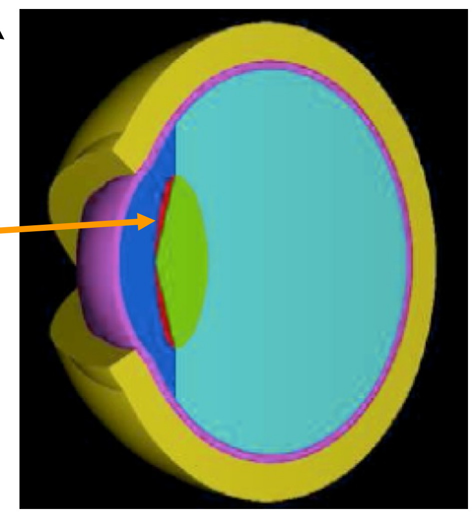
Sagittal cuts of the ocular bulb



MC complex model of the ocular bulb
Courtesy Behrens et al.



Red regions are the radio-sensitive zones of the lens



Courtesy R. Behrens

Courtesy R. Behrens

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ORAMED TASK 2 TOPICS: eye lens dosimetry

Critical review of the operational quantity and the way it was calculated until now: the purpose is to guarantee an accuracy of the same level of the recent works by Behrens et al (this workshop) on the limiting quantity.

The flow diagram of the study is as follows starting from a) (this presentation):

a) H_T(eye lens)(this workshop) to **H_p(3) numerical evaluation**,

b) the definition of an appropriate type test and calibration protocol in terms of H_p(3) (this workshop),

c) the design and fabrication of a dosemeter with a suitable response in terms of H_p(3) (this workshop), should contribute to a "quality assurance based" eye lens dose assessment.

Considerations on $H_p(3)$

-Absence of $H_p(3)$ tabulation for photons in ICRU-57 and ICRP-74.

-$H_p(3)/\Phi$ conversion coefficients calculated for electrons on a 30x30x15 cm^3 slab phantom and reported in ICRU-57 and ICRP-74 (some mixing present between $H'(d)$ and $H_p(d)$, a bit misleading).

-Whilst for electrons (due to their short ranges) the shape and mass of the head phantom is relatively of secondary importance for $H_p(3)$, for photons the phantom contributes in a significant way to the scattered component and to the angular behaviour.

-The present studies are dealing with only photons. Future investigation will deal with electrons and neutrons

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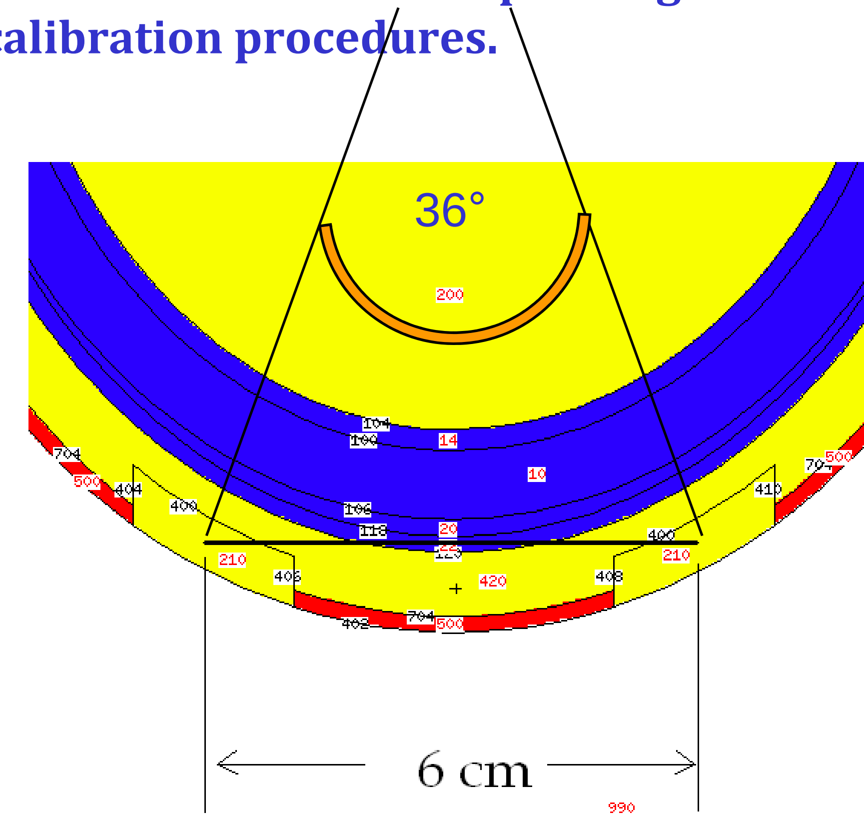
The decision within ORAMED: Proposal of a cylindrical ICRU Tissue material phantom for Conversion Coefficients calculations and a corresponding PMMA water filled phantom for type test and calibration procedures.

Simulation of a cylindrical phantom (diameter = 20 cm, height = 20 cm)



- Inter-ocular distance (ADAM) = 6 cm (angle -18° + 18° =36°)
- $H_p(3,\alpha)$:
  α = 0°, 10°, 20°, 30°, 40°, 45°, 50°, 60°, 70°, 75°, 80°, 90°, 100°, 110°, 120°,130°,140°,145°,150°,160°, 170°,180°
- Energies :
  10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500, 600, 800 keV and 1, 2, 3, 6, 8, 10 MeV

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Computational methods and assumptions

- Both MCNPX (at ENEA) and PENELOPE (at CEA LNHB) were employed with the same geometry. A very good agreement was obtained on the whole investigated range. MCNPX was used in the kerma approximation (p mode), whilst PENELOPE both with and without kerma approximation. This makes a significant difference at energies > 1 MeV (3 mm in tissue is the 800 keV electron range) due to the lack of electronic equilibrium.

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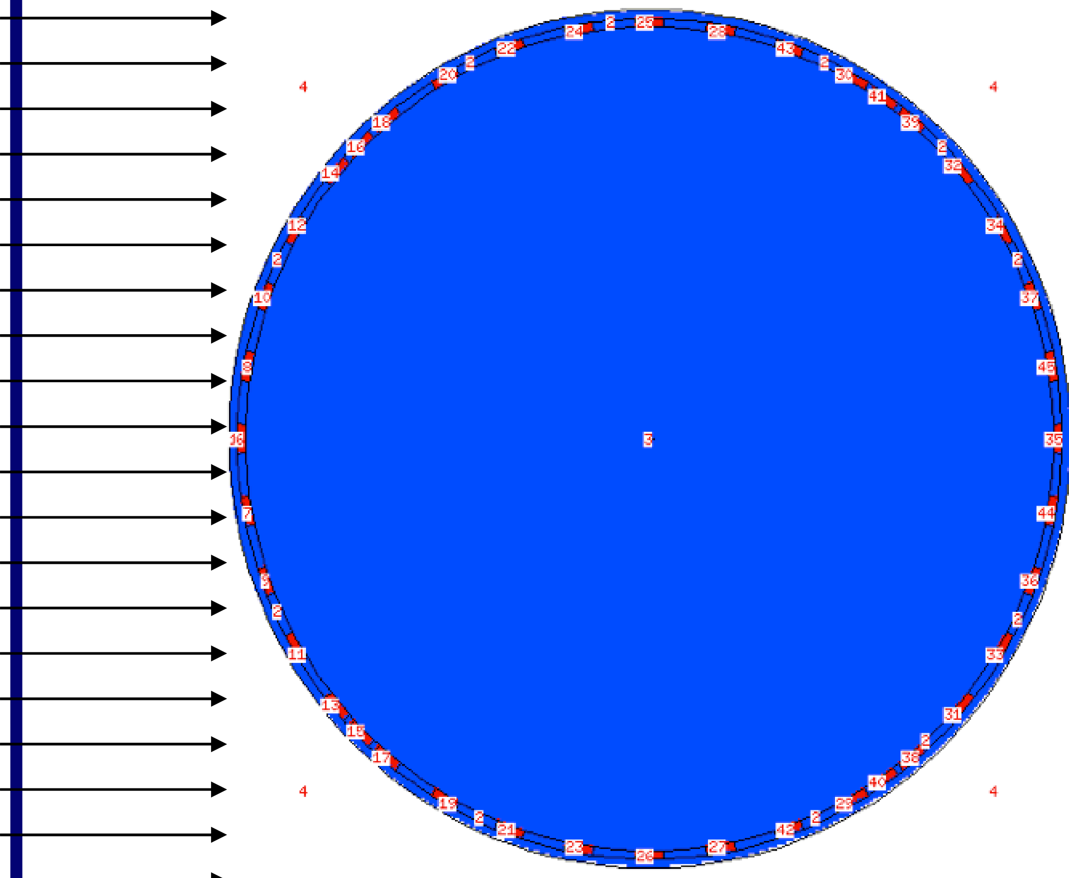
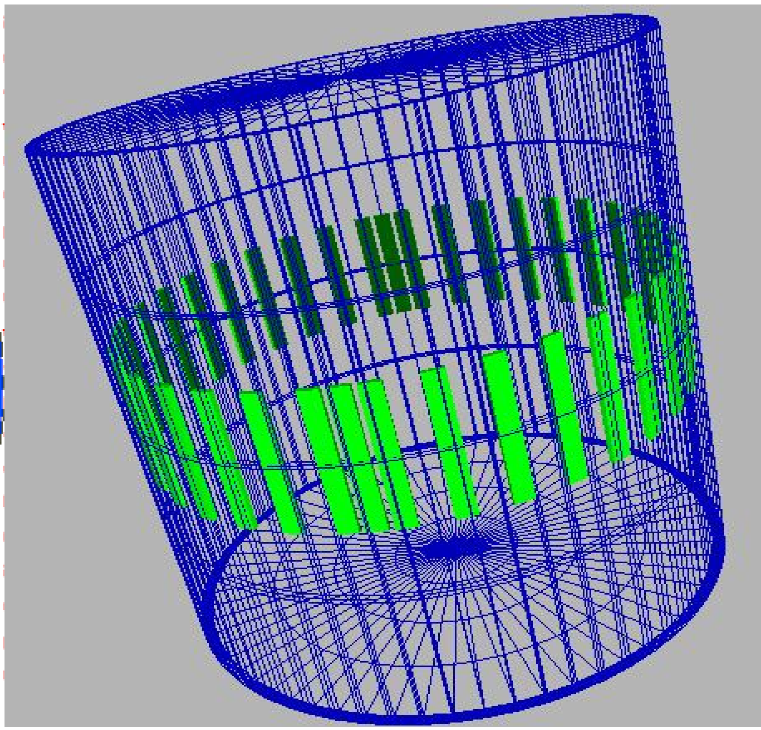
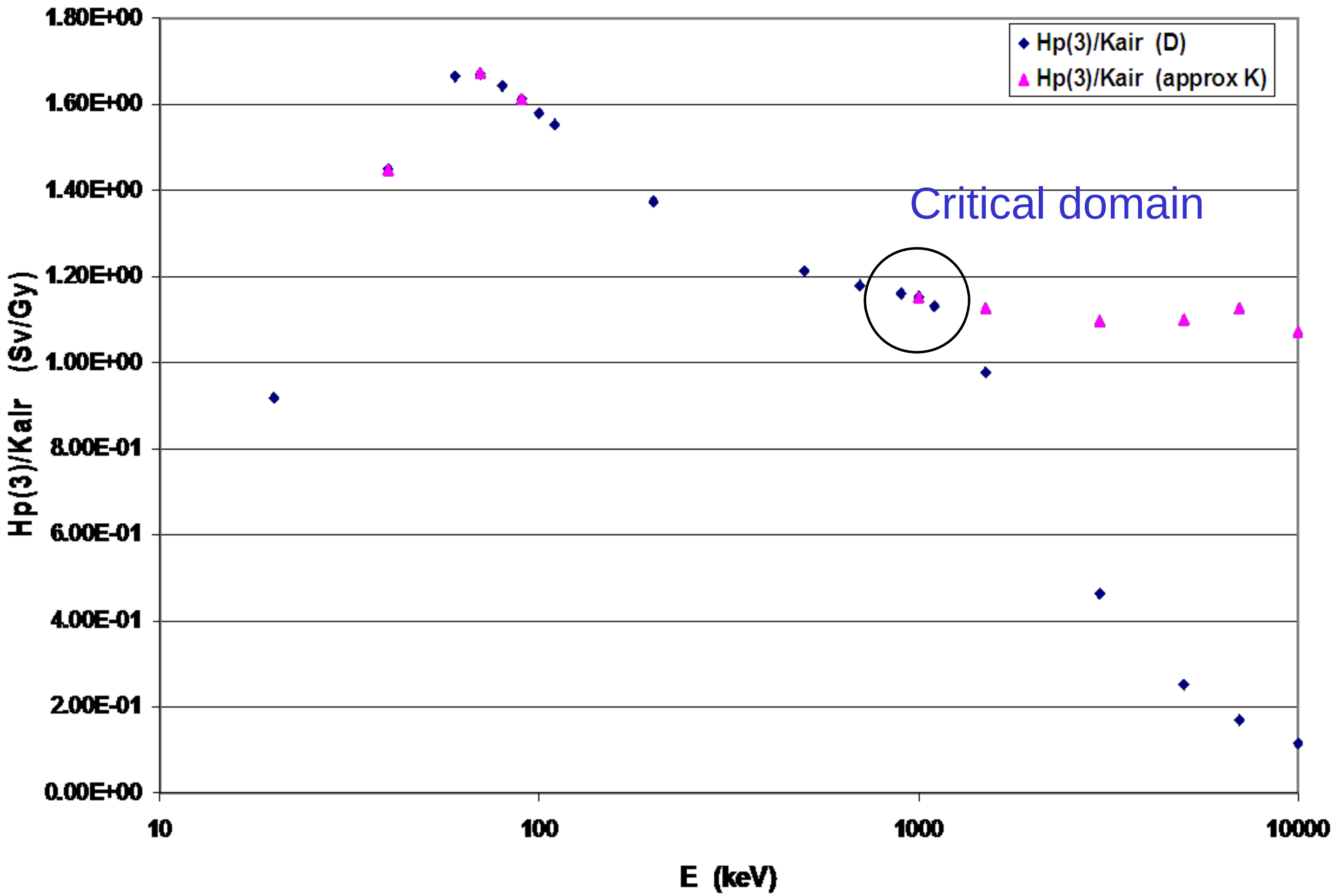
Geometry MC model of the phantom





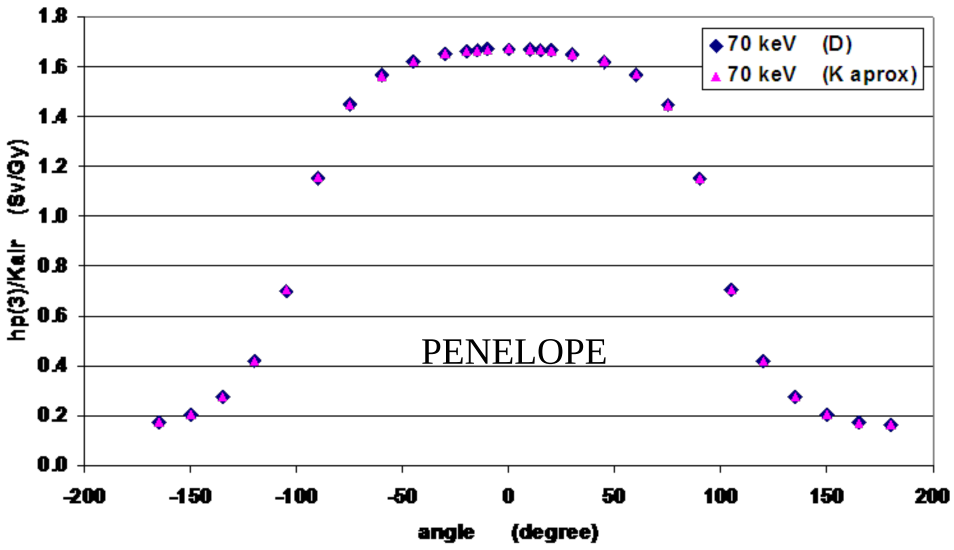
MCNP 2-D plot and 3-D Moritz™ plot of the adopted geometry
Immediate advantage: Only 1 run per energy necessary to get all the $H_p(3,\alpha)$ values in contrast with the usage of slab phantoms

KERMA vs Fully coupled photon-electron transport

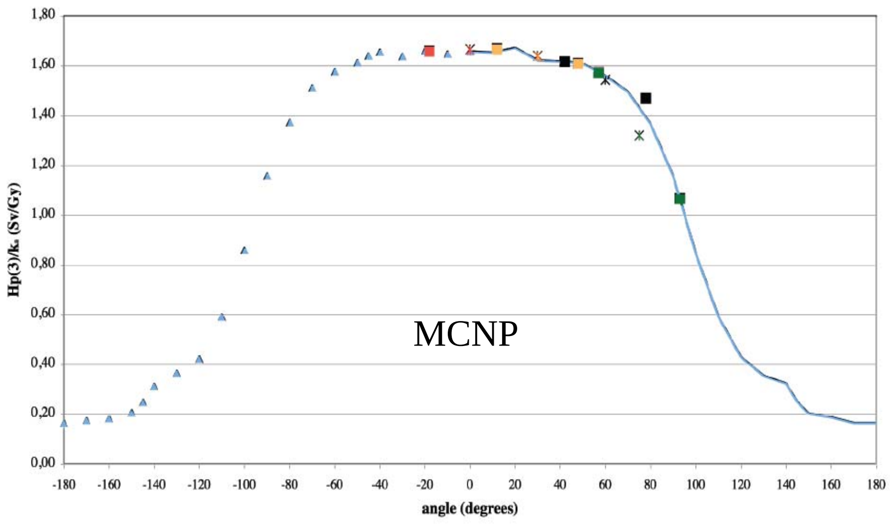


PENELOPE *Hp*(3)/*Kair* at 0 degree

70 keV

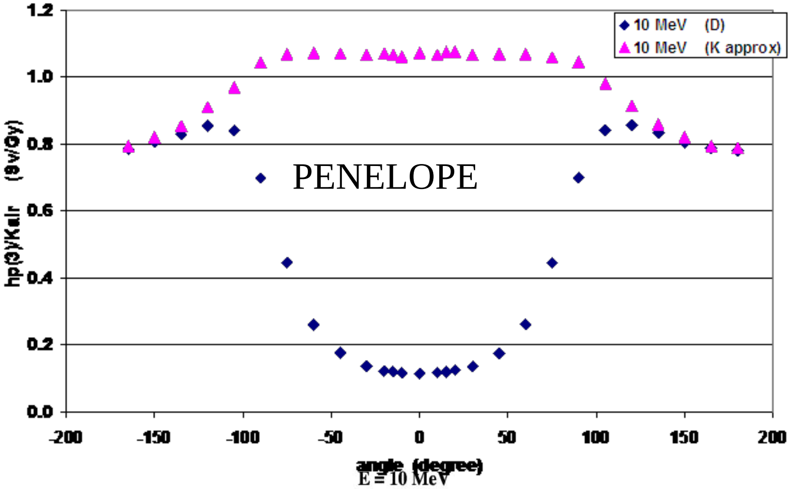


E = 70 keV

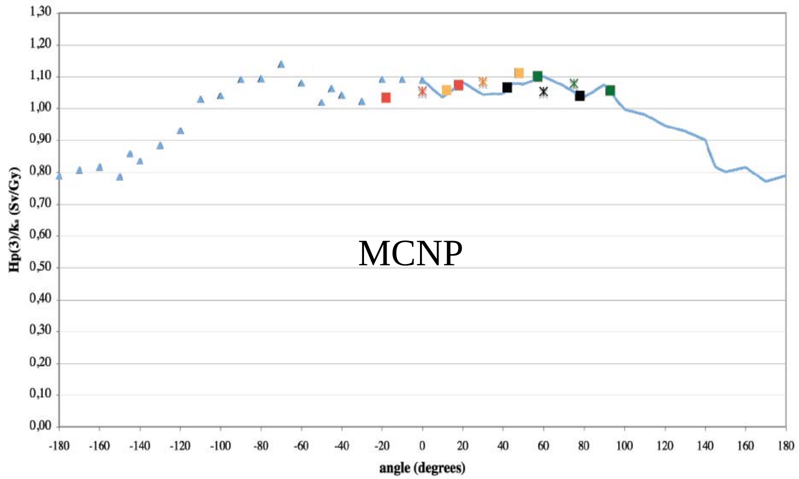


At 70 keV the kerma approximation is O.K for 3 mm depth

10 MeV

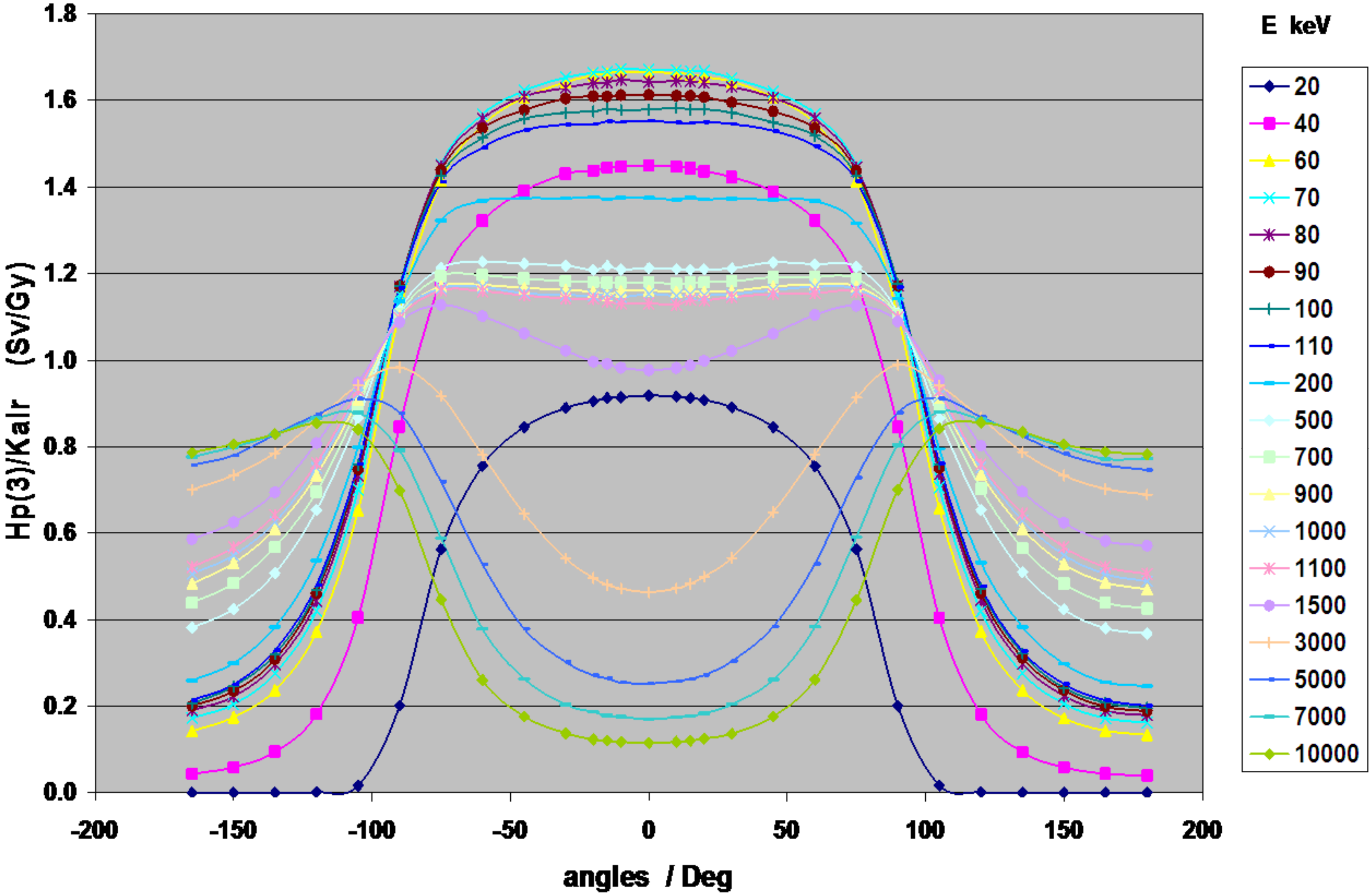


E = 10 MeV

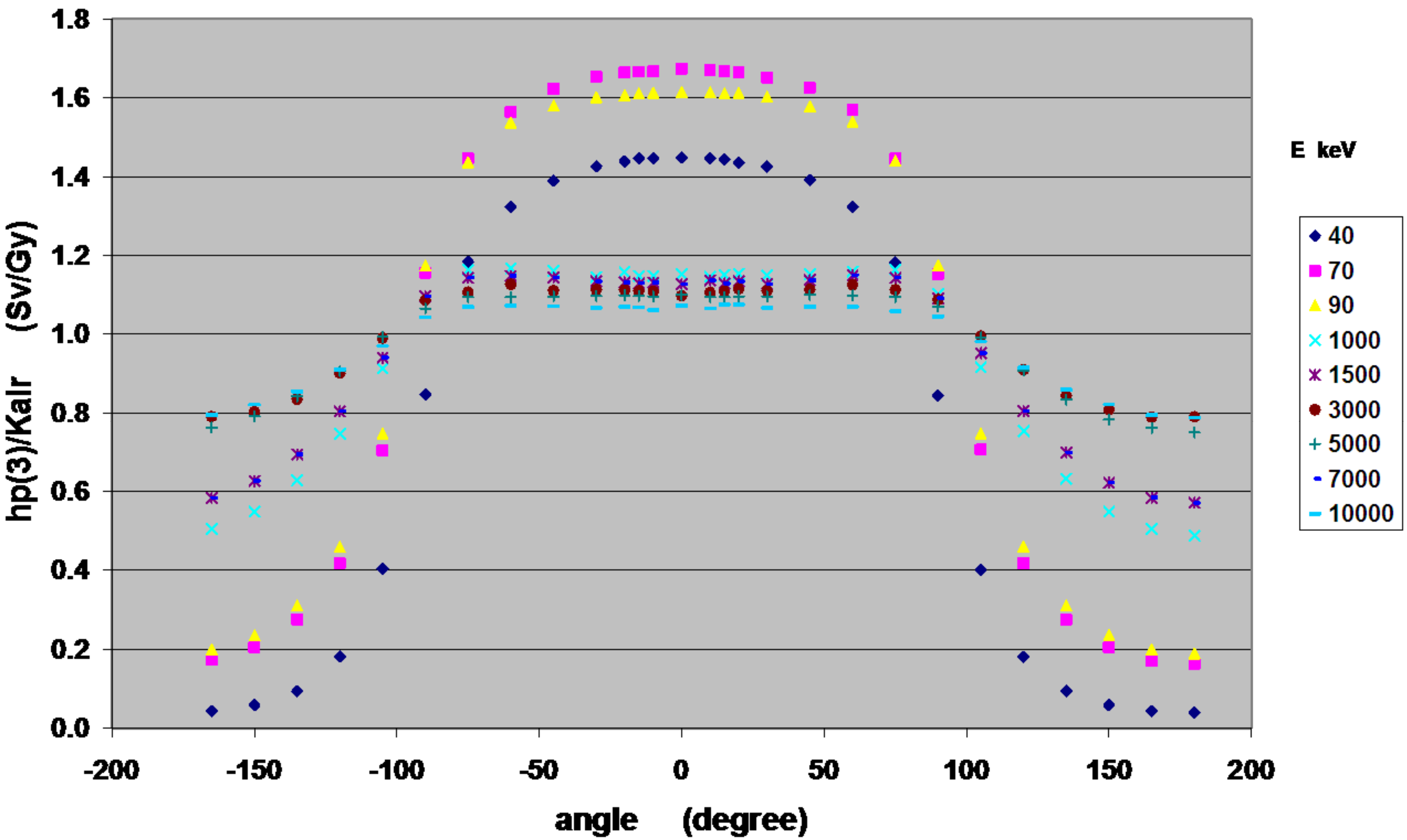


At 10 MeV (very extreme situation not of practical interest for the eye lens protection) the kerma approximation is of course not OK.

PENELOPE (photons and secondary electrons)



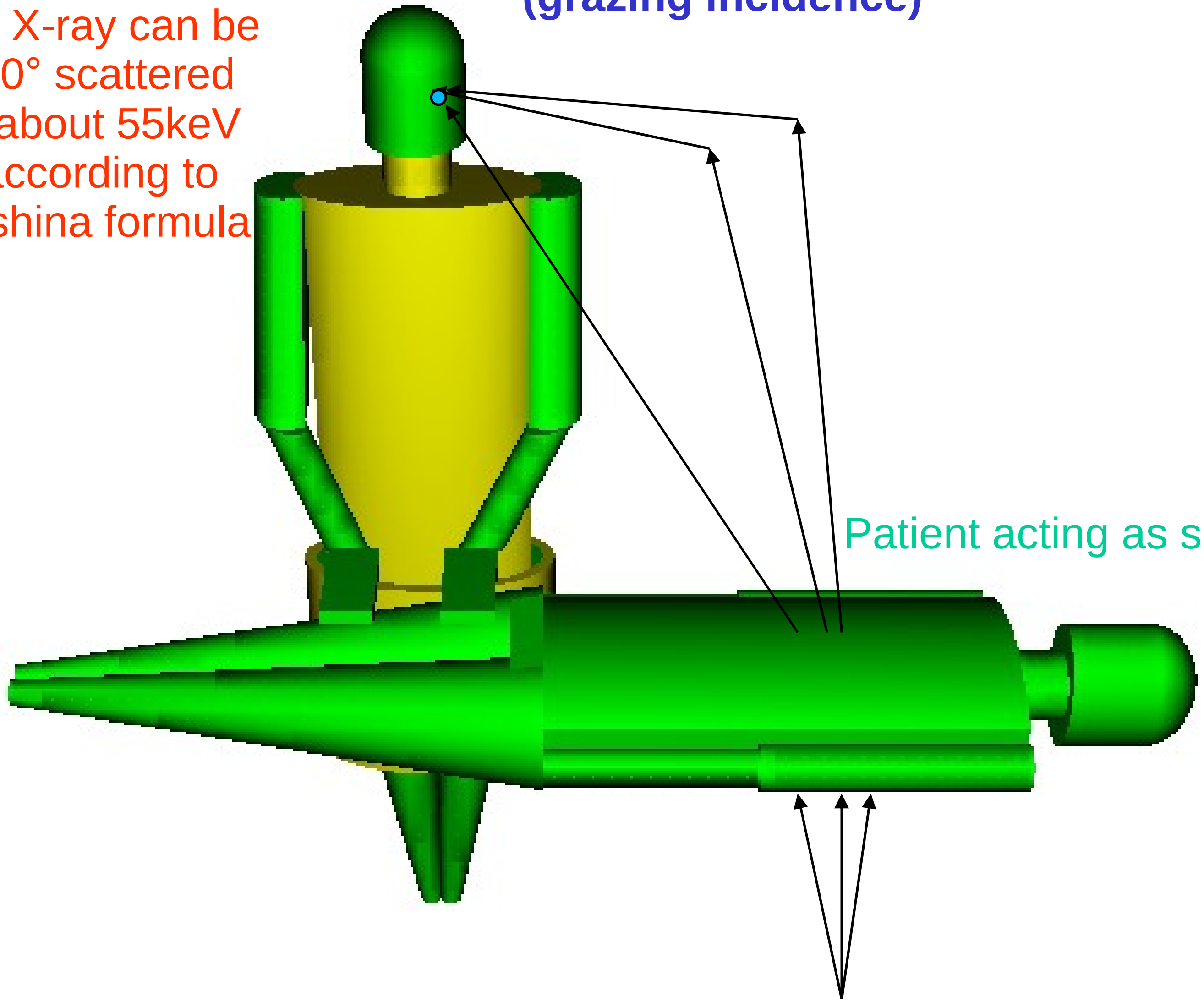
PENELOPE (pure photon transport: kerma approximation)



ADAM-MIRD type model: Typical posture for IR procedures (e.g. catheter insertion from the femoral artery) eye lens target

The typical mean energy of the source X-ray can be 60 keV, the 90° scattered Photons are about 55keV (1 collision) according to The Klein-Nishina formula

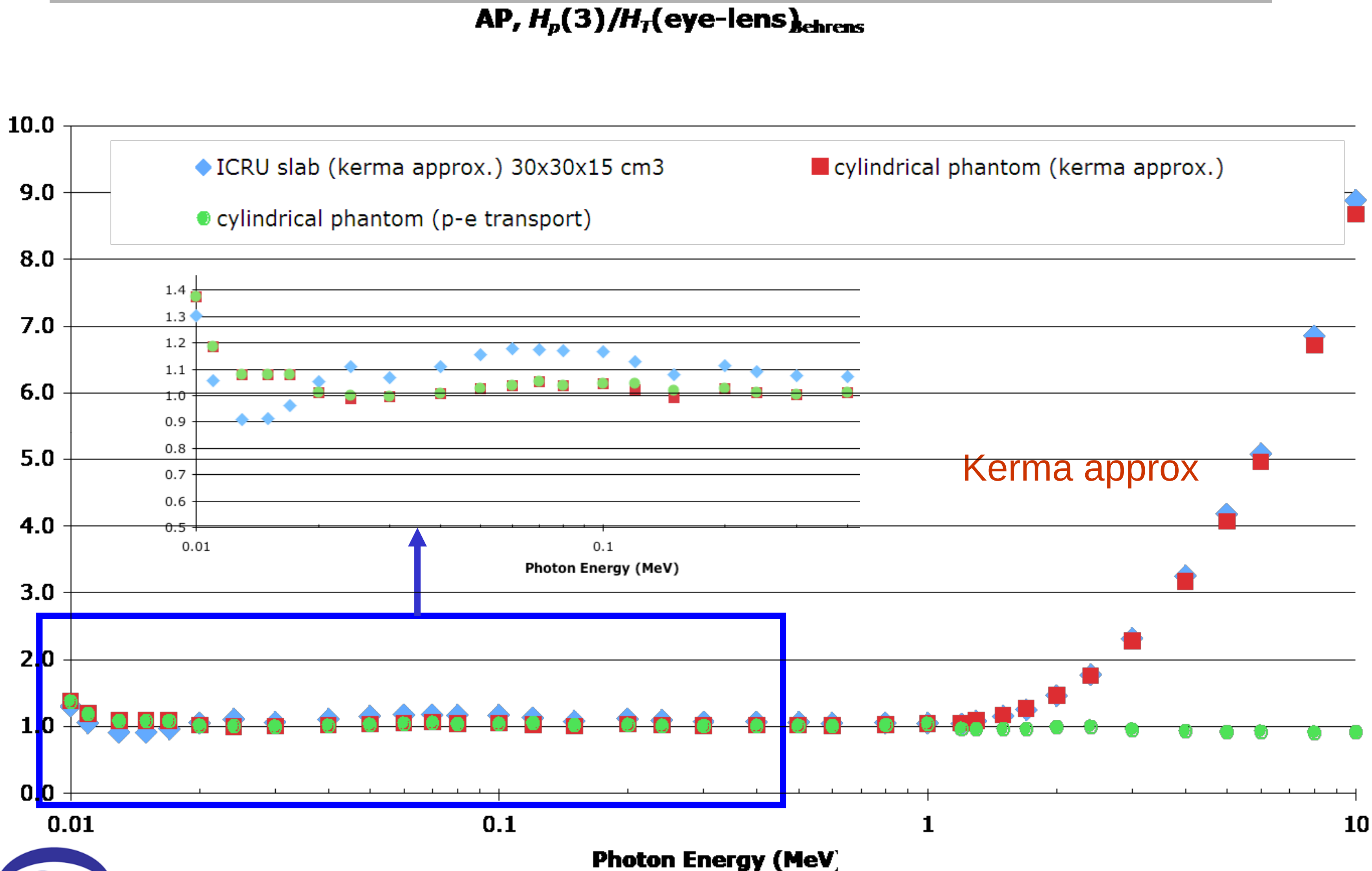
Importance of the nearly LAT exposure (grazing incidence)



TESTS ON THE CONVERSION COEFFICIENT SUITABILITY FOR PHOTONS

The new set of conversion coefficients obtained both in the kerma approximation and following also secondary electrons (p e mode) was compared with those proposed for the 30x30x15 cm^3 phantom (existing data) taking as reference quantities the H_T values by Behrens et al.

For AP the two simplified phantoms well fit the Behrens data, with an overestimate of max 20% for the ICRU slab due to the higher massive contribution to the backscatter.



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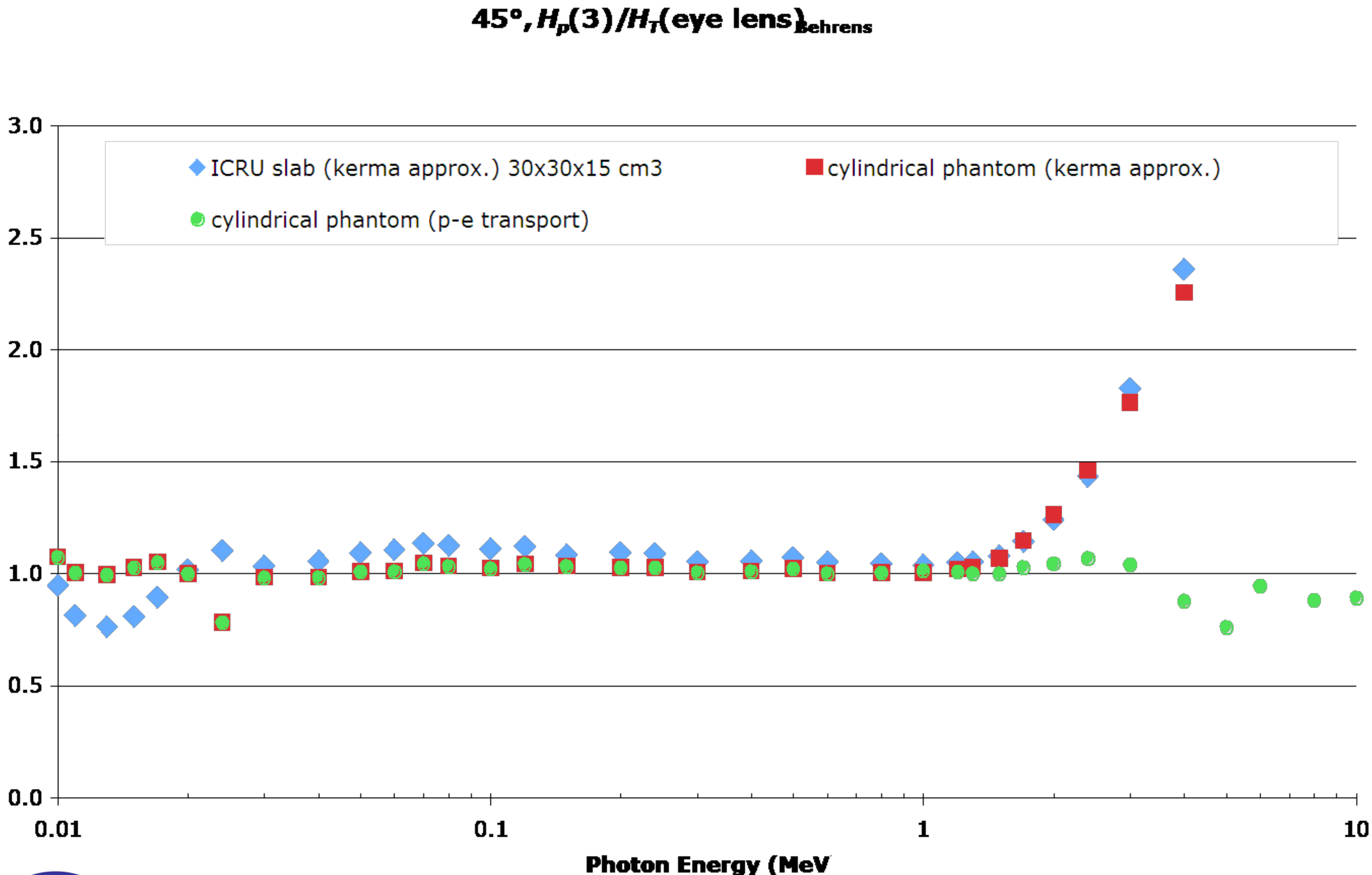
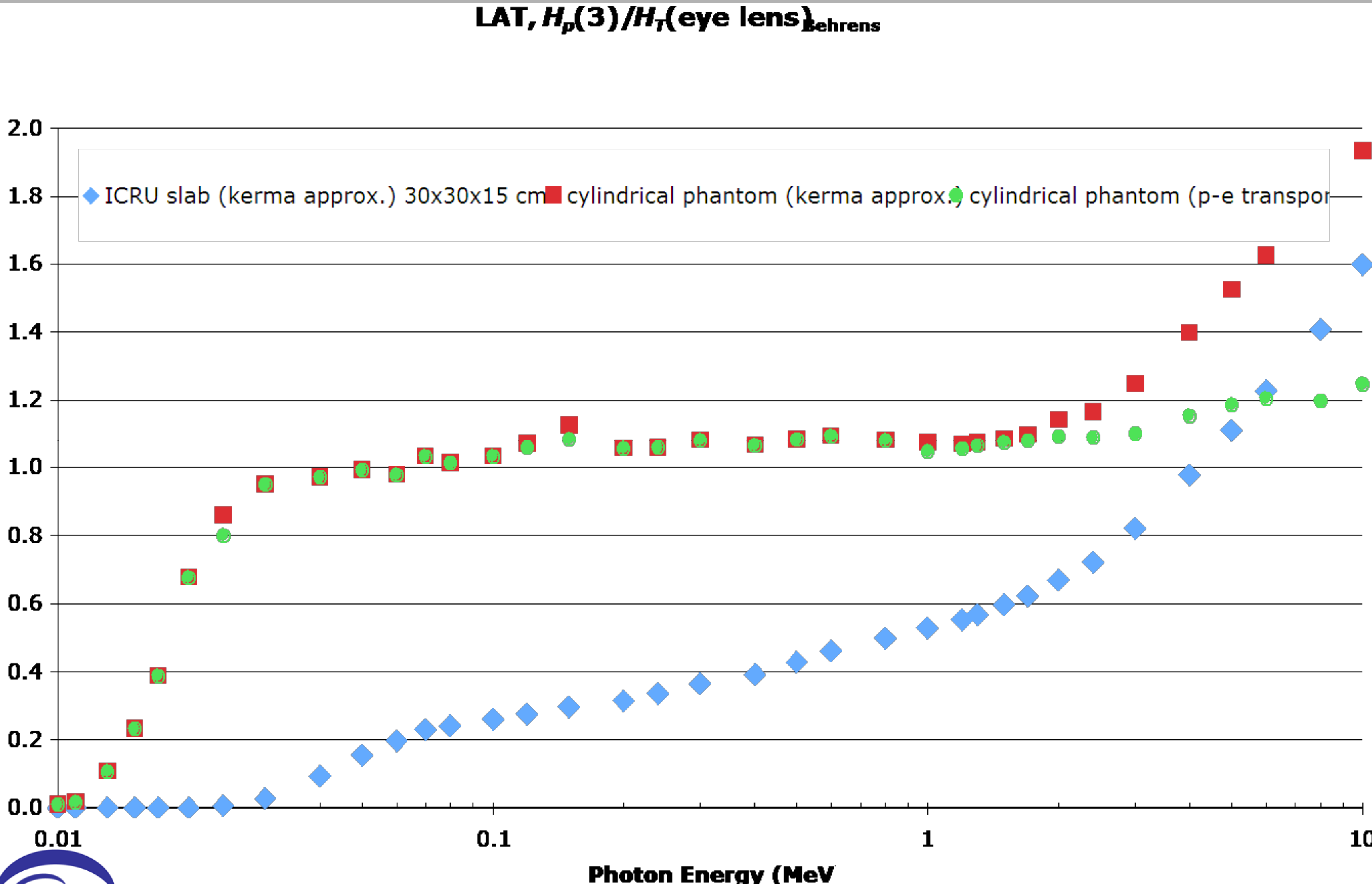
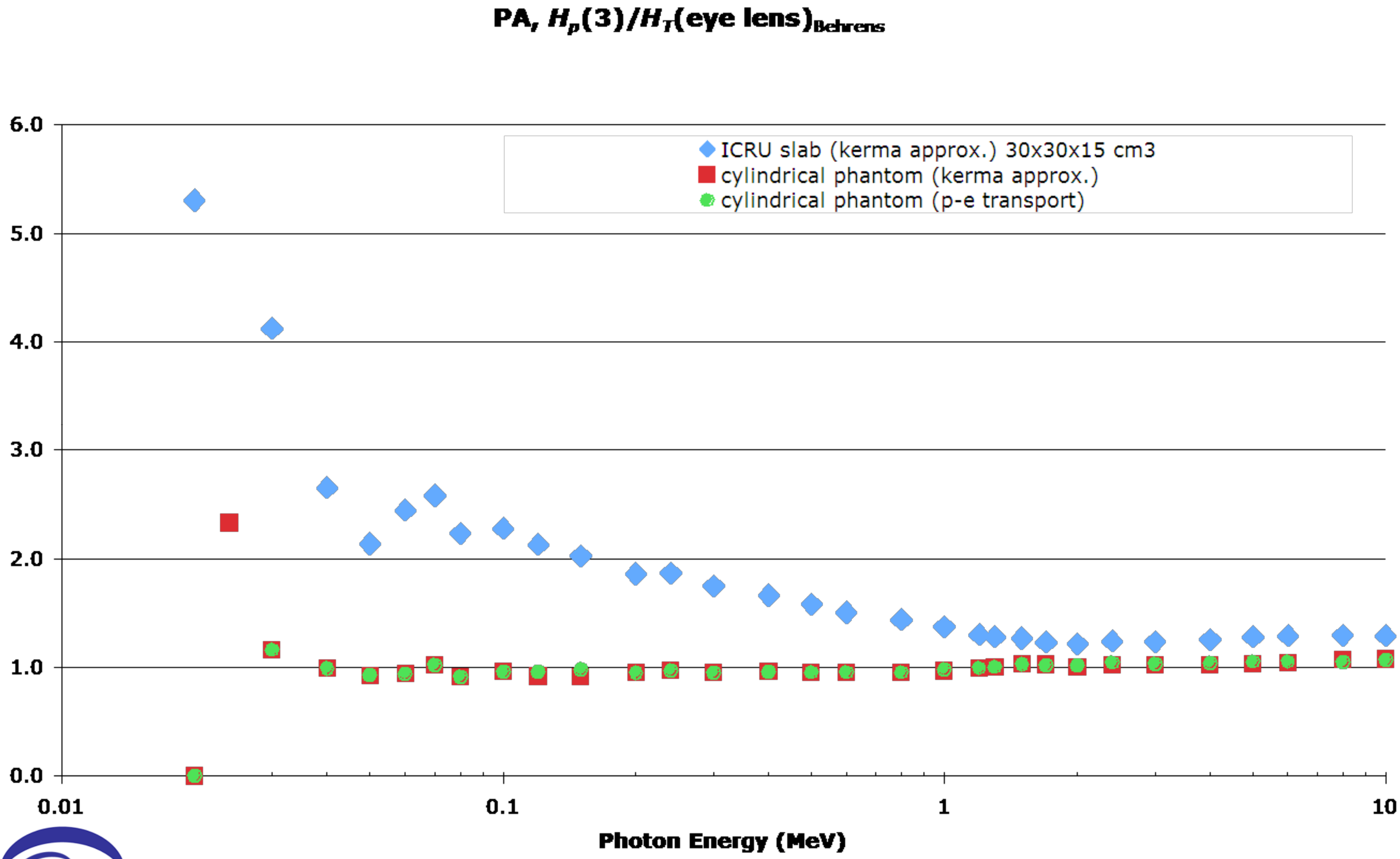
For 45° incident angle similar behaviour to 0° incidence



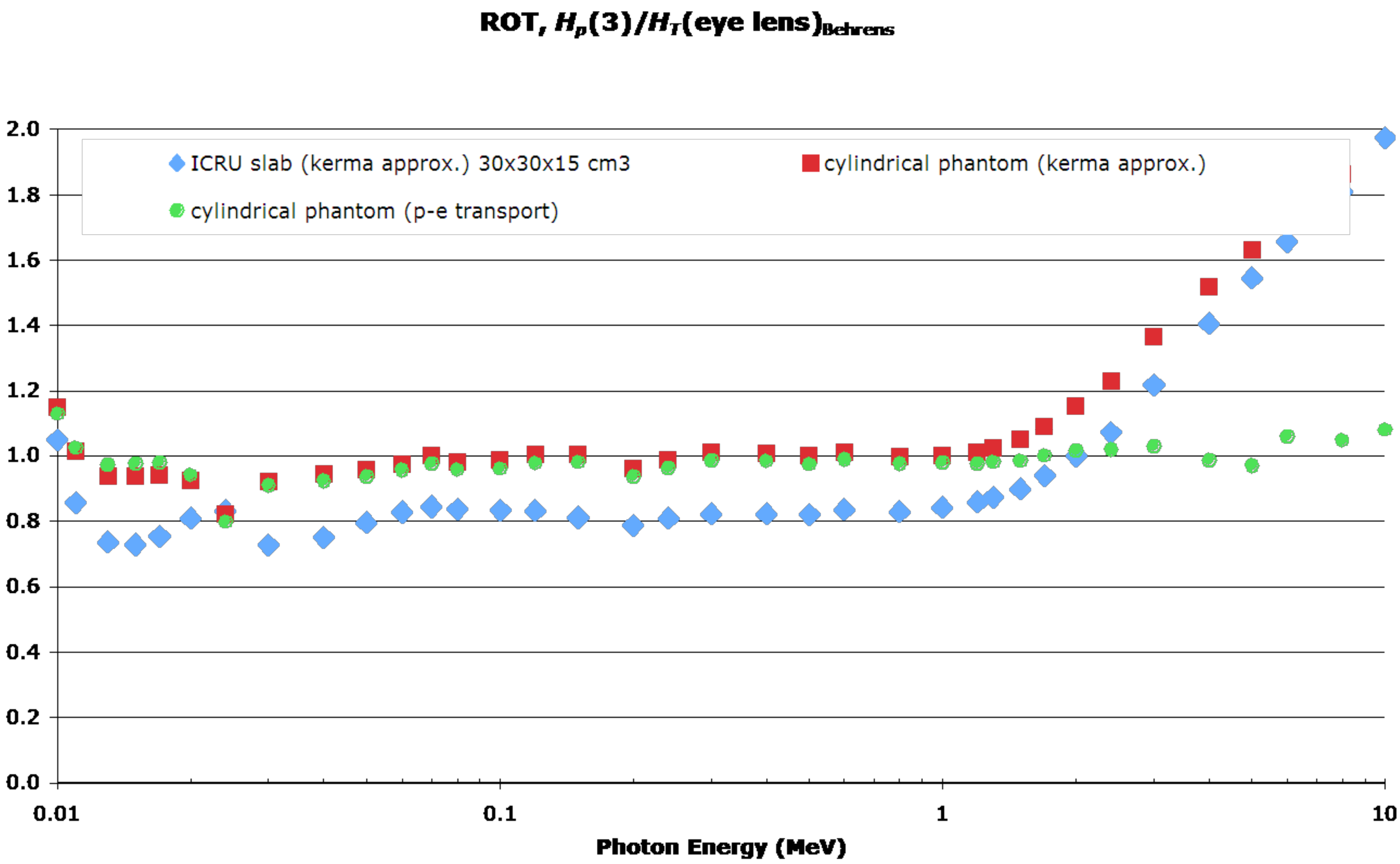
For LAT incidence the cylidrical phantom well phantoms well fit the Behrens data Above 30 keV (the geometry is here paying a critical role). The ICRU slab phantom provides very low results due to the 90° edge shielding effect.



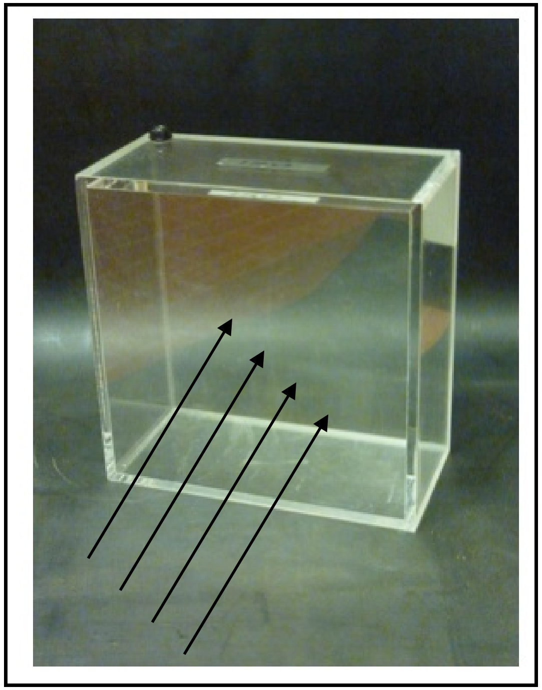
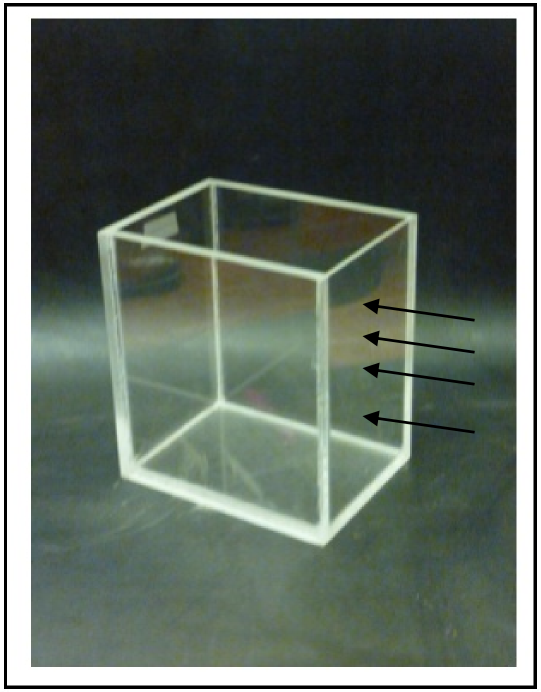
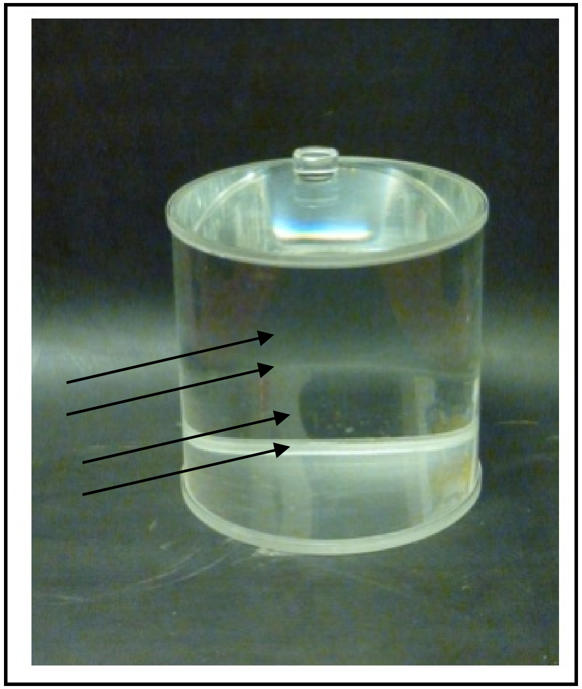
For PA (180°) due to the geometry of the head used in the H_T calculations, again for energies higher than 30 keV the cylinder better fits the limiting quantity whilst the slab overestimates (15 cm thickness is too scarce to comply with the head major axis (about 20 cm))



The cylinder herewith proposed is also well fitting the Behrens data in ROT Exposure. The grazing incident angles give small contributions for the slab therefore inplying an underestimation of the organ equivalent dose of about 25%



MC simulations to support calibrations (Backscatter factor studies)

From the left: 1- ISO 30x30x15 cm3 slab calibration phantom
2- Reduced 15x20x20 slab calibration phantom (previous ENEA proposal)
3- Cylindrical calibration phantom (20 cm diameter 20 cm height) (this work)

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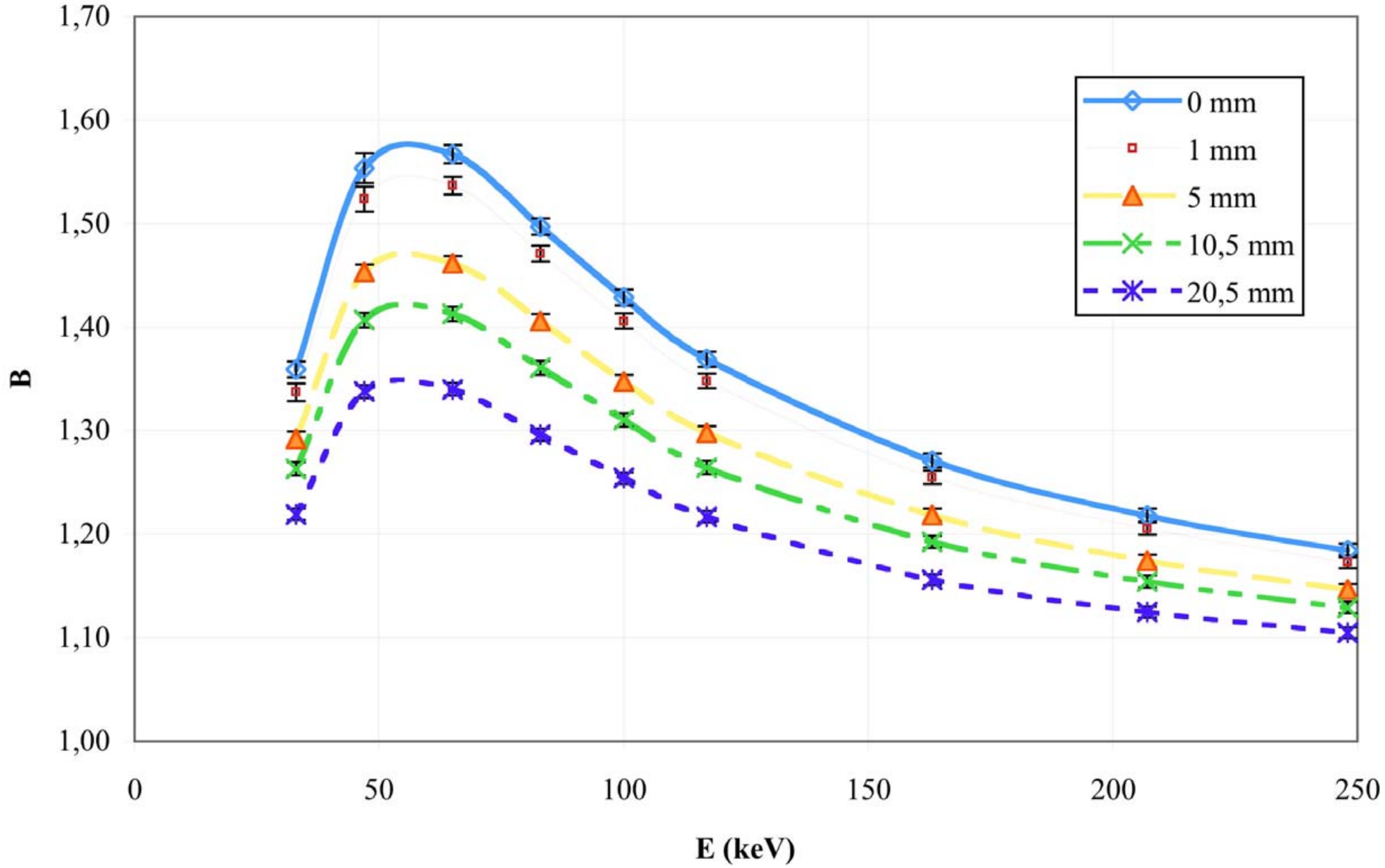
Air kerma backscatter factor for the proposed cylinder for 0° incident angle



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Usefulness of the backscatter factor knowledge

- The backscatter factor is a phantom-dependent parameter. It should as much as possible reproduce the real situation when the dosemeter is worn on the operator body (trunk (where? abdomen-chest etc…it makes difference!!!!)-head-wrist-finger-ankle etc.)
- It is possible to compare the parameter (also angle dependent) among various potentially chosen calibration phantoms. Such a parameter is one of those guiding the ISO choices (e.g. the taken decision to introduce two specific phantoms for the wrist/ankle and finger)

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FURTHER DELIVERABLES of TASK2 (1)

Type test and calibration Protocol

All the procedure for type testing and calibrating dosemeters in terms of $H_p(3)$ using the new cylindrical proposed phantom is described in detail in a Report (Deliverable of ORAMED)

It will be presented within this Workshop

Bordy, Jean Marc

"PROPOSAL FOR EYE-LENS DOSEMETER CALIBRATION AND TYPE TESTING"

FURTHER DELIVERABLES of TASK2 (2)

Design and fabrication of a dosemeter optimized to respond in terms of $H_p(3)$

Monte Carlo and experimental work were coupled to obtain a design and a prototype of a dosemeter well suited for $H_p(3)$, developed at RADCARD (Pl)

Its main features will be presented in the present Workshop

Bilski, Pawel

A NEW DOSEMETR FOR MEASUREMENTS OF $H_p(3)$ FOR MEDICAL STAFF

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Future Work and conclusions

To complete the study about the operational quantity the future plans are to calculate conversion coefficients for electrons until 10 MeV for the same cylindrical model.

Also neutron exposure situations will be analyzed in a second moment.

The opinion of the authors is that the adoption of a cylindrical phantom should guarantee a better simulation of the real head in which the eyes are located and a higher accuracy in the overall dosimetric procedure at least for photons. This has to be considered a feasibility study and a proposal in the framework of an increased interest about eye lens dosimetry, to guarantee a good quality assurance process in all the steps of the dosimetry assessment.

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THANK YOU FOR YOUR ATTENTION !!

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