Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Angular dependence of $H_p(3)$ – *radial vs. polar rotation* – RAP25-17

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PTB, Department ”Radiation protection dosimetry” (6.3)

Hyperlinks underlined and in light blue

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Radiation transport simulations for $H_p(3)$ (EGSnrc, EGSpp)

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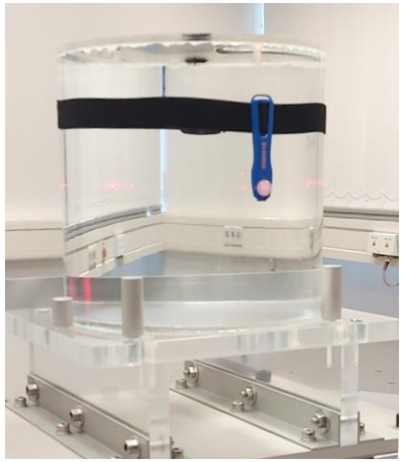
Introduction: motivation

Eye lens dosemeters for $H_p(3)$

Typical
eye lens dosemeter

https://awst.mirion.com/leistungen-produkte/teilkorperdosimetrie/augenlinsendosimeter/

usual type test
geometry

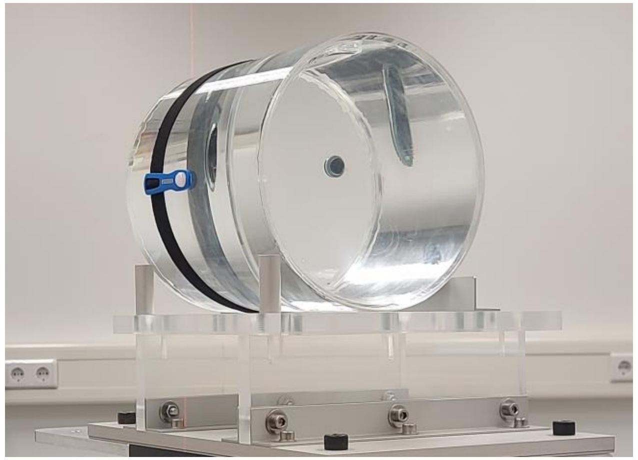


Photograph: PTB, Khanbabaee

but
... typical irradiation geometry:
oblique from bottom

https://www.klinikum-lueneburg.de/diagnostische-und-interventionelle-radiologie/interventionelle-radiologie/

➔ additional type test geometry:
oblique from bottom



Photograph: PTB, Khanbabaee

radial rotation vs. polar rotation

The same conventional quantity (true) value?
In other words: the same conversion coefficient for $H_p(3)$ for radial and polar rotation?

Contents

Definition of $H_p(3)$

Personal dose equivalent at a **depth of 3 mm *in* the person** at the point where the dosemeter is worn, $\mathbf{H_p(3)}$

- Conservative: $\mathbf{H_p(3) \geq H_{lens}}$ (homogeneous field)
- 3 mm is the approximate depth of the eye lens

Eye lens dosemeter
worn at representative position

Accordingly:

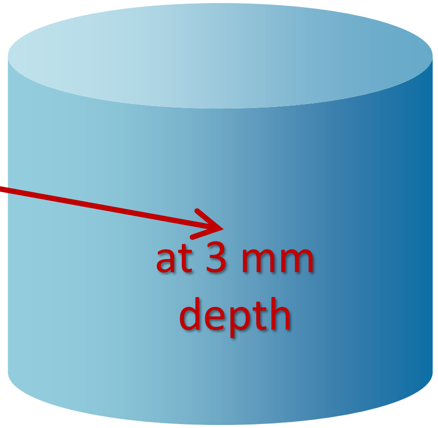
$H_p(10) \geq E$

$H_p(0.07) \geq H_{local\ skin}$

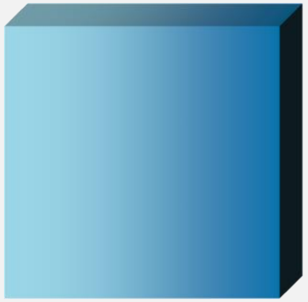
Definition of $H_p(3)$ – for calibration

For calibration at a **depth of 3 mm *in* a cylinder phantom** made of **ICRU 4-element tissue, $H_p(3)$**

- Conservative: $H_p(3) \geq H_{lens}$ (homogeneous field)
- 3 mm is the approximate depth of the eye lens



Accordingly:



$H_p(10) \geq E$

$H_p(0.07) \geq H_{\text{local skin}}$

Eye lens dose

represented at 3 mm depth

Calibration in $H_p(3)$

Calibration *on* a waterfilled PMMA cylinder phantom
to mimic the backscatter of a person:
$H_p(3)$

Eye lens dosemeter
on appropriate phantom

Accordingly:

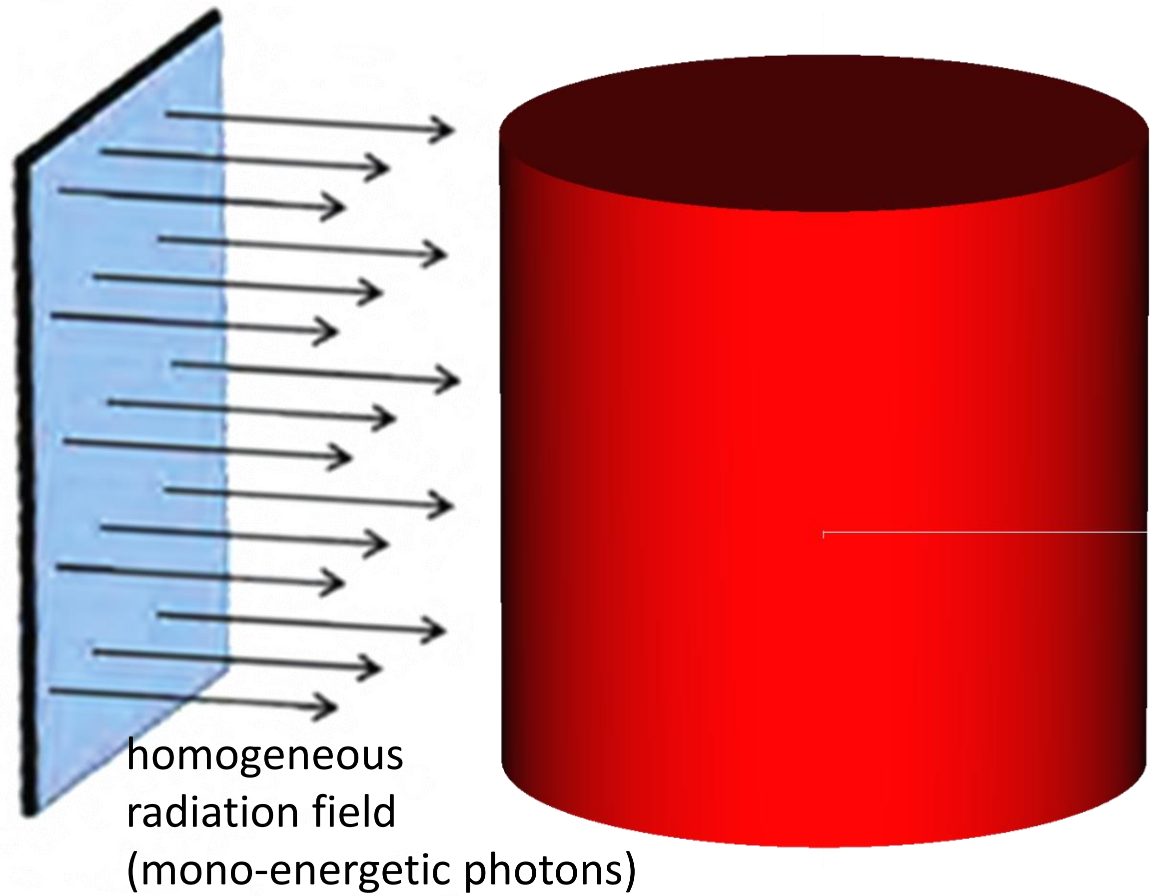
$H_p(10)$

$H_p(0.07)$

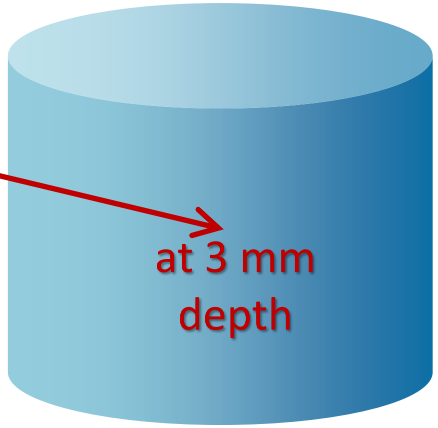
Contents

Calculation of $H_p(3)$ – for calibration: photons

Calculation at a **depth of 3 mm *in* a cylinder phantom** made of **ICRU 4-element tissue, $H_p(3)$**



0° polar
= 0° radial

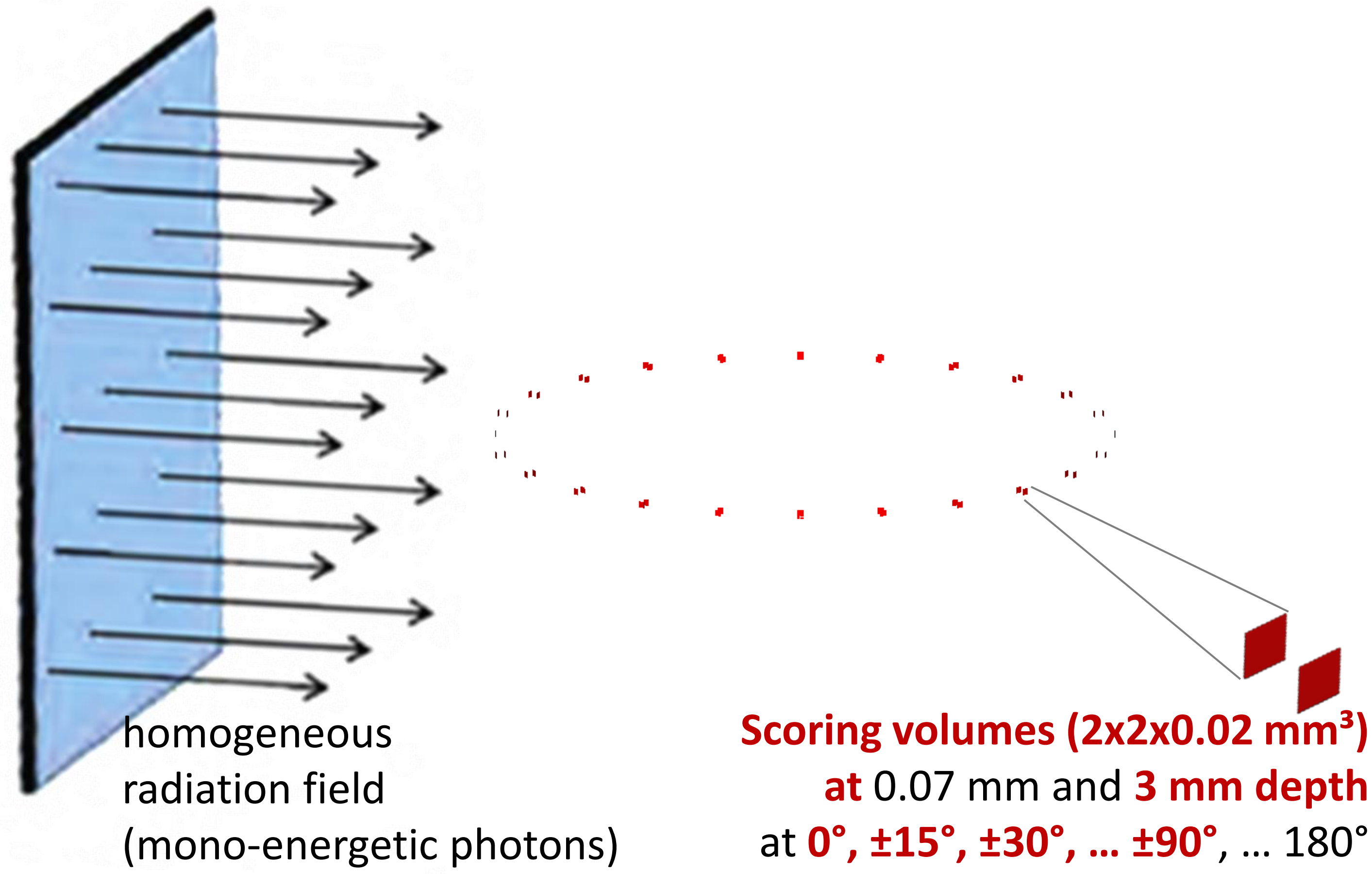


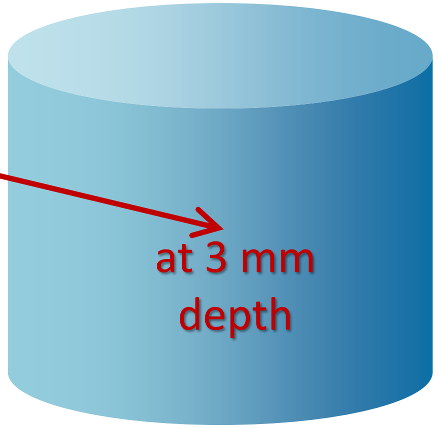
Eye lens dose
represented at 3 mm depth

➔ **radial rotation** calculated **simultaneously**

Calculation of $H_p(3)$ – for calibration: photons

Calculation at a **depth of 3 mm *in* a cylinder phantom** made of **ICRU 4-element tissue, $H_p(3)$**



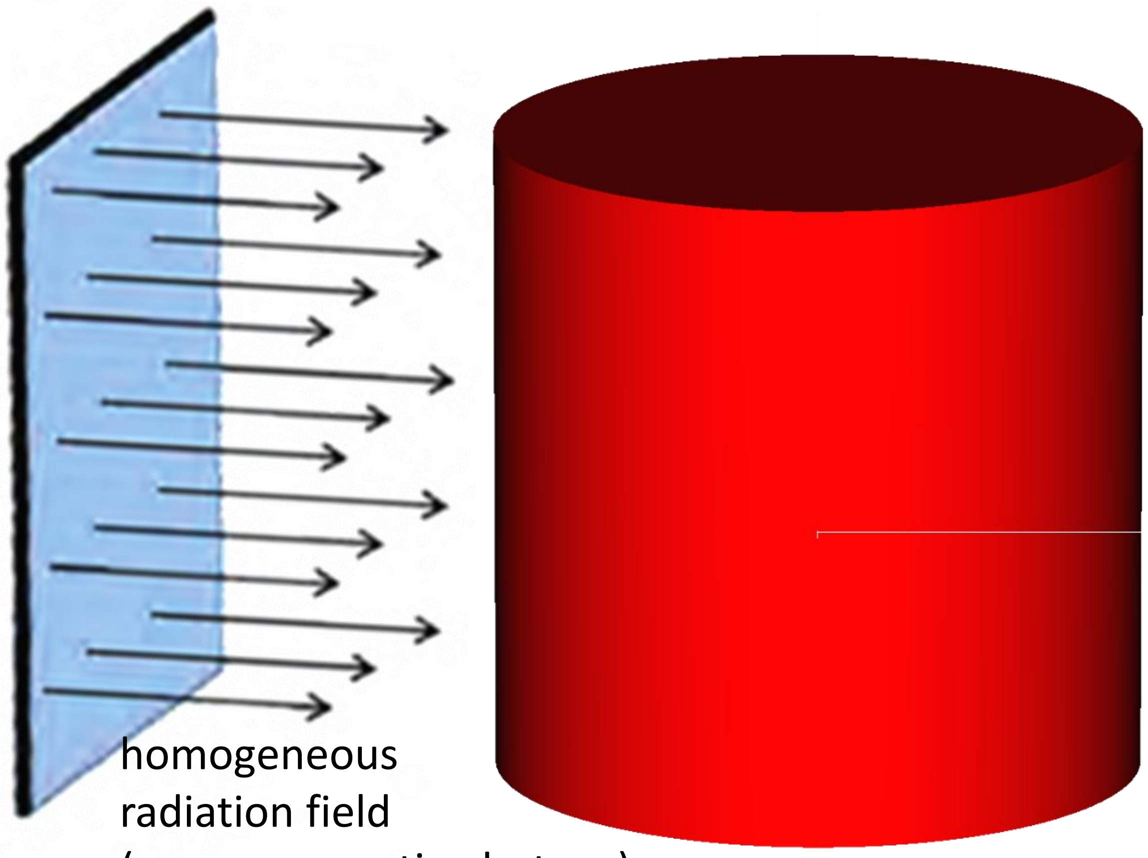


Scoring volumes (2x2x0.02 mm³)
at 0.07 mm and **3 mm depth**
at **0°, ±15°, ±30°, … ±90°**, … 180° ➔ **radial rotation** calculated **simultaneously**

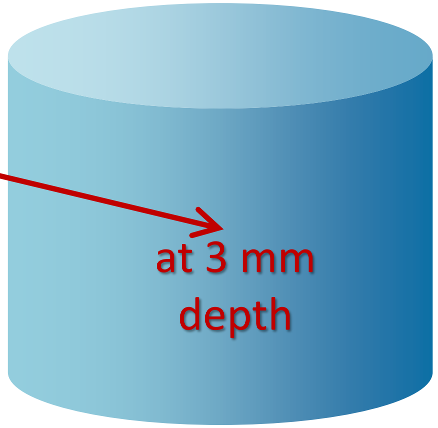
Eye lens dose
represented at 3 mm depth

Calculation of $H_p(3)$ – for calibration: photons

Calculation at a **depth of 3 mm *in* a cylinder phantom** made of **ICRU 4-element tissue, $H_p(3)$**



0° polar
= 0° radial

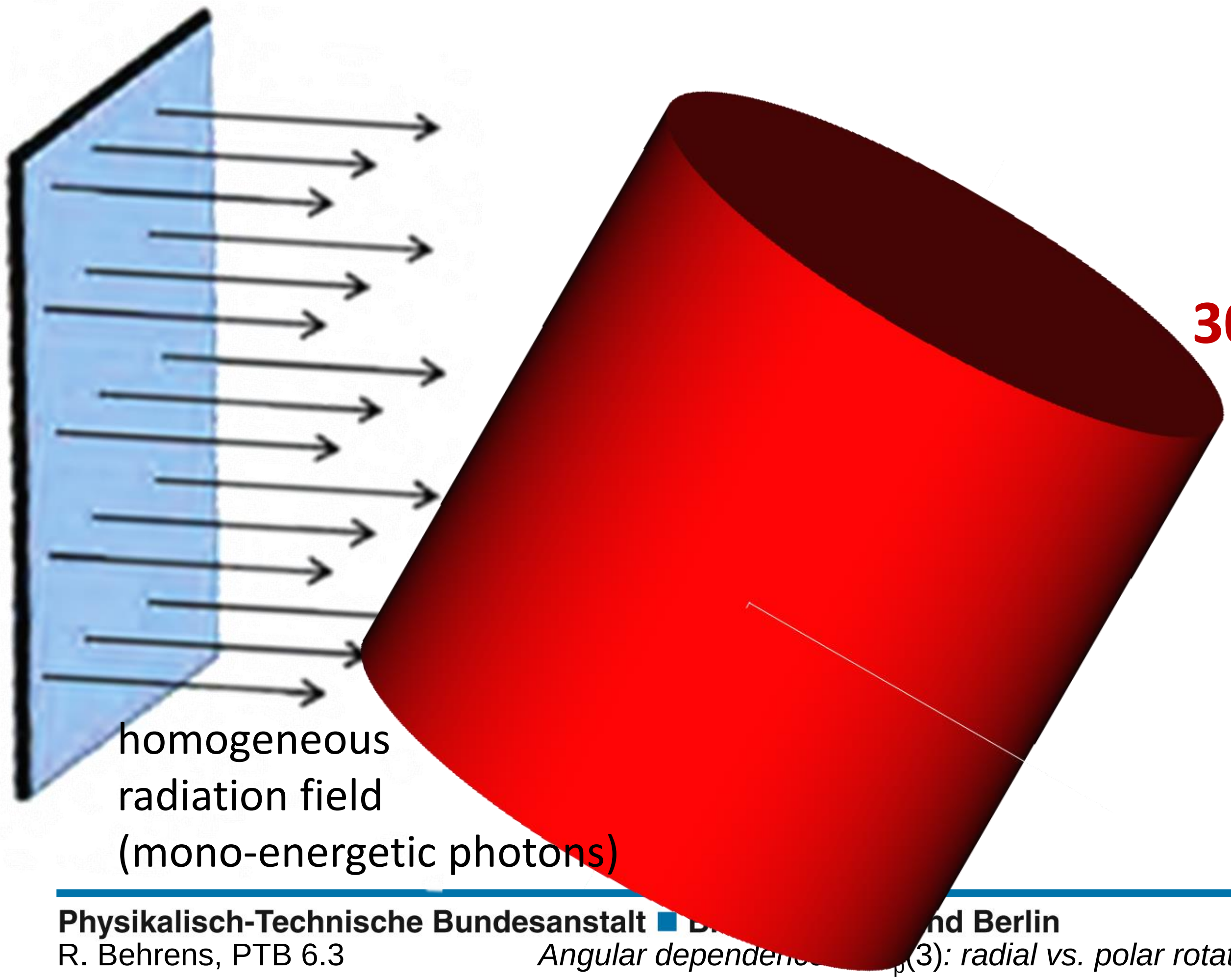


Eye lens dose
represented at 3 mm depth

➔ **radial rotation** calculated **simultaneously**

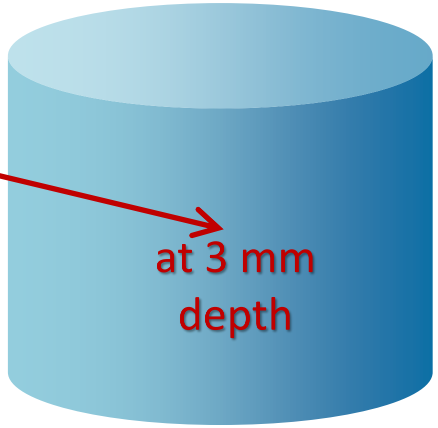
Calculation of $H_p(3)$ – for calibration: photons

Calculation at a **depth of 3 mm *in* a cylinder phantom**
made of **ICRU 4-element tissue, $H_p(3)$**



homogeneous
radiation field
(mono-energetic photons)

30° polar:
0°, 15°, 30°, … 90°



Eye lens dose
represented at 3 mm depth

➔ **polar rotation** calculated **separately**

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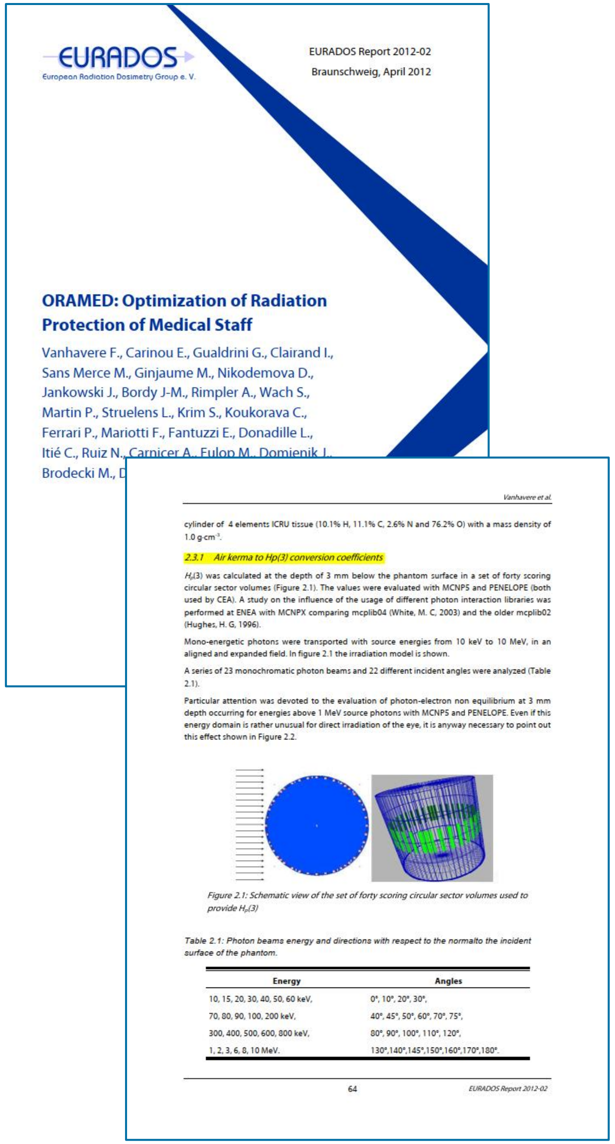
Introduction

Definition of $H_p(3)$

Radiation transport simulations for $H_p(3)$ (EGSnrc, EGSpp)

Results for photons

Results: photons, $H_p(3)$ — validation: ORAMED mean(PENELOPE;MCNP5)



EURADOS
European Radiation Dosimetry Group e. V.

EURADOS Report 2012-02
Braunschweig, April 2012

ORAMED: Optimization of Radiation Protection of Medical Staff

Vanhavere F., Carinou E., Gualdrini G., Clairand I., Sans Merce M., Ginjaume M., Nikodemova D., Jankowski J., Bordy J-M., Rimpler A., Wach S., Martin P., Struelens L., Krim S., Koukorava C., Ferrari P., Mariotti F., Fantuzzi E., Donadille L., Itié C., Ruiz N., Carnicer A., Fulop M., Domienik J., Brodecki M., D

Vanhavere et al.

cylinder of 4 elements ICRU tissue (10.1% H, 11.1% C, 2.6% N and 76.2% O) with a mass density of 1.0 g·cm^{-3}.

2.3.1 Air kerma to Hp(3) conversion coefficients

$H_p(3)$ was calculated at the depth of 3 mm below the phantom surface in a set of forty scoring circular sector volumes (Figure 2.1). The values were evaluated with MCNP5 and PENELOPE (both used by CEA). A study on the influence of the usage of different photon interaction libraries was performed at ENEA with MCNPX comparing mcplib04 (White, M. C, 2003) and the older mcplib02 (Hughes, H. G, 1996).

Mono-energetic photons were transported with source energies from 10 keV to 10 MeV, in an aligned and expanded field. In figure 2.1 the irradiation model is shown.

A series of 23 monochromatic photon beams and 22 different incident angles were analyzed (Table 2.1).

Particular attention was devoted to the evaluation of photon-electron non equilibrium at 3 mm depth occurring for energies above 1 MeV source photons with MCNP5 and PENELOPE. Even if this energy domain is rather unusual for direct irradiation of the eye, it is anyway necessary to point out this effect shown in Figure 2.2.

Figure 2.1: Schematic view of the set of forty scoring circular sector volumes used to provide $H_p(3)$

Table 2.1: Photon beams energy and directions with respect to the normalto the incident surface of the phantom.

Energy	Angles
10, 15, 20, 30, 40, 50, 60 keV,	0°, 10°, 20°, 30°,
70, 80, 90, 100, 200 keV,	40°, 45°, 50°, 60°, 70°, 75°,
300, 400, 500, 600, 800 keV,	80°, 90°, 100°, 110°, 120°,
1, 2, 3, 6, 8, 10 MeV.	130°,140°,145°,150°,160°,170°,180°.

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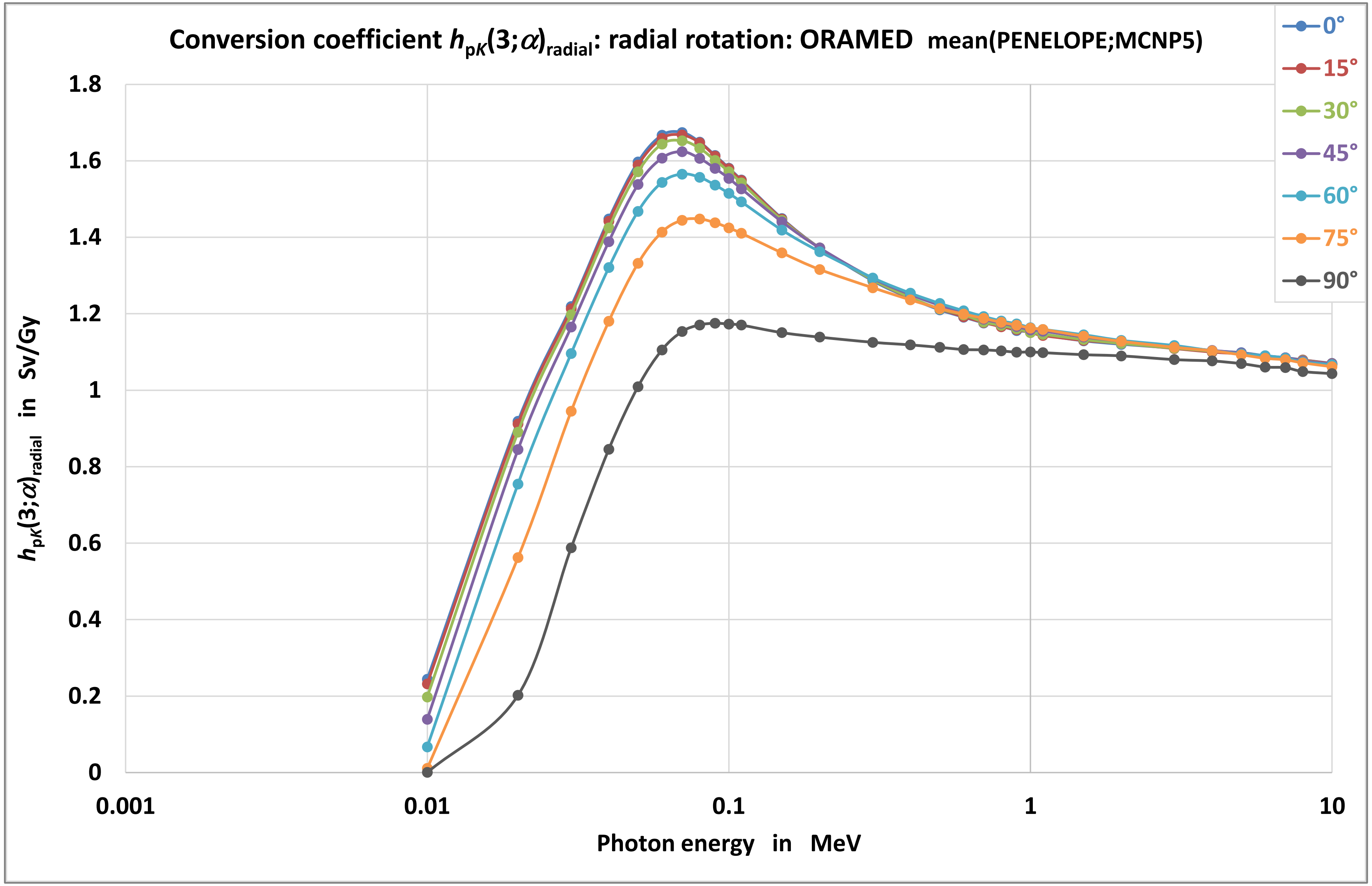
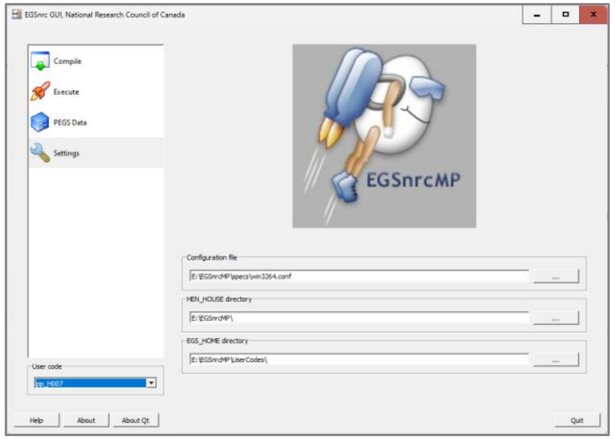
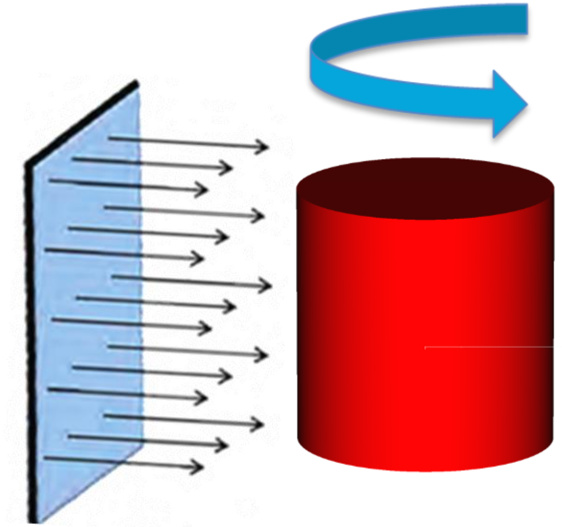
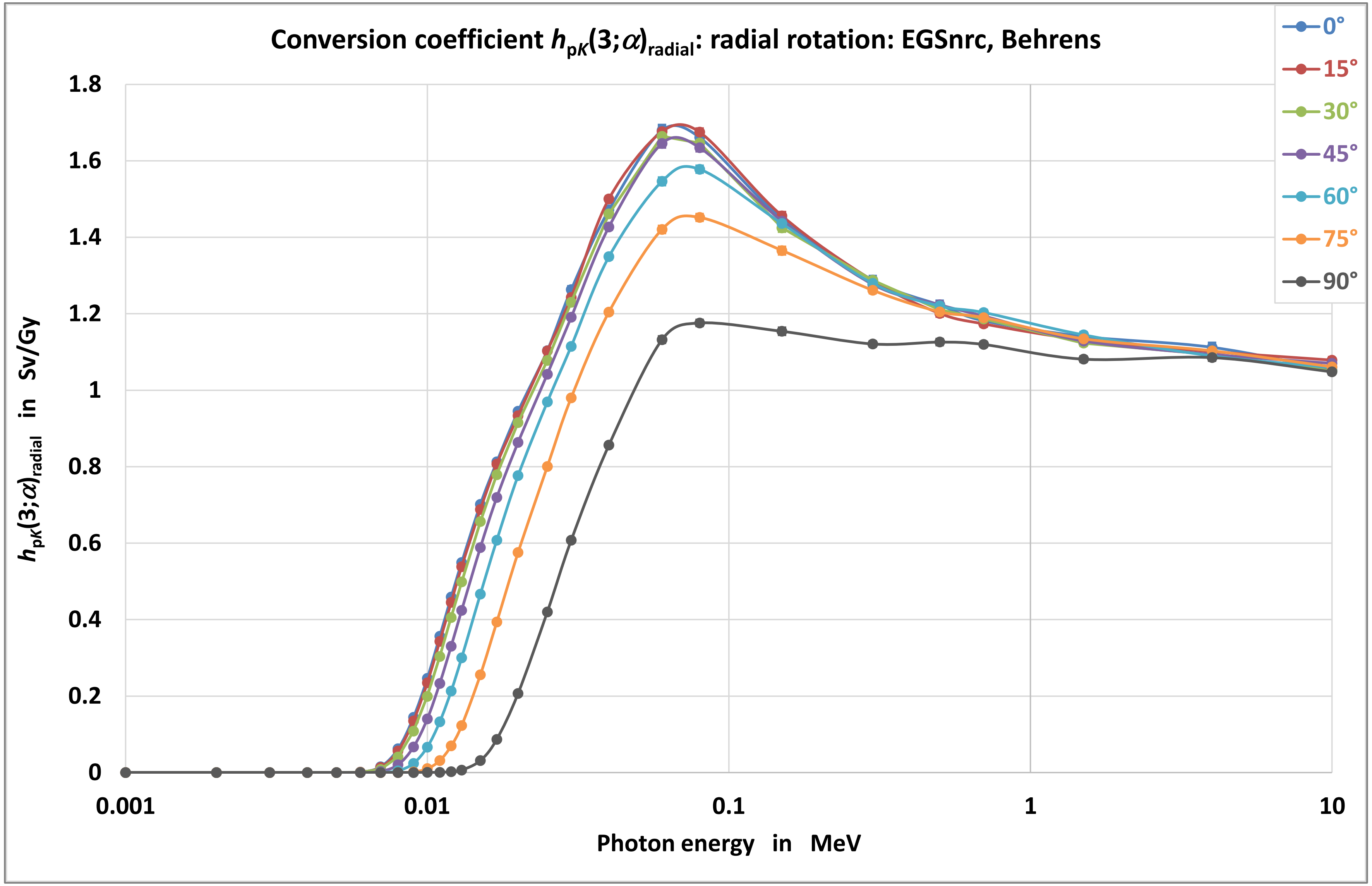


Results: photons, $H_p(3)$ – validation: EGSnrc



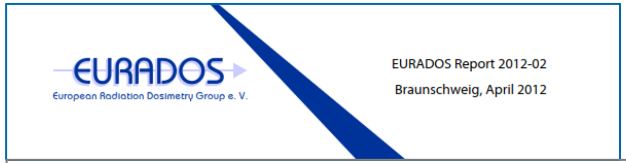




Results: photons, $H_p(3)$ – validation: *ratio: EGSnrc/ORAMED*

Ratio:

$$\frac{\mathit{EGSnrc}}{\mathit{mean(PENELOPE;MNCN5)}}$$



Cross section variability

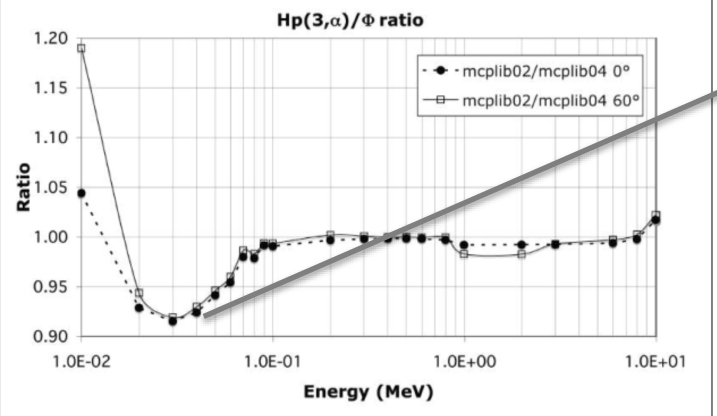
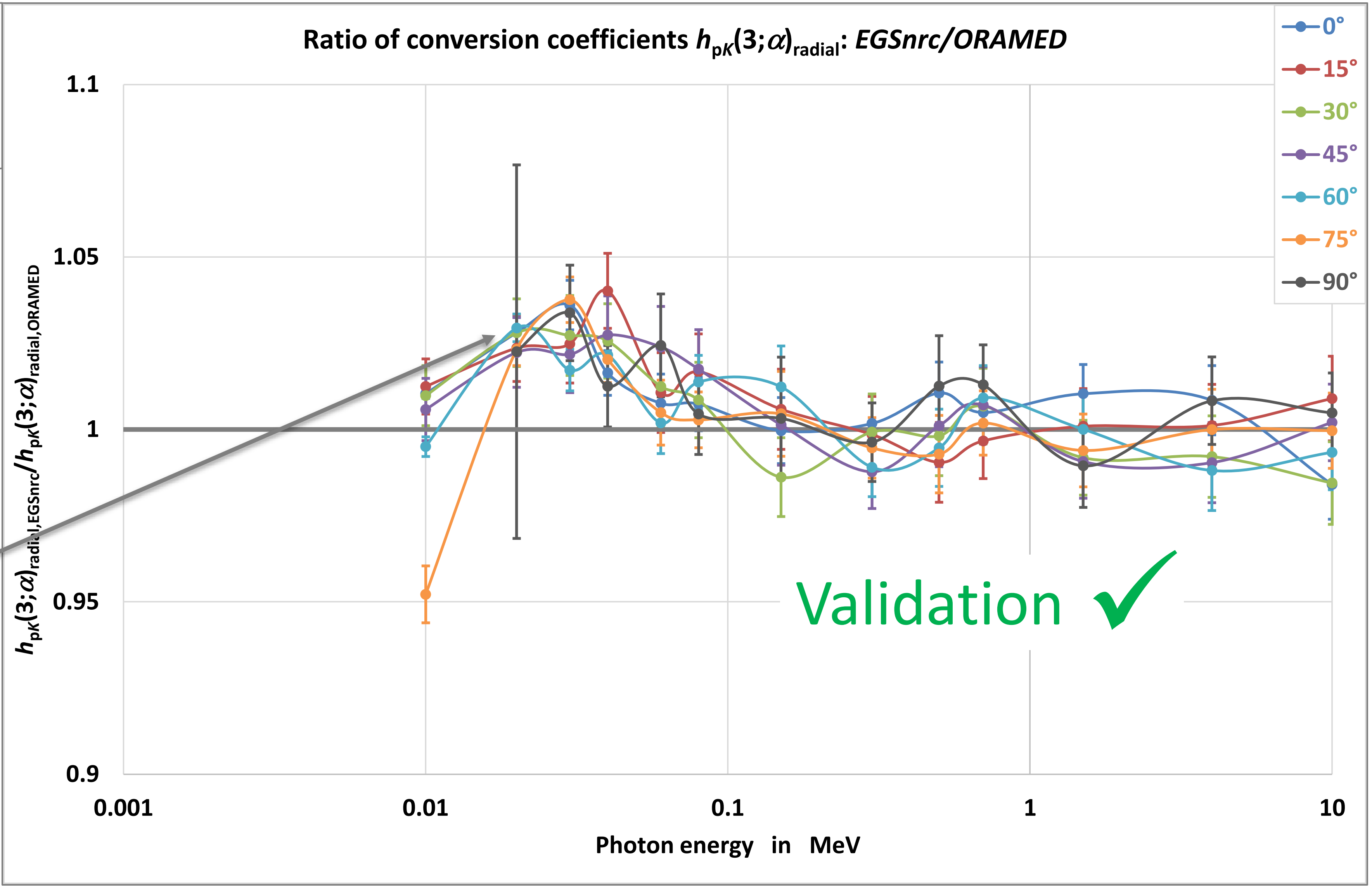
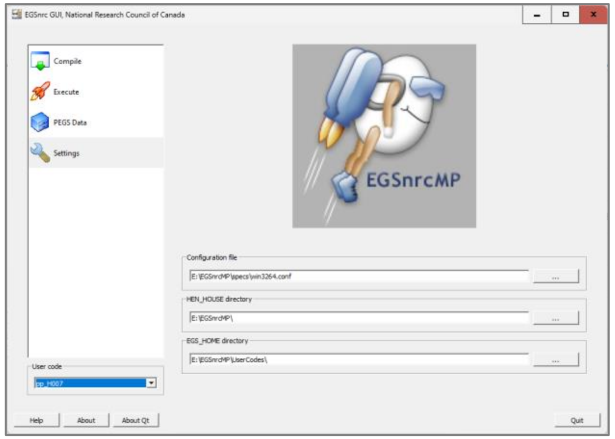
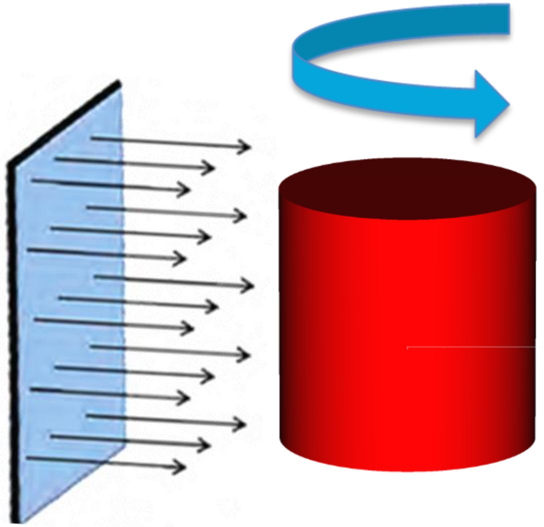


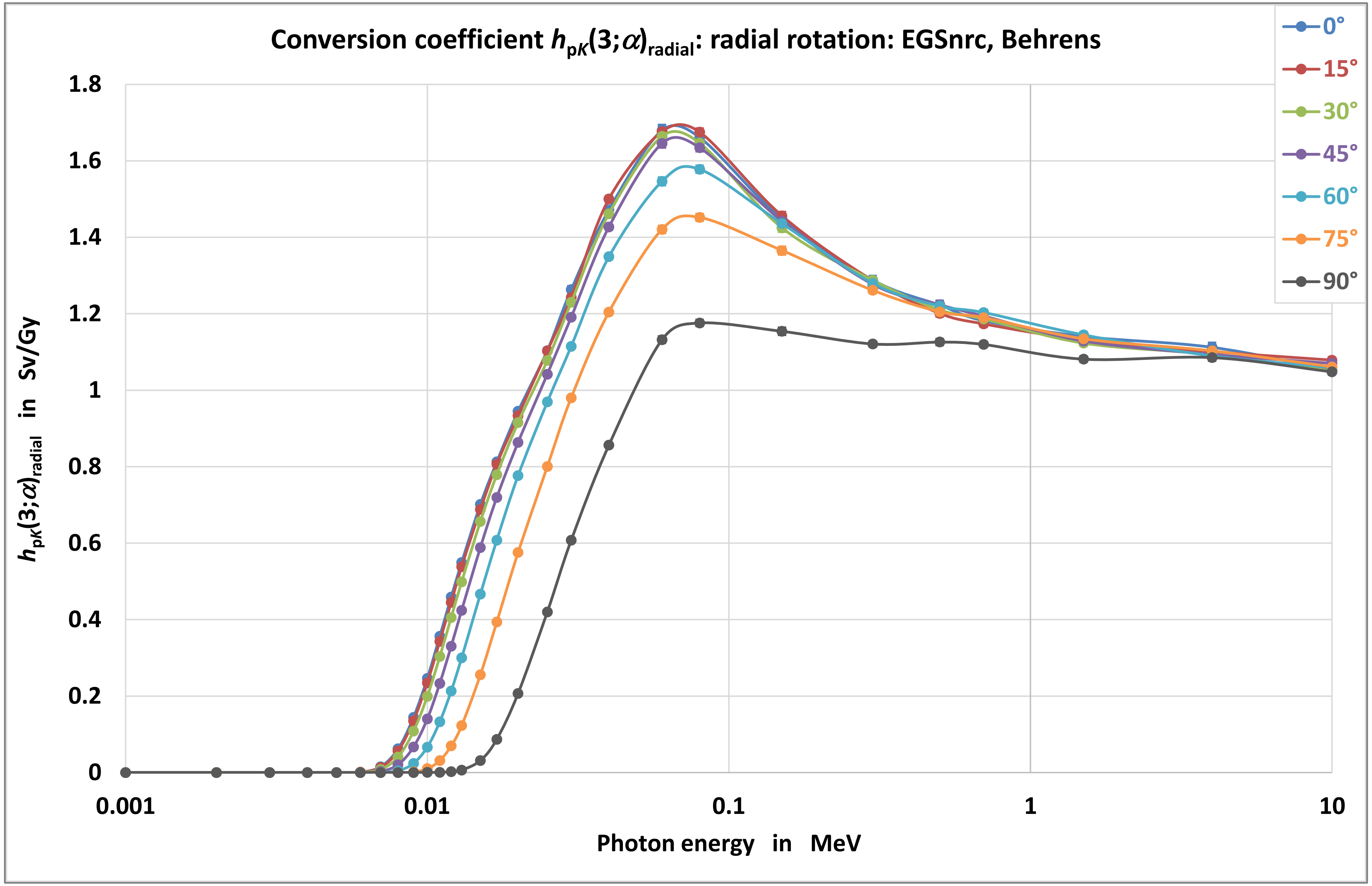
Figure 2.10: $H_p(3)/\Phi$ ratio between values based on mcplib02 and mcplib04



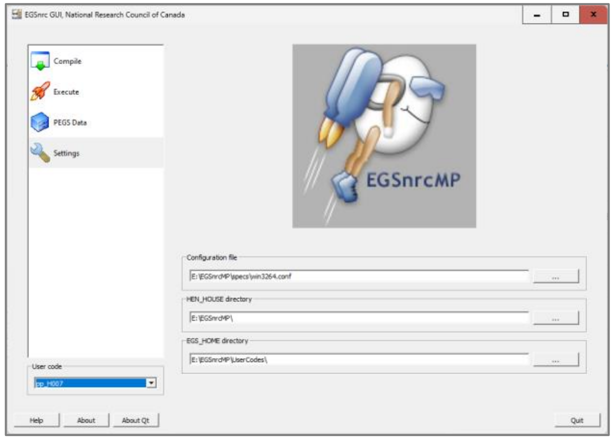
Results: photons, $H_p(3)$ – rotation radial

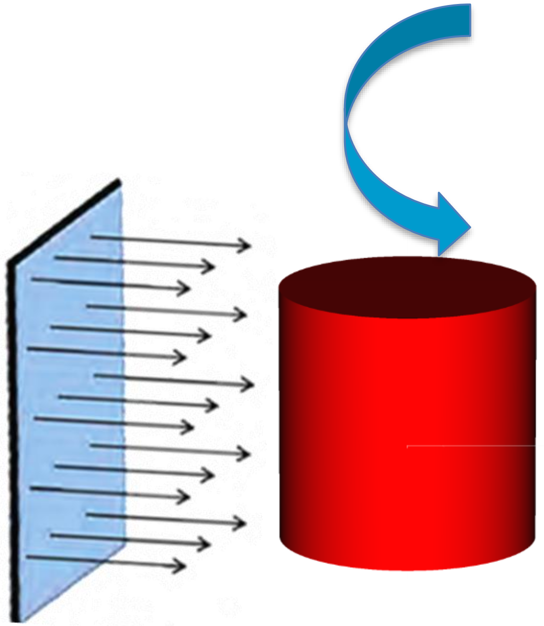


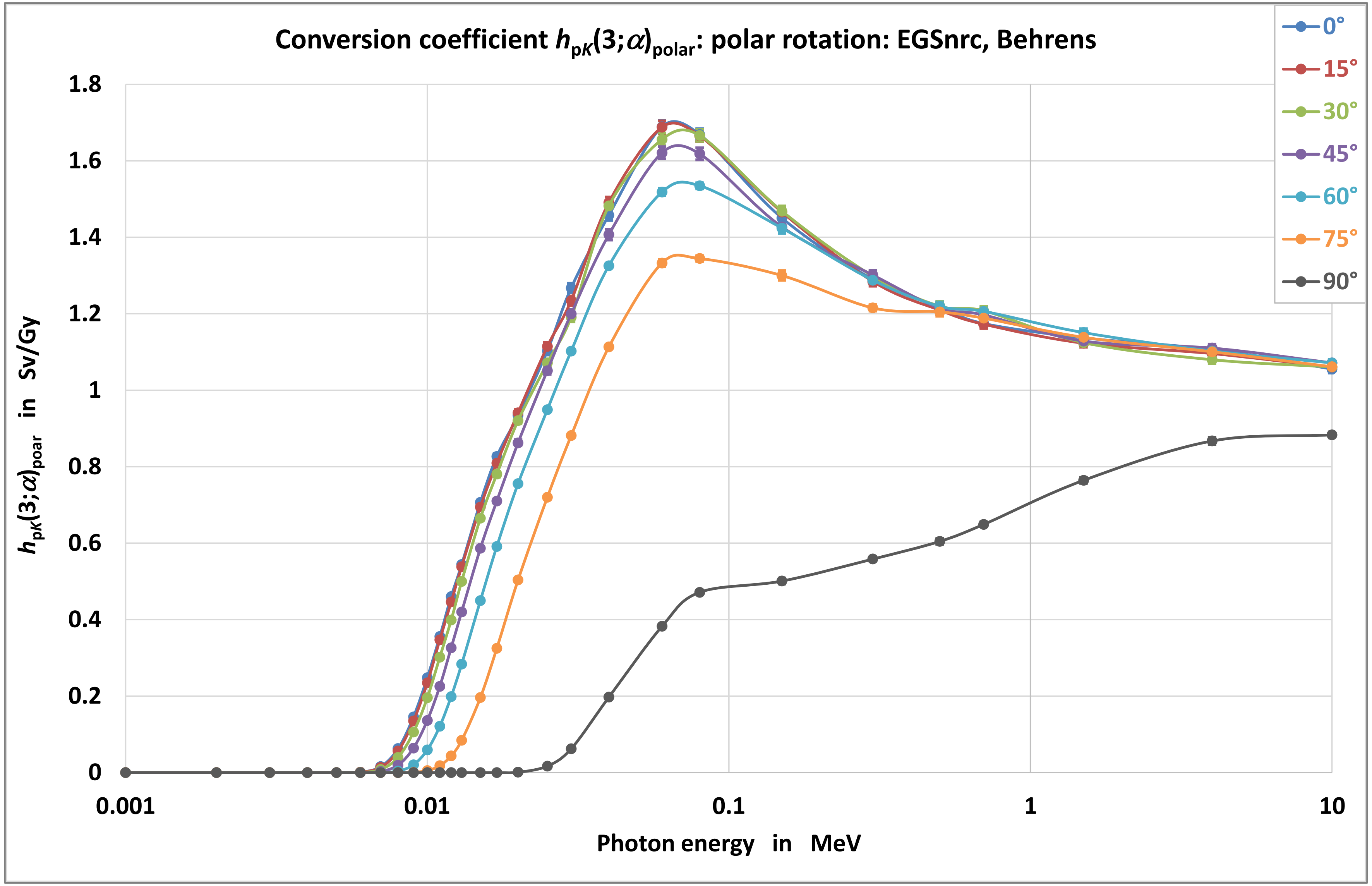




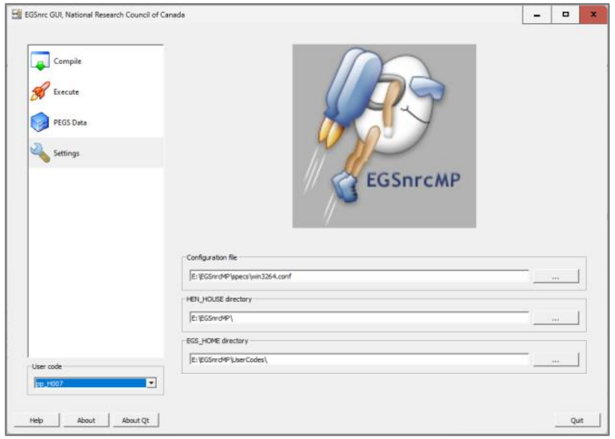
Results: photons, $H_p(3)$ – rotation polar

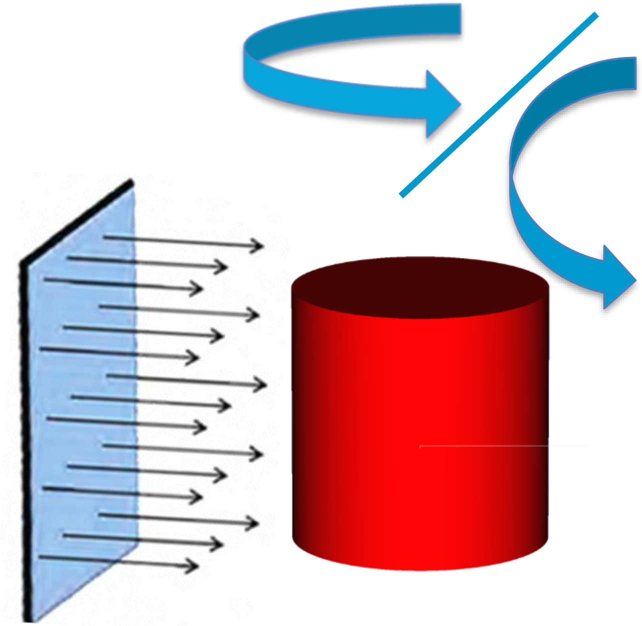


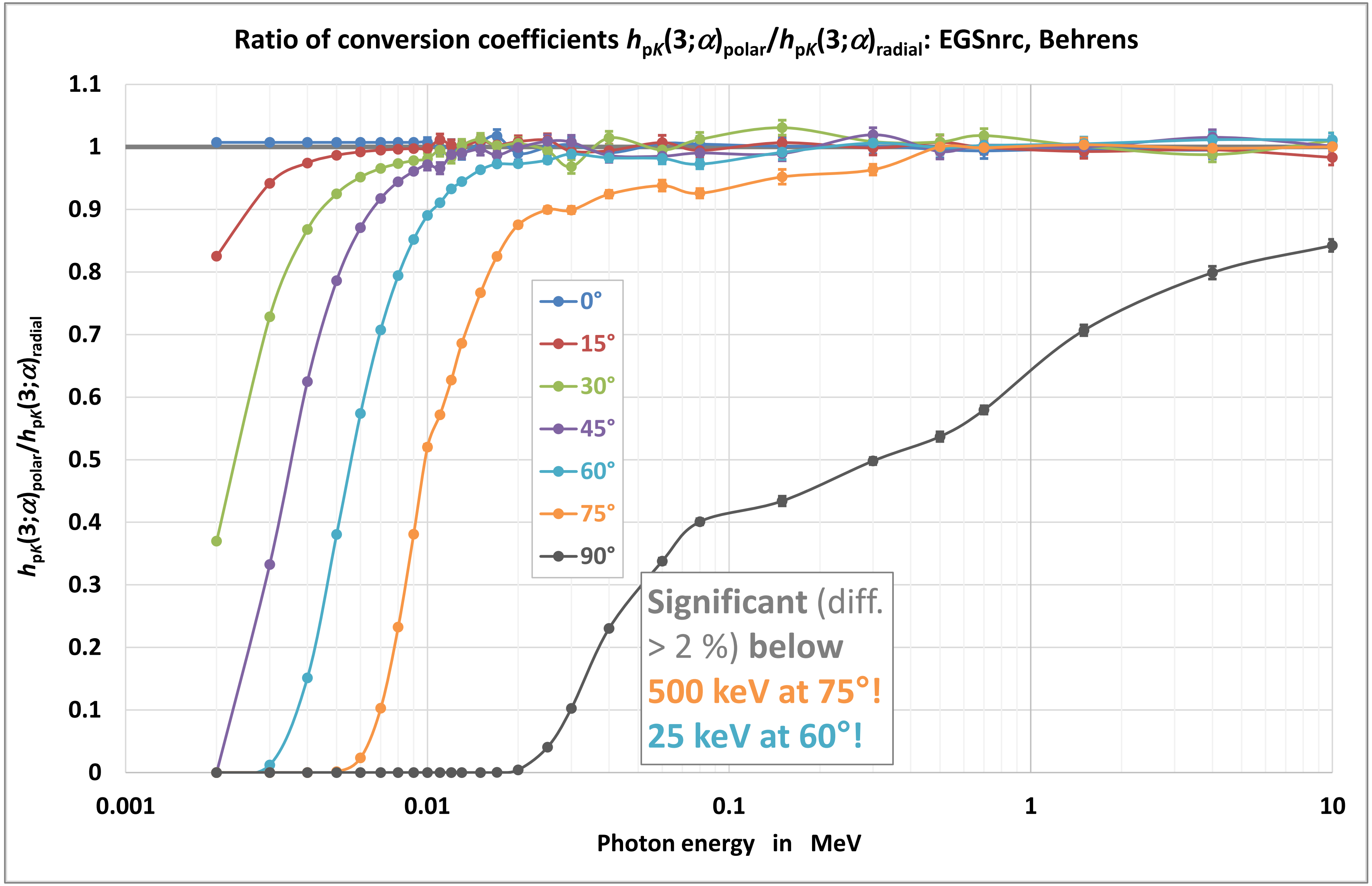




Results: photons, $H_p(3)$ – *ratio: polar / radial*

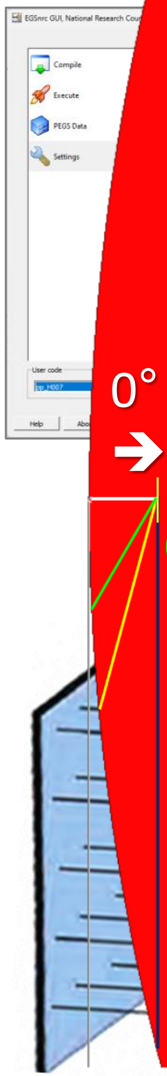






Results: pathlengths, $H_p(3)$ – *radial vs. polar*

Cylinder:
view from top

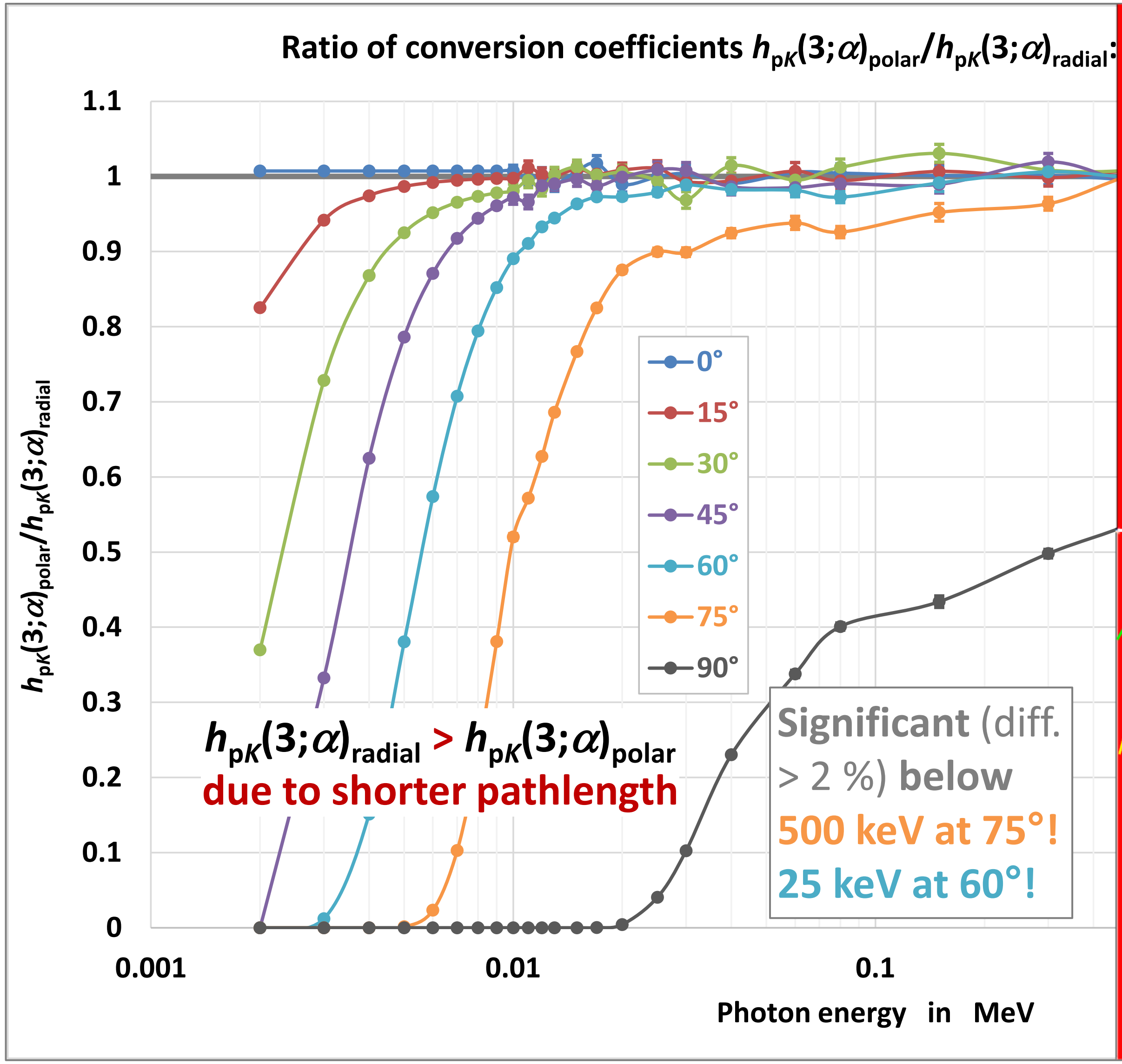


0° radial
→ 3.00 mm

60° radial
→ 5.75 mm

75° radial
→ 9.8 mm

90° radial
→ 24.3 mm



Cylinder:
view from side

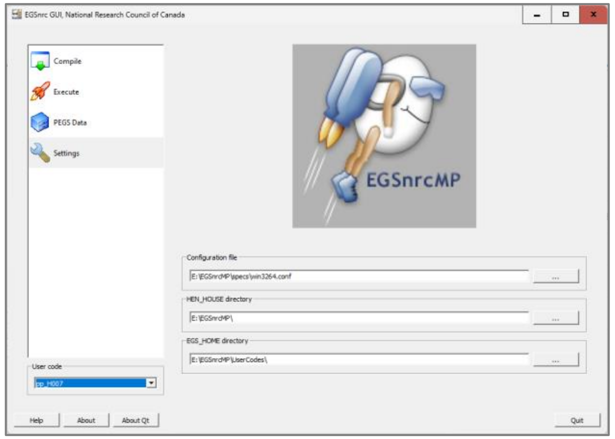
0° polar
→ 3.00 mm

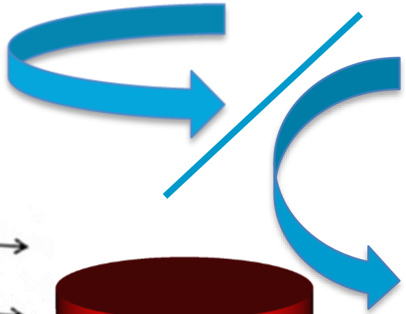
60° radial
→ 6.00 mm

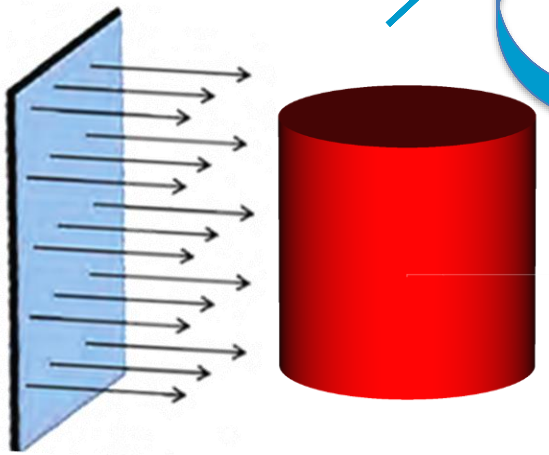
75° polar
→ 11.6 mm

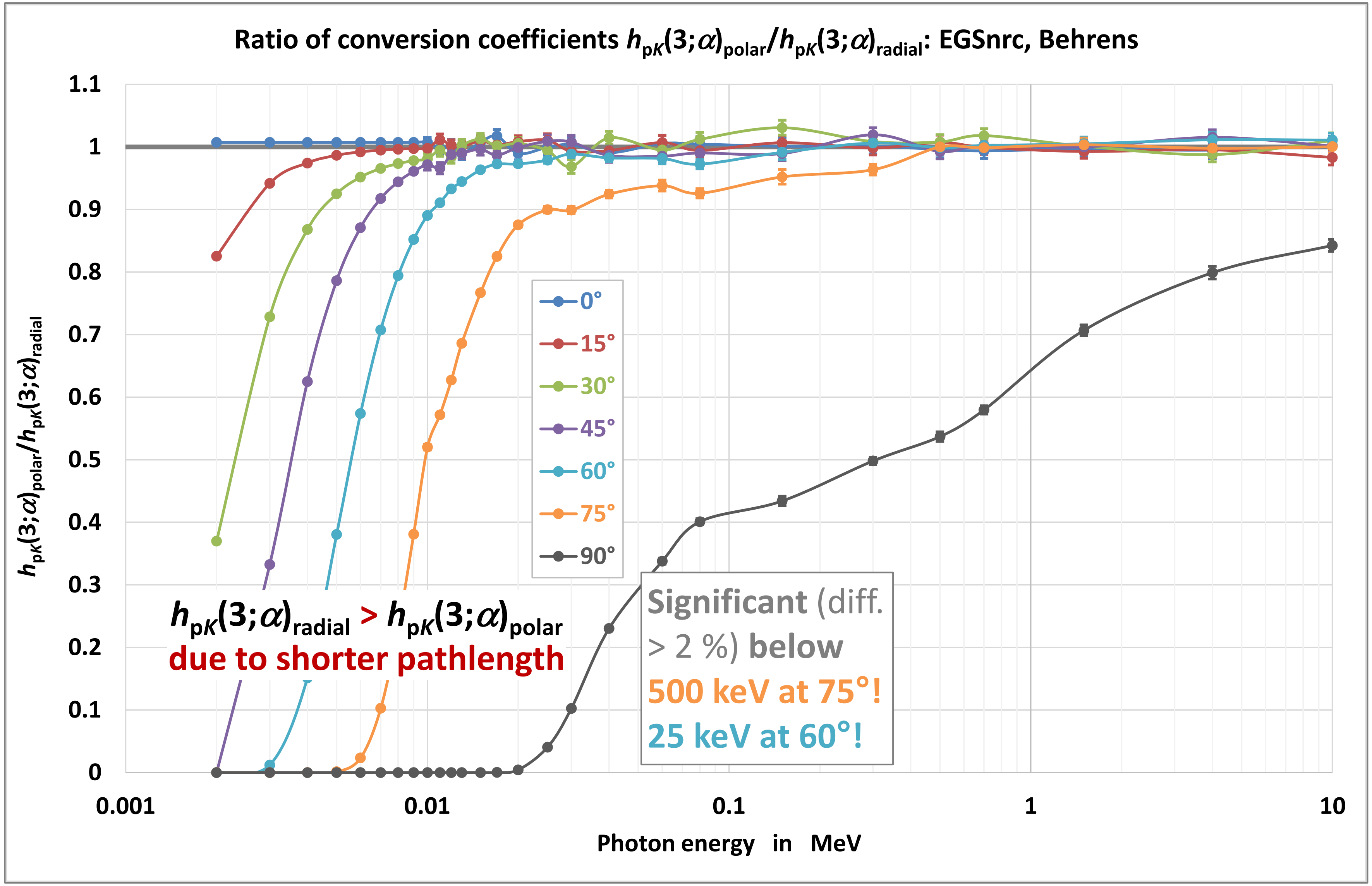
90° polar
→ 100 mm

Results: photons, $H_p(3)$ – *ratio: polar / radial*









The end

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