Estimation of shielding thicknesses for white beam enclosures

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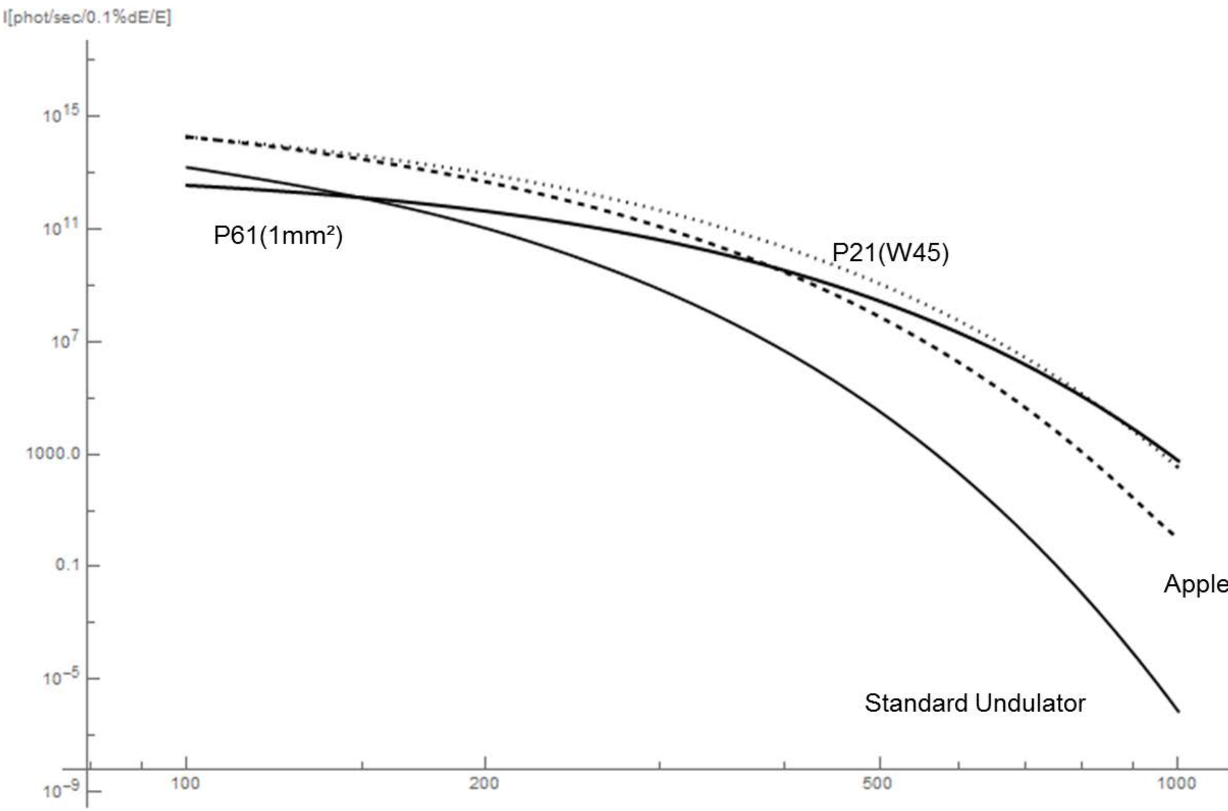
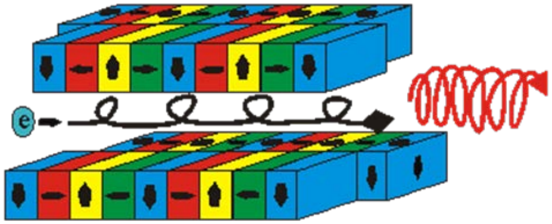
HELMHOLTZ ASSOCIATION

DESY

New insertion devices





P61 high energy beamline

Dose rate due to secondary radiation

$$D < N_0 E_S \frac{Z r_e^2 C_{KN} + \sigma_\alpha + \sigma_\beta}{A u \pi r^2} \, \mathrm{e}^{-\mu_H t_{eff}}$$

For monochromatic radiation : $t_{\text{eff}} > \ln\left(N_0 E_S \frac{Z r_e^2 C_{KN} + \sigma_\alpha + \sigma_\beta}{A u \pi r^2 \mathrm{D}}\right) / \mu_H$

T. Wroblewski: Radsynch15

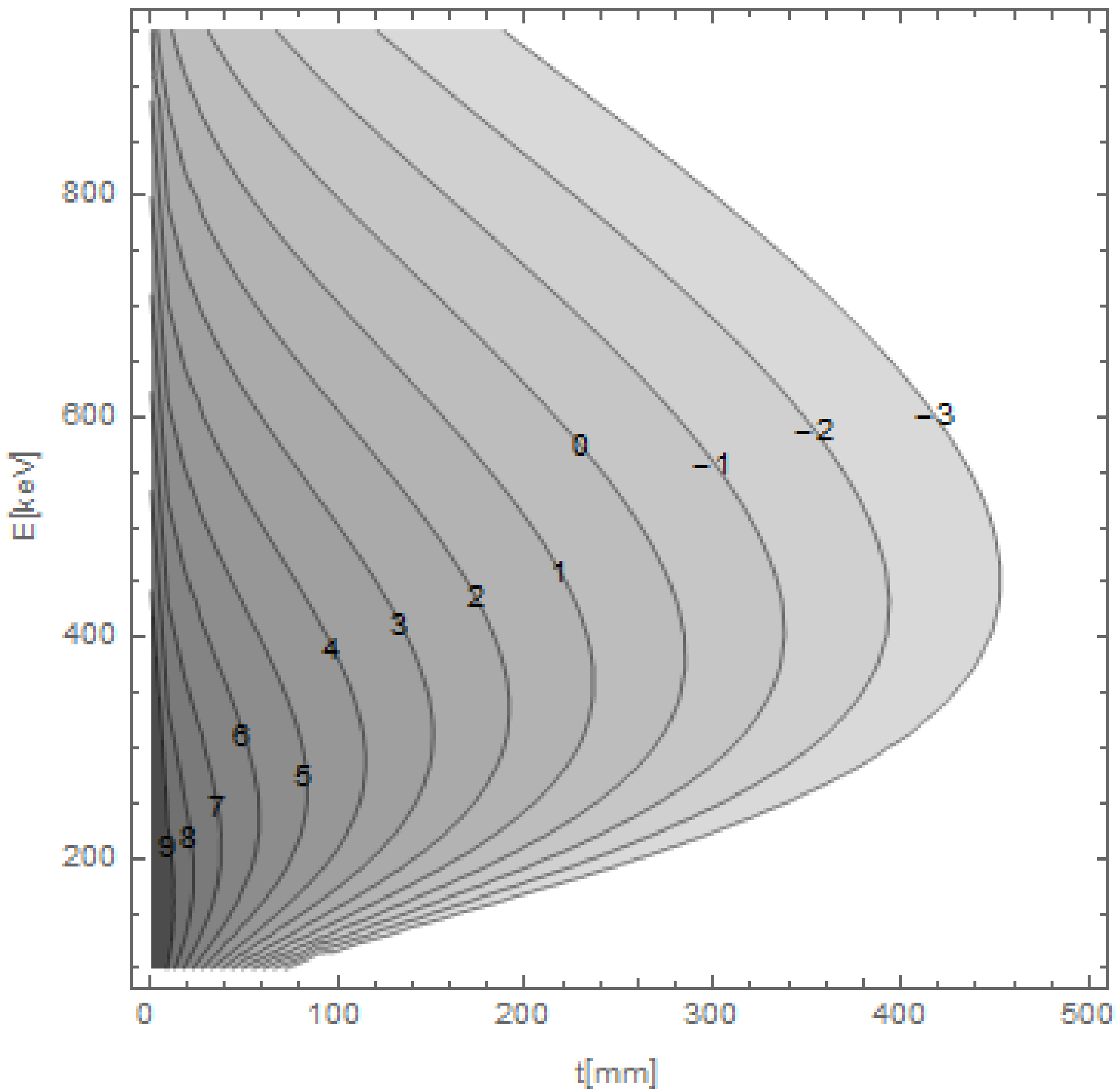
For white radiation the integral over all energies must be calculated yielding the dose(rate) as function of the shielding thickness.

Scattering can be treated analytical: $D < \int dE \; N_0 E_S \frac{Z r_e^2 C_{KN}}{A u \pi r^2} \, \mathrm{e}^{-\mu_H t_{eff}}$

In a first approach the worst case of forward scattering is calculated

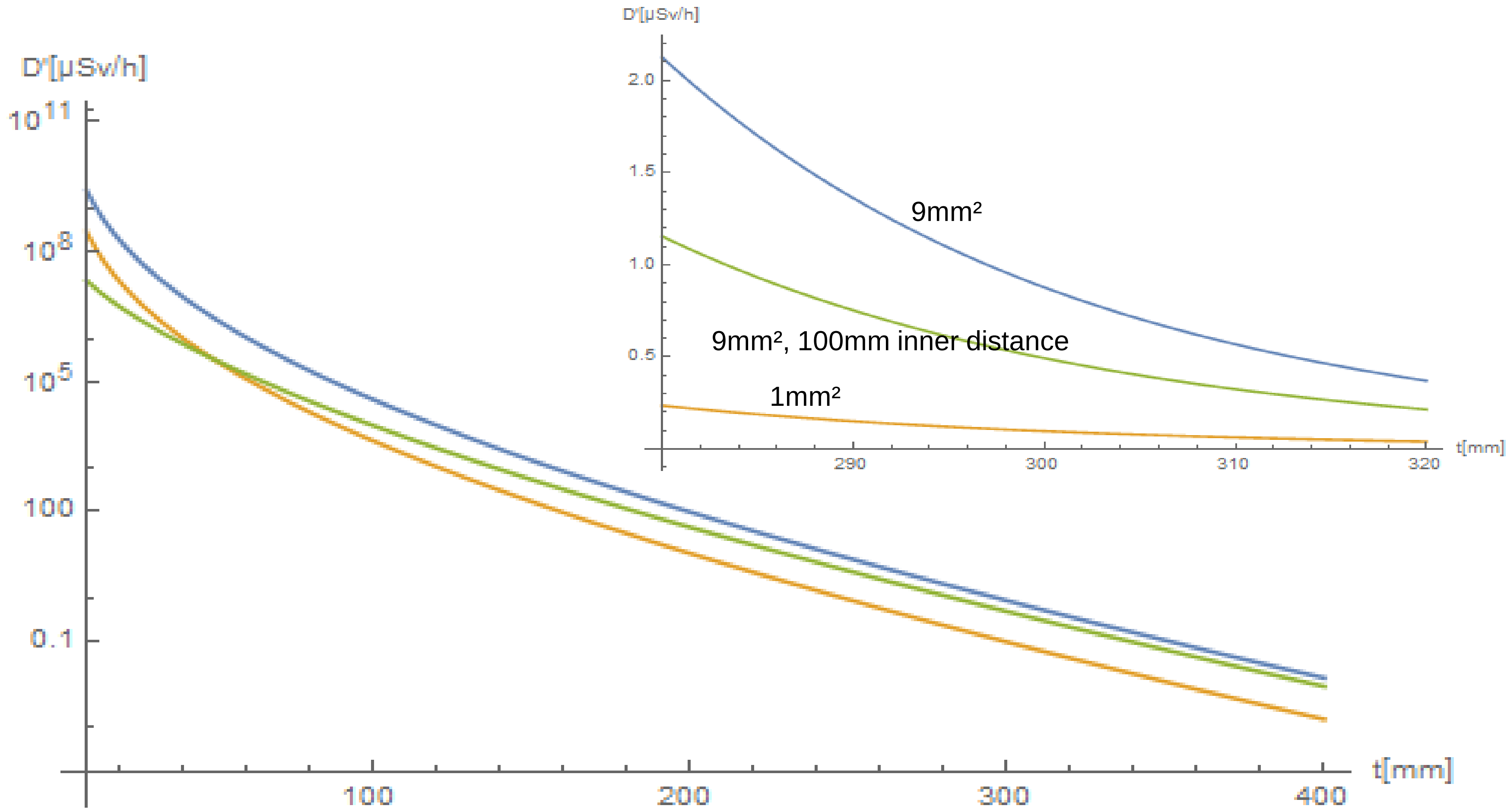
$(C_{KN} = 1, E_S = E)$

Beam hardening by shielding



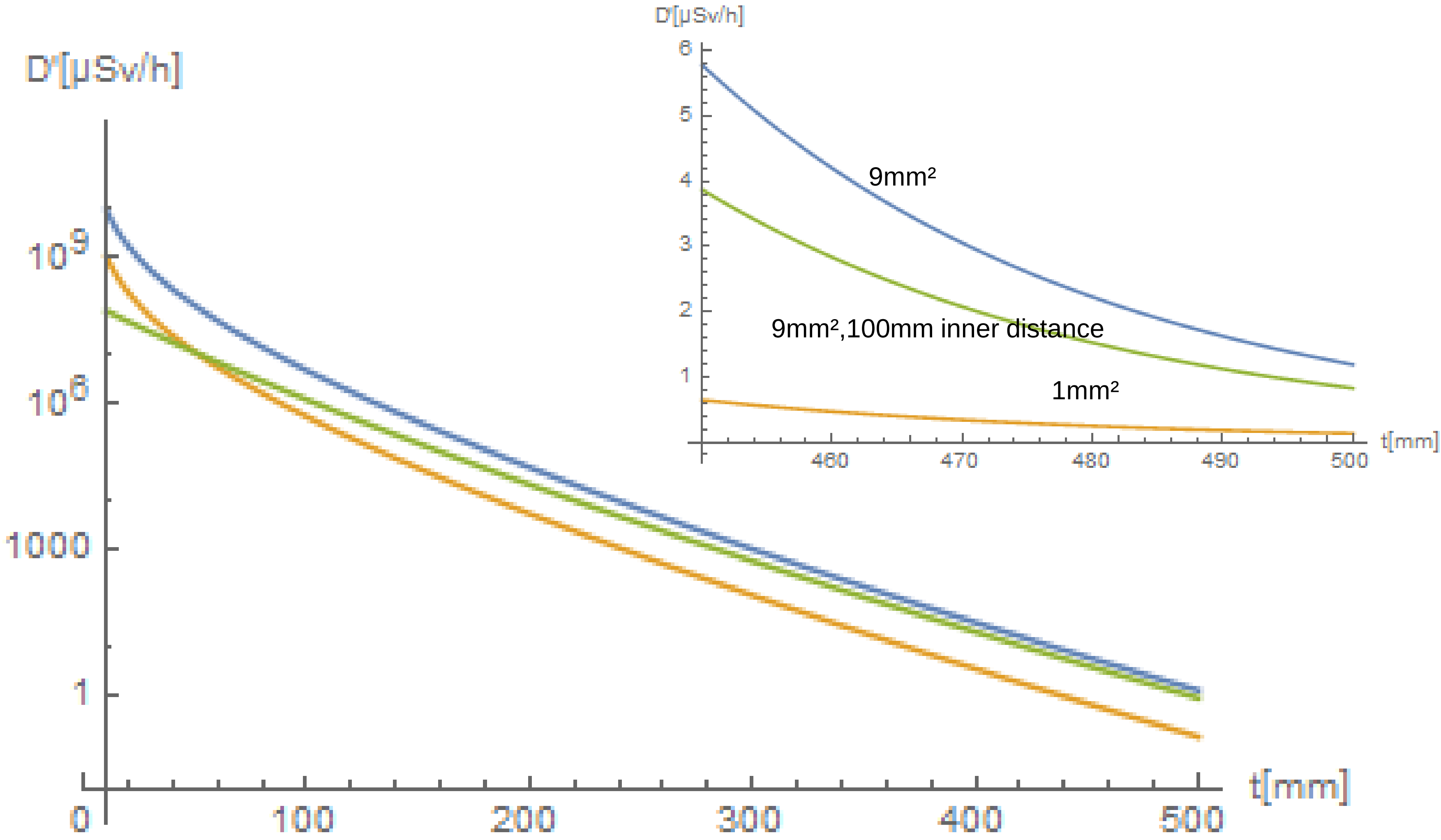
Magnitude of dose rate in baryte as function of energy and thickness
(nSv/h/keV,
thickness equals distance to scatterer)

Integral dose rate (baryte)



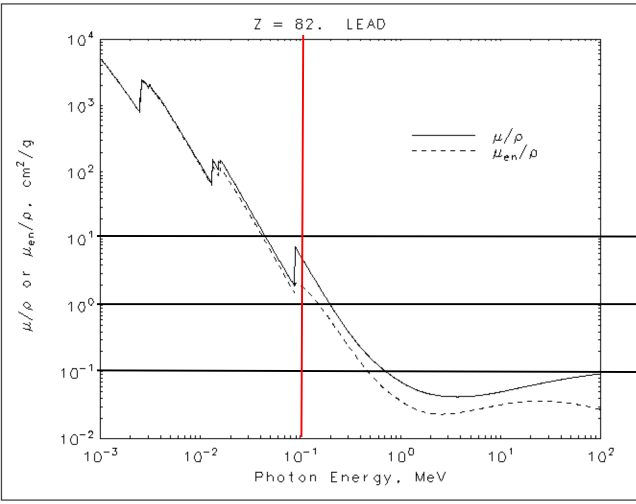
Dose rate for different beam sizes and distances (forward)

What about ordinary concrete ?

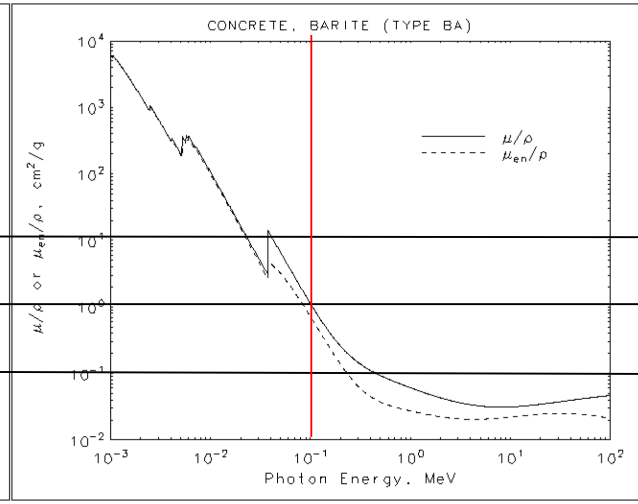


Attenuation/absorption of different materials

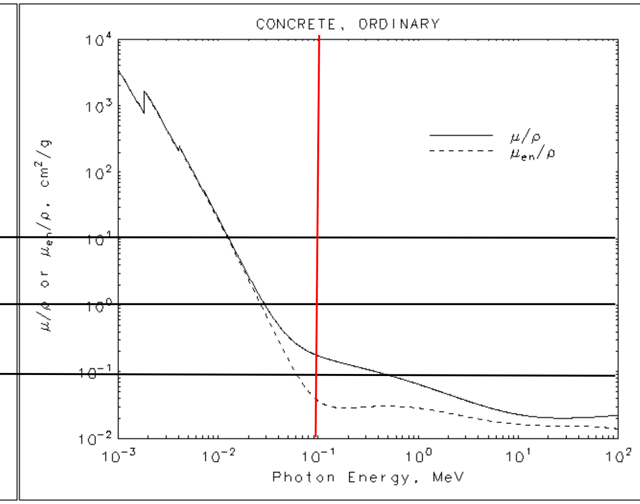
https://www.nist.gov/pml/x-ray-mass-attenuation-coefficients



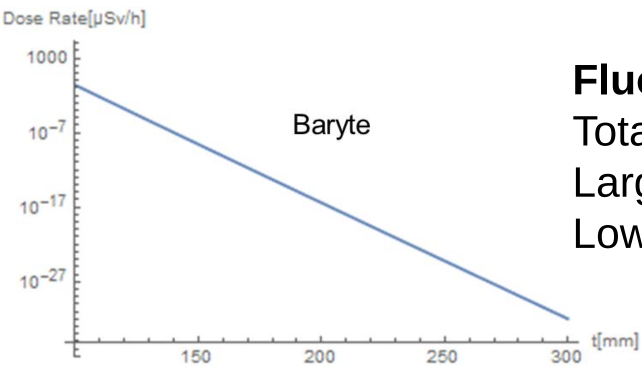
ρ=11.35 g/cm³



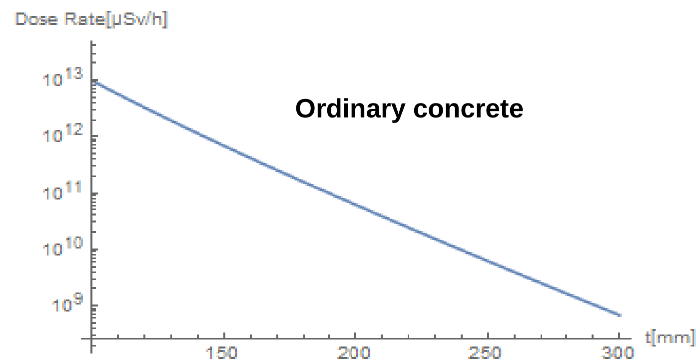
ρ=3.350 g/cm³



ρ=2.300 g/cm³

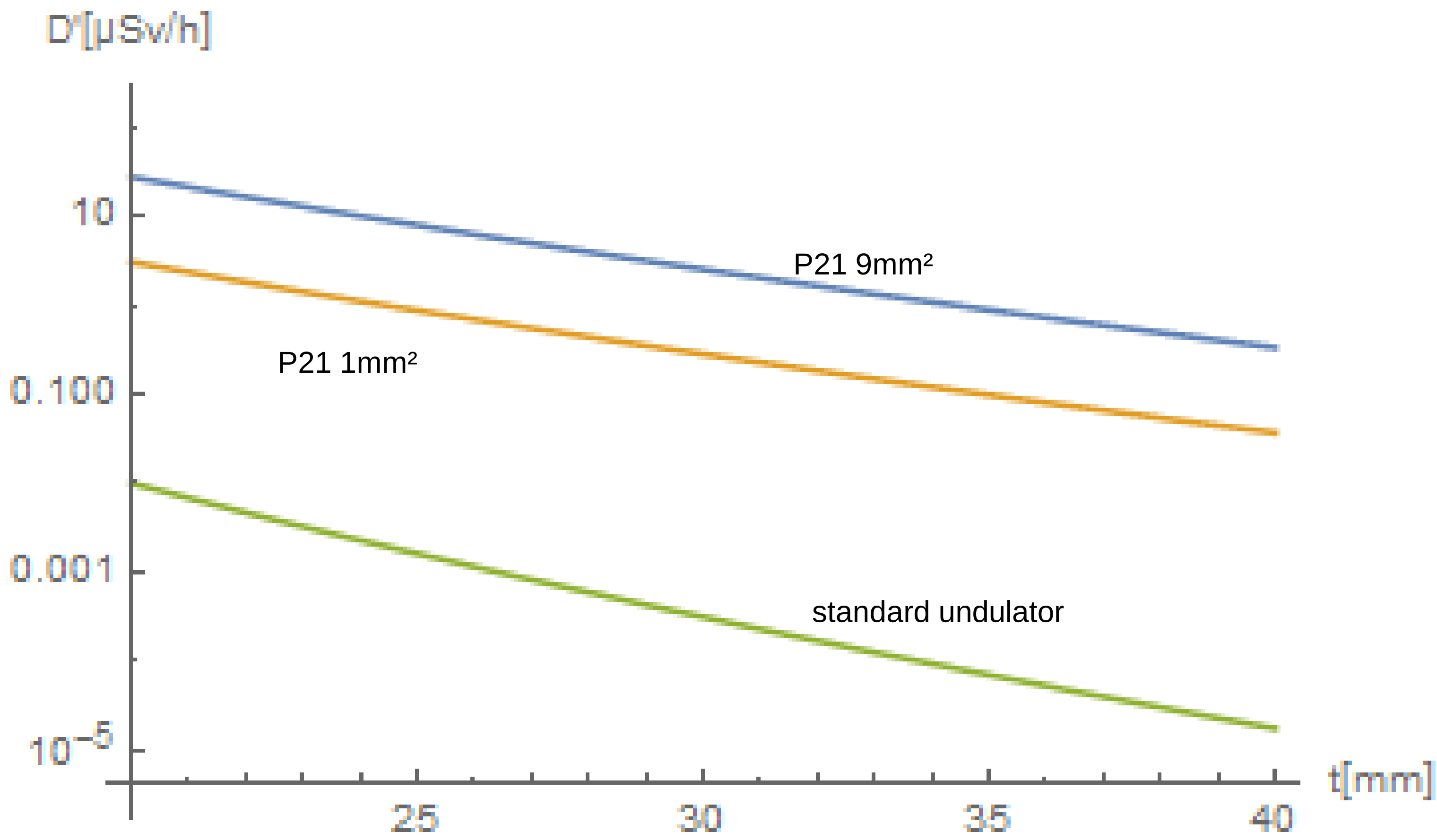


Fluorescence:
Total number of photons
Largest cross section
Lowest attenuation (113keV)



Ordinary concrete is not a good idea

What about lead ? (Door 1m distance from beam)



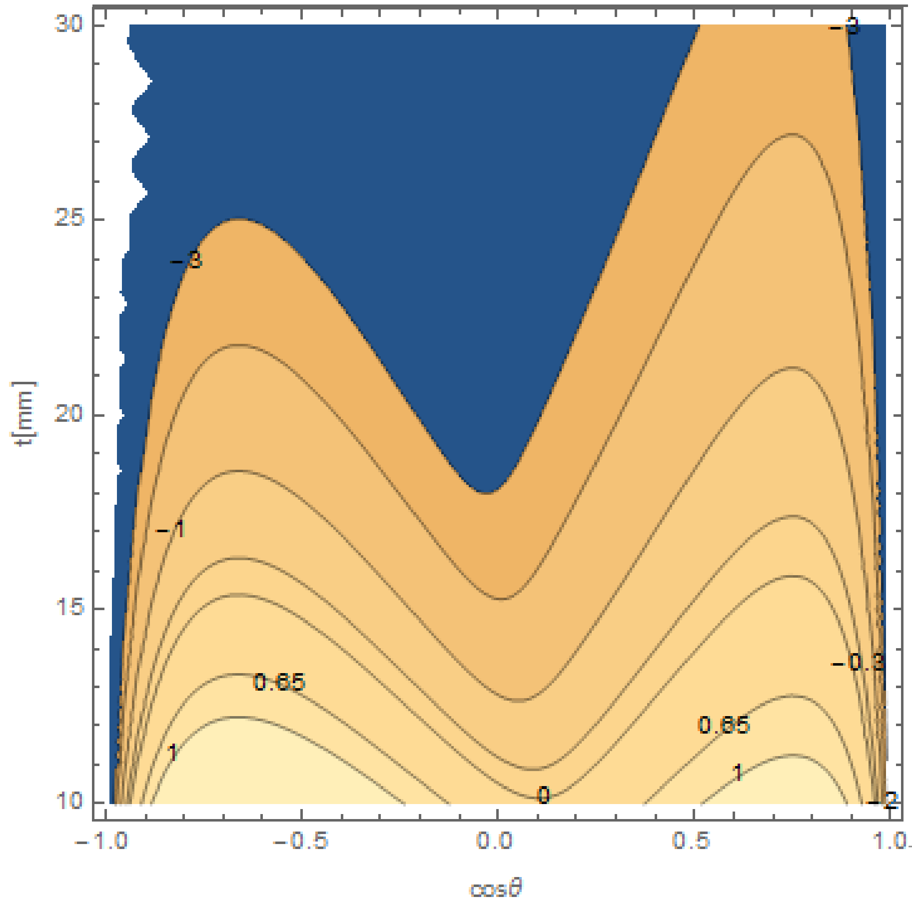
Requires further thinking: Anisotropy of inelastic scattering

Lead 1m from beam, beamsize 9 mm²

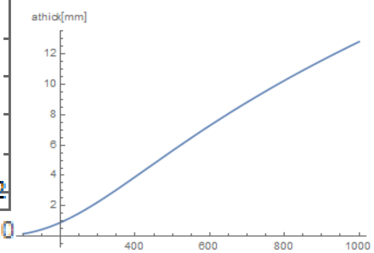
Cross section varies by a factor of ~3 (ln3=1.1)

Inelastic scattering decreases energy of secondary photons (with increasing angle)

Worst case scenario: attenuation coefficient below 150keV replaced by attenuation below K-edge



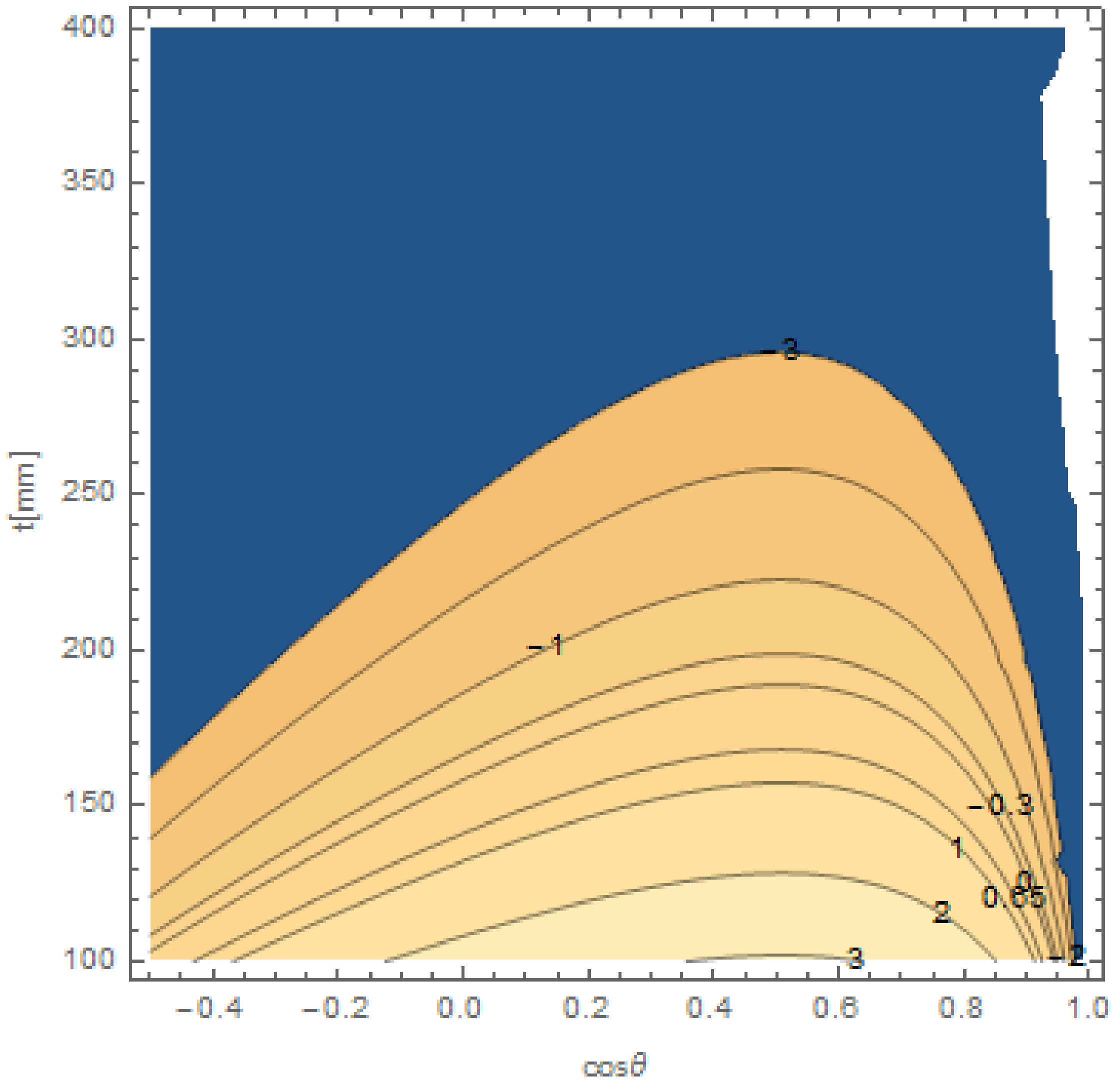
$t_{eff}=t/\sin\theta$



Large lead thickness required (~5mm per order of magnitude)
Alternatives: reduction of beamsize, larger distance to scatterer

At a closer look: no problem with baryte

Beamsize 9mm²
Thickness equals
Distance to scatterer



Summary

> Shielding of the white beam entails beam hardening
> leading to an increased (average) attenuation length.
> Other means of dose reduction should be considered as

- confining of the incoming beam by (fixed) appertures
- Increasing the distance to the scatterer

End of Part A

To Err is Human;

To Really Foul Things Up Requires a Computer

Example 1:

Wrong line of code:

```
mubaryte = {5.549, 2.014, 0.9985, 0.4031, 0.2323, 0.1614, 0.1248, 0.0887, 0.07102}
densbaryte = 3.35
```

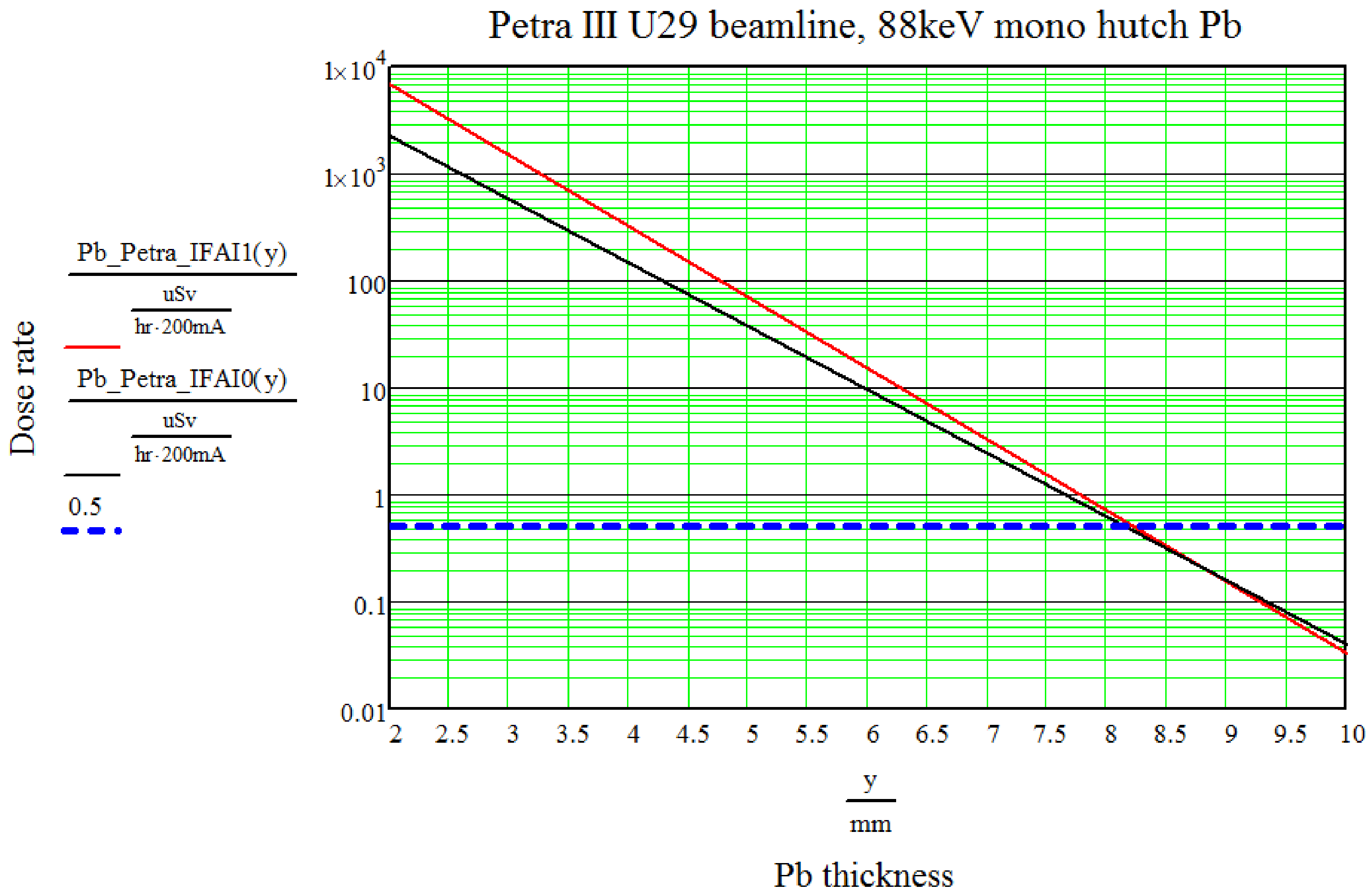
Resulting from copy and paste

```
mupb = {5.549, 2.014, 0.9985, 0.4031, 0.2323, 0.1614, 0.1248, 0.0887, 0.07102}
denspb = 11.
```

Correct code:

```
mubaryte = {1.122, 0.4423, 0.2568, 0.146, 0.1104, 0.0931, 0.08245, 0.06936, 0.0611}
densbaryte = 3.35
```

Example 2: Use of external code



Different attenuation for polarized (red) and unpolarized (black) radiation

Example3: Different results from different approaches

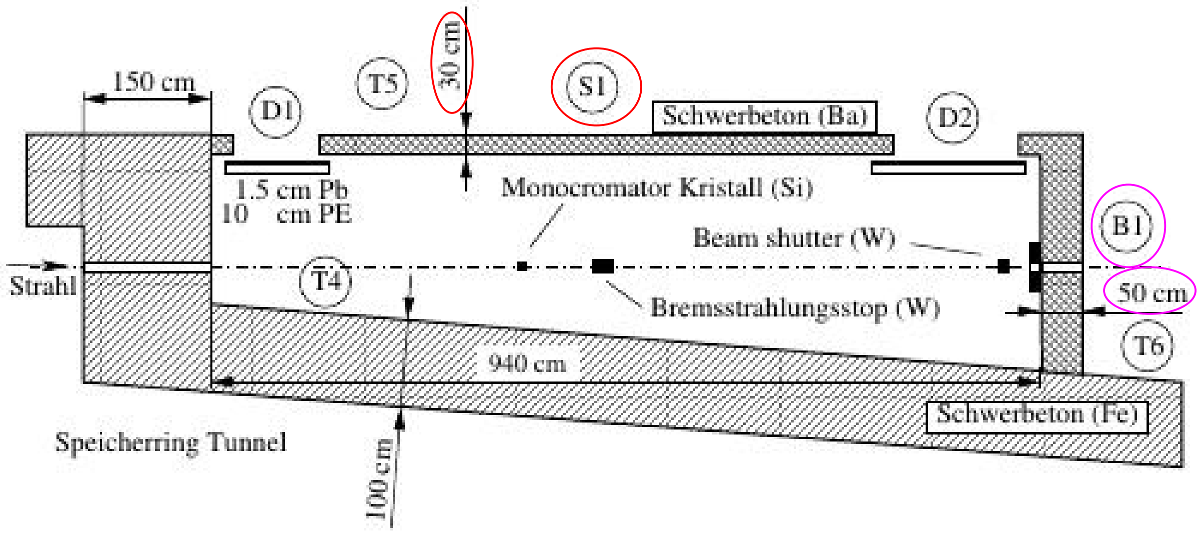


Abbildung 5: Draufsicht der Optikhütte mit den für den Strahlenschutz wesentlichen Komponenten.

Ort s.Abb.5	Strahlungsart	Bremsstrahlung γ	Bremsstrahlung Neutron	Synchrotronstrahlung Spec-U	Synchrotronstrahlung Apple-U	Summe
D1	Tür, vorne	0.1 mSv	0.6 mSv	0.00004 mSv	(0.0005 mSv)	1.6 mSv
S1	Abschirmung, seitlich	0.3 mSv	1.6 mSv	0.1 mSv	(1.9 mSv)	2.0 mSv
D2	Tür, hinten	1.0 mSv	0.3 mSv	0.2 mSv	(6.0 mSv)	1.5 mSv
B1	Abschirmung, hinten	2.2 mSv	0.2 mSv	0.8 mSv	(15.6 mSv)	3.2 mSv
Ziel						3.0 mSv

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Conclusion

- To err is human
- Human errors may be amplified by computers

Therefore we should combine our efforts

- Exchange of codes (not only between authors)
- Define model cases (round robin)
- Compare calculations with measurements (inside enclosures)

We should start now!

Final goal handbook:
Radiation protection at SR sources

Including interlock, hutch design, surveys, etc.