Abteilung für Medizinische Strahlenphysik
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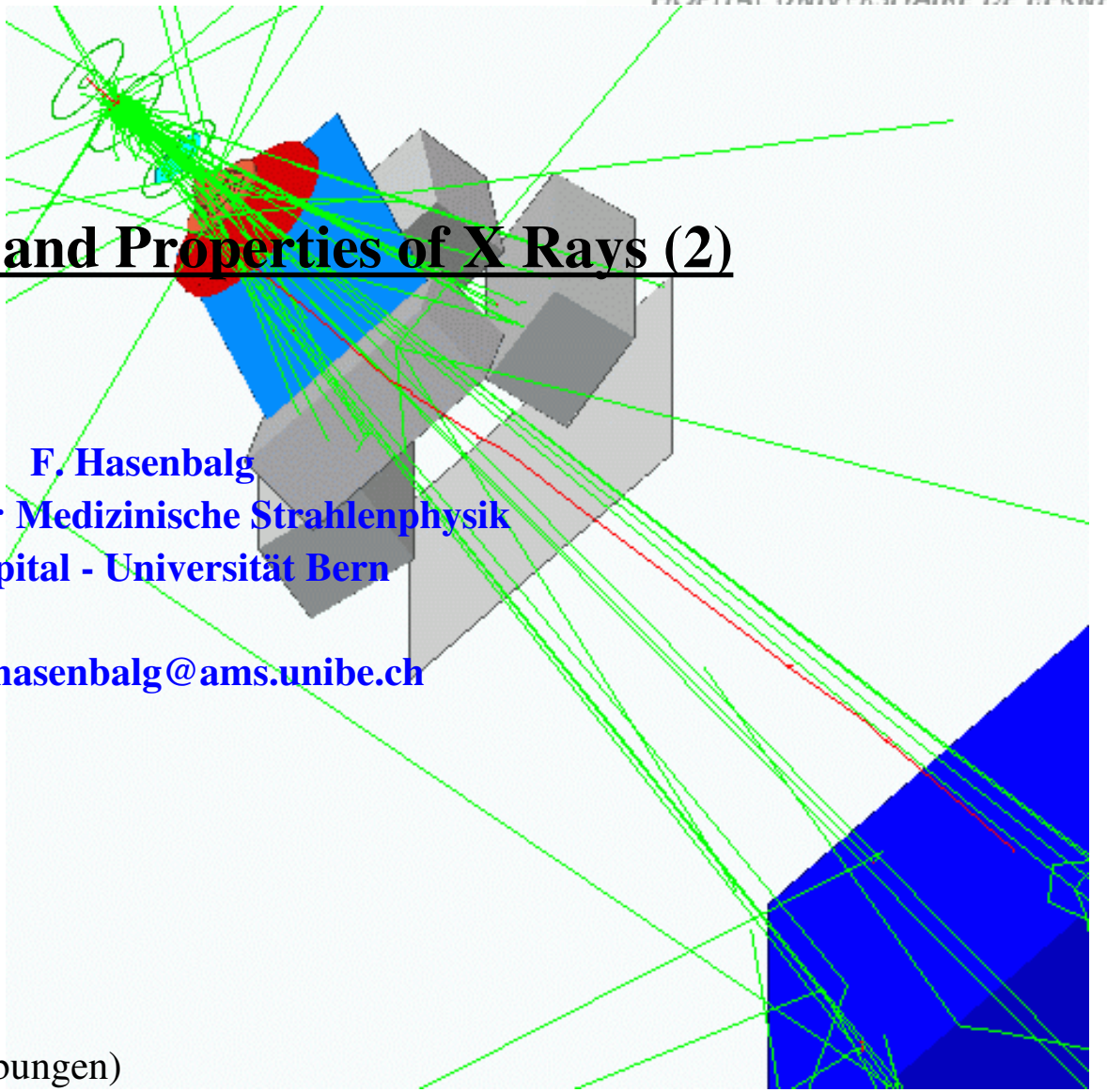
Production and Properties of X Rays (2)



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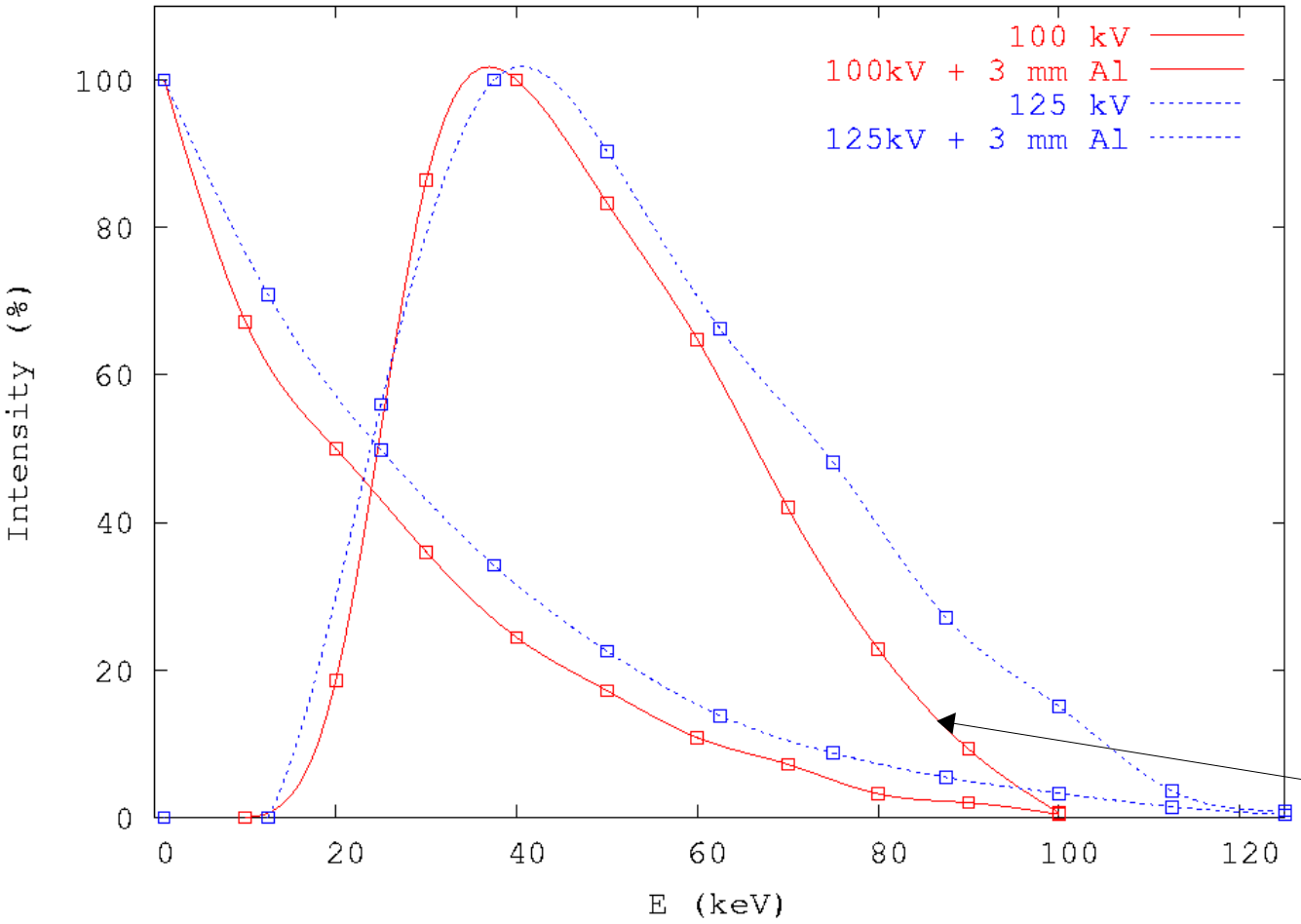
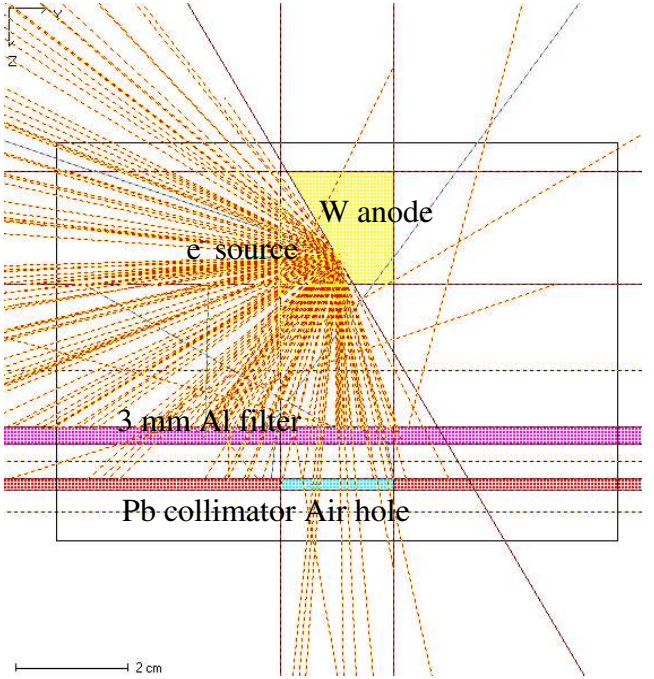
Results assignment 05: X-Ray Production





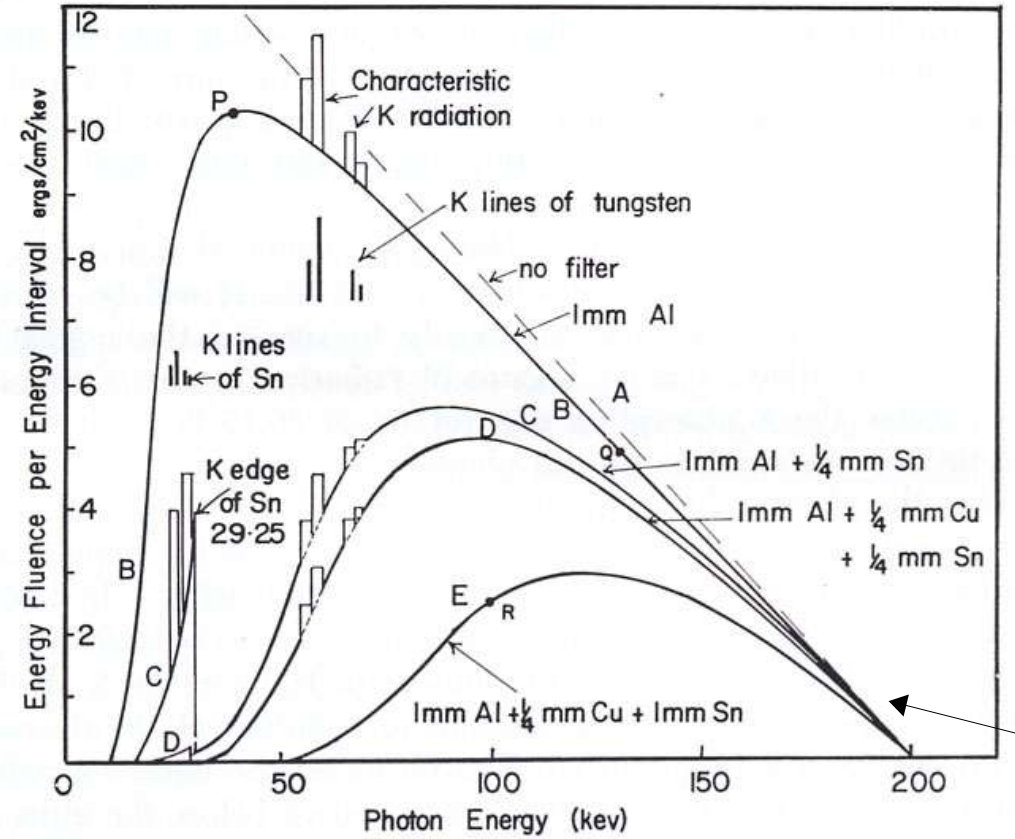
Gnuplot:
plot '100kv.spc' smooth csplines w lin 1

Spectrum mean energies (weighted averages)

Anode
- 100 kV 28.46 keV
- 125 kV 33.59 keV

After 3 mm Al
- 100 kV 48.34 keV
- 125 kV 53.55 keV

Quality of X Rays: Beam Hardening



Beam Hardening

Larger absorber thickness
-> fewer low energy photons
-> higher mean beam energy

Determination through homogeneity grade H

$$H = \frac{d_{1/2}^{(1)}}{d_{1/2}^{(2)}} \qquad d_{1/2}\text{: half value layer}$$

homogeneous beam H = 1
heterogeneous beam H < 1

Dif. energy fluence: $E\frac{d\Phi}{dE}$ shifts the distribution towards the high energy end of the spectrum and the area under the curve gives the total energy fluence.

Disadvantages of low energy photons:

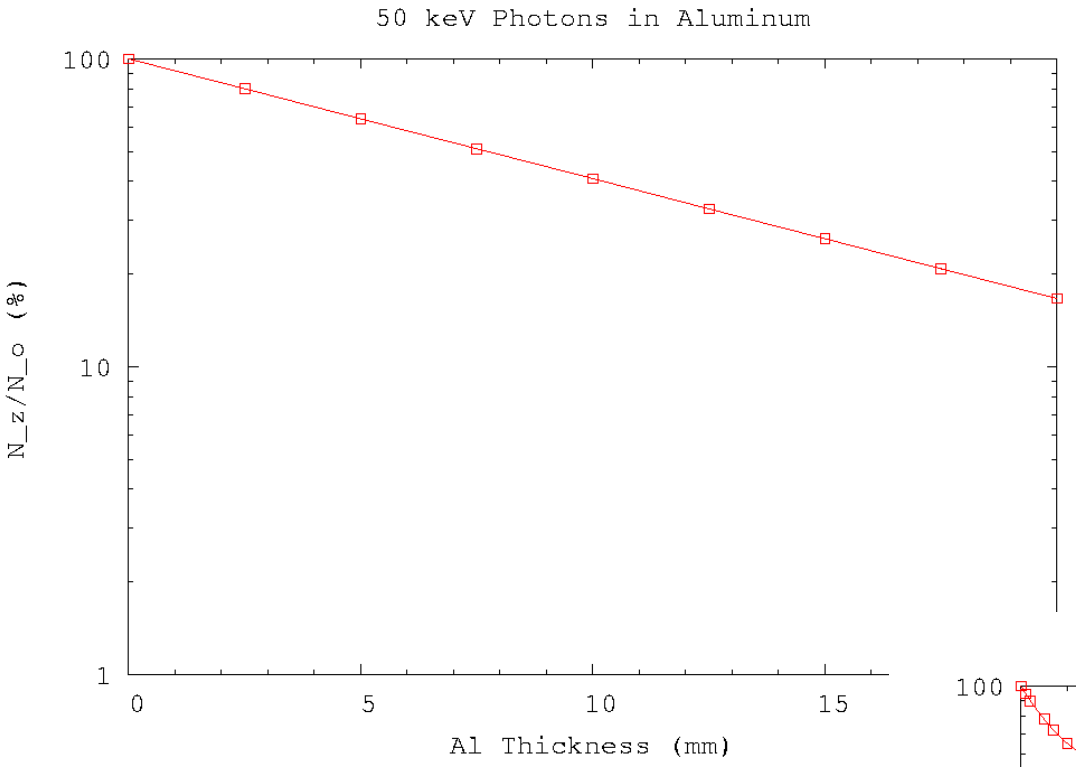
Diagnostic: they do not reach the imaging device but contribute to the dose to the patient

Therapy (superficial tumors): do not penetrate to the tumor and increase the dose to the skin

Half value layer: measures the beam ability to penetrate some known material

Al: U < 120 kV
Cu: 120- 400 kV

Quality of X Rays: Beam Hardening



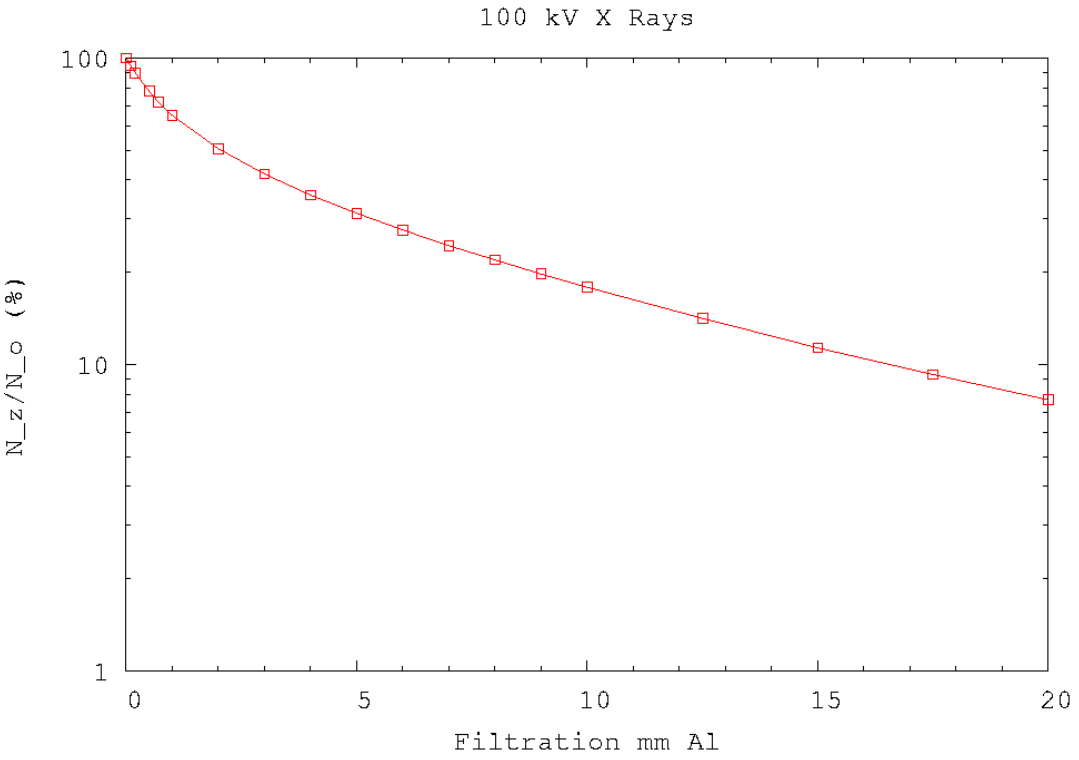
Previous example with a homogeneous
50 keV photon beam in aluminum

H = 1

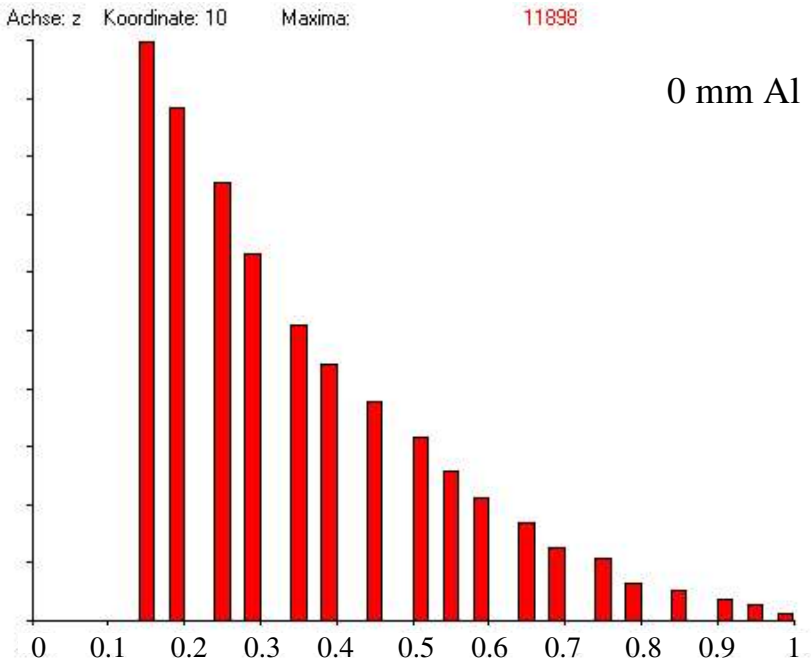
Histogram analysis

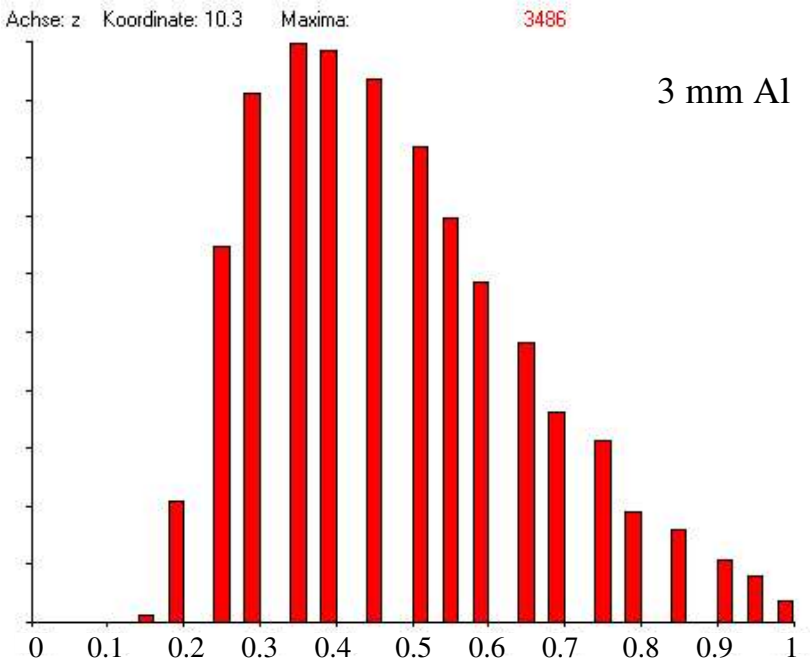
New example with a heterogeneous
100 kV photon beam in aluminum

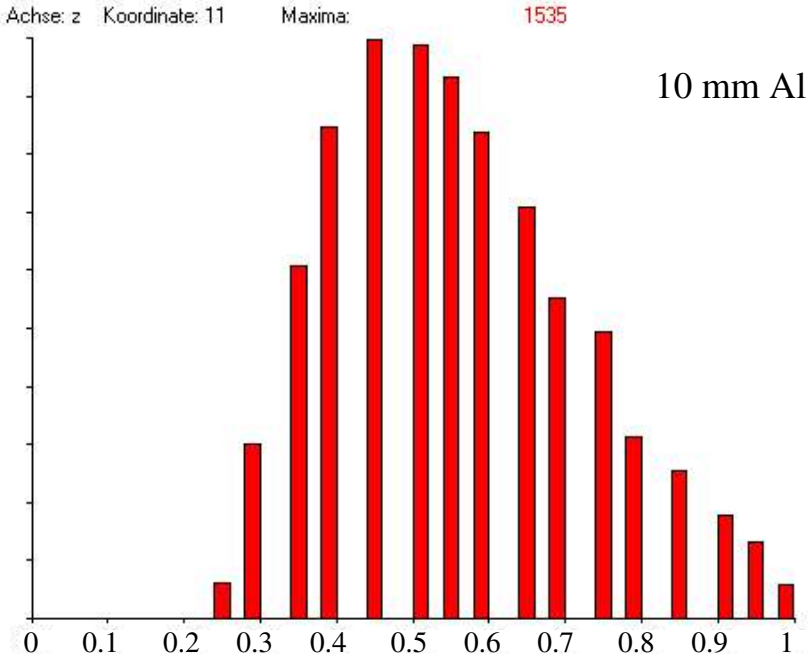
H < 1

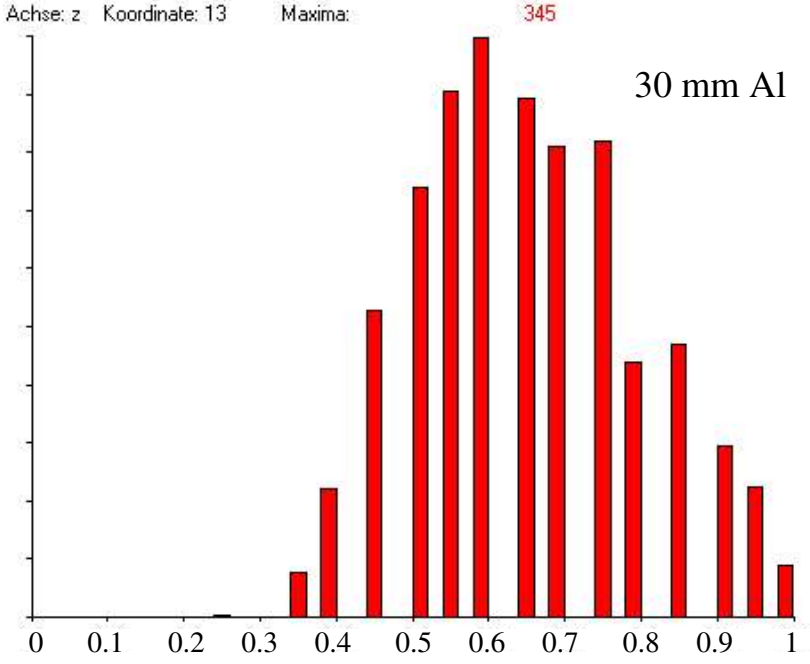


Beam Hardening









EGS-Ray: attenuation of a heterogeneous photon beam

pencil beam (parallel geometry)

Program control:

Generation

Only the doses of a determined generation (primary, secondary,etc) of particles is registered (number of the generation to be summed)

Generation

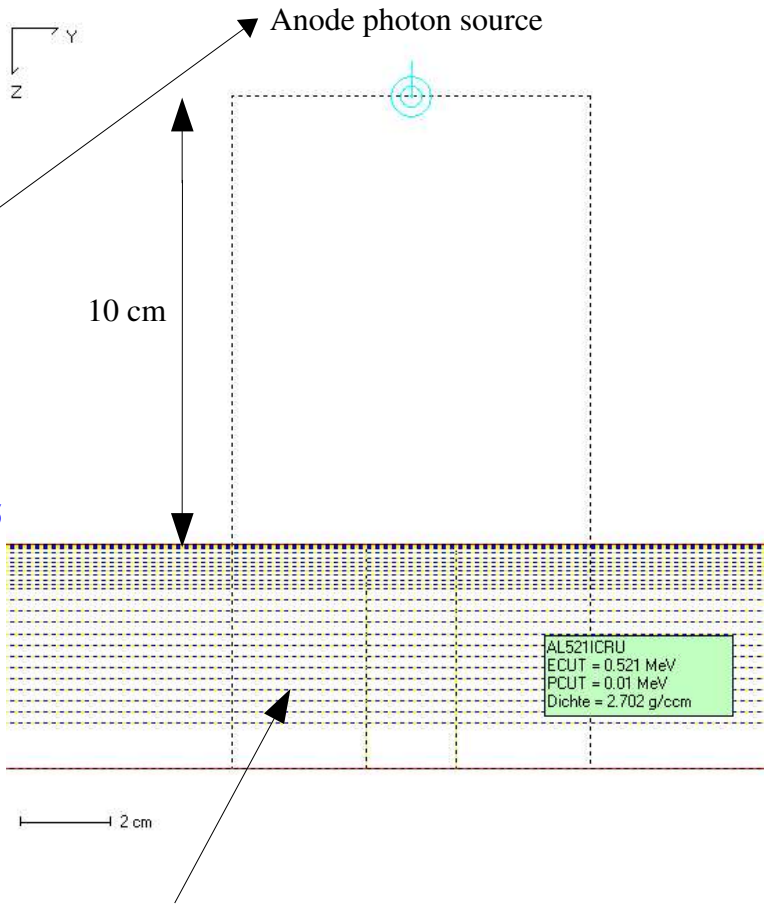
1

adds the doses of only the first interacting particles, primary photons in this case. For more details look in the manual.

Histogram analysis on x or y direction.

Result and performance independent of voxel size.

```
Daten
D:\...\521icru.dat
Randomseed
1802 9373
Histories
100000
Punktquelle
0  0  0
Richtung
0  0  1
Photonen
Spektrum
D:\...\100kv.spc
Rechenraum
-4  -4  0  4  4  15
Scoringraum
-1  -1  10  1  1  15
Voxelgröse
2  2  1
PLatte
AL521ICRU
2  10 15
Histogramm
2  10
Histogramm
2  10.01
Histogramm
2  10.02
...
Histogramm
2  14
Generation
1
```



Suggested values: 0.1, 0.2, 0.5, 07,
1, 2, ... 10,
12.5, 15, 17.5, 40 mm

EGS-Ray: attenuation of a heterogeneous photon beam (2)

Anode tension: 100 kV Al filter Pb collimator

divergent beam **Histogram analysis**

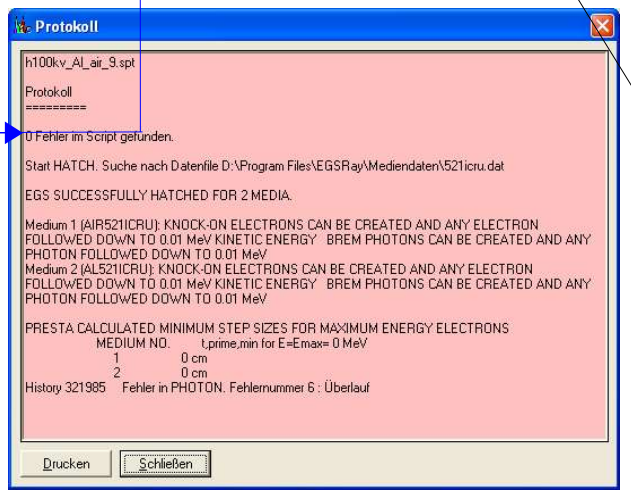
```
Daten
D:\... \521icru.dat
Randomseed
1802  9373
Histories
400000
Punktquelle
0  0  0
Richtungsbereich
-1  1  -1  1  0.99  1
Photonen
Spektrum
D:\...\100kV.spc
Rechenraum
-2 -2 -0.5 2 2 7
Scoringraum
-0.5  -0.5  2   0. 5  0. 5  7
Voxelgröße
1  1  1
```

photon source

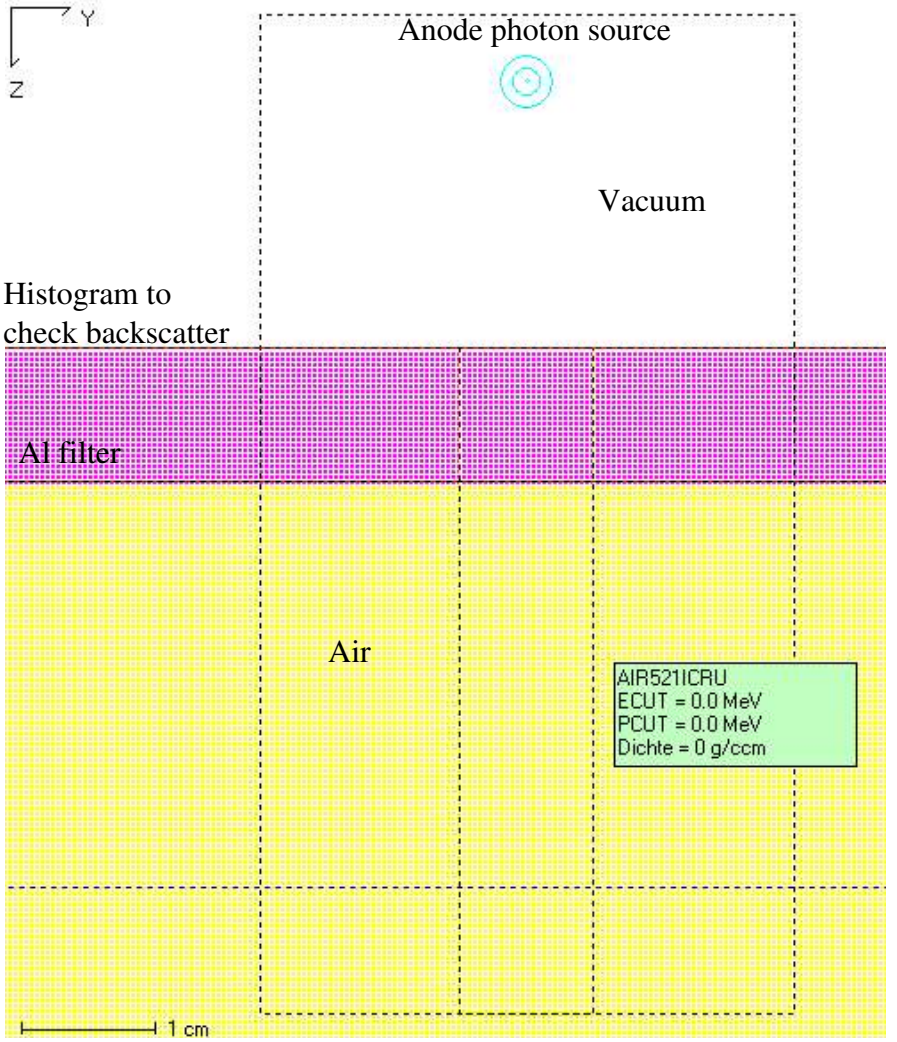
Anode spectrum 100 kV

```
Halbraum
AIR521ICRU
2  2  1
Histogramm
2  2
rem Filter
rem 10 mm
PLatte
AL521ICRU
2  2  3
Histogramm
2  6.05
Presta
```

10 mm Al filter



Ignore Protokoll messages !



Results are voxel independent

EGS-Ray: attenuation of a heterogeneous photon beam (3)

Anode tension: 100 kV

3mm Al filter

divergent beam

Total doses addition

Use
-> Objekte
-> integrale
Energie dosis
of Pb box

to make the measurements

```
Daten
D:\...\521icru.dat
Randomseed
1802 9373
Histories
100000
Punktquelle
0 0 0
Richtungsbereich
-1 1 -1 1 0.999 1
Photonen
Spektrum
D:...\100kV.spc
Rechenraum
-5 -5 -2 5 5 114
Scoringraum
-5 -5 -1 5 5 114
Voxelgröße
2 2 2
PLatte
AL521ICRU
2 3 3.3
Histogramm
2 3.5
PLatte
AL521ICRU
2 10 11
Histogramm
2 50
Box
PB521ICRU
-0.5 -0.5 100 0.5 0.5 101
Presta
```

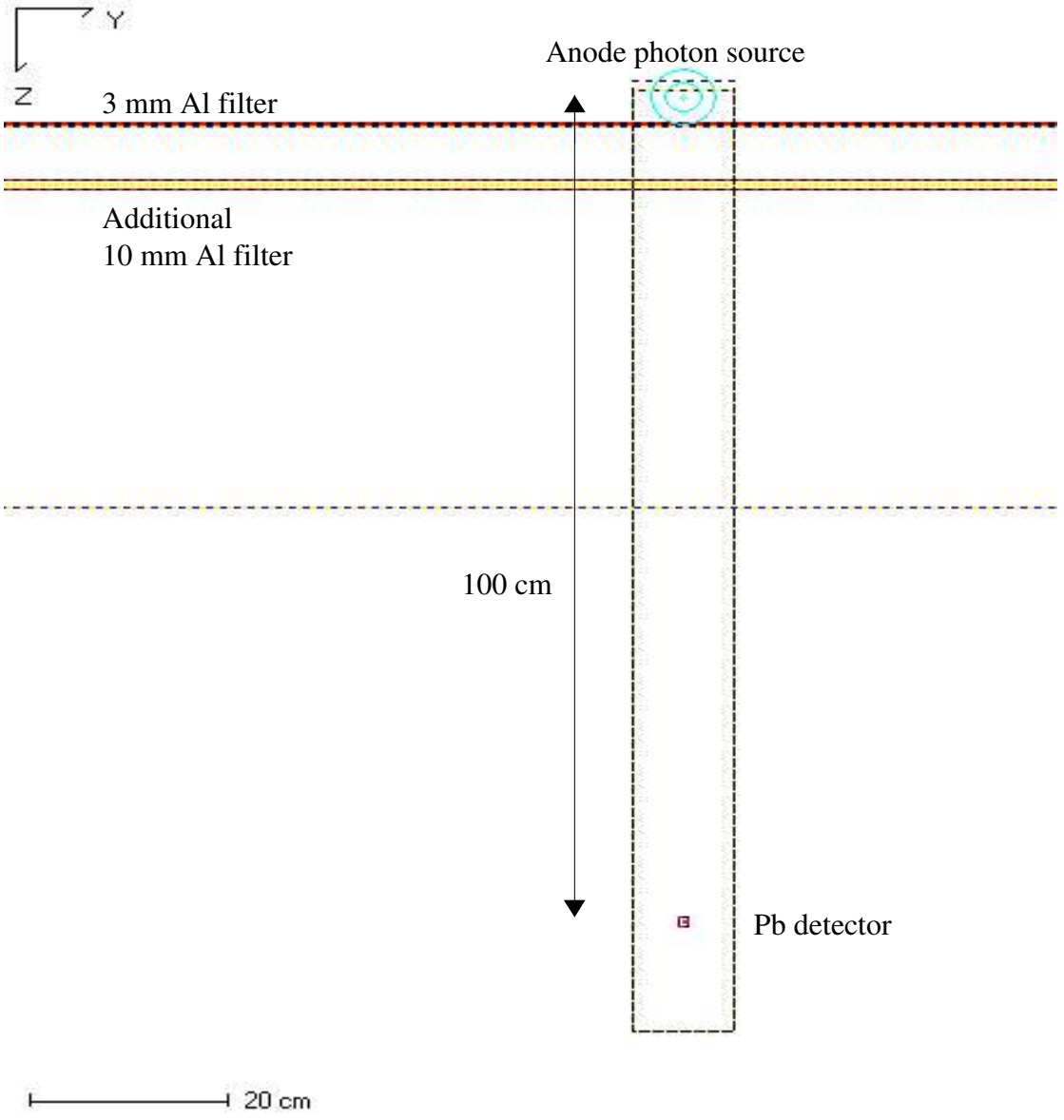
photon source

Anode spectrum 100 kV

3 mm Al filter

10 mm additional Al filter

1 cm³ Pb detector



Assignment 06: X ray properties

X-ray properties:

Use one of the anode spectra obtained in part 1) either 100 kV or 125 kV (or both)

Simulate: parallel X ray beams
with several filters: 0.1, 0.2, 1, 2, ..., 10, 12.5, 15, 17.5 and 30 mm Al

Analysis: Using histogram analysis determine the 1st and 2nd half value layers and the homogeneity grade:

$$H = HVL1/HVL2$$

Discuss the limitations of this approach for real measurements

Simulate: a) divergent X ray beams
with several filters: 0.1, 0.2, 1, 2, ..., 10, 12.5, 15, 17.5 and 30 mm Al
Measure the photon intensity using a histogram analysis
b) divergent X ray beams + 3mm Al filter
with several additional filters: 1, 3, 7, 5, 11, 13 and 15 mm Al
Measure the photon intensity with a "virtual" ionization chamber
Source to detector distance: 100 cm

Analysis: Using histogram analysis determine the 1st and 2nd half value layers and the homogeneity grade:

$$H = HVL1/HVL2$$

Discuss the results

Scoring dimensions and voxel size adapted to each case. Enough statistics.