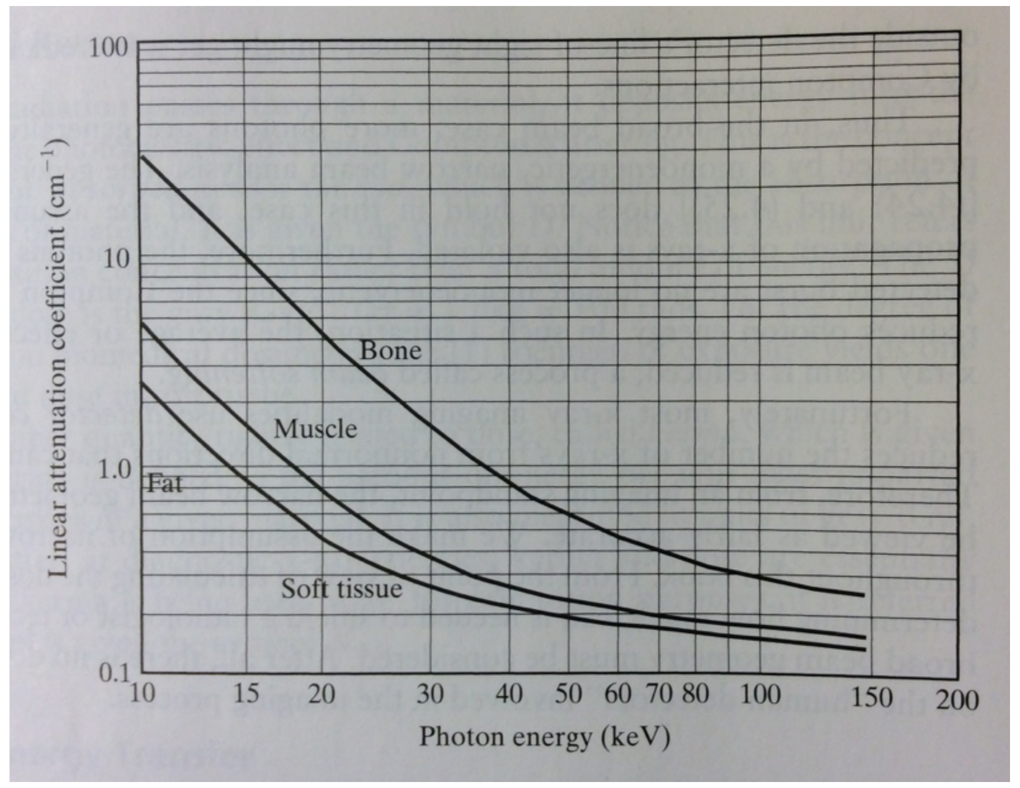
Transmission 3

Unfiltered spectrum:

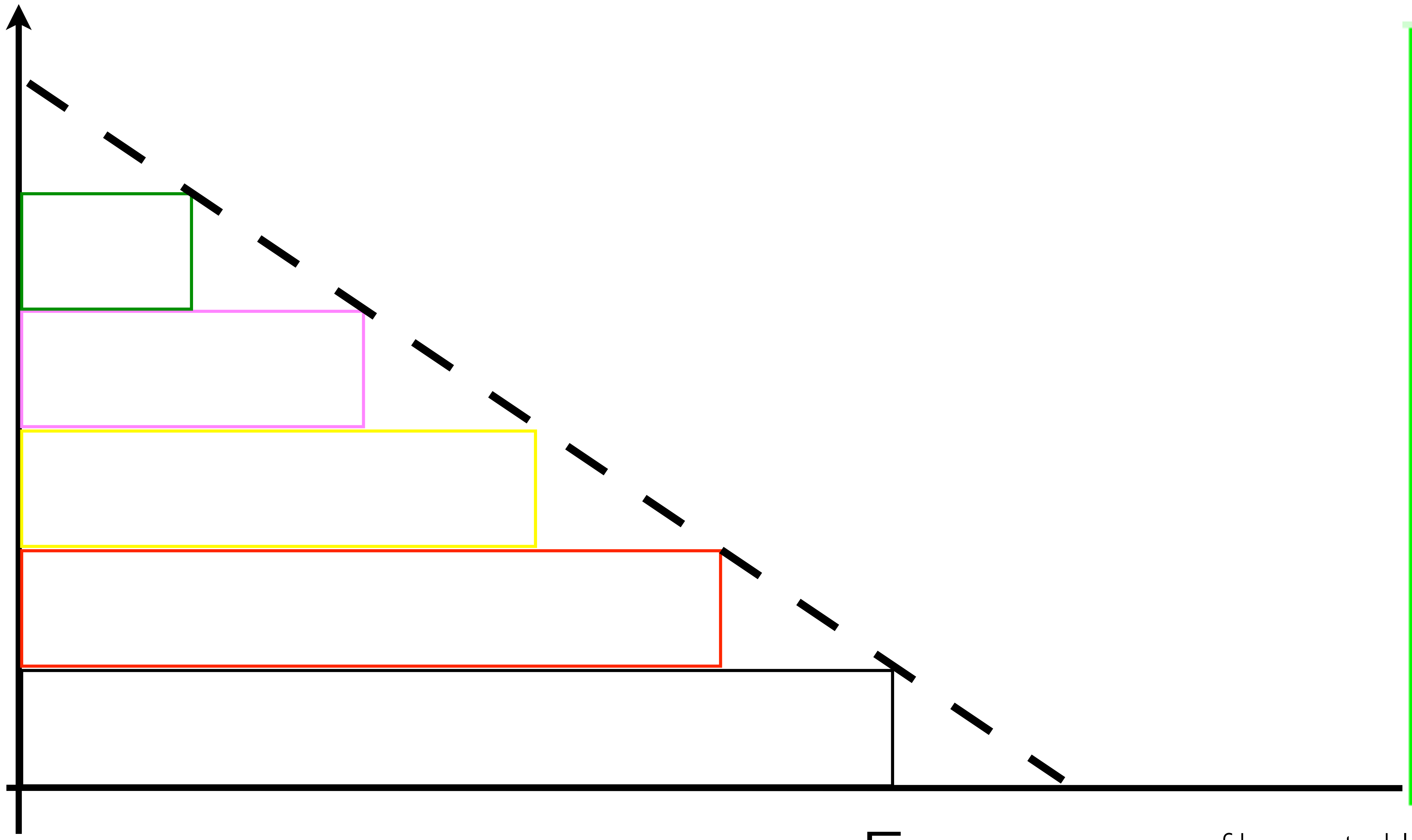


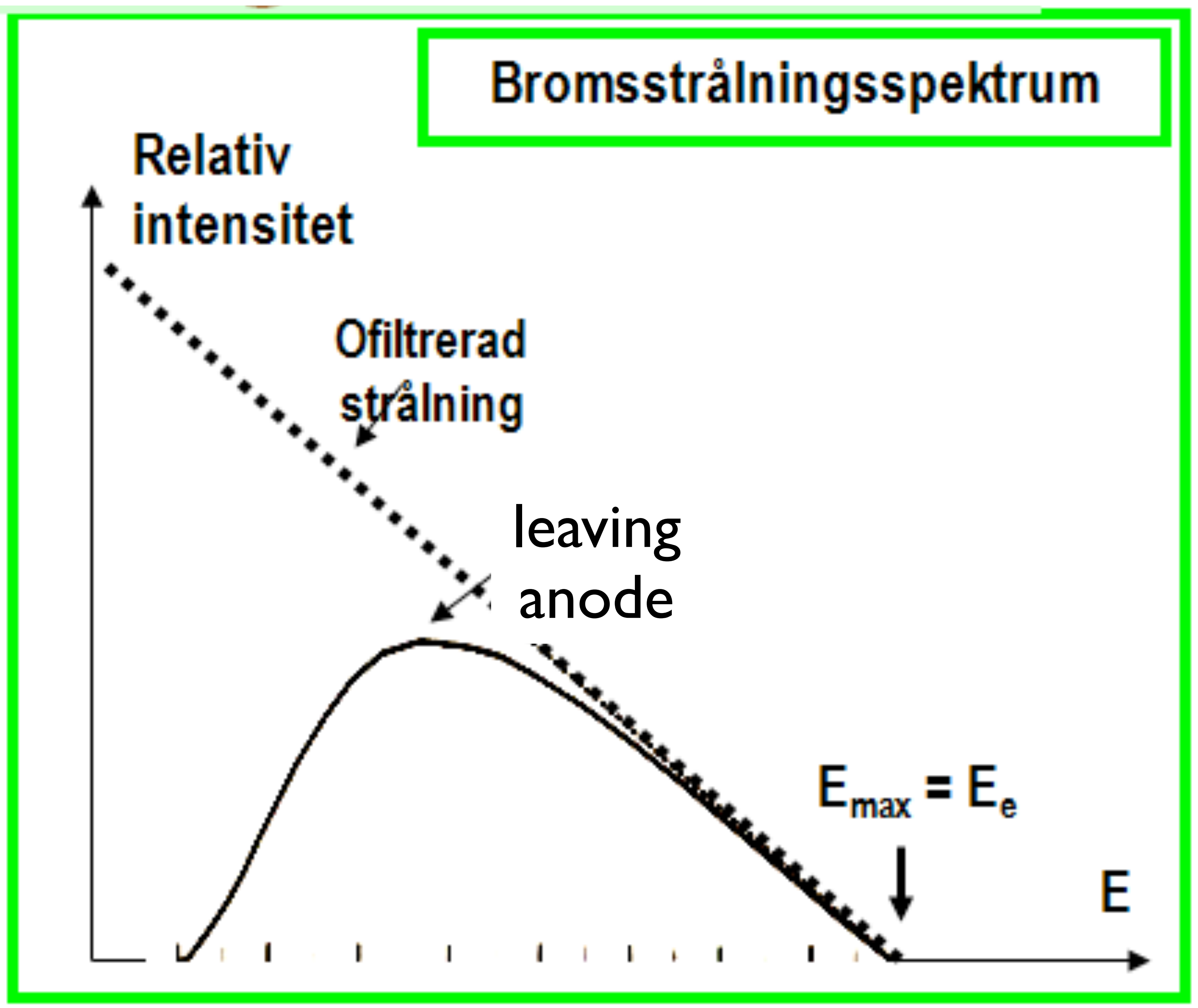
e^-, E_e

thin anode

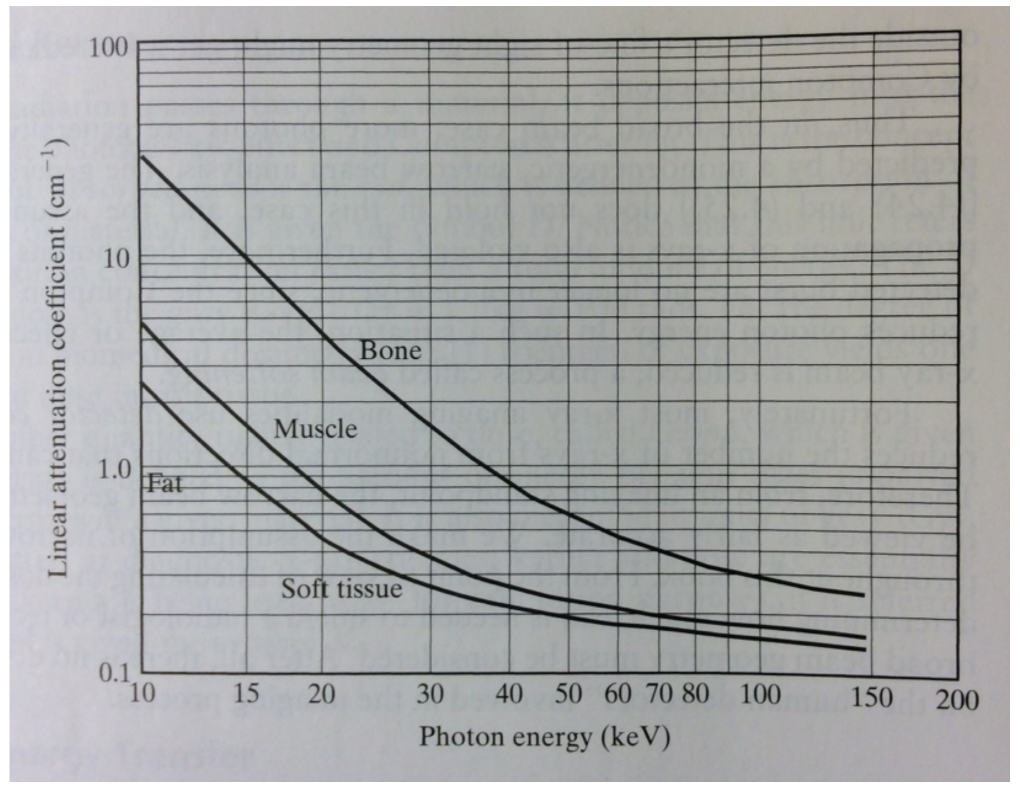
energifördelning av Bromsstrålning + attenueringens energiberoende

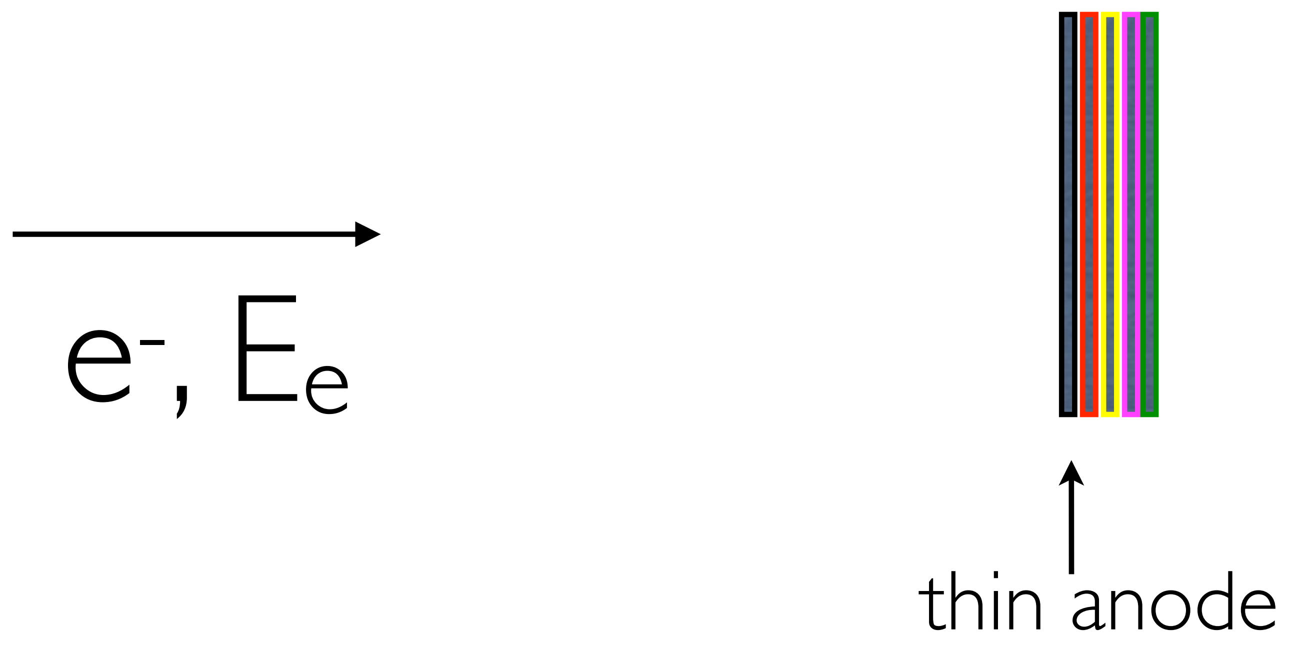
number of photons / energy bin
―――――――――――――
total number of photons



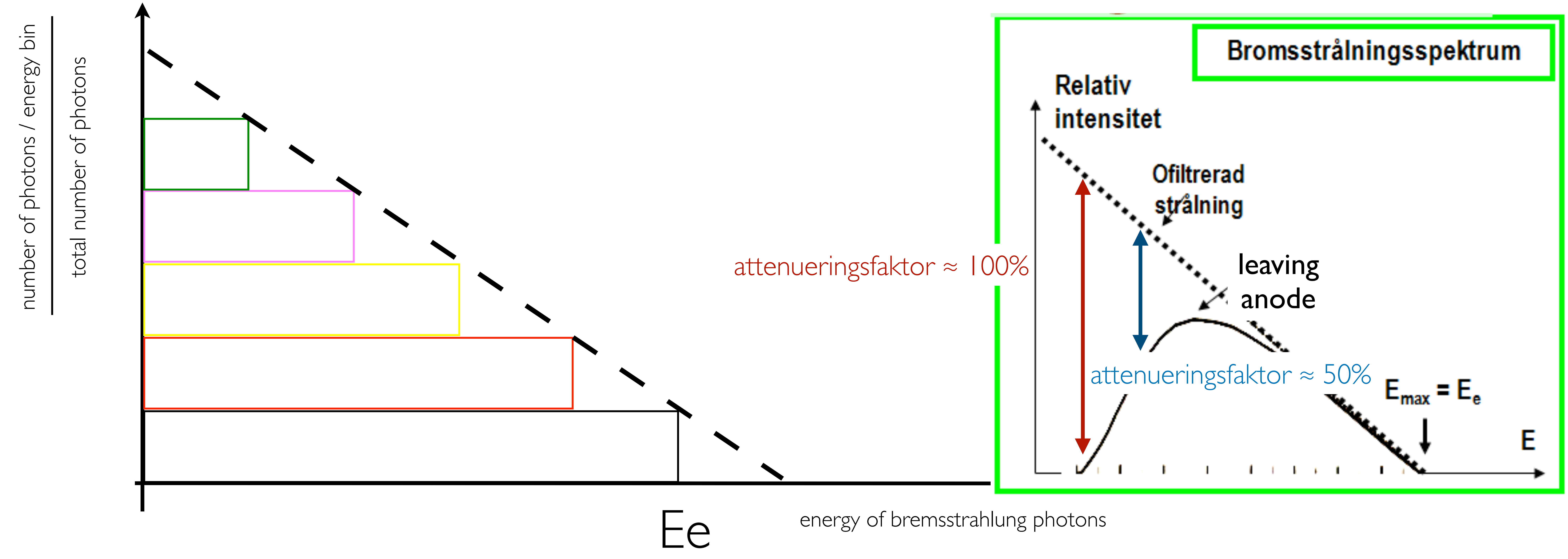


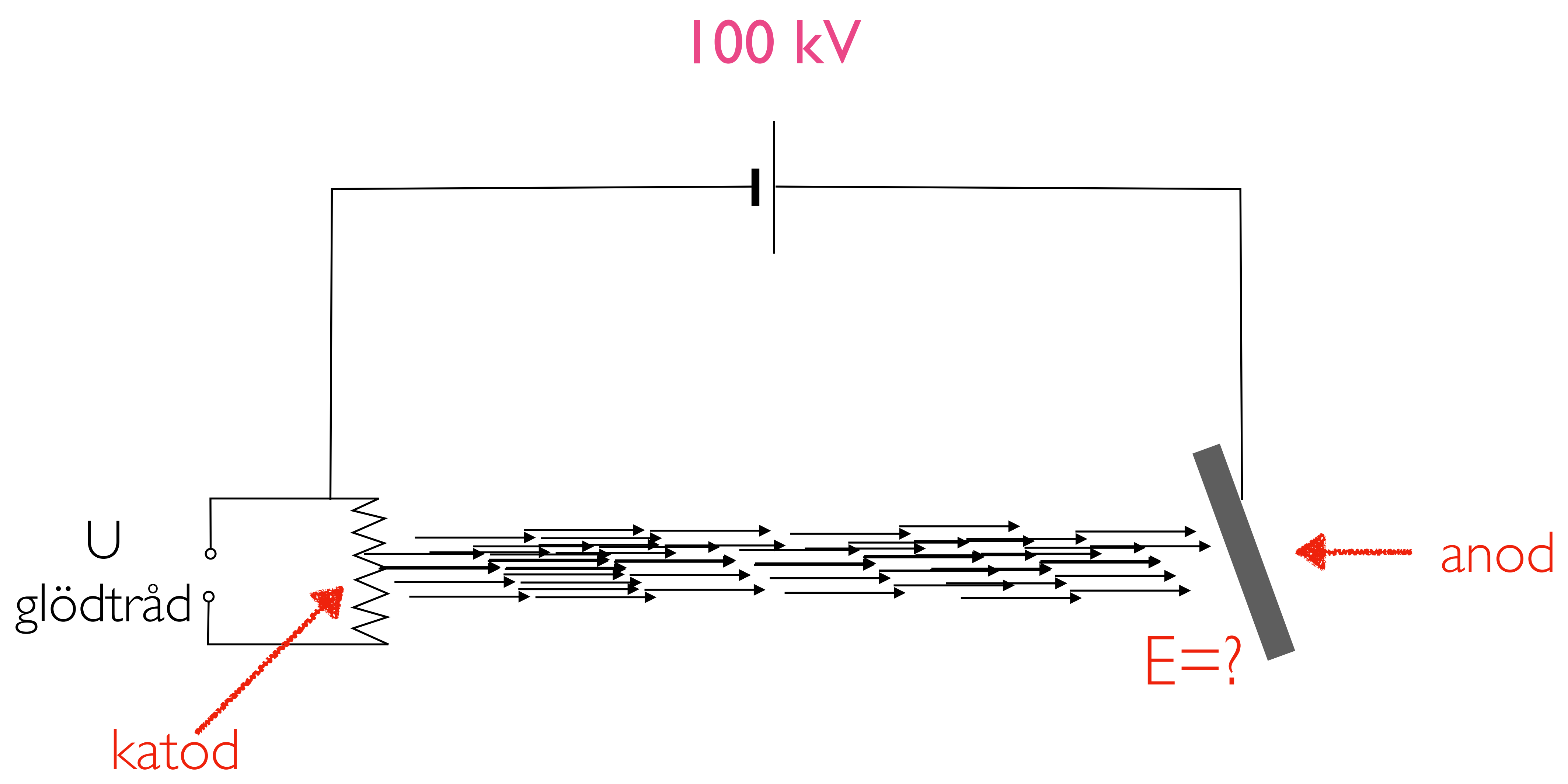
Unfiltered spectrum:





energifördelning av Bromsstrålning + attenueringens energiberoende





Suppose that the accelerating potential is 100 kV. Just before they hit the anode, the energy of the electrons emitted at the cathode is:

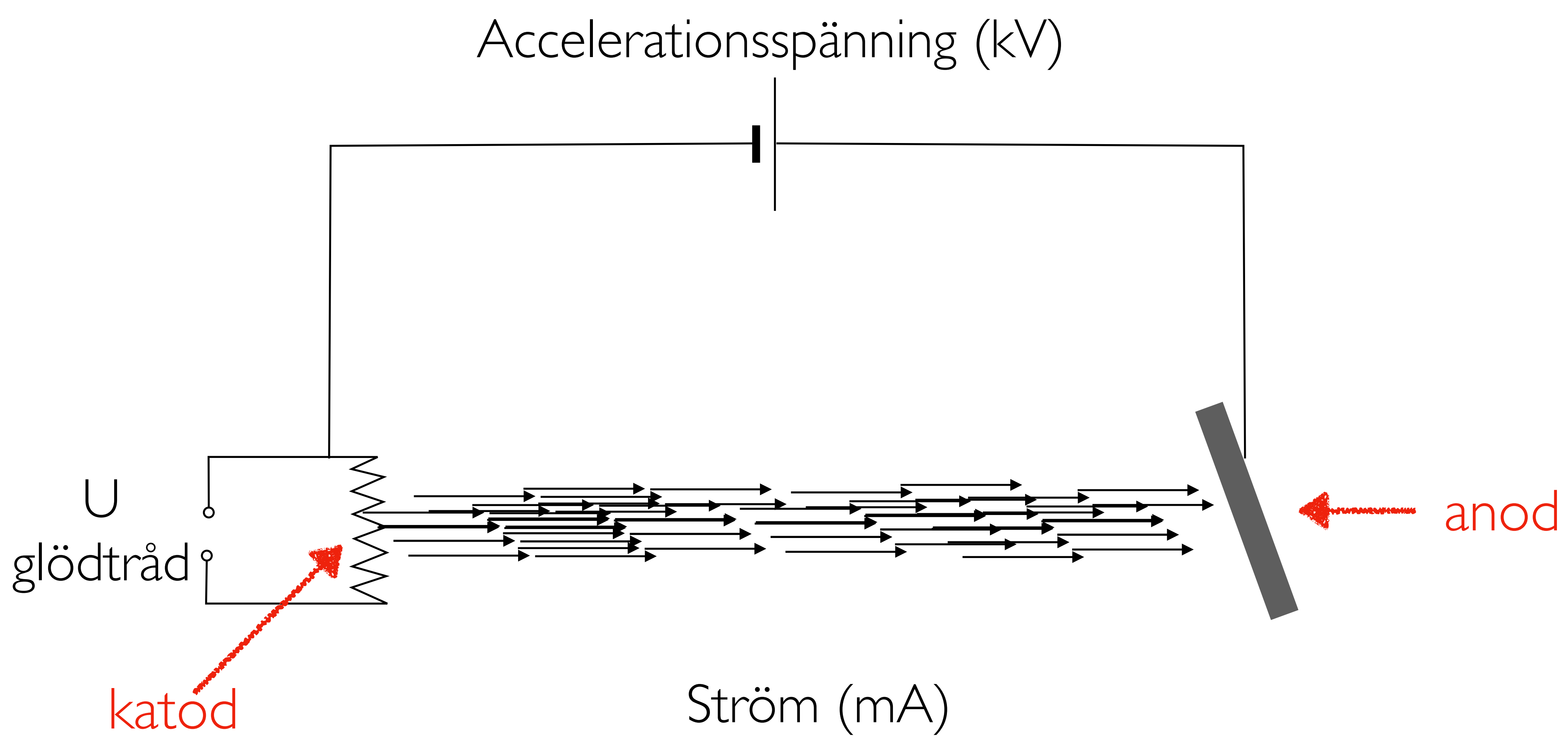
~~1. very high~~

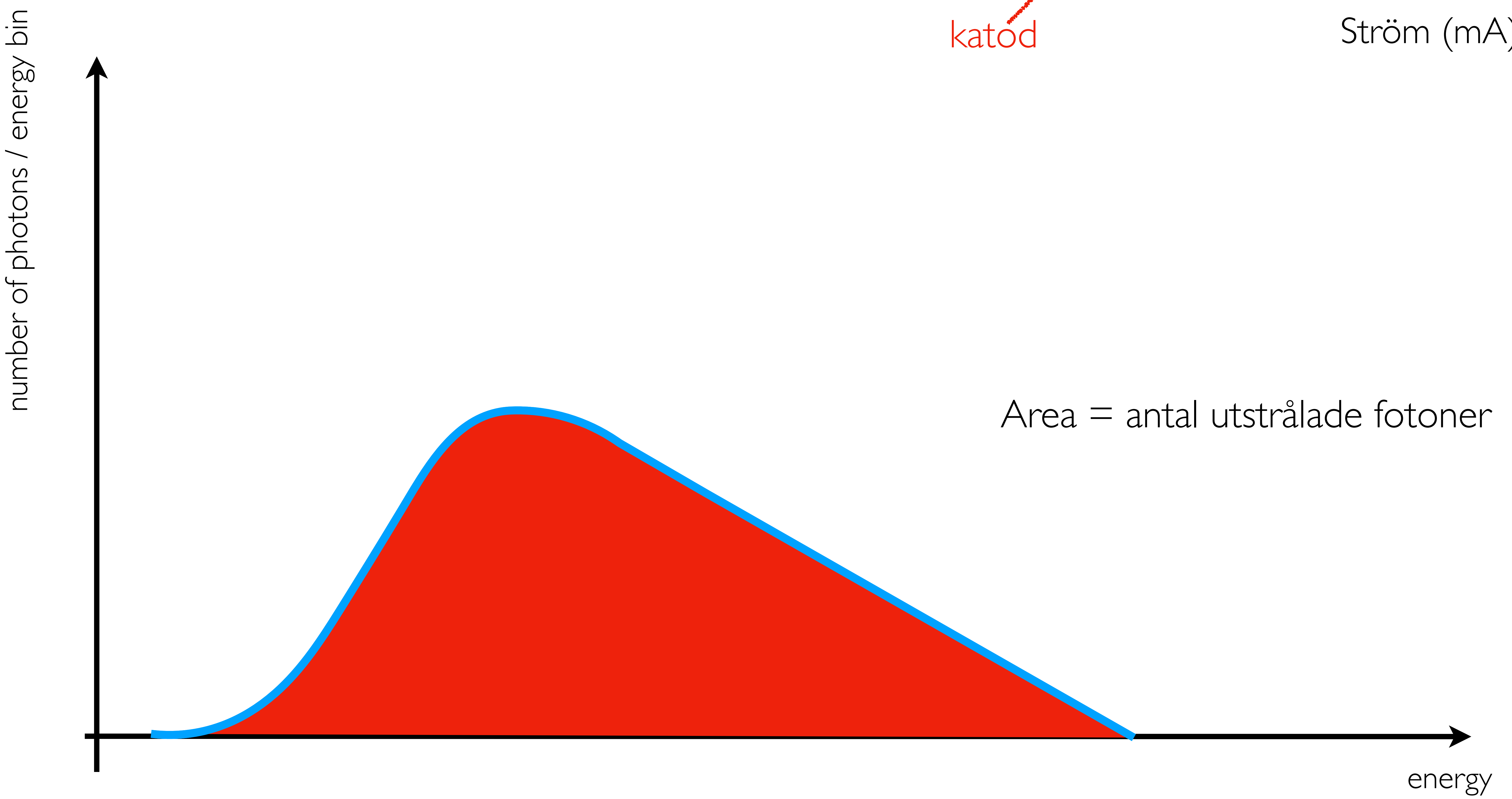
~~2. anything between 0 and 100 keV~~

3. 100 keV

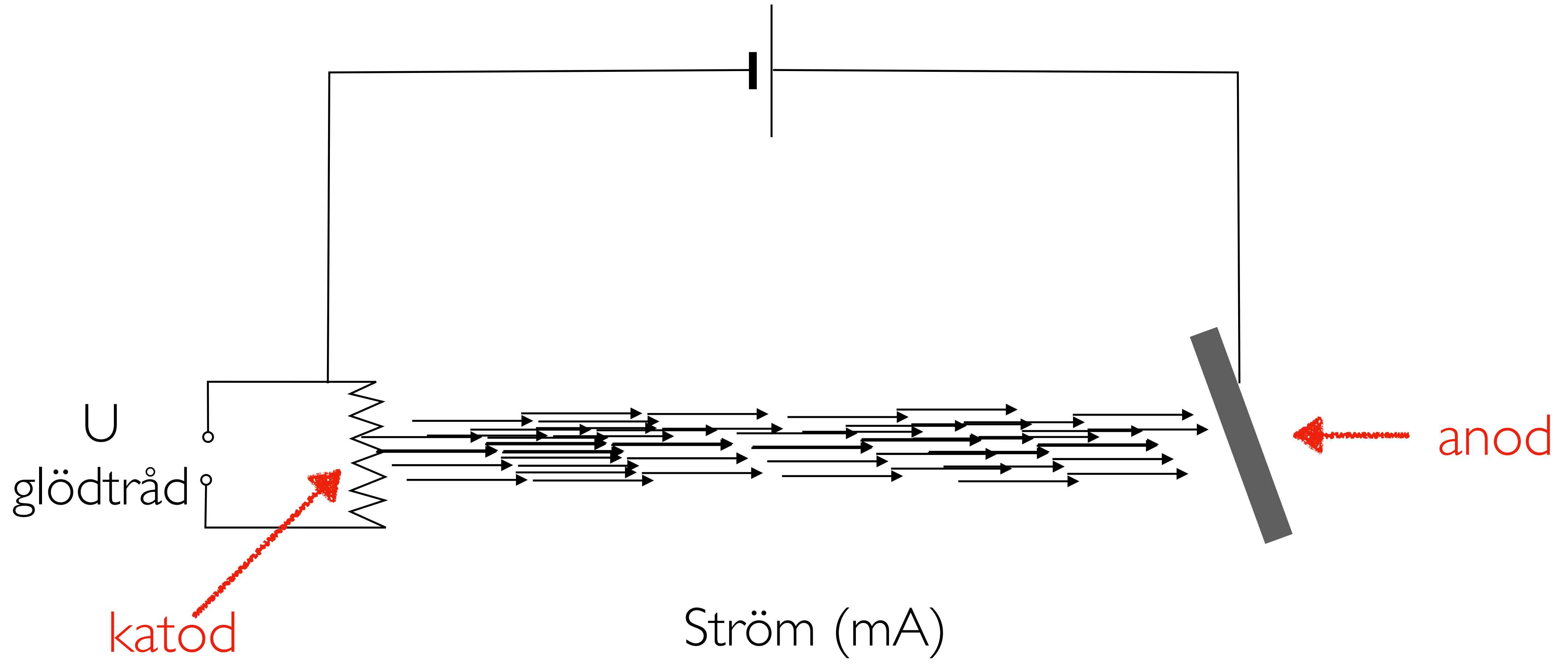
~~4. impossible to say, more information is needed~~

Enkla resonemang kring spektrumet

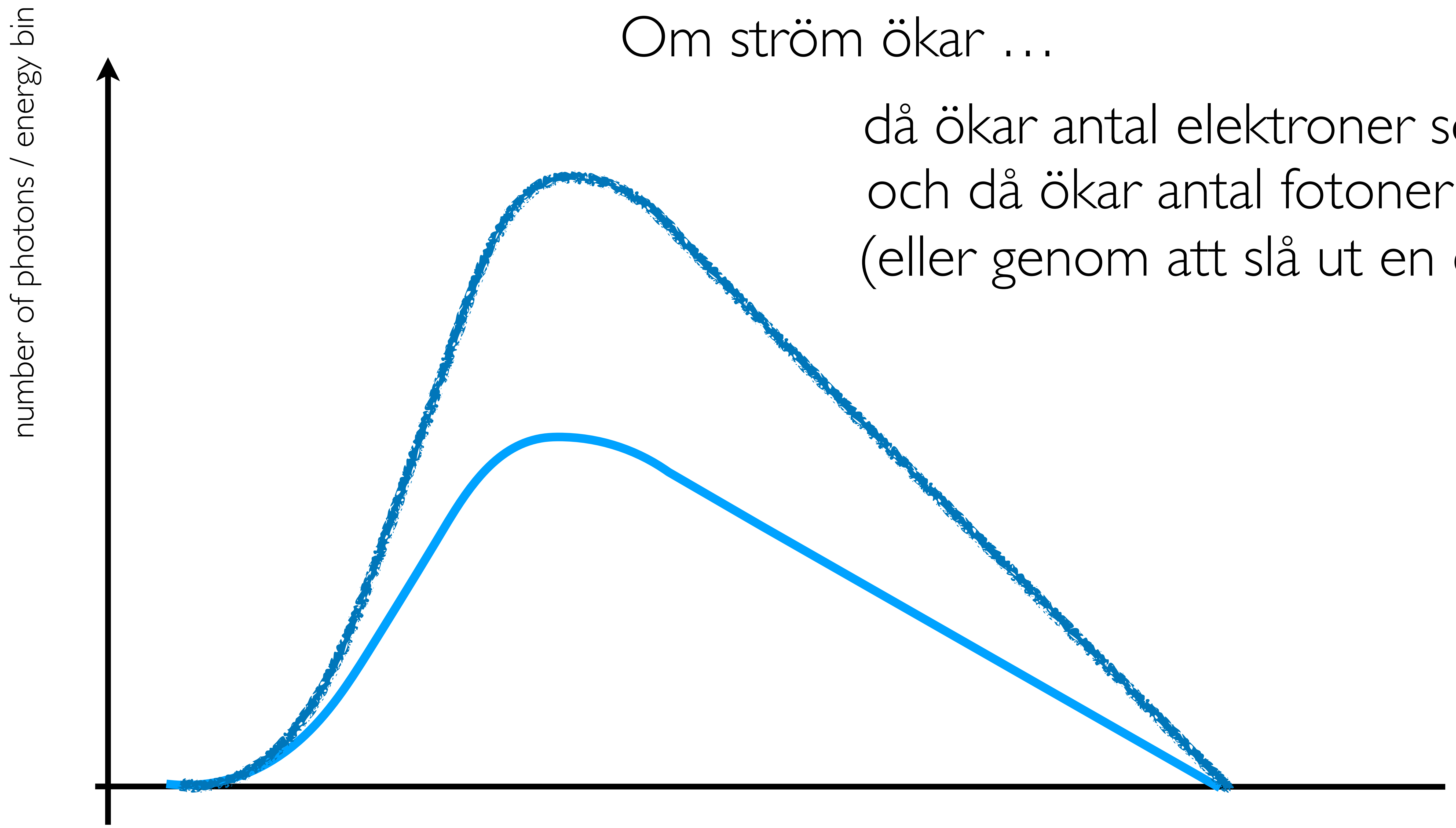




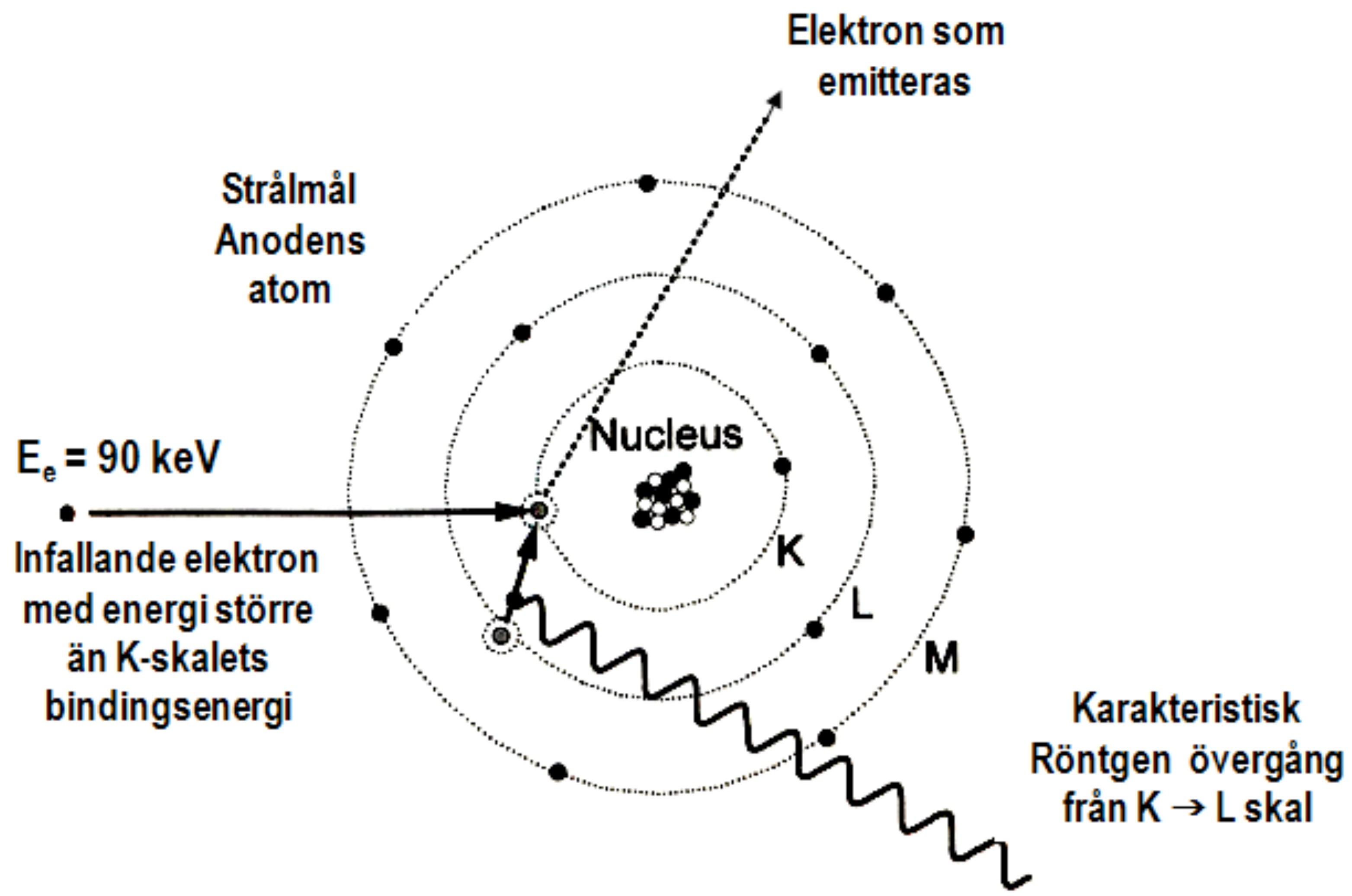
Enkla resonemang kring spektrumet



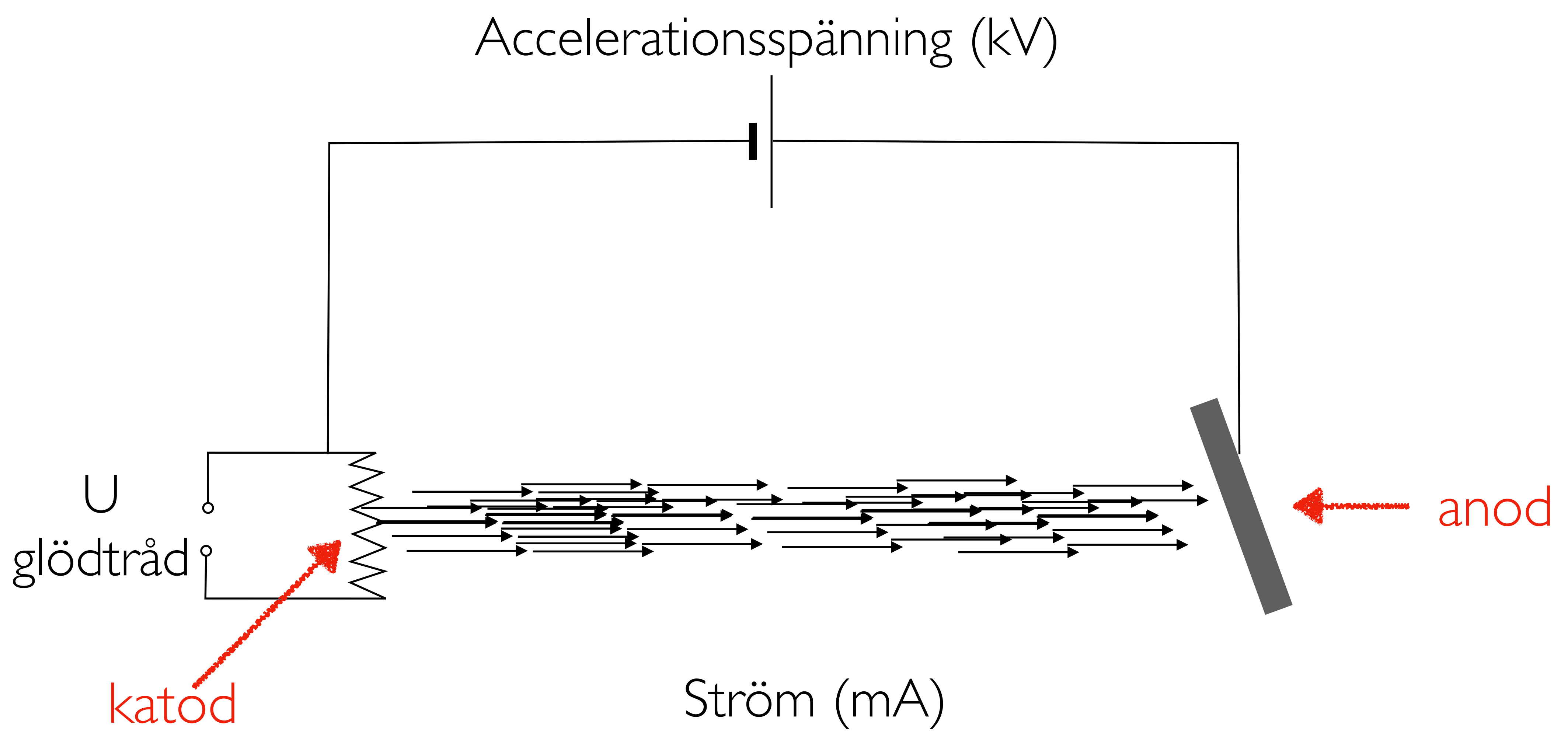
Om ström ökar …



då ökar antal elektroner som träffar anoden
och då ökar antal fotoner som utstrålas via bromsstrålning
(eller genom att slå ut en elektron i en atom i anoden)



Enkla resonemang kring spektrumet

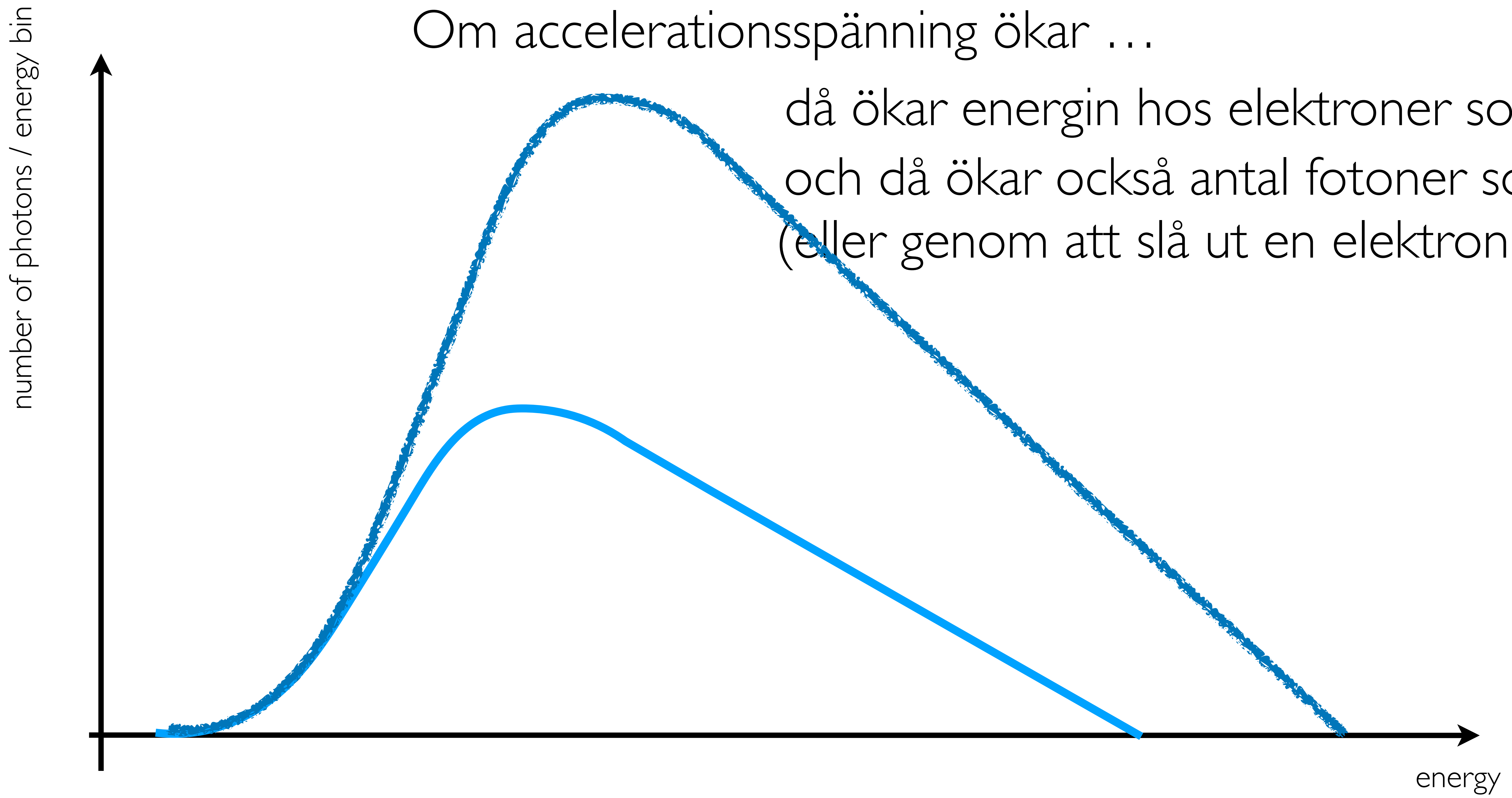


Om accelerationsspänning ökar …

då ökar energin hos elektroner som träffar anoden

och då ökar också antal fotoner som utstrålas via bromsstrålning

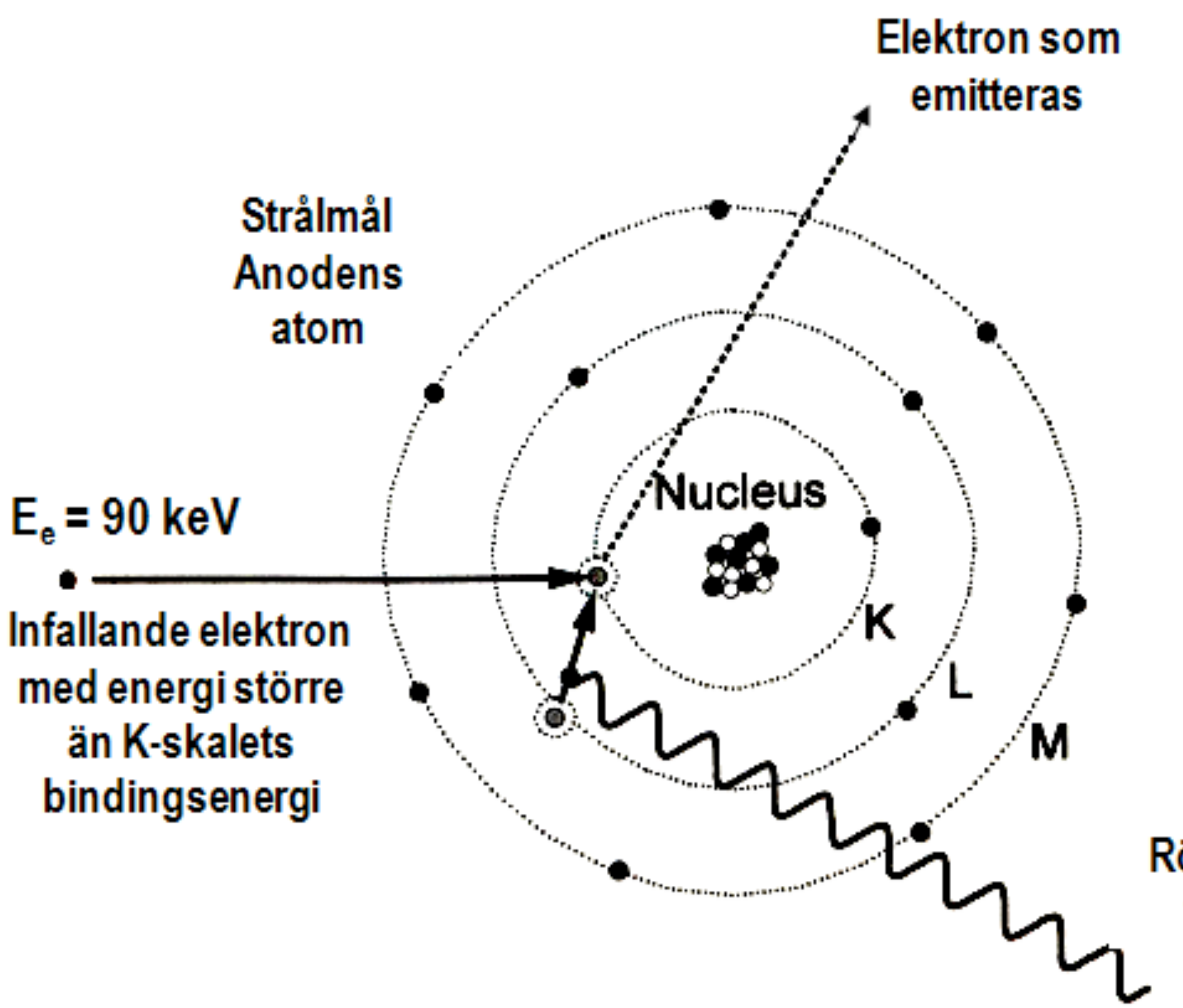
(eller genom att slå ut en elektron i en atom i anoden)

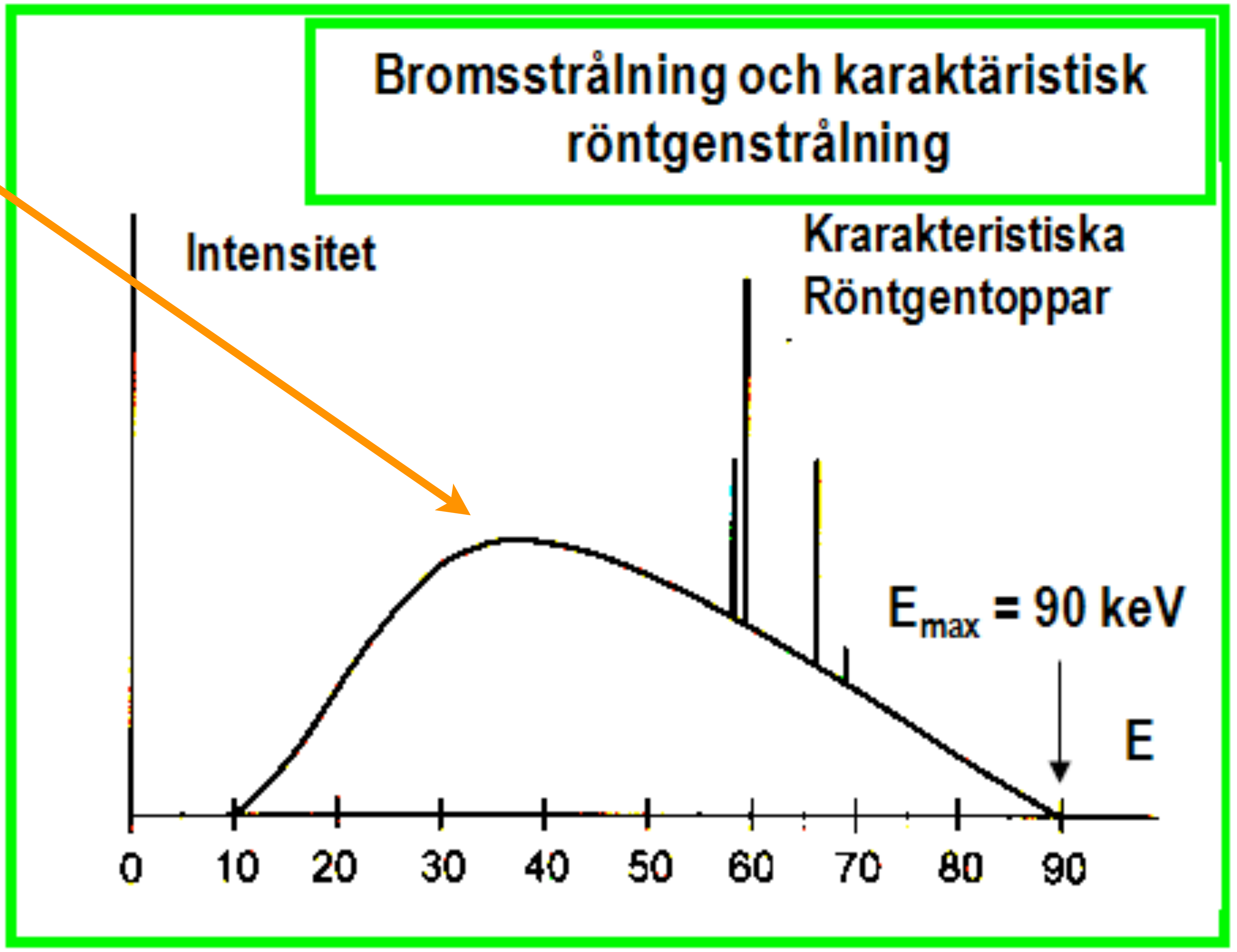


Röntgenstrålning och bromsstrålning

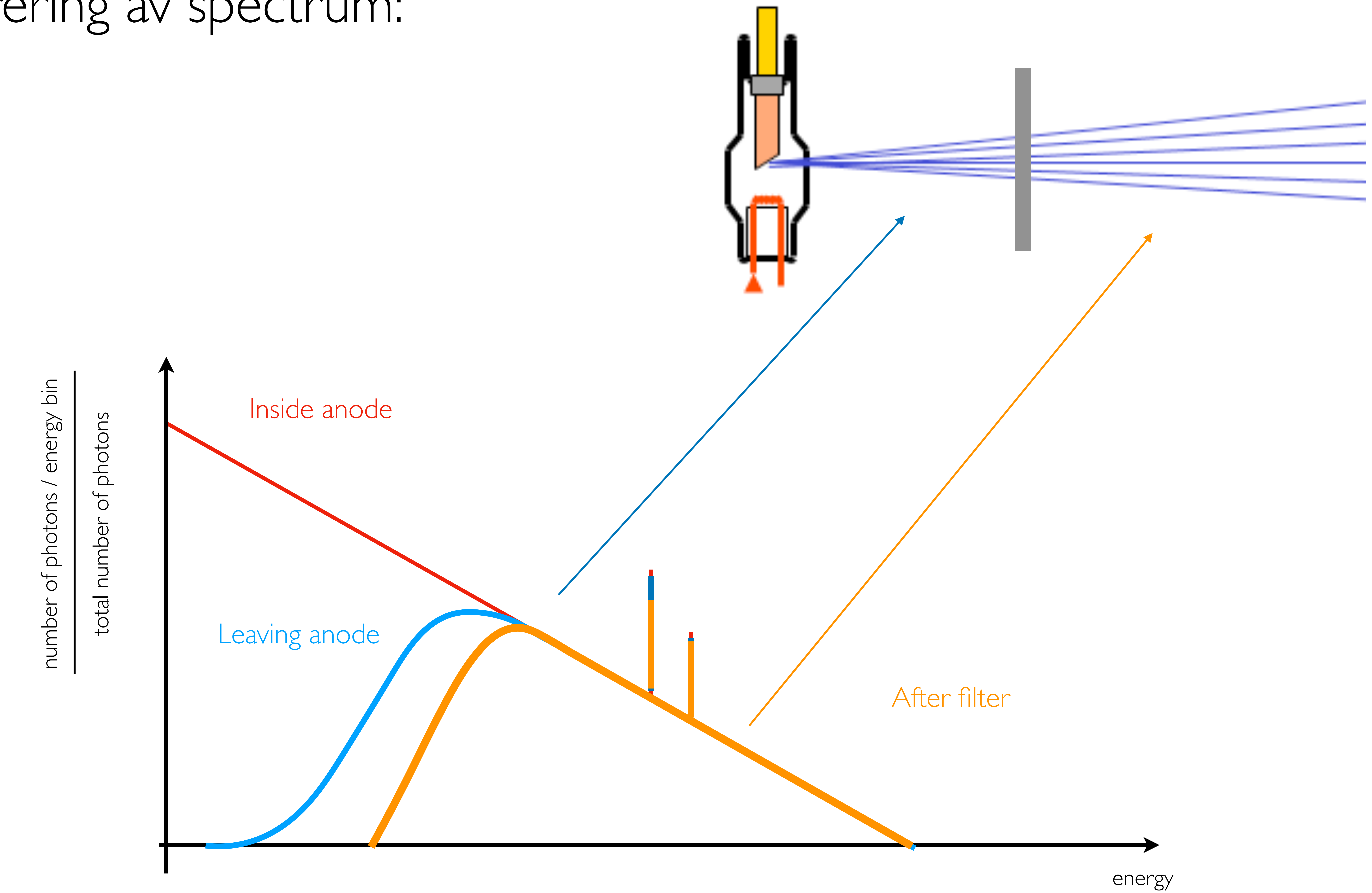
- Om elektronernas energi är tillräcklig kan de slå ut elektroner från anodens atomer. En foton med karakteristisk Röntgenenergi emitteras.
- Dessa kan observeras överlagrade bromsstrålsspektrat

OBS: max intensitet @ 1/3-1/2 av E_{max}





Filtrering av spectrum:

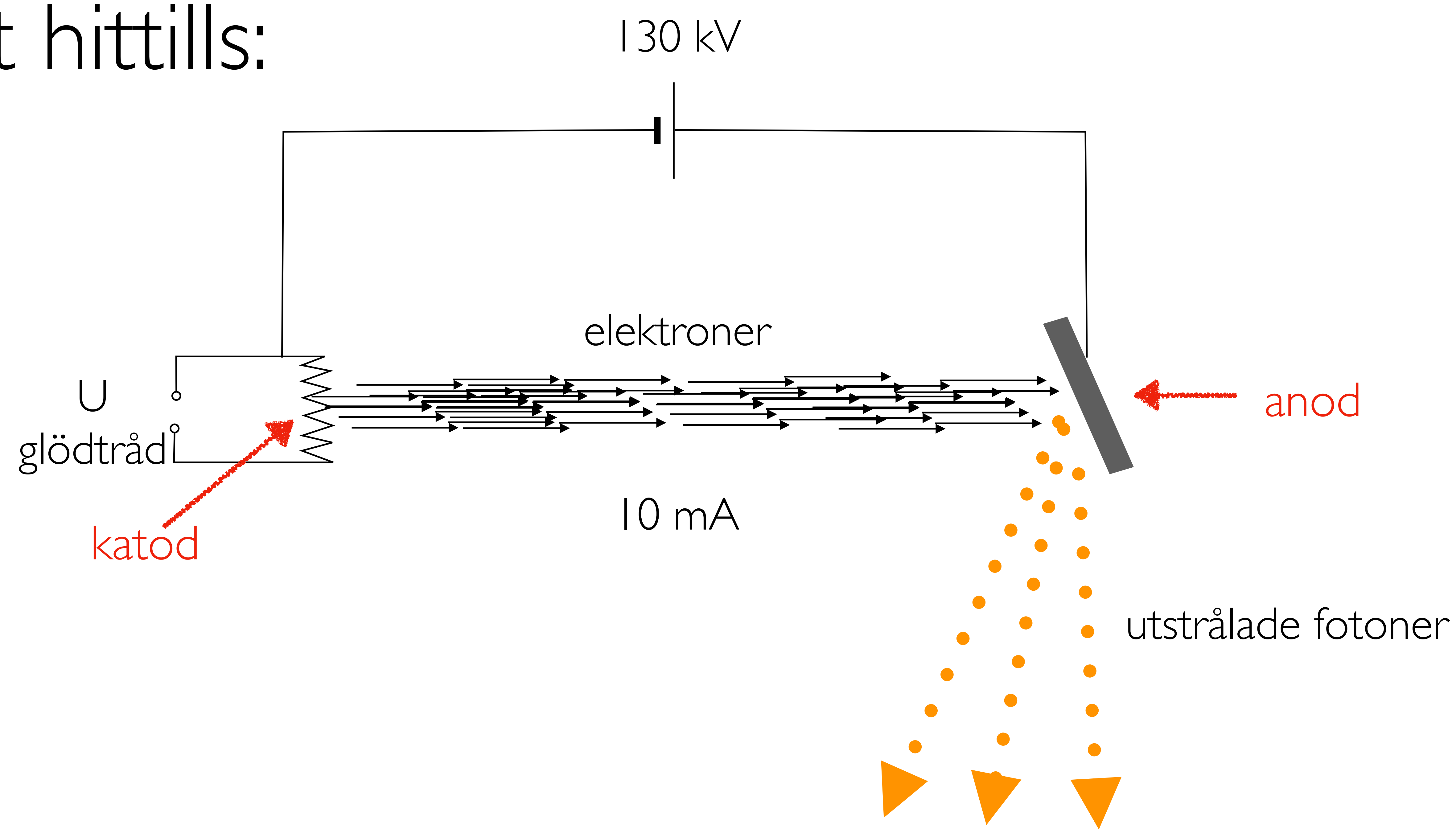


Övningar som du ska kunna klara om du har tagit till dig stoffet om röntgenspektrum vi avhandlat hittills:

Övning I

Beakta röntgenröret (schema) i figuren bredvid.

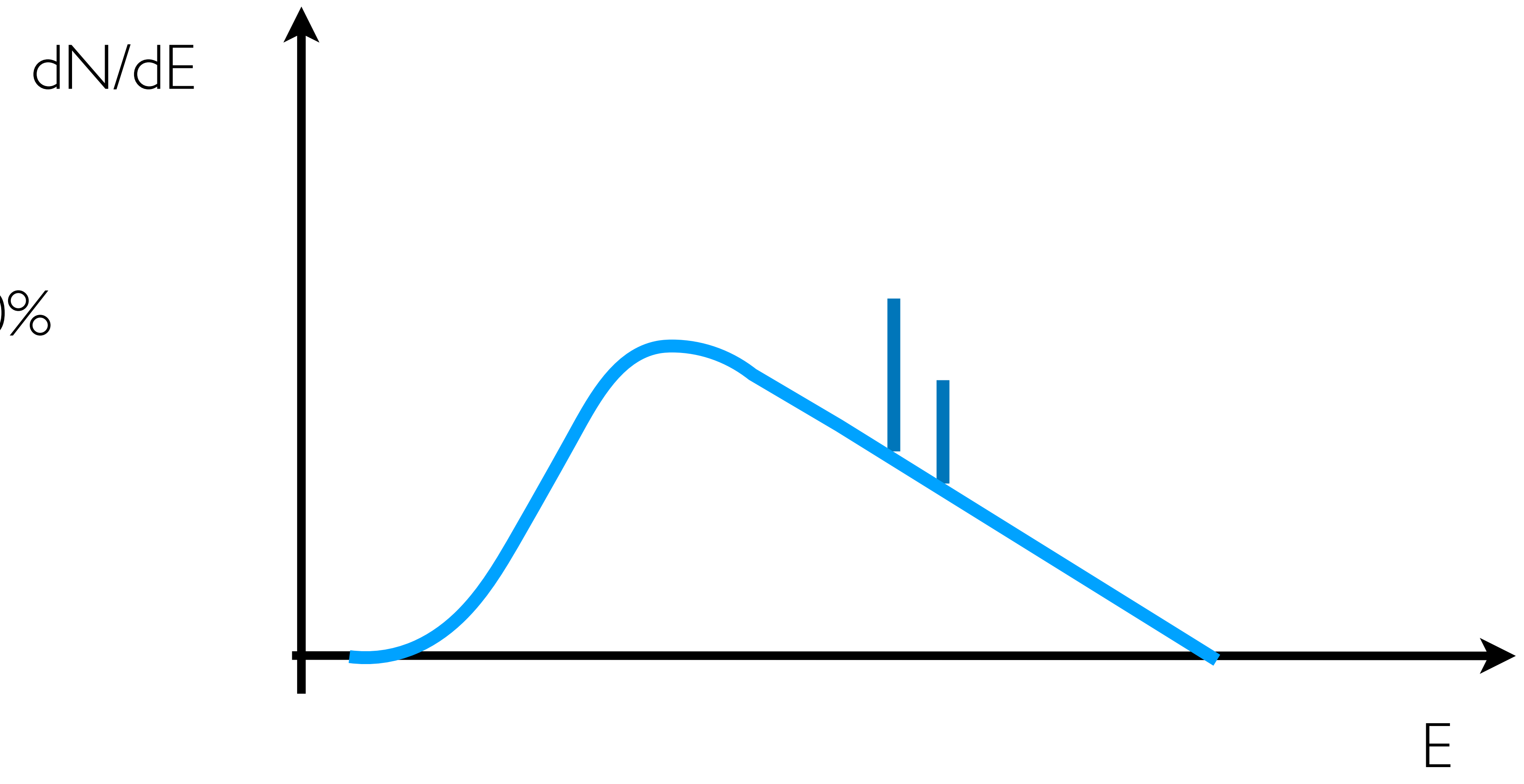
1. Vilken är fotonernas maximala energin?
2. Vilken energin har elektronerna precis före de träffar anoden?
3. Hur många elektroner per sekund når anoden?
4. Vad är effekten på anoden?
5. Vad är "rörets output"? Det vill säga mängden energin per sekund som strålas ut i form av fotoner från anoden



Övning II

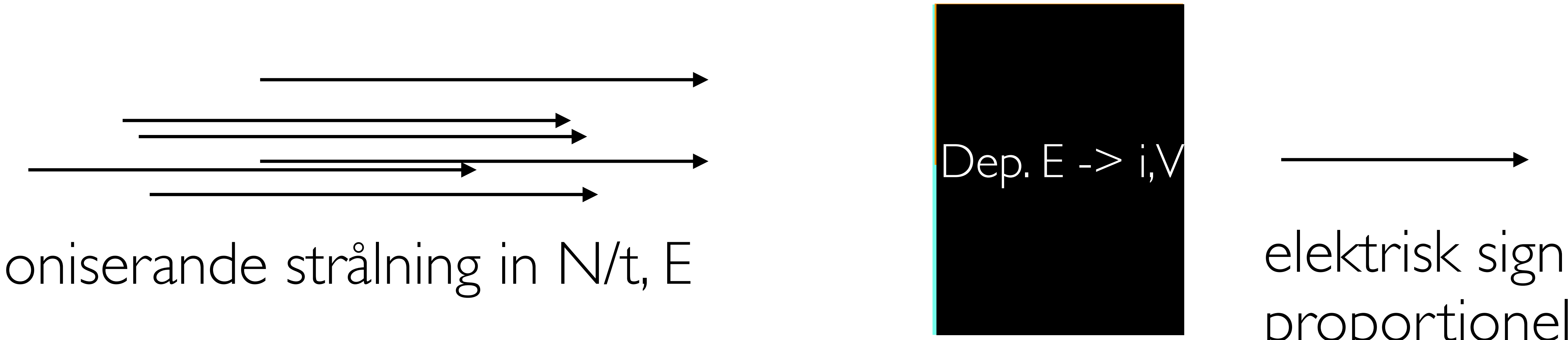
Beakta spektrumet i figuren bredvid.

1. Rita spektrumet från samma röntgenrör om accelerationsspänning ökar med 20%
2. Och spektrumet om i stället ström ökar med 20%
3. Rita även spektrum efter ett filter



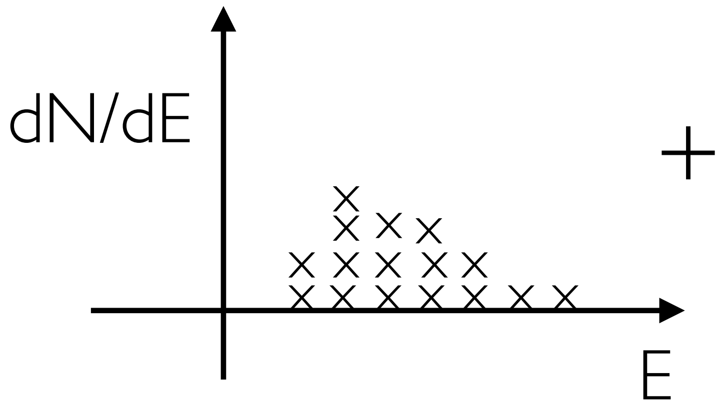
Joniserande strålnings detektorer: grundläggande principer

Joniserande strålnings detektorer: grundläggande principer



elektrisk signal
proportionell till
deponerad energin

räknar varje foton för sig
(photon-counting detector)



+ räknehastighet

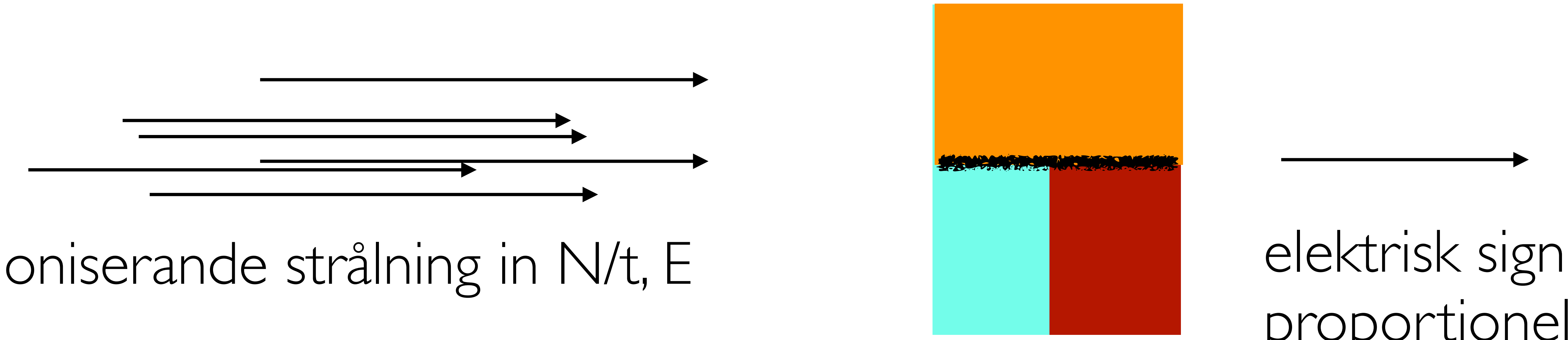
kallas också "pulse mode"

integrerar signalen över en viss tid
(energy-integrating detector)

kallas också "current mode"

Joniserande strålnings detektorer: grundläggande principer

omvandlar direkt
röntgen/gamma till
elektrisk signal



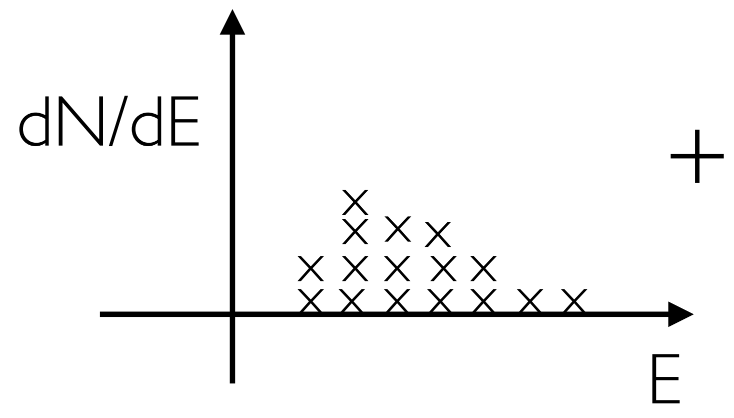
joniserande strålning in N/t, E

elektrisk signal
proportionell till
deponerad energin

scintillator:
omvandlar röntgen/
gamma till optiska
fotoner (ofta UV)

photosensor:
omvandlar optiska
fotoner till elektrisk
signal

räknar varje foton för sig
(photon-counting detector)



+ räknehastighet

kallas också "pulse mode"

integrerar signalen över en viss tid
(energy-integrating detector)

kallas också "current mode"

Pappersflygplans detektorer: allmänna principer

Barn kastar pappersflygplan i klassrummet under en viss tid. Jag hittar 3 i min “detektorkorg”.

Hur många pappersflygplan har kastats under tiden?

1. ≤ 3
2. 3
3. ≥ 3

Pappersflygplans detektorer: allmänna principer

Barn kastar pappersflygplan i klassrummet under en viss tid. Jag hittar 3 i min "detektorkorg".

Hur många pappersflygplan har kastats under tiden?

1. ≤ 3
2. 3
3. ≥ 3

Om du i framtiden ville uppskatta antal kastade från de som hamnar i korgen, vad skulle du göra?

Detector efficiency (effektivitet):

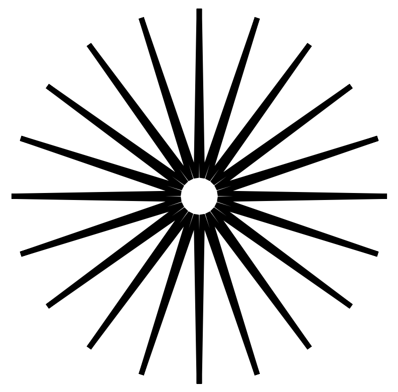
geometry (solid angle) & "intrinsic" efficiency

before that:

difference between activity (decay/s),
emitted photons and
detected photons
count rate

detection efficiency or sensitivity
(effektivitet eller känslighet)

S

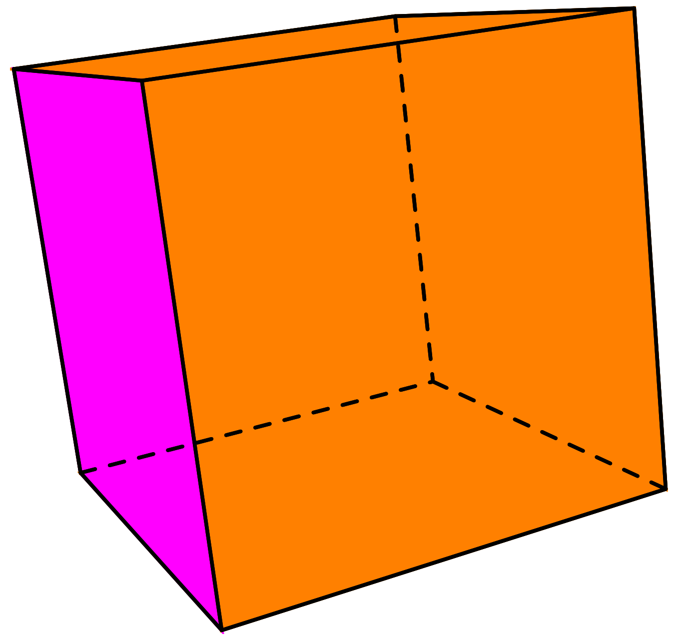


A = 1 kBq

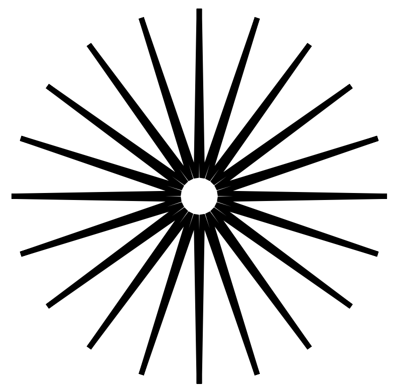
1000 decays/s

does this imply that 1000 photons/s are emitted?

D



S

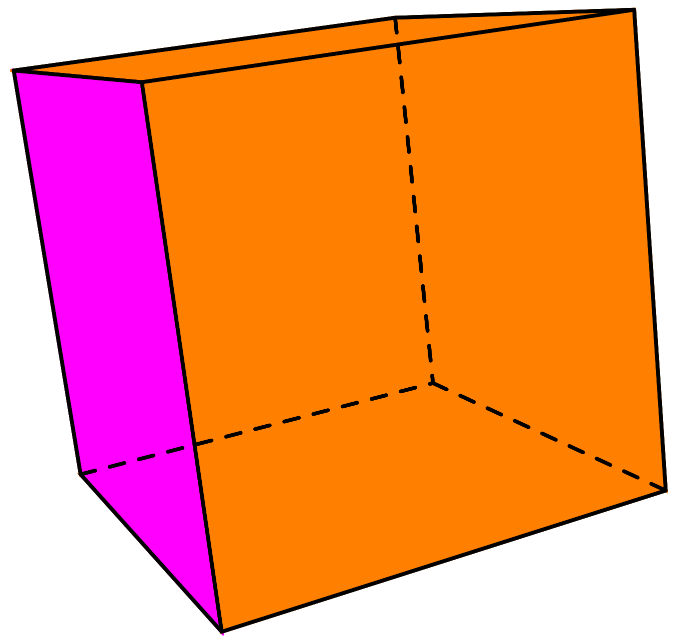


A = 1 kBq

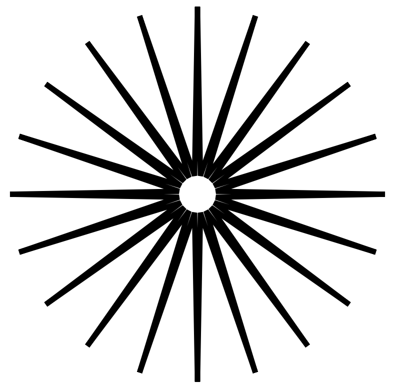
1000 decays/s

# of emitted photons depends on decay scheme!

D



S



A = 1 kBq

1000 decays/s

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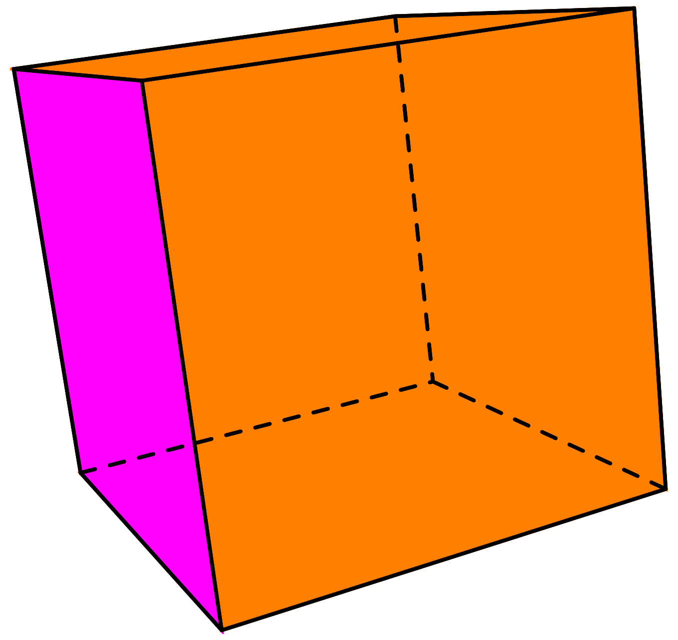
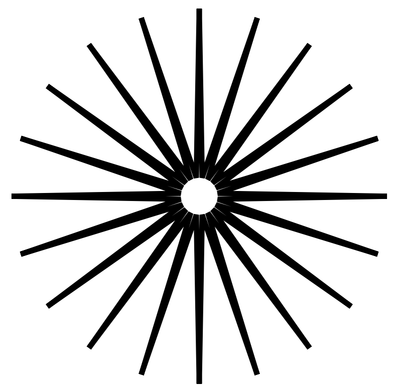
photons depends
on decay scheme!

D



# of detected
photons?

S



A = 1 kBq

1000 decays/s

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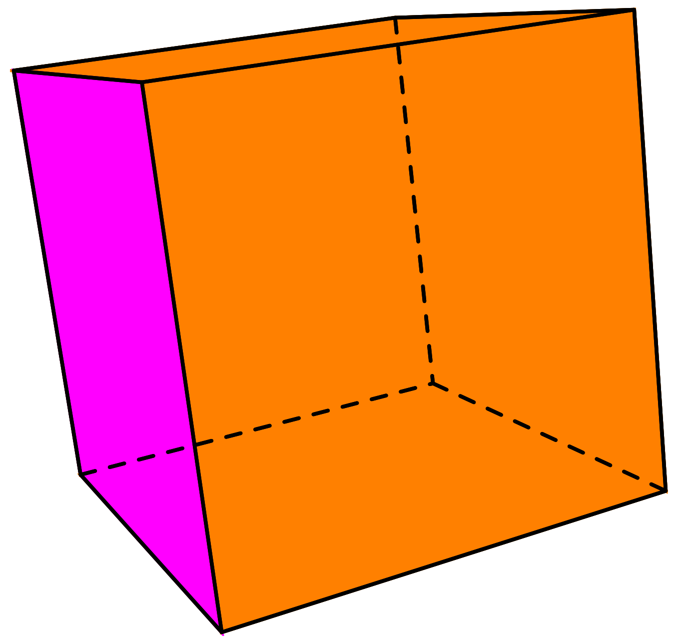
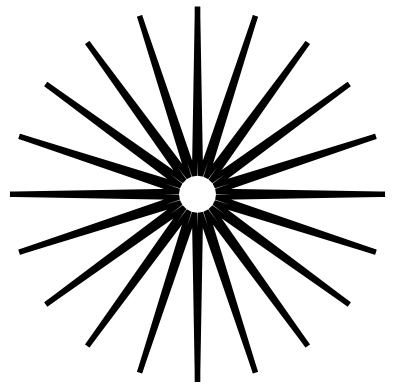
D



# of detected photons?

efficiency: $\dfrac{\text{\# detected photons}}{\text{\# emitted photons}}$

S



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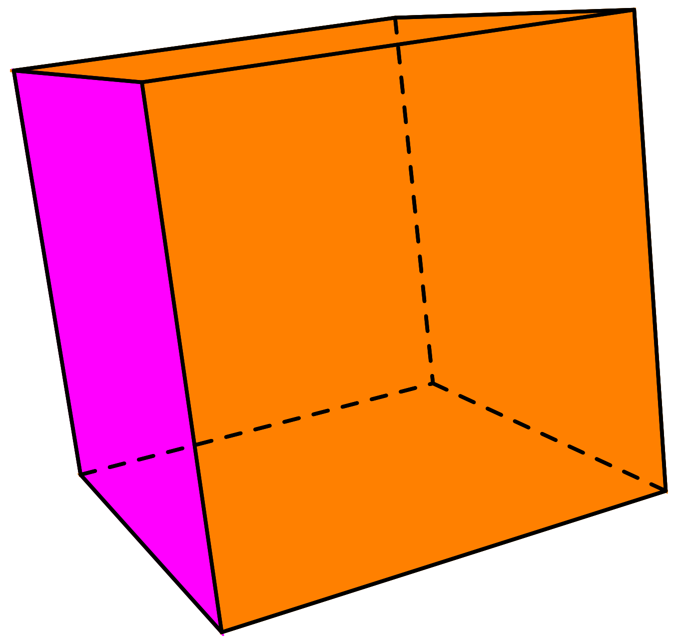
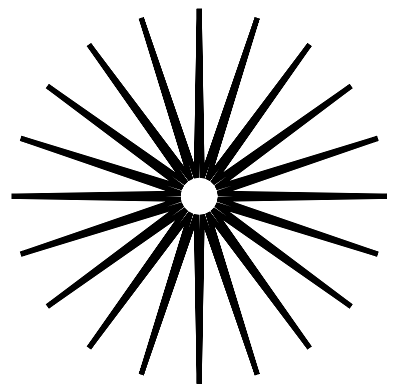
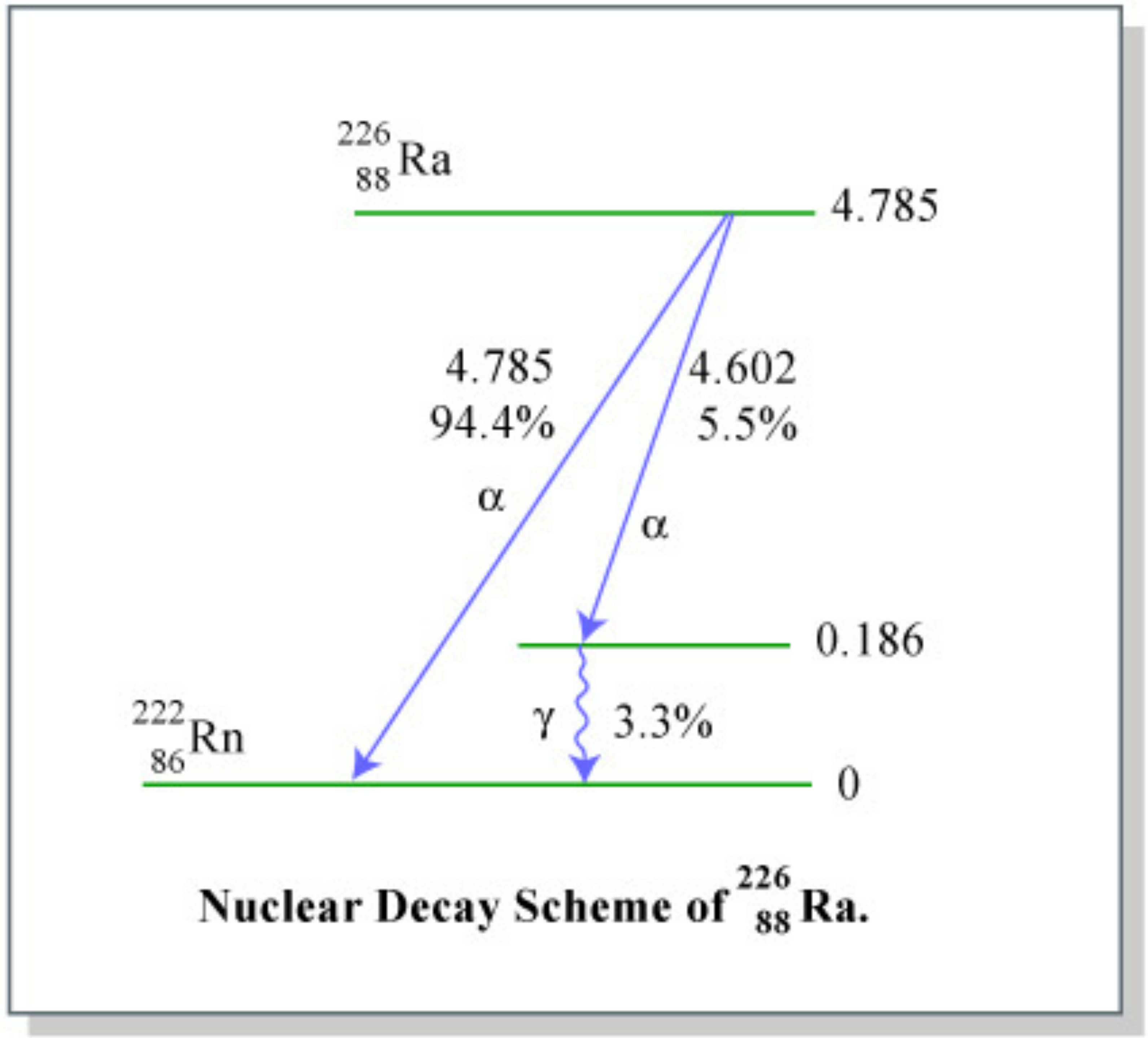


S



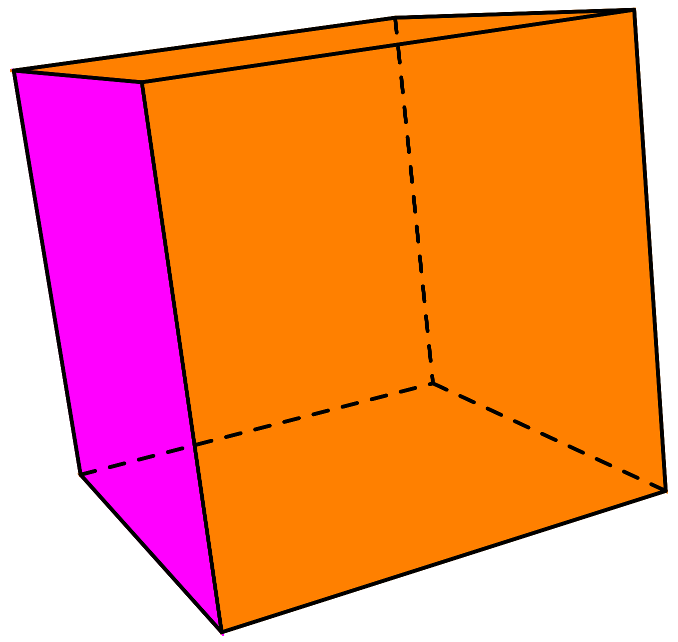
A = 1 kBq

1000 decays/s

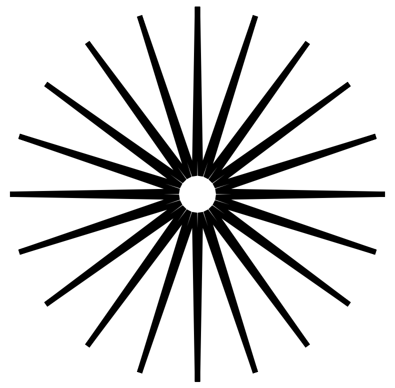


Nuclear Decay Scheme of $^{226}_{88}$Ra.

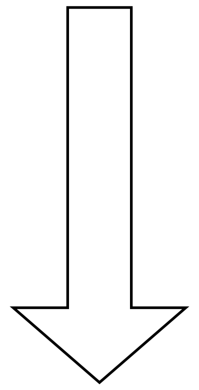
D



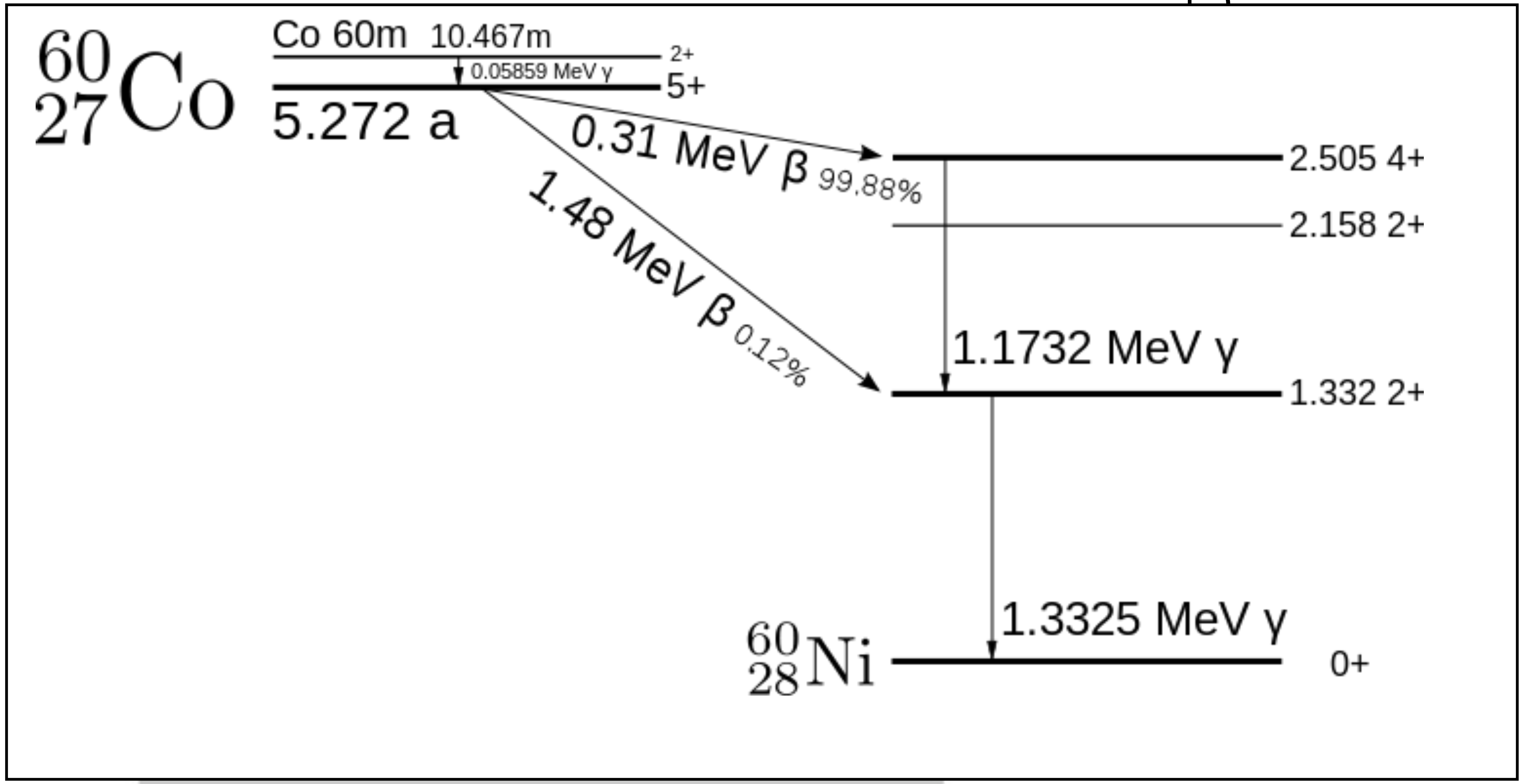
S



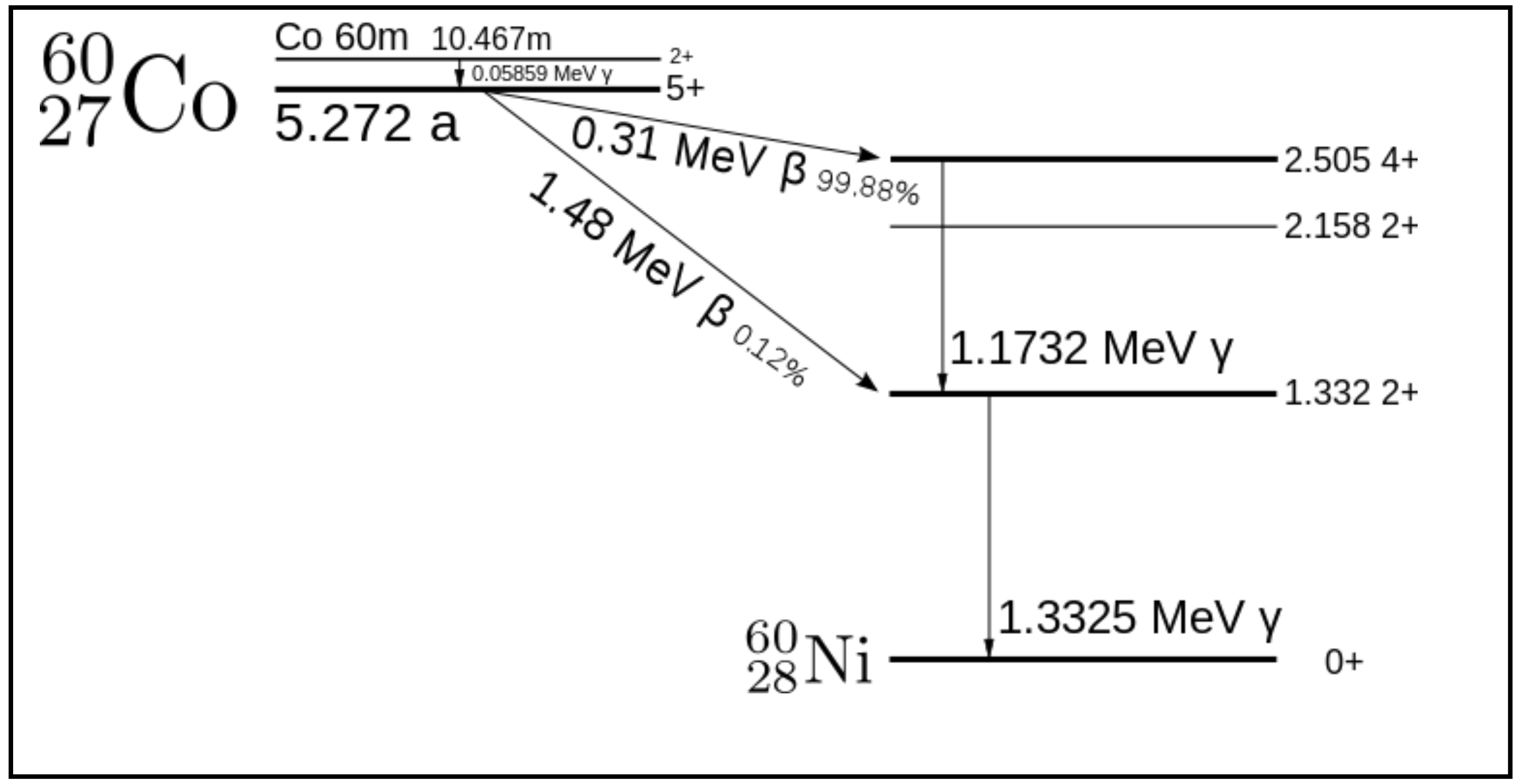
A = 1 kBq



1000 decays/s

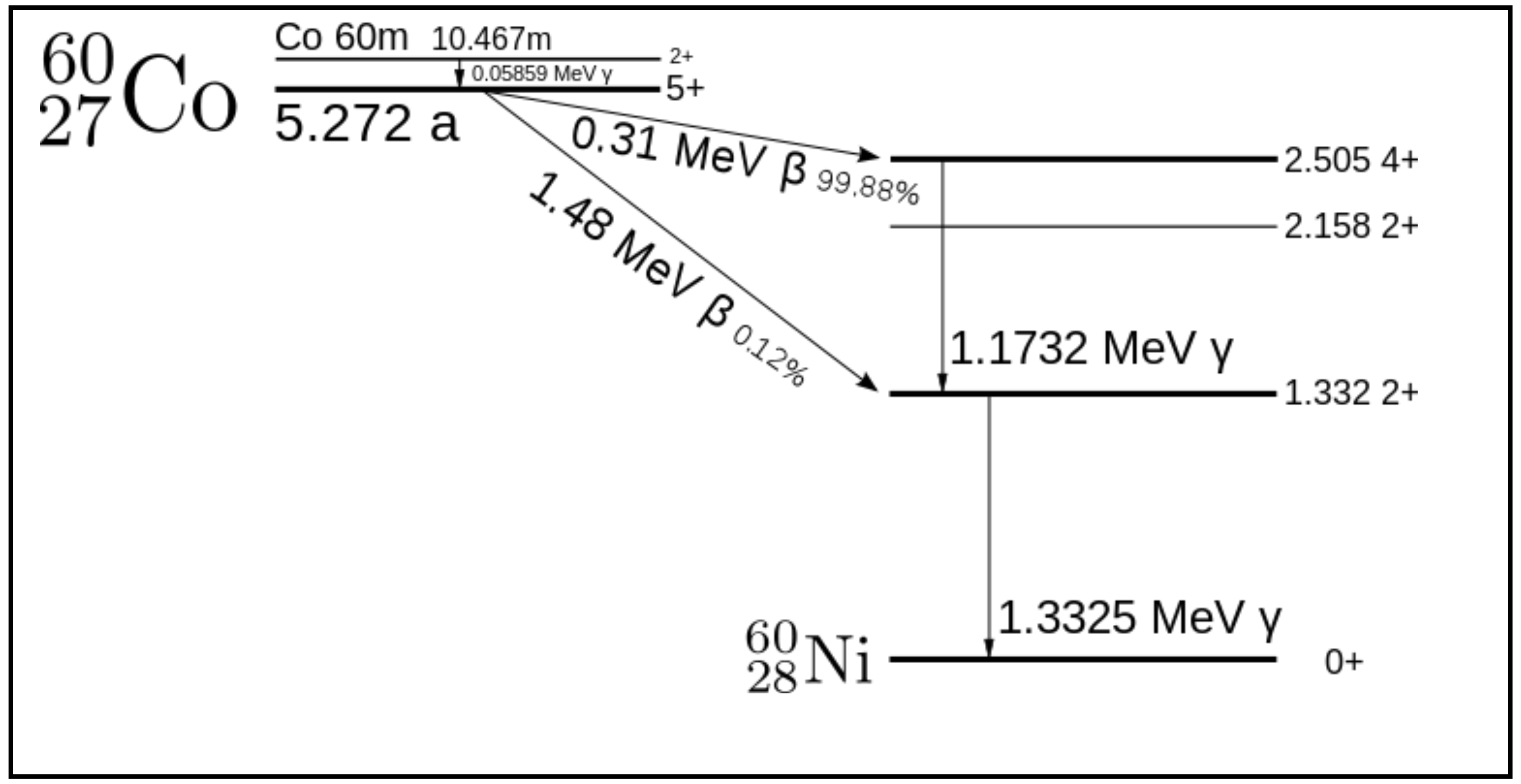


On average, how many photons are emitted in a ^{60}Co-decay?



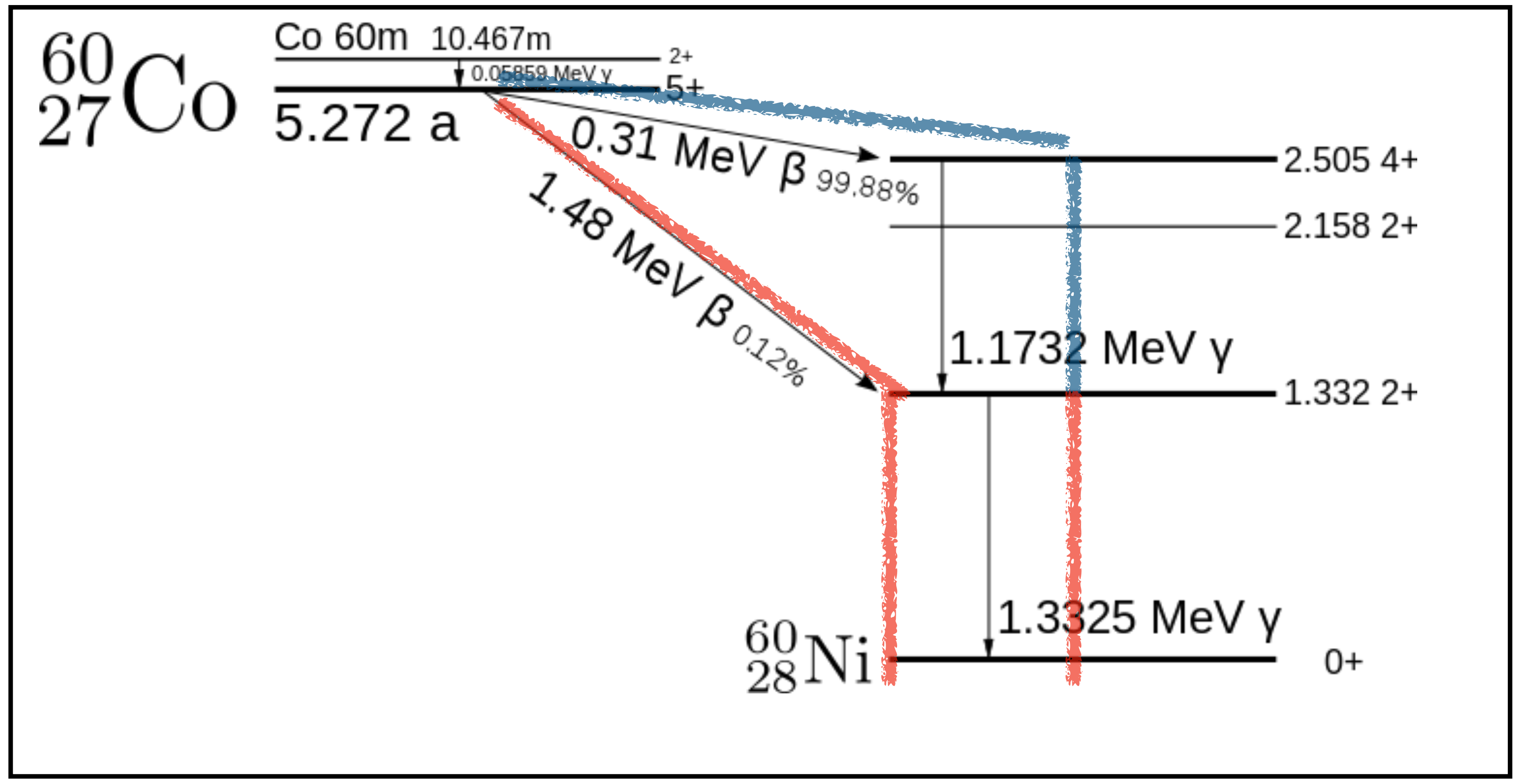
1. 1
2. 2
3. 0,9988
4. 1,9988
5. anything between 0 and 2 depending of what happens in the nucleus

On average, how many photons are emitted in a ^{60}Co-decay?

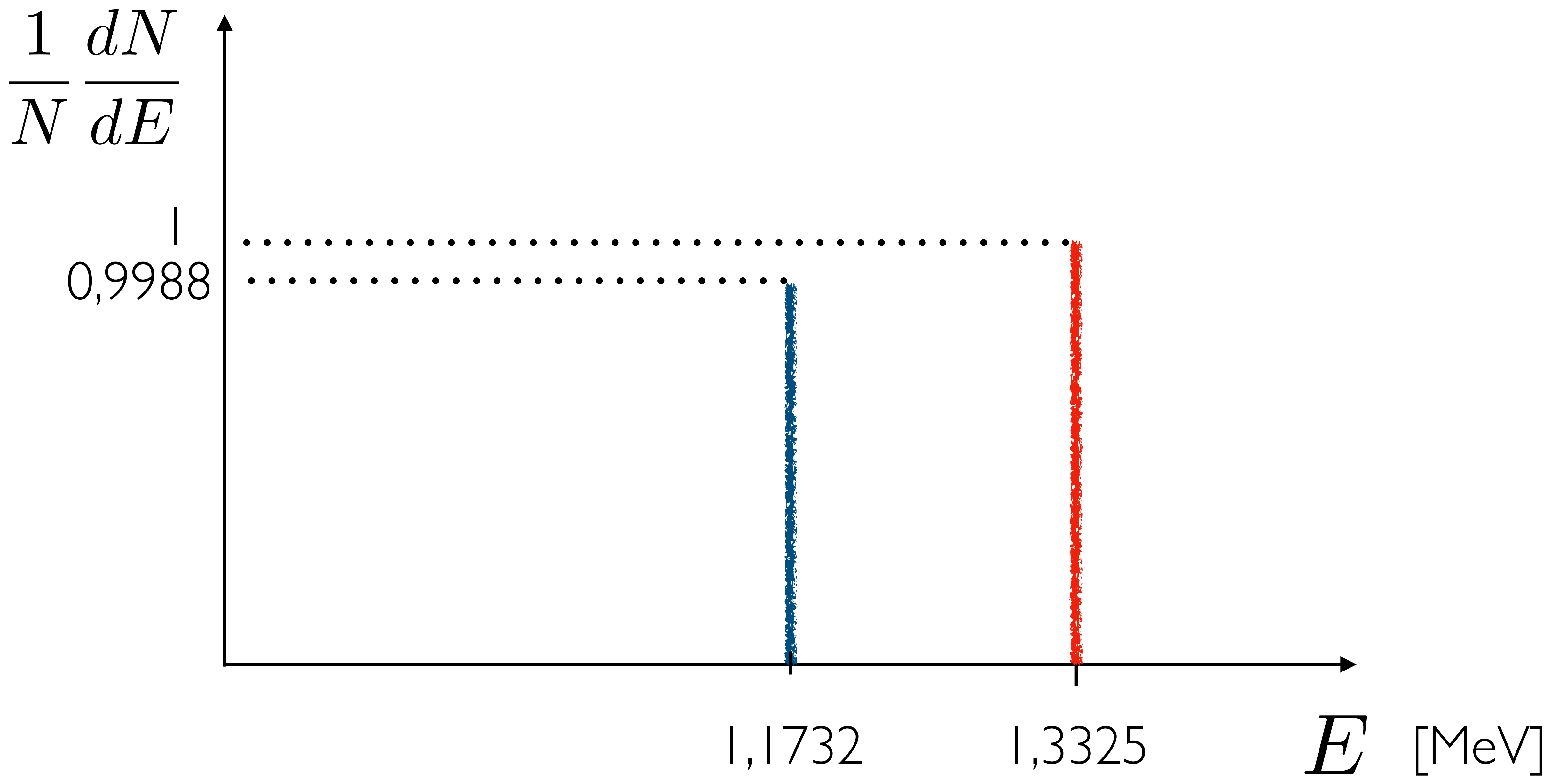


1. 1
2. 2
3. 0,9988
4. $\boxed{1,9988}$
5. anything between 0 and 2 depending of what happens in the nucleus

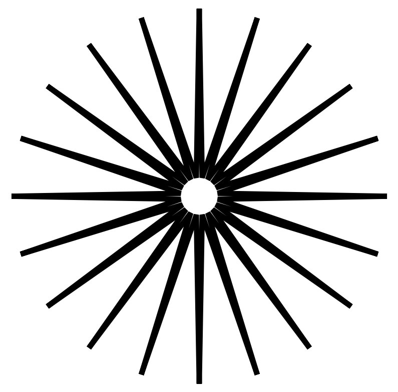
Draw the emission spectrum of ^{60}Co



$$\frac{\text{number of photons / energy bin}}{\text{number of photons}}$$



S

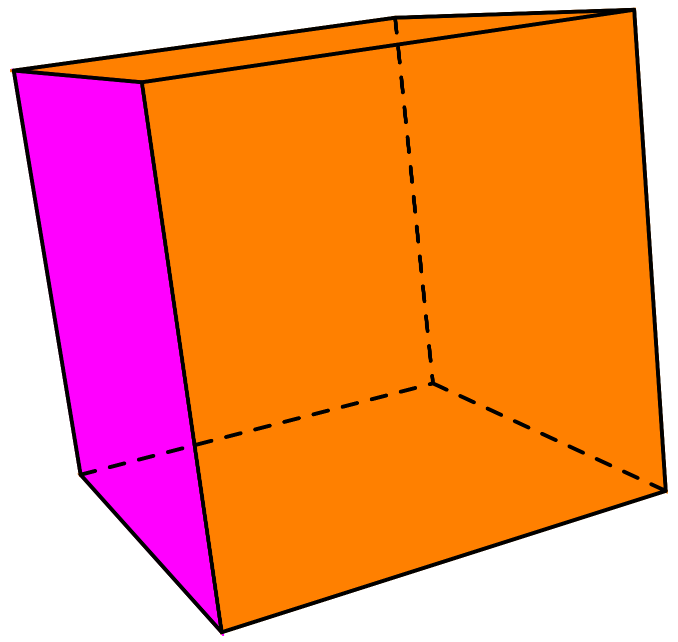


A = 1 kBq

1000 decays/s

# of emitted photons depends on decay scheme!

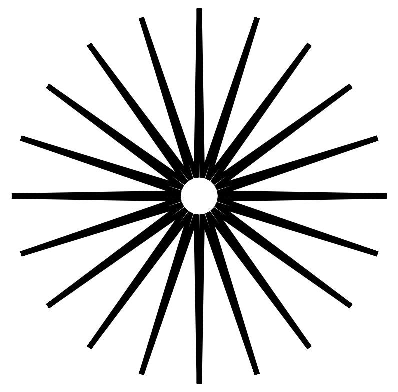
D



# of detected photons?

efficiency: $\dfrac{\text{\# detected photons}}{\text{\# emitted photons}}$

S

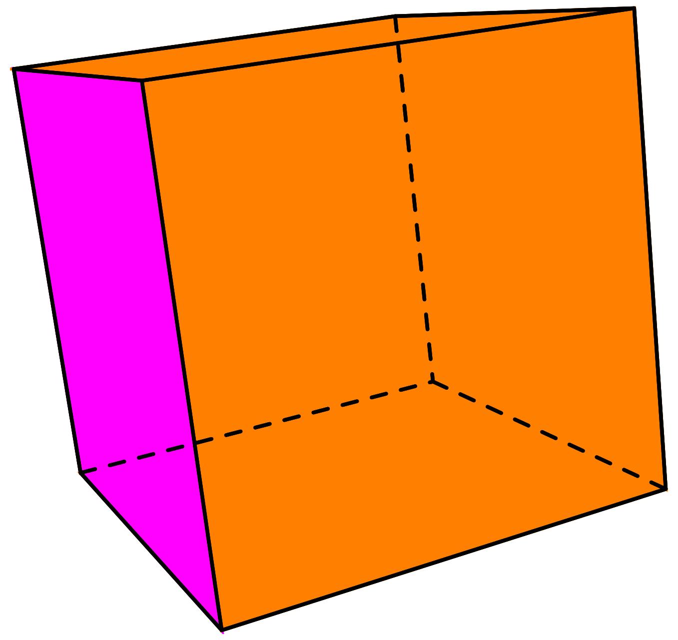


A = 1 kBq

1000 decays/s

# of emitted photons depends on decay scheme!

D



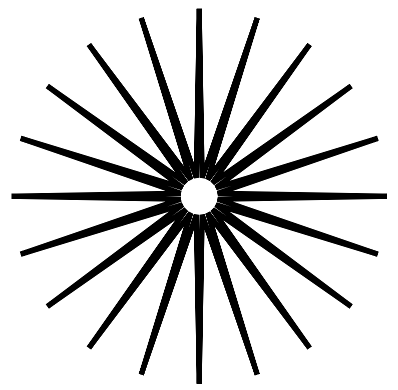
# of detected photons?

$$\text{efficiency:} \quad \frac{\text{\# detected photons}}{\text{\# emitted photons}}$$

count rate = detected photons?

NO!
(only for photon counting detectors)

S

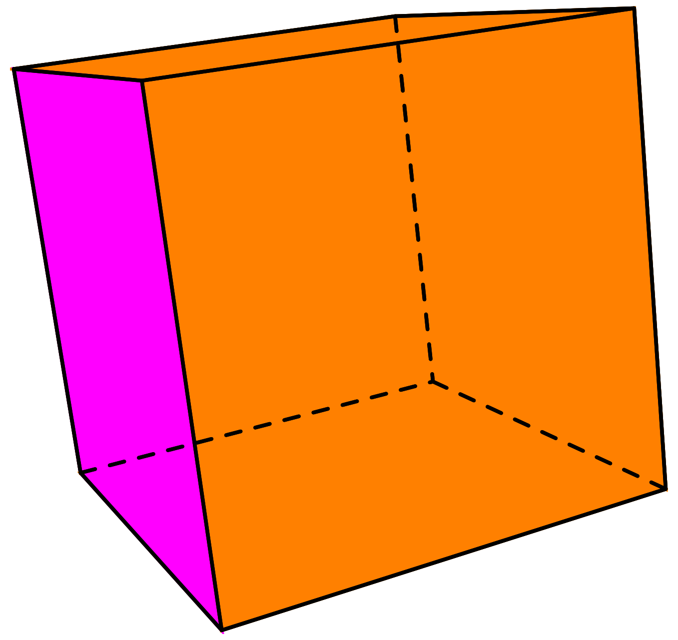


A = 1 kBq

1000 decays/s

# of emitted photons depends on decay scheme!

D



# of detected photons?

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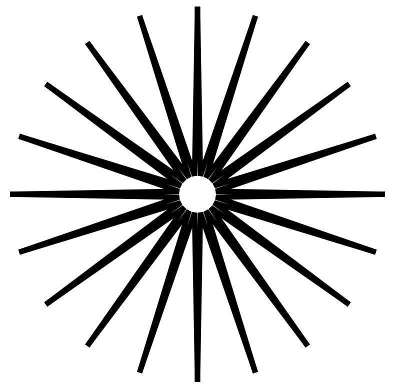
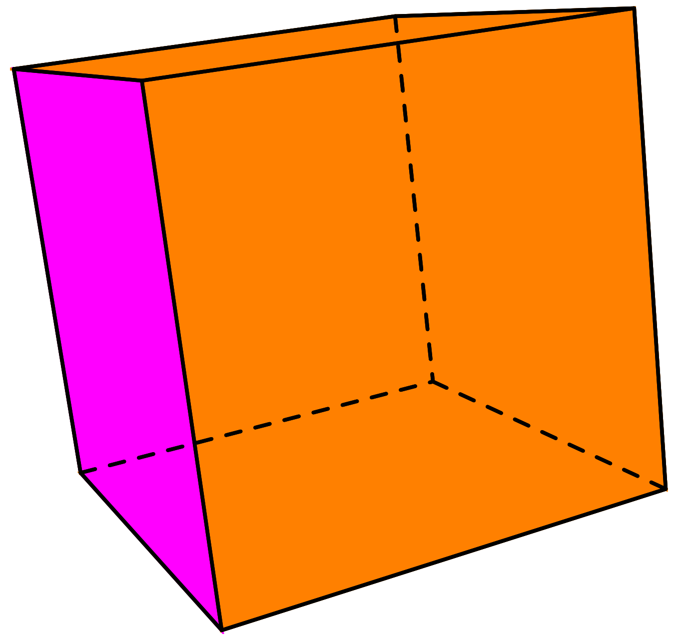


A = 1 kBq

1000 decays/s

# of emitted photons depends on decay scheme!

D



# of detected photons?

efficiency: $\frac{\#\text{ detected photons}}{\#\text{ emitted photons}}$

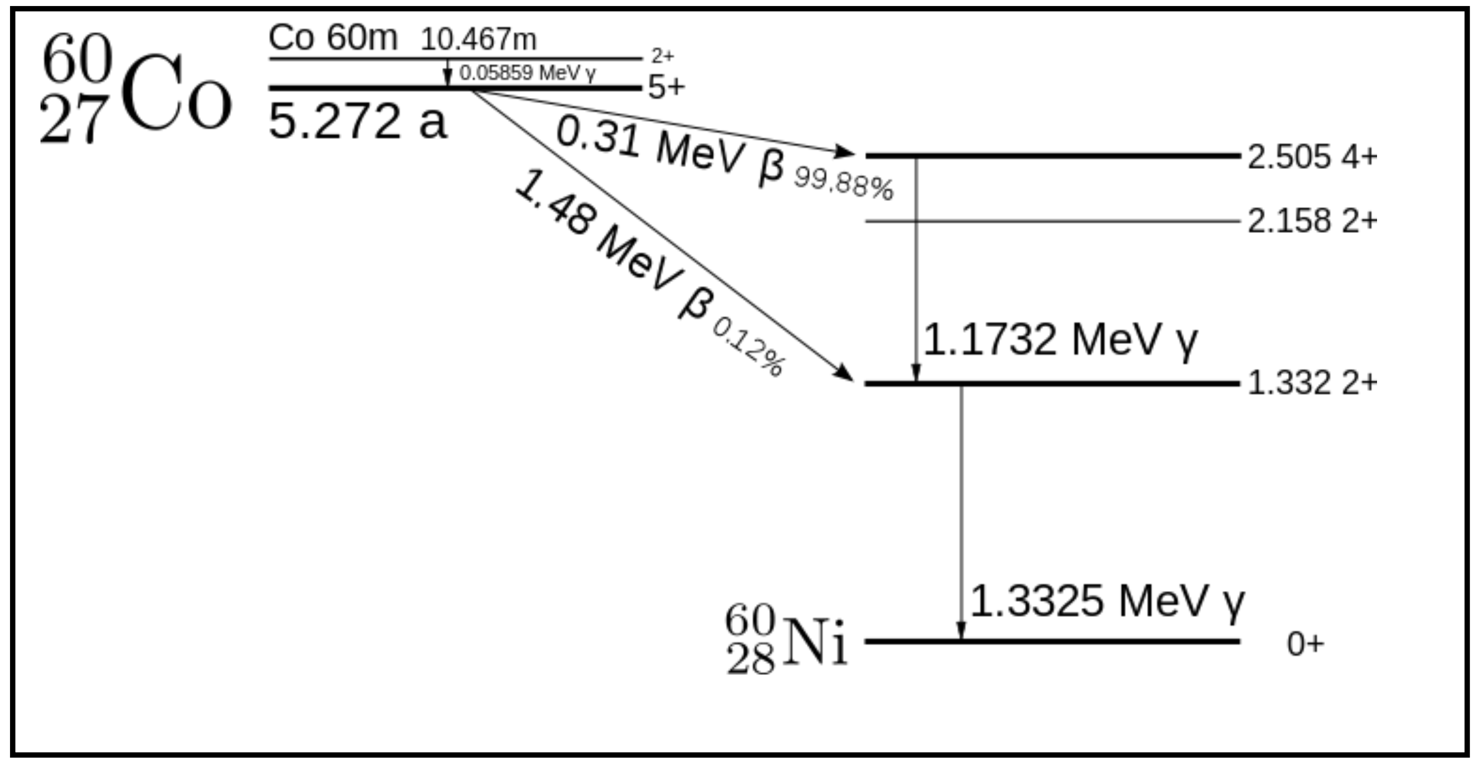
count rate = detected photons?

NO!
(only for photon counting detectors)

A detector with efficiency 2% detects 100 photons per second.
The average number of emitted photons per second is then:

1. 2
2. impossible to say, but more than 100
3. 5000

A detector with efficiency 2% detects 100 photons per second from a ^{60}Co-source. The activity of the source can be estimated to be:



1. around 100 Bq
2. impossible to say, but more than 100 Bq
3. around 2500 Bq
4. around 5000 Bq

Source **Detector**

What needs to happen for a photon emitted by the source to be detected?

1. The photon needs to hit the detector

Def: geometric efficiency = fraction of emitted photons that hit the detector $= \dfrac{\#\text{ of photons hitting detector}}{\#\text{ of emitted photons}}$

2. The photon needs to deposit energy (interact) in the detector

Def: intrinsic efficiency = fraction of the photons hitting the detector that interact in the detector $= \dfrac{\#\text{ of photons interacting in detector}}{\#\text{ of photons hitting detector}}$

Then the fraction of detected photons will be the product of the two above[§]:

Def: efficiency = fraction of the emitted photons that are detected $= \dfrac{\#\text{ of photons hitting detector}}{\#\text{ of emitted photons}} \cdot \dfrac{\#\text{ of photons interacting in detector}}{\#\text{ of photons hitting detector}}$

([§]under the hypothesis that the two are independent of each other)

Warning to the audience!!!!!!!!1112121212121

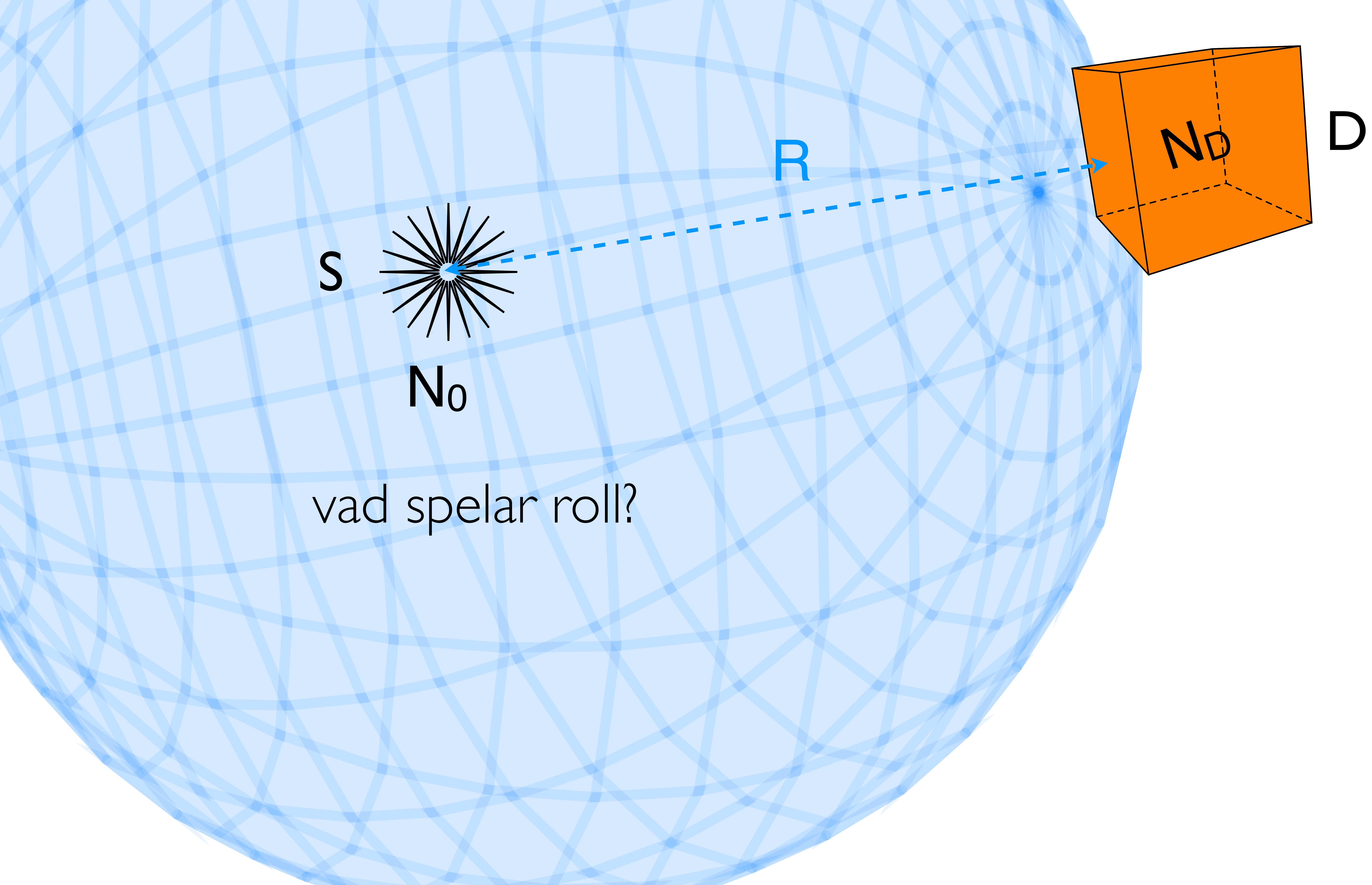
Now we have few definitions! The definitions are always true!

Do not confuse them with the calculation of the efficiency in a particular case, which might result in a number or a symbolic expression!
The latter are only valid in that particular case!

We are now going to find an expression for the efficiency, the geometric efficiency and the intrinsic efficiency ***in a particular case!***

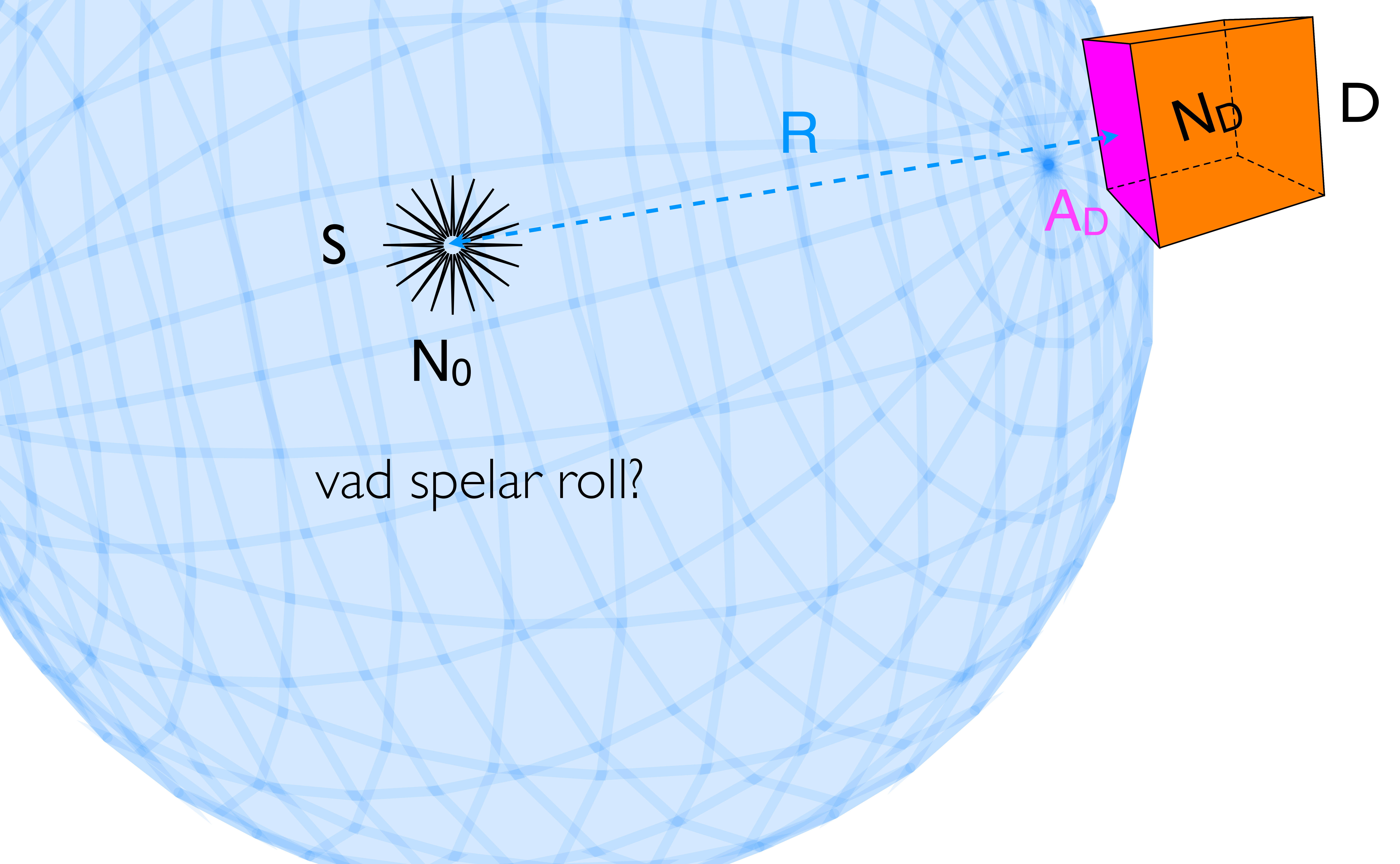
It is an example, to help you:
- better understand the definitions
- understand how to calculate these quantities in various situation by using their definitions

$$\text{effektivitet:} \quad \frac{\#\ \text{detekterade}}{\#\ \text{emitterade}} = \frac{N_D}{N_0}$$



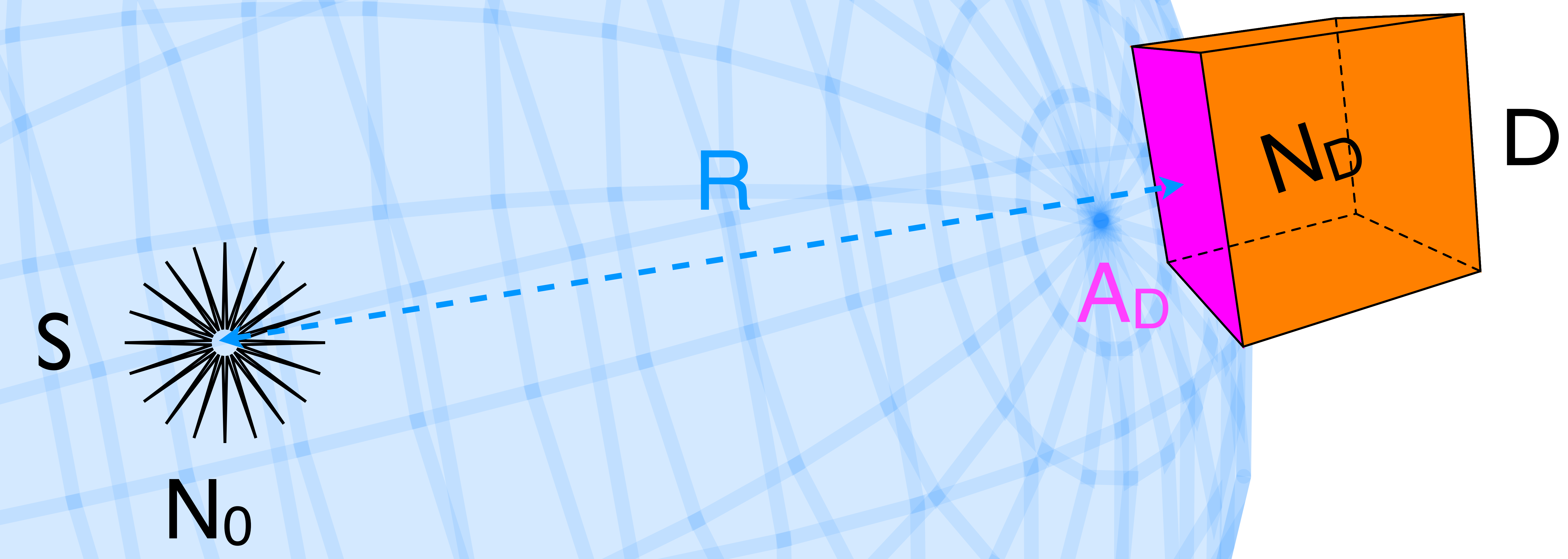
vad spelar roll?

effektivitet: $\dfrac{\#\ \text{detekterade}}{\#\ \text{emitterade}} = \dfrac{N_D}{N_0}$



vad spelar roll?

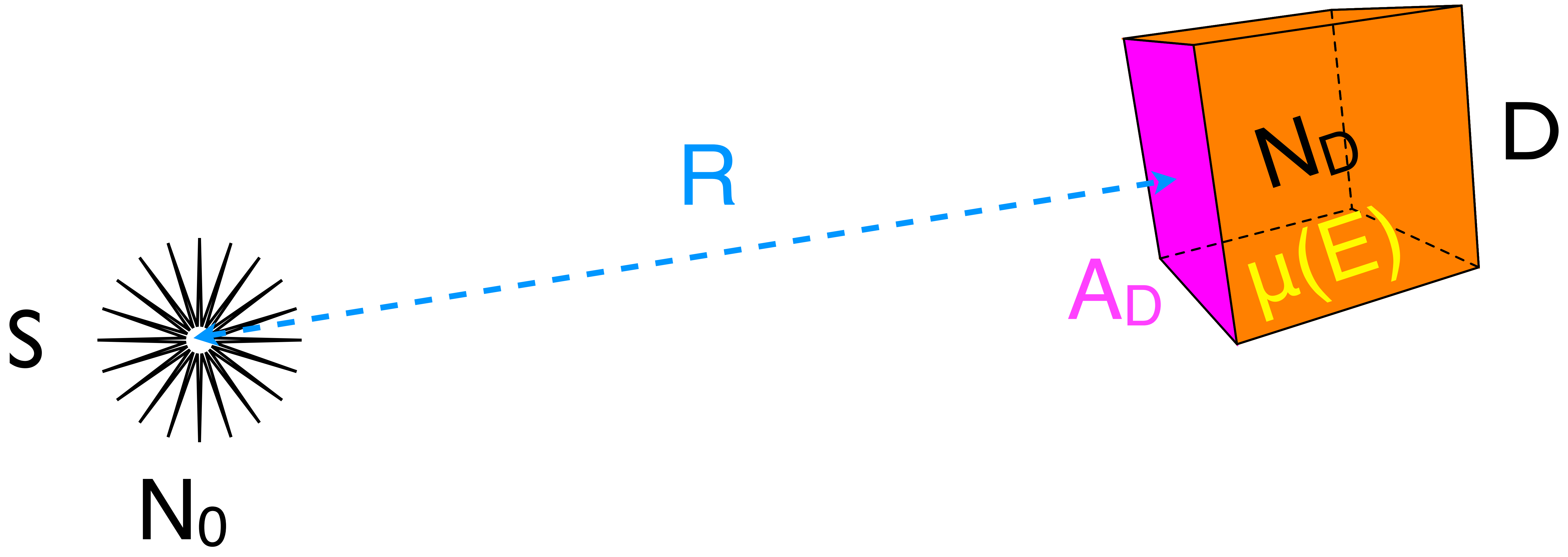
effektivitet: $\dfrac{\#\ \text{detekterade}}{\#\ \text{emitterade}} = \dfrac{N_D}{N_0}$



vad spelar roll?

geometri: $\dfrac{\#\ \text{träffar D}}{\#\ \text{emitterade}} = \dfrac{A_D}{4\pi R^2}$

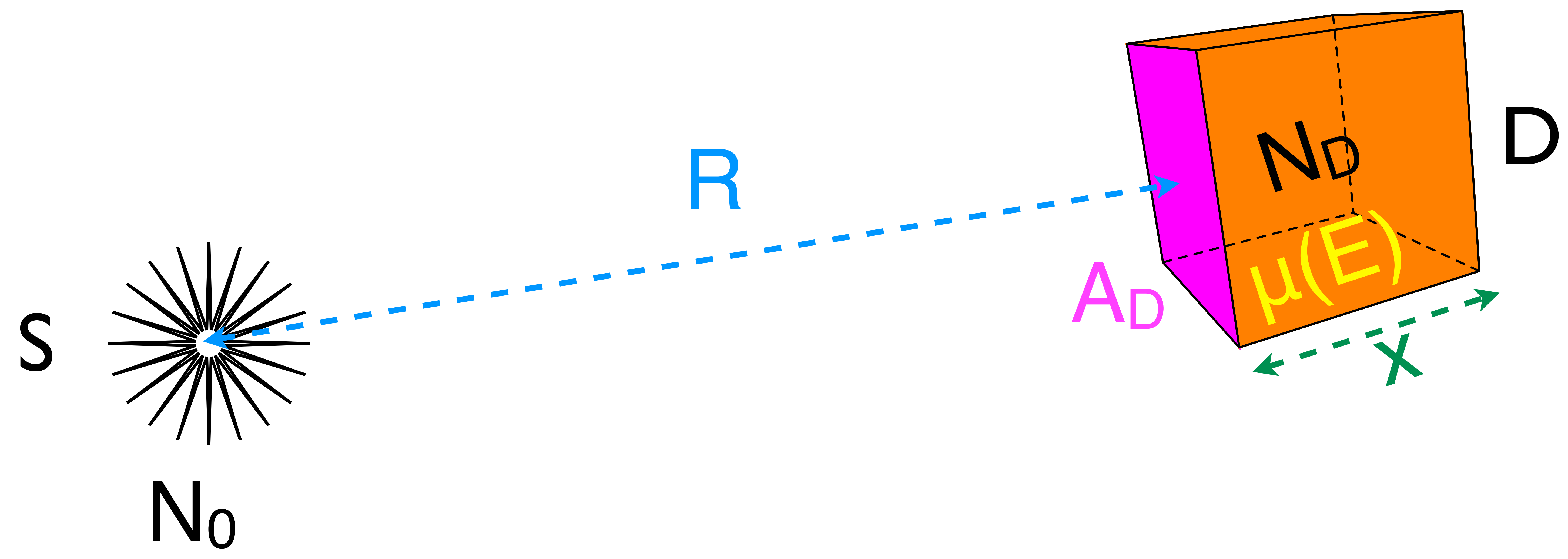
effektivitet: $$\frac{\#\ \text{detekterade}}{\#\ \text{emitterade}} = \frac{N_D}{N_0}$$



vad spelar roll?

geometri: $$\frac{\#\ \text{träffar D}}{\#\ \text{emitterade}} = \frac{A_D}{4\pi R^2}$$

$$\text{effektivitet:} \quad \frac{\#\ \text{detekterade}}{\#\ \text{emitterade}} = \frac{N_D}{N_0}$$

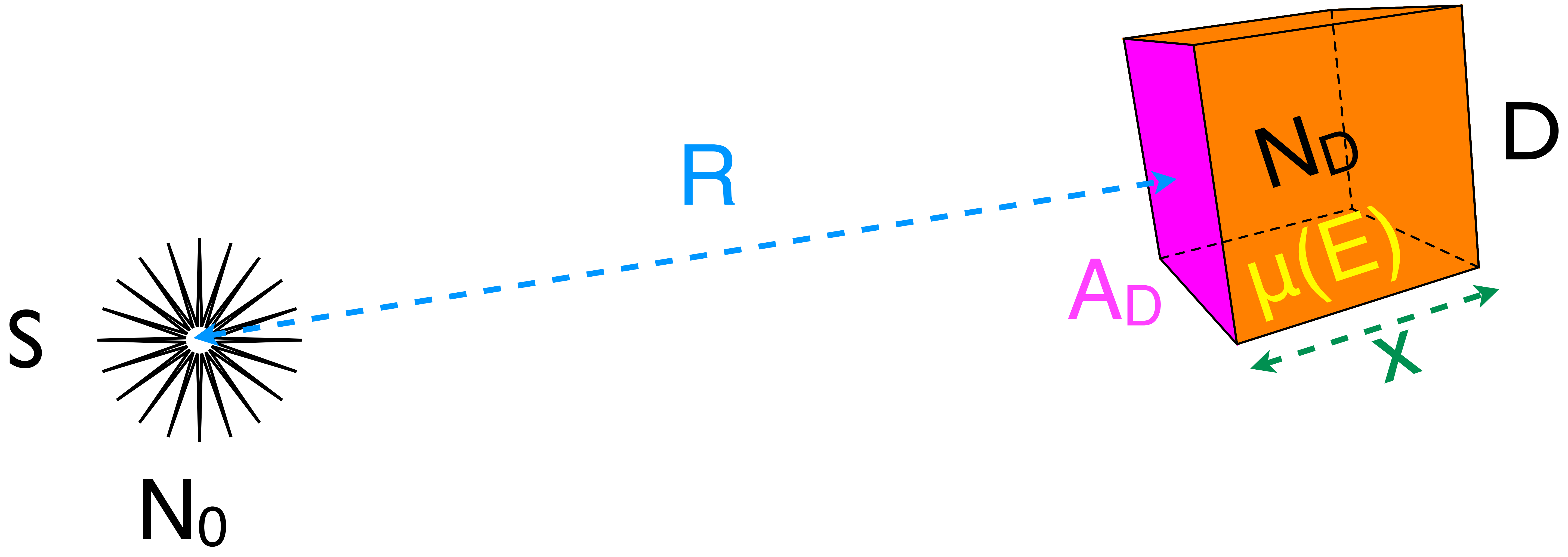


vad spelar roll?

$$\text{geometri:} \quad \frac{\#\ \text{träffar D}}{\#\ \text{emitterade}} = \frac{A_D}{4\pi R^2}$$

$$\text{“intrinsic efficiency”:} \quad \frac{\#\ \text{attenuerade}}{\#\ \text{träffar D}} = 1 - e^{-\mu(E)x}$$

effektivitet: $\dfrac{\#\ \text{detekterade}}{\#\ \text{emitterade}} = \dfrac{N_D}{N_0} = \dfrac{A_D\,(1 - e^{-\mu(E)x})}{4\pi R^2}$



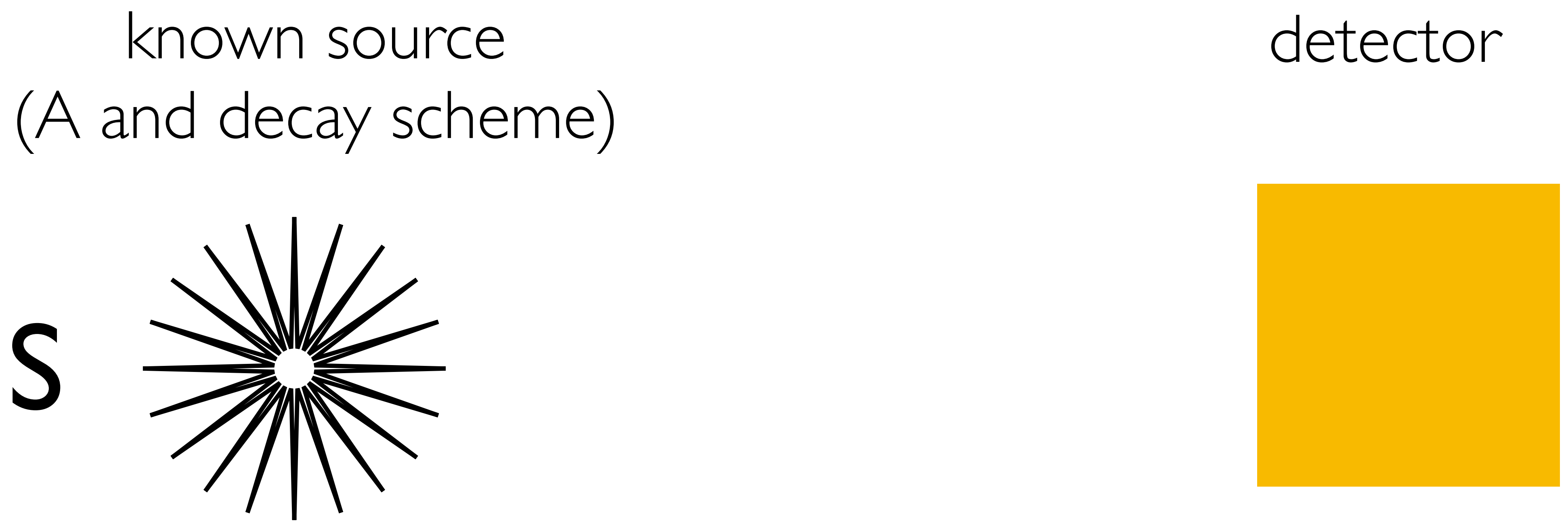
vad spelar roll?

geometri: $\dfrac{\#\ \text{träffar D}}{\#\ \text{emitterade}} = \dfrac{A_D}{4\pi R^2}$

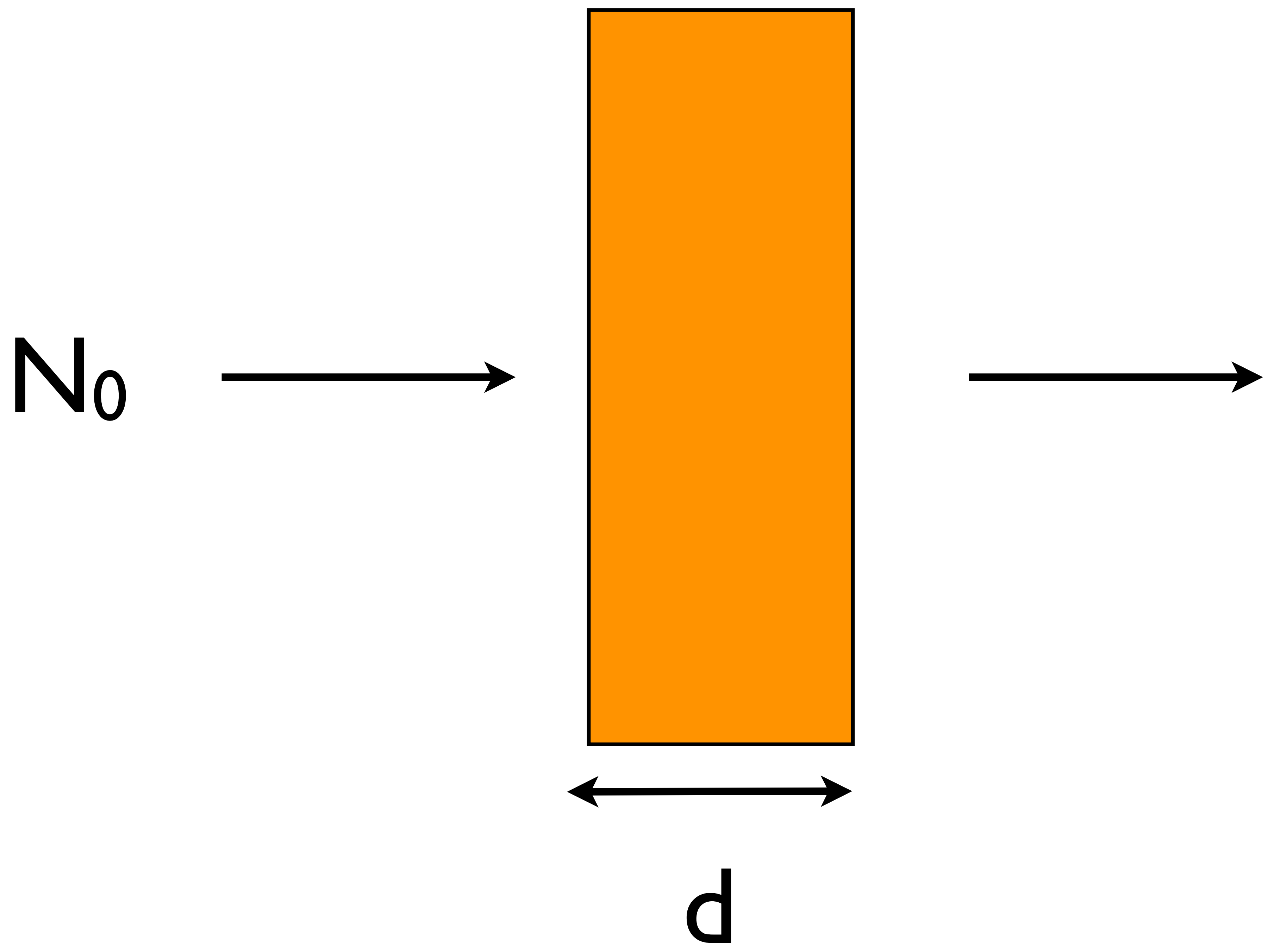
"intrinsic efficiency": $\dfrac{\#\ \text{attenuerade}}{\#\ \text{träffar D}} = 1 - e^{-\mu(E)x}$

Detection efficiency can also be experimentally determined (measured):

Def: efficiency = fraction of the emitted photons that are detected

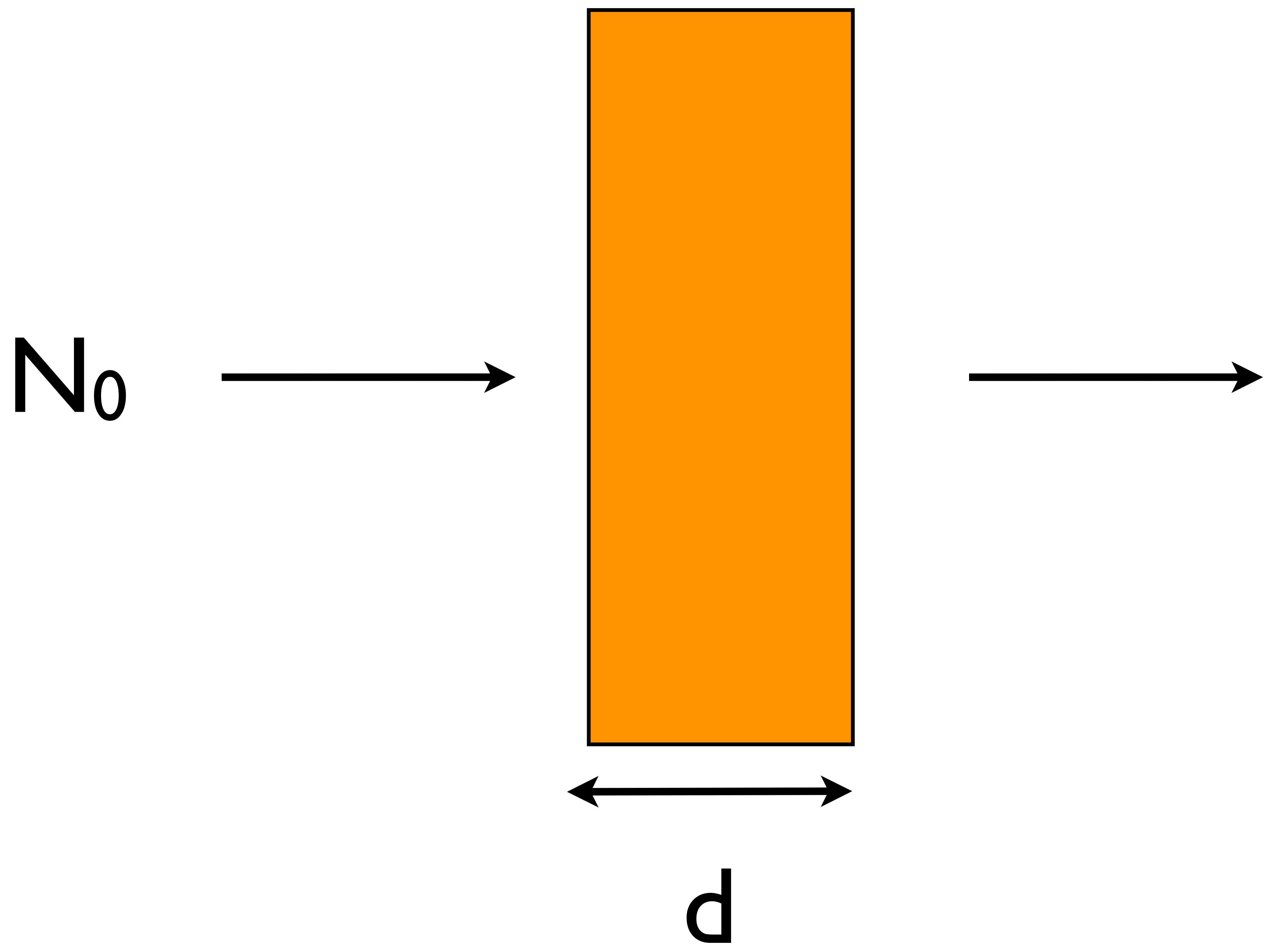


$$\text{efficiency} = \frac{\text{number of counts from detector under acquisition time}}{\text{number of photons emitted under acquisition time}}$$



$$N = N_0 e^{-\mu d}$$

1. N är antal som har gått genom
2. N är antal som har attenuerats
3. N är antal som har absorberats



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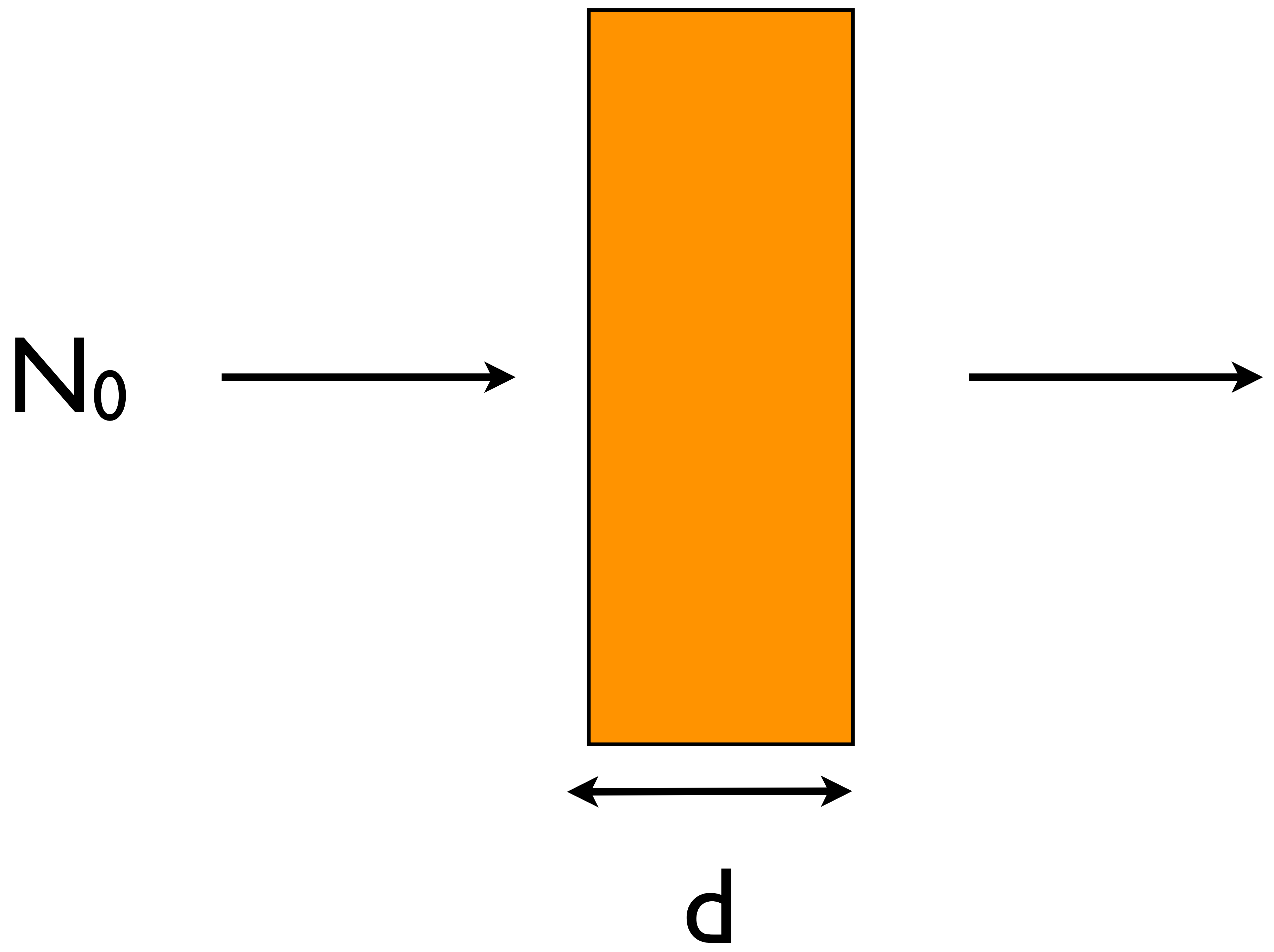
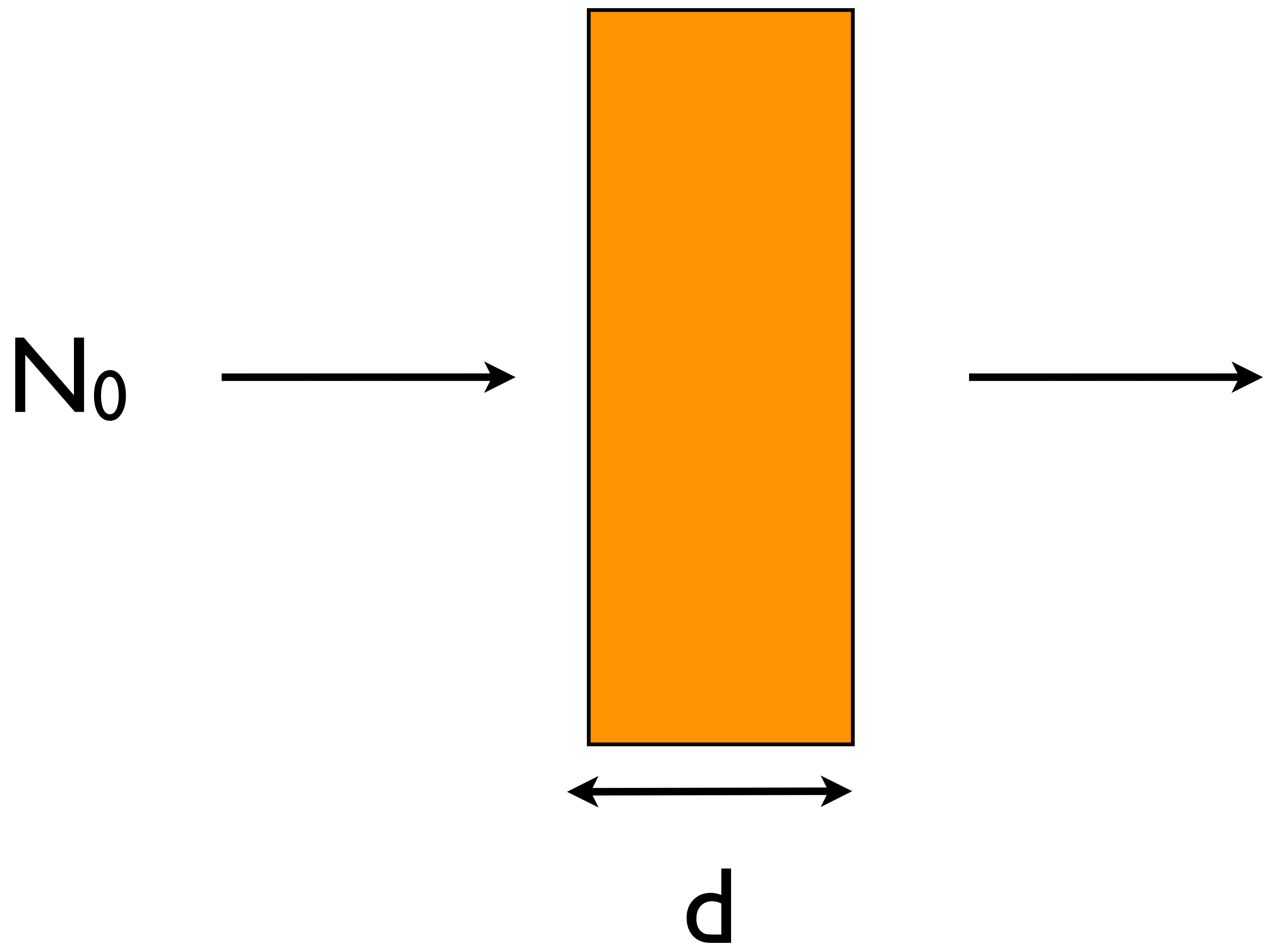


$$N = N_0 e^{-\mu d}$$

Antag att: $$\frac{N}{N_0} = 0,9$$

1. 90% har stoppats
2. 90% har attenuerats
3. 10% har stoppats
4. 10% har attenuerats



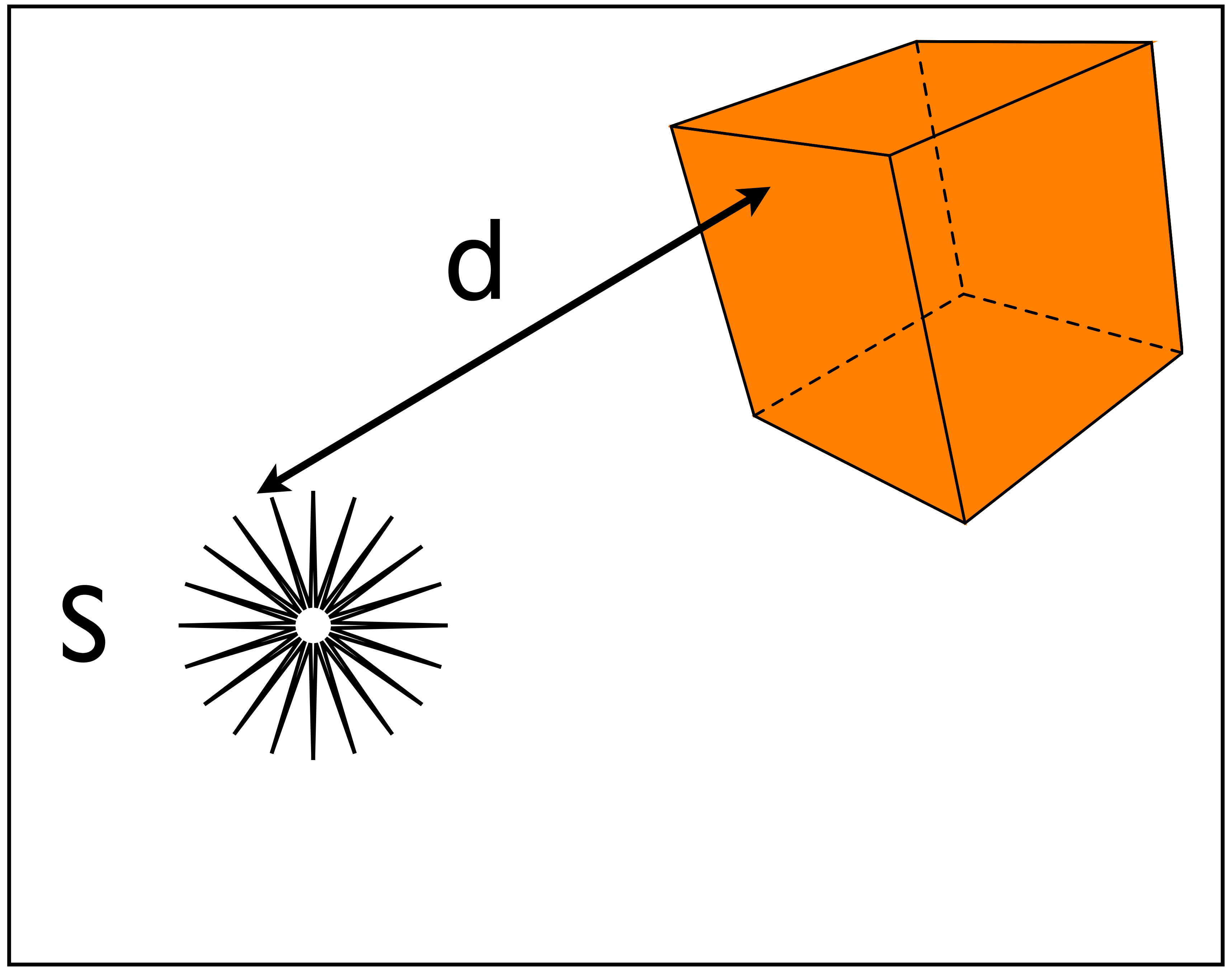
$$N = N_0 e^{-\mu d}$$

Antag att: $$\frac{N}{N_0} = 0,9$$

1. 90% har stoppats
2. 90% har attenuerats
3. 10% har stoppats
4. 10% har attenuerats

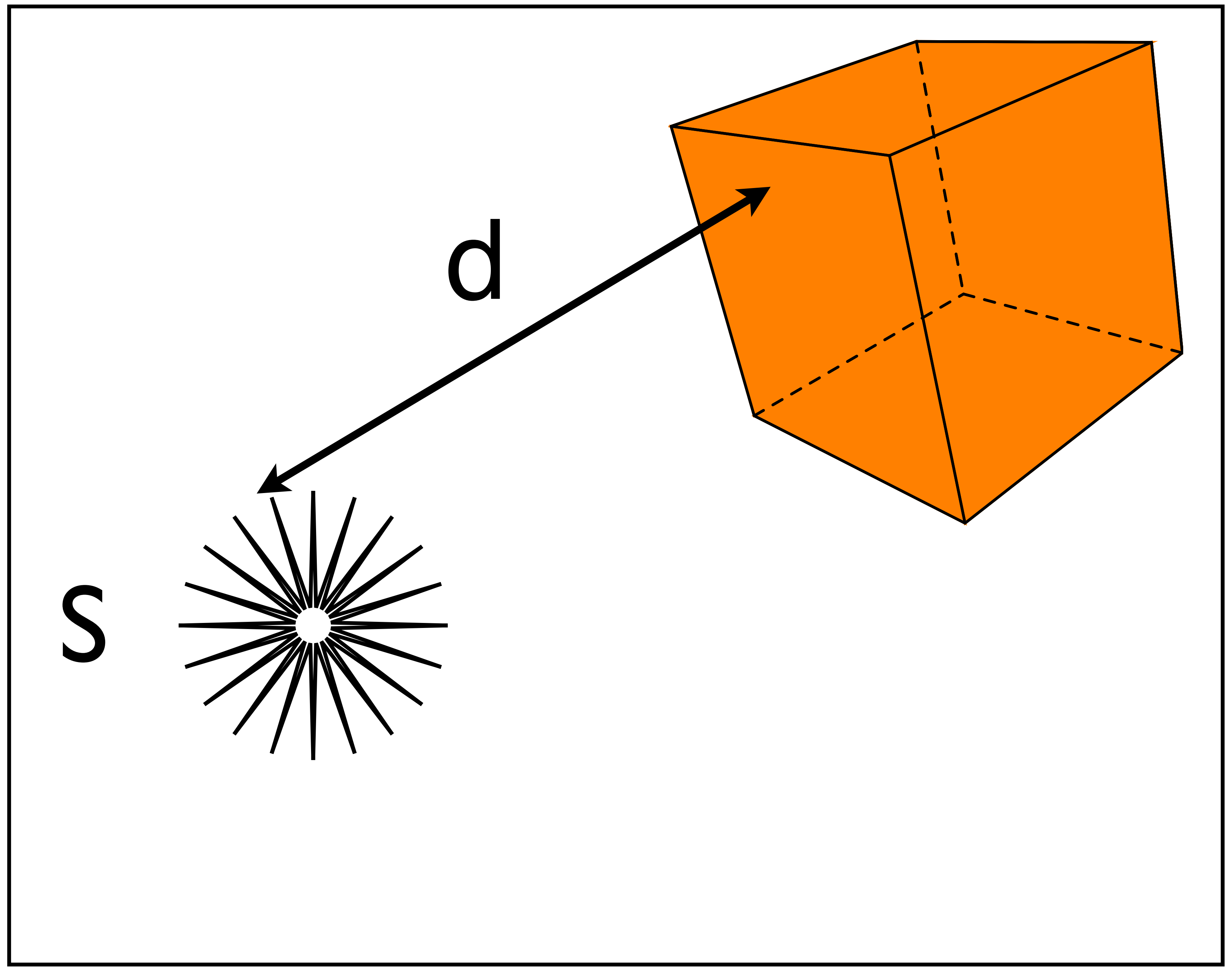
När källan S ställs på avståndet d från detektorn så är räknehastigheten hos detektorn N counts/s.

Om källan flyttas till avståndet 2d så blir räknehastigheten:



1. 4N   2. 2N   3. N   4. N/2   5. N/4

När källan S ställs på avståndet d från detektorn så är räknehastigheten hos detektorn N counts/s.

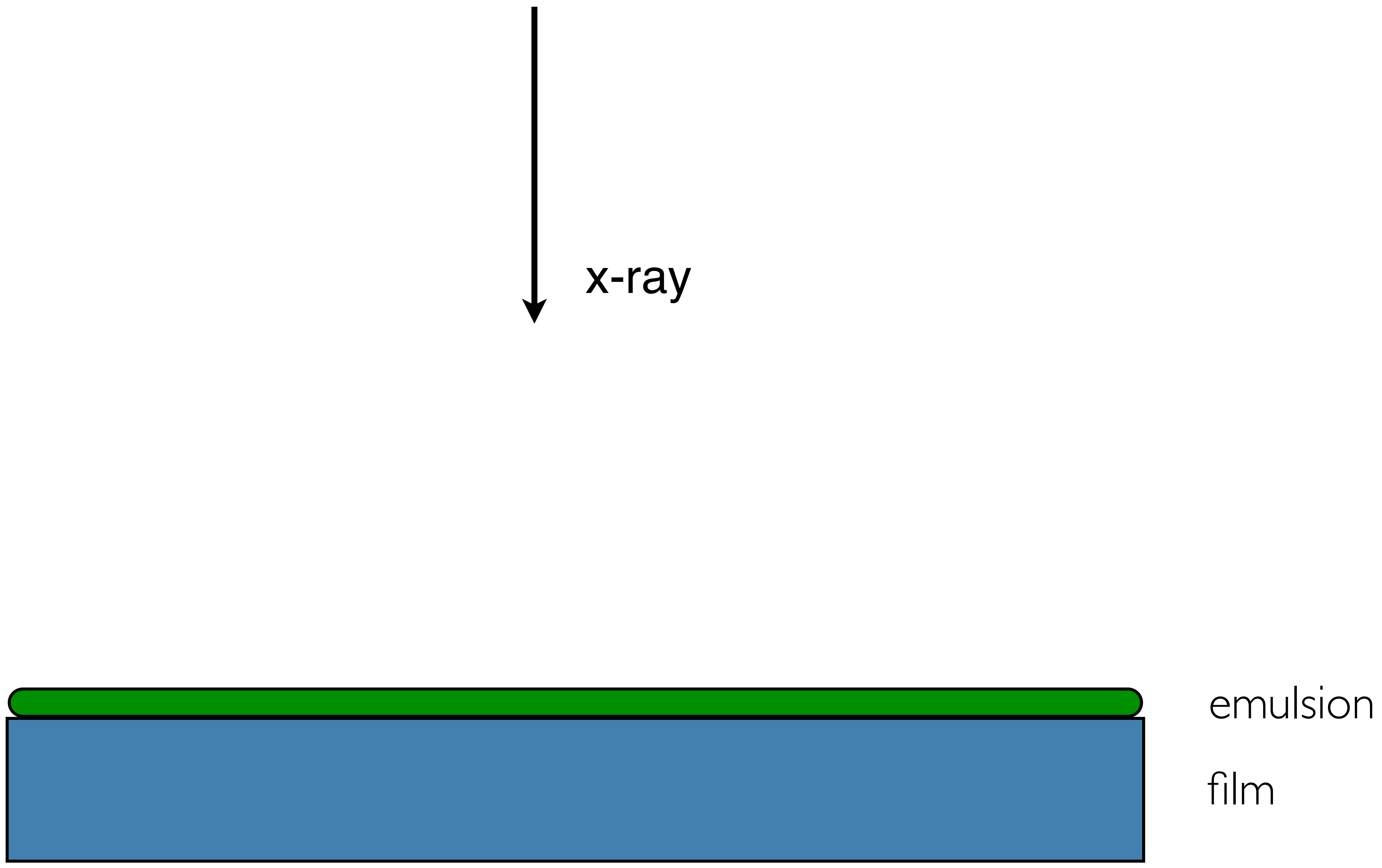


Om källan flyttas till avståndet 2d så blir räknehastigheten:

1. 4N
2. 2N
3. N
4. N/2
5. N/4

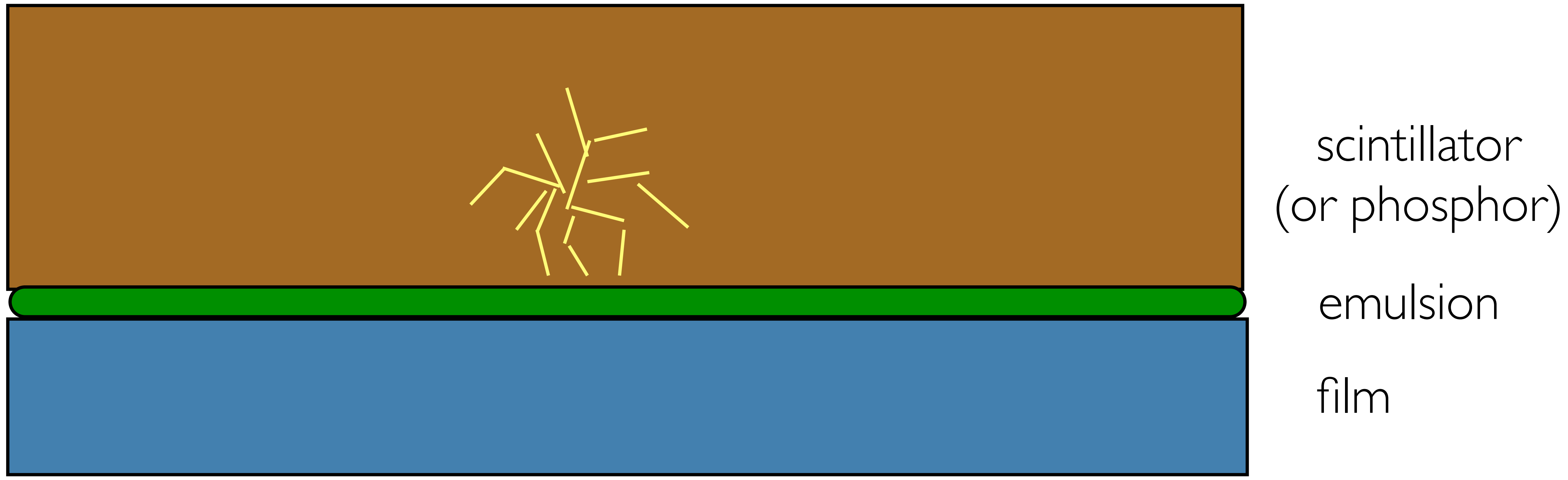
Filmcassette:

Filmcassette:



Filmcassette:

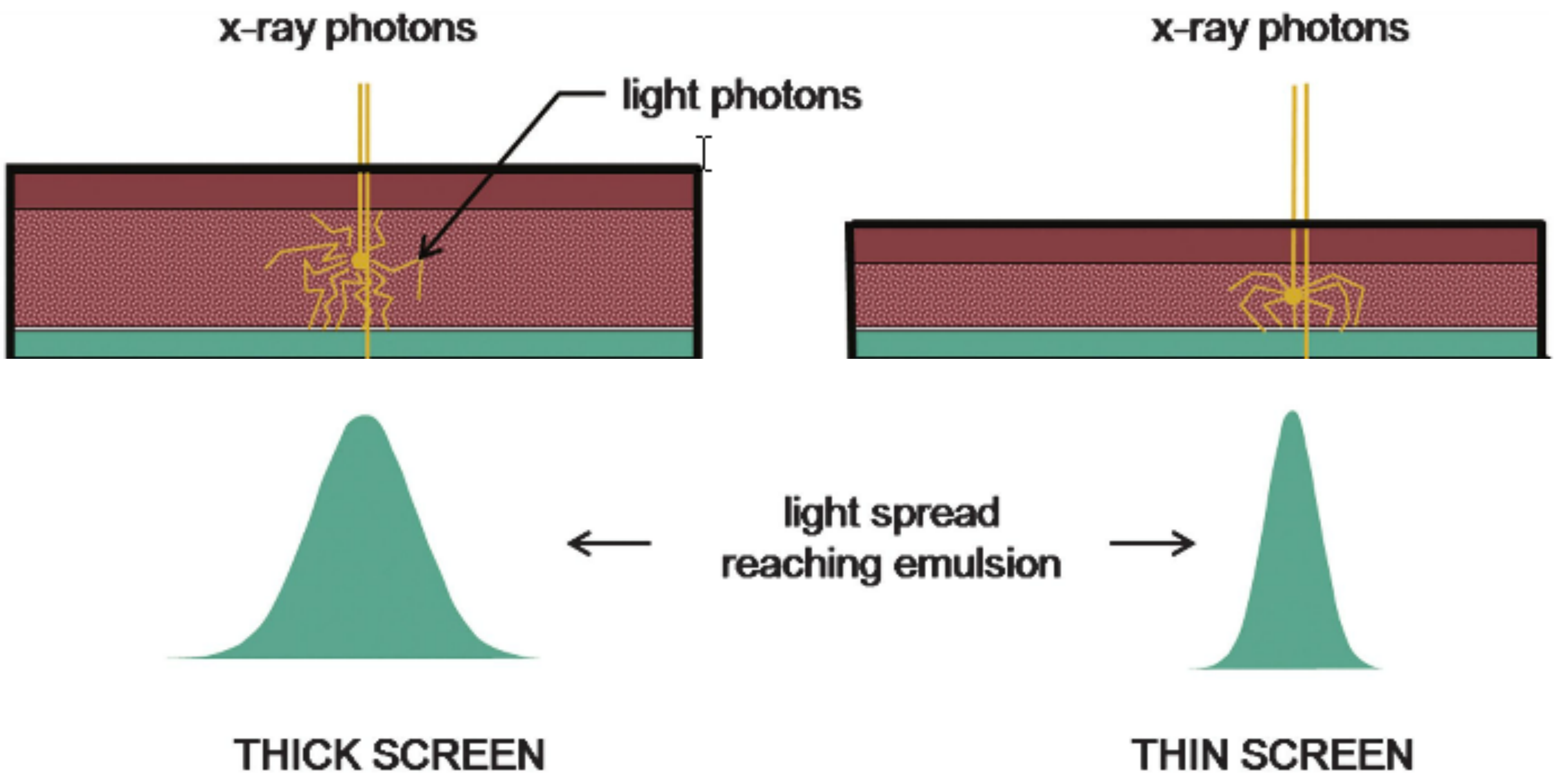
Filmcassette:



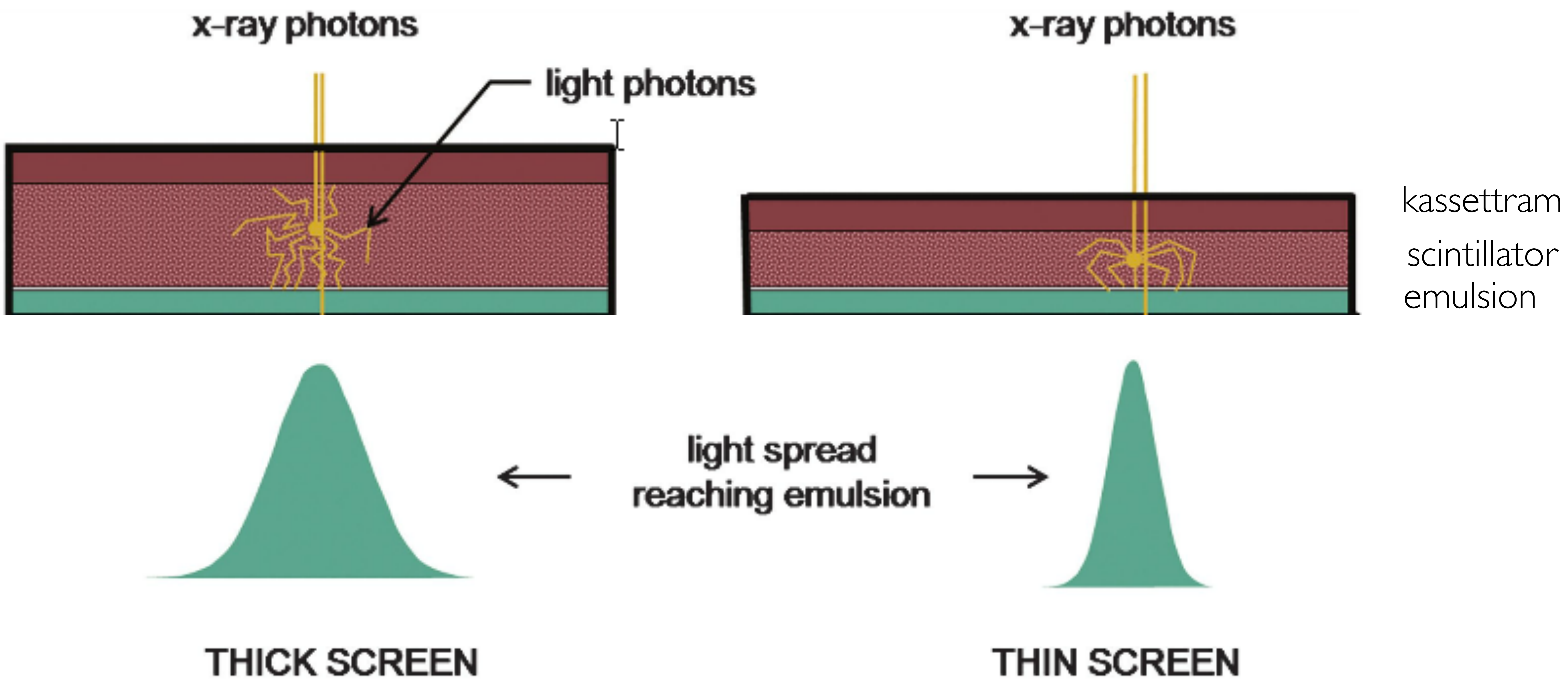
The role of the scintillator is:

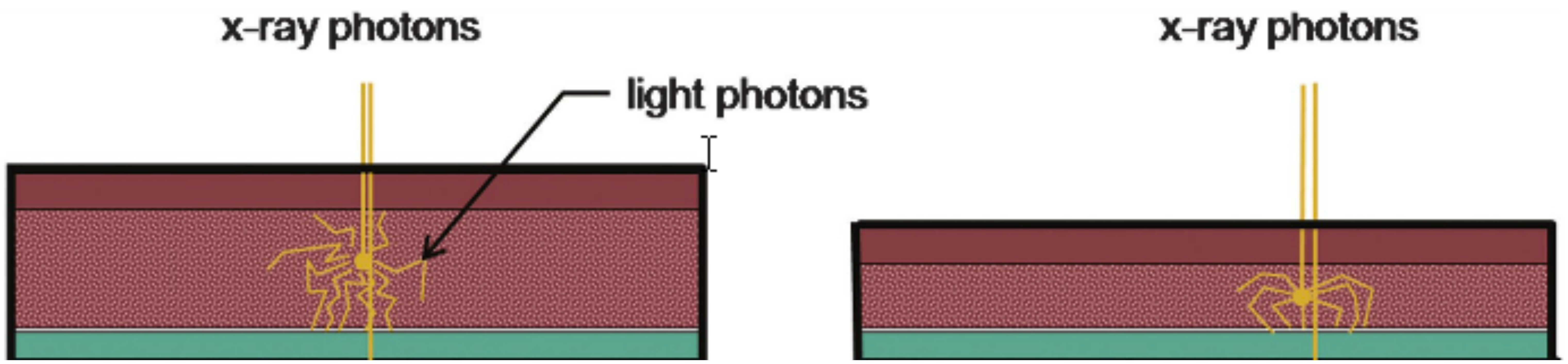
1. increase detection efficiency
2. protect film from radiation exposure
3. "translate" x-rays to visible light
4. increase uniformity
5. increase spatial resolution

Filmcassette: effect of the scintillator



Filmcassette: effect of the scintillator

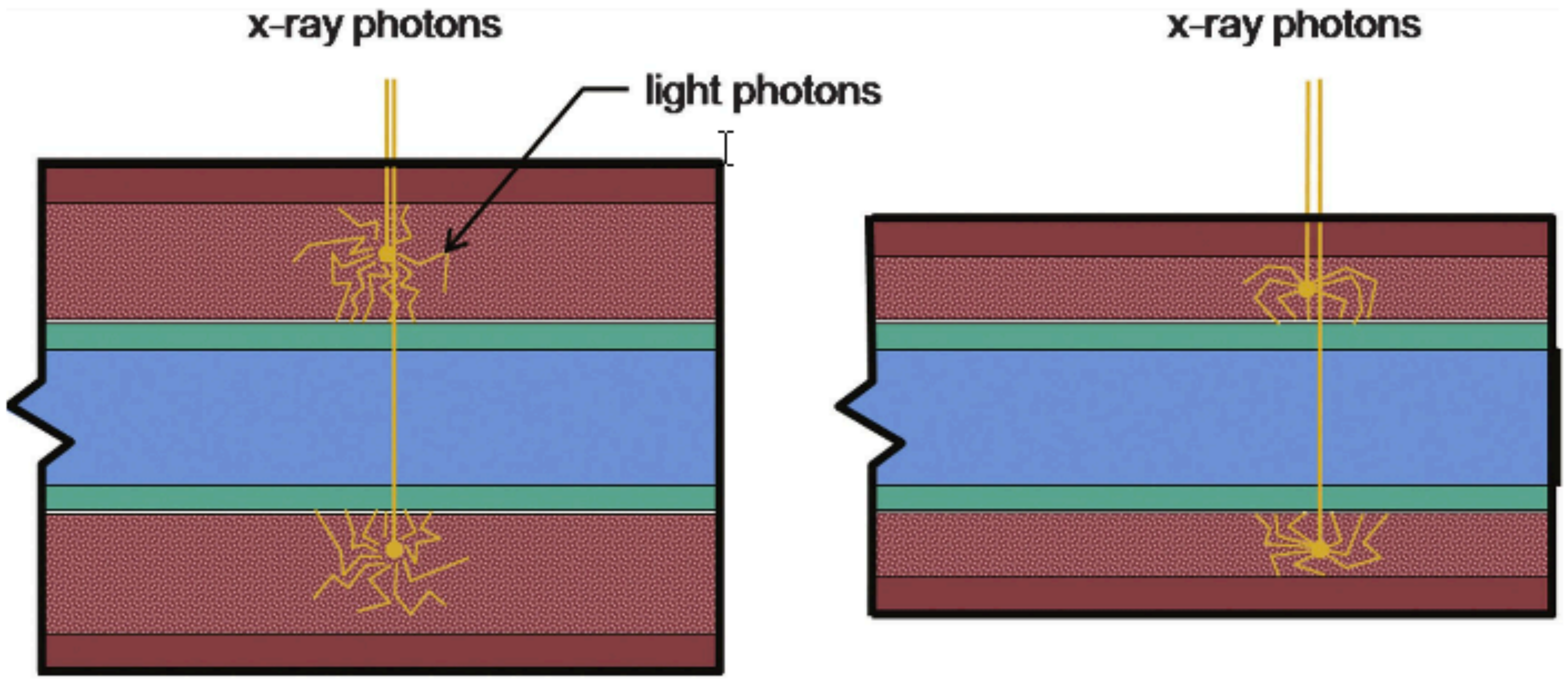




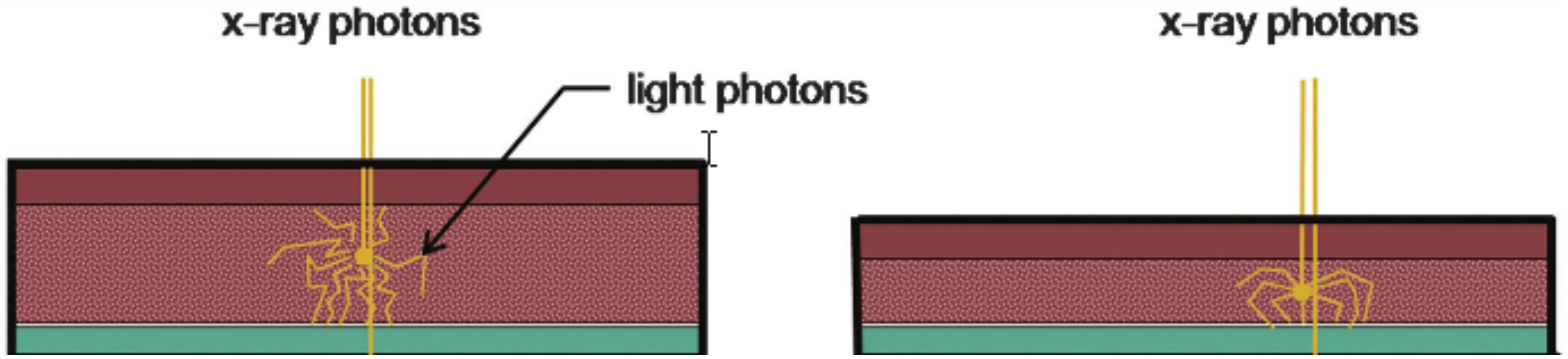
1 x-ray 40keV -> hur många optiska fotoner?

1. 10 - 40
2. 10-40 thousand
3. 100-400 thousand
4. 10 - 40 millions

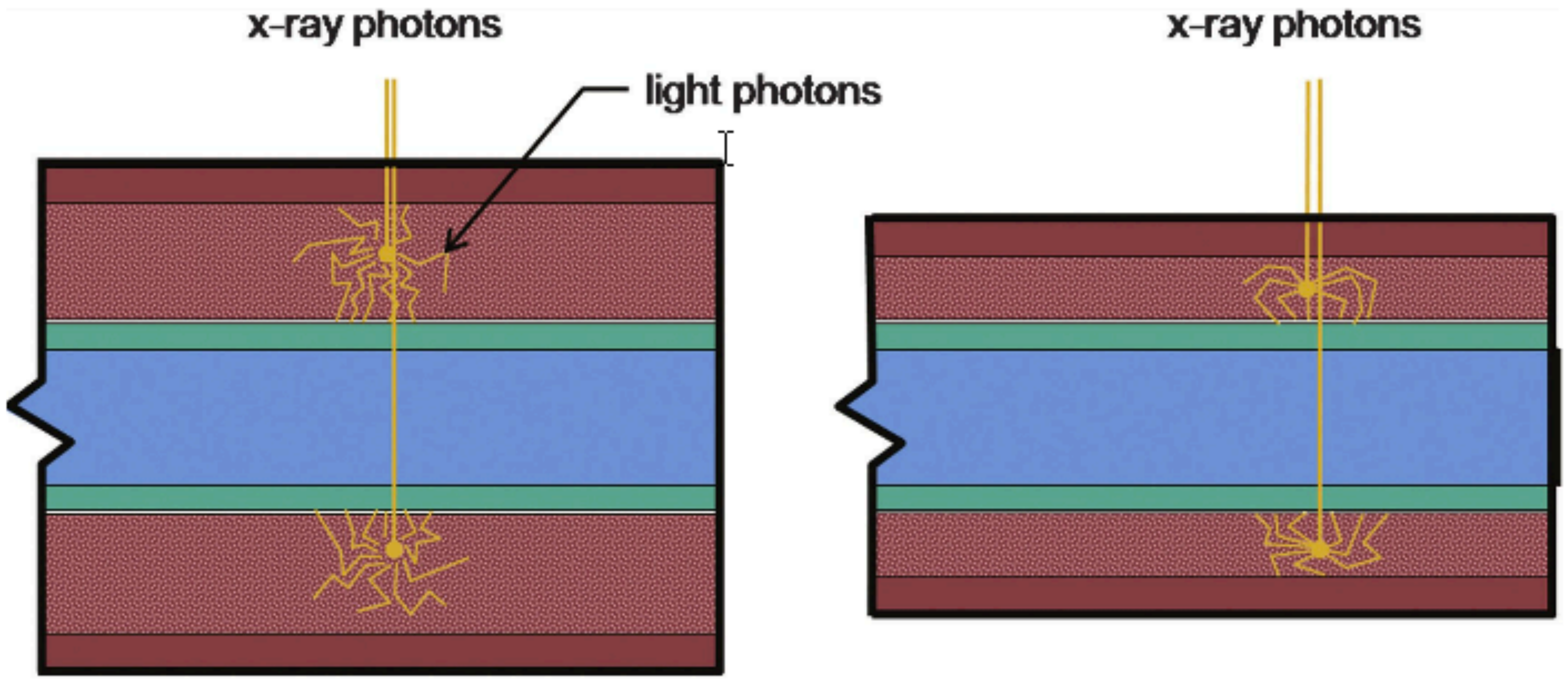
Filmcassette:



jfr med

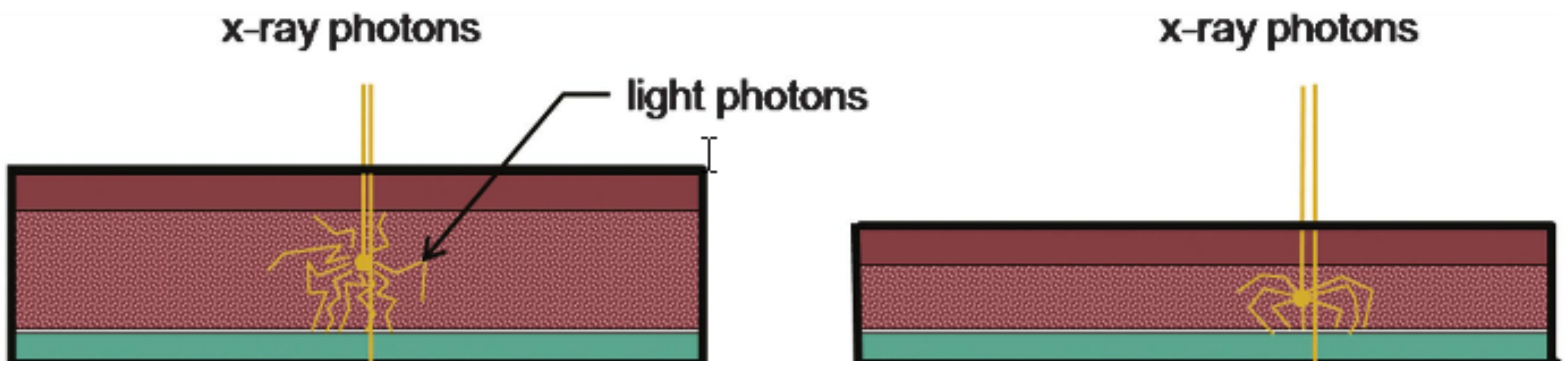


Filmcassette:

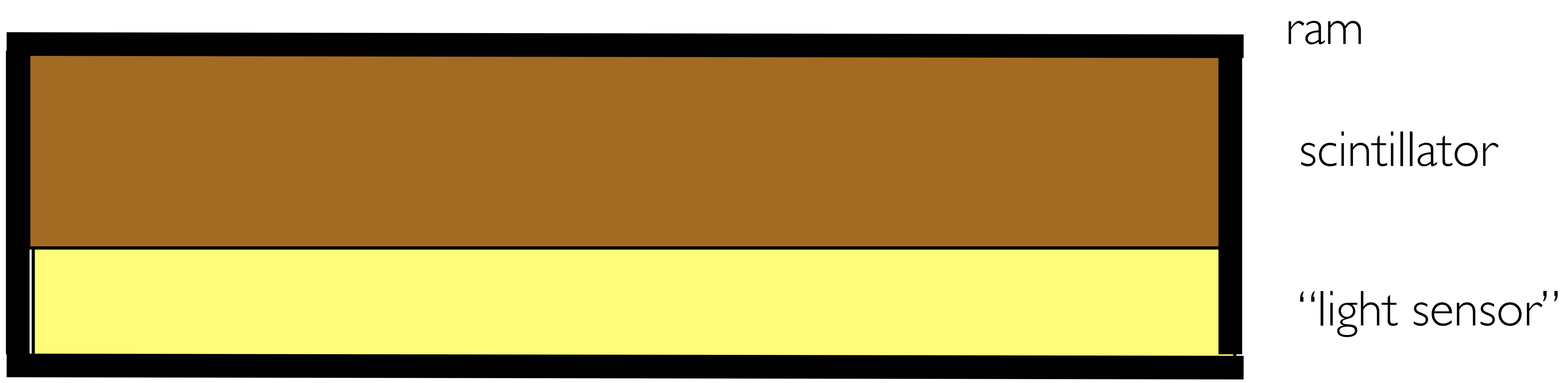


dubbelt så stor effektivitet med samma rumupplösning

jfr med

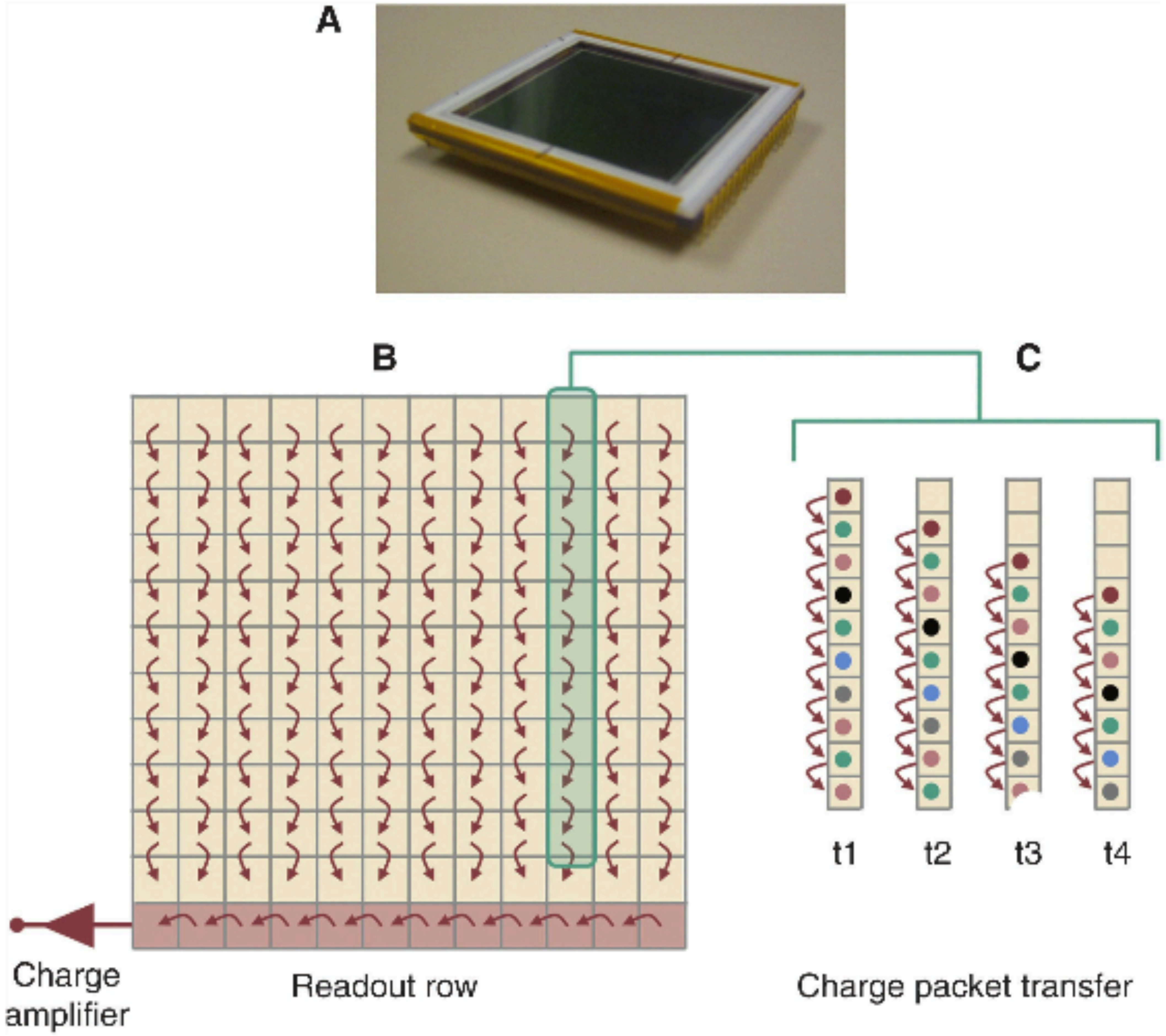


Better than film!

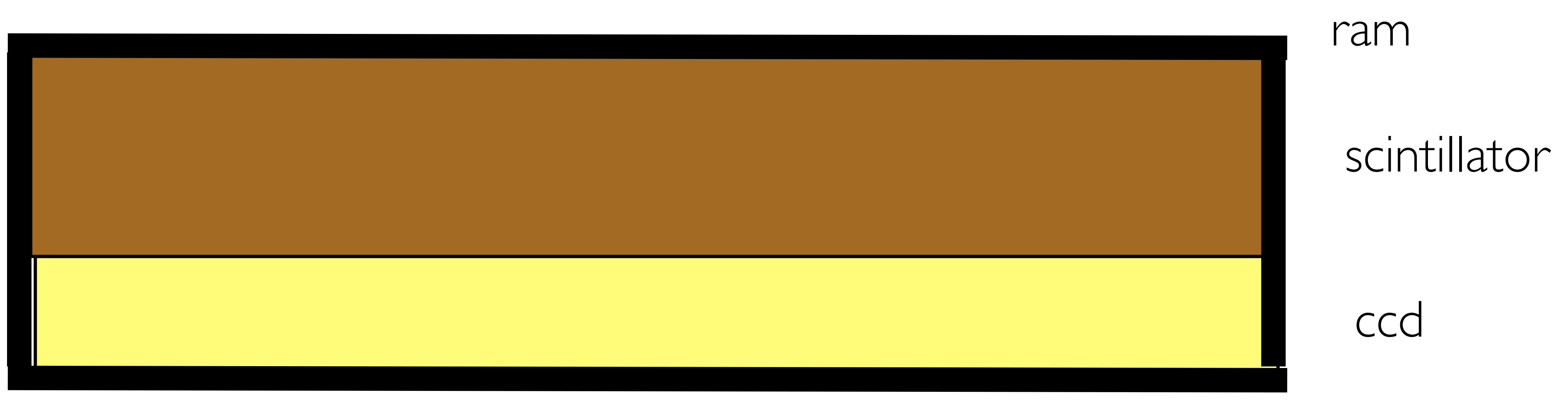


DR: CCD & CMOS

Charge-Coupled Device:

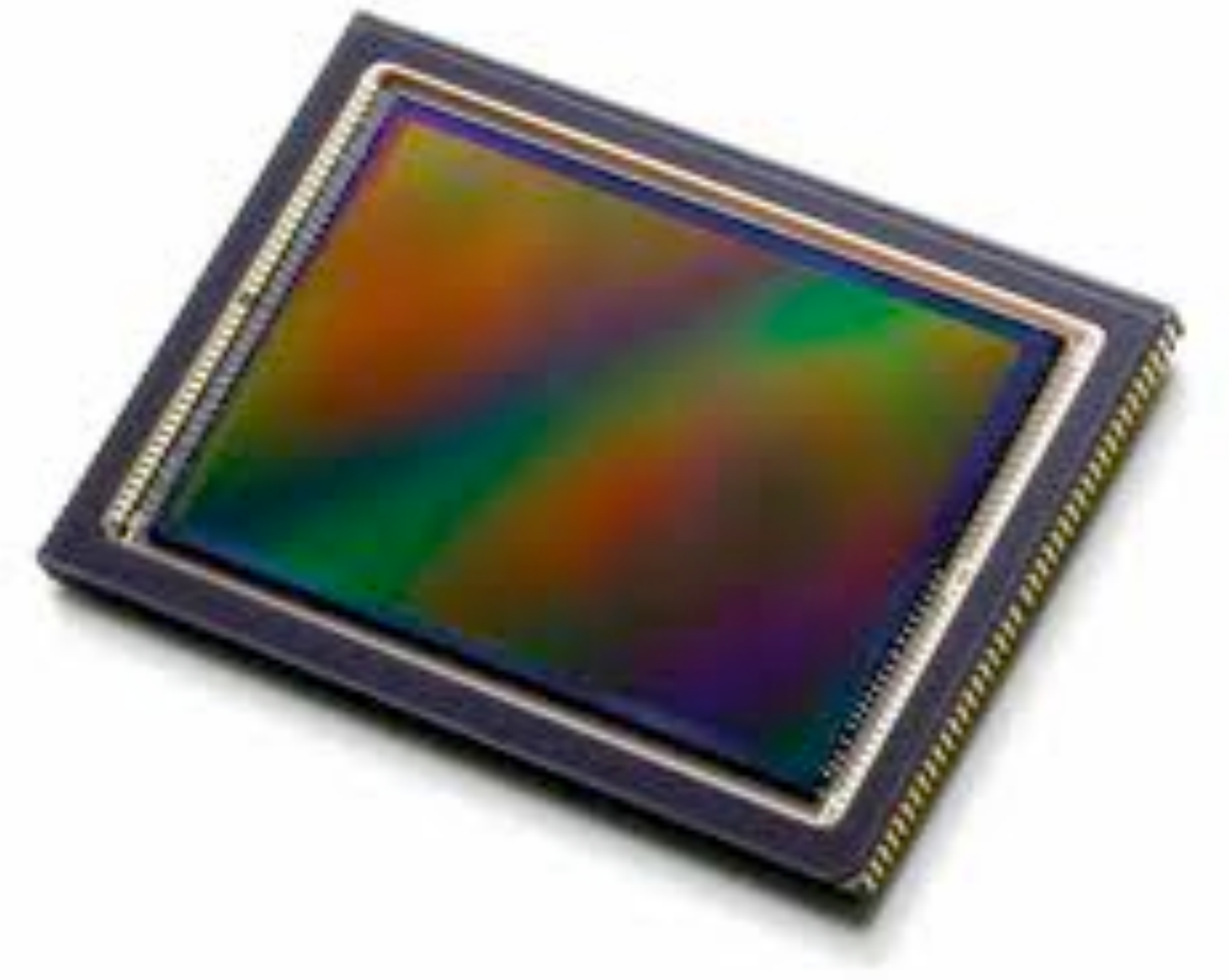


CCD kan användas i stället för film:



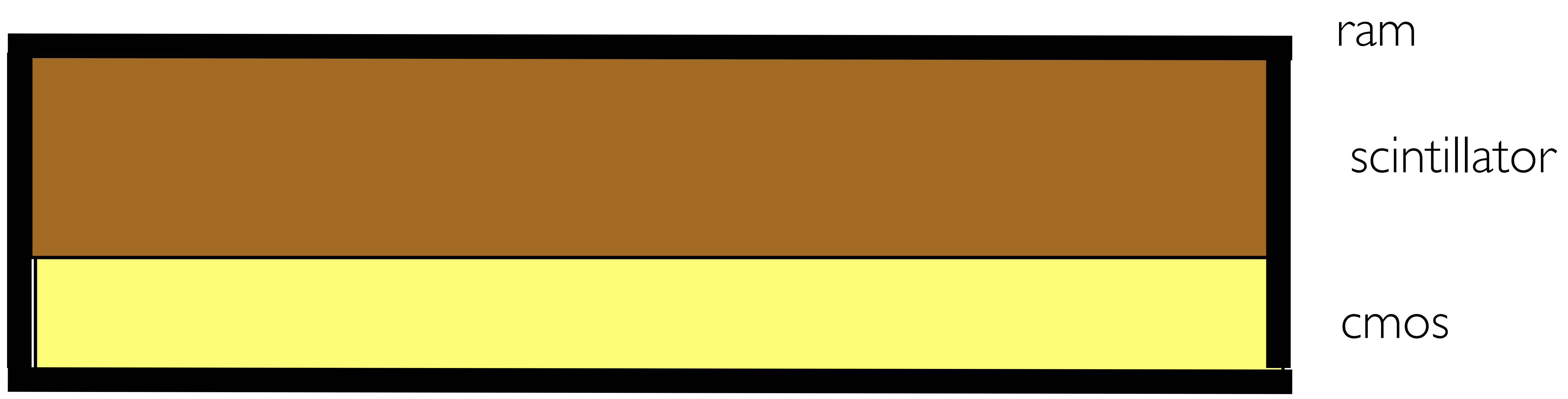
Complementary Metal-Oxide Semiconductor:

same as CCD, fotons -> electrons

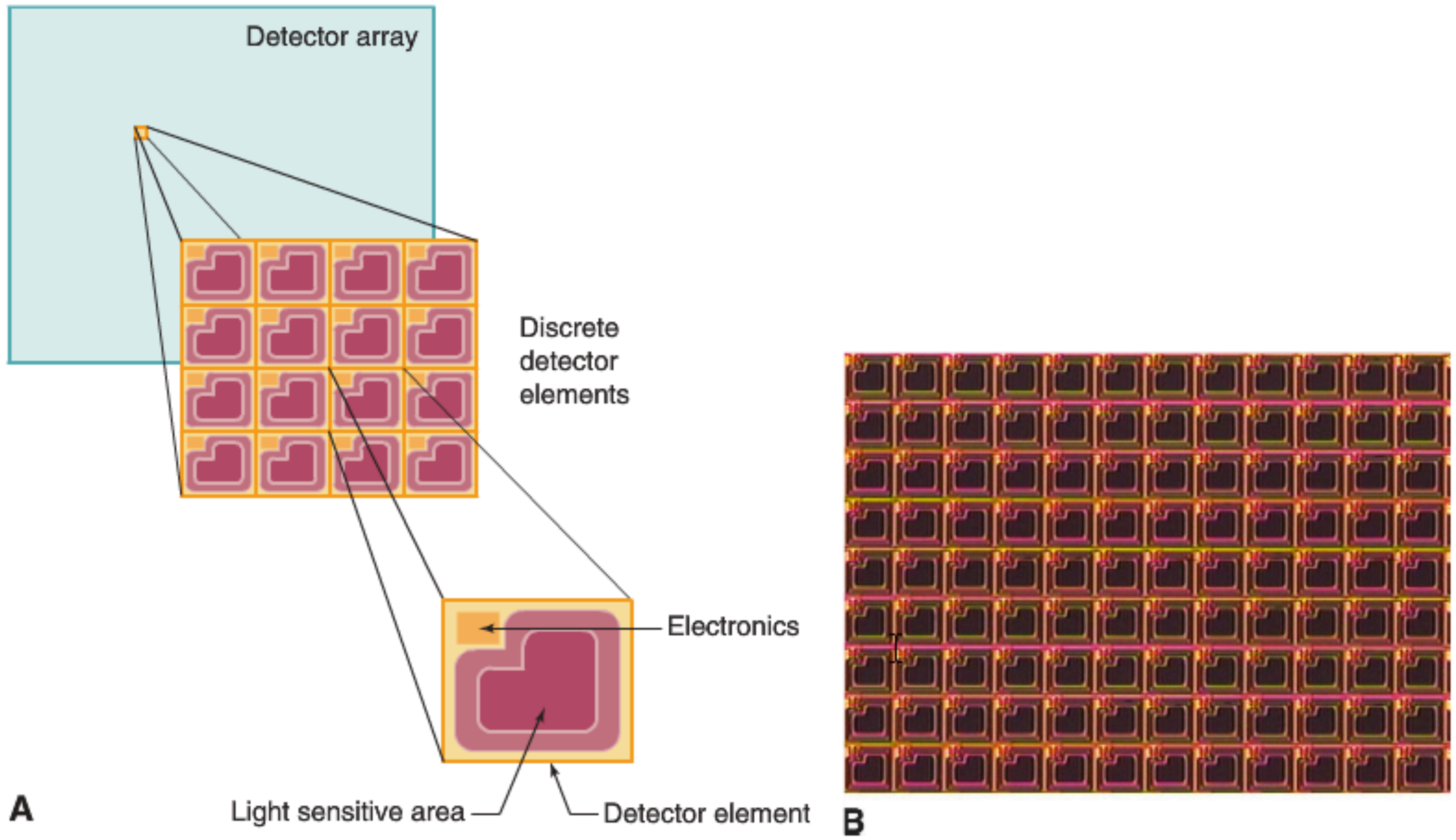


+ each pixel can be accessed random!
- noise
- size (small FOV 10 x 15 cm)

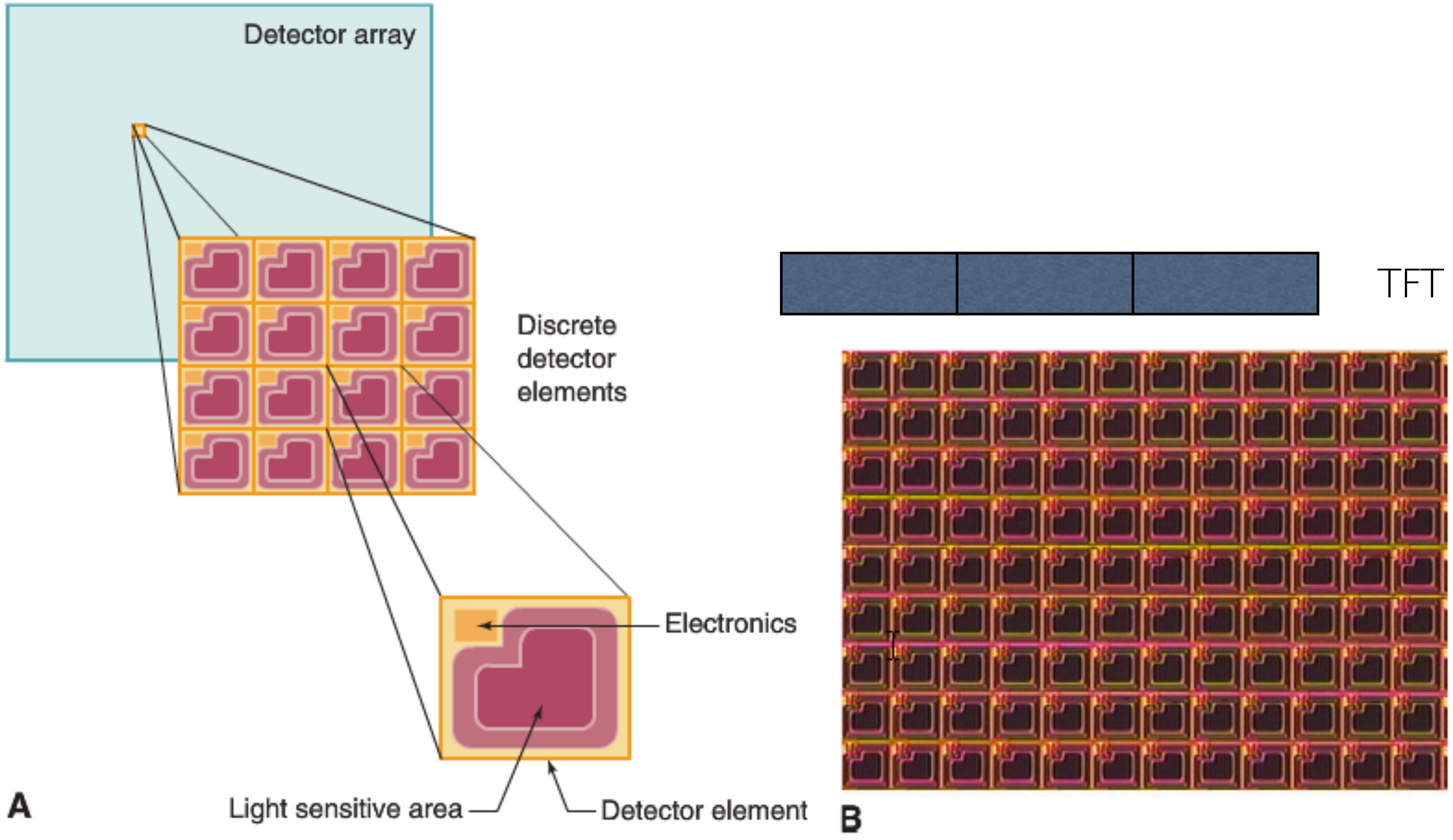
CMOS kan användas i stället för film:



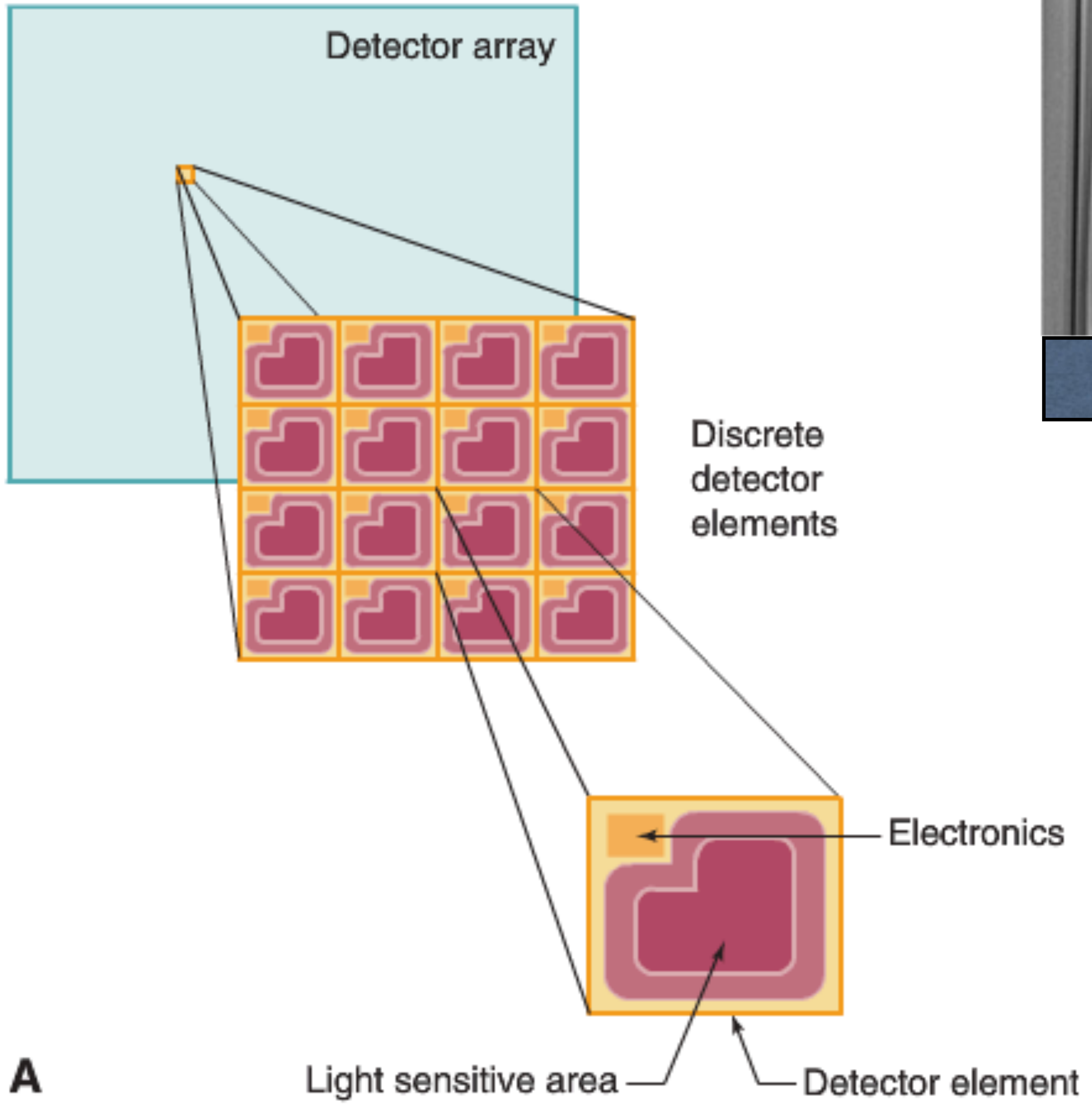
Flat Panel Thin-Film-Transistor Array Detectors



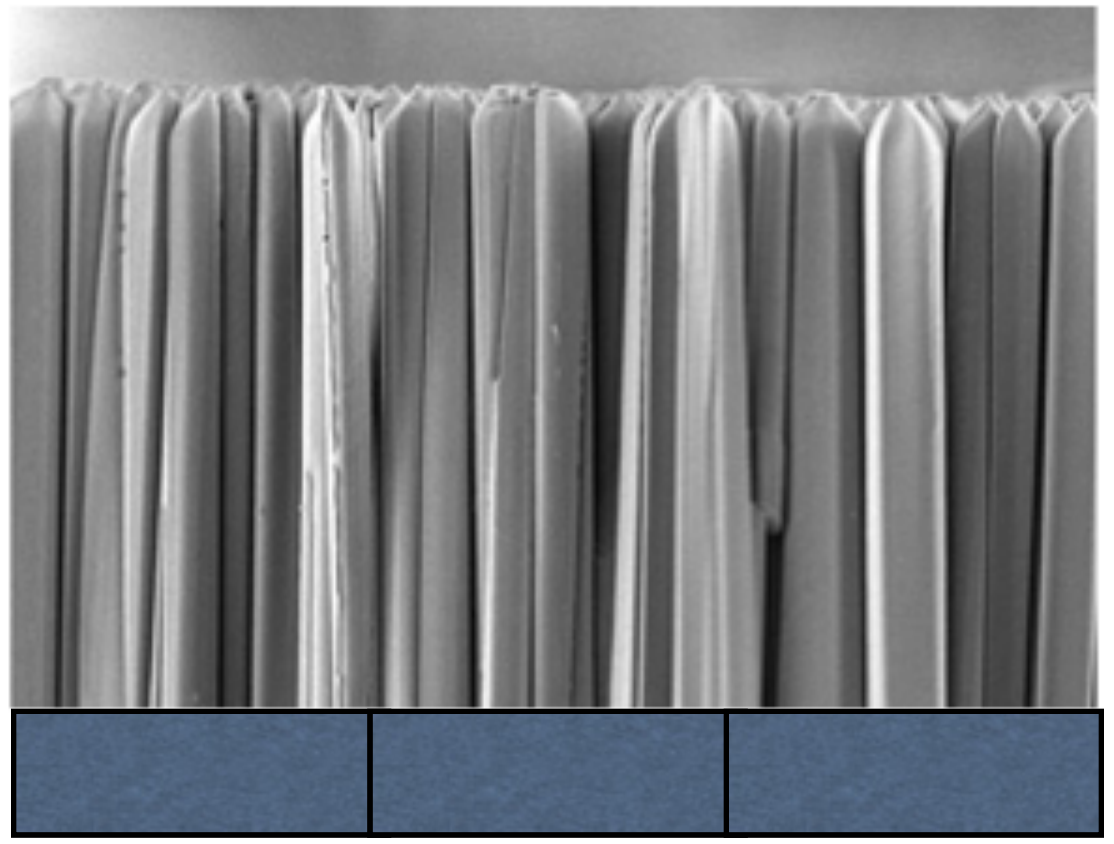
Flat Panel Thin-Film-Transistor Array Detectors



Flat Panel Thin-Film-Transistor Array Detectors

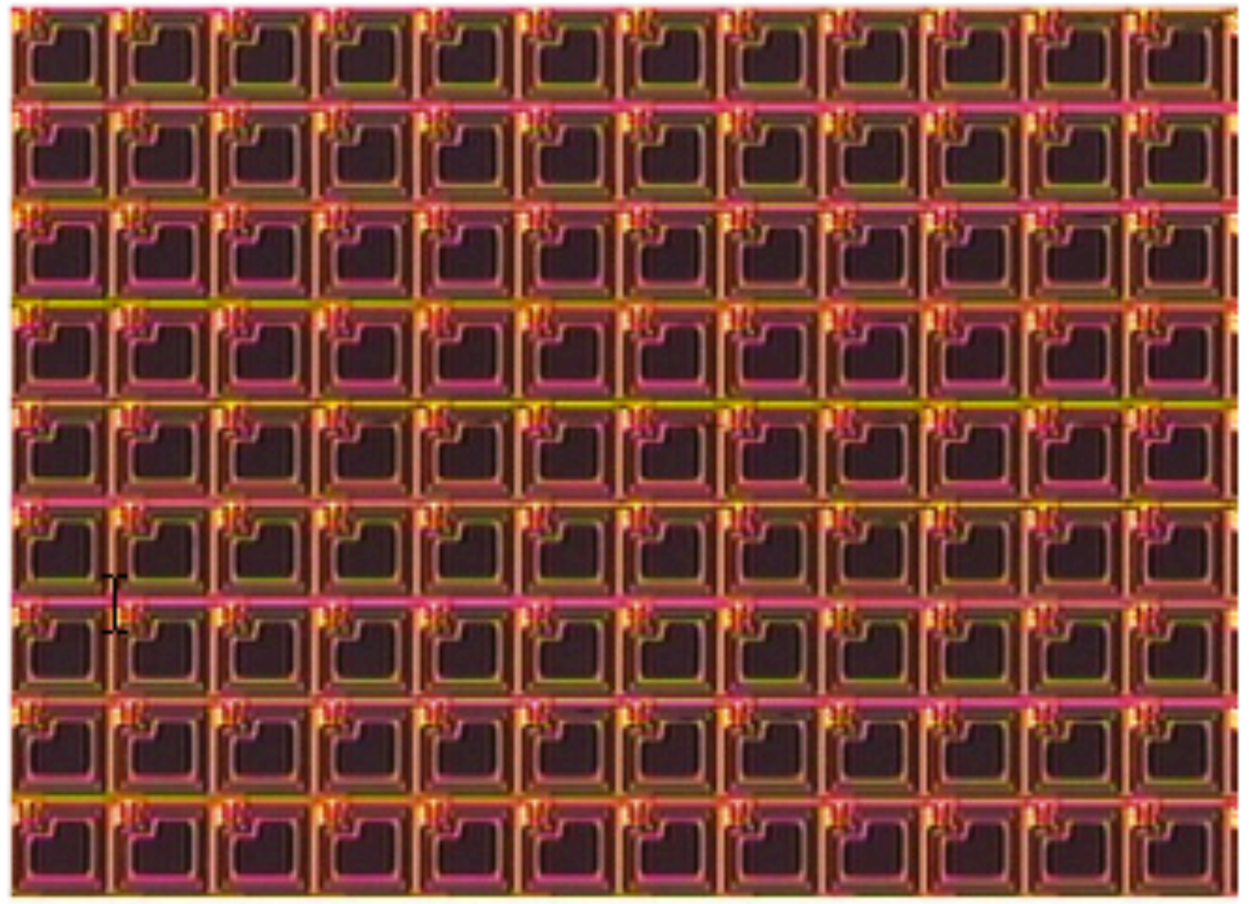


A



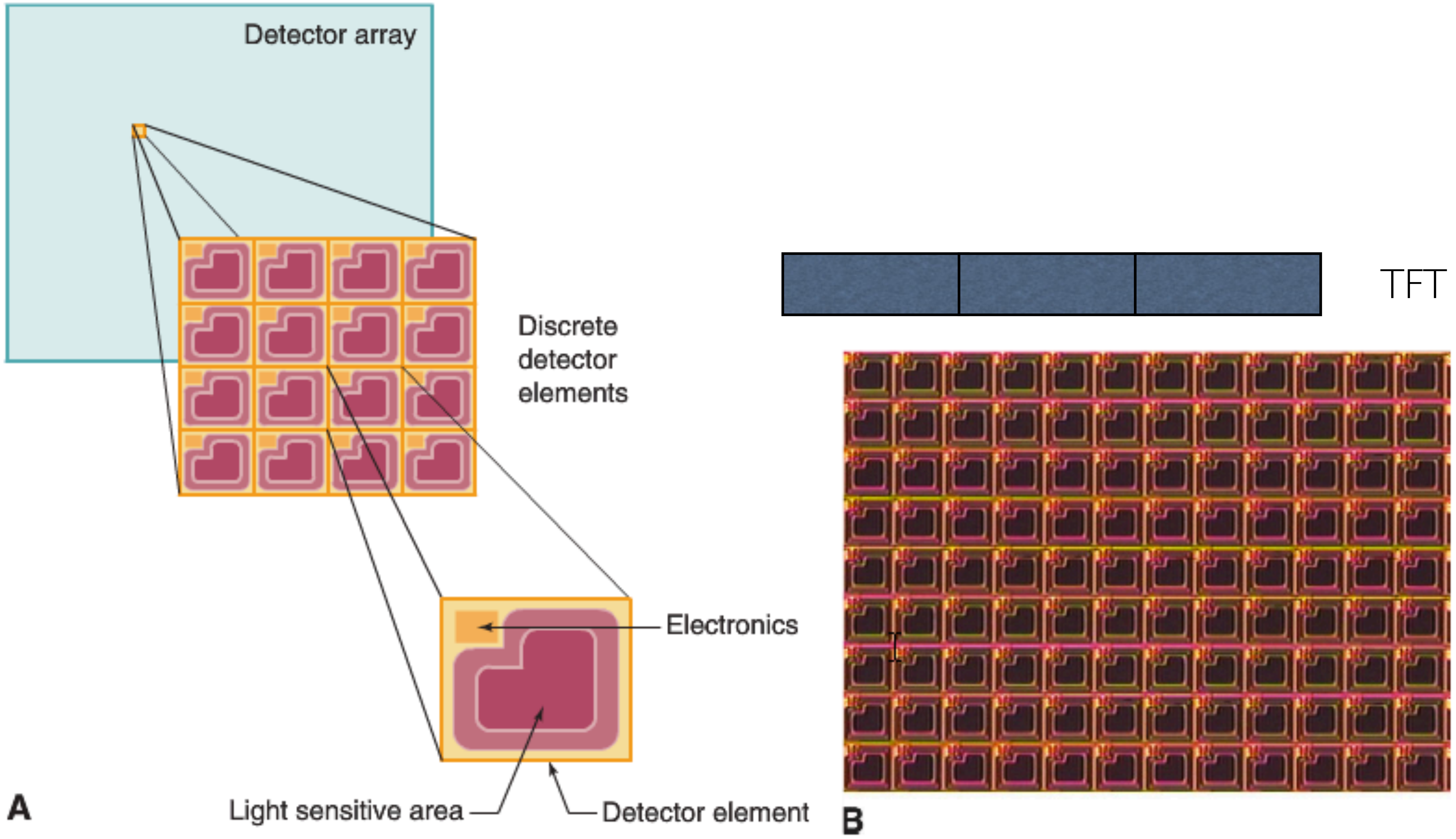
Scintillator:
CsI needles

TFT

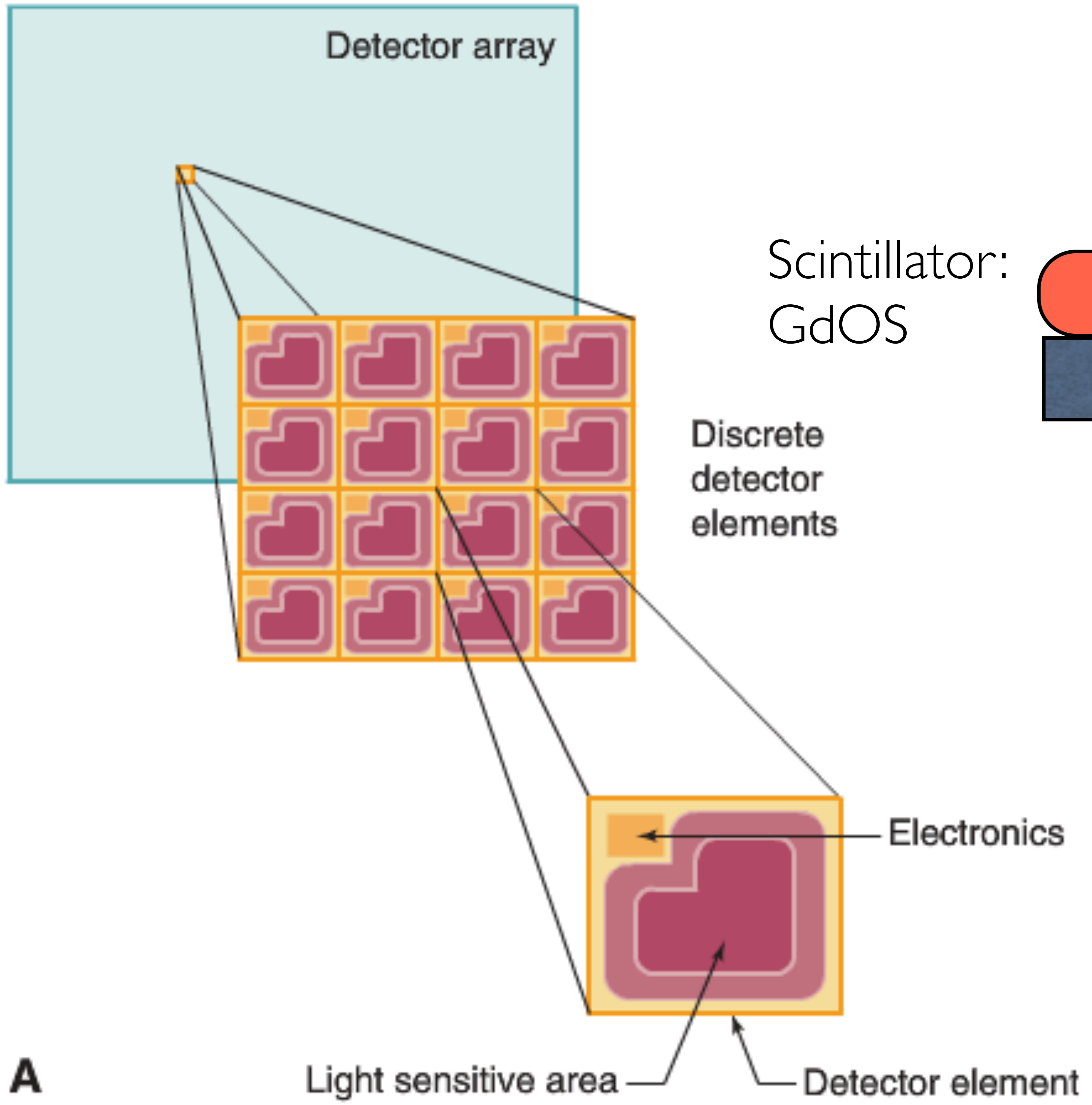


B

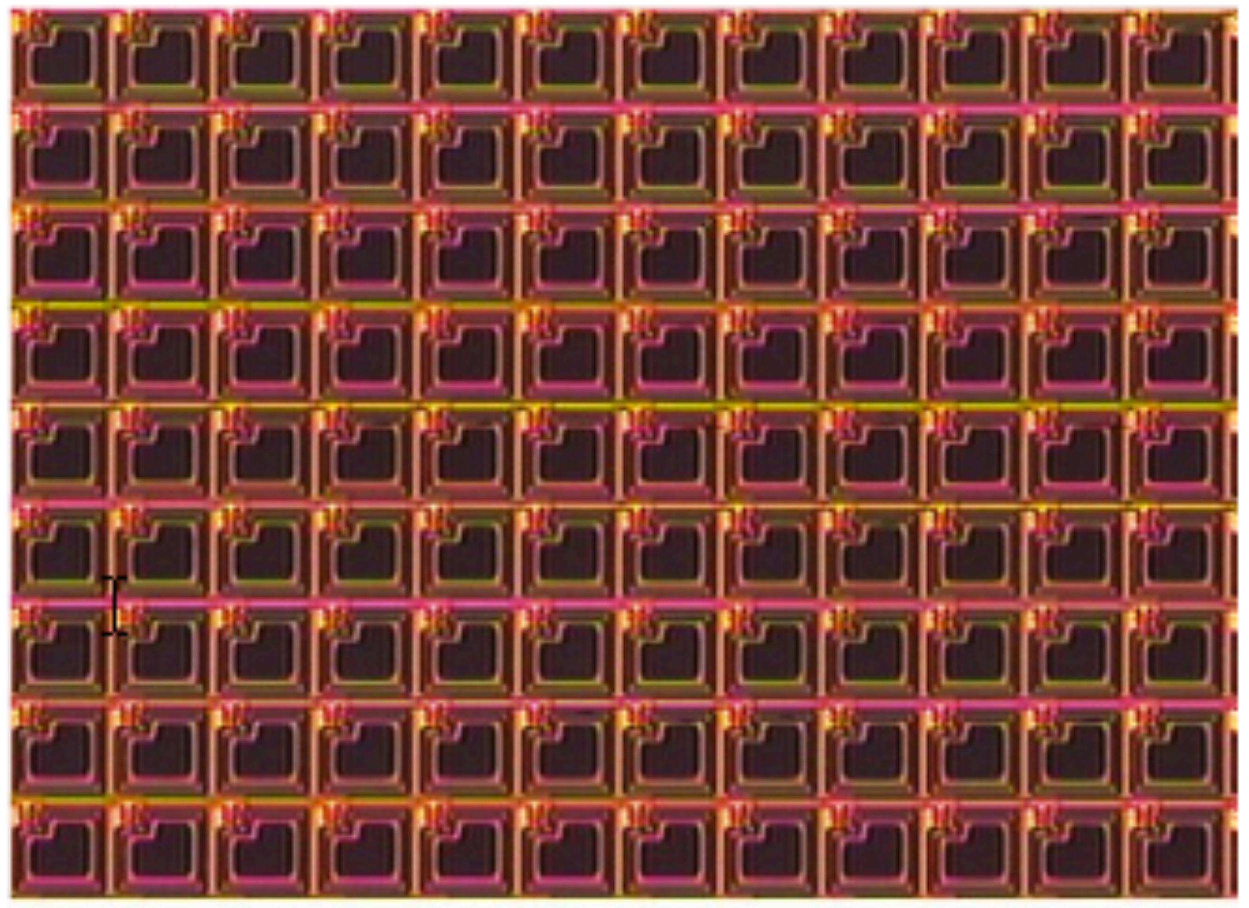
Flat Panel Thin-Film-Transistor Array Detectors



Flat Panel Thin-Film-Transistor Array Detectors

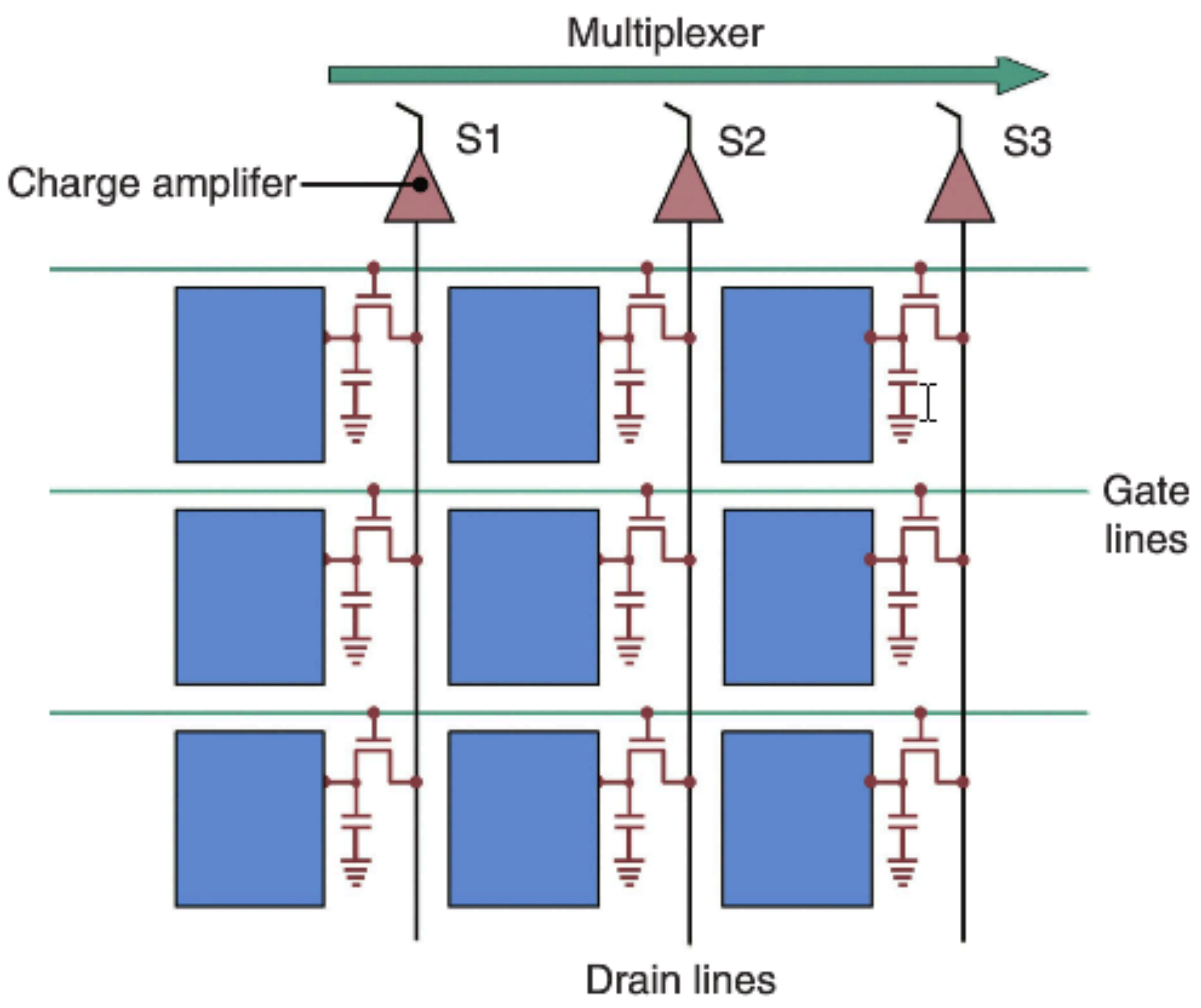


A



B

Flat Panel TFT Array Detectors: read out

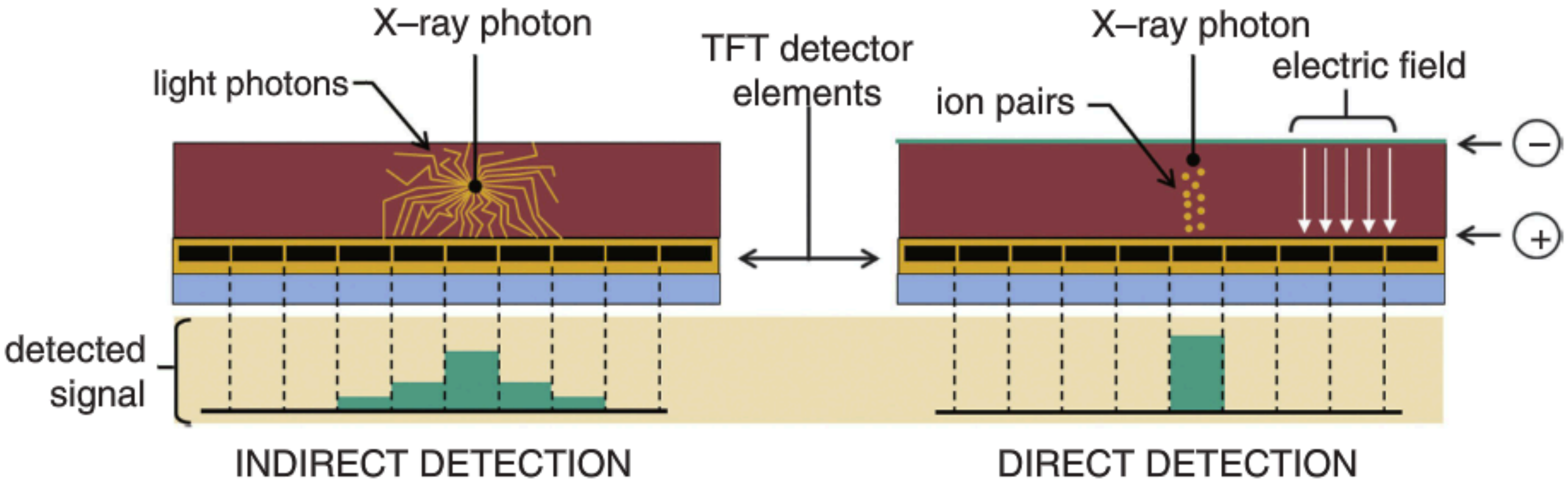


Flat Panel Thin-Film-Transistor Arrays have the same function as:

1. film
2. scintillator
3. phosphor
4. CCD
5. CMOS

direct detection detectors in radiography:

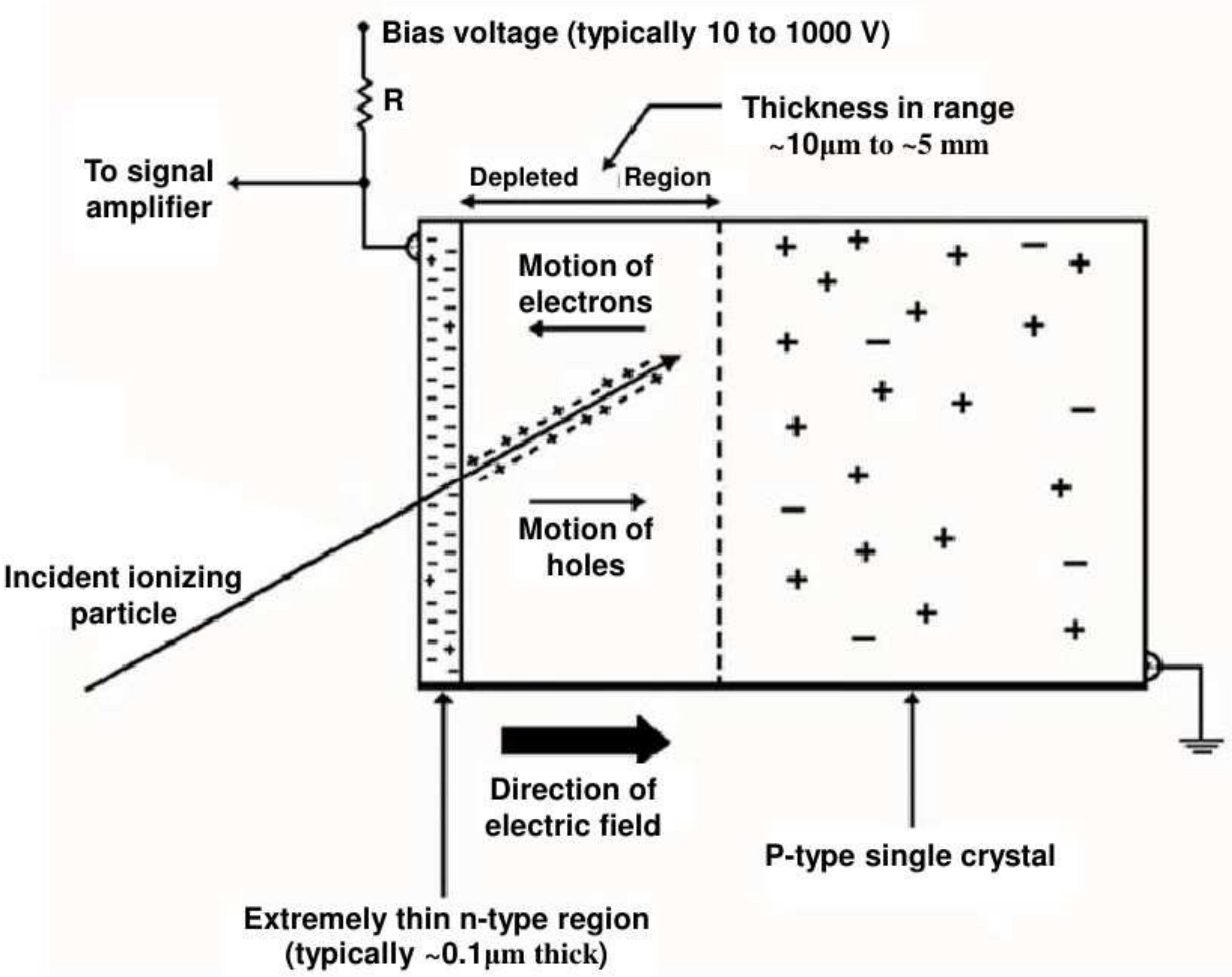
Direct vs Indirect detection

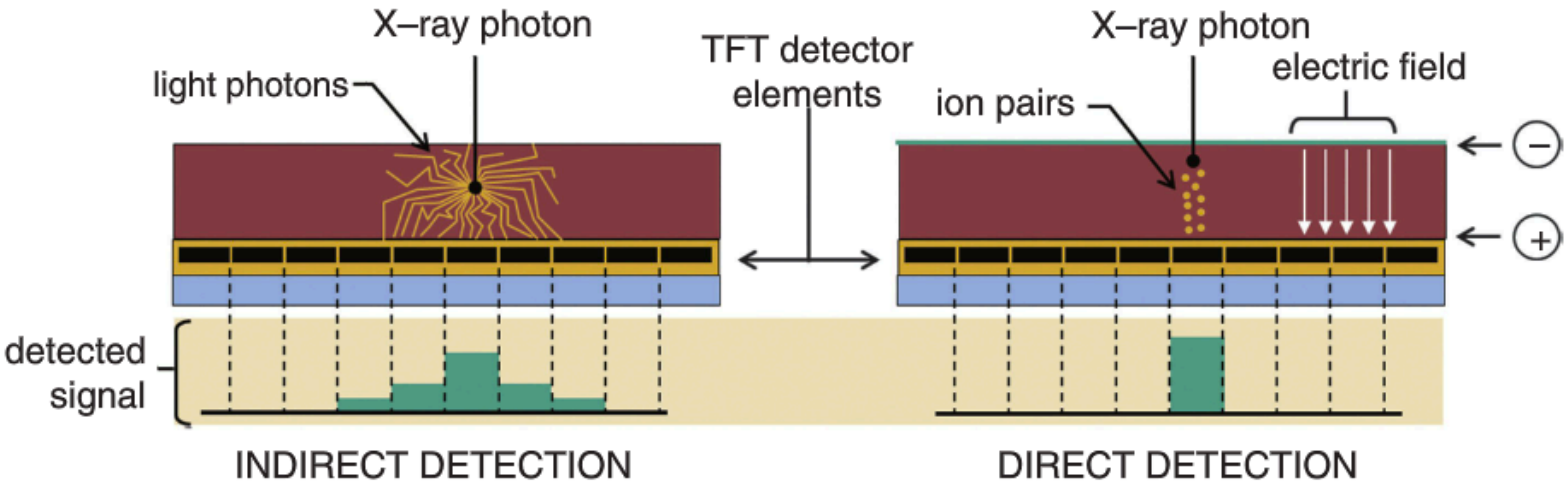


Name	Formula	Density (g/mm³)	Zeff	Light yield (ph/MeV)	Primary Decay time (ns)	Emission (nm)
LSO:Ce	Lu_2SiO_5:Ce	7.40	66	35,000	32	420
GSO:Ce	Gd_2SiO_5:Ce	6.71	59	20,000	60	440
LPS:Ce	$Lu_2Si_2O_7$:Ce	6.2	64	23,000	30	380
GPS:Ce	$Gd_2Si_2O_7$:Ce	5.5	58	30,000	46	380
BGO	$Bi_4Ge_3O_{12}$	7.13	74	8,000	300	480
YAP:Ce	$YAlO_3$:Ce	5.35	34	20,000	24	365
LuYAG:Pr	$Lu_{2.25}Y_{.75}Al_5O_{12}$:Ce	6.20	60	33,000	20	310
GGAG:Ce	$Gd_3Ga_3Al_2O_{12}$:Ce	6.5	54	47,000	51	540

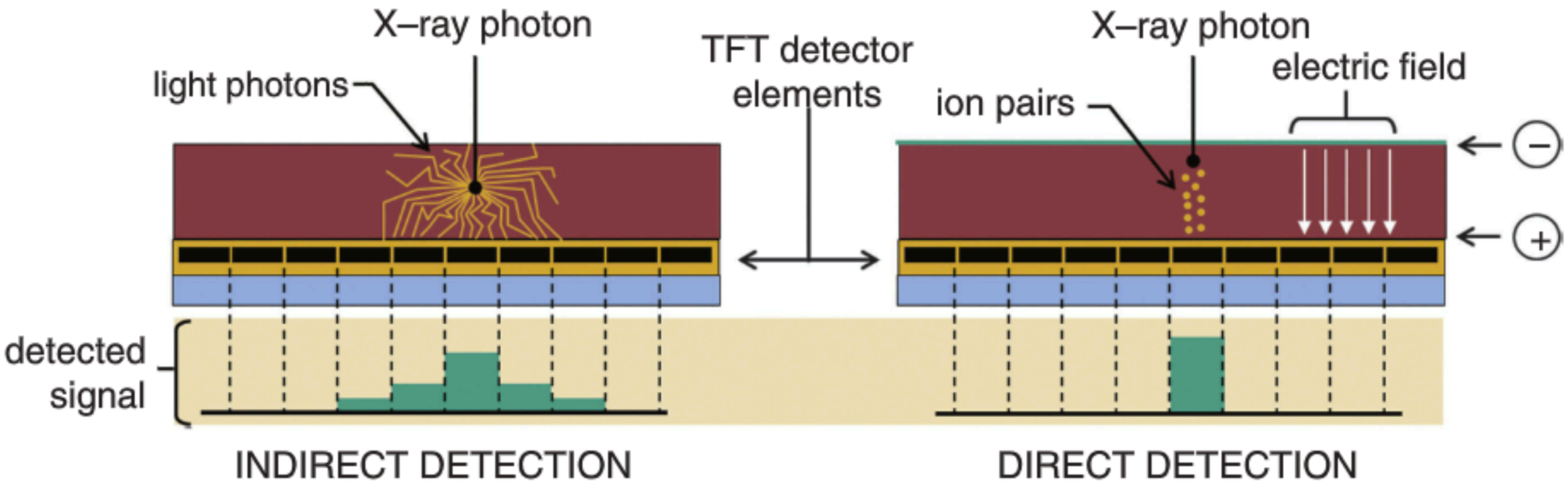
semi-conductor	density [g/cm^3]	Z	E_{gap} [eV]	ϵ [eV]	X_0 [cm]
Si	2.33	14	1.12	3.6	9.37
Ge	5.33	32	0.67	2.9	2.30
CdTe	5.85	48,52	1.44	4.43	1.52
CdZnTe	5.81		1.6	4.6	
HgI_2	6.40	80,53	2.13	4.2	1.16
GaAs	5.32	31, 33	1.42	4.3	2.29

E_{gap} : band gap energy
ϵ : an ionization potential
X_0 : radiation length


Bias voltage (typically 10 to 1000 V)
R
Thickness in range
~10μm to ~5 mm
To signal
amplifier
Depleted
Region
Motion of
electrons
Motion of
holes
Incident ionizing
particle
Direction of
electric field
P-type single crystal
Extremely thin n-type region
(typically ~0.1μm thick)



1. 0,15 mm
2. 1,5 mm
3. 1,5 cm
4. 15 cm



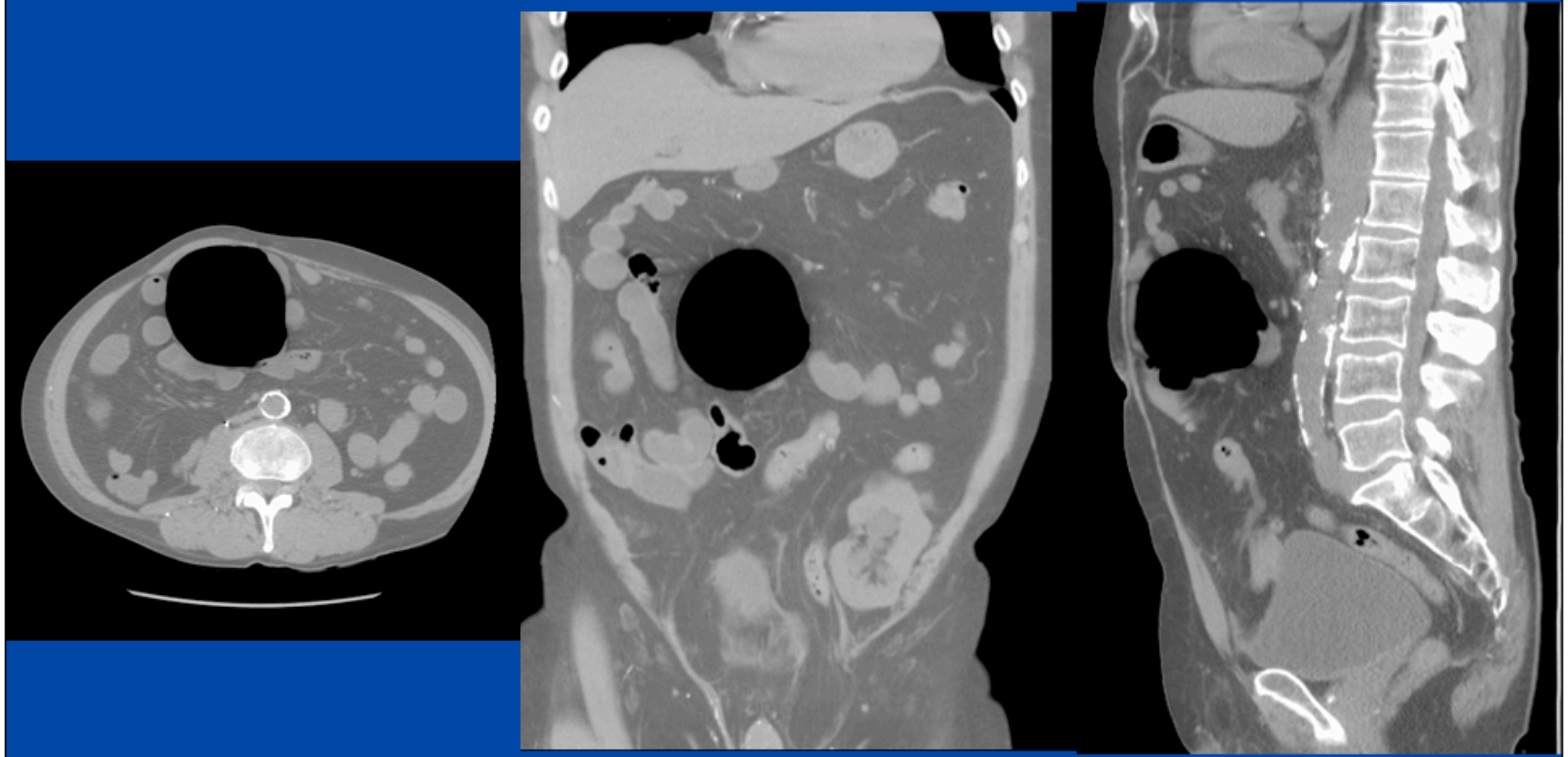
Consider 40keV x-ray and Si, how thick (approximately) has Si to be to detect 90%?
(please, calculate on your own before choosing an answer)

1. 0,15 mm
2. 1,5 mm
3. 1,5 cm
4. 15 cm

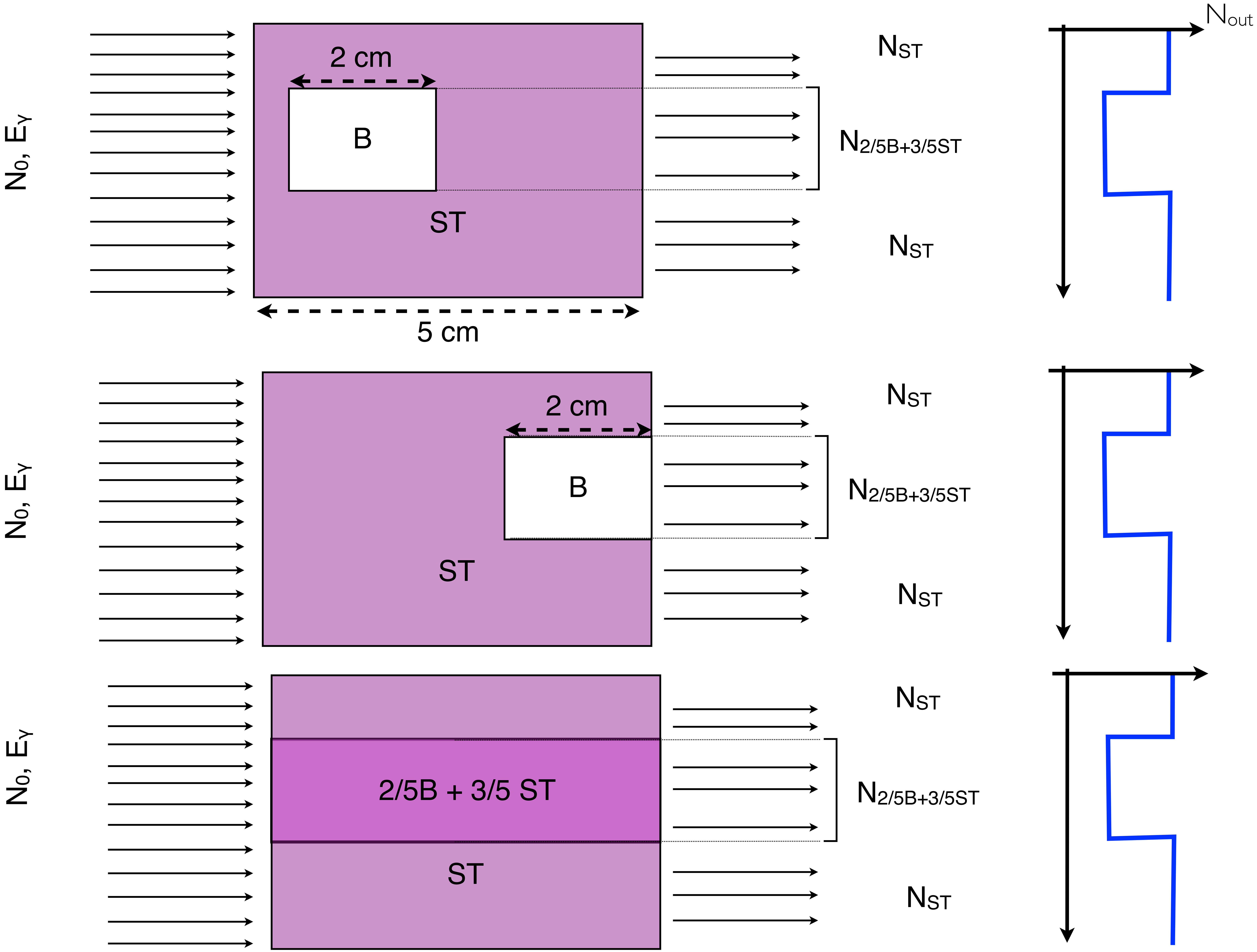
3D avbildning: CT

Modern datortomograf

CT bilder från Danderyds Sjukhus



64 slice CT - samma undersökning av buken, rekonstruerad i tre plan



N_0, E_γ
2 cm
B
ST
5 cm
N_{ST}
$N_{2/5B+3/5ST}$
N_{ST}
N_{out}
N_0, E_γ
2 cm
B
ST
N_{ST}
$N_{2/5B+3/5ST}$
N_{ST}
N_0, E_γ
2/5B + 3/5 ST
ST
N_{ST}
$N_{2/5B+3/5ST}$
N_{ST}

Back to x-ray CT

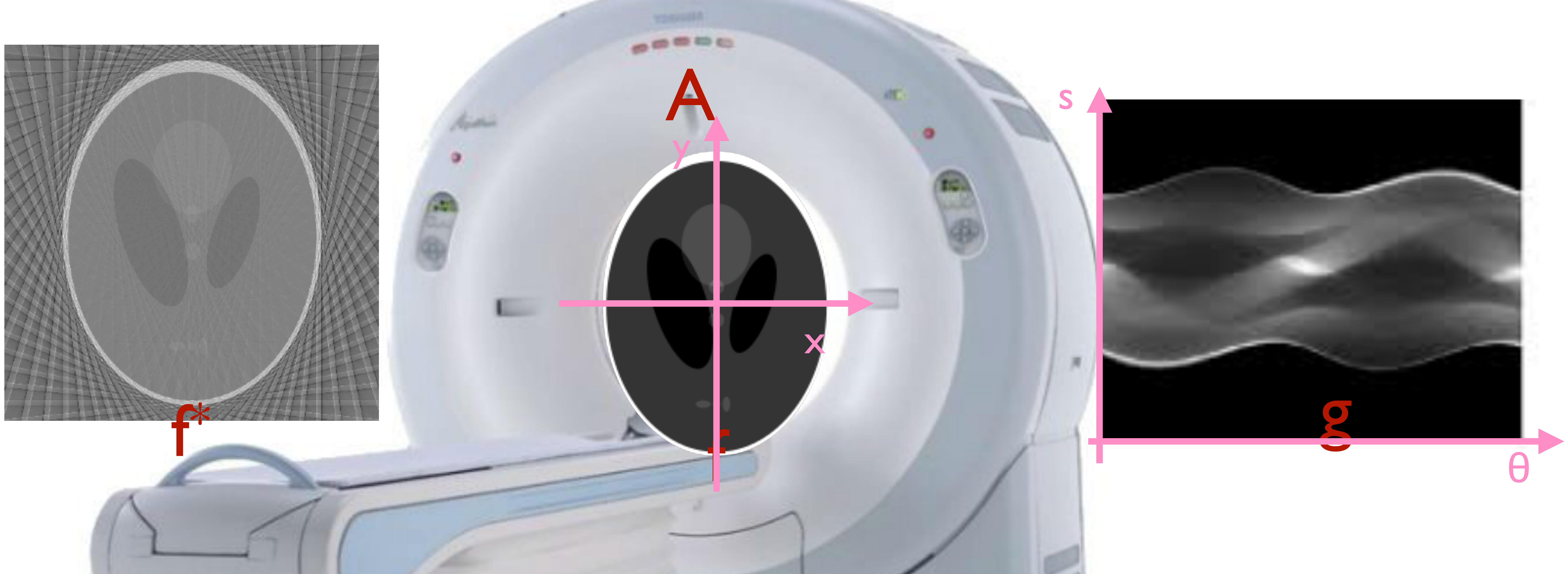
consider an integrable function $f : \mathbb{R}^3 \to \mathbb{R}$ (object/image)

and a measuring protocol described by the *forward operator:* A (scanner + protocol)

data acquisition is then described by the equation: $g = Af$ (1) (g: data, i.e. projections)

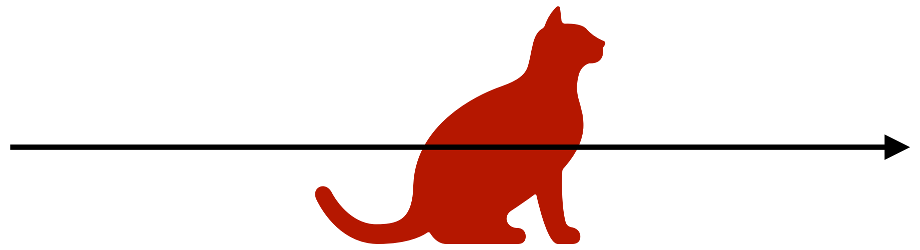
the image can be then obtained from data by "inverting" (1): $f = A^{-1}g$ (reconstruction)

(in practice, the reconstructed image will often be only an approximation of the object: : $f^* = A^* g$)



Back to x-ray CT

What is the forward operator A in x-ray CT (or CAT scan)?

"Physics of the forward problem": $I_{in}(E)$  $I_{out}(E) = I_{in}(E)e^{-\int \mu(x,y,E)dl}$

$$\Rightarrow -\ln \frac{I_{out}(E)}{I_{in}(E)} = \int \mu(x,y,E)dl$$

"Geometry of the forward problem":

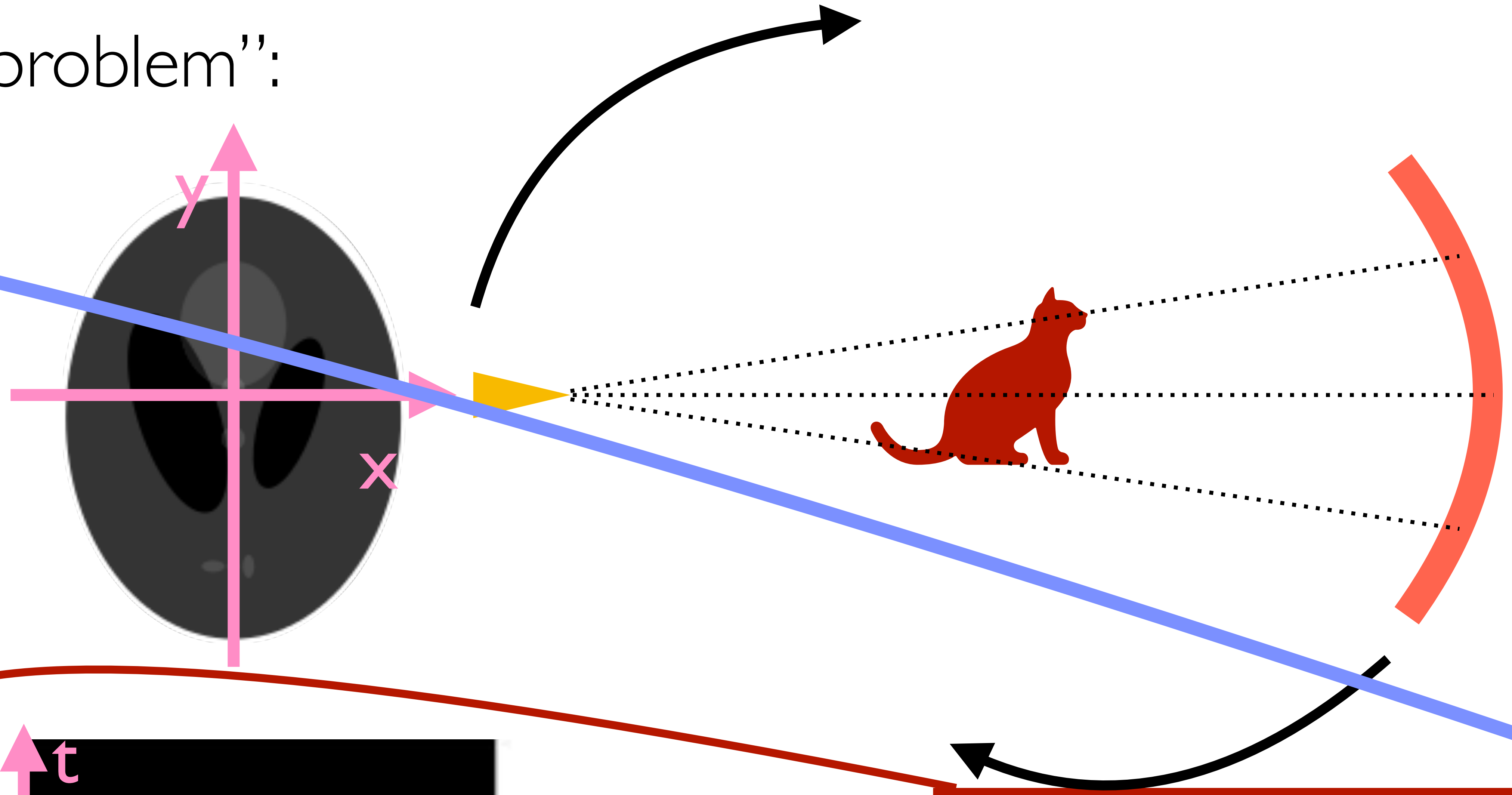
Radon transform

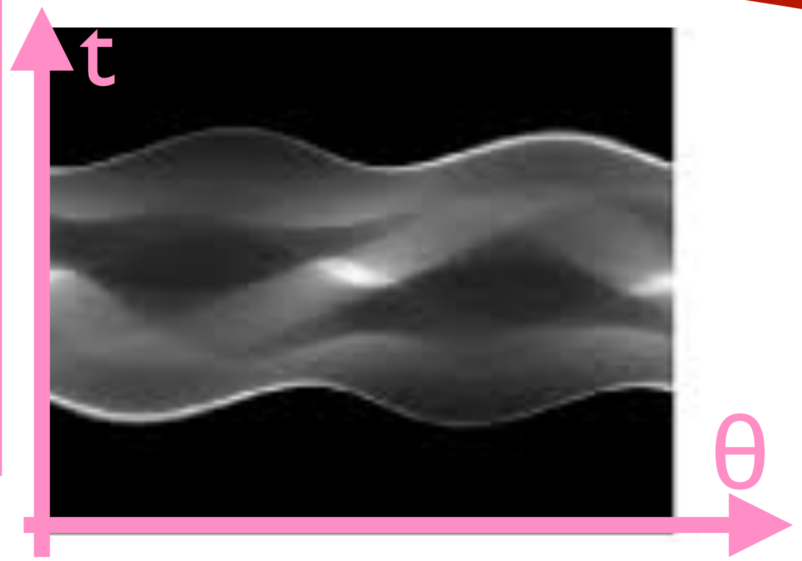
$$Af = g$$

$$f(x,y) := \mu(x,y)$$

$$A(\cdot) := \int (\cdot)\, dl, \forall \text{ lines in } \mathbb{R}^2$$

$$g(t,\theta) := \int_{l(t,\theta)} \mu(x,y)dl$$



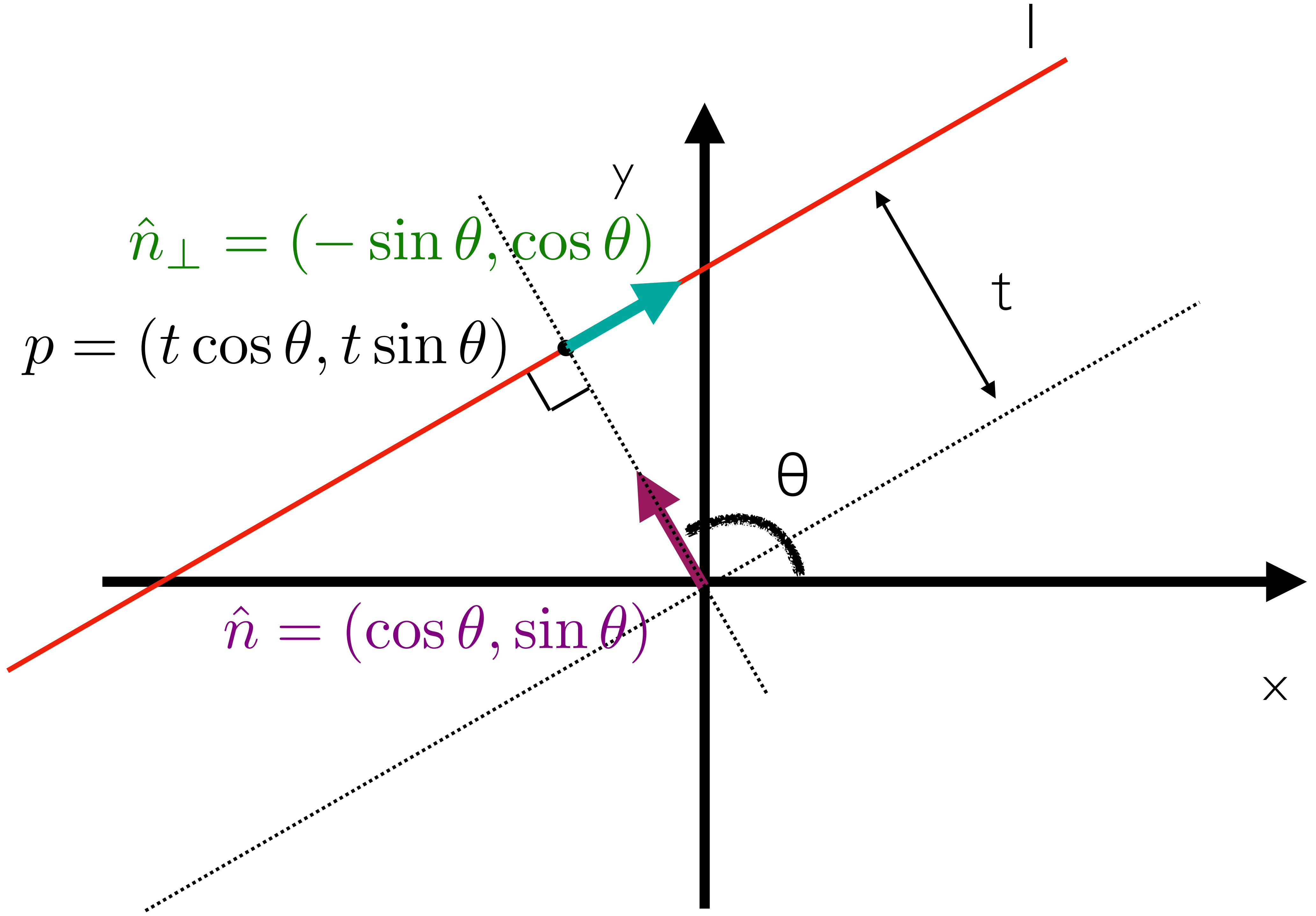


lines joining tube's focal spot to detector pixels at different rotation angles (I will show you shortly that those can be parametrised with the help of two parameters, say, t and θ)

a sampling of

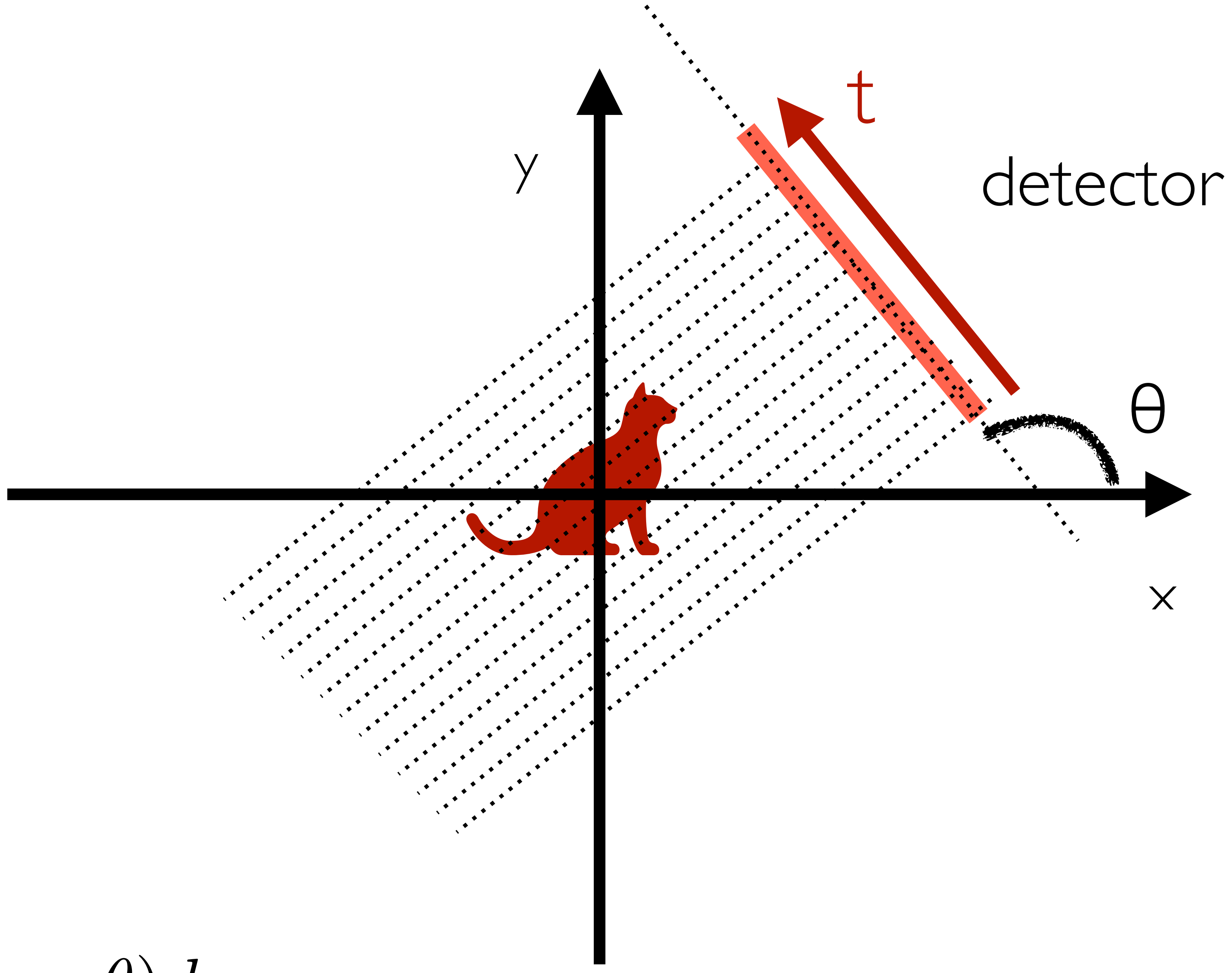
Well, you wish! In reality all lines from tube focal spot to detector pixels during a complete acquisition

Parametrisation of lines in 2D-plane



$$l_{t,\theta} = \{(t\cos\theta - s\sin\theta, t\sin\theta + s\cos\theta) : -\infty < s < \infty\}$$

Sounds unnecessarily complicated?

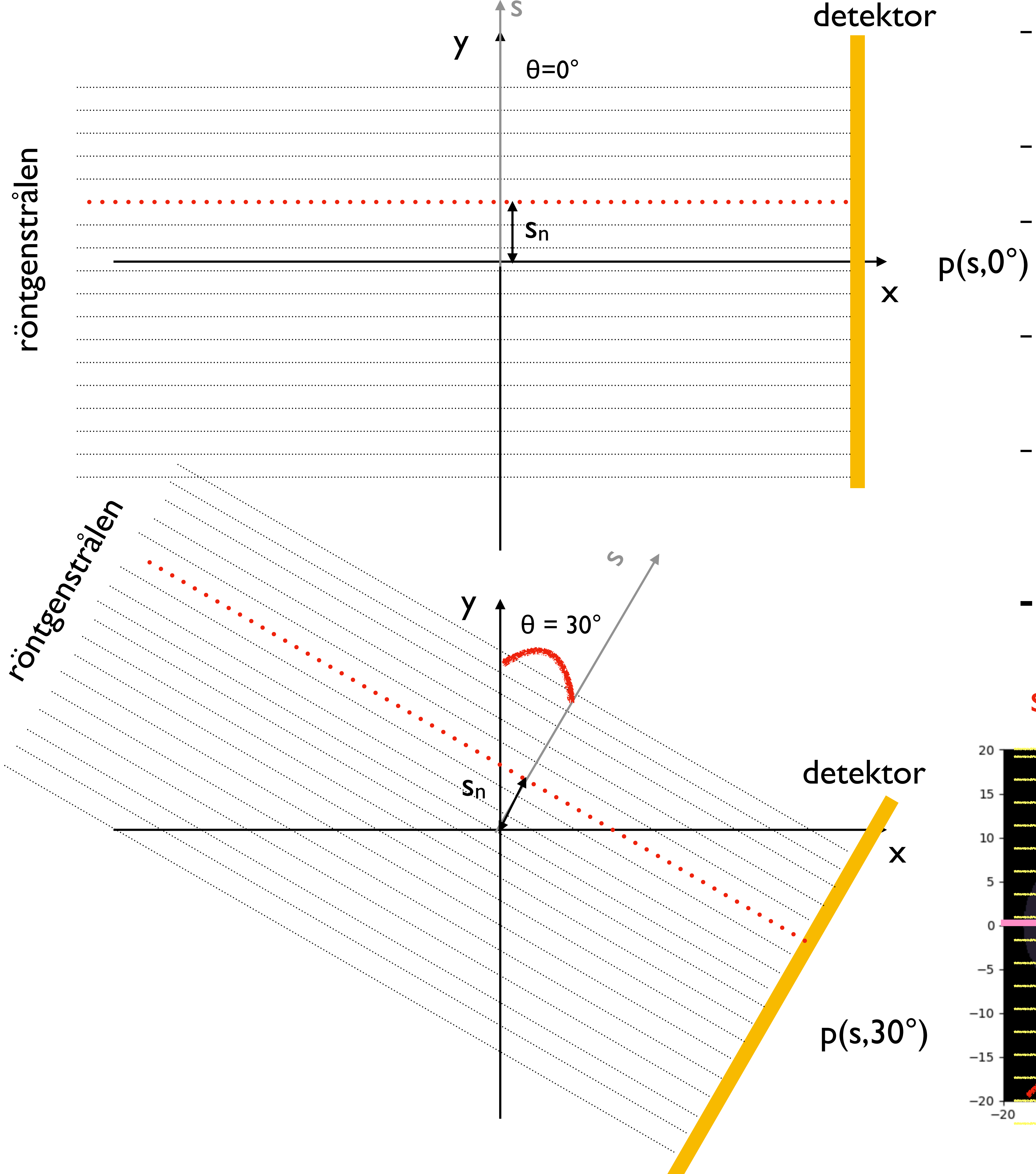


After all this work, we can write line integrals of a function, f, in the plane as:

$$\int_{l_{t,\theta}} f(x,y)dl = \int_{-\infty}^{\infty} f(t\cos\theta - s\sin\theta, t\sin\theta + s\cos\theta)ds$$

and write the Radon transform, $\mathcal{R}$, in a more compact form:

$$\mathcal{R}f(t,\theta) := \int_{l_{t,\theta}} f(x,y)dl = \int_{-\infty}^{\infty} f(t\cos\theta - s\sin\theta, t\sin\theta + s\cos\theta)ds$$

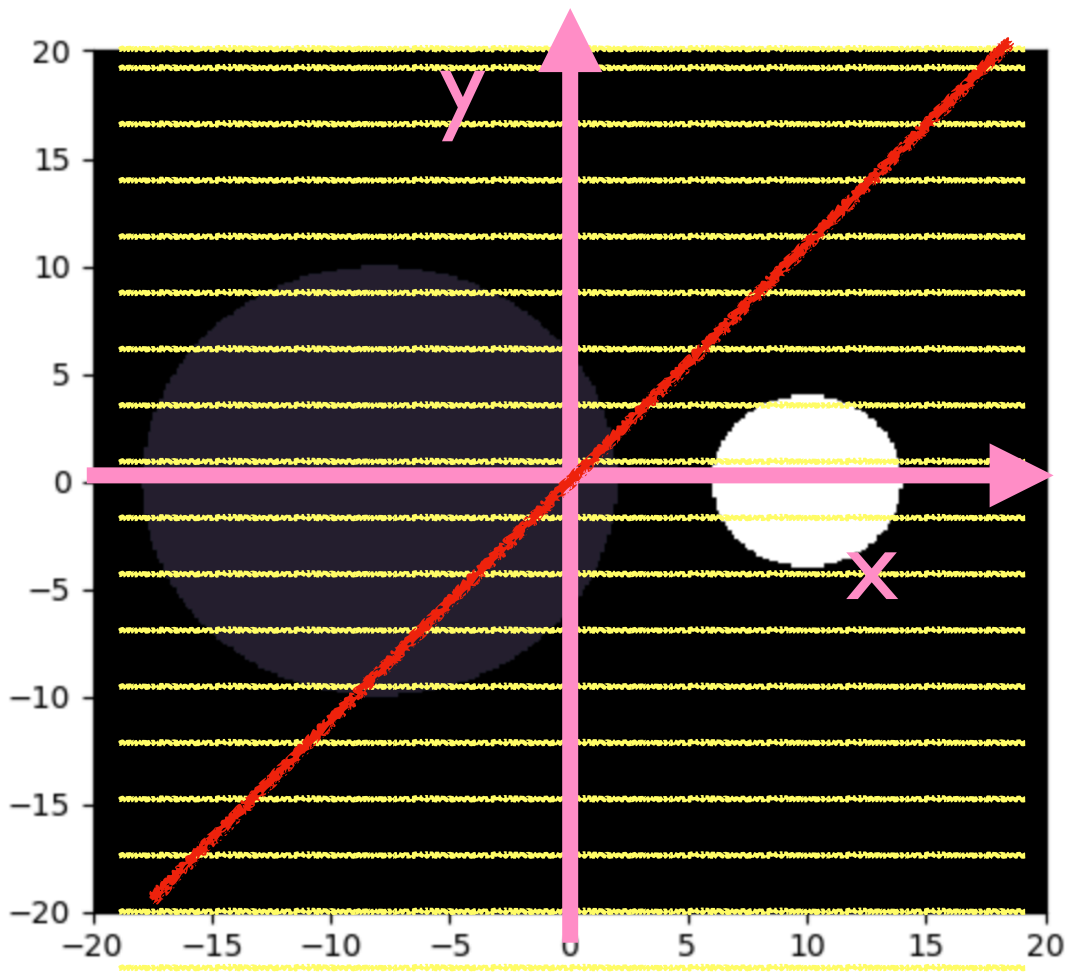


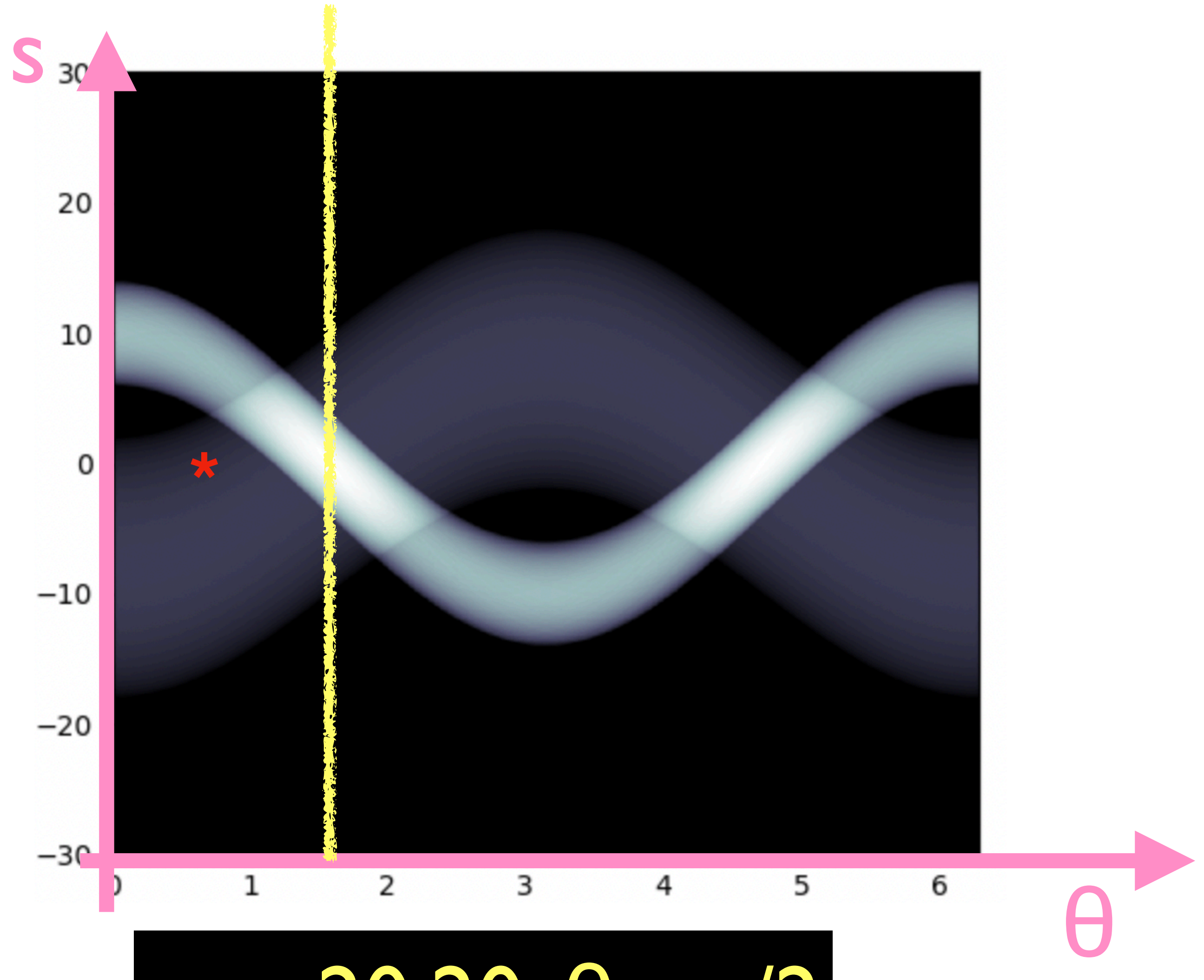
- samtliga linjer i xy-plan kan beskrivas med hjälp av parametrar s och θ
- om θ behölls konstant, så får man alla parallella linjer när s varieras
- om s behölls konstant så får man alla linjer som tangerar en cirkel när θ varieras
- $p(s_n,\theta_n)$ betecknar integralen av objektet längs linjen som bestäms av s_n samt θ_n (den röda i figuren)
- p(s,0°) betecknar projektionen vid θ = 0°, p(s,30°) projektionen vid 30° (det är det som detektor mäter vid 0° respektive 30°)
- **p(s, θ), dvs samtliga projektioner vid alla vinklar, kallas sinogram.**

i | i sinogrammet får vi en projektion längs vinkeln θ= π/2

i * i sinogrammet får vi summan av attenuering längs linjen s = 0, θ= π/4

s = 0, θ= π/4

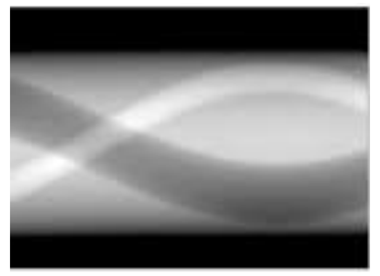




s = -20:20, θ= π/2

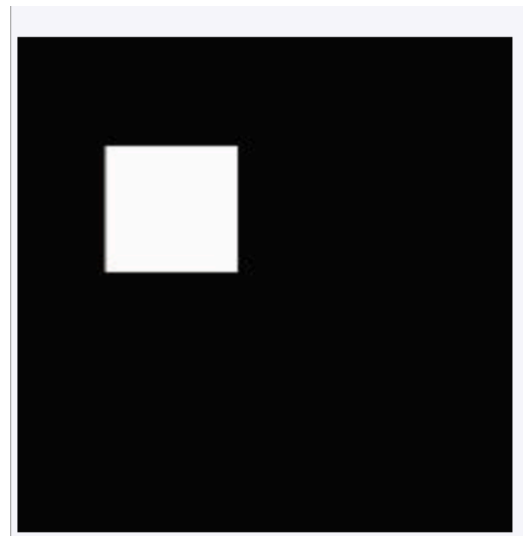
CT: "rekonstruera" objekt från projektioner

objekt

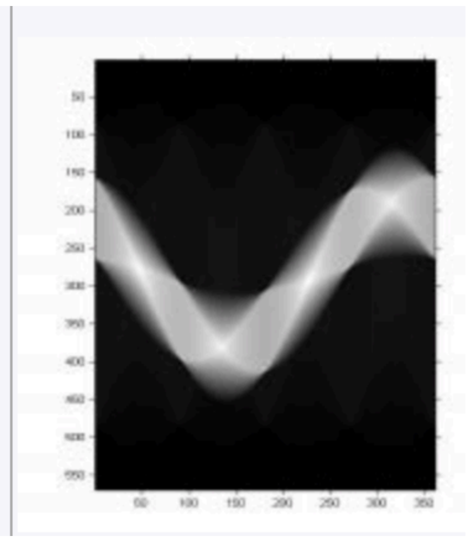


sinogram

Johann Radon, 1917:
… *an image of an unknown object could be produced if one had an infinite number of projections through the object.*



objekt

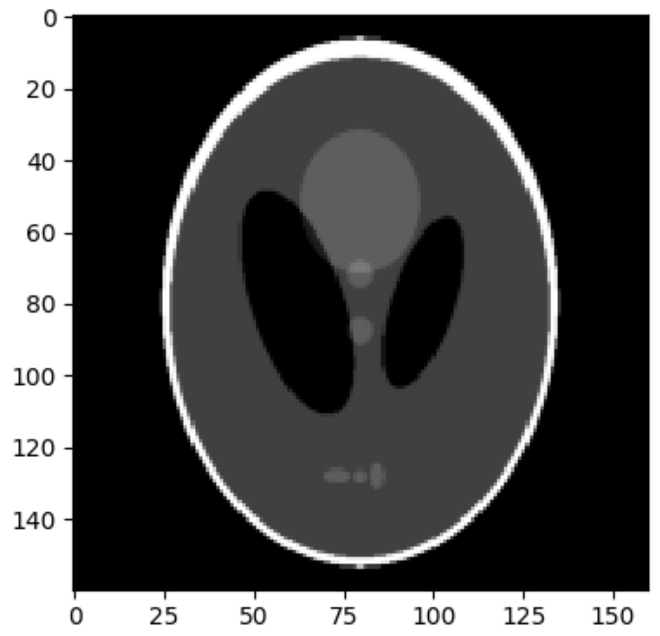


sinogram

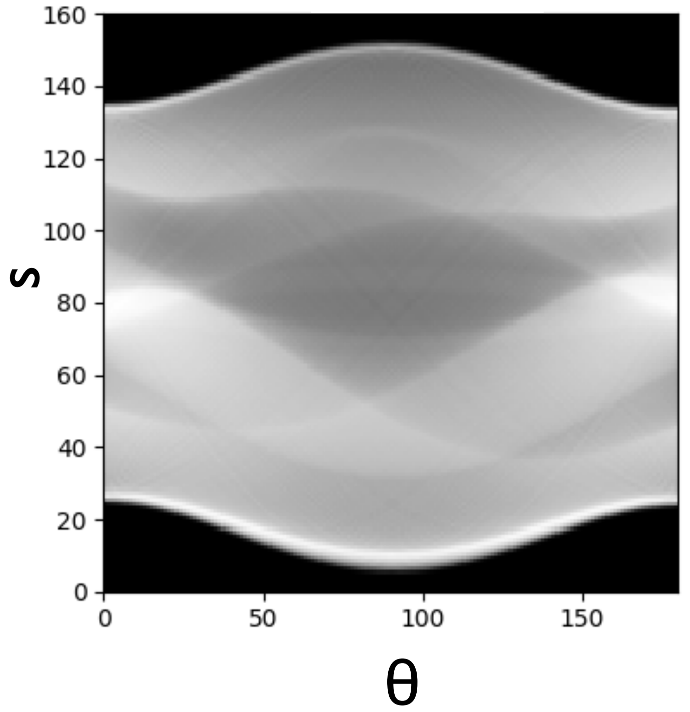
Informationen i sinogram är tillräcklig (egentligen samma) för att beräkna bilder

(Om ni vill veta hur man gör det, så är ni välkomna att läsa kursen:
3D Image Reconstruction and Analysis in Medicine (HL2027) på masternivå)

objek

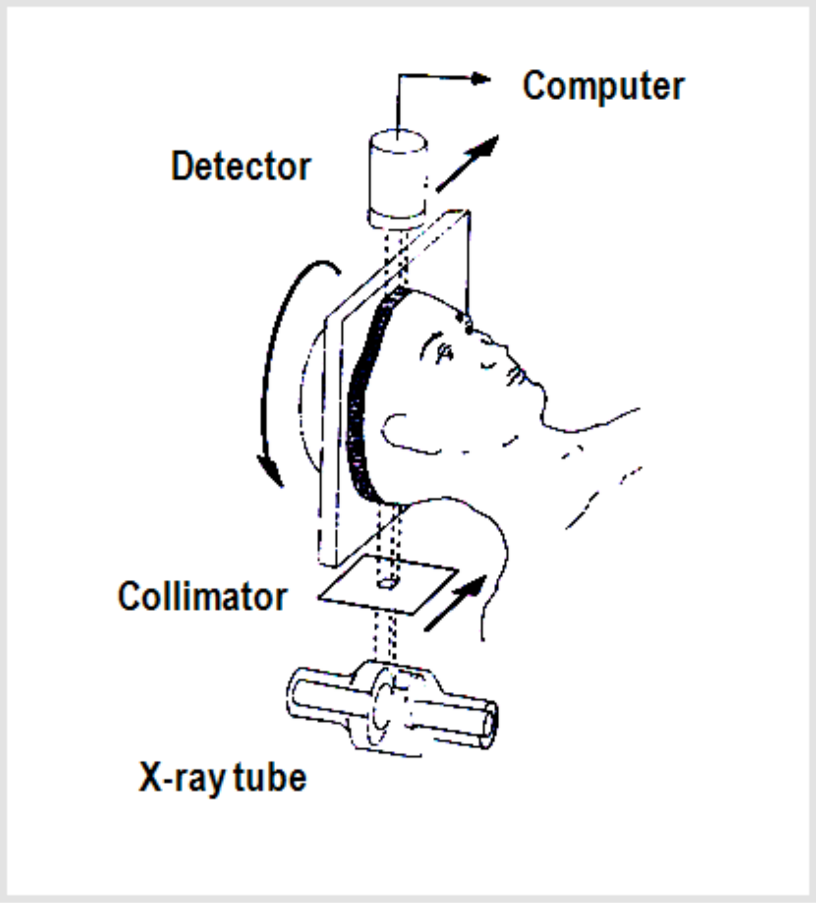


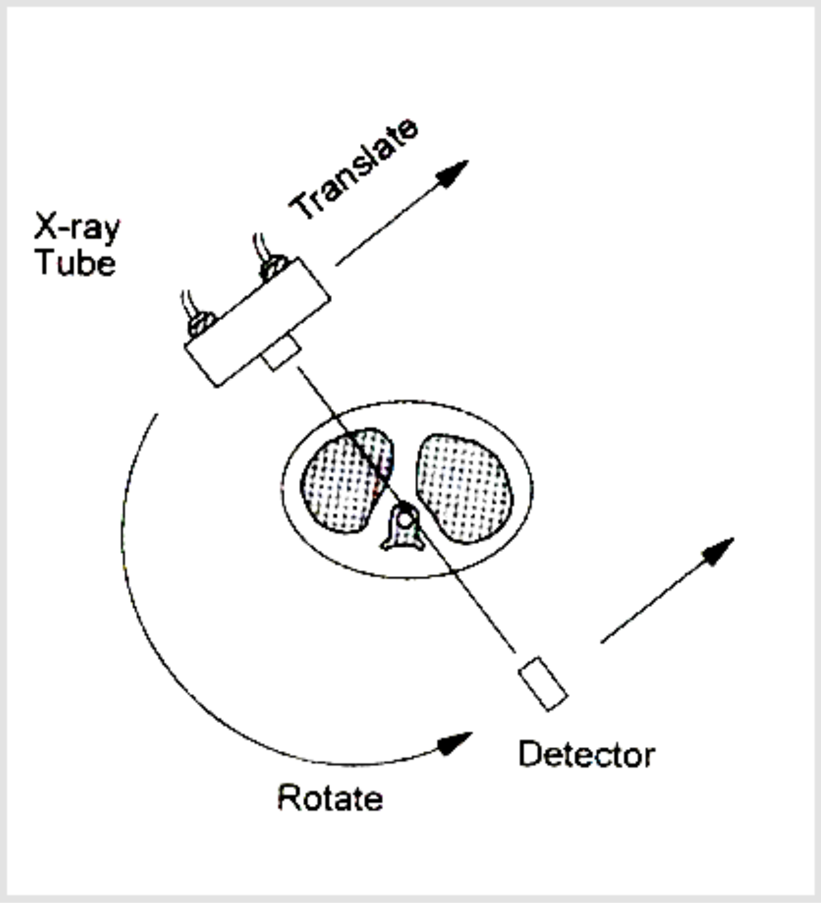
sinogram



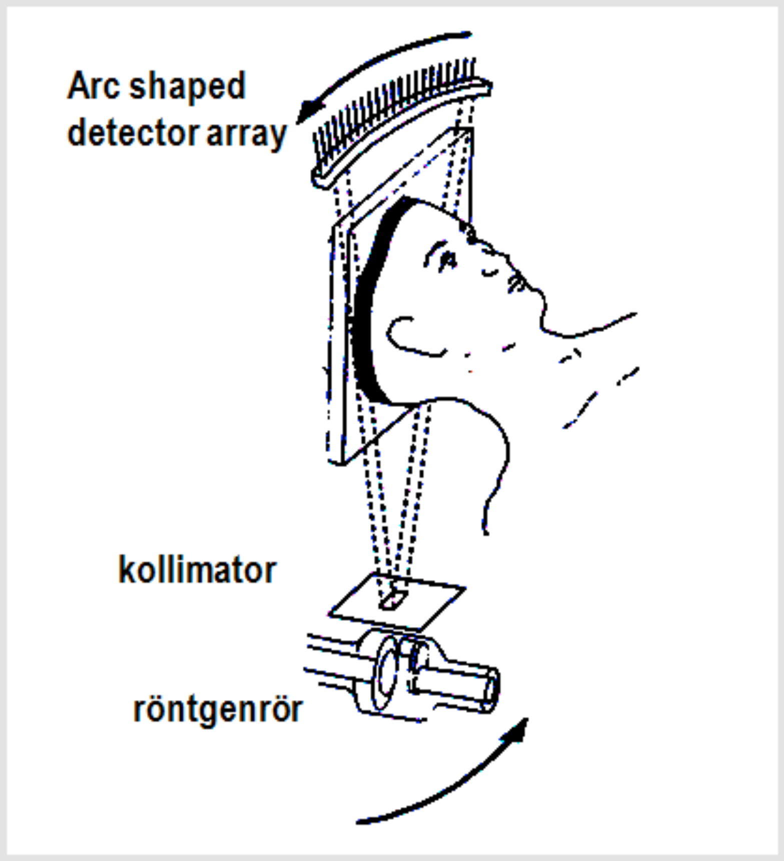
CT: acquisition geometries

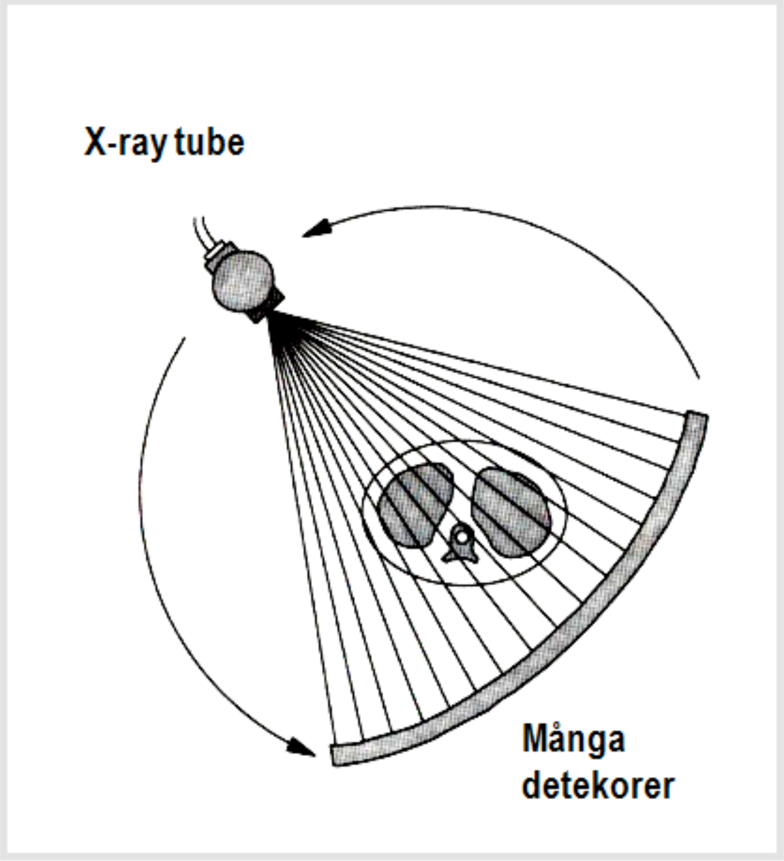
1rsta generation: translate-rotate





3dje generation: fan-beam

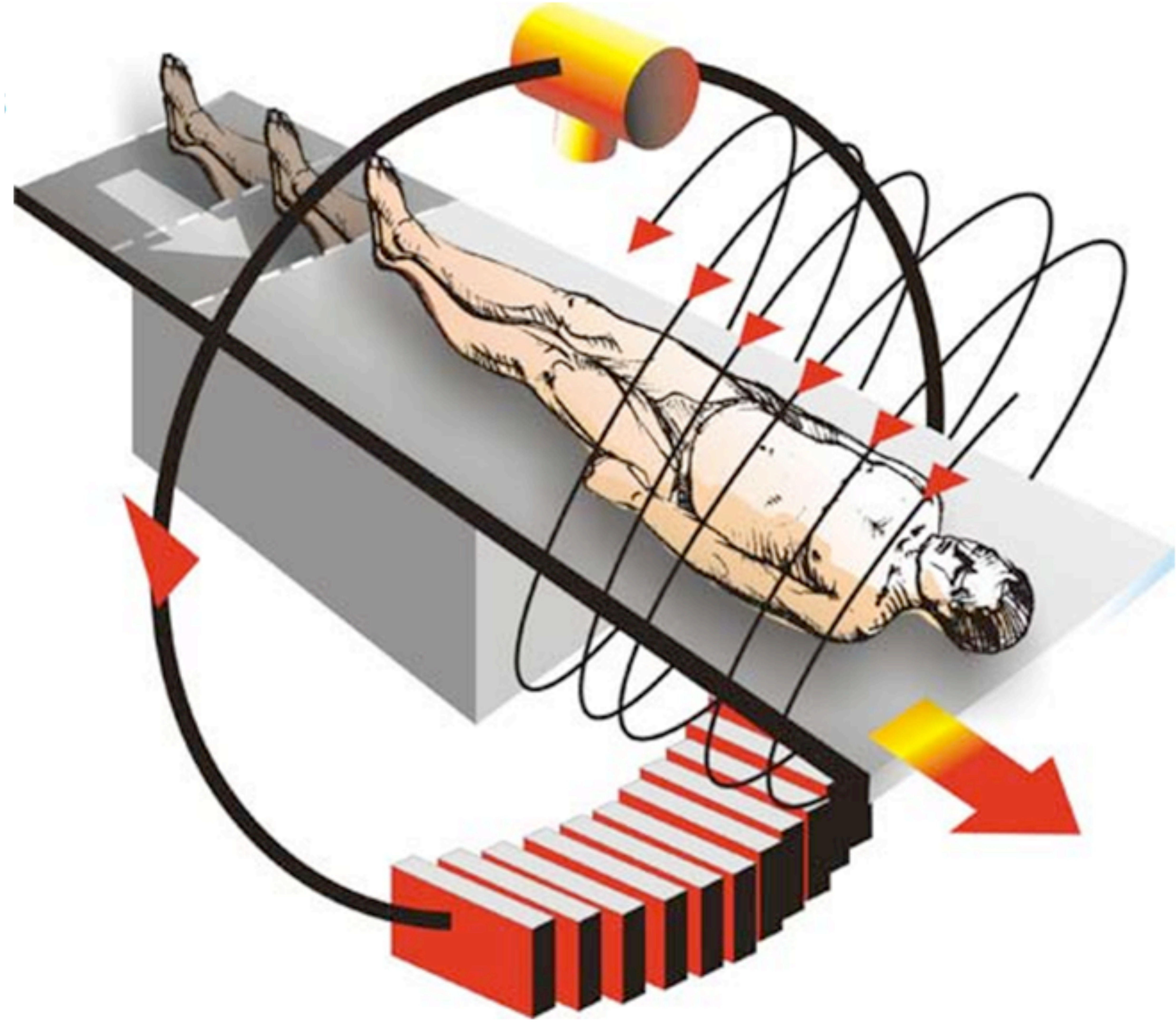




Mycket snabbare
MEN Comptonspridda fotoner ger signal i detektor!

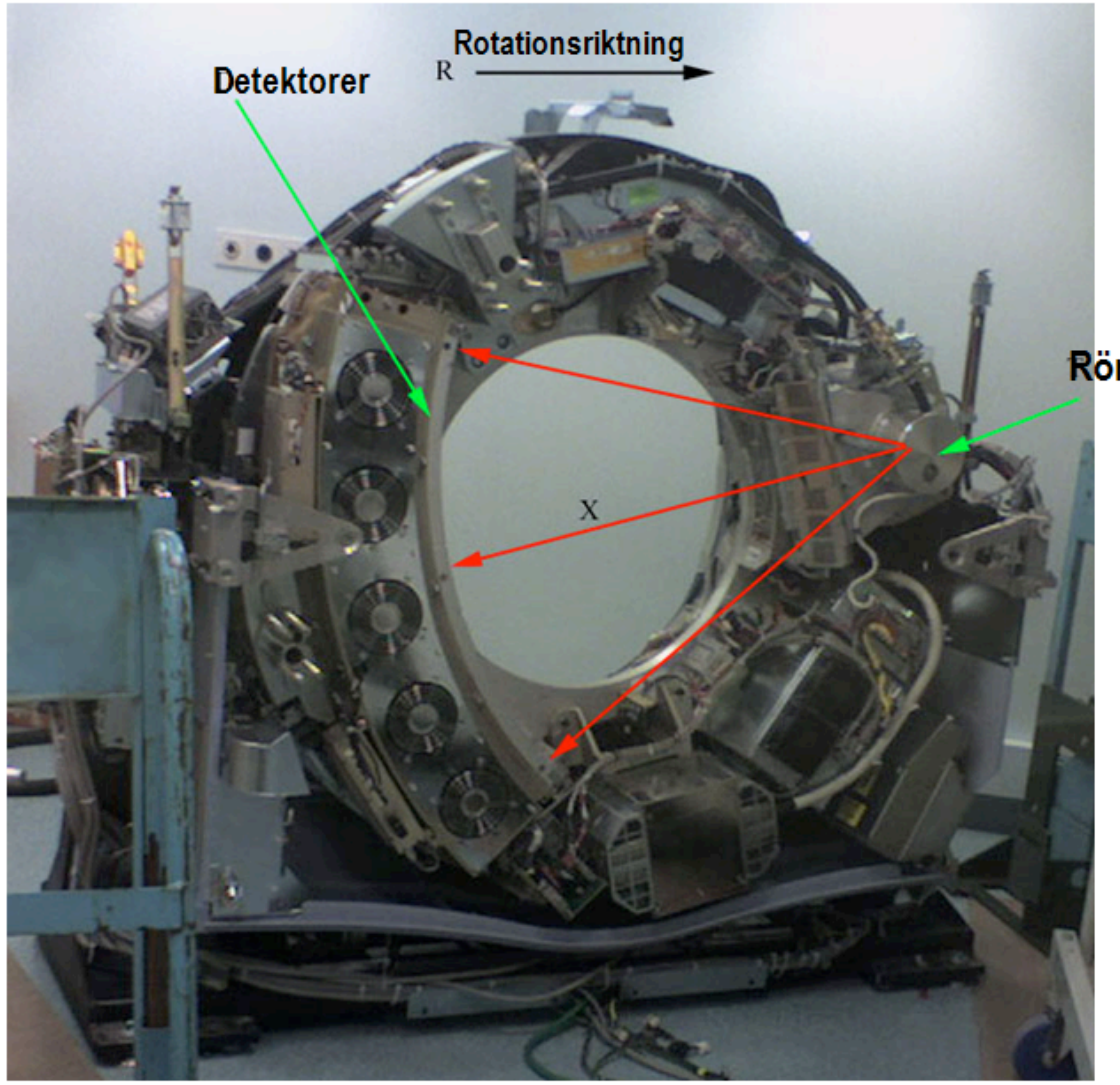
Moderna skanner: Helix (or spiral) CT

Mycket snabbare,
något bökigare rekonstruktion.

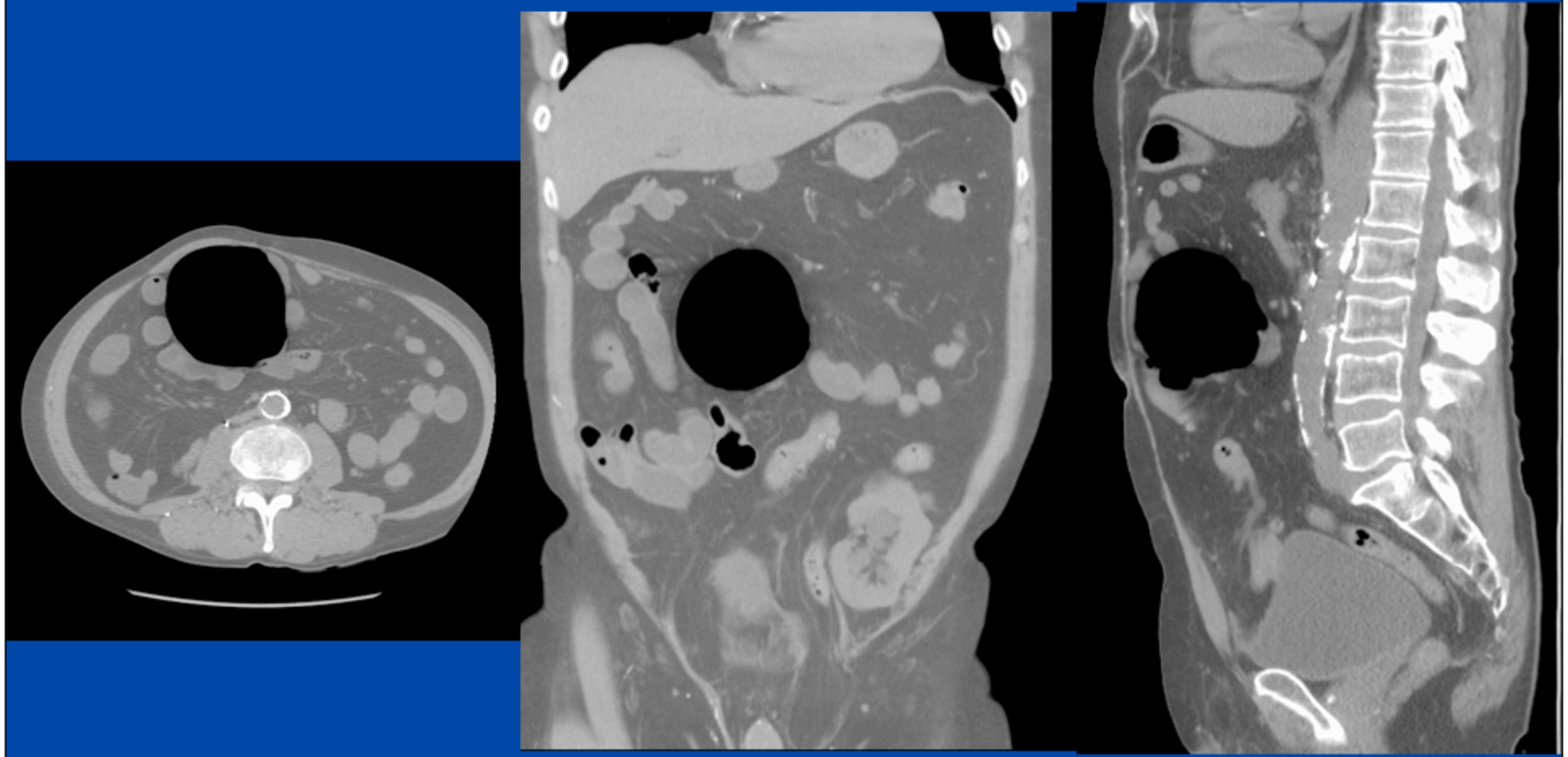


Modern datortomograf

A. Kerek



CT bilder från Danderyds Sjukhus



64 slice CT - samma undersökning av buken, rekonstruerad i tre plan

Övning:

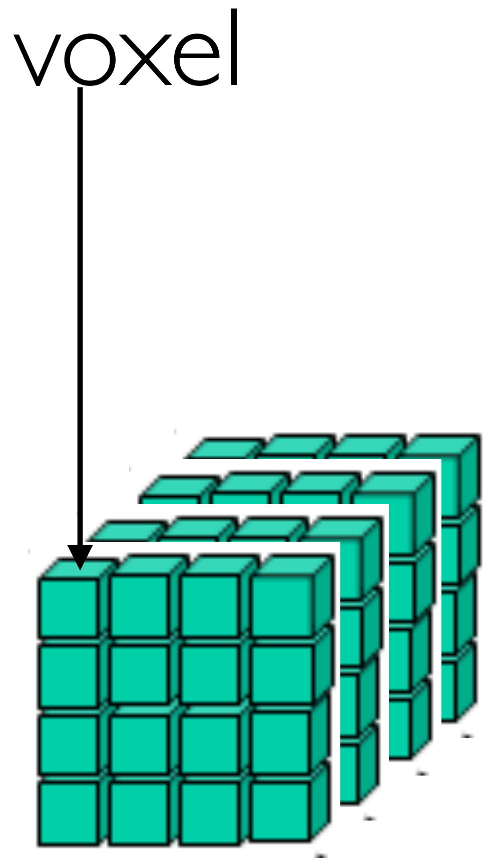
What is a CT image, actually?

1. a 3D-matrix with linear attenuation coefficients (or something related to it) for each voxel of the object

2. a binary file that gives grey levels associated with each voxel of the object

3. a file with coordinates of each voxel so that with the help of a computer the object can be visualised

4. it depends on the manufacturer of the CT-scanner



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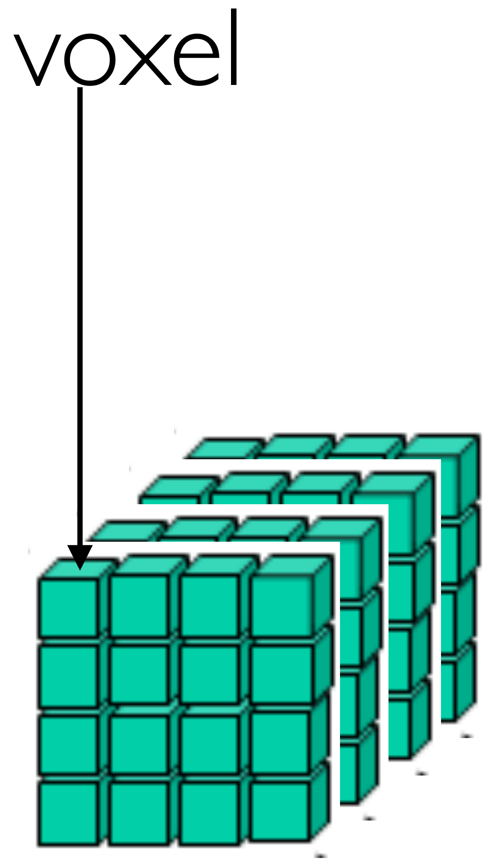
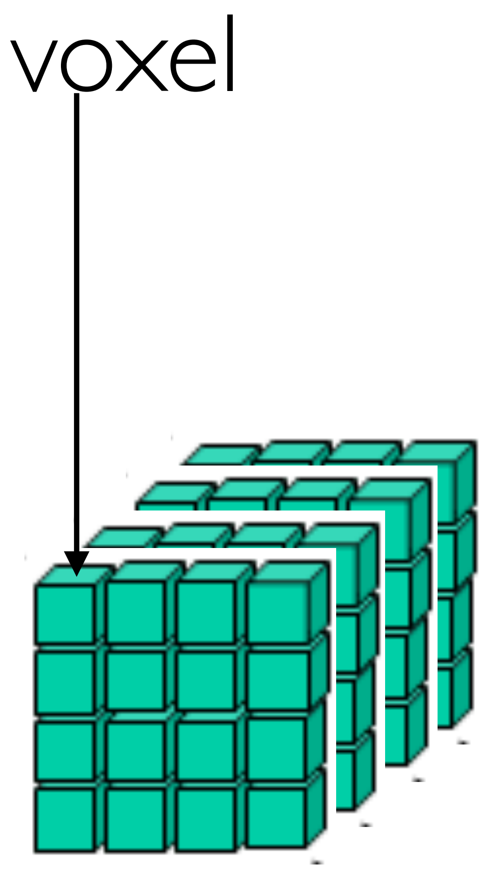


Övning:

Kommer värden i en CT bild bero på kV, mA, akvisitionsgeometri, rekonstruktionsalgoritm, detektors egenskap?

1. Ja

2. Nej



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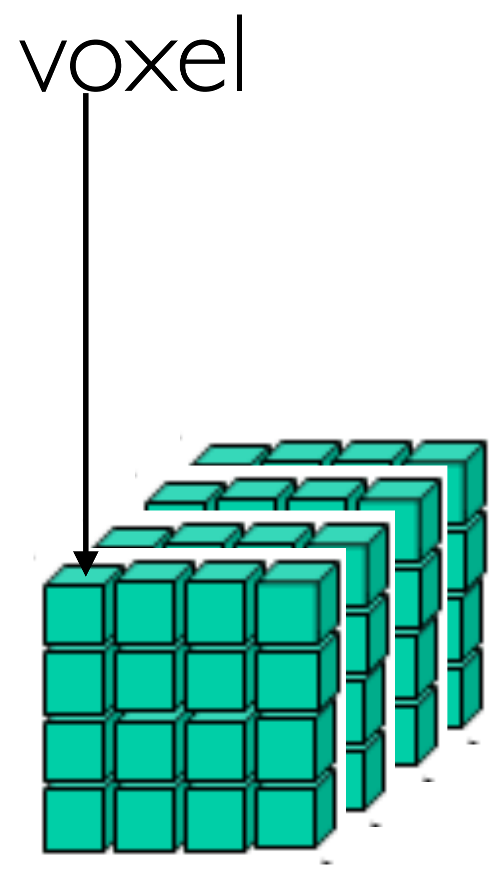
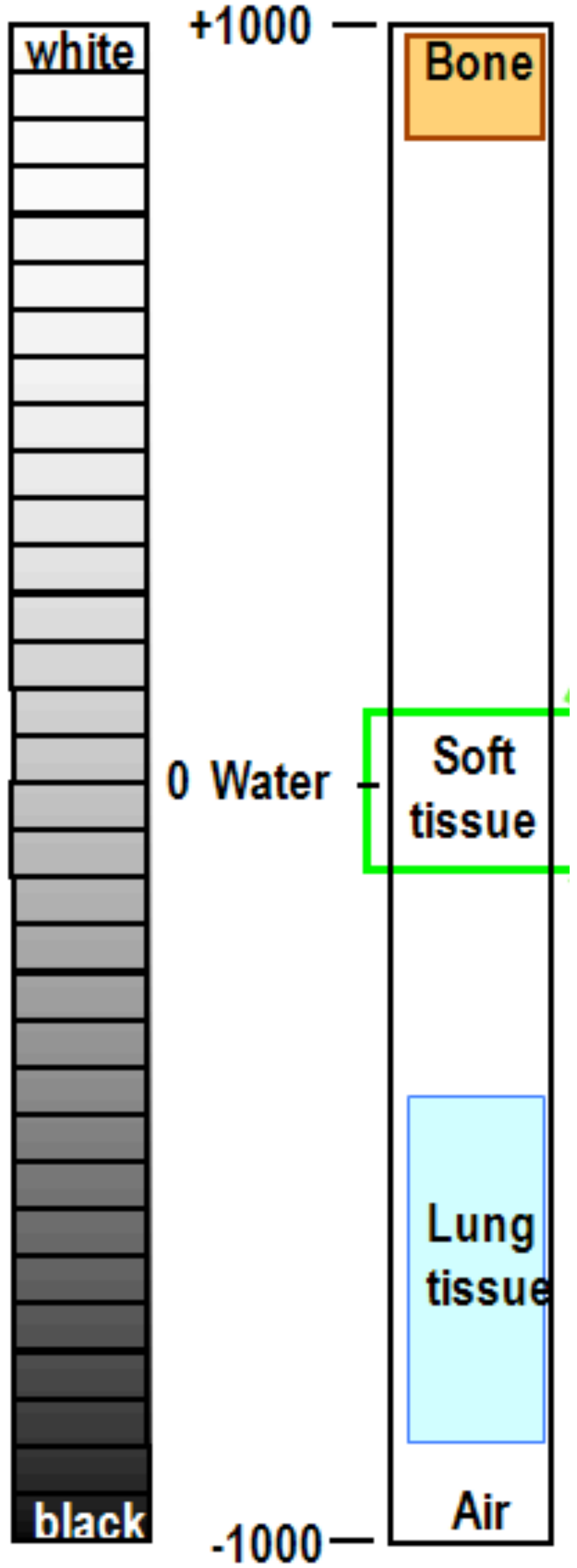


In CT images we use Hounsfield Units (HU) or CT-numbers, which are proportional to the relative attenuation of the tissue compared to water.



- CT number =
$$=1000(\mu_{tissue}-\mu_{water}) / \mu_{water}$$

The CT-number (HU) of something that attenuates x-rays less than water is:

1. between 0 and 1
2. greater than zero
3. lower than zero
4. exactly 1000
5. exactly -1000

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1. between 0 and 1
2. greater than zero
3. lower than zero
4. exactly 1000
5. exactly -1000

Övningar:

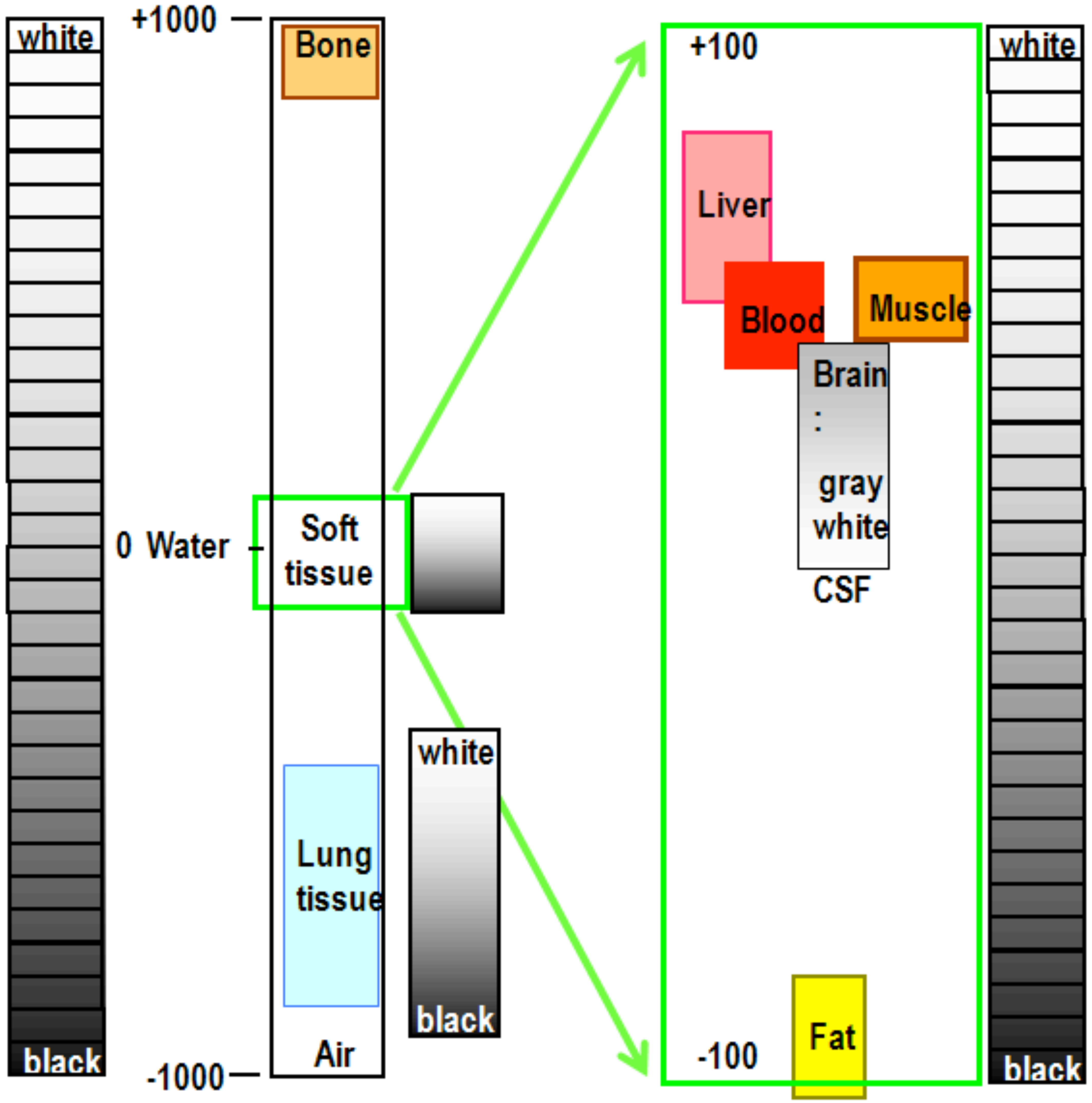
- CT number =
$=1000(\mu_{tissue}-\mu_{water}) / \mu_{water}$

1. The CT-number (HU) depends on the tube voltage:
    1. Less than the linear attenuation coefficient
    2. As much as the linear attenuation coefficient
    3. Much more than the linear attenuation coefficient

   Motivate your answer using equations and/or graphs together with text.

2. Think about the "progression" from simple examples with pencil-beam, monochromatic sources and thin targets to the clinical set up with an x-ray tube and a patient and list all the reasons you can come up with for using HU instead for linear attenuation coefficient in x-ray CT images.

Hounsfield (CT) units and windowing

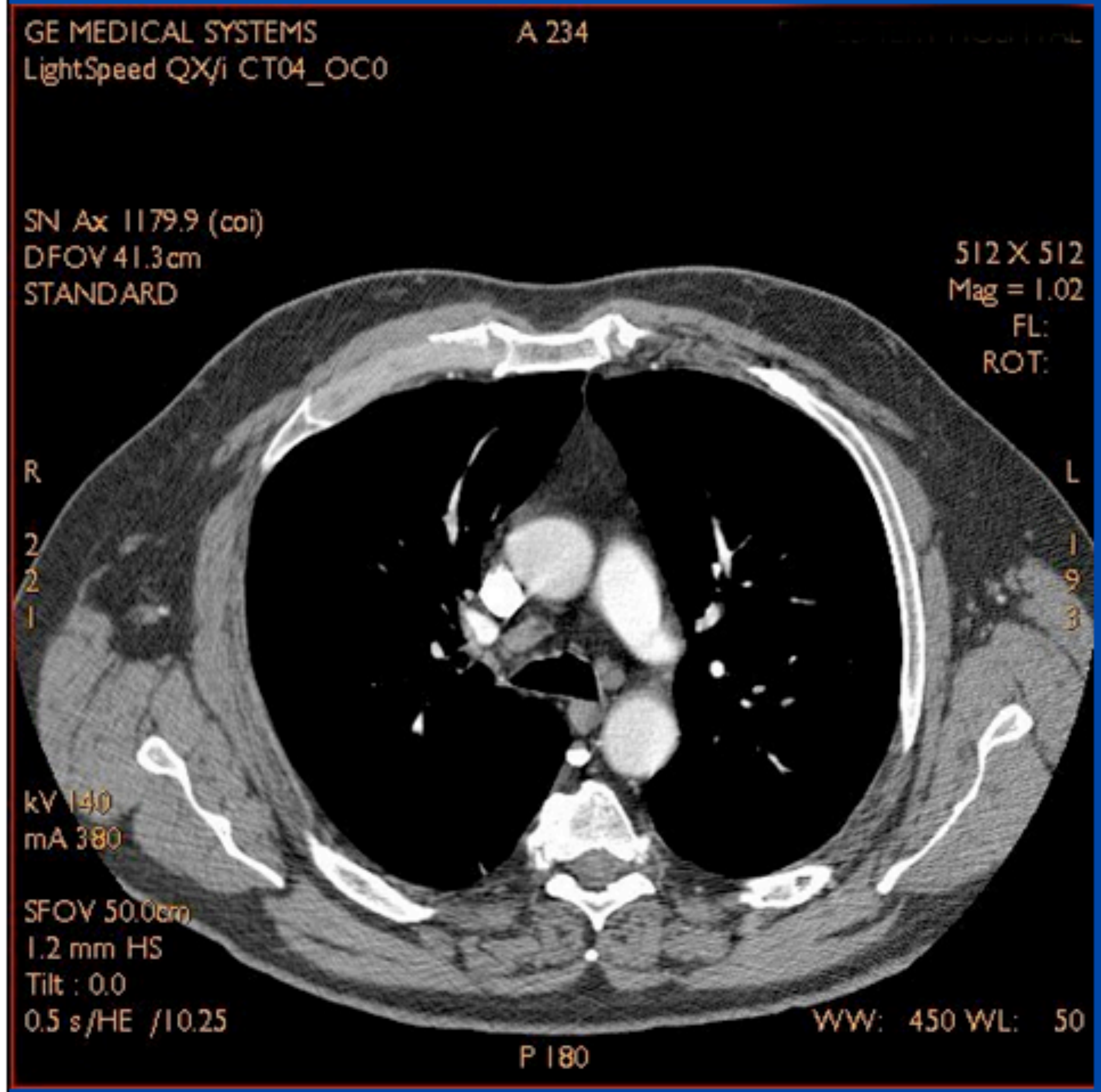


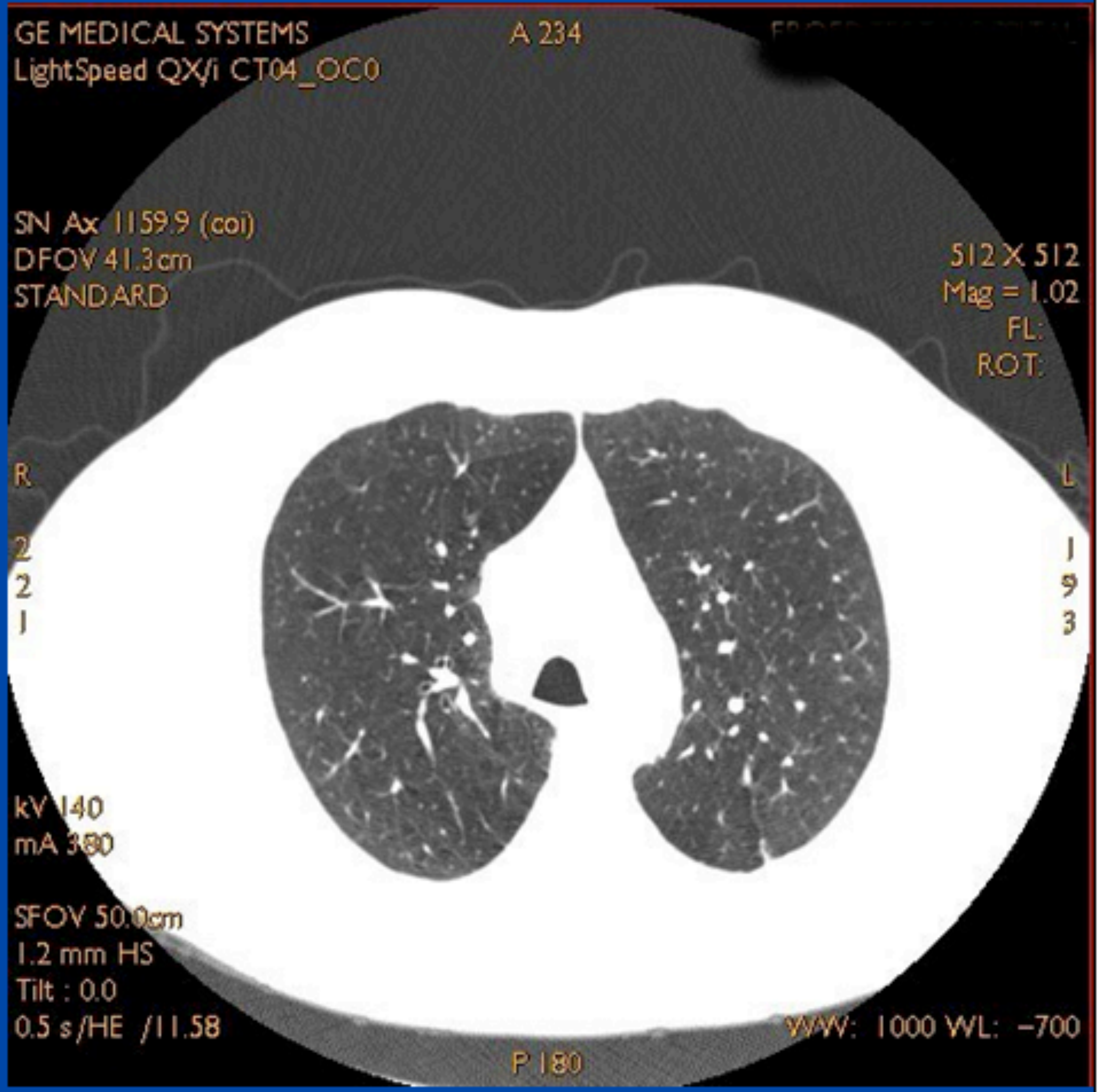
A. Kerek

- CT number = $=1000(\mu_{tissue}-\mu_{water}) / \mu_{water}$

- The human eye is able to distinguish between white and black approx 30 shades (=5 bits)
- The contrast for each pixel of the CT image data is stored with 10-11 bits precision
- Windowing is applied for detailed studies and to enhance the image quality after data acquisition

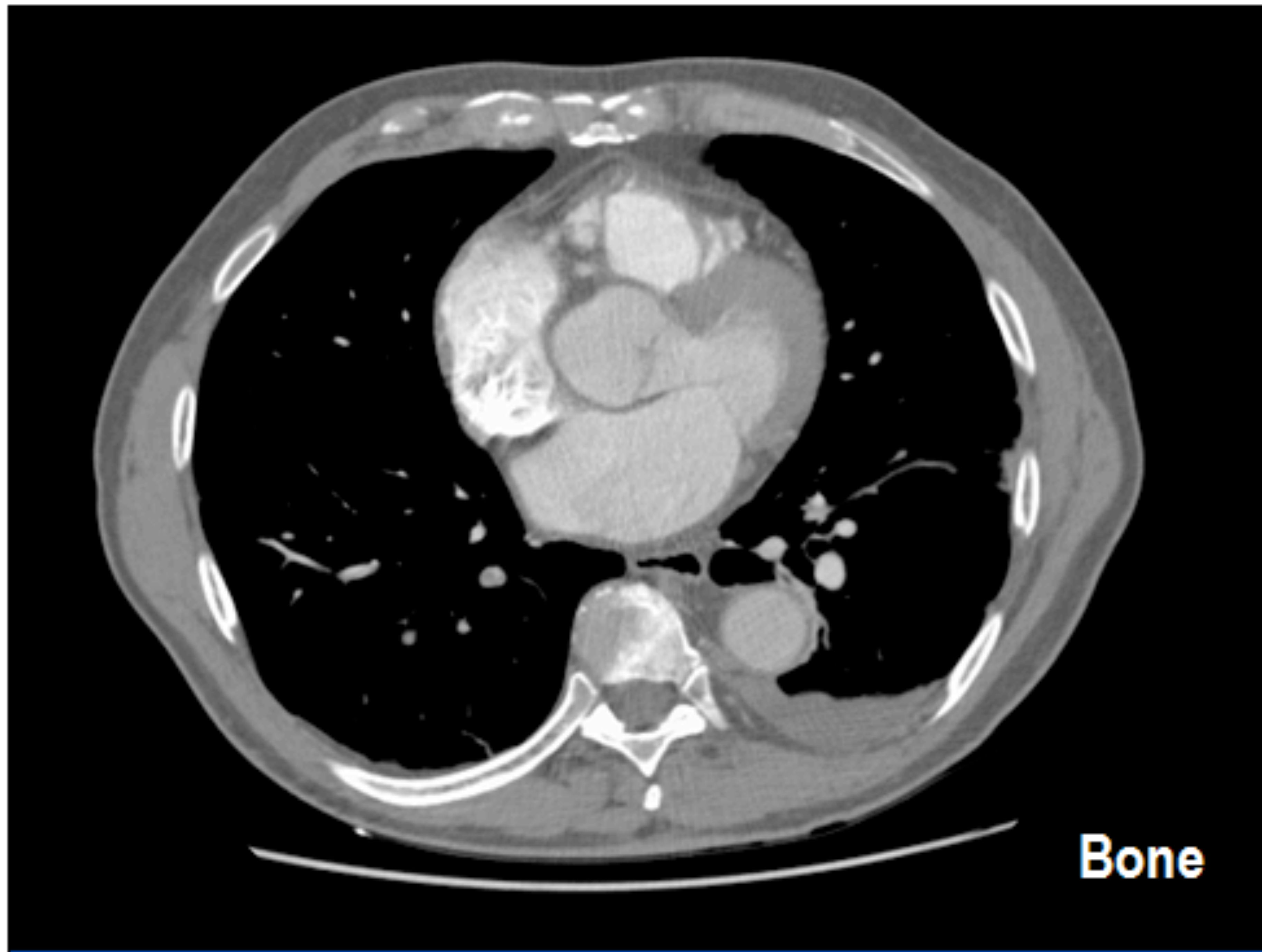
Fönstersättning: 2 snitt genom Thorax

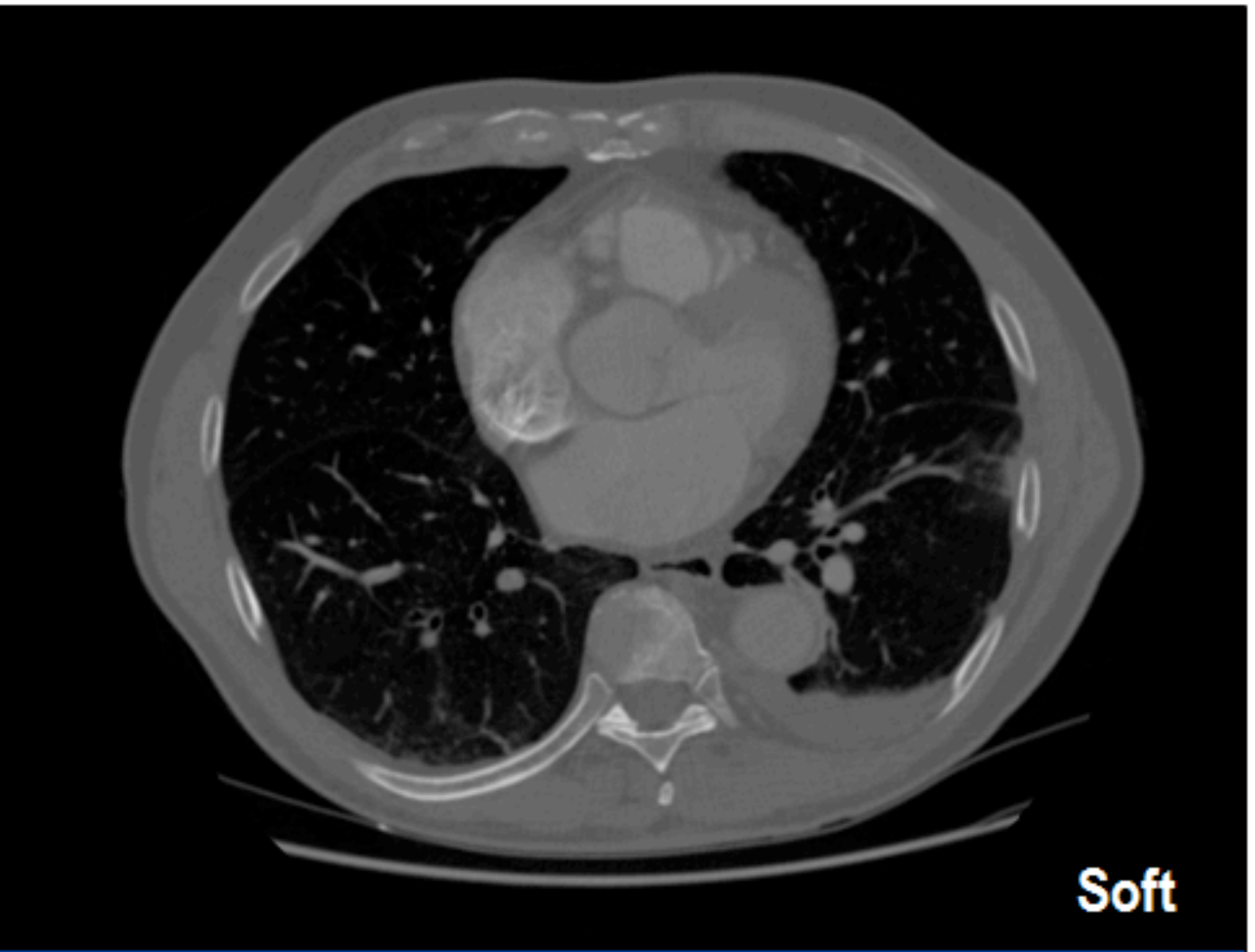


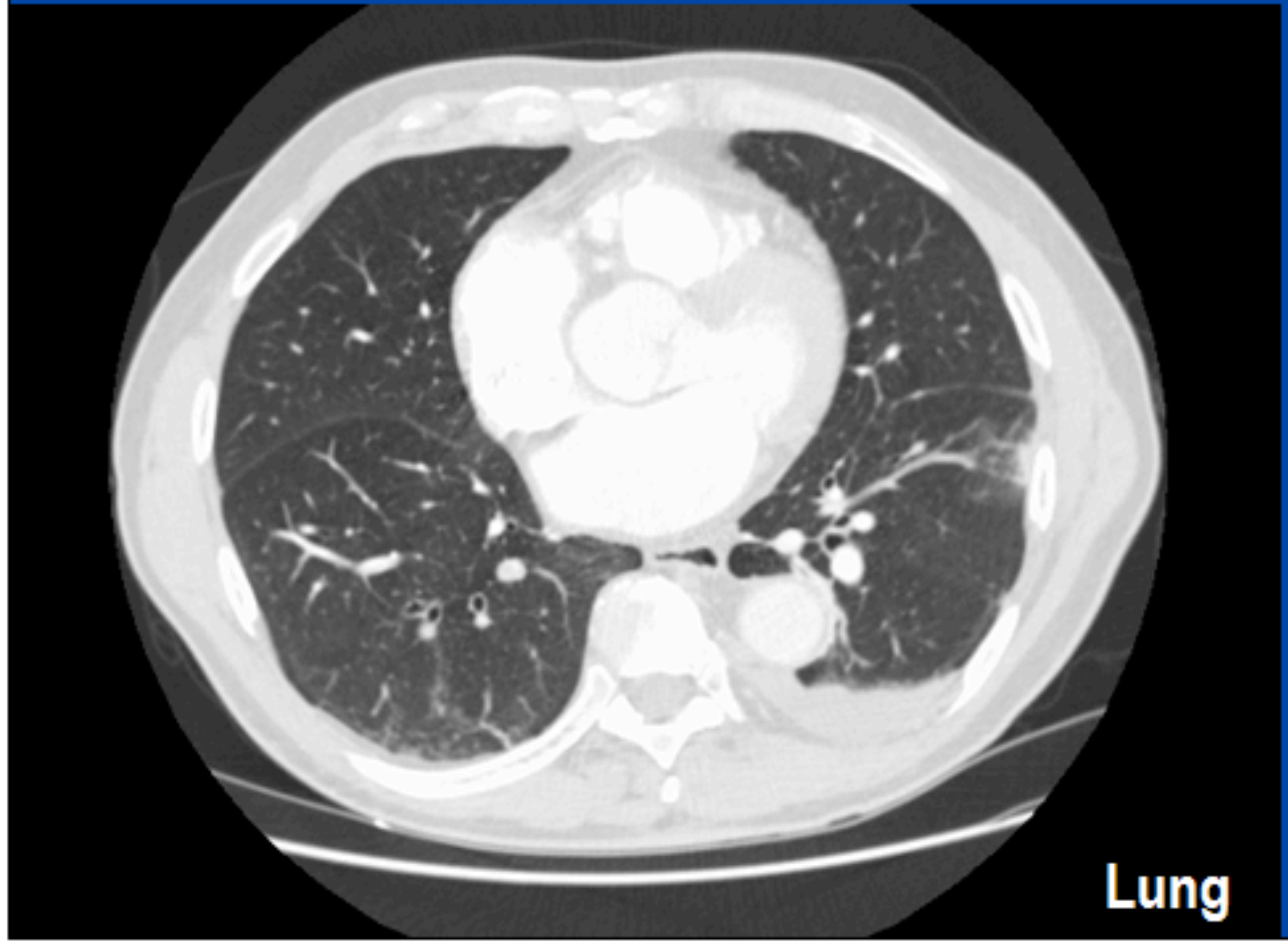


Window Width = 450
Window Level = 50

Window Width = 1000
Window Level = -700



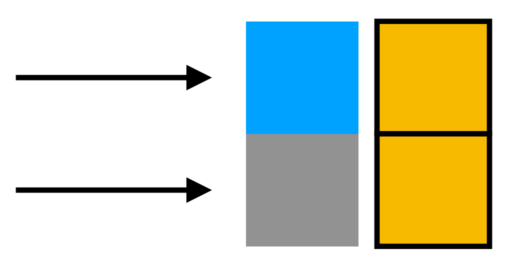




CT bilder från Danderyds Sjukhus

Thorax - Datatomografi med intravenös kontrast med olika fönstersättning (mjukdelar, lungor, ben)

Övning:



Bestäm objektkontrast samt SDNR i följande fall:

1. Vatten och aluminium, 1 cm tjocka, samma antal fotoner in, N_0, med E = 60 keV. Bestäm detta för $N_0 = 10, 10^3, 10^5$. Presentera ditt svar som en 2x3 tabell (objektkontrast och SDNR vs antal fotoner).
2. Samma som ovan, men vatten och aluminium bitar läggs på 0,3 mm bly.
3. Skriv ned det du har lärt dig genom övningen om objektkontrast samt SDNR.

Roligare övning:

Man vill bestämma om ett block post-it lappar innehåller 1000 eller 1001 post-it genom planröntgen. Antag att man använder en energi vid vilken pappers linear attenuation coefficient är 0,1 cm^{-1} och att källan som används strålar 10^5 fotoner/s mot blocket. Bestäm minsta möjliga tiden som krävs. (Du måste göra en uppskattning på tjockleken på en post it).

(Dokumentet kontrastochSDNR.pdf i CANVAS kan vara av hjälp)