



Skandionkliniken:

Hur kommer radiologin in
- Särskilda krav jämfört med
konventionell strålbehandling



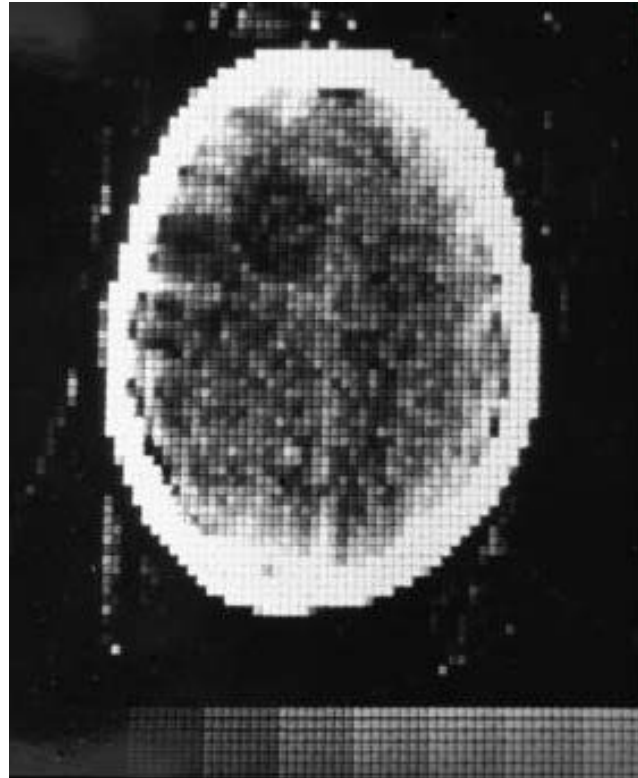
Håkan Nyström
Skandionkliniken, Uppsala



Strålbehandling – mer än ett sekel av kontinuerlig utveckling och framgång



Den verkliga framgången kom med radiologins utveckling



Datortomografi, tidigt 70-tal

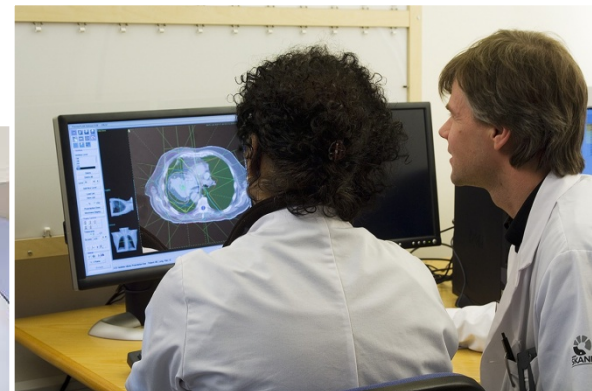
Radioterapiprocessen



CT för dosplanering



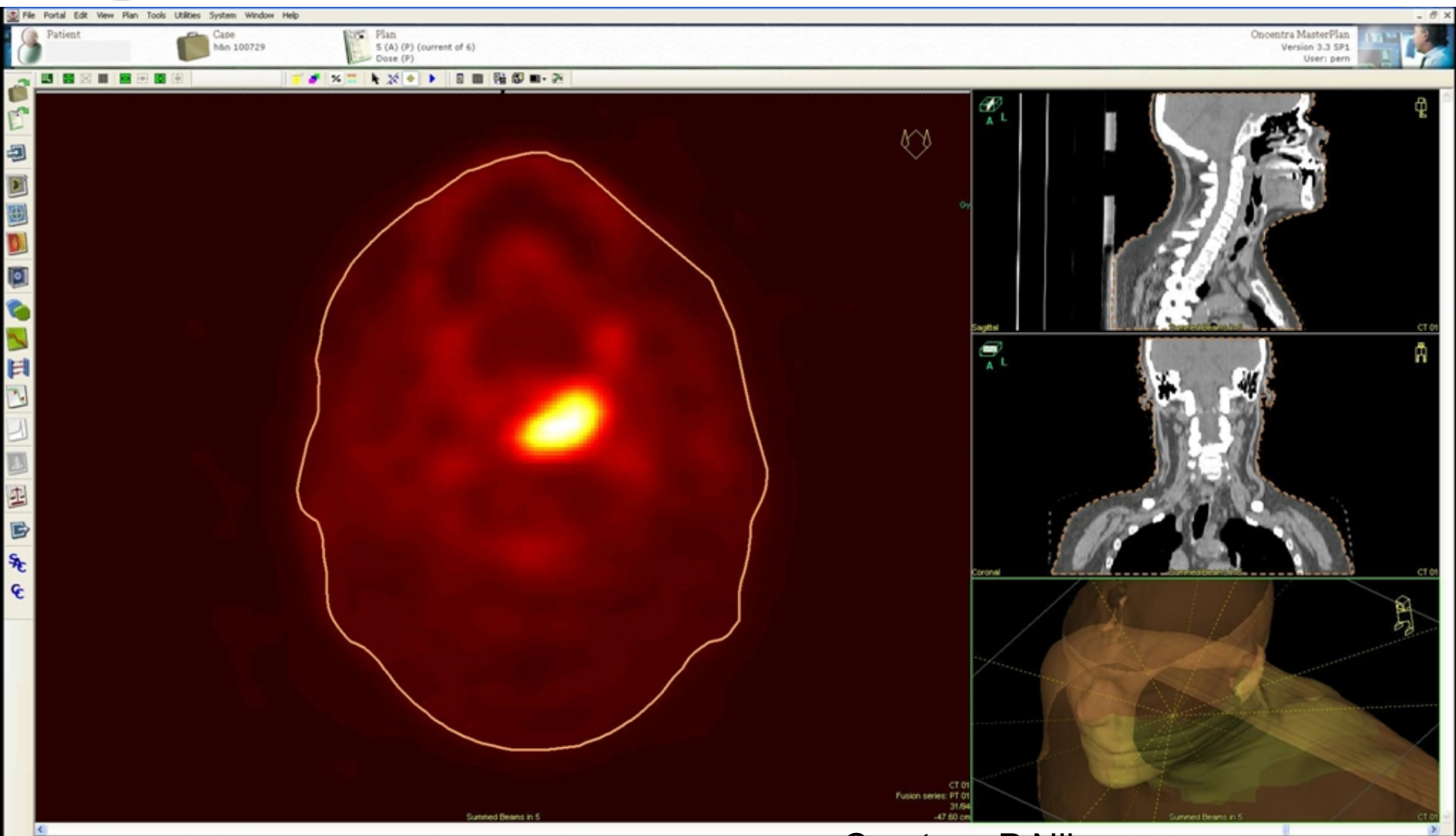
fixation



Inritning av target och riskorgans



F-18 FDG PET



Courtesy P Nilsson

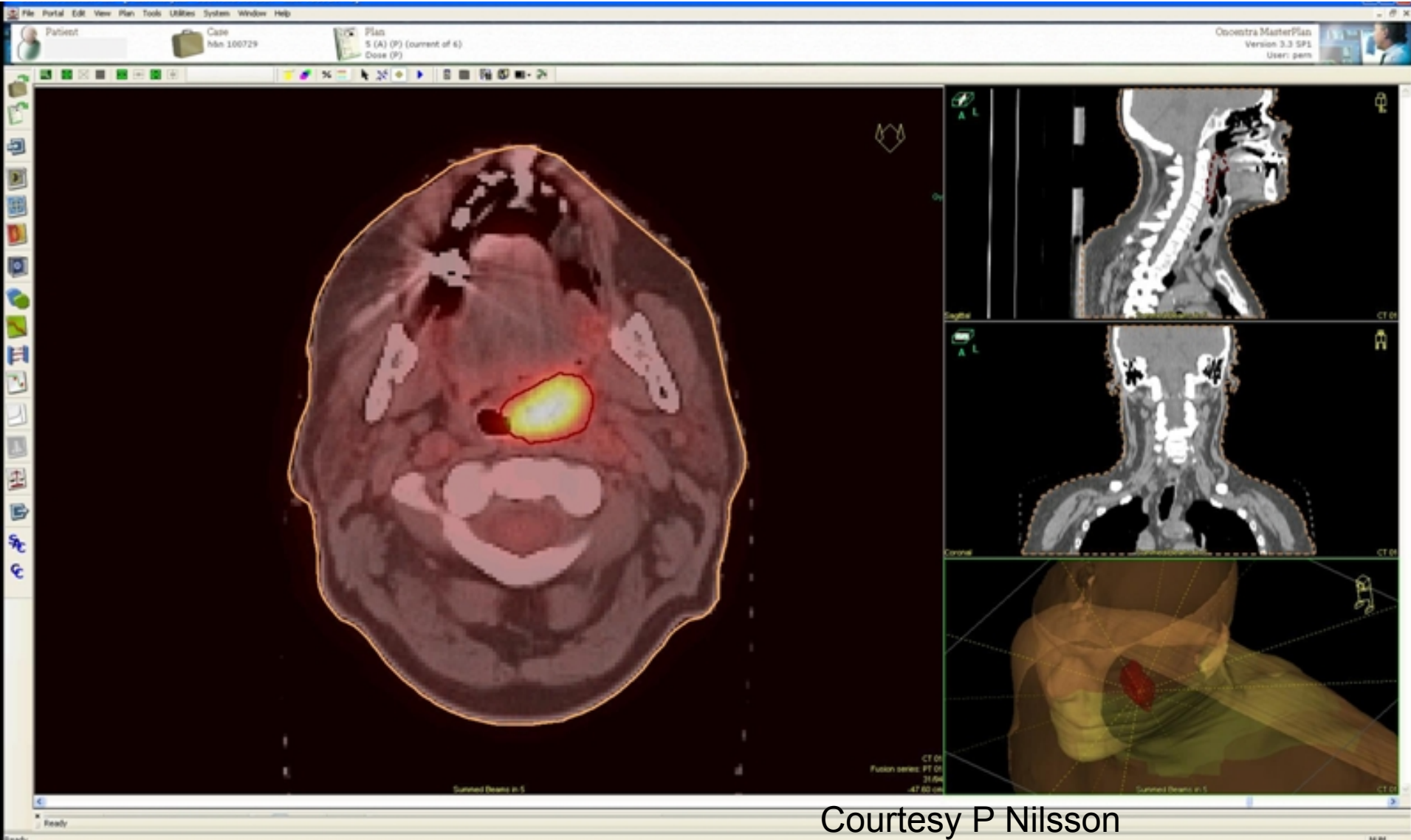


PET-CT

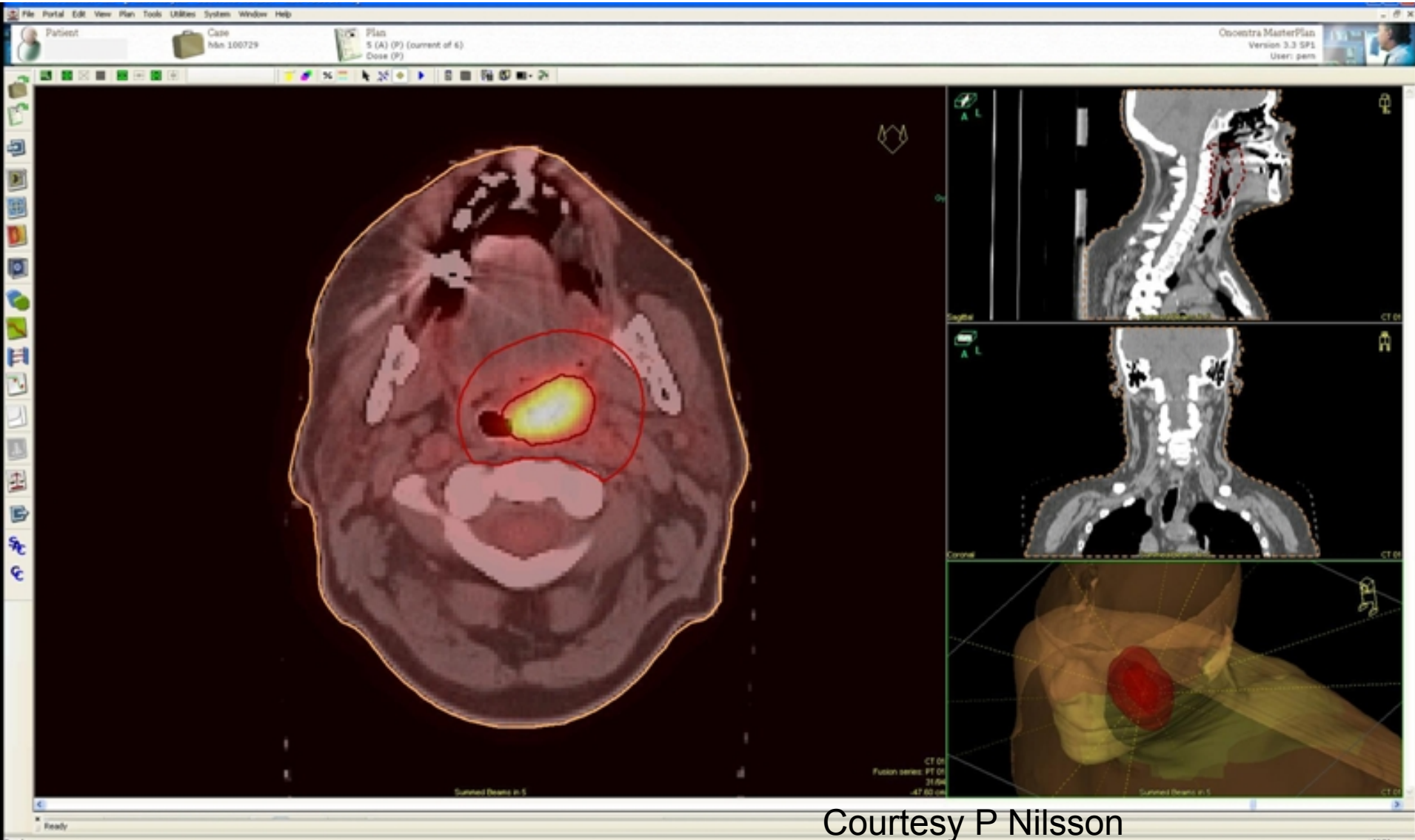


Courtesy P Nilsson

Inritning av targetet med PET-CT

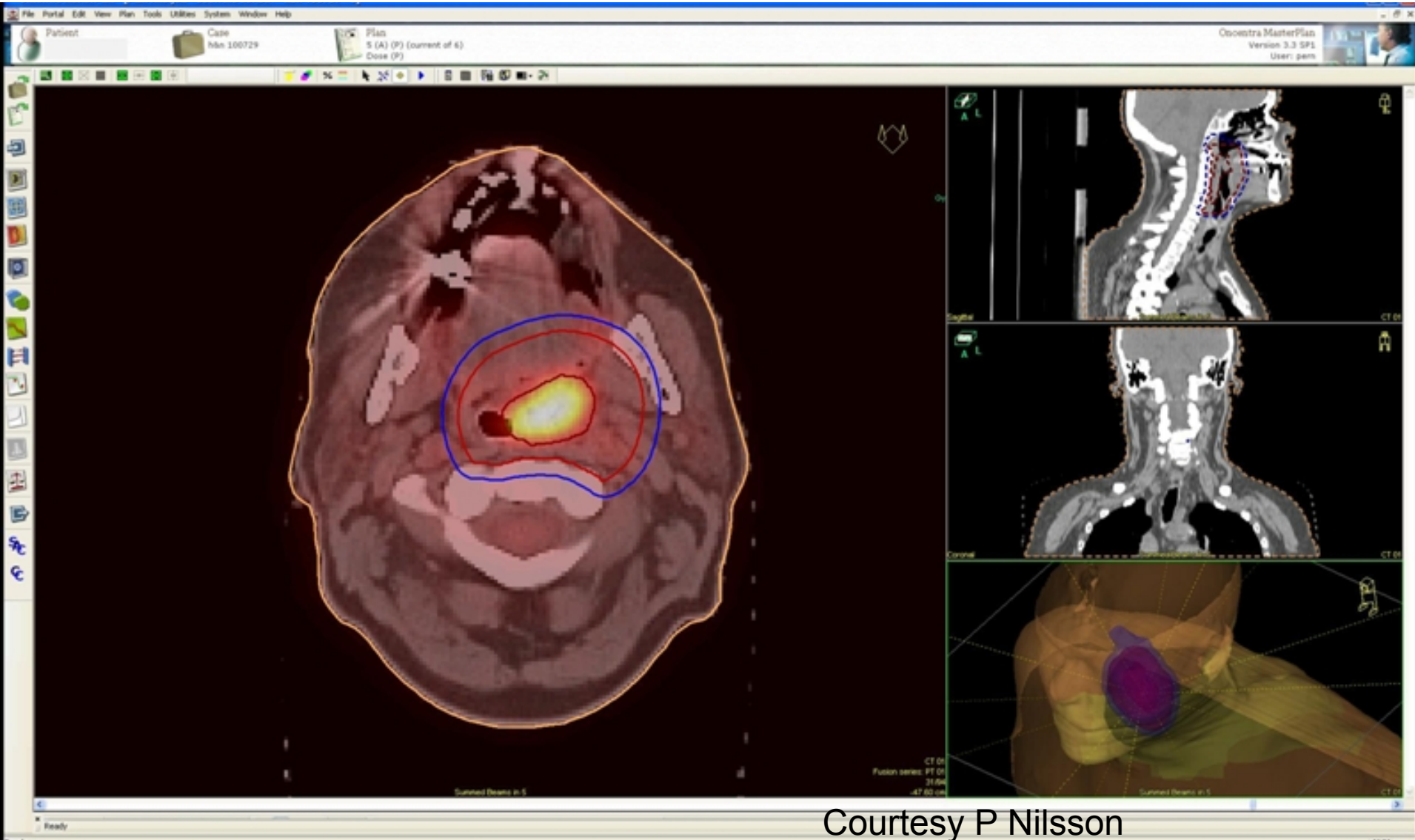


Definition av marginaler

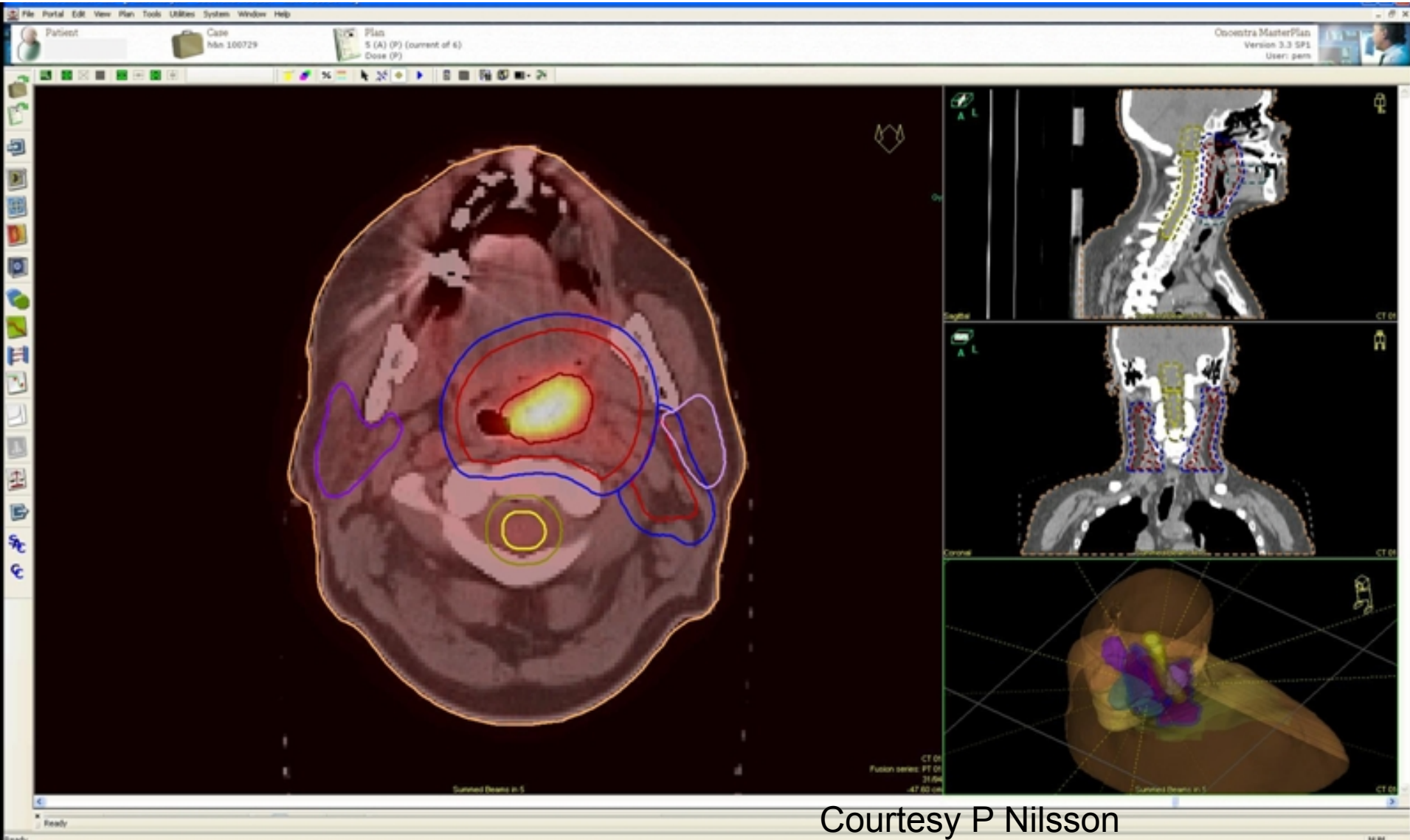


Courtesy P Nilsson

Definition av marginaler



Riskorgan

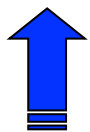


Courtesy P Nilsson

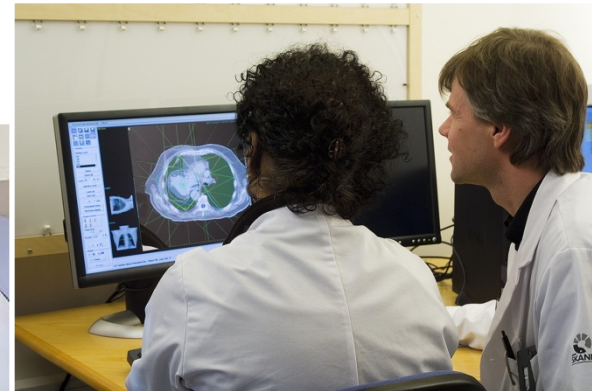
Radioterapiprocessen



CT för dosplanering



fixation



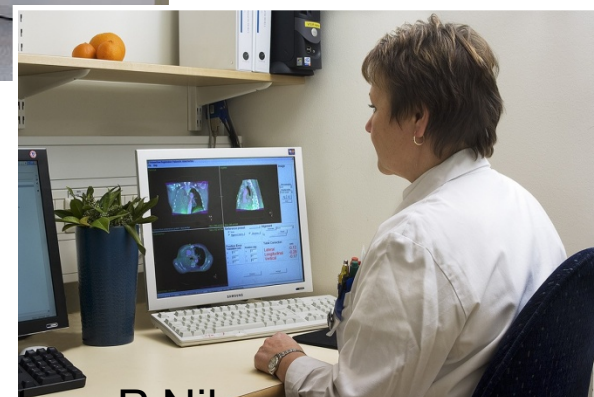
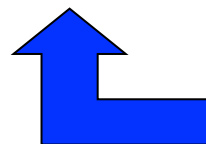
Inritning av target och riskorgans




Verifikation



Behandling



Courtesy P Nilsson



Radiological Use of Fast Protons

ROBERT R. WILSON

Research Laboratory of Physics, Harvard University

Cambridge, Massachusetts

EXCEPT FOR electrons, the particles which have been accelerated to high energies by machines such as cyclotrons or Van de Graaff generators have not been directly used therapeutically. Rather, the neutrons, gamma rays, or artificial

per centimeter of path, or specific ionization, and this varies almost inversely with the energy of the proton. Thus the specific ionization or dose is many times less where the proton enters the tissue at high energy than it is in the last centimeter of the path

Wilson R. *Radiology* 1946 (47) 487-491

Skandionkliniken

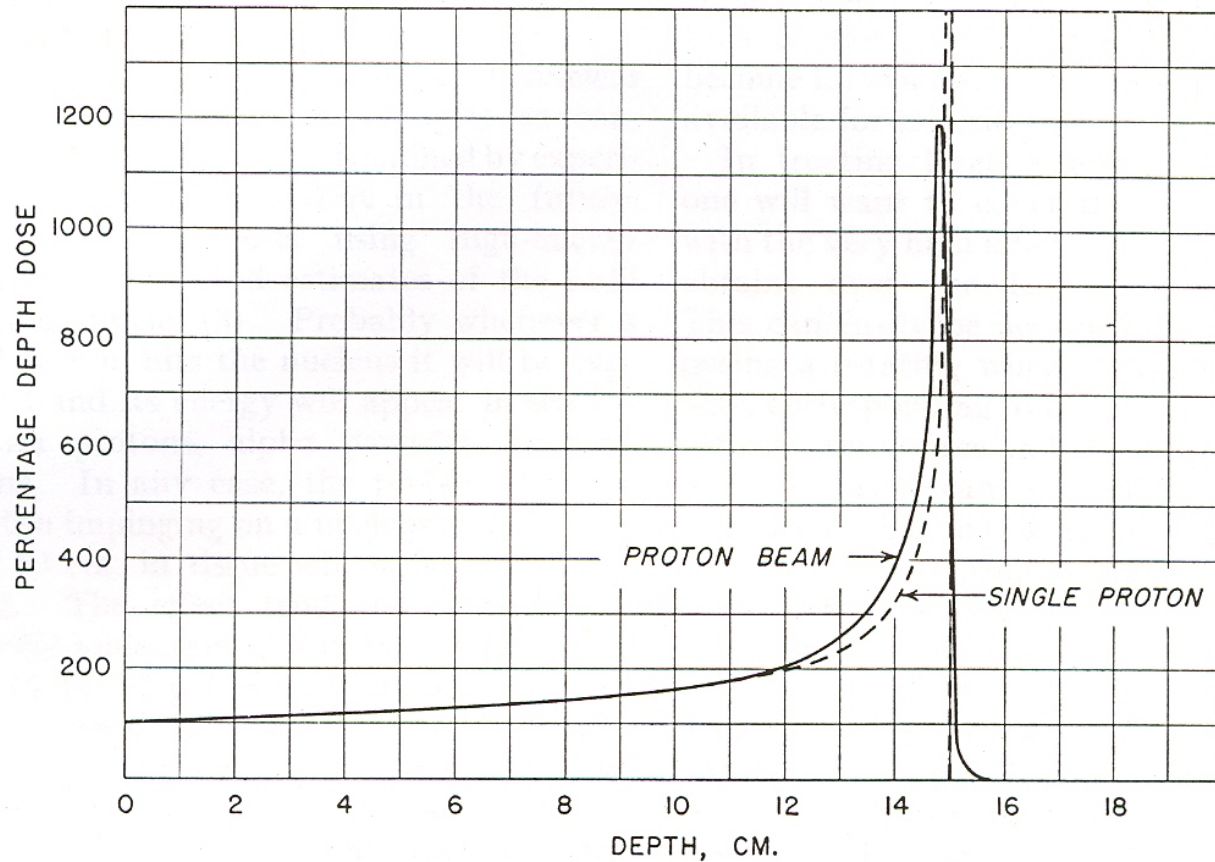


Fig. 2. The dotted curve shows the relative dose due to a single 140 Mev proton. The full curve shows qualitatively the depth dose curve for a beam of 140 Mev protons in tissue.

Wilson R. *Radiology* 1946 (47) 487-491

Skandionkliniken

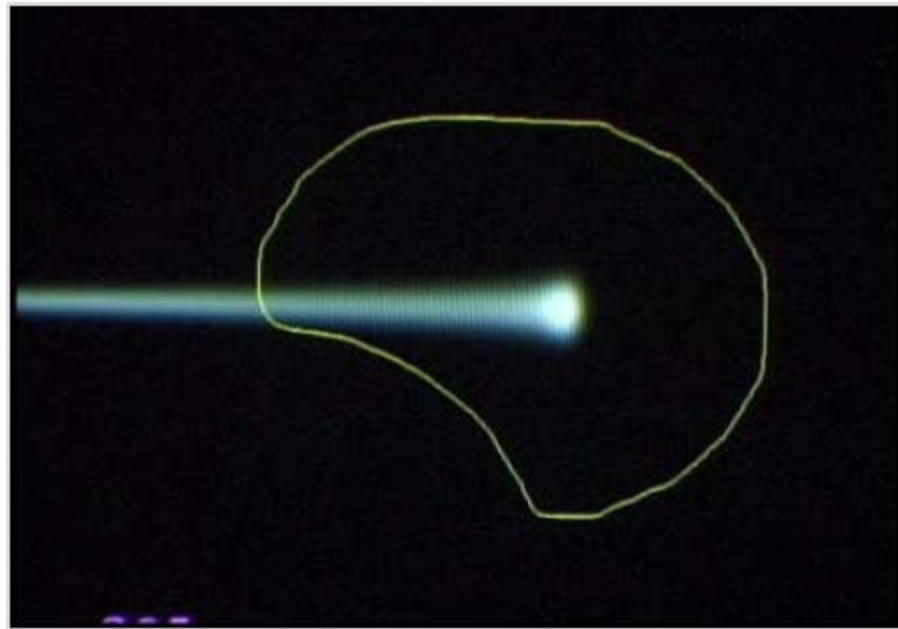
Protoner (och tåg) stannar!





Spot Scanning

En penselstråle

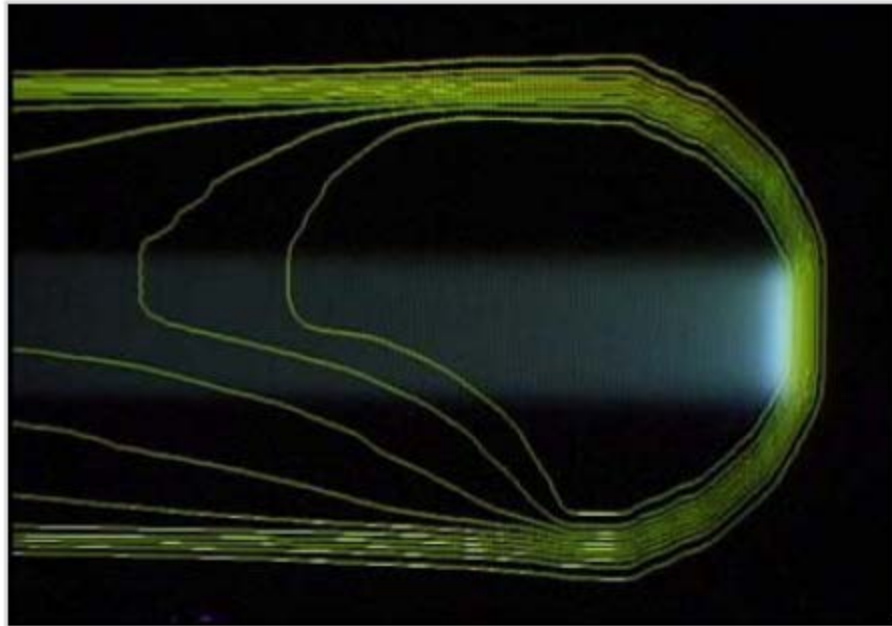


Courtesy A Lomax, PSI



Spot Scanning

Ett "målat" doslager

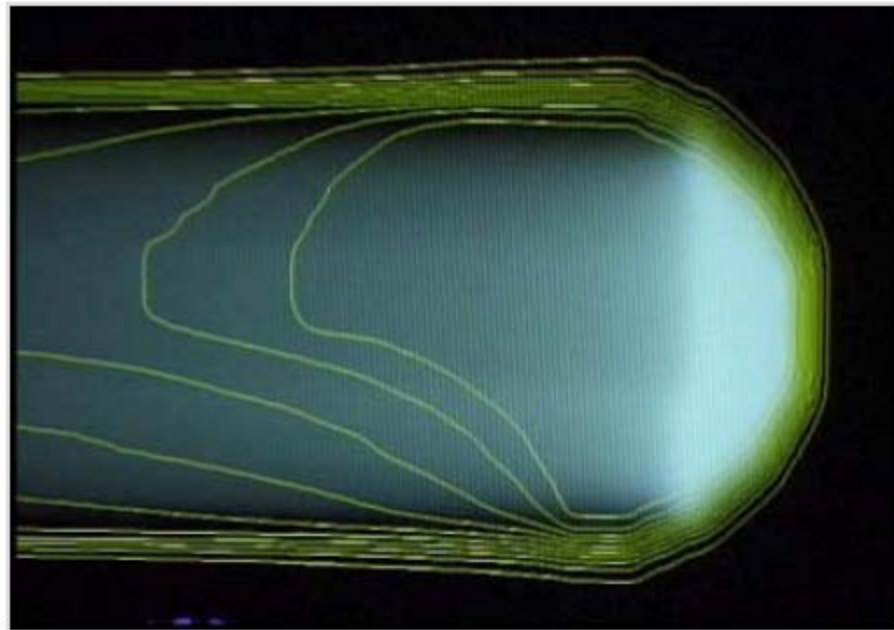


Courtesy A Lomax, PSI



Spot Scanning

Flera "målade" doslager

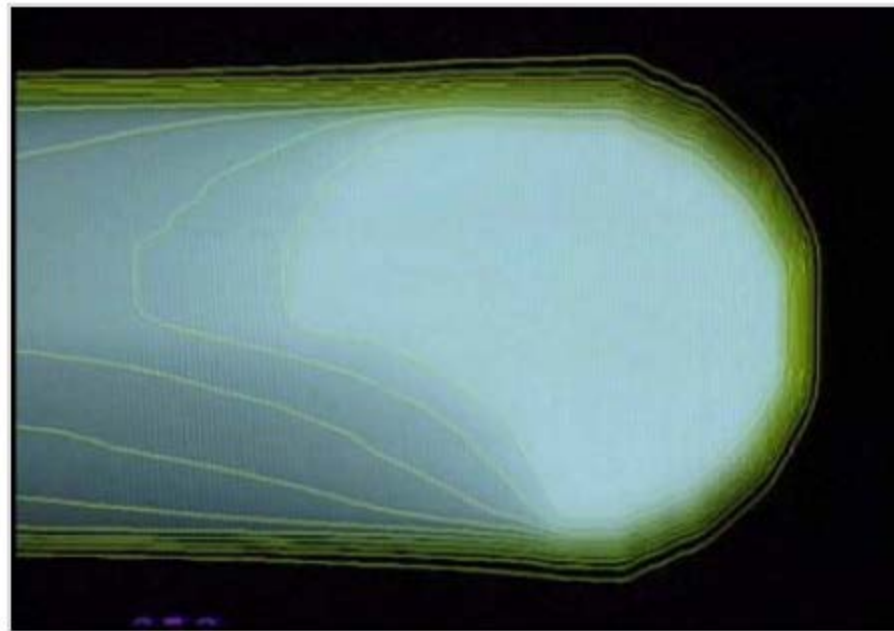


Courtesy A Lomax, PSI



Spot Scanning

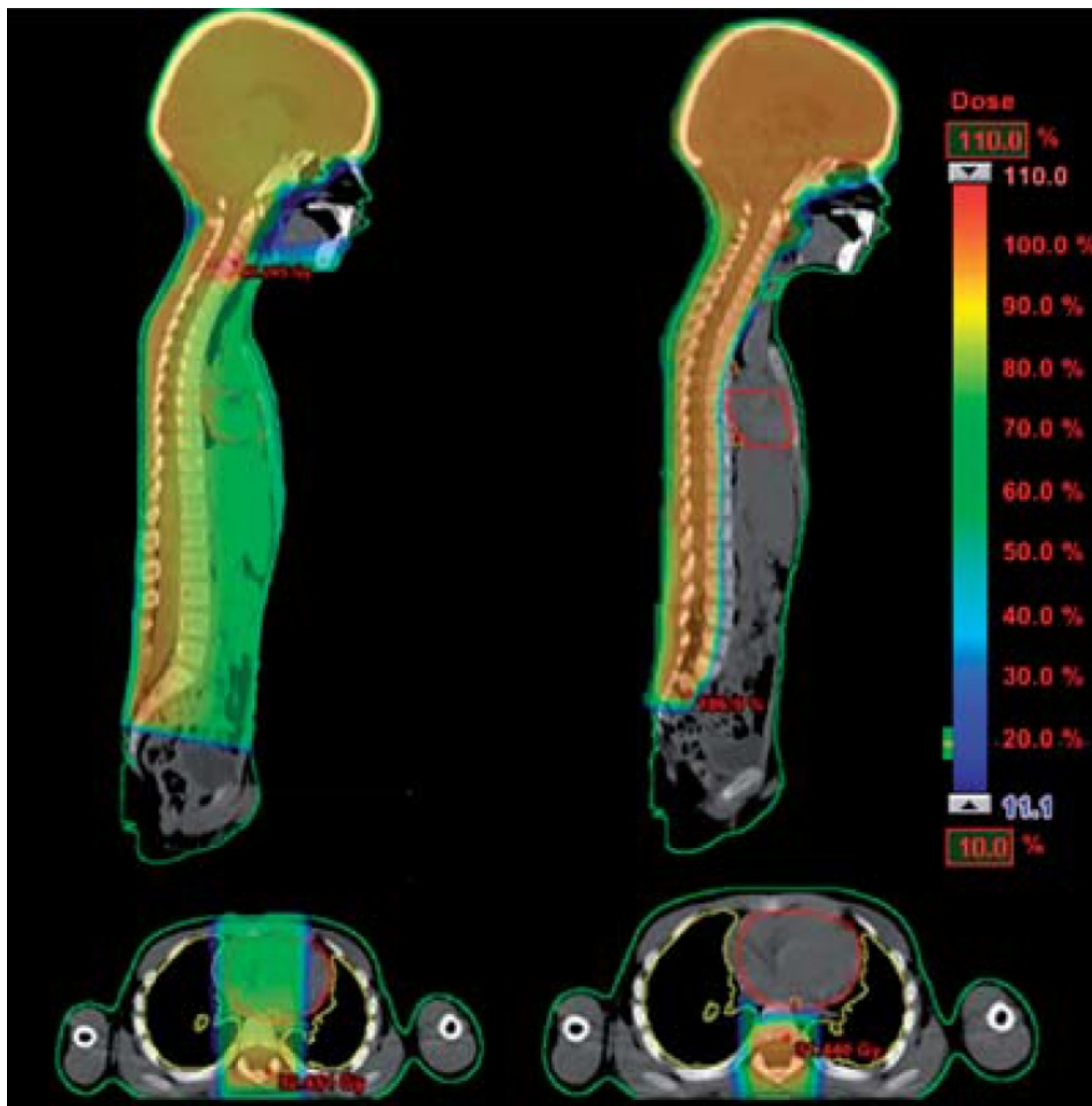
...och hela volymen



Courtesy A Lomax, PSI

Medulloblastom

Fotoner



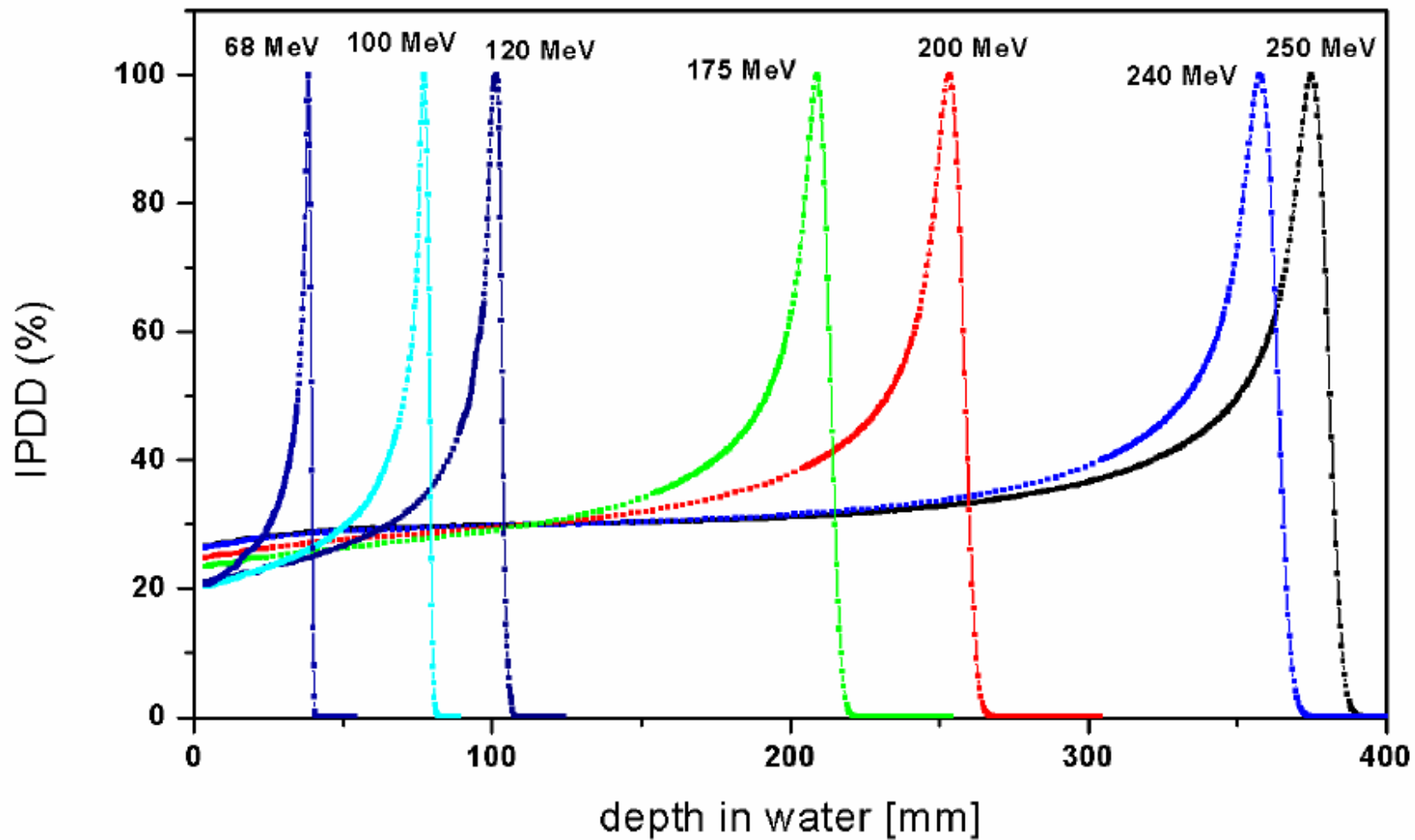
Protoner

Protoner (och tåg) stannar!



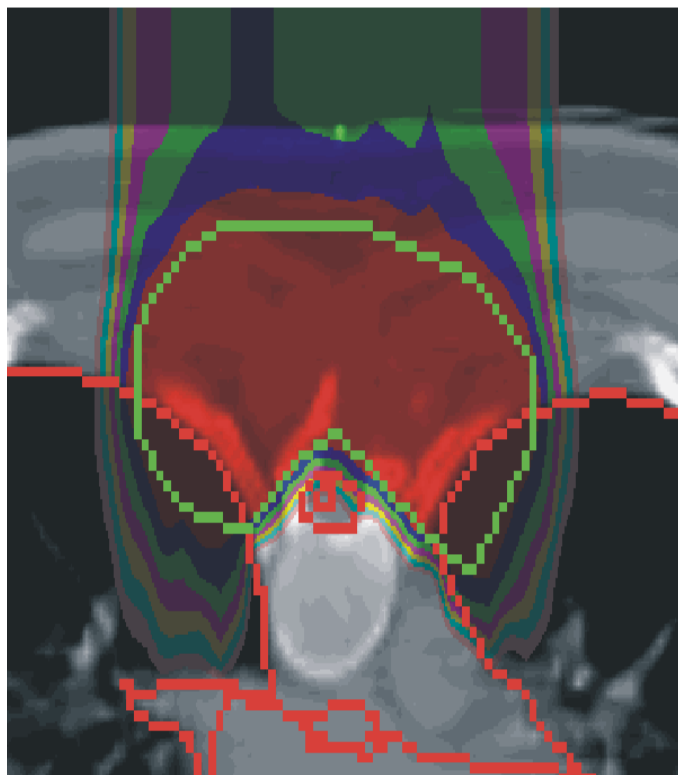
Men vet vi var...?







Braggtoppen ger möjlighet till
mycket skarpa fältgränser!



Bilder från A Lomax

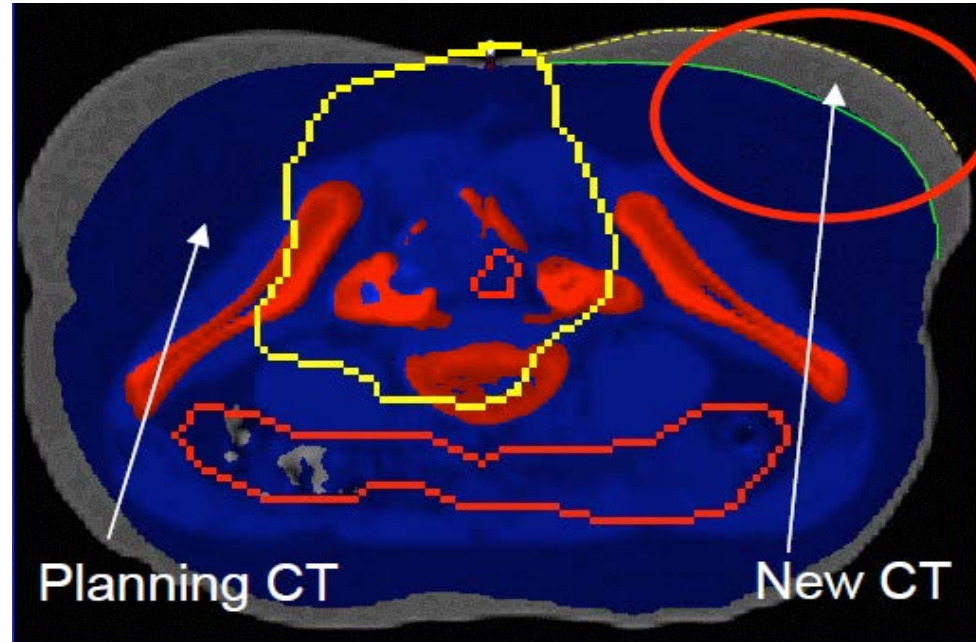
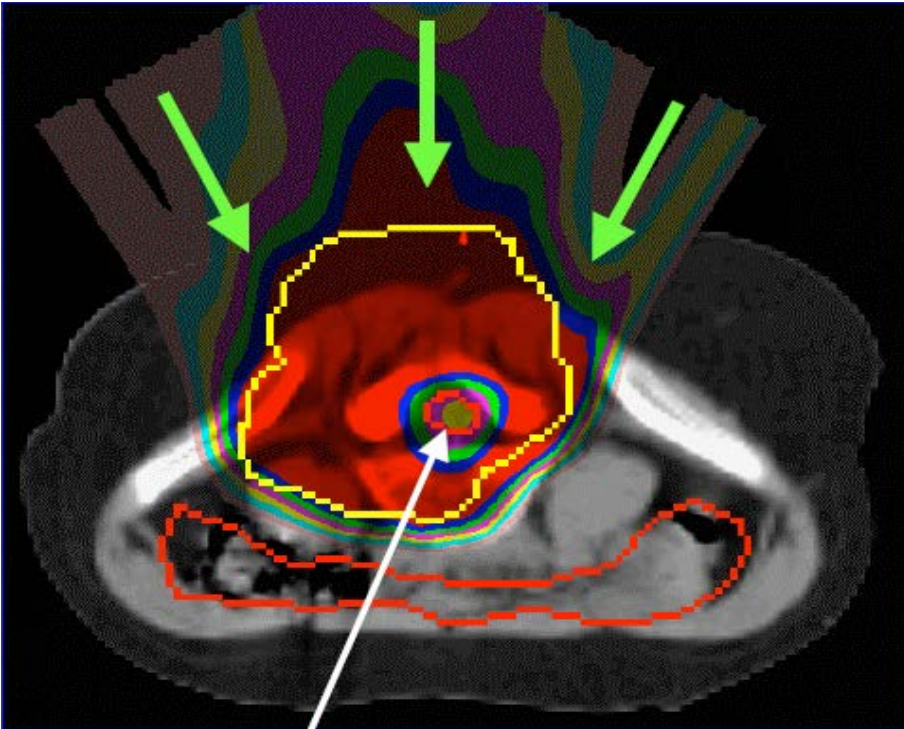


Källor till räckviddsosäkerheter

- Begränsningar i CT data (beam hardening, brus, upplösning etc) [$\Sigma \sim 1\%$]
- Variationer i patientanatomi [Σ]

Pojke, 8 år...

...ökade 1.5 kg i vikt



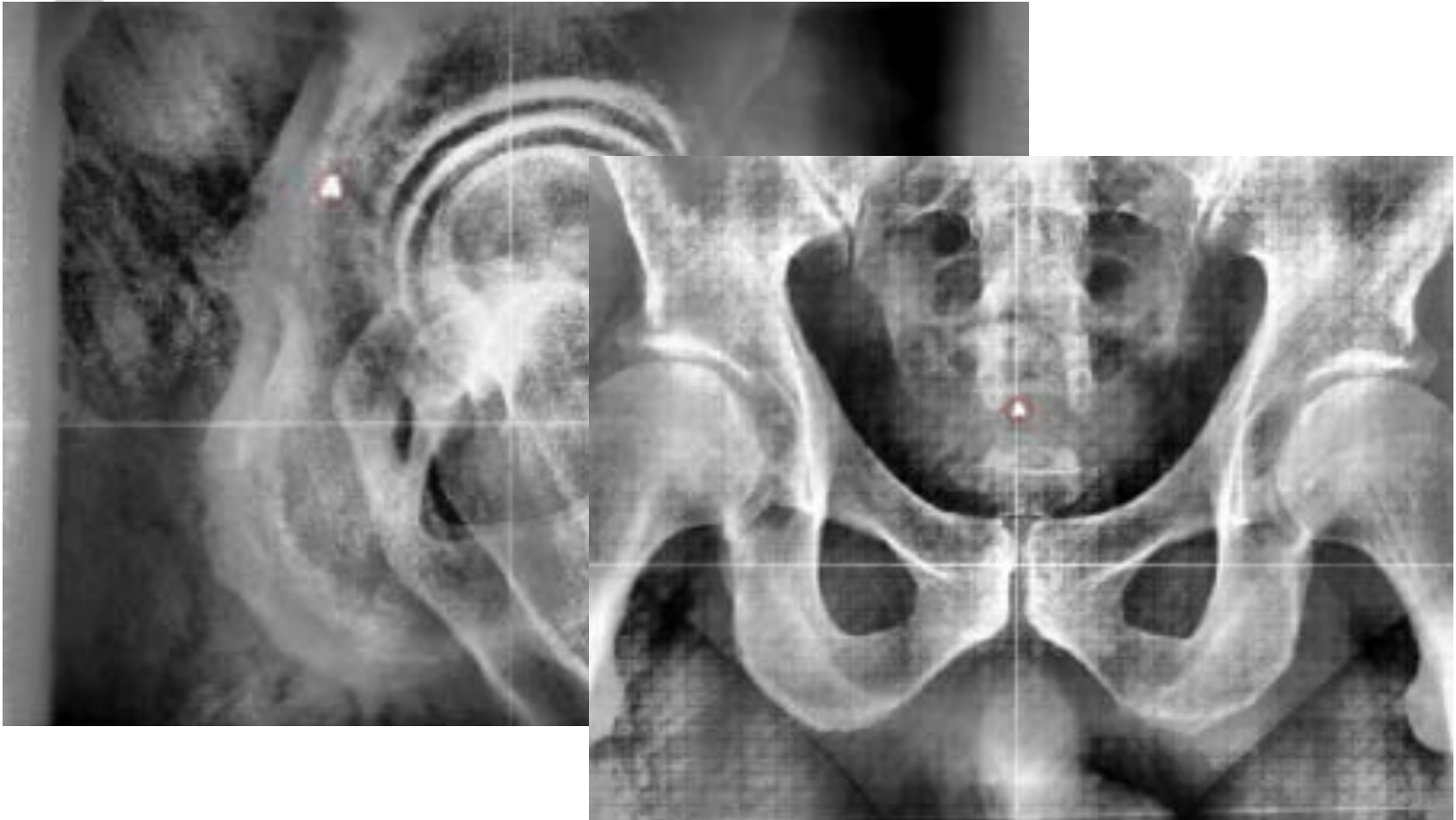
Courtesy A Lomax, PSI

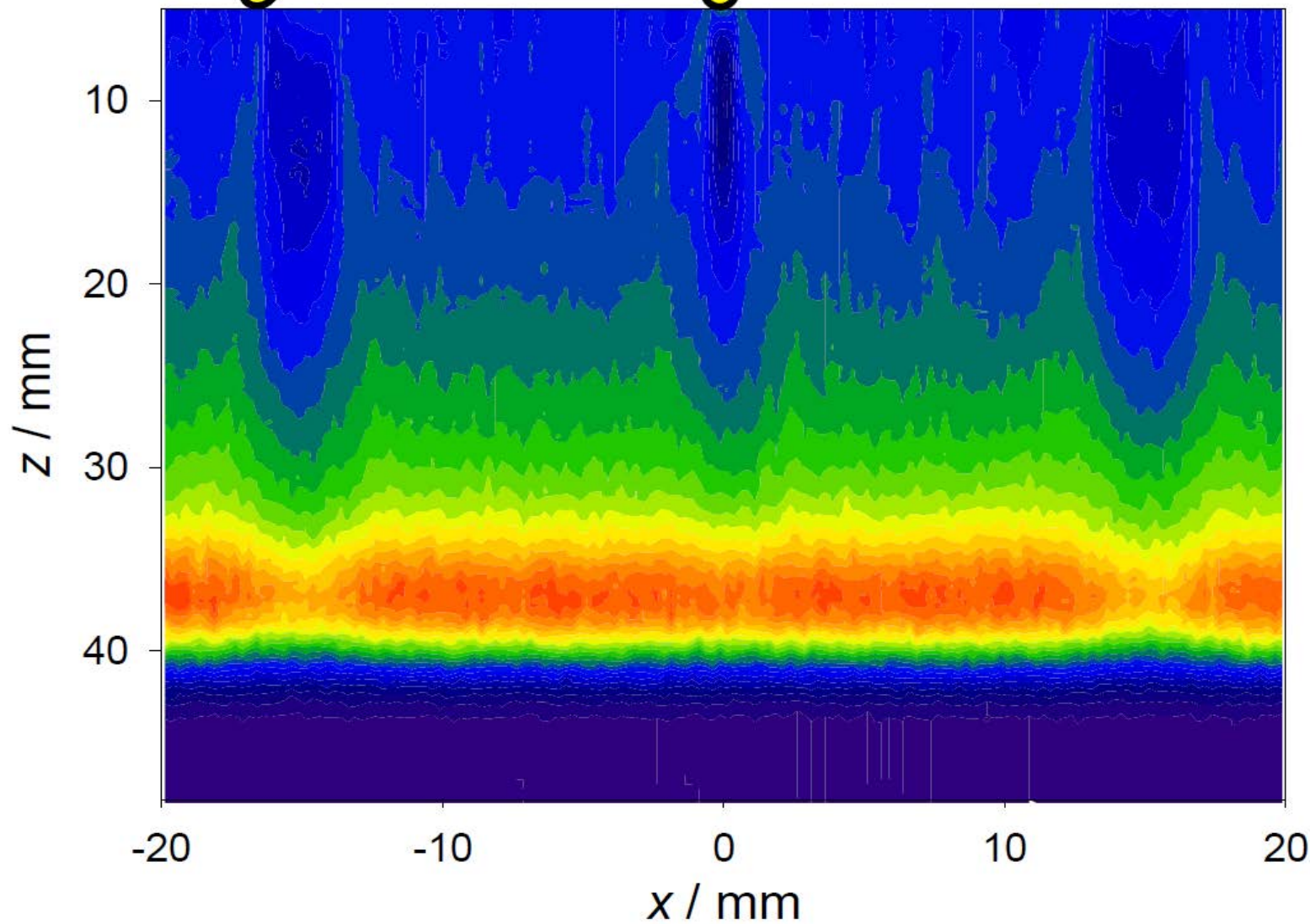
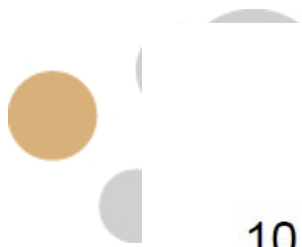


Källor till räckviddsosäkerheter

- Begränsningar i CT data (beam hardening, brus, upplösning etc) [$\Sigma \sim 1\%$]
- Variationer i patientanatomi [Σ]
- CT-artifakter [Σ]

Exempel: Markörer i prostata

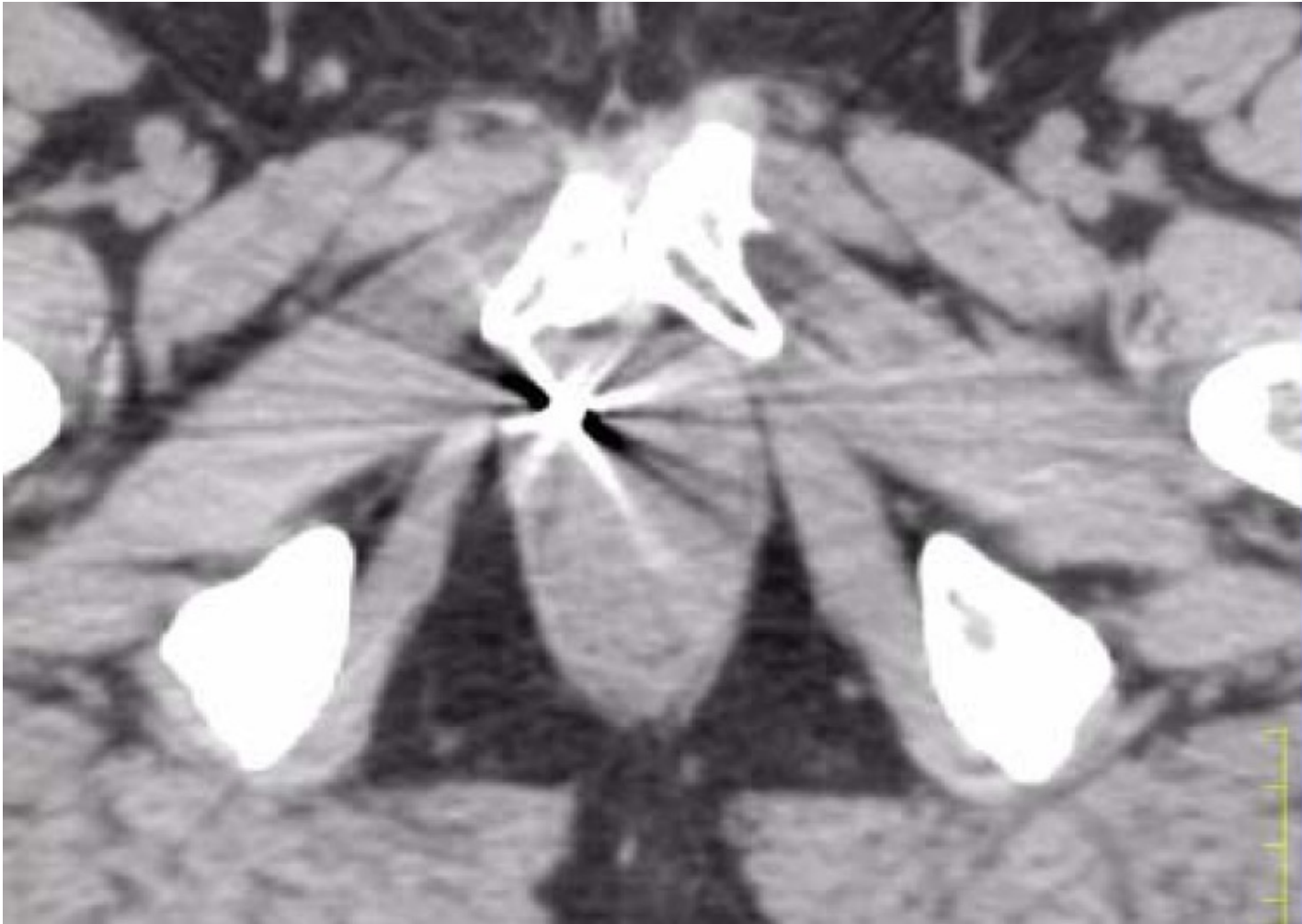




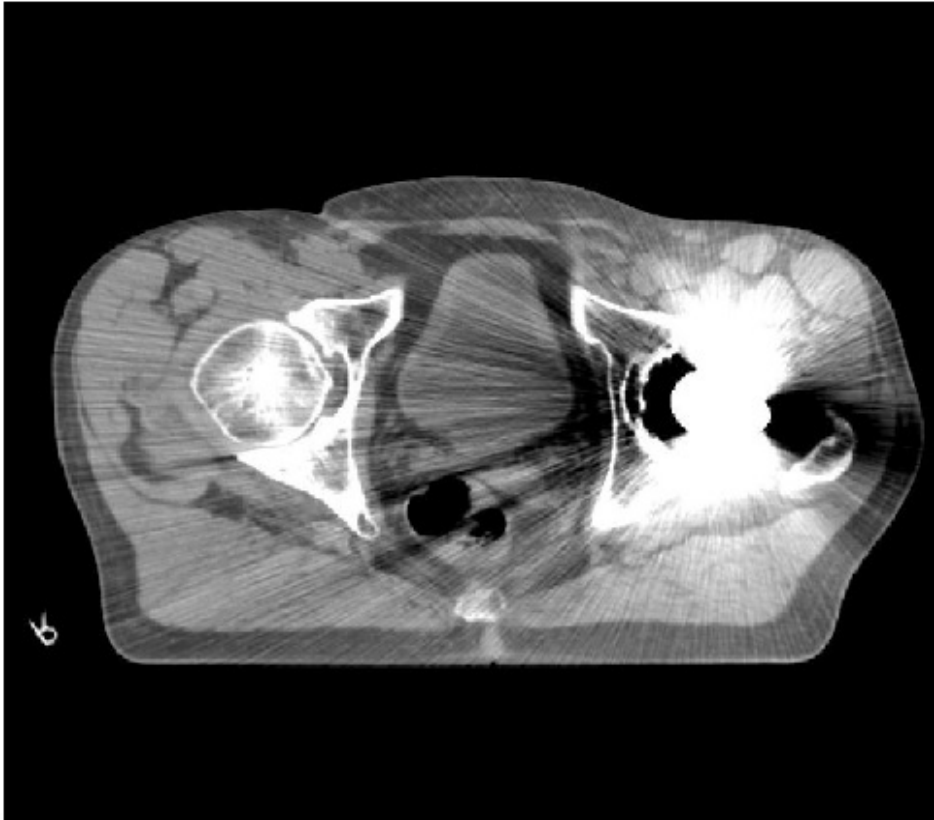
Neuhauser et al 2007

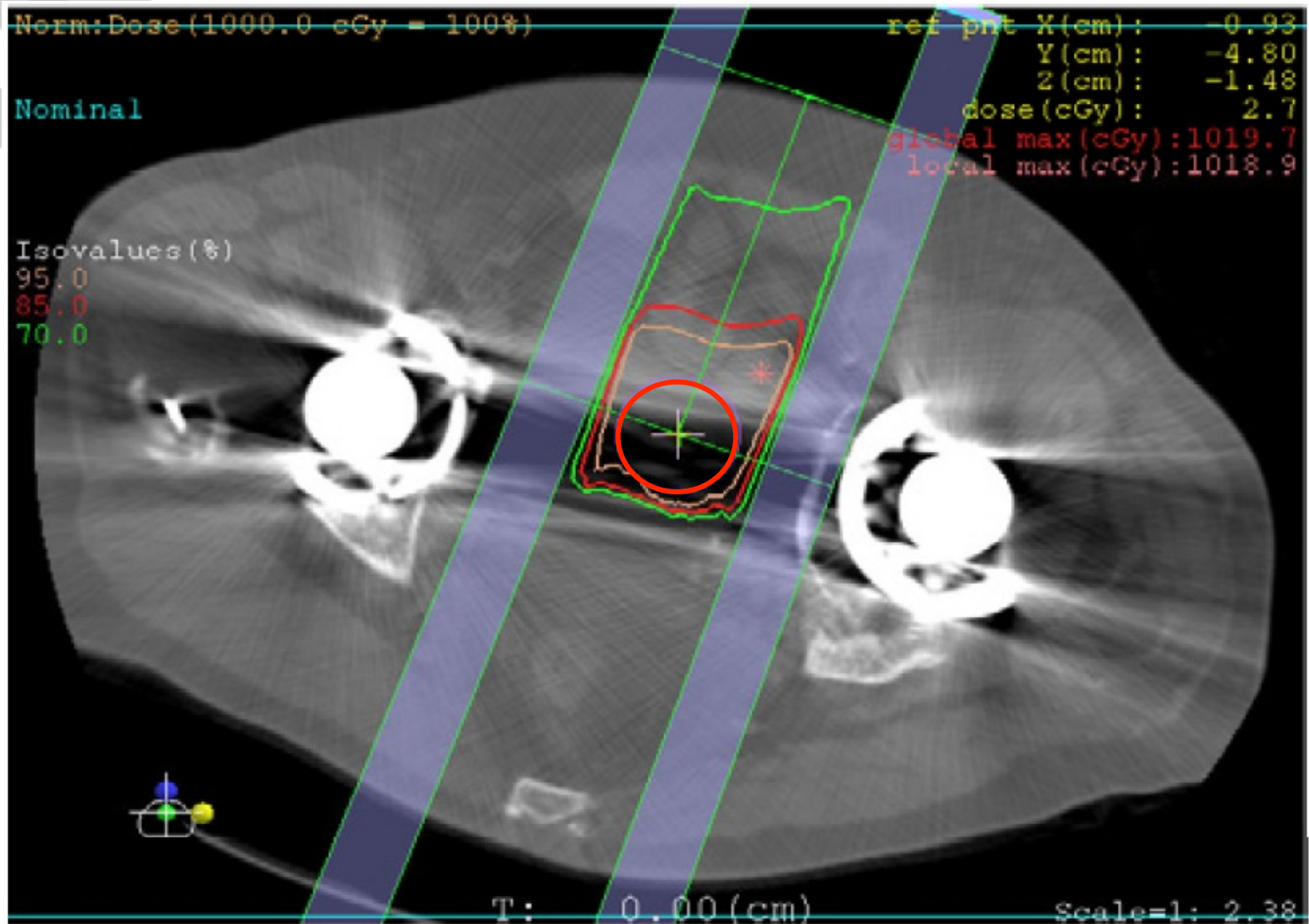
Skandionkliniken

Exempel: Markörer i prostata



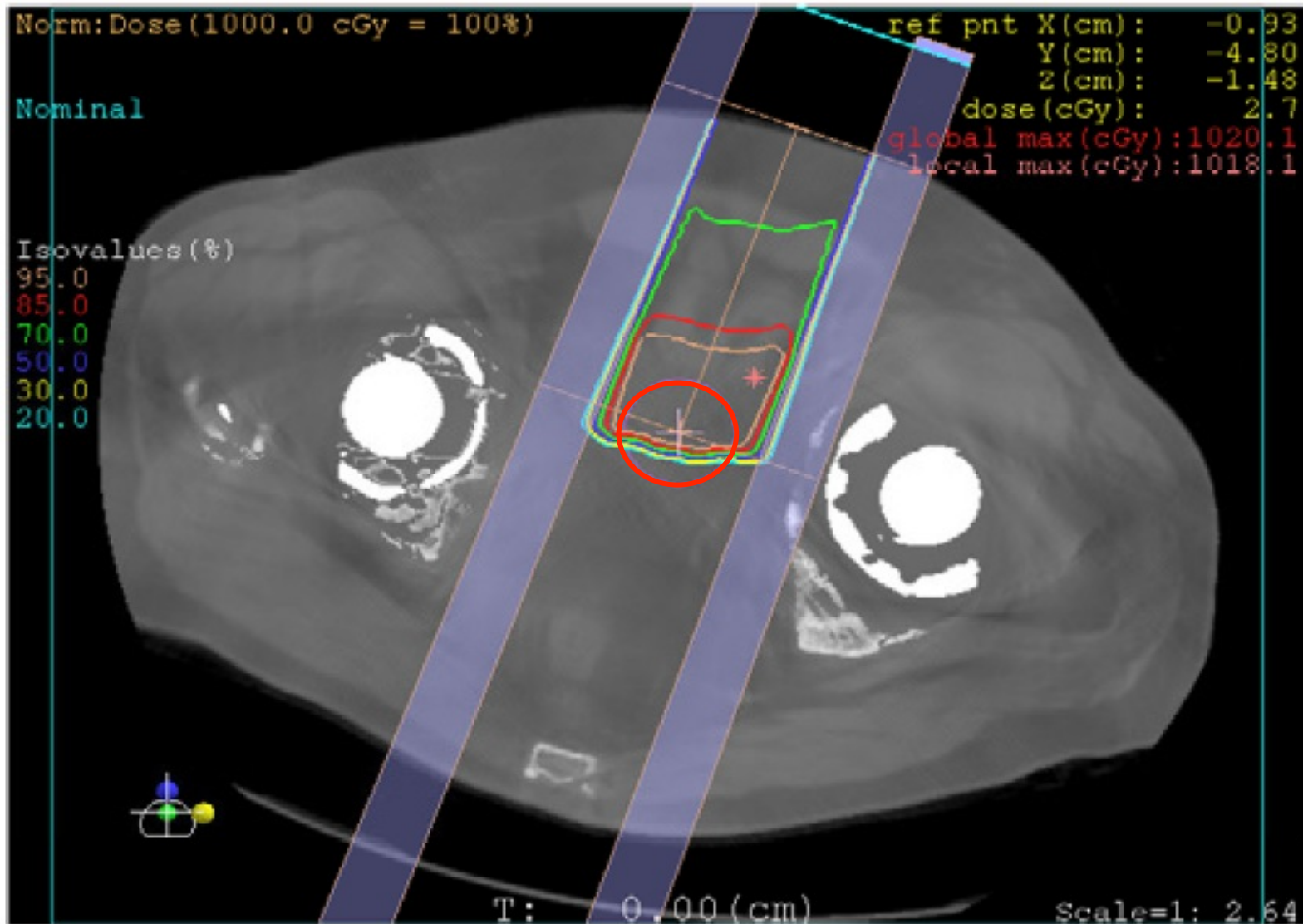
Artefakter ger förstås problem!





(a)

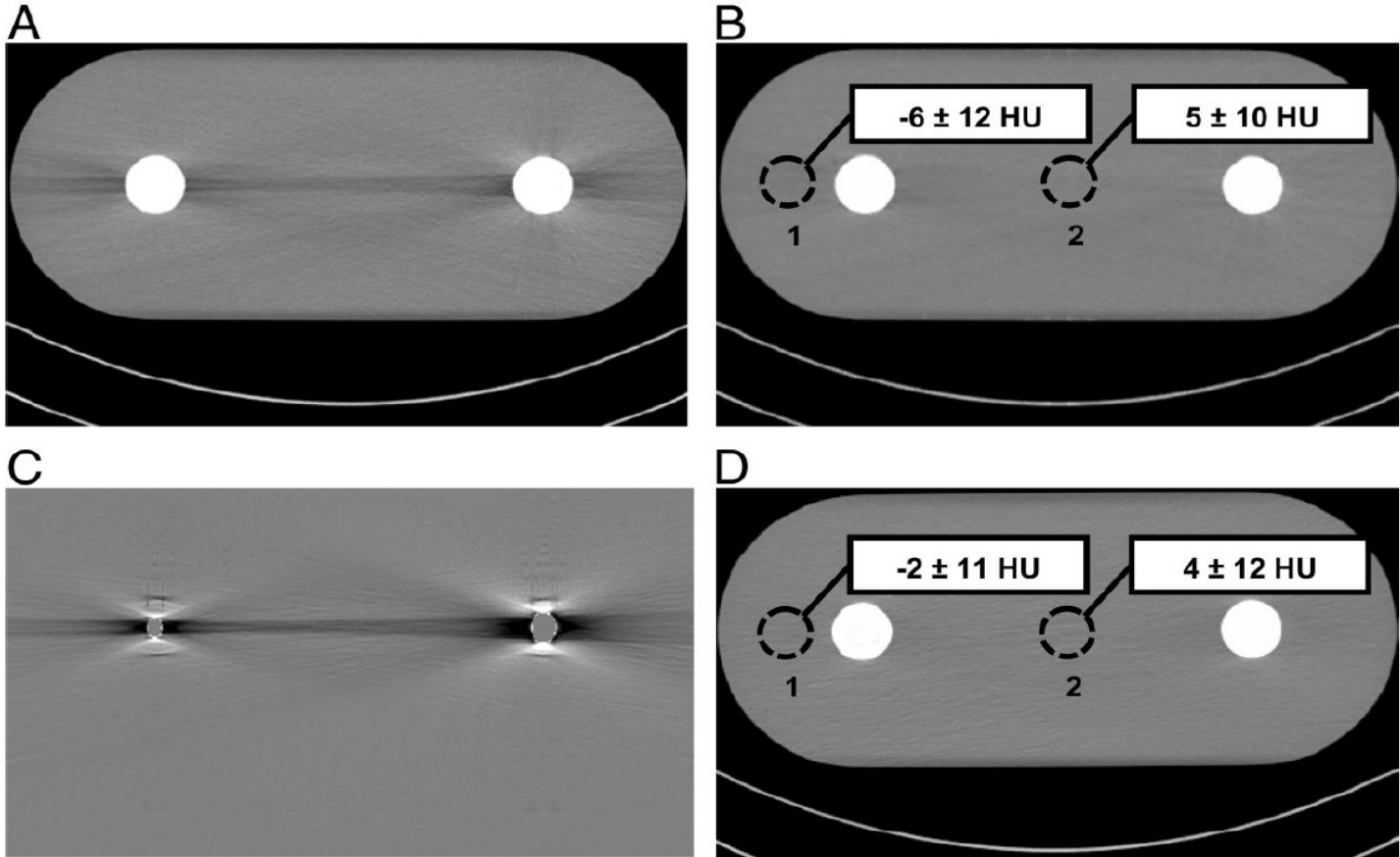
Wei et al, 2006



(b)

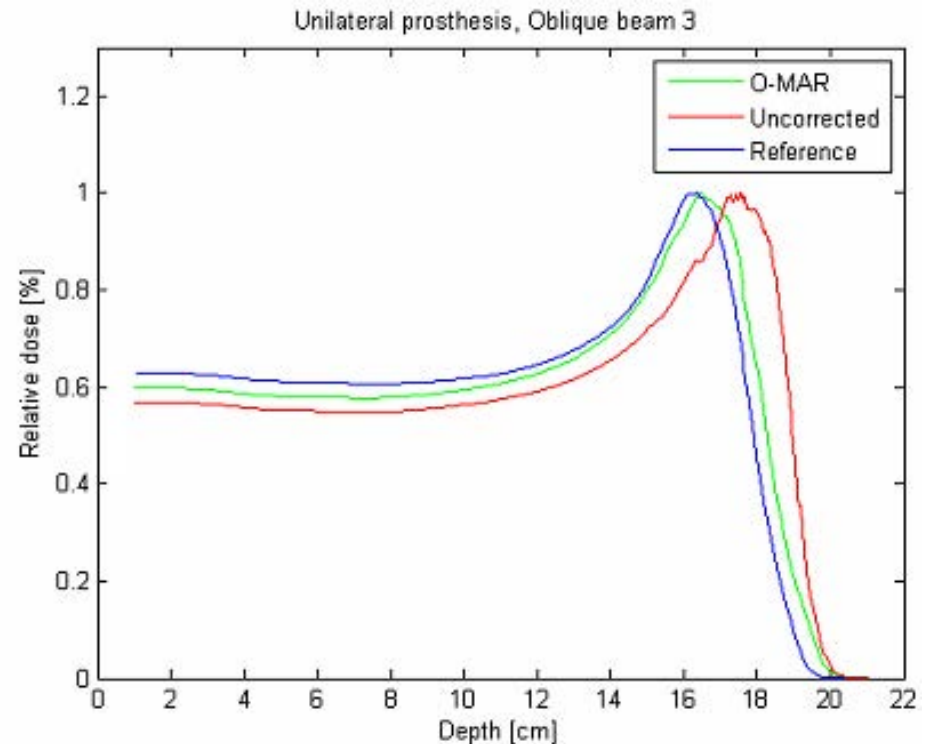
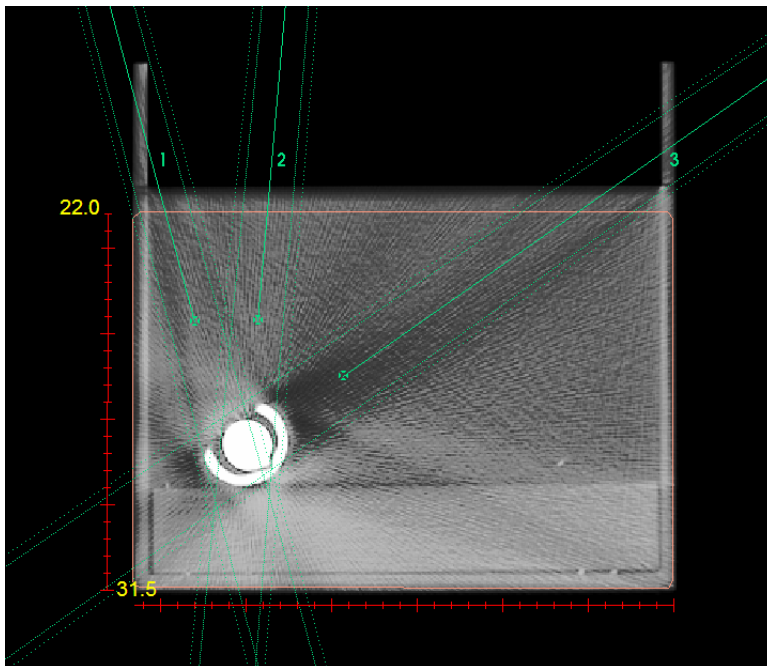
Wei et al, 2006

Iterativa rekonstruktions algoritmer?



Metal Artefact Reduction "O-MAR" (Philips)

Exempel. Fält 3 längs med artefakt
Djupdoskurva 180 Mev p+



K Andersson, MSc thesis, Stockholm Univ. 2012

Röntgenveckan 2013

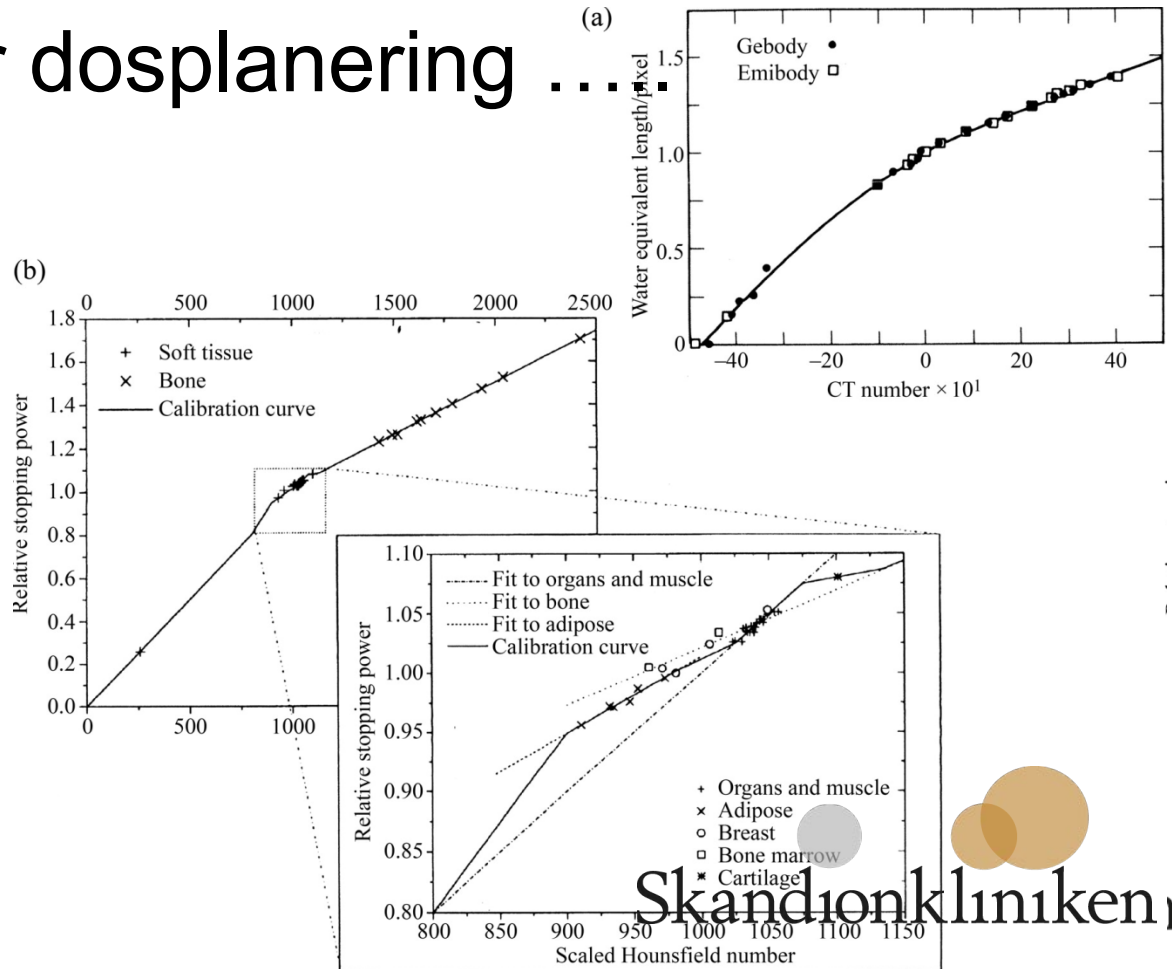


Källor till räckviddsosäkerheter

- Begränsningar i CT data (beam hardening, brus, upplösning etc) [$\Sigma \sim 1\%$]
- Variationer i patientanatomi [Σ]
- CT-artifakter [Σ]
- Kalibrering av CT till stopping power [$\Sigma \sim 1-2\%$]

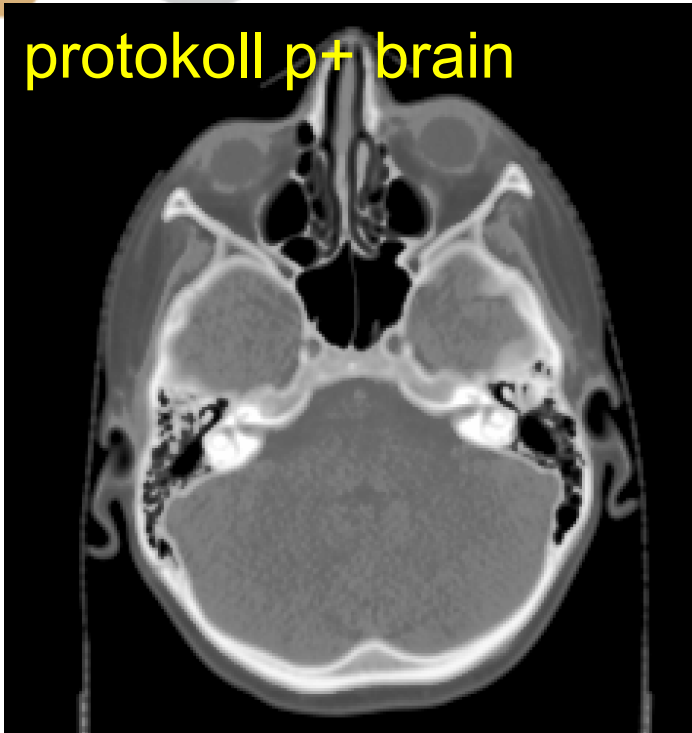
CT-kalibrering

- Ett stort antal CT-skannrar kommer att användas för dosplanering

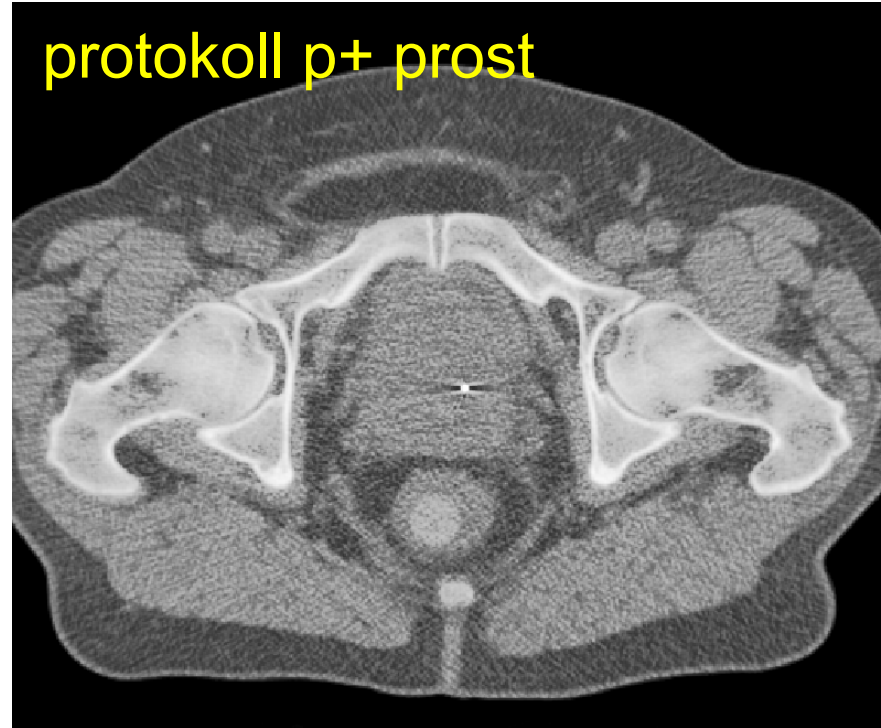


Exempel HU-tolkning Akademiska, CT strålbeh.

protokoll p+ brain

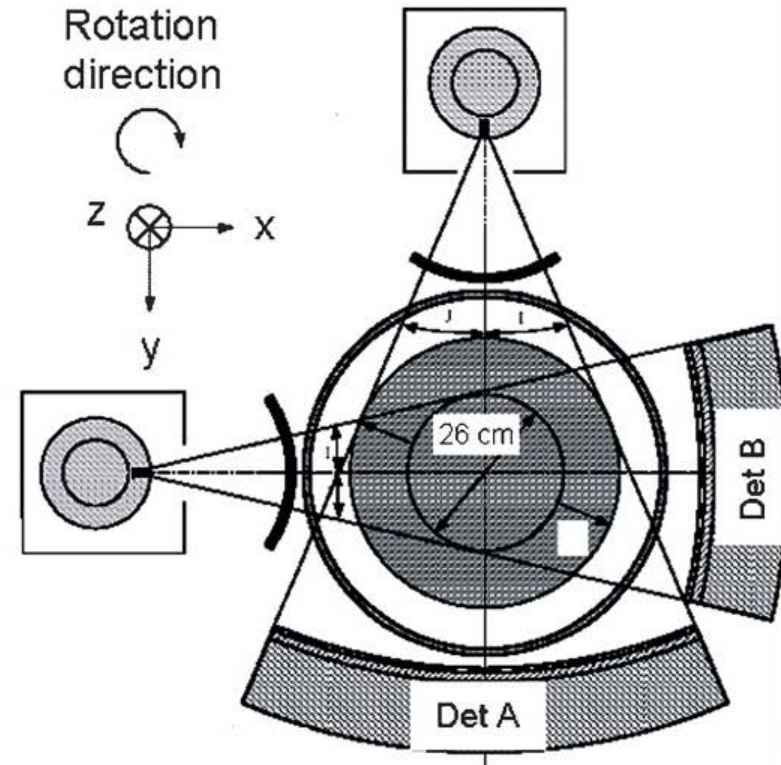
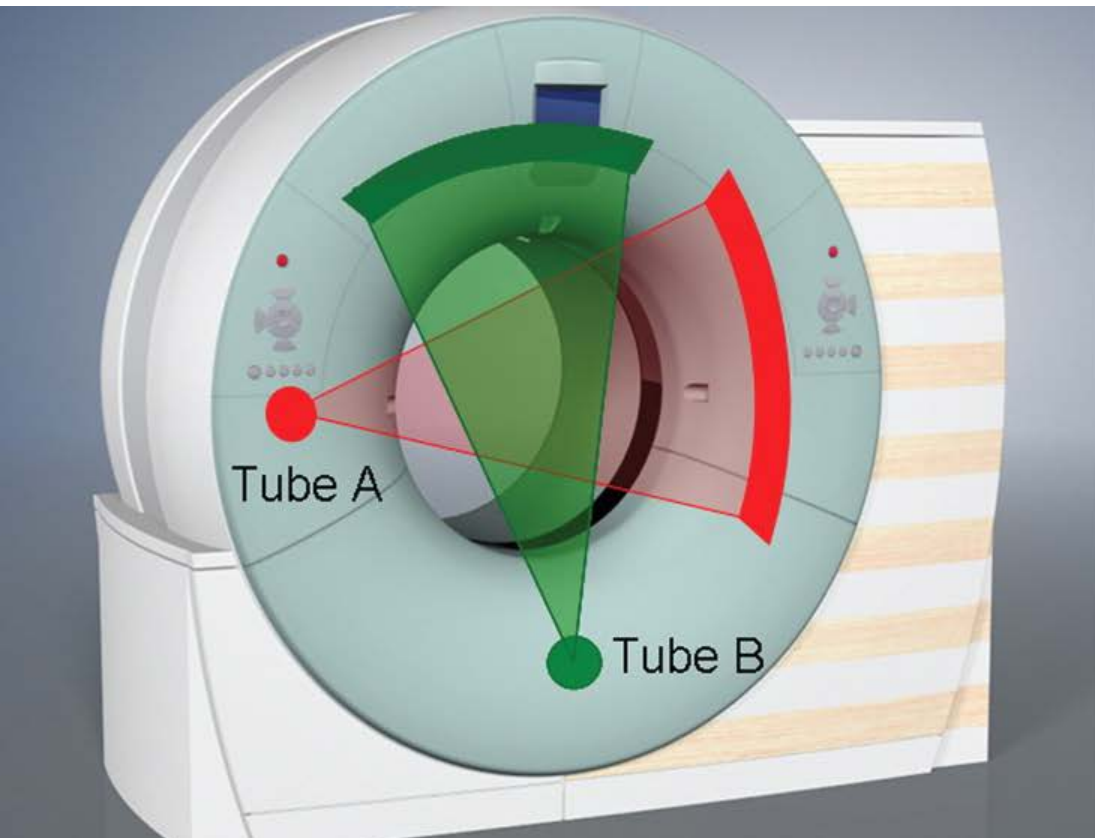



protokoll p+ prost



HU prot. p+ brain	HU prot p+ prost	Tolkning i TPS
-71	-71	fett / massdensitet 0.95
43	43	muskel / 1.05
99	100	brosk / 1.10
1321	1358	ben / 1.85

Dual energy scanners..?





Kan man verifiera räckvidden med PET..?

OPTIC(a)

Soft Tissue:
25.6 C, 60.2 O, 2.7 N

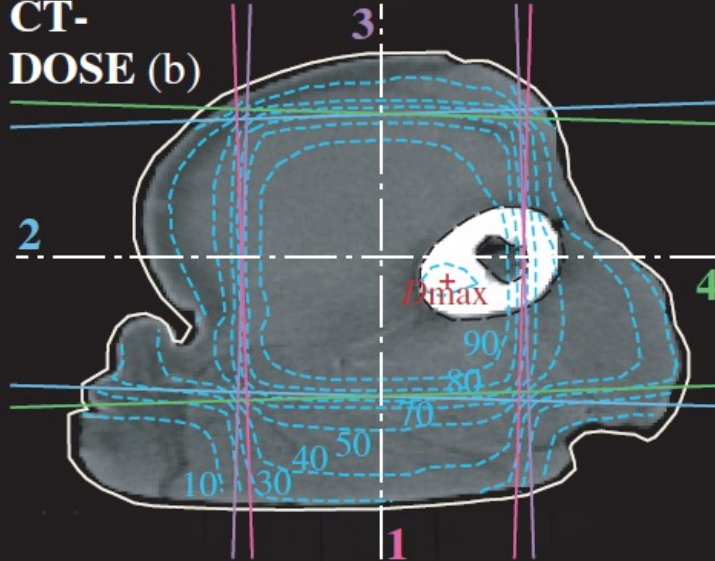
Adipose
Tissue:
71.9 C,
13.8 O,
3.0 N

Yellow marrow:
64.4 C, 23.1 O, 0.7 N

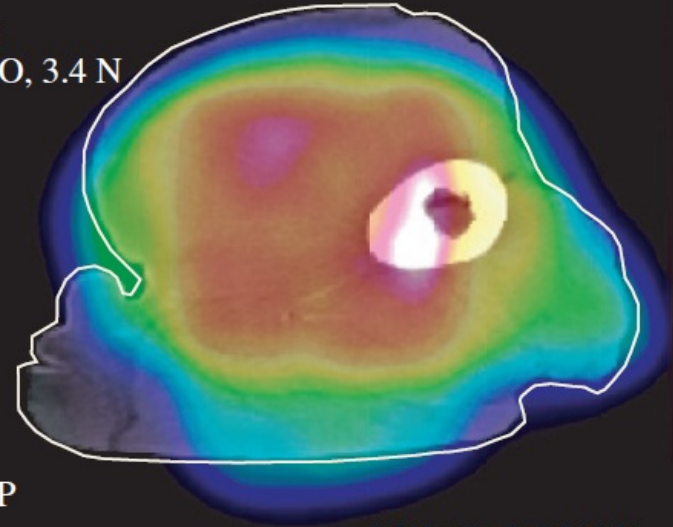
Red marrow:
41.4 C, 43.9 O, 3.4 N

Cortical Bone: 15.5 C, 43.5 O, 4.2 N, 22.5 Ca, 10.3 P

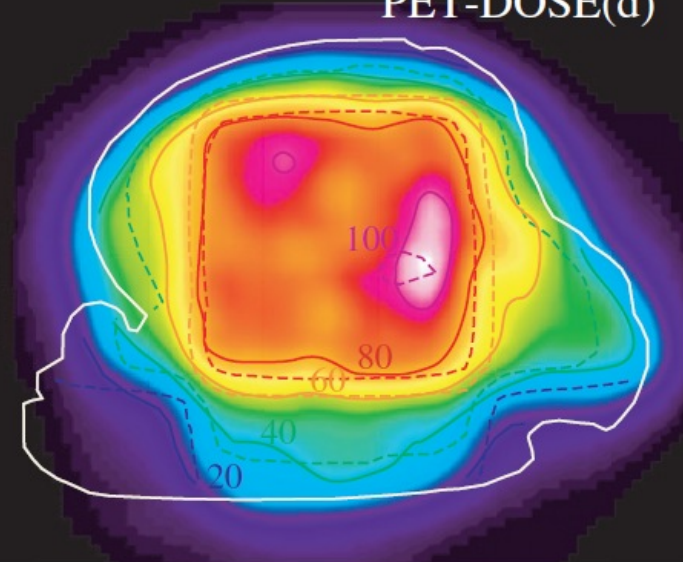
CT-DOSE (b)

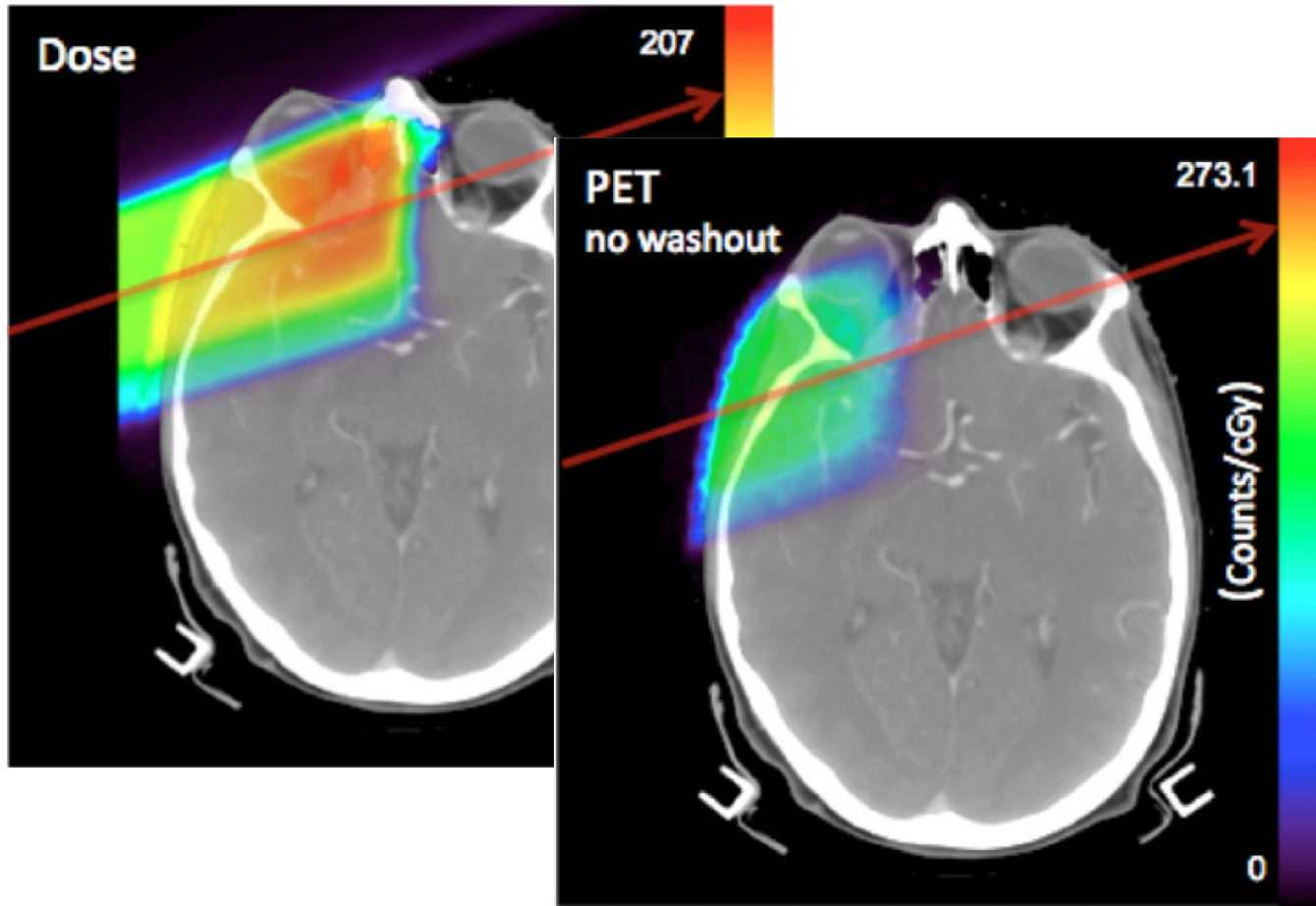


PET-CT(c)

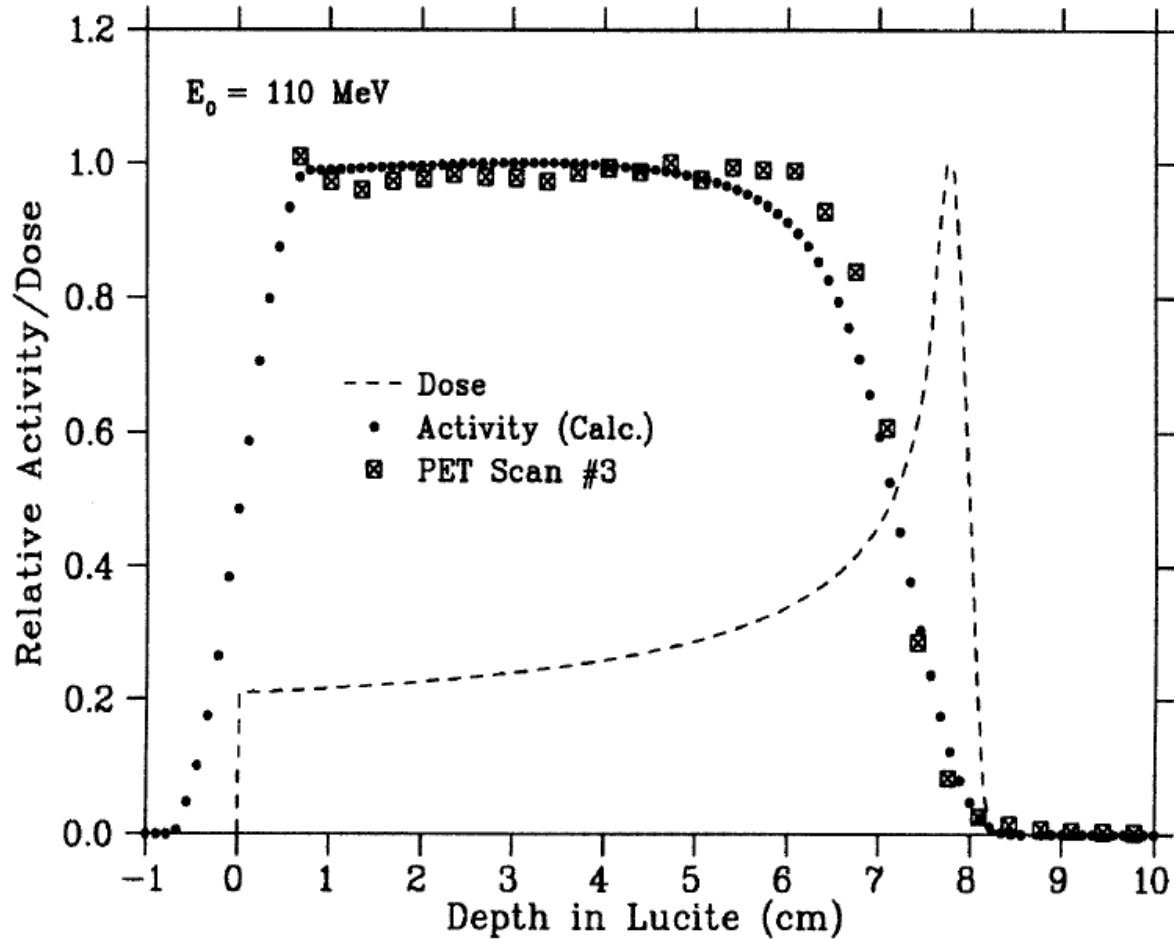


PET-DOSE(d)





Proton dose monitoring with PET





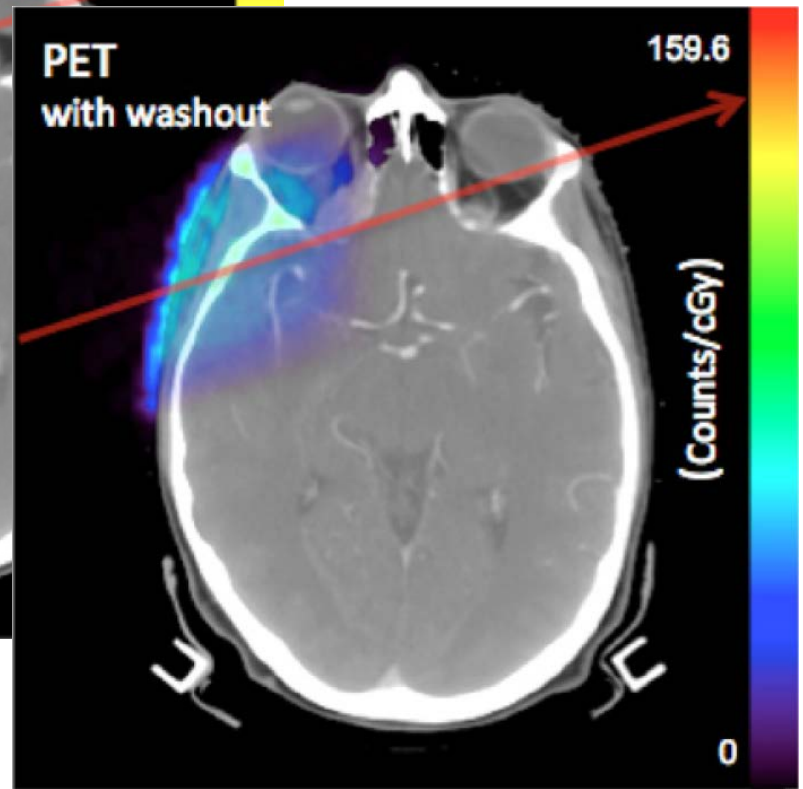
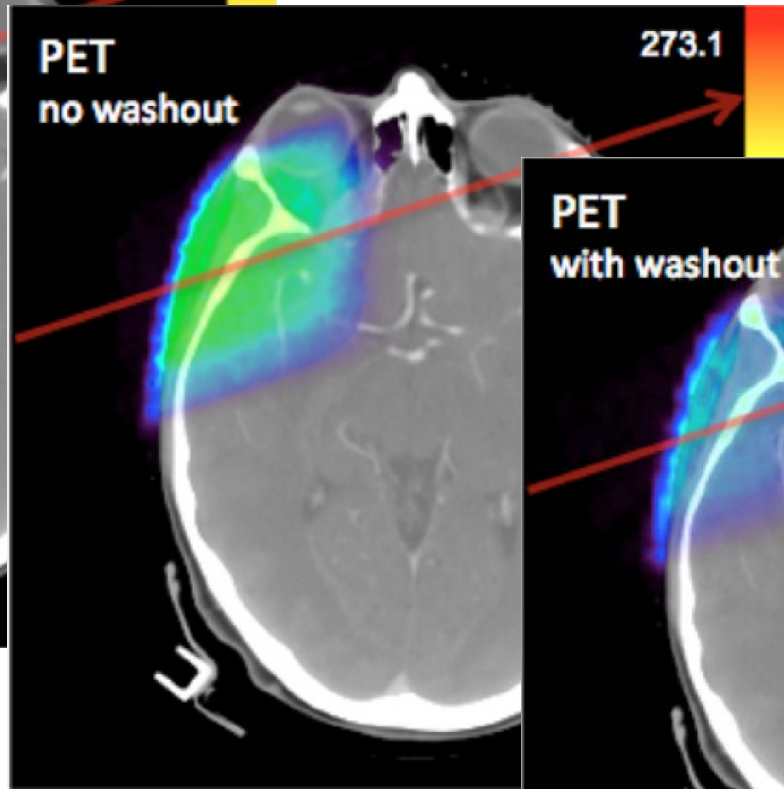
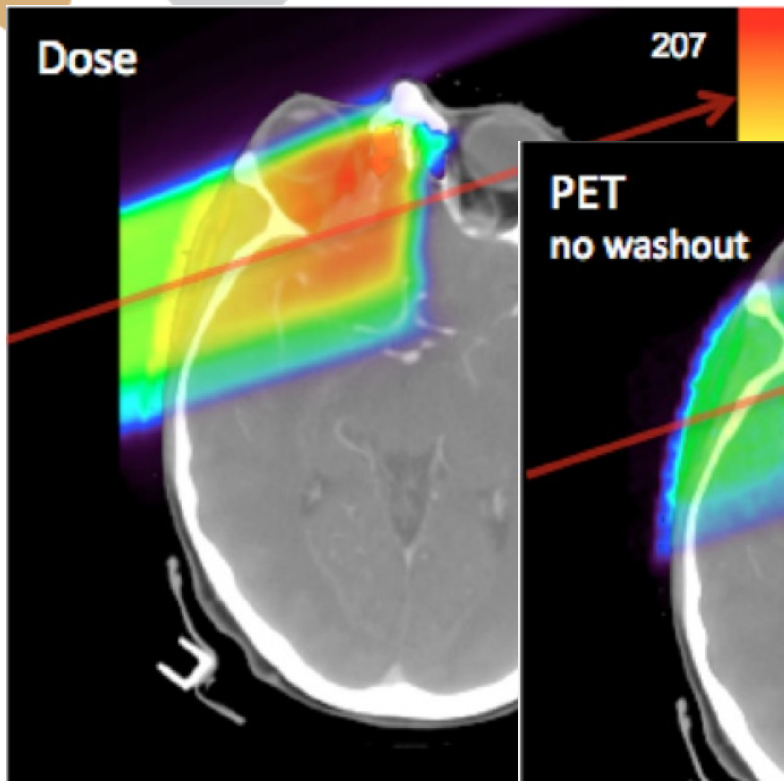
$T_{1/2} = 2 \text{ min}$


$T_{1/2} = 10 \text{ min}$

$T_{1/2} = 20 \text{ min}$

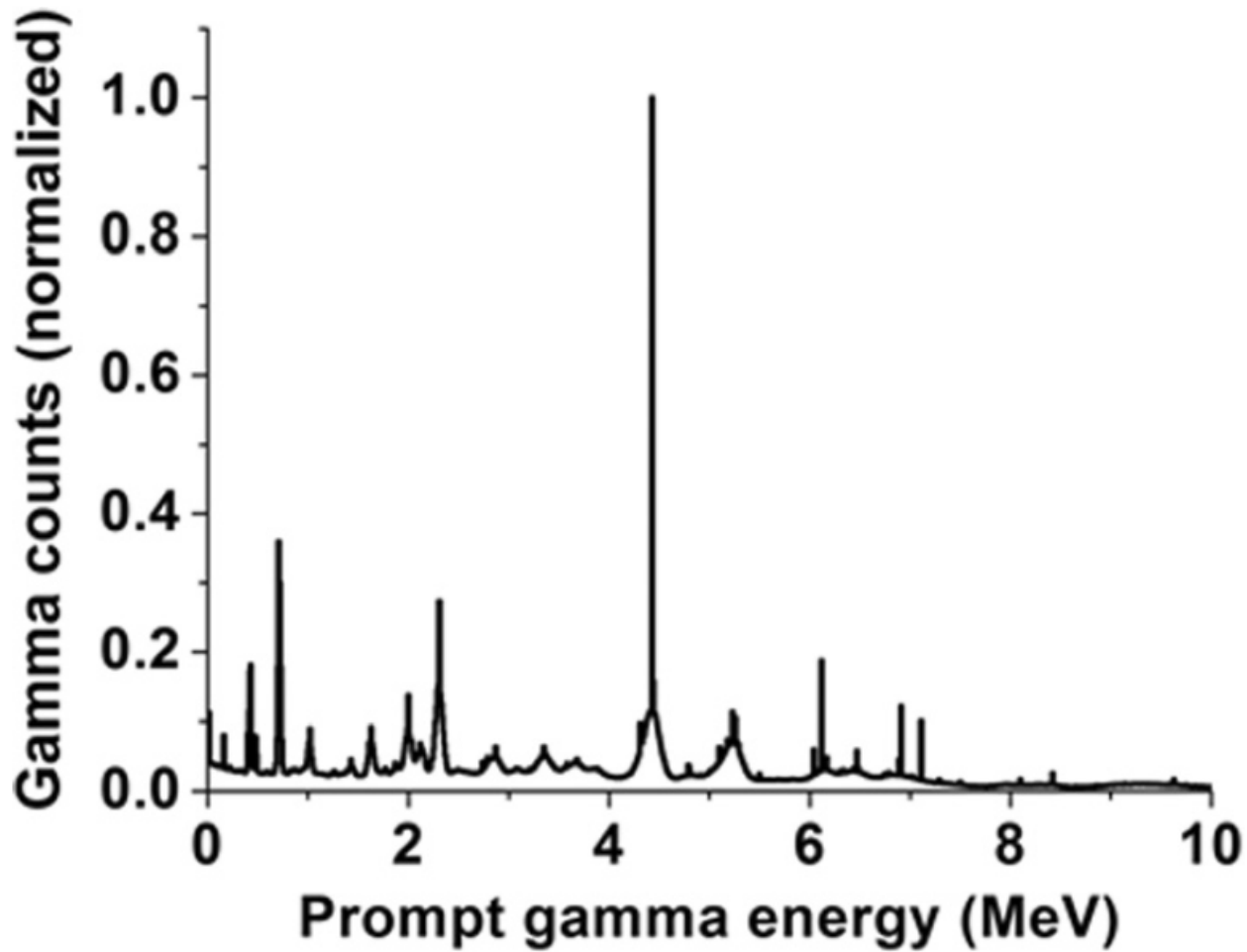
Table 1. Isotope production processes.

Activation process	E_{TI} (MeV)	λ_I (min^{-1})	$E_{e^+}^{max}(I)$ (MeV)
$p + {}^{16}\text{O} \rightarrow {}^{15}\text{O} + (p, n)$	16.6	0.3414	1.73
$p + {}^{16}\text{O} \rightarrow {}^{13}\text{N} + \alpha, 2(p, n)$	5.5	0.0695	1.19
$p + {}^{16}\text{O} \rightarrow {}^{11}\text{C} + 3(p, n)$	14.3	0.0340	0.96
$p + {}^{14}\text{N} \rightarrow {}^{13}\text{N} + (p, n)$	11.2	0.0695	1.19
$p + {}^{14}\text{N} \rightarrow {}^{11}\text{C} + \alpha, 2(p, n)$	3.1	0.0340	0.96
$p + {}^{12}\text{C} \rightarrow {}^{11}\text{C} + (p, n)$	20.1	0.0340	0.96





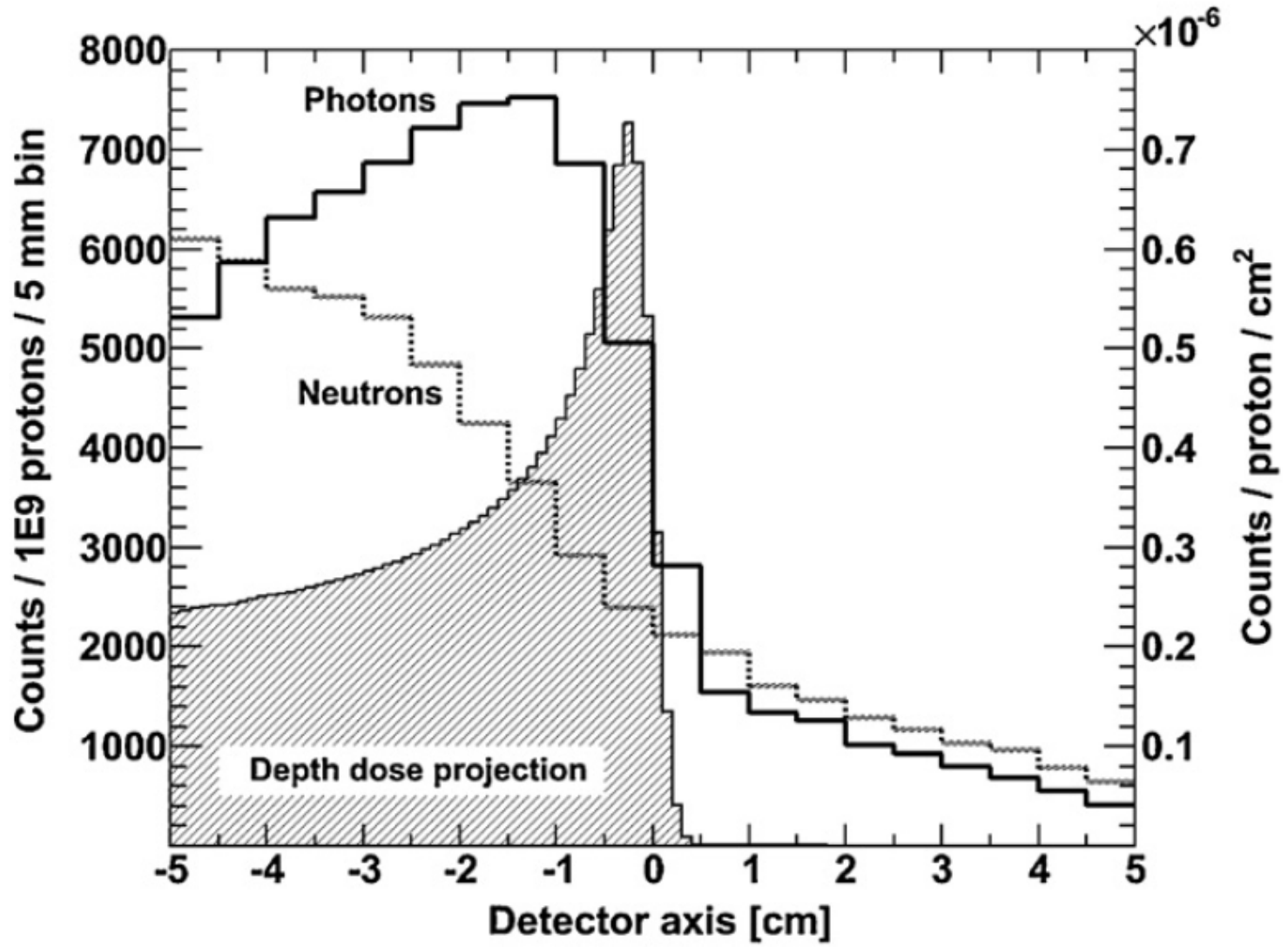
Kan man verifiera räckvidden med Prompt Gamma Imaging..?



Kim et al, MP 39(2) (2012) p1001

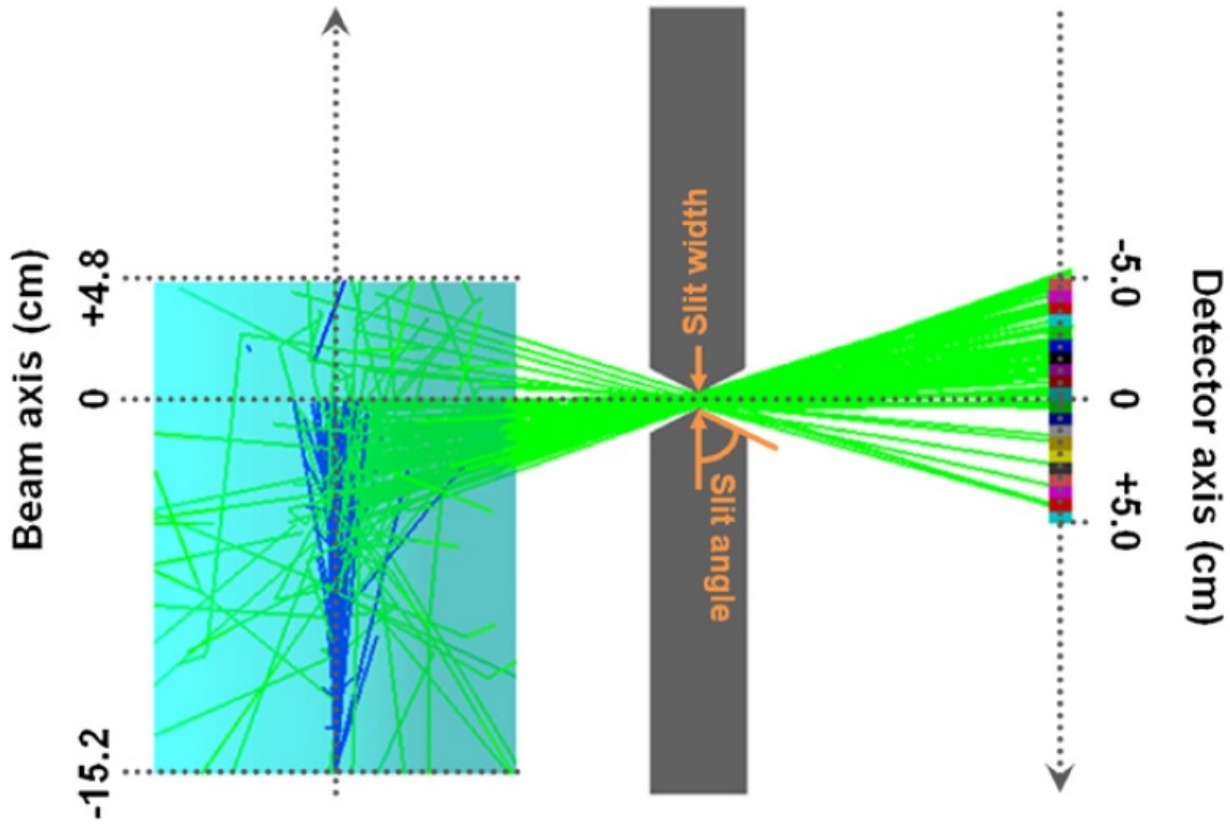
Röntgenveckan 2013

Skandionkliniken





Secondary particle	Quantity per proton
Neutron	0.120 33(2)
Photon	0.092 28(2)
Electron	0.002 135(3)
Proton	0.001 716(3)
Deuteron	0.000 0484(4)
Alpha	0.000 0043(1)
Triton	0.000 001 48(8)
Helium-3	0.000 000 98(6)



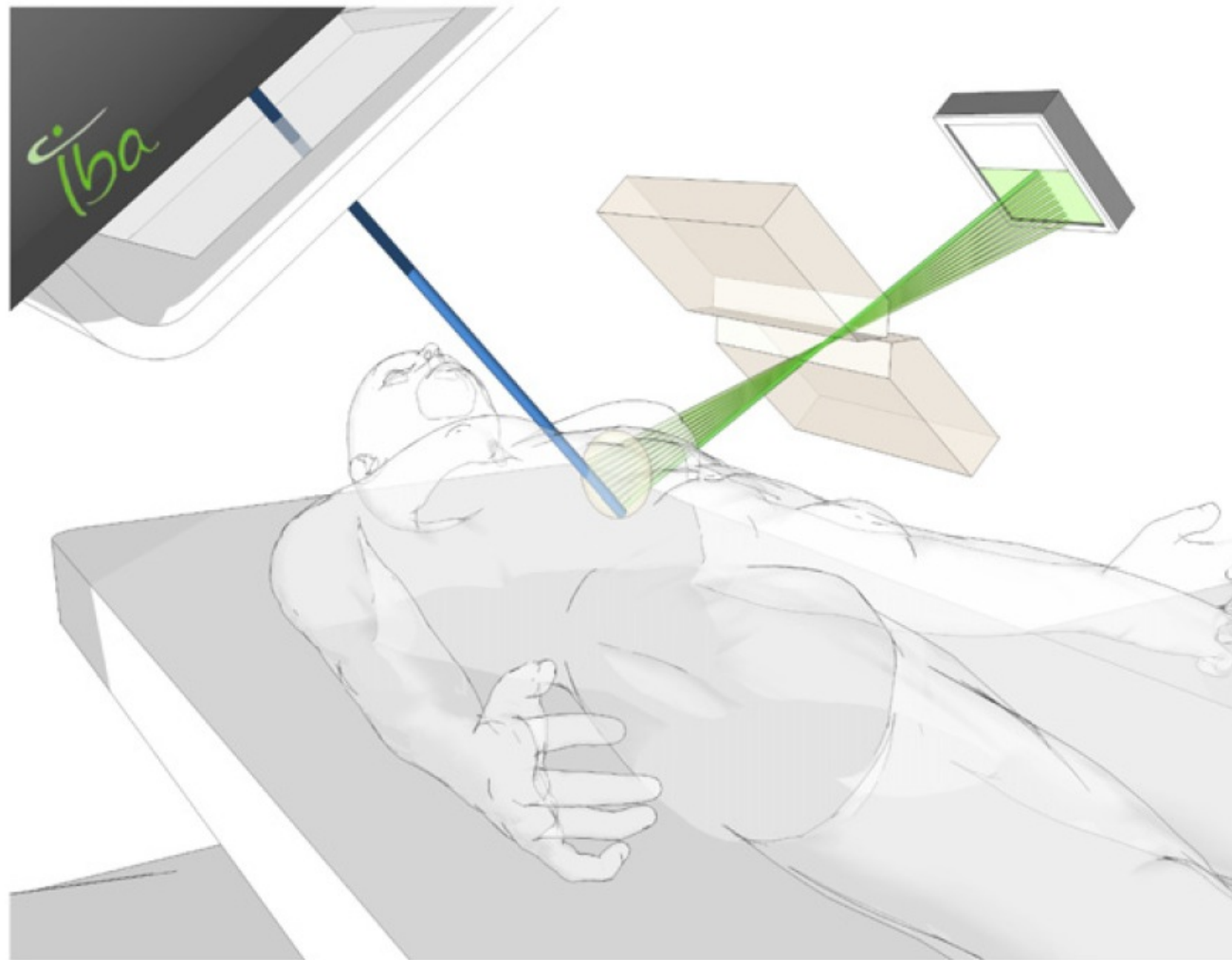
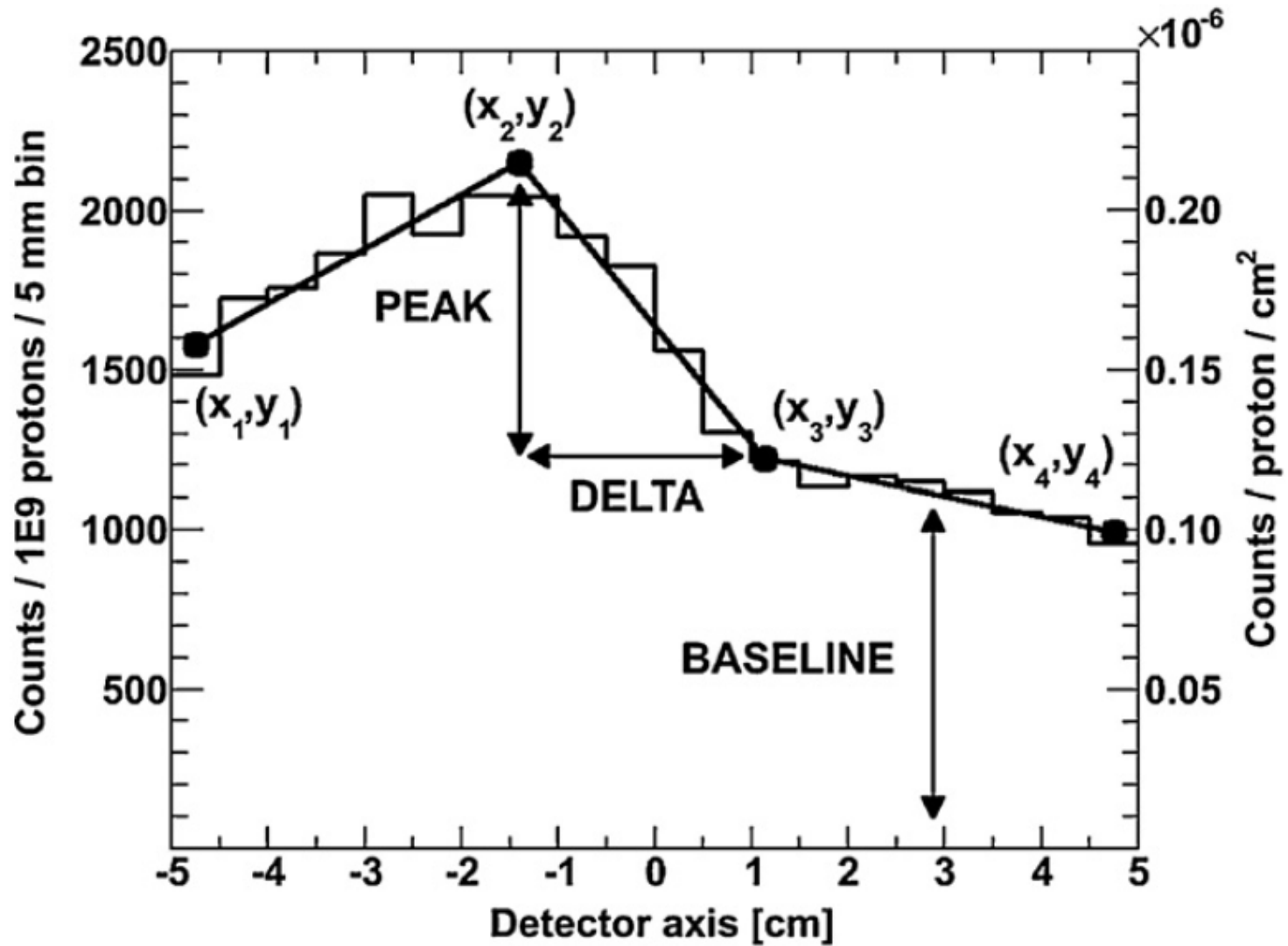


Figure 1. Proton beam range measurement with a slit gamma camera.



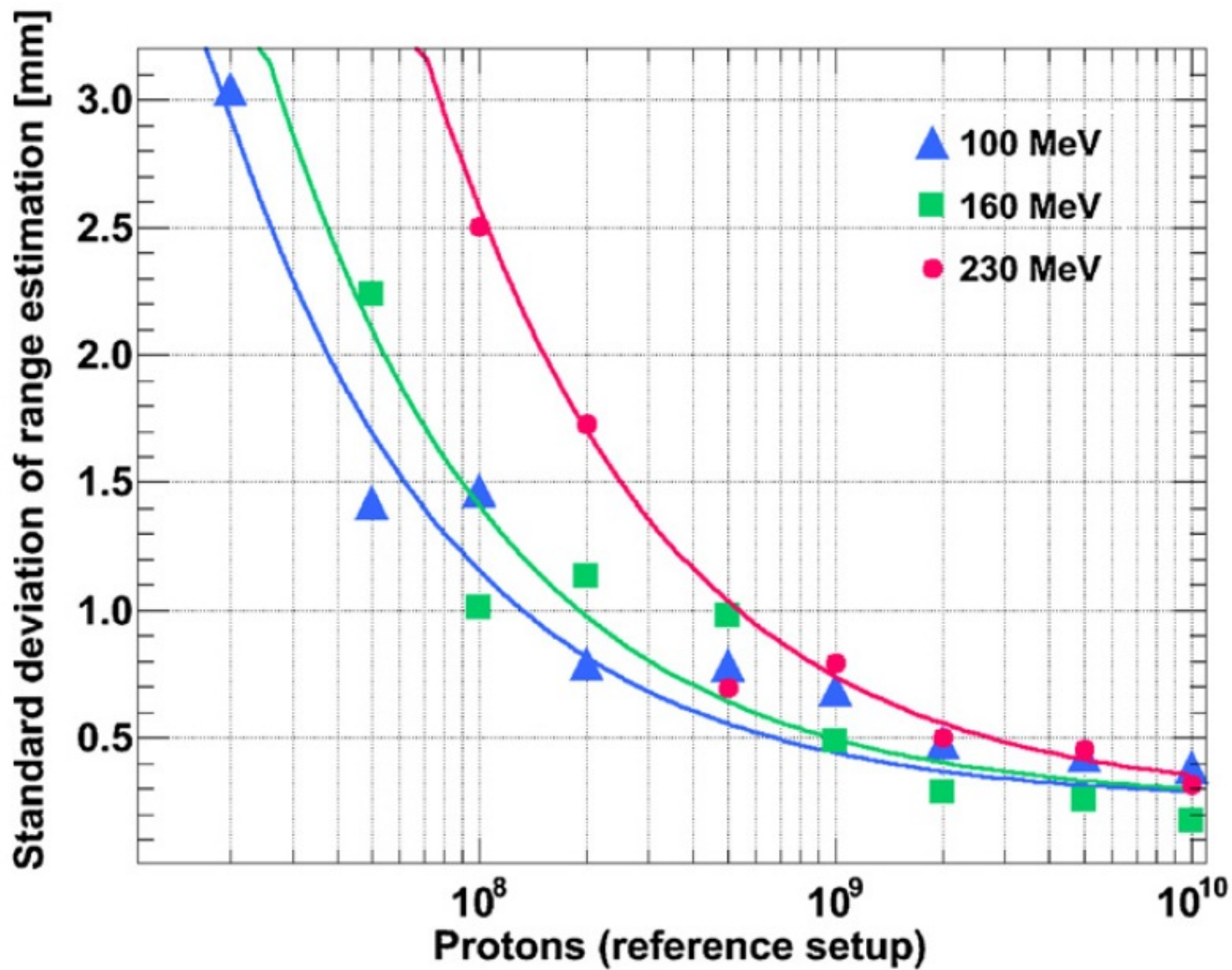
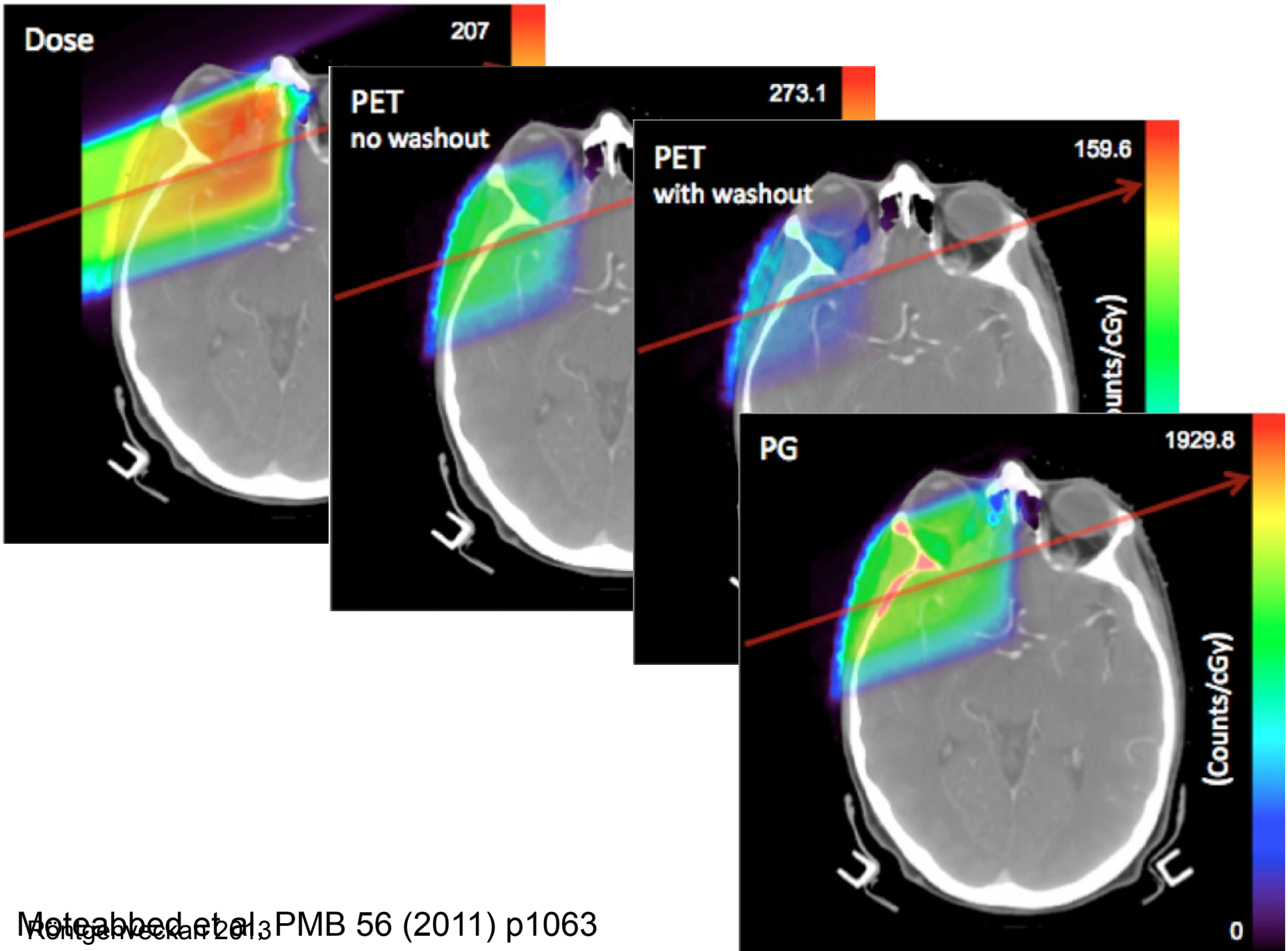


Figure 18. Accuracy of the shift retrieving method as a function of the number of incident protons for pencil beams of 100, 160 and 230 MeV.





Slutsatser:

- Bra radiologi är grunden till framgångsrik radioterapi
- För protonbehandling skärps kraven på radiologin ytterligare
- Skandionkliniken kommer att behöva ett nära samarbete med svensk radiologi!



Röntgenveckan 2013


Skandionkliniken