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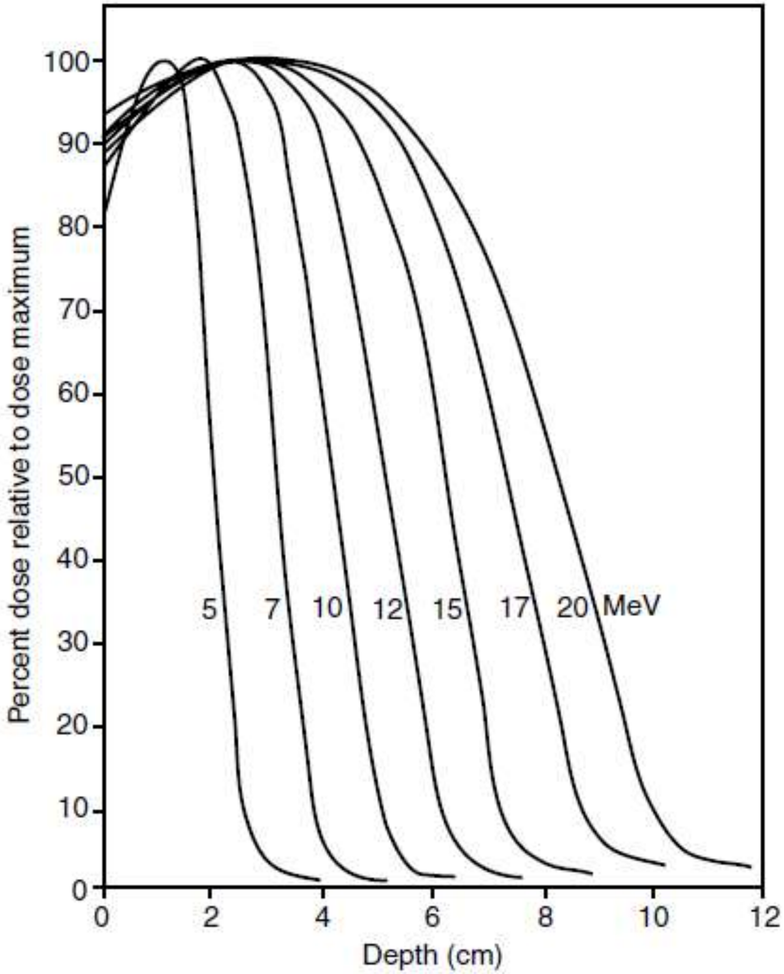
Electron-MRT for Breast Cancer Patients using an add-on Multileaf-Collimator

Elisabetta Gargioni, AK-IMRT, 08.04.2011

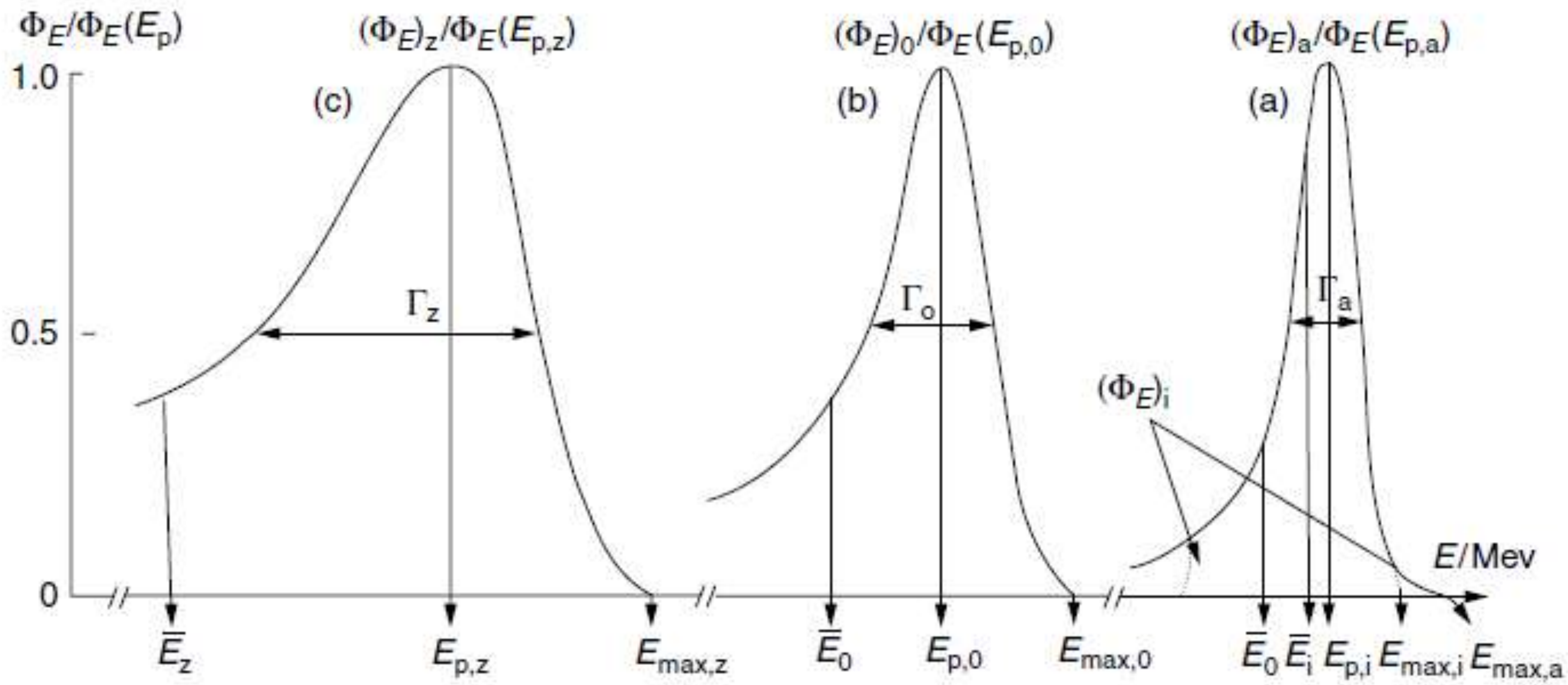
Why electrons?



Treatment of shallow tumours with a homogeneous dose

Minimisation of the dose to distal critical organs

Electrons scatter a lot!



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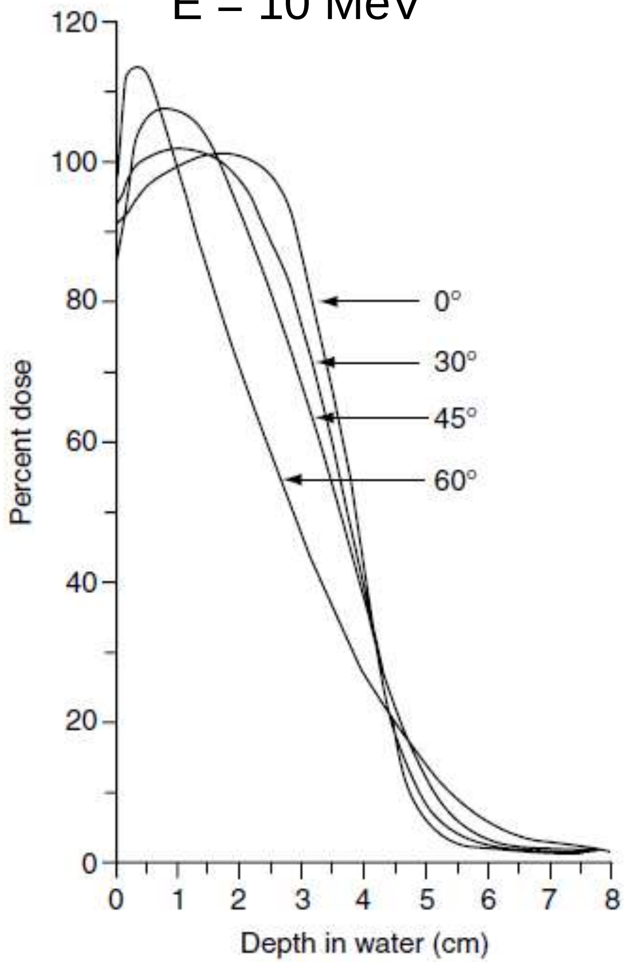
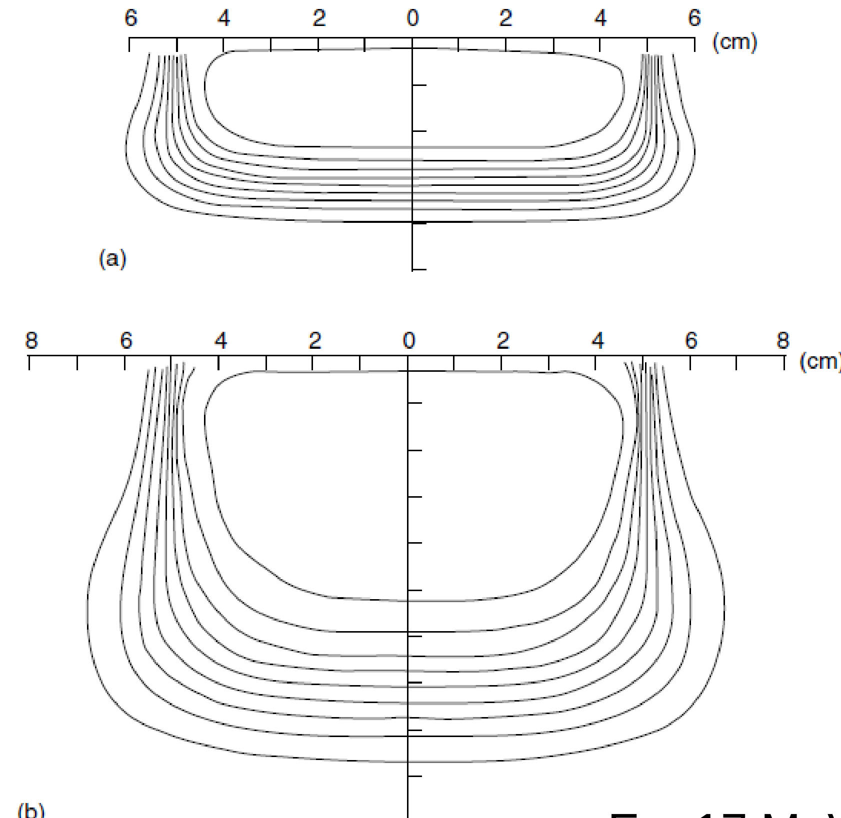
Scattering in air and water

E = 10 MeV



E = 7.5 MeV



E = 17 MeV

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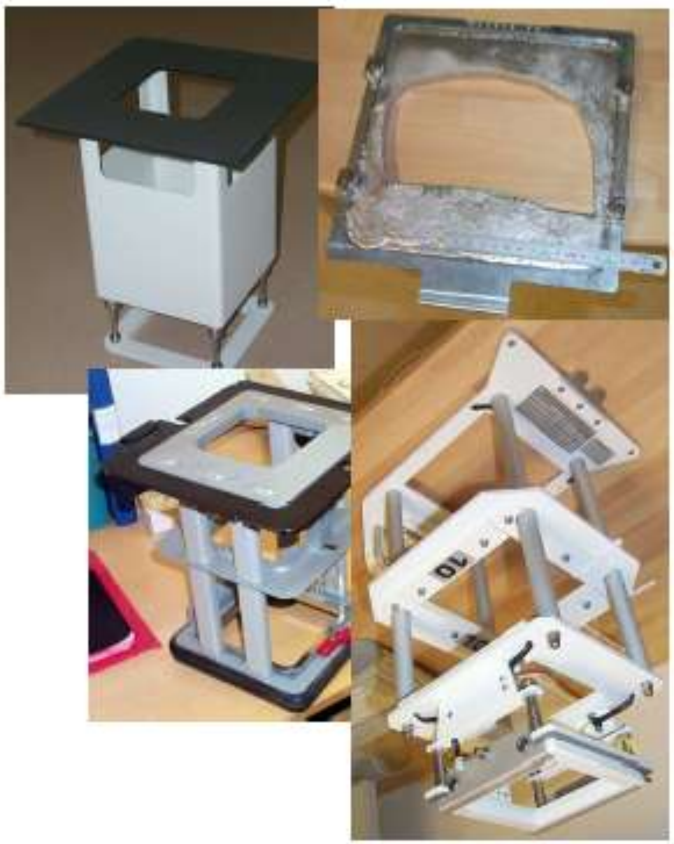
Applicators and cut-outs



Labour intensive (cutouts, bolus,...)

Limited exploitation of depth and lateral conformity potential

Laborious planning and delivery process

No inverse planning nor remote/automatic beam delivery

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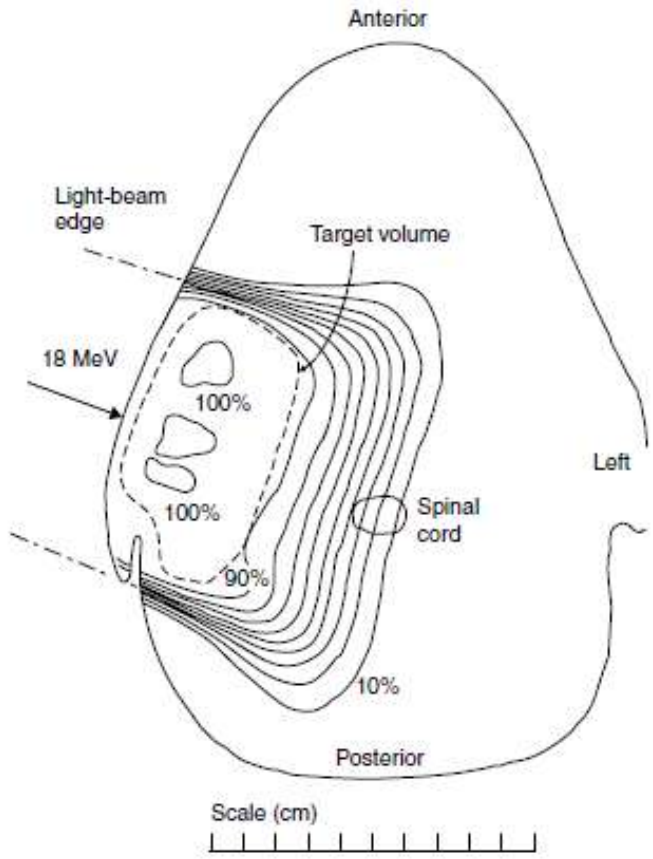
Treatment of shallow tumours – „simple“ case



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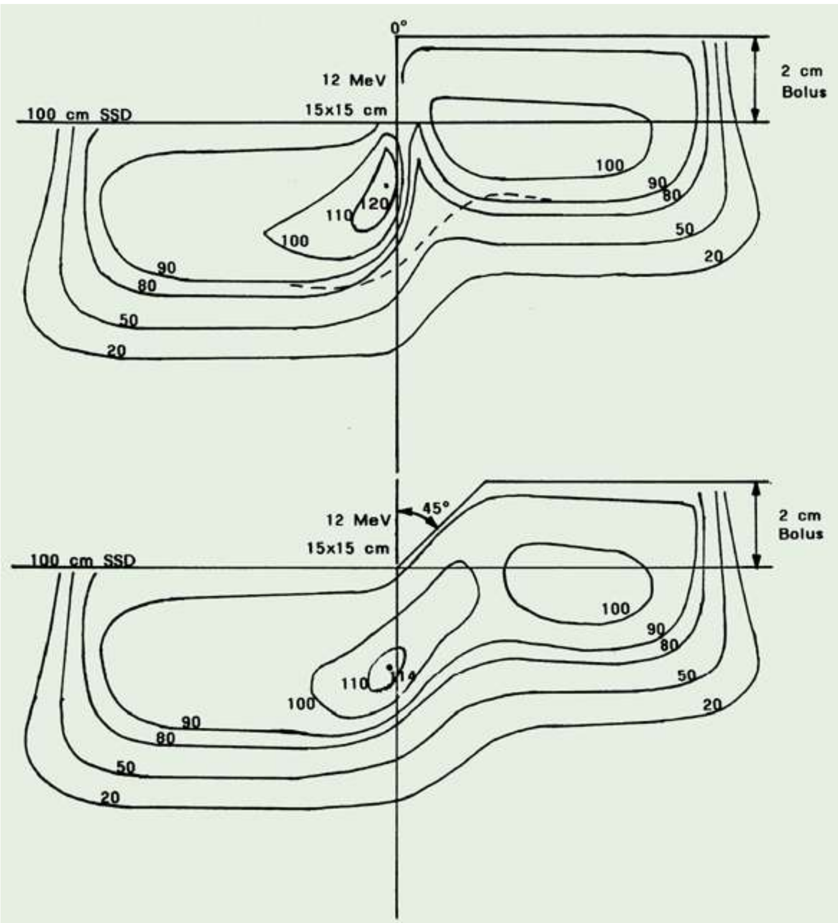
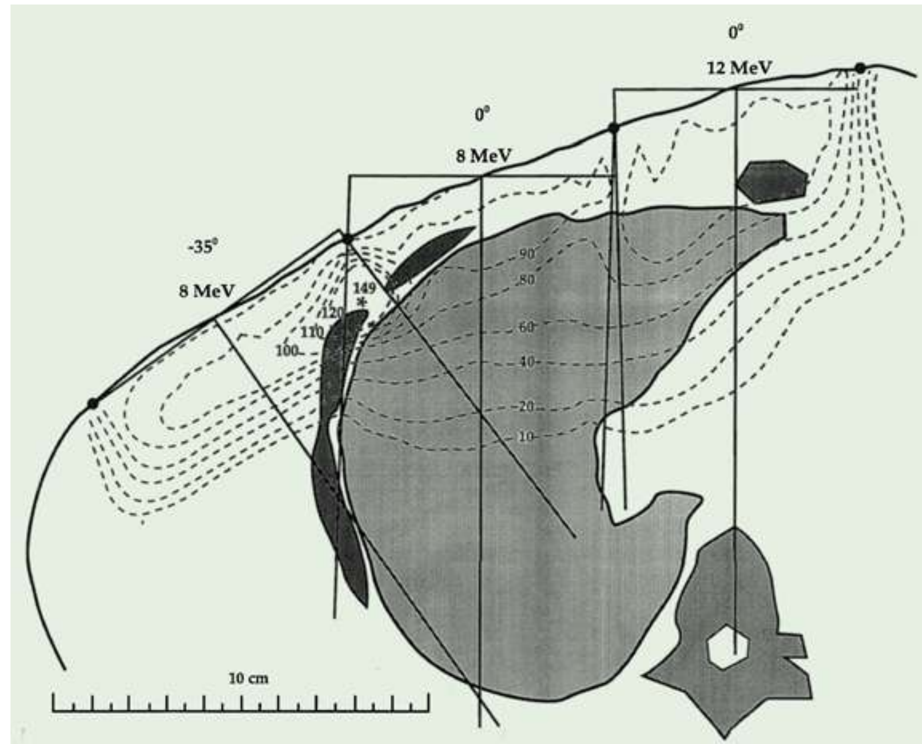
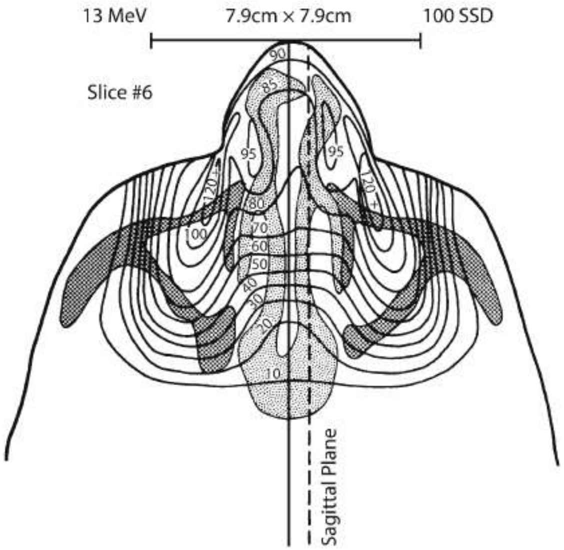
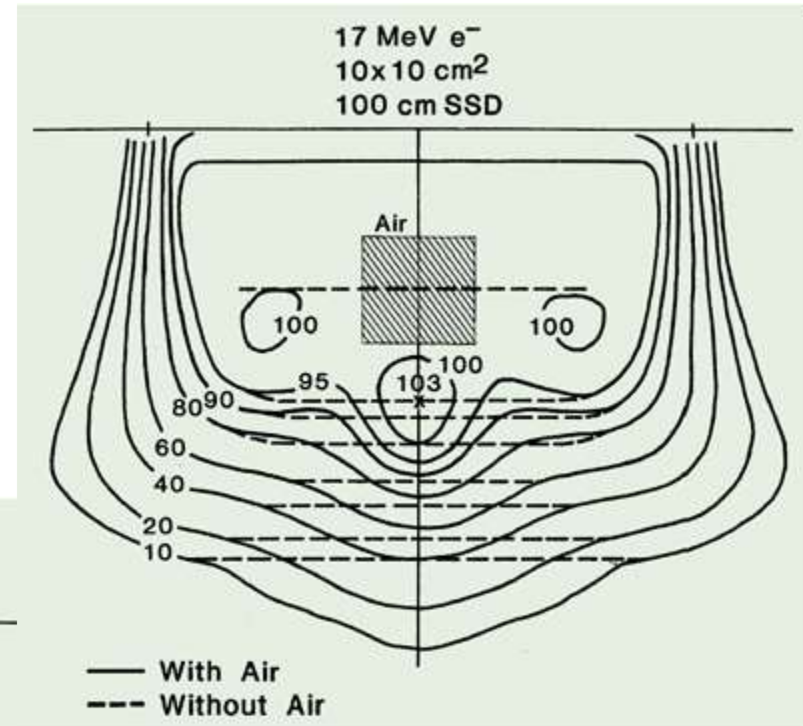
Surface effects

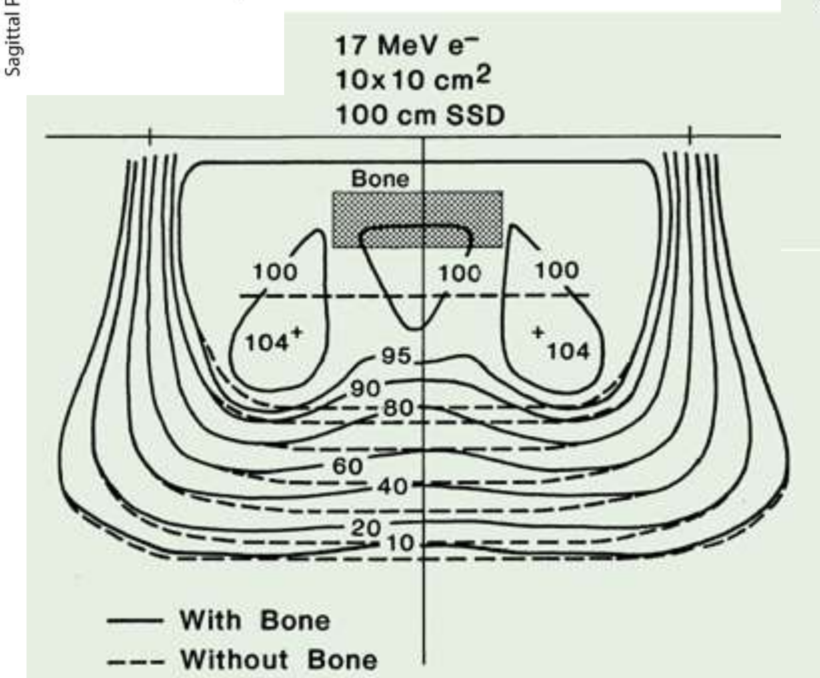




Inhomogenities







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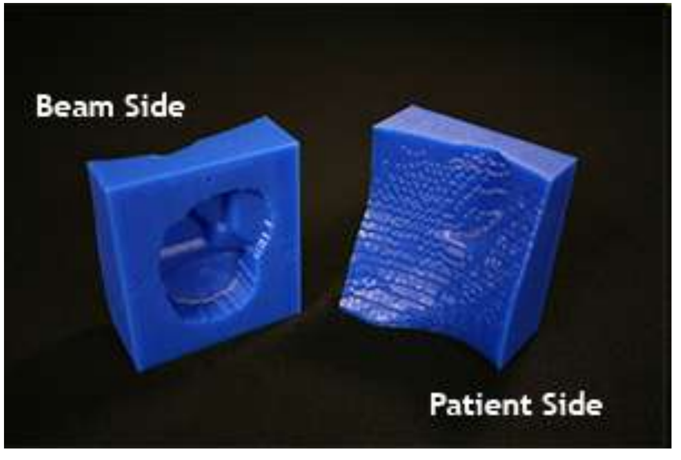
A possible solution

Modulated electron radiotherapy (MERT) to correct scatter perturbation effects and to obtain better conformality via energy and/or intensity modulation



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Clinical benefits of MERT

- General: near-surface targets
- Breast carcinoma:
  - Whole breast and chest wall irradiation
  - Breast irradiation including lymph nodes
  - Integrated tumor boost irradiation
  - Partial breast and partial chest wall irradiation
- Posterior wall sarcoma
- Head-and-neck carcinoma:
  - Pharynx
  - Parotid
- Inguinal lymph nodes

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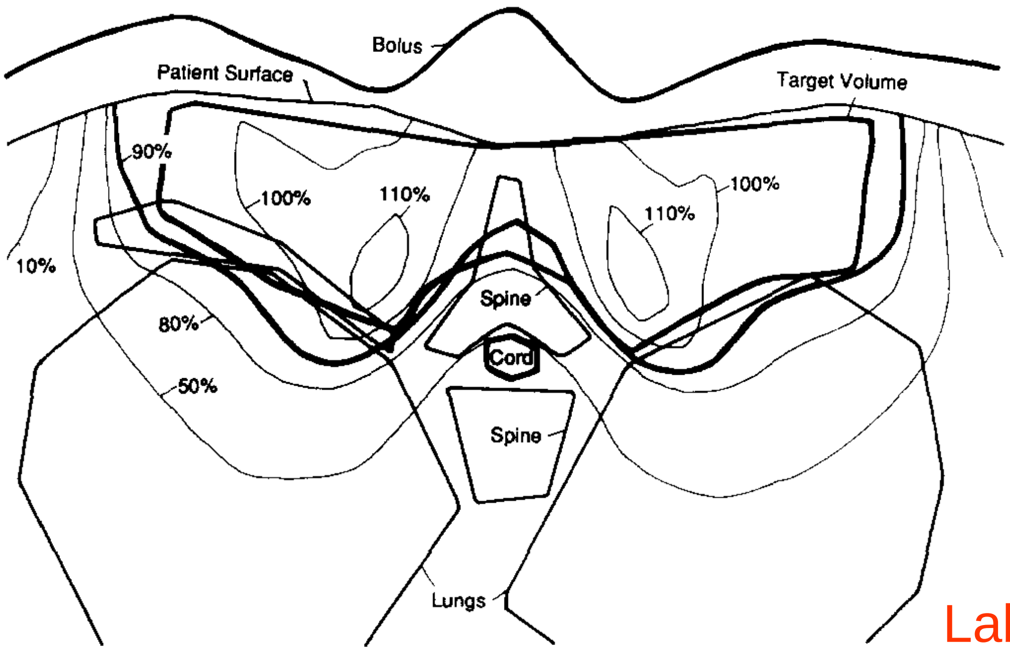
MERT delivery - I

custom fabricated bolus (energy modulation)



Labour intensive

source: Daniel Low et al., Medical Physics (1992)

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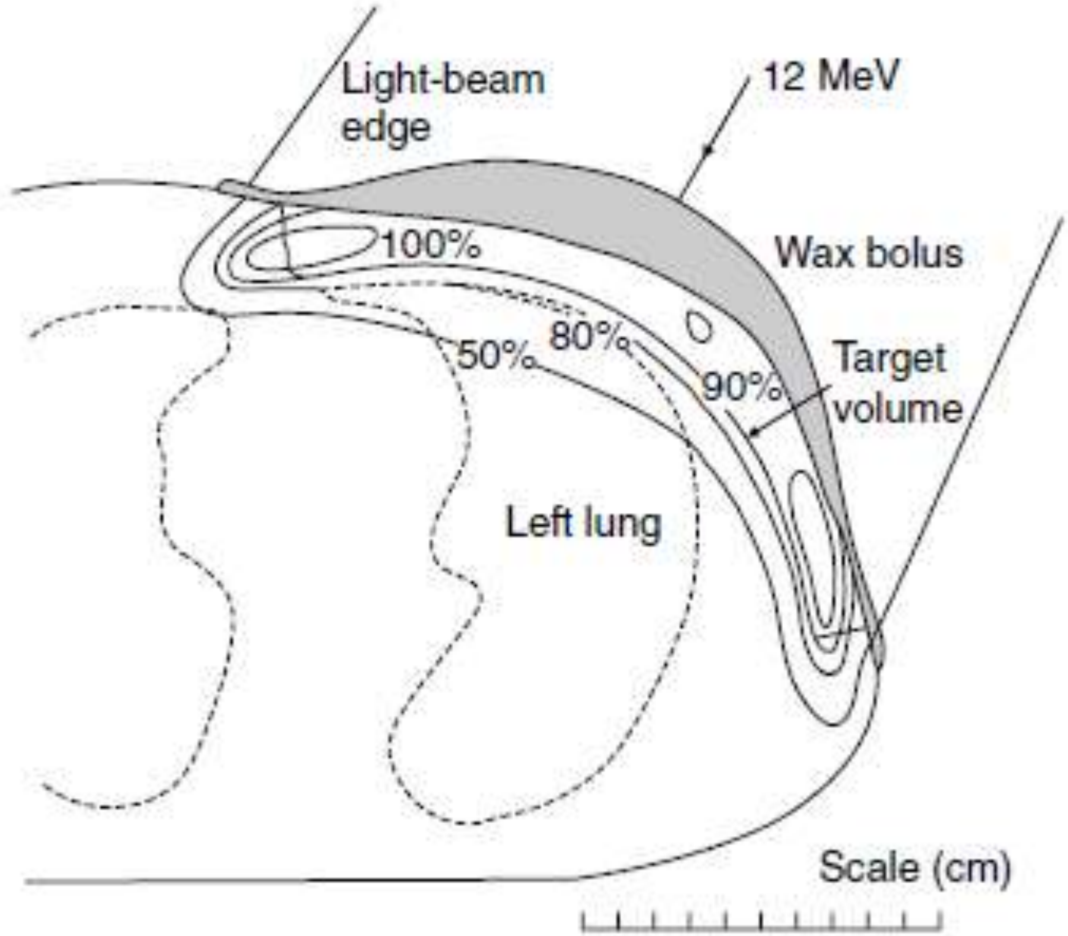
Irregular patient surface



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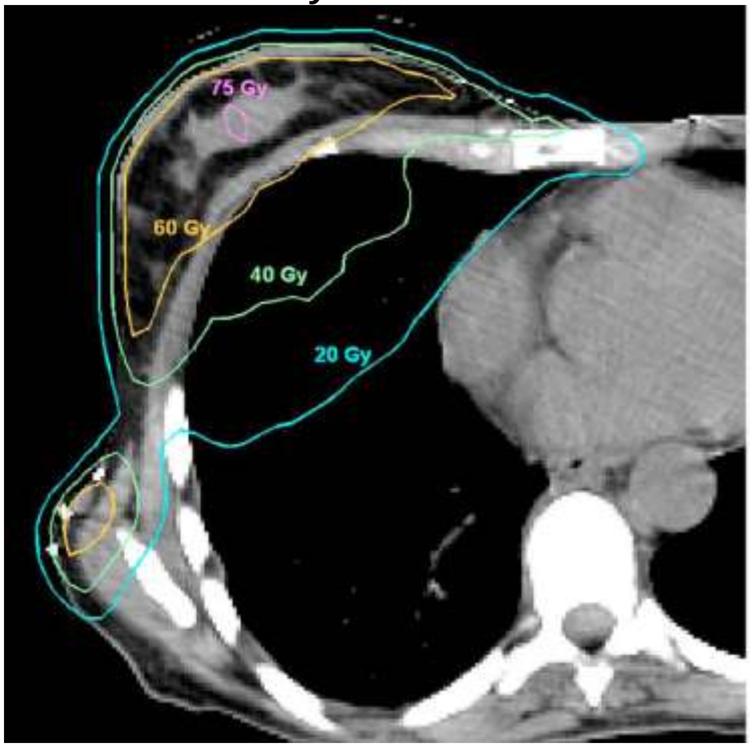
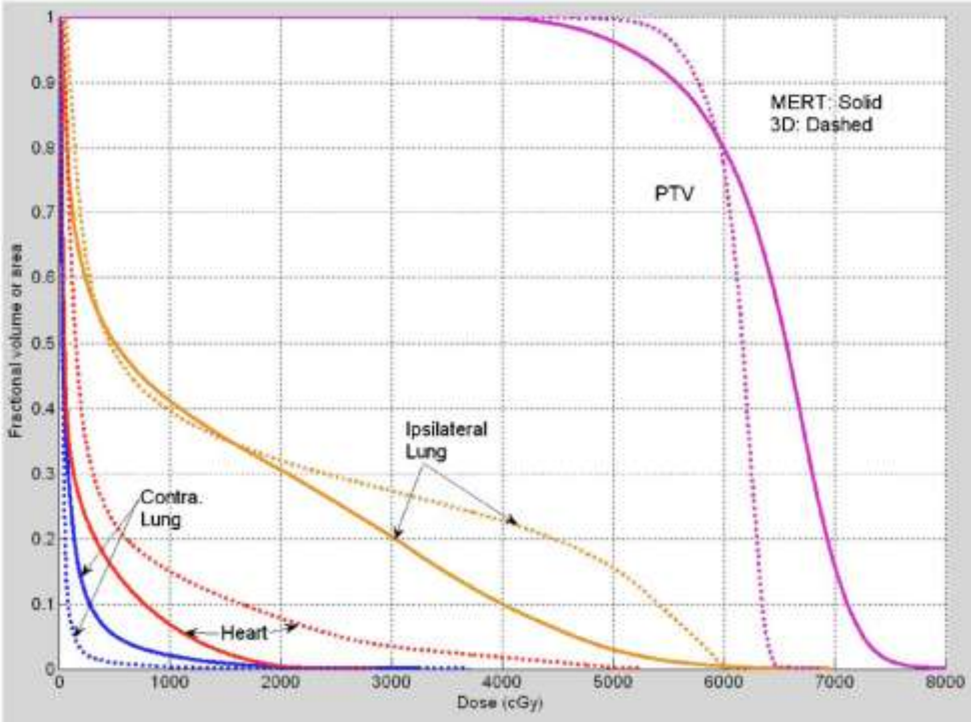
MERT delivery - II

use of a conventional photon-MLC (xMLC)

100% = 60 Gy





source: Murat Surucu et al., Medical Physics (2010)

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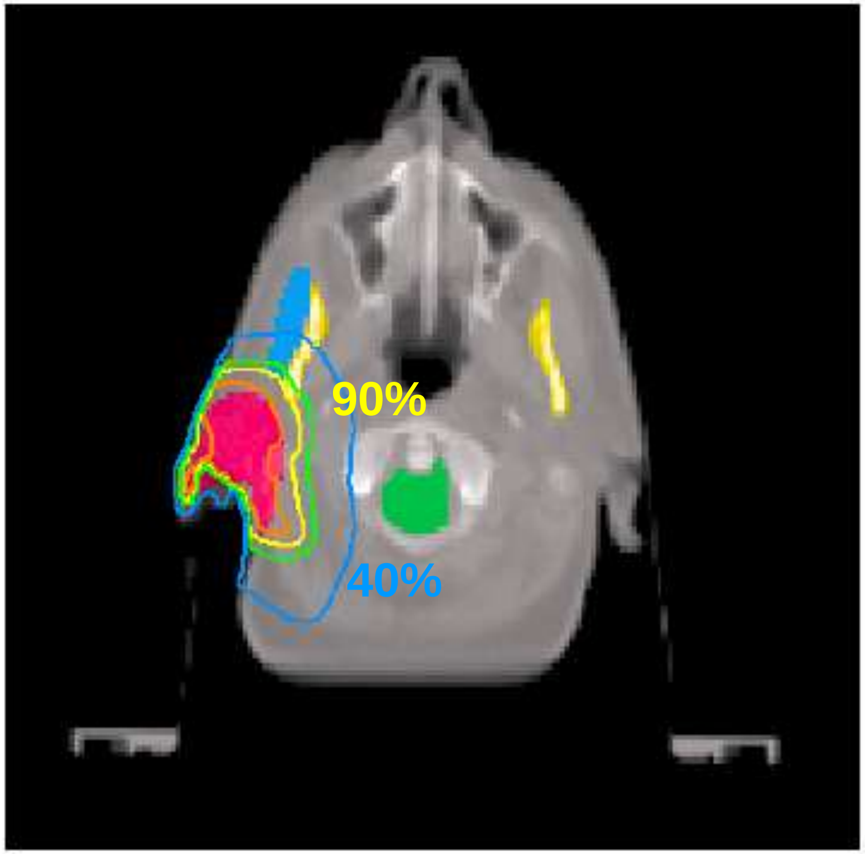
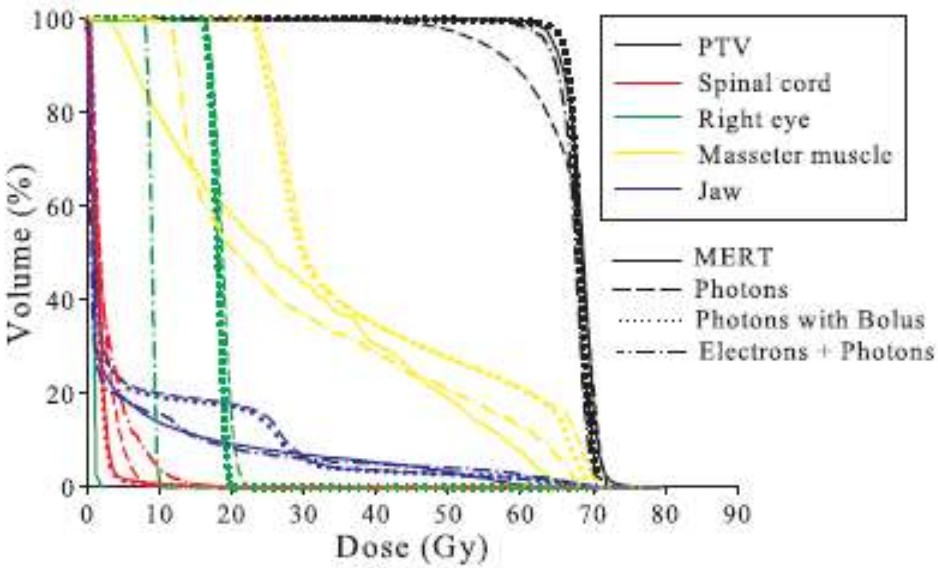
MERT with xMLC

100% = 66 Gy





source: Salguero et al., Physics in Medicine and Biology (2010)

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Using a pMLC…

+	-
… allows to simplify the workflow	… electron scattering → SSD = 60-70 cm
…allows to use a wide range of gantry positions	…too large penumbra
…allows the use of mixed techniques	…same location for e- and X-ray virtual sources

MERT delivery - III

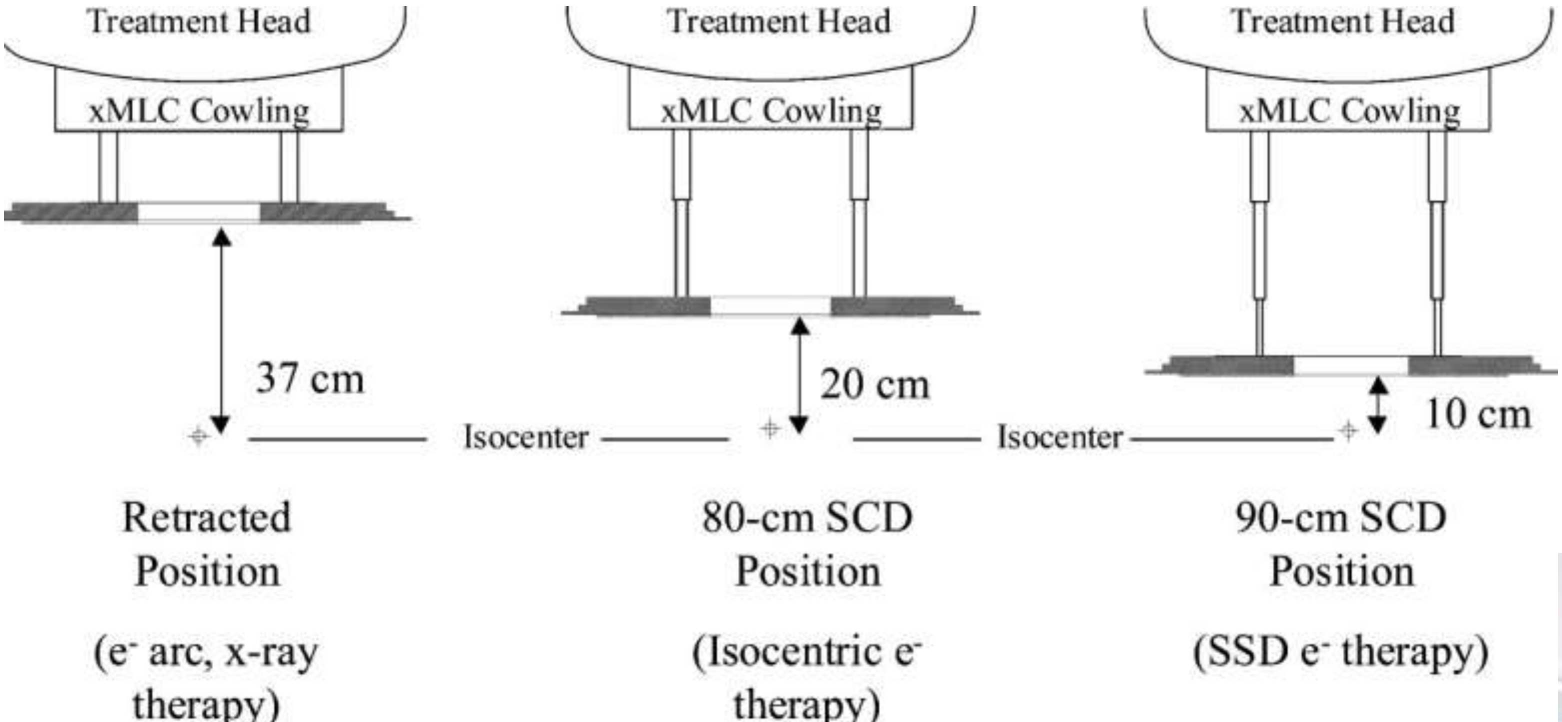
add-on electron MLC:

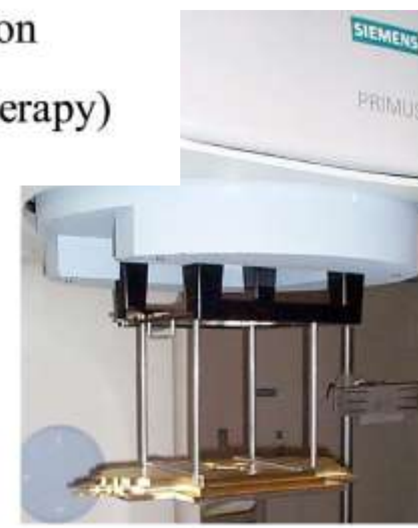
Multiple fields of different energy

Multiple gantry positions

SSD = 100 cm or isocentric treatments

eMLC @ Texas University





source: Kenneth R. Hogstrom et al., Medical Physics (2004)

eMLC @ UKE

euromechanics medical

source: Tobias Gauer, PhD Thesis (2009)

www.euromechanics.com

Motorised and remote controlled

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eMLC @ UKE

- Distance to isocenter: 16 cm
- Max. field dimensions: 21x21 cm^2
- Weight: 25 kg

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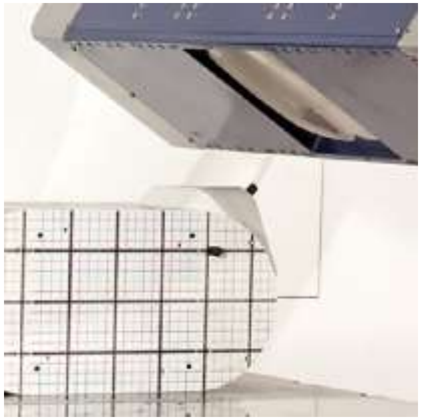
Materials & Methods

TP with Oncentra® Masterplan (Monte Carlo)

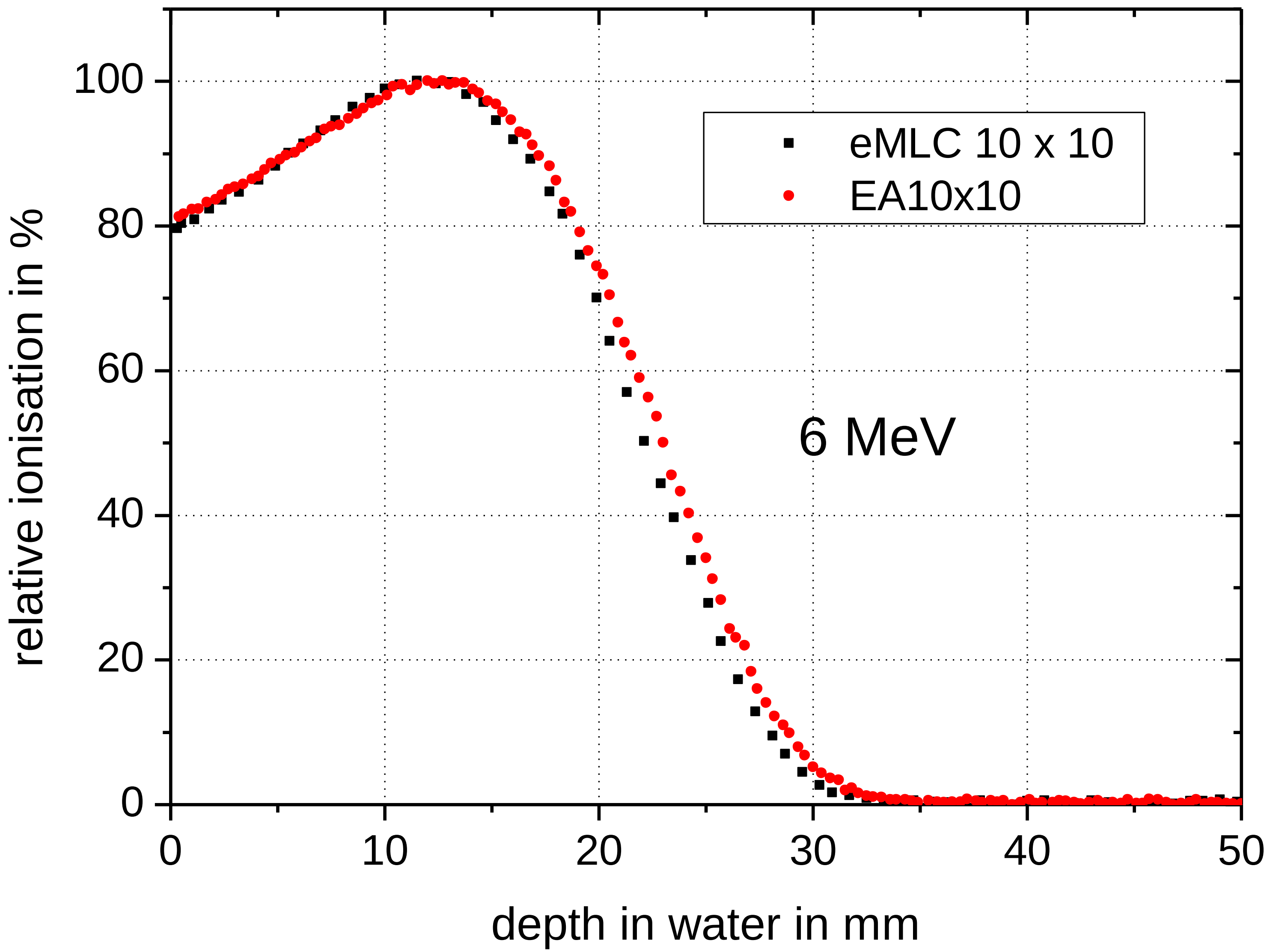
Automatic field shaping and delivery →

- ✓ conventional applicators not needed
- ✓ fast MERT delivery

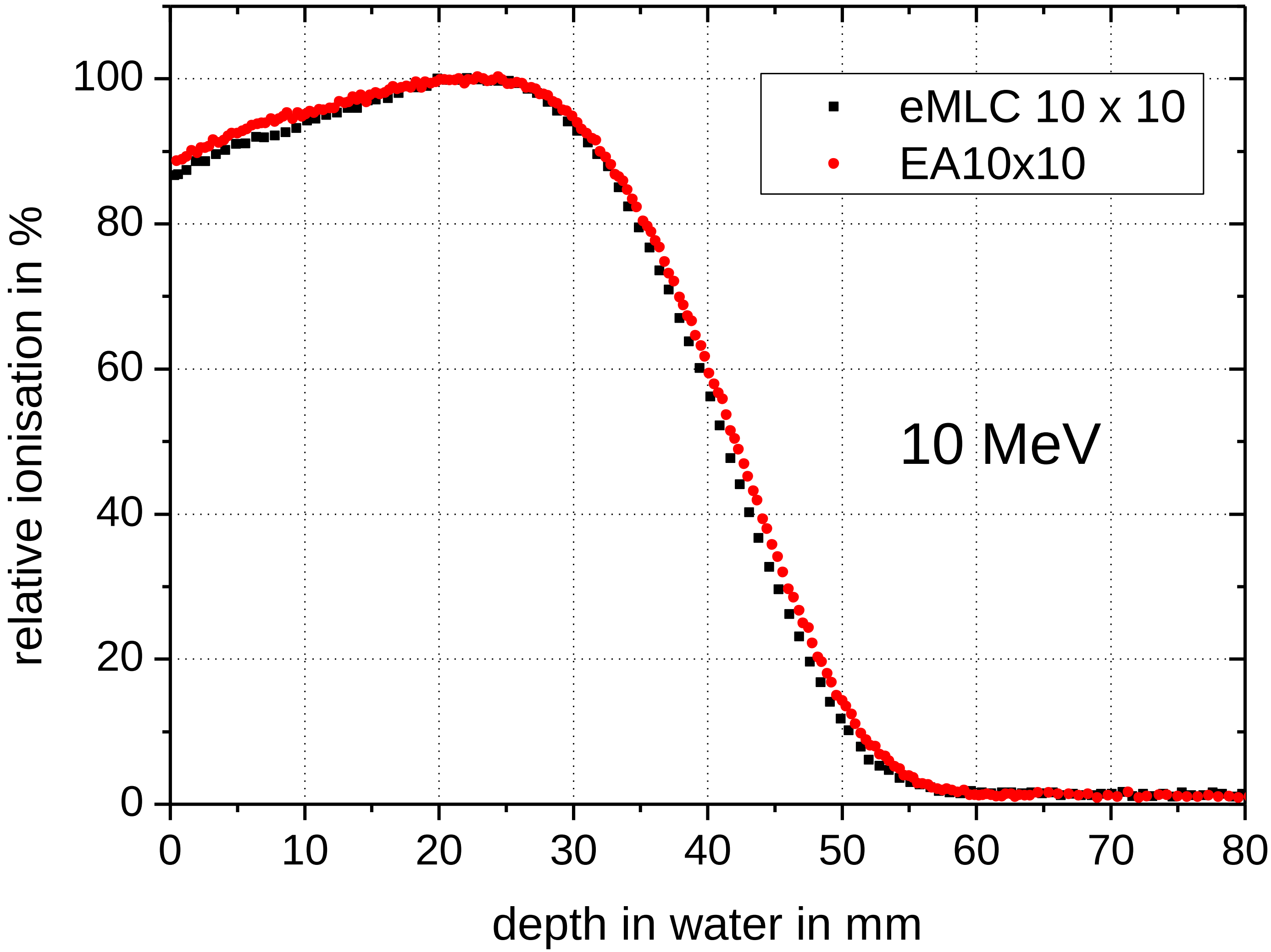
Patient QA with GafChromic films



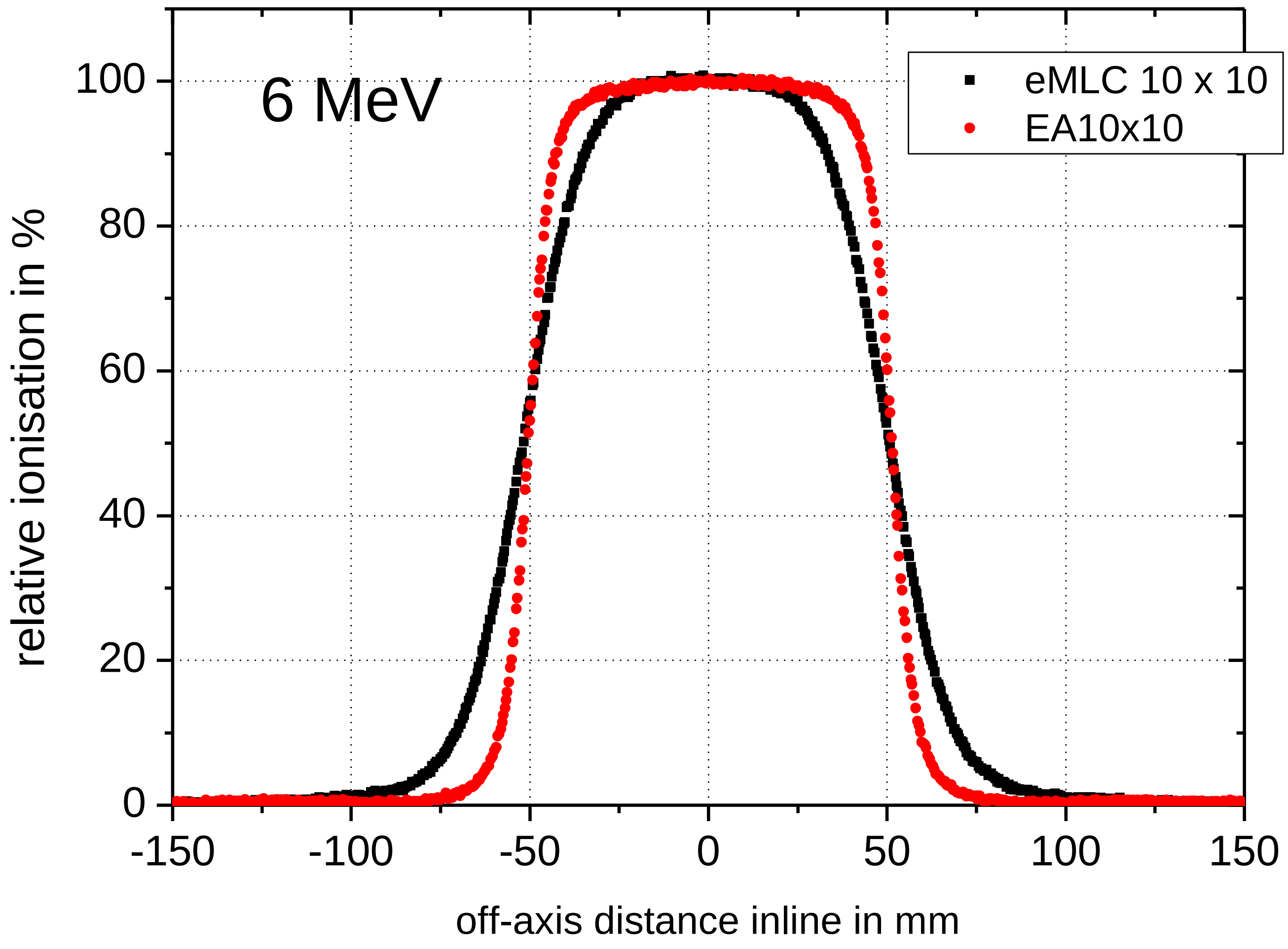
Some results: comparison with standard applicator



… another energy …

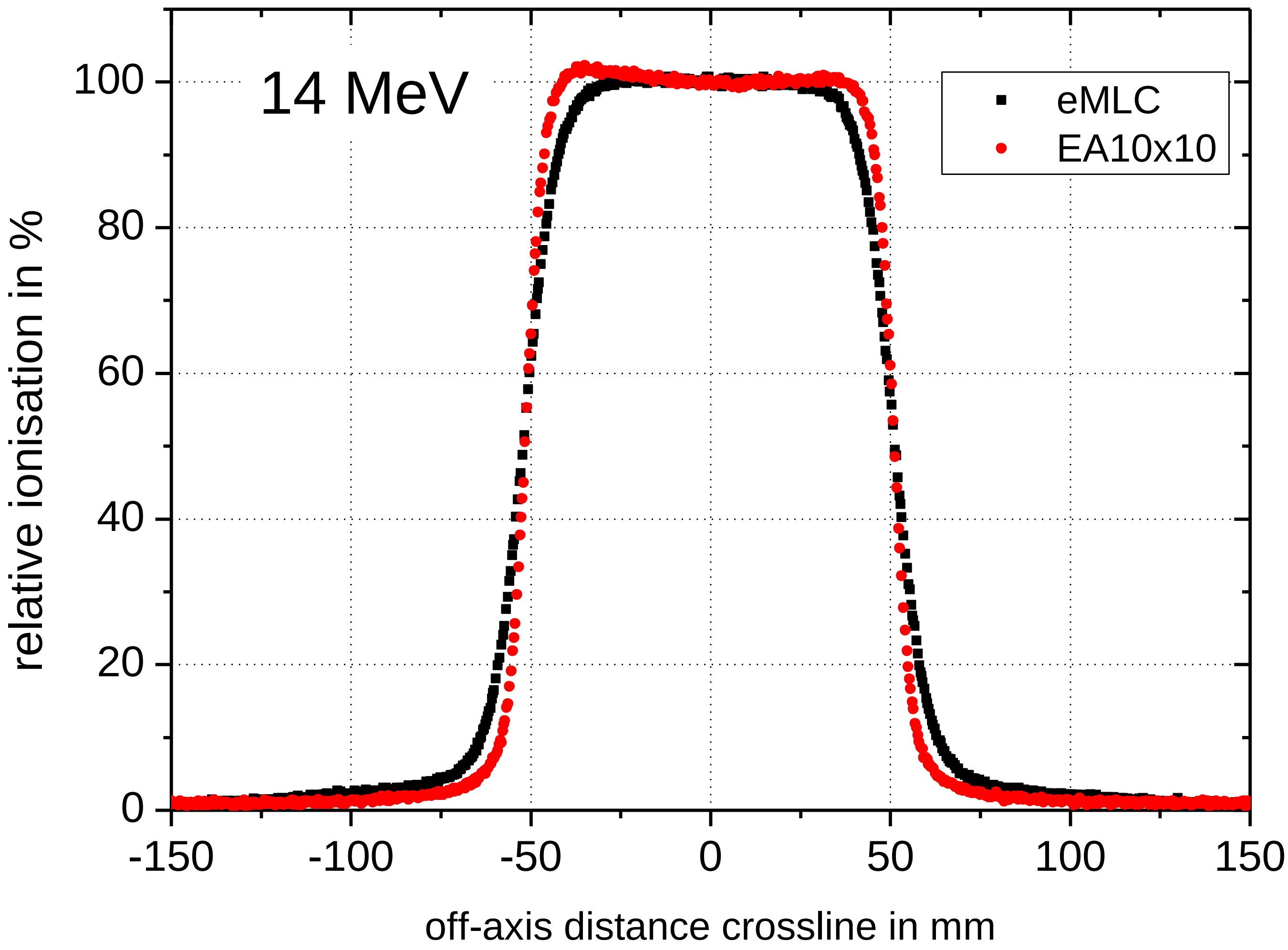


…profiles …



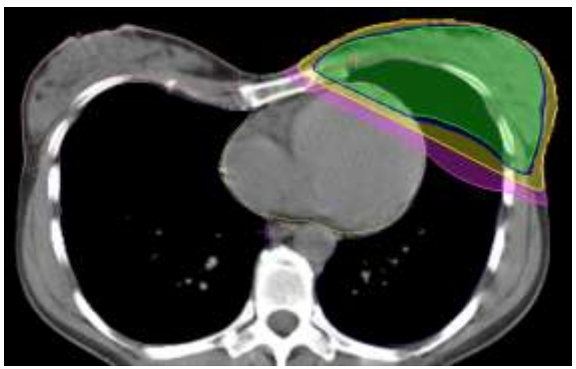
6 MeV
eMLC 10 x 10
EA10x10
relative ionisation in %
0
20
40
60
80
100
-150
-100
-50
0
50
100
150
off-axis distance inline in mm

…another energy

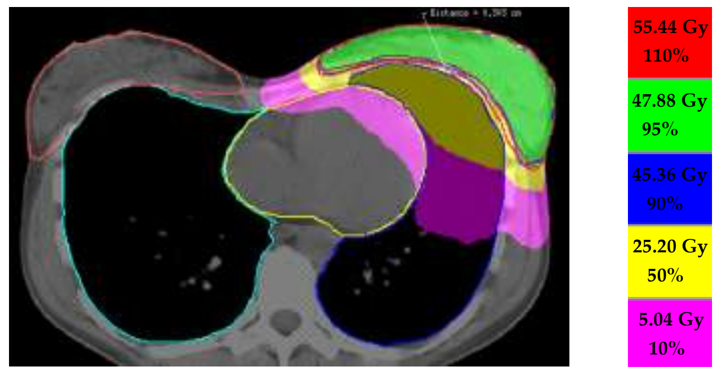


eMLC: towards clinical applications

Proposal for a clinical study:
Left breast and chest wall



Conventional photon treatment



MERT

Risk of a cardiac desease after left-side irradiation of breast / chest wall

Risk of heart infarction significantly increases 15 years after irradiation
→ Long term studies

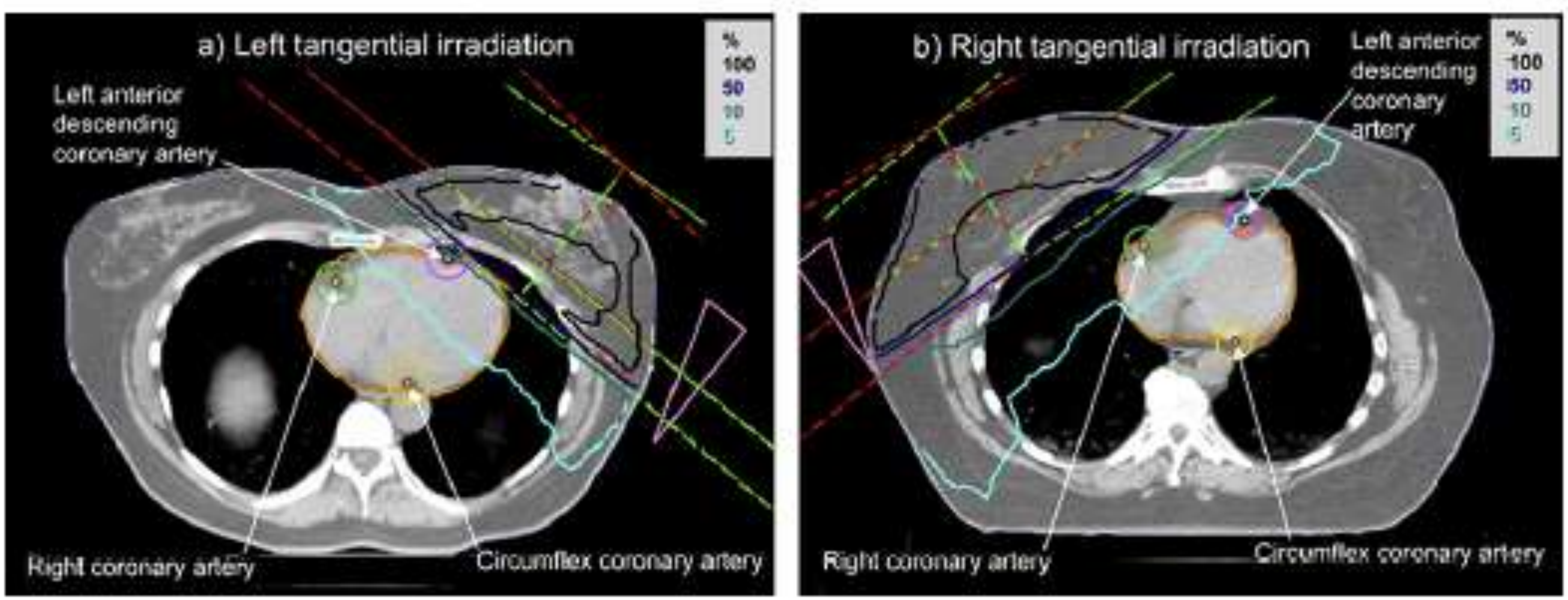
Data from 1970: risk 16% higher for left-side irradiations
→ Cardiac radiation dose plays an important role

What can we expect today?

Heart toxicity assessment:
Important structures?

Breast and chest wall

LAD coronary artery ist mostly affected by arterioscleroses
→what happens after irradiation?



GHD = 40 Gy, ED = 2,67 Gy

source: C.W. Taylor *et al.*, Int. J. Radiat. Oncology Biol. Phys. (2007, 2008)

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Plan studies show…

CLINICAL INVESTIGATION

CARDIAC DOSE FROM TANGENTIAL BREAST CANCER RADIOTHERAPY IN THE YEAR 2006

Carolyn W. Taylor, F.R.C.R.,[*] Julie M. Povall, M.Sc.,[†] Paul McGale, Ph.D.,[*]
Andrew Nisbet, Ph.D.,[‡] David Dodwell, M.D.,[†] Jonathan T. Smith, F.R.C.R.,[†]
and Sarah C. Darby, Ph.D.[*]

Table 1. Mean and maximum doses to the heart and three main coronary arteries from tangential pair radiotherapy

	Heart	LAD coronary artery	Right coronary artery	Circumflex coronary artery
Average mean dose (SD)* (Gy)				
Left-sided irradiation	2.3 (0.7)†	7.6 (4.5)†	2.0 (0.3)	1.8 (0.3)
Right-sided irradiation	1.5 (0.2)	1.6 (0.2)	2.0 (0.3)	1.2 (0.1)
Average maximum dose (SD)* (Gy)				
Left-sided irradiation	30.7 (10.8)†	35.2 (8.8)†	2.5 (0.3)	2.4 (0.4)
Right-sided irradiation	2.6 (0.3)	1.9 (0.2)	2.5 (0.4)	1.5 (0.2)

What happened in the past?

Decrease of cardiac dose from 1970

Table 2. Reduction in mean dose to cardiac structures from left tangential radiotherapy, 1970s–2006

Calendar period	Heart	LAD coronary artery	Right coronary artery	Circumflex coronary artery
Mean dose (Gy)				
1970s (Sweden) (4)	13.3	31.8	9.1	6.9
1990s (Sweden) (4)	4.7	21.9	2.0	2.8
2006 (United Kingdom)	2.3	7.6	2.0	1.8
Mean dose (% tumor dose)				
1970s (Sweden) (4)	26.6	63.6	18.2	13.8
1990s (Sweden) (4)	9.4	43.8	4.0	5.6
2006 (United Kingdom)	5.8	19.0	5.0	4.5

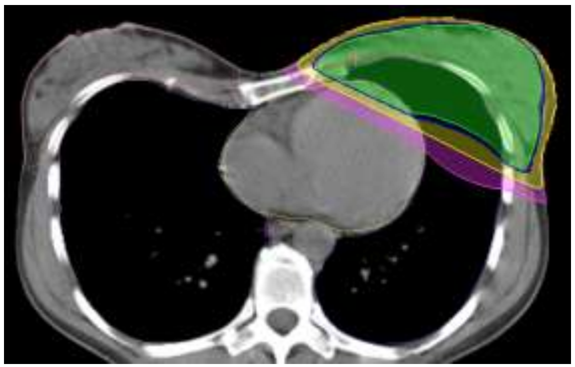
Improvement of irradiation techniques in the last 10-15 years allowed for dose reduction to heart and lungs

However: combined radio-chemotherapy, in some cases increase of risk

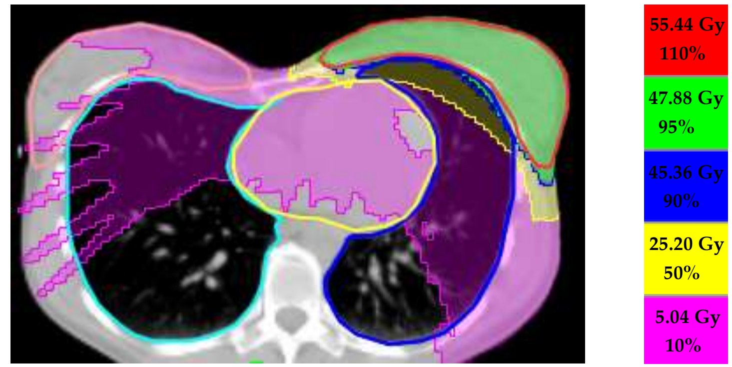
Application of an IMRT-technique can further reduce cardiac toxicity

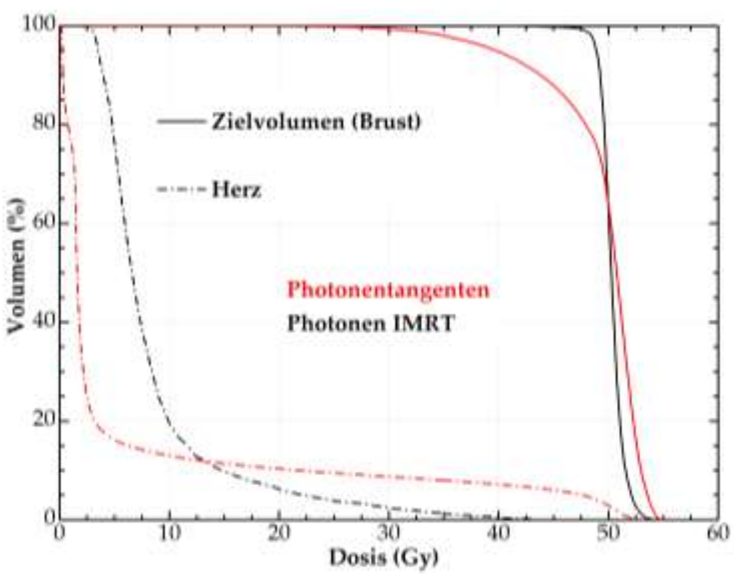
Photon-IMRT vs Tangent

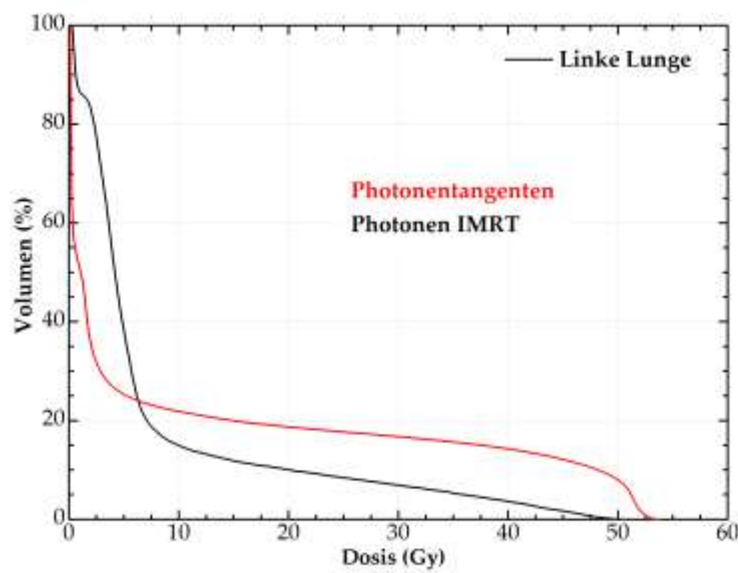
Standard (Photons)



Photon IMRT





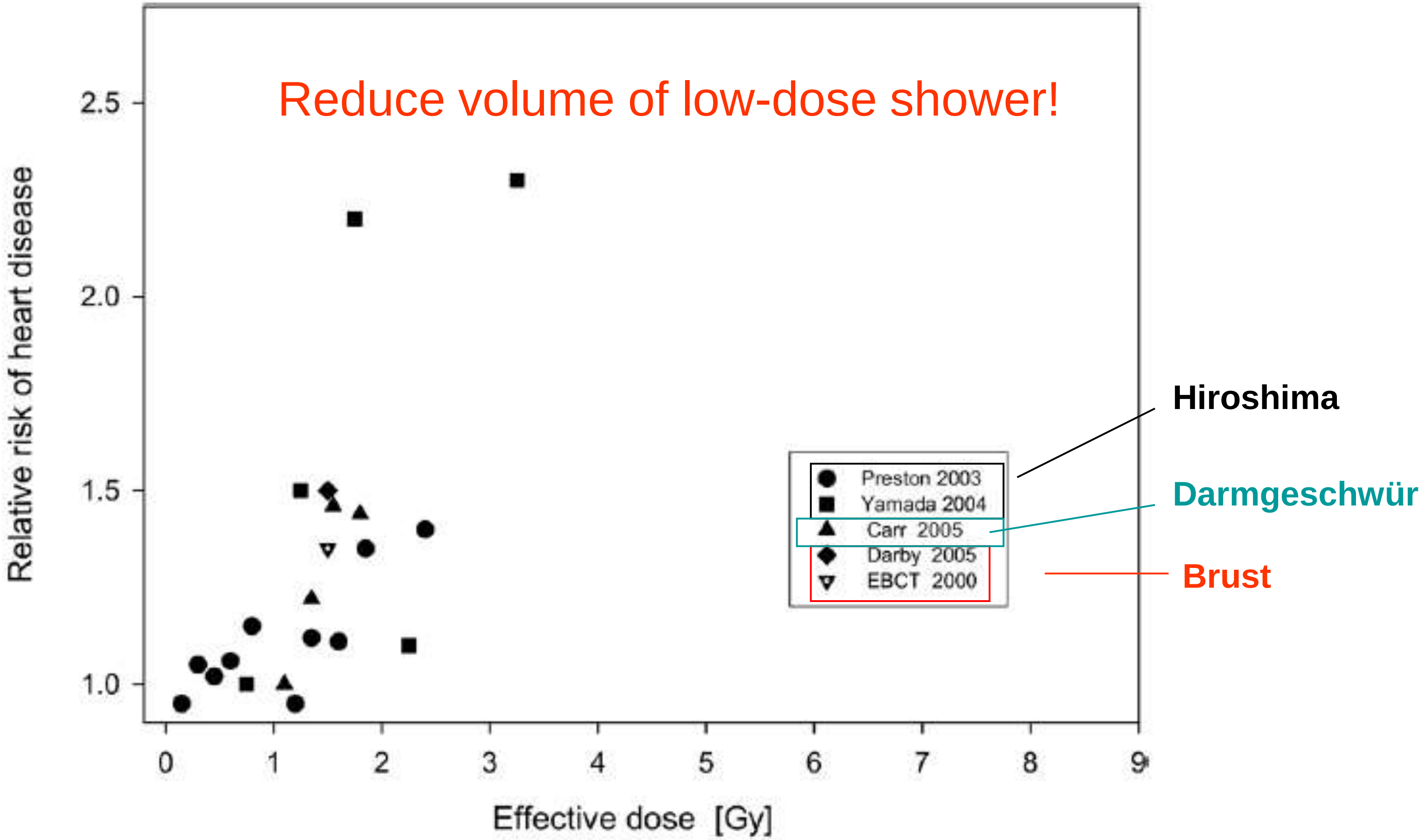


Photon-IMRT vs Tangent

Risk structure partial dose volume	Mean (Gy)	Median (Gy)	Maximum (Gy)	Dose to 60% of volume (Gy)	Dose to 30% of volume (Gy)
Heart					
IMRT	8.52 ± 1.08	6.44 ± 1.02	35.5 ± 4.33	5.91 ± 1.68	9.22 ± 2.21
3D-CRT	6.85 ± 2.51	2.77 ± 0.64	49.56 ± 1.43	2.8 ± 0.59	3.63 ± 0.97
Left ventricle					
IMRT	9.7 ± 2	7.86 ± 2.27	33.97 ± 3.9	6.77 ± 2.04	11.08 ± 3.29
3D-CRT	10.86 ± 4.12	3.75 ± 1.66	49.14 ± 1.24	3.17 ± 0.97	6.22 ± 3.48
Right breast					
IMRT	5.4 ± 1.18	4.4 ± 0.91	23.39 ± 4.95	4 ± 0.99	5.75 ± 1.53
3D-CRT	1.15 ± 0.76	0.61 ± 0.7	18.82 ± 17.52	0.37 ± 0.6	1.26 ± 1.08
Right lung					
IMRT	4.24 ± 1.26	3.22 ± 1.23	19.89 ± 5.92	2.70 ± 1.27	5.52 ± 1.64
3D-CRT	0.45 ± 0.15	0.08 ± 0.02	3.99 ± 1.23	0.06 ± 0.05	0.32 ± 0.42
Left lung					
IMRT	9.84 ± 1.35	6 ± 1.68	42.37 ± 2.4	4.58 ± 1.23	10.1 ± 2.97
3D-CRT	8.36 ± 3.13	2.5 ± 0.57	51.8 ± 1.68	2.15 ± 0.5	4.15 ± 1.48
Spinal cord					
IMRT	1.26 ± 0.86	8.1 ± 25.5	4.22 ± 1.9	0.75 ± 0.64	1.59 ± 0.95
3D-CRT	0.25 ± 0.43	0.16 ± 0.24	1.4 ± 1.67	0.1 ± 0.15	0.3 ± 0.75

source: F. Lohr *et al.*, Int. J. Radiat. Oncology. Biol. Phys. (2008)

„A little to a lot…or a lot to a little?“



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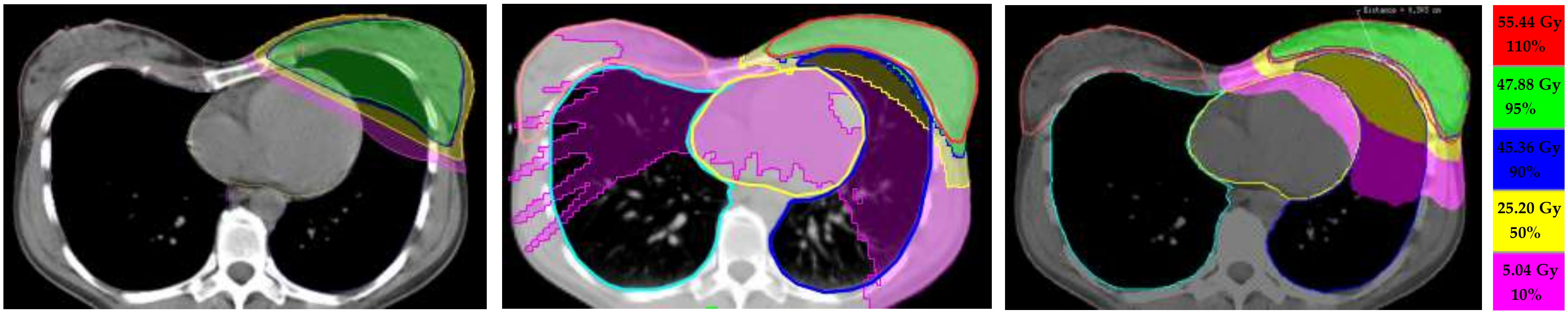
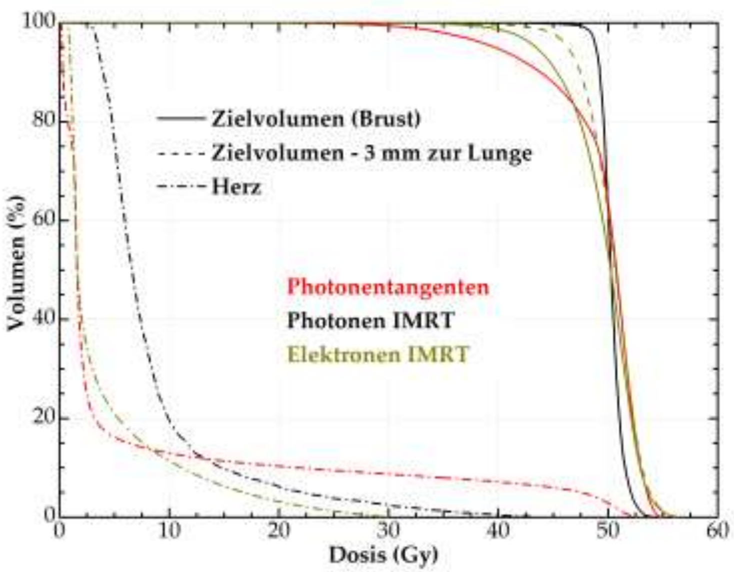
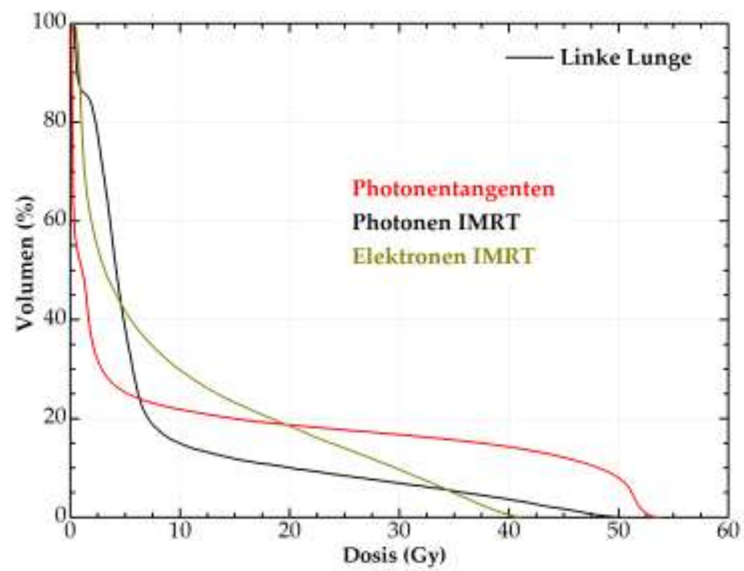
Quelle: S. Schultz-Hector & K.-R. Trott, Int. J. Radiat. Oncology Biol. Phys. (2007)

First results (plan feasibility)

Standard (Photonen) | **Photonen IMRT** | **Elektronen IMRT**





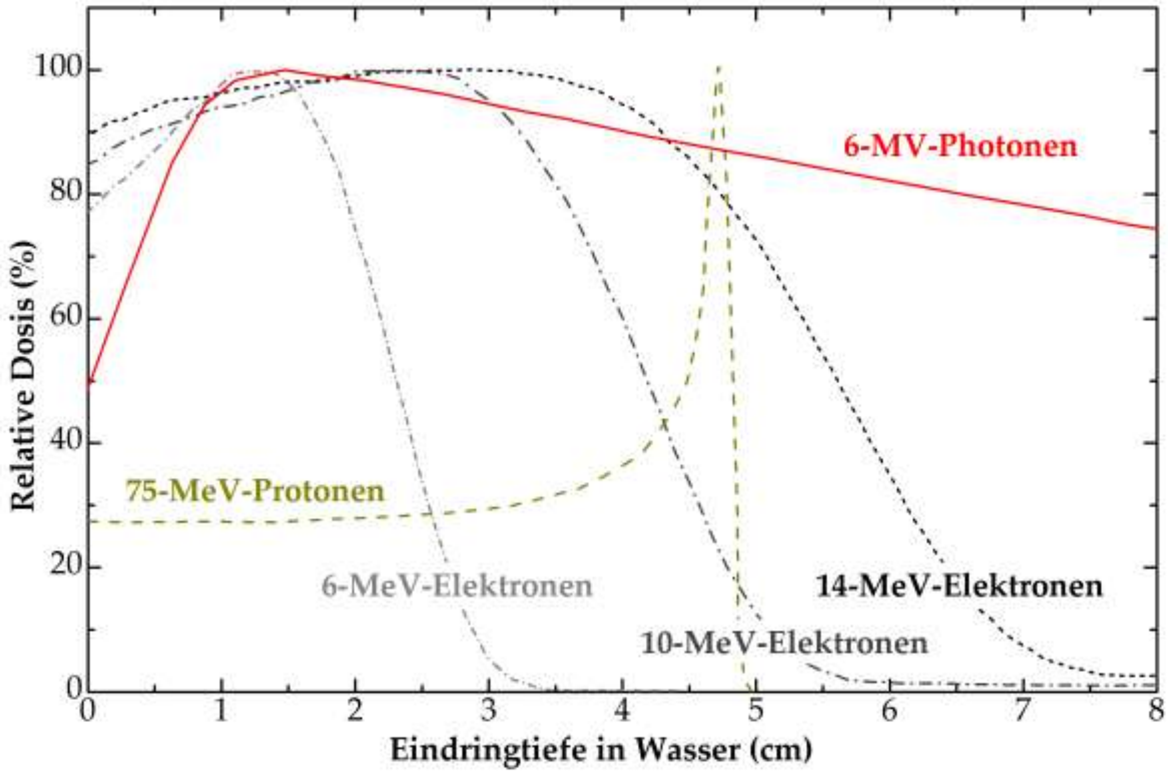


Advantages of MERT

Tumour		Whole breast			Chest wall + Lymph nodes		
Beam technique		Photon CRT	Photon IMRT	Electron IMRT	Photon CRT	Photon IMRT	Electron IMRT
PTV	D_{mean} (Gy)	49.5	50.3	49.6	47.6	50.7	50.2
	D_{max} (Gy)	54.1	52.8	54.8	55.3	54.3	54.8
	$V_{95\%}$ (%)	80.1	99.0	76.8	65.0	99.1	81.8
PTV 2	D_{mean} (Gy)	–	–	50.4	47.3	50.2	49.7
	D_{max} (Gy)	–	–	54.8	52.5	52.7	54.5
	$V_{95\%}$ (%)	–	–	87.0	72.2	96.0	75.1
Lung (ipsi)	D_{mean} (Gy)	9.8	7.5	9.1	9.0	8.2	10.9
	D_{max} (Gy)	52.1	45.5	38.6	52.5	45.7	42.6
	$V_{45\,Gy}$ (%)	12.1	1.7	0	7.6	1.8	0.6
	$V_{20\,Gy}$ (%)	18.7	10.1	18.5	14.3	10.1	19.9
	$V_{5\,Gy}$ (%)	25.3	38.2	41.8	27.7	54.4	51.6
Lung (contra)	D_{mean} (Gy)	0.2	4.8	0.7	1.0	6.5	2.3
	D_{max} (Gy)	1.5	15.0	2.3	2.1	19.8	15.0
	$V_{45\,Gy}$ (%)	0	0	0	0	0	0
	$V_{20\,Gy}$ (%)	0	0.3	0	0.3	1.4	0.9
	$V_{5\,Gy}$ (%)	0.0	41.9	0.2	0.9	55.8	7.2
Breast (contra)	D_{mean} (Gy)	0.8	4.9	0.9	1.3	5.2	2.3
	D_{max} (Gy)	1.9	11.7	4.1	3.5	10.9	22.0
	$V_{45\,Gy}$ (%)	0	0	0	0	0	0
	$V_{20\,Gy}$ (%)	0	0	0	0.2	0	1.8
	$V_{5\,Gy}$ (%)	0	32.1	0.6	0.6	43.3	7.7
Heart	D_{mean} (Gy)	6.3	8.5	4.1	4.7	9.1	5.5
	D_{max} (Gy)	51.0	33.8	24.2	44.1	30.2	24.8
	$V_{45\,Gy}$ (%)	6.0	0	0	1.5	0	0
	$V_{20\,Gy}$ (%)	10.3	6.2	3.2	5.7	5.3	3.9
	$V_{5\,Gy}$ (%)	16.2	76.3	21.5	15.1	85.1	33.5
Healthy tissue	D_{mean} (Gy)	2.3	4.3	2.4	3.1	4.8	3.5
	D_{max} (Gy)	49.8	38.1	33.5	45.5	38.3	37.8
	$V_{45\,Gy}$ (%)	2.3	0.9	0.1	1.6	0.8	0.4
	$V_{20\,Gy}$ (%)	4.1	4.0	3.7	4.3	4.8	4.9
	$V_{5\,Gy}$ (%)	5.8	26.6	9.3	8.7	30.9	13.7

source: T. Gauer *et al.*, Radiotherapy and Oncology (2010)

Skin dose: drawback of MERT?



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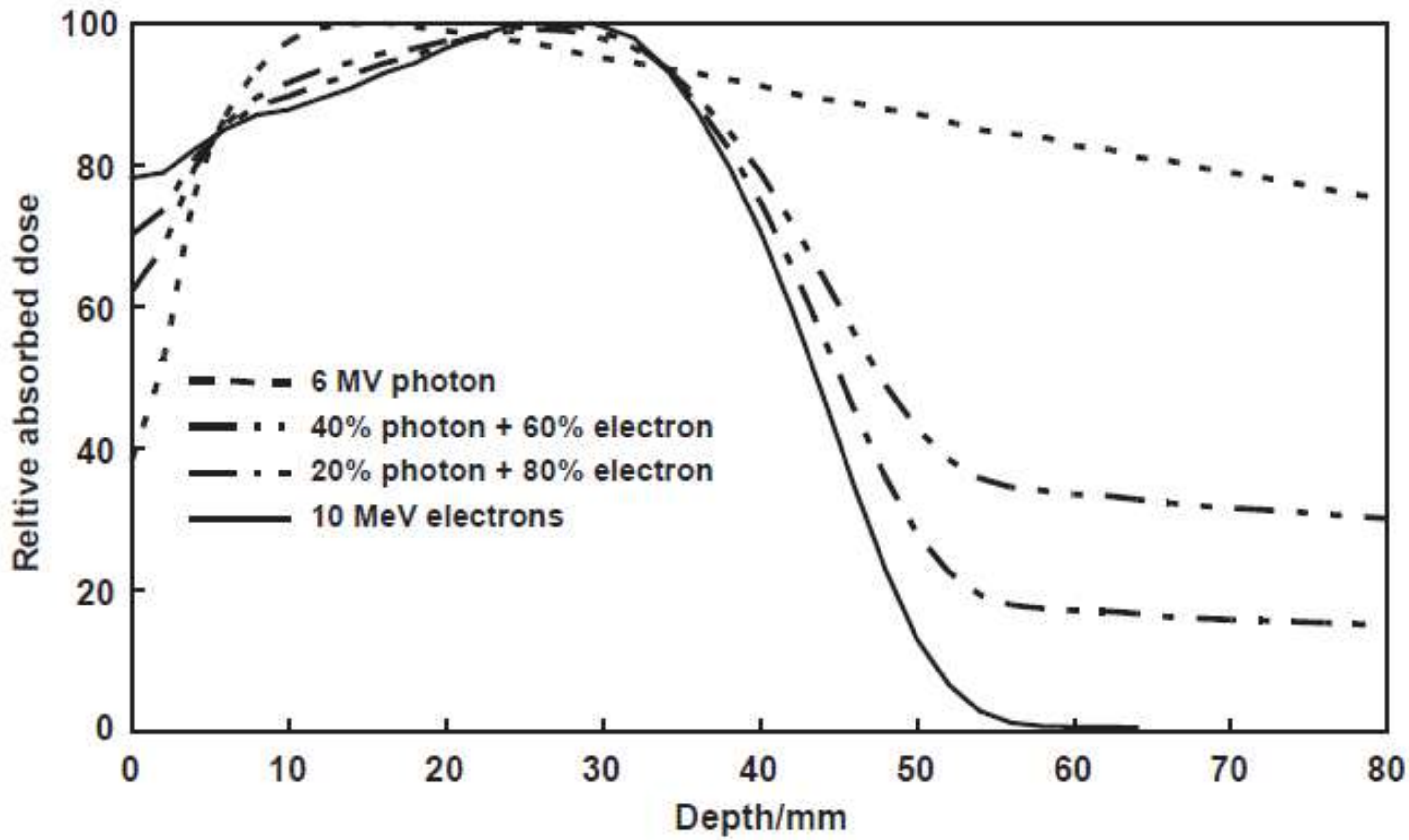
MC calculation at approx 2 mm depth

6 MV	Medial (%)				Apex (%)				Lateral (%)			
Conventional tangents	55	62	68	86	88	96	98	84	78	76	66	63
IMRT tangents	56	66	70	83	87	93	96	84	68	64	62	69
Multi field IMRT	56	64	74	77	80	90	88	82	74	67	64	66
MERT	89	92	99	96	94	99	101	93	91	95	87	70

Quelle: C.M. Ma et al., Phys. Med. Biol. (2003)

… mixing photons & electrons?



Source: Mu et al., Acta Oncologica (2004)

Summary

✓MERT easier to realise with a motorised eMLC (isocentric positioning)

✓Implementation into Oncentra Masterplan

✓Inverse planning & optimisation

✓Remote control → fast delivery

Add-on MLC: important aspects

Tumour contouring

Patient QA

Patient positioning

Workflow & security

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Next steps

- First clinical applications: skin metastases / inguinal lymph nodes
- Plan study for breast cancer patients
- Skin dose investigation
- Clinical study

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