Commissioning of treatment planning systems

Paweł Kukołowicz

Medical Physics Department
Warsaw, Poland

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Before you start

- Understand
  - the calculation model
    - What you may and may not expect from the system?
      - pencil beam algorithm – collapse cone algorithm
  - Problem of interpolation and extrapolation
    - range of beams you may calculate dose distribution
      - applicability of the system for radiosurgery
  - Bolus problem
    - air gaps

Before you start

- Do not expect good results without
  - precisely measured input data
    - output factors (1)
    - depth dose (2)
      - effective point of measurement for cylindrical chamber
    - profiles (3)
      - the finite size of the chamber
        - penumbra increase
  - Analyse the data carefully!

Data analysis

Output factors (cGy/MU)

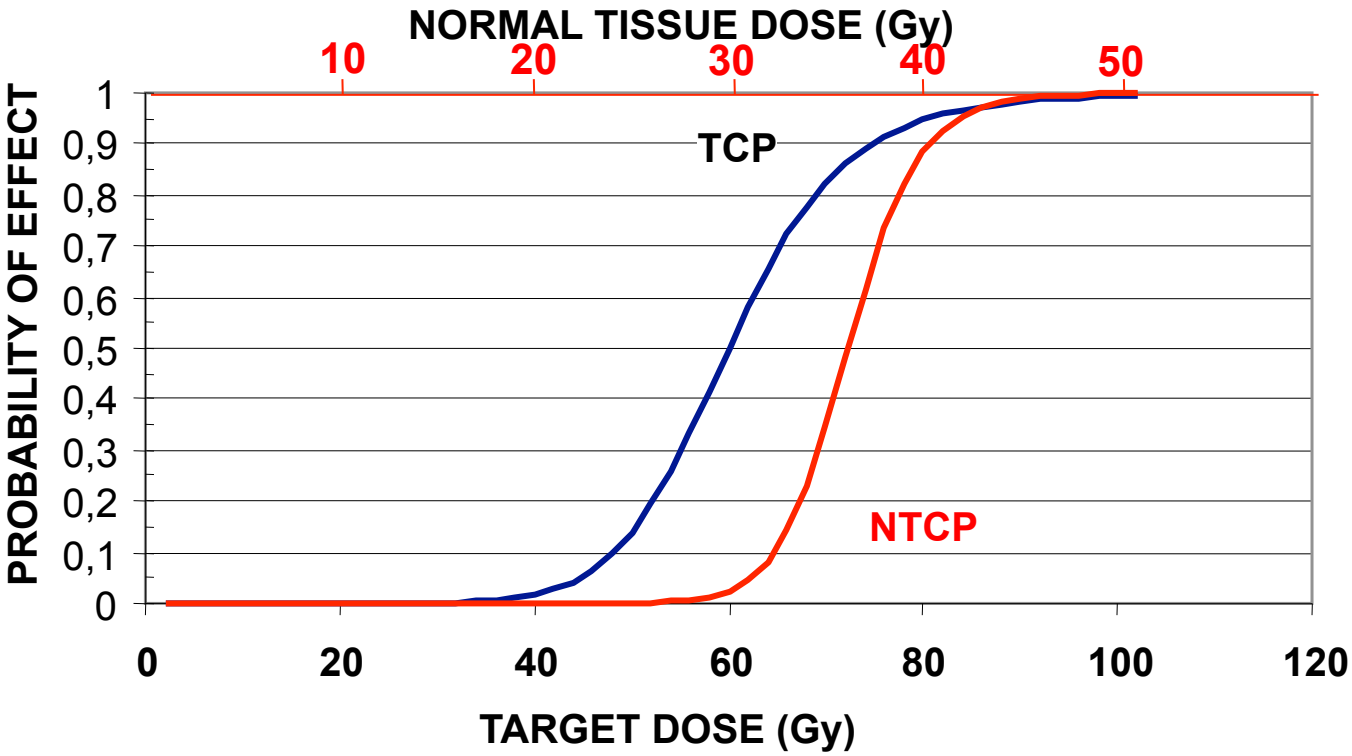
Y

X	2	3	4	5	6	8	10	12	15	20	30	40
2	0,64	0,671	0,681	0,688	0,694	0,702	0,707	0,71	0,714	0,718	0,723	0,724
3	0,658	0,693	0,707	0,717	0,724	0,737	0,743	0,75	0,755	0,761	0,766	0,768
4	0,665	0,704	0,721	0,733	0,742	0,757	0,767	0,774	0,779	0,788	0,794	0,797
5	0,67	0,712	0,731	0,744	0,757	0,774	0,786	0,794	0,802	0,811	0,818	0,822
6	0,675	0,718	0,739	0,756	0,768	0,787	0,801	0,811	0,82	0,829	0,839	0,843
8	0,685	0,729	0,752	0,769	0,784	0,808	0,823	0,834	0,846	0,858	0,868	0,873
10	0,689	0,736	0,76	0,779	0,797	0,821	0,84	0,853	0,867	0,881	0,893	0,898
12	0,694	0,739	0,765	0,785	0,803	0,829	0,85	0,864	0,879	0,894	0,909	0,916
15	0,696	0,742	0,771	0,791	0,809	0,838	0,86	0,875	0,891	0,91	0,927	0,935
20	0,699	0,746	0,775	0,797	0,815	0,847	0,869	0,887	0,907	0,927	0,948	0,956
30	0,7	0,749	0,777	0,801	0,822	0,853	0,879	0,898	0,919	0,944	0,966	0,977
40	0,702	0,752	0,78	0,805	0,826	0,859	0,885	0,903	0,927	0,952	0,978	0,987

Before you start

- Electron density conversion function (EDCF)
- Very important!
  - Almost all measuremets will be made in water
    - homogenous absorber
- Calculation are made in inhomogenous absorber
  - You just rely on calculations
    - You can't rely on them without well established EDCF

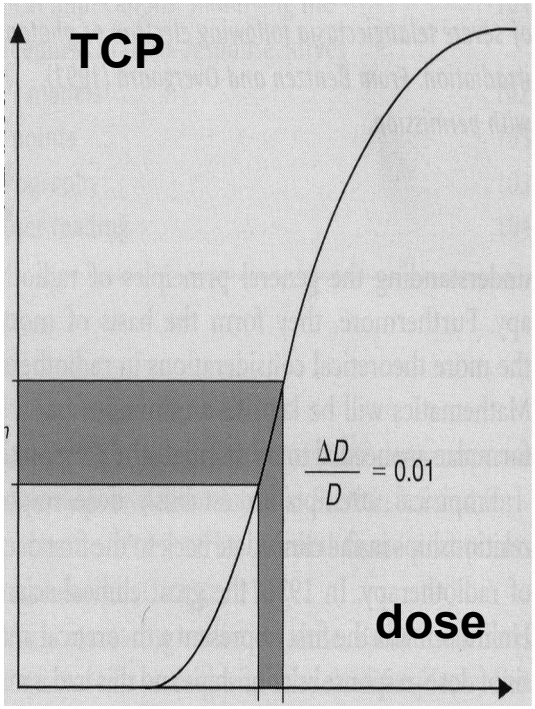
What accuracy is needed in contemporary radiotherapy?



Normalized dose gradient

$$\gamma_p = \Delta D \cdot \left. \frac{dTCP}{dD} \right|_{TCP=p}$$

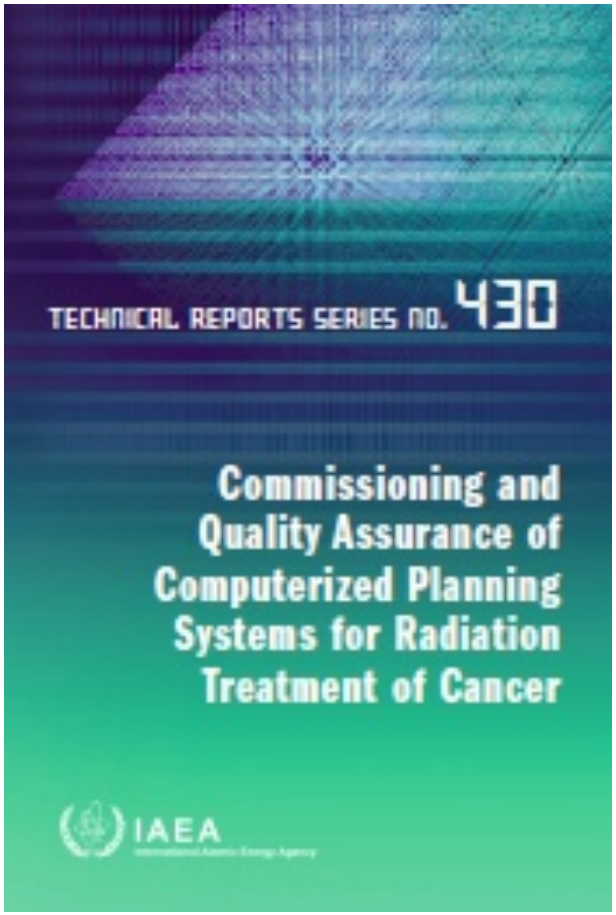
γ

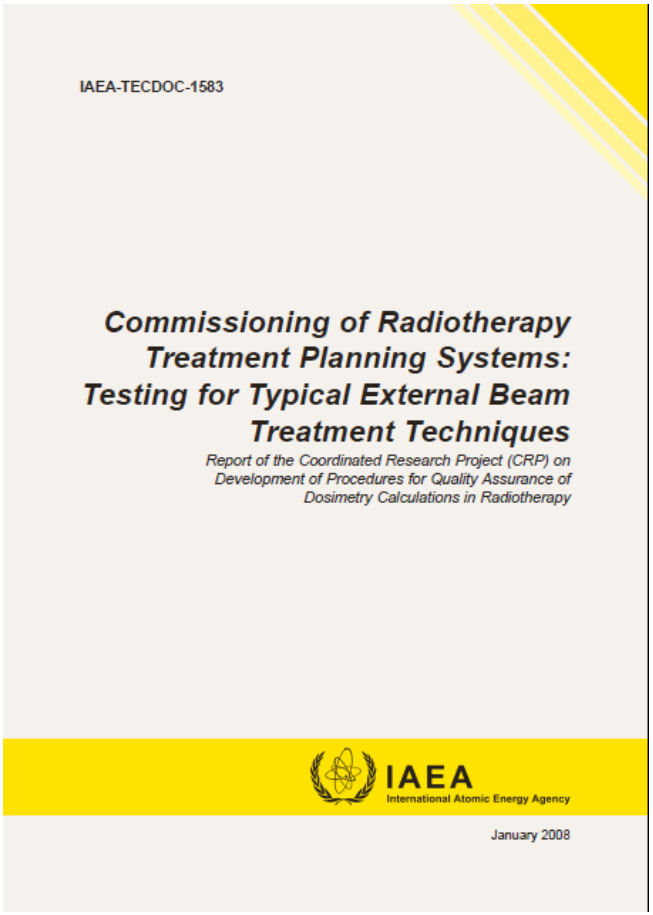


Commissioning of a TPS

- Several reports were published concerning commissioning of a TPS
  - AAPM
  - Dutch
  - ESTRO
  - IAEA
  - Polish – in Polish only

IAEA proposals





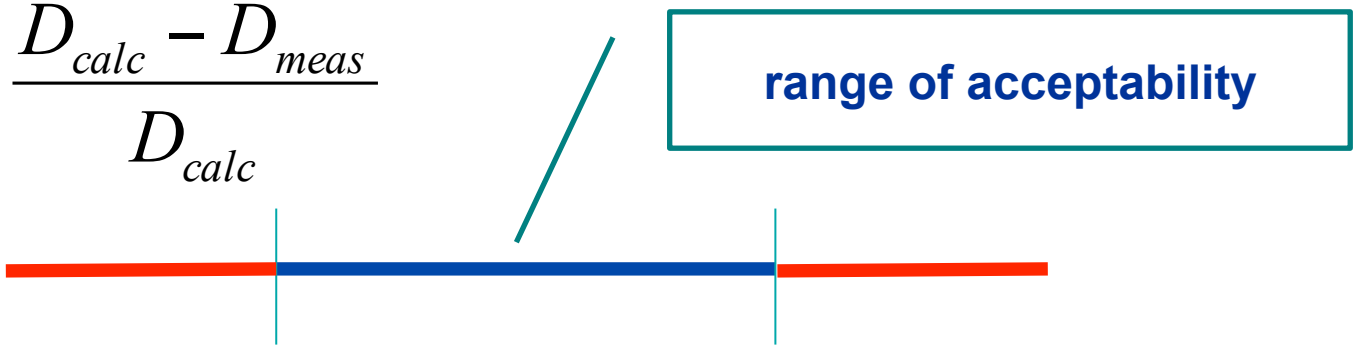
Before you begin!

- Understand the philosophy of the system
  - 2D or 3D system
  - what we may and may not expect from the system
- Try to understand the possibilities and limitations of the system
  - all extrapolations are quite dangerous!
- Get information and understand the algorithm impelemented in the system
  - non homogenous absorber

How to compare calculations and measurements?

- Quantitative tests
  - tolerances should be defined
- Tolerance is strictly defined as the range of acceptability beyond which corrective action is required.

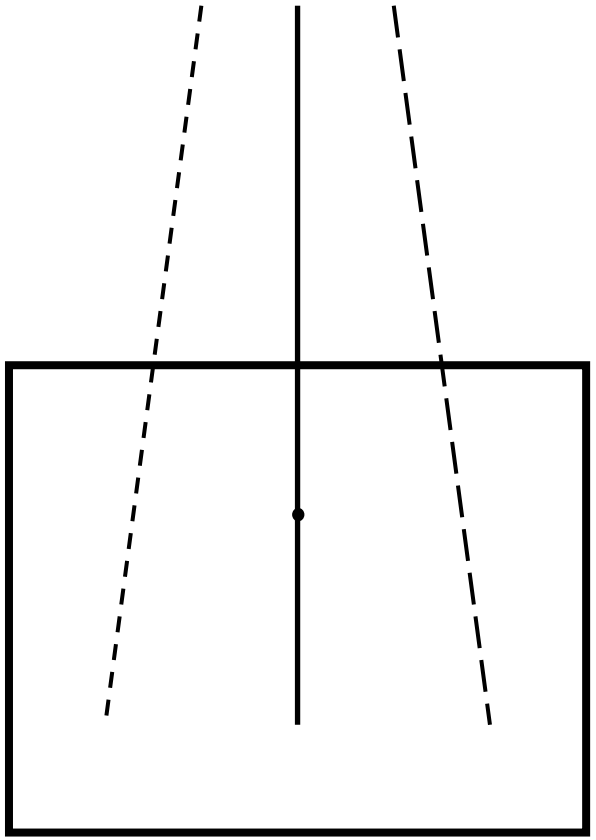
$$\delta = 100 \times \frac{D_{calc} - D_{meas}}{D_{calc}}$$



What we should remember?

$$\left(D_{meas}\right)_{corr} = D_{meas} \cdot \frac{OF_{TPS}}{OF_{Act}}$$

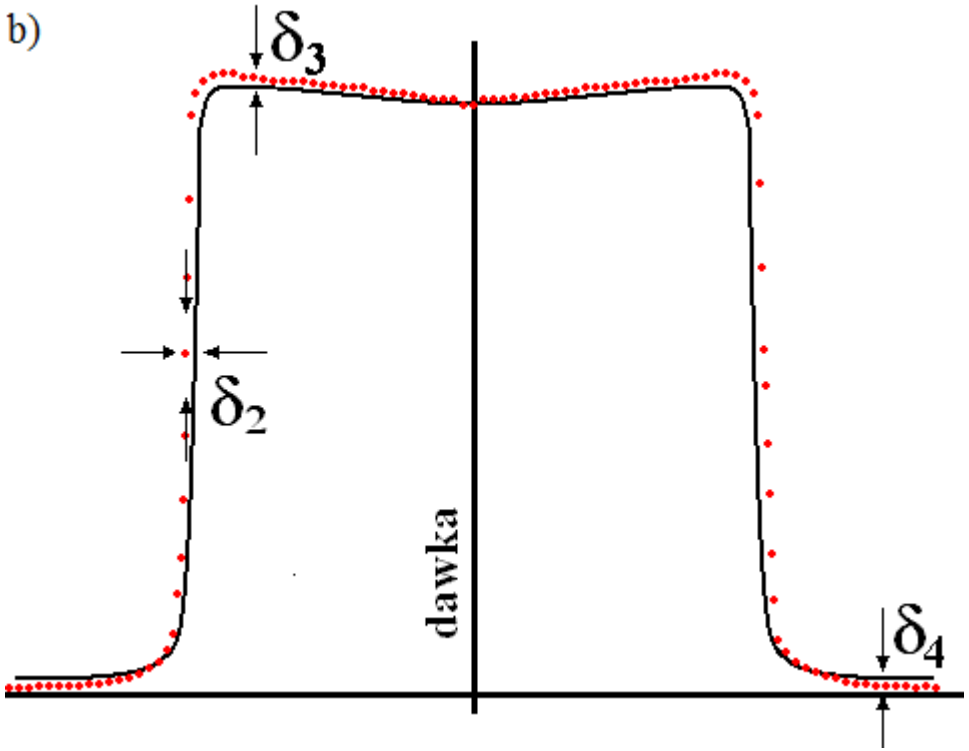
$$\delta = 100 \times \frac{D_{calc} - \left(D_{meas}\right)_{corr}}{D_{calc}}$$



$$|\delta|$$

Tolerances comments

- Tolerances can be expressed in terms of
  - dose (low gradient), and
  - in terms of distances (high gradient)



IAEA proposal

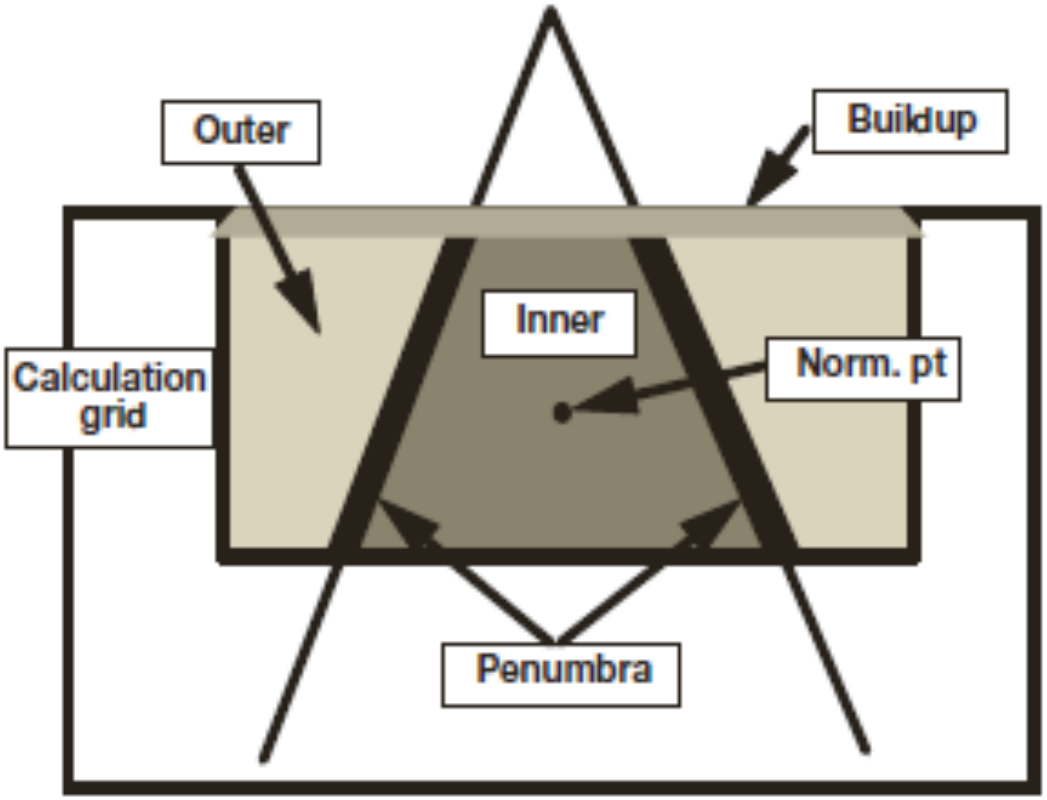


TABLE 17. SAMPLE CRITERIA OF ACCEPTABILITY FOR EXTERNAL DOSE CALCULATIONS

(Adapted, with permission, from Ref. [18].)

Situation	Absolute dose at normalization point (%)[a]	Central ray (%)	Inner beam (%)	Penumbra (mm)	Outer beam (%)	Buildup region (%)
Homogeneous phantoms						
Square fields	0.5	1	1.5	2	2	20
Rectangular fields	0.5	1.5	2	2	2	20
Asymmetric fields	1	2	3	2	3	20
Blocked fields	1	2	3	2	5	50
MLC shaped fields	1	2	3	3	5	20
Wedged fields	2	2	5	3	5	50
External surface variations	0.5	1	3	2	5	20
SSD variations	1	1	1.5	2	2	40
Inhomogeneous phantoms[b]						
Slab inhomogeneities	3	3	5	5	5	—
3-D inhomogeneities	5	5	7	7	7	—

Note: Percentages are quoted as per cent of the central ray normalization dose.

[a] Absolute dose values at the normalization point are relative to a standard beam calibration point.

[b] Excluding regions of electronic disequilibrium.

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Overall acceptability IAEA TRS 430

- A useful way to compare calculations and measurements is to analyse the deviations statistically. Although a given tolerance may be assigned to individual point value comparisons, **the decision of overall acceptability is not based on strict adherence to the tolerance at each point**. Rather, decisions are based on confidence limits or other similar criteria; for example, a few points may fail to meet a tolerance of 2%, but this may be acceptable if 95% of points fall within 2%.

Comment

- For more detailed discussion of tolerances please refer to IAEA document or directly to Venseelar work

- VENSELAAR, J., WELLEWEERD, H., MIJNHEER, B., Tolerances for the accuracy of photon beam dose calculations of treatment planning systems, Radiother. Oncol. **60 (2001) 191–201.**

When to make and which tests?

Starting situation	Range of tests	Remarks
New TPS	Full range	To be acquinted with the experience of other users of the system.
New accelerator (beam) in the TPS	Tests which are able to demonstrate that the data are properly prepared and entered into the system.	If the beam is a copy of other beam (twin accelrators) testing might be limited.
New version of the software	Tests which are able to demonstrate that the new software did not deteriorate the system.	Detailed analysis of changes. To have contact with other users.

What to start with?

- The most important is to be sure that there is no errors in input data.
  - visual verification of the data is obligatory
- In most systems
  - output factors
  - depth doses
  - profiles

What to start with?

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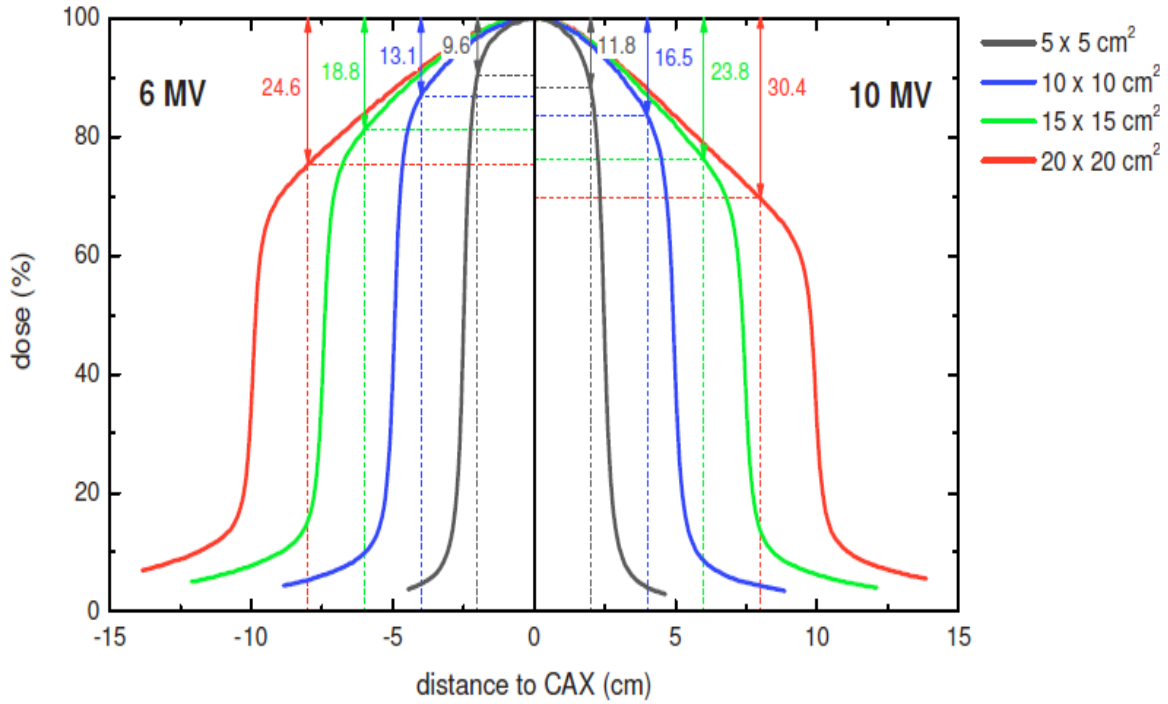
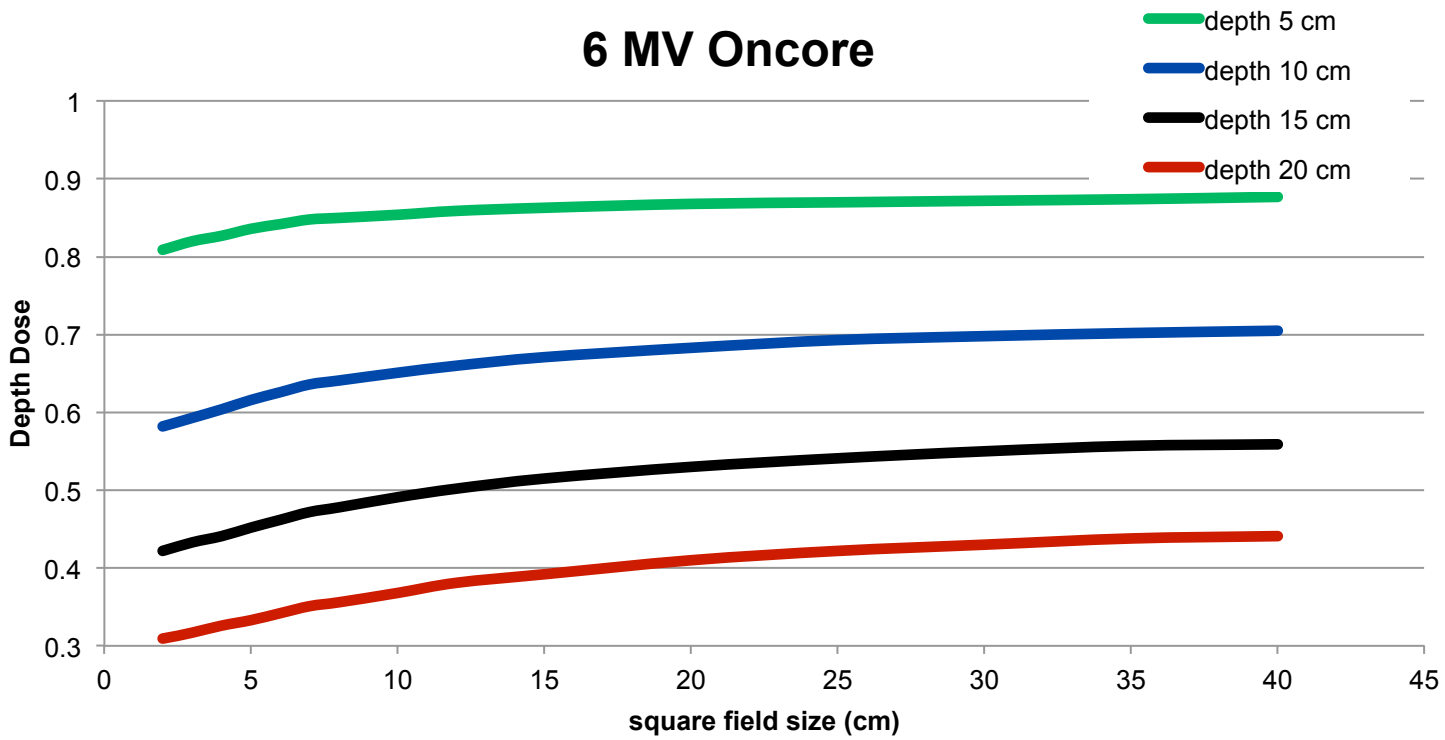
- Profiles
  - visual verification of the data is obligatory



What to start with?

- Depth Doses versus field size



What to start with?

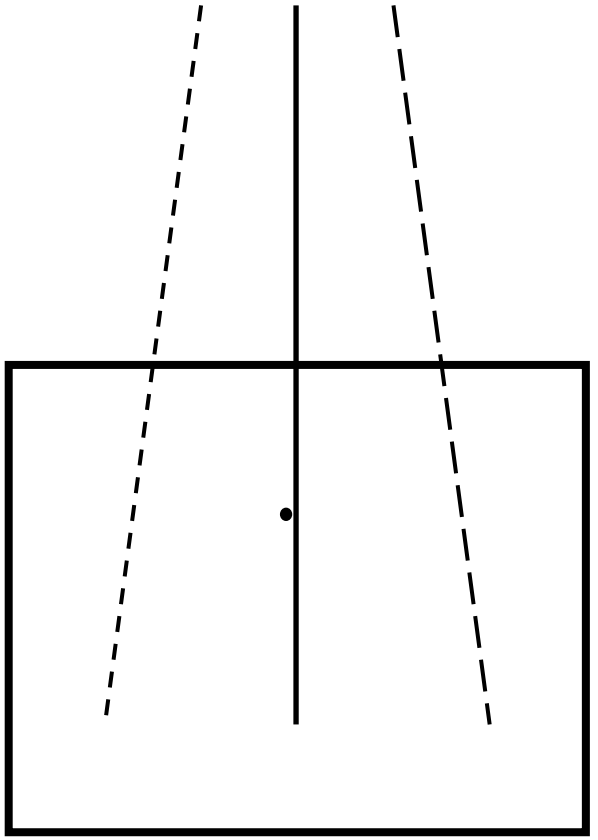
Graphs should be prepared and analyzed.

Output factors (cGy/MU)

X \ Y	2	3	4	5	6	8	10	12	15	20	30	40
2	0,64	0,671	0,681	0,688	0,694	0,702	0,707	0,71	0,714	0,718	0,723	0,724
3	0,658	0,693	0,707	0,717	0,724	0,737	0,743	0,75	0,755	0,761	0,766	0,768
4	0,665	0,704	0,721	0,733	0,742	0,757	0,767	0,774	0,779	0,788	0,794	0,797
5	0,67	0,712	0,731	0,744	0,757	0,774	0,786	0,794	0,802	0,811	0,818	0,822
6	0,675	0,718	0,739	0,756	0,768	0,787	0,801	0,811	0,82	0,829	0,839	0,843
8	0,685	0,729	0,752	0,769	0,784	0,808	0,823	0,834	0,846	0,858	0,868	0,873
10	0,689	0,736	0,76	0,779	0,797	0,821	0,84	0,853	0,867	0,881	0,893	0,898
12	0,694	0,739	0,765	0,785	0,803	0,829	0,85	0,864	0,879	0,894	0,909	0,916
15	0,696	0,742	0,771	0,791	0,809	0,838	0,86	0,875	0,891	0,91	0,927	0,935
20	0,699	0,746	0,775	0,797	0,815	0,847	0,869	0,887	0,907	0,927	0,948	0,956
30	0,7	0,749	0,777	0,801	0,822	0,853	0,879	0,898	0,919	0,944	0,966	0,977
40	0,702	0,752	0,78	0,805	0,826	0,859	0,885	0,903	0,927	0,952	0,978	0,987

Next step

- To check how the input data are restored in the system
  - to do this dose distributions are calculated in the water phantom
  - Results are compared with the input data



Functional tests

- These are qulitative tests that ensure the right interpretation of the treatment plan parameters
- Here are some of them
  - conventions concerning angles
  - coordinats systems used by the system
  - naming of collimator jaws
  - naming and orientation of wedges
    - Varian maschines are equiped in 8 different wedges!

Functional tests

- Errors may lead to
  - irradiation of the wrong patient side
  - wrong rotation of the collimator
  - wrong wedge or wrong wedge orientation

Qualitative tests (QT)

- Check of input and output image data
  - input CT data
  - Digitally Reconstructed Radiographs

Qualitative tests (QT)

- QT
  - Check of input and output image data
    - input CT data
    - Digitally Reconstructed Radiographs
  - Comparison of calculated and measured dose
    - some of these tests have already been performed
  - Non standard conditions (examples)
    - oblique incidence
    - lack of scatter
    - asymmetric beam

Block geometry

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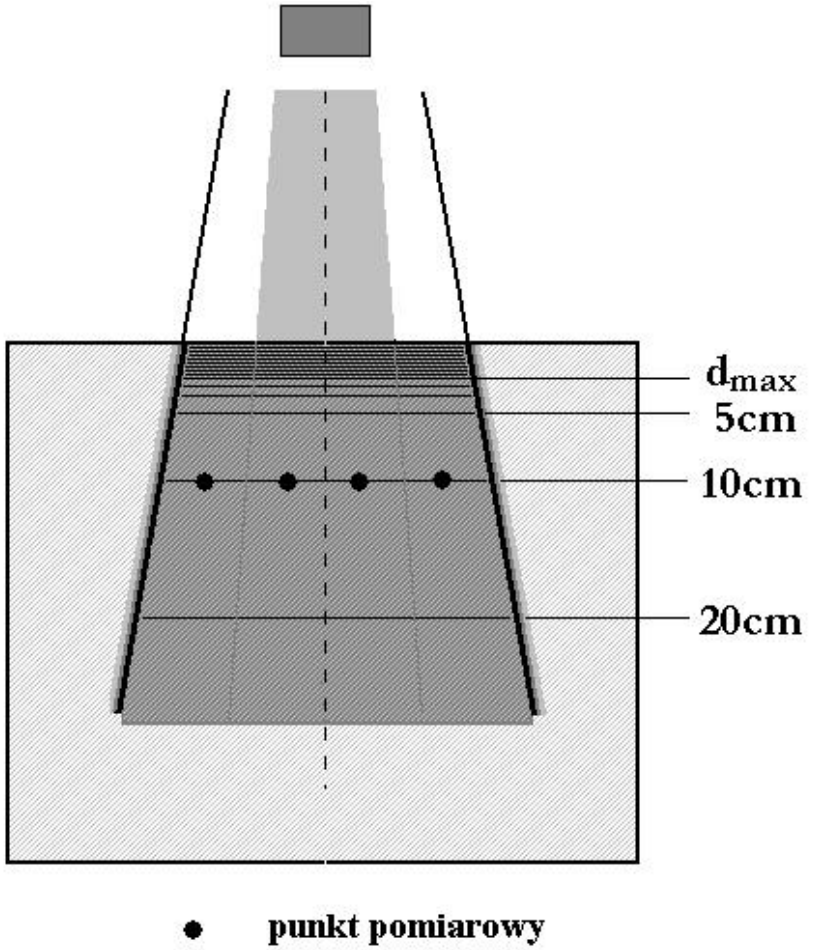
Field 25 cm x 25 cm
Block 10 cm x 10 cm



Oblique incidence

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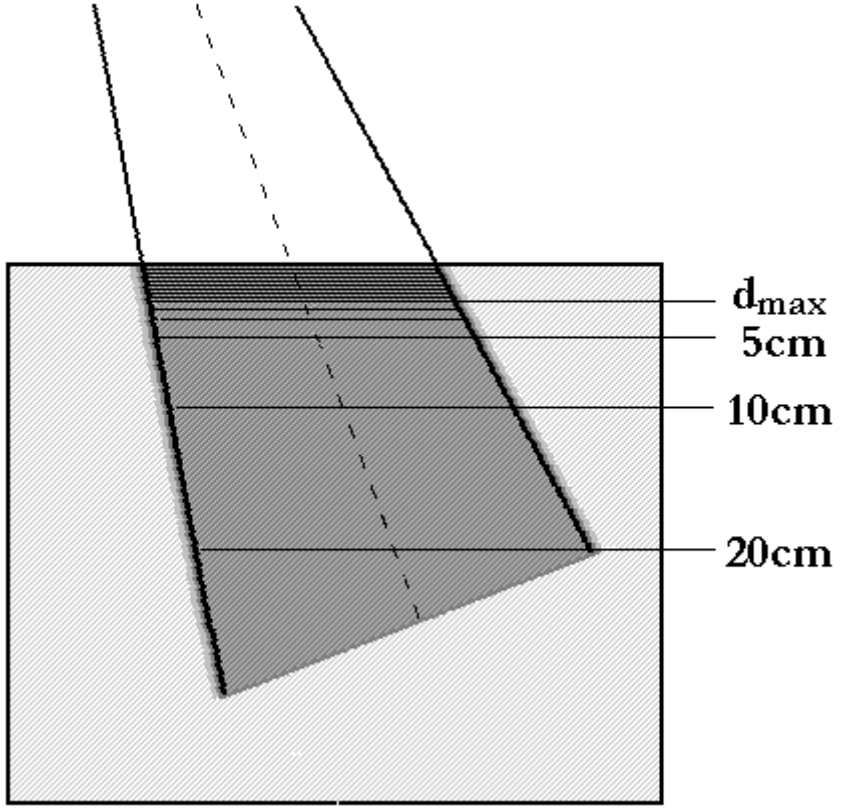
Field 10 cm x 10 cm
45°



Lack of scattered radiation

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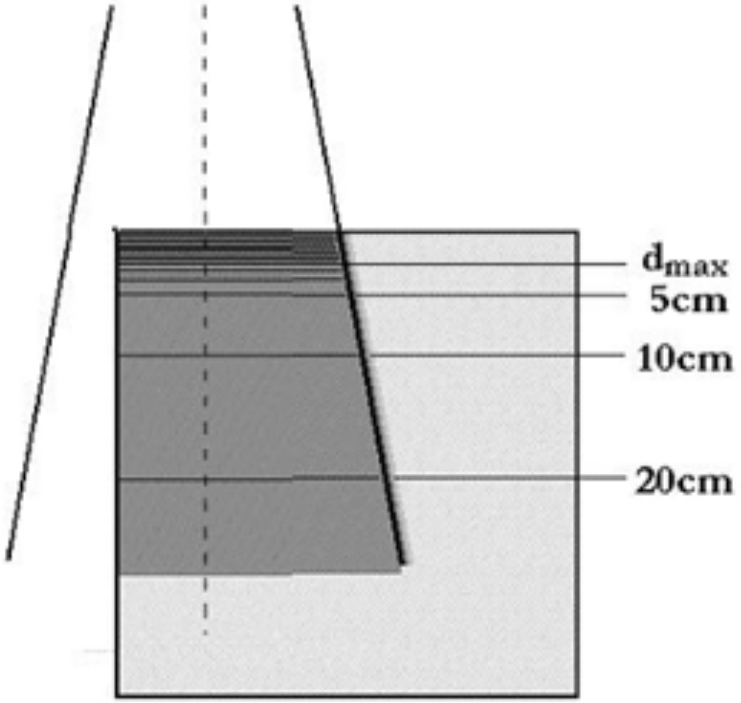
Field 20 cm x 20 cm
¼ field out of phantom



Wedge beams
output factors

		Field size X [cm]					
		Min.	5	10	15	30	Max.
Field size Y [cm]	Min.						
	5						
	10			1			
	15						
	30						
	Max.						

Inhomogeneities

- Analysis of the algorithm
  - What is possible?
- Measurements
  - in the antropomorphic phantom
  - in the slab phantom
- Comparison the calulation results with the published results of measurements
  - AAPM Report No. 85

- R. K. Rice, B. J. Mijnheer, L. M. Chin, “Benchmark measurements for lung dose corrections for x-ray beams,” *Int. J. Radiat. Oncol. Biol. Phys. 15:399–409* (1988).

Stability of TPS

- I recommend to
  - repeat the same procedure for the same (antropomorphic) phantom
    - planning CT examinations
    - transfer to TPS
    - contour automatically some organs (lung, bones, etc.)
    - import contour of the target (it may be also the same target eg. cicle of a given radius with the center in the same point)
    - prepare the same plan
    - make the same dose prescription, and

End-to-end test

- Phantom
  - CT examination
  - Contouring
  - Plan
  - Dose distribution calculation
- Irradiate the phantom and measure dose distribution
  - Compare measurements with calculations

Stability of TPS

- Calculate a dose distribution, and
  - compare it to reference dose distribution

- Comparison may be performed different way
  - transfer to spread sheet and compare
  - compare several indicies, eg. Mean dose to target, V20Gy to lung etc.

Commissioning non-conventional machines

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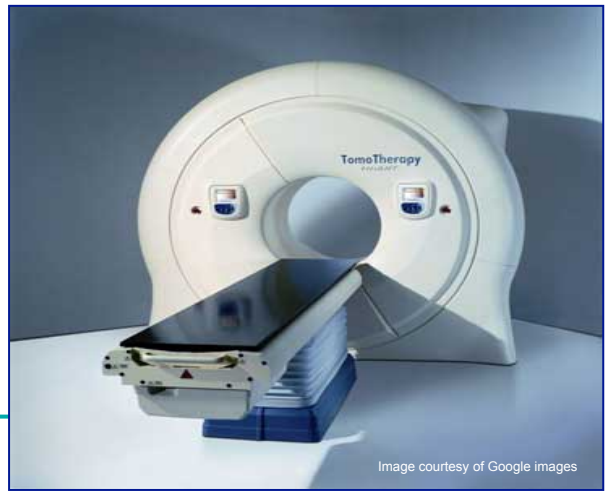
CyberKnife

GammaKnife

TomoTherapy



Summary

- Commisioning of TPS is a must!
  - is very labor extensive (boring), and
    - you never can fully trust the system, so
    - please always analyse the data you receive
      - double check
- Robustness depends not on the system alone, but also on the user.
  - the limitations of the system should be known

Summary

- It is not recommended to change the version of the software, unless
  - really new important possibilities are implemented.

- Please be esspecially carefull when you start with using a new system
  - all strange information should be treated seriously.

Thank you very much
for your attention!