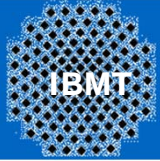


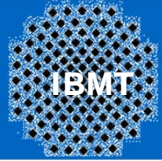
1. Überblick
 1. Strahlungseinrichtungen, Strahlungsarten und -energie
 2. Strahlentherapeutische Methoden
 3. Aufbau von Bestrahlungsgeräten
 4. Versorgungssituation
2. Röntgentherapieeinrichtungen
 1. Nahbestrahlungsröhren
 2. Weichstrahlröhren
 3. Tiefentherapieröhren
 4. Therapiegeneratoren
3. Beschleuniger
 1. Physik. Grundlagen
 2. Linearbeschleuniger
 3. Betatron
 4. Zyklotron



Strahlentherapieeinrichtungen, Strahlenarten und -energien



1. Beschleunigung geladener Teilchen
 1. Röntgentherapieeinrichtungen
 - e- Röntgenbremsstrahlung Energien 6 – 350 keV
 - Weichstrahlröhren
 - Tiefentherapieröhren
 - Therapiegeneratoren
 2. Linearbeschleuniger
 - Elektronen: 4 – 20 (40) MeV
 - Bremsstrahlung: 4 – 25 MeV
 3. Betatron
 - Elektronen: 17 - 42 MeV
 - Bremsstrahlung: bis 30 MeV
 4. Mikrotron
 - Elektronen: bis 30 MeV
 - bis 30 MeV
 5. Zyklotron
 - Geladene Teilchen / Kernreaktionen / Nuklidproduktion
 - Bremsstrahlung: bis 30 MeV
2. Umschlossene Radioaktive Nuklide
 1. Künstliche Nuklide
 - Co-60 (1,17; 1,33 MeV)
 - Ir-192 (370 keV)



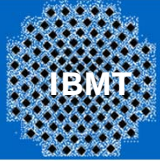
Strahlentherapieeinrichtungen, Strahlenarten und -energien



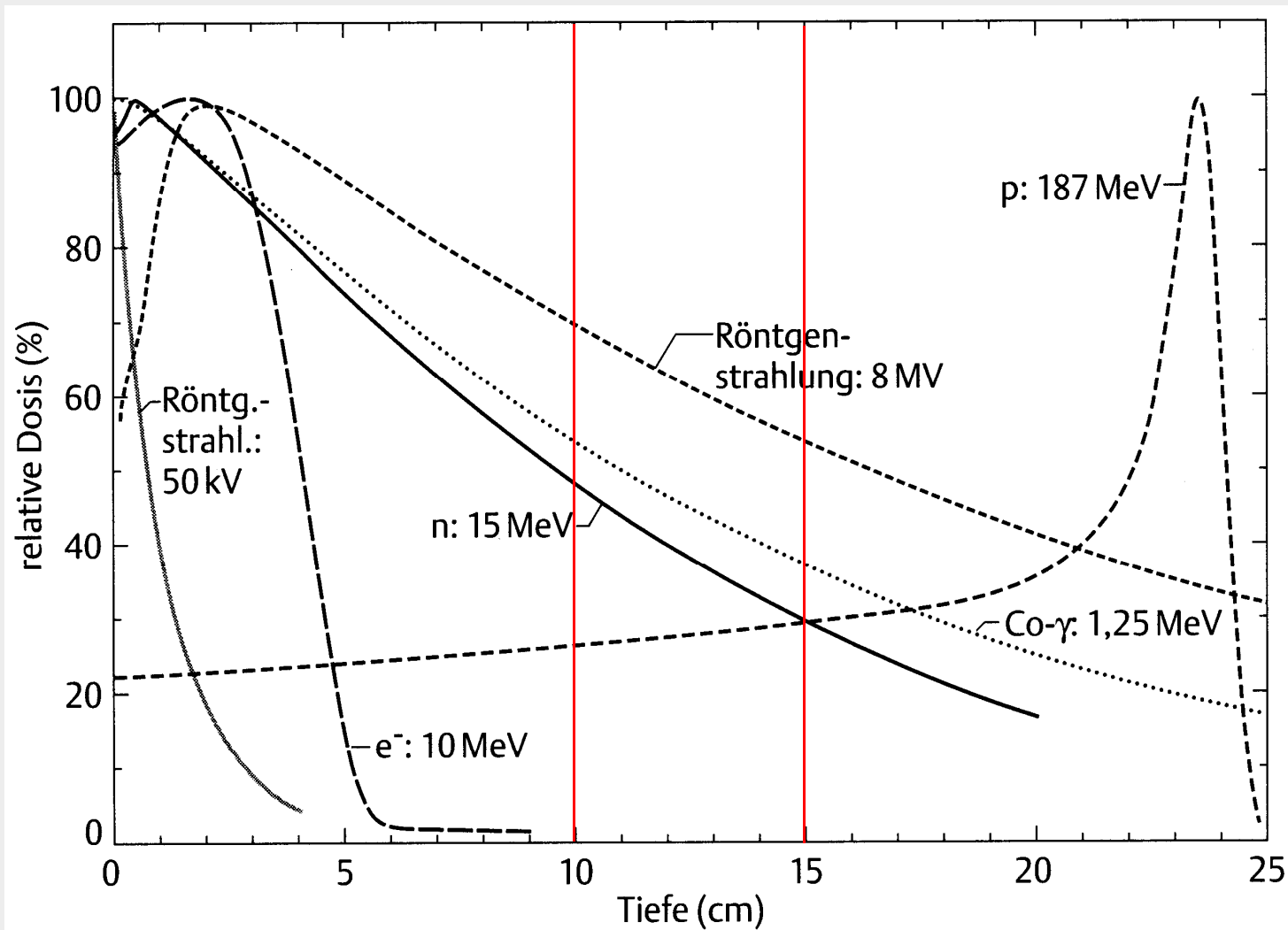
Strahlentherapieeinrichtungen:

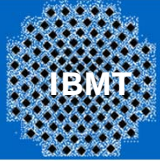
Teletherapieeinrichtungen

Afterloadingeinrichtungen



Strahlentherapieeinrichtungen, Strahlenarten und -energien

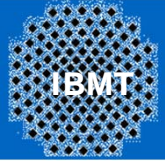




Strahlentherapeutische Methoden Bestrahlungstechniken



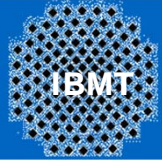
- Teletherapie
 - Ferntherapie, typischer Abstand
Fokus-Isozentrum = 100cm
- Brachytherapie
- Kontakttherapie



Strahlentherapeutische Methoden wichtigste Strahlungsquellen



- Umschlossene Radionuklide für
 - Kontakttherapie (Sr-90, Ru-228)
 - Intrakavitäre Therapie (Ir-192, Cs-137)
 - Interstitielle Therapie (Ir-192, Cs-137, Ru-228)
- konventionelle Röntgentherapieanlagen (7-400 kV)
- Telegammabestrahlungseinrichtungen (Co-60, Cs-137)
- Teilchenbeschleuniger (> 1 MeV)

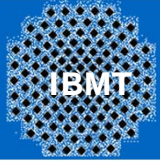


Strahlentherapeutische Methoden

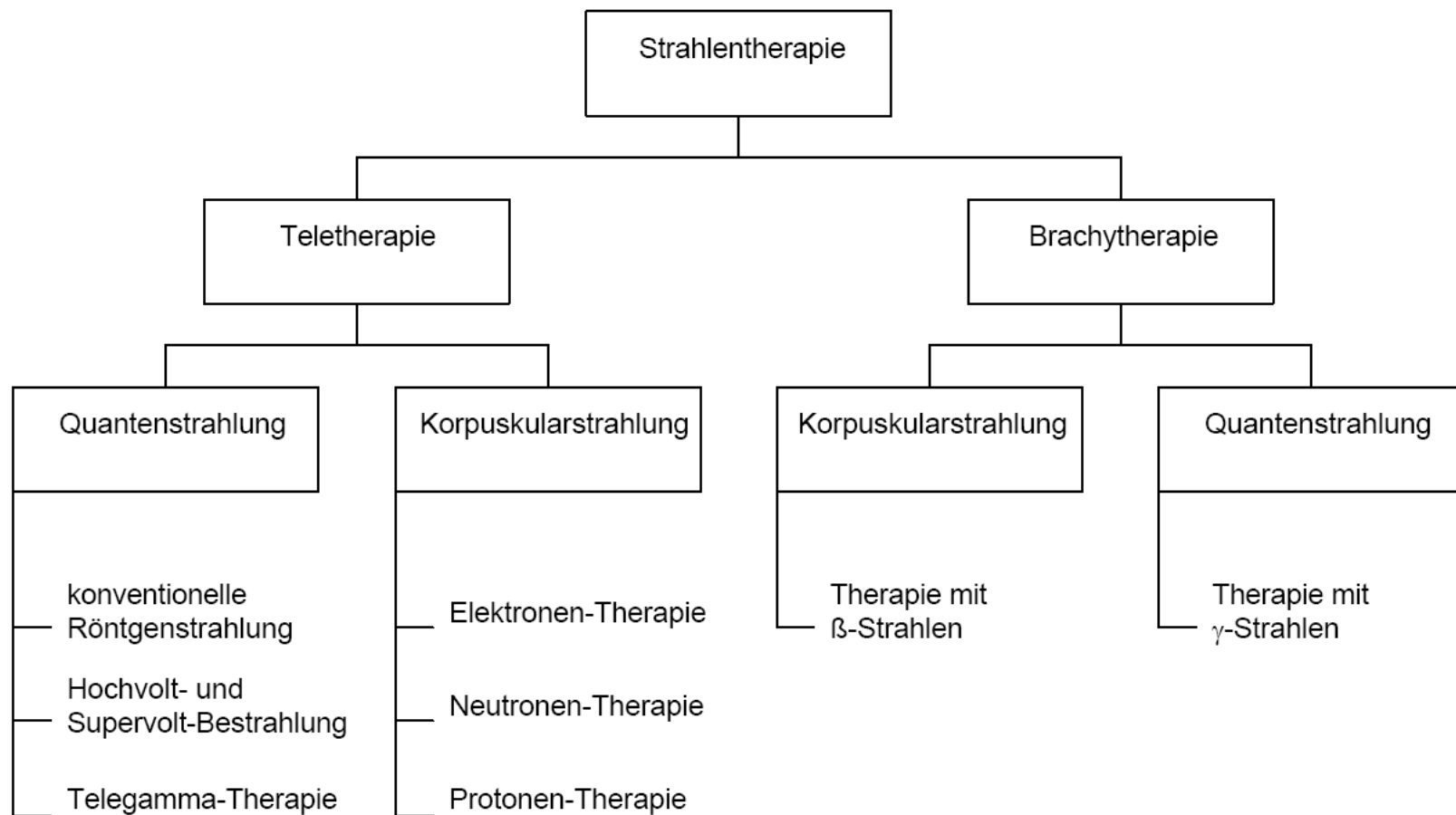
Einteilung nach Energien

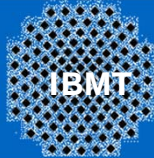


- Weichstrahltherapie (bis 20 keV)
- Halbtiefen- und Tiefentherapie (bis 350 keV)
- Hochvoltherapie

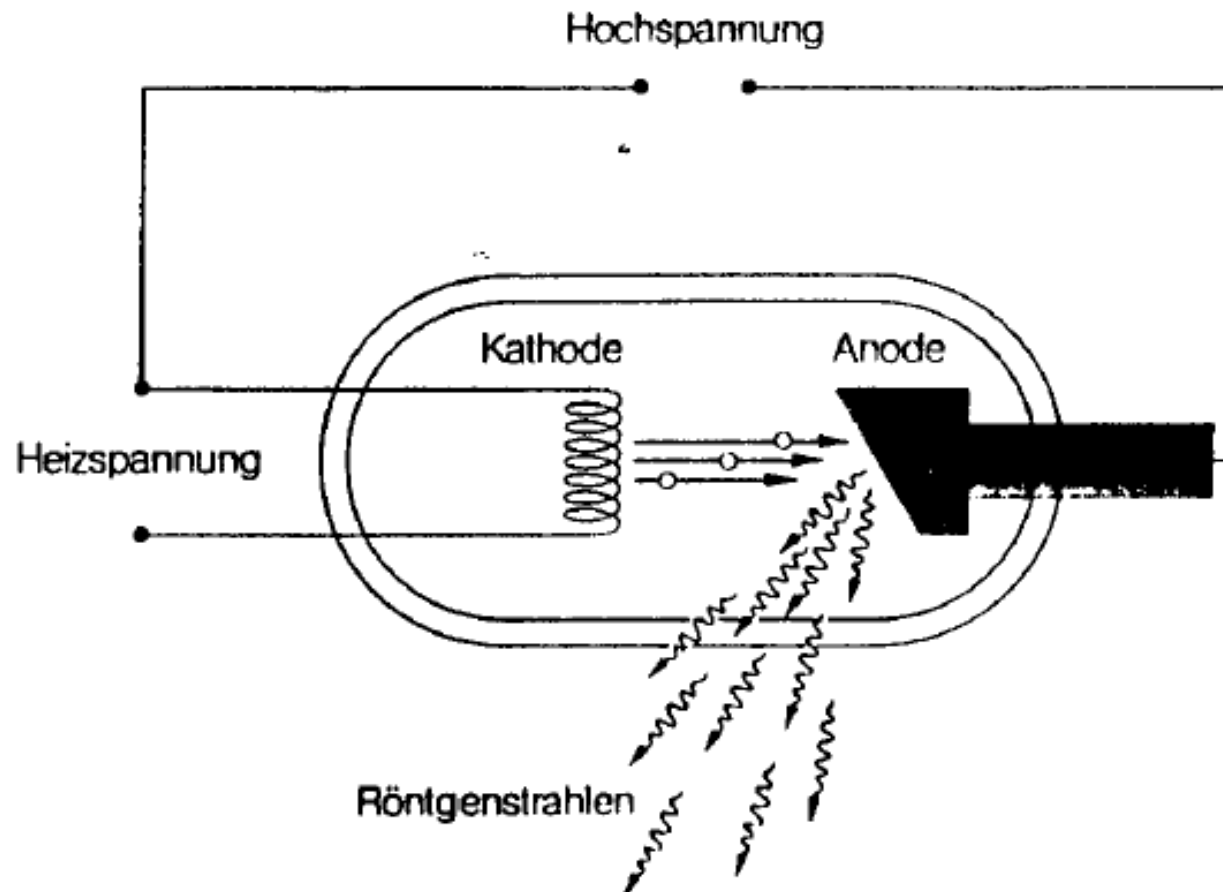


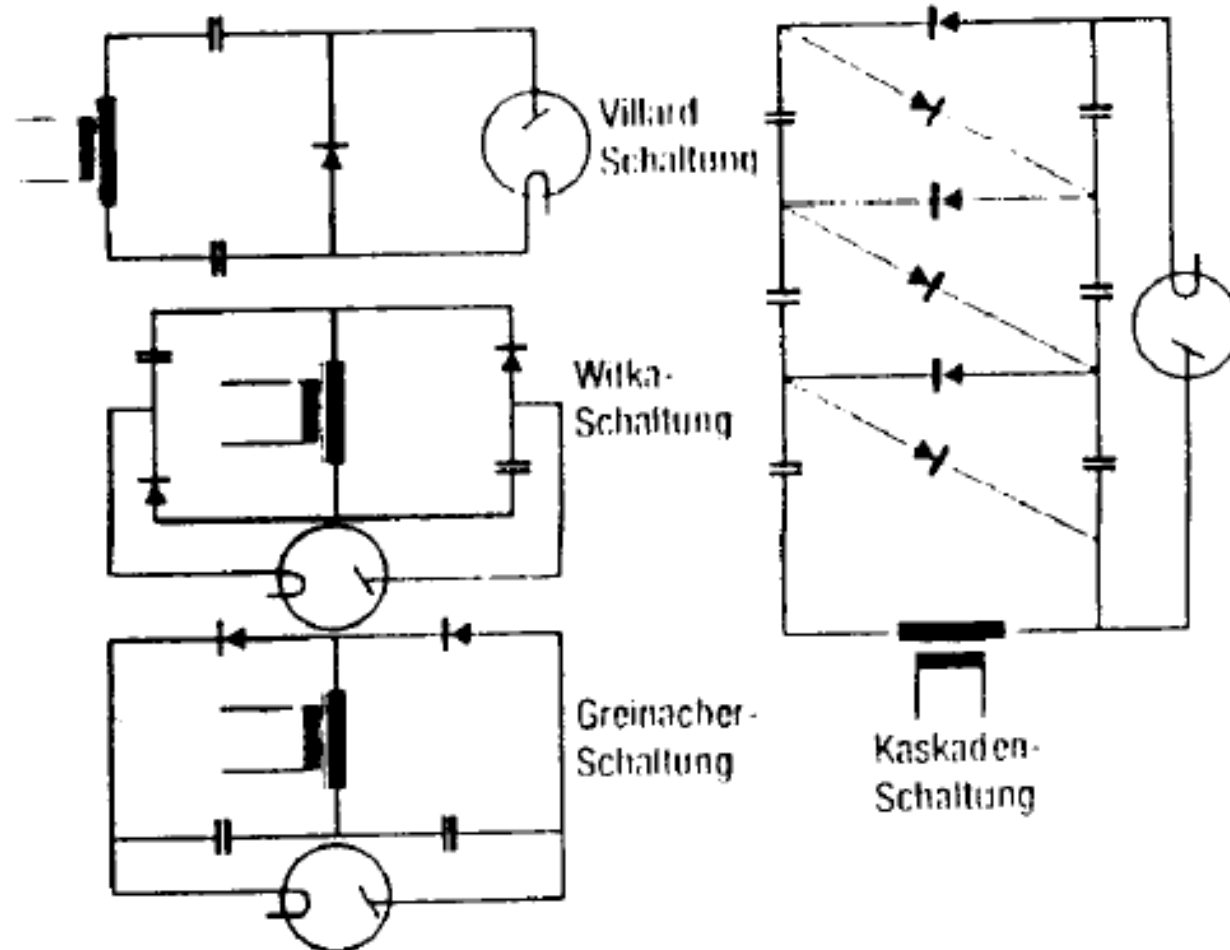
Einteilung Therapieeinrichtungen

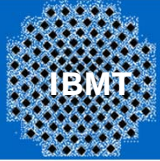




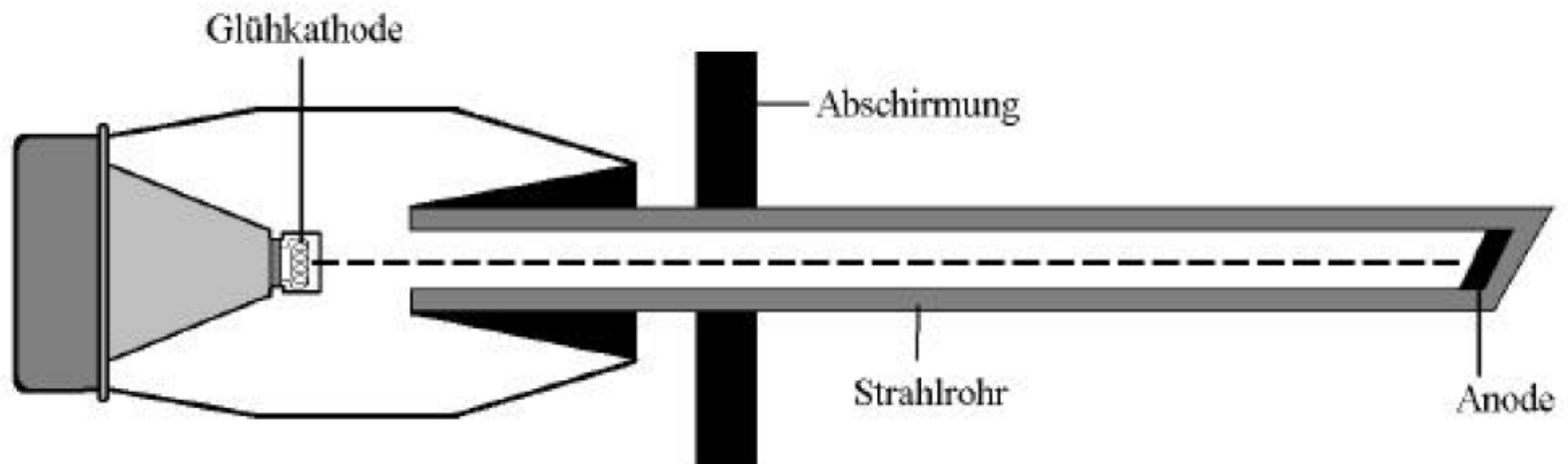
Prinzip der Röntgenröhre

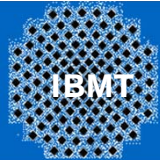




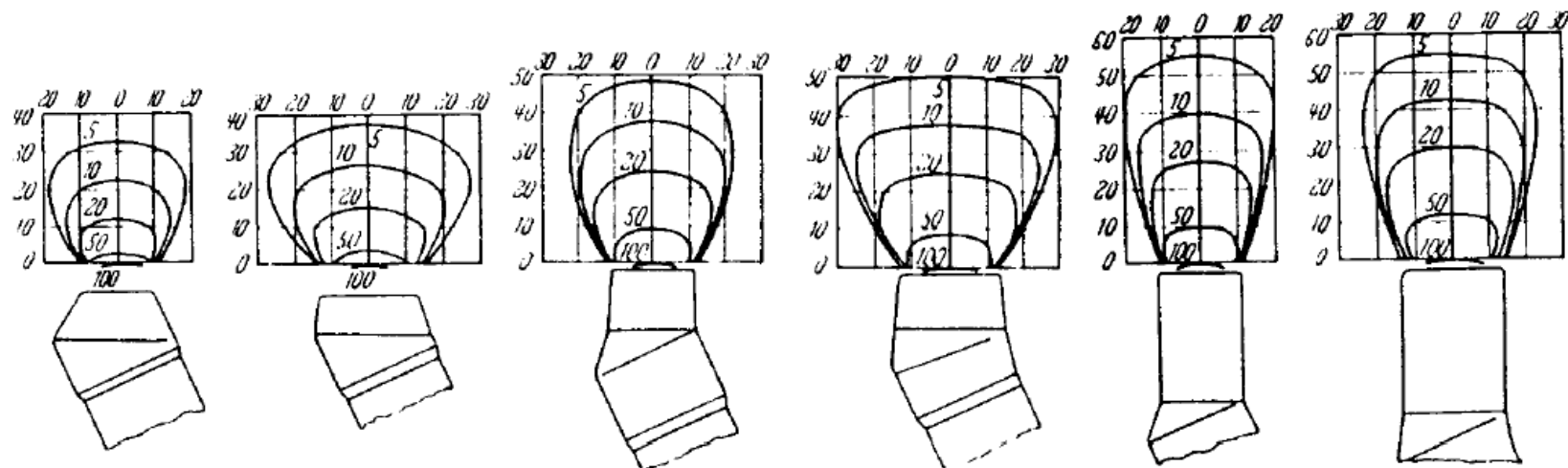


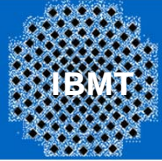
Festanoden-Therapieröhre



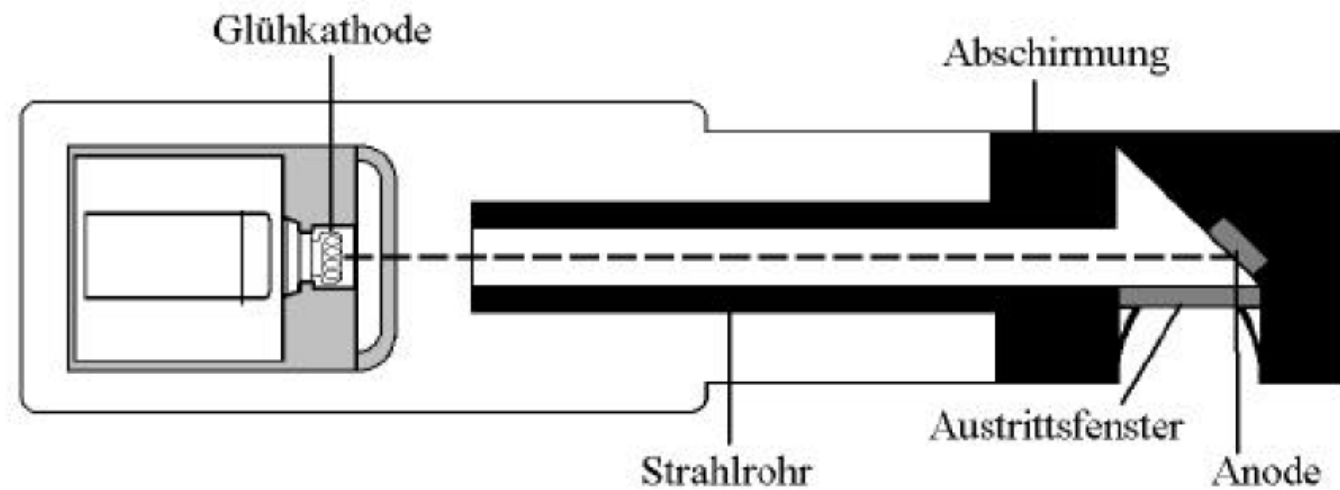


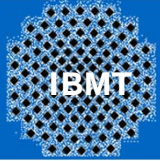
Dosisverteilung Weichstrahltherapie





Halbtiefentherapieröhre

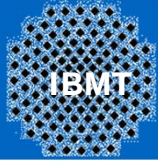




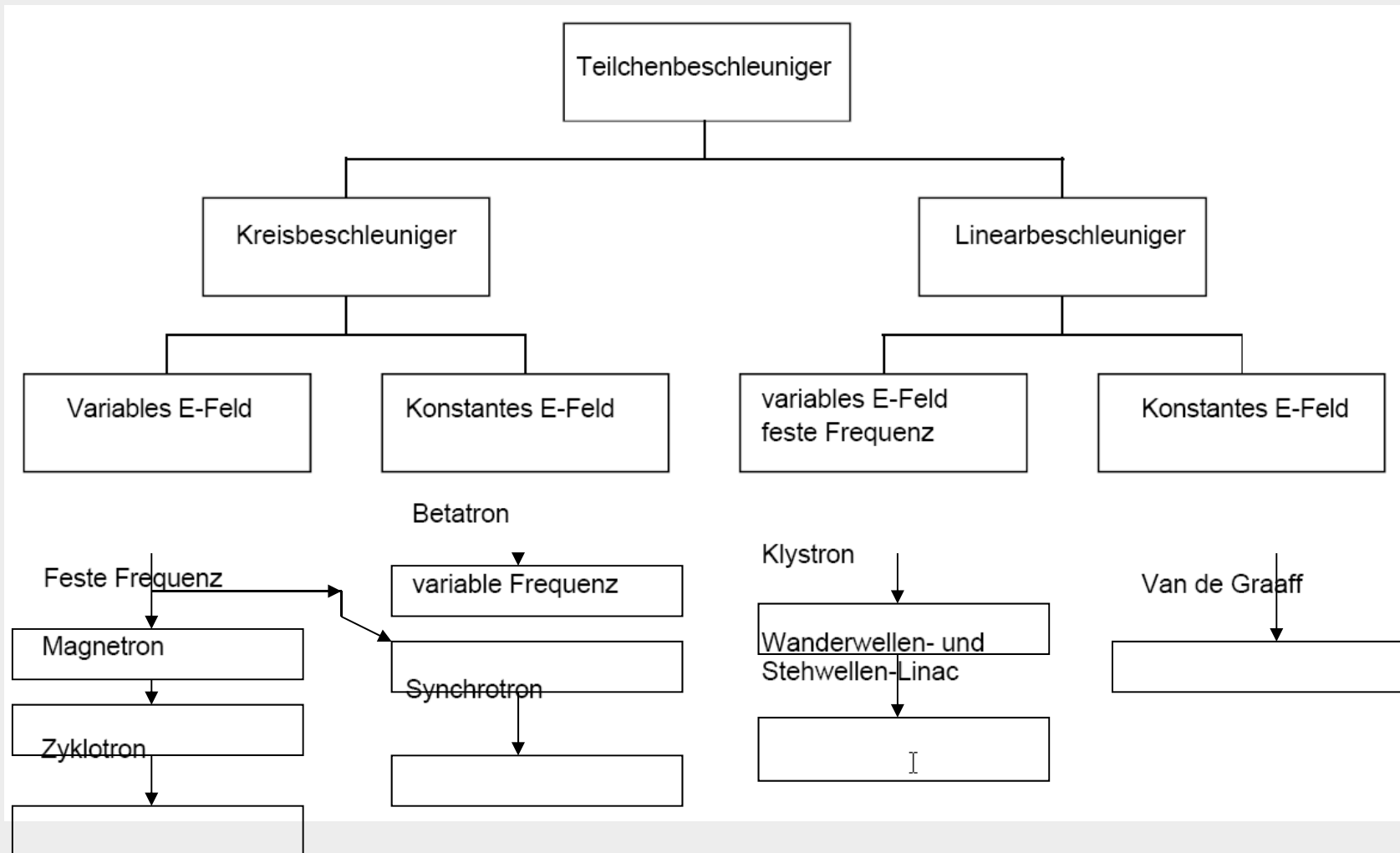
Vergleich Röntgengeneratoren

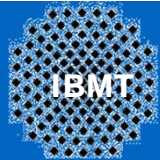


	Diagnostik	Therapie
Betriebsart	Kurzzeitbetrieb	Langzeitbetrieb
Leistung	Kurzzeitnennleistung 100kW	Langzeitnennleistung 4 kW
Schaltzeit	ms - s	s - min
Anode	Drehanode	Festanode

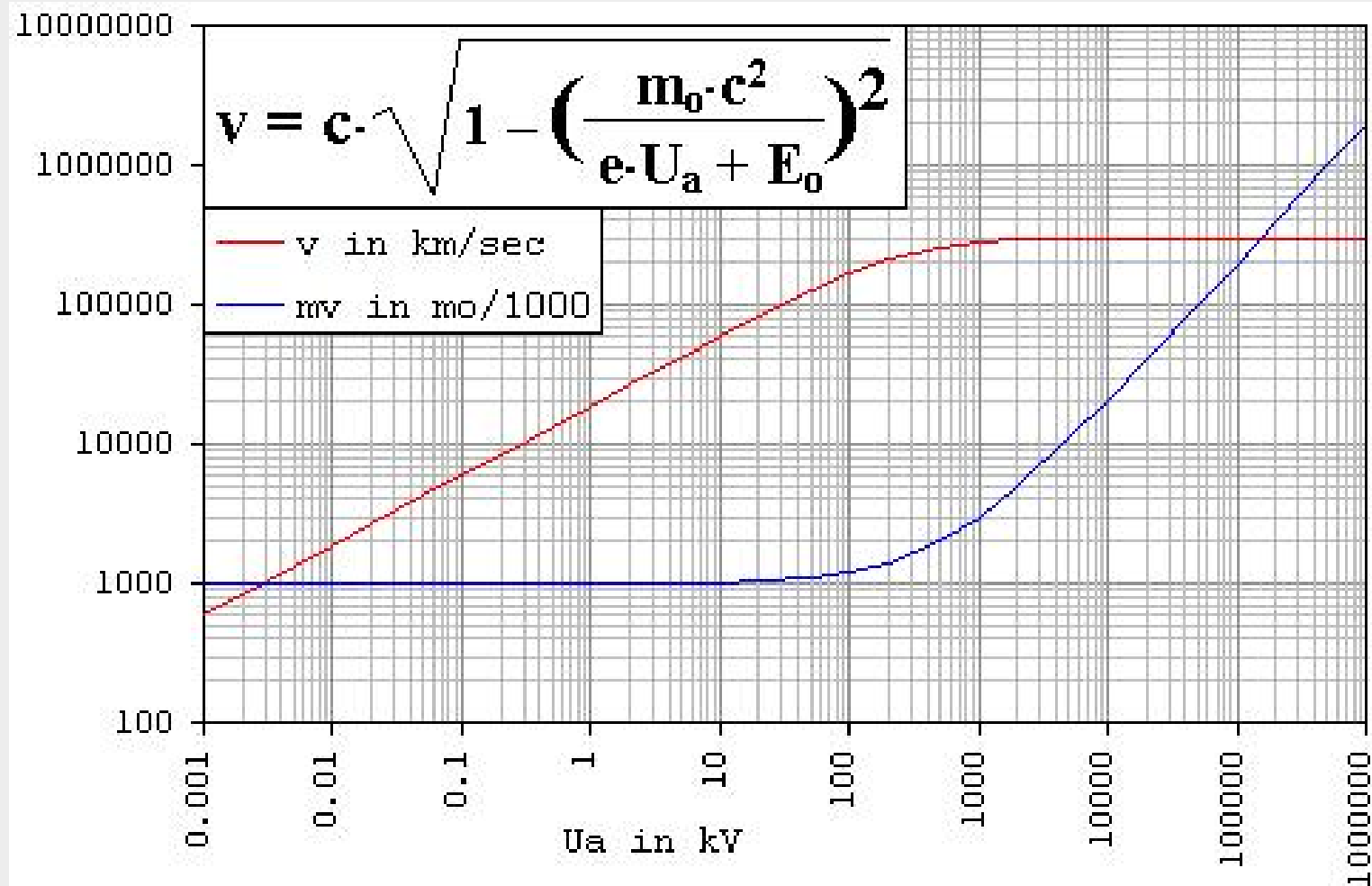


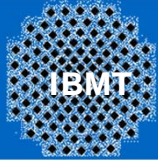
Einteilung Teilchenbeschleuniger



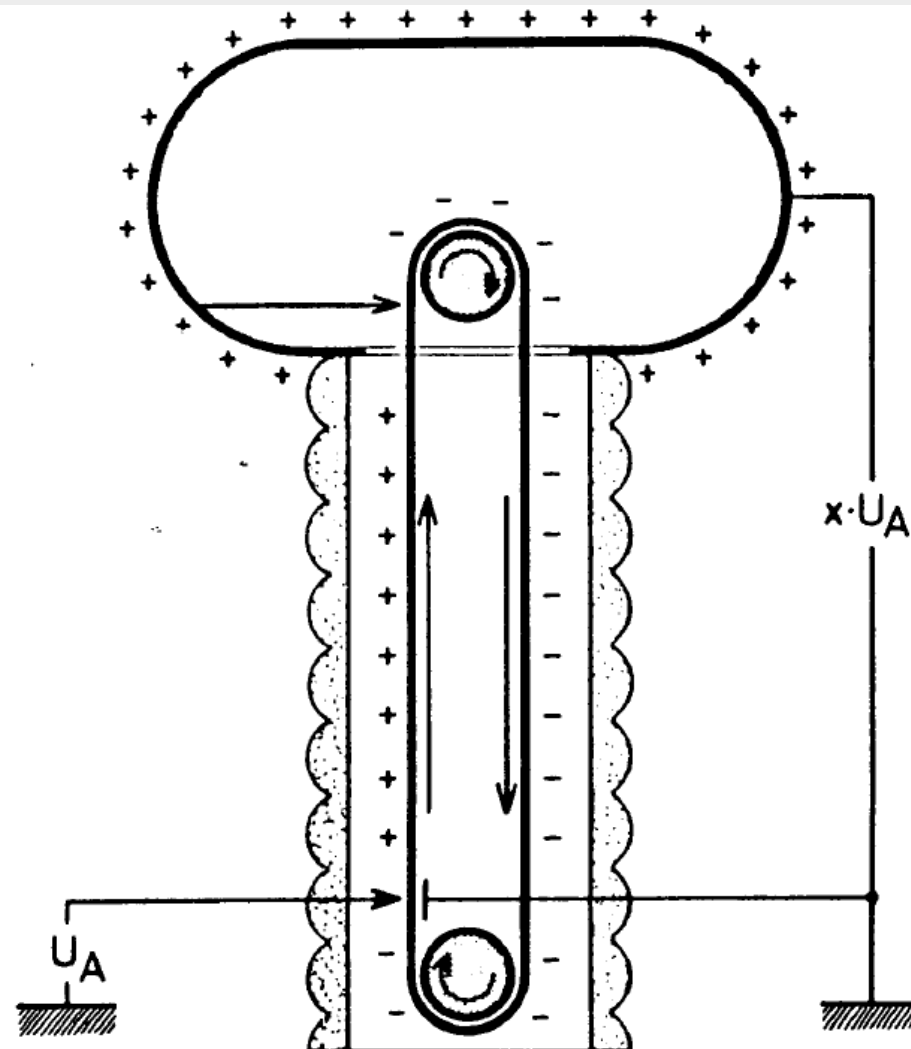


Relativistischer Massenzuwachs

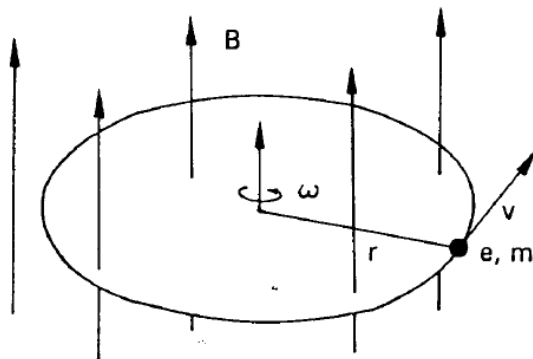




Van-de-Graaff Generator



Kreisbeschleuniger

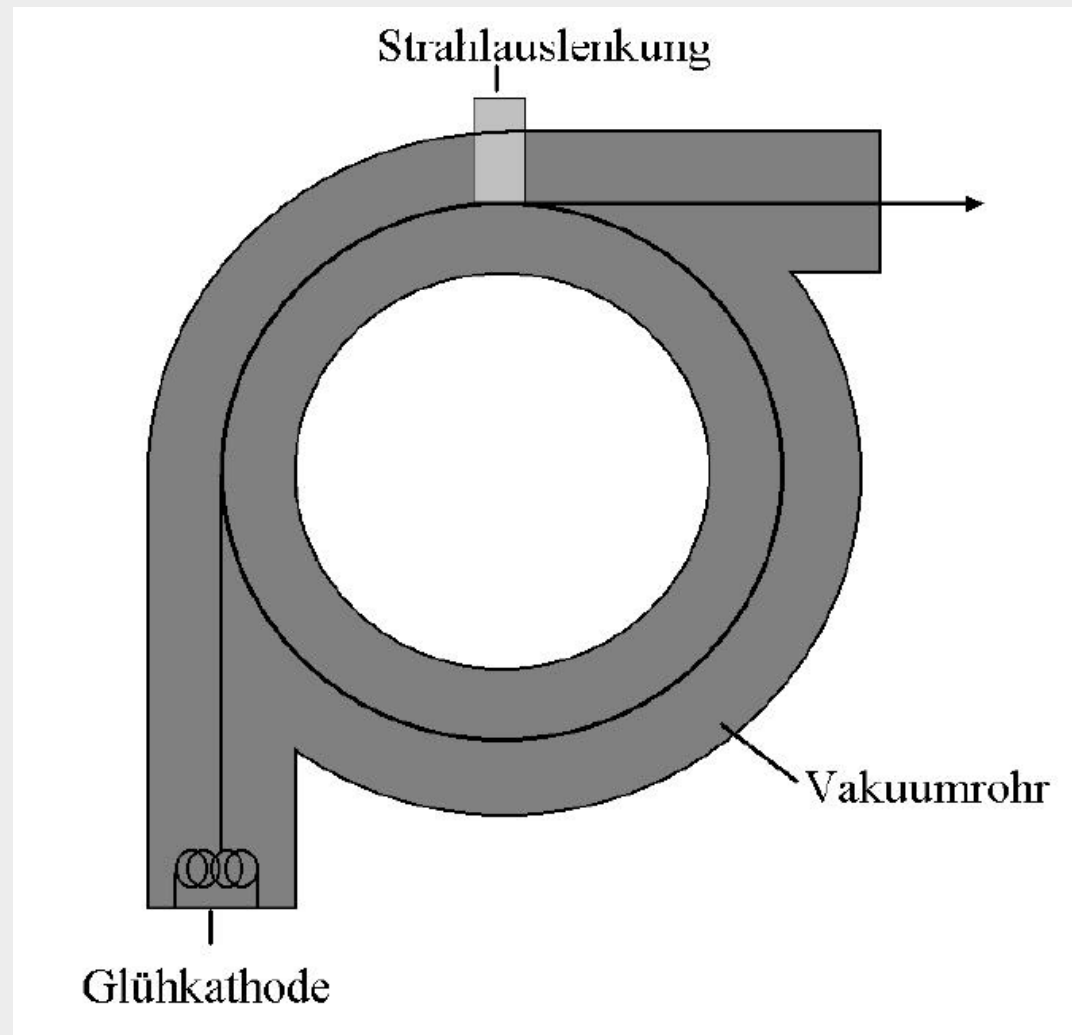


$m v = e B r$
$\omega = \frac{v}{r} = \frac{e}{m} \cdot B$

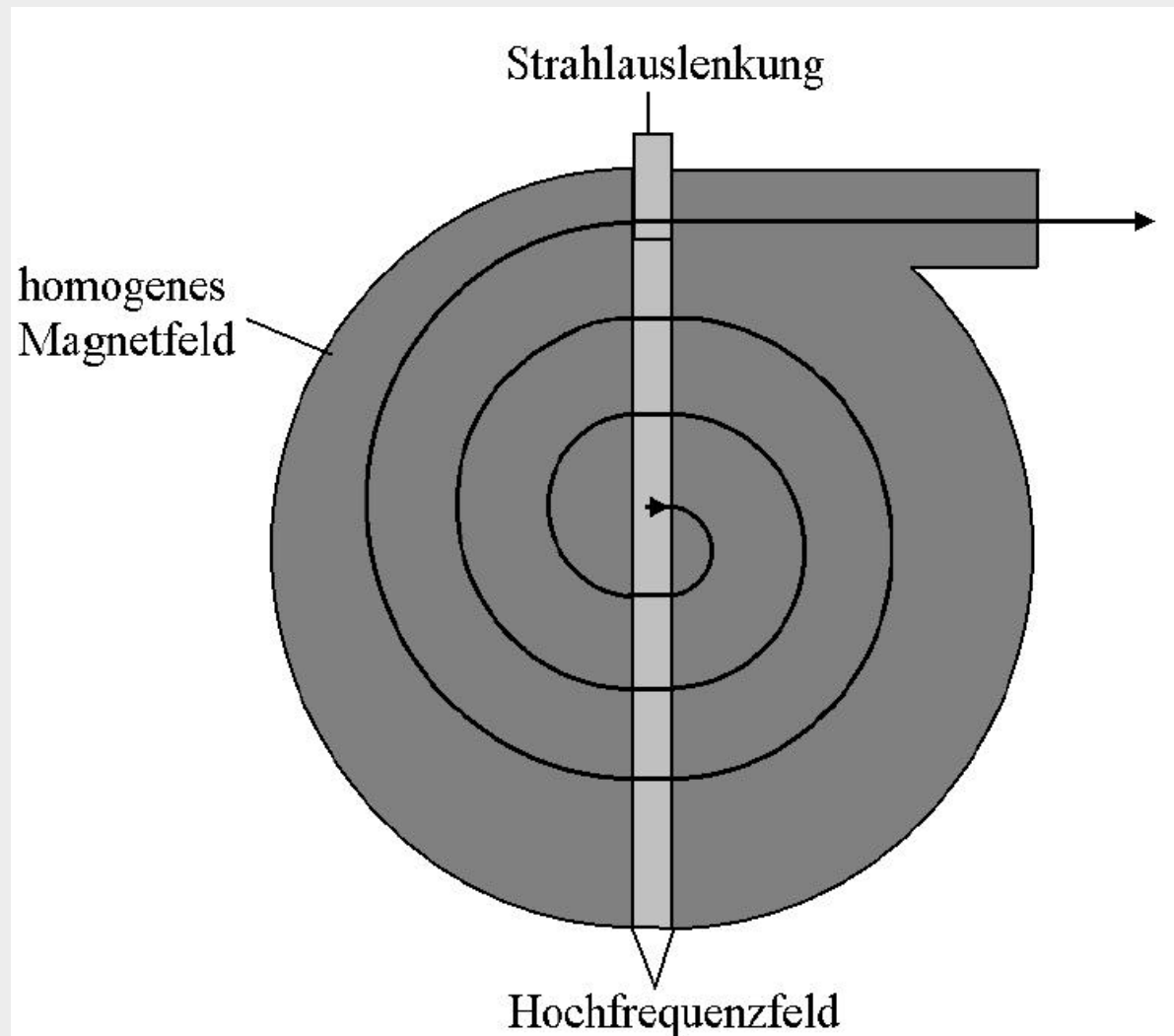
	Zyklotron
e ⁻	Mikrotron
	Synchrozyklotron
e ⁻	Synchrotron
e ⁻	Betatron

ω	r	B
C	V	C
V	V	C
V	V	C
V	C	V
V	C	V

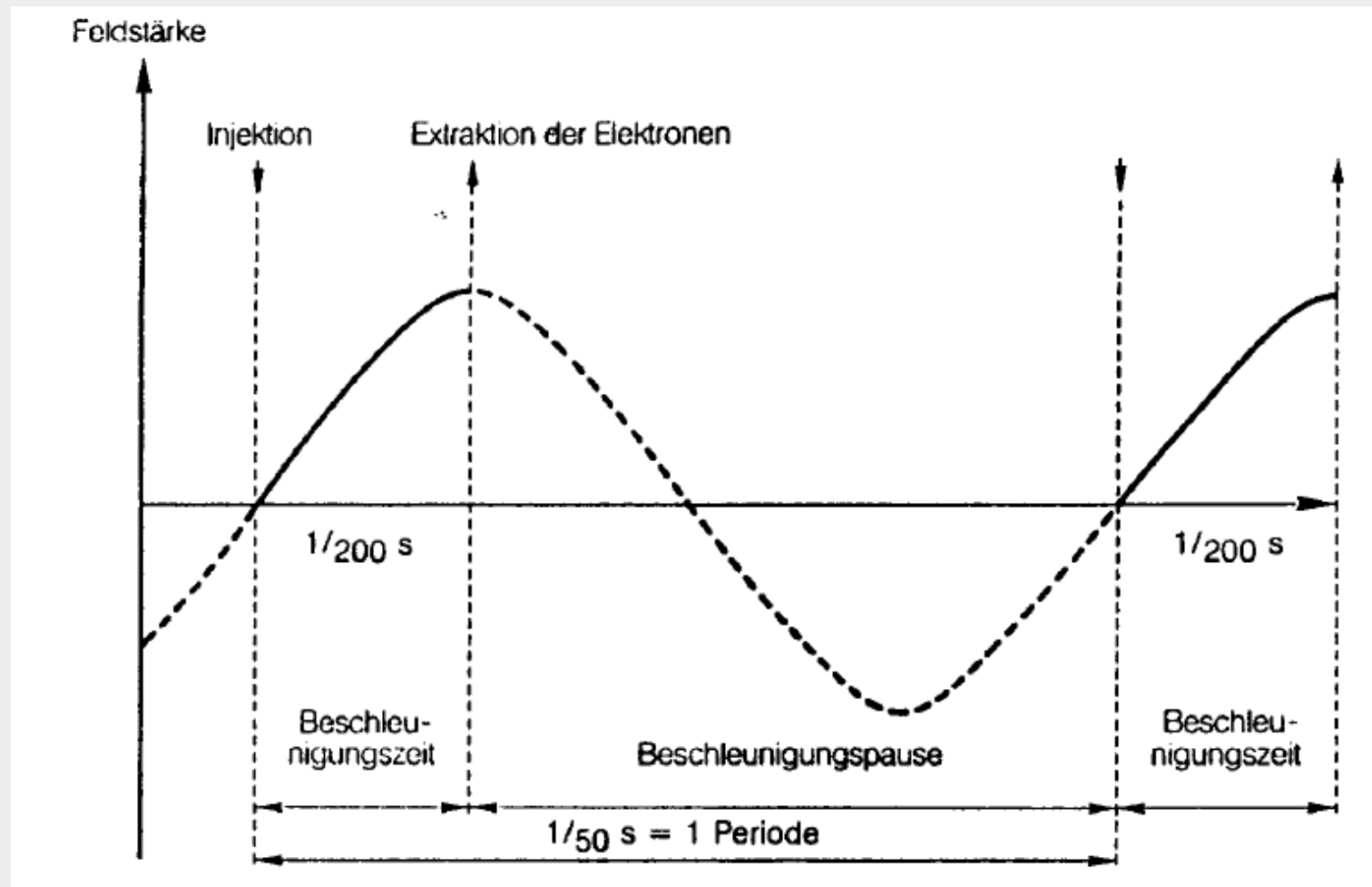
Betatron



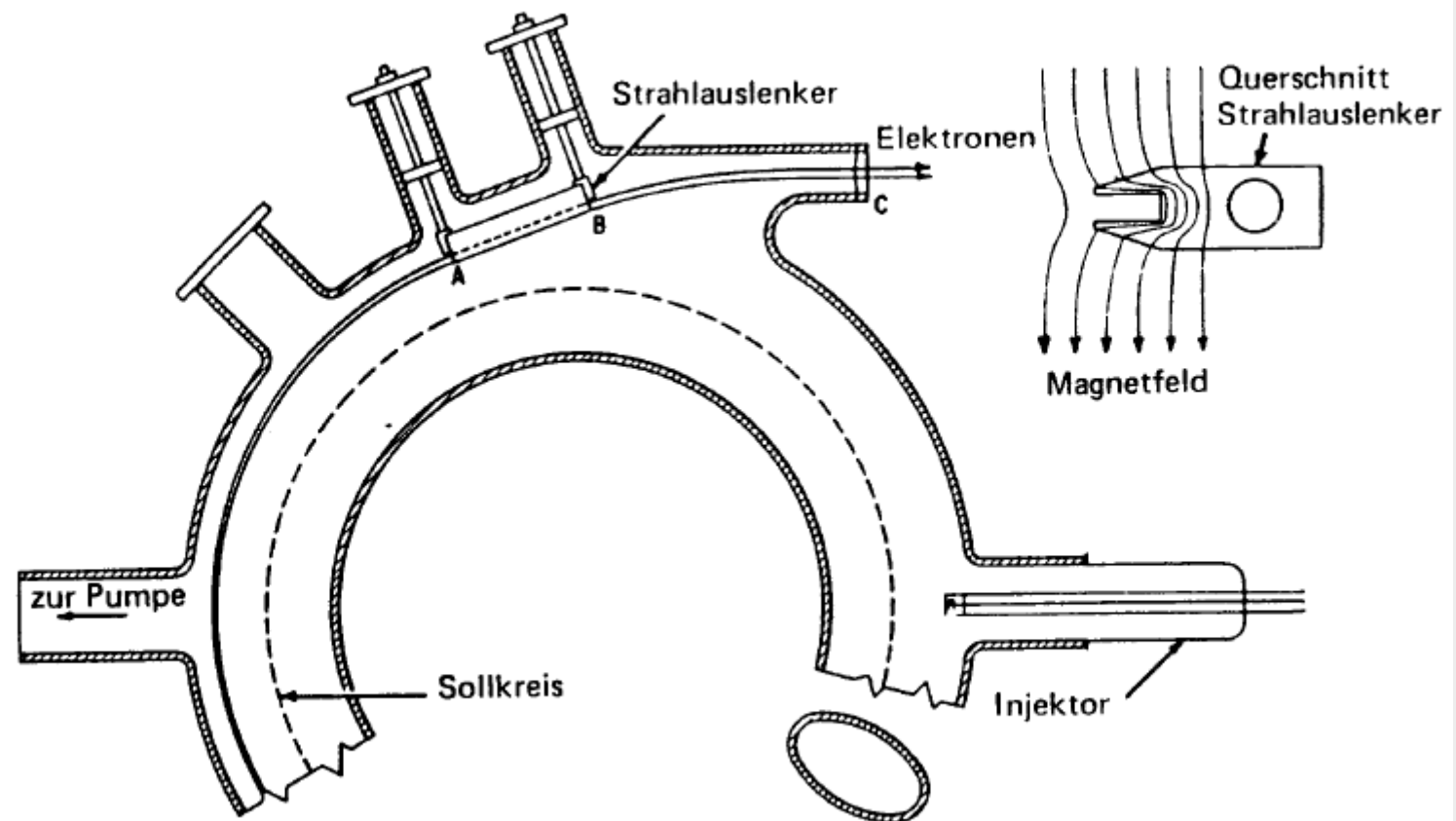
Zyklotron



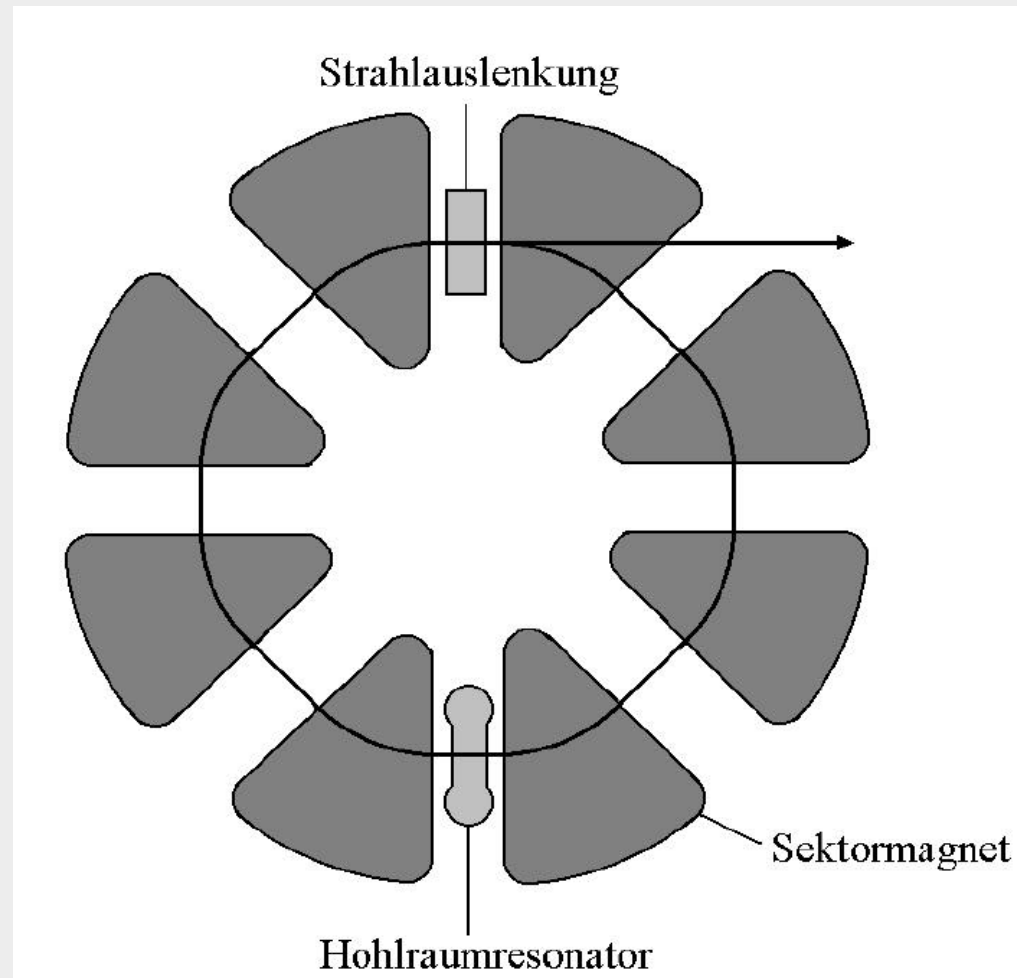
Betatron



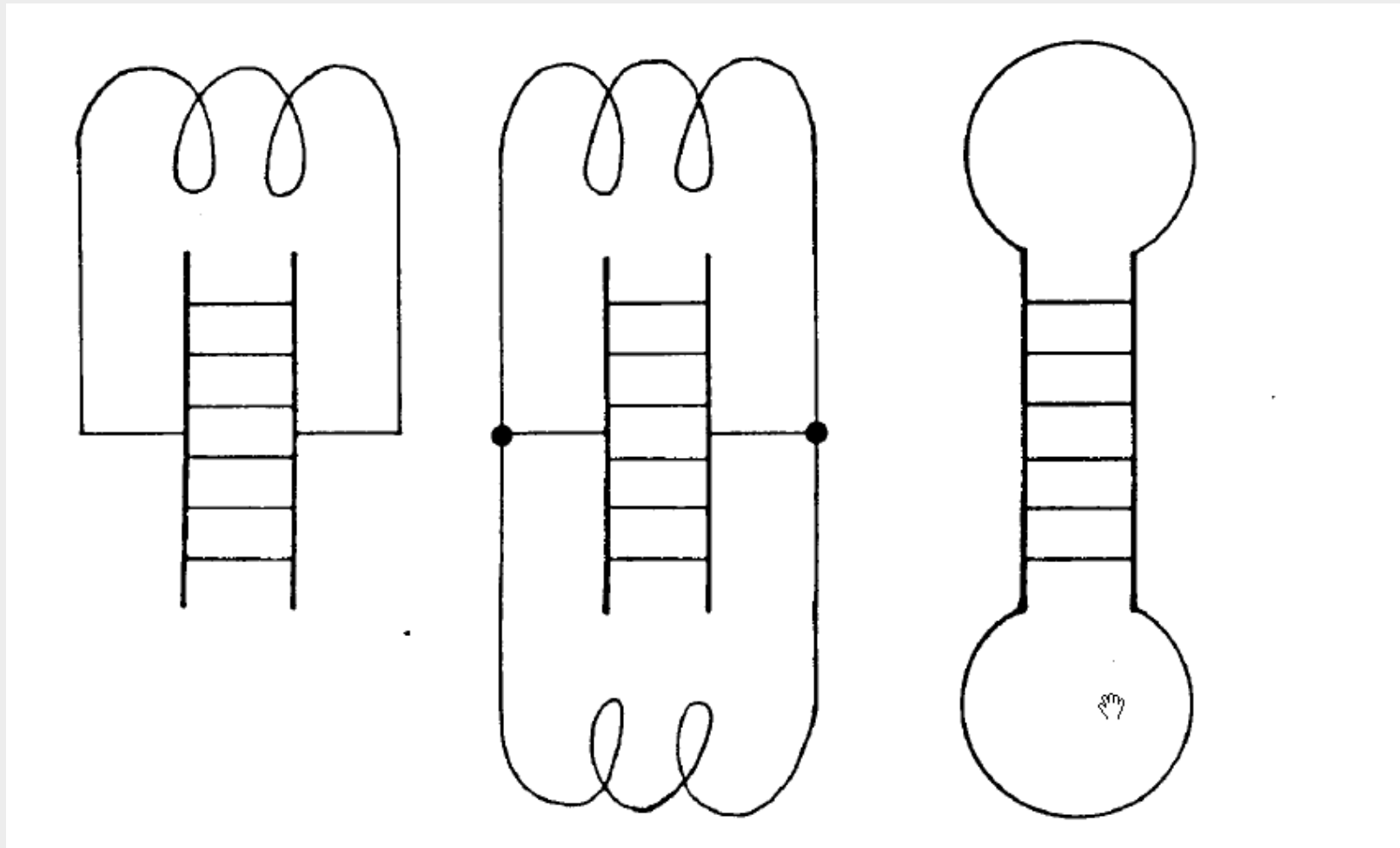
Betatron



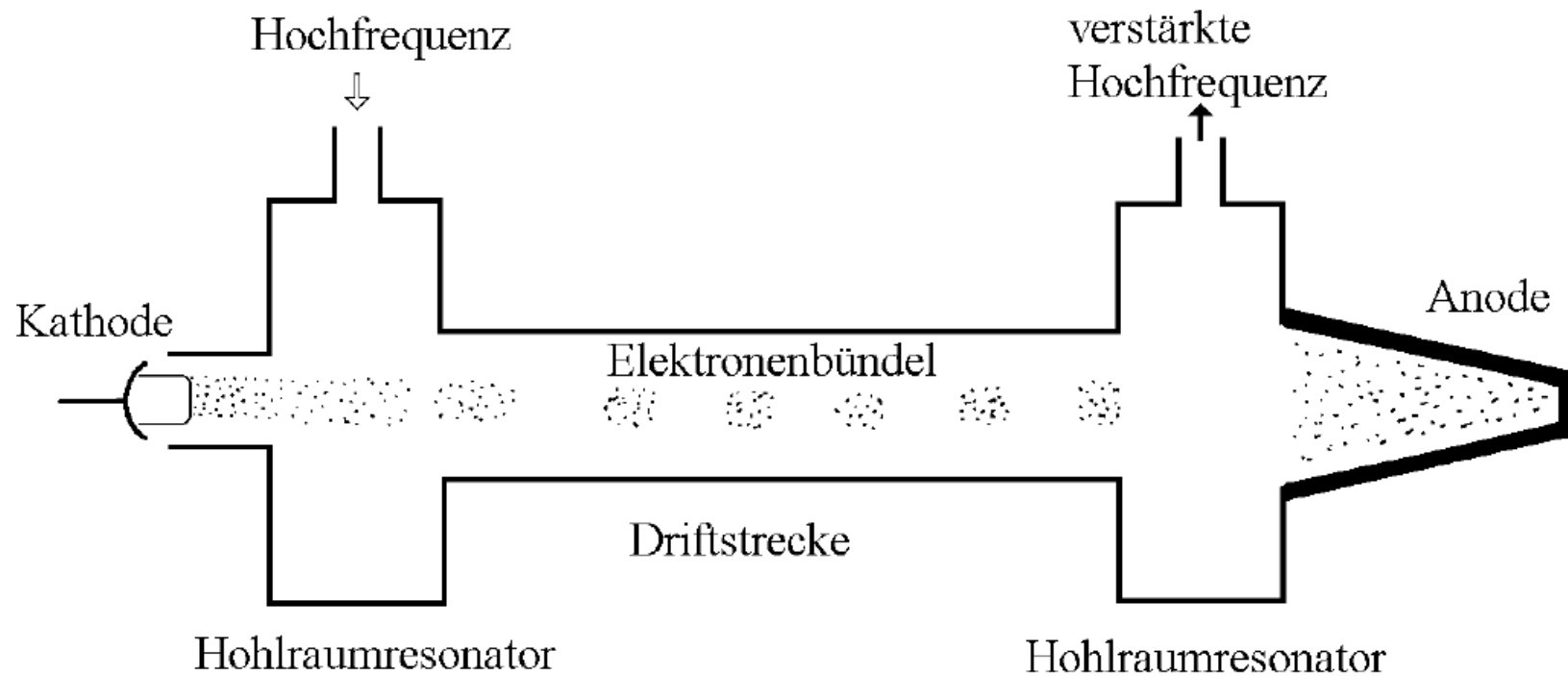
Synchrotron



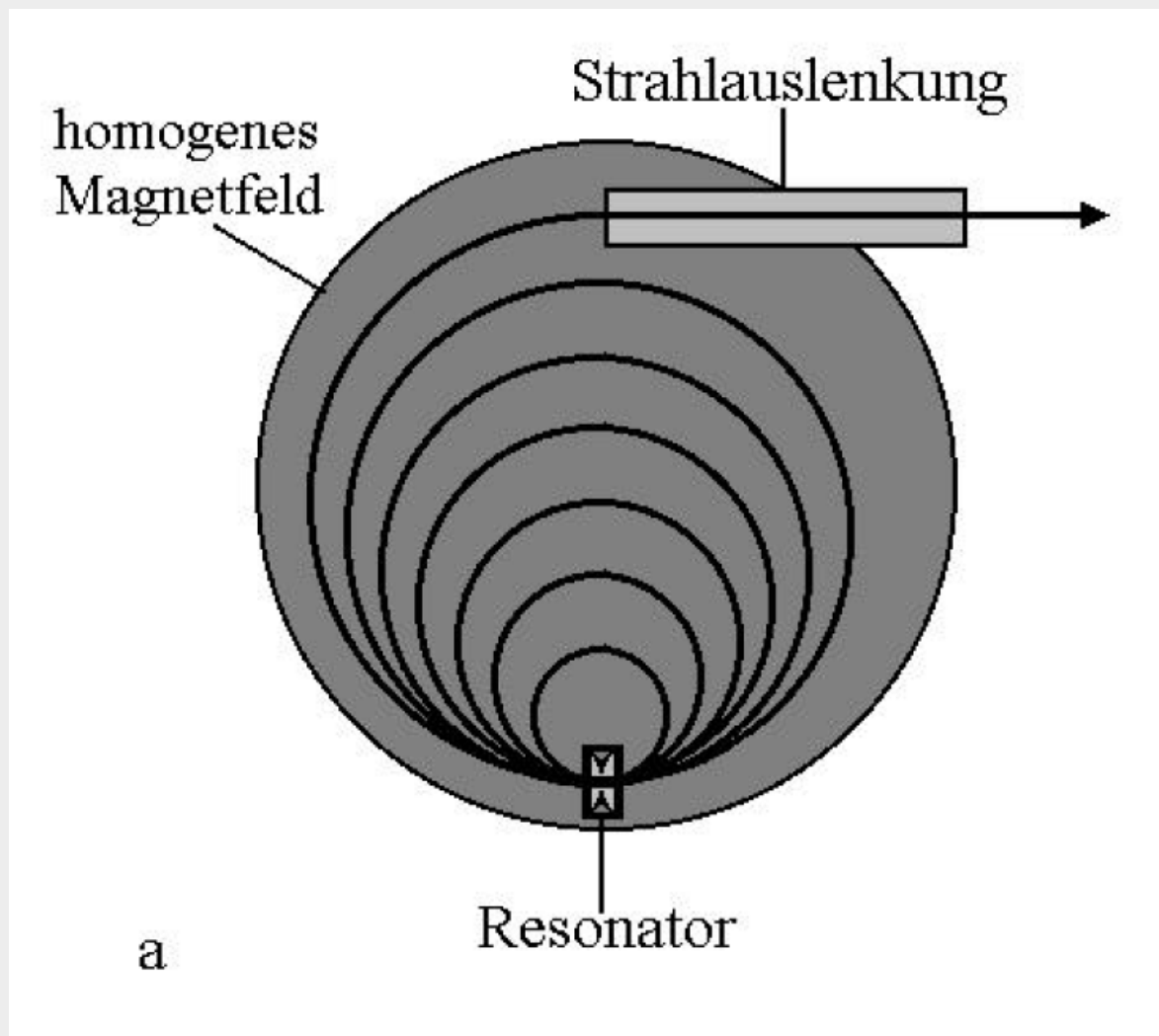
Hohlraumresonator



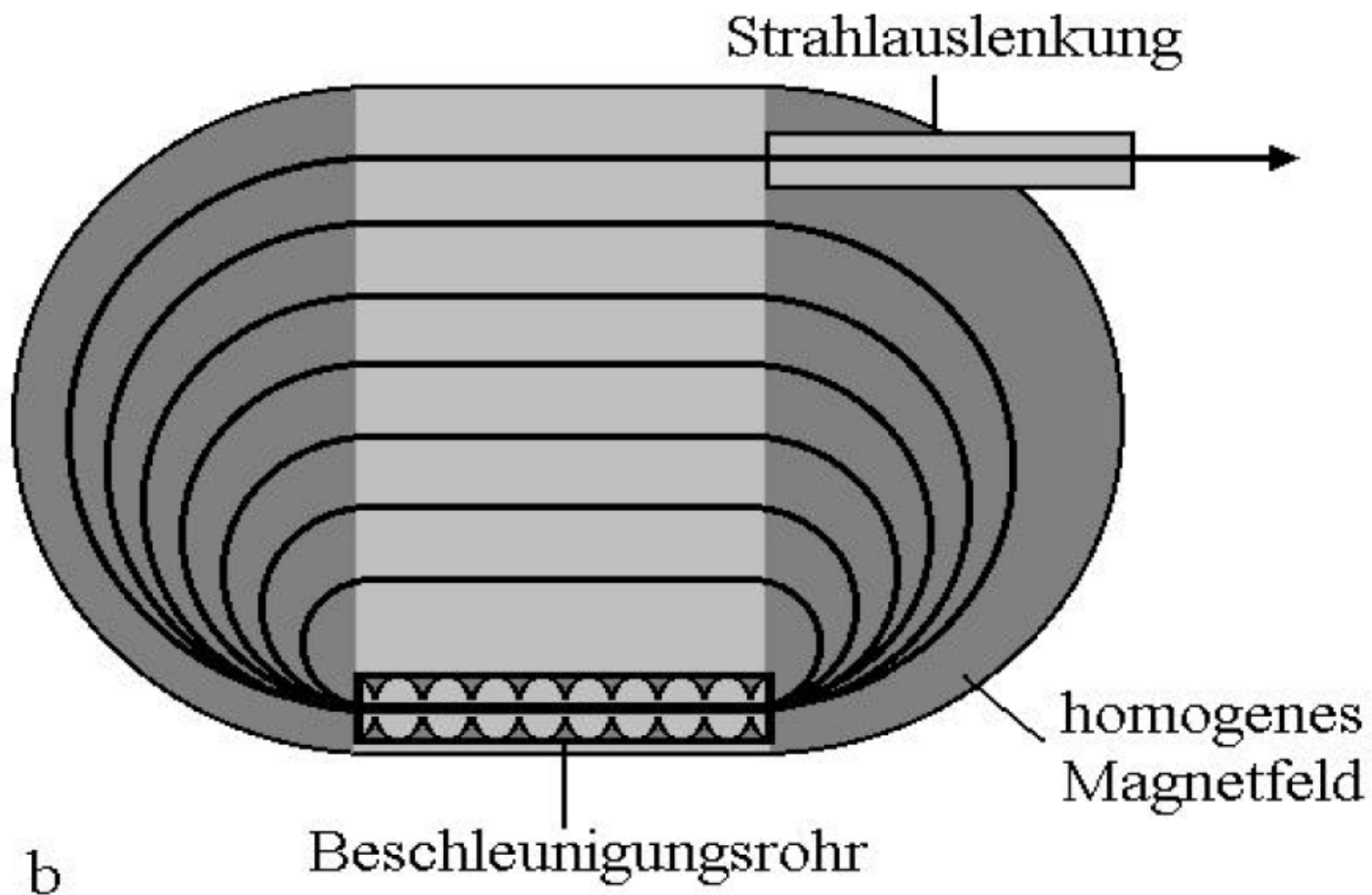
Klystron



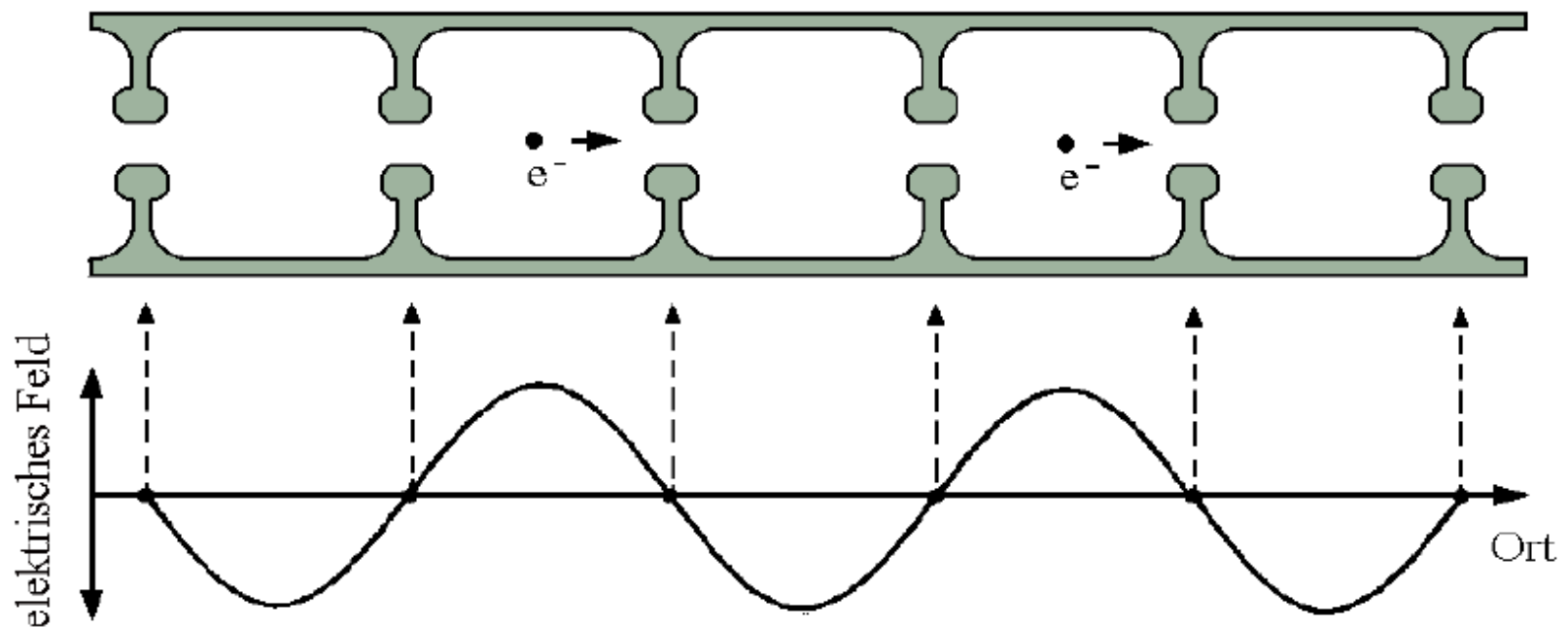
Mikrotron



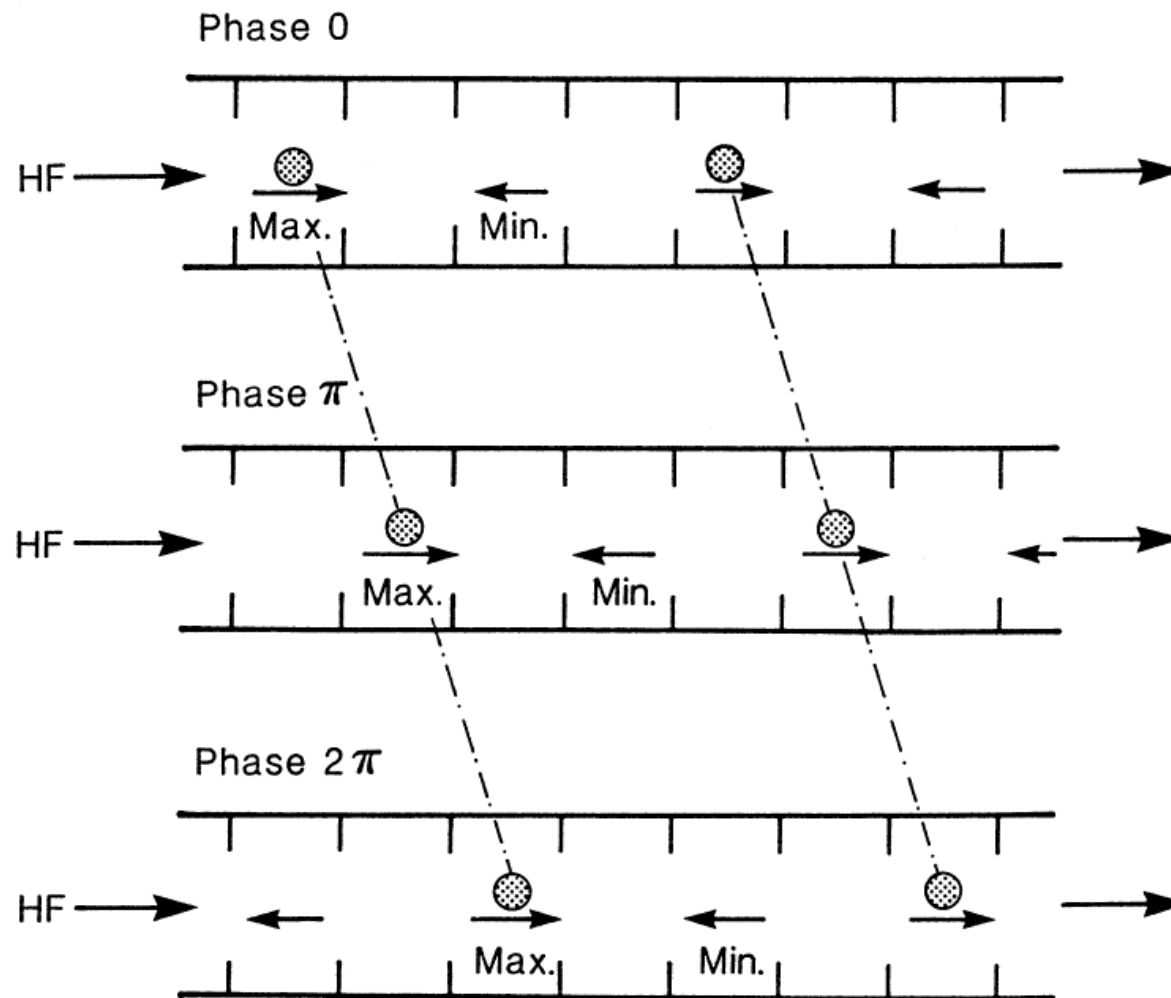
Racetrak-Mikrotron



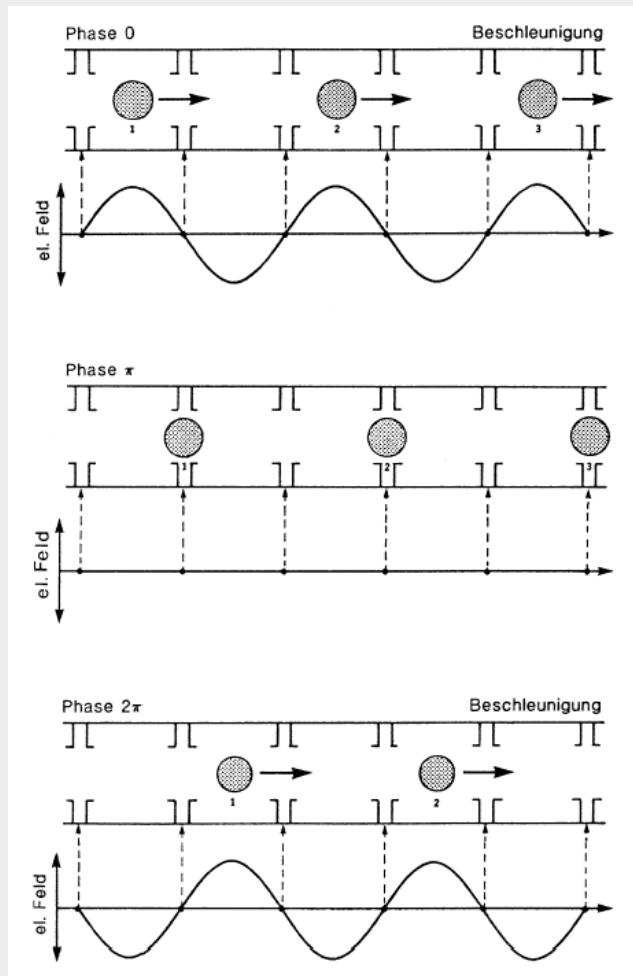
Linearbeschleuniger



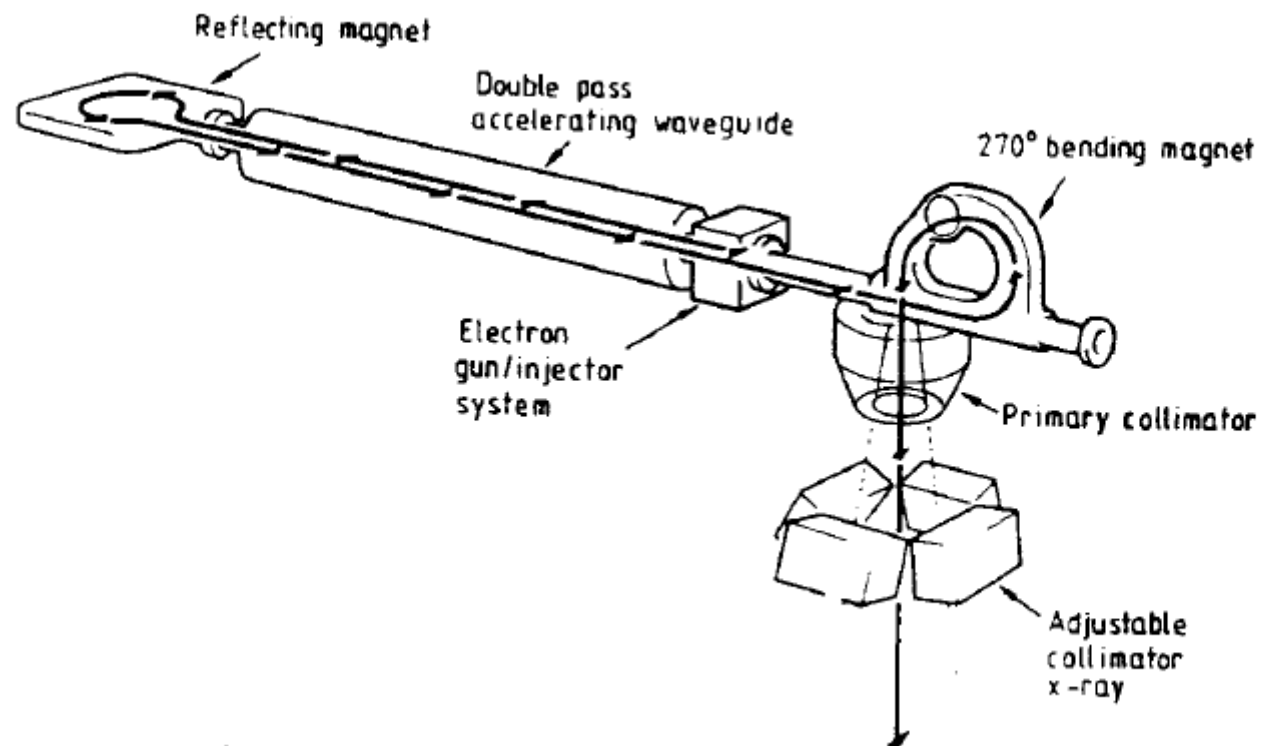
Wanderwellenbeschleunigung



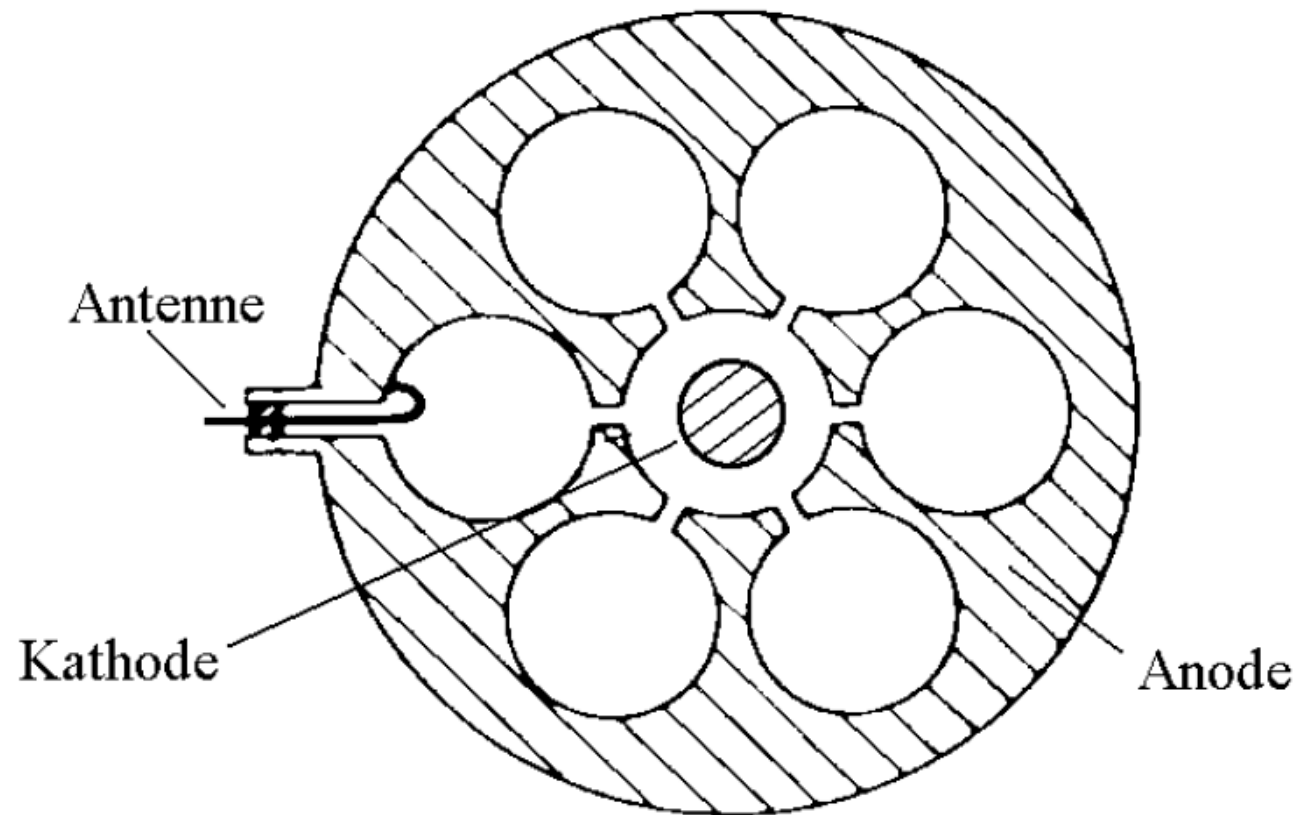
Stehwellenbeschleunigung



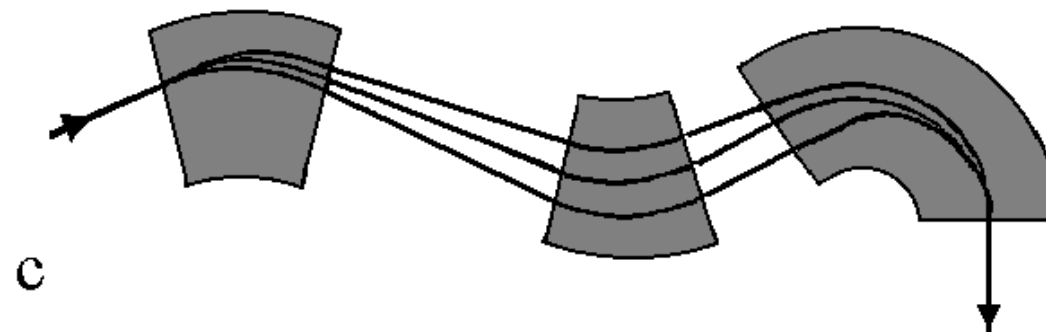
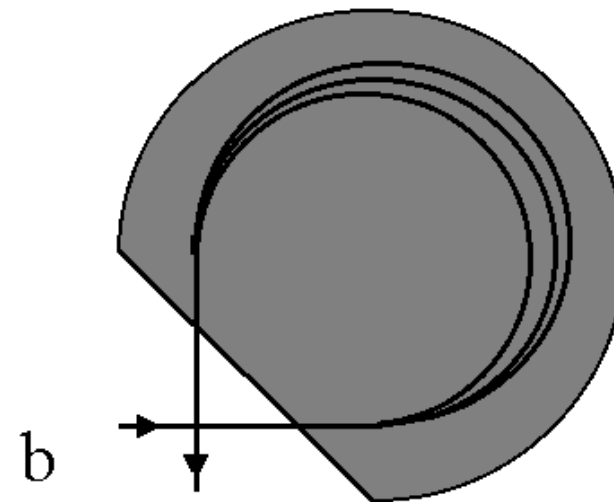
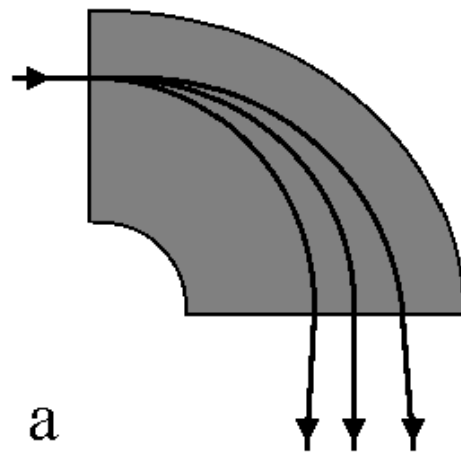
Stehwellenbeschleuniger



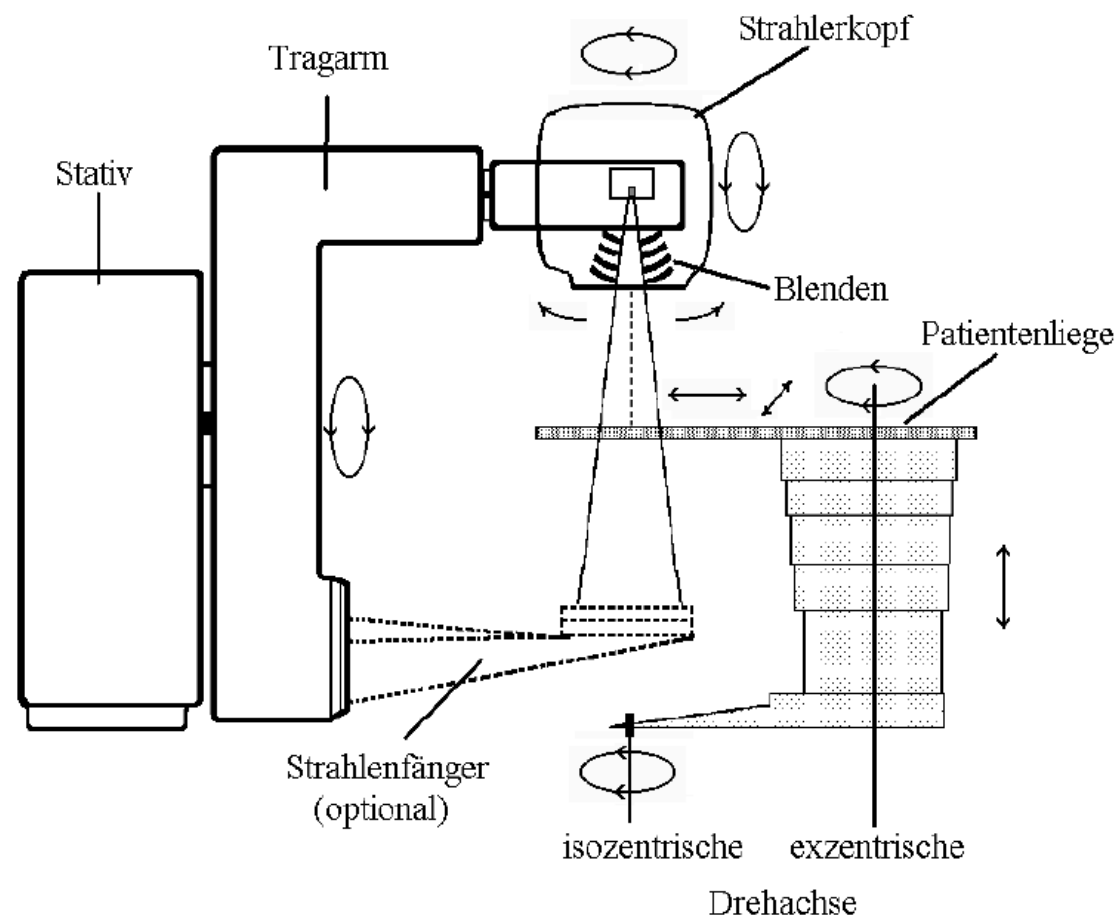
Magnetron



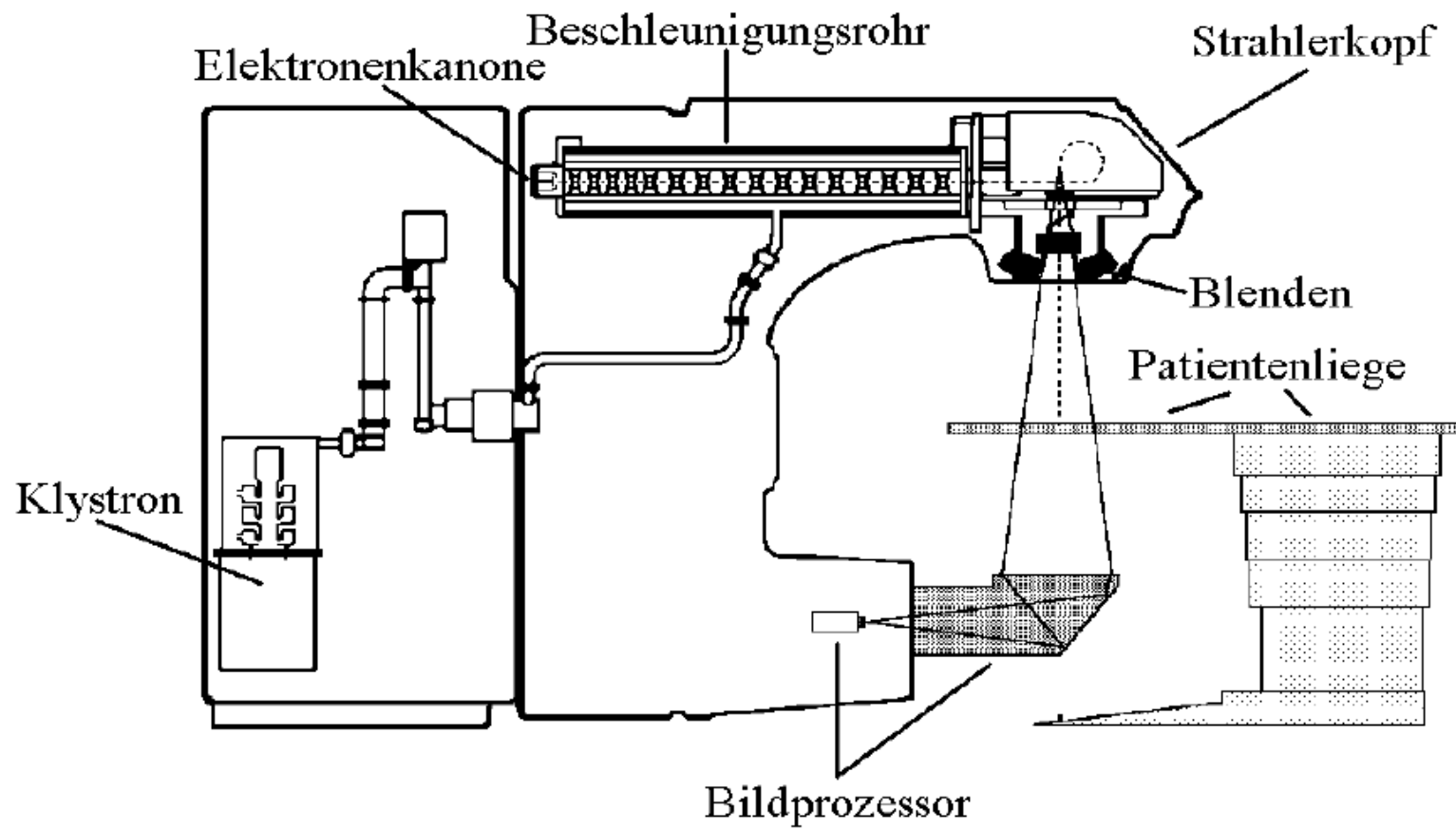
Strahlumlenkung



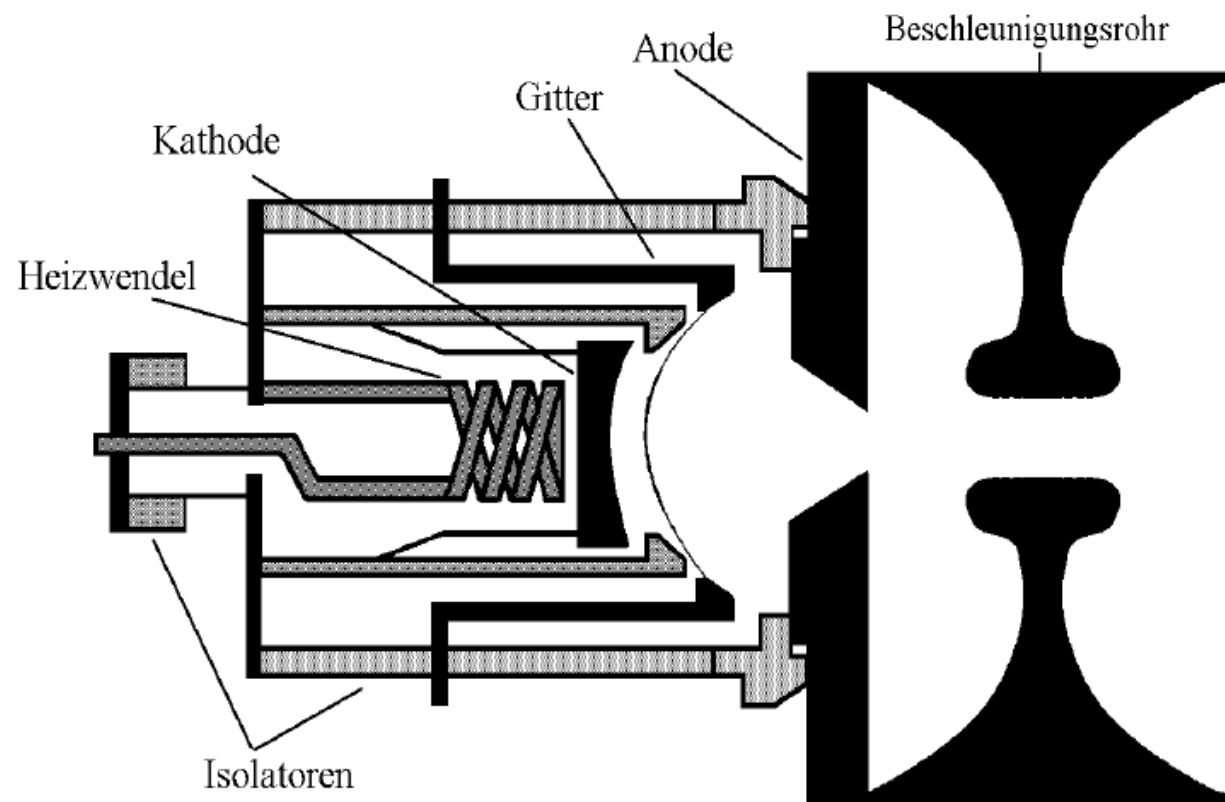
2.3. Aufbau von Teletherapieeinrichtungen



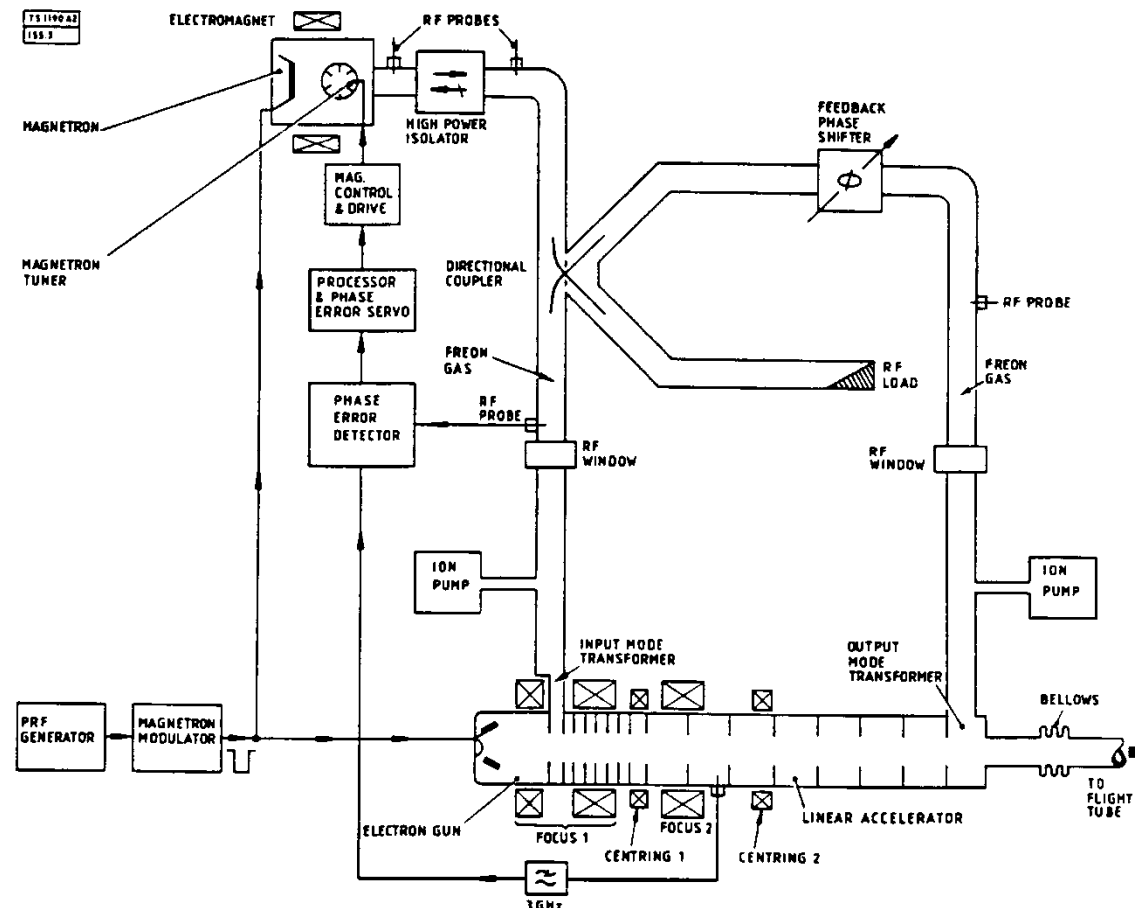
Prinzip Linac



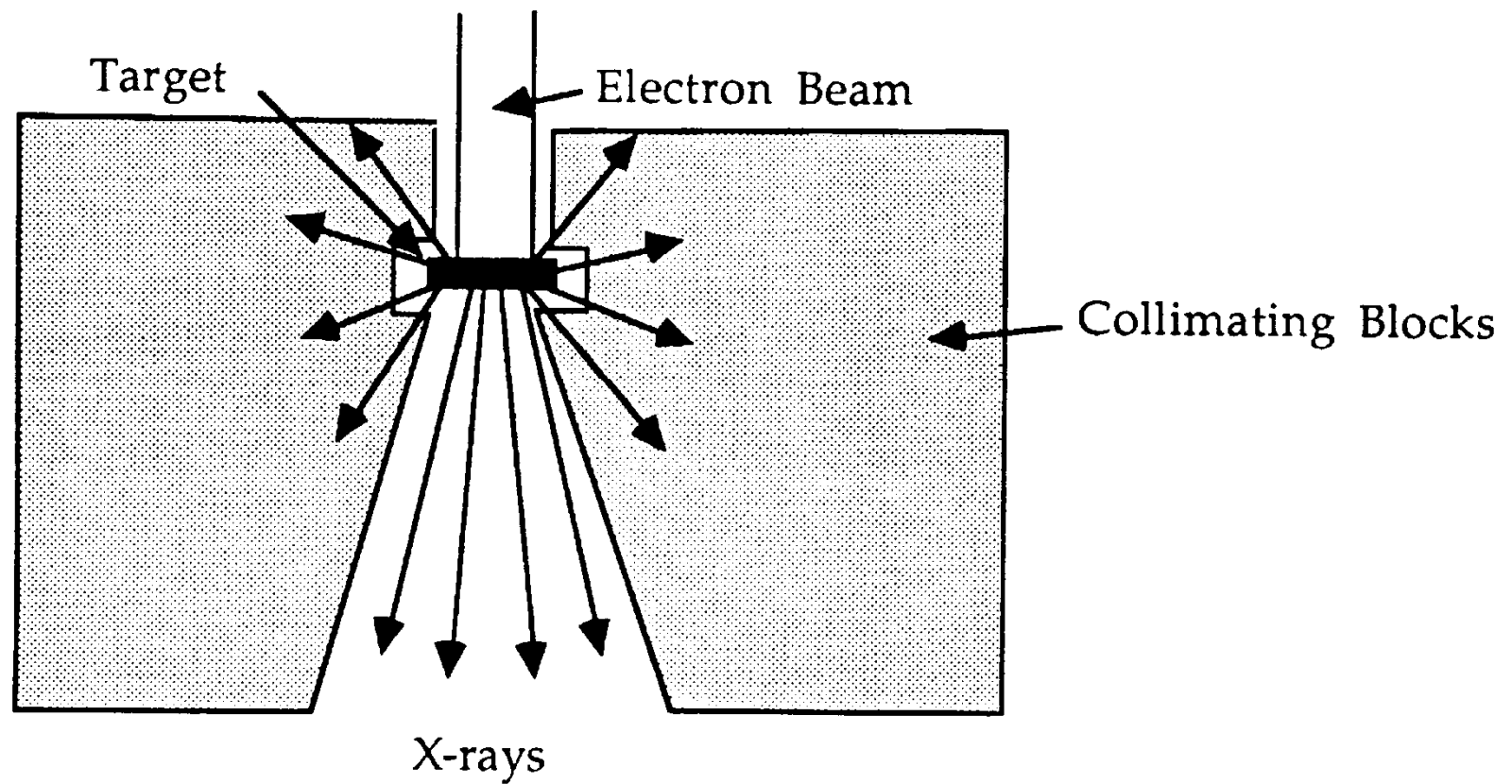
Elektronenkanone (Gun)



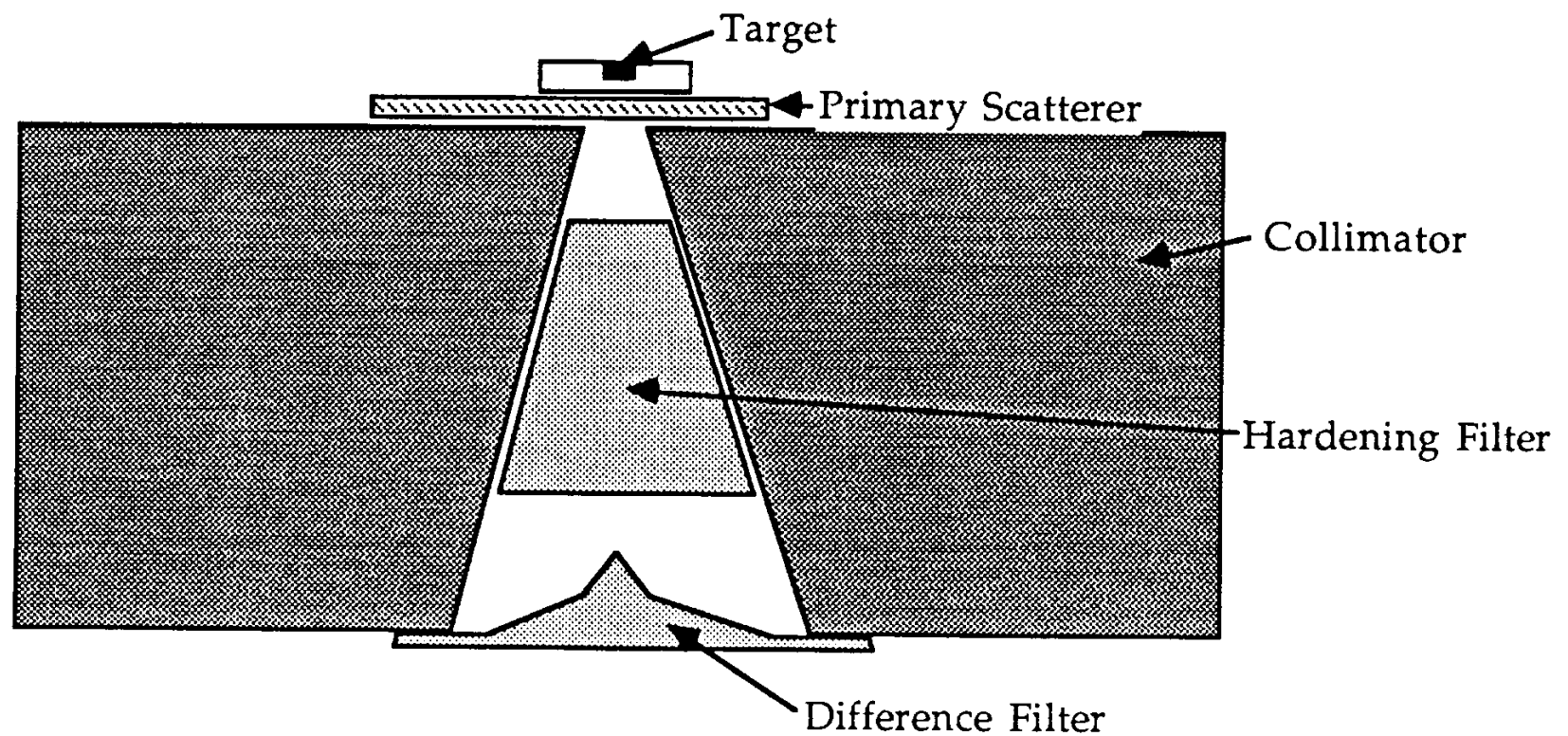
HF-System



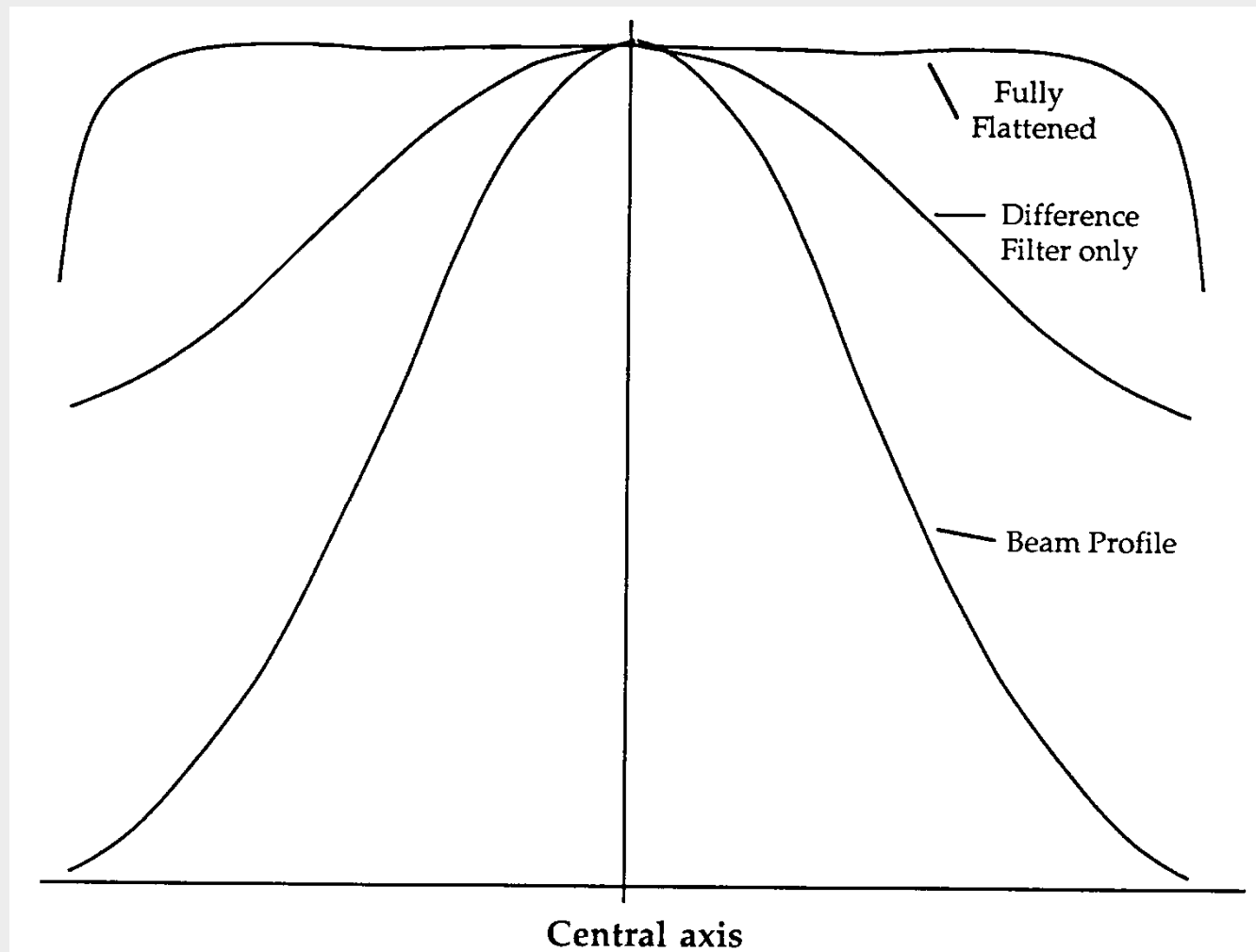
Target



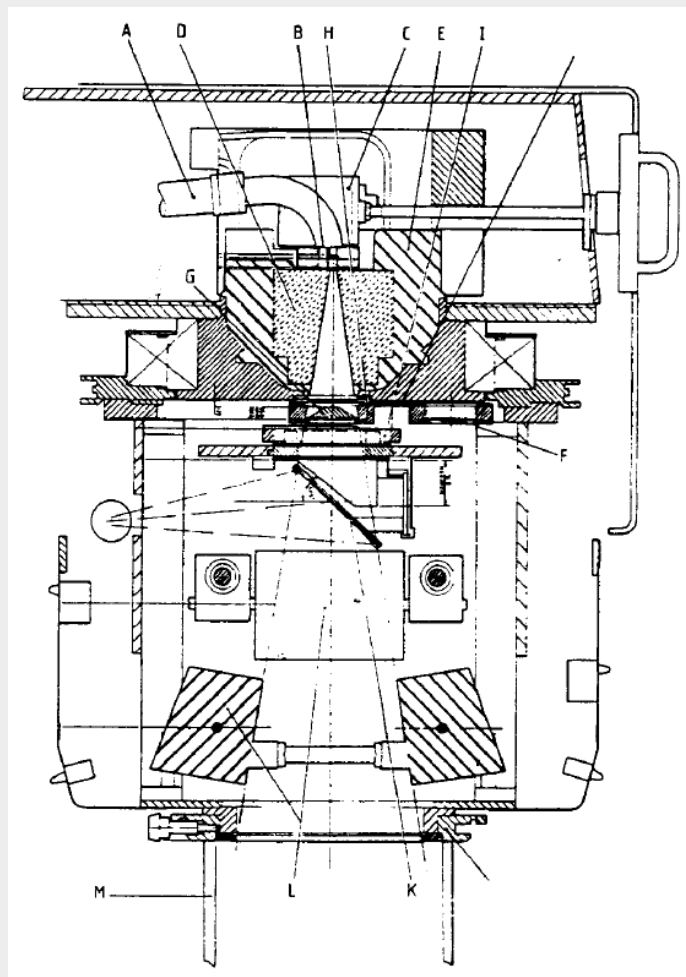
Primärkollimator



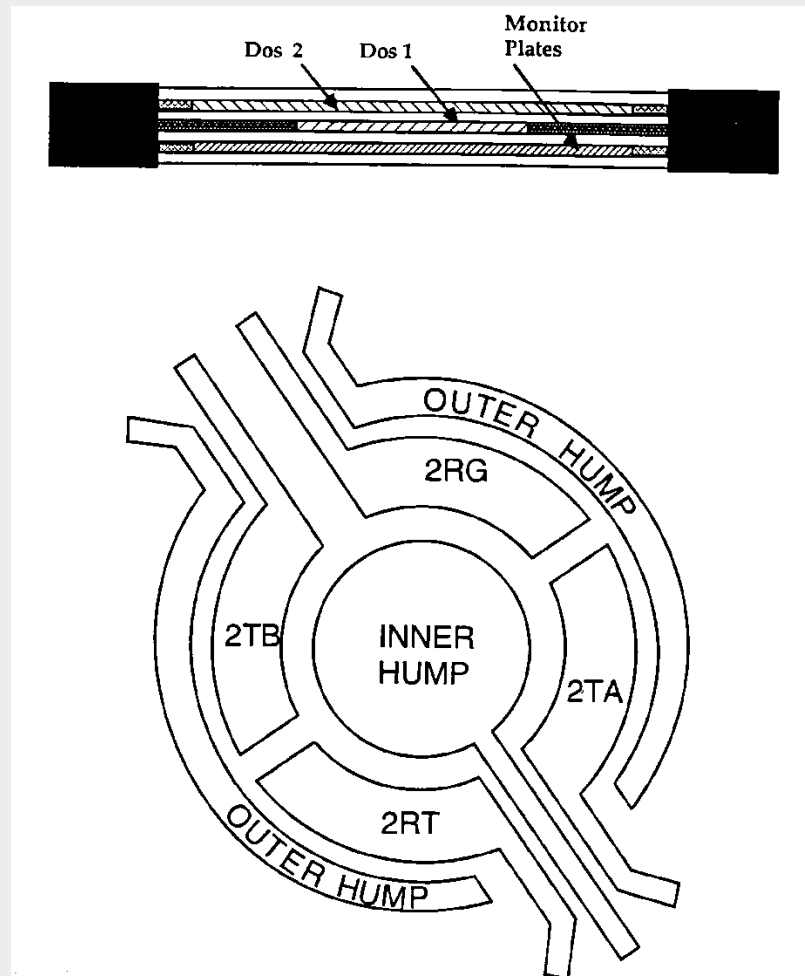
Querprofil



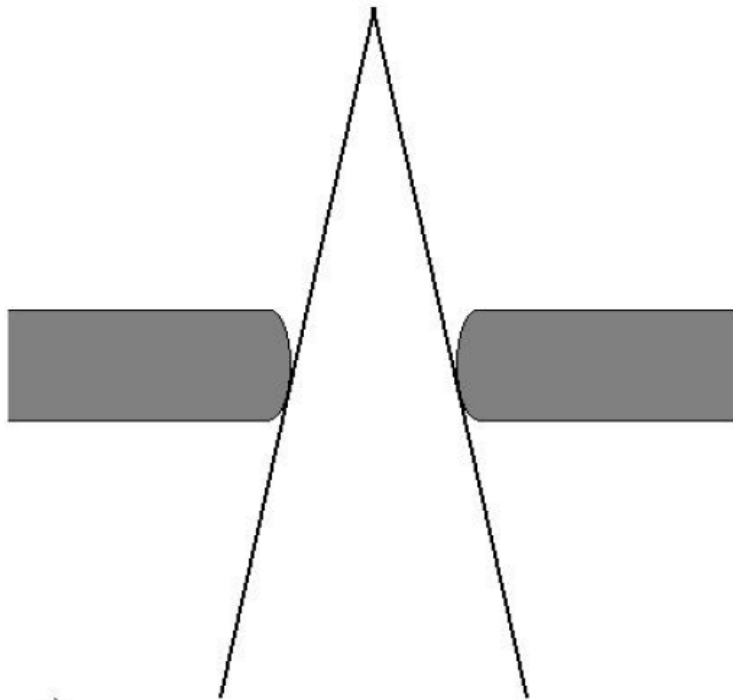
Strahlerkopf Linac



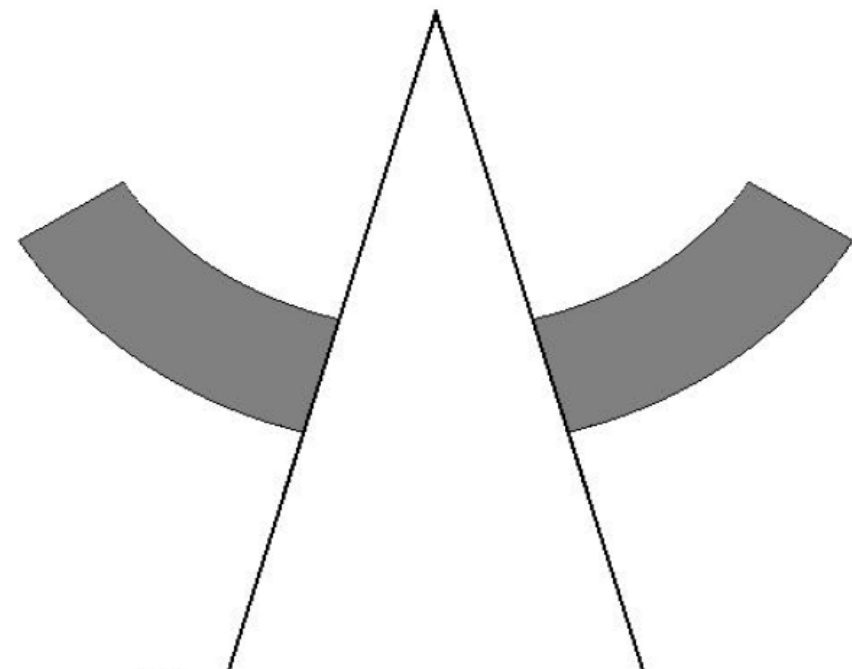
Monitorkammer



Prinzip der fokussierenden Blende

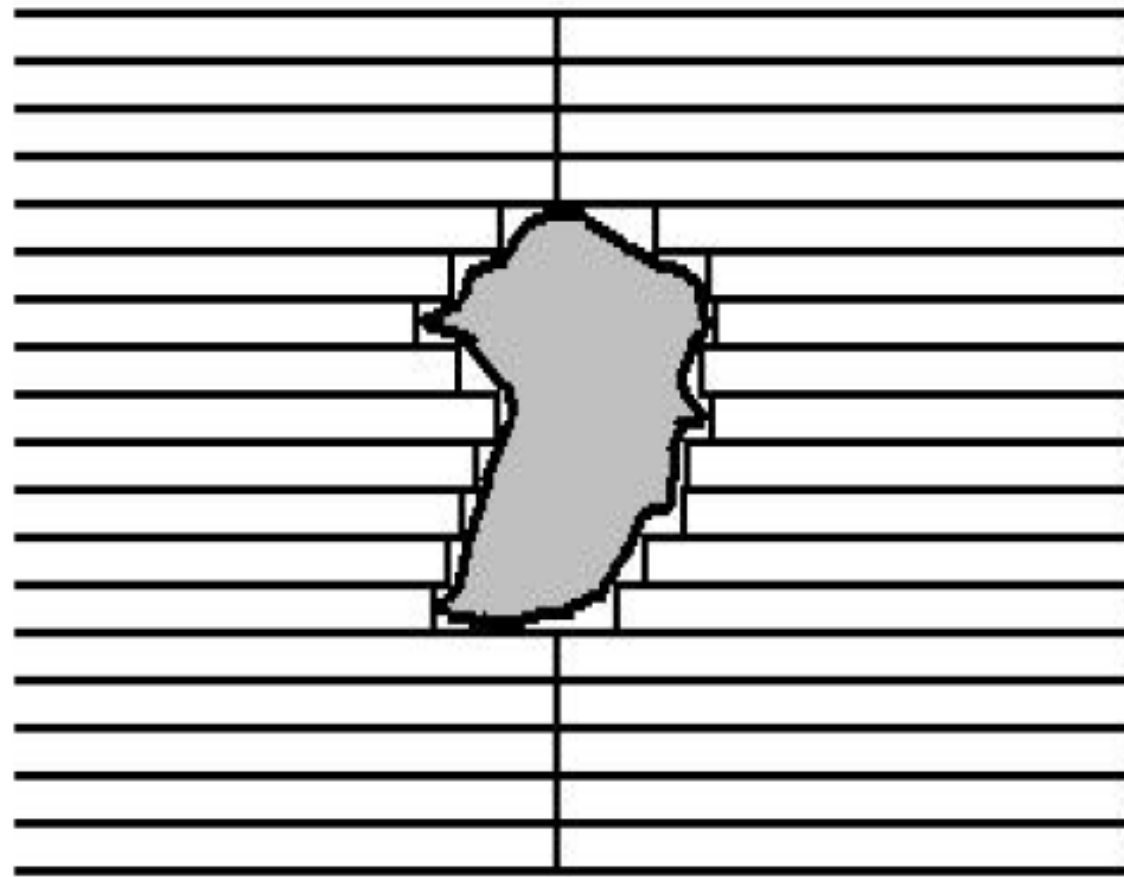


a)



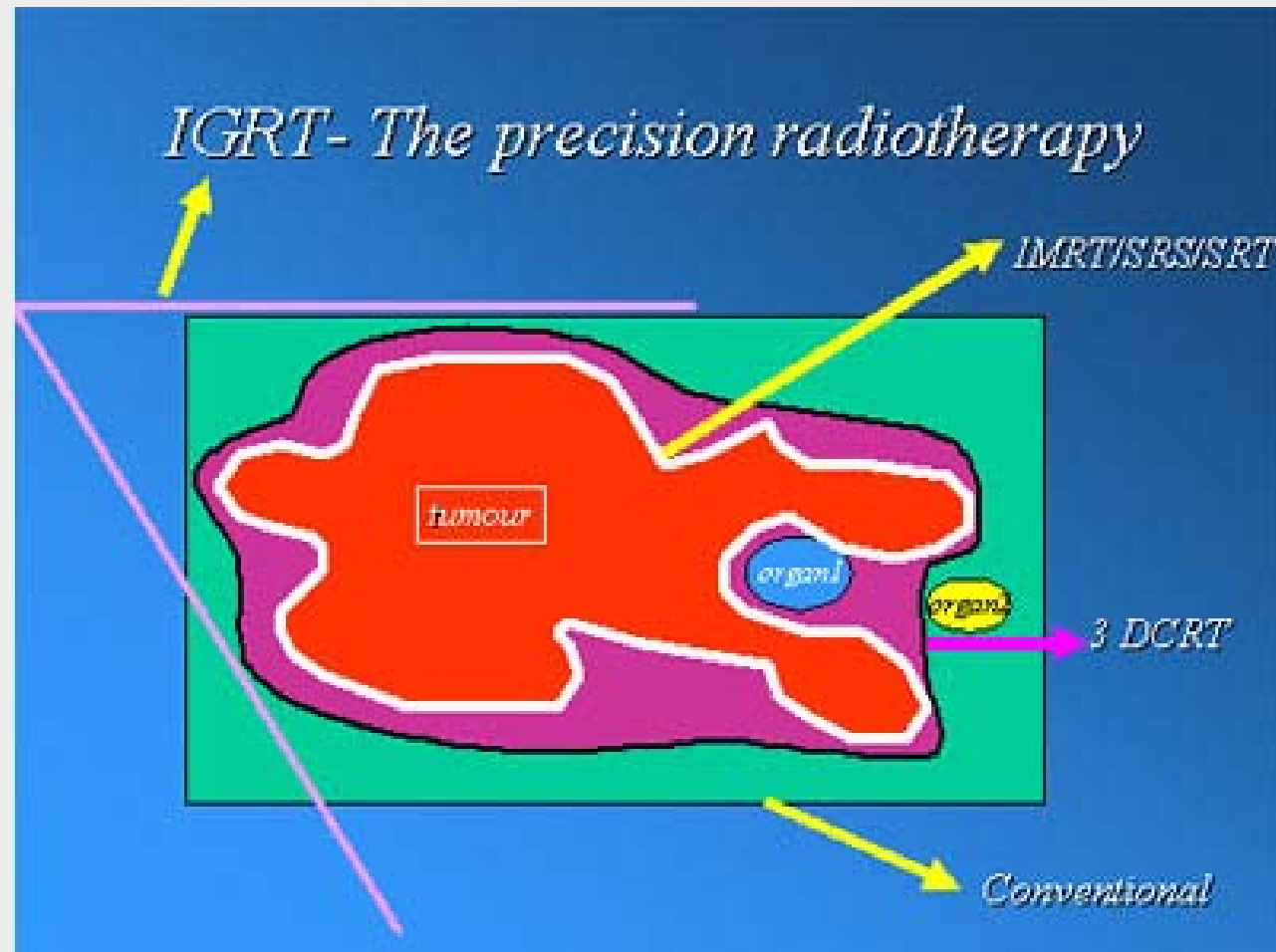
b)

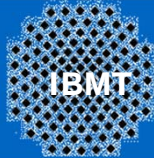
Viellamellenkollimator (MLC)



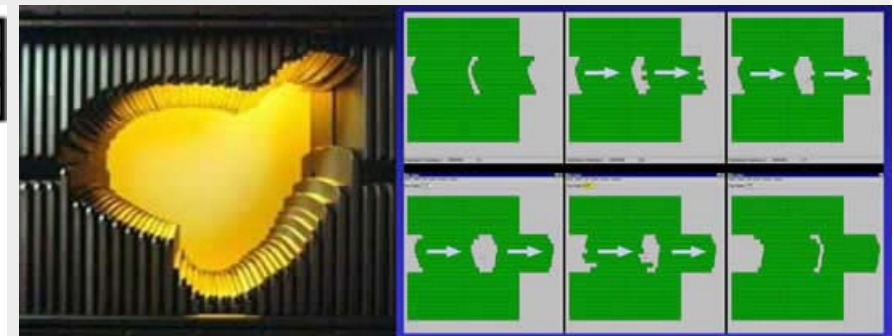
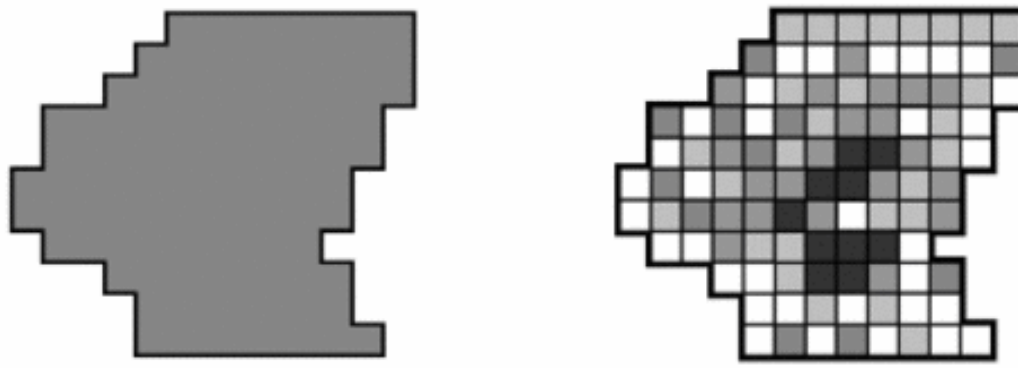
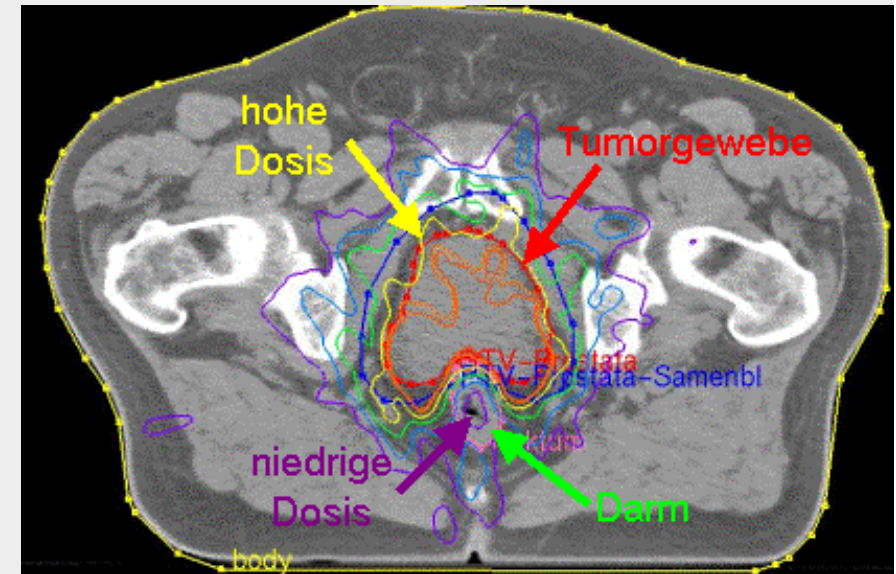
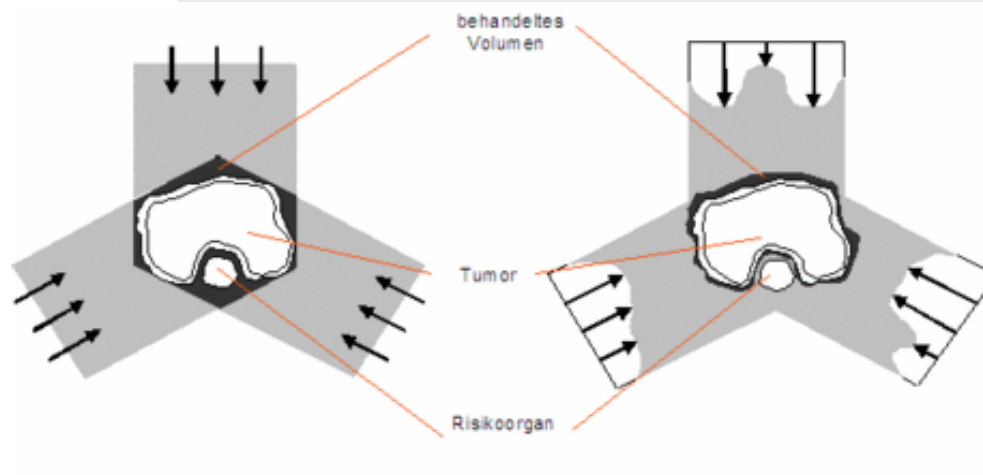
Linac

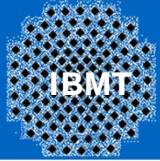






Linearbeschleuniger IMRT





Vorteile/Nachteile IMRT

Vorteile

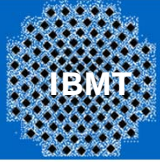
- Hohe Dosiskonformität
- Steile Gradienten
- Möglichkeit der Dosisescalation
- Möglichkeit der Dosisvariation im PTV (SIB, Dose Painting)

Probleme/Nachteile

- Zusätzlicher Aufwand QA
- Patientenpositionierung
- Organbewegungen

Lösungsansatz:

Bildgebung am Beschleuniger

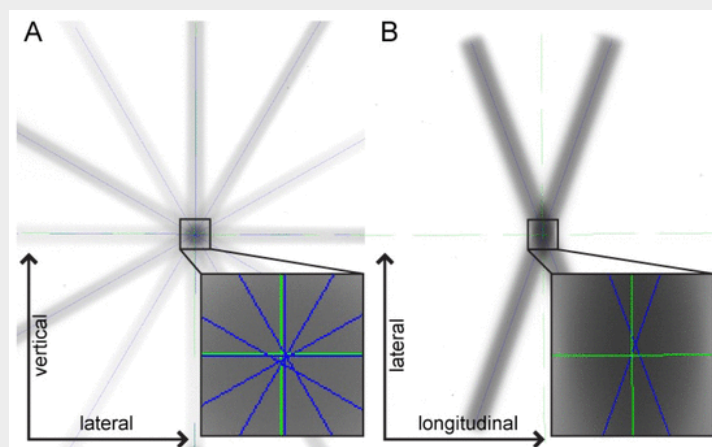
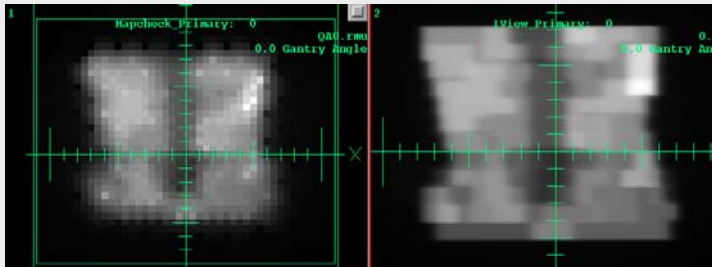


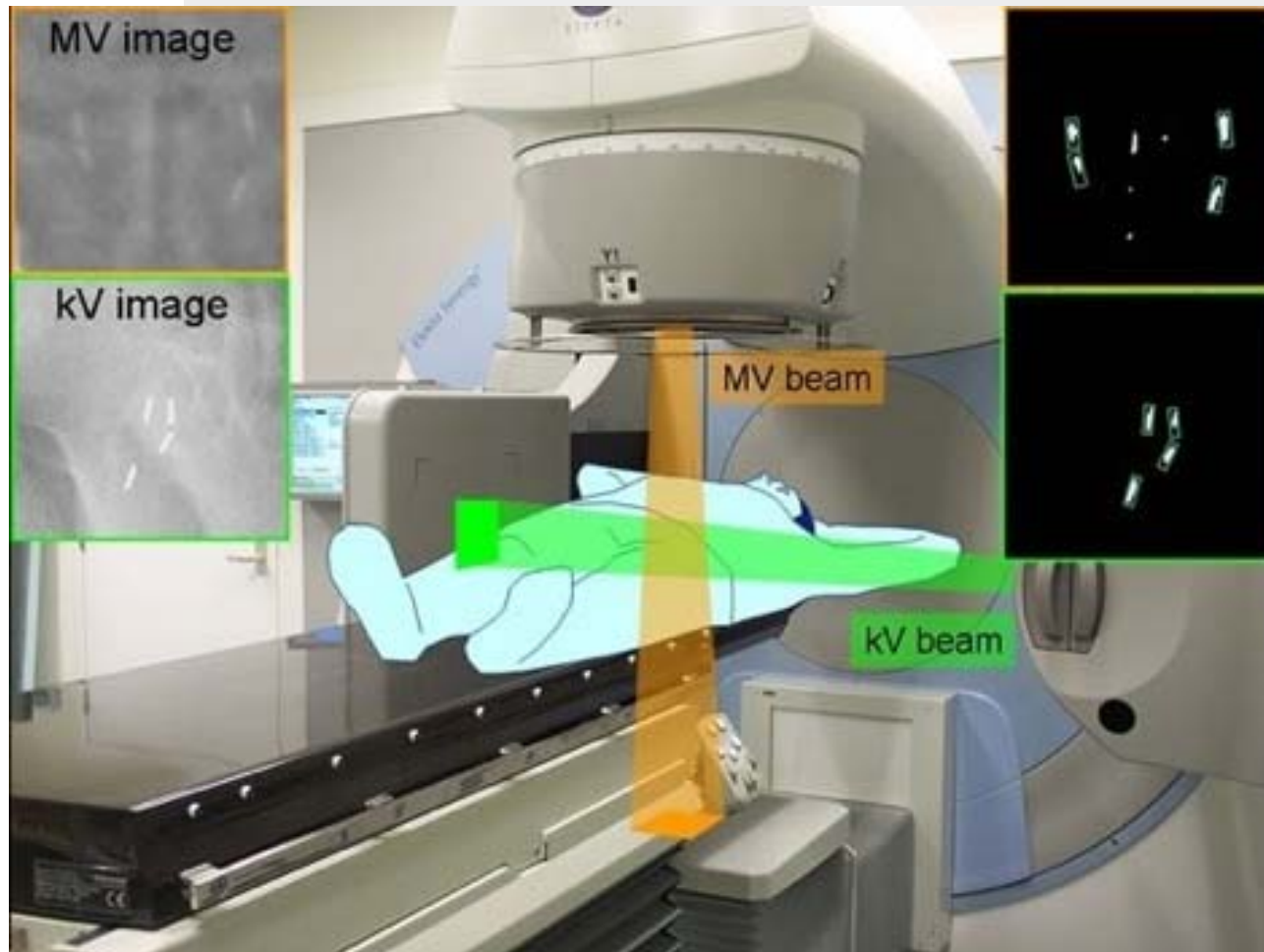
Bildgebende Verfahren am Linac



MV-Imaging

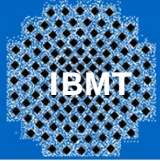
- Soll-/Istbildvergleich
- Verschiebevektor 3D
- Anatomie
- Schlechte Bildqualität
- Einsatz:
 - Klinik
 - QA





MV/kV-Imaging

- Soll-/Istbildvergleich
- Verschiebevektor 3D
- Anatomie
- gute Bildqualität
- CBCT
- Einsatz:
 - Klinik
 - QA



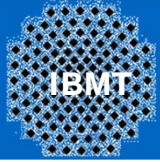
Aktuelle Möglichkeiten

- Optimierung der Lagerung
- Verkleinerung der Margins durch die Möglichkeit der Visualisierung des PTV (Weichteilkontrast)
- CBCT/Planungs CT
- Image Guided RT (IGRT)
- Erhöhung der Genauigkeit der Lagerung

Zukünftige Möglichkeiten

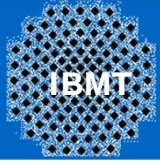
- Adaptive RT
- Plan in aktueller Position
- Berücksichtigung von Patienten/Organbewegungen zwischen 2 Fraktionen
- Erhöhung der Präzision

Bildgebung Voraussetzung für weitere techn./klin. Entwicklungen



Patientenlagerung

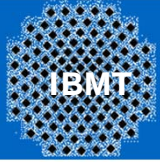




Zusammenfassung 1



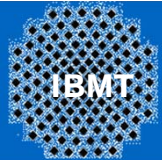
- Ziel der Strahlentherapie: Dosisescalation
 - Sicherheit
 - Kleine Margins
 - Hohe Konformität
- Voraussetzung:
 - Bildgebung
 - Lagerung
- Weitere techn. Entwicklungen
 - MLC
 - VMAT



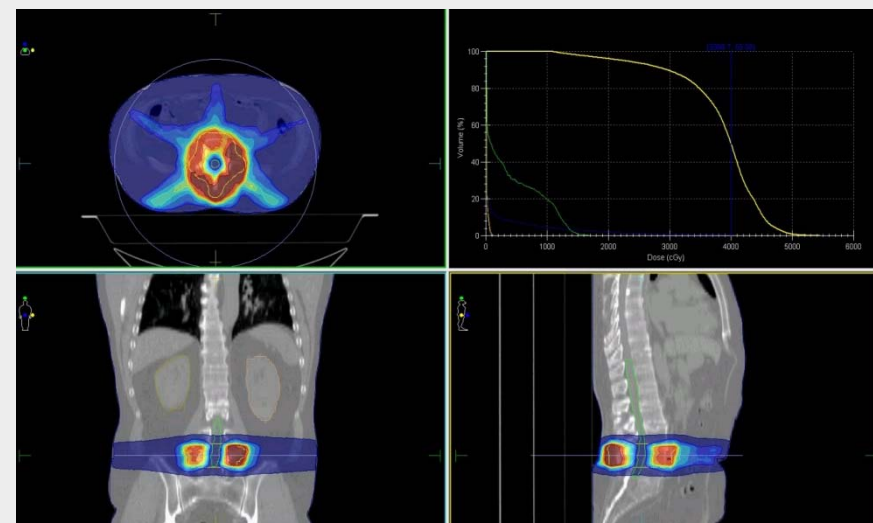
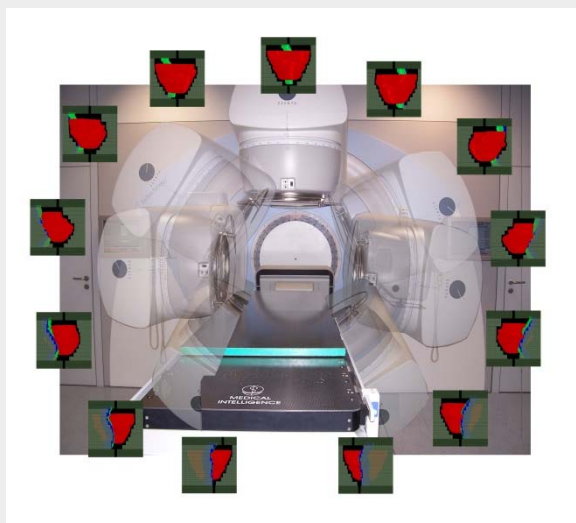
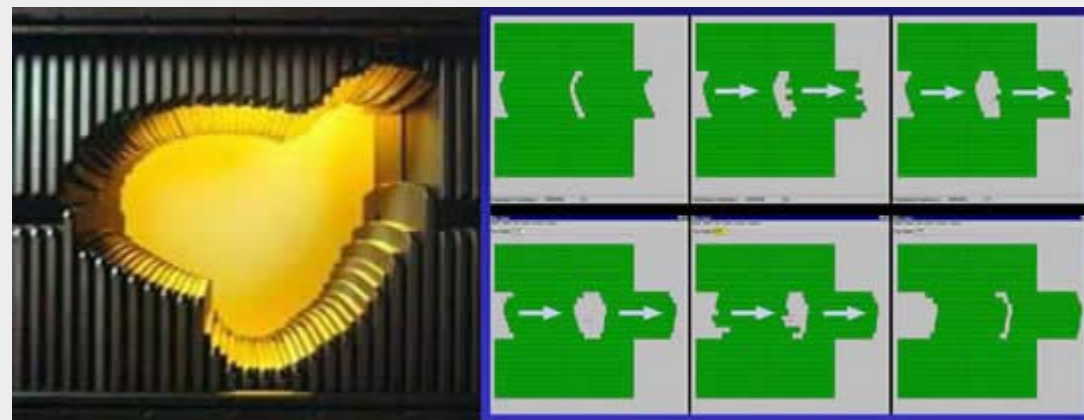
MLC: Elekta Agility



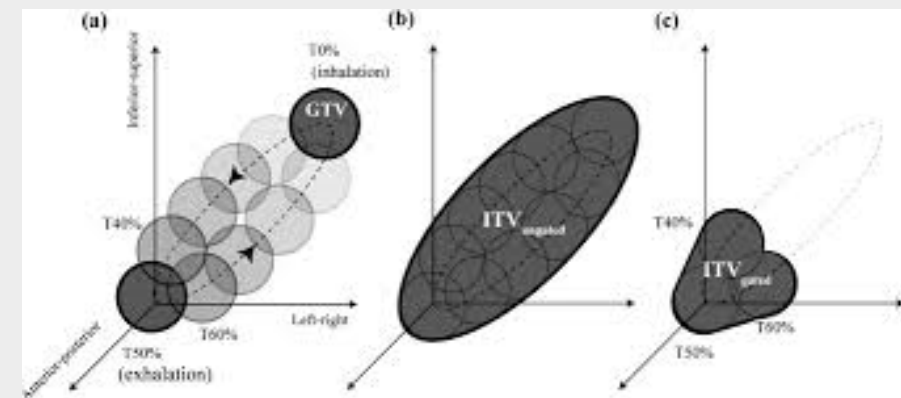
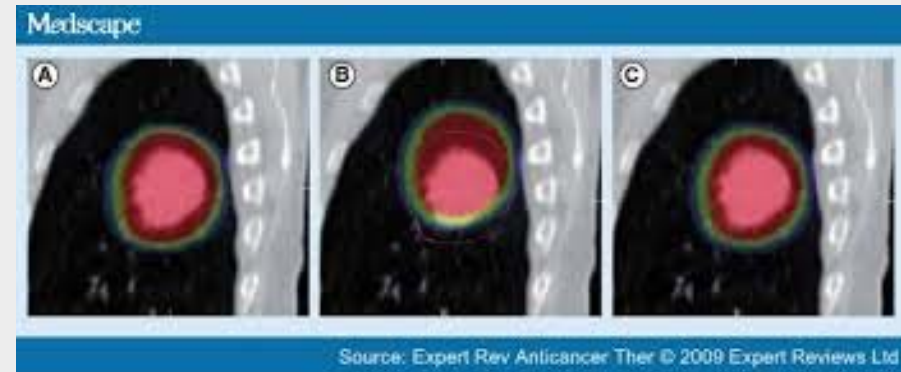
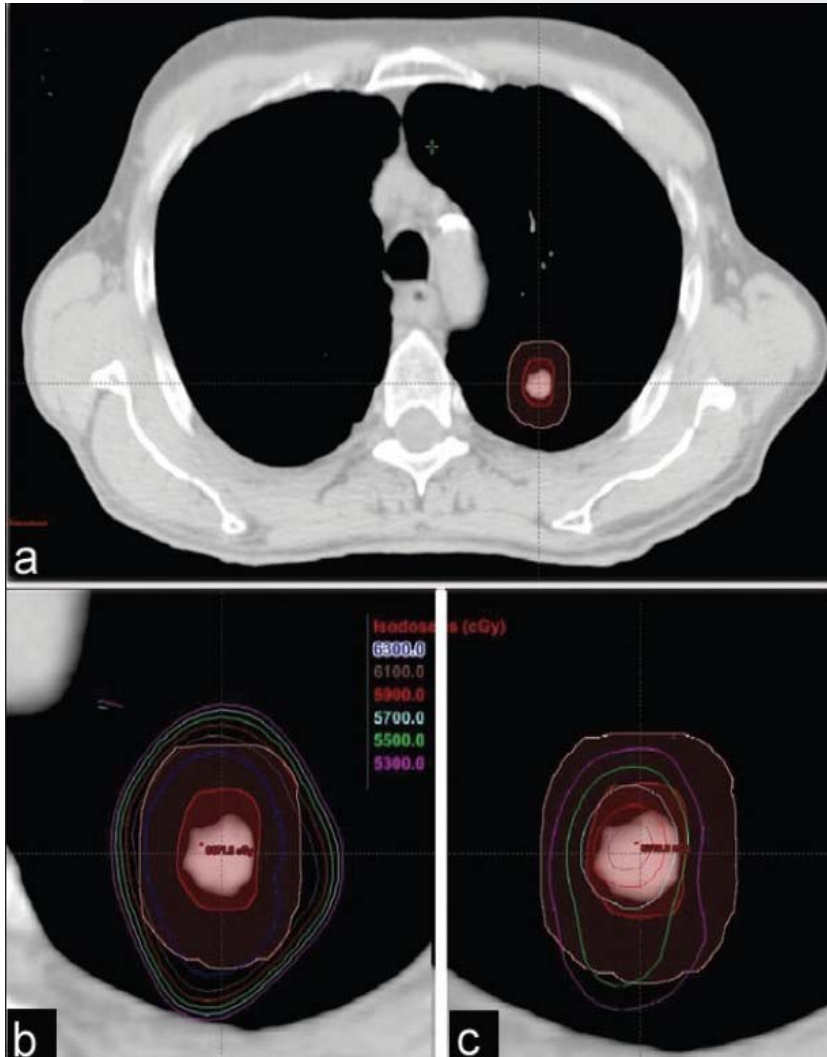
160 Leafs
5mm Breite (IZ)



VMAT



1. Ansatz: ITV-Konzept (Internal Target Volume)

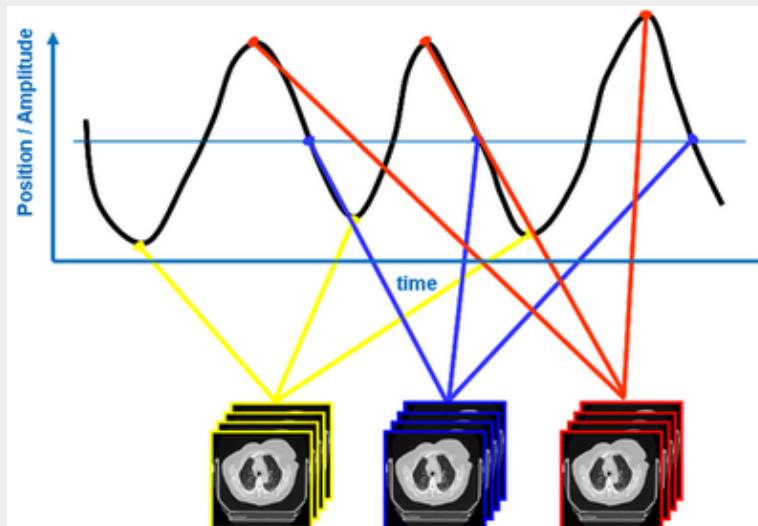


- ITV beinhaltet Bewegung des GTV
- PTV umfasst das ITV
- Großes PTV
- Dosislimitierung

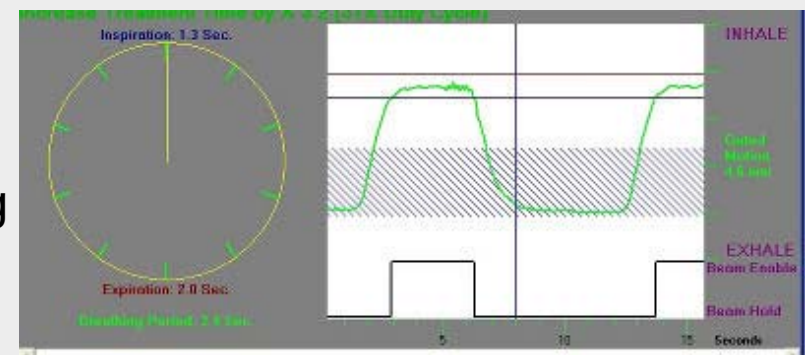
2. Ansatz: Tumortracking

Möglichkeiten

- Nachführung des Strahls (Cyberknife)
- Gaiting
 - Fixation in einer Atemlage
 - 4D

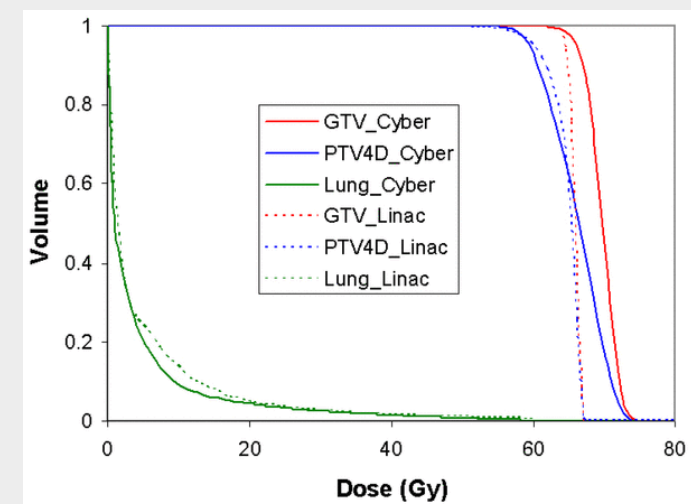
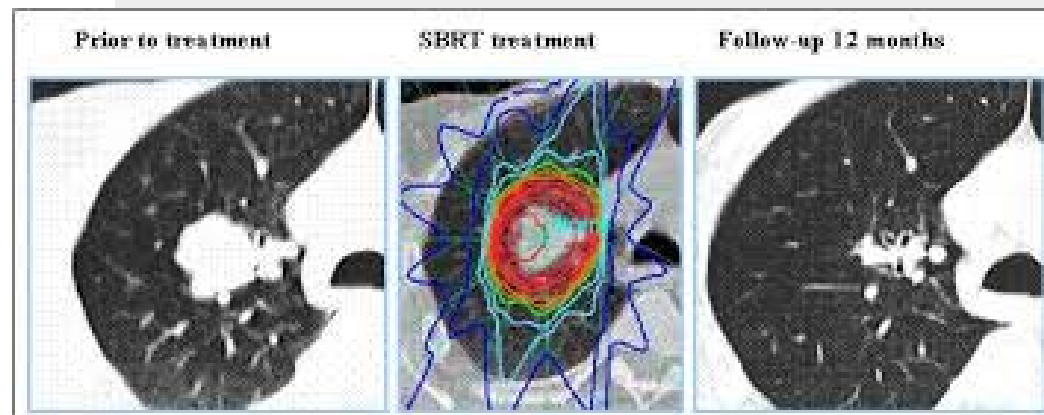
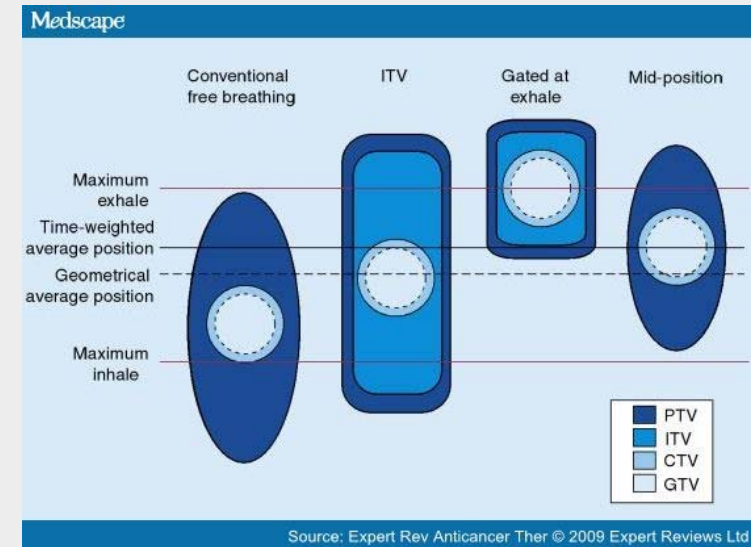
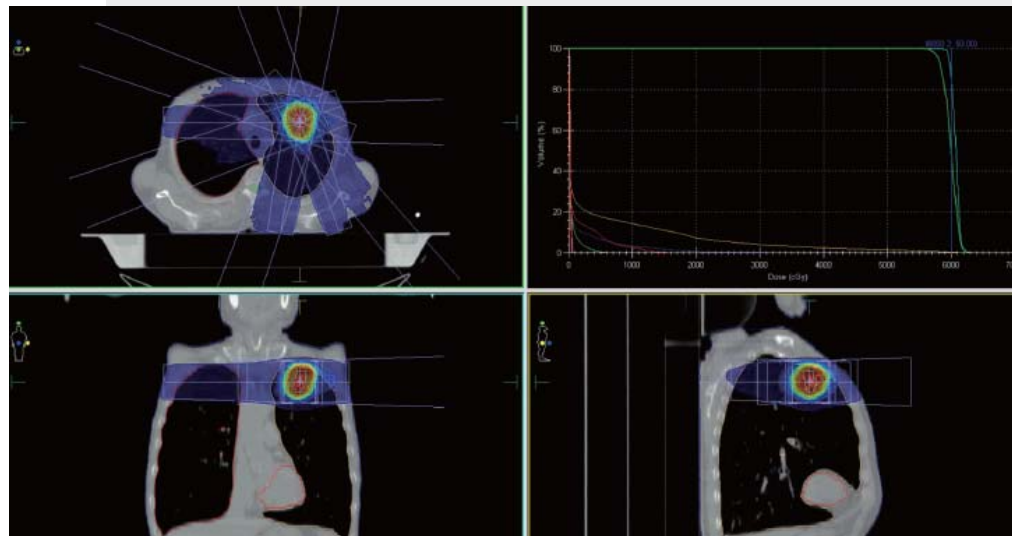


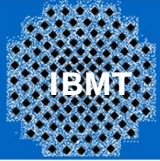
Patient steuert den Linac mit der Atmung
ABC (Active Breathing Control)





SBRT (Stereotactic Body RT)

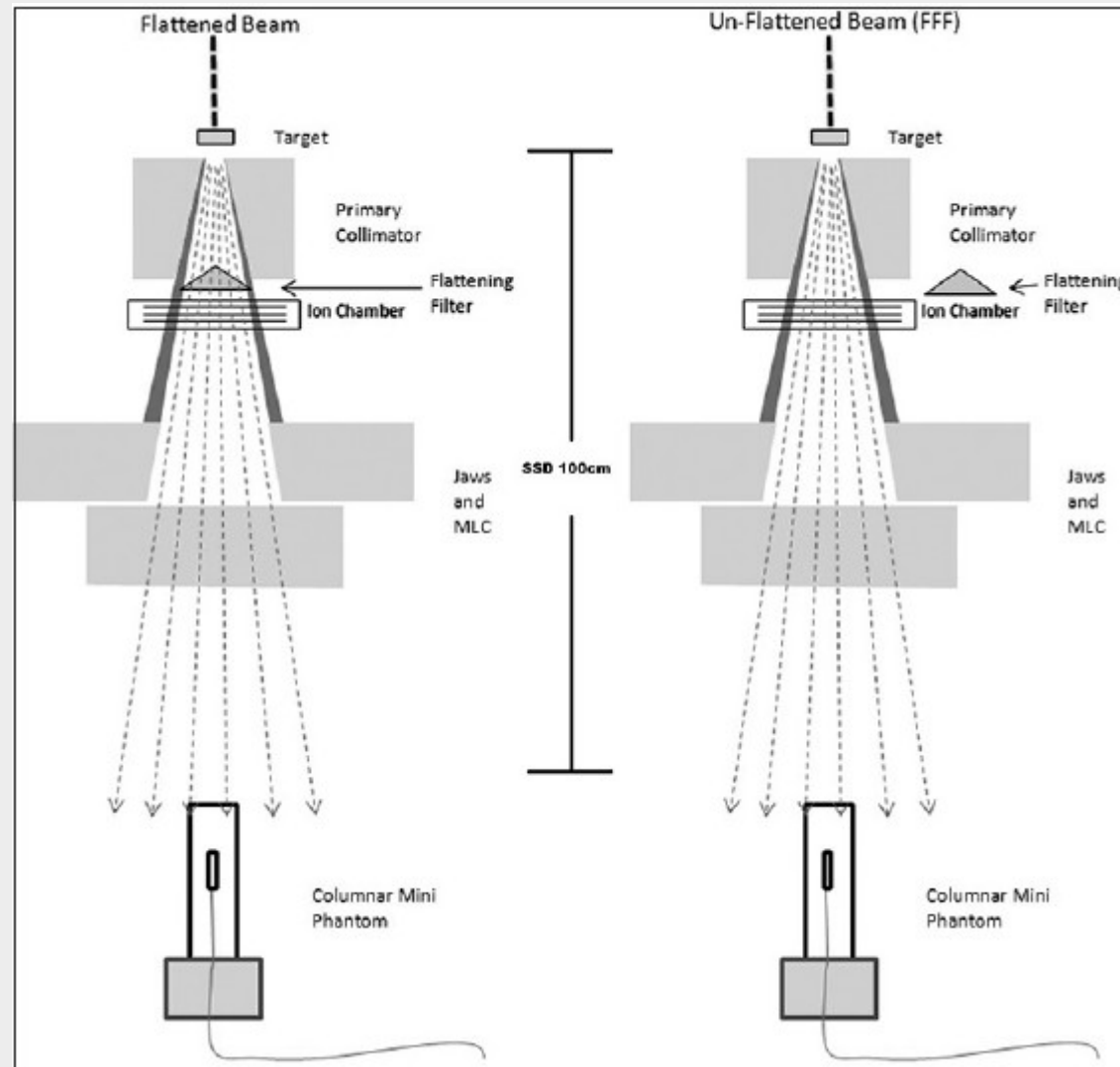




Zusammenfassung 2

- Stand der modernen Strahlentherapie
 - Lagerung (Imaging)
 - IMRT/VMAT
 - SBRT
- Überwiegend kleine Felder im Einsatz
 - Stereotaxie
 - IMRT (Segmente)
- Weitere techn. Entwicklungen
 - Geschwindigkeit der Dosisapplikation (Dosisleistung)
 - FFF

FFF (Flatening Filter Free)

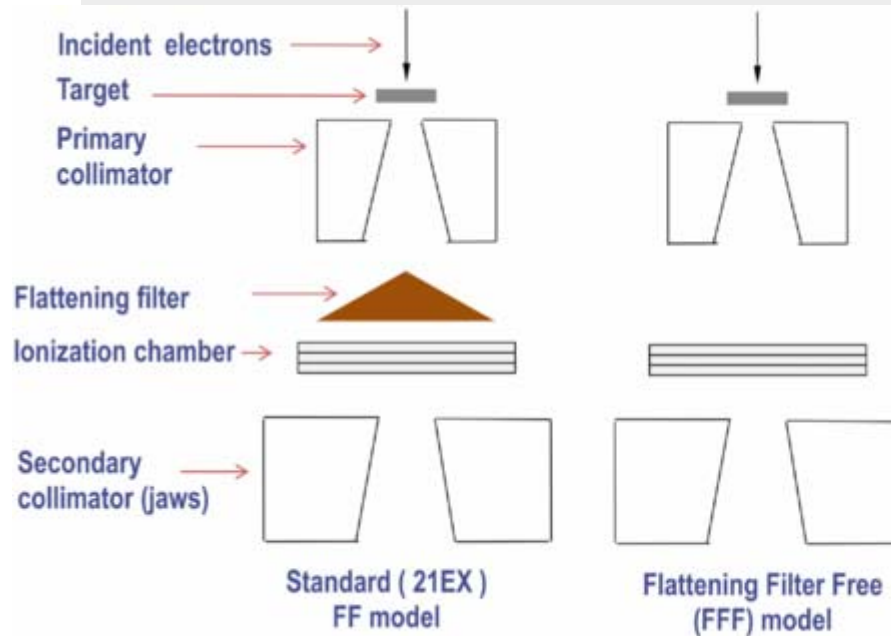


4 Gy/min

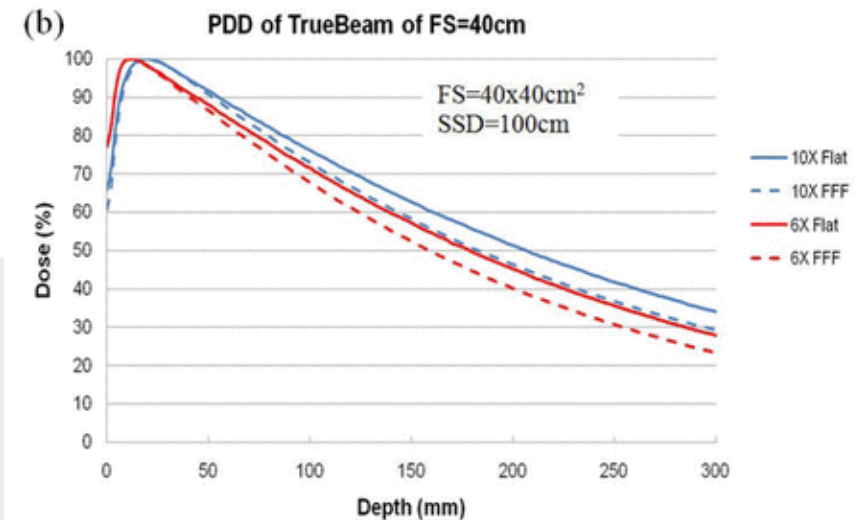
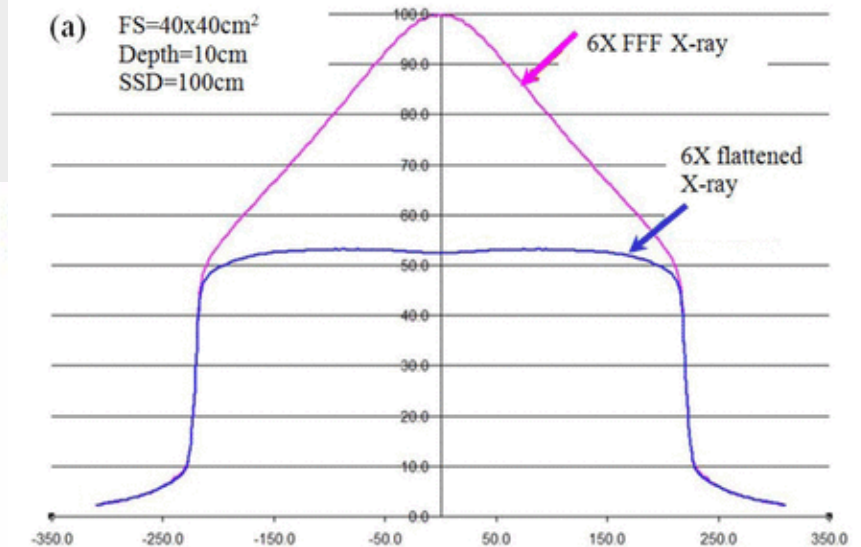
bis 20 Gy/min



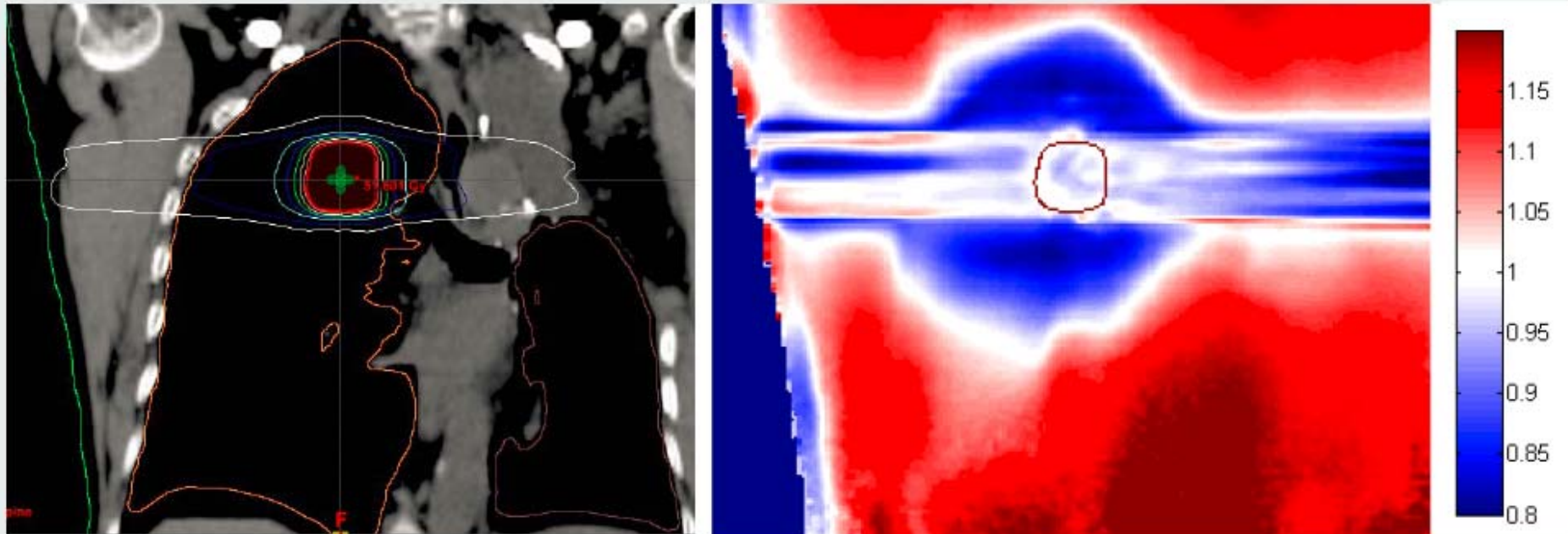
FFF (Flatening Filter Free)



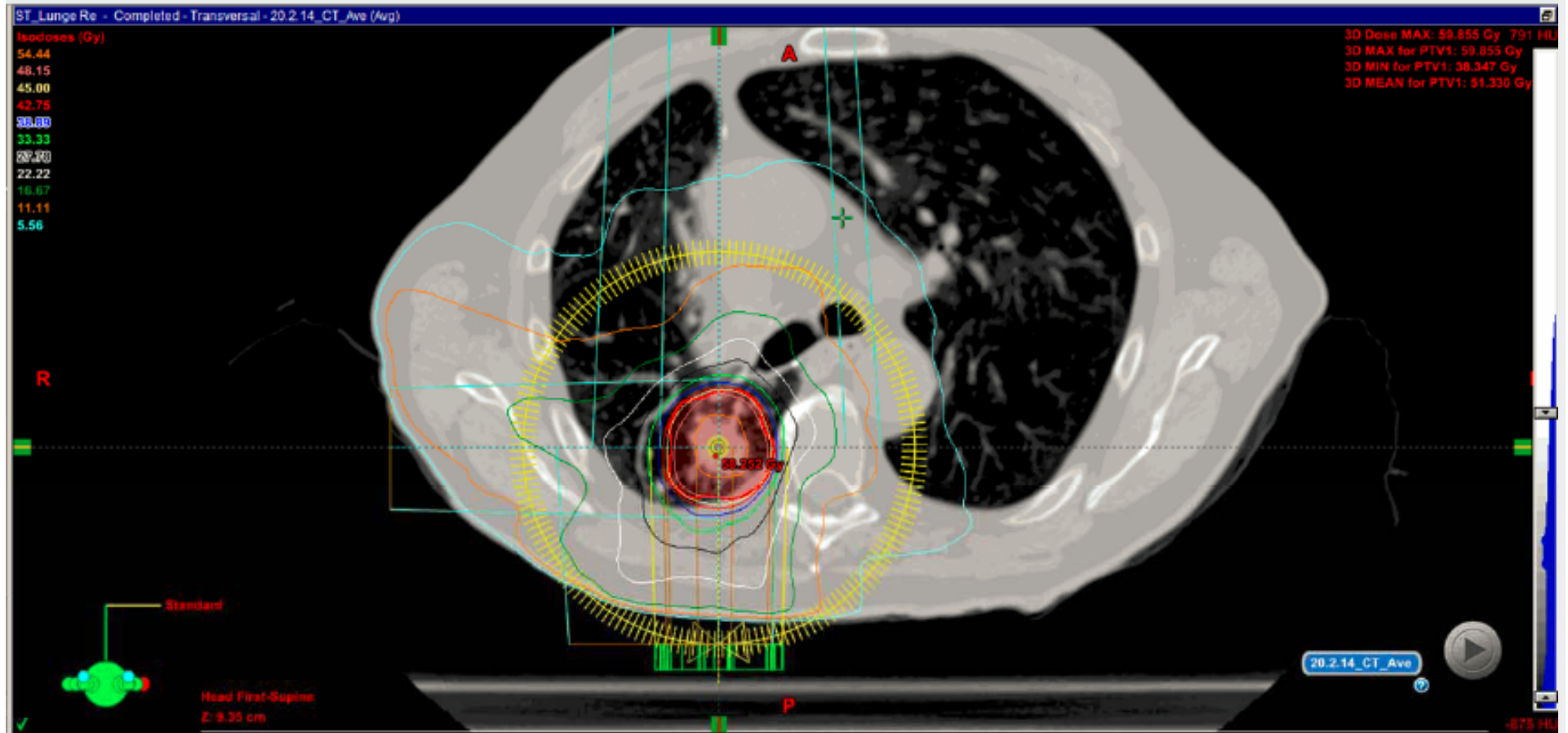
4 Gy/min

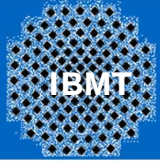


bis 20 Gy/min

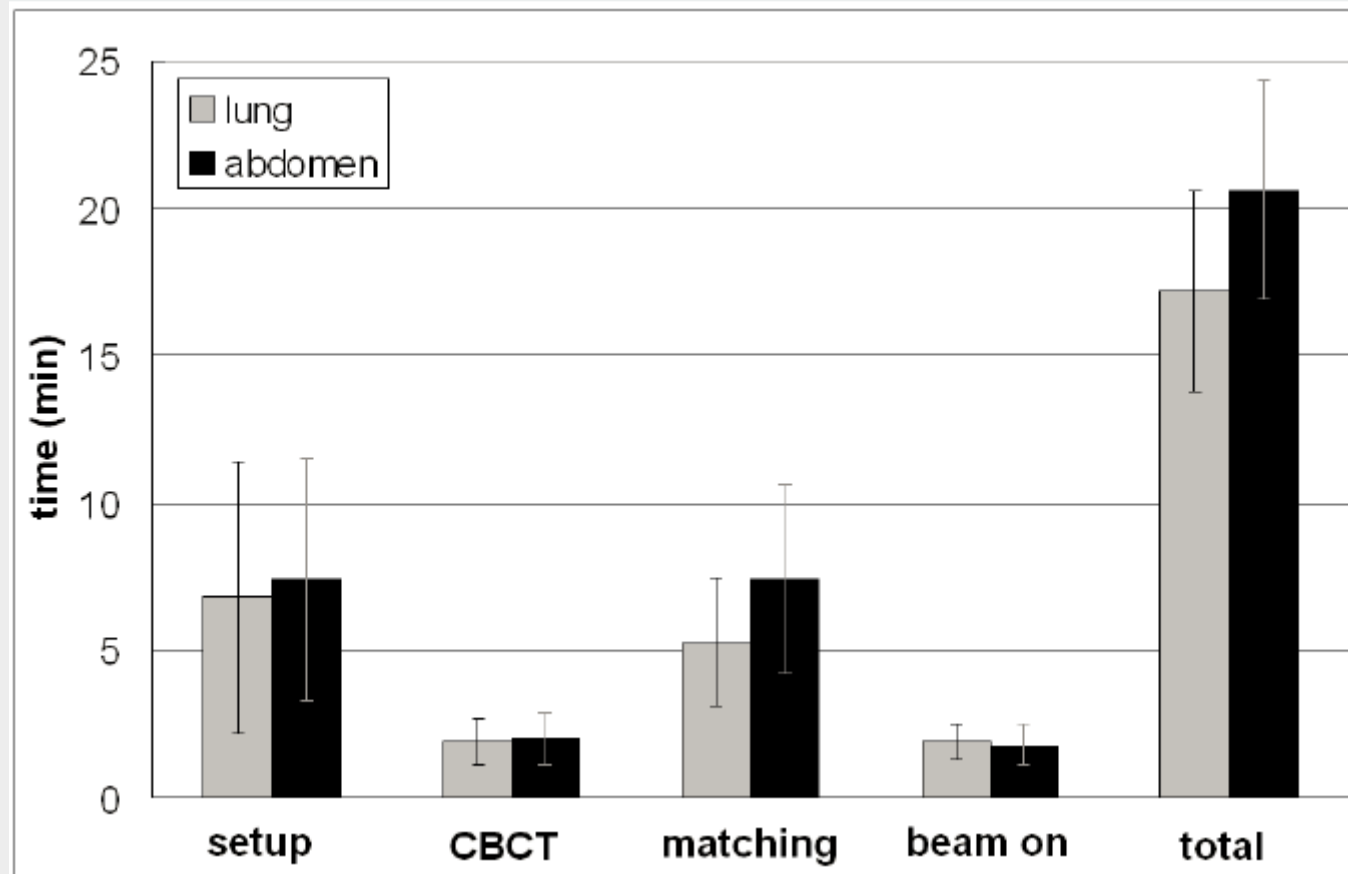


- X6FFF beam provides sharpest gradient
- gradient measure is reduced by 4.2 % ($p < 0.001$)
- V25Gy/VPTV reduced by 4.6 % ($p < 0.001$).
- V20Gy and V12.5Gy of lung are reduced by 5 % ($p < 0.001$).
- treatment time: 2 min

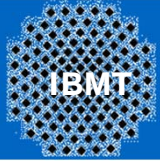




Anwendung FFF /SBRT



Reduktion Bestrahlungszeit um Faktor 2-3



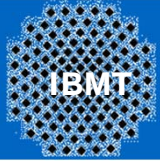
Zusammenfassung FFF

Vorteile FFF

- Reduktion der Bestrahlungszeit
- Dosisgradient
- Verkleinerung Volumina
- Anwendung:
 - SBRT
 - VMAT (?)

Probleme FFF

- Dosimetrie
- Sättigungseffekte
- Gültigkeit 6800-2



Elekta Versa HD



MV Imaging (Iview GT)
kV Imaging (XVI)
FFF
MLC Agility
HexaPod