Augen-Tumor-Therapie mit 68 MeV Protonen
am Hahn-Meitner-Institut Berlin
C.Rethfeldt / SF4-ATT

1. Ionenstrahllabor ISL
2. Augen-Tumor-Therapie als Anwendung am ISL
3. DFG-Projekt: CT-basierte Therapie-Planung
Magnetic Spectrometer
Low Energy Target Area and Dual Beam Line

extremely slow Ions

5.5 MV Van de Graaff - Injector
200 kV - Injector + 14 GHz ECR - Source
RFQ Structure Injector 90 - 360 keV/amu

Eye - Tumor - Therapy k = 130 Cyclotron 14 GHz ECR - Source

Hahn-Meitner-Institut Berlin
**ERDA-measuring principle**

Example: SiNxH layer on Si scattered to 230 MeV $^{129}$Xe-ions

**PIXE-measuring principle**

Test on Modern Glass with Thin Gold Foil

- Glass
- Glass + Gold foil
- Air
- $E_g = 68$ MeV
- $I = 10$ pA
- $t = 200$ sec
**PIXE-measuring principle**

**RBS-measuring principle**
5.5 MV Van de Graaff - Injector

200 kV - Injector + 14 GHz ECR - Source

RFO Structure Injector 90 - 360 keV/amu

Low Energy Target Area and Dual Beam Line

Vertical Beam Line

Magnetic Spectrometer

k = 130 Cyclotron

14 GHz ECR - Source

extremely slow Ions

Eye - Tumor - Therapy

Hahn-Meitner-Institut Berlin

Irradiation of Foils

Irradiation Etching Stopping Rinsing Drying

ERDA (Elastic Recoil Detection Analysis)
PIXE (Proton induced X-ray emission)
RBS (Rutherford Backscattering helium or heavy ions)

Irradiation Study of Semiconductor Elements

Proton Therapy of Eye Tumors

ISL-Applications

Ion beam analysis at ISL
ISL-Applications

Irradiation of Foils

Irradiation Study of Semiconductor Elements

Proton Therapy of Eye Tumors
ISL-Applications

Irradiation of Foils

Irradiation Study of Semiconductor Elements

Proton Therapy of Eye Tumors

Eye Tumor Therapy with 68 MeV Protons at Hahn-Meitner-Institut-Berlin

1995 Start of the ISL-Project

1998 First patient treated

2000 167 patients
Why Protons?

Typical Fundus View

Macula
Optic Nerve
Tumor
Tantalum Clips
Treatment Method

- Range shifter
- X-ray screen
- Dose monitor

Tantalum Clips: Positioning landmarks
Treatment Method

Very precise Positioning System

Tantal Clips: Positioning landmarks

Axial Image
Lateral Image

Treatment Method

repeatability of patient positions
Treatment Method

Treatment Planning: EYEPLAN ➔ OUTPUT

- View Angles: polar/azimuthal
- Proton range
- Beam Modulation
- Shape Collimator
- 3D Position of Clips
Treatment Method

Proton Beam Physics
treatments June 1998 – March 2000

- 118 patients in 20 treatment weeks
- patient age: 10 – 85 years
- 85 choroidal melanomas
- 17 choroidal hemangiomas
- 12 iris melanomas
- 4 conjunctival melanomas
- dose/fractions:
  - uveal melanomas: 60 CGE/4 fract./4 days
  - hemangiomas: 20 CGE/4 fract./4 days
  - iris melanomas: 50 CGE/4 fract./4 days

(CGE = Cobalt Gray Equivalent, RBE = 1.1)

<table>
<thead>
<tr>
<th>tumor category</th>
<th>max. diameter</th>
<th>tumor height</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>10 mm</td>
<td>&lt; 3 mm</td>
</tr>
<tr>
<td>T2</td>
<td>10 - 15 mm</td>
<td>3 – 5 mm</td>
</tr>
<tr>
<td>T3</td>
<td>&gt; 15 mm</td>
<td>&gt; 5 mm</td>
</tr>
</tbody>
</table>
choroidal melanomas

tumor localisation
and volume (CTV)

CTV = 0.1 cm³

distance to
macula [mm]

distance to optic disc [mm]

follow-up of first patient

6 months after treatment, 19 months after treatment
collaborators

- **Hahn-Meitner Institut Berlin:**
  J. Heese, H. Kluge, H. Fuchs, H. Homeyer, H. Morgenstern, C. Rethfeldt, I. Reng, W. Hahn

- **university hospital Benjamin Franklin, Berlin:**
  - **dept. of radiation oncology**
    M. Nausner, W. Hinkelbein, K. Kalk
  - **dept. of ophthalmology:**
    M.H. Foerster, N. Bechrakis

- **university eye clinic, Essen:**
  N. Bornfeld

**DFG-Project: CT-based Treatment Planning**

HMI-Berlin / DKFZ Heidelberg

**Advantages:**
- individual organ shape
- more precise dose calculation
Introduction / Motivation

Wide Angle Fundus View

EYEPLAN Tumor Draw

Introduction / Motivation

Wide Angle Fundus View

EYEPLAN Dose Distribution
Problems:
> Human Eye is not a “Ideal Sphere”
> Individual Anatomy

Correction of Primary Field / Beamline Geometry

Beamline Set-up at Hahn-Meitner Institute Berlin

- Quadrant Ion Chamber
- Range Modulator
- Range Shifter
- Steel Tube
- Collimator

1.5 m Beamlne

H₂O Phantom

GEANT Monte Carlo Geometry
Correction of Primary Field / Beamline Geometry

GEANT Data-Set for Range Shifter = 0 mm

\[
P_1 = \frac{1 + \exp \left( \frac{x - P_2}{P_3} \right)}{P_3}
\]

Approach:
\[
\text{Slope} = 2.0 + 0.2 \times \sqrt{RS}
\]
\[
P_2 = P_1 \times 4.39 \times (90 - 10\% \text{Dose Slope})
\]

Field \((d, x, y) = \text{Coll}(x, y) \odot \text{PSF}(RS)\)

Lateral Field on Air at “Eye Entry”

\rightarrow 65 \text{mm behind Collimator}
Correction of Primary Field / Wedge Application

45deg Wedge

Collimator

Wedge

Effective Thickness

\[ d = F(\text{curve}\_{\text{collimator}}) \]

\[ \text{slope} = F(\text{curve}\_{\text{collimator}}) \]

\[ d = z_0 + 0.088 \log_{10}(z) \]

\[ \text{90-10 Dose slope} \]

\[ \tau(x) = \frac{(19.2\text{MeV})^2}{L_E} \left(1 + 0.088 \log_{10} \frac{z}{L_E} \right)^2 \int_0^z (z' - x')^2 \frac{d x'}{(p y)} \]
Correction of Primary Field / Wedge Application

Wedge + 10mm Range Shift

Wedge Approach  Conventional Version
Verification

7 Chamber Phantom

CT-Slice / Sugar Solutions

Hounsfield based Density

Comparison of Radiological Depths

Deviation: 0.99 ± 0.03

Verification

Proton Beam
Verification

Depth: 24.5 mm  Density: 1.133 g/cm³
Depth: 17.5 mm  Density: 1.163 g/cm³
Depth: 10.5 mm  Density: 1.236 g/cm³
Depth:  3.5 mm  Density: 1.295 g/cm³

Features of the Dose Algorithm

Physical Model Input:

Beam Energy / Gaussian Width  -> Modelling Bragg Curve
optional: measured Bragg Curve
Slope_90_10 = F(Range Shifter)  -> GEANT Beamline Study
optional: measured Slopes
Density of Wedge Material
Features of the Dose Algorithm

Treatment Planning Output:

Dose Distribution Cube for Overlays in Planning Programs

Radiological Range and Modulation Width of the Spread Out Bragg Peak

Practical Usage of Dose Algorithm

Artificial CT based Dose Calculation
Summary

Introduced Corrections of the Primary Radiation Field
- Influence of Range Shifter
- Influence of Wedge Application

A Series of Verifications
- CT-based Calculations versus Measurement using “7-Chamber” Phantom

First practical Usage in Treatment Planning
- Running in Problems with ‘Clip’ Artefacts