

## Augen-Tumor-Therapie mit 68 MeV Protonen

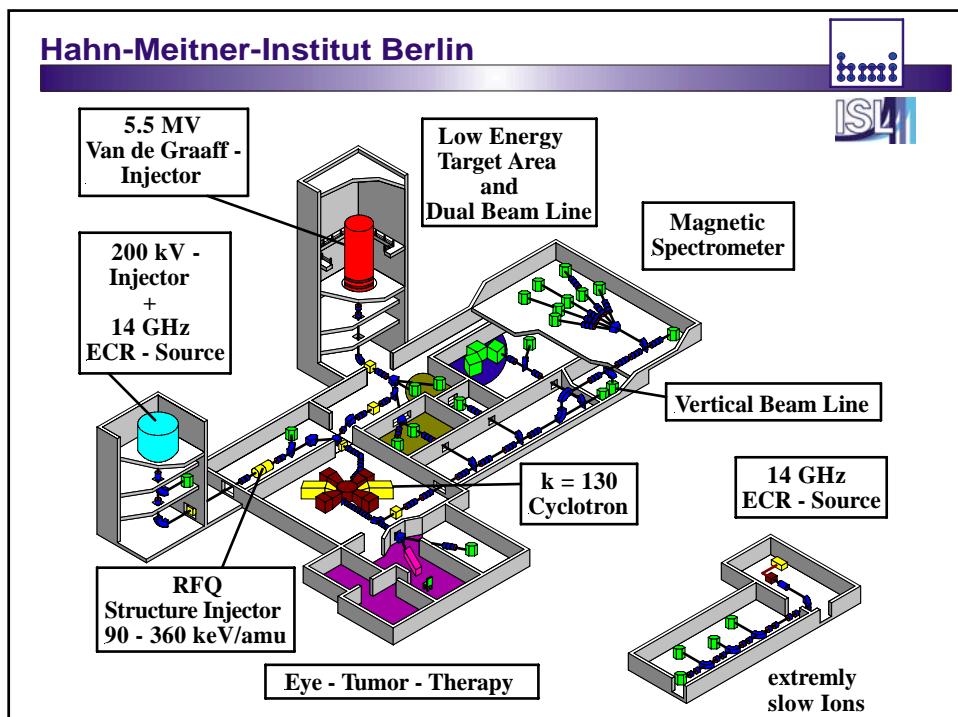
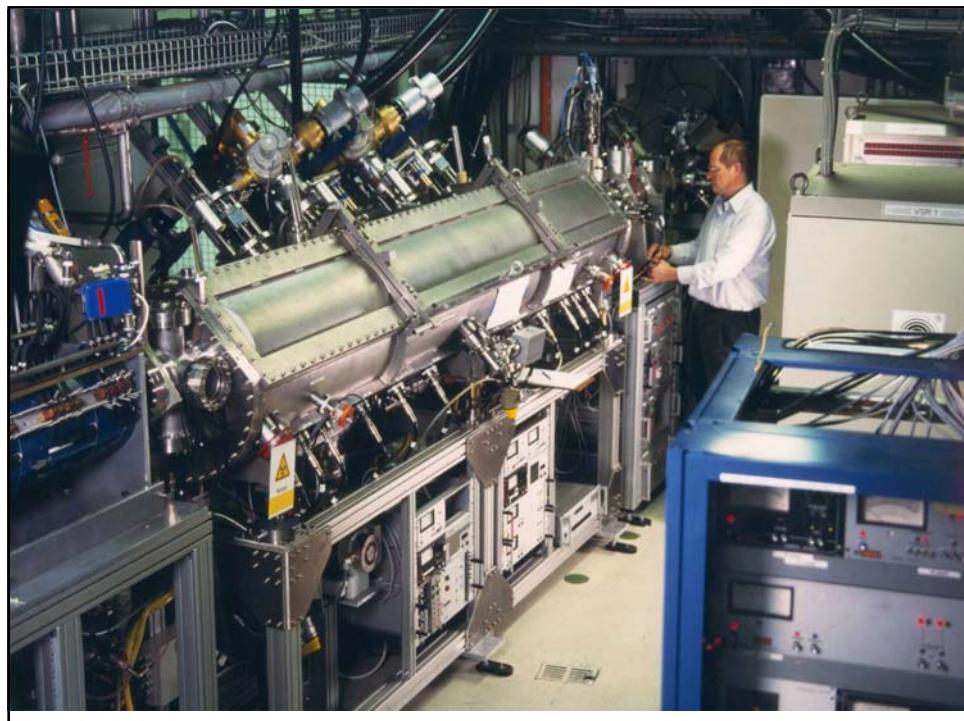
am Hahn-Meitner-Institut Berlin

C.Rethfeldt / SF4-ATT

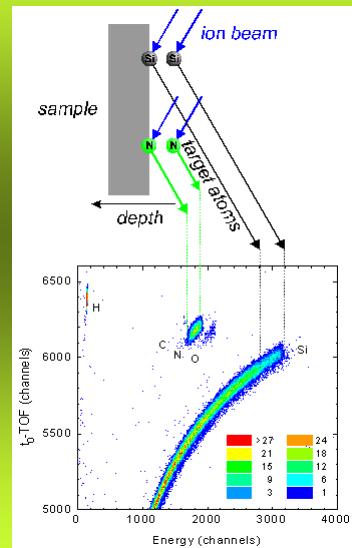
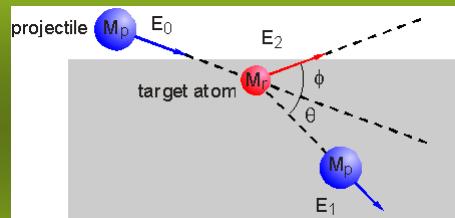
1. Ionenstrahllabor ISL
2. Augen-Tumor-Therapie als Anwendung am ISL
3. DFG-Projekt: CT-basierte Therapie-Planung





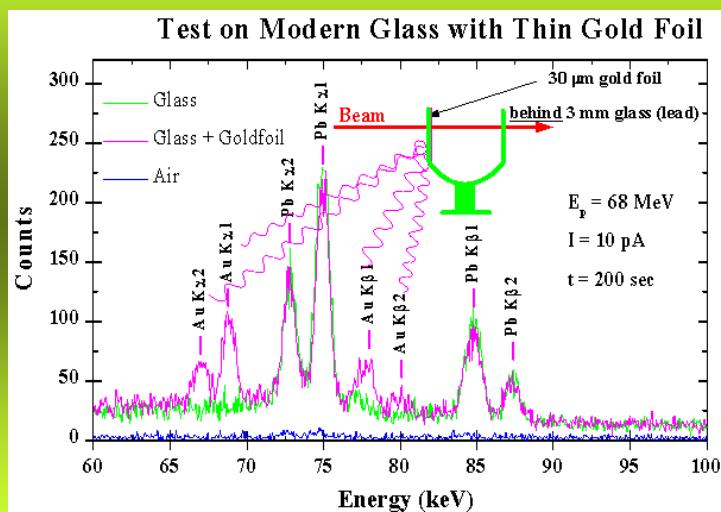


## ERDA-measuring principle



Example:  $\text{SiN}_x\text{H}$  layer on Si  
scattered to 230 MeV  $^{129}\text{Xe}$ -ions

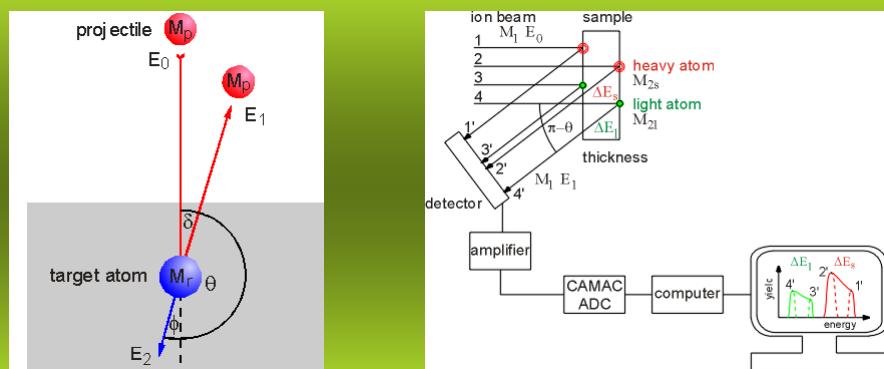
## PIXE-measuring principle

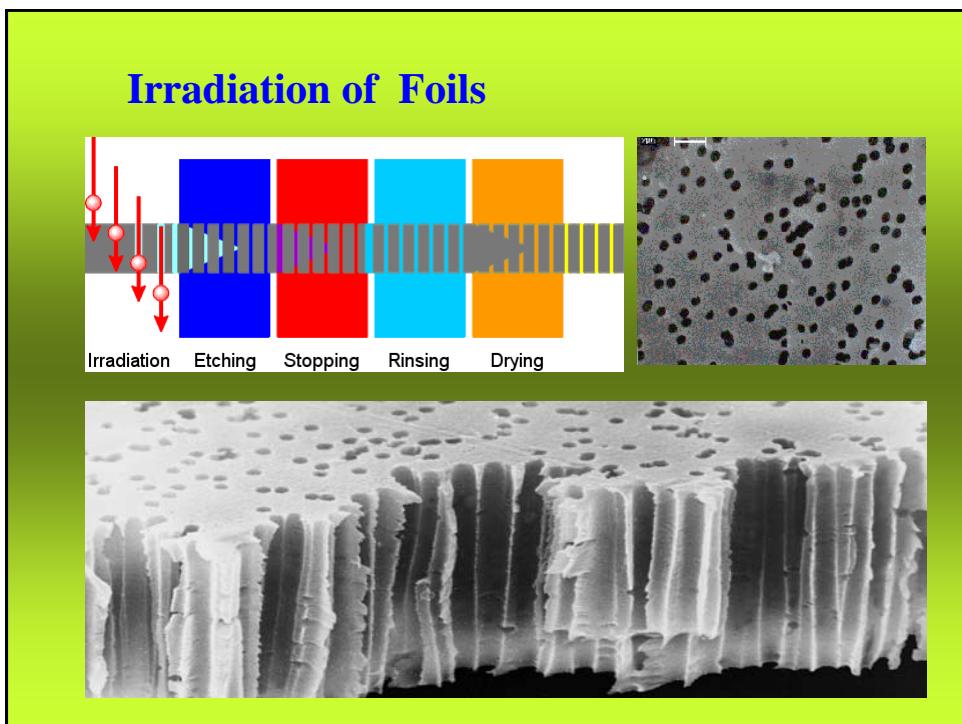
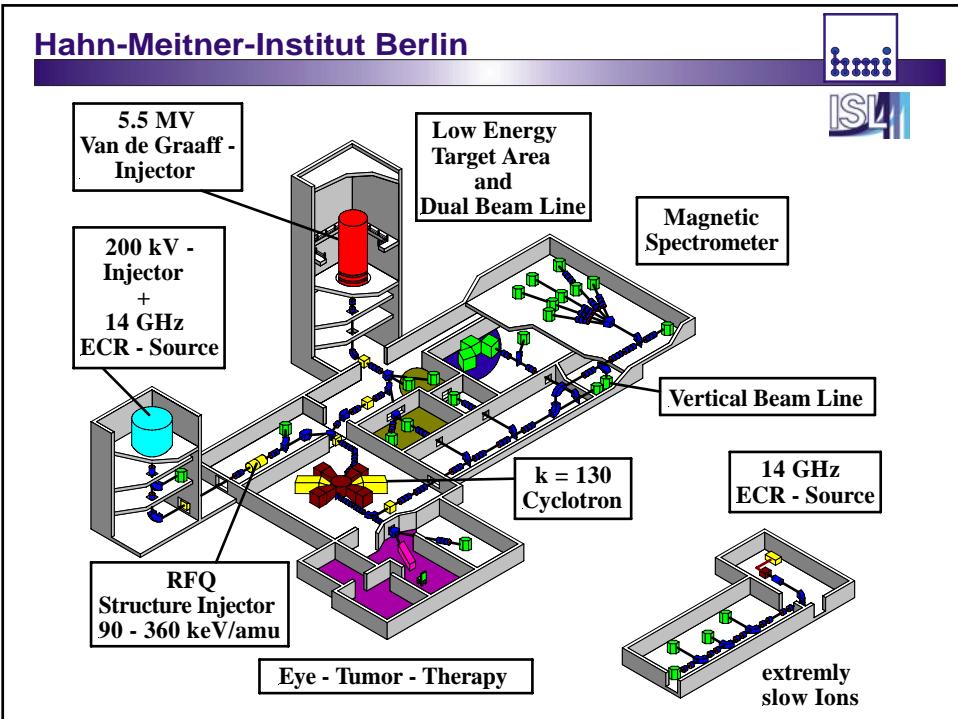


## PIXE-measuring principle



## RBS-measuring principle





## ISL-Applications

Irradiation of Foils

Irradiation Study of Semiconductor Elements

Proton Therapy of Eye Tumors

## Irradiation Study of Semiconductors



## ISL-Applications

Irradiation of Foils

Irradiation Study of Semiconductor Elements

Proton Therapy of Eye Tumors

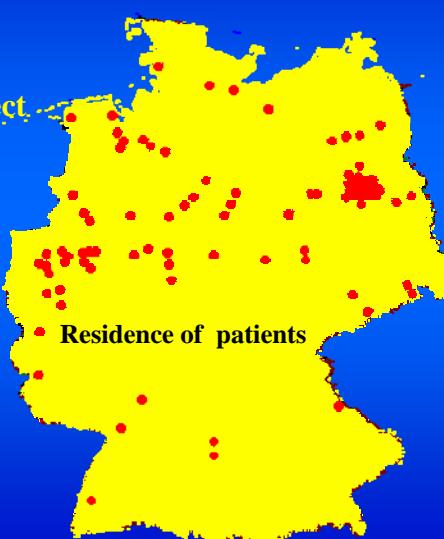
### Eye Tumor Therapy with 68 MeV Protons

at Hahn-Meitner-Institut-Berlin

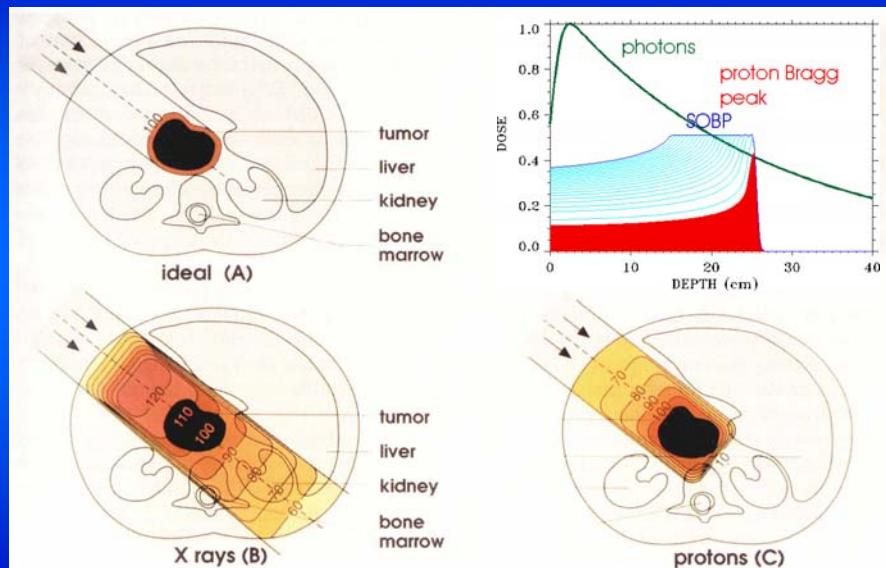
1995 Start of the ISL-Project

1998 First patient treated

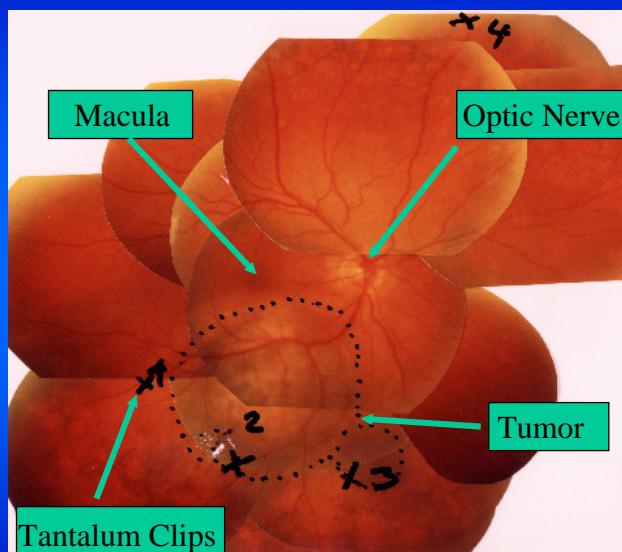
2000 167 patients



## Why Protons ?

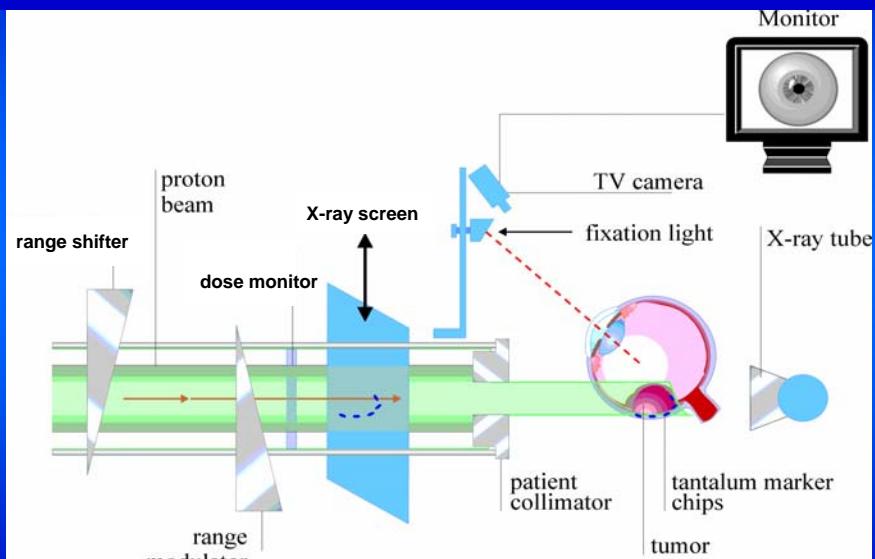


## Why Protons ?

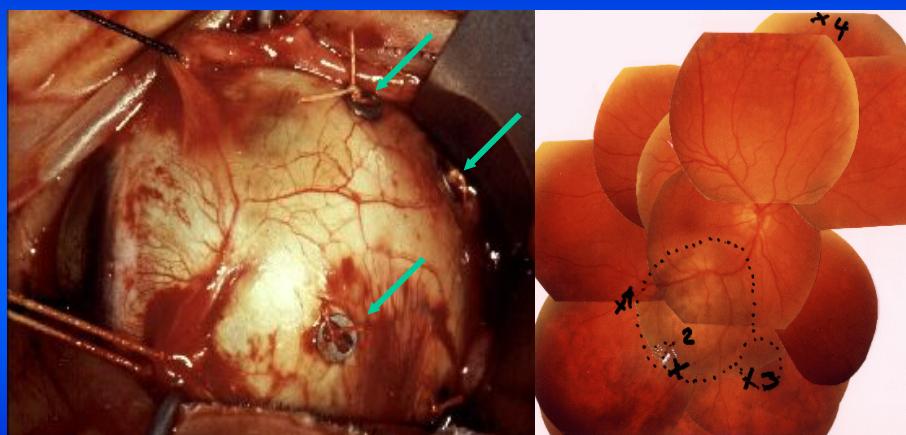


Typical Fundus View

## Treatment Method



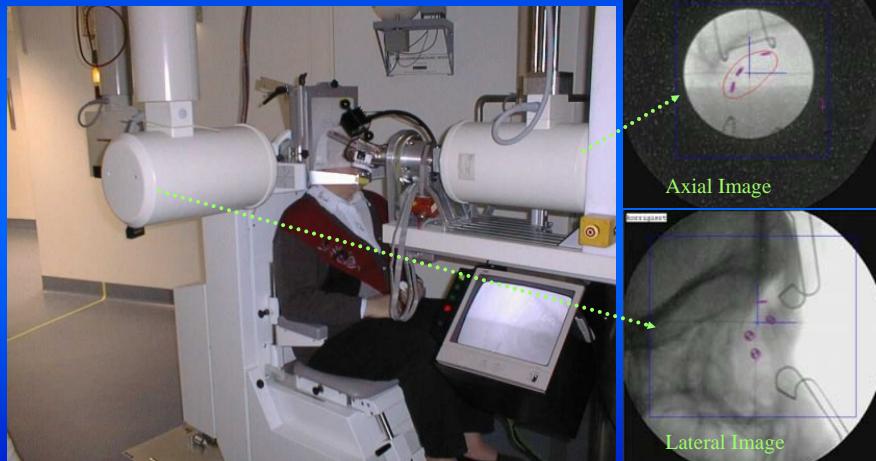
## Treatment Method



Tantalum Clips: Positioning landmarks

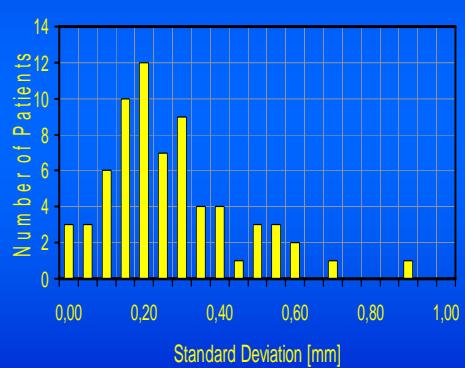
## Treatment Method

### Very precise Positioning System

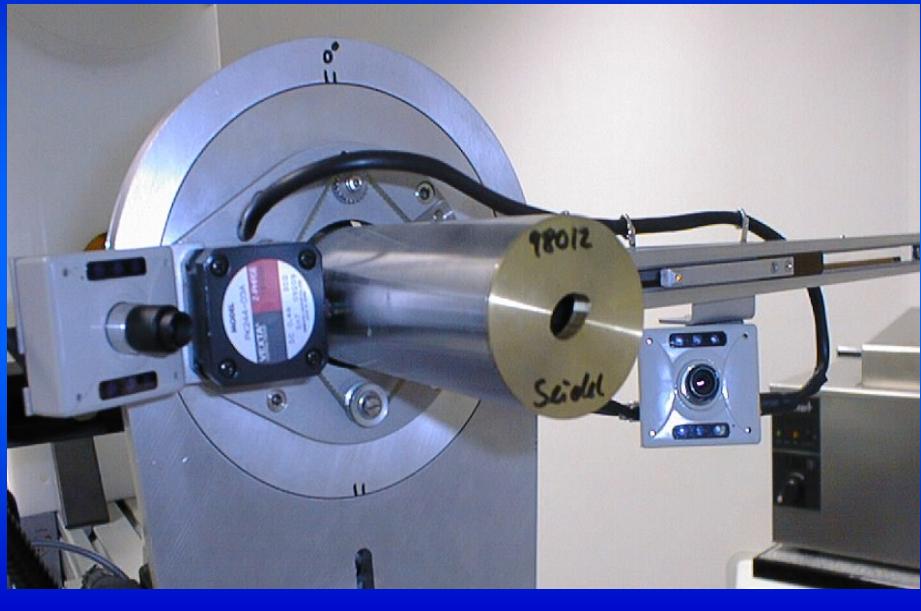


## Treatment Method

### repeatability of patient positions

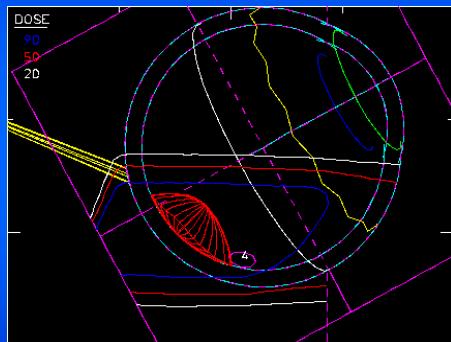


## Treatment Method



## Treatment Method

Treatment Planning: EYEPLAN ————— OUTPUT



**View Angles: polar/azimuthal**

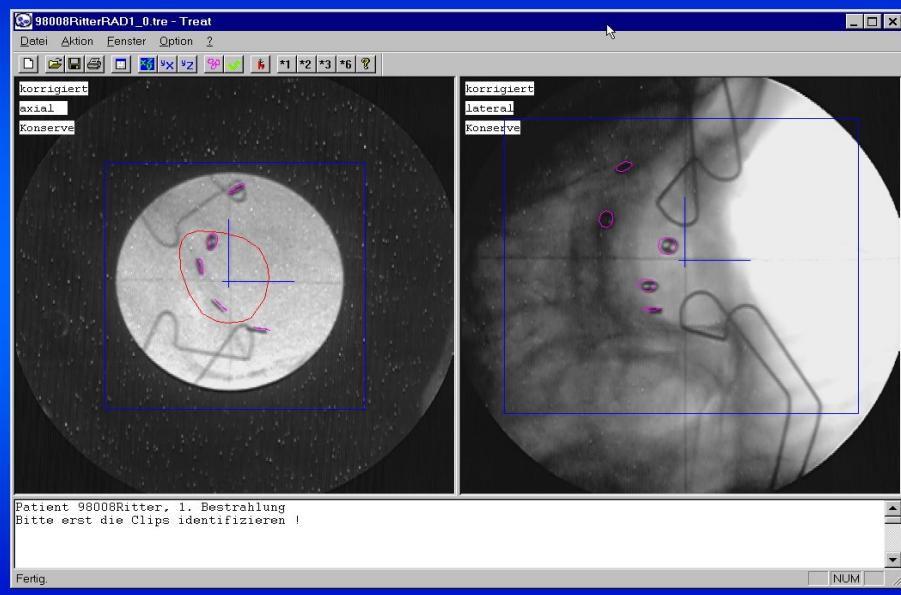
**Proton range**

**Beam Modulation**

**Shape Collimator**

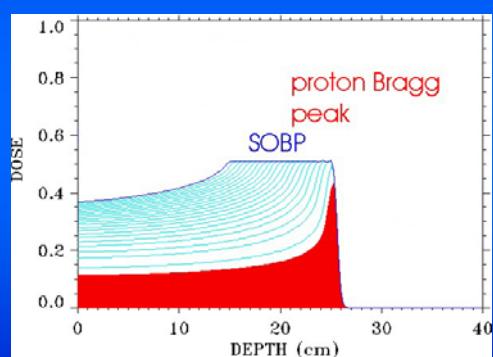
**3D Position of Clips**

## Treatment Method



## Treatment Method

### Proton Beam Physics



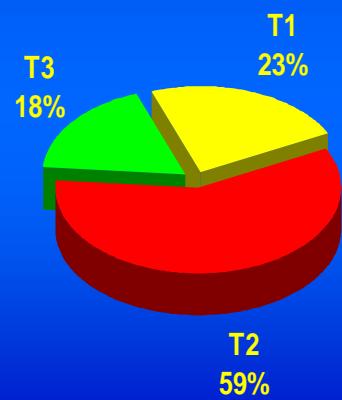
## treatments June 1998 – March 2000

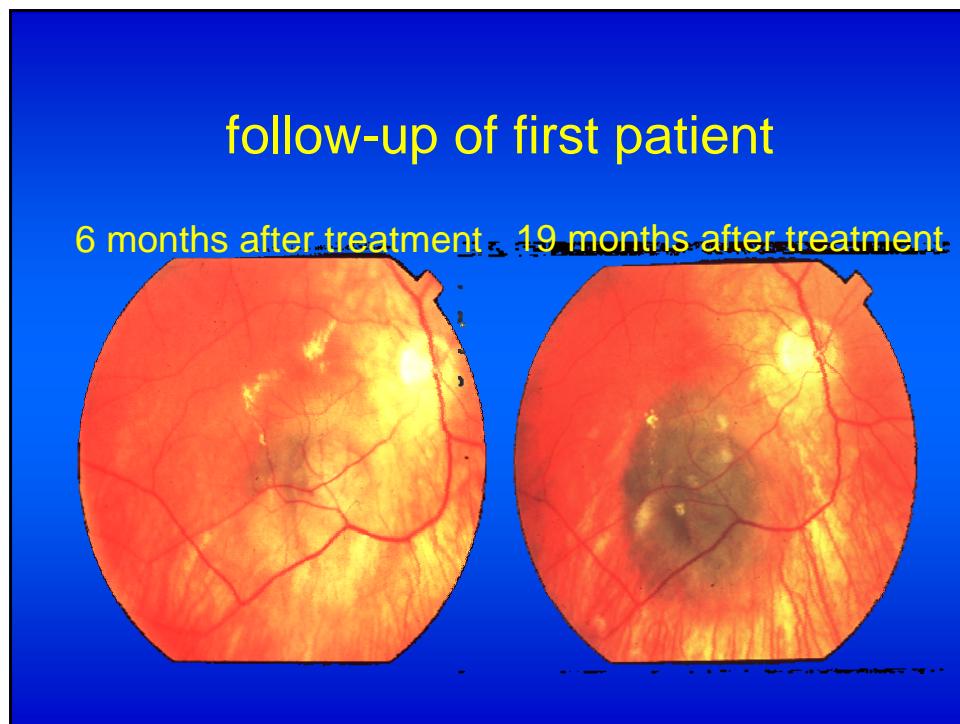
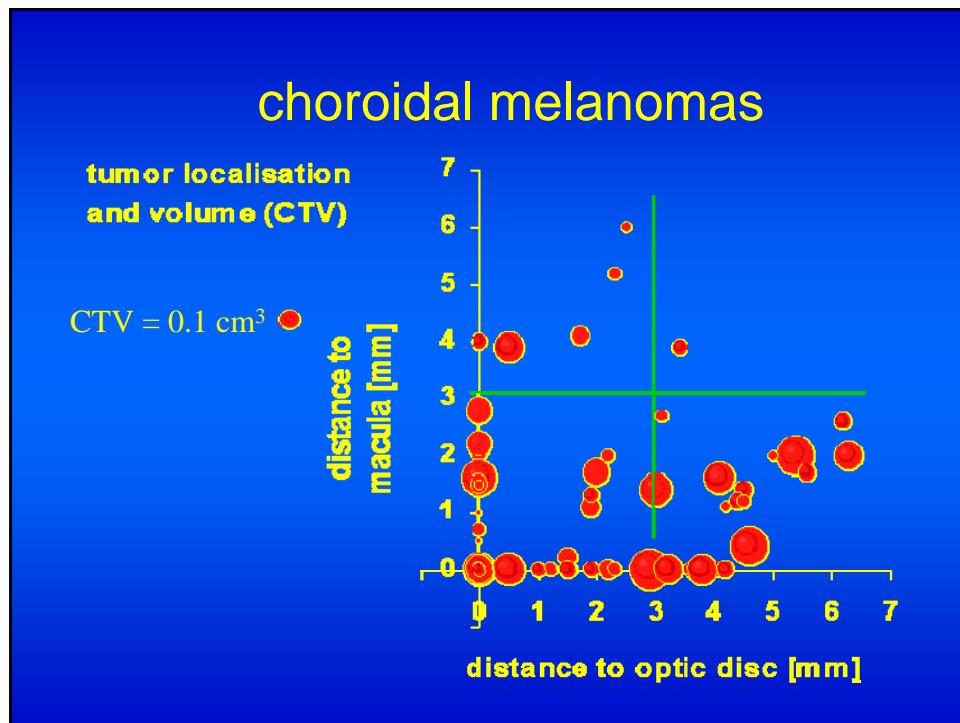
- 118 patients in 20 treatment weeks
- patient age: 10 – 85 years
- 85 choroidal melanomas
- 17 choroidal hemangiomas
- 12 iris melanomas
- 4 conjunctival melanomas
- dose/fractions:
  - uveal melanomas: 60 CGE/ 4 fract./ 4 days
  - hemangiomas: 20 CGE/ 4 fract./ 4 days
  - iris melanomas: 50 CGE/ 4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

(CGE = Cobalt Gray Equivalent, RBE = 1,1)

## tumor stages

tumor category	max. diameter	tumor height
T1	10 mm	< 3 mm
T2	10 -15 mm	3 – 5 mm
T3	> 15 mm	> 5 mm



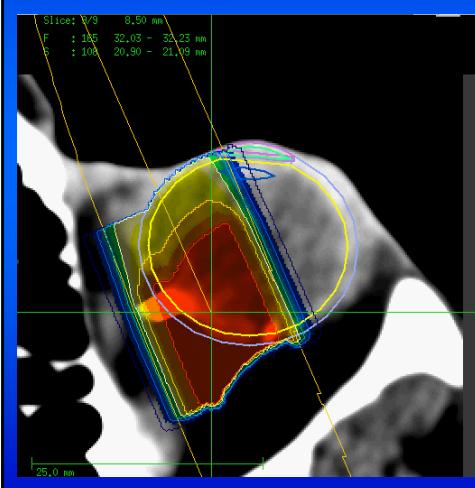


## collaborators

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C. Rethfeldt, I. Reng, W. Hahn
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  - dept. of ophthalmology:  
M.H. Foerster, N. Bechrakis
- **university eye clinic, Essen:**  
N. Bornfeld

## DFG-Project: CT-based Treatment Planning

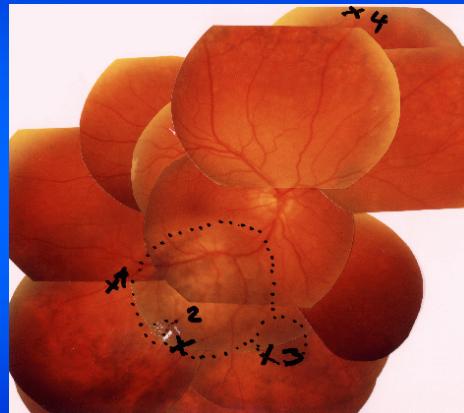
HMI-Berlin / DKFZ Heidelberg



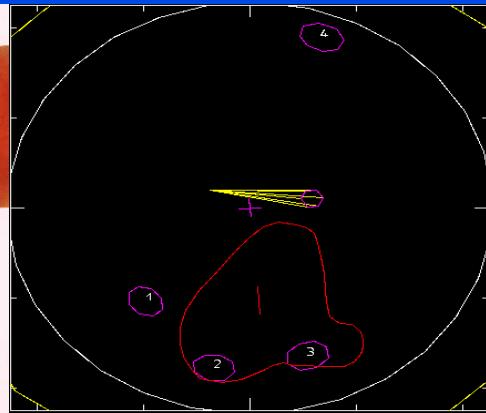
### Advantages:

- individual organ shape
- more precise dose calculation

## Introduction / Motivation

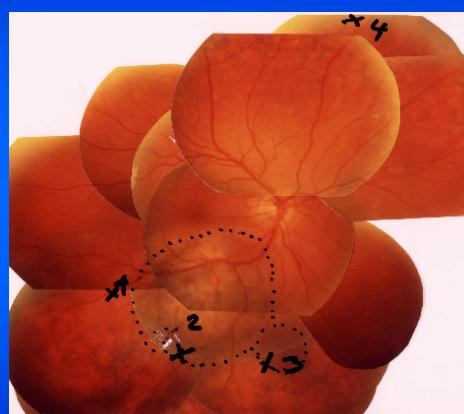


Wide Angle Fundus View

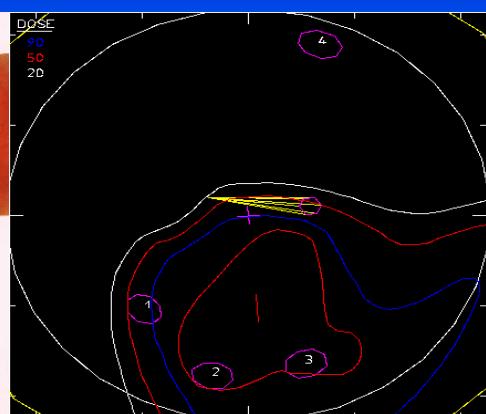


EYEPLAN Tumor Draw

## Introduction / Motivation

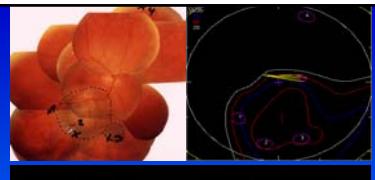


Wide Angle Fundus View



EYEPLAN Dose Distribution

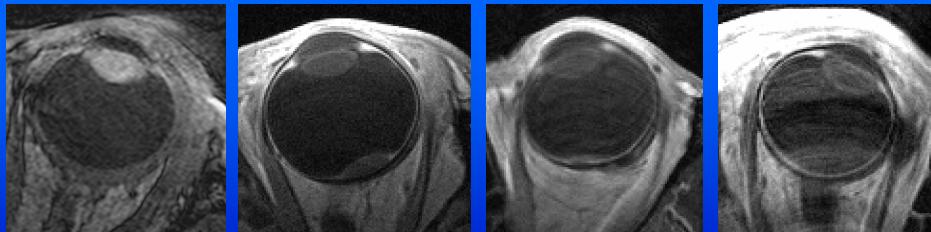
## Introduction / Motivation



### Problems:

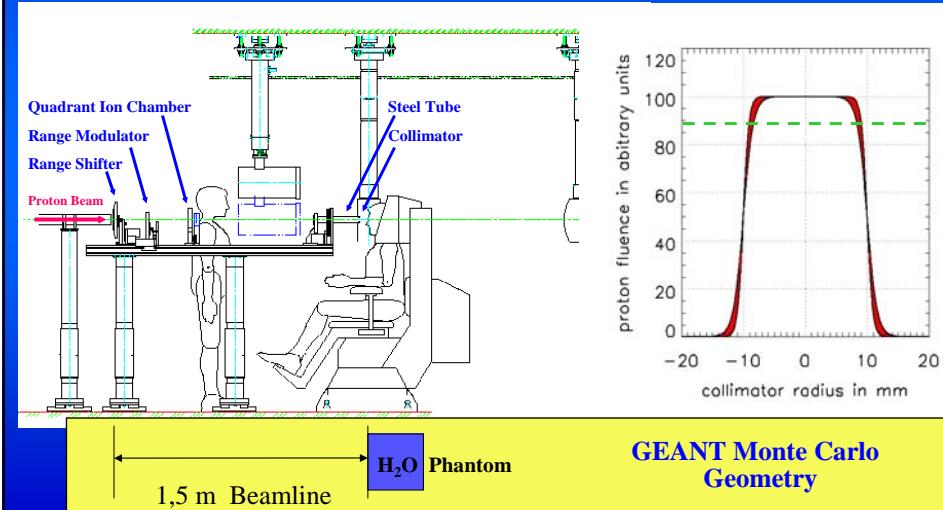
> Human Eye is not a “Ideal Sphere”

> Individual Anatomy



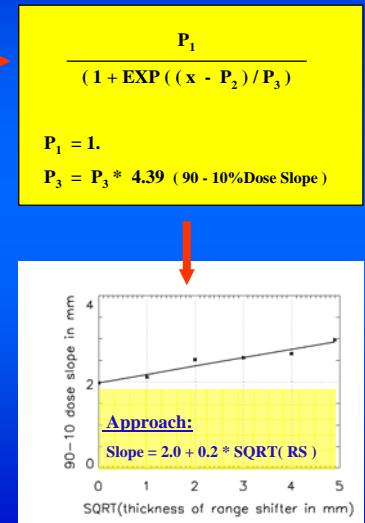
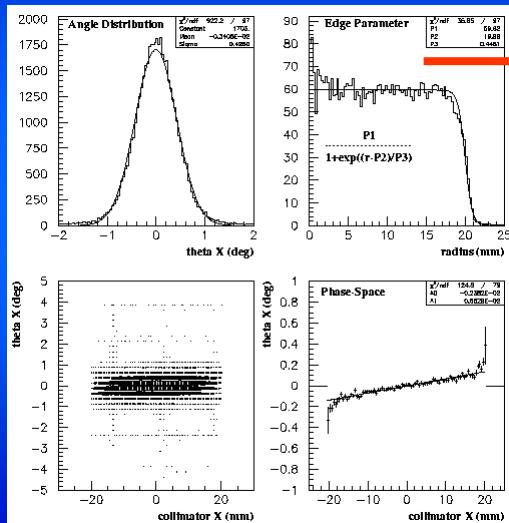
## Correction of Primary Field / Beamline Geometry

### Beamline Set-up at Hahn-Meitner Institute Berlin

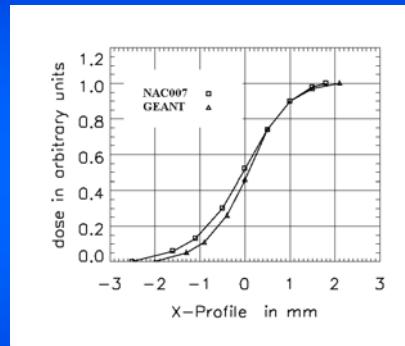
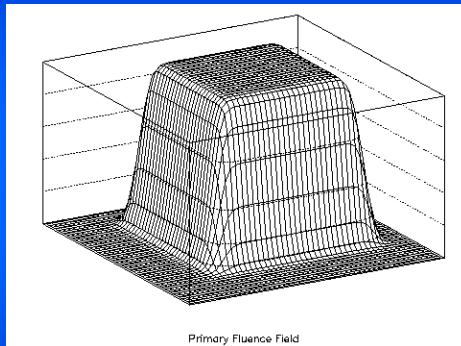


## Correction of Primary Field / Beamline Geometry

GEANT Data-Set for Range Shifter = 0 mm



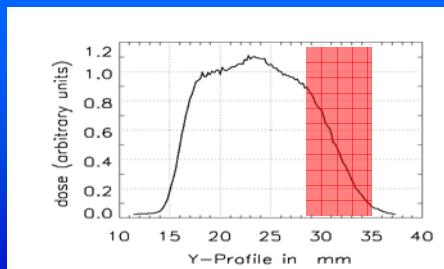
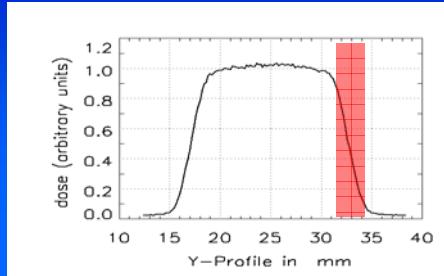
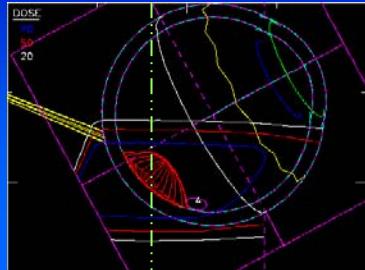
## Correction of Primary Field / Beamline Geometry



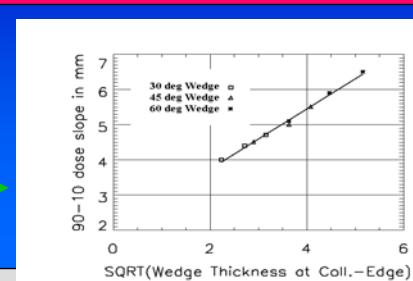
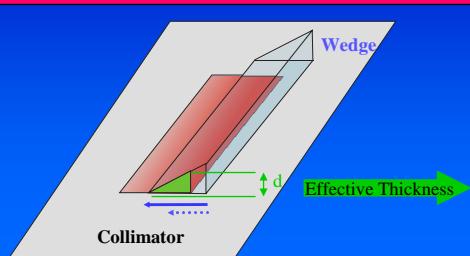
Field ( $d(RS), x, y$ ) = Coll( $x, y$ )  $\otimes$  PSF( $RS$ )

Lateral Field on Air at "Eye Entry"  
---> 65mm behind Collimator

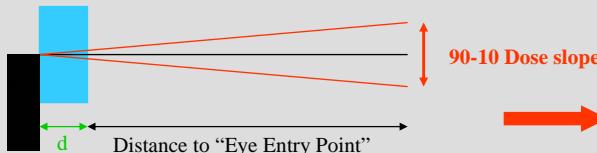
## Correction of Primary Field / Wedge Application



## Correction of Primary Field / Wedge Application



### Approach

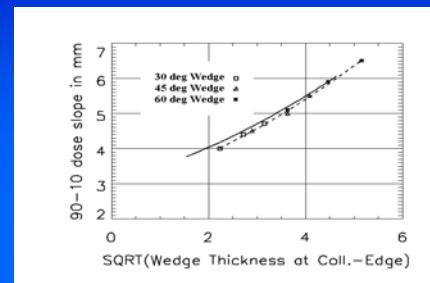
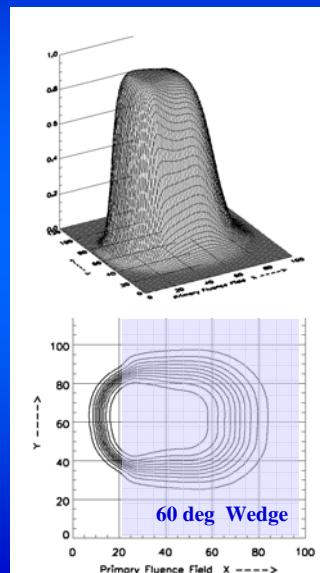


### Multiple Coulomb Scattering

$$\bar{r}^2(z) = \frac{(19.2 \text{ MeV})^2}{L_R} \left(1 + 0.088 \log_{10} \frac{z}{L_R}\right)^2 \int_0^z (z - z')^2 \frac{dz'}{(p v)^2}$$

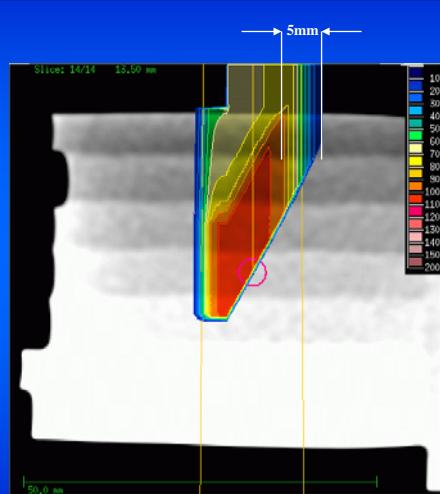
$d = F(\text{curve}_{\text{collimator}})$   
 $\text{Slope} = F(\text{curve}_{\text{collimator}})$

## Correction of Primary Field / Wedge Application

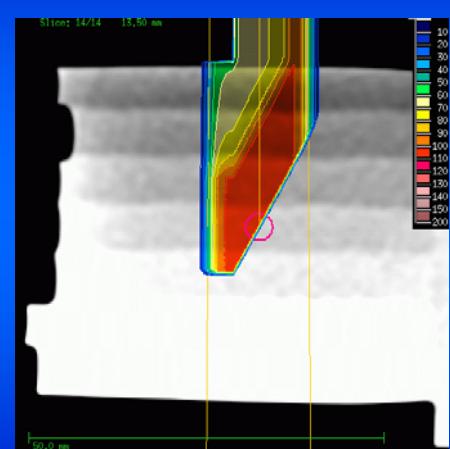


Wedge + 10mm Range Shift

## Correction of Primary Field / Wedge Application

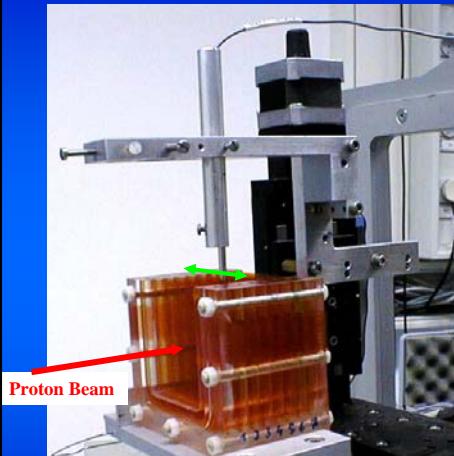


Wedge Approach

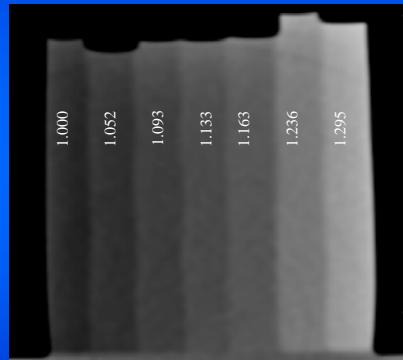


Conventional Version

## Verification

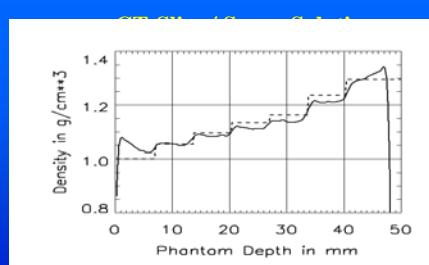


7 Chamber Phantom

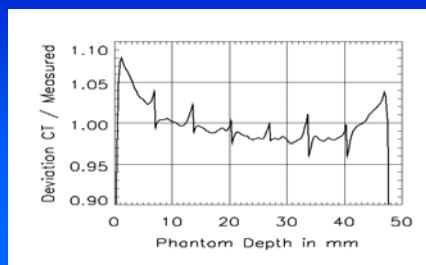


CT-Slice / Sugar Solutions

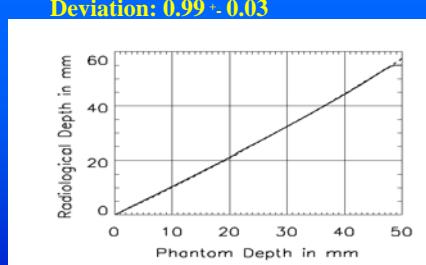
## Verification



Hounsfield based Density

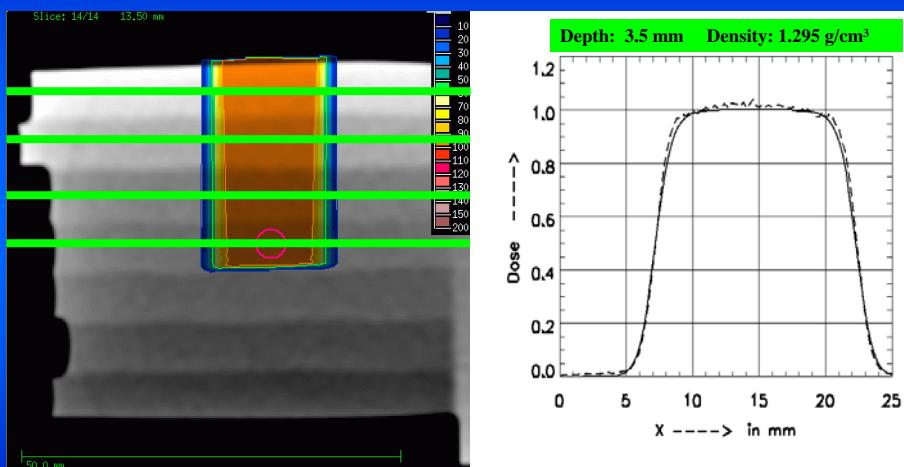


Deviation:  $0.99 \pm 0.03$



Comparison of Radiological Depths

## Verification



## 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 Beamlne Study

optional: measured Slopes

Density of Wedge Material

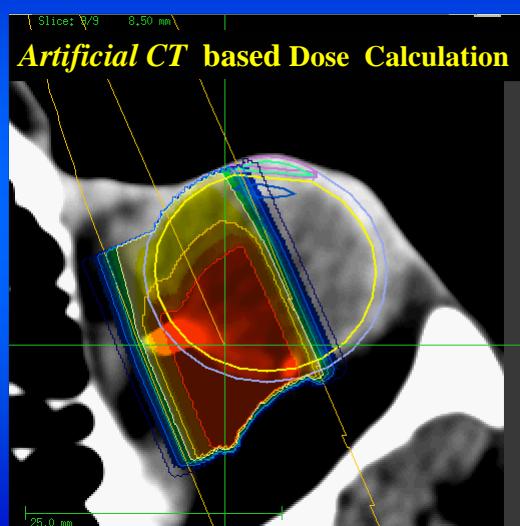
## Features of the Dose Algorithm

### 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



## 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