Proton Therapy Center at the Institute of Nuclear Physics in Kraków - from the Eye Treatment to the Scanning Gantry

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National Centre for Hadron Radiotherapy at IFJ PAN, February 2013

Symposium on Applied Nuclear Physics and Innovative Technologies
Jagiellonian University Kraków, June 03-06, 2013 Poland

The Henryk Niewodniczański Institute of Nuclear Physics Polish Academy of Sciences, IFJ PAN

- established 1955
- 480 employees (190 with Ph.D. degree)+95 Ph.D. students

- main scientific fields:

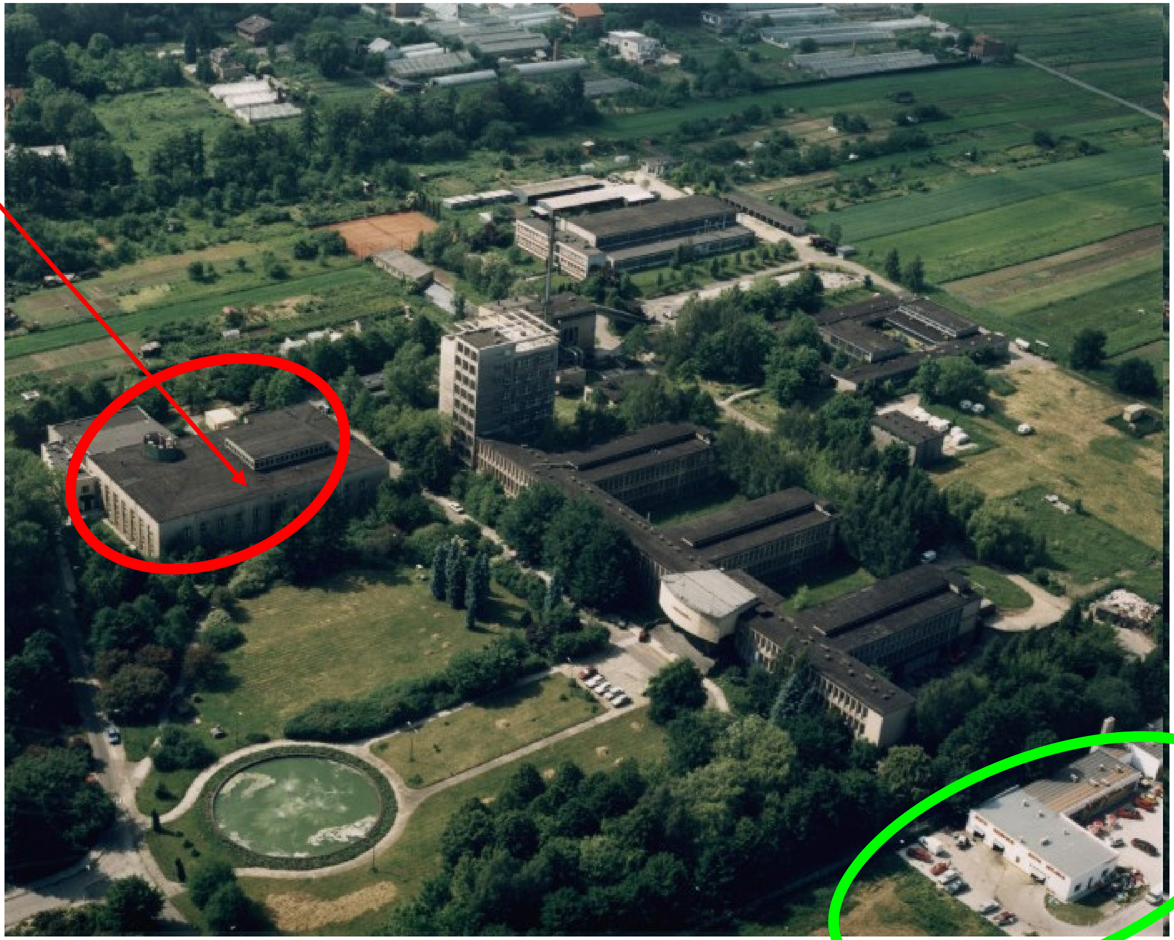
- **Particle Physics and Astrophysics**
- **Nuclear and Strong Interactions Physics**
- **Condensed Matter Physics**
- **Interdisciplinary Applications of Physics**

International co-operation: CERN-Geneva, French institutes IN2P3, Institute Laue-Langevin JINR-Dubna, German institutes: DESY-Hamburg, KFZ-Jülich, GSI-Darmstadt, Max-Planck Institut für Plasmaphysik (IPP)-Greifswald, Univerity in Münster and Konstanz, National Laboratory-Brookhaven, KEK-Tsukuba Laboratories in Legnaro, Milano and Gran Sasso (Italy) and with numerous institutes in 26 countries.

Proton Radiotherapy Center at the IFJ PAN

CCB
AIC-144
cyclotron

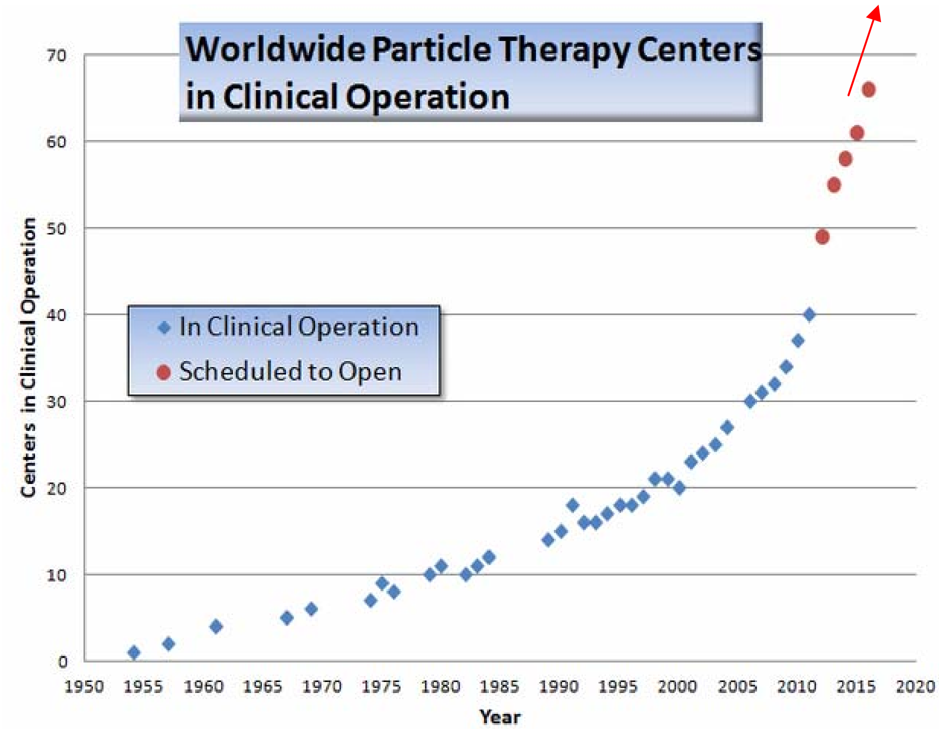
Proton radiotherapy of eye melanoma started at the IFJ PAN in Kraków (cooperation with Clinic of Ophthalmology and Centre of Oncology in Kraków) in February 2011.



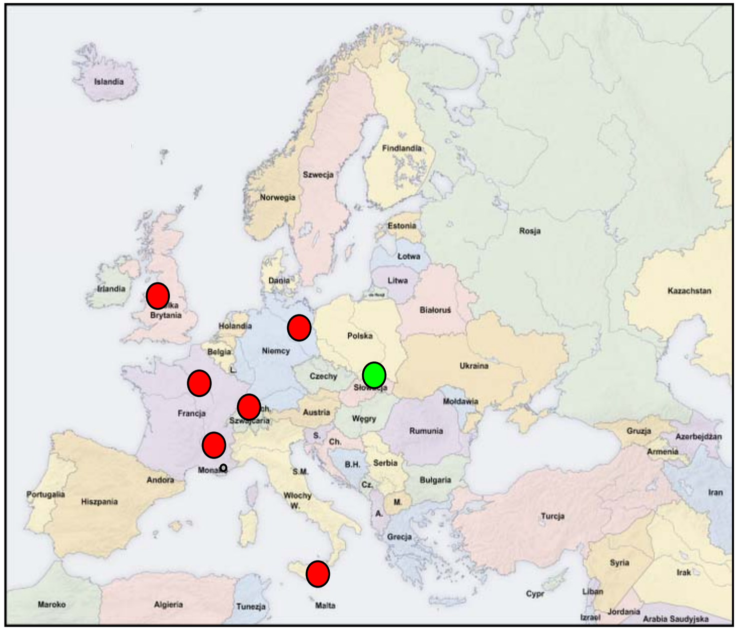
CCB
Proteus C-235
cyclotron

Proton Radiotherapy Centers in the World

2013 – 42 centers



http://www.israelprotontherapy.com

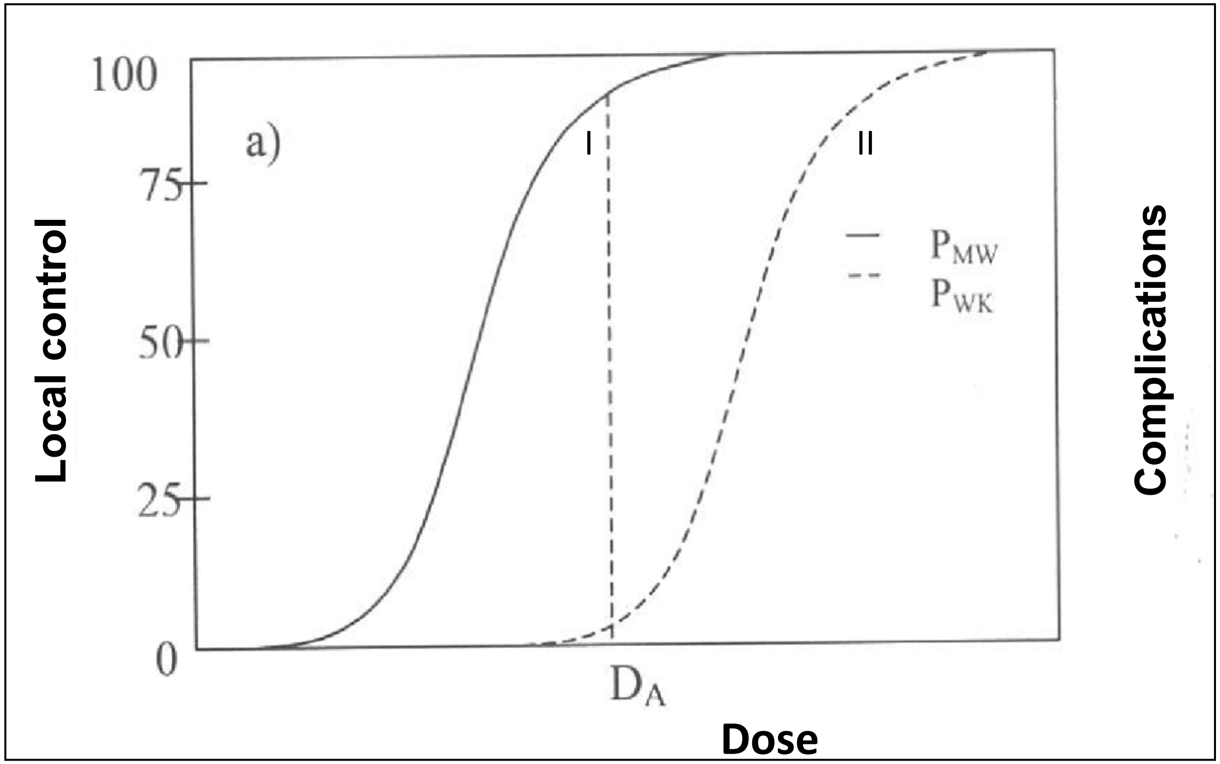


In Europe 6 7 centers

- Berlin, HMI, D
- Catania, INFN, I
- Orsay, Inst. Curie, F
- Clatterbridge, UK
- PSI Viligen, CH
- **IFJ Kraków**

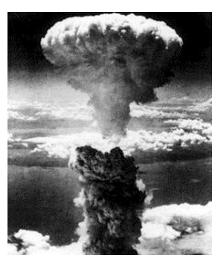
Principles of Proton Radiotherapy

Required dose in the treated volume – minimal dose to healthy tissue
Highest local control – with limited complications



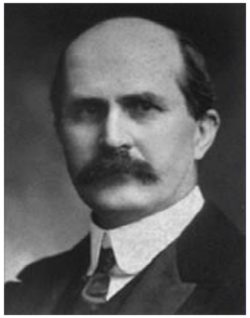
I – dose response curve (local tumor control - recovery, cancer destroyed)

II – complications - radiation side effects (normal tissue damages)

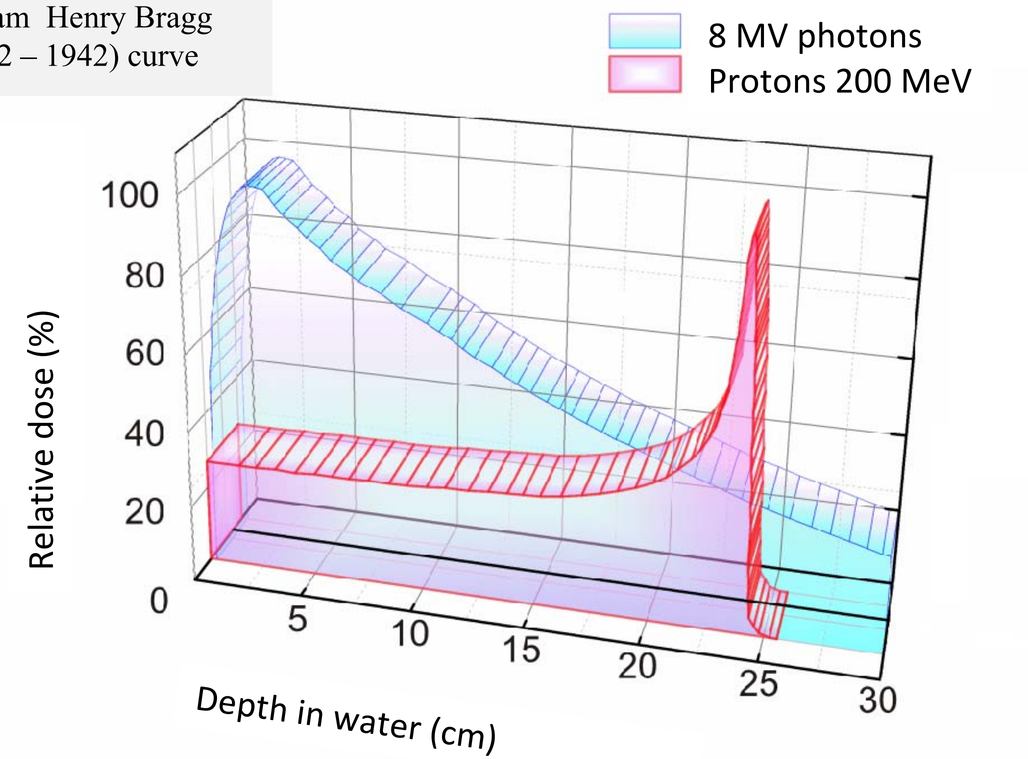


Ionizing radiation can induce cancer …and ….. can treat cancer

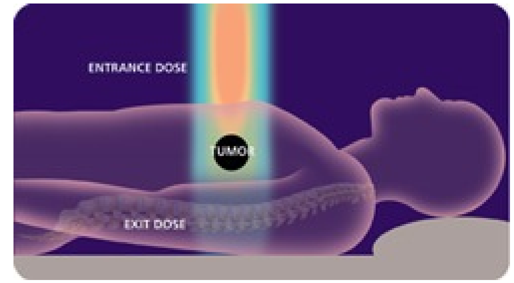
Principles of Proton Radiotherapy
Why Protons?



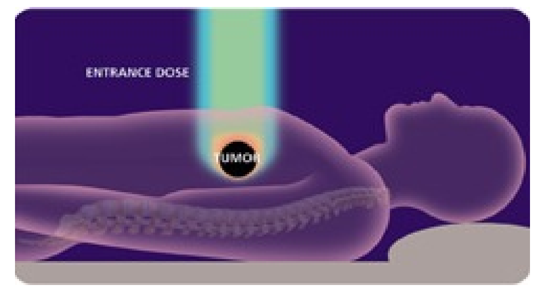
William Henry Bragg
(1862 – 1942) curve



Depth dose distribution in water



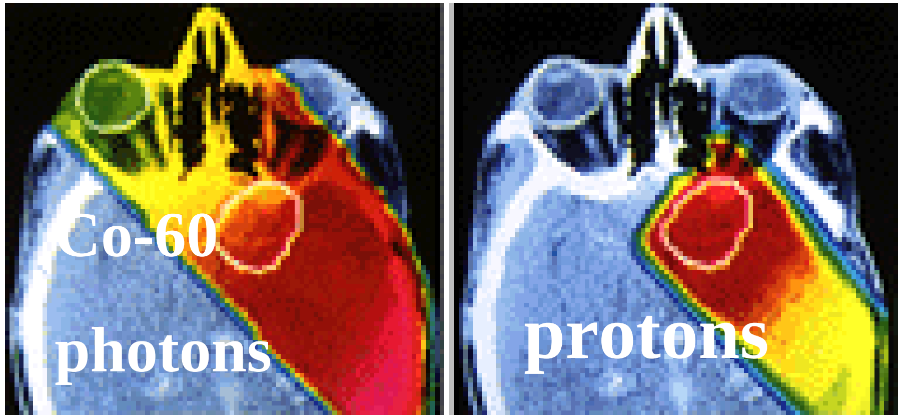
Conventional radiotherapy

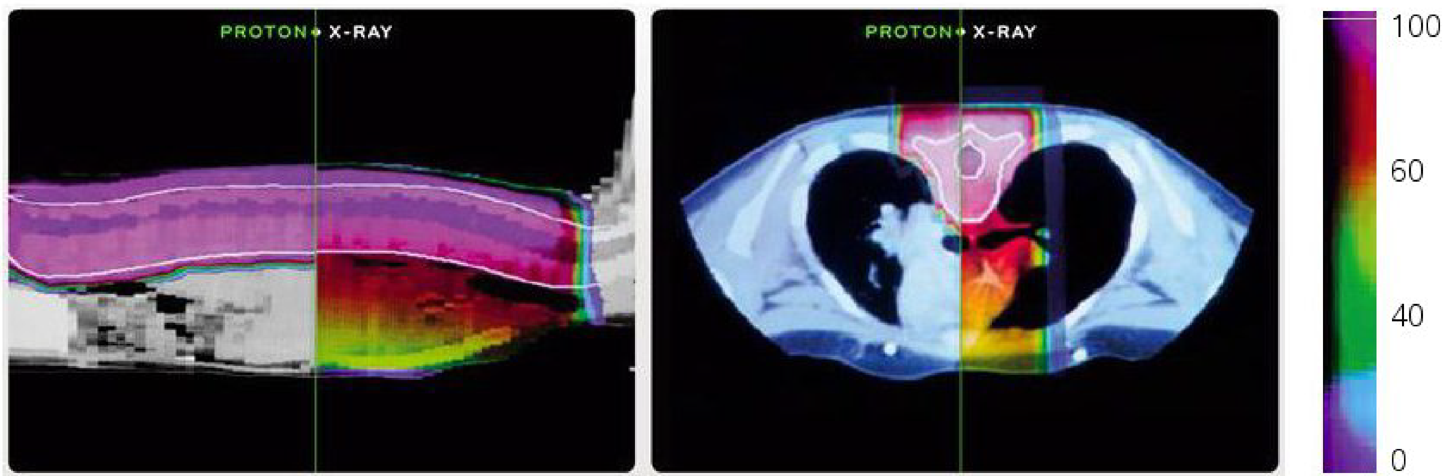


Proton radiotherapy

Protons:
Well defined range
decreased distal dose
Lower entrance dose
Limited beam scattering

Protons vs. Photons





Group of head, neck and spine tumors - irradiation of meduloblastome.
Larger photon energy deposition in comparison with protons (from IBA).

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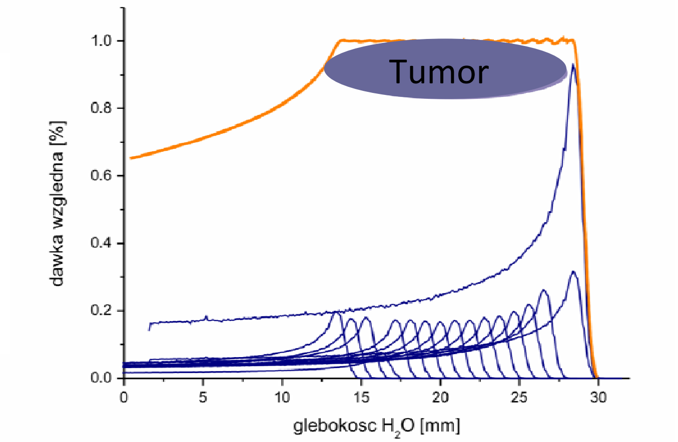
Principles of Proton Radiotherapy

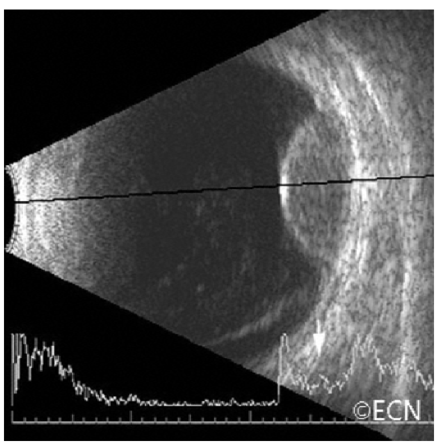
Spread Out Bragg Peak

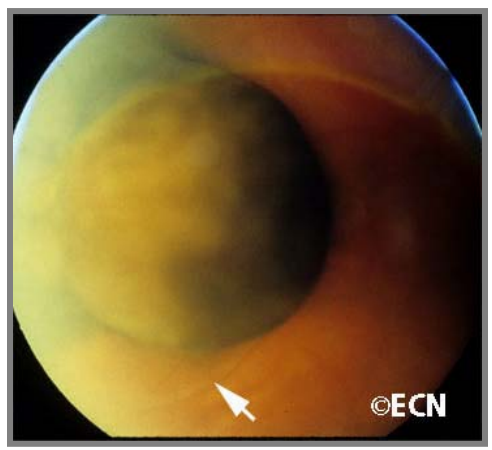
Spread out Bragg peak

Relative dose (%)



Depth in water (mm)





Ultra sound - tumor size

Fundus view – tumor size

Range modulator – uniform depth dose distribution in tumor volume

Range modulator - individual therapy element (parameters from patient treatment plan)

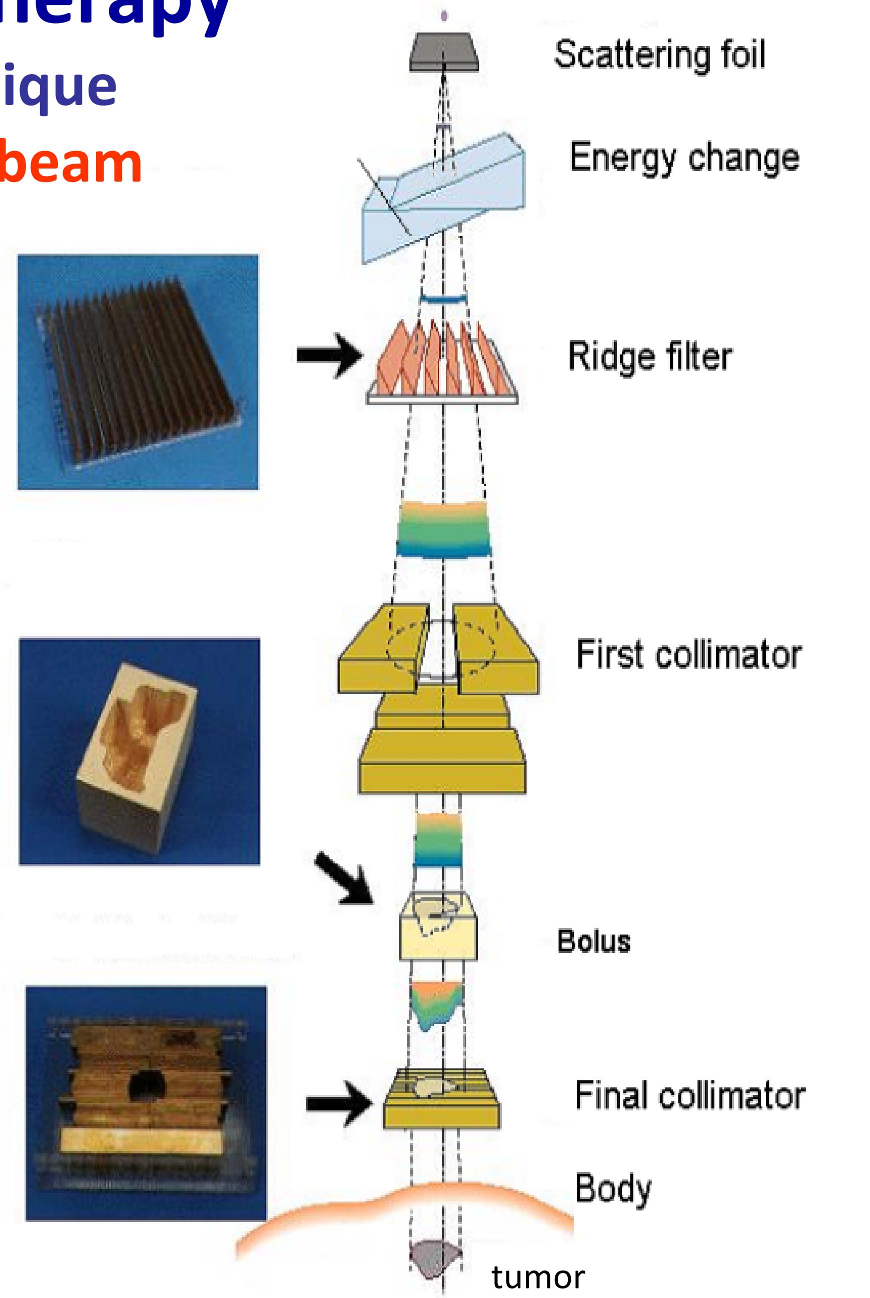
Principles of Proton Radiotherapy

Proton Passive Scattering Technique

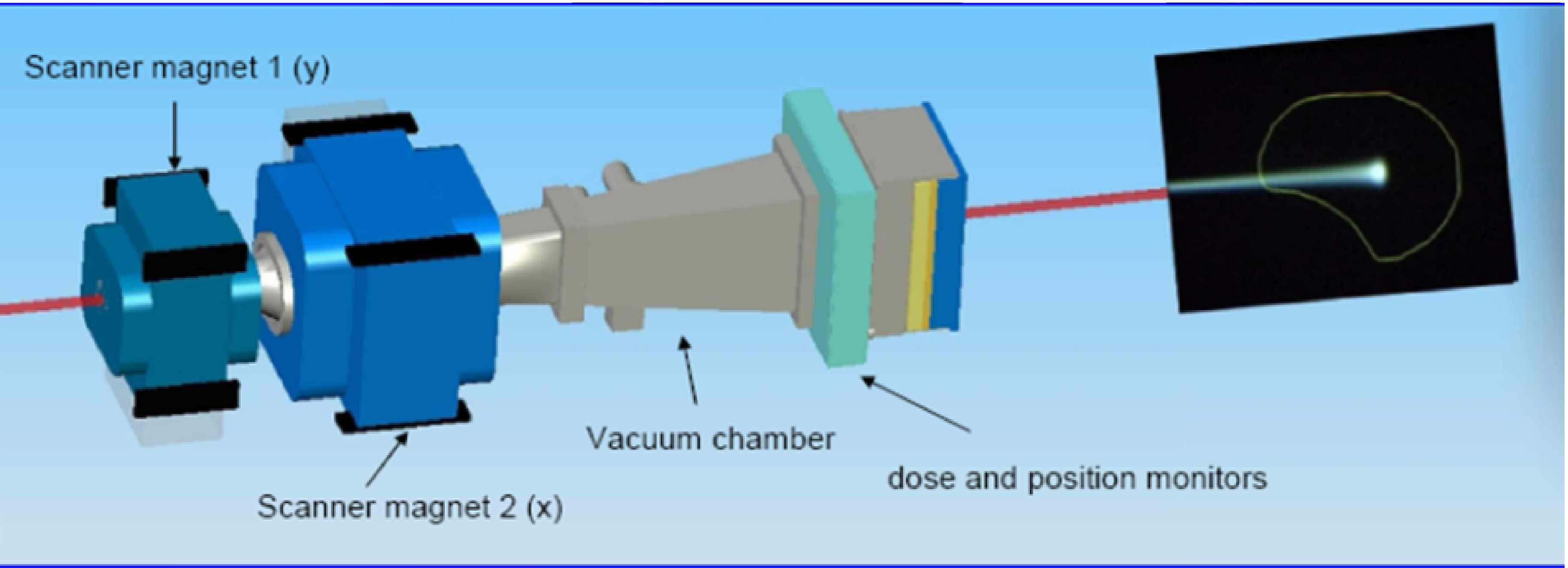
Mechanical formation of proton beam

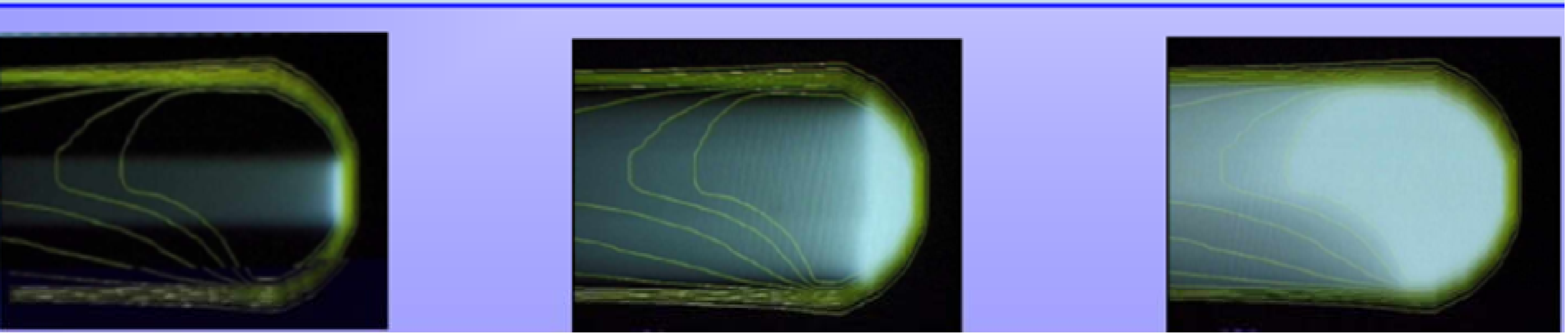
Mechanical elements prepared for each individual irradiation field

- expensive and time consuming



Principles of Proton Radiotherapy
Proton Active Technique - scanning beam



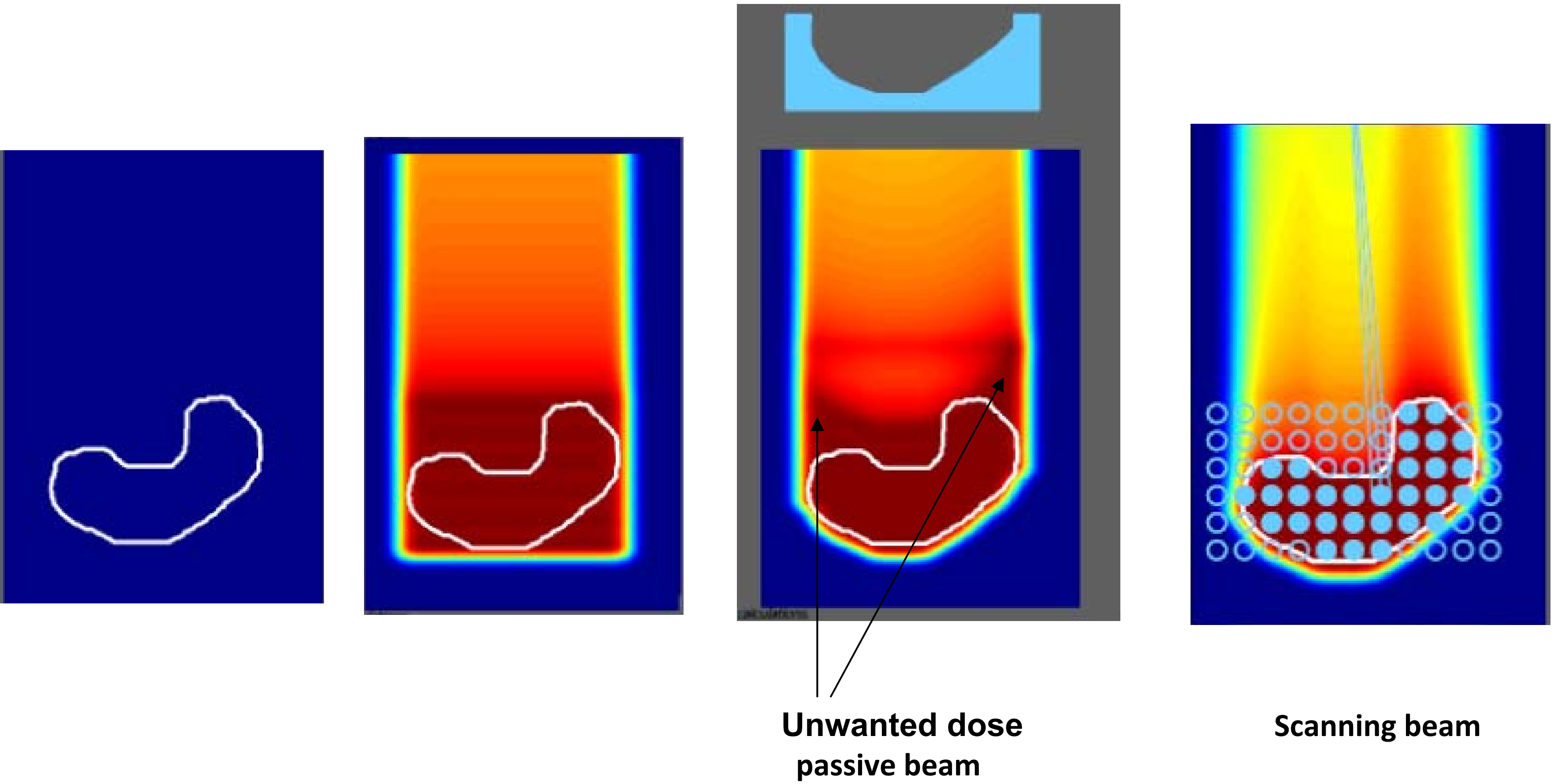


No individual mechanical elements needed

*

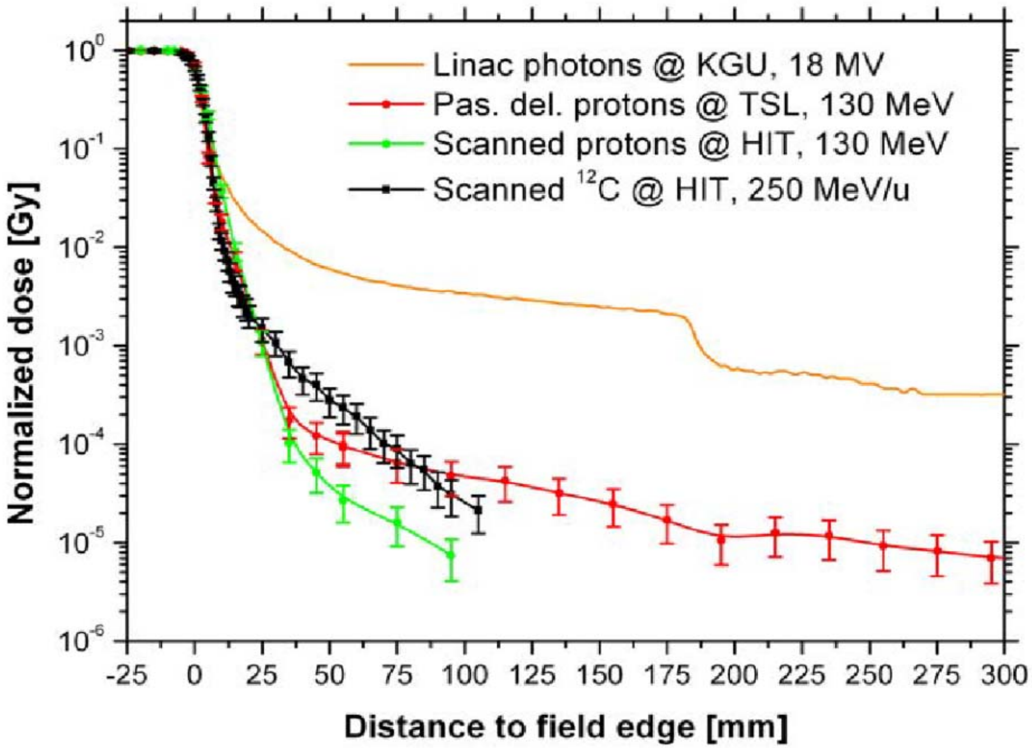
Principles of Proton Radiotherapy

Comparison of scattered and scanned beams



Principles of Proton Radiotherapy
Unwanted doses from scattered radiation – out-of-field doses

Lateral profiles for 5x5 cm² field using different beam delivery techniques



Robert Kaderka, Ph.D Thesis, GSI, 2011

For scanning proton beam doses outside the treated target volume 2-3 orderes of magnitude lower as compared to conventional MV X-rays radiotherapy

Proton Radiotherapy of Eye in Krakow

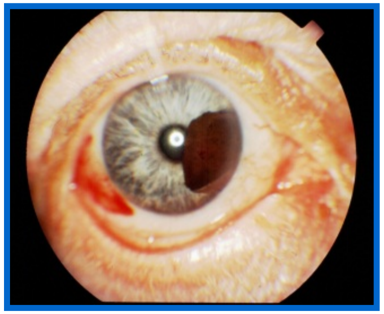
Project of the Proton Radiotherapy of Eye at the IFJ PAN

Eye melanoma

- malignant cancer
- groving inside the eye-ball
- mainly in white population
- **250 cases/year in Poland**

Qualifications: eye melanoma close to optic disc, optic nerve and macula

Choroidal melanoma - 90%



Iris melanoma - 3%

Ciliary body melanoma- 7%

Proton ocular radiotherapy – the most effective treatment – survival > 90%

Proton radiotherapy of eye melanoma started in Krakow in cooperation with Clinic of Ophthalmology and Centre of Oncology in February 2011.

Proton Radiotherapy of Eye in Krakow

First treatment - February 2011

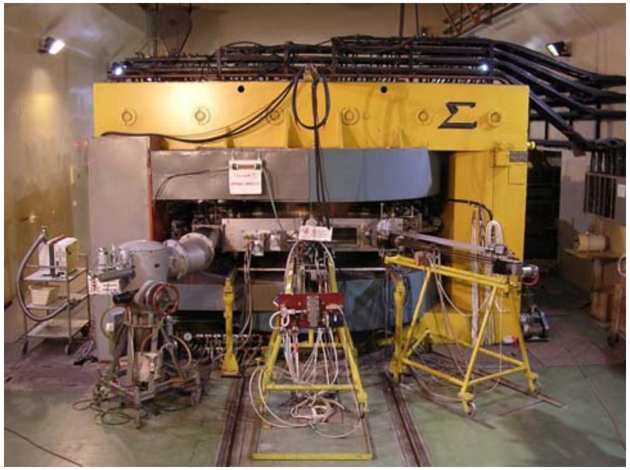
Partners:
Prof. B. Romanowska –Dixon, SU Kraków, CMUJ
Prof. M. Reinfuss, Institute of Oncology, Kraków
Dr. J. Swakoń, IFJ PAN

Cyclotron: AIC-144 at IFJ PAN
Beam: 60 MeV protons

Patients: 15 patients of the Clinic of Ophtalmology and Ophtalmic Oncology 2011 - 2012

Regular treatment- from April 2013

The first patient treated at IFJ PAN facility



Isochronic cyclotron AIC-144 (1995)
60 MeV protons

Proton Radiotherapy of Eye in Kraków IFJ PAN

Eye Treatment Room

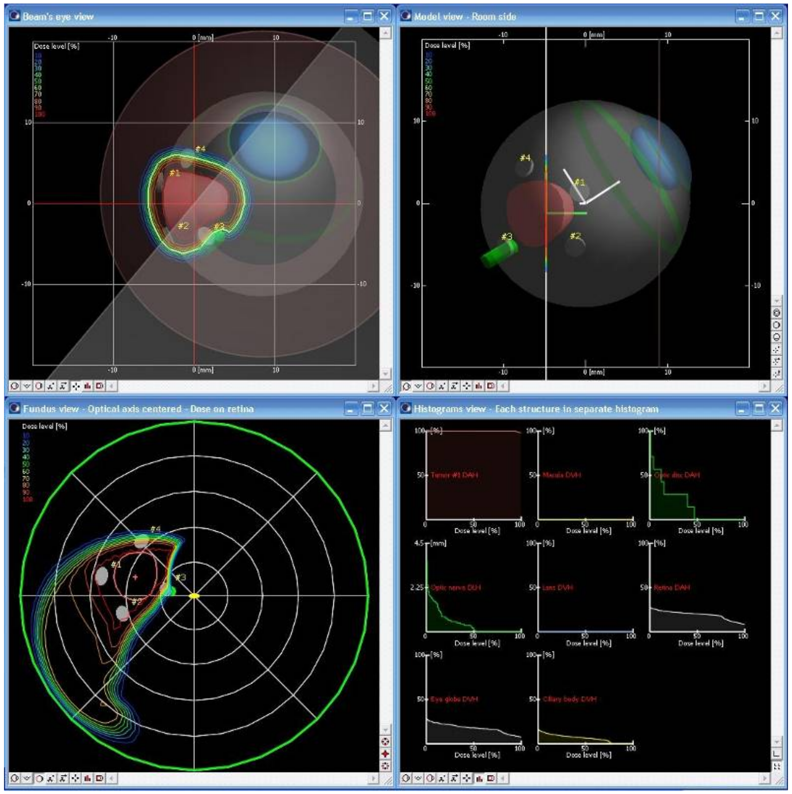
Therapy room developed at IFJ 2006-2009 in collaboration with Helmholtz Centre, Berlin

Proton Radiotherapy of Eye in Kraków, IFJ PAN

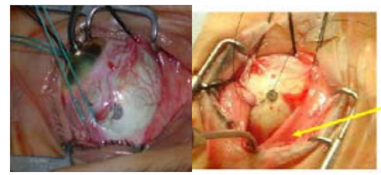
Beam forming and monitoring elements

Proton radiotherapy of Eye in Kraków IFJ PAN

Planning system



T. Kajdrowicz, M. Bajer
EOPP - Eclipse Ocular Proton Planning (Varian)

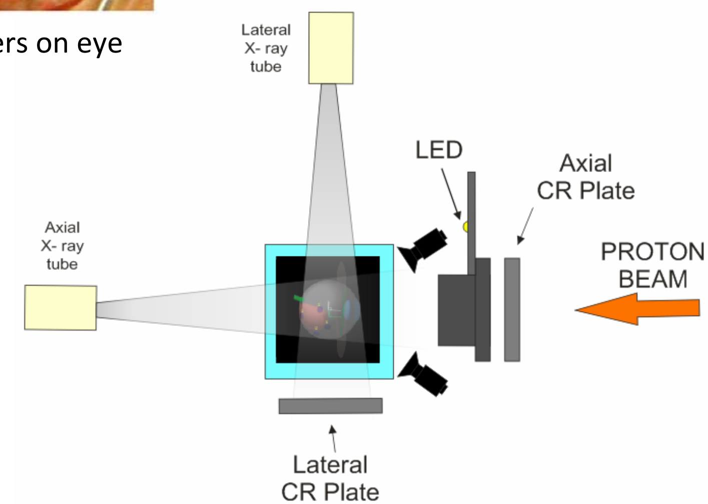


Tantalum markers on eye

EOPP input data

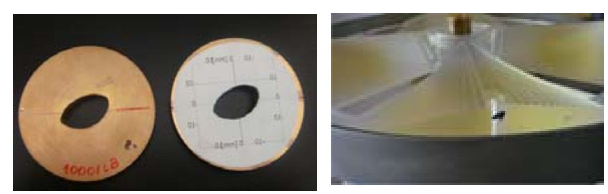
Data from clinical investigation of eye - ultrasound, optical biometry, fundus view photographs, MRI

X-ray images (lateral, axial - DICOM) of eye with Ta markers for precise patient positioning



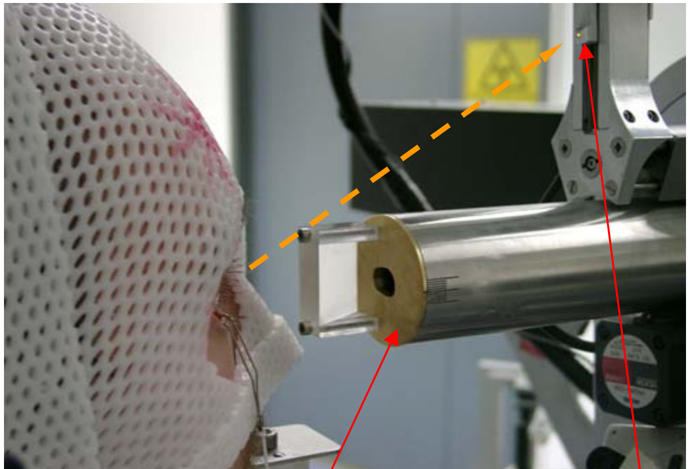
EOPP output data

Proton range
SOBP - modulation
Aperture of patient collimator
Optimal gazing angle
Dose histograms for eye structures



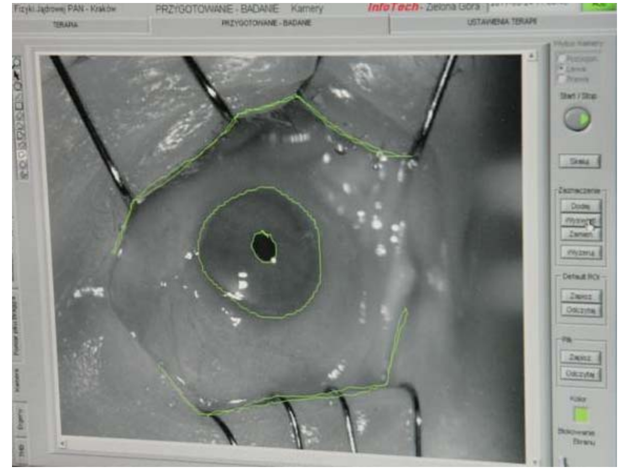
Proton radiotherapy of Eye in Kraków IFJ PAN

Patient Positioning System



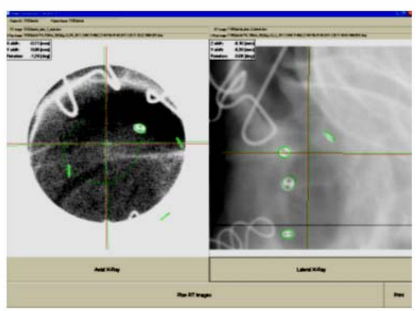
Patient collimator

Positioning diode



Eye visualization

Eyelids retracting



Dose:
Choroidal melanoma
4 fractions * 15,0 CGE = 60 CGE
Iris melanoma
4 fractions * 12,5 CGE = 50 CGE
(CGE = Cobalt Gray Equivalent)

Secondary Radiation

neutrons and gamma-rays - measurements and MC modelling

Dosimetry:

Active and passive detectors:

FHT 762 (Wendi-2) and FHT-192 for the measurement of the ambient dose equivalent rate **dH*(10)/dt** for neutrons and gamma-rays

TLD 700 and TLD 600 and PADC track detectors situated inside the anthropomorphic Rando phantom

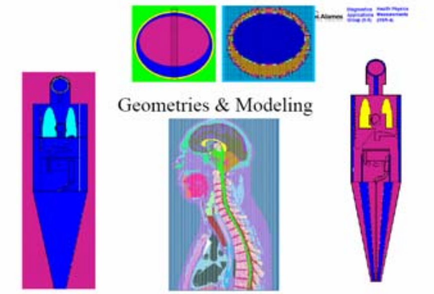
Wendi-2 FHT-192

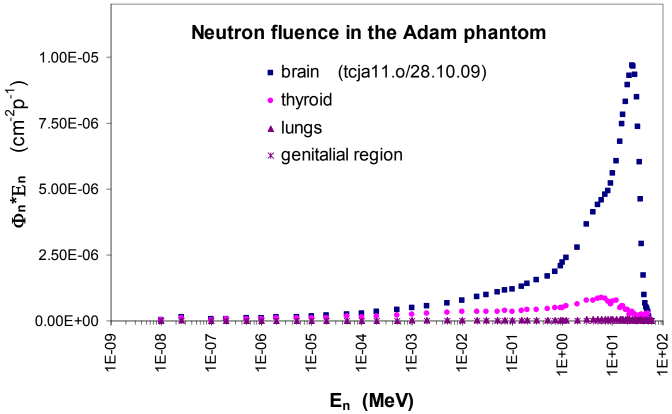
TLD and PADC detectors

Rando phantom

Numerical Dosimetry

MCNPX v. 2.5 - a general purpose Monte Carlo radiation transport code





Secondary neutrons and gamma-rays:

Effective dose **E < 0,2 mSv**

Risk of secondary cancer induction **R ~ 0,001%**

Project of the
National Centre of Hadron Radiotherapy

at IFJ PAN

Poland in European Union

1 May 2004 Poland joined European Union

In 2007 -2013 60 billions € used for reconstruction of infrastructure in form of Structural Funds

1.3 billion € for infrastructure in science and technology

National Centre of Hadron Radiotherapy, NCRH –CCB
The project

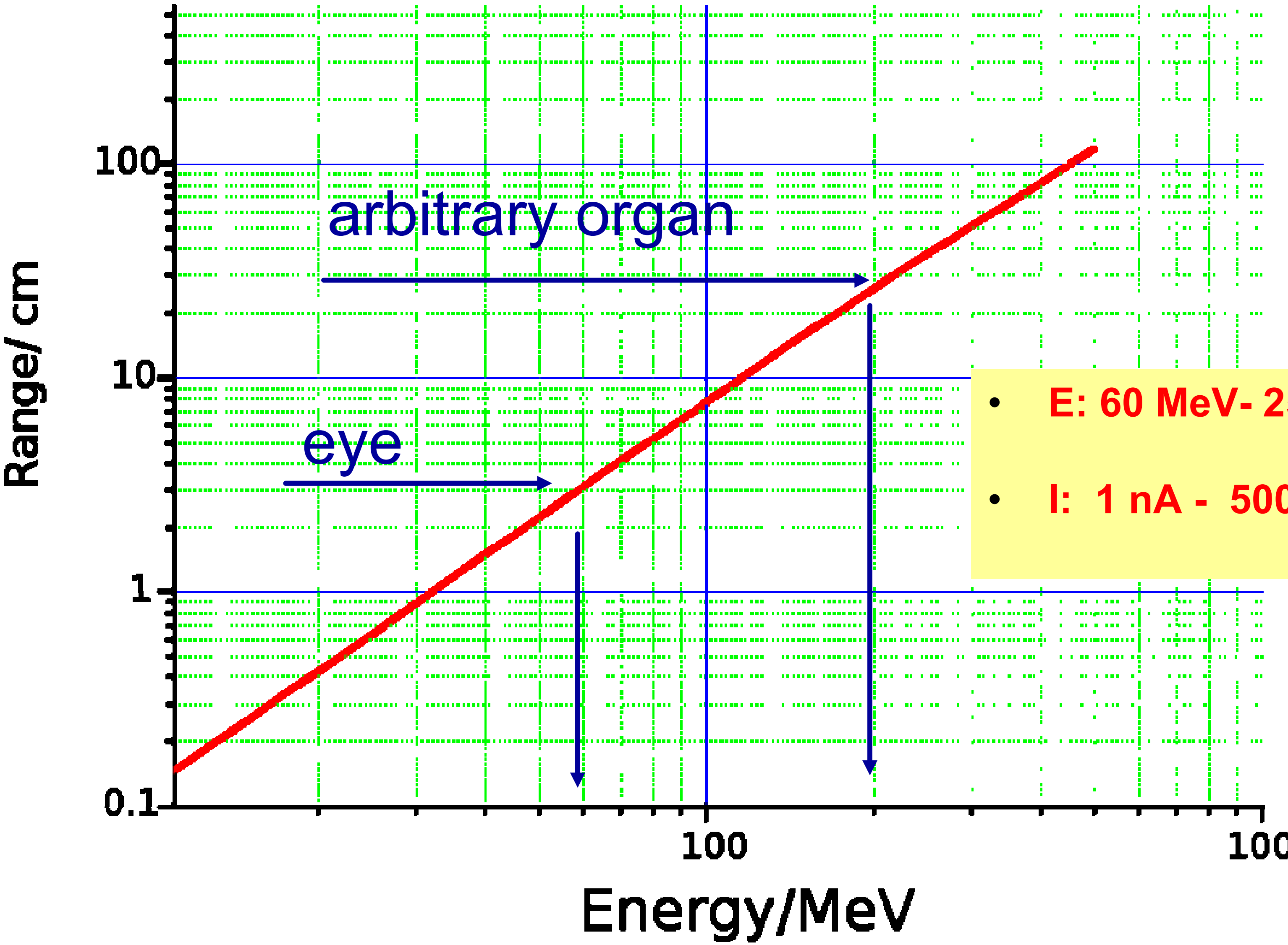
Split into two parts:

Part 1 „Cyclotron”:
- building + Proteus C-235 cyclotron
• funds: 116 Mzl ~ 27 M€
• the project ready till Dec 2012
• vendor: contract signed with Ion Beam Application (IBA), Belgium

Signing the contract for the Part 1
IFJ PAN – IBA 2 August 2010

Part 2 „Gantry”
• medical building + proton gantry
• funds: 79 Mzl ~ 18 M€
• project signed in Nov. 2011
• the project ready till June 2014

What proton beam do we need?



- **E: 60 MeV- 250 MeV**
- **I: 1 nA - 500 nA**

CCB - Proteus 235 cyclotron

Proteus 235 cyclotron, IBA, Belgium

- Proton energy: 230 MeV
- range in water: 32 cm
- For proton radiotherapy, nuclear physics, radiobiology, materials engineering

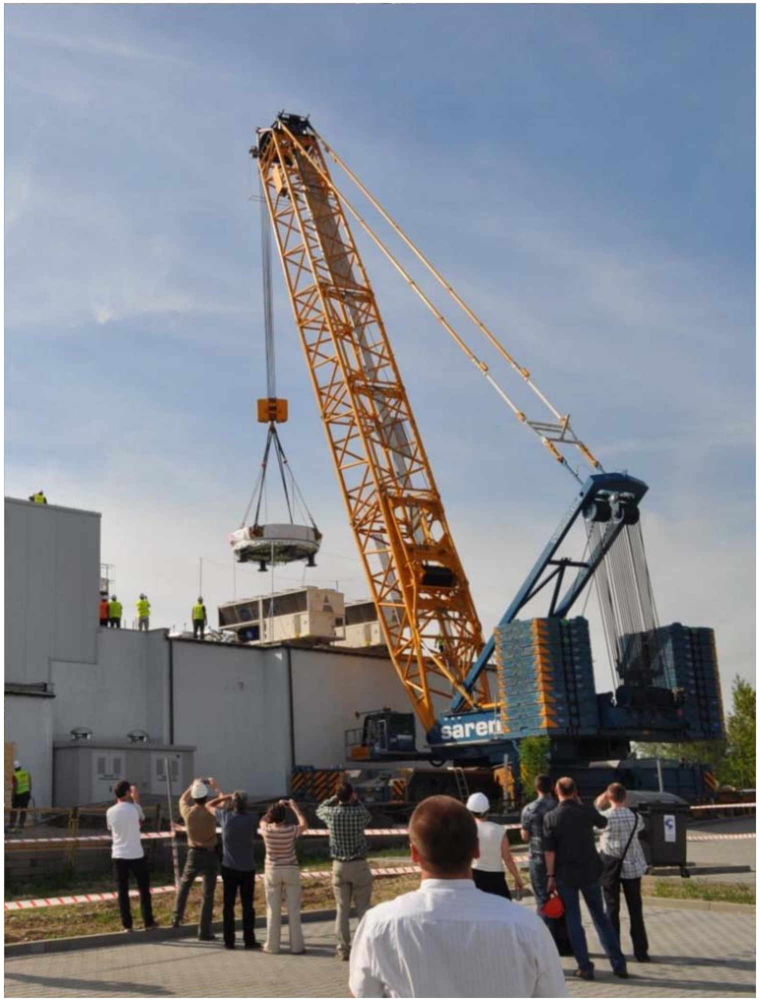
3.03 2011 Just before the start …..

First stone
17 March 2011

11 May 2012

National Centre for Hadron Radiotherapy
Installation of the Proteus C-235 cyclotron

11 May 2012

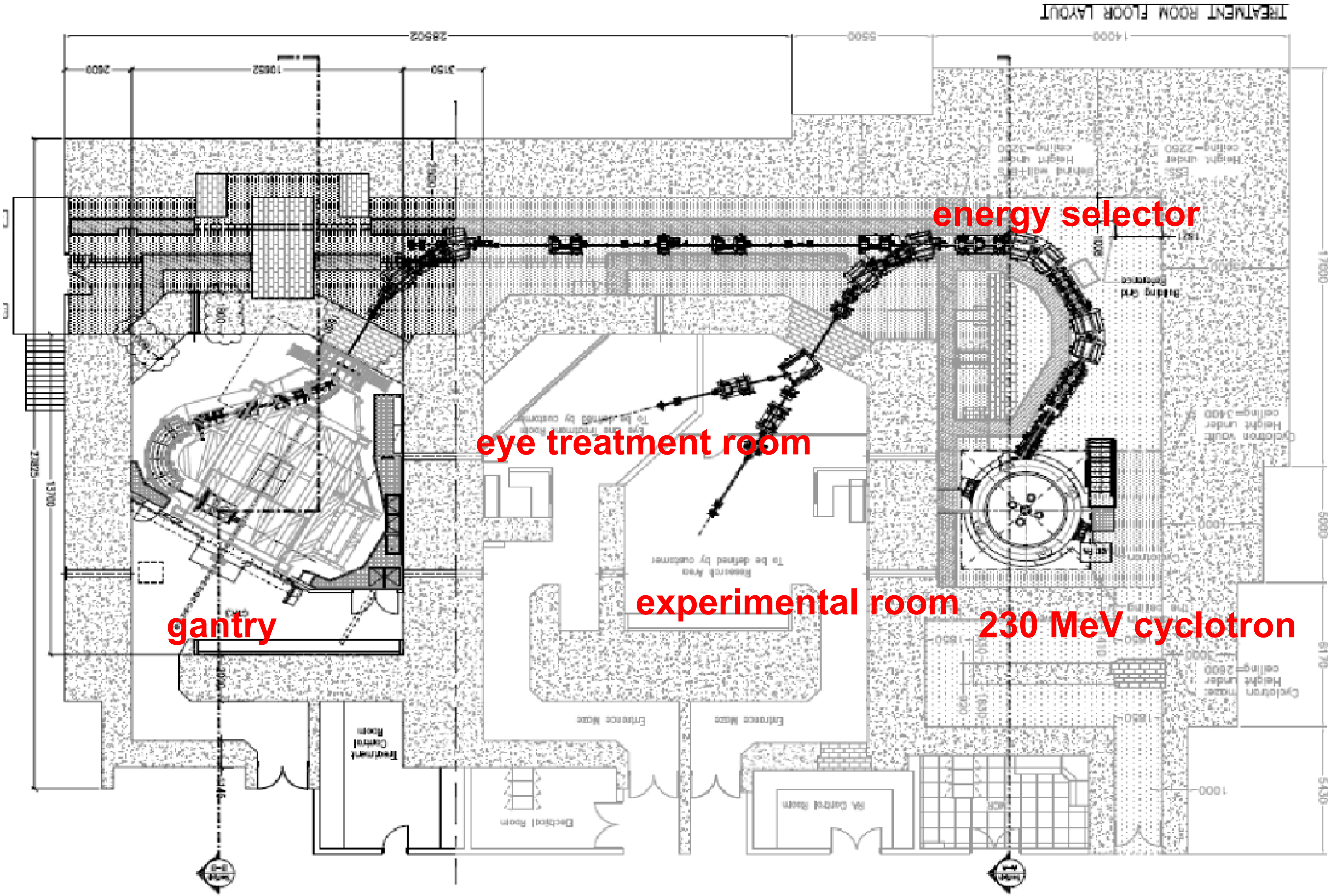


11 May 2012

Timetable of NCRH – CCB

- signing the contract 2.08.2010
- building permission 10.02.2011
- start of the construction 17.03.2011
- installation of the C-235 cyclotron 05.2012
- acceptance tests 11.2012
- medical building 06.2013
- installation of gantry 07.2013
- end of the contract 06.2014

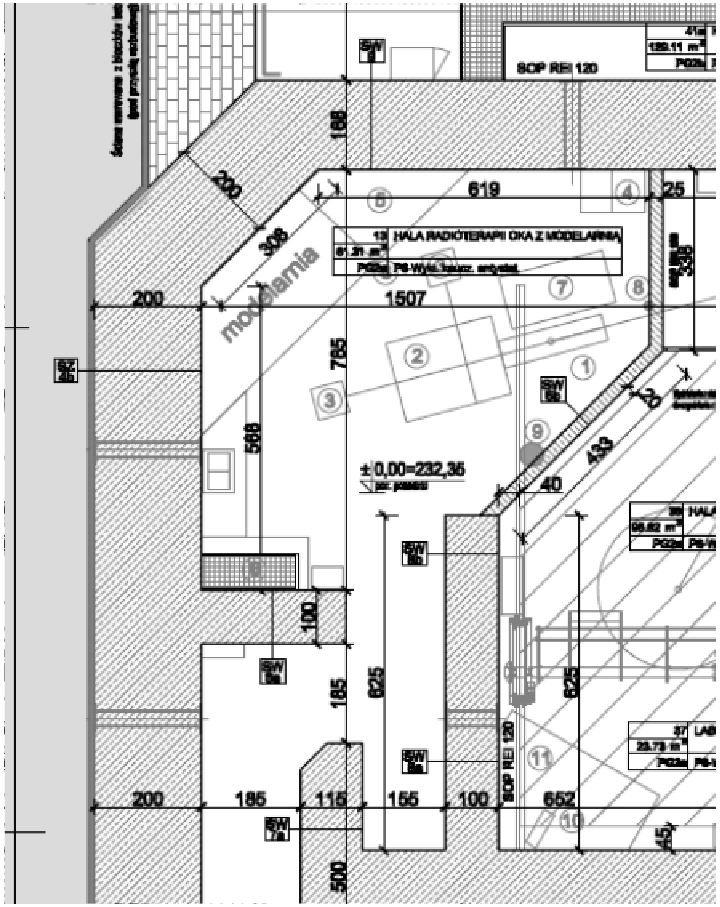
Beamlines in NCRH – CCB



P. Olko M. Jezabek NCRH

National Centre for Hadron Radiotherapy

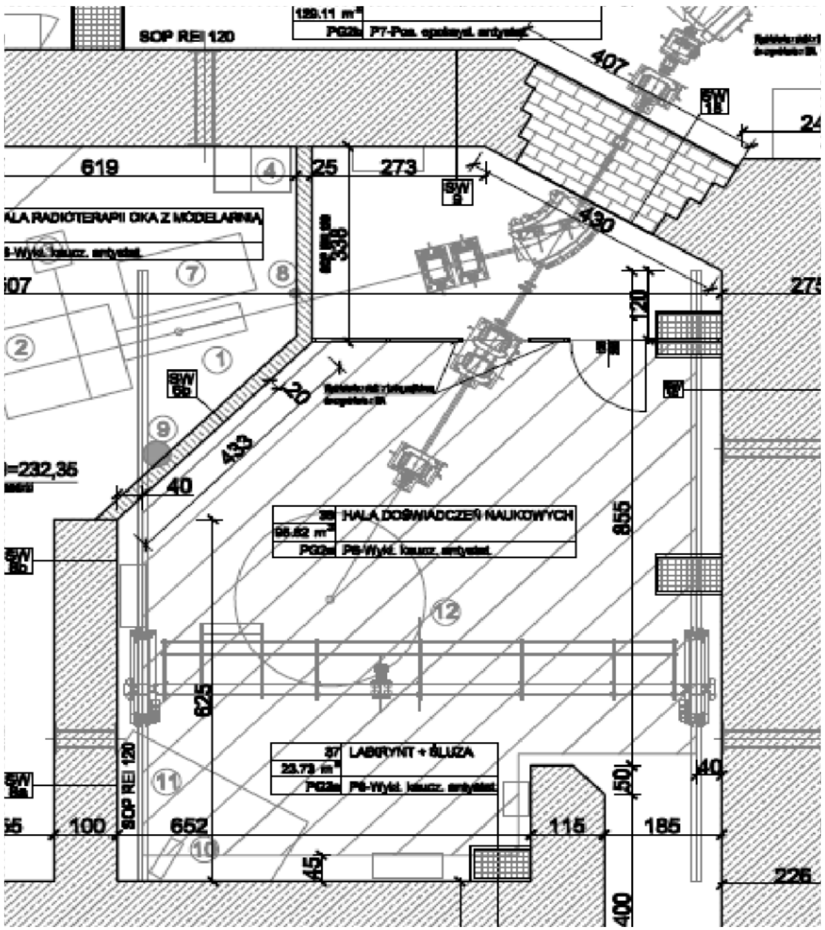
New eye treatment room



Installation of the new eye line at NCRH-CCB

National Centre for Hadron Radiotherapy

Experimental hall for nuclear physics and radiobiology



National Centre for Hadron Radiotherapy

Laboratories for radiobiology

- Two rooms for preparation of biological materials

- Preparation of the irradiation stand

- Collaboration in radiobiology with UJ (prof. Urbańska), Institute of Oncology (prof. Słonina) and other partners

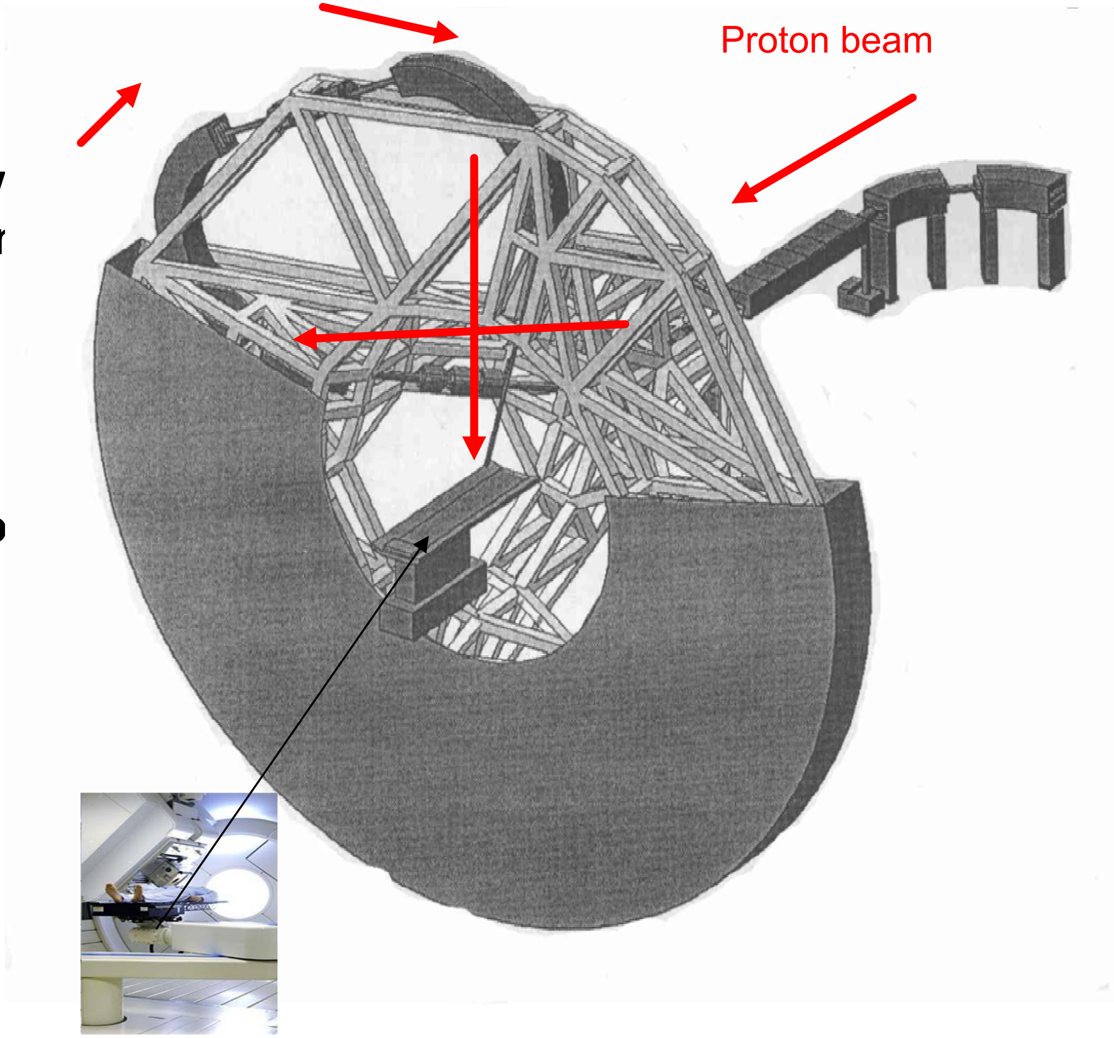
National Centre for Hadron Radiotherapy

Gantry

Gantry:
is a radiotherapy toll which allow to treat patients with protons fro all directions

Problem:
The weight of the magnets more than 10 tons. Required precisio of irradiation 1 mm

Solution:
Rotating construction, 100 tons, 11 m in diameter



National Centre for Hadron Radiotherapy

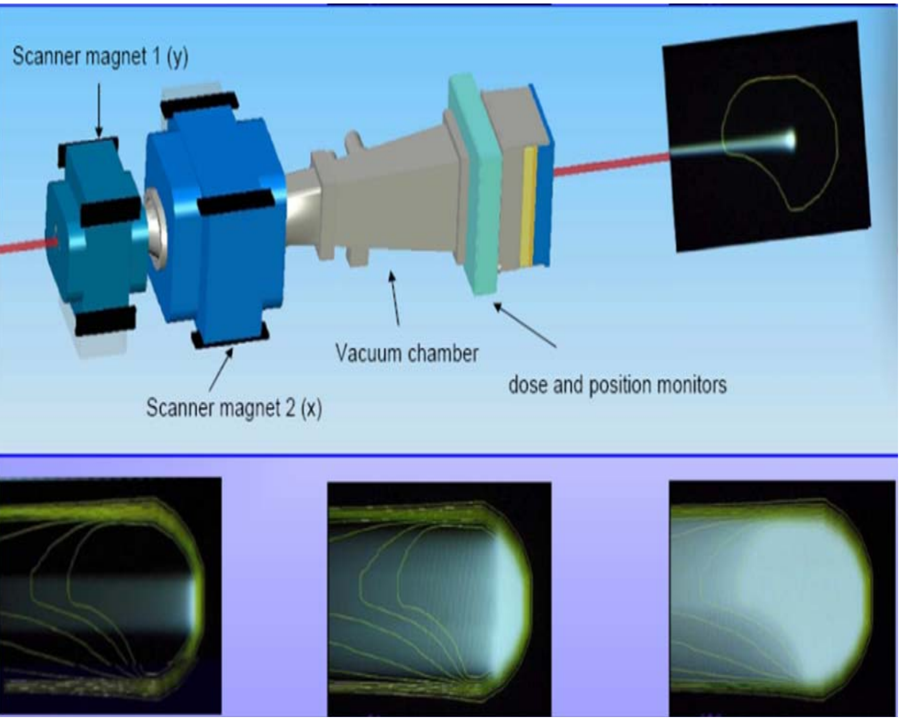
Gantry

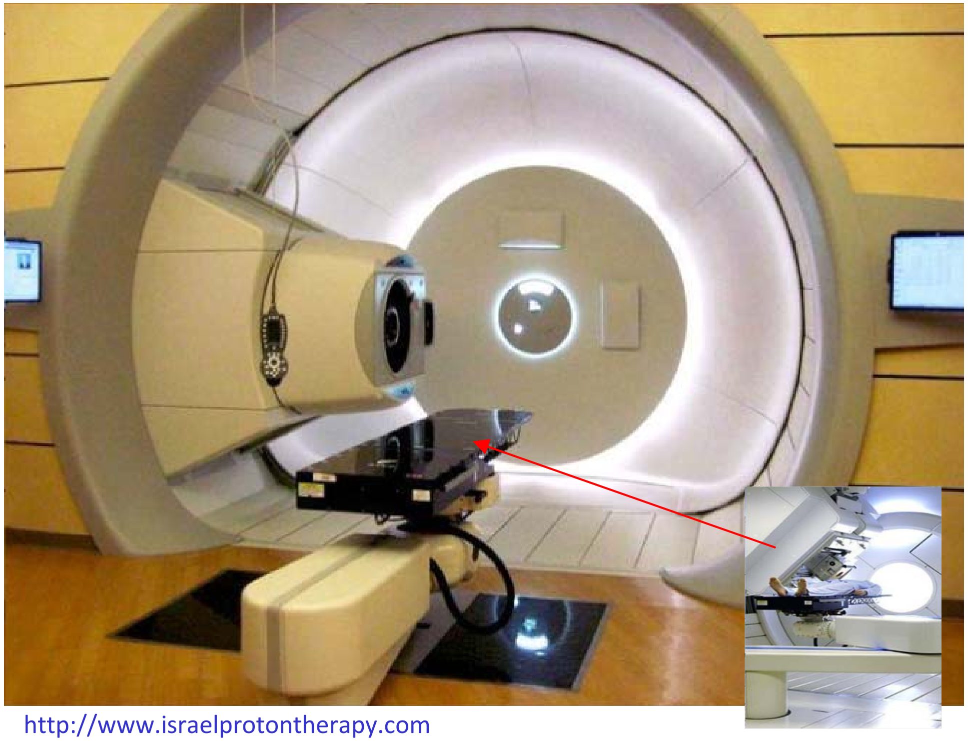
Gantry ready for transport to Kraków

Gantry instalation in IFJ PAN Kraków – 3 June 2013

National Centre for Hadron Radiotherapy

Gantry with the scanning beam





http://www.israelprotontherapy.com

Proton Radiotherapy Centres with Gantry in Europe

● Existing centres

1. Orsay
2. PSI Villigen
3. Heidelberg
4. Munchen
5. Prague

○ In construction : 5 centers

Dresden
Essen
Krakow
Trento
Uppsala

Summary

- Proton radiotherapy is a precise method of tumors irradiation.

- Proton radiotherapy of eye melanoma started in Kraków in cooperation with Clinic of Ophthalmology and Centre of Oncology in February 2011.

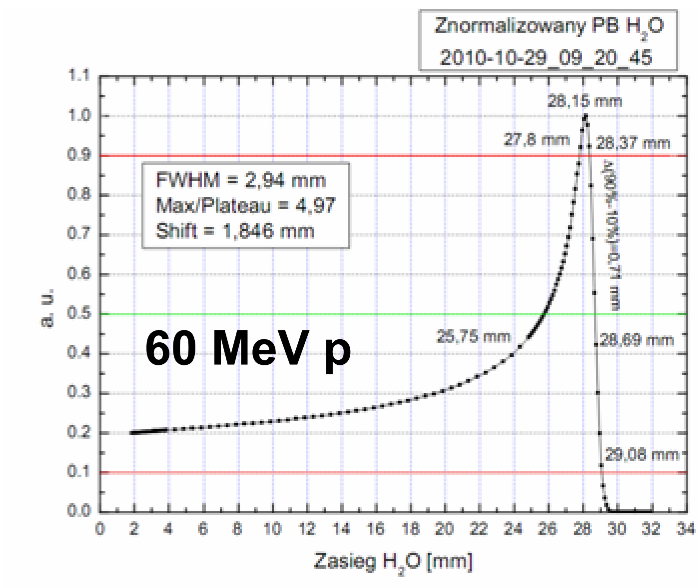
- The 230 MeV IBA cyclotron at the IFJ PAN is in operation since December 2012 and the scanning gantry will be from mid of 2014.

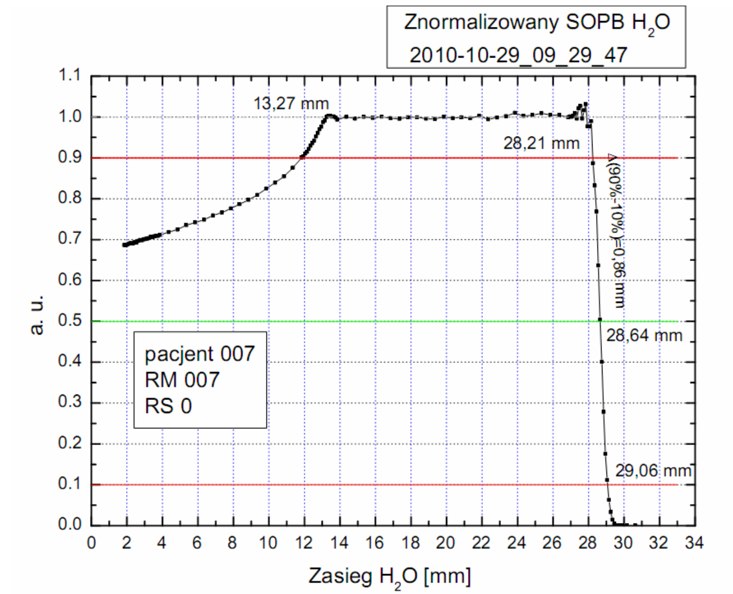
- Extensive R&D is planned at the IFJ PAN in connection to proton therapy

Thank you !

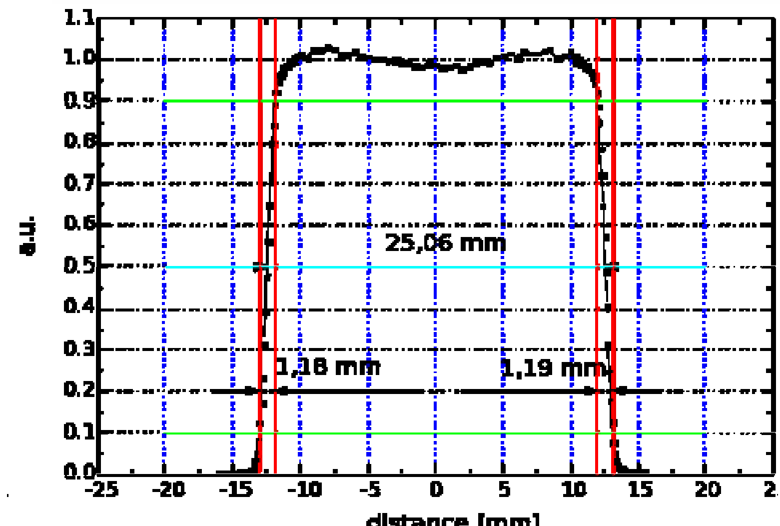
Basic Physical Principles of Proton Therapy

Parameters of the proton beam





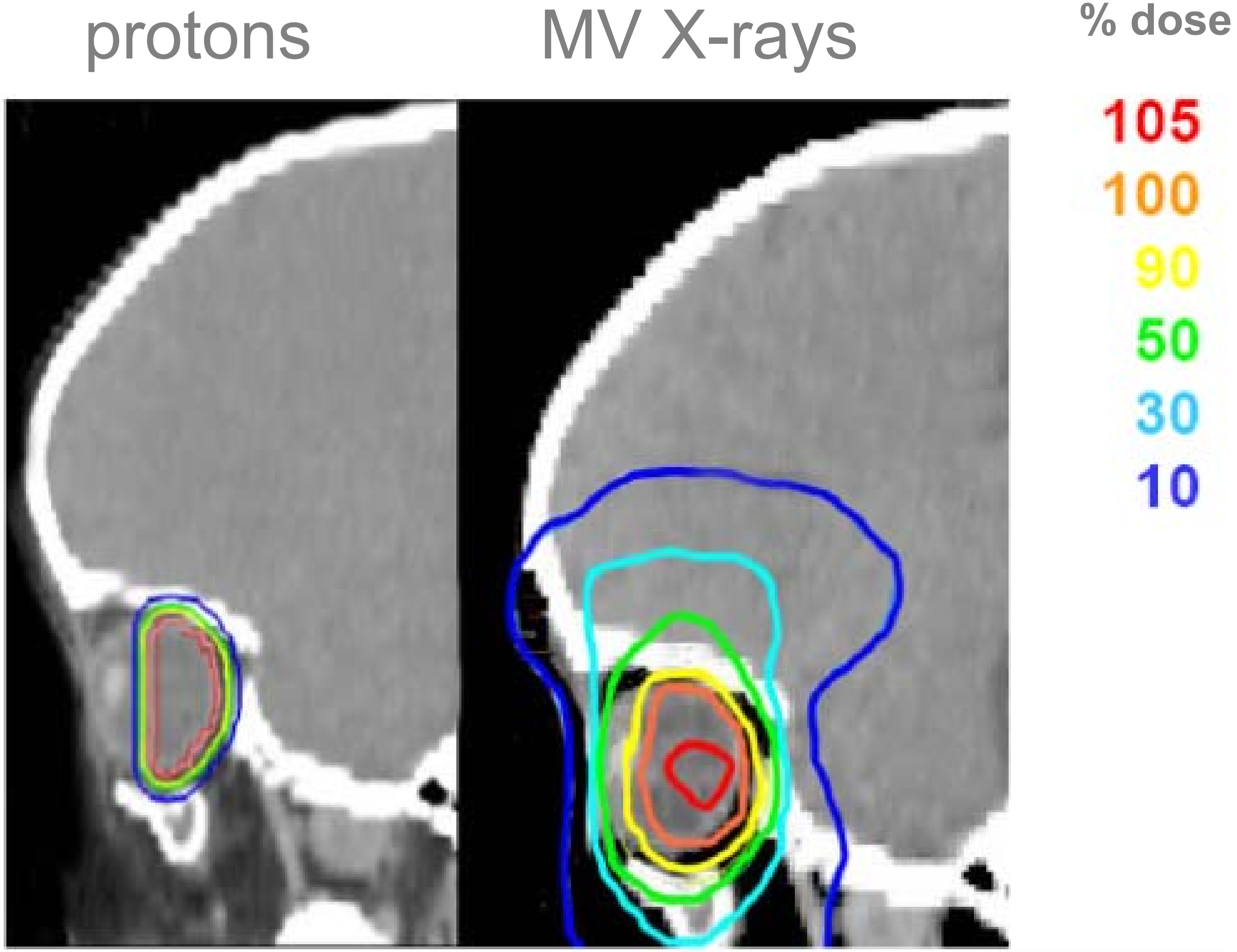
Range	**0 – 320 mm**
Dose rate	**1 Gy/min – 1 Gy/s**
Distall fall-off	**1 mm– few mm**
Penumbra	**1 mm – few mm**
Beam uniformity	**2-3 %**



J. Swakoń, 2010

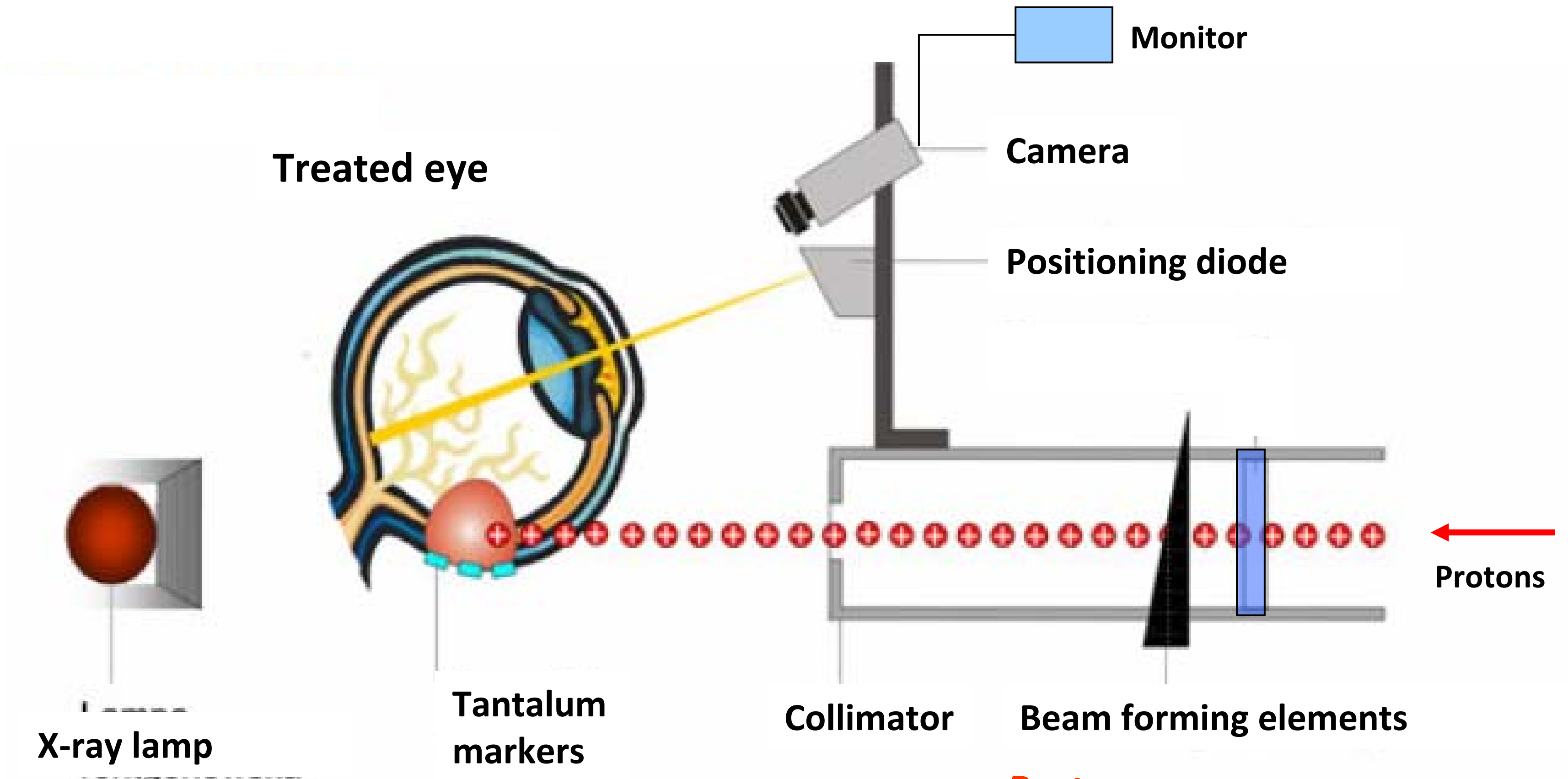
Ions versus photons

Better isodoses



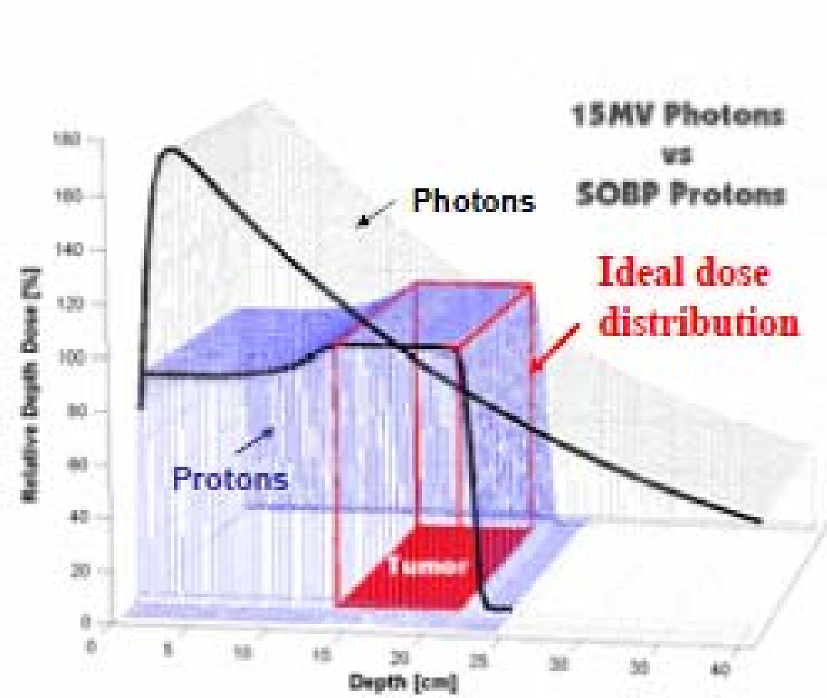
Proton Irradiation of Eye Cancer

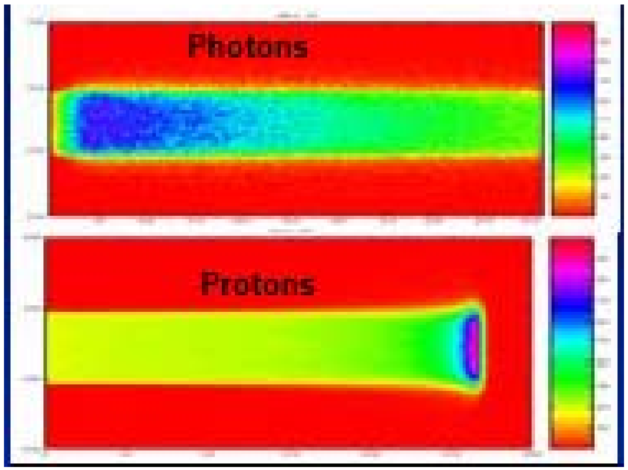
Simplified scheme of proton ocular radiotherapy facility



Protons:
Well defined range
decreased distal dose
Lower entrance dose
Limited beam scattering

Proton Radiotherapy Advantages





Precise localization of dose distribution at target
Rapid distal fall-off – advantageous for critical organs
Decreased entrance (proximal) dose
– Increased numbers od recoveries (increased local control of tumors)
– Decreased numbers of the radiation side effects
– Quality of life improved