Cyclotron Centre in Poland and 2D thermoluminescence dosimetry

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PRESENTATION PLAN

Two chapters

Cyclotron facility

- Institute of Nuclear Physics
- Existing facility
- Incoming CCB facility
- Status of CCB project

2D dosimetry system

- Thermoluminescence
- 2D thermoluminescence dosimetry system (2D TLD)
  - elements
  - properties
  - Applications
KRAKÓW – PRAGUE

walking: 440 km
by car: 540 km
Institute of Nuclear Physics in Kraków

- Est. 1960
- Area 8 ha
- ~500 res.
  - 41 full prof.
  - 30 ass. prof.
  - 147 PhD
  - ~100 stud.
- 5 divisions

The best institute now in Poland (A+ note from MSHE)
IFJ PAN - Main Research Equipment

2 x Proton Cyclotrons

Van de Graaff Accelerator

X-ray microprobe

source of thermal neutrons

Two-beam ion implanter

The 14 MeV Pulsed Neutron Generator

Stands for calibration (Cs-137 source)

Prof. Agnieszka Zalewska elected President of CERN Council
Institute of Nuclear Physics in Kraków
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Existing cyclotron facility
EXISTING CYCLOTRON FACILITY

Cyclotron AIC-144 (~60 MeV protons)

- 25 patients till June 2012
- Financed by NFZ

Eye treatment room

- Regular treatment from April 2013
Established in Sep. 2006

- Institute of Nuclear Physics – coordinator
- University of Science and Technology
- Warsaw University of Technology
- University of Silesia
- Universitas Varsoviensis
- Medical University, Warszawa,
- Center of Oncology, Warszawa
- Center of Oncology, Kraków
- Holycross Center of Oncology, Kielce
- Institute of Nuclear Problems, Warszawa
National Centre of Hadron Radiotherapy

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contract for Bronowice Cyclotron Centre

contract for gantry

June 2009
December 2010

\(~50 \text{ M€}\)
Bronowice Cyclotron Centre - Kraków

Foundation act signing ceremony 17.03.2011

Prof. dr hab. Marek Jeżabek

Prof. dr hab. Paweł Olko

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
first beam in the gantry 09.2013
first gantry ready 06.2014
second gantry ready 09.2015
Bronowice Cyclotron Centre

March 2011
Bronowice Cyclotron Centre

March 2011

May 2012
CCB – MAIN BUILDING PLAN

- Eye treatment room
- Beam lines
- Energy selector
- Experimental room
- Gantry
- 230 MeV cyclotron
- Medical Part
- Laboratories
CCB – cyclotron

Cyclotron Proteus C-235

- IBA, Belgium
- diameter 4.34 m / 2.1 m
- magnet 3.1 T - scanning

- Particle: protons
- energy 70-230 MeV
- $6 \cdot 10^8 - 4 \cdot 10^{12}$ part/s
- FWHM 3-9 mm (scanning gantry)
**CCB – ENERGY SELECTOR**

- energy range 70-230 MeV
- switching time < 1s for 10MeV
- $\Delta p/p < 1\%$

Beryllium absorber
CCB – PROTON GANTRY
The proton beam will be shared between 4 lines:

1) Experimental room – main user from Jan. 2013
2) Eye therapy room – tests of the new eyeline 2013-2014
3) Gantry 1 and 2 – start of acceptance tests May 2013

Starting in October 2015
From September 2013 to June 2014 the priority to the gantry
~200 patients/gantry
~100 eye melanoma patients

Full operation in 2020
About 600 – 800 patients/year
about 18 500 fractions/year
Different tools for beam QA

- Radiographic films
- Gafchromic® films
- 2-D arrays of ionization chambers
- Flat-panel detectors
- 2D TLD
- Scintillator + camera
- multi-wire proportional chamber
- Single/multi photodiodes
TL PHENOMENA

Thermoluminescence is an emission of light by certain materials during heating after previous irradiation.

Amount of light $\propto$ absorbed dose
The principle of 2D TL Dosimetry

Preparation of foil

Irradiation

Heating

Collection of emitted light

Data analysis
**Dosimetric system – TLD foils**

TL foil = TL powder + polymer + heat

1. The mixture needs to be uniformly distributed.

2. The detector is formed in a press.

3. The mixture is welded at high temperature.

Dr Mariusz Kłosowski
Dosimetric system – TLD foils

Two types of TL:
- LiF:Mg,Cu,P (MCP-2D)
- CaSO$_4$:Dy

- Water resistance and flexibility
- Up to 20 x 20 cm$^2$
- Reusability
- Relative WER: 1.6 (d=0.3-0.4 mm)
- Linearity of dose response: 0.05-20 Gy

Z$_{\text{eff}}$

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<th>MPC-2D</th>
<th>CaSO$_4$</th>
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<td>Z$_{\text{eff}}$</td>
<td>8.1</td>
<td>13.4</td>
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Dosimetric system – hardware

Laboratory Reader:
- detector size 50 x 50 mm²
- resolution 640 x 480 px²
- fully adjustable

Clinical Reader:
- detector size 200 x 200 mm²
- resolution 1024 x 1024 px²
- easy and safe to use
- pixel size below 0.2 mm
Dosimetric properties – uniformity

After corrections the uniformity of readouts is around 3%
DOSIMETRIC PROPERTIES – REPRODUCIBILITY

More than 20 equivalent irradiations and readouts

Repeatability was found below 3%

For previous reader and software it was 5%

For radiochromic films it is 1-6%

Amount of light $\propto$ absorbed dose

**Energy/LET dependence**

Higher LET – lower efficiency

Good agreement with other experiments

**Scanning Beam QA – Single Spots**

- **Positions** agree in <1% (~0.3mm)
- **Shapes** the same in ~10%

**Reference methods:**
- Fluka simulations
- Kodak® EDR2 films
- Multiwire Proportional Chamber

![Graphs showing spot images and profiles](image)
SCANNING BEAM QA – UNIFORM FIELDS

Uniformly irradiated fields = hundreds of spots

~2%

~5%
Irradiations have been performed with 60 MeV proton beam at IFJ PAN in Kraków (AIC-144 cyclotron)
The aim is to check the applicability of the 2-D system for measuring complicated radiation fields.

Microbeam Radiation Therapy (MRT) at European Synchrotron Radiation Facility (ESRF)

Peak-to-peak: 400 μm
FWHM: 50 μm
1 px ≈ 20x20 μm²

Peak-to-peak: 400 μm
The goal is to prepare the system to distinguish between static and dynamic exposure.
APPLICATIONS – STATIC/DYNAMIC EXPOSURE

New reader with CCD camera

- Linear heating rate up to 25 °C/s
- Linear dose response from 1 mGy
- Resolution 100 LP/mm
- No geometric distortion
- No vignetting effect

The system tested by clients of Personal Dosimetry Laboratory
Advantages of 2-D dosimetry:

- reusability
- water resistance and flexibility
- direct image readout
- spatial resolution (<0.5mm) adequate for clinical applications

Disadvantages:

- difficulties of obtaining uniform sensitive foils
- energy and LET dependencies
Thank You for Your attention