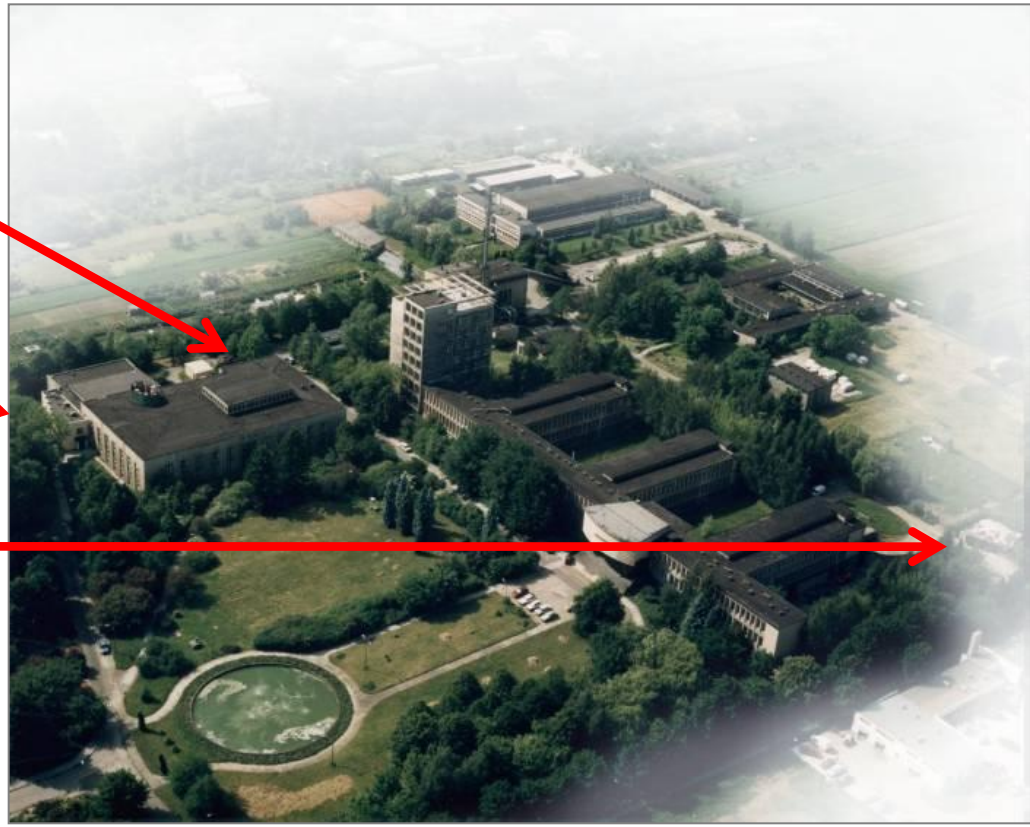
Hadron Radiotherapy in Poland – where are we going?

Paweł Olko and Marek Jeżabek

Institute of Nuclear Physics (IFJ PAN), Kraków, POLAND

Outline

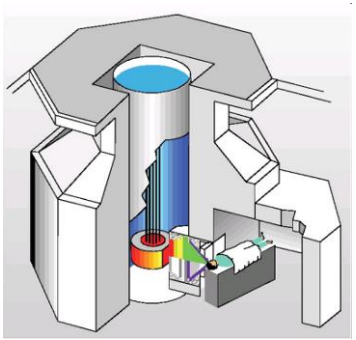
1. Fast neutron radiotherapy (1978 – 1995) on U-120
2. Proton radiotherapy of eye (2011) on AIC-144
3. Cyclotron Centre Bronowice at IFJ PAN with IBA Proteus cyclotron and gantry (2013)
4. Where are we going?



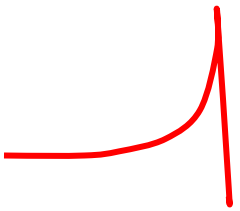
Premises of Institute of Nuclear Physics IFJ PAN Kraków

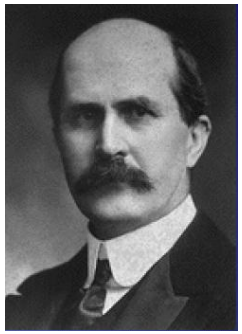
Hadron radiotherapy

- Neutron radiotherapy
  - Fast neutrons — 6-50 MeV
  - Boron Neutron Capture Therapy, BNCT — 0.025- 1 eV
- Ion radiotherapy
  - Proton radiotherapy — 60-250 MeV
  - Carbon ion radiotherapy — 250 - 400 MeV/amu



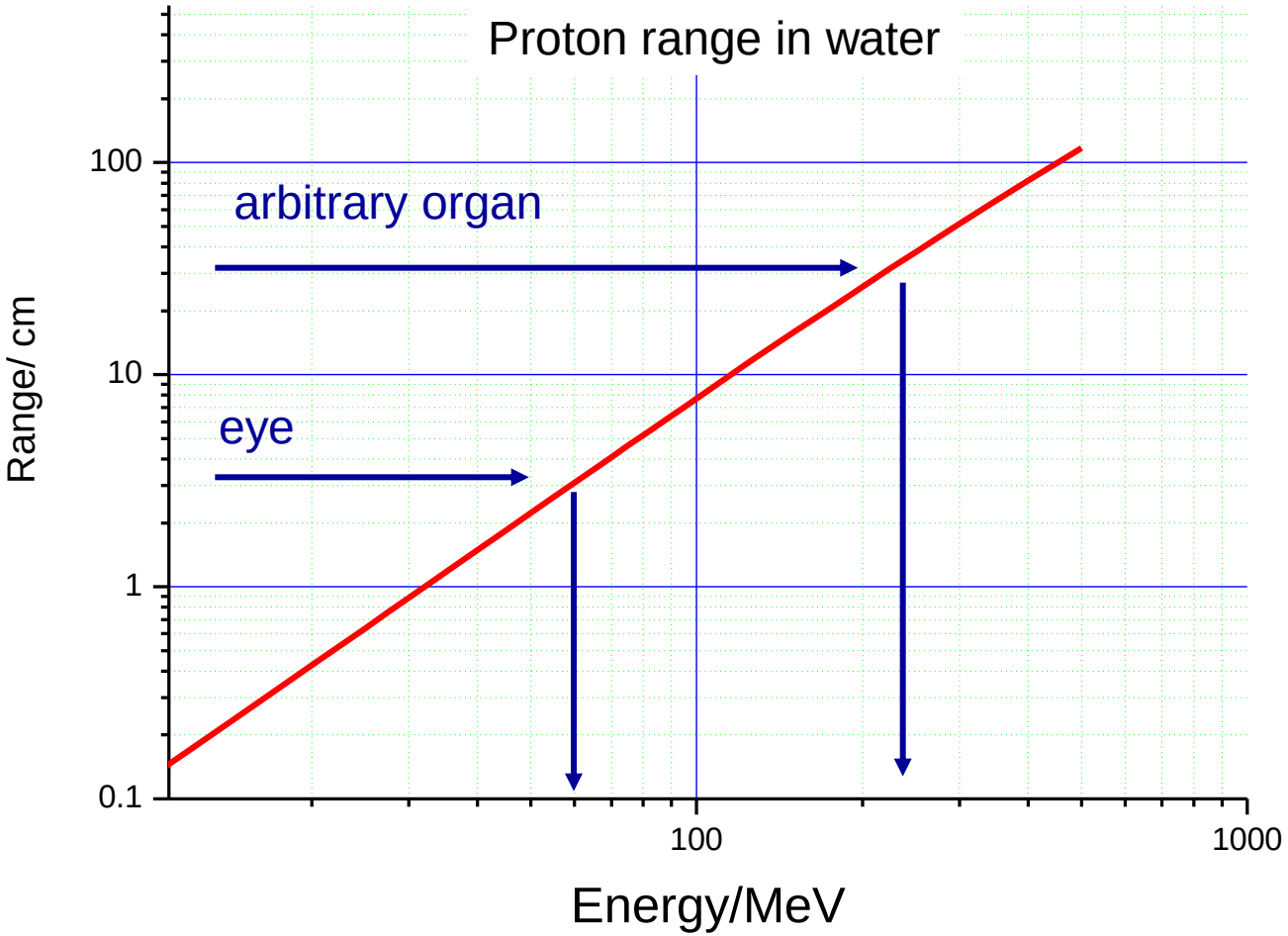
$^{10}B + n \rightarrow {}^{4}He + {}^{7}Li$





William Henry Bragg (1862 – 1942) curve

Beam properties for ion radiotherapy



Accelerators currently used for ion radiotherapy

ACCELARATORS

- Cyclotrons
- Synchrotrons
- Synchrocyclotrons

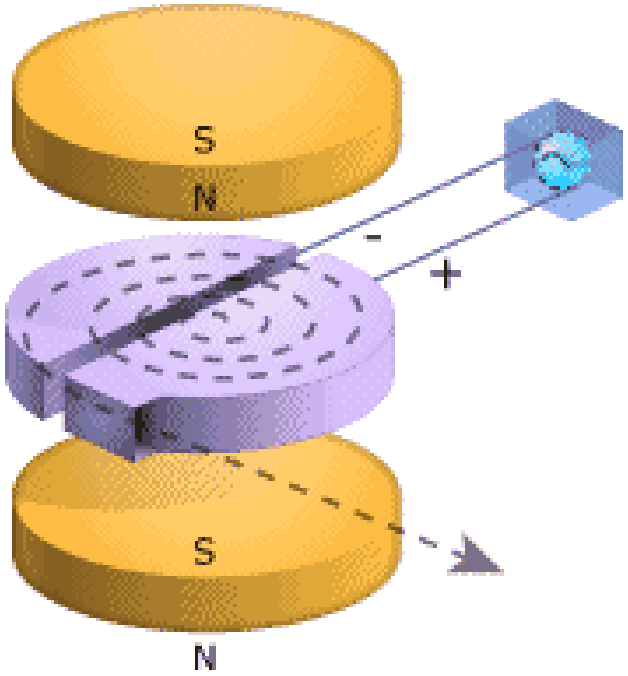
ENERGY

Protons : 60 - 250 MeV

Carbon ions: 150 - 400 MeV/amu

BEAM CURRENT

1- 500 nA



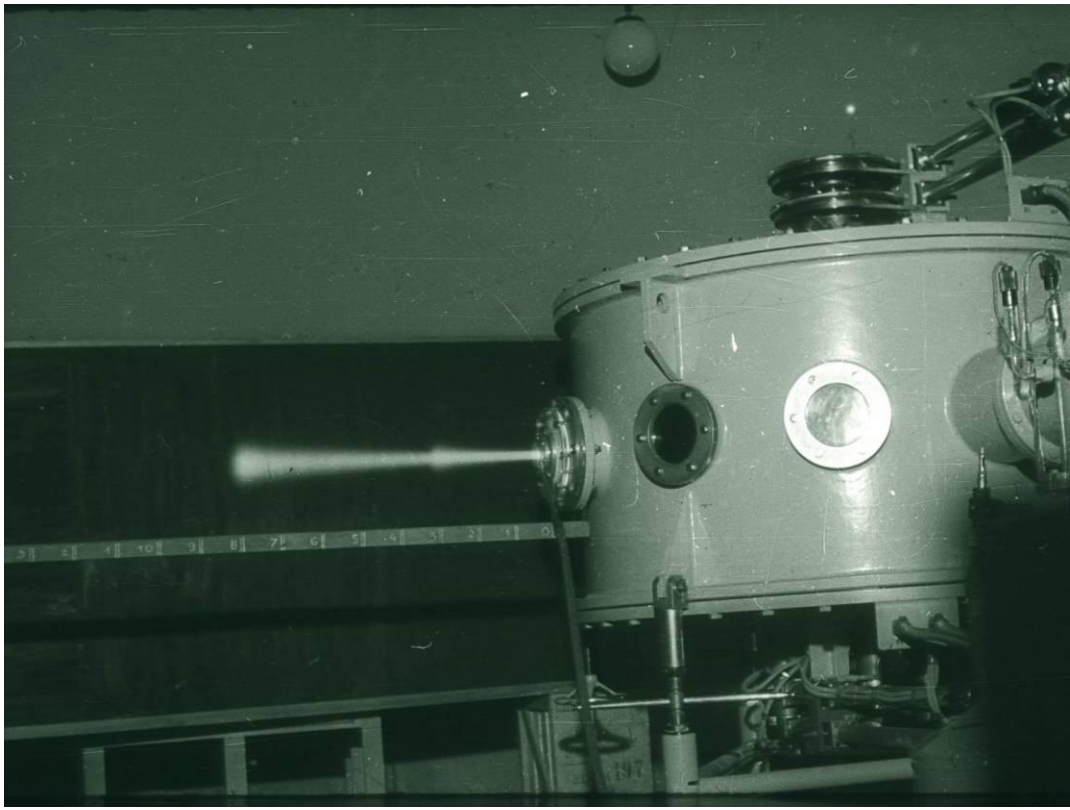
Cyclotrons at IFJ PAN

- first cyclotron in Poland developed, 48 cm (1955)

- classical cyclotron U-120 (opened 22.11.1958, stopped 1994)

-cyclotron isochrones AIC-144 (from 90's) 60 MeV protons

- Proteus C-235 – 230 MeV protons (start of operation Dec 2012)



U-120, 1958

Cyclotrons at IFJ PAN

- first cyclotron in Poland developed, 48 cm (1955)

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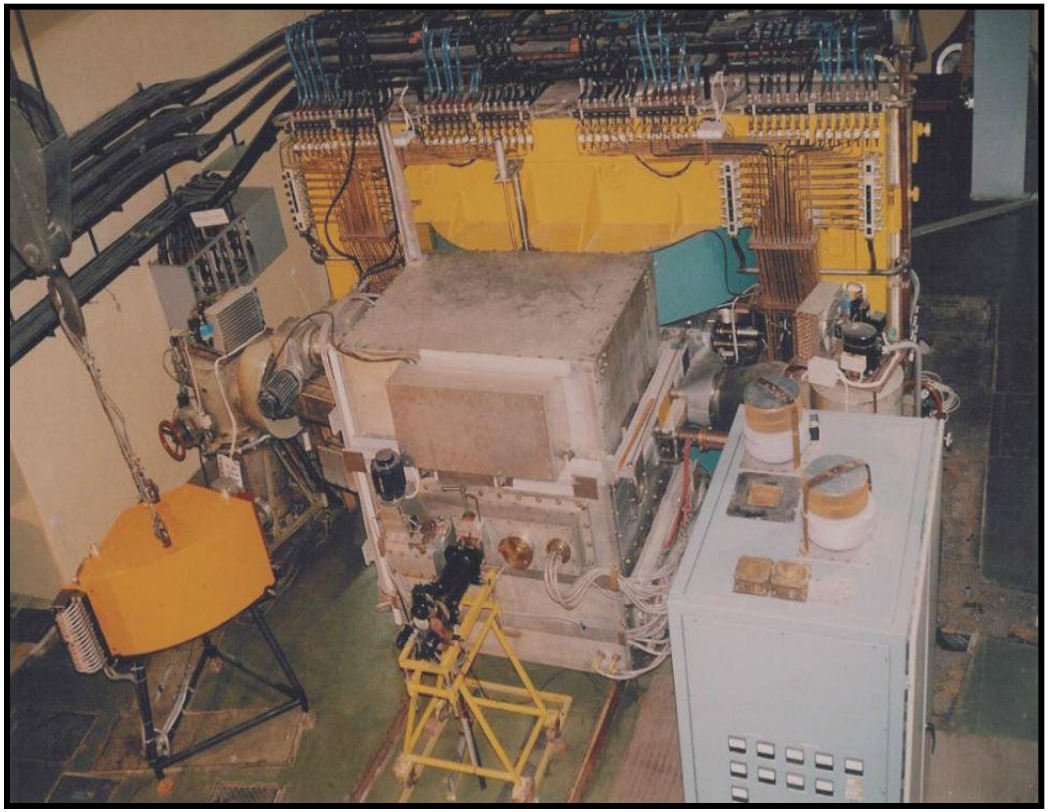


AIC -144, 1995

Cyclotrons at IFJ PAN

- first cyclotron in Poland developed, 48 cm (1955)

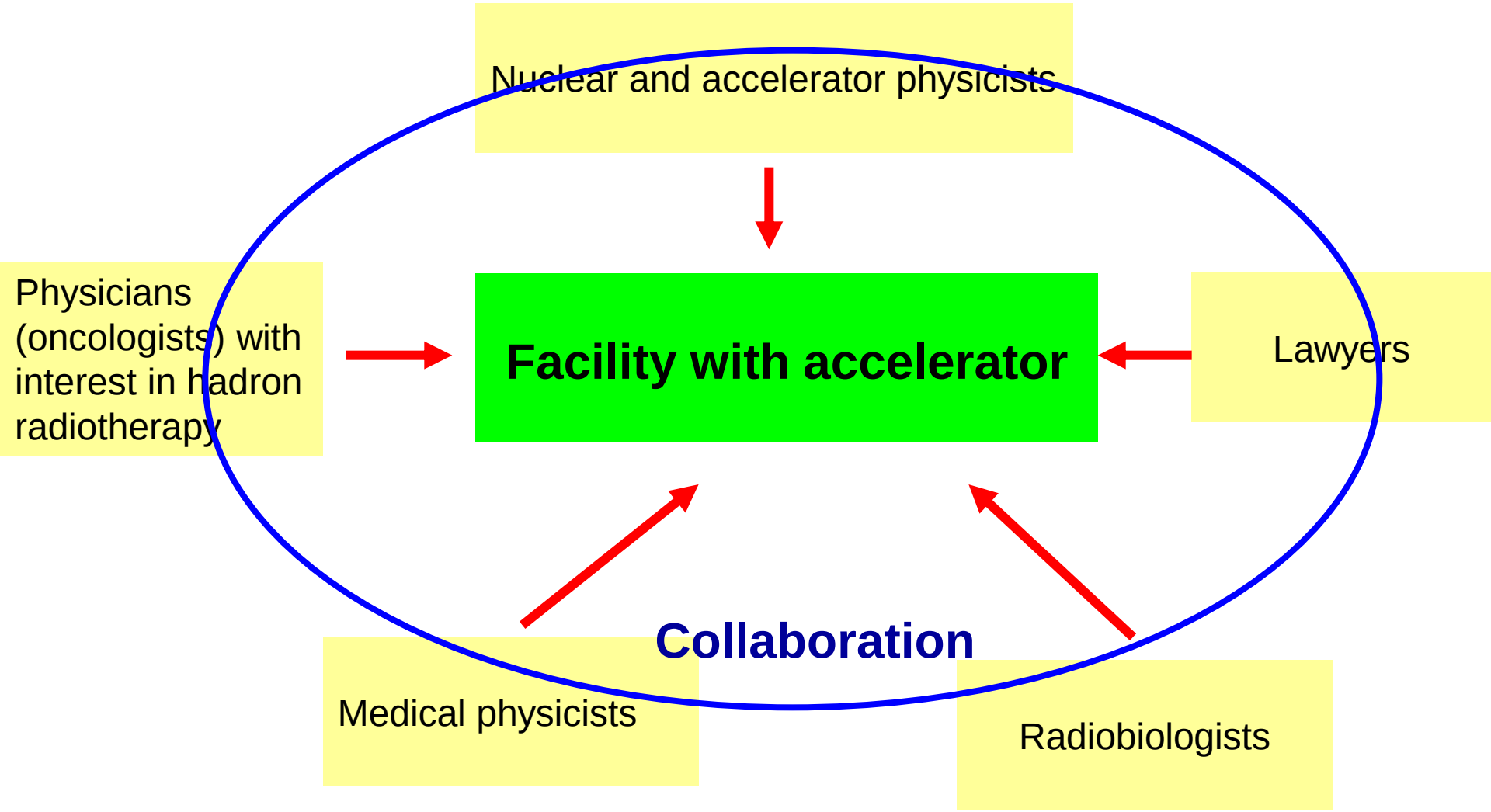
- classical cyclotron U-120 (opened 22.11.1958, stopped 1994)

-cyclotron isochrones AIC-144 (from 90's) 60 MeV protons

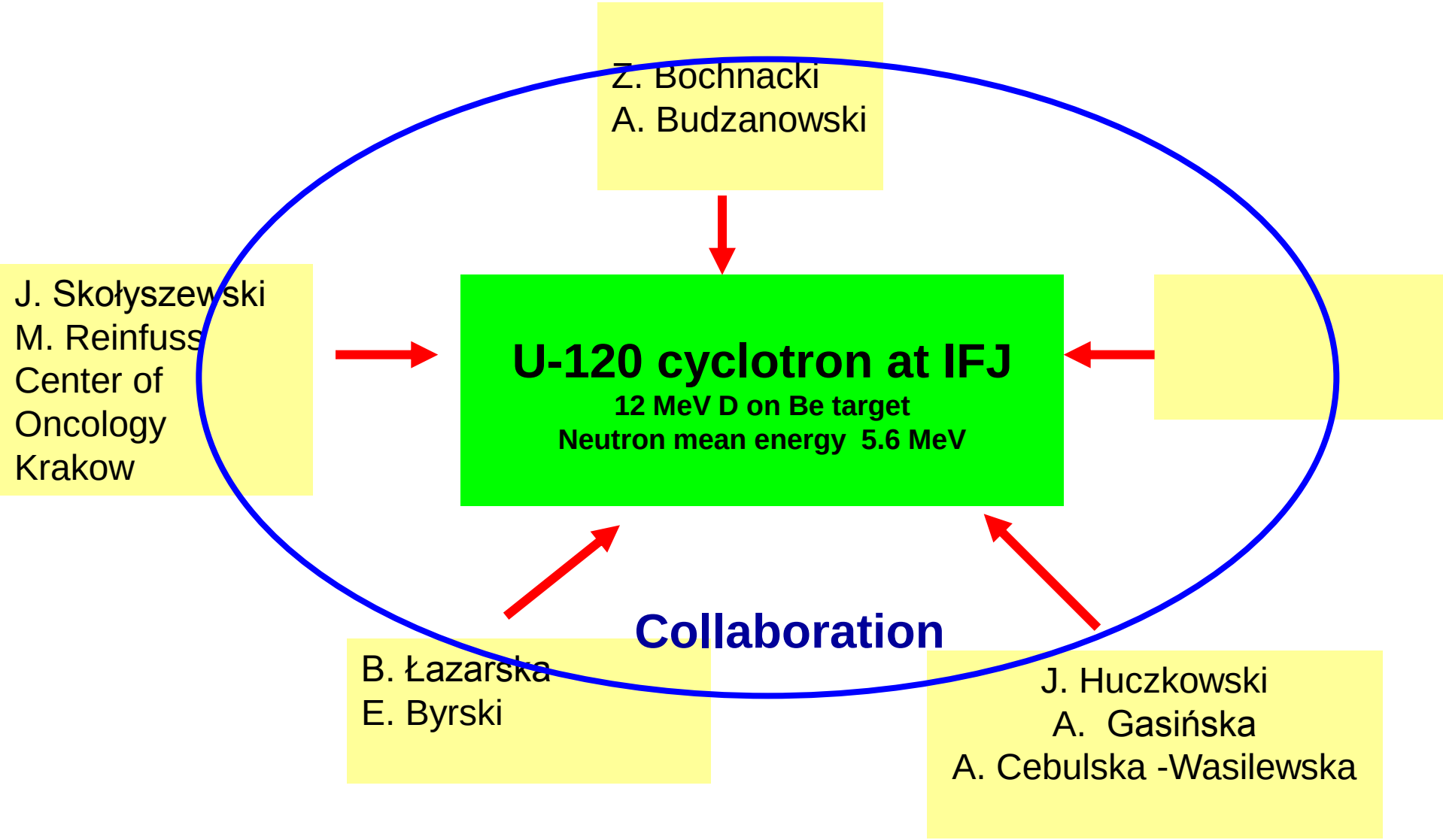
- Proteus C-235 – 230 MeV protons (start of operation Dec 2012)

Installed at IFJ PAN on May 11, 2012

What is needed to hadron radiotherapy?



Fast neutron radiotherapy in Kraków 1978 -1995



Fast Neutron Radiotherapy in Kraków 1978 - 1995

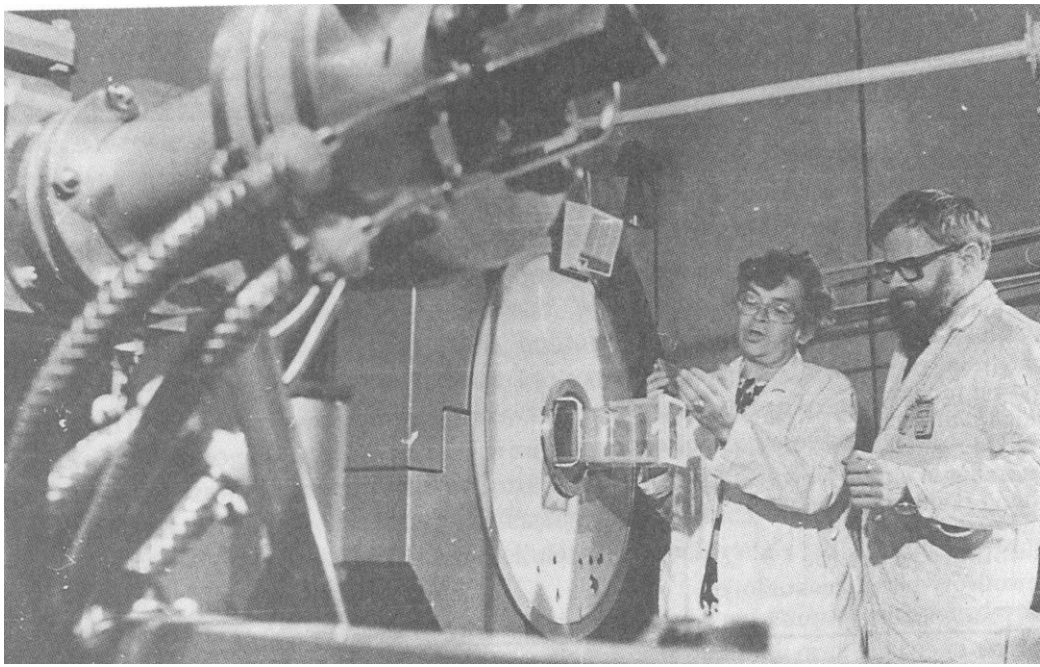
Facility at IFJ PAN

U-120 cyclotron

Treatment room developed at IFJ PAN workshop

Neutron beam:

- 5.6 MeV neutrons
- dose rate 0.12 Gy/min
- γ-rays contribution < 10%



Medical team: Centre of Oncology Kraków

Prof. Jan Skołyszewski

486 patients

- head and neck cancer
- salivary glands
- recurrences after mastectomy

First publication:

Skołyszewski J, Byrski E, Chrzanowska A, Gasińska A, Reinfuss M, Huczkowski J, Lazarska B, Michałowski A, Meder J.
A preliminary report on the clinical application of fast neutrons in Krakow.
Int J Radiat Oncol Biol Phys. 1982 Oct;8(10):1781-6.

Fast Neutron Radiotherapy in Kraków 1978 - 1995

Advanced head & neck cancer

	Dose ($Gy_{n,gamma}$)	Number of fractions	Number of patients
1978-86	13.2	20	114
1986-88	10-12	10	17
1988-90	10-13	5	87

2 years survival without cancer

	20F		5-10F		All	
	N	% surv.	N	% surv.	N	% surv.
salivery glands	6	33%	11	45%	17	41%
neck nodes	9	33%	48	21%	57	23%
others	99	13%	45	7%	144	11%
All	114	16%	104	17%	218	17%

J. Skołyszewski et all

Fast neutron radiotherapy at IFJ PAN was completed in 1995, after decommissioning of U-120 cyclotron

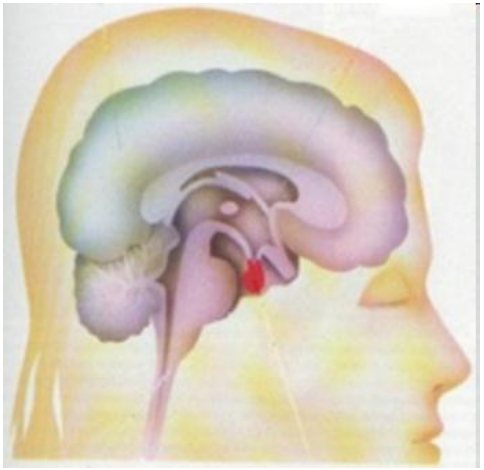
Boron Neutron Capture Radiotherapy, BNCT at NCBJ Świerk-Otwock ?

Boron Neutron Capture Therapy, (BNCT),

- boron compounds enriched in 10B, are introduced into the body and accumulated in cancer cells
- patient is irradiated with epithermal neutron beam;
- short range alpha particles and 7Li ions destroy tumor cells;
- the surrounding normal tissue, containing less boron, is not seriously affected.

N. Golnik, K. Pytel
Project started 2004, not continued

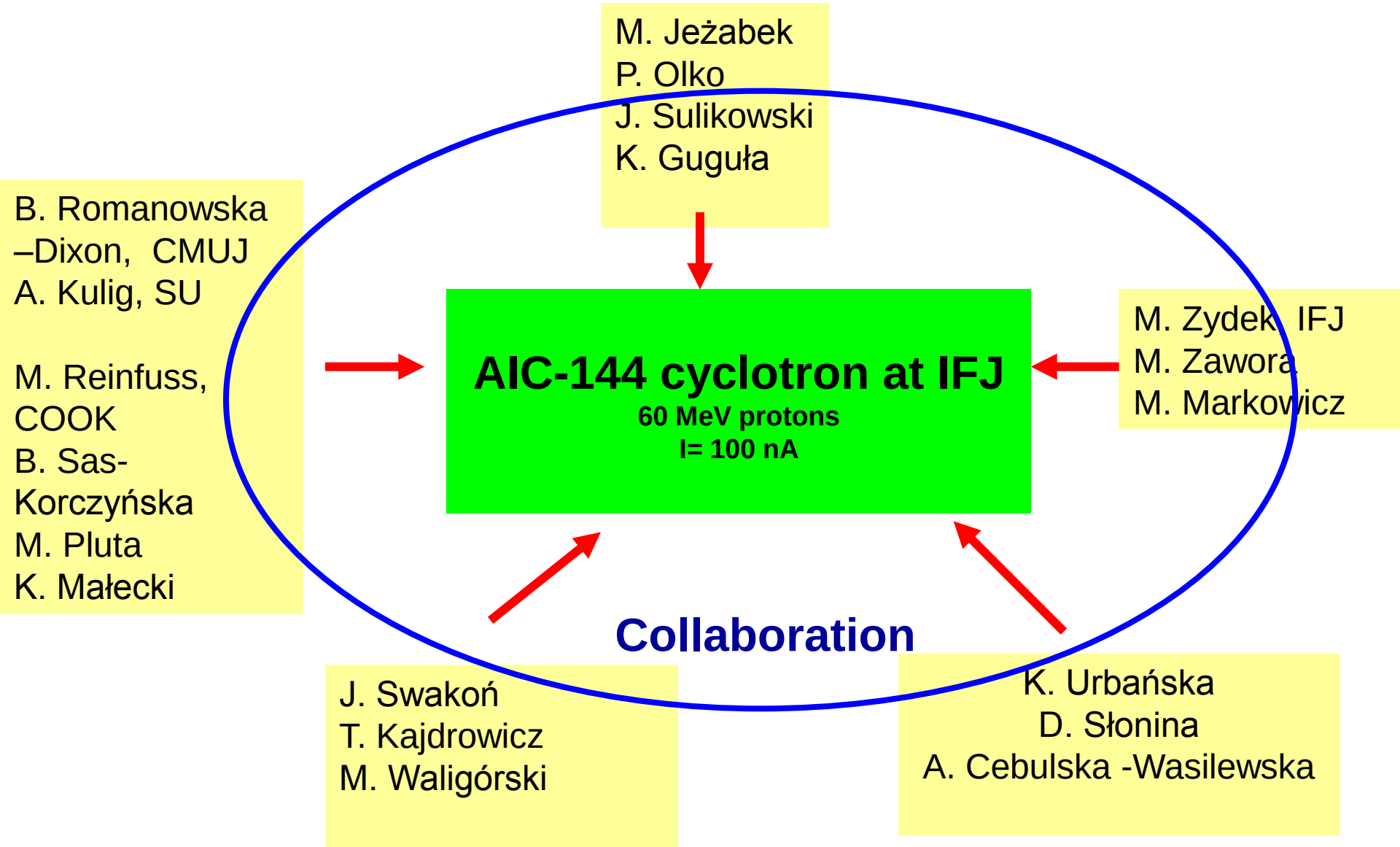
30 MW Maria reactor at Świerk



$^{10}B + n \rightarrow {}^{4}He + {}^{7}Li$

Proton radiotherapy of eye in Kraków

Proton radiotherapy of eye melanoma in Krakow



Proton radiotherapy of eye melanoma

Partners

Prof. Bozena Romanowska –Dixon, Clinic of Ophthalmology and Ophthalmic Oncology, Collegium Medicum UJ Krakow	**Chief of the clinic**
Dr. Jan Swakon IFJ PAN Kraków	**Chief of the Proton Radiotherapy Group**
Prof. Marian Reinfuss, Centre of Oncology, Kraków	**Director**

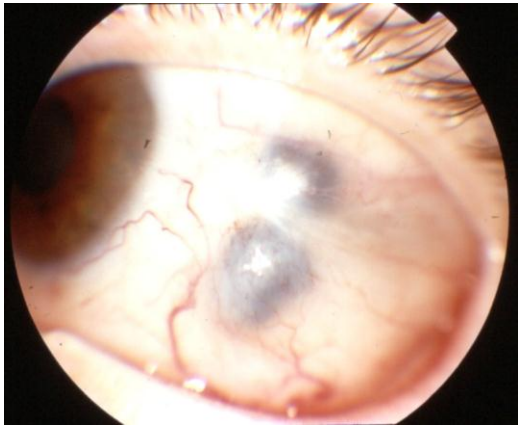
- **Clinic of Ophthalmology and Ophthalmic Oncology treats practically all ocular melanoma cases in Poland**
- **more than 250 new patients per year**
- **started in 1960's using Co-60 brachytherapy plaques**
- **currently: surgery, laser, Ru-106 and I-125 brachytherapy**

Proton radiotherapy of eye melanoma

Eye melanoma
- malignous cancer,
- growing inside the eye-ball
- mainly in white population
- approx. 250 new cases/year in PL

Proton radiotherapy of eye is considered as the most successful radiotherapy with survival > 90%

In Europe 7 centers:
- Berlin,
- Catania, INFN, I
- Orsay, Inst. Curie, F
- Nice, F
- Caterbridge, UK
- PSI Villigen, CH
- IFJ PAN Kraków, PL



Eye melanoma cancer

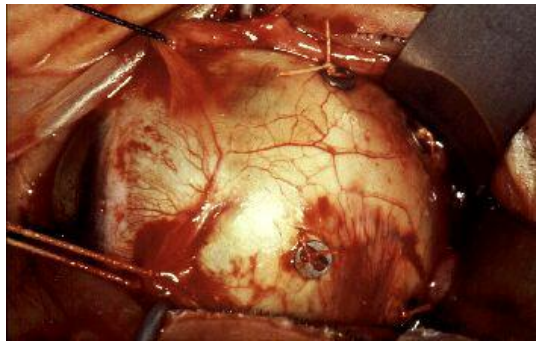
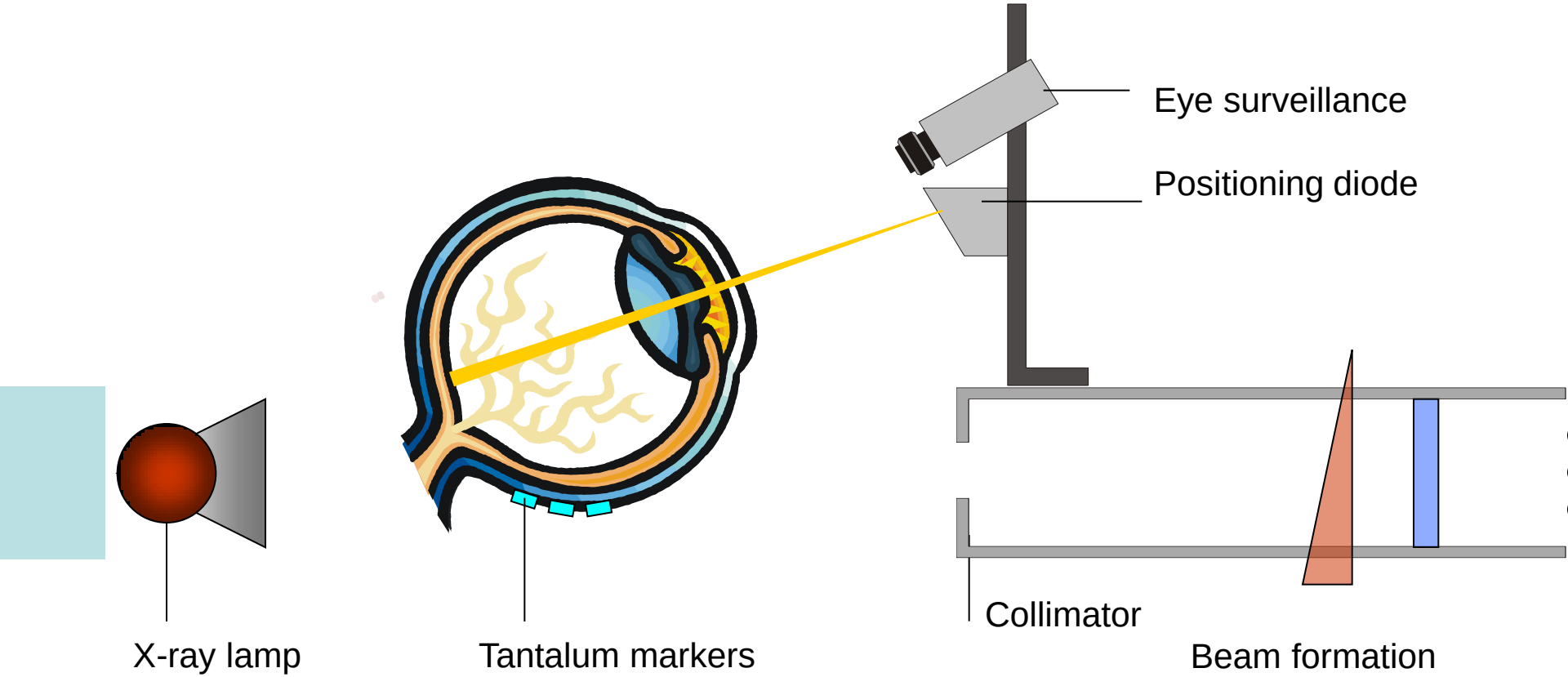


Fig from B. Romanowska-Dixon

Proton radiotherapy of eye melanoma

Principles of operation



Cancer irradiation

Proton radiotherapy of eye melanoma

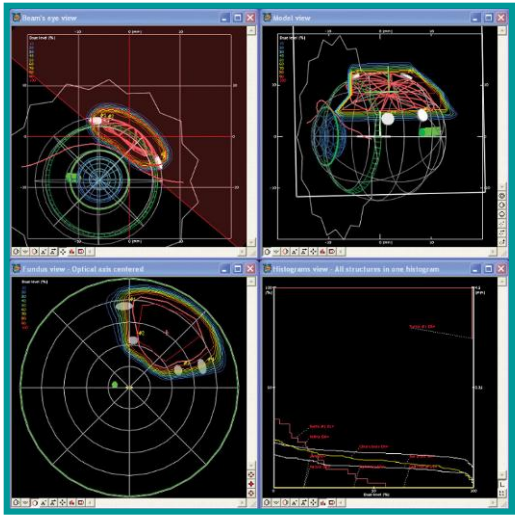
IFJ PAN treatment room

Therapy room developed at IFJ 2006-2009

Proton radiotherapy of eye melanoma

The procedure

1. Diagnosis, ultrasonography, MRI
2. Installation of the tantalum markers (surgery)
3. Therapy plan with Eclipse Ocular
4. Patient positioning (Monday)
5. Radiotherapy (Tu-Fr, 4 x 15 Gy)



Proton radiotherapy of eye melanoma
First patient: February 2011

Cyclotron: AIC-144 at IFJ PAN

Beam: 60 MeV protons

Patients: 15 patients till March 2012

Waiting for financing from the National Health System

The regular patient treatment expected from January 2013

The first patient treated at IFJ PAN facility

National Centre for Hadron Radiotherapy
NCRH

Poland in European Union

Poland joined European Union on May 1, 2004

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

1.3 billion € for infrastructure in science and technology

Consortium of the National Centre of Hadron Radiotherapy NCRH

Signed Sept. 2006

Akademia Górniczo-Hutnicza,

Centrum Onkologii – Oddział w Warszawie,

Centrum Onkologii - Oddział w Krakowie,

Świętokrzyski Ośrodek Onkologii,

Centrum Onkologii Gliwice,

Instytut Problemów Jądrowych,

Politechnika Warszawska ,

Uniwersytet Śląski,

Uniwersytet Jagielloński,

Uniwersytet Warszawski

Warszawski Uniwersytet Medyczny

Goals of the National Centre of Hadron Radiotherapy, NCRH

Development of infrastructure for ion radiotherapy and using it for research and patient treatment

Two phases of the NCRH project:

Phase I: proton cyclotron 230-250 MeV + gantry for IFJ PAN Krakow, research, treatment and training (Bronowice Cyclotron Centre, CCB)

Phase II: Construction in Warsaw the dedicated clinical centre with proton and ^{12}C beam (2 gantries + horizontal beam)

Funding available for Phase I NCRH- CCB project at IFJ PAN

Operational Programme Innovative Economy

June 2009 **Contract with Ministry of Science for construction of NCRH – Centrum Cyklotronowe Bronowice 117 mln zł (building, cyclotron)**

December 2010 **Contract with Ministry of Science for construction of medical building and the gantry (79 mln zł)**

INNOWACYJNA GOSPODARKA
NARODOWA STRATEGIA SPÓJNOŚCI

Total funding about 45 M€

UNIA EUROPEJSKA
EUROPEJSKI FUNDUSZ
ROZWOJU REGIONALNEGO

National Centre of Hadron Radiotherapy, NCRH -CCB

Financing split into two parts:

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

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

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


3.03 2011 Just before the start …..
P. Olko, M. Jeżabek NCRH

First stone
17 March 2011

11 May 2012


11 May 2012
iba
Krakow – Proton Therapy Center

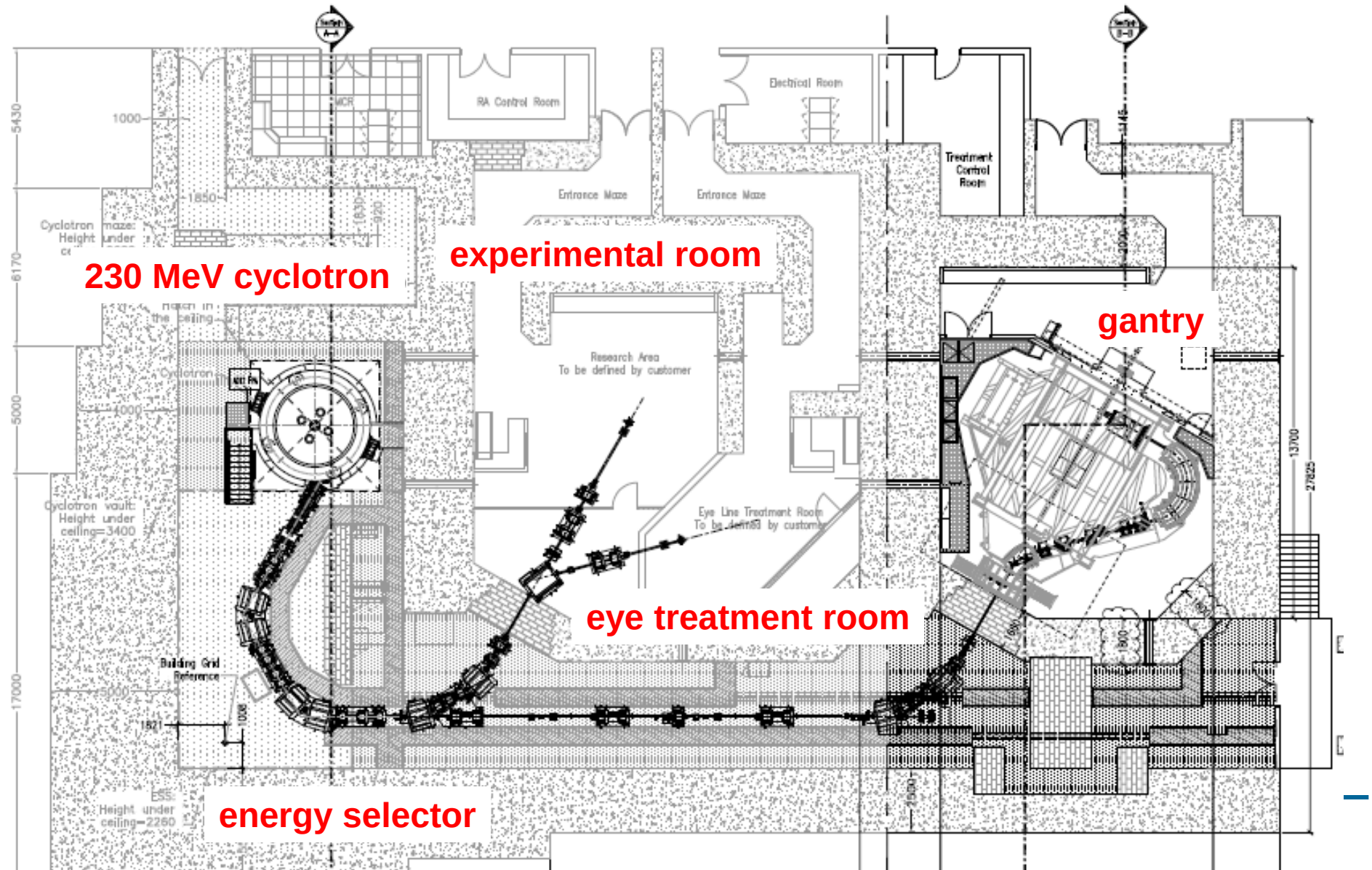
Timetable of NCRH – CCB

- 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

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

What is foreseen in NCRH – CCB?



What is foreseen in NCRH – CCB?
Proteus C-235 cyclotron with energy selector

Ion Beam Applications S.A. (IBA), Louvain-la-Neuve, Belgium

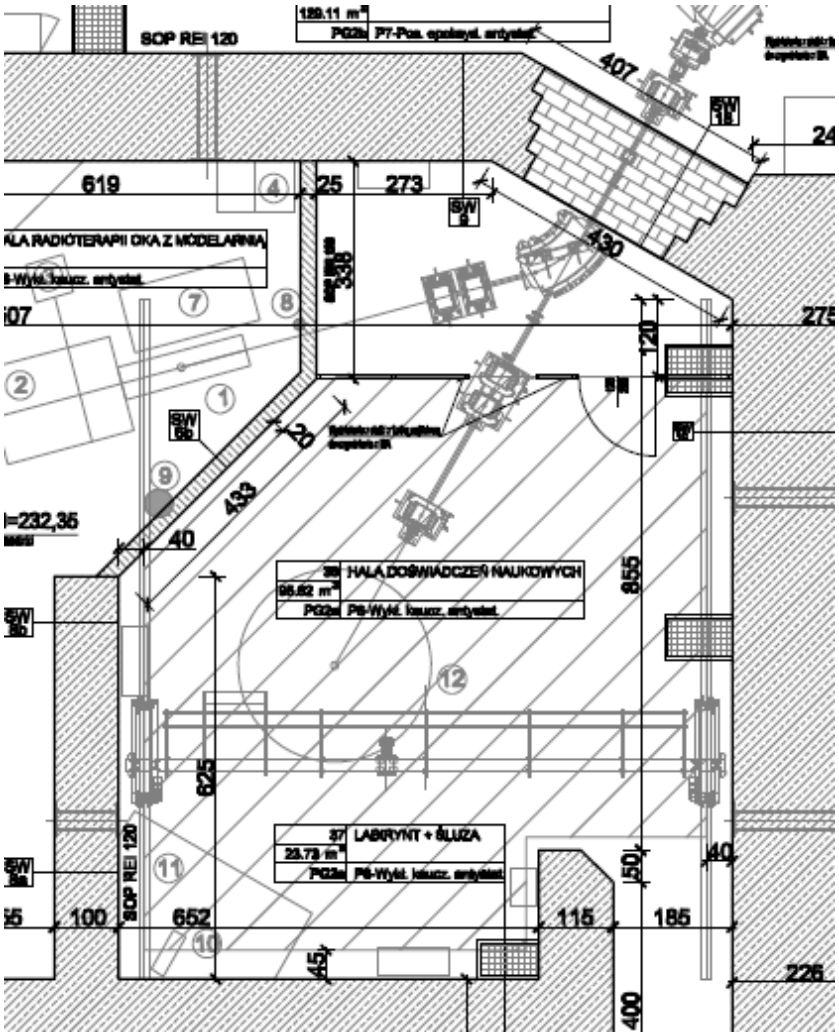
cyclotron:	isochronic, 4-sectors, CW
particles	protons
ion source:	P.I.G with hot cathode
proton energy:	230 MeV (β = 0.596, γ = 1.245), constant
energy dispersion:	$\Delta E/E$ < 0.7%
beam intensity:	**600 nA (4 x 10^{12} p/s) – 0.1 nA (6 x 10^{8} p/s)**
emmitance	horizontal - 11 π mm mrad,

cyclotron

energy selector:
70-230 MeV
$\Delta E/E$ < 1 %

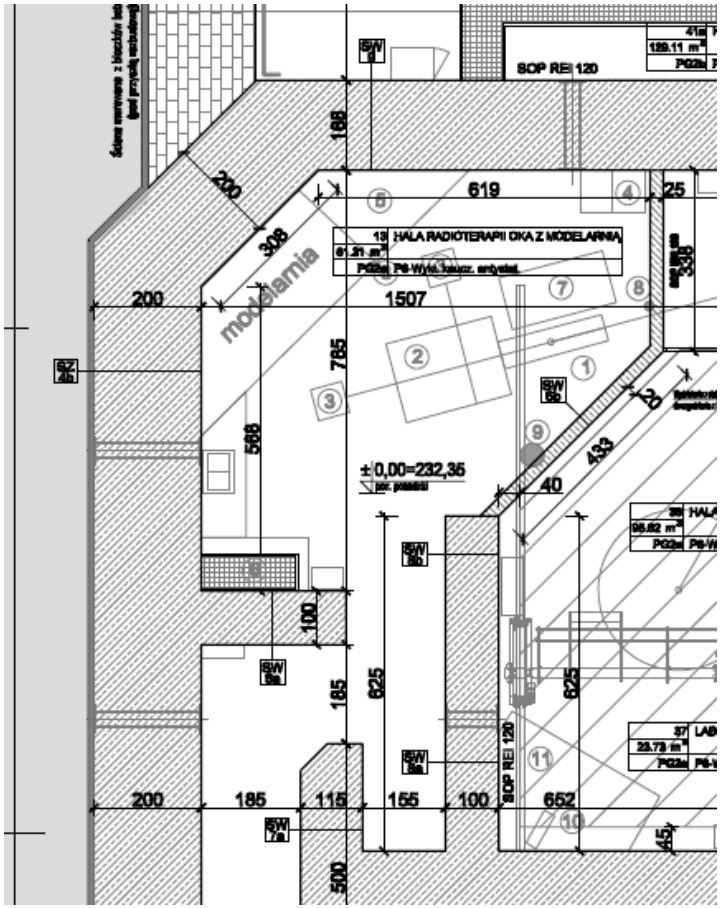
What is foreseen in NCRH – CCB?

Experimental room for nuclear physics nad radiobiology



Experimental room, completed in May 2012

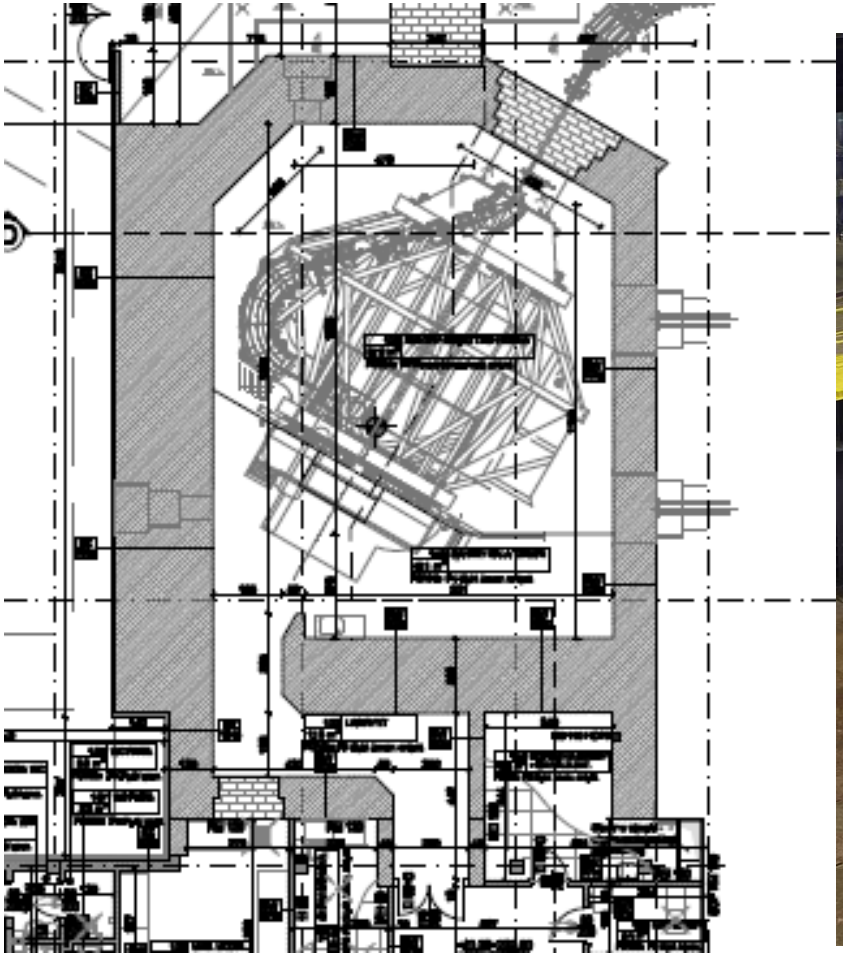
What is foreseen in NCRH – CCB?
Proton radiotherapy of eye



In preparation, completed till end of 2012

What is foreseen in NCRH – CCB?

Gantry with the scanning beam



In preparation, to be completed in 2014

What is foreseen in NCRH – CCB?
Gantry with the scanning beam

Applications

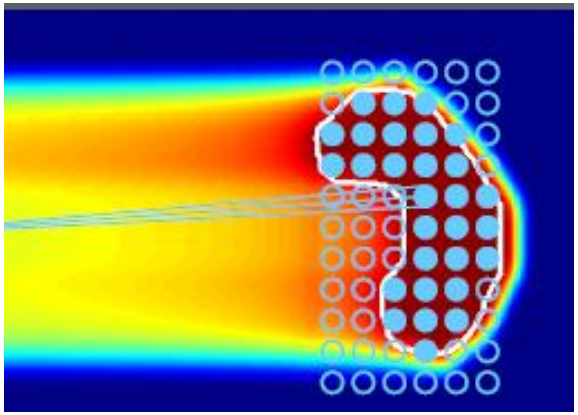
-Central Nervous System

- head and neck

- prostate

- children

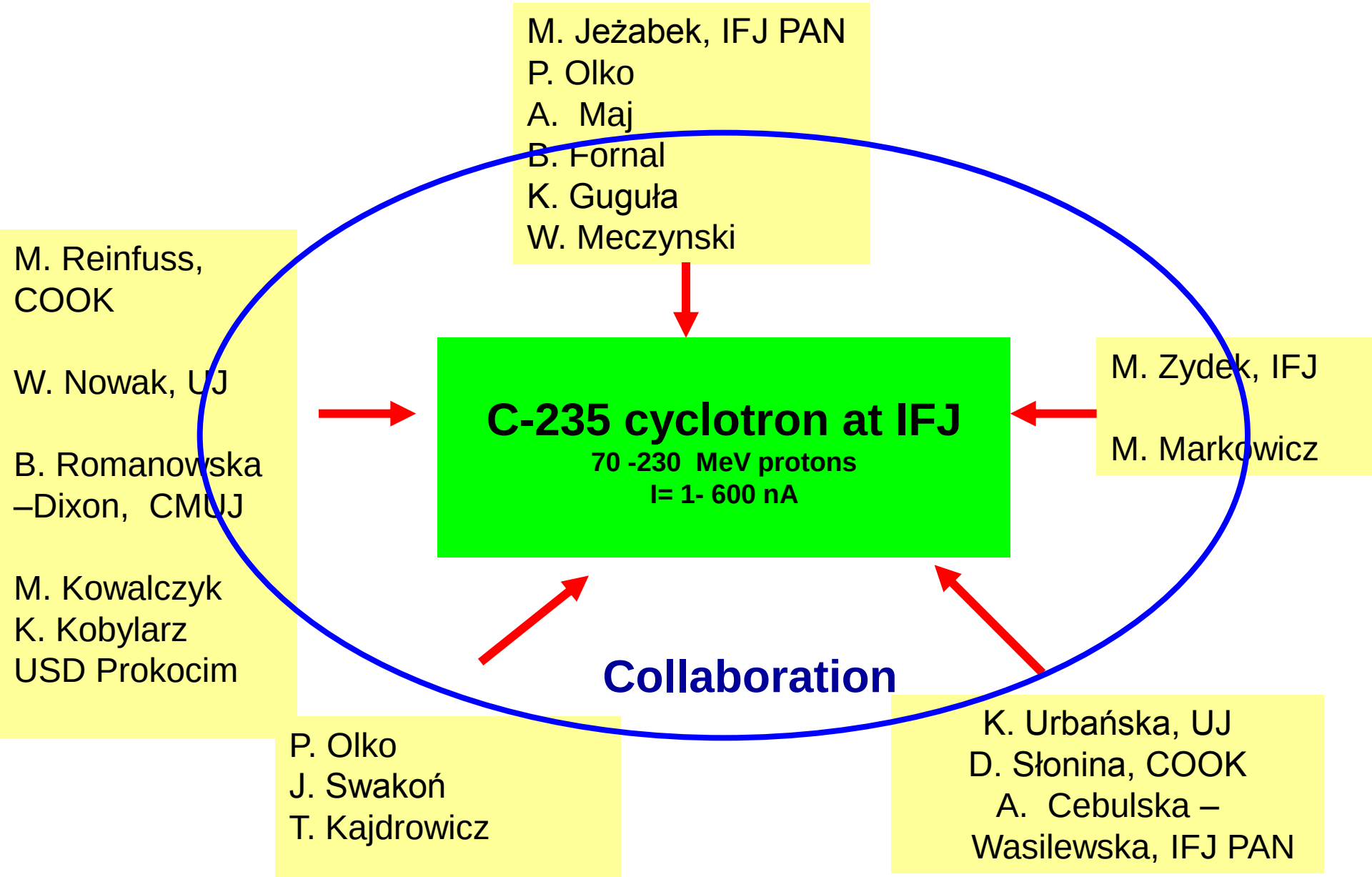
- others?



3 mm and 9 mm scanning beams will be available

Where are we going?

Proton radiotherapy and research at NCRH-CCH



Patient treatment at NCRH-CCB

1. **AIC-144 cyclotron**
   Regular eye melanoma proton radiotherapy starting from January, 2013 if financed by the National Health System (self-financing).
   - Team: University Hospital Krakow, Centre of Oncology, IFJ PAN
   - 50 to 100 patients per year

2. **C-235 cyclotron**
   - commissioning of scanning gantry in 2014
   - start the patient treatment from January 2015.
   - cooperation with COOK, SU, USD and others.
   - 100 - 400 patients per year
   - eye-melanoma treatment from January 2015
   - patient treatment should finance the facility

1. Radiobiology

2. Nuclear physics

3.Clinical research

4. Dosimetry

Radiobiology for treating cancer

- Is the RBE for scanning beam equal to RBE for scattered beam?
- Is for scanning beam the bystander effect observed?
- Is the higher RBE at the end of Spread Out Bragg peak clinically relevant?
- Probability of secondary cancer

Collaboration

- Centre of Onclogy Kraków
- Jagiellonian University
- IFJ PAN and others

Scientific programme of NCRH

1. Radiobiology

2. Nuclear physics

3.Clinical research

4. Dosimetry

Experimental Physics Case

- Dynamics of few-nucleon systems
- Particle and gamma decays of high-lying resonance states by inelastic scattering of 200 MeV protons
- Giant Dipole Resonances in hot nuclei
- Search for the Giant Pairing Vibrations
- Isomers populated in proton induced fission of ^{238}U

Collaboration

- Jagiellonian University, Kraków
- Warsaw University, Warszawa
- Silesian University, Katowice
- INFN and University of Milano (Italy)
- IPN Orsay (France)
- KVI Groningen (Netherlands)

Scientific programme of NCRH

1. Radiobiology

2. Nuclear physics

3.Clinical research

4. Dosimetry

1) Dynamics of few-nucleon systems
Stanisław Kistryn, Elżbieta Stephan, Adam Kozela
Nasser Kalantar-Nayestanaki, Indranil Mazumdar, Kimiko Sekiguchi et al.

2) Study of particle and gamma decays of high-lying resonance states by inelastic scattering of 200 MeV protons **Adam Maj, Silvia Leoni et al.**

3) Giant Dipole Resonances in hot nuclei studies using proton beams **M. Kmiecik, F. Camera et al.**

4) A possibility of using the NESSI detector at CCB and spallation reaction measurements with proton b eam of ~ 200 MeV energy **S. Kliczewski et al**.

5) Search for the Giant Pairing Vibrations **Bogdan Fornal et al.**

6) Studies of isomers populated in proton induced fission of 238U and other heavy targets **W. Królas, B. Fornal et al.**

7) Investigations of nuclear reactions relevant in cancer therapy **Andrzej Magiera, Achim Stahl et al.**

8) In beam tests at CCB of acceleration components for the EURISOL radioactive beam facility **P. Bednarczyk1, A. Facco2 et al.**

Scientific programme of NCRH

1. Radiobiology

2. Nuclear physics

3.Clinical research

4. Dosimetry

University Children Hospital, Kraków

Studies in pediatric oncology
- cancers of brain and the Central Nervous System
-head and neck

Centre of Oncology Kraków
-Proton boost

Clinic of Ophtalmology Krakow
-Ocular melanoma outside the eye globe

Scientific programme of NCRH

Calibration of cosmic –ray detectors for space dosimetry

1. Radiobiology

2. Nuclear physics

3.Clinical research

4. Dosimetry

99% of ions in cosmic-rays are protons

Phantom with TLDs from IFJ

Scientific programme of NCRH

Other hadrontherapy projects in Poland

Warsaw:
Leader: S. Nazarewski, vice-rector
Institution: Warsaw Medical University
Localization: Ochota Campus
Facility: ^{12}C + p + classical radiotherapy
Status: first proposals prepared


Koncepcja urbanistyczno-architektoniczna campusu „Ochota"

Poznan:
Leader: L. Malicki, director
Institution: Wielkopolskie Centre of Oncology
Localization: Campus Morasko
Facility: proton facility
Status: letter of intention signed, ground available, ready before 2020

Summary

1. **Proton radiotherapy of eye melanoma started in Krakow on AIC-144 cyclotron in February 2011.**

2. **The National Centre for Hadron Radiotherapy (Phase 1) will be completed in 6 months. 230 MeV IBA cyclotron will be used for research from Jan. 2013**

3. **The scanning proton gantry will be operational in 2014. Patient treatment at NCRH-CCB will start in January 2015.**

4. **Warsaw and Poznan want to build hadron radiotherapy centers.**