Proton Irradiation for Space Research at IFJ PAN Kraków

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Outline

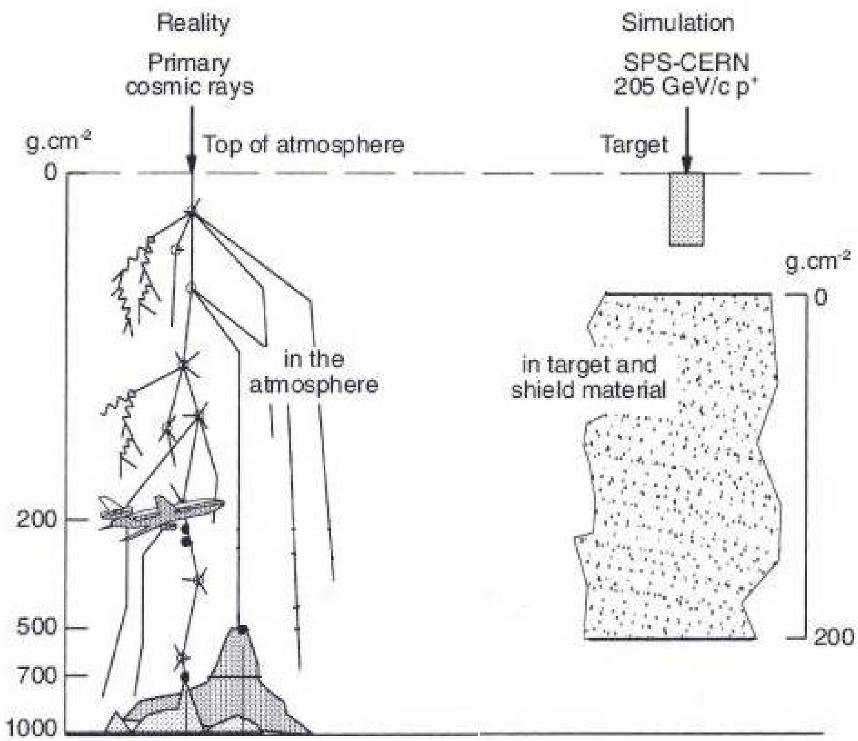
1. Calibration needs for space dosimetry

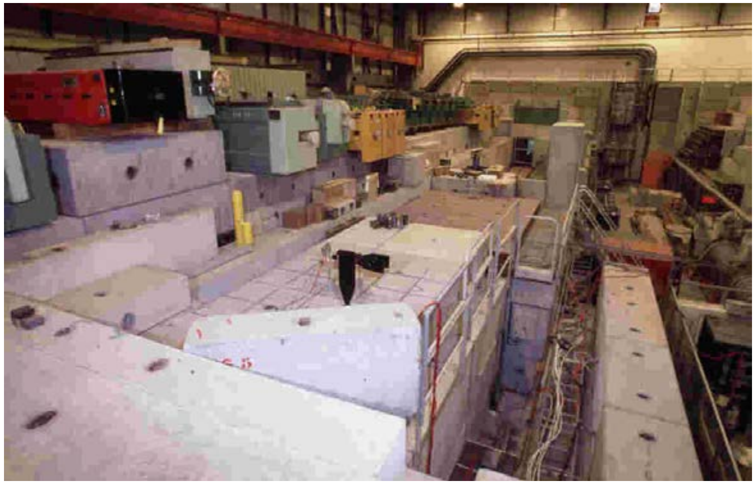
2. Photons at IFJ

3. Protons at IFJ
   2.5 MeV protons from Van de Graaff
   60 MeV from AIC-144 cyclotron
   70MeV - 230 MeV from C-235 cyclotron

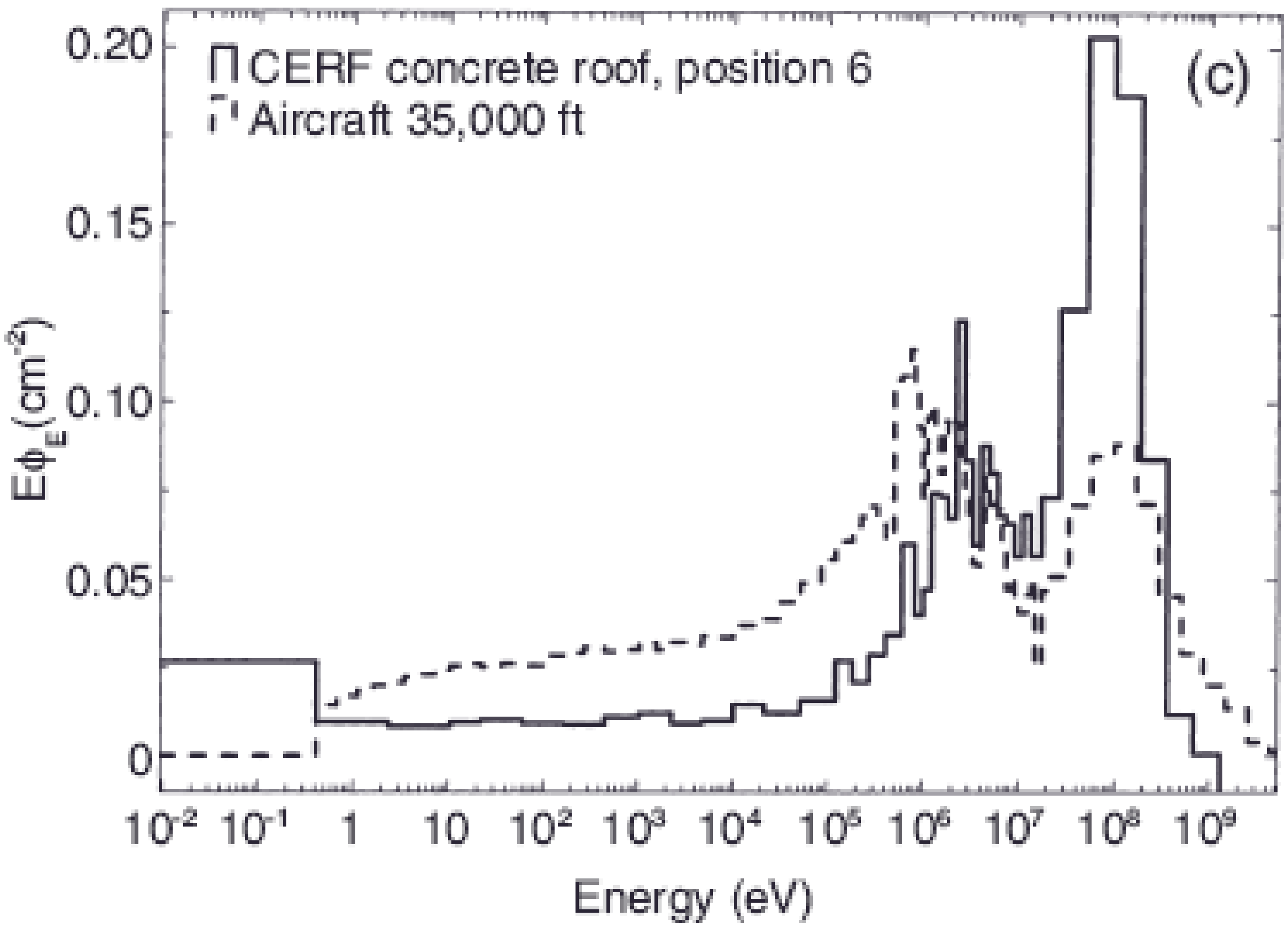
4. How to make irradiations at IFJ PAN?

CERF calibration field for aircrew dosimetry





CERF calibration field for aircrew dosimetry

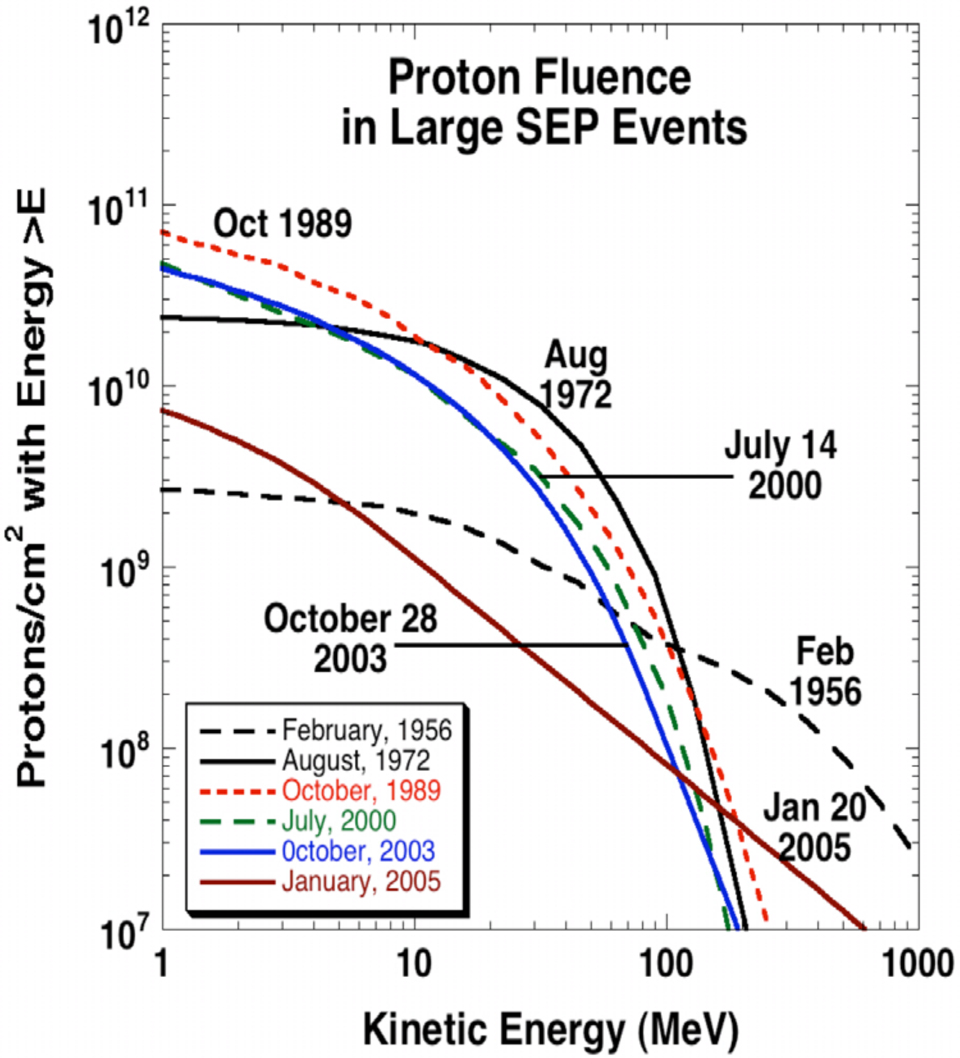


Calibration of space dosimeters

1. Primary and secondary fields complicated
   - protons + heavy ions
   - electrons
   - neutrons
   - gamma
   - others

2. There is no single one relevant calibration field for space dosimetry

3. No specific protocol



Calibration laboratory

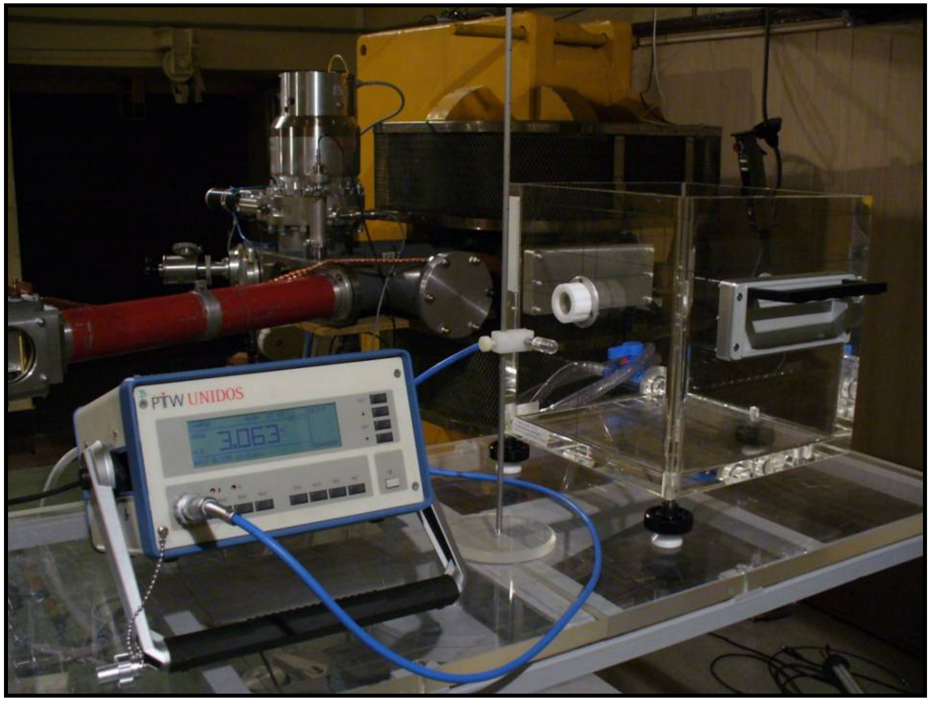
Cs-137 : 100 nGy/h – 1 Gy/h

Philips 300 kVp –X-rays ;
1 Gy/min

Traceability: Polish Main Office of Measurements

THERATRON 780E

^{60}Co γ-rays
Dose rate 0.5 -2 Gy/min
Traceability: Secondary Standard Laboratory, Centre of Oncology Warszawa (->IAEA)



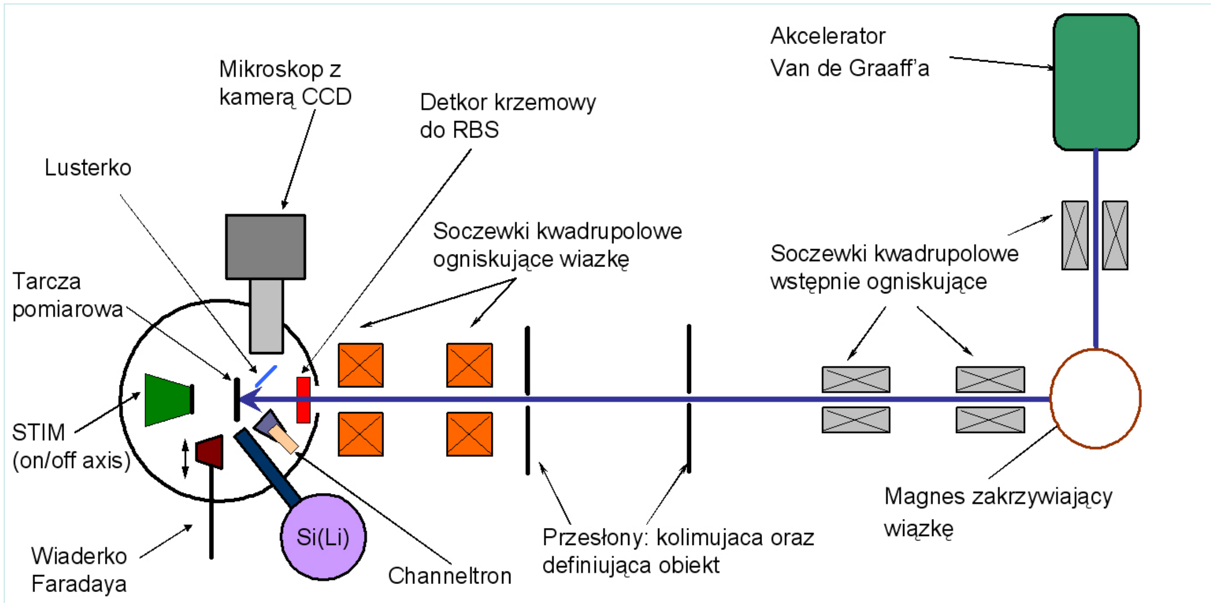
Van de Graaff accelarator

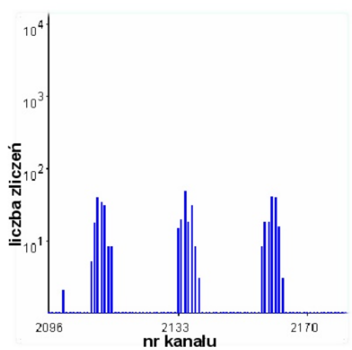
Beams: 2.5 MeV p

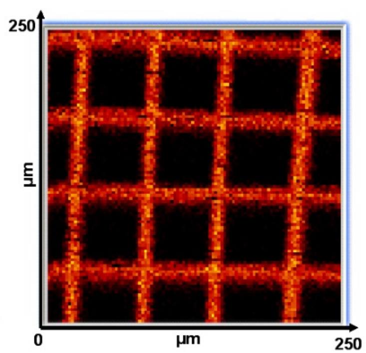
2 μm beam spot at 100 pA

Applications: μbeam, single proton irradiation

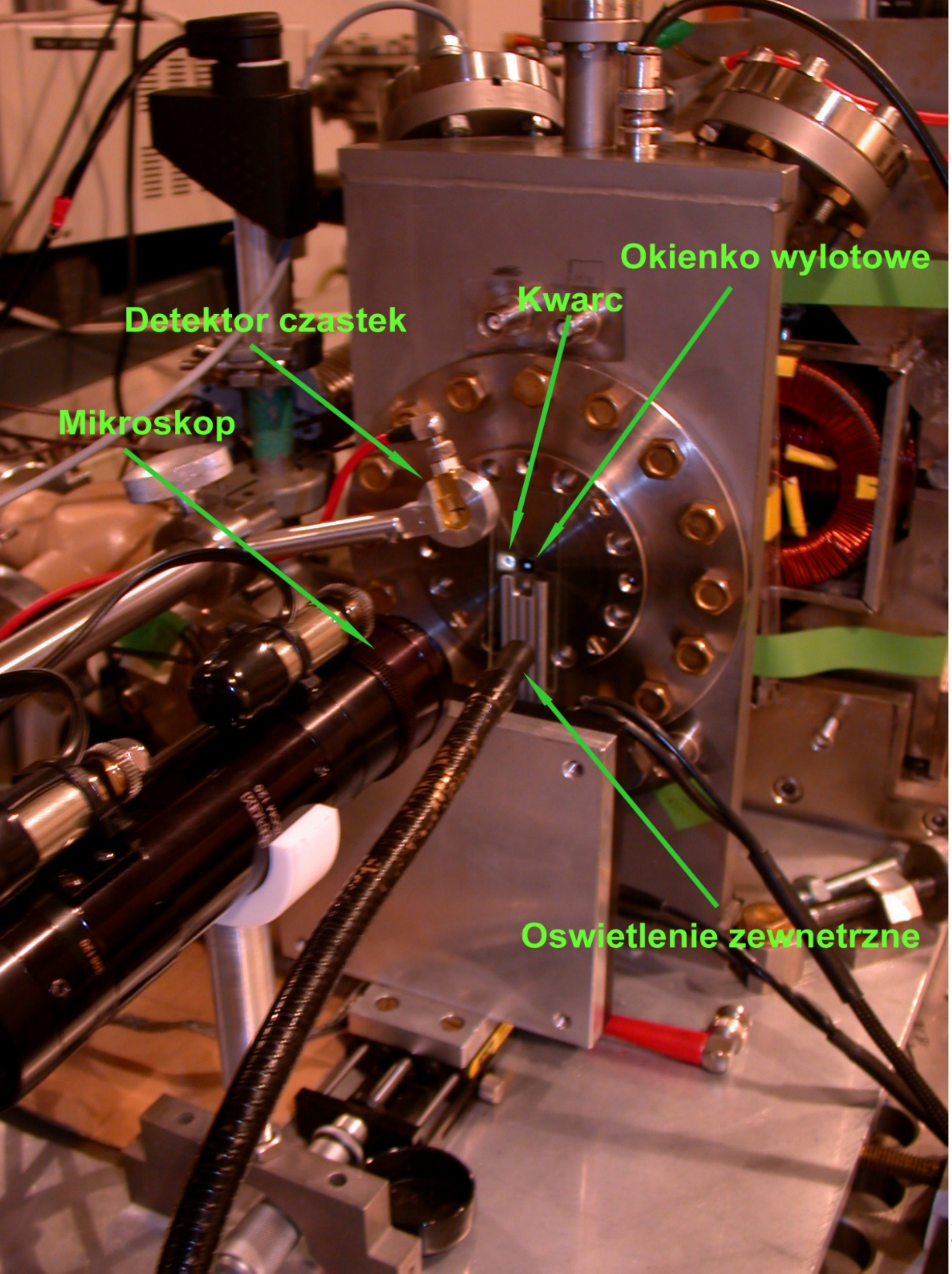
Van de Graaff accelarator - μbeam





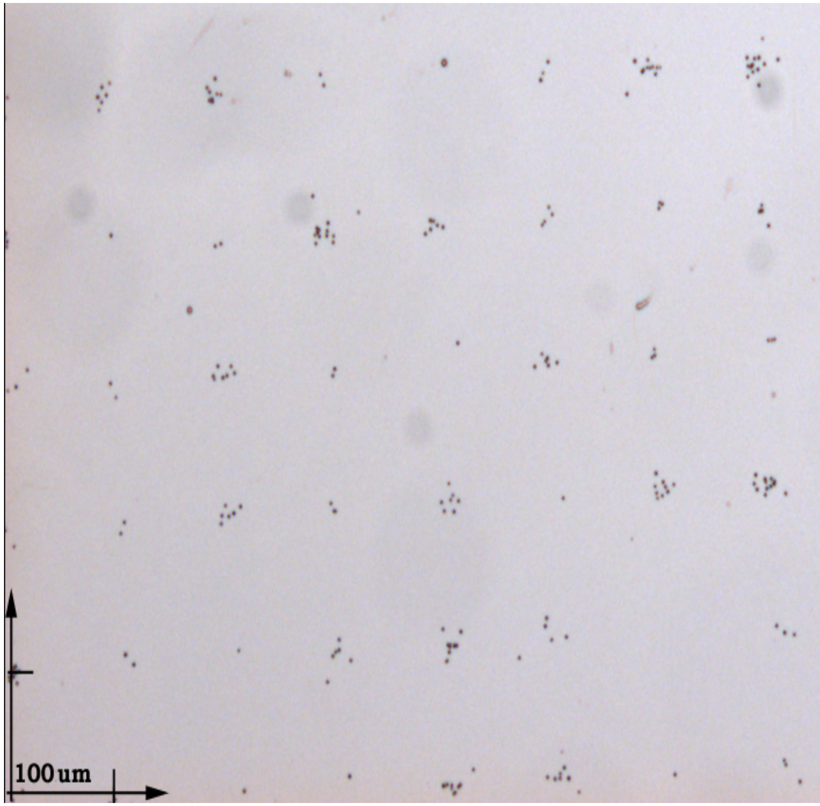


2 μm beam spot at 100 pA



Single Proton Irradiation faclility at IFJ

2.5 MeV protons



CR-39

Protons from cyclotrons

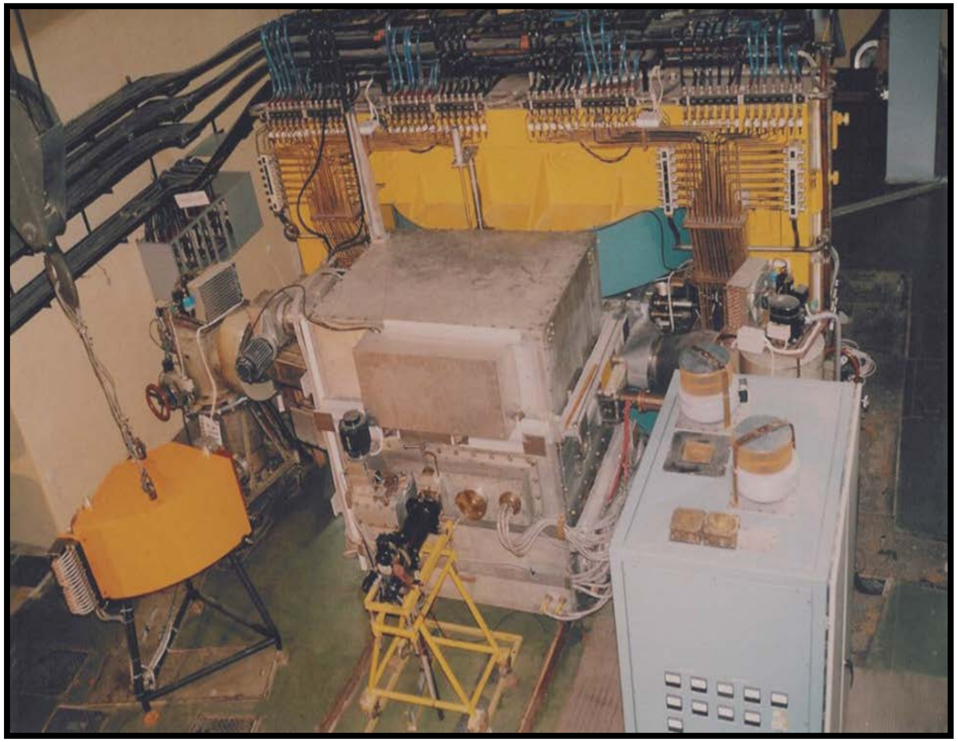
Cyclotrons at IFJ PAN

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

-Soviet built classical U-120 (opened 22.11.1958, stopped 1994), 12 MeV deuterons

-isochronic AIC-144 developed at IFJ PAN (from 1995) **60 MeV protons**

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

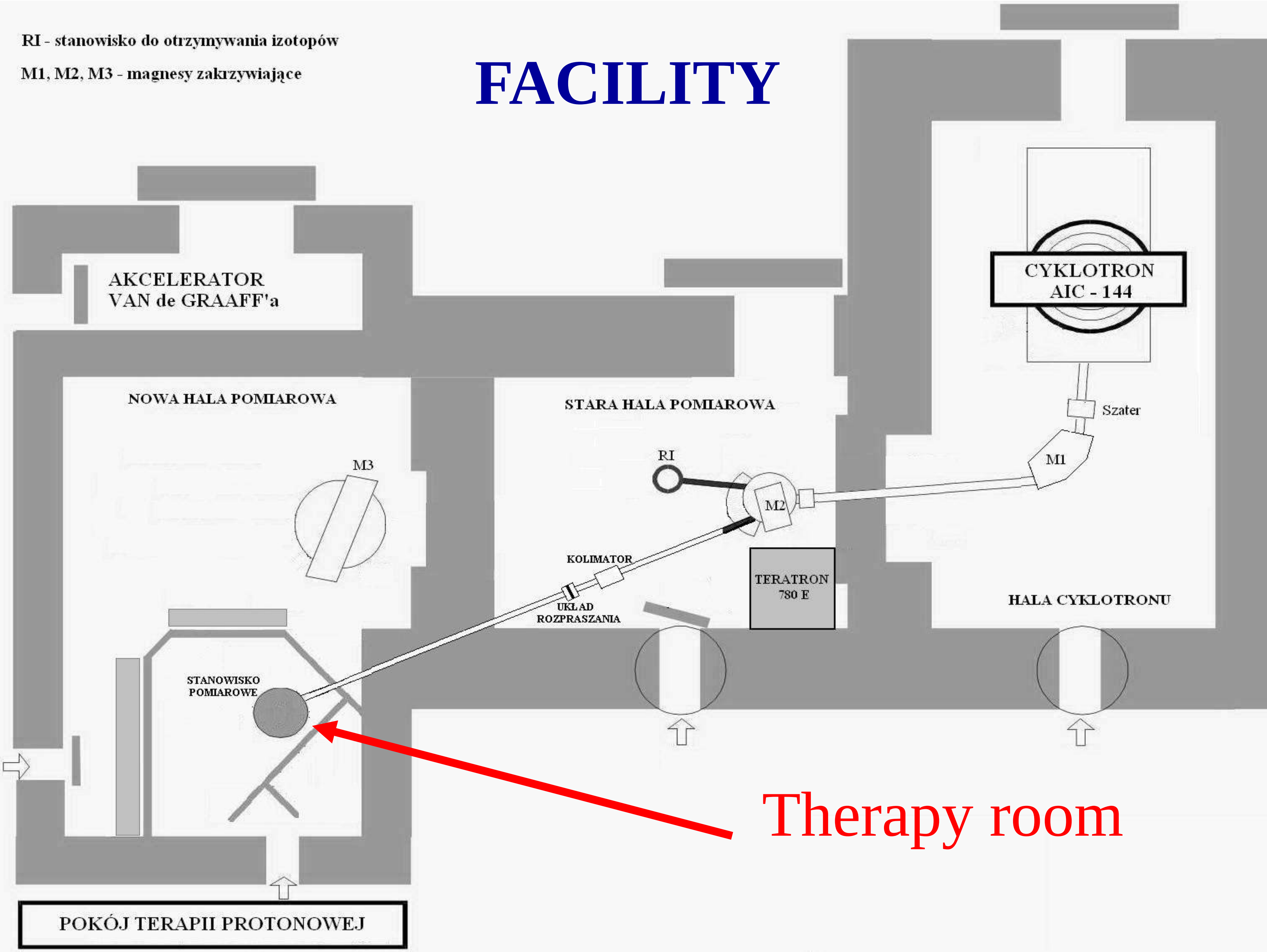


AIC -144, 1995

RI - stanowisko do otrzymywania izotopów

M1, M2, M3 - magnesy zakrzywiające

FACILITY



IFJ PAN eye treatment room at AIC-144

Regular patient treatment

- The first patient treated at IFJ PAN in February 2011
- From April 2013 the eye proton therapy financed by the National Health System
- 72 patients treated till July 2014
- The eye treatment on AIC-144 will be performed at least to September

Dosimetric equipment

Markus chmber
PTW 23343

Farmera chamber
PTW 30010

Dosimetric diode
PTW 60012

Unidos dosemeter PTW 10001

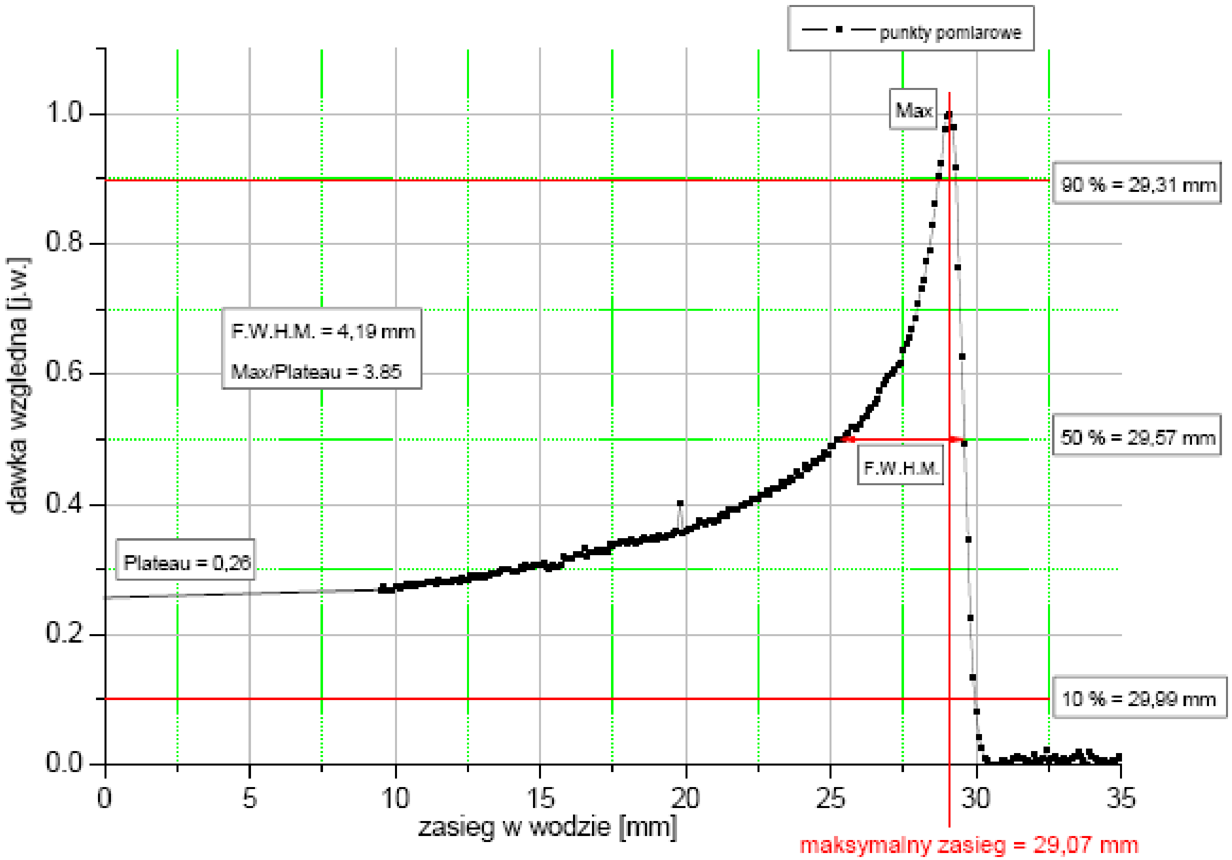
Transsmision chamber
PTW 7862

Thimble chamber
PTW 31002

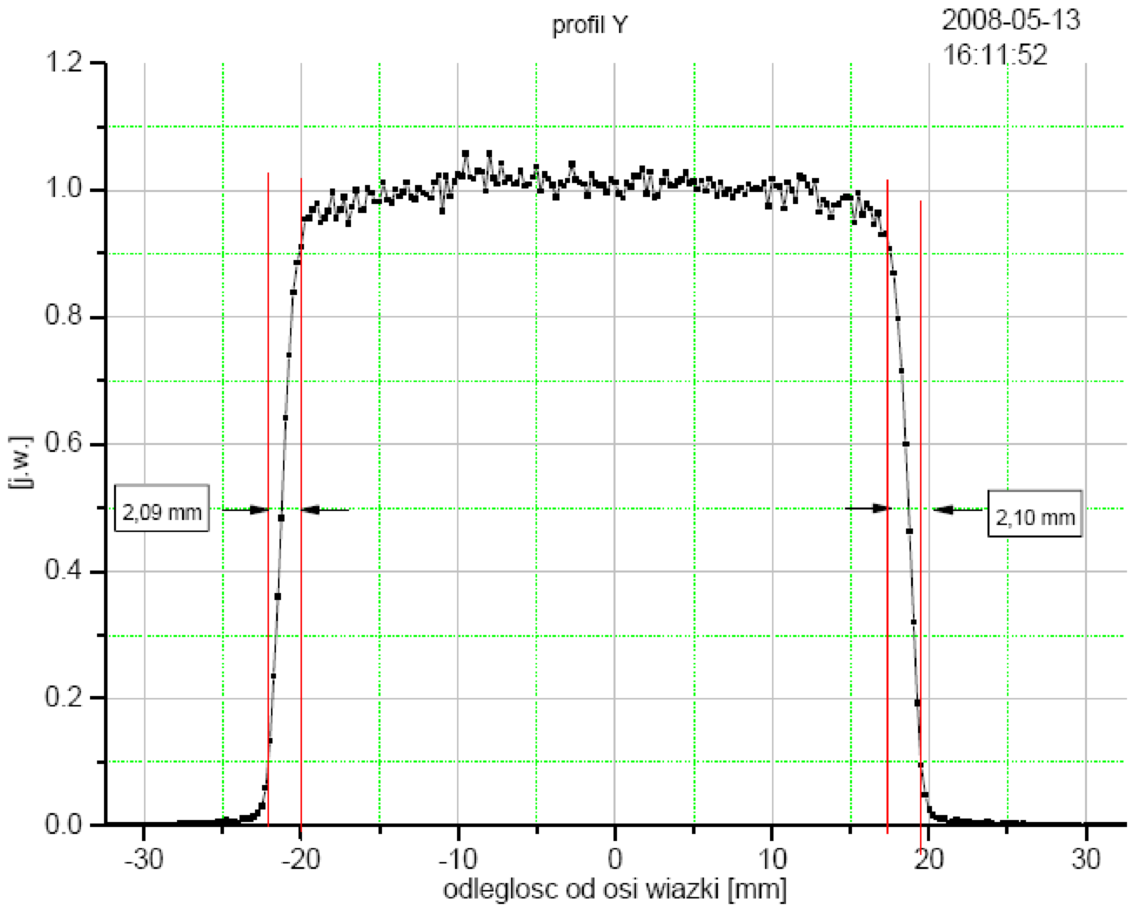
Unidos dosemeter PTW T-10021

Depth-dose distribution

- **Range in water - 29 mm**
- **Energy at the izocenter 58 MeV**



Beam profile



Y - profile for 40 mm beam diameter

National Center of Hadron Radiotherapy – Bronowice Cyklotron Centre

NCRH CCB

National Centre of Hadron Radiotherapy, NCRH –CCB
The project

Split into three parts:

Part „Cyclotron"
- building + Proteus C-235 cyclotron
- the project ready till Dec 2012
- vendor: contract signed with Ion Beam Application (IBA), Belgium

Part „Gantry 1"
- medical building + proton gantry
- project signed in Nov. 2011 ended May 2014

Part „Gantry 2"
- the project ready till Sept. 2015

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

Timetable of NCRH – CCB

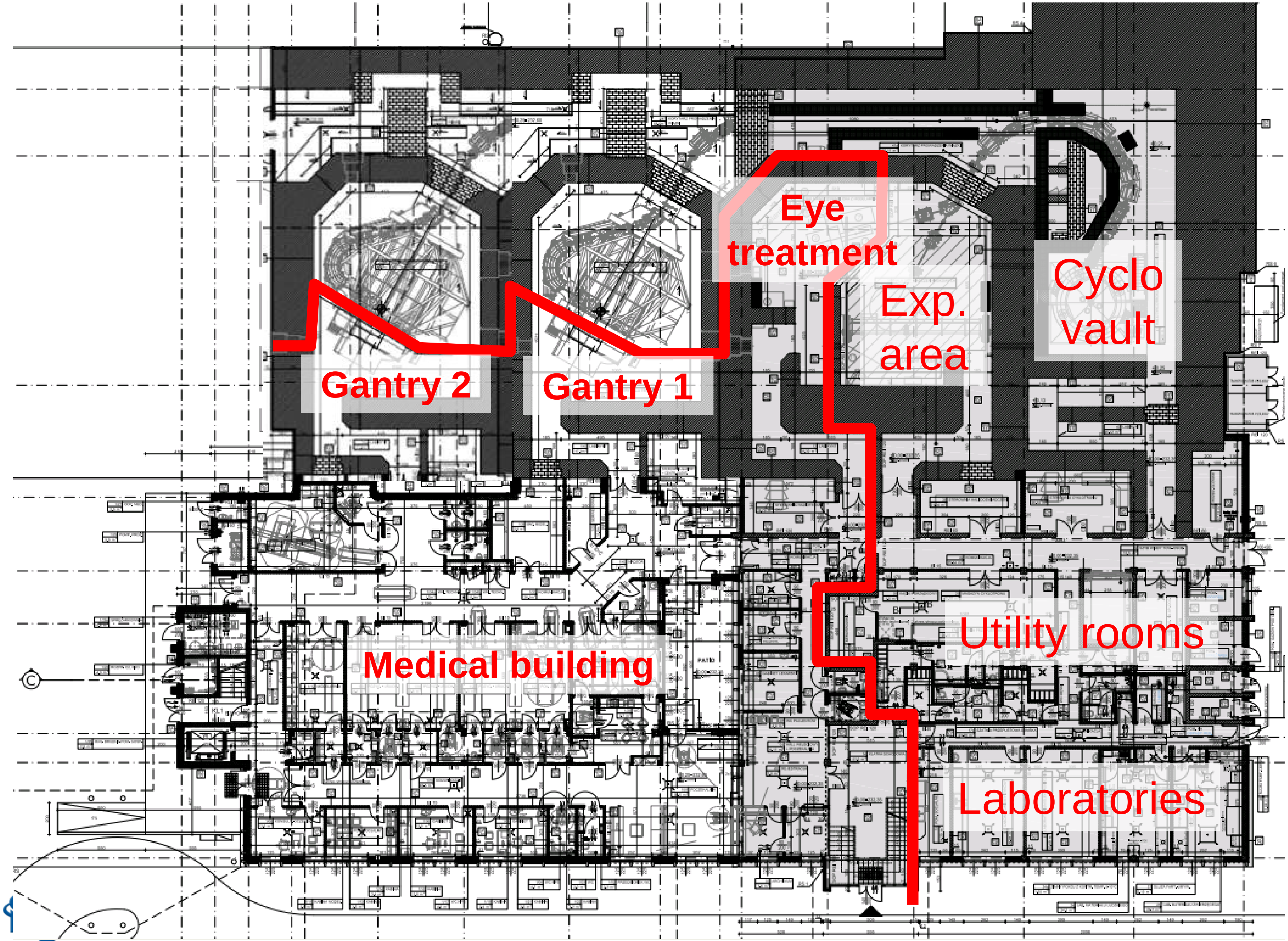
- signing the contract	2.08.2010
- building permission	10.02.2011
- start of the construction	17.03.2011
- installation of the C-235 cyclotron	05.2012
- acceptance tests	11.2012
- medical building	06.2013
- installation of gantry	07.2013
- gantry 1 in operation	06.2014
- **gantry 2 in operation – end of the contract**	**09.2015**

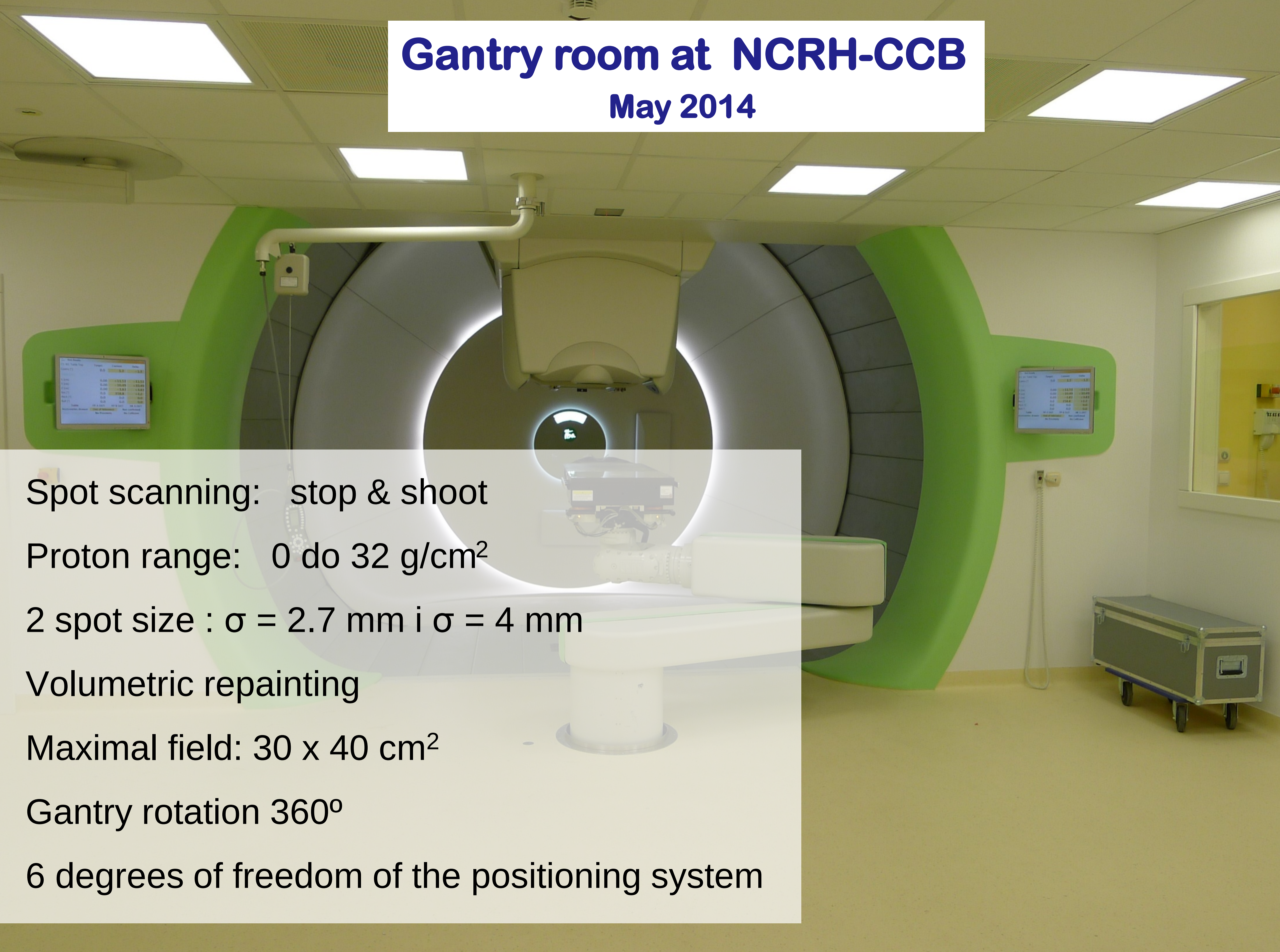
The cyclotron and energy selector

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

cyclotron:	isochronic, 4-sectors, CW
particles	protons
ion source:	P.I.G with hot cathod
proton energy:	230 MeV (β = 0.596, γ = 1.245), constant
energy dispersion:	$\Delta E/E$ < 0.7%
beam intensity:	**500 nA (4 x 10^{12} p/s) – 0.1 nA (6 x 10^8 p/s)**
emmitance	horizonthal - 11 π mm mrad,

General layout of NCRH-CCB





Gantry room at NCRH-CCB

May 2014

Spot scanning: stop & shoot

Proton range: 0 do 32 g/cm^2

2 spot size : σ = 2.7 mm i σ = 4 mm

Volumetric repainting

Maximal field: 30 x 40 cm^2

Gantry rotation 360º

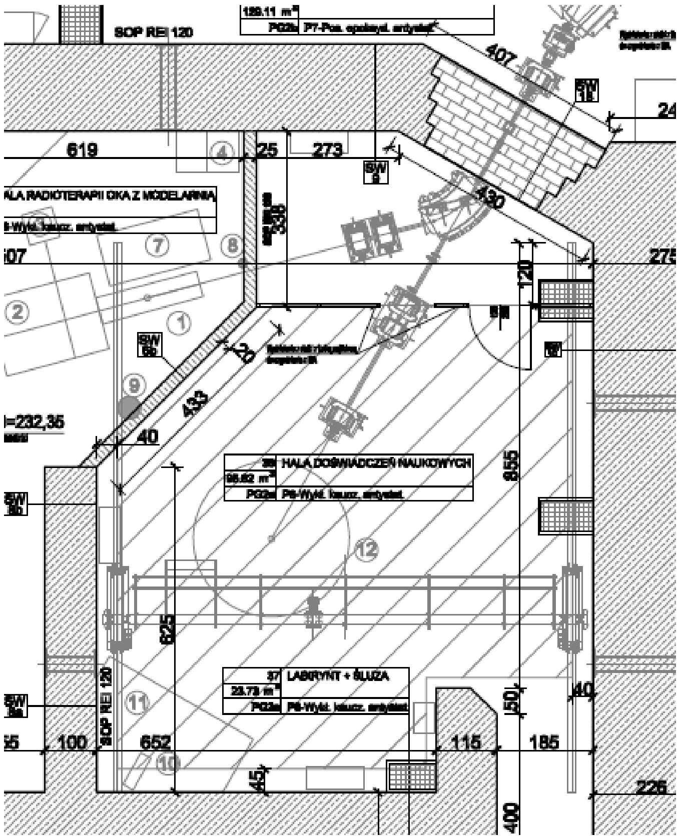
6 degrees of freedom of the positioning system

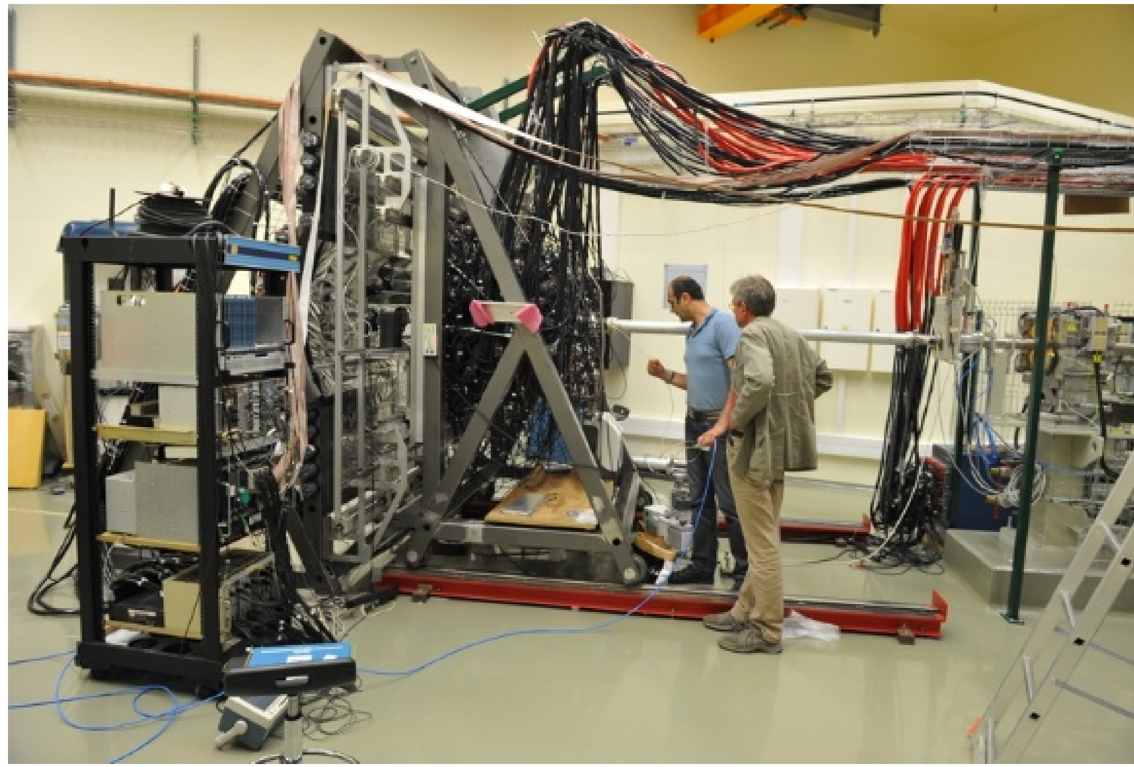
Development of the new eye line

New eye therapy room under development by IFJ PAN will undergo CE marking

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 biology irradiation line (2015?)

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

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Regular paper

Metastasis inhibition after proton beam, β- and γ-irradiation of melanoma growing in the hamster eye*

Bożena Romanowska-Dixon[1], Martyna Elas[2]✉, Jan Swakoń[3], Urszula Sowa[3], Marta Ptaszkiewicz[3], Małgorzata Szczygieł[2], Martyna Krzykawska[2], Paweł Olko[3] and Krystyna Urbańska[2]

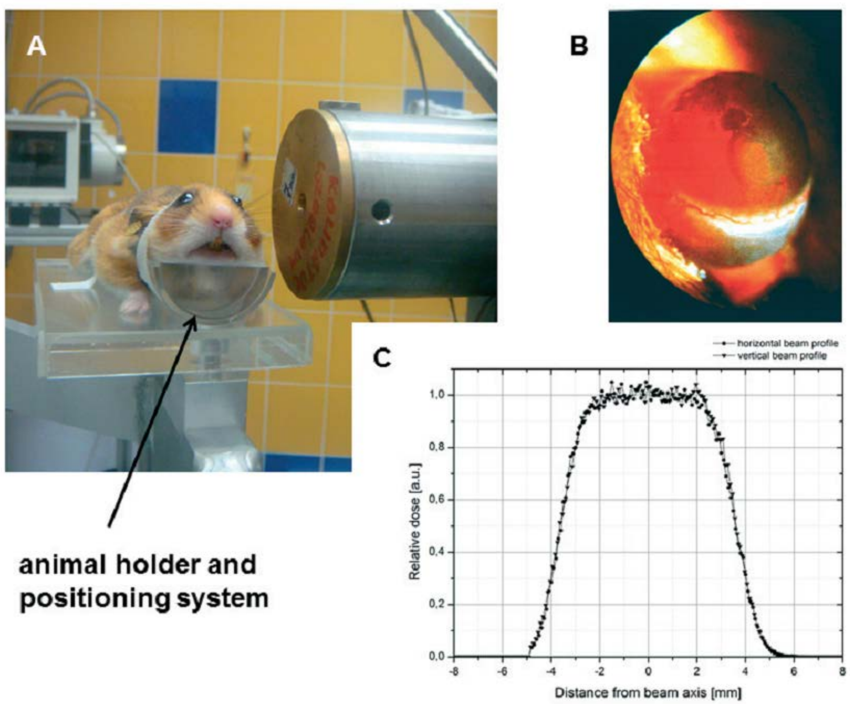


Figure 1. Hamster eye irradiation with proton beam.
(**A**) Hamster in the animal positioning system, (**B**) hamster eye with the tumor, magnification 10x and (**C**) proton beam dose depth distribution and lateral profiles of the beam used for hamster eye irradiation.

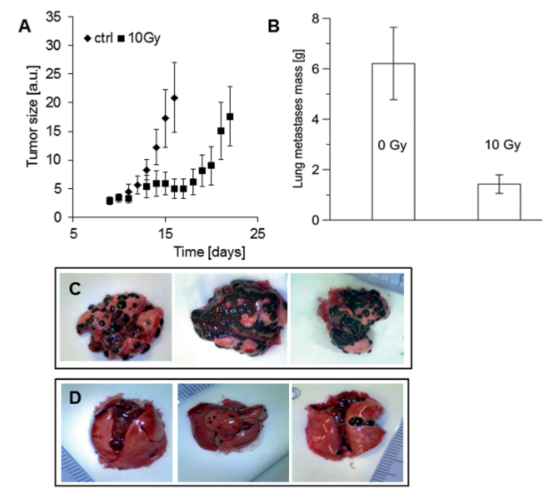


Figure 3. (A) Inhibition of BHM melanoma tumor growing in the hamster eye, irradiated with a proton beam at a single dose of 10 Gy (n=7, black square), in comparison with untreated control (n=6, black diamond). (B) The mass of metastases to the lung decreased 4.35 times after proton beam irradiation (10 Gy) of BHM melanoma tumor growing in the hamster eye (*p*=0.0052). Average mass with SEM is shown. The number of control animals was 6, and the number of irradiated animals was 7. Representative isolated lungs with metastases from untreated (C) and irradiated (D) animals.

Relative biological effectiveness of the 60-MeV therapeutic proton beam at the Institute of Nuclear Physics (IFJ PAN) in Kraków, Poland

Dorota Słonina · Beata Biesaga ·
Jan Swakoń · Damian Kabat · Leszek Grzanka ·
Marta Ptaszkiewicz · Urszula Sowa

Radiat Environ Biophys
DOI 10.1007/s00411-014-0559-0

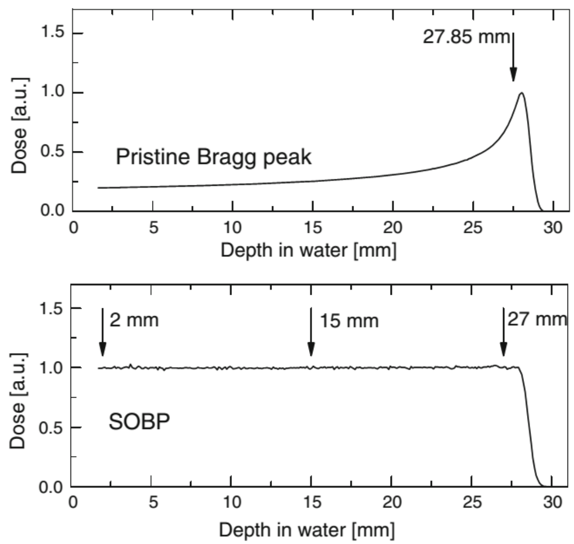


Fig. 1 Depth–dose distributions of the proton beam produced at the IFJ PAN Kraków (nominal energy 60 MeV) measured in a water phantom using a Marcus ion chamber. *Upper panel*: pristine beam; *lower panel*: SOBP. *Arrows* indicate positions at which cells (human fibroblasts) were irradiated: near (at 27.85 mm) the maximum of the Bragg peak in a pristine beam, and at three depths (2, 15, and 27 mm) of the SOBP of full width 28.4 mm

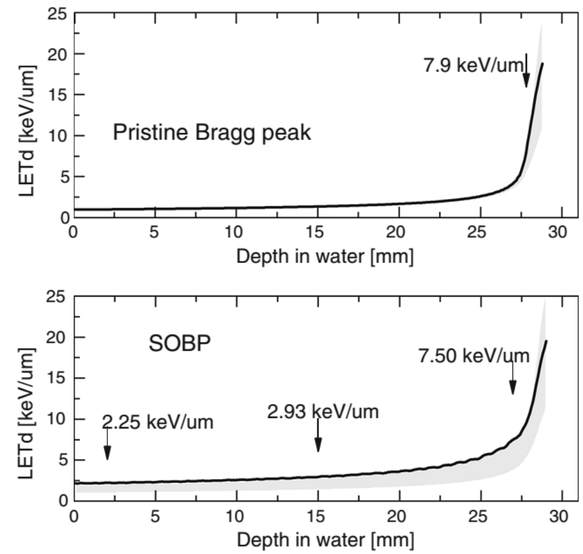
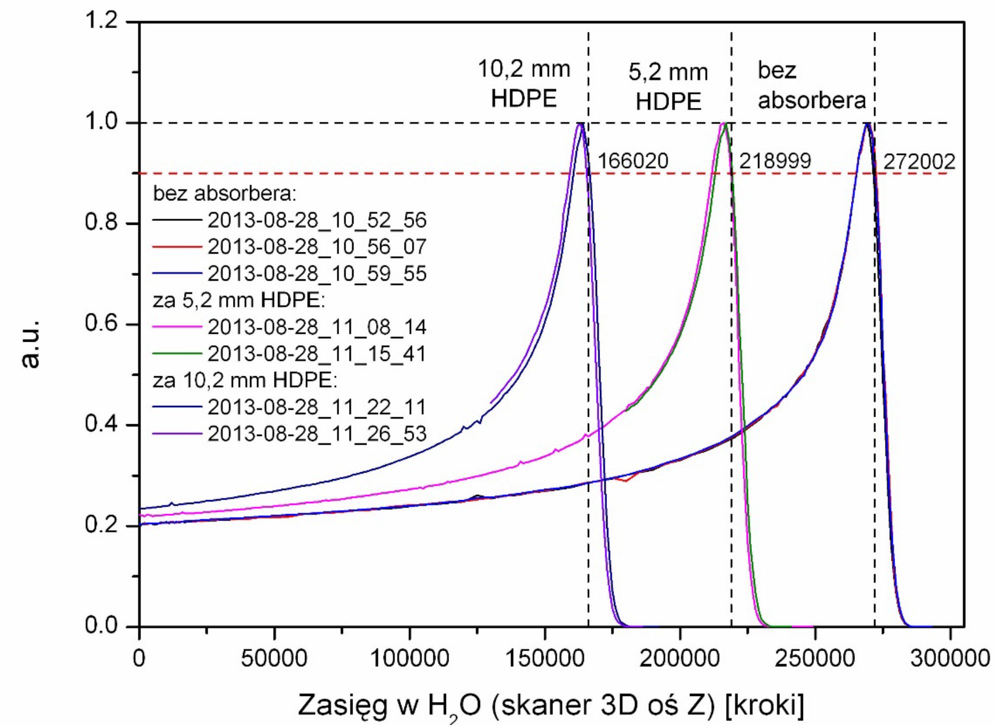
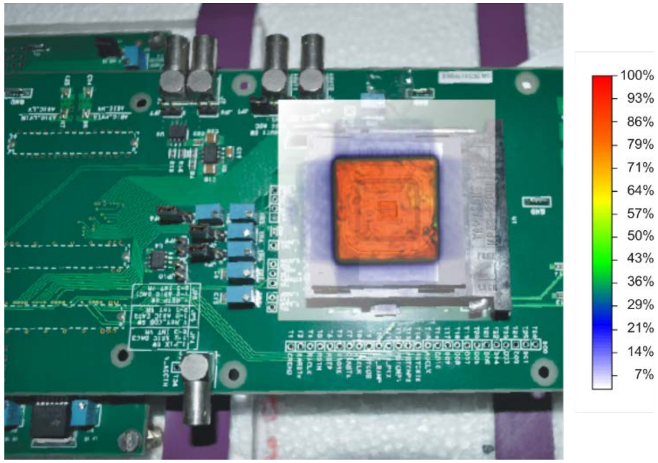


Fig. 2 Depth distributions of dose-averaged LET (LET_d) and of IQR of LET_d (*shaded*) of the proton beam produced at the IFJ PAN, simulated by Monte Carlo calculations. *Upper panel*: pristine beam; *lower panel*: SOBP. Calculated values of LET_d at irradiation positions are also shown

Irradiation of CCD chips for the Copernicus satellite



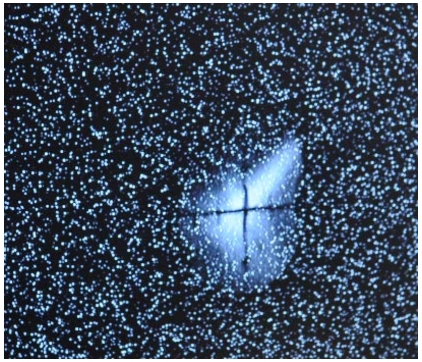
Irradiation of semiconductor CMOS SOI pixel prototype detector INTPIX3

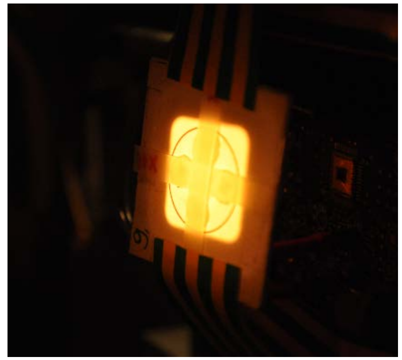


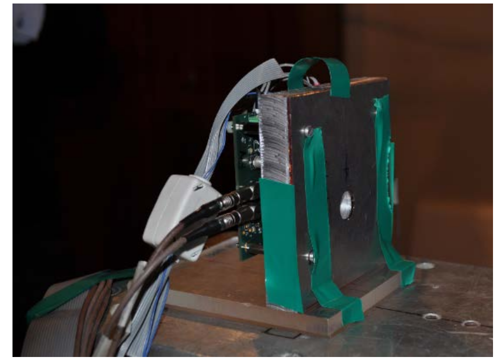
	Exposure time [min]	Dose [Gy]	Dose verification with alanine detector
First error detected (chip error)	278 min	398 Gy (±12 Gy)	-
Chip disconnection	300 min	430.5 Gy (±13 Gy)	417 Gy (± 23 Gy)
Total dose delivered on chip	305 min	437.5 Gy (±13.5 Gy)	-

Irradiation of electronic system for LHCb detector:

CLARO - the 4 channel, 0.35um CMOS prototype detector







		MARKUS CHAMBER		TLD - dose control		ALANINE- dose control	
	Irradiated detector	*Dose in water (Gy)*	*Dose estimated for Si (using stopping power ratio 1,82) (Gy)*	*TL dose (Gy)*	*Dose estimated for Si (using stopping power ratio 1,82) (Gy)*	*ALANINE dose (Gy)*	*Dose estimated for Si (using stopping power ratio 1,82) (Gy)*
26.02.2014		**estimated from dose rate: 6,6 Gy/s (kGy)**	***(kGy)***	**(kGy)**	**(kGy)**	**(kGy)**	**(kGy)**
	board1	1.98	*3.6*	3.2(±0.9)*	5.8	1.66(±0.07)	3.0
	board1	19.8	*36*	17.7(±4.2)	32	16.1(±0.7)	29
	board2	1.98	*3.6*	3.0(±0.7)	5.5	1.99(±0.08)	3.6
	board2	19.8	*36*	18.1(±4.1)	33	18.2(±0.7)	33
	board2	19.8	*36*	19.5(±4.5)	35	18.8(±0.8)	34
27.02.2014		**estimated from dose rate: 6.7 Gy/s (kGy)**	***(kGy)***	**(kGy)**		**(kGy)**	**(kGy)**
	board3	2.01	*3.7*	3.8(±1.0)	6.9	2.72(±0.11)	5.0
	board3	40.2	*73*	35.2(±7.4)	64.1	38.4(±0.2)	70

* results for TLDs coloured with grey are considered to be overestimated due to the lack of correct calibration in discussed dose range

How to make an iradiation at IFJ PAN?

dr J. Swakoń

Contact jan.swakon@ifj.edu.pl

Commercial → Contract

Scientific → Simple cooperation agreement

Gantry? Eye line? Experimental Hall

International Advisory Committee

The aim of the International Advisory Committee is to coordinate all activities related to the Fundamental Physics Research Program at Cyclotron Center Bronowice.

Members of the CCB International Advisory Committee:

Faical Azaiez (IPN, Orsay, France)
Angela Bracco (University of Milano and INFN, Italy)
Bogdan Fornal (IFJ PAN, Kraków, Poland) - Deputy Chair
Zsolt Fulop (ATOMKI, Debrecen, Hungary)
Mushin Harakeh (KVI, Groningen, Netherlands) - Chair
Robert Janssens (Argonne National Laboratory, USA)
Stanisław Kistryn (Jagiellonian University, Kraków, Poland)
Marek Lewitowicz (GANIL, Caen, France)
Adam Maj (IFJ PAN, Kraków, Poland)
Krzysztof Rusek (Warsaw University, Poland)
Hideyuki Sakai (RIKEN, Japan)
Christoph Scheidenberger (GSI, Germany)
Nicolae Victor Zamfir (IFIN-HH, Bucharest, Romania)
Wiktor Zipper (University of Silesia, Katowice, Poland)

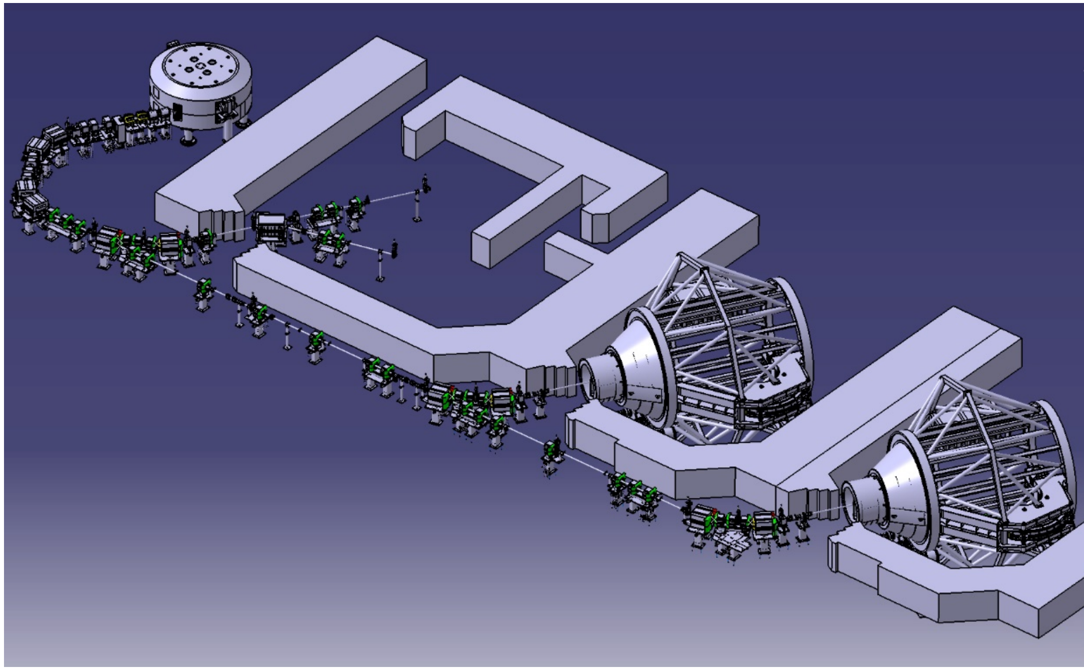
Daily beam use during the normal operation

1. Patient preparation: 25 min (2015) to 15 minutes (2020)

2. Patient irradiation: 1-1.5 minutes

3. Beam for experimental hall can be probably used for about 10 minutes and switched to gantry

4. Experimental hall cannot be used during eye irradiation but eyeline used only one week per month



4 rooms:
- gantry 1,
- gantry 2,
- eyeline,
- experimental room

Summary

1. Proton and γ-ray calibration available at IFJ for WRIMIS participants

2. 60 to 230 MeV proton beams are available at IFJ , including scanning beams.

3. International Advisory Committee prepares the ranking of experiments at the experimental hall

4. Therapy beams are available night/weeend for non-biological experiments

5. Is WRIMIS group interested in development of the dedicated calibration site for cosmic rays?