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EYE PROTONTHERAPY: PROPOSED FEASIBILITY PLAN

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Abstract. Accelerated proton radiotherapy of tumors and ocular adnexa is required in addition to brachytherapy as a valuable tool in the destruction of these tumors and preservation of vision. The survival up to 5 years without the tumor may reach values as high as 90%. Although medical needs require it, Romania does not have this feature, which is why this article is trying to suggest a plan of medical feasibility, an organizational and technological plan that could be implemented in collaboration with organizations and companies from European Community. In this way, it is the present proposal to use the existing cyclotron, TR-19, to generate a beam of protons of 19MeV and, with a sufficient intensity, to provide a linear accelerator of protons the proton beam sufficiently accelerated to 90-120MeV to be used in the treatment of eye tumors. This project was originally proposed by the Italian Foundation for dissemination of the hadrontherapy, TERA, who called the hybrid cyclotron-LIBO, Cyclinac and applied this idea in the treatment of eye tumors. Technical facilities and real estate in Romania allow its implementation and it need for a medical facility, also possible.

Keywords: Proton therapy of the eye, Nuclear Medicine, Feasibility Plan, CYCLINAC, TR 19 cyclotron, LIBO.

1. INTRODUCTION

The current article represents a summary of the pre-feasibility study performed in order to implement hadrontherapy through the treatment of eye tumors via protontherapy in Romania.

Radiation therapy has been used for more than 100 years with X-rays (photons). X-rays were successful in destroying tumors but also destroy healthy tissue around the tumor. Protontherapy is the method of conformational radiotherapy which treats a malignant tumor avoiding irradiation of the body located between tumor target volume and the output radiations from the body.

For the case of eye tumors, this area is mostly represented by the brain of the patient, a vital organ.

Proton energy does not decrease exponentially with depth (as do X-rays) but deposit more energy as they slow down, culminating in a peak (called the Bragg peak). Accelerated proton beams can be very precisely controlled to where they exert maximum energy. More than 90000 patients worldwide have been successfully treated with protons or carbon ions as yet.

In Romania, from a total of 440 933 cancer patients in evidence in 2012, were reported as new cases of cancer a number of 58632 patients. From these, a total of 2047 new cases of eye cancer have been reported in the period 2008–2012, from whom 249 patients were reported deceased, alive remaining a number of 1798 patients with malignant tumor of the eye and adnexa. For the reported period of for years, a total number of 53 patients have benefited from brachytherapy.

Table 1

Romania, the situation of location cancers of the eye

	2008	2009	2010	2011	2012	TOTAL
	46161	47155	47337	48070	48843	
New Cases	521	411	398	458	259	2047
Died	53	38	45	54	59	249
Remaining	468	373	353	404	200	1798

It is known from literature that the eye protontherapy provides a degree of cure of malignant tumor of the eye by about 90% (86%–93%), this, in the conditions in which patient's function of the eye remains functional.

If the eye cancer were to be treated by protontherapy, the percentages above would look like this: number of deaths from cancer of the eye would have been about 204 patients, remaining 1843 patients being able to be declared healthy with vision preserved without disabilities, a burden for them, their families and the Romanian state, continuously having the perspective of dying.

The treatment of approximately 150-200 patients / year would make this facility to be economically feasible; as shown in the table above, the needs are far greater.

Inexistent in Romania, the native patients who want to be treated using protontherapy are addressed to the foreign centers where prices for such treatment vary between 12000 and 24000 euro.

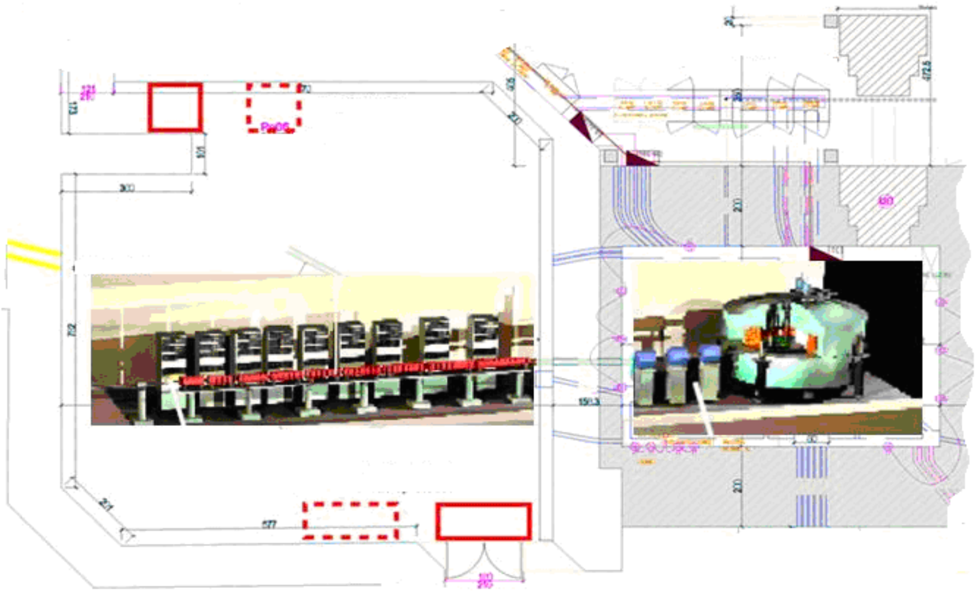

Fig. 1 – A proposal for the Cyclinac based on the TR-cyclotron and LIBO who can be built at IFIN HH, Magurele, Bucharest for eye protontherapy.

In this way there is an economic differentiation between patients and a loss for the national health insurance in favor of the countries that have such a facility (Poland, Czech Republic, Switzerland, Germany, France, Russia, Sweden, Italy, England).

The Romanian Society of Hadrontherapy (RSH) has been founded in the year 2006. The RSH is a professional, scientific organization of physicians and other high-educated specialists (physicists, biologists, chemists, biophysicists, engineers, etc.) who are working in domains regarding the use of hadrons in diagnostic and medical treatment and who action for studying, implementing and developing of hadronotherapy in Romania. RSH is an independent society which can affiliate to others societies with the same profile and can cooperate with other medical and academic societies from Romania and abroad. RSH's main aim is the implementation of hadrontherapy in Romania, as this treatment represents a very significant step ahead for cancer treatment. Since protontherapy is considered to be a hadrontherapeutical treatment technique, SRH actively tries to implement this treatment technique as a first step to the successful implementation of hadrontherapy in Romania.

In addition the difference in it is widening scientific expertise both professional and in research between us and those countries.

Currently three countries are on the verge of developing this treatment facility: Greece, Turkey and Austria.

This type of treatment, in addition to the advantages brought to health, would save and bring to the country's budget approximately 1000000 euro annually.

The success of radiotherapy with accelerated proton beams is impressive, up to about 3500 patients, local developments without tumor at five years is 95% - 98% for ocular melanoma. The overall survival at 5 years without metastases is 80%, with a better outcome for smaller lesions (95%) and a worse outcome (60%) for larger lesions. Improving vision depends on the initial state of the eye, tumor size, location and if there is a retinal detachment [13].

2. ORGANIZATIONAL STRUCTURE

Our center must be organized optimally to meet the objectives while maintaining responsibility quality, and efficiency.

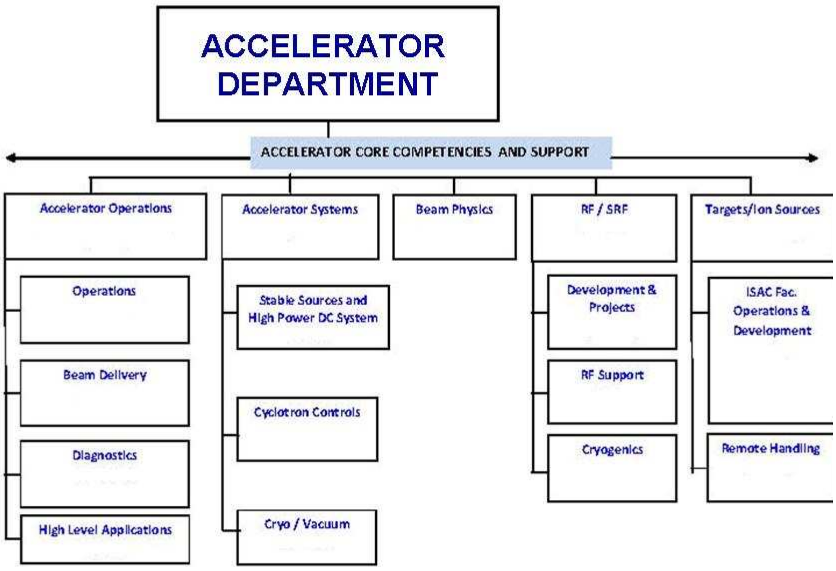

Fig. 2 – Organizational chart of accelerator department [8].

2.1. DEPARTMENT OF ACCELERATOR

Accelerator Department has operational responsibilities, maintenance and upgrade required for cyclotron and LIBO.

The group in charge of maintaining infrastructure for proton beam, their magnets and other devices [8].

Computer: From intensive data acquisition network, storage, processing and supply conclusions.

Design Office: Office design translates research concepts and intentions of scientists in drawings, models and instruments necessary for production and services [8].

Group for detectors: The Group develops and implements the best technology to record the particles and how they interact [8].

Diagnostic Group: This team monitors and controls the proton beam [8].

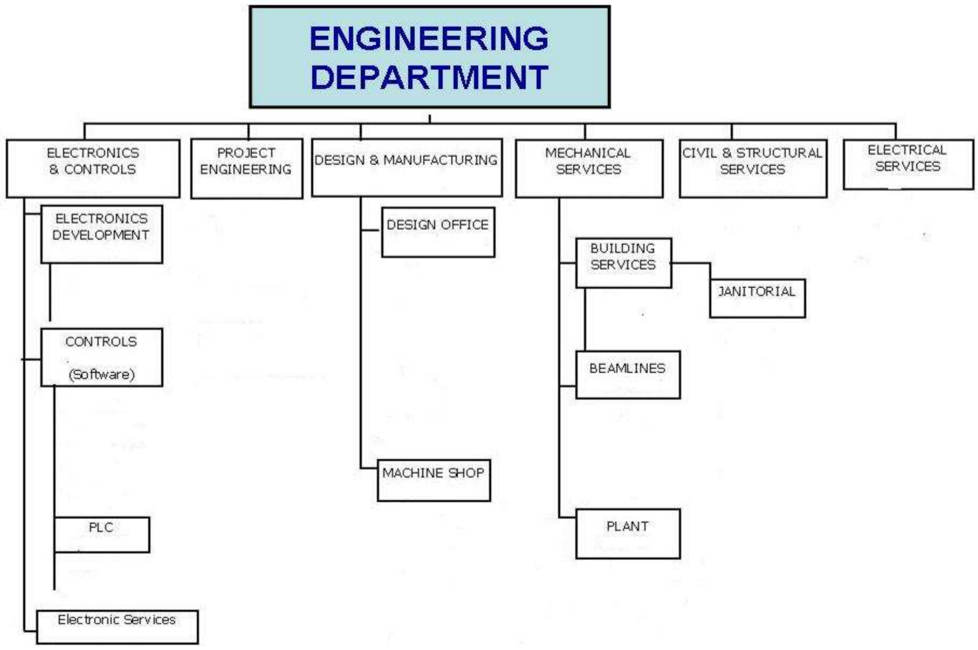

Fig. 3 – Organizational chart of engineering department [8].

2.2. ENGINEERING DEPARTMENT

From design to construction to operation and maintenance engineering team is involved. Engineering Department has overall responsibility for engineering, design and manufacturing mechanical components, structural and electronic.

The department is also responsible for electrical and mechanical services and maintenance of the facility [8].

The operations team: In every hour of every day of the year, the operations team provides performance of safe and optimal conditions of the accelerator, collateral facilities everywhere in the center [8].

It deals with the detection, monitoring, control and protection of people and the environment from ionizing radiation [8].

Radiation Protection Group:

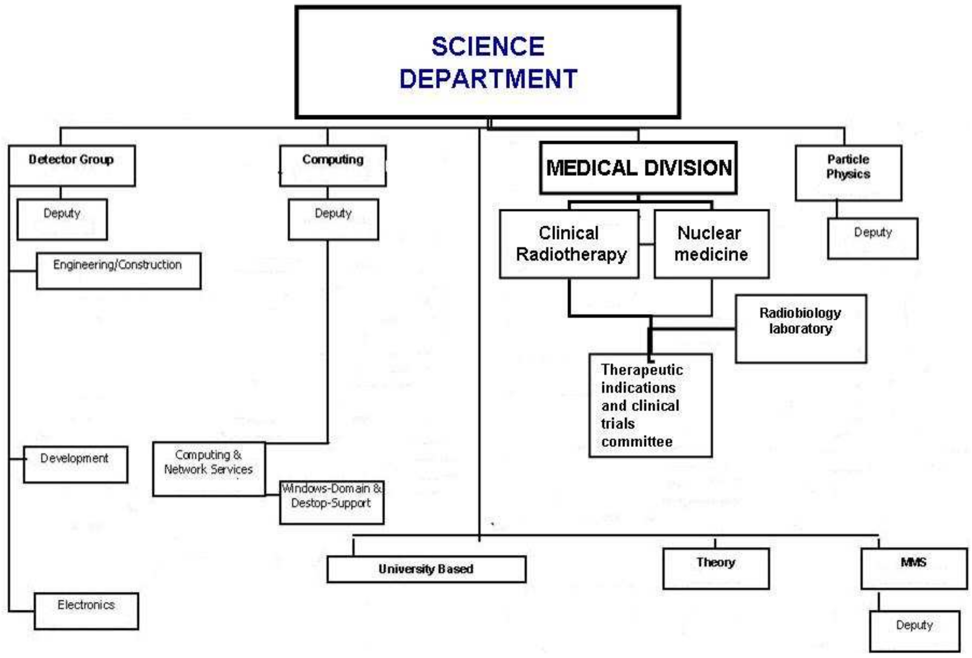

Fig. 4 – Organizational chart of science department [8].

2.3. SCIENCES DEPARTMENT

Science department is responsible for experiments approved and programmed as to the proper application of proton radiotherapy. Science department is also responsible for the design, installation, operation and maintenance of components, systems and subsystems for all experimental operations. Science department is also responsible for coordinating support infrastructure for external programs [8].

General presentation: Our center must establish a project-oriented a management system. In this system, the allocation of any resource in our center will be directed to a specific project or undertaking official engagements on a list to be approved.

Criteria for project approval: For a project to be approved should fulfill a set of criteria set out in the document containing the criteria for approval of these projects and programs [8].

Group supervision: This group solves the problems of the projects, is responsible for the general implementation and monitoring the project management system [8].

Industrial Innovation and Partnerships: Carries out activities of knowledge and technology transfer between our center and other organizations.

Romanian Society of Hadrontherapy (SRH) is a non-profit scientific society incorporated into our center partner in the development and commercialization of technologies [8].

2.4. MEDICAL DEPARTMENT

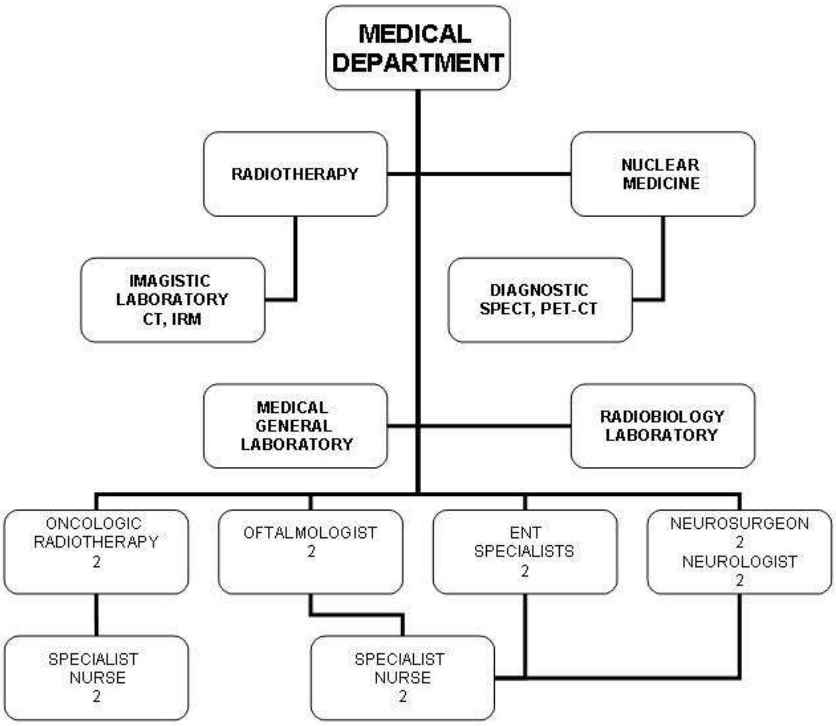

Fig. 5 – Organizational chart of medical department [8].

The medical department is triple subordinate. Methodological reports to University of Medicine and Pharmacy “Carol Davila” (UMF CD), administratively the Institute of Nuclear Physics and Technology "Horia Hulubei" (IFIN HH) and from the point of view of scientific policy is subordinated to the National Research Council (CNCS).

2.5. DEPARTMENT OF RADIOTHERAPY

It deals with the organization of radiotherapy, treatment schedule, consultation, therapeutically obeying instructions, proper performance of radiotherapy, follow up post therapeutic monitoring and periodical control of patients. It has a general medical laboratory as a sub department. The Department of Radiobiology, will be working closely with the Nuclear Medicine Department. It has the load of the study efficiency of proton radiotherapy of the eye; radiation therapy efficiency analyzes proposing to continue optimization trials with proton radiotherapy of the eye. Keep in touch with ophthalmology and oncology centers to participate in diagnostic and therapeutic indications Commissions, in protontherapy of eye.

2.6. DEPARTMENT OF NUCLEAR MEDICINE

Department of Nuclear Medicine is responsible for supporting projects approved and supports collaborations with other research and educational institutions using radionuclides produced in our center.

This department is also responsible for the design, installation, operation and maintenance of components, systems and subsystems for radioisotope production and processing facilities for diagnosis in our center [8].

2.7. ADMINISTRATIVE DEPARTMENT

Administrative Department has general supervisory duties for the following business and administrative functions:

- general administration,
- human resources
- risk managment and site security
- quality assurance.

Supplementary supervision shall be for Innovation and Industrial Partnerships, proton therapy, and nuclear medicine specialist group that focus on the production of radioactive isotopes [8].

Director Office: The overall responsibility for the operation and development of our center and its scientific program at national and international level.

Director General has oversight responsibilities for the following: health and safety, finance, project management, strategy planning, communication.

All projects and ongoing commitments of our center are on the list of commitments. This is a controlled document approved by the Director. Only commitments on this list can access resources of our center.

2.8. DEPARTMENT OF BUSINESS AND MANAGEMENT ACCOUNTING

In charge with distribution of information about the Centre accounting, control, monitoring, planning, etc.

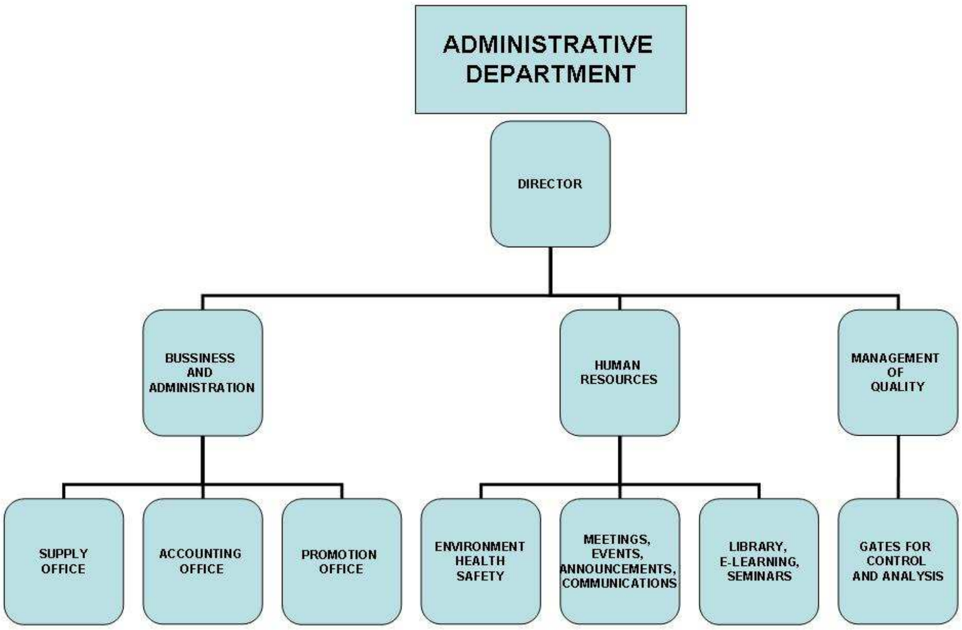

Fig. 6 – Organizational chart of administrative department [8].

Provisioning: Resolve all the needs of purchase and transport procurement, transportation, receipt and distribution of necessary goods, department.

Department of advertising and advertising: In charge of advertised products and services of the Center [8].

2.9. DEPARTMENT OF HUMAN RESOURCES

Access to all information on human resources, employment, job descriptions, benefits, payroll, policies and procedures. Engages our staff efficient problem solving, brainstorming, and various aspects of organizational management [8].

Meetings, events, announcements, communications: Record and report what is happening in the areas of interest of our center provides office services and communication resources: copy, print, fax, e-mail, phone services.

Organize seminars, courses, workshops and conferences together with the advertising and promotion department.

Environment, Health and Safety: Responsibility has documented safety procedures, health and environment relating to our center.

Quality Management: In charge with the distribution of information about daily management of Quality Assurance in our center.

2.10. DEPARTMENT FOR GENERATION AND BEAM ACCELERATION

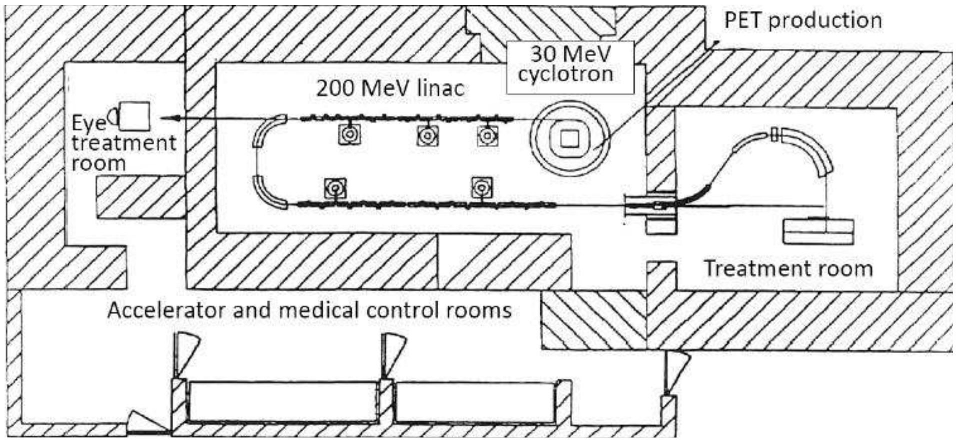

Fig. 7 – TERA proposal Cyclinac [5].

History: 2001: Proposal TERA project IDRA
2003–2005 Technology Transfer LIBO construction industry:
2003–2004: Proposal for a new TERA ion linear accelerator (cluster)

In 2001, TERA proposed Cyclinac construction of a provider of accelerated proton beam [1, 2, 6, 7].

The main idea is to combine in the same place four activities in research and treatment of cancer:

- production of radioisotopes for diagnostic PET and SPECT
- production of radioisotopes for systemic cancer endotherapy
- proton therapy
- research in nuclear medicine and radiotherapy
- one or more treatment rooms.

In the same way we think our center. IFIN HH, UMF CD, SRH supported by CNCS may be involved in the development of these facilities in Romania.

In this respect IFIN HH has a 19 MeV proton beam with an intensity 10 times higher than is necessary to protontherapy, which would mean purchasing a proton linear accelerator to increase acceleration voltage of 19 MeV to 90–100 MeV, accelerator that is where to place it in order to provide proton beam treatment room.

Therefore it is necessary to supplement the existing building with a treatment room and other rooms to prepare the patient, post therapy surveillance, waiting room, consultation cabinet. The equipments needed are: kit patient immobilization and marking, a treatment chair, devices required to adapt the beam to the target, devices and apparatus necessary for beam dosimetry and area, furniture. The personnel required will be activated as described above. The three institutions above IFIN HH, UMF CD, SRH, could provide recruitment, contacts necessary for specialization abroad quality procedures, business continuity in this interdisciplinary unit, research and development of a method.

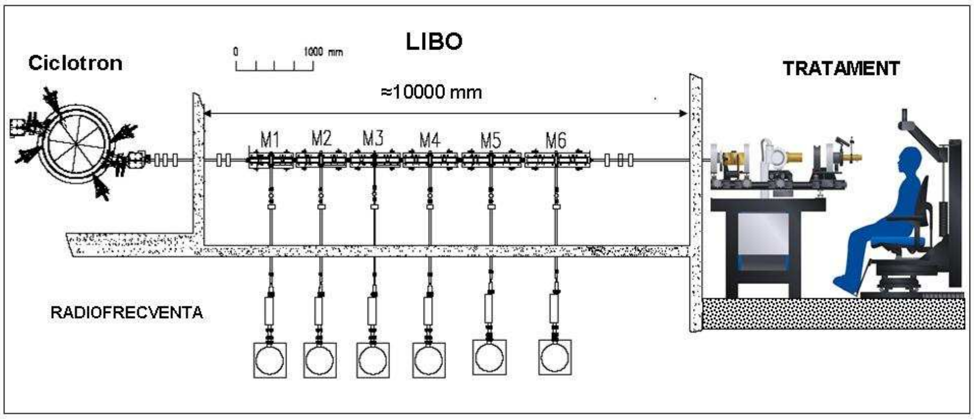

Fig. 8 – Our proposed scheme Cyclinac dedicated eye protontherapy.

3. CICLOTRON

THE TR 19 CYCLOTRON SYSTEM

Fig. 9 - TR 19 cyclotron system.

Manufacturer: ADVANCED CYCLOTRON SYSTEMS INC. (ACSI), Richmond, British Columbia, Canada

Installed in IFIN-HH: 2012 (5 July–4 August)

Site Acceptance Tests (SAT): 2012 Oct 24;

SAT report: All equipment of TR19 were responding very well and acting very stable. During the tests we witness that the cyclotron was performing better than “performance guarantee” required by contract.

Description

TR 19 is a negative ion cyclotron ion source external and generating two beams leaving at 180°. Since the energy extraction can be varied the cyclotron TR19 by varying the the radius of extraction extracted beam energy can be varied at the choice of the operator. At TR19, it can extract protons at an energy of 14 MeV to 19 MeV. There are two simultaneous beams with intensities independent variables up to a maximum beam current. TR-series cyclotron magnet 19 are designed to generate such a strong focus and avoid resonated frequencies horizontal and vertical focus. This is done by sector geometry. The magnetic poles are nickel-plated to maintain a clean, a low gassing rate. TR-19 using an external ion source. This technology allows for higher beam currents, easier maintenance and flexibility for future upgrades. TR-19 provides more than 300 μA beam of protons on target and has the ability to increase the intensity of 2mA. TR-19 functions to ~ $5x10^{-7}$ Torr an order of magnitude better than machinery having internal ion source. At 18.5 MeV, only 1% of the proton beam is lost in the vacuum tank. To maintain vacuum TR-19, both the ion source and the main tank is a vacuum pump that provides clean cryopumps [14, 15].

Beam extraction system

Because the extraction probe is inserted radially in the plane of acceleration, extracted beam energy can be varied by adjusting the radius of the anterior edge of the probe.TR-19 can extract 14-19 MeV proton beam with a 0.1MeV step. The radial movement of the extraction probes allows the extraction of two beams simultaneously in any report of division.

It is not necessary to control the RF magnetic field; cyclotron maintaining optimal set does not affect the beam extraction [14, 15].

High stability due to proper cooling system

As a result, the derived frequency RF system is small, and the isochronous frequency of circulating particles does not deviate in time.Therefore, the system is extremely easy to start and reaching a stable operating mode can be accomplished in a very short time.

It is necessary to adjust the RF or magnet system during the startup process. System deviations are kept to a minimum due to the limited temperature variations from critical components [14].

The main parameters of TR 19 cyclotron

Table 2

Cyclotron Type [14]

Negative Hydrogen
External Ion Source
Local Shielding
2 Extracted Beams
8 External Targets
Beam Current
Nominal - 300µA H^-
Beam Energy (Variable Energy)
Energy Range 14 MeV to 19 MeV H^-

Table 3

Magnet [14]

Weight	22 Tons
Geometry	4 Sectors (Closed)
Hill Angle	45 degrees
Hill Field	1.9 Wb/m2
Valley Field	0.5Wb/m2
Magnet Power	19 kW
Hill Gap	4 cm (nominal)
Valley Gap	20 cm
Pole Radius	57 cm
Max Energy	19 MeV
Amp Turns	8.4 x 104

Table 4

RF System [14]

Number of Dees	2 (45 degrees)
Dee Voltage	50 kV
RF Frequency	74 MHz
Power Req'd	13 kW
Energy per Rev	200 keV

Table 5

Ion Source (External) [14]

Type	Multicusp
Output Current	2.8 mA
Emittance	< 0.3 pi mm mrad (normalized)
Injection Line	1 Quadrupole doublet, tilted spiral inflector
Bias Voltage	25 kV

Table 6

Vacuum System [14]

Operating Pressure	5 x 10-7 Torr
Base Pressure	2 x 10-7 Torr
Pumps	2 Cryopumps (4000 l/s H2O speed each)
	2 Turbomolecular
	2 Two Stage Rotary Vane

Table 7

Computer System [14]

Computer System	Intel based
Controllers	Allen- Bradley Industrial PLC Modules
Interface	Graphical User Interface (RSVIEW)

LIBO

LIBO is a proton accelerator used for radiotherapy.
The main advantages of a medical linear accelerator for protons are:

- ✓ energy output varies as the synchrotron;
- ✓ simple injection and extraction
- ✓ modular construction
- ✓ structure can be built in stages

Table 8

The main parameters of LIBO [2]

Accelerated particles	p+1
Type of Linac	CCL
RF Frequency (MHz)	2998.5
Input energy (MeV)	30
Output energy (MeV)	230
The total length of the linac (m)	18.5
Cells per tank / tanks on the module	16/2
Number of accelerating modules	20
The thickness of half of cell it in a container (mm)	6.3–14.6
The diameter of the beam hole (mm)	7.0
Normalized transversal acceptance (mm mrad)	1.8 π
Number of permanent magnetic quadrupoles	41
The length of PMQ (mm)	30
PMQ Gradients (T / m)	130–153
Synchronous phase (degrees)	−15
Peak power per module (20% loss) (MW)	3.0
Shunt effective impedance ZT2 (inj.-extr.) (MQ / m)	30–90

Table 8 (continued)

Axial electric field (inj.-extr.) (MV / m)	15–17
Number of klystrons (peak power = 7.5MW)	10
Total peak power all RF klystrons (MW)	60
RF klystron efficiency	0.42
Repetition rate (Hz)	≤ 200
The duration of a pulse of protons (pS)	1.5
Max. Number of protons in 1.5 pS	4 · 107(2 Gy L-1 min-1)
The actual length of each RF pulse (SP)	3.2
RF cycle	3.2 · 10−4
Power at 100 Hz + 100 auxiliary kW (kW)	150

Table 9

Clinical requirements for hadrontherapy [2]

Clinical requirement		**Has influence on**
Beam range in patient	2-20 cm continuously adjustable	Energy: 180MeV + 20 MeV accounting for energy loss in the spreading devices to obtain a 20 x 20 cm^2 field with a throw of 3 m.
Field size	20 x 20 cm^2	Beam spreading – beam intensity
Range modulation Range adjustment	continuously adjustable continuously adjustable	
Dose rate		
large fields	>2 Gy/min	Beam intensity
small fields	>> 10 Gy/min	Beam intensity
Field homogeneity		
Longitudinal	<= 111%	Beam delivery system
Orthogonal	<= 105%	Beam spreading
Field symmetry	<= 105%	Beam spreading – beam delivery system
Lateral penumbra	< 2 mm at the entrance	Multiple scattering spreading devices
		Source site – source to axis distance
Distal fall-off	< 2 mm	Range straggling (energy) – energy spread
		Source to axis distance

Beam delivery system

The beam has two dipole magnets, five quadripolar magnet for focusing and three centering steering magnets. There are also safety locks in this section. If one of them detects that something is wrong, beam is turned off instantly [2].

Table 10

Cooling system of LIBO-62 prototype [2]

Applied peak power	4.2 MW
Duty cycle	0.2%
Average power inside LIBO	8400 W

Table 10 (continued)

Fluid channel	
Section	100 mm2 (a x b = 10 x 10 mm) E = 17.5 mm, R = 8.75 mm
Number of turns	n = 11
Length of the fluid circuit	Lcs = 1.98 m
Two parallel circuits for each tank.	
Thermal parameters	
Power in a tank	2100 W
ΔTwater (in-out)	0.7 K
Water flux	Qv = 45.9 l/min
Water velocity	3.825 m/sec
Heat exchange	forced convection system in turbulent regime (Re = 38250)
Transfer convection coefficient	h = 13900 W/(m2 K)
Heat exchange surface of the fluid	Sest = 0.079 m2
ΔTfluid-External wall (Tc – T∞)	1.01 K
Estimated by 2 and 3D ANSYS computations	ΔTexternal wall-Nose = 7 K

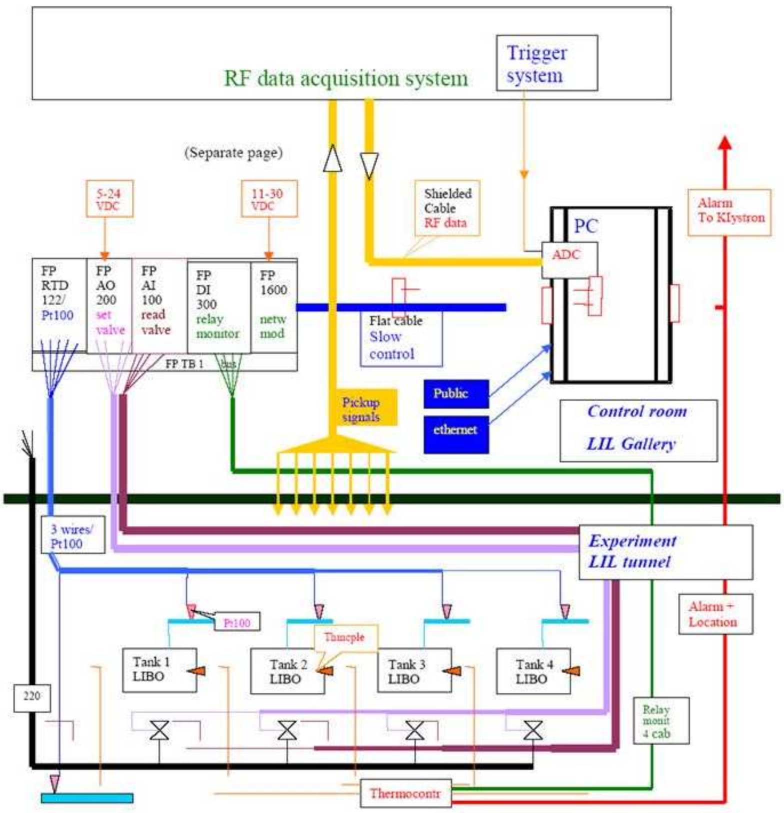

Fig. 10 – Controls and Data Acquisition for high power tests of LIBO-62 prototype at CERN [2].

4. MEDICAL PHYSICS DEPARTMENT

Physico-medical facility with accelerated protons for eye tumor radiotherapy

Beam depth range reached

Eye treatments require a variable interval between 2.5 cm and 3.2 cm depth [2].

Bragg peak modulation and beam adjustment

Bragg peak modulation is defined by dose curve depth, the distance between the proximal and distal points corresponding to 90% of the peak height.

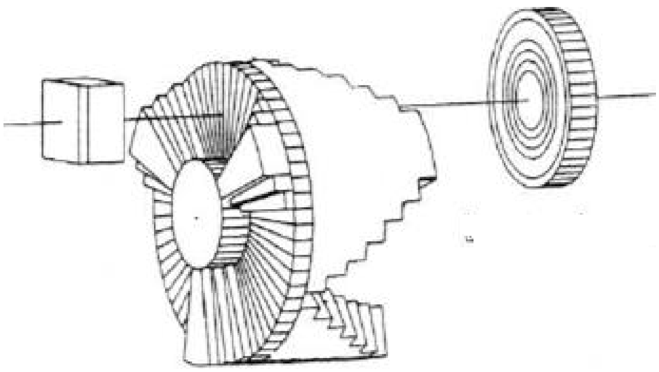

Fig. 11 – Degrading rotating wedge [2].

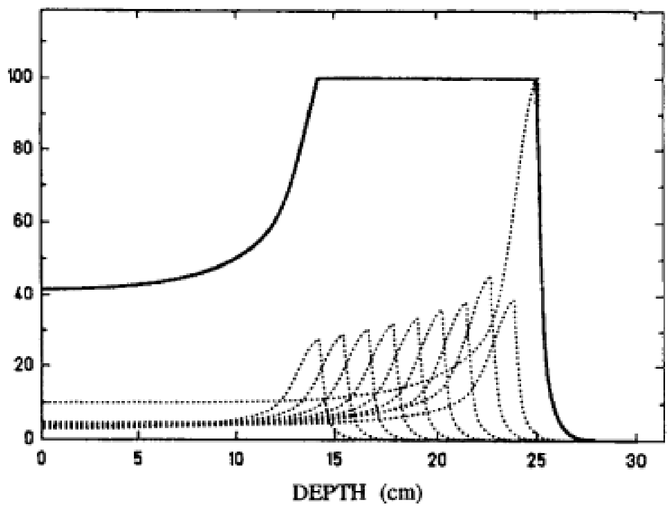

Fig. 12 – Schematic drawing of the superposition of several Bragg peaks to produce a Bragg Peak, enlarged plane (SOBP) [3].

Normally, the adjustment range refers to the ability to translate SOBP depth. The modulation of the Bragg peak should be variable in steps of 0.05 cm for the expansion to ≤ 5 cm and by 0.1 cm for the expansion in> 5 cm. The depth of treatment can be varied through the degrading rotating wedge which is located between the first and second collimator.

Modulator wheel rotates at 240 RPM and has four modulations per revolution. A number of wheel modulators are processed to vary the width of the Bragg peak covering the treatment required depth of 5 to 25 mm in 1 mm steps.

The dose rate

For ocular treatments, were a very short irradiation time (≤ 20-30 sec) is needed, requires high rates of SOBP dose (30-45 Gy / min), as greater accuracy in dose deposition is necessary [12].

Output power distribution LIBO-62

These parameters are required for volumes smaller than 50 cm^3 of cancer.

Field size

For a fixed horizontal beam, the field size should range from 2 by 2 to 15 by 15 cm^2 cm^2 on the beam entry area projected on the patient.

The dimensions of the irradiated region can be increased by the translation of chair treatment. In all cases, the dimensions of the field must be adjustable in steps of 1 mm (± 0.05 mm).

Field homogeneity and symmetry

The homogenity of on the axis of the beam is defined as:

$$Rl = (P\ max / P\ min) \times 100 \qquad \text{Eq. 1}$$

where P_{max} is the maximum absorbed dose throughout the the field of radiation, averaged over an area not more than $1cm^2$, and P_{min} is the minimum absorbed dose homogeneity region, averaged over an area not more than $1cm^2$.

Given a plane transverse to the beam axis, field symmetry is defined as the maximum value (in percent) of the ratio between highest and lowest dose absorbed, averaged over an area no more than 1 cm^2, for each pair of symmetrical positions in relation to the axis of the beam within the homogenity region. Uniformity across (R_t) and longitudinal (R_l) field must be: $Rt \leq 105\%$, $Rl \leq 111\%$.

The symmetry of the field is less than 105% [2].

Methods of alignment

A laser system is initially used as a rough guide to align the beam directly to the tumor.

Fig. 13 – A laser system to align the beam [10].

This is done by a chair that is electronically controlled by servomotors. Seat position can be changed in six modes.

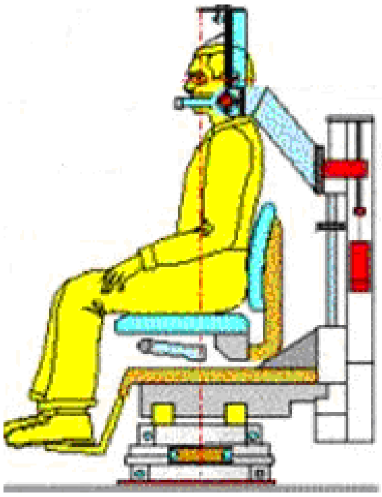

Fig. 14 – Treatment chair [8].

Distal dose at stopping power

Considering the depth dose curve beam axis, distal dose at stopping power is defined as the distance between the 80% and 20% absorbed dose points on the beam axis beyond the Bragg peak.

100% maximum corresponding to the SOBP. Distal dose at stopping power due to dispersion of the beam must be less 2-3 mm against the stopping power of the beam [2].

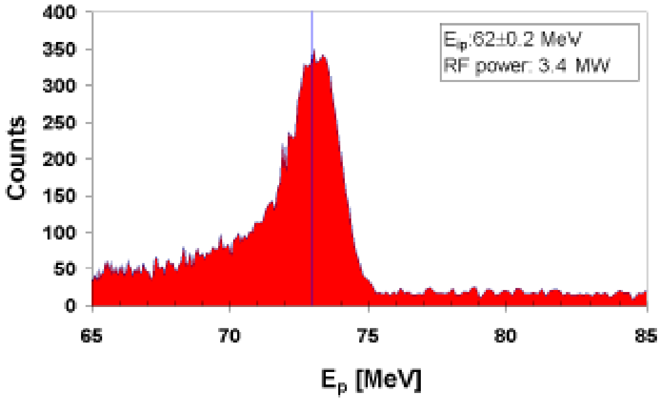

Fig. 15 – Energy spectrum obtained downstream at the LIBO prototype after passing through a Perspex absorber 30 mm thick. The peak corresponds to a proton beam accelerated by 73 MeV [5].

Lateral penumbra

Consider a measured dose profile along one of the major axis of the field. Lateral penumbra is defined as the distance between the points 80% and 20% of the absorbed dose. 100% corresponds to the position of the beam axis. Lateral penumbra of the beam must be not greater than 2 mm on each side [2].

Treatment plan

Treatment planning uses a software which builds a model of the eye, the tumor the manner and dosage of treatment for each patient.

Table 11

Data on the generation of a beam directed at an ocular melanoma exposed per unit time (sec.) [12]

Proton incidence	Collimator diameter (mm)	Range shifter thickness (mm)	Incident protons (per session)	Current (nA)	ID
1.00×10^6 without modulation	7.5	0	0.62 × 1010	0.99	1
	7.5	4	2.34 × 1010	3.77	2
	2.0	8	4.83 × 1010	7.78	3
	1.0	8	8.05 × 1010	12.95	4
1.08×10^6 with modulation	7.5	0	1.36 × 1010	2.19	5
	7.5	2	2.02 × 1010	3.24	6
	7.5	4	2.53 × 1010	4.07	7
	2.0	8	7.44 × 1010	11.97	8
	1.0	8	12.02 × 1010	19.34	9

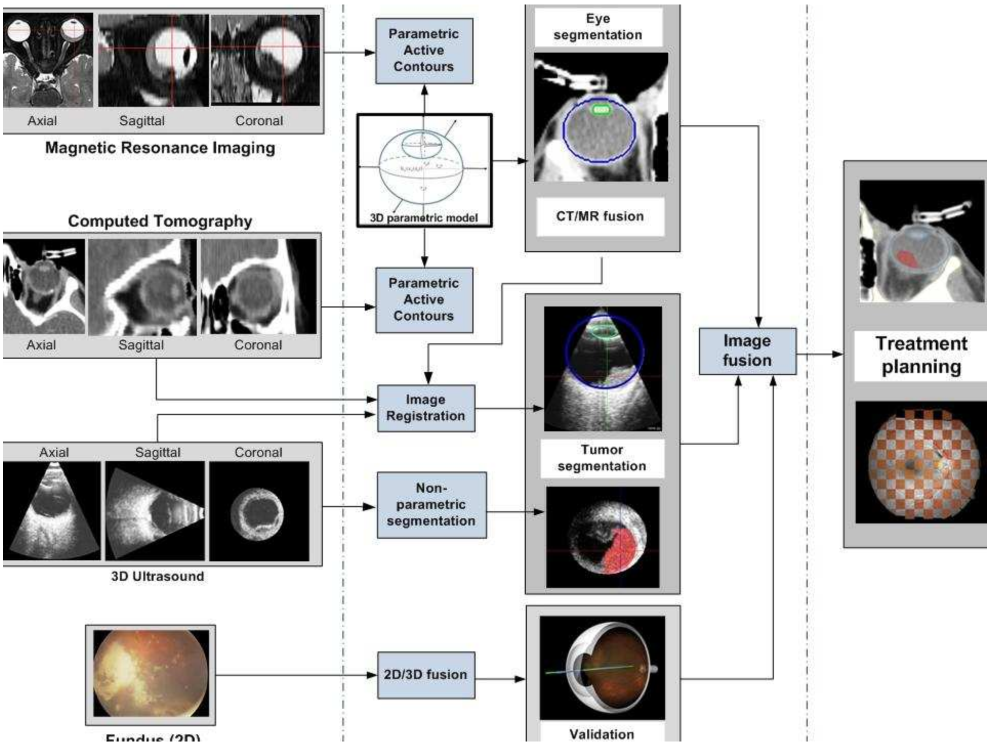

Fig. 16 – Steps for the treatment plan protontherapy eye dedicated [8].

Once a treatment plan is developed, it should adapt the beam energy especially for the treatment of the patient's eye.

A thermoplastic facial mask and an immobilizer for head position (which will be „bitten" by the patient) will be adjusted, in such manner as to immobilize the patient during the treatment. The collimator is usually adapted to the tumor characteristics.

5. MEDICAL DEPARTMENT

Clinical indications of Ocular protontherapy

Choroidal melanomas are the most common primary intraocular tumor: estimated incidence rate is approximately 6-7 new cases per million inhabitants [11].

- ❖ Ocular melanoma: including those who only partially responded to other treatments
- ❖ Melanoma of the conjunctivae
- ❖ Retinoblastoma
- ❖ Metastatic tumors in the eye

- ❖ Eye benign tumors: choroidal hemangioma and angioma
- ❖ For patients with detached retina and other eye disorders
- ❖ Age related macular degeneration.

Not everyone is a candidate for protontherapy. Imaging studies are needed and an evaluation by an eye specialist to ensure that the treatment is appropriate for each case.

Patient preparation

First, under general anesthesia, an ophthalmologist attaches small tantalum clips to the outer surface of the eye to define tumor boundaries. The patient has three to five markers attached around the base of the tumor.

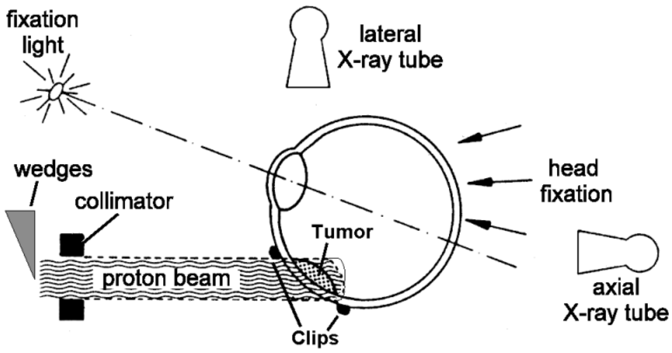

Fig. 17 – Eye protontherapy technique [11].

This helps orientation and determination of the best treatment position (using a radiology device), so that the patient can be positioned properly – the error margin must be 0.1 to 0.2 mm at most. This includes the treatment angle (the direction in which the patient will look) and the isocenter of the tumor [11].

The treatment

Because the eye is not immobilized itself, it is crucial that patient does not move the eye during treatment. However, to help the patient, room lights are off and the patient is asked to look at a flashing light to determine the position of the eye.

Normally, the patient is allowed to blink, as treatment duration is short; in order to keep it to minimum, specific treatment should be applied.

To correctly position the affected eye, the patient fixes a light point on a coordinate grid. Ahead of each radiotherapy session, the eye position is verified through radiology. Only when the position deviates less than 0.2 mm from the correct position the radiotherapy session can be performed.

Fig. 18 – Eye protontherapy technique [9].

The position of the of the eye is monitored during treatment with closed-circuit television. If for any reason the patient moves the eye, the beam is turned off to avoid damage to other parts of the eye. If the eye treated is fully blind, then the other eye can be used to fix the flashing light.

The total dose may vary for each radiotherapy center and is about 60 Gy (at 54.5 Gy in 4 Uppsala fractions; in other centers it may be 56.4 Gy). Therapeutic fractions can be single or multiple. Usually, the treatment consists of four identical treatment doses spread out over four days, with a duration of each session of approximately 30, 60 or 90 seconds. Sometimes, patients can see a blue light when a higher energy dose is used for a retrooculary tumor [8].

Patient follow up and control

Following treatment, patients receive usual care and monitoring from their doctors or by ophthalmologists carrying out inspections every six months for the rest of their life.

Secondary effects

There is a small risk of glaucoma, palpebral radiodermatitis, keratitis sicca, keratoconjunctivitis sicca or xerophthalmia (eye dryness if the lacrimal glands are hit). Loss of vision is a possibility, but errors are unlikely, because targeting the tumor is precise and neighboring tissue are protected [13].

6. CONCLUSIONS

Construction of the Cyclinac is techncally feasible at IFIN HH. Founding of a medical center for eye protontherapy at IFIN HH is possible, with the collaboration of „Carol Davila" University of Medicine and Pharmacy and the Romanian Society of Hadrontherapy, as long as financing of a feasibility plan will be accepted by the CNCS, in order to establish a theoretical basis to obtain funding from the European Community. Cooperation with specialized institutions from the EU is necessary, cooperation which SRH has already established.

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