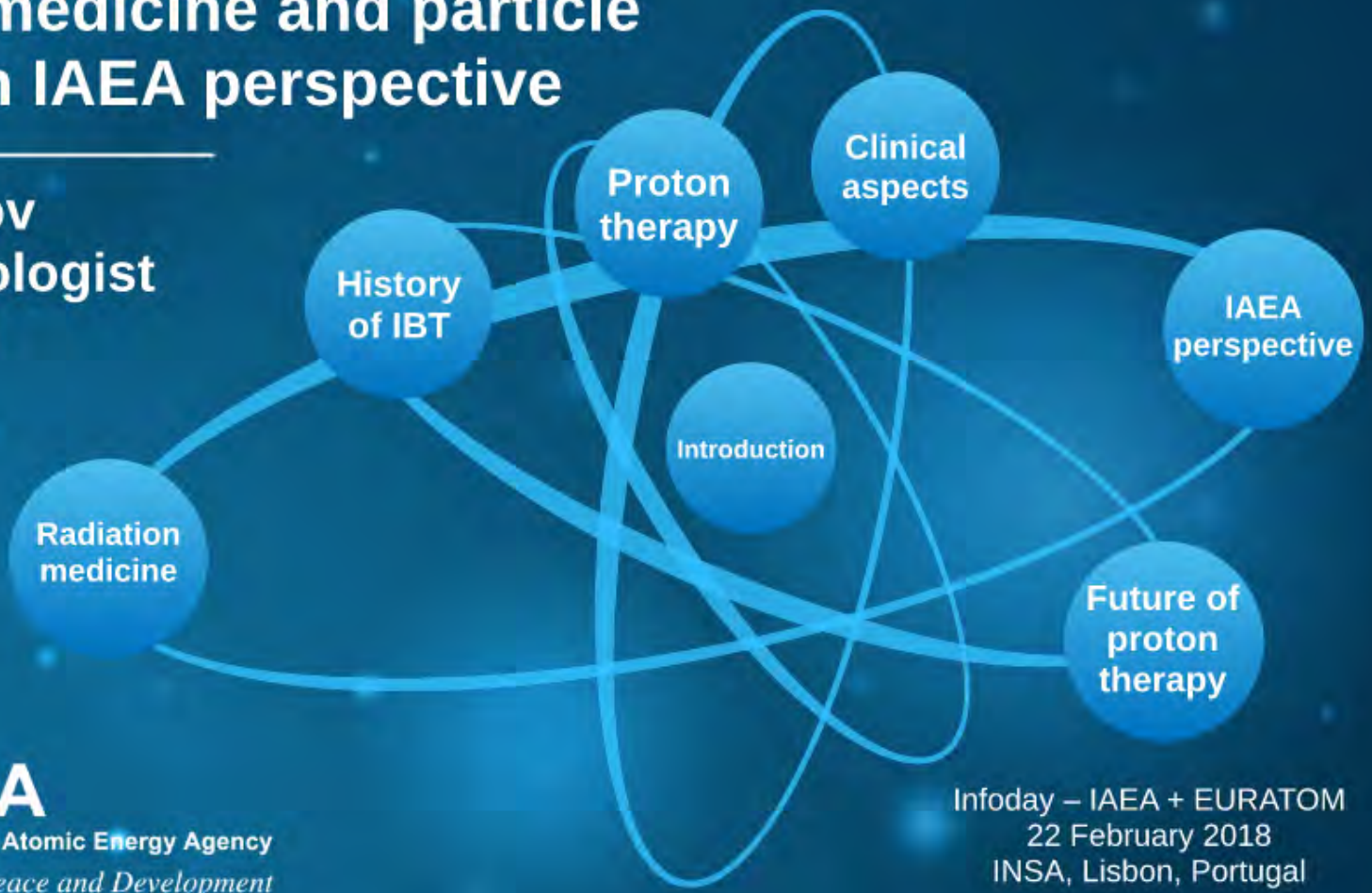
Radiation medicine and particle therapy: an IAEA perspective

Oleg Belyakov
Radiation Biologist
ARBR/NAHU
IAEA

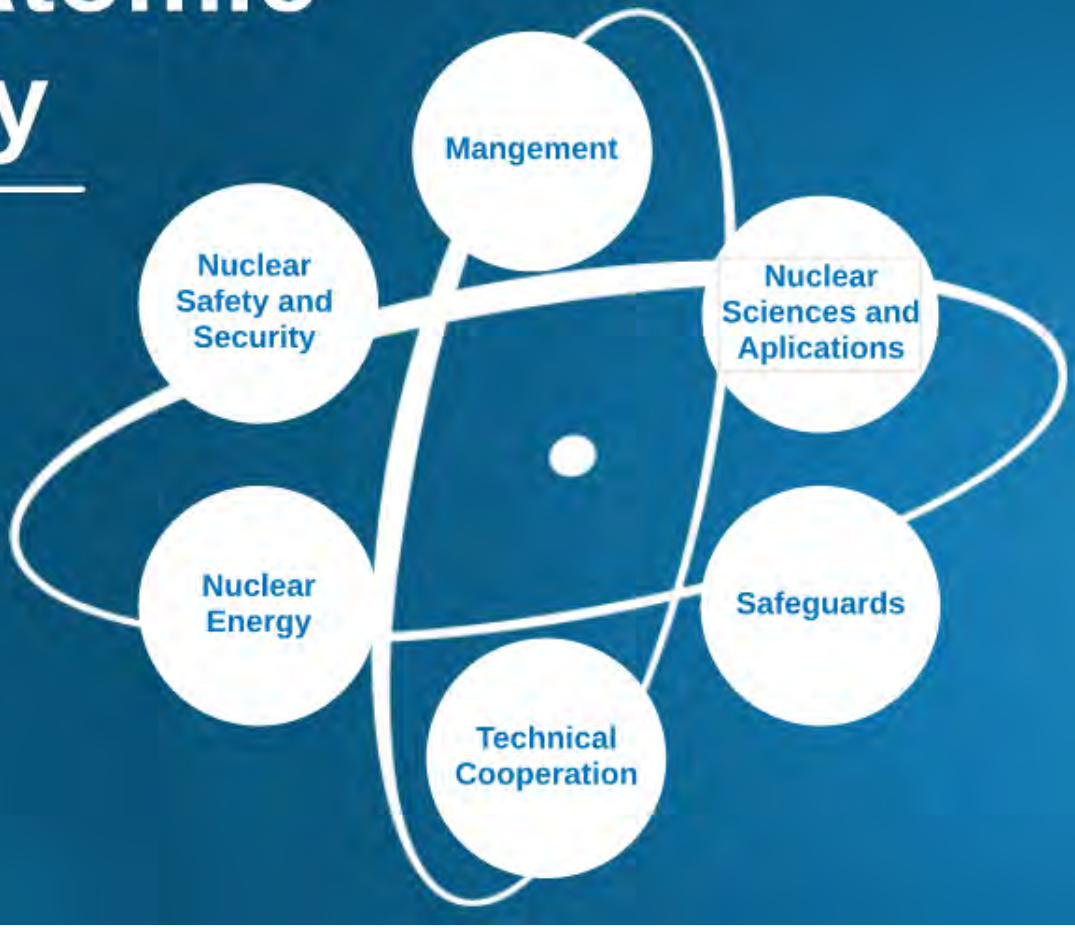


IAEA
International Atomic Energy Agency
Atoms for Peace and Development

Infoday – IAEA + EURATOM
22 February 2018
INSA, Lisbon, Portugal

International Atomic Energy Agency

- Established as an autonomous organisation on 29 July 1957
- The IAEA Statute says: “The Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world”
- Consited of 6 departments



Division of Human Health (NAHU)

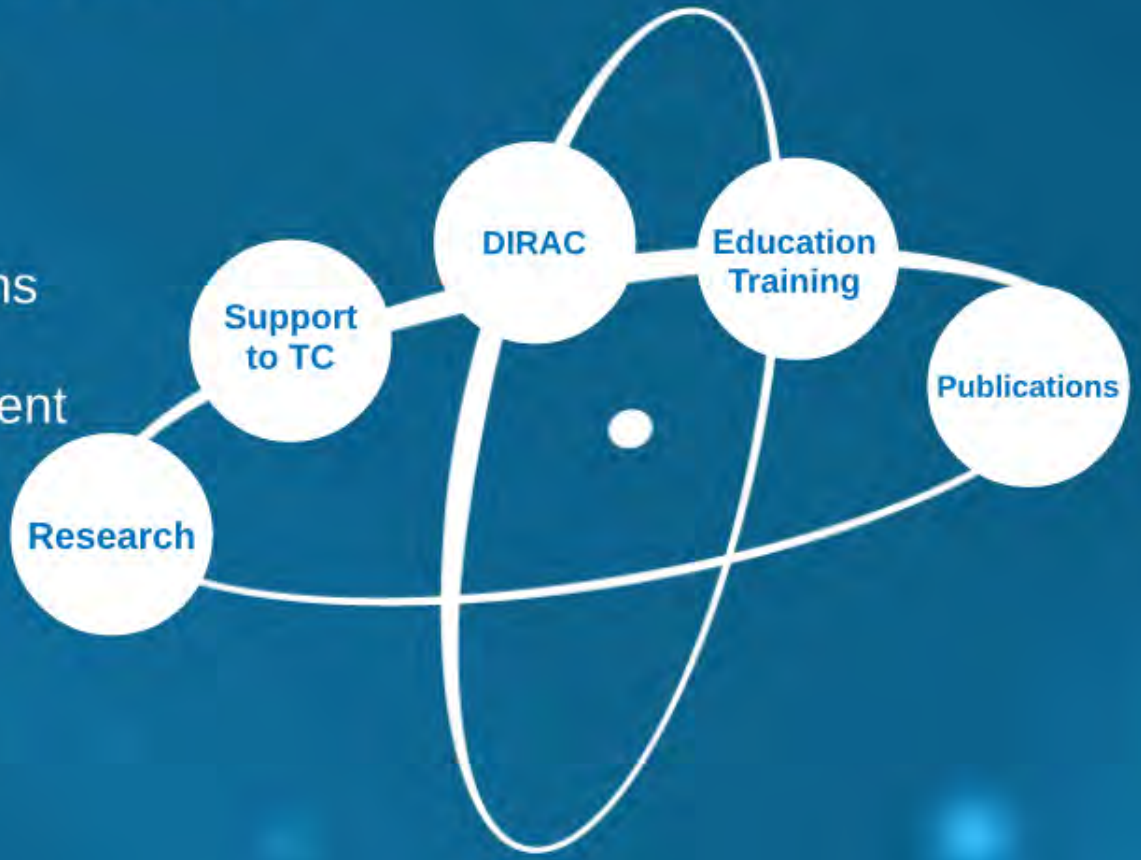
- Nuclear Medicine and Diagnostic Imaging Section
- Applied Radiation Biology and Radiotherapy Section (ARBR)
- Dosimetry and Medical Radiation Physics Section + Dosimetry Laboratory
- Nutritional and Health-Related Environmental Studies Section

https://humanhealth.iaea.org/hhw/Portfolio

Applied Radiation Biology and Radiotherapy Section (ARBR)

NAHU Radiation Medicine activites

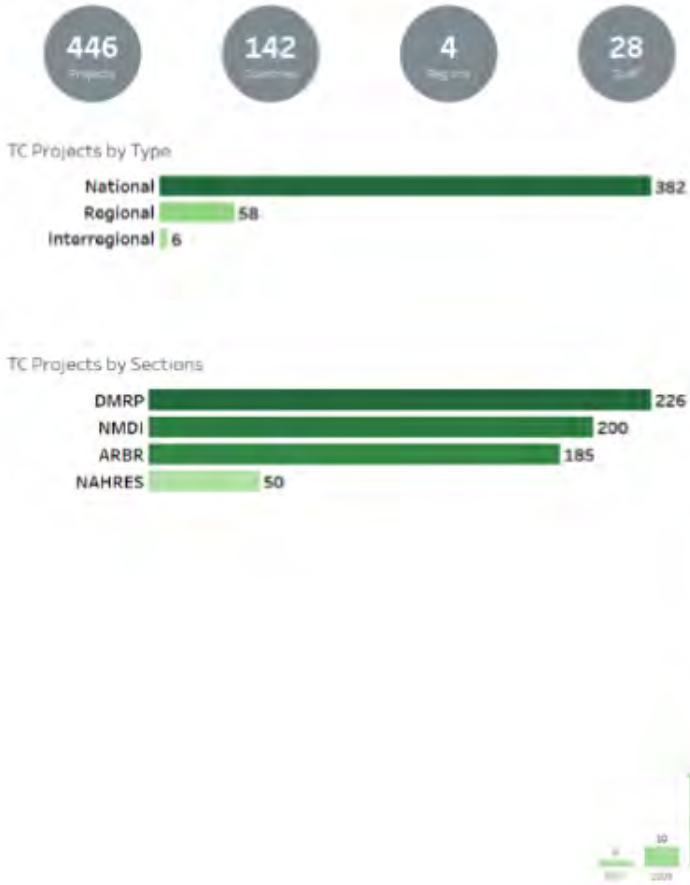
- Education
- Training
- Guidelines/Recommendations
- Quality Assurance, Improvement and Management
- Research
- Dosimetry Lab activities
- Technical Cooperation (TC) Program support
- Collaboration with other relevant organizations

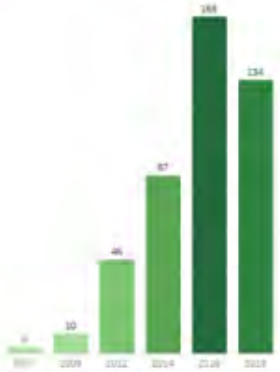


Active Coordinated Research Projects (CRPs) in NAHU

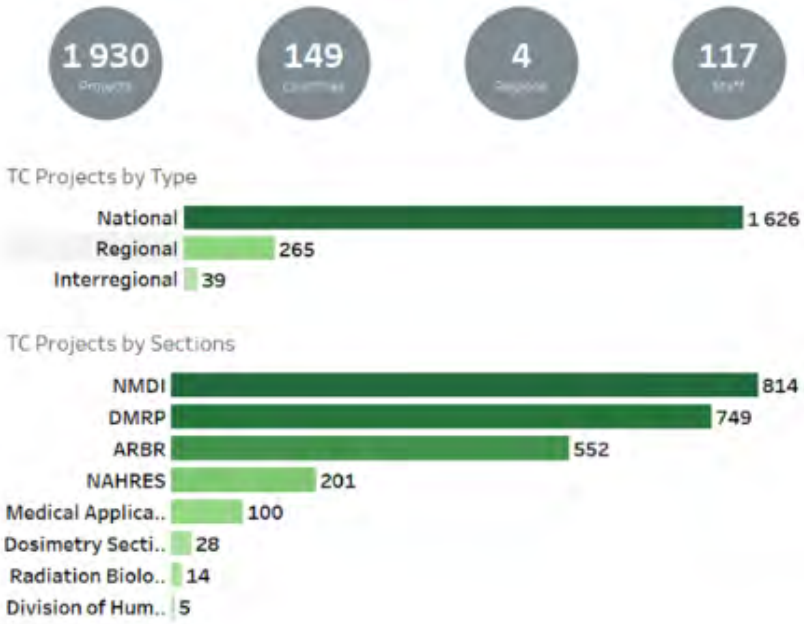
CRPs in NAHU since 1975

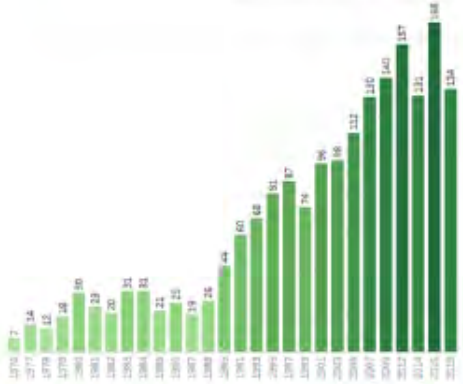
Active Technical Cooperation (TC) Projects in NAHU





TC Projects in NAHU since 1975





Status of Radiation Therapy Equipment

DIRAC (Directory of RAdiotherapy Centres)

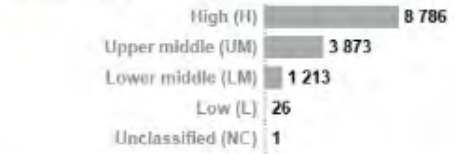
141	7 216	13 899	11 702	2 102	81	14
Countries	RT centers	Equipment	Clinical accelerator	Radionuclide teletherapy	Particle therapy	Circular accelerator

Click on equipment type, **Income groups** or **Regions** to create your own view.
Ctrl+click to select multiple

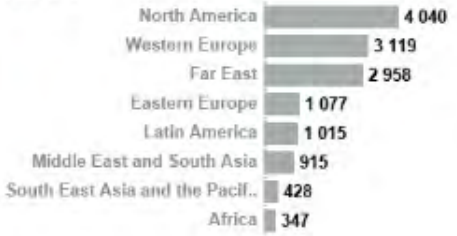
Click here

(Updated on : 2018-01-23 09:47:23)

Income groups



Regions

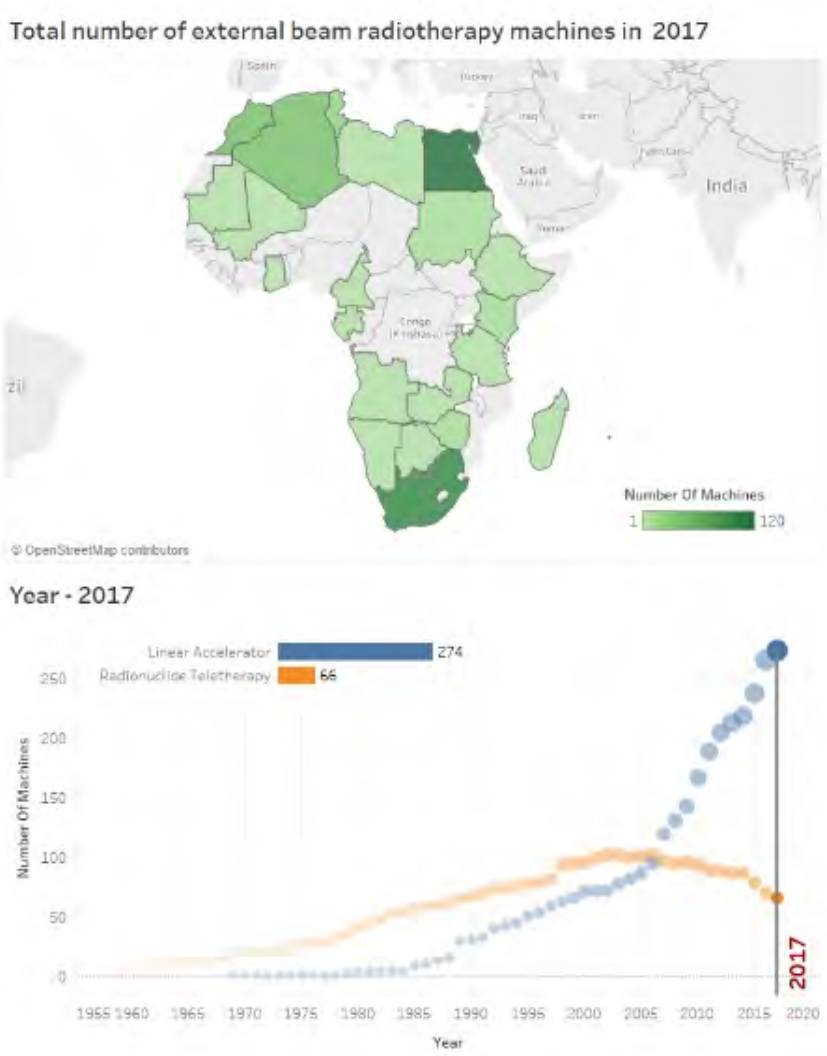


Disclaimer

DIRAC (Directory of RAdiotherapy Centres) contains data collected since 1995 on radiotherapy resources worldwide. This on-line edition is updated regularly and features the most current information available to the IAEA, based on replies to the questionnaires circulated. The IAEA makes no warranties, either expressed or implied, concerning the accuracy, completeness, reliability, or suitability of the information. The mention of names of specific companies or equipment does not imply any intention to infringe proprietary rights, nor should it be construed as an endorsement or recommendation on the part of the IAEA. Extracts from the material contained in DIRAC may be freely used provided acknowledgement of the DIRAC database is made.

Region IAEA regions

Country



Courtesy of Yaroslav Pynda, IAEA

Meetings in NAHU from 2010

488 Meetings

5 336 Participants

140 Countries

27 Host Countries

6 Conference or Symposium

263 Consultancy Meeting

25 Cooperation Meeting

3 Other Events

124 Research Coordination Meeting

41 Technical Meeting

26 Training Meeting

Number of meetings per year

MeetingType	2010	2011	2012	2013	2014	2015	2016	2017	2018
Consultancy Meeting	36	24	34	26	31	29	36	37	10
Research Coordination Meeting	14	13	17	18	11	17	12	17	5
Technical Meeting	5	6	10	6	6	3	3	2	
Cooperation Meeting	3	3	3	5	3	2	6		
Training Meeting	1	2	1	2	1	3	3	6	7
Conference or Symposium	1			1	1	1		1	1
Other Events									3

Sections

Meetings in NAHU in 2017

63 Meetings

1 003 Participants

98 Countries

3 Host Countries

1 Conference or Symposium

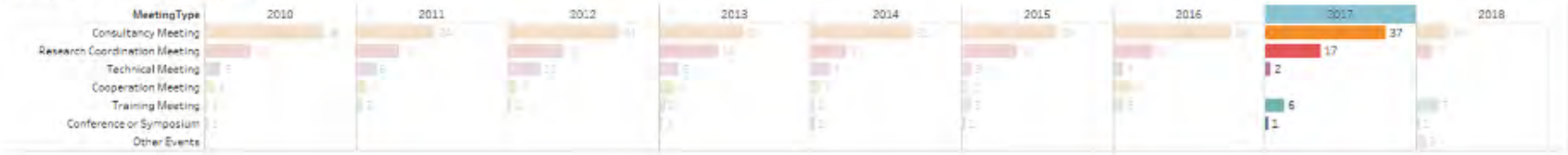
37 Consultancy Meeting

17 Research Coordination Meeting

2 Technical Meeting

6 Training Meeting

Number of meetings per year

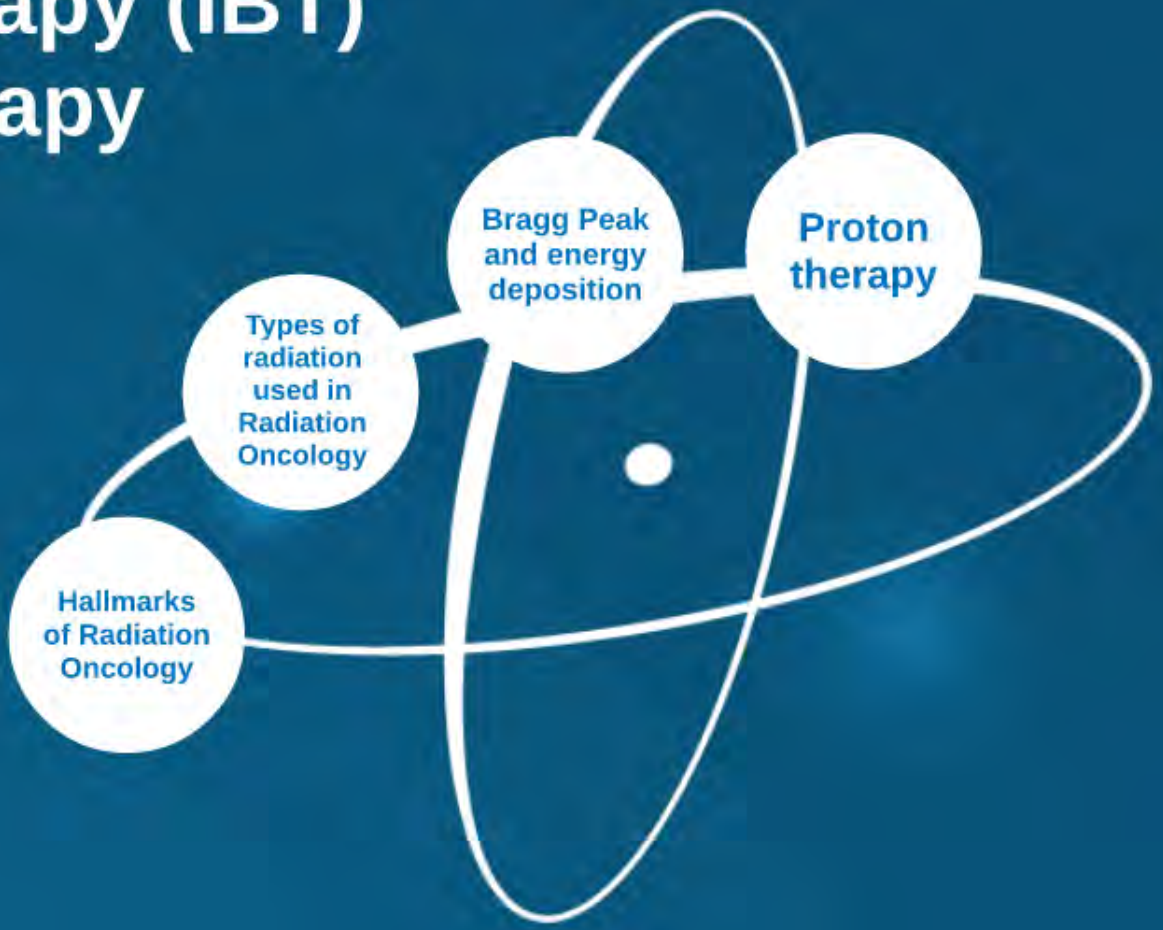


Sections


radiotherapy
radiation
medicine
health
nuclear
cancer
iaea
clinical
dosimetry
member
diagnosis
patients
treatment
therapy
states
protection
planning
isotope
countries
radiology
tomography
personnel
education
high
resonance
emission
measures
training
safety
sciences
assurance
stable
imaging
digital
dose
magnetic
computed
physicists
breast
milk
saliva
cooperation
assessment
photon
intake
beams
life
income
infants
study
roles
design
ftir
cqmp
ct
pet
low
tracers
programme
diseases
spine
rate

Ion Beam Therapy (IBT) or particle therapy

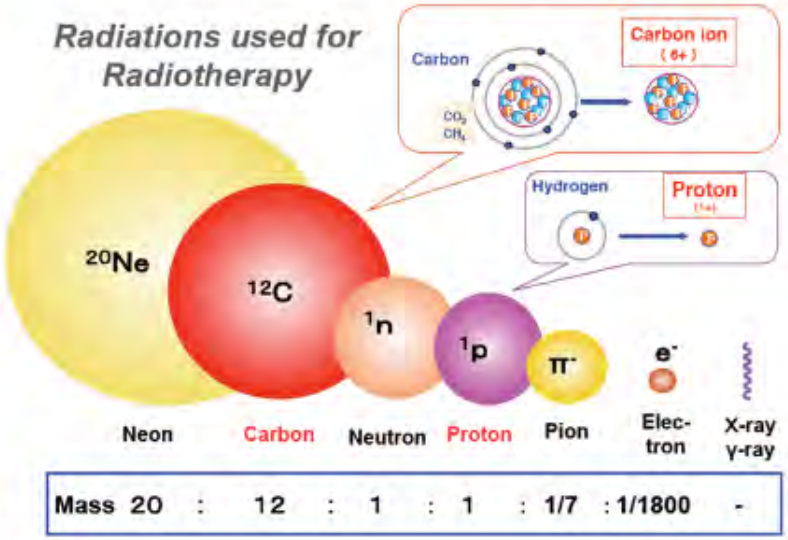
IBT is a form of external beam radiotherapy, which use beams of accelerated (typically by cyclotrons or synchrotrons) charged particles (protons, carbon ions) for cancer treatment



Hallmarks of Radiation Oncology

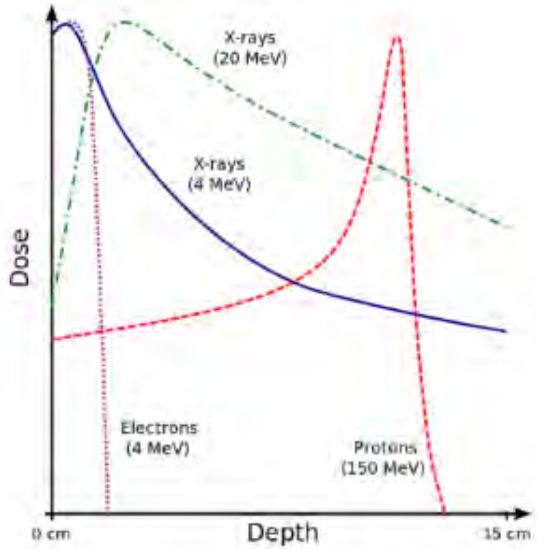
1896 – First case of radiotherapy
1920's – X-ray therapy for laryngeal cancer; radium therapy for cervical cancer
1930's – Fractionated radiotherapy by Coutard
1950's – Co-60 treatment for cancer
1954 – First patient treated with Proton (Berkeley)
1970's – Applying CT in the diagnosis and planning for radiotherapy
1977 – First patients treated with Carbon/Neon
1980's – Intensity modulated radiotherapy (IMRT)
2000's – Imaging guided radiotherapy (IGRT)

Types of radiation used in Radiation Oncology



Courtesy of Prof Jiade J. Lu, Shanghai Proton and Heavy Ion Center, China

Bragg Peak and energy deposition



Protons and other heavier charged particles, deposit energy more selectively than photons due to the “Bragg peak”

Proton therapy

Proton therapy

- has intrinsic physical properties to precisely target the tumours, reducing side effects
- has remarkable biological effects on tumour cells
- is relatively expensive

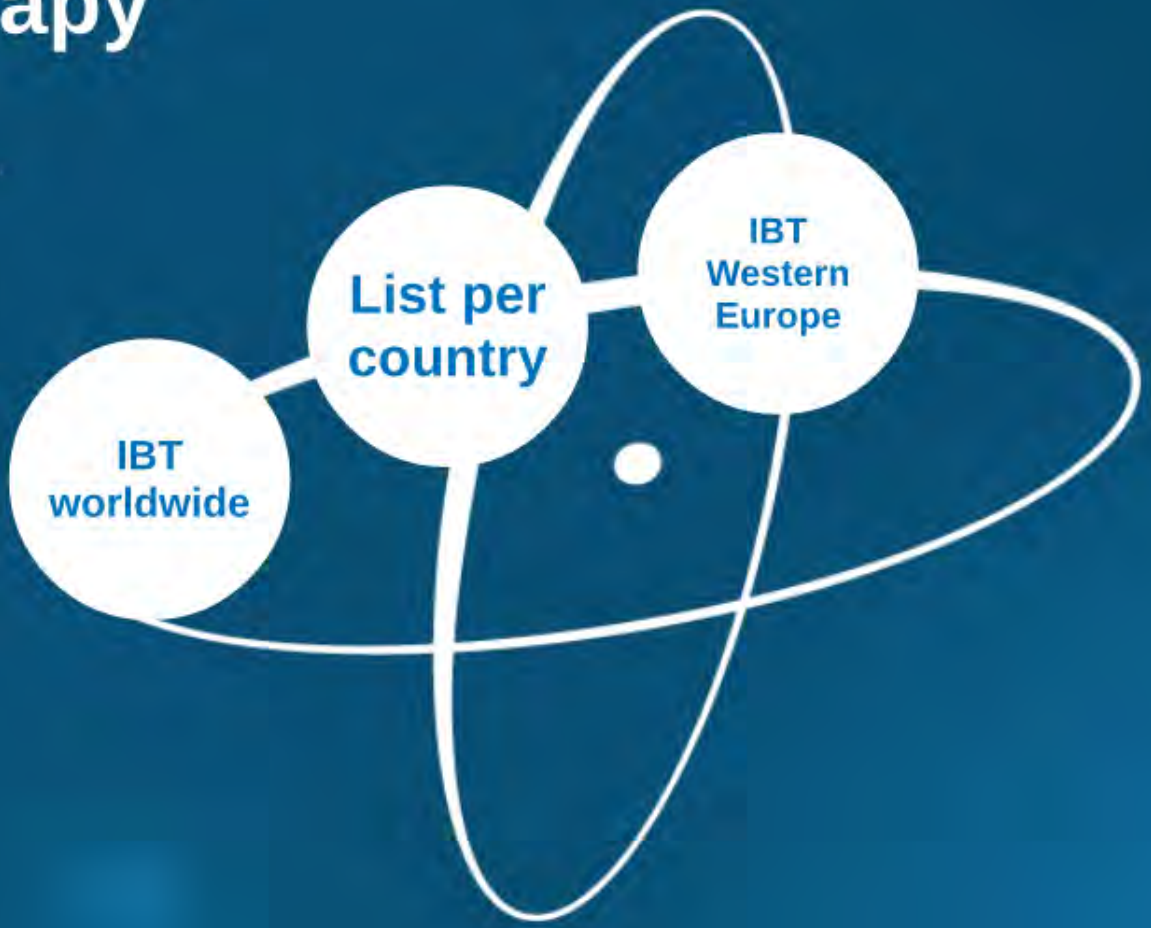
Continuously growing

- technologies development
- improved physics and biological knowledge
- extended cost/benefit and clinical outcomes analyses

Courtesy of Dr E. Cisbani, Italian National Institute of Health, Rome, Italy

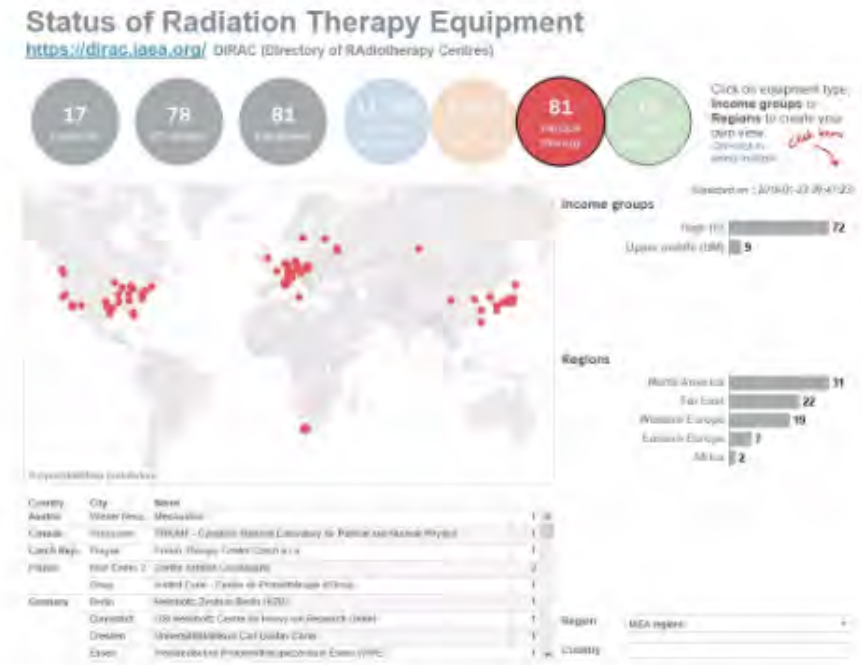
Ion Beam Therapy worldwide

DIRAC (DIrectory of RAdiotherapy Centres)
https://dirac.iaea.org/



IBT worldwide

Courtesy of Yaroslav Pynda, IAEA



Cyclotrons, Synchrotrons, Synchro Cyclotrons, etc.

Status of Radiation Therapy Equipment

https://dirac.iaea.org/ DIRAC (DIrectory of RAdiotherapy Centres)

17 Countries | 78 RT centers | 81 Equipment | 11 702 | 2 107 | 81 Particle therapy | 14

Click on equipment type, **Income groups** or **Regions** to create your own view.
Ctrl+click to select multiple
click here

(Updated on : 2018-01-23 09:47:23)

Income groups

Regions

Country	City	Name	
Austria	Wiener Neus..	MedAustron	1
Canada	Vancouver	TRIUMF - Canada's National Laboratory for Particle and Nuclear Physics	1
Czech Rep..	Prague	Proton Therapy Center Czech s.r.o.	1
France	Nice Cedex 2	Centre Antoine Lacassagne	2
	Orsay	Institut Curie - Centre de Protonthérapie d'Orsay	1
Germany	Berlin	Helmholtz-Zentrum Berlin (HZB)	1
	Darmstadt	GSI Helmholtz Centre for Heavy Ion Research GmbH	1
	Dresden	Universitätsklinikum Carl Gustav Carus	1
	Essen	Westdeutsches Protonentherapiezentrum Essen (WPE)	1

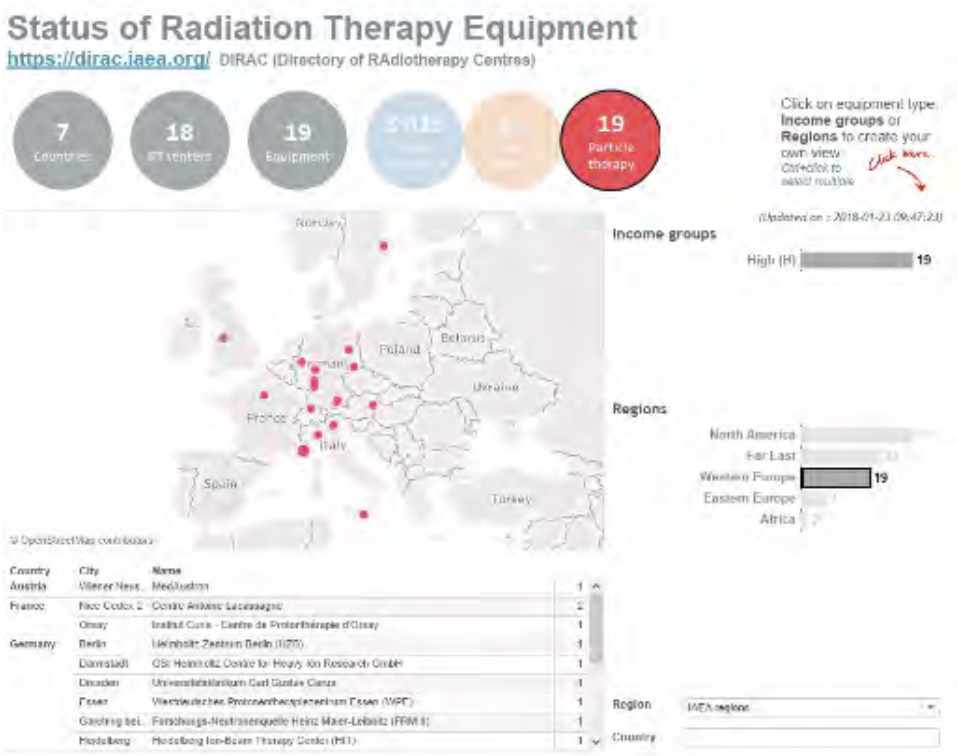
Region: IAEA regions

Country:

List per country

Austria, Wiener Neustadt, MedAustron
Canada, Vancouver, TRIUMF - Canada's National Laboratory for Particle and Nuclear Physics
Czech Republic, Prague, Proton Therapy Center Czech s.r.o.
France, Nice Cedex 2, Centre Antoine Lacassagne
France, Orsay, Institut Curie - Centre de Protonthérapie d'Orsay
Germany, Berlin, Helmholtz-Zentrum Berlin (HZB)
Germany, Darmstadt, GSI Helmholtz Centre for Heavy Ion Research GmbH
Germany, Dresden, Universitätsklinikum Carl Gustav Carus
Germany, Essen, Westdeutsches Protonentherapiezentrum Essen (WPE)
Germany, Garching bei München, Forschungs-Neutronenquelle Heinz Maier-Leibnitz (FRM II)
Germany, Heidelberg, Heidelberg Ion-Beam Therapy Center (HIT)
Germany, Marburg an der Lahn, Marburger Ionenstrahltherapie-Zentrum
Germany, München, Rinecker Proton Therapy Center
Italy, Catania, Centro di Protonterapia CATANA (Centro di AdroTerapia ed Applicazioni Nucleari Avanzate)
Italy, Pavia, Fondazione CNAO (National Centre of Oncological Hadrontherapy)
Italy, Trento, Agenzia Provinciale Per la Protonterapia (ATreP)
Japan, Chiba-shi, National Institute of Radiological Sciences (HIMAC), Research Center of Charged Particles
Japan, Fukui-shi, Fukui Prefectural Hospital
Japan, Ibusuki-shi, Medipolis Proton Therapy and Research Center (MPTRC)
Japan, Kashiwa-shi, National Cancer Center Hospital East
Japan, Koriyama-shi, Southern TOHOKU Proton Therapy Center
Japan, Maebashi-shi, Gunma University Heavy Ion Medical Center
Japan, Matsumoto-shi, Aizawa Hospital
Japan, Nagaizumi-shi, Shizuoka Cancer Center
Japan, Nagoya-shi, Nagoya Proton Therapy Center
Japan, Okayama-ken, Tsuyama Chuo Hospital Okayama University Proton Beam
Japan, Sapporo, Hokkaido Prefecture, Hokkaido University Hospital PBTC
Japan, Tatsuno-shi, Hyogo Ion Beam Medical Center
Japan, Tosu-shi, SAGA HIMAT – Heavy Ion Cancer Treatment Center
Japan, Tsukuba, Proton Medical Research Center (PMRC), University of Tsukuba
Japan, Tsuruga-shi, The Wakasa Wan Energy Reseach Center
Japan, Yokohama-shi, i-ROCK (ion-beam Radiation Oncology Center in Kanagawa)
People's Republic of China, Lanzhou Shi, Heavy Ion Research Facility in Lanzhou (HIRFL)
People's Republic of China, Shanghai City, Shanghai Proton and Heavy Ion Center (SPHIC)
People's Republic of China, Zibo City, Wanjie Proton Therapy Center (WPTC)
Poland, Krakow, Bronowice Cyclotron Center
Republic of Korea, Goyang, National Cancer Center
Republic of Korea, Seoul, Samsung Medical Centre
Russian Federation, Dubna, Joint Institute for Nuclear Research (JINR)
Russian Federation, Gatchina, Petersburg Nuclear Physics Institute Synchrocyclotron (PNPI)
Russian Federation, Moscow, Institute of Theoretical and Experimental Physics (ITEP)
Russian Federation, Tomsk, Tomsk Cancer Research Institute
South Africa, Faure, iThemba Laboratory for Accelerator Based Sciences (L.A.B.S.)
Sweden, Uppsala, Skandion Clinic
Switzerland, Villigen, Paul Scherrer Institute
Taiwan (China), Taoyuan, Chang Gung Memorial Hospital - LinKou
United Kingdom, Merseyside, Clatterbridge Cancer Centre NHS Foundation Trust
United States of America, Baltimore, Maryland Proton Treatment Center
United States of America, Boston, Massachusetts General Hospital Burr Proton Therapy Center
United States of America, Cleveland, University Hospitals - Seidman Cancer Center - Proton
United States of America, Dallas, Texas Center for Proton Therapy - Irving
United States of America, Detroit, Karmanos Cancer Institute - Wayne State University
United States of America, Hampton, Hampton University - Proton Therapy Institute
United States of America, Houston, M D Anderson Proton Center
United States of America, Jacksonville, Ackerman Cancer Center - Proton
United States of America, Jacksonville, Univ of Florida Proton Therapy Institute
United States of America, Knoxville, Provision Center for Proton Therapy
United States of America, Liberty Township, Cincinnati Children's Proton Therapy Center
United States of America, Loma Linda, J. Slater PTC, Loma Linda
United States of America, Memphis, St. Jude Children's Research Hospital-Proton
United States of America, New Brunswick, Robert Wood Johnson Univ. Hosp. - Proton
United States of America, Oklahoma City, ProCure Proton Therapy Center - Oklahoma
United States of America, Oklahoma City, University of Oklahoma HSC - Proton
United States of America, Orlando, University of Florida Health Proton - Orlando
United States of America, Philadelphia, Perelman Center for Advanced Medicine (proton center)
United States of America, Phoenix, Mayo Clinic Arizona - Proton
United States of America, Rochester, Mayo Clinic Rochester - Proton
United States of America, Royal Oak, William Beaumont Hospital
United States of America, Sacramento, UC Davis Health System - Proton Eye Center
United States of America, San Diego, Scripps Proton Therapy Center
United States of America, San Francisco, UCSF-Long Hospital
United States of America, Seattle, SCCA Proton Therapy Center - Procure Ctr
United States of America, Seattle, Univ of Washington Medical Center
United States of America, Shreveport, Willis-Knighton Cancer Center - Proton
United States of America, Somerset, ProCure Proton Therapy Center - New Jersey
United States of America, St Louis, Barnes-Jewish Hospital/Washington University
United States of America, Warrenville, ProCure CDH Proton Center

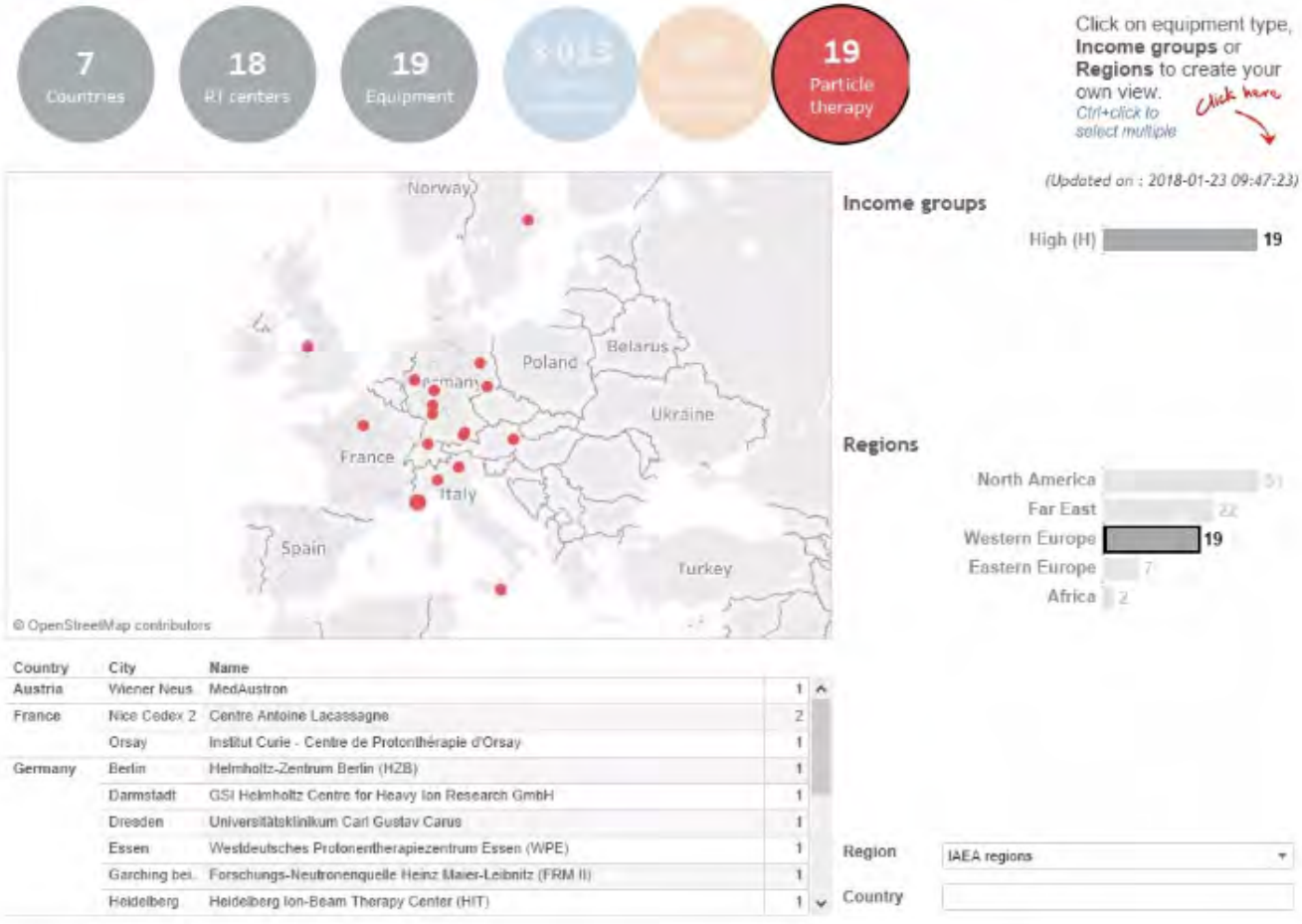
IBT Western Europe



Courtesy of Yaroslav Pynda, IAEA

Status of Radiation Therapy Equipment

https://dirac.iaea.org/ DIRAC (DIrectory of RAdiotherapy Centres)

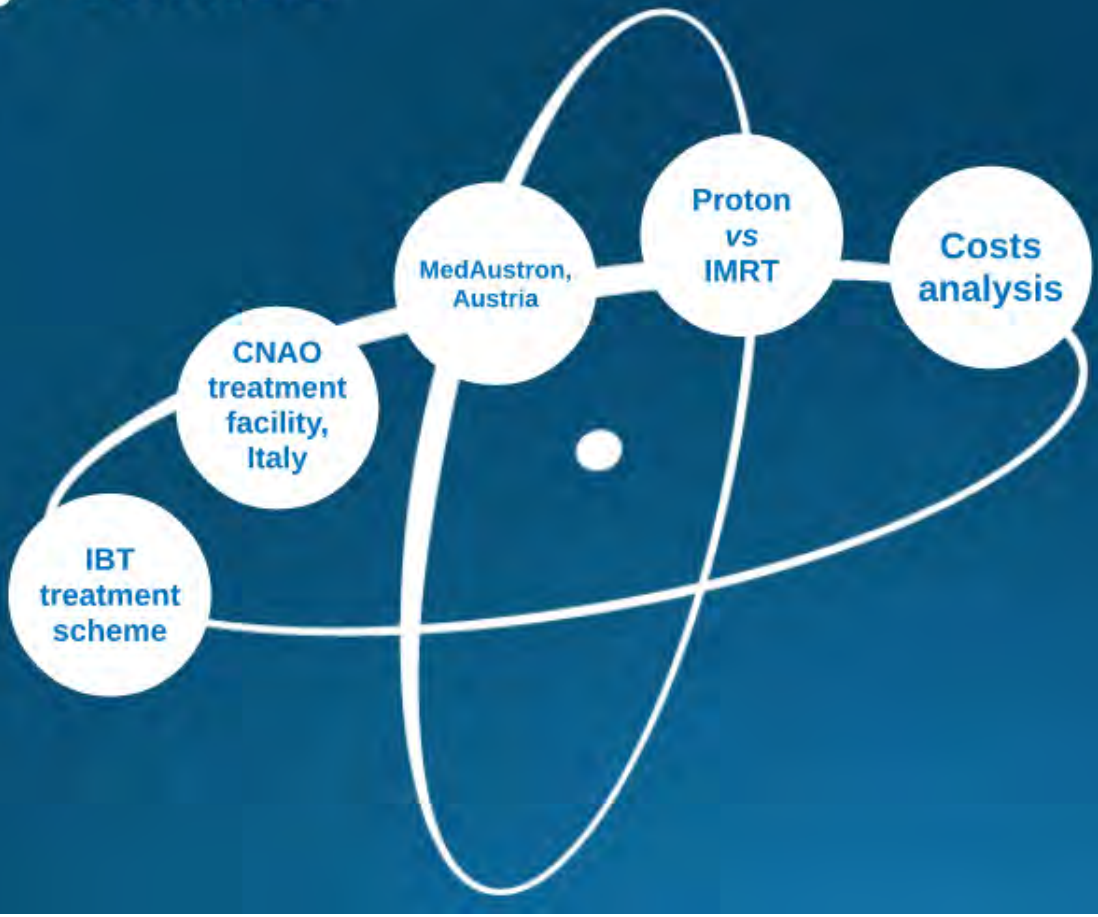


Country	City	Name	
Austria	Wiener Neus	MedAustron	1
France	Nice Cedex 2	Centre Antoine Lacassagne	2
	Orsay	Institut Curie - Centre de Protonthérapie d'Orsay	1
Germany	Berlin	Helmholtz-Zentrum Berlin (HZB)	1
	Darmstadt	GSI Helmholtz Centre for Heavy Ion Research GmbH	1
	Dresden	Universitätsklinikum Carl Gustav Carus	1
	Essen	Westdeutsches Protonentherapiezentrum Essen (WPE)	1
	Garching bei...	Forschungs-Neutronenquelle Heinz Maier-Leibnitz (FRM II)	1
	Heidelberg	Heidelberg Ion-Beam Therapy Center (HIT)	1

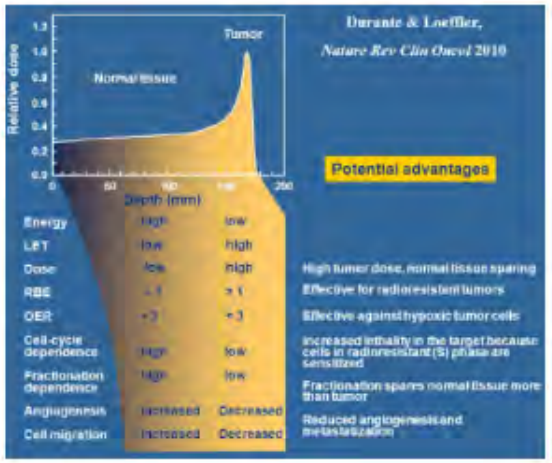
Courtesy

Physics-Biology-Clinics Interplay

Clinical outcomes depend on how well we know and control the physics and the biological processes involved in the Ion Beam Therapy and how we make them happen



IBT treatment scheme



Patient Preparation
- CT (PET) imaging
- Positioning/ Alignment
- Immobilization
- Treatment Planning

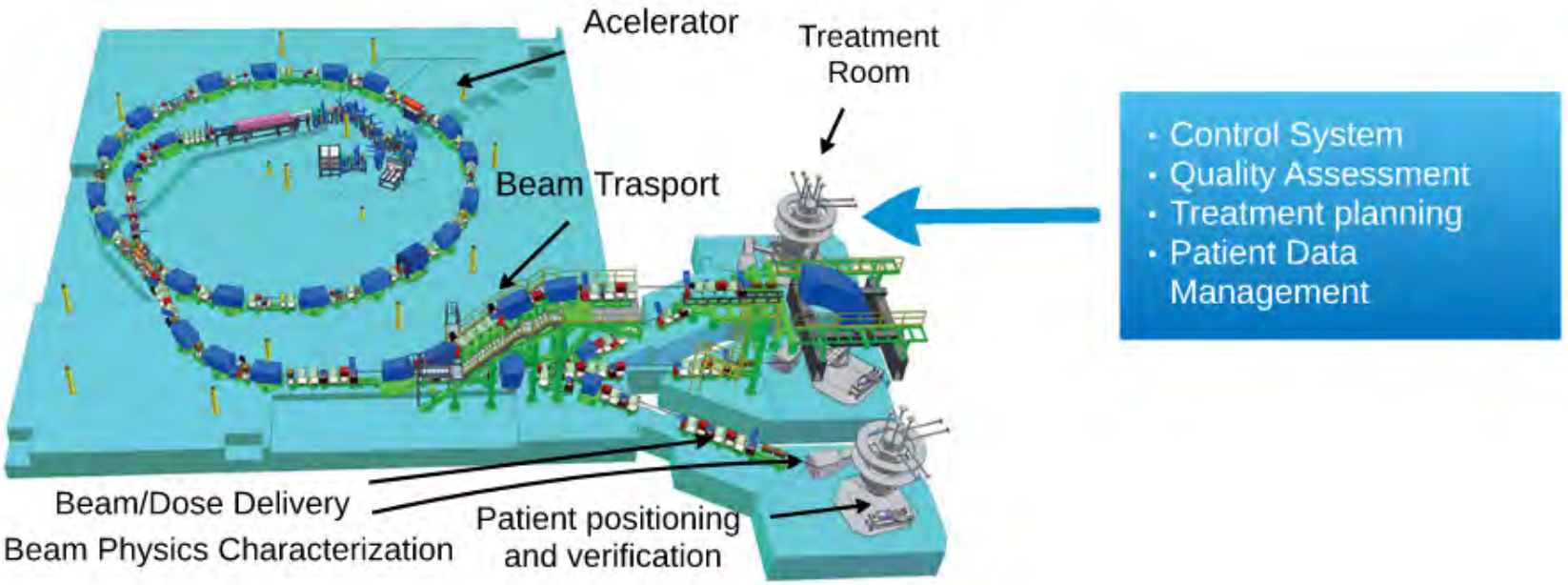
Treatment
- Continuous monitoring
- Stop at prescribed dose

Assessment
- On-line
- Offline imaging

Machine
- Design and construction
- Daily quality checks

Adopted from Dr E Cisbani, Italian National Institute of Health, Rome, Italy

CNAO treatment facility, Italy

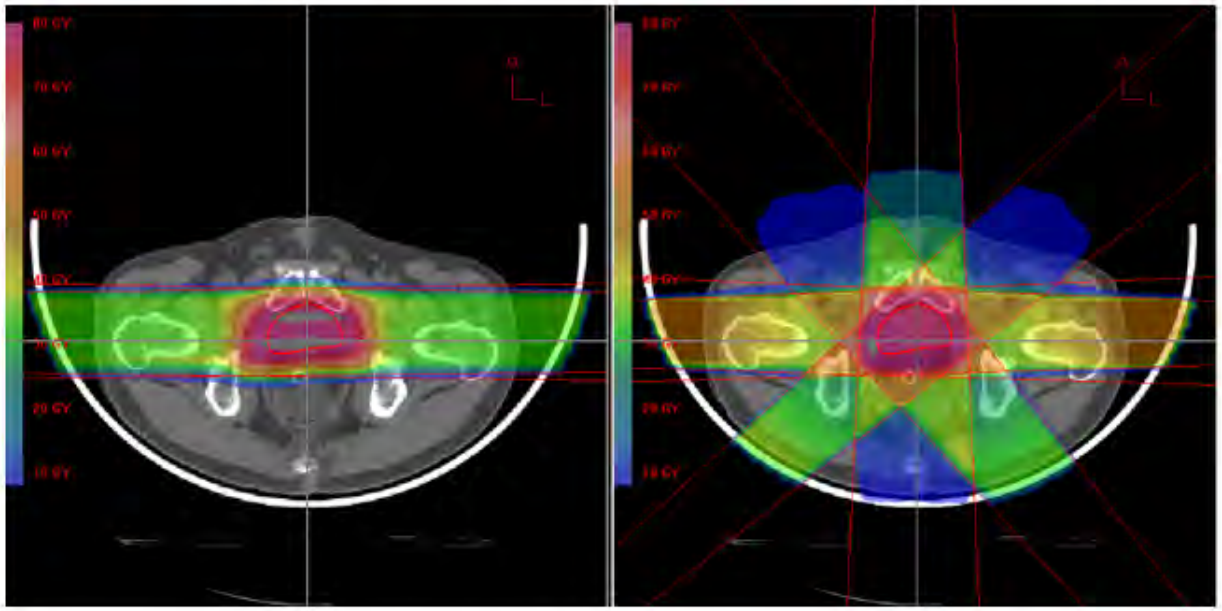


Courtesy of Dr E. Cisbani, Italian National Institute of Health, Rome, Italy

MedAustron, Austria

MedAustron, the centre for ion therapy and research is located in Wiener Neustadt in Lower Austria, about 50 kilometres south of Vienna started treatment cancer patients with protons in 2016

Proton *vs* Intensity-Modulated Radiation Therapy – Prostate Cancer

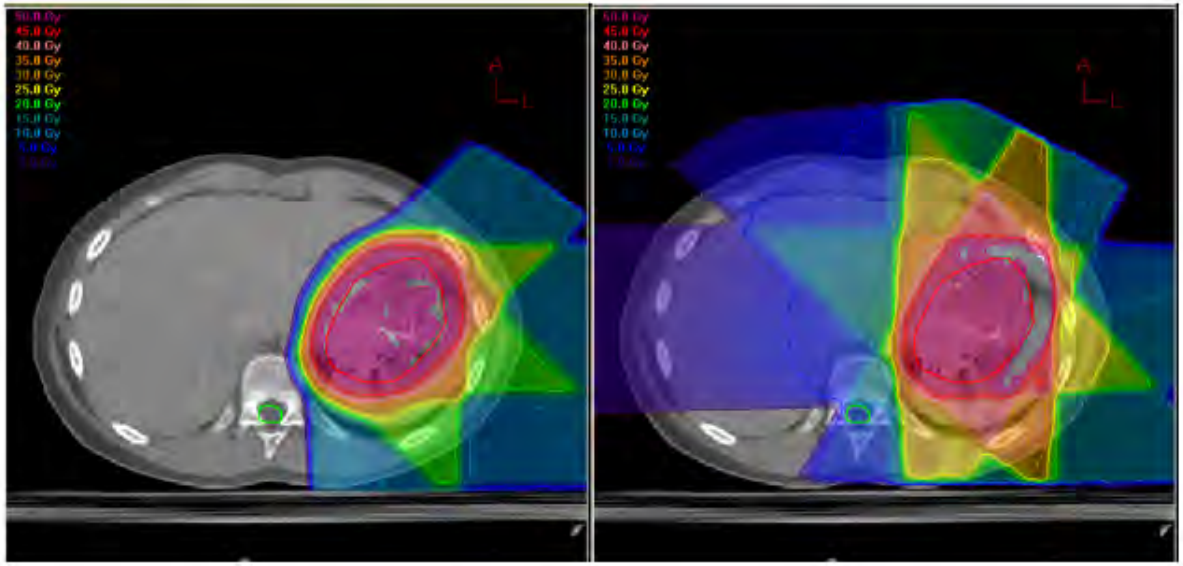


Courtesy of Prof Jiade J Lu, Shanghai Proton and Heavy Ion Center, China

- ratio of integral dose to body outside target = 1.81
- ratio of volume of body outside target receiving > 2 Gy = 2.59

Proton *vs* Intensity-Modulated Radiation Therapy – Chest Tumour

Courtesy of Prof Jiade J Lu, Shanghai Proton and Heavy Ion Center, China



- ratio of integral dose to body outside target = 1.76
- ratio of volume of body outside target receiving > 2 Gy = 2.47

Costs analysis

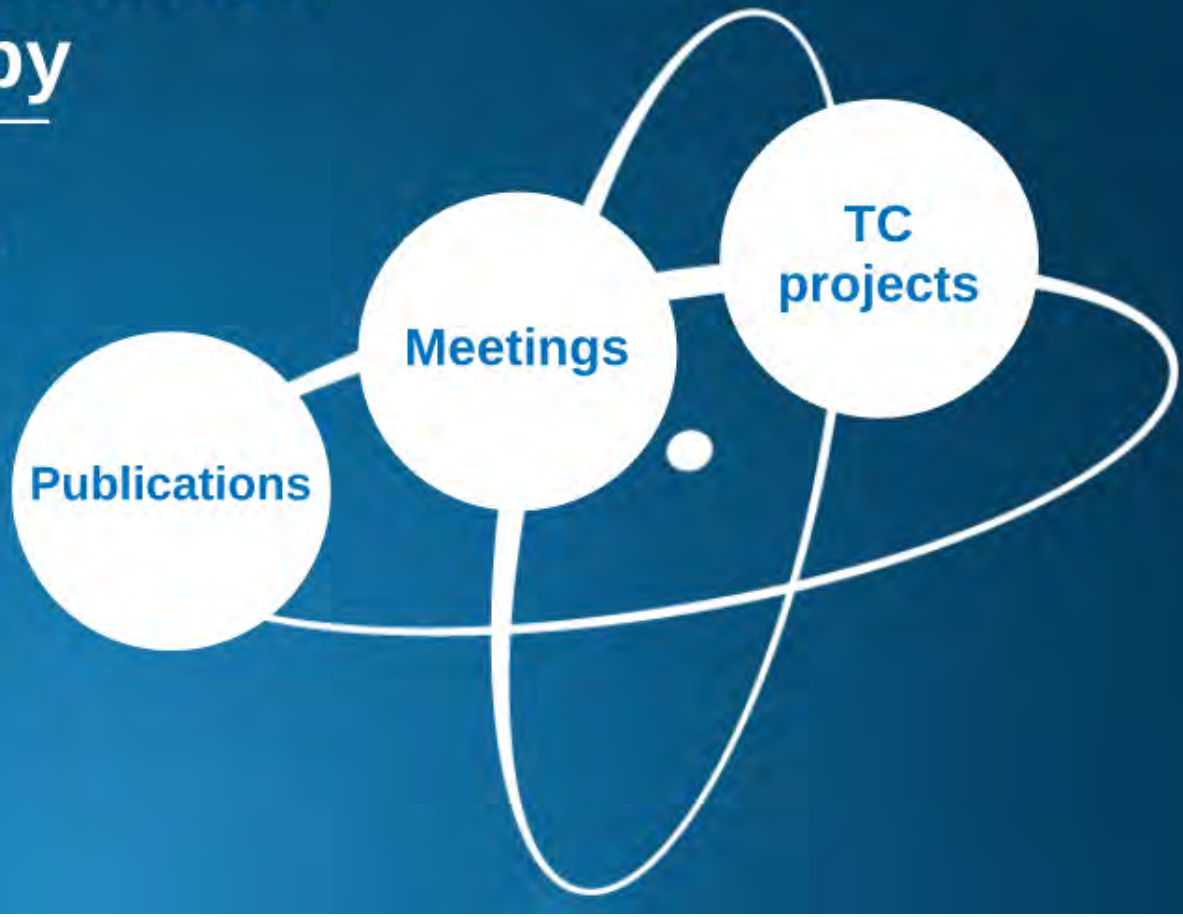
Costs (Euro)	Capital	Operation/year	Fraction	Treatment
Carbon + Proton	140 000 000	37 000 000	1.1000	10 000 - 30 000
Proton	95 000 000	25 000 000	700	12 000 – 39 000
Photon	23 000 000	10 000 000	200	4 000 - 18 000

Surgery: 14 000 - 57 000 USD, Pharmacologic: 1 000 - 120 000 USD
Cost/treatment strongly depends on tumor and modality

Adapted from A. Peeters et al., Rad. & Onc. 95 (2010) 45-53

IAEA initiatives in Ion Beam Therapy

- Publications
- Scientific meetings
- Technical cooperation projects in member states requesting assistance



IAEA publications related to IBT

- Dose Reporting in Ion Beam Therapy, Proceedings of a Meeting Organized Jointly by the IAEA and the ICRU held in Ohio, USA, 18–20 March 2006, IAEA TECDOC No. 1560
- International Commission on Radiation Units and Measurements Report 78, J ICRU 2007;7(2), Oxford University Press, Oxford, 2007
- Relative Biological Effectiveness in Ion Beam Therapy, IAEA Technical Reports Series No. 461, 2008

Consultants Meeting on Particle Therapy in the 21st Century

- IAEA Consultants Meeting on Particle Therapy in the 21st Century, with particular attention to middle and low income countries, took place from 11-14 November 2014
- It was organised to discuss the state of the art of IBT and future trends in the development of this fast growing field
- The report “Particle Therapy in the 21st Century: Relevance to Developing Countries” was produced, it is available at NAHU “Human Health Campus”, humanhealth.iaea.org

February 2015 issue of CERN / ENLIGHT HIGHLIGHTS

IAEA CONSULTANTS MEETING on Particle Therapy in the 21st Century:

Relevance to Developing Countries, IAEA headquarters, Vienna, Austria
by Oleg BELYAKOV, International Atomic Energy Agency

An International Atomic Energy Agency (IAEA) Consultants Meeting on Particle Therapy with particular attention to middle and low income countries took place on 11-14 November 2014. It was organised by the Section of Applied Radiation Biology and Radiotherapy (ARBR). The meeting brought together 11 experts from IAEA, CERN, Austria, Belgium, France, Germany, Italy, Japan, and USA to discuss the state of the art of light ion therapy and future trends in the development of this fast growing field.

The meeting was opened by the Director of the IAEA Division of Human Health Imaad Wahab and the Head of Dosimetry and Medical Radiation Physics Section Ahmed Meghzifene.

The first part of the meeting was devoted to physical (Alejandro Mazal, France) and radiobiological aspects of particle therapy (Oleg Belyakov, IAEA), implementation of light ion beam therapy facilities (Stan Vatnitsky, MedAustron, Austria), clinical and operational aspects of proton beam delivery (Zelig Tochner, USA), epidemiology of ion beam therapy (Ramona Mayer, MedAustron, Austria) and evolving role of proton therapy for paediatric patients (Anita Mahajan, USA). It was followed by a report on recent progress in carbon ion radiotherapy by Kumiko Kanasawa from the National Institute of Radiological Sciences (NIRS), Chiba, Japan with particular attention to treatment of bone and soft tissue sarcomas (Reiko Imai, IAEA/NIRS). The current status of carbon ion radiotherapy in Gunma University, Japan was reviewed by Hiroyuki Katoh. Discussion on the potential role of high LET particle therapy in the multidisciplinary cancer care system led by Piero Fossati, Italy, who revealed the need for cooperative research and planned structural investments. The topic of current challenges in particle beam therapy in Germany, it terms of perspectives for radiation oncology (Beate Timmerman), finalised the first day of the meeting.

During the second day the history and the future of proton therapy was elaborated by Yves Jongen, Chief Research Officer of the IBA. It was highlighted that, contrary to common opinion, the modern proton accelerator is not the most expensive part of the treatment system. The gantry and treatment room equipment would be a major investment. Manjit Dosanjh reported the progress of CERN and the ENLIGHT programme for particle therapy in Europe highlighting an urgent need for establishing the international radiobiological laboratory to identify areas of potential breakthrough in light ion radiotherapy, i.e. specific tumours, fractionation schedules and combined treatments. Mr. Eduardo Rosenblatt, head of ARBR section, paid a special attention to costs of particle therapy treatment and the value for money invested. It was mentioned that proton and carbon therapy offers clear clinical advantages compared with conventional photon radiation therapy (IMRT, IGRT, SBRT) for a number of cancer types. Arguably, this is the only option for many complex cases. However, it is associated with higher investment and there is a need to find a balance between costs and clinical benefits. Therefore, the value of light particle therapy for low and middle income countries should be considered on a case-by-case basis.

The following two and half days were devoted to in depth discussion and report writing. The main subjects of discussions were indications for particle therapy; patient selection; clinical trials and methodological issues connected to that; carbon ion radiotherapy dose prescription recording and reporting; dosimetry and commissioning of particle therapy facilities; present and future of compact accelerators; carbon ion treatment concomitant with systemic and specific targeted therapy; health economy issues and relevance to developing countries; how to link particle facilities to referral networks. Finally, the issue of development and maintenance of platforms to share clinical data, registries and surveys were discussed. It was highlighted that a shared patient database for carbon ion toxicity and common validation of specific dose constraints are needed. Training and education in particle therapy was identified as the major need to foster development of the field.

IAEA plans to continue activities related to the light ion therapy. A Technical Meeting on Radiobiology of Charged Particle Therapy is planned in November 2015 at IAEA headquarters in Vienna.

Proceedings paper, main conclusions

- Particle therapy requires considerable financial investment, as well as physics and clinical expertise
- Validation of the existing technology and techniques can be achieved in a reasonable timeframe, if multicenter collaboration is implemented worldwide
- The cost of particle therapy will decrease and access for appropriately selected patients will increase worldwide, including in low and middle income countries

Rosenblatt, E., A. Meghzifene, O. Belyakov and M. Abdel-Wahab (2016). "Relevance of Particle Therapy to Developing Countries." Int J Radiat Oncol Biol Phys 95(1): 25-29.

Technical Meeting on the Radiobiology of Charged Particle Therapy

IAEA HQ, Vienna, Austria, 11-13 November 2015

Highlights of the meeting

- The main purpose of the meeting was to discuss radiation biology implications and issues for the design of ion beam therapy (IBT) clinical trials
- Not much is known about radiobiological mechanisms behind IBT
- Clinical trials comparing different modalities of IBT and photon therapy are needed
- Meeting report was published at NAHU “Human Health Campus”, humanhealth.iaea.org, the paper is pending
- The future activities will be related to monitoring of advances in IBT
- Consultants meeting is planned in 2019 to formulate a new CRP in 2020-2021

Future directions

- Also IBT is not considered as a high priority topic for NAHU/ ARBR, NAHU will continue monitoring of the progress in the field
- Continue to response to IAEA Member States (MSs) requests related to IBT: a number of Low and Middle Income Countries (LMIC) are in process of consideration, planning and implementation: Argentina, Thailand, India etc.
- Possibly a new IAEA CRP on IBT radiobiology and/or clinical trials will be implemented
- IAEA plans to continue collaboration with CERN related to OPENMED project

IAEA Department of Technical Cooperation projects related to IBT

- Argentina - ARG6015 Developing Human Resource Capabilities in the Area of Advanced Radiotherapy 2014, active
- Portugal - POR6005 Ongoing Supporting Multidisciplinary Research and Clinical Cyclotron Facility, 2014, active
- Singapore - SIN6005 Building up Expertise and Capability in the Application of Proton Therapy 2016, active
- Thailand - THA6040 Developing Human Resources for the National Proton Therapy Centre in Thailand, 2016, active

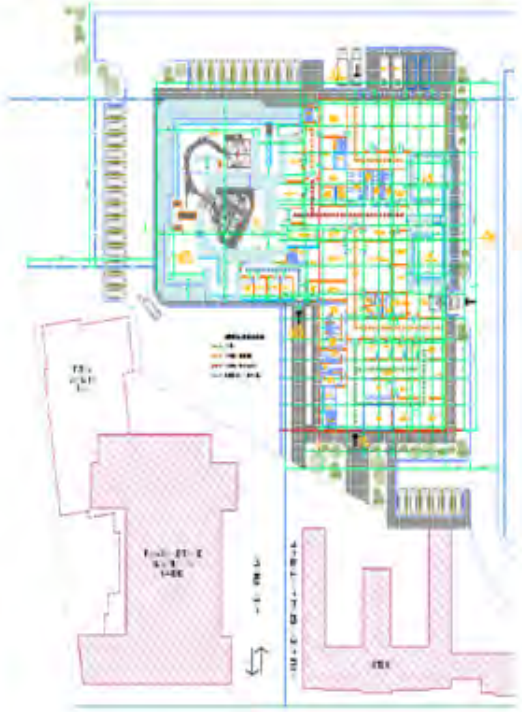
THA6040 Developing Human Resources for the National Proton Therapy Centre in Thailand

Projects	Fellows	Technical officers	Home countries	Host countries
1	9	4	1	4

In the framework of THA6040 9 fellows were trained in Austria, Singapore, South Korea and Japan

Argentina - ARG6015 Developing Human Resource Capabilities in the Area of Advanced Radiotherapy

- Proton Therapy and Advanced Radiotherapy Center
- Proteus Plus IBA, sincrociclotron protons AC230, Gantry 360º
- Planning: CT, RMN, PET-CT
- Cyberknife
- Versa

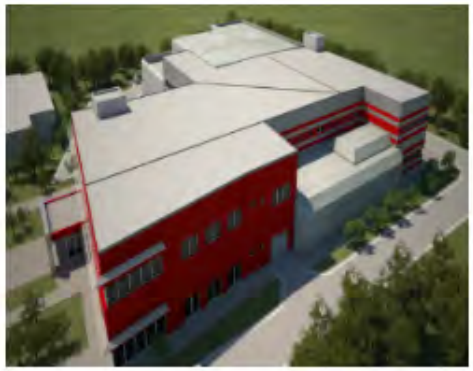


Comisión Nacional de Energía Atómica

Ministerio de Planificación Federal, Inversión Pública y Servicios Presidencia de la Nación

Courtesy of Dr Berta Roth, Institute of Oncology "Angel H. Roffo", University of Buenos Aires, Argentina

The first center of Pronton Therapy in Latin America



IAEA TC activities, ARG6015

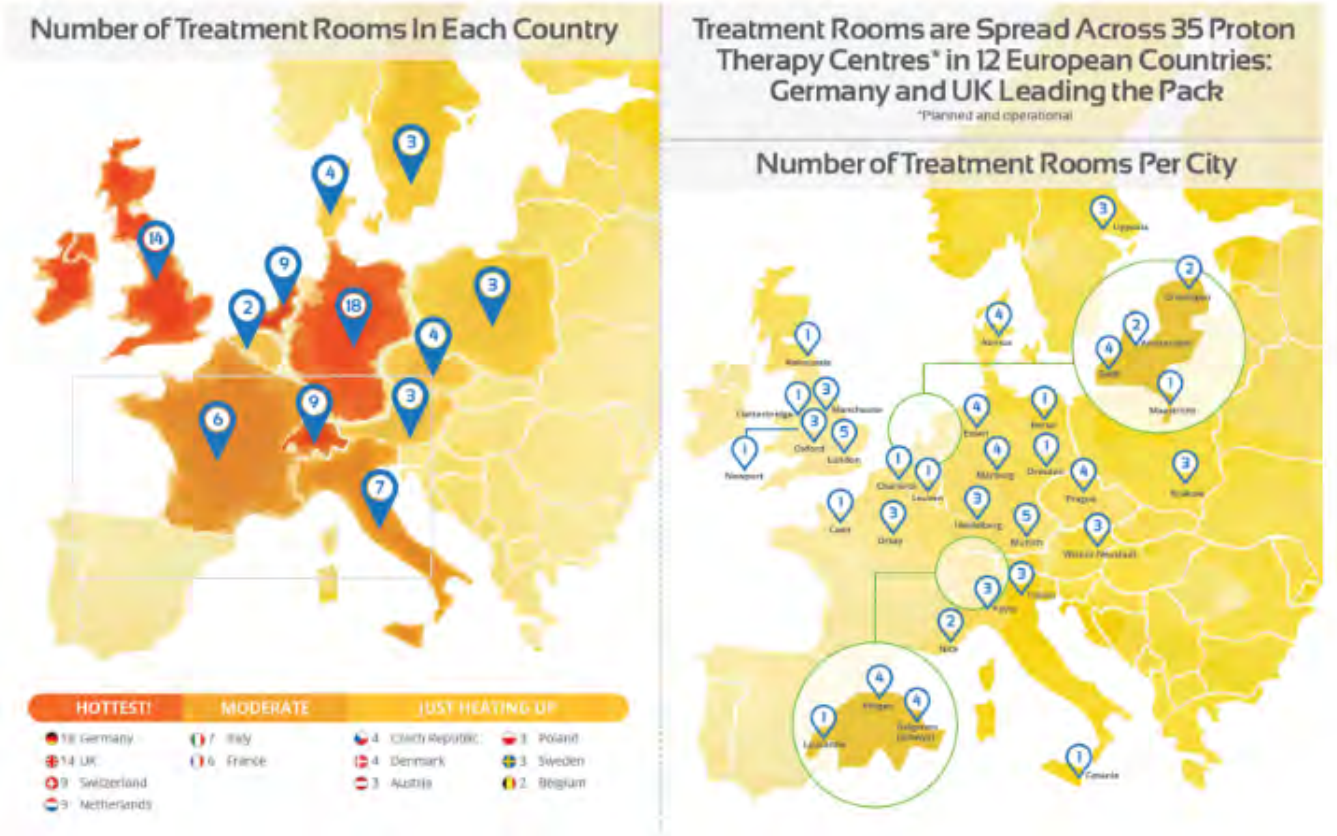
Training of MD in hadrontherapy-radiation oncology.	Fellowships	2014
Training in on-line dosimetry and treatment planning.	Fellowships	2014
Attendance of physicist to USPAS (United States Particle Accelerator School) or CAS (CERN Accelerator School).	Fellowships	2014
Organization of workshop to discuss in-depth technical questions (both physical and medical) related to the implementation of an ion beam therapy centre (2014).	Meetings	2014
Intensive course in cyclotron physics and technology.	Experts	2014
Two simultaneous scientific visits in cyclotron technology, protontherapy and radiation oncology (1 MD, 1 physicist)	Scientific Visits	2014
Visit of expert in accelerator physics and technology or radiation oncology/protontherapy.	Training Courses	2014
Training in on-line dosimetry and treatment planning	Fellowships	2015
Attendance of physicist to USPAS (United States Particle Accelerator School) or CAS (CERN Accelerator School). 1 month stay	Fellowships	2015
Transfer of experience in legal and administrative issues.	Experts	2015
Scientific visit in protontherapy and radiation oncology.	Scientific Visits	2015
Visit of expert in accelerator physics and technology or radiation oncology/protontherapy.	Experts	2015
Training in accelerator technology. Attendance of engineer to USPAS (United States Particle Accelerator School) or CAS (CERN Accelerator School). 1 month stay.	Fellowships	2015
MD to be trained in hadrontherapy-radiation oncology.	Fellowships	2016
Training of medical physicist in on-line dosimetry and treatment planning in hadrontherapy.	Fellowships	2016
Training in cyclotron physics and technology.	Fellowships	2016
Transfer of experience in legal and administrative issues.	Experts	2016
Scientific visit in cyclotron technology.	Fellowships	2016
Visit of expert in accelerator physics and technology or radiation oncology/protontherapy.	Experts	2016
Organization of workshop to discuss in-depth technical questions (both physical and medical) related to the implementation of an ion beam therapy centre (2016).	Meetings	2016
Training in cyclotron technology and operation.	Fellowships	2016
MD to be trained in hadrontherapy-radiation oncology.	Fellowships	2017
Training in cyclotron physics and technology.	Fellowships	2017
Training in cyclotron technology and operation.	Fellowships	2017

Future of proton therapy

New centres, clinical trials and technologies

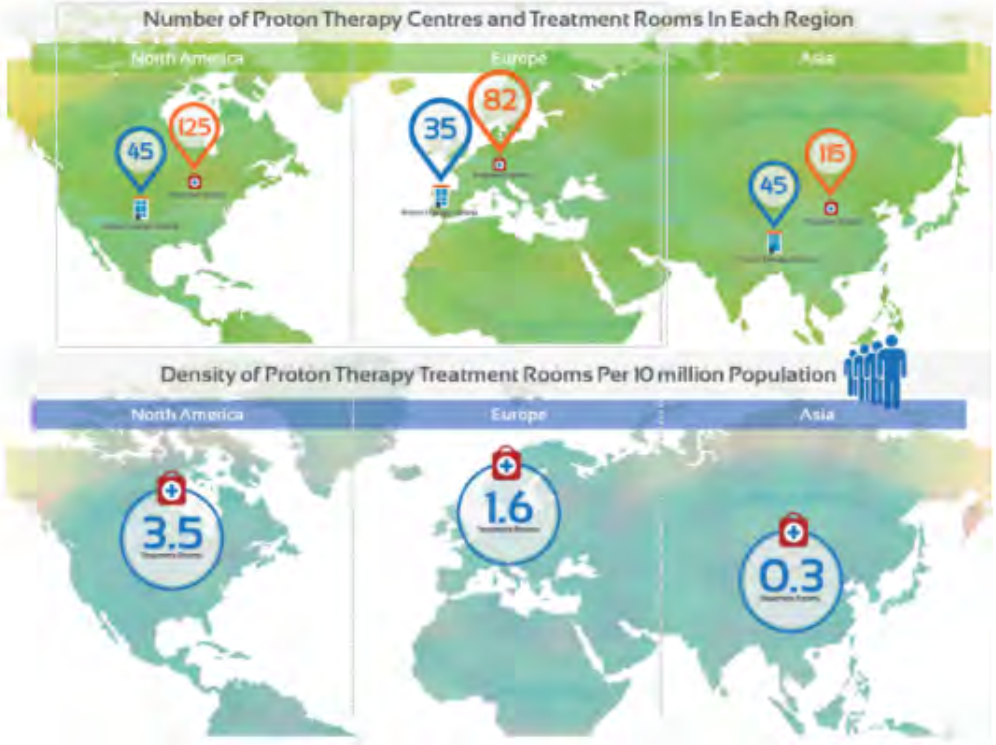
Single room facility from Dielectric Wall Accelerator, Caporaso et al (2009), artistic view

80+ Treatment Rooms to be Operational in Europe by 2020



This infographic was created in collaboration with MEDraysintell, in coordination for the Proton Therapy Congress hosted by Kisaco Research in London, 20-21 September 2016

European Proton Therapy Centres Fast-Approaching North America and Asia Providers



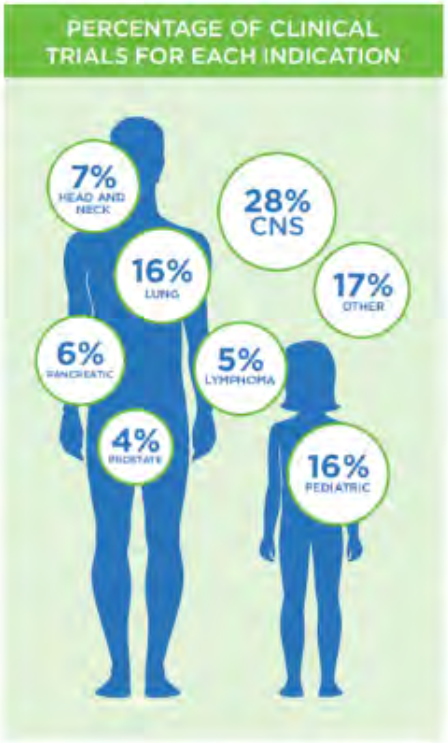
This infographic was created in collaboration with MEDraysintell, in coordination for the Proton Therapy Congress hosted by Kisaco Research in London, 20-21 September 2016

Proton therapy in figures

- Growth Rate: The global proton therapy sales orders has almost doubled each year from 2013 to 2015 to reach a record level at just over US$ 1 billion in 2015
- Industry Projected Value: by end of 2015, 171 particle therapy treatment rooms were operational worldwide, and projections by 2030 anticipate the proton therapy world market to reach between 1,200 and 1,800 treatment rooms worldwide
- Number of Patients Treated by 2030: the estimation is that 300,000 patients could be treated by particle therapy during the year 2030 within the 1,200 treatment rooms, compared to the 14,500 patients that were treated in 2014

This review was created in collaboration with MEDraysintell, in coordination for the Proton Therapy Congress hosted by Kisaco Research in London, 20-21 September 2016

Where are the European hotspots for proton therapy clinical trials?



Data is sourced from ClinicalTrials.gov manually using the search terms 'proton therapy' alongside each illustrated indication. November 2016. Based on Kisaco Research infographics prepared for the Proton Therapy Congress, 28-30 March 2017, Amsterdam, the Netherlands

Robust Treatment Planning

Physics Processes

Accurate (a few %) and extended low energy nuclear physics data will allow tracking particles in heterogeneous matter

Biological Effects

Radiobiology data on Anatomic and Functional Imaging of the patient will allow to estimate Tumour and Normal Tissue Biological and Personalised Response

Planning System

Detailed and validated accelerator description will allow

- Decision support (AI)
- MonteCarlo methods
- Computing Power

Future directions for reseach

- Study of hypofractionation
- Biology of combined treatments (with chemo- and immunotherapies)
- Radiogenomics
- Studies on late effects focused on the response of the microenvironment
- Study of second primary tumours
- Non-cancer effects and non-targeted (abscopal) effects
- Further investigations regarding the relative biologic effectiveness (RBE) and the isoeffective dose should be performed
- Research to select proton *vs* carbon ion therapy based on the alpha/beta values of the target and surrounding normal tissue structures

Current technology developments trends

Main directons

- Improved planning
- Improved dosimetry
- Optimal dose delivery
- Improved assessment
- Implementation of pencil beam scanning and intensity modulated proton therapy
- Accurate quality assurance

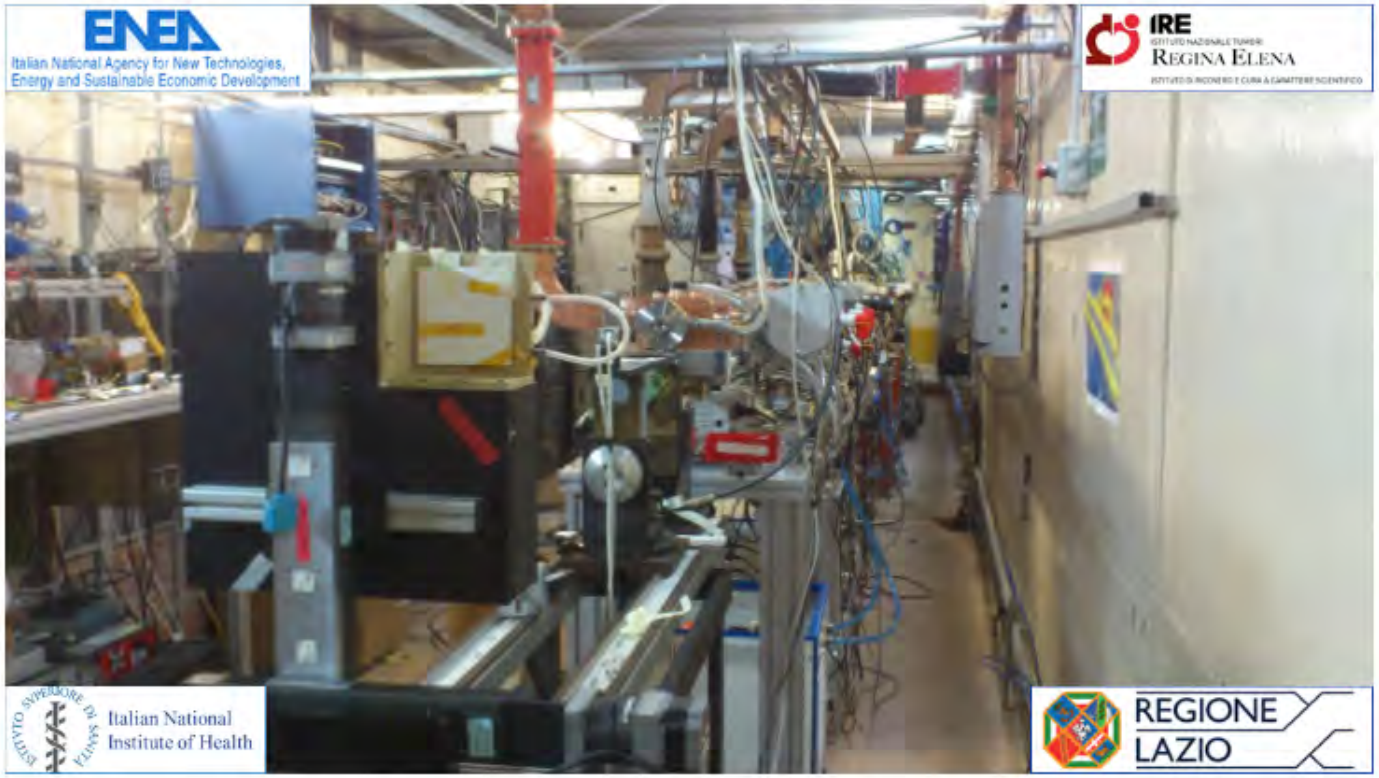
Reducing system costs

- Lower power needs
- Smaller size and weight
- Simpler procedures

New acceleration technologies

- Linear Accelerator
- Superconducting Accelerator
- Fixed-Field Alternating Gradient Accelerator (FFAG)
- Laser Acceleration
- Dielectric Wall Accelerator

LinAc for Proton Therapy becoming real (TOP-IMPLART facility)



Energy: 35 MeV
(150 MeV in 3 years)
Current/Pulse: 30 uA
Already in operation for:

- Beam and diagnostics characterization
- Radiobiology studies
- Cultural heritage analyses
- New development (e.g. LiF dosimetry)
- Radioprotection optimization studies

Current development costs: 6 000 000 Euro

Courtesy of Dr E. Cisbani, Italian National Institute of Health, Rome, Italy