



The National Centre for Oncological Hadrontherapy: status and perspectives

Sandro Rossi

ENLIGHT for SEEIIST
July 23rd 2020

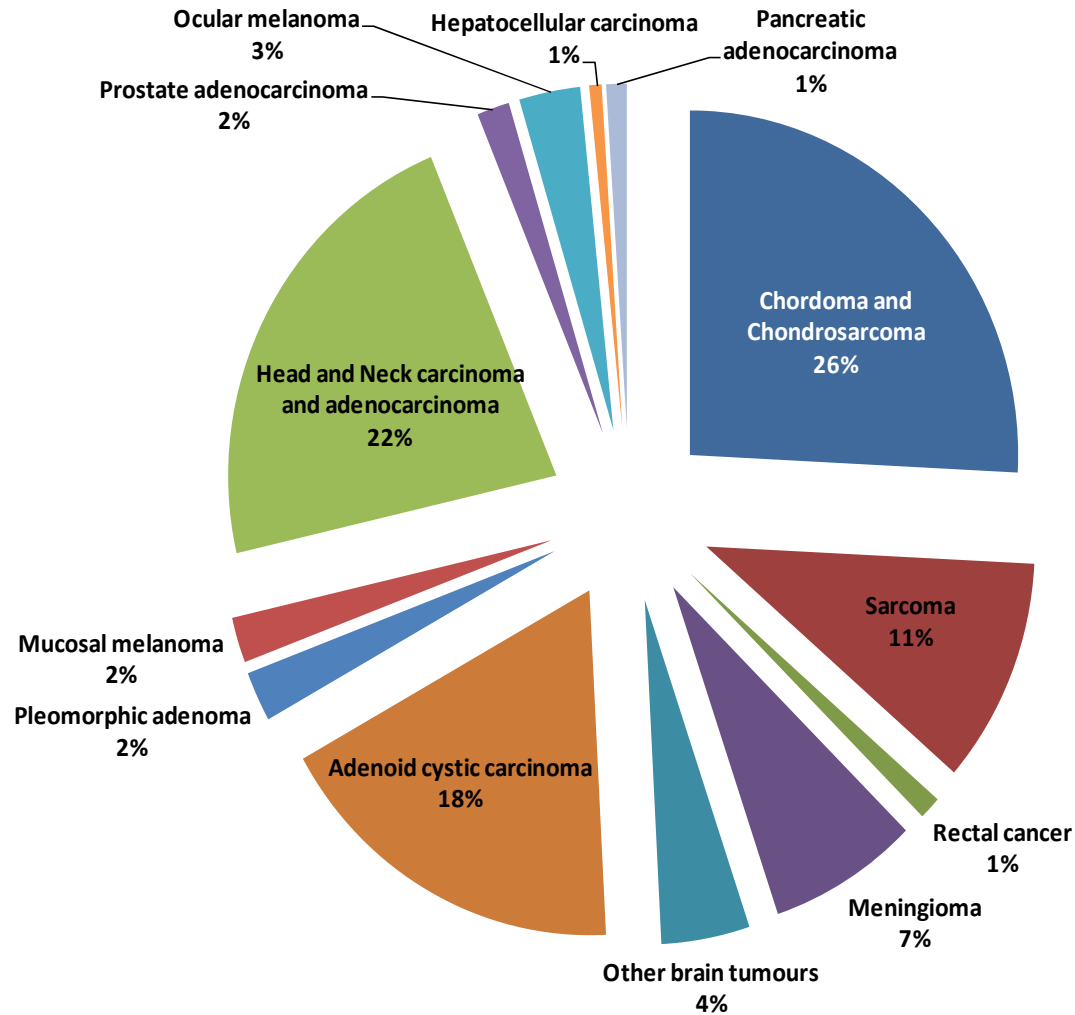
Not-for-profit private Foundation
Created by the Italian Ministry of Health in 2001
with the purpose to build and run a hadrontherapy Centre

2011 First patient
(1991 Amaldi launched the idea)

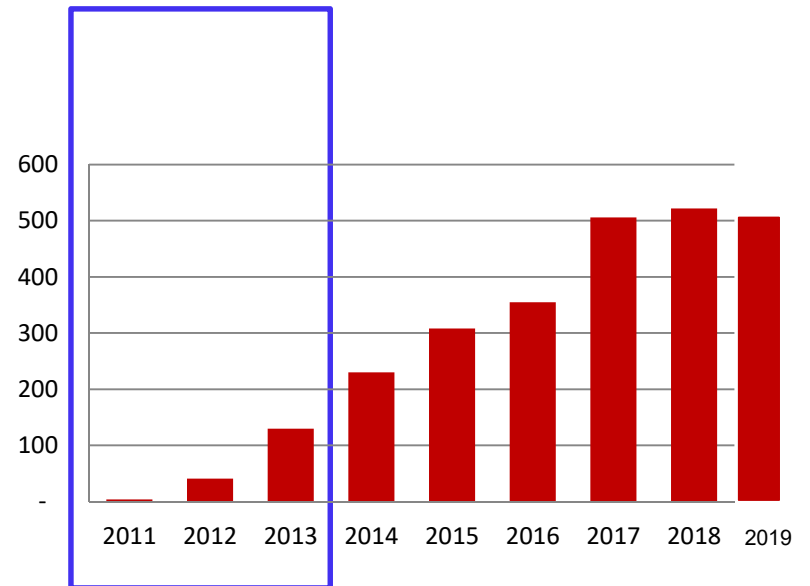


CNAO: 3000 patients treated

57% carbon ions - 43% protons



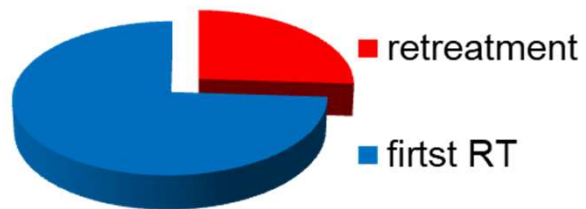
CE marking trials



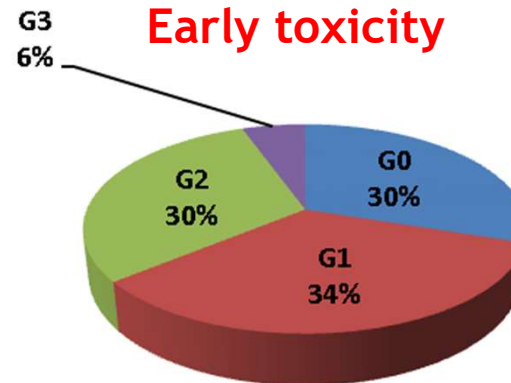
Patients per year

Treatments: **efficacy + reduced toxicity**

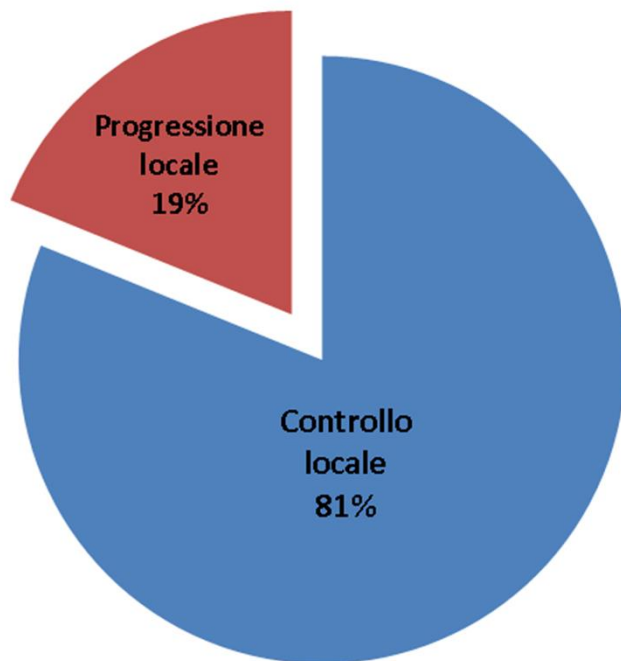
26% re-treatment



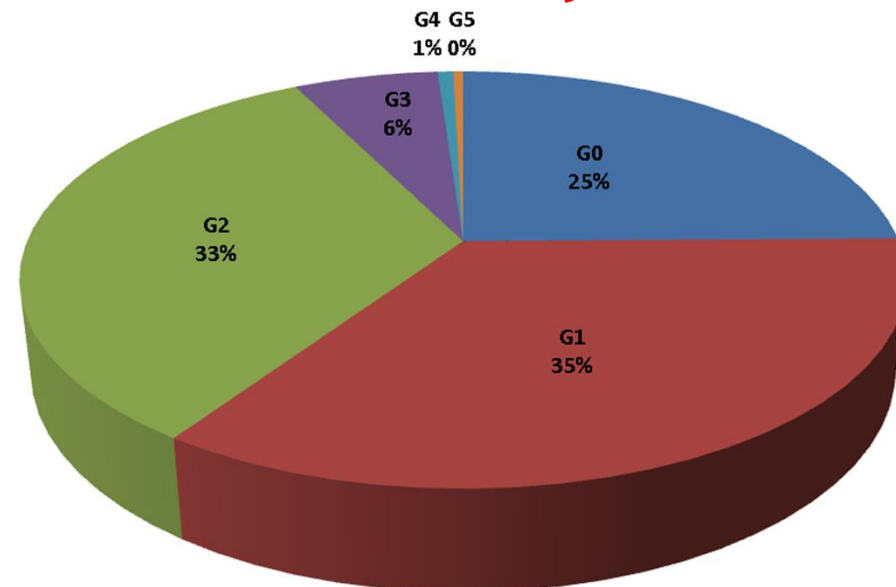
Early toxicity



Undistinguished local control



Late toxicity



Essential Levels of Assistance (LEA)

1. Chordoma & chondrosarcoma base/spine
2. Meningiomas
3. Brain tumors (trunk)
4. ACC Salivary Glands
5. Orbit tumors including eye melanoma
6. Sinonasal carcinoma
7. Soft Tissue & bone Sarcoma (every sites)
8. Recurrent tumors (retreatment)
9. Patients with immulogical disorders
10. Pediatric solid tumors
11. Tumors for which hadrontherapy guarantees a better dose distribution wrt the best alternative providing a 10% better result in terms of NTCP or TCP

In Italy (60 million inhabitants) estimated cases 1-10:

Protons: about 5.000 patients/year

Carbons: about 1.000 patients/year

Non oncological application: **ventricular arrhythmia**



In press on:
European Journal of Heart Failure

Non-invasive Proton Radiotherapy for Refractory Ventricular Tachycardia in advanced heart failure: first in-man case.

Veronica Dusi^{1,2}, MD, PhD; Viviana Vitolo⁵, MD; Laura Frigerio^{1,3}, MD; Rossana Totaro^{1,3}, MD; Adele Valentini⁴, MD; Amelia Barcellini⁵, MD; Alfredo Mirandola⁵, PhD; Giovanni Battista Perego⁶, MD; Michela Coccia³, MD, Alessandra Greco³, MD, Stefano Ghio³, MD, Massimiliano Gnecci^{1,2}, MD, PhD; Luigi Oltrona Visconti³, MD, Roberto Rordorf^{1,3} MD.

¹ Cardiac Intensive Care Unit, Arrhythmia and Electrophysiology and Experimental Cardiology, Fondazione IRCCS Policlinico San Matteo, Pavia, Italy

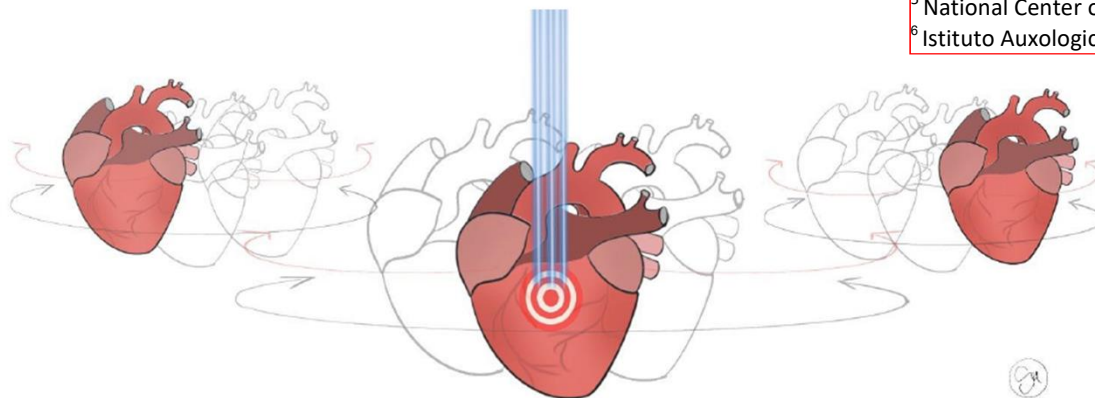
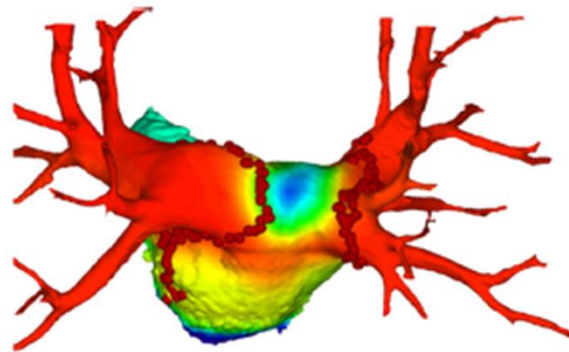
² Department of Molecular Medicine, Section of Cardiology, University of Pavia, Pavia, Italy

³ Department of Cardiology, IRCCS Fondazione Policlinico S. Matteo, Pavia, Italy

⁴ Department of Radiology, IRCCS Fondazione Policlinico S. Matteo, Pavia, Italy

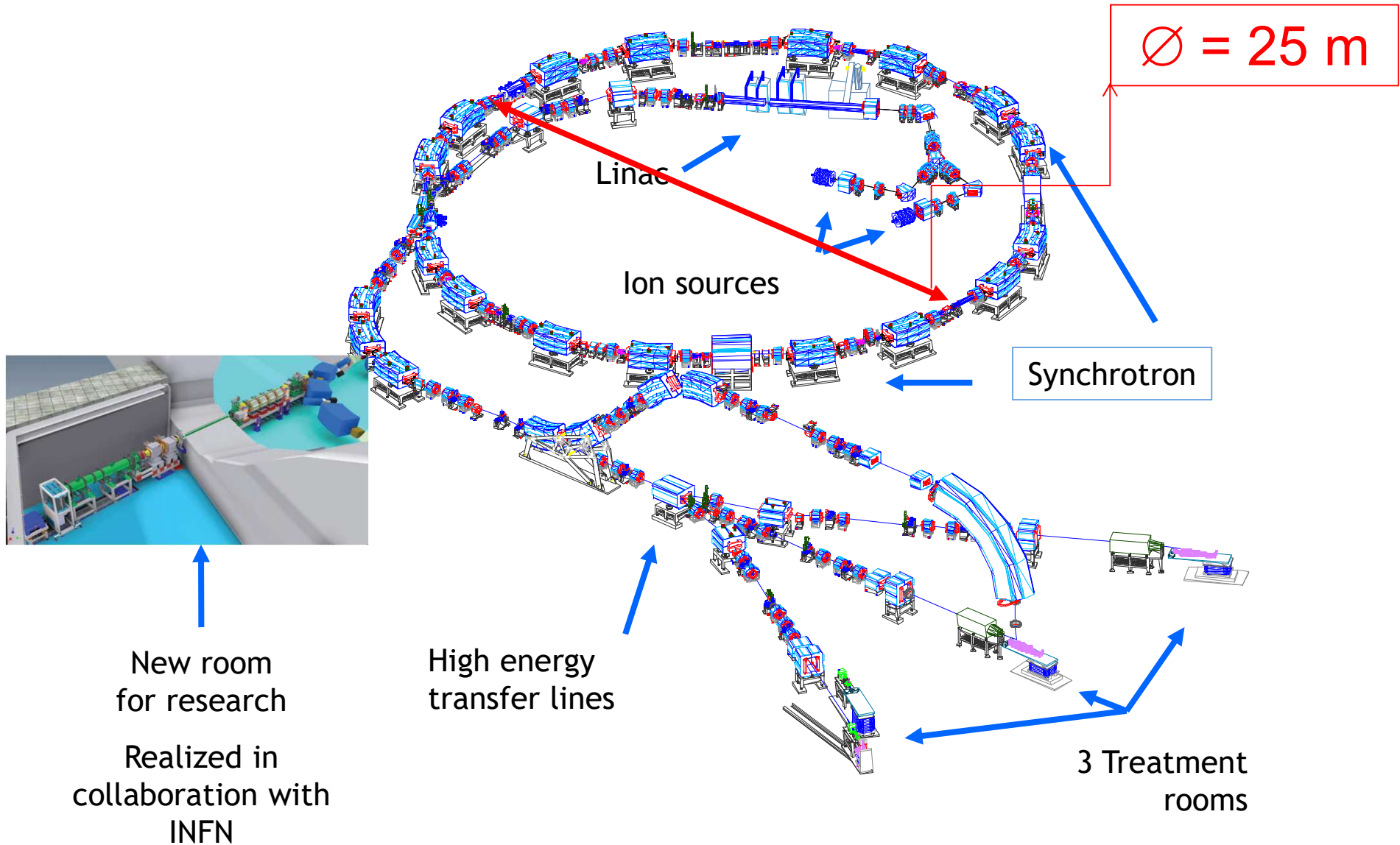
⁵ National Center of Oncological Hadrontherapy (Fondazione CNAO), Pavia, Italy.

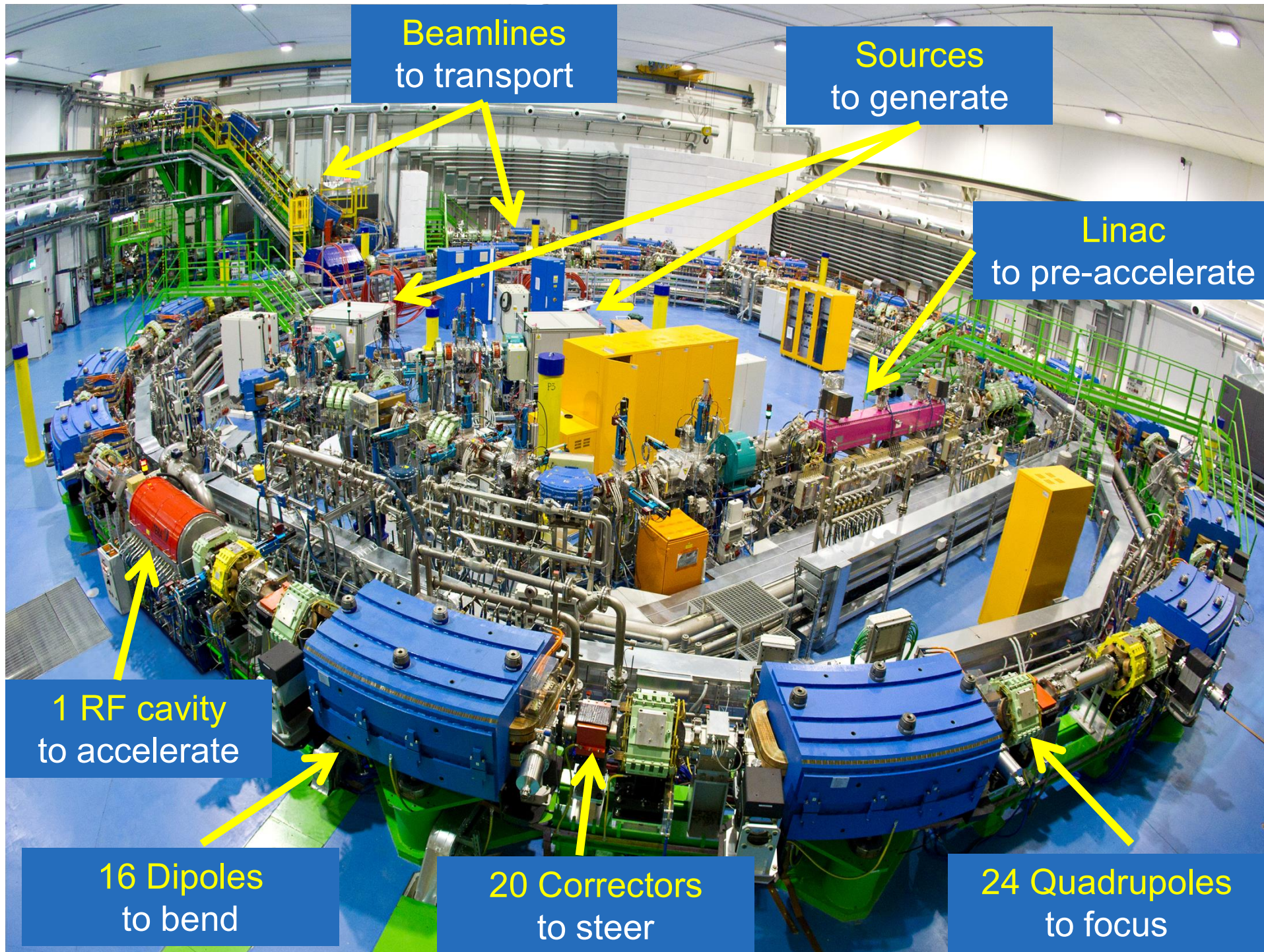
⁶ Istituto Auxologico Italiano, Ospedale San Luca, Milan, Italy.



Accelerator at CNAO: compact design

Intellectual property shared by CNAO - INFN - CERN





Beamlines
to transport

Sources
to generate

Linac
to pre-accelerate

1 RF cavity
to accelerate

16 Dipoles
to bend

20 Correctors
to steer

24 Quadrupoles
to focus

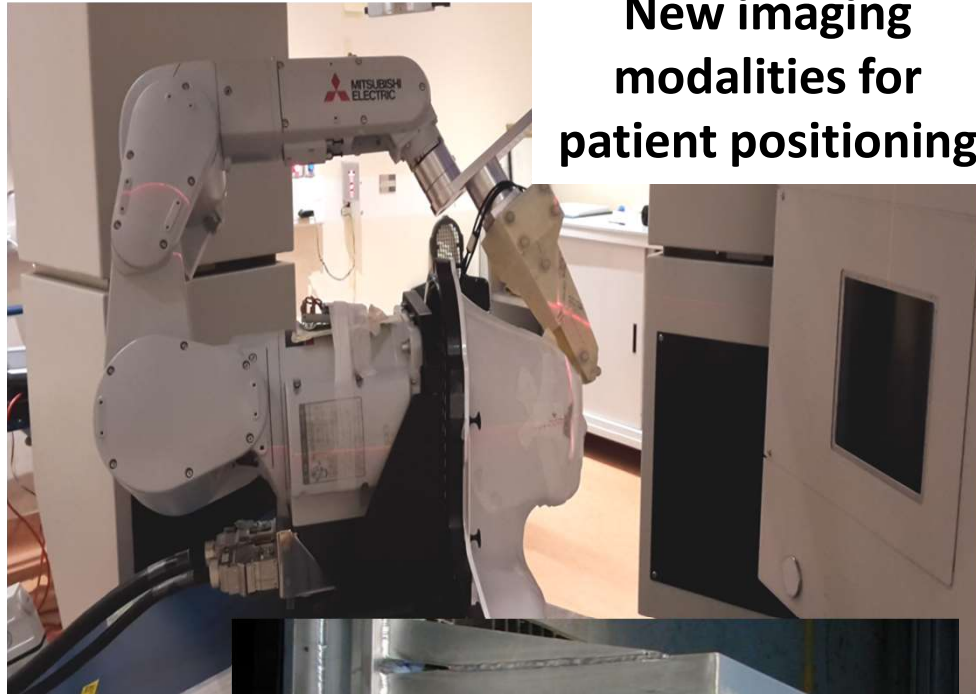
Performance CNAO from Nov. 2011 to Dec. 2019

- 2746 running days
- 2003 treatment days
- 189 dd preventive maintenance
- 36 dd faults
- **System availability: 92.4%**
- **System reliability (dd): 98.5%**
- **System reliability (sessions)**

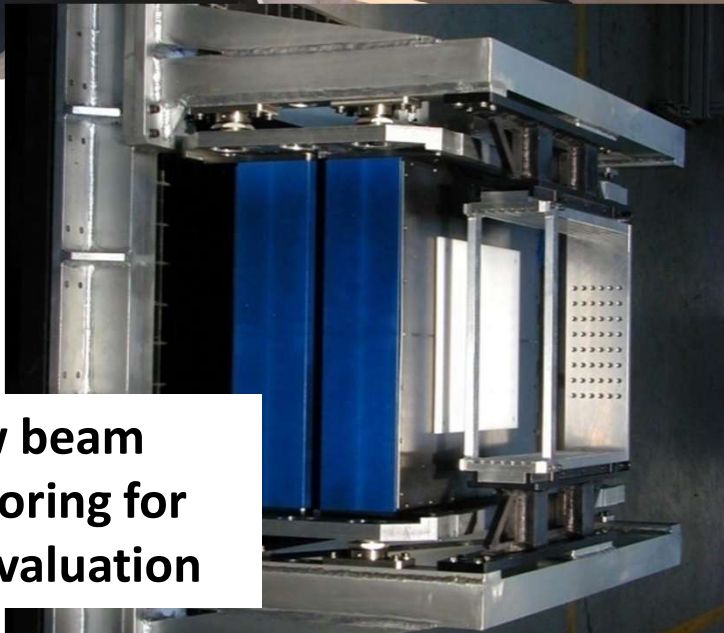
Year 2019

- 329 dd
- 240 dd
- 28 dd
- 0 dd
- **92.2%**
- **100%**
- **96.1 % (417 vs 10604)**
(417 = 149 T + 269 C; T=1.4%)

Ongoing Research Projects

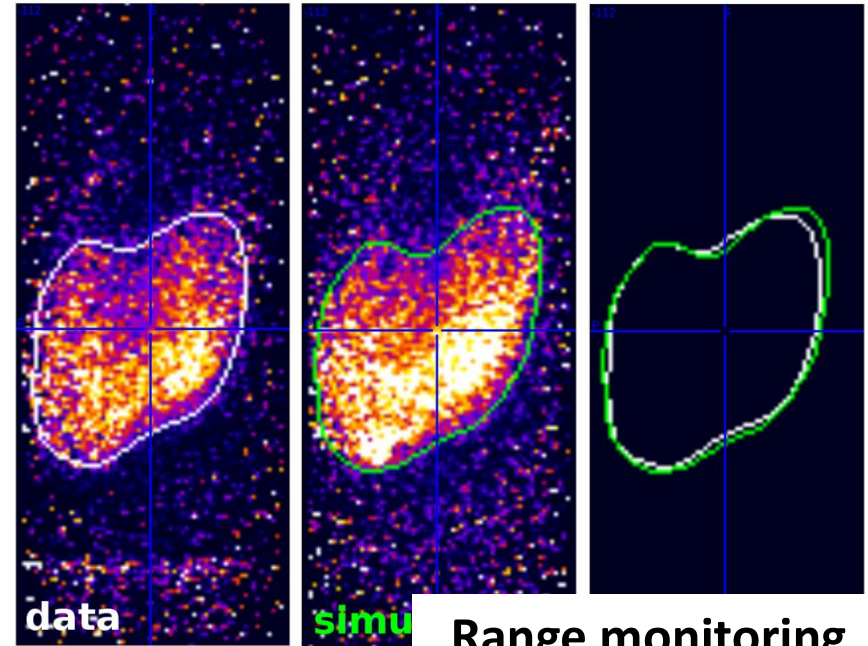


New imaging modalities for patient positioning



New beam monitoring for dose evaluation

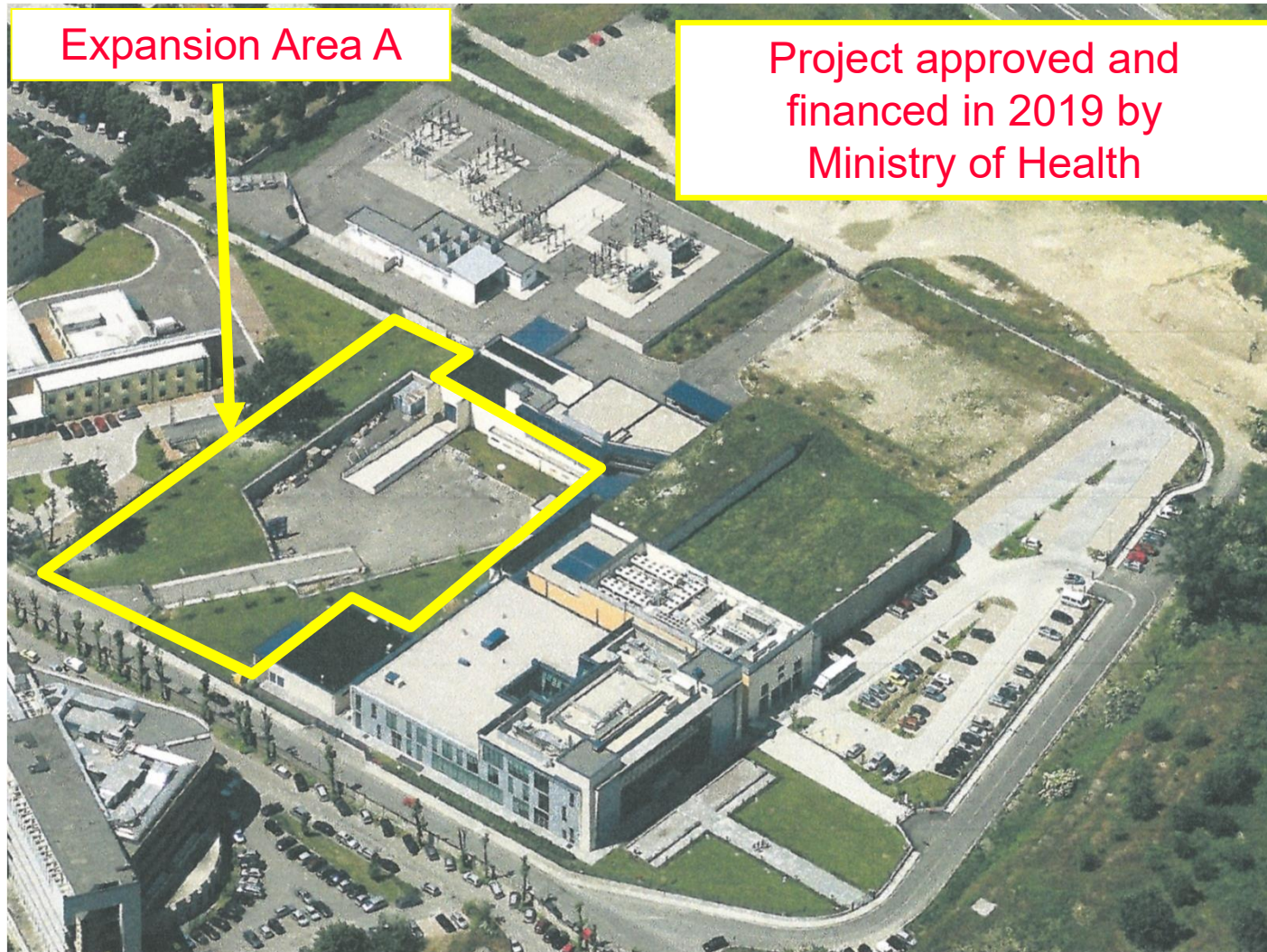
Patient - 01/12/2016
Proton beam
4 min treatment + 1min after



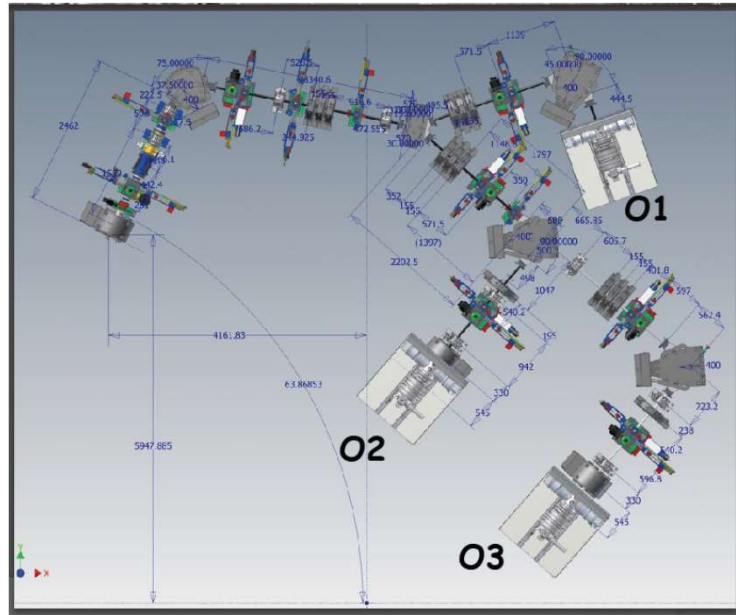
Range monitoring – in beam PET



Expansion project: to keep CNAO at cutting edge of the technology



Third source: **new ion species**



Collaboration CNAO-INFN-HiFuture

A facility **I**nnovativa di irraggiamento con **S**orgente per **I**oni per **R**icerca e studi di radiation hardness con applicazioni **I**ndus**T**riali e cliniche **I**NS**P**IRIT - ID 1161908

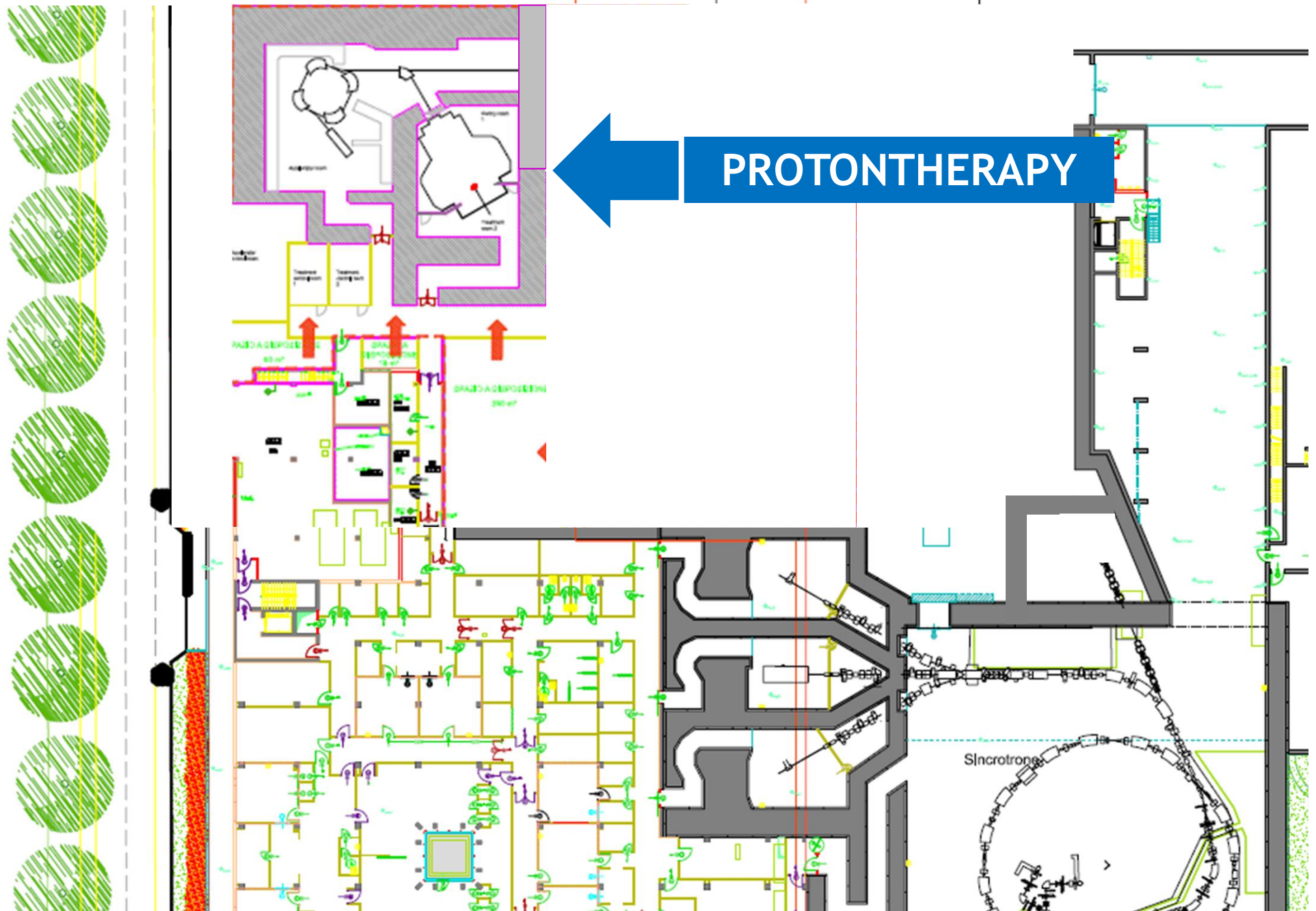
Call HUB ricerca e Innovazione - EU/Regional funds

Expected currents

Ion beam production (eμA)

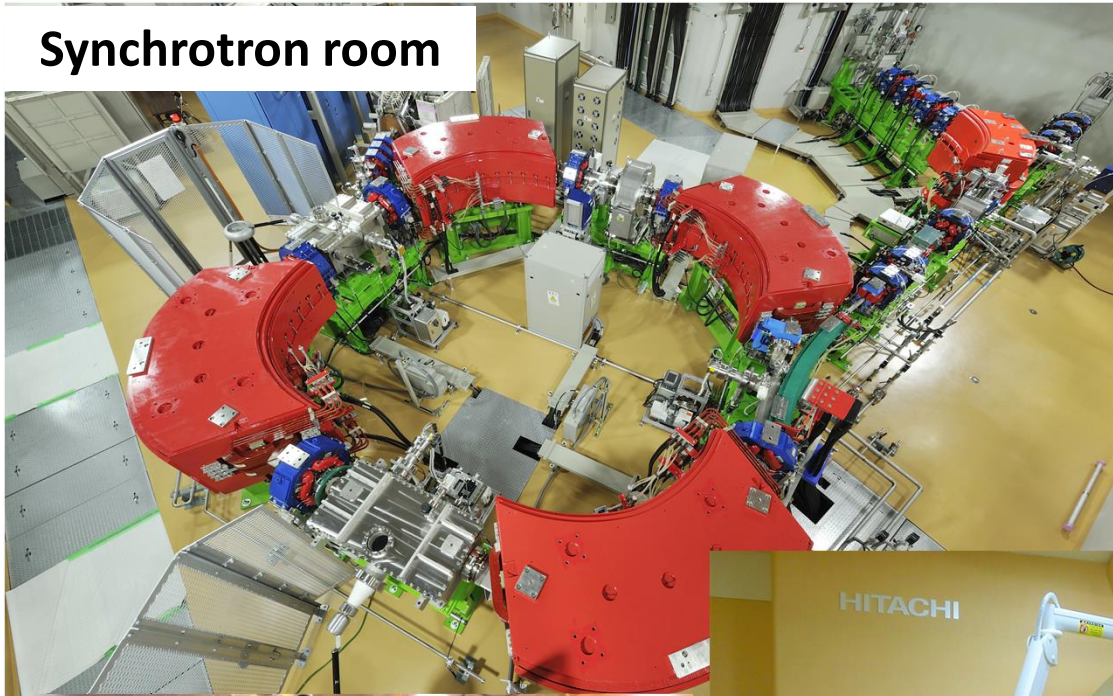
Ion	Supernanogan (14 GHz)	AISHa (18 GHz + TFH)
H ⁺	2000	4000
H ₂ ⁺	1200	2000
H ₃ ⁺	1000	1500
³ He ⁺	800	2000
¹² C ⁴⁺	250	800
⁶ Li ²⁺ - ⁷ Li ²⁺	//	800
¹⁰ B ³⁺ - ¹¹ B ³⁺	//	600
¹⁸ O ⁶⁺	400	1000
²¹ Ne ⁷⁺	120	500
³⁶ Ar ¹²⁺	20	150

Expansion Area A



New single-room for protons

Synchrotron room



Contract signed with Hitachi:
December 5th, 2019

Operational 2023

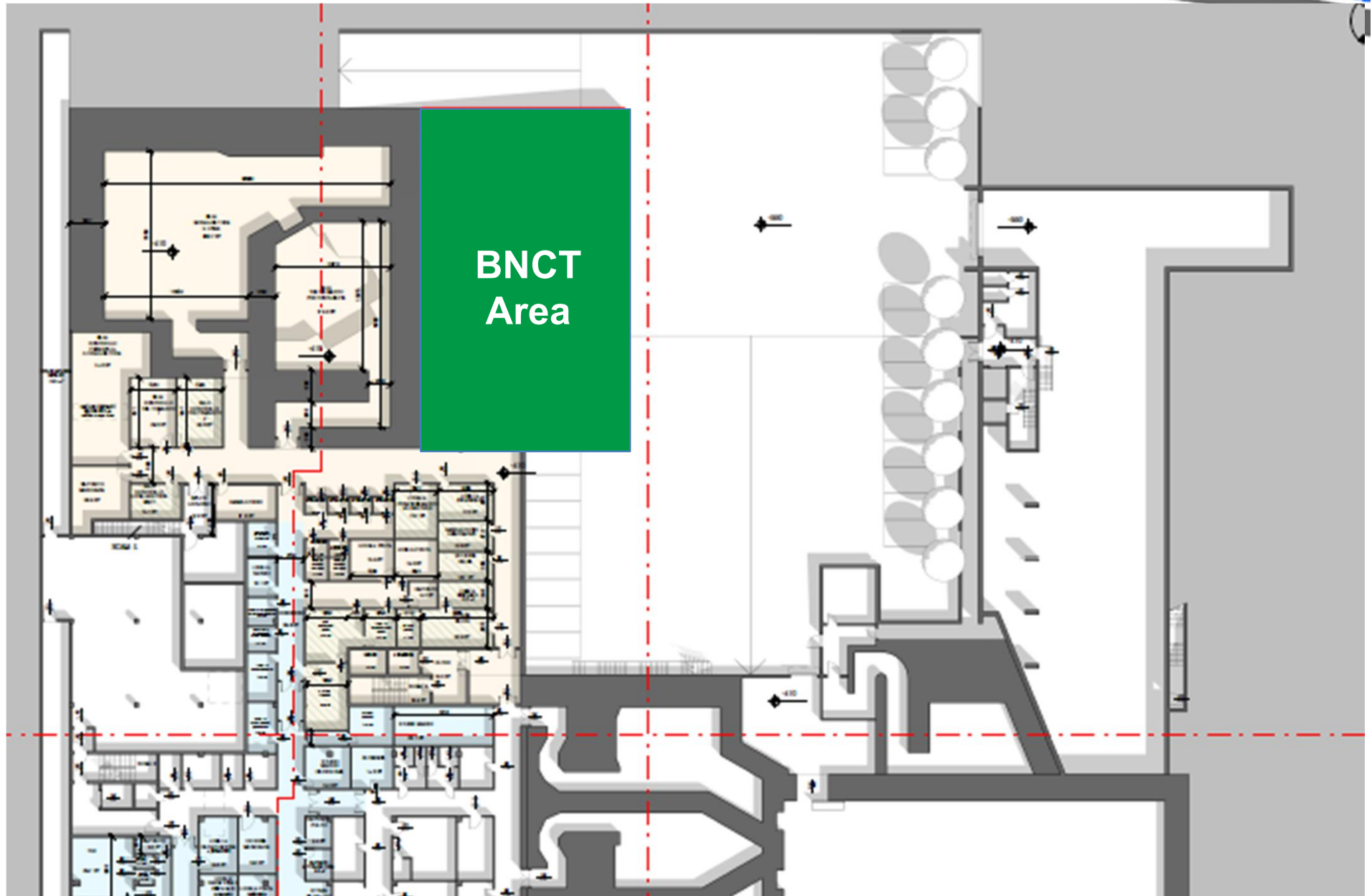


**360° isocentric gantry
(Field size: 30x40 cm²)**

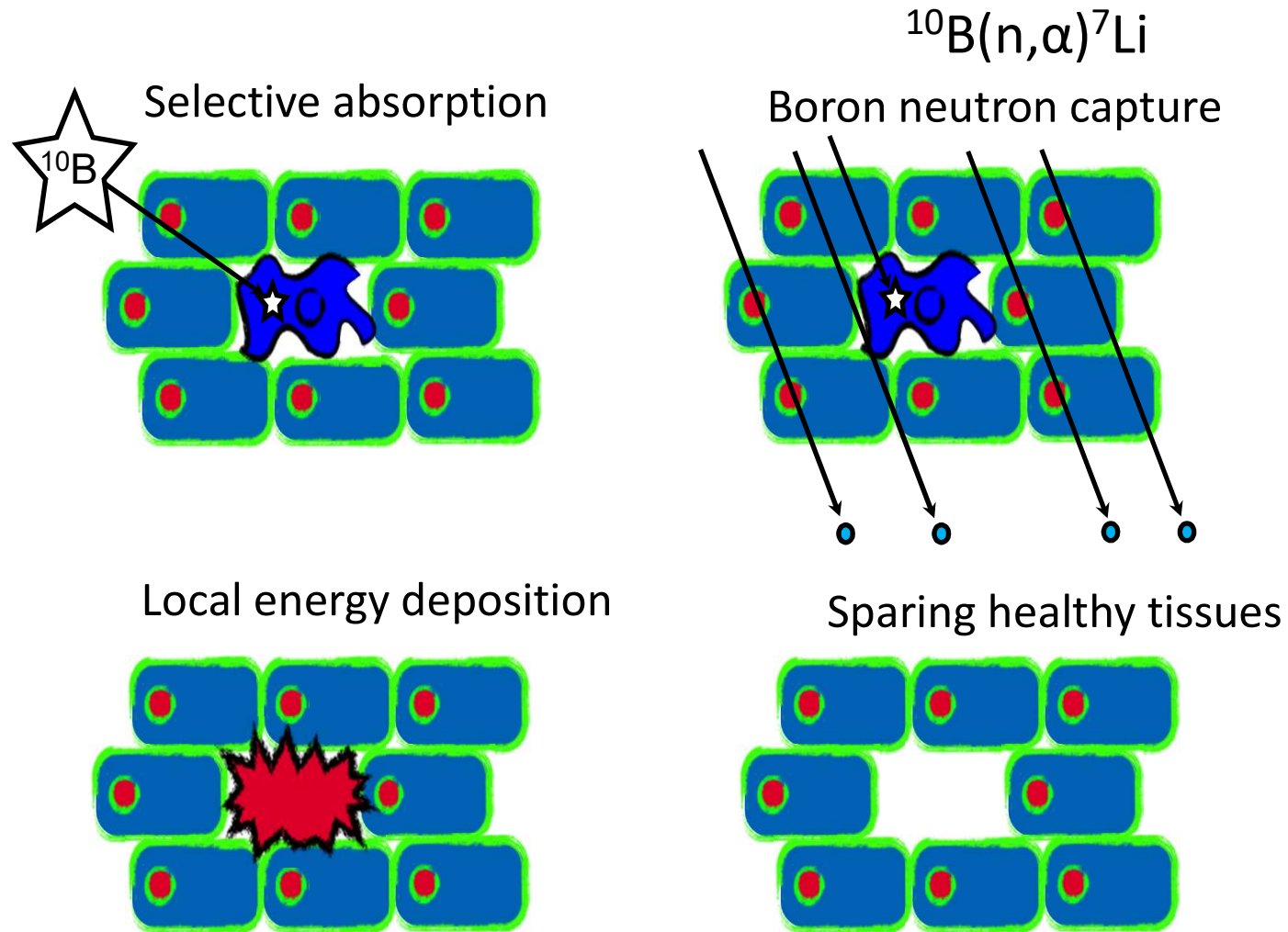
Treatment room



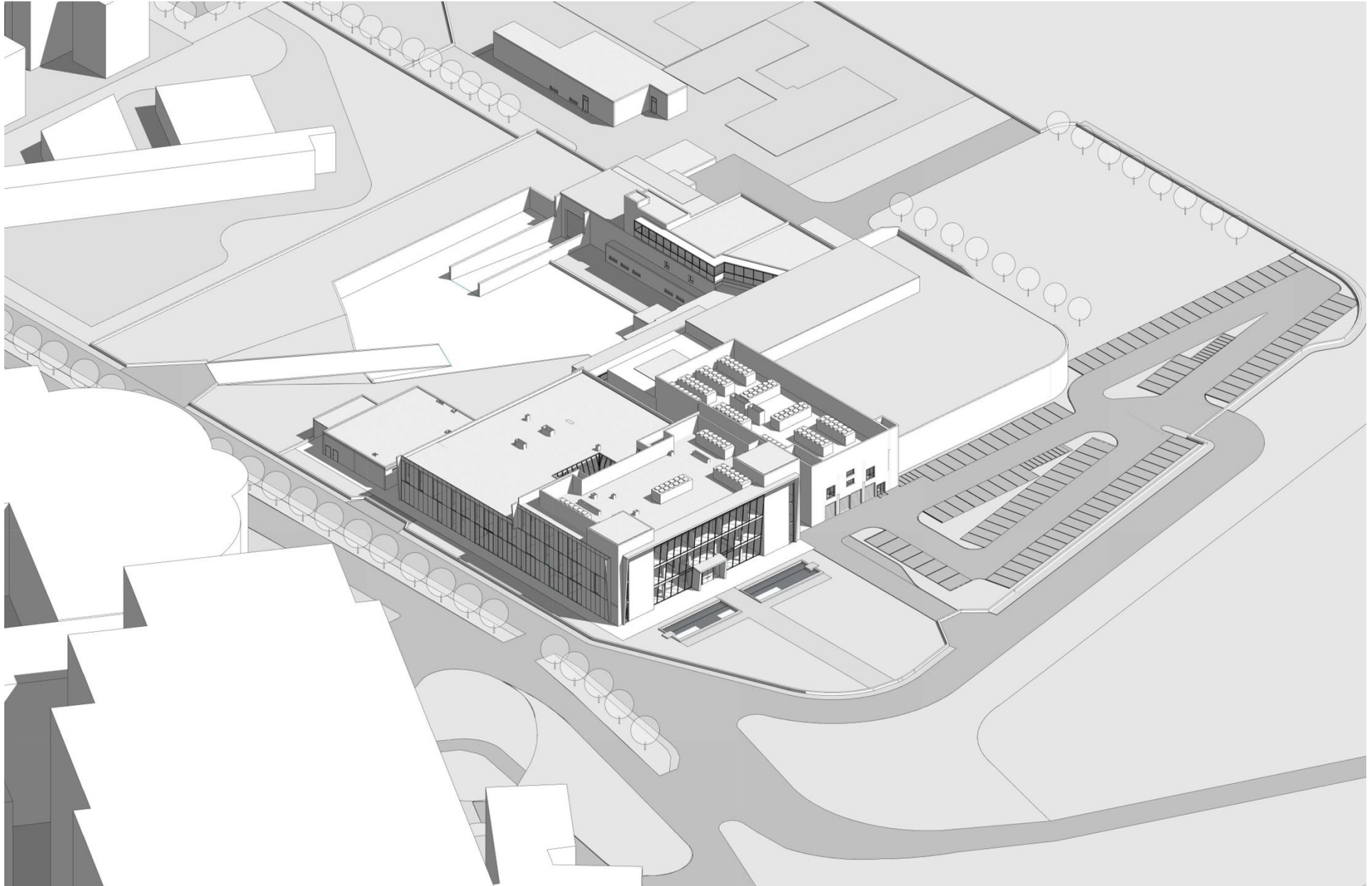
Expansion Area A: integrating BNCT



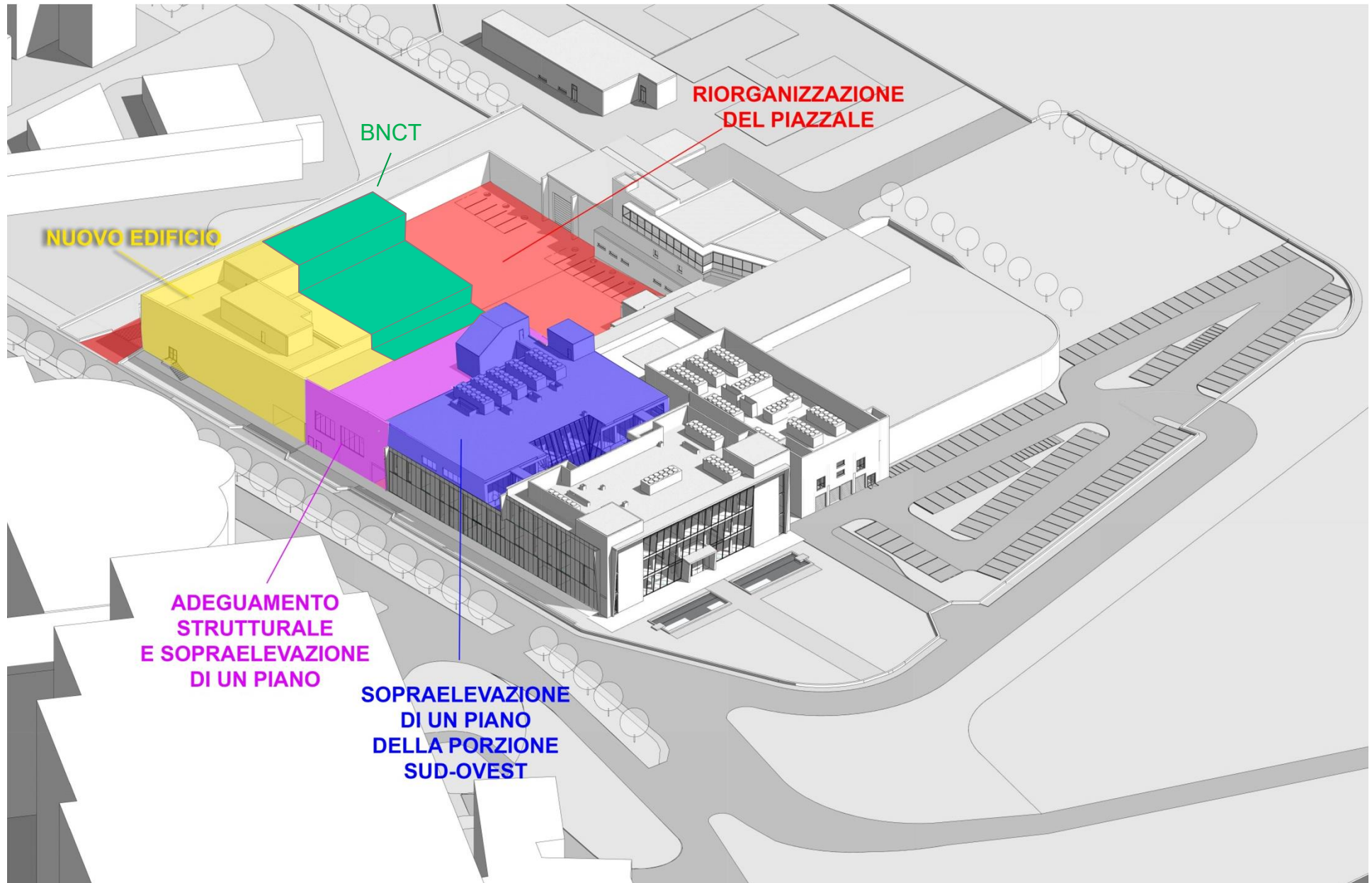
BNCT: research approach for metastatised tumours



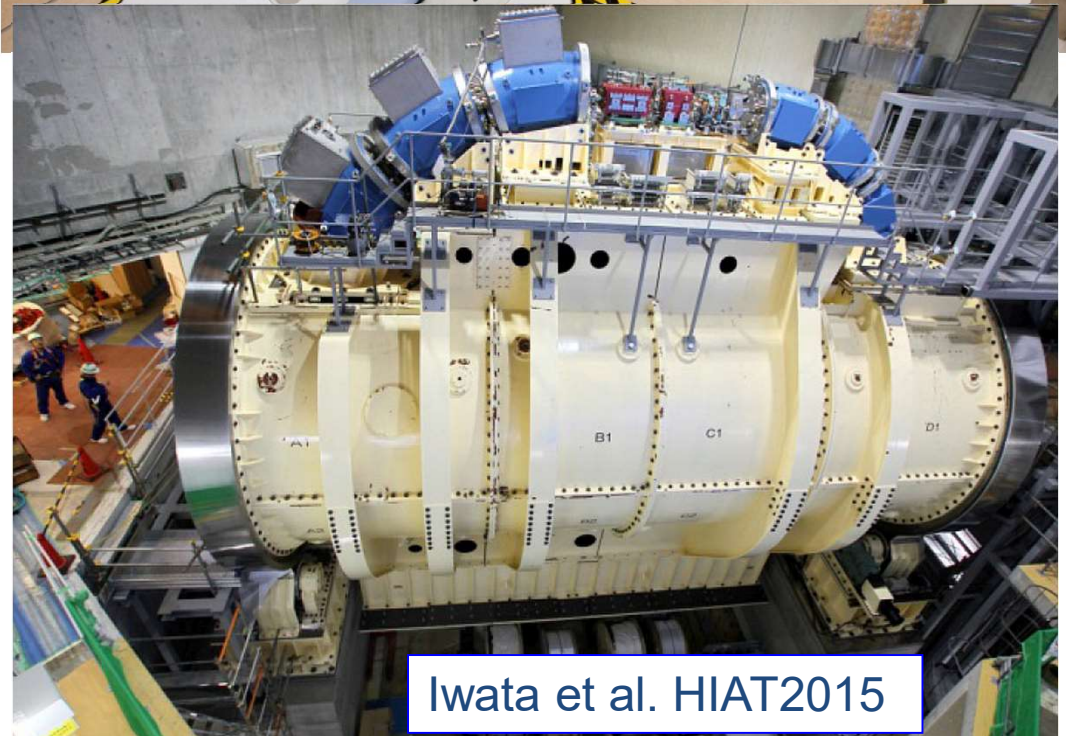
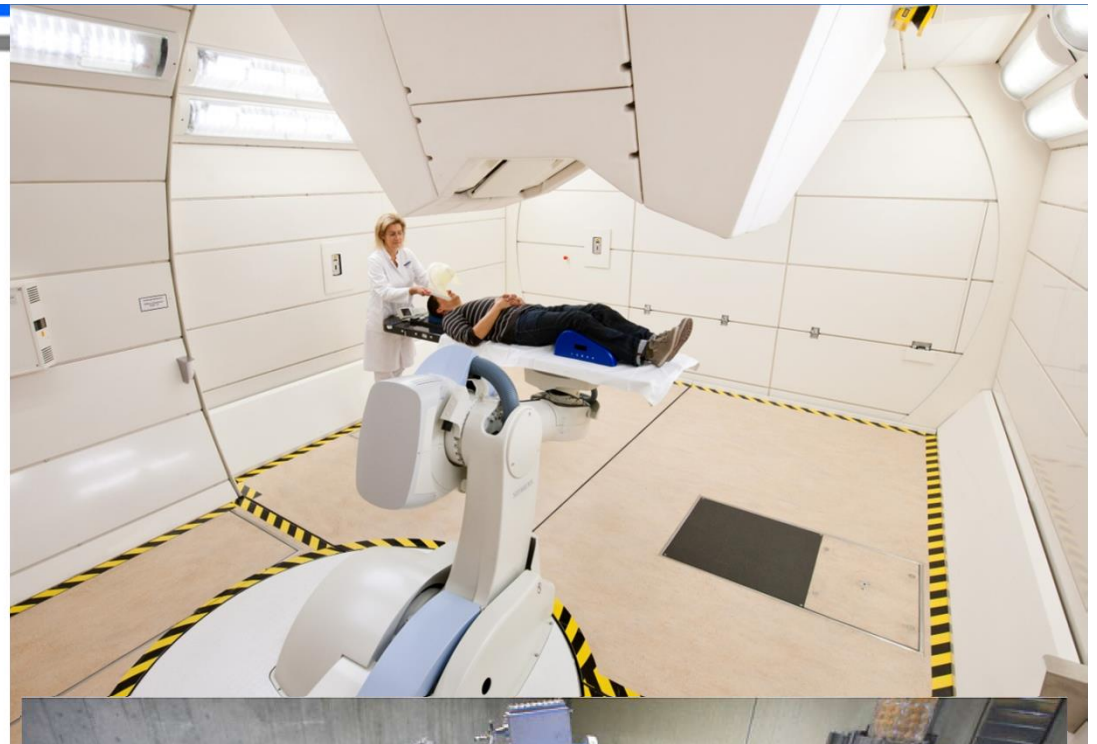
ACTUAL SITUATION



SITUATION in 2023



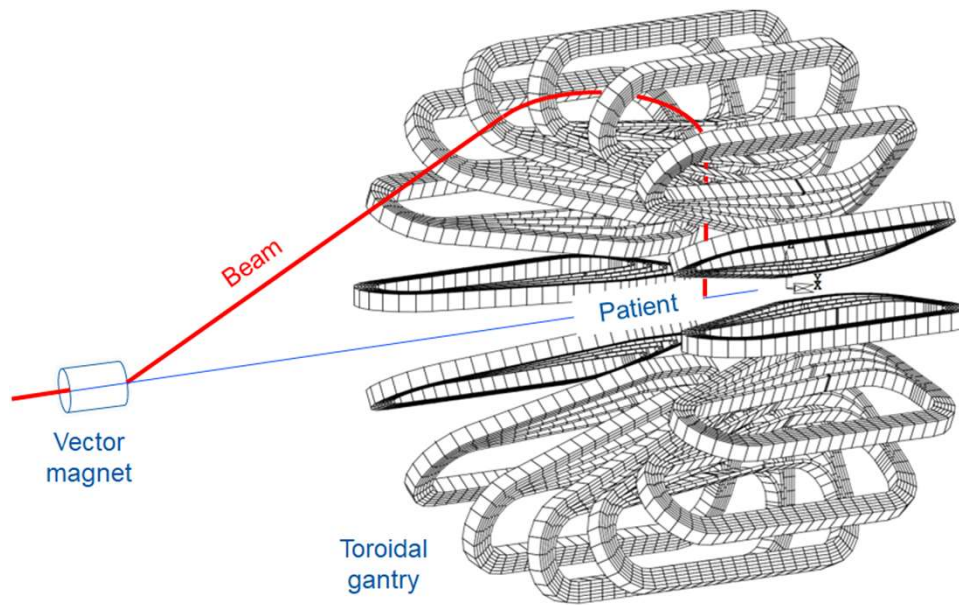
Gantry: flexibility and conformation



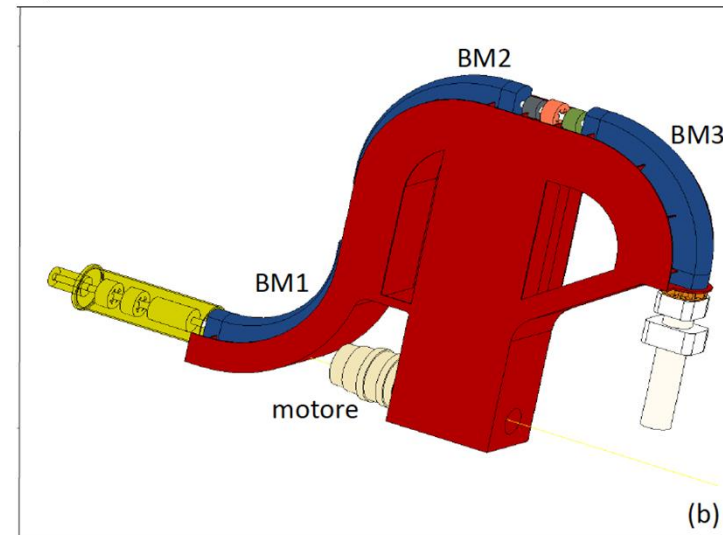
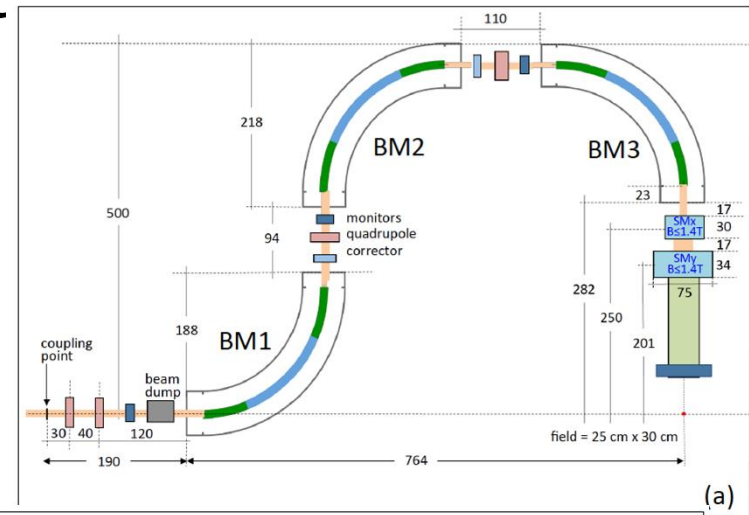
Iwata et al. HIAT2015

R&D: carbon ions gantry

Collaboration CNAO-INFN-CERN-MedAustron
under discussion: start 2021, 3 years project

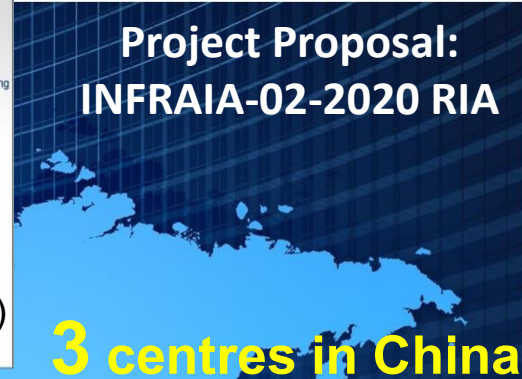
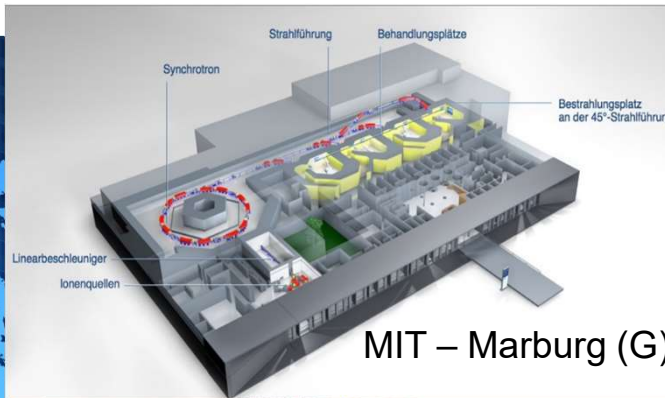


Toroidal magnet SC design (L. Bottura)



TERA-CERN-LBNL (SC canted cosine theta)

HITRIplus: Heavy Ion Therapy Research Integration *plus*



HITRIplus PARTICIPANTS

22 Institutes

(4 CIRT centres, 10 research institutions, 5 universities, 3 SMEs)

14 European Countries

Participant No *	Participant organisation name	Country
1 (Coordinator)	Fondazione Centro Nazionale di Adroterapia Oncologica (CNAO)	IT
2	Bevatech GmbH (BEVA)	DE
3	Commissariat à l'énergie atomique et aux énergies alternatives (CEA)	FR
4	European Organisation for Nuclear Research (CERN)	IEIO
5	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)	ES
6	Cosylab Laboratorij za kontrolne sisteme dd (CSL)	SI
7	GSI Helmholtzzentrum für Schwerionenforschung GmbH (GSI)	DE
8	Universitätsklinikum Heidelberg (UKHD/HIT)	DE
9	Istituto Nazionale di Fisica Nucleare (INFN)	IT
10	EBG MedAustron GmbH (MEDA)	AT
11	Marburger Ionenstrahl-Therapie Betreibergesellschaft mbH (MIT)	DE
12	Paul Scherrer Institut (PSI)	CH
13	South East European International Institute for Sustainable Technologies (SEEIIST)	CH
14	Universita ta Malta (UM)	MT
15	Philipps-University Marburg (UMR)	DE
16	Uppsala University (UU)	SE
17	Wigner Research Centre for Physics (Wigner RCP)	HU
18	Riga Technical University (RTU)	LV

Third party participation linked to SEEIIST		
Participant No *	Participant organisation name	Country
19	Ss, Cyril and Methodius University in Skopje, Republic of North Macedonia (UKIM)	MK
20	Clinical Centre of Montenegro (CMSM)	ME
21	Sentronis a.d. (SEN)	RS
22	Jožef Stefan Institute (IJS)	SI





WP1: Management



WP2: Networking and Communication, Dissemination and Outreach



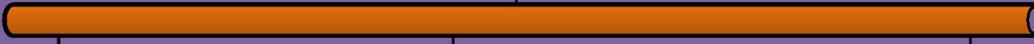
WP3: Clinical networking



WP4: Innovation, technology transfer, industry relation



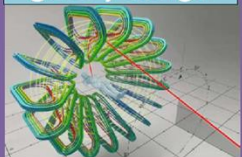
WP5: Education and Training



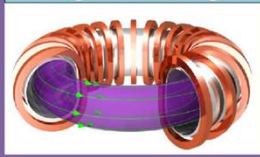
JRA
Joint Research Activities

TNA
WP6
Transnational Access

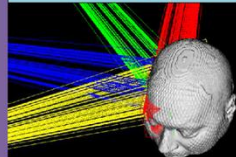
WP7: Advanced accelerator and gantry design



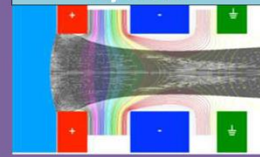
WP8: Superconducting magnets design



WP9: Advanced beam delivery



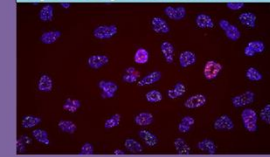
WP10: Multiple energy extraction system



WP11: Controls and safety



WP12: Radiobiology and quality assurance





“A global network of Scientists and institutions
from around the world,
covering a range of disciplines,
cooperating to validate and implement BNCT”



Objectives

- Establishing BNCT in Europe (and USA) by
- Supporting BNCT clinical activities in Japan by:
 - Exchanging information and staff
 - Implementing joint research projects
 - Bringing patients to Japan for treatment

Coordinated by DGBNCT – Essen – Germany

RENOVATE is a very interdisciplinary consortium bringing together experienced international teams able to perform translational research in all required domains, taking developments from the laboratory to technical realization at the hospital bed in a coordinated and systematic manner.



CNAO involved in:

- Dosimeter and Neutron Field Characterization (CNRS)
- Irradiation Sources (UNIPV)
- Clinical trial protocol (University Jena)
- Standards (DGBNCT)



Thank you

"Real progress happens only when advantages of a new technology become available to everybody"
H. Ford