STATUS OF CARBON ION THERAPY CENTRES IN THE WORLD

ENLIGHT – Valencia – 18.6.09

Ugo Amaldi

University Milano Bicocca and TERA Foundation

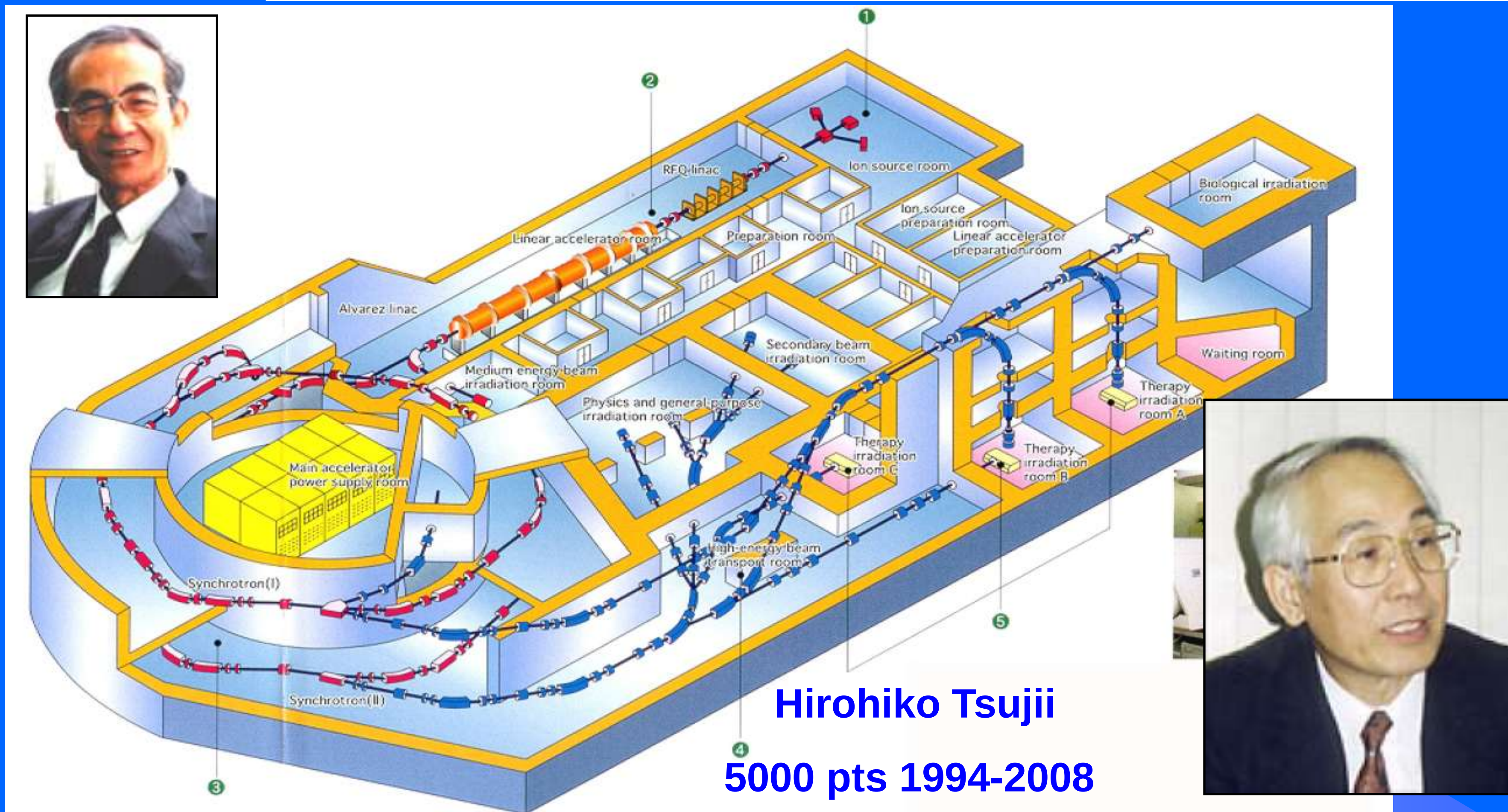
TERA

Carbon ion centres treating patients

HIMAC in Chiba is the pioner of carbon therapy (Prof H. Tsujii)

Yasuo Hirao

[15] Hirao, Y. et al, "Heavy Ion Synchrotron for Medical Use: HIMAC Project at NIRS Japan" Nucl. Phys. A538, 541c (1992)



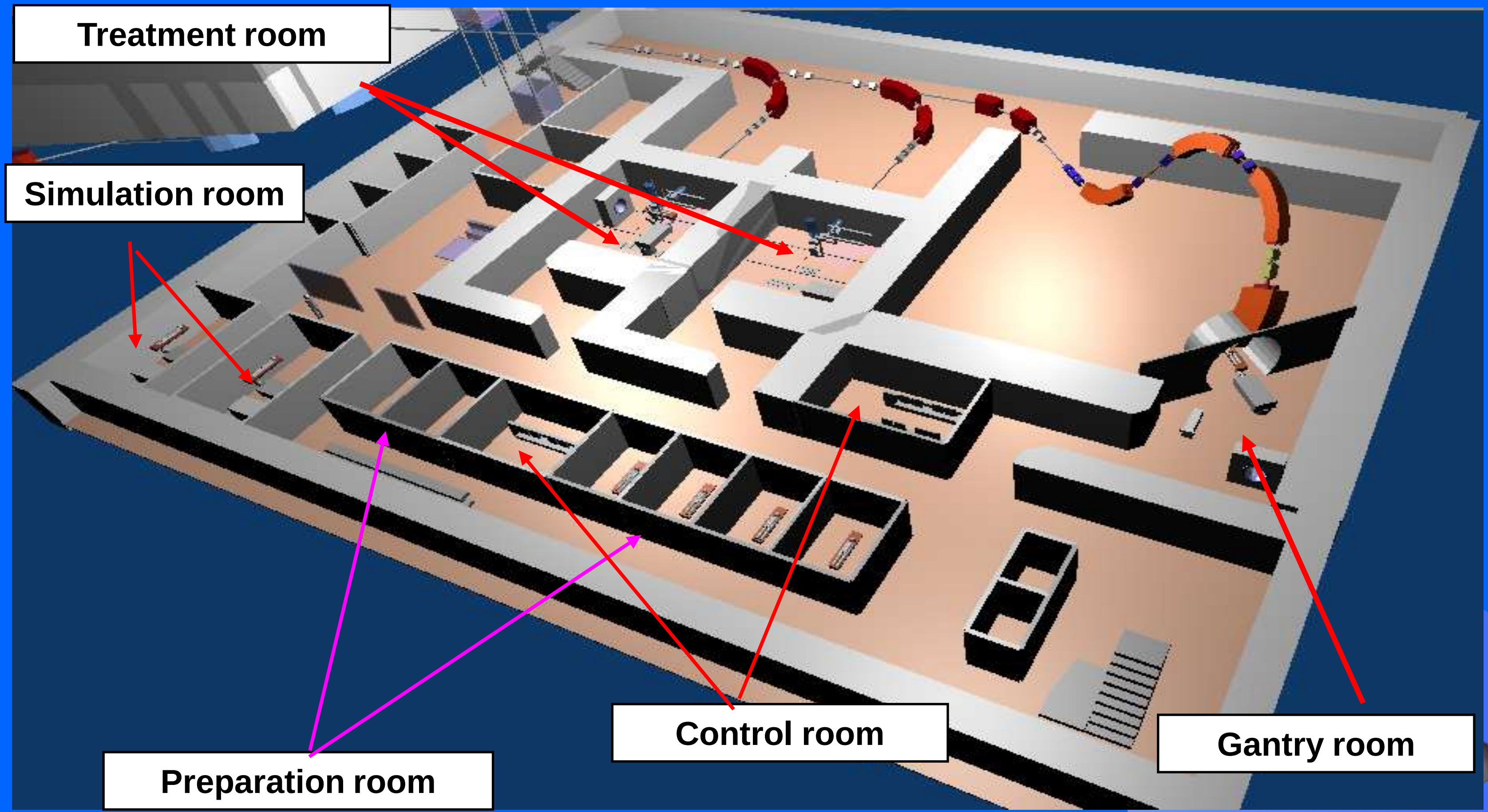
Hirohiko Tsujii

5000 pts 1994-2008

Courtesy H. Tsujii

HIMAC new facility: specifications

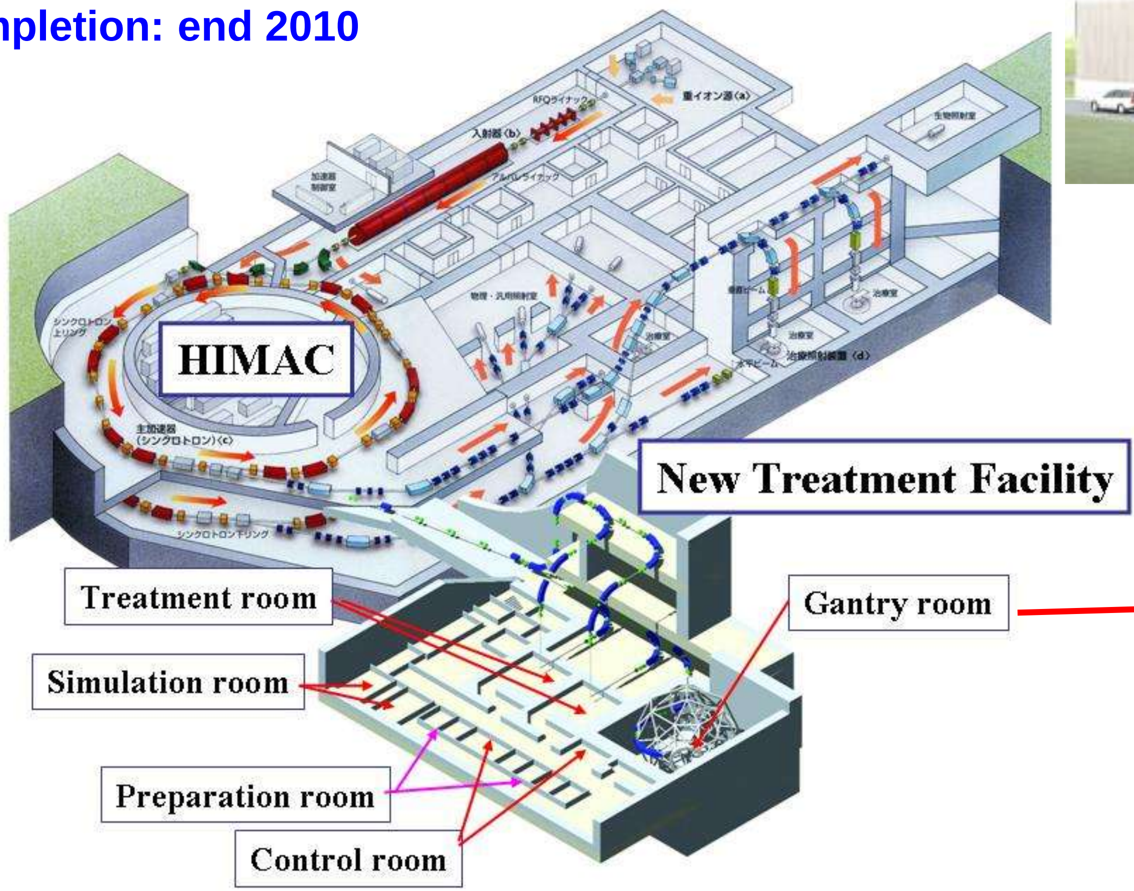
1. Ion species: ^{12}C, ^{16}O (^{11}C, ^{15}O)
2. Maximum irradiation area: 22x22 cm^2 for Fixed Port
   15x15 cm^2 for Gantry
3. Delivered Intensity: 10^7 - 10^9pps (C ions)

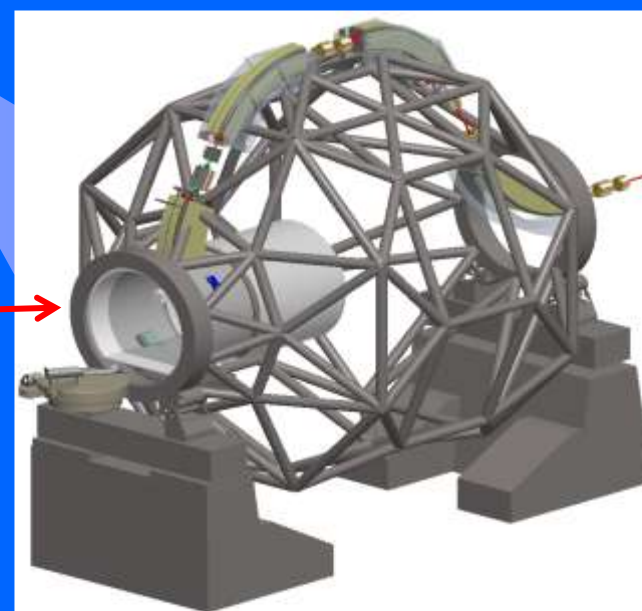


Courtesy H. Tsujii

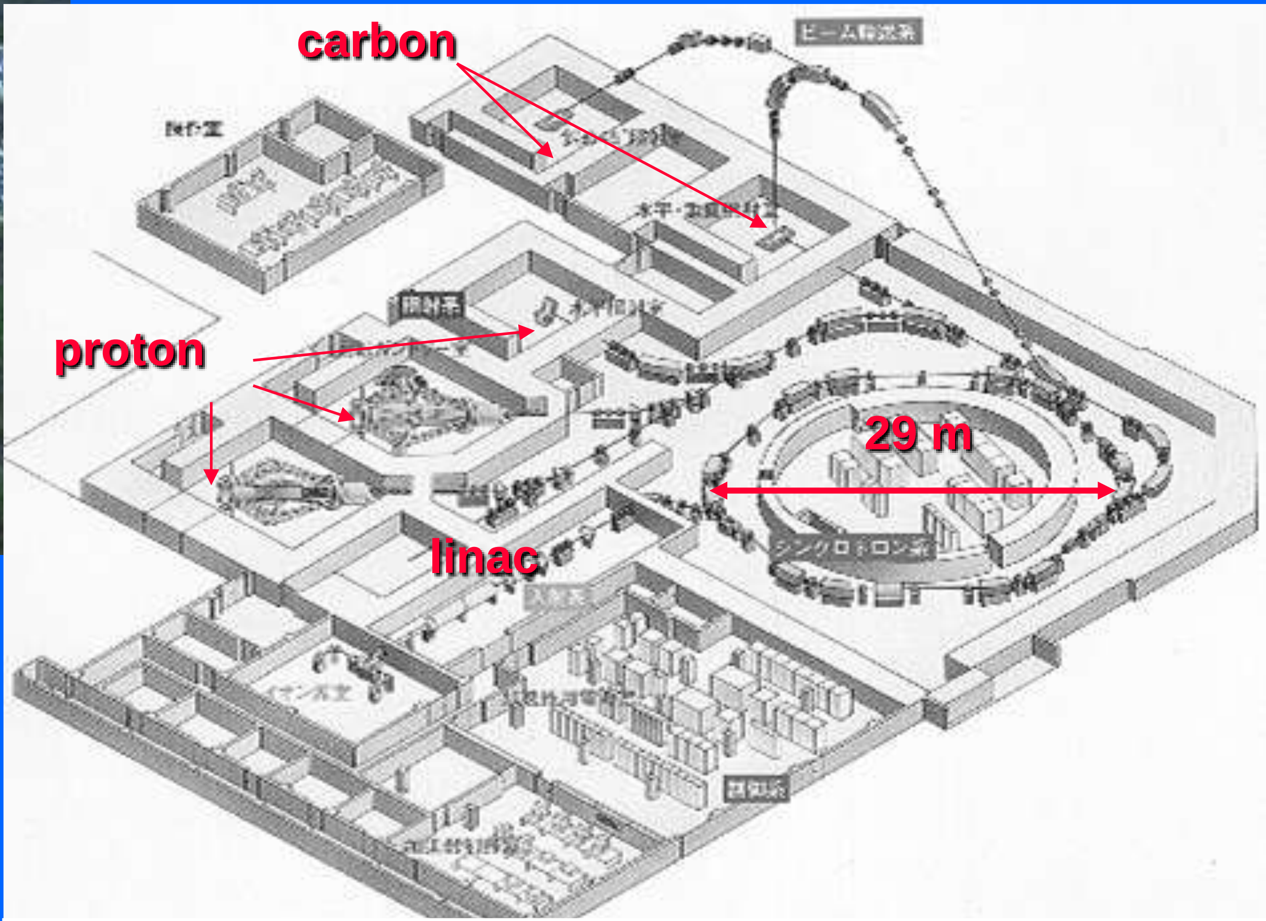
HIMAC new facility

Completion: end 2010





The Hyogo ‘dual’ Centre



End of 2008

protons: 2000 patients

carbon ions: 500 patients

Mitsubishi: turn-key system

Courtesy H. Tsujii

Patients treated with proton beams at Hyogo

	2001	2002	2003	2004	2005	2006	2007	2008	Total	
H&N Skull Base	4		9	35	64	62	71	52	297	14.6
Lung	5		15	23	38	38	37	42	198	9.8
Liver	5		20	27	53	70	63	60	298	14.7
Prostate	16		136	179	163	158	222	185	1059	52.2
Bone/Soft Tissue										
Others				10	23	35	72	36	176	8.7
Total	30	-	180	274	341	363	465	375	2028	%

Courtesy H. Tsujii

Patients treated with carbon ion beams at Hyogo

	2001	2002	2003	2004	2005	2006	2007	2008	Total	
H&N Skull Base		19			4	21	30	61	135	29.6
Lung		3			7	21	25	19	75	16.4
Liver		6			2	35	24	59	126	27.6
Prostate										
Bone/Soft Tissue		2			9	18	27	22	78	17.1
Others					1	1	19	21	42	9.2
Total		30			23	96	125	182	456	%

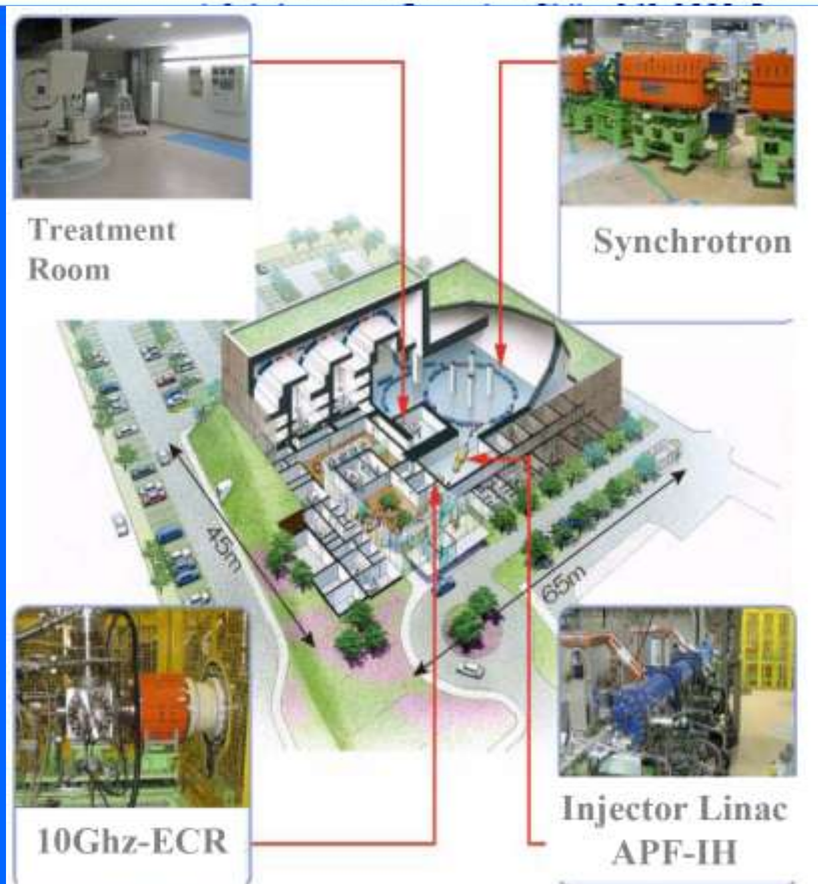
Carbon ion centres under construction

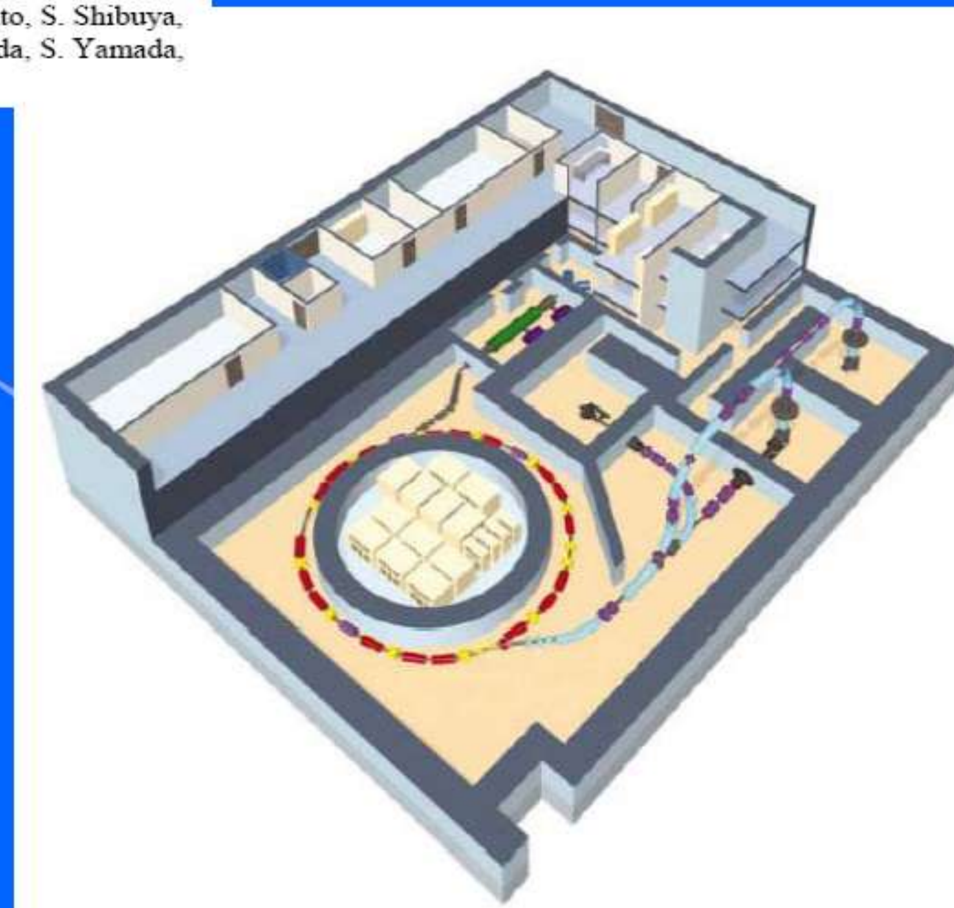
Gunma University

Proceedings of APAC 2004, Gyeongju, Korea

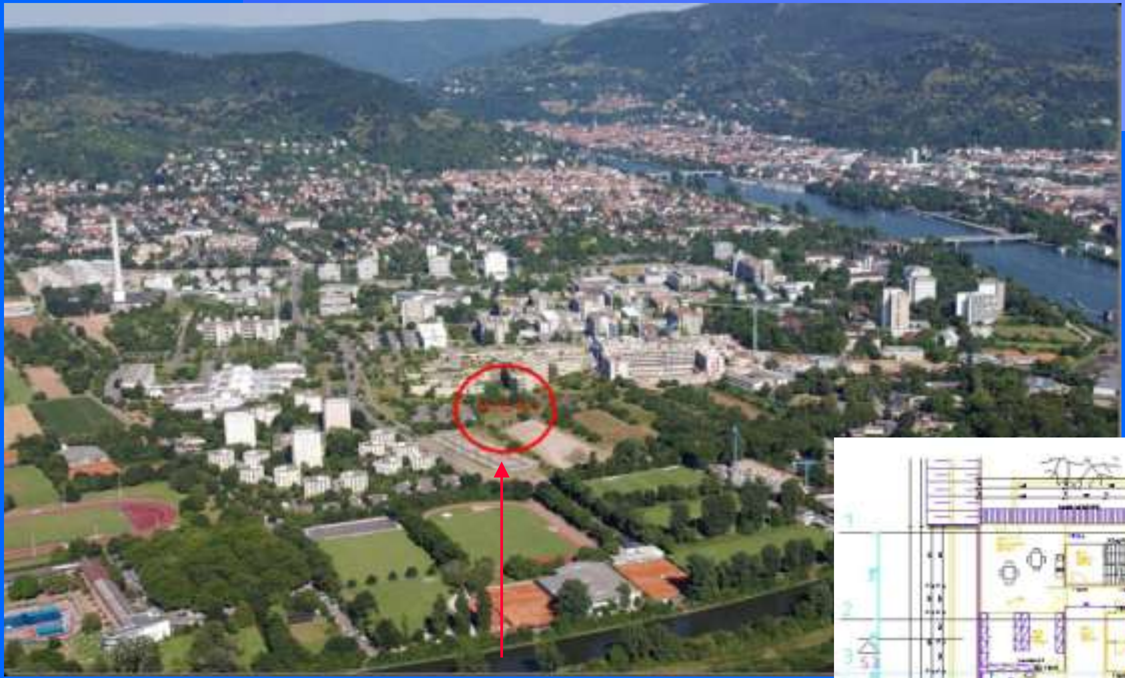
HIMAC AND NEW FACIILITY DESIGN FOR WIDE SPREAD USE OF CARBON CANCER THERAPY

K. Noda, T. Fujisawa, T. Furukawa, Y. Iwata, T. Kanai, M. Kanazawa, N. Kanematsu, A. Kitagawa, Y. Kobayashi, M. Komori, S. Minohara, T. Murakami, M. Muramstsu, S. Sato, Y. Sato, S. Shibuya, F. Soga, E. Takada, O. Takahashi, M. Torikoshi, T. H. Uesugi, E. Urakabe, K. Yoshida, S. Yamada,
National Institute of Radiological Sciences,





The site of HIT the Heidelberg Ion Therapy



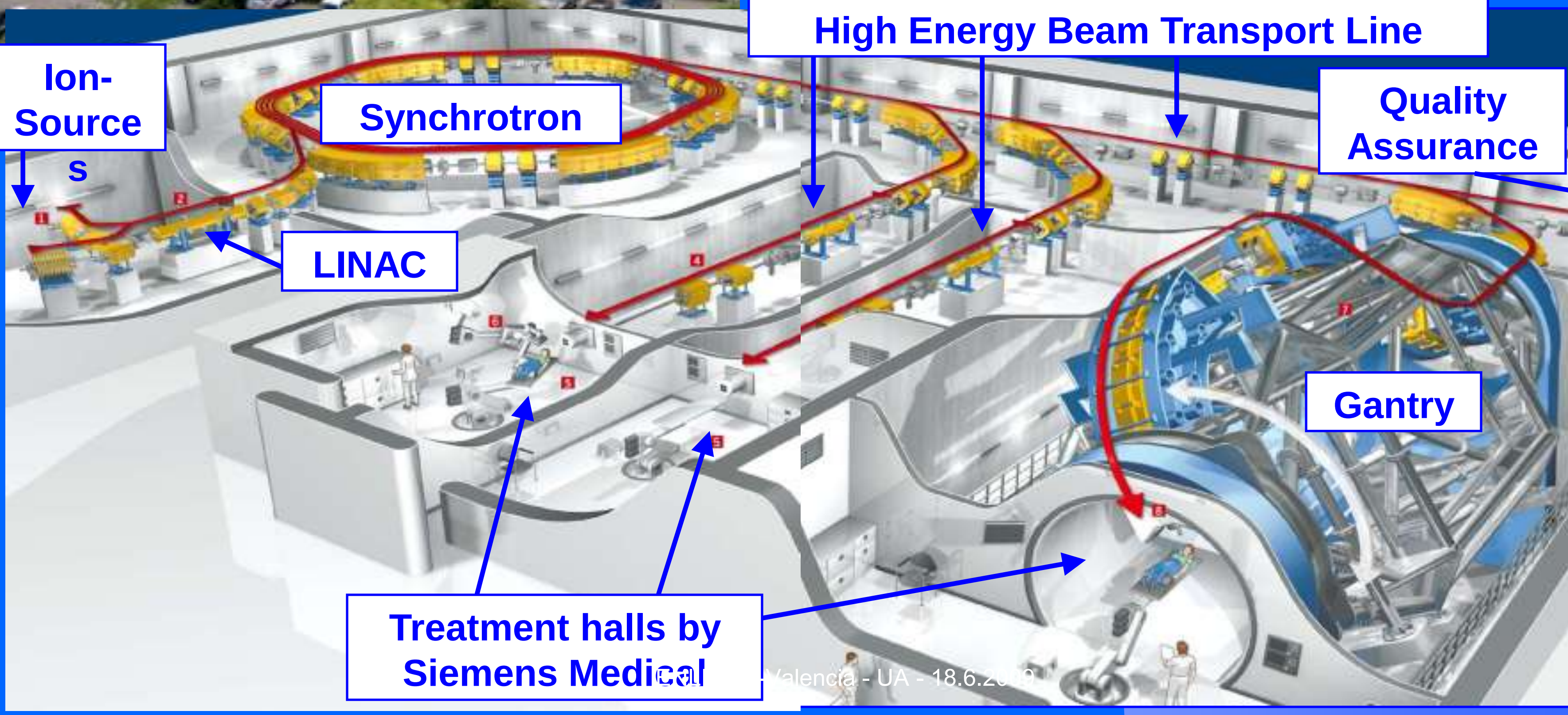
Medical Director: J. Debus

Technical Director: T. Haberer

HIT at Heidelberg

First beam extracted in 2007

First patient: by summer 2009



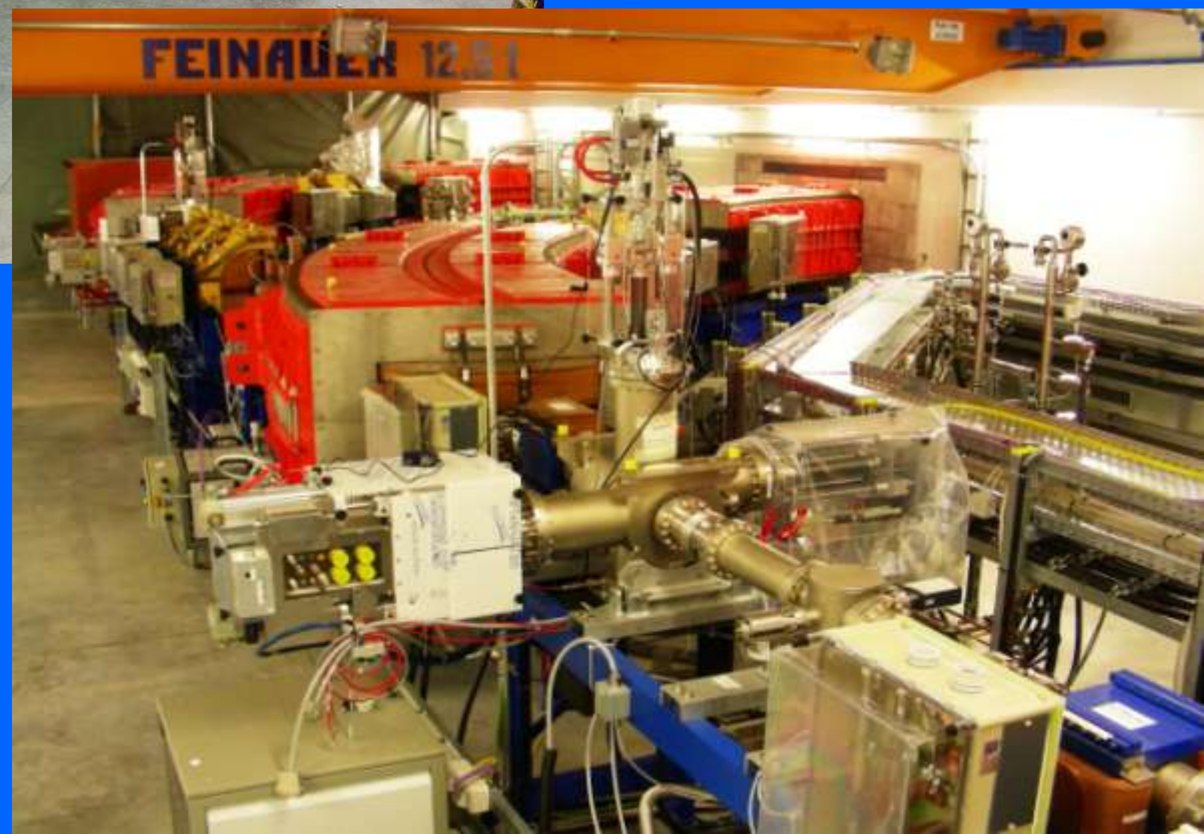
HIT at Heidelberg

Courtesy T. Haberer

synchrotron

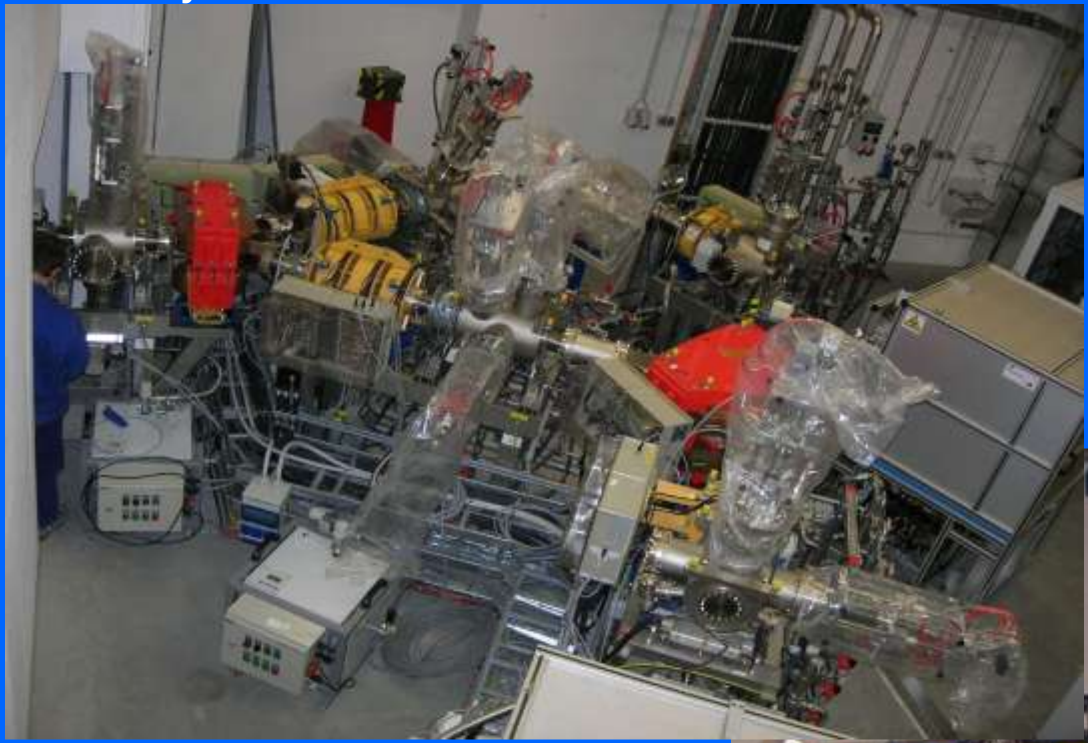
high energy

beam transport



Courtesy T. Haberer

Injector



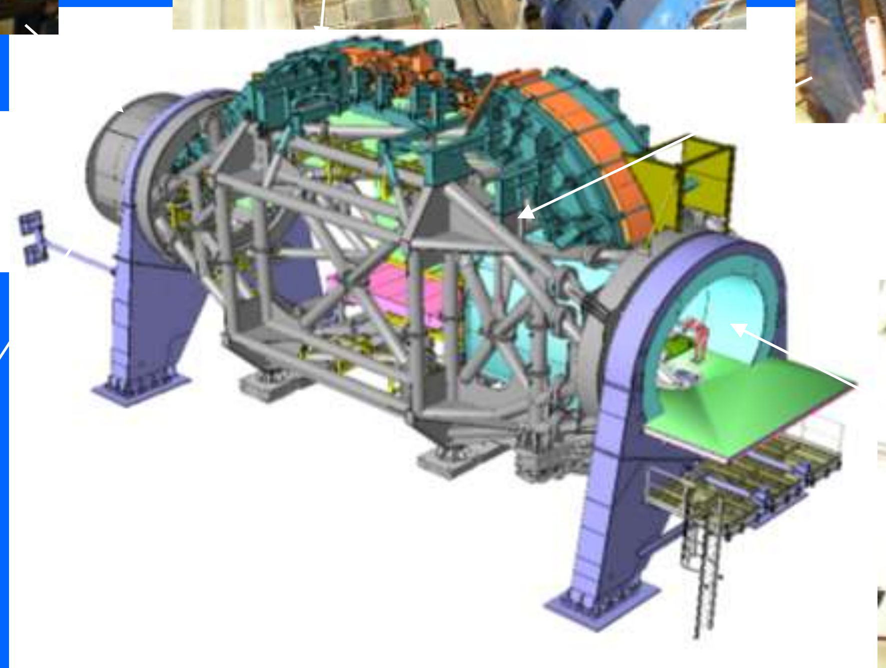
Ion sources

RFQ + IH-DTL

Built by GSI also for CNAO

Courtesy T. Haberer

Heidelberg ion gantry: 600 tons and 400 kW



MT AEROSPACE

Courtesy T. Haberer

Heidelberg ion gantry: patient room

Patient Gantry Room November 2007

Tilt floor, pending on Gantry position

Nozzle

Bumber mats

Patienttable, Roboter

Courtesy T. Haberer

Accelerator status

Sources, injector and synchrotron fully commissioned for protons, carbon and oxygen (256 energies each)

H1 / H2: pencil beam libraries (E F I) for protons and carbon in therapeutical quality reached in April, 2008

R+D-cave: protons, carbon and oxygen energy libs established

Gantry: proof of principle for protons and carbon (representative settings in the full phase space (E F I α))

To do: intensity upgrade (x3) under way (sources, LEBT, RFQ)

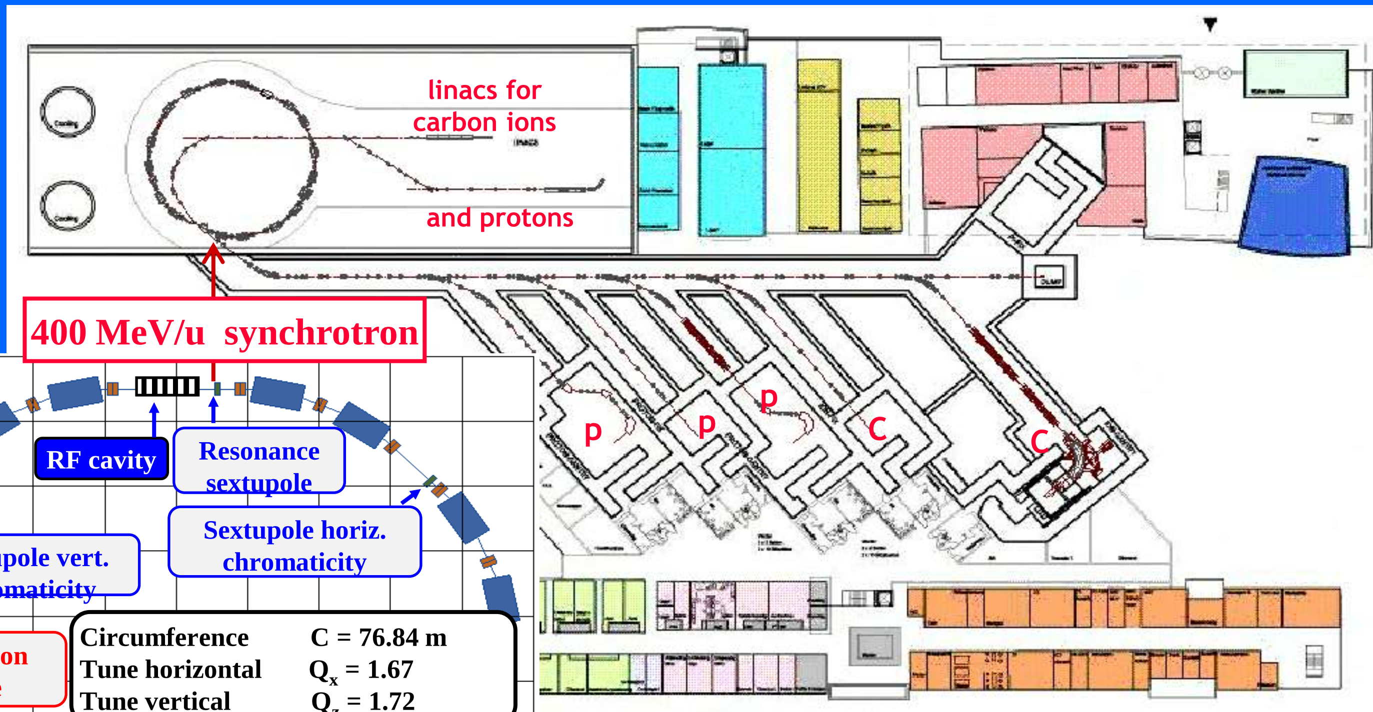
Operation scheme 2008: 24 h/7 days, 330 days, 2 shutdowns 14 d

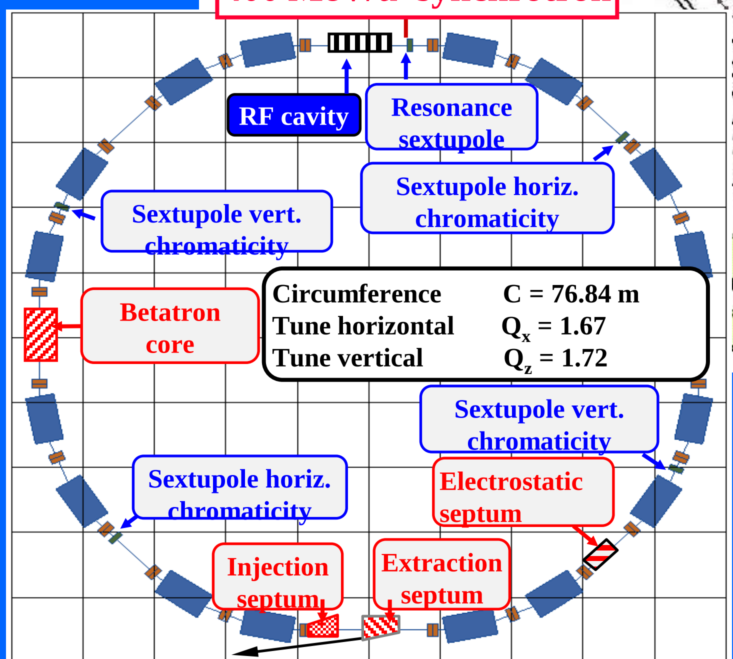
- **Availability** of the pencil beams @ H1/2: ≈ 98%

PIMMS at CERN from 1996 to 2000

CERN–TERA–MedAustron Collaboration for optimized medical synchrotron

Project leader: P. Bryant **Chairman of the PAC: G. Brianti**





3 extraction systems:
- <u>betatron core</u>
- 1/3 resonance
- RF knock-out

The main features

Philip Bryant : **Project leader**

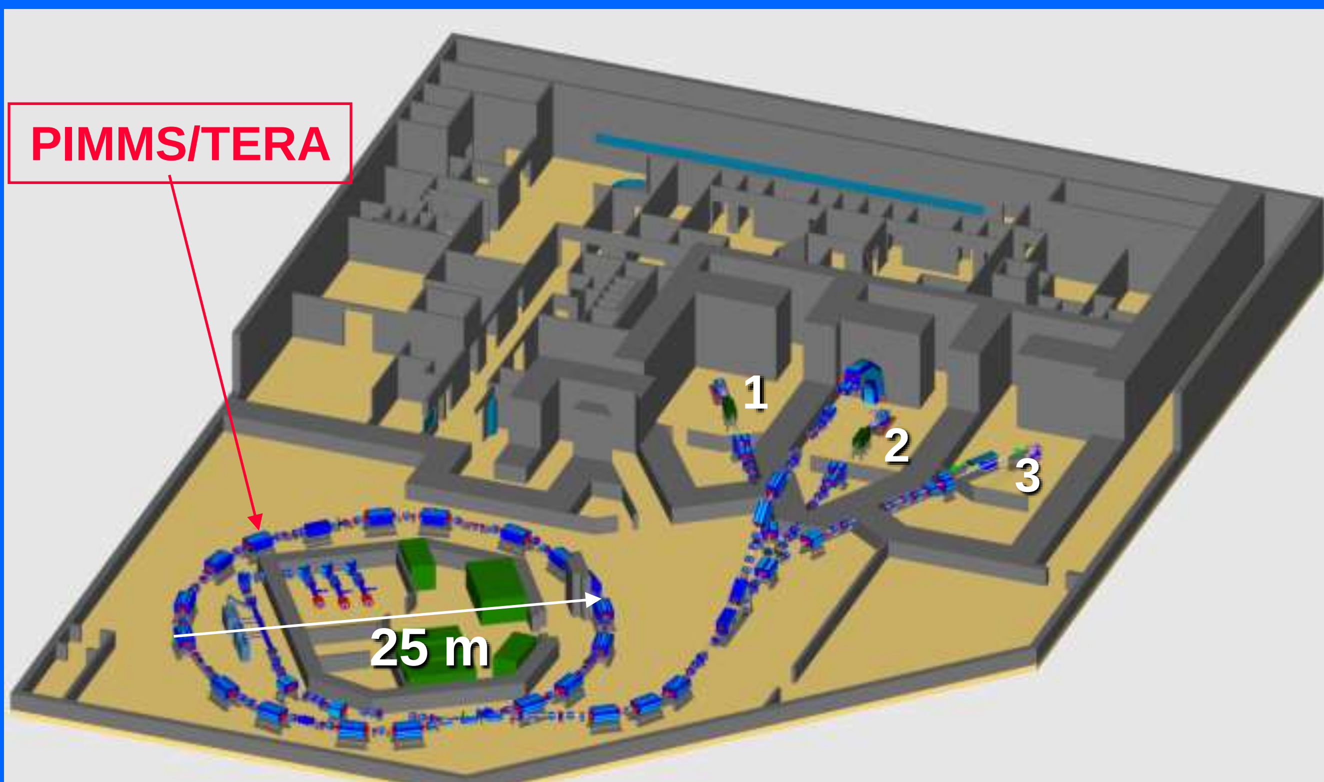
Giorgio Brianti: **Chairman of PAC**

1) two dispersion-free zones for injection and RF acceleration in a lattice made of 16 short and cheap bending magnets;
2) single-turn injection from the inside of the ring;
3) slow extraction based on the excitation of a "betatron core" while all the currents in the other machine components are kept unchanged and the lattice satisfies the "Hardt condition";
4) an 'empty' bucket that increases the velocity of the particles entering the extraction resonance, thus reducing the intensity fluctuations of the extracted beam;

CNAO = Centro Nazionale di Adroterapia

CNAO Foundation created by the Italian Government in 2002:
4 Hospitals in Milan, 1 Hospital in Pavia and TERA

In October 2003 TERA passed to CNAO
the design of CNAO (3000 pages) and 25 people



Since 2004 INFN is "Istitutional Participant" with people and important construction responsabilities

(Caudio Sanelli)

INFN runs CATANA for eye protontherapy in Catania

TERA

CNAO = Centro Nazionale di Adroterapia at Pavia

President: Erminio Borloni

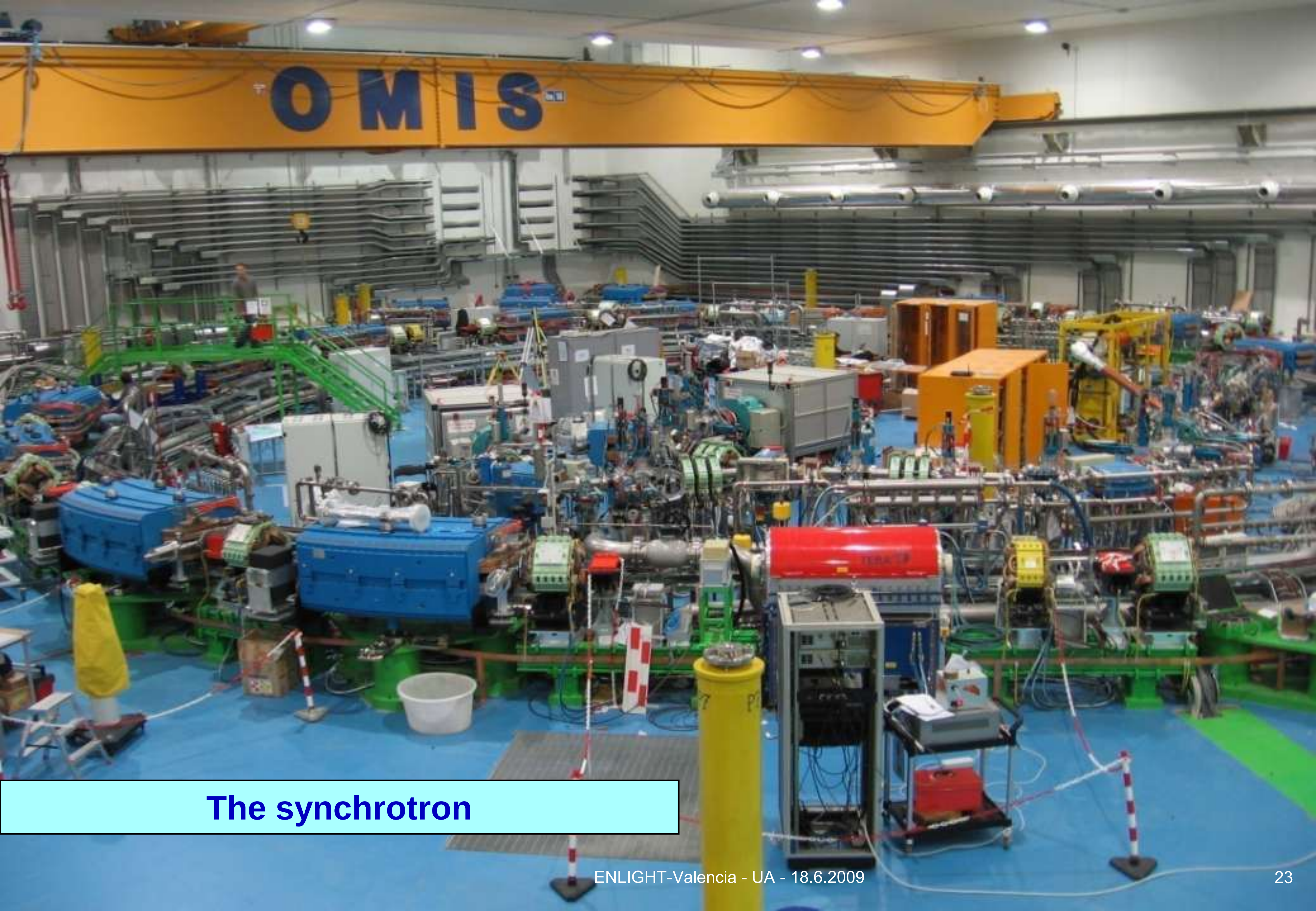
Medical Director: Roberto Orecchia **Technical Director: Sandro Rossi**

Hospital building

High-tech building

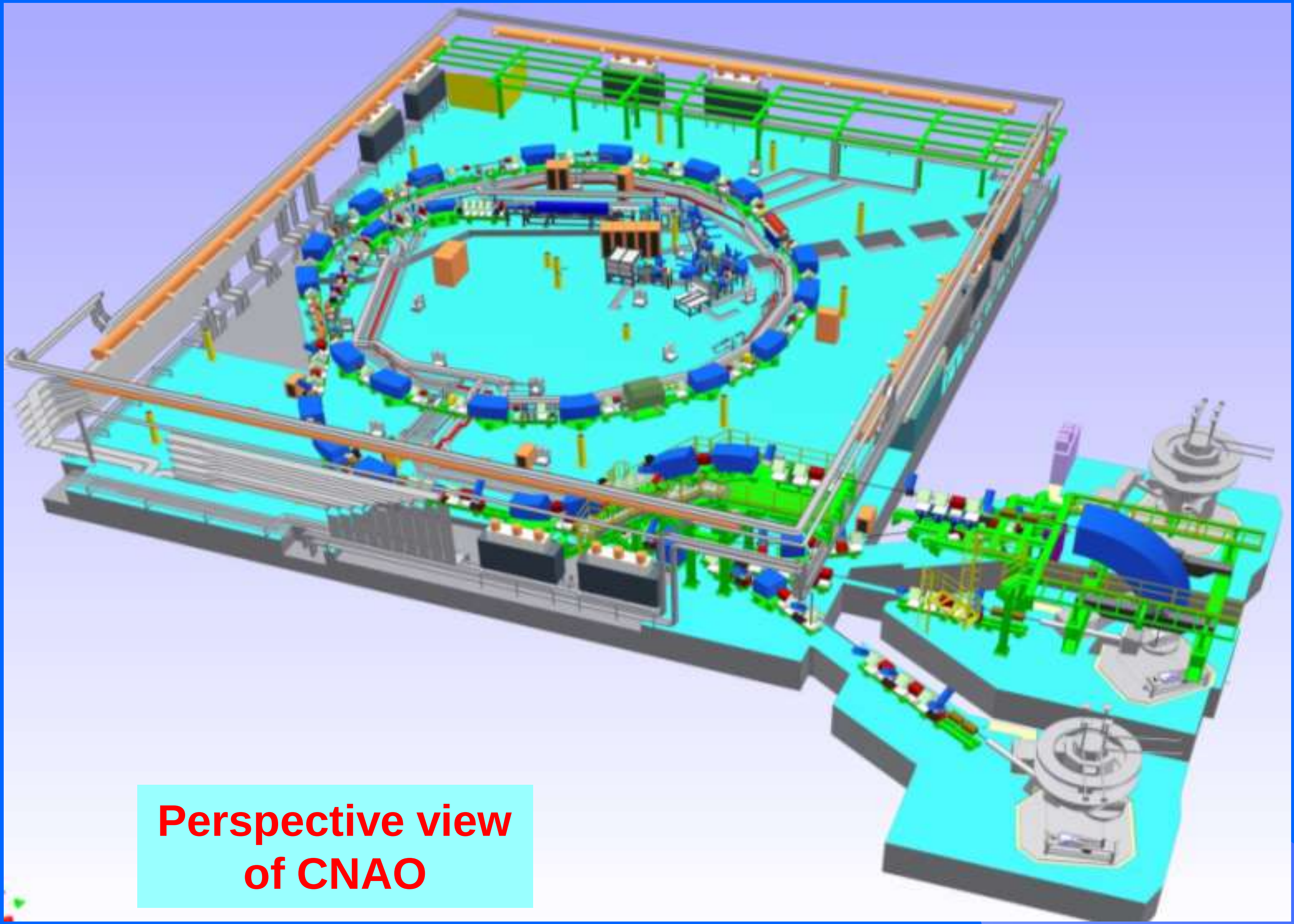
CNAO = Centro Nazionale di Adroterapia at Pavia

TERA



The synchrotron

CNAO at Pavia

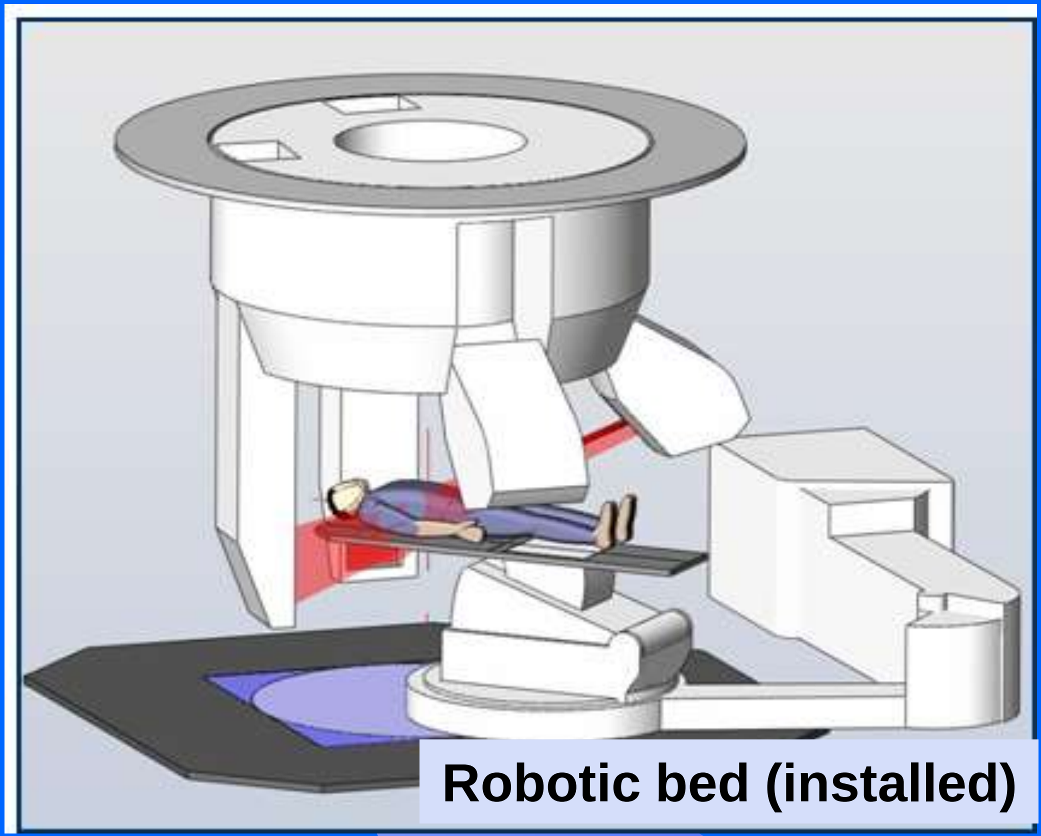


Perspective view of CNAO

Treatment rooms

Courtesy of Schaer Engineering AG, Switzerland

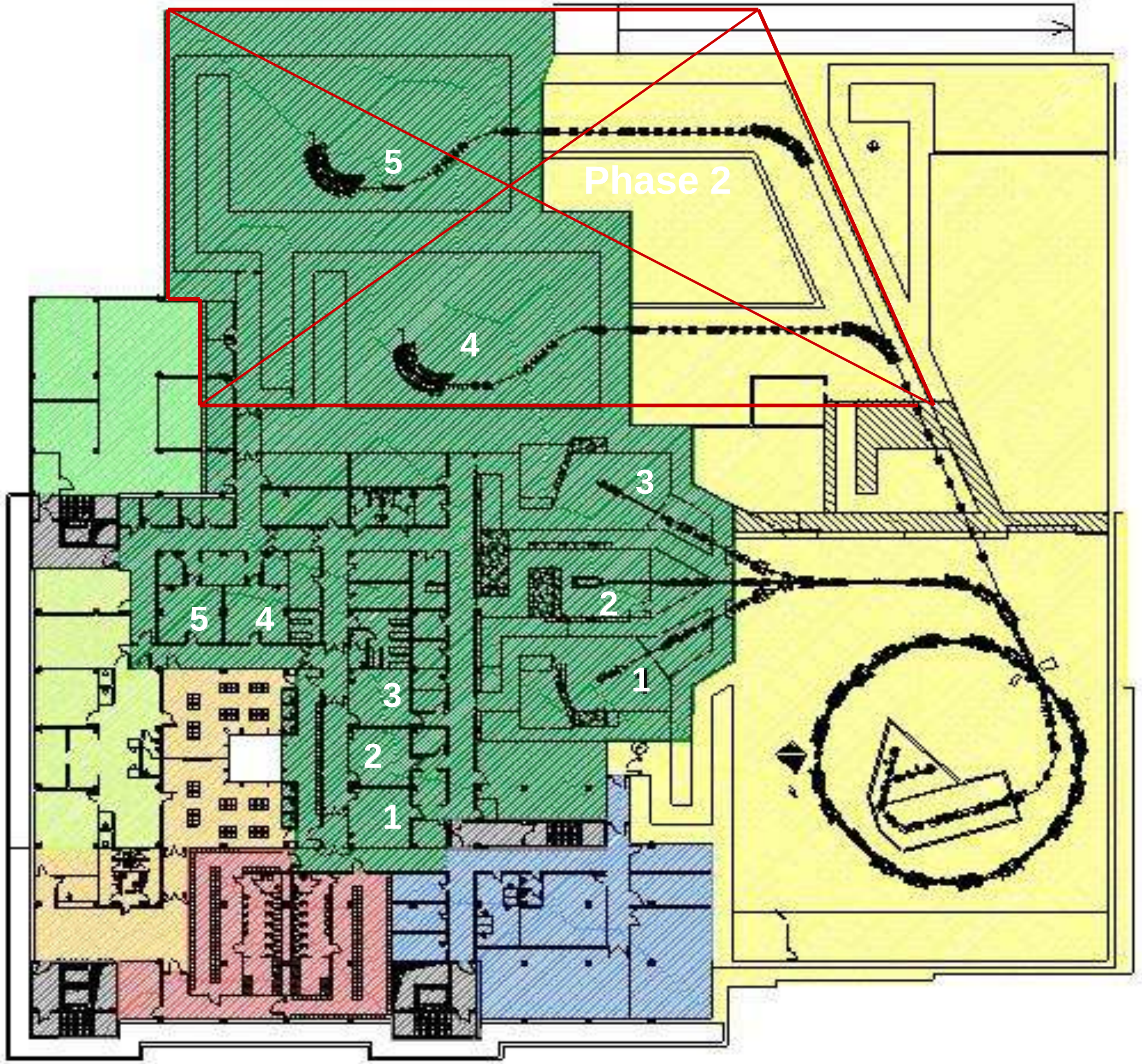
Chair for head and neck

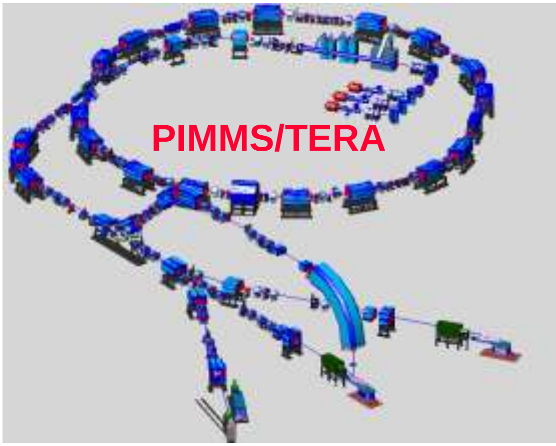


Robotic bed (installed)

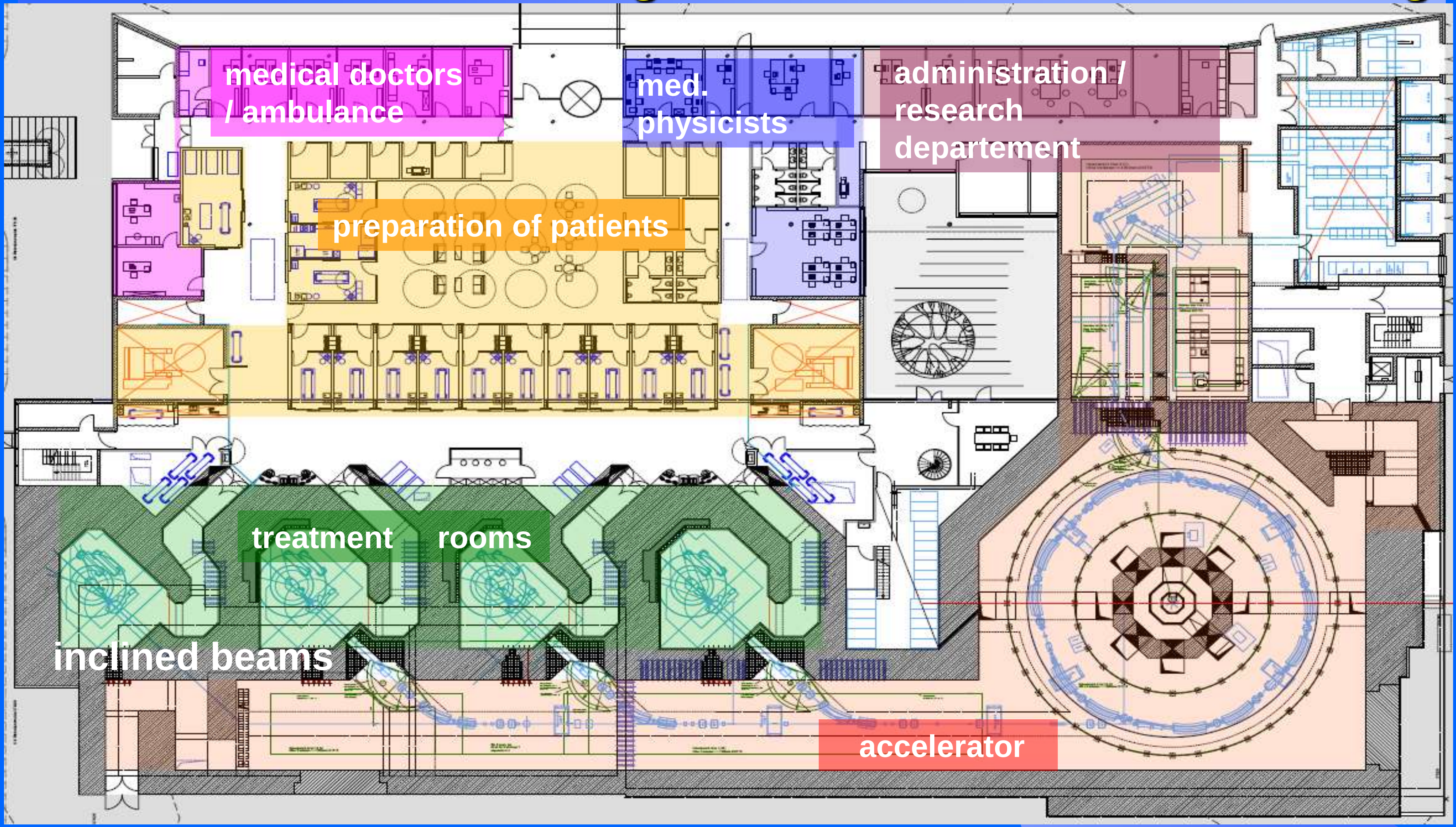
First patient foreseen by the end of 2010 - 2800 patients per year in 2014

The underground floor of CNAO and the Phase 2 with





Siemens Medical is building for 2010 a 'dual' centre in Marburg

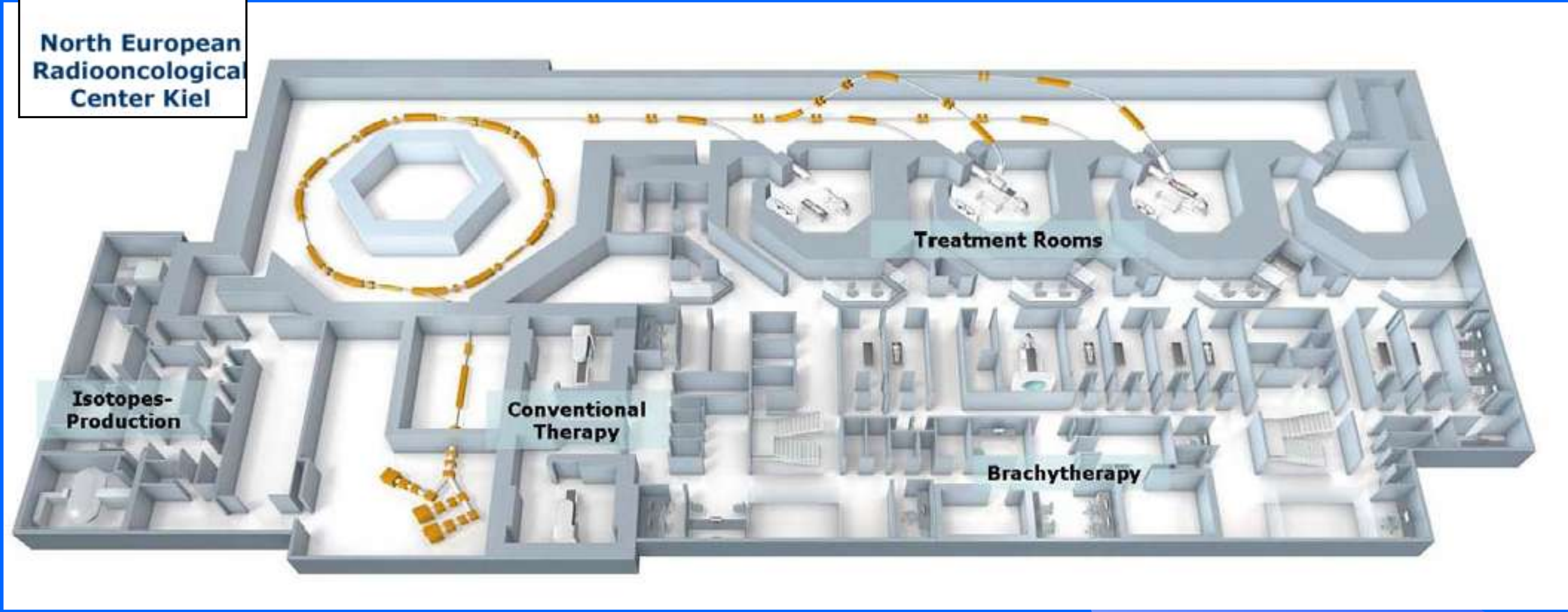


Courtesy R. Kampf

Siemens Medical is building for 2012 a 'dual' centre in Kiel

NRoCK

North European Radiooncological Center Kiel



Med University Center Schleswig-Holstein, Kiel

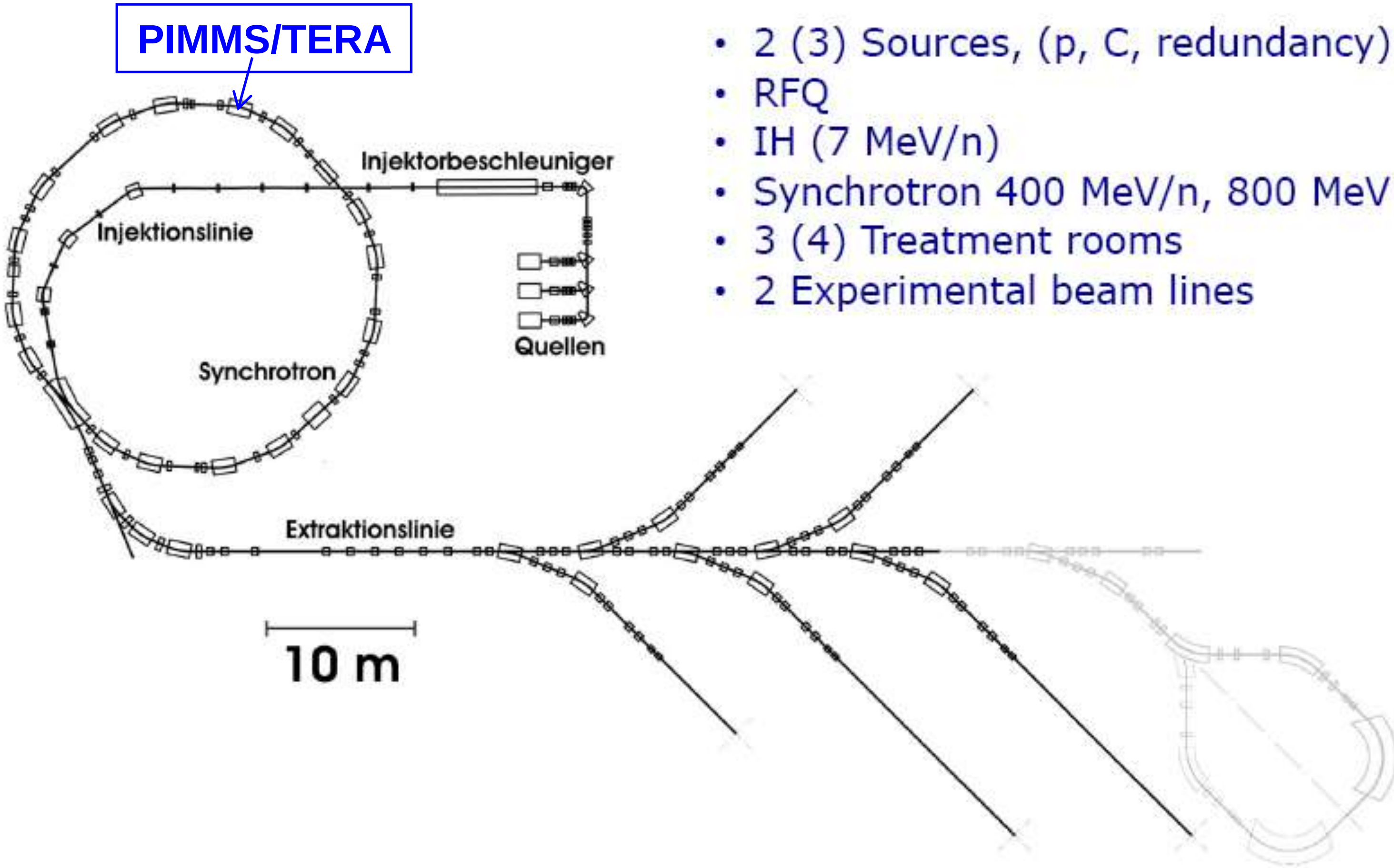
Courtesy R. Kampf

Siemens Medical is building for 2012 a ‘dual’ centre in Kiel

Carbon ion centres in the planning phase

Courtesy M. Benedikt

In 2007 MedAustron has been approved for Wiener Neustadt



- 2 (3) Sources, (p, C, redundancy)
- RFQ
- IH (7 MeV/n)
- Synchrotron 400 MeV/n, 800 MeV
- 3 (4) Treatment rooms
- 2 Experimental beam lines

MedAustron will build a centre based on the CNAO construction drawings (by agreement with CERN-CNAO-INFN)

Courtesy M. Benedikt

MedAustron timetable

- Conceptual design for end 2008:
- Mid 2009 – end 2011: tendering, purchasing, reception
- 2011 – 2012: installation, system integration
- End 2012 start commissioning
- End 2013 first patient
- End 2014 “routine” operation

Lyon 1 — Rhône-Alpes Région — République Française, ministère délégué à la Recherche — GRANDLYON communauté urbaine

Projet ETOILE

Courtesy J. Balosso

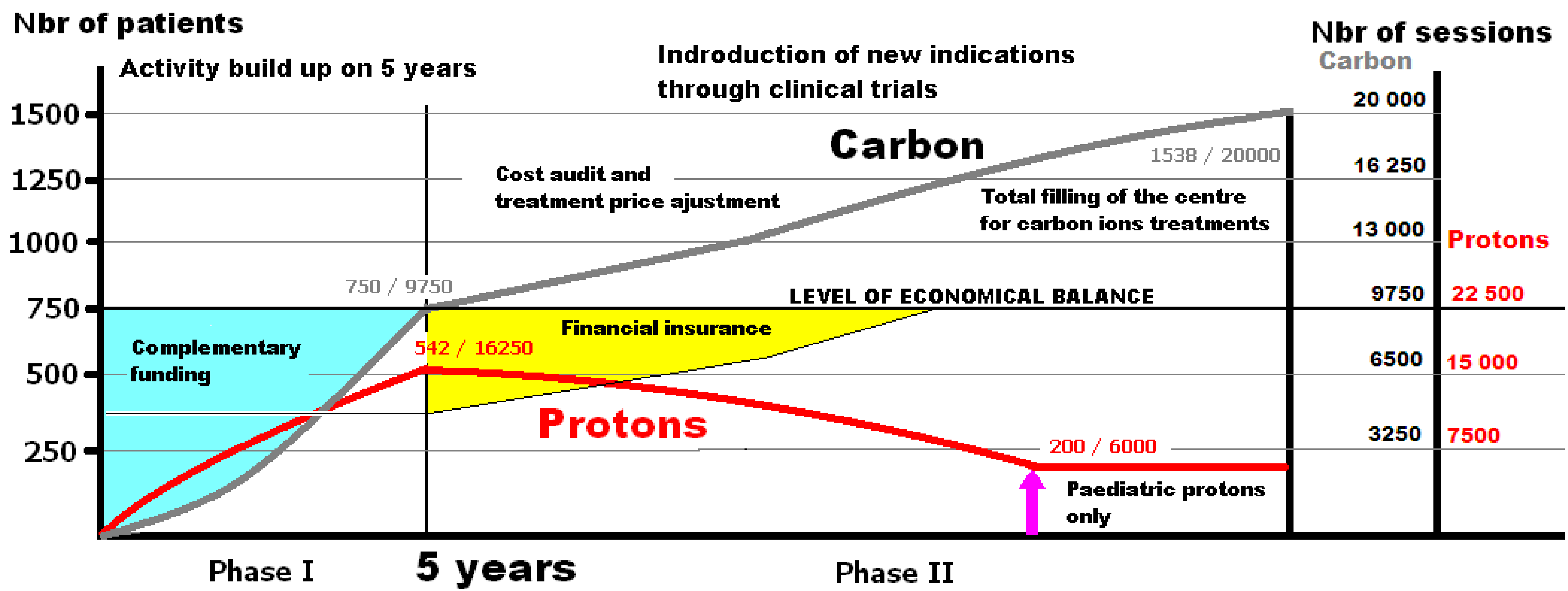
The basic principles of ETOILE

- **Public health** principles: *equity for accessibility (health insurance),*
  economy, evaluation
- **Evidence based** medical indications
- An target of 100% **prospective studies**
- **National networking** with the other hadron facilities
- **European networking** for multicentric evaluation
- An **open institution** with time limited contracts
- **No competition** with other projects
- An **industrial construction** and not a prototype

- **2007**: **<u>Governmental green light (February),</u>** GCS (March, **5 regional hospitals**)
- **2008**: **<u>Financial model assessment</u>** (MAPPP) (February)
- **2008: <u>Call for bids</u>** (February), Choice of 3 candidates (March),
- **2009**: **<u>Competitive negotiation</u>**, 1st round June 2008, 2nd round April 2009, **last round end of 2009**
- **End of 2010** construction until **2013**; **2014** opening….???

Courtesy J. Balosso

Provisional activity of ETOILE



Courtesy R. Miller

Status of carbon ion therapy in the States

- No light ion facilities under construction in the US as of June 2009.

- US institutions with current or past interest in carbon ion radiotherapy:

  Mayo Clinic – currently developing philanthropic options

  University of Michigan

  Tuoro University

  University of Alabama

  Ohio State University

Courtesy R. Miller

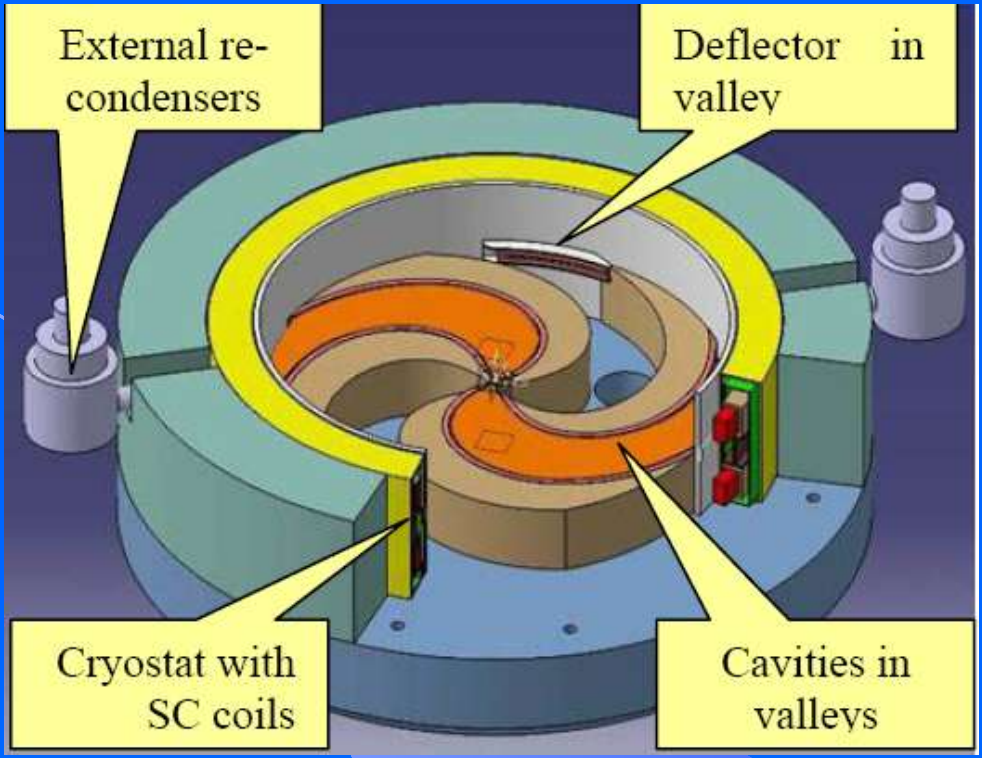
Mayo Clinic carbon ion facility

- Non-profit proton/carbon/light ion medical treatment and research facility
- Capacity of 1,800 patients/year, treated on clinical trials or enrolled in Mayo HCP Registry
- 4 conventional and 1 stereotactic treatment rooms - 2 proton gantries
- Two phase construction (with two acceleration systems)
  - Phase I – Proton radiotherapy (year 3 after construction begins)
  - Phase II – Carbon/light ion radiotherapy (year 6-8)

Courtesy Y. Jongen

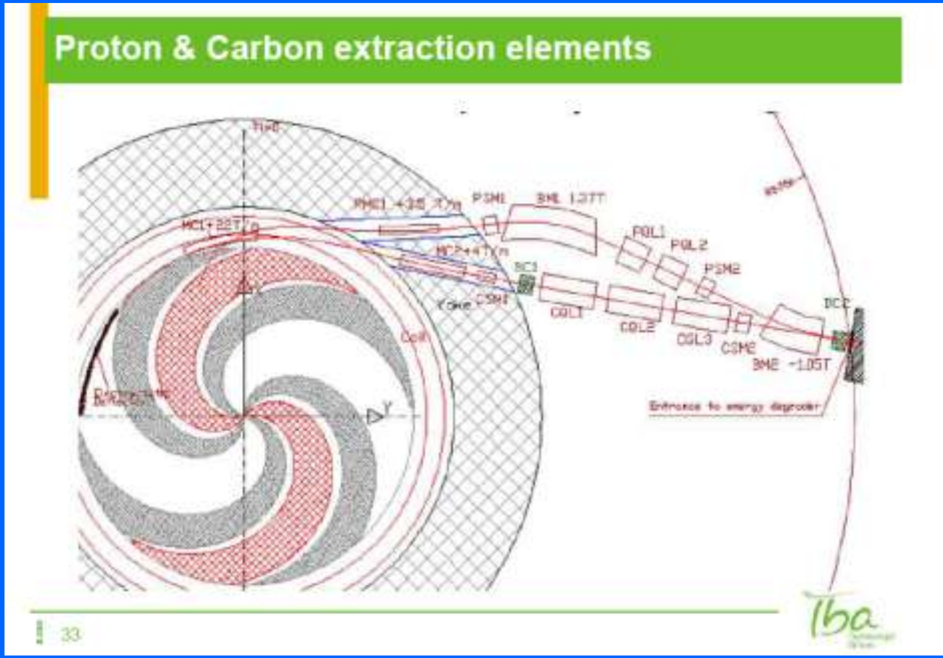
IBA superconducting cyclotron

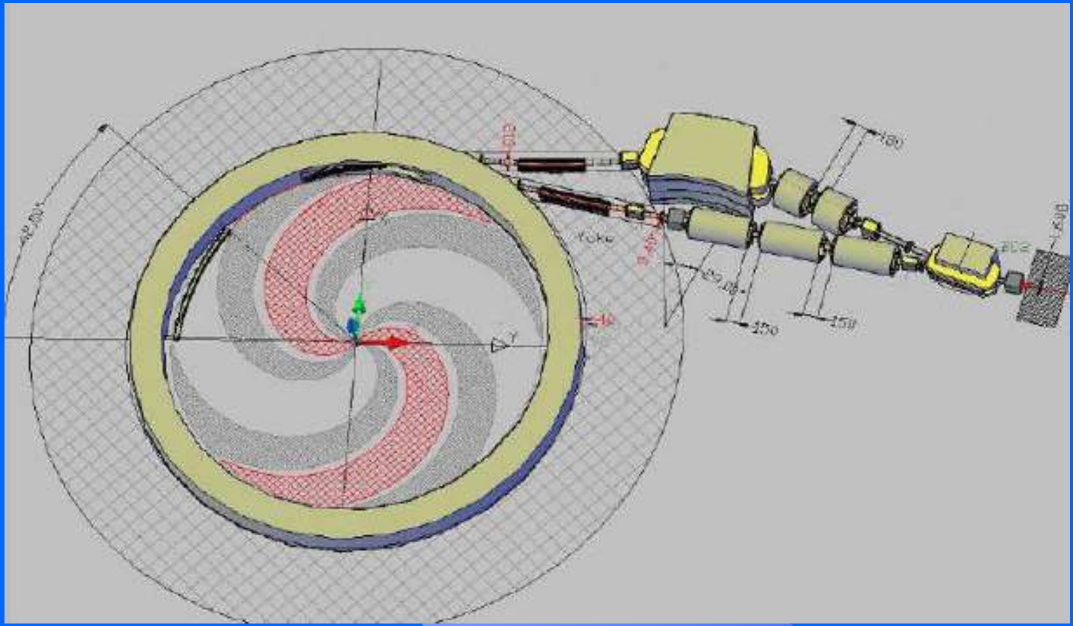
General properties	
type	compact isochronous
accelerated particles	H_2^+, $^4He^{2+}$, ($^6Li^{3+}$), ($^{10}B^{5+}$), $^{12}C^{6+}$
ion sources	ECR, ECR, multicusp
injection	axial with spiral inflector
final energy of ions,	400 MeV/u
protons	260 MeV/u
extracted ions, protons	by deflector by stripping
extraction efficiency	80 %
number of turns	1300 - 1500
Magnetic system	
total weight	700 tons
outer diameter	6.06 m
height	2.76 m
pole radius	1.87 m
valley depth	60 cm
bending limit	K = 1600
hill field	4.5 T
valley field	2.45 T



Courtesy Y. Jongen

"Archade" (AT Ganil in Caen, Fr) is based on the new IBA400 MeV/u superconducting cyclotron

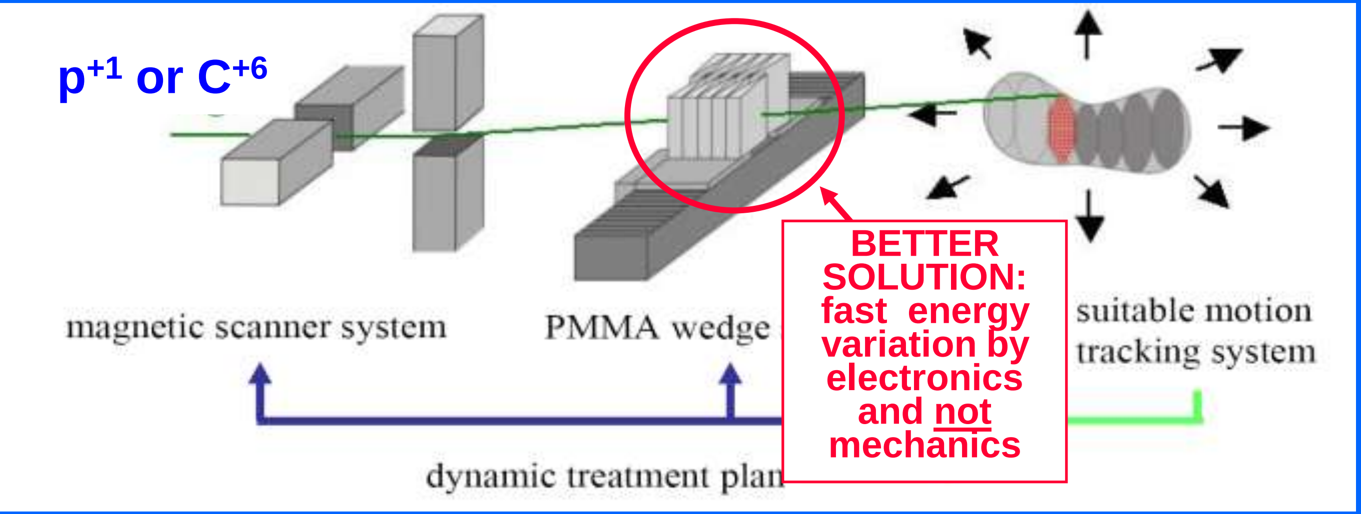


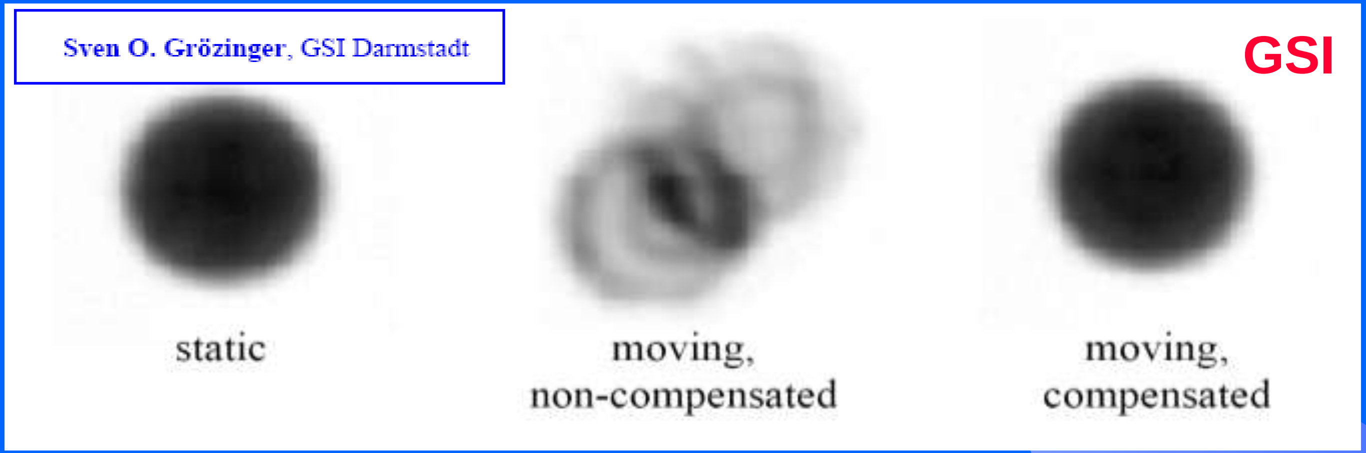


- As soon as the agreement with Archade is finalized, IBA will start the construction of the prototype

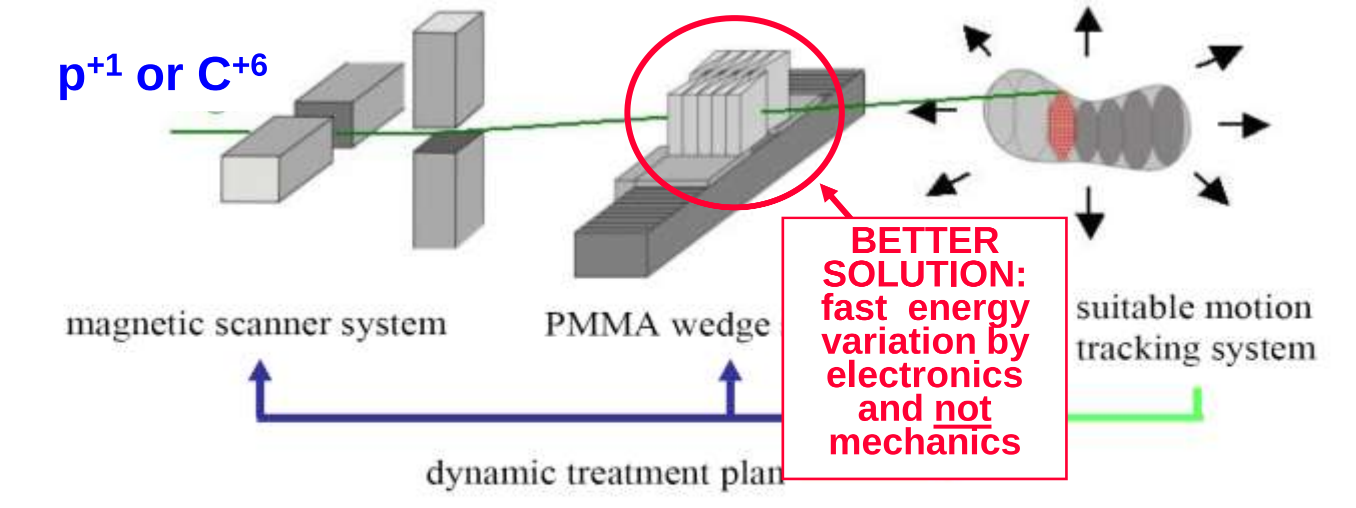
The next fast cycling accelerators for carbon ion therapy

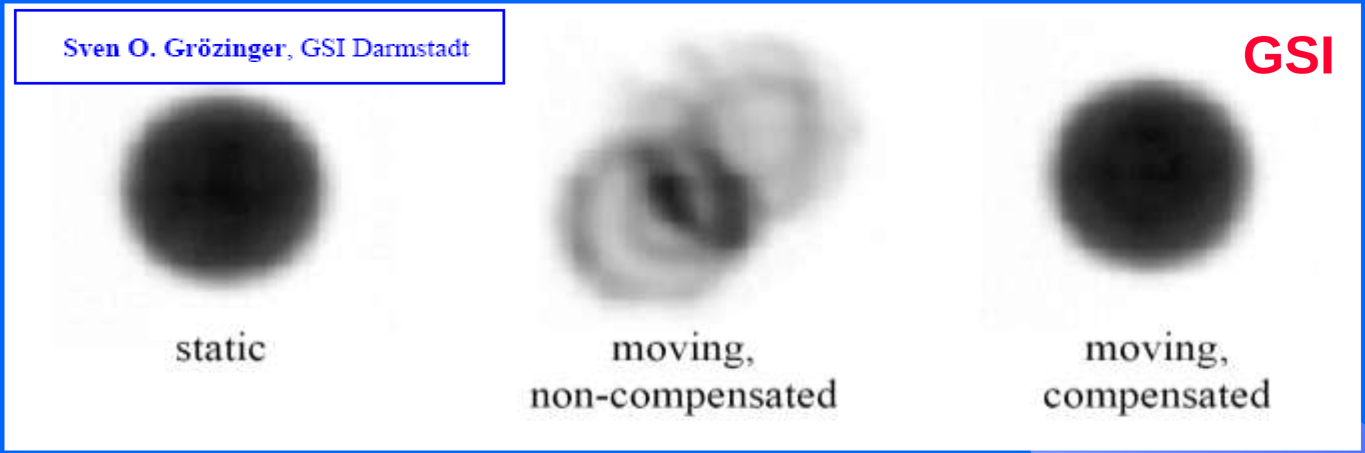
GSI approach to treat moving organs: depth with fast absorbers





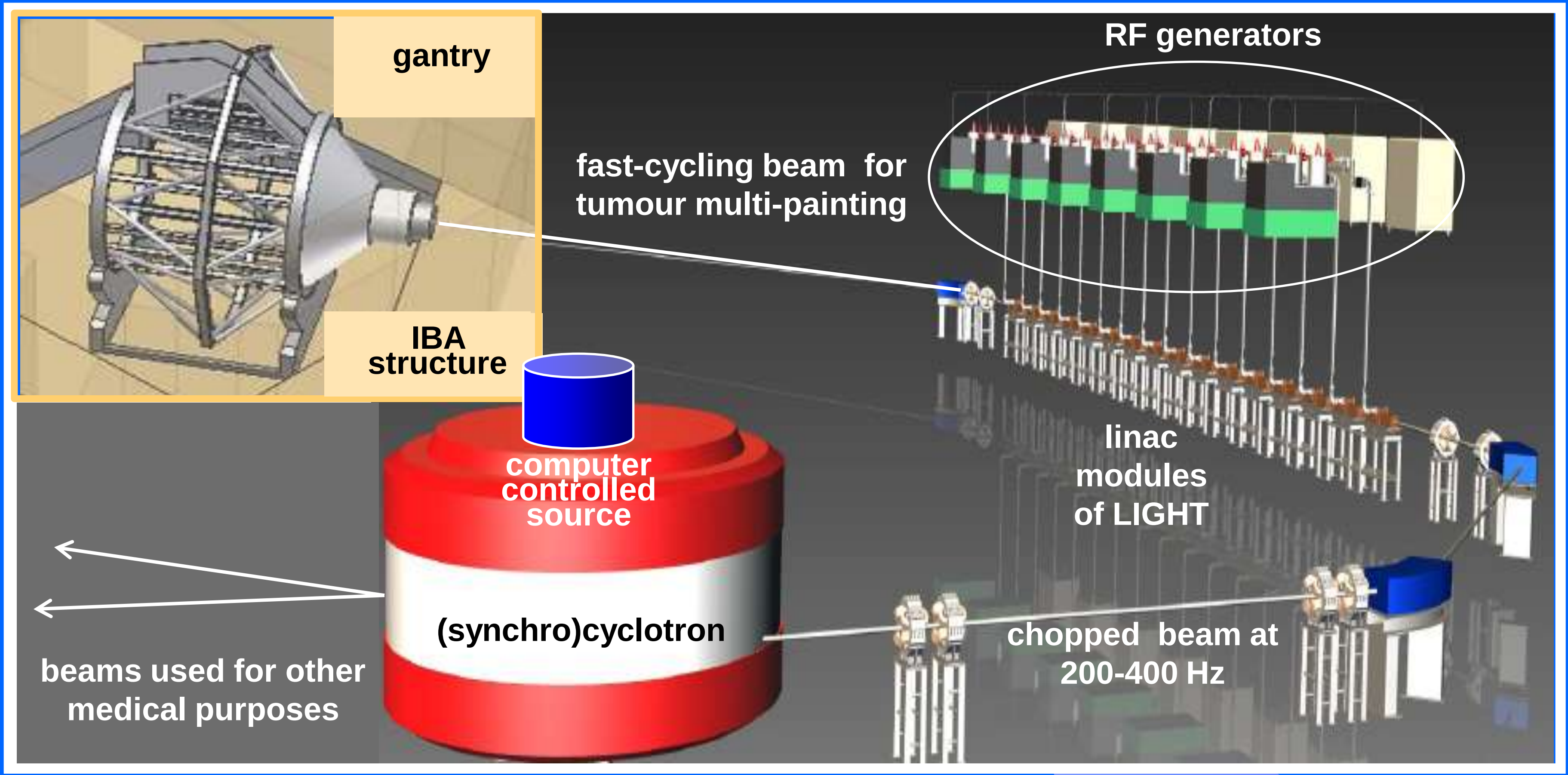
GSI approach to treat moving organs: depth with fast absorbers





Fast cycling allows 'repainting' and error correction

Cyclinac = Cyclotron + Linac for Image Guided HadronTherapy



The energy is adjusted in 2 ms in the full range by changing the power pulses sent to the 16-22 accelerating modules

The charge in the next spot is adjusted every 2 ms with the computer controlled source

Prototype of the 4th module of LIGHT

Mario Weiss project leader of

INFN (Mi- Na) – CERN -TERA Collaboration 1999-2002

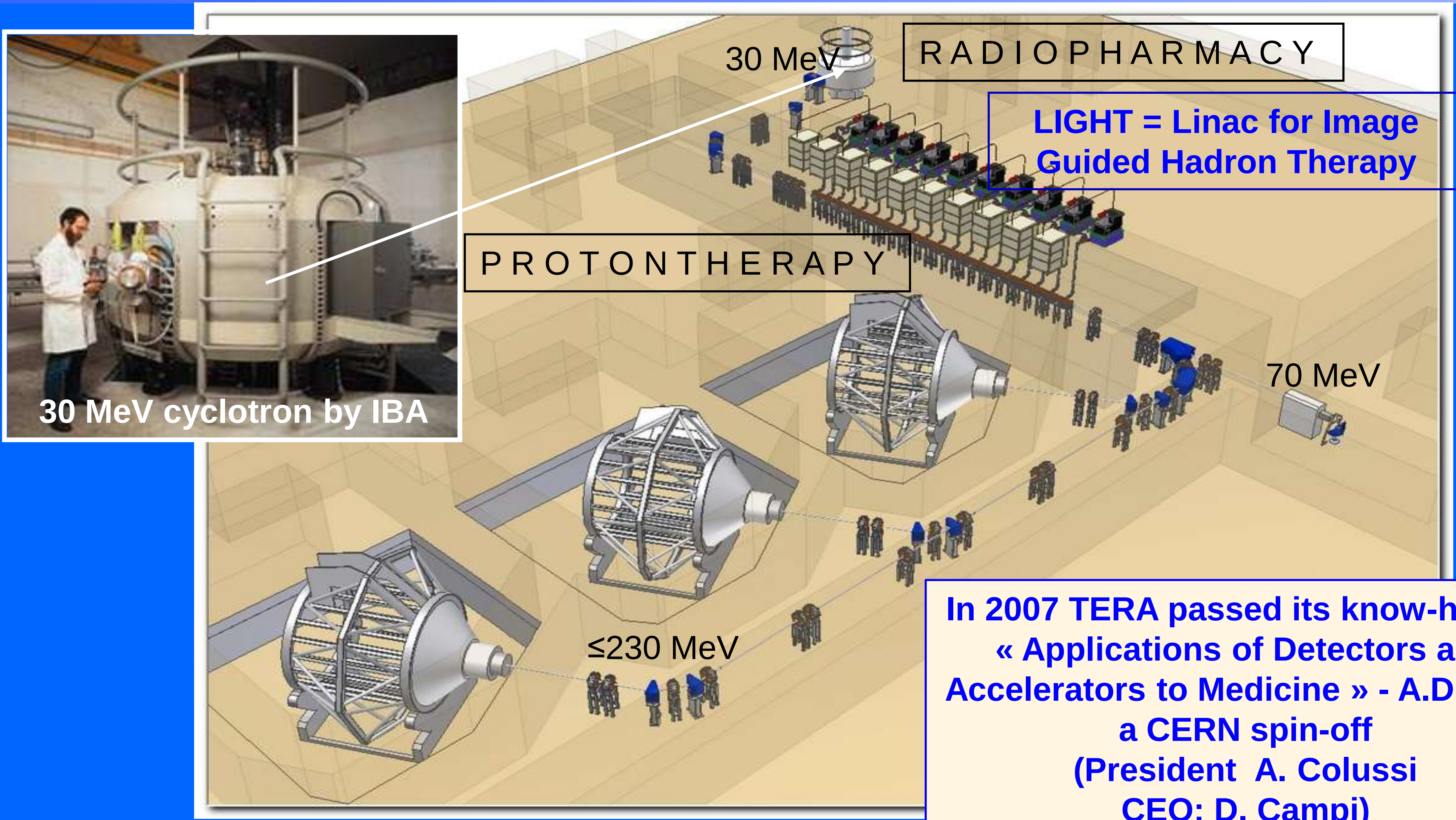
C. De Martinis et al

V. Vaccaro et al.

E. Rosso et al

Protons accelerated at LNS, Catania, from 62 to 74 MeV

IDRA = Institute for Diagnostics and RAdiotherapy is a proton cyclinac



In 2007 TERA passed its know-how to « Applications of Detectors and Accelerators to Medicine » - A.D.AM. - a CERN spin-off (President A. Colussi CEO: D. Campi)

Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Nuclear Instruments and Methods in Physics Research A 562 (2006) 1009–1012
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

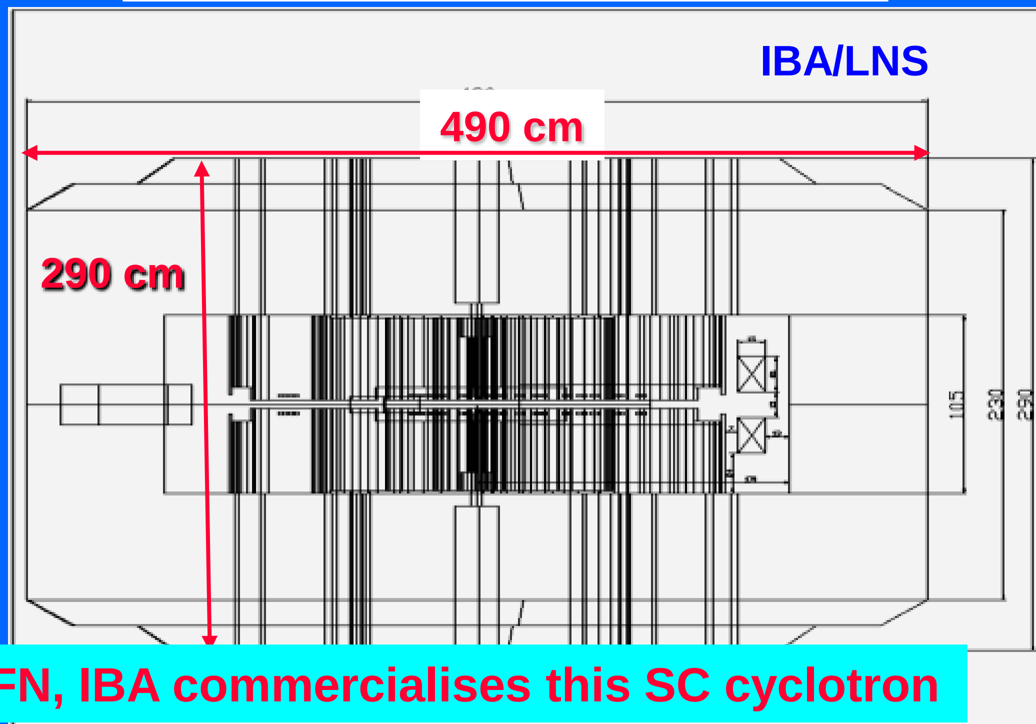
A novel superconducting cyclotron for therapy and radioisotope production

Luciano Calabretta[a,*], Giacomo Cuttone[a], Mario Maggiore[a,b], Maurizio Re[a], Danilo Rifuggiato[a]
[a] LNS-INFN, Via S. Sofia 62, Catania 95123, Italy
[b] University of Catania, Via S. Sofia 64, Catania 95123, Italy

Available online 6 March 2006

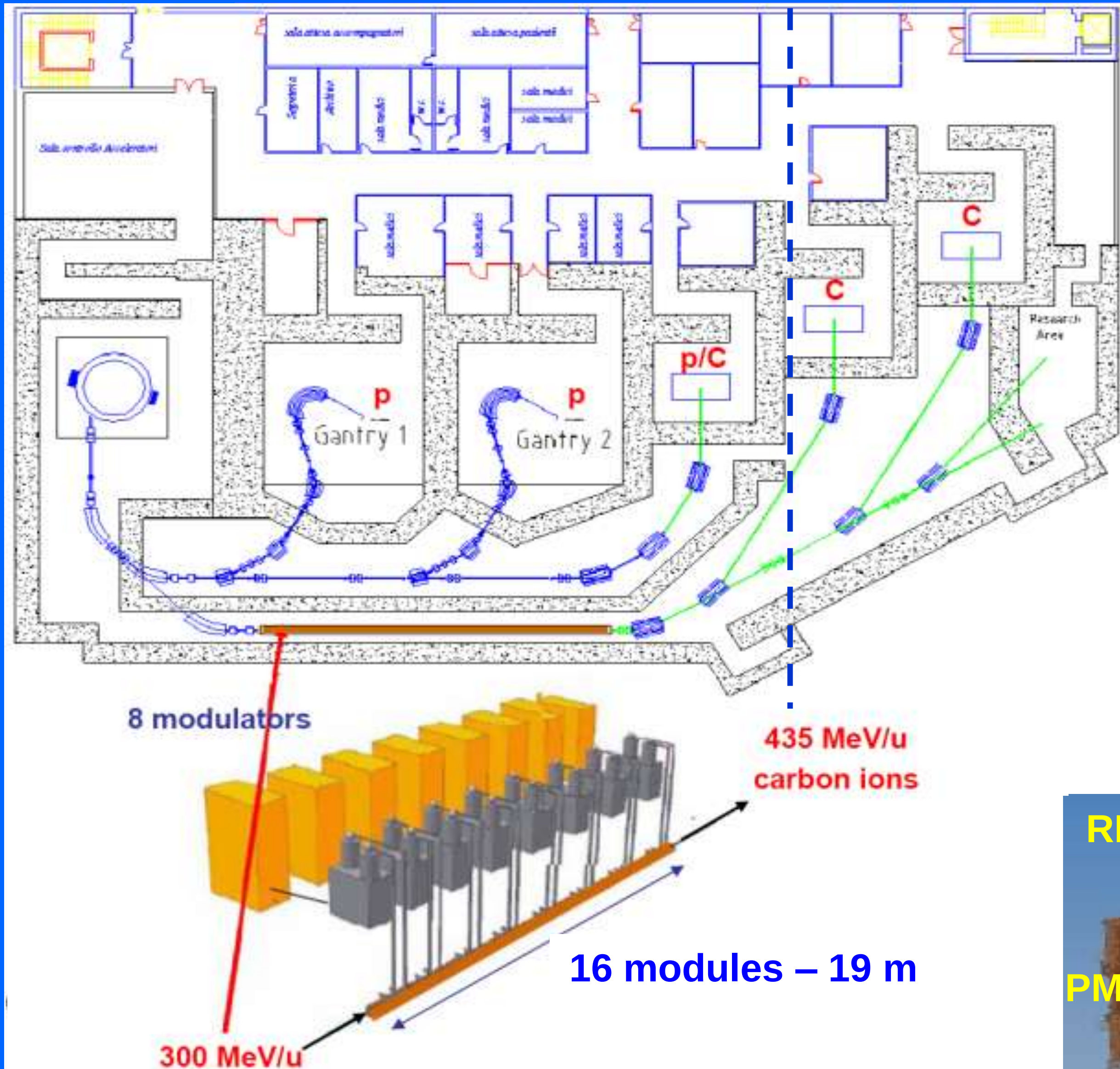
For Cannizzaro Hospital a novel SC cyclotron has been proposed by Laboratori Nazionali del Sud

250 MeV/u H_2^{+1}, 300 MeV/u C^{+6}



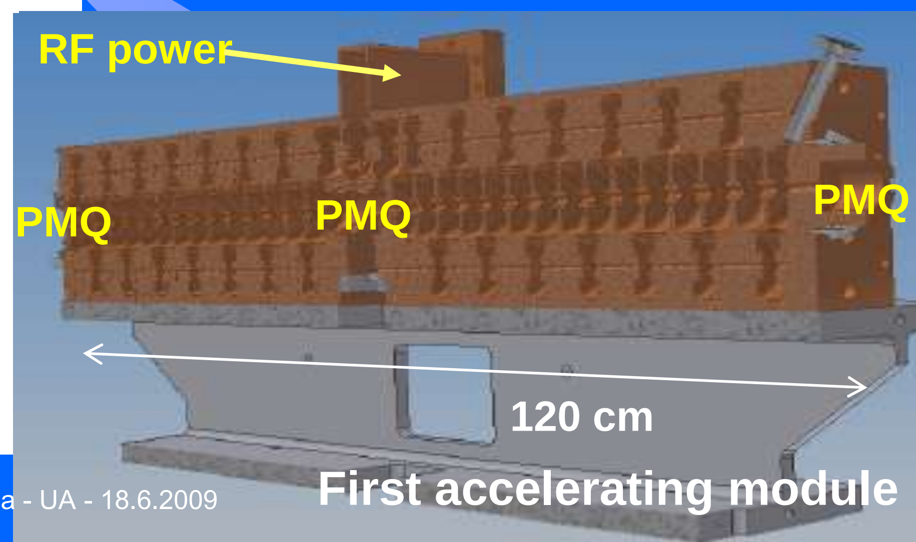
In agreement with INFN, IBA commercialises this SC cyclotron

Catania Centre: G. Cuttone p and 300 MeV/u carbon ions



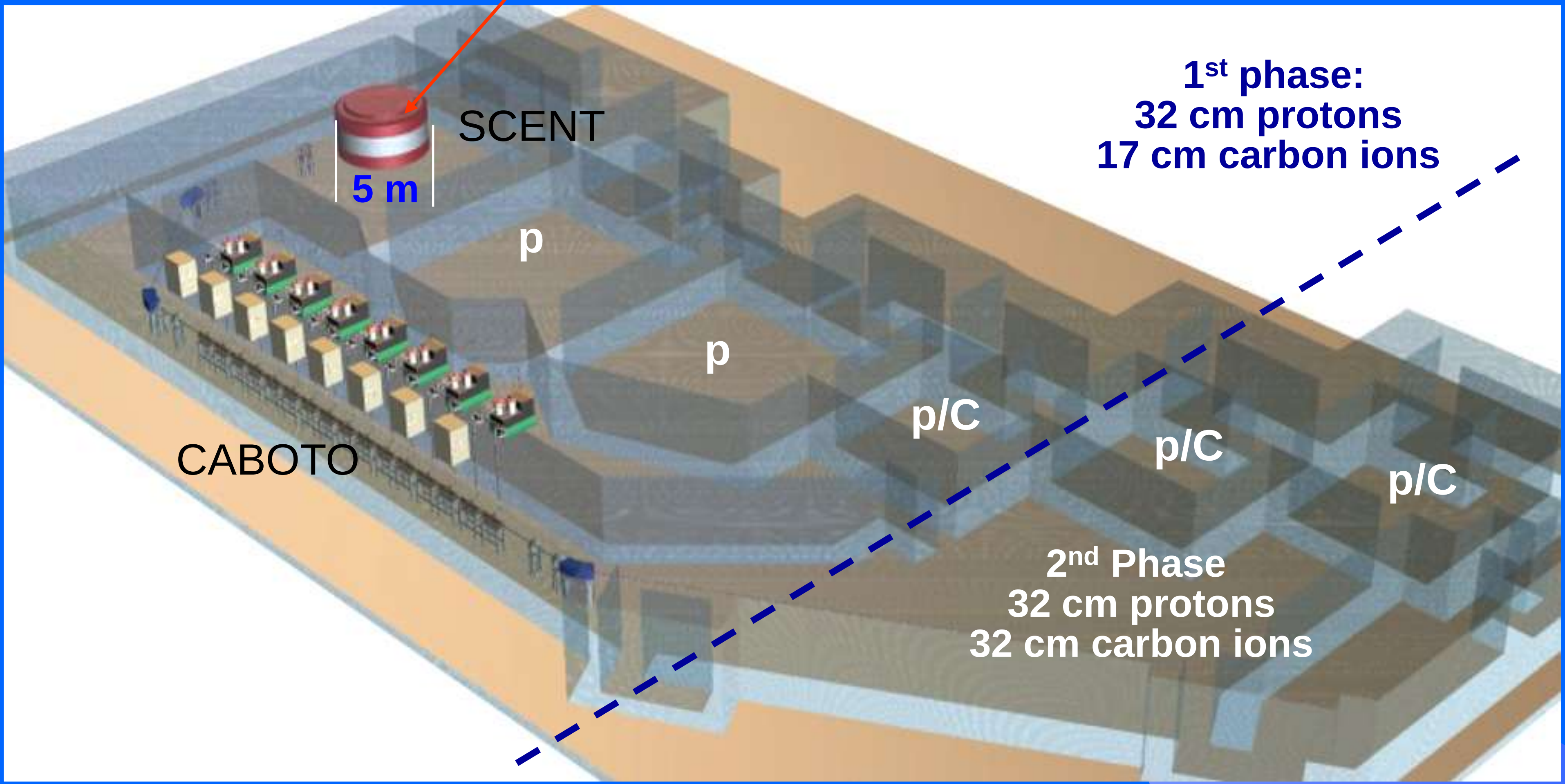
CArbon BOoster for Therapy in Oncology

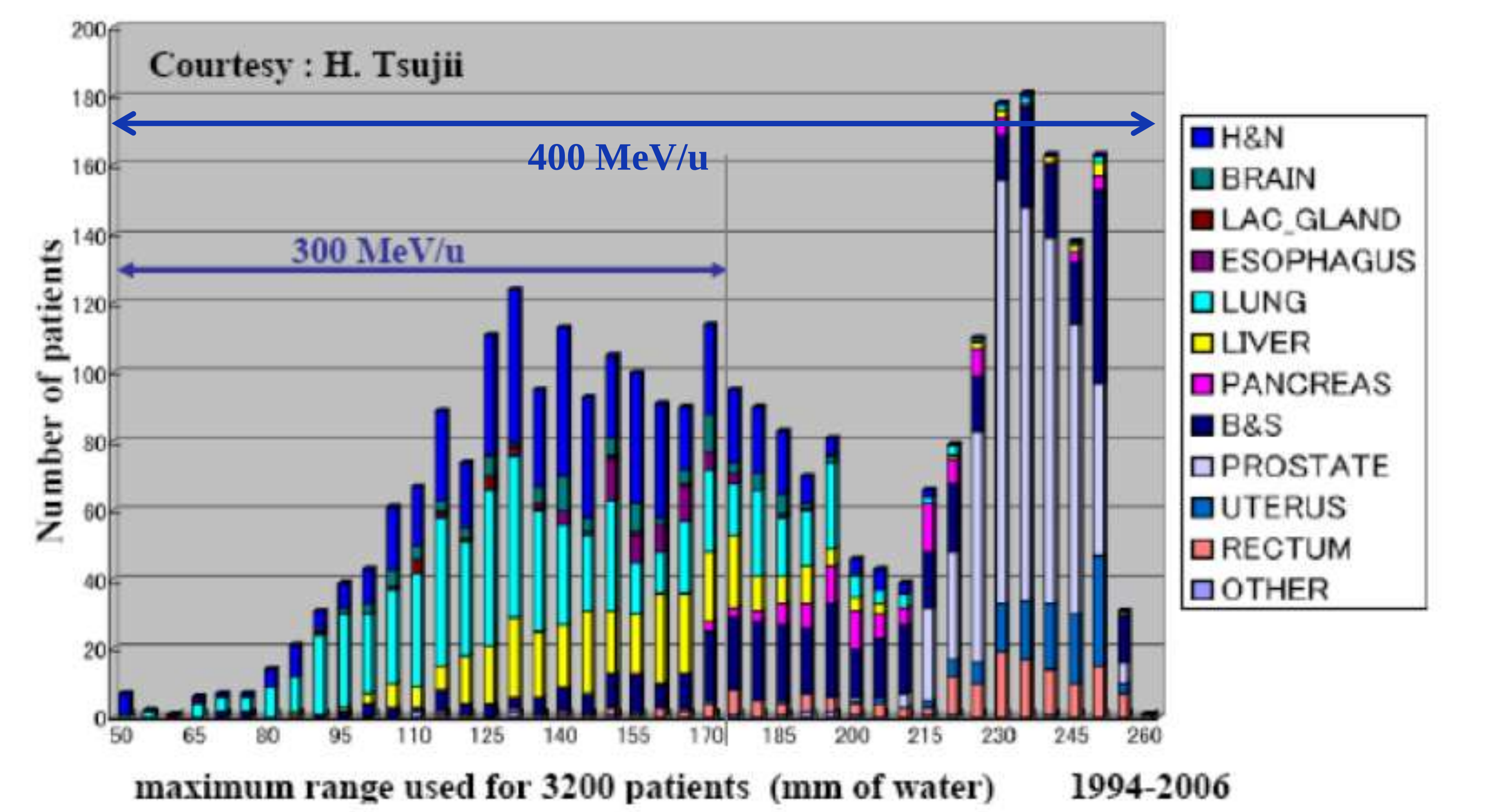
a carbon cyclinac



The two phases of the dual centre for Catania

Superconducting cyclotron by LNS/IBA (250 MeV protons and 3600 MeV carbon ions) is commercialized by IBA





Tumours treatable with 300 MeV/u.

Head Neck and Brain: 85%; Lung and Liver: 80%; Bone and Soft Tissues sarcomas: $\leq$ 20%; Pancreas, Prostate, Uterus, and Others: $\leq$ 3%.

Properties of the cyclinac beam

Accelerator	Beam always present during treatments	Energy variation by electronic means	Time needed for varying the energy
Cyclotron	Yes	No	50 ms (*)
Synchrotron	No	Yes	1 second
Cyclinac	Yes	Yes	1 millisecond

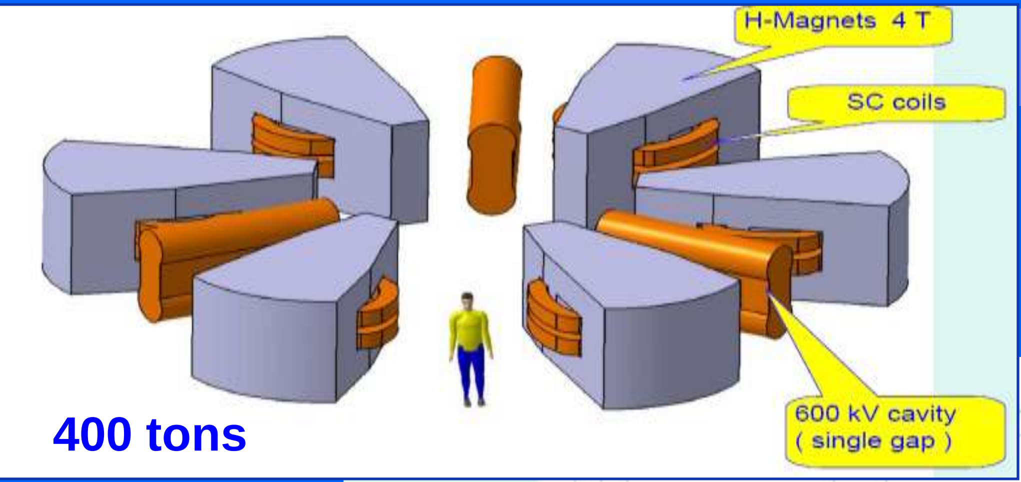
(*) With movable absorbers

The energy is changed by adjusting the RF pulses to the modules

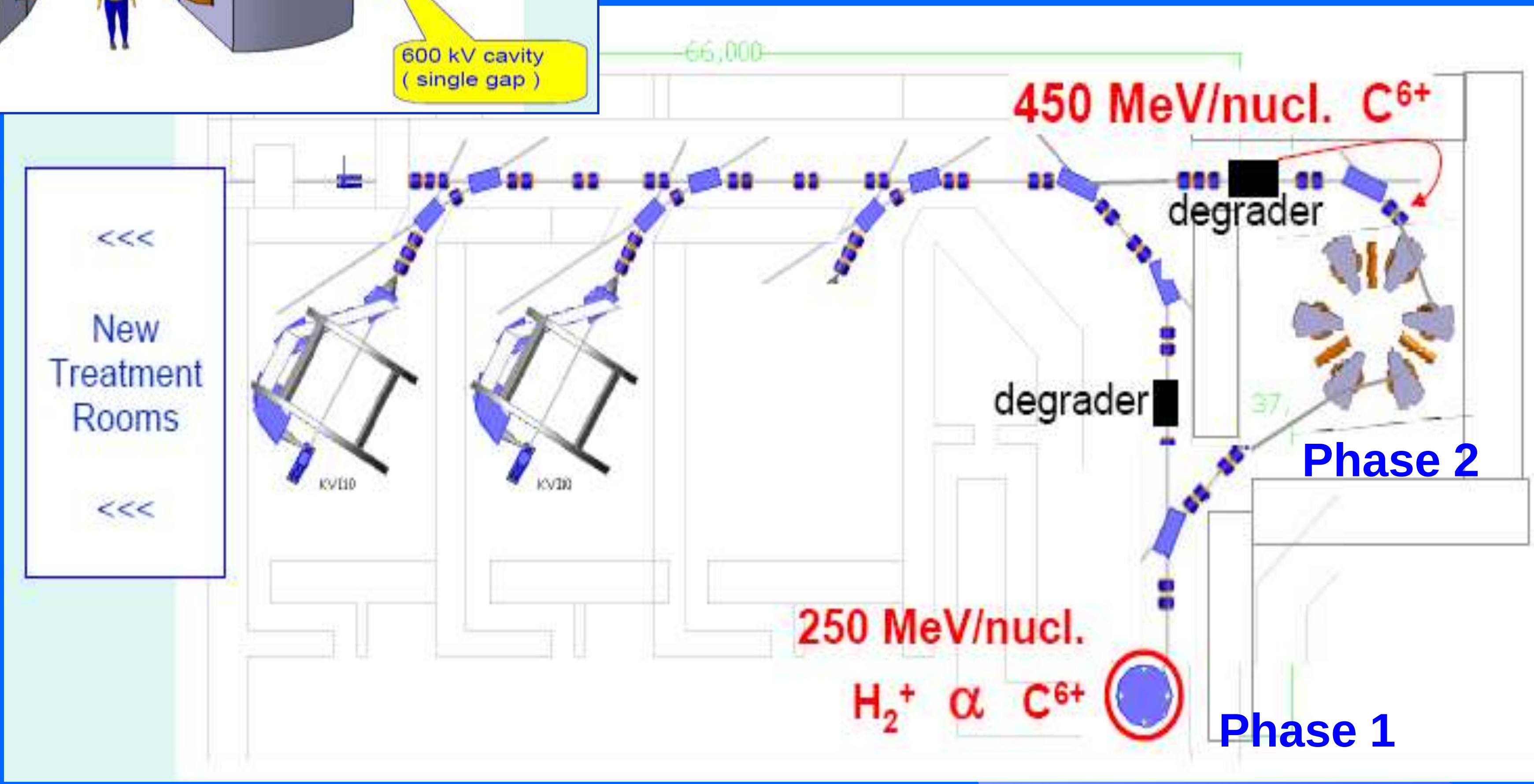
The cyclinac beam is ideal to paint many times moving tumours in 3D without variable absorbers

PSI proposal of a sector cyclotron injected by a cyclotron (M. Schippers et al)

The 450 MeV/u sector cyclotron



400 tons



Summary

15 years ago the first patient was treated with carbon ions at HIMAC

Europe, which was coming out from the 1992 EULIMA debacle, has recovered the delay

Two centres designed in two nuclear physics laboratories have been financed and are almost completed. Three others are in the planning phase.

Two European companies offer commercial products for carbon ions and protons

New concepts are proposed and developed

THE NEXT GOAL IS TO TREAT PATIENTS WITH p AND C AND COMPARE THE RESULTS TO DEFINE THE PATOLOGIES


THE END