



PARTICLES FOR TUMOUR TREATMENTS: THE NATIONAL CENTRE FOR ONCOLOGICAL HADRONTHERAPY

Sandro Rossi

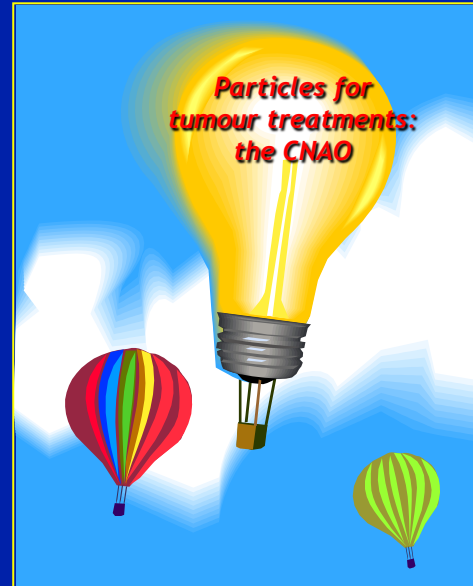
Università degli Studi di Pavia – 21 Maggio 2015

Rationale for hadrontherapy

Hadrontherapy in the world

The CNAO

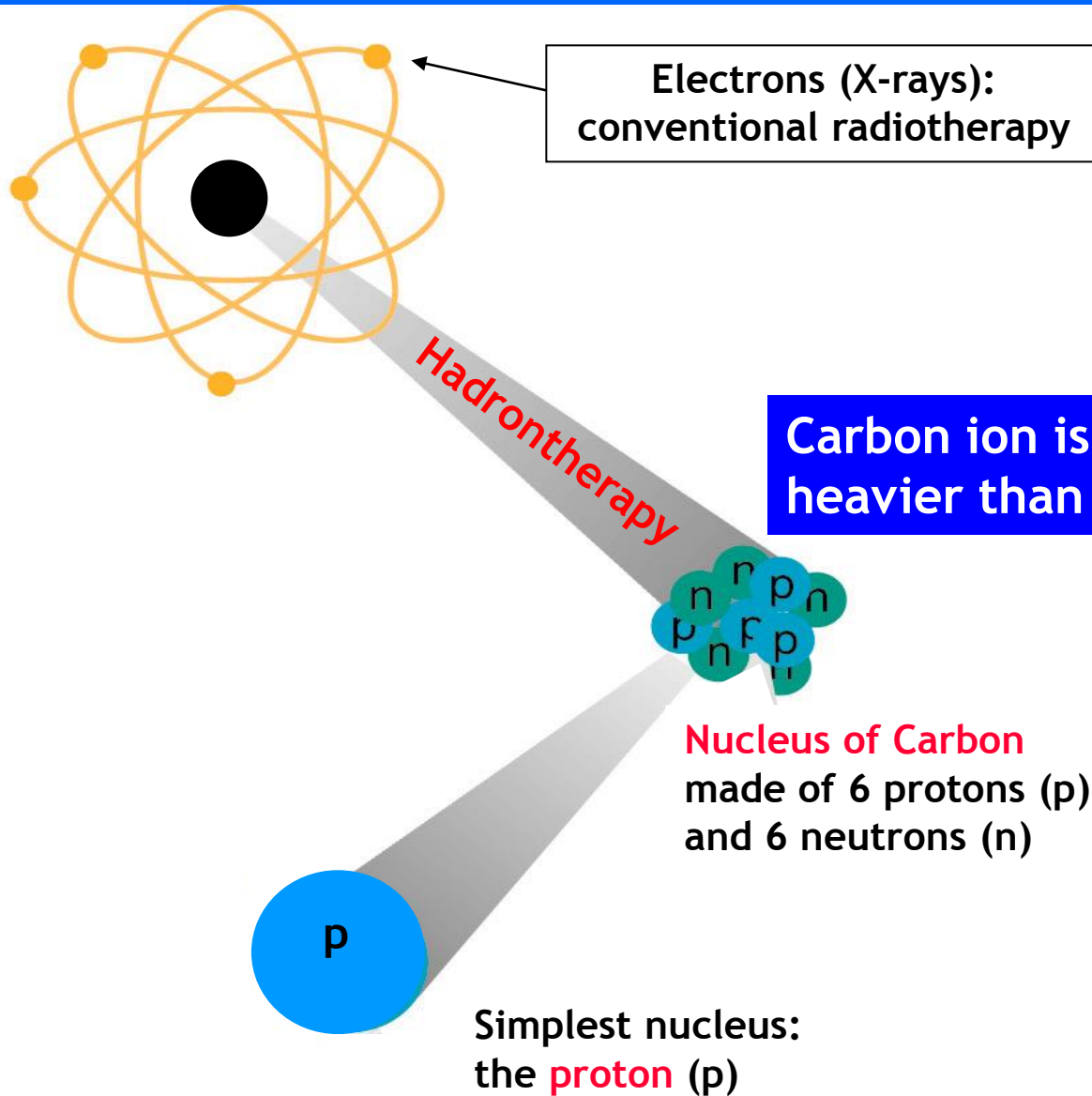
Clinical results at CNAO



Evidence on the research topics



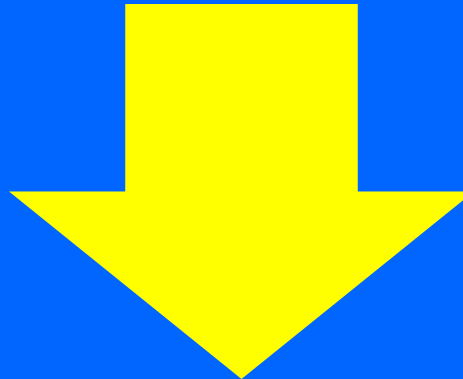
Hadrontherapy ?



Proton is 2000 times heavier than electron

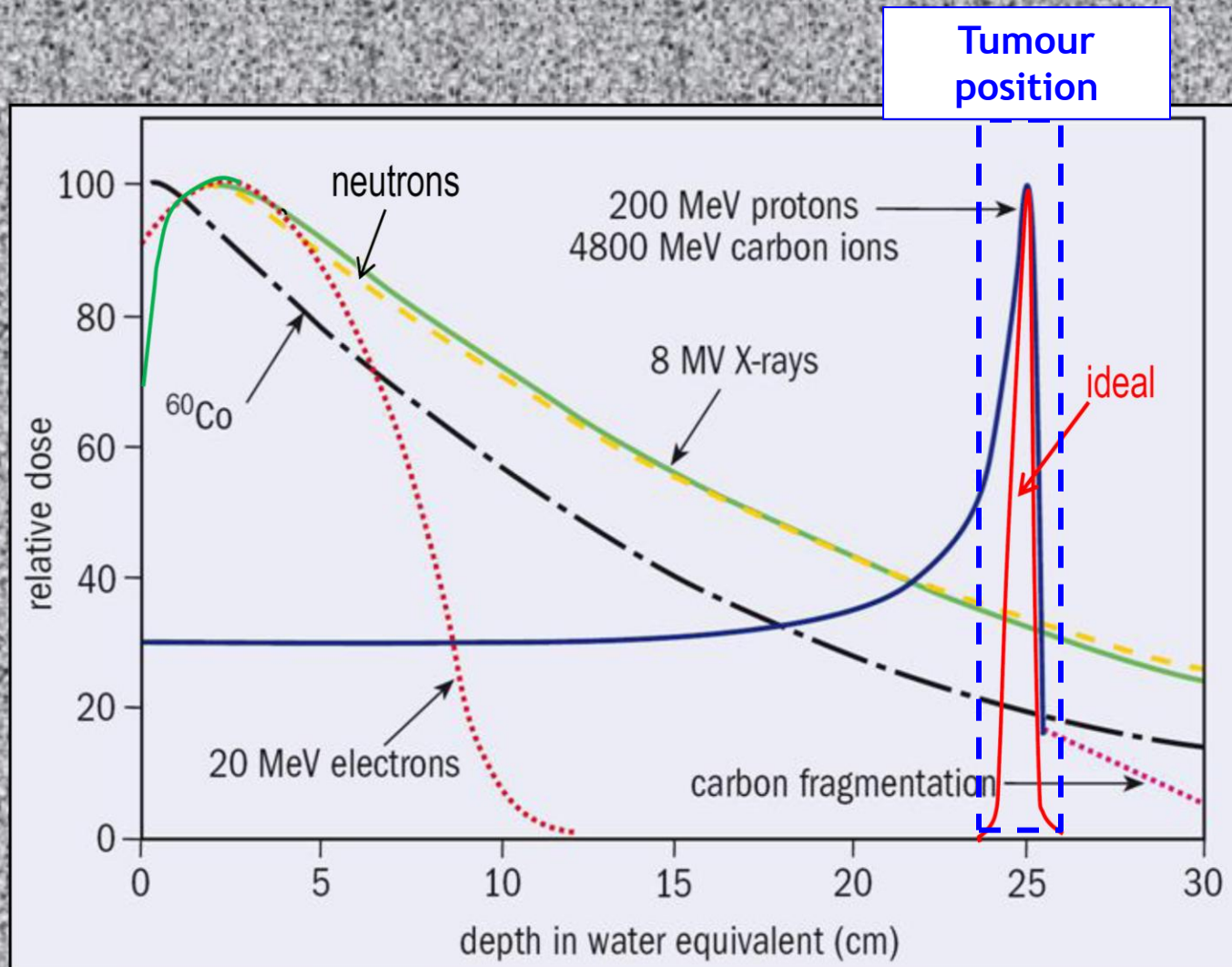
Which advantages with hadrons ?

+ PRECISION

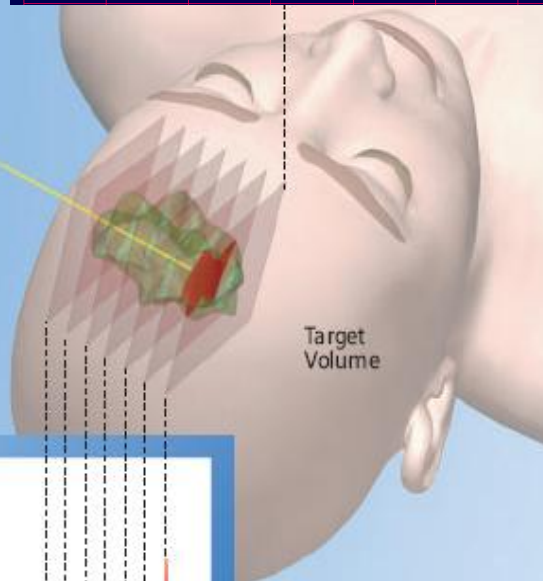
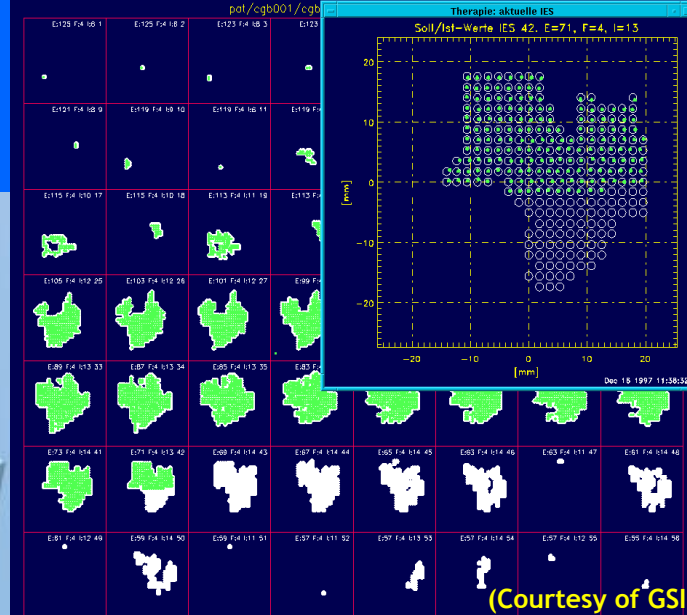
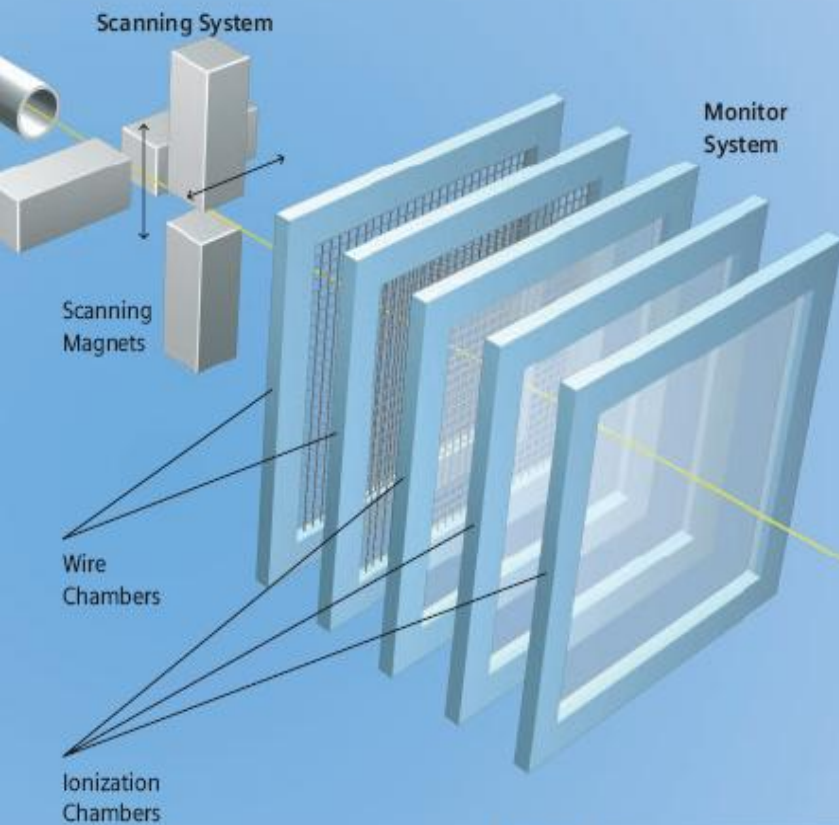


**Conformal irradiation of tumour volume
(= reduced damages to healthy tissues)**

Precision in hadrontherapy



Beam direction in the patient body

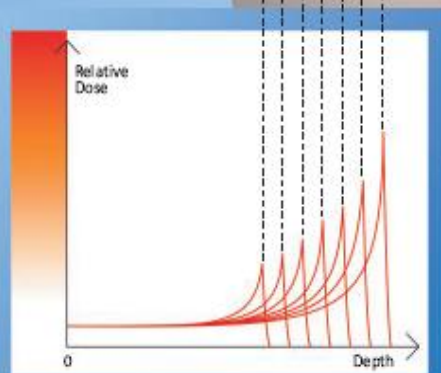


***Irradiation
technique
active scanning***

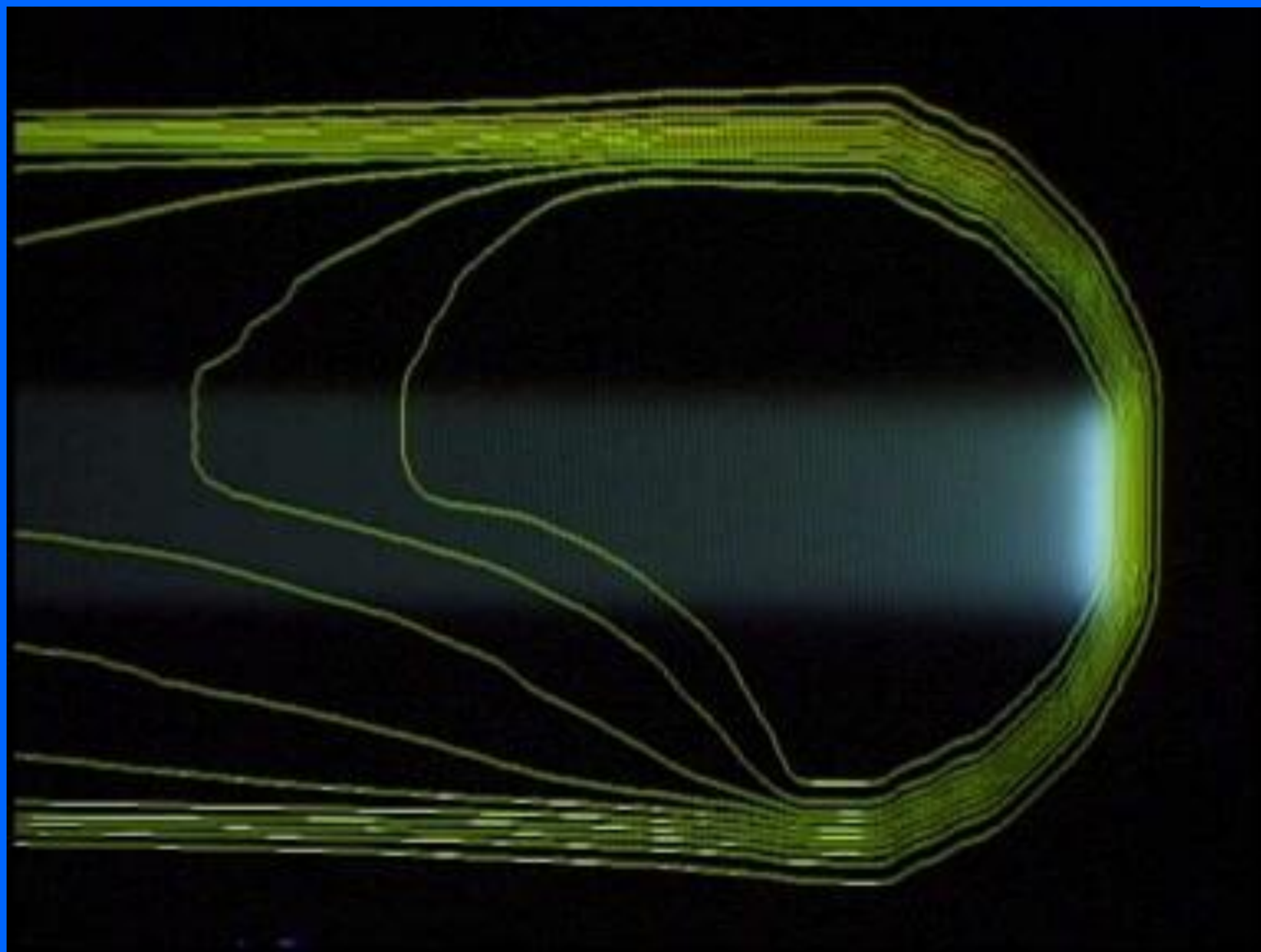
Example:

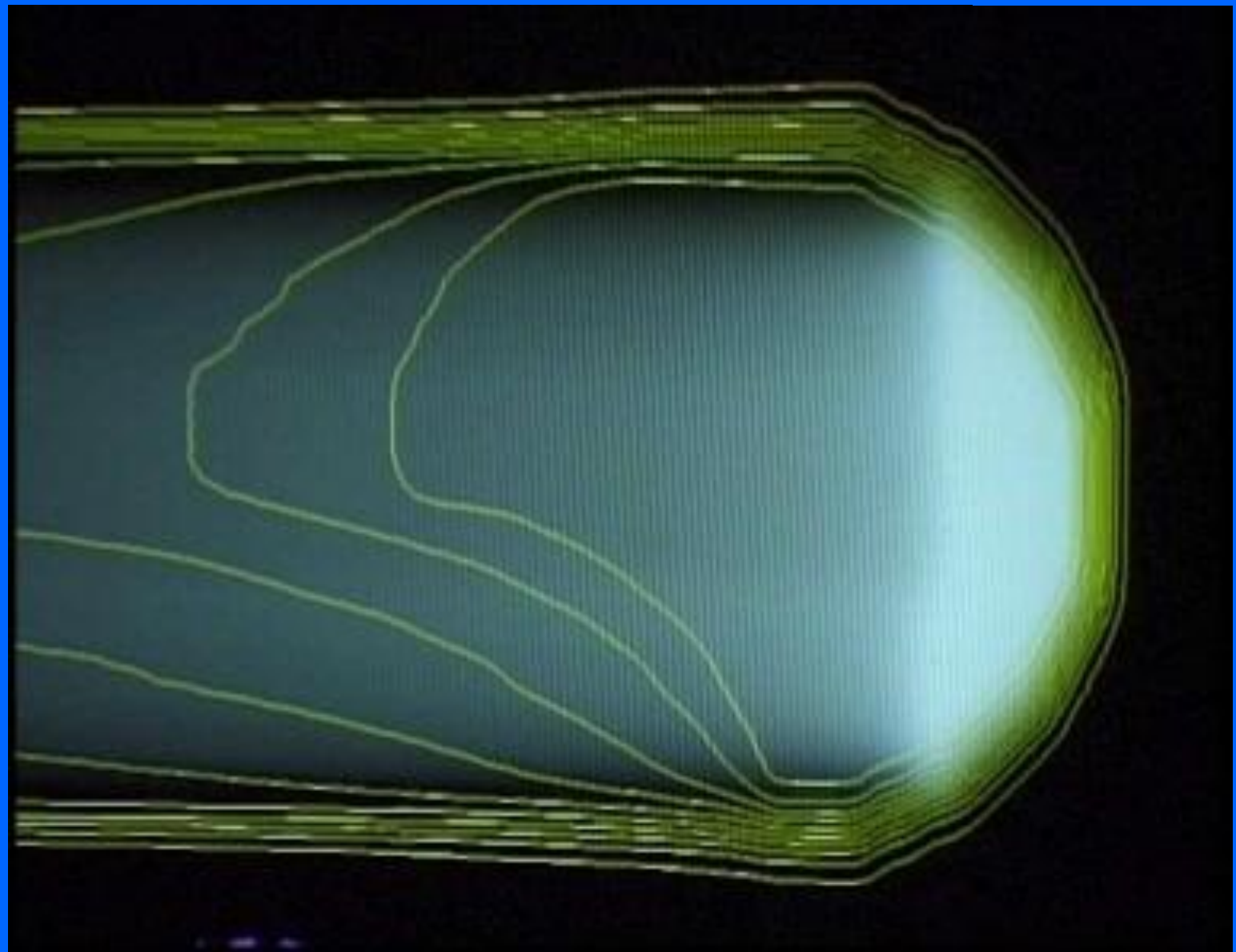
Depth 5 cm:
Proton 80 MeV
Carbon 150 MeV/u

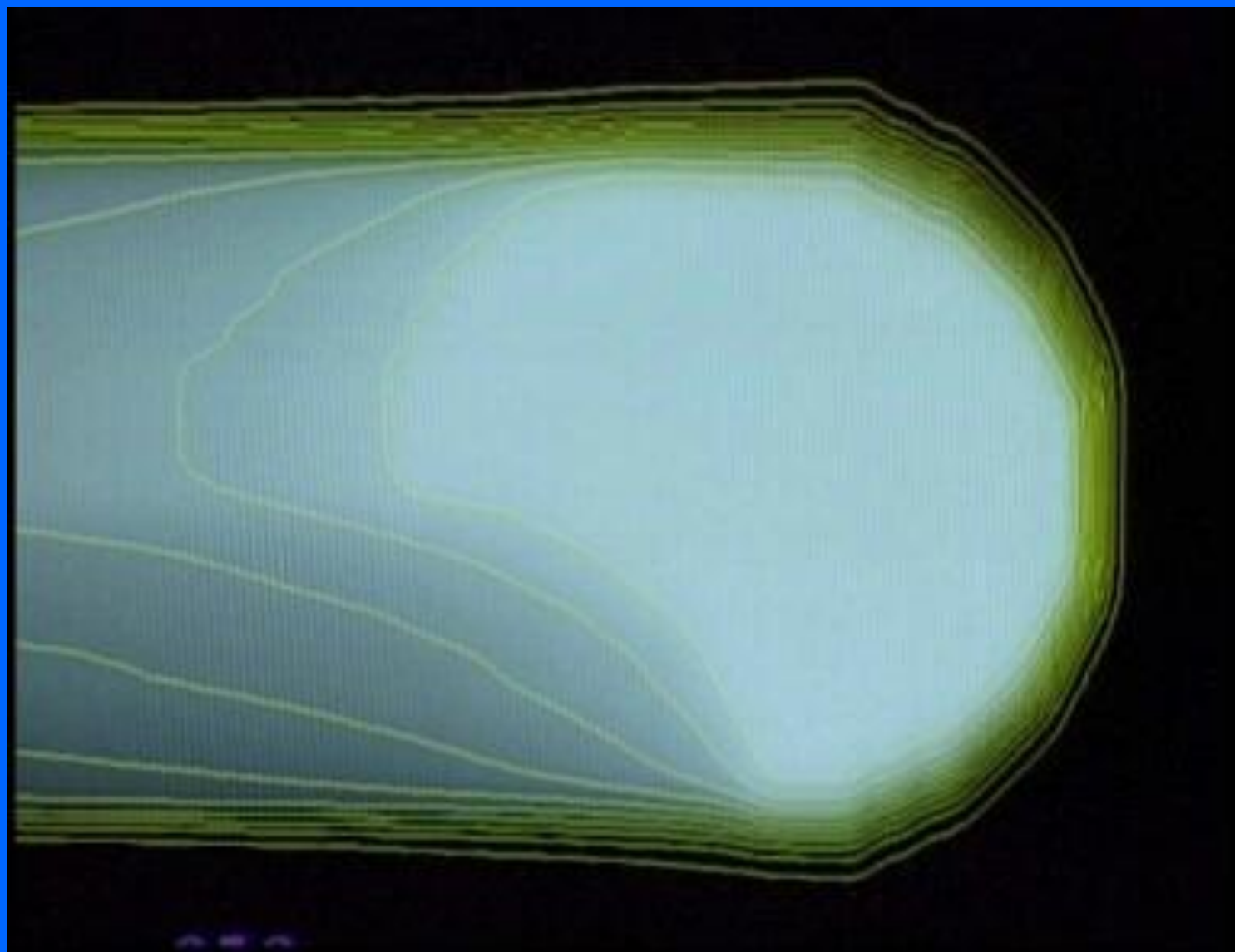
Depth 25 cm:
Proton 195 MeV
Carbon 380 MeV/u



(Courtesy of Siemens Medical)

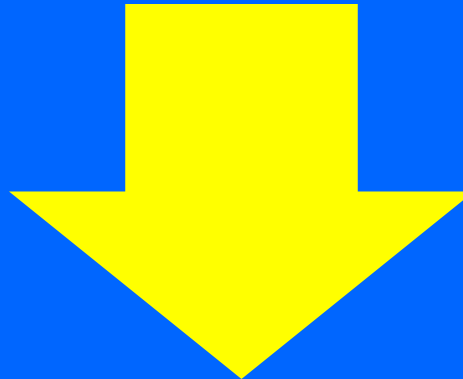






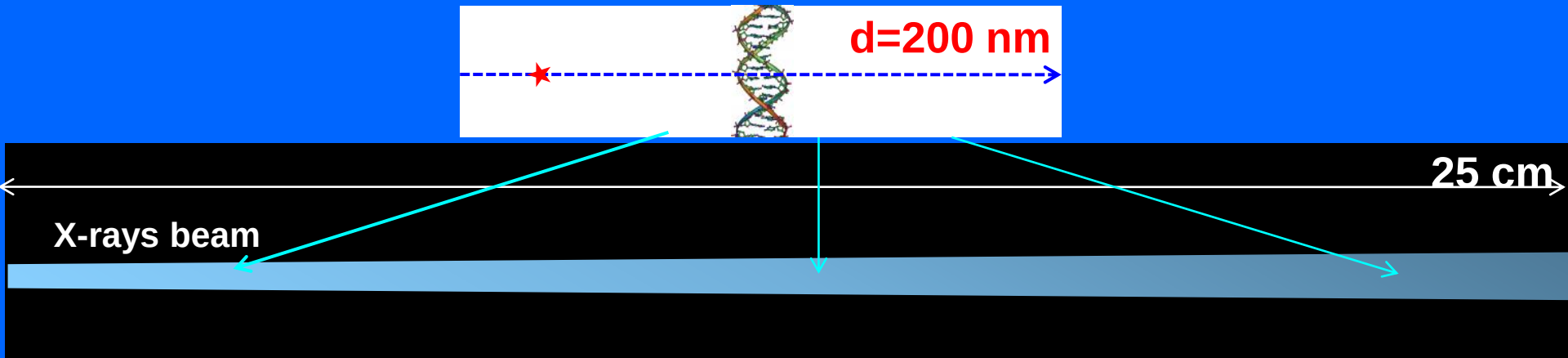
Which advantages with hadrons ?

+ EFFICACY

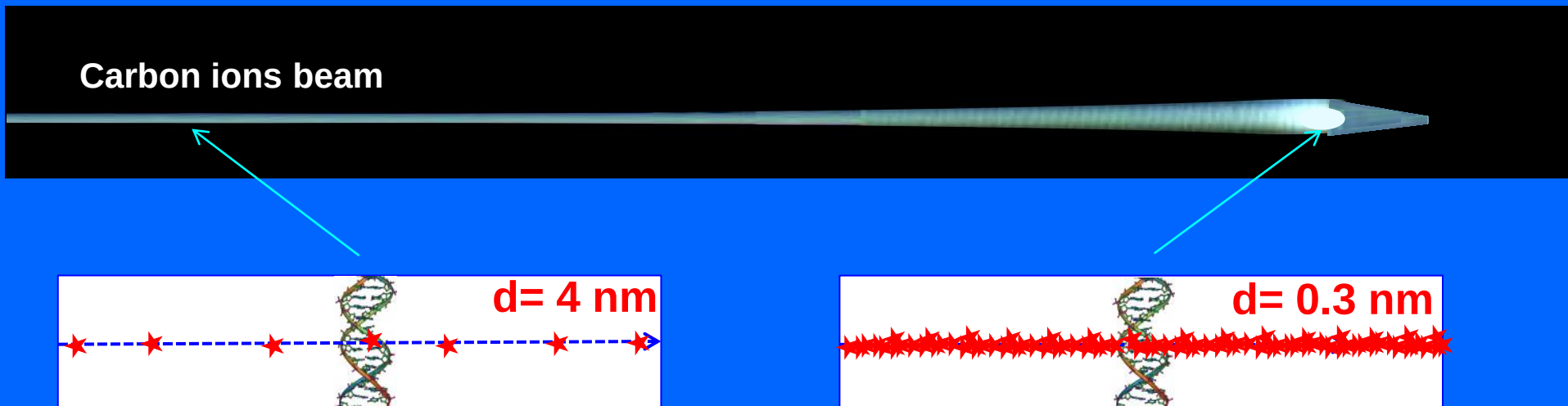


Increased radiobiological efficacy of carbon ions wrt X-rays
(= DNA of tumour cells directly destroyed in multiple hits)

X-rays: sparse damage and indirect effects



Carbon ions: clustered damage only on tumour and direct effect



Hadrontherapy in Italy

Number of potential patients

(Commission Ministry of Health - Year 2009)

ITALY: **60** MILLIONS HABITANTS

X-Ray therapy (photons 5 – 20 MeV)

New patients per year: 150'000 pts/y

Protons

Categoria A: elective patients = 1'000 pts/y

Categoria B: good indications = 12'000 pts/y

Carbon ions

% radioresistant tumours 1'500 pts/y



1 dual centre (p and C): CNAO

Possibly 1 protontherapy centre every 10 M citizens

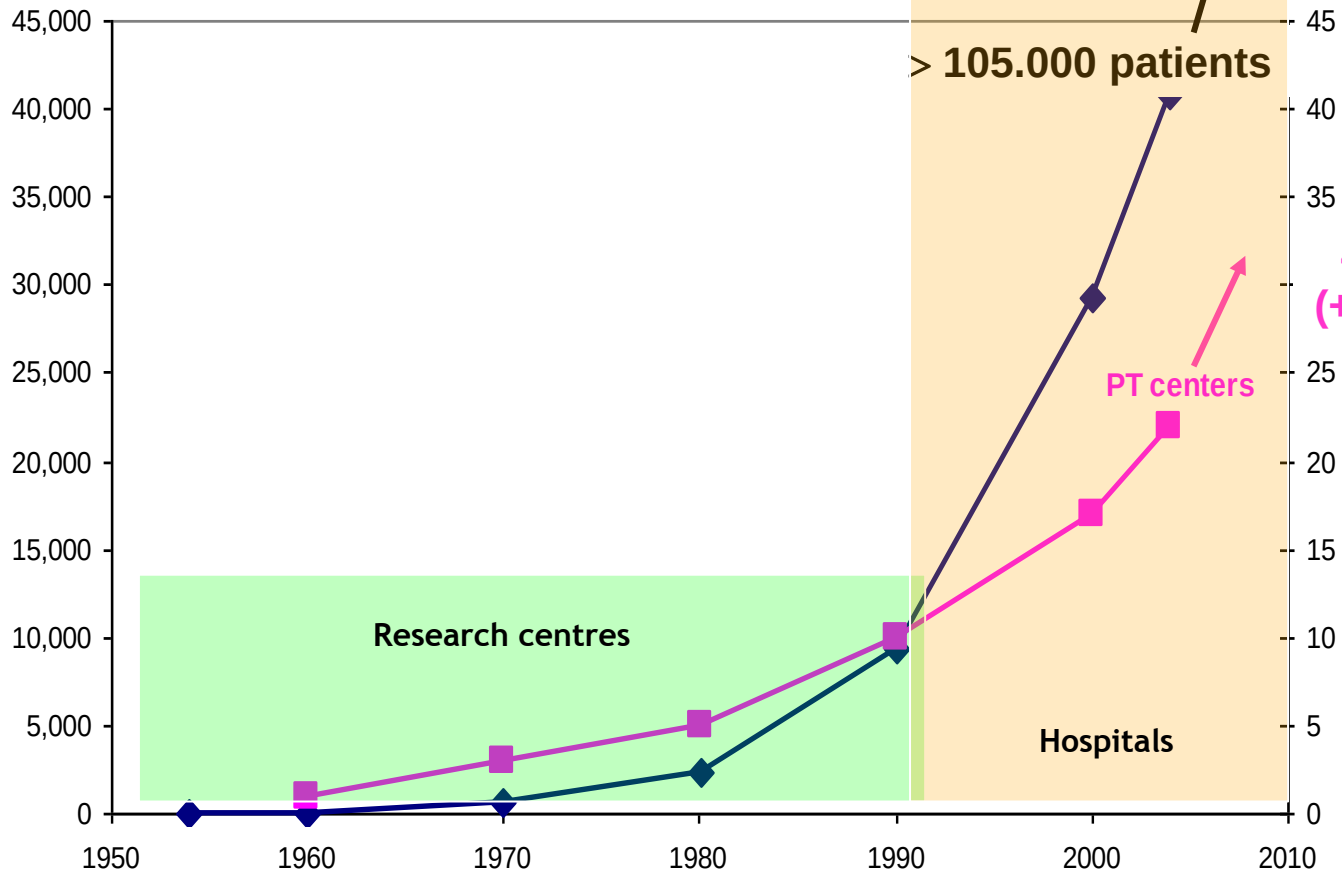
***Particles for
tumour treatments:
the CNAO***

**Hadrontherapy
in the world**

Protontherapy is booming (www.ptcog.psi.ch)

+ 46,000 pat. in the past 5 years

≈ 10,000 pat. per year



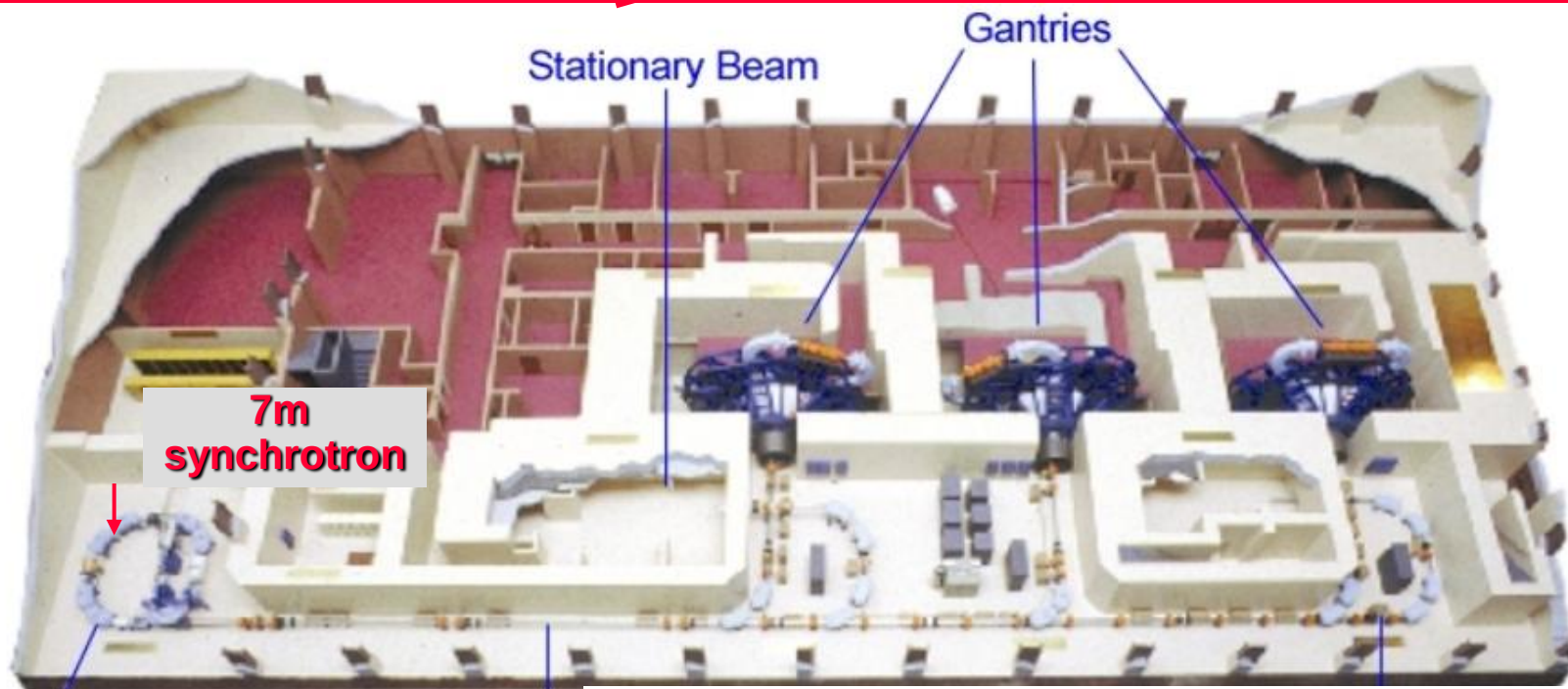
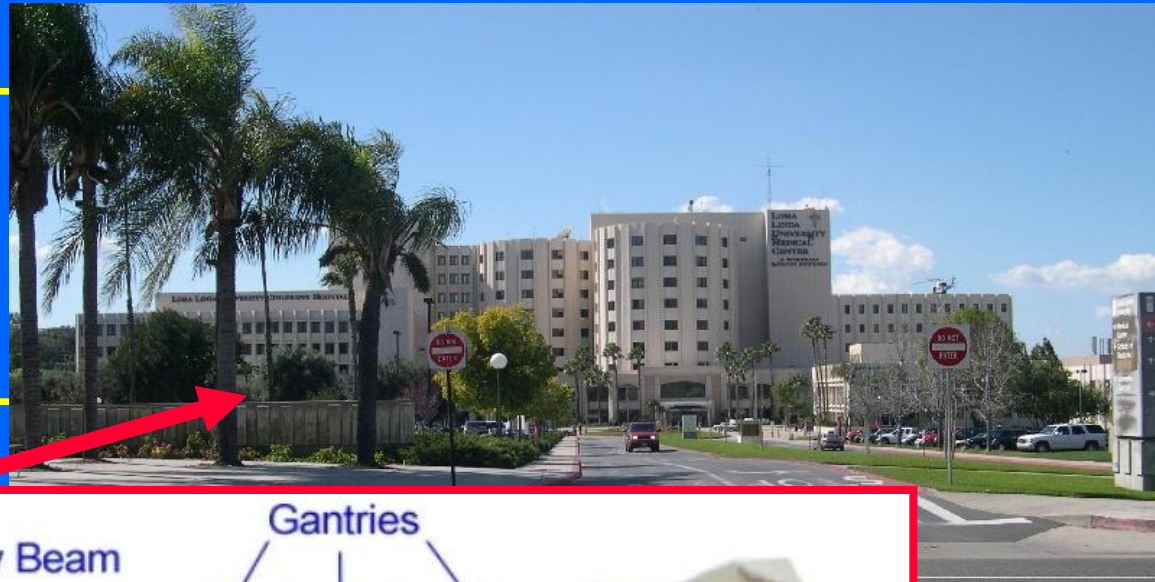
48 centres
(+25 planned)

Carbon Ions: > 13.000 patients; 8 centres (+3 planned)

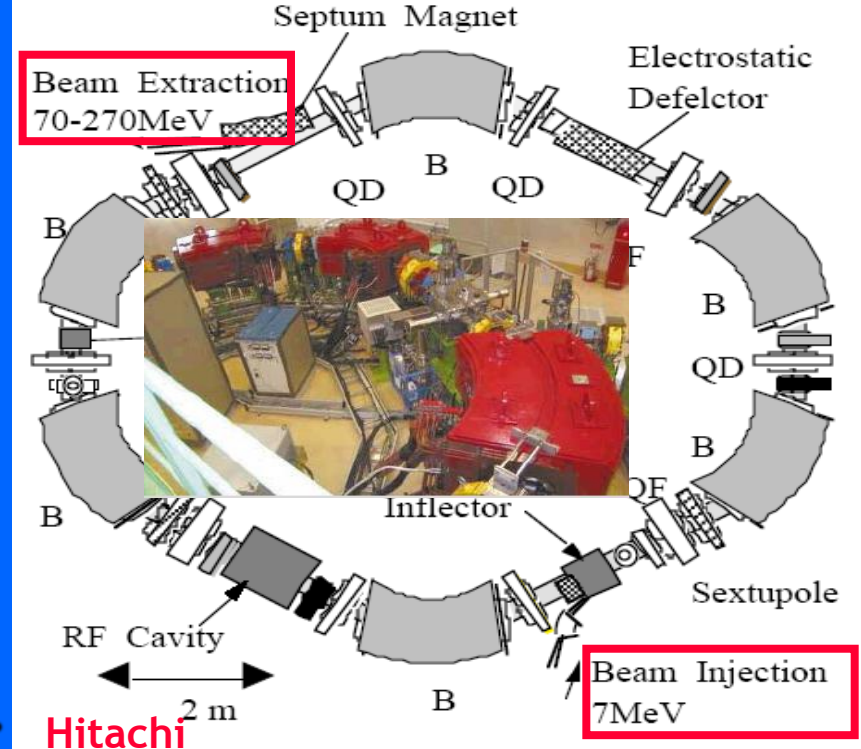
Loma Linda University Medical Center: first patient 1992

First hospital based
protontherapy centre
(1992)

2012:160 sessions/d



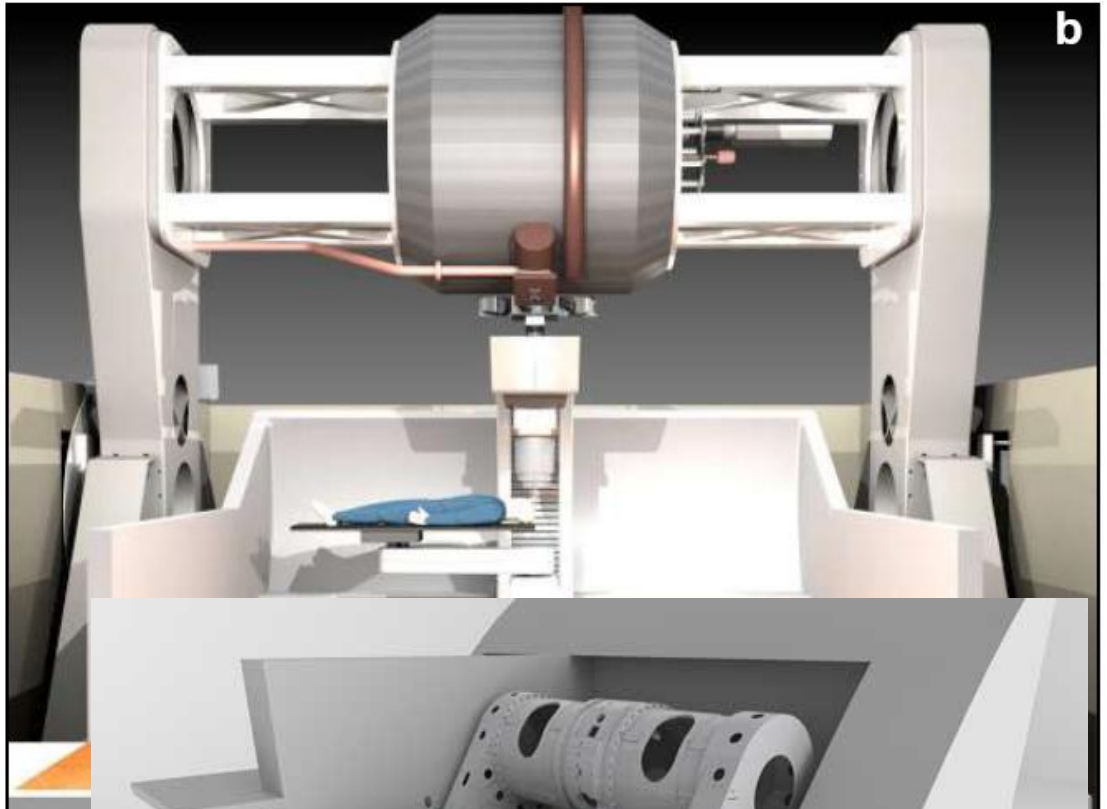
Optivus Ltd. commercialises this centre



Protontherapy: a market exists ...



Coming up: single room facility
250 MeV synchrocyclotron rotating around the patient

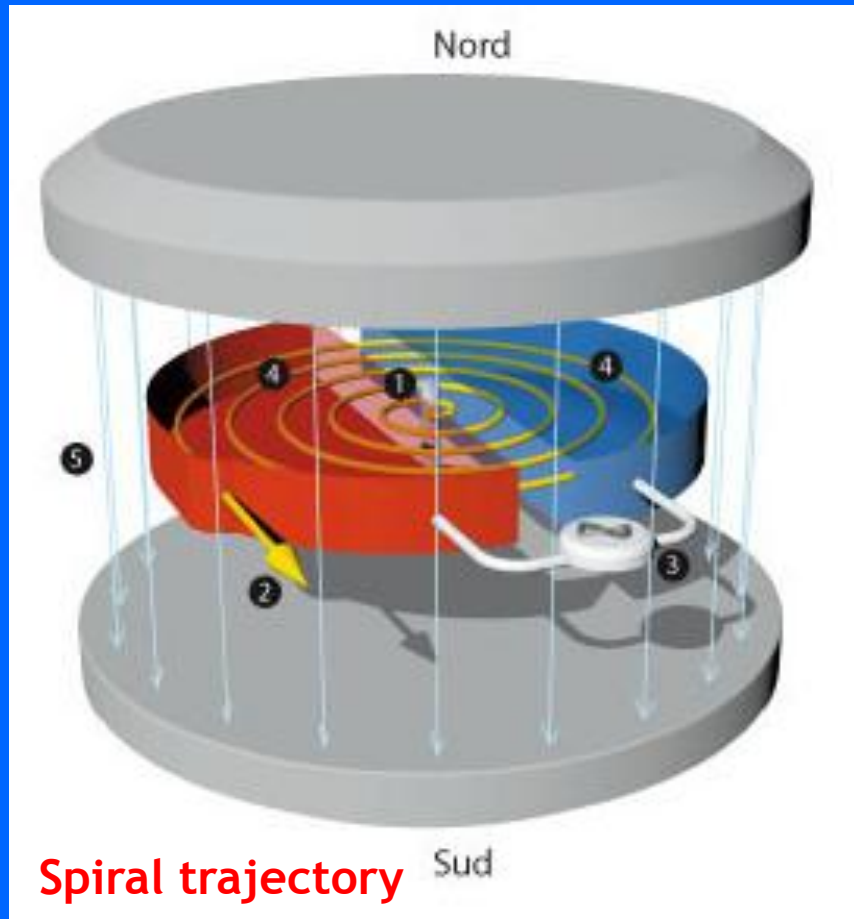


MEVION S250

Superconducting SC
Diameter 1.8 m



Cyclotron

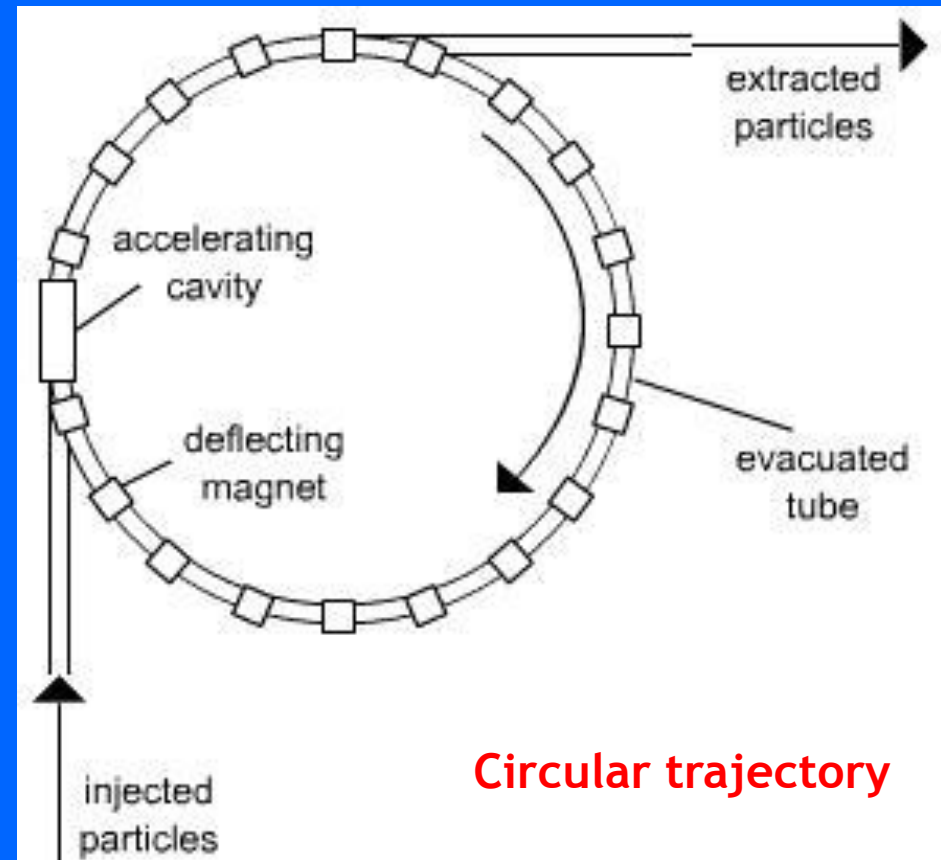


$B = \text{constant}$

Dynamic law:
$$\omega_{\text{rev}} = \frac{qB}{m}$$

Fixed frequency, high intensities

Synchrotron



$\rho = \text{constant}$

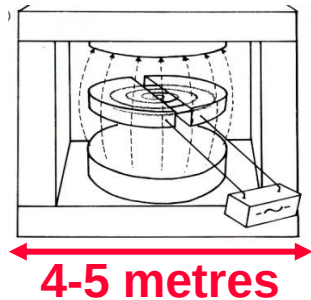
Dynamic law:
$$p = qB\rho$$

Energy increases with B

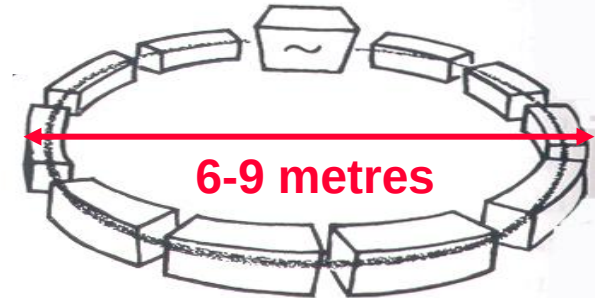
The accelerators used today in hadrontherapy are “circular”

Teletherapy with protons (200-250 MeV)

CYCLOTRONS (*) (Normal or SC)



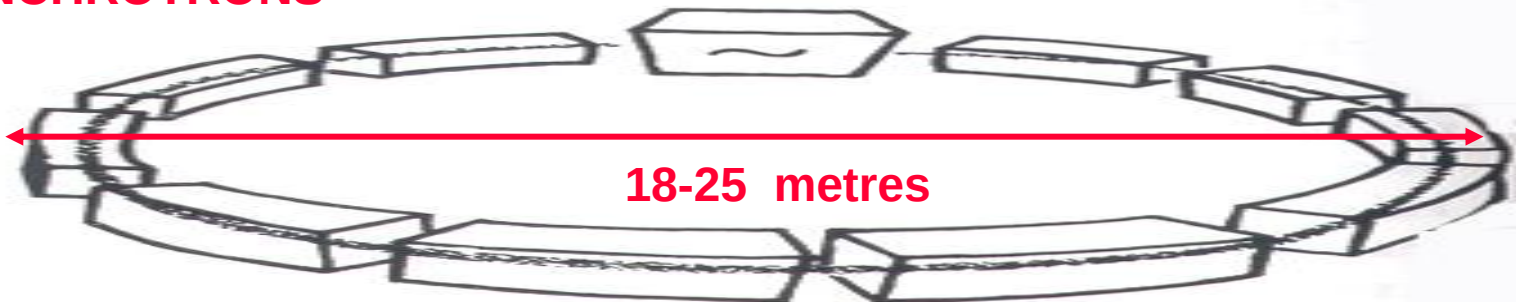
SYNCHROTRONS

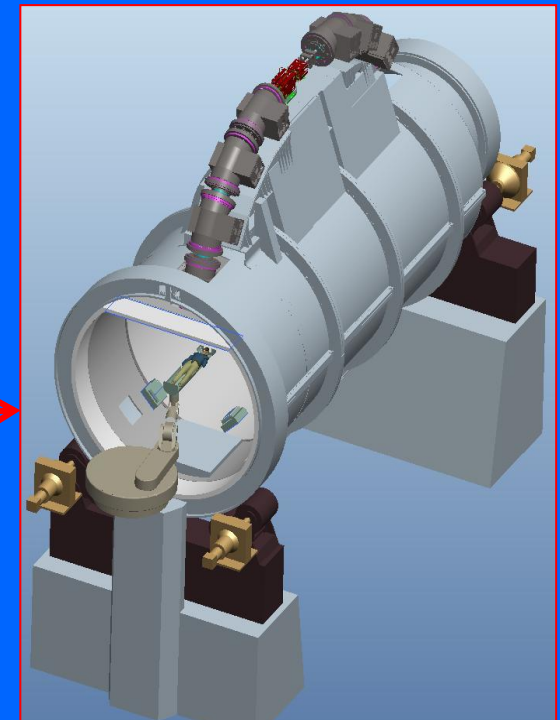


(*) also synchrocyclotrons

Teletherapy with carbon ions (4800 MeV = 400 MeV/u)

SYNCHROTRONS

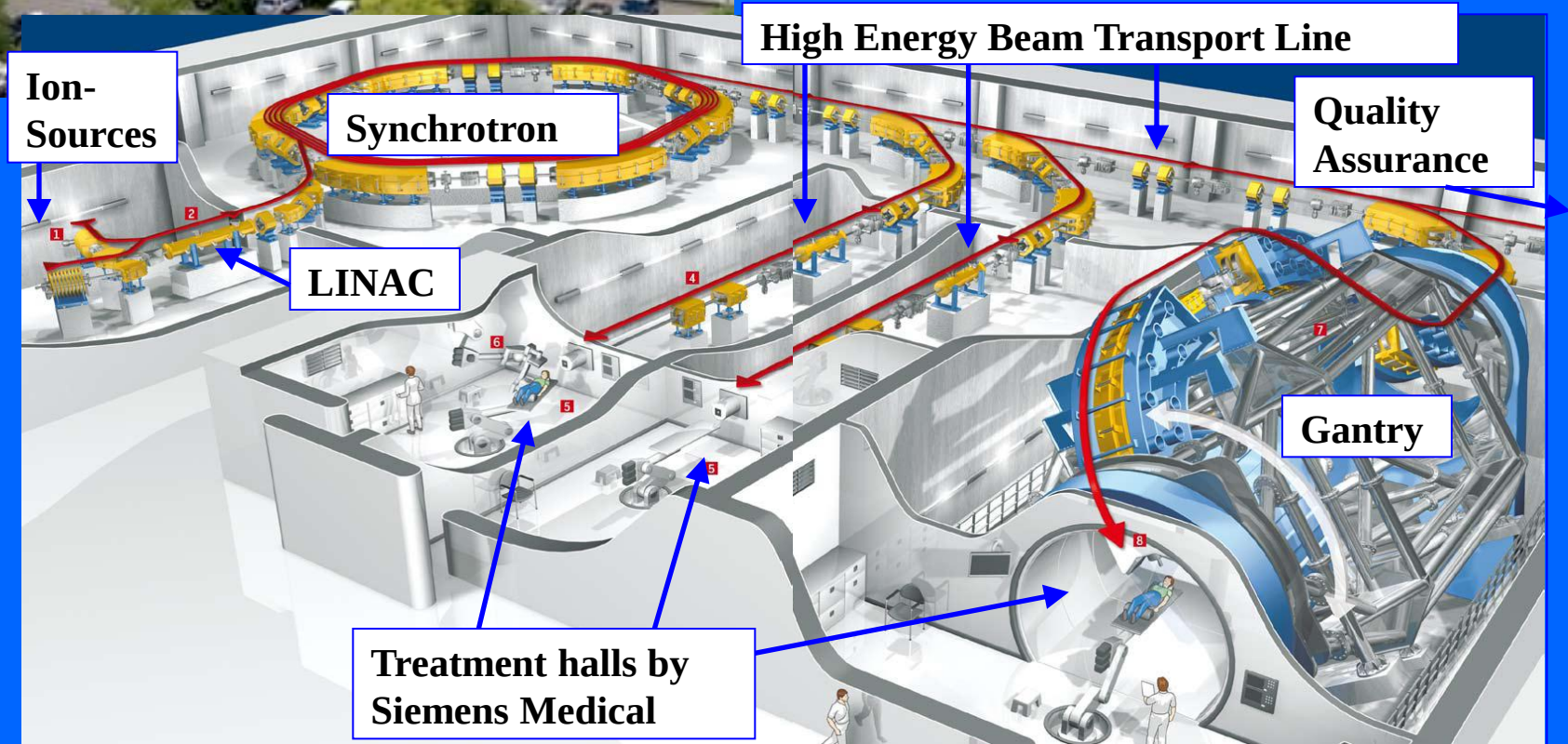




HIT - Heidelberg

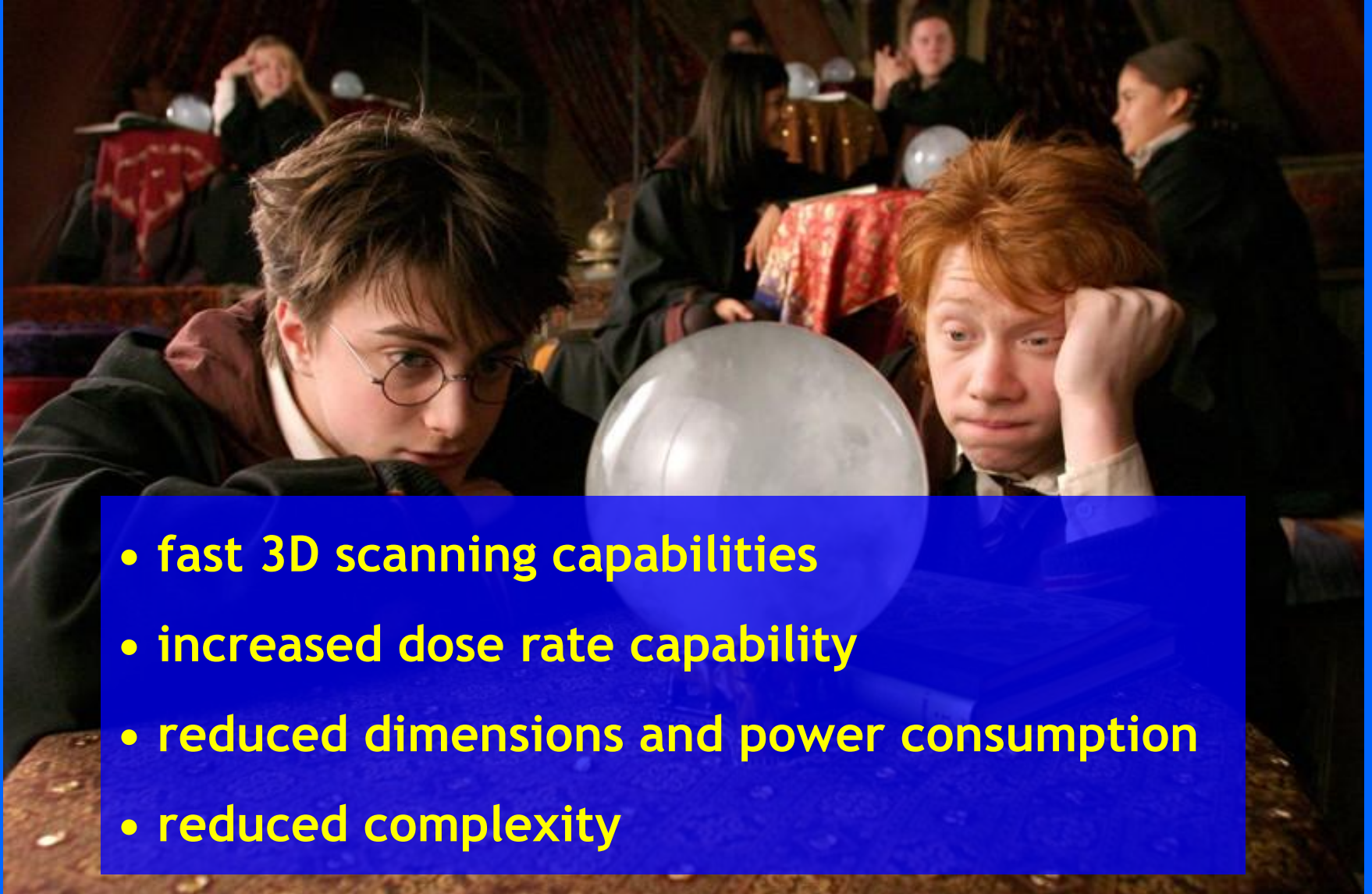
First patient: end 2009

So far about 2.000 patients



Research issues...

New accelerators for hadrontherapy



- fast 3D scanning capabilities
- increased dose rate capability
- reduced dimensions and power consumption
- reduced complexity

***Particles for
tumour treatments:
the CNAO***

The CNAO

Background: 2 main steps

CERN/PPE/UA/eo

25 Maggio 1991

Per un Centro di Teleterapia con Adroni

Ugo Amaldi

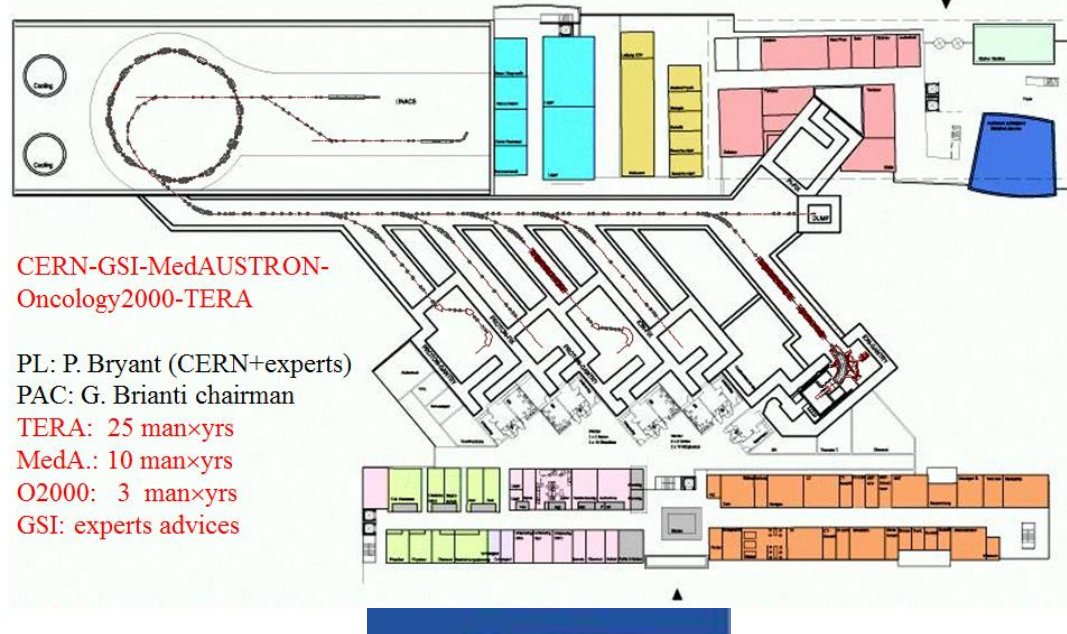
CERN e Università di Milano

Giampiero Tosi

Ospedale di Niguarda, Servizio di Fisica Sanitaria,
e Università di Milano



PIMMS (Proton-Ions Medical Machine Study): 1996-1999 at CERN



CERN-GSI-MedAUSTRON-
Oncology2000-TERA

PL: P. Bryant (CERN+experts)

PAC: G. Brianti chairman

TERA: 25 man×yrs

MedA.: 10 man×yrs

O2000: 3 man×yrs

GSI: experts advices



The Phases of CNAO

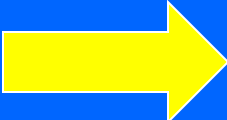
Phase 0: organisation

 Years: 2002 - 2004

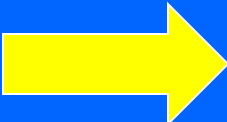
Phase 1: construction

 Years: 2005 - 2010

Phase 2: experimentation

 Years: 2010 - 2013

Phase 3: running

 Years: 2014 ...

The numbers of CNAO's construction

N. 14

European tenders completed

More than 1000

Orders and contracts

N.600 (500 Italian)

Firms worked for CNAO

About 80

Authorisation procedures completed

Cost 135 MEuro

Much less than market cost

Starting point... THE PATIENT

Hospital based: safety, efficiency, reliability, maintainability

1	Beam particle species	p, He ²⁺ , Li ³⁺ , Be ⁴⁺ , B ⁵⁺ , C ⁶⁺ , O ⁸⁺
2	Beam particle switching time	≤ 10 min
3	Beam range	1.0 g/cm ² to 27 g/cm ² in one treatment room 3.1 g/cm ² to 27 g/cm ² in two treatment rooms Up to 20 g/cm ² for O ⁸⁺ ions
4	Bragg peak modulation steps	0.1 g/cm ²
5	Range adjustment	0.1 g/cm ²
6	Adjustment/modulation accuracy	≤± 0.025 g/cm ²
7	Average dose rate	2 Gy/min (for treatment volumes of 1000 cm ³)
8	Delivery dose precision	≤± 2.5%
9	Beam axis height (above floor)	150 cm (head and neck beam line) 120 cm (elsewhere)
10	Beam size ¹	4 to 10 mm FWHM for each direction independently
11	Beam size step ¹	1 mm
12	Beam size accuracy ¹	≤± 0.25 mm
13	Beam position step ¹	0.8 mm
14	Beam position accuracy ¹	≤± 0.2 mm
15	Field size ¹	5 mm to 34 mm (diameter for ocular treatments) 2×2 cm ² to 20×20 cm ² (for H and V fixed beams)
16	Field position accuracy ¹	≤± 0.5 mm
17	Field dimensions step ¹	1 mm
18	Field size accuracy ¹	≤± 0.5 mm

(Basic specifications of CNAO facility)



View of the site



Copyright ©2008 Pictometry I



Mains

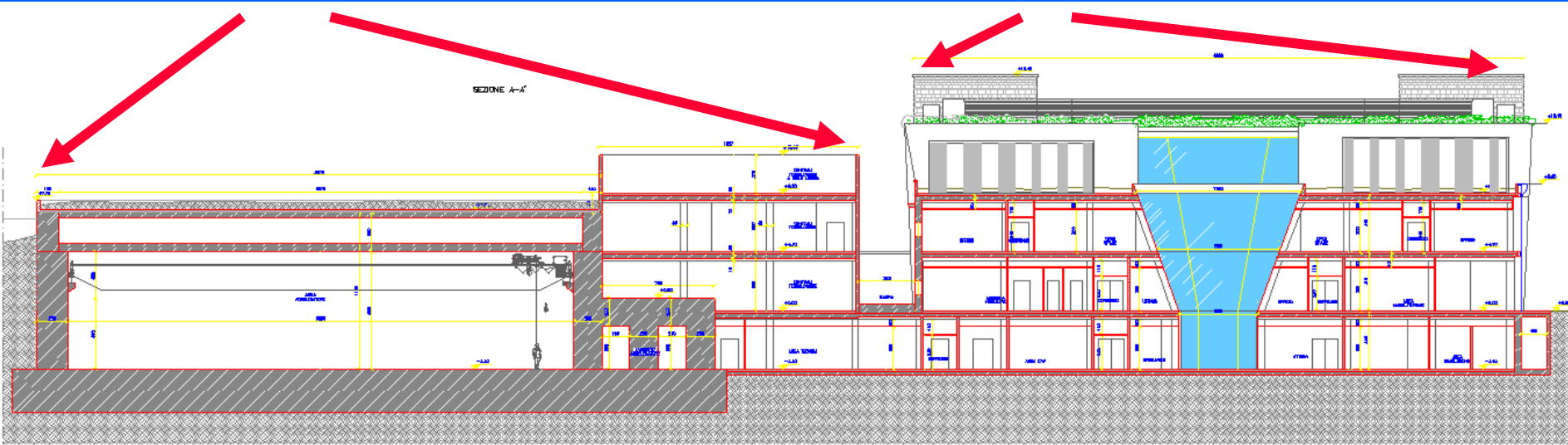
... done together with UniPv

Power supplies



Technical areas

Hospital facility



HOSPITAL FACILITY DEVELOPING ON FOUR LEVELS

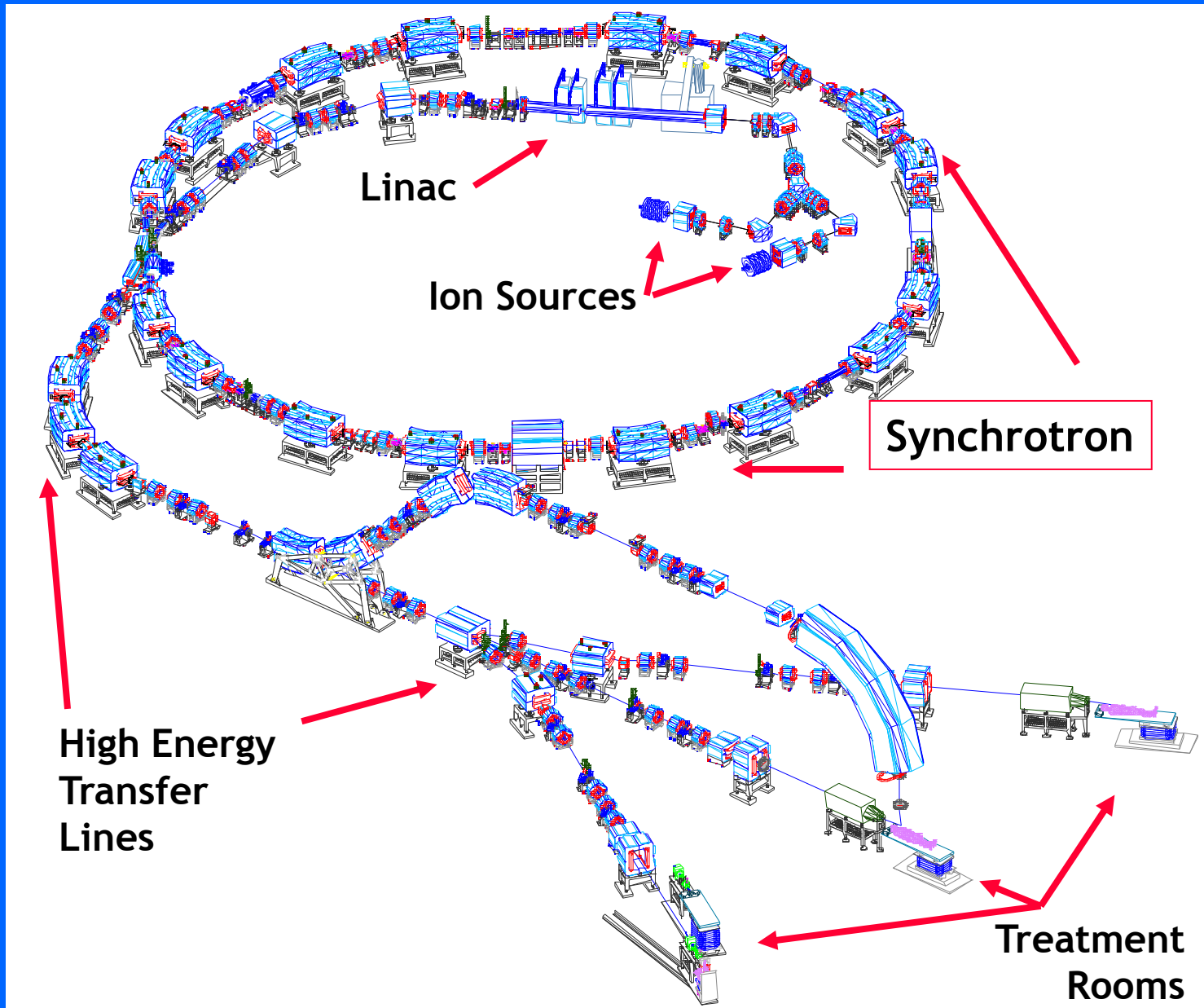
Surface Level (L.0): reception, first visit and medical imaging

Underground level (L. -1): treatment area

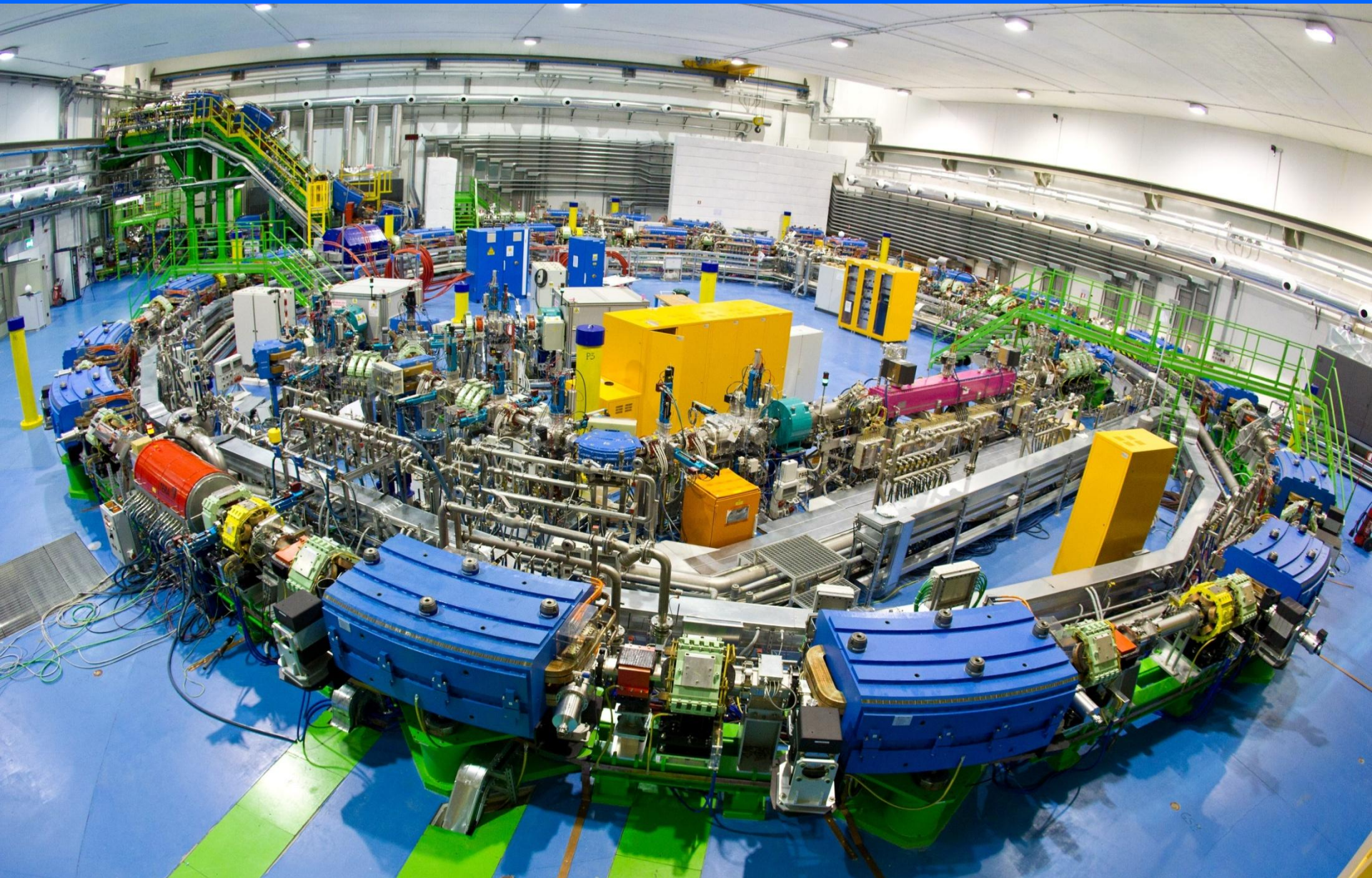
First floor (L. 1): administration, offices and laboratories

Second floor (L. 2): direction, conference and meeting rooms

Hospital based: safety, efficiency, reliability, maintainability
COMPACT DESIGN



The synchrotron for protons and carbon ions





LEBT

0.008 MeV/u H^{3+}
0.008 MeV/u C^{4+}

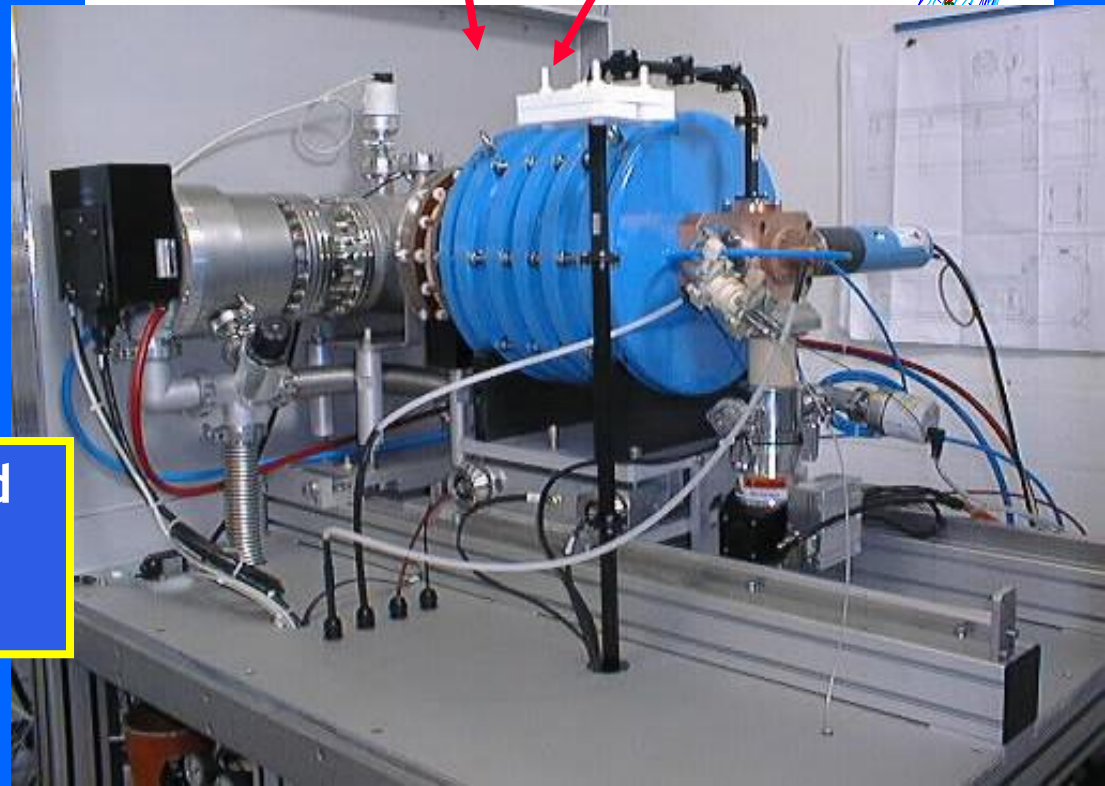
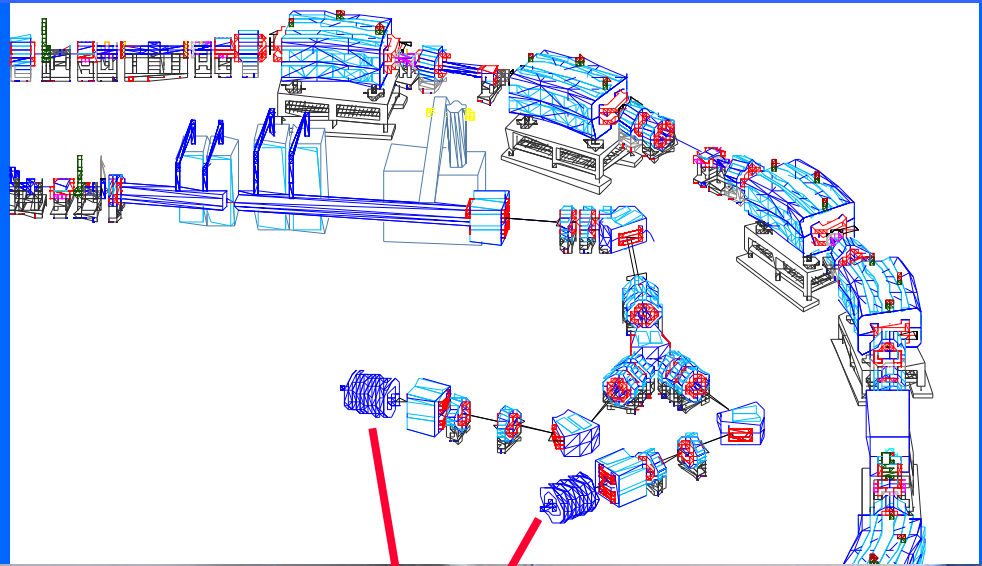
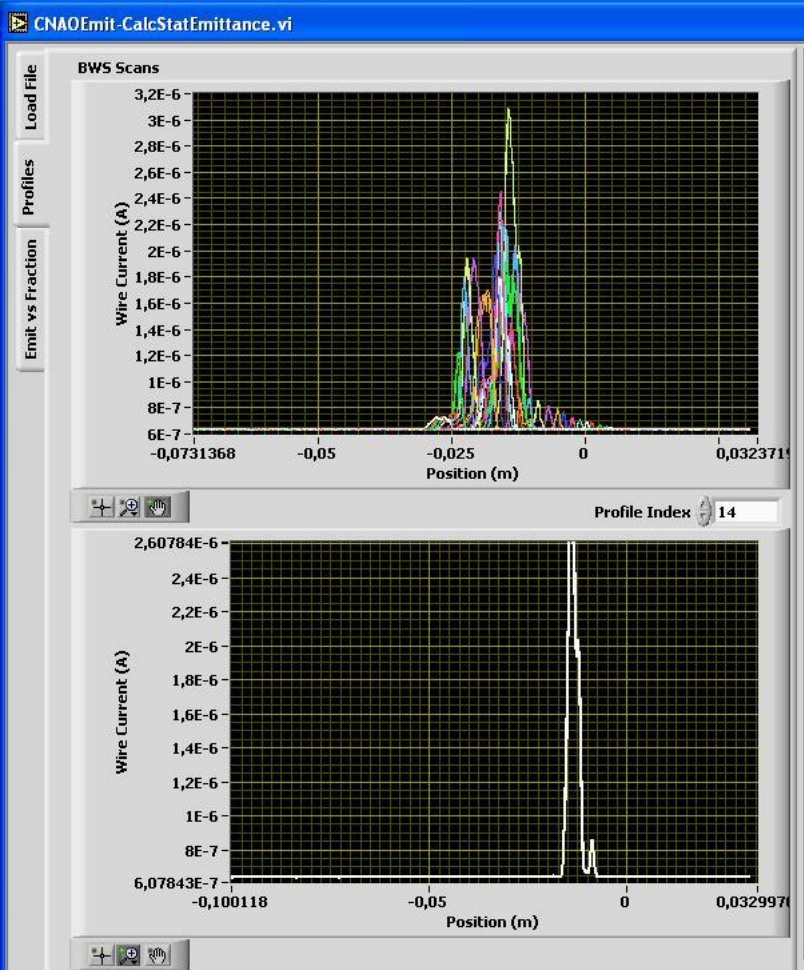
$I \sim 0.5 \text{ mA}$ (H^{3+})
 $I \sim 0.2 \text{ mA}$ (C^{4+})

Two ECR sources

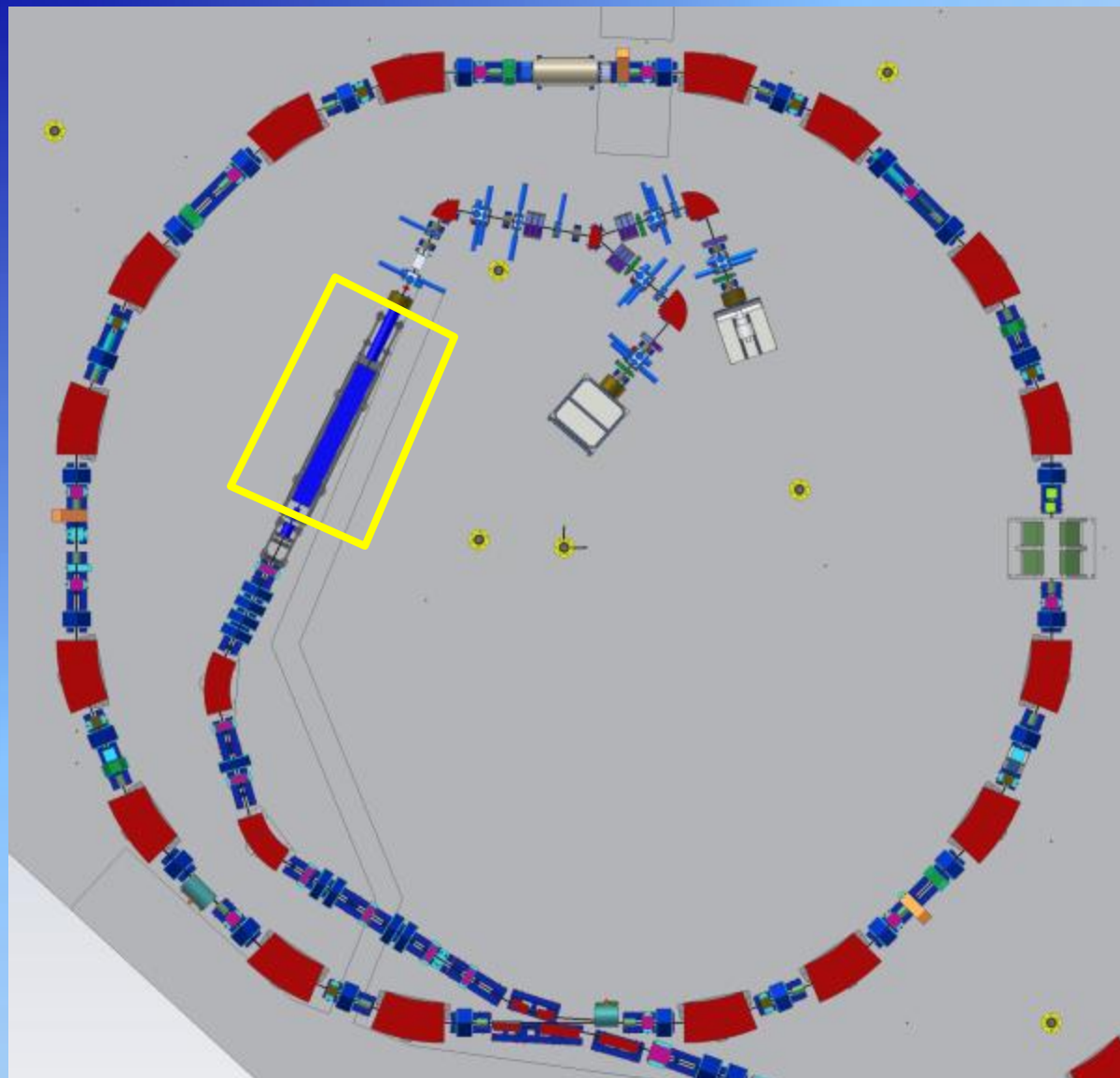
Continuous beam

LEBT Chopper

Ion sources ... were protons and carbon ions are generated



Each source produces a cloud formed by 1 billion of carbon ions or 10 billions of protons



Linac=RFQ+IH

217 MHz

RFQ

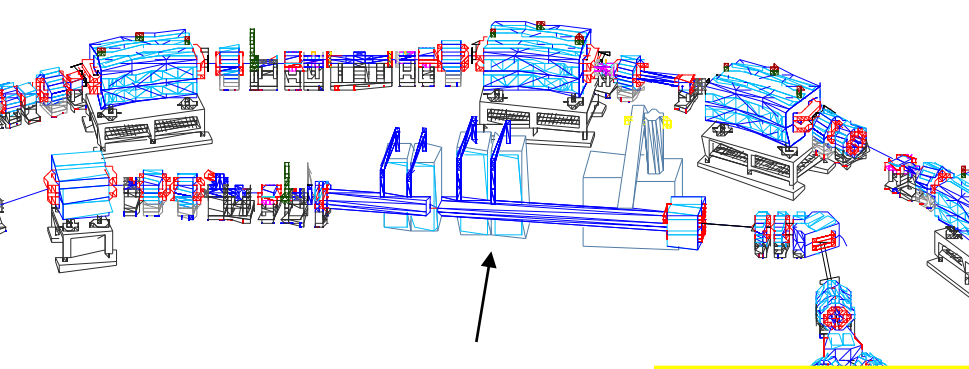
0.008-0.4 MeV/u H^{3+}

0.008-0.4 MeV/u C^{4+}

IH

0.4-7 MeV/u H^{3+}

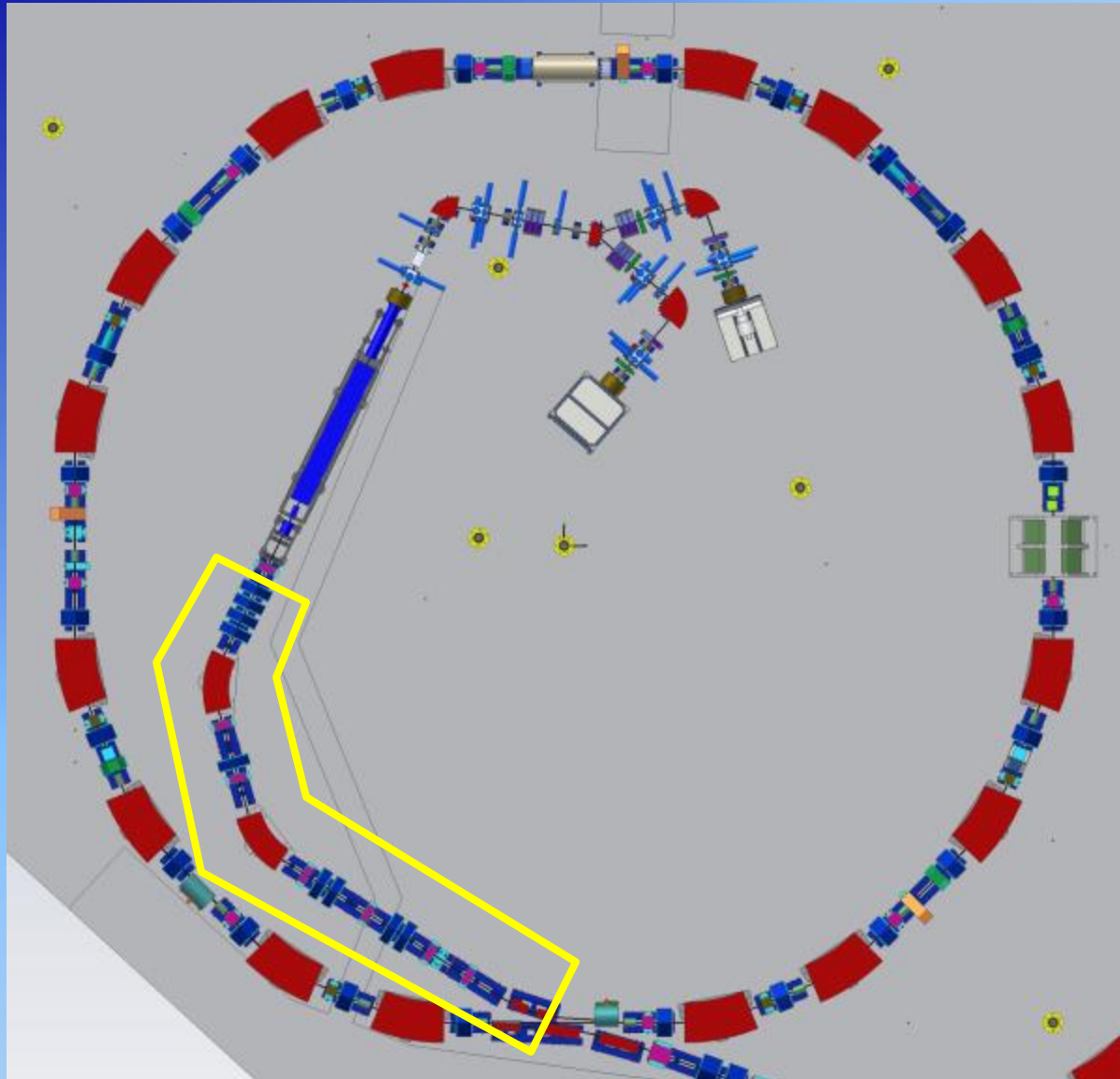
0.4-7 MeV/u C^{4+}



The Linear accelerator for ions

In about 6 meters the beam increases the energy by a factor 1000 - to reach 1/10th of light speed... 30'000 km/sec





MEBT

7 MeV p
7 MeV/u C⁶⁺

$I \sim 0.75$ mA (p)
 $I \sim 0.12$ mA (C⁶⁺)

Stripping foil

Current selection

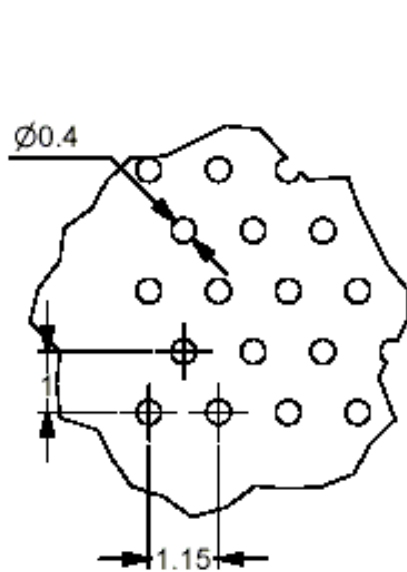
Debuncher

Emittance dilution

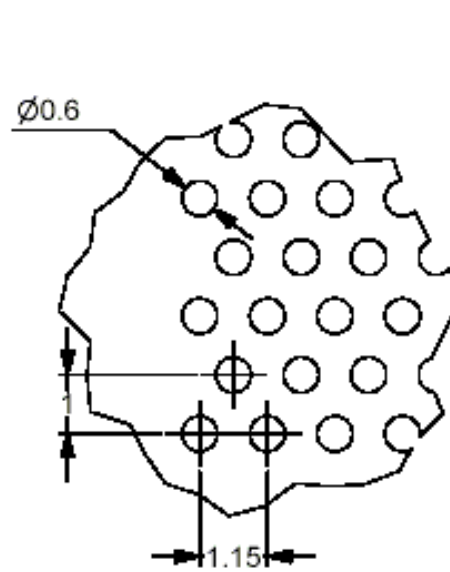
Match betas

$(x, x')_{inj}$

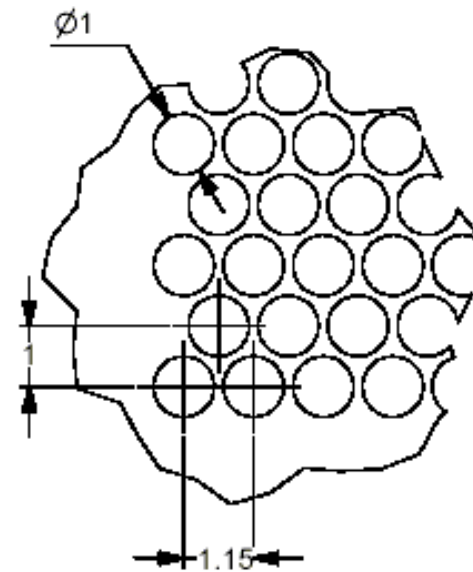
Intensity degrader



F10 Filter



F20 Filter



F50 Filter



4 transmission levels: 100%, 50%, 20%, 10%
Keep overall emittance unchanged

Multiturn injection

Create an orbit “bump”

Incoming beam

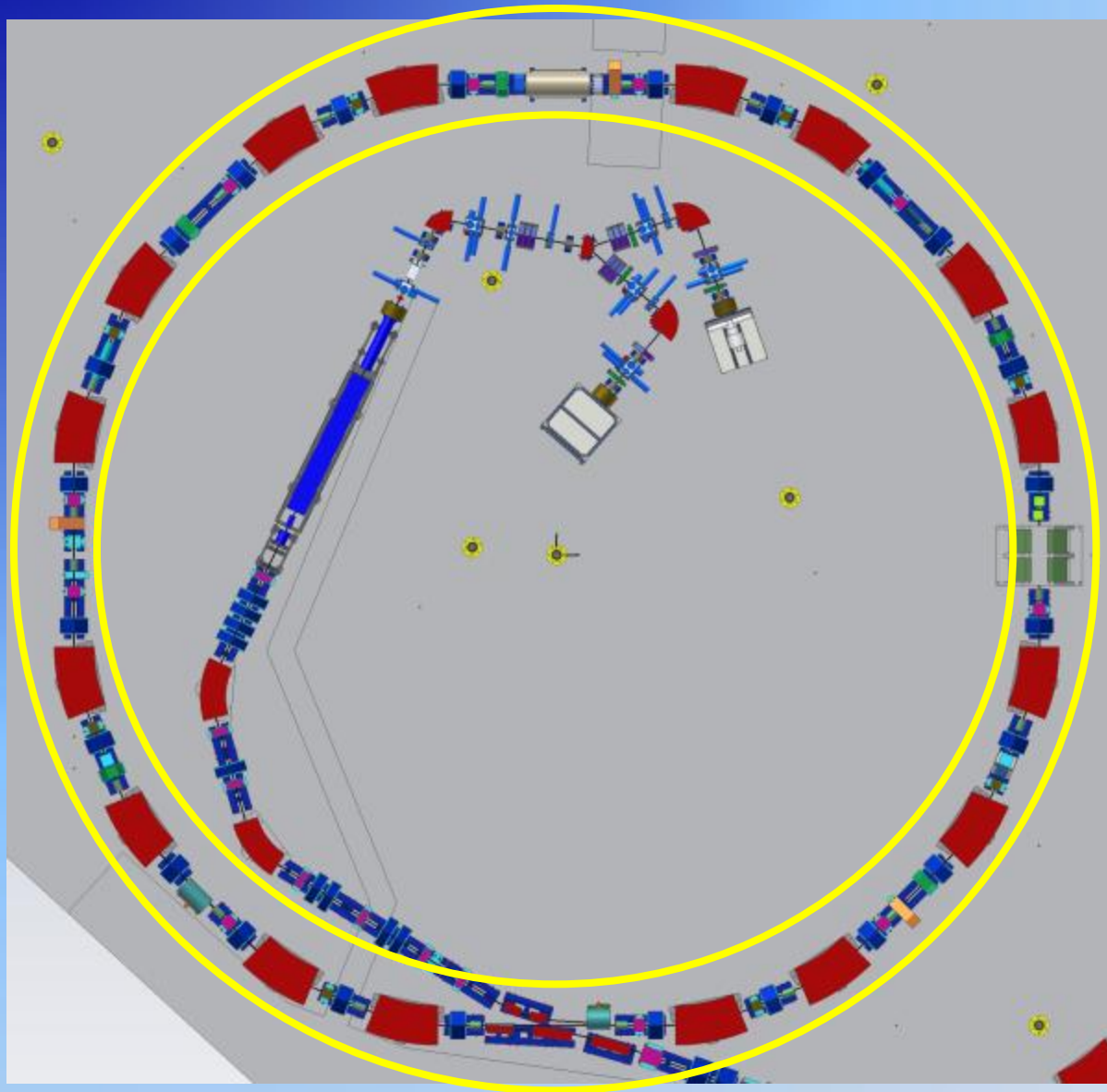
Septum

Bumper

Bumper



Generally there are 2, 3 or 4 bumpers.
The bump collapses in tens of turns



Synchrotron

7-250 MeV p
7-400 MeV/u C

$I \sim 0.1\text{-}5\text{ mA (p)}$
 $I \sim 0.03\text{-}1.5\text{ mA (C)}$

Slow extraction

Betatron core

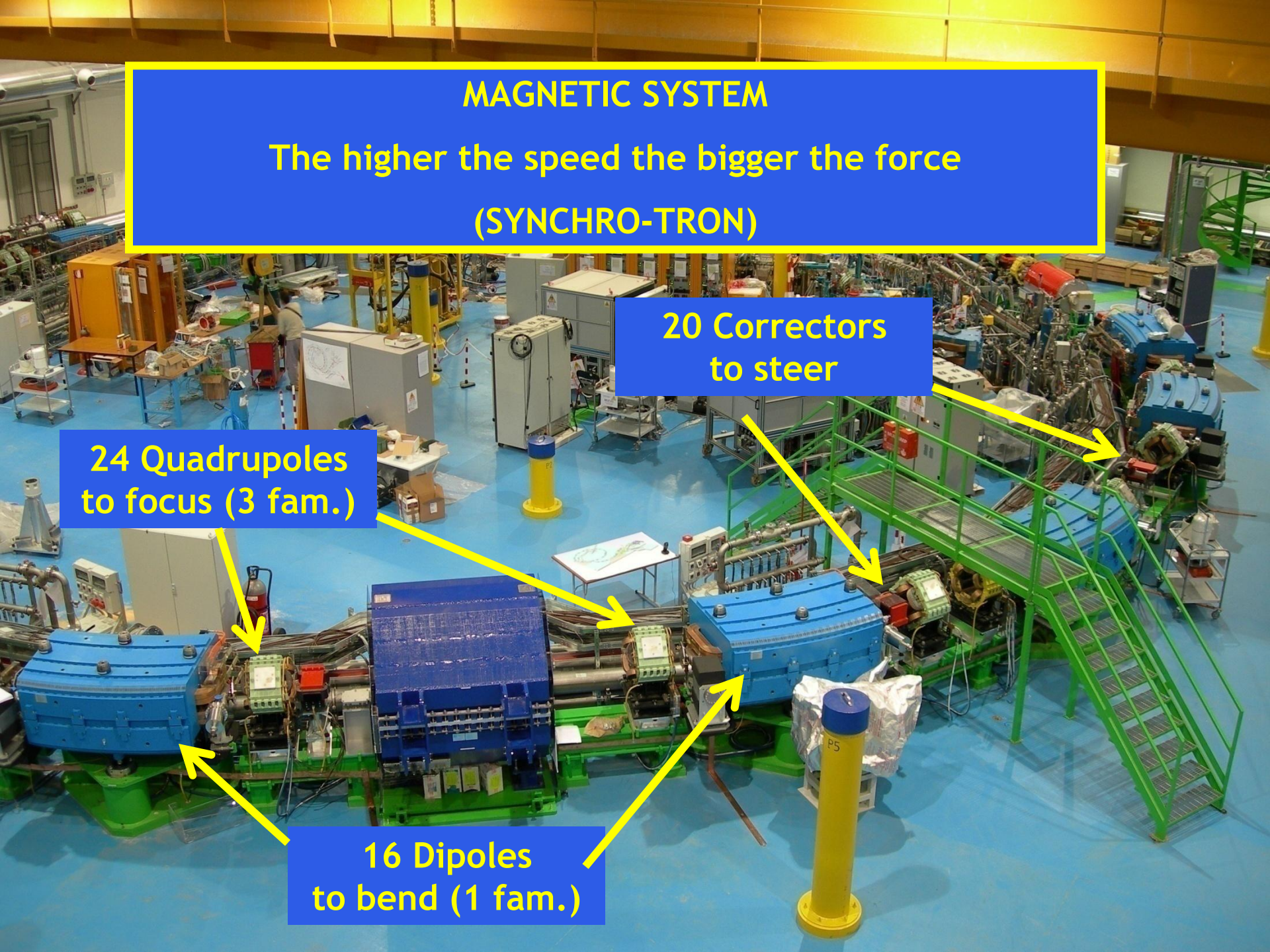
MAGNETIC SYSTEM

The higher the speed the bigger the force
(SYNCHRO-TRON)

20 Correctors
to steer

24 Quadrupoles
to focus (3 fam.)

16 Dipoles
to bend (1 fam.)

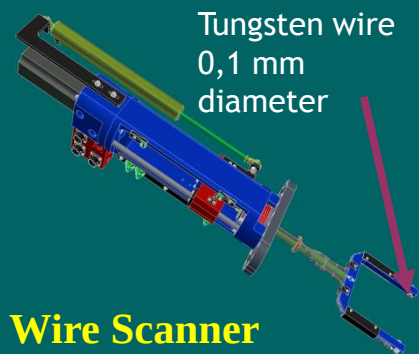
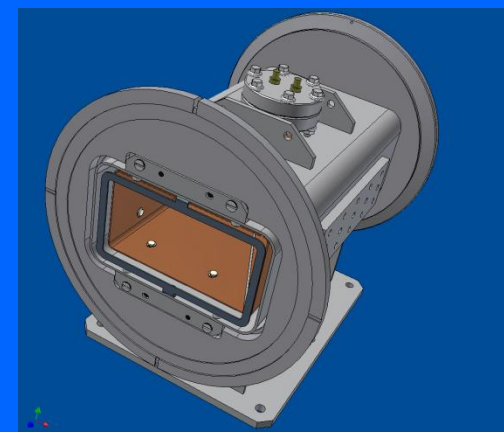


Beam Diagnostics

Designed and specified
by CNAO-INFN-CERN



Beam Position Monitor



Wire Scanner



Faraday Cup

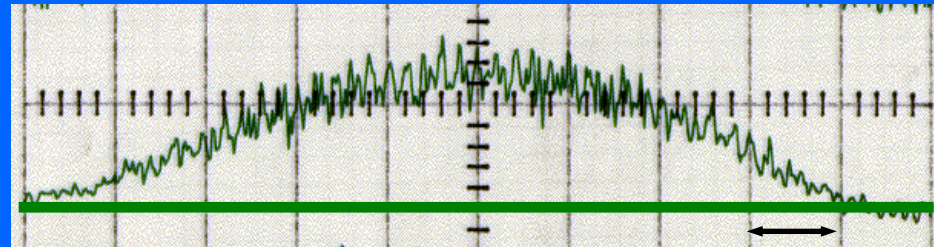


Flag

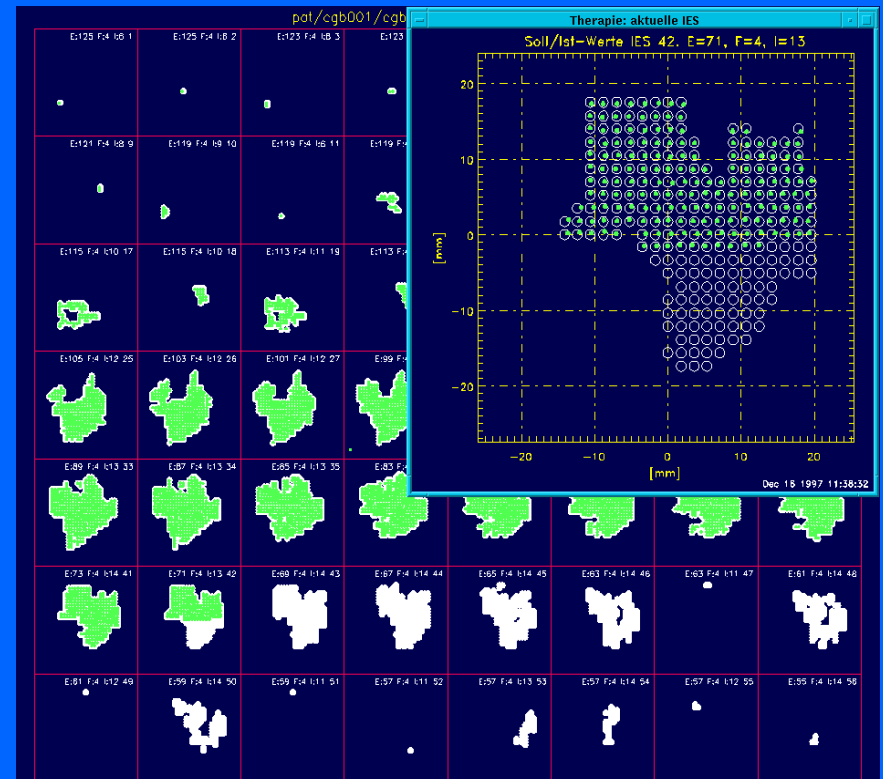


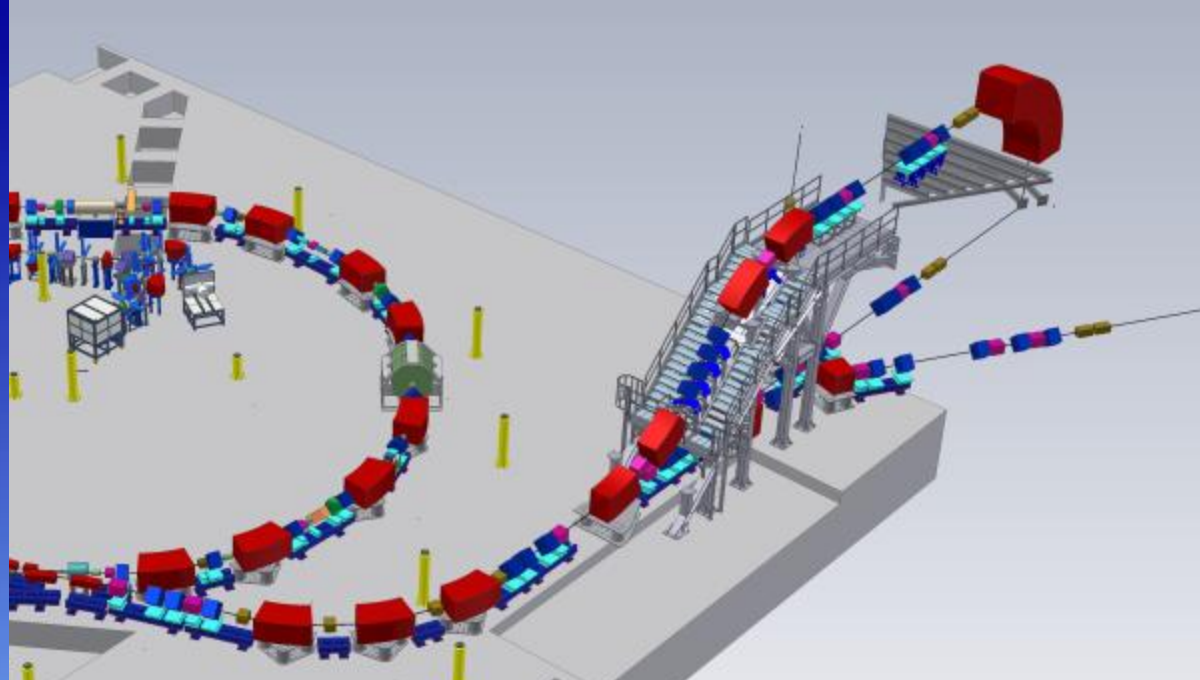
Smooth spill to allow tumour painting

Intensity ripple ($\Delta I/I$) $\leq \pm 20\%$ at 2 kHz
(extraction with a betatron core - PIMMS)



50 ms





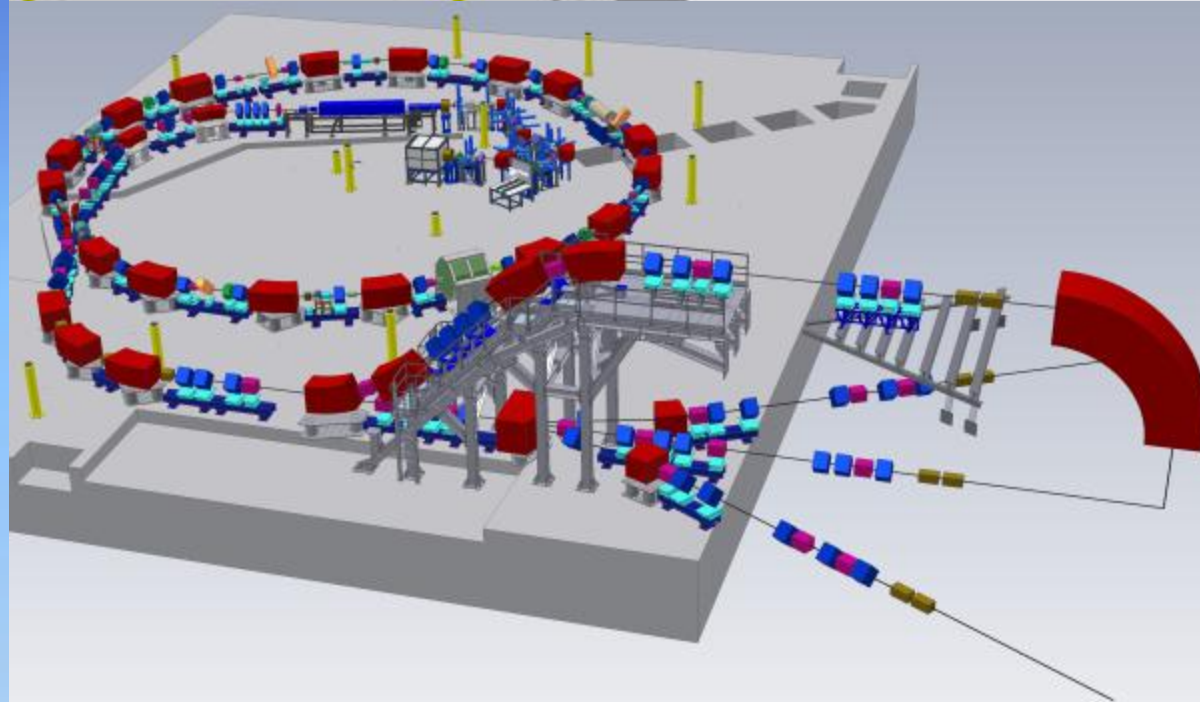
HEBT

60-250 MeV p
120-400 MeV/u C

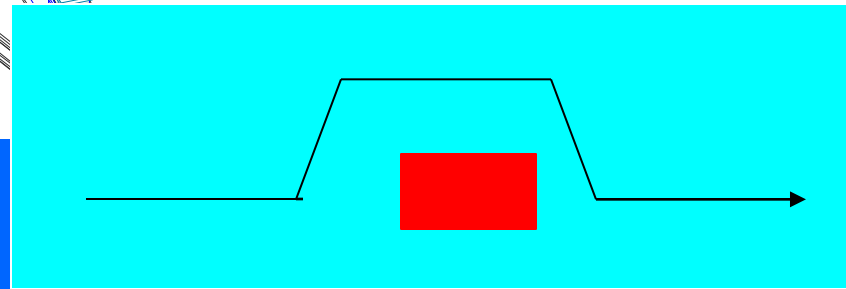
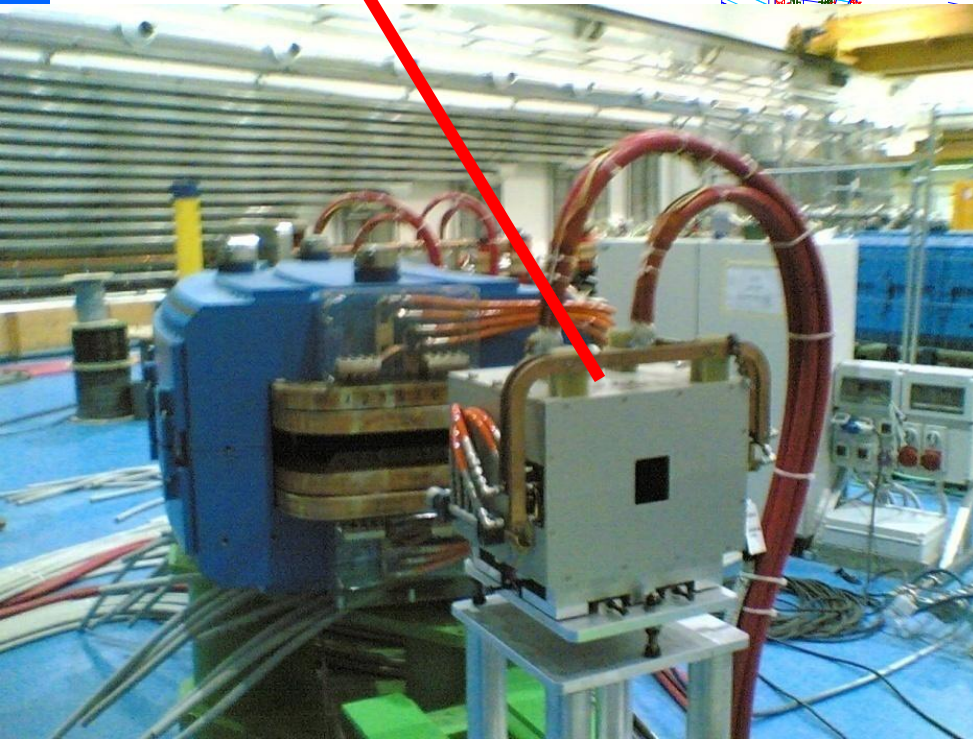
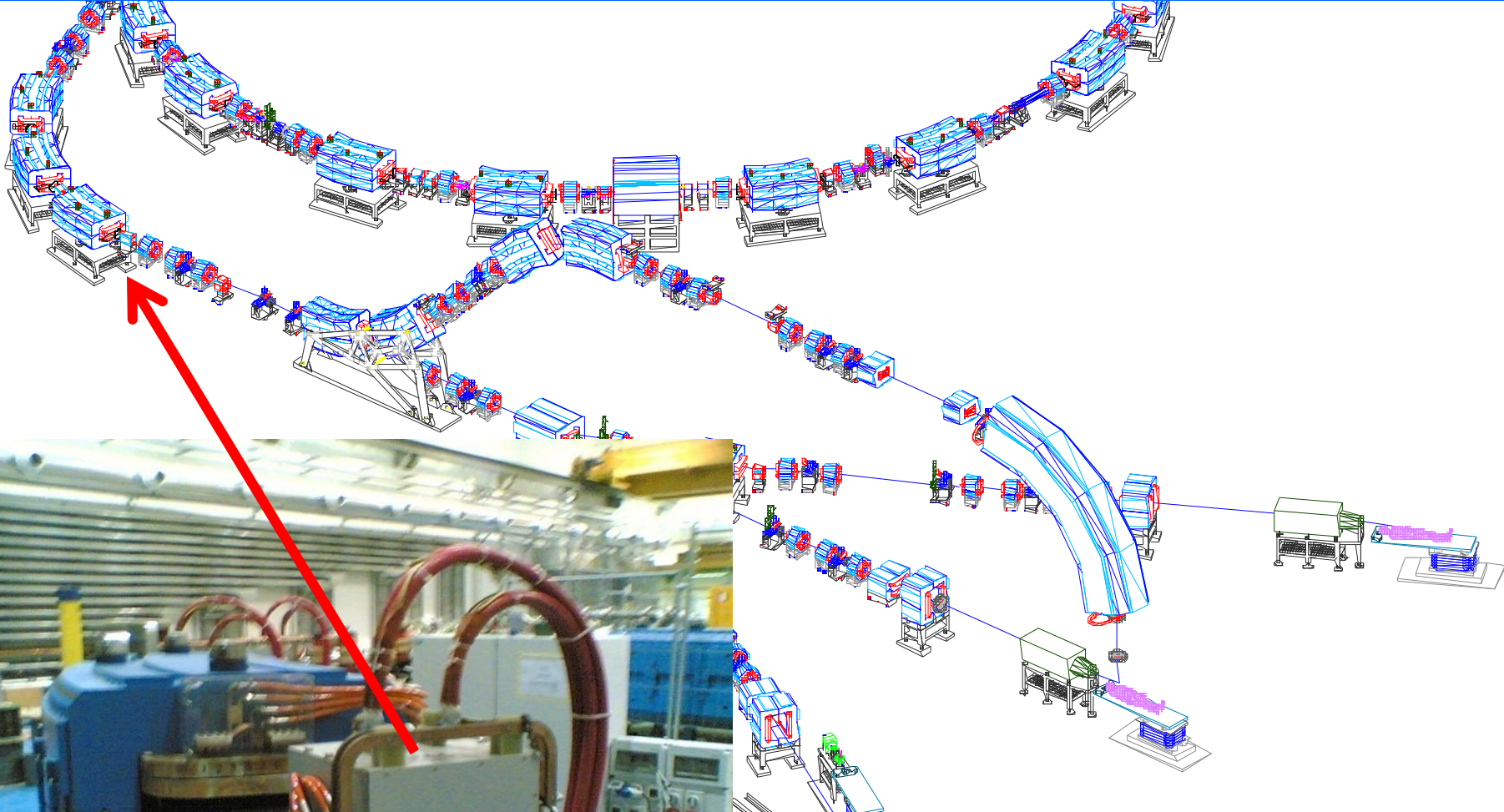
10^{10} p/spill (~ 2 nA)
 $4 \cdot 10^8$ C/spill (~ 0.4 nA)

different settings for

- Treatment Line
- Horizontal beam size
- Vertical beam size
- Extraction energy



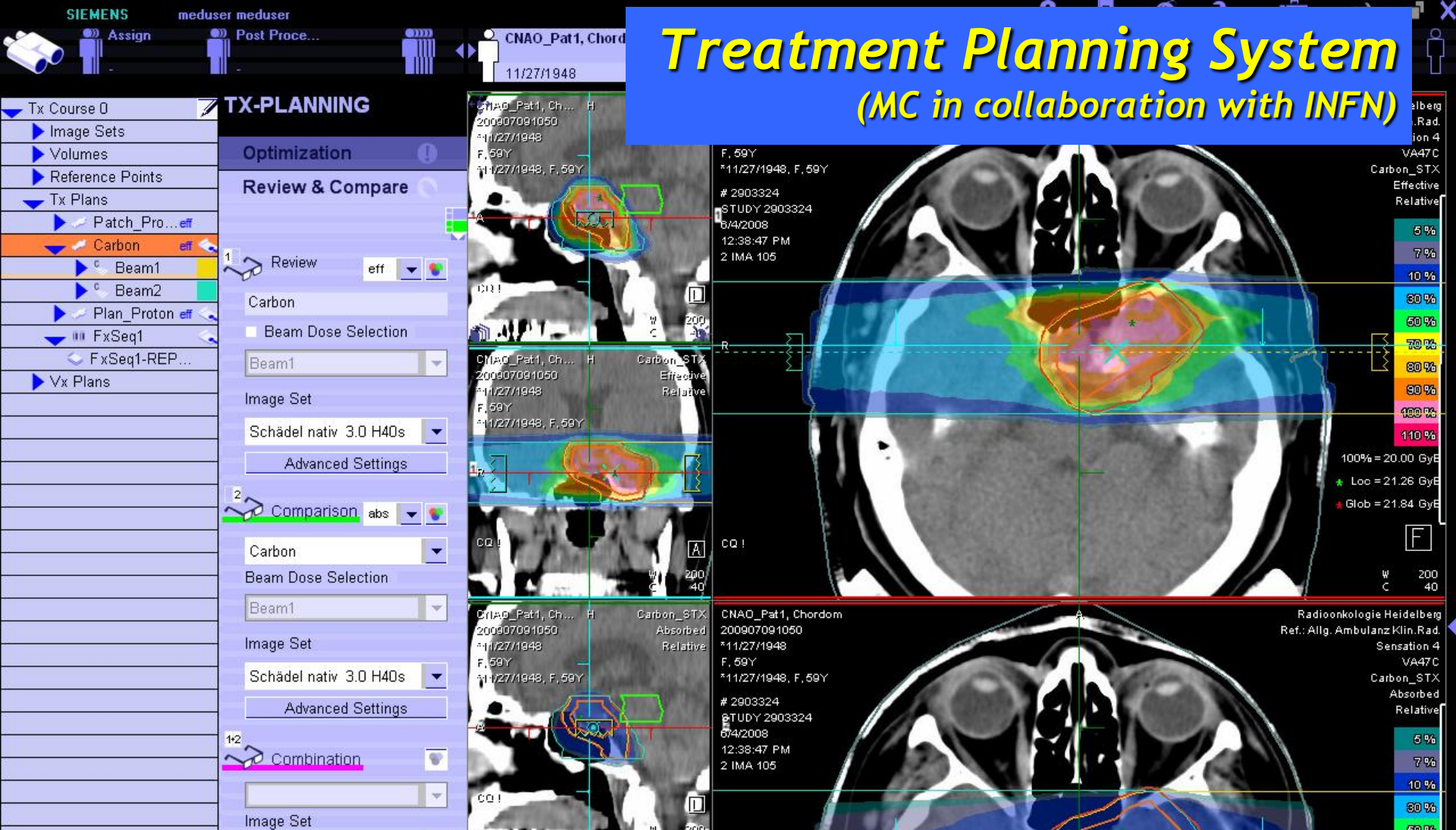
The extraction lines (safety is an issue)



High precision devices for patient positioning



Collaboration CNAO-PoliMi

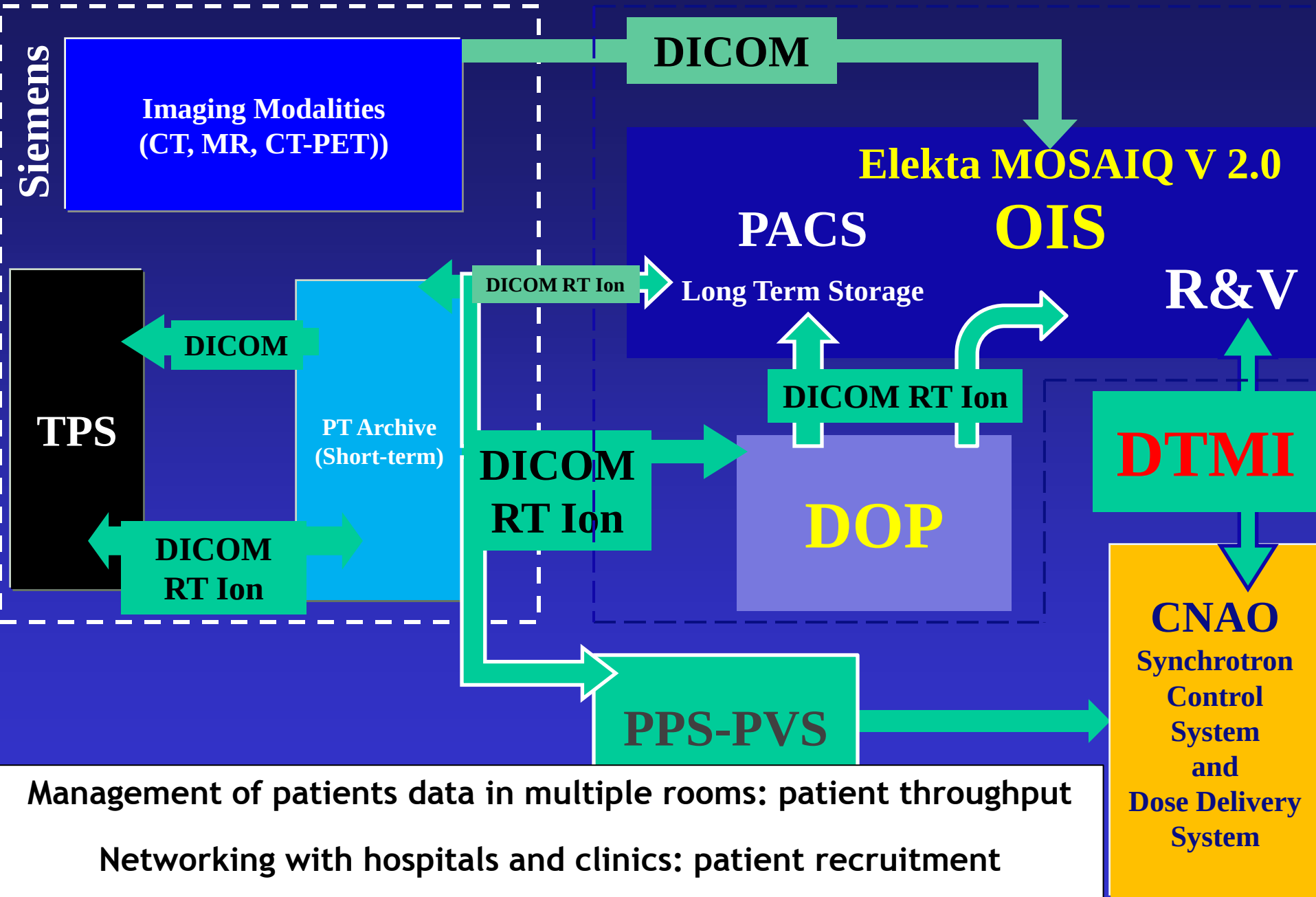


TPS is directly related to scanning modality and RBE evaluation model

Need to include management of moving organs and integration of in-room imaging

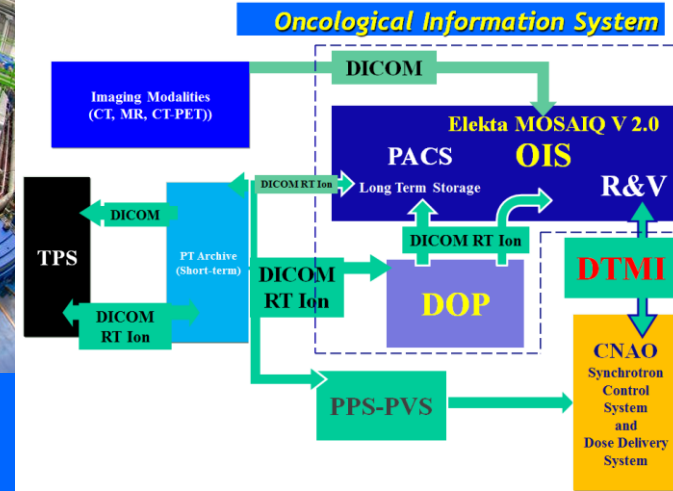
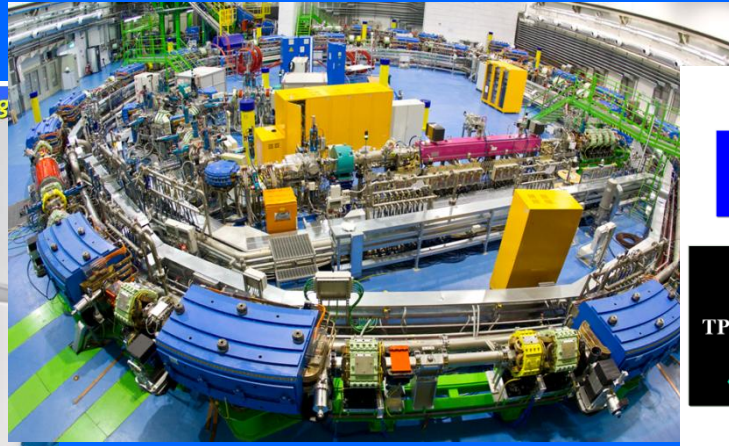
(TPS used at CNAO)

Oncological Information System

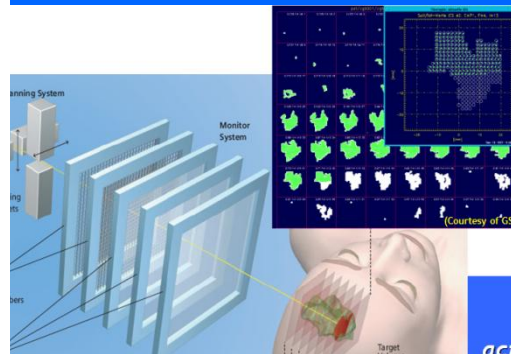
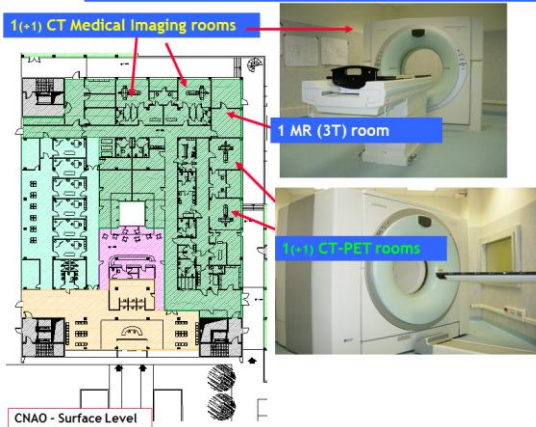


Much more than ... “just” ... an accelerator

High precision devices for patient positioning

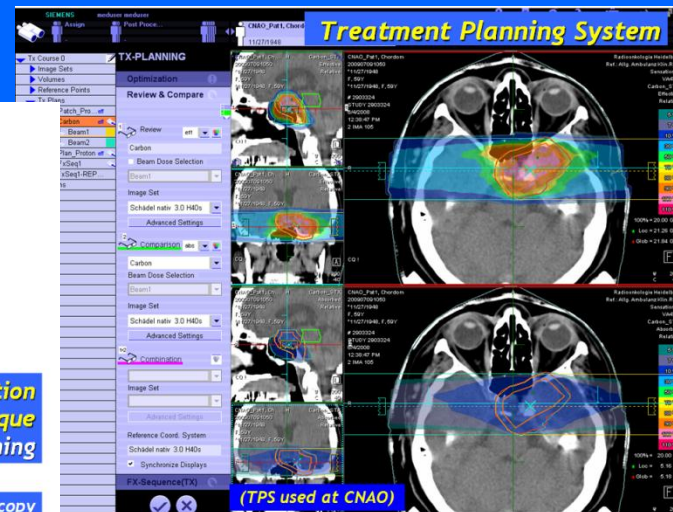
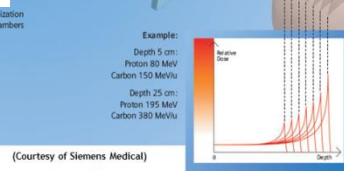


Advanced Medical Imaging Modalities (fusion sw)



Irradiation
technique
active scanning

In construction copy
for EBG-MedAustron



Research issues...

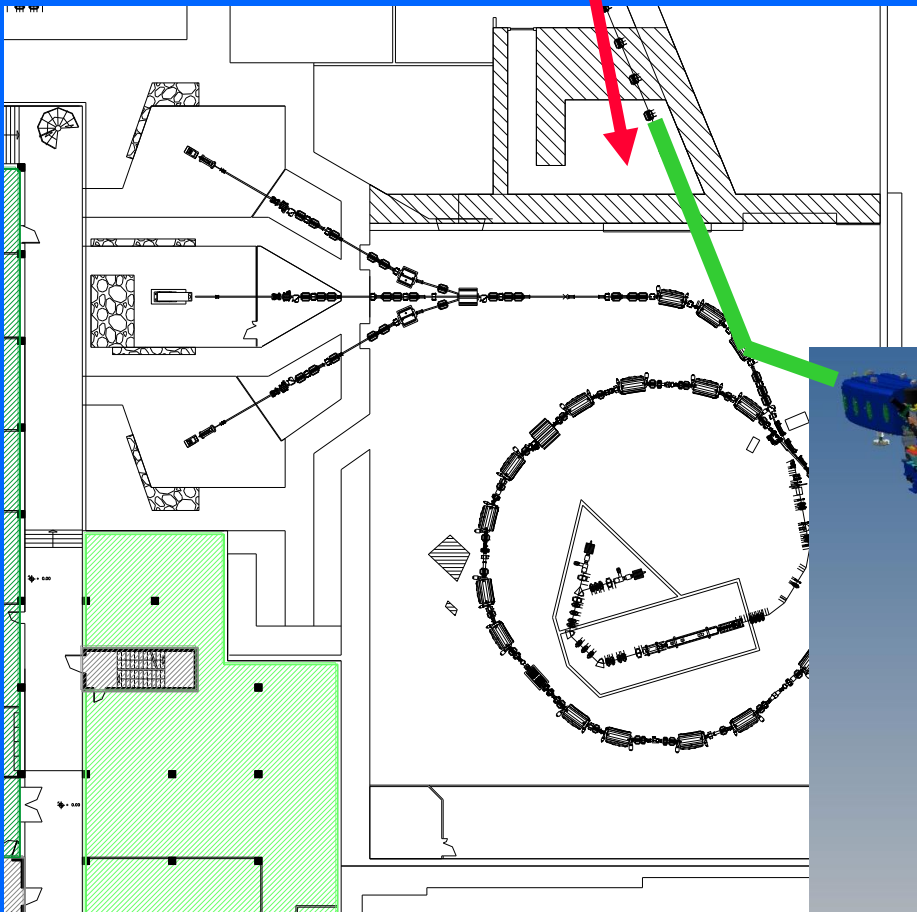


Research topics at CNAO

Research is a must to keep CNAO up-to-date

Research labs at the first floor

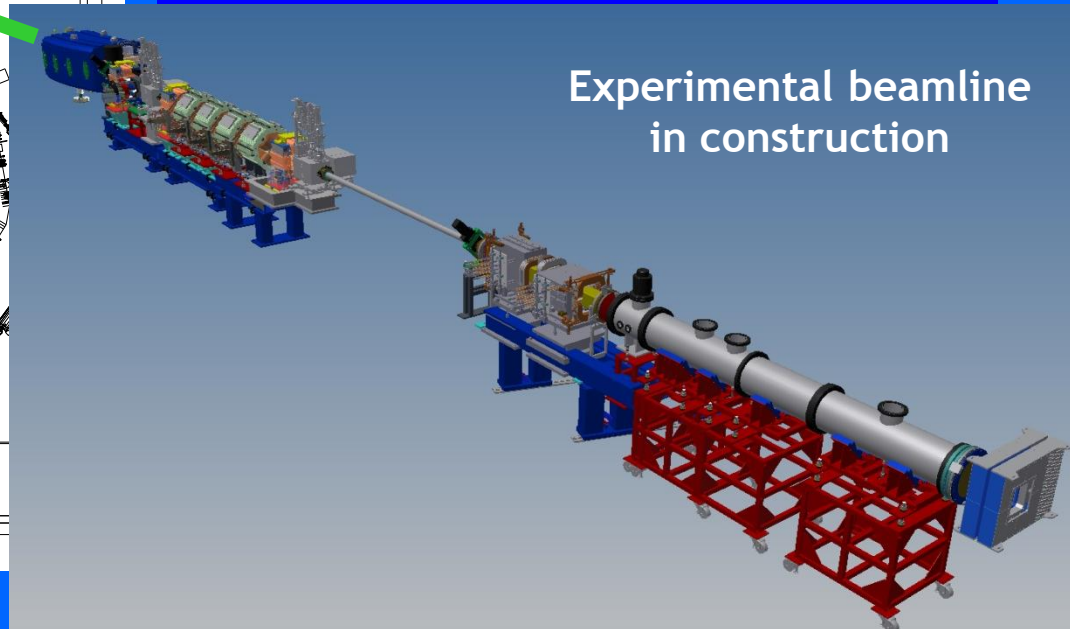
Experimental room



European Network for LIght ion Hadron Therapy

Collaboration with INFN

Experimental beamline
in construction



Production of radioisotopes for imaging
Collaboration with UniPv
Interests of Pavia hospitals



Cyclotron already installed at LENA could be re-used in a clinical&research environment for radioisotopes production to improve imaging capabilities
Radioarmacy and drugs development (chemistry)

Advanced Medical Imaging Modalities (fusion sw)

1(+1) CT Medical Imaging rooms



1(+1) CT-PET rooms

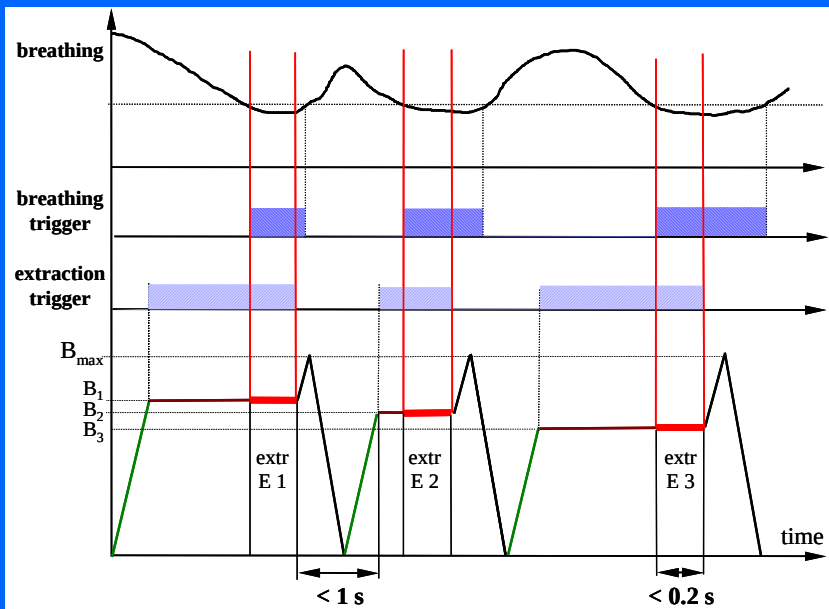


Advanced 3D molecular imaging modalities
→ tumour molecular profiling
→ dose painting with different LET ions
(→ sources and accelerators choices)
(O. Jäkel, in IBT, Springer2011)

CNAO - Surface Level

Improvements: On-line imaging and Tumour tracking

“Minimal” choice: breathing synchronisation
(already applied in Chiba and HIT)



External surrogates with correlation models

X-rays

Ultrasound, MRI

Particle radiography

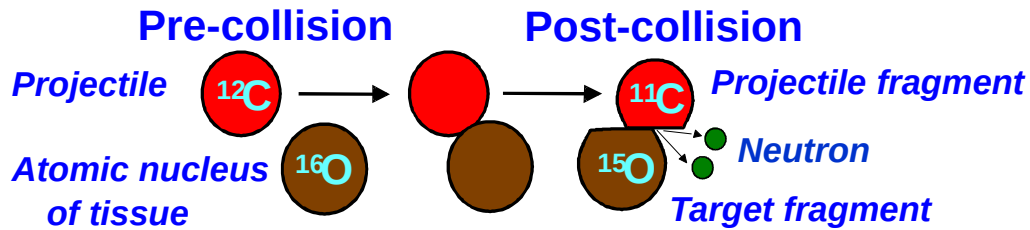
Interesting also for IMRT:
lots of efforts and devices



(Review in Riboldi et al, Lancet Oncology 2012)

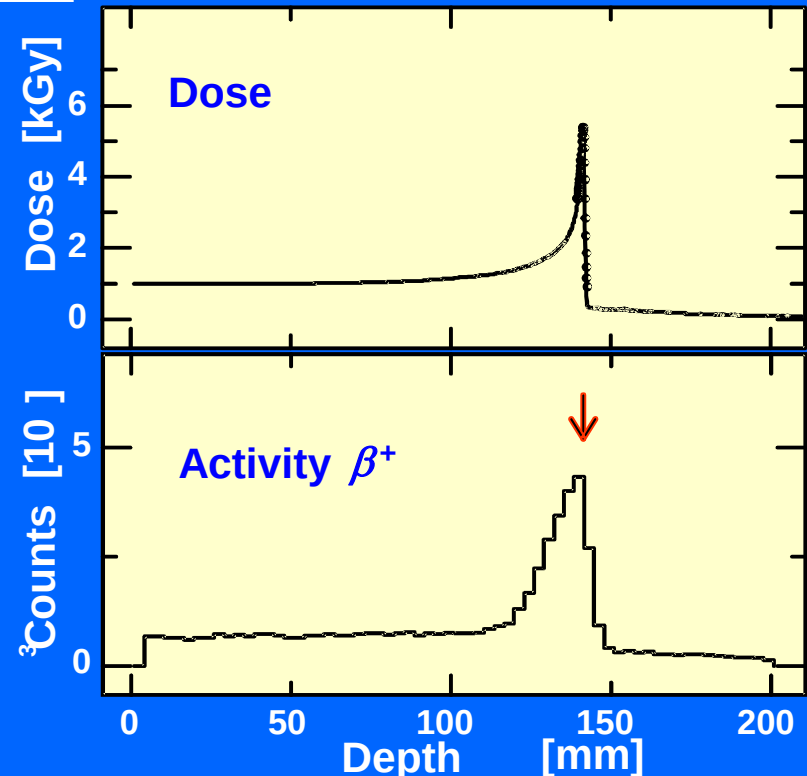
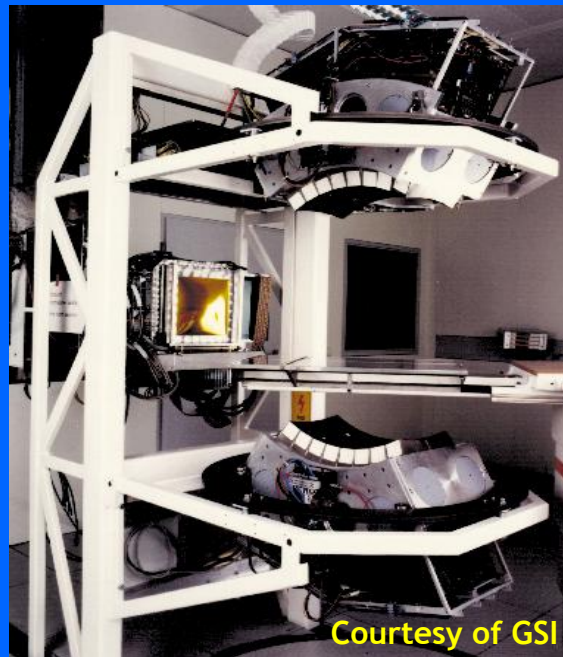
(Courtesy of Medical Intelligence)

Dose visualisation: “in beam PET” + secondaries



R&D Topics:

Increase efficiency, solid angle coverage, new detectors (gas), quantitative measurements of the dose



**Collaborations
with INFN groups**

ISSUES: low statistics;
blood flow dilution;
off-line PET → logistics

BNCT: Boron Neutron Capture Therapy

RFQ at LNL for BNCT



Collaboration
INFN, UniPv, CNAO

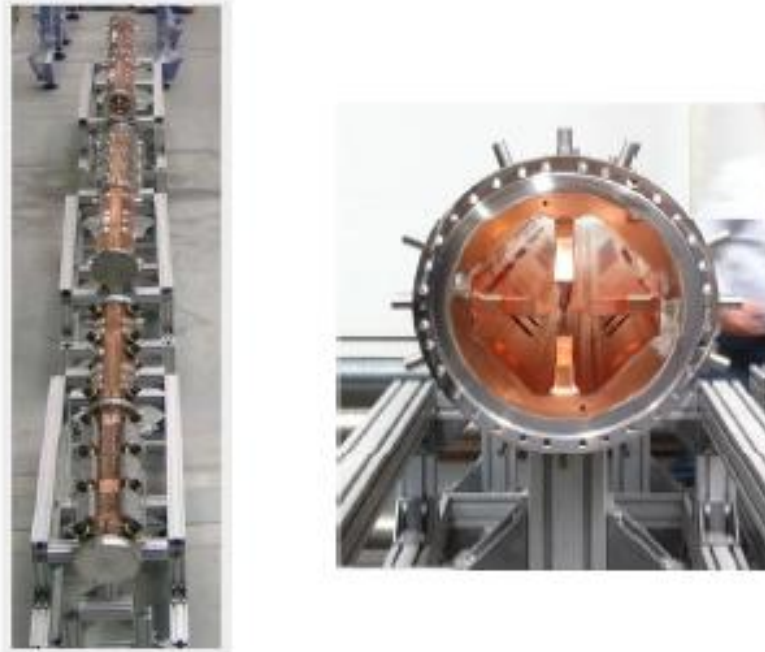
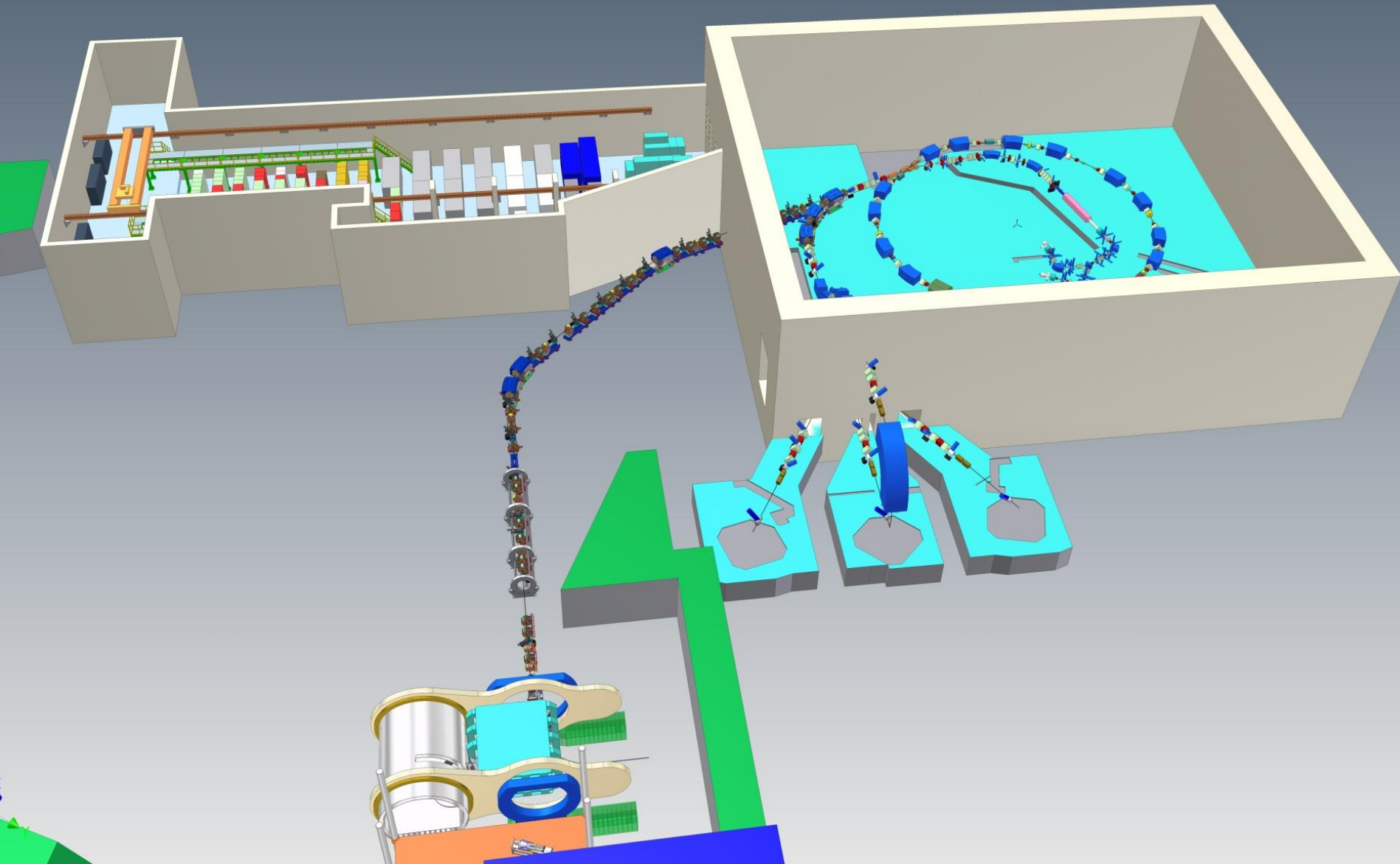


Figure 1: the accelerator is made up of three segments 2.4 m long (left), the quadrupole (right)

Table 1: accelerator elements and characteristics

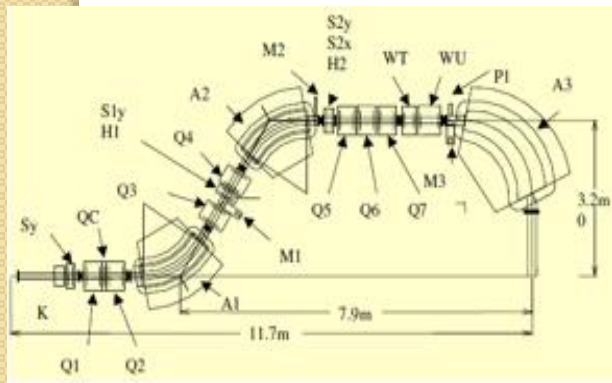
Ion source	TRIPS	80 keV protons, 50 mA intensity
Accelerator type	RFQ	Radio Frequency Quadrupole
Final Energy	5 MeV	
Beam current	30 mA	
Useful cycle	CW	Continuous accelerated beam
Neutron Converter	Beryllium	Incident power on converter: 150 kW
Neutron source intensity produced in the converter	$\sim 10^{14} \text{ s}^{-1}$	Mean neutron energy: 1.2 MeV. Neutron emitted per second in the whole solid angle
RF power	1.3 MW	
Electrical power in function	3.3 MVA	
Thermal power at the refrigerating system	2.9 MW	Two different closed circuits: 1.1 MW with maximum temperature $T_{\text{max}} = 11^\circ\text{C}$ and 1.8 MW with $T_{\text{max}} = 20^\circ\text{C}$

Future expansion of CNAO



Comparison of dimensions

Conventional RT



Proton Gantry

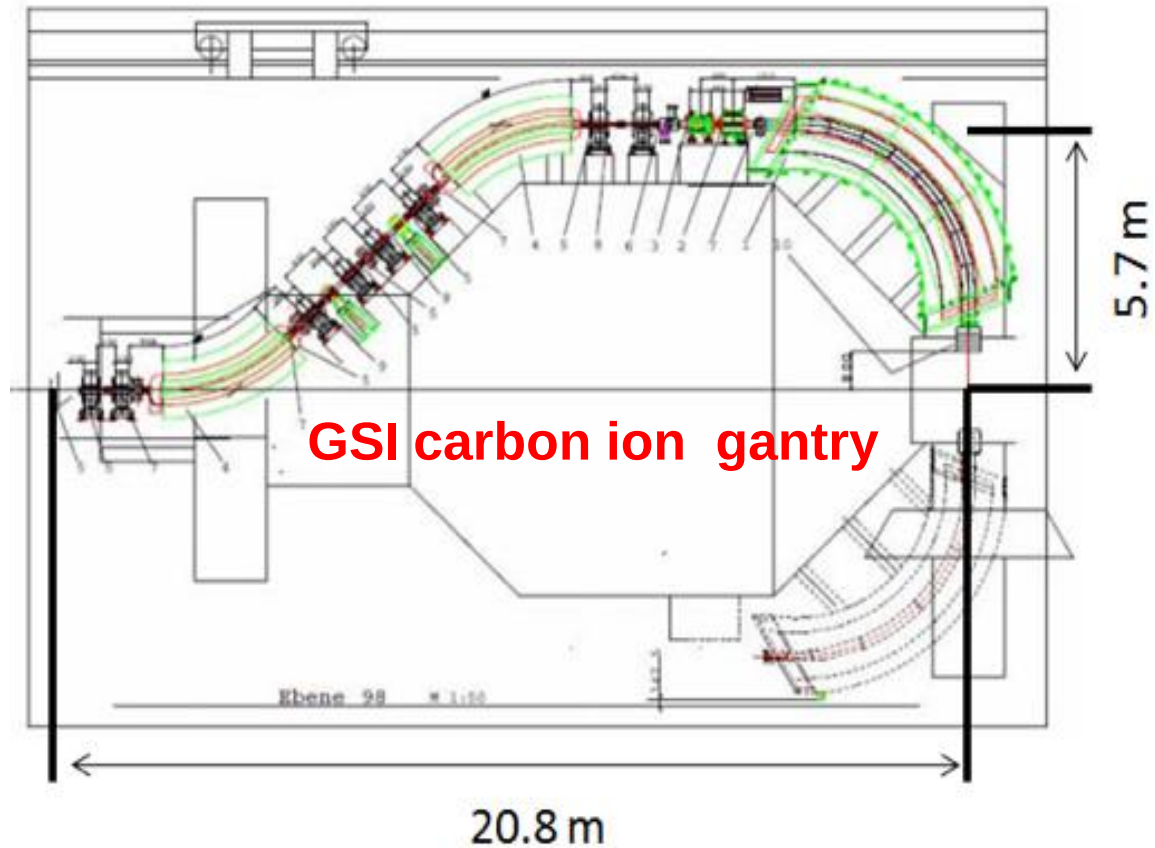
$Br < 2.4 \text{ Tm}$

PSI proton gantry

(Courtesy M. Pullia)

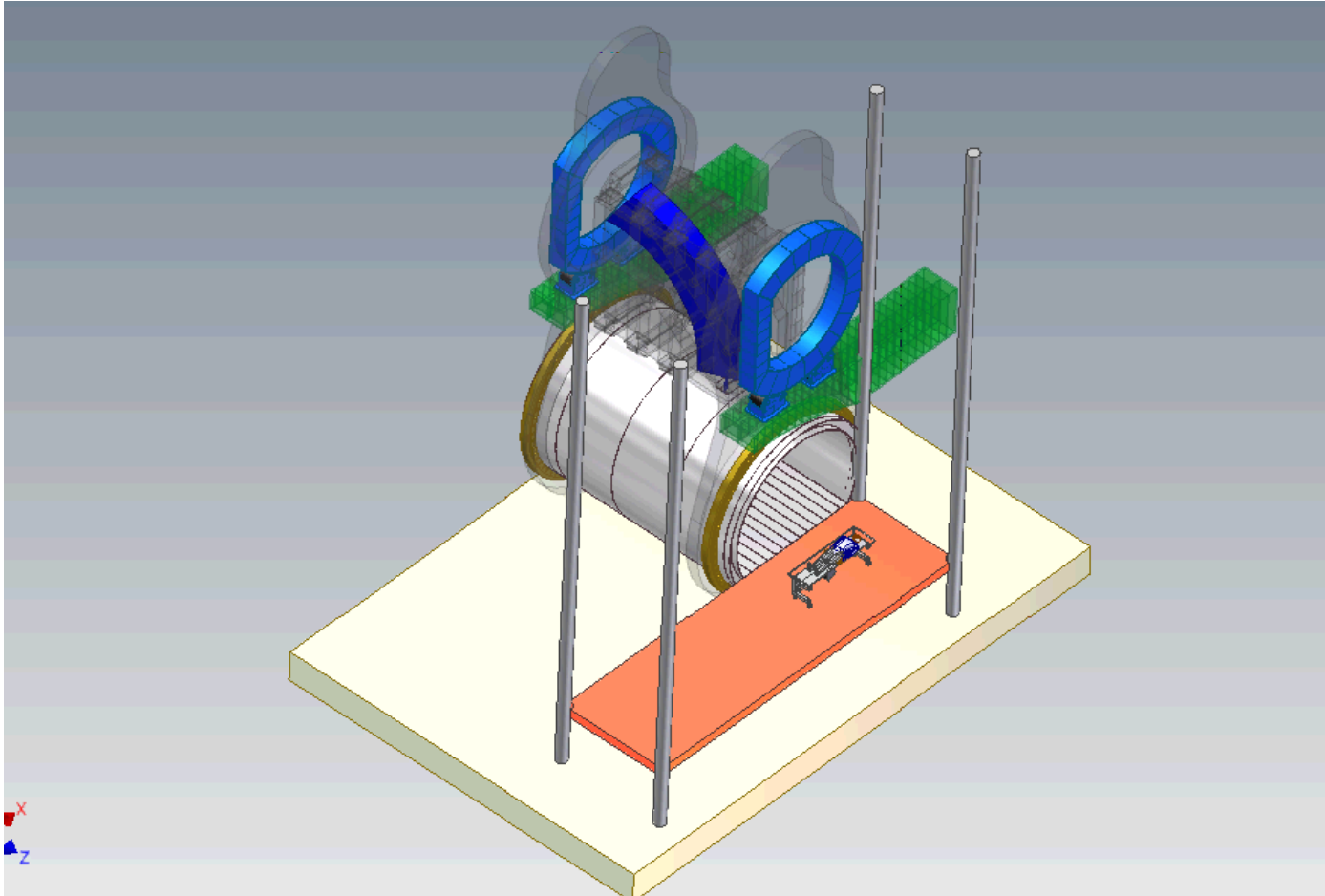
Carbon Ion Gantry

$Br < 6.4 \text{ Tm}$



Novel gantry for carbon ions

The ULICE WP6 collaboration realized a conceptual design of a **mobile isocenter gantry**,



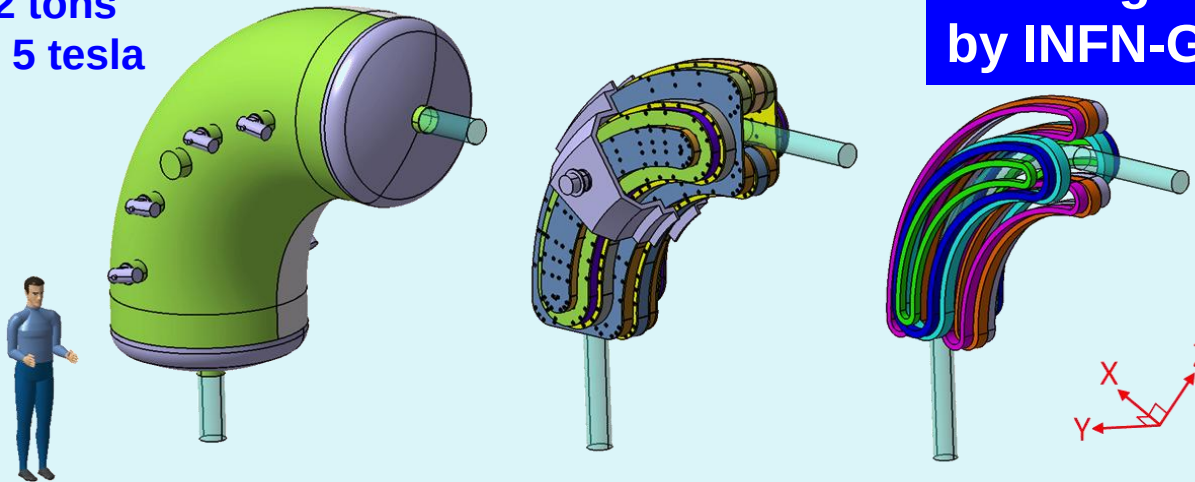
Rationale for the choice

- Innovative layout
- Cheaper and simplified mechanical structure
- Less magnets in the gantry line
- Total weight reduced as well as deformations
- Well known magnet technology
- Layout scalable to SC magnets

Project in progress by CEA (France) in collaboration with IBA

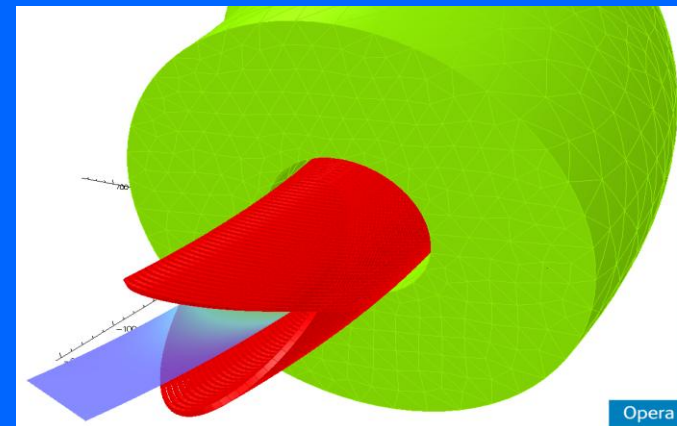
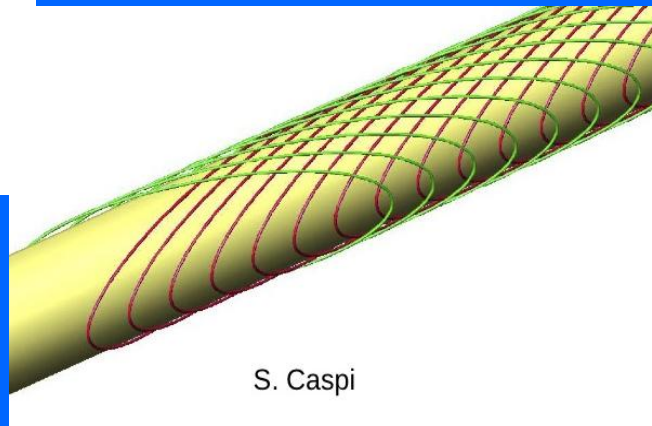
12.2 tons
 $B = 5$ tesla

90° magnet following a design
by INFN-Genoa and TERA



Project in progress at LBL - Berkeley

Two layer helical wires
on a straight cylinder
give a dipole field
(S. Caspi et al.)

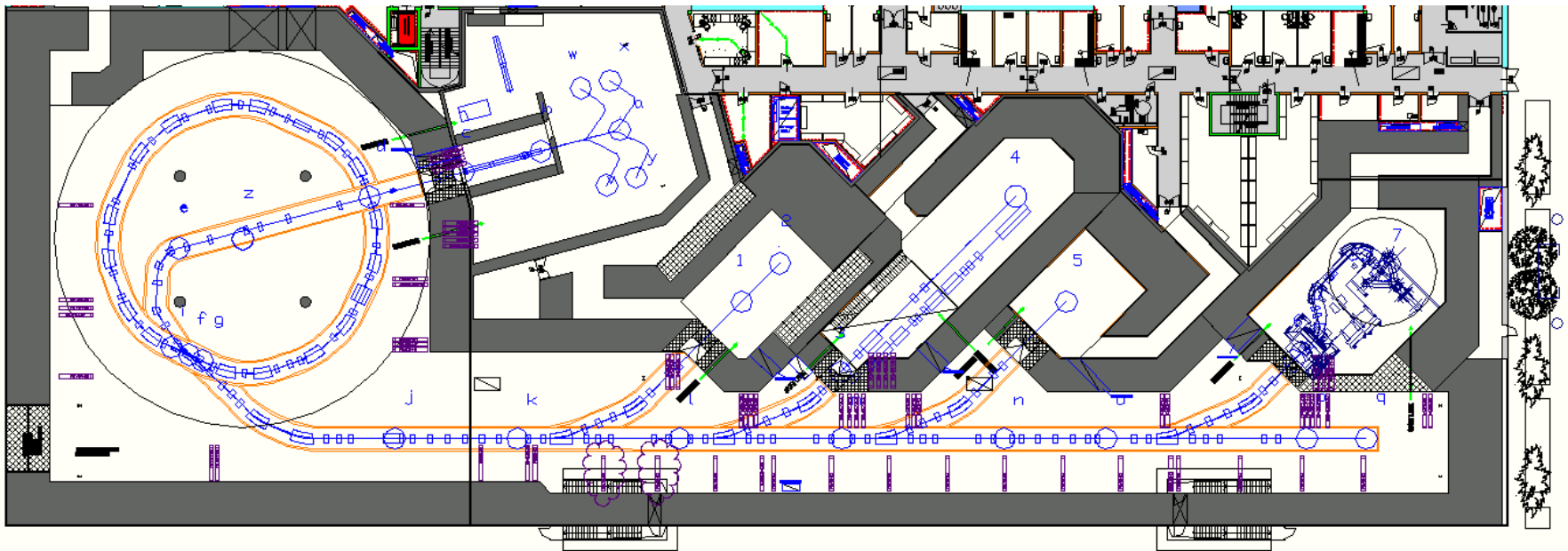


ISSUES: field quality for scanning beams;
changing fields (energy) for active scanning

CNAO model: requests from the world

Austria, Croatia, United Arab Emirates, South Korea, Australia, USA: various projects request collaboration and support

Med-Austron (Wien): based on projects of CNAO/INFN/CERN



Med-Austron (Wien) from CNAO: DDS + db + commissioning

***Particles for
tumour treatments:
the CNAO***

Clinical results at CNAO

PROGETTO DI SPERIMENTAZIONE CLINICA

A CURA DI:

Erminio Borloni – Presidente
Roberto Orecchia – Direttore Scientifico
Sandro Rossi – Segretario Generale e Direttore Tecnico



IL CENTRO NAZIONALE DI ADROTERAPIA ONCOLOGICA

Strada Privata Campeggi – 27100 Pavia



Sedi: Via Caminadella, 16 - 20123 Milano
Iscrizione al Registro delle Persone Giuridiche della Prefettura di Milano n. 192
P.IVA n. 03491780965
Codice Fiscale n. 97301200156

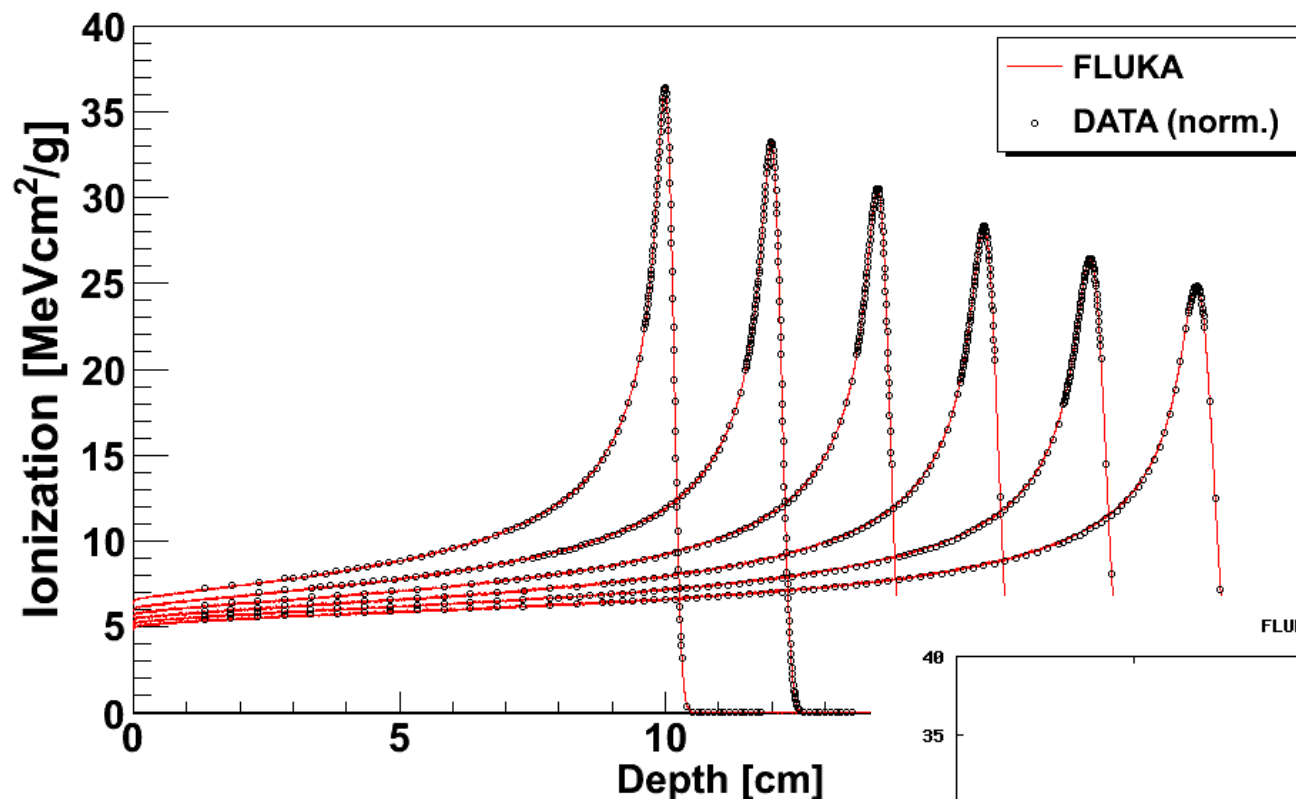
CE Procedure

October 2010 approved by:

- Ministry of Health
- Region Lombardy

Main Tasks:

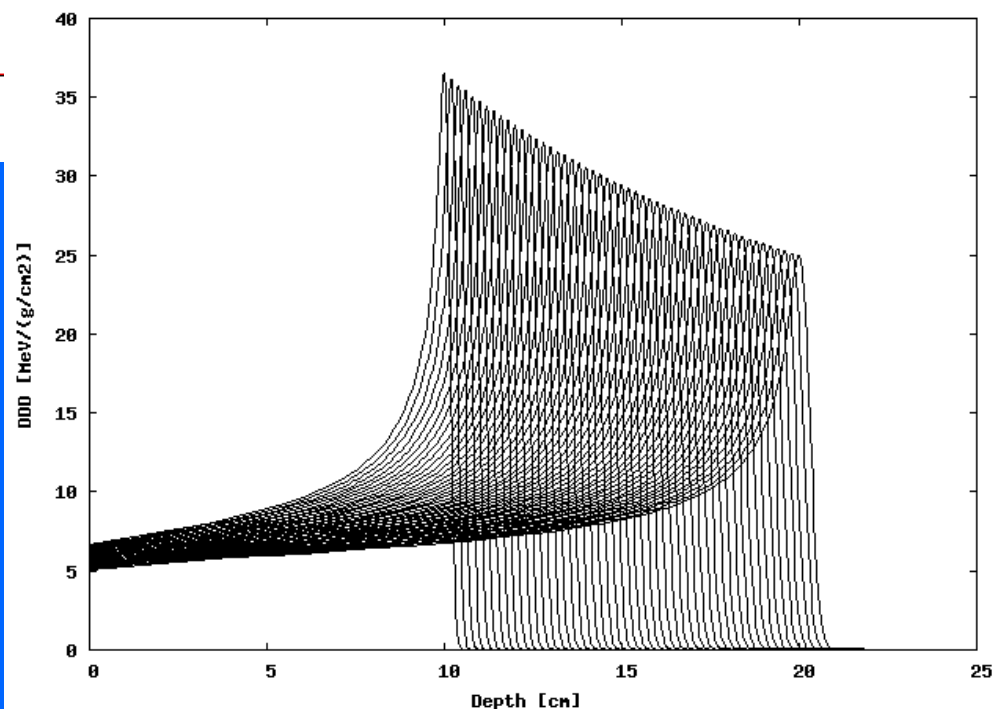
- Dosimetry characterisation
- Radiobiology characterisation
- Patient treatments



FLUKA proton ddd database

$I_{\text{pot}} = 76.9 \text{ eV}$
(similar to $I_{\text{pot}} \text{ c/o HIT} = 79 \text{ eV}$)

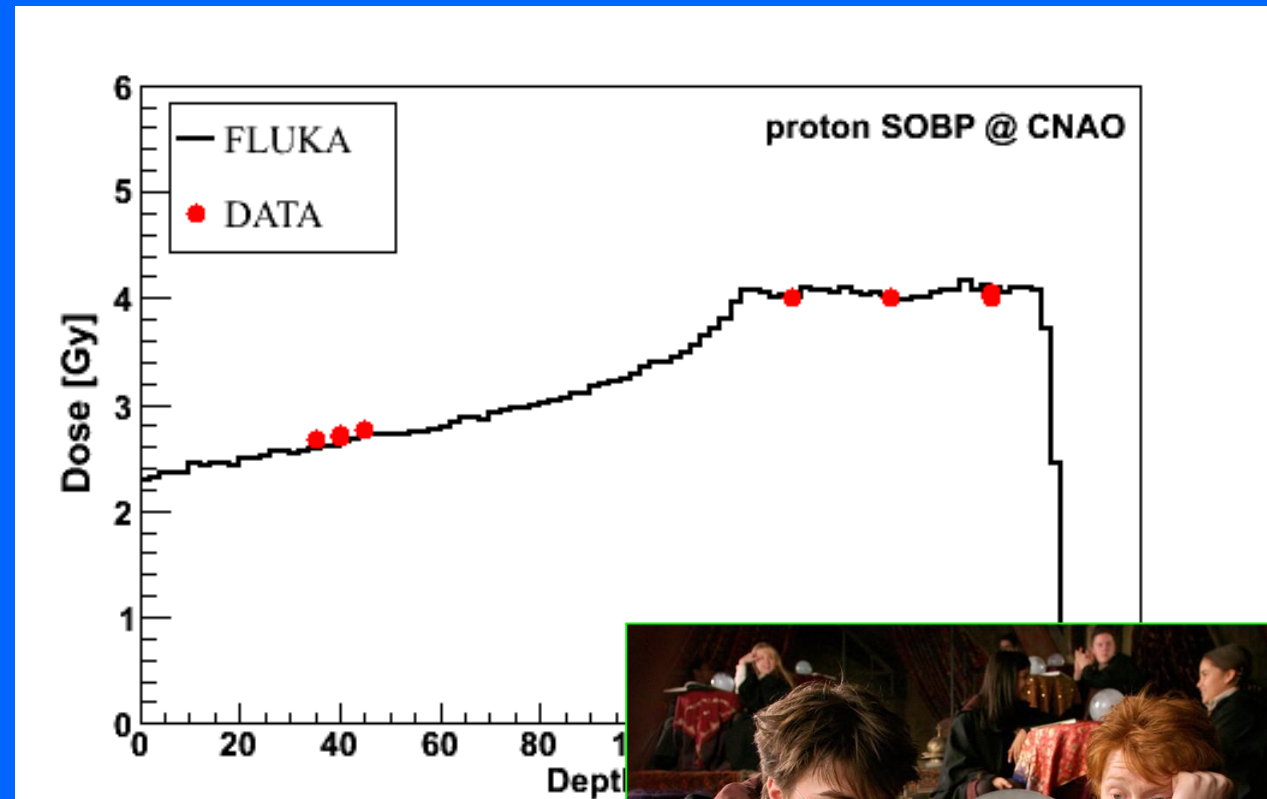
$|BP_{\text{sperim}} - BP_{\text{FLUKA}}| \leq 0.1 \text{ mm}$



Radiobiology: cell lines irradiations



Field $10 \times 10 \text{ cm}^2$,
33x33 spots,
scanning step 3 mm



In collaboration with INFN groups
(LNL, Mi, Na, Rm3, ISS - Coordinator:

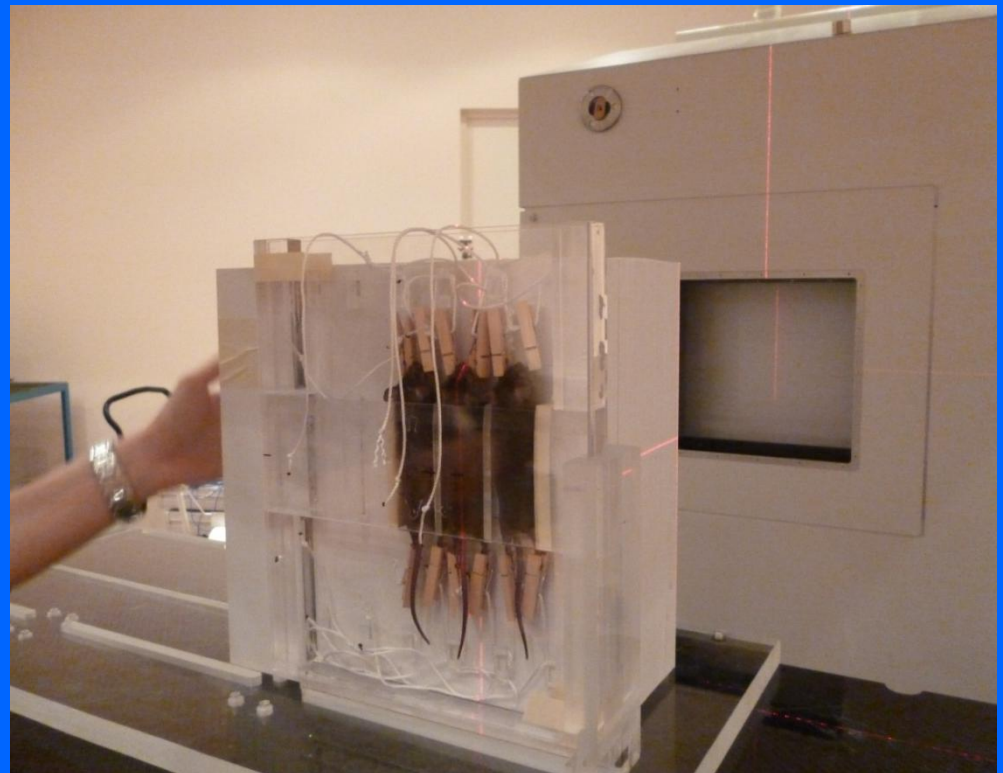
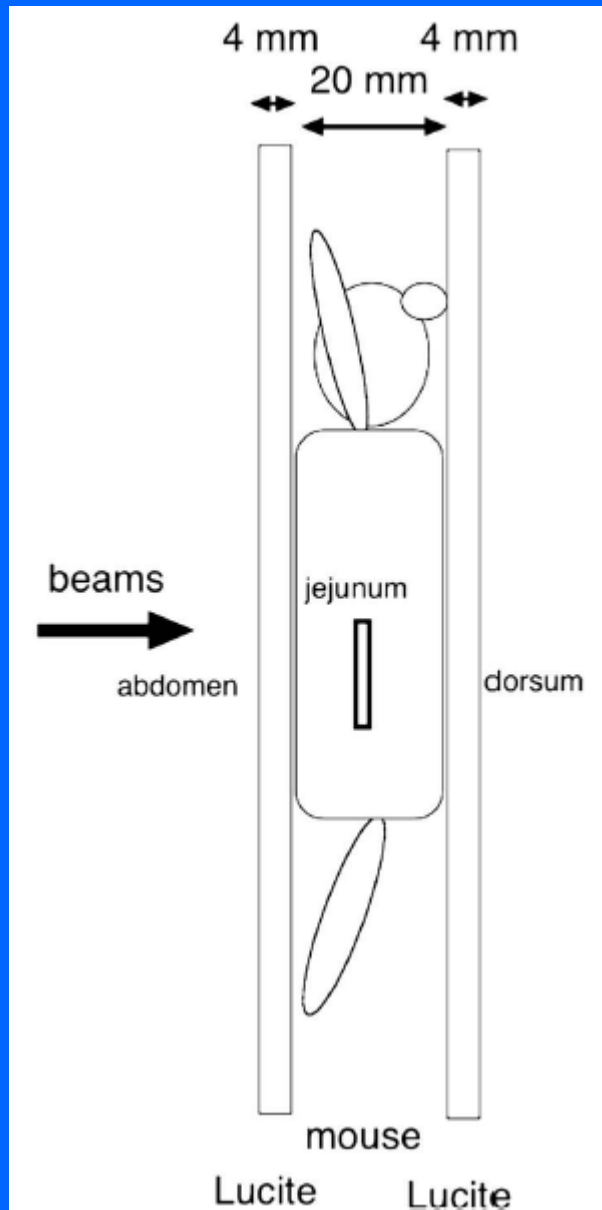


Still ongoing research topics in
collaboration with Uni, INFN, CNR of Pavia

In vivo experiments

Horizontal beam of carbon ions

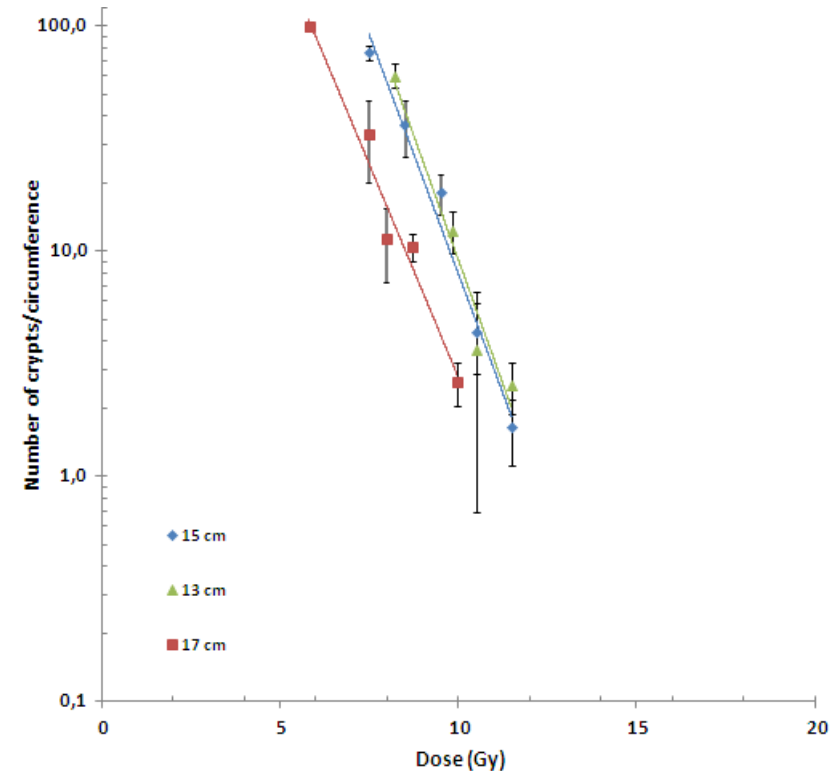
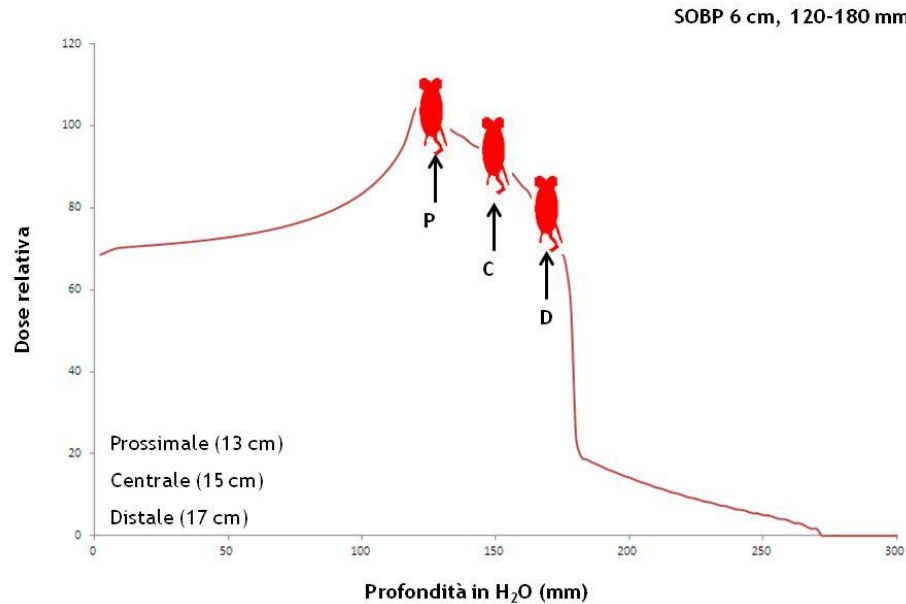
3 animals per field



In collaboration with NIRS and UniPv

Results

✓ Survival curves of cells crypts in 3 SOBP positions



Facility	Beam position	D ₁₀ (Gy)	Variance D ₁₀	RBE ₁₀	Variance (%)
Cobalt-60 γ rays	---	14.86±0.08(*)			
NIRS	Proximal	10.38 (+)		1.44 (*)	
	Middle	9.46(+)		1.57(*)	
	Distal	8.29(+)		1.80(*)	
GSI	Proximal	10.21(+)		1.47(*)	
	Middle	9.40(+)		1.63(*)	
	Distal	8.37(+)		1.80(*)	
CNAO	Proximal	9.85	5.1 % NIRS 3.5% GSI	1.51	4.7% NIRS 2.7 % GSI
	Middle	9.75	3.1% NIRS 3.7% GSI	1.52	3.18% NIRS 6.7% GSI
	Distal	8.5	2.5% NIRS 1.5% GSI	1.75	2.78% NIRS 2.78% GSI

Carb
iden
(diff



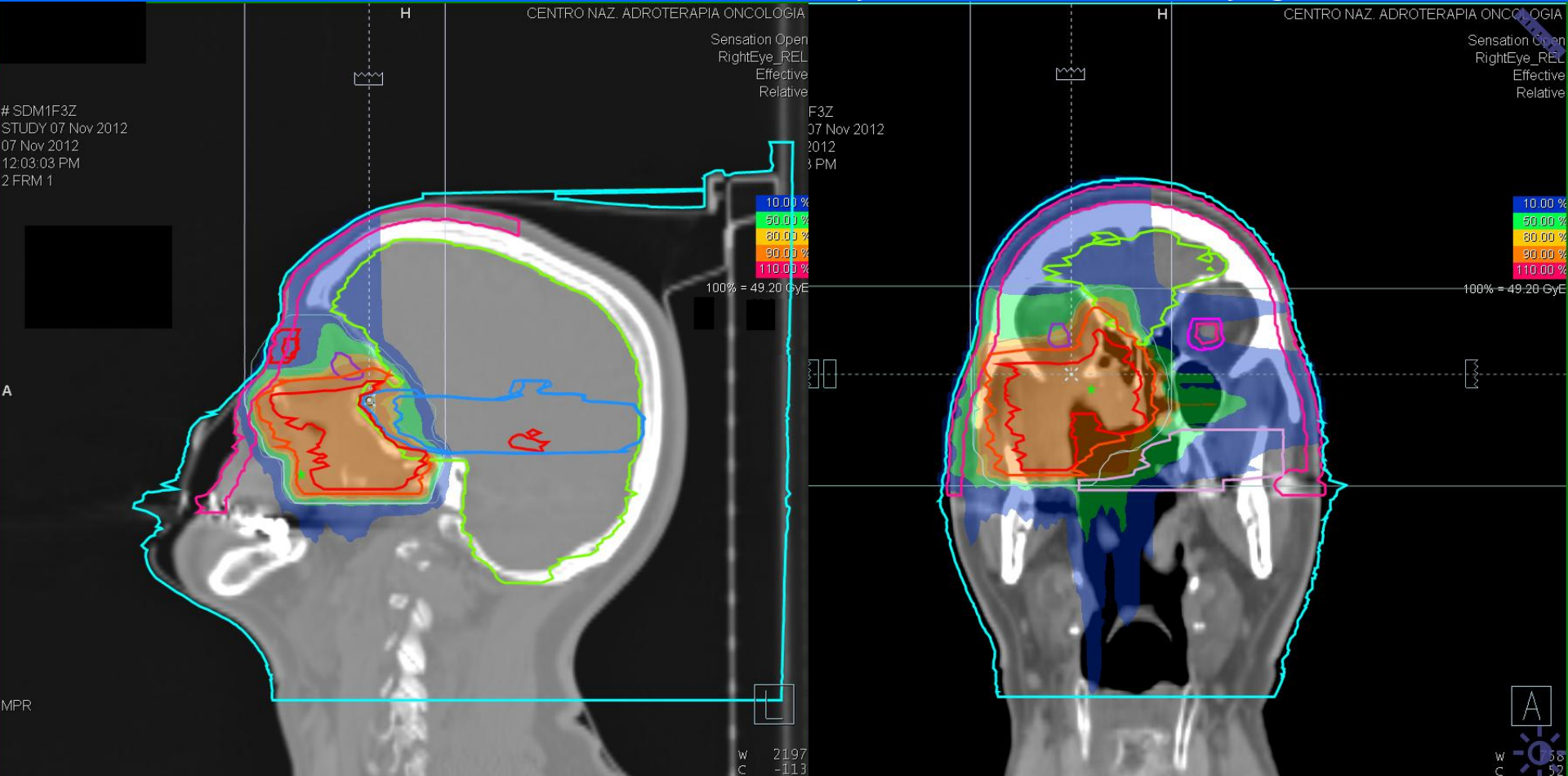
Still ongoing research topics in collaboration with Uni, INFN, CNR of Pavia

22 September 2011
First treatment session at CNAO with protons



13 November 2012: first patient treated with Carbon Ions

Local recurrence of adenoid cystic ca. salivary gland



- 12 fractions 4.1 GyE , 4 fractions per week, 49.2 GyE total dose. Boost of 4 fractions in case of good tolerance.
- 3 fields of IMPT

CE label!!!

CNAO is the only Ion-Centre with CE label, after clinical experimentation



Istituto Superiore di Sanità

Organismo Notificato n° 0373

Sez. presso il Dipartimento di Tecnologie e Salute

Notified Body n° 0373 - Unit relating to Department Technology and Health

Roma, 13 DIC 2013

VIALE REGINA ELENA, 299
00161 ROMA
TELEGRAMMI: ISTISAN ROMA
TELEFONO: 06 494904
TELEFAX: 06 49387118
http://www.iss.it

CERTIFICAZIONE CE

Secondo l'allegato III della Direttiva Europea 93/42/CEE e successive modifiche
Attuate con DLgs. 37 del 25.01.2010

EC CERTIFICATION

According to Annex III of Directive 93/42/EEC and subsequent modifications
Transposed by DLgs. 37 of 25.01.2010

Certificato n° 20131213 036 3303 CT
Certificato n°

L'Istituto Superiore di Sanità, Organismo Notificato n° 0373, certifica che il prodotto sotto menzionato soddisfa i requisiti essenziali di cui all'allegato I della Direttiva 93/42/CEE e successive modifiche verificati in accordo all'allegato III della stessa Direttiva.

The Italian National Institute of Health, as Notified Body n° 0373, certifies that the product hereinbelow described satisfies the essential requirements set out in Annex I and verified in compliance with Annex III of Directive 93/42/EEC and subsequent modifications.

Tipo e modello: Type and model:	Acceleratore per adroterapia Accelerator for hadrontherapy
Descrizione: Description:	[34469] ACCELERATORE DI PARTICELLE, RADIOTERAPIA [34469] PARTICLE ACCELERATOR, RADIOTHERAPY
Destinazione d'uso: Intended use:	Vedi allegato di 3 pagine See annex of 3 pages
Numero di serie: Serial number:	0001/2012
Fabbricante: Manufacturer:	Fondazione CNAO (Centro Nazionale Adroterapia Oncologica) Sede Legale: Via Caminadella, 16 - 20133 Milano Sede Operativa: Strada Campeggi, 53 - 27100 Pavia

Rapporto di conformità n° Conformity report n°	2013 003 33 003	del of	13/12/2013 dd/mm/yyyy
Il presente certificato è valido dal This certificate is valid from	13/12/2013 dd/mm/yyyy	al until	08/07/2018 dd/mm/yyyy

Il Direttore del Dipartimento Tecnologie e Salute F.F.
The Acting Director of Department Technology and Health
(Ing. Pietro Bartolini)

fondazione CNAO

Centro Nazionale di Adroterapia Oncologica



Fondazione CNAO
Via Caminadella 16
20123 MILANO
ITALIA

Sede operativa:
Strada Campeggi 53
27100 PAVIA
ITALIA
Tel. +39 0382 078608



0373

ACCELERATORE PER ADROTERAPIA

SN 0001/2012



From 2014 on ... the running phase

The treatments will be performed in the frame of the National Health System

Progressively increase the number of patients to reach in 2017 about 1000 patients per year

A network is set up to connect CNAO with national and international hospitals to efficiently recruit patients

Research activities are of paramount importance for CNAO. A dedicated room is in preparation



direzionemedica@cnao.it

serviziomedico@cnao.it



Tel 0382 078963



CNAO Protocols



Virtual consultation



medical consultation



<http://folder.cnao.it>

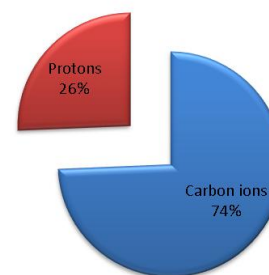
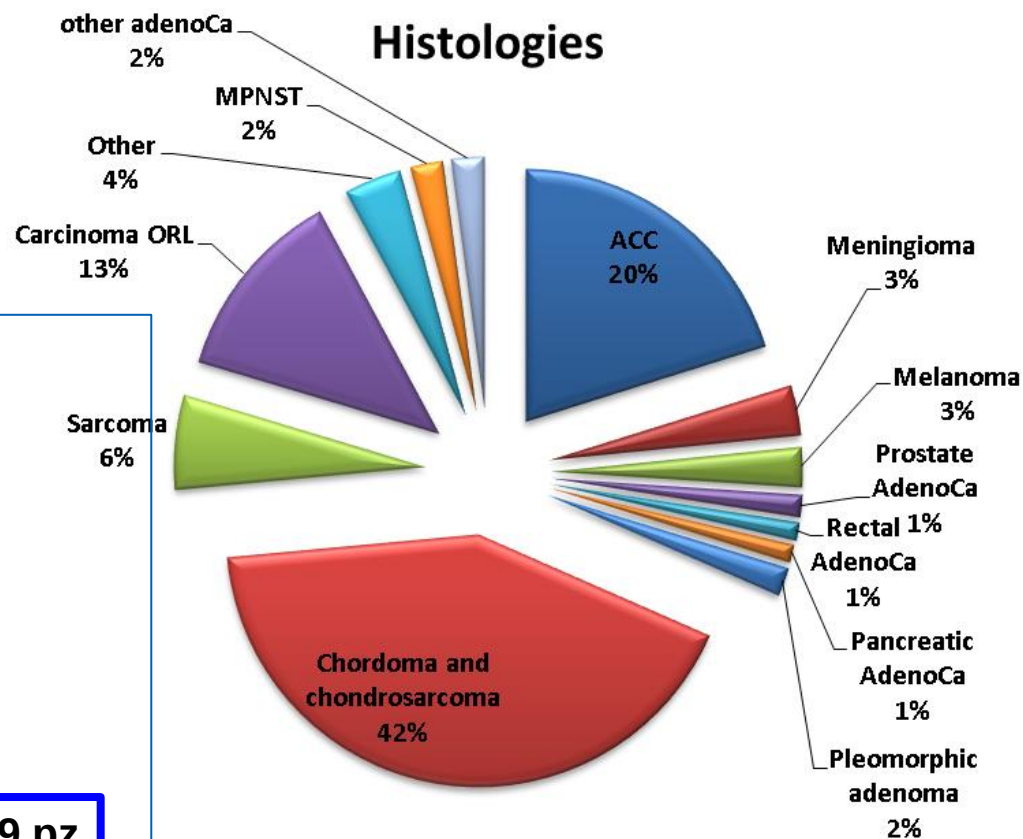


Clinical Activity :

30 Phase II Trials

- Skull base chordoma and chondrosarcoma
- Spinal and sacral chordoma and chondrosarcoma
- Intracranial Meningioma
- Boost for locally advanced head and neck cancer
- Salivary gland tumors
- Spine and H&N bone and soft tissue sarcoma
- Mucosal melanoma
- Recurrent pleomorphic adenoma
- Reirradiation of head and neck tumors
- Orbital tumor
- High risk prostate cancer
- Locally advanced pancreatic cancer
- Reirradiation of local recurrence rectal cancer
- Hepatocarcinoma
- Hodgkin Lymphoma stage I -II

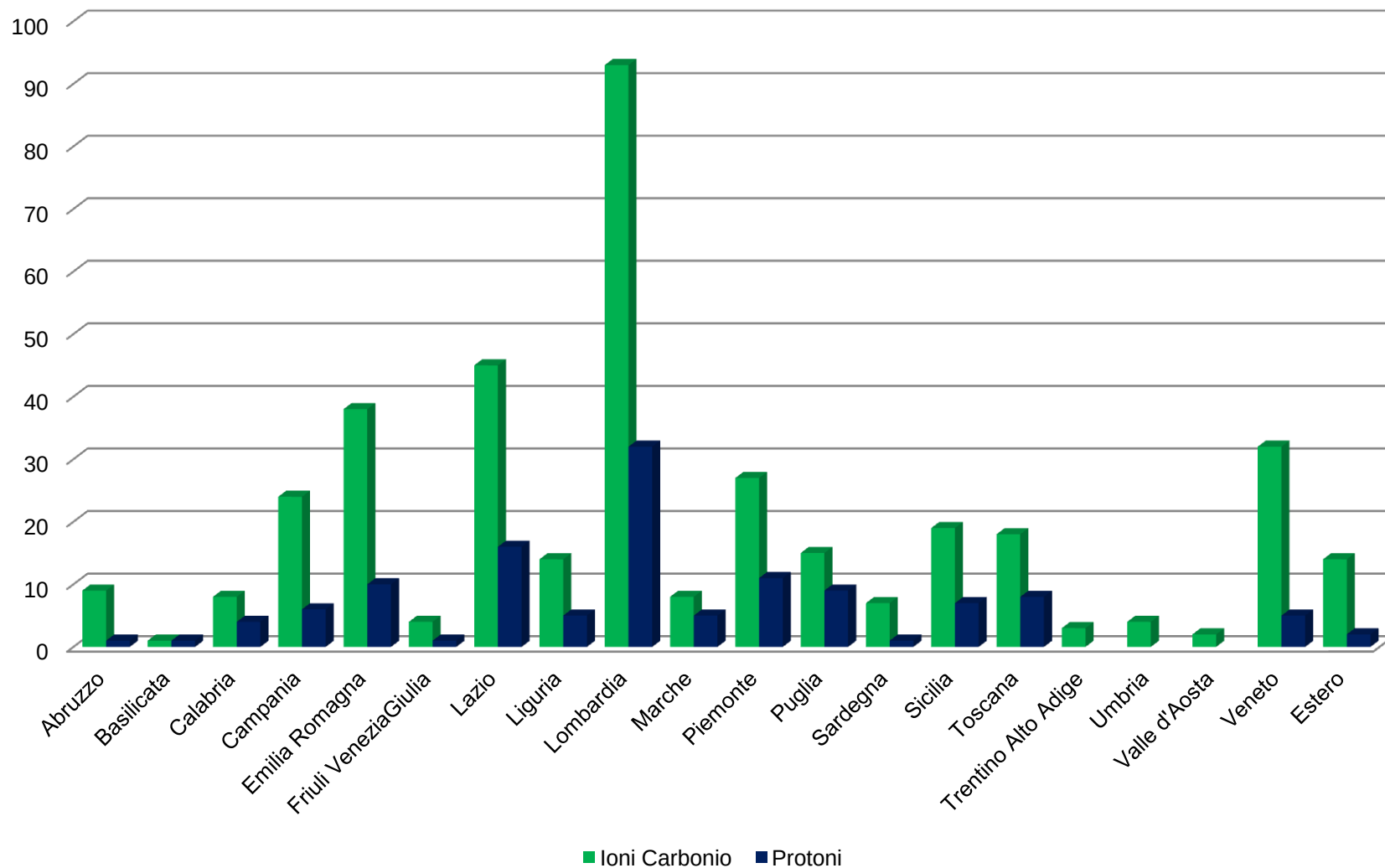
509 pz



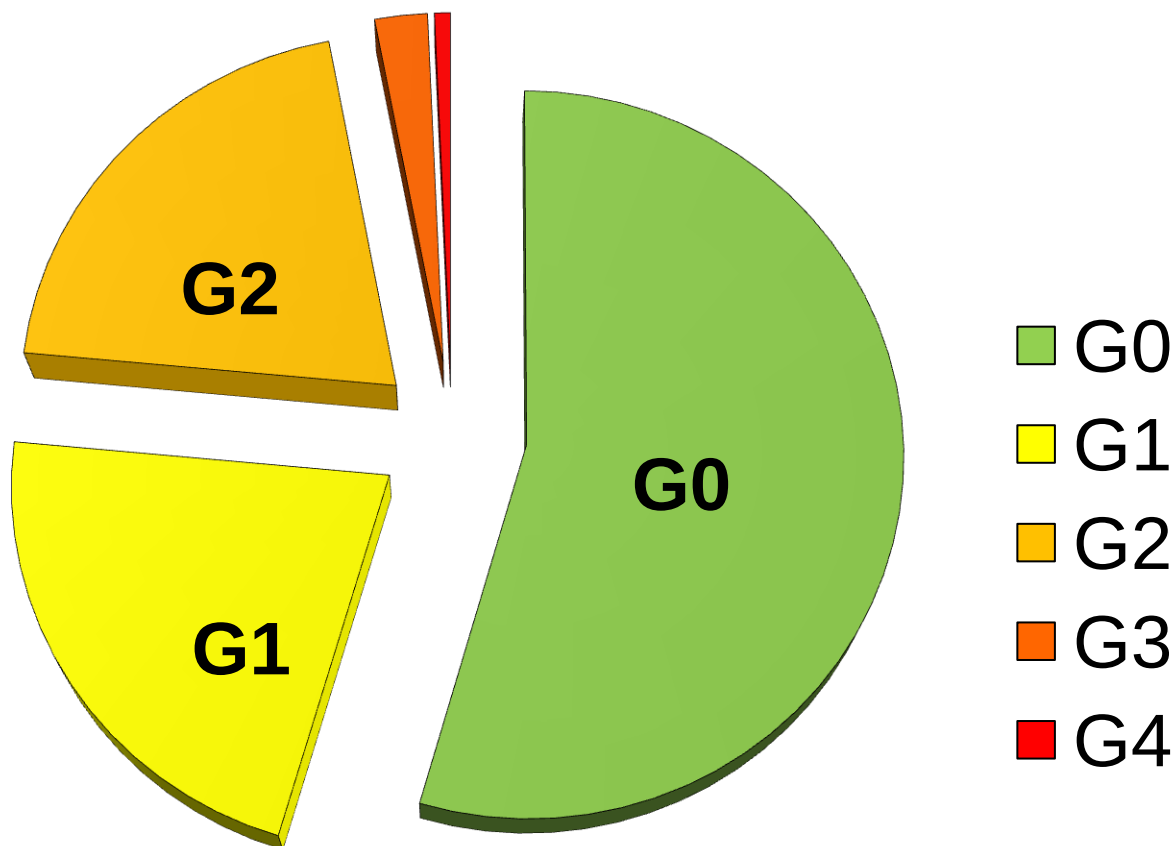
Geographical distribution of patients

22/09/ 2011 - 10/04/2015

Total number of patients 509 (of wich: 133 included in clinical trial + 358 post clinical trial + 19 out of clinical trial)

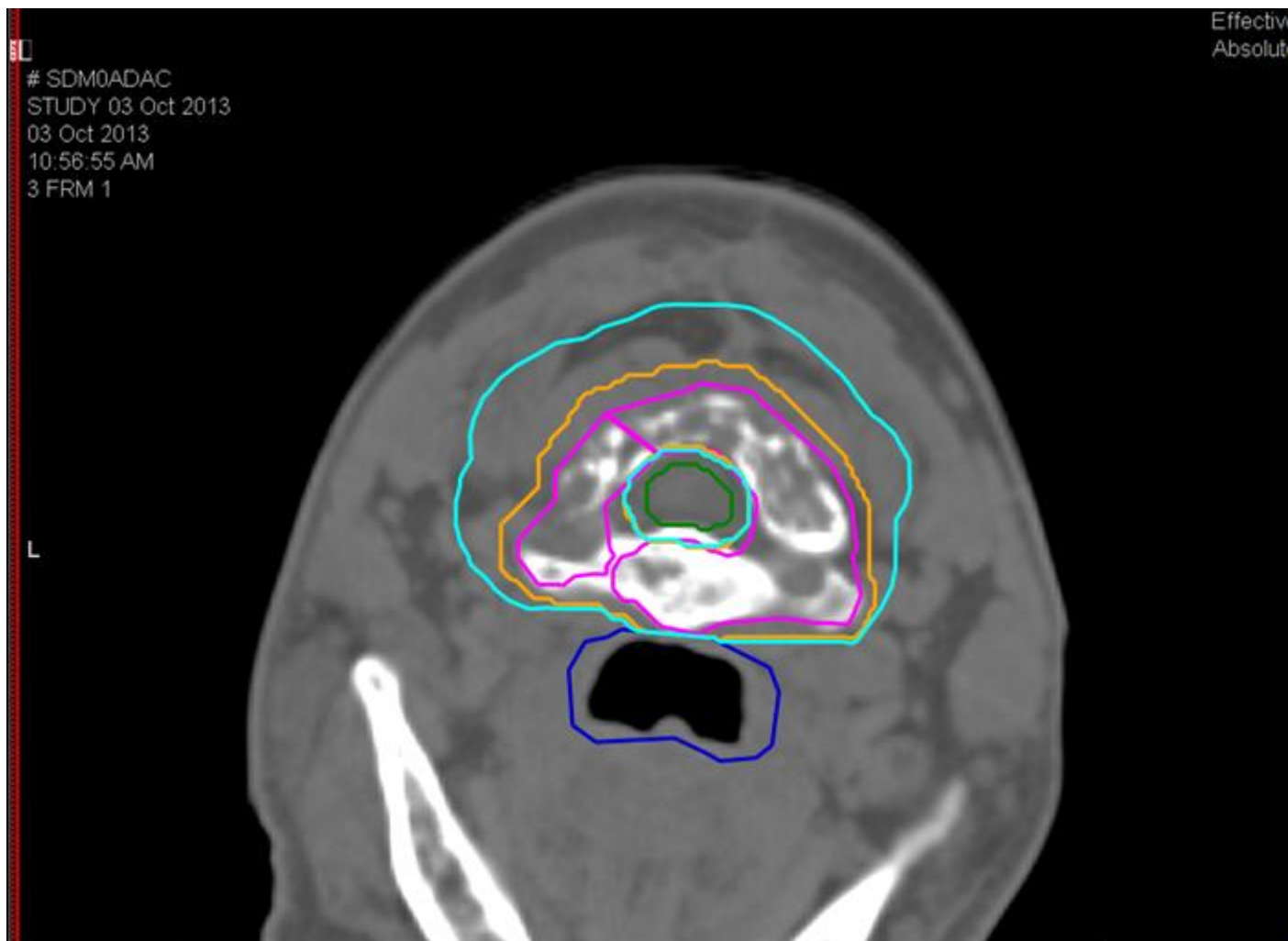


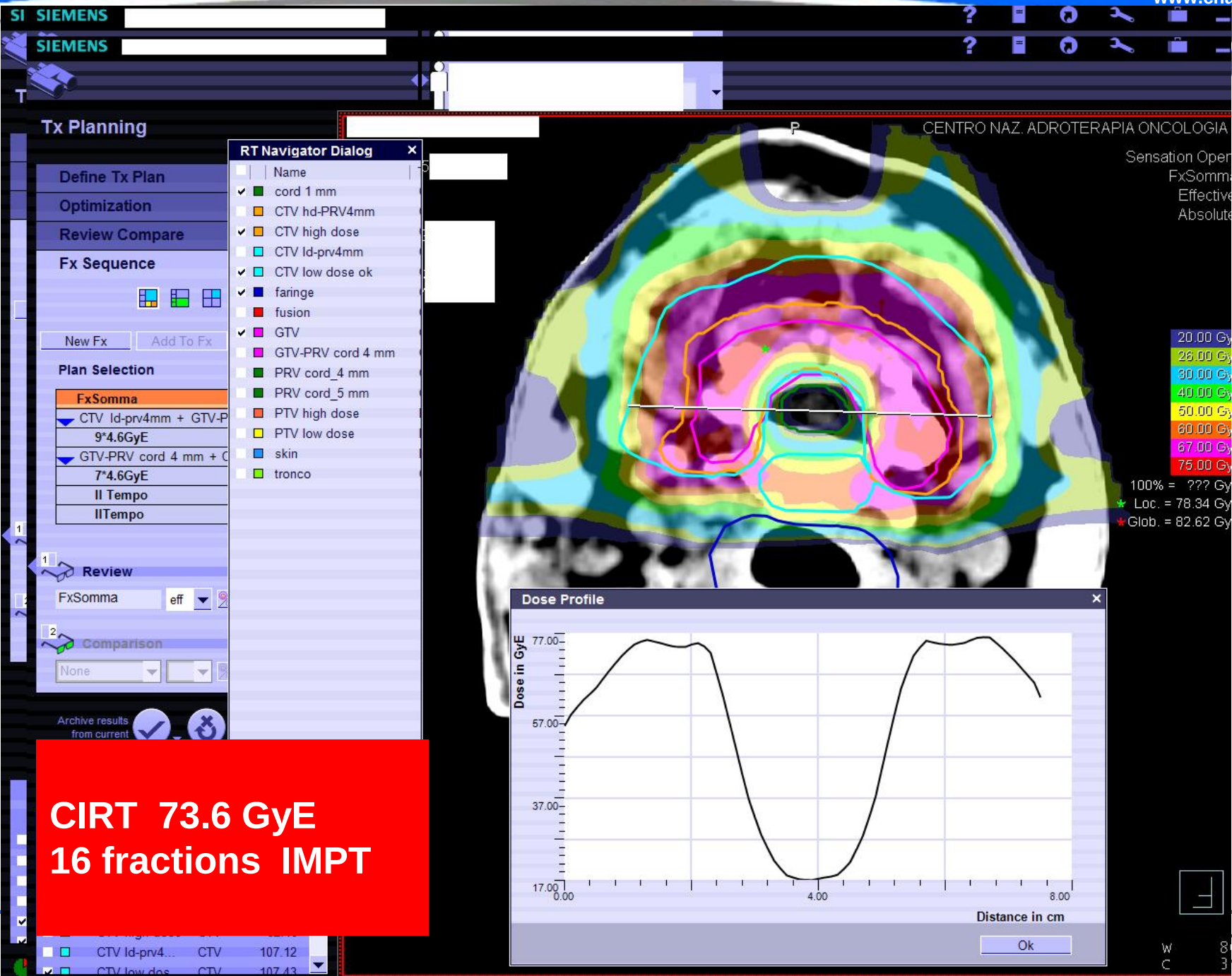
Acute toxicity (CTCAE criteria)



Very good results: G3+G4 less than 4% !

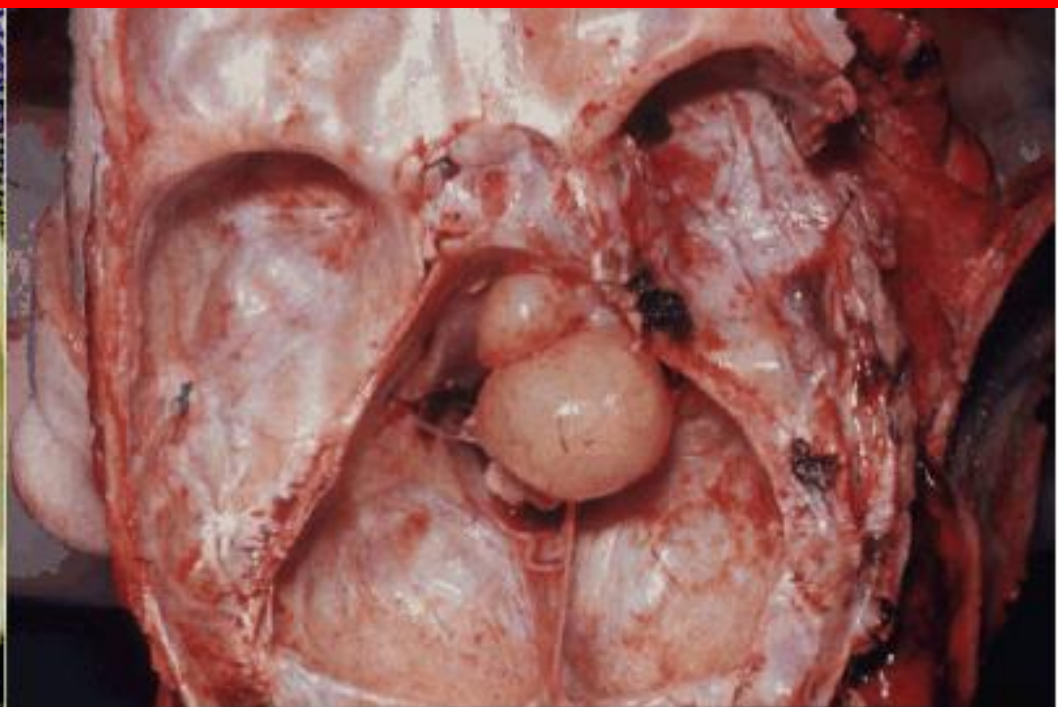
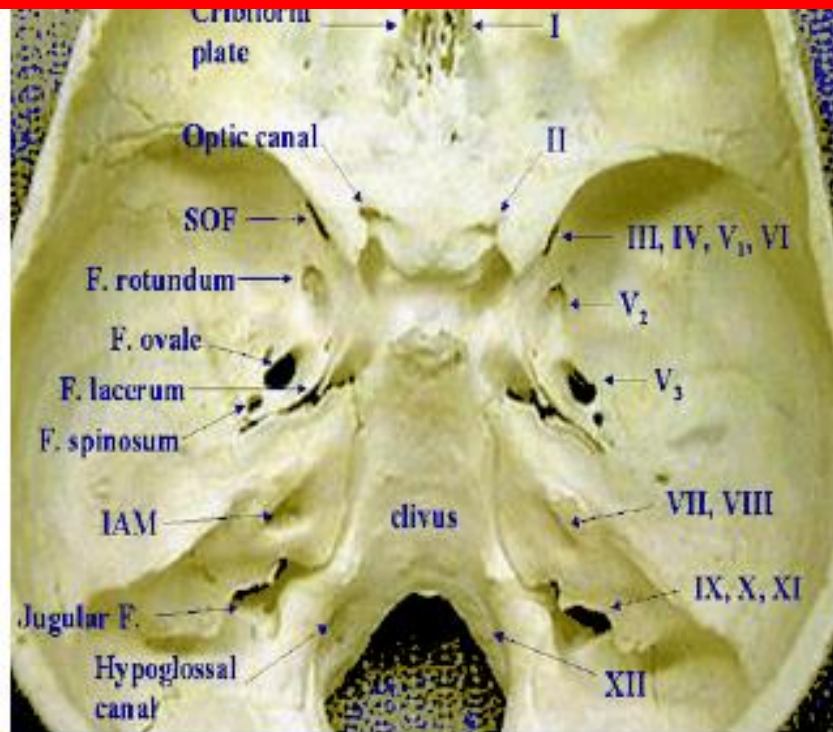
low-grade osteosarcoma of cervical vertebrae, C1-C2 56 years old male



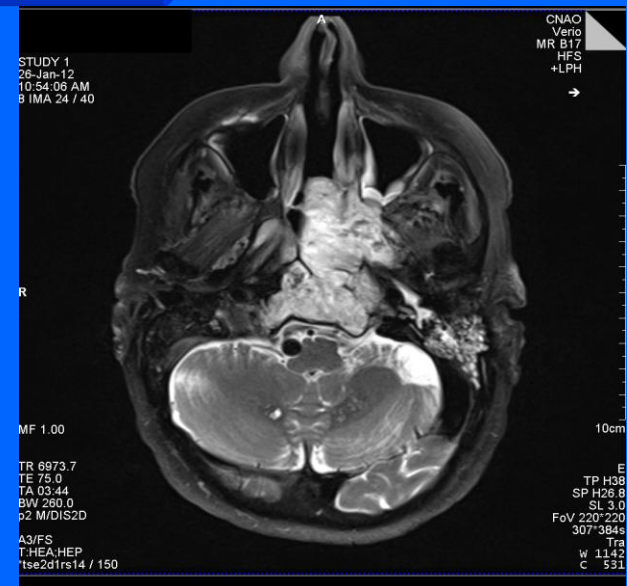


Clinical efficacy

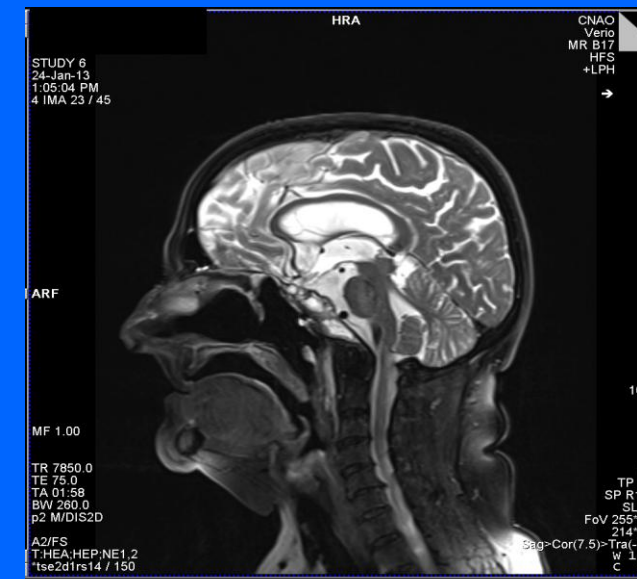
Protons. Local control at 5 years
Chordoma more than 80%
Chondrosarcoma about 98%



SKULL BASE CHORDOMA: Proton therapy



10 months F-UP

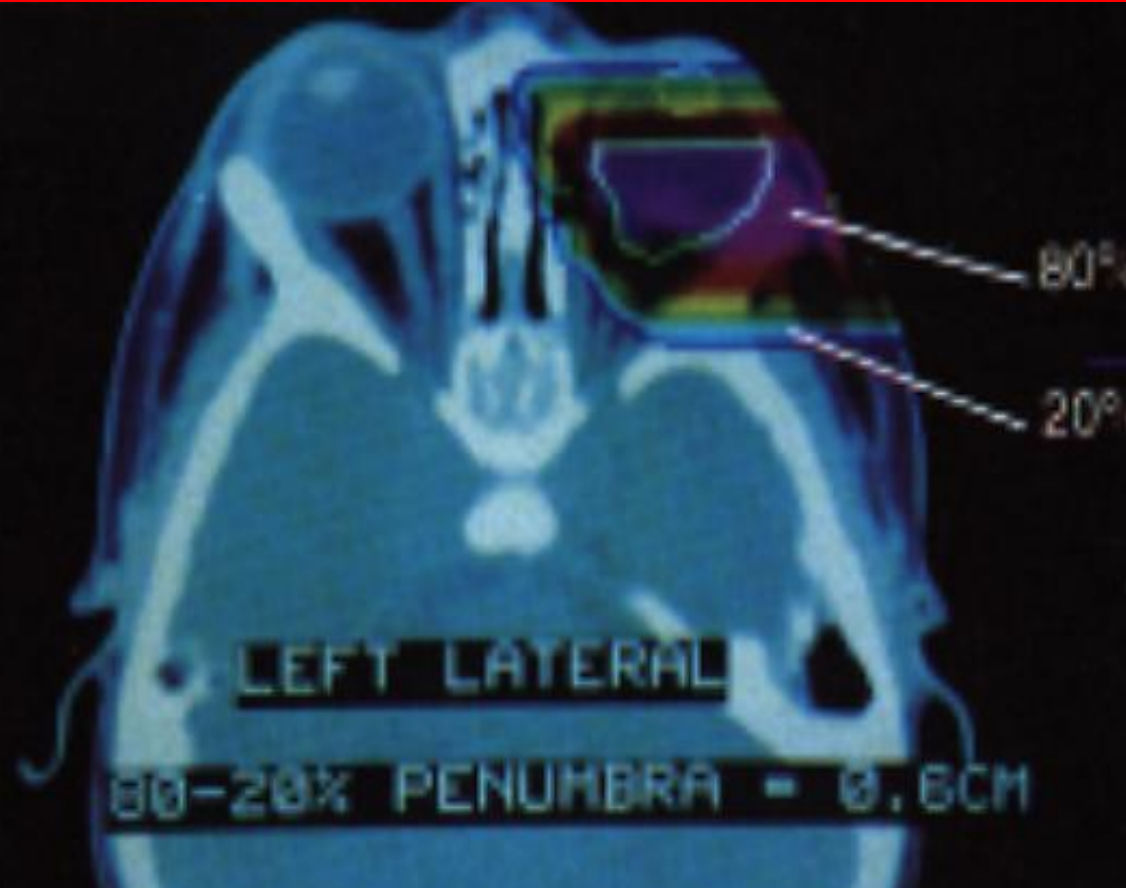


Clinical efficacy

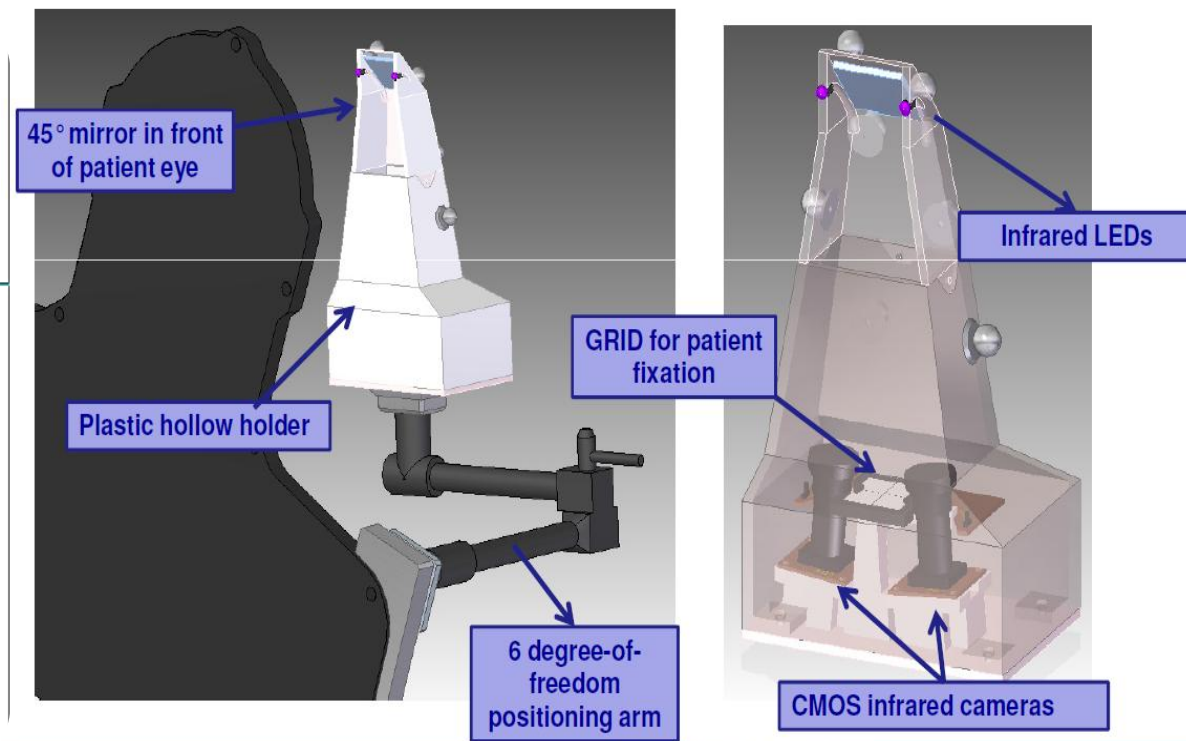
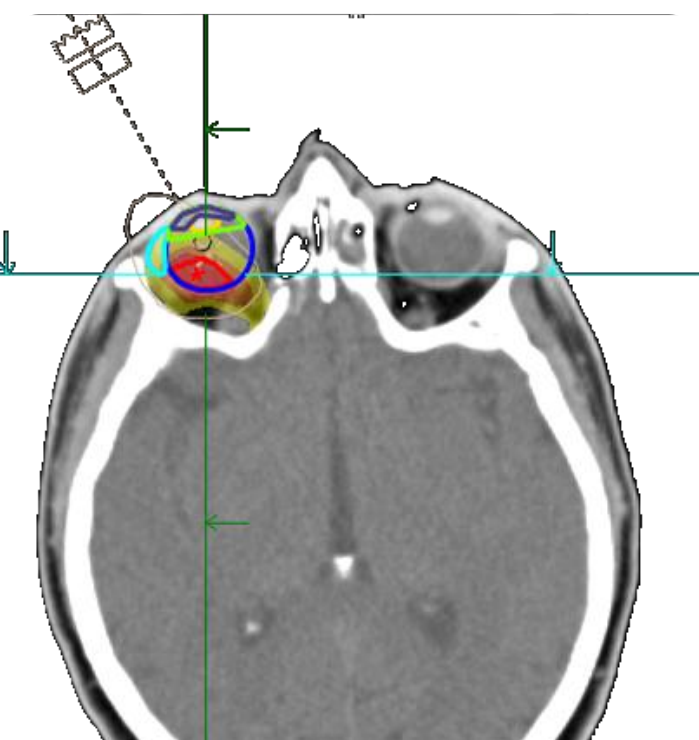
Protons. Ocular melanoma

Local control at 5 years more than 95%

- Eye preservation
> 90%
- Vision acuity
> 45%



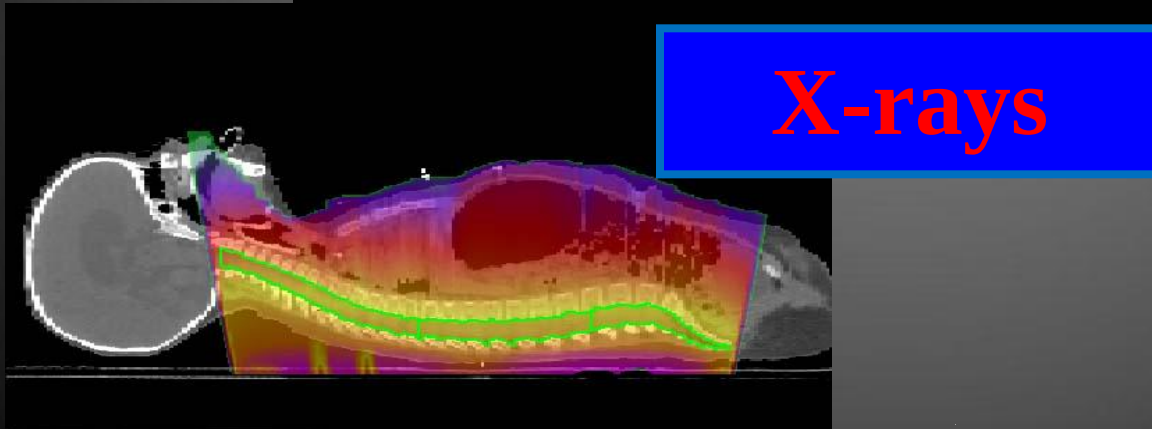
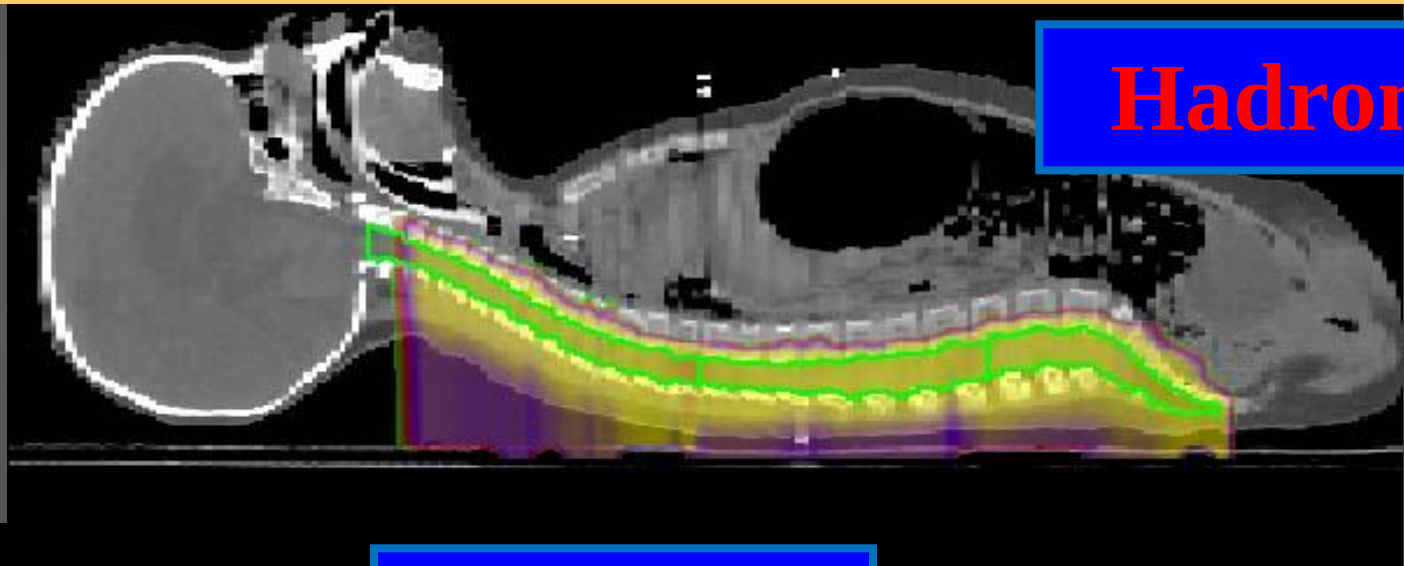
Non invasive eye tracking system for intraocular tumor localization in proton therapy treatment



POLITECNICO DI MILANO

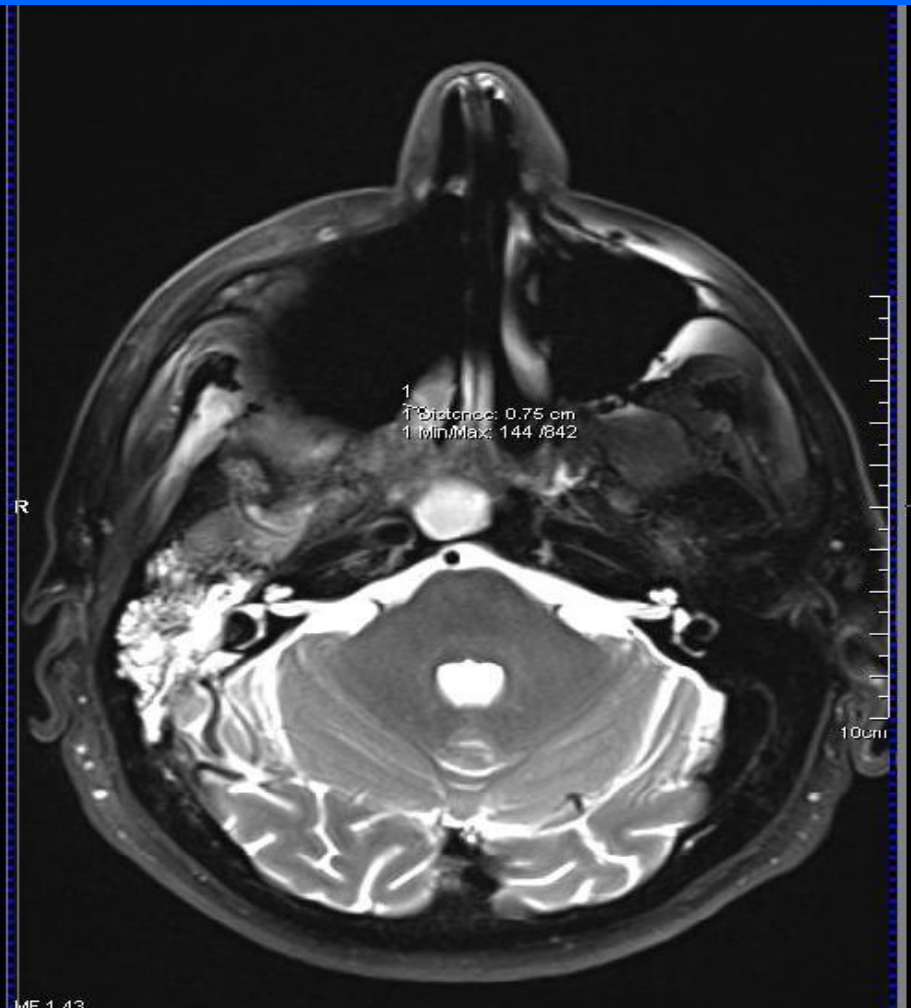
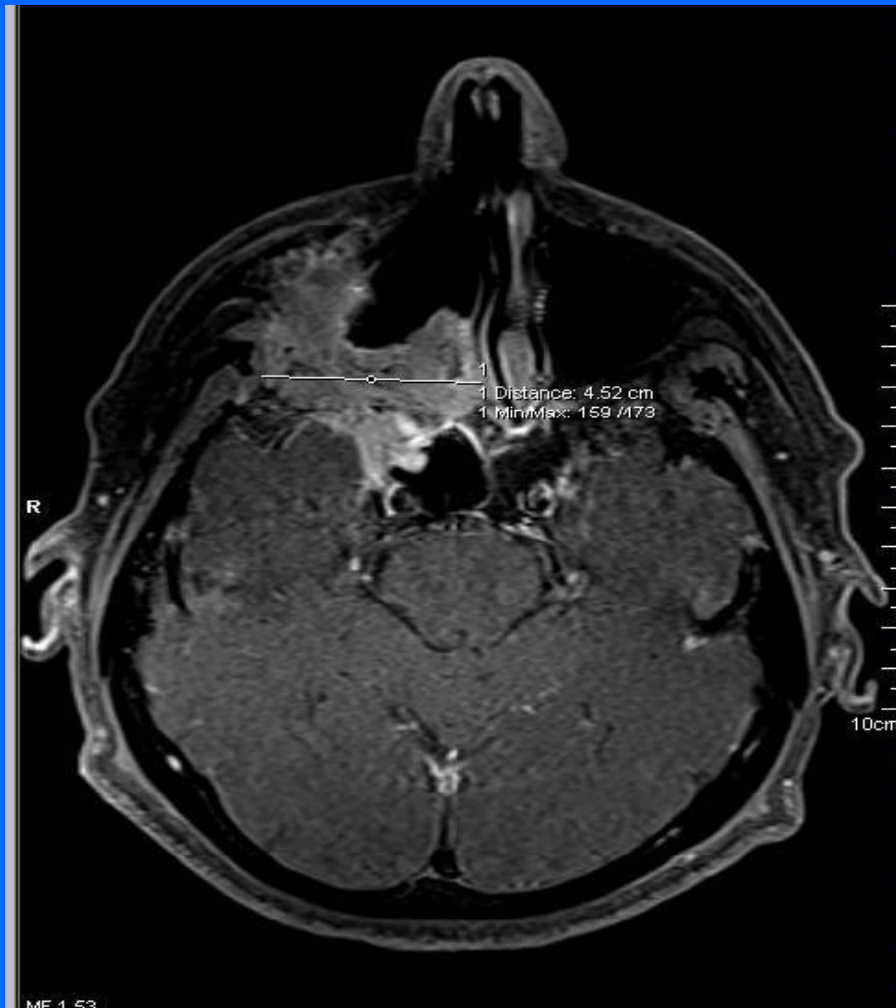
In collaboration with INFN and UniPv

Toxicity reduction (spine irradiation)



Relapsed ACC in right pterygopalatine fossa post Surgery and RT (60 Gy)

***6 Nov 2012 >> Re-irradiation with Carbon RT >> 12 march 2013
65.6 Gy(RBE) - 4.1 Gy(RBE)/fx, 16 fx (3 months after CIRT)
performed in CNAO. 13/11-06/12/12***

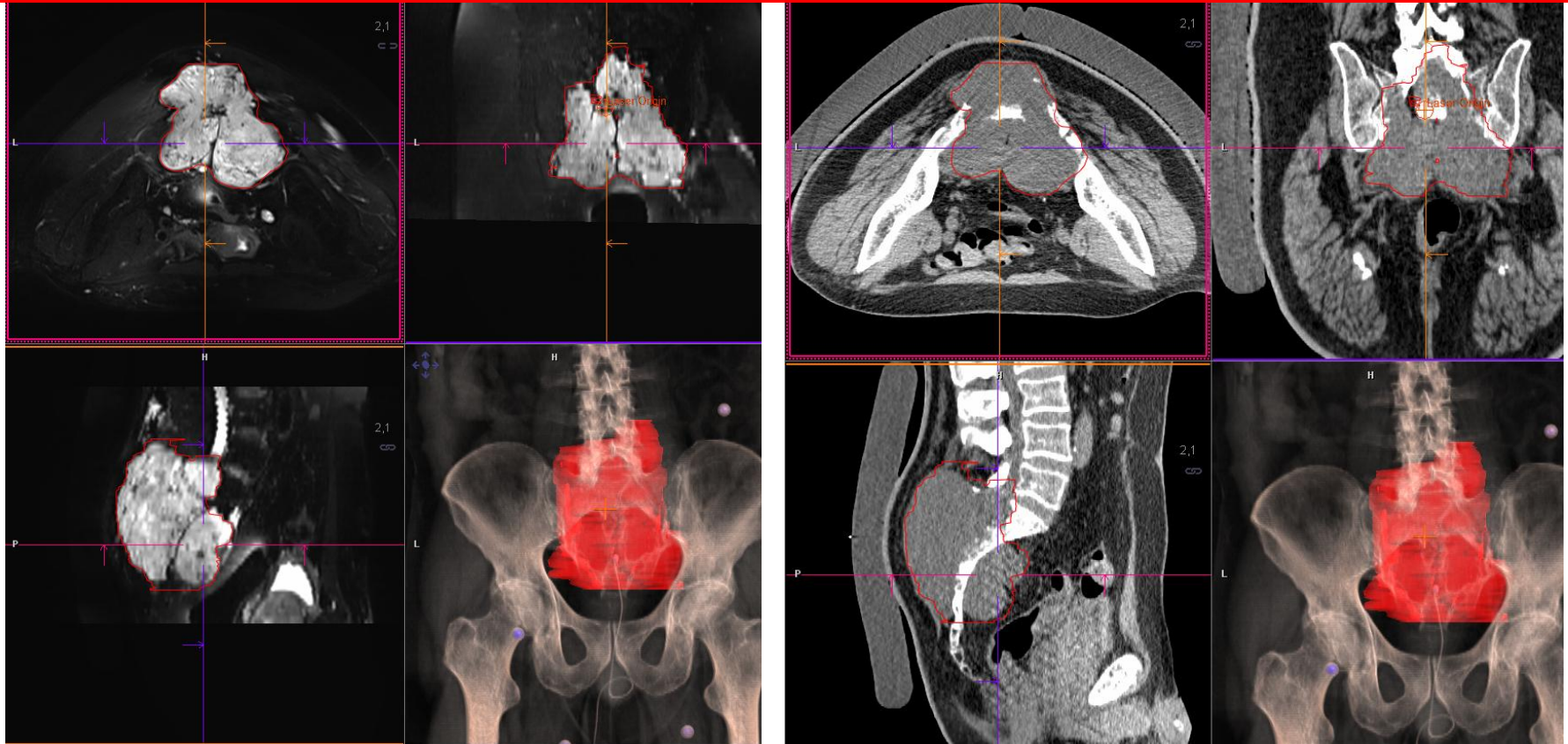


Skin Toxicity (not more than G2)



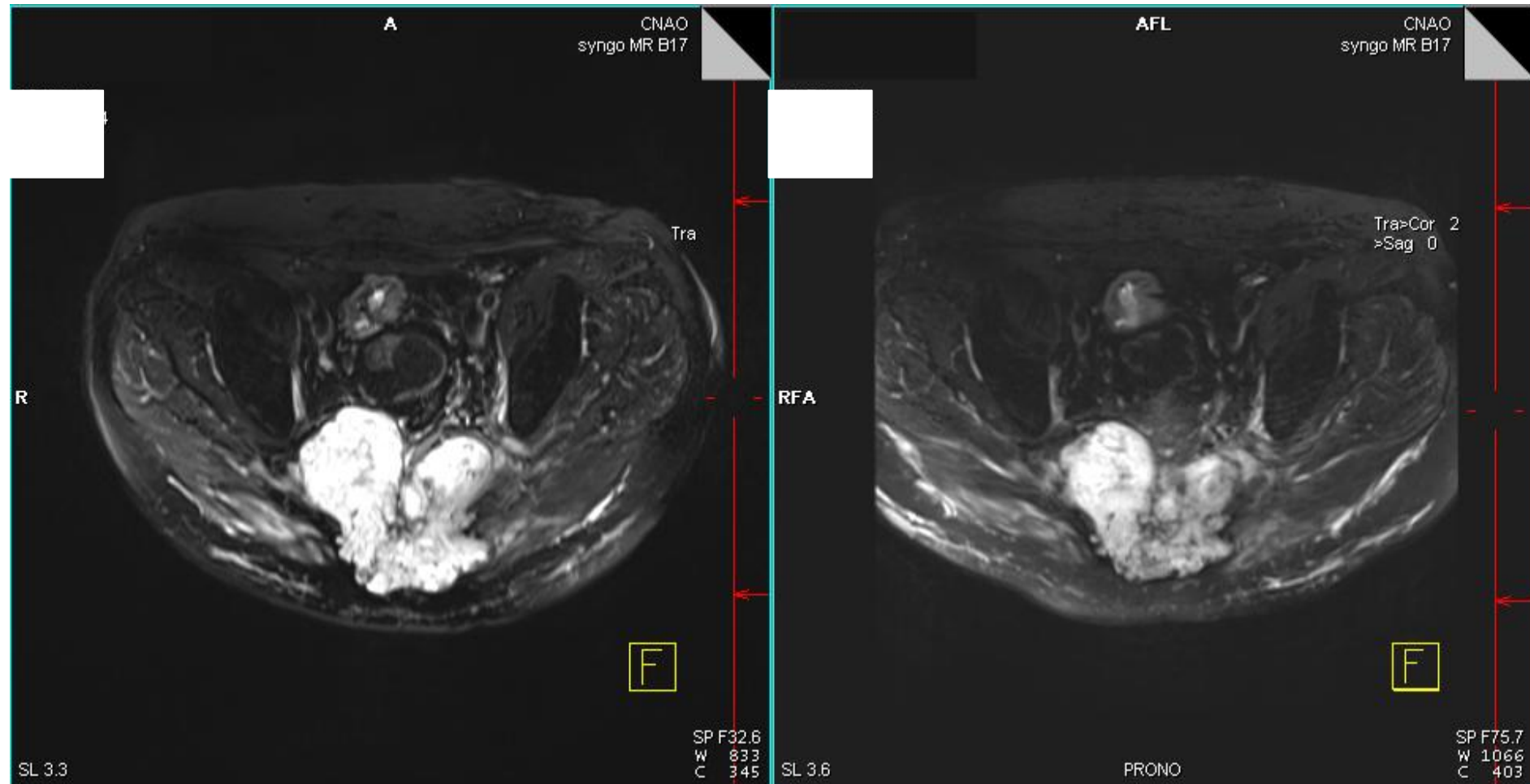
Carbon. Chordoma of the sacrum

Local control at 5 years: 85%



Diagnosis

1 year after treatment



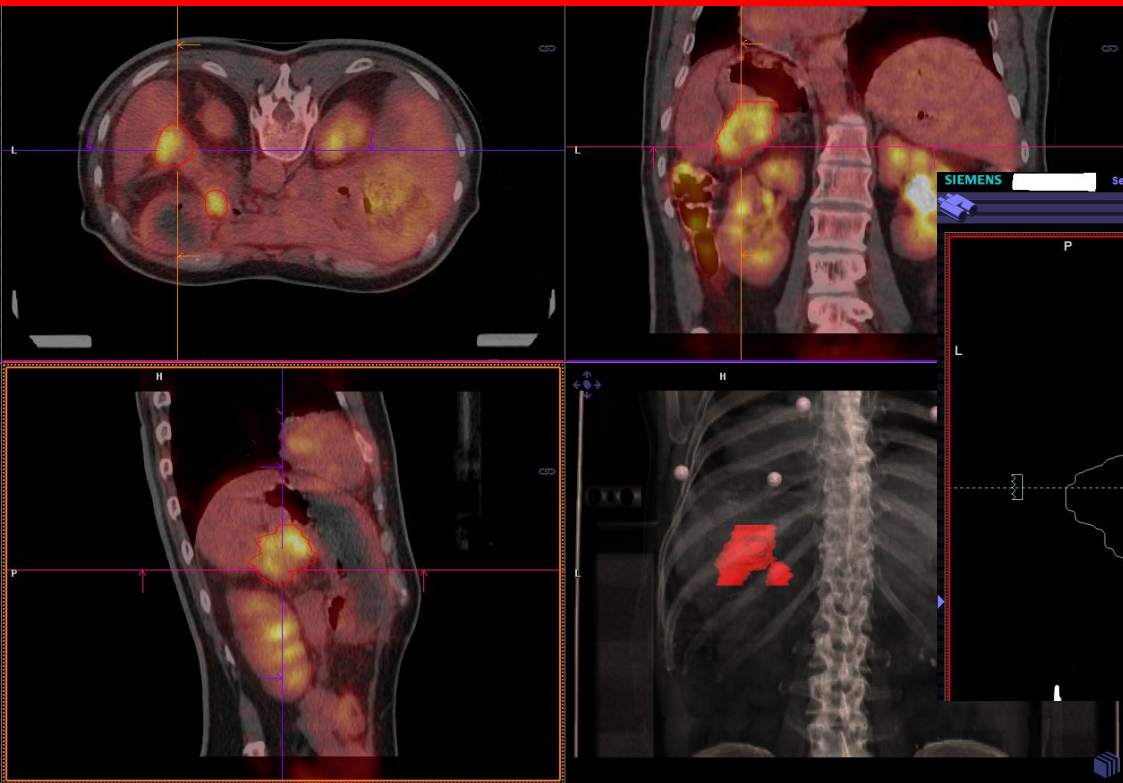
Carbon. Clinical case at CNAO

Clinical Efficacy

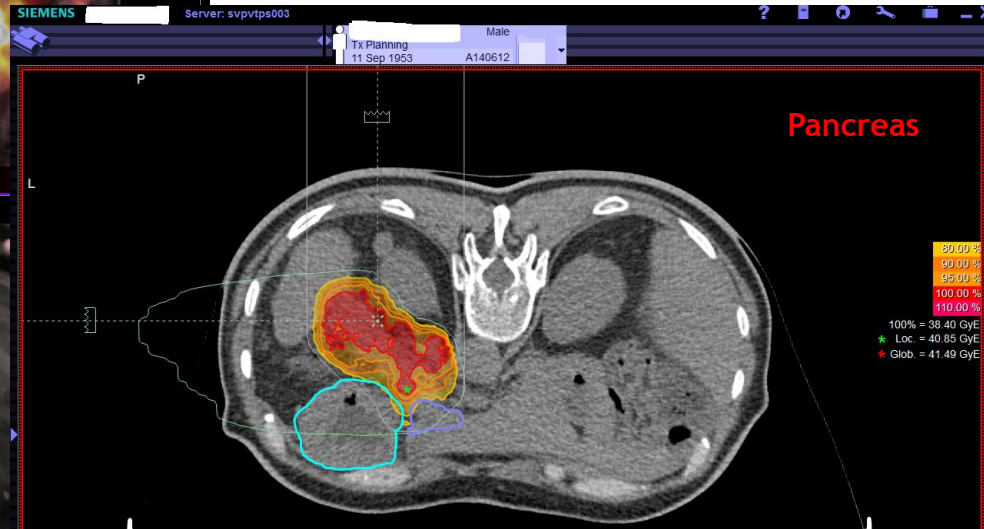
Carbon. Pacreatic carcinoma

Survival at 2 years: 50%

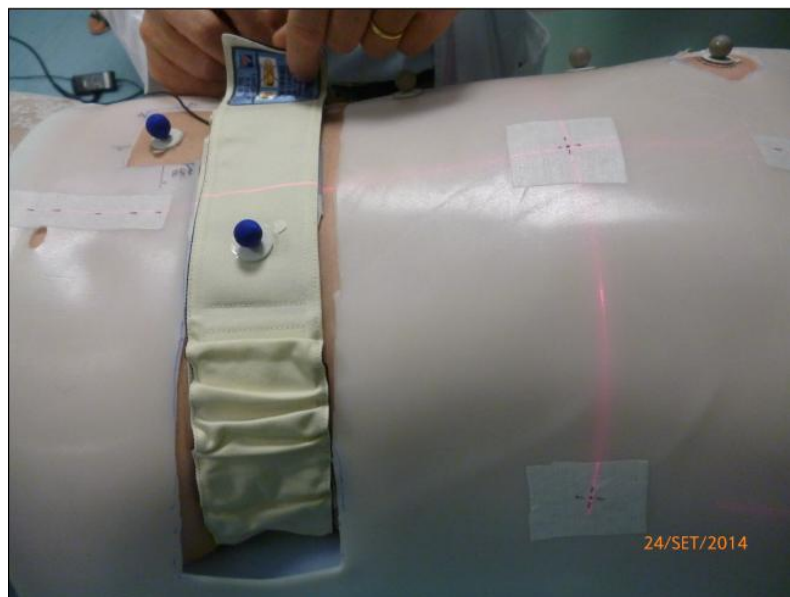
Median survival double wrt best standard RTOG/USA



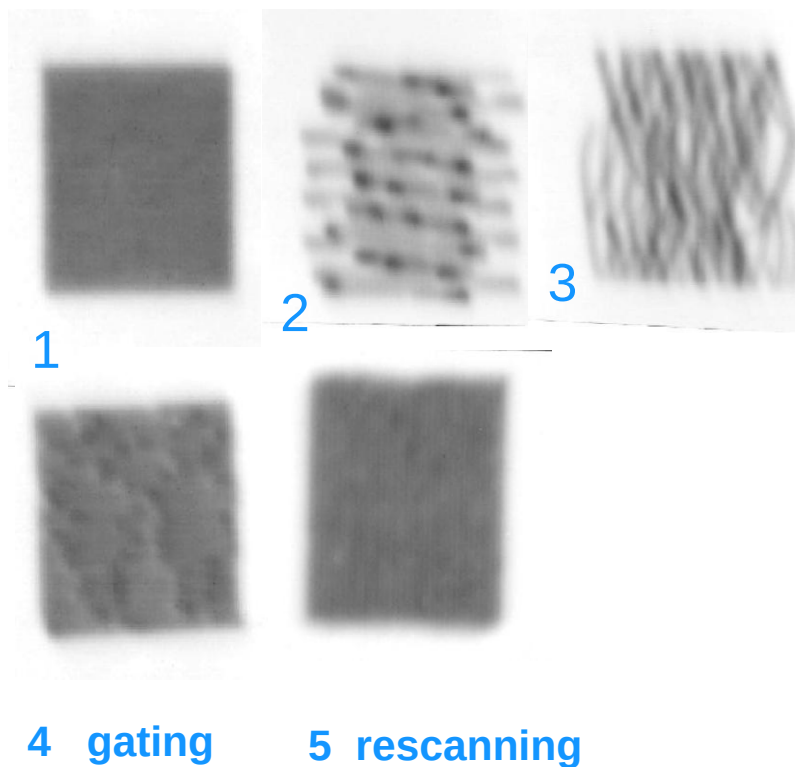
NCI sponsored study



Moving organs: 4-D treatment strategies at CNAO



- **Reducing respiratory motion** (less than 5 mm) using thermo-plastic mask or compression band
- **Multiple fields** (2-3) and fractionated treatment
- **Gating** (ref. Phase: max expiratory; **Anzai system and OTS**) + rescanning (N = 5)





CLINICAL RESEARCH

Protons Hypofractionated dose

Phase III: Carbon Ions vs conventional RT (ACC and sarcomas)

Melanoma of the rectum and vagina

Advanced lung cancer

Paediatric patients

Phase III study: Carbon ions vs RT / CT in locally advanced pancreatic

Formation an important issue

SECOND LEVEL INTERNATIONAL MASTER IN HADRONTHERAPY



**Hadrontherapy:
physics, biology,
medicine and
technology**

Organized by the University of Pavia with the State University of Milan and Milan Bicocca, in collaboration with CERN, CNAO and INFN.

Applicants are expected to have obtained a Diploma at the end of a five-year Course in: Physics, Biology, Biotechnology, Medicine and Engineering.

The Course will be held over a twelve-month period. Those taking the Course are expected to attend full-time. Lectures will be given in English.

Applications must be made no later than the **25th of November 2011**.

Teaching will commence in January 2012. Eight Scholarships will be awarded on the basis of merit.

Director: Prof. Michele Livan
Dipartimento di Fisica Nucleare e Teorica
Università di Pavia | Via Bassi 6 - 27100 Pavia, Italy
michele.livan@unipv.it



Information: <http://www.pv.infn.it/imh> • mail: imh@pv.infn.it

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UNIVERSITÀ
DEGLI STUDI
DI MILANO



In collaboration with



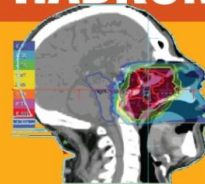
Fondazione CNAO



Funded by



SECOND LEVEL INTERNATIONAL MASTER IN HADRONTHERAPY



**Hadrontherapy:
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The Course will be held over a twelve-month period. Those taking the Course are expected to attend full-time. Lectures will be given in English.

Applications must be made no later than the **14th of September 2012**.

Teaching will commence in November 2012. Eight Scholarships will be awarded on the basis of merit.

Director: Prof. Michele Livan
Dipartimento di Fisica
Università di Pavia | Via Bassi 6 - 27100 Pavia, Italy
michele.livan@unipv.it



Information: <http://www.pv.infn.it/imh> • mail: imh@pv.infn.it

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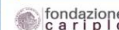
In collaboration with



Fondazione CNAO



Funded by



Communication ... another one

www.cnao.it

CNAO

fondazione **CNAO**
Centro Nazionale di Adroterapia Oncologica per il trattamento dei tumori



CERCA



CHI SIAMO CONTATTI EVENTI COME RAGGIUNGERCI SOSTENITORI



sostienici

AREA PAZIENTI



AVEVAMO UN SOGNO... L'ABBIAMO REALIZZATO.



LA SPERIMENTAZIONE CLINICA



L'ADROTERAPIA



MATERIALE INFORMATIVO



IL SINCROTRONE

Fondazione CNAO
Strada Campeggi, 53
27100 - Pavia

tel: 03820781
email: info@cnao.it



RASSEGNA STAMPA

Kicking Cancer With Carbon Ions

Master al Cnao per formare chi cura i tumori

Meno pazienti da fuori regione Dea e Cnao carte per il rilancio

Il primo paziente al Cnao Partita la sperimentazione

Protonterapia, purtroppo avremo molti clienti
Oncologia e adroterapia

LAVORA CON NOI

Al momento non ci sono posizioni aperte

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LINKS

Cern | European Organization for Nuclear Research

InfN | Istituto Nazionale di Fisica Nucleare

NIRS | National Institute Of Radiological Sciences

ULice | Union of Light Ion Centres in Europe

Partner | Particle Training Network for European Radiotherapy

NEWS

Inizio attività clinica

Il Ministro della Salute Fazio autorizza nuovo trattamento per tumori a base di protoni

Sistema Sanitario  Regione Lombardia


Ministero della Salute

Acknowledgments 1



Today at CNAO 115 persons

Acknowledgments 2

The Technical-Scientific Collaborations

NATIONAL

TERA Foundation: final design and high tech specifications

INFN: co-direction HT, technical issues, radiobiology, research, formation

University of Milan: medical coordination and formation

University of Pavia: technical issues, radiobiology, formation

University of Catania: medical physics

University of Florence: medical physics

University of Turin: interface beam-patient, TPS

Polytechnic of Milan: patient positioning, radioprotection, authorisations

European Institute of Oncology: medical activities, authorisations

San Matteo Foundation: medical activities, logistics

Town of Pavia: land and authorisations

Province of Pavia: logistics and authorisation

Acknowledgments 3

The Technical-Scientific Collaborations

INTERNATIONAL

CERN (Geneva): technical issues, PIMMS heritage

GSI (Darmstadt): linac and special components

LPSC (Grenoble): optics, betatron, low-level RF, control system

Med-Austron (Vienna): technical collaboration for MA centre

Roffo Institute (Buenos Aires): medical and research activities

NIRS (Chiba): medical activities, radiobiology, formation

HIT (Heidelberg): research activities



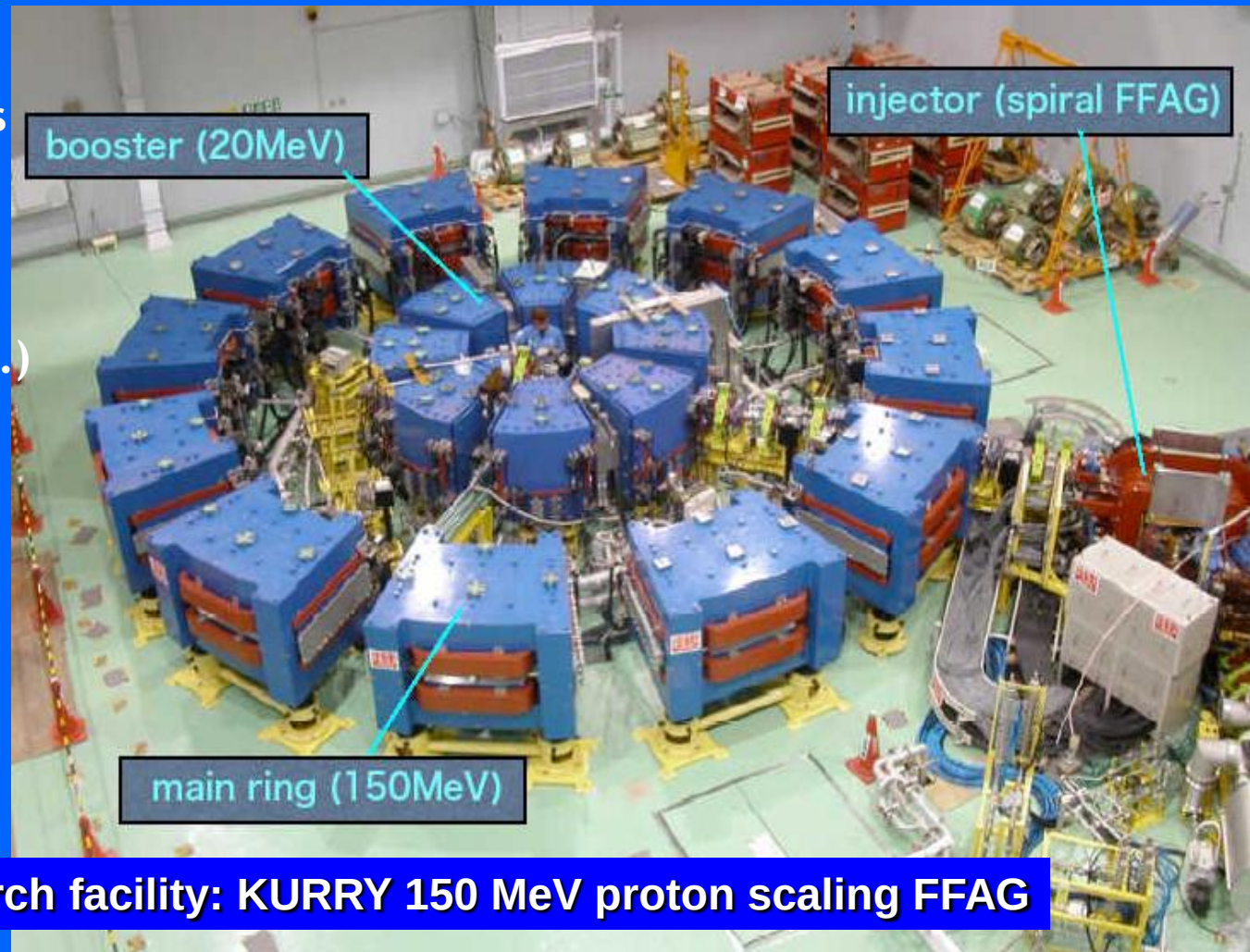
Grazie dell'attenzione

“C'è vero progresso solo quando i vantaggi di una nuova tecnologia diventano per tutti”
H. Ford

New medical accelerators (?): FFAG

(original idea dates back to 1950's)

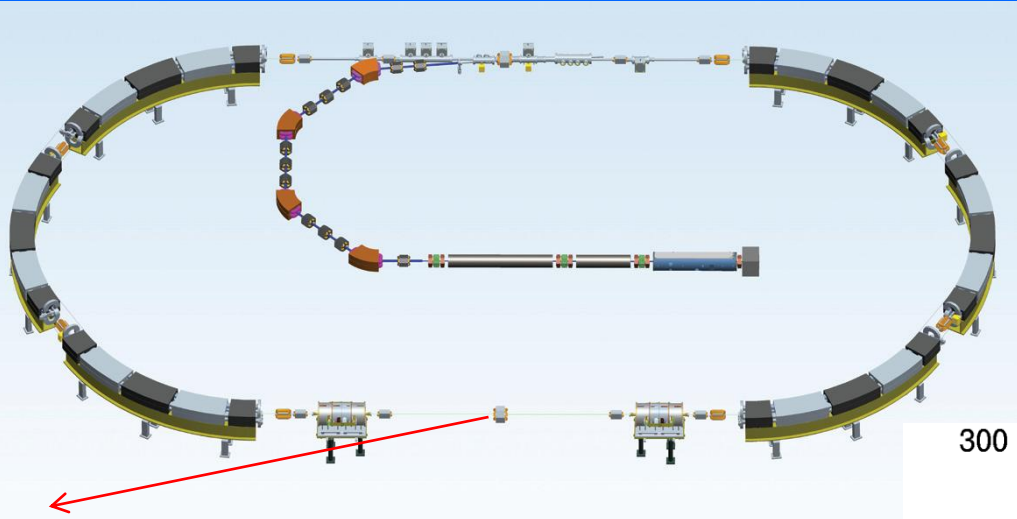
- + Simplicity of fixed field
- + Potential for fast (ms) variable energy
- + Rapid cycling (200 Hz, repainting)
- High intensities
- Multistage accelerators
- Complicated magnets
- Complicated RF cavity
- Dense lattice (ext. diff.)



Only existing reasearch facility: KURRY 150 MeV proton scaling FFAG

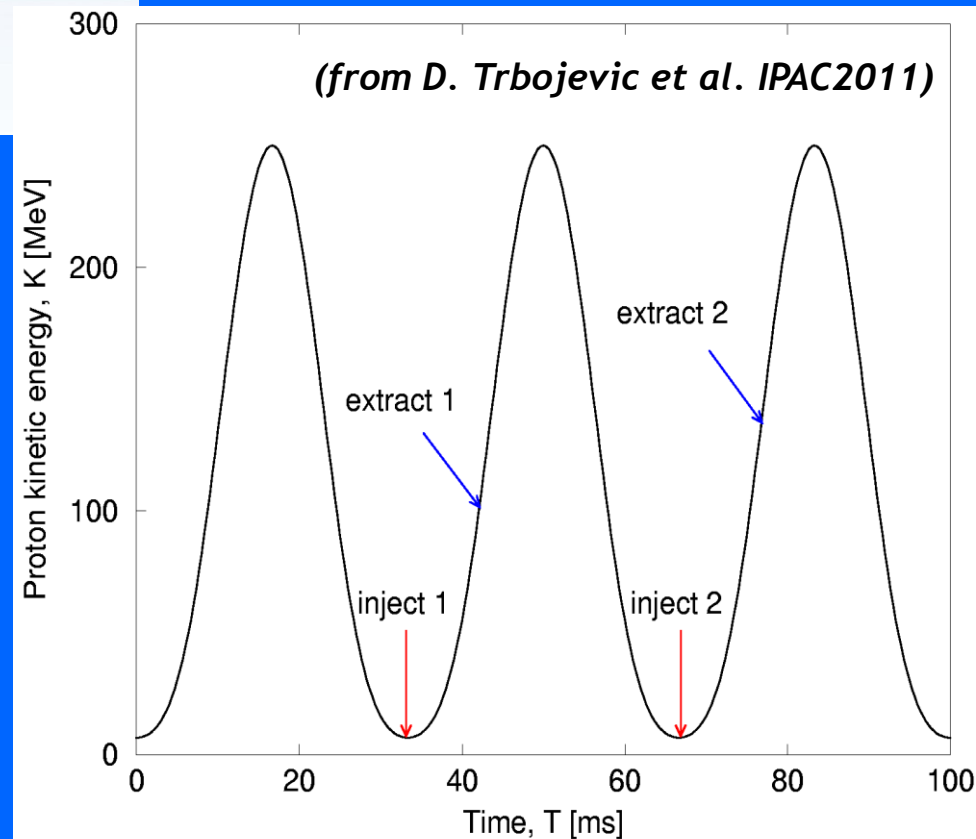
New medical accelerators (?): BNL fast cycling synchrotron

(first publication 1999's, S. Peggs et al.)

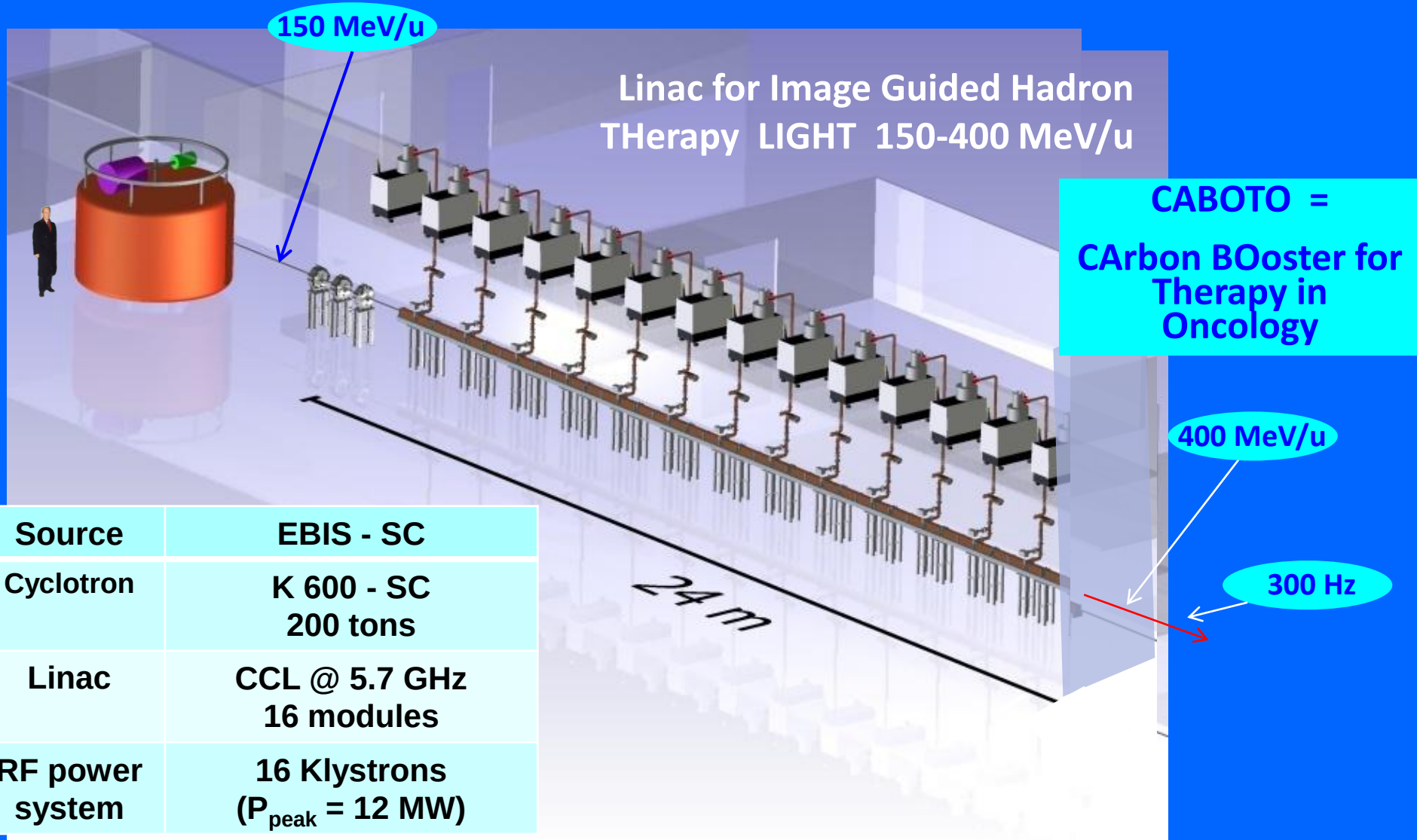


Injection linac at 8 MeV/u
Racetrack, FODO in the arcs, D=0 ss
Fast inj+extr, C = 60 m

30 Hz repetition rate (repainting?)
Fast energy change



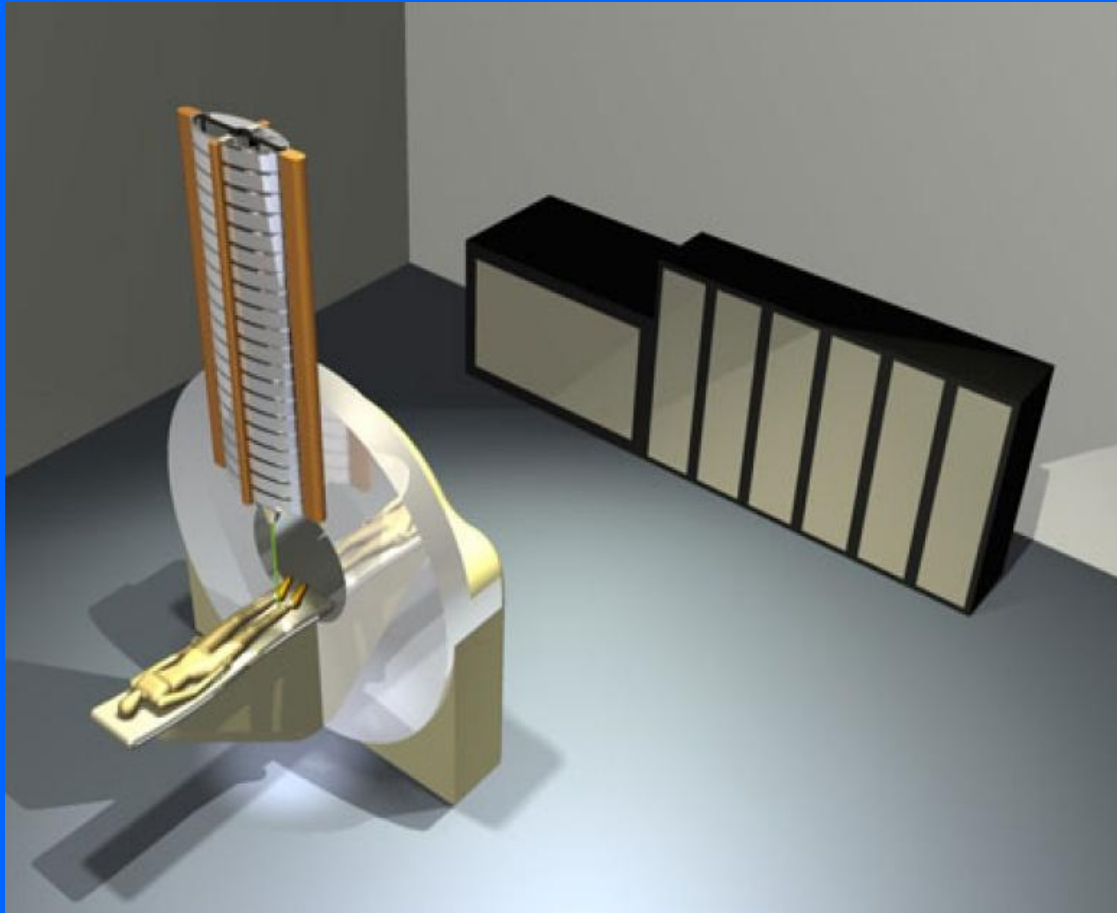
New medical accelerators (?): TERA cyclinac for C-ions



Energy is adjusted in 2 ms in the full range by changing the power pulses sent to the accelerating modules

Charge in the spot is adjusted every 2 ms with the computer controlled source

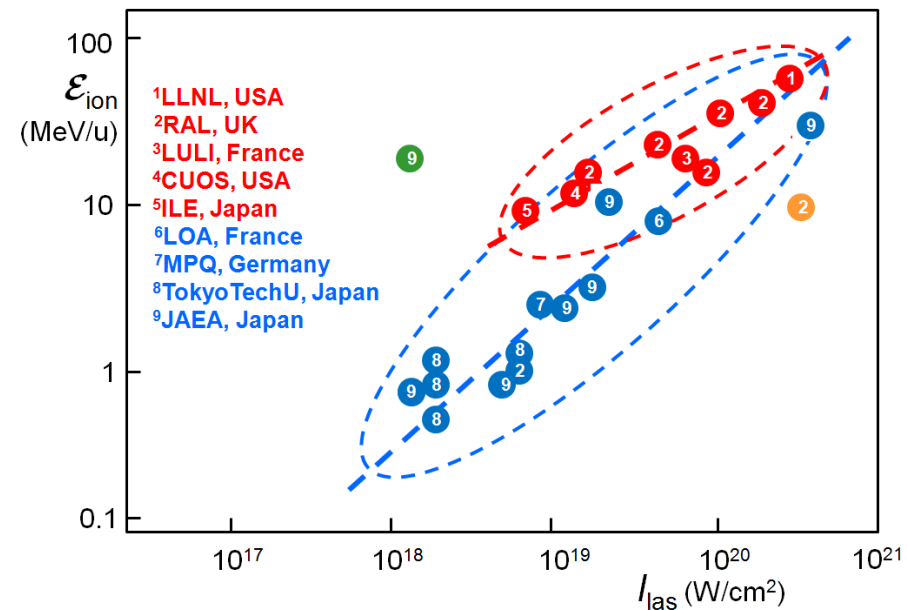
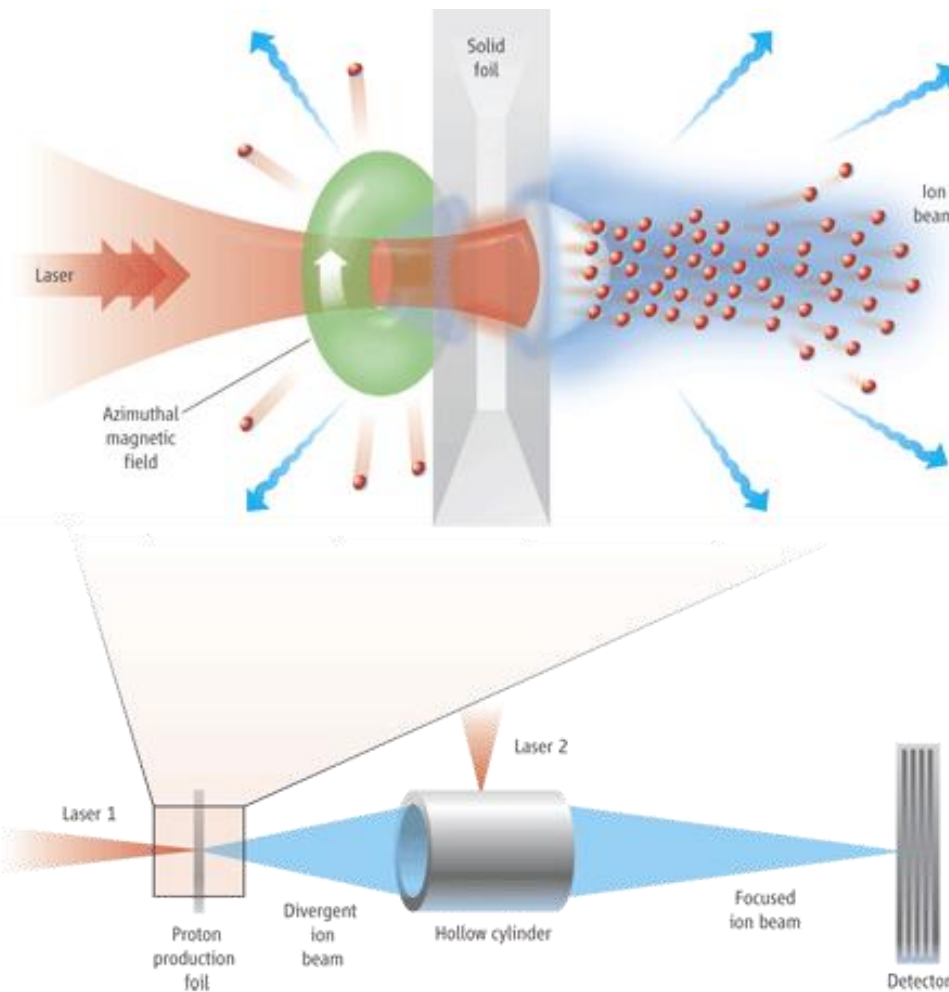
Los Alamos solution: Dielectric Wall Accelerator (DWA)



Pulsed High-Voltage accelerators (G. Caporaso et al)
built in collaboration with Tomotherapy – Madison (T. Mackie)

Far into the future

Laser-driven particle accelerators



courtesy of S.D.Kraft & G. Kraft

Toncian et al., *Science* 2006