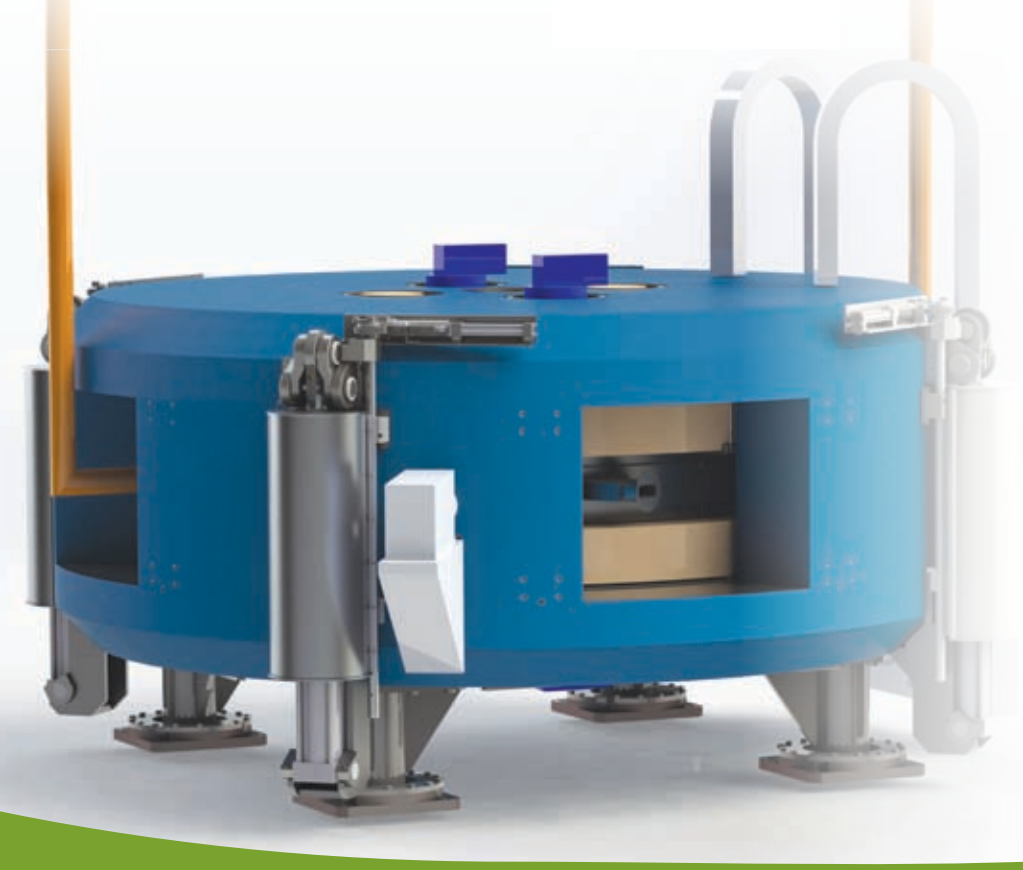

Best®
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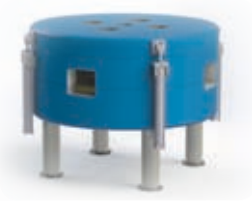

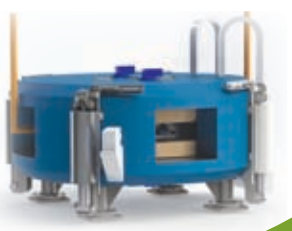

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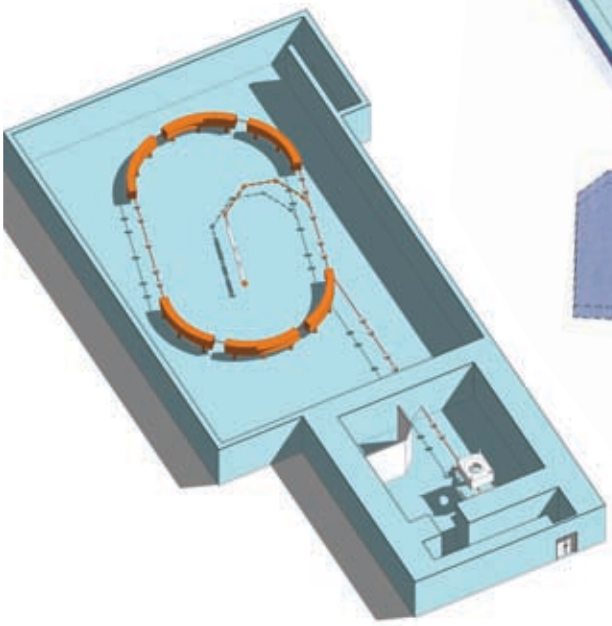

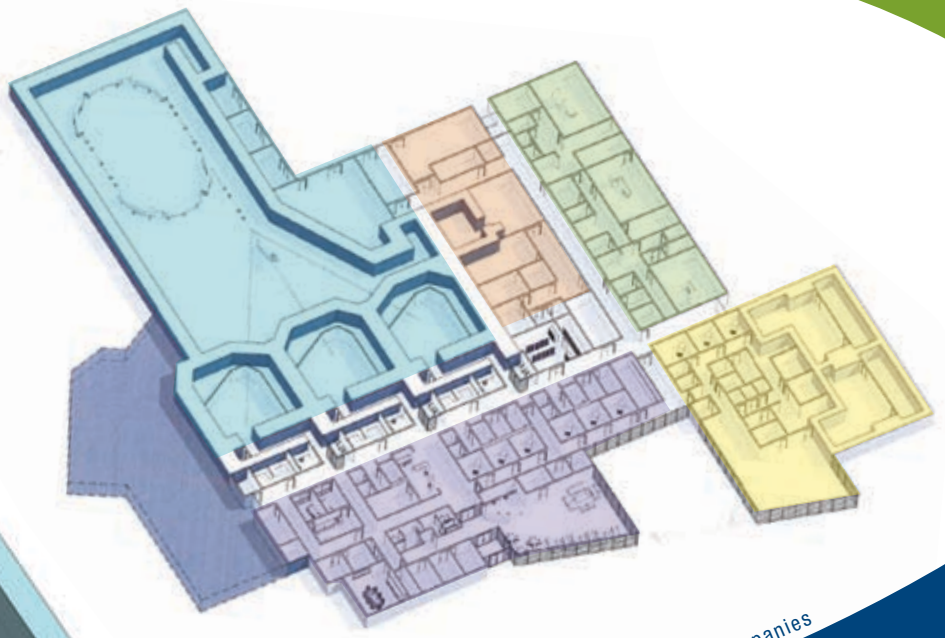

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Best Particle Therapy tel: 412 312 6700 www.bestproton.com

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v23_06152017_web

The Best Family of PET/SPECT/Research Cyclotrons 15, 20u/25, 28u/35 & 70 MeV

TeamBest offers a range of cyclotrons that are designed with the end product in mind, high reliability and low maintenance systems. The important key features of the systems are compatible targetry for production of varieties of isotopes, fully automated multiple extractor foils, cryogenic vacuum systems, stable radio frequency and magnet systems, and external ion sources.

TeamBest provides turnkey systems that not only include a cyclotron specific to your isotope requirements but also targets, automated radiochemistry, infrastructure, operations, and maintenance support. As consistent supplies of radioisotopes become more uncertain, particularly for reactor-supplied isotopes, the Best family of cyclotrons provides a Total Solution™ for the medical community that is less dependent on unreliable sources.

Best Cyclotron Capabilities Summary

Cyclotron	Energy (MeV)	Isotopes Produced
Best 15	15	F^{18}, Tc^{99m}, C^{11}, N^{13}, O^{15}, Cu^{64}, Ga^{67}, I^{124}, Pd^{103}
Best 20u/25	20–15, 25–15	Best 15 + I^{123}, In^{111}, Ge^{68}/Ga^{68}
Best 28u (Upgradeable)	28–15	Best 15 + I^{123}, In^{111}, Ge^{68}/Ga^{68}
Best 35	35–15	Greater production of Best 15, 20u/25 isotopes plus Tl^{201}, Rb^{81}/Kr^{81}
Best 70	70–35	Sr^{82}/Rb^{82}, I^{123}, Cu^{67}, Kr^{81} + research

Radioisotope, radiochemical, and radiopharmaceutical production requires targets, chemistry, QC, documentation, and packaging for the radioproducts to be shipped and used. Teambest has developed this array of radiopharmacy support so that routine steps and protocols may be obtained from TeamBest and its broad base of service and allows rapid deployment of radiochemicals and radiopharmaceuticals after facility commissioning. The cyclotrons and production processes are tailored to each application.

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Best Cyclotron Systems vs. Others

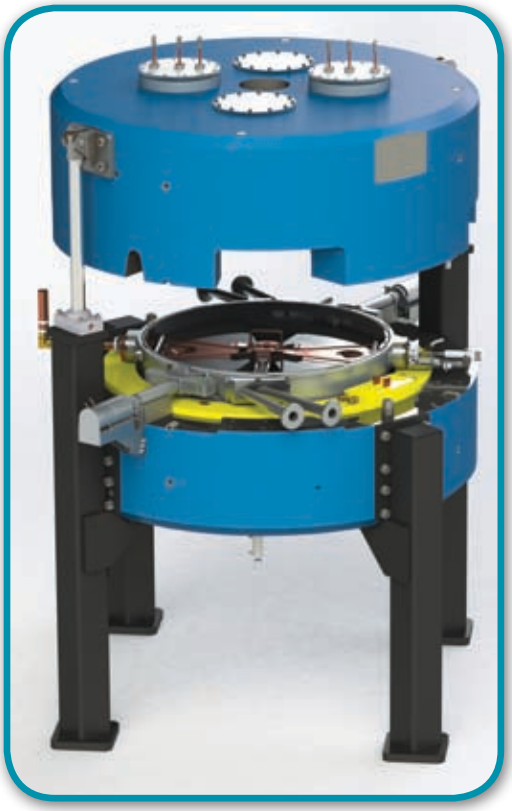
Cyclotron System			Targetry & Process Details		Facility Support		OTHER COMPANIES
BEST 15	External ion source (mA)	5					Not available in all systems
	Energy (MeV)	15	liquid	3 cc 150 µA	Facility design	yes	Only higher energy
	Beam current (µA)	>400 (800)	gas	80 µA	Radiation field profiles	yes	Only lower current
	Beam loss in cyclotron	<1%	solid	400 µA or 1000 µA	Certification support	yes	>40% beam loss (internal sources)
	Base vacuum (cryogenic) Torr	$<3 \times 10^{-8}$	transfer	yes	On line performance monitor	yes	$> 10^{-6}$ Torr (diffusion pumps)
	Magnet and RF stability	$< 10^{-4}$	Target supply	yes	Radiation field profiles	yes	Not available in all systems
	Beam Stability	< 1%	Radiochemical separation	yes	Certification support	yes	Not available in all systems
	Stripper foil changer	Fully automated multiple foil extractor (22 carbon foils)					0 to 5 carbon foils only
Cyclotron System			**Targetry & Process Details**		**Facility Support**		**OTHER COMPANIES**
BEST 20U/25	External ion source (mA)	5					Not available in all systems
	Energy (MeV)	15–25	liquid	3 cc 150 µA	Facility design	yes	Comparable energy
	Beam current (µA)	>400	gas	80 µA		yes	Only lower current
	Beam loss in cyclotron	<1%	solid	400 µA or 1000 µA	Radiation field profiles	yes	Not available in all systems
	Base vacuum (cryogenic) Torr	$<3 \times 10^{-8}$	transfer	yes	Certification support	yes	$> 10^{-6}$ Torr (diffusion pumps)
	Magnet and RF stability	$< 10^{-4}$	Target supply	yes	On line performance monitor	yes	Not available in all systems
	Beam Stability	< 1%	Radiochemical separation	yes	Continental Support centers	yes	Not available in all systems
	Stripper foil changer	Fully automated multiple foil extractor (22 carbon foils)					0 to 5 carbon foils only

Best Cyclotron Systems vs. Others

Cyclotron System			Targetry & Process Details		Facility Support		OTHER COMPANIES
BEST 28U/35	External ion source (mA)	5–10					External/Internal ion source
	Energy (MeV)	15–35	liquid	3 cc 150 µA	Facility design	yes	Comparable energy
	Beam current (µA)	>400 to 1000	gas	80 µA		yes	Not available in all systems
	Beam loss in cyclotron	<1%	solid	400 µA or 1000 µA	Radiation field profiles	yes	Not available in all systems
	Base vacuum (cryogenic) Torr	$<3 \times 10^{-8}$	transfer	yes	Certification support	yes	$> 10^{-6}$ Torr (diffusion pumps)
	Magnet and RF stability	$< 10^{-4}$	Target supply	yes	On line performance monitor	yes	Not available in all systems
	Beam Stability	< 1%	Radiochemical separation	yes	Continental Support centers	yes	Not available in all systems
	Stripper foil changer	Fully automated multiple foil extractor (22 carbon foils)					0 to 5 carbon foils only

Cyclotron System			Targetry & Process Details		Facility Support		OTHER COMPANIES
BEST 70	External ion source (mA)	8–10					External/Internal ion source
	Energy (MeV)	35–70	liquid	3 cc 150 µA	Facility design	yes	Comparable energy
	Beam current (µA)	700–1000	gas	80 µA		yes	Only lower current
	Beam loss in cyclotron	<1%	solid	400 µA or 1000 µA	Radiation field profiles	yes	Not available in all systems
	Base vacuum (cryogenic) Torr	$<3 \times 10^{-8}$	transfer	yes	Certification support	yes	$> 10^{-6}$ Torr (diffusion pumps)
	Magnet and RF stability	$< 10^{-4}$	Target supply	yes	On line performance monitor	yes	Not available in all systems
	Beam Stability	< 1%	Radiochemical separation	yes	Continental Support centers	yes	Not available in all systems
	Stripper foil changer	Fully automated multiple foil extractor (22 carbon foils)					0 to 5 carbon foils only

Best 15 MeV Cyclotron
Ideal for FDG & Tc-99m Supply



Best 15

Best 15

- 15 MeV fixed energy H^- cyclotron
- External ion source
- 400 µA extracted proton beams
- 2 simultaneous extracted beams
- 4 target positions

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Isotope Production Capabilities

Best 15 Isotopes

PET	
Isotope	**Application**
Carbon-11	Broad Substitution
Nitrogen-13	Ammonia: blood flow
Oxygen-15	Blood flow, volume, oxygen utilization
Fluorine-18 aqueous	FDG mainly, many others
Fluorine-18 gas	Radiolabeling from gas phase
Copper-64	Integration through chelation chemistry
Iodine-124	Monoclonal antibodies

SPECT	
Isotope	**Application**
Gallium-67	Fe analog, inflammatory lesions
Technetium-99m	**Many**

Therapeutic	
Isotope	**Application**
Palladium-103	Interstitial implants, brachytherapy

Specifications within are subject to change.

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Best 20u/25 MeV Cyclotron
For a Broader Range of Isotopes

Best 20u/25

Best 20u/25

- 25 and 20 MeV fixed energy H^- cyclotron
- 400 µA extracted proton beams
- 2 simultaneous extracted beams
- 4 target positions

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Best 28u/35 MeV Cyclotron
The World's ONLY Upgradeable Cyclotron

Best 28u/35

Best 28u

- 28 and 20 MeV fixed energy H^- cyclotron
- 400 µA extracted proton beams
- 2 simultaneous extracted beams
- 4 target positions
- Fully upgradeable to Best 35

Best 35

- 35–15 MeV variable energy H^- cyclotron
- 1000 µA extracted proton beams
- 2 simultaneous extracted beams
- Up to 6 independent beam lines and target positions

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Isotope Production Capabilities

Best 20u/25/28u/35 Isotopes	
Isotope	**Application**
Iodine-123	Low dose imaging agent, replacing I^{131}
Indium-111	Blood cell labeling
Gallium-68 (generator)	Blood-brain barrier integrity, tumor localization
Thallium-201	Myocardium functional assessment
Krypton-81m (generator)	Gas for ventilation imaging or in solution for perfusion imaging
Plus all the isotopes the Best 15 can produce	

Best 70 Isotopes	
Isotope	**Application**
Rubidium-82 (generator)	Diagnosis of coronary artery disease, coronary stenosis, myocardial infarction imaging, viability, collateral function and cardiomyopathy
Iodine-123	Low dose imaging agent, replacing I^{131}
Copper-67	Used in radiotherapy by accumulation in tumour tissue using monoclonal antibodies
Krypton-81m (generator)	Used either in gaseous form for ventilation imaging or in solution for perfusion imaging
Research: Physics, chemistry, Radioactive Ion Beam, activation energy, etc.	

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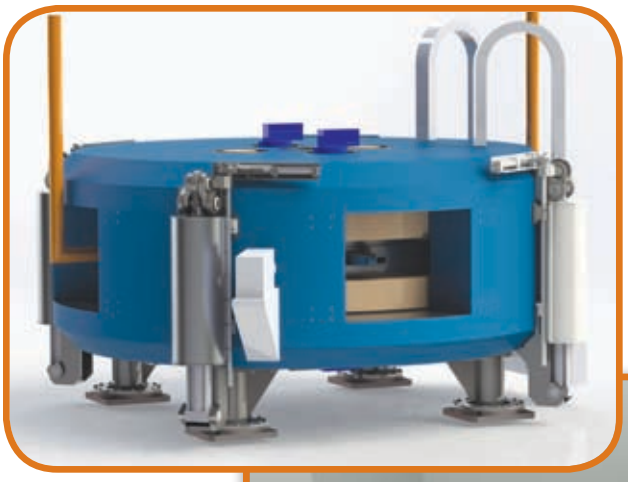
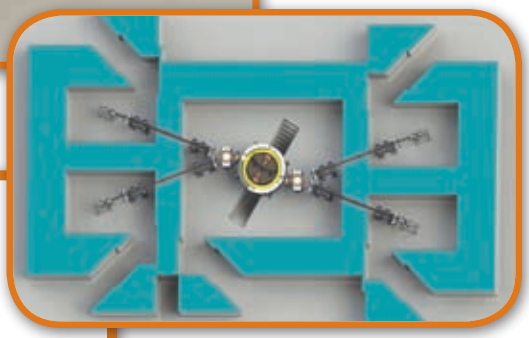
Best 70 MeV Cyclotron
Ideal for Sr-82/Rb-82 Supply & Research



Best 70



Best 70

- 70–35 MeV variable energy H^- cyclotron
- 700 μA extracted proton beams
- 2 simultaneous extracted beams
- Multiple independent beam lines and target positions

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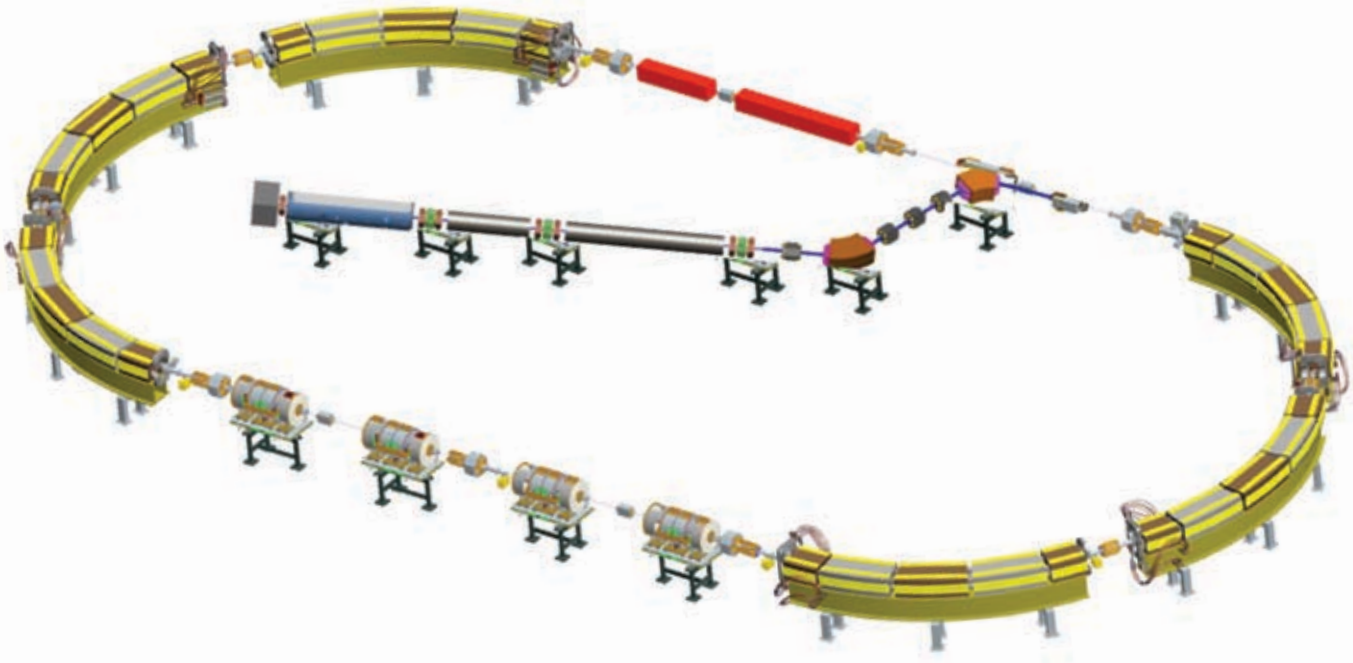
Best Particle Therapy

Best/BNL ion Rapid Cycling Medical Synchrotron (iRCMS)

The growing interest in radiation therapy with protons and light ions has driven demand for new methods of ion acceleration and the delivery of ion beams.

One exciting new platform for ion beam acceleration and delivery is the rapid cycling synchrotron.

20 m x 10 m (75' x 38')
Smaller Area Footprint



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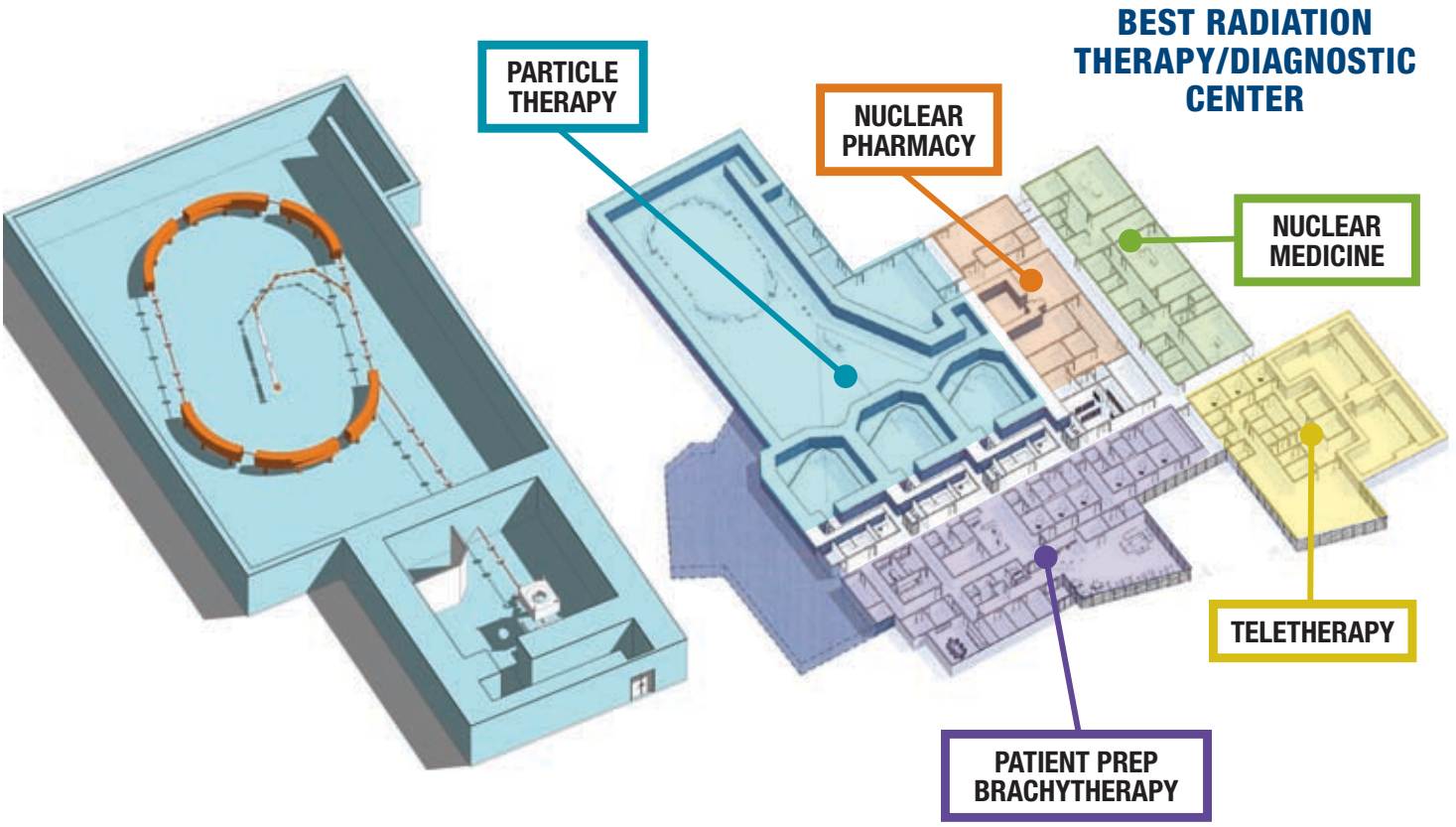
Proton-to-Carbon Upgradeable Single & Multi-Room Solutions



Best Proton-to-Carbon Therapy System

- A unique combination of advanced spot scanning with rapid energy modulation
- Elimination of neutron contamination associated with patient specific hardware

Rapid Cycling Technology:

- Intrinsically small beams facilitating beam delivery with precision
- Small beam sizes – small magnets, light gantries – smaller footprint
- Highly efficient single turn extraction
- Efficient extraction – less shielding
- Flexibility – protons and/or carbon, future beam delivery modalities

** All products shown are pending regulatory approval and not available for sale currently.*

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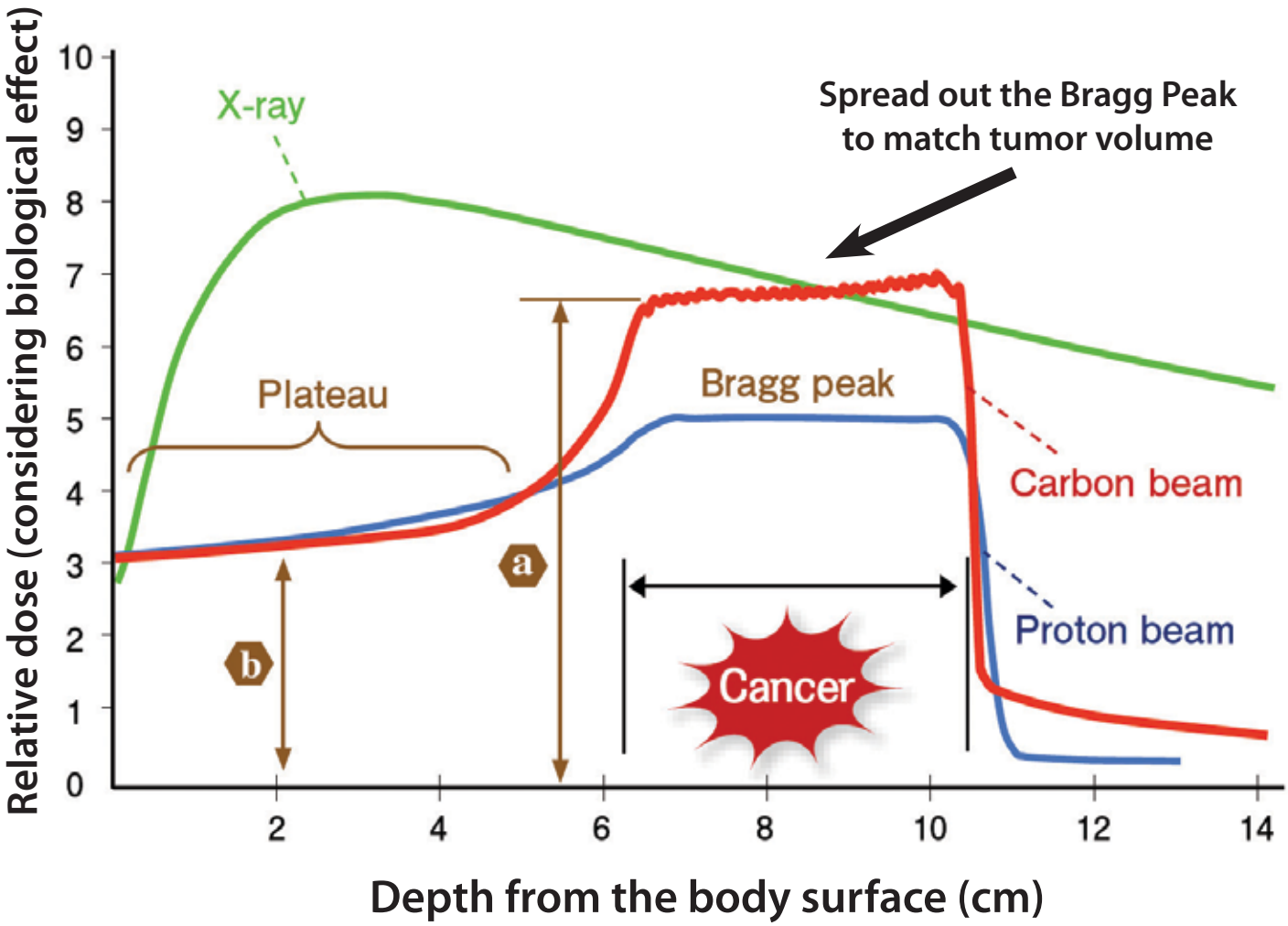
Clinical Comparison:
X-rays • Protons • Carbon Ions

Peak-to-Plateau ratio of the RBE (a/b) is larger in carbon ion beams than for proton beams.



Graph courtesy of Hirohiko Tsujii et al., Radiological Sciences, 50(7), 4, 2007

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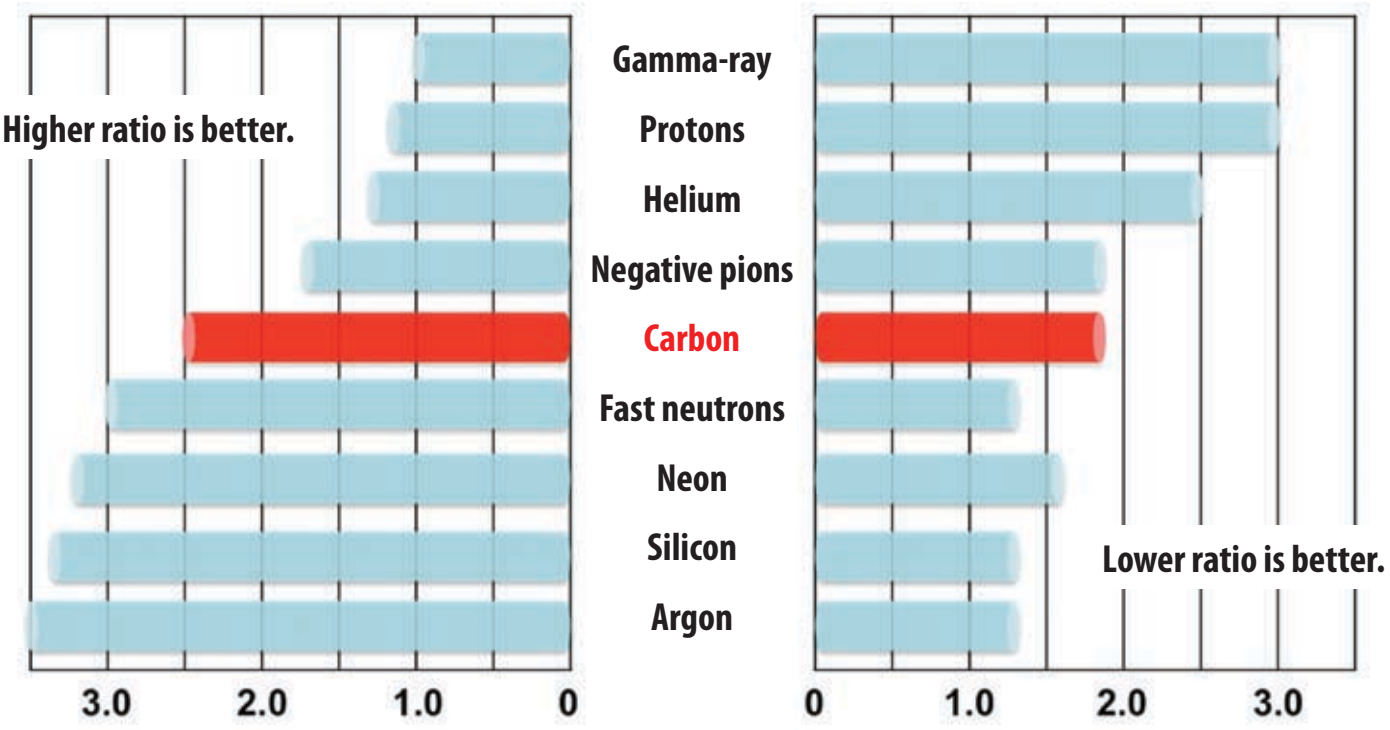
Biological Effectiveness Comparison: Protons • Carbon • Neon

RBE: Relative Biological Effectiveness
OER: Oxygen Enhancement Ratio



RBE represents the biological effectiveness of radiation in the living body. The larger the RBE, the greater the therapeutic effect on the cancer lesion.

OER represents the degree of sensitivity of hypoxic cancer cells to radiation. The smaller the OER, the more effective the therapy for intractable cancer cells with low oxygen concentration.

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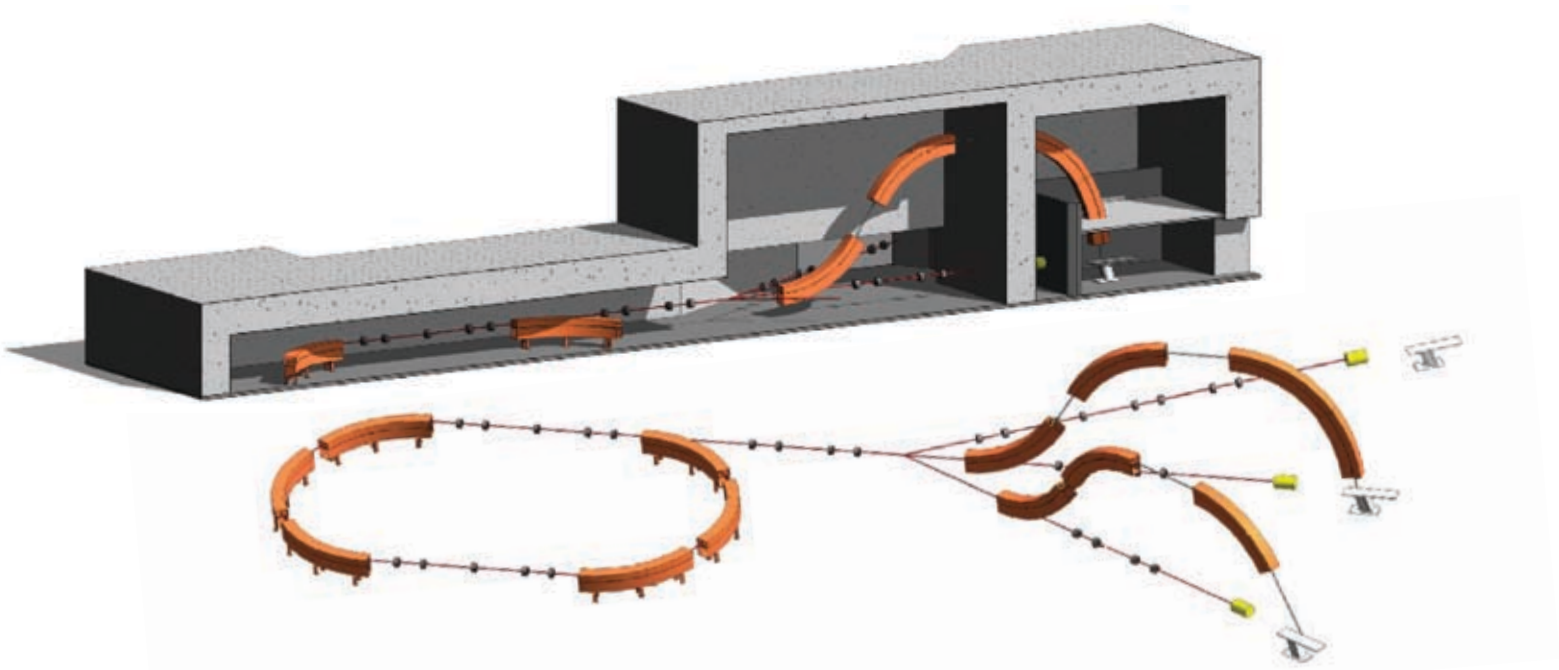
Advanced Beam Delivery — Less Shielding



Accelerator Comparison Table

				Maximum Credible Incidence (MCI)	
	Energy *Maximum* (MeV)	**Avg. Current** *Delivered* (nA)	**Charge** *Accelerated* (nC/s)	**Risk Ratio** *MCI/ Delivered*	**Shielding (50 mSv/yr)** *Concrete @10.00 m* (m)
Protons (206 MeV)					
Isochronous Cyclotron (NC)	230	2	1250	625	2.89
Isochronous Cyclotron (SC)	250	2	313	156	2.44
Synchro Cyclotron (SC)	250	2	1	0.50	0.54
Slow Cycling Synchrotron	250	2	20	10	1.53
Best ion Rapid Cycling Medical Synchrotron (iRCMS)	**1200**	**2**	**0.133**	**0.067**	**0.13**

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Planning a Carbon Ion Therapy Facility

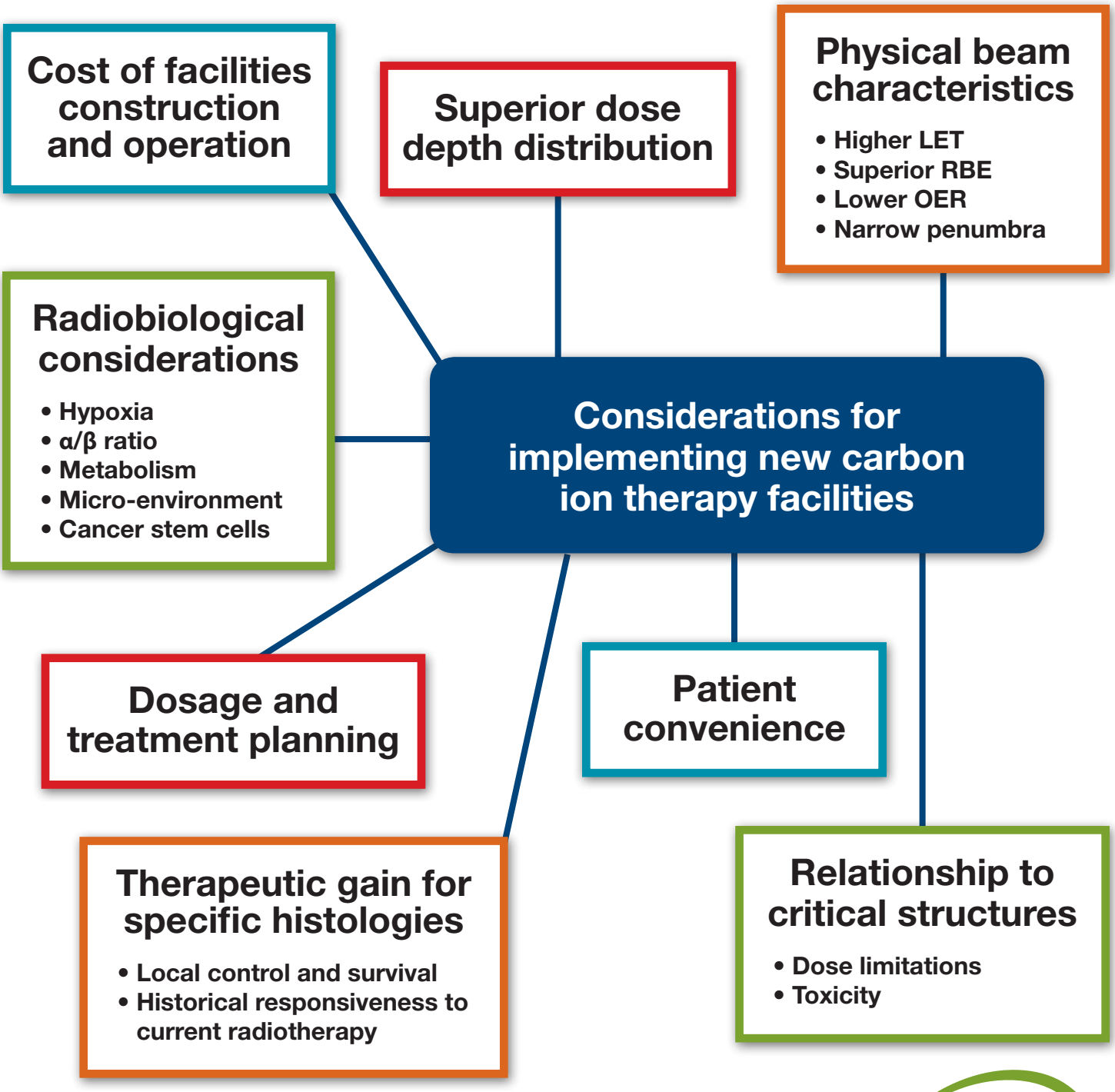

Chart adapted from Schlaff et al., Radiation Oncology 2014, 9:88

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