Best® Particle Therapy

ION RAPID CYCLING MEDICAL SYNCHROTRON (IRCMS) STATUS AND FUTURE PLANS

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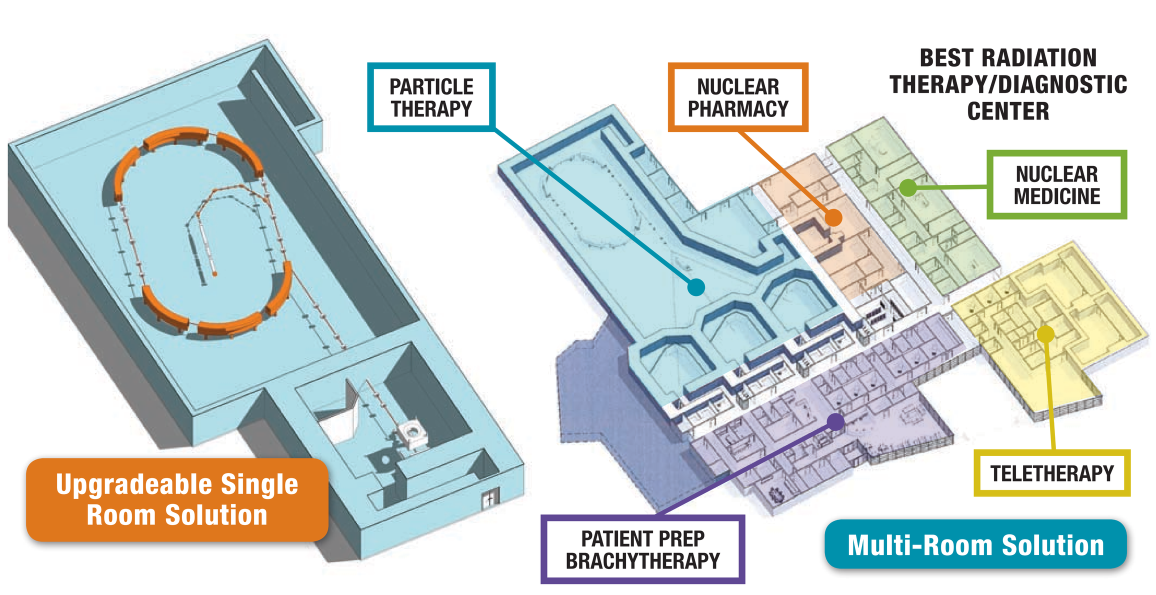
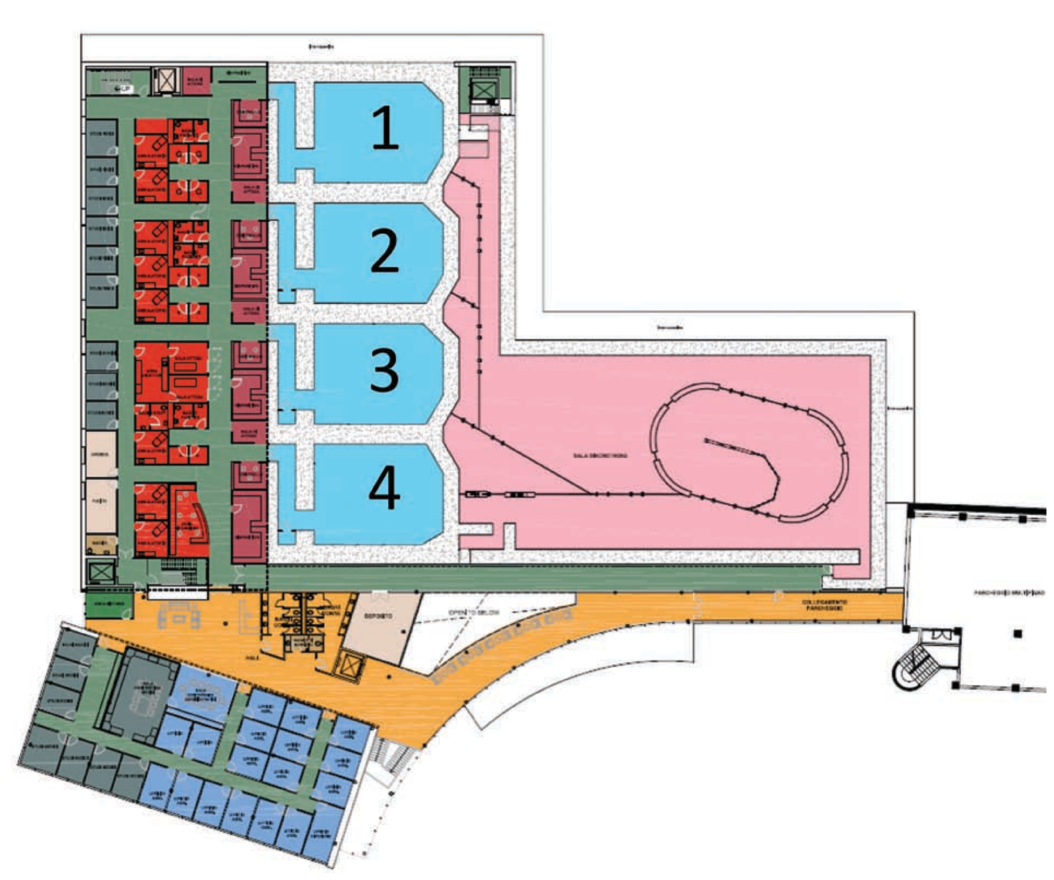
Best Medical International (BMI) entered a Cooperative Research and Development Agreement (CRADA) with Brookhaven National Laboratory to advance the design of the ion Rapid Cycling Medical Synchrotron (iRCMS). The iRCMS is a state-of-the-art synchrotron designed for future cancer therapy facilities that foresee the need to deliver clinical or pre-clinical beams heavier then typical protons. The Collider Accelerator Department (CAD) at Brookhaven National Laboratory (BNL) has optimized an accelerator design under the CRADA funded by BMI specifically for the generation of carbon ions with a maximum energy of 400MeV/u in addition to protons of typical clinical energies. The accelerator is optimized to cycle with a frequency of 15 Hz to the top energy required to deliver treatment at a maximum depth of 27 cm. The iRCMS uniquely combines advanced spot scanning with rapid energy modulation thereby eliminating the contamination associated with patient specific hardware. Extremely small beam emittances are also associated with rapid cycling, which facilitates the generation of particle beams with unprecedented precision. The iRCMS lattice design is a racetrack with two zero dispersion parallel straight sections ideal for injection, extraction and RF systems. The racetrack is 12 meters wide and 23 meters long with the two arcs having a bending radius of ~5 meters. These arcs are made up of 24 combined function magnets with a maximum magnetic field of Bmax~1.3 Tesla. The iRCMS was conceived to include highly efficient single turn injection and extraction and shall utilize a linac to inject carbon ions and protons at a kinetic energy of 8 MeV/u.

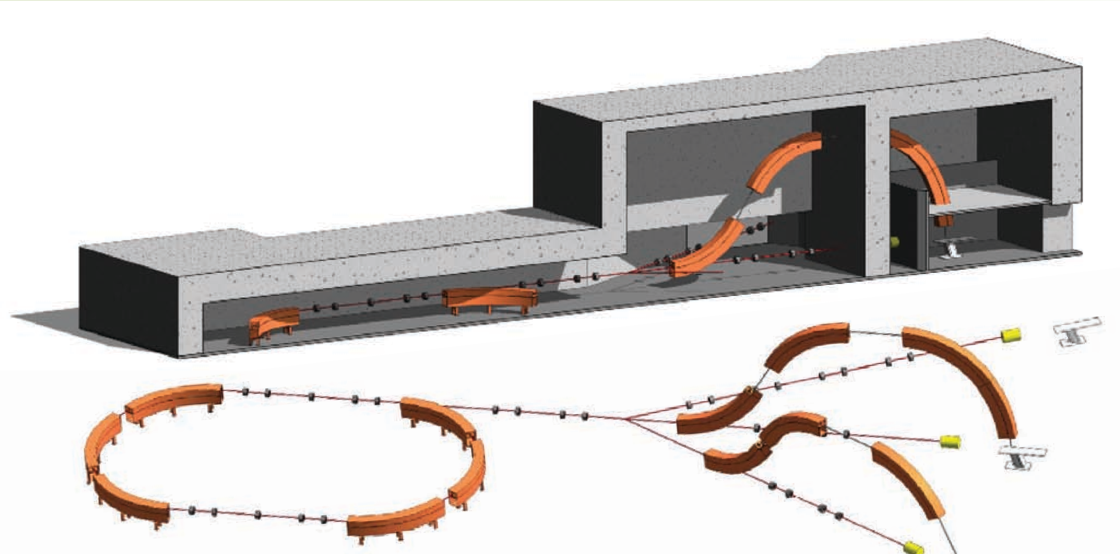
Best Particle Therapy Rapid Cycling Synchrotron



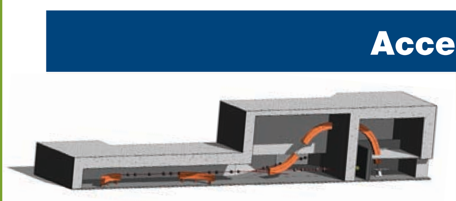
Best Medical Synchrotrons with Variable Energy from Proton to Carbon, in Single or Multi-Room Solutions, with or without Gantry



Advanced Beam Delivery – Less Shielding



Shielding Estimate Comparisons



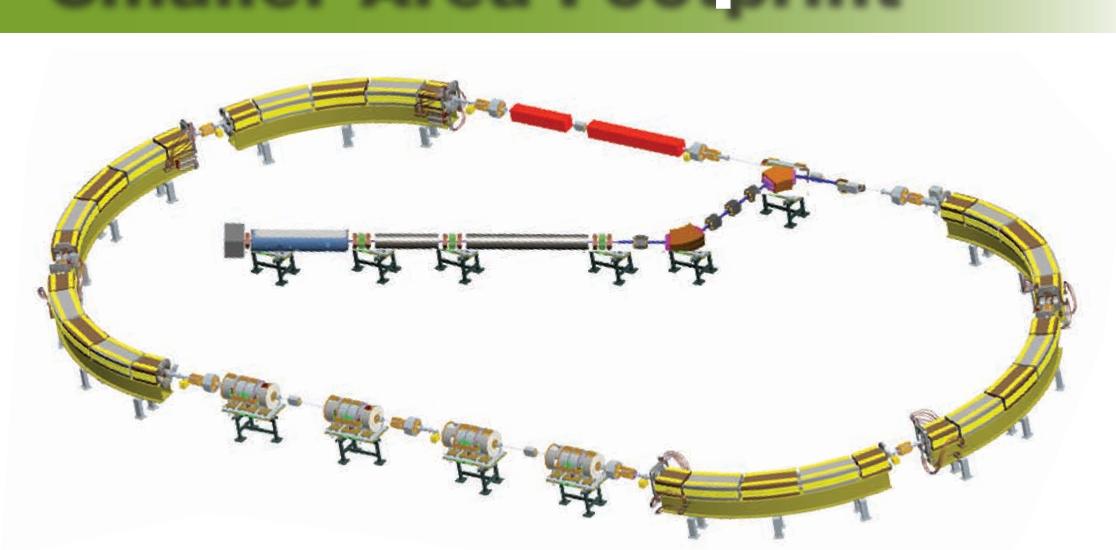
Accelerator Comparison Table

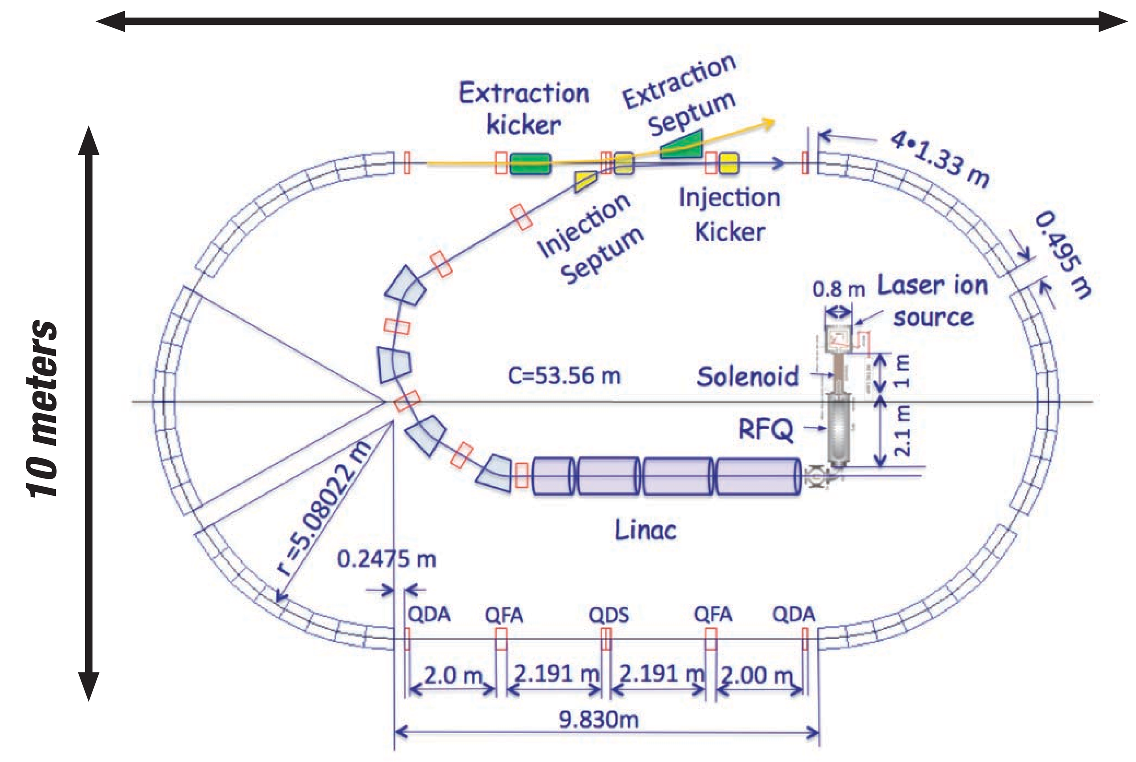
				Maximum Credible Incidence (MCI)	
	Energy *Maximum* (MeV)	**Avg. Current** *Delivered* (nA)	**Charge** *Accelerated* (nC/s)	**Risk Ratio** *MCI/Delivered*	**Shielding (50 mSv/yr)** *Concrete @10.00 m* (m)
Protons (206 MeV)					
Isochronous Cyclotron (NC)	230	2	1250	625	2.89
Isochronous Cyclotron (SC)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

Estimates above *were calculated using the Moyer Model*
Neutron source terms for 177 MeV protons
Neutron transmission factors
Neutron attenuation length in concrete (SLAC PUB 130339)

Final shielding calculations *use a full scale Monte Carlo method (MCNPX, GEANT, FLUKA)*

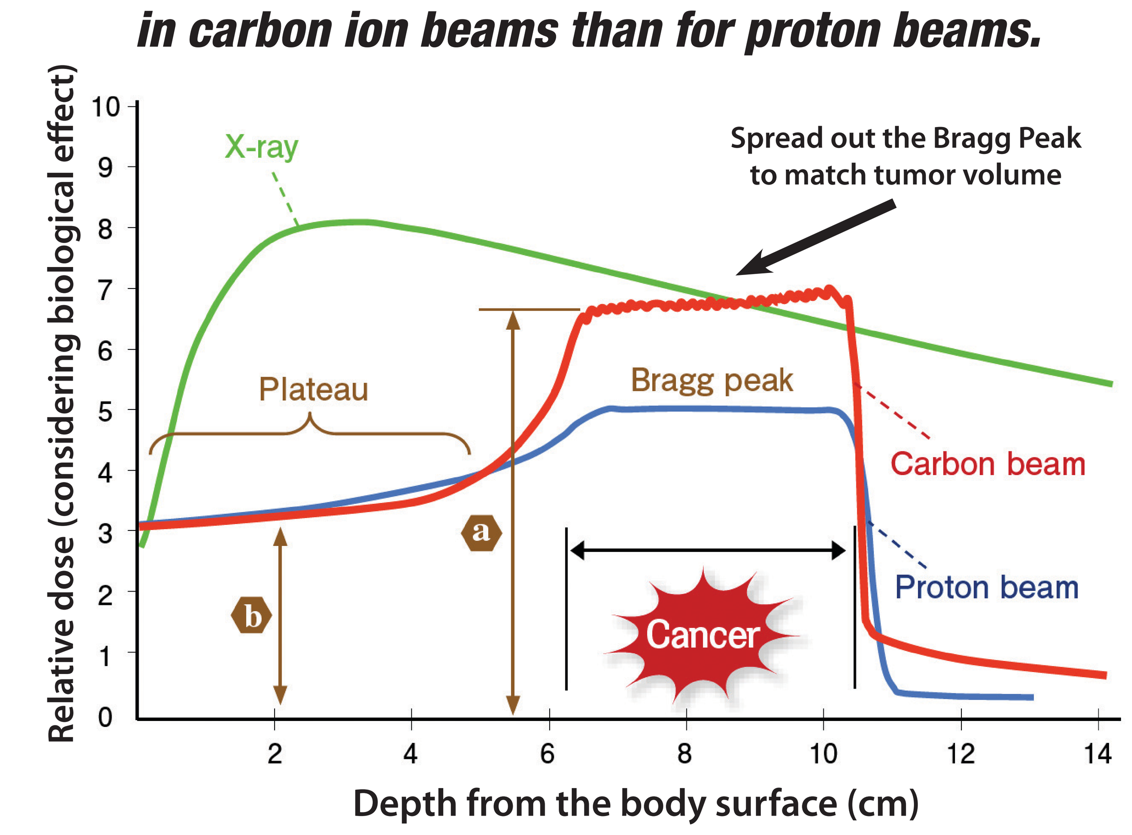
Racetrack Synchrotron – Smaller Area Footprint





Clinical Comparison: X-rays, Protons & Carbon Ions

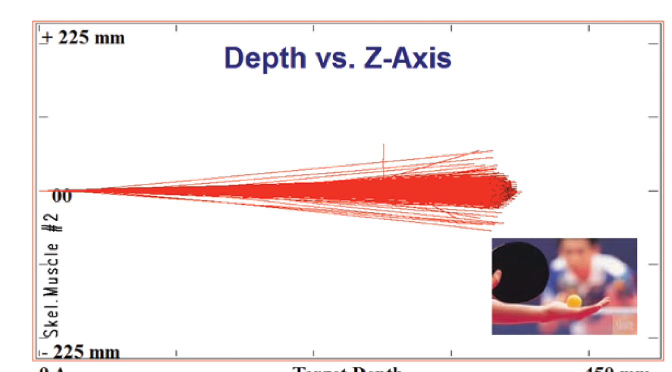
Peak-to-Plateau ratio of the RBE (a/b) is larger in carbon ion beams than for proton beams.



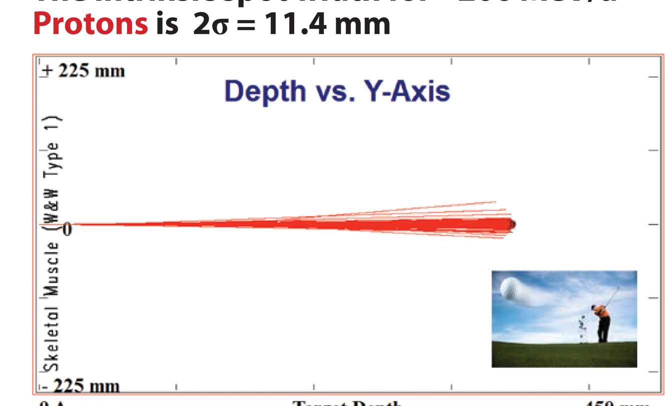
Protons – Base/Peak = 60% Carbon Ions – Base/Peak = 45%

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

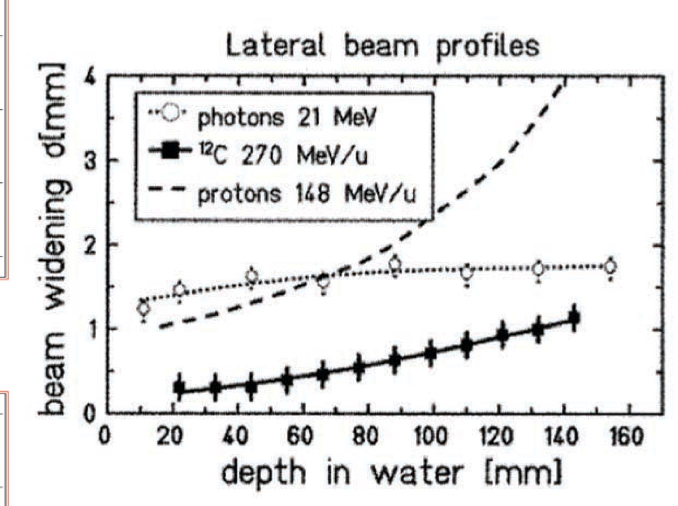
Carbon Ions are more precise than Protons



The intrinsic spot width for ~206 MeV/u **Protons** is 2σ = 11.4 mm



The intrinsic spot width for ~400 MeV/u **Carbon Ions** is 2σ = 2.93 mm



"Lines to guide the eye"
U. Weber GSI (1996)

Prototype iRCMS Combined Function Magnet

Summary

BMI & BNL have jointly developed a rapid cycling proton/carbon synchrotron that enables advanced features including:

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

Rapid cycling technology has several natural advantages:

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