Medical FFAG - 2006

Accelerators and Gantries etc.

Jay Flanz, MGH

5/19/06

Rapporteur

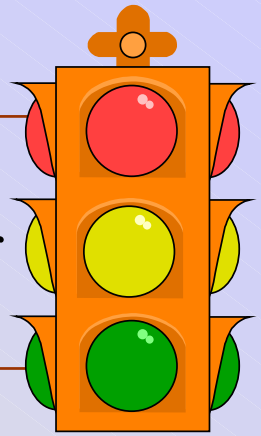
FFAG Medical Session:

- *Clinical and Beam Requirements for Medical Accelerators* - Flanz
- *Industrial Perspectives on Medical FFAGs* - Jongen
- *Report on Activities in Japan on Medical FFAGs* - Mori
- *Designs of Medical Non-Scaling FFAG and Gantries* - Trbojevic
- *Report on Activities on Medical FFAGs in France and Comparison to other Accelerators* - Meot

Medical FFAG

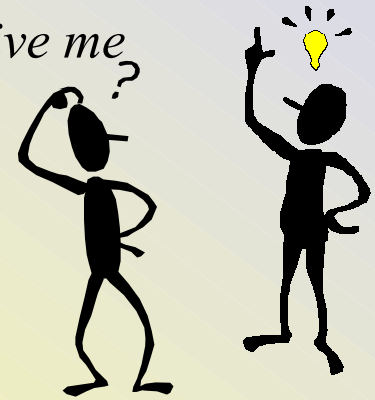
- What is needed (and by whom?)
- Proton
- Heavier Ions
- BNCT
- "Novel" Ideas ?
- Is there a compelling reason to continue?

Are we ready to build an FFAG medical accelerator for clinical use**?**



"I need a better accelerator/gantry, can you please give me one? "

"I have an accelerator/gantry can you use it for medicine?"

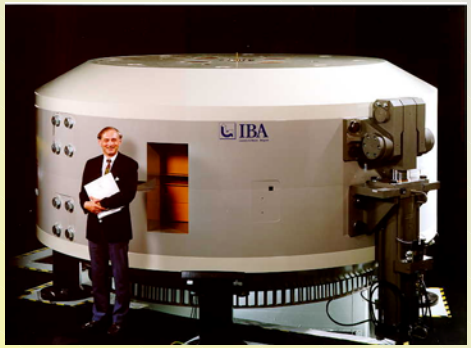


Upcoming Particle Therapy Technology Challenges:

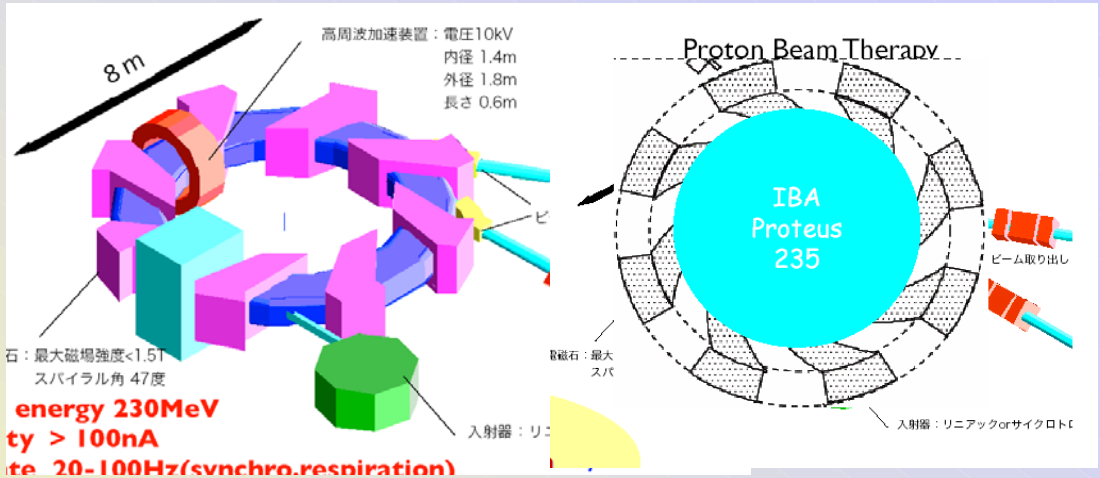
- IMPT
- Time to treat patients
- Tumour Tracking
- Heavy Ion machines of smaller size
- Cost $

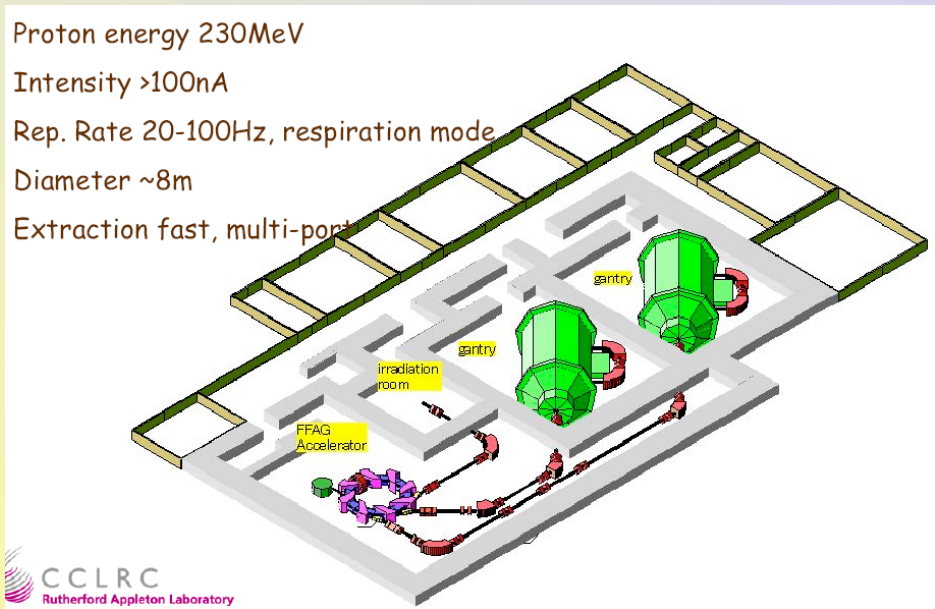
What's wrong with existing ones? - Depends on which one you consider. SIZE, COST, BEAM CONTROL,...

Proton Options Proven Solutions, New Options

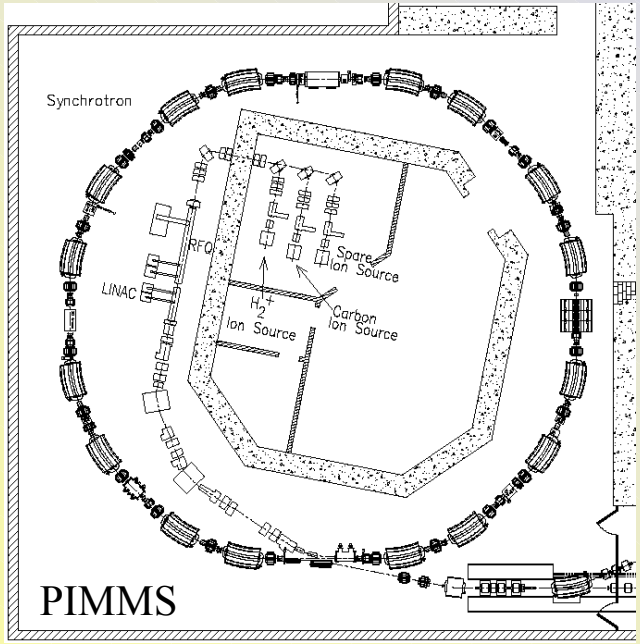


4 m Diam

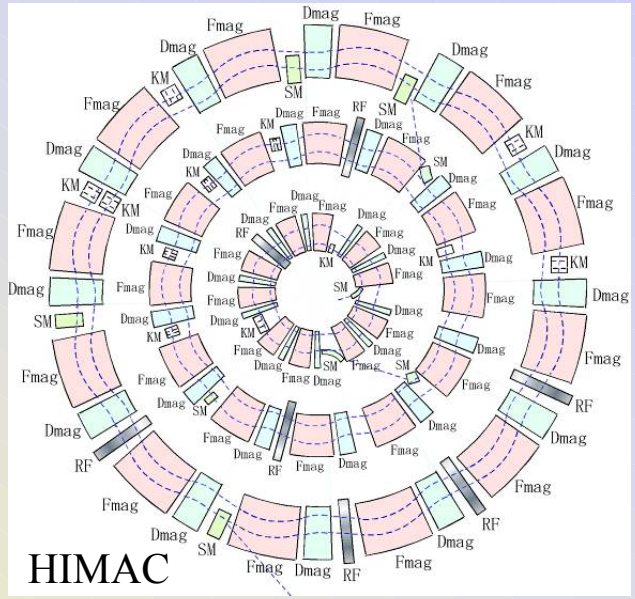




Heavier Ion Options All NEW Options



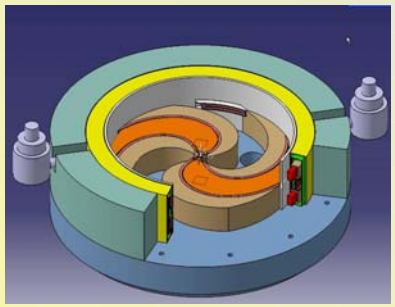
25 m Diam



20.5m Diam

Scaling/ Non-Scaling

Frequency …



6.3m Diam

15m Diam

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Many Challenges already "overcome":

- Lattice Solutions
- Harmonic Jumping
- Calculational Tools
- Injection and Extraction
- Some Magnet Designs
- Rapid Cycling Solutions
- Beam Current Requirements
- Advantage of Non-Scaling FFAG (Lightweight/smaller)

Advantages of FFAG in PT according to Y. Mori

Another Opinion = ~~disagree~~

	Synchrotron	Cyclotron	FFAG
➢ **Intensity (>100nA)**	~~Low~~ 1-16nA	Plenty	Plenty >100nA
➢ **Maintenance**	Normal	~~Hard~~	Normal
➢ **Extraction eff (>90%)**	Good	~~Poor~~ <70%	Good >95%
➢ **Operation**	~~Not easy~~	Easy	Easy
➢ **Ions**	Yes	~~No~~	Yes
➢ **Variable energy**	Yes	No	Yes
➢ **Multi-extraction**	Difficult	No	Yes
CW Operation		Yes	
Injector/PreAccelerator	Yes	No	Yes

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F. Meot's Table

Not Good Good Maybe

Jay's Subjective Rating

Comments on the acceleration methods, proton

		SCS	RCS	cyclo	FFAG S Spiral	FFAG S AG	FFAG NS
Injection		multiturn	single bunch	CW	single bunch		
Extraction		slow spill	fast	CW	fast		
		$1-10$ s	μs scale		μs scale		
machine size	ϕ (m)	>8	large R/ρ	<5	<8 ?		large R/ρ
multiport		difficult		no	possible		
doable dose	Gy.l/min	2 space ch. limit	>5	>5	>5		
rep. rate	(Hz)	< 1	up to 30	CW	potential for kHz limit is RF		
variable E		pulse to pulse		ED+ESS	range shifter (fast) variable K (slow)		
within time scale	Hz	< 1 Hz	30	< 10	future ? (p 2 p ?)		
beam shape	ϵ_z/ϵ_x	>10		round			

kHz

Current Modulation

FFAG 2006, BNL/Port Jefferson, 18 May

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Partial Summary of Parameters - What is needed what is being considered?

			PROTONS				IONS					
								Meot				
	Flanz et. al.		Jongen	Mori	Meot	Dejan	Jongen	Jongen		Mitsubishi	HIMAC	Dejan
								PIMMS				
Range		4cm - 33cm						2-27 cm				
	Energy						100-400 Mev/	80-400 MeV/n		4-400 MeV	100-400 MeV/n	
			70-230	230 MeV	7-230 MeV			50-200MeV P				
	dE/E											
	Stability											
Dose Delivery		2-10Gy/min		> 5 Gy/min								
	Accel Current			89 nA								
	Nozzle Current		0.2-10nA				0.01-0.5nA					
	Dynamic Range	50:1										
	Modulation Speed	<1 sigma	~ kHz									
Time Structure		Scanning										
	Rep Rate			20-100Hz						0.5 Hz	200 Hz	
	Beam Pulse			<1 usec								
Beam												
	Size (FWHM)	~ 5mm sigma						4-10mm				
	Stability	5 % sigma										
	Position Stability	10 % sigma										
Treatment												
	Time	< 2 minutes										
	Repainting	Yes										
	Gating	Yes		Yes								
	Tracking	Yes										
IMPT												
	Type of Scanning	Raster ?		Spot								
	Times											
	Beam on											
	Beam off											
	Energy Change		2 sec				2 sec					
	Moving spot											
	Layer Paint Time											
	Other Times											
Accelerator												
	Availability	99%	98%				98%					
	Maintainability			High								
	Limiting Parameters			Rf?								
	Multiple Ports?	Possibilities		Yes								
	Rf			10kV								
	Power Consumption											
Facility												
	Cost		Low?									
	Size	~ 5m	4.7m Diar	8m diam		4.5 m	6.3m Diam	25 m		15m	20.5 m	8m
	# Patients/Year?	infinite		>500								

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*Some **Perceived** Concerns with FFAG*

- Rf System?
  - Level of Power or Ability to Tune multiple cavities
- Low rep rate or slow spill (*if wanted?)?*
- Fast and Accurate Current Control?
- Not Compact - but lighter
- Cost?

- Intensity in one pulse - is it too high for safety control?
- High Peak Current issues with Instrumentation (**KEK Experience indicates ok** - Russia not ok ??)
- Pushing limits? - Momentum acceptance (minimizing number of cascading rings)

What needs to be done?

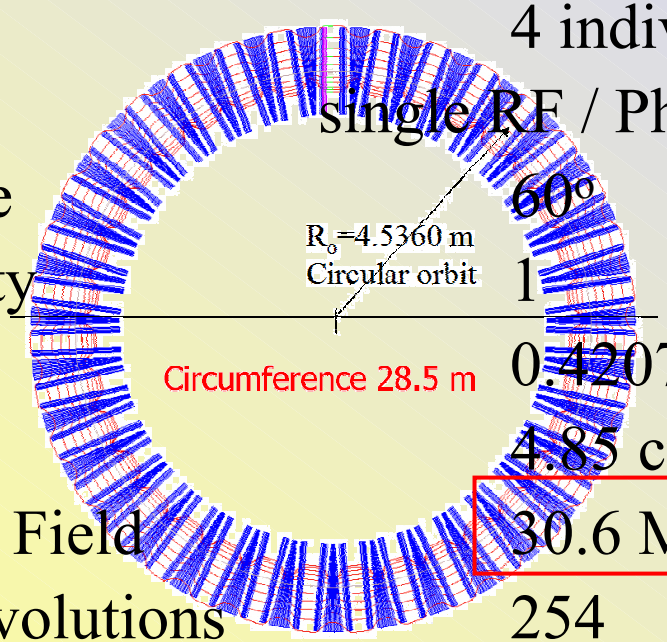
- Refine the Entries in these preceding tables.
- Refine the Criteria used to judge these entries.
- Work on those areas of FFAG solutions to address potential concerns.

Workshop Solution !

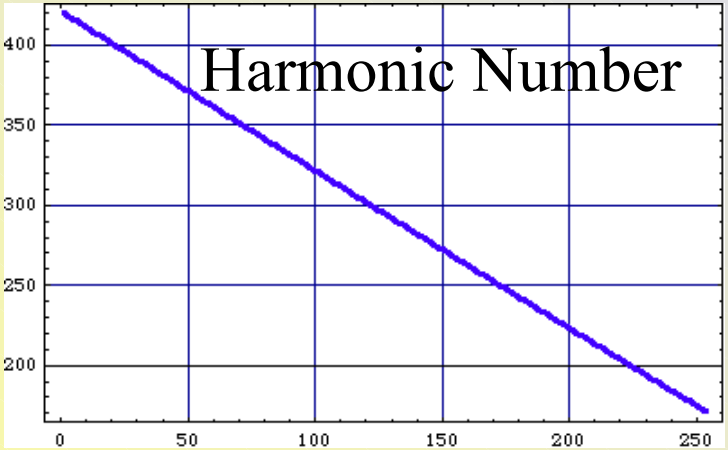
Trbojevic + Ruggiero

• Energy (protons)	30 to 250 MeV
• Circumference	24 m
• Periodicity	36
• RF	1.3 GHz
• Cavities	4 indiv. Phased
• Mode	single RF / Phase Modulation
• Final RF Phase	60°
• Cells per Cavity	1
• $beta_0$	0.4207
• Cell Gap	4.85 cm
• Average Axial Field	30.6 MVolt/m
• Number of Revolutions	254
• Acceleration Period	57.6 μs

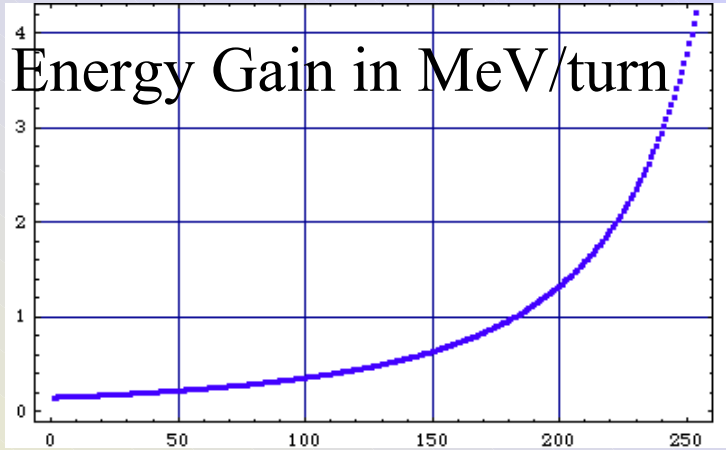
D=9m + Injector …



Details of the Solution



Number of Turns



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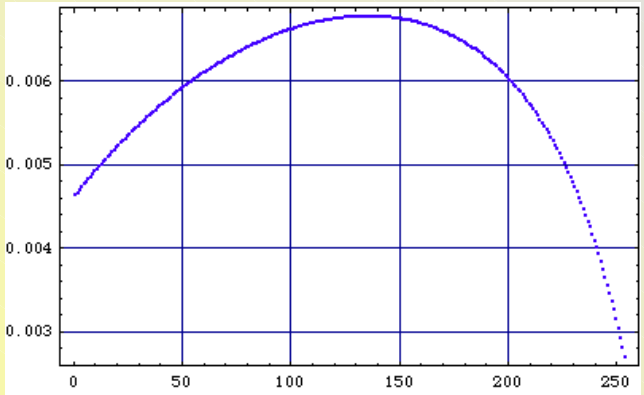


Bucket Half Height Δp/p vs.
Number of Turns

BNCT

[9B.06] Clinical Requirements and Accelerator Concepts for BNCT

Bernhard A. Ludewigt (Lawrence Berkeley National Laboratory, Berkeley, CA 94720)

Accelerator-driven epithermal neutron sources are an attractive alternative to nuclear reactors for Boron Neutron Capture Therapy (BNCT). In BNCT the goal of delivering a sufficient dose to the tumor without exceeding the dose limits of the surrounding normal tissues is achieved by administering a ^10B-containing compound which is selectively taken up in the tumor cells. Subsequent irradiation with epithermal neutrons leads to the release of short ranged (< 10 \mum) ionizing particles via the ^10B(n,\alpha)^7Li neutron-capture reaction. By carefully shaping the neutron spectrum the background dose, partially due to recoil protons and external gamma radiation, can be minimized and the depth dose distribution optimized. Excellent epithermal neutron beams for BNCT can be produced by bombarding a Li-target with a high current proton beam at energies ranging from the (p,n) reaction threshold to 2.5 MeV and subsequent moderation and filtering of the primary neutrons. In comparison the use of Be-targets and higher proton or deuteron energies, up to 20 MeV, leads to higher neutron yields but also to higher primary neutron energies requiring more moderation and resulting in less desirable neutron spectra. Accelerator options for possible neutron sources include dc-accelerators, RFQs, LINACs and cyclotrons. An electrostatic quadrupole (ESQ) accelerator has been chosen to provide a 2.5 MeV proton beam for the BNCT facility currently being designed at LBNL. An ESQ-accelerator is ideally suited to provide the high beam currents which are desired for producing high quality neutron beams for BNCT treatments. A novel power supply based on the air-coupled transformer concept is under development. It will enable the accelerator to deliver proton beam currents up to about 50 mA. A Li-target has been designed which can handle beam power in excess of 50 kW establishing the practicability of this approach. Monte Carlo simulation studies have shown that at a proton beam current of 20 mA high quality treatments for brain tumors can be delivered in about 40 minutes.

FFAG Gantry Implementation

Patented !

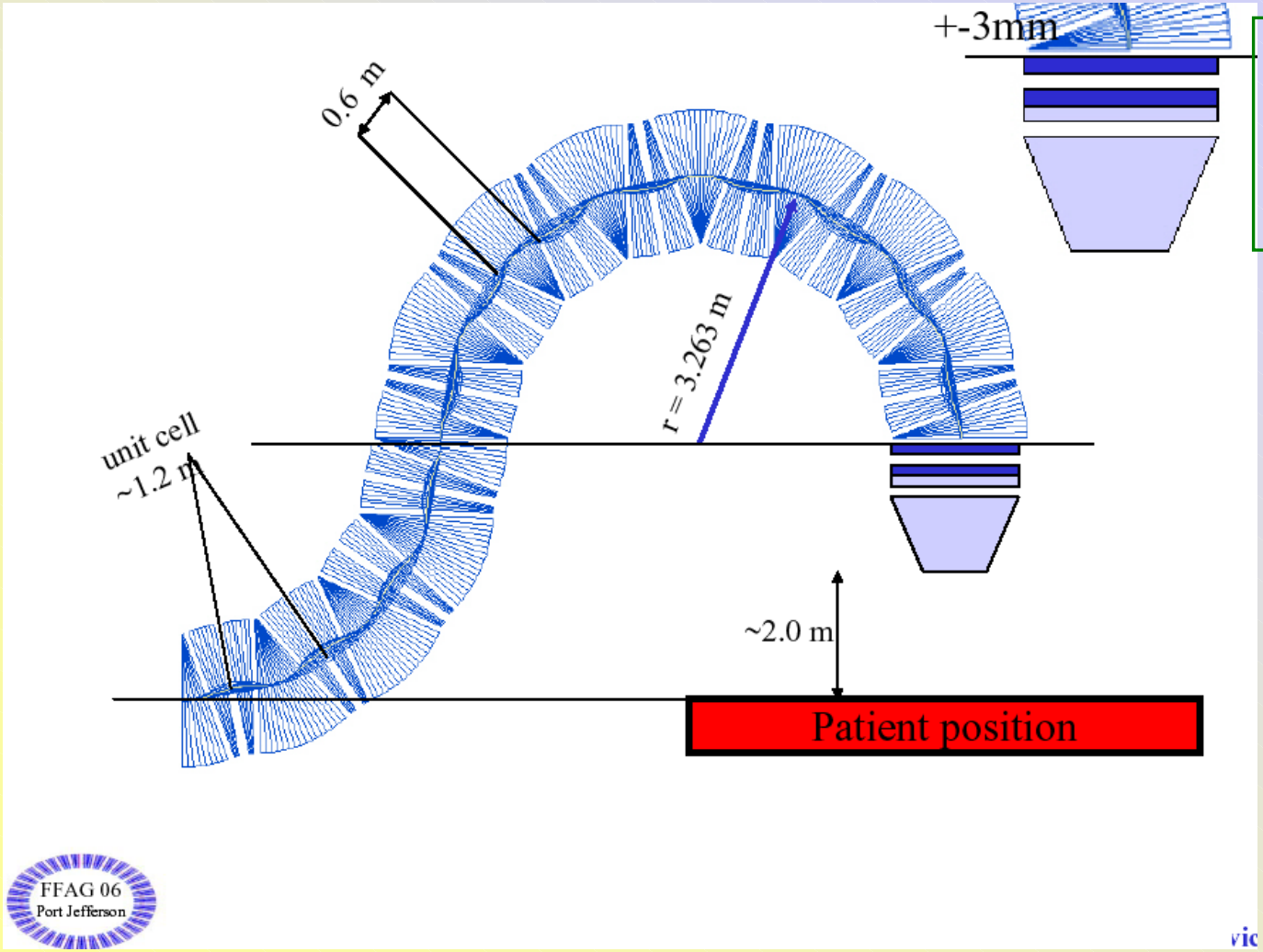
Issues:

Injection Matching Optics

Optics to Patient

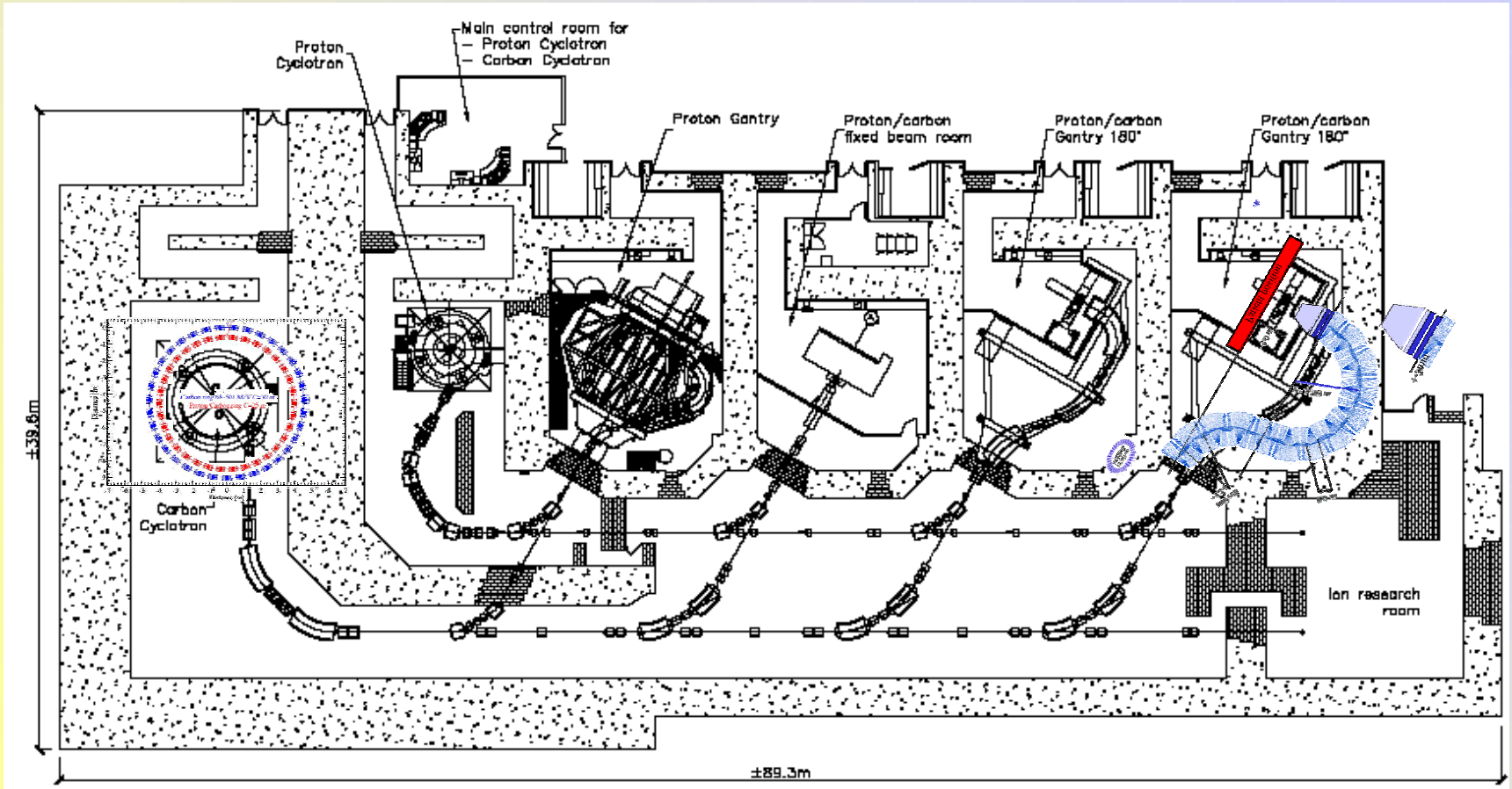
Scanning Implementation

Other Constraints



Non-Scaling FFAG !

Can you have it all?

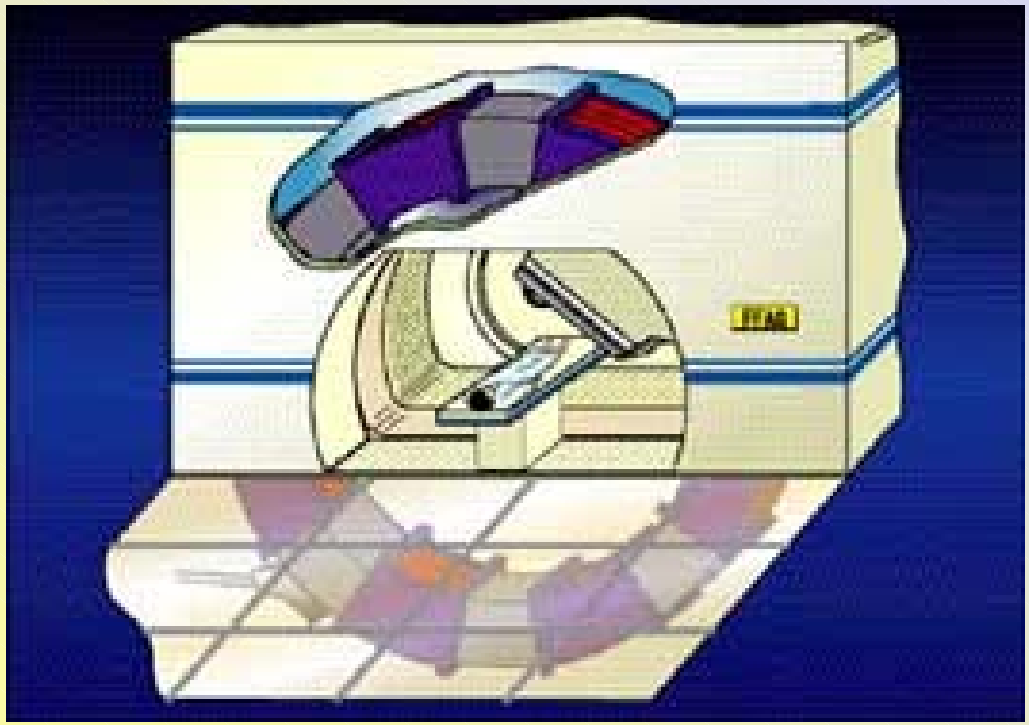


Now is the time to get into the act to make a difference in the next generation of facilities !

What is needed is a way to implement a 'new' idea to it's best advantage !

This is a very attractive one !

Non-Scaling FFAG ?



Here's a place where multiple ports are needed !

End Slides
jbf

It was my pleasure to participate in this exciting forward looking workshop. I hope these ideas are carried out to the next phases !