Accelerator for medical applications – CAS'15

CAS Working group #2

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Introduction

- We have chosen Canada as the country for our hadron therapy facility

- We propose a facility for both *carbon ion and proton* therapy. Other ion species, with Q/m=1/2 (or "slightly" different, i.e. C11) could be used as well

- The accelerator technology that we propose is a *full linear solution*

- Given the absence of an available commercial facility, we propose a 2 years-long design study (same scheme of the *PIMMS study*), at the end of which a committee will decide whether to turn into construction phase or to stop the project

- Budget has to be allocated for the design study (see dedicated slide)

MAPLE

Medical **A**ccelerator for **P**rotons and **L**ight ions for **Ex**tinction of cancer

Number of patients

Map 15.1 Population Density, 2006

Population density (persons per km²)
- >= 256
- 64 to < 256
- 10 to < 64
- 0.4 to < 10
- Sparsely populated

1:58,000,000
0 250 500 kilometres

Percent of Canada's Population (2011)

- Ontario (ON)
- Quebec (QC)
- British Columbia (BC)
- Alberta (AB)
- Manitoba (MB)
- Saskatchewan (SK)
- Nova Scotia (NS)
- New Brunswick (NB)
- Newfoundland and Labrador (NL)
- Prince Edward Island (PE)
- Northwest Territories (NT)
- Yukon (YT)
- Nunavut (NU)

ON 38.4%
QC 23.6%
BC 13.1%
AB 10.9%
MB 3.6%
SK 3.1%
NS 2.8%
NB 2.2%
NL 1.5%
PE 0.4%
NT 0.1%
YT 0.1%
NU 0.1%

|		
	Total population	36.16M
62%	South-East Ontario South Quebec	22.4M
1%	Cancer patient	224k
20%	Radio therapy	44.8k
15%	Hadron therapy	7k
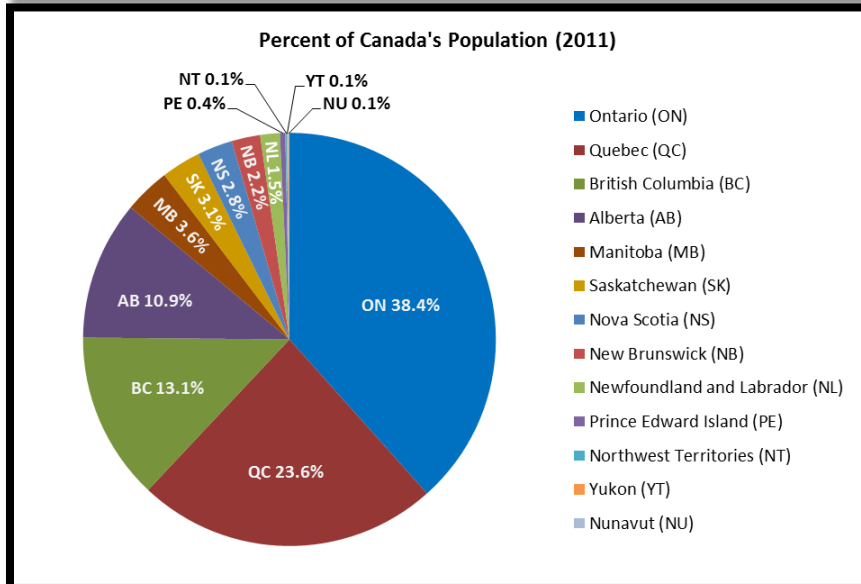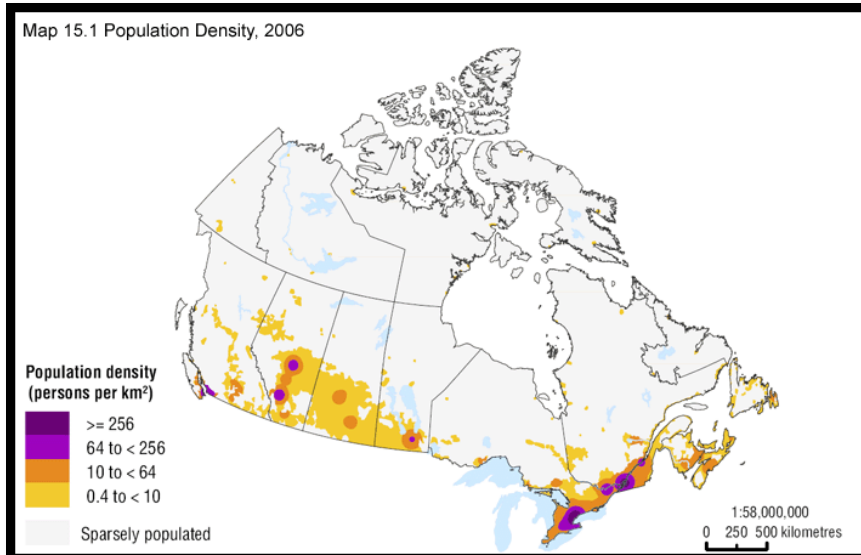
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GPTC (NL)	600 p/y
Scandion clinic (SE)	1000 p/y
MedAustron (A)	1400 p/y

5	min/fraction
12	fraction/hour
12	hours/day
144	fraction/day
250	days/year
36000	fraction/year
20	fraction/patient
1800	patients/year

# Rationale of a full linear solution

- BEAM ENERGY. Can be varied actively, at the machine level, from pulse to pulse. 200 Hz repetition rate is doable.

- BEAM QUALITY. No need of degraders, i.e. no beam size spreading.

- COST-EFFECTIVE SOLUTION. A 3-room facility (without gantries) would cost around 40 M€ (source: ADAM)

- COMPACT SOLUTION. Bottom right picture has the footprint of CNAO.
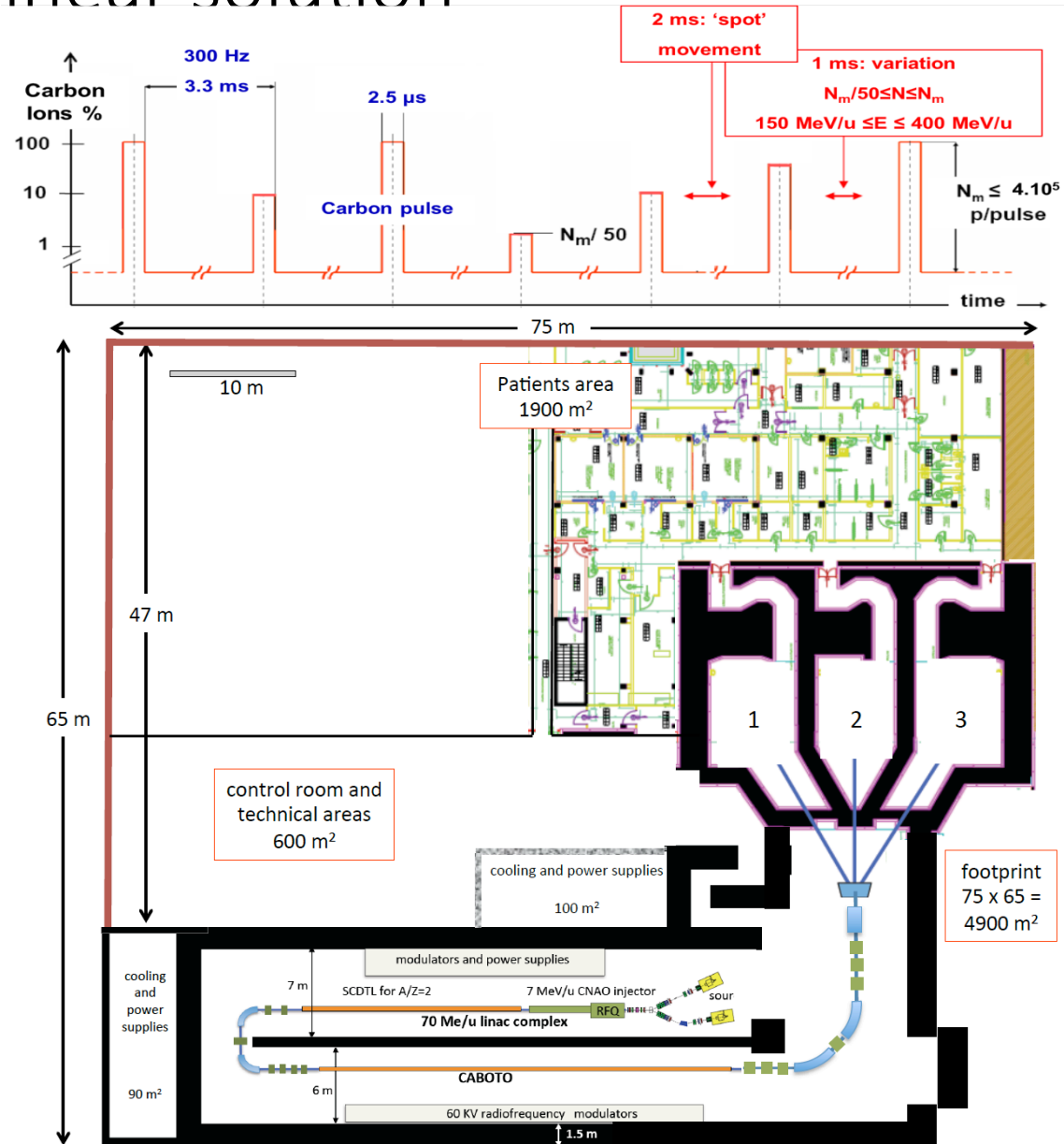
Main design parameters
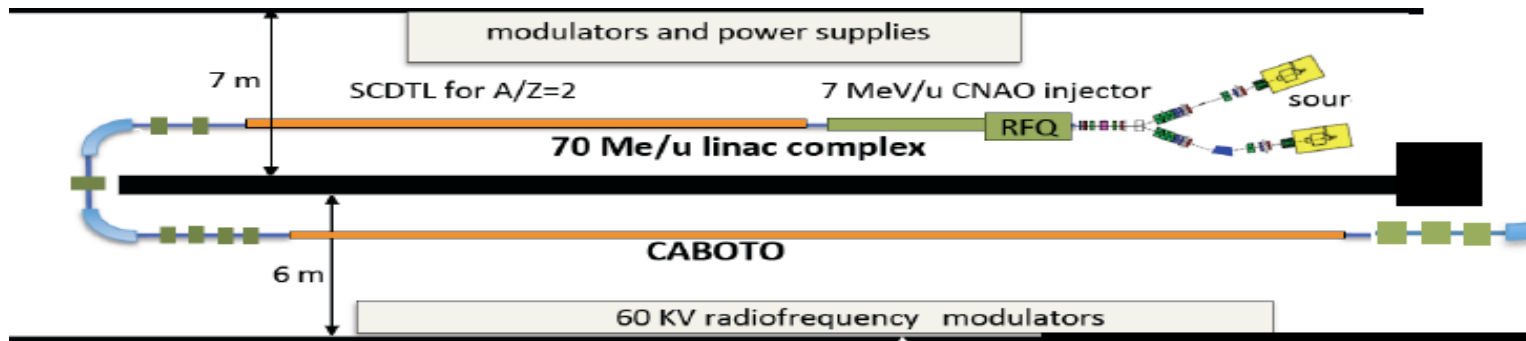
- Final beam energy: 450 MeV/u
- Energy variation range:
  70 MeV/u – 450 MeV/u
- Average beam intensity:
  1-2 nA
- Spot size:
  FWHM adjustable 4 mm – 12 mm
- Field size: 30 x 30 cm
- Active scanning,
  energy adjustable each 5 ms
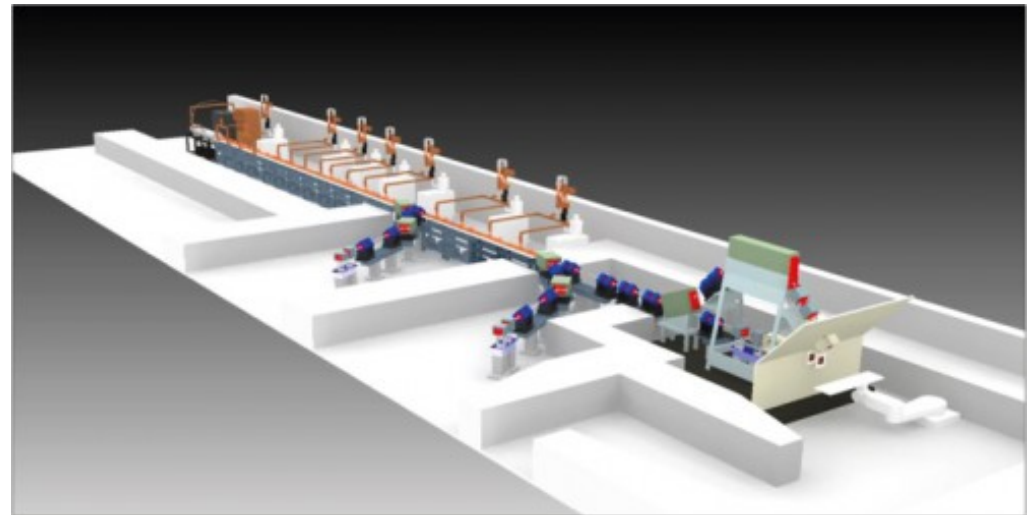
Technical specifications

- ION SOURCE. EBIS type. High frequency intense pulsed C6+ and other species. Repetition rate (eventually with two sources) up to 400 Hz. Pulse length: 5 µs. Number of ions per µs: 2e+8. Pulse stability: <5%. Beam emittance: 0.1 to 0.2 mm.mrad.

- INJECTOR. RFQ. Frequency: 750 MHz. Input energy: 20 KeV/u. Output energy: 2.5 MeV/u. Transmission: >95%.

- INTERMEDIATE β STRUCTURE. IH type. Frequency: 3 GHz. Output energy: 70 MeV/u. Transmission: >15%. FODO lattice: PMQs.

- HIGH β STRUCTURE. CCL type. Frequency: 3 GHz. Output energy: 450 MeV/u. Transmission: >95%. FODO lattice: PMQs.

- Transfer lines: 180° MEBT with two 90° SC (?) dipoles and quadrupole in between to close dispersion. HEBT. Straight HEBT à la MedAustron.

RF power consumption estimation $\Delta W = \sqrt{Z\cdot LP}$

CCL:
- Delta energy gain = 450 MeV/u – 70 MeV/u = 380 MeV/u = 760 MeV
- Approx. length = 35 m
- Avg Shunt Impedance= 100 Mohm/m
- Peak power: 165 MW ish… -> Avg. gradient 22 MV/m

H-structure:
- Delta energy gain = 70 MeV/u – 2.5 MeV/u = 67.5 MeV/u = 135 MeV
- Approx. length = 15 m
- Avg Shunt Impedance= 60 Mohm/m
- Peak power: 20 MW ish… -> Avg. gradient 10 MV/m

Total RF peak power (with 1 MW RFQ) = 186 MW (225 with 20% wg losses)
D.C. = 4 µs x 400 Hz = 1.6e-3

Average RF power consumption = 360 kW

RF power source

M3 ScandiNova modulator

THALES TH 2157

K1 ScandiNova modulator

KIU-147/BAC

No oil tank. Possibility to operate klystron at a distance.

	THALES TH 2157	KIU-147/BAC	
Frequency range	2998.5		MHz
RF output power			
• peak	7.5	7.7	MW
• average	8	30	kW
RF pulse duration	6	6	μ sec
Saturated gain	48	51	dB
Efficiency	48	77	%
Electrical characteristics			
Cathode voltage	150	52	kV
Beam current	105	195	A

No focusing solenoid (3 kW)
Weight 90 kg
Length 0.90 m

Timeline and business plan

	1				2				3				4				5				6				7			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4

Design Study

Construction

Accelerator Installation

Beam commisioning

Acceptance tests

Total costs			
Fixed		**Variable/running**	
- Ground (3 ha)	15	- Maintenance / consumables	6
- Building	20	- Energy (2MW x 16h/d)	1
- Accelerator	25	- Personnel (120 persons)	8
- 2x Gantry	20	- Patient hotel (100 patients for 250 days)	2.5
- Commissioning incl personnel	10		
- Treatment planning	7		
- Patient positioning	10		
- Imaging systems (1 MRI, CT, 1 PET-CT, 4 CBCT)	2		
- Permits	1.5		
- Decomissioning including removal of activated material	**???**		
A Brahme et al. Nucl. Instr. And Meth. In Phys. Res. B			
Sum	**110.5**		**17.5**

Total income			
Fixed		**Variable/running**	
		- 1800 patients x 20.000	36

Expertise needed

- BOARD

- HR

- Radioprotection

- FDA certifications and quality

- Safety

- Clinical Dep.

- Radiotherapy Dep.

- Medical Physics Dep.

- Imaging Dep.

- Radiobiology Dep.

- Bioengineering Dep.

- Administrative Dep.

- Finance Dep.

- Infrastracture Dep. (Electr, Mech, IT…)

- Accelerator Dep.

- R&D Dep.

- Operation Dep.

- Maintenance Dep.

Around 120 FTE (Full Time Equivalent) needed

Process map