FFAG'14 WORKSHOP, BNL, LI, 22-26 SEPT. 2104

Medico-economical study of a FFAG based, multi-port simultaneous beam delivery hadrontherapy facility

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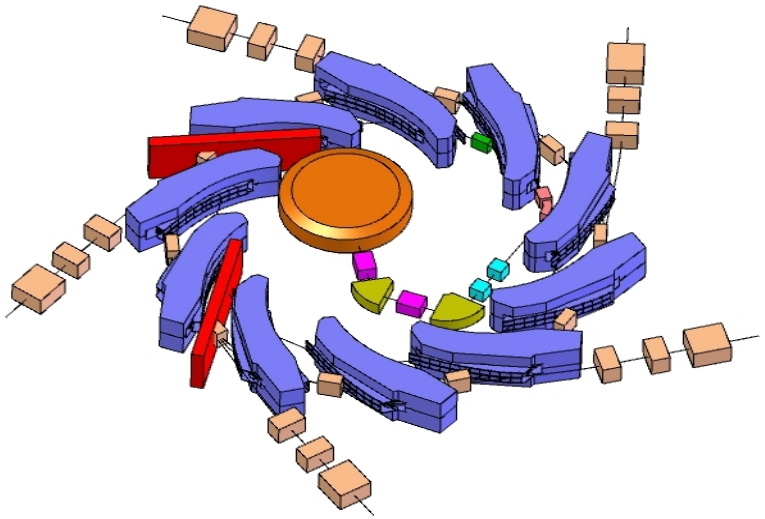
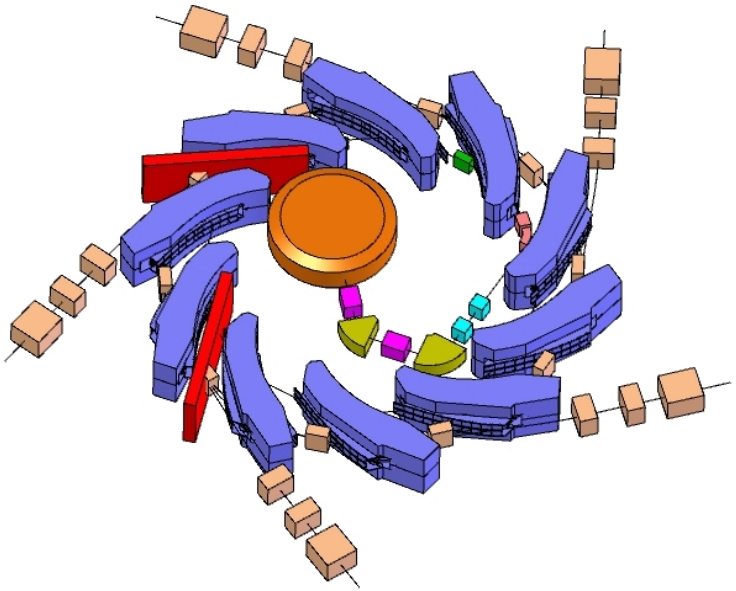
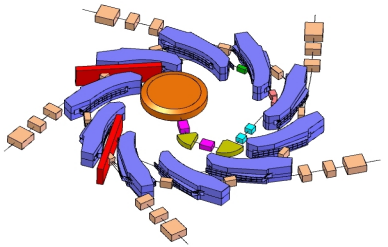


After a presentation at Walter Reed National Military Medical Center as part of the answer to an RFI, by

Particle Accelerator Corp.

17 Jan, 2014





Our starting point in this medico-economical point:

The consideration that

present cost of an irradiation session is ~750 €,

about 3x IMRT (250 €)

Can it be lowered? By how much ?

Contributors :

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(c) Protontherapy-oncologist, MD, Pr – Orsay and Nice pTh Centers

(d) Medical physicist, Grenoble University Hospital

(e) Civil engineering agency, specialized in the construction of hospitals - SNC-Lavallin, Lyon

bibliography :

- Principes d'un centre de hadronthérapie basé sur le synchrotron à champ fixe RACCAM, F. Méot, Y. Mori, Tech. Note BNL C-A/AP/432 (2011)

- Etude medico-economique d'un centre de protontherapie equipe d'un accelerateur FFAG a extraction multiple : RACCAM, Ch. Mazzara, Internship report, CNRS/IN2P3 /LPSC (2010).

Cost calculation, costing models :

[14] Cout de l'installation RACCAM, F. Méot , Int. rep. CNRS/IN2P3 LPSC (RACCAM) (2009). http://lpsc.in2p3.fr/service accelerateurs/raccam.htm

[15] A. Peeters, Radiotherapy and Oncology (2010)

[17] Huybrechts M, Obyn C, Gailly J, Mambourg F, Vinck I, Ramaekers D. Hadrontherapy. Health Technology Assessment (HTA), Brussels: Federaal Keniscentrum voor de Gezondheidszorg (KCE).

[18] Peeters A, Grutters JP, Pijls-Johannesma et al., How costly is particle therapy? Cost analysis of external beam radiotherapy with carbon-ions, protons and photons. Radiother Oncol. 2010 Apr;95(1):45-53

[19] Lambin P, Fekkers H, Daniels E, et al. Euregional ion therapy institute. Maastricht: Business Plan; Internal report, unpublished. 2005.

[A PARENTHESIS IN PASSING : A "SYNCHROTRON RADIATION USER'S FACILITY"]

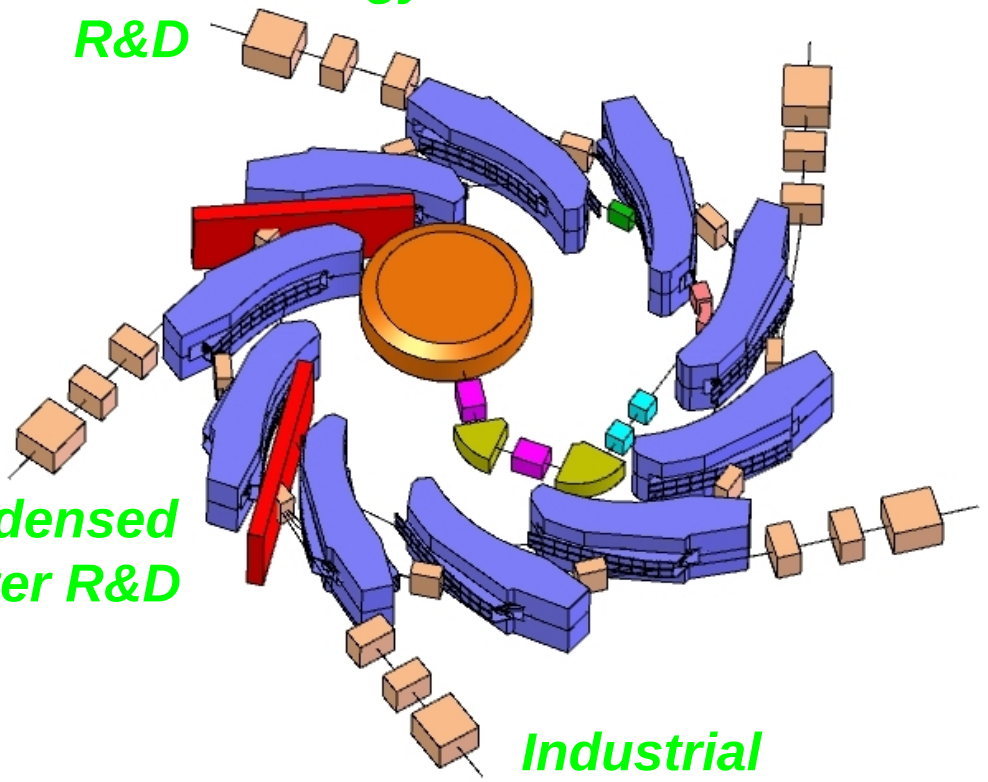
- **Various particle species, delivered to a community of users, at various energies around the ring.**

- **The limitation in energy stems from the rigidity,**

e.g., 6.35 T.m allows

430 MeV/u C, ~1.2 GeV p,

and any other, He, Li, ...

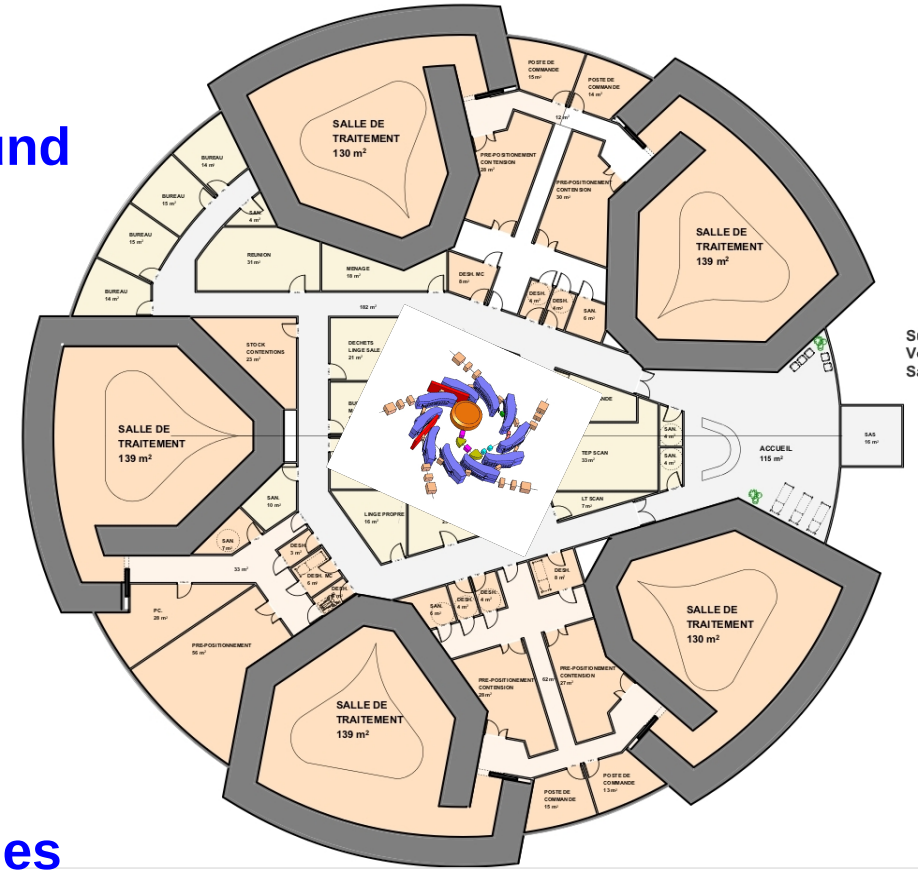


THE RACCAM MULTI-PORT, SIMULTANEOUS BEAM DELIVERY LAYOUT

- Simultaneous delivery to 5 rooms
- In a 2π/N-polygonal arrangement
- FFAG accelerator located underground

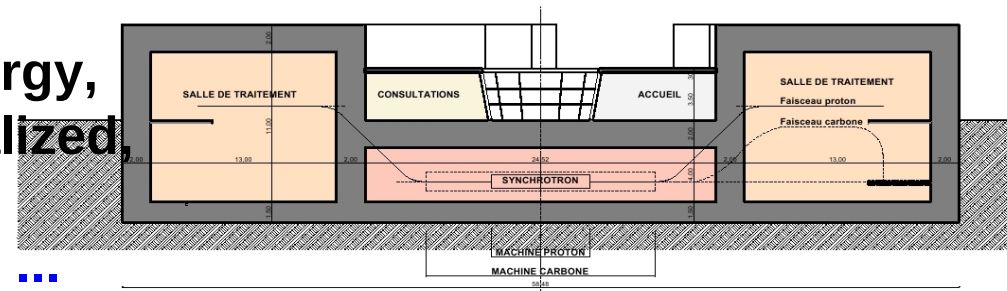
o Various ways of dealing with beam energy are foreseeable :

- global variation of beam energy by varying the accelerator B field
- "synchronized kick extraction" at arbitrary energy in a given room
- rooms with "fixed" energy [J. Flanz, MGH, priv. Comm.]
- a combination of the above
- 10-50 MeV range-shifters in beam lines add flexibility



o Another possibility : a single energy, same at all ports, indication-specialized, e.g., an "Eye Treatment Hospital", a "Head-Neck Treatment Hospital", ...

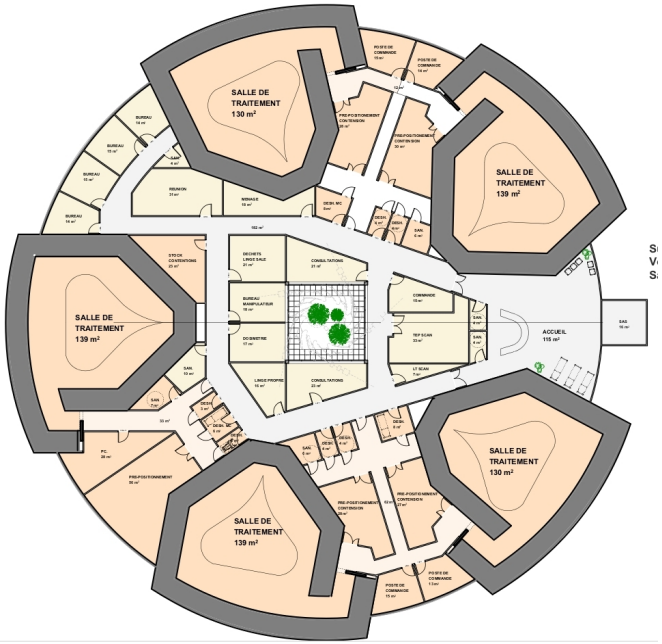
AGC & SNC-Lavallin



Underground space is sized for Carbon FFAG

PROPERTIES OF A CYLINDRICAL SYMMETRY LAYOUT

A classical, rectangular-layout model, with single extraction hence sequential beam delivey, has been designed for comparison, with operational surface equivalent to that of the cylindrical multi-port delivery layout.



Outcomes of the comparison:

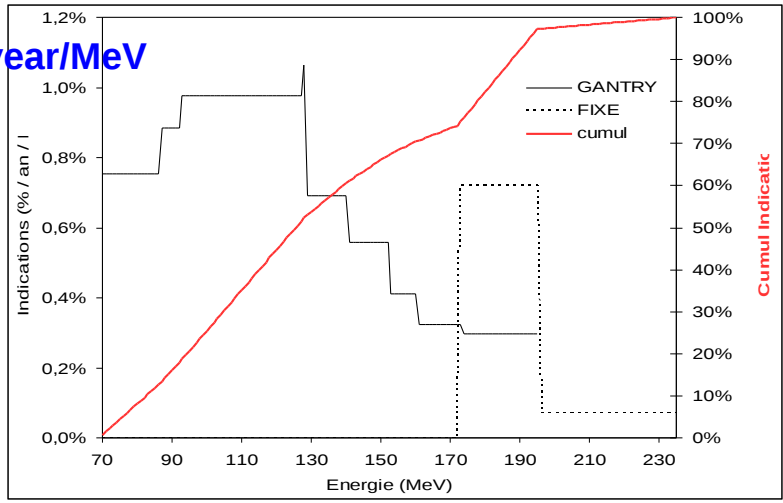
- **Smaller footprint :** **58*58~3400 m² versus 87*48~4200 m²**
- **A reduction of non-productive surface (e.g., beam transport area)**
- **Cost of building reduced : 16 M€ versus 18 M€**
- **Reduced walking distances and flux, both for personnel and patients**
- **Reduced operational costs**

COMPUTING SESSION COST : WORKING HYPOTHESES

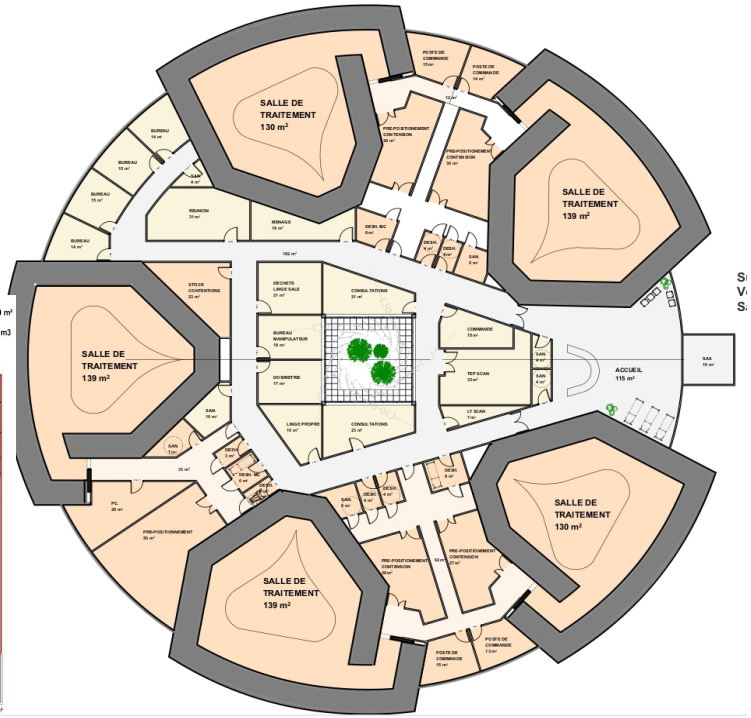
o **The reference layout in this impact study regarding session cost has been assigned *all the features of a conventional hadrontherapy center* sized for 5 treatment rooms :**

- 4 treatment rooms with 200 MeV gantries
  + 1 room with horizontal beam
- 6 rooms for medical examinations
- 6 specialized rooms (ORL/2, pediatry/2, Ophtalmo/2)
- specialized waiting rooms (children, adults, reduced mobility)
- 3 rooms dedicated to anesthesy process
- a specific pathway for child patient
- etc.

o The same hypotheses are considered in the compared rectangular layout with single extraction and sequential delivery



An histogram of the recruitment.
Hence 4 x 200 MeV gantries.



MULTI-PORT SIMULTANEOUS VS SEQUENTIAL BEAM DELIVERY : PATIENT FLOW

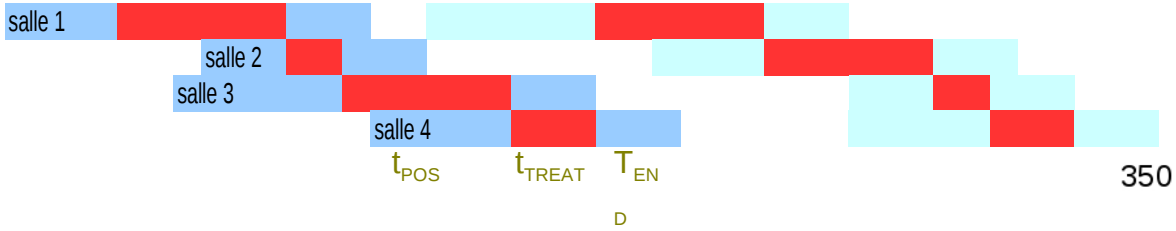
Taking hold	Patient preparation	Verify position.	Irradiation	Recond. Room	Verify treatement	Ending

t_{POS}(8min) t_{TREAT}(7min) $T_{END.}$(7min)

Room Occupation Ratio

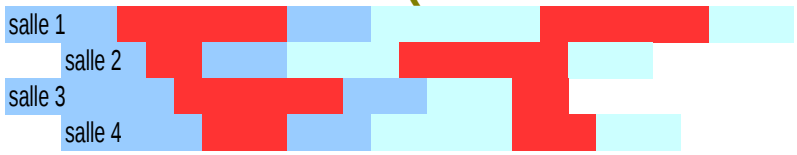
$$ROR = \frac{\overline{t_{POS}} + \overline{t_{TREAT}} + \overline{t_{END.}}}{n\,\overline{t_{TREAT}}}$$

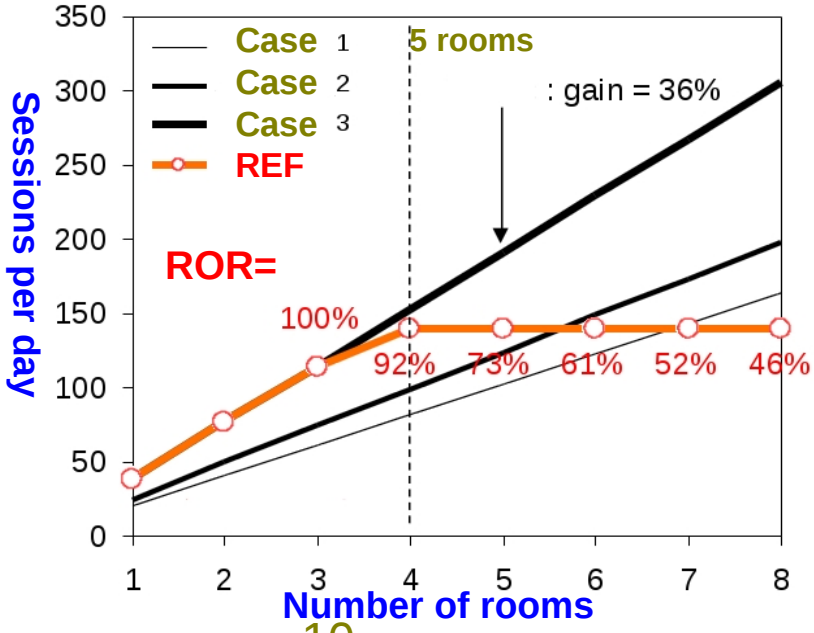
REFERENCE SEQUENTIAL BD (ROR < 100%)



Simultaneous beam delivery eliminates the constraint to correlate the rooms

SIMULTANEOUS BD (ROR close to 100%)





WE HAVE BUILT AN ECONOMICAL MODEL

Précision ~ 10%

$$\overline{C} = \frac{C_{CAPITAL} + C_{OPERATION}}{N_{ANNUAL}}$$

$$C_{OPERATION} = C_{PERSONNEL} + C_{EQPMNT} + C_{CONSMMBLES} + C_{OVERHEAD}$$

On this spreadsheet :

BLUE : values may be varied

WHITE : fixed parameters

ORANGE : intermediate results

YELLOW : overall cost

	photon		proton
CAPACITE			
temps traitement (h / jour)	14		14
jours travaillés / semaine	5		5
semaines travaillées / an	50		50
nb de salles de traitement	2		5
temps traitement (min / an)	420000		1050000
taux de disponibilité des salles (%)	98%		96%
temps moyen / fraction (min)	10		18
nb moyen fractions / patient	18		20
fractions / an	**41160**		**56000**
patients / an	**2287**		**2800**

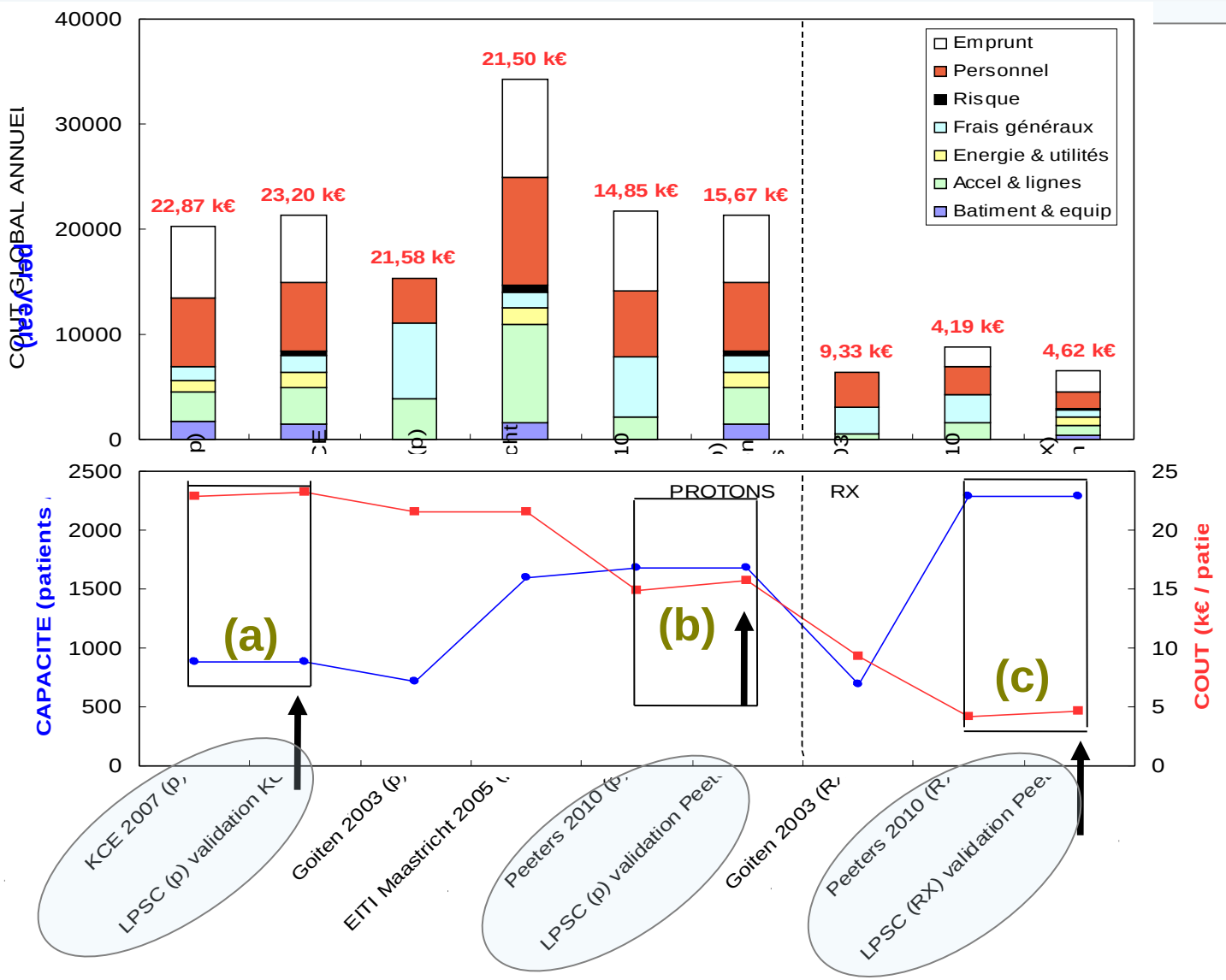
PARAMETRES ECONOMIQUES				
surface (m2)		2000		10000
durée de vie (an)		30		30
durée remboursement (an)		20		20
taux emprunt (%)		5,00%		5,00%
TVA (%)		19,60%		19,60%
inflation salaires (% / an)		2,50%		2,50%
inflation énergie (% / an)		2,00%		2,00%
inflation service (% / an)		2,00%		2,00%
salaire moyen 2010 FTE (k€ / an / pers)		77		77
patients / FTE		56,609		17,125
personnel (FTE)		**40**		**164**

COUT CAPITAL TTC (k€ / an)		**29604**		**114435**
batiment (k€ HT)	9180	10979	24000	28704
conception & gestion projet (k€ / m2)	0,1	200	0,4	4000
équipement médical général (k€)		7000	0,864	8640
accélérateur (k€)		5000		7000
lignes de faisceau (k€ / m)		0	15	
lignes de faisceau (m)		0	100	1500
faisceau fixe (k€ / faisceau)		0	5000	5000
gantry (k€ / gantry)		0	10000	40000
TPS (k€)		2500		2500
PET-CT (k€ / unité)		0	2300	2300
imprévus (k€)		0		0
risque batiment (k€ / m2)	0,375	750	0,375	3750
risque équipement	0,15	2175	0,15	10041
mise hors service après 30 ans (k€)		1000		1000

COUT OPERATIONNEL (k€ / an)		**10575**		**36700**
1 **RENOUVELLEMENT D'ACTIF (k€ / an)**		**829**		**1591**
batiment (% pa)	3%	329	3%	861
TPS (% pa)	20%	500	20%	500
dépréciation diagnostic (% pa)			10%	230
2 **GESTION D'EQUIPEMENT (k€ / an)**		**482**		**4245**
propriété (€ / m2)	15	30	15	150
maintenance batiment (€ / m2)	8	16	8	80
maintenance services (€ / m2)	15	30	15	150
maintenance équip. généraux (€ / m2)	20	40	20	200
maintenance bureaux (€ / m2)	7	14	7	70
maintenance surfaces & jardins (€ / m2)	1	2	1	10
maintenance équip. traitement (% pa)	7,00%	350	6,70%	3585
3 **ENERGIE & UTILITES (k€ / an)**		**828**		**1537**
conso proton traitement (kW / h)		0		600
nb heures / jour (h)		0		16
conso proton traitement (MWh / an)		0		2400
conso proton hors traitement (kW / h)		0		250
conso proton hors traitement (MWh / an)		0		1190
autres consommations (MWh / an)		5000		5000
TOTAL (MWh / an)		**5000**		**8590**
électricité (€ (HT) / MWh)	98	586	98	1007
gas (€ / m2)	6	12	6	60
eau (€ / m2)	4	8	4	40
égouts (€ / m2)	3	6	3	30
4 **FRAIS GENERAUX (k€ / an)**		**1731**		**2818**
télécommunications(€ / m2)	10	20	10	100
déchets (€ / m2)	4	8	4	40
lingerie (€ / m2)	0,4	1	0,4	4
nettoyage (€ / m2)	35	70	35	350
services stériles (€ / m2)	2	4	2	20
courrier & impressions (€ / m2)	4	8	4	40
sécurité (€ / m2)	2	4	2	20
assurances pour essais (k€ / an)		0		0
autre (€ / m2)	11	22	11	110
fournitures médicales (€ / patient)	500	1143	500	1400
EMPRUNT (k€ / an)		**1960**		**7576**
supplément construction (% capital)	10%	2960	10%	11444
capital initial (k€)		32565		125879
apport initial (%)	25%	8141	25%	31470
somme empruntée (k€)		24424		94409
RISQUE (k€ / an) (% 1+2+3+4)	5%	**194**	5%	**510**
PERSONNEL (k€ / an)		**4552**		**18424**

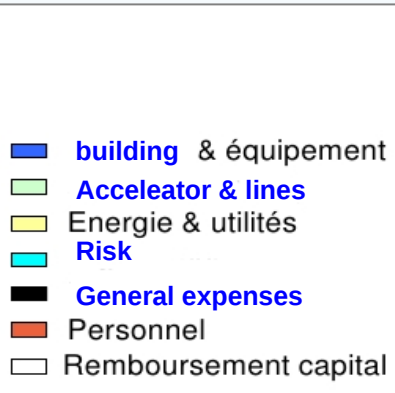
cout / fraction (€)	**257**	**655**
cout / patient (k€)	**4,62**	**13,11**

OUR MODEL HAS BEEN BENCHMARKED AGAINST EXISTING ONES

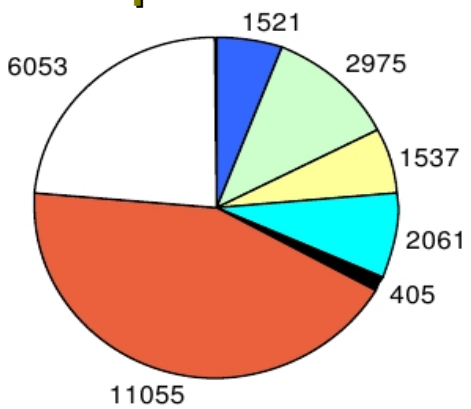


Our version of the costs (black arrows) use the same data as compared ones, respectively, (a) "KCE", (b) "Peeters -proton", (c) "Peeters-RX"

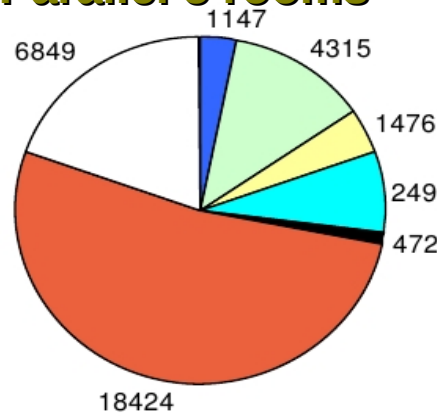
COSTING & VARIABILITY STUDY OF THE MULTI-PORT HOSPITAL



Sequ. 3 rooms



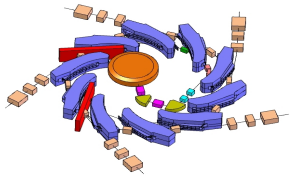
Parallel 5 rooms



- **What favors an increase towards X-ray's 56 patients / FTE, in the simultaneous BDS case :**
  - **simultaneous BDS increases treatment capacity**
  - **cylindrical layout reduces flux of patient & personnel**
  - **a number of functionalities can be shared**

	State of art [15]		Simultaneous beam delivery, 5 rooms								
	IMRT	proton	base	A	B	C	D	E	F	G	H
	14	14	14								16
	5	5	5								
	50	50	50								
	2	3	5							10	
	98%	96%	96%	80%							
/ fraction (min)	10	18	18		22						
fractions / patients	18	20	20								
patients / FTE	56,609	17,125	17,125			56,609	30	40	50	40	40
(m€)	10,979	28,704	23,92							40	
	2287	1680	2800	2333	2291	2800	2800	2800	2800	5600	3200
personnel (FTE)	40	98	164	136	134	49	93	70	56	140	80
[15] / fraction	233 €	743 €									
LPSC / fraction	257 €	762 €	628 €	681 €	687 €	399 €	487 €	440 €	412 €	407 €	407 €
ratio / RX	1,00	2,96	2,44	2,65	2,67	1,55	1,89	1,71	1,60	1,58	1,58
gain / [15]			-18%	-11%	-10%	-48%	-36%	-42%	-46%	-47%	-47%

CONCLUSIONS



- **Introducing the « Room Occupation Ratio », a significant gain in capacity, based on simultaneous beam delivery, has been demonstrated**

- **The simultaneous beam delivery method favors today's trend that *more time should be allowed in the treatment room [S. Meyroneinc, IC-CPO, priv. Comm.]***

- **The 2π/N-symmetry building layout reduces costs : construction, equipment, operation, ...**

- **An economical model has been constructed & validated (accuracy ~ 10%), and shows the strong impact of manpower on cost**

- **Simultaneous beam delivery favors the patient/FTE ratio, with potential effect of substantially decreasing the cost of an irradiation session (X-R is ~257€/session):**

SEQUENT. BEAM DELIVERY, 5 ROOMS	SIMULTANEOUS BEAM DELIVERY, 5 ROOMS		
17 (~STD)	30(~half-way)	56(~X-R)	patients / FTE
628	487	399	€ / session
-18%	-36%	-48%	reduction (wrt. state of the art, 3 rooms)

THANK YOU FOR YOUR ATTENTION

SO... €750 → €400 ?