F. Méot, CEA & CNRS
LPSC, Grenoble

The RACCAM FFAG project 2006 - 2008

ANR Contract

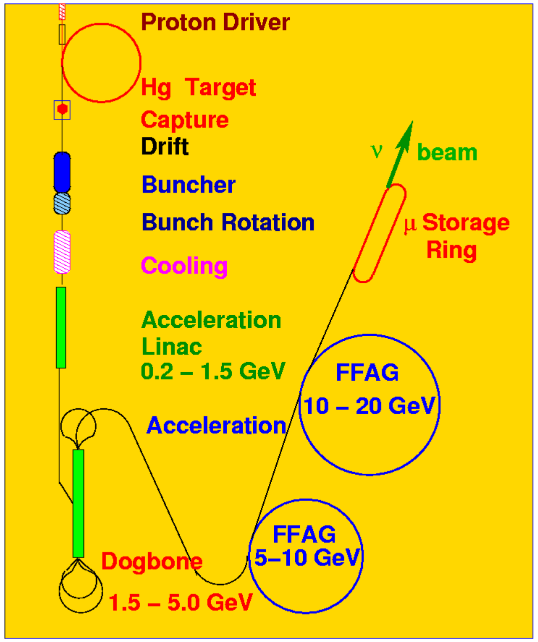
Contents

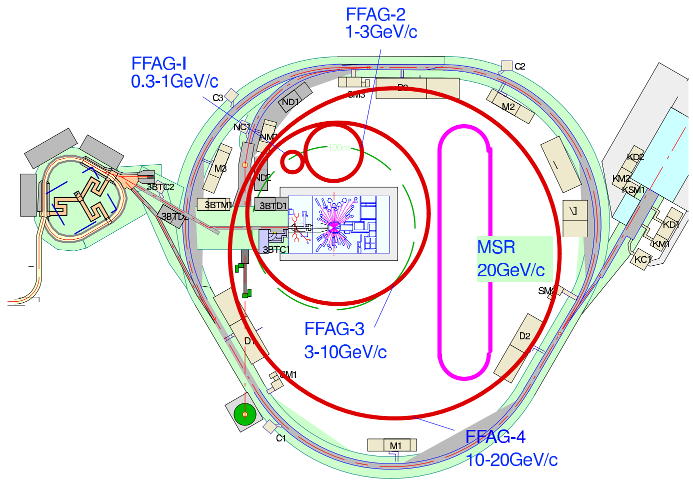
1 Why a FFAG project

1.1 HEP programs in our Labs.

- Strong commitment in Neutrino Factory projects, within CARE/BENE EU FP6 funding program.

Muons are brought to storage energy using the FFAG method : allows large acceptance, rapid acceleration.





- RACCAM was born in the frame of these NuFact activities, and as such seen as a way to enhance our expertise and involvement in FFAG accelerators R&D.

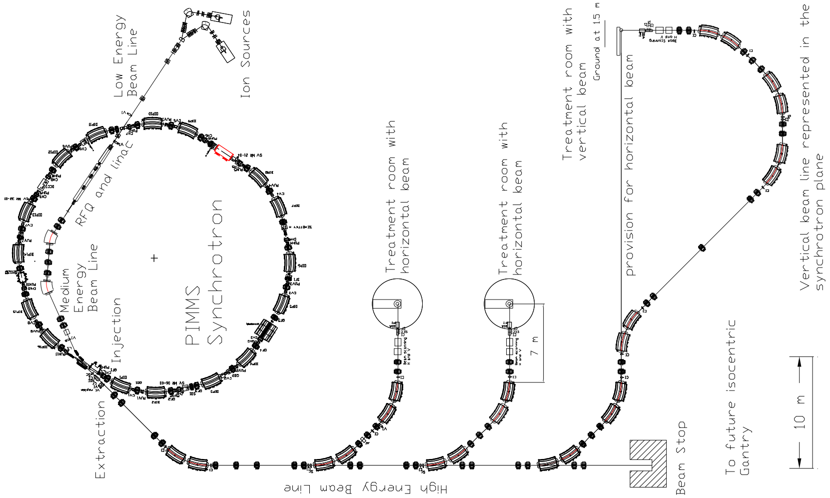
- Hence the first goal in RACCAM :

- constitute in France a team of accelerator physicists and engineers
active in FFAGs,
in the on-going international collaborations,
at beam dynamics, magnet calculations, etc.,

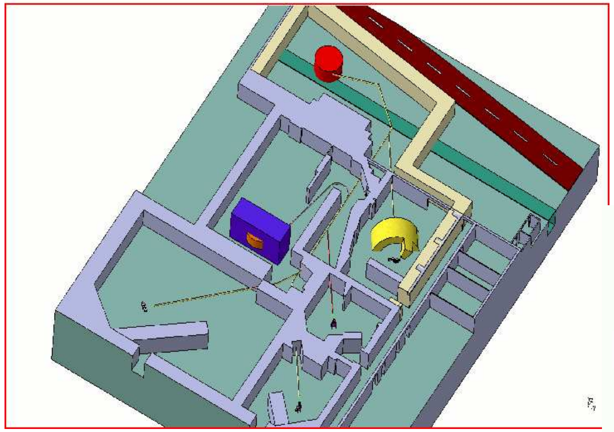
- this also means, contribute to the electron models of a non-scaling FFAG / EMMA

1.2 Why medical application

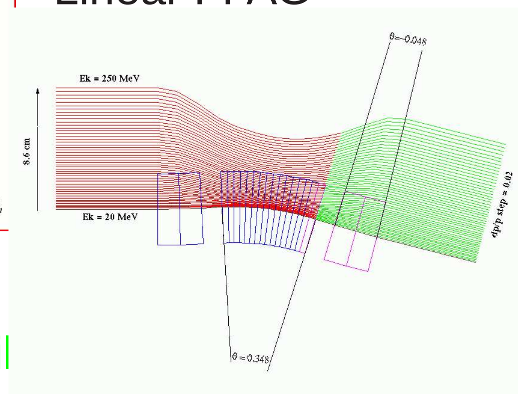
(i) The medical side in RACCAM can be understood as a sub-product of hadrontherapy facility design activities in our Labs. these last 5-6 years.



Le projet d'établissement du CPO 2004-2008



Linear FFAG



(ii) It also relies on an important precept :
"If a technological breakthrough could make proton beams easily available to radiotherapy, protons would totally dominate radiotherapy and would undoubtedly represent in the future more than two thirds of the indications, if not even more. This is a domain with potentially very strong development, with purely technical and economical constraints."

Scaling FFAG

- Hence the second goal in RACCAM :

- contribute to application of FFAGs in the medical domain,
with the goal of a second generation medical synchrotron,
performing better, simpler to build and to operate,
more compact, cheaper than conventional pulsed synchrotrons.

1.3 Magnet prototyping

- The 3rd goal in RACCAM is magnet prototyping,
  this is done in association with SIGMAPHI,
  in relation with the medical R&D in RACCAM application,
  and we have in view the following :

* Compactness of the ring (cyclotron type of size)

* Technological simplicity of the magnet

* In that respect scaling spiral lattice is very attractive, provides
  - simplest cell (! dipole)
  - smallest circumference factor in the FFAG method

* Designing an adjustable-K, spiral magnet for a proton ring in the 200 MeV range, which is still a challenge

* achieve a variable energy FFAG design

* multiple extraction

1.4 RACCAM team

Bruno Autin	LPSC, collaborator
Jacques Balosso (MD)	Gren. Hospital
Johann Collot	LPSC
Joris Fourrier (PhD)	LPSC
Emmanuel Froidefond	LPSC
Franck Lemuet	CEA & CERN
François Méot	CEA & LPSC
Damine Neuveglise	SIGMAPHI
Jaroslaw Pasternak	LPSC
Thomas Planche (PhD)	SIGMAPHI
Pascal Pommier (MD)	Lyon Hospital
students	
Florence Martinache	ENSPG (2006)
Abdulhamed Chaikh	Medical Phys., Gren.
Matthias Grimm	Munich Univ.
Jean-Baptiste Lagrange	ENSPG

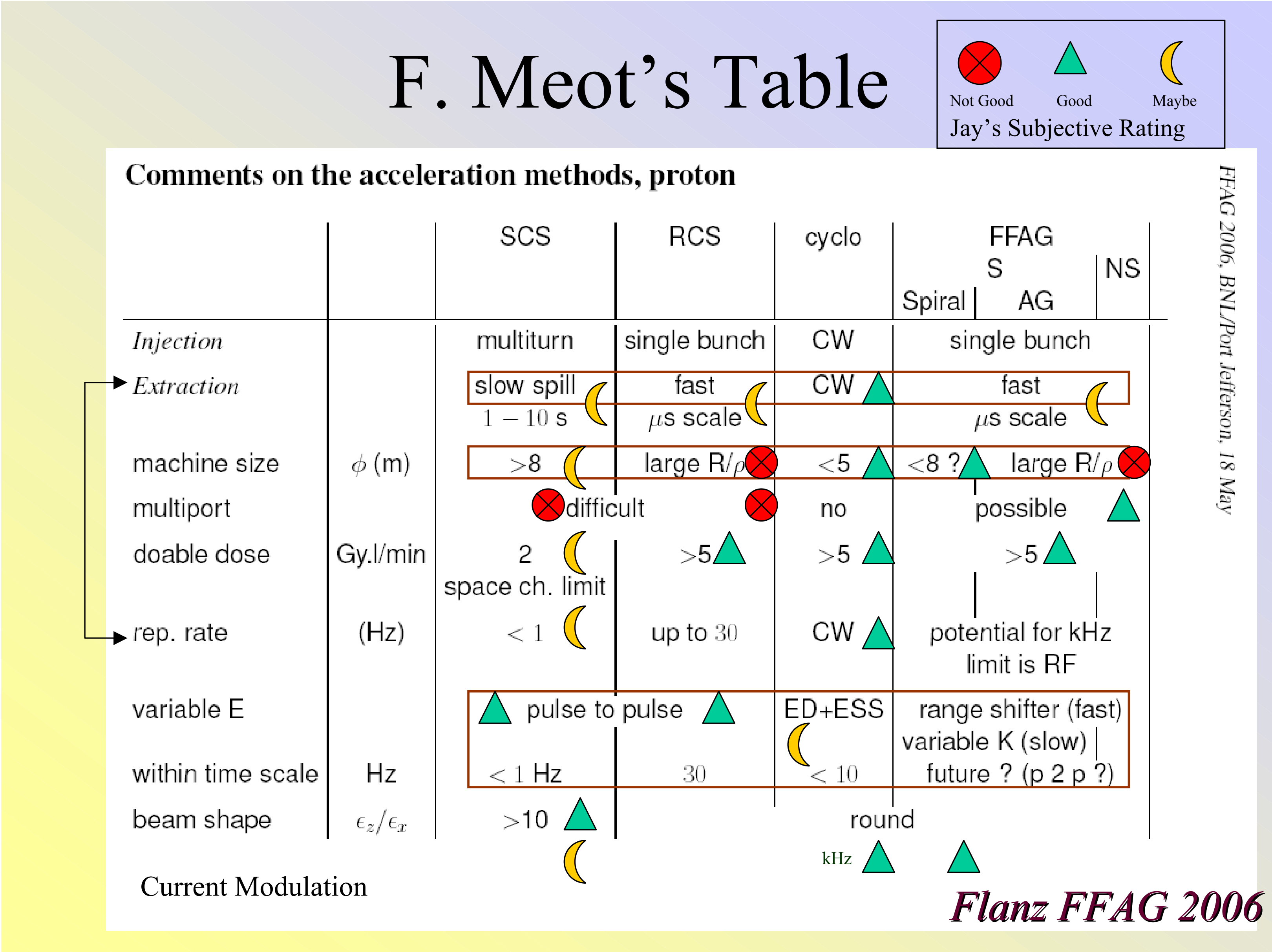
Establishing collaboration with MEDICYC p-Therapy center, Nice, in view of

180 MeV upgrade project,
FFAG based

LPSC : 6 + students, SIGMAPHI : 2, Hospital : 2

2 Hadrontherapy R&D in RACCAM

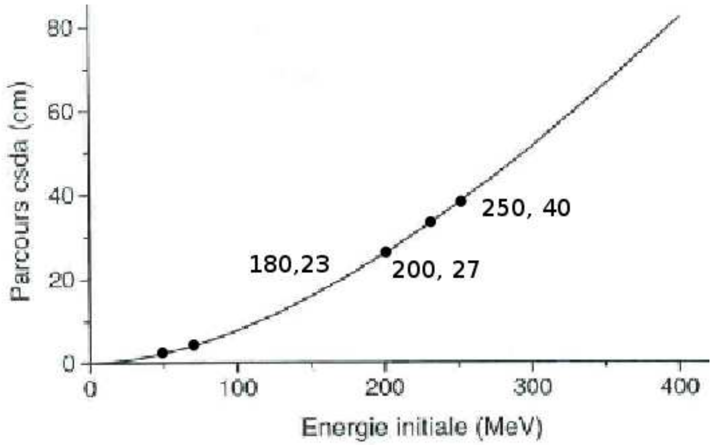
Why FFAG ? **Seen at FFAG 2006 Wrkshop, BNL - J. Flanz :**



		SCS	RCS	cyclo	FFAG S Spiral	FFAG S AG	FFAG NS
Injection		multiturn	single bunch	CW		single bunch	
Extraction		slow spill $1 - 10$ s	fast μs scale	CW		fast 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) future ? (p 2 p ?)	
within time scale	Hz	<1 Hz	30	<10			
beam shape	ϵ_z/ϵ_x	>10		round			
Current Modulation				kHz			

Hadrontherapy - FFAGs have potentialities for best fufillment of medical use requirements

Bragg peak epth-energy dependence



[After discussions with J. Flanz, FFAG 2006 Wrkshop, BNL]

Clinical properties of the beam and accelerator		
Range	2 - 30 cm in water	$50 - 230$ MeV extraction
Dose Rate	potential for > 5 Gy/min$\times$liter	High average I
Distal falloff	no (or vry limited) Bragg peak spread	variable E
Beam characteristics		
Current	potential for $>$100 nA, av.	high rep. rate
Current dynamic Range	$\times$10s	either av. or peak
Energy Range	goal 70 - 230 MeV	variable B_0/E_{inj}
		synchronized xtraction kick, ...
Energy spread	10^{-3}	
beam delivery	machine dependent ?	FFAG specific BDS ?
Expected operational performance		
Beam stability	very high	fixed field
Availability	very high	technological simplicity
Reliability	very high	ibid.
Complexity	very low	ibid.

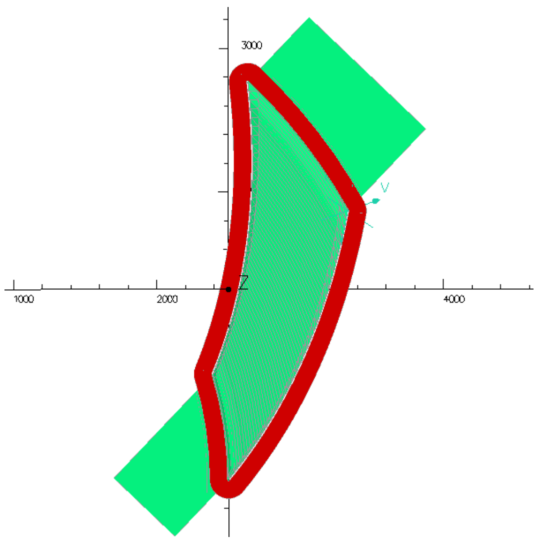
RACCAM hadrontherapy R&D - on-going studies
(i) Magnet prototyping, (ii) proton ring design,
(iii) medical specifications for FFAG beams | Talk by J. Balosso |

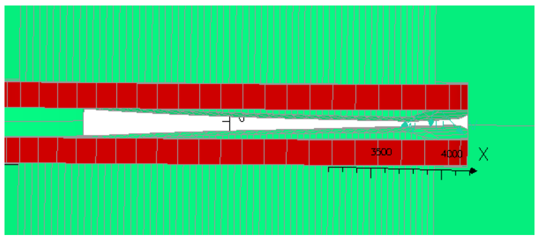
Magnet prototyping
by SIGMAPHI and LPSC

- **Consruction 2007**
- **Tests 2007 - 2008**

Talks by D.Neuvéglise, Th.Planche, E.Froidefond

$$B(r,\theta) = B_0 \times (r/r_0)^k \times flutter(r,\theta)$$

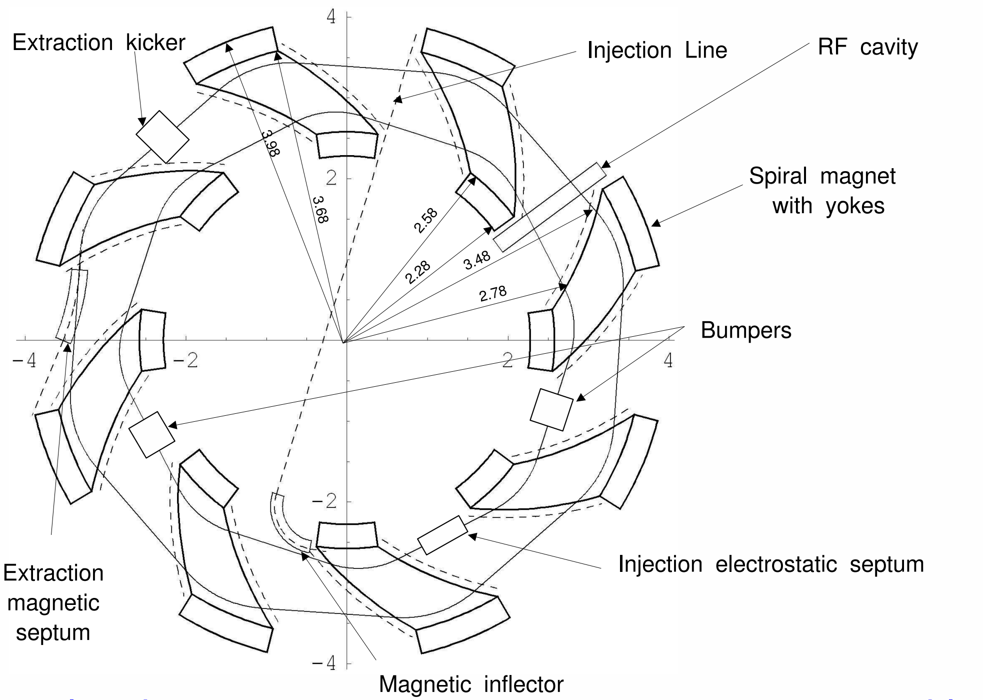




Validation of magnet options by lattice design, BD studies

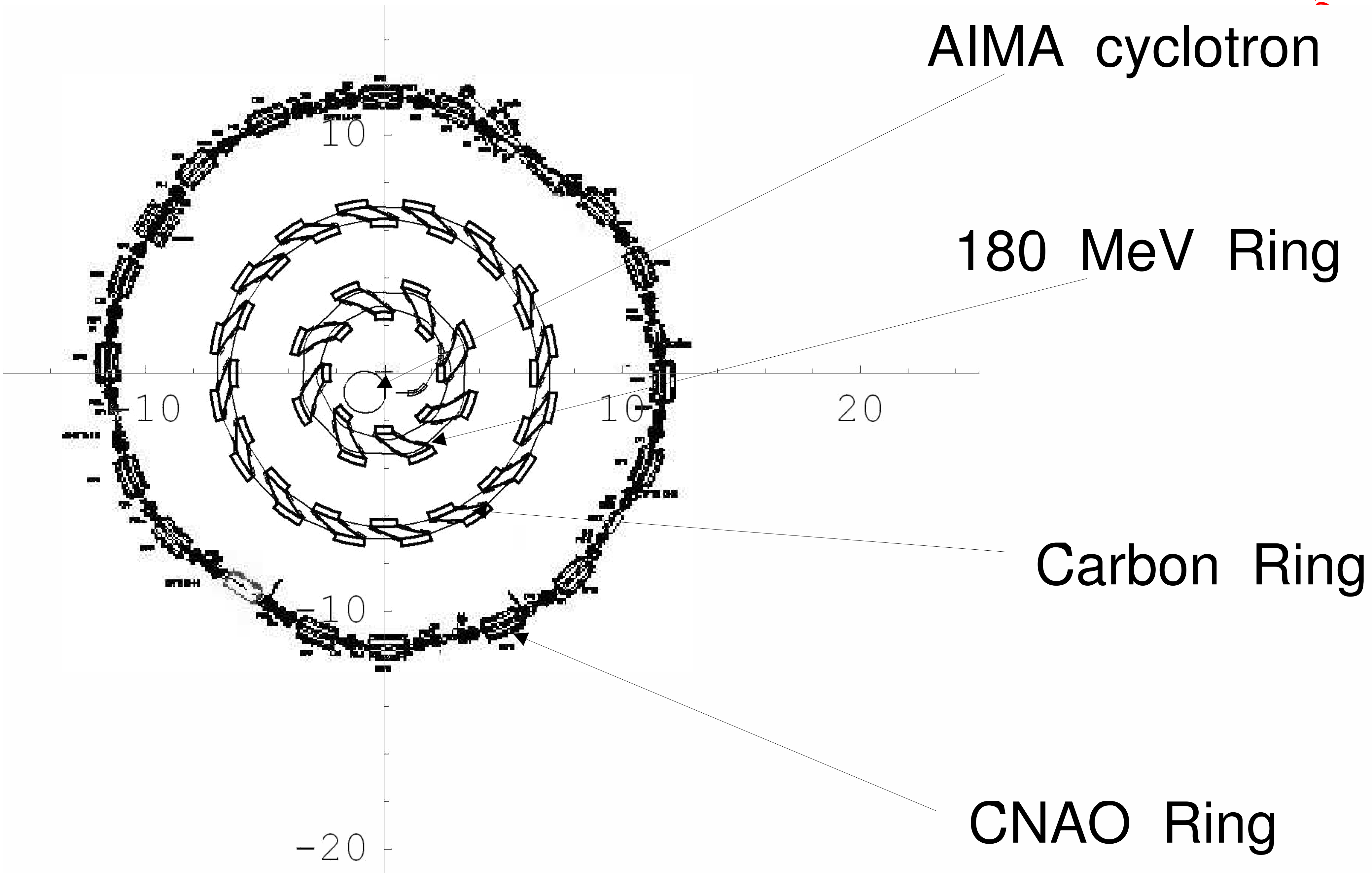
- **In view : 180 MeV upgrade of the 65 MeV existing cyclotron based installation**

Talks by M.Conjat/J.Mandrillon, J.Fourrier, J.Pasternak



Acceleration range : $6 \rightarrow 70$ MeV to $17 \rightarrow 180$ MeV, tunable
Prospects for bunch to bunch energy variation

Thinking further : compact Carbon ring



3 HEP FFAG R&D

RACCAM R&D activities avec a strong overlap with

NuFact collaborations ISS, CARE/BENE	muon acceleration
EMMA, Daresbury	electron model of linear FFAG

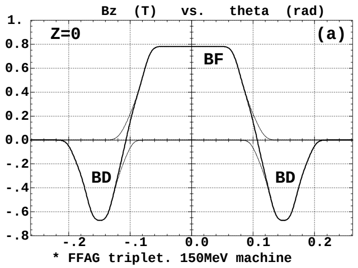
Neutrino factory

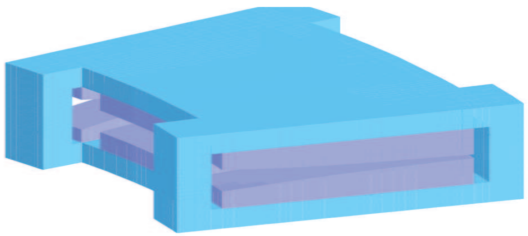
- BD code development
- tracking simulations

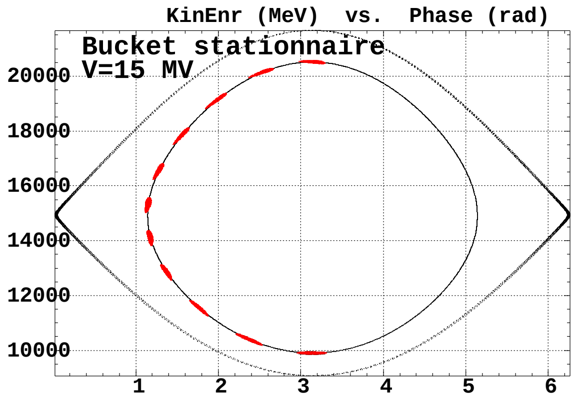
Application, examples :

Full 6-D simulation of muon beam transmission in

scaling FFAG / DFD triplet cell



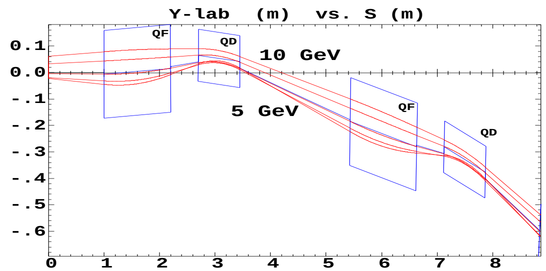


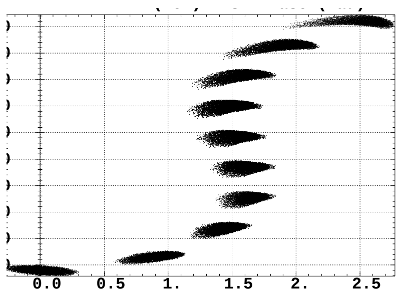


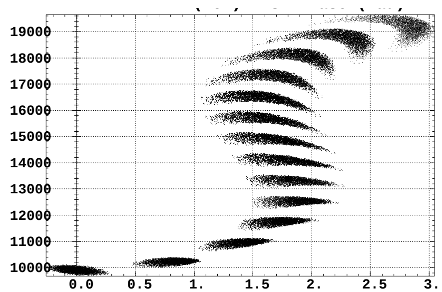
10 – 20 GeV

$\epsilon_x = \epsilon_z = 3\,\pi\text{cm},\ \epsilon_l = 0.05$ eV.s

linear FFAG / FD doublet cell





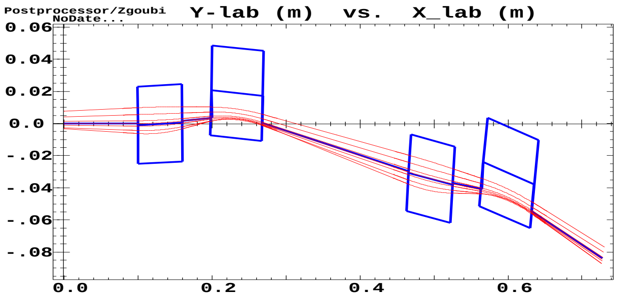


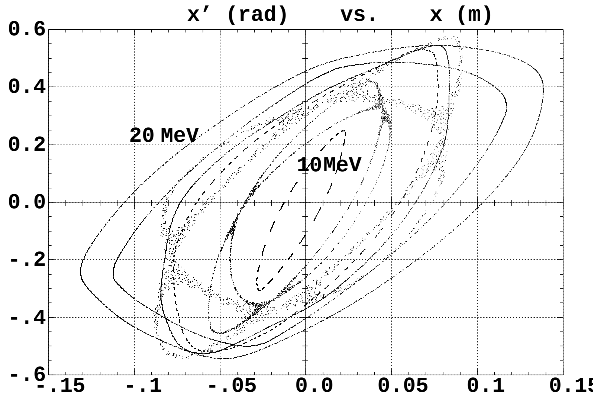
5 - 10 GeV 10 - 20 GeV

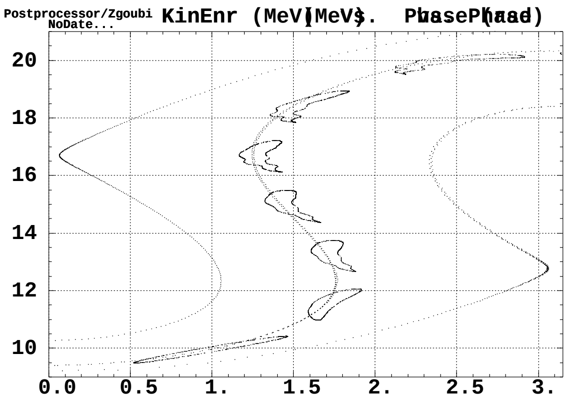
$\epsilon_x = \epsilon_z = 3\,\pi\text{cm},\ \epsilon_l = 0.05$ eV.s

e-modeling

EMMA : 10 - 20 MeV

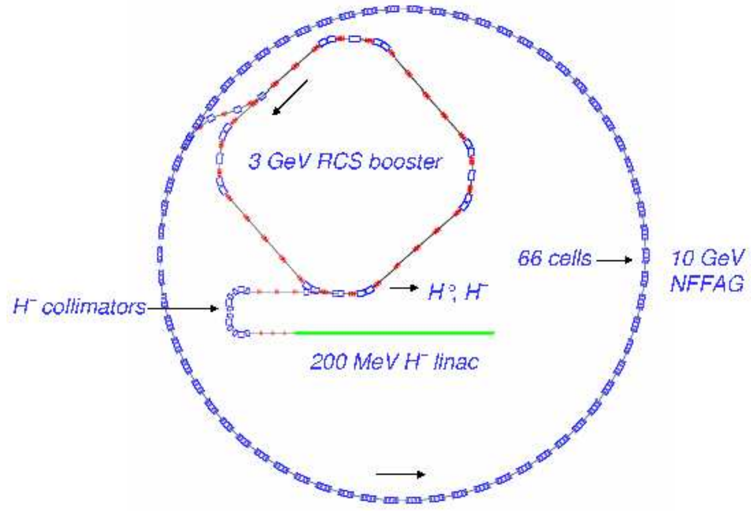


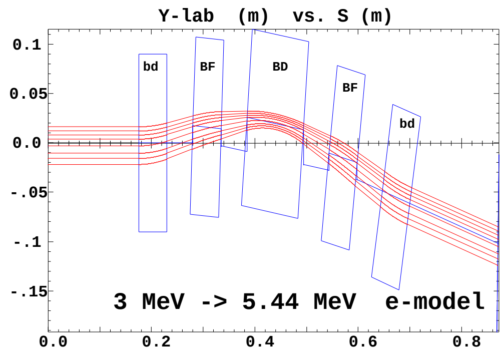


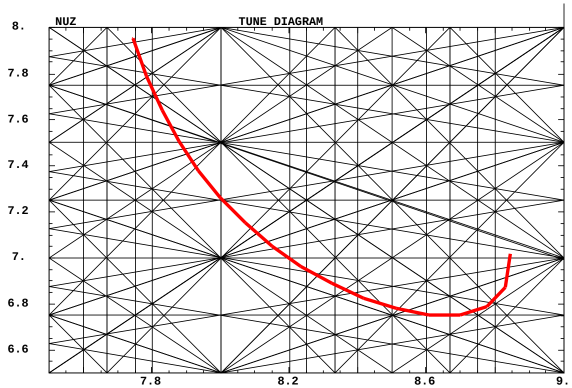


3-10 GeV proton driver model : 3 - 5.44 MeV

Talk by F. Lemuet, Monday







Thank you