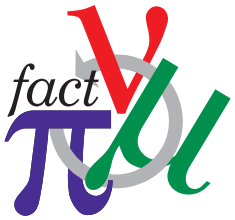


A and DA tracking in NuFact muon chain - status -

F. Méot
CEA & IN2P3
LPSC, Grenoble

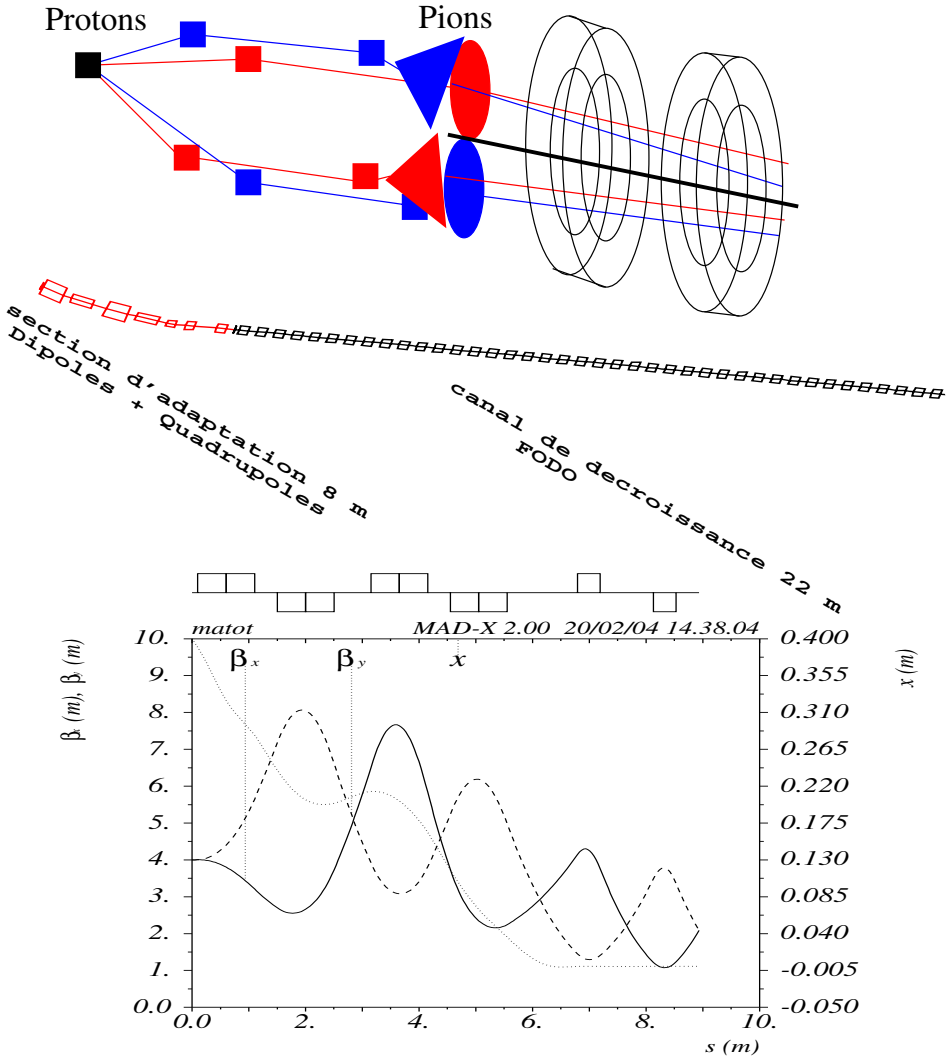
IDS NuFact meeting, Jan. 16-17, 2008, RAL

Contents

1 Muon front end

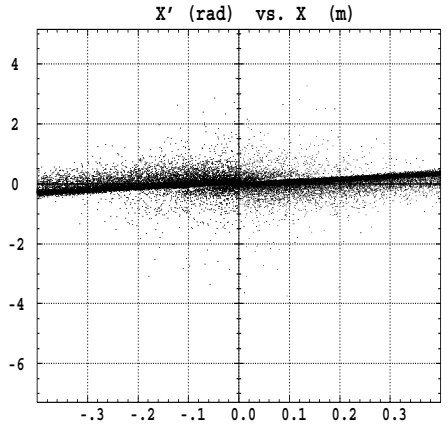
In the 2002-2004 period a muon front end has been studied at CERN, based on a quadrupole funnelling channel (in view of a 4-target system, aimed at decreasing the power on each target), and on a quadrupole collect channel. Transmission of π/μ beam over the 32 meter long structure has been optimized.

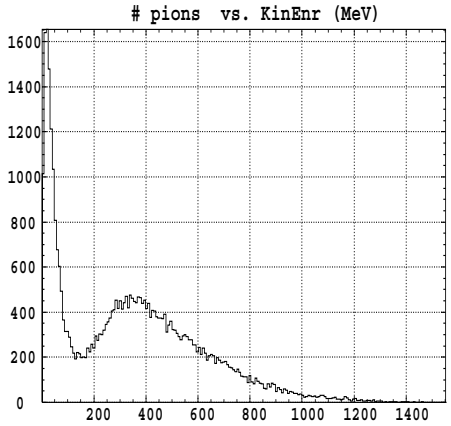
Transmission through a 30 m long purely solenoid channel with optimized field, has been computed for comparison.



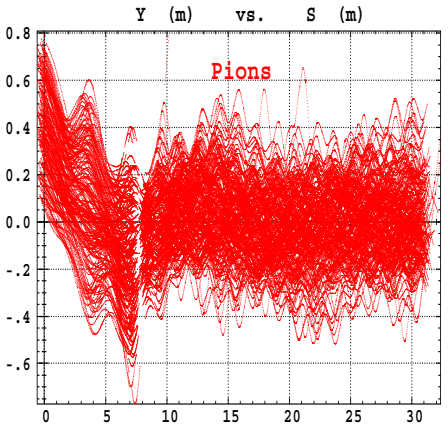
Optical functions and beam centroid orbit in funnel, from horn exit ($s = 0$) to entrance of collect channel ($s = 10$ m).

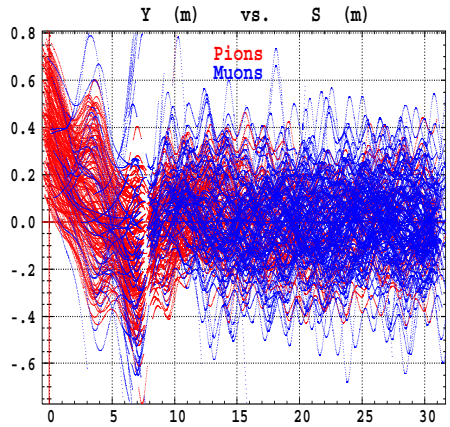
MARS distributions at horn exit are used.





Aperture diameters are 80 cm in funnel, 40 cm in collect channel.



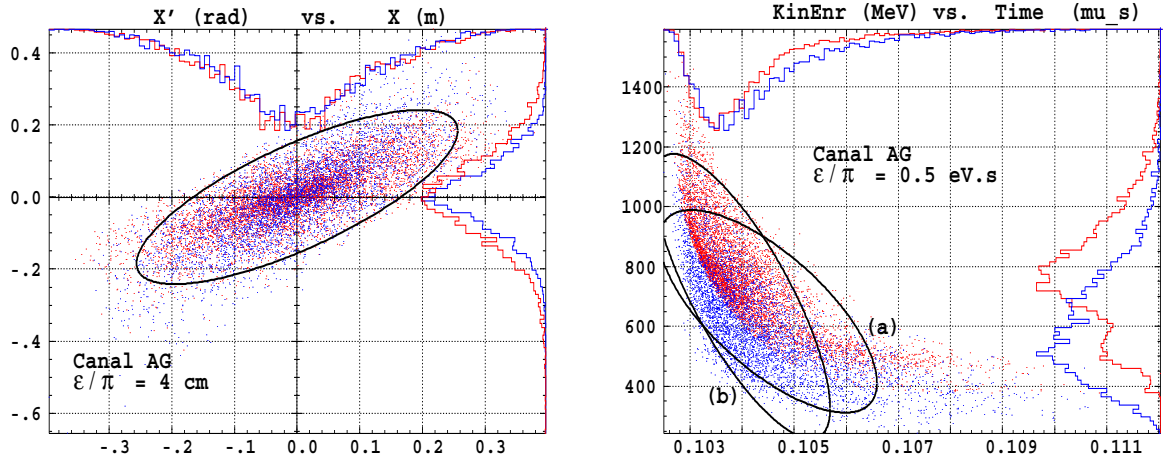


Optimization of transmission :

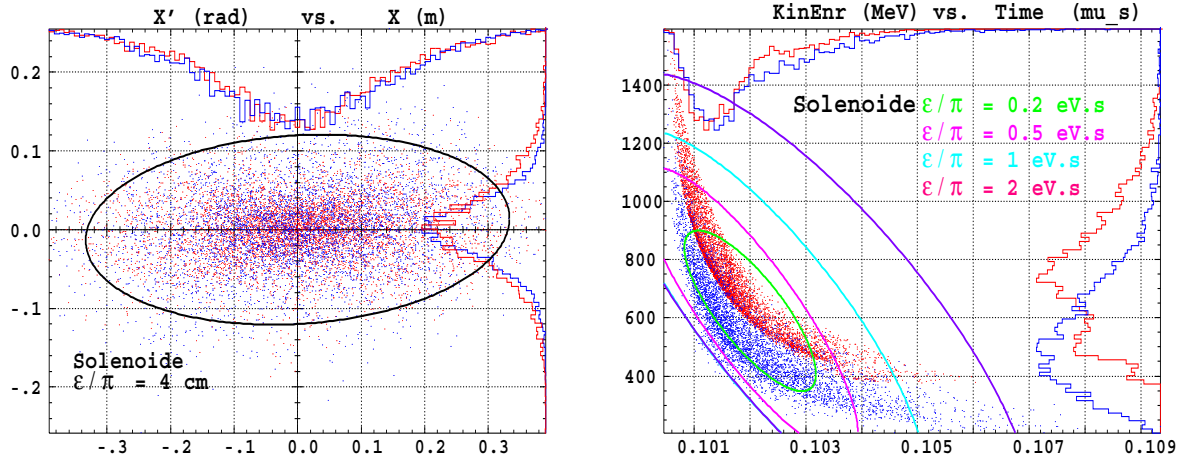
- counting through transverse ellipses (π or 4π, geometrical) and longitudinal ellipses ($0.2 - 2$ eV.s) are maximized,

- fit variables are ellipse shape and positionning, and optical parameters (magnetic fields, etc.).

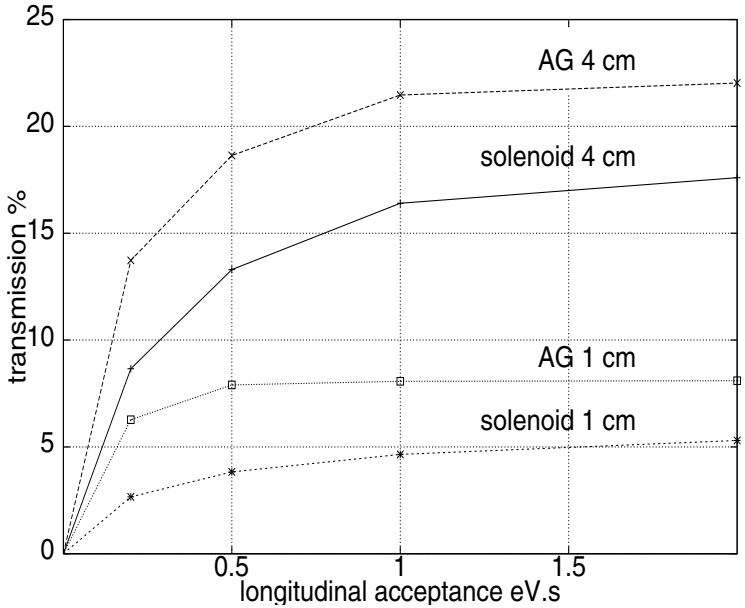
- apertures are fixed, 40 cm in solenoid, 40 cm in quadrupole channel, 80 cm in funnel.



Funnel + quadrupole channel, 32 m long.



Full solenoid channel, 30 m long.



Transmission.

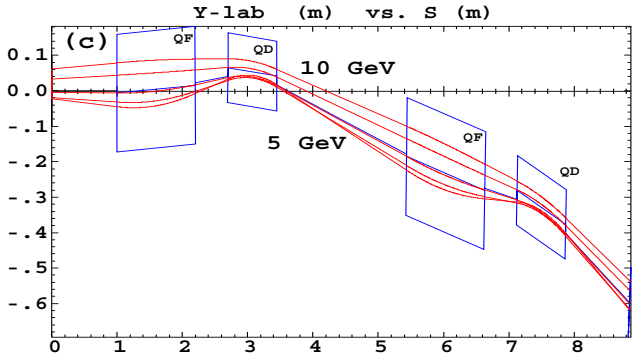
2 Acceleration, US-Study2a FFAG optics

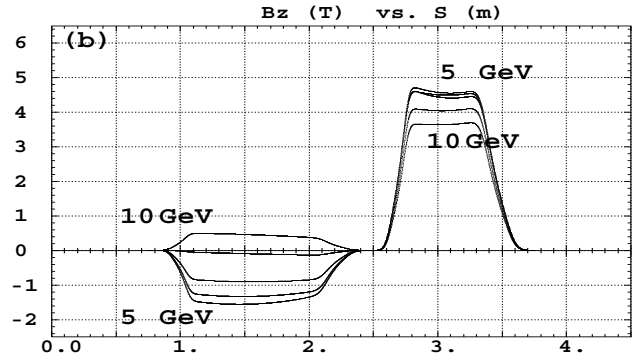
DA in 10→20 GeV NuFact-J scaling FFAG rings has been tracked. Cells of concern are shown below. All characteristics accounted for in these simulations are those given on web ISS-NuFact webpage.

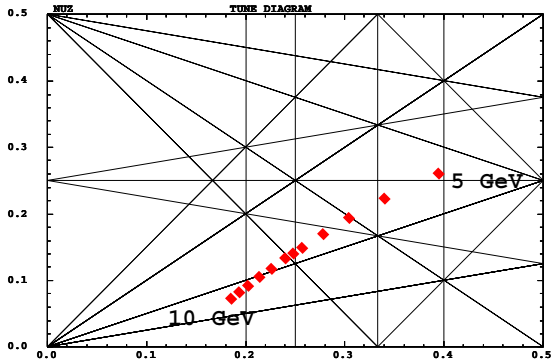
Linear FFAG optics of concern :

5-10 GeV

64 cells, 284 m circ., 10.3 turns

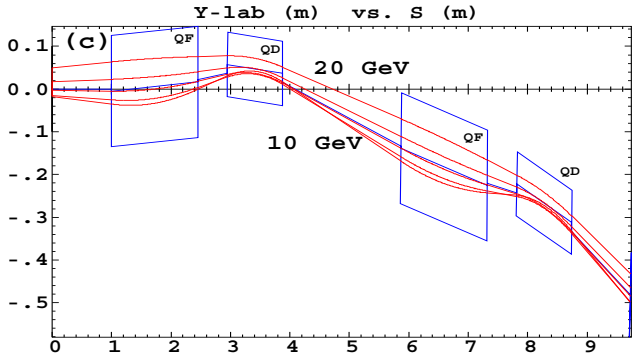


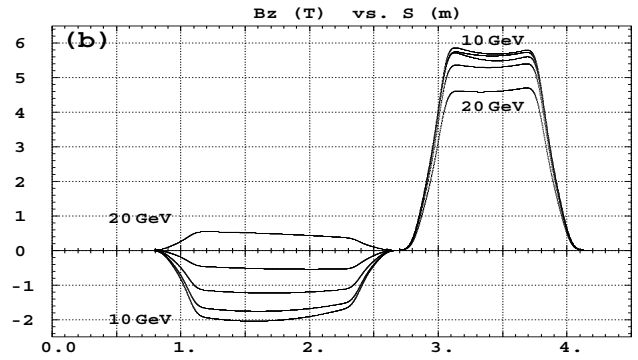


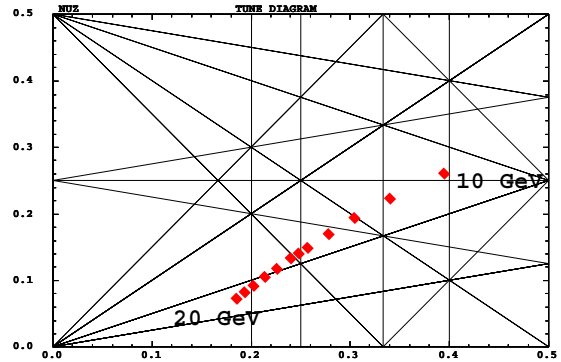


10-20 GeV

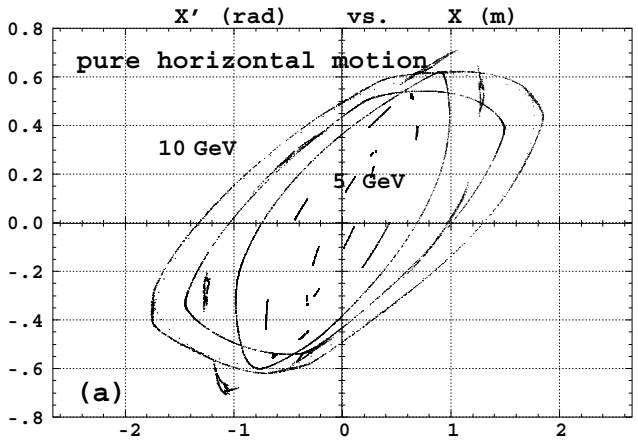
84 cells, 409 m circ., 15.5 turns

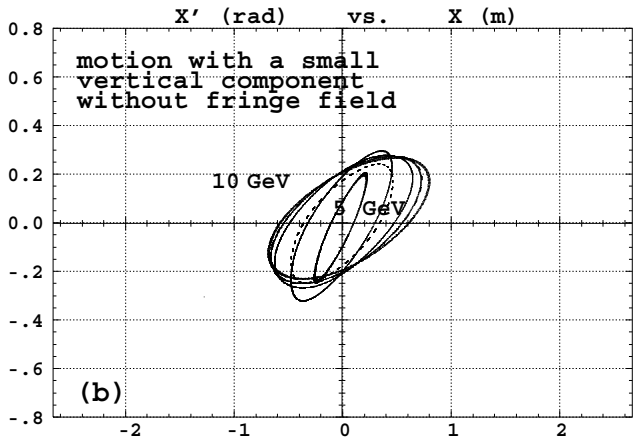


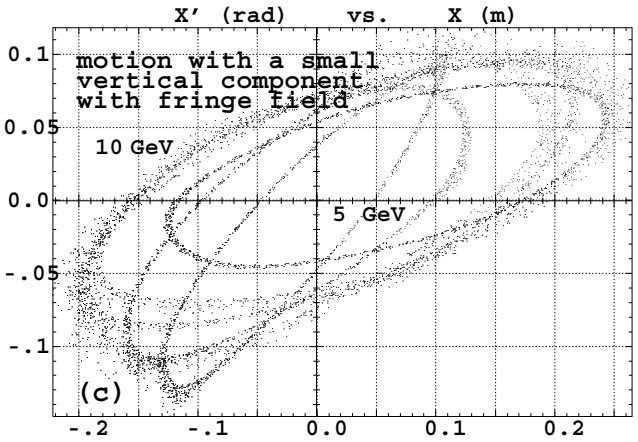


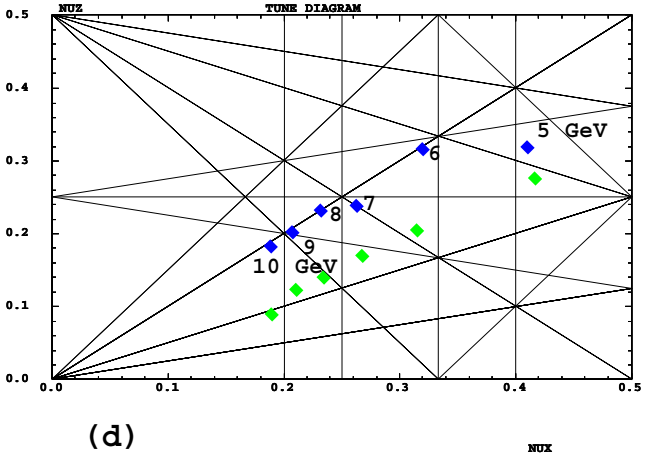


5-10 GeV



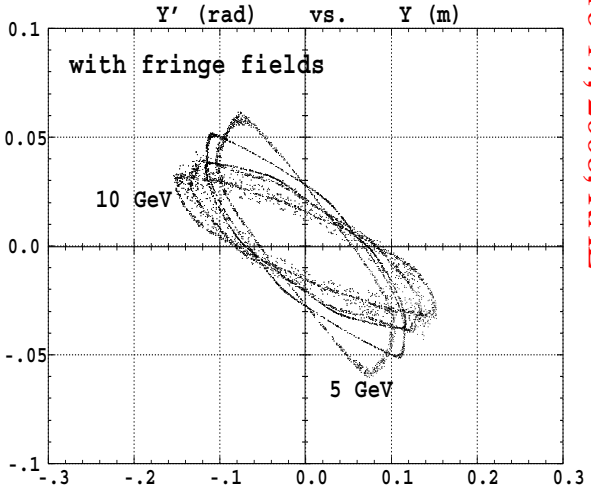






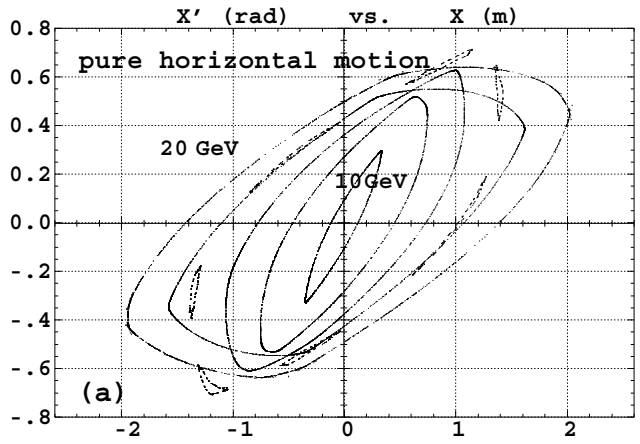
(d)

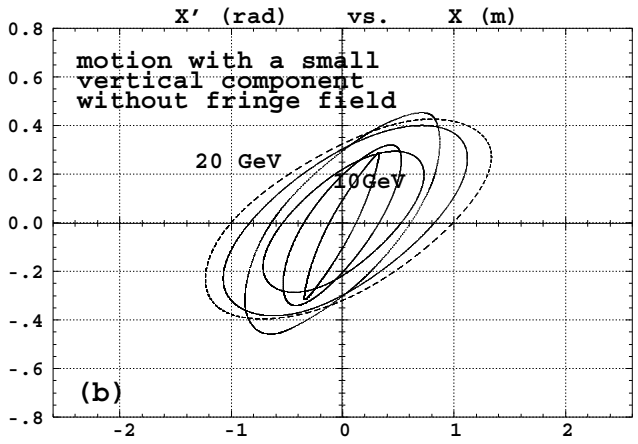
Horizontal stability limits for energies 5,6,7,8,9,10 GeV.
(a) and (b) : hard edge. (c) : fringe fields set. Note the different scales in (c).
Qx-Qz path : green squares correspond to (b), blue squares correspond to (c).

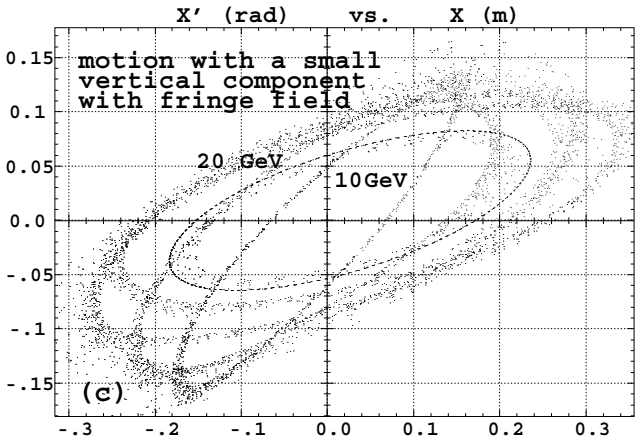


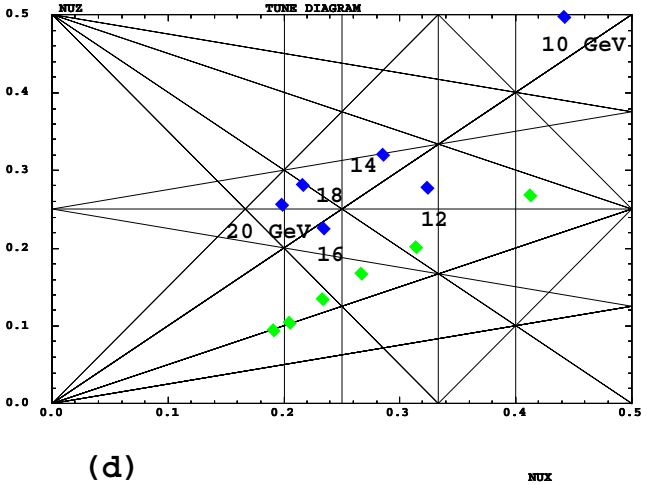
Vertical stability limits.

10-20 GeV



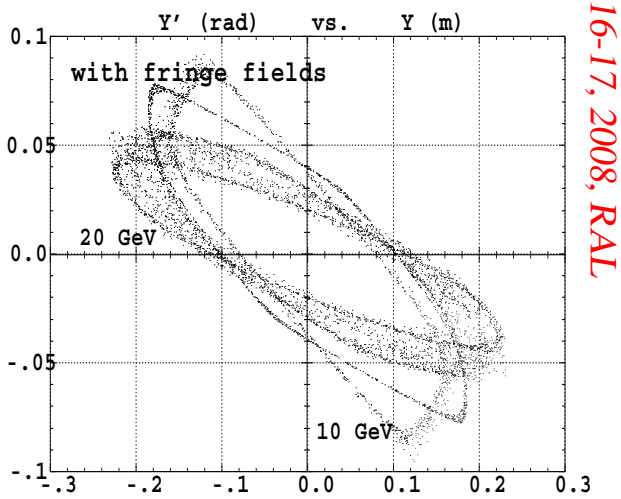






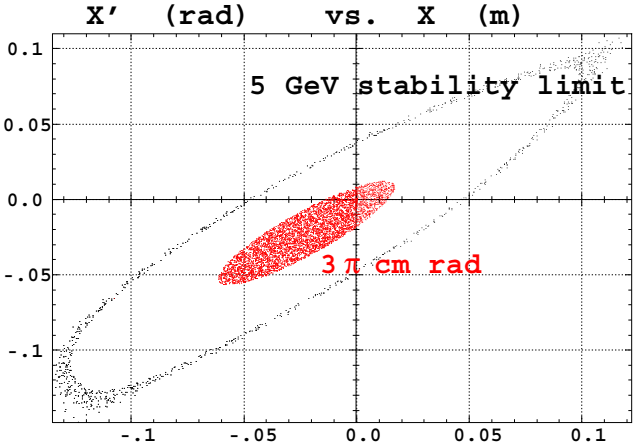
(d)

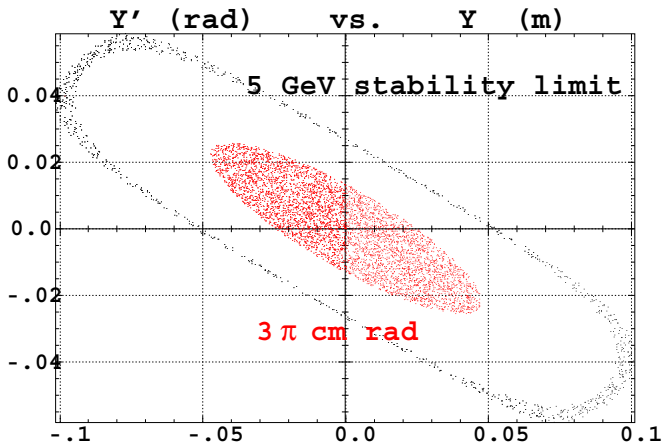
Horizontal stability limits for energies 10,12,14,16,18,20 GeV.
(a) and (b) : hard edge. (c) : fringe fields set. Note the different scales in (c).
Qx-Qz path : green squares correspond to (b), blue squares correspond to (c).



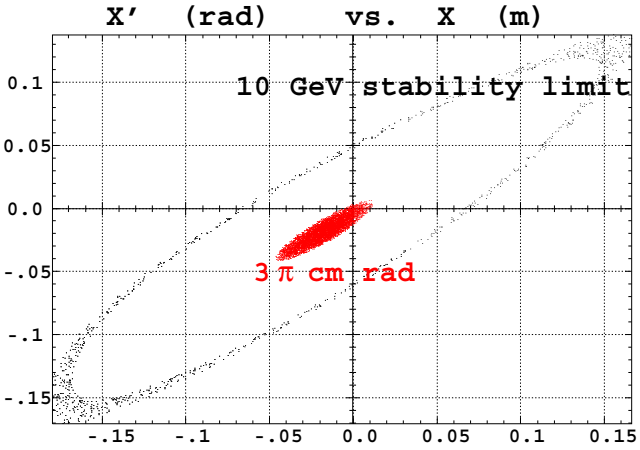
Vertical stability limits.

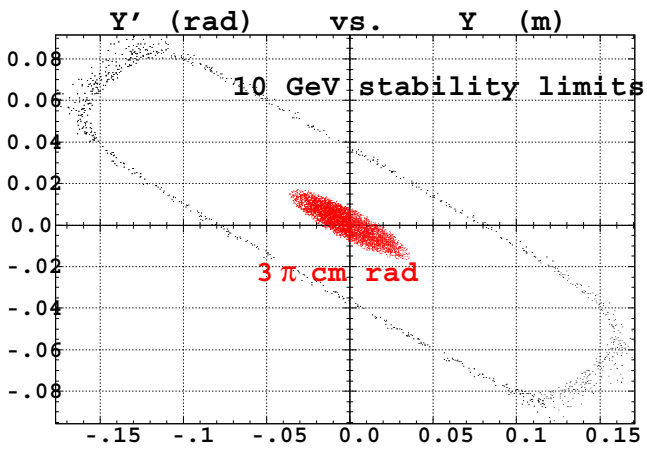
5-10 GeV





10-20 GeV



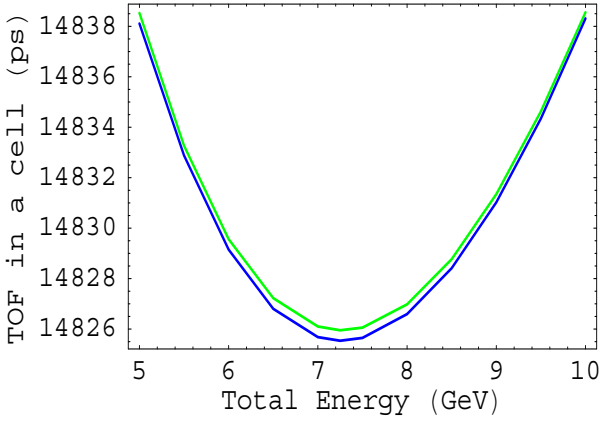


The 3π cm beam, inscribed in horizontal and vertical stability limits.

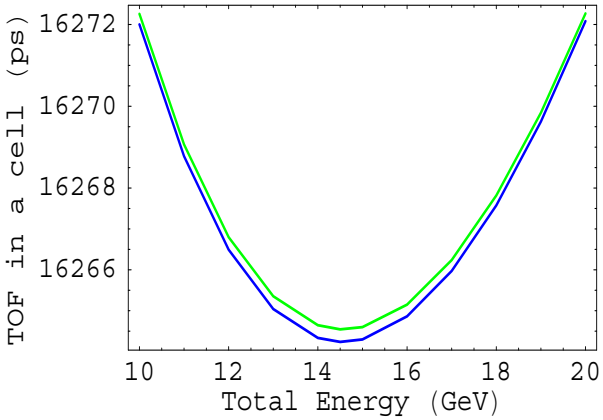
Acceleration of a $3\ \pi$ cm rad and $\epsilon_l = 0.05\ \pi$ eV.s bunch :

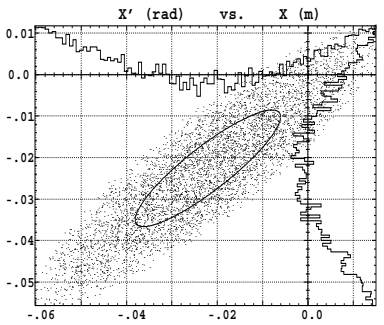
TOF parabolæ

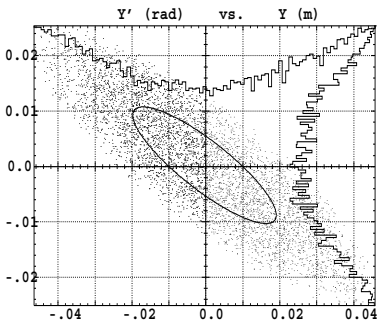
FFAG 5-10 GeV

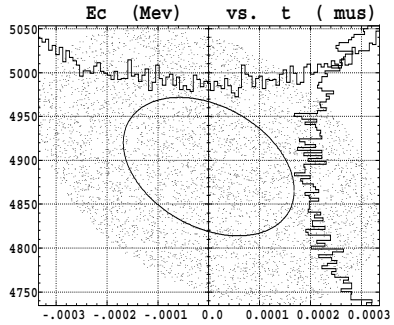


FFAG 10-20 GeV



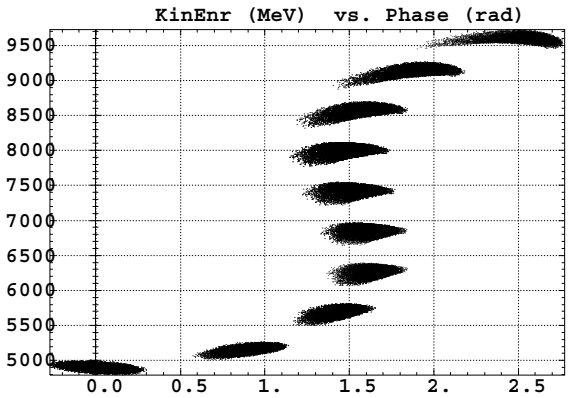




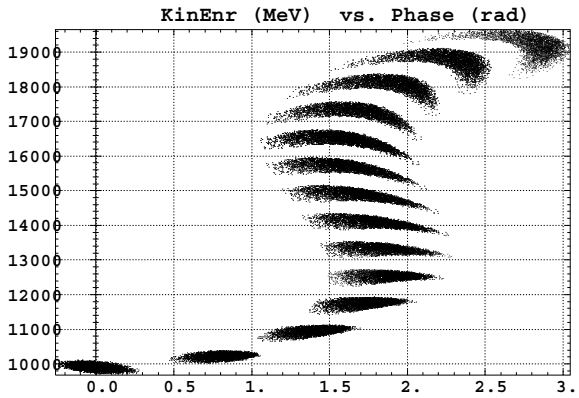


5 GeV distribution of 5000 muons, in normalized emittances $3\ \pi$ cm rad and $\epsilon_l = 0.05\ \pi$ eV.s.

FFAG 5-10 GeV
10.3 turns



FFAG 10-20 GeV
15.5 turns



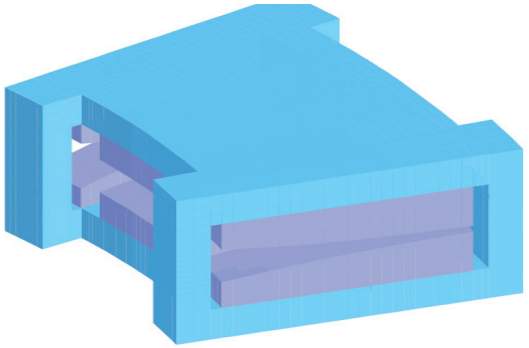
Longitudinal motion of the 5000 muons during the acceleration cycle.

100% transmission is observed in both rings (no decay).

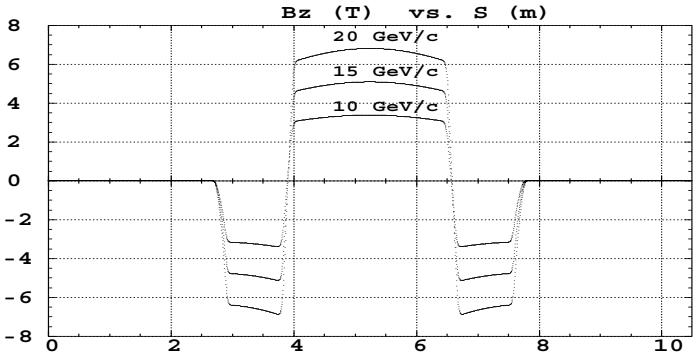
3 Acceleration, NuFact-J optics

DA in 10→20 GeV NuFact-J scaling FFAG rings has been tracked. Magnet of concern is shown below. All characteristics accounted for in these simulations are NuFact-J Report ones, also available on web ISS-NuFact webpage.

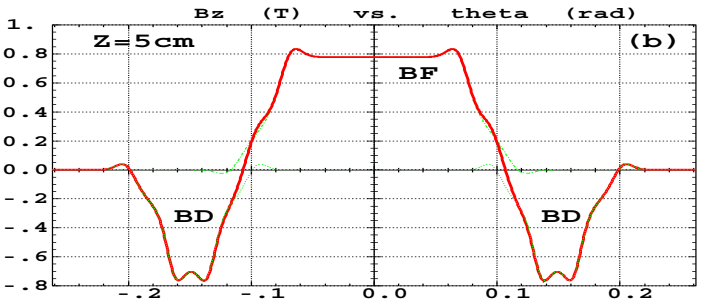
120 cells, k=280, R=200 m, 6 T in dipole



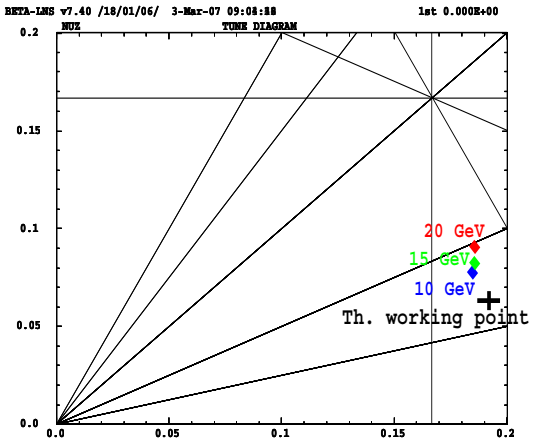
Type of magnet considered in this DA study.

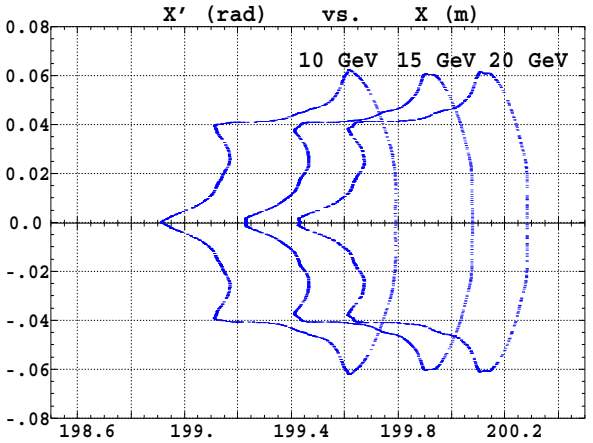


Typical field on closed orbits, in mid-plane.

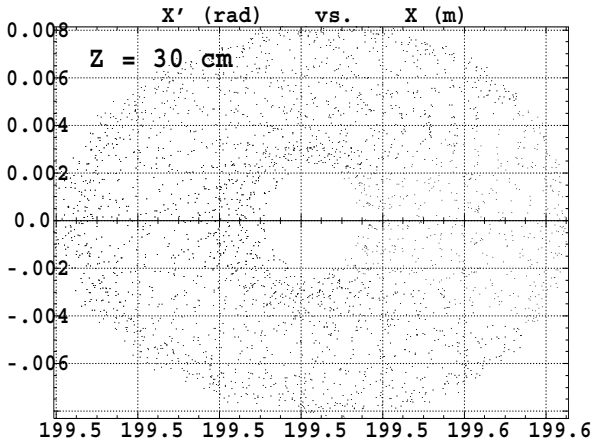


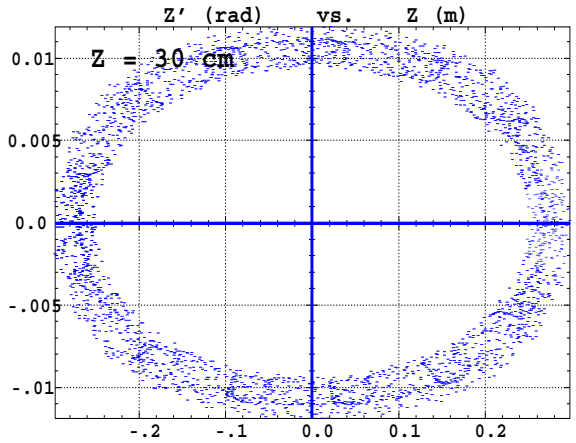
Off mid-plane field behaves ok...



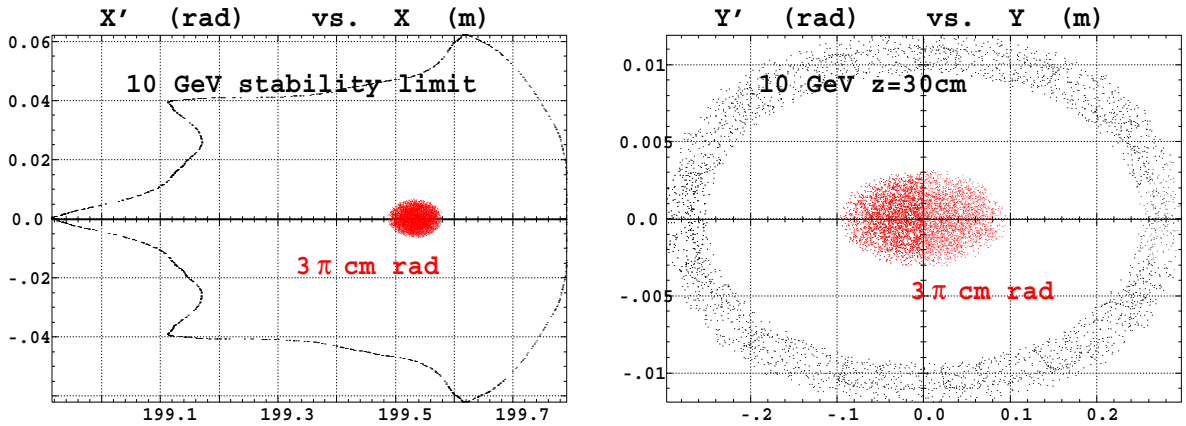


Tunes on DAs (left) at 10, 15 and 20 GeV, and horizontal DAs (pure H motion).





Horizontal motion induced (left), for a 10 GeV particle launched on $z_0 = 30$ cm (right). Donuts due to proximity of $Q_x = 2Q_z$ are stable, an indication of symplectic behavior.

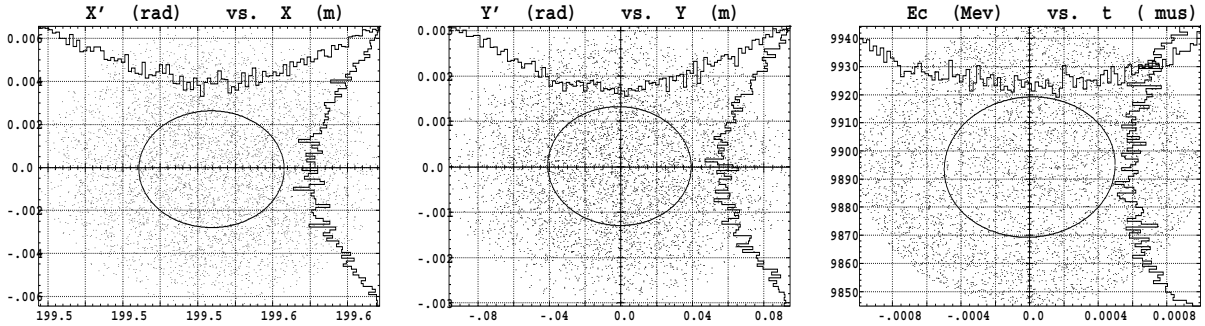


Transverse normalized emittances $\epsilon_{N,x,z} = 3\ \pi$ cm rad within the stability limits at 10 GeV.

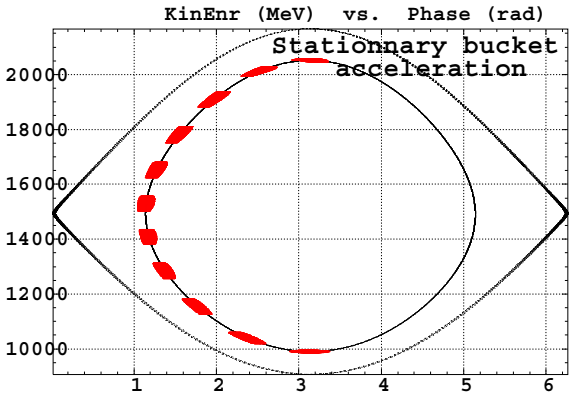
10 → 20 GeV transmission

- taking $\epsilon_x = \epsilon_z = 3\,\pi$cm, norm., $\epsilon_l/\pi = 0.05$ eV.s (by far too small, needs be re-visited)

- we get 100% efficiency (regardless of decay) :



Initial distributions in $\epsilon_{N,x,z} = 3\ \pi$ cm rad and $\epsilon_l = 0.05\ \pi$ eV s.



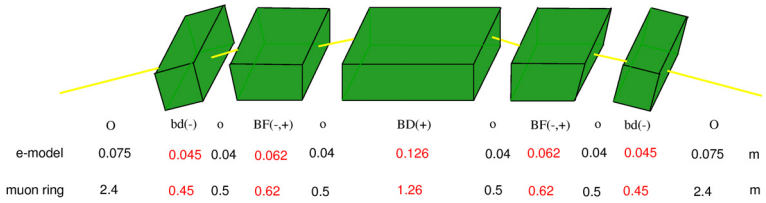
Muon acceleration in stationary bucket.

4 Acceleration, RAL isochronous FFAG

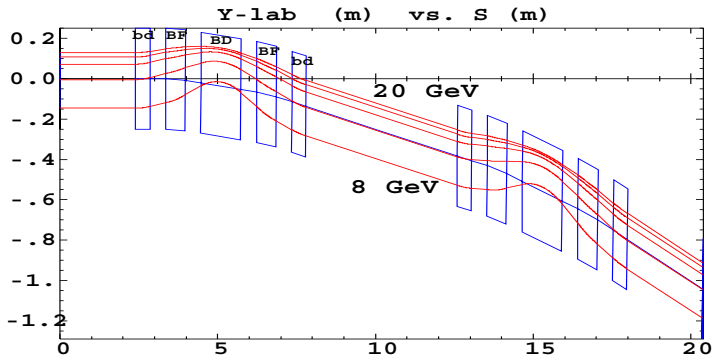
DA in 8→20 GeV isochronous FFAG has been tracked.

Machine parameters are the following :

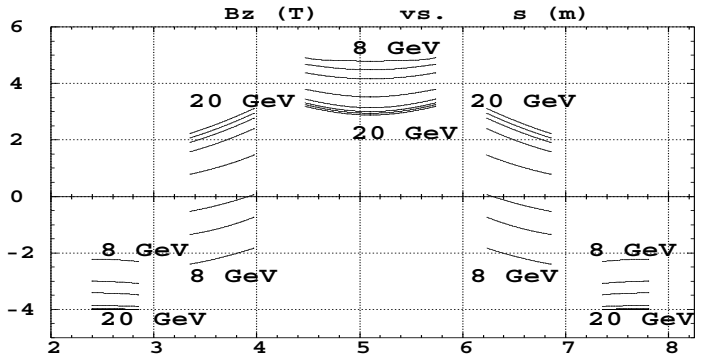
123 cells, circumference 1255 m, acceleration in 16 turns using 201 MHz, 18.3 MV RF, 1 cavity/3 cells.



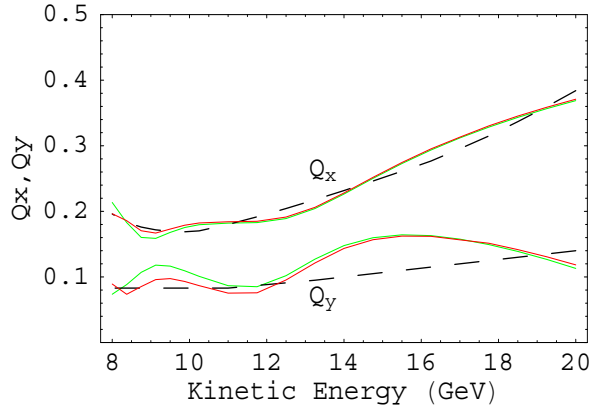
Isochronous cell.



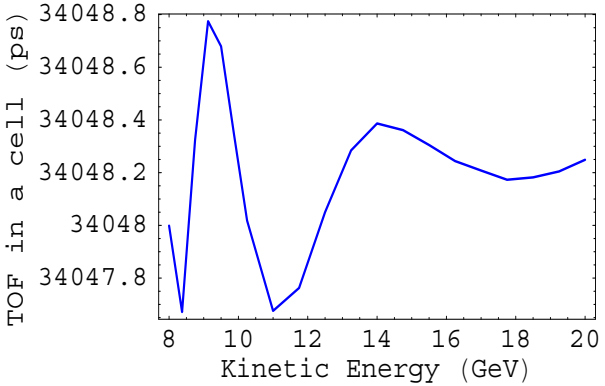
Closed orbits



Magnetic fields along the closed orbits (we used hard edge model).

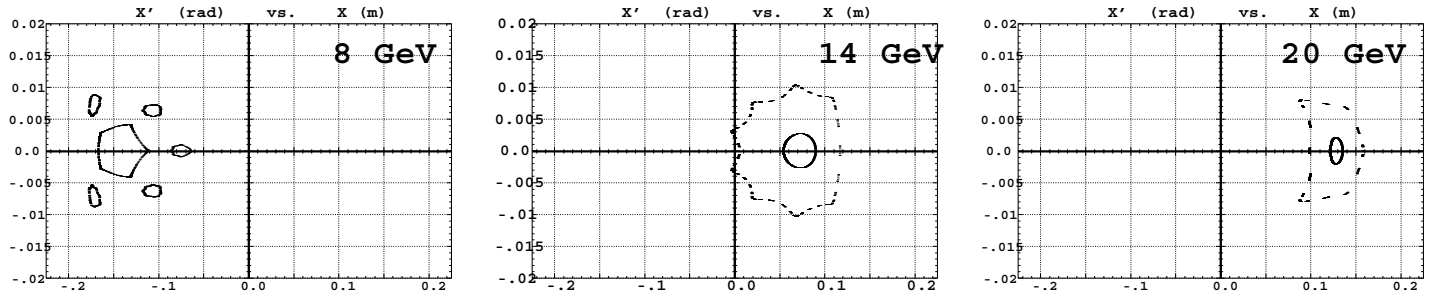


Tunes.

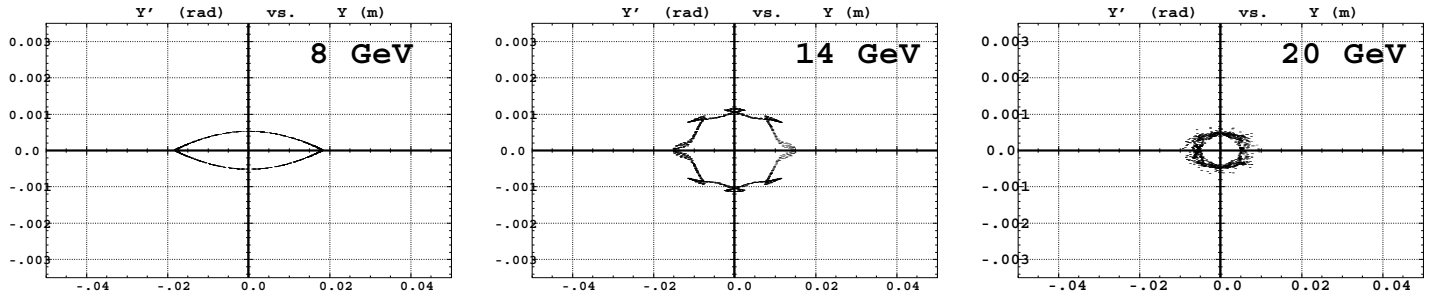


Time of flight (excursion about 1/10 that in linear FFAG optics)**.**

Horizontal stability limits, 8, 14 and 20 GeV :

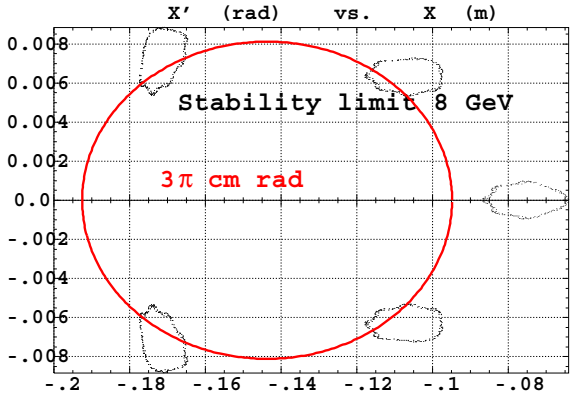


Vertical stability limits, 8, 14 and 20 GeV :

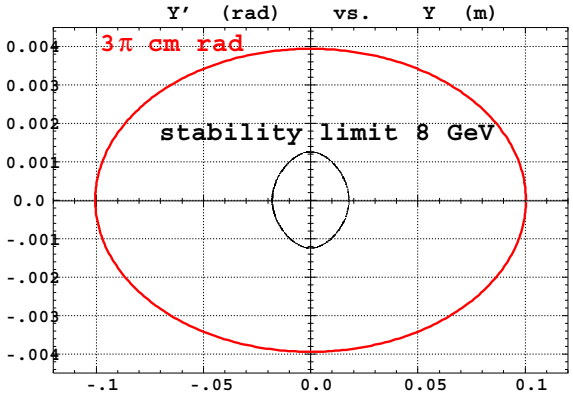


Comparing to 3π cm emittance (red ellipse) :

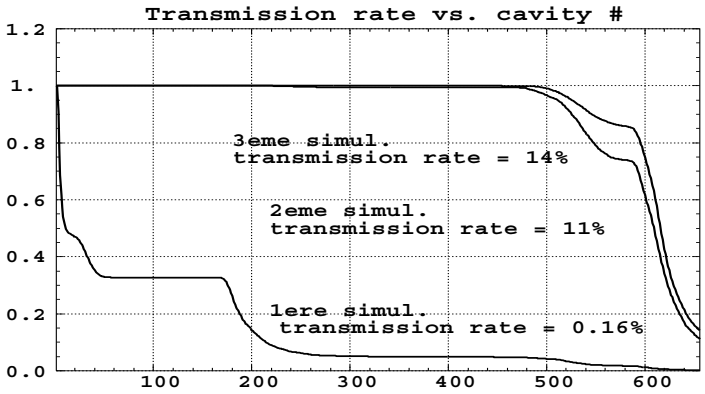
Horizontal



Vertical

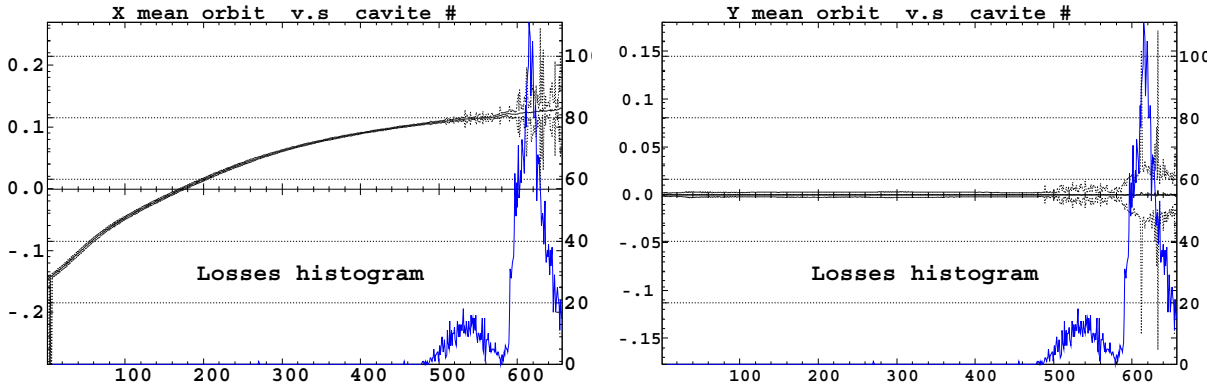


Muon Transmission :

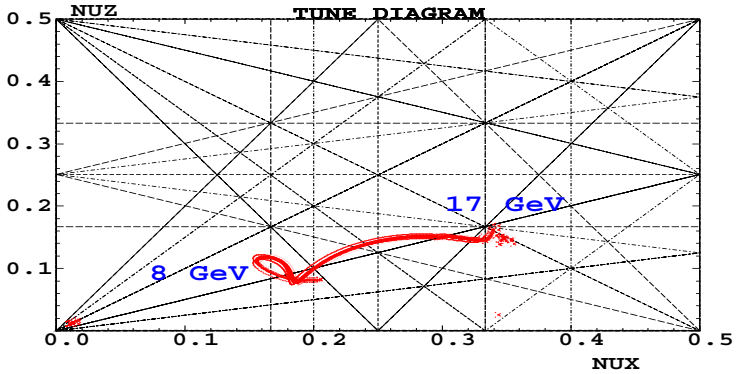


Transmission rate as a function of the number of passages through the cavities.

Lossless transmission up to 17 GeV, for $\epsilon_{N,x} \leq 2\ 10^{-3}\ \pi$ cm, $\epsilon_{N,y} \leq 0.5\ 10^{-4}\ \pi$ cm.



Horizontal and vertical beam envelopes and histograms of the muons losses.

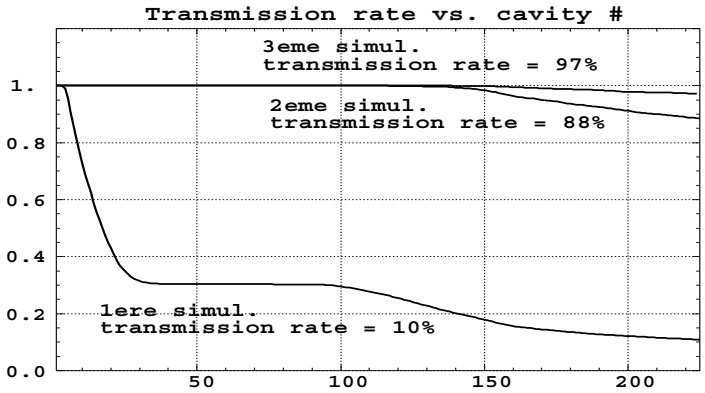


Beam trajectory in the tune diagram

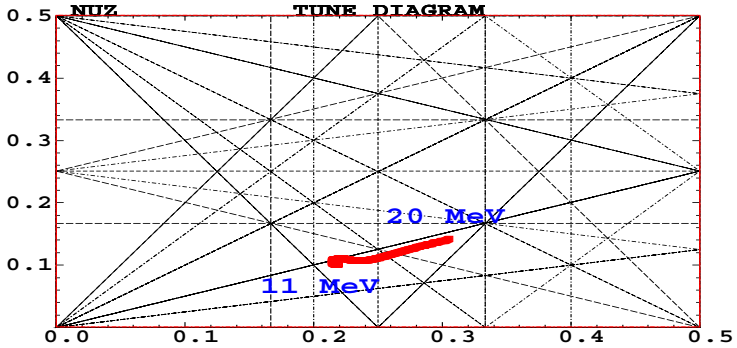
(regular systematic resonances up to the 6th order shown)**.**

Notes :

(i) case of the 11-20 MeV electron model



Transmission rate as a function of the number of passages through the cavities.



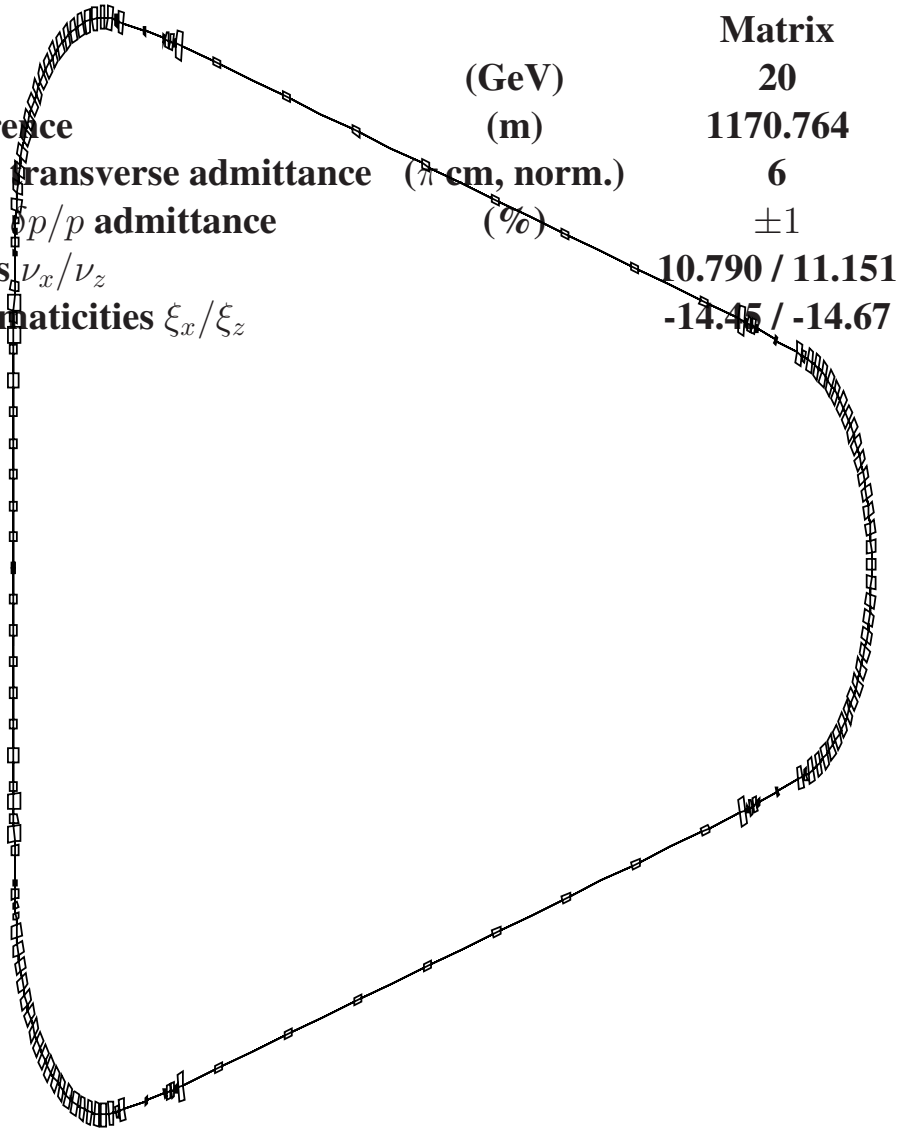
Beam trajectory in the tune diagram (regular systematic resonances up to the 6th order shown)**.**

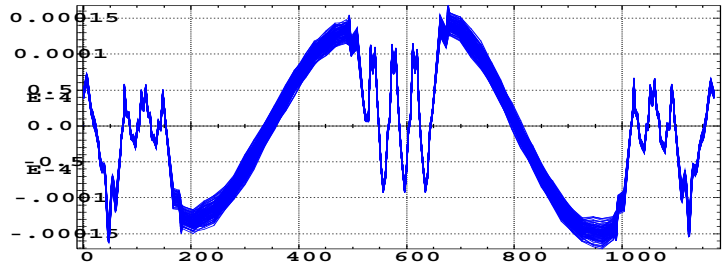
(ii) optics with insertion was also proposed, lower Qz and Qx excursions, still needs be tracked

5 Muon storage ring, triangle

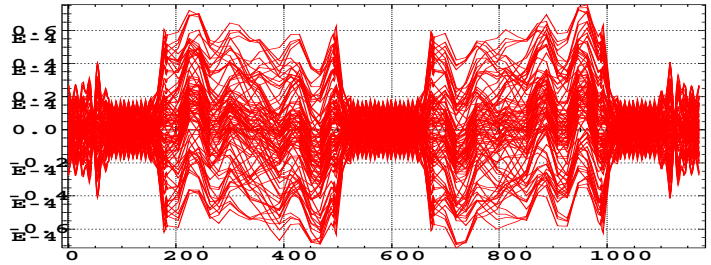
Table 1 : Muon storage ring parameters.
The right column gives, where worth, the stepwise ray-tracing data.

		Matrix	Ray-tracing
Energy	**(GeV)**	**20**	
Circumference	**(m)**	**1170.764**	
Requested transverse admittance	**(π cm, norm.)**	**6**	
Requested $\delta p/p$ admittance	**(%)**	± 1	
Total tunes ν_x/ν_z		**10.790 / 11.151**	**10.791 / 11.147**
Total chromaticities ξ_x/ξ_z		**-14.45 / -14.67**	**-14.35 / -14.92**

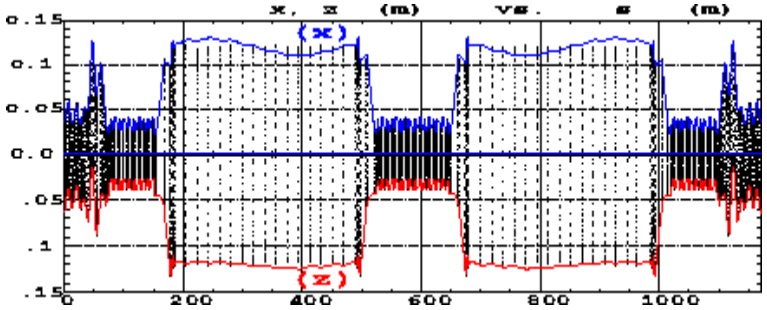




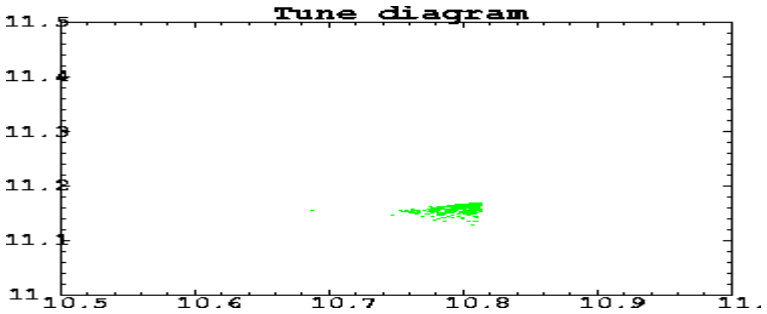
Residual H closed orbit, chromaticity corrected.



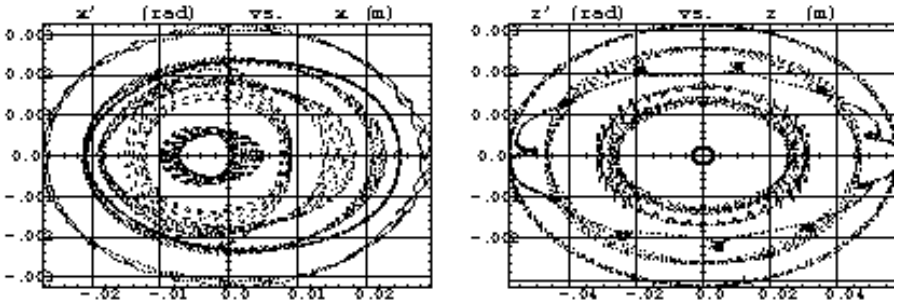
Residual V closed orbit, chromaticity corrected.



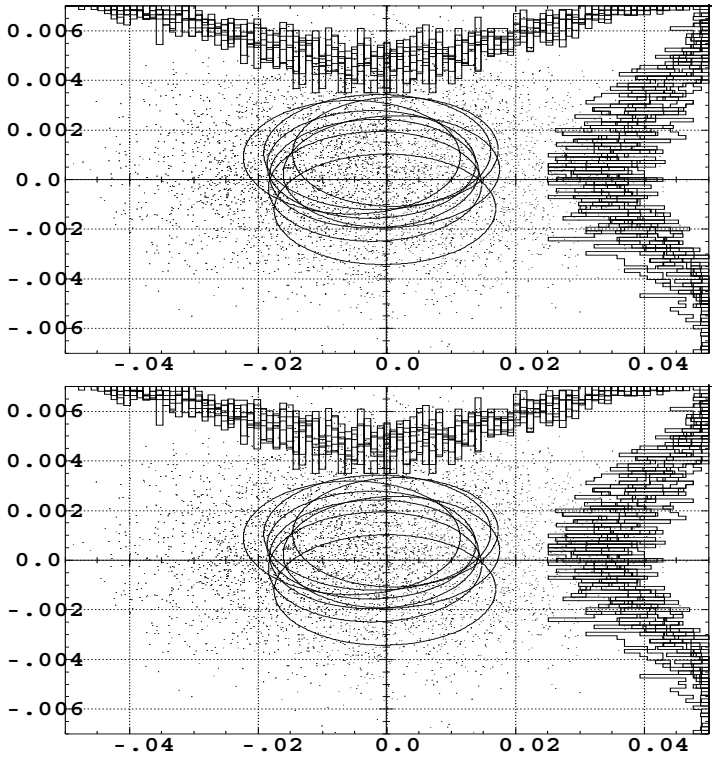
Beam envelopes, 6π cm emittance.



Beam footprint in tune diagram, chromaticity corrected, 6π cm emittance, $dp/p = \pm 4\%$.



Sample multiturn tracking, arbitrary particles with various H, V and $\delta p/p$ conditions. It shows the good behavior of the numerical integration (no evidence for prohibitive non-symplectic behavior).



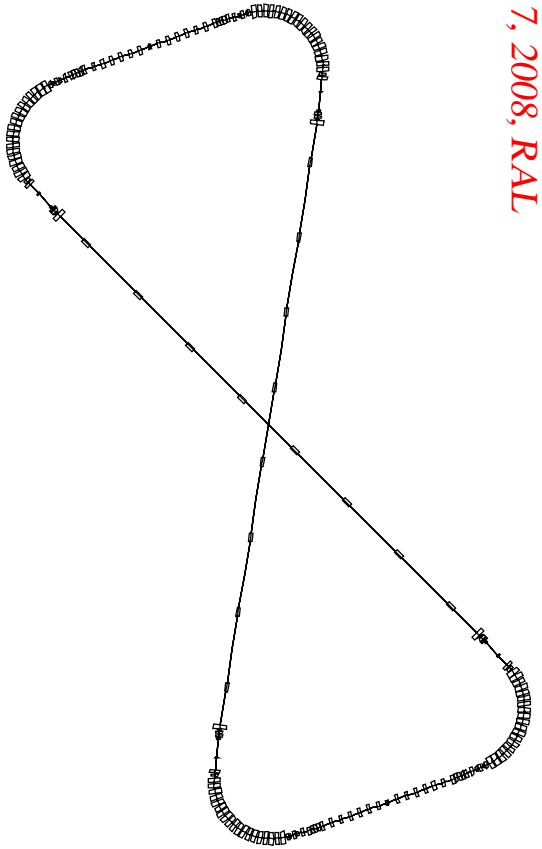
Horizontal (top) and vertical (bottom) admittance, for various sets of errors. The rms matching ellipses correspond to more than 3π cm norm., total.

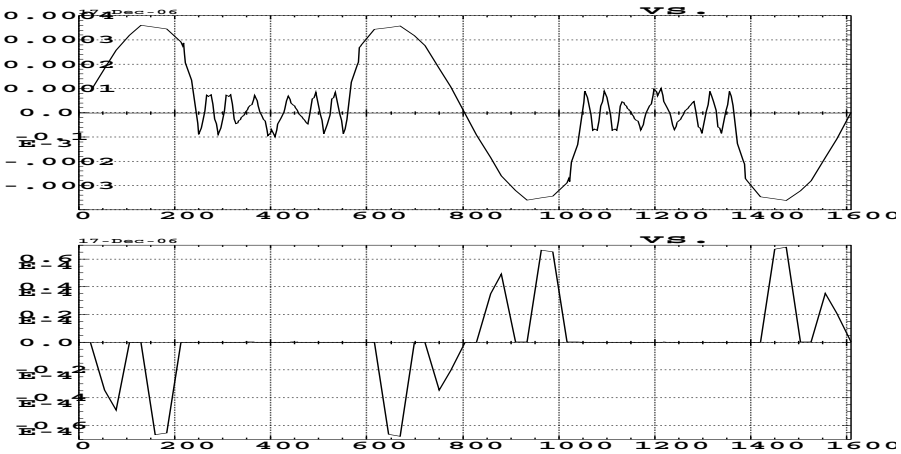
6 Muon storage ring, bowtie

Ray-tracing data files have been installed.

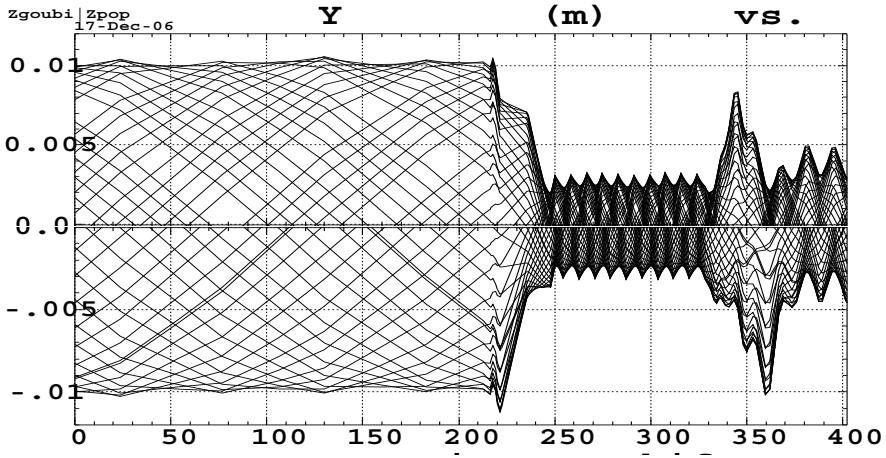
Muon storage ring parameters.

							Matrix
Energy			**(GeV)**				**20**
Circumference			**(m)**				**1608.8**
Requested transverse admittance			**(π cm, norm.)**				**6**
Requested $\delta p/p$ admittance			**(%)**				± 1
Total tunes ν_x/ν_z							**14.3749 / 12.7882**
Total chromaticities ξ_x/ξ_z							**-17.7 / -17.7**
Phase adavnces, H/V :			(2π)				
Arc cell							**0.2 / 0.2**
production straight							**0.69963 / 0.69963**
sol./arc match section							**0.252525 / 0.205128**
tuning straight							**1.98279 / 1.284238**
Matching conditions :	β_x	α_x	β_x	α_z	D_x	D'_x	
collimation st centre	**8.86984**	**0**	**21.08630**	**0**	**0**	**0**	
arc input/output	**3.78758**	**0**	**12.67568**	**0**	**0.837046**	**0**	
production st waists	**94.21980**	**0**	**94.21980**	**0**	**0**	**0**	





Residual geometrical closed orbits. The (negligile) vertical one is due to residual coupling in the silenoid.



Horizontal (top) and vertical (bottom) beam envelopes ($\epsilon_{x,z} = 1$) in the bowtie ring, from ray-tracing.

Ready for DA tracking. Ready for spin tracking too.

7 Conclusions

- **Tools are there**
- **Defect studies can be persued**
- **A lot is ready for s2e tracking**
- **It might be a good idea to have a kind of reference magnet design, 3D, including multipole defects and fringe fields.**
- **Planning to take a PhD student in the frame of EURONu program to work on IDS-NuFact topics**

8 Bibliography

Muon front end and acceleration : Franck Lemuet, PhD thesis, CEA & CERN, April 2007.

Triangle storage ring : F. Mot, G. Rees, Report CEA DAPNIA-06-04 / IN2P3 LPSC 06-38

Bow-tie storage ring : F. Mot, Note LPSC 06-127(NuFact)