Initial Cooling with HFOFO Snake

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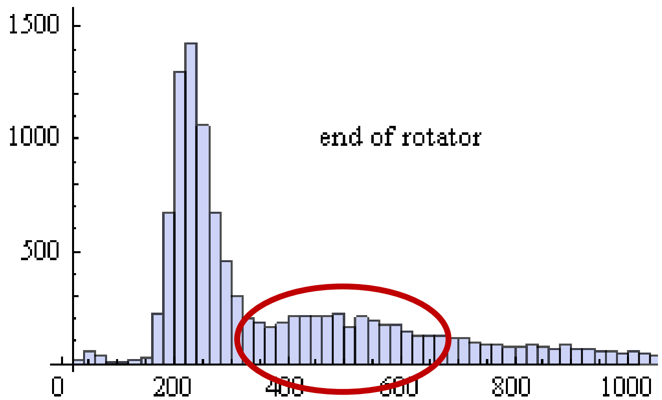
Motivation for Using HFOFO in a NF Front End:

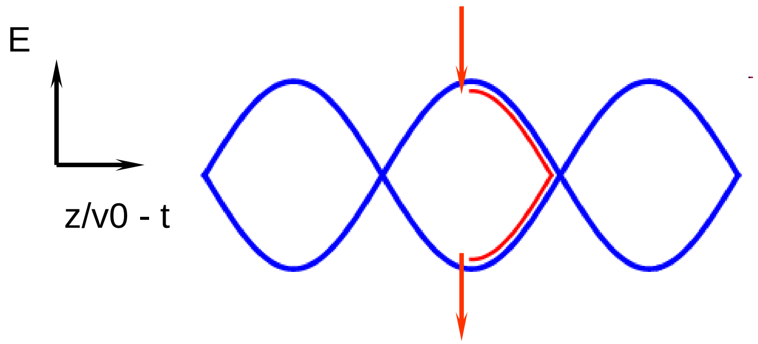


Distribution in muon momentum (MeV/c)

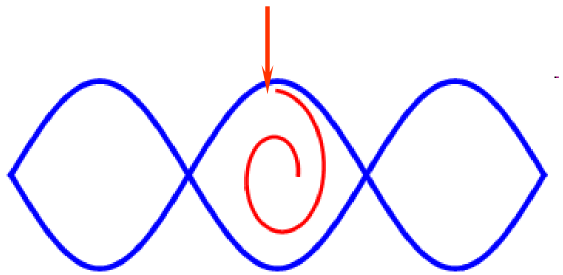
- Capture higher momentum muons
- Retain muons already in the range 150-300 MeV/c
- Reduce r.m.s. momentum spread

If successful it will:

- Increase muon beam intensity
- Alleviate requirements on the muon accelerator momentum acceptance
- Increase the optimum p-driver energy simplifying problems with p-beam focusing



w/o longitudinal damping



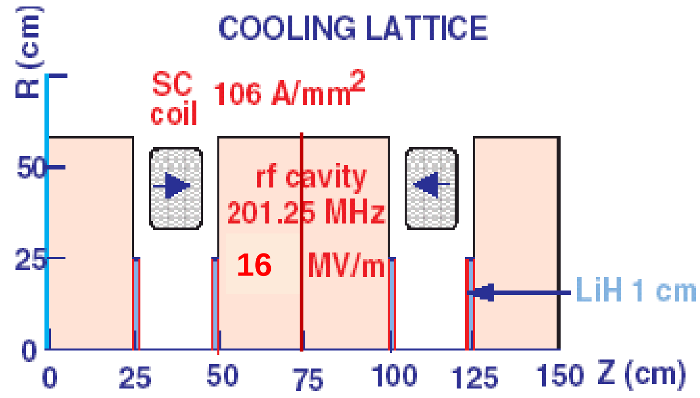
with longitudinal damping

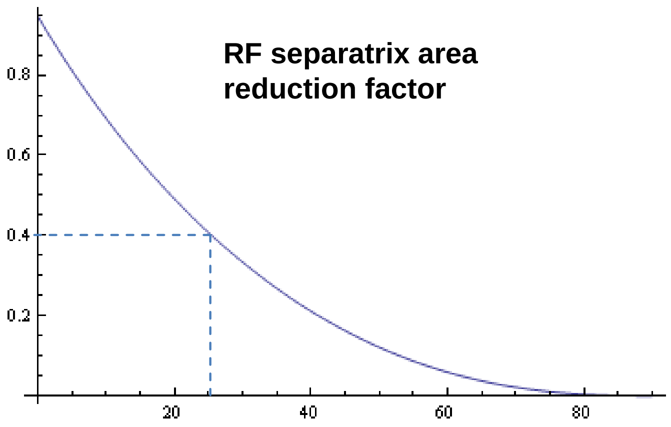
G4BL model for Front End and Cooler (courtesy of Cary Y.)

CapSol	Drift	Buncher	Rotator	Match. + Cooler	
12.9 m	43.5 m	31.5 m	36 m	3 m	90 m

Buncher starts with 366.9 MHz (window radius?)
Rotator: 202.1 MHz 15 MV/m ⇒ <E>= 10 MV/m

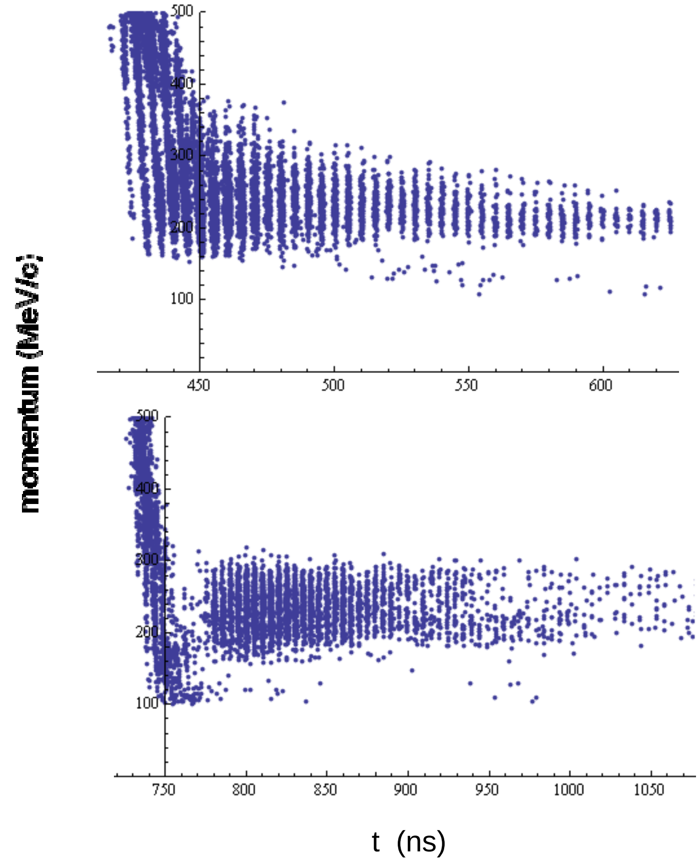
Cooler: 201.25 MHz 16 MV/m ⇒ <E>= 10.67 MV/m, φ=25.8°
(the transit factor a bit larger due to splitting cavities it two)





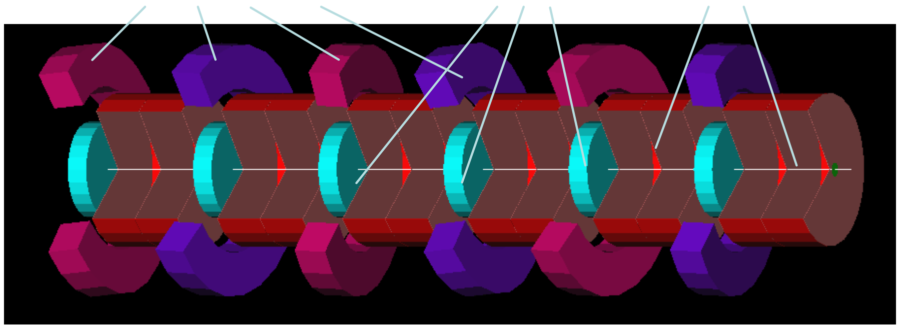
φ (deg)

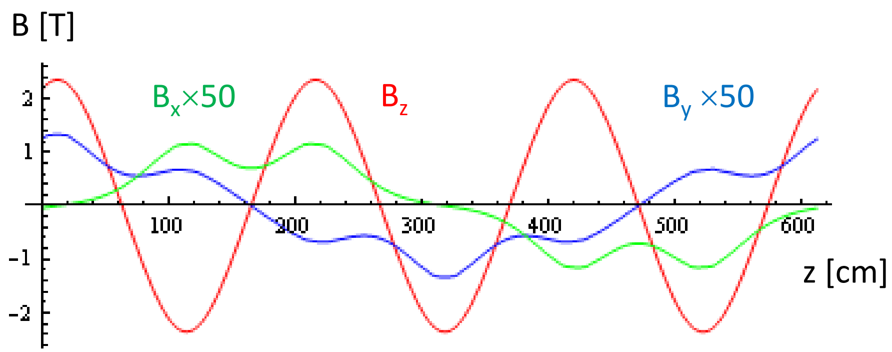
	μ+(total)	μ-(total)	μ+ (150<p<300)
End Rotator	12388	12382	5821 (47%)
End Cooler	6890 (56%)	7230 (59%)	4139 (71%)

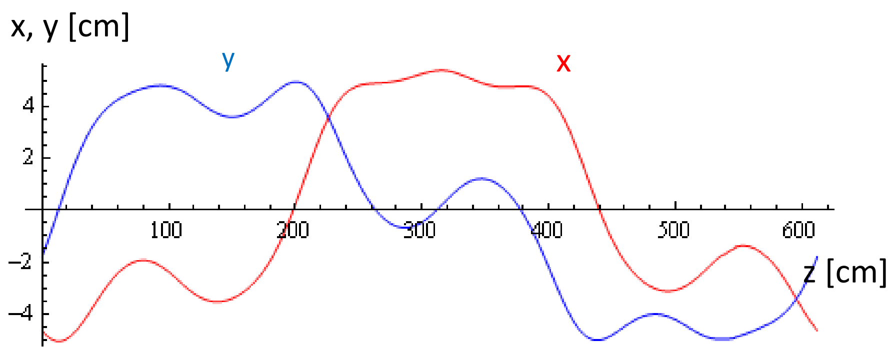


The RF separatrix area reduction may be a major problem: requires a 6-fold increase in <E> to completely compensate for!

Helical FOFO Snake

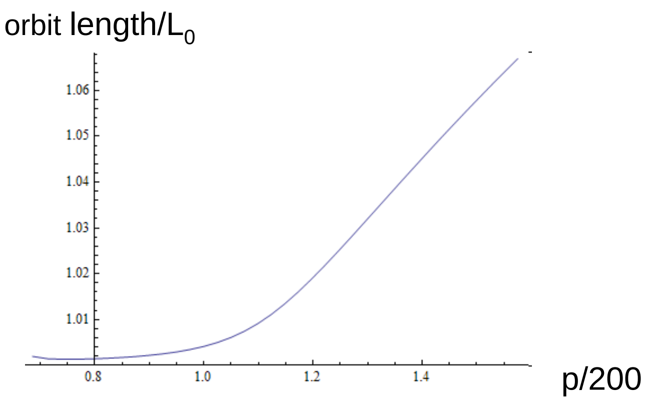






Periodic orbit for p0=200MeV/c

Solenoids: L=24cm, Rin=60cm, Rout=92cm, pitch 7mrad, $B_z$max=2.16T (p0=200MeV/c)
RF: 200 MHz pillbox 2x36cm, Emax=16MV/m, <E>=11.3 MV/m
Absorbers: 15cm **LH2** planar



Momentum compaction factor:

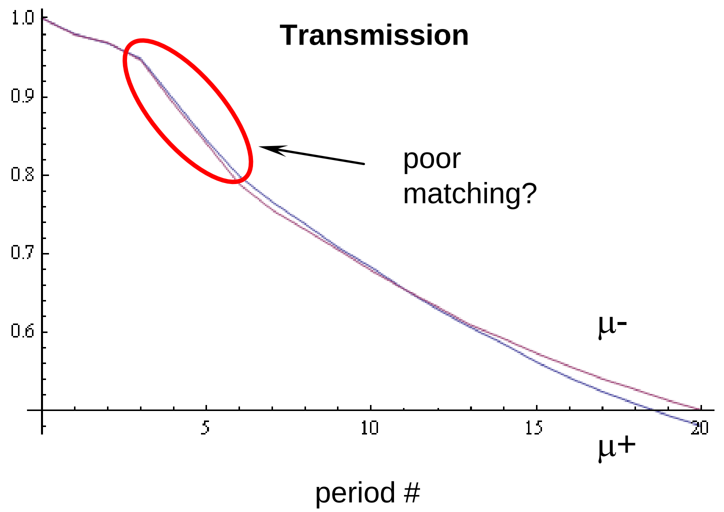
$$\alpha_p \approx 0.1 < 1/\gamma_0^2 \approx 0.22$$

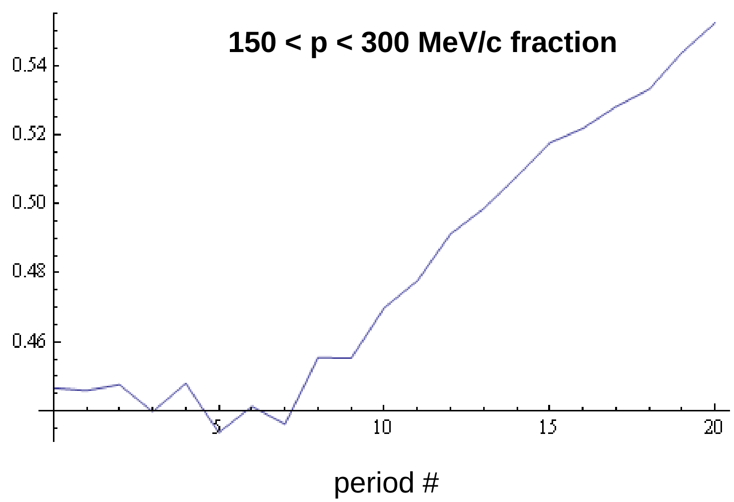
reduces the slippage factor almost by half

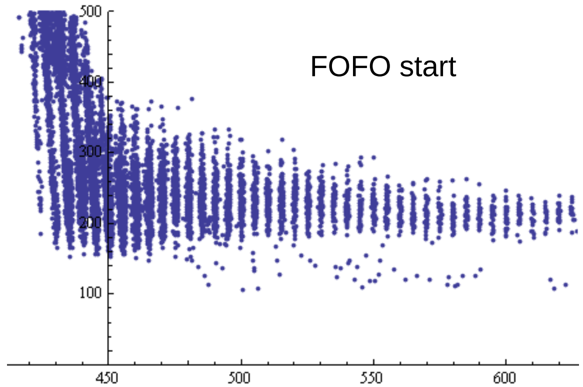
mode	I	II	III
tune	1.24+0.009i	1.29+0.009i	0.18+0.004i
ε_eq (cm)	0.39	0.38	0.47

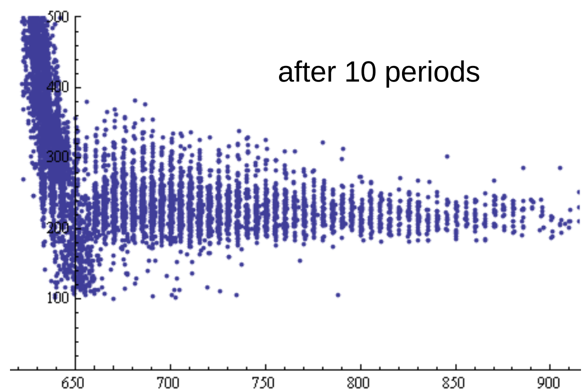
G4BL Simulation of HFOFO snake

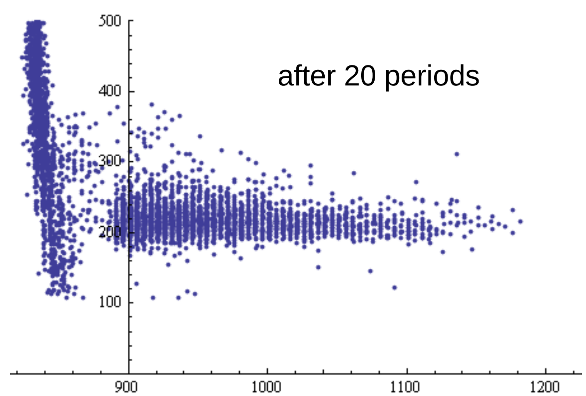
First 2 periods (12.24m): linear rise of solenoid tilt, absorber length and RF phase angle, next 18 periods no tapering







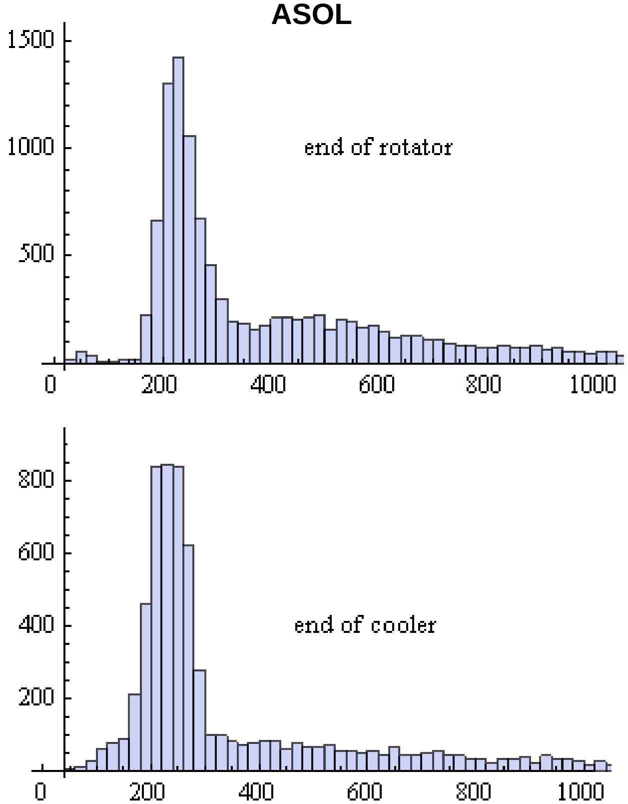




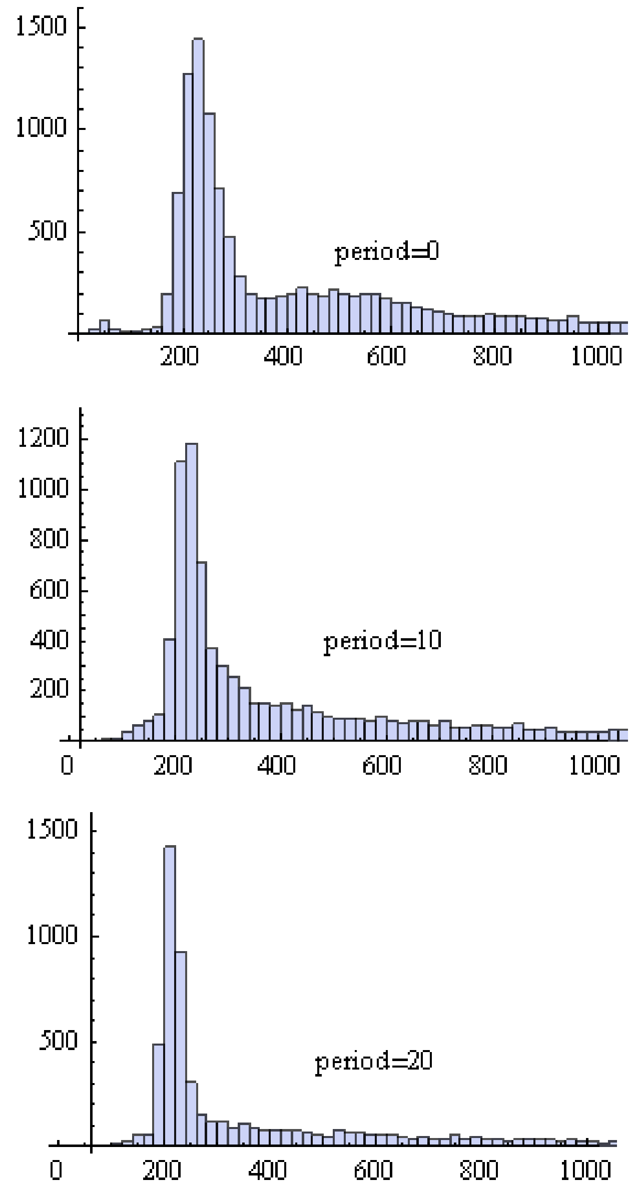
Distribution in μ+ Momentum (MeV/c)

ASOL

Out[34]=

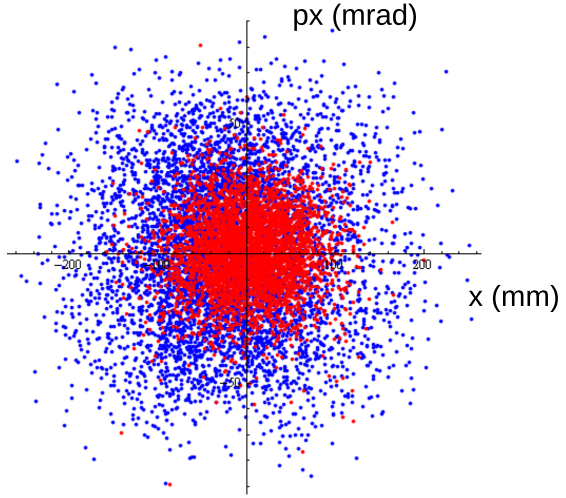


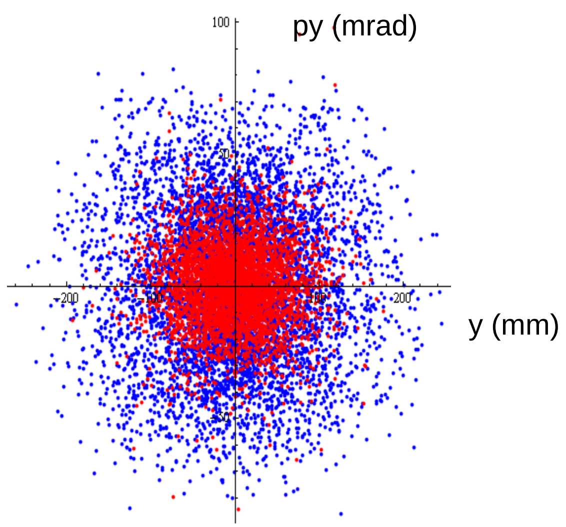
HFOFO



Transverse Phase Space Distribution for 150<p<300 MeV/c

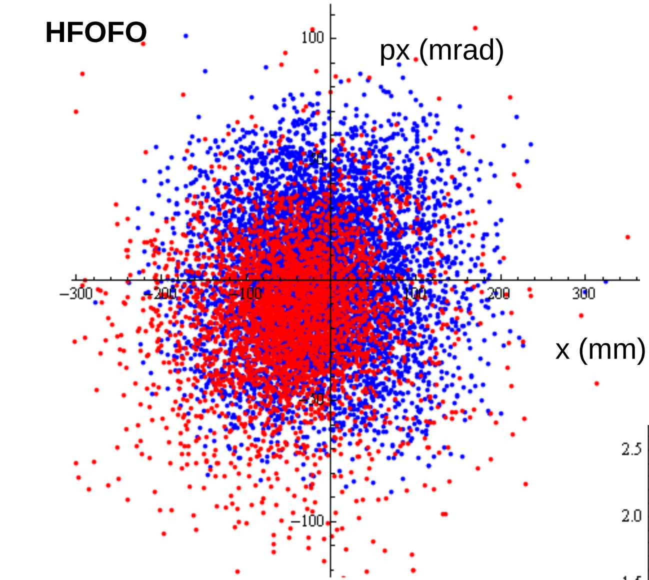
ASOL

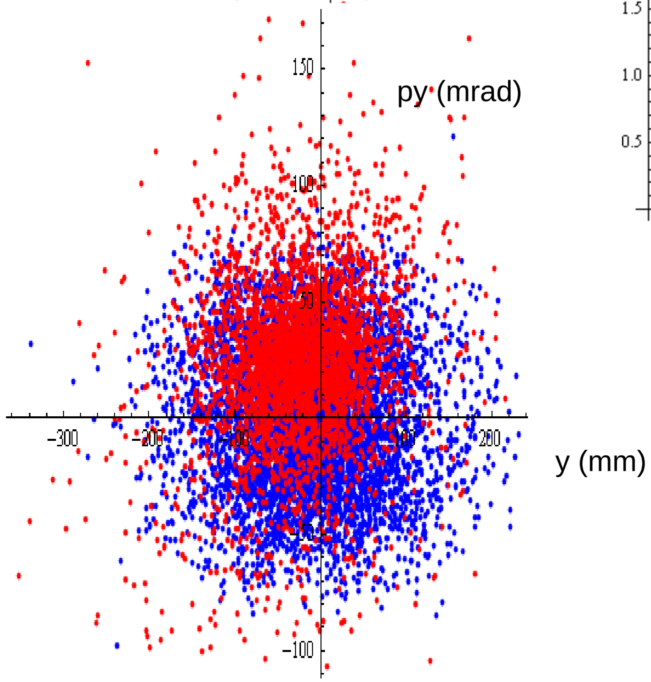




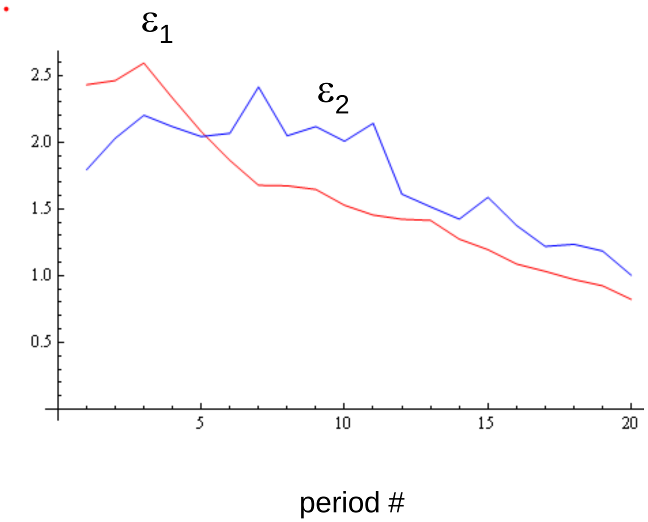
$\varepsilon_{r.m.s.}$ 2.19 cm → 0.68 cm

HFOFO





Normal mode emittances in HFOFO from Gaussian fit:



Many more muons are going to be lost later!

How to improve HFOFO transmission?

Standard expression for the RF separatrix area (not exact for weak relativism):

$$A = \frac{8L}{\pi c h^{3/2}} \left(\frac{E_0 eV}{2\pi\eta} \right)^{1/2}, \quad \eta = \frac{1}{\gamma_0^2} - \alpha_p, \quad h = f_{RF} L / v_0$$

Increase in the reference momentum up to ~250 MeV/c will be highly beneficial ($A \sim p_0^{3/2}$ for small α_p).

Now for HFOFO p_0=200MeV/c, for ASOL p_0=220MeV/c. But this will require additional length.

Summary

- The first attempt to attach HFOFO snake to Dave's front end was relatively successful: it gave 3505 μ+ in 150<p<300 MeV/c window vs 4139 from ASOL but with a much smaller momentum spread.
- The transverse emittance from 122m HFOFO is higher than from 93m ASOL (1cm vs 0.7cm).
- It is still higher than the eqillibrium value of 0.4cm with LH2 absorbers used:
    - replacement of LH2 with LiH will not affect the performance much;
    - with LH2 cooling may proceed further.
- The hope to capture high-momentum muons has not materialized so far.
- The HFOFO performance can be improved by more careful tapering and increase in the reference momentum.
- The optimization (including some tweaking of the front end) will require ~ 6pm + learning time for that person (not found yet)