First-cut Lattice Design for NUMAX decay ring

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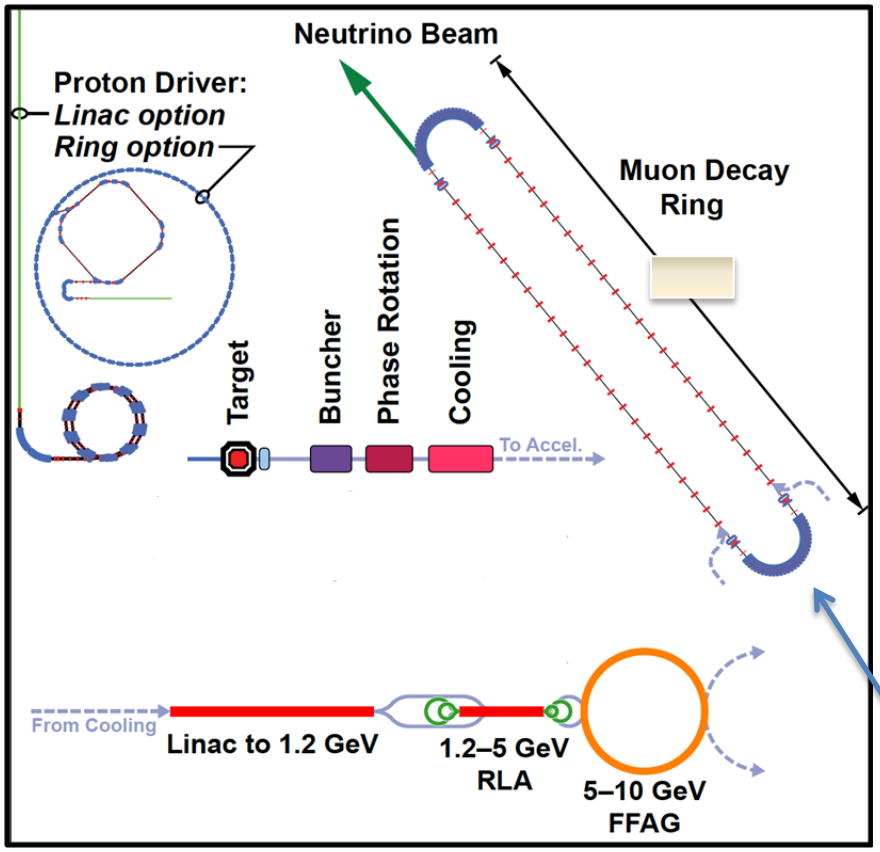
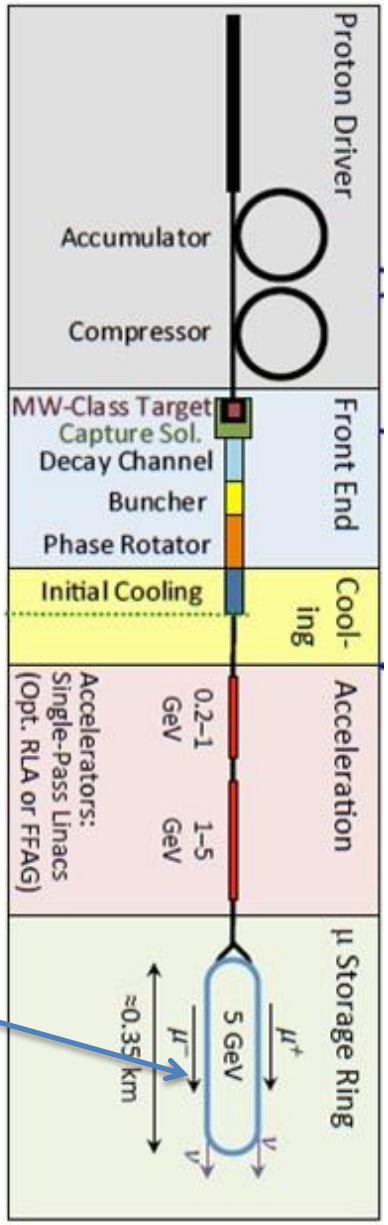
- Conclusions

Introduction



IDS-NF

?



NuMAX

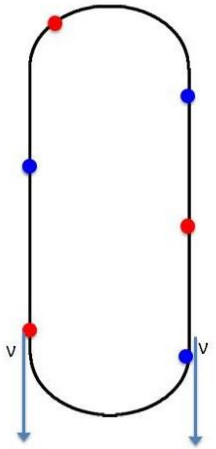
We were asked to look at possible design of the NuMAX decay ring.
We decided to use our IDS-NF decay ring design as a starting point,

IDS-NF Decay Ring

•Key assumption for IDS-NF is the need to accommodate 3+3 bunches.

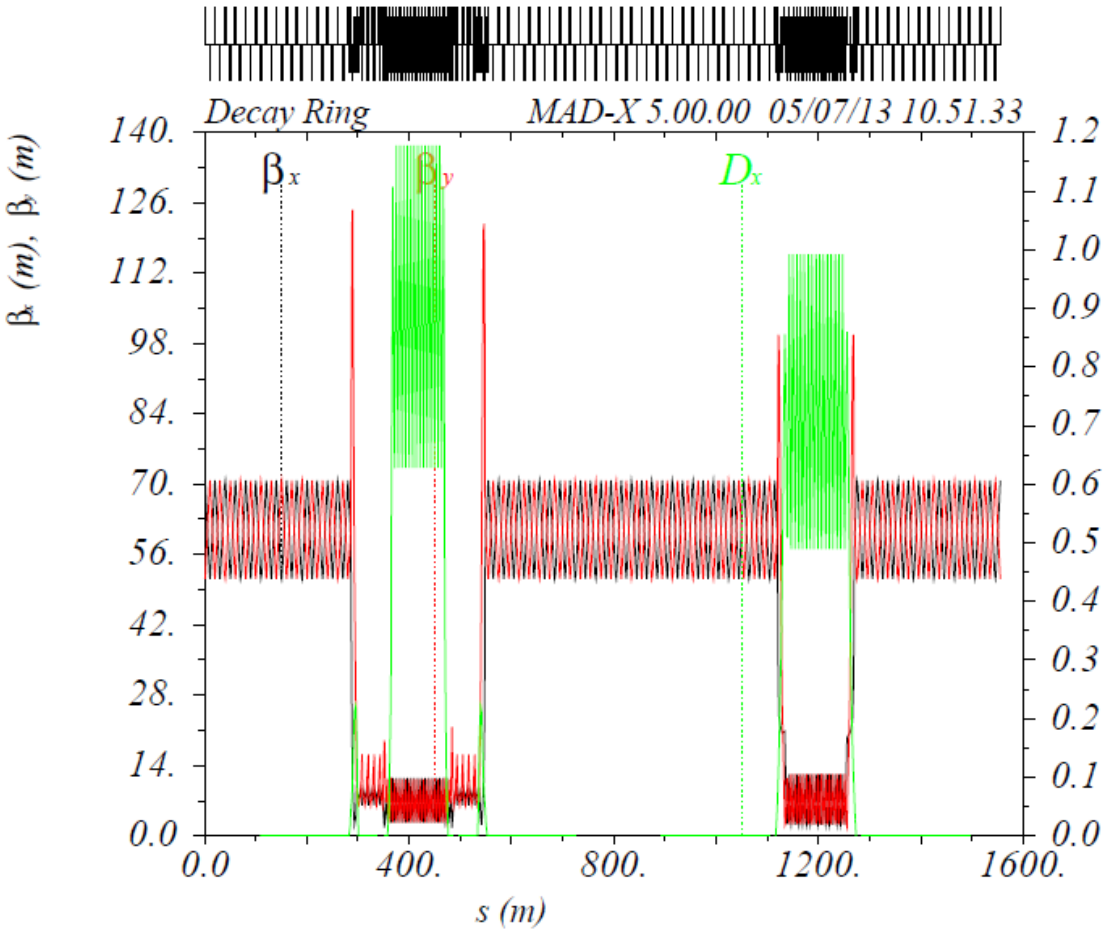
• This makes the injection into the production straight impossible due to the kicker magnet limitations (rise/fall time) and requires a dedicated insertion.

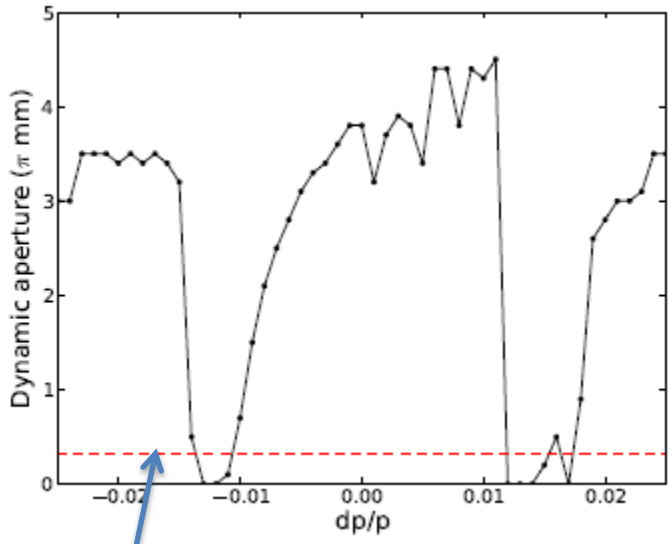
•This pushes the ring circumference.



Production straight	562.0×2	m
Upper arc (incl. disp supp)	121.155	m
Lower arc	112.729	m
Insertion	46.4×2	m
Matching sections (total)	104.987	m
Circumference	1555.672	m
Width of ring	74.565	m
Length of ring	737.228	m
Angle of inclination	10	deg
Maximum depth of ring	128.02	m
Production efficiency η_p	$36.1\% \times 2$	
Total tune (H,V)	14.77, 13.73	
Chromaticity (H,V)	$-17.11, -20.23$	
Phase slip η	2.8×10^{-3}	
Turns per mean lifetime	40.07	

IDS-NF ring (optics and dynamics)





Requirement

NuMax Parameters

- 5 GeV muon energy (total)
- Normalised acceptance 20 Pi mm rad
- Single pair of bunch trains injected at 60 Hz rep rate, 50 bunches per train, 325 MHz rf, ~170 μs train duration
- 1400 km to far detector
- Inclination angle ~5.8 degrees

Design considerations

Design Aims
Maximise neutrino production efficiency (η)
Low beam divergence in production straight (<0.1/γ)
Maintain bunch separation (100 ns)
Allow realistic injection scheme
Ensure reasonable momentum acceptance

Beam divergence in production straight

- Want to keep beam divergence << natural decay cone of neutrinos
- Imposes a minimum beta in the production straight

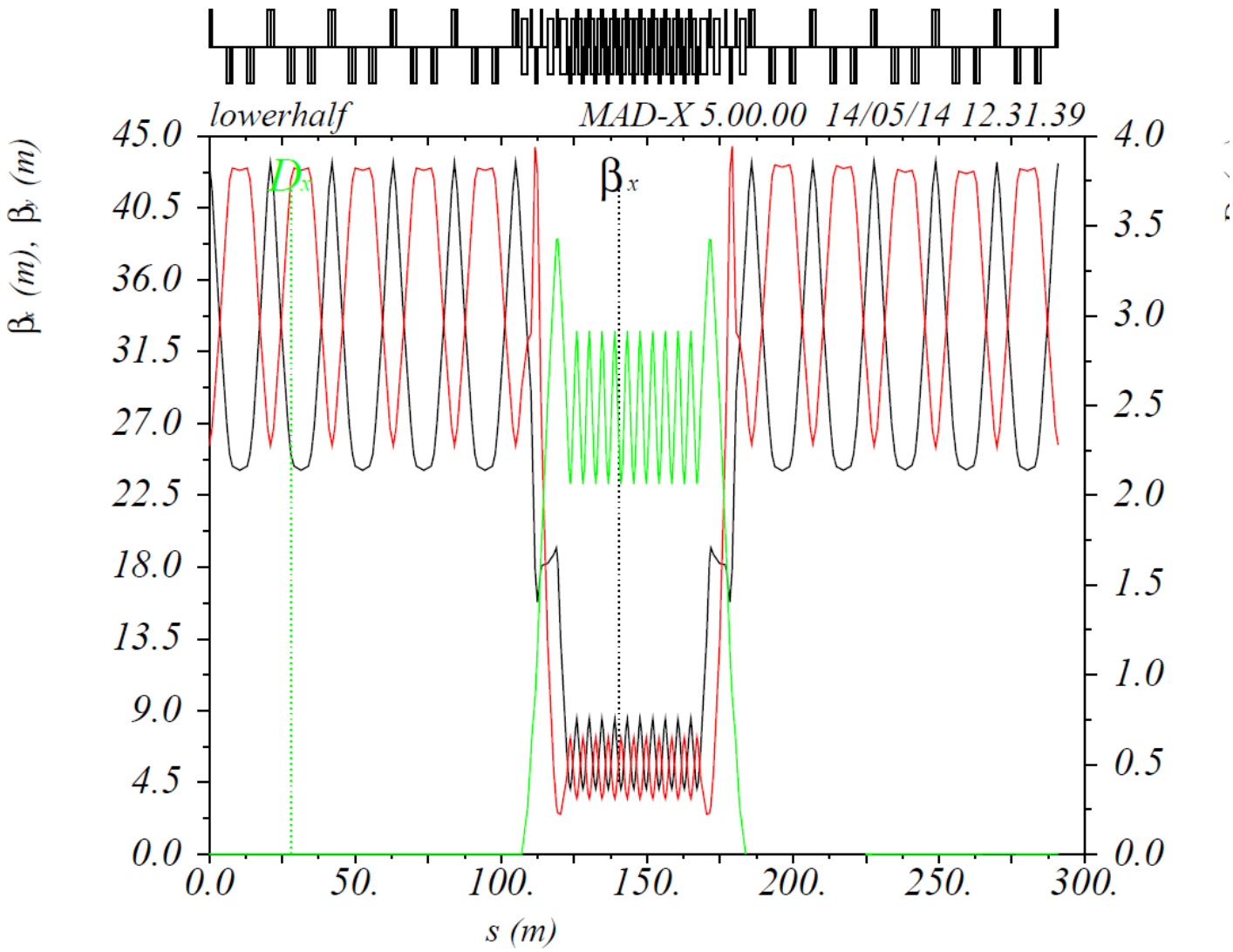
Beam divergence condition $$x' = \sqrt{\frac{\varepsilon_{rms}}{(\beta_r \gamma_r)\beta}} < \frac{0.1}{\gamma_r} \quad \Rightarrow \quad \beta \propto \gamma_r$$

ε_{rms} =~ 5.7 π m rad (approximately) implies β >~ 25 m

Preliminary Lattice overview (FDDF in the production straight)

Section		Cell No.	Total length (m)
Production	21 m (cell length)	10	210x2
Matching	-	-	18.7x4
Arc	4.34 m (cell length)	10	43.41x2
Ring	-	-	581.62
Dipole field	2.4 T		
η	2x36.1%		
transition gamma	6.83		
Ring tune (Qx, Qy)	5.4, 6.13 (needs readjusting		
Chromaticity (ξx, ξy)	-5.1, 6.1		

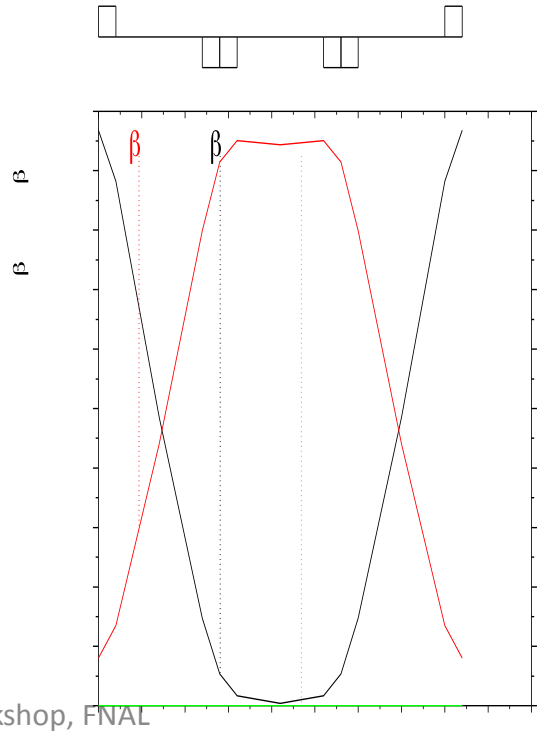
Preliminary optics



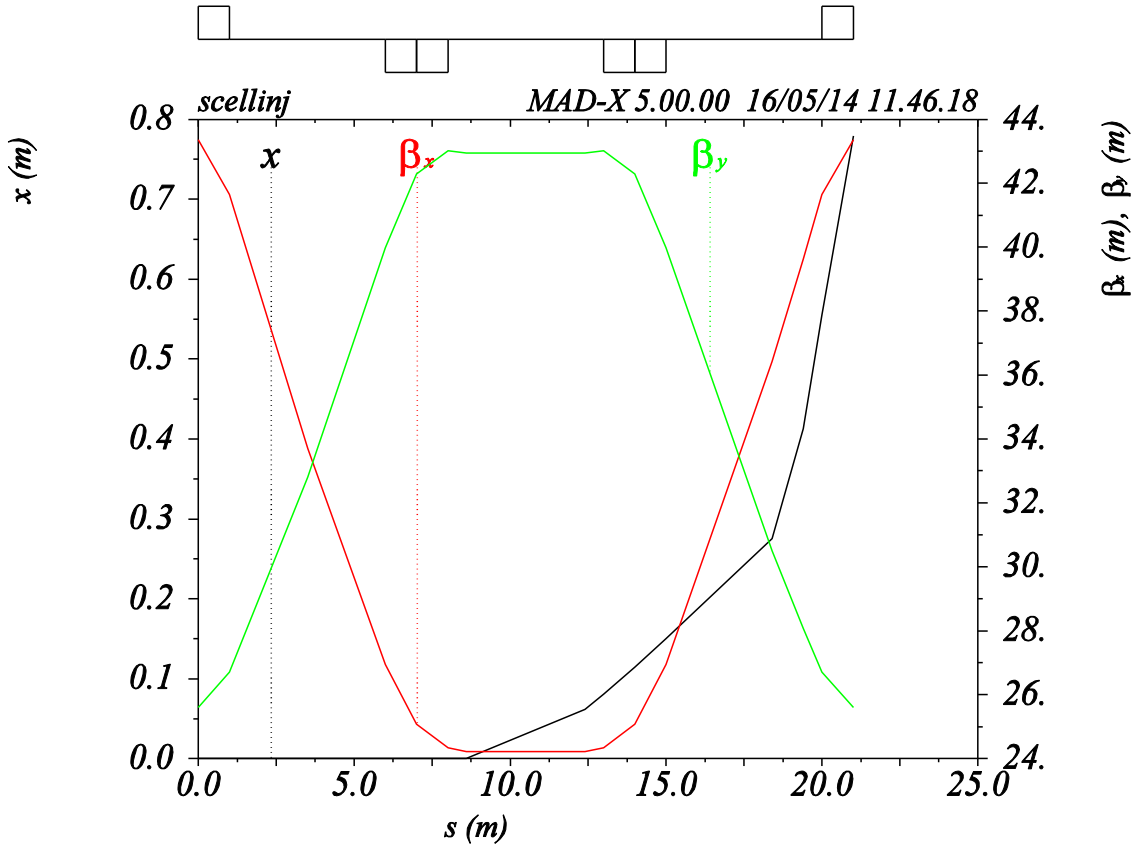
Production Straight (FDDF)

- FDDF lattice adopted for symmetric injection
- Drift length chosen to reduce variation of beta but allow space for injection elements

	Length	Field/Gradient
Drift	5 m	-
QF	2.0 m	0.65 T/m
QD	2.0 m	0.33 T/m
Beam envelope in quads	14.4 cm	-



Injection

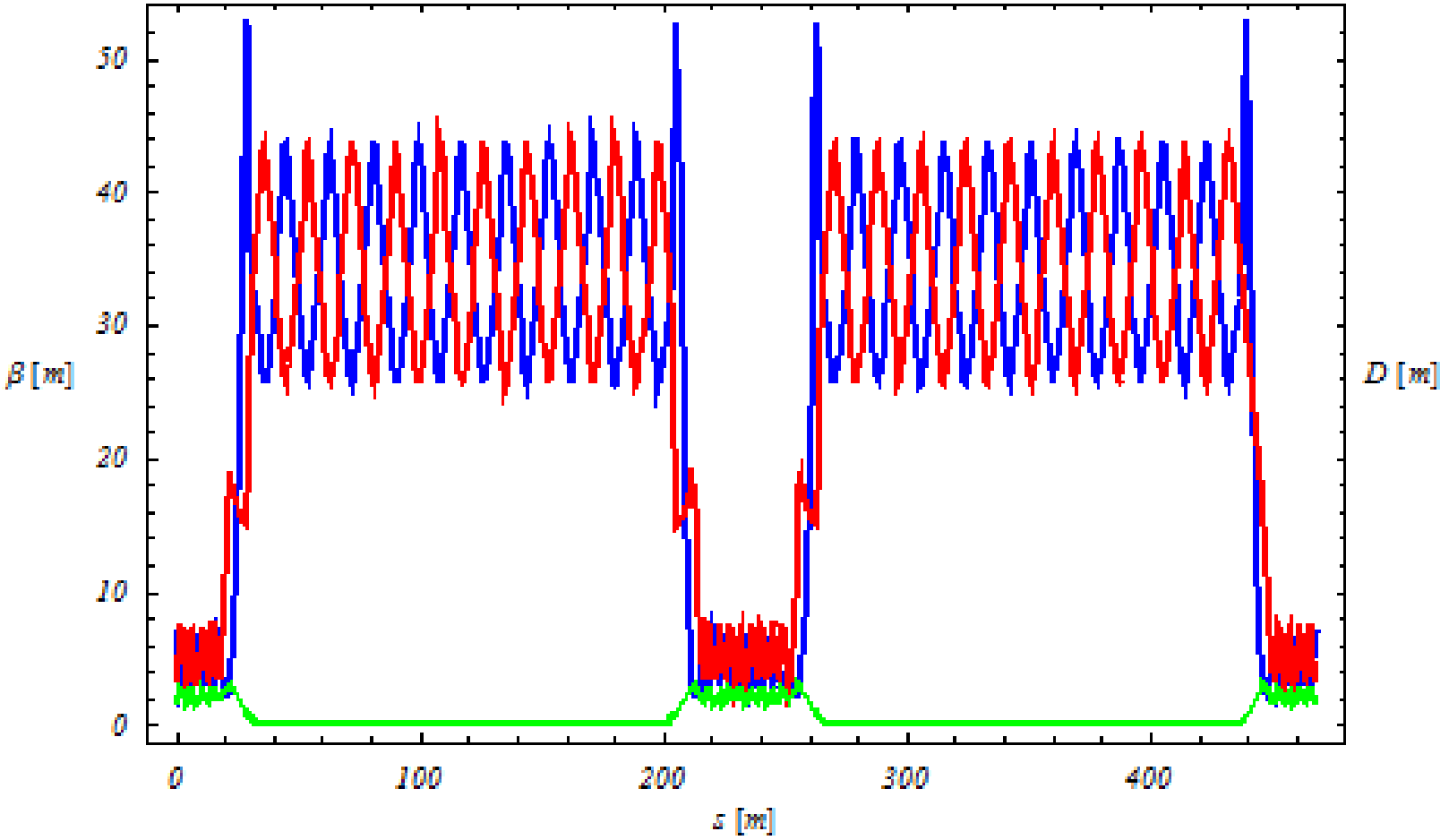


- FDDF allows for symmetric injection of both muon charges.
- Length of the straight section is 5 m.
- Single kicker scenario requires 0.14 T top B field (kicker) -> too much, but distributed kickers may work. Assumed kicker length – 3.8 m.
- Septum 1.67 T, 1m long

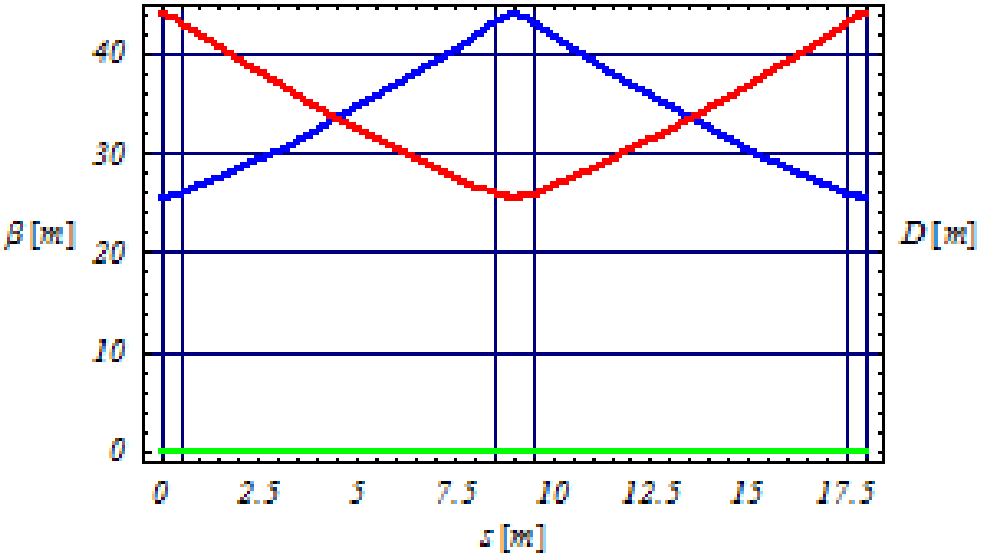
Preliminary Lattice overview (FODO in the production straight)

Section		Cell No.	Total length (m)
Production	18 m (cell length)	9	162x2
Matching	-	-	18.7x4
Arc	4.34 m (cell length)	8	34.7x2
Ring	-	-	468.2
Dipole field	3 T		
η	2x34.6%		
transition gamma	6.33		
Ring tune (Qx, Qy)	4.65, 5.7 (needs readjusting)		

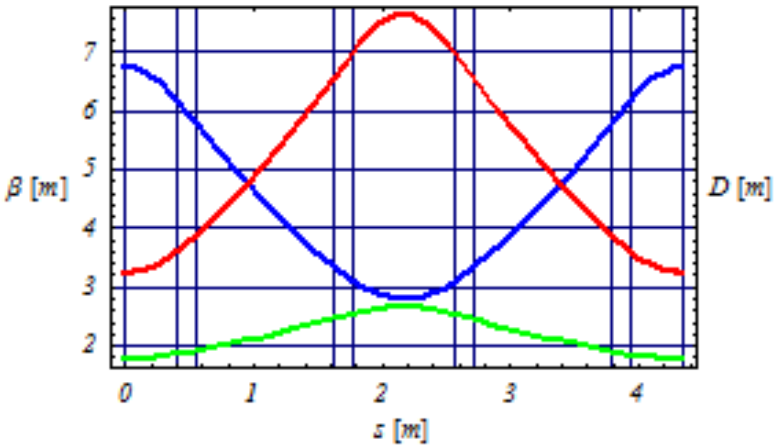
Preliminary NuMax ring with FODO production straight



Cells of the ring with FODO-type production straight



FODO Production cell:
- 8 m drift
- Room temperature quads
- Large β
- Zero dispersion



Arc cell:
- Very short drifts
- All magnets SC in the common cryostat.

Dipole field 3 T.
- Small β
- Non-zero, but small dispersion

Comments on injection (ring with the FODO straight)

- Ring with FODO-type production cells has 8 m drifts, which may allow for injection into the production straight using a single kicker.
- Kicker approximate parameters:
  - 6.4 m long, subdivided into sub-kickers.
  - 0.05 T top B field
  - Rise/fall time ~1.3 us
  - Aperture ~0.35 m
- Septum – 1.2T, 3m long
- This scheme requires confirmation.

Conclusions

- As NuMax design assumes only 1 bunch/charge, the ring size can be reduced.
- We have two preliminary designs of 581.6 and 468.2 m.
- In both rings production straight and matching can be based on room temperature magnets, but arcs need SC ones.
- Injecting directly into the production straight avoids the need for the dedicated insertion (like in the IDS-NF), which allows to makes the ring smaller.
- Limitation for the size of the ring is again rise/fall time of the kicker.
- A large aperture kicker(s) with modest strength is(are) required, which seems to be feasible (to be confirmed).
- Further tuning and simulation studies would be required to evaluate (improve) the performance.