Design of NuMAX decay ring

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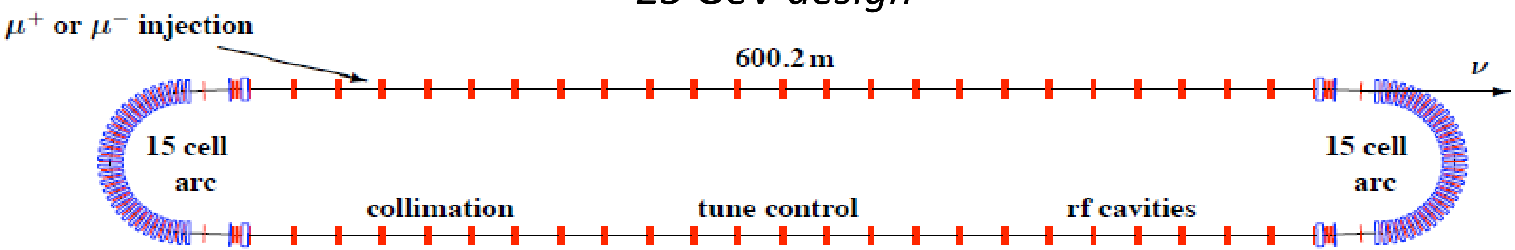
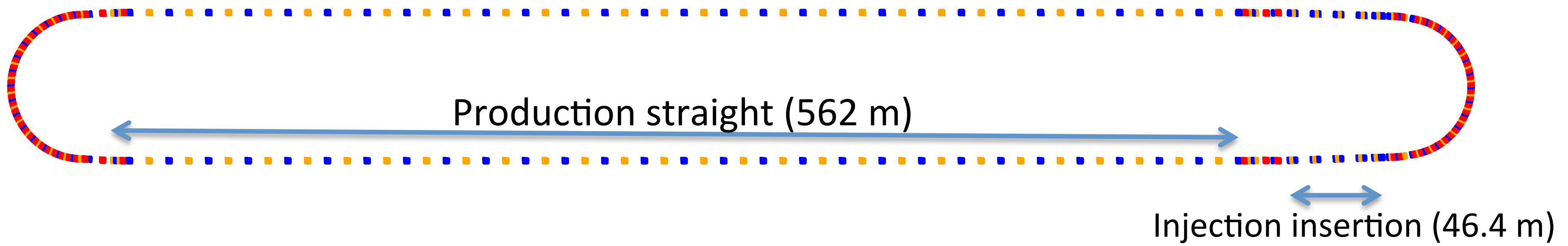
Racetrack decay ring

25 GeV design



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

IDS-NF 10 GeV design



- In IDS-NF wanted to store 3 pairs of counter-rotating muon bunch trains
- Rise/fall time available for injection kicker magnets for n bunch pairs

$$\tau_{rise/fall} = \frac{C}{cn} - t_b$$

- Since there is less than 1μs rise/fall time available in a 1km ring, it was decided to include a dedicated insertion to ease injection.
- This pushed the circumference of the ring to 1555.7 m to achieve a neutrino production efficiency of 36.1%x2.

IDS-NF vs NuMAX

	IDS-NF	NuMAX
Muon energy [GeV]	10	5
Number of bunch pairs	3	1
Bunch train [µs]	250	~170
Normalised acceptance [pi mm rad]	30	20
Ring inclination	10°	5.8°

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   implies β > 25 m is required.

FODO vs FDDF production straight

- FDDF considered as it allows symmetric injection of both muon signs.
- However, longer straights possible in FODO easing the peak field kicker requirement.

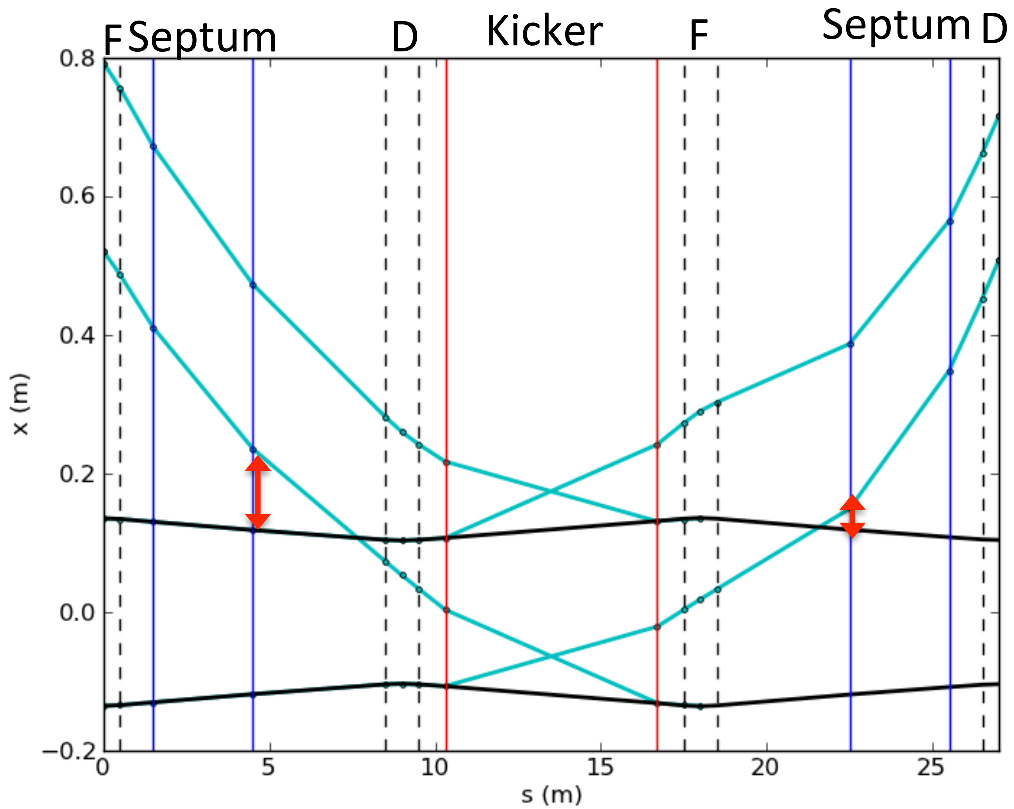
	Length (m)	Gradient
Drift	8	-
QF	1	1.03 T/m
QD	1	-1.03 T/m

	Length (m)	Gradient
Drift	5	-
QF	2	0.65 T/m
QD	2	-0.33 T/m

FODO injection

- Kickers and septa in consecutive cells.
- 6.8 m kicker with 0.09 T peak field
- 3 m septum with 0.4 and 0.2 T.
- Higher kicker field needed when injecting through the F than the D.

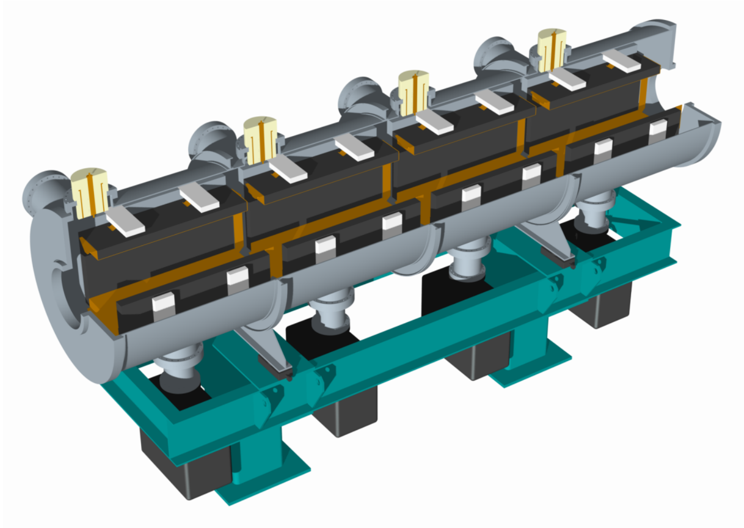
- In the FDDF case, the kicker peak field required is 0.14 T.



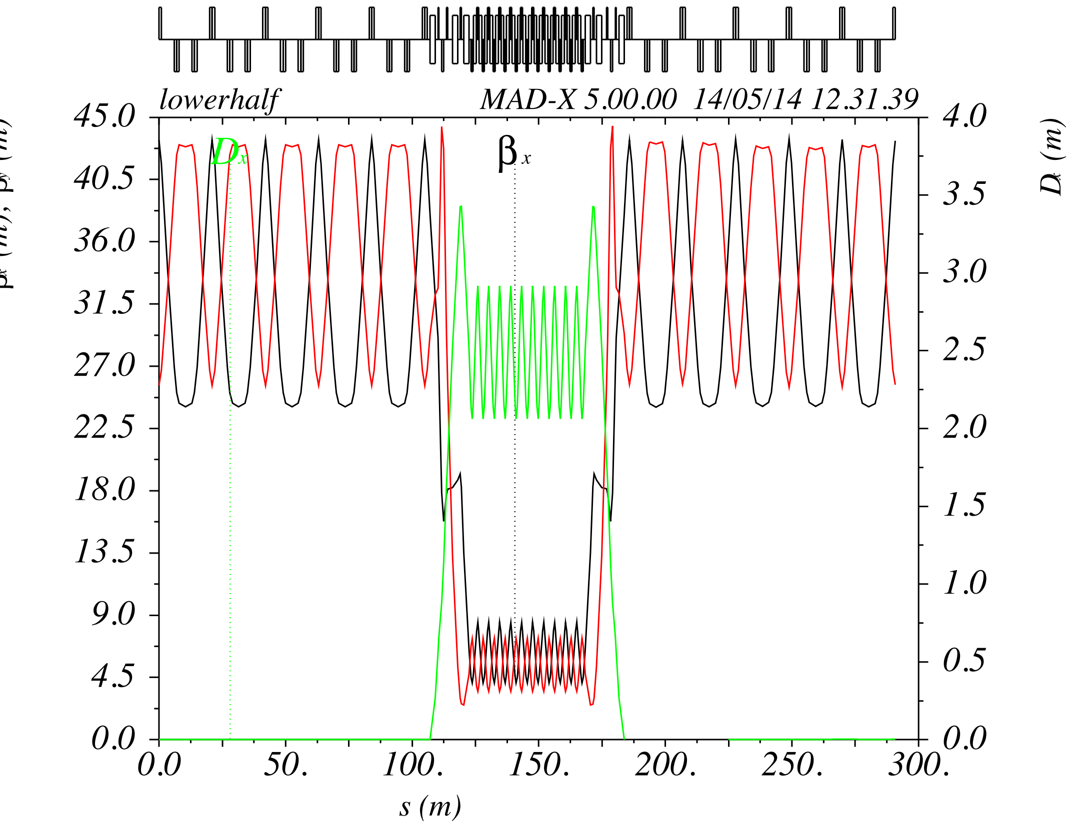
Kicker magnet design (IDS-NF)

Table XXVIII. Parameters of the kicker system

Kicker total aperture (h×v)	0.3×0.3 m
Kicker length	4.4 m
Rise/fall time (5-95%)	1.9 μs
Kicker max field	≈0.1 T
Kicker pulse duration at the top	0.3 μs
Charging voltage	60 kV
Peak current in the magnet	30 kA
Kicker inductance	5.1 μH
Kicker impedance	1 Ω
Peak current at switch	10 kA
Repetition rate	50 Hz
Number of sub-kickers	4-5
Number of PFNs per micro-pulse per sub-kicker	3
Total number of PFNs	36 (for 4 sub-kickers)
Total averaged power per kicker	≈1.25 MW
Total peak power per kicker	≈2.5 MW



Ring optics for FDDF case



Straight – High beta values to minimise beam divergence (< 0.1/γ

Matching – 6D matching beween production straight and arcs

Arc – Low beta value to minimise aperture.

Preliminary Lattice overview (FDDF)

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

Kicker fall time ~ 1.76μs

Momentum acceptance roughly 0.25/ξ if tuned appropriately, i.e. ~4%.

Preliminary Lattice overview (FODO)

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		Kicker fall time ~ 1.4μs
η	2x34.6%		
transition gamma	6.33		
Ring tune (Qx, Qy)	4.65, 5.7 (needs readjusting)		

Conclusions

- Injecting a single bunch pair, and doing without an injection inserion, allows the NuMAX decay ring circumference to be reduced.
- SC magnets in arc, normal conducting elsewhere.
- Circumference of ring largely limited by kicker fall time.
- Large aperture kicker required for injection into the production straight.
- Special large aperture quadrupoles may be needed in injection region.