HE-LHC nonlinear correctors & dynamic aperture

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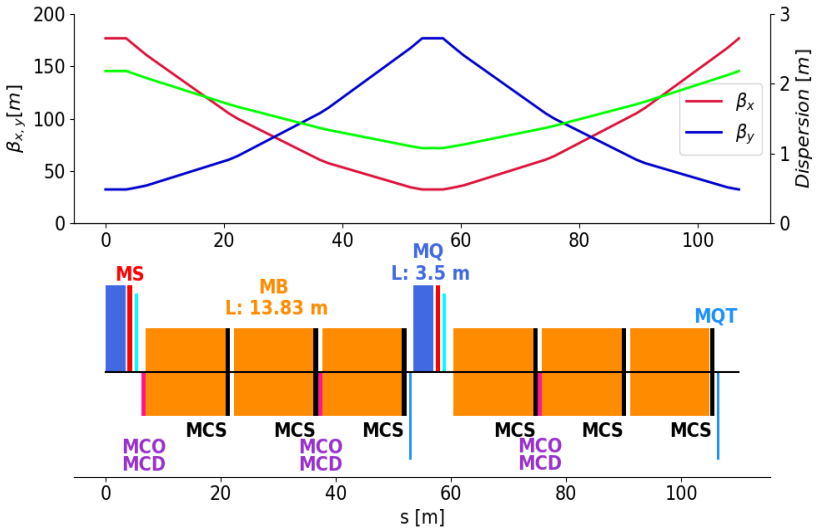
Motivation & Status FCC week 2018

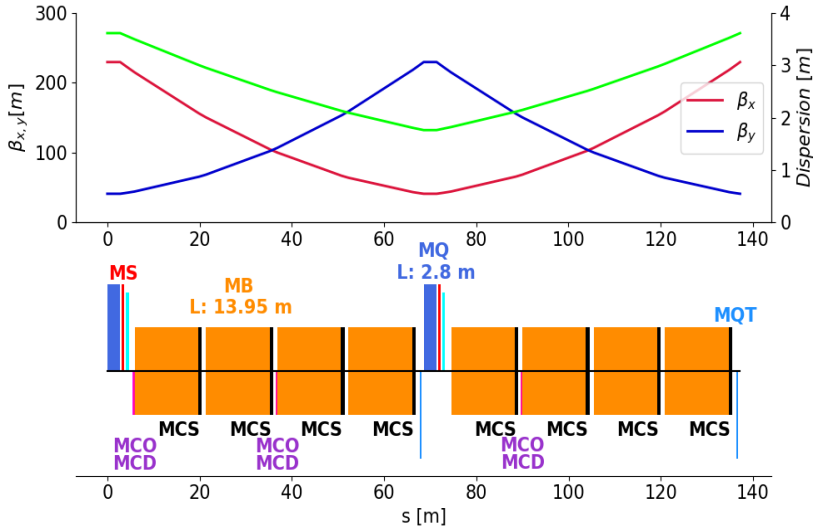
- Study the impact of magnetic field imperfections on the Dynamic Aperture (DA) for the two HE-LHC lattices
- At injection energy, the field quality of the main dipoles becomes critical
- Evaluate DA at injection energy with LHC-like correction scheme and, where needed, look into alternatives to achieve sufficient DA
- At FCC-Week 2018 in Amsterdam the DA for the two HE-LHC lattices at three different injection energies (450 GeV, 900 GeV, 1300 GeV) was presented
  - DA only in LHC-like lattice and highest considered injection energy of 1.3 TeV was close to the target DA of 12 σ
  - In all other cases, DA below 5 σ

Lattices

- Latest status of the HE-LHC lattices already presented in the previous presentation
  - Note that for these tracking studies an older lattice version was used (same lattice as for FCC week 2018) to allow for comparison
- Same nonlinear correction scheme used as in the LHC
  - One sextupole spool piece corrector (MCS) per dipole, one family per arc
  - Combined octupole & decapole spool piece corrector (MCO & MCD), again one family per arc



"LHC-like" 23 cell lattice



18 cell lattice

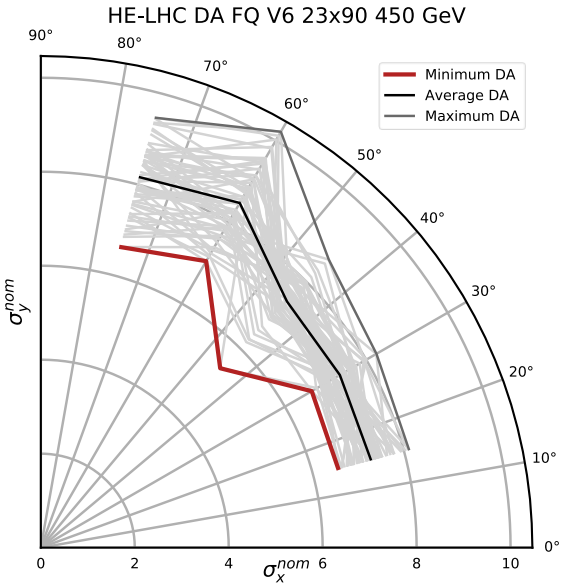
Tracking parameter

- Tracking conducted with SixTrack
- Errors assigned following LHC convention [1]

$$b_n = b_{n_s} + \frac{\xi_U}{1.5} b_{n_u} + \xi_R b_{n_r}$$

where ξ_U and ξ_r are random number with Gaussian distrib truncated at 1.5 σ and 3 σ, respectively

- Same uncertainty component for all dipoles in one arc
- Even normal components change sign between dipole apertures
- For tracking a_1,a_2, b_1 and b_2 harmonics were excluded
- Result presented in the following only show the minimum DA of those 60 seeds and five angles
- Using most recent RF-parameter as presented in HE-LHC CDR



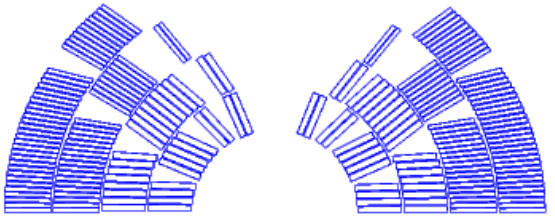
n_{turns}	10^5
No. of seeds	60
No. of angles	5
ε_n	2.5 µm

23x90	450 GeV	900 GeV	1300 GeV
Voltage [MV]	10.4	10.5	10.6
dp/p [10^{-4}]	8.27	5.84	4.86

18x90	450 GeV	900 GeV	1300 GeV
Voltage [MV]	10.7	10.8	10.8
dp/p [10^{-4}]	6.53	4.61	3.84

[1] S. Fartoukh & O. Bruning, Field Quality Specifications for the LHC Main Dipole Magnets, LHC Project Report 501

Main dipole field quality

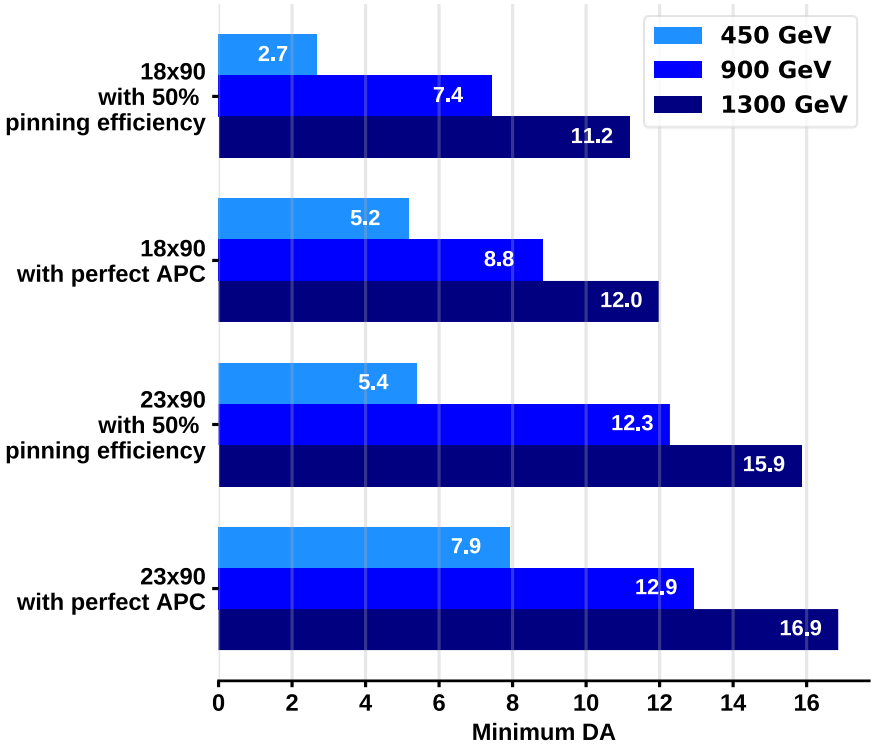


- Since FCC-Week 2018,
  new asymmetric dipole design with
  larger separation and corresponding new FQ tables
  - 20 µm filament size and artificial pinning center
    to reduce magnetization at low field
  - Two tables, one assuming full pinning efficiency and assuming only half pinning efficiency
  - Quadrupole component at collision energy went down from -46 to 0.025 units
  - Random sextupole component at 450 GeV decreased from 10 units to 0.69 units
  - Due to asymmetric design, nonzero systematic b_4, b_6, …

	450 GeV Systematic		900 GeV Systematic		1300 GeV Systematic		Random & Uncertainty
	Full artificial pinning	Half artificial pinning	Full artificial pinning	Half artificial pinning	Full artificial pinning	Half artificial pinning	
b_3	-23.93	-50.76	-12.76	-24.86	-9.25	-16.20	0.69
b_4	0.80	0.64	0.88	0.80	0.90	0.85	0.47
b_5	5.05	12.26	2.56	5.11	1.80	3.19	0.28
b_6	0.66	1.08	0.49	0.67	0.44	0.54	0.19
b_7	-1.31	-3.50	-0.54	-1.31	-0.30	-0.73	0.11

Dynamic aperture at injection

- From DA point of view, LHC-like lattice provides sufficient DA for injection energy > 900 GeV
  - Only small difference between 50% artificial pinning center (APC) efficiency and full APC efficiency
- 18x90 only at 1.3 TeV meets LHC target DA
  - Again, going from 50% APC to full APC does not change the conclusion significantly
- Here DA criteria used is 12 σ with +2/+2 chromaticity, which should provide margin for special operation conditions



Impact of single harmonics on DA

- Following studies looked into the impact of single harmonics on the DA
  - Only case with insufficient DA under study
  - Allows also to assess eventual need of higher order corrector
- Sextupole and Decapole corrector are needed
  - Octupole corrector can potentially be removed
  - Furthermore, no need for higher order correctors

Lattice	18x90		23x90
E_{inj} [GeV]	450	900	450
nominal min. DA	2.7	7.4	5.4
50 % b_{3s}	4.4	8.1	7.0
50 % b_{5s}	2.8	7.7	5.4
no b_3 correction	0	1.7	0.8
no b_4 correction	2.6	7.7	6.4
no b_5 correction	1.1	4.1	2.0
$b_{6s} = 0$	2.7	7.4	5.5
$b_{7s} = 0$	2.9	8.2	5.5
$b_{9s} = 0$	2.7	7.7	5.3

Dipole sorting on b3

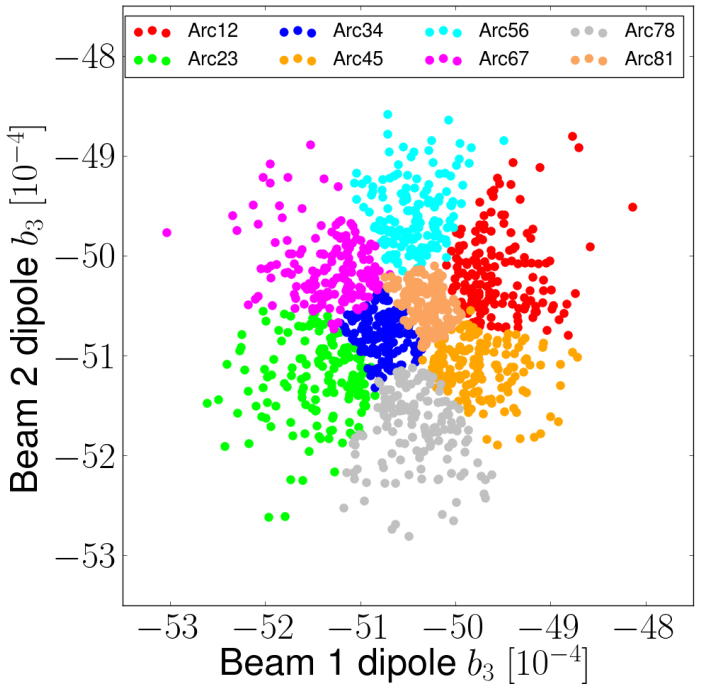
- For the previous FQ table the high random sextupole component of the MB at 450 GeV was identified as one of the limiting factors
- A simple sorting on b_3, taking into account all dipoles, showed significant improvements
- In the LHC, a correlation between the b3 in the two apertures was observed
  - Sorting only in one beam should in turn also help in beam 2

		Aperture 2						
		b3	**b4**	**b5**	**b6**	**b7**	**b8**	**b9**
Aperture 1	**b3**	0.88	-0.03	0.43	0.01	0.23	0.02	0.13
	b4	-0.07	-0.31	-0.05	-0.14	0.04	-0.05	0.05
	b5	0.42	-0.12	0.93	-0.04	0.27	0.18	0.58
	b6	-0.15	-0.08	-0.21	-0.14	-0.30	-0.06	-0.20
	b7	0.22	-0.09	0.26	0.17	0.90	0.05	0.54
	b8	0.08	-0.12	0.04	-0.03	0.12	-0.01	0.09
	b9	0.11	-0.19	0.58	-0.02	0.55	0.14	0.89

Correlation calculated based on magnetic measurements of the LHC dipoles

- Since no physical driver for this correlation has so far been identified, this cannot be assumed for the 16T dipoles

Dipole sorting on b3 II



- An adapted K-means clustering algorithm was used to sort on the sextupole component in both apertures simultaneously
  - Reduces the variance of b_3 in on arc, thereby increased efficiency of correction
  - Assumes that all dipoles are available and measured before installation
- DA improves by minimum 0.8 σ
  - However, at 450 GeV, DA still low

	Lattice	Energy [GeV]		
		450	900	1300
Without sorting	18 x 90	2.7	7.4	11.2
	23 x 90	5.4	12.3	15.9
With sorting	18 x 90	3.8	9.0	14.4
	23 x 90	6.2	13.9	18.1

Summary

- The DA in the HE-LHC lattices, based on the latest Field quality estimates for the 16T dipoles, has been presented
  - Compared to the results presented at FCC-Week 2018, the DA significantly increased
  - The LHC-like lattice shows DA above 12 σ for both 900 GeV and 1300 GeV
  - For cases above 900 GeV, only a small difference in DA is observed between 50% pinning efficiency and 100% pinning efficiency
  - 18 arc cell lattice meets target only in case of 1300 GeV injection energy
  - In both lattices the DA at 450 GeV is still low
- From DA point of view no need for additional correctors in the arcs
- Further refinement of the b_3 correction envisaged to increase DA

Thank you for your attention

FQ at 450 GeV injection energy
Full artificial pinning

Courtesy S.I. Bermudez

HE-LHC Dipole field quality version 5 28 September 2018- R_{ref}=16.7 mm. 0.45 TeV Injection
0.45 TeV Injection (Binj = 0.53 T); Deff = 20 μm , Artificial pinning

		Systematic				Uncertainty		Random	
Normal	Geometric	Saturation	Persistent	Injection	High Field	Injection	High Field	Injection	High Field
2	3.680	-3.655	1.786	5.466	0.025	0.929	0.929	0.929	0.929
3	-2.364	2.470	-21.564	-23.928	0.106	0.668	0.668	0.668	0.668
4	0.952	-0.639	-0.148	0.804	0.313	0.467	0.467	0.467	0.467
5	0.296	-0.113	4.753	5.049	0.182	0.283	0.283	0.283	0.283
6	0.345	0.002	0.312	0.657	0.347	0.187	0.187	0.187	0.187
7	0.170	0.014	-1.473	-1.303	0.184	0.109	0.109	0.109	0.109
8	0.346	0.028	0.111	0.458	0.375	0.072	0.072	0.072	0.072
9	0.525	0.043	1.484	2.009	0.568	0.047	0.047	0.047	0.047
10	0.120	0.010	0.097	0.217	0.130	0.028	0.028	0.028	0.028
11	1.021	0.083	0.020	1.042	1.105	0.015	0.015	0.015	0.015
12	0.081	0.007	0.000	0.081	0.088	0.010	0.010	0.010	0.010
13	-0.227	-0.019	0.000	-0.227	-0.245	0.005	0.005	0.005	0.005
14	0.026	0.002	0.000	0.026	0.028	0.003	0.003	0.003	0.003
15	-0.020	-0.002	0.000	-0.020	-0.022	0.002	0.002	0.002	0.002
Skew									
2	0.000	0.000	0.000	0.000	0.000	1.103	1.103	1.103	1.103
3	0.000	0.000	0.000	0.000	0.000	0.754	0.754	0.754	0.754
4	0.000	0.000	0.000	0.000	0.000	0.473	0.473	0.473	0.473
5	0.000	0.000	0.000	0.000	0.000	0.329	0.329	0.329	0.329
6	0.000	0.000	0.000	0.000	0.000	0.205	0.205	0.205	0.205
7	0.000	0.000	0.000	0.000	0.000	0.114	0.114	0.114	0.114
8	0.000	0.000	0.000	0.000	0.000	0.069	0.069	0.069	0.069
9	0.000	0.000	0.000	0.000	0.000	0.038	0.038	0.038	0.038
10	0.000	0.000	0.000	0.000	0.000	0.023	0.023	0.023	0.023
11	0.000	0.000	0.000	0.000	0.000	0.015	0.015	0.015	0.015
12	0.000	0.000	0.000	0.000	0.000	0.008	0.008	0.008	0.008
13	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.005	0.005
14	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.003	0.003
15	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.002

FQ at 450 GeV injection energy
Half artificial pinning

Courtesy S.I. Bermudez

HE-LHC Dipole field quality version 6 28 September 2018- R_{ref}=16.7 mm.
0.45 TeV Injection (B_{inj} = 0.53 T); Deff = 20 μm , Half artificial pinning

	Systematic					Uncertainty		Random	
Normal	Geometric	Saturation	Persistent	Injection	High Field	Injection	High Field	Injection	High Field
2	3.680	-3.655	4.149	7.828	0.025	0.929	0.929	0.929	0.929
3	-2.364	2.470	-48.399	-50.764	0.106	0.668	0.668	0.668	0.668
4	0.952	-0.639	-0.314	0.638	0.313	0.467	0.467	0.467	0.467
5	0.296	-0.113	11.968	12.263	0.182	0.283	0.283	0.283	0.283
6	0.345	0.002	0.733	1.077	0.347	0.187	0.187	0.187	0.187
7	0.170	0.014	-3.671	-3.501	0.184	0.109	0.109	0.109	0.109
8	0.346	0.028	0.266	0.612	0.375	0.072	0.072	0.072	0.072
9	0.525	0.043	3.617	4.142	0.568	0.047	0.047	0.047	0.047
10	0.120	0.010	0.237	0.357	0.130	0.028	0.028	0.028	0.028
11	1.021	0.083	0.031	1.052	1.105	0.015	0.015	0.015	0.015
12	0.081	0.007	0.000	0.081	0.088	0.010	0.010	0.010	0.010
13	-0.227	-0.019	0.000	-0.227	-0.245	0.005	0.005	0.005	0.005
14	0.026	0.002	0.000	0.026	0.028	0.003	0.003	0.003	0.003
15	-0.020	-0.002	0.000	-0.020	-0.022	0.002	0.002	0.002	0.002
Skew									
2	0.000	0.000	0.000	0.000	0.000	1.103	1.103	1.103	1.103
3	0.000	0.000	0.000	0.000	0.000	0.754	0.754	0.754	0.754
4	0.000	0.000	0.000	0.000	0.000	0.473	0.473	0.473	0.473
5	0.000	0.000	0.000	0.000	0.000	0.329	0.329	0.329	0.329
6	0.000	0.000	0.000	0.000	0.000	0.205	0.205	0.205	0.205
7	0.000	0.000	0.000	0.000	0.000	0.114	0.114	0.114	0.114
8	0.000	0.000	0.000	0.000	0.000	0.069	0.069	0.069	0.069
9	0.000	0.000	0.000	0.000	0.000	0.038	0.038	0.038	0.038
10	0.000	0.000	0.000	0.000	0.000	0.023	0.023	0.023	0.023
11	0.000	0.000	0.000	0.000	0.000	0.015	0.015	0.015	0.015
12	0.000	0.000	0.000	0.000	0.000	0.008	0.008	0.008	0.008
13	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.005	0.005
14	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.003	0.003
15	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.002

FQ at 900 GeV injection energy
Full artificial pinning

Courtesy S.I. Bermudez

HE-LHC Dipole field quality version 5 28 September2018 - R_{ref}=16.7 mm.
0.90 TeV Injection (Binj = 1.07T), Deff = 20 μm , Artificial pinning

	Systematic					Uncertainty		Random	
Normal	Geometric	Saturation	Persistent	Injection	High Field	Injection	High Field	Injection	High Field
2	3.680	-3.655	0.832	4.511	0.025	0.929	0.929	0.929	0.929
3	-2.364	2.470	-10.391	-12.756	0.106	0.668	0.668	0.668	0.668
4	0.952	-0.639	-0.074	0.878	0.313	0.467	0.467	0.467	0.467
5	0.296	-0.113	2.265	2.561	0.182	0.283	0.283	0.283	0.283
6	0.345	0.002	0.150	0.494	0.347	0.187	0.187	0.187	0.187
7	0.170	0.014	-0.706	-0.536	0.184	0.109	0.109	0.109	0.109
8	0.346	0.028	0.053	0.400	0.375	0.072	0.072	0.072	0.072
9	0.525	0.043	0.716	1.241	0.568	0.047	0.047	0.047	0.047
10	0.120	0.010	0.047	0.167	0.130	0.028	0.028	0.028	0.028
11	1.021	0.083	0.009	1.030	1.105	0.015	0.015	0.015	0.015
12	0.081	0.007	0.000	0.081	0.088	0.010	0.010	0.010	0.010
13	-0.227	-0.019	0.000	-0.227	-0.245	0.005	0.005	0.005	0.005
14	0.026	0.002	0.000	0.026	0.028	0.003	0.003	0.003	0.003
15	-0.020	-0.002	0.000	-0.020	-0.022	0.002	0.002	0.002	0.002
Skew									
2	0.000	0.000	0.000	0.000	0.000	1.103	1.103	1.103	1.103
3	0.000	0.000	0.000	0.000	0.000	0.754	0.754	0.754	0.754
4	0.000	0.000	0.000	0.000	0.000	0.473	0.473	0.473	0.473
5	0.000	0.000	0.000	0.000	0.000	0.329	0.329	0.329	0.329
6	0.000	0.000	0.000	0.000	0.000	0.205	0.205	0.205	0.205
7	0.000	0.000	0.000	0.000	0.000	0.114	0.114	0.114	0.114
8	0.000	0.000	0.000	0.000	0.000	0.069	0.069	0.069	0.069
9	0.000	0.000	0.000	0.000	0.000	0.038	0.038	0.038	0.038
10	0.000	0.000	0.000	0.000	0.000	0.023	0.023	0.023	0.023
11	0.000	0.000	0.000	0.000	0.000	0.015	0.015	0.015	0.015
12	0.000	0.000	0.000	0.000	0.000	0.008	0.008	0.008	0.008
13	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.005	0.005
14	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.003	0.003
15	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.002

FQ at 900 GeV injection energy
Half artificial pinning

Courtesy S.I. Bermudez

HE-LHC Dipole field quality version 6 28 September 2018 - R_{ref}=16.7 mm.
0.90 TeV Injection (B_{inj} = 1.07T); Deff = 20 μm , Half artificial pinning

	Systematic					Uncertainty		Random	
Normal	Geometric	Saturation	Persistent	Injection	High Field	Injection	High Field	Injection	High Field
2	3.680	-3.655	1.927	5.607	0.025	0.929	0.929	0.929	0.929
3	-2.364	2.470	-22.492	-24.856	0.106	0.668	0.668	0.668	0.668
4	0.952	-0.639	-0.155	0.797	0.313	0.467	0.467	0.467	0.467
5	0.296	-0.113	4.813	5.109	0.182	0.283	0.283	0.283	0.283
6	0.345	0.002	0.325	0.669	0.347	0.187	0.187	0.187	0.187
7	0.170	0.014	-1.482	-1.312	0.184	0.109	0.109	0.109	0.109
8	0.346	0.028	0.115	0.461	0.375	0.072	0.072	0.072	0.072
9	0.525	0.043	1.511	2.036	0.568	0.047	0.047	0.047	0.047
10	0.120	0.010	0.099	0.220	0.130	0.028	0.028	0.028	0.028
11	1.021	0.083	0.026	1.048	1.105	0.015	0.015	0.015	0.015
12	0.081	0.007	0.000	0.081	0.088	0.010	0.010	0.010	0.010
13	-0.227	-0.019	0.000	-0.227	-0.245	0.005	0.005	0.005	0.005
14	0.026	0.002	0.000	0.026	0.028	0.003	0.003	0.003	0.003
15	-0.020	-0.002	0.000	-0.020	-0.022	0.002	0.002	0.002	0.002
Skew									
2	0.000	0.000	0.000	0.000	0.000	1.103	1.103	1.103	1.103
3	0.000	0.000	0.000	0.000	0.000	0.754	0.754	0.754	0.754
4	0.000	0.000	0.000	0.000	0.000	0.473	0.473	0.473	0.473
5	0.000	0.000	0.000	0.000	0.000	0.329	0.329	0.329	0.329
6	0.000	0.000	0.000	0.000	0.000	0.205	0.205	0.205	0.205
7	0.000	0.000	0.000	0.000	0.000	0.114	0.114	0.114	0.114
8	0.000	0.000	0.000	0.000	0.000	0.069	0.069	0.069	0.069
9	0.000	0.000	0.000	0.000	0.000	0.038	0.038	0.038	0.038
10	0.000	0.000	0.000	0.000	0.000	0.023	0.023	0.023	0.023
11	0.000	0.000	0.000	0.000	0.000	0.015	0.015	0.015	0.015
12	0.000	0.000	0.000	0.000	0.000	0.008	0.008	0.008	0.008
13	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.005	0.005
14	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.003	0.003
15	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.002

FQ at 1300 GeV injection energy
Full artificial pinning

Courtesy S.I. Bermudez

FCC Dipole field quality version 4 - 28 Sep 2018- R_{ref}=16.7 mm.
1.3 TeV Injection (Binj = 0.42 T); Deff = 20 μm , A ificial pinning

	Systematic					Uncertainty		Random	
Normal	Geometric	Saturation	Persistent	Injection	High Field	Injection	High Field	Injection	High Field
2	3.680	-3.655	2.300	5.980	0.025	0.929	0.929	0.929	0.929
3	-2.364	2.470	-27.036	-29.400	0.106	0.668	0.668	0.668	0.668
4	0.952	-0.639	-0.181	0.771	0.313	0.467	0.467	0.467	0.467
5	0.296	-0.113	6.014	6.310	0.182	0.283	0.283	0.283	0.283
6	0.345	0.002	0.392	0.737	0.347	0.187	0.187	0.187	0.187
7	0.170	0.014	-1.860	-1.690	0.184	0.109	0.109	0.109	0.109
8	0.346	0.028	0.141	0.487	0.375	0.072	0.072	0.072	0.072
9	0.525	0.043	1.865	2.390	0.568	0.047	0.047	0.047	0.047
10	0.120	0.010	0.123	0.243	0.130	0.028	0.028	0.028	0.028
11	1.021	0.083	0.019	1.040	1.105	0.015	0.015	0.015	0.015
12	0.081	0.007	0.000	0.081	0.088	0.010	0.010	0.010	0.010
13	-0.227	-0.019	0.000	-0.227	-0.245	0.005	0.005	0.005	0.005
14	0.026	0.002	0.000	0.026	0.028	0.003	0.003	0.003	0.003
15	-0.020	-0.002	0.000	-0.020	-0.022	0.002	0.002	0.002	0.002
Skew									
2	0.000	0.000	0.000	0.000	0.000	1.103	1.103	1.103	1.103
3	0.000	0.000	0.000	0.000	0.000	0.754	0.754	0.754	0.754
4	0.000	0.000	0.000	0.000	0.000	0.473	0.473	0.473	0.473
5	0.000	0.000	0.000	0.000	0.000	0.329	0.329	0.329	0.329
6	0.000	0.000	0.000	0.000	0.000	0.205	0.205	0.205	0.205
7	0.000	0.000	0.000	0.000	0.000	0.114	0.114	0.114	0.114
8	0.000	0.000	0.000	0.000	0.000	0.069	0.069	0.069	0.069
9	0.000	0.000	0.000	0.000	0.000	0.038	0.038	0.038	0.038
10	0.000	0.000	0.000	0.000	0.000	0.023	0.023	0.023	0.023
11	0.000	0.000	0.000	0.000	0.000	0.015	0.015	0.015	0.015
12	0.000	0.000	0.000	0.000	0.000	0.008	0.008	0.008	0.008
13	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.005	0.005
14	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.003	0.003
15	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.002

FQ at 1300 GeV injection energy
Half artificial pinning

Courtesy S.I. Bermudez

HE-LHC Dipole field quality version 6 28 September 2018 - Rref=16.7 mm.
1.3 TeV Injection (B_{inj} = 1.54 T); Deff = 20 μm , Half artificial pinning

	Systematic					Uncertainty		Random	
Normal	Geometric	Saturation	Persistent	Injection	High Field	Injection	High Field	Injection	High Field
2	3.680	-3.655	1.105	4.785	0.025	0.929	0.929	0.929	0.929
3	-2.364	2.470	-13.833	-16.197	0.106	0.668	0.668	0.668	0.668
4	0.952	-0.639	-0.102	0.850	0.313	0.467	0.467	0.467	0.467
5	0.296	-0.113	2.891	3.187	0.182	0.283	0.283	0.283	0.283
6	0.345	0.002	0.196	0.541	0.347	0.187	0.187	0.187	0.187
7	0.170	0.014	-0.898	-0.728	0.184	0.109	0.109	0.109	0.109
8	0.346	0.028	0.070	0.416	0.375	0.072	0.072	0.072	0.072
9	0.525	0.043	0.915	1.440	0.568	0.047	0.047	0.047	0.047
10	0.120	0.010	0.060	0.180	0.130	0.028	0.028	0.028	0.028
11	1.021	0.083	0.017	1.038	1.105	0.015	0.015	0.015	0.015
12	0.081	0.007	0.000	0.081	0.088	0.010	0.010	0.010	0.010
13	-0.227	-0.019	0.000	-0.227	-0.245	0.005	0.005	0.005	0.005
14	0.026	0.002	0.000	0.026	0.028	0.003	0.003	0.003	0.003
15	-0.020	-0.002	0.000	-0.020	-0.022	0.002	0.002	0.002	0.002
Skew									
2	0.000	0.000	0.000	0.000	0.000	1.103	1.103	1.103	1.103
3	0.000	0.000	0.000	0.000	0.000	0.754	0.754	0.754	0.754
4	0.000	0.000	0.000	0.000	0.000	0.473	0.473	0.473	0.473
5	0.000	0.000	0.000	0.000	0.000	0.329	0.329	0.329	0.329
6	0.000	0.000	0.000	0.000	0.000	0.205	0.205	0.205	0.205
7	0.000	0.000	0.000	0.000	0.000	0.114	0.114	0.114	0.114
8	0.000	0.000	0.000	0.000	0.000	0.069	0.069	0.069	0.069
9	0.000	0.000	0.000	0.000	0.000	0.038	0.038	0.038	0.038
10	0.000	0.000	0.000	0.000	0.000	0.023	0.023	0.023	0.023
11	0.000	0.000	0.000	0.000	0.000	0.015	0.015	0.015	0.015
12	0.000	0.000	0.000	0.000	0.000	0.008	0.008	0.008	0.008
13	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.005	0.005
14	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.003	0.003
15	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.002	0.002