Lattice for Collimation

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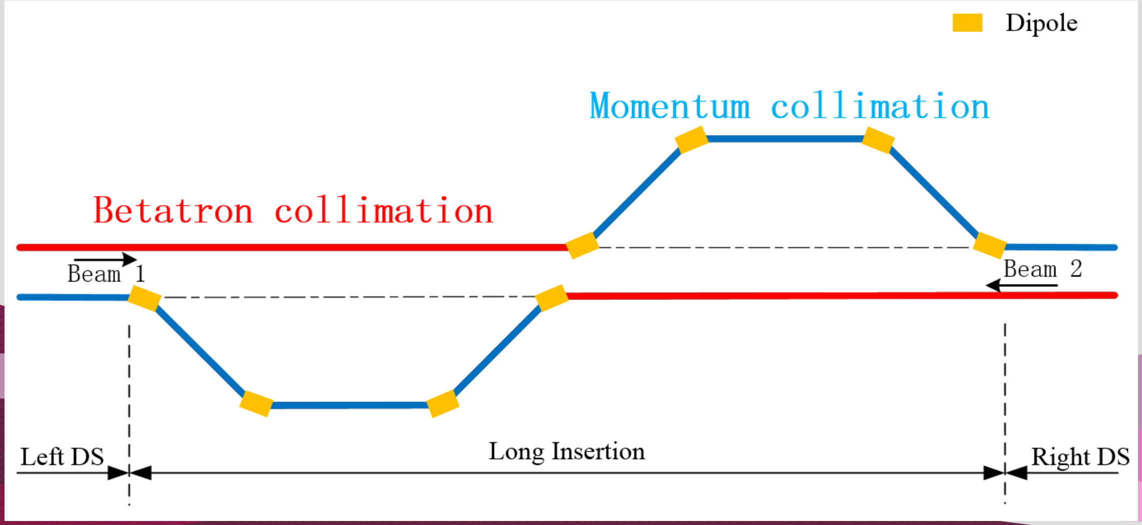
Institute of High Energy Physics

❖ Outline

- **Review**
- **Requirements for collimation insertion**
- **Lattice design**
  - Betatron collimation
  - Momentum collimation
- **Multiparticle simulation**
- **Optimizing designing**
- **Next to do**

Review

- HL-LHC
  - Partical losses in the DS are the highest cold losses around the ri ng, may pose a certain risk for inducing magnet quenches
  - Single Dsifractive scattering drives the secondary hole to dispers ion suppressor(DS)
- New idea for SPPC collimation
  - put the betatron collimation insertion and the momentum colli mation insertion into one straight section

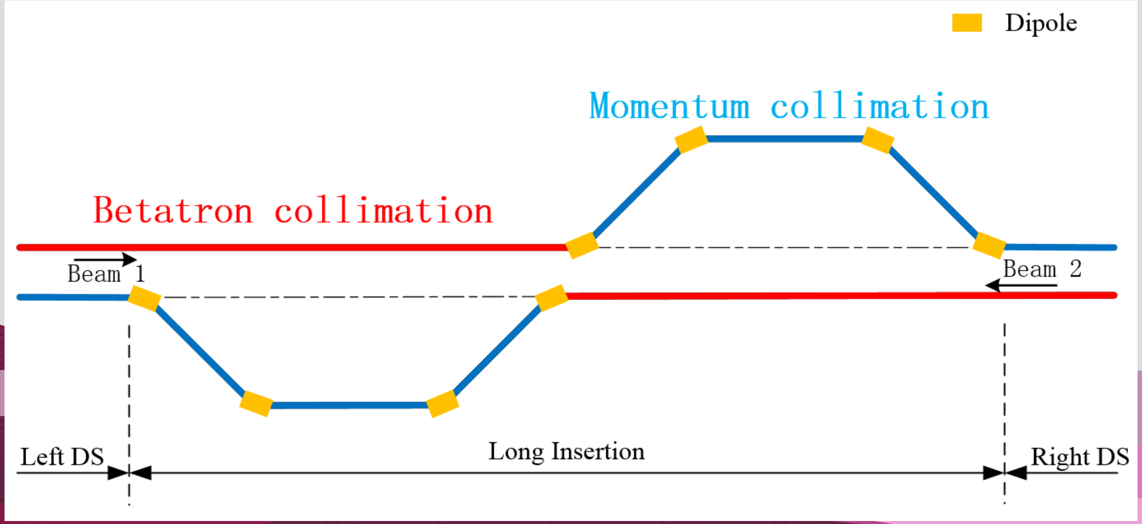


Requirements for coll. insertion

- Betatron Coll.
  - Large beta function
  - Phase advanced greater than π
- Momentum Coll.
  - Good ratio Dx/ β x at location of primary collimator, with β x lower than for betatron primaryone.
  - β x at location of secondaries collimators lower than β x at primaryone.
  - Dx as small as possible for secondaries.
  - The start and the end must in a straight line

Lattice design

- required to have an achromatic end at the joint between the momentum collimation and the transverse collimation sections.
- need some dipole magnets to produce the required dispersion for the momentum collimation and cancel the dispersion at the end.
- betatron collimation requires significantly longer space for multi-stage collimation and the two proton beams
- the two ends of the long straight section which connect the two adjacent arcs should not be affected by the introduced dipoles.



Betatron collimation

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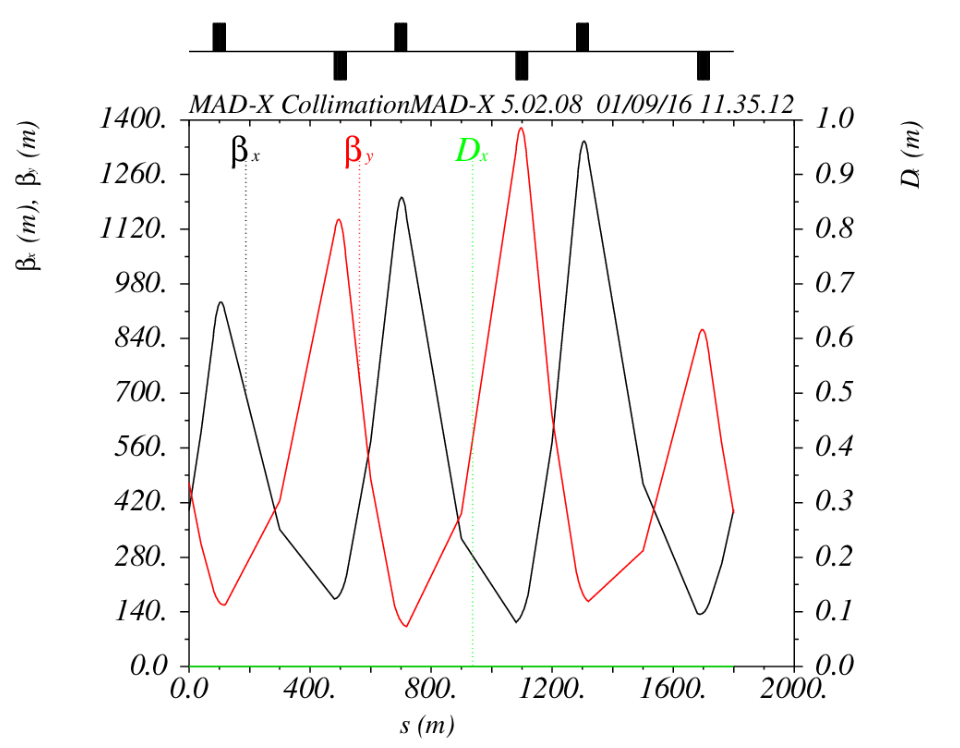
- Stored beam energy 6.6 GJ
- The cleaning inefficiency should achieve e-6 or even less to prevent the quenching of superconducting magnets
- Warm quadrupoles are used for the transverse collimation section

B=0.6T,R=0.25m, K=0.000205		
mu	Mux/2π	0.905
	Muy/2π	0.912
betx	Min/m	113.6
	Max/m	1345.1
bety	Min/m	102.2
	Max/m	1379.3



Momentum collimation

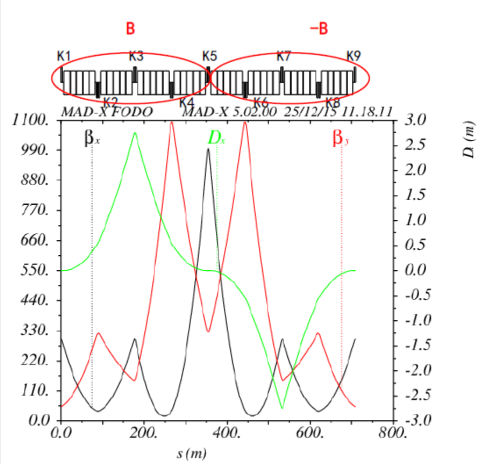
- need some super-conducting dipole magnets to produce the higher dispersion
- Dispersion supressor
- All dipoles palced in the form of symmetry
- β x lower than for betatron Coll. so super-con ducting quadrupoles are used

- (B,-B,-B,B) → Local anti-symmetry DS
- (B,-B,-B,B) → symmetry DS

Momentum collimation

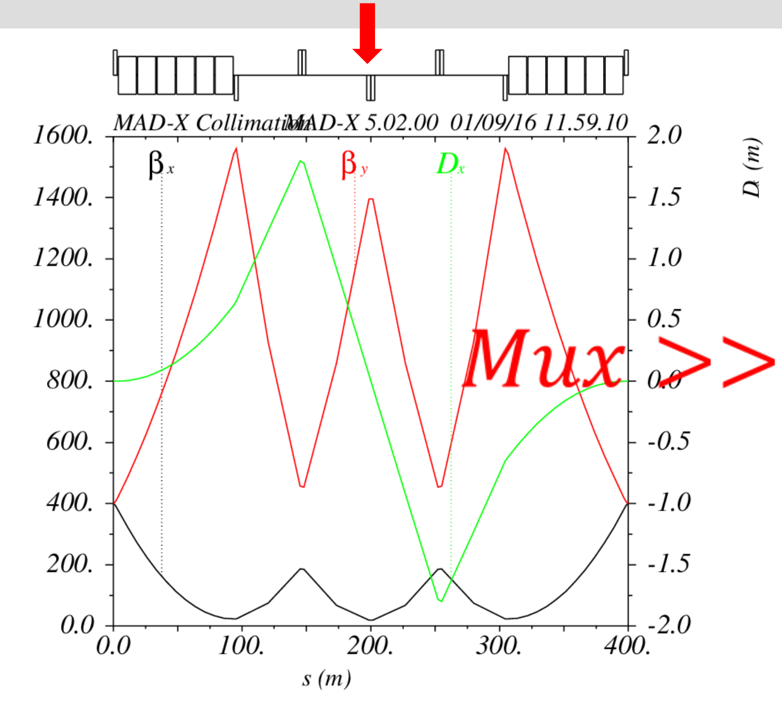
- (B,-B,-B,B)
- Local anti-symmetry DS

$$constraint: \begin{cases} dx = 0 \\ alfx = 0 \\ alfy = 0 \end{cases}$$

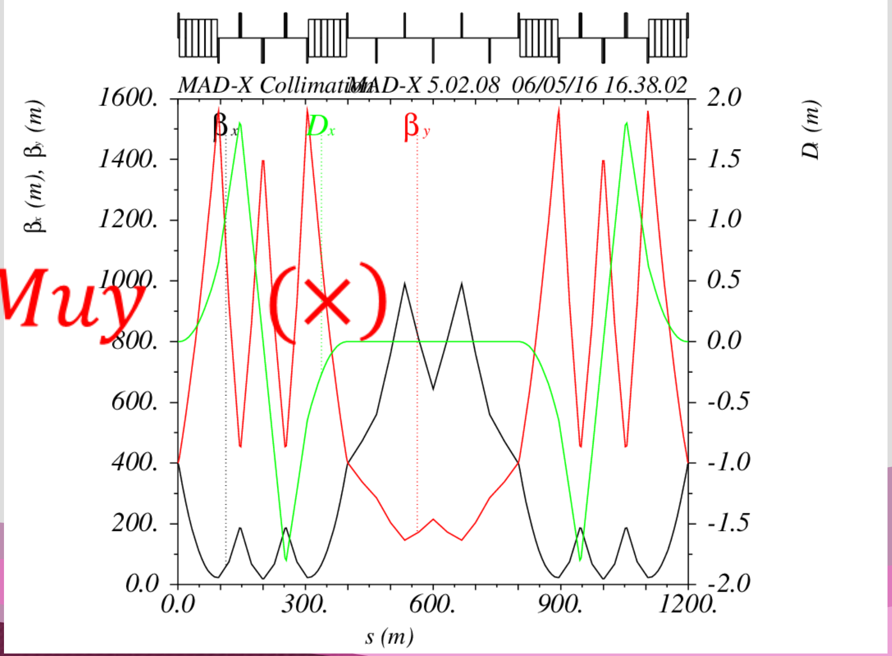


Combination of four regular FODO cells

From:
Chen Yukai



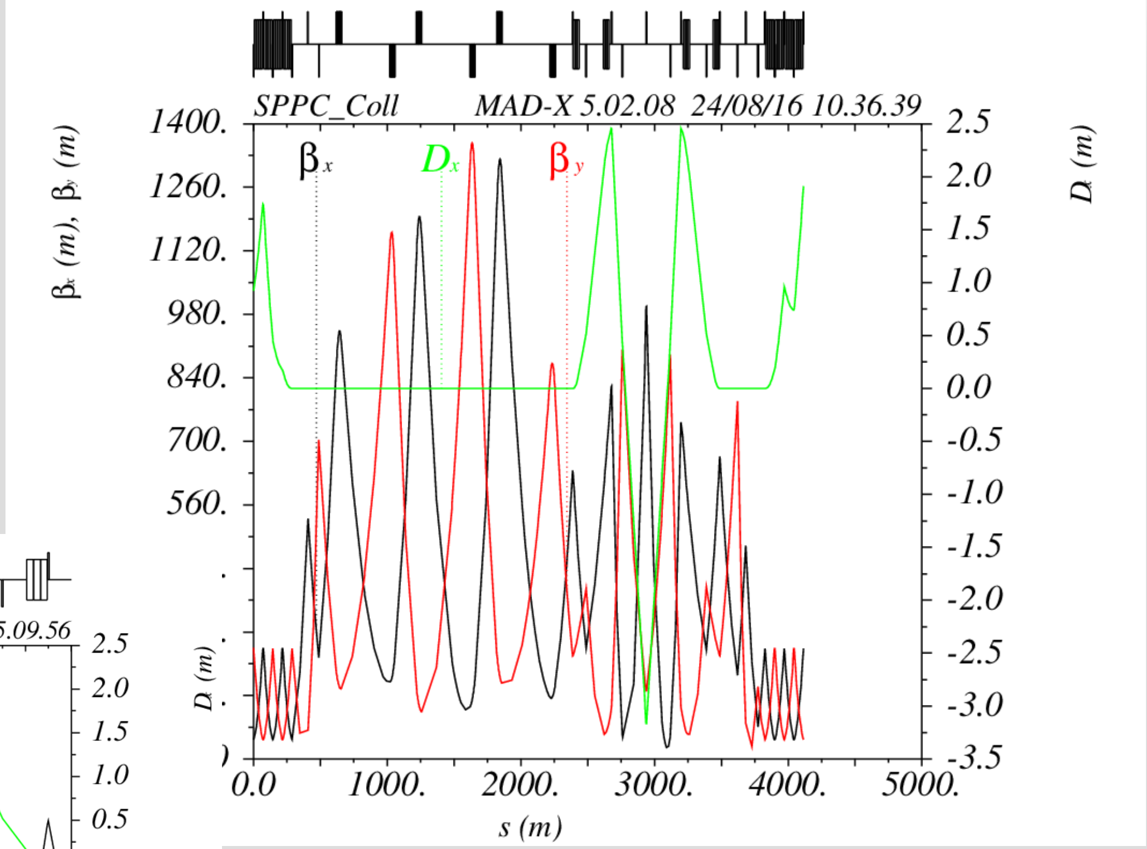
$Mux >> Muy$ (×)

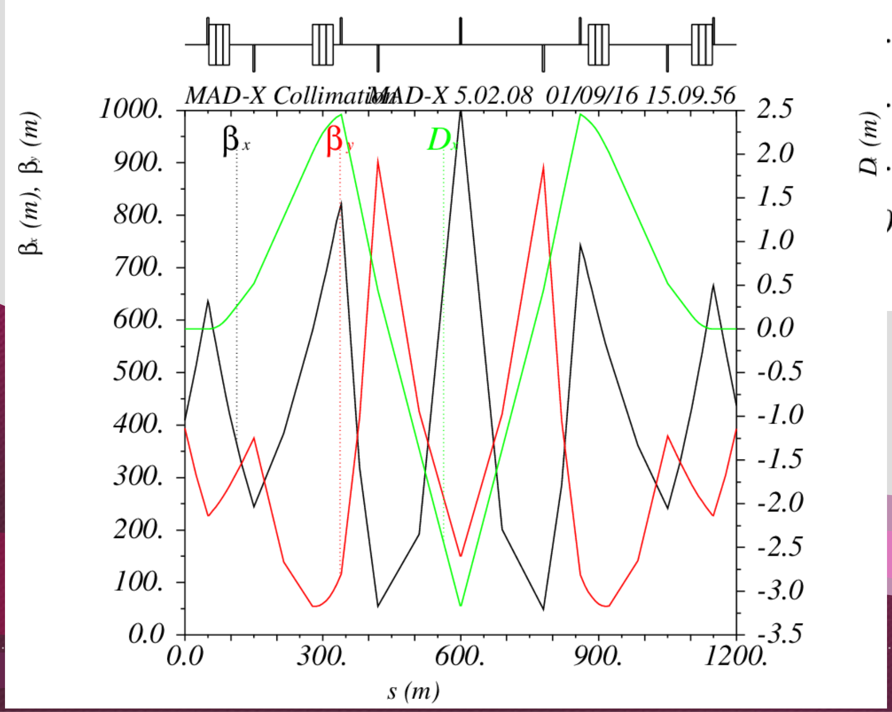


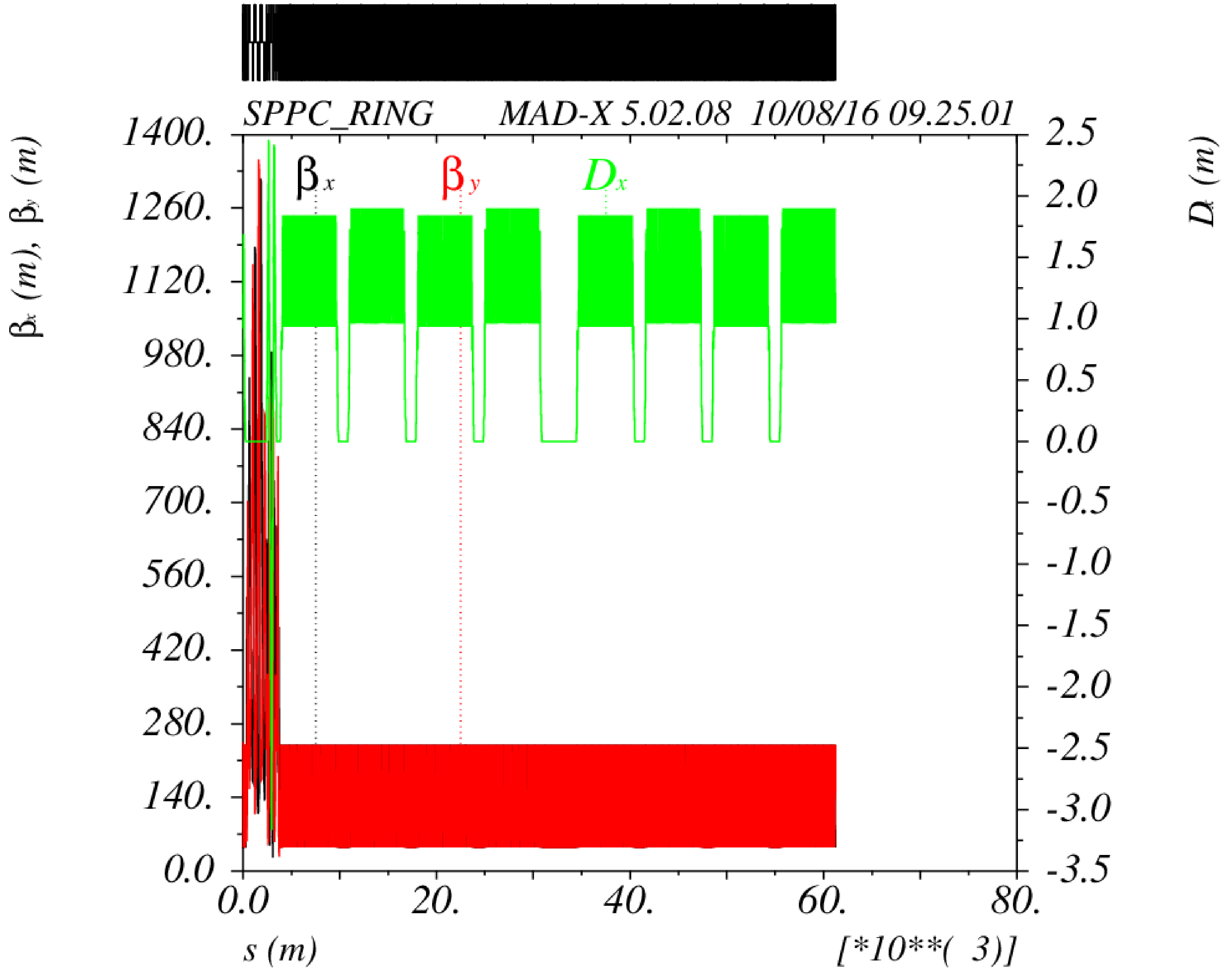
Momentum collimation

- (B,-B)(-B,B)
- symmetry DS

$$constraint:\begin{cases} dpx=0 \\ alfx=0 \\ alfy=0 \end{cases}$$



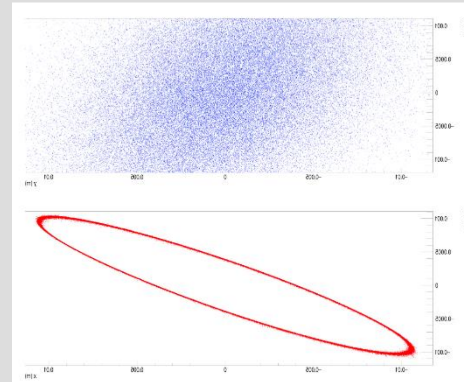




SPPC_RING MAD-X 5.02.08 10/08/16 09.25.01
βx (m), βy (m)
Dx (m)
βx
βy
Dx
1400.
1260.
1120.
980.
840.
700.
560.
420.
280.
140.
0.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
0.0
20.
40.
60.
80.
s (m)
[*10**(3)]

Multiparticle simulation

- Bunch distribution
  - Horizontal: halo distribution
  - Vertical: gauss distribution
  - Particle number: e7



- Aperture of collimator (top energy)

Coll.	Insertion	Nominal	Relaxed
TCP/TCSG/TCLA	betaColl.	6.0/7.0/10.0	7.0/10.3/13.0
	MomentumColl.	13/15.6/17.6	13/15.6/17.6

NAME
TCP.1
TCP.2
TCP.3
TCSG.1
TCSG.2
TCSG.3
TCSG.4
TCSG.5
TCSG.6
TCSG.7
TCSG.8
TCSG.9
TCSG.10
TCSG.11
TCLA.1
TCLA.2
TCLA.3
TCLA.4
TCLA.5
TCPM.1
TCSGM.1
TCSGM.2
TCSGM.3
TCSGM.4
TCLAM.1
TCLAM.2
TCLAM.3
TCLAM.4

- Position of collimator
  - same Mux with LHC
- Aperture of ARC is set to 25 mm

Dp=0

Dp=0.001

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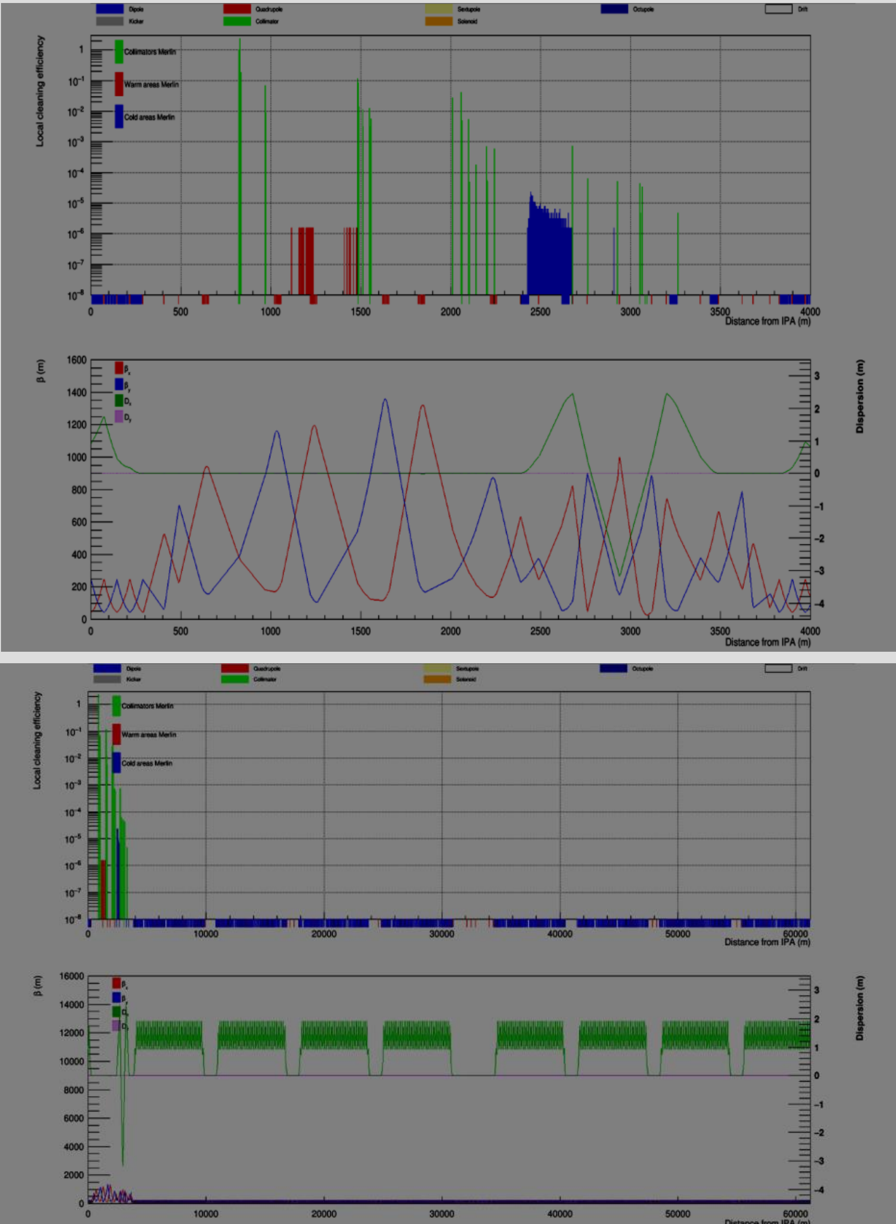

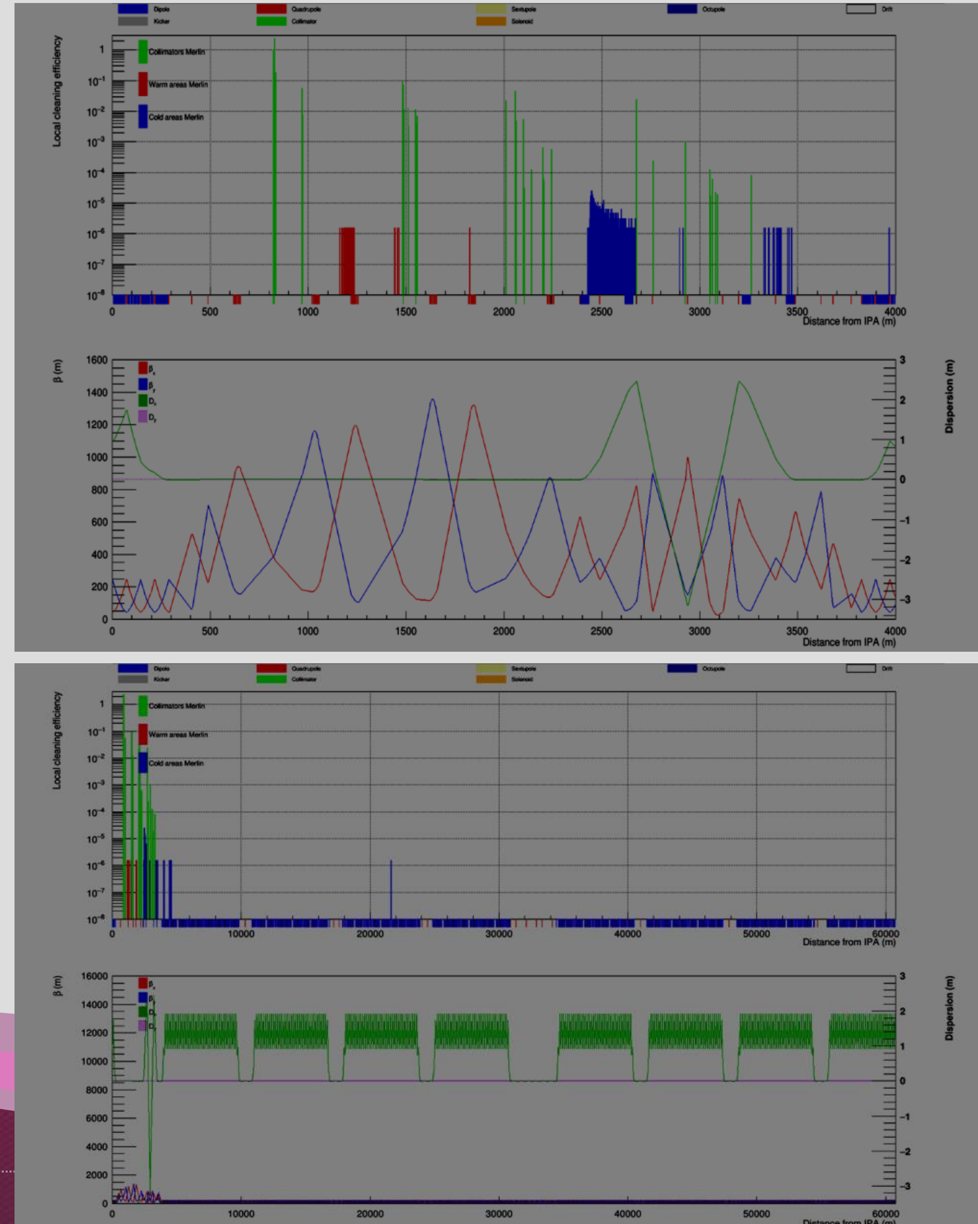

Dp=0.001 with TCPR

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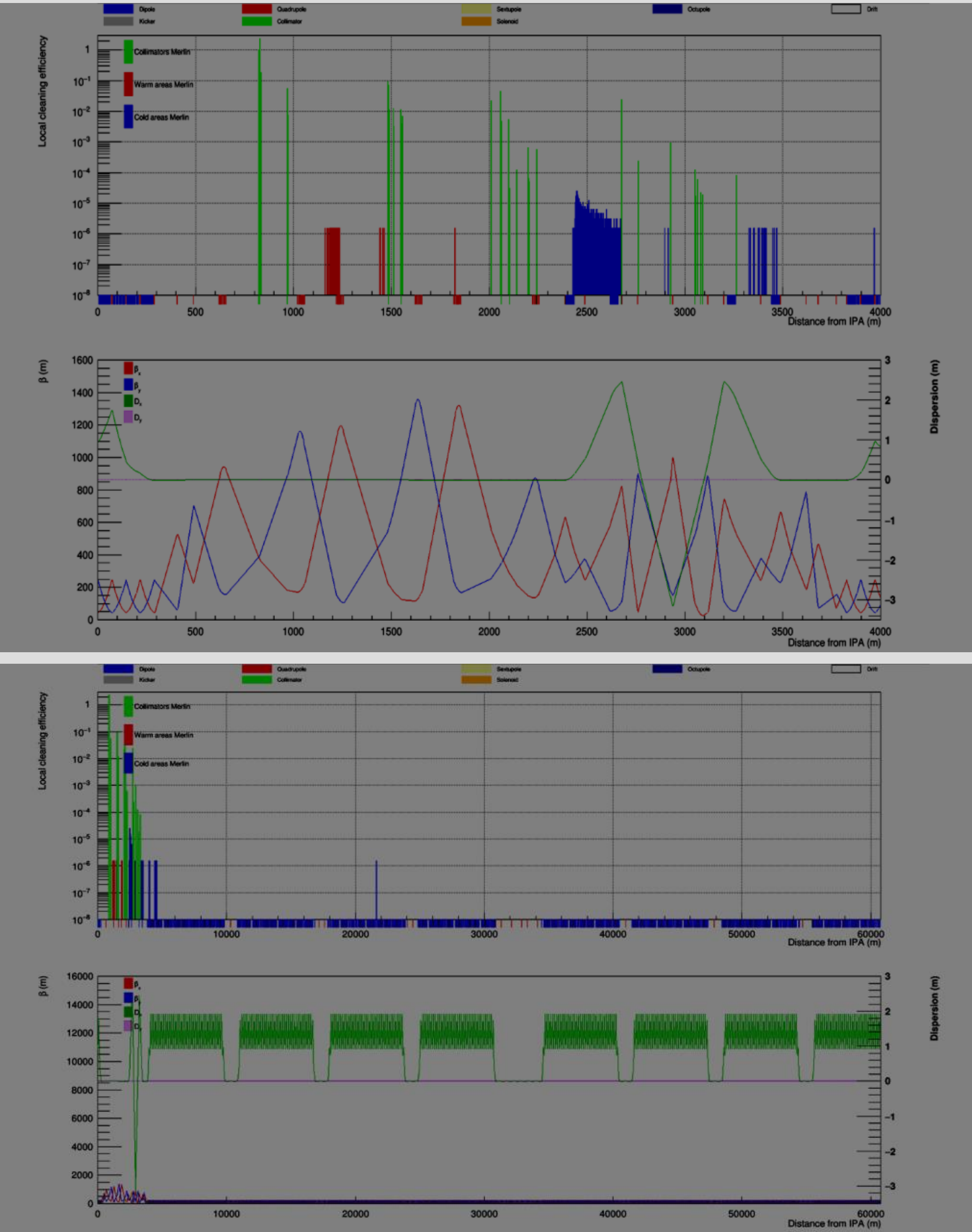
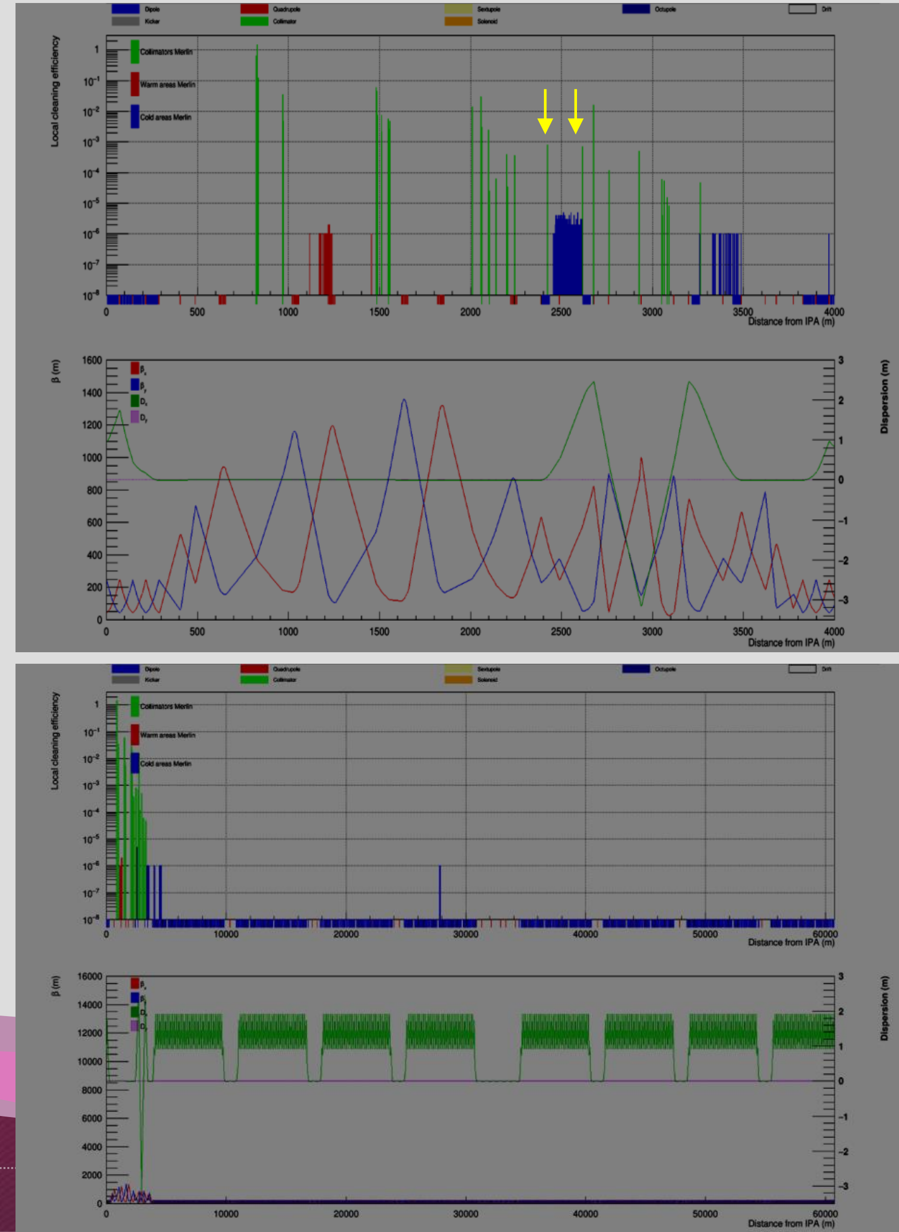
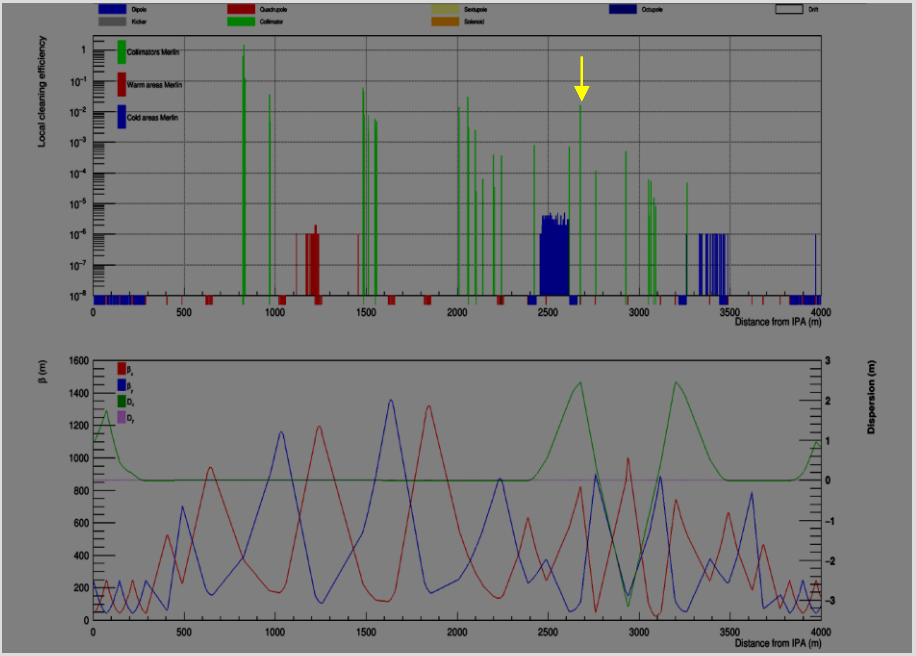
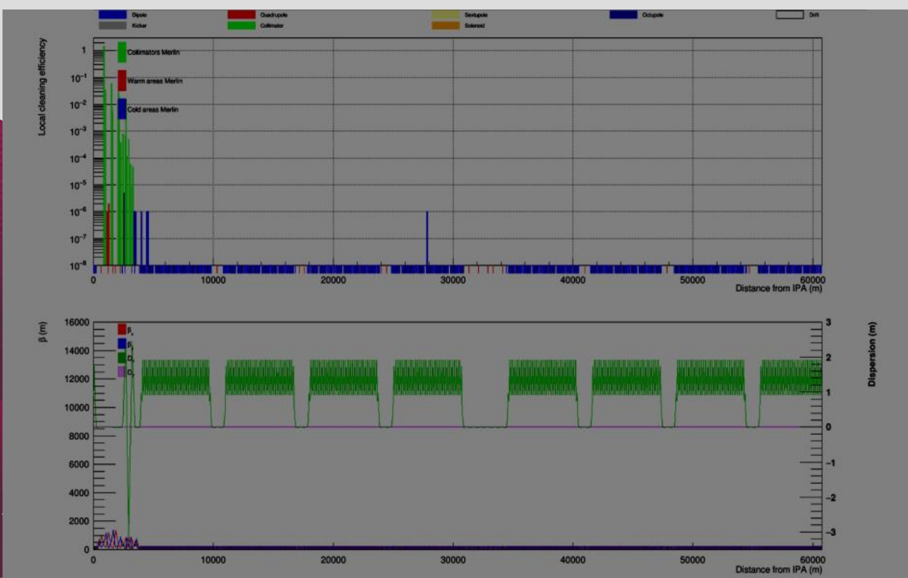


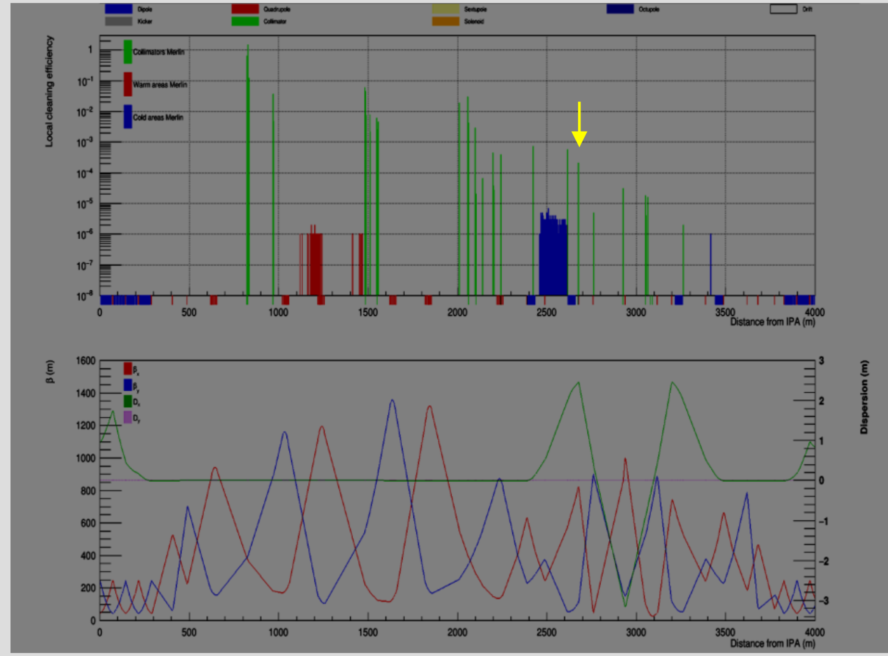


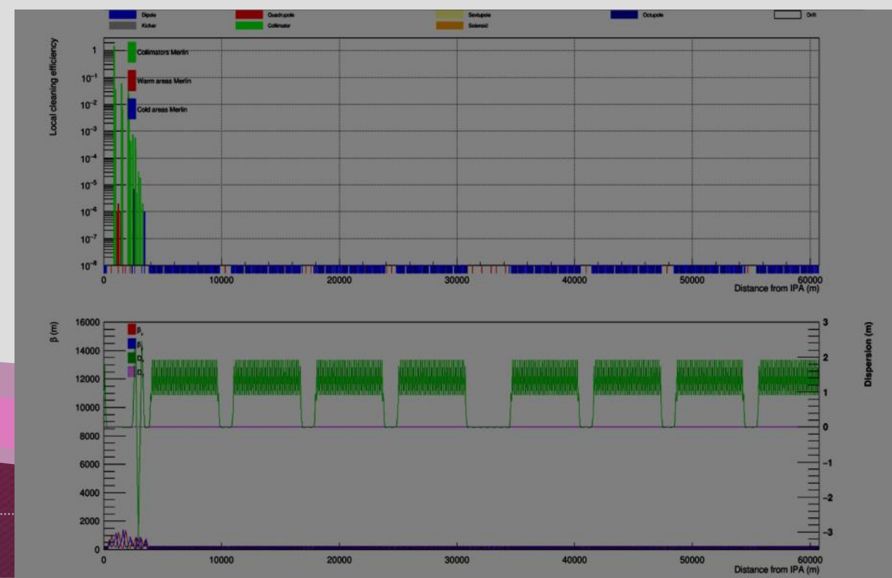
Dp=0.001





Dp=4e-5





Optimizing designing

- Beam size
- Inject energy
  - Gamma=2239
  - $\varepsilon = 1.83$ nm

	beta	ε_x
ARC：	42.57 m	0.28 mm
	245 m	0.67 mm
COLL：	1321.7 m	1.56 mm

- Top energy
  - 37313
  - $\varepsilon = 0.11$ nm

	beta	ε_x
ARC：	42.57 m	0.068 mm
	245 m	0.164 mm
COLL：	1321.7 m	0.381 mm

Optimizing designing

- Requirement of dispersion for the momentum collimation

$$\eta_{D,\ prim}(n_1) \geq \frac{n_1 \eta_{D,arc(with-error)}}{A_{arc,inj}\ (\delta_p=0)\ - (n_2^2 - n_1^2)^{1/2}}$$

- Inject energy

$$A_{arc,inj}(\delta_p=0) = 22.3, n_2 = 9.3, n_1 = 8$$

$$\eta_{D,\ arc(with-error)} = 0.246 m^{1/2}$$

$$\eta_{D,\ prim}(n_1) \geq 0.112\ \mathrm{m}^{1/2}$$

but, $\eta_{D,\ prim}(n_1) = \frac{2.5}{\sqrt{800}} = 0.088\ \mathrm{m}^{1/2}$

Optimizing designing

- Requirement: key point
  - Ensure that the cut made on the secondary halo does not depend on the relative momentum

$$X = n_1, \qquad X' = \delta_{\mathrm{in}} \chi_1'.$$

$$X_\beta = X - \delta_{\mathrm{out}} \chi_1 = n_1 - \delta_{\mathrm{out}} \chi_1 \quad \text{and} \quad X_\beta' = \delta_{\mathrm{in}} \chi_1' + K - \delta_{\mathrm{out}} \chi_1.$$

$$X_{\mathrm{sec}} = X_\beta \cos\mu + X_\beta' \sin\mu + \delta_{\mathrm{out}} \chi_2$$

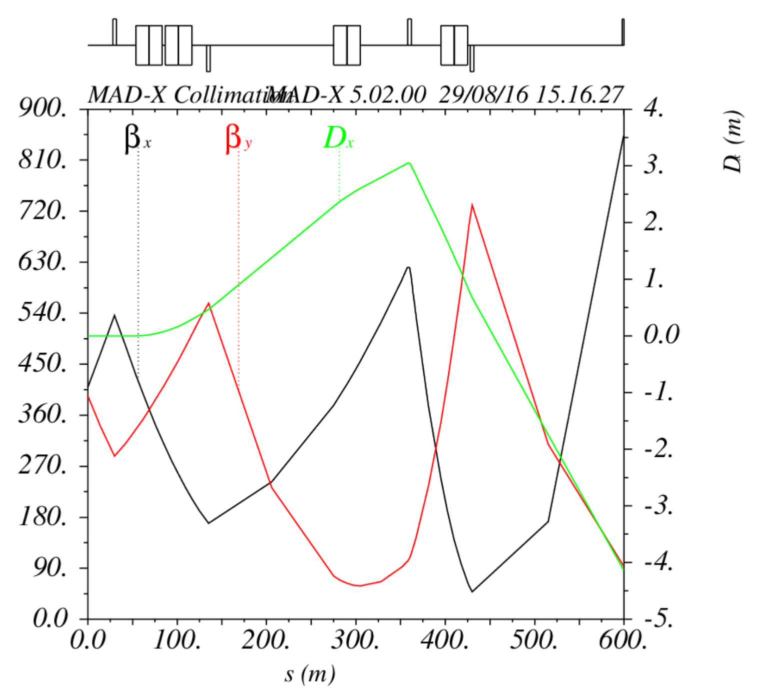
$$K_{\mathrm{c}} = \frac{n_2 - n_1 \cos\mu}{\sin\mu} + \delta_{\mathrm{out}} \frac{\chi_1 \cos\mu - \chi_2}{\sin\mu} + (\delta_{\mathrm{out}} - \delta_{\mathrm{in}}) \chi_1'.$$

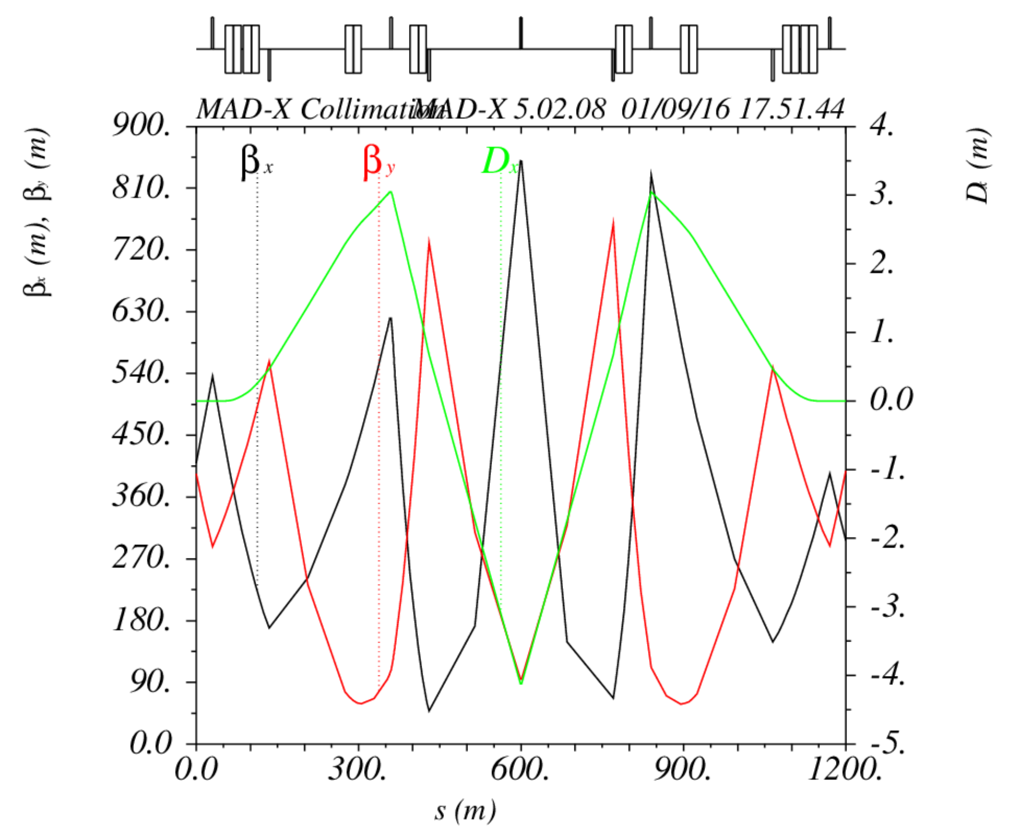
$$\chi_2 = \chi_1 \cos\mu + \chi_1' \sin\mu.$$

$$K_{\mathrm{c}} = \frac{n_2 - n_1 \cos\mu}{\sin\mu} - \delta_{\mathrm{in}} \chi_1'.$$

$$\chi_1' = 0 \qquad \text{or in non-normalised coordinates} \qquad D_1' = -\frac{\alpha_1}{\beta_1} D_1.$$

Optimizing designing





- $\eta_{D,\quad prim}(n_1) = \frac{3.1}{\sqrt{600}} = 0.126$

Optimizing designing

$$-\frac{\alpha_x \cdot D_x}{\beta_x \cdot D'_x}$$

	A	B	C	D	E	F	G	H	I	J	K
1	NAME	S	BETX	ALFX	BETY	ALFY	DX	DPX	MUX	MUY	#VALUE!
2	%s	%le	%le	%le	%le	%le	%le	%le	%le	%le	#VALUE!
3	DRIFT_2	304.95	455.3019	-1.39678	58.85494	0.034544	2.601182	0.008403	0.172252	0.248571	0.949691
4	MBCOLL02$	305	455.4416	-1.39711	58.85153	0.033694	2.601602	0.008403	0.172269	0.248706	0.949774
5	DRIFT_7	328.25	523.9107	-1.5478	66.48039	-0.36182	2.796965	0.008403	0.179848	0.309319	0.983392
6	M41	351.5	599.387	-1.69849	92.50049	-0.75733	2.992327	0.008403	0.186453	0.357227	1.009131
7	DRIFT_8	352	601.0871	-1.70173	93.26207	-0.76583	2.996528	0.008403	0.186585	0.358083	1.009613
8	M42	352.5	602.7905	-1.70498	94.03216	-0.77434	3.00073	0.008403	0.186717	0.358933	1.010091
9	DRIFT_8	353	604.4971	-1.70822	94.81075	-0.78284	3.004931	0.008403	0.186849	0.359776	1.010567
10	M43	353.5	606.2069	-1.71146	95.59785	-0.79135	3.009132	0.008403	0.186981	0.360612	1.01104
11	DRIFT_8	354	607.92	-1.7147	96.39345	-0.79986	3.013334	0.008403	0.187112	0.361441	1.01151
12	M44	354.5	609.6363	-1.71794	97.19756	-0.80836	3.017535	0.008403	0.187243	0.362263	1.011978
13	DRIFT_8	355	611.3559	-1.72118	98.01017	-0.81687	3.021736	0.008403	0.187373	0.363078	1.012443
14	M45	355.5	613.0787	-1.72442	98.83129	-0.82537	3.025938	0.008403	0.187503	0.363887	1.012905
15	DRIFT_8	356	614.8047	-1.72766	99.66091	-0.83388	3.030139	0.008403	0.187633	0.364689	1.013365
16	M46	356.5	616.534	-1.7309	100.499	-0.84238	3.03434	0.008403	0.187762	0.365484	1.013821
17	DRIFT_8	357	618.2665	-1.73414	101.3457	-0.85089	3.038542	0.008403	0.187891	0.366272	1.014276
18	M47	357.5	620.0023	-1.73738	102.2008	-0.85939	3.042743	0.008403	0.188019	0.367054	1.014727
19	DRIFT_9	357.75	620.8714	-1.739	102.6316	-0.86365	3.044844	0.008403	0.188083	0.367443	1.014952
20	QFCOLLML3	360	620.2505	2.482652	108.0438	-1.63305	3.043019	-0.01232	0.188659	0.370853	0.98836
21	DRIFT_9	362.25	598.7785	6.553155	117.4952	-2.50288	2.989541	-0.03288	0.189245	0.37404	0.995001
22	M51	362.5	595.5065	6.534808	118.7505	-2.51833	2.98132	-0.03288	0.189311	0.374377	0.994924
23	DRIFT_8	363	588.99	6.498113	121.2843	-2.54925	2.964879	-0.03288	0.189446	0.37504	0.994766
24	M52	363.5	582.5102	6.461418	123.849	-2.58016	2.948438	-0.03288	0.189582	0.37569	0.994606
25	DRIFT_8	364	576.0672	6.424724	126.4446	-2.61108	2.931997	-0.03288	0.189719	0.376325	0.994442
26	M53	364.5	569.6608	6.388029	129.0711	-2.64199	2.915555	-0.03288	0.189858	0.376948	0.994275
27	DRIFT_8	365	563.2911	6.351335	131.7286	-2.6729	2.899114	-0.03288	0.189998	0.377559	0.994105
28	M54	365.5	556.9581	6.31464	134.4169	-2.70382	2.882673	-0.03288	0.19014	0.378157	0.993931
29	DRIFT_8	366	550.6618	6.277946	137.1362	-2.73473	2.866231	-0.03288	0.190284	0.378743	0.993753
30	M55	366.5	544.4022	6.241251	139.8864	-2.76564	2.84979	-0.03288	0.190429	0.379317	0.993572
31	DRIFT_8	367	538.1793	6.204556	142.6675	-2.79656	2.833349	-0.03288	0.190577	0.379881	0.993387
32	M56	367.5	531.9931	6.167862	145.4795	-2.82747	2.816908	-0.03288	0.190725	0.380433	0.993198
33	DRIFT_10	381.25	376.2521	5.158761	234.9241	-3.67759	2.364773	-0.03288	0.195617	0.392281	0.986032
34	MBCOLL02$	395	248.2613	4.14966	347.7472	-4.52772	1.912638	-0.03288	0.20278	0.399941	0.972235
35	DRIFT_2	395.05	247.8465	4.145991	348.2001	-4.53081	1.910994	-0.03288	0.202812	0.399964	0.972164
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

key point

Optimizing designing

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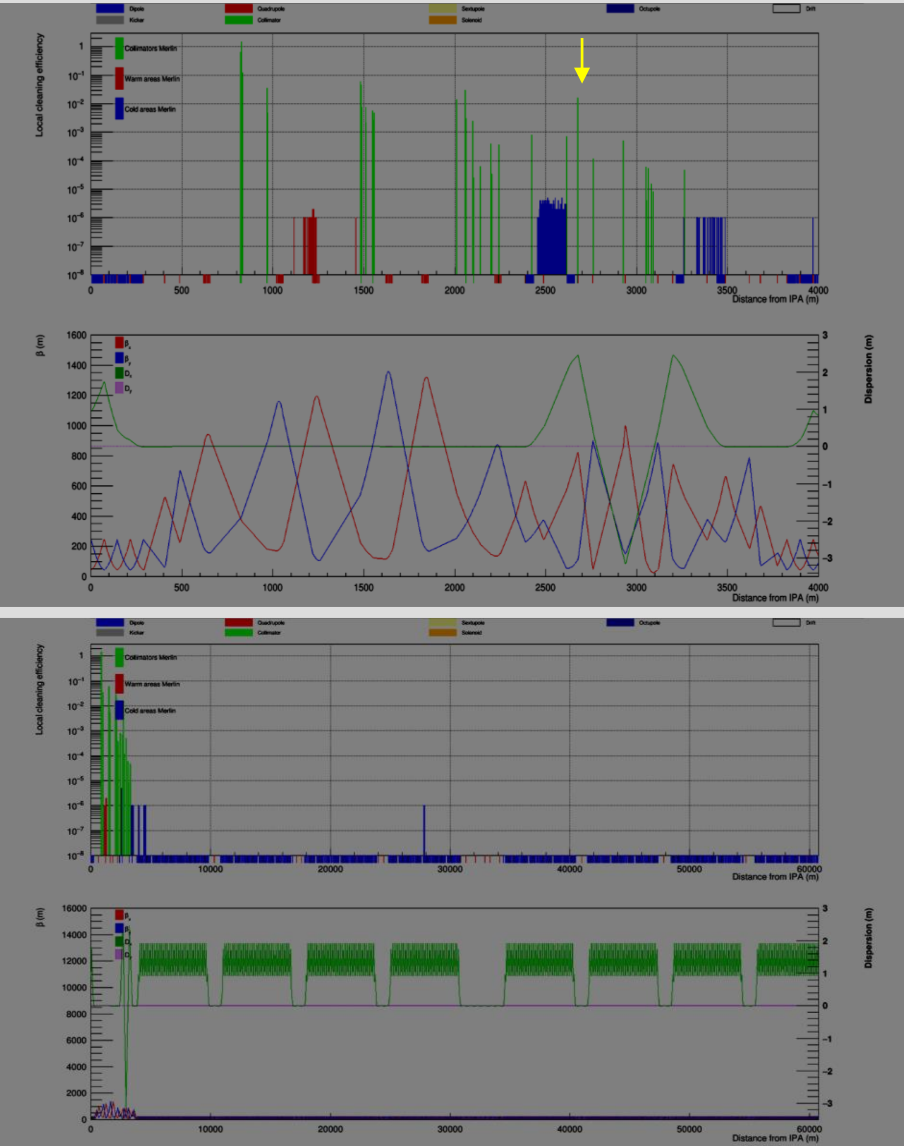
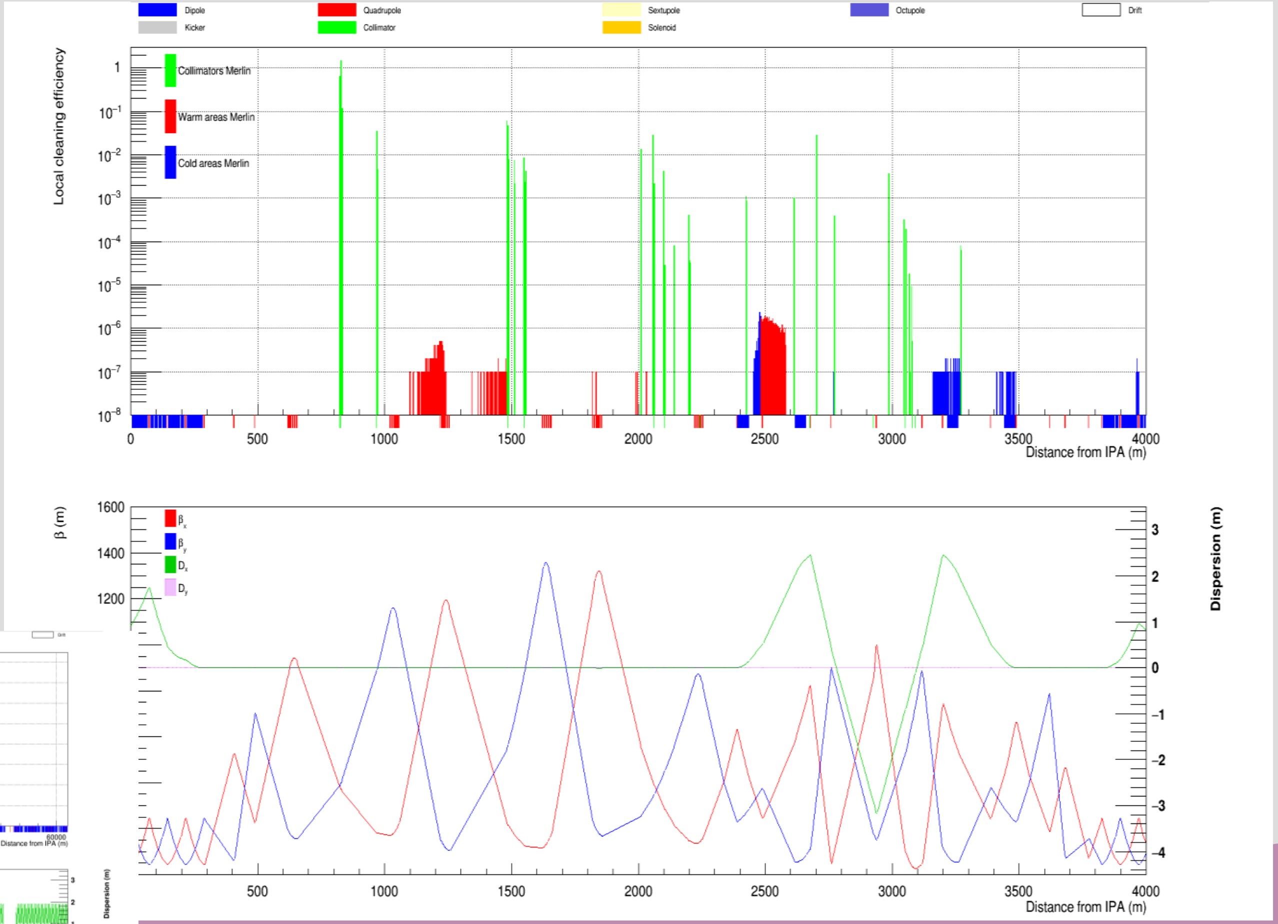
- Old lattice

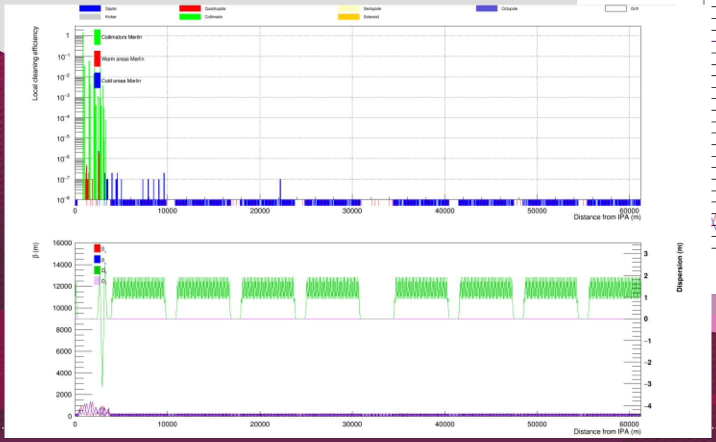


New lattice

Optimizing designing

- More particles
- E8
- Need more





Next to do

- Try to get the phase diagram in different positions after different turns
- Add other insertion such as collision, injection and extraction insertion to the lattice
- Study MerLin in depth
- …

Thank you!