Drive beam frequency multiplication system

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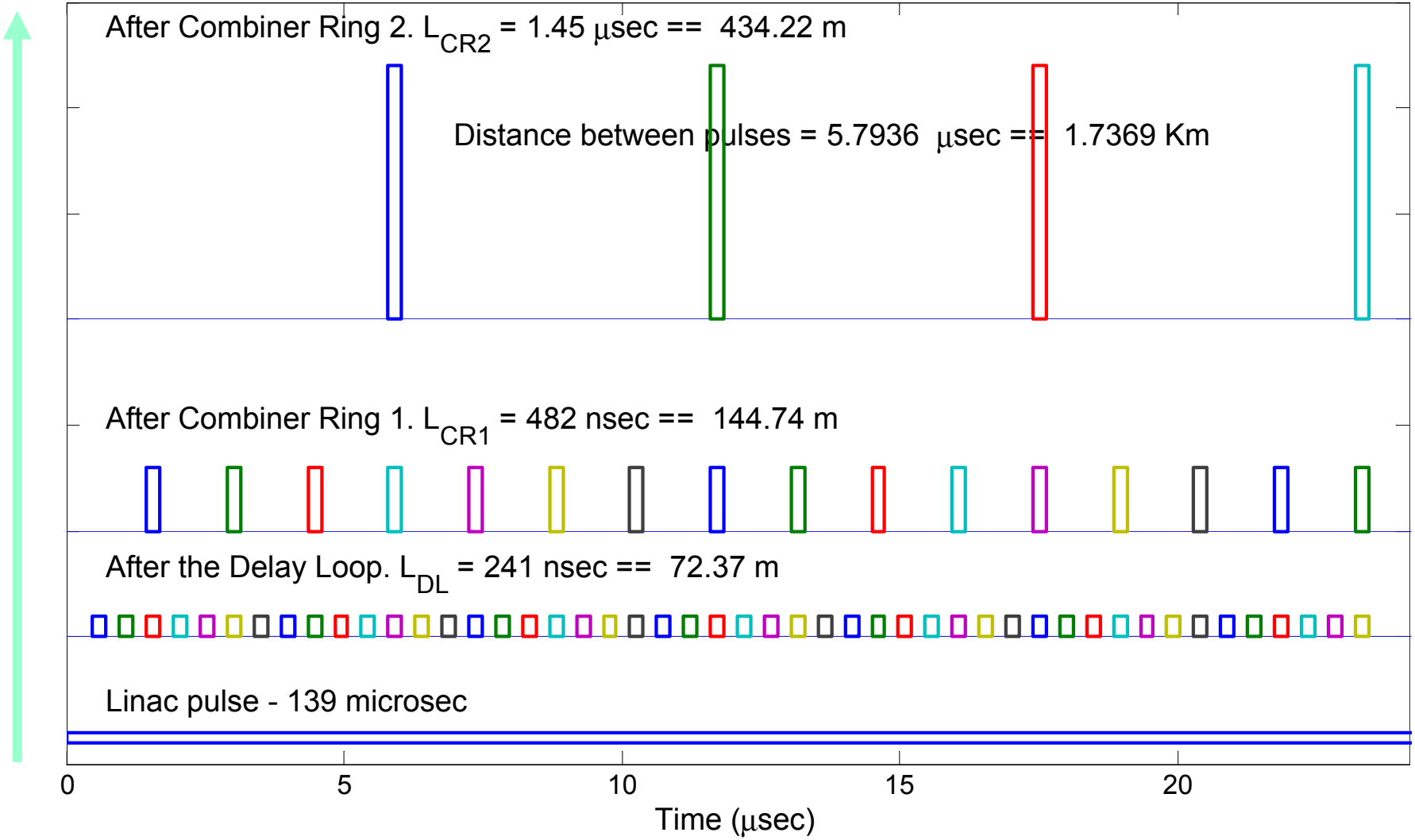
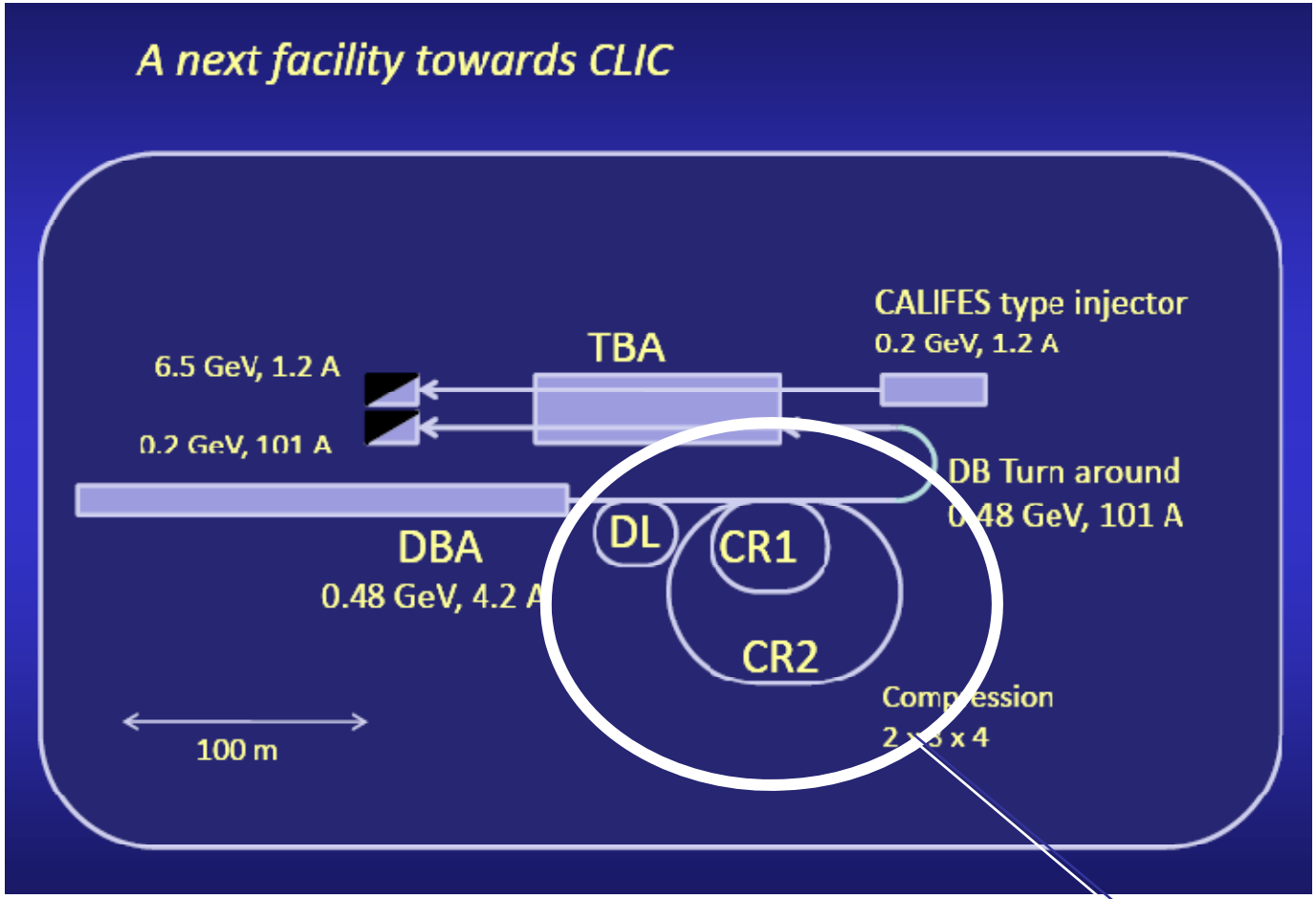
DRIVE BEAM Basic Parameters

Energy (decelerator injection)	$E_{in,dec}$	2.37	GeV
Energy (final, minimum)	$E_{fin,dec}$	237	MeV
Average current in pulse	I_{dec}	101	A
Train duration	t_{train}	243.7	ns
No. Bunches / train	$N_{b,dec}$	2922	
Bunch charge	$Q_{b,dec}$	8.4	nC
Bunch separation	$D_{b,dec}$	0.083	ns
Bunch length, rms	$\sigma_{s,dec}$	1	mm
Normalized emittance, rms	$\gamma\varepsilon_{dec}$	150	μm rad

Beam temporal structure along the frequency multiplication system



From Hans Braun's yesterday presentation



3 isochronous rings

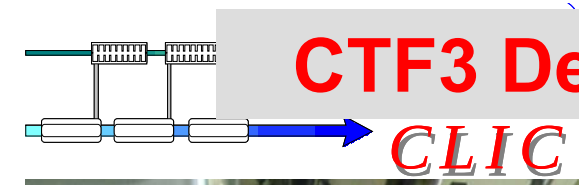
Delay Loop

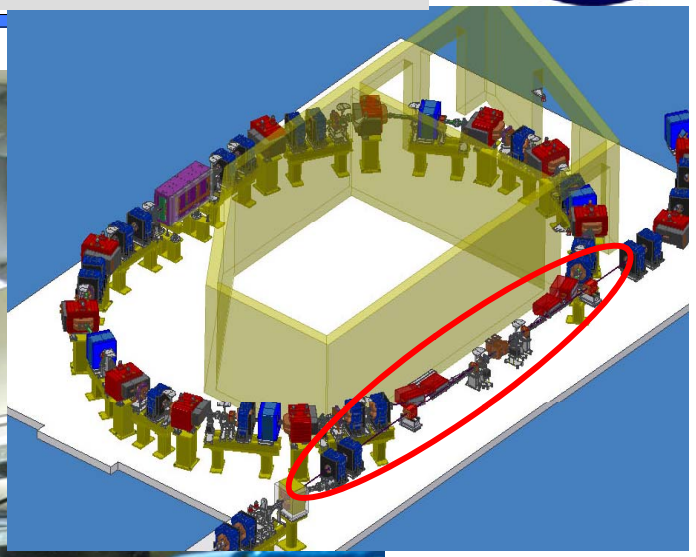
- Total length : 241 nsec = 72.37 m
- Only one passage
- Isochronicity in half Loop
- Trajectory length tunability - wiggler as in CTF3
- Normal conducting technology
  (Bdipoles = 1.7 T)
  $B\rho$ = 8 Tm - ρ = 4.7 m
  Total length of dipoles = 30 m

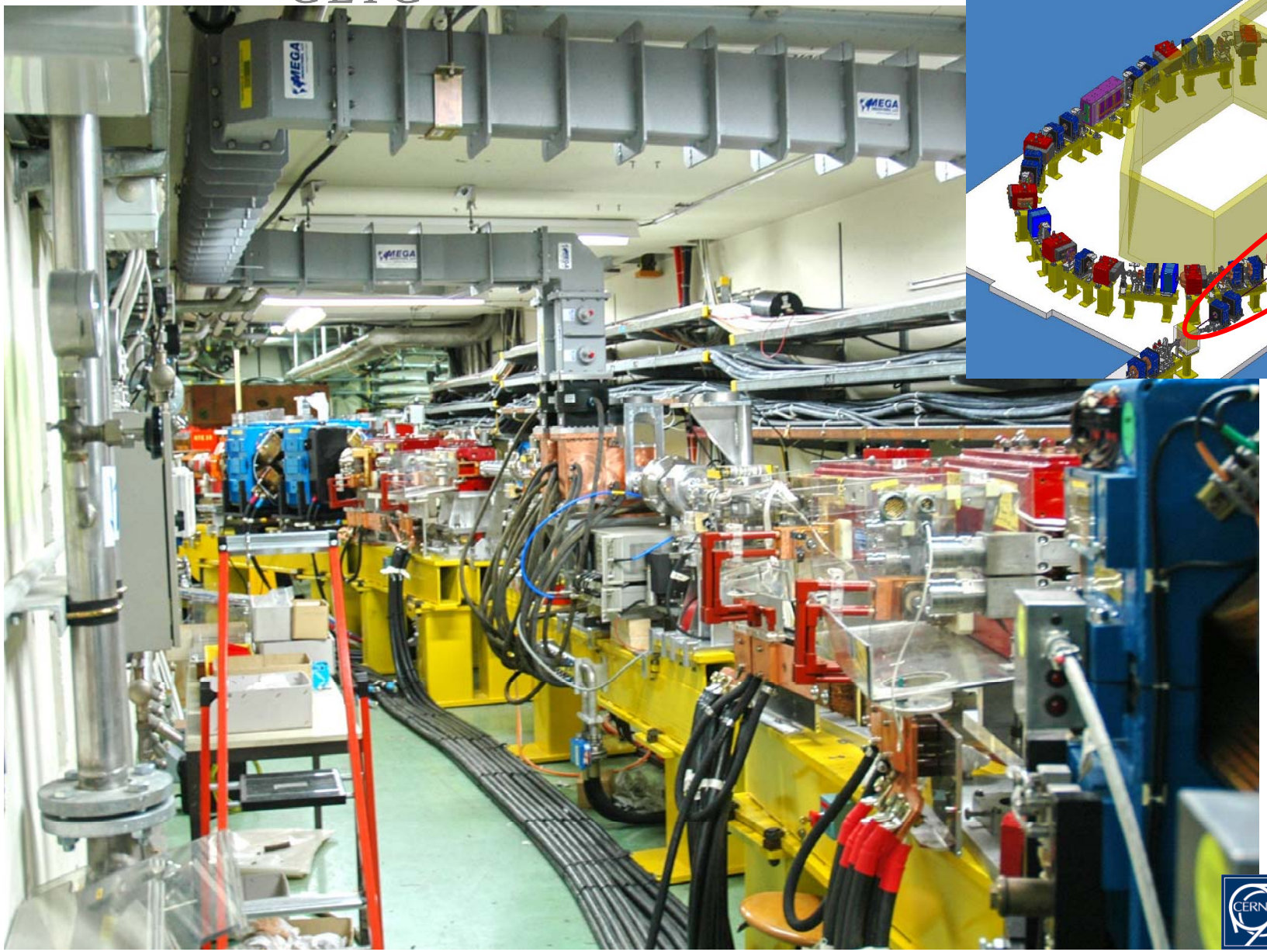
- Dipoles with field index to eliminate defocusing quads

- Rf deflector 500 MHz

CTF3 Delay Loop injection/extraction



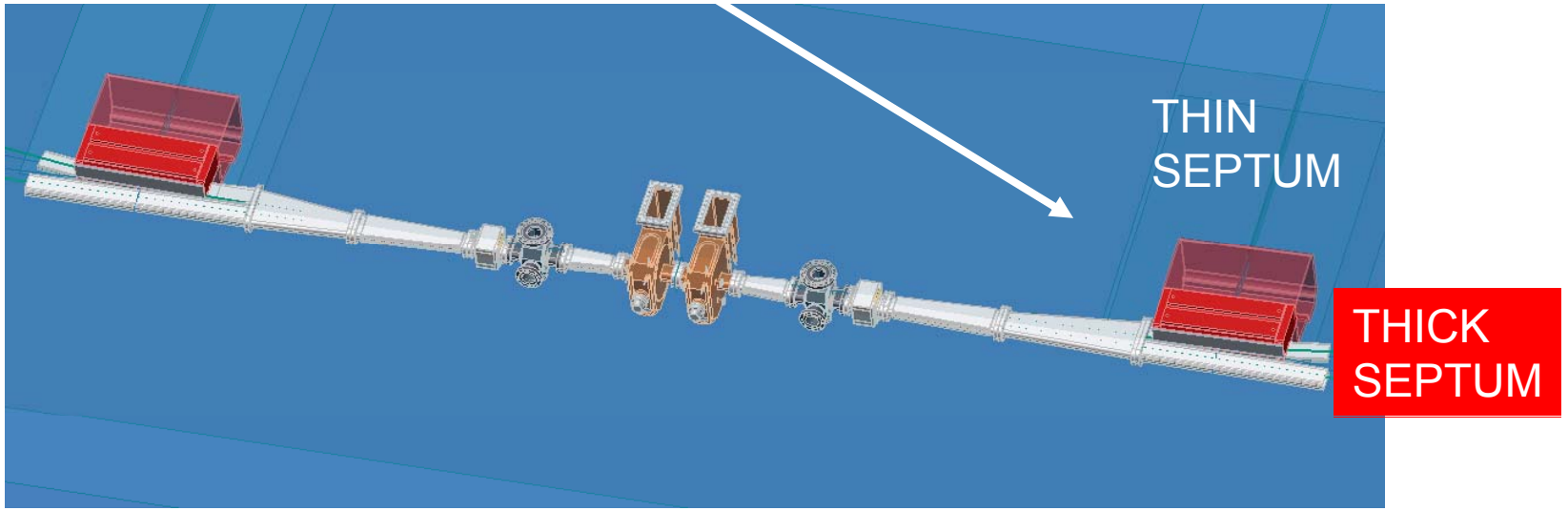




2005

Injection-extraction DL comparison CTF3 - CLIC

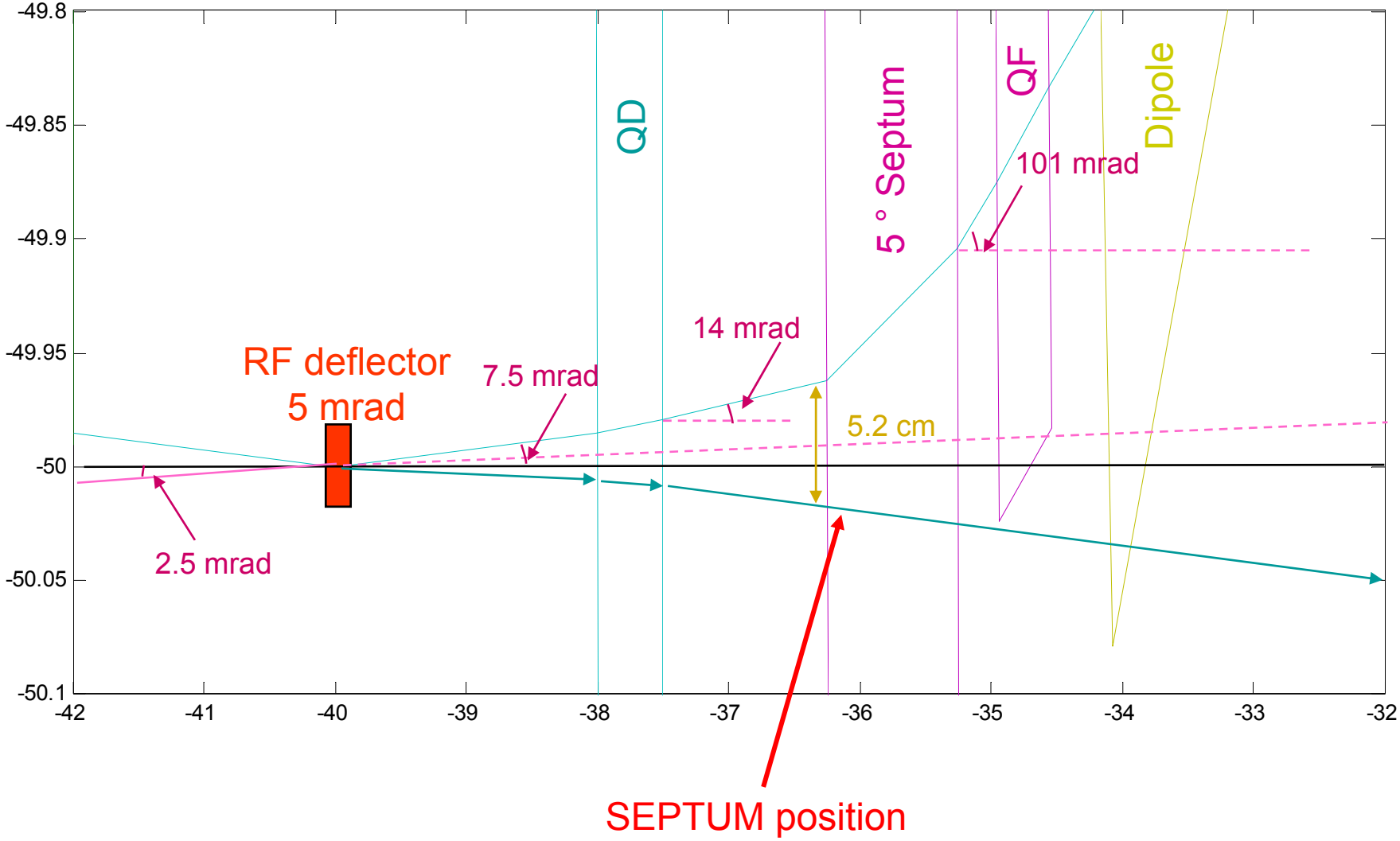
	CTF3	CLIC
Energy	0.3 MeV	2.4 GeV
RF deflector frequency	1.5 GHz	0.5 GHz
Rf deflection angle	15 mrad	5 mrad
Thin Septa angle	6.7°	?
Thick Septa angle	22°	?



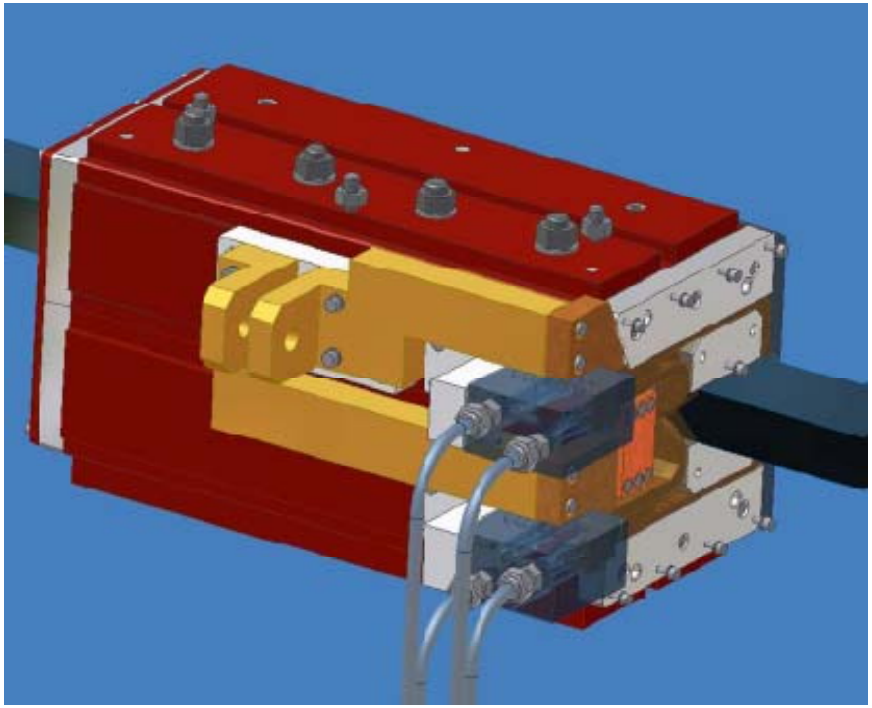
ADDING a Dquad between the rf deflector and the septum

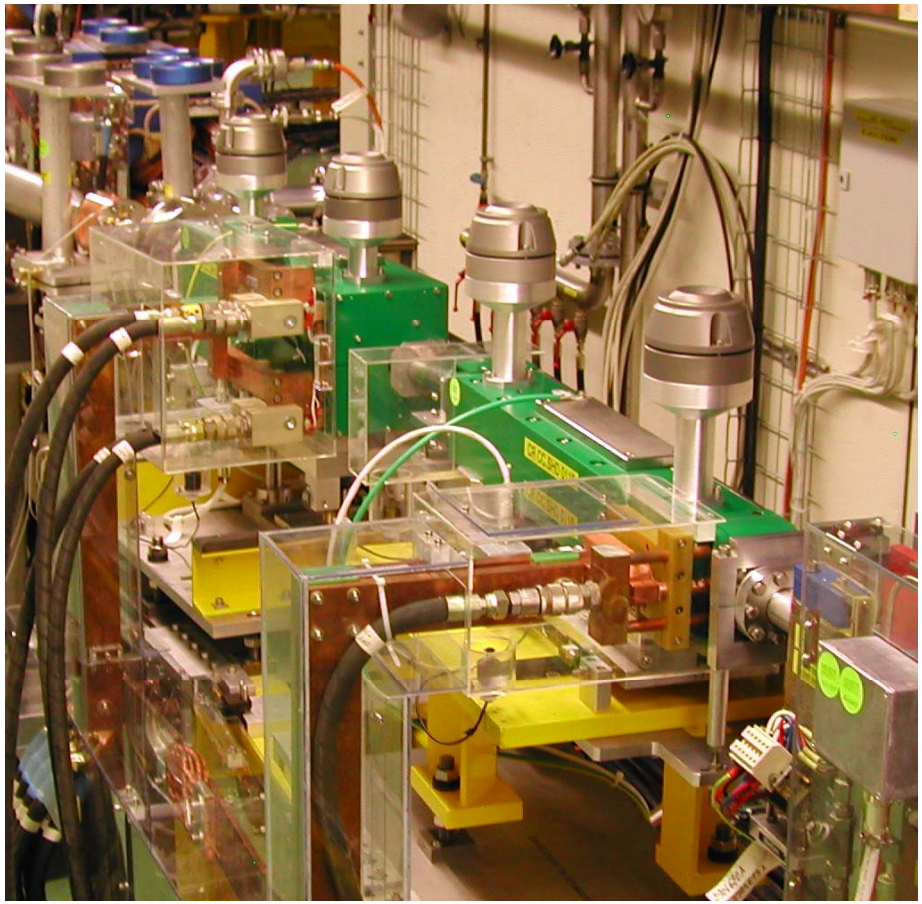
The odd and even bunches are separated and vertically focused on the septum position

DL injection - extraction region



CTF3 Combiner Ring Thick Septum



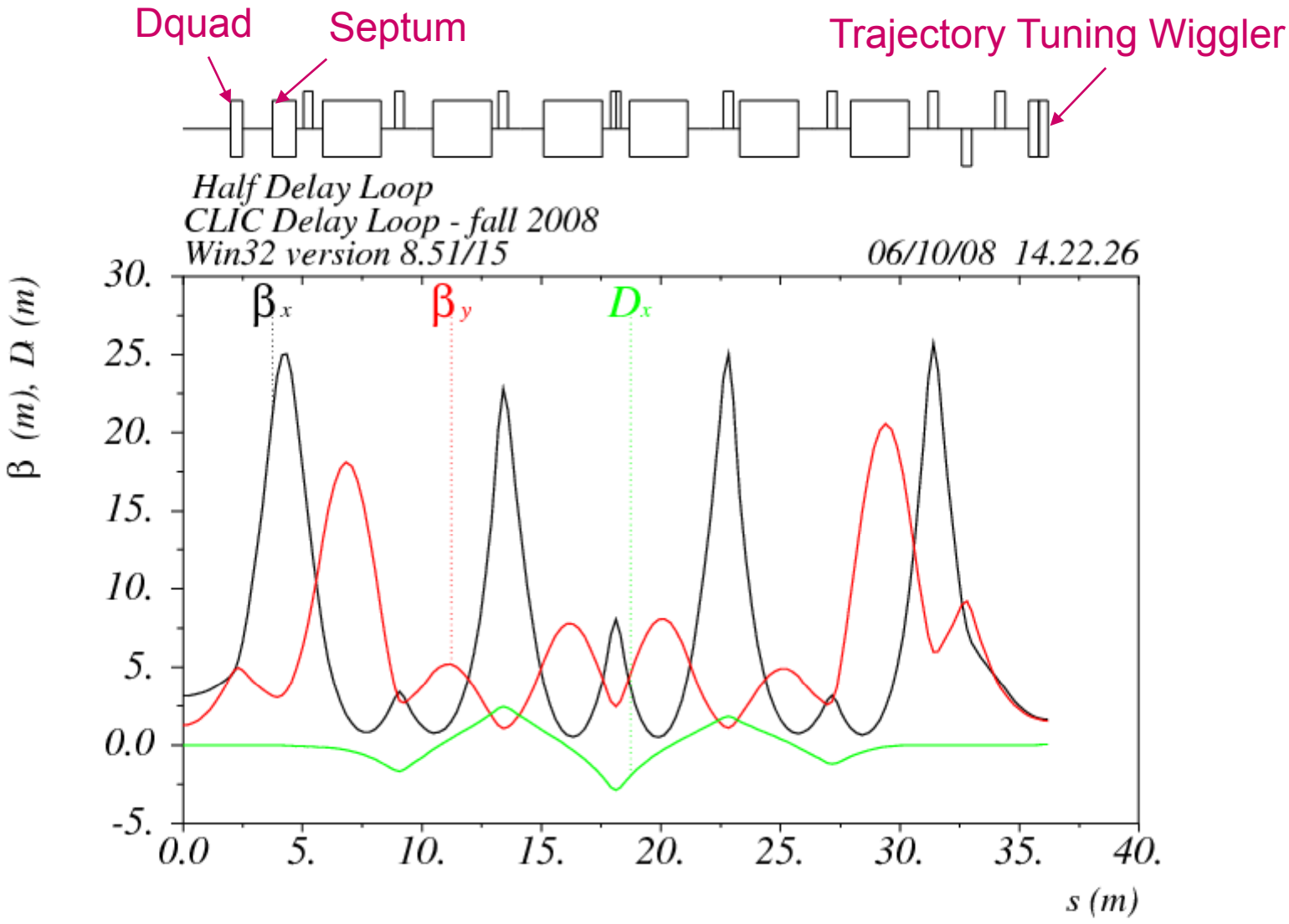


Design based on TERA septa evolution from EPA design.
Built by CIEMAT (Spain)
200 mrad @ 300 MeV

CTF3 Combiner Ring Thick Septum Parameters

CLIC DL

	thin	thick	
Integrated field [mT.m]	48	161	800
Gap field [T]	62	248	
Septum thickness [mm]	2	11.4	< 25
Septum conductor thickness [mm]	1.7	9.5	
Gap h × w [mm^2]	40 × 70	40 × 80	30x80
Physical length [mm]	900	692	1000
Magnetic length [mm]	782	650	
Current [A]	1974	1974	
Number of turns	1	4	
Magnet inductance [μH]	2	29.6	
Electrical resistance [mΩ]	0.3	0.9	



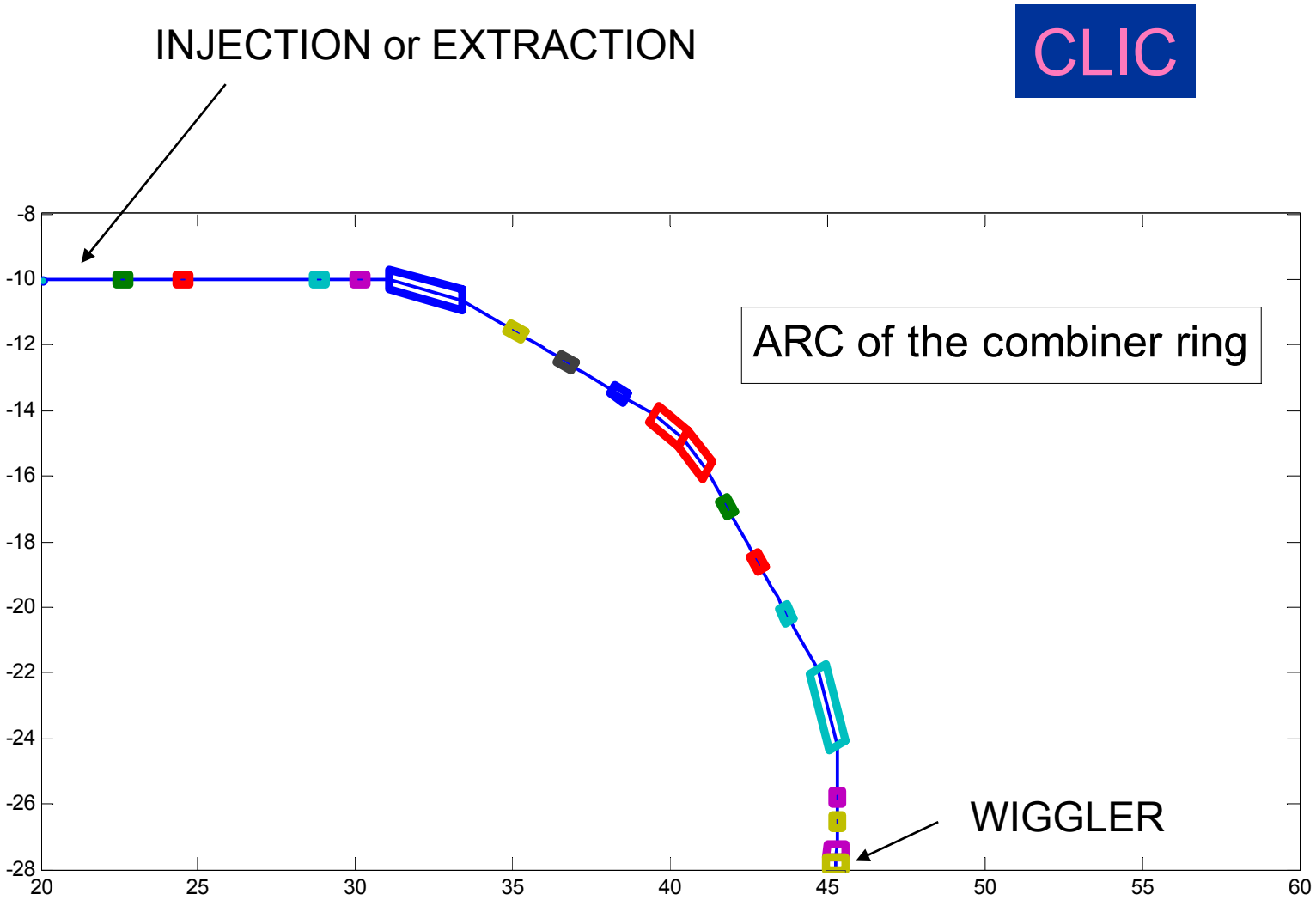
Optical functions in half Delay Loop
Qx = 5.1 Qy = 3.04

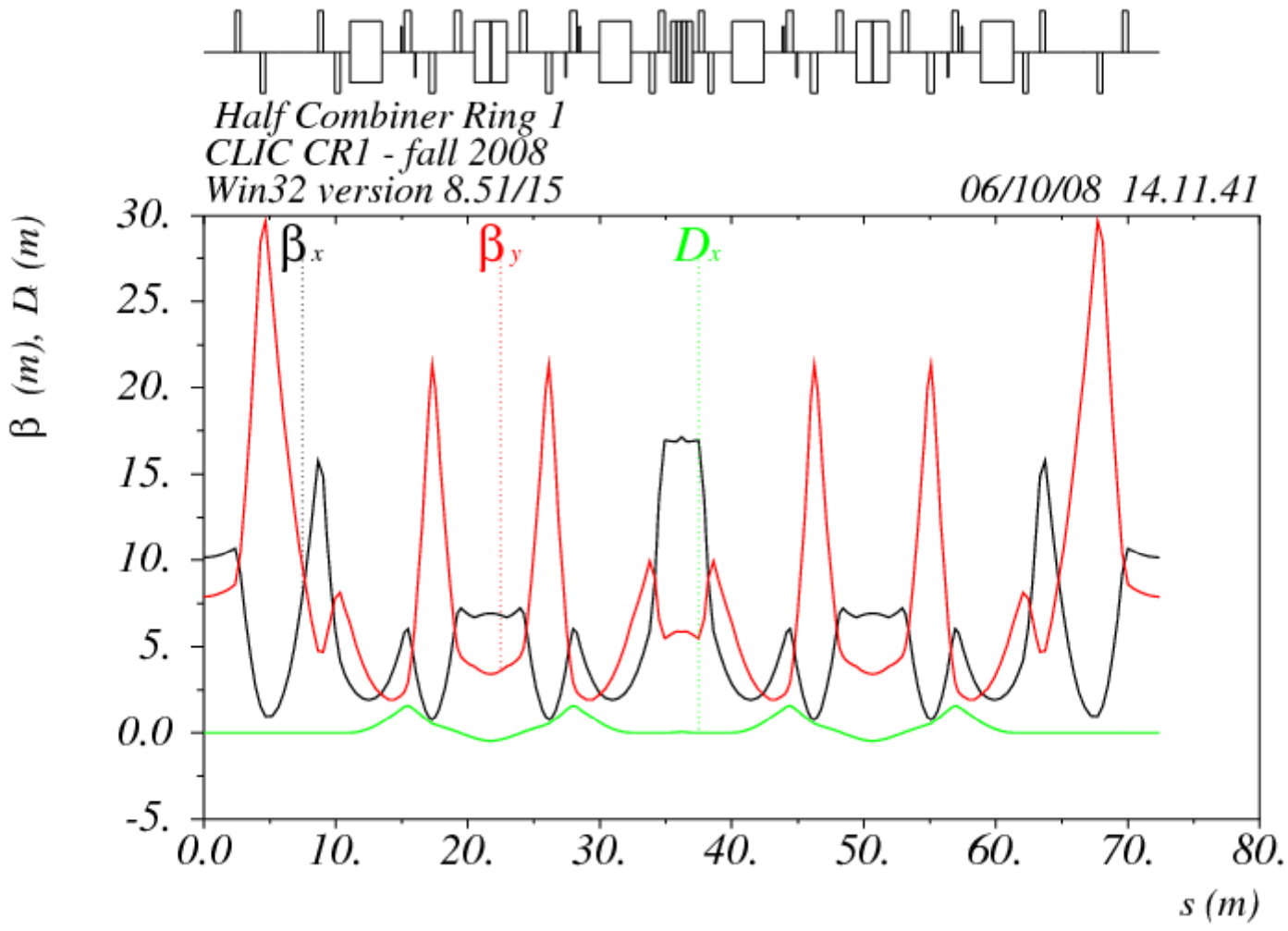
Combiner Ring 1

- Total length : 482 nsec =146 m
- Up to three passages
- Trajectory length tunability - 2 wigglers
- Normal conducting technology
  (Bdipoles = 1.7 T)
  Bρ = 8 Tm - ρ = 4.7 m
  Total length of dipoles = 30 m (as in Delay Loop)
- Parallel poles Dipoles

- Rf deflector 1 GHz

- Design based on CTF3 Combiner Ring:
- Isochronous arc with three dipoles


INJECTION or EXTRACTION
CLIC
ARC of the combiner ring
WIGGLER
-8
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
20
25
30
35
40
45
50
55
60



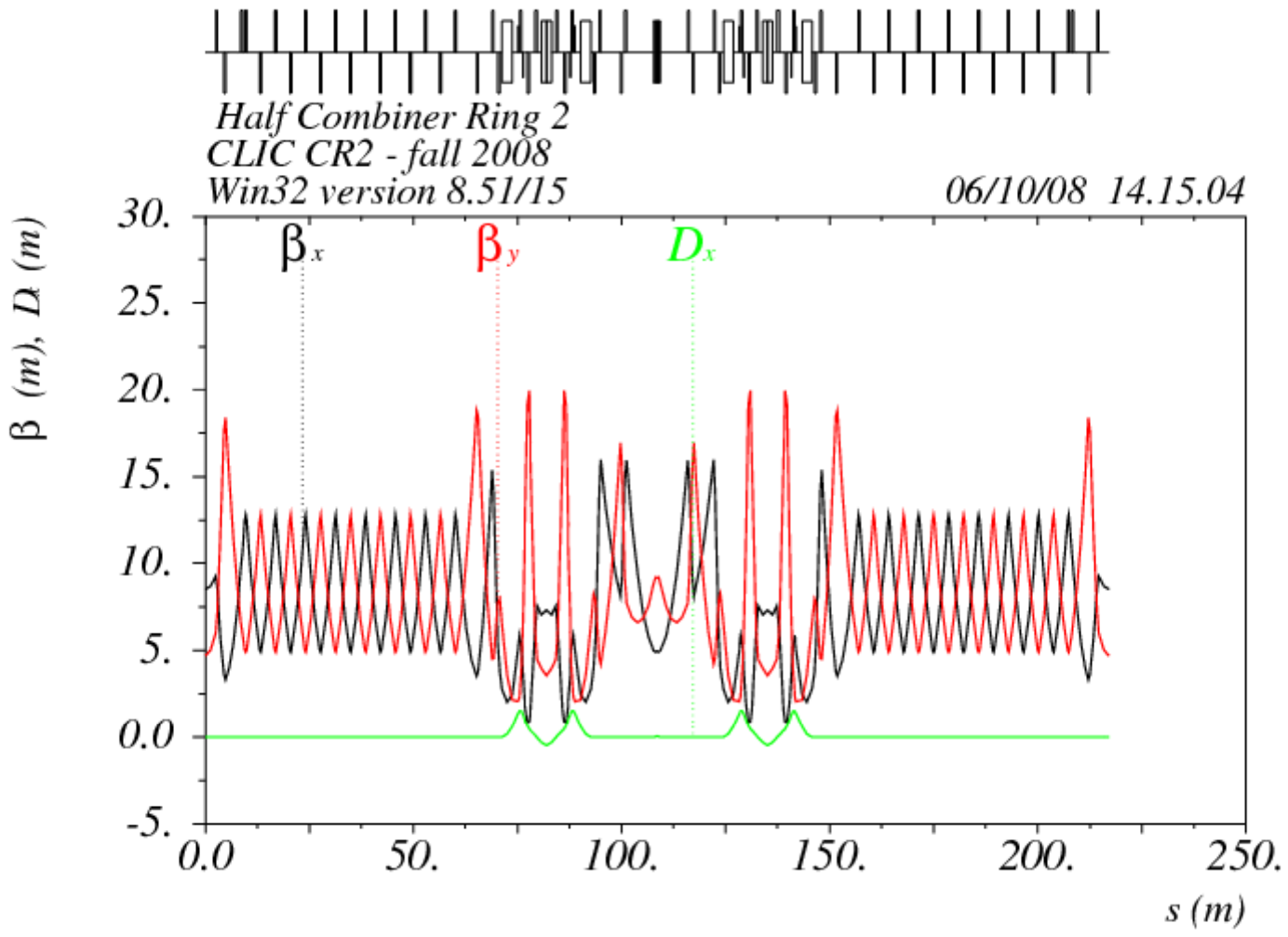
Optical functions in half COMBINER RING 1
Qx = 22.2 Qy = 13.6

Combiner Ring 2

- Total length : 1450 nsec =434 m
- Up to four passages
- Trajectory length tunability
- Normal conducting technology
  (Bdipoles = 1.7 T)
  Bρ = 8 Tm - ρ = 4.7 m
  Total length of dipoles = 30 m
- Parallel poles Dipoles

- Rf deflector 3 GHz

- Same arc of COMBINER RING 1
- Length filled with FODO cells



Optical functions in half COMBINER RING 2
Qx =38.1 Qy = 32.2

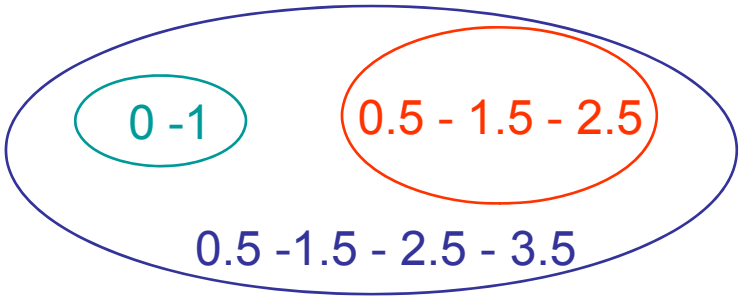
Main parameters of the 3 rings

Parameter		**DL**	**CR1**	**CR2**
Energy	GeV	**2.37**	**2.37**	**2.37**
Emittance	μm rad	**< 100**	**< 100**	**< 100**
Energy spread		**< 1 %**	**< 1 %**	**< 1 %**
L	m	**73.05**	**146.09**	**438.28**
Combination factor		**2**	**3**	**4**
RF deflector frequency	MHz	**499.8**	**999.5**	**2998.6**
Bunch length (rms)	mm	**2**	**2**	**2**
N of dipoles		**12**	**12**	**12**
ρ	m	**4.7**	**4.7**	**4.7**
B	T	**1.7**	**1.7**	**1.7**
N of quadrupoles / families		**18 / 9**	**48 / 9**	**64 + fodo quads**
l_q * dB/dx max	T		**6**	**6**

Energy loss per turn (Synchrotron radiation)

$$U_0(keV) = 88.46 \frac{E(GeV)^4}{\rho(m)} = 0.6\,MeV$$

ρ = 4.7m



From 1 turn to 7 turns: energy loss from 0.6 to 4.2 MeV

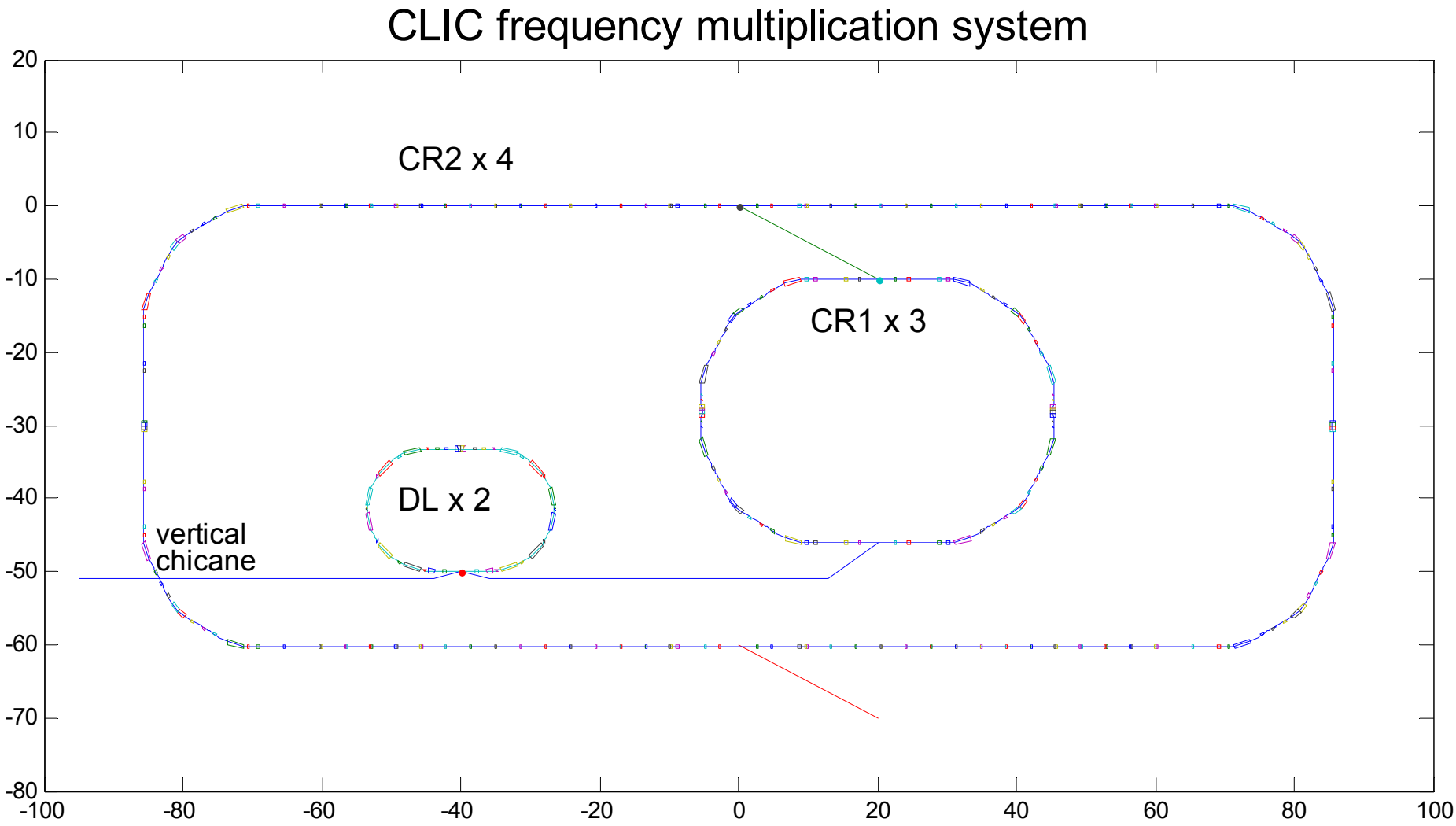
ΔE/E < 0.2 %

Correction of 2° order momentum compaction terms correcting chromaticity to almost zero

	T566 Sext off	T566 Sext on	SEXT STRENGH
CR1	-19.0	0.12	Ksx=46,-34 (L = 0.1 m)
CR2	-19.0	0.3	Ksx=62,-53 (L = 0.1 m)

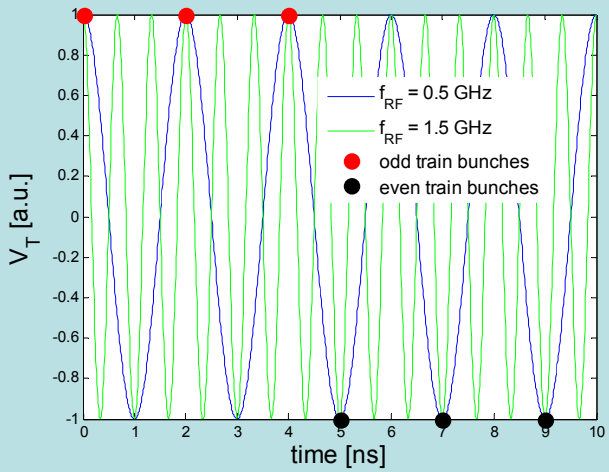
(To be tested with tracking- in progress)

LAYOUT of the three RINGS



RF deflectors

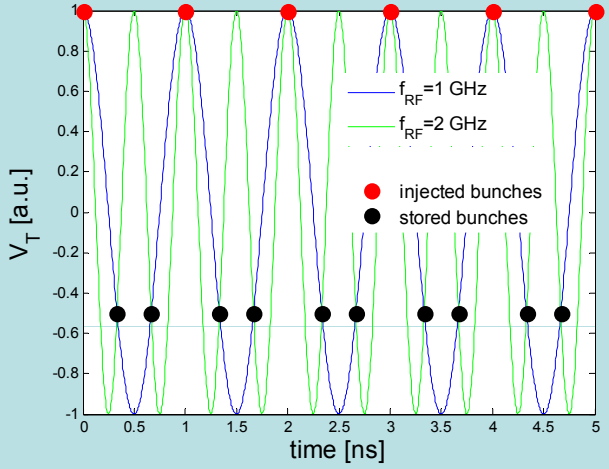
Deflector Frequencies



Delay Loop:

$f = f_{linac}/2\ (2n+1)$, n=0,1,2,…

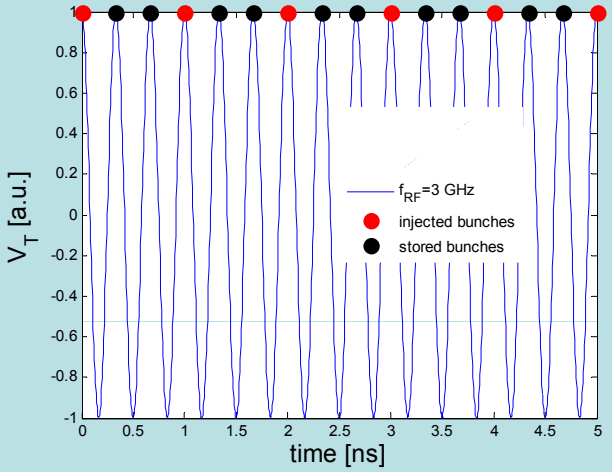
f = 0.5 GHz, 1.5 GHz, 2.5 GHz,…



Combiner Ring 1:
(recombination factor m = 3)

$f = nf_{bunch}$, n=1,2,4,5,…
(but n≠m and
its multiple integers)

f = 1 GHz, 2 GHz, 4 GHz,…



Same rule for CR2 (recombination factor m = 4):

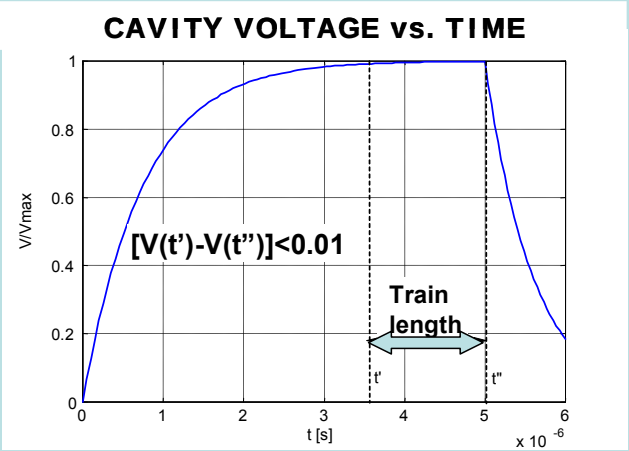
f = 3 GHz, 6 GHz,…

Standing Wave Deflectors

A SW structure is already used for the CTF3 Delay Loop

CTF3 DL DEFLECTOR DESIGN PARAMETER	
Frequency **[GHz]**	**1.4995**
angle of deflection **[mrad]**	**15**
Max. Beam energy **[MeV]**	**300**
Klystron output Power **[MW]**	**20**
Pulse length **[μs]**	**5**
Cavity unloaded/loaded Q (*)	**23000 / 3200**
# of cells	**2**

(*) β ~ 6 to reduce Q_L and filling time



In **CLIC** the linac pulse (~ 140 μs) is generally much longer than the cavity filling time even in case of cavity with high loaded Q (that means higher efficiency structures).

Only input coupling coefficient β=1 are considered → no reflected power from the cavity (excepted the RF pulse transients)

→ minimization of the klystron power

Delay Loop Standing Wave RF deflector

beam energy: 2.38MeV

deflection: 5mrads

freq [GHz]		# of cells	cell radius [mm]	total lenght [mm]		Q_0 [x 1000]	β	Q_L [x 1000]	filling time [μs]		single cell dissipated PWR_{av} [kW]	Klystron PWR_{peak} [MW]	R_{shunt} [MΩ]
0.5		**1**	**365**	**300**		**50**	**1**	**25**	**16**		**360**	**48**	**1.5**
0.5		**2**	**365**	**600**		**50**	**1**	**25**	**16**		**90**	**24**	**3.0**
1.5		**1**	**122**	**100**		**29**	**1**	**14.5**	**3.1**		**620**	**83**	**0.86**
1.5		**2**	**122**	**200**		**29**	**1**	**14.5**	**3.1**		**155**	**42**	**1.72**
1.5		**4**	**122**	**400**		**29**	**1**	**14.5**	**3.1**		**39**	**21**	**3.43**
2.5		**1**	**73**	**60**		**22**	**1**	**11**	**1.4**		**800**	**106**	**0.66**
2.5		**4**	**73**	**240**		**22**	**1**	**11**	**1.4**		**50**	**27**	**2.66**

Combiner Ring 1 Standing Wave RF deflector

beam energy: 2.38MeV

deflection: 5mrads

freq [GHz]		# of cells	cell radius [mm]	total lenght [mm]		Q_0 [x 1000]	β	Q_L [x 1000]	filling time [μs]		single cell dissipated PWR_{av} [kW]	Klystron PWR_{peak} [MW]	R_{shunt} [MΩ]
1		**1**	**183**	**150**		**35**	**1**	**17.5**	**5.6**		**506**	**67**	**1.05**
1		**4**	**183**	**600**		**35**	**1**	**17.5**	**5.6**		**32**	**17**	**4.2**
2		**1**	**91**	**75**		**25**	**1**	**12.5**	**2.0**		**715**	**95**	**0.74**
2		**4**	**91**	**300**		**25**	**1**	**12.5**	**2.0**		**45**	**24**	**2.96**
4		**1**	**46**	**38**		**17**	**1**	**8.5**	**0.7**		**1012**	**135**	**0.52**
4		**4**	**46**	**150**		**17**	**1**	**8.5**	**0.7**		**63**	**34**	**2.1**

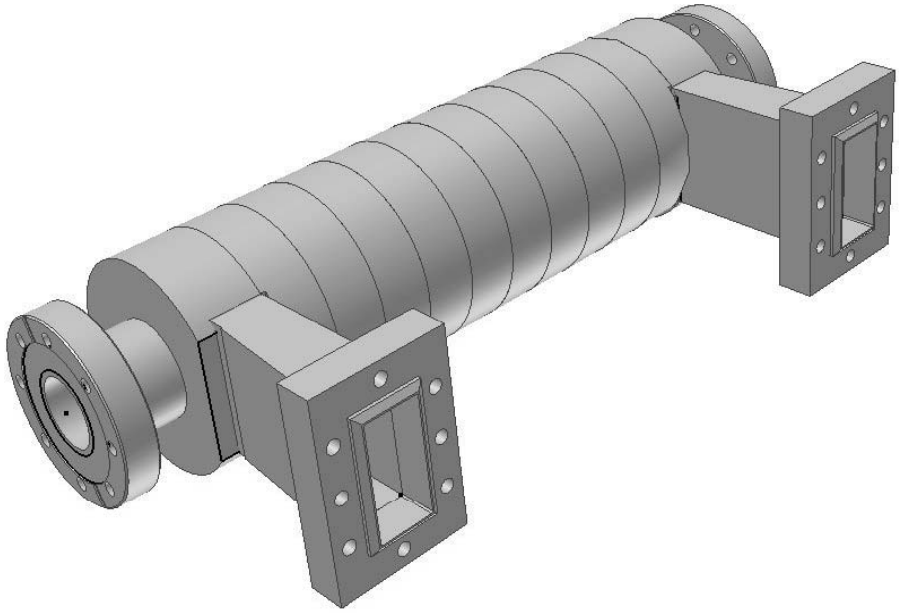
Combiner Ring 2 Standing Wave RF deflector

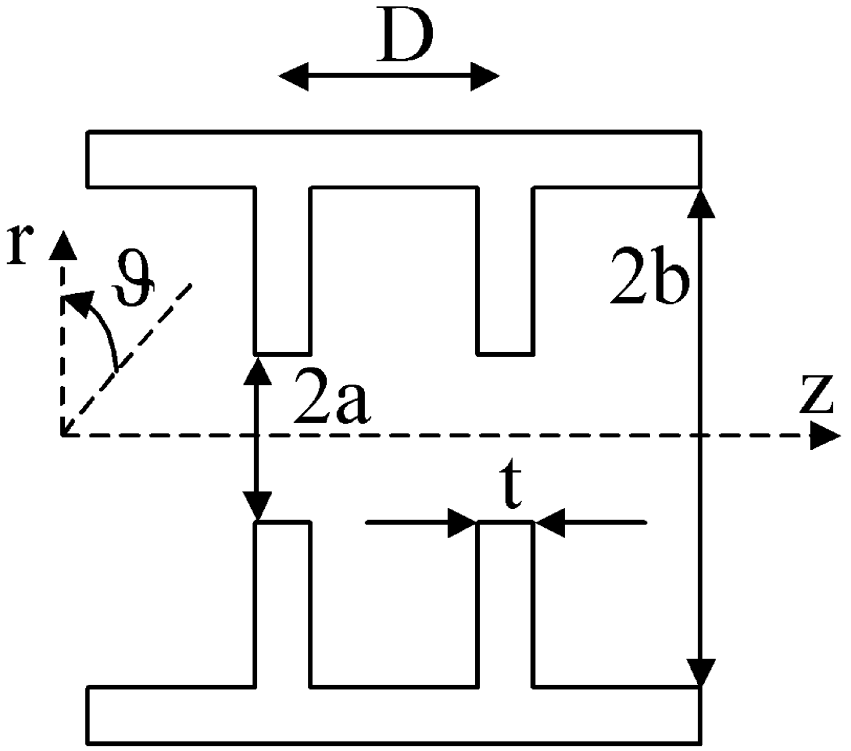
beam energy: 2.38MeV

deflection: 5mrads

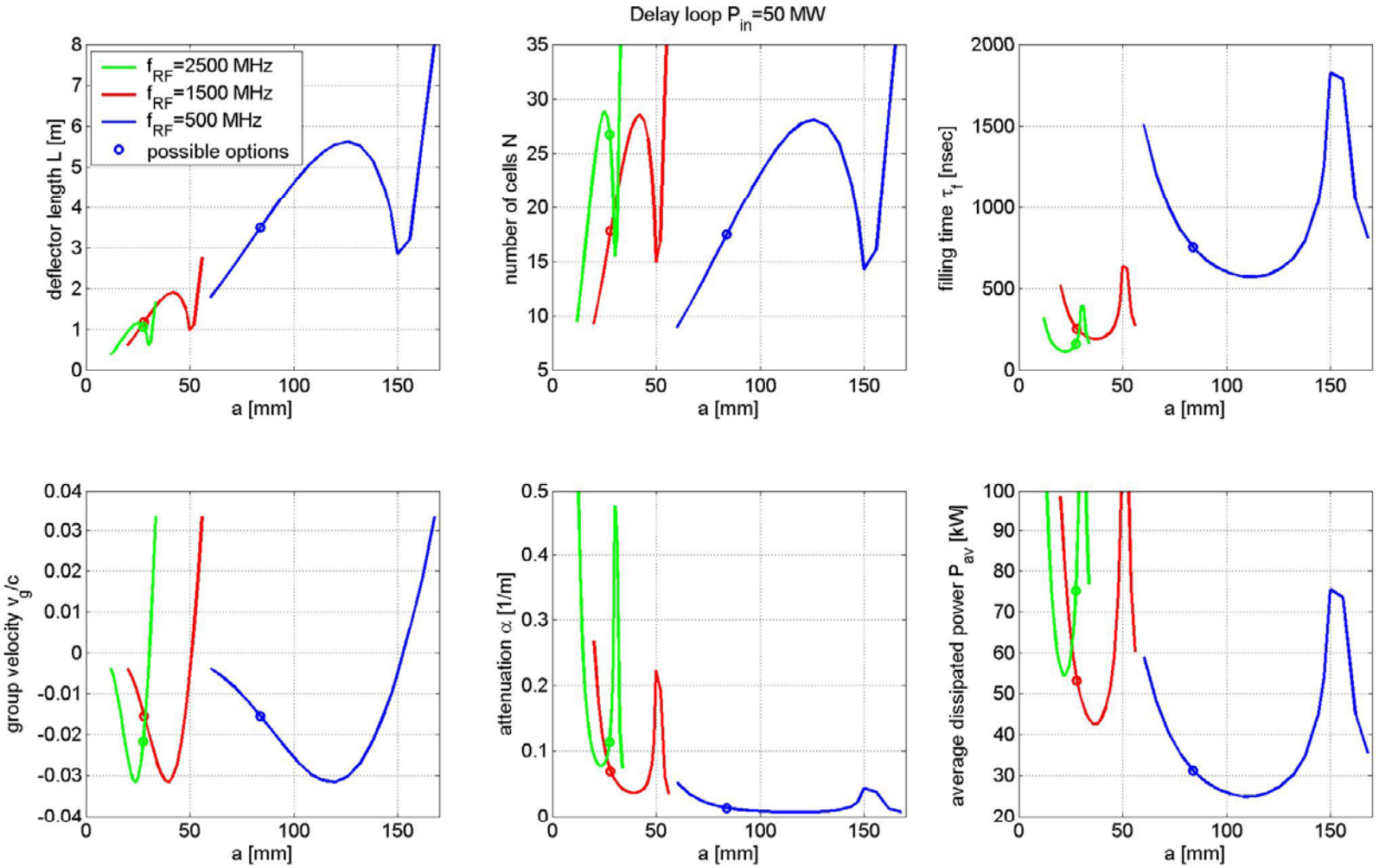
freq [GHz]		# of cells	cell radius [mm]	total lenght [mm]		Q_0 [x 1000]	β	Q_L [x 1000]	filling time [μs]		single cell dissipated PWR_{av} [kW]	Klystron PWR_{peak} [MW]	R_{shunt} [MΩ]
3		**1**	**61**	**50**		**20**	**1**	**10**	**1.1**		**876**	**117**	**0.6**
3		**4**	**61**	**200**		**20**	**1**	**10**	**1.1**		**55**	**29**	**2.4**
3		**6**	**61**	**300**		**20**	**1**	**10**	**1.1**		**24**	**20**	**3.6**
6		**4**	**30**	**100**		**14**	**1**	**7**	**0.4**		**77**	**41**	**1.7**
6		**6**	**30**	**150**		**14**	**1**	**7**	**0.4**		**34**	**28**	**2.6**

TW RF DEFLECTORS



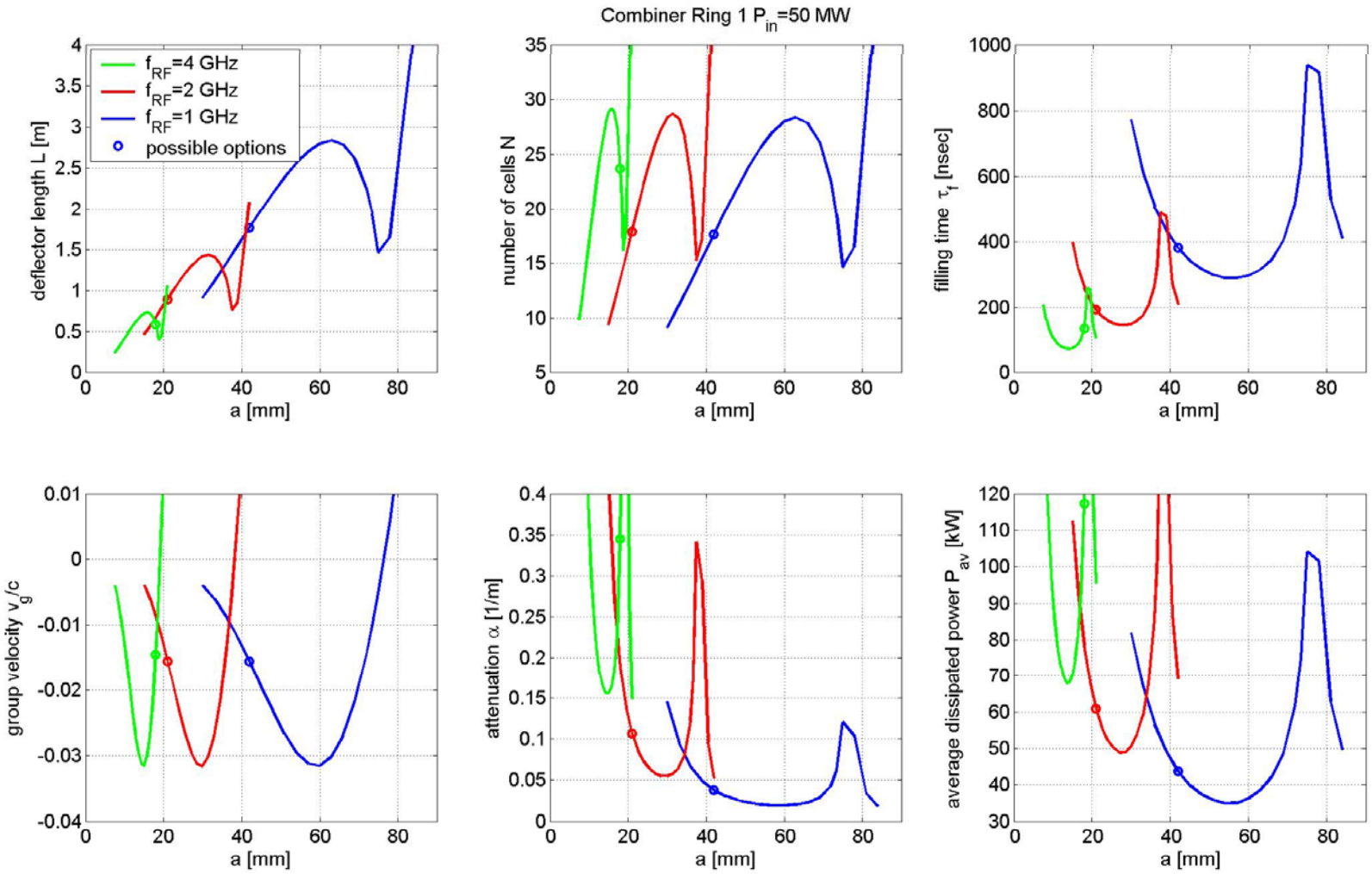


DELAY LOOP



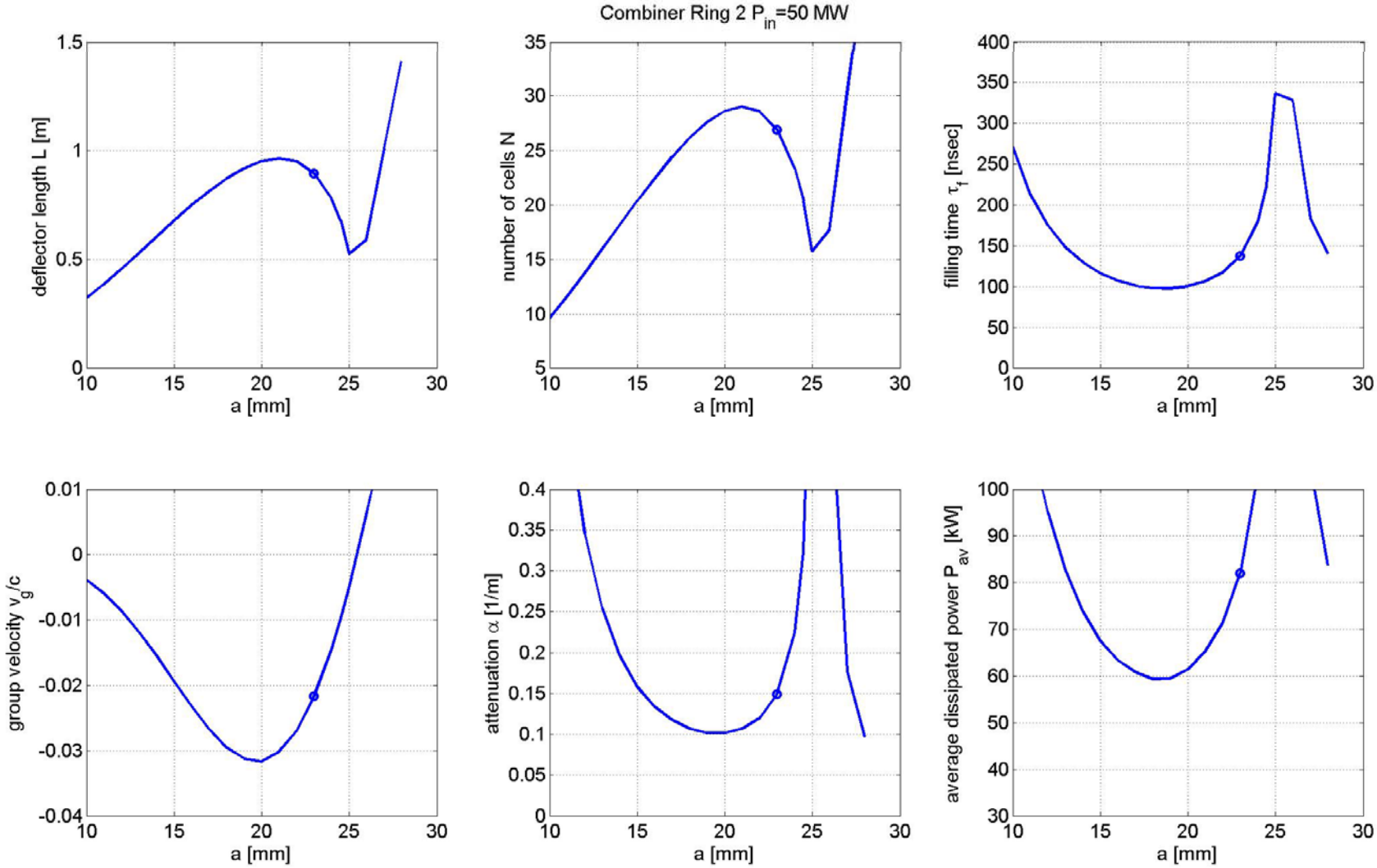
f [GHz]	a (mm)	L (m)	N	τ_f [ns]	v_g/c	α [1/m]	P_{av} [kW]	Z [$V^2/m^2/W$]
0.5	83	3.5	17	752	-0.016	0.013	31	2.5e5
1	28	1.2	18	255	-0.016	0.07	53	2.1e6
2	27	1.1	27	164	-0.02	0.1	75	2.8e6

COMB RING 1



f [GHz]	a (mm)	L (m)	N	τ_f [ns]	v_g/c	α [1/m]	P_{av} [kW]	Z [$V^2/m^2/W$]
1	42	1.7	17	379	-0.016	0.04	44	9.6e5
2	21	0.9	18	192	-0.016	0.1	60	3.7e6
4	18	0.6	24	136	-0.014	0.34	117	9.8e6

COMB RING 2



f [GHz]	a (mm)	L (m)	N	τ_f [ns]	v_g/c	α [1/m]	P_{av} [kW]	Z [$V^2/m^2/W$]
3	23	0.9	27	137	-0.022	0.15	82	4e6