

CLIC booster linac Proposal

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CLIC Booster Linac scans

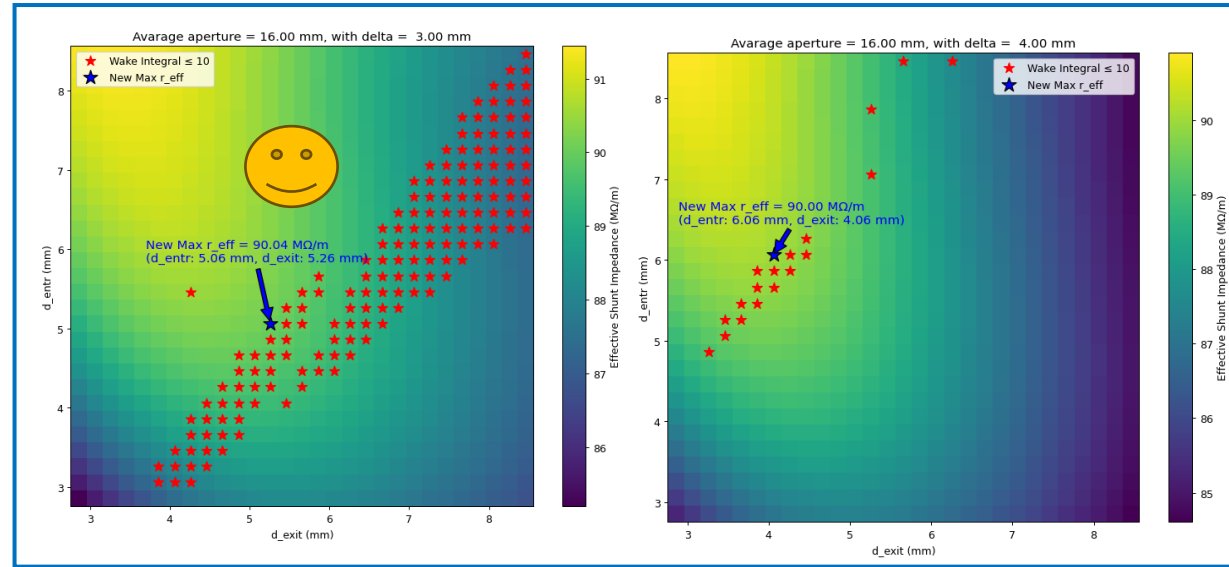
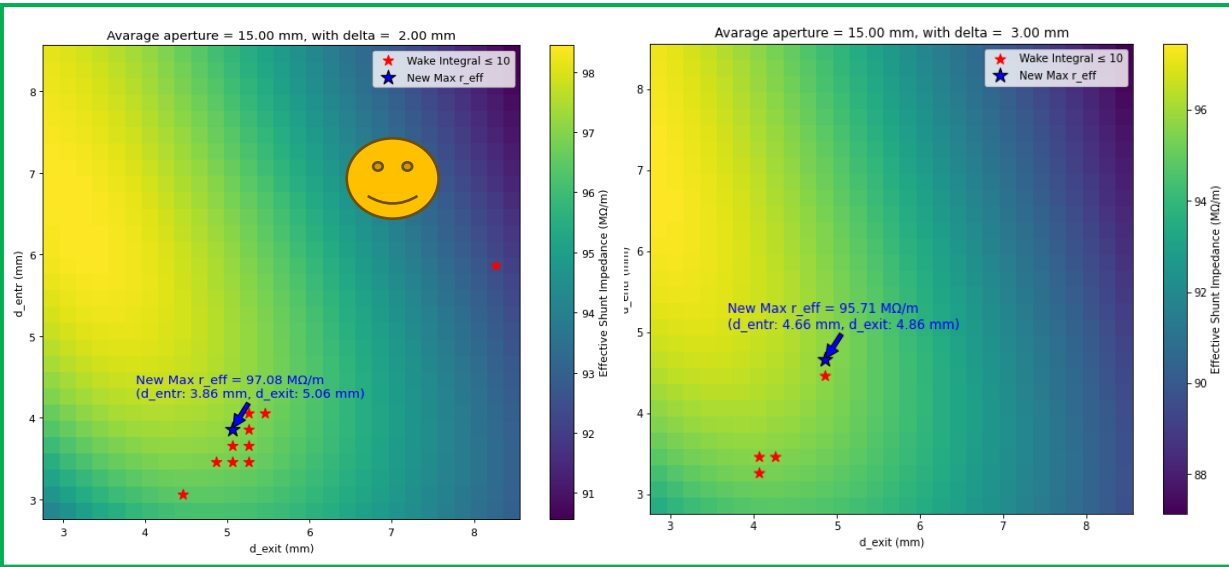
- Parameters for the structure:

- $f = 2 \text{ GHz}$, Length = 3m, Phase advance = $2\pi/3$, $Q_{0,SLED} = 2e5$, $T_{\text{klystron}} = 5 \text{ us}$, $G_{\text{avg}} = 25 \text{ MV/m}$.

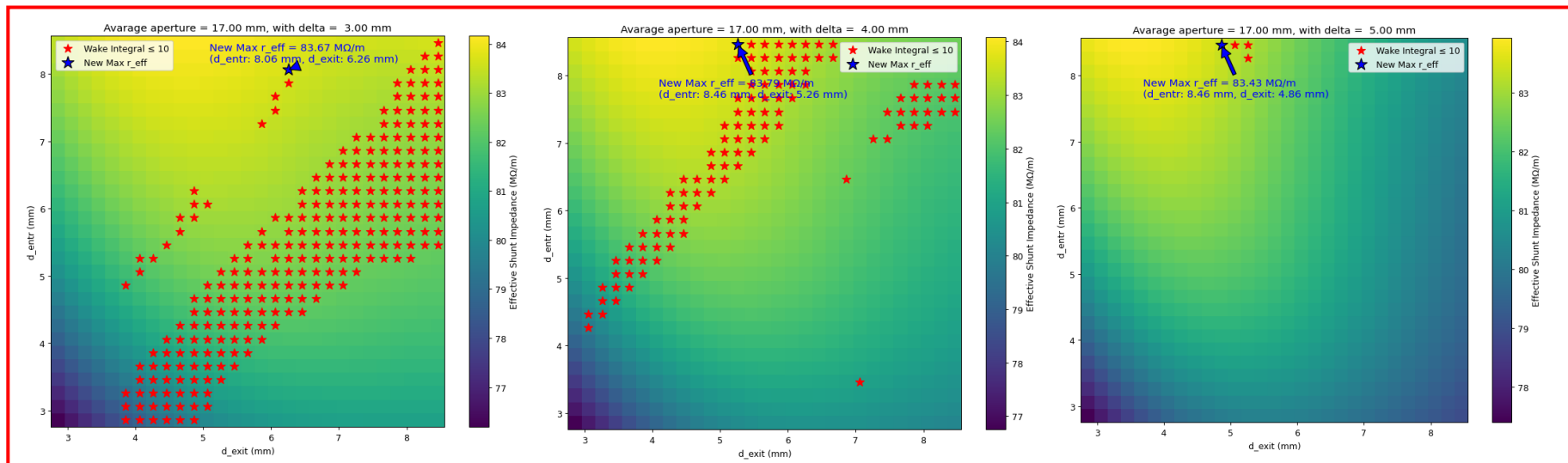
Scanned from avg. aperture 12 mm to 17 mm.
Avg. Aperture 15 mm and above satisfy the wake conditon.

15 mm

16 mm



17 mm

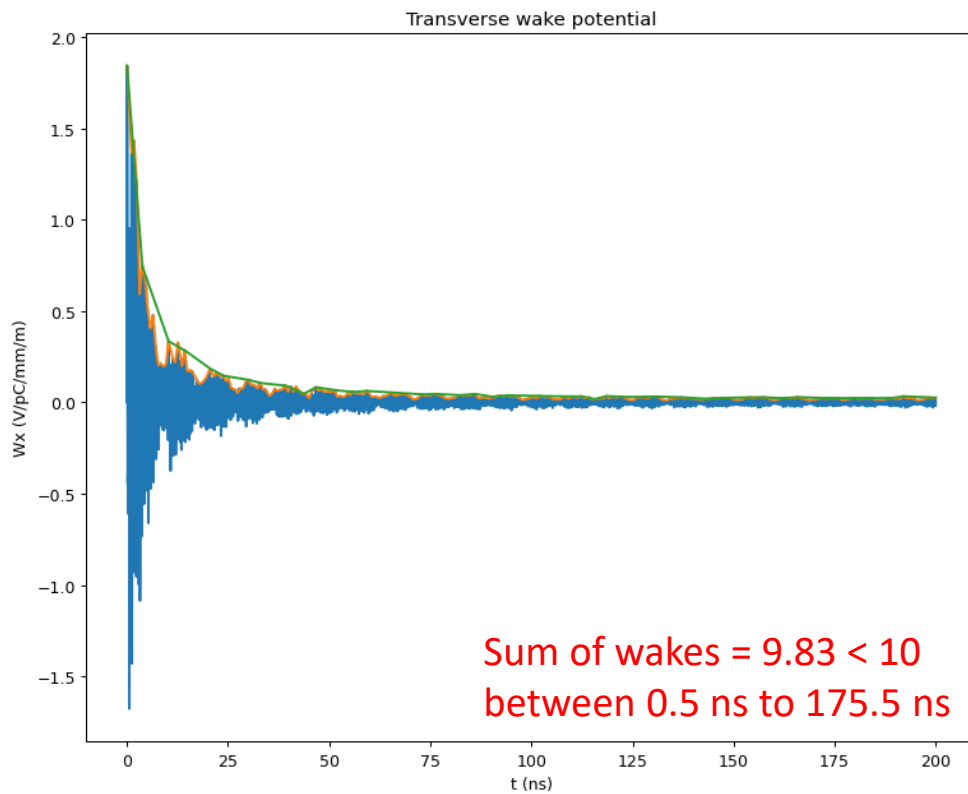


CLIC Booster Linac structure wakefields

- Parameters for the structure:

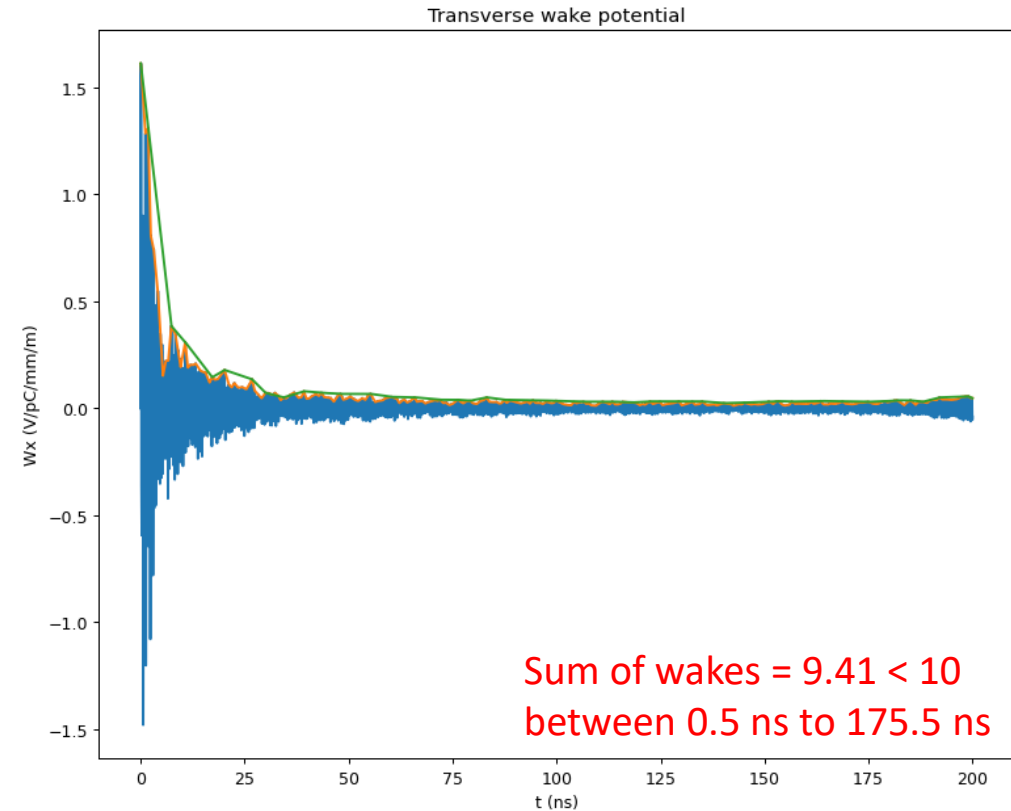
- $f = 2 \text{ GHz}$, Length = 3m, Phase advance = $2\pi/3$, $Q_{0,\text{SLED}} = 2e5$, $T_{\text{klystron}} = 5 \text{ us}$, $G_{\text{avg}} = 25 \text{ MV/m}$.

Avg. Aperture 15 mm with delta = 2mm



Wake_15mm_aperture.txt

Avg. Aperture 16 mm with delta = 3mm



Wake_16mm_aperture.txt

CLIC Booster Linac structure proposals

- Parameters for the structure:
- $f = 2 \text{ GHz}$, Length = 3m, Phase advance = $2\pi/3$, $Q_{0,\text{SLED}} = 2e5$, $T_{\text{klystron}} = 5 \text{ us}$.

	Avg. Aperture: 15 mm		Avg. Aperture: 16 mm	
	Delta = 2 mm		Delta = 3 mm	
Entr., exit aperture	17 mm → 13 mm		19 mm → 13 mm	
Iris thickness	3.86 mm → 5.06 mm		5.06 mm → 5.26 mm	
Vg (% c)	2.13 → 0.77		2.71 → 0.76	
r/Q (kOhm/m)	3.0 → 3.39		2.76 → 3.37	
Q	19598 → 19261		19398 → 19208	
Filling time	794 ns		710 ns	
SLED coupling	13		13	
Eff. shunt impedance	97.1 MΩ/m		90.04 MΩ/m	
Integral of WT (V/pC/mm/m)	9.83		9.41	
Klystron power per structure	(2 struc. per klyst.) 31 MW	(4 struc. per klyst.) 15.5 MW	(2 struc. per klyst.) 31 MW	(4 struc. per klyst.) 15.5 MW
G_{avg}	31.68 MV/m	22.4 MV/m	30.51 MV/m	21.58 MV/m
E_{max} (instant.)	100 MV/m	50 MV/m	103 MV/m	73 MV/m
$S_{\text{c,max}}$ (instant.)	742 mW/μm ²	186 mW/μm ²	712 mW/μm ²	356 mW/μm ²

- Calculations are done considering the same RF power technology of the FCC.

CLIC Booster Linac Design

$$\Delta E = E_{\text{final}} - E_{\text{initial}} = 9.00 \text{ GeV} - 2.86 \text{ GeV} = 6.14 \text{ GeV}$$

	Avg. Aperture: 15 mm		Avg. Aperture: 16 mm	
	Delta = 2 mm		Delta = 3 mm	
Klystron power per structure	(2 struc. per klyst.) 31 MW	(4 struc. per klyst.) 15.5 MW	(2 struc. per klyst.) 31 MW	(4 struc. per klyst.) 15.5 MW
G_{avg}	31.68 MV/m	22.4 MV/m	30.51 MV/m	21.58 MV/m
Total length of LINAC	193.82 m	274.11 m	201.25 m	284.63 m
Number of structures	65	92	68	95
Number of klystrons	33	23	34	24

$$\text{Total Length of LINAC} = \frac{\Delta E}{\text{Average Gradient}}$$

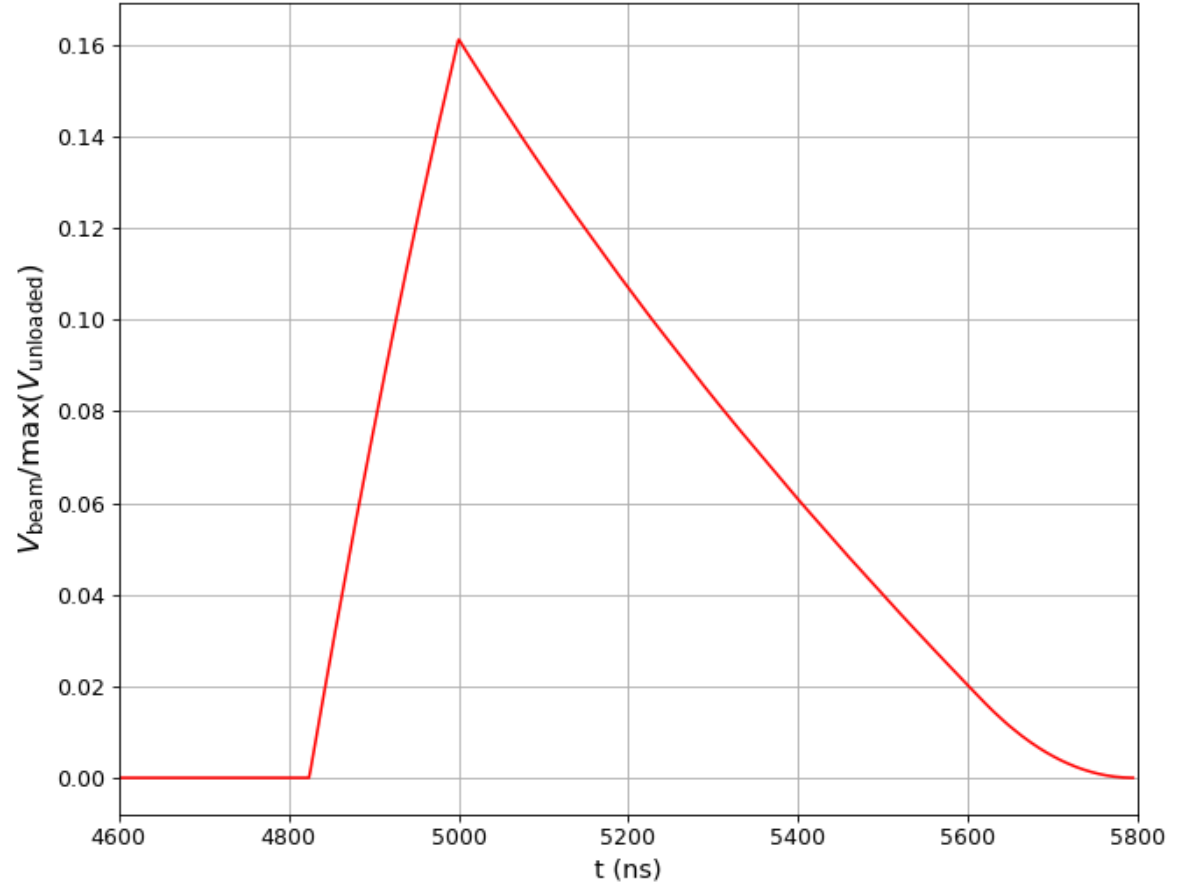
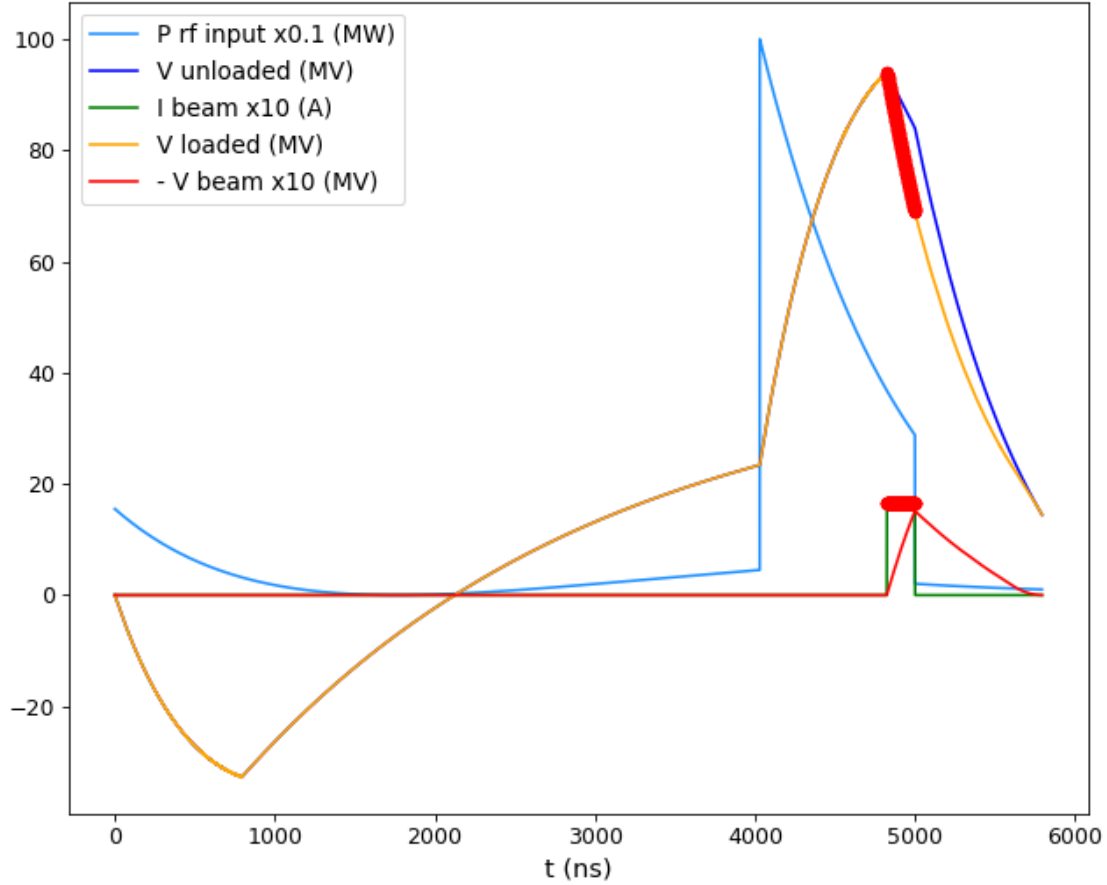
$$\text{Number of Structures} = \frac{\text{Total Length of LINAC}}{\text{Length of One Structure}}$$

$$\text{Number of Klystrons} = \frac{\text{Number of Structures}}{\text{Structures per Klystron}}$$

Energy spread minimization of booster linac

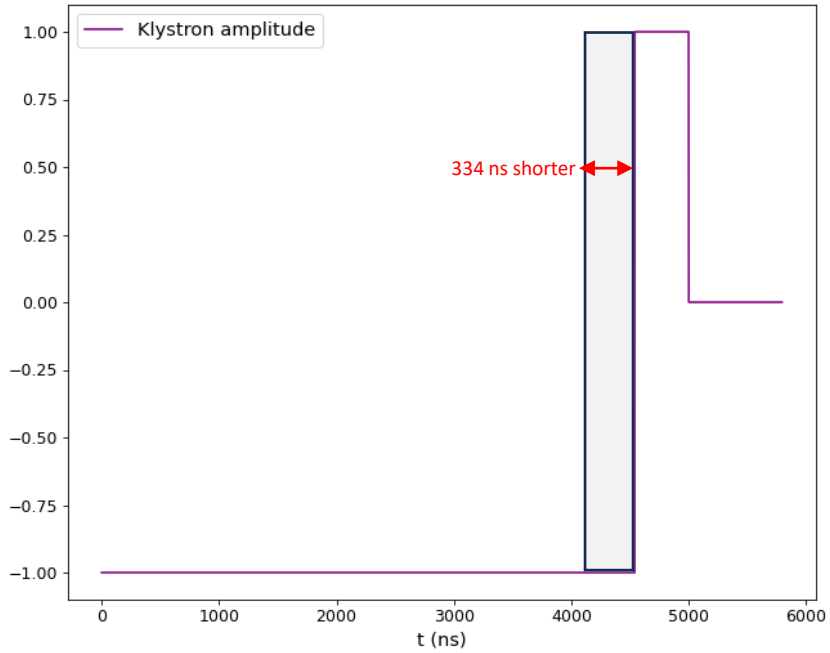
Avg. aperture = 15mm, 2 structure per klyst.

Quantities over time

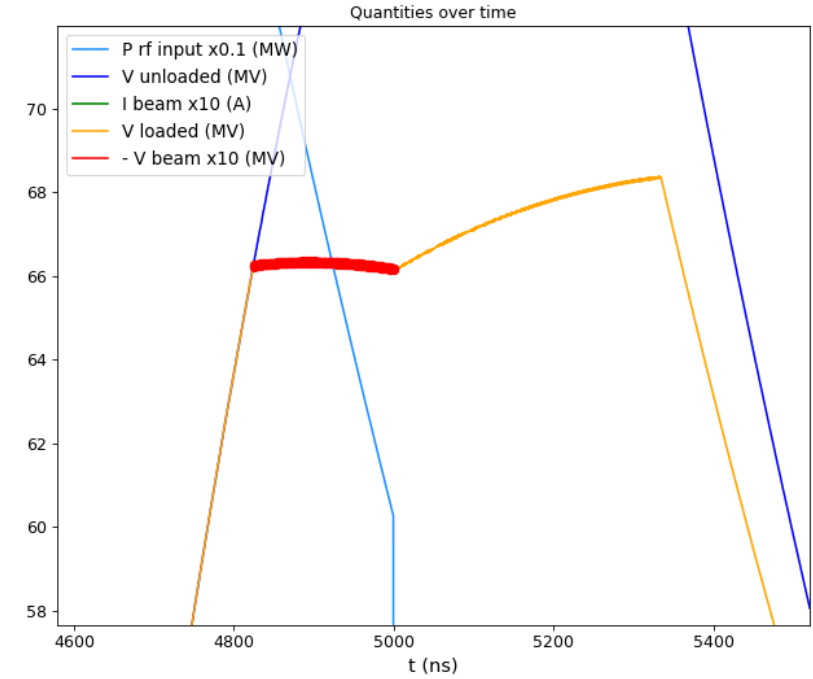
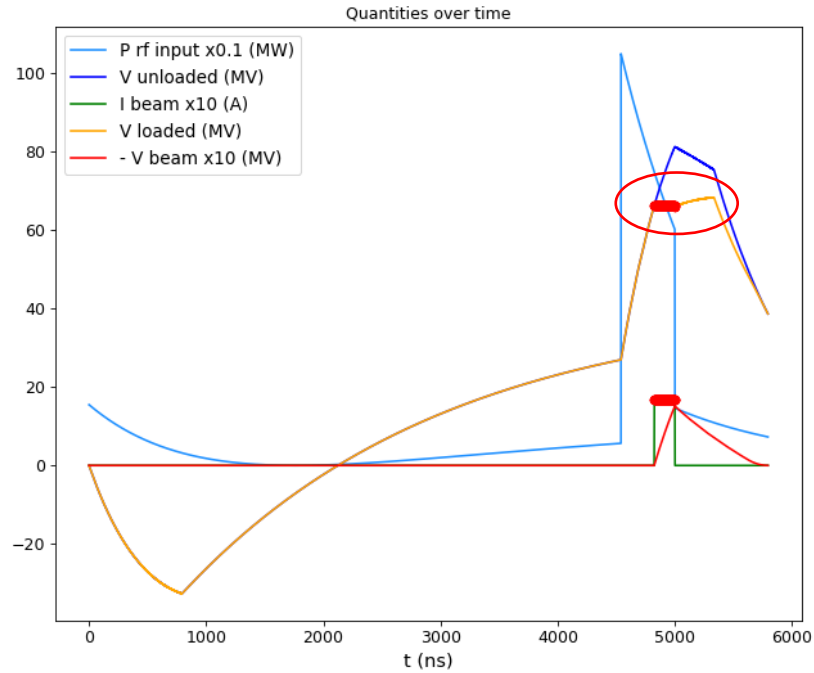


Avg. aperture = 15mm, 2 structure per klystr.

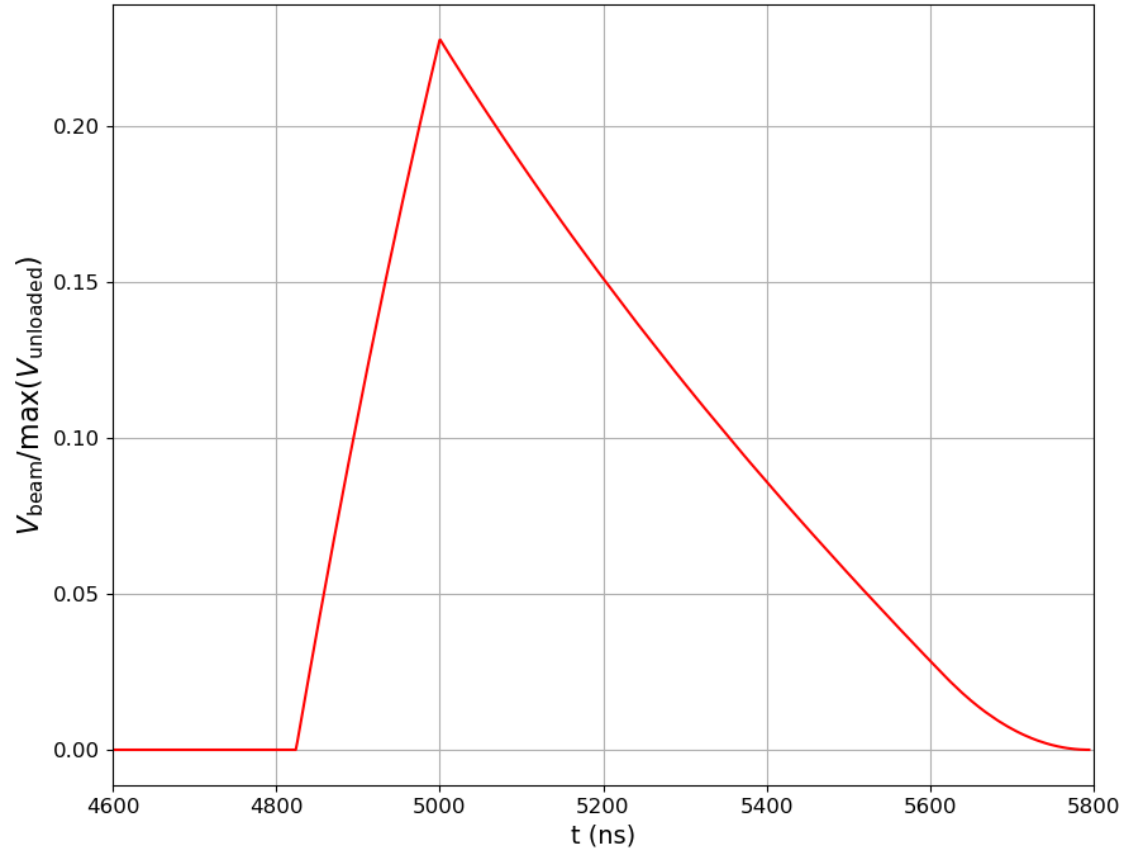
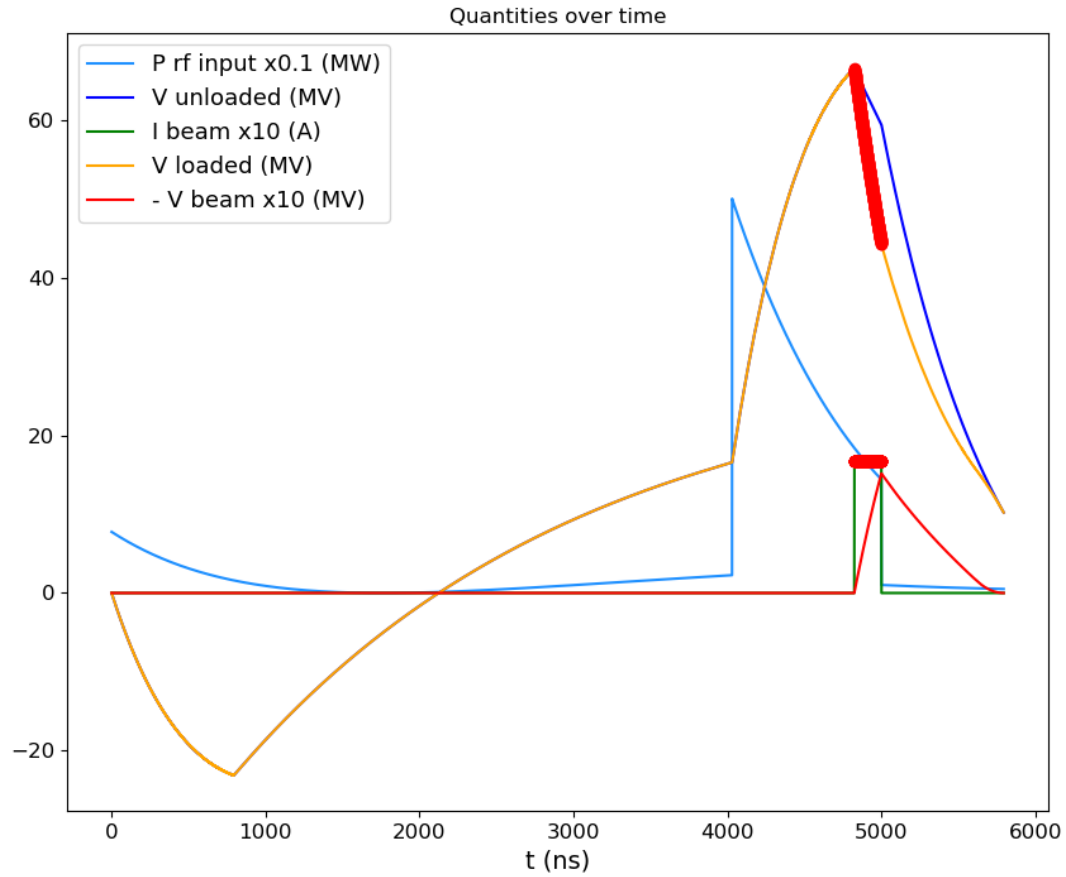
$T_{\text{fill}} = 794 \text{ ns}$



Maximum difference between 352 bunches:
 $\Delta V = 0.2 \text{ MV}$
0.3% energy spread

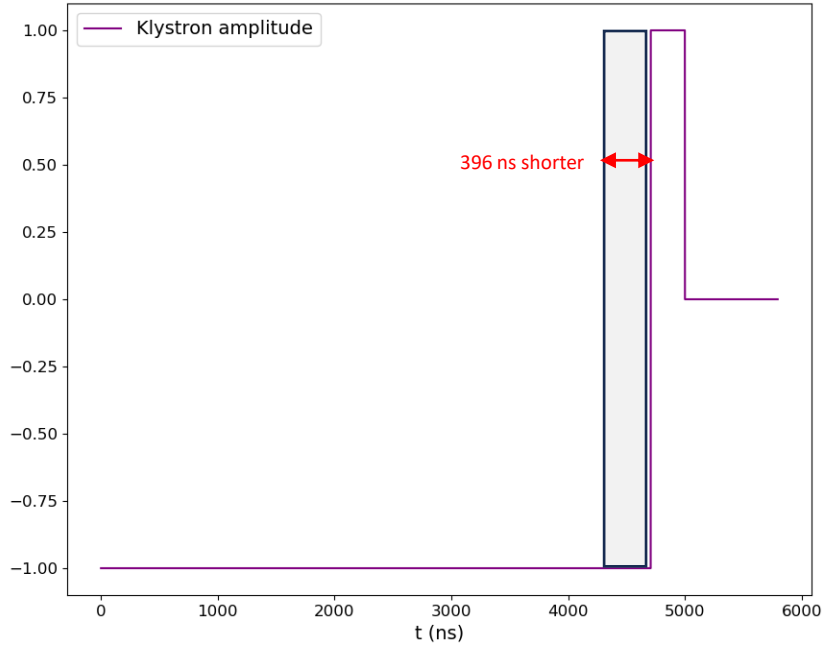


Avg. aperture = 15mm, 4 structure per klyst.

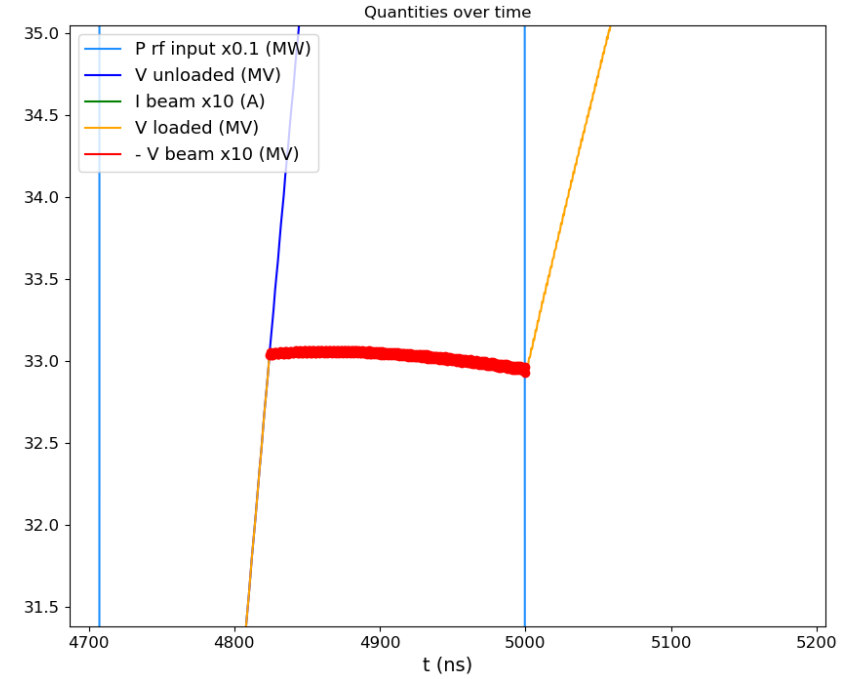
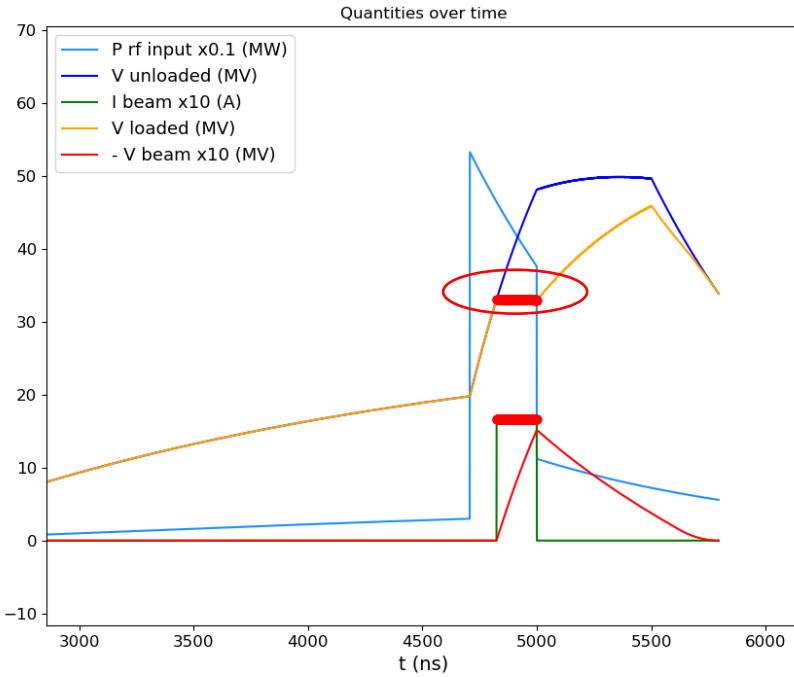


Avg. aperture = 15mm, 4 structure per klystr.

$T_{\text{fill}} = 794 \text{ ns}$

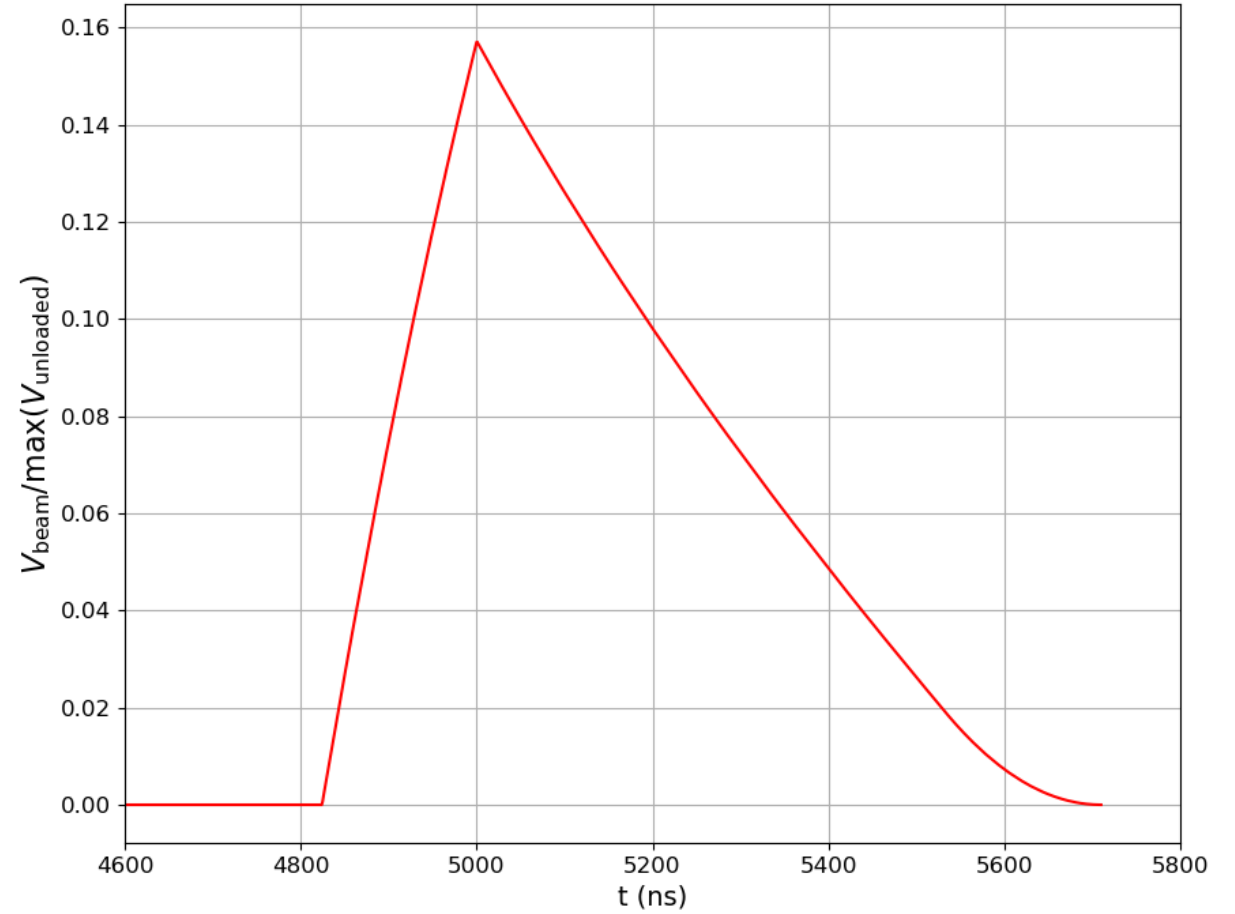
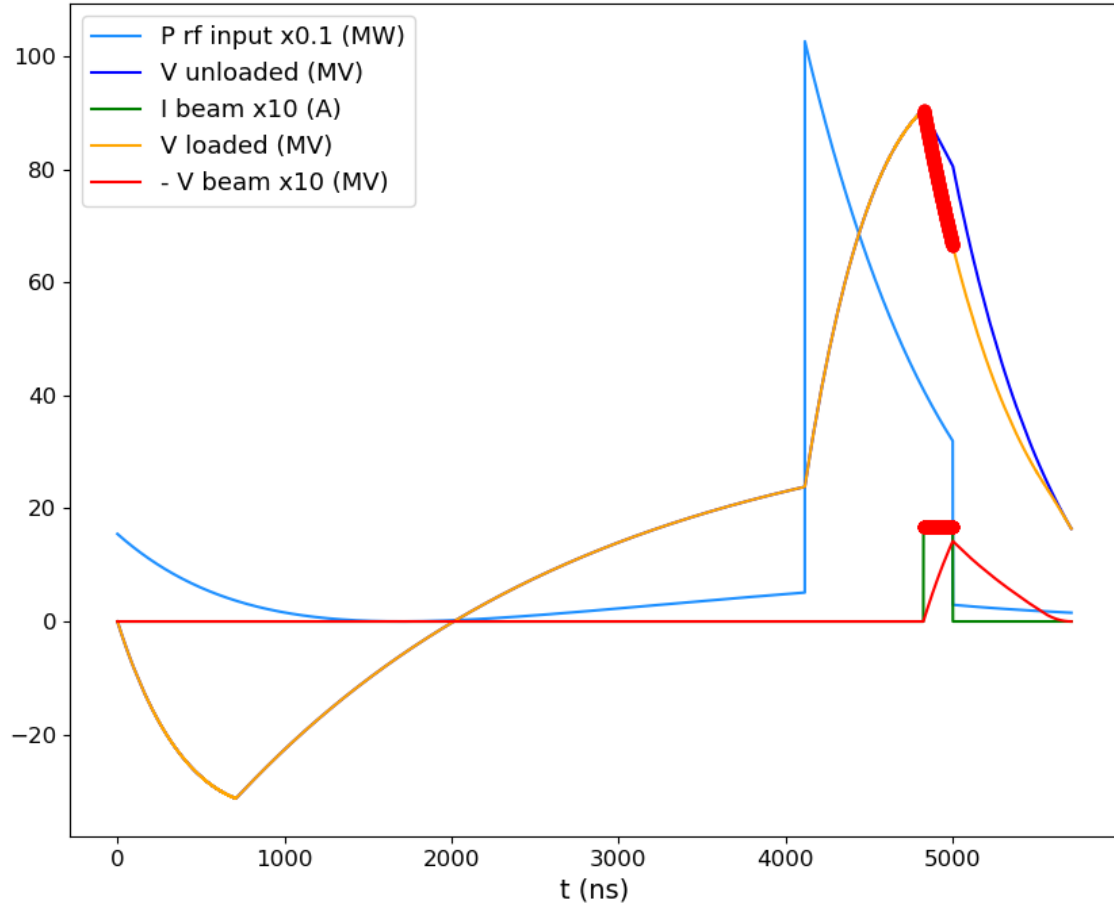


Maximum difference between 352 bunches:
 $\Delta V = 0.1405 \text{ MV}$
0.42% energy spread



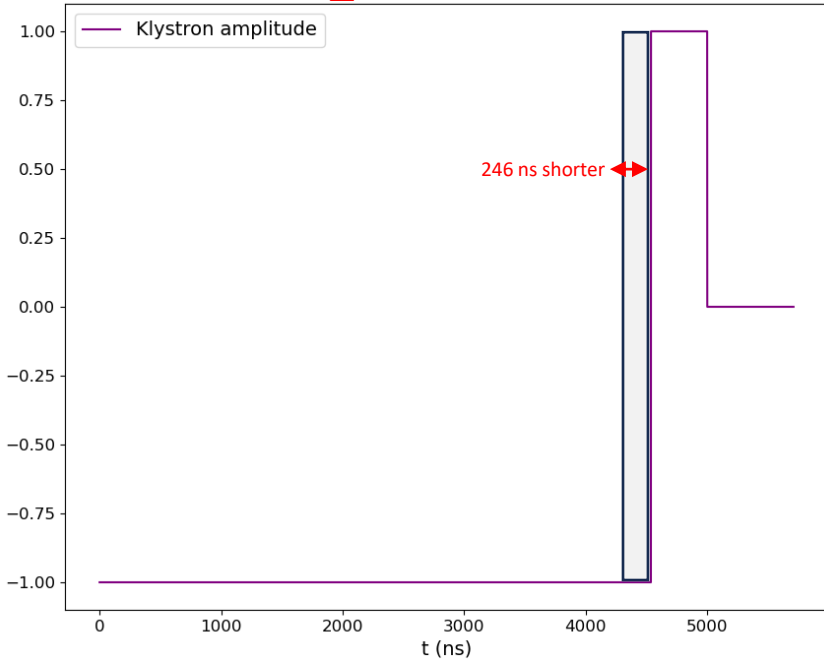
Avg. aperture = 16mm, 2 structure per klyst.

Quantities over time

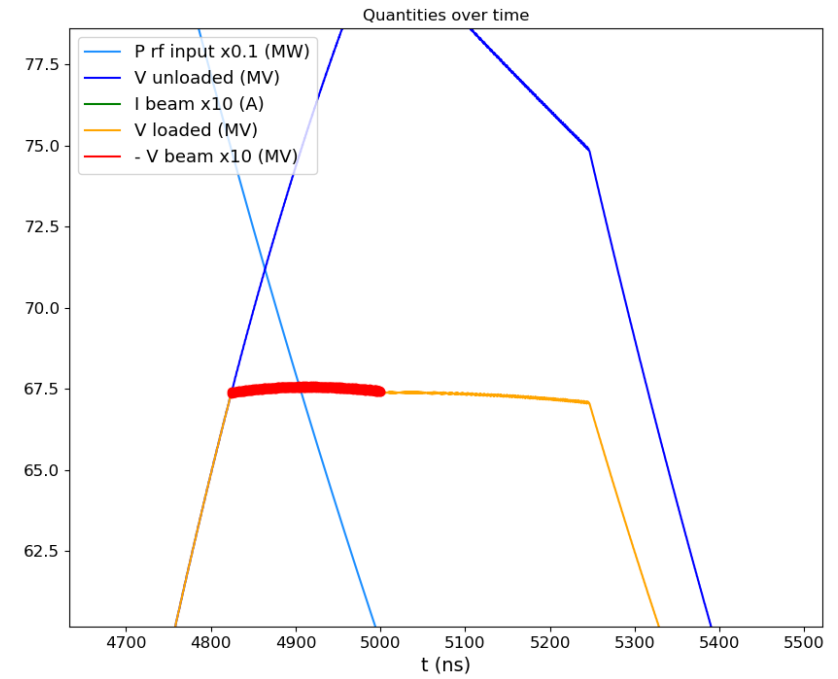
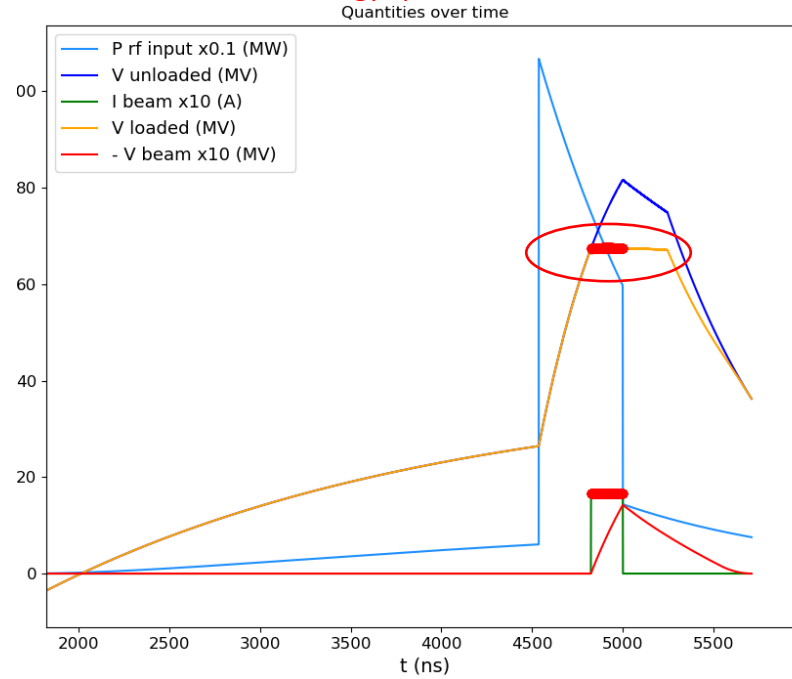


Avg. aperture = 16mm, 2 structure per klystr.

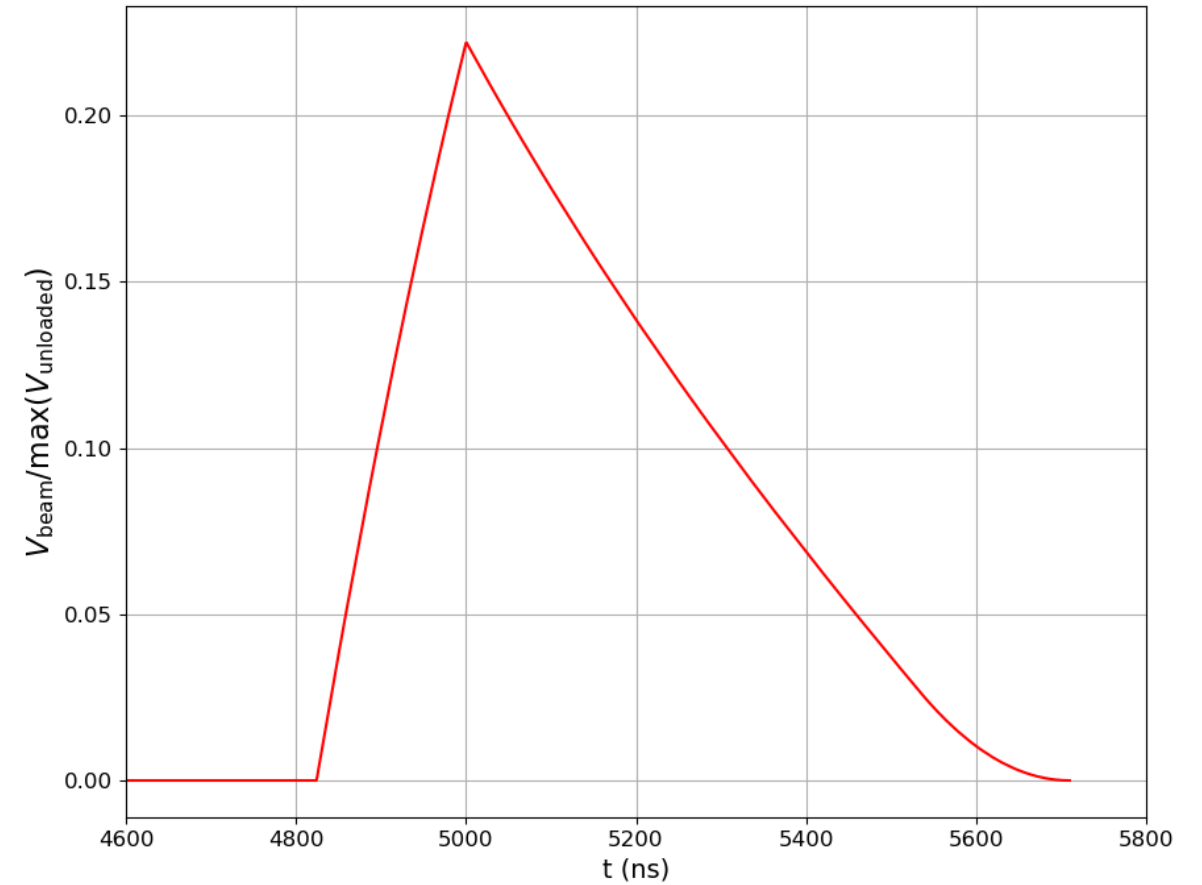
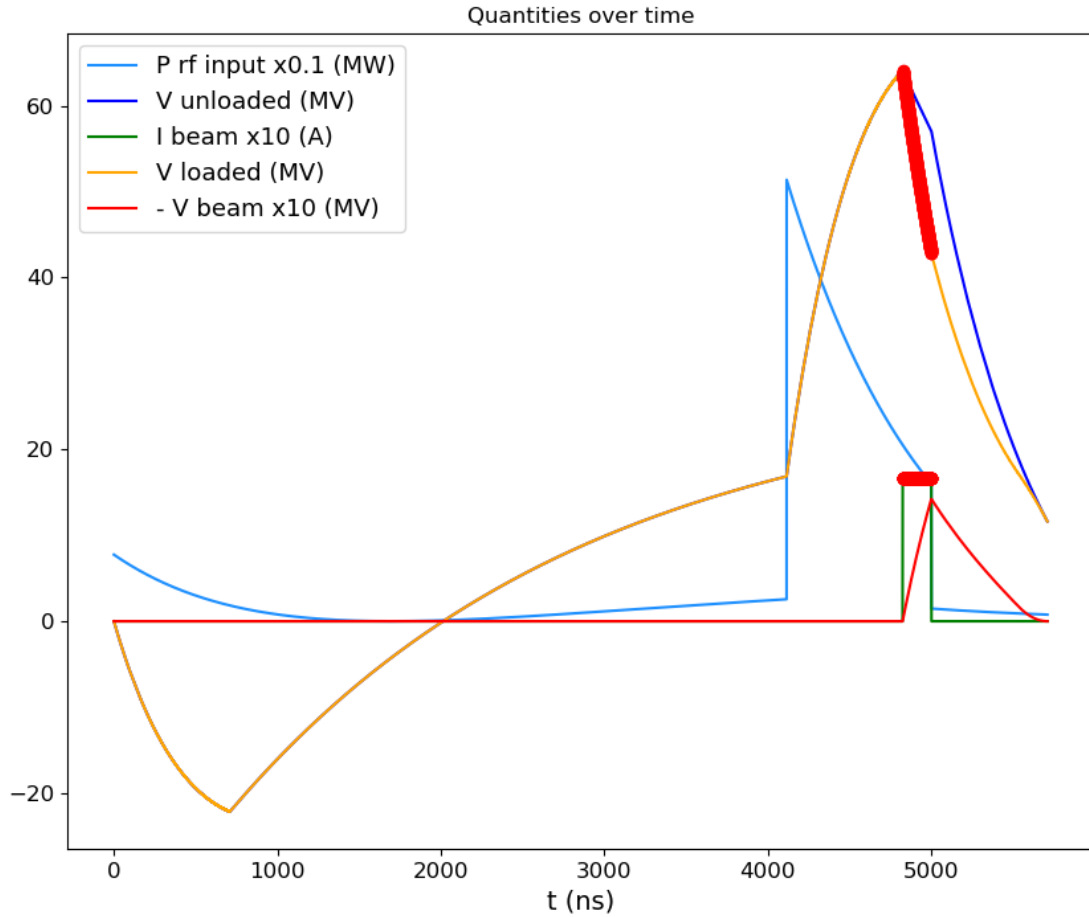
$T_{\text{fill}} = 710 \text{ ns}$



Maximum difference between 352 bunches:
 $\Delta V = 0.22 \text{ MV}$
0.33% energy spread

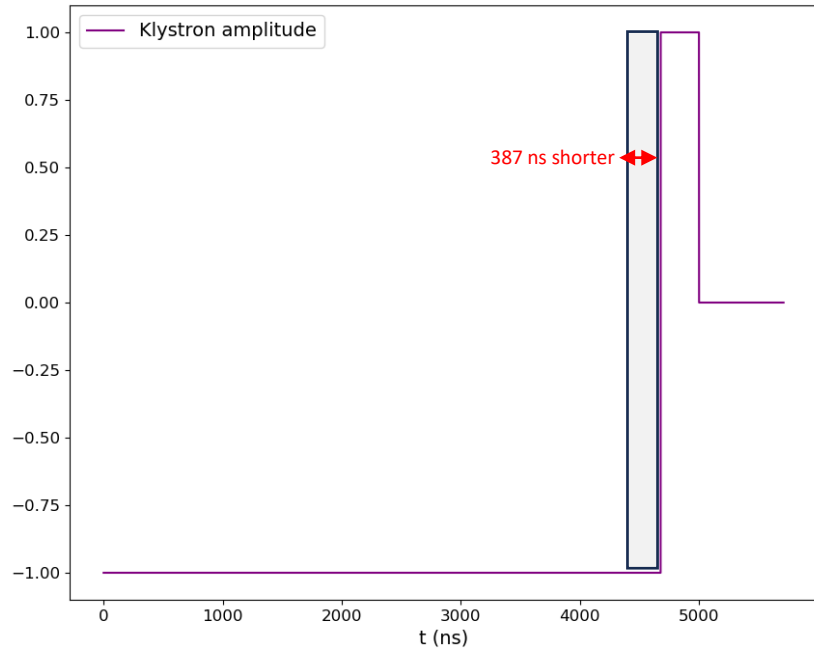


Avg. aperture = 16mm, 4 structure per klystr.

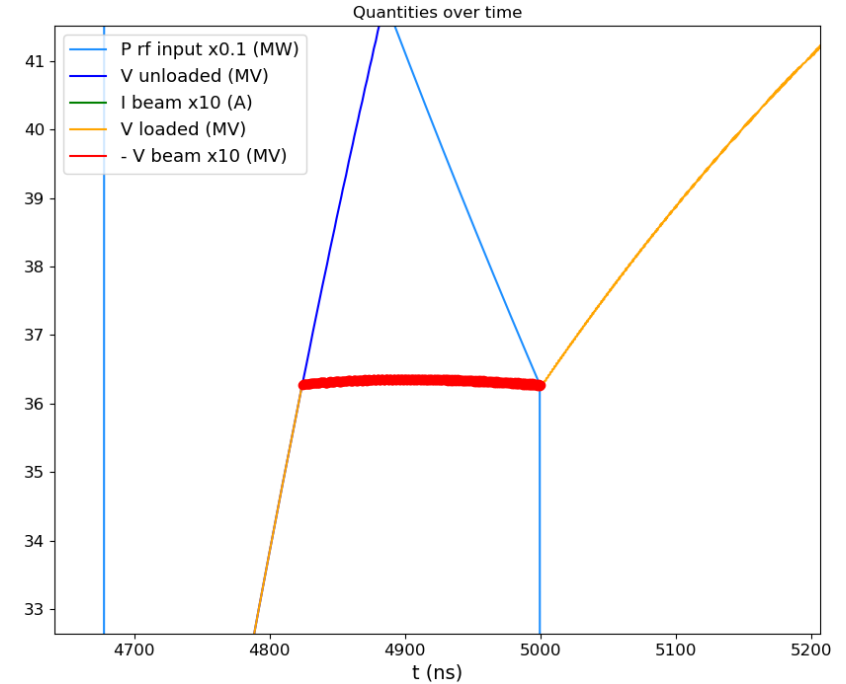
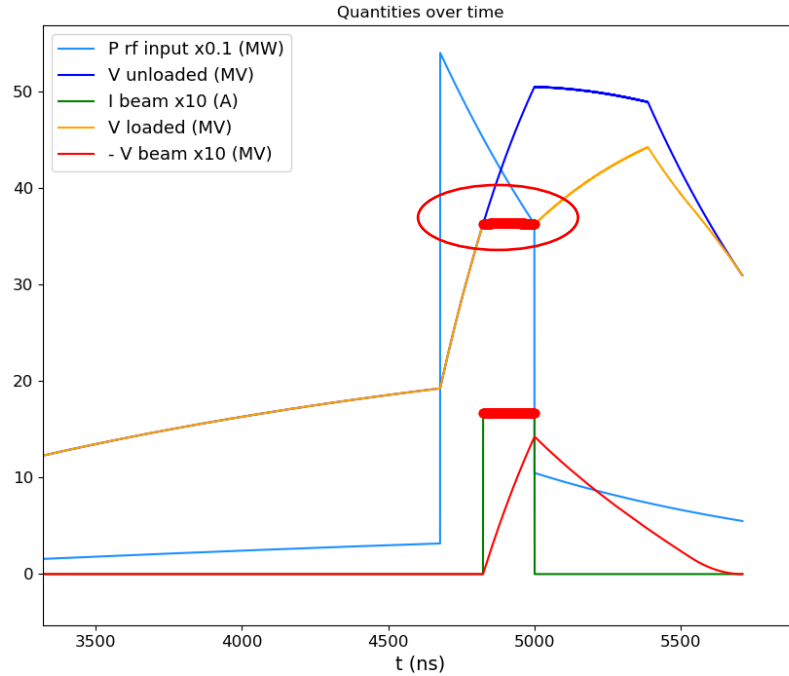


Avg. aperture = 16mm, 4 structure per klystr.

$T_{\text{fill}} = 710 \text{ ns}$



Maximum difference between 352 bunches:
 $\Delta V = 0.1 \text{ MV}$
0.28% energy spread



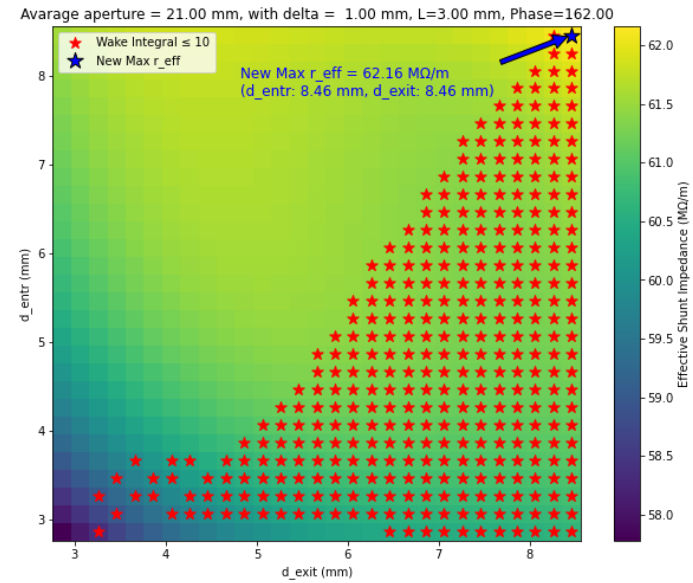
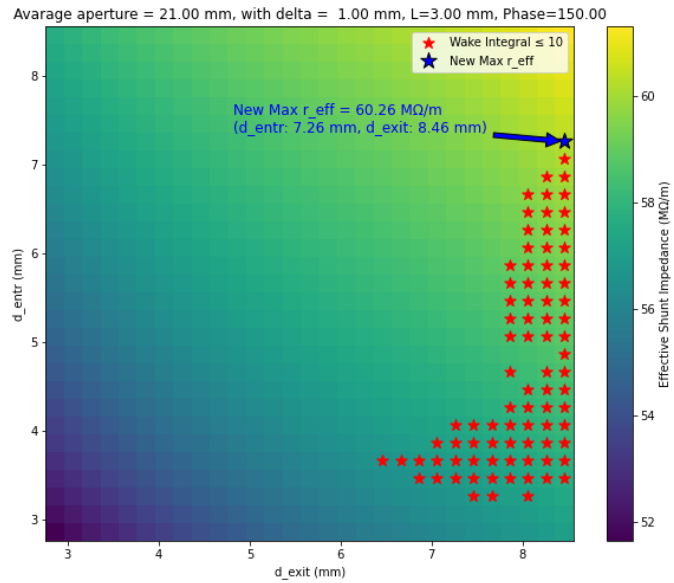
15 mm, 2 klyst. per struct.	Loaded V	Rsh	
Single Bunch	94.904 MV	97 MΩ/m	
352 Bunches	~66.28 MV	47.31 MΩ/m	~51.22 % lower Shunt imp.
15 mm, 4 klyst. per struct.	Loaded V	Rsh	
Single Bunch	67.09 MV	97 MΩ/m	
352 Bunches	~33.02 MV	23.50 MΩ/m	~75.77 % lower Shunt imp.

16 mm, 2 klyst. per struct.	Loaded V	Rsh	
Single Bunch	91.40 MV	90.04 MΩ/m	
352 Bunches	~67.51 MV	49.12 MΩ/m	~45.45 % lower Shunt imp.
16 mm, 4 klyst. per struct.	Loaded V	Rsh	
Single Bunch	64.64 MV	90.04 MΩ/m	
352 Bunches	~36.32 MV	28.42 MΩ/m	~68.43 % lower Shunt imp.

Injector Linac Scans

CLIC Injector Linac scans

- Parameters for the structure:
- $f = 2$ GHz, Length = 3m, Phase advance = $2\pi/3$, $Q_{0,SLED} = 2e5$, $T_{klystron} = 5$ us, $G_{avg} = 25$ MV/m.



CLIC Injector Linac scans

	Avg. Aperture: 21 mm Delta = 1 mm	
	Length = 3m Phase adv = 150	Length = 3m Phase adv = 162
Entr., exit aperture	22mm → 20 mm	22mm → 20 mm
Iris thickness	7.26 mm → 8.46 mm	8.46 mm → 8.46 mm
Vg (% c)	2.16 → 1.49	1.31 → 0.96
r/Q (kOhm/m)	2.00 → 2.16	1.81 → 1.96
Q	22106 → 21713	23138 → 22992
Filling time	558ns	883 ns
SLED coupling	15	13
Eff. shunt impedance	60.26 MΩ/m	62.16 MΩ/m
Integral of WT (V/pC/mm/m)	9.93	9.38
G_{avg}	24.96 MV/m	25.48 MV/m
Klystron power per structure	31 MW	31 MW
E_{max} (instant.)	73 MV/m	100 MV/m
$S_{c,max}$ (instant.)	427 mW/μm ²	429 mW/μm ²

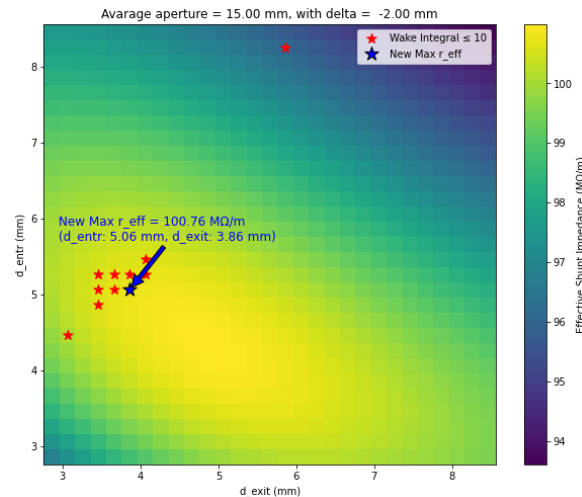
Backup Slides

CLIC Booster Linac scans

	Avg. Aperture: 15 mm		Avg. Aperture: 16 mm		Avg. Aperture: 17 mm		
	Delta = 2 mm	Delta = 3 mm	Delta = 3 mm	Delta = 4 mm	Delta = 3 mm	Delta = 4 mm	Delta = 5 mm
Entr., exit aperture	17 mm → 13 mm	18 mm → 12 mm	19 mm → 13 mm	20 mm → 12 mm	20 mm → 14 mm	21 mm → 13 mm	22 mm → 12 mm
Iris thickness	3.86 mm → 5.06 mm	4.66 mm → 4.86 mm	5.46 mm → 4.26 mm	6.06 mm → 4.06 mm	8.07 mm → 6.26 mm	8.46 mm → 5.26 mm	8.46 mm → 4.86 mm
Vg (% c)	2.13 → 0.77	2.37 → 0.60	2.63 → 0.84	2.94 → 0.66	2.57 → 0.9	2.93 → 0.76	3.40 → 0.60
r/Q (kOhm/m)	3.0 → 3.39	2.88 → 3.50	2.74 → 3.42	2.62 → 3.53	2.57 → 3.21	2.47 → 3.38	2.38 → 3.50
Q	19598 → 19261	19466 → 19298	19294 → 19294	19162 → 19469	18590 → 18943	18532 → 19208	18572 → 19298
Filling time	794 ns	861 ns	680 ns	732 ns	660 ns	676 ns	714 ns
SLED coupling	13	12	14	13	14	14	13
Eff. shunt impedance	97.1 MΩ/m	95.71 MΩ/m	90.4 MΩ/m	90 MΩ/m	83.67 MΩ/m	83.79 MΩ/m	83.43 MΩ/m
Integral of WT (V/pC/mm/m)	9.83	9.92	9.96	9.6	9.93	9.56	10
G_{avg}	24.74 MV/m	24.56 MV/m	23.88 MV/m	23.82 MV/m	22.96 MV/m	22.98 MV/m	22.93 MV/m
Klystron power per structure	18.9 MW	18.9 MW	18.9 MW	18.9 MW	18.9 MW	18.9 MW	18.9 MW
E_{max} (instant.)	78 MV/m	84 MV/m	90 MV/m	96 MV/m	69 MV/m	86 MV/m	96 MV/m
$S_{C,max}$ (instant.)	445 mW/μm ²	446 mW/μm ²	519 mW/μm ²	559 mW/μm ²	362 mW/μm ²	487 mW/μm ²	556 mW/μm ²

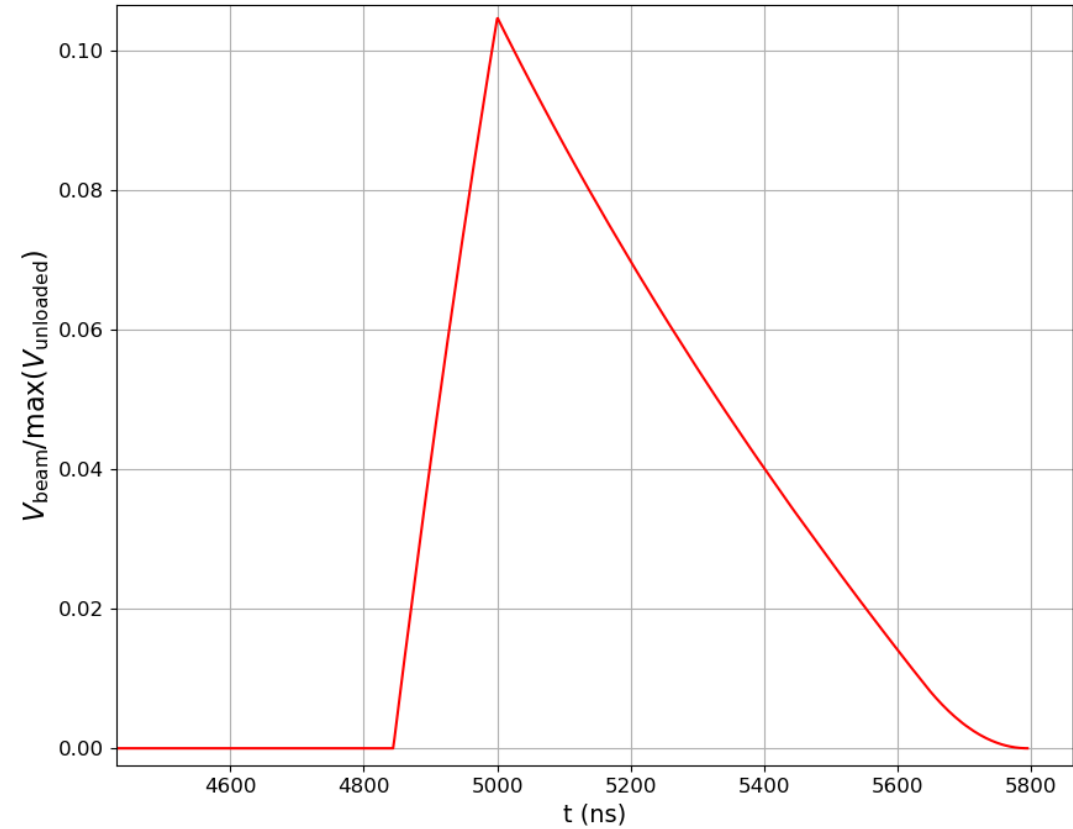
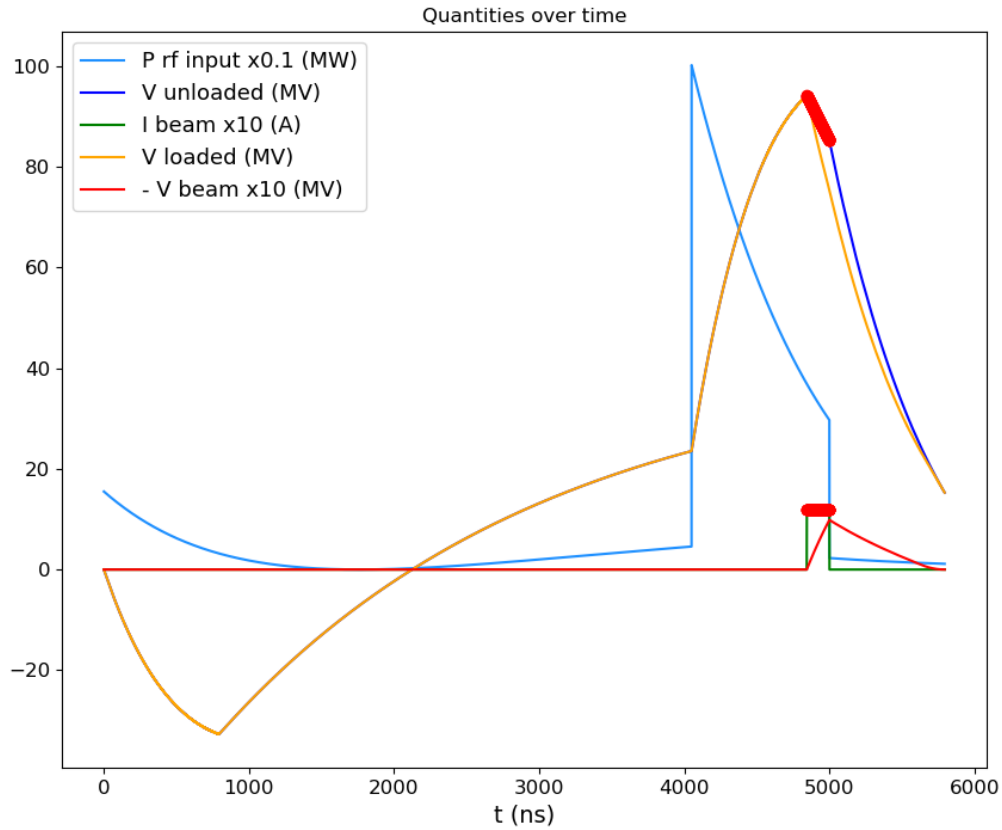
Alternative structure?

	Avg. Aperture: 15 mm	
	Delta = 2 mm	
Entr., exit aperture	17 mm → 13 mm	
Iris thickness	5.06 mm → 3.86 mm	
Vg (% c)	0.77 → 2.13	
r/Q (kOhm/m)	3.39 → 3.0	
Q	19261 → 19598	
Filling time	794 ns	
SLED coupling	14	
Eff. shunt impedance	100.76 MΩ/m	
Integral of WT (V/pC/mm/m)	9.83	
Klystron power per structure	(2 struc. per klyst.) 31 MW	(4 struc. per klyst.) 15.5 MW
G_{avg}	32.28 MV/m	22.82 MV/m
E_{max} (instant.)	128 MV/m	64 MV/m
$S_{c,max}$ (instant.)	1081 mW/μm ²	270 mW/μm ²



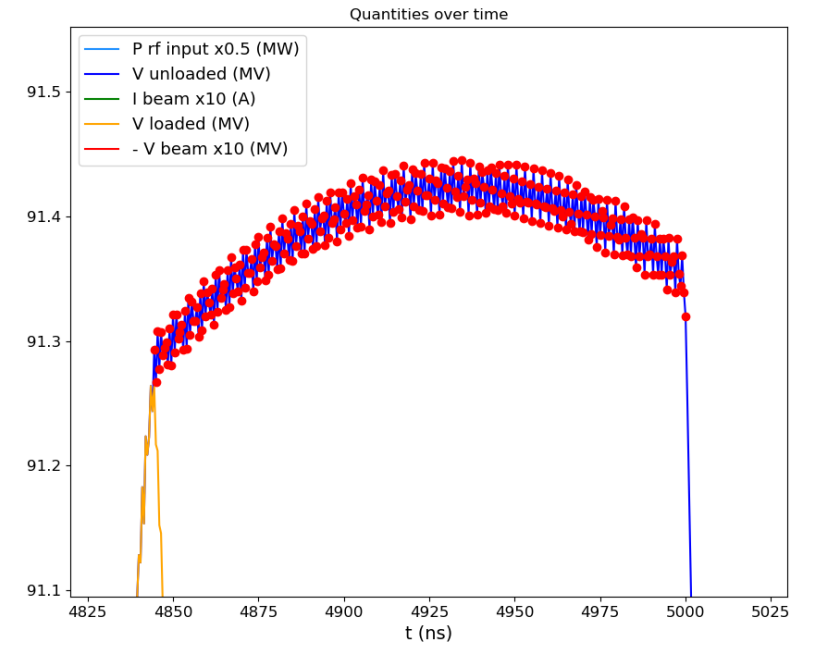
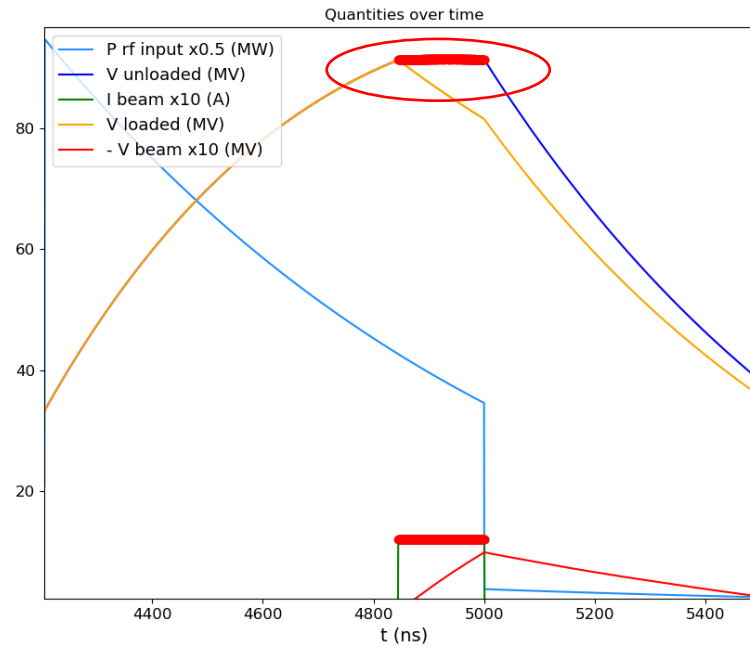
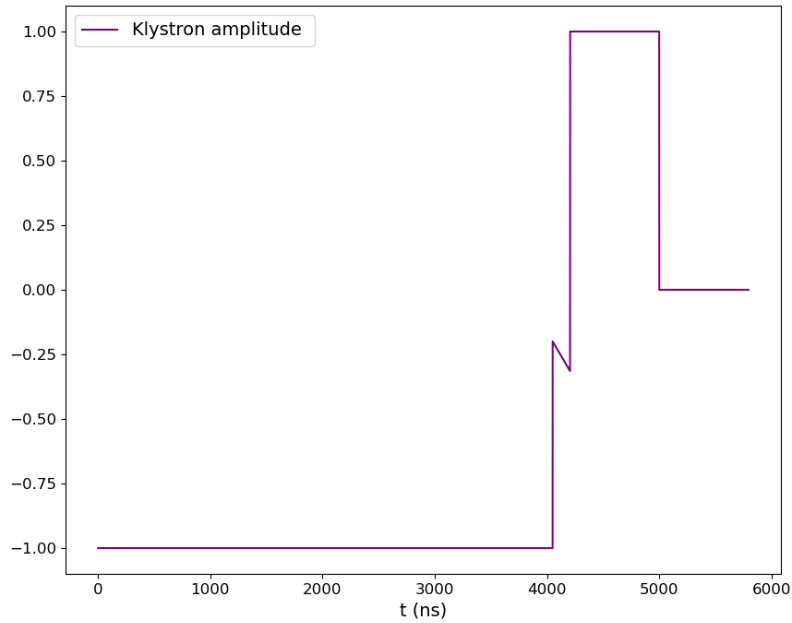
	Avg. Aperture: 15 mm	
	Delta = 2 mm	
Klystron power per structure	(2 struc. per klyst.) 31 MW	(4 struc. per klyst.) 15.5 MW
G_{avg}	32.28 MV/m	22.82 MV/m
Total length of LINAC	190.21 m	269.06 m
Number of structures	63	90
Number of klystrons	32	23

Avg. aperture = 15mm, 2 structure per klyst.

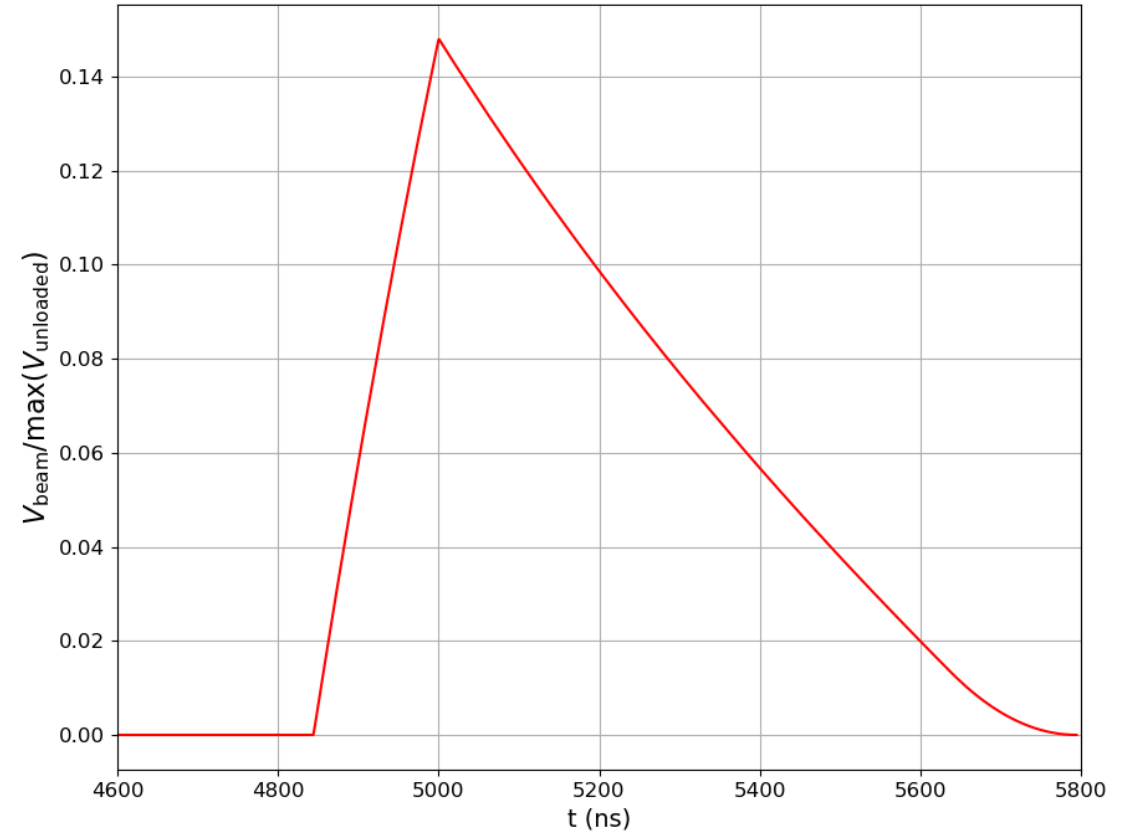
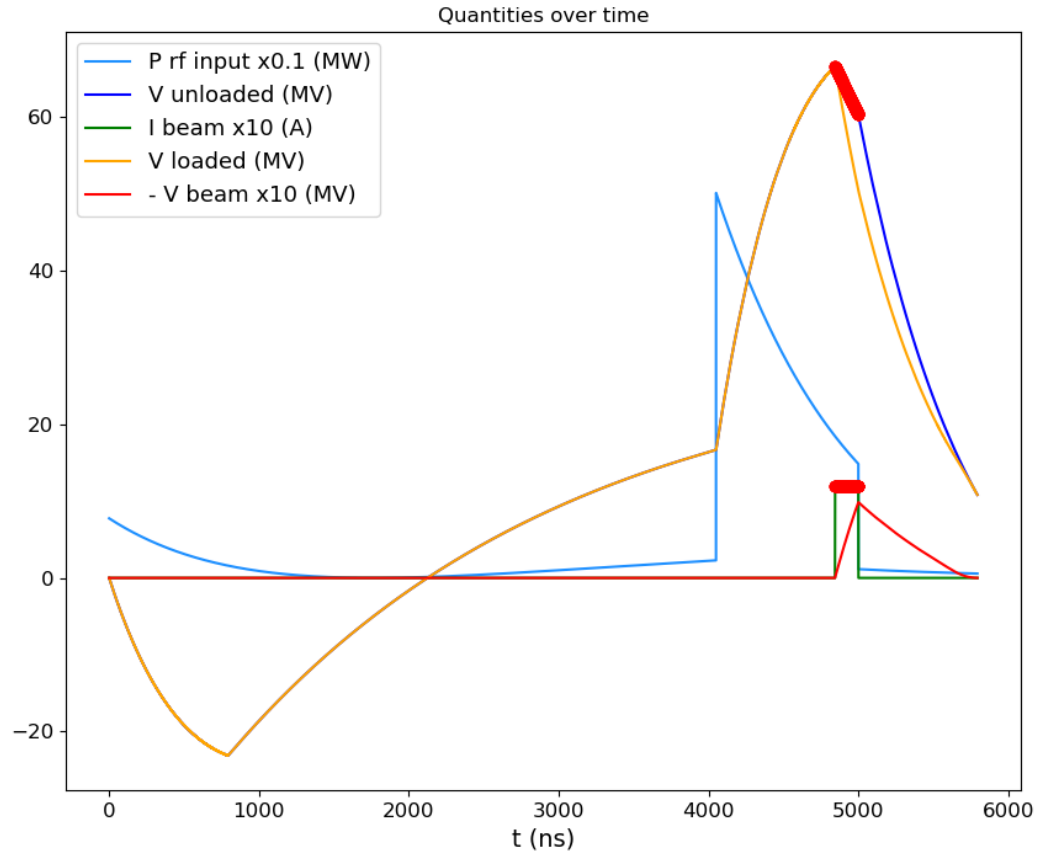


Avg. aperture = 15mm, 2 structure per klystr.

Maximum difference between 312 bunches:
 $\Delta V = 0.18 \text{ MV}$
0.2% energy spread

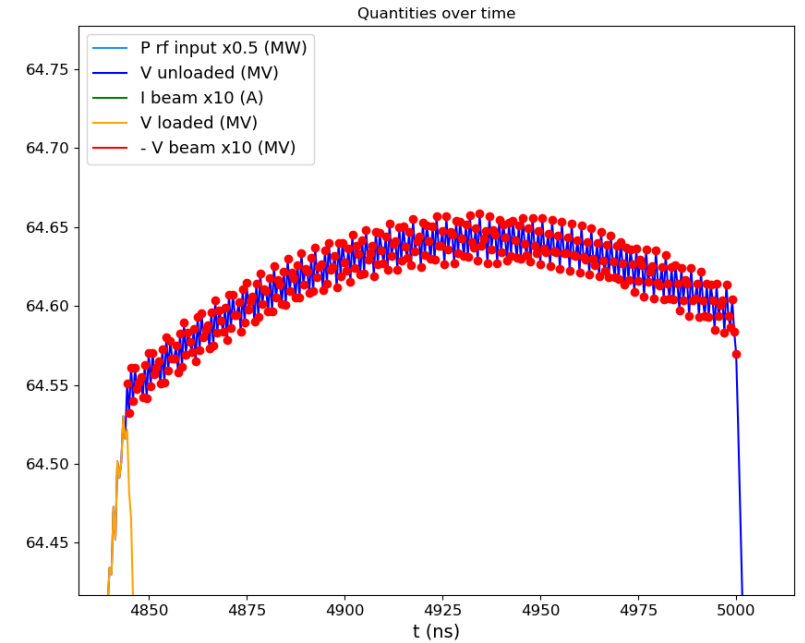
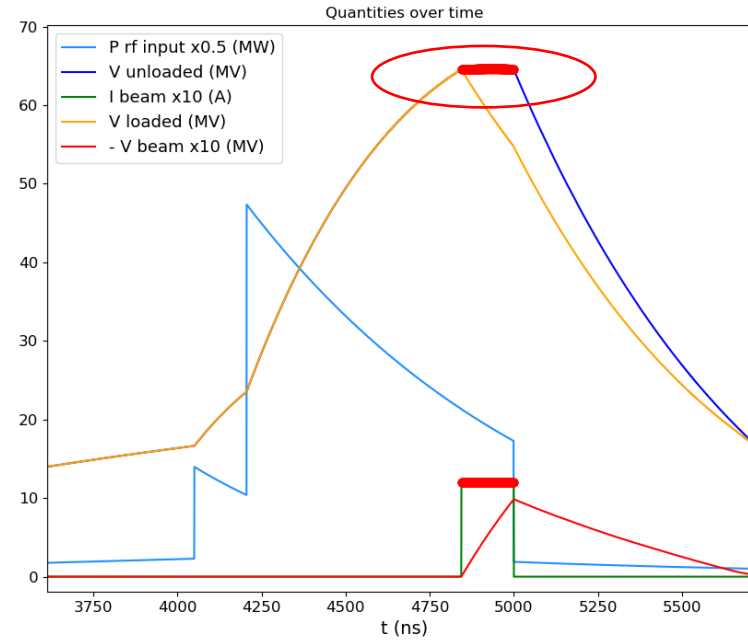
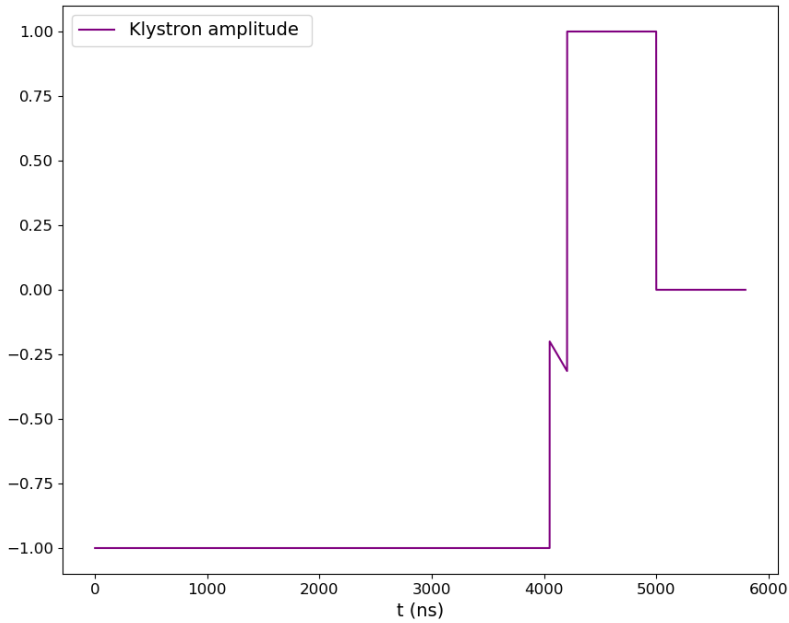


Avg. aperture = 15mm, 4 structure per klyst.

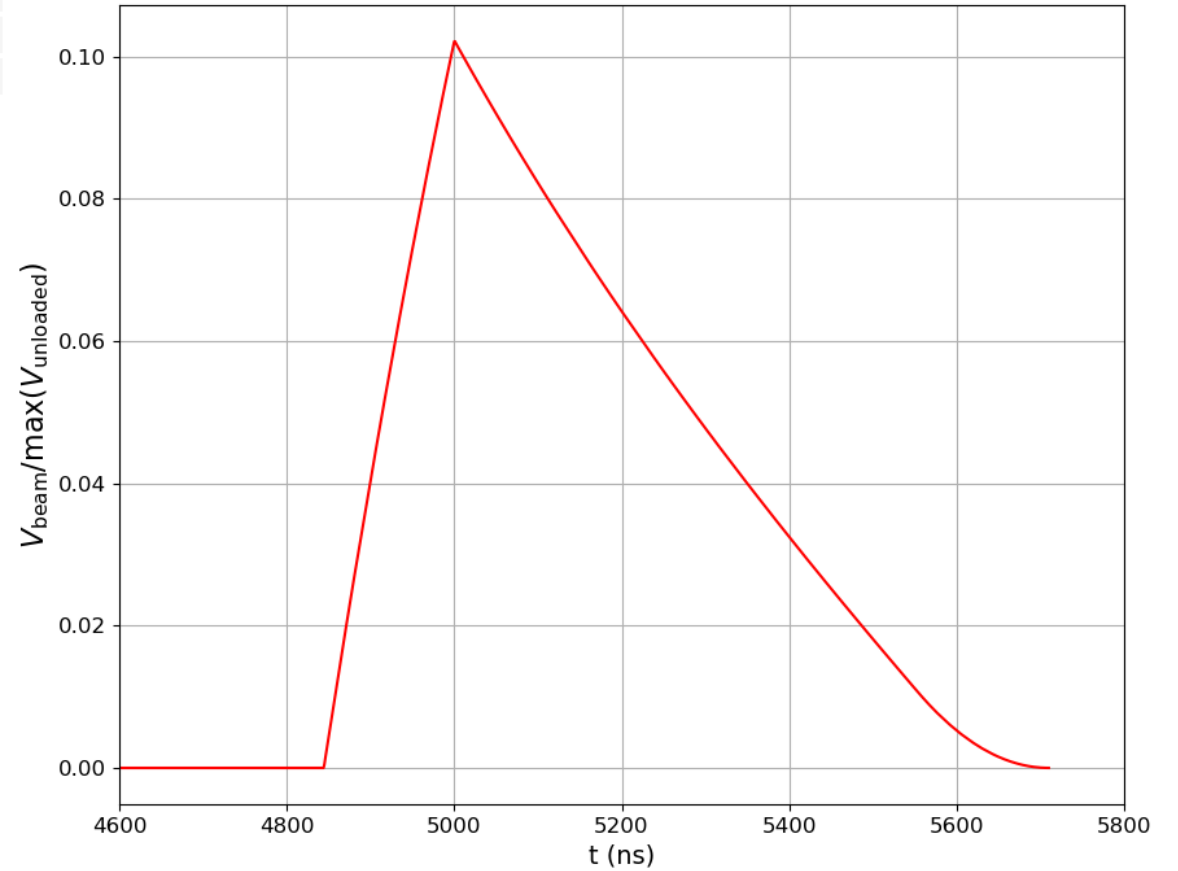
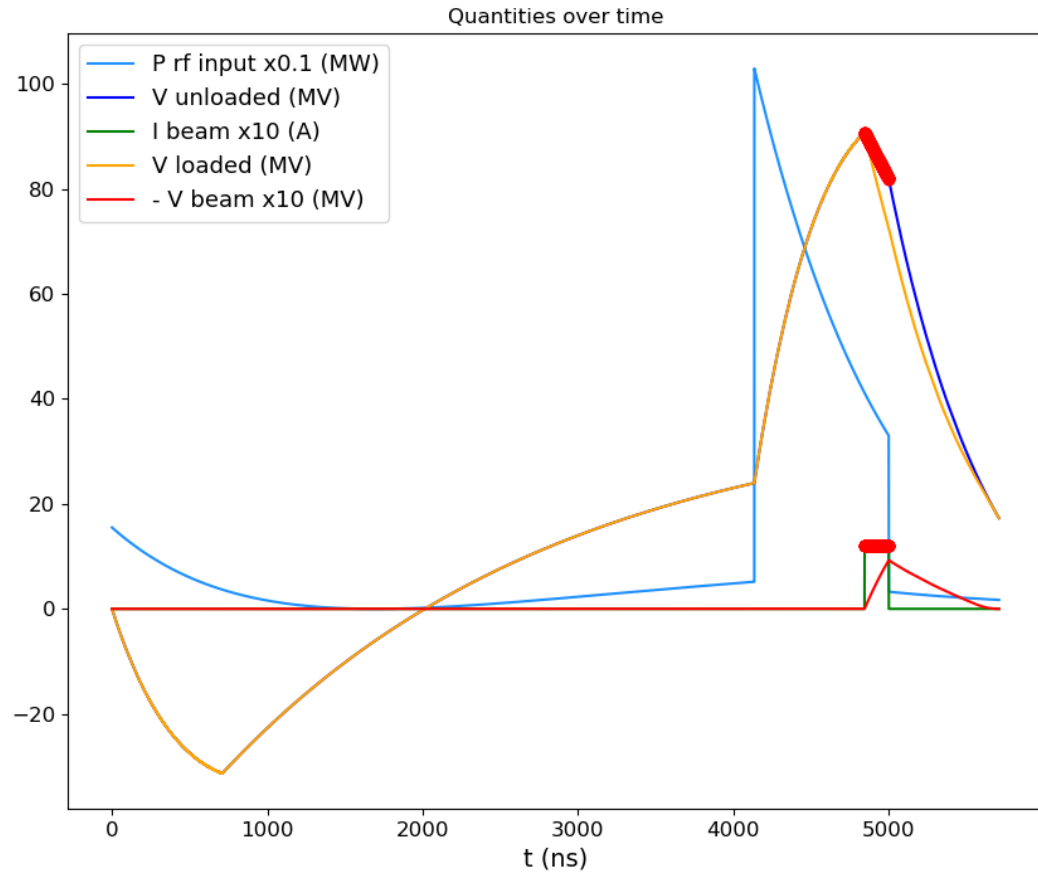


Avg. aperture = 15mm, 4 structure per klyst.

Maximum difference between 312 bunches:
 $\Delta V = 0.13$ MV
0.2% energy spread

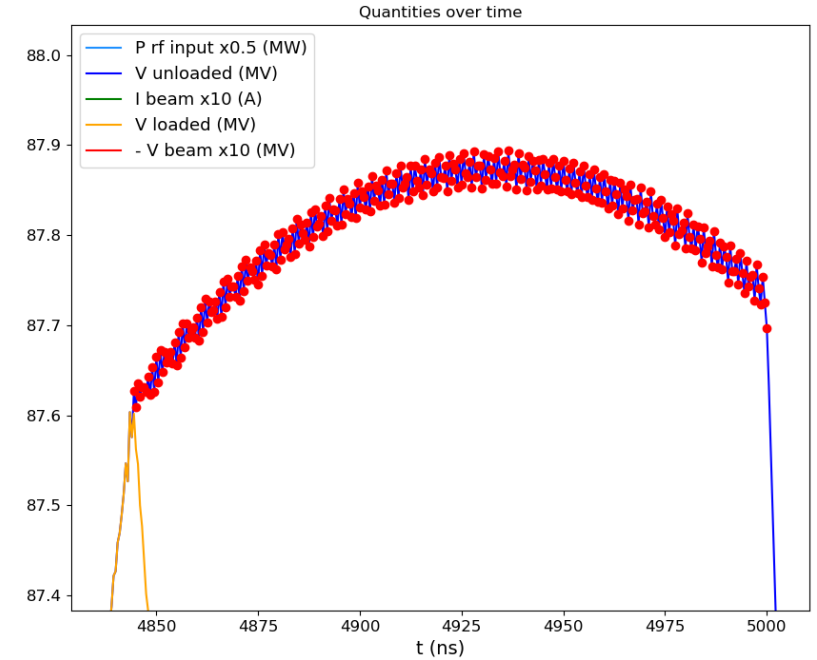
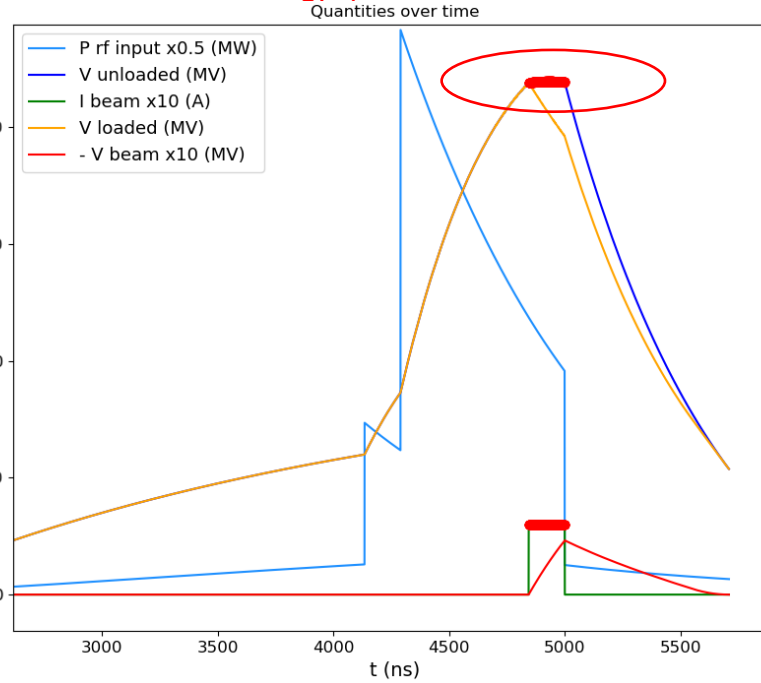
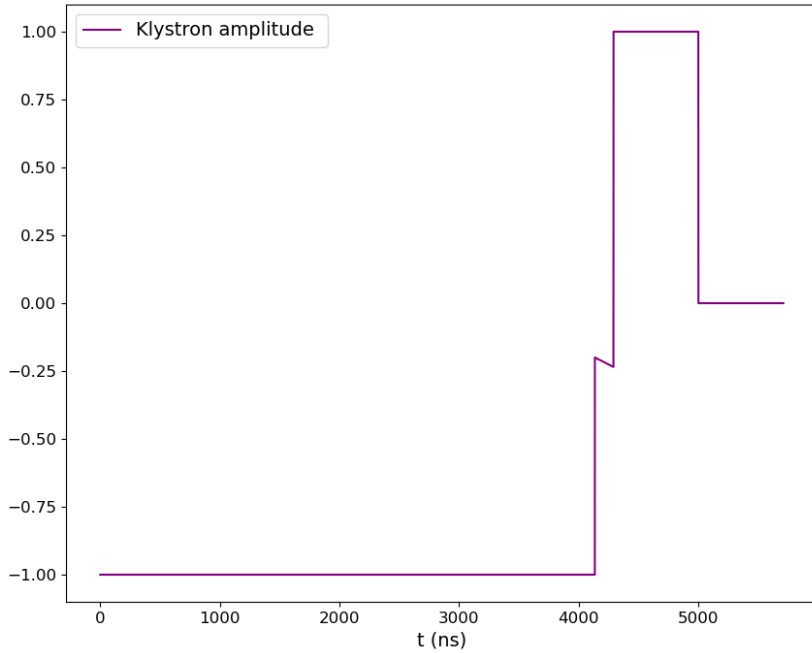


Avg. aperture = 16mm, 2 structure per klystr.

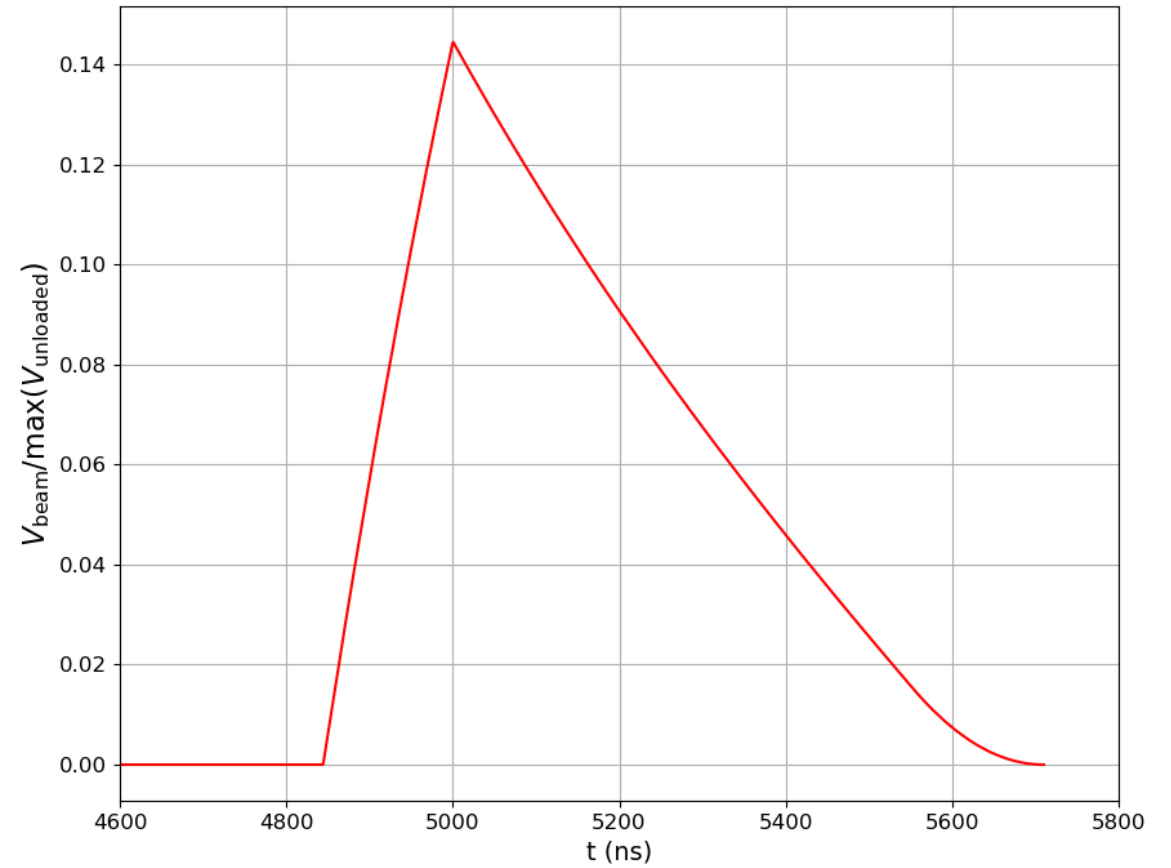
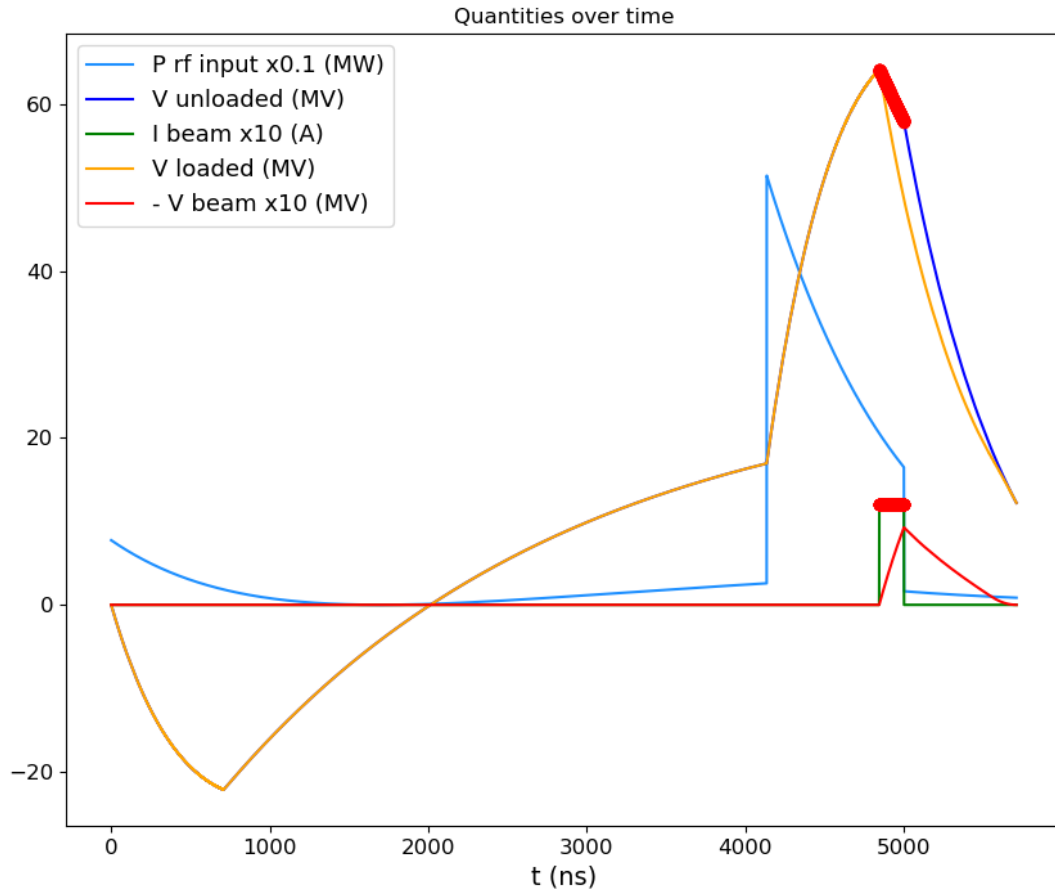


Avg. aperture = 16mm, 2 structure per klystron.

Maximum difference between 312 bunches:
 $\Delta V = 0.28 \text{ MV}$
0.3% energy spread

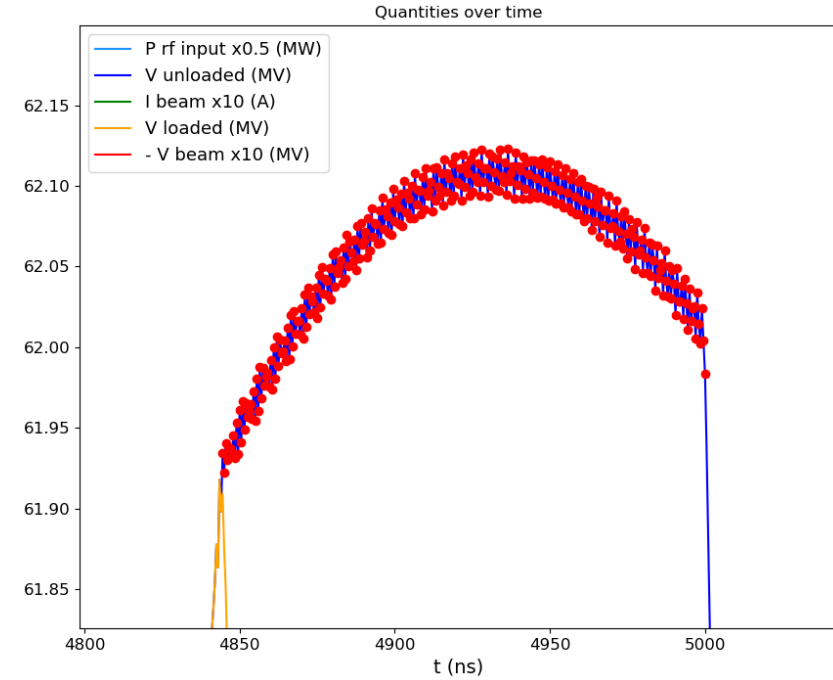
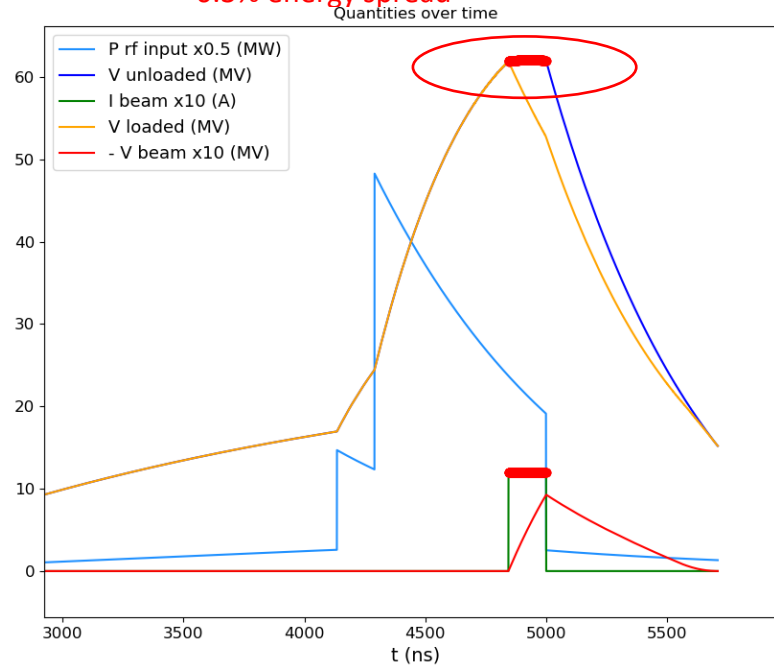
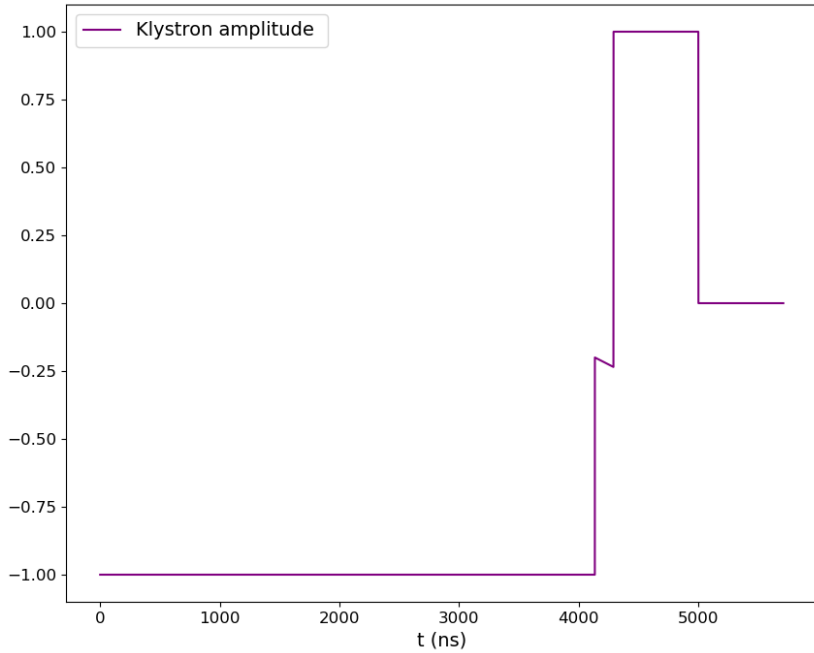


Avg. aperture = 16mm, 4 structure per klyst.



Avg. aperture = 16mm, 4 structure per klystr.

Maximum difference between 312 bunches:
 $\Delta V = 0.2$ MV
0.3% energy spread



15 mm, 2 klyst. per struct.	Unloaded V	Rsh	
Single Bunch	94.13 MV	97 MΩ/m	
312 Bunches	~91.4 MV	91.45 MΩ/m	~5.72% lower Shunt imp.
15 mm, 4 klyst. per struct.	Unloaded V	Rsh	
Single Bunch	66.56 MV	97 MΩ/m	
312 Bunches	~64.61 MV	91.39 MΩ/m	~5.78% lower Shunt imp.

16 mm, 2 klyst. per struct.	Unloaded V	Rsh	
Single Bunch	90.72 MV	90.04 MΩ/m	
312 Bunches	~87.8 MV	84.33 MΩ/m	~6.34% lower Shunt imp.
16 mm, 2 klyst. per struct.	Unloaded V	Rsh	
Single Bunch	64.14 MV	90.04 MΩ/m	
312 Bunches	~62.06 MV	84.29 MΩ/m	~6.79% lower Shunt imp.

CLIC Booster Linac Design

$$\Delta E = E_{\text{final}} - E_{\text{initial}} = 9.00 \text{ GeV} - 2.86 \text{ GeV} = 6.14 \text{ GeV}$$

	Avg. Aperture: 15 mm		Avg. Aperture: 16 mm	
	Delta = 2 mm		Delta = 3 mm	
Klystron power per structure	(2 struc. per klyst.) 31 MW	(4 struc. per klyst.) 15.5 MW	(2 struc. per klyst.) 31 MW	(4 struc. per klyst.) 15.5 MW
G_{avg}	30.74 MV/m	21.73 MV/m	29.53 MV/m	20.87 MV/m
Total length of LINAC	200 m	282.6 m	208 m	294 m
Number of structures	67	94	70	98
Number of klystrons	34	24	35	25

$$\text{Total Length of LINAC} = \frac{\Delta E}{\text{Average Gradient}}$$

$$\text{Number of Structures} = \frac{\text{Total Length of LINAC}}{\text{Length of One Structure}}$$

$$\text{Number of Klystrons} = \frac{\text{Number of Structures}}{\text{Structures per Klystron}}$$