Wakefield Damping in Distributed Coupling Structures

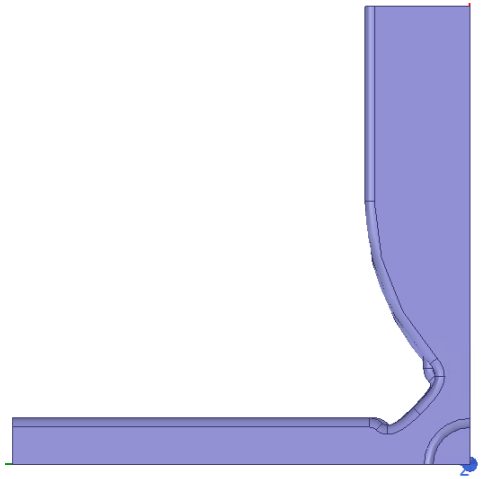
CERN + SLAC
Cool Meeting

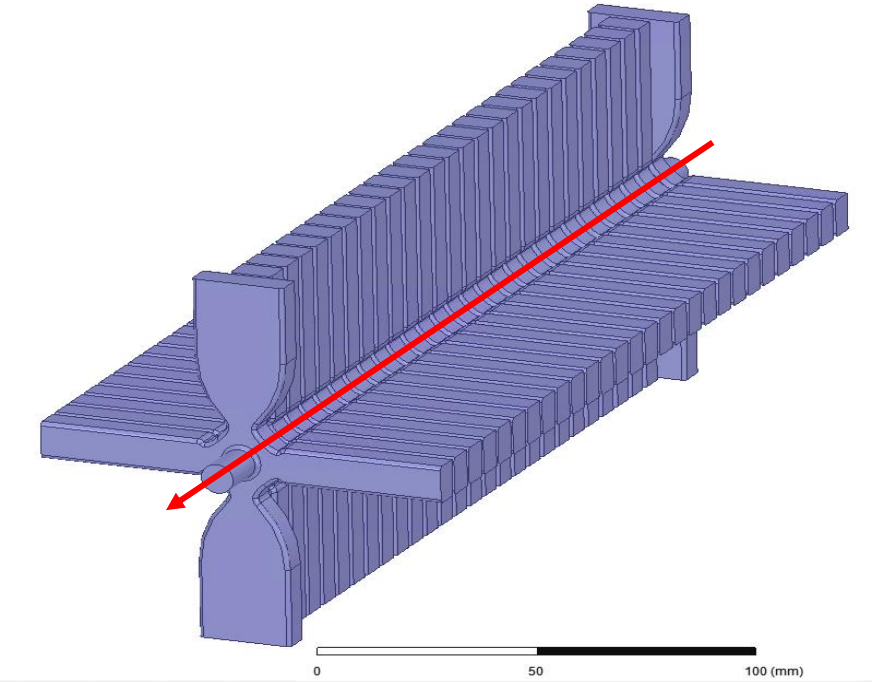
Evan Ericson

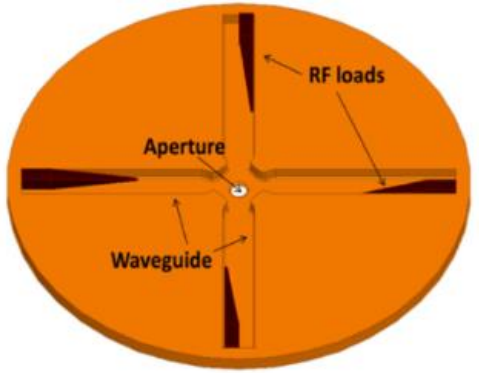
Alexej Grudiev

CLIC-G* TW structure

- Power in upstream, power out downstream
- HOM waveguides with loads

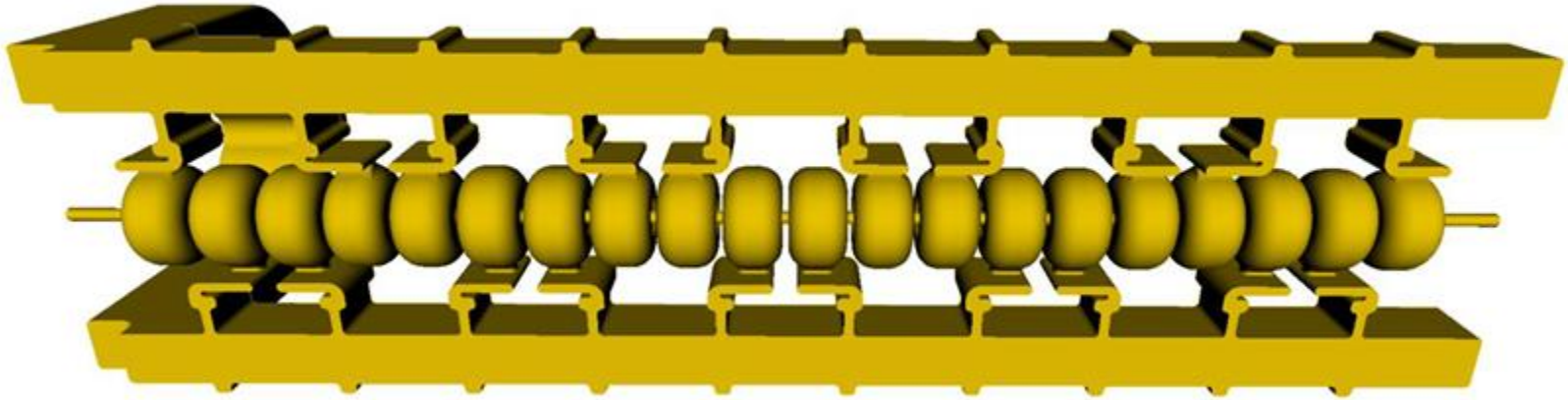






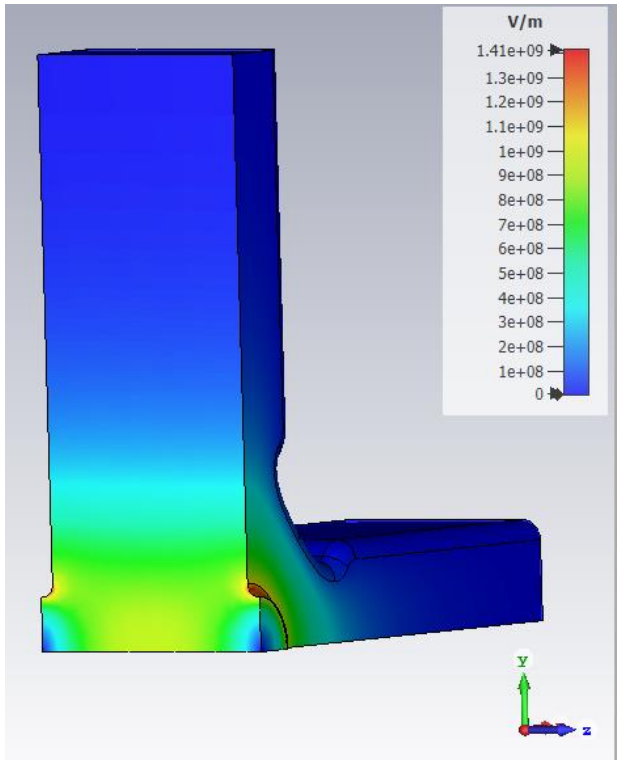
Distributed coupling structure

- Each cell is connected to waveguide
- Potential for increased high gradient performance



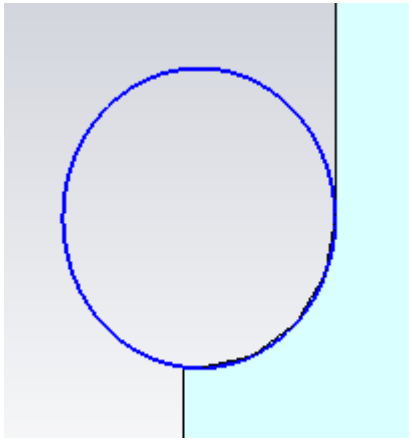
Standing wave (SW) cell pre-optimization

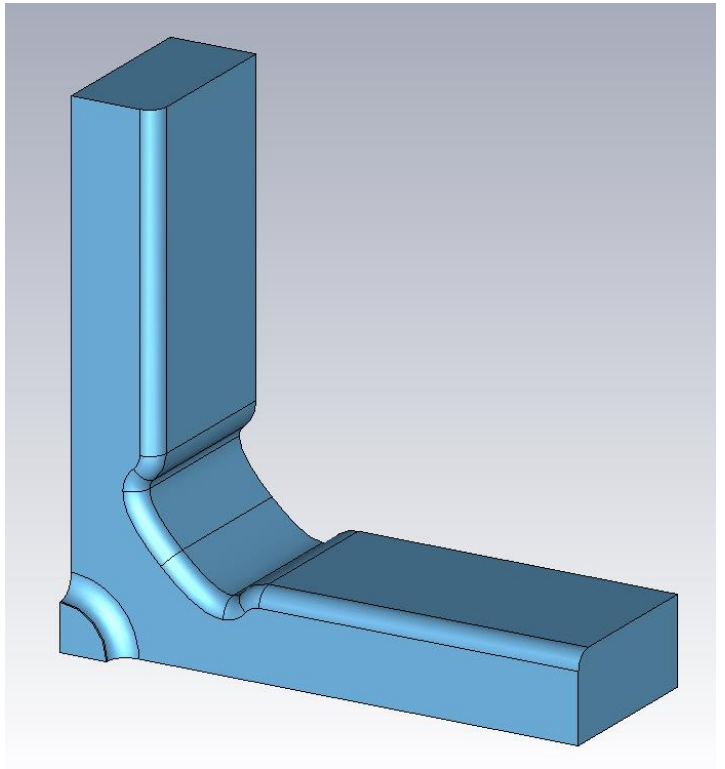
- Adjusted the cell length and outer radius to get correct phase advance and frequency



	SW – Opt0
f_0 (GHz)	11.9947
Phi (deg)	180
Q	7140
v_g/c (%)	0
R/Q (Ohm/m)	11219
R (Mohm/m)	80.10
E_s/E_a	2.486
H_s/E_a (mA/V)	4.432
S_c/E_a^2 (mA/V)	0.296

Optimized SW designs





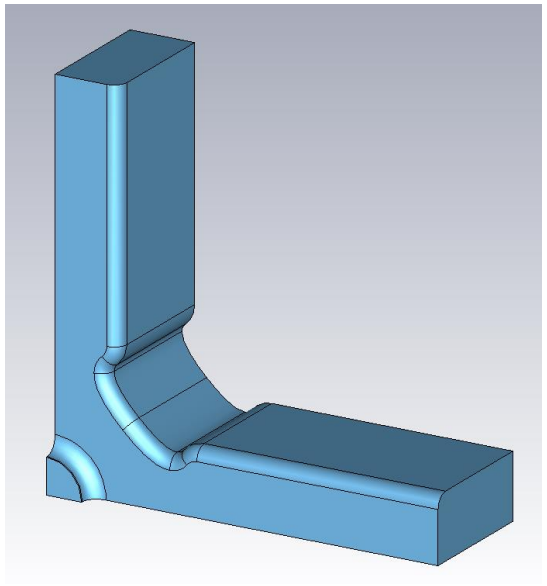
- Opt0 – non-optimized SW cell
- Opt1 – optimize E_s/E_a for high gradient performance
- Opt2 – optimize R for efficiency (same E_s/E_a as TW)
- Opt3 – optimize S_c/E_a^2 for high gradient performance

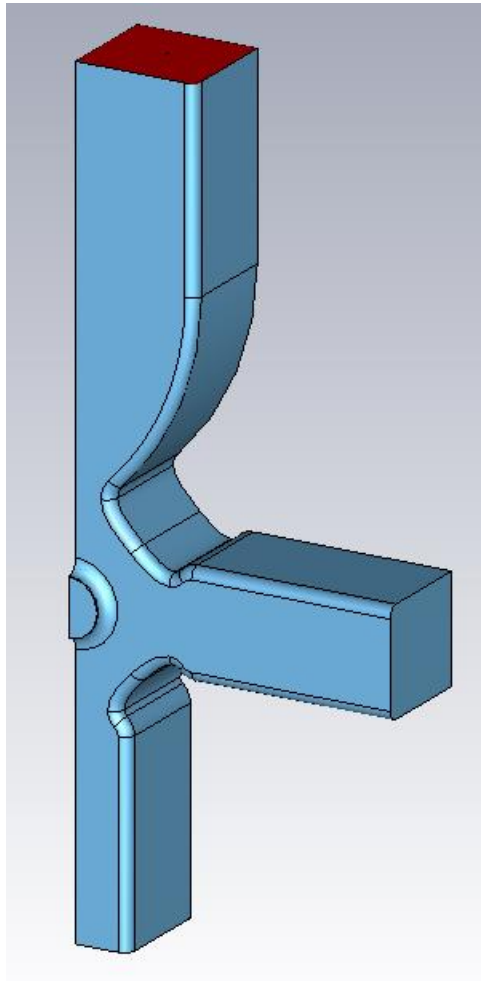
Comparing SW cell options

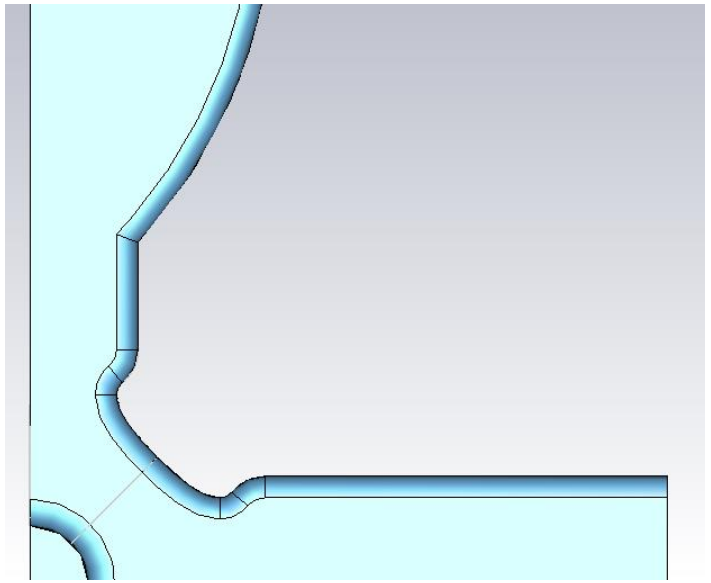
	unit	TW	SW – Opt0	SW – Opt1	SW – Opt2	SW – Opt3
Iris thickness	mm	1.333	1.333	2.6	2.3	2.35
Iris ellipticity		1.153	1.102	2.400	1.600	1.179
f_0	GHz	11.9952	11.9947	11.9943	11.9943	11.9939
Q		5843	7140	6930	6940	6920
R/Q	Ohm/m	16515	11219	10980	11208	11368
R	MOhm/m	96.49	80.10	76.09	77.78	78.67
E_s/E_a		1.98	2.486	1.79	1.98	2.11
H_s/E_a	mA/V	3.73	4.432	4.67	4.60	4.59
S_c/E_a^2	mA/V	0.33	0.296	0.34	0.33	0.33

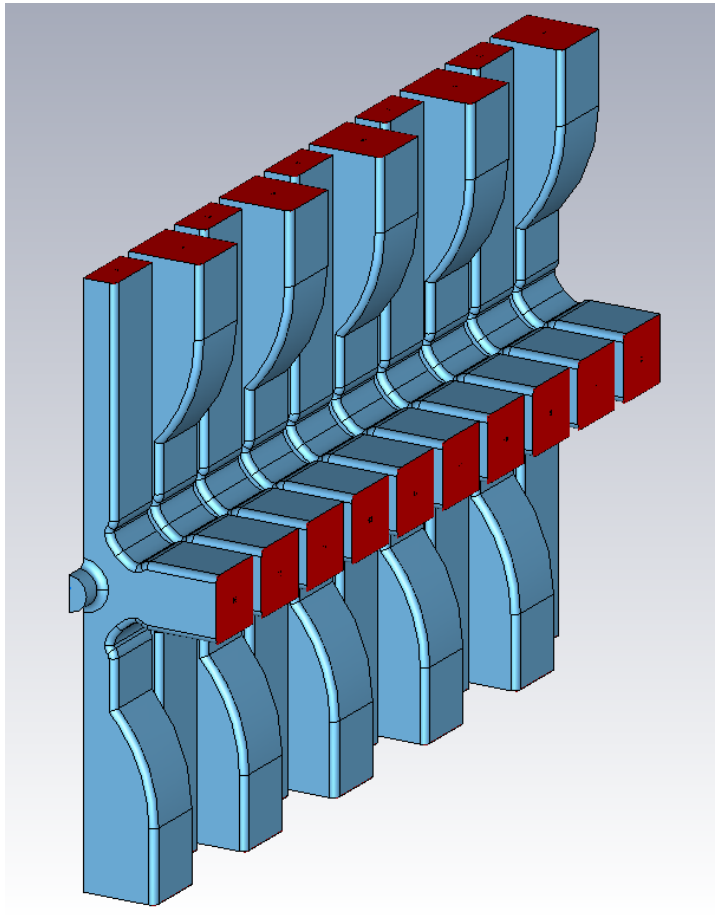
Comparing SW structure options

	unit	TW	SW – Opt0	SW – Opt1	SW – Opt2	SW – Opt3	limit
N		26+2	18	18	18	18	
L	mm	230	225	225	225	225	
E_{acc}^{load} avg	MV/m	100	100	100	100	100	
V_{acc}	MV	23	22.5	22.5	22.5	22.5	
P_{diss}	MW	33.17	28.09	29.57	28.93	28.60	
P_b	MW	27.232	26.64	26.64	26.64	26.64	
P_0	MW	60.4	54.73	56.21	55.57	55.24	
τ	ns		64.27	63.40	63.05	62.65	
E_{acc}^{UL} avg	MV/m	120	139.58	137.87	138.60	138.98	
t_{fill}	ns	62.6	80.99	81.92	80.61	79.65	
t_p	ns	218.6	236.99	237.92	236.61	235.65	
total RF-beam efficiency	%	27.8	32.04	31.08	31.61	31.93	
Ea in middle cell	MV/m	105	100	100	100	100	
Es	MV/m	232	248.60	179.00	198.00	211.00	240
Hs	MA/m	0.39	0.44	0.47	0.46	0.46	
ΔT - pessimistic	K	49.70	42.06	46.79	45.27	44.98	40
Sc scaled to 200 ns	MW/mm^2	5.67	3.13	3.60	3.49	3.49	4

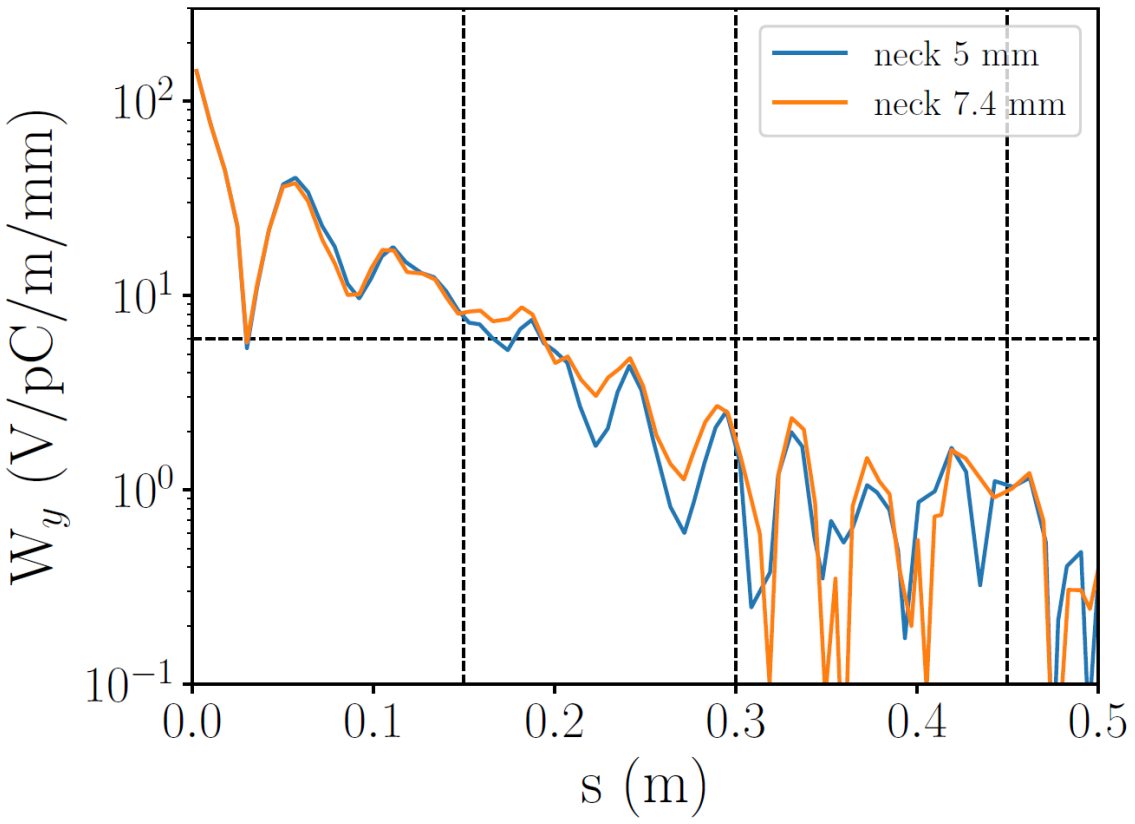


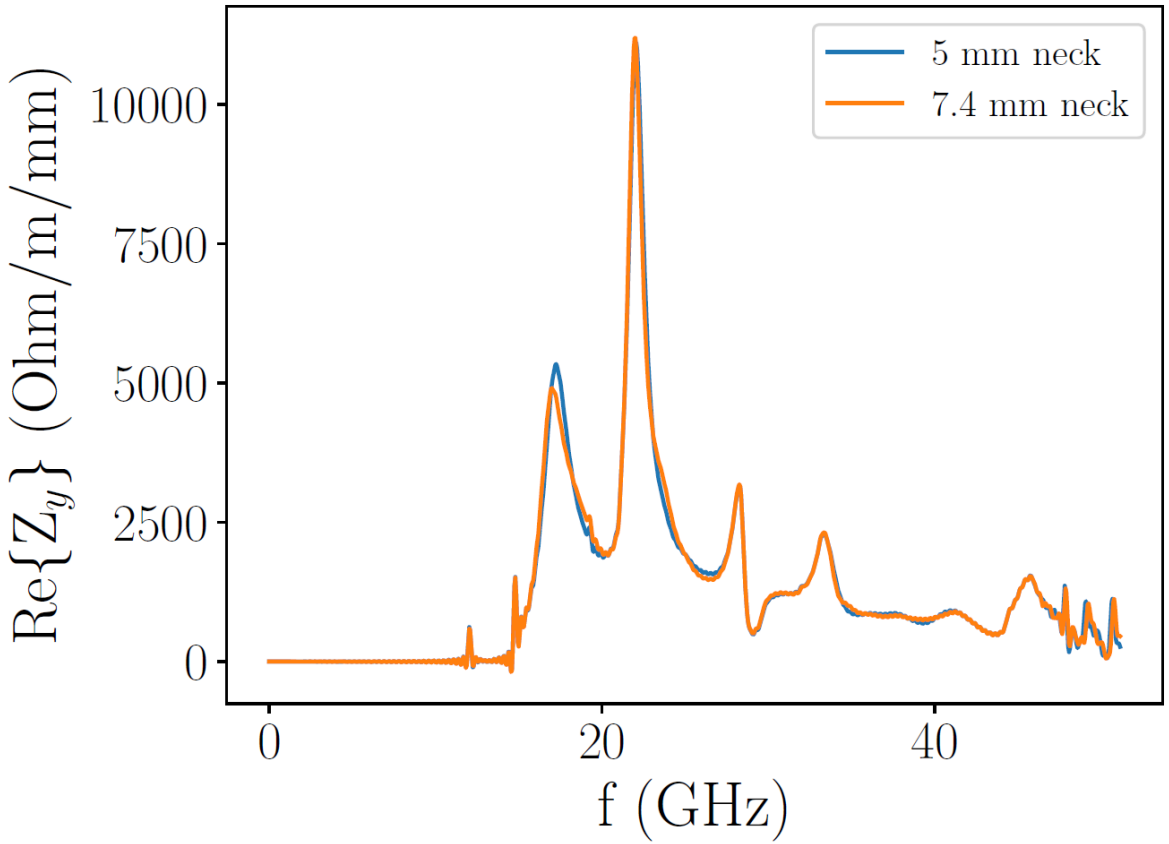






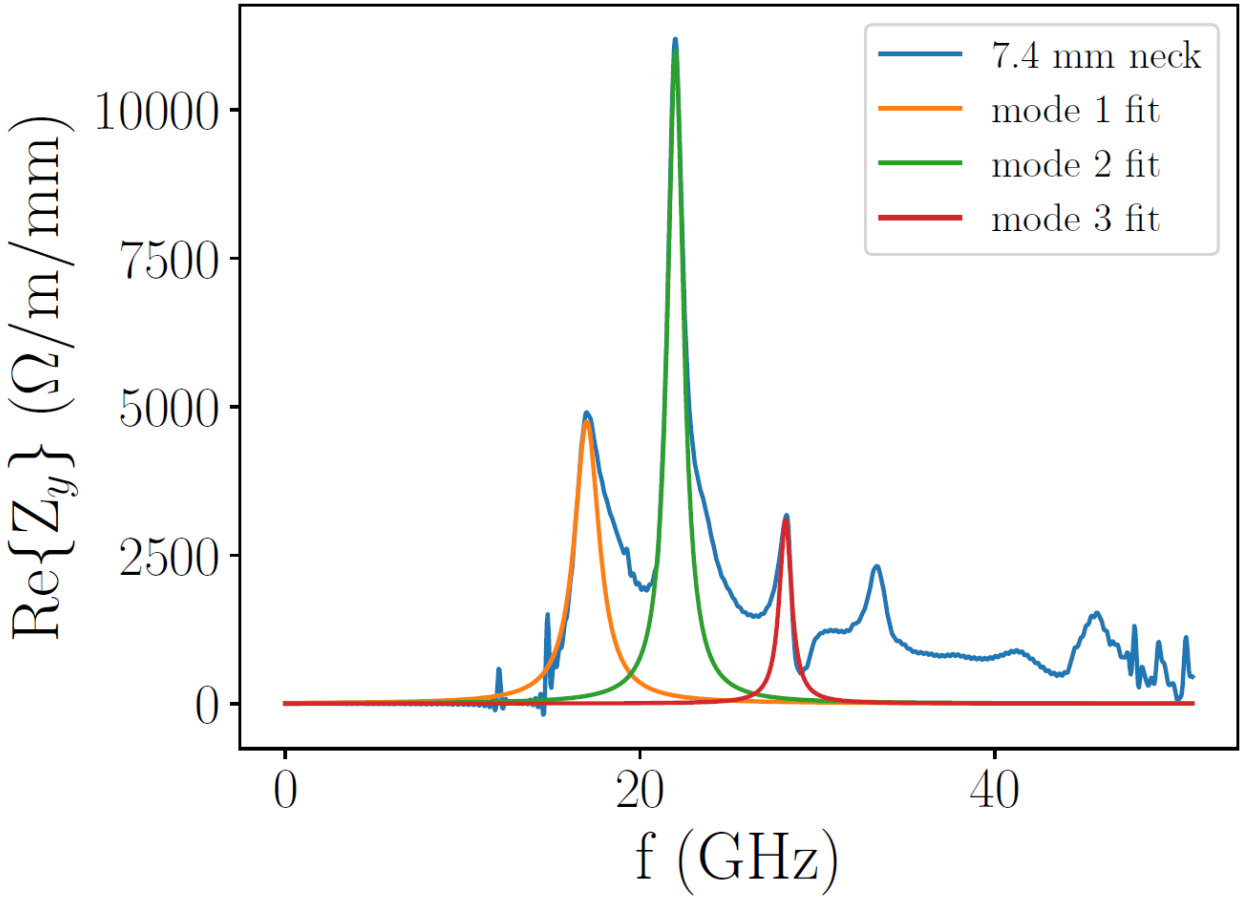
Neck length





Peaks at 17, 22 GHz

Impedance fitting

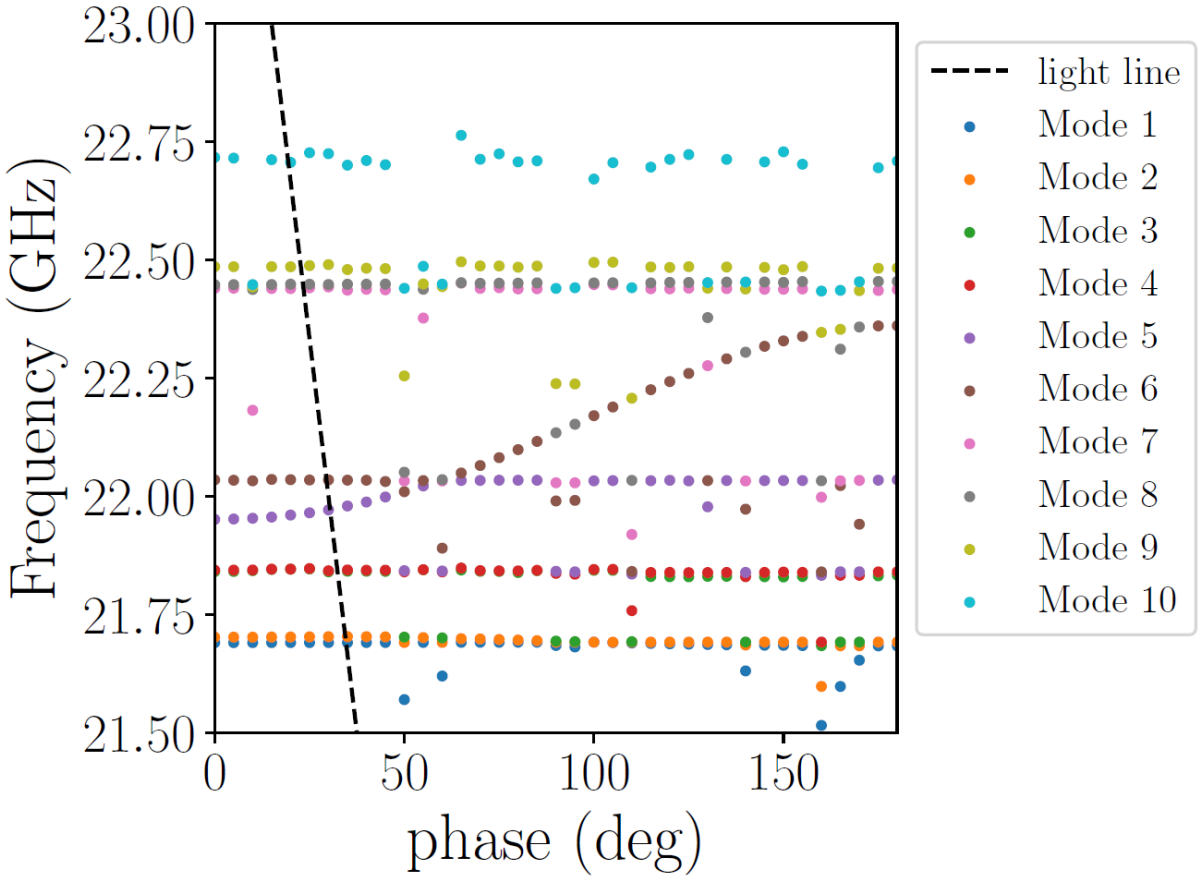


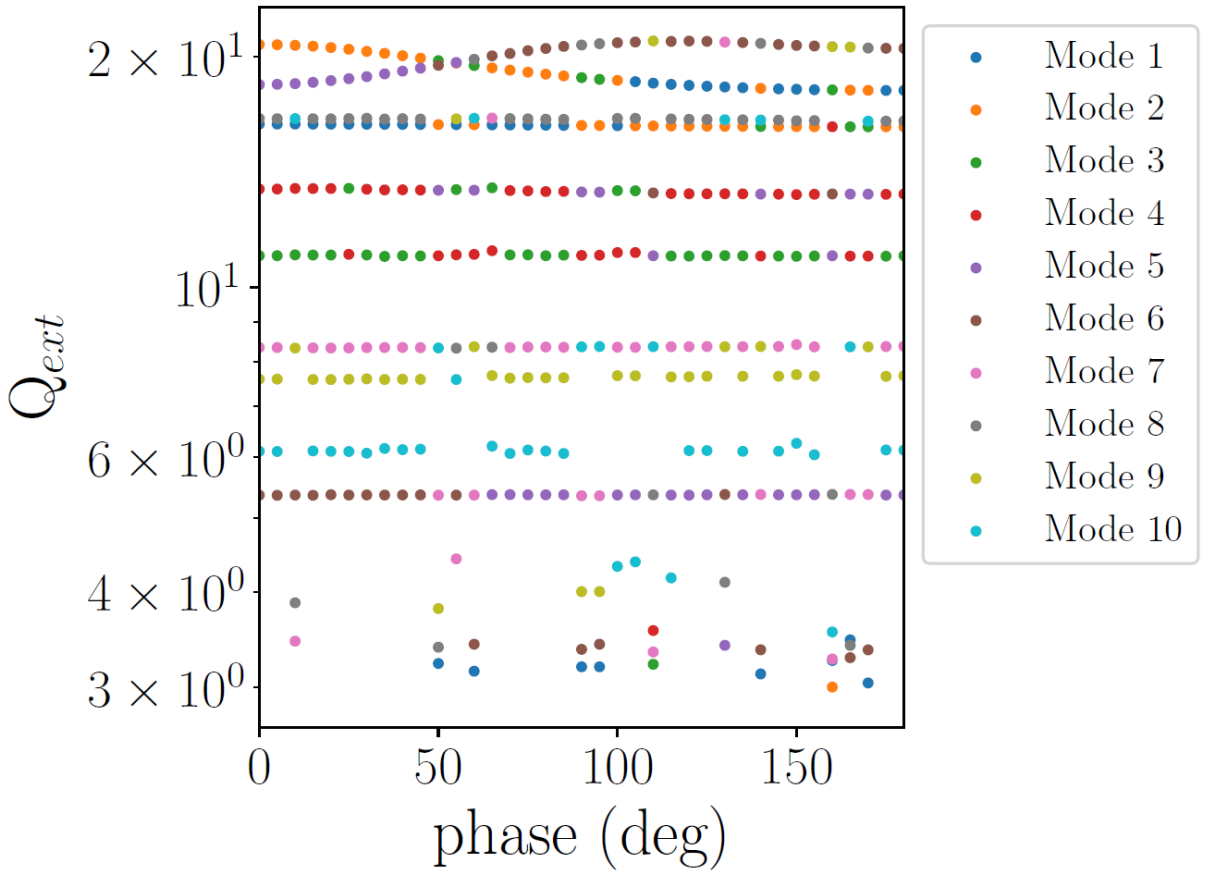
Asymmetric impedance peaks,
Cutoff near 16 GHz

	Mode 1	Mode 2	Mode 3
f (GHz)	17*	22*	28.2
Q_ext	10*	20*	34
Z = R/2	9,500	22,000	6,200

* Confirmed by HFSS

slotLength=7.4 mm

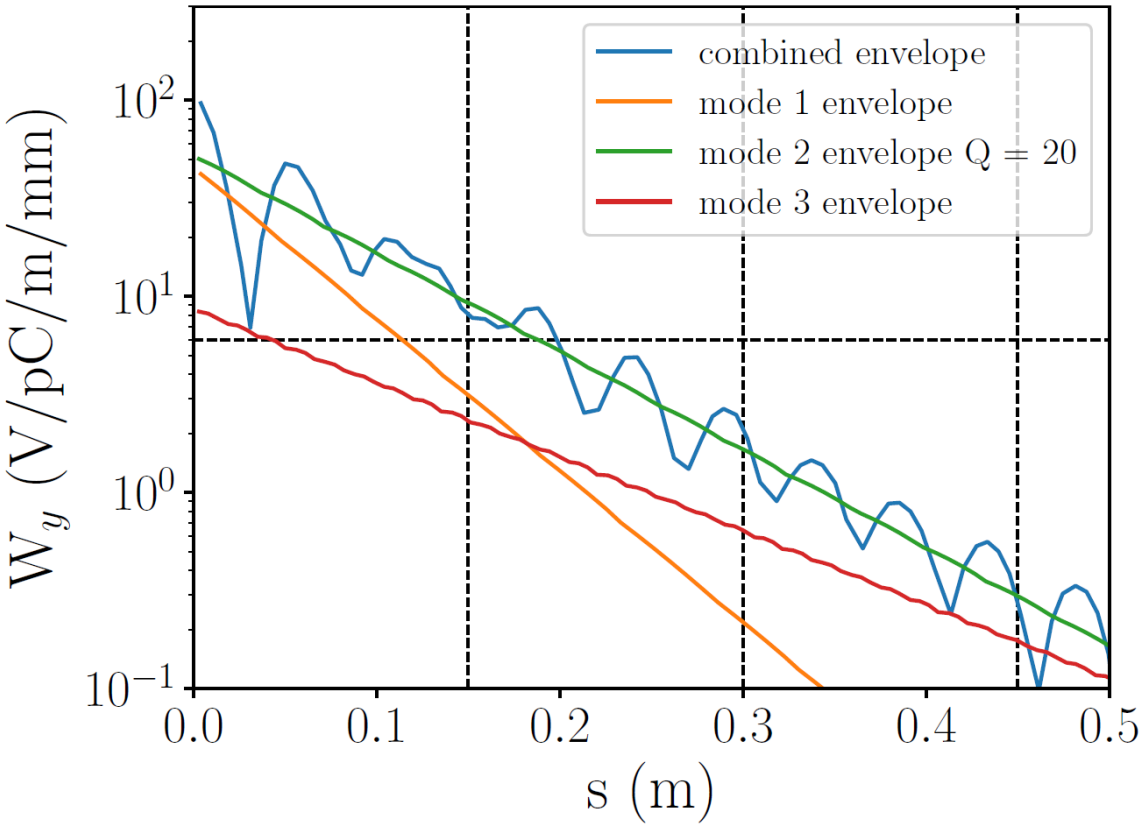


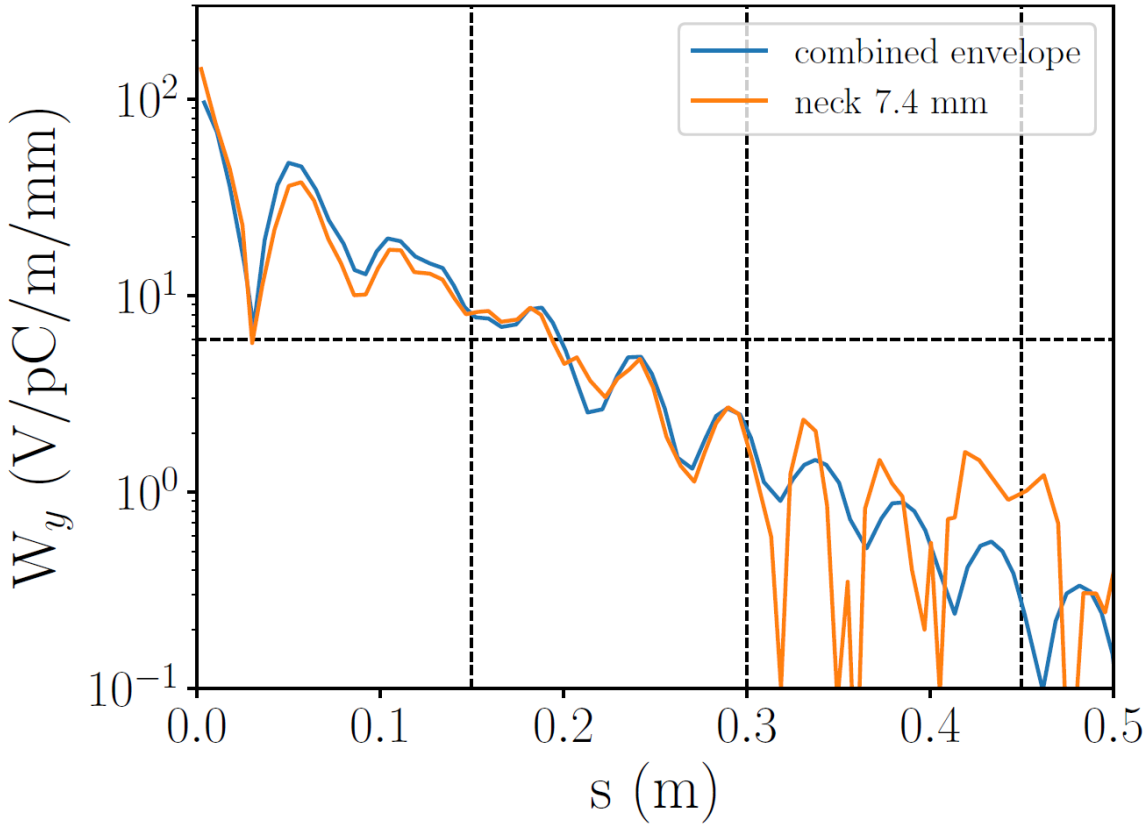


22 GHz at 30 degree phase advance

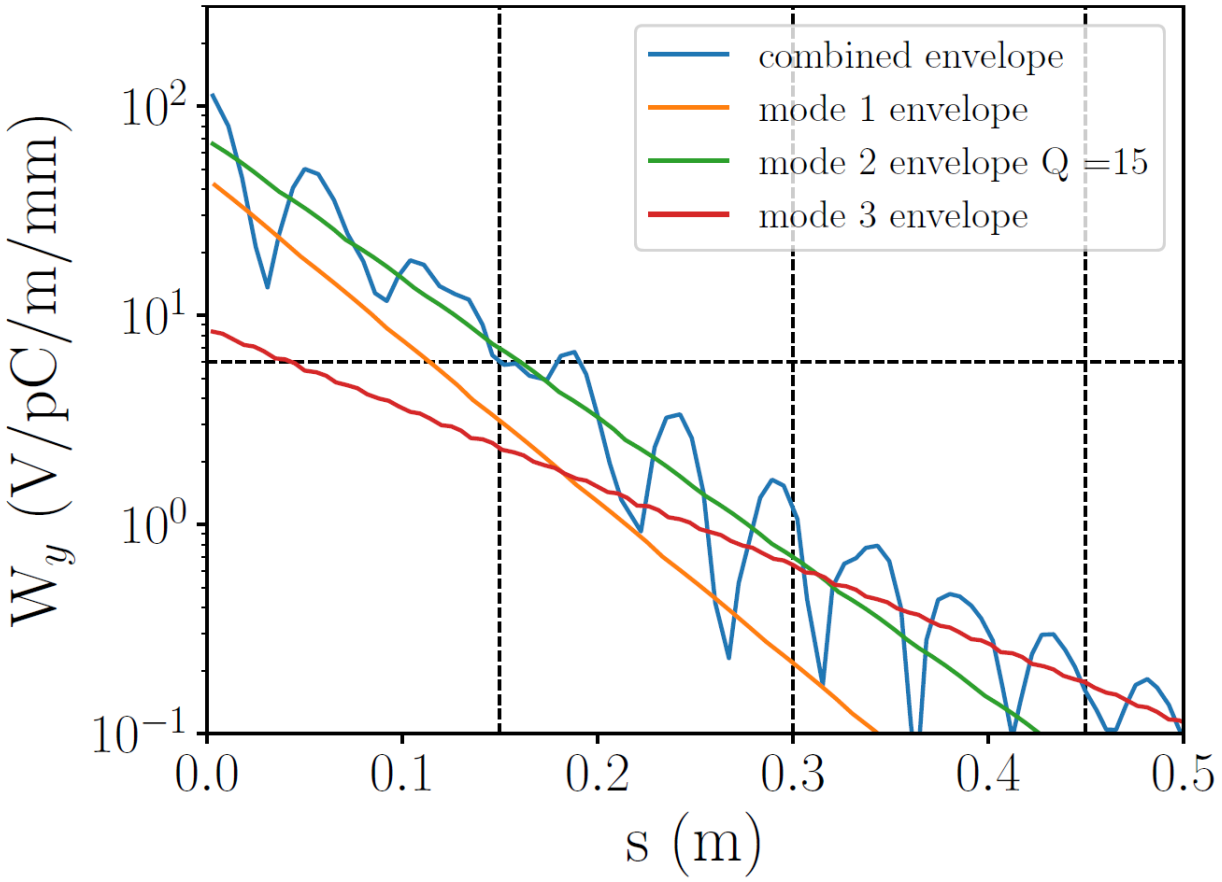
Wakepotential

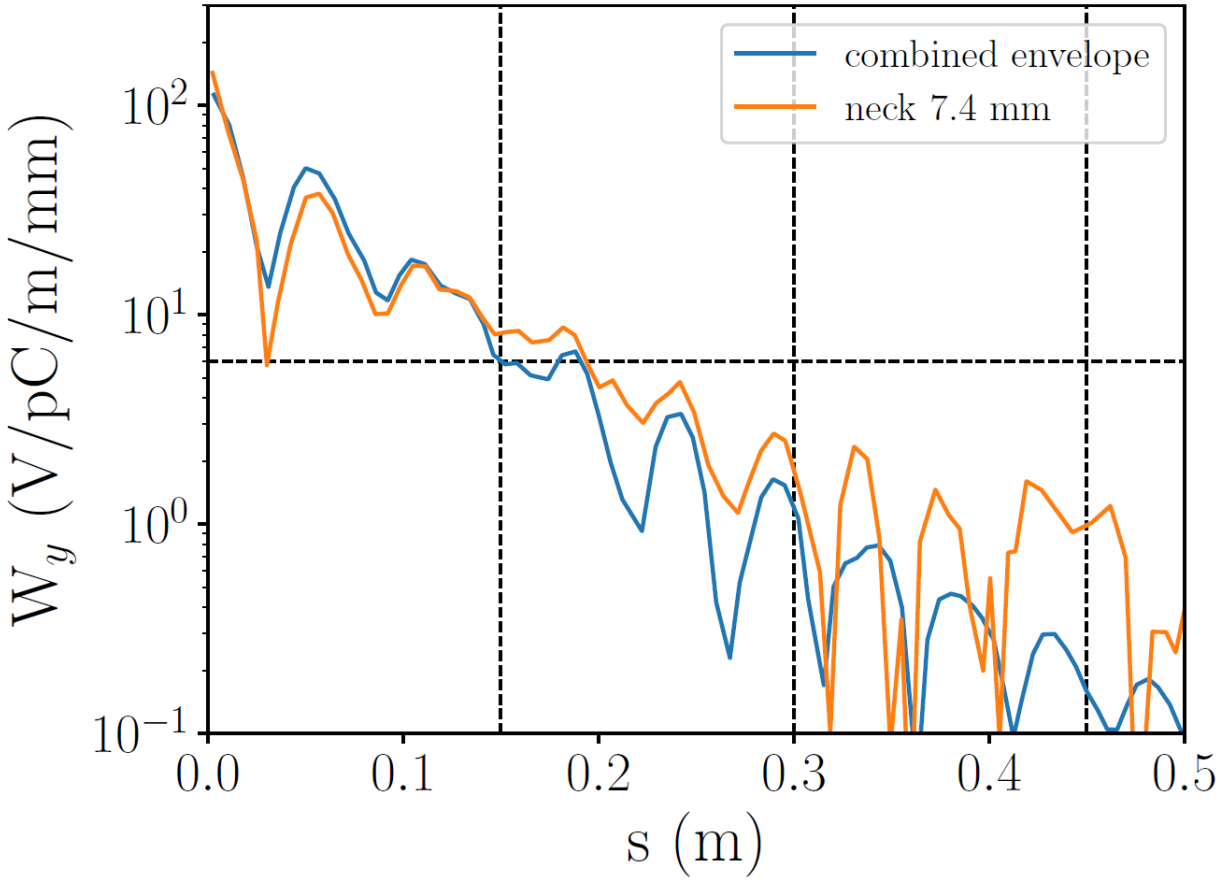
- Mode 2 dominates at location of 2nd bunch





Q = 20 -> 15


combined envelope
mode 1 envelope
mode 2 envelope Q =15
mode 3 envelope
W_y (V/pC/m/mm)
s (m)


combined envelope
neck 7.4 mm
W_y (V/pC/m/mm)
s (m)

Cryogenic LINAC

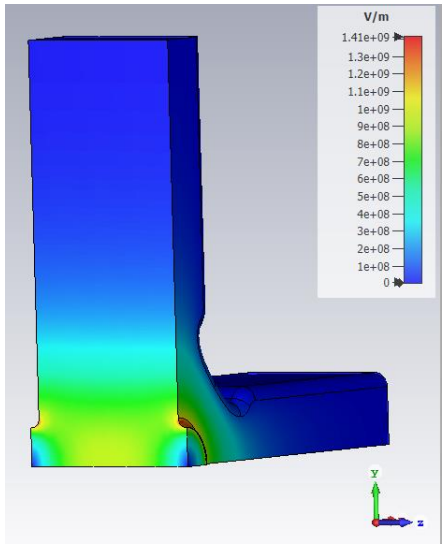
		TW	SW - Opt3	CLIC DB SOURCE		limits	CLIC DB SOURCE 77K		limits
Q		5637	6920	6920	6920		15570	15570	
R/Q	Ohm/m	16227	11368	11368	11368		11368	11368	
R	MOhm/m	91.47	78.67	78.67	78.67		177.00	177.00	
Eaccload avg	MV/m	100	100	109.75	100		142.25	100	
number of bunches in train		312	312	312	330		248	319	
Pin	MW	60.4	55.24	63.69	55.24	63.5	63.62	39.35	63.5
tp	ns	240.5	235.65	241.73	244.65	244	244.19	244.26	244
total RF-beam efficiency	%	27.7	31.92	29.63	32.52		30.25	44.20	
relative RF-beam efficiency		1.00	1.15	1.07	1.17		1.09	1.60	
ΔT - pessimistic	K	49.7	39.51	40.02	40.26	~40	19.25	19.26	~40
Sc scaled to 200 ns	MW/mm^2	5.5	3.485	4.23	3.53	~4	7.14	3.527	~8

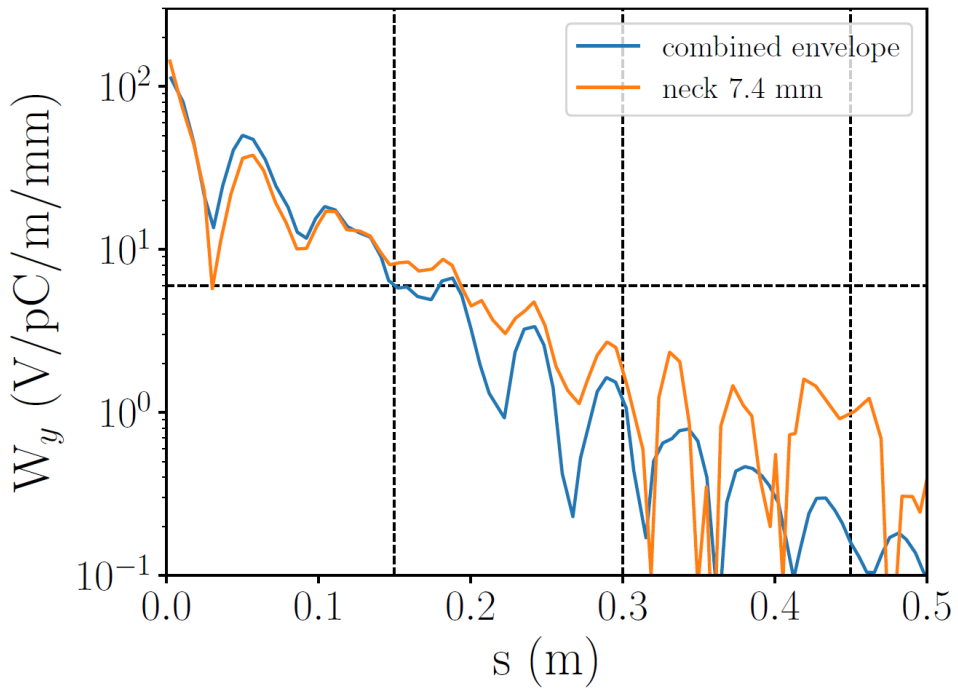
Cryogenic LINAC II

		TW	SW-Opt3	CLIC DB SOURCE		CLIC DB SOURCE 77K	
Eaccload avg	MV/m	100	100	109.75	100	142.25	100
relative RF-beam efficiency		1.00	1.15	1.07	1.17	1.09	1.60
				NEW SOURCE		NEW SOURCE 77K	
Eaccload avg	MV/m			106.85	100	147.25	100
relative RF-beam efficiency				1.09	1.17	1.18	2.25

- Assumption: square RF pulse, temperature rise likely smaller

Conclusion


V/m
1.41e+09
1.3e+09
1.2e+09
1.1e+09
1e+09
9e+08
8e+08
7e+08
6e+08
5e+08
4e+08
3e+08
2e+08
1e+08
0


combined envelope
neck 7.4 mm
W_y (V/pC/m/mm)
10^2
10^1
10^0
10^{-1}
0.0
0.1
0.2
0.3
0.4
0.5
s (m)