Status of the sub-harmonic bunching system for the CLIC DB injector front end

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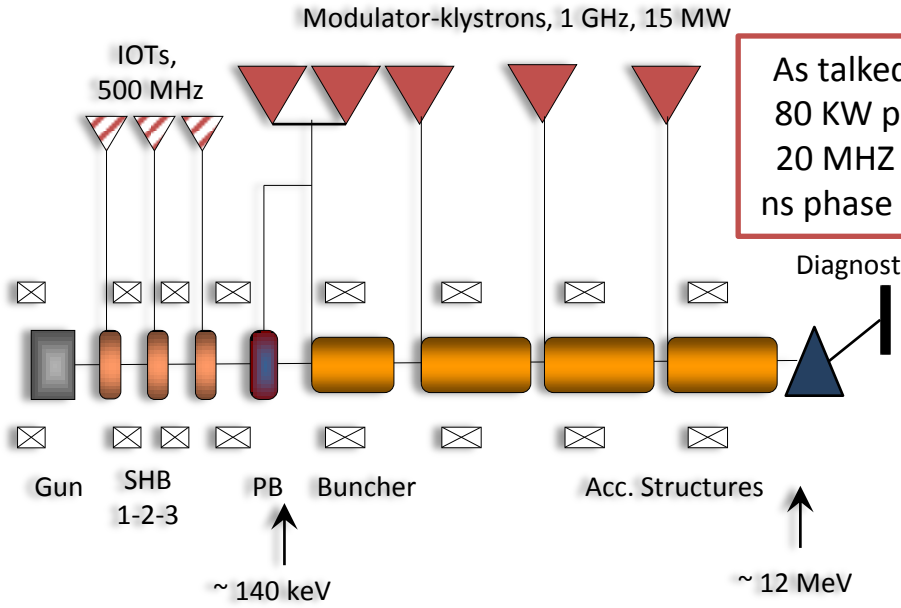
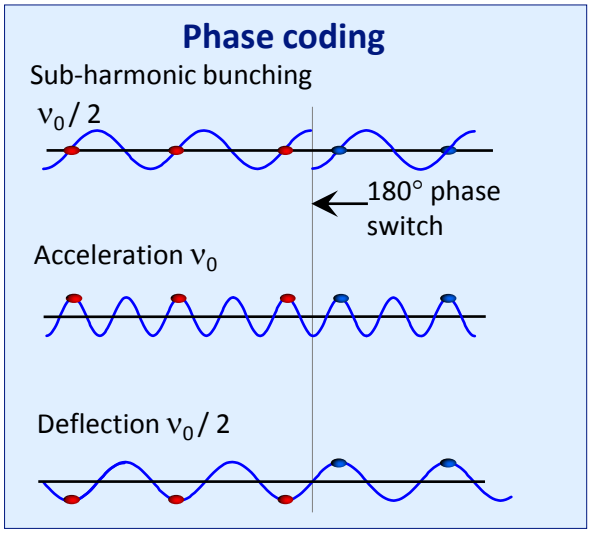
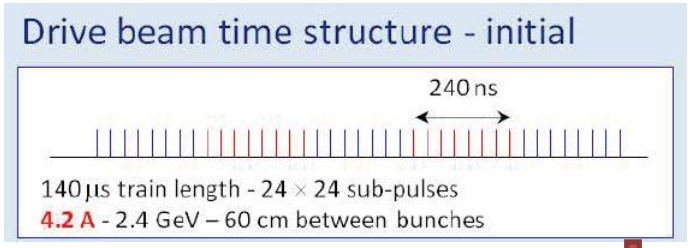
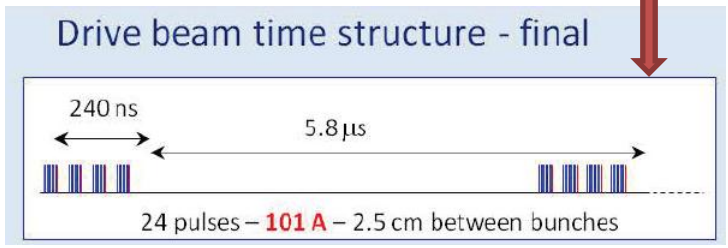
Sub Harmonic Bunchers (SHBs)



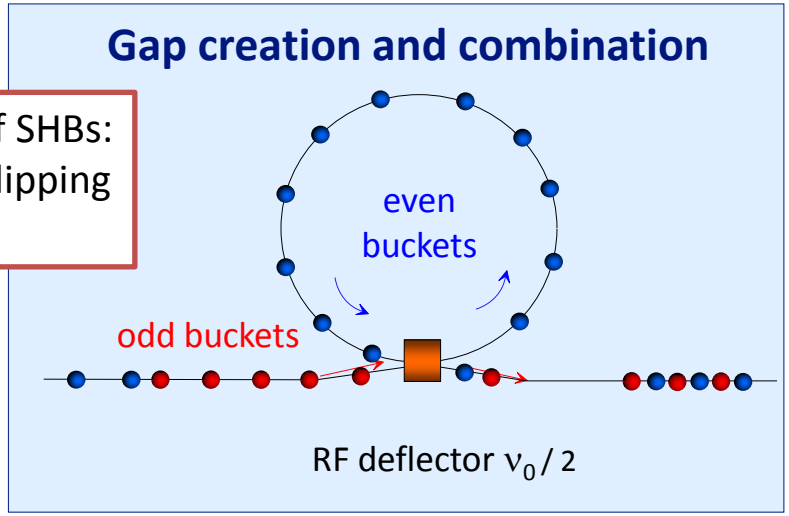
As talked with Thales for IOTs, 80 KW peak power and about 20 MHZ bandwidth (about 30 ns phase flipping) is achievable.





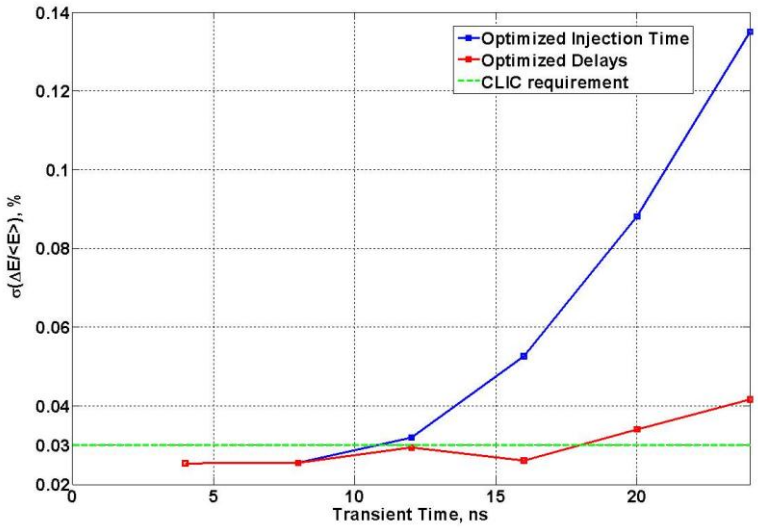


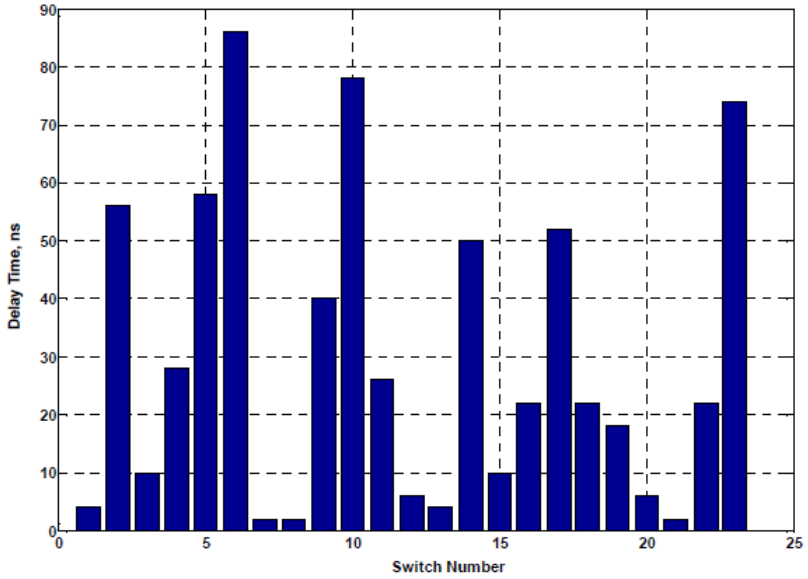
Main challenge of SHBs: Fast 180° phase flipping capability

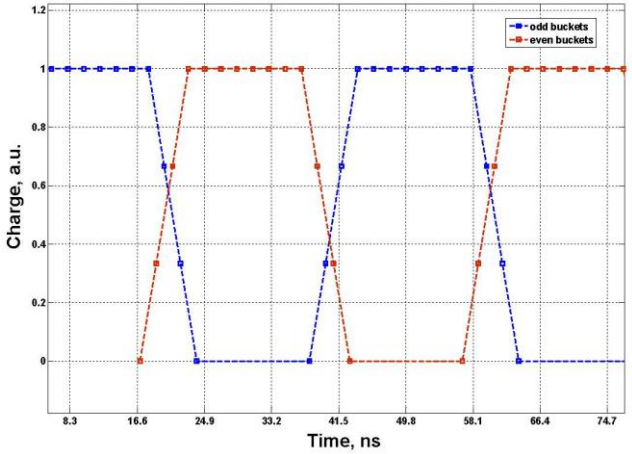


Borrowed from Oleksiy Kononenko

Phase flipping- how much fast?







In the normal case the time interval between phase switching is constant (243.7 ns). In the Oleksiy model these intervals are not constant to have better energy dispersion at the end of main beam linac. It also give us an idea that how much the minimum phase flipping should be. The result shows us it should be less than 18ns. In my design I use 10ns similar to CTF3 SHBs.

Parameter for optimization

Travelling Wave Structure

$$\frac{R'}{Q}=\frac{(\frac{V}{L})^2}{\omega W'}=\frac{(\frac{V}{L})^2}{\omega\frac{P}{v_g}}\Rightarrow\frac{R}{Q}=\frac{V^2}{\omega P\frac{L}{v_g}}\Rightarrow P=\frac{V^2}{\omega\tau\frac{R}{Q}}$$

$$P=\frac{V^2}{\omega\tau\frac{R}{Q}}=\frac{V^2}{\omega\tau}\times\frac{1}{n\left(\frac{R}{Q}\right)_{cell}}$$

R : Effective shunt impedance
R': Effective shunt impedance per length
Q : Unloaded quality factor
P: Source power
V : Gap voltage
W' : Stored energy per length
L: Structure length
v_g : Group velocity
n : Cell numbers

P_d : Power disappears on surface.
β : Coupling coefficient
$Q_e = \omega\tau$: External quality factor
τ : Filling time

For the known gap voltage and filling time our goal is to increase **R/Q** to reduce the input power.

τ=10ns
V=36.5 KV

Drive Beam Injector design in CDR

The values was found by S. Bettoni et al. during CLIC DB Injector design and optimization.

CLIC DB Injector (CDR)	Field (MV/m)	Length (cm)	Voltage (KV)	Input Power (CTF3 scaling)
Gun			140 (β=0.62)	
SHB - I	0.224	15.6	35	1.1 MW
SHB - II	0.234	15.6	36.5	1.2 MW
SHB - III	0.249	15.6	38.8	1.4 MW

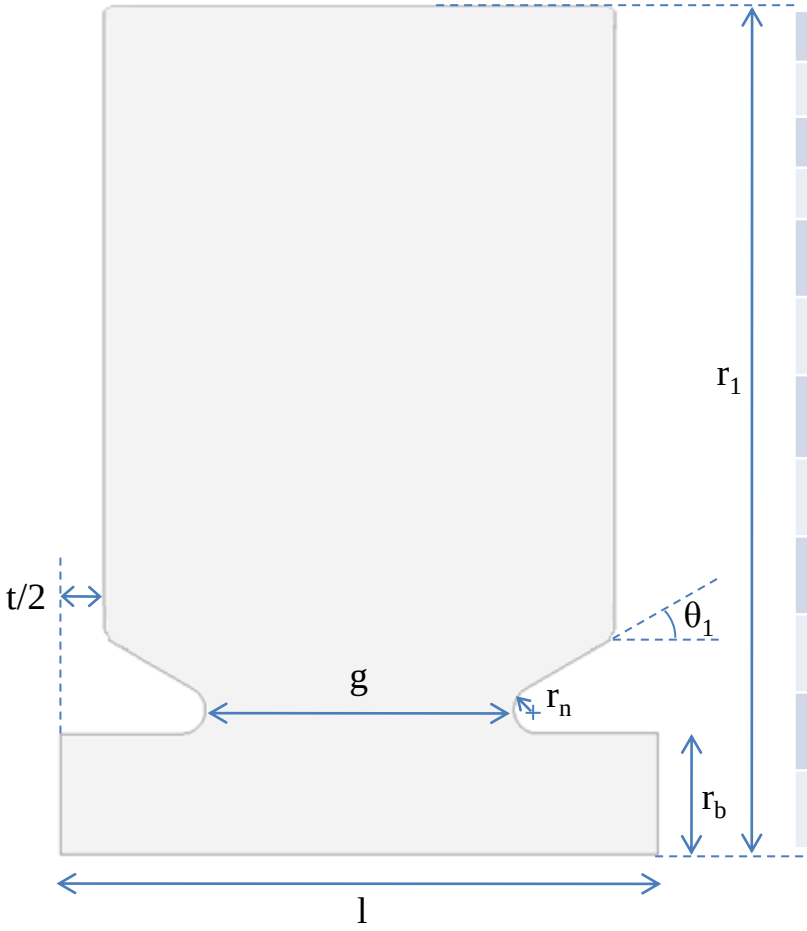
Initial design of RF structures was started with these numbers. But these values should be corrected afterward depend on the structure and the power source restrictions.

To scale, using this fact that The CTF SHBs have the same length and their voltages are 20 KV with 40KW input power.

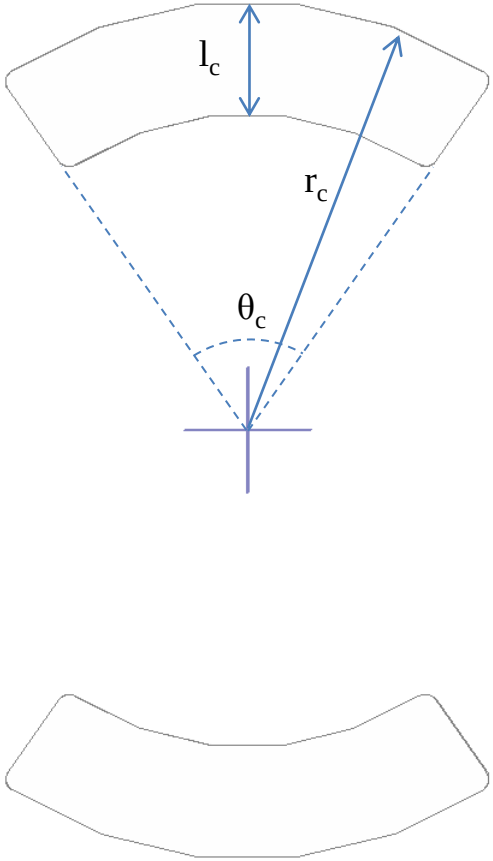
The optimization process to find minimum power needed for an electrical coupling structure doesn't shows a better result.

Then we should looking for another structure.

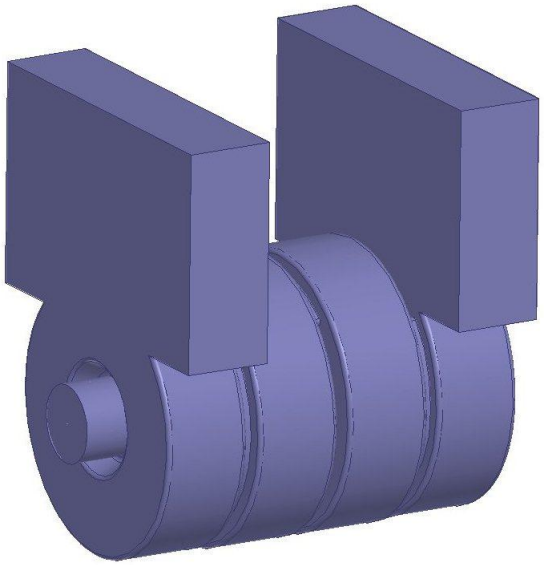
Magnetic coupling TW structure



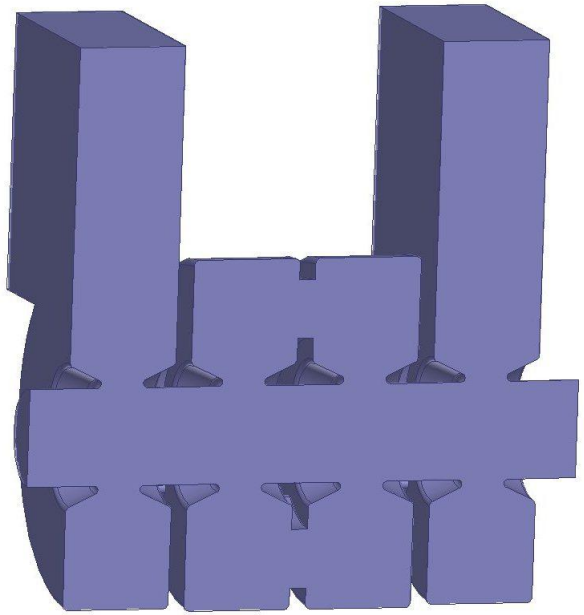
g	40 mm
r_b	45 mm
r_n	4 mm
θ_1	25°
t (disk thickness)	15 mm
Frequency	499.75 MHz
l (for 108° phase advance per cell)	≈115.18 mm
r_1	161.55 mm
r_c	142 mm
l_c	54 mm
θ_c	86°
Phase velocity	0.64c

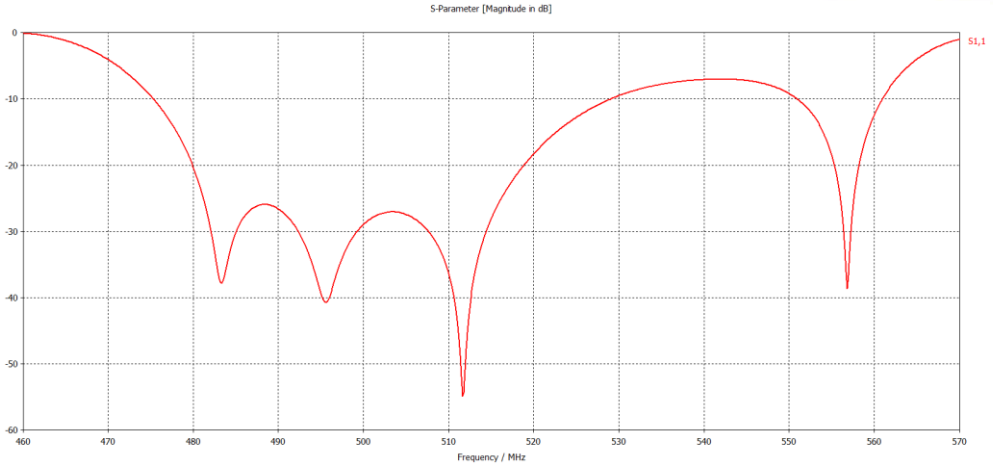


Four cells structure with waveguide couplers

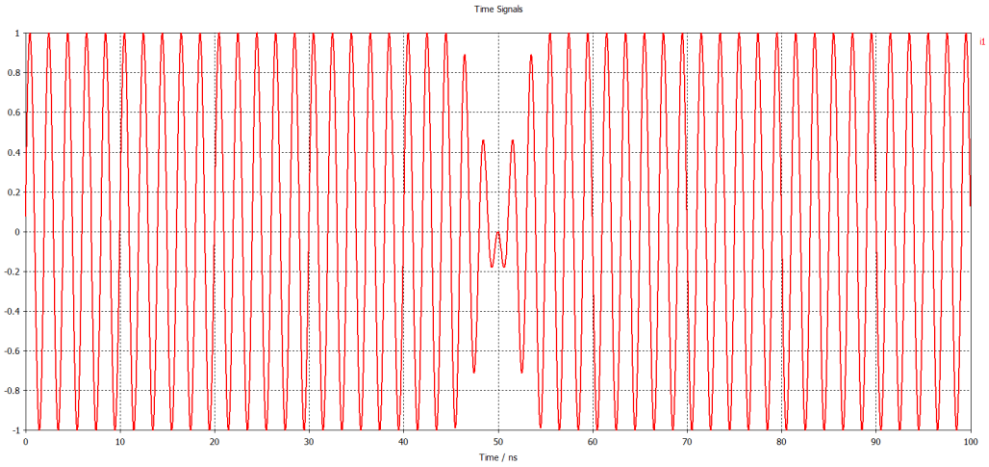


In this design for the first SHB about 73 MW peak power is needed for 10ns filling time and 36.5 KV gap voltage.



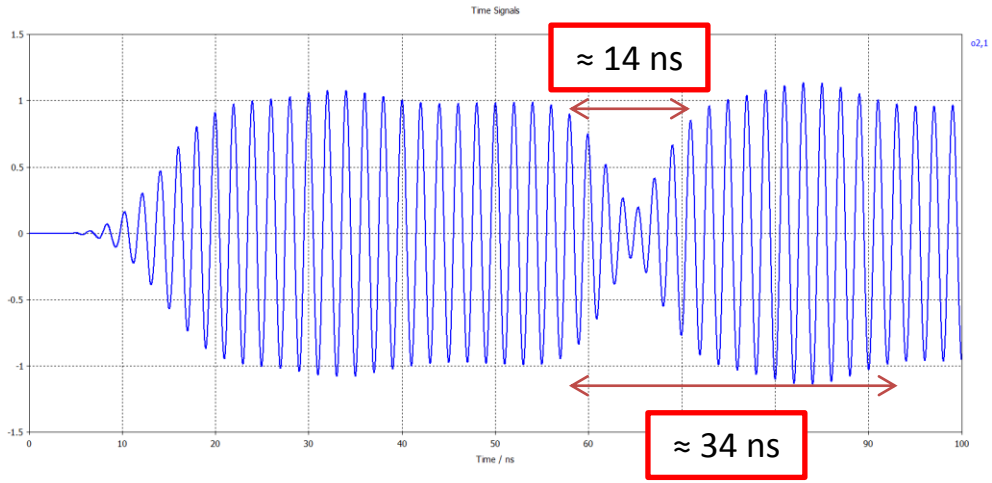


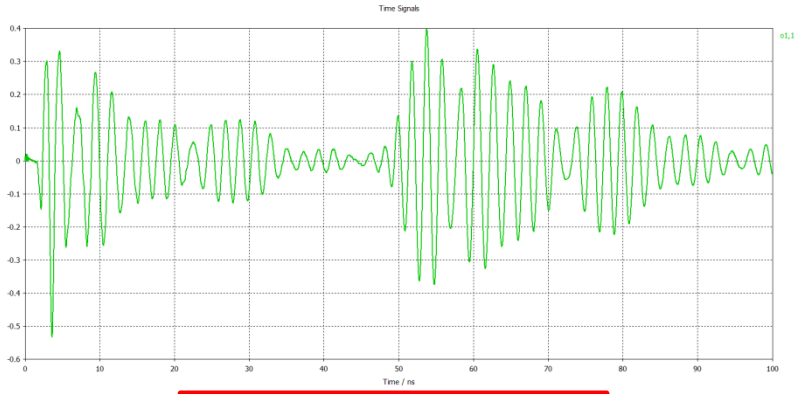
Phase flipping simulation – 10 ns



Excitation signal – port 1

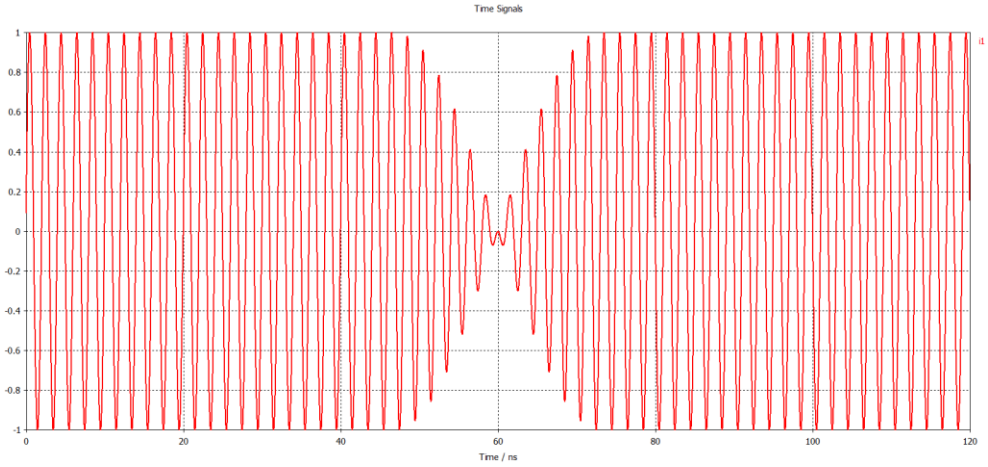
Output signal – port 2





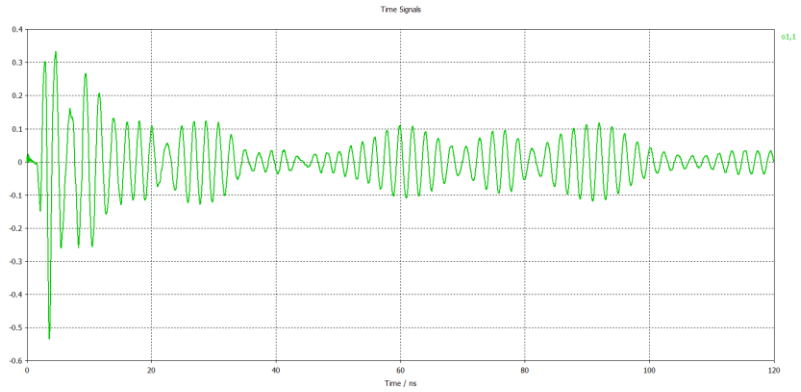
Output signal – port 1

Phase flipping simulation – 26 ns

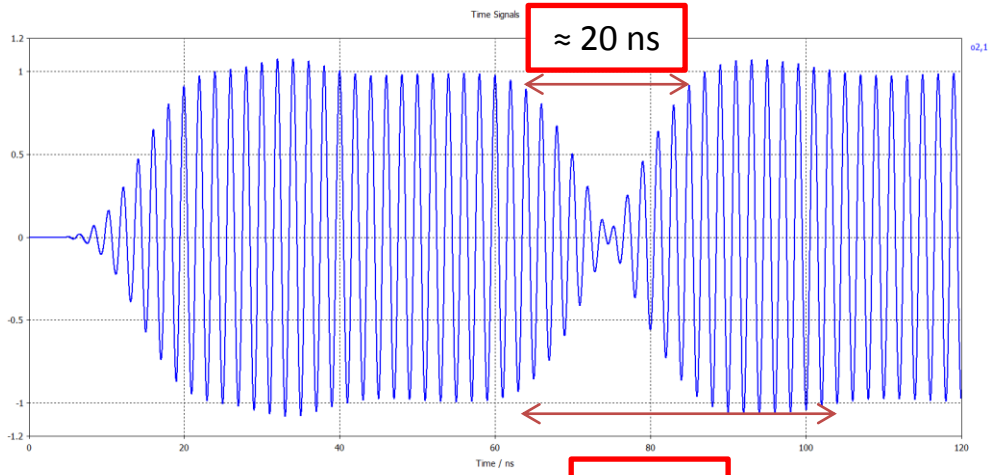


Excitation signal – port 1

Output signal – port 2



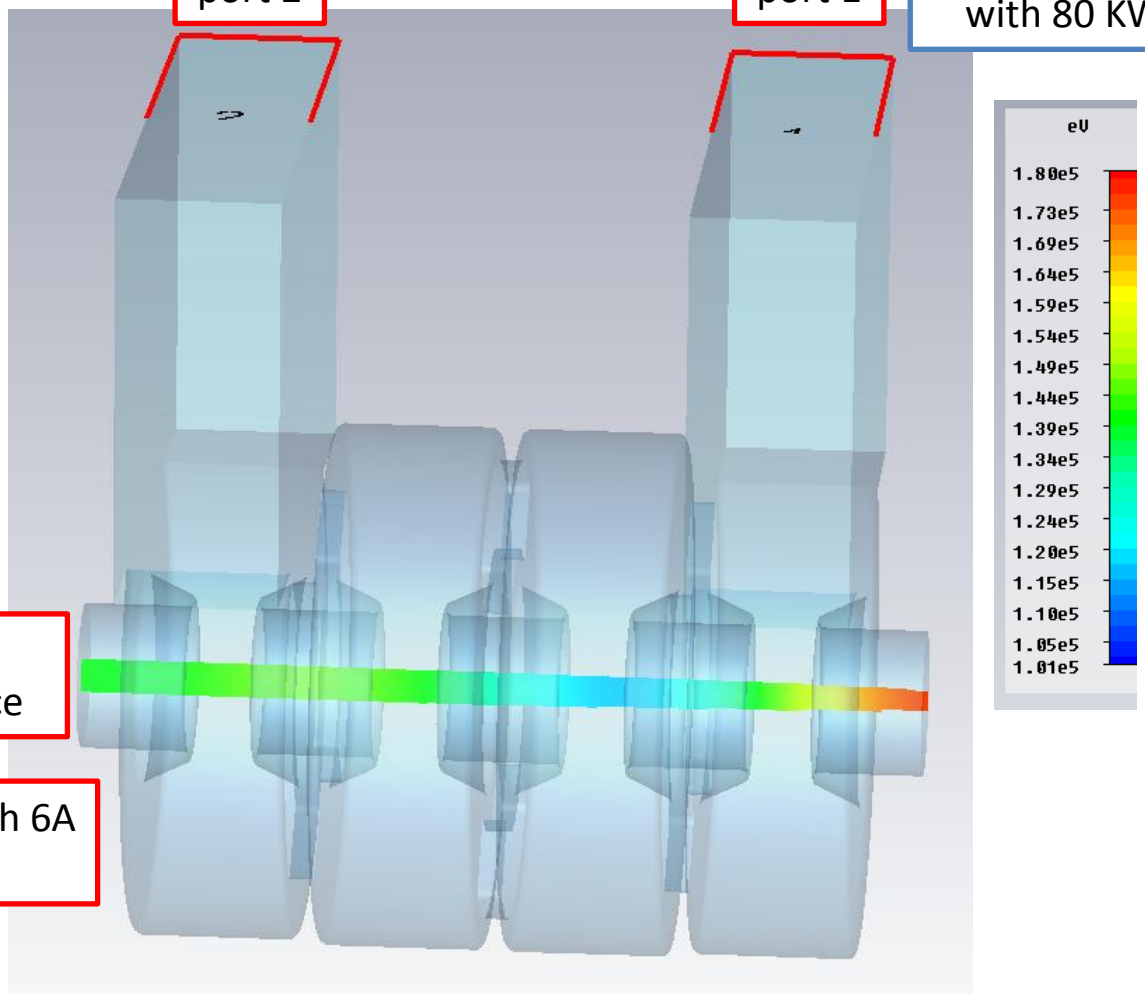
Output signal – port 1



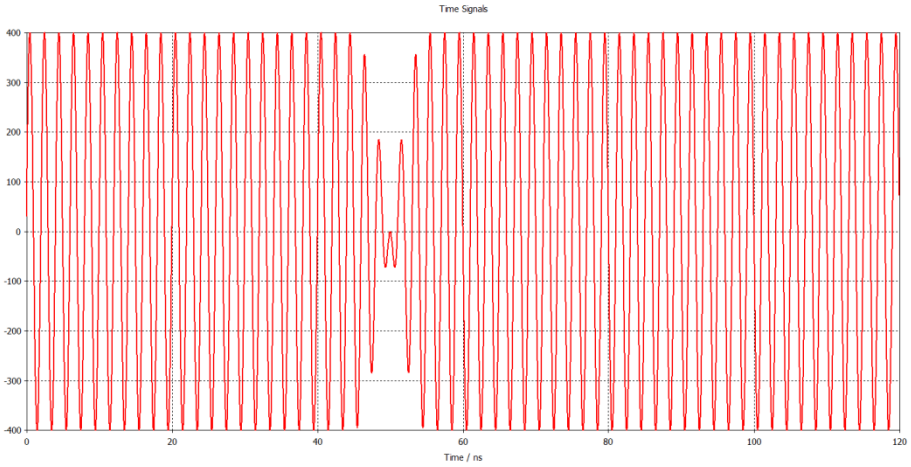
≈ 20 ns

≈ 40 ns

Phase flipping simulation with beam – 10 ns

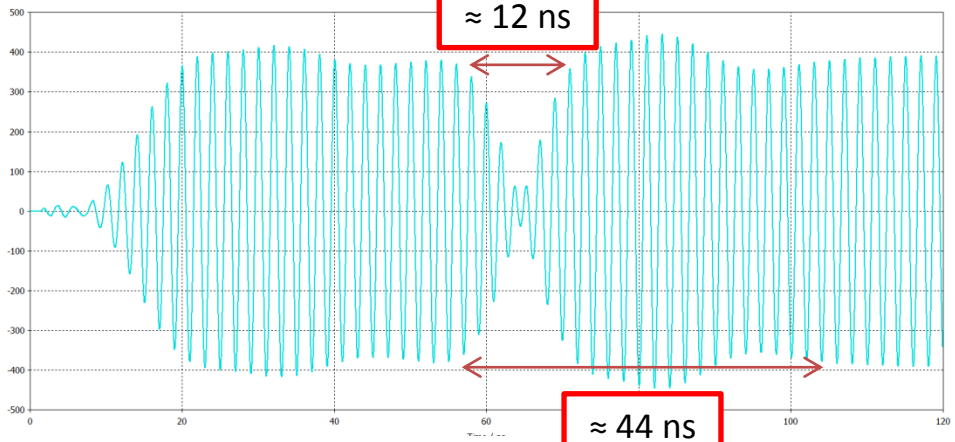


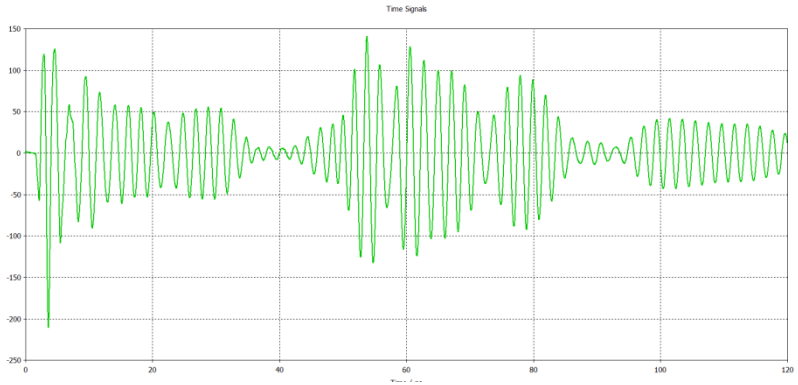
Phase flipping simulation with beam – 10 ns



Excitation signal – port 1

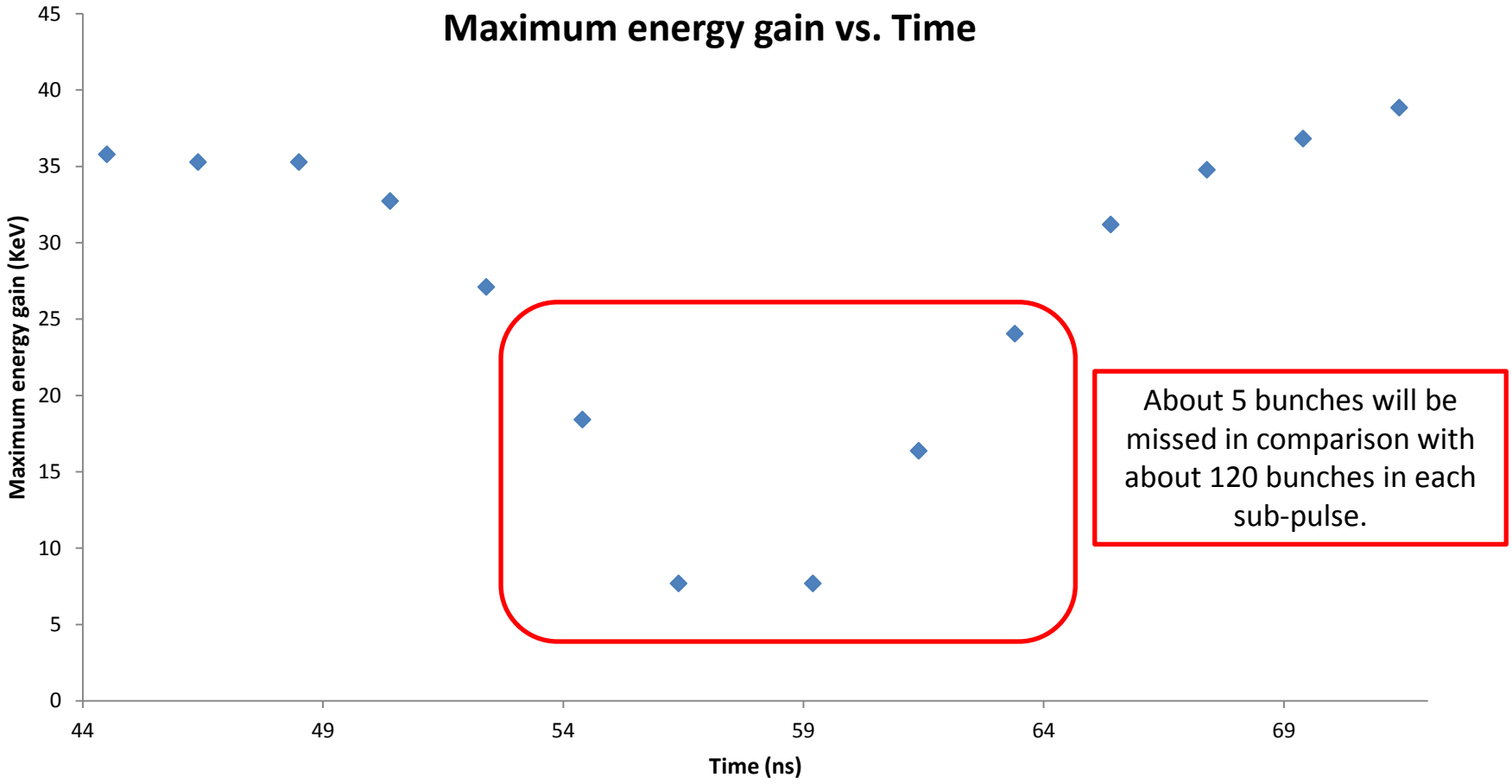
Output signal – port 2





Output signal – port 1

Phase flipping simulation with beam – 10 ns



Conclusion

- One SHB design is ready for mechanical design.
- Looking for any RF power source (80 KW peak power, about 60 MHZ band width).
- Beam dynamic simulation of DB Injector should be start with new parameters.
- Another SHBs will be designed depend on the beam dynamic simulation result.

Acknowledgment

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