Pulse Shape Optimization for the Beam Loading Compensation in CLIC Main Linac

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4th Annual X-band Structure Collaboration Meeting, May 3-5, 2010

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- Drive beam generation scheme
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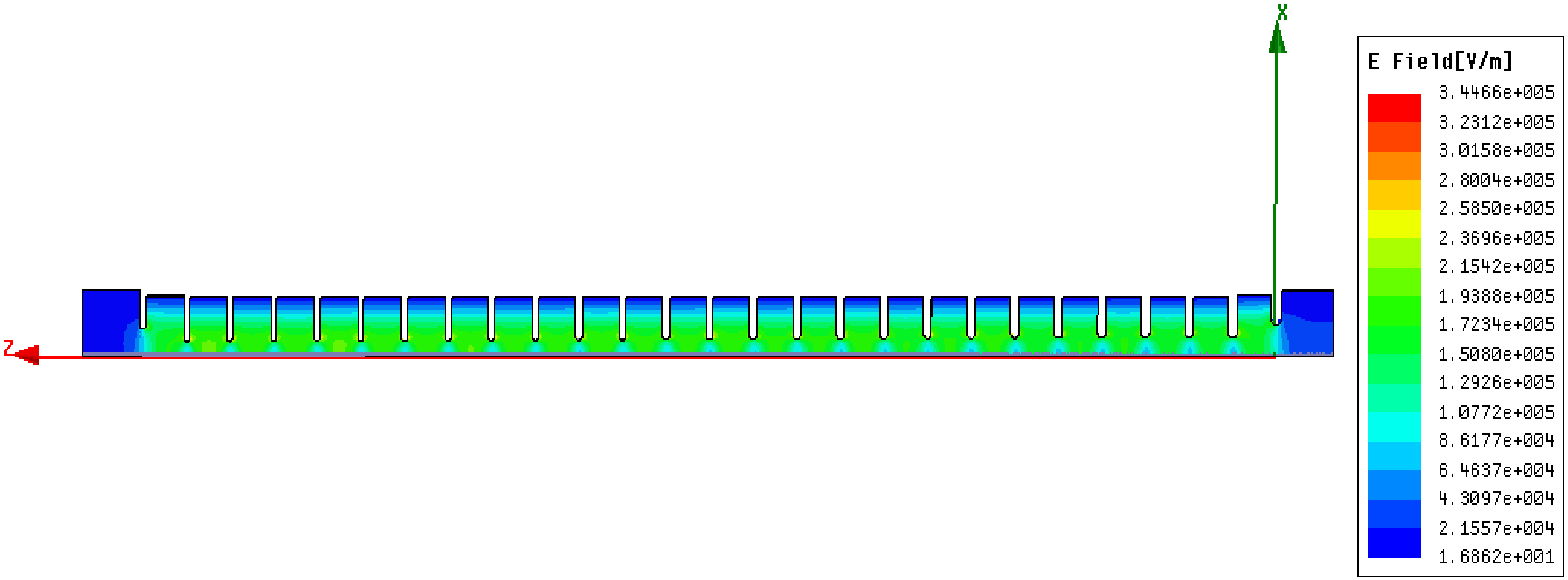
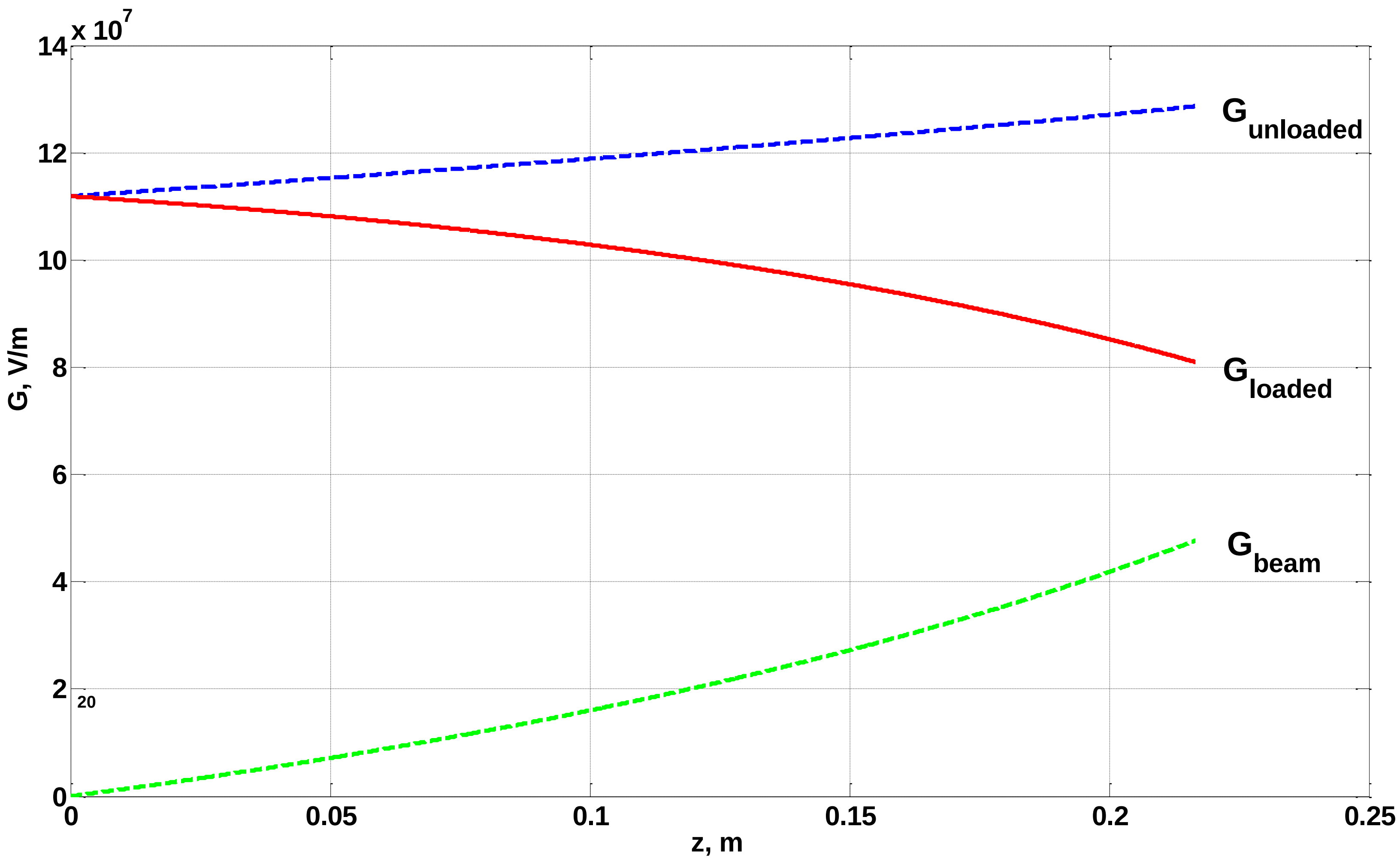
Introduction: E-field in T24 structure

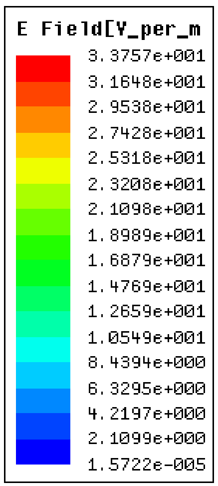


Considering T24 CLIC main accelerator structure

Beam Loading: Steady State



Beam Loading: Plane Wave Approach

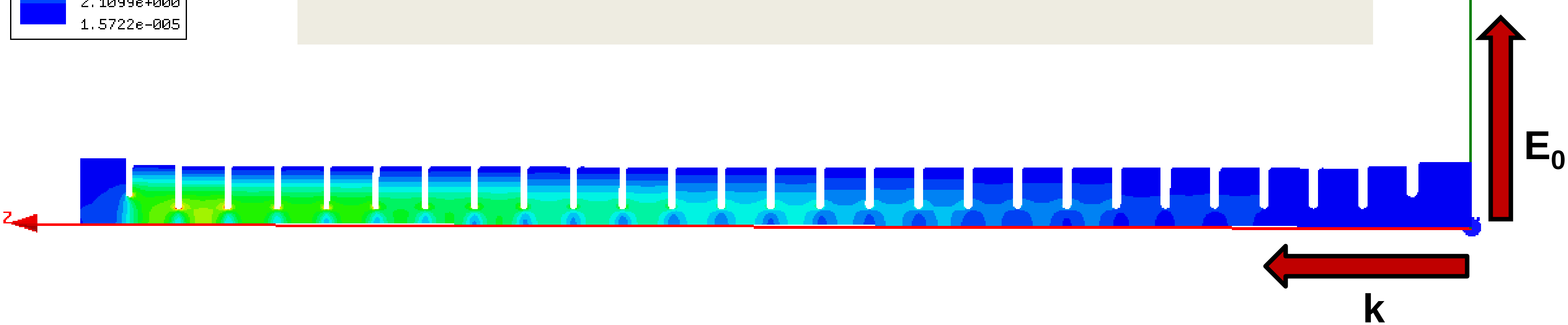


Plane Wave Approach:

- takes into account dispersion

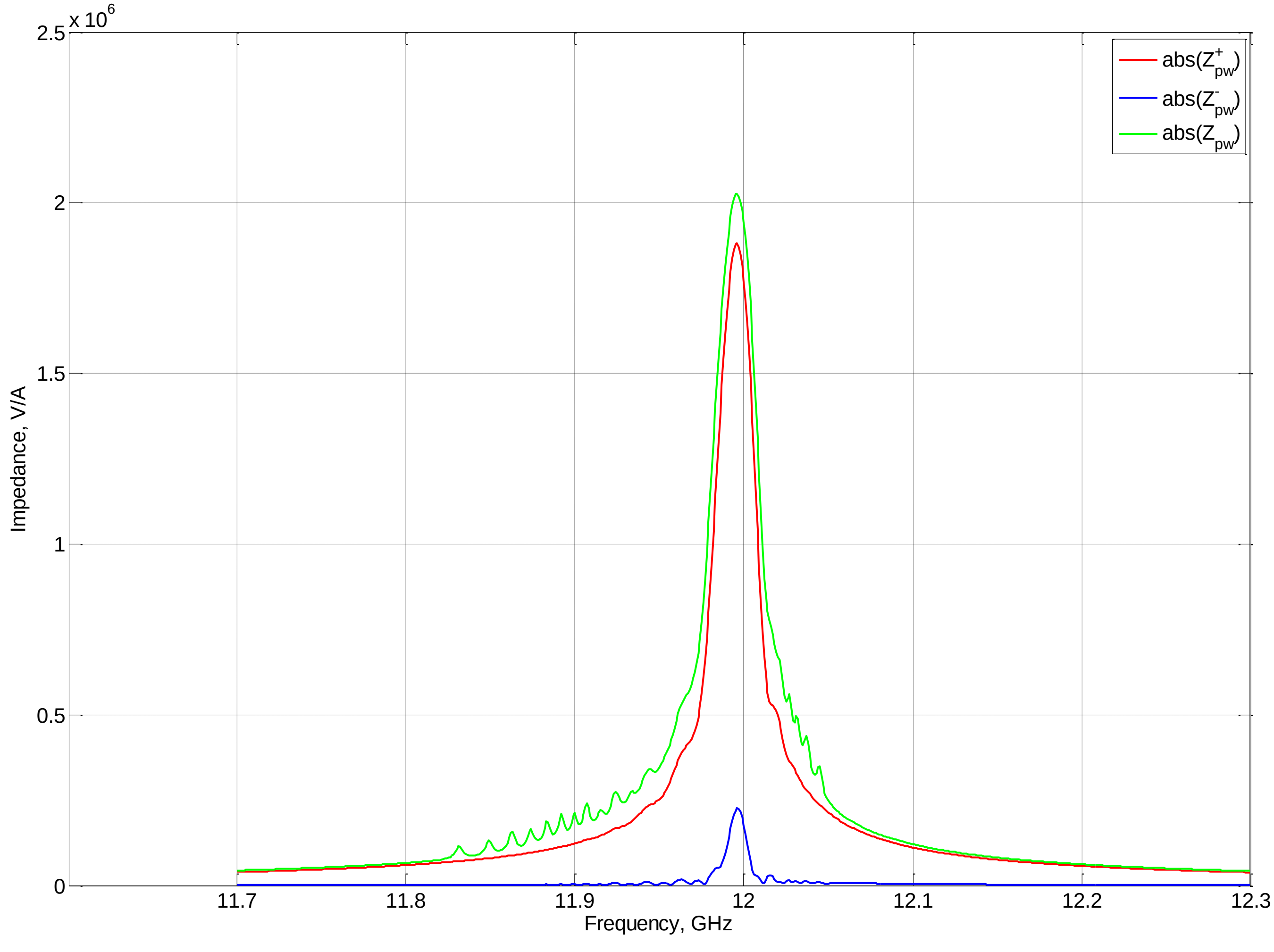
- takes some time to calculate since Fast Sweeps in HFSS are not supported for the projects which involve plane wave sources, need to use Discrete Sweep

- has rather good correlation with the CST WakeField Solver



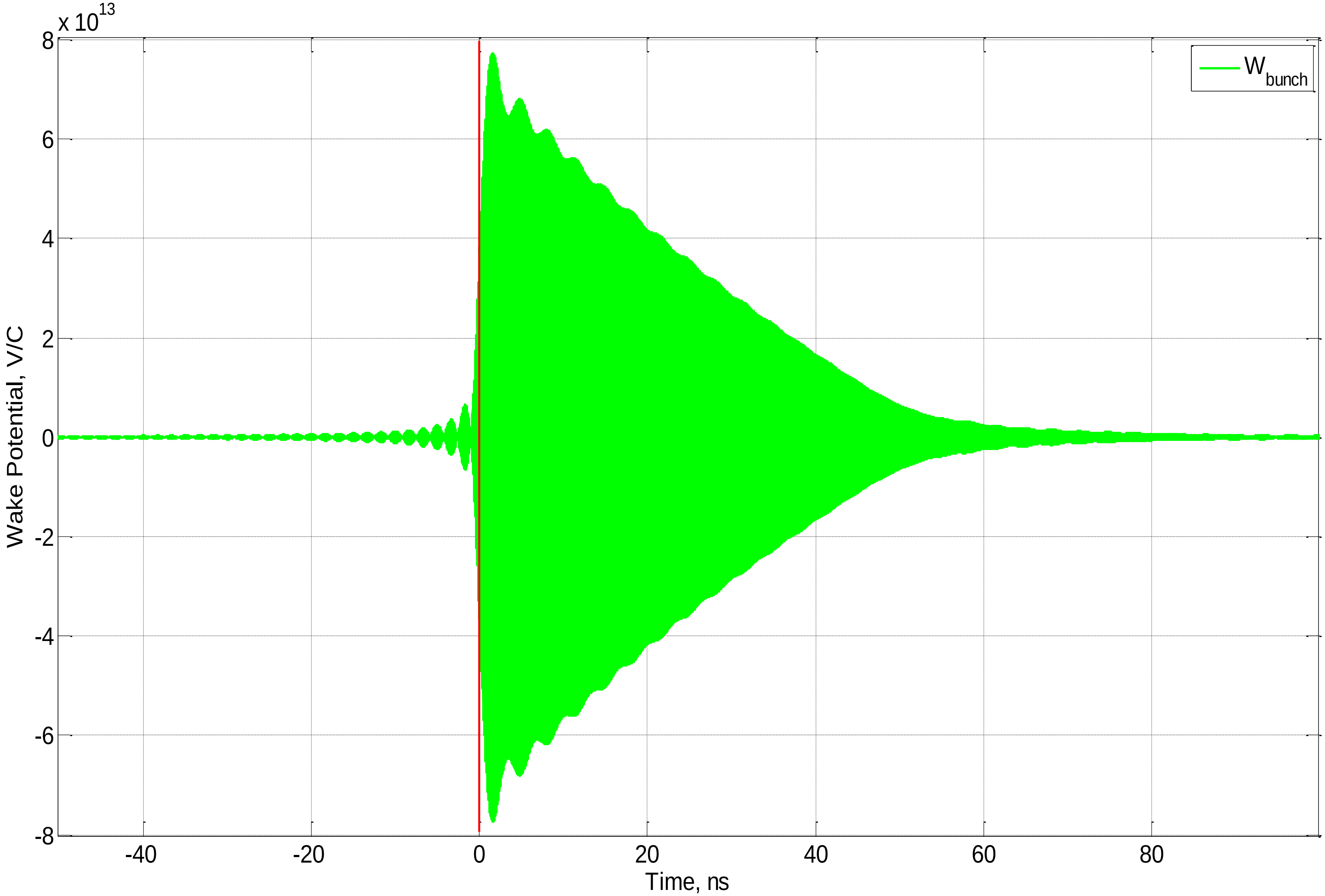
*Thanks for the help to Valery Dolgashev (SLAC)

Beam Loading: Wake Impedance



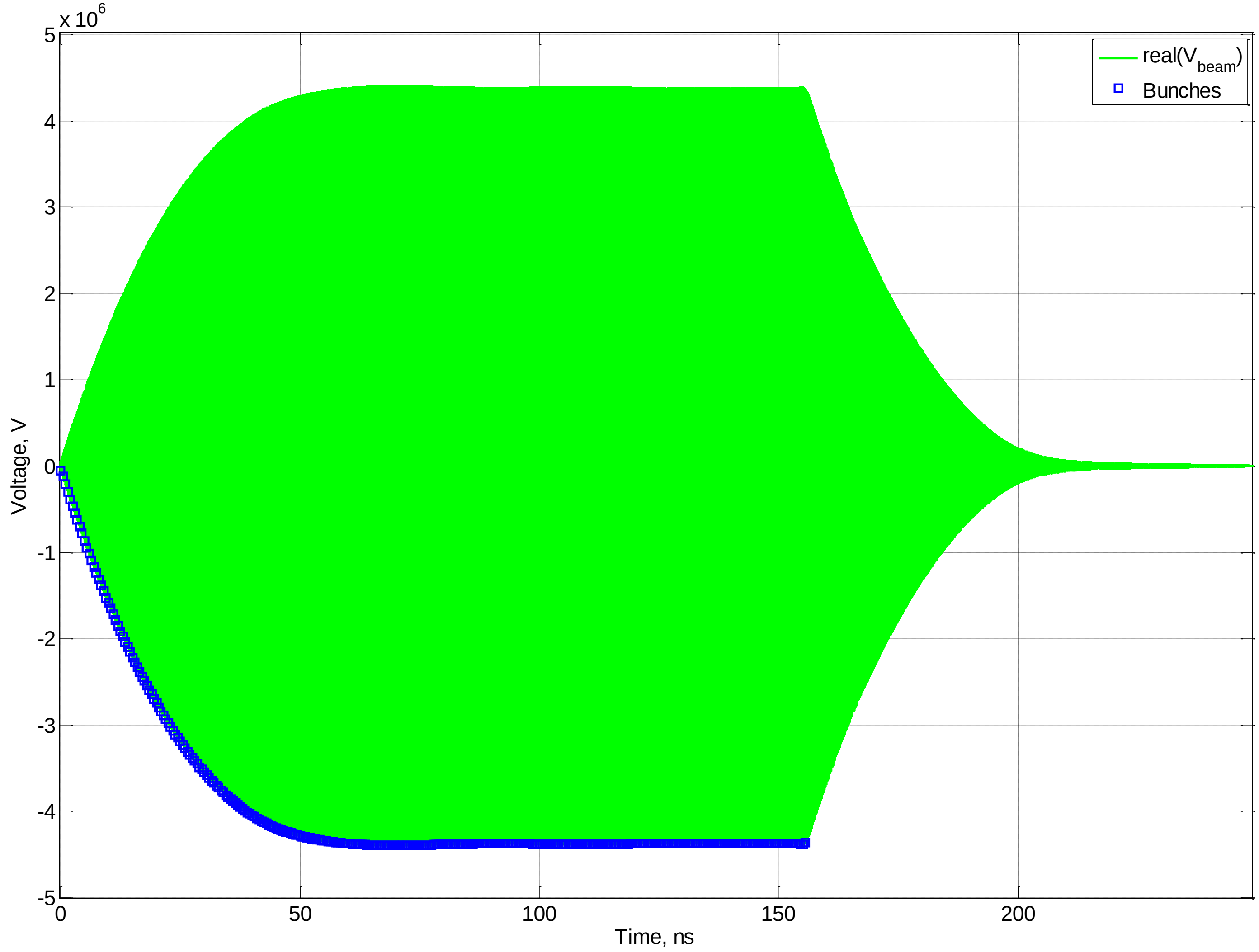
$E_z(z,f) \rightarrow [\ \exp(\pm i * z * \omega/c)\ ] \rightarrow [\ \int dz\ ] \rightarrow V(f) \rightarrow [I_{HFSS} = 2*\pi*r * \mathbf{E_0 / Z_0}] \rightarrow Z(f)$

Beam Loading: Wake Potential



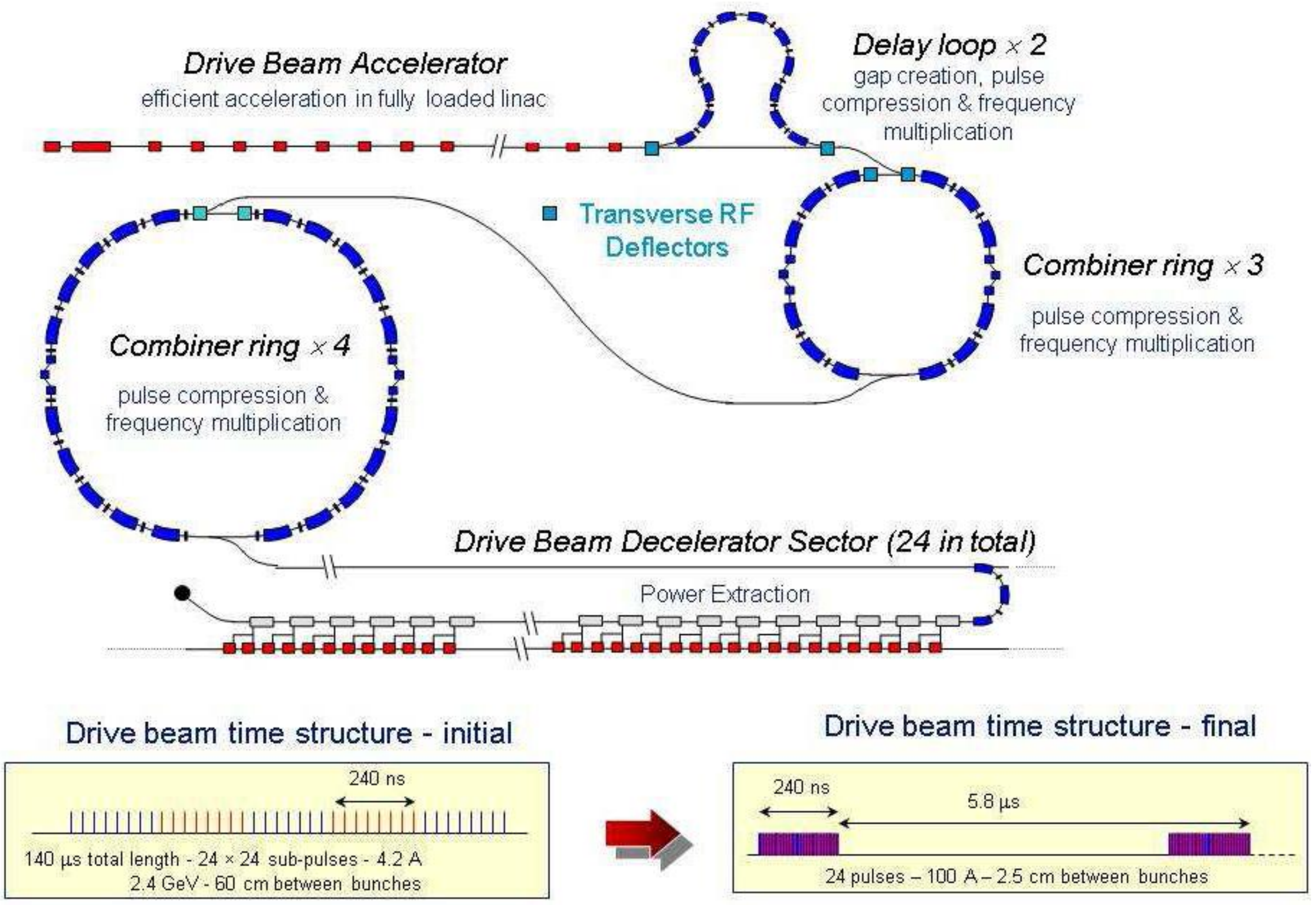
W_{bunch} = ifft(Z^{+})

Beam Loading: Voltage



$V_{beam} = q * \sum W_{bunch} (t+T_{bunch})$

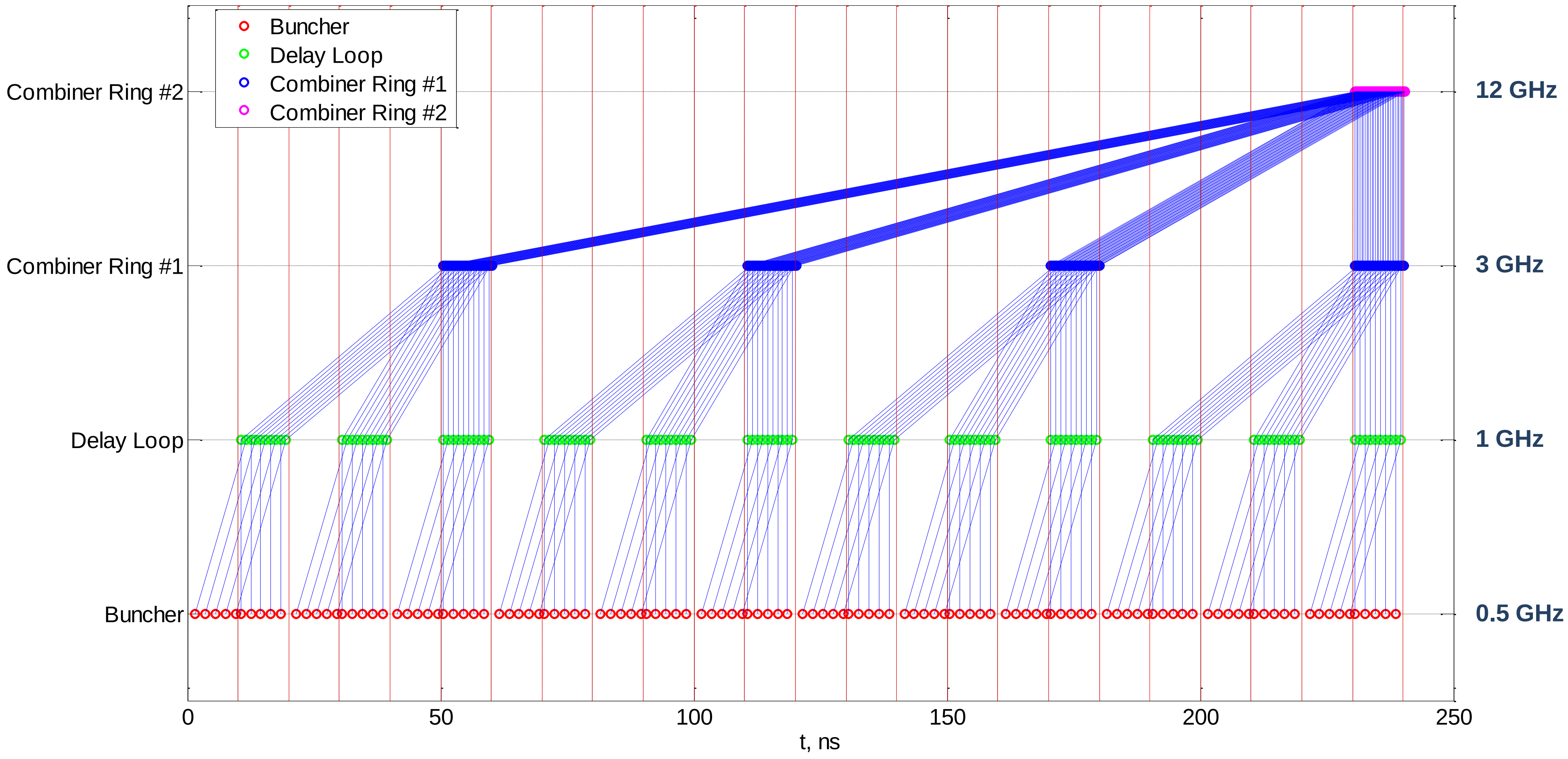
Drive Beam Generation Complex



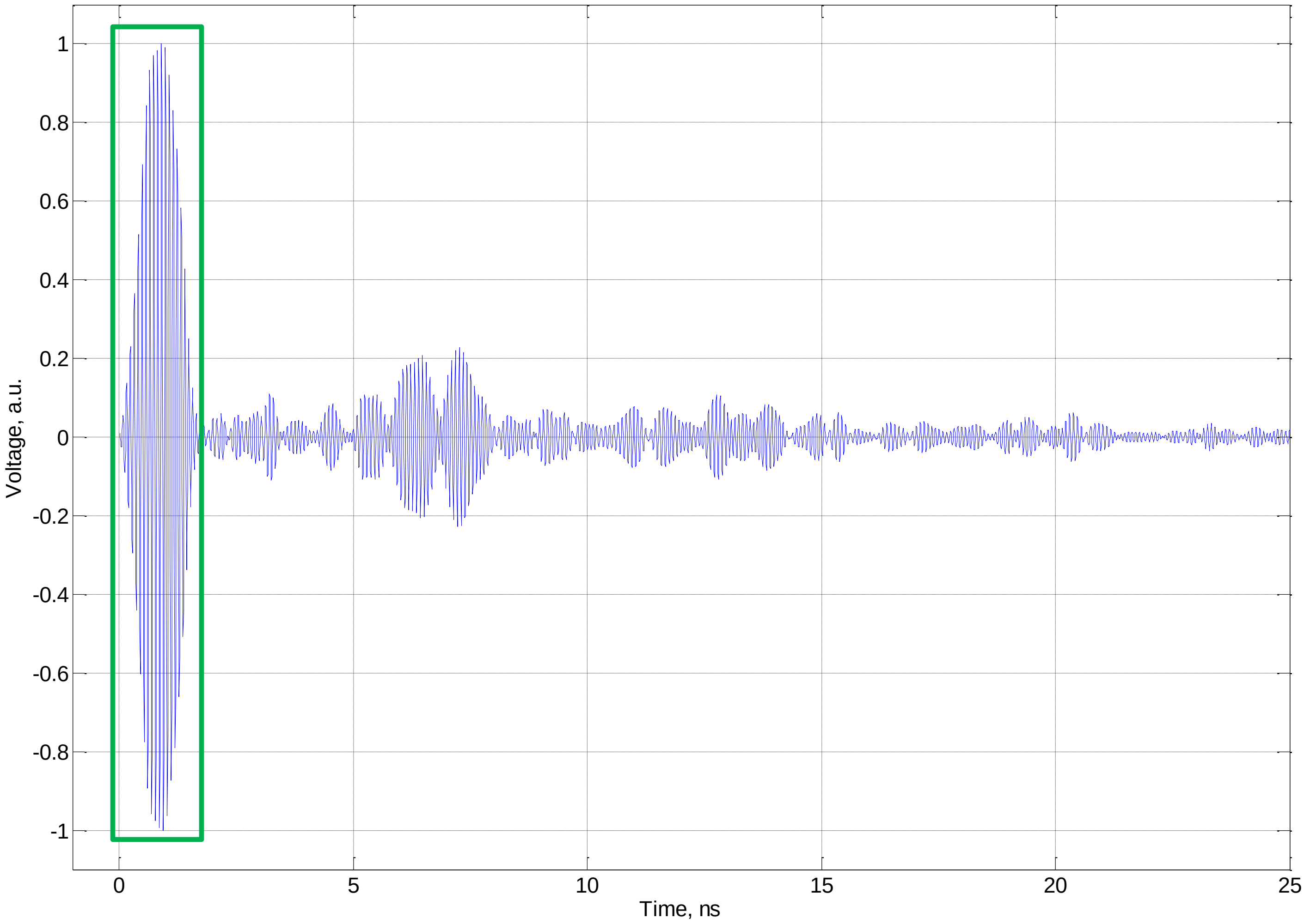
*CLIC-Note-764

Drive Beam Combination Steps

$f_{beam} = 4 * 3 * 2 * f_{buncher}$

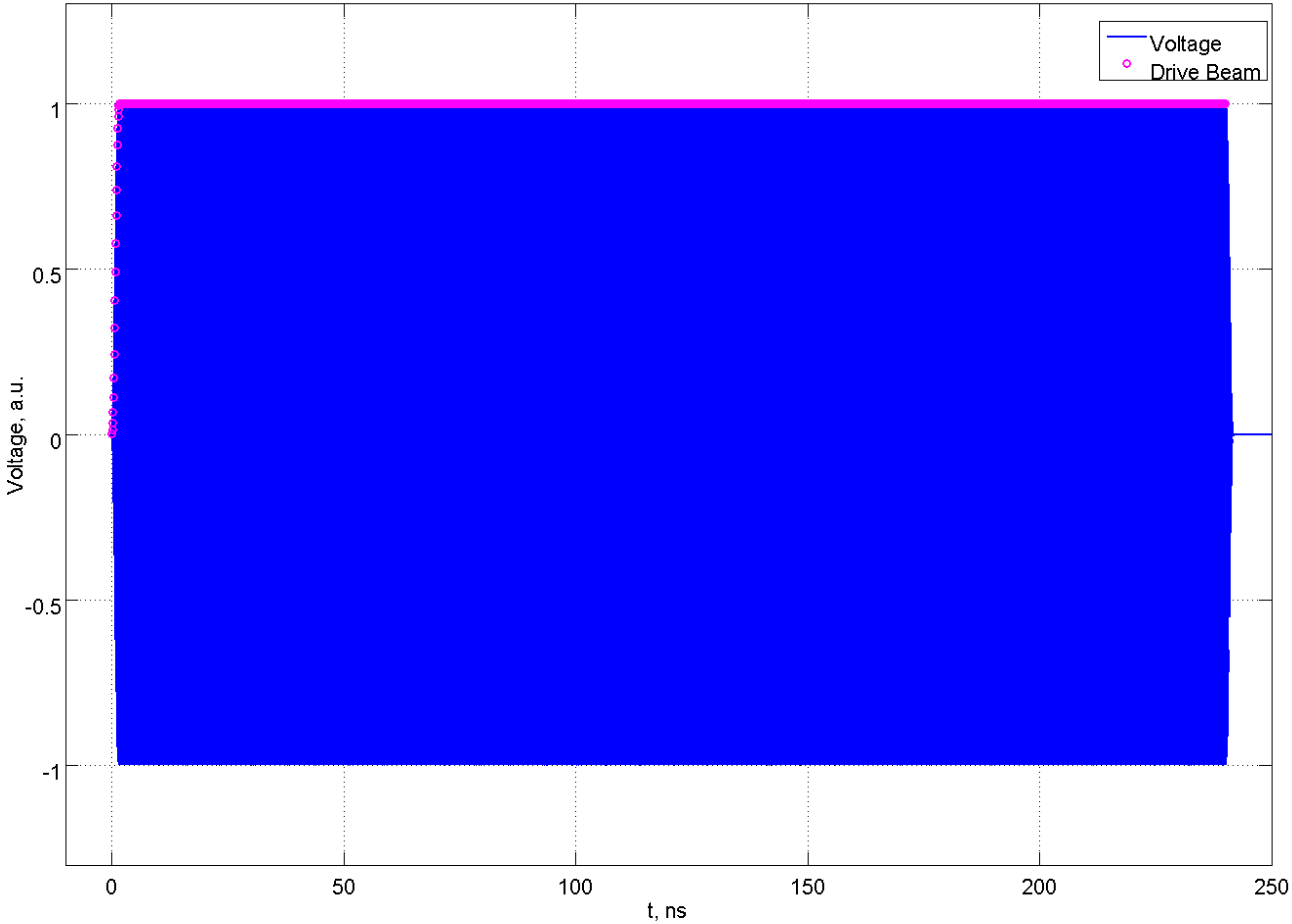


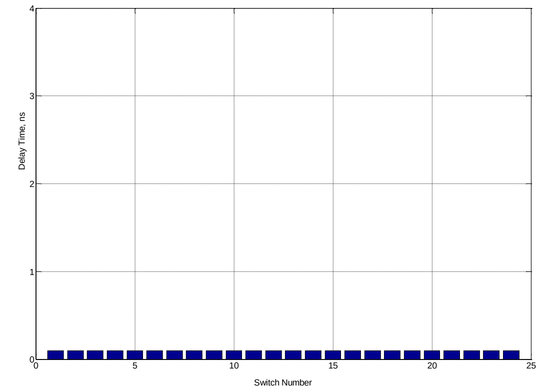
PETS: Single Bunch Response



*Alessandro Cappelletti, Igor Syratchev (CERN)

PETS: Generated Rectangular Pulse

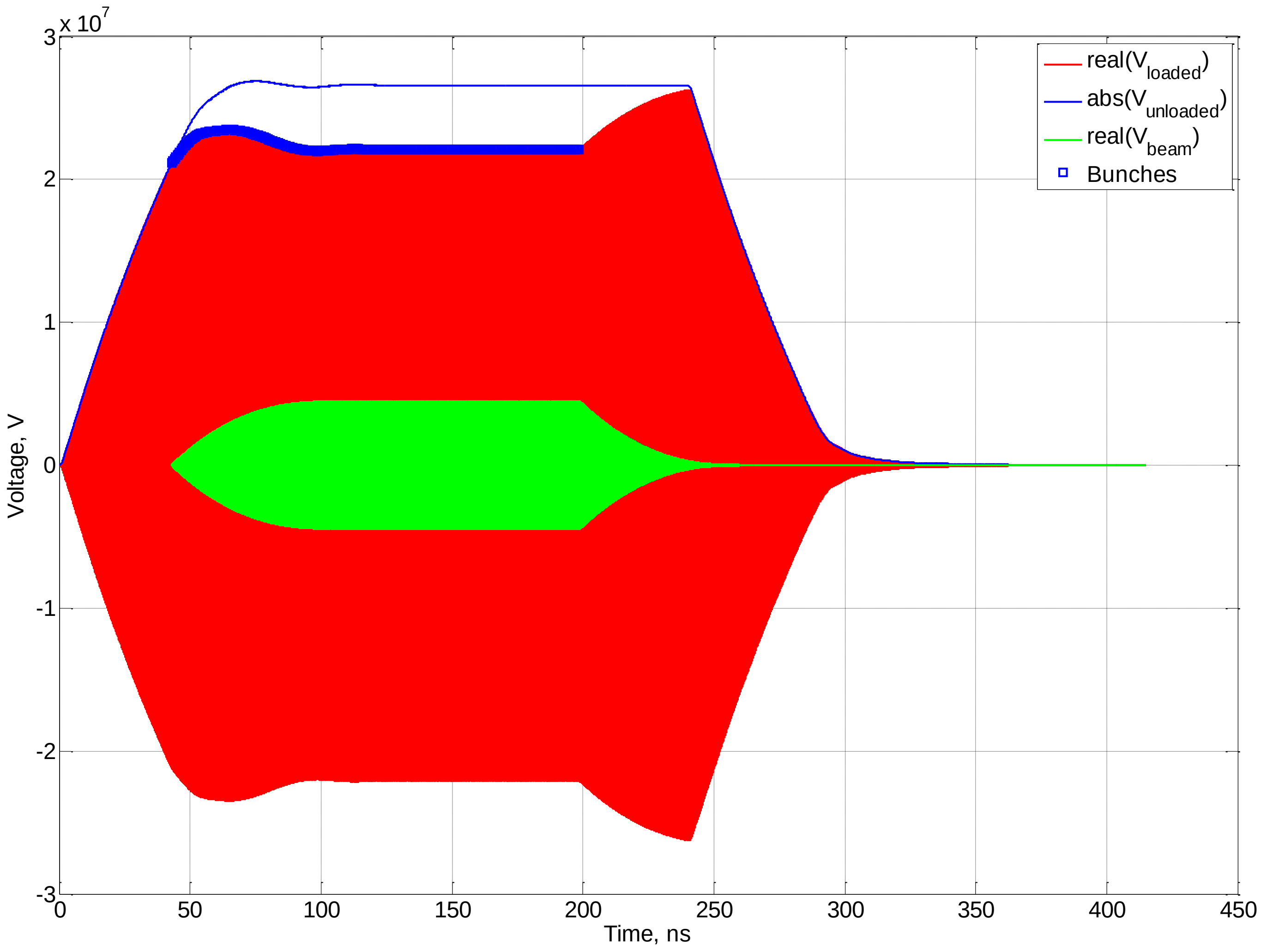




No delays, just nominal (~240ns) switch times in buncher

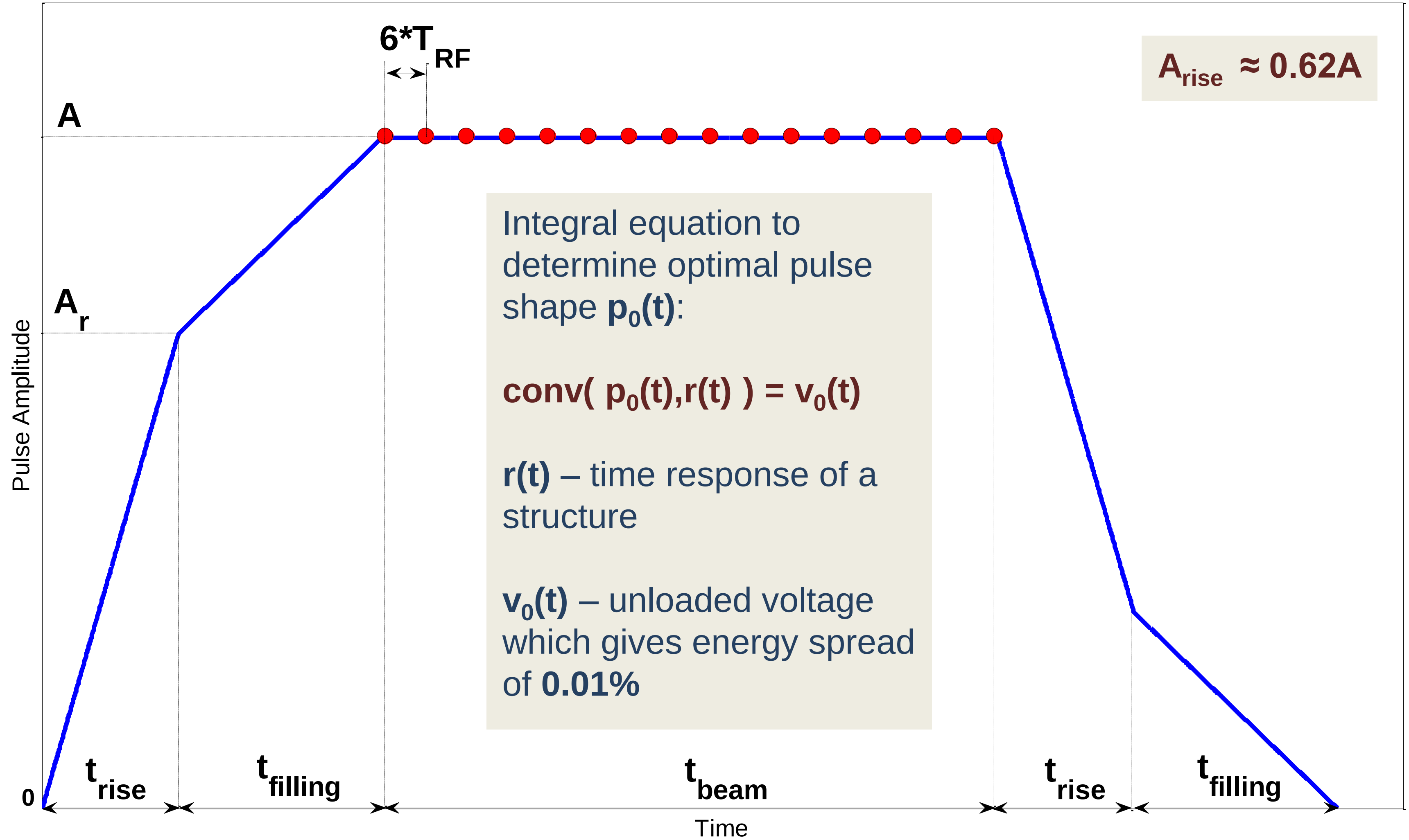
t_{rise} ≈ 1.5 ns

Rectangular Pulse in Main Linac

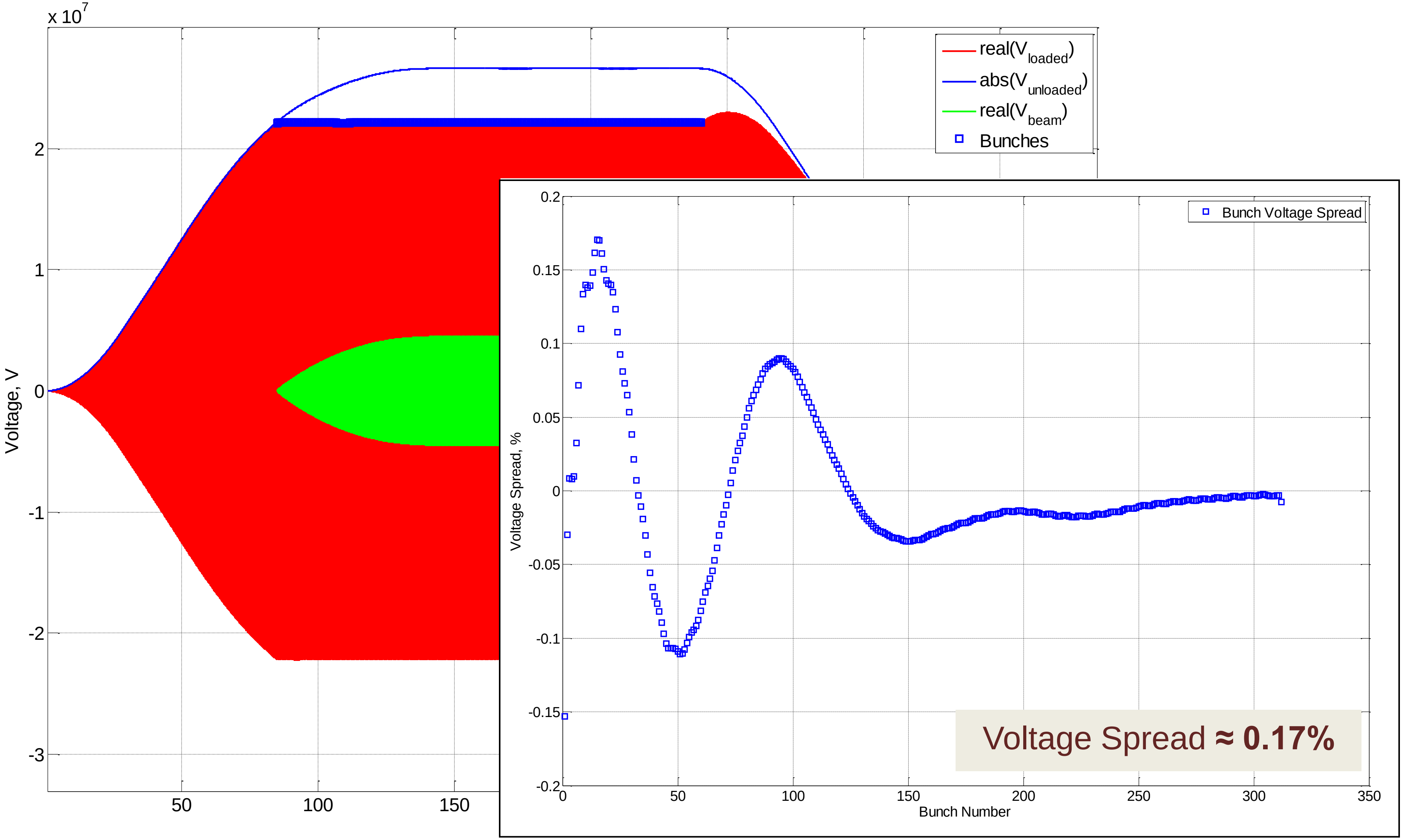


Voltage Spread ≈ **6%**

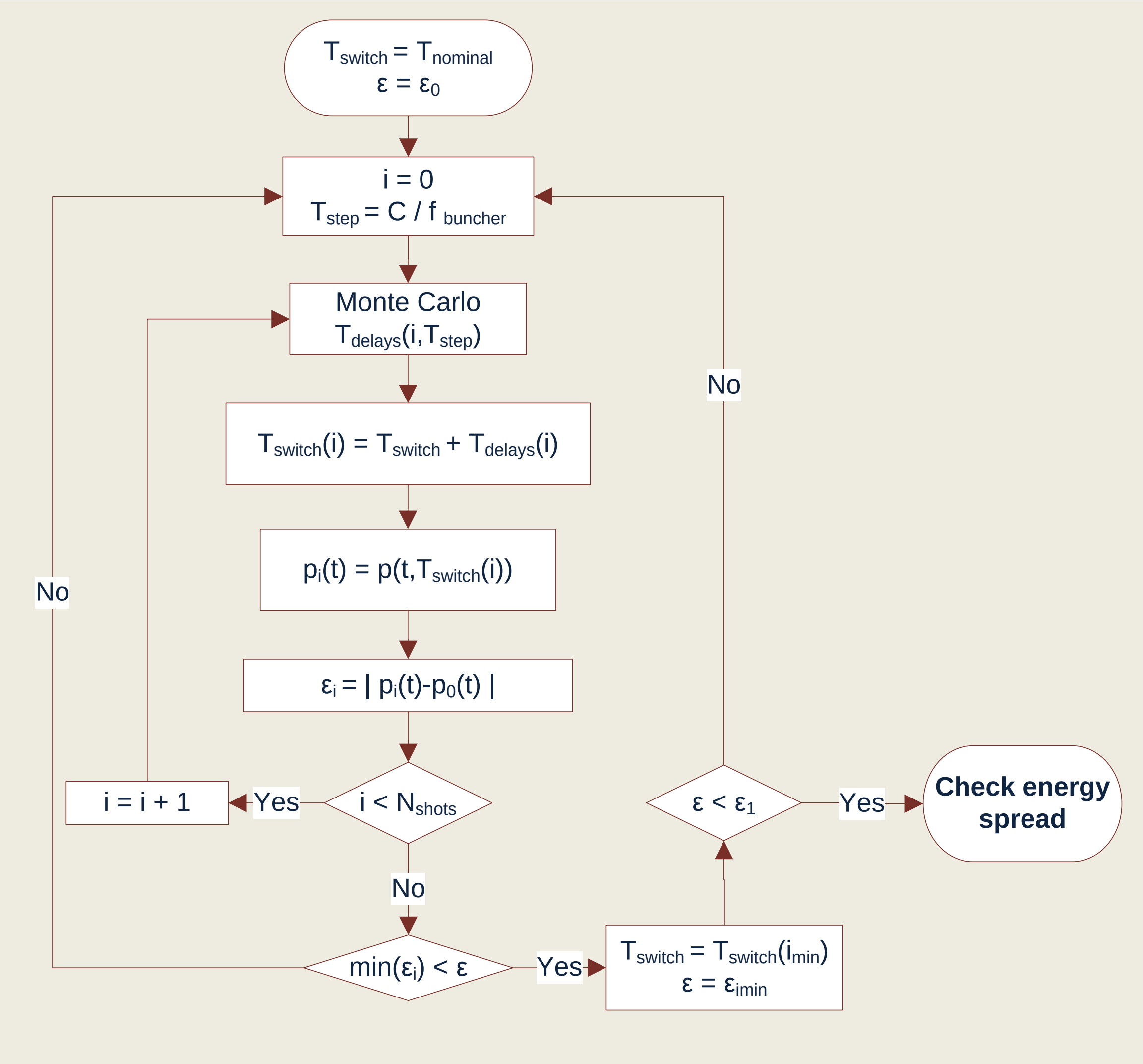
“Perfect” trapezoidal pulse



Trapezoidal Pulse in Main Linac



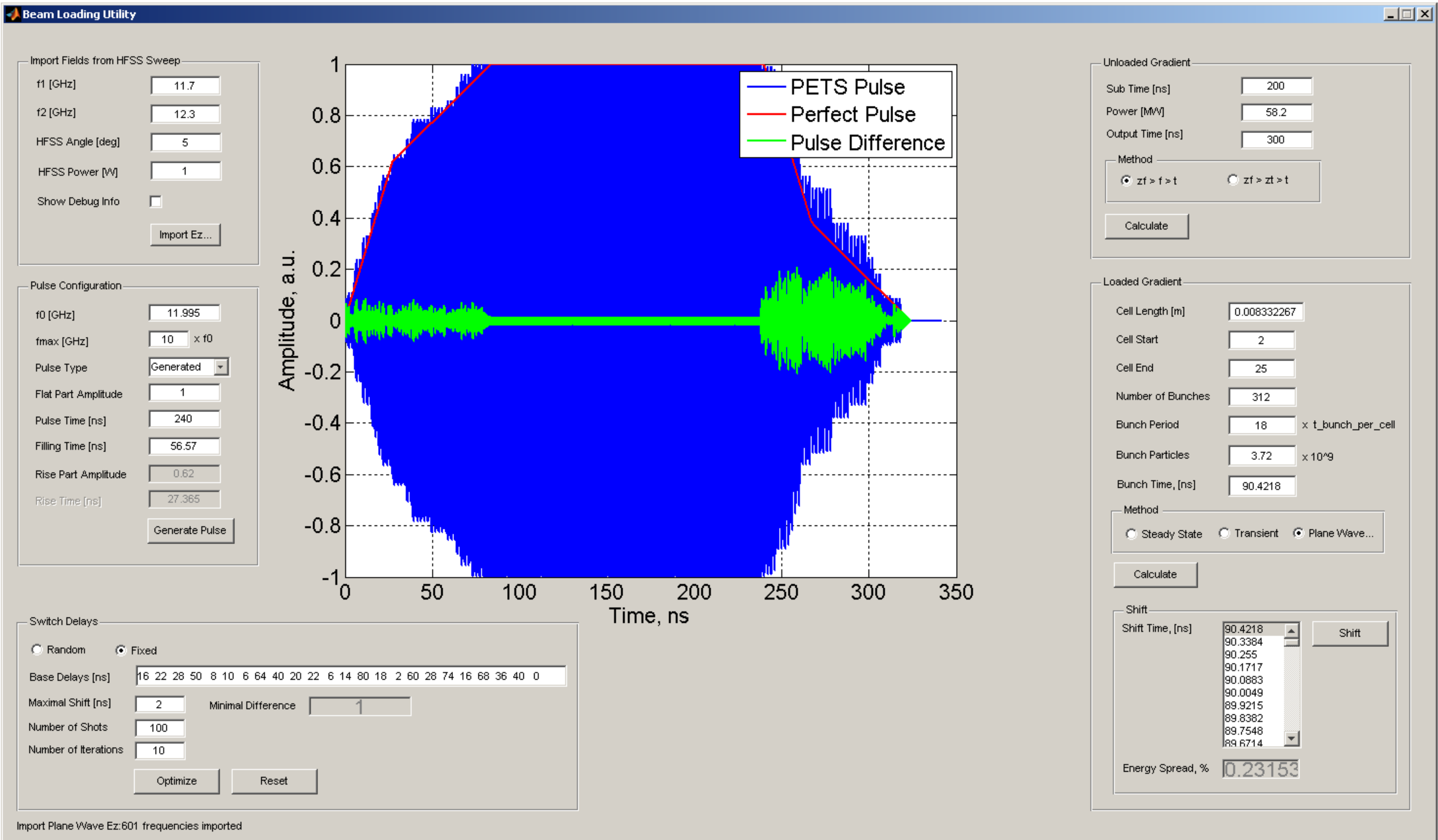
Pulse Shape Optimization Algorithm



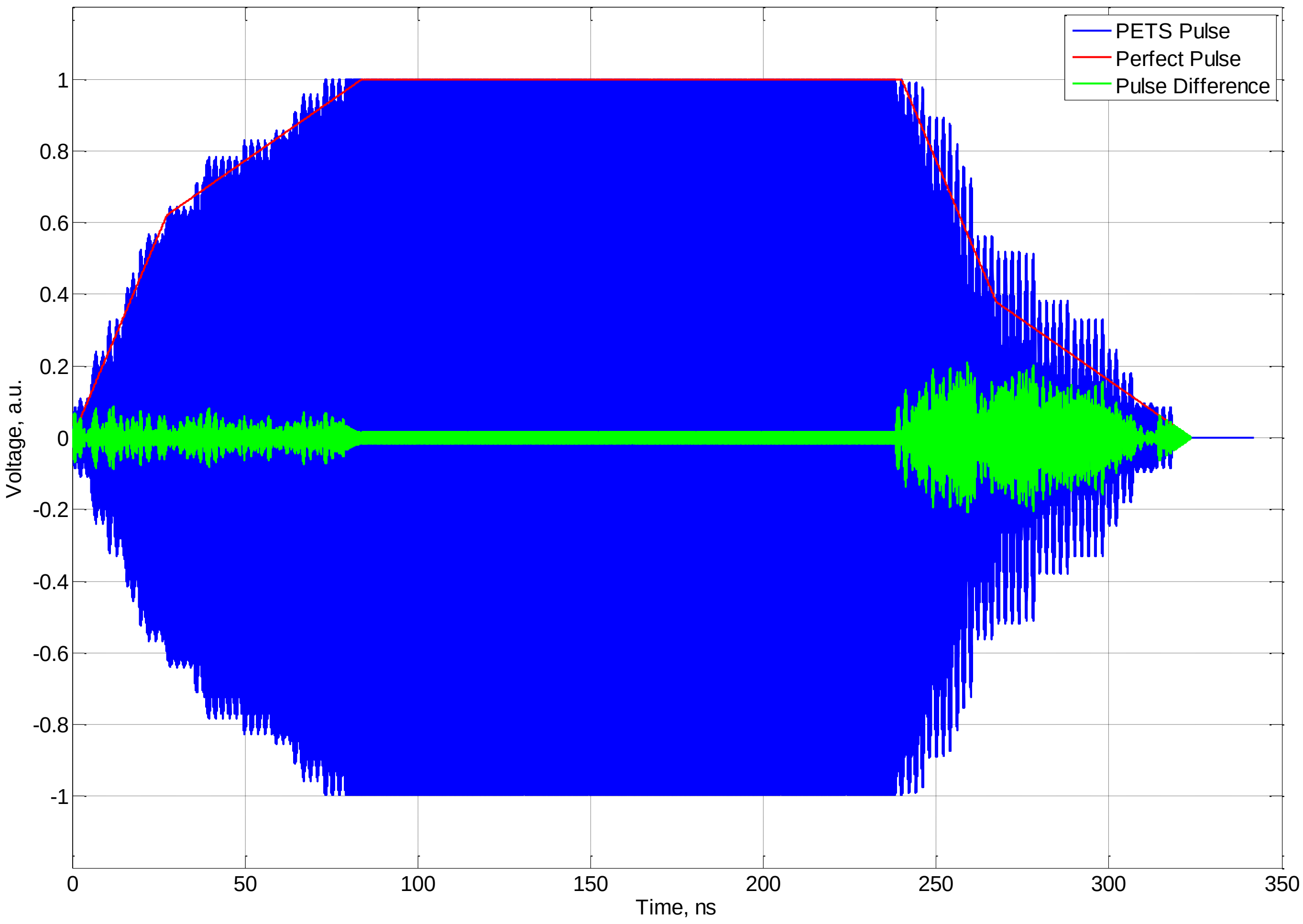
Brief Description:

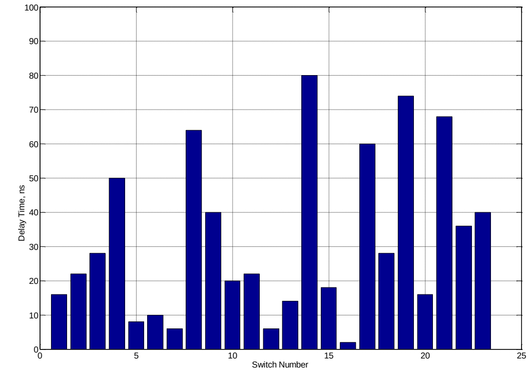
- generate ‘reference’ pulse
- generate random pulses
- find the minimal difference
- adjust delay step
- check energy spread

Beam Loading Utility



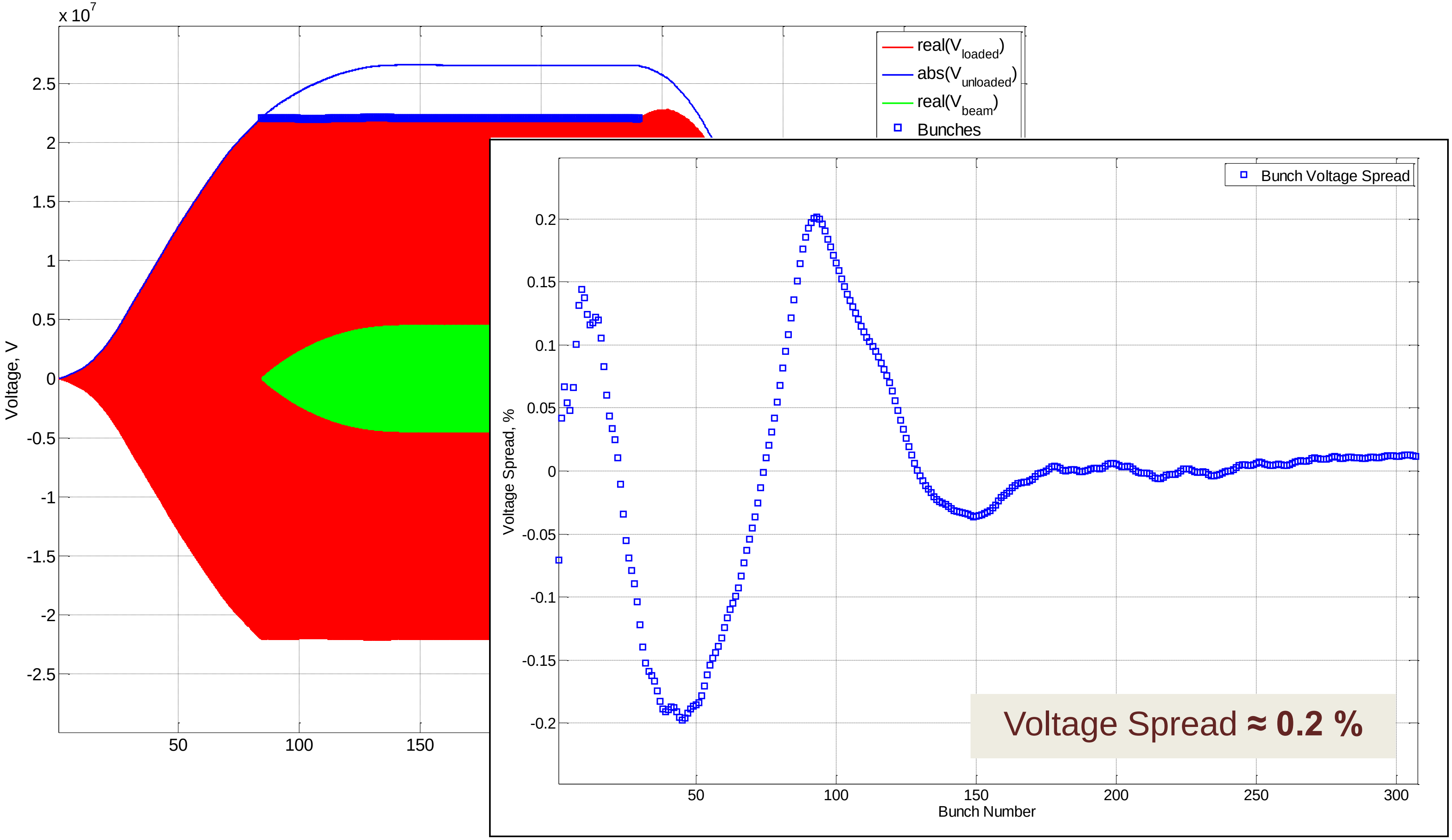
Optimized Pulse Shape



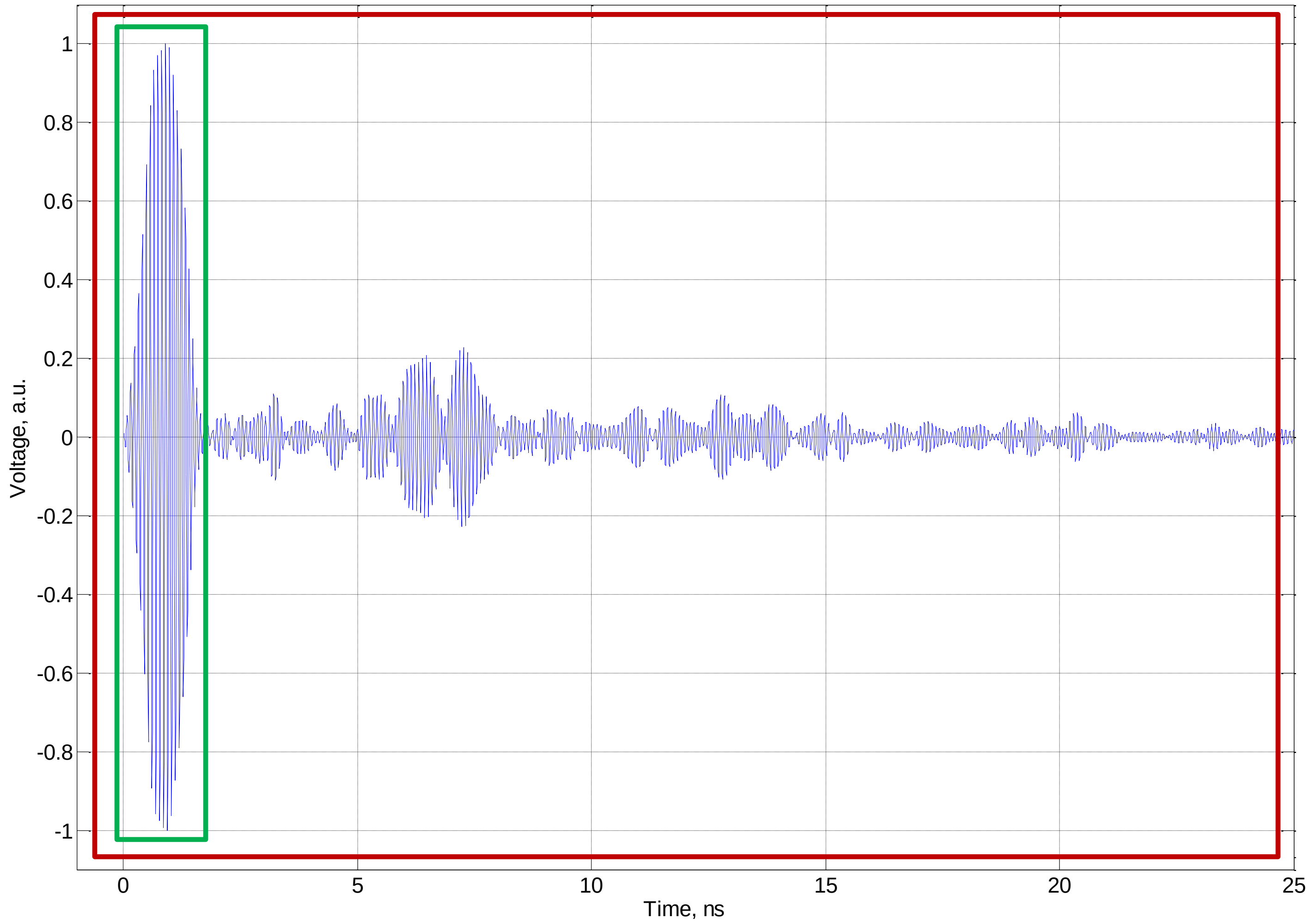


Corresponding switch delays in buncher

Optimized Pulse in Main Linac

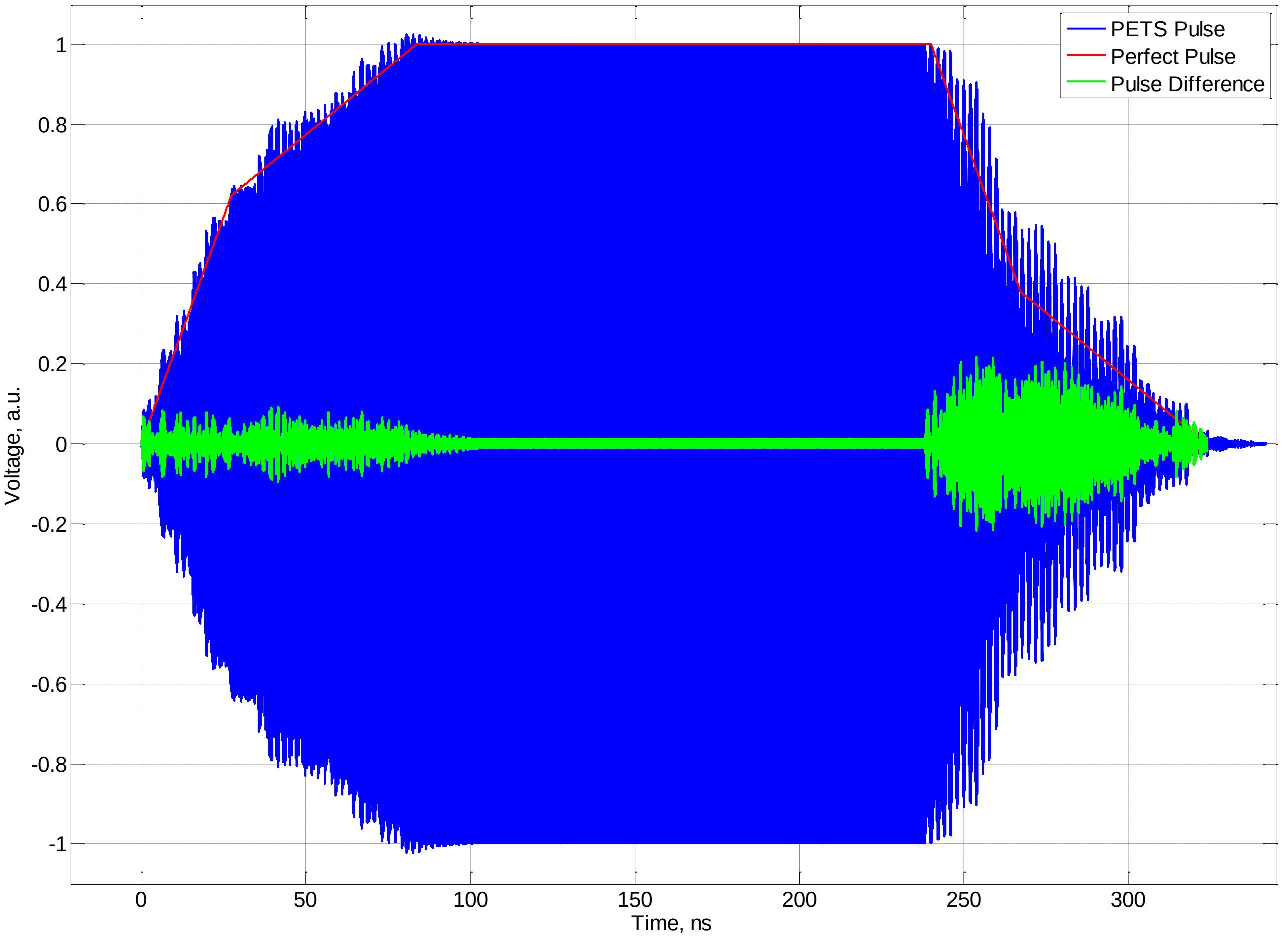


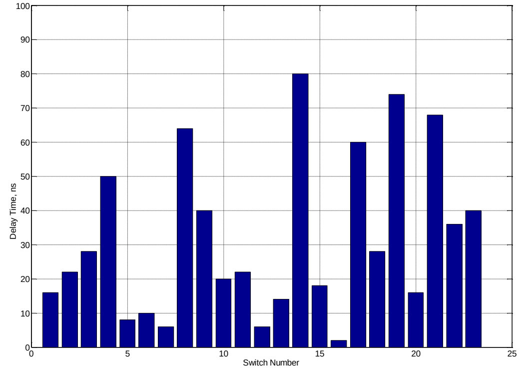
PETS: Single Bunch Response



*Alessandro Cappelletti, Igor Syratchev

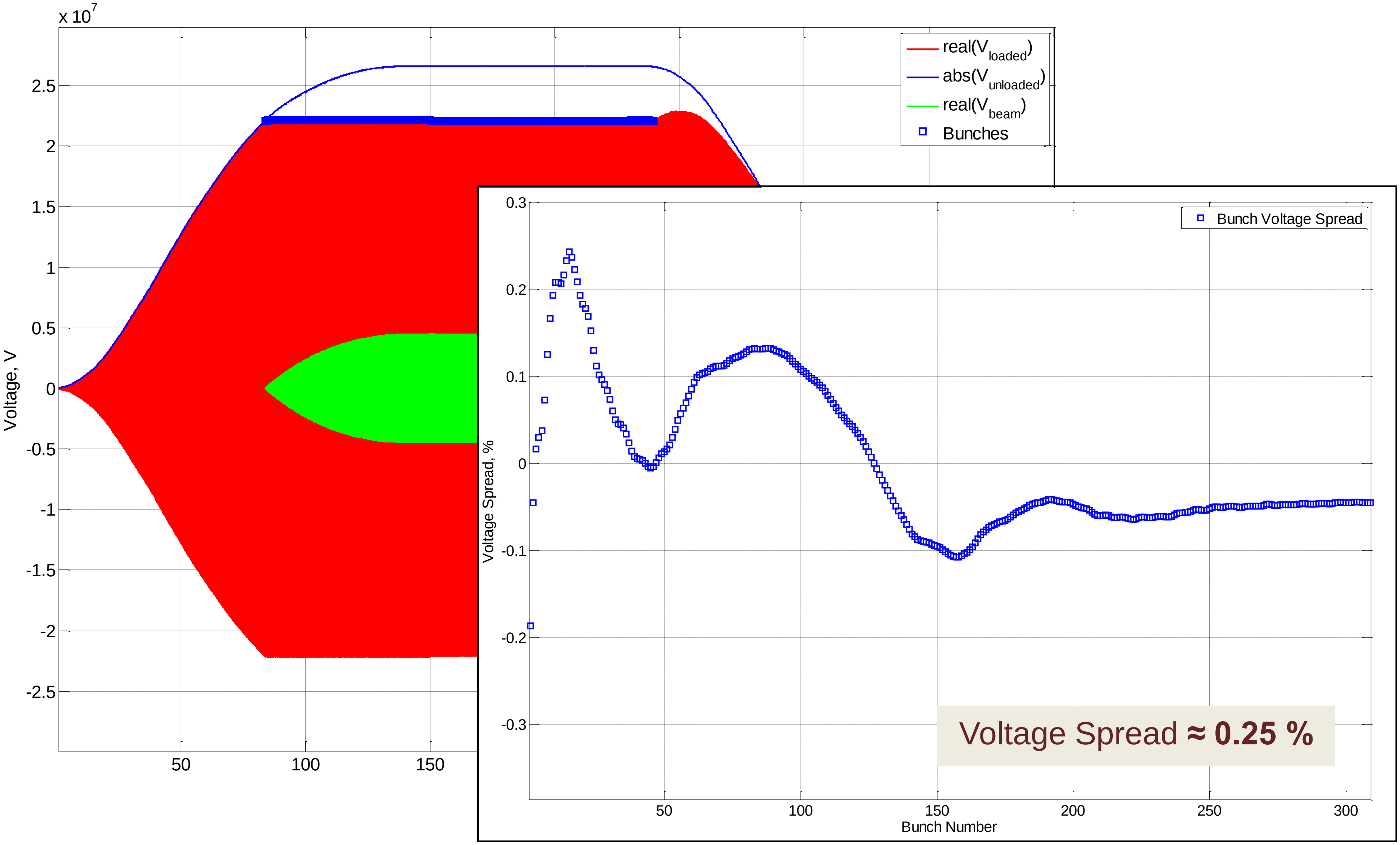
Full PETS Bunch Response Calculations





The same switch delays as for the simplified bunch response in PETS

Full PETS Bunch Response Calculations



Possible CTF3 experiment

	CTF3	CLIC
Delay loop	x2	x2
Combiner Ring #1	x3	x4
Combiner Ring #2	x4	-
Bunch Frequency	1.5 GHz	2 GHz
Number of Bunches	1-226	312
Bunch Charge	Total charge of 12 nC	0.6 nC
Energy	177 MeV	2.424 GeV
Energy spread	2% (from CALIFES)	0.134% (from damping ring)
PETS length	1 m	0.213 m

CTF3 Collaboration Technical Meeting: Frank TECKER, "Status of CTF3. Feasibility studies: experimental program in 2010, 2011", May 5, 2010 at 14:30

Conclusions

1. Beam loading model based on the plane wave approach seems to be a reasonable one

2. Pulse shape optimization algorithm gives the same order of the voltage spread as the “perfect” trapezoidal one

3. Reflections in the tail of the PETS bunch response can increase voltage spread but not dramatically.

Further steps

1. Parabolic and analytical “perfect” pulse calculations
2. Possible different optimization techniques usage, i.e. genetic algorithm
3. CTF3 experiment for the beam loading compensation

Thank you for the attention!