# Compensation of Transient Beam-Loading in CLIC Main Linac

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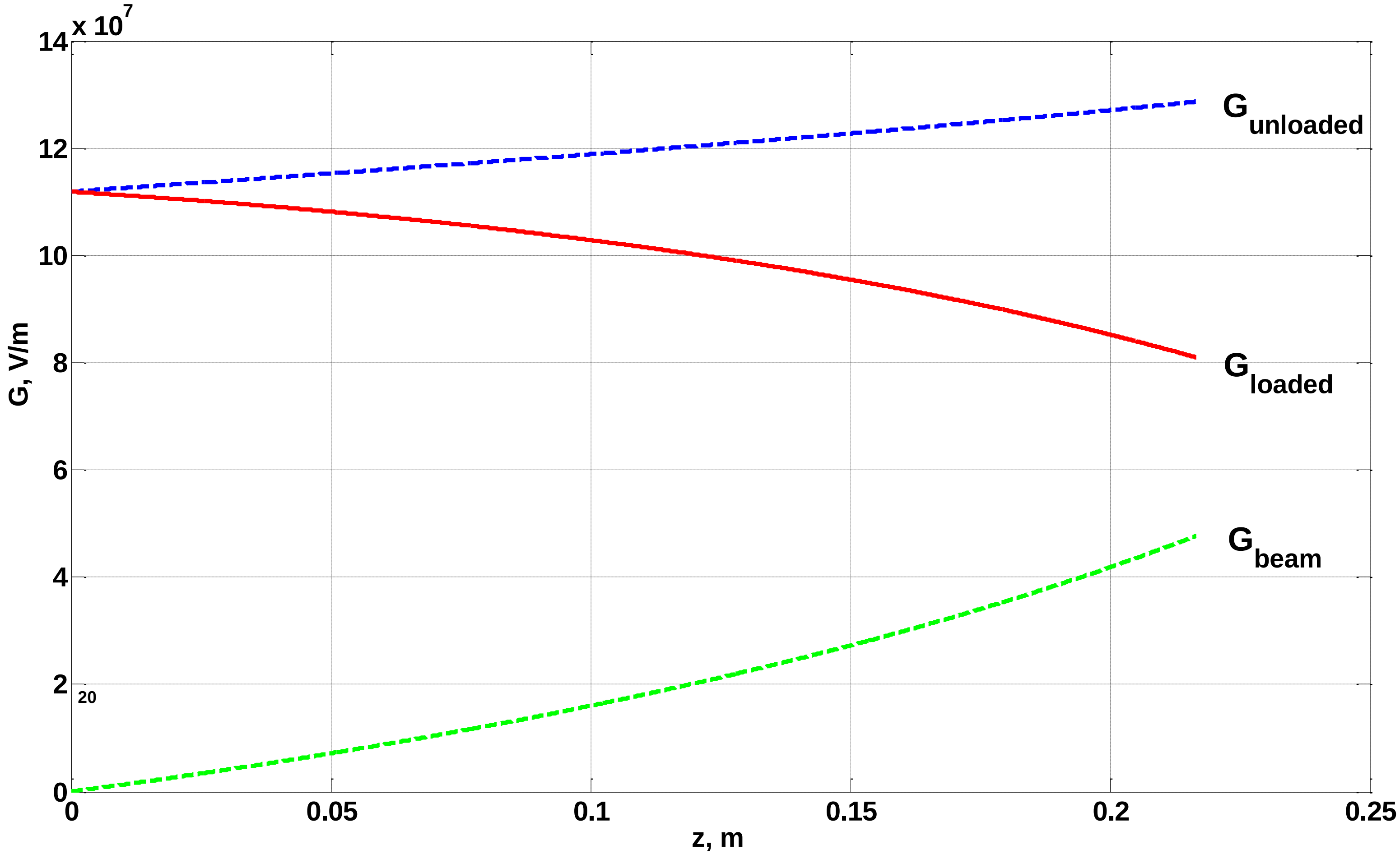
# Motivation: CLIC Performance Issue

In order to have luminosity loss less than 1%, the RMS bunch-to-bunch relative energy spread must be below 0.03%

*CLIC-Note-764, private conversations with Daniel Schulte (CERN)

# Beam Loading: Steady State




*Beam loading for arbitrary traveling wave accelerating structure. A. Lunin, V. Yakovlev

# Energy Spread Minimization Scheme

## Unloaded Voltage in AS

- fix phase switch times in buncher
- generate corresponding drive beam profile
- take into account PETS (+PETS on/off) bunch response
- calculate unloaded voltage

↓

## Loaded Voltage in AS

- calculate AS bunch response
- calculate total beam loading voltage
- add to unloaded voltage

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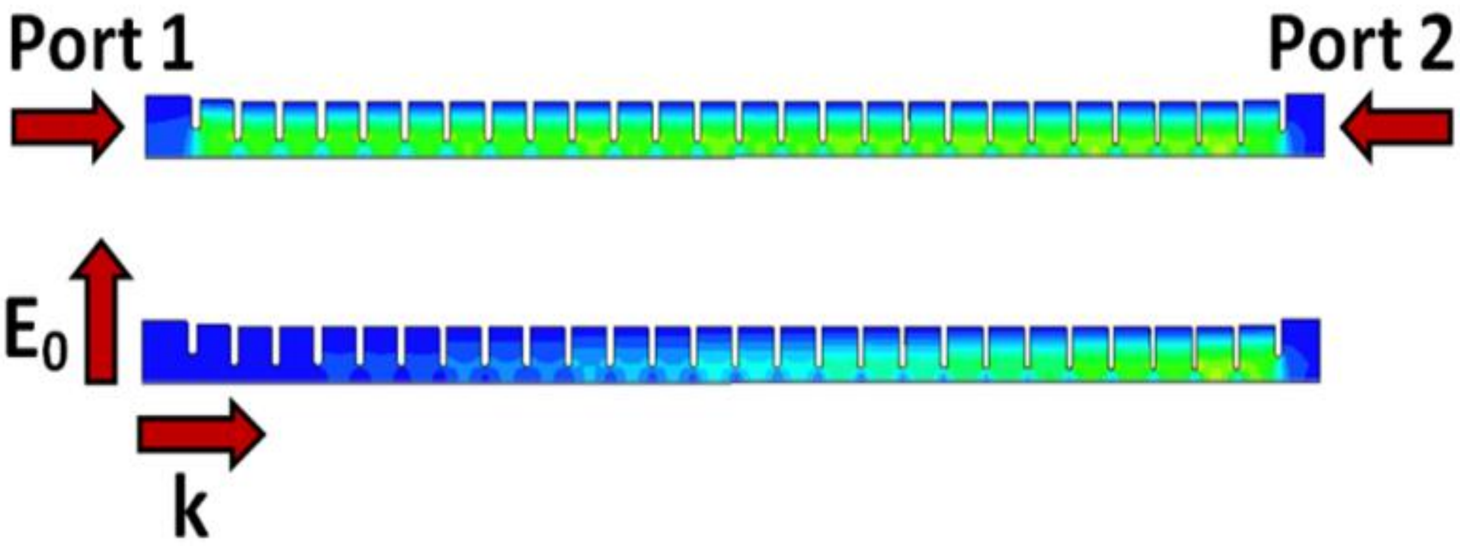
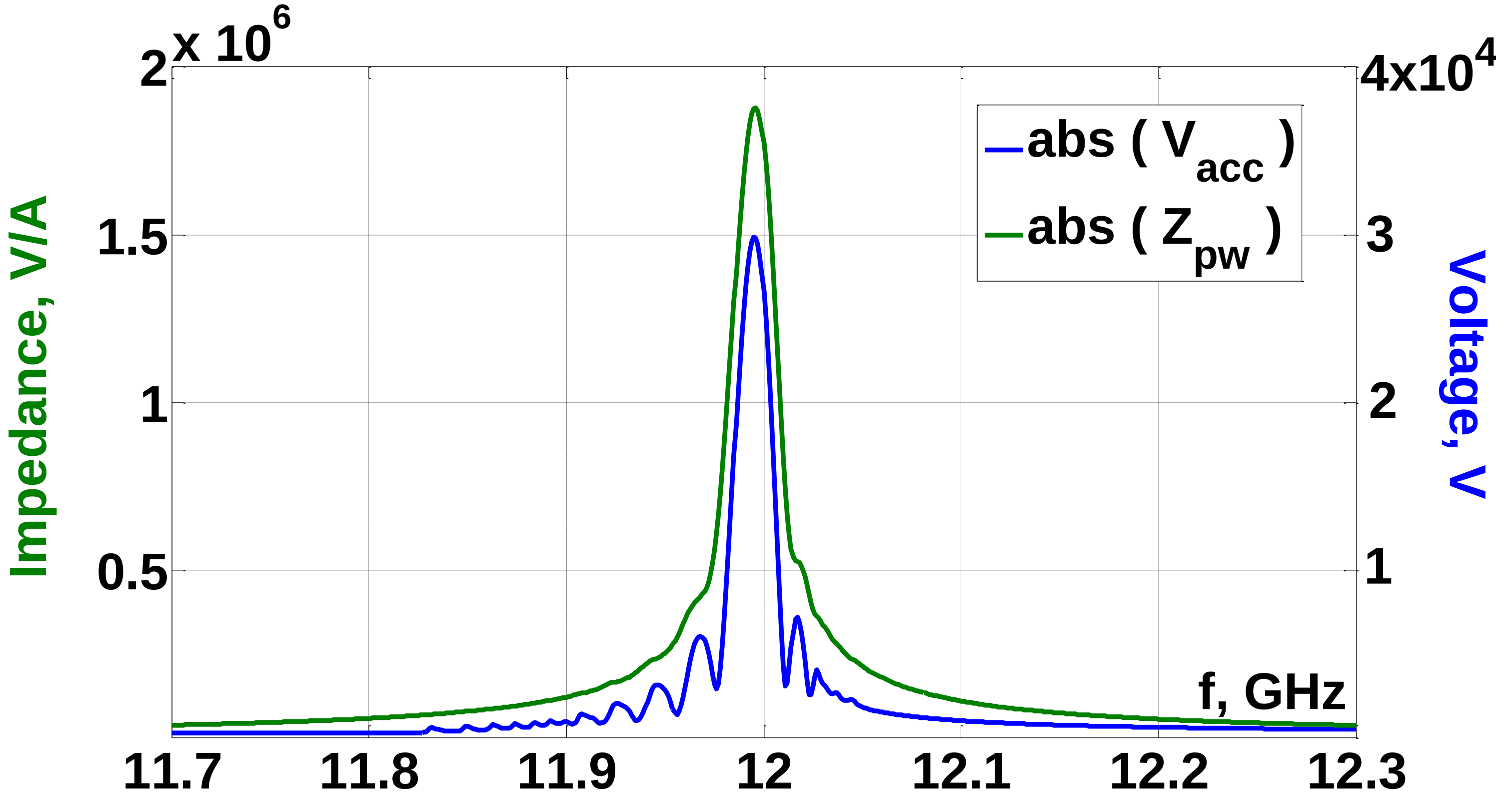
## Energy Spread Minimization varying buncher delays

# Electric Field Distribution for Port and Plane Wave Excitations



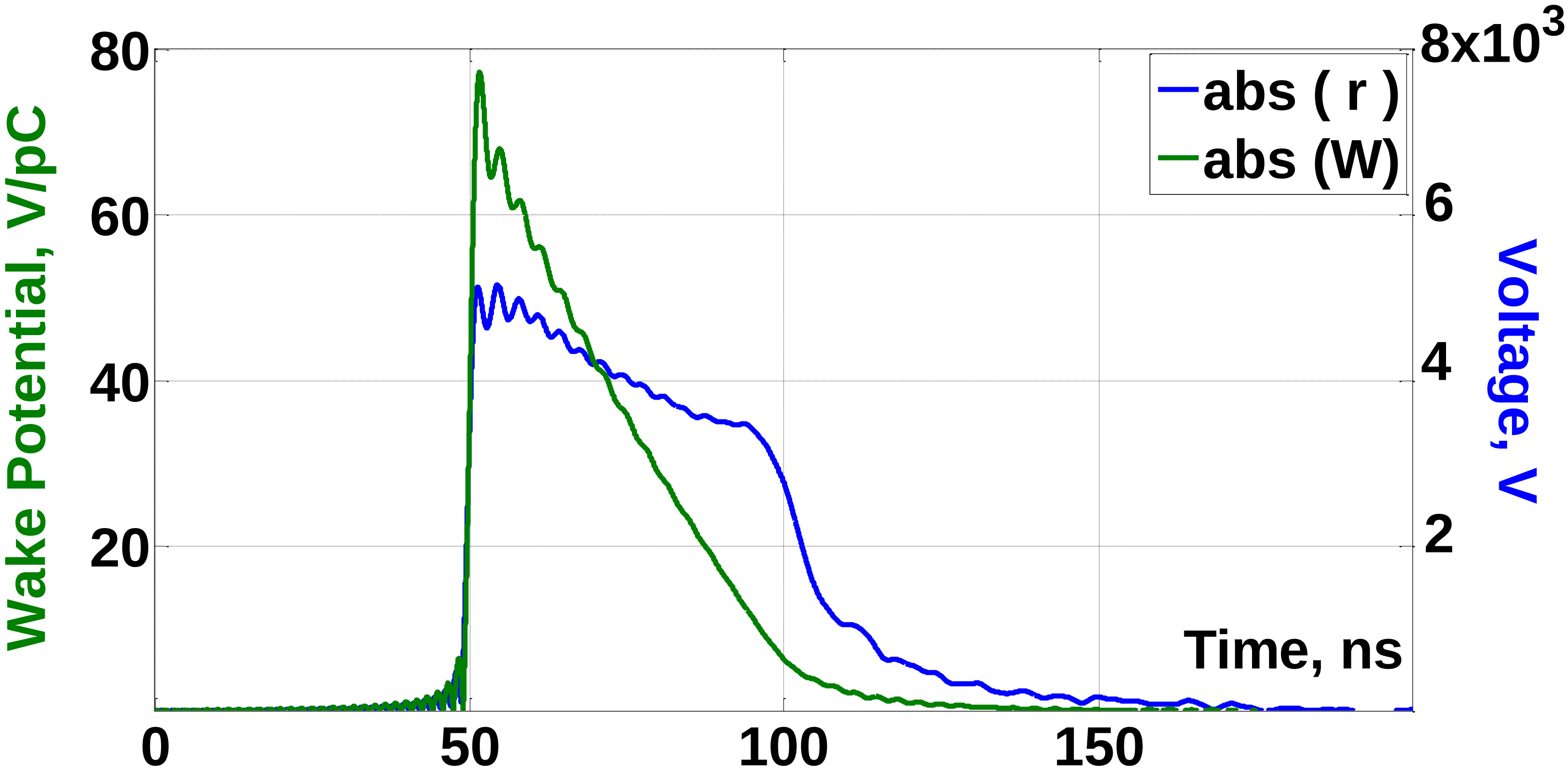

Considering T24 CLIC main accelerator structure

# Accelerating Voltage for the Port excitation and Beam Impedance

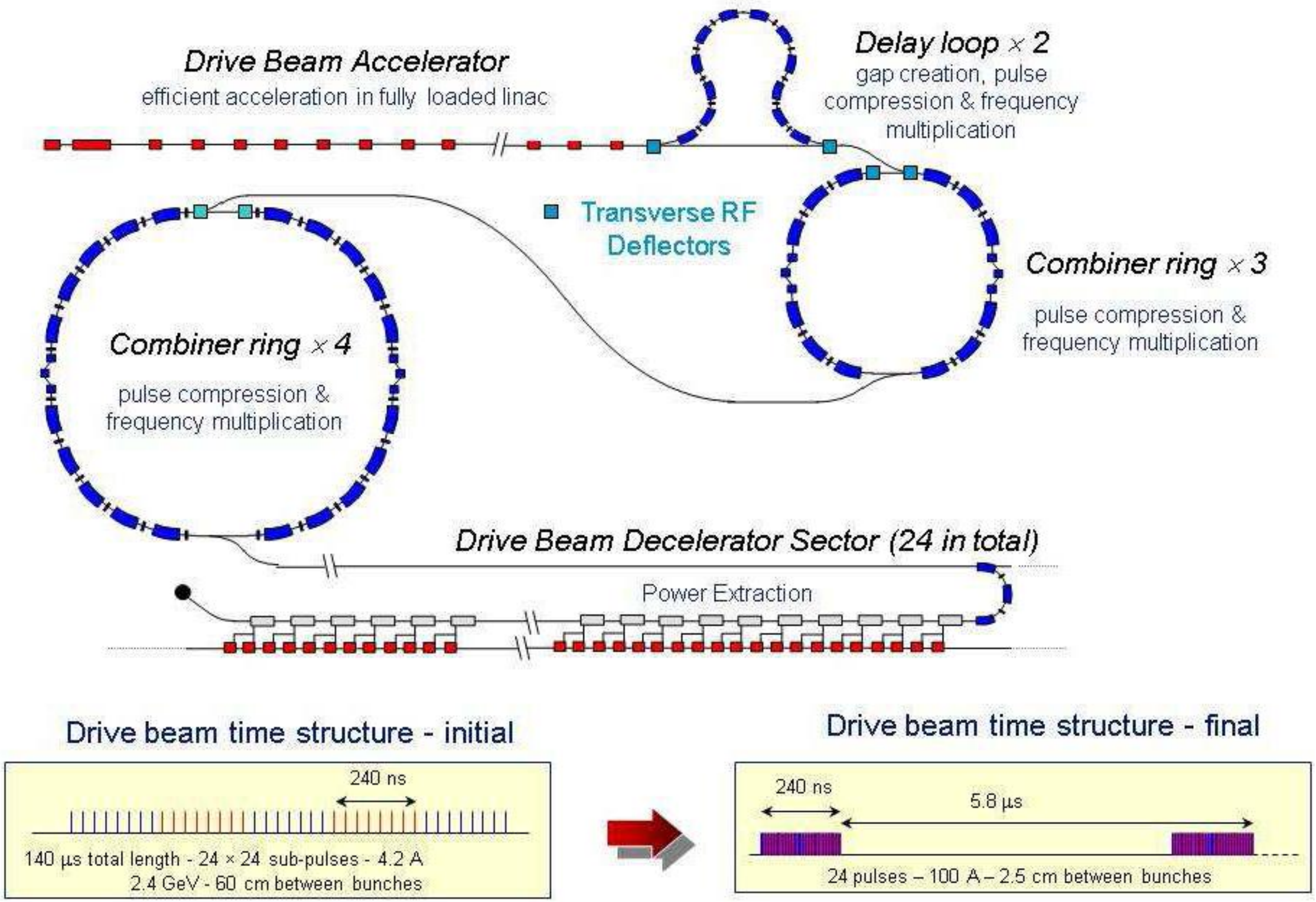



**$E^{port}_z$ (z,f)** → [ exp ( ± i *z *ω/c ) ] → [ ∫ dz ] → **$V_U$ (f)**
**$E^{pw}_z$(z,f)** → [ exp ( ± i *z *ω/c ) ] → [ ∫ dz ] → V (f) → [$I_{HFSS}$ = 2*π*r * $E_0$ / $Z_0$] → **Z(f)**

# Envelopes of the Time Response for the Port Excitation and Wake Potential



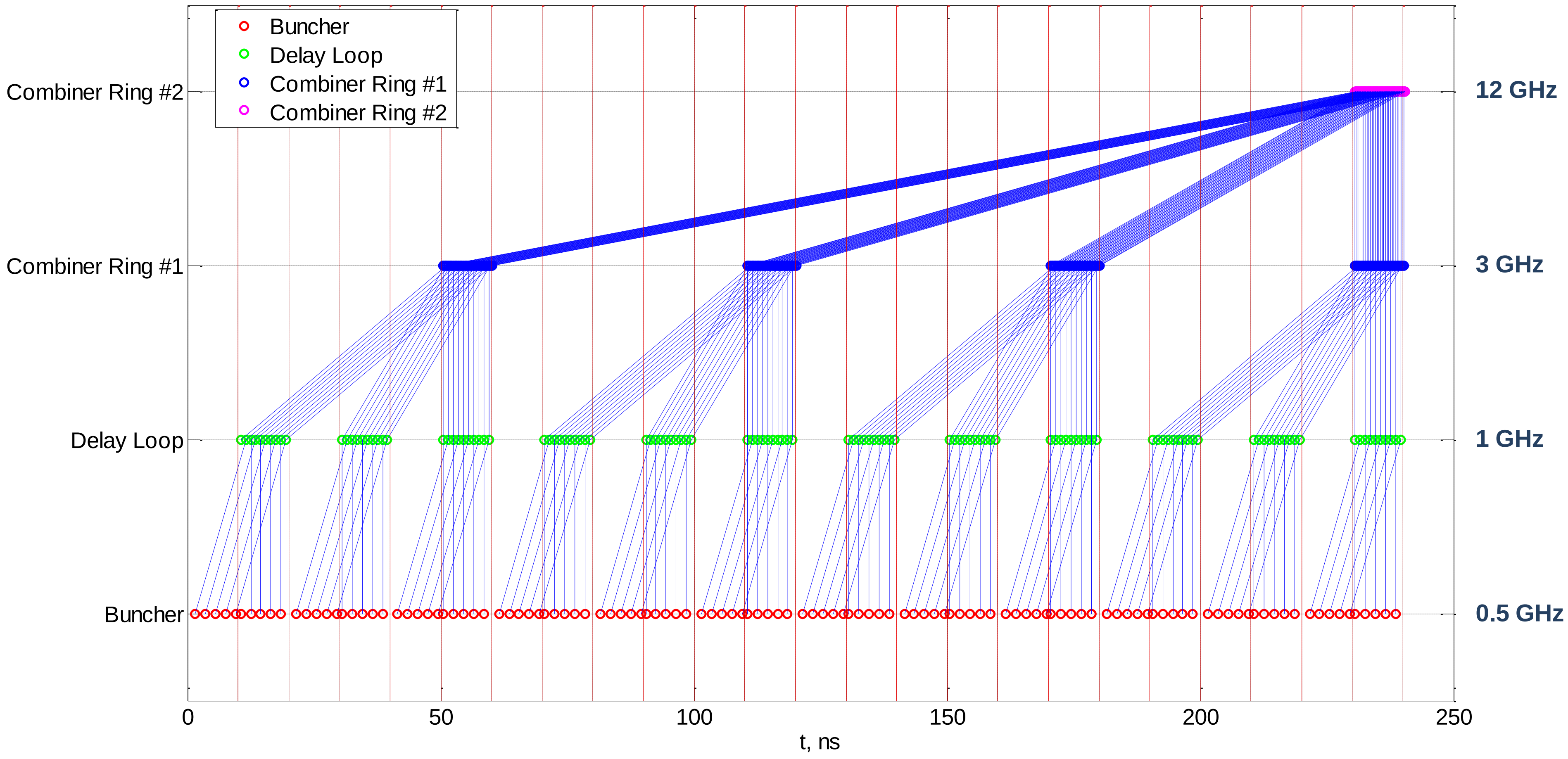
# CLIC Drive Beam Generation Complex



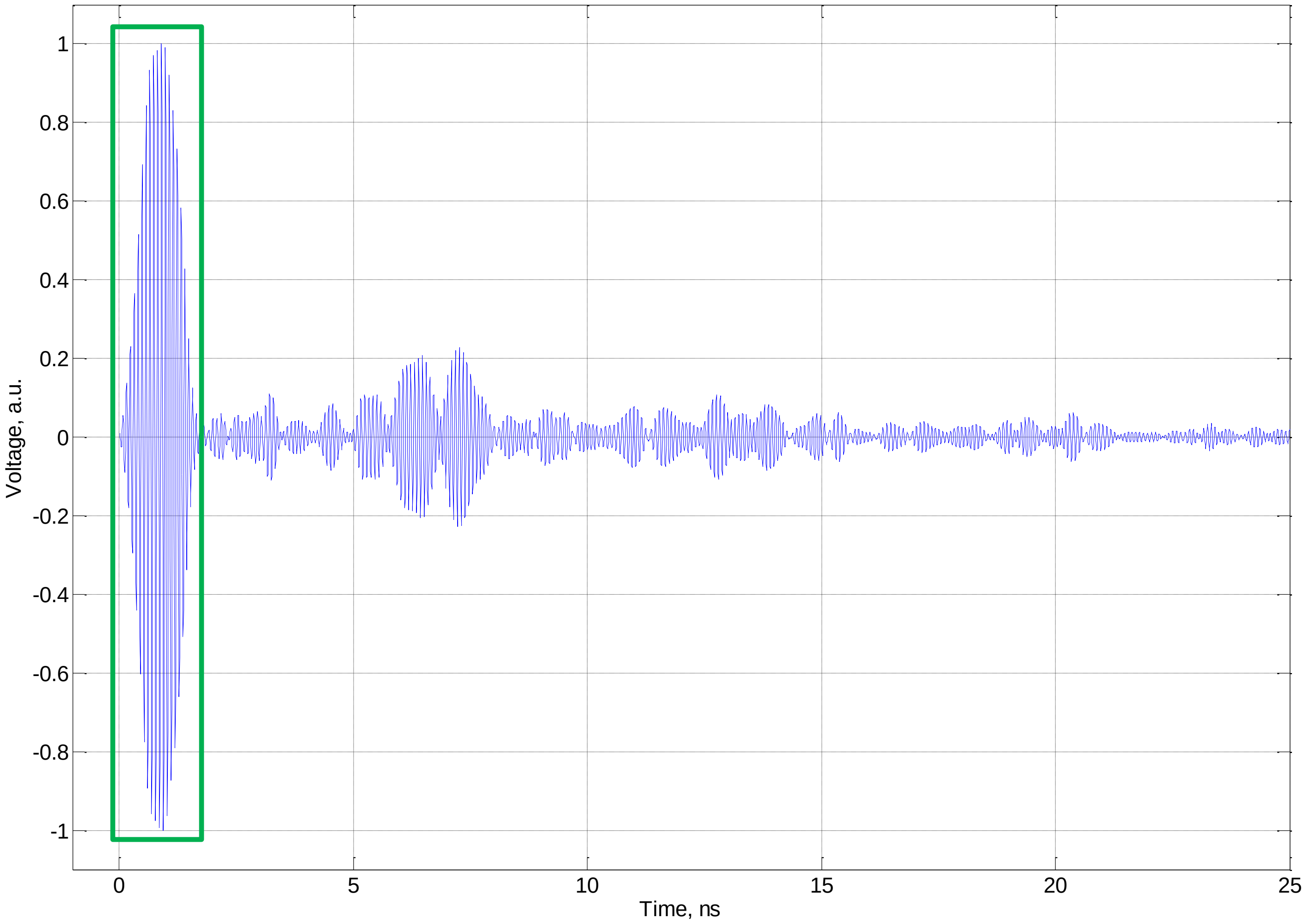

*CLIC-Note-764

# Drive Beam Combination Steps

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

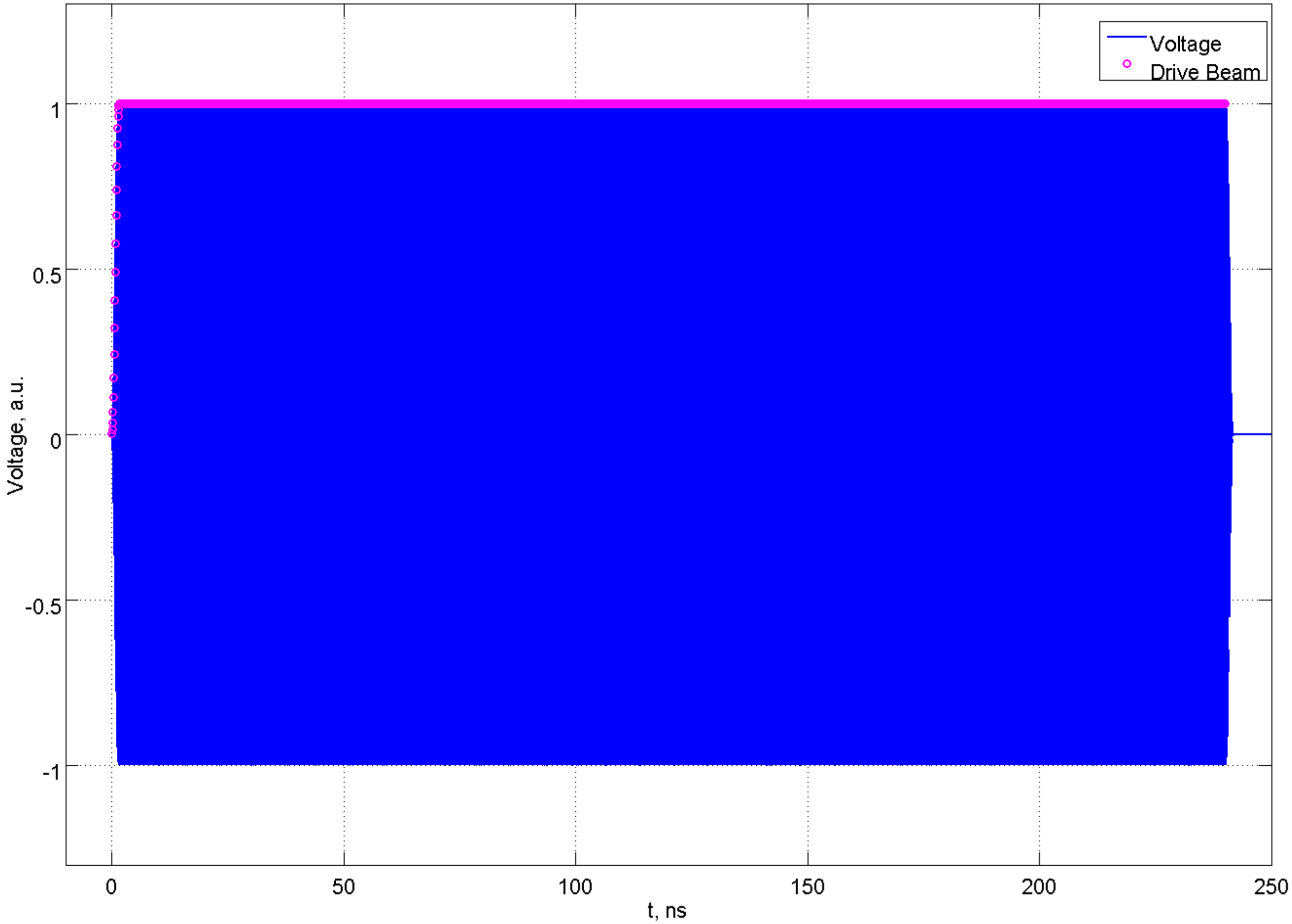


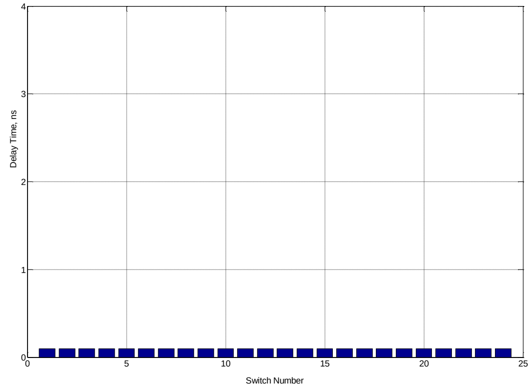
# PETS: Single Bunch Response




*kindly provided by Alessandro Cappelletti, Igor Syratchev (CERN)

# PETS: Generated Rectangular Pulse

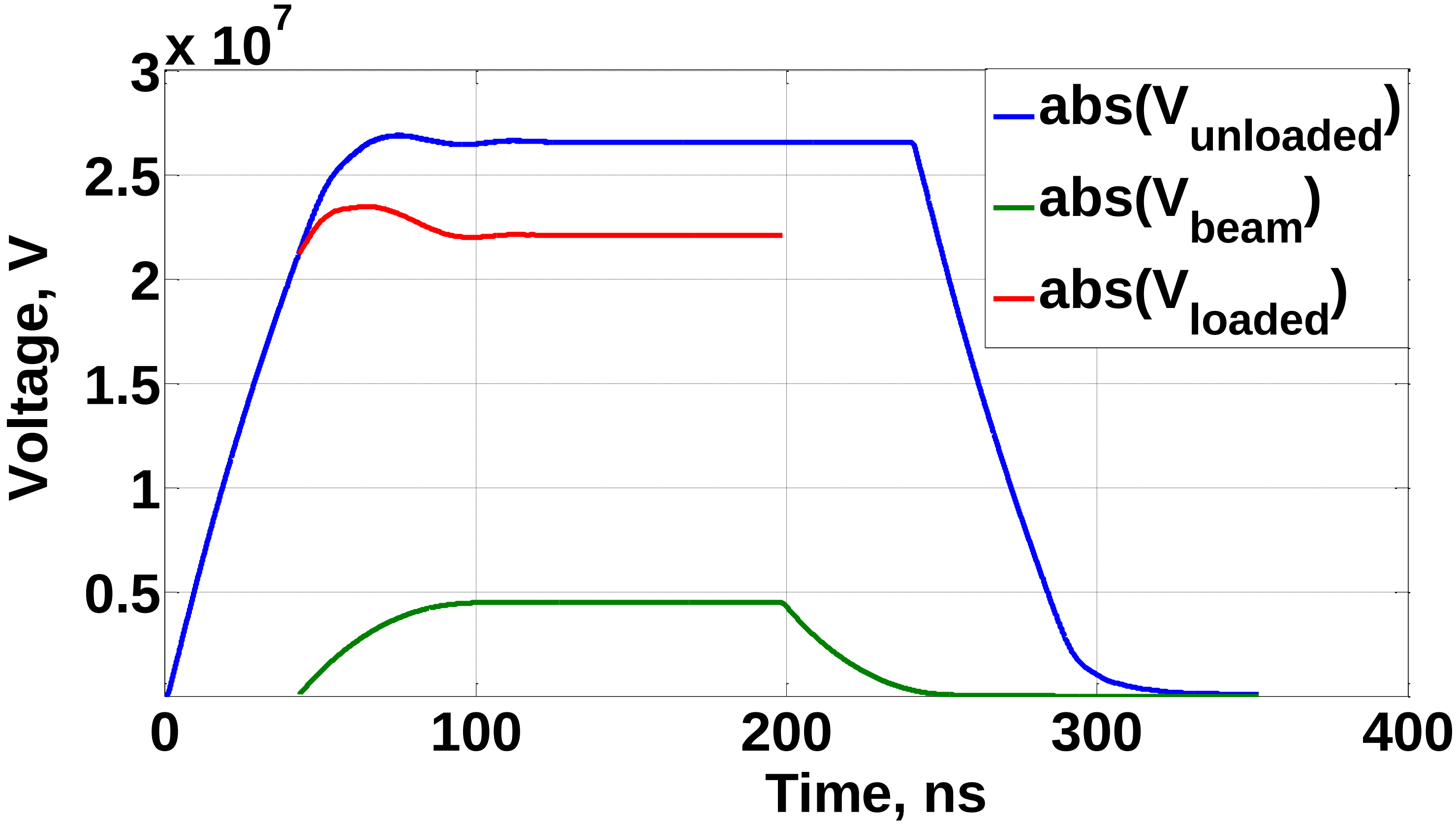



No delays, just nominal (~240ns) switch times in buncher

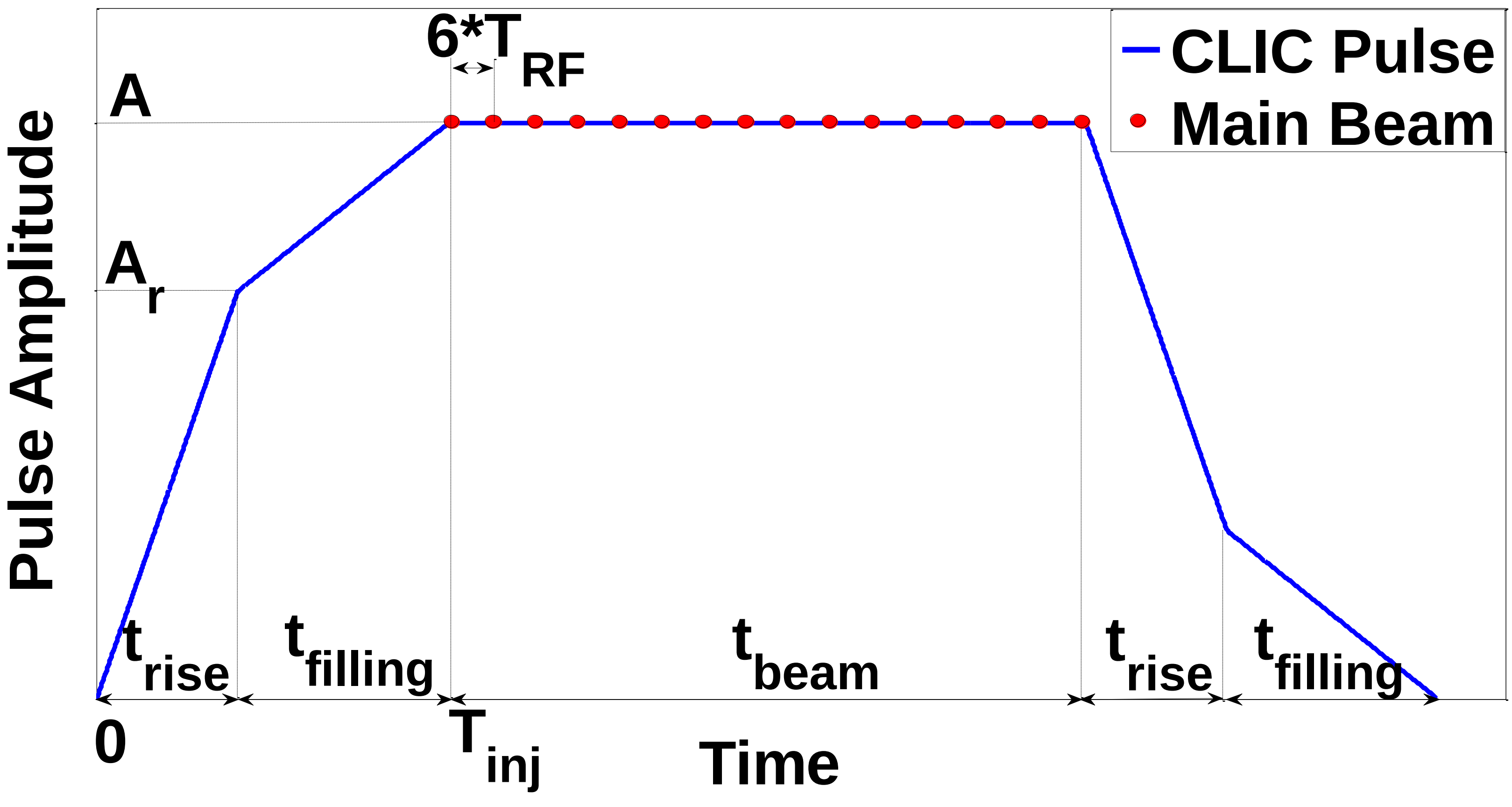
$t_{rise} \approx 1.5$ ns

# Rectangular Pulse in Main Linac

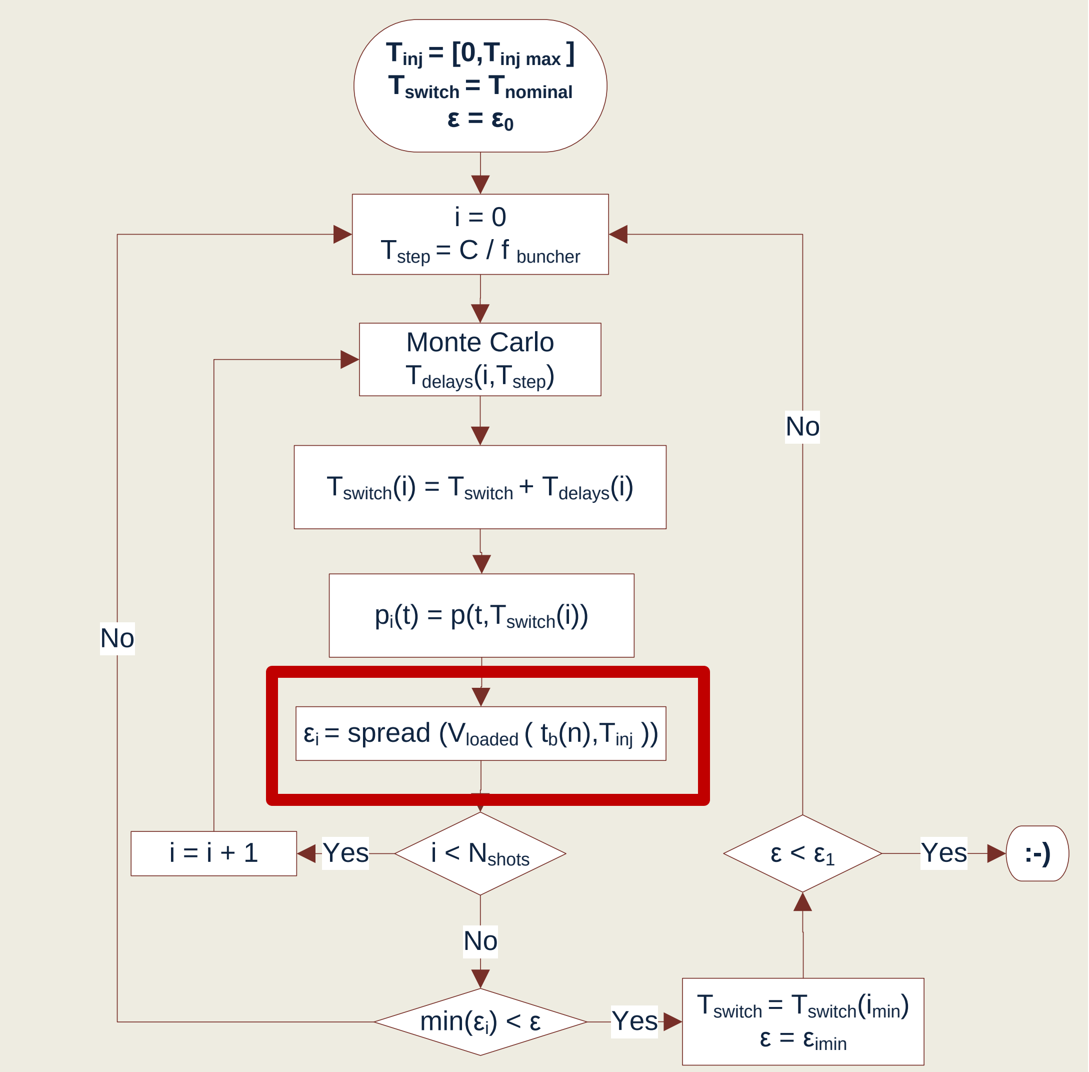



Optimizing injection time one can
optimize the energy spread down to the level of **6%** only

# Schematic Pulse Shape for CLIC



# Optimization Algorithm




**Brief Description:**

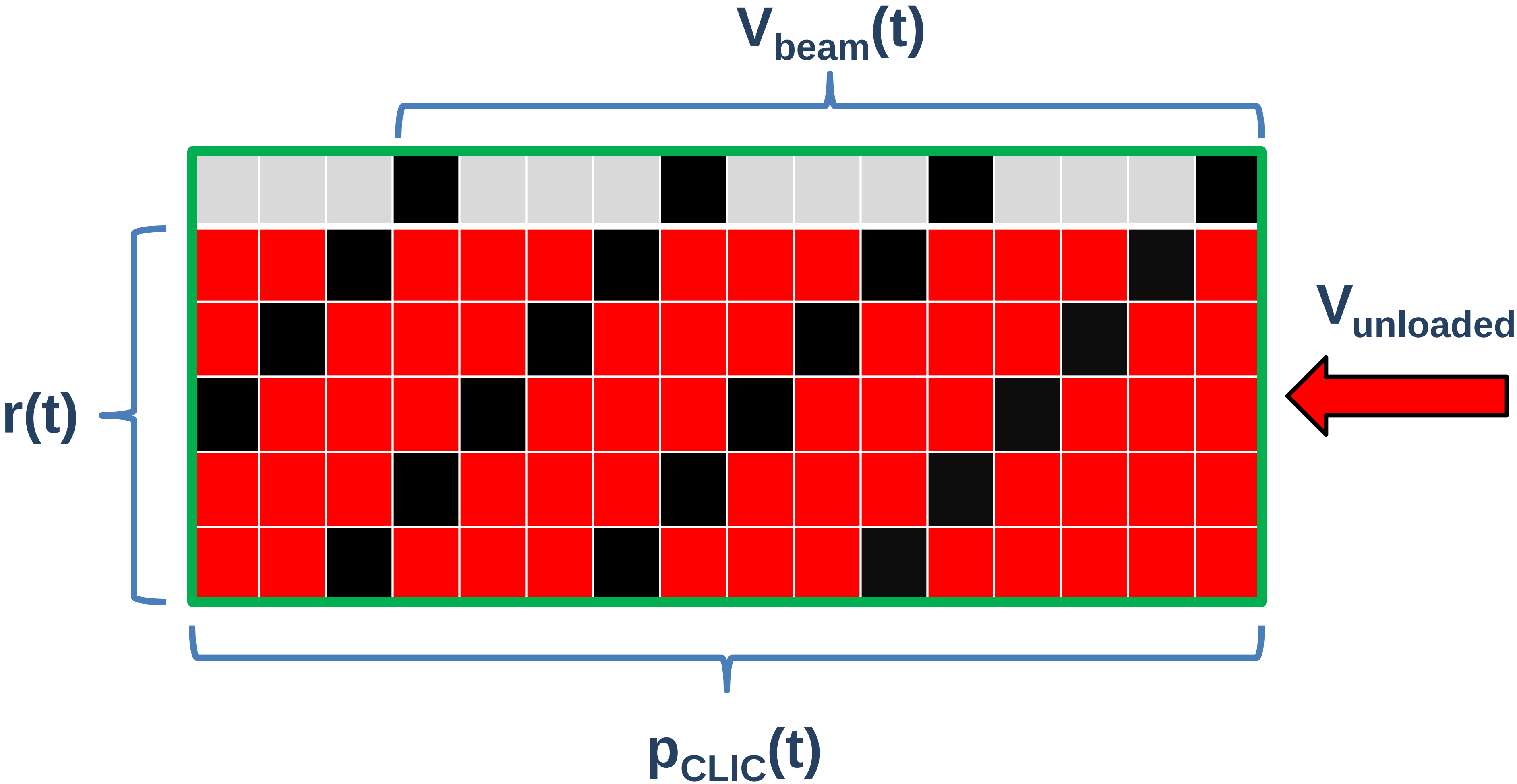
1. Fix injection time

2. Generate delays

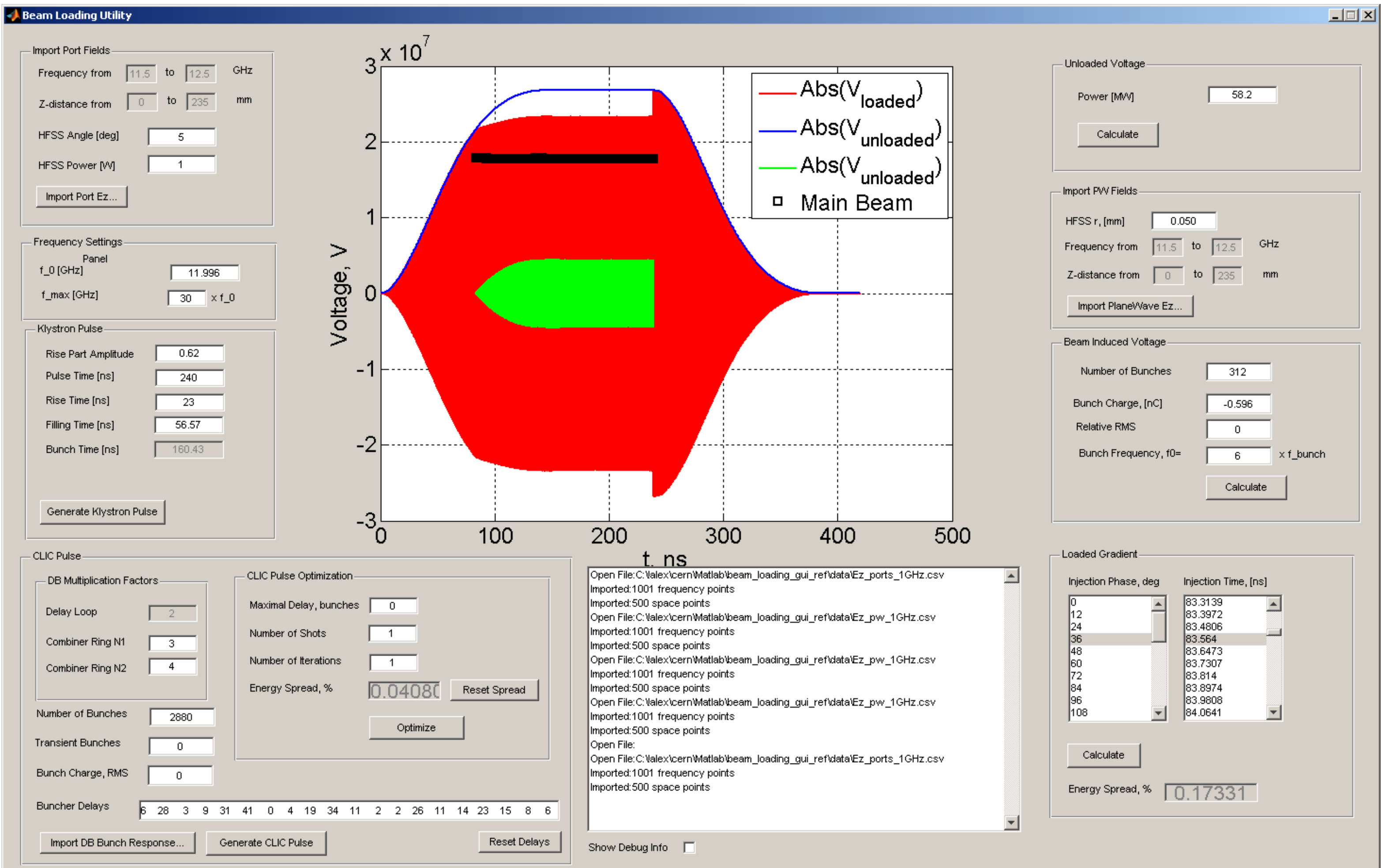
3. Find the minimal energy spread and optimal delays

4. Repeat 2. starting from the optimal delays

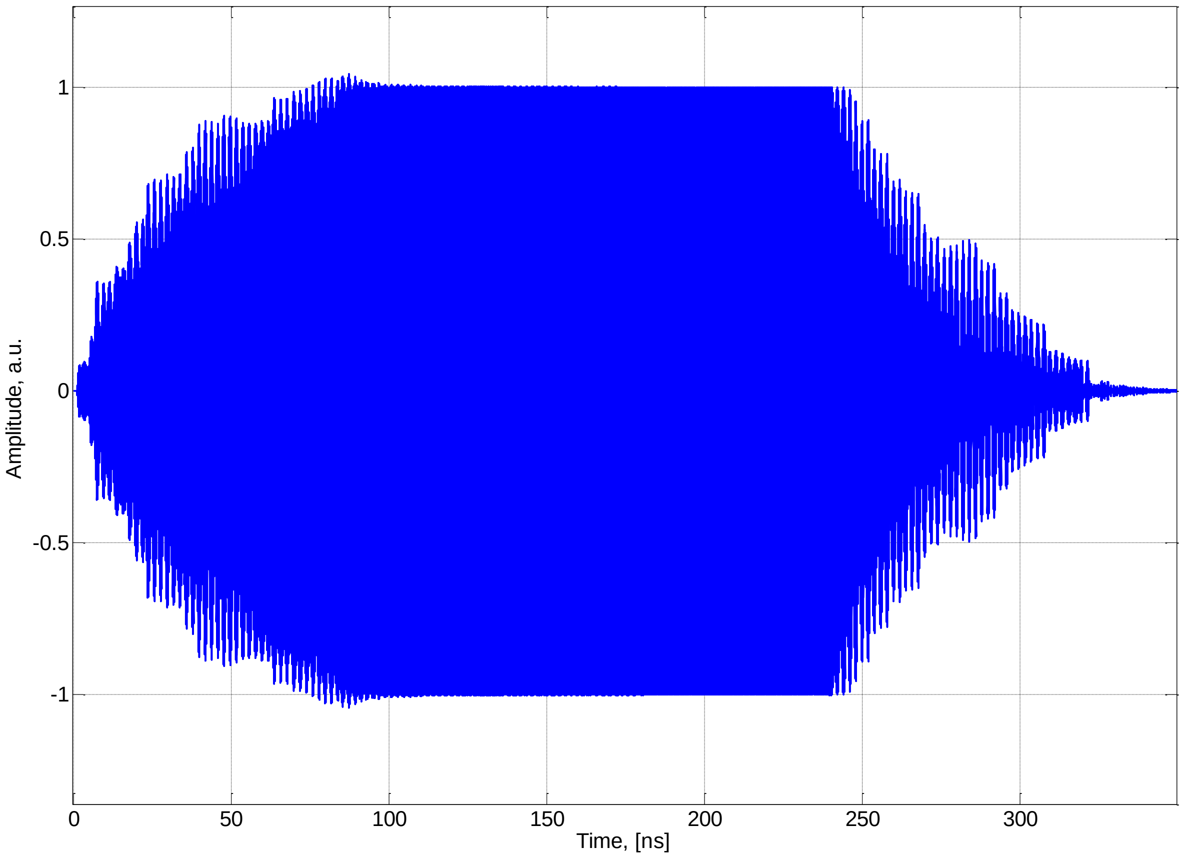
# Energy Spread Calculation

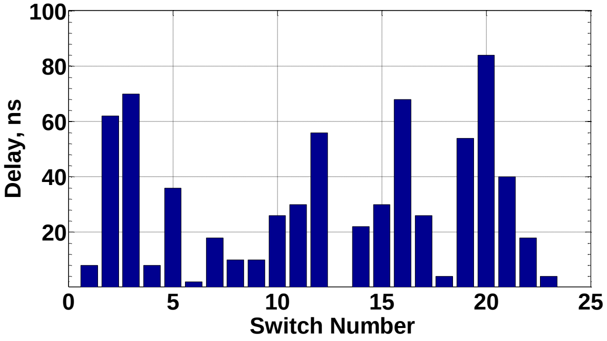


# Energy Spread Optimization Utility



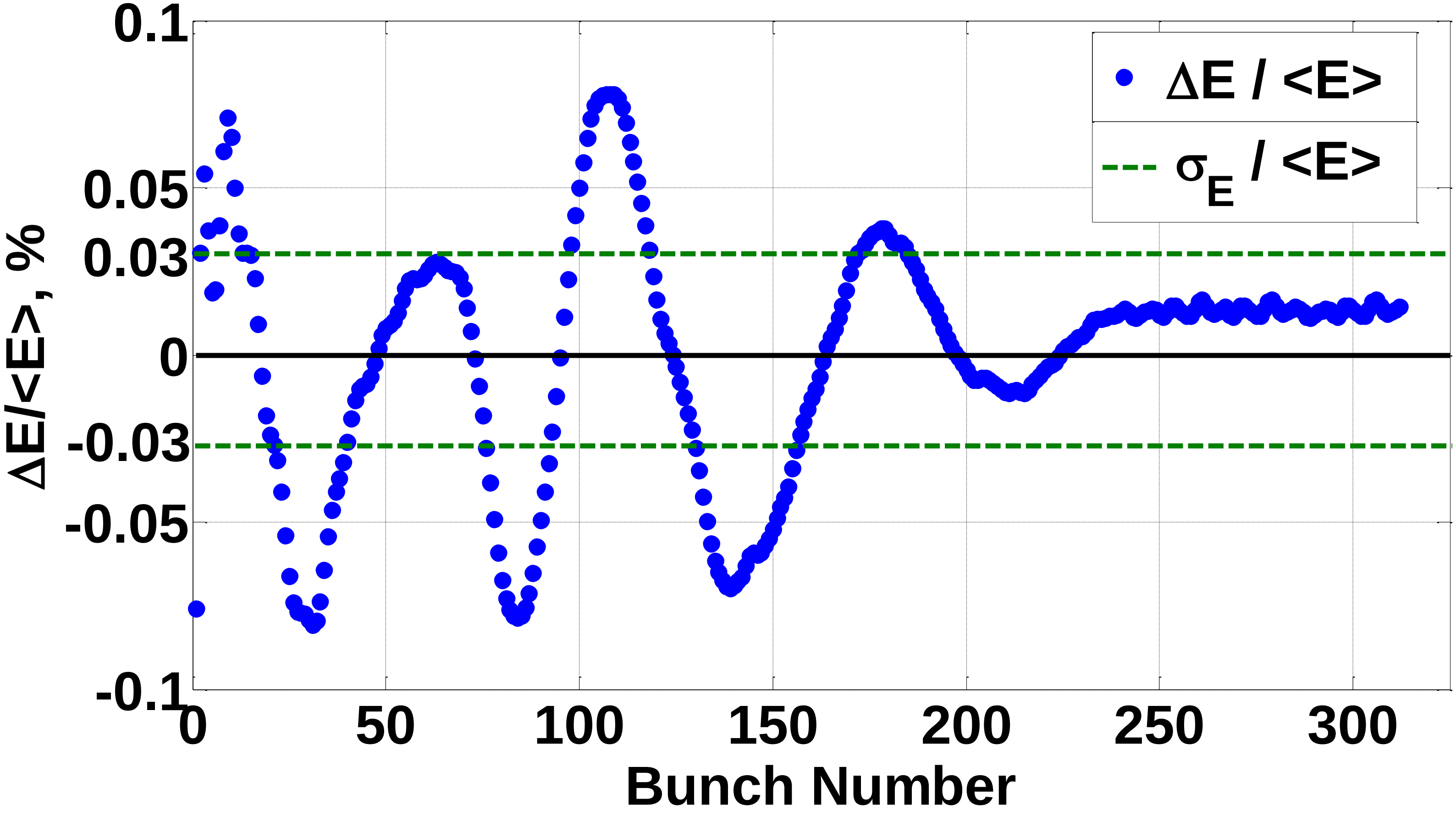
# Optimized Pulse Shape




**Corresponding switch delays in buncher**

# Optimized Energy Spread along the Main Beam



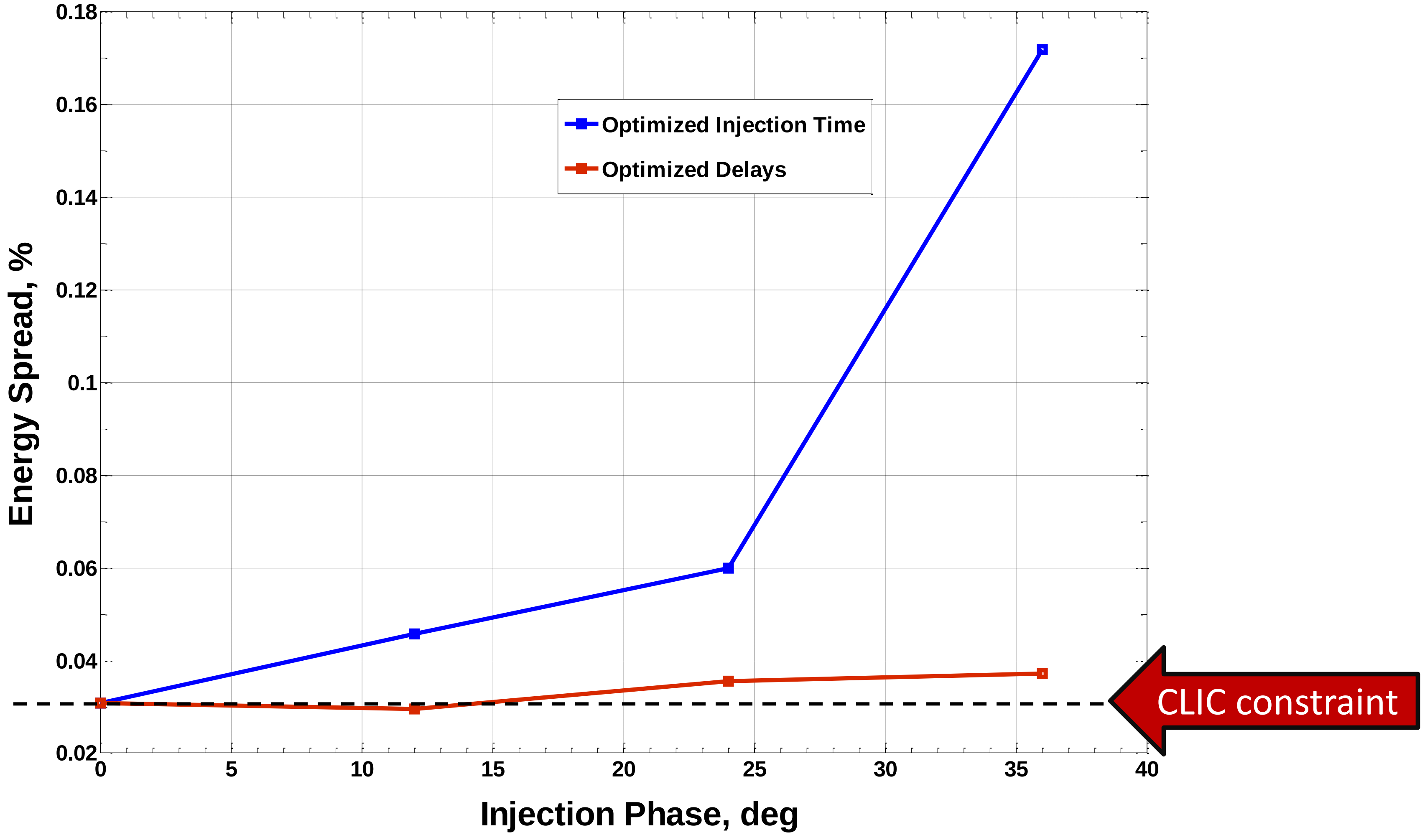

RMS bunch-to-bunch relative energy spread is around **0.03%**

# Model Improvements

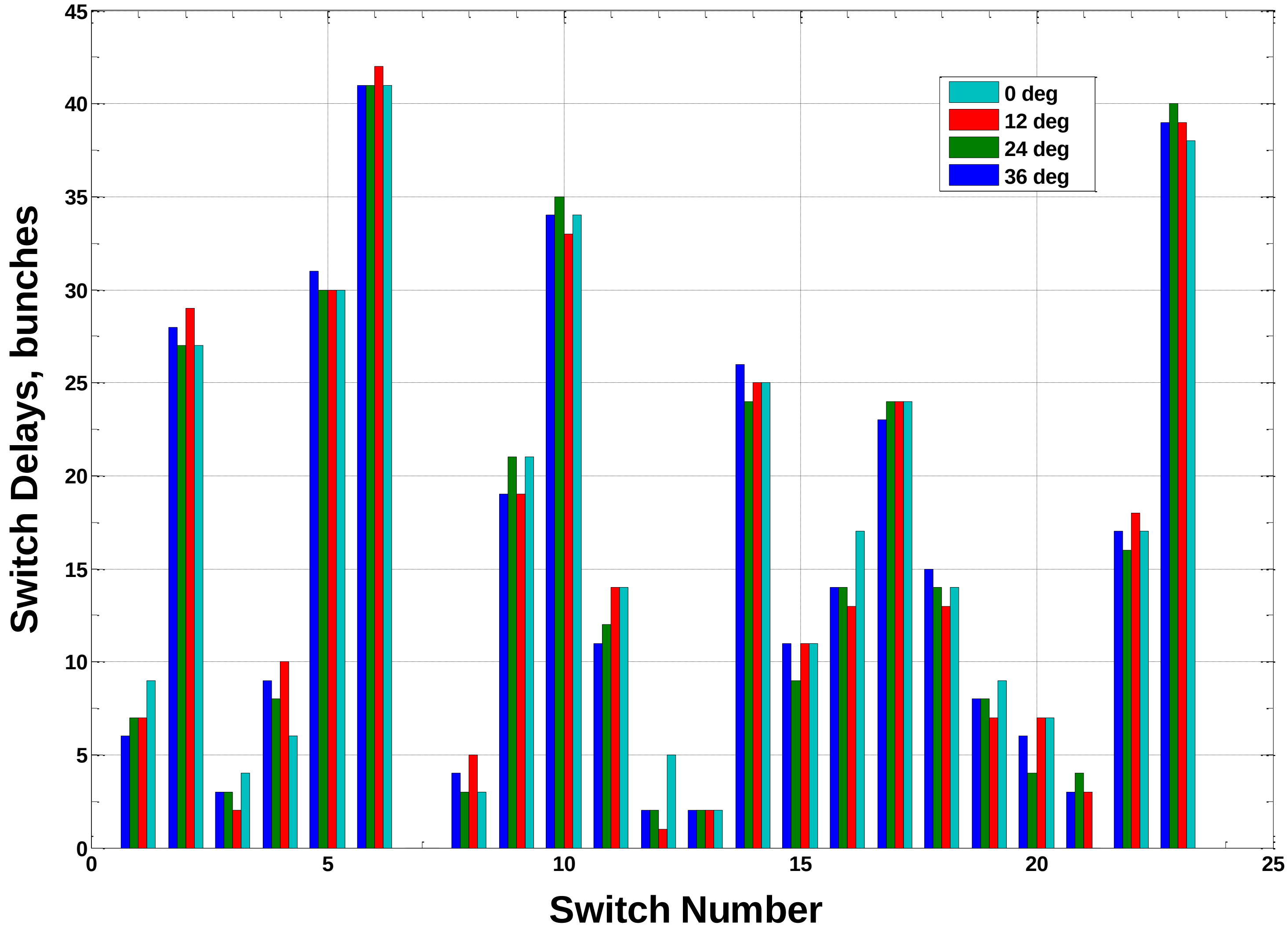
1. For BNS damping it is necessary to inject bunches a bit (10 - 30 deg) off-crest

2. Take into account transient in the subharmonic buncher during DB phase switch

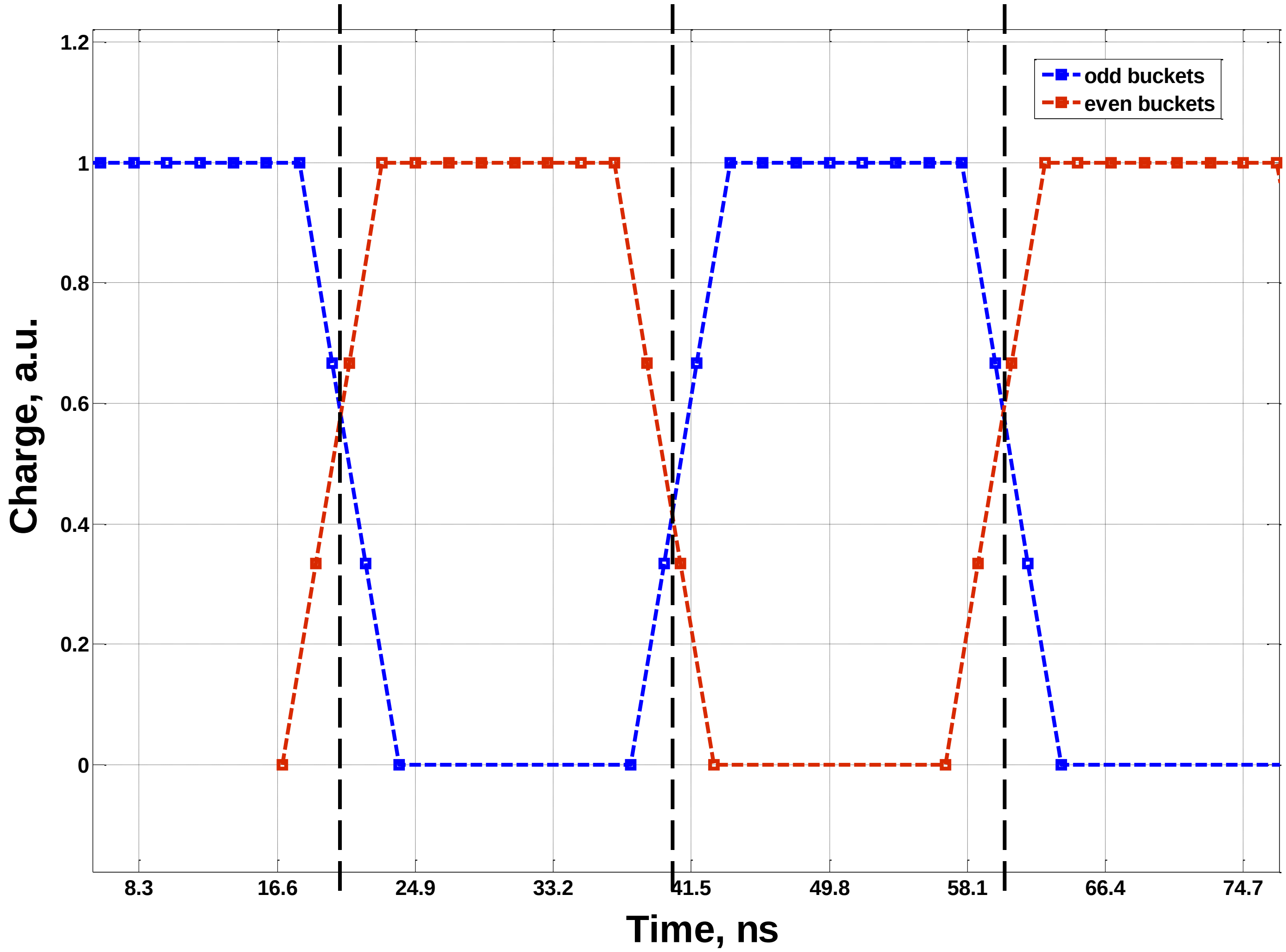
# Energy Spread Dependence on the Injection Phase



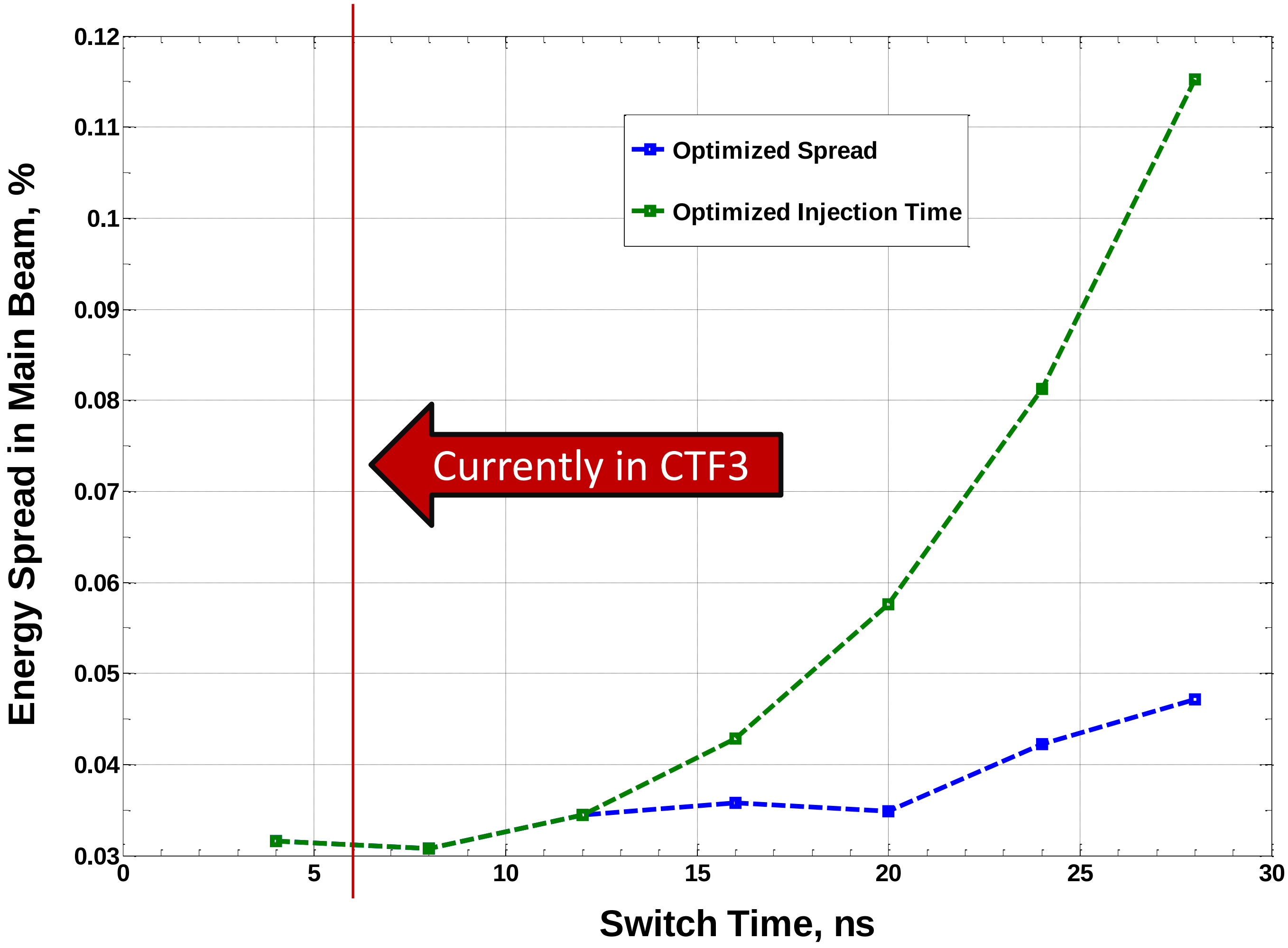
# Optimal Switch Delays for the Different Injection Phases



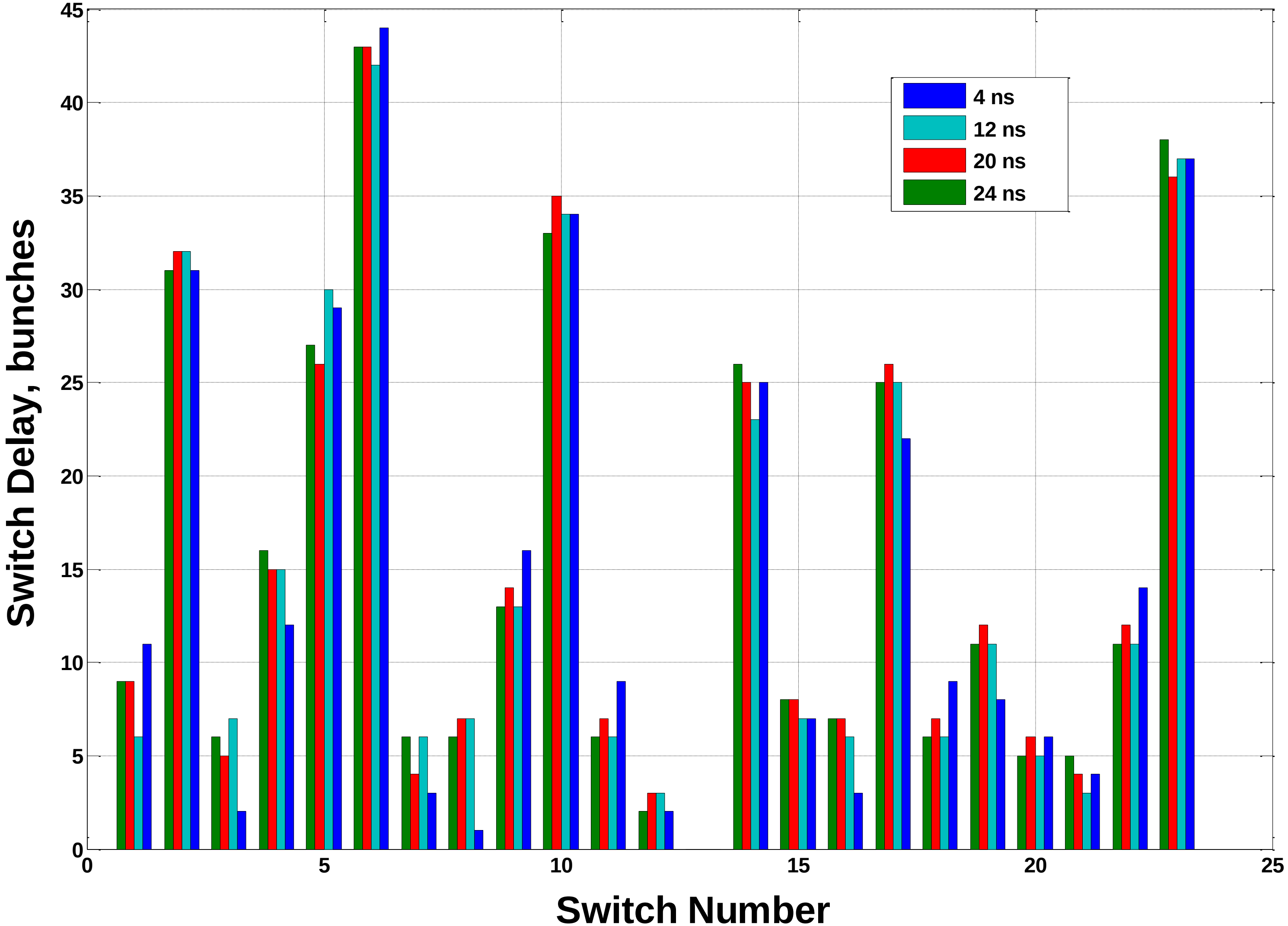
# Transient in the Subharmonic Buncher During DB Phase Switch



# Energy Spread Dependence on the Buncher Switch Time



# Optimal Switch Delays for the Different Buncher Switch Times

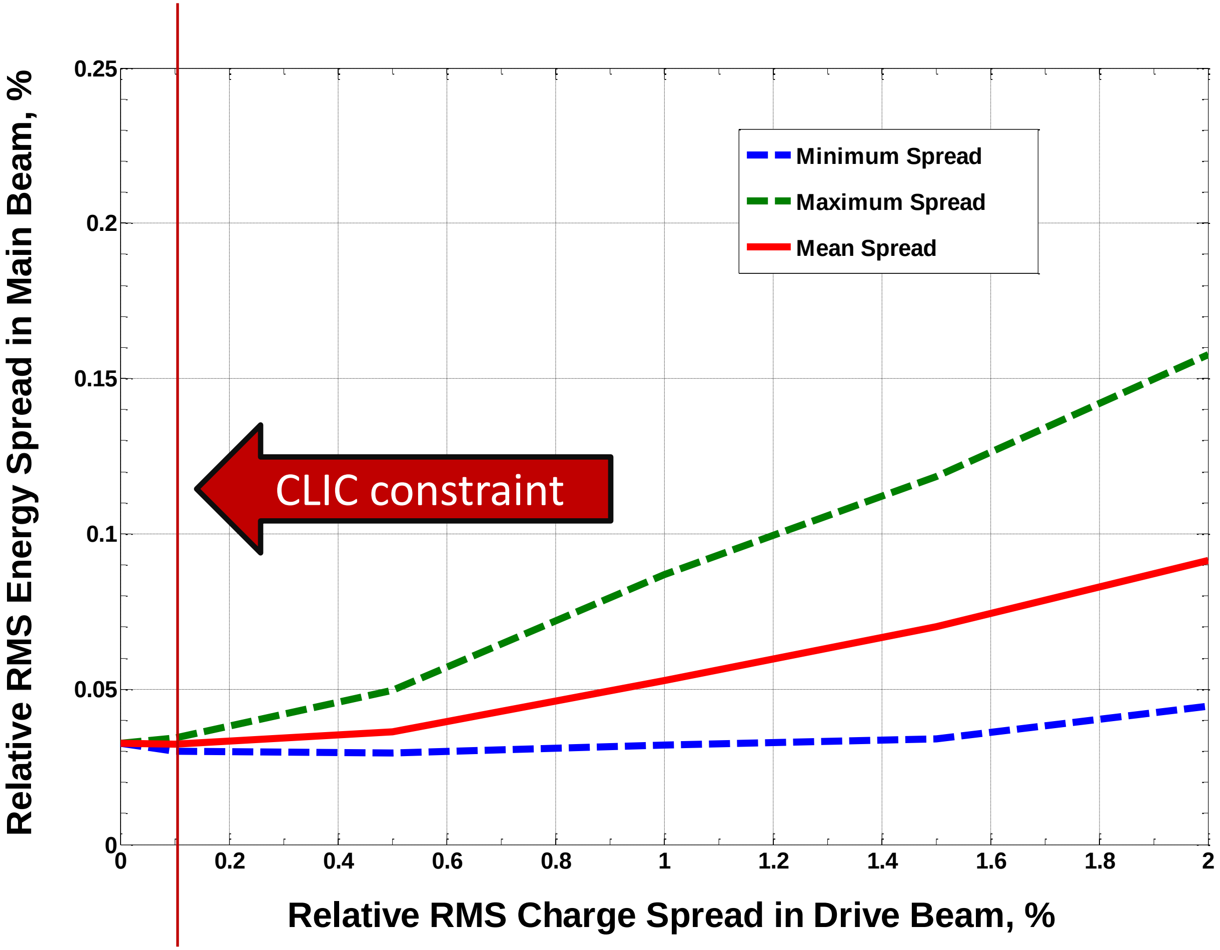


# Study of the Charge JitterInfluence on the Energy Spread

1. Gaussian drive/main beams charge distribution with relative rms spread of 0.1%

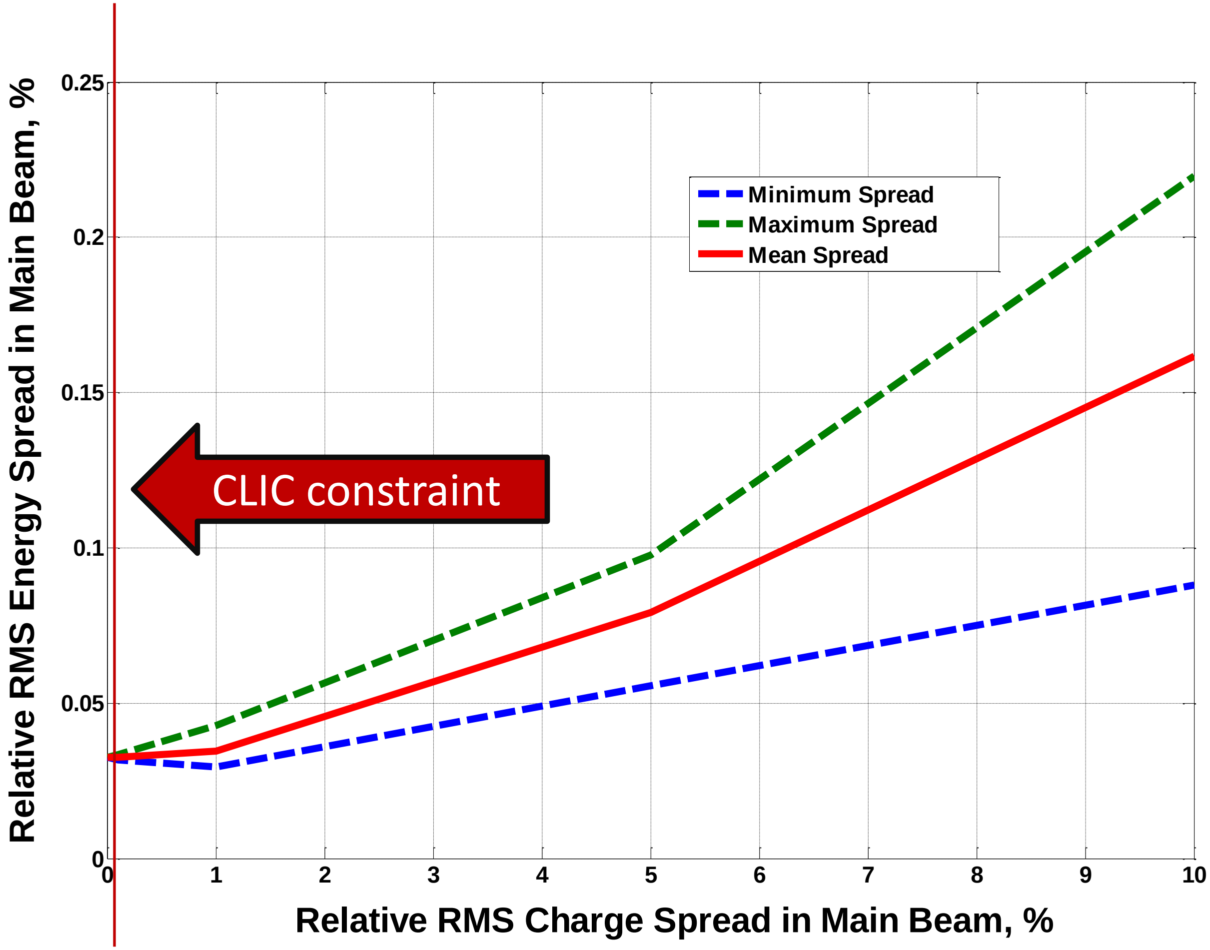
2. “White noise” jitter of the charge along the drive/main beams

# Drive Beam Charge Spread Effect




Constraint of 0.1% charge spread in drive beam (D. Schulte, CERN) is ok for the energy spread minimization

# Main Beam Charge Spread Effect




Constraint of 0.1% charge spread in main beam (D. Schulte, CERN) is ok for the energy spread minimization

# Conclusions

1. Developed pulse shape optimization method allows to reach acceptable level of 0.03% in the main beam energy spread

2. Performing optimization for the different possible buncher switching times and injection phases the same CLIC acceptable level of energy spread is reached

3. Randomly distributed along the bunch train 0.1% rms spread charge jitters in drive and/or main beams don't increase the final energy spread in the main beam

# Thank You for the Attention!