- Title

Velocity Compliant Bunching Scheme with Amplitude Modulation

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Contents:

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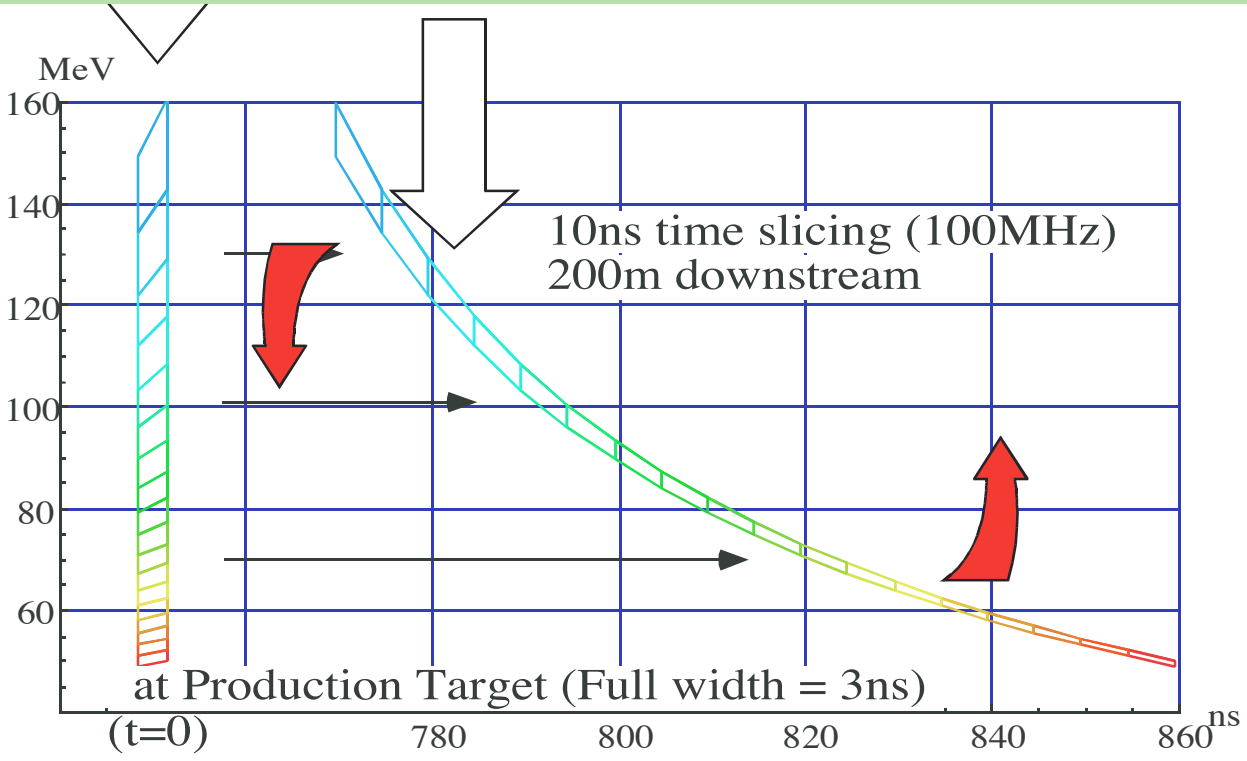
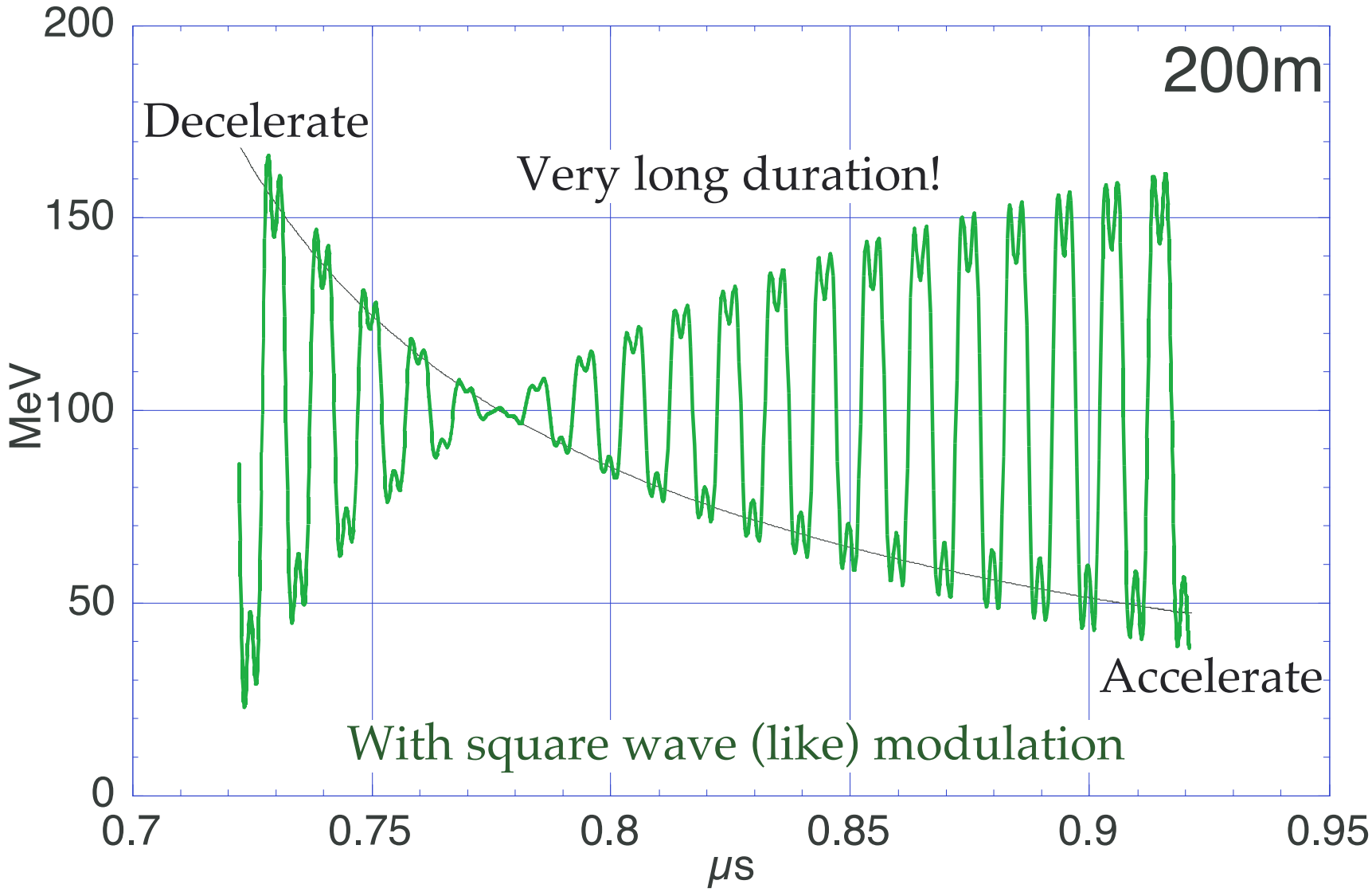
- Introduction

Utilise muons with very large spread
as many as possible.

Use TOF information after certain drift space.
and phase rotate to reduce the energy spread.



- TOF Matched Voltage



- Decomposition

ø rotation　　modulation

$$\left[\sin(\omega t-\phi_1)+\frac{1}{4}\sin(2\omega t-\phi_2)\right]\left[\cos\omega_c t+\frac{1}{6}\cos 3\omega_c t\right]$$

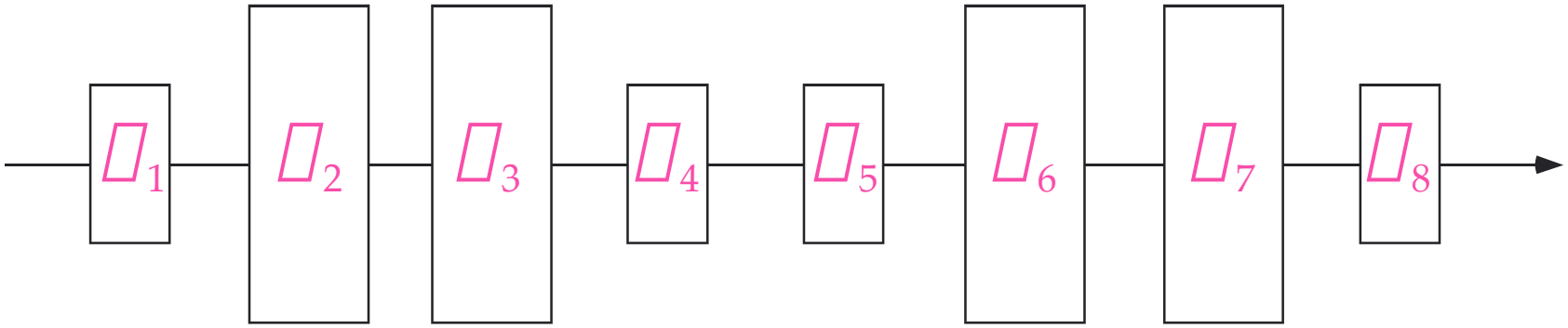
reduction of trigonometric function
straightforward - 8 terms

$$=\frac{1}{48}(-4\sin(\omega t-3\omega_c t-\phi_1)+24\sin(\omega t-\omega_c t-\phi_1)+24\sin(\omega t+\omega_c t-\phi_1)-4\sin(\omega t+3\omega_c t-\phi_1)$$

$$+\sin(2\omega t-3\omega_c t-\phi_2)-6\sin(2\omega t-\omega_c t-\phi_2)-6\sin(2\omega t+\omega_c t-\phi_2)+\sin(2\omega t+3\omega_c t-\phi_2))$$

$$=\sum a_n\sin(b_n\omega_n t+\phi_n)$$

ω_c: carrier frequency



Phase splips between cavities may be harmful!

Small terms may be neglected

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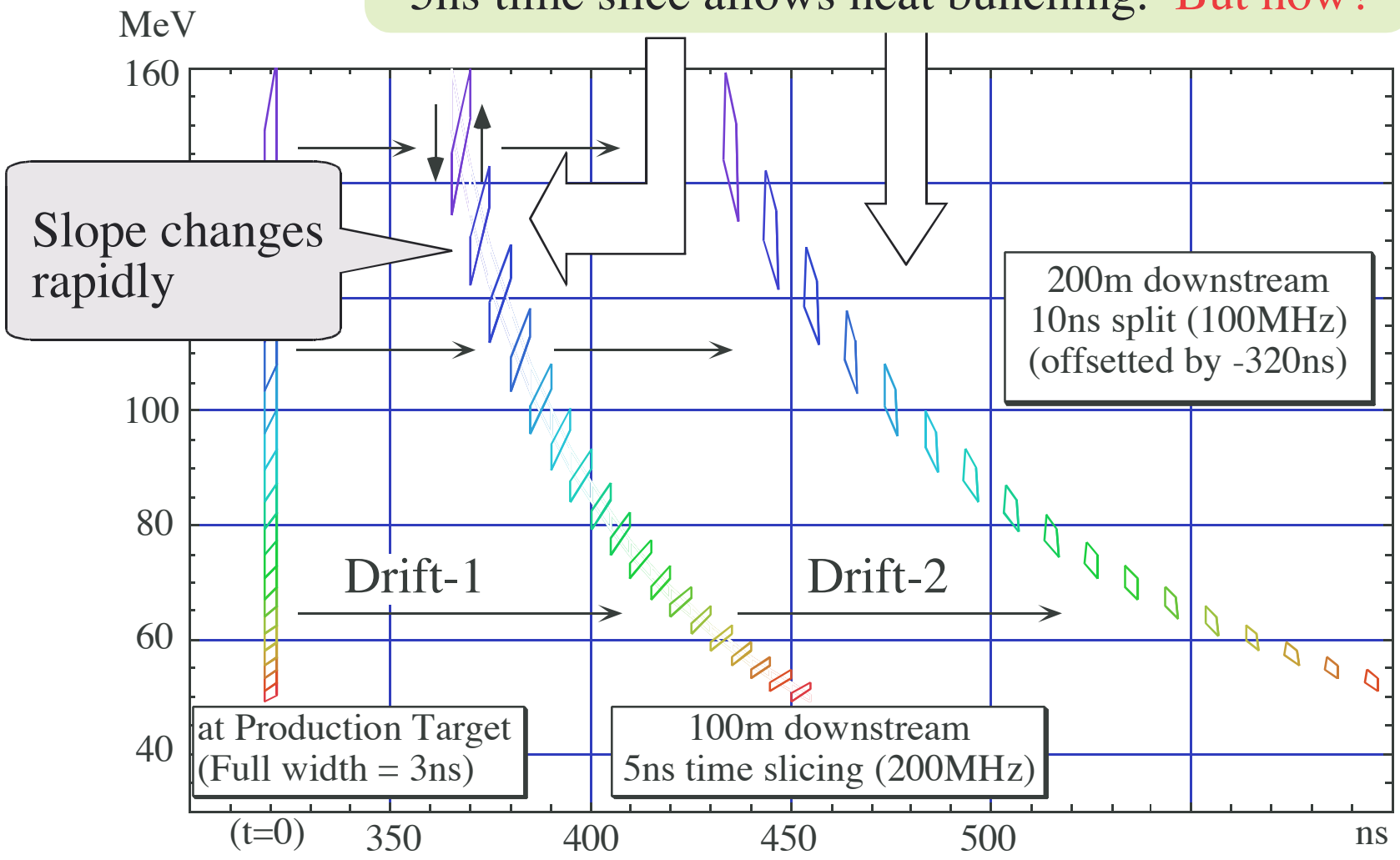
• Neat Bunching (Velocity Compliant)

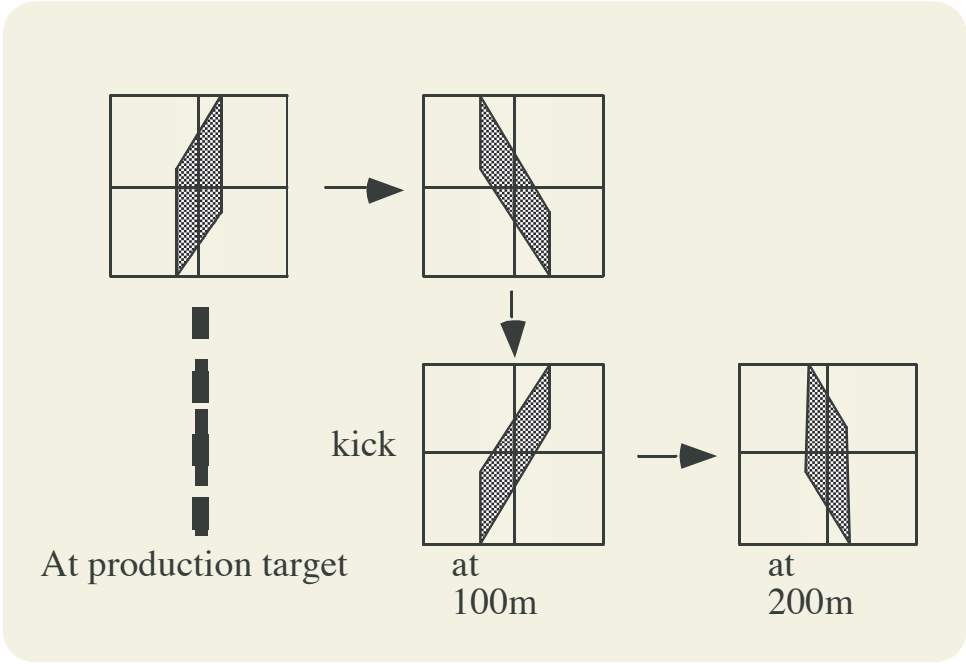
Flipping phase space distribution for each
5ns time slice allows neat bunching. But how?



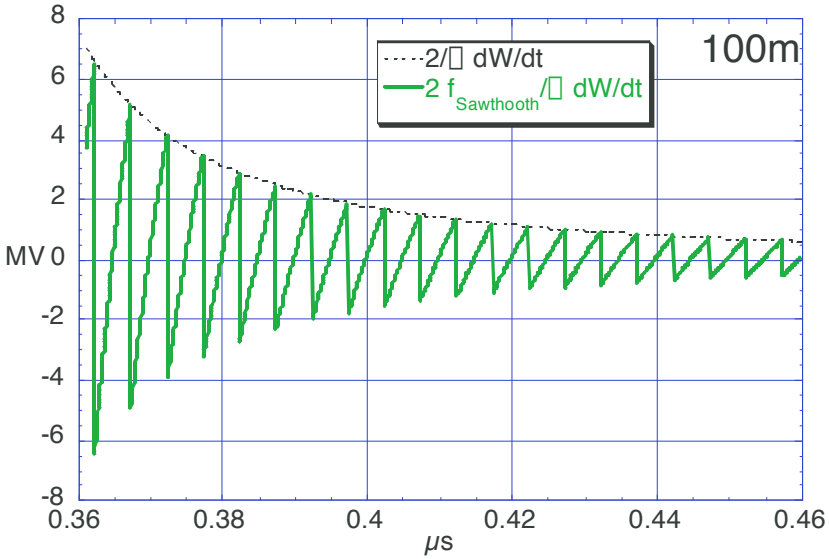
- Local phase space

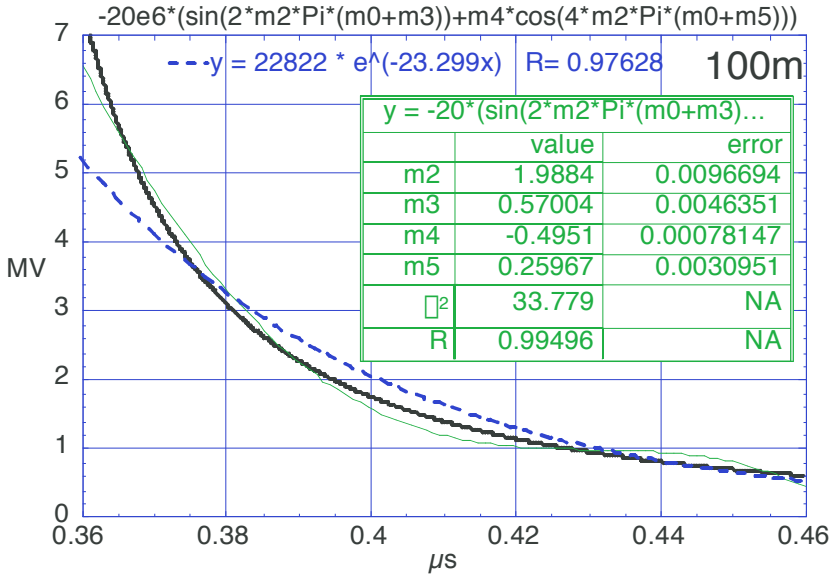
The slope in each slice changes rapidly.

Quick modulation of buncher amplitude is needed!



• Required Waveform for Velocity Compliant Bunching





Sawtooth is ideal.
Sine wave easy.

Amplitude changes rapidly.
(Envelope)

$$V(t) = 2\frac{\sin(\square_b t)}{\square_b}\frac{dW_\square(t)}{dt}, W_\square(t) = m_\square\left(\frac{ct}{\sqrt{c^2t^2+L^2}}-1\right)$$

Amplitude Modulation

Fitting:

The variation is faster than an exponential fn.

Two frequency components can fit the envelope.

$$V_{envelop}(t) = 20\left(\sin(\square_e t+\square_1)+A\sin(2\square_e t+\square_2)\right)\text{[MV]}$$

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- Trigonometric Reduction (some math.)

Buncher waveform to be synthesized:

$$V(t) = 20\sin(\omega_b t)\left(\sin(\omega_e t + \phi_1) + A\sin(2\omega_e t + \phi_2)\right)$$

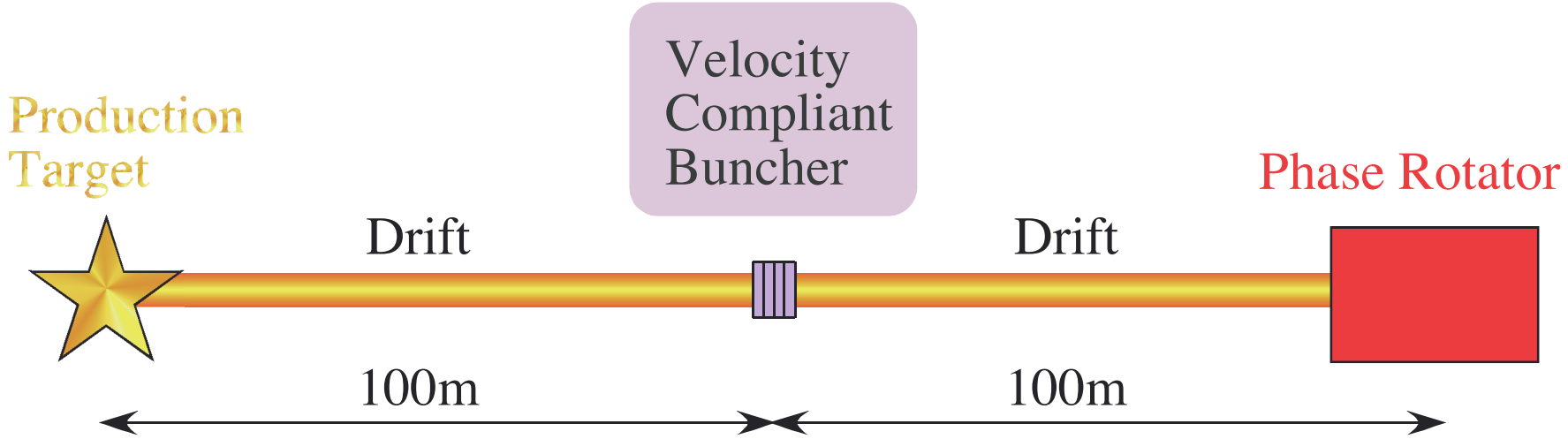
Buncher　　Envelope

Trigonometric reduction makes...

$$V(t) = 10\left\{\cos\left((\omega_e - \omega_b)t + \phi_1\right) - \cos\left((\omega_e + \omega_b)t + \phi_1\right)\right\}$$
$$+ 10A\left\{\cos\left((2\omega_e - \omega_b)t + \phi_2\right) - \cos\left((2\omega_e + \omega_b)t + \phi_2\right)\right\}.$$

Broken into four components.

- Layout (Single station @100m)



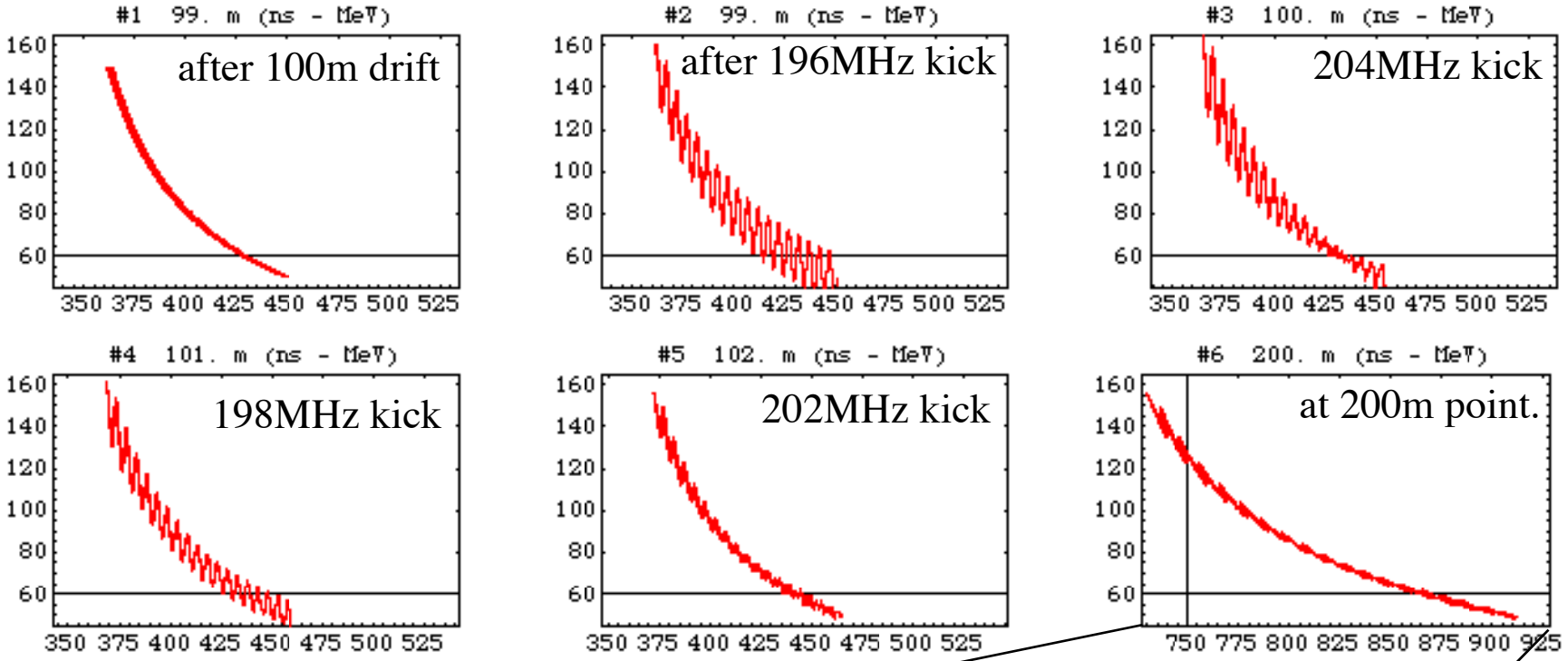
Four Frequencies,
length:1m each.

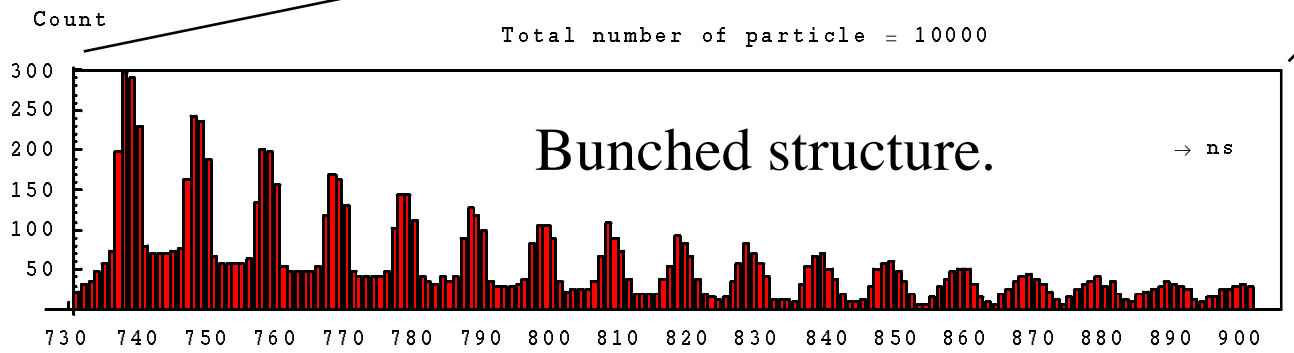
Cavities:

	Voltage	Frequency
#1	10 MV	198MHz
#2	10 MV	202MHz
#3	4.795 MV	196MHz
#4	4.795 MV	204MHz

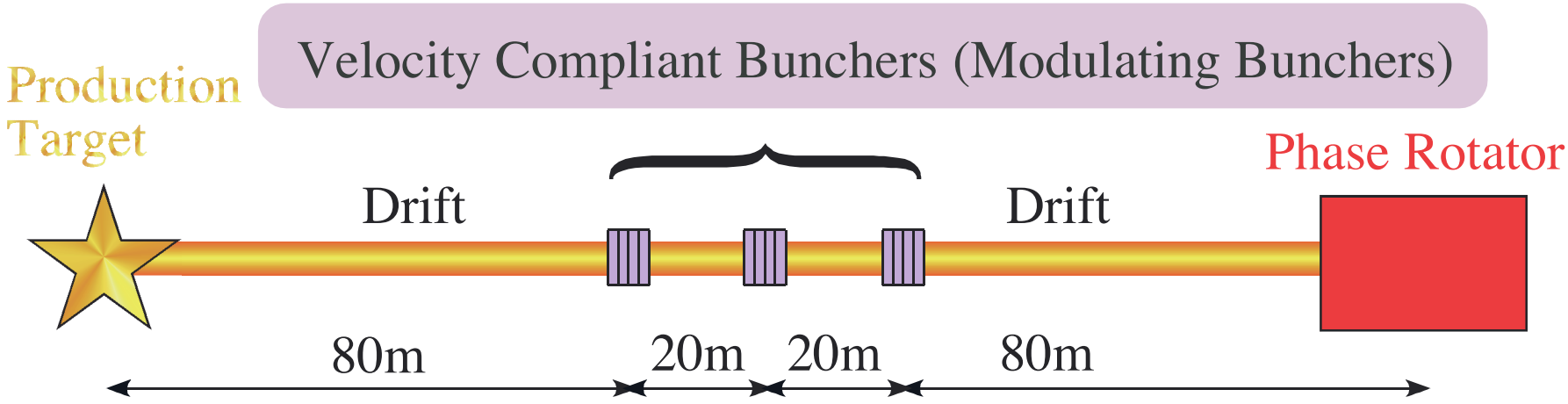
x1.1 after optimization

- Simple simulation results of the modulating buncher





- Layout (Three stations @80,100,120m)



Four Frequencies, 1m long each.

	Cavitiy @80m Voltage	Frequency	Cavitiy @100m Voltage	Frequency	Cavitiy @120m Voltage	Frequency
#1	4.7MV	247MHz	6.5MV	198MHz	6.8MV	165MHz
#2	4.7MV	253MHz	6.5MV	202MHz	6.8MV	168MHz
#3	2.3MV	245MHz	3.1MV	196MHz	3.3MV	164MHz
#4	2.3MV	255MHz	3.1MV	204MHz	3.3MV	170MHz

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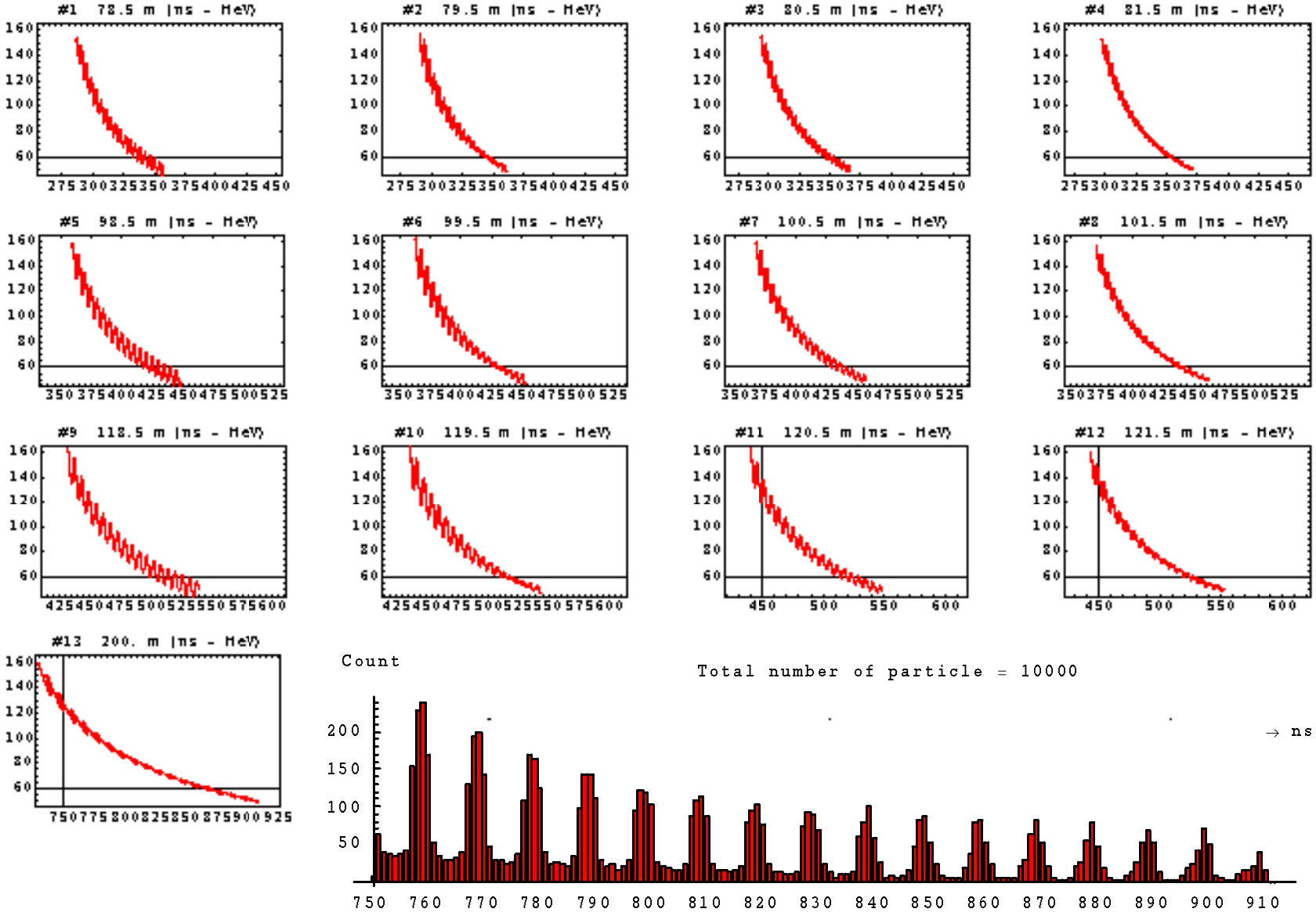
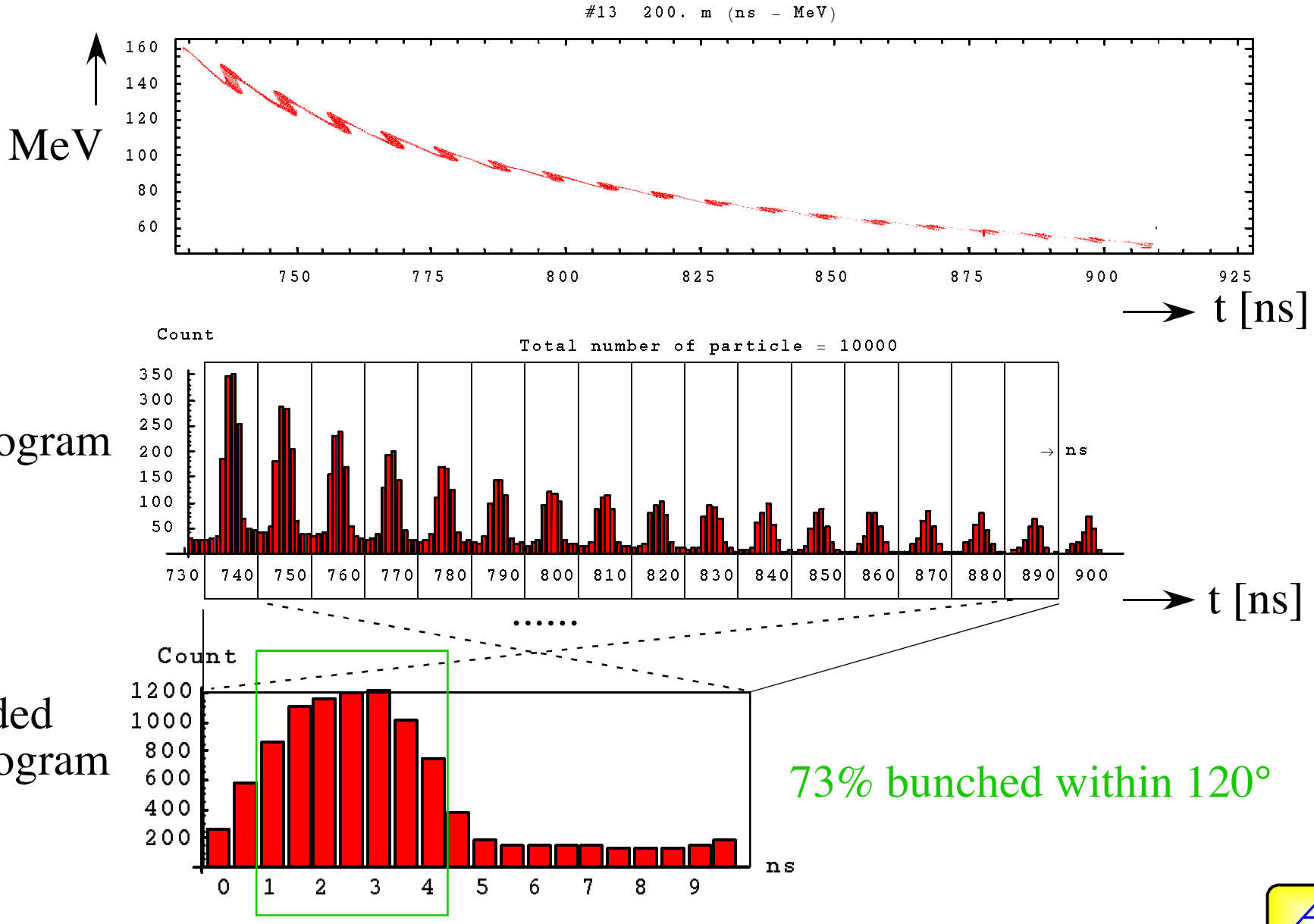
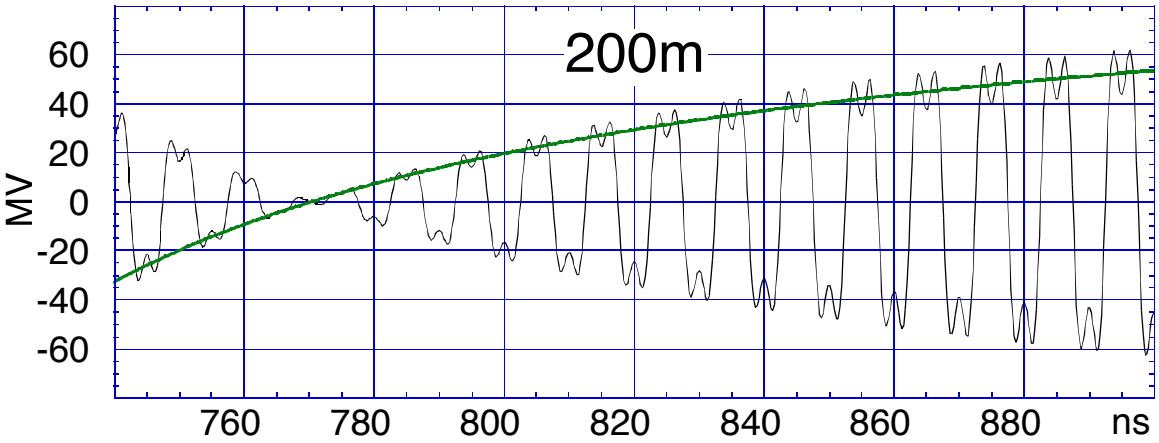
- Simple simulation results of the modulating buncher: 3 stations



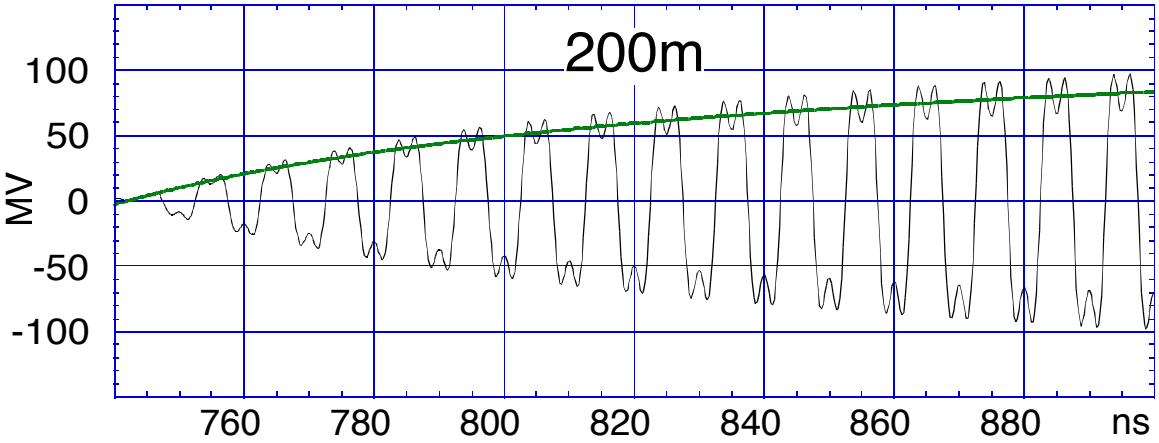
- Simple simulation results of the modulating buncher: 3 stations – cont.



- Two options for Energy Compression



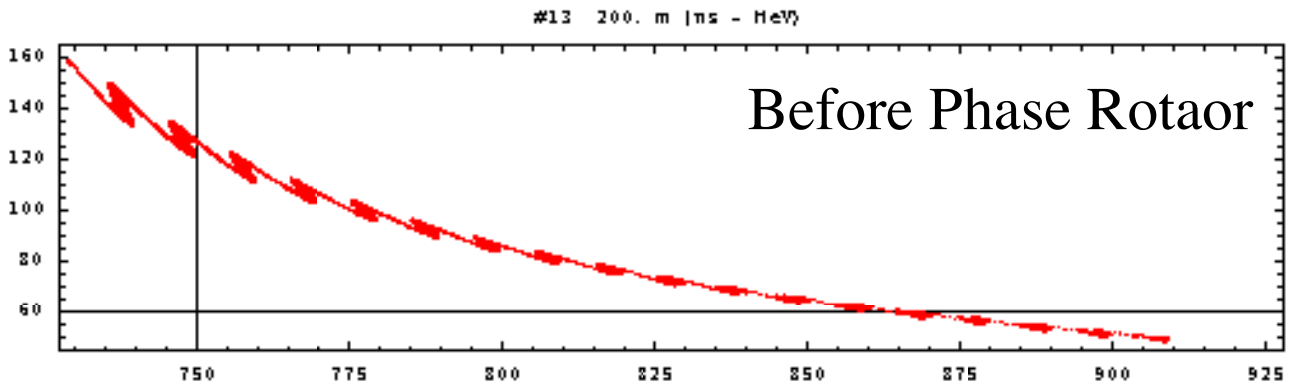
Ec=100MeV
Smaller voltage:
both acc. and deccel.
~50MV

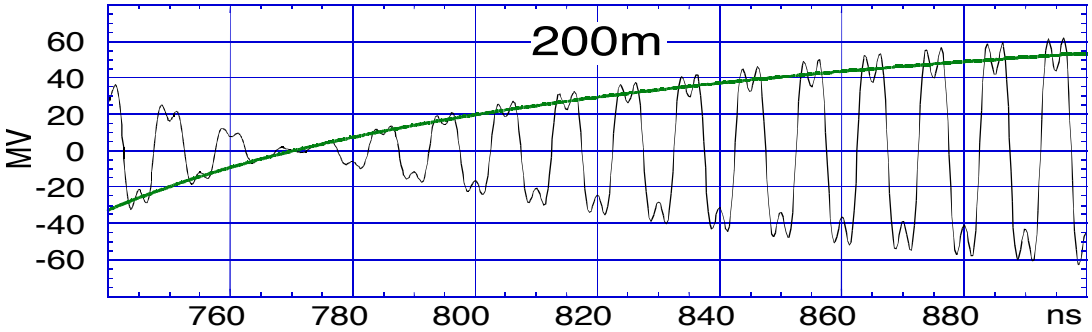


Ec=150MeV
Higher voltage:
only acceleration.
~80MV

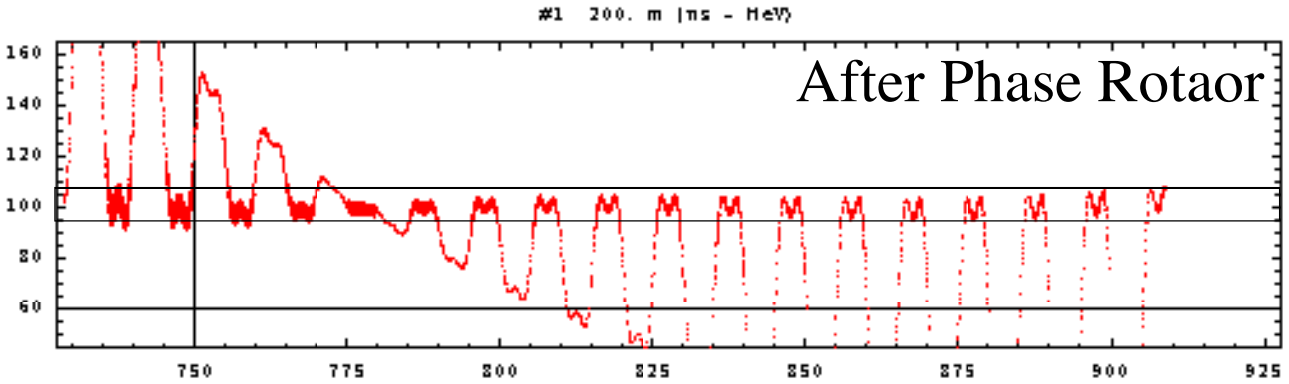
"Phase rotation" waveform modulated by approximated square waveform.

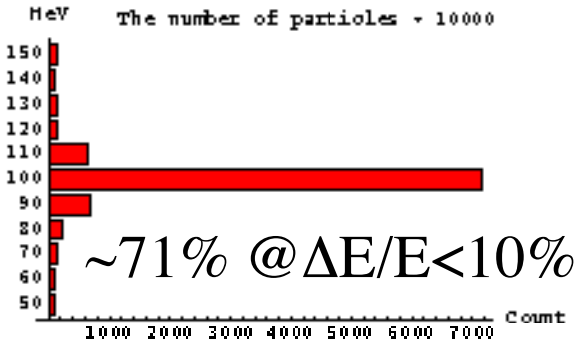
- Simple simulation results: after the Phase Rotator (CPEC)





This example shows rough idea how it works!





~71% @ΔE/E<10%

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- Summary

★ Rapid amplitude modulation can be realized by adding a few frequency components (four enough?).

★ Use of more stations in conjunction with adjusting their amplitudes improves the yield: 1D simulation shows that 73% of muons can be bunched into 120° with 12 cavities of 1m length (~50MV total) while the global TOF correlation is kept. (2nd order harmonic may improve the performance)

★ The phase rotator with Comb Pulse like waveform will Compress the Energy spread $\Delta E/E<10\%$ for 71% muons.

★ More realistic simulation should be followed...