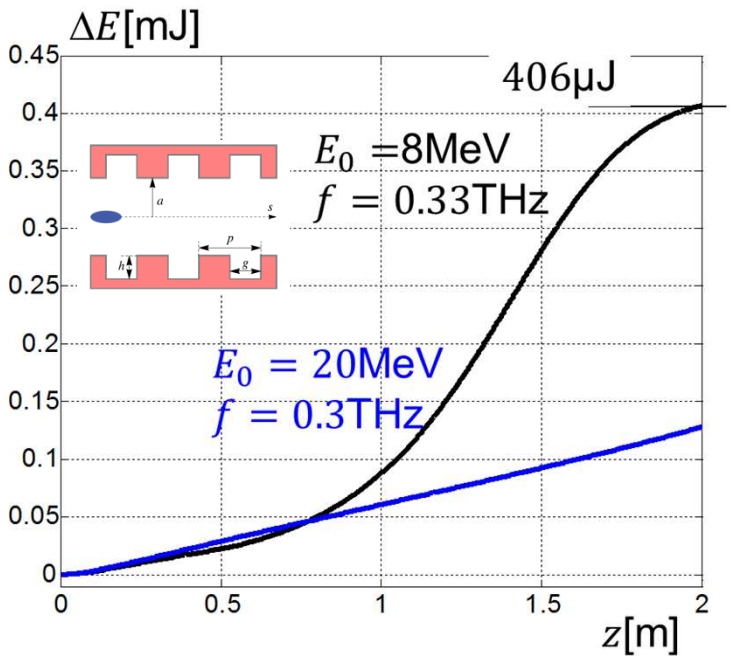
Subterahertz Radiation from Corrugated Pipe



Self-Consistent Simulation of Longitudinal Dynamics

Igor Zagorodnov

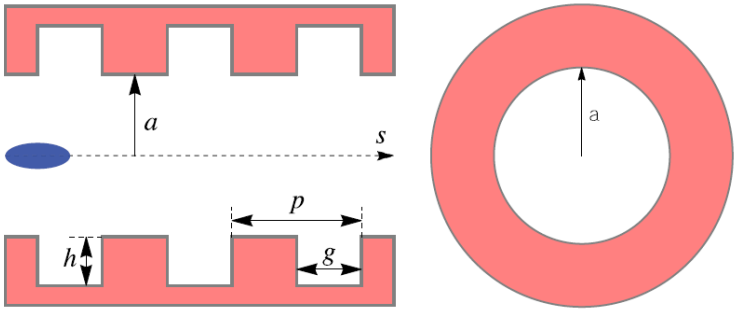
Mini-workshop on THz option at PITZ (piTHz)

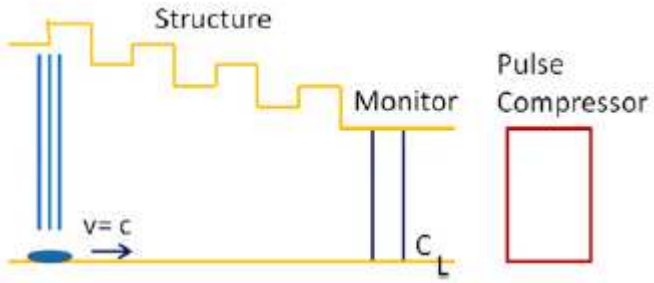
Zeuthen
22. September 2015

HELMHOLTZ GEMEINSCHAFT

DESY

Problem fomulation. Relativistic bunch.





Nuclear Instruments and Methods in Physics Research A 677 (2012) 67–73

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journal homepage: www.elsevier.com/locate/nima

Terahertz radiation from a pipe with small corrugations☆

K.L.F. Bane*, G. Stupakov

SLAC National Accelerator Laboratory, Stanford University, Stanford, CA 94309, United States

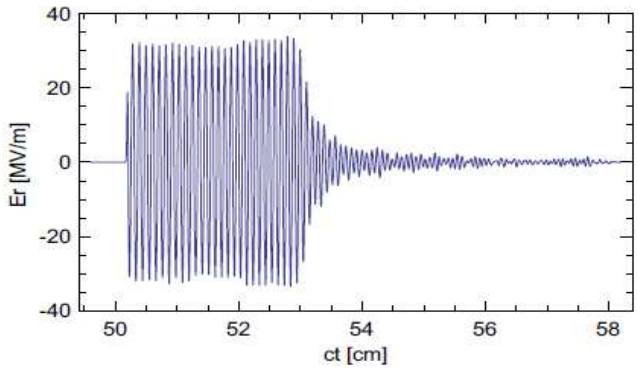


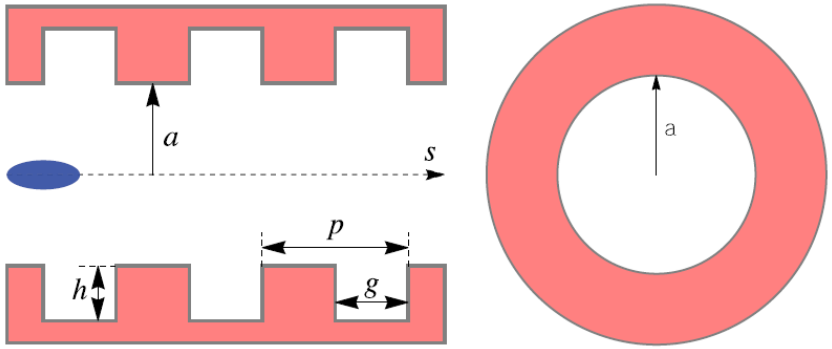
Table 1
Parameters for the standard tapered, corrugated structure and for the exciting bunch, to be used in simulations given in the next section.

Pipe radius a, mm	2–1
Pipe length L, cm	50
Depth δ, μm	50
Period p, μm	40
Gap g, μm	20
Bunch charge Q, nC	1
Bunch length σ_z, μm	100

Table 2
Radiation properties (numerical results).

Frequency f, THz	0.30–0.44
Pulse energy U, mJ	2.3
Pre-compression	
Peak power P, MW	20
Pulse length ℓ, cm	3.5
Post-compression	
Peak power P, MW	250
Pulse length ℓ, cm	0.3

Problem fomulation. Low energy



PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **18,** 030709 (2015)

Using pipe with corrugated walls for a subterahertz free electron laser

Gennady Stupakov*
SLAC National Accelerator Laboratory, Menlo Park, California 94025, USA
(Received 1 January 2015; published 18 March 2015)

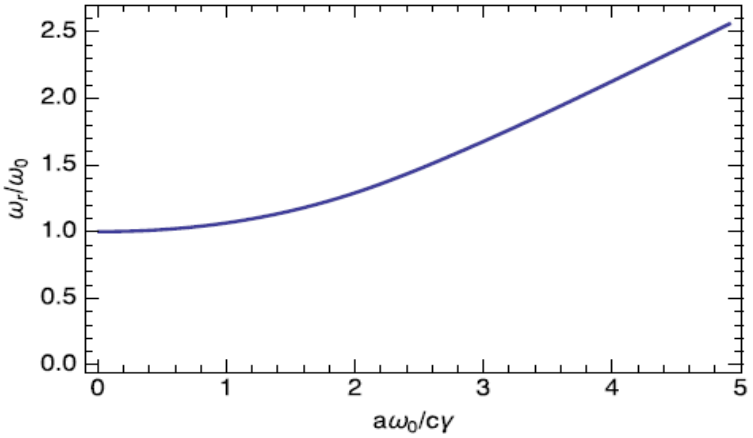
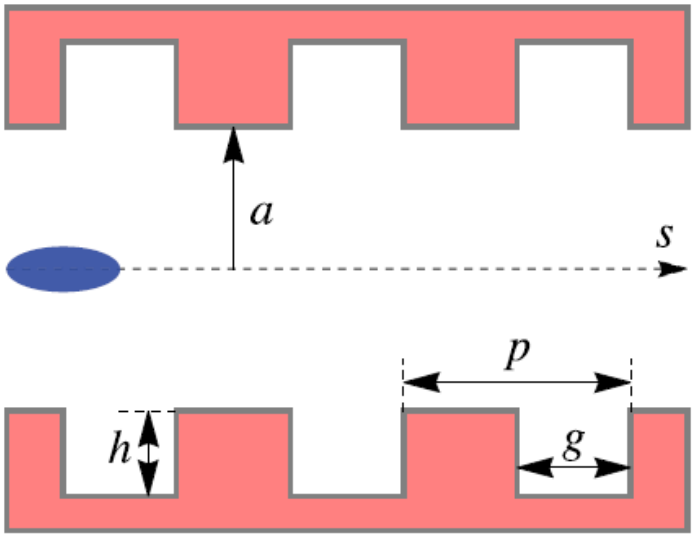
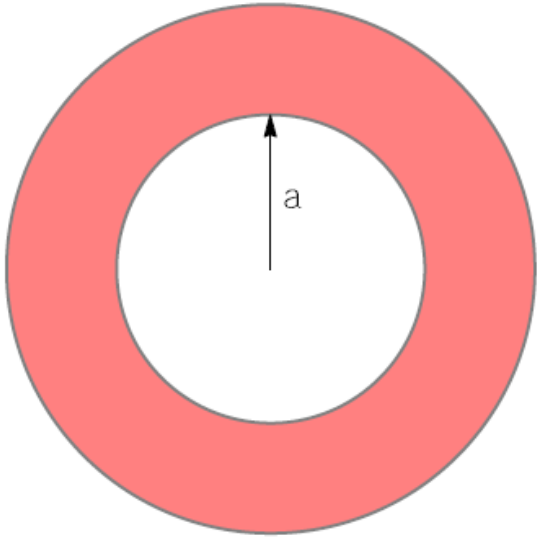


TABLE I. Corrugation and beam parameters.

Pipe radius (mm)	2
Depth h (μm)	50
Period p (μm)	40
Gap g (μm)	10
Bunch charge (nC)	1
Energy (MeV)	5
Bunch length (ps)	10

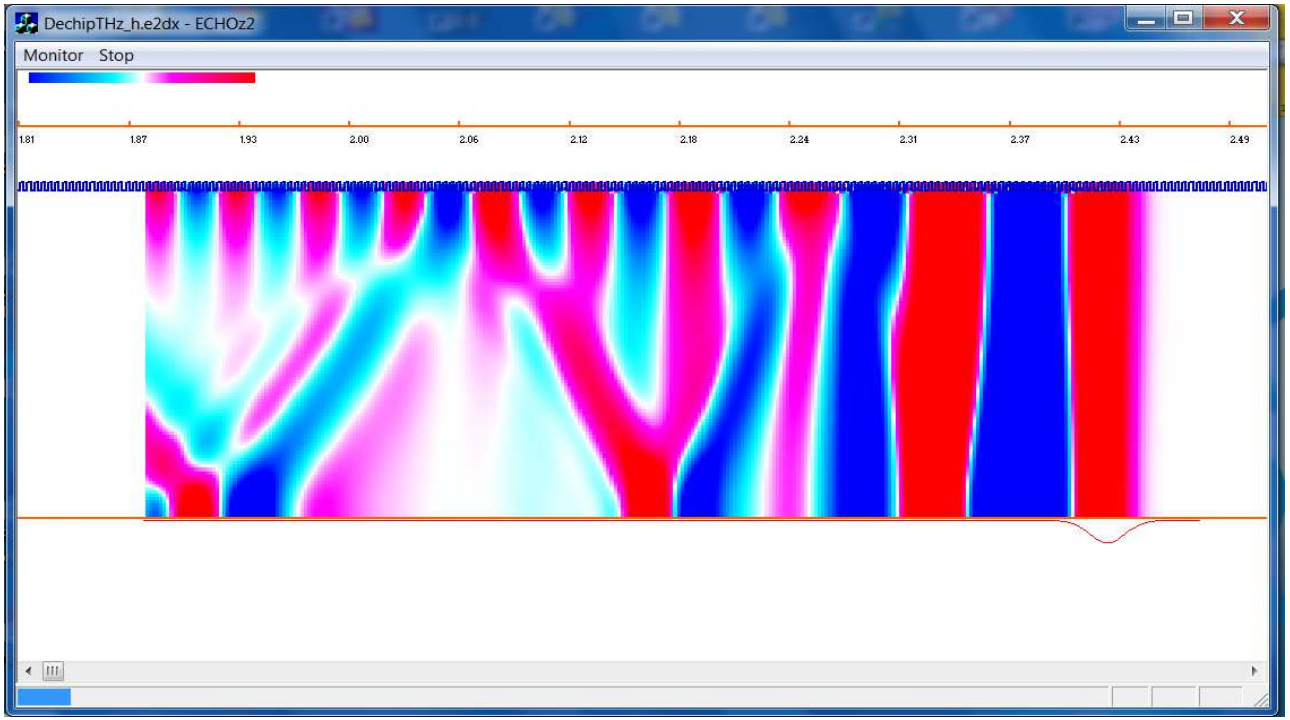
Problem fomulation. Geometry





Pipe radius a, mm	2
Pipe length L, m	0.5-2
Corrugation depth h, mm	0.05
Corrugation period p, mm	0.04
Corrugation gap g, mm	0.02
Gausiian bunch rms σ, mm	0.1-0.3(*8)

Code modification



Wakefield code ECHO
(with resistivity)

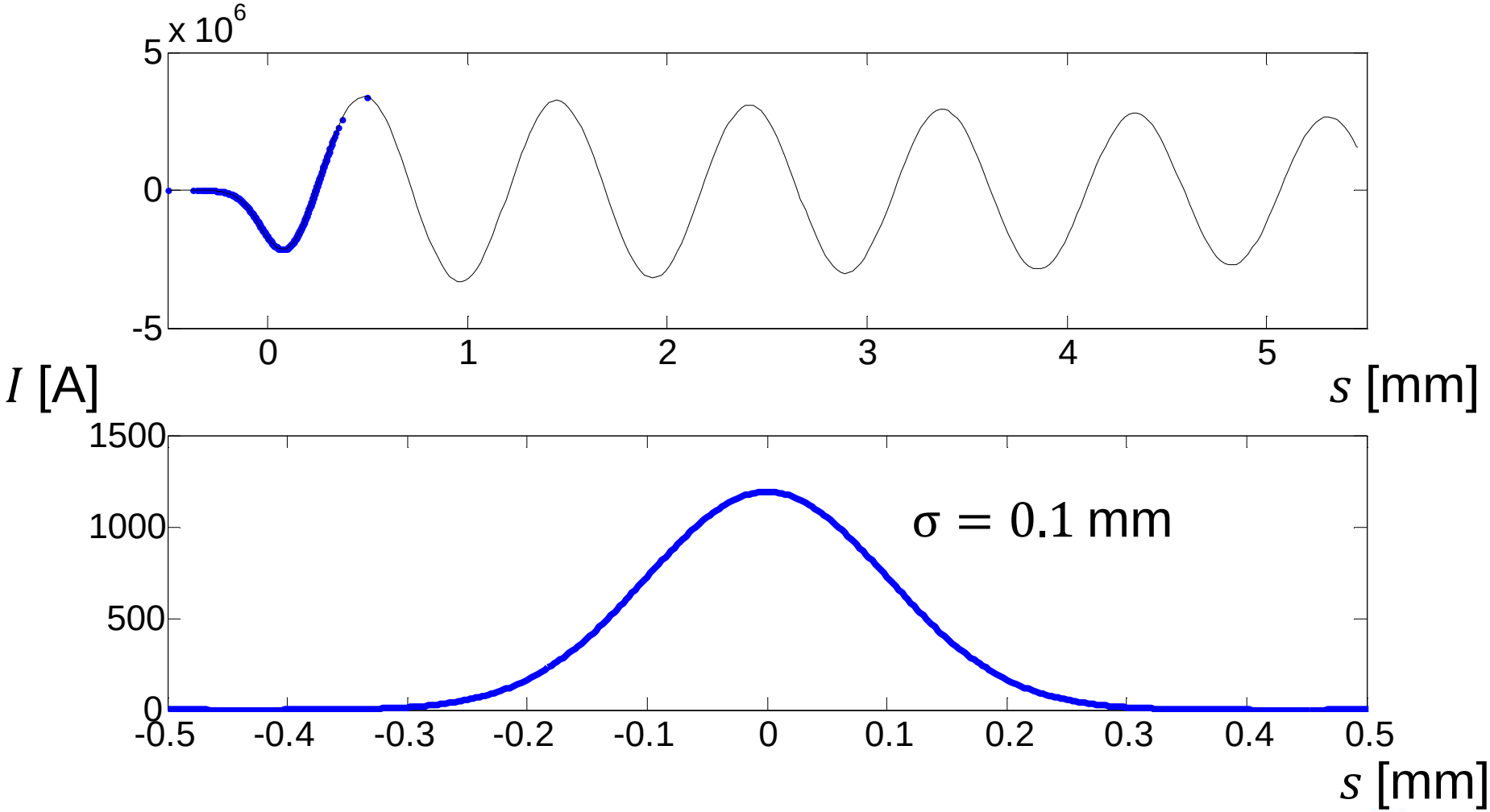
Particle-in-Cell code ECHO-PIC
(only longitudinal dynamics)

Short bunch. High charge. High Energy

Pipe length L, m	0.5
Bunch enegry E_0, MeV	14000
Gausian bunch rms σ, mm	0.1
Charge Q, nC	1

Short bunch. High charge. High Energy

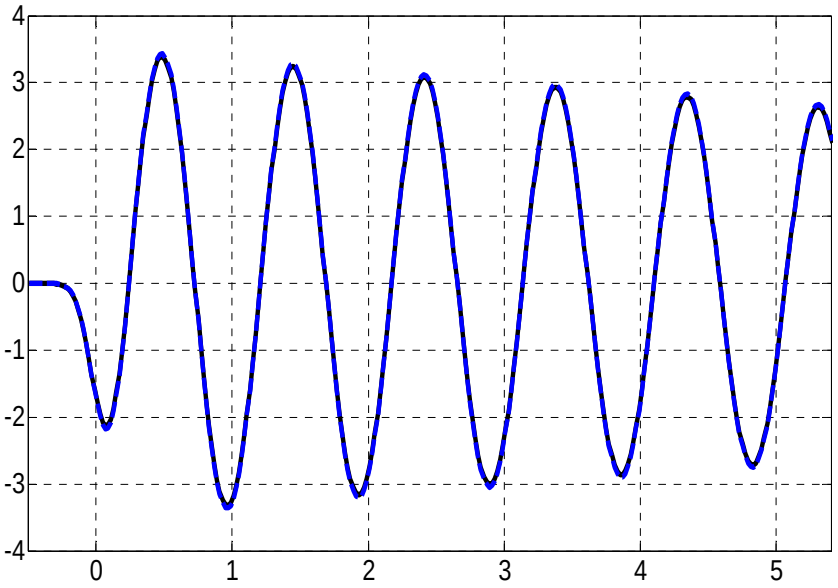
$2\Delta E$ [eV/m] $Q = 1$ nC $E_0 = 14$ GeV



Short bunch. High charge. High Energy

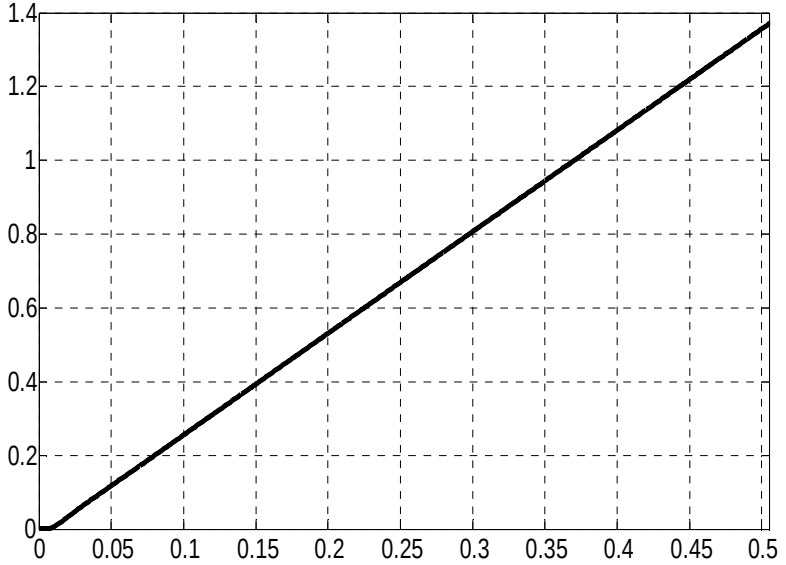
$Q = 1$ nC $\quad E_0 = 14$ GeV $\quad \sigma = 0.1$ mm

ΔE [MeV]



s [mm]

ΔE [mJ]



z [m]

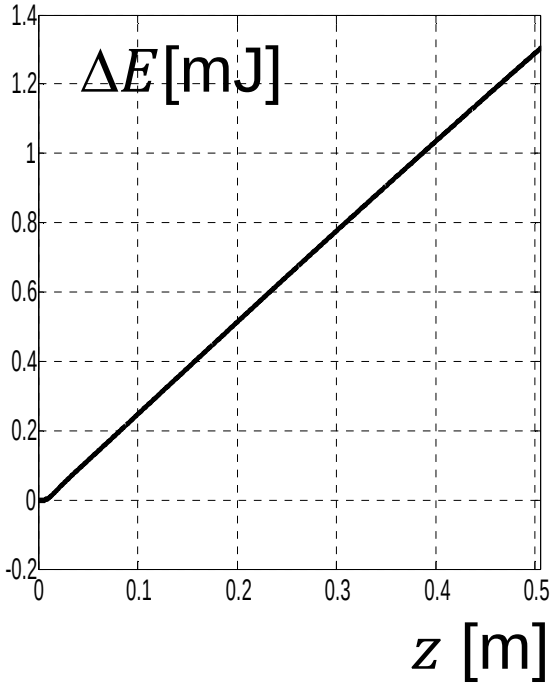
Short bunch. High charge. Low Energy

Pipe length L, m	0.5
Bunch enegry E_0, MeV	5-20
Gausian bunch rms σ, mm	0.1
Charge Q, nC	1

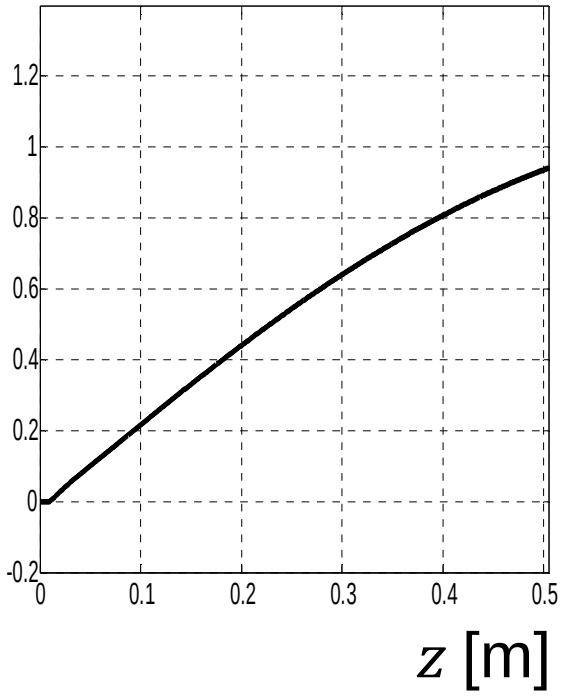
Short bunch. High charge. Low Energy

$Q = 1$ nC $\quad \sigma = 0.1$ mm

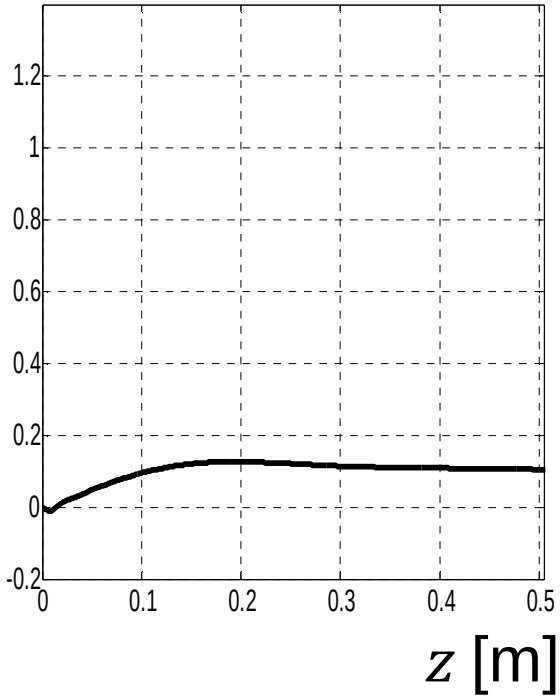
$E_0 = 20$ MeV



$E_0 = 10$ MeV



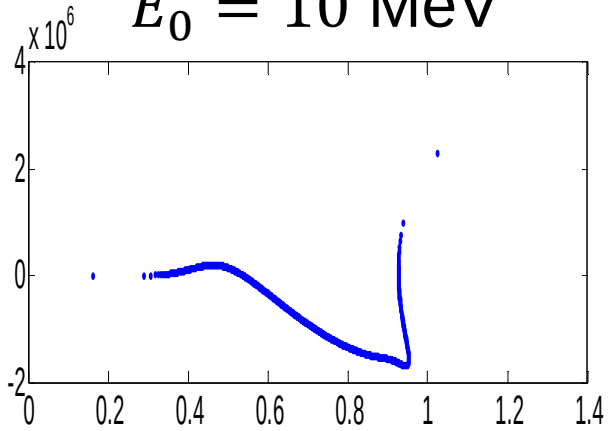
$E_0 = 5$ MeV



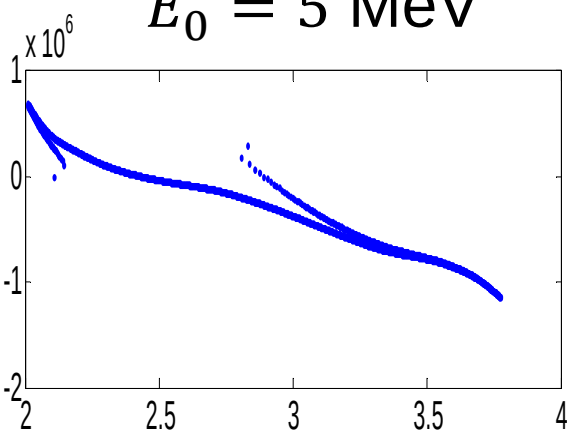
Short bunch. High charge. Low Energy

$Q = 1$ nC $\sigma = 0.1$ mm $I_0 = 1200$ A

$E_0 = 10$ MeV

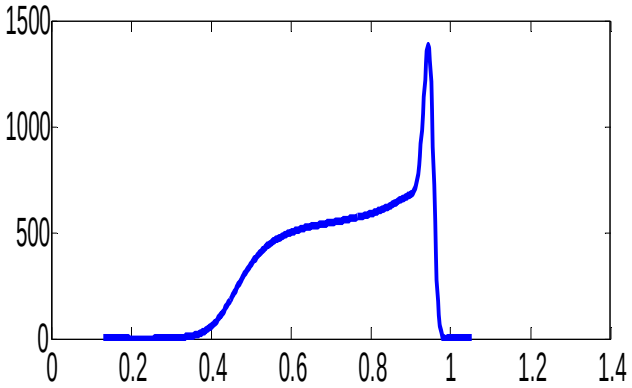


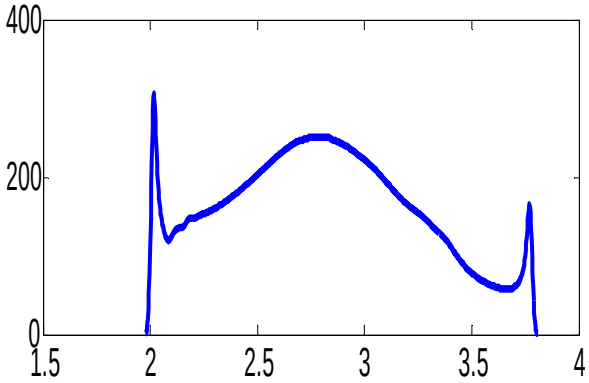
$E_0 = 5$ MeV



ΔE [eV]

I [A]





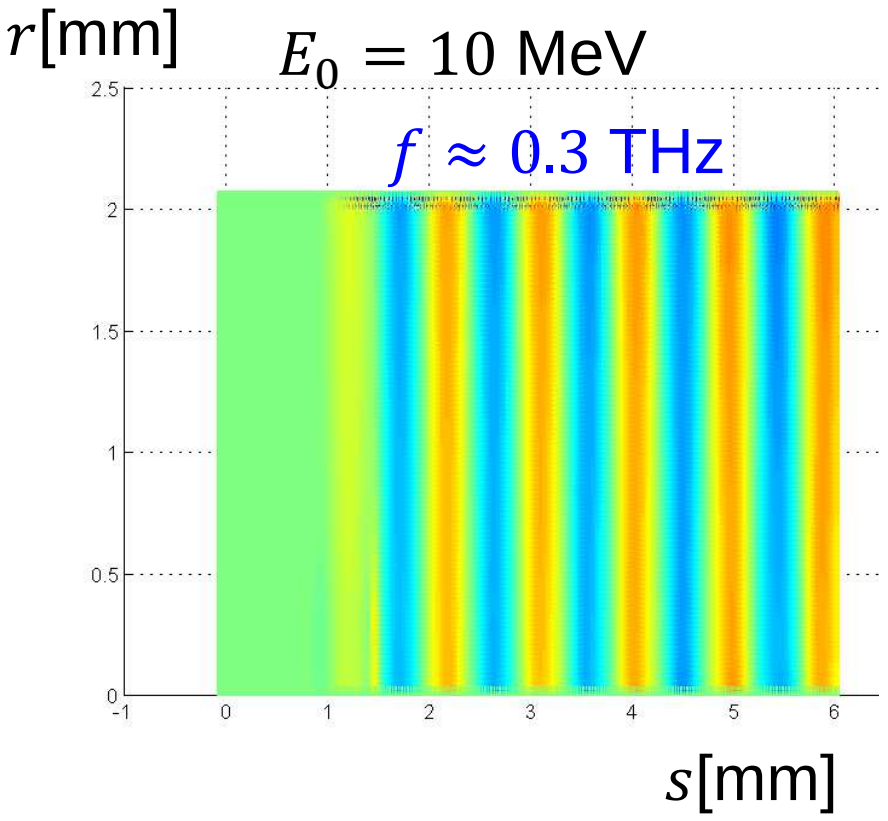
s [mm]

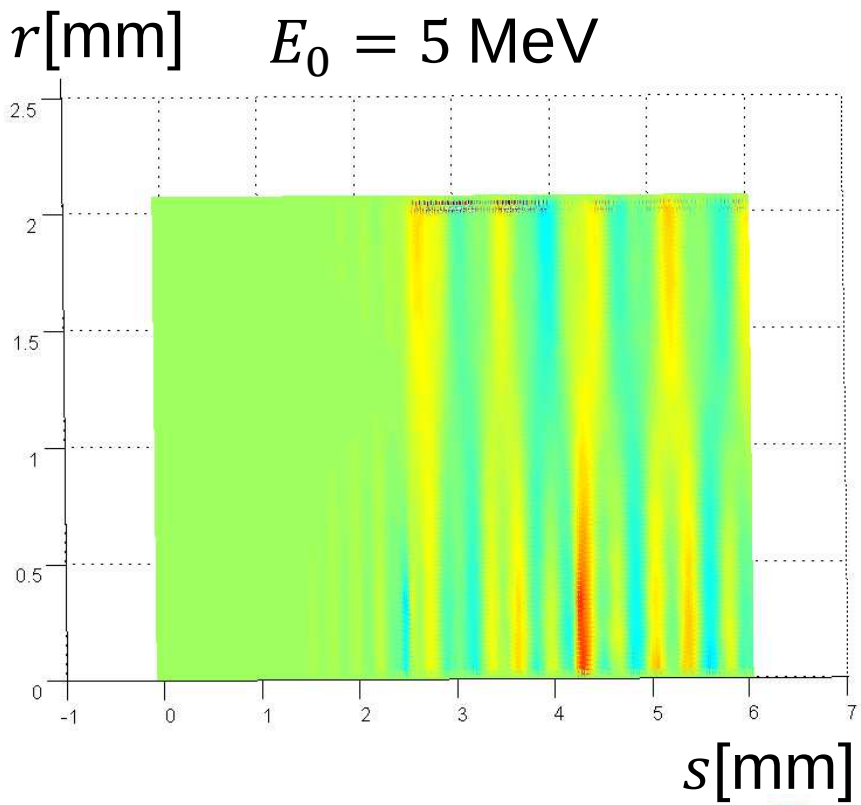
s [mm]

Short bunch. High charge. Low Energy

Longitudinal electric field component E_z

$Q = 1$ nC $\quad \sigma = 0.1$ mm





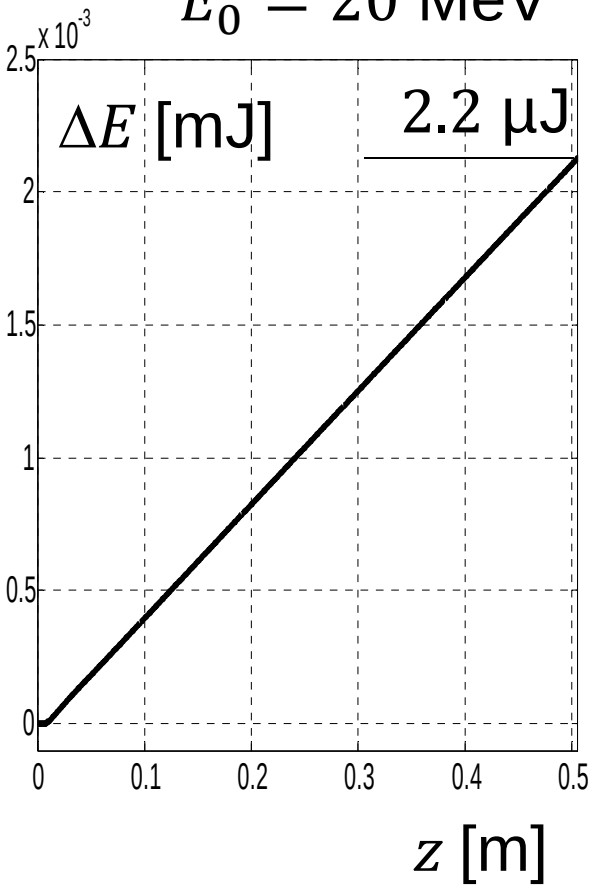
Short bunch. Low charge. Low Energy

Pipe length L, m	0.5
Bunch enegry E_0, MeV	5-20
Gausian bunch rms σ, mm	0.1
Charge Q, nC	0.04

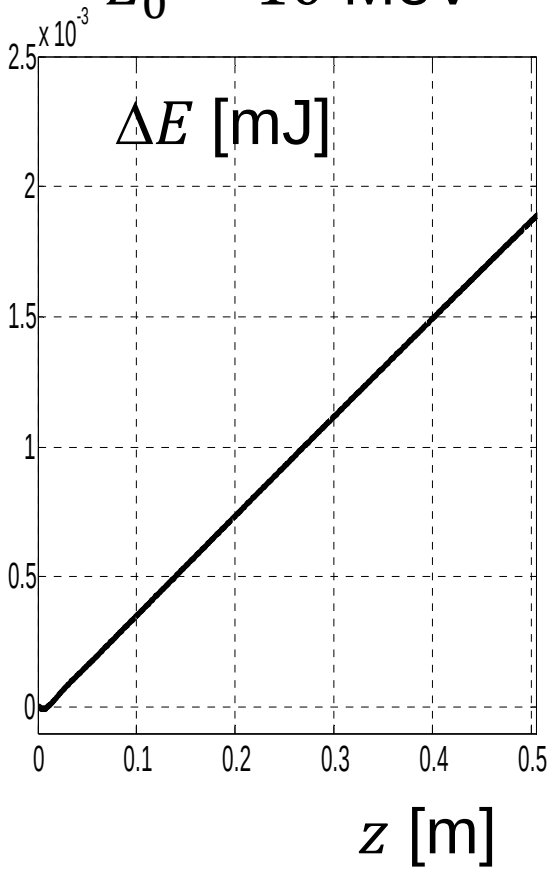
Short bunch. Low charge. Low Energy

$Q = 40$ pC $\sigma = 0.1$ mm $I_0 = 48$ A

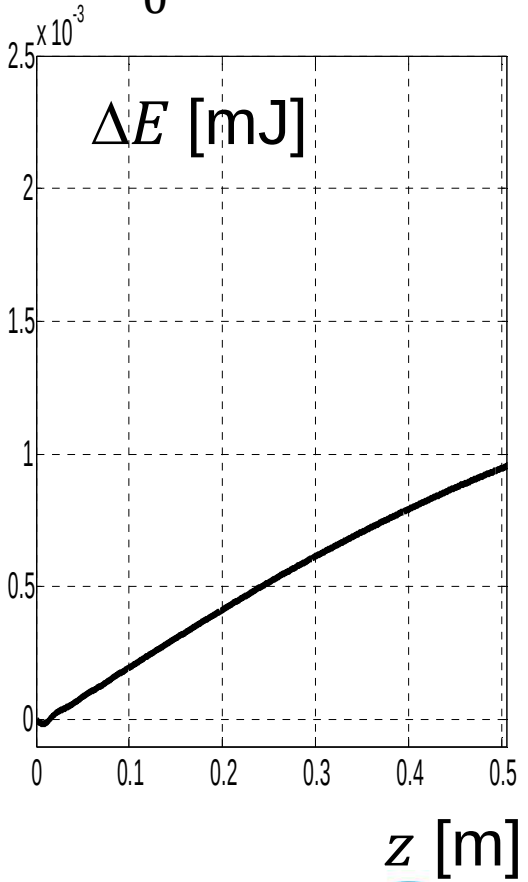
$E_0 = 20$ MeV



$E_0 = 10$ MeV



$E_0 = 5$ MeV

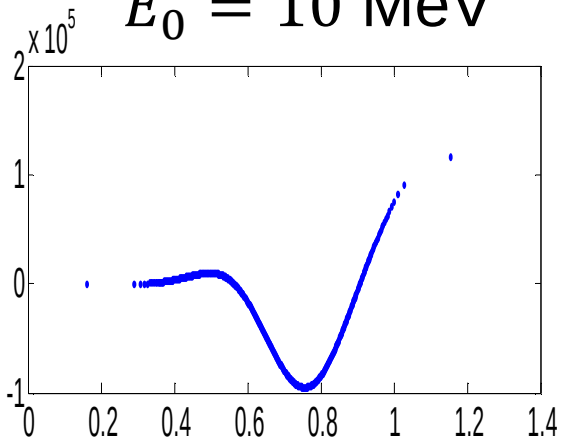


Short bunch. Low charge. Low Energy

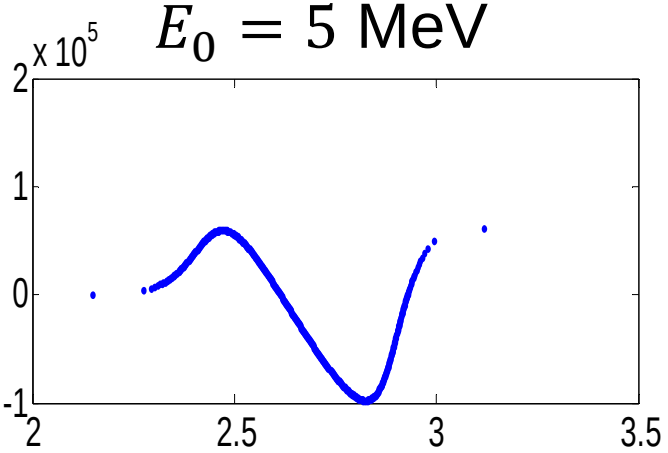
$Q = 40$ pC $\sigma = 0.1$ mm $I_0 = 48$ A

$E_0 = 10$ MeV

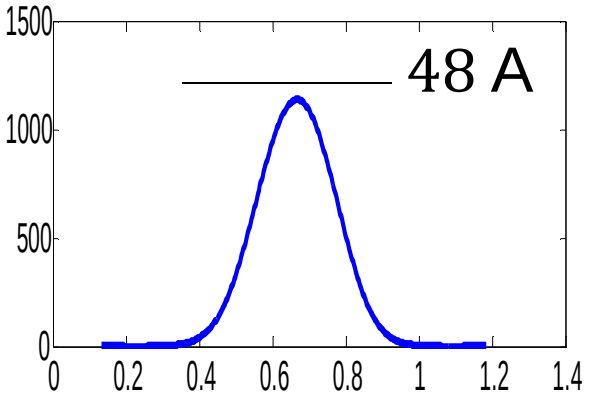
ΔE [eV]

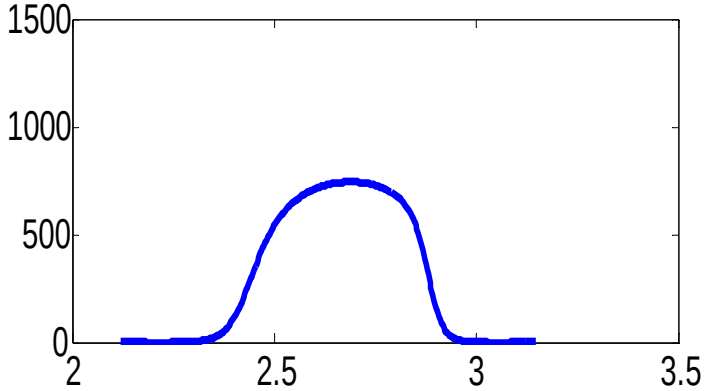


$E_0 = 5$ MeV



25*I [A]





s [mm]

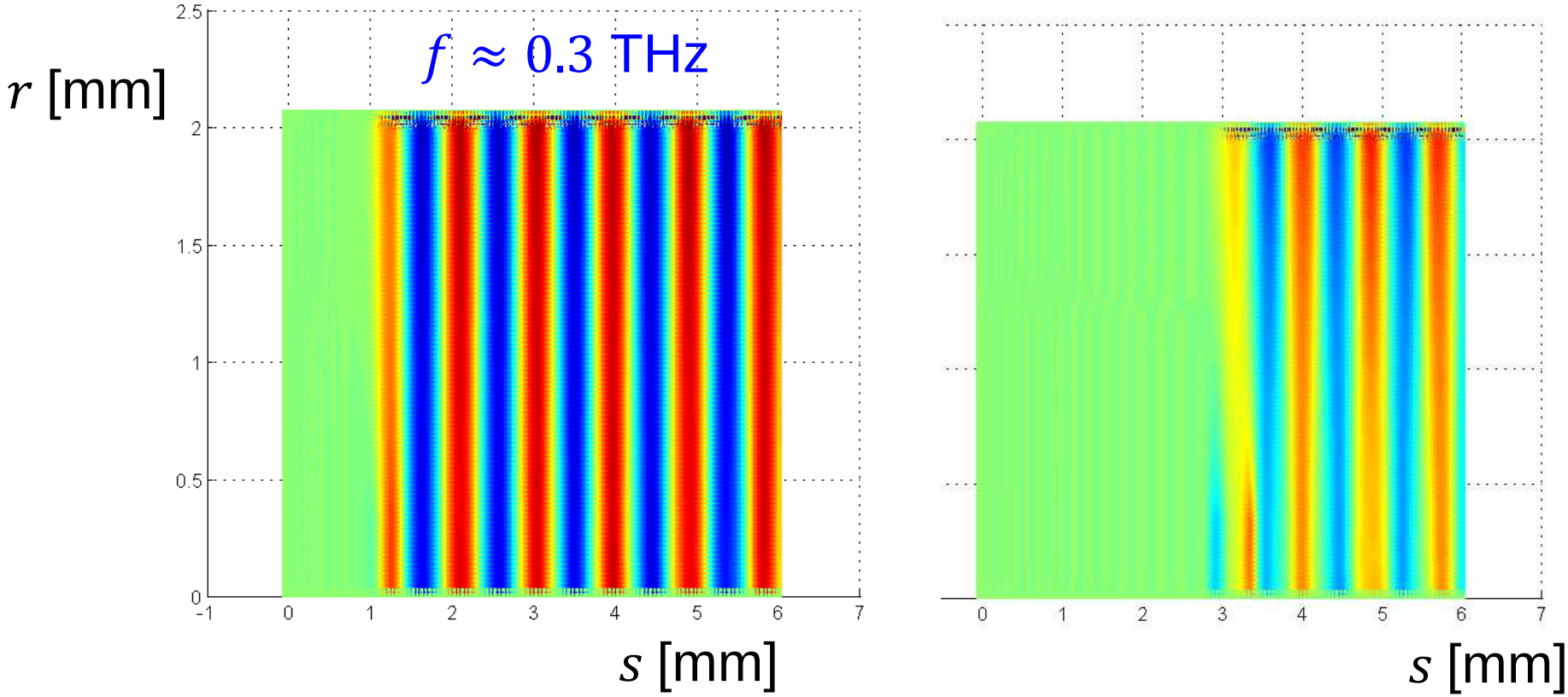
s [mm]

Short bunch. Low charge. Low Energy

Longitudinal electric field component E_z

$E_0 = 10$ MeV

$E_0 = 5$ MeV



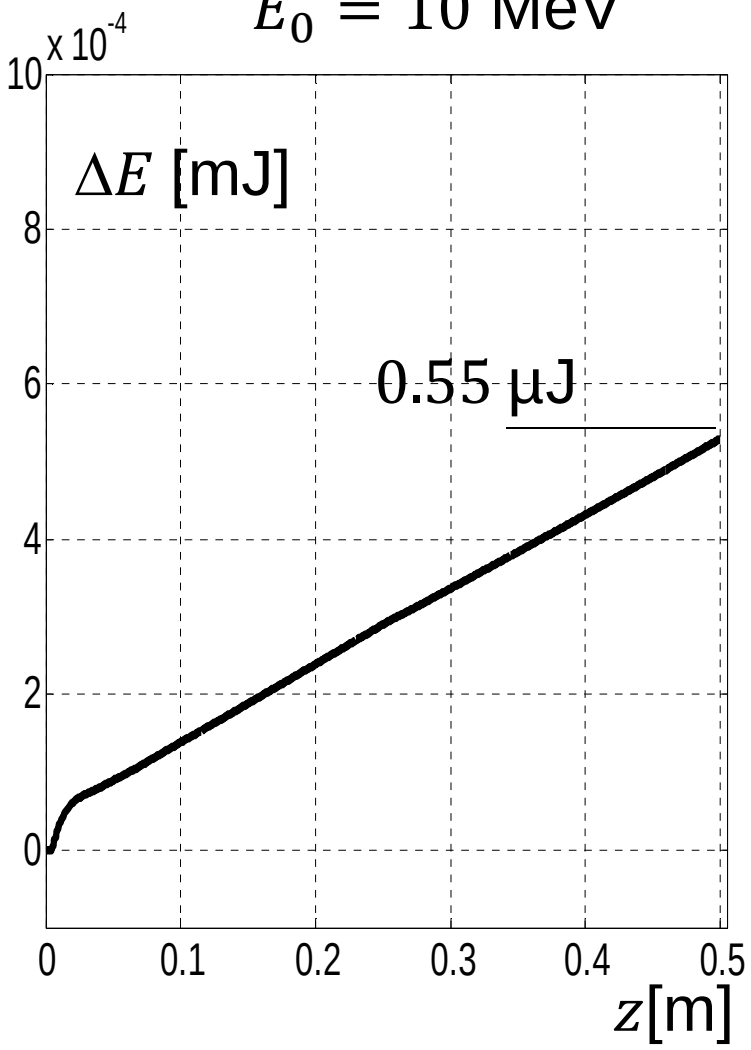
Middle bunch. Middle charge. Low Energy

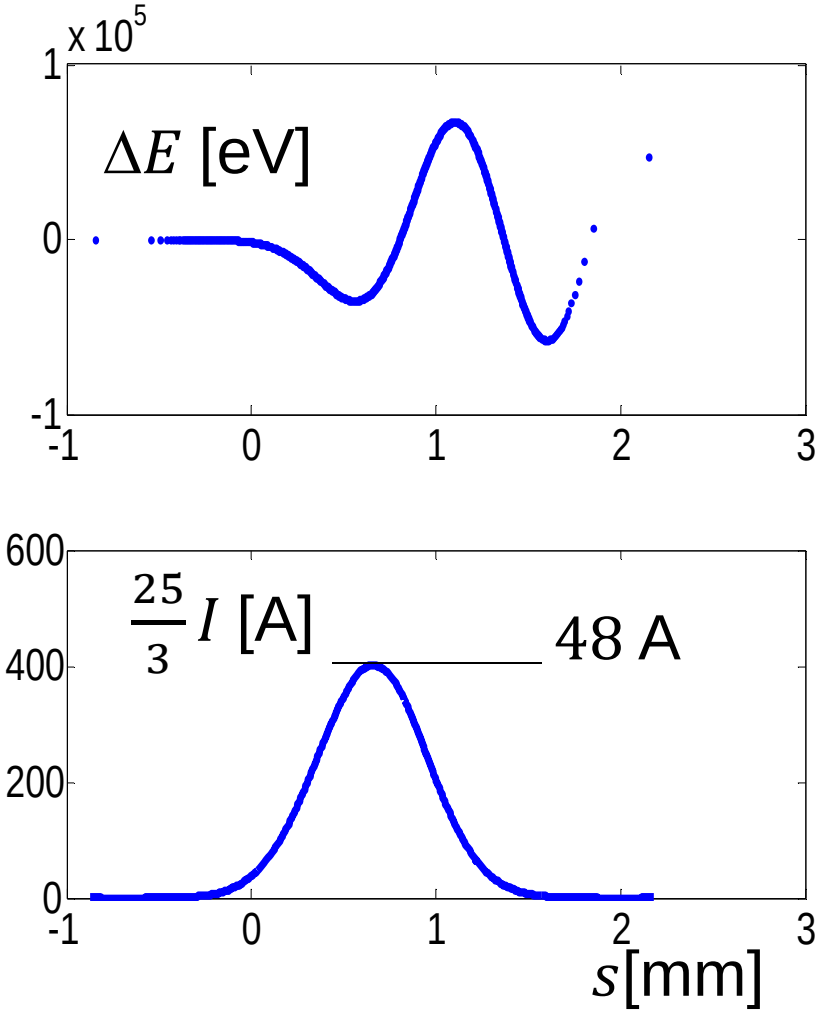
Pipe length L, m	0.5
Bunch enegry E_0, MeV	10
Gausian bunch rms σ, mm	0.3
Charge Q, nC	0.12

Middle bunch. Middle charge. Low Energy

$Q = 120$ pC $\quad \sigma = 0.3$ mm $\quad I_0 = 48$ A

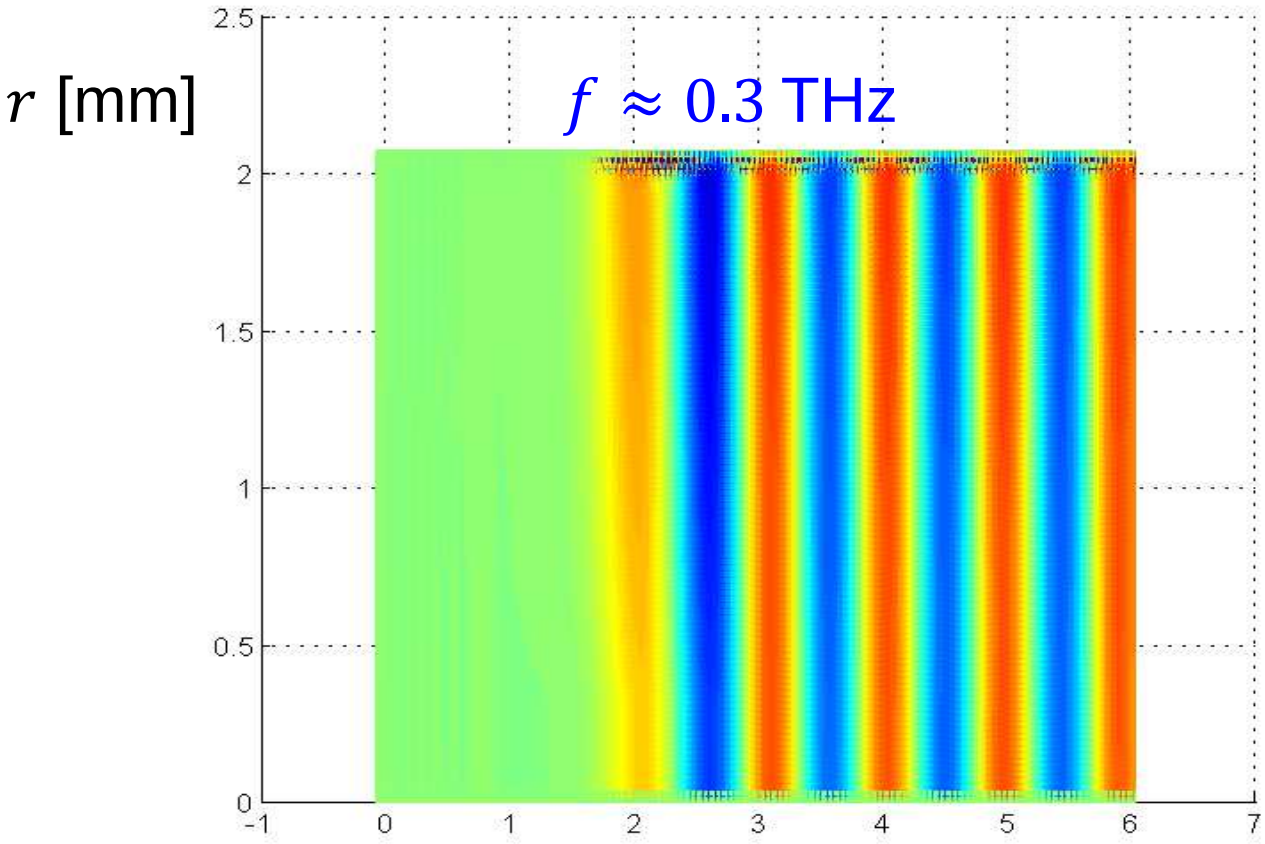
$E_0 = 10$ MeV



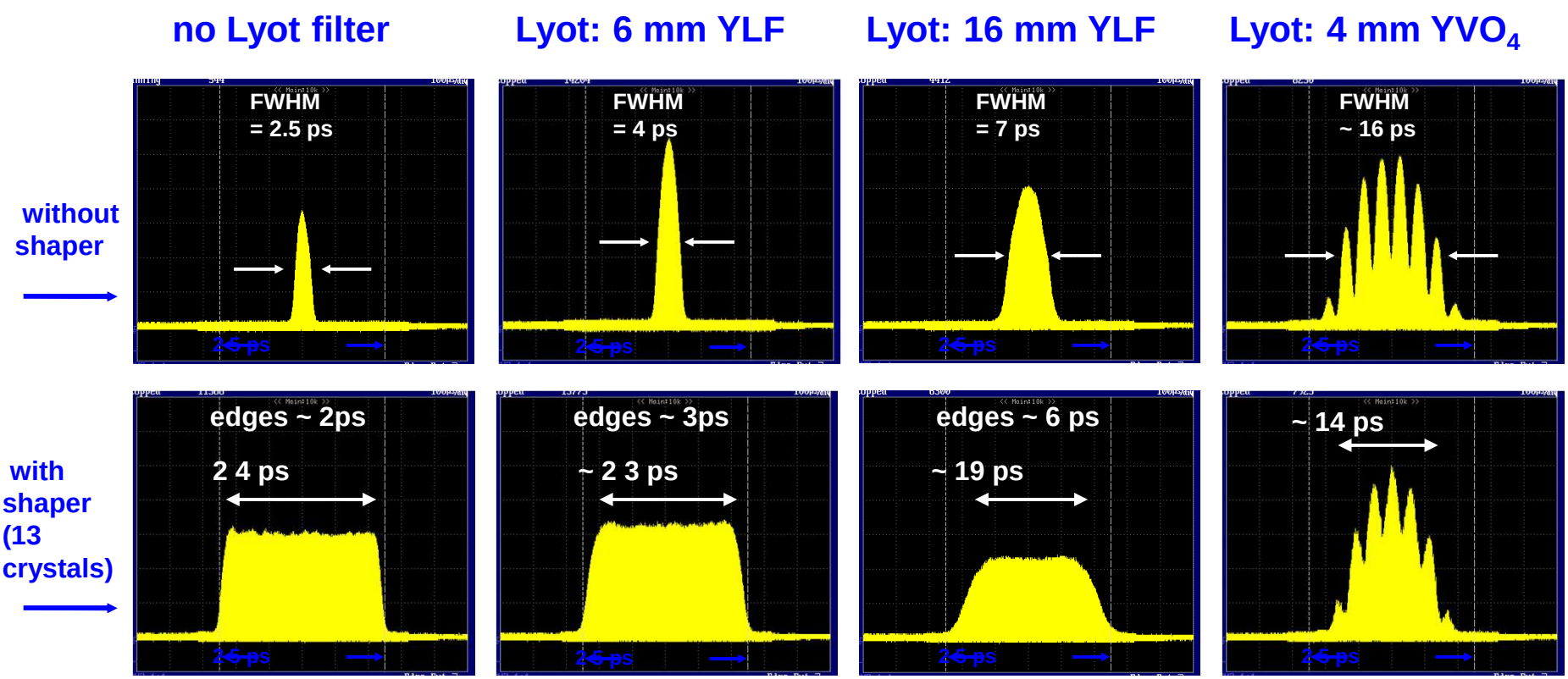


Middle bunch. Middle charge. Low Energy

Longitudinal electric field component E_z



Premodulated bunch (from M. Krasilnikov)

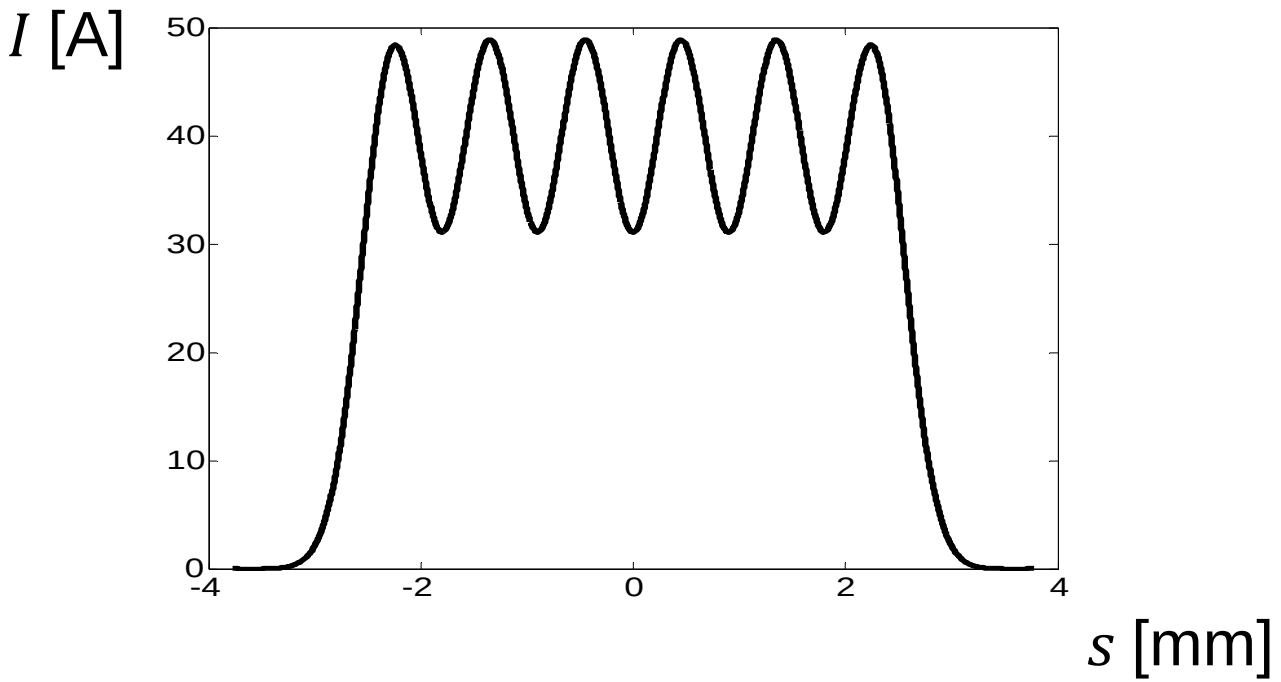


- Edges of the flat-top pulses are slightly shorter than FWHM of the Gaussian pulse (measured without shaper)
- **"Smoothening" of the Modulations** in the flat-top region of the pulse

I. Will, G. Klemz „Increasing the flexibility in pulse shape of a Yb:YAG photocathode laser" 20.06.2009

Premodulated bunch. 6 microbunches

Pipe length L, m	0.5
Bunch enegry E_0, MeV	5
Gausian bunch rms σ, mm	0.3*6
Charge Q, nC	0.12*6

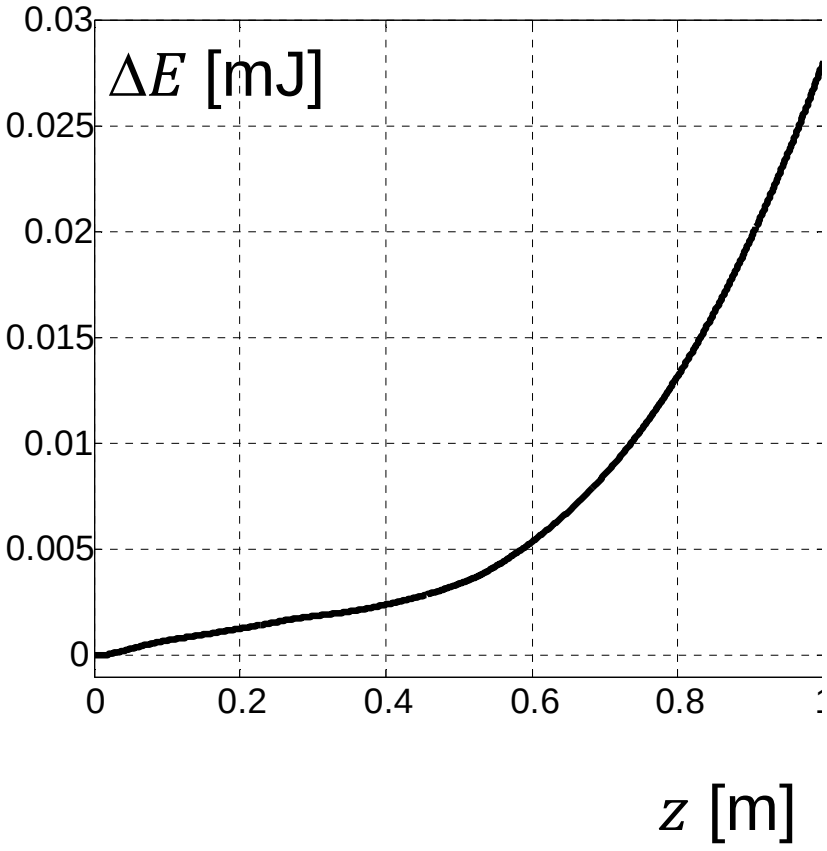


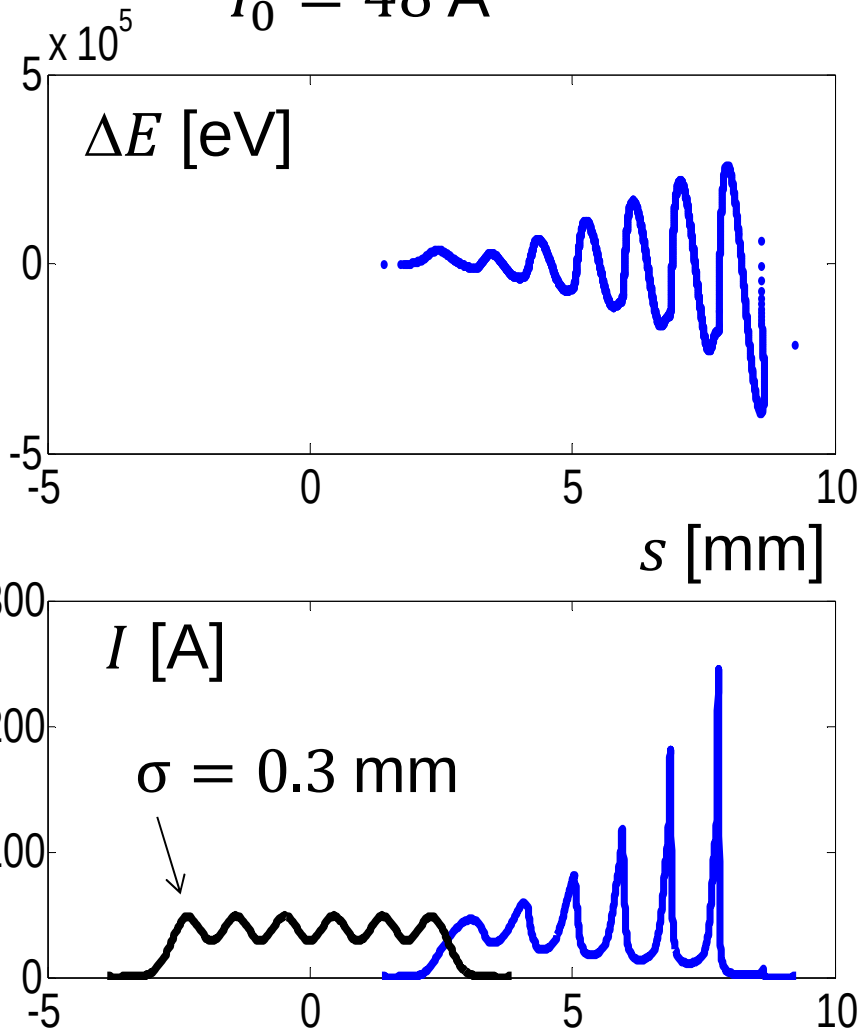
Premodulated bunch. 6 microbunches

$E_0 = 5$ MeV

$Q = 6 * 120$ pC

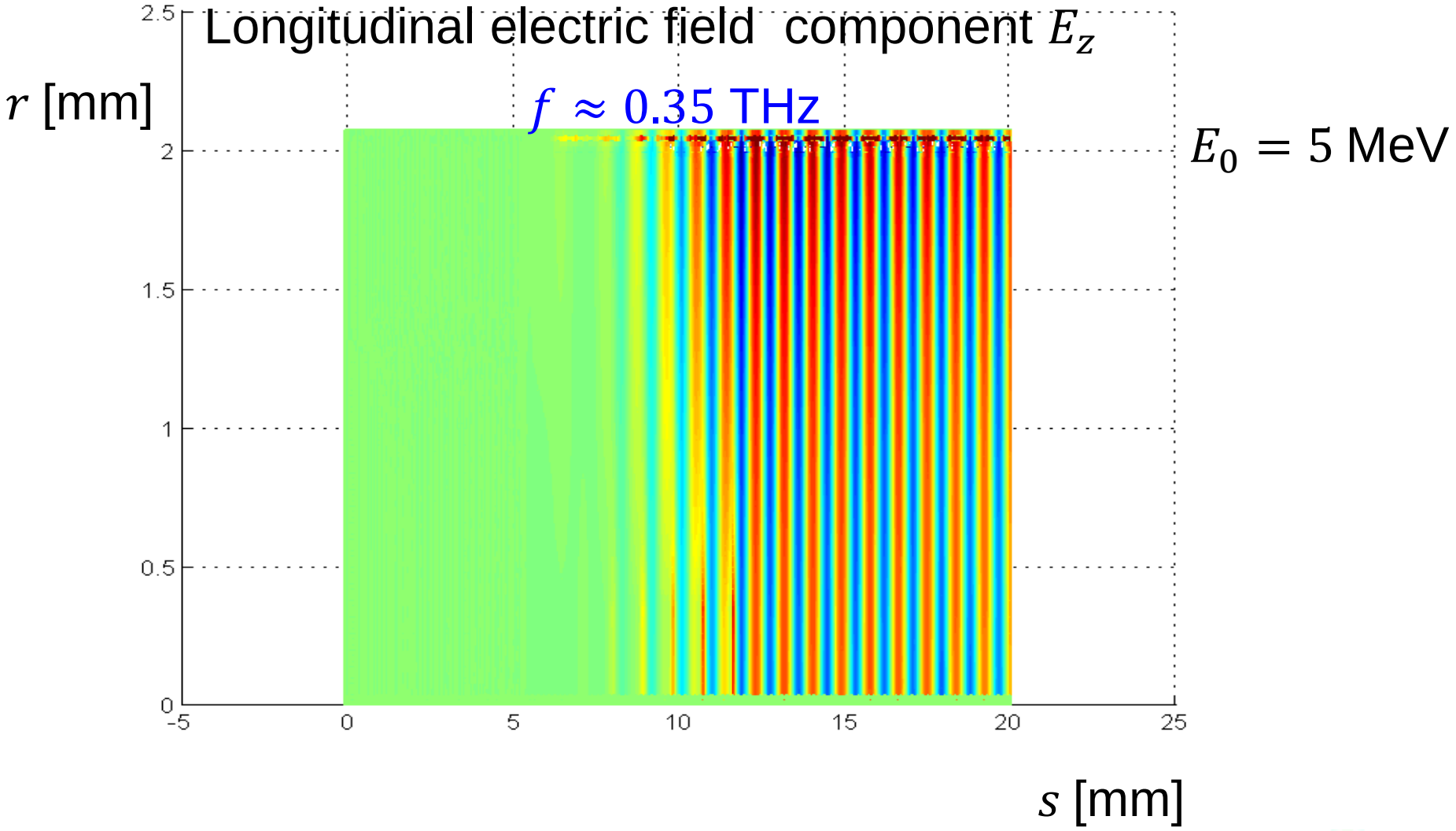
$I_0 = 48$ A



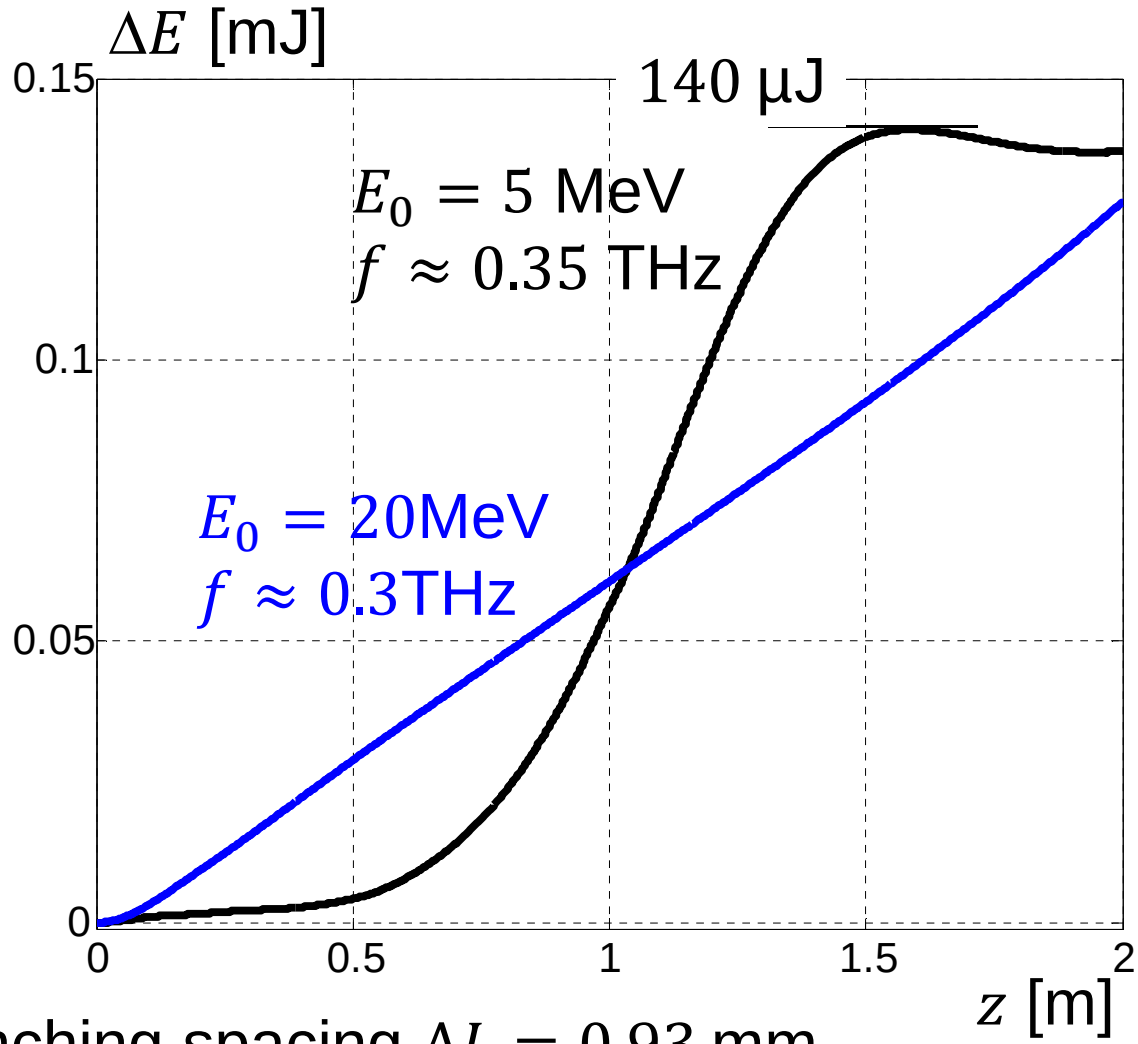


Microbunching spacing $\Delta L = 0.93$ mm

Premodulated bunch. 6 microbunches



Premodulated bunch. 8 microbunches

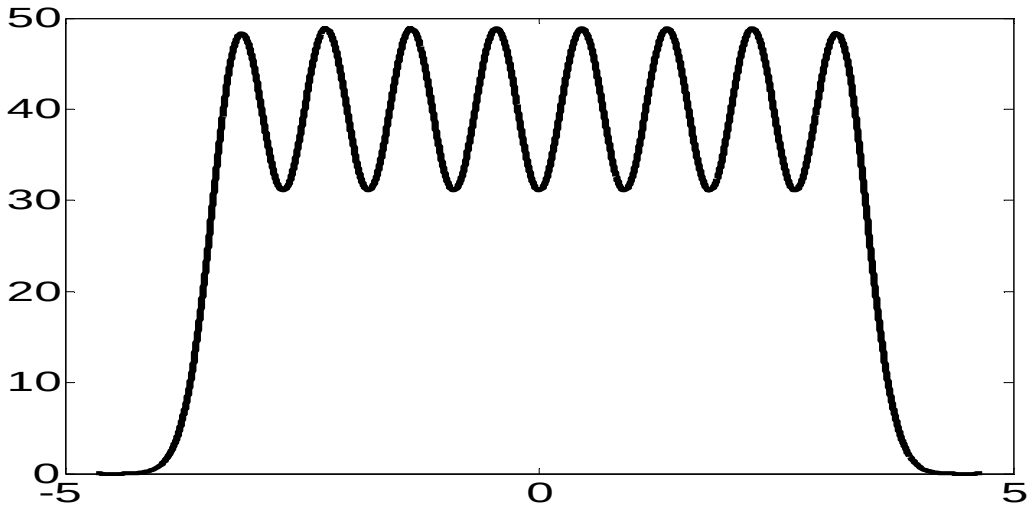


Microbunching spacing $\Delta L = 0.93$ mm

Premodulated bunch. 8 microbunches

Pipe length L, m	1.5-2
Bunch enegry E_0, MeV	5
Gausian bunch rms σ, mm	0.3*8
Charge Q, nC	0.12*8

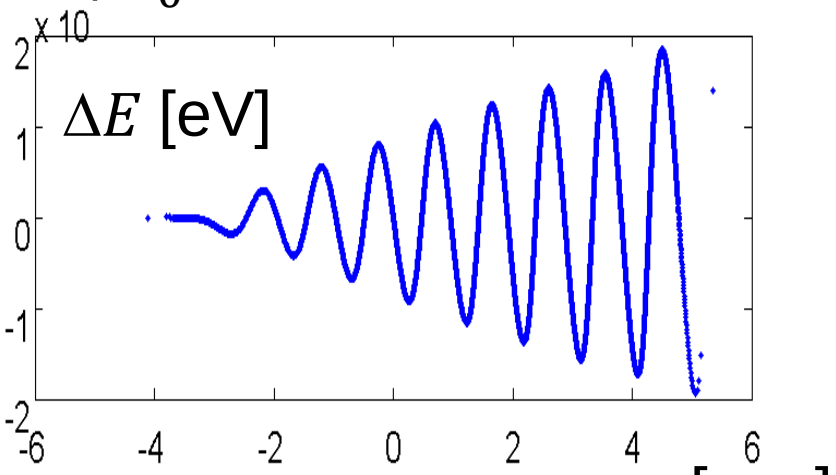
I [A]

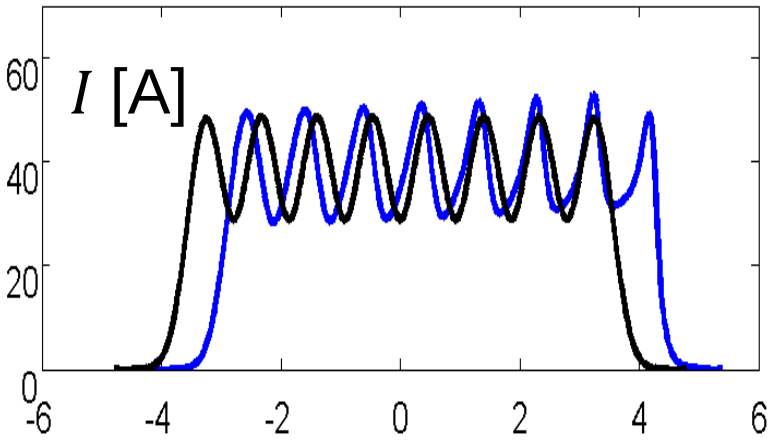


s [mm]

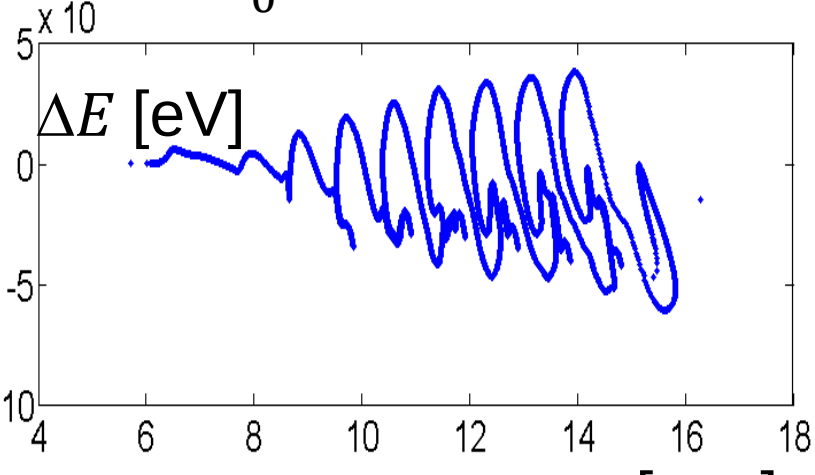
Premodulated bunch. 8 microbunches

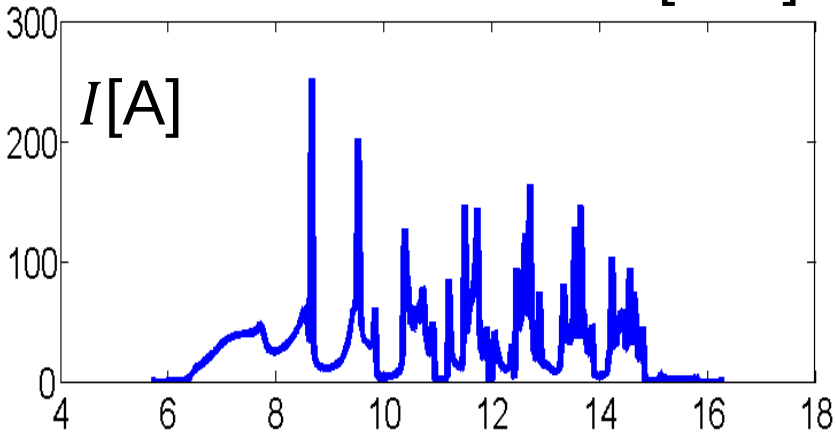
$E_0 = 20$ MeV





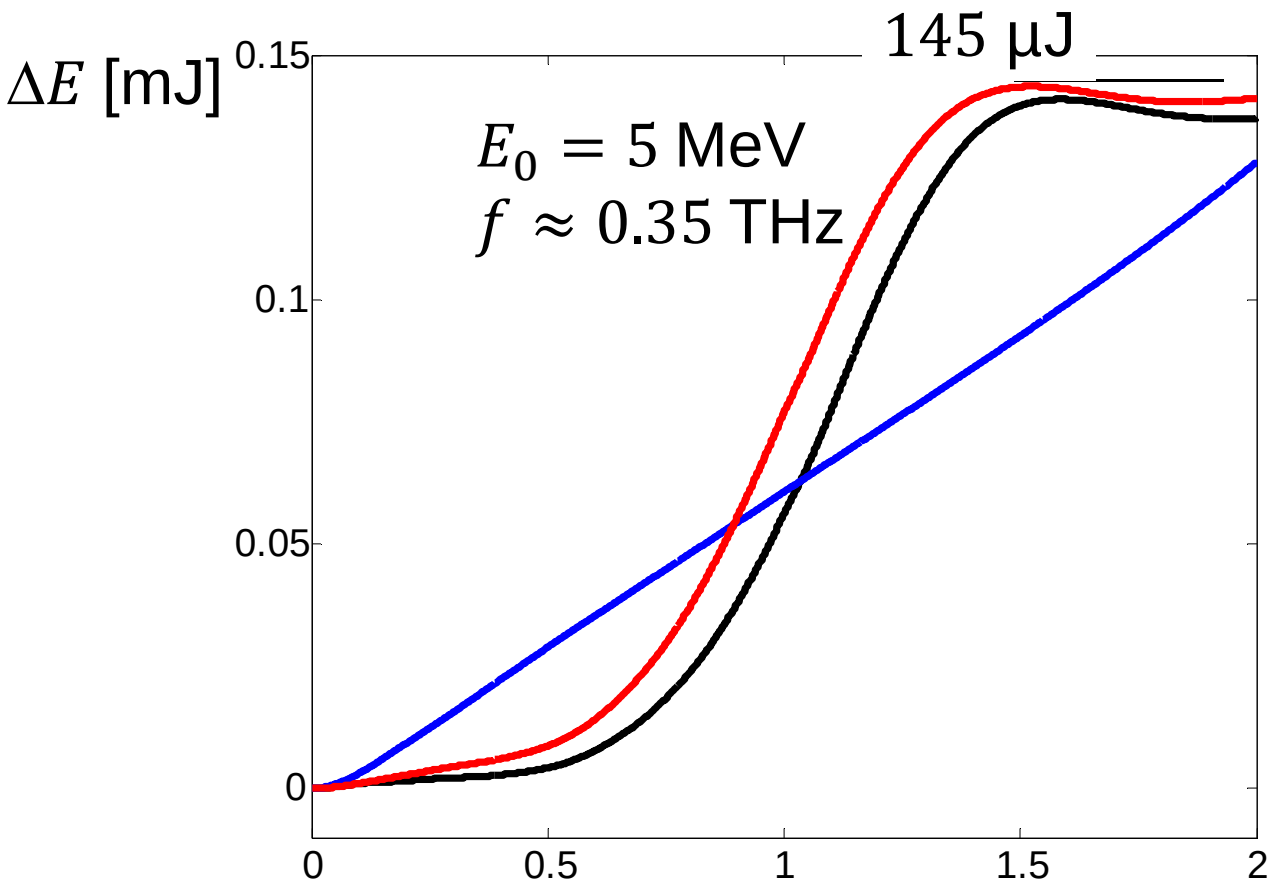
$E_0 = 5$ MeV





Microbunching spacing $\Delta L = 0.93$ mm

Premodulated bunch. 8 microbunches

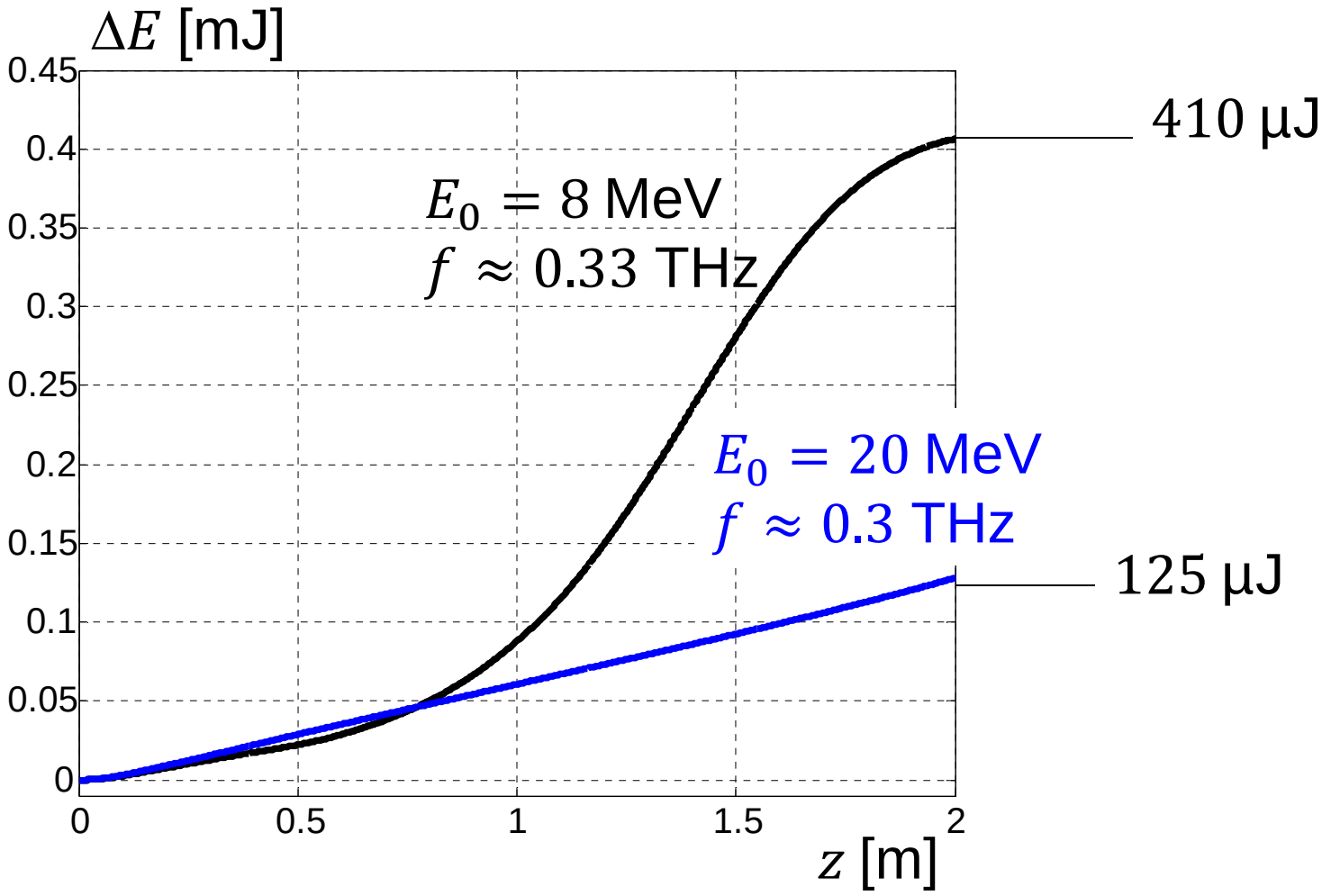


Microbunching spacing $\Delta L = 0.88$mm

Premodulated bunch. 8 microbunches

Pipe length L, m	2
Bunch enegry E_0, MeV	8
Gausian bunch rms σ, mm	0.3*8
Charge Q, nC	0.12*8

Premodulated bunch. 8 microbunches

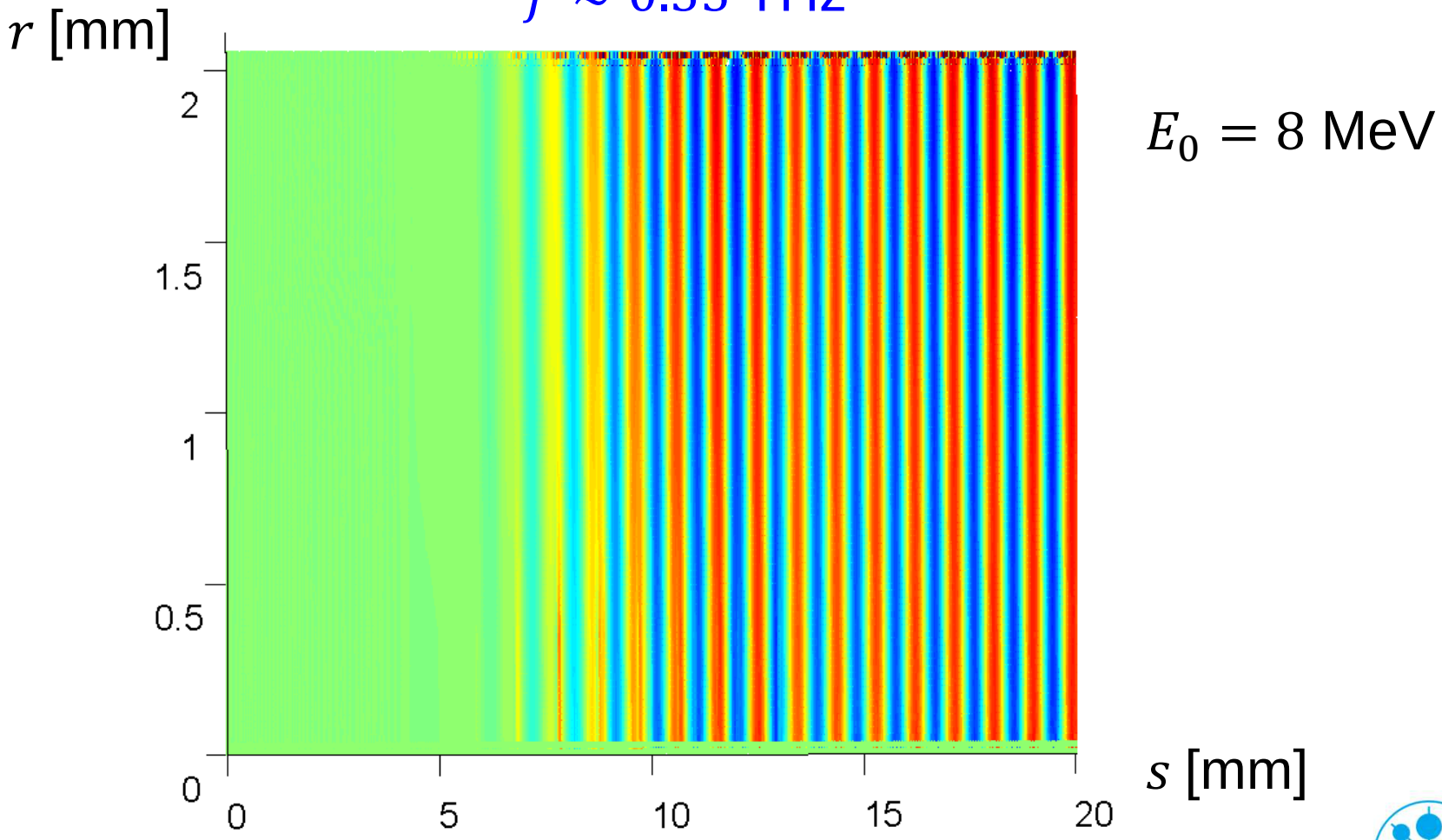


Microbunching spacing $\Delta L = 0.93$ mm

Premodulated bunch. 8 microbunches

Longitudinal electric field component E_z

$f \approx 0.33$ THz



$E_0 = 8$ MeV

Summary

Charge, [pC]	Beam energy, [MeV]	RMS length, [mm]	Number of bunches	Pipe Length [m]	Field energy, [uJ]	Frequ-ency, [THz]
1000	14000	0.1	1	0.5	1400	0.3
1000	20	0.1	1	0.5	1300	0.3
40	10	0.1	1	0.5	2	0.3
120	10	0.3	1	0.5	0.55	0.3
120*8	20	0.3	8	1.5	85	0.3
120*8	5	0.3	8	1.5	140	0.35
120*8	8	0.3	8	2	410	0.33

Summary

To consider:

- transverse dynamics,
- tapering, resonance condition,
- resistivity (already implemented in code),
- rectangular pipe (wakefield code available),
- start from shot noise,
- start with short driving bunch,
- optimal prebunching, optimal energy.