DIELECTRIC WAKEFIELD ACCELERATOR

Experiment code # A19

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Dielectric Wakefield Accelerator
Multimode Dielectric Wakefield Accelerator

"Multimode"
is used to indicate that the field inside the structure is the superposition of many modes

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For sake of simplicity we call further this as

D W A

Components/ Elementary Parts of DWA, and their Purpose

DWA consists of/uses:

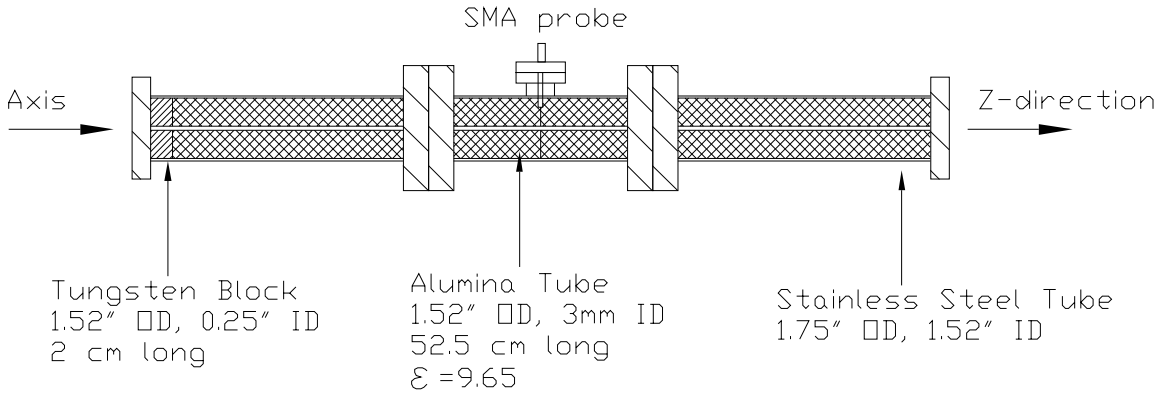
1)

Structure –

annular layer of dielectric enclosed into metal casing, with a narrow channel for electron bunches to pass

Purpose –

helps to create and maintain the wakefield (which has periodicity, and large longitudinal electric field at some points on the axis)



2)

Train of drive bunches –

narrow electron bunches propagating along the structure axis, spaced by the distance = wake period

Purpose –

create, and amplify the wakefield

3)

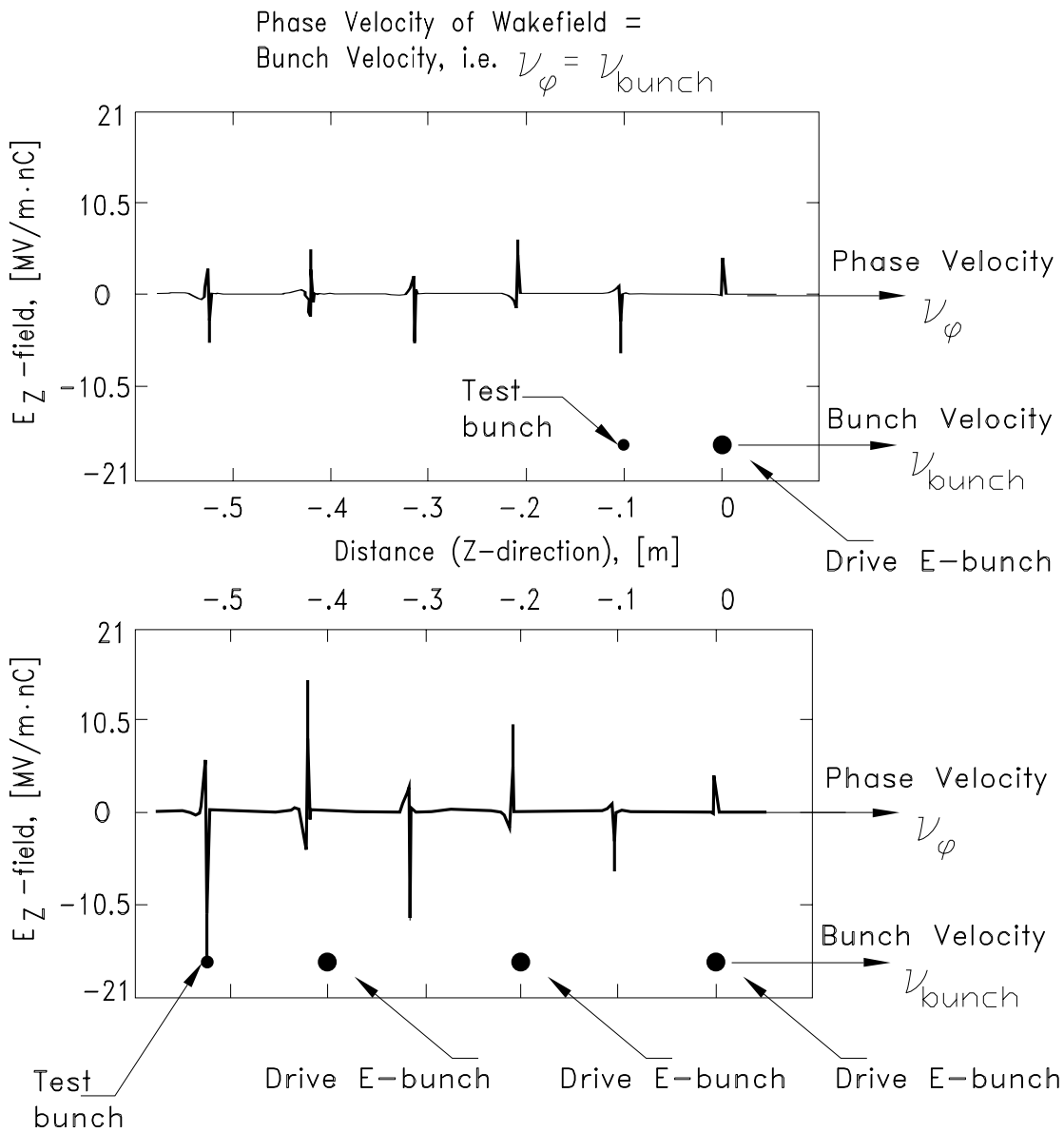
Test bunch –

narrow bunch of electrons, introduced after the drive train at the distance of 1/2 of wake period behind

Purpose –

to consume the energy stored in the wakefield, and, consequently to be accelerated

Examples of wakefield, drive train



Wakefield after a single Drive Bunch (top), and after three Drive Bunches (bottom)

DWA performance:

Efficiency
Acceleration Gradient
Energy Spread

are predicted through the Energy Balance Equation

describing:
interaction between Wakefield, and Train of Bunches

derived so that every bunch can be:

- at any (arbitrary) chosen location along Z- axis
- with any charge
- with any charge distribution (longitudinal/transverse)

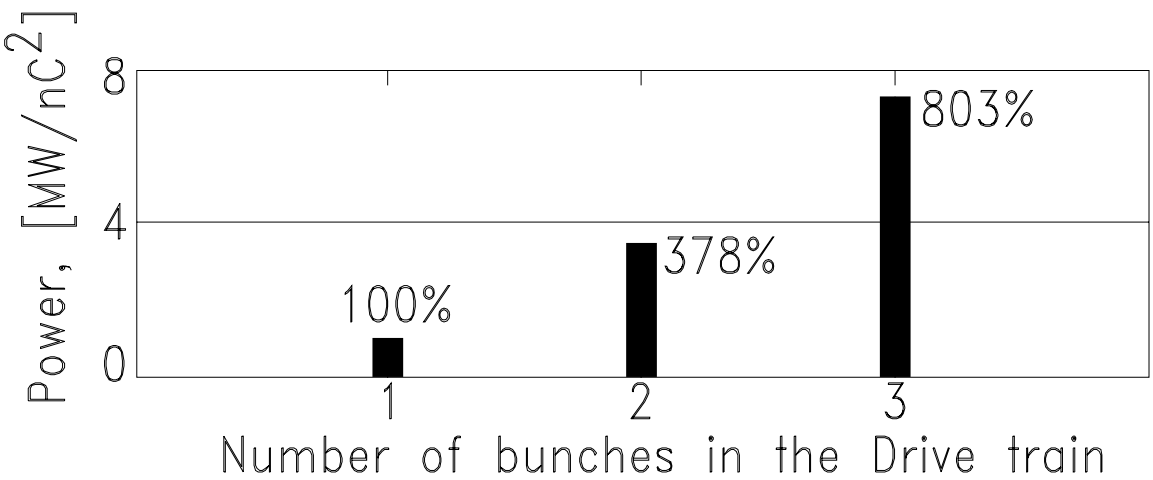
All other related quantities – predicted too

What to observe/monitor:

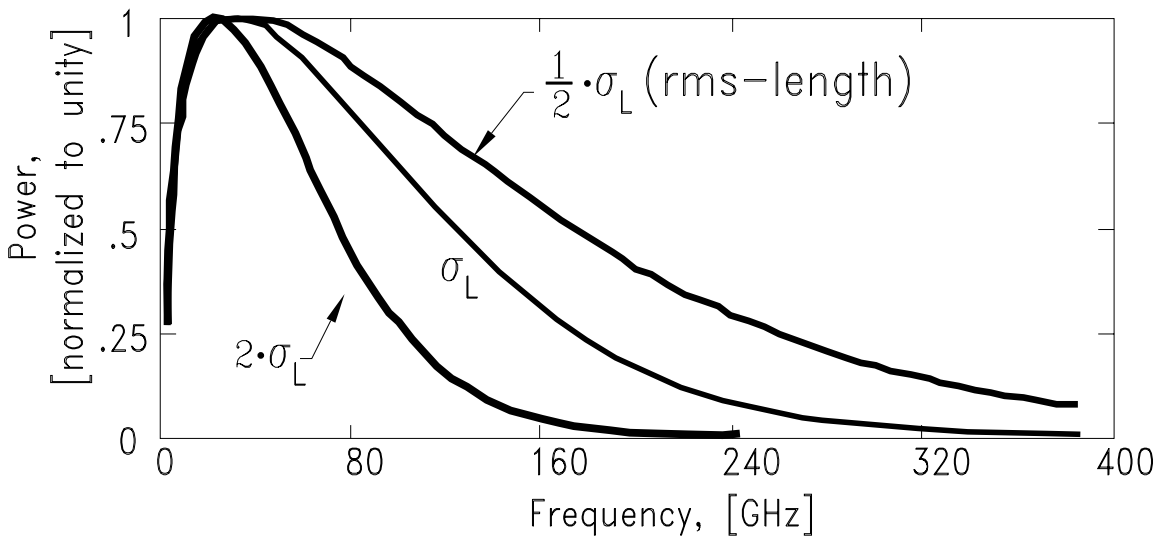
- convenient to monitor
- sufficient to draw conclusion about other quantities

One can observe:

- Radiated Power
- Spectrum
- Test bunch energy gain
- Drive bunch(es) energy losses

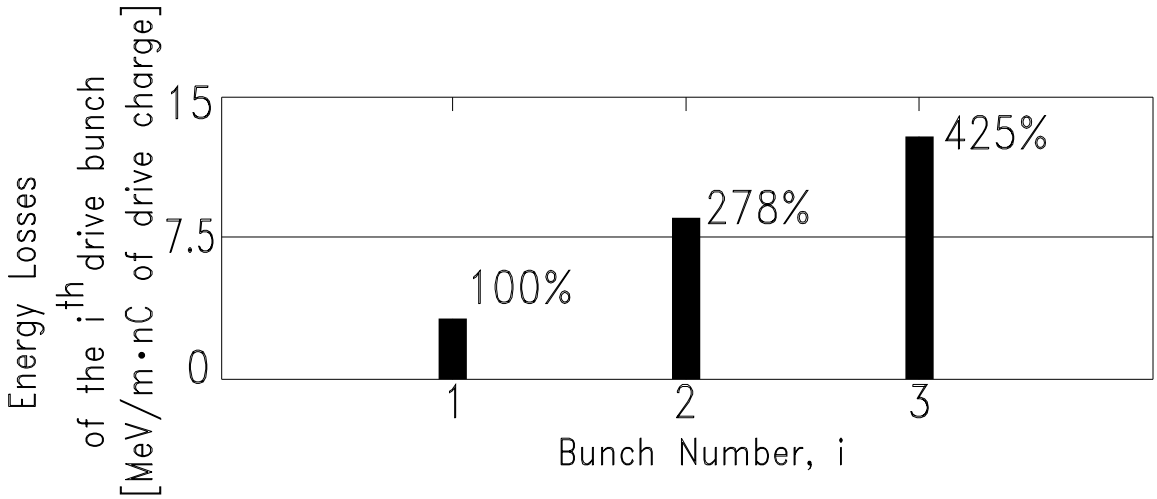


Radiated into wakefield Power, after a given number of driving bunches
(spacing = wake period, i.e. Coherent Regime)



Predicted Spectrum after a single bunch with different rms-length

Acceleration Gradient, acting on a test bunch, after a given number of driving bunches
(drive bunch spacing = wake period, i.e. Coherent Regime)

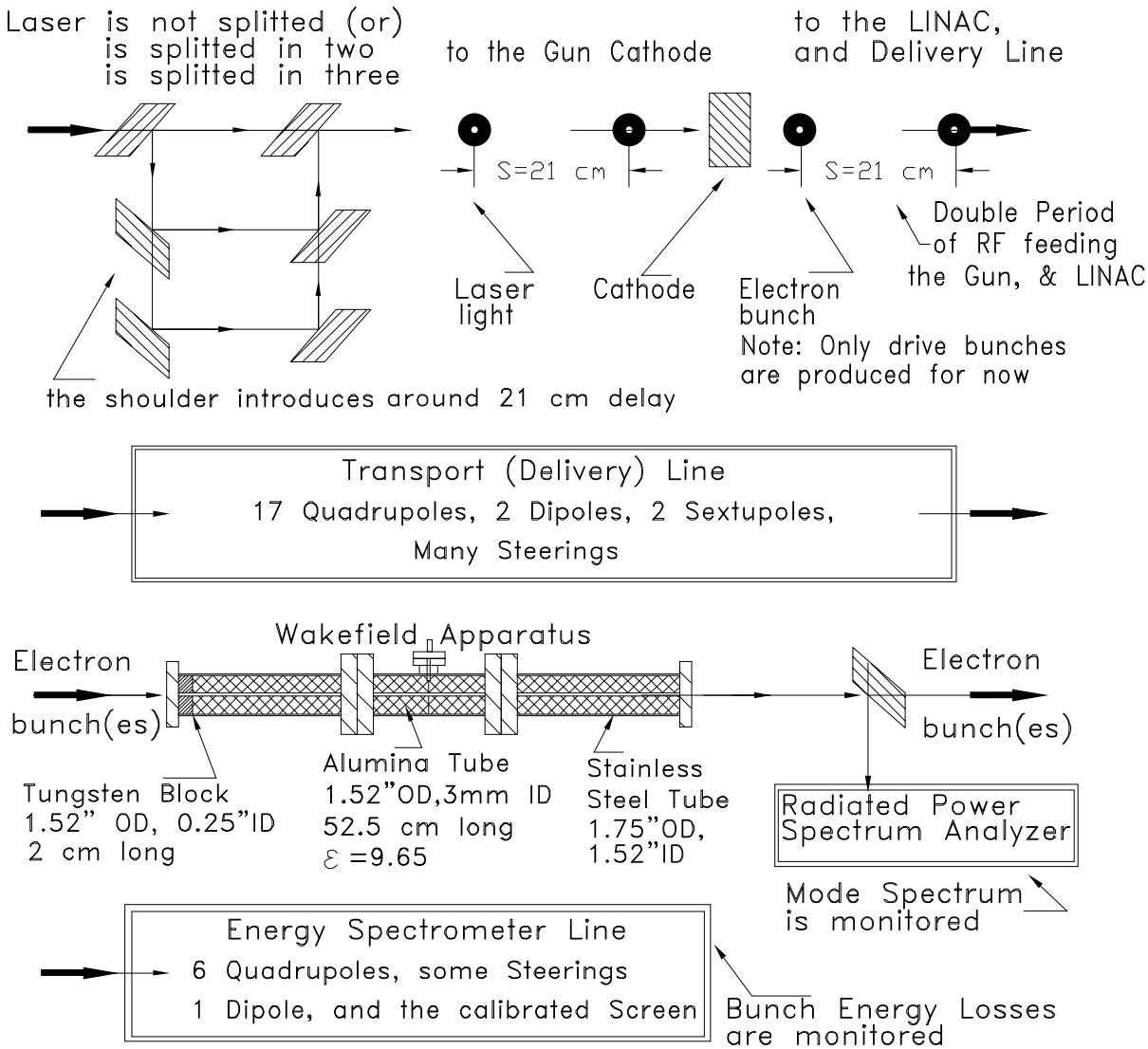


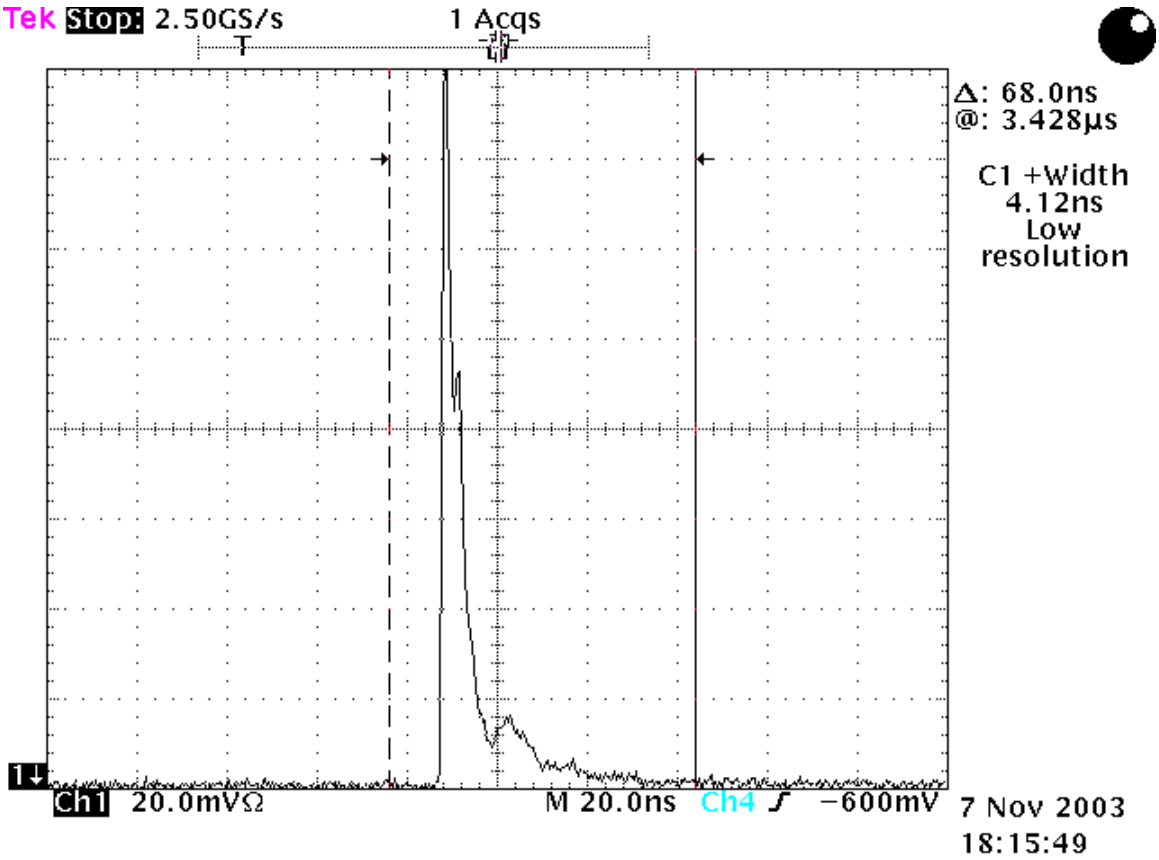
Energy Losses experienced by every consecutive drive bunch (spacing = wake period, i.e. Coherent Regime)

In experiment the following is observed/monitored

- Spectrum
- Drive bunch(es) energy losses

The following Set up is used





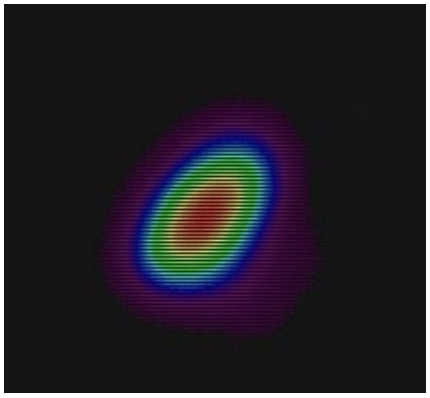
Signal from Detector Unit

Mirror with a slit:	reflects radiation, permits electron to pass
Mesh Filter:	(several), to pick up frequency
Antenna &Crystal:	to measure amount of power carried by the given frequency

Goes in less than a month

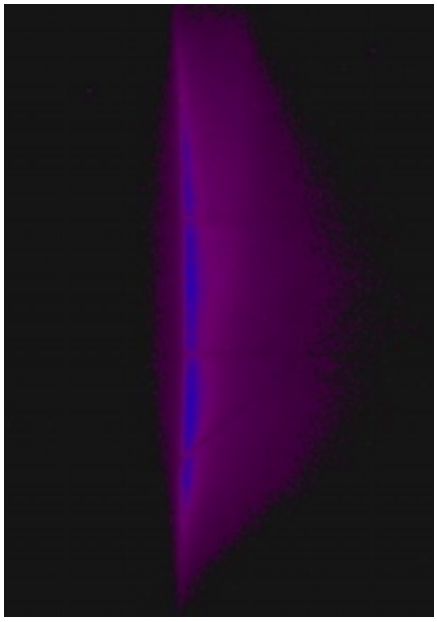
Energy Losses by drive bunches

Single Bunch:

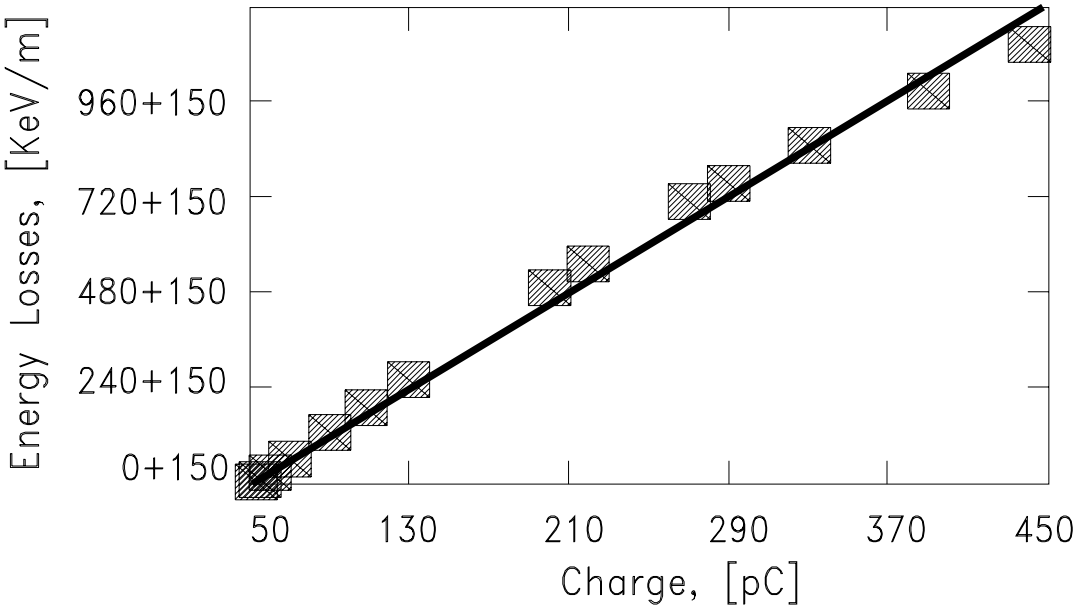


Entrance/ Exit of wake apparatus

$\sigma_X, \sigma_Y \leq 250$ [μm]



Spectrometer Screen



Note: matches with $\sigma_L \approx 1.8 \pm 0.15$ [psec], and $\sigma_{tail}/\sigma_{head} \approx 2:1$

Two drive bunches: Energy Losses

Dispersion related issues - to be addressed

Why?

- every beam transport line has D_X, and D_Y

- if the First Bunch with energy W_1 follows some path (reference orbit)

- the Second Bunch with energy W_2 (close to W_1) follows a different path, so that:

$$\Delta X = D_X \cdot \frac{W_2 - W_1}{W_1} \qquad \Delta Y = D_Y \cdot \frac{W_2 - W_1}{W_1}$$

- if a narrow aperture is somewhere along the line, it can happen that:

ΔX, $\Delta Y \geq$ aperture (radius =1.5 [mm], length =0.5 [m])

the Second bunch may not go thru the Aperture

- consequently one must keep

ΔX, ΔY - very low at the aperture location, & to do so:

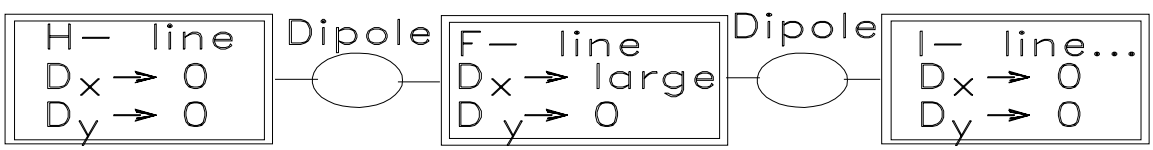
1) W_2 close to W_1

- not ideally possible due to adjustment error (**0.2 MeV**)
- not possible if the Bunch Spacing is intentionally different from the Integer of the RF period (e.g. 21 cm) – bunch Spacing = Wake Period ≠ Integer of RF Period

had routinely up to $|W_2 - W_1| \approx 0.44$ MeV

2) D_X, D_Y close to zero

Delivery Line (MAD v.8.01 - simulation):



D_X, D_Y $\approx 7 \div 12$ [cm], or ≥ 1.5 mm/MeV @ 50 MeV

Energy Acceptance ≈ 0.2 MeV - (taking into account that the electron spot size $2 \cdot \sigma_{x,y} \approx 0.5$ mm)

- $D_X \rightarrow 0$, use quadrupoles in F-line: make dispersion almost exactly "zero"
- $D_Y \rightarrow 0$, cannot use quadrupoles; use steering magnets (like a small dipole); use sextupoles (but, can "spoil" D_X)

D_X	0.75 [cm]	150 μm/MeV @ 50 MeV
D_Y	0.9 [cm]	180 μm/MeV @ 50 MeV

Energy Acceptance = 1.5 ÷ 1.8 MeV

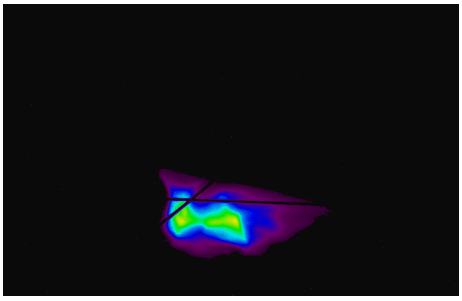


Image at FPOPUP1 (two beams: energy difference up to 0.44 MeV)

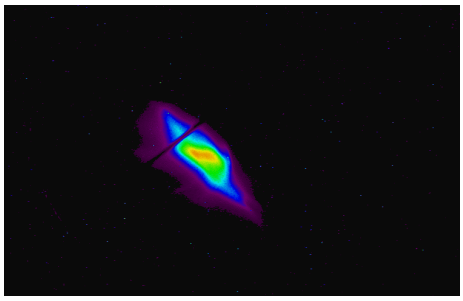
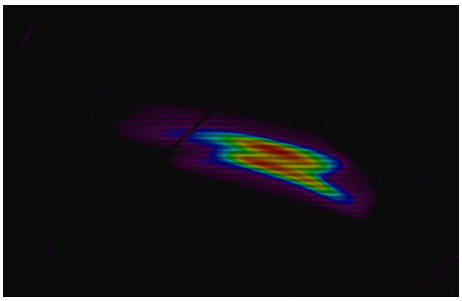


Image at Entrance (two beams: spots coincide; size $\sigma_{x,y} \approx 220$ μm)



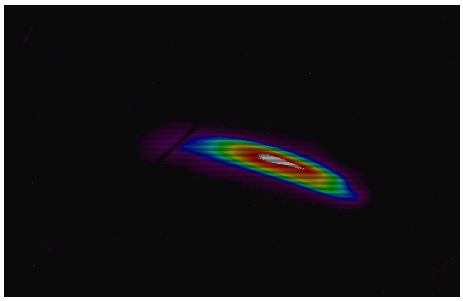
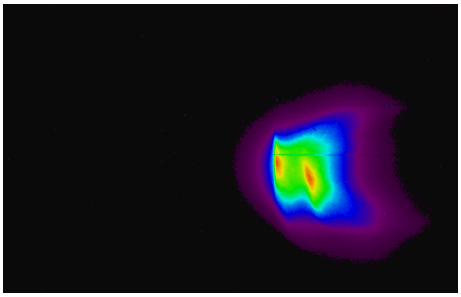
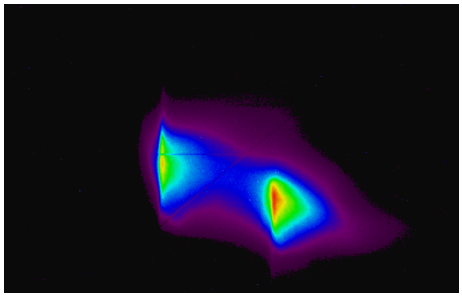


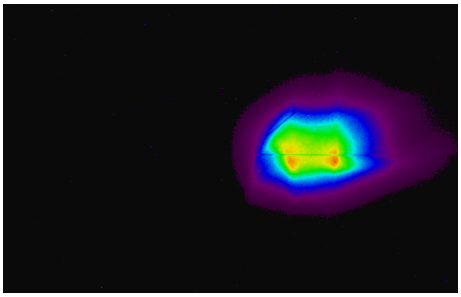
Image at Exit (size $\sigma_{x,y} \approx 190 \div 320$ μm)



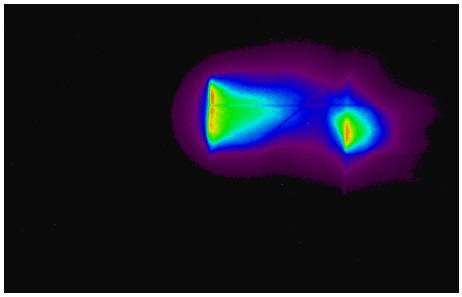
$Q_1 \approx 417$; $Q_2 \approx 303$ [pC]



$Q_1 \approx 695$; $Q_2 \approx 504$[pC]



$Q_1 \approx 545$; $Q_2 \approx 395$[pC]



$Q_1 \approx 811$; $Q_2 \approx 588$ [pC]

Images on Spectrometer Screen. Note: $Q_2/Q_1 \approx 0.725$

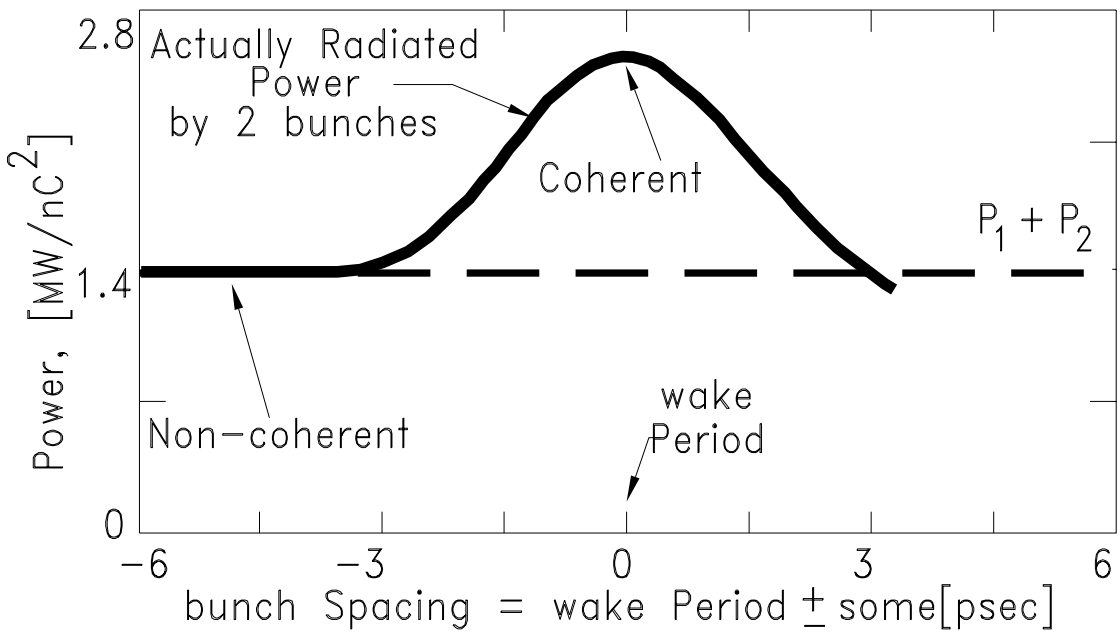
Note: $Q_2 = Q_1 \cdot 0.725$ – experiment settings

$E_1 = E_1(Q_1)$ - energy loss, first bunch

$E_2 = E_2(Q_1, S, L)$ - energy loss, second bunch;
S- bunch Spacing, L – wake Period

E_2 –

depends on how bunch Spacing – close to – wake Period



- **Non-coherent** Regime:

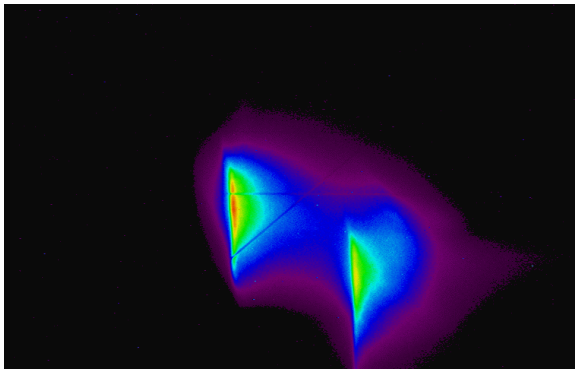
E_2/ E_1 ≈ 0.73	because Q_2/Q1≈ 0.73
$E_2 - E_1$ vs. Q_1	has always **negative** slope

- **Coherent** Regime:

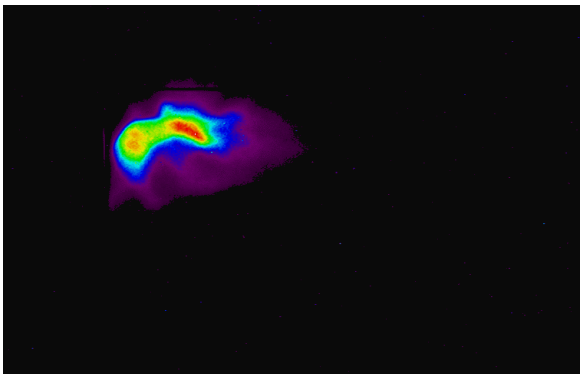
E_2/ E_1 > 2.2	even though Q_2/Q1≈ 0.73
$E_2 - E_1$ vs. Q_1	has always **positive** slope

Number: $E_2 - E_1$ vs. Q_1

- $E_2 - E_1$ - nicely predictable (previous page)
- $E_2 - E_1$ - simple to measure

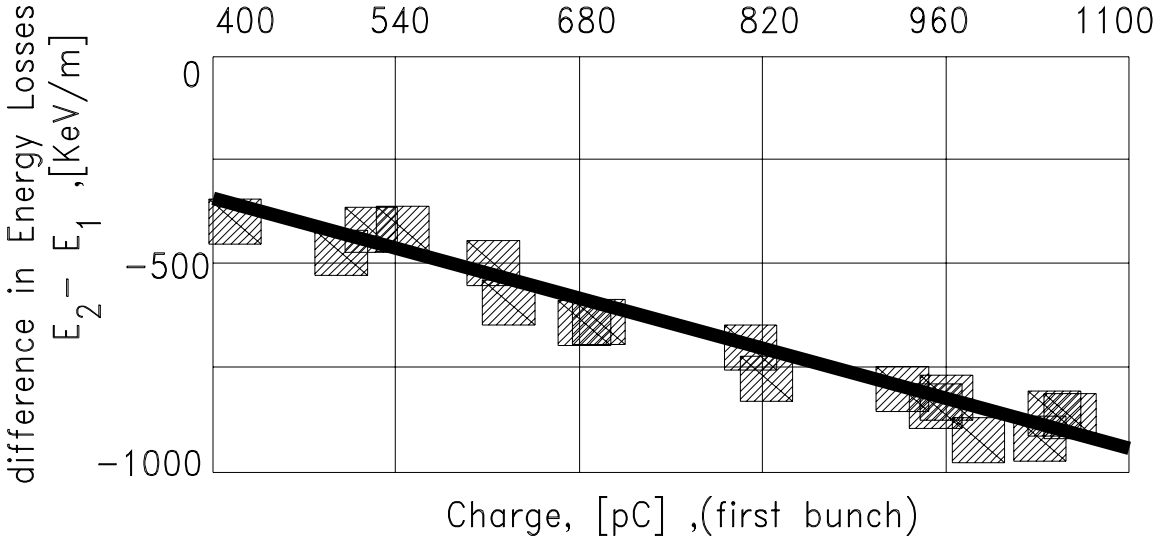


Spectrometer: higher energy is to the right



Two beams in F-line: the energy difference

- <u>Left</u> Fig.: Distance [KeV] between spots gives + info about the initial energy difference, see <u>Right</u> Fig. gives **$E_2 - E_1$**



Non-coherent regime. Note: matches with $\sigma_L \approx 1.8 \pm 0.15$ [psec], $\sigma_{tail}/\sigma_{head} \approx 2:1$ (bunch spacing – much different from – wake), with $E_2/E_1 = 0.73$ because $Q_2/Q_1 \approx 0.73$

Summary:

1) Achieved

- Radiated Power – nicely detectable signal;
- One (1) bunch – energy losses is measured, match with theory
- Two (2) bunches – energy losses in Non-coherent regime is measured, match with theory

2) To finish up [**by June/2004**]

- Radiated Power – resolve Spectrum;
- Two (2) bunches – hit Coherent regime
- Three (3) bunches – hit Coherent, and Non-coherent regimes

Run Time – wanted

This finishes the presentation:

DIELECTRIC WAKEFIELD ACCELERATOR

PI: Marshall, Thomas C., presented by: Shchelkunov, Sergey V. (Columbia Univ. NYC)

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