Beam Dynamics in Low Energy Part of XFEL Accelerator

(Intermediate report)

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XFEL Beam Dynamics Group Meeting , 17 Dec 2007

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- Misalignments in Injector Linac
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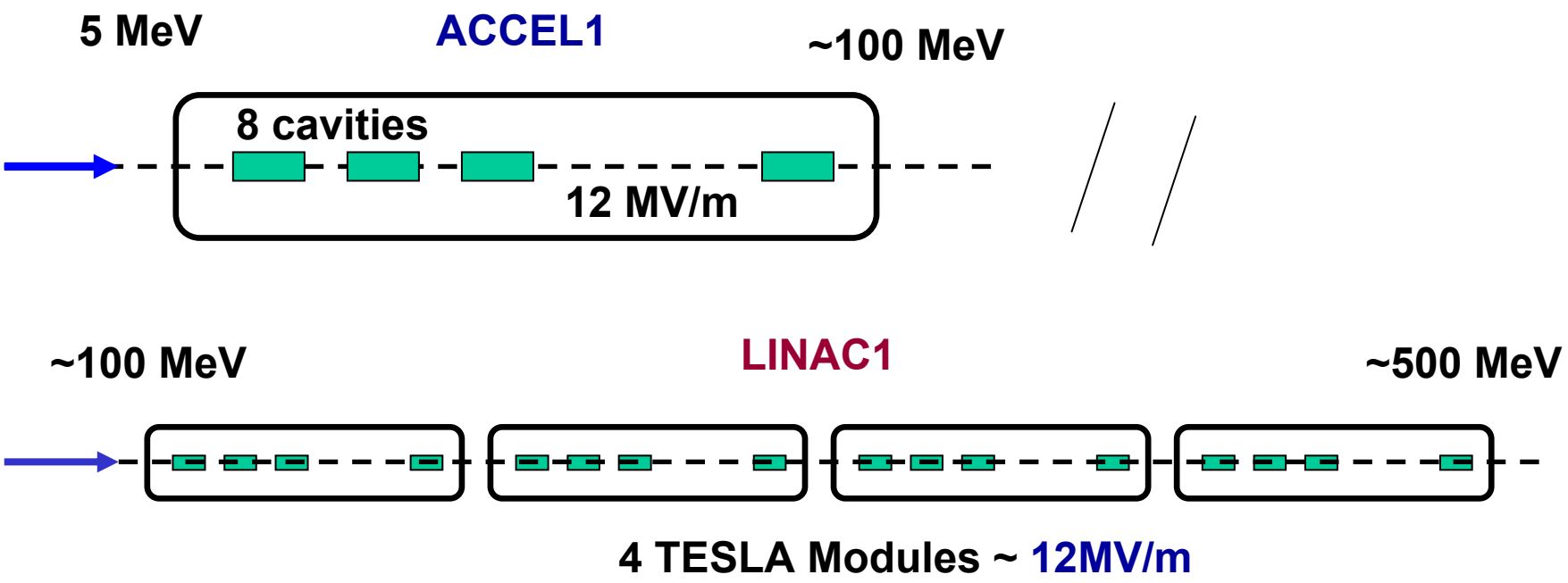
Parameter list

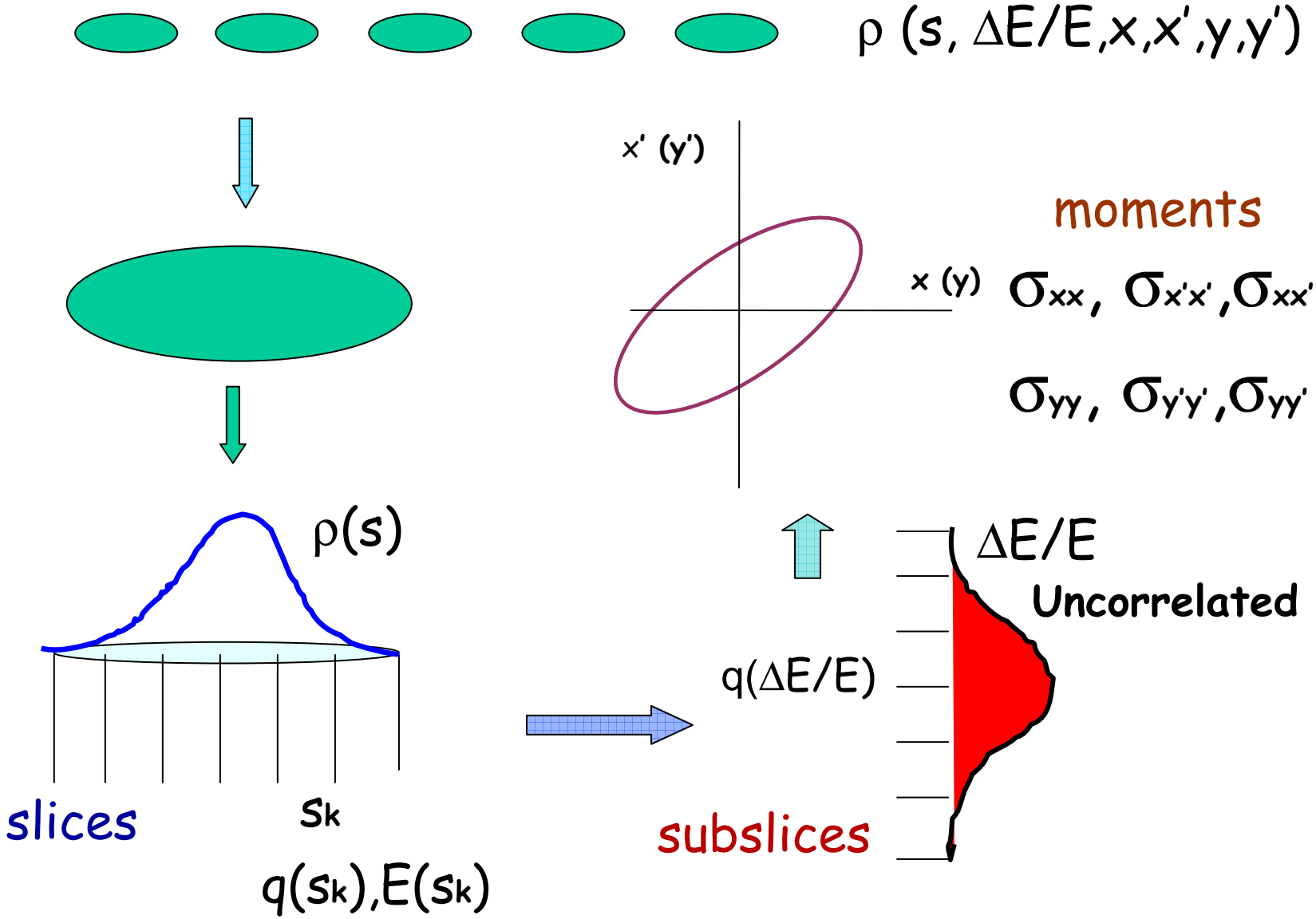


Bunch Charge – 1nC

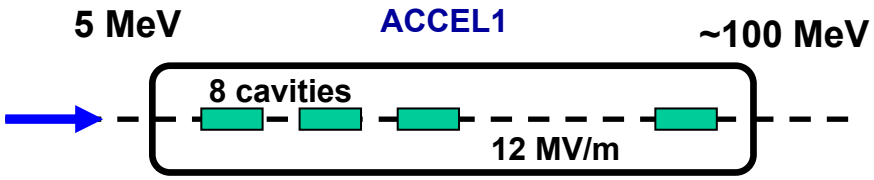
Bunch rms length – 2mm

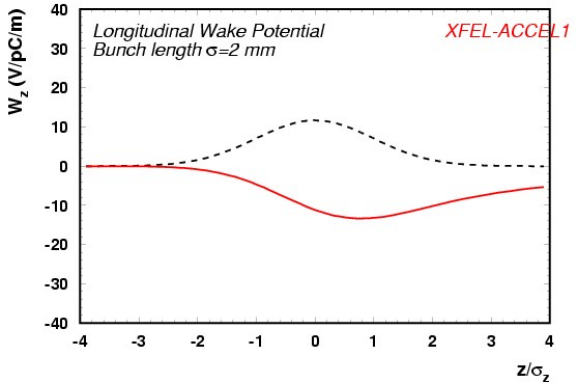
Normalized emittance – 1mm*mrad

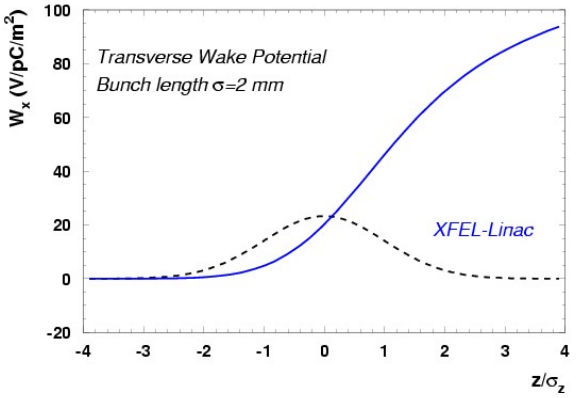
Beam Model for Particle Tracking

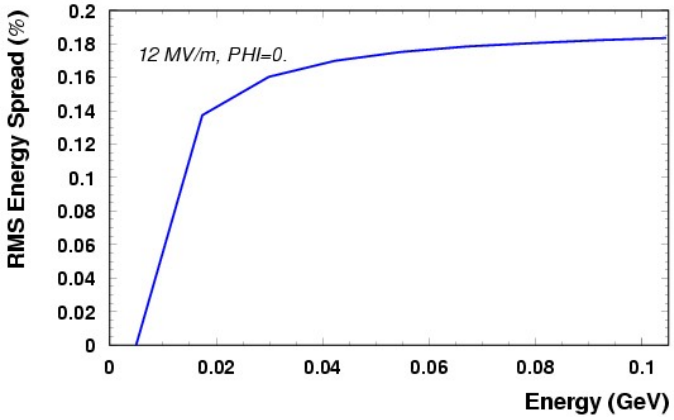


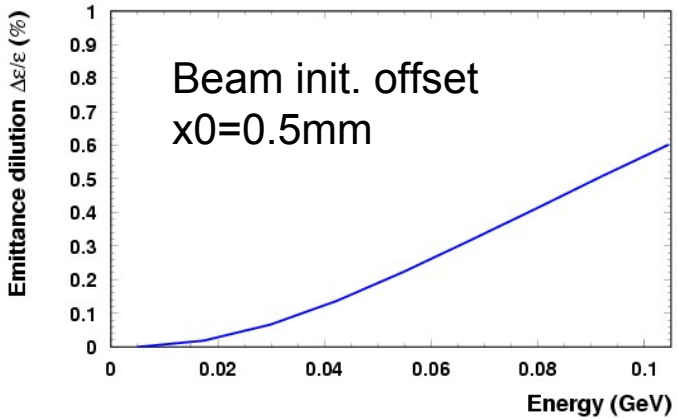
ACCEL 1


5 MeV
ACCEL1
~100 MeV
8 cavities
12 MV/m


Longitudinal Wake Potential
Bunch length σ=2 mm
XFEL-ACCEL1
W_z (V/pC/m)
z/σ_z


Transverse Wake Potential
Bunch length σ=2 mm
XFEL-Linac
W_x (V/pC/m^2)
z/σ_z

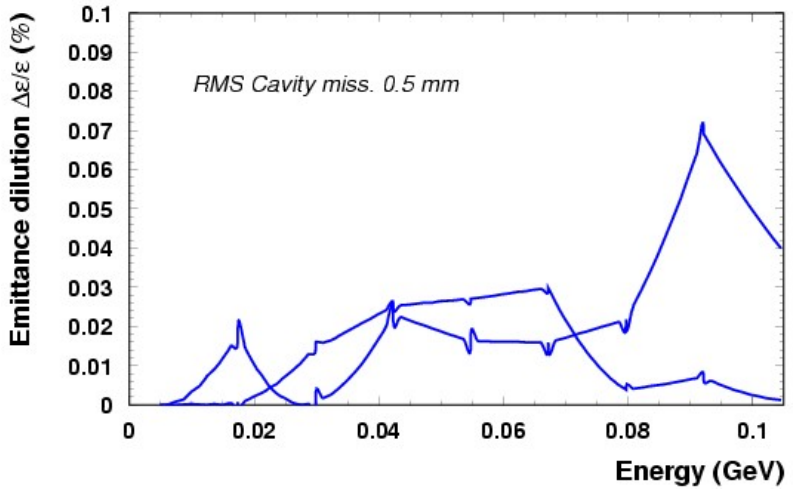

12 MV/m, PHI=0.
RMS Energy Spread (%)
Energy (GeV)


Beam init. offset
x0=0.5mm
Emittance dilution Δε/ε (%)
Energy (GeV)

ACCEL1 – Emittance Dilution

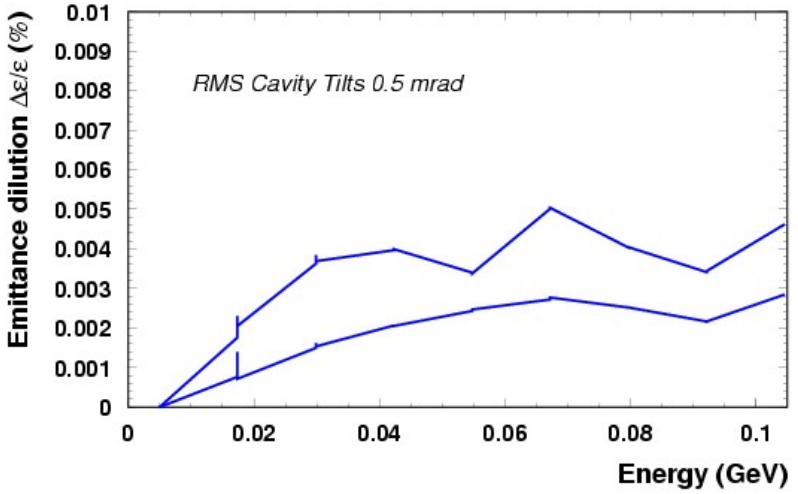
Cavity misalignment

RMS -0.5 mm



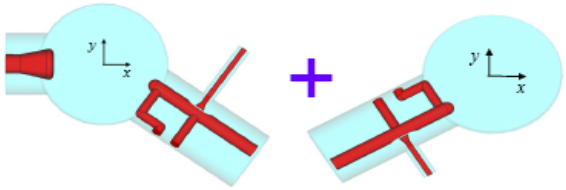
Cavity random tilts

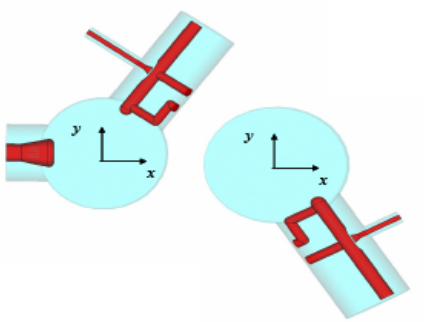
RMS – 0.5 mrad

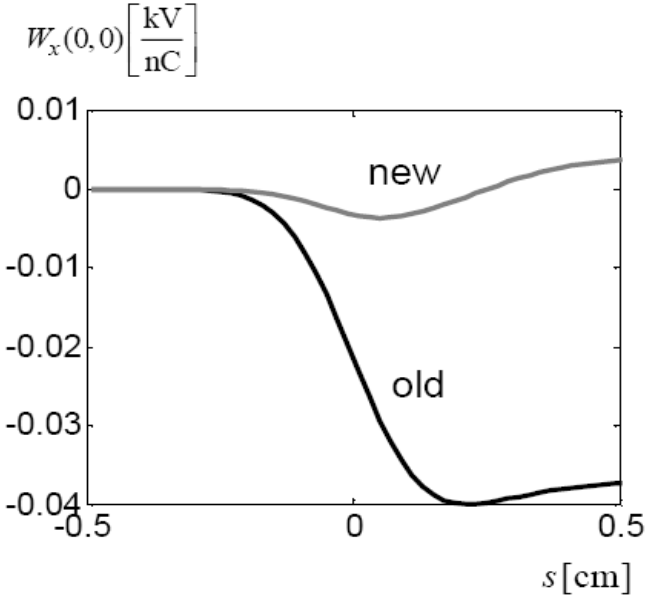


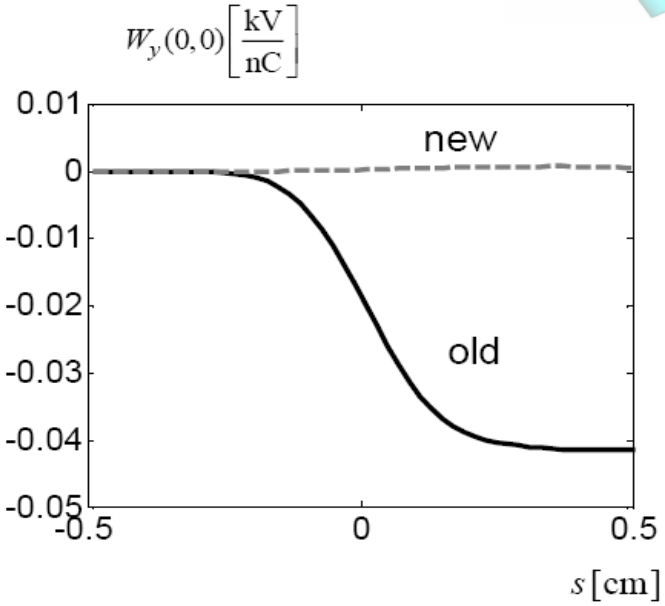
Coupler Wakes

Wake kick for the new orientation









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Coupler Kick Parameters: Wake and RF field

Head-Tail Kick (rms kick)

$$k_{\perp}^{rms} \approx k_{\perp}^{0,rms} + k_{\perp}^{1,rms} r$$

$$k_{\perp}^{0,rms}\left[\frac{V}{nC * cavity}\right]$$

RMS bunch length,μm	Coupler wake	Coupler RF field	Cavity tilt by 1 mrad (on crest / 10 grad)	Cavity wake
2400	Design= 16.4 New=1.4	58	23 / 88	0
120		2.9	0.06 / 4	
25		0.6	0.002 / 0.9	

$$k_{\perp}^{1,rms}\left[\frac{V}{nC * mm * cavity}\right]$$

RMS bunch length, μm	Coupler wake	Coupler RF field	Cavity wake
2400	Design= 2.5 New= 1.3	2.7	21.6
120		0.14	3.5
25		0.03	0.77

I.Zagorodnov, M.Dohlus, 04. 2007

Notation and Definitions

$\lambda(s)$ – Gaussian bunch with rms width σ

$$k_\perp = \langle W \rangle = \int W(s)\lambda(s)ds \text{ – kick factor}$$

$$k_\perp^{\text{rms}} = \left\langle (W - k_\perp)^2 \right\rangle^{0.5} = \left[\int \left(W(s) - k_\perp \right)^2 \lambda(s) ds \right]^{0.5} \text{ – rms kick factor}$$

- For linear approximation of W(s): $K \sim \sqrt{3}\, K_{rms}$
- Scaling with accel grad and bunch length for Coupler RF → $K_{rf} \sim V_{cav} * \sigma_z$

RF kick for

U=12 MV/m, σ=2 mm →

Monopole term

Ko=66.4 V/nC/cav

Krms=38.4 V/nC/cav

Dipole term

Krms=1.8 V/nC/mm/cav

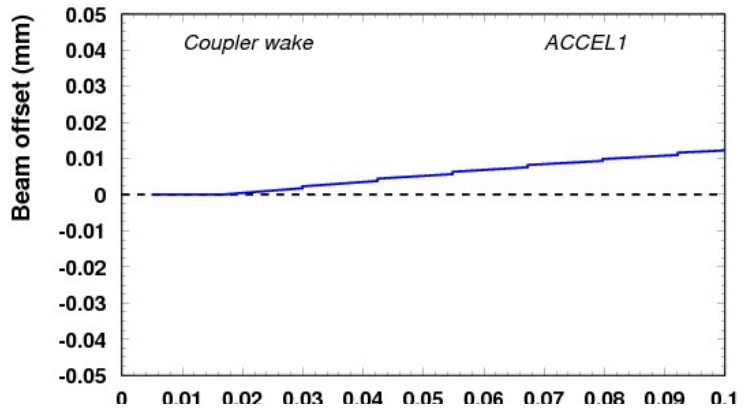
Ko=3.0 V/nC/mm/cav

Coupler Wakes

Monopole term

K_o=-2.5 V/nC/cavity

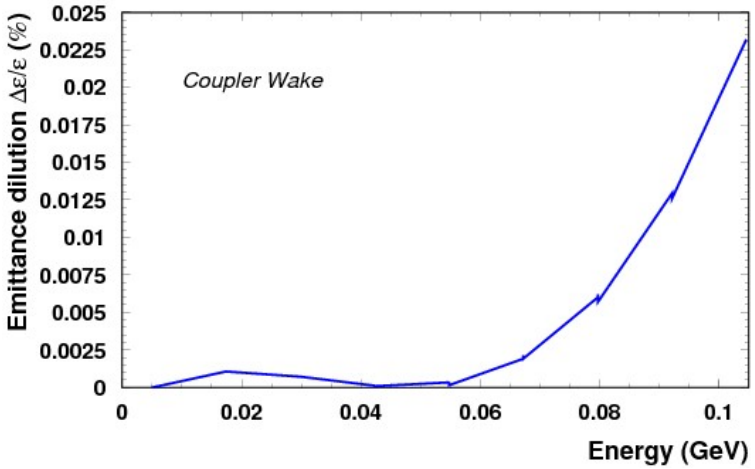
K_{rms}=1.4 V/nC/cavity



Dipole term

Krms=1.3 V/nC/mm/cav

Ko=2.25 V/nC/mm/cav

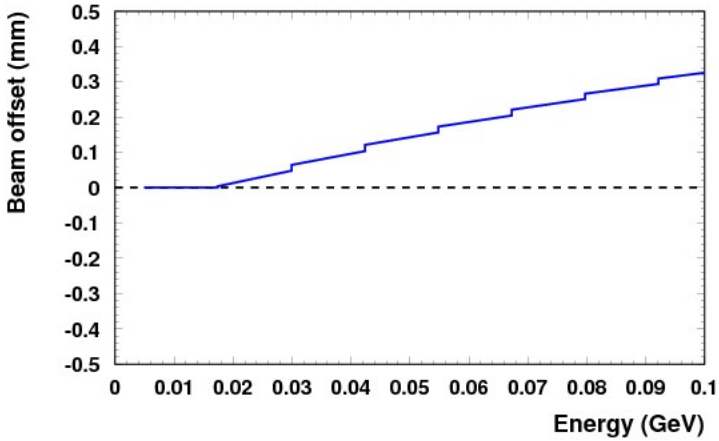


Coupler RF Field

Monopole term

K_o=66.4 V/nC/cavity

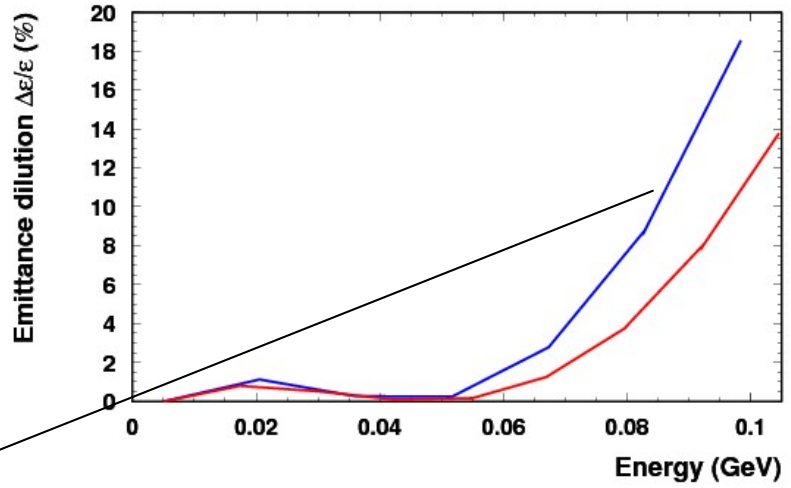
K_{rms}=38.4 V/nC/cavity



Dipole term

Krms=1.8 V/nC/mm/cav

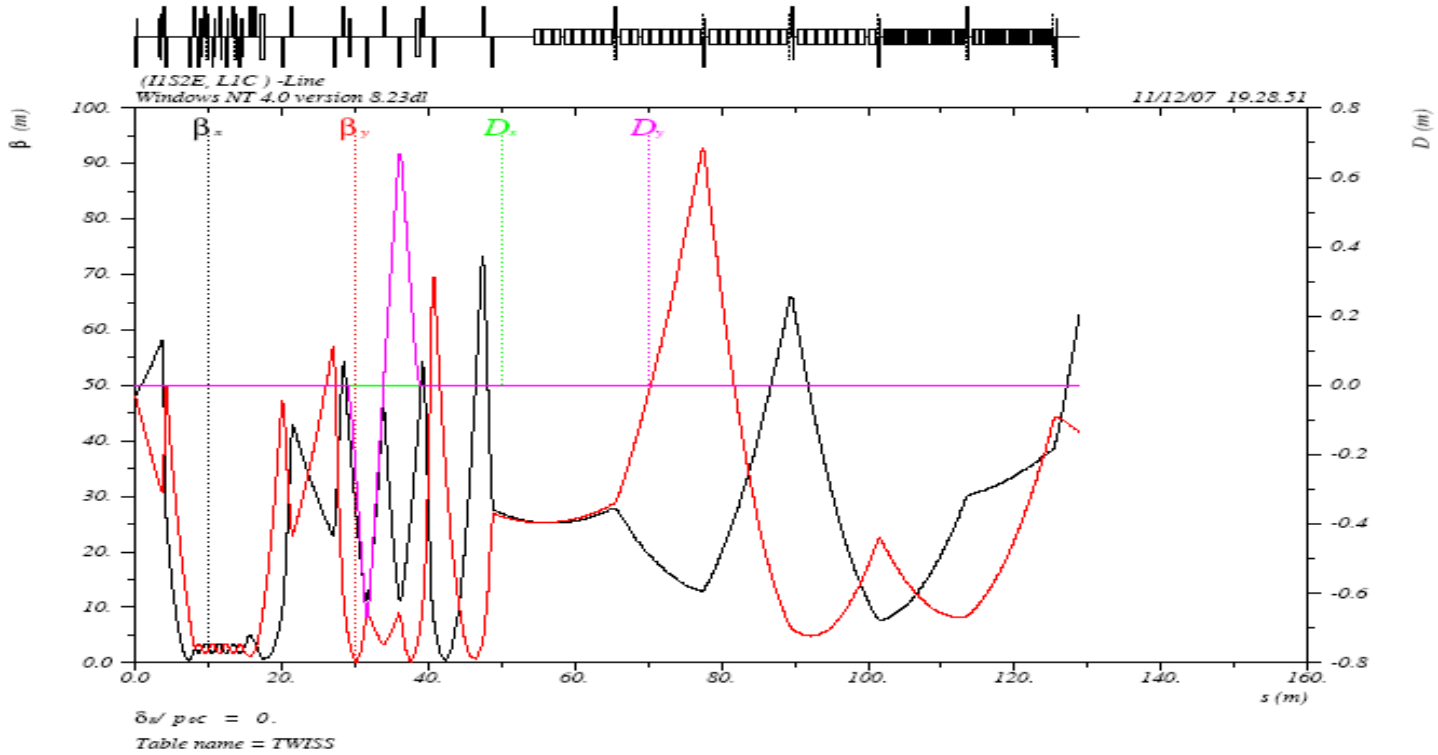
Ko=3.0 V/nC/mm/cav



U=15 MV/m, σ=2.4 mm

LINAC1

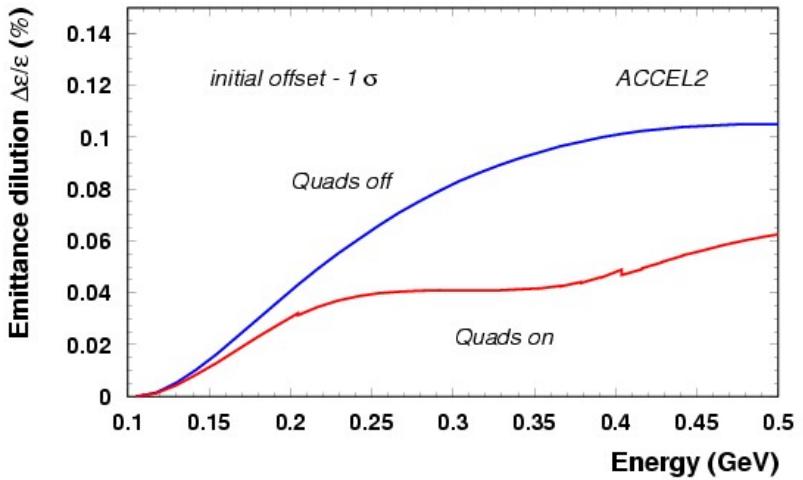
4 TESLA Modules ~ 12MV/m



W. Decking

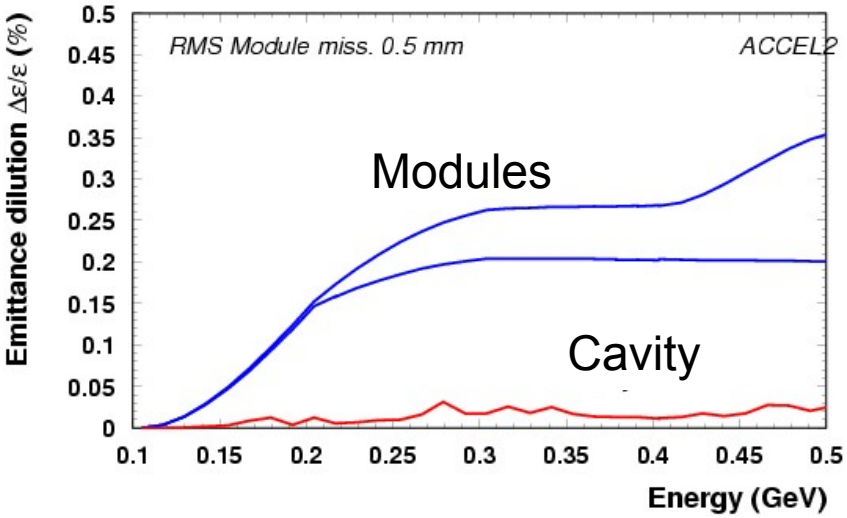
Components errors

Beam initial offset 1 sigma ~0.35 mm



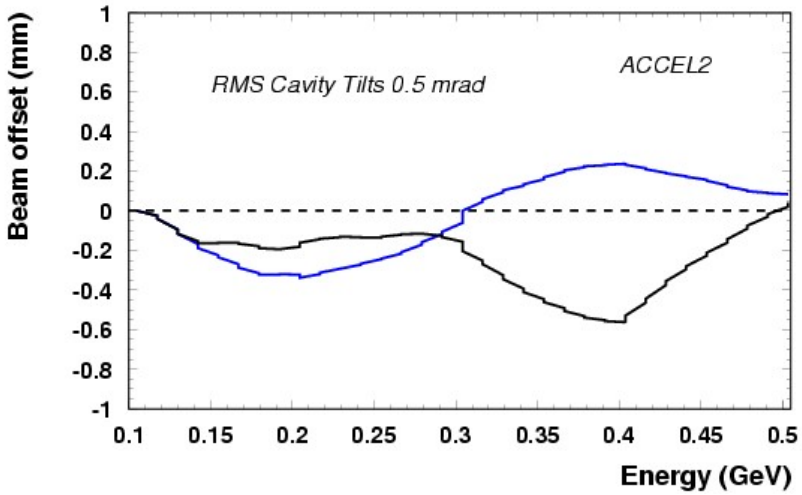
Cavity & Modules misalignment

RMS offset- 0.5mm

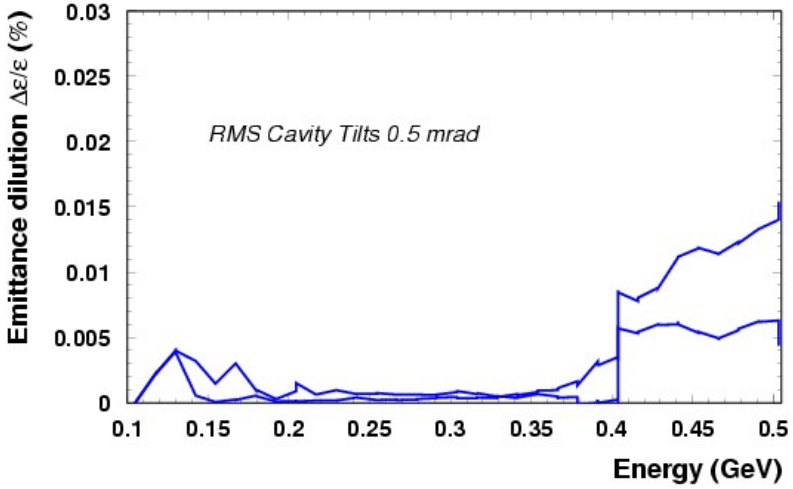


Cavity tilts

Beam trajectory



Emittance dilution

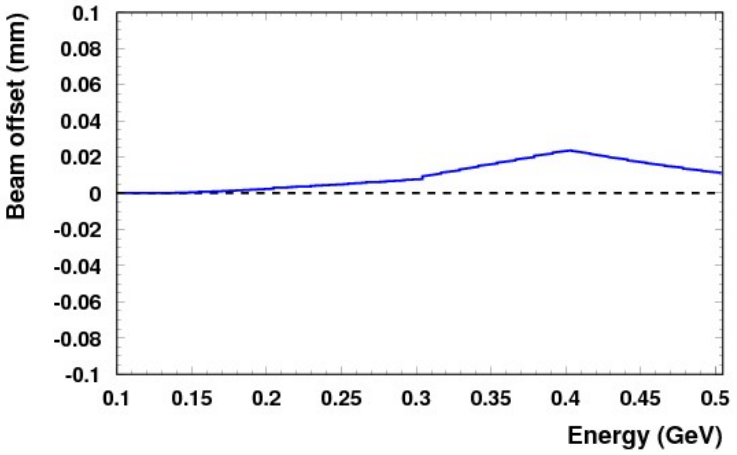


Coupler Wakes

Monopole term

K_o=-2.5 V/nC/cavity

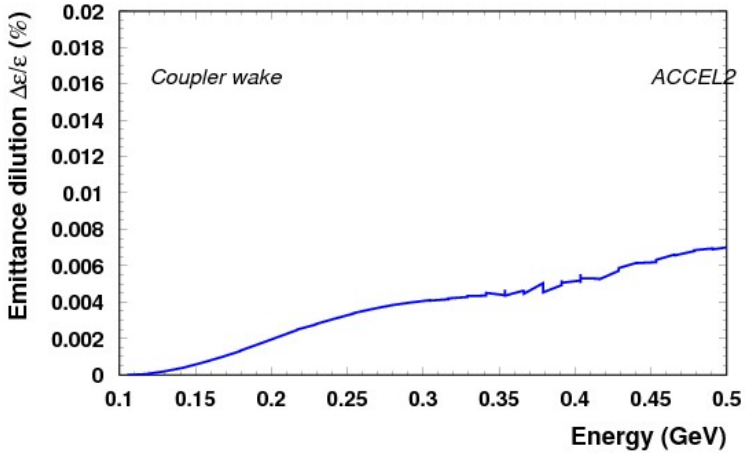
K_{rms}=1.4 V/nC/cavity



Dipole term

Krms=1.3 V/nC/mm/cav

Ko=2.25 V/nC/mm/cav

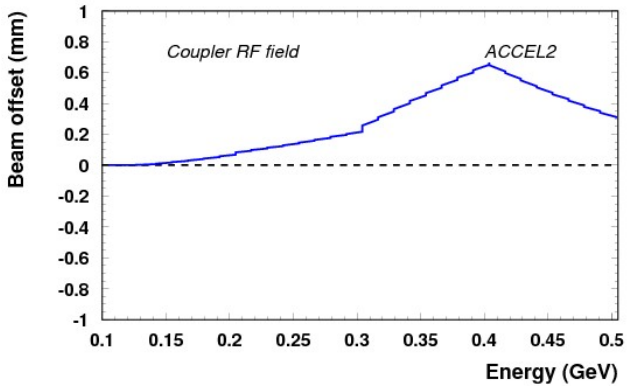


Coupler RF Field

Monopole term

K_o=66.4 V/nC/cavity

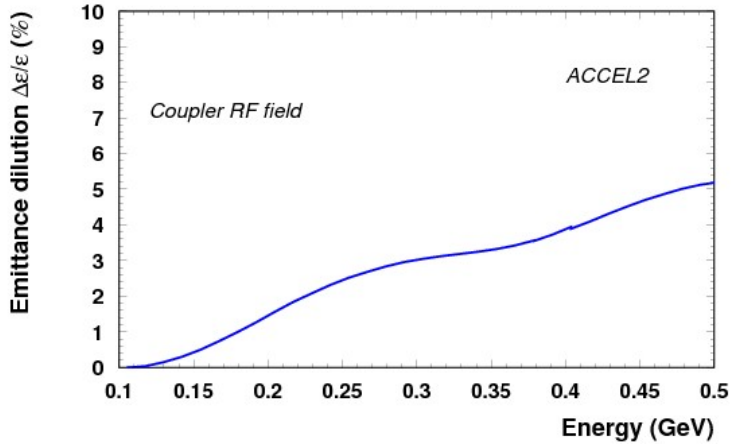
K_{rms}=38.4 V/nC/cavity



Dipole term

Krms=1.8 V/nC/mm/cav

Ko=3.0 V/nC/mm/cav



Summary

- Coupler RF Field effects

ACCEL1 – 5-100 MeV

Emittance growth - 14 %

Linac 1 – 100-500 MeV

Emittance growth – 5%

- Other effects - below 1%