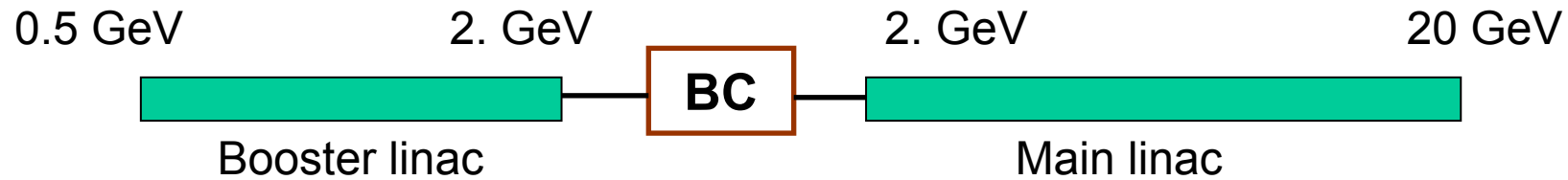


XFEL Beam Dynamics Activity at CANDLE

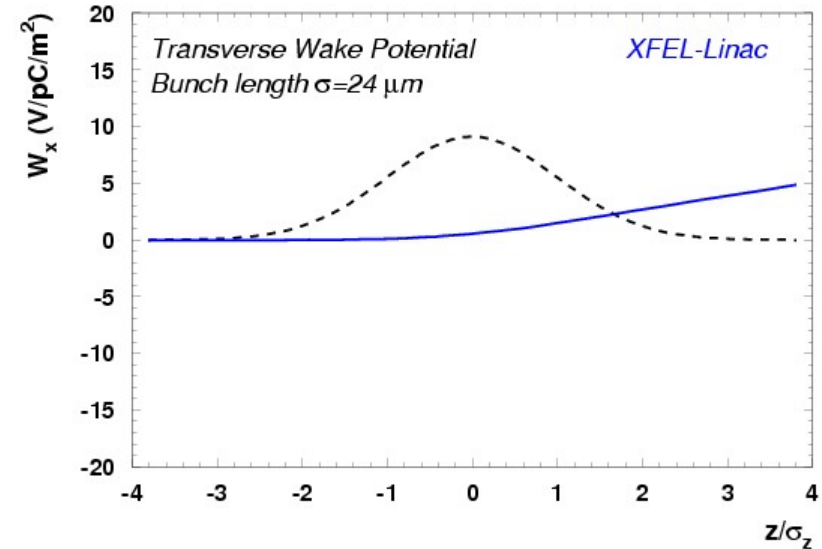
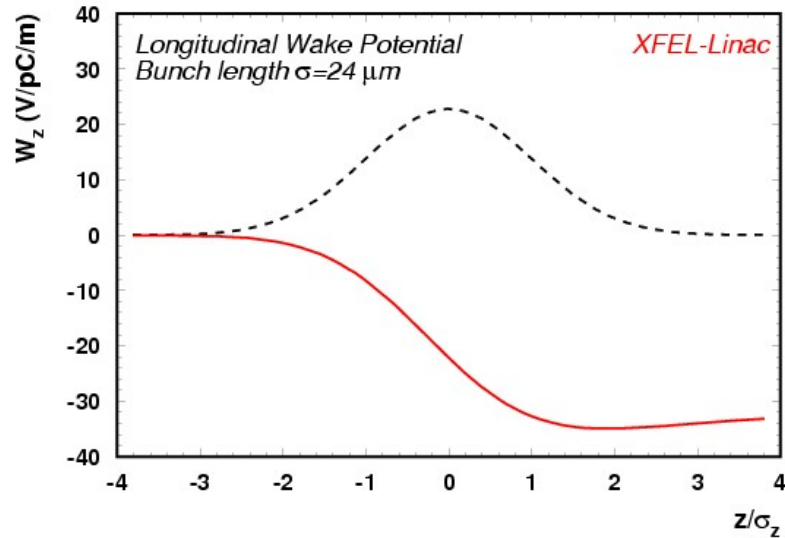
V. Tsakanov for CANDLE (Armenia)

Parameter list



	Booster	Linac
• Energy (GeV)	0.5-2.0	2.0-20
• Accel. Grad (MV/m)	16	20.8
• FODO cells	6	50
• Emittance (mm-mrad)	1.4	1.4
• Bunch charge (nC)	1	1
• Bunch rms length (μm)	112	24
• Initial cor. energy spread	1.75%	0.4%
• Initial uncor. Energy spread (includes laser heater)	500 keV	2500 keV
• Misal. Quads, Cav. (mm)	0.5	0.5
• BPM – 0.1mm, res – 0.02mm		

Wake Potentials



Wake functions

$$w_z(s) = 41.5 \exp\left(\sqrt{\frac{s}{1.74\text{mm}}}\right), \left[\frac{V}{\text{pC} \cdot \text{m}} \right]$$

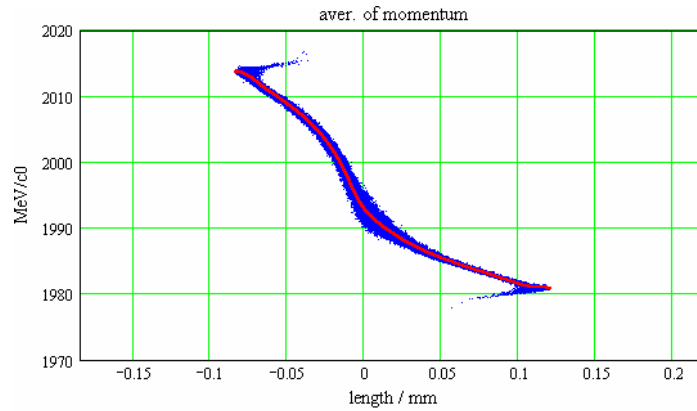
$$w_x(s) = 12 \left[1 - (1 + p(s)) e^{-p(s)} \right], \left[\frac{V}{\text{pC} \cdot \text{m}^2} \right]$$

$$p(s) = \sqrt{s / 0.92\text{mm}}$$

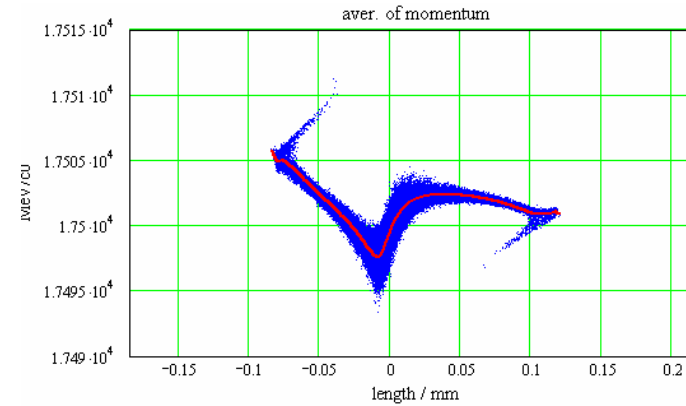
T. Weiland, I. Zagorodnov, TESLA Rep. 2003-19, 2003.

Energy Spread

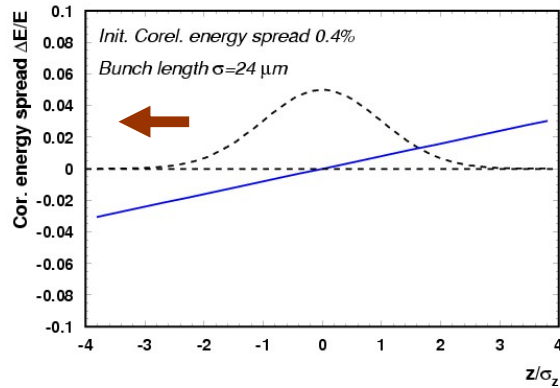
M. Dohlus



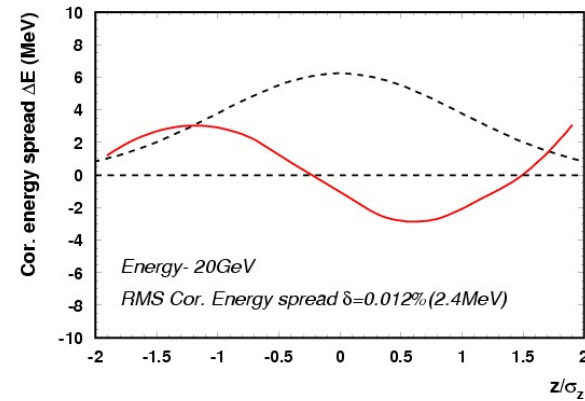
Linac Entrance-2 GeV



Linac End - 20 GeV



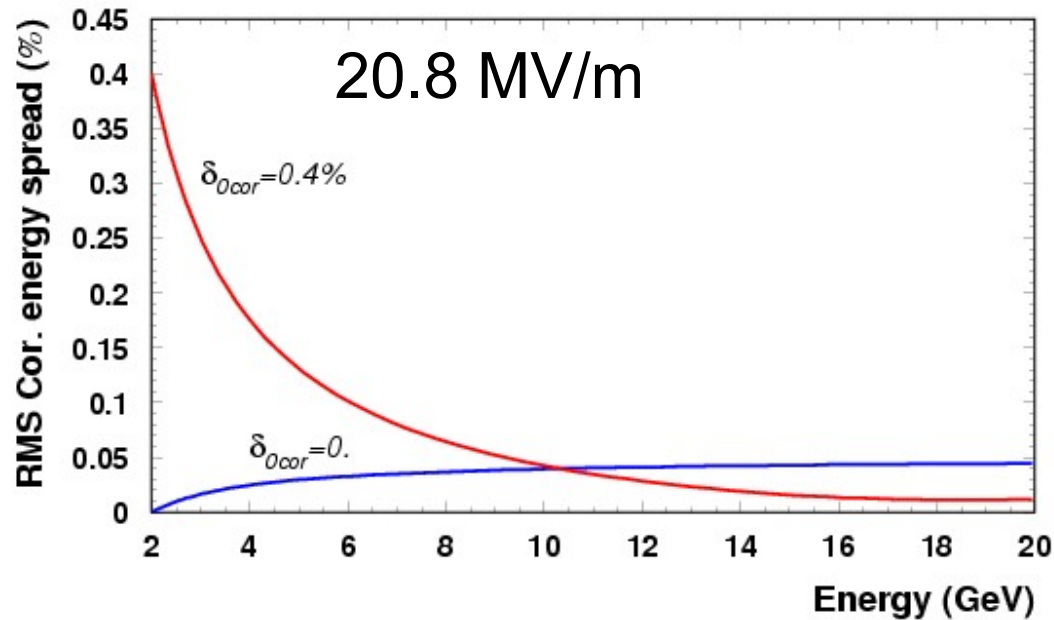
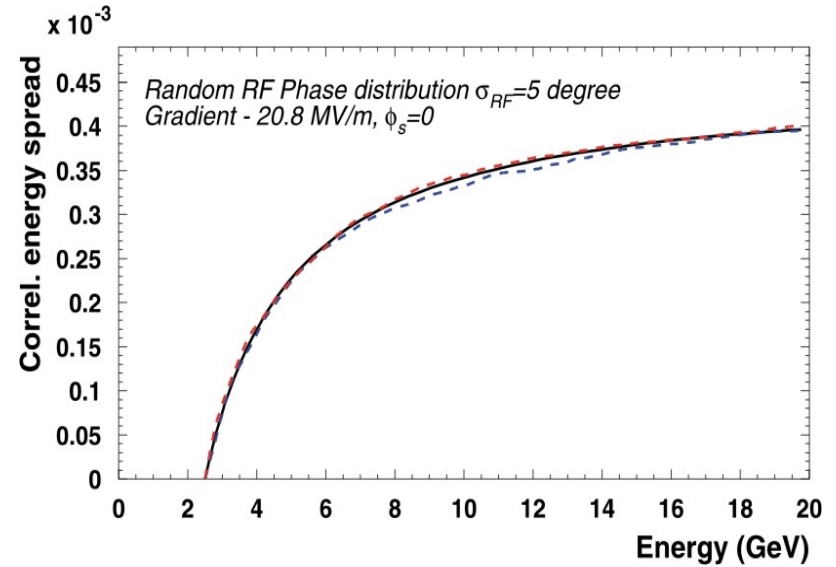
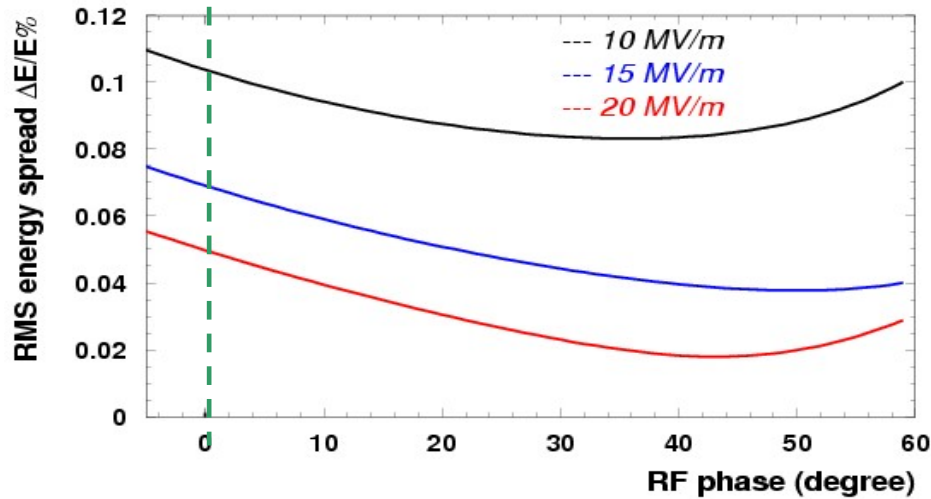
$$\sigma_{\text{cor}} = 0.4\%$$



$$\sigma_{\text{cor}} = 0.012\% \text{ (2.4 MeV)}$$

Energy spread

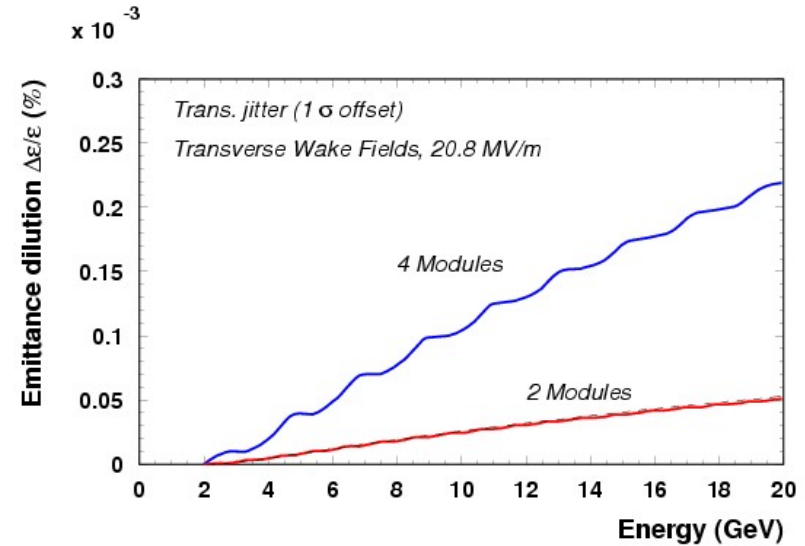
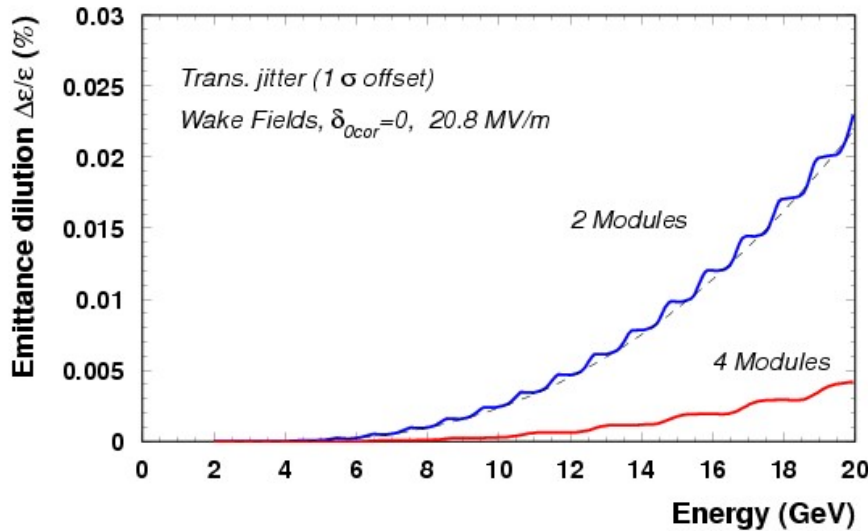
Without initial energy spread



With initial energy spread

Coherent Oscillations

Wakefield Effects (Zero initial energy spread)



Longitudinal Wake (chromatic)

$$\frac{\Delta\epsilon}{\epsilon} = 2\sigma_c^2 t g^2 (\mu/2) \frac{\gamma_0^2}{\Delta\gamma^2} \left[\frac{\gamma}{\gamma_0} - \ln \frac{\gamma}{\gamma_0} - 1 \right]^2$$

Transverse wake

$$\frac{\Delta\epsilon}{\epsilon} = \frac{1}{128} \left(\frac{QW_D L_{cell}}{G \sin \mu} \right)^2 \ln^2 \frac{\gamma}{\gamma_0}$$

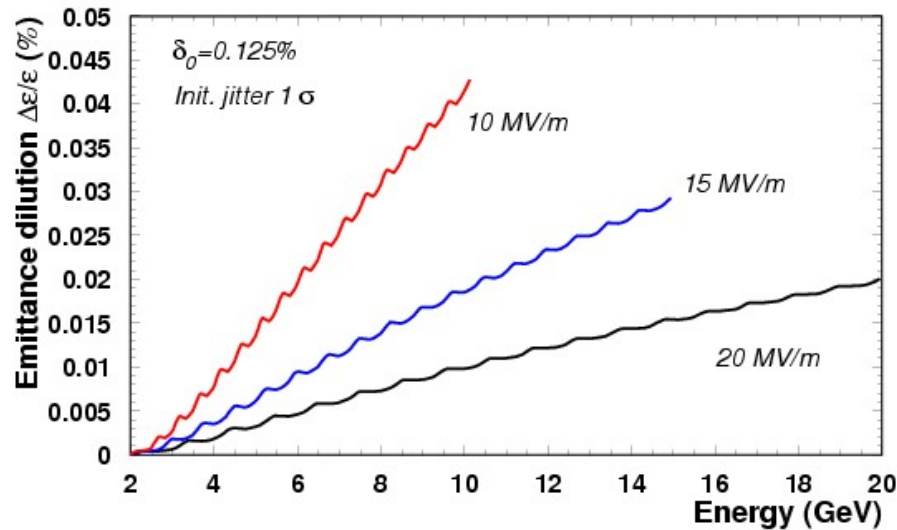


XFEL Lattice : chromatic dominated emittance dilution

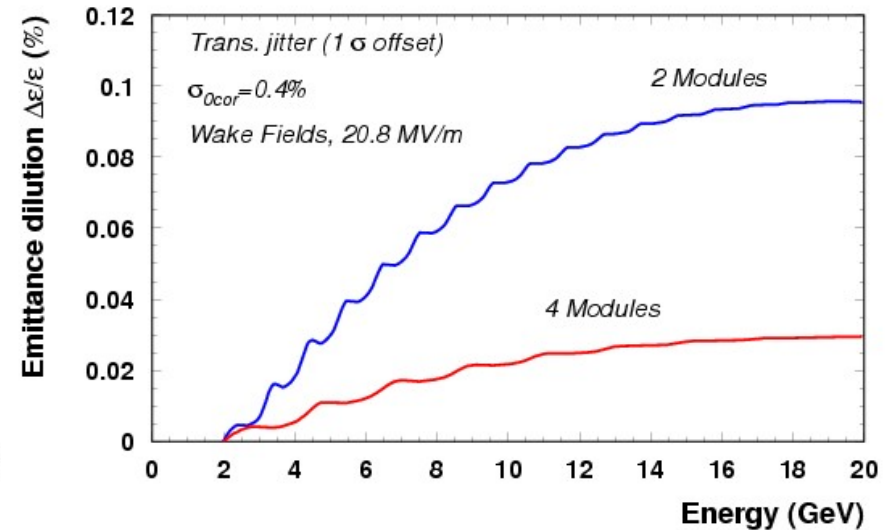
Coherent Oscillations

Chromatic effects (initial energy spread)

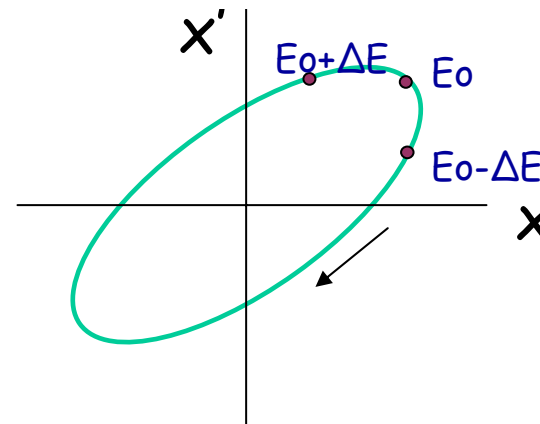
Uncorrelated



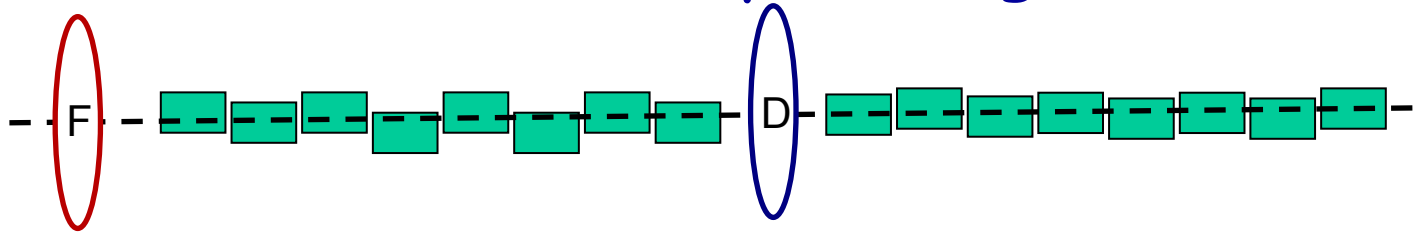
Correlated



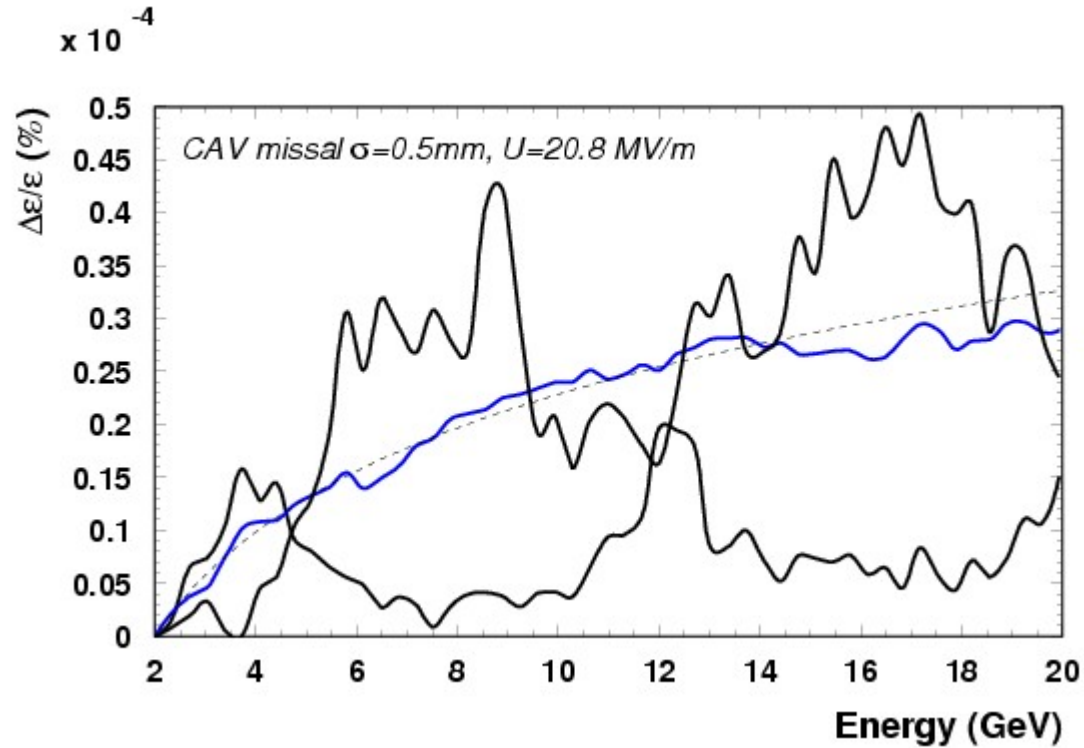
$$\frac{\Delta\epsilon}{\epsilon} = 2\sigma_0^2 \tan^2(\mu/2) \frac{\gamma_0^2}{\Delta\gamma^2} \ln^2 \frac{\gamma}{\gamma_0}$$



Cavity Misalignments

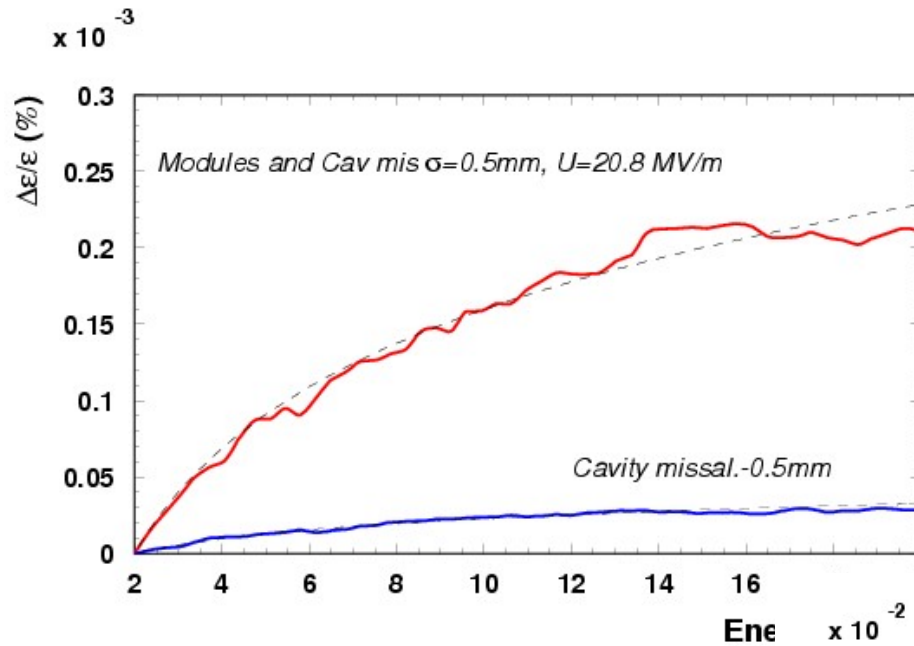


$\sigma_{\text{cavity}}=0.5\text{mm}$



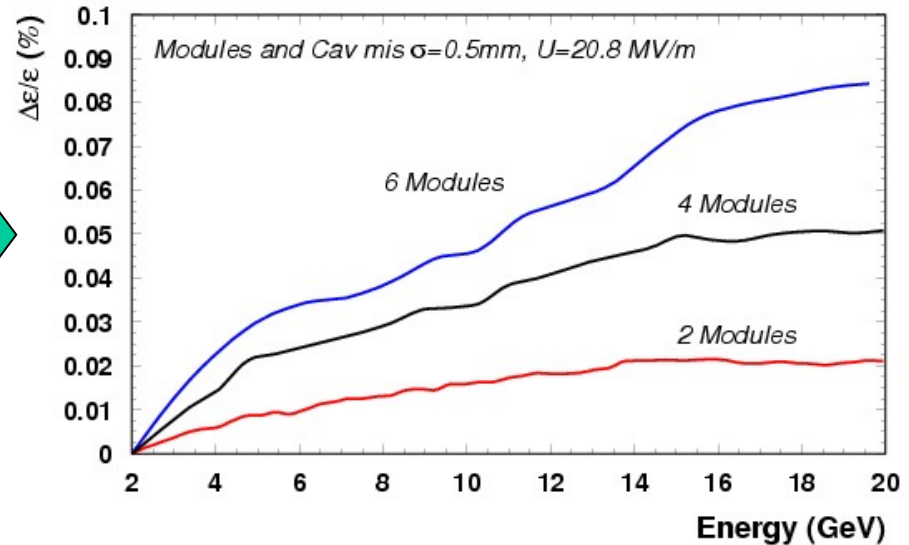
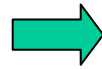
$$\frac{\Delta\epsilon}{\epsilon} = \frac{\langle x_A^2 \rangle}{32N_{\text{cav}}\epsilon_0} \left(\frac{QW_D}{G} \right)^2 \frac{L_{\text{cell}}}{\sin\mu} \frac{\Delta\gamma}{\gamma_0} \ln \frac{\gamma}{\gamma_0}$$

Modules Misalignments

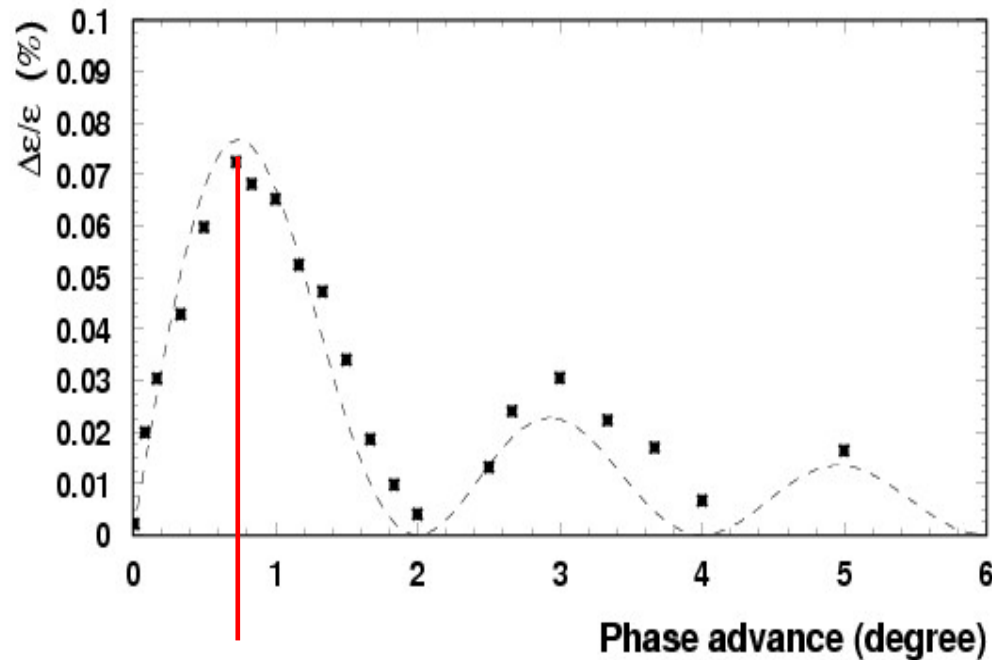
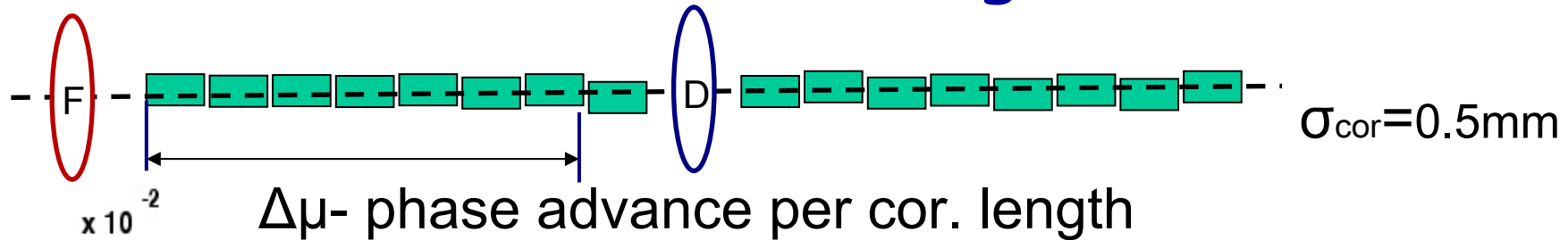


Standard cell

2,4 and 6 modules
per FODO cell



Correlated Misalignments



$\Delta\mu=130^\circ$ (~4 modules)

Betatron phase contrib.

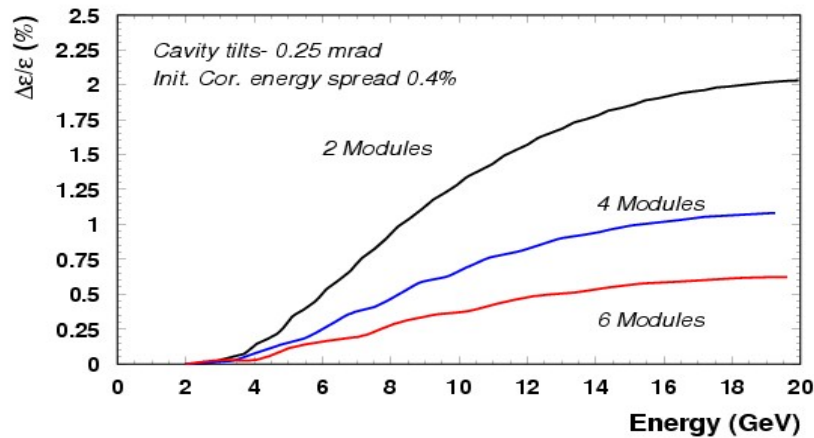
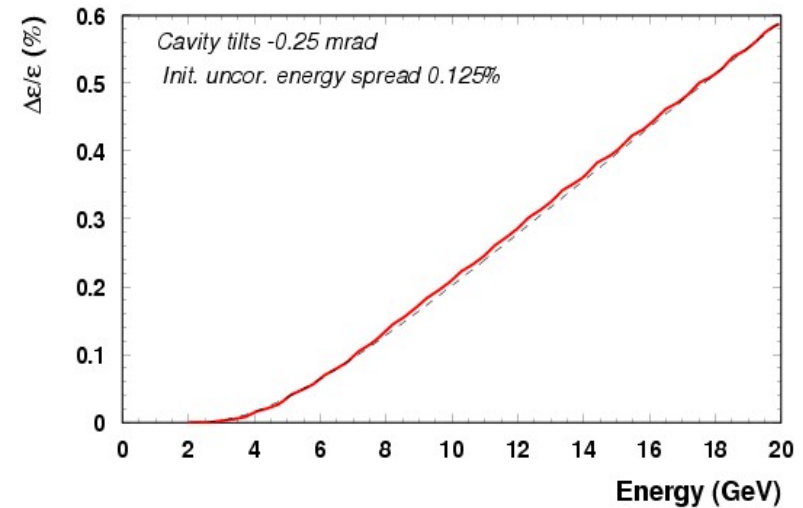
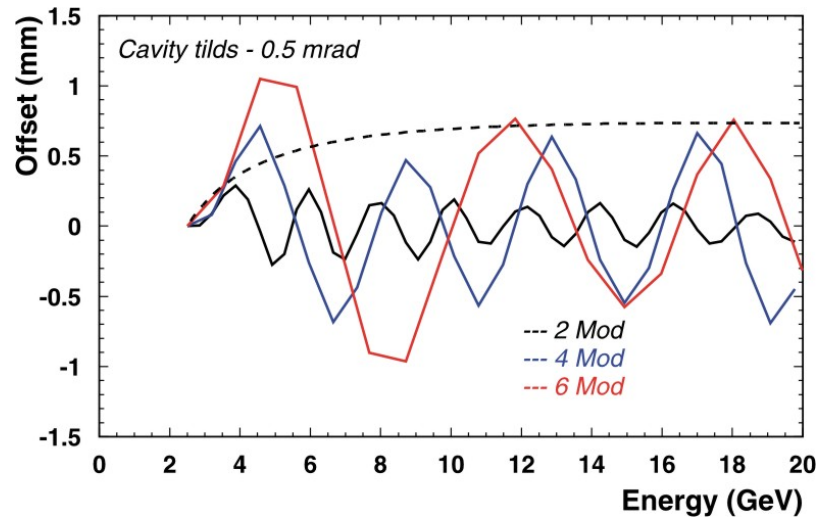
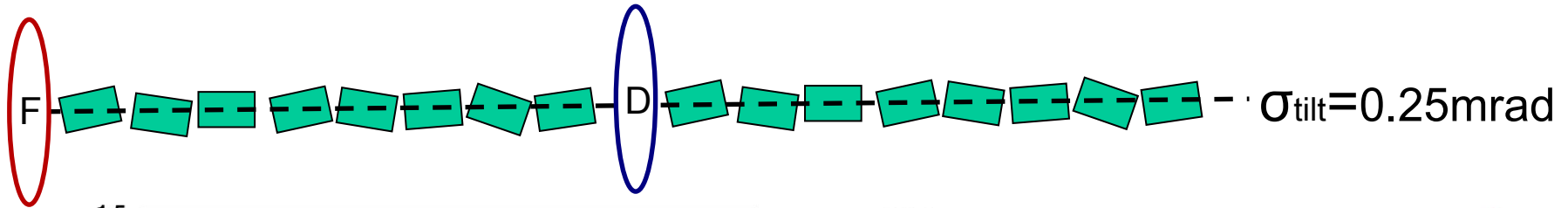
$$F \approx \frac{1}{\Delta\mu^2} \int_0^{\Delta\mu} \int_0^{\Delta\mu} \cos(\phi' - \phi'') d\phi' d\phi''$$

$$F = \frac{4}{\Delta\mu^2} \sin^2 \frac{\Delta\mu}{2}$$

R.Brinkmann, V.Tsakanov,
Snowmass, 2001

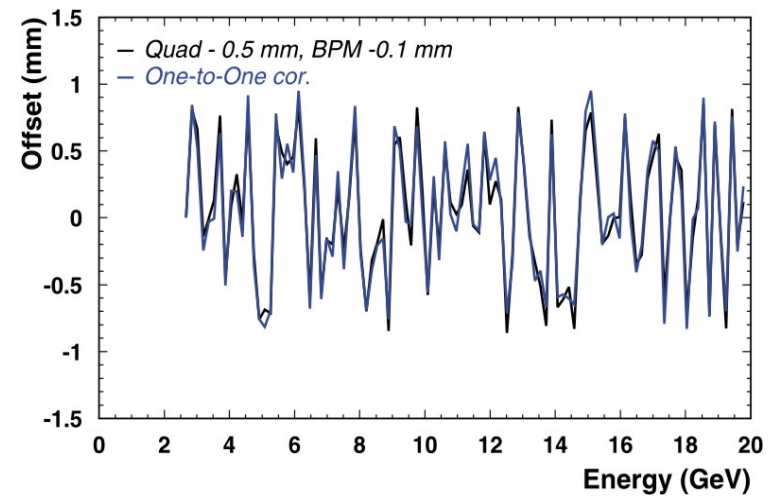
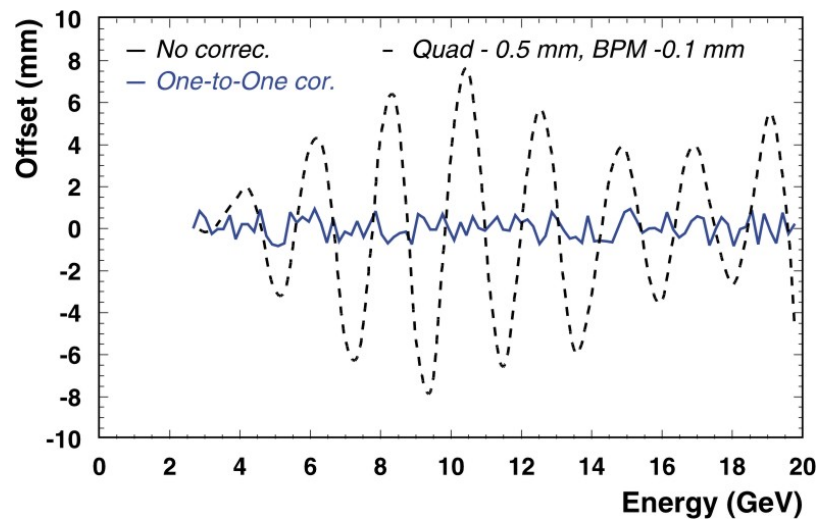
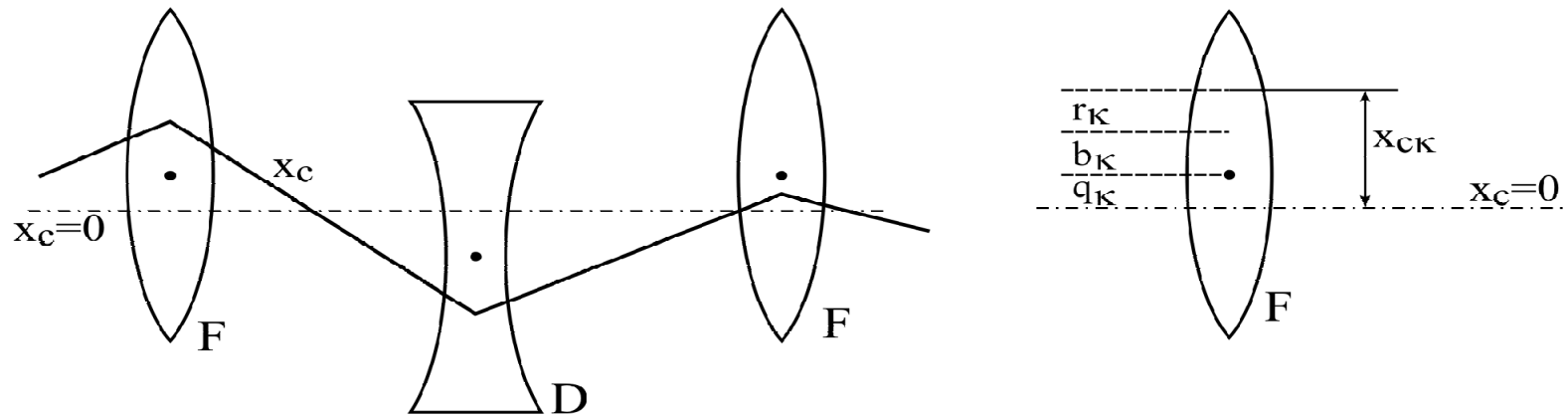
$$\frac{\Delta\epsilon}{\epsilon} = \frac{\langle x_A^2 \rangle}{8\epsilon_0} \left(\frac{QW_D}{G} \right)^2 \frac{L_{cell}}{\mu \sin \mu} \frac{\sin^2 \Delta\mu / 2}{\Delta\mu} \frac{\Delta\gamma}{\gamma_0} \ln \frac{\gamma}{\gamma_0}$$

Cavity tilts



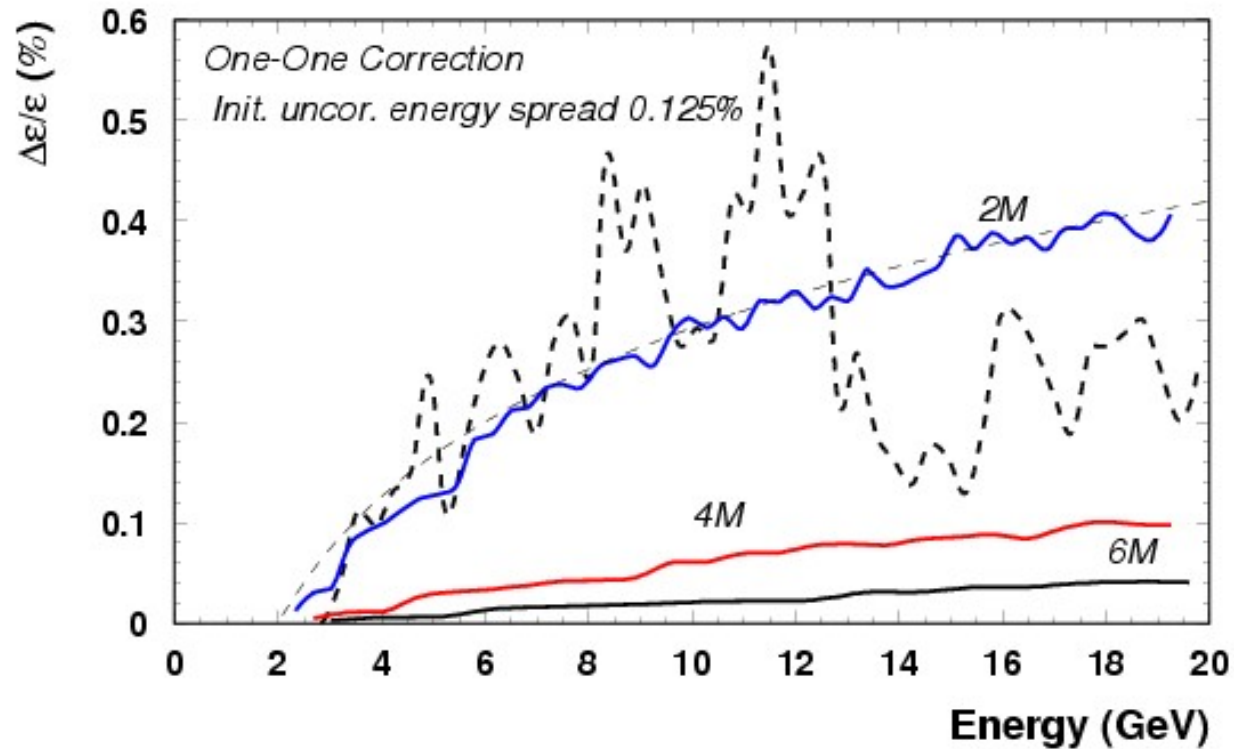
$$\frac{\Delta E}{E} = \frac{4}{3} \langle \alpha^2 \rangle \frac{\sigma_0^2 d^2 N_{\text{cav}}}{\epsilon_0 L_c \sin \mu} \text{tg}^2 \frac{\mu}{2} \frac{\gamma_0}{\Delta \gamma} \ln^3 \frac{\gamma}{\gamma_0}$$

Quadrupoles misalignments. One-to-One Correction



One-to One Correction

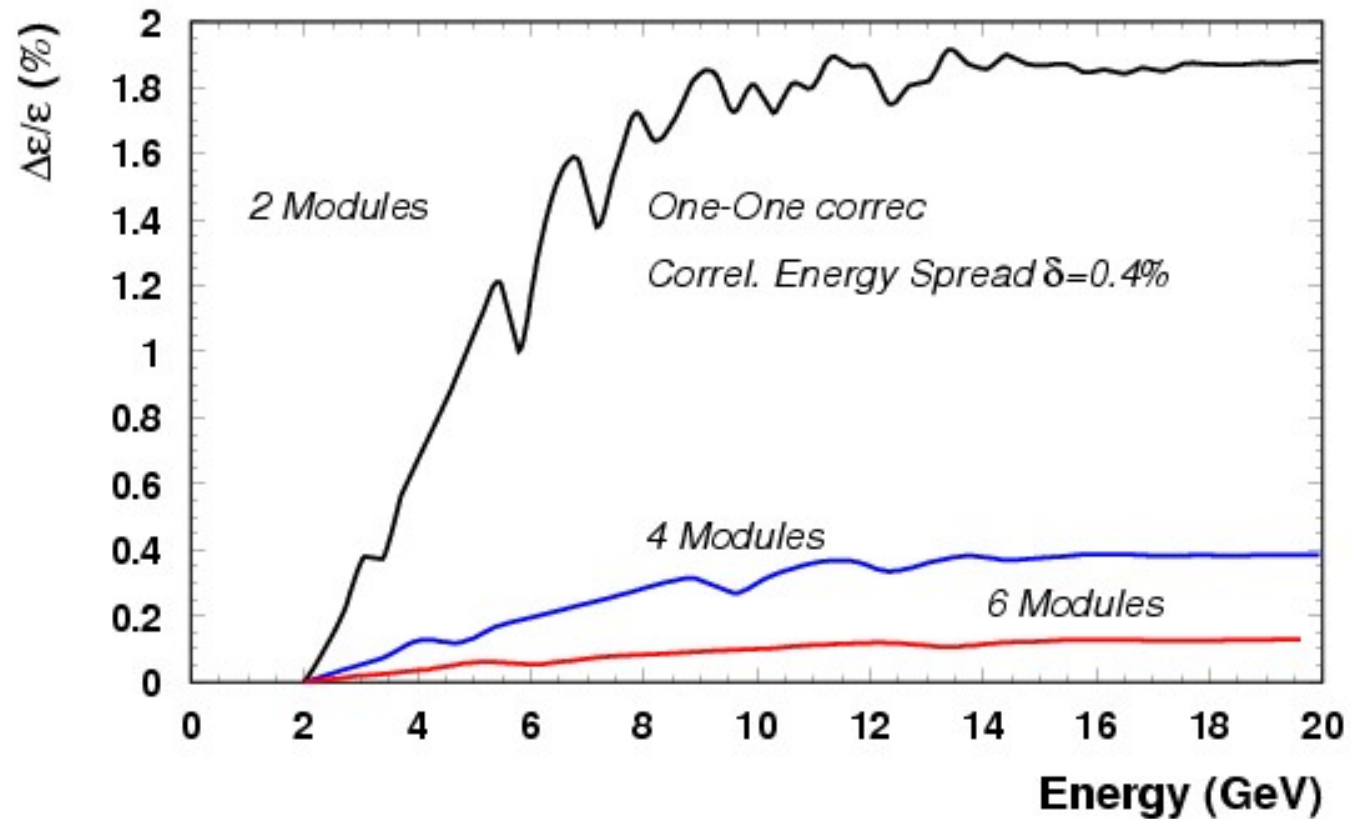
Uncorrelated effects



$$\frac{\Delta\epsilon}{\epsilon} = 8\sigma_0^2 \frac{\langle x_c^2 \rangle \tan\mu/2}{\epsilon_0 L_{cell}} \frac{\gamma_0}{\Delta\gamma} \ln \frac{\gamma}{\gamma_0}$$

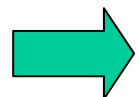
Quad misalignments. One-to-One Correction

Correlated effects



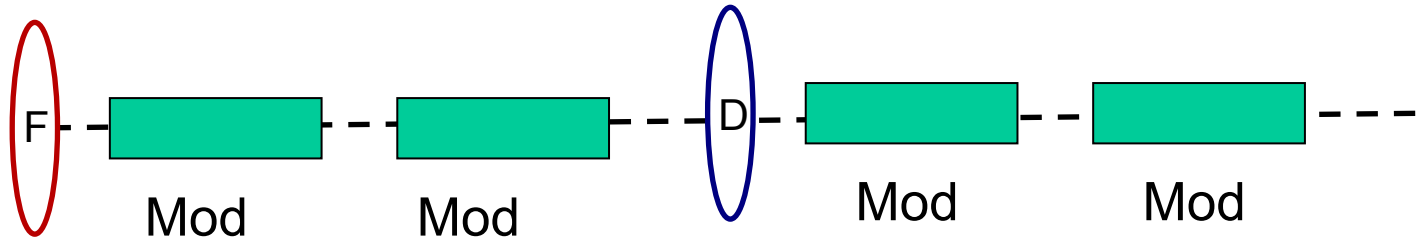
Summary of Emittance Dilution (Standard Cell)

	Booster	Linac
• Coherent oscillations		
uncorrelated	$6 \cdot 10^{-6}$	$2 \cdot 10^{-4}$
correlated	$2 \cdot 10^{-3}$	$1.2 \cdot 10^{-3}$
• Cavity Misalignments	$5 \cdot 10^{-6}$	$3 \cdot 10^{-7}$
• Modules Misalignments	$4 \cdot 10^{-5}$	$2.5 \cdot 10^{-6}$
• Correlated Misal. (130°)	-	$7 \cdot 10^{-6}$
• Cavity tilts		
uncorrelated	$5.8 \cdot 10^{-5}$	0.6%
correlated	0.6%	1.9%
• One-to-One correction		
uncorrelated	$6.3 \cdot 10^{-5}$	0.4%
correlated	1.7%	2%



Total Emittance dilution <5% with 2 Modules/Cell

Possible modification



Modules per cell	2 Mod	4 Mod	6 Mod
Emittance preservation	<5%	< 2%	~ 1%
Beta max	40m	~ 70 m	~100m
Number of FODO cells	52	26	18
Number of quads	104	52	36
Quad Strength K (m ⁻²)	0.28	~0.17	~0.12
Total length	1248m	~1050m	~1000m