SparxNote_02
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ENERGY SPREAD BUDGET ALONG THE SPARX LINAC

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Abstract:

To achieve the required 2 kA peak current with a 1 nC bunch for the Sparx FEL experiment, two stages of bunch compression have been considered.

We study in this note the energy spread budget required for magnetic compression and the way to reduce it to a level of 0.1 % before injecting the beam in the undulator.
Rf compressor options will be reported in a future work.

By means of a simple two particles model including short range longitudinal wake fields, rf phasing and adiabatic damping effects , energy spread along the 2.5 GeV Sparx linac is computed . The wake fields contribution to energy spread compensation is underlined.

The two particle model is applied for comparison to the LCLS case with results in very good agreement with more detailed simulations.

Possible working points for the S-band version of the Sparx linac with two beam extraction lines are discussed.

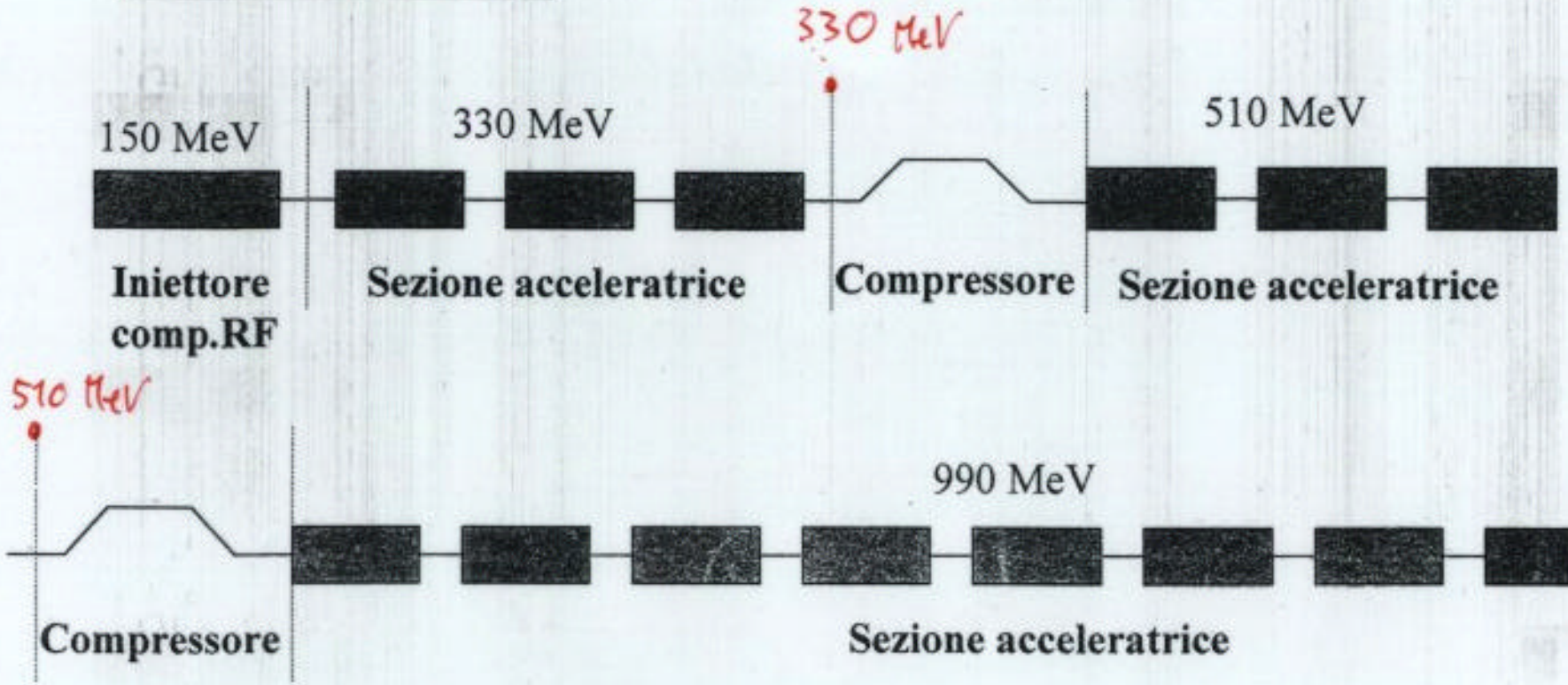
A comparison with the TESLA_FEL design is also reported .

Energy spread compensation in an L-band linac by means of short range longitudinal wake fields results to be less effective than in an S-band linac, thus requiring magnetic compressors with higher R56.

Space charge and CSR effects are not taken in to account in this note.

LAY-OUT della SORGENTE a 1 GeV

Gradiente: 20 MV/m
1 cavità : 3 m



$E = 1$ GeV

$\frac{\Delta E}{E} < 0.1\ \%$

$I = 2$ kA

$\varepsilon_n < 2$ mm-mrad

A two particles model for longitudinal beam dynamics study

$$-\frac{\Delta E}{E} \qquad R_{56} \qquad +\frac{\Delta E}{E}$$

$$\sigma_{zf} = \sigma_{zi} + \frac{\Delta E}{E} R_{56}$$

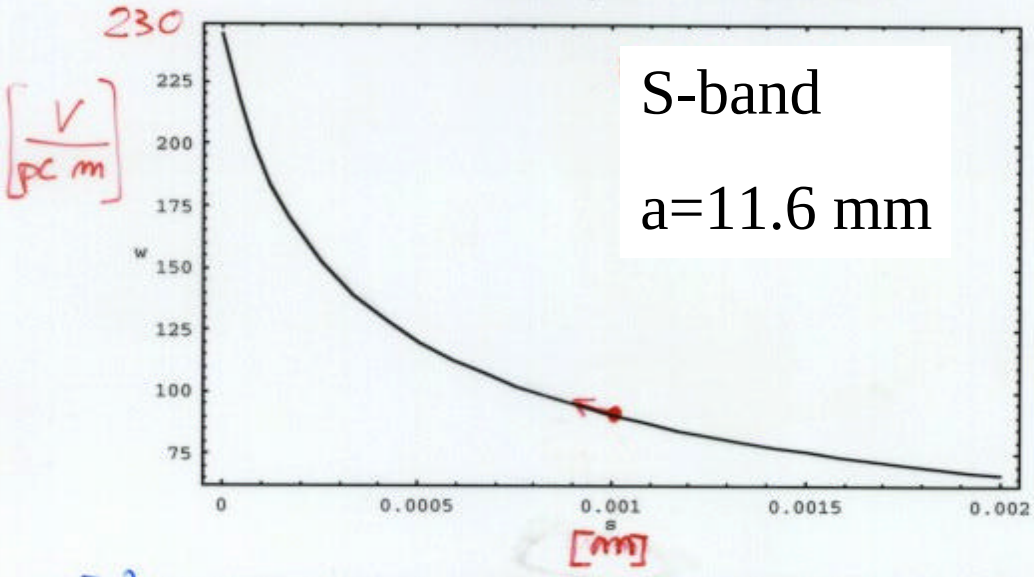
$$\frac{\Delta E}{E_f} = \frac{Ne^2}{2} \frac{W(\sigma_z)}{E_f} L + k_{rf}\sigma_z \left(1 - \frac{E_i}{E_f}\right) tg(\varphi_{rf})$$

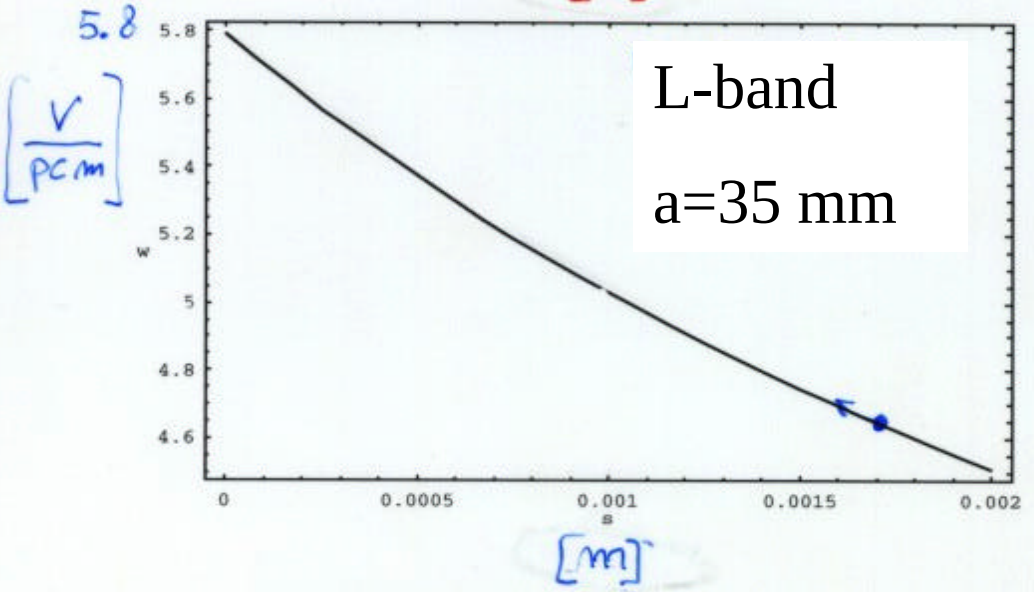
$$\approx \frac{Ne^2}{2Ga^2}$$

$$L = \frac{E_f - E_i}{G\cos(\varphi_{rf})}$$

Delta wake function for the Slac structure

$$W_{//}(s) = \frac{Z_o c}{\pi a \sqrt{a^2 + 8.6 s \lambda}}$$





Red line: RF induced DE
Blue line: wake field induced DE
Green line: total induced DE

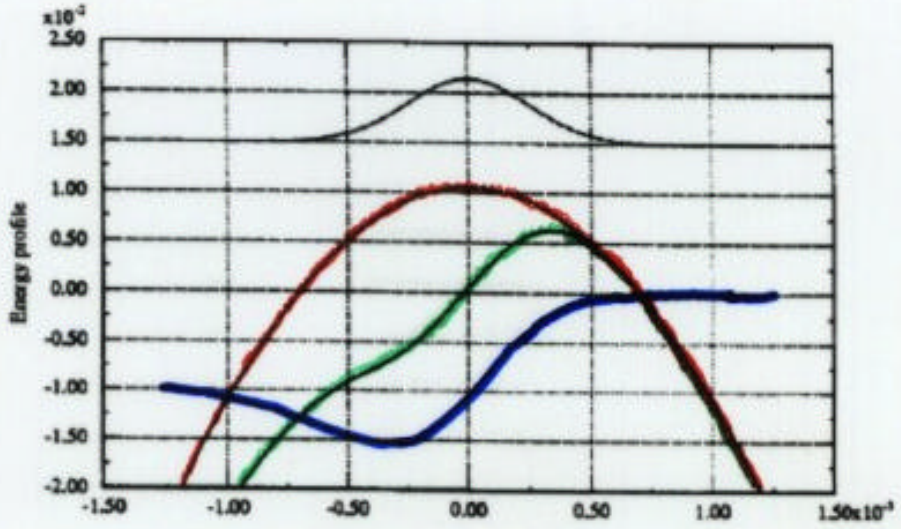


Fig. 5 Energy profile within the bunch sitting on the crest of the rf wave

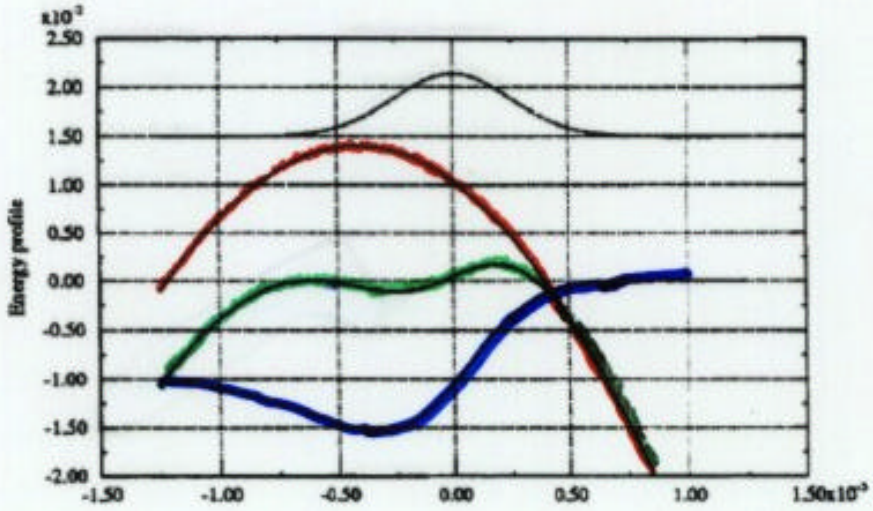
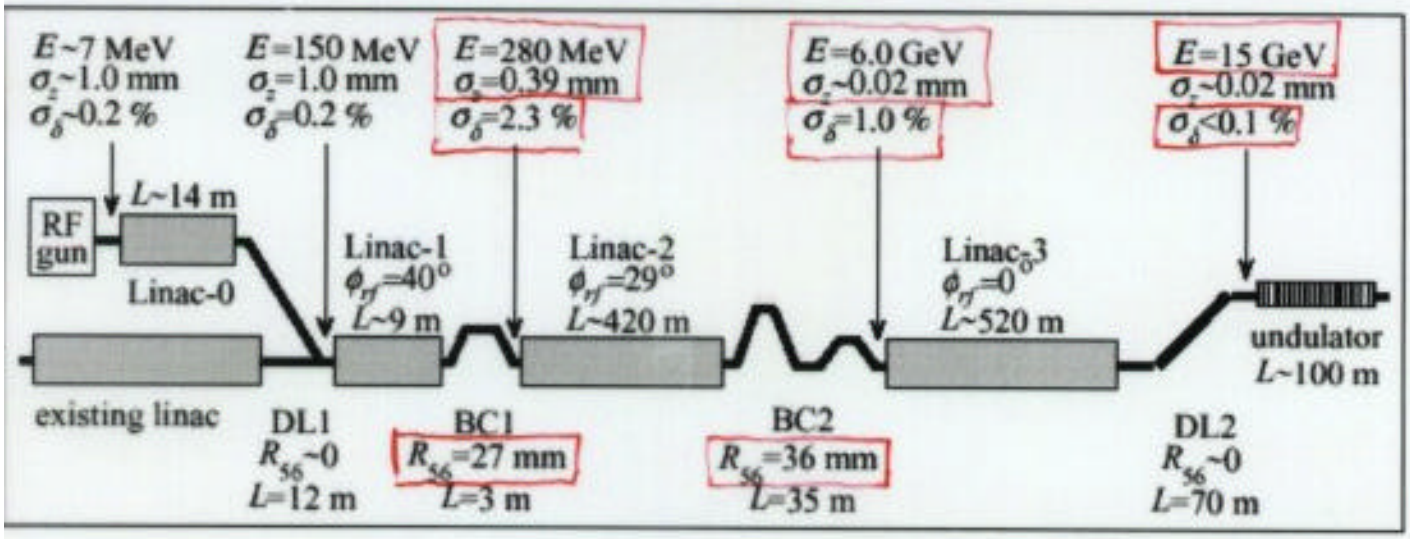
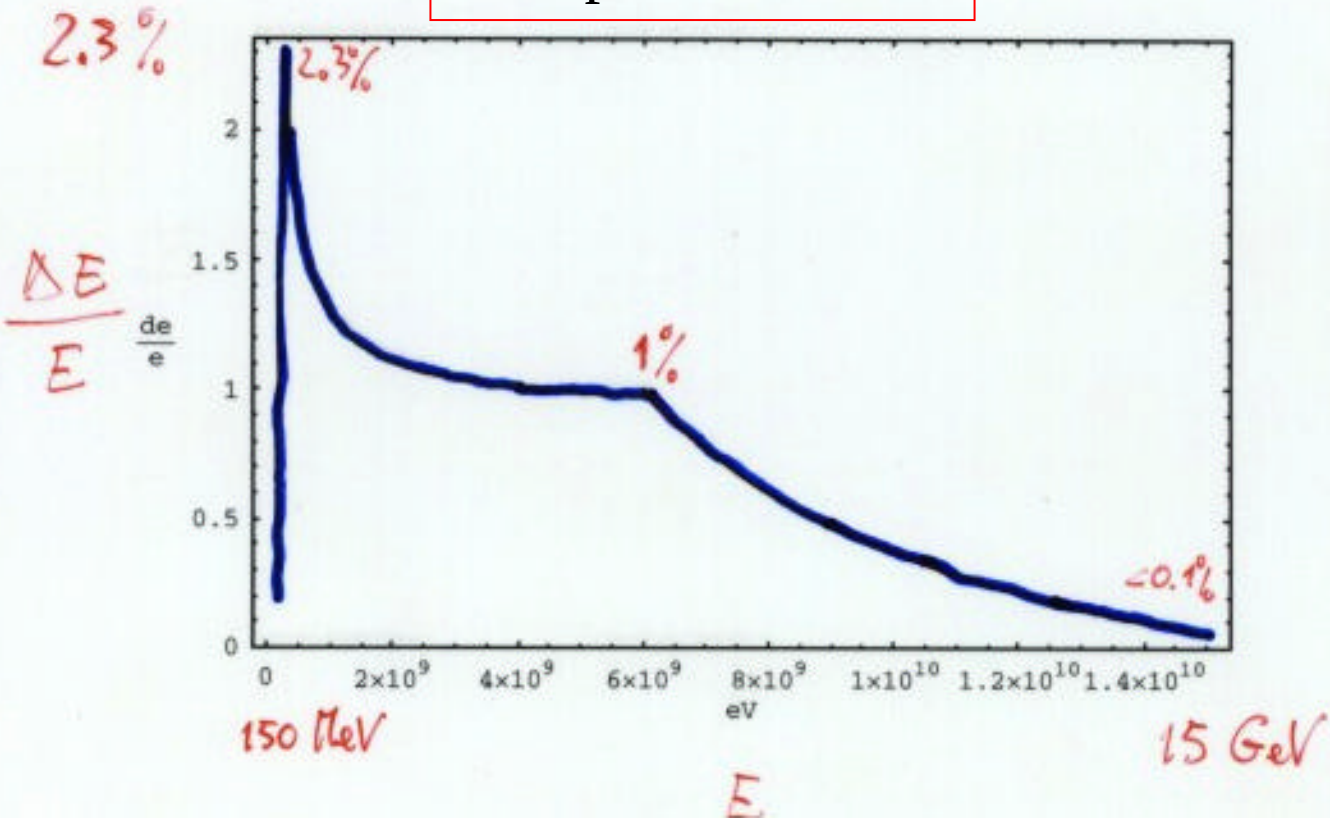


Fig. 6 Energy profile within the bunch after optimization of the rf phase

LCLS ENERGY SPREAD



Two particle model



LCLS TDR simulation

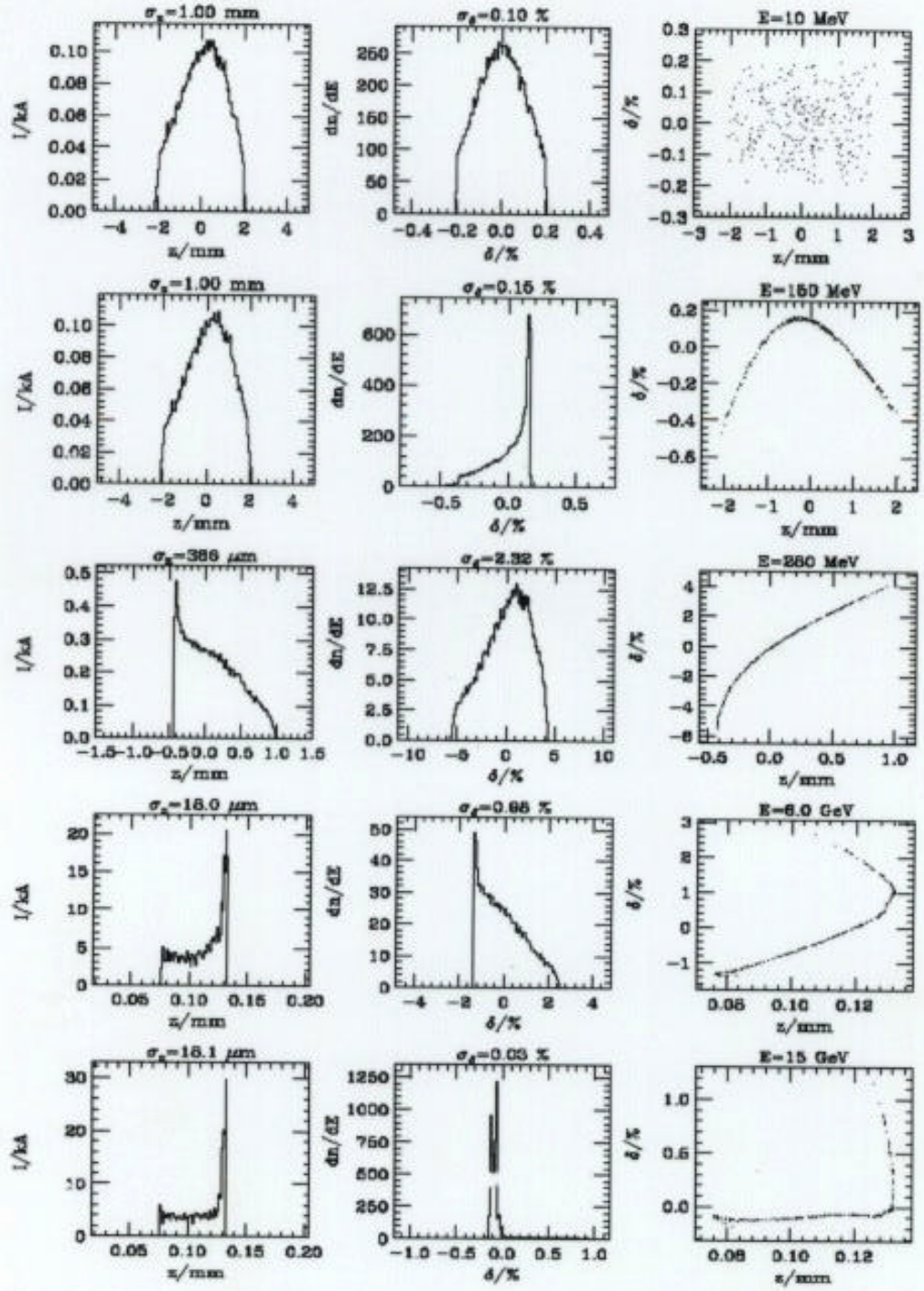


Figure 7.2-2. Axial (left column) and energy (center column) distributions and longitudinal phase space (right column) after gun at 10 MeV (top row), after DL1 at 150 MeV (2nd row), after BC1 at 280 MeV (3rd row), after BC2 at 6 GeV (4th row), and at the undulator at 15 GeV (bottom row). All effects discussed are included except for resistive wall wakefields (bunch head at left).

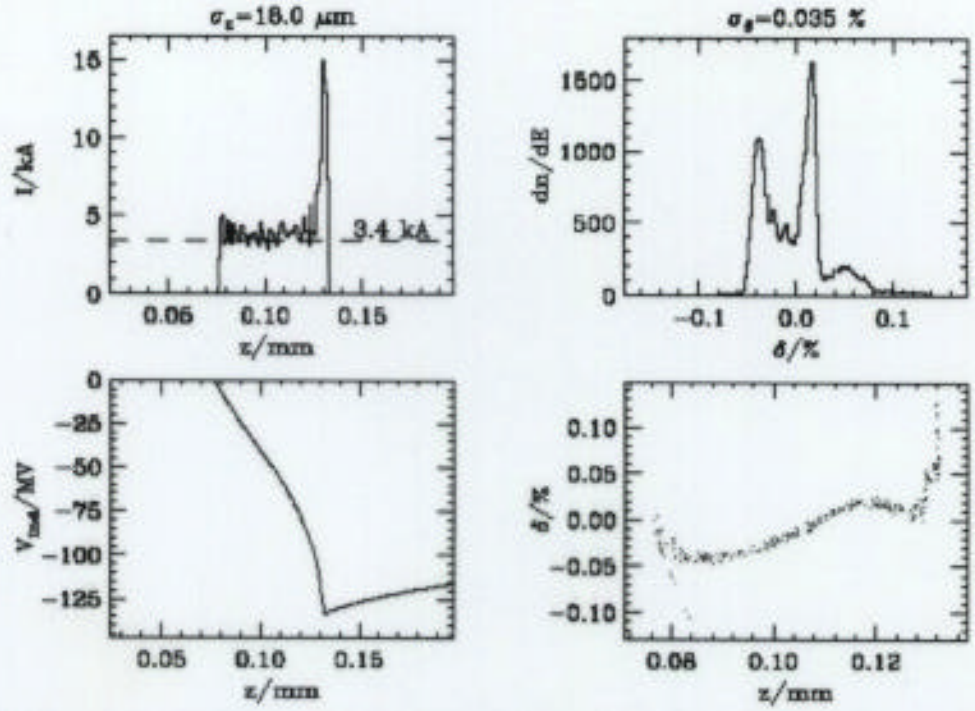


Figure 7.2-3. Longitudinal phase space (lower right), axial (upper left) and energy (upper right) distributions and bunch induced voltage (lower left) at undulator input (15 GeV). After cutting 15% of the charge with high energy tails (see Fig. 7.2-2), the final rms bunch length is 18 μm and the rms energy spread is 0.035% in this ±0.15% energy window. Geometric wakefields, T_{566}, rf-curvature, and synchrotron radiation of all bends are included (bunch head at left).

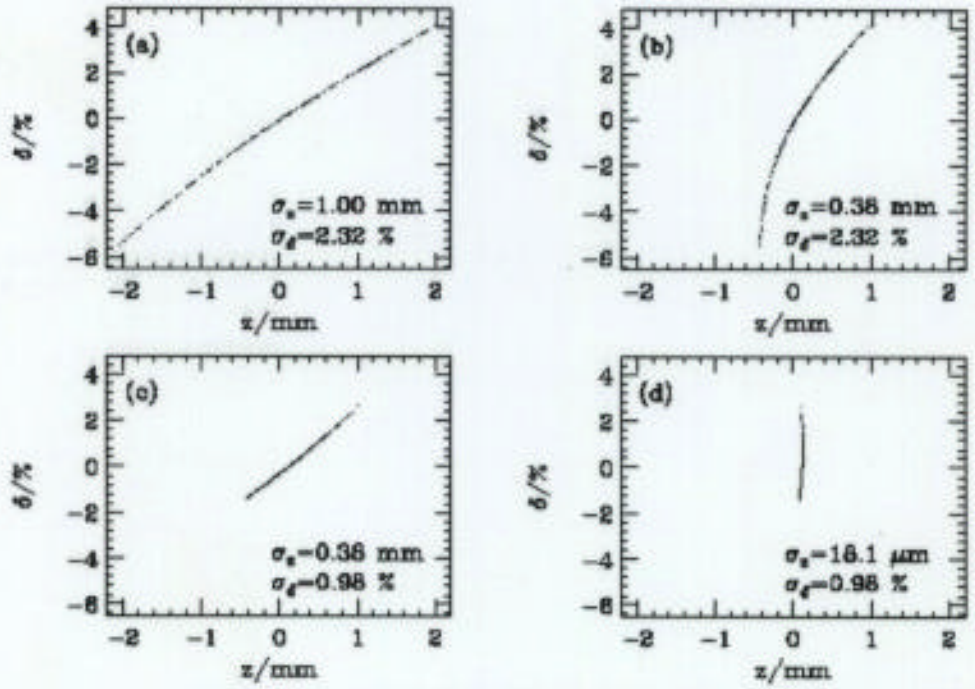
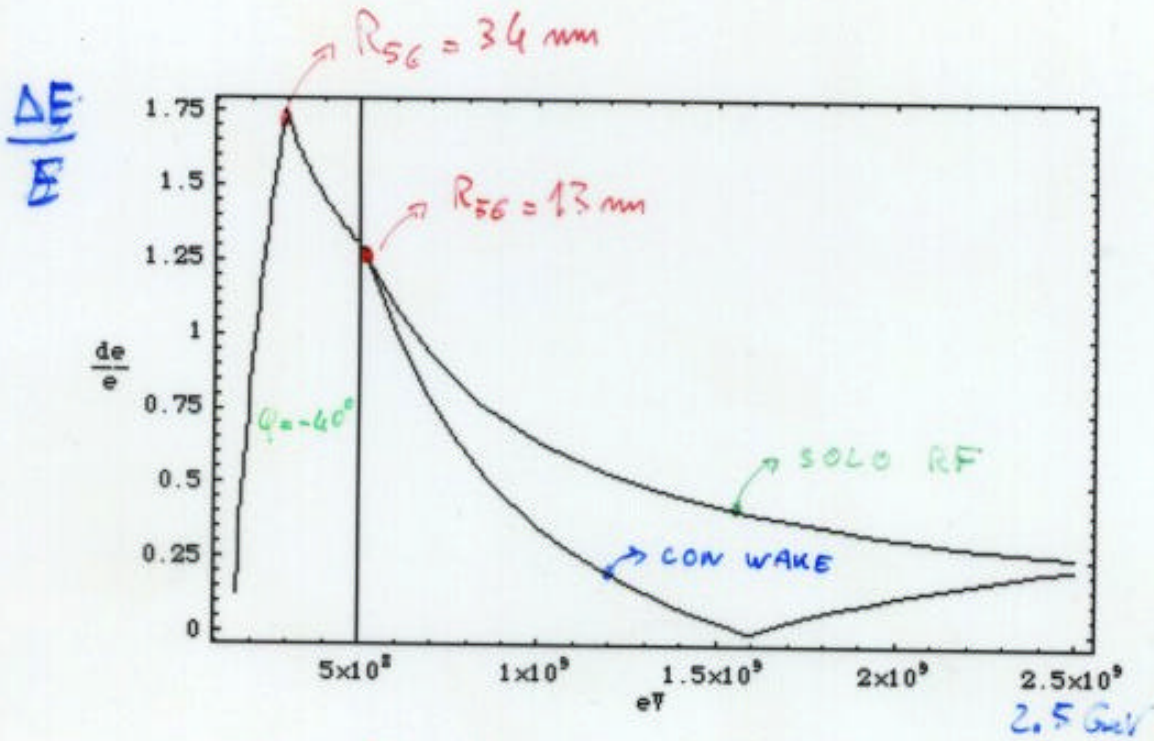
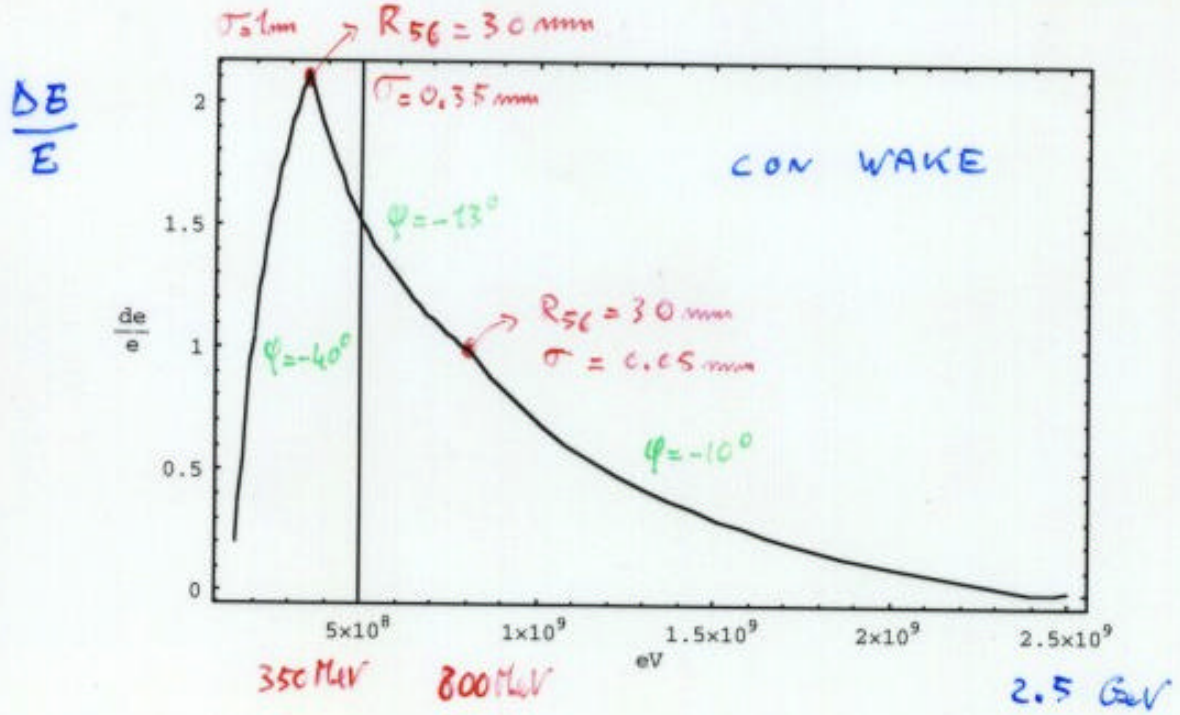
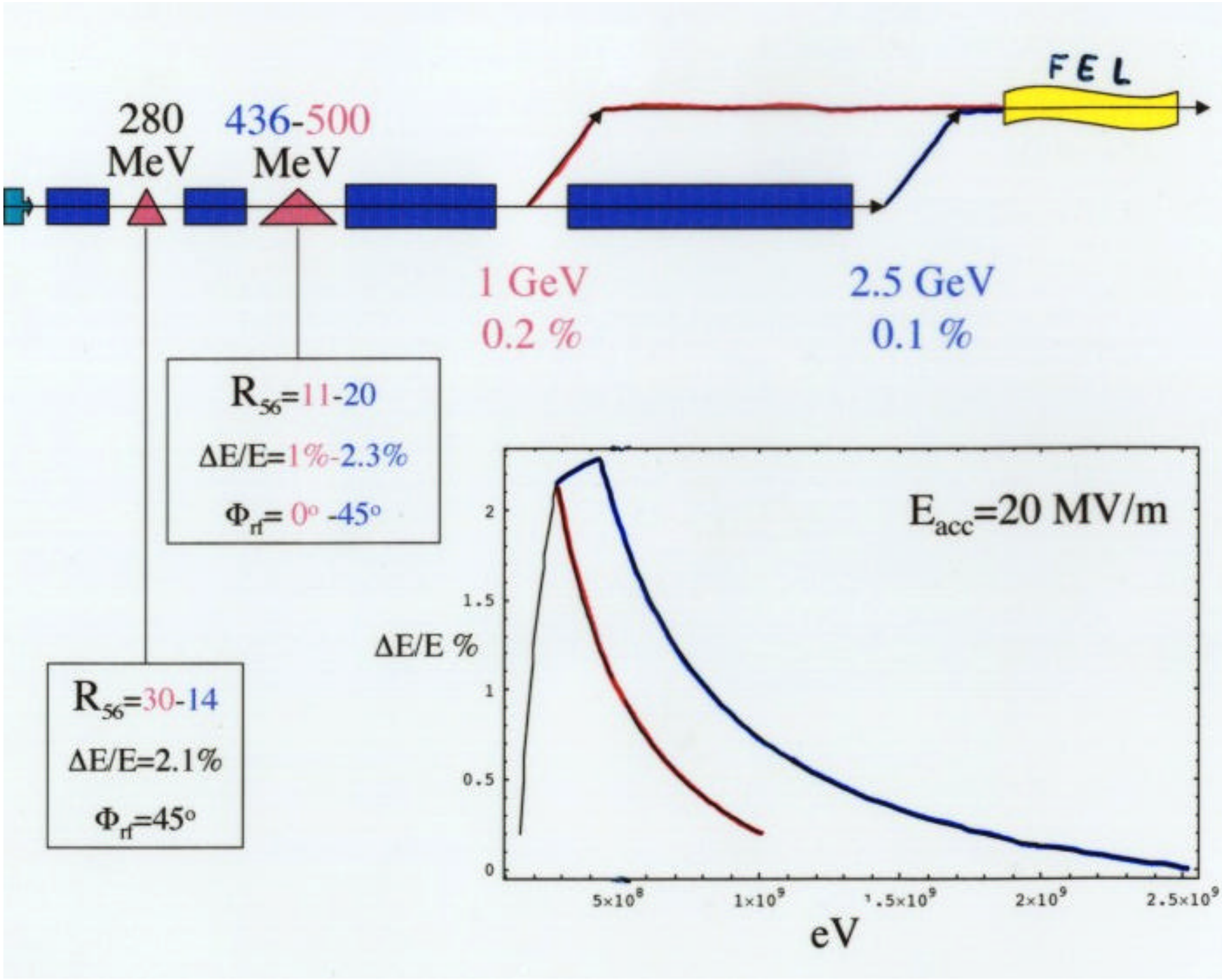


Figure 7.2-4. Longitudinal phase space at (a) start of BC1, (b) end of BC1, (c) start of BC2 and (d) end of BC2. End of linac is shown in Fig. 7.2-3. Parameters are those of Table 7.2-1 with $N = 6.3\times10^9$ and geometric wakefields and T_{566} included (bunch head at left).

S-band Sparx linac






FEL
280 MeV
436-500 MeV
1 GeV
0.2 %
2.5 GeV
0.1 %
R56=11-20
ΔE/E=1%-2.3%
Φrf= 0° -45°
R56=30-14
ΔE/E=2.1%
Φrf=45°
Eacc=20 MV/m
ΔE/E %
2
1.5
1
0.5
0
5×10^8
1×10^9
1.5×10^9
2×10^9
2.5×10^9
eV

TESLA-XFEL bunch compression scheme

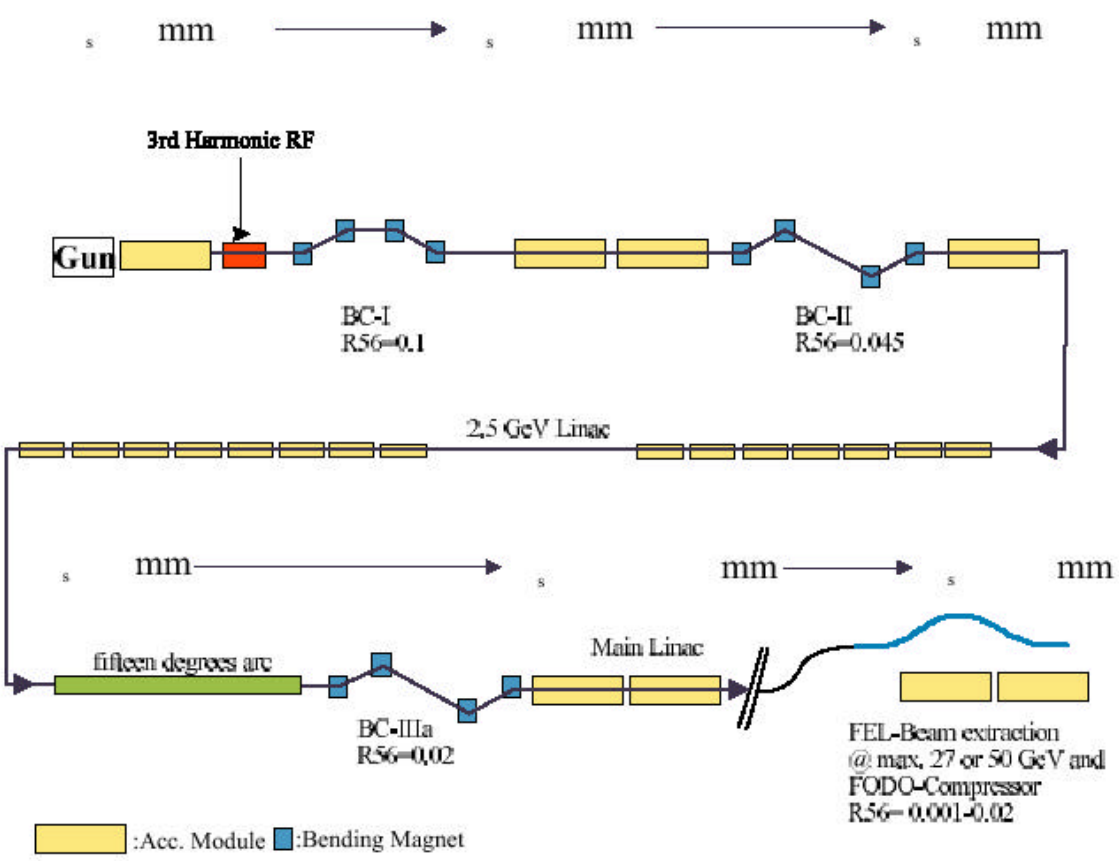


Figure 9.4.1: *Bunch compression scheme for the TESLA XFEL. The "FODO compressor" is optional.*

L-band Sparx linac