High-Precision Field-Maps of TESLA Cavity
some conclusions

computation by W. Ackermann:
  field maps (ASTRA format)
  different resolution, different coupling (pen = 0 .. 10mm)
  decay-mode

preparation for ASTRA:
  center of cavity to origin
  conversion to fill-mode and sw-mode
  easy to use --> http://www.desy.de/fel-beam/s2e/codes.html

discrete coupler kicks:

extensive simulations: of XFEL-ACC1, all working-points (20pC .. 1nC)
data reduction: discrete coupler kicks

normalized complex coupler kick

\[ \tilde{V}(x, y) = \int dz \times (E(x, y, z) + c e_z B(x, y, z)) \exp(j \omega z/c) \]

\[ V(x, y) = \frac{\tilde{V}(x, y)}{\tilde{V}(0,0)} \]

\[ V_x(x, y) = V_x + V_{x,x} x + V_{x,y} y \]
\[ V_y(x, y) = V_y + V_{y,x} x + V_{y,y} y \]
\[ V_z(x, y) = 1 + V_{z,x} x + V_{z,y} y \]

(normalized) coupler kick coefficients

\[ V_x \] horizontal kick
\[ V_y \] vertical kick
\[ V_{x,x} = -V_{y,y} \] dipole kick (from Maxwell Eq.)
\[ V_{x,y} = V_{y,x} \] skew kick (symplecticity)
kicks per coupler

naive upstream/downstream splitting does not work

\[ \tilde{V}(x, y) = \tilde{V}_{\text{up}}(x, y) + \tilde{V}_{\text{down}}(x, y) \]

with \[ \tilde{V}_{\text{up}}(x, y) = \int_{-\infty}^{\text{center}} \times (\cdots) \exp(j \omega z/c) \]
\[ \tilde{V}_{\text{down}}(x, y) = \int_{\text{center}}^{\infty} \times (\cdots) \exp(j \omega z/c) \]

sensitive to position of center (if off axis)

solution: extract monopole part

\[ \Delta E = E(r) - E_m(r) \]
\[ \Delta B = B(r) - B_m(r) \]

\[ \Delta \tilde{V}_{\text{up}}(x, y) = \int_{-\infty}^{\text{center}} (\Delta E \cdots \Delta B \cdots) \exp(j \omega z/c) \]
\[ \Delta \tilde{V}_{\text{down}}(x, y) = \int_{\text{center}}^{\infty} (\Delta E \cdots \Delta B \cdots) \exp(j \omega z/c) \]

insensitive!

normalization to \( \tilde{V}(0,0) \) !!!
cavity operation

a) penetration depth of power coupler (downstream)

<table>
<thead>
<tr>
<th>pen/mm</th>
<th>Q_{e}/1E6</th>
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<tr>
<td>0</td>
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<tr>
<td>2</td>
<td>8.3</td>
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<td>4</td>
<td>5.57</td>
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<td>6</td>
<td>3.81</td>
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<tr>
<td>8</td>
<td>2.67</td>
</tr>
<tr>
<td>10</td>
<td>1.90</td>
</tr>
</tbody>
</table>

close to standard operation conditions

b) fill mode

decay mode (no forward power), simulated by W.A.

"perfect" fill mode (no reflected power)

standing wave mode

approximation:  
\[ E^{SW} \approx \text{Re}\{E^{\text{decay}}\} \quad E^{\text{fill}} \approx \text{Re}\{E^{\text{decay}}\} - j\text{Im}\{E^{\text{decay}}\} \]
\[ B^{SW} \approx j\text{Im}\{B^{\text{decay}}\} \quad B^{\text{fill}} \approx -\text{Re}\{B^{\text{decay}}\} + j\text{Im}\{B^{\text{decay}}\} \]
independent of cavity operation

upstream coupler kick

\[ V_x \times 10^6 = -56.80 + j10.76 \]
\[ V_y \times 10^6 = -41.08 + j0.58 \]
\[ V_{x,x} \times 10^6 \text{mm} = 1.009 - j0.785 \]
\[ V_{x,y} \times 10^6 \text{mm} = 3.456 - j0.422 \]

downstream: vertical and skew kick

\[ V_y \times 10^6 = 36.55 + j7.95 \]
\[ V_{x,y} \times 10^6 \text{mm} = 2.88 - j0.009 \]

dependent on cavity operation  

horizontal, downstream – no wonder!

time dependent!

compensation of vertical kick is not bad!
beam dynamics simulation with full field map
ASTRA, XFEL-ACC1, 1nC case
penetration depth 8mm

average horizontal and vertical offset

vs. beamline coordinate

length of ACC1 with 8 cavities is ~ 10m
beam dynamics simulation with full field map
ASTRA, XFEL-ACC1, 1nC case
penetration depth 8mm

after ACC1: normalized slice emittance

vs. bunch coordinate
comparison
(a) complete 3D fields
(b) rz-field + coupler kicks
(c) rz-field + offset-independent coupler kicks

offset:

emittance:
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discrete coupler kicks:
upstream/downstream – horizontal/vertical/dipole/skew-kicks
mode and coupling dependent: downstream: horizontal & dipole

extensive simulations: of XFEL-ACC1, all working-points (20pC .. 1nC)
0\textsuperscript{th} order: \(x_{av} \), \(x'_{av} \), \(y_{av} \) and \(y'_{av} \) depend on mode, coupling and working point
1\textsuperscript{st} order: growth of proj. emittance (time- & offset-dependence)
growth of vert. slice emittance (offset-dependence)