PEP-II Lattice Development

Tor Raubenheimer
Speaking on behalf of lots of other people

PEP-II MAC Meeting
10/9/03
Introduction

• Status of lattice upgrades
• Options and plans

• Work performed by:
  – Gerry Yocky, Yiton Yan, Mark Woodley, Andy Wolski, Uli Wienands, Jim Turner, Andrei Terebilo, Peter Tenenbaum, Christoph Steier, Andrei Seryi, James Safranek, Mauro Pivi, Yuri Nosochkov, Martin Donald, Franz-Josef Decker, Yunhai Cai
Present Focus (Fall ’03)

• Diagnose present lattice
  – Start with an online model based on best knowledge of optics
  – Measure actual (linear) optics to establish best measured model
    • Try combination of MIA and ORM and phase advance measurements
    • Possibly vary sextupoles and solenoid to improve coupling measurements
  – Discussions of how to proceed from here: tune the machine to the model or tune the model to the machine but ….
    • Establish accurate knobs for tuning the IP
  – Thoughts on measuring nonlinear model to get better understanding of performance limitations
    • Probably not necessary right now but will become important
  – Details discussed by Uli
Lattice Improvements in FY04 and FY05

- Higher luminosity parameters call for smaller $\beta_y^*$
- Presently have $1.2 \sim 1.3$ cm bunches
  - Aim for beta-functions of 6 mm $\rightarrow$ 6mm bunches?
  - Other problems with shorter bunches/low $\alpha_p$ $\rightarrow$ flexible solution?

<table>
<thead>
<tr>
<th>PEP-II Future RF Stations</th>
<th>Max beam bunches (mA)</th>
<th>Number two cavity stations</th>
<th>Number four cavity stations</th>
<th>Total number cavities</th>
<th>RF voltage per cavity (MV/cavity)</th>
<th>Total RF voltage (MV)</th>
<th>Momentum (Ty)</th>
<th>Synch tune</th>
<th>Synch tune length (mm)</th>
<th>Bunch length (mm)</th>
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</thead>
<tbody>
<tr>
<td>LER July 2003</td>
<td>2700</td>
<td>1050</td>
<td>3</td>
<td>0 6</td>
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<td>0.00123</td>
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<td>1700</td>
<td>4</td>
<td>0 8</td>
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<td>1450</td>
<td>3</td>
<td>5 26</td>
<td>0.6</td>
<td>15.6</td>
<td>0.00241</td>
<td>6.54</td>
<td>0.0480</td>
<td>11.1</td>
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<td>HER Oct 2004</td>
<td>1800</td>
<td>1500</td>
<td>5</td>
<td>4 26</td>
<td>0.7</td>
<td>18.2</td>
<td>0.0018</td>
<td>6.10</td>
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<td>1700</td>
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<td>3 26</td>
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<td>0.0013</td>
<td>5.55</td>
<td>0.0407</td>
<td>7.1</td>
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</tbody>
</table>
Lattice Improvements in FY04 and FY05

• Bunch length scales as $\sigma_z \propto (\alpha_p / J_E \, dV_{RF}/dt)^{1/2}$
• Shorter bunches through a combination of decreasing $\alpha_p$ and increasing $V_{RF}$
  – Other options include changing $J_E$ and higher harmonic cavities
  – Changing $J_E$ is possible in HER but more difficult in LER
  – Increasing $V_{RF}$ is easier (cheaper) in LER

• To change $\alpha_p$:
  – High cell phase advance: $\alpha_p \propto 1/\nu^2$
  – Modulate focusing strengths
  – Change cell structure (add $\pi$ inserts)
  – Increase number of cells: $\alpha_p \propto \theta^2$
  – Modulate bending strengths

• In all cases, worry about dynamic aperture, stability, and $\epsilon_x$
HER Lattice

- HER lattice uses arcs adjacent to IR to correct IR $\xi$s
  - Only modify other 4 arcs to simplify IR correction
  - Need to consider IR modifications in future
LER Lattice

- LER lattice also uses arcs adjacent to IR to correct IR $\xi$s
  - Only modify other 4 arcs to simplify IR correction
- LER has 2-fold symmetry
HER Momentum Compaction

• Simplest is to increase FODO arc phase advance
  – Modify 4 out of 6 arc regions to limit impact on IR
  – Studies to increase HER from 60 to 90 degrees per cell

<table>
<thead>
<tr>
<th>HER Lattice</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>60 degree</td>
</tr>
<tr>
<td>Mom. Comp.</td>
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<tr>
<td>Eps X</td>
</tr>
<tr>
<td>90 degree</td>
</tr>
<tr>
<td>Mom. Comp.</td>
</tr>
<tr>
<td>Eps X</td>
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</tbody>
</table>

• Changing four arcs yields ~30% reduction in $\alpha_p$
• Small number of modifications to existing ring
• Decrease in $\varepsilon_x$ can be recovered with an $\eta$-mismatch (?)
• Chromatics and dynamic aperture look reasonable although smaller
HER Dynamic Aperture

Dynamic aperture of HER-60 with $\beta_y^* = 1$ cm

Dynamic aperture of HER-90 with $\beta_y^* = 1$ cm

Calculations by
Yuri Nosochkov

$\varepsilon_x/\varepsilon_y = 48/24$ nm

90 degree lattice looks good (although 10 sigma line is for smaller $\varepsilon_x$)
HER 90-degree Phase Advance

• 90-degree phase advance looks possible
• Magnet strengths need to increase
  – Requires two new 90-deg arc quadrupole supplies plus a few others
    • New QD90 and QF90 PS (arc and η quads are 120 ~ 130% max)
    • Split off η-suppression quads QDS3S and QDS3E from QD90
    • One or two other new quadrupole PS
    • New SD sextupole supply (SD’s are 170% max)

• Chromaticity and sextupole strengths increase significantly
  – New sextupole strengths ~2.5x present (PS & magnet cooling)
  – Should investigate alternate option of 30-degree vertical phase advance to reduce ξy and ease the magnet/PS requirements
Shorter Bunch Length (HER)

• 90 degree phase advance does not get to $\alpha_p \sim 1.3 \times 10^{-3}$
• Need to investigate other options but nothing else has been explored at this time
  – Need to check issue of changing all six arcs

• Changing the damping partition would be convenient because it also restores the $\varepsilon_x$
  – To increase $\varepsilon_x$ from 30 nm $\rightarrow$ 50 nm, $J_E = 2 \rightarrow 2.4$
  – $dJ_x/d\delta \sim -200$ for 90 degree lattice $\rightarrow$ 0.2% change to arc magnets or shift QF magnets by $\sim 1.5$ mm
  – Easy to adjust as desired for $\varepsilon_x$ and $\sigma_z$
  – Still not quite enough but ….
LER Momentum Compaction

- Similar procedure in LER is more difficult
  - Studies to increase LER from 90 to 108 degrees per cell

<table>
<thead>
<tr>
<th>LER Lattice</th>
<th>Mom. Comp.</th>
<th>Sig. Z</th>
<th>Eps X</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 degree</td>
<td>1.25E-03</td>
<td>1.1 cm</td>
<td>23.8 nm</td>
</tr>
<tr>
<td>108 degree</td>
<td>1.04E-03</td>
<td>1.0 cm</td>
<td>18.6 nm</td>
</tr>
</tbody>
</table>

- Chromatics and dynamic aperture are more difficult
  - Present study adds roughly 50 sextupoles to lattice
  - Additional studies may likely improve results but ….

- Still a lot of work needed:
  - Want to try separating X and Y phase advances
  - Want to consider further phase advance increase for smaller $\alpha_p$
  - Want to investigate more extreme solutions
LER Dynamic Aperture

90 degrees/cell

LER (2.0) with errors, nominal IR x-phase
beta = 50/1.25 cm, Q = 38.53/38.510
ex = 23 mm, ey = 2, dp = 8 sigma
rms x/y orbit: 0.22/0.24 mm (eigen 80)
rms x/y delta/beta: 2.3/2.6 %
rms x/y dispersion: 23/6.5 mm (eigen 5)
dash: 10 random error settings
solid red: 10 sigma ellipse
solid green: average aperture
02–26–03

Dynamic Aperture

Calculations by Yuri Nosochkov

108 degrees/cell

LER–108 (mar00) with errors
10 SF + 10 SD global sextupoles per arc
beta = 50/1.25 cm, Q = 41.52/40.910
ex = 21 mm, ey = 2, dp = 8 sigma
rms x/y orbit: 0.29/0.25 mm (eigen 125)
rms x/y delta/beta: 1.6/2.1 %
rms x/y dispersion: 15/6.7 mm (eigen 5)
dash blue: 7 (out of 10) random error settings
solid red: 10 sigma ellipse
solid green: average aperture
05–17–03

Dynamic Aperture

Both calculations for the same emittances of $\varepsilon_x/\varepsilon_y = 24/12$ nm
LER 108-degree Phase Advance

• 108-degree phase advance looks difficult but needs further exploration
  – Provides 20% change to $\alpha_p$
  – Needs are not clear – rf in LER is ‘cheap’

• 108-degree phase advance will require new sextupole magnets and multiple power supplies
  – 48 new sextupole magnets to establish interleaved correction over 10 cells (2 x 5) in four arcs
  – A number of power supplies/magnets are at their limit
  – A number of additional supplies will be needed for dispersion suppressors, injection region, and arc quadrupoles
Shorter Bunch Length (LER)

- 108 degree phase advance does not get to $\alpha_p \sim 0.7e^{-3}$
- Need to investigate other options but nothing else has been explored at this point
  - Changing $J_E$ looks difficult in LER ($dJx/d\delta \sim -30 \rightarrow$ need %’s $dE/E$ or cm-scale offsets)
  - Many other lattice options that need investigation
  - Want to check 135/45 degree phase advance
- Geometrics cancel over 12 rather than 10 cells

<table>
<thead>
<tr>
<th></th>
<th>HER 60/60</th>
<th>HER 90/90</th>
<th>HER 90/30</th>
<th>LER 90/90</th>
<th>LER 108/108</th>
<th>LER 108/36</th>
<th>LER 135/45</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qf [K1]</td>
<td>0.19</td>
<td>0.27</td>
<td>0.25</td>
<td>0.27</td>
<td>0.31</td>
<td>0.29</td>
<td>0.34</td>
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<tr>
<td>Qd [K1]</td>
<td>-0.19</td>
<td>-0.27</td>
<td>-0.17</td>
<td>-0.27</td>
<td>-0.30</td>
<td>-0.18</td>
<td>-0.21</td>
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<tr>
<td>Sf [K2]</td>
<td>0.23</td>
<td>0.62</td>
<td>0.63</td>
<td>0.62</td>
<td>0.90</td>
<td>0.97</td>
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<td>Sd [K2]</td>
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<td>-2.06</td>
<td>-1.24</td>
<td>-2.06</td>
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<td>Chromx</td>
<td>-0.19</td>
<td>-0.31</td>
<td>-0.24</td>
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<td>-0.60</td>
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<tr>
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<td>dJx/d\delta</td>
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<td>-194</td>
<td>-124</td>
<td>-31</td>
<td>-24</td>
<td>-16</td>
<td>-13</td>
</tr>
</tbody>
</table>
Shorter Bunch Length (LER)

- More extreme modifications to LER lattice might be possible
  - Modulate focusing strengths or the bending magnet strengths
  - Add quadrupoles to increase the number of cells or create $\pi$ insertion
    - Constrained by vacuum system but LER has weak magnets
    - May be possible to add C-magnets around existing vacuum system
  - What else?
    - Looking for clever ideas but can’t explore everything!
  - Some ideas could be combined for greater effect
    - Ideally find an adjustable solution(s)
  - Assume that $\varepsilon_x$ can be recovered using the wigglers
LER – New Arc Cells (1)

- New LER arc cells with stronger focusing
  - Add a new quadrupole and sextupole around the ante-chamber
  - New magnet strengths are reasonable
  - Need to also modify η-suppressors
  - Modify 4 arcs → factor of 1.6 in $\alpha_p \sim 0.00076$ and $\varepsilon_x \sim 14$ nm
LER – New Arc Cells (2)

- Dynamic aperture studies using some new tools
  - Tracking of arcs yield an aperture of 25 sigma

Studies by Andy Wolski
LER – Other Options (1)

- Vary bend magnet strengths
  - Easy in 90-degree lattice to create $\eta$-bumps
  - Possible for other phase advances as well
  - Issues:
    - Creates trajectory offset
    - Increased bend angle may exceed photon stops
  - Example:
    - 90-degree lattice
    - 6 cm maximum offsets
    - 20% reduction to $\alpha_p$ with four arcs
    - Can the vacuum system accommodate this?

Studies by Andrei Seryi
LER – Other Options (2)

- Vary quadrupole magnet strengths to achieve $\alpha_p = 0$
  - Drive the dispersion negative with factor of two changes to quadrupole strengths – brute force matching
  - Use 12 arc cells and match $\beta$ and $\eta$ to unperturbed cells
  - May make dynamic aperture very difficult!
  - With 4 arcs $\alpha_p \sim 30\%$ or 0.00041

Studies by Andrei Seryi

\[ \alpha_p = 0 \]
Lattice Plans

• HER
  – Looks like 90-degree solution will work
  – Check reducing vertical phase advance
  – Check changing $J_E$
  – Check modifying all six arcs and integrating new IR developments

• LER
  – Check 108/36 and 135/45 lattices
  – Explore new cell option further
  – Check alignment and vacuum limitations
  – Think about smarter way to vary quadrupole strengths
  – Study dynamic aperture limitations before we proceed too far

• Need to understand timescales
  – Results needed soon?