Further Studies of NLC Main Linac Steering

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1. Description of the “Standard” Algorithm, changes to same
2. Simulations of Standard Algorithm on Main Linac (LIAR)
3. “Afterburner” to Standard Algorithm
4. “French Curve” Algorithm
5. Steering with ATL
6. Conclusions

“The safest way, the straight and narrow
No confusion, no surprise”

Divides linac into N regions containing equal numbers of quads, steering magnet located at first and last quad in each region

In each region:

- Move all quads but first and last s.t. BPMs in quads are zeroed
  → Constraint: Apply “penalty function” to $\chi^2$ for large magnet moves (increase $\chi^2$ by 1 for each mm of motion)
  → Use 1st quad’s corrector to steer beam into last quad’s BPM
- Move structure girders to zero average of 6 S-BPMs on each girder (one at each end of each structure)

Changes for 1998 to Standard Algorithm:
- Mover “Trim” function goes to mover detente closest to desired setpt
- Girder alignment uses all S-BPMs on girder
2. Simulations with Standard Algorithm on “new” (3 structure/girder, 3 supersectors/linac) Main Linac

Used linac of June, 1998, 1.8 meter structure with a/h = 0.18 (SR wake provided by G. Stupakov), 1 bunch only; 5 passes of std algorithm per region

Parameters:

Static Q-BPM offset: 2 μm RMS
Q-BPM resolution: 1 μm RMS
S-BPM resolution: 5 μm RMS
Structure misalignments: 15 μm RMS
Girder misalignments: 50 μm RMS
Quad misalignments: 50 μm RMS
Beam Parameters: $1.1 \times 10^{10}$ electrons, 145 μm RMS length, $10 \text{ GeV} \rightarrow 500 \text{ GeV}$, 36 x 0.4 NLC units $\varepsilon \left(10^{-7}\right)$
Emittance Dilution versus BNS Overhead, Standard Algorithm for Linac Steering
Emittance Dilution versus Mover Step Size, Standard Algorithm

Emittance Dilution (%) vs. Mover Step Size (nm)
Results of Standard Algorithm studies:

- **Emittance** dilution increases from 44% to 72% as BNS overhead is increased

- For mover stepsizes > 100 nm, emittance dilution increases rapidly

Can the amount of emittance dilution be improved with improvements in the algorithm?

Yes...
3. “Afterburner” to Standard Algorithm

Uses **MICADO** algorithm – selects $M$ best quads to move in each region to reduce RMS orbit

Same lattice, BNS case 5 (3.7% overhead) – 5 passes Standard Algorithm followed by 3 passes **MICADO** “afterburner” per region

**MICADO** RMS orbit tolerance: $1 \, \mu\text{m}$
Max number of **MICADO** movers: 7
MICADO “Afterburner” reduces *additional* dilutions due to large mover steps, does not improve *baseline* performance (dilution with perfect movers).

Also, Standard Algorithm assumes wide availability of steering correctors – may not be the case in NLC linac (prefer to have few of them).

Could substitute “moved” quads for correctors, but algorithm becomes tricky and orbit on z-plot looks terrible!

A better algorithm would not require correctors at all, and would also reduce the *emittance* dilution...
4. “French Curve” Algorithm

Very similar to Standard Algorithm:

- **Linac** divided into \( N \) regions with equal quads in each region
- In each region Q-BPM RMS orbit is minimized, large magnet moves are penalized, first and last magnets are not moved, girders are moved to zero average of 6 **S-BPMs**

Differences:

- No correctors are used
- After several iterations aligning region \( n \), the quads at the **center** of regions \( n \) and \( n + 1 \) are used as endpoints and region between them is aligned

Orbit is still constrained to the mechanical survey line without dipole magnets!
Several studies of the “French Curve” algorithm:

- With perfect quad movers, $\varepsilon$ blowup for min/max BNS overhead cases
- With 3.7% BNS overhead, $\varepsilon$ blowup versus mover step size
- Convergence $-\varepsilon$ versus number of iterations per region
- $\varepsilon$ blowup versus S-BPM resolution
- Emittance blowup for FC Algorithm + MICADO “Afterburner” (no improvement)
Emittance Dilution versus BNS Overhead, 2 Steering Algorithms

- Standard Algorithm
- "FC" Algorithm
Convergence Speed -- "FC" Algorithm

- 50 nm steps
- 300 nm steps

Emittance Dilution (%) vs. Number of Iterations
Emittance Increase as a Function of RF BPM Resolution — "French Curve" Algorithm

Emittance Increase (%)

RF BPM resolution (microns)
5. Steering with ATL

All this steering takes a finite length of time – FC Algorithm requires (3 passes of quad align + 3 passes of RF align) * 28 regions = 168 operations.

Assume misalignment due to ATL law: Use NLC nominal ATL coefficient \((5 \times 10^{-7} \text{ \mu m/m/sec})\), assume each iteration of quad or RF align = 60

For 3.7% BNS overhead, 50 nm mover steps, \(\epsilon\) blowup \(\rightarrow 63\% \) fro

Is improvement possible? Yes...
After first steering with 3 iterations per region, do second, third, fourth... with one iteration/region

Assume that later iterations take only 30 seconds per operation (automated steering job takes over)
6. Conclusions

- Standard Algorithm for linac steering has acceptable emittance dilution for small mover step sizes, not for large ones.
- Standard Algorithm + MICADO has acceptable emittance dilution for larger step sizes.
- “French Curve” Algorithm produces less emittance dilution for all mover step sizes, BNS cases; MICADO does not improve “French Curve” performance.
- S-BPM resolution worse than 5 μm RMS rapidly degrades emittance.
- Adding ATL motion to FC Algorithm increases emittance dilution from 36% to 63%; with continual l-iteration alignment from upstream to downstream, can achieve 49% equilibrium emittance dilution.
- Further study of effect of unequal BPM offsets (F vs D quads), feedbacks running during steering.