Studies of NLC Main Linac Steering and Alignment

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1. Description of steering algorithms and assumptions – canonical, "afterburner", "French Curve"
2. Vertical Emittance dilution versus mover size, S-BPM performance, iterations…
3. ATL and alignment performance

1. The "Standard" Linac Steering Algorithm -- by R. Assmann, T. Raubenheimer, *et al* – used in ZDR studies

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 χ^2 for large magnet moves (increase χ^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:	1.1×10^{10} electrons, 145 μm RMS length, 10 GeV→ 500 GeV, 36 x 0.4 NLC units ε (10^{-7})

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 μm
Max number of MICADO movers:	7

4. “French Curve” Algorithm

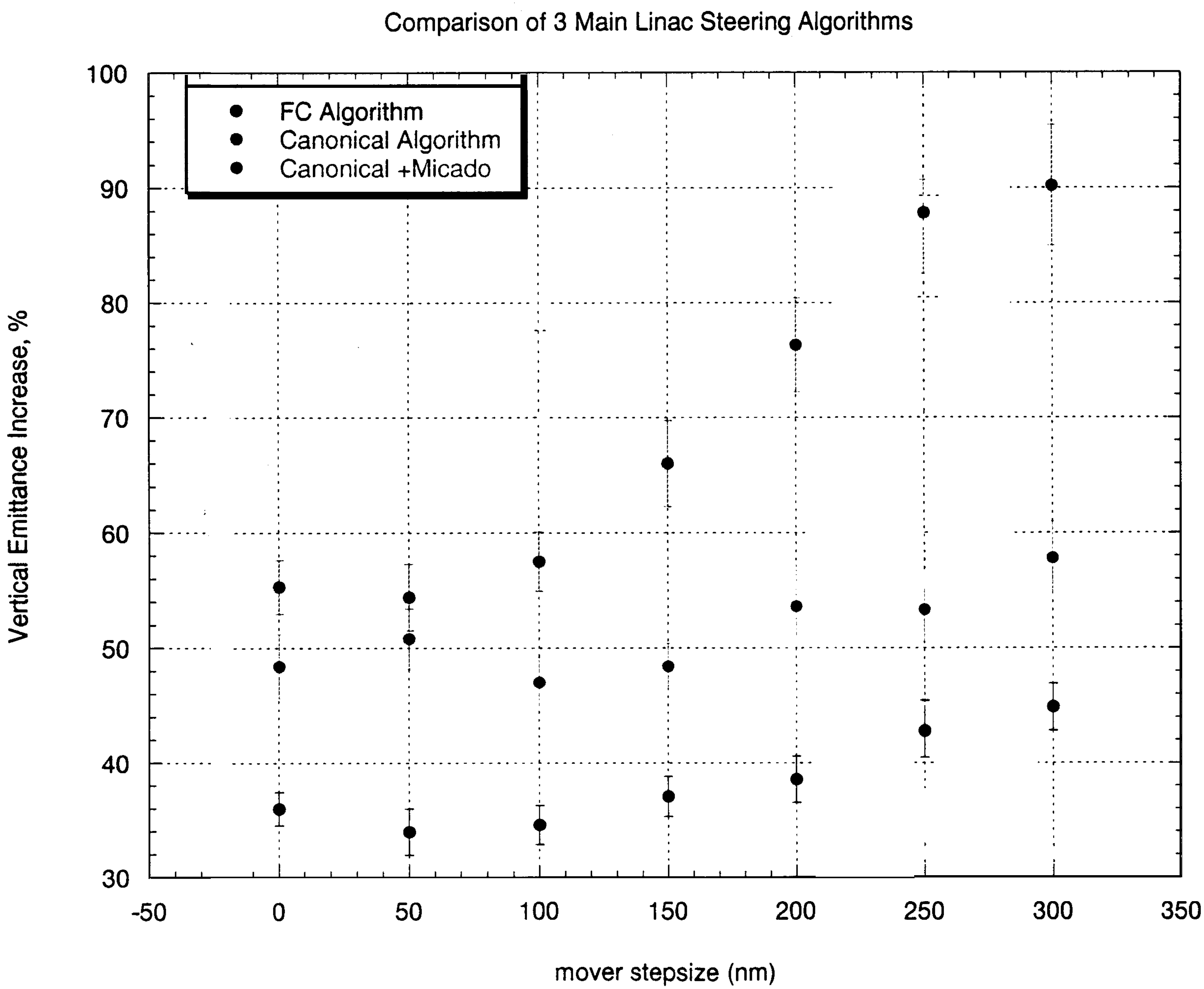
Very similar to Standard Algorithm:

- 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

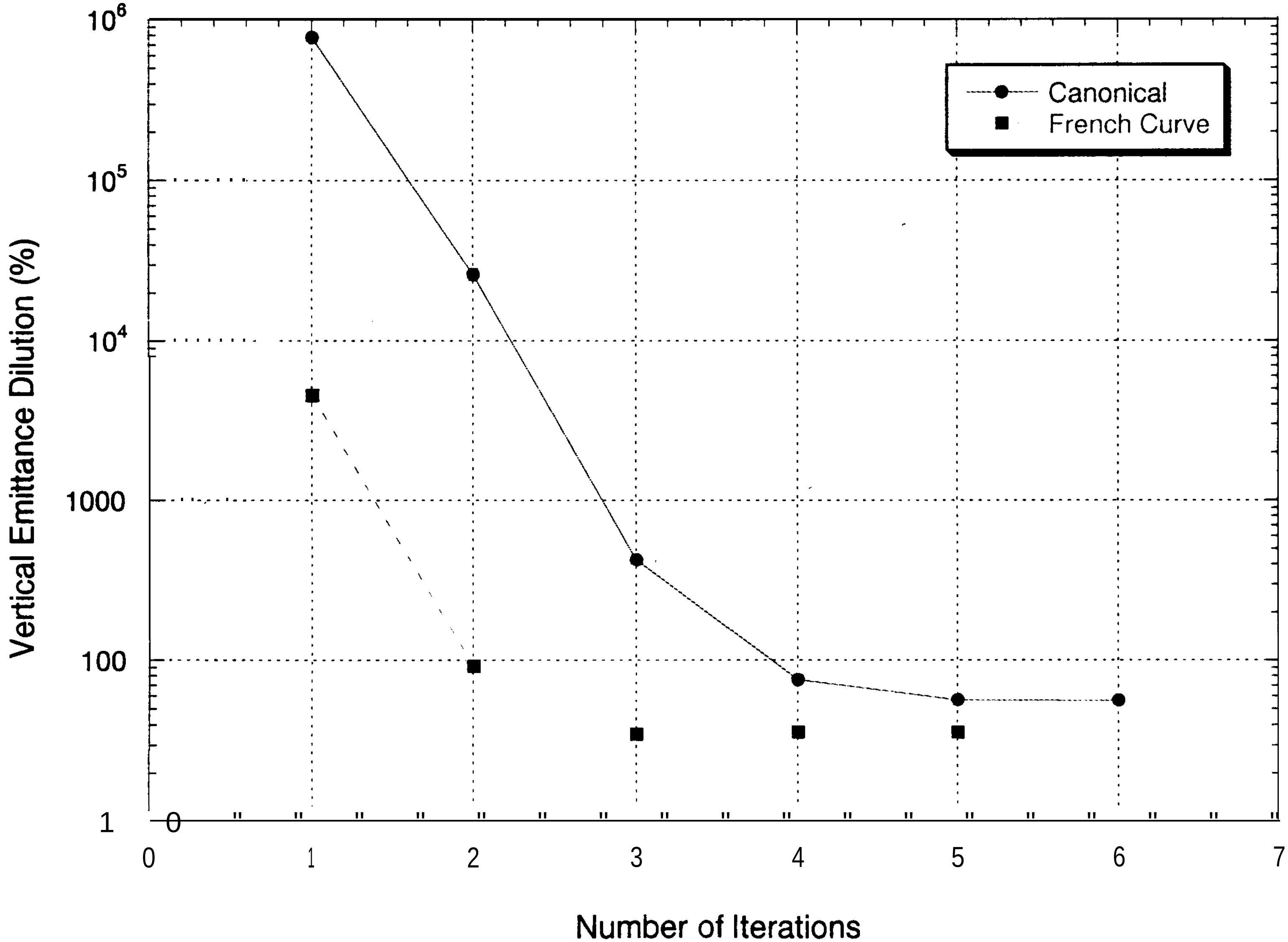
Differences:

- 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

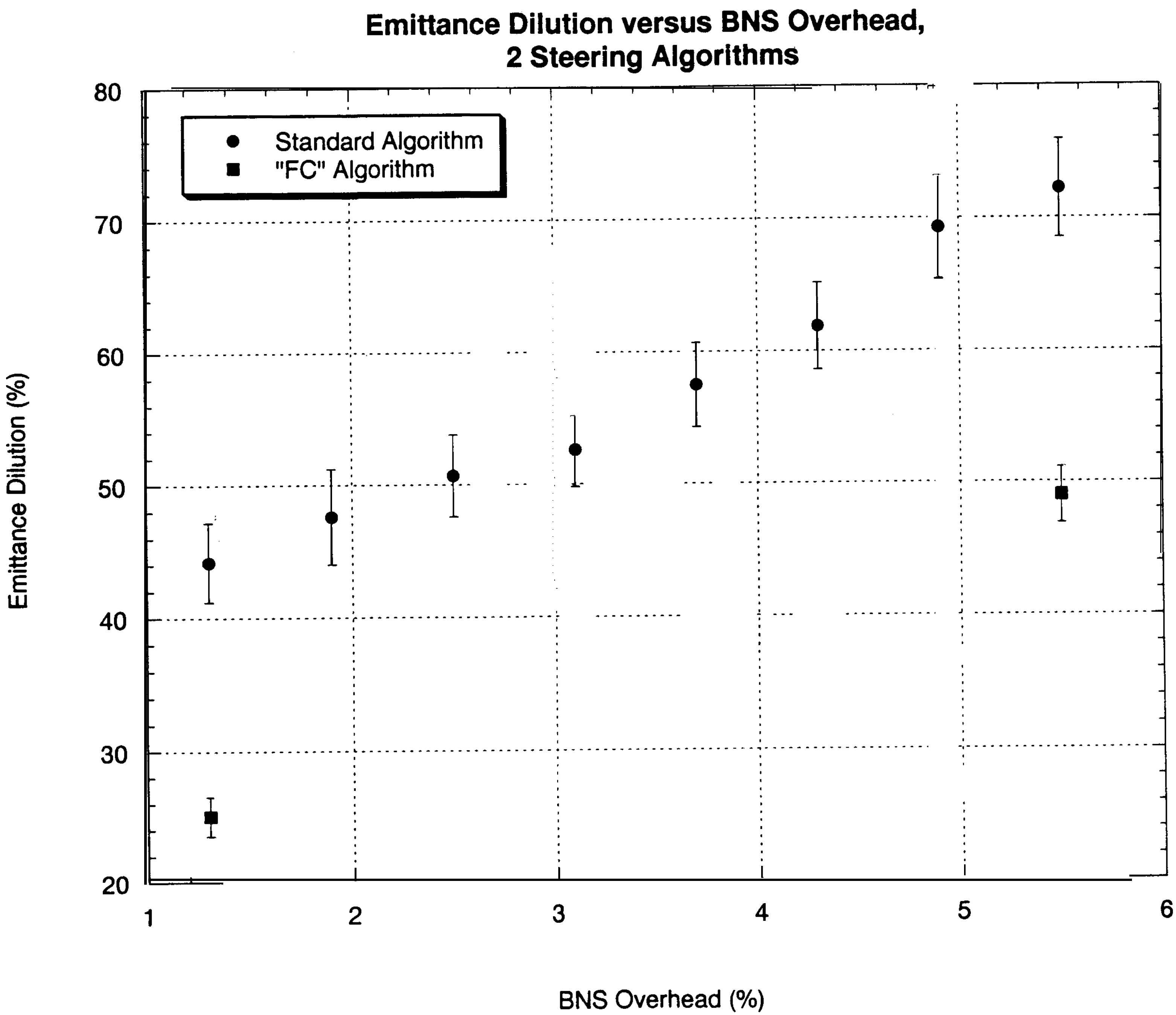
Orbit is still constrained to the mechanical survey line without dipole magnets!



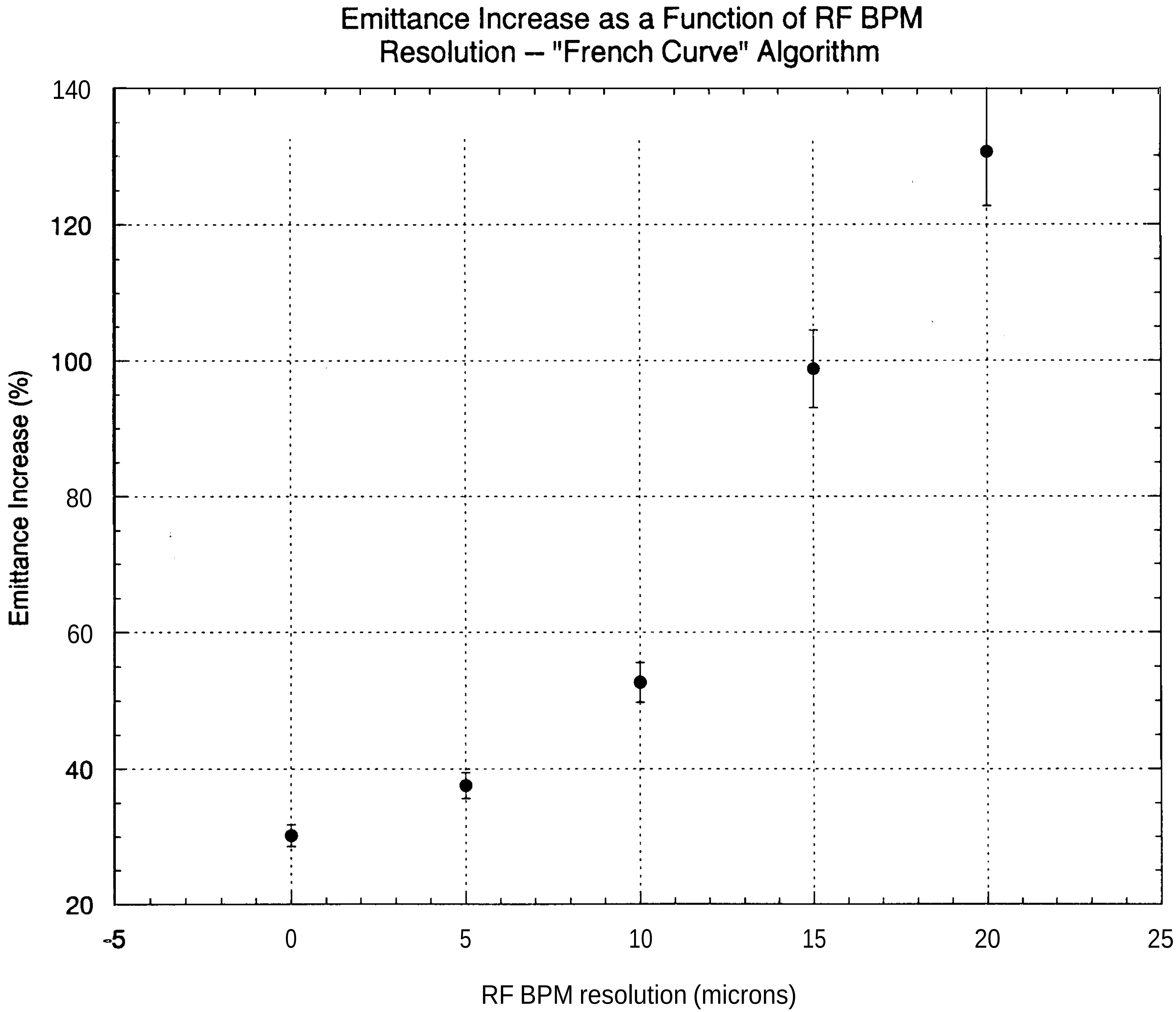
Comparison of 3 Main Linac Steering Algorithms
FC Algorithm
Canonical Algorithm
Canonical +Micado
Vertical Emittance Increase, %
100
90
80
70
60
50
40
30
-50
0
50
100
150
200
250
300
350
mover stepsize (nm)



Canonical
French Curve
Vertical Emittance Dilution (%)
10^6
10^5
10^4
1000
100
1
0
0
1
2
3
4
5
6
7
Number of Iterations



Emittance Dilution versus BNS Overhead,
2 Steering Algorithms
Standard Algorithm
"FC" Algorithm
Emittance Dilution (%)
80
70
60
50
40
30
20
1
2
3
4
5
6
BNS Overhead (%)



Emittance Increase as a Function of RF BPM
Resolution -- "French Curve" Algorithm
Emittance Increase (%)
RF BPM resolution (microns)
140
120
100
80
60
40
20
-5
0
5
10
15
20
25

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 (5×10^{-7} μm/m/sec), assume each iteration of quad or RF align = 60 seconds

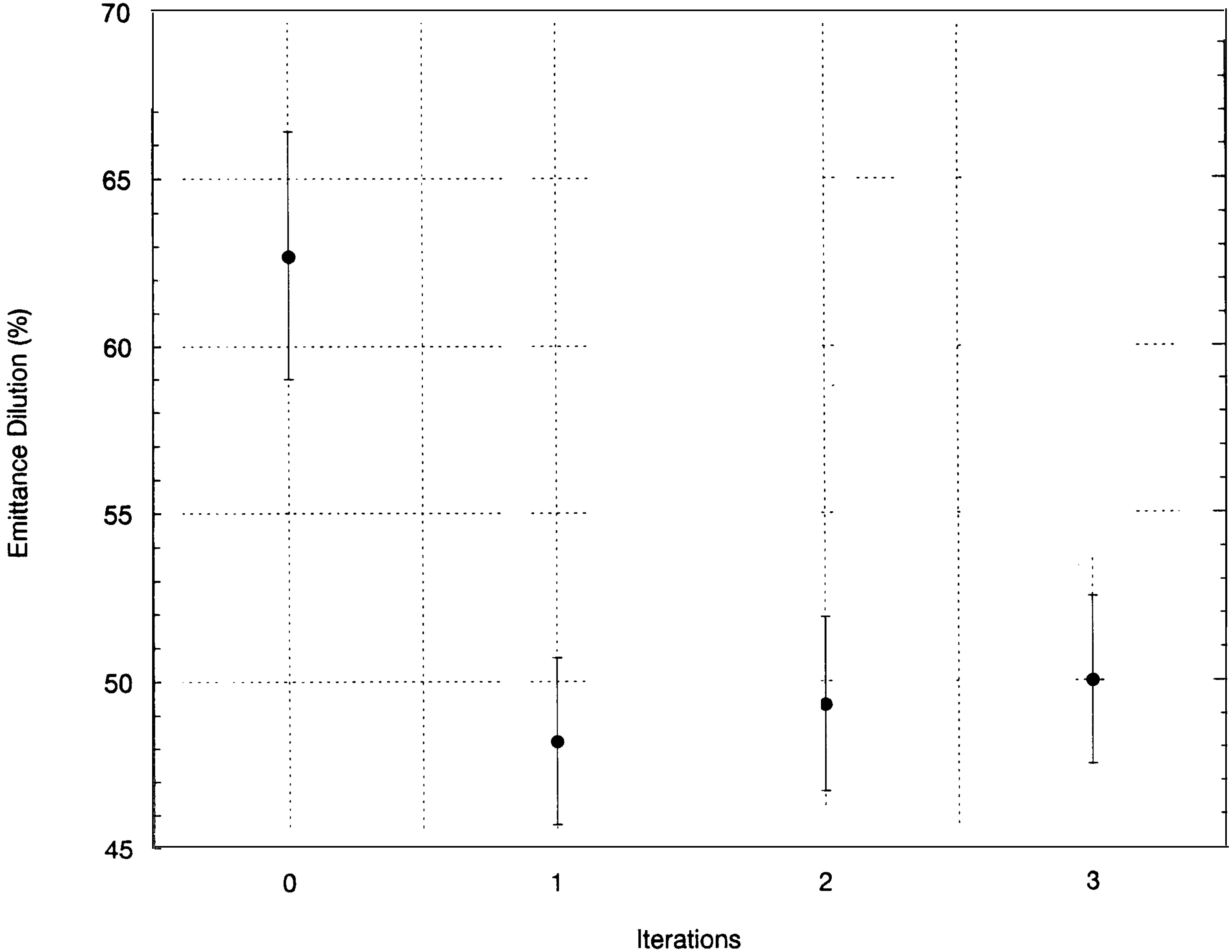
For 3.7% BNS overhead, 50 nm mover steps, ε blowup → 63% from 36%

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)

"FC" Algorithm with ATL: Emittance Dilution Versus Iterations of Automated Alignment



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