RTML Emittance Studies

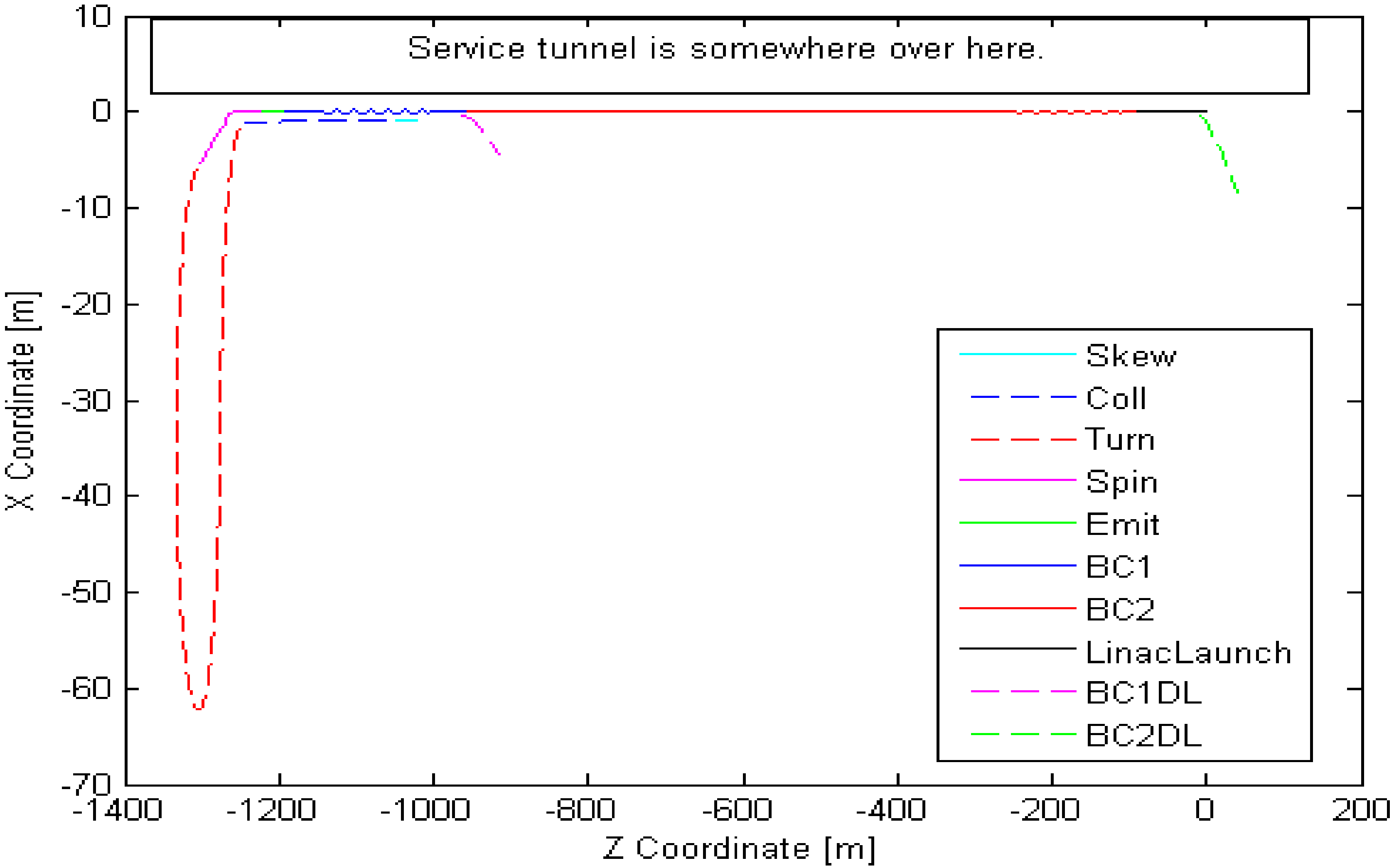
PT

SLAC

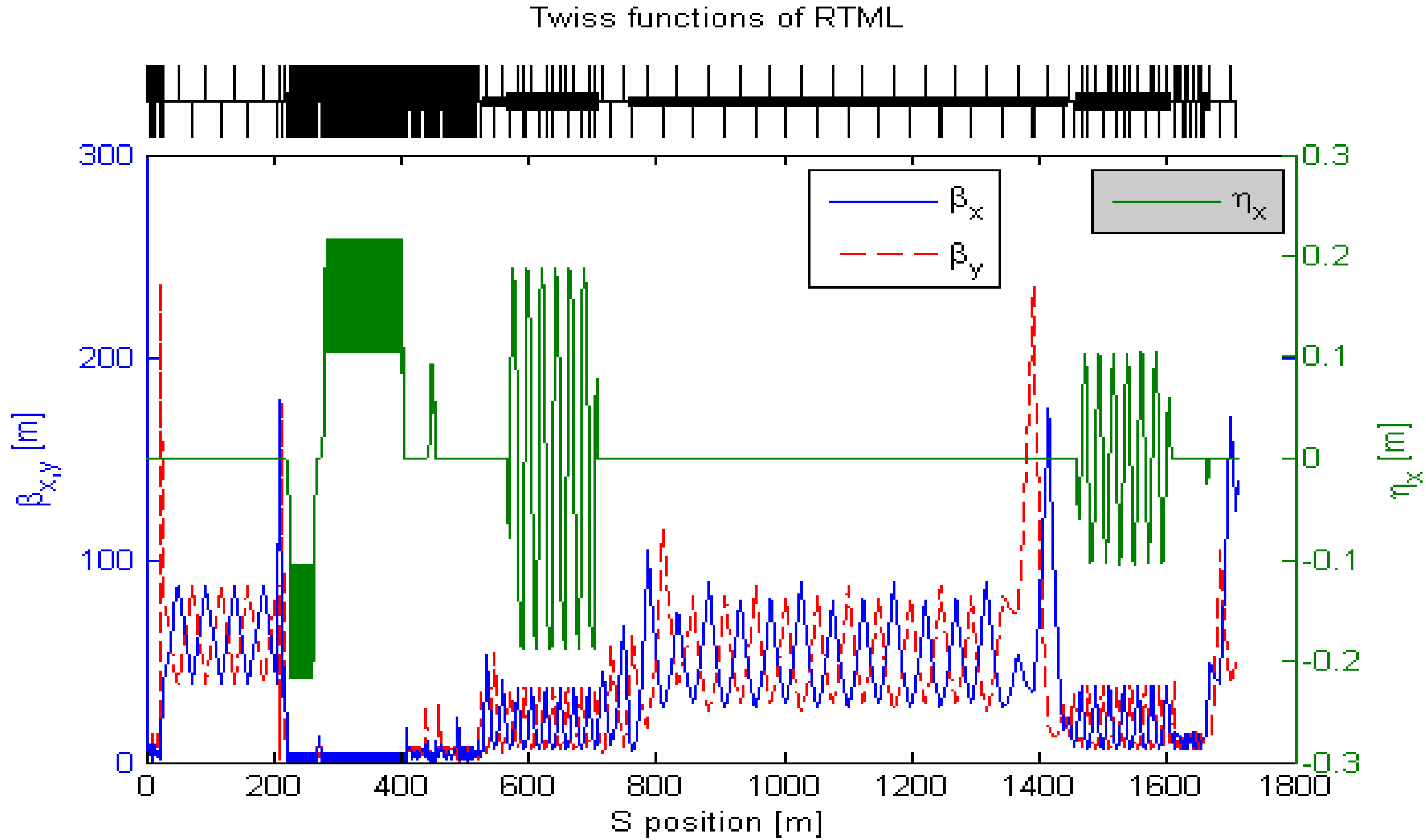
Quick Review of RTML

- Single-pass transfer line from the damping ***R***ings ***T***o the ***M***ain ***L***inac
  - **Duh!**
  - **But does not include single-pass Damping Ring Extraction (DRX) line**
- Optical modules in S order:
  - **Skew correction**
  - **Collimation + Feed-forward measurement**
  - **Turnaround**
  - **Spin Rotation**
  - **Feed-forward correction + Emittance measurement**
  - **Two-stage bunch compressor including acceleration from 5 GeV to ~15 GeV**
  - **Emittance measurement + matching into main linac**
  - **Plus two pulsed extraction lines**
    - After BC1 – 10% power (220 kW)
    - After BC2 – full power (660 kW)

Obligatory RTML Footprint



Obligatory RTML Twiss Parameters



Luminosity Challenges in the RTML

- Vertical Dispersion
  - **Misaligned quads and BPMs**
  - **Rolled quads in turnaround**
  - **Rolled bends in turnaround and BCs**
  - **Pitched RF cavities**
- Horizontal Dispersion
  - **Quad strength errors in turnaround**
  - **Bend strength errors in turnaround and BCs**
- XY coupling
  - **Rolled quads and (slightly) bends**
  - **Strength errors in spin rotator solenoids and quads**
- Wakefields
  - **Misaligned cavities and CMs, esp in BC1**
- YZ coupling
  - **Pitched RF cavities**
- Bunch length, centroid energy, arrival time
  - **RF and bend errors**
- Collimator Wakefields
  - **Mainly in Collimation section (Duh, again!)**

Obvious Trouble Spots and their Mitigation

- Turnarounds
  - **A lot of cells with very strong focusing**
  - **A lot of bends with strong bending**
  - **Normal and skew quads for disperison tuning**
- Spin Rotators
  - **Delicate cancellation of strong coupling from solenoids**
  - **Skew correction section in front of RTML**
- Bunch Compressors
  - **RF, with all the problems that entails**
  - **Strong bends**
  - **Normal and skew quads for dispersion tuning**

What has been done so far

- Very preliminary investigations of emittance tuning upstream of BC1
  - **See how well dispersion and coupling corrections really work**
- Use of dispersion knobs in BC1/BC2 to tune out effects of pitched RF cavities
  - **Cavities produce YZ correlation due to time-varying transverse kick**
  - **Also produce EZ correlation due to time-varying energy gain**
  - **Results in YE correlation, aka disperison**
  - **Reported on at LET meeting, CERN, Feb2006**

RTML "Front End" Tuning

- Static Errors:
  - **Quads:**
    - 150 µm RMS offsets in x and y (may be possible based on FFTB experience)
    - 0.25% strength errors (based on FFTB experience)
    - 300 µrad rotation errors (tough!)
  - **Bends:**
    - 0.5% strength errors (a bit better than in FFTB)
    - 300 µrad rotation errors (tough!)
  - **BPMs:**
    - Perfect resolution so far
    - Two different models of offsets
      - 150 µm RMS offsets to survey line, or
      - 70 µm RMS offsets to nearest quad
        - » Based on FFTB fiducialization experience
    - No rotations or scale errors yet
  - **Laser Wire Scanners:**
    - Entirely perfect devices so far
- This entire region in room-temperature, so alignment tolerances which are tighter than the linac's can be met

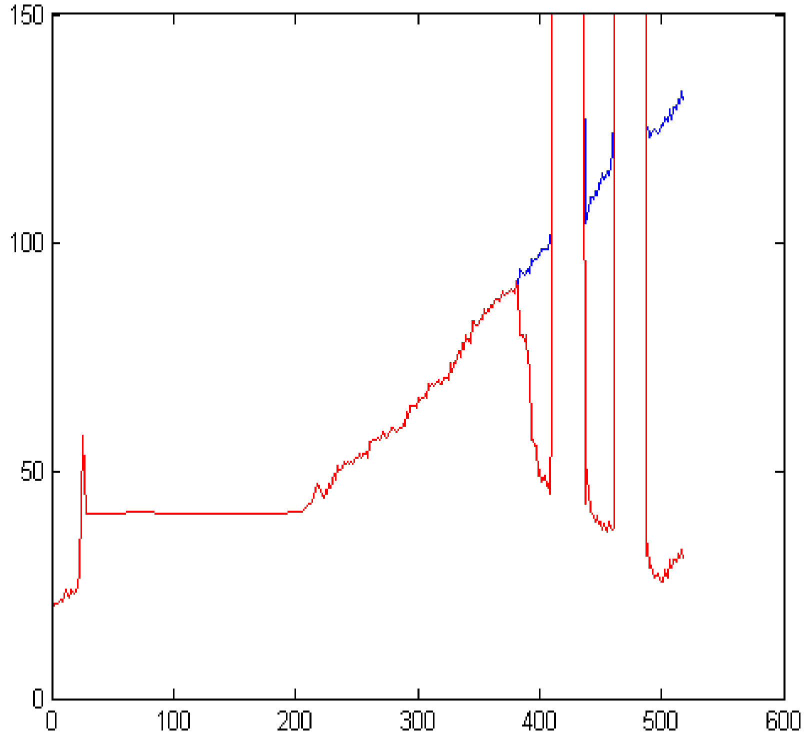
A Reminder: Emittance Budget

- DR extracted emittance specification is 20 nm
- IP emittance specification in nominal parameters is 40 nm
  - **Smaller in some parameter sets – as small as 30 nm!**
- Exact budget for each region unknown
  - **Probably not bad to use last known NLC budget:**
    - 4 nm (20%) RTML
    - 10 nm (50%) ML
    - 6 nm (30%) BDS
- Is that a mean budget?
  - **Probably not! Distribution generally has a long tail which goes out to several times the mean**
  - **For safety, may want to use 90% CL**

"Front End" Tuning (1)

- Start with y offsets of BPMs and quads only
- First thing you would think to do: steer flat and then use dispersion knobs on wires
  - **Painful discovery: phase advance between knob quads and wire is important!**
    - Phase of 90° optimal
    - Phase of 0° useless
    - Intermediate phases can be problematic
      - Expect that 2 sets of knobs at 45° and 135° should be just as good as knobs at 0° and 90°
      - Not true! If $\alpha_y \neq 0$ at wire, knob-to-wire phase far from 90° results in optimization getting the wrong answer!
      - In this system, knobs are in fact about 45° out of phase with wires
        - » Constructed "knob of knobs" – linear combination of knobs with correct phase advance to wire scanners

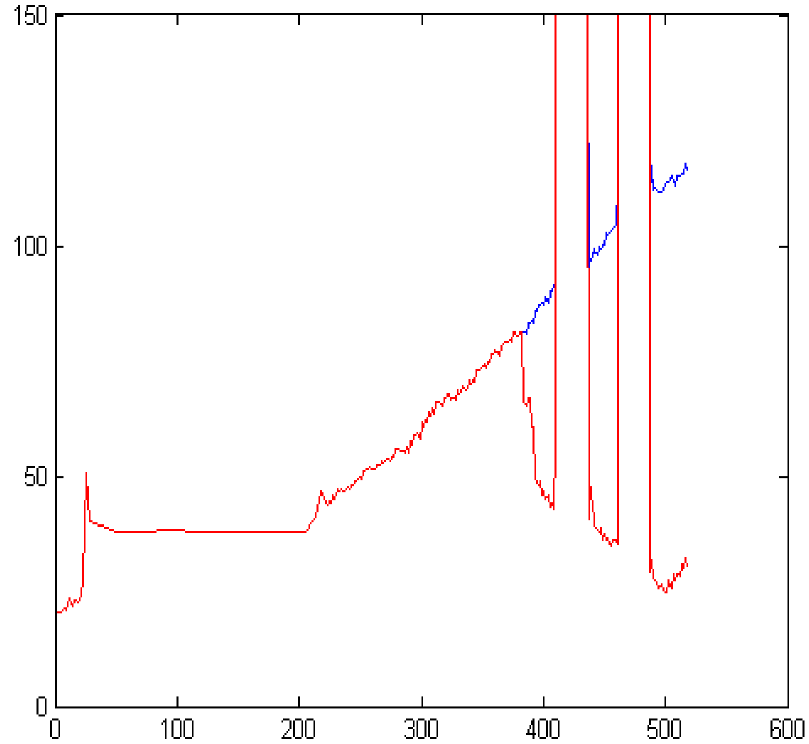
Steer Flat + Dispersion Knobs



BPMs misaligned 70 µm WRT quads:

After steering, <γε> → 131 nm

After knobs, <γε> → 31 nm



BPMs misaligned 150 µm WRT survey line:

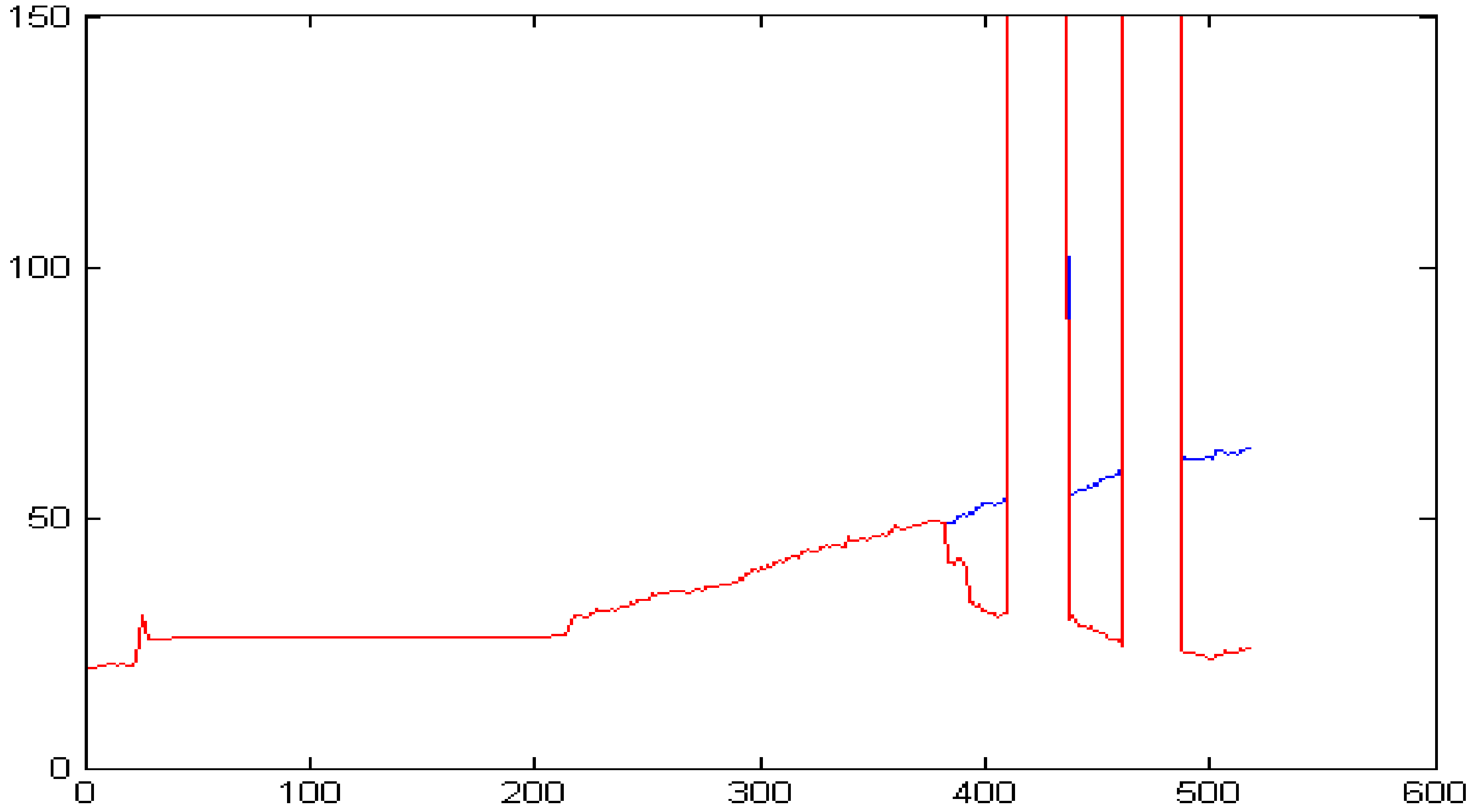
After knobs, <γε> → 31 nm

In both cases, mean of 100 seeds considered

Improvements

- Can use a variant of Kubo's Method (aka Kick Minimization) to improve steering results
  - **If BPMs were known to be perfect but quads misaligned, we would steer to zero BPMs and ignore corrector strengths**
  - **If quads were known to be perfect but BPMs misaligned, we would steer to zero correctors and ignore BPM readings**
  - **Since both BPMs and quads are misaligned, we should constrain *both* in the steering solution**
  - **Set up a least-squares steering which constrains BPMs to 150 μm RMS offsets, and correctors to field equivalent to 150 μm RMS quad offsets**
    - Each corrector constrained based on nearest quad
    - Only done in case with BPMs misaligned wrt survey line – BPMs aligned to quads is more complicated and I was in a hurry

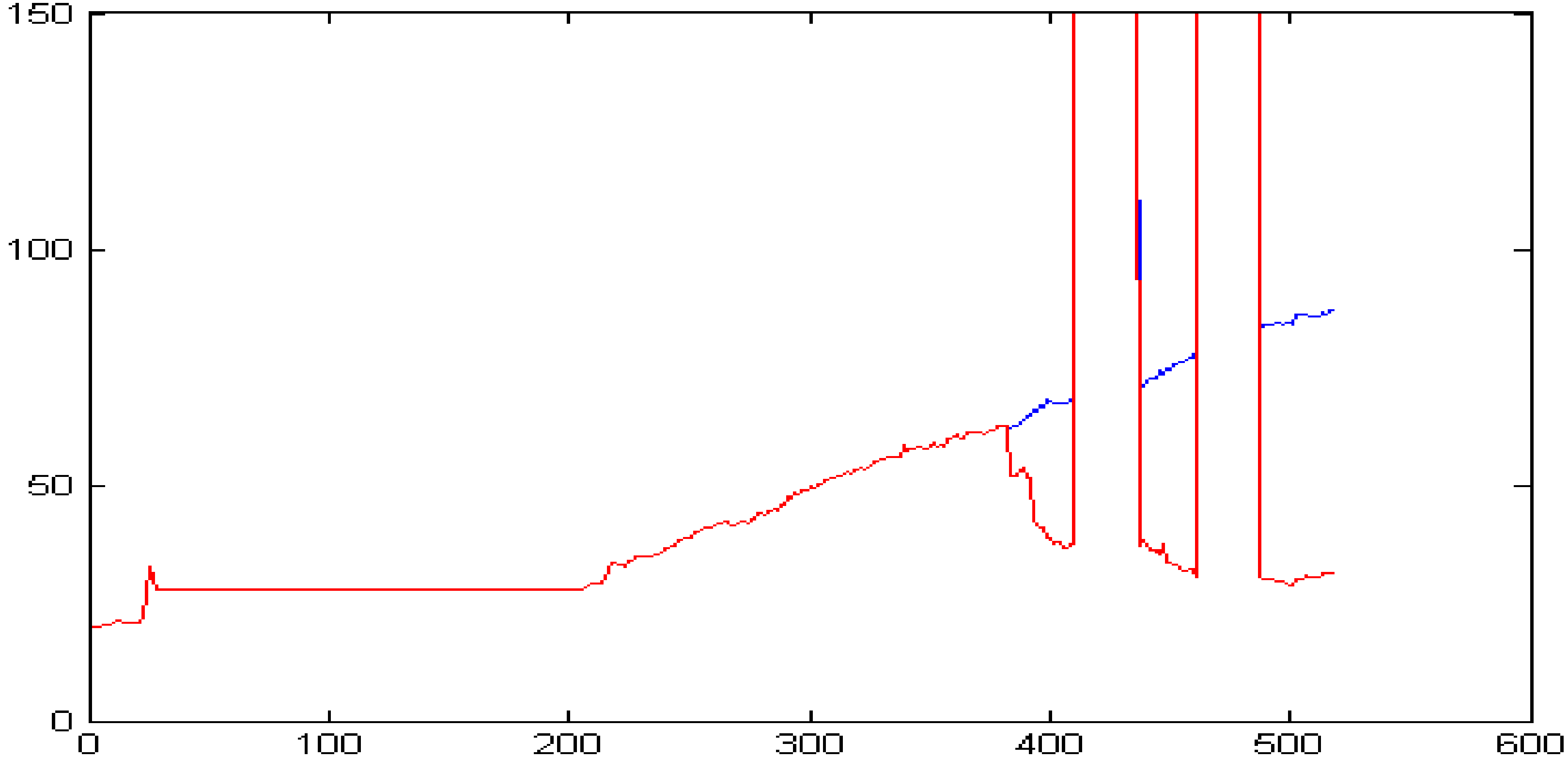
KM + Knobs Method



Mean after steering 64 nm, mean after knobs 24 nm!

KM + Knobs Method (2)

What happens when all errors turned on?



Emittance after steering → 87 nm, emittance after knobs → 31 nm

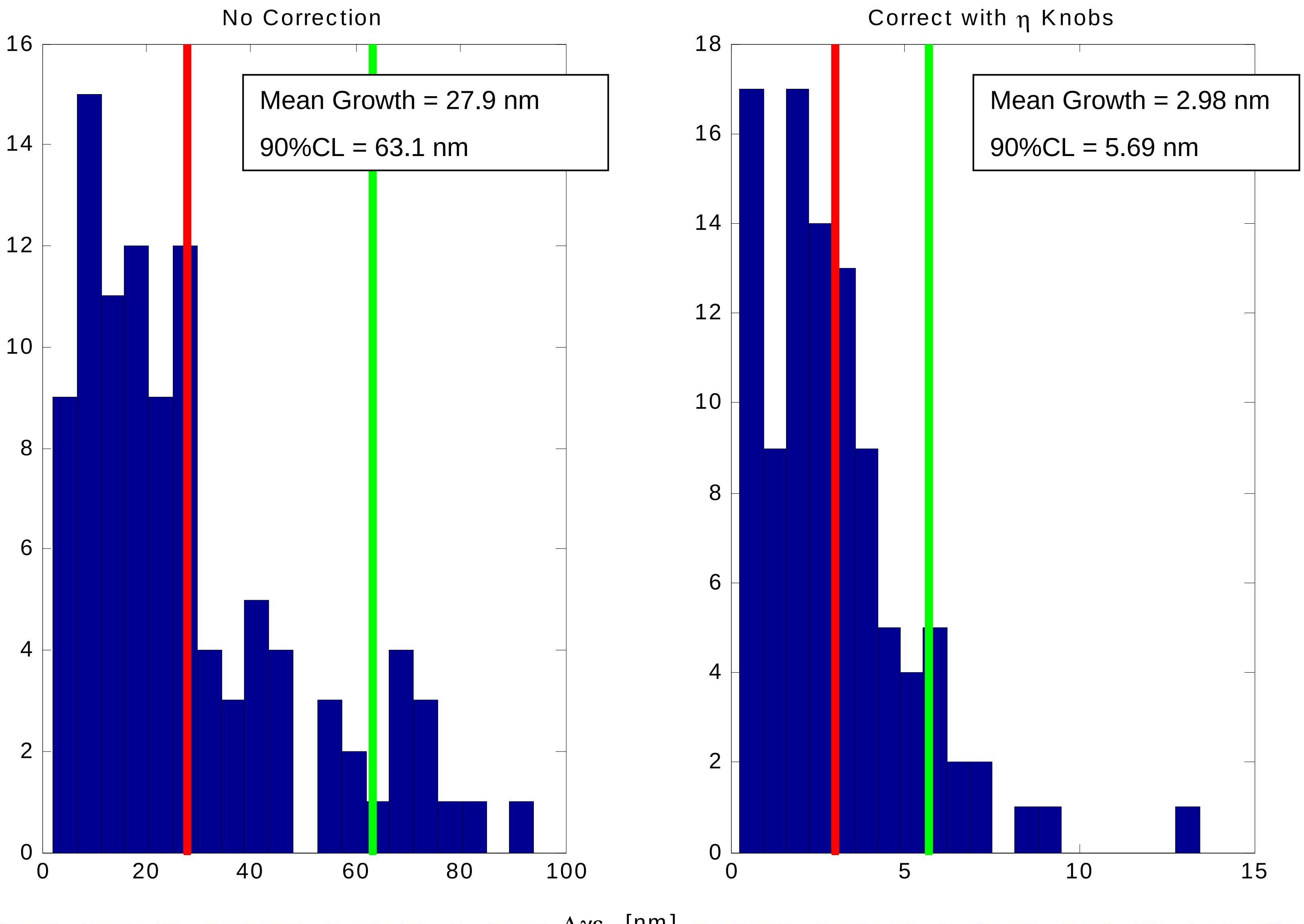
What Happened?

- With just quad and BPM errors, the relative weight between BPM and corrector constraints was right
- With additional errors, it was no longer correct
  - **Need to err on side of more corrector strength**
  - **May have caused some of the growth in emittance after steering**
- After knobbing, expected ~27 nm emittance
  - **Knobs usually take out 90% of emittance growth**
  - **Got 31 nm – additional 4 nm from xy coupling?**
  - **Need to learn how to use decoupling knobs in RTML launch!**

Emittance From Pitched Cavities

- Test of Walker's Hypothesis
  - **Namely that dispersion correction can take out emittance growth from this source**
  - **Rationale already discussed**
    - YZ coupling + EZ coupling = YE coupling
  - **Used pre-RDR 2-stage compressor lattice**
  - **Scanned each of 4 dispersion knobs, measured projected emittance, found minimum of parabola, went there**
    - Reported at February LET meeting
    - Nothing new since then
    - Note that simulation of "measurement" quite different from study of turnaround knobs – should repeat with wisdom learned from that experience

Emittance ***Growth*** from Pitched Cavities



Summary

- Emittance Growth in RTML is a serious issue
- Neither of the effects studied to date are under control to our satisfaction
- There is a lot of work to be done!