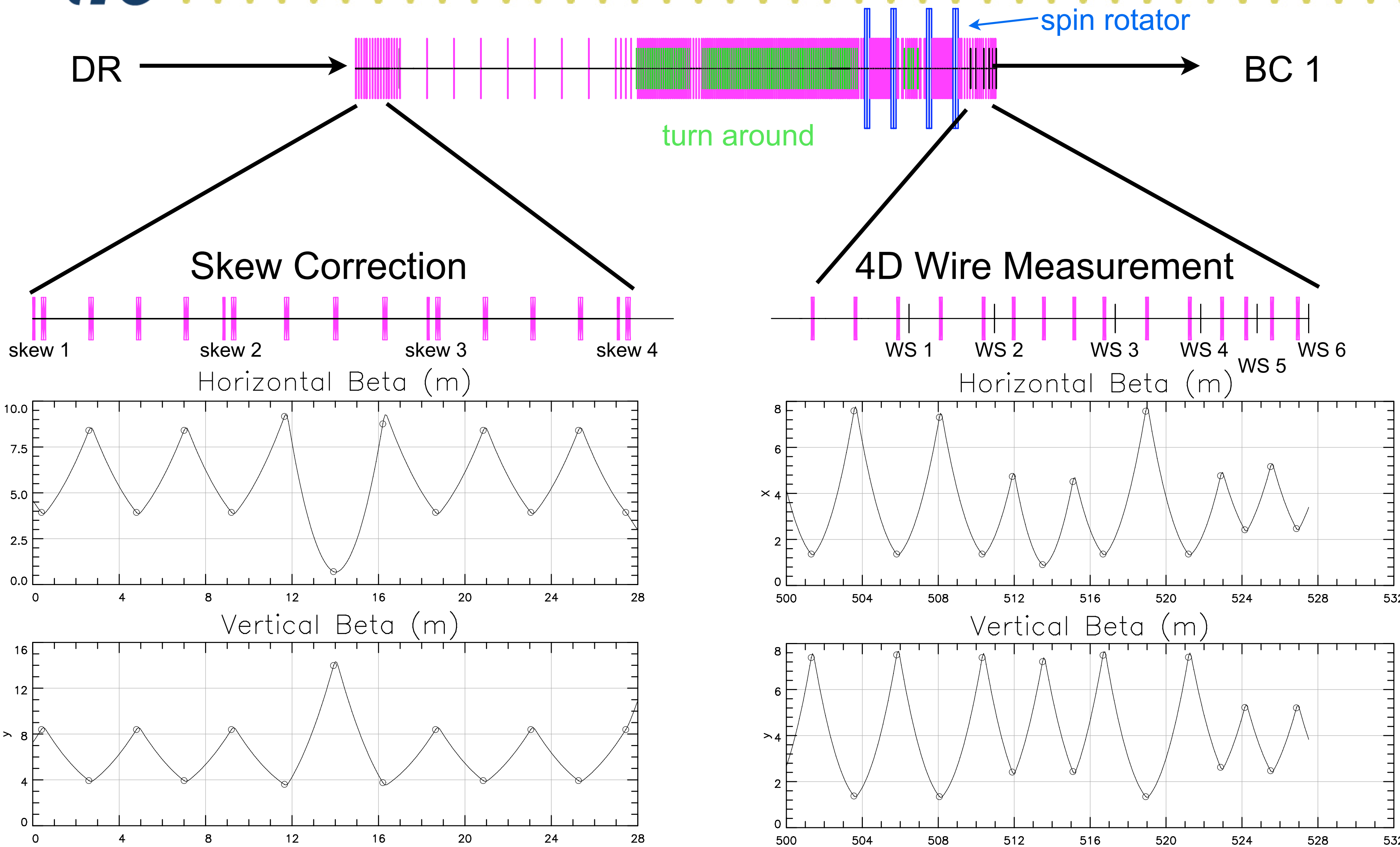
# RTML LET in ILCv

Jeffrey Smith
Cornell University
*with Peter Tenenbaum and*
*Mark Woodley, SLAC*

# Emittance preservation

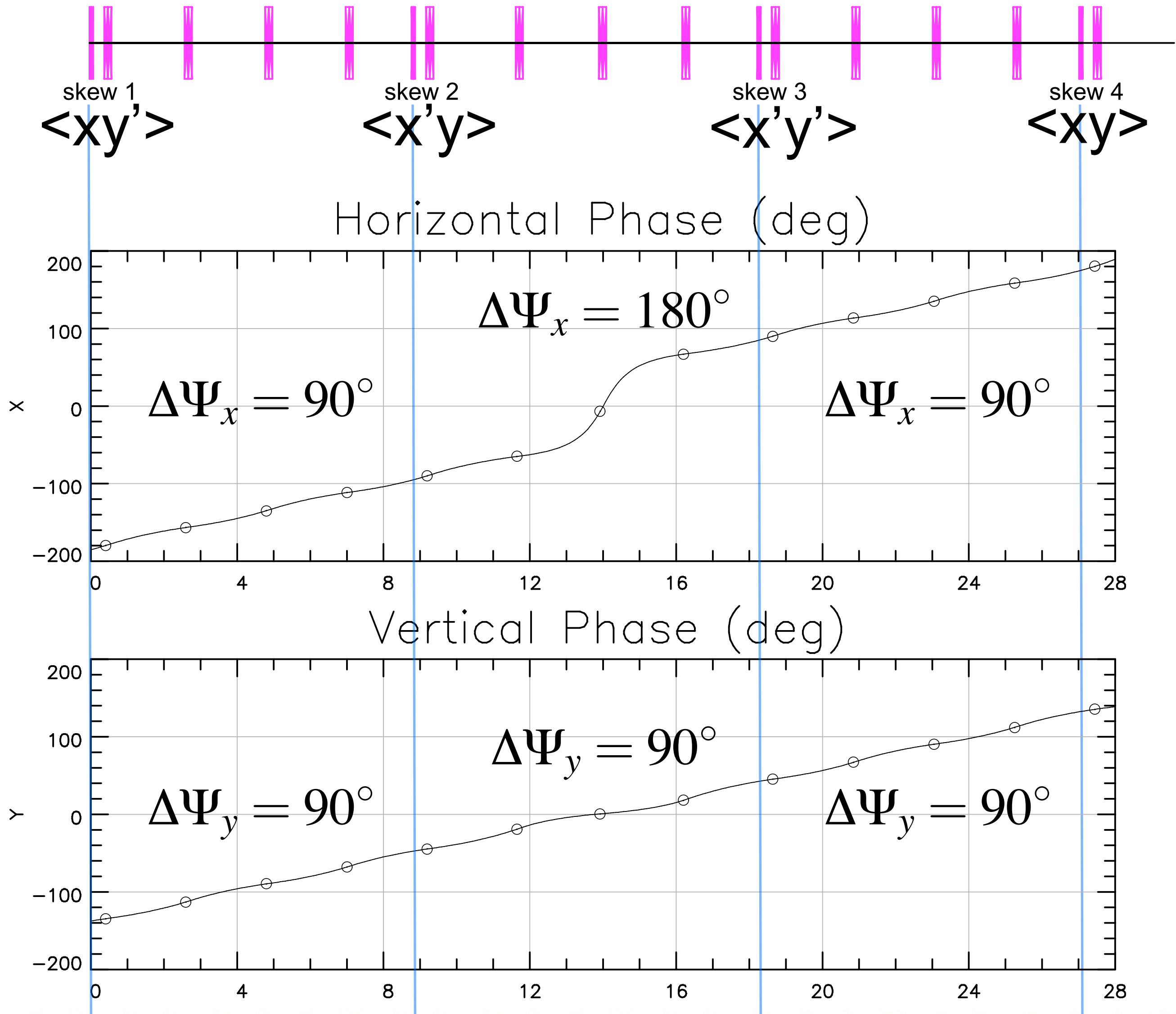
- Using combintations of
  - **1-1,**
  - **Baliistic Alignment or BA**
  - **Kick Minimisation or KM**
  - **Dispersion Bumps**
    - As described in PT's talk
  - **Skew correction**
    - As described below
- Only looked at emittance preservation up to BC1
- Simulations in ILCv/BMAD

# Skew Correction and Wire Scanners



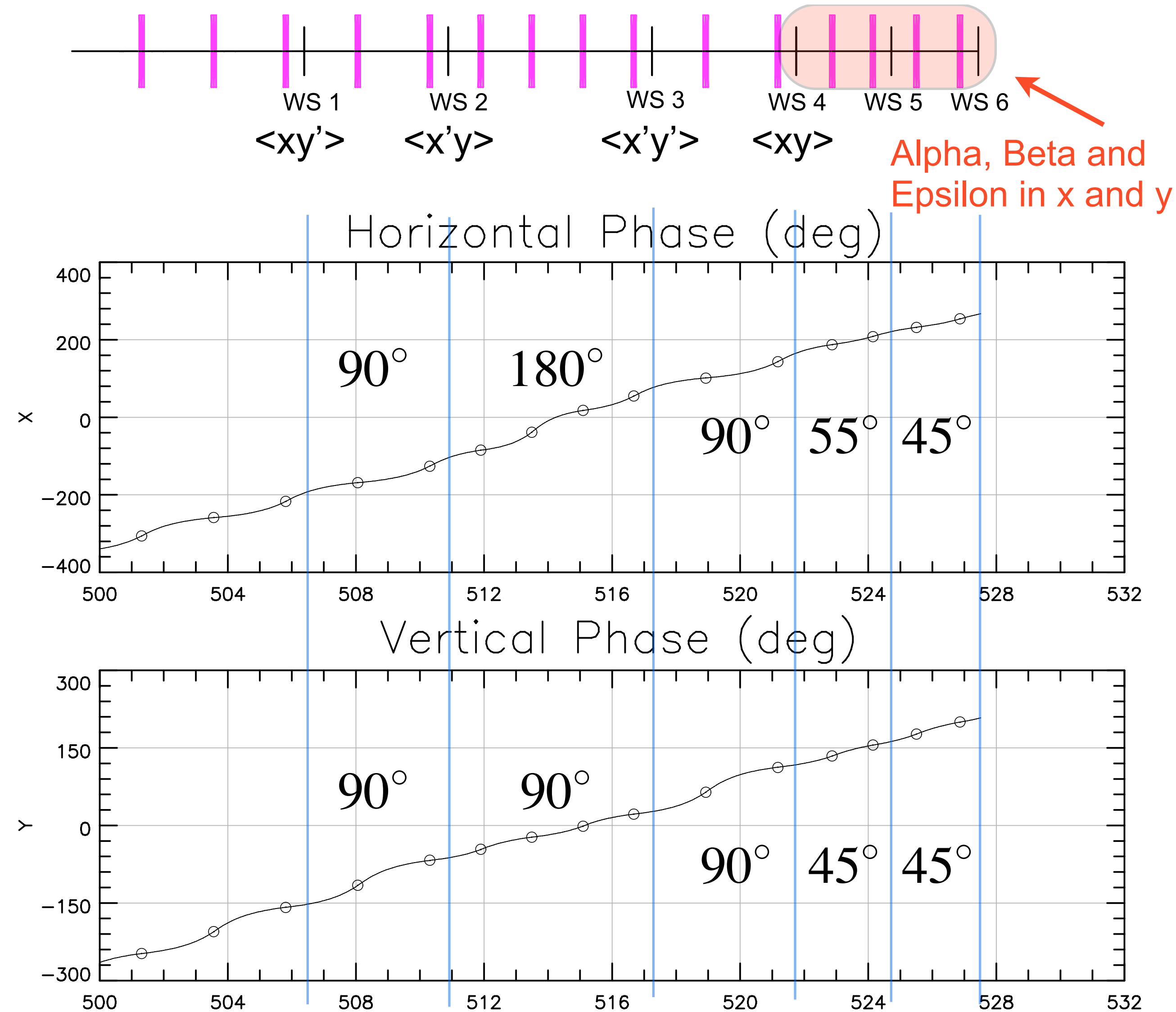
# Skew Correction

- Four Skew quadrupoles phased properly can eliminate all four coupling components: <xy>, <x'y>, <xy'> and <x'y'>



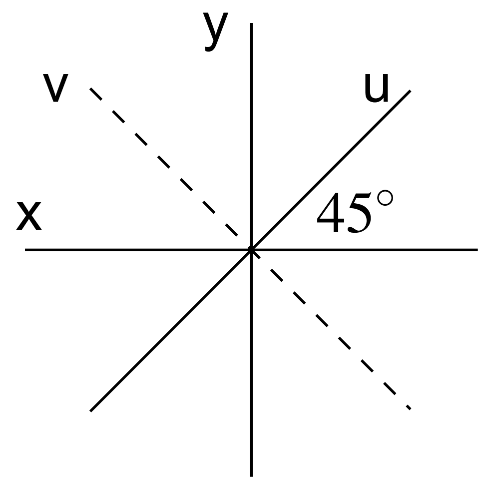
# 4D Emittance Measurement

- 6 Wire scanners properly phased can measure all four coupling parameters plus the three beam parameters for x and y (alpha, beta and epsilon)



# Coupling Parameter Calculation

- Three wires in wire scanner that measure the beam size along three axis: x, y and u
- These three beam measurements can be used to calculate the x-y coupling parameter <xy>
- The angled wire measures the beam size along a skewed axis so a rotational transformation relates the skewed wire measurement to the other wire measurements




$$\sigma_{uv} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \cdot \sigma_{xy} \cdot \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix}$$

$$\sigma_{uv}^{11} = \sigma_{xy}^{11}\cos^2\theta + \sigma_{xy}^{22}\sin^2\theta + 2\sigma_{xy}^{12}\sin\theta\cos\theta$$

$$< xy > = \frac{\sigma_{uv}^{11} - \sigma_{xy}^{11}\cos^2\theta - \sigma_{xy}^{22}\sin^2\theta}{2\sin\theta\cos\theta}$$

# Beam Parameter Calculation

- <xx> and <yy> are measured at the last three wire scanners each about 45 degrees apart
- The relation between the <xx> measured at each wire is described by the transfer matrix, R, between the wire scanners:

$$\sigma_2^{11} = \sigma_1^{11} R_{11}^2 + 2\sigma_1^{12} R_{11} R_{12} + \sigma_1^{22} R_{12}^2$$

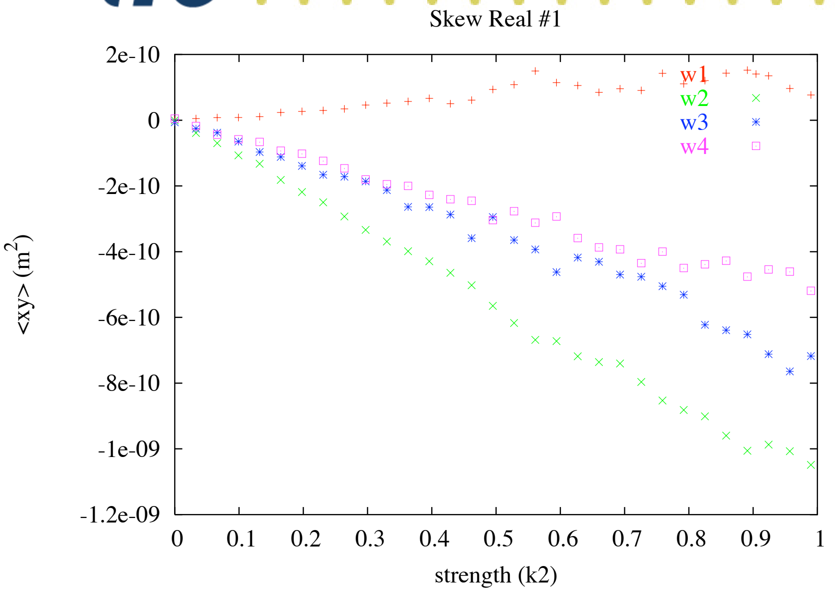
- If <xx> is measured at three wires and the wires are approximately 45 degrees apart then the full sigma matrix can be found at one of the wires:

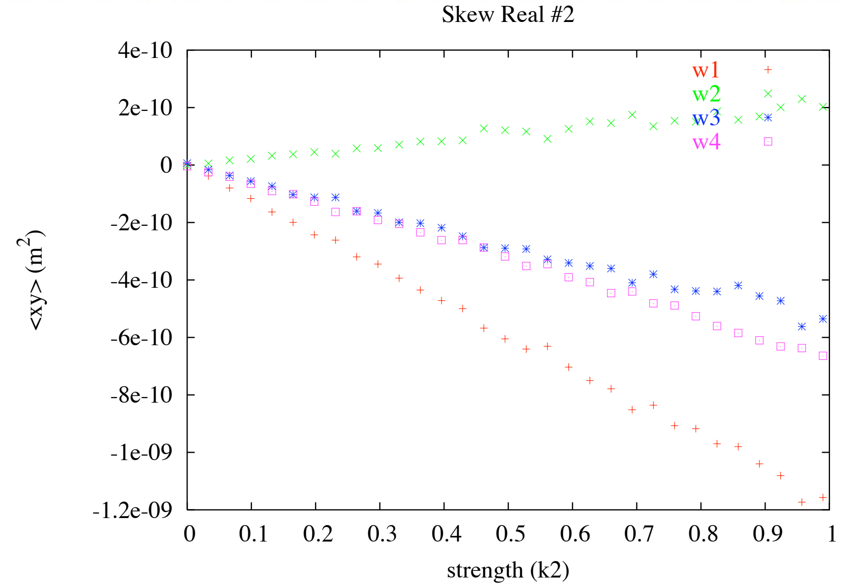
$$\begin{pmatrix} \sigma_1^{11} \\ \sigma_2^{11} \\ \sigma_3^{11} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ (R_{11}^{12})^2 & 2R_{11}^{12} R_{12}^{12} & (R_{12}^{12})^2 \\ (R_{11}^{13})^2 & 2R_{11}^{13} R_{12}^{13} & (R_{12}^{13})^2 \end{pmatrix} \cdot \begin{pmatrix} \sigma_1^{11} \\ \sigma_1^{12} \\ \sigma_1^{22} \end{pmatrix}$$

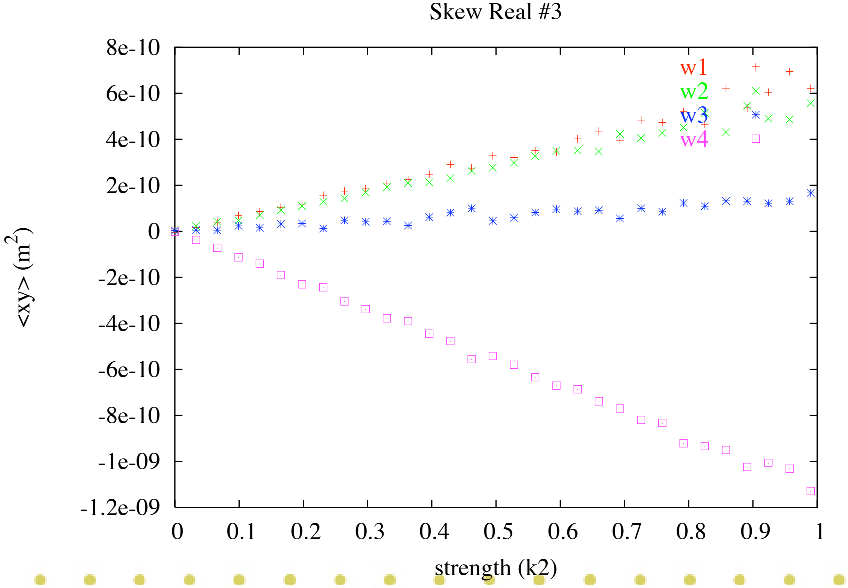
- From the sigma matrix alpha, beta and epsilon can be found.

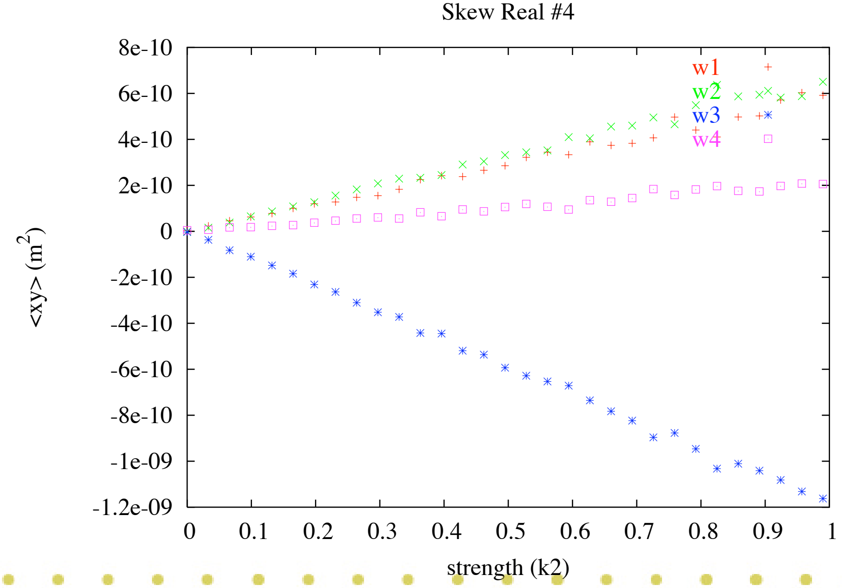
$$\sigma^{11} = \varepsilon\beta; \quad \sigma^{12} = -\varepsilon\alpha; \quad \sigma^{22} = \varepsilon \frac{1+\alpha^2}{\beta}$$

# Wire <xy> response for each Skew



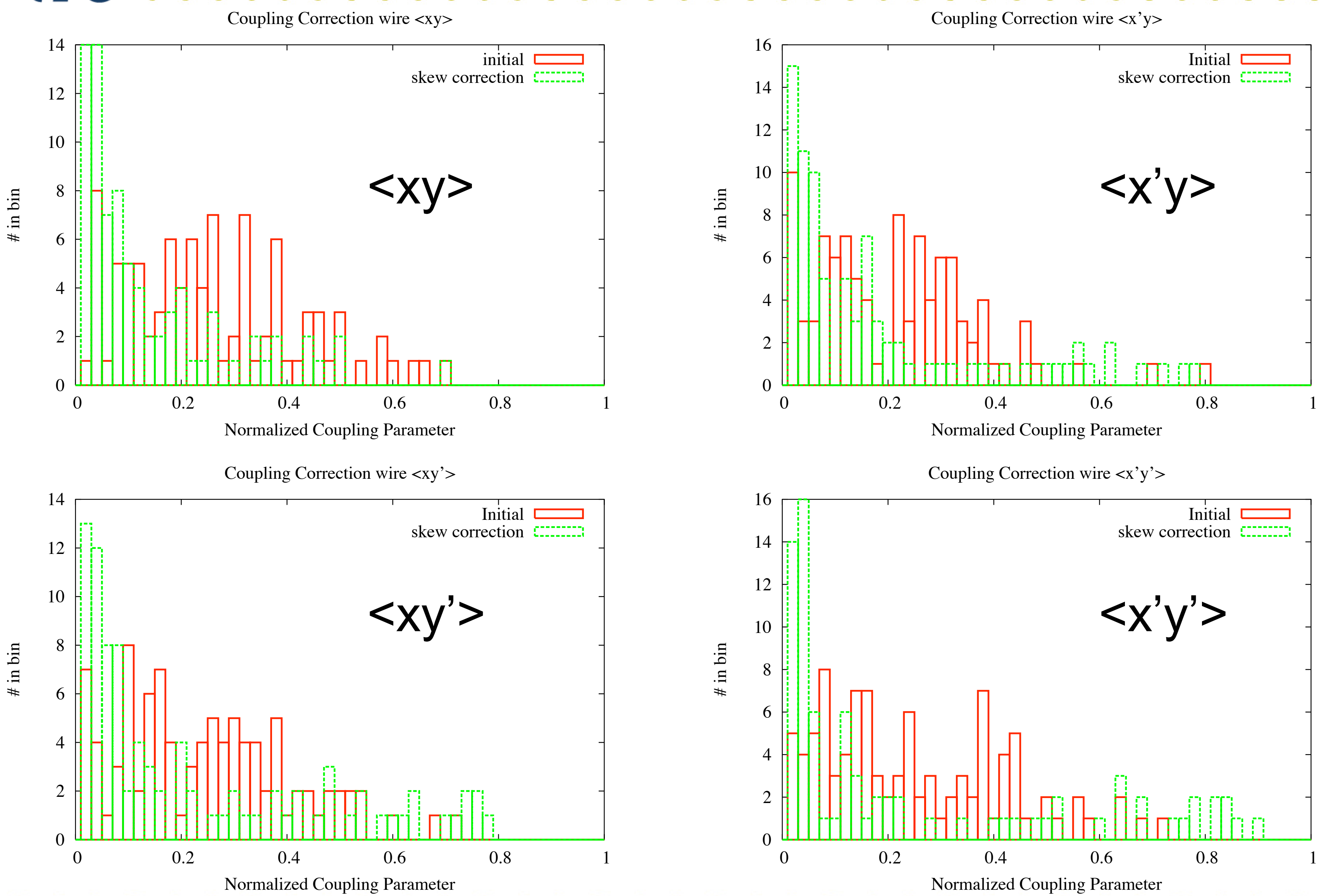
# Skew correction method

- Attempted to make orthogonal skew knobs
  - each wire would be sensitive to only one knob
  - was not successful in creating orthogonal bumps!?
- Skew correction method found to perform the best:
  - Find wire with largest coupling value
  - Use skew quad that the above wire is most responsive to and zero <xy> term in wire
  - iterate until all 4 wires are zeroed
- In practice, many times a condition will be presented where two wires will work against each other.
  - Example:
    - zero wire #2 and wire #4 shoots up
    - Now zero wire #4 and wire #2 shoots up
  - Again, attempts to create orthogonal knobs were unsuccessful, maybe could get the to work with more effort.

# Nominal Misalignments

- Slightly different from PT errors:
  - **Quads:**
    - 150 μm RMS offsets in x and y
    - 0.25% strength errors
    - 300 μrad rotation errors
  - **Bends:**
    - 0.5% strength errors
    - 300 μrad rotation errors
  - **Solenoids**
    - 1% strength error
  - **BPMs:**
    - 1 um resolution
    - 70 μm RMS offsets x and y to nearest quad
    - No rotations or scale errors
  - **Laser Wire Scanners:**
    - 1% error on measurement on each wire
    - 0 degree angle error on skewed wire
      - so, <xy> error: 1.73%
      - This is probably too precise

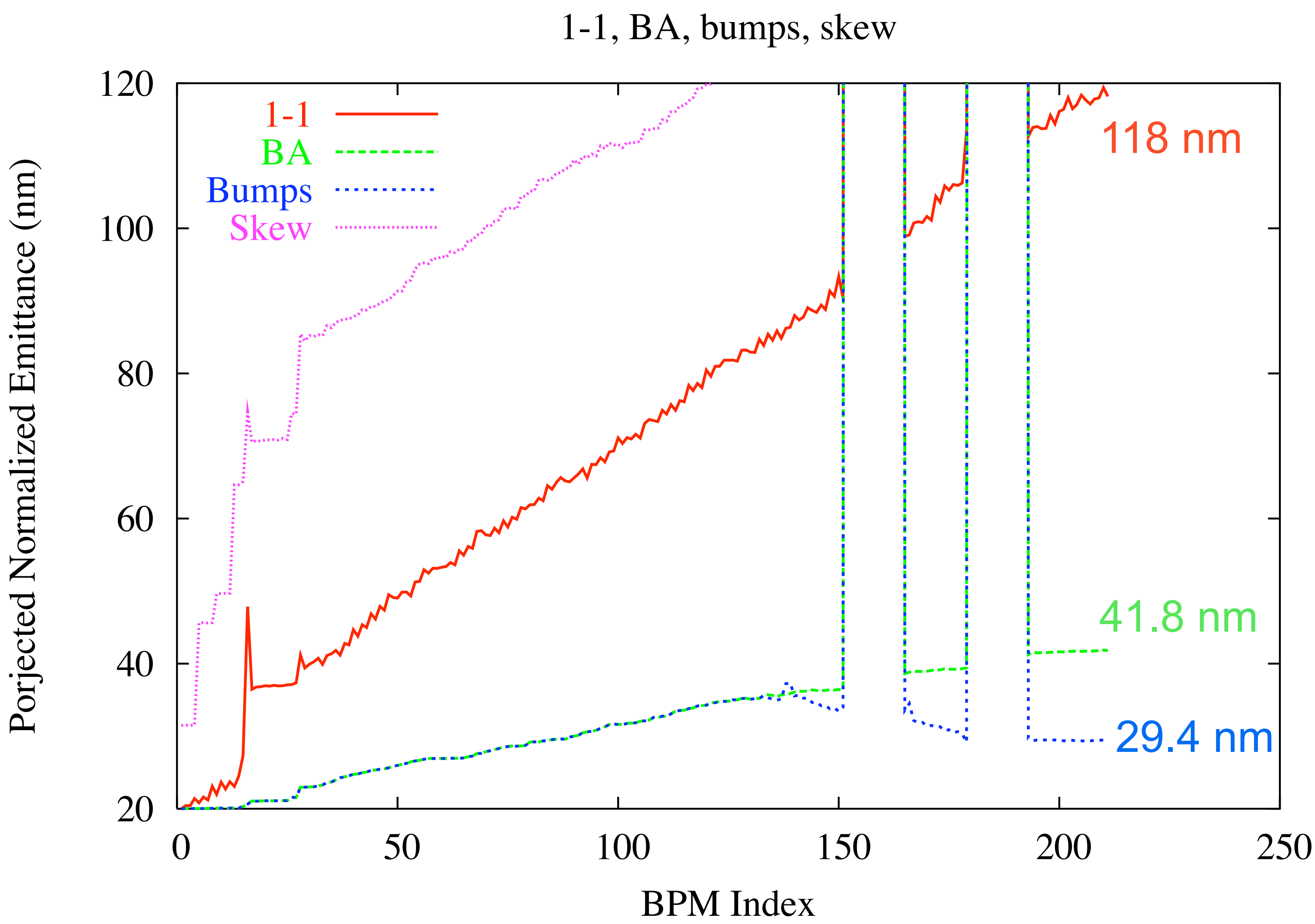
# Skew Correction Performance: Not at all good enough yet!



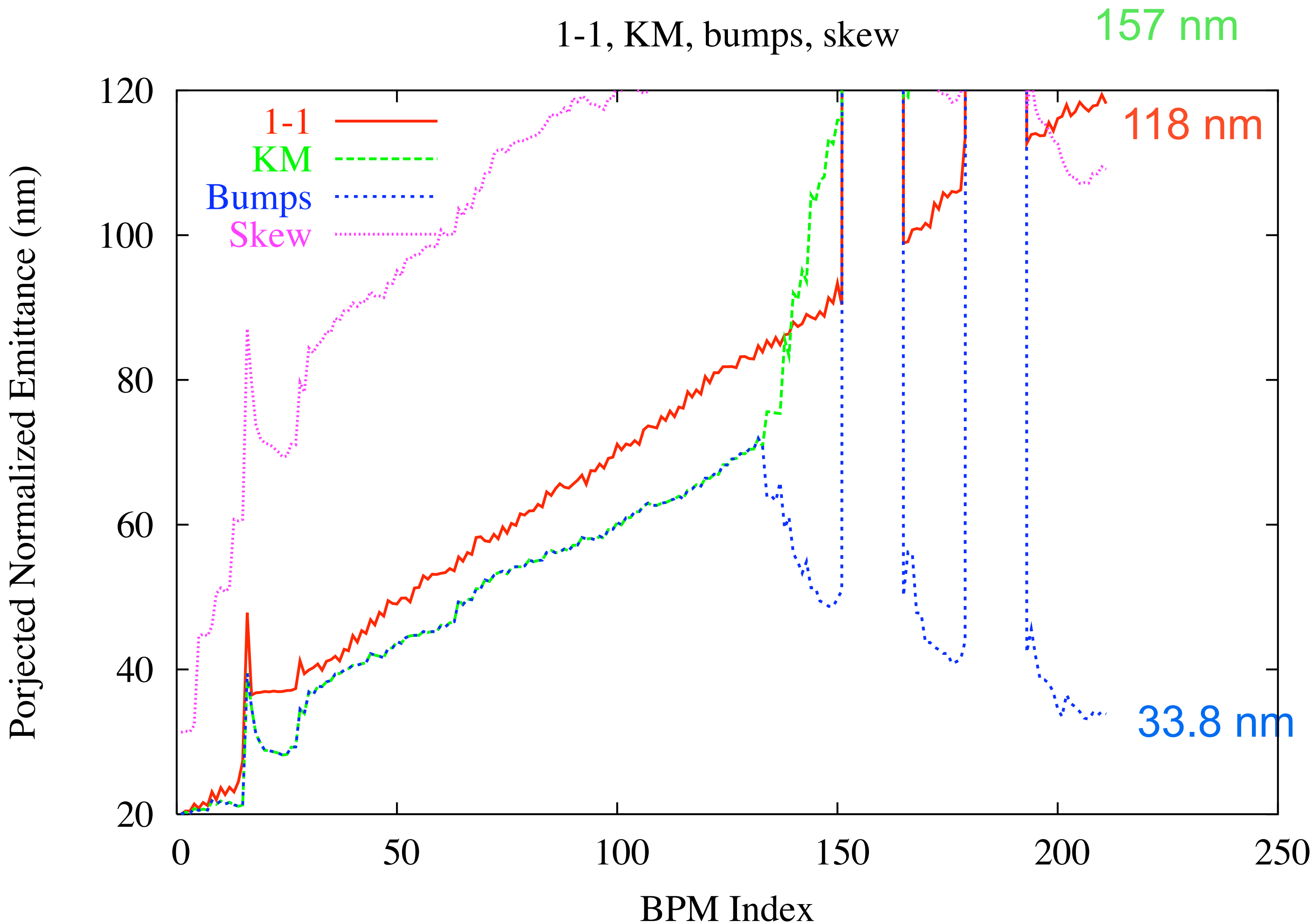
# Alternative Approach

- Another method would be a more analytical approach where the four measured coupling terms along with the beam parameters (alpha, beta, epsilon) are used to generate the full 4D sigma matrix.
- An analytical solution (assuming a perfect lattice) will then be found so that the four skew quads zero the coupling at the wires
- This has not yet been tested but is on the to-do list

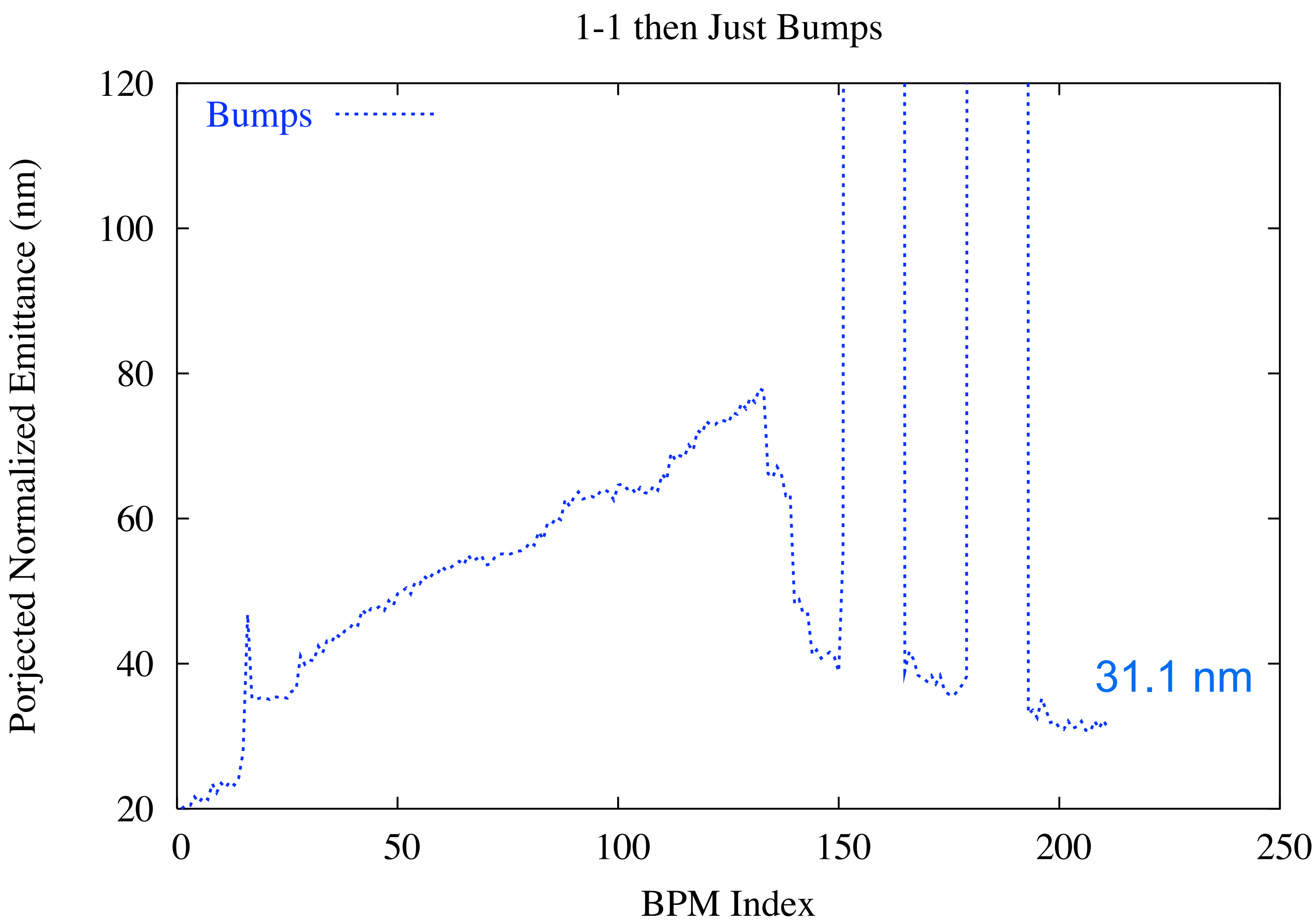
# 1-1 then BA then Bumps then Skews



# 1-1 then KM then Bumps then Skews



# 1-1 then just Bumps



# Observations on 1-1, BA and KM

- With nominal misalignments and no corrections beam hits aperture within a few meters (yes, METERS)
- 1-1 must be applied in both x and y simultaneously or else beam still hits aperture
- BA must be applied in both x and y
- Optimum weighting for KM found to be highly dependent on each individual seed
  - **For above results KM weight = 0.5, but for individual seeds anywhere from 0 to 1.0 worked best (where 0 means 1-1 correction, 1.0 means Kick minimization maximally weighted).**
  - **That's probably why performance is so poor for KM above, will redo with variable weighting**

# Observations on Bumps and Skew Correction

- Bumps where most effective method and when used right after 1-1 would work just as well on their own without BA or KM.
- Skew correction is hit and miss:
  - Sometimes it would decouple beam and reduce emittance
  - Sometimes it would decouple beam and increase emittance
  - Sometimes it would decouple the beam and completely kill the emittance!
  - Sometimes two wires would work against each other  and either increase emittance or leave emittance alone
  - Sometimes no solution could be found to zero wire with largest coupling term.
  - In general, coupling by itself does not introduce much emittance growth (a couple nm) and as of now, the best method to preserve emittance is to leave the coupling alone!