LET Studies at FNAL

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ILC International Linear Collider

Update on ILC ML Lattice Design

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May 23, 2007

Outline

- **Basic layout**
- **Matching**
- **Lattice Repository**
- **Summary and Outlook**

ILC

Lattice Design

- Defined by cryo segmentation
- Versions of segmentation
  - » 9-8-9 scheme, Dec 28 2006
- Basic segmentations:

RF Unit

without	with	without
quad	quad	quad
12.652	12.652	12.652

string

RFU	RFU	RFU	RFU	EndBox

Cryogenic Unit

warm							warm
drift	service			x N		service	drift
space	end box					end box	space
7.652	2.500	N strings				2.500	7.652

Main Linac

		warm			warm			undulator region			13	strings	warm			for
10	strings	drift	16	strings	drift	14	strings	warm	supercon	warm	2	short strin	drift	16	strings	3.50%
40	RF units	space	64	RF units	space	56	RF units	space	magnets	space	58	RF units	space	64	RF units	more
1545.7		7.652	2471.7		7.652	2163.0		600	290.0	367	2241.4		7.652	2471.7		368.6
	1549.6			2479.3			3056.9					2612.3			2475.5	400.0

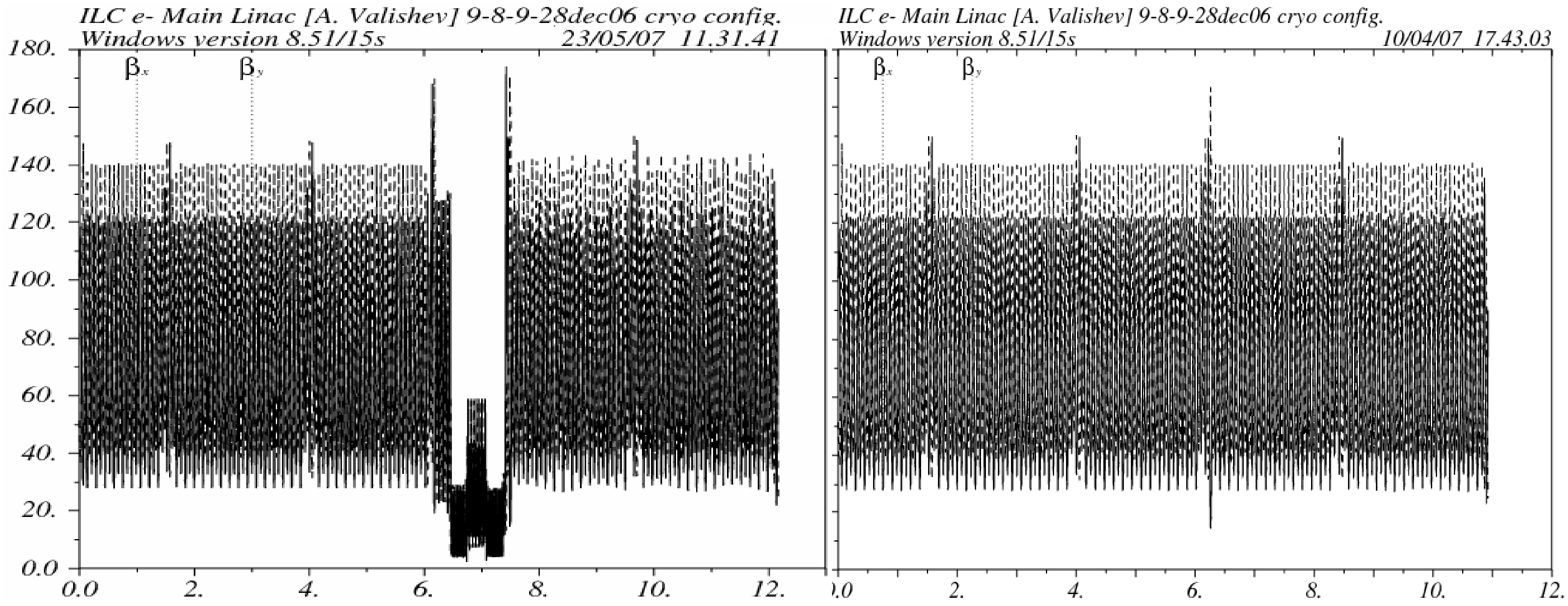
Lattice Revision History

Date	Cav/CM	Q/CM	Comments
1/06	12	1/2	USColdLC by PT, TESLA-like, straight
3/06	8	1/4	PT + curved
5/06	8	1/3	BCD-like, simple periodic lattice
5/06	8	1/3	Added cryo boxes and warm straights
6/06	8	1/3	May 31 (ver. 3) cryo layout
9/06	8	1/3	SBEND version *)
10/06	8	1/3	M.Woodley RTML-ML-BDS **)
1/07	8	1/3	“8-8-8” Nov 21. cryo layout (ver. 4)
2/07	9-8-9	1/3	“9-8-9” Dec 28. cryo layout
4/07	9-8-9	1/3	“9-8-9” ML re-matched to BDS

*) http://tdserver1.fnal.gov/project/ILC/ARCHIVE/ILC-ML-SbendCurvature.zip

**) http://www.slac.stanford.edu/~mdw/ILC/2006e/

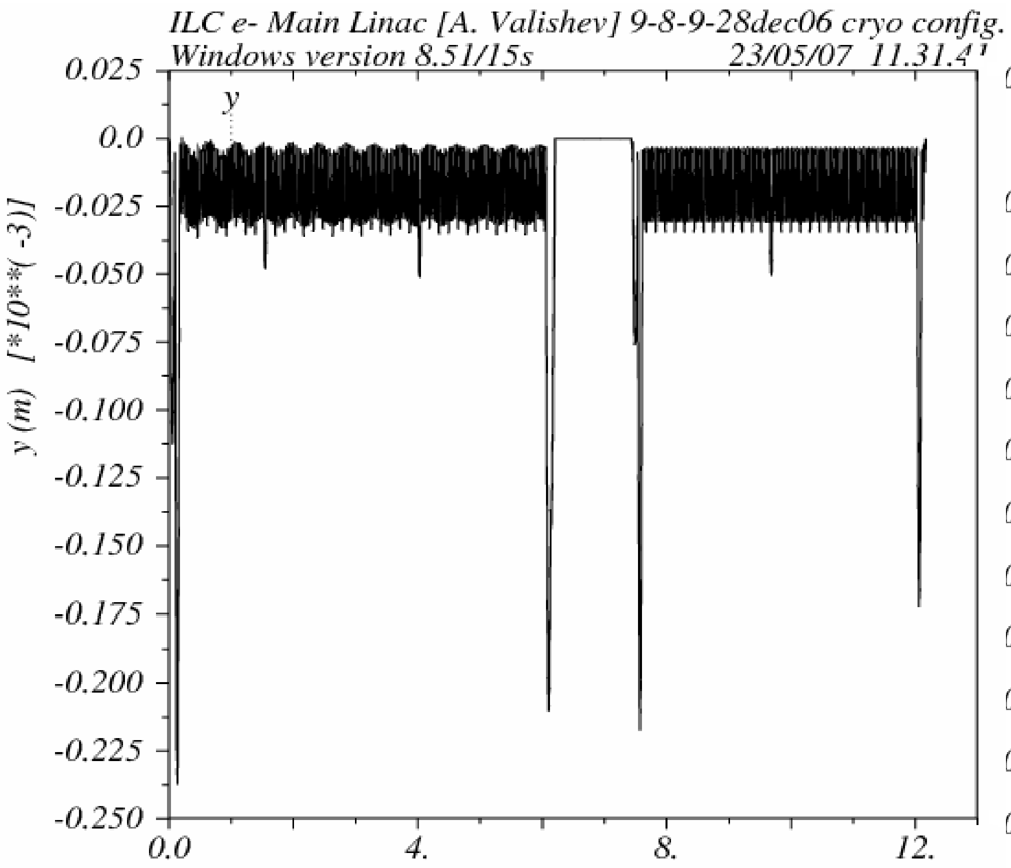
9-8-9 Lattice β-functions



989-28dec06

989-28dec06-NoUND

9-8-9 lattice Orbit



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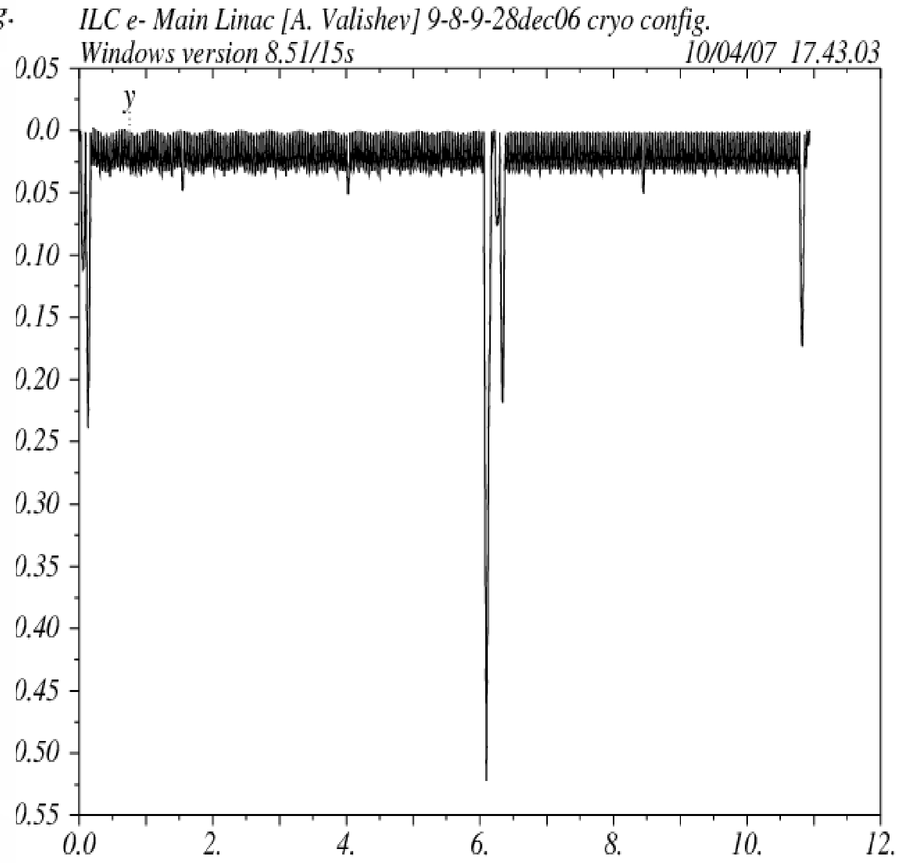

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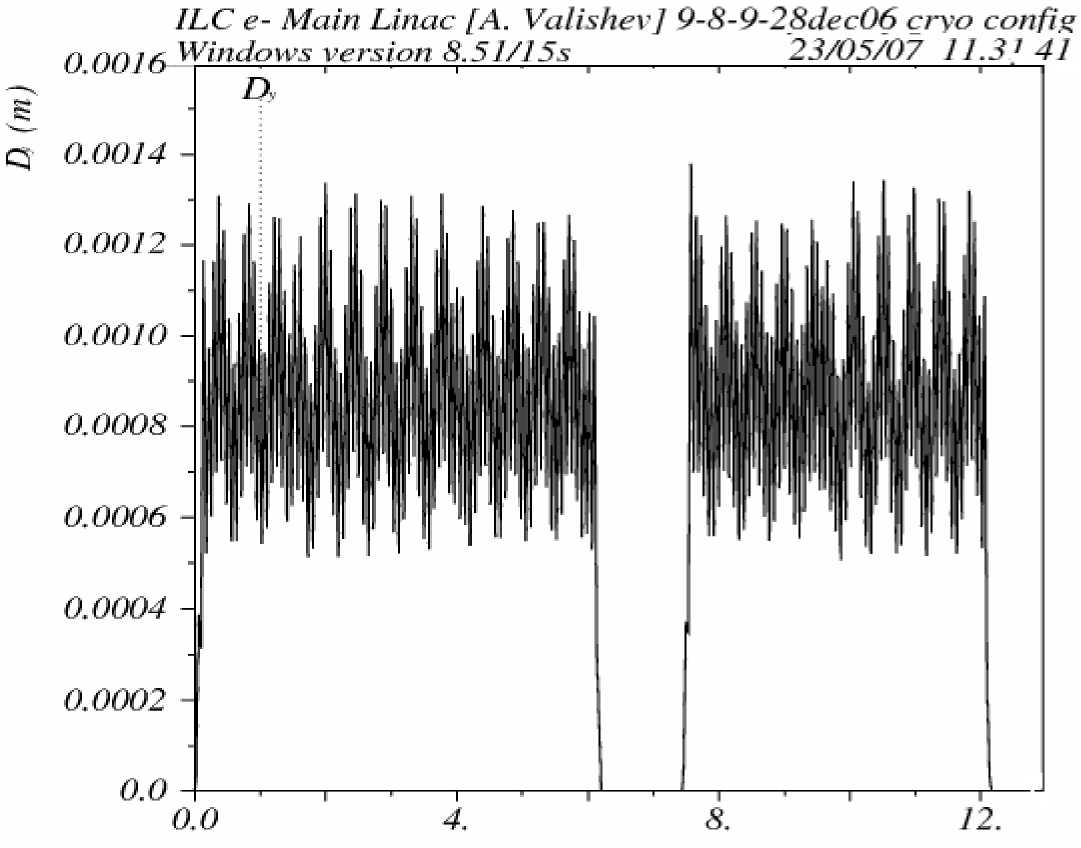
9-8-9 lattice Dispersion



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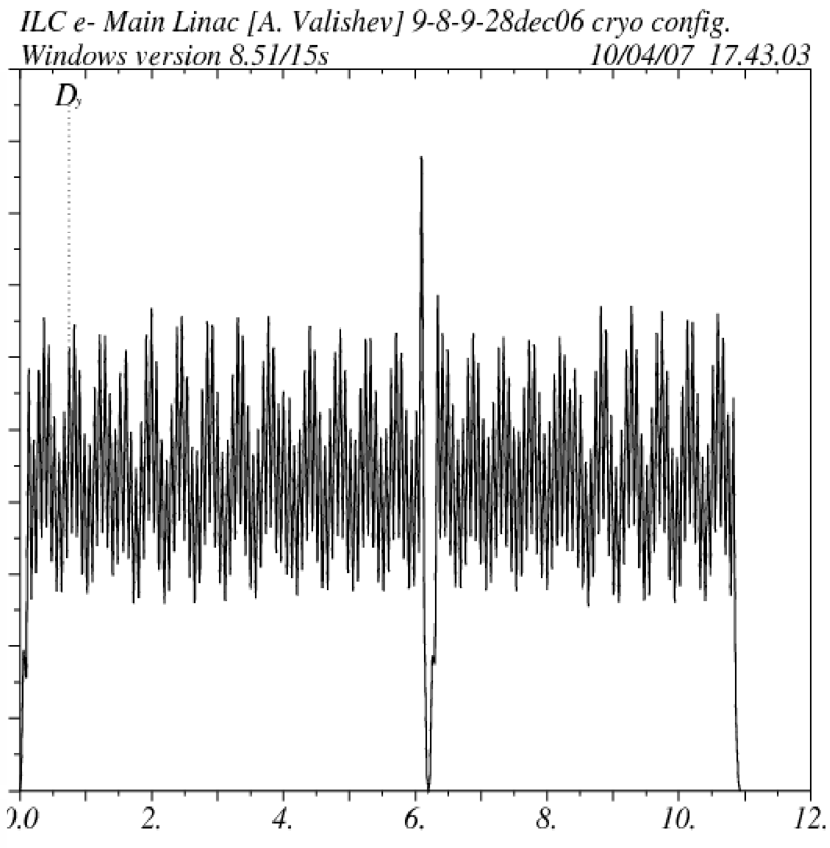


989-28dec06-NoUND

Lattice Repository

- **Accelerator Division of Fermilab supports centralized lattice repository**
  - » Controlled write access
  - » Revision history
- **ILC ML lattices have been placed into the repository https://lattices.fnal.gov/**
  - » Read-only->Lines->ILC Linac->unofficial->valishev->
    - ILC2006e-989-28dec06
    - ILC2006e-989-28dec06-NoUND

Summary

- **ML lattice based on 9-8-9 (28dec06) cryogenic layout has been developed**
- **Two versions of decks exist**
  - » Main Linac with Undulator section
  - » Main Linac without Undulator section
- **Kick angles of Dispersion matching orbit bumps were kept below 5e-6 to minimize SR power**
- **Lattices available in FNAL Lattice Repository https://lattices.fnal.gov/**

TODO

- **Placement and Strategy of emittance measurement in ML**
  - » Laser Wire in warm sections
- **SR radiation issues in energy upgrade (next slide)**

ILC Synchrotron Radiation in a Single Corrector

$$B = \frac{E}{0.3}\frac{\alpha}{L} \qquad U_{SR} = 8.85 \times 10^4 E^4 \frac{\alpha^2}{L}$$

$$P_{SR} = U_{SR} \cdot Iav$$

L = 0.335 (separate dipole corrector)
Iav=4.1e-5 A for 0.9 ms beam at 5Hz

E – particle energy [GeV]
α – bending angle
L – corrector length [m]
B – corrector field [T]
U_{SR} – particle energy loss [eV]
Iav – average beam current [A]
P_{SR} – average radiated power [W]

	E=250 GeV		E=500 GeV	
α	U_{SR} [keV]	P_{SR} [W]	U_{SR} [keV]	P_{SR} [W]
5e-6 *	26	1.1	413	18
1e-5	100	4.5	1650	72
5e-5	2600	110	41280	1800

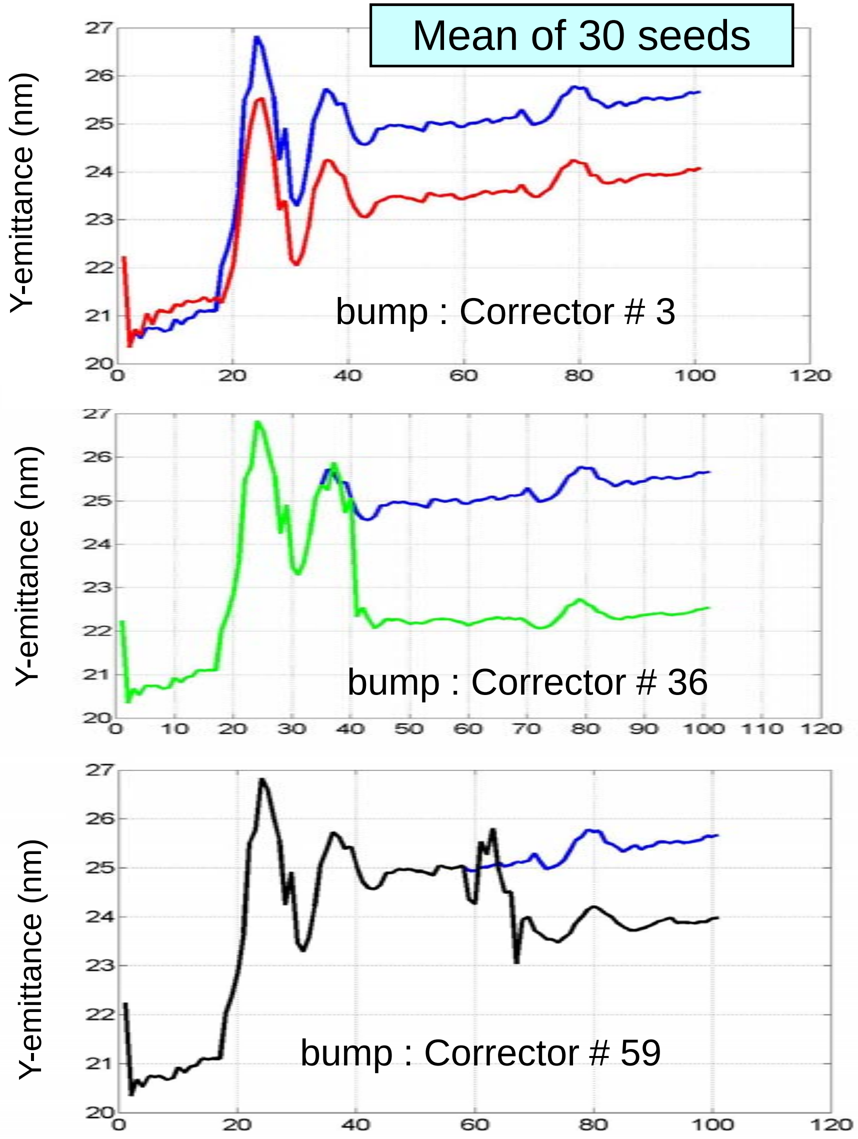
* Nominal Earth curvature steering angle

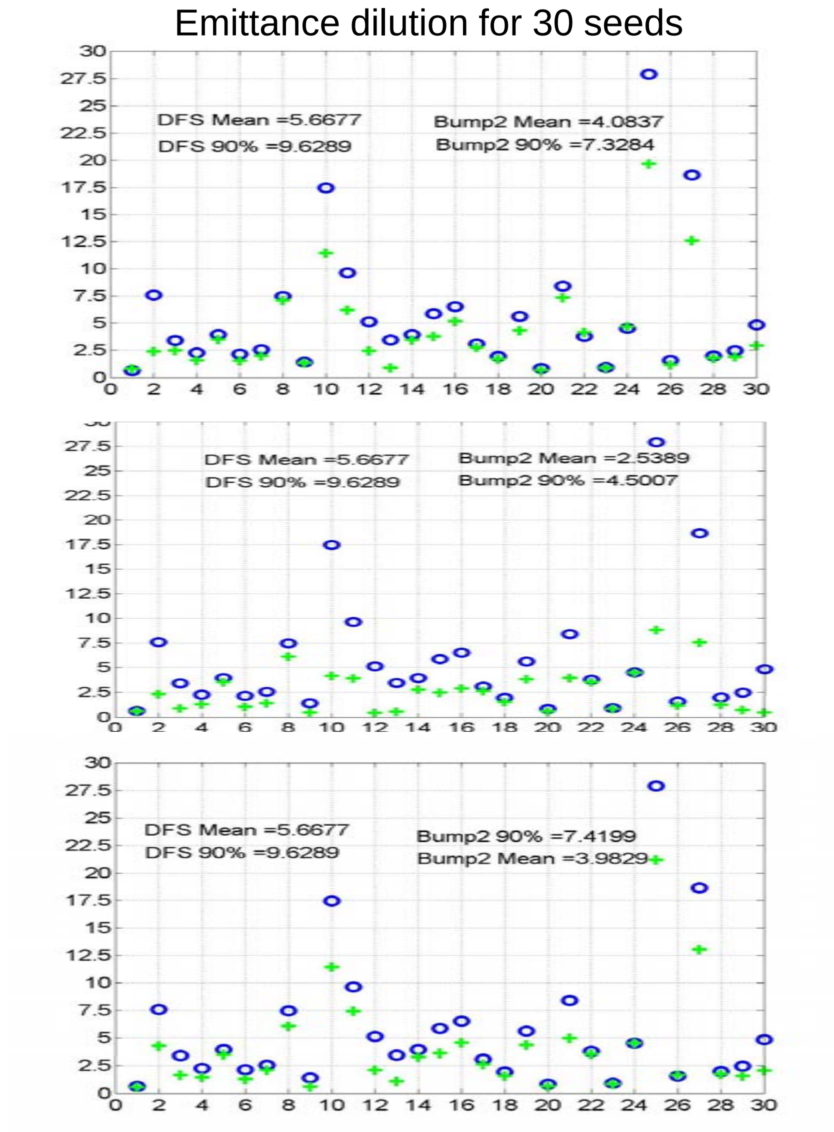
Bumps Studies for Static Tuning

- **Local Bumps**
  - » Optimize Bumps Position
  - » Number of bumps ?
  - » Combination of Dispersion and Wake bumps

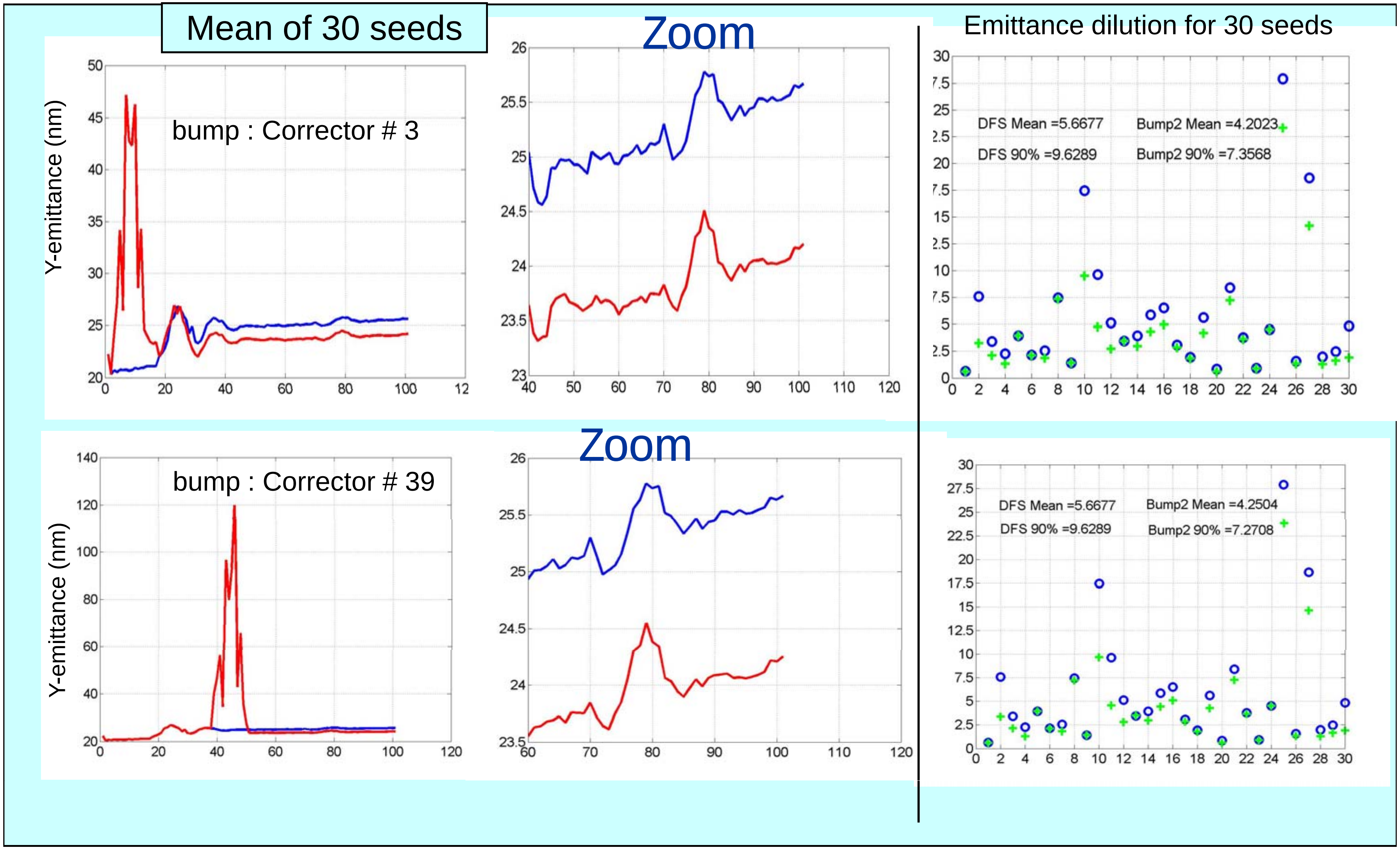
- **Global Bumps – in progress**
  - » Number of Global Knobs (Bumps)

Short Lattice: Only 1 dispersion bump

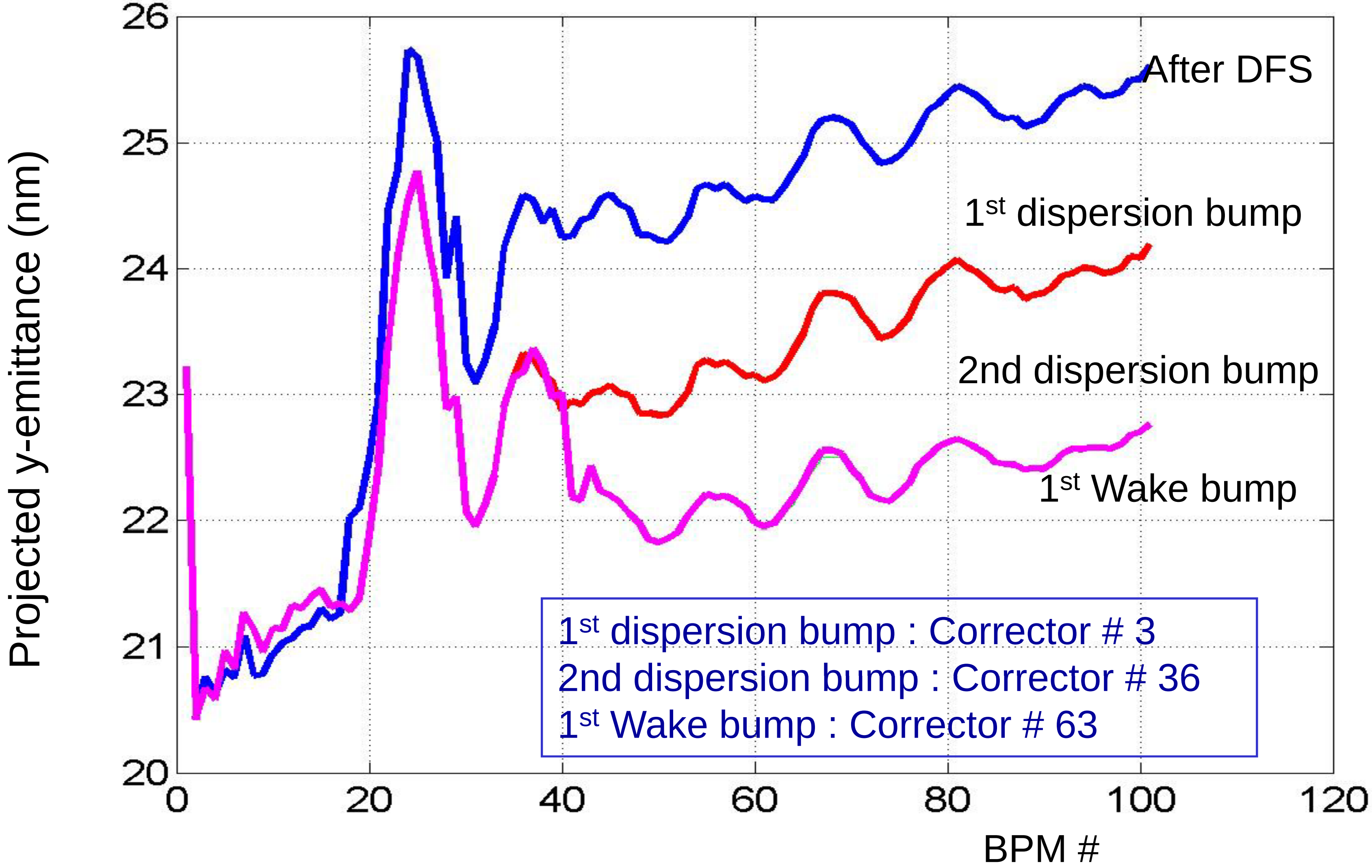




Short Lattice: Only 1 Wake bump



Short Lattice: 2 Dispersion and 1 Wake Bumps



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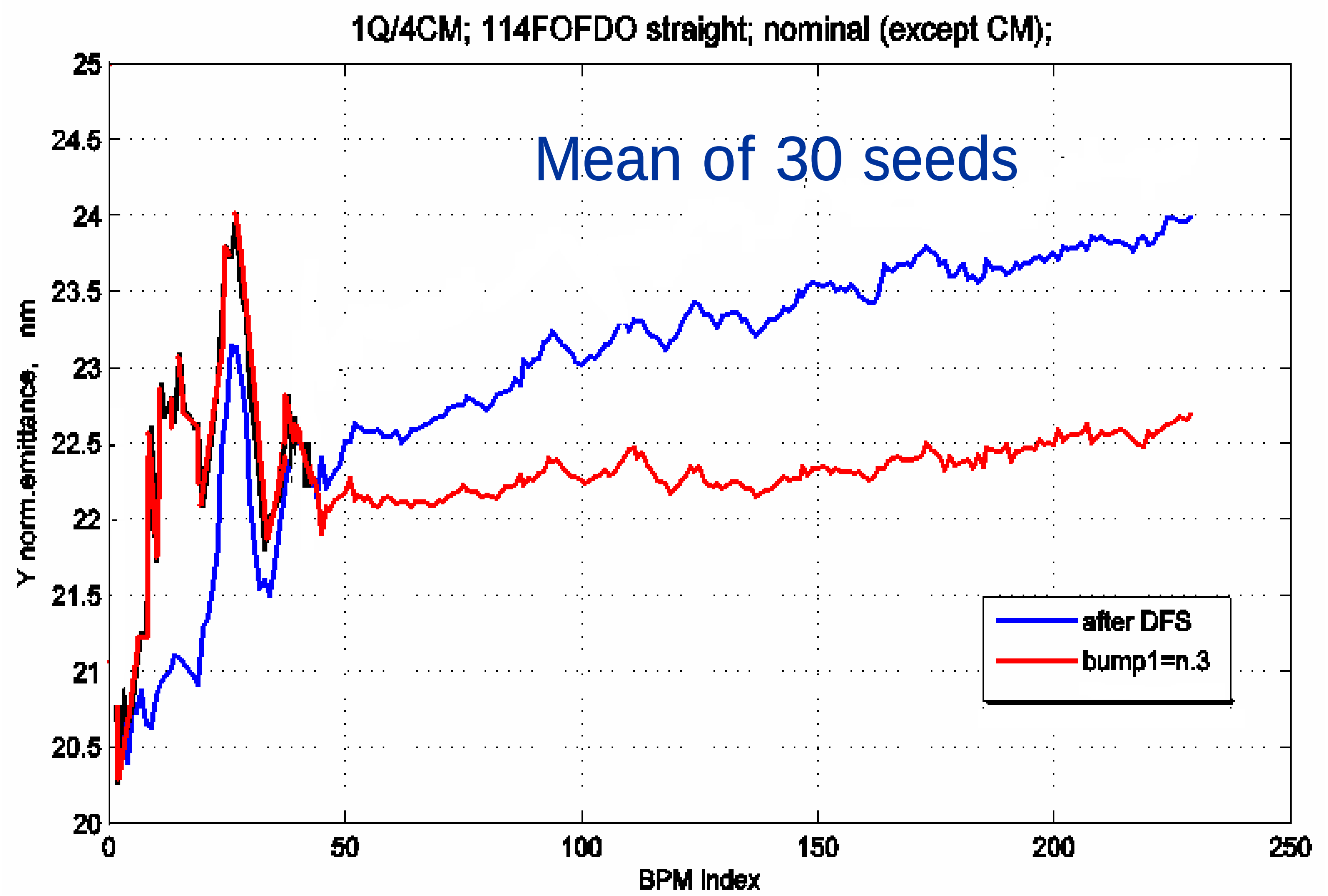
Full Lattice



Dynamic Simulations

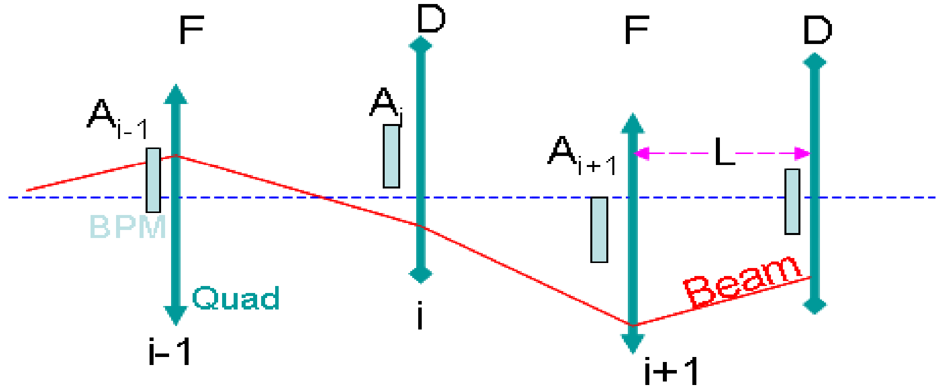
Ground Motion
&
Adaptive Alignment

Kirti Ranjan, Nikolay Solyak, Valentin Ivanov

Adaptive Alignment (AA) – Basic Principle

Ground Motion in Lucretia

- AA in Perfect Lattice
- One-to-one in Perfect Lattice
- Effect of BPM resolution on AA



- ✓ Proposed by V.Balakin in 1991 for VLEPP project

- ✓ **"local" method**: *BPM readings (A_i)* of only 3 (or 5 or so on) neighboring quads are used to determine the necessary shifting of the central quad (Δy_i).

$$\Delta y_i = Gain * 1/3 * [A_{i+1} + A_{i-1} - A_i * \{2 + K_i . L . (1 - \frac{\Delta E}{2E})\}]$$

conv : Speed of convergence of algorithm
A_i : BPM reading of the central quad and so on
K_i : Inverse of quad focusing length
L : Distance between successive quads (assuming same distance b/w quads)
ΔE : Energy gain between successive quads
E : Beam Energy at central quad

quad & New position of BPM:

$$y_i = y_i + \Delta y_i$$

- ✓ The procedure is iteratively repeated

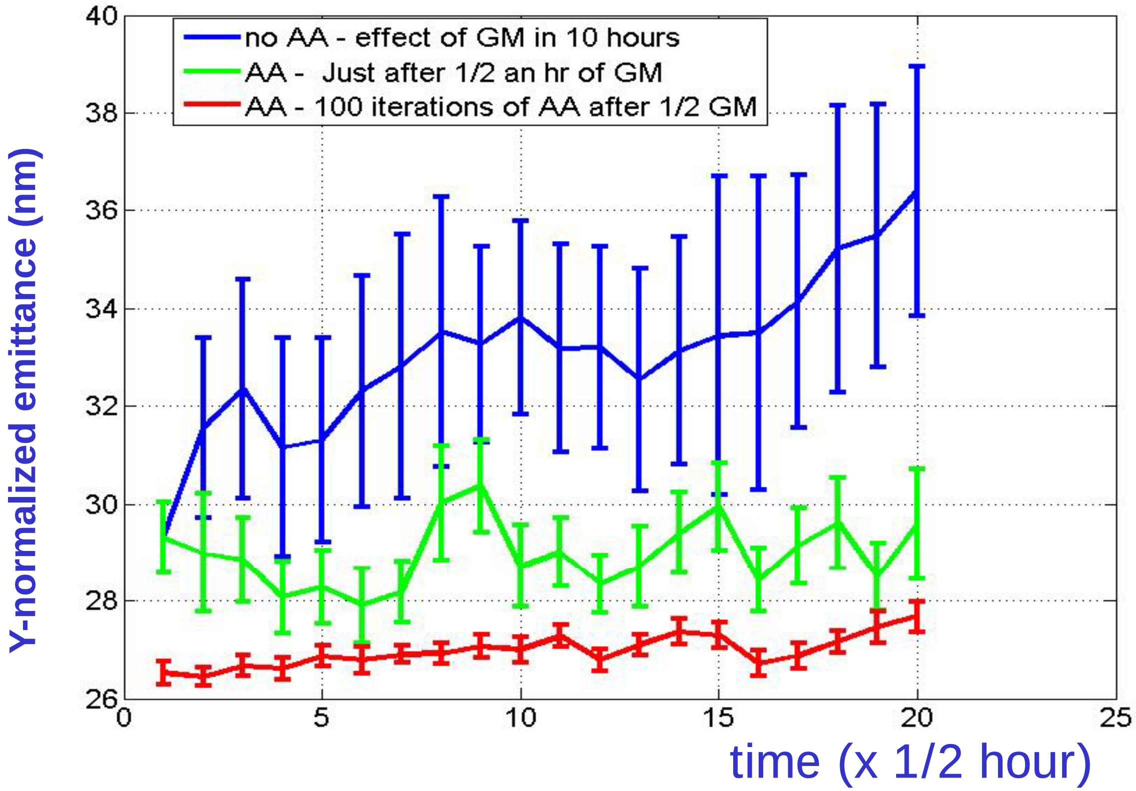
AA and 121 dynamic tuning: Preliminary results (Feb 2007)

- **Short Lattice: 50 FODO (Daresbury LET meeting, Jan. 2007)**
  - » AA keeps the emittance growth even for model C under control for ~10 days
  - » DF Steered and perfect linac are similar. DFS settings is used as reference.
  - » Sensitive to BPM resolution, averaging along bunches in train will help
  - » Emiitance growth is higher after 121 steering

Ground Motion – Effect on DFS Lattice

- 30 different GM seeds (Model C)
- **Case2**: GM of 10 hrs. in step of 1/2 hr.
- When AA incorporated: AA of 100 iterations after every 1/2 hr. (conv. = 0.2)

Y-emittance (nm) @ Linac exit vs. time (1/2hrs.)
Mean of 30 seeds

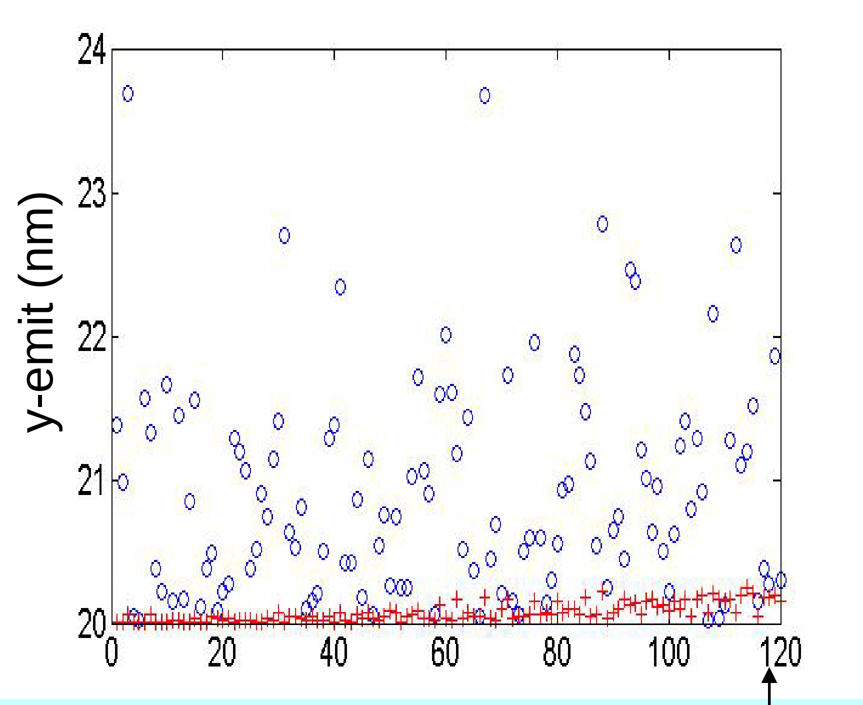


In half an hour of GM, emittance dilution increases by as much as ~ 5 nm b/w the subsequent AA iterations, which implies that AA will have to be done at this order or better!

ILC Adaptive Alignment: Ground Motion Model : C

Time: 10 days in step of 2 hr.   0.6*0.33 (AA convergence) @100 AA steps

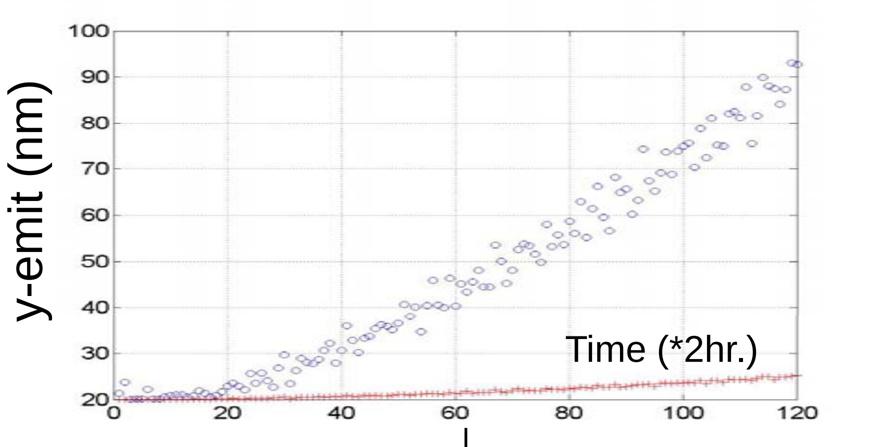
Ycor setting from the previous hour considered during the new iteration



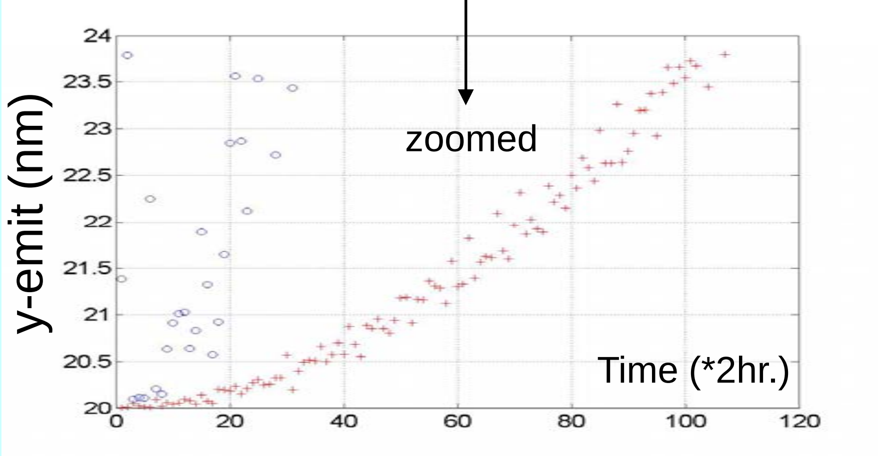
Time (x 2 hrs)

10 days

Ycor setting from the previous hour NOT considered during the new iteration



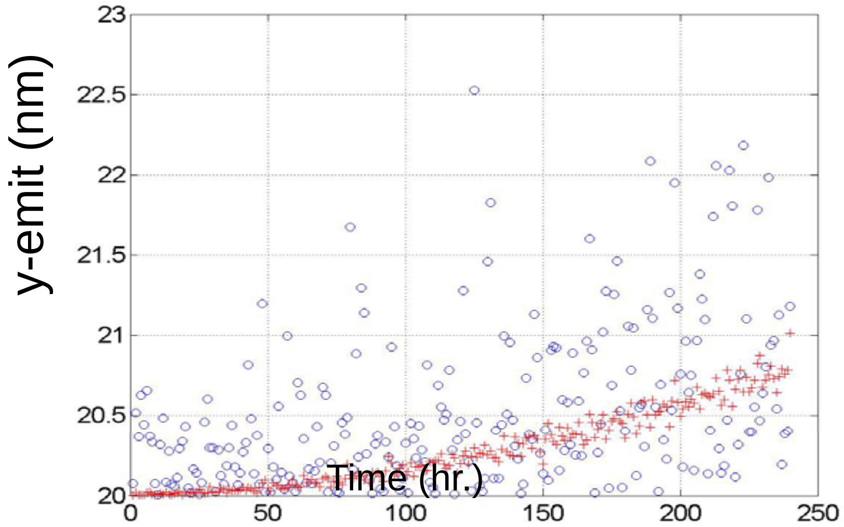
zoomed



121: GM Model : C

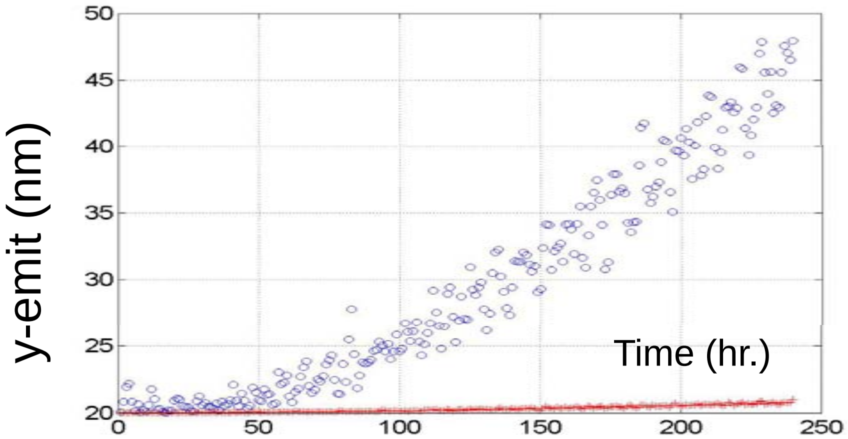
Time: 10 days in step of 1 hrs; gain =0.3 (121 gain) @ 20 steps

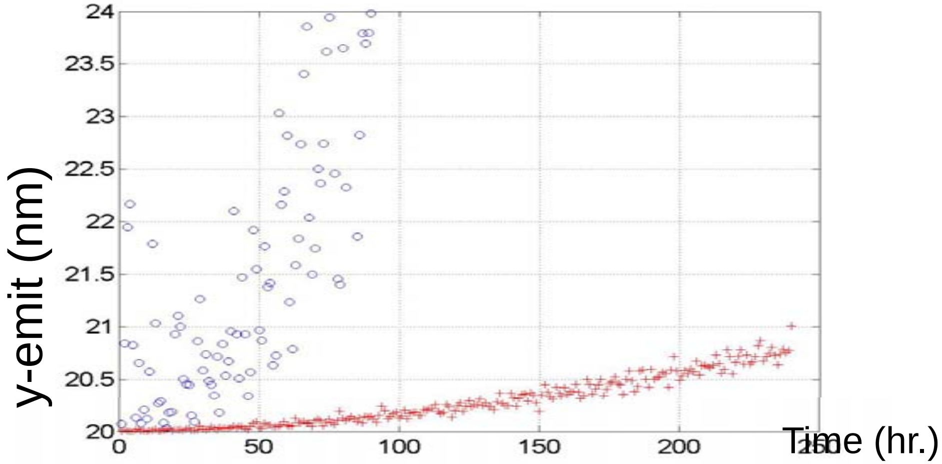
Ycor setting from the previous hour considered during the new iteration



10 days

Ycor setting from the previous hour **NOT** considered during the new iteration





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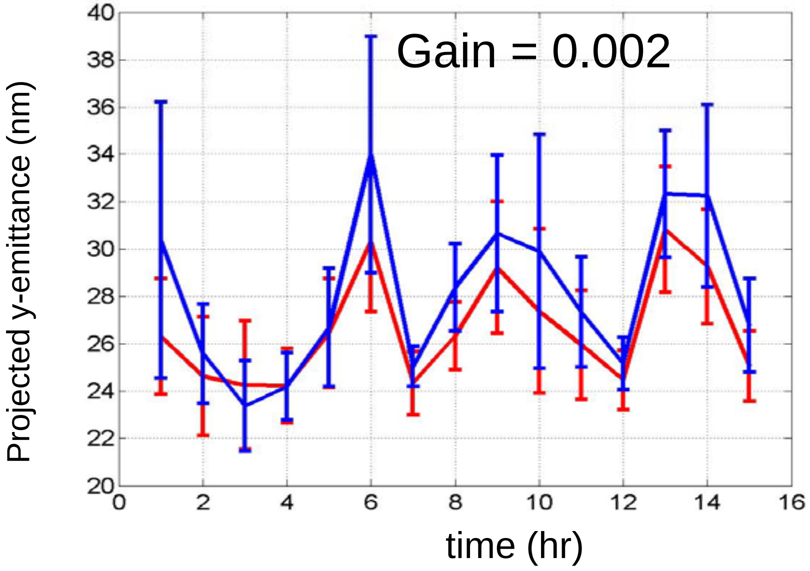
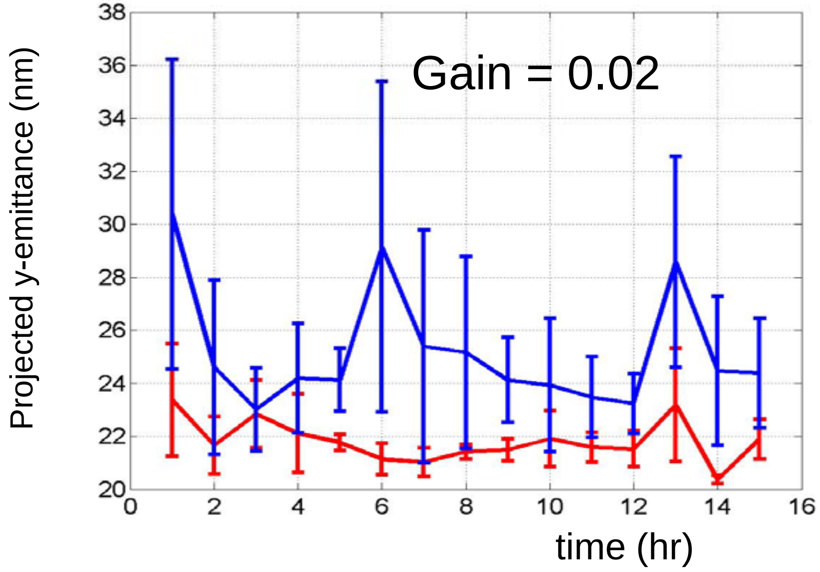
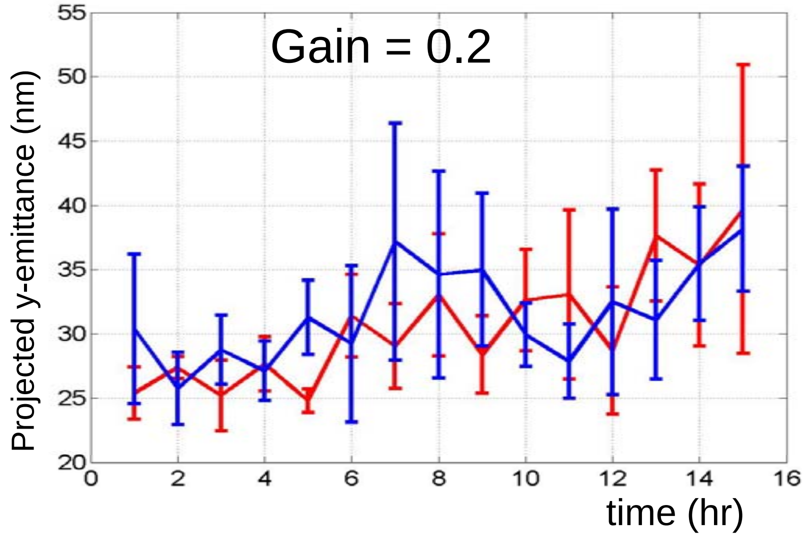
AA with different Gains: GM Model C





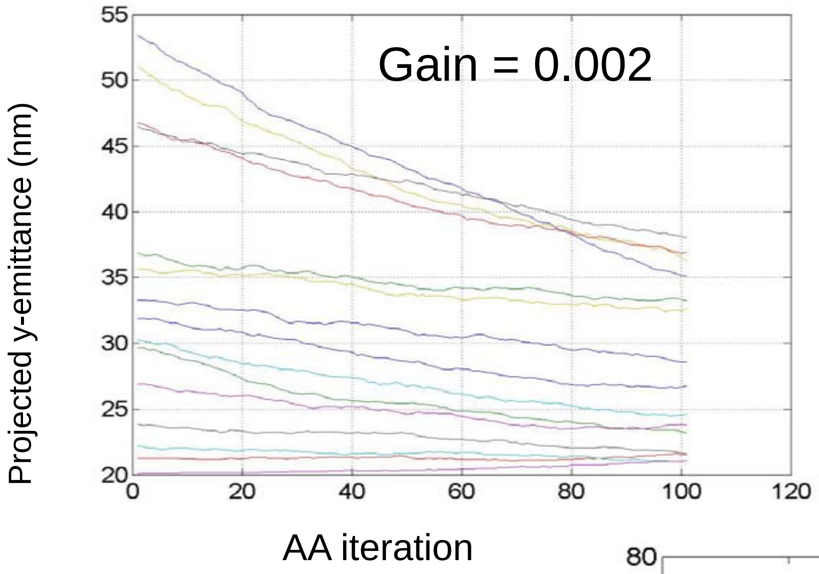
15 hours of GM

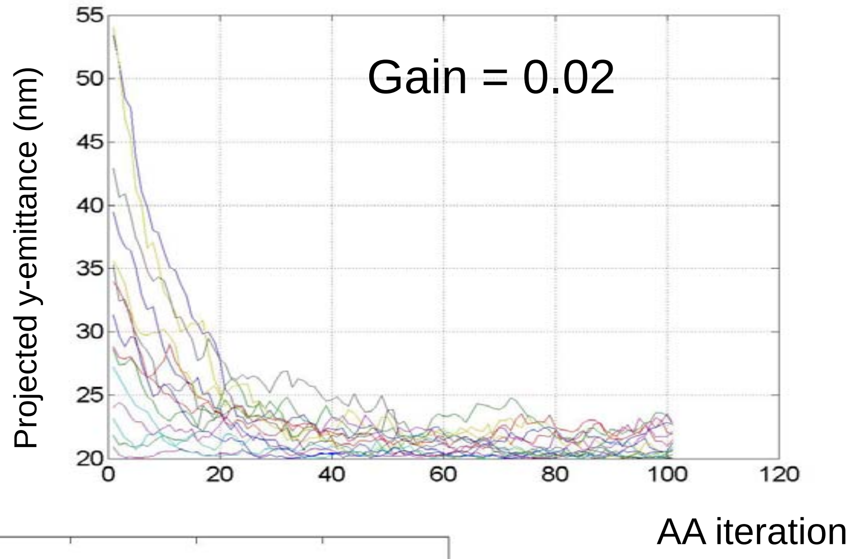
Mean of 5 seeds
BPM res = 1μm
Step = 1 hrs
100 AA iterations



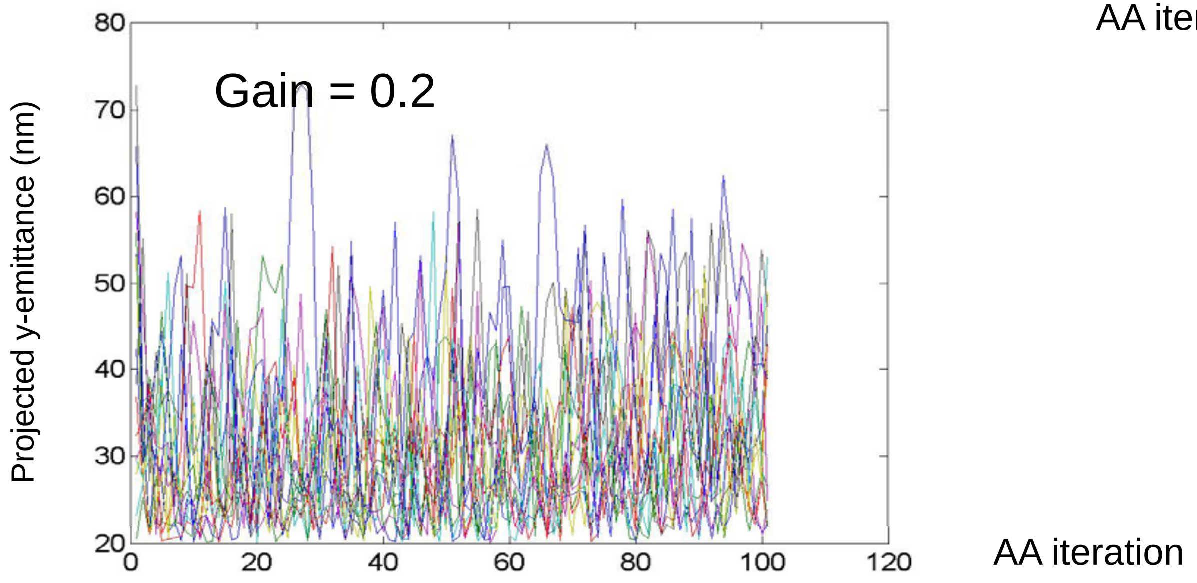
It is important to find proper Gain factor
OR
Optimize between gain factor and number of AA iterations

Effect of AA for 15 hours and different Gains





Seed # 3

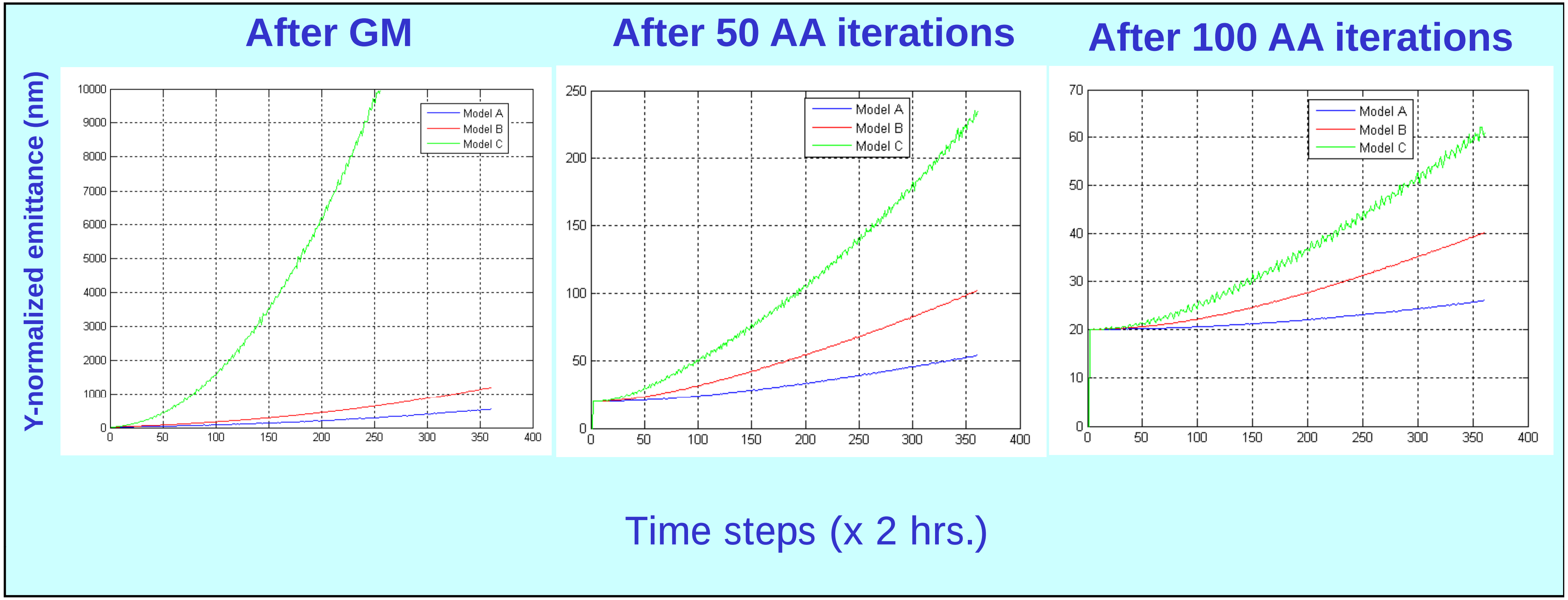


AA: Effect on Perfect Lattice for Different GM Models

- Perfectly straight lattice – ILC BCD Like Straight Lattice (114 FODO cells)
- 20 different GM seeds (GM – Models 'A' , 'B' and 'C')

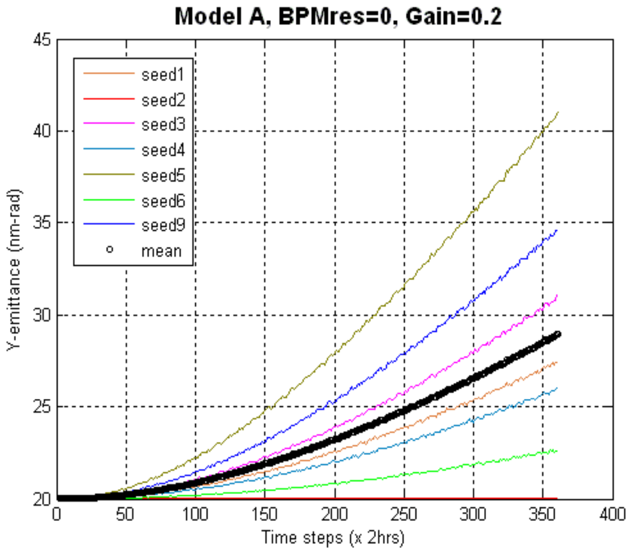
In each seed:

- GM of 30 days in step of 2 hrs.
- When AA incorporated: AA of 100 iterations after every 2 hrs. (perfect alignment, BPMres=0, Gain = 0.6*0.33, no GM during AA iterations)

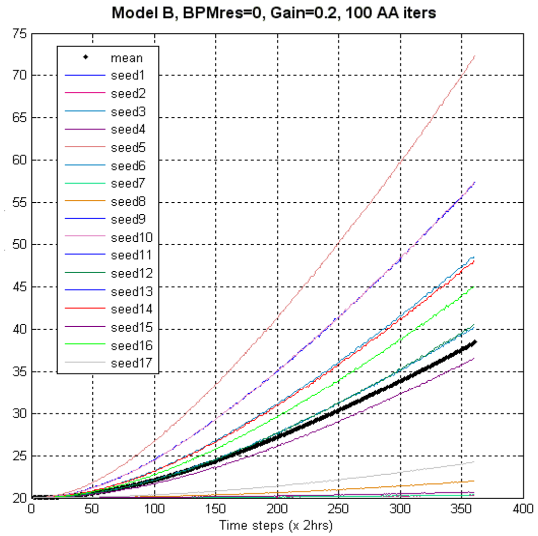


Different GM Models – Effect on Perfect Lattice

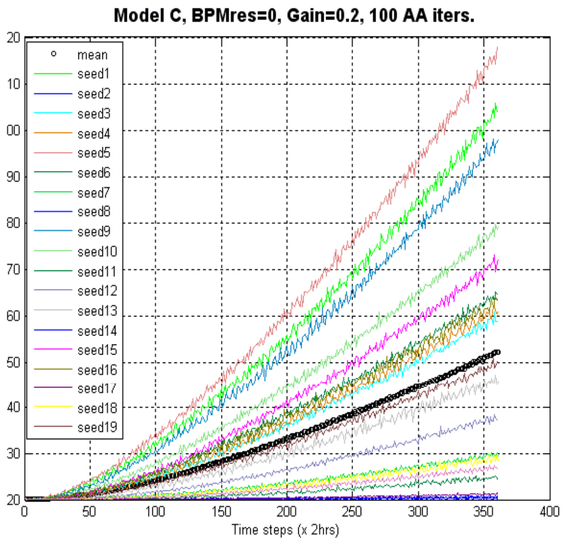
Y-emittance (nm) @ Linac exit after 100 AA iteration for different seeds



Model A



Model B

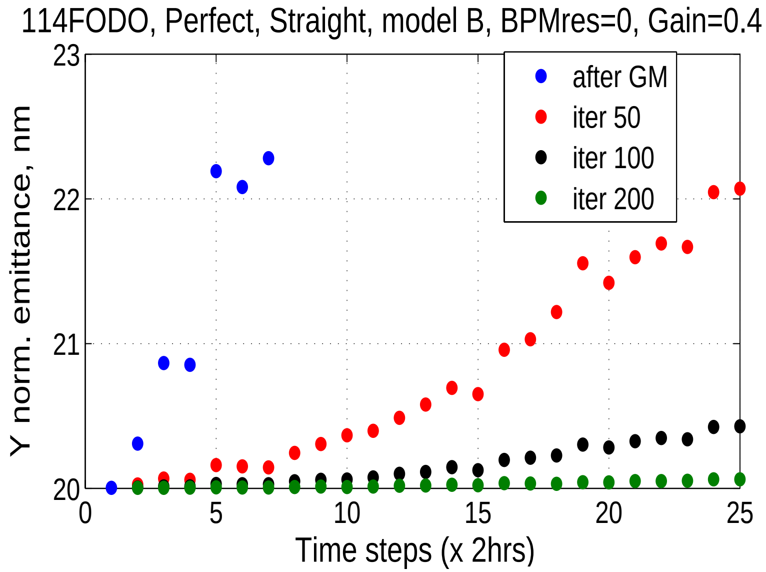


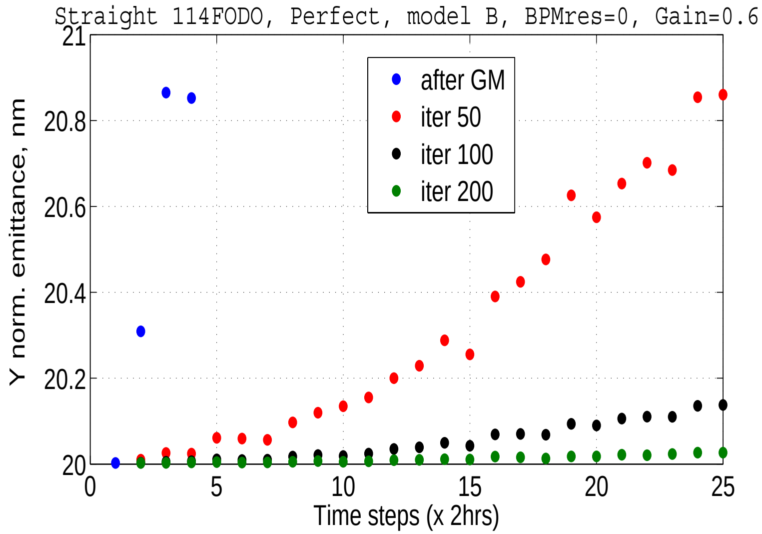
Model C

Time 30 days with step 2hrs

Individual variation for different seeds & GM models can affect substantially on beam emittance

Effect of Gain and Number of iterations



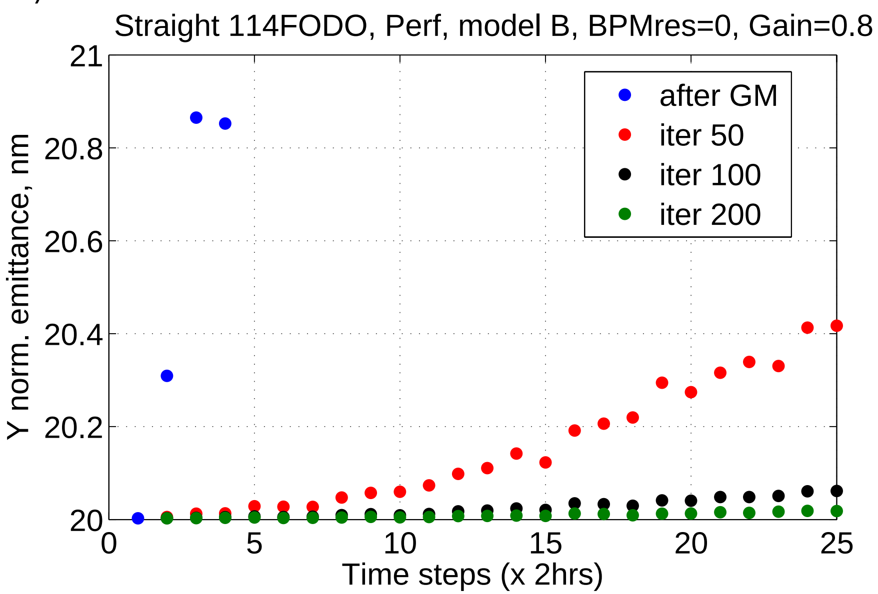


Adaptive Alignment

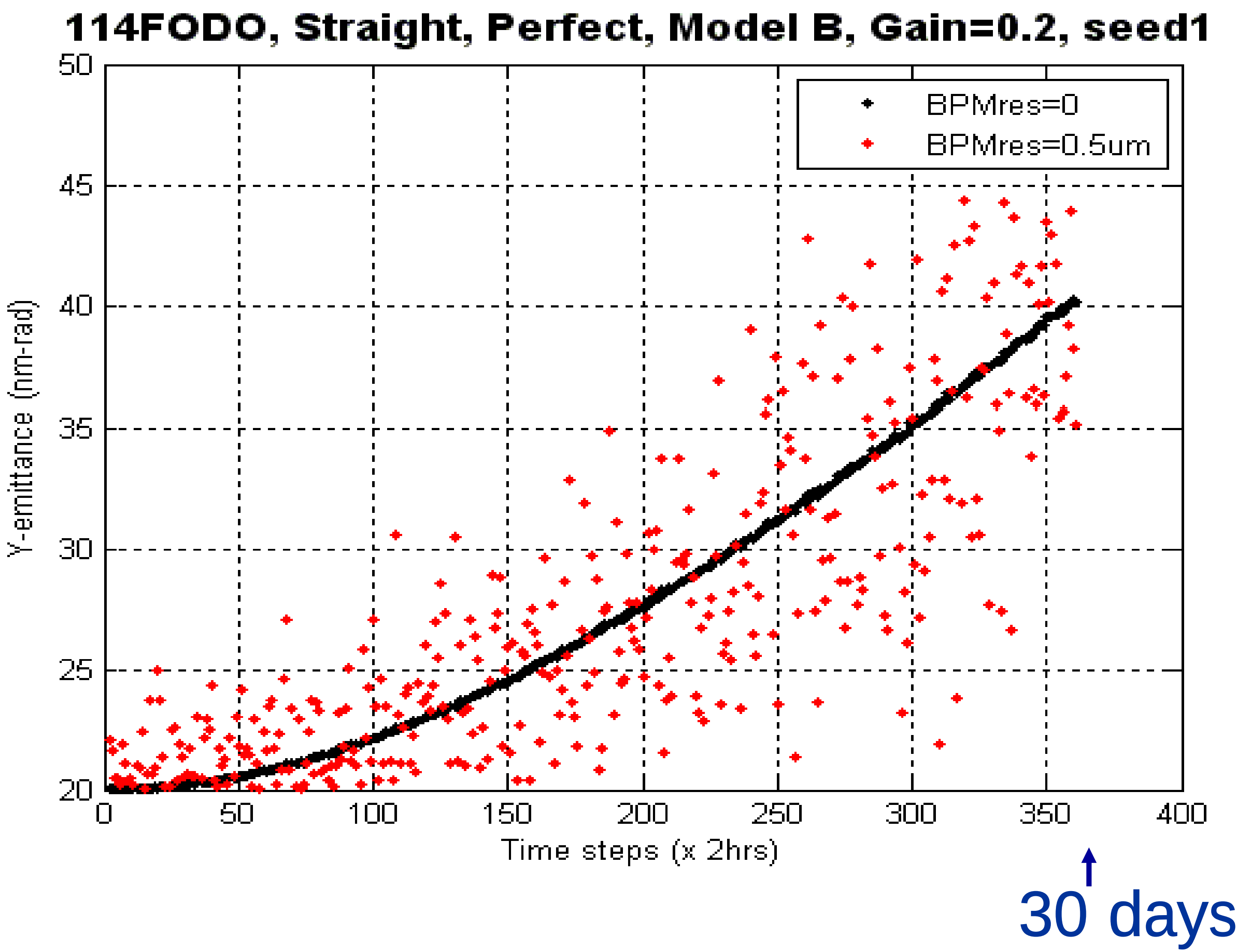
GM Model B

Time 50 hrs

Step 2hrs



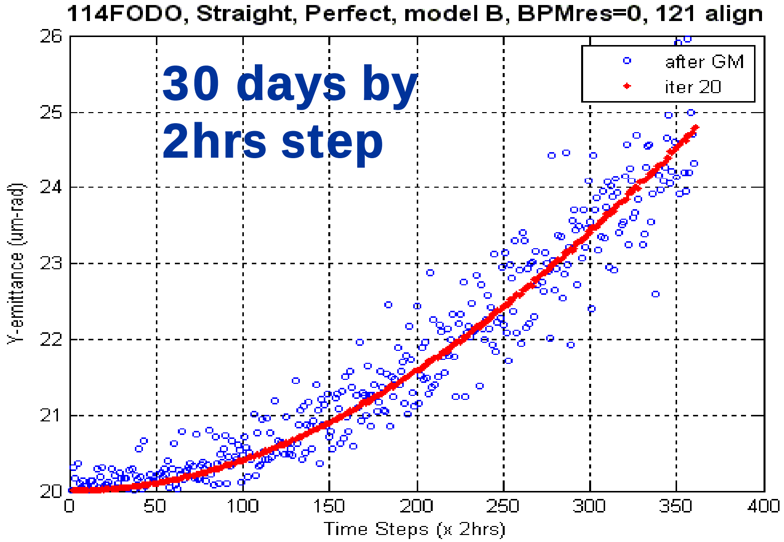
Beam Steering vs. BPM resolution

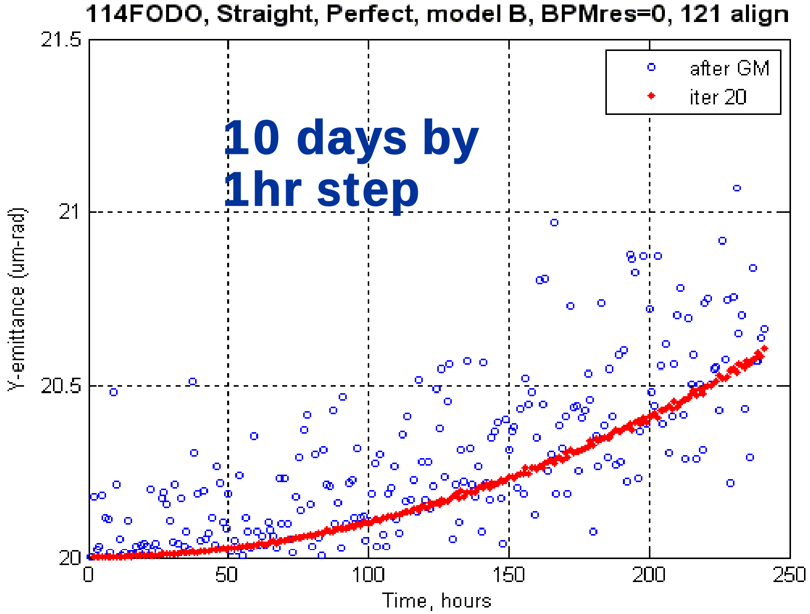


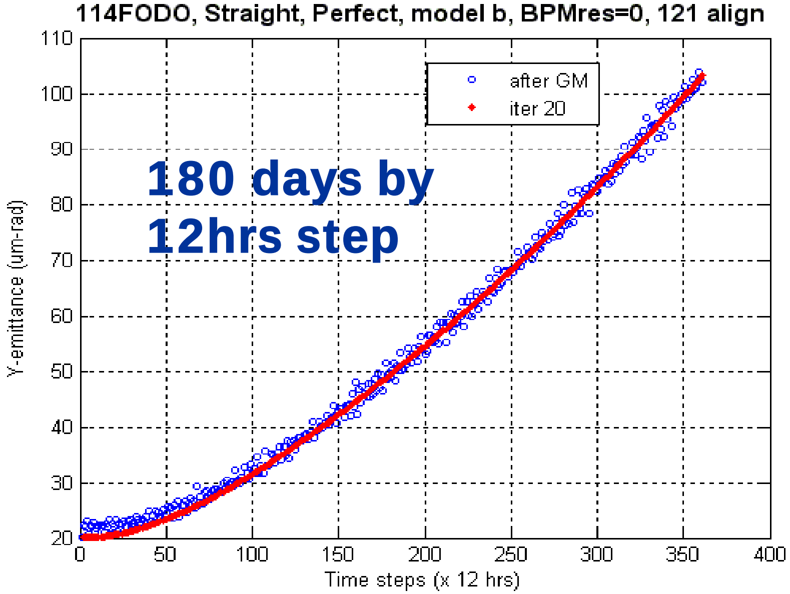
121 Dynamic alignment

One-to-one steering scheme for different time periods:

- Straight Lattice 114FODO
- Perfect alignment
- BPM resolution = 0
- GM model B
- Use setting after previous steering







Summary

- Lattices are available in FNAL Lattice Repository https://lattices.fnal.gov/
- Bumps Studies shows that emittance can be effectively corrected using a few Bumps (~3)
- Adaptive Alignment keeps emittance under control for ~10-30 days
- 121 Steering shows the similar behaviour as AA (quadratic growth in time).