Fermilab ideas for ILC test linac

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Vancouver GDE Meeting

July 21, 2006

What needs to be tested with beam?

- Assume that we are already constructing a one-rf-unit beam test facility: test LLRF, HLRF, HOM
- A multi (~10) rf-units test linac will allow to develop:
  - Beam-based emittance correction algorithms, both static and dynamic.
  - Beam-based feedback loops
  - System test of multiple rf units
  - Beam position stability at the end of the test linac.
  - Dark currents and beam losses in a cryo-string
  - Beam phase, beam energy stability
  - Maybe: add curvature to simulate curved linac dispersion effects

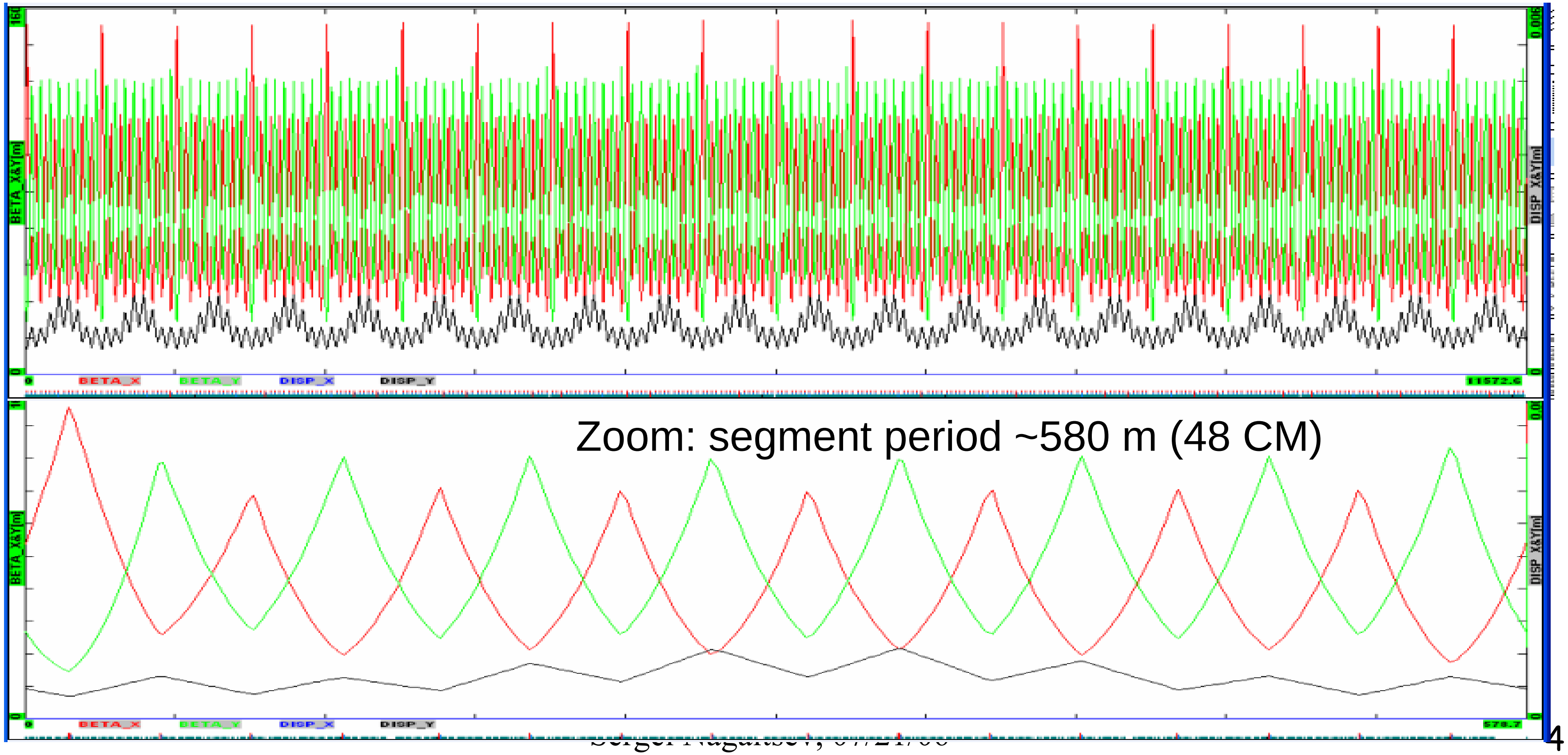
Civil Construction Issues (5 GeV linac)

A 5 GeV linac should duplicate as much of the ILC infrastructure as possible:

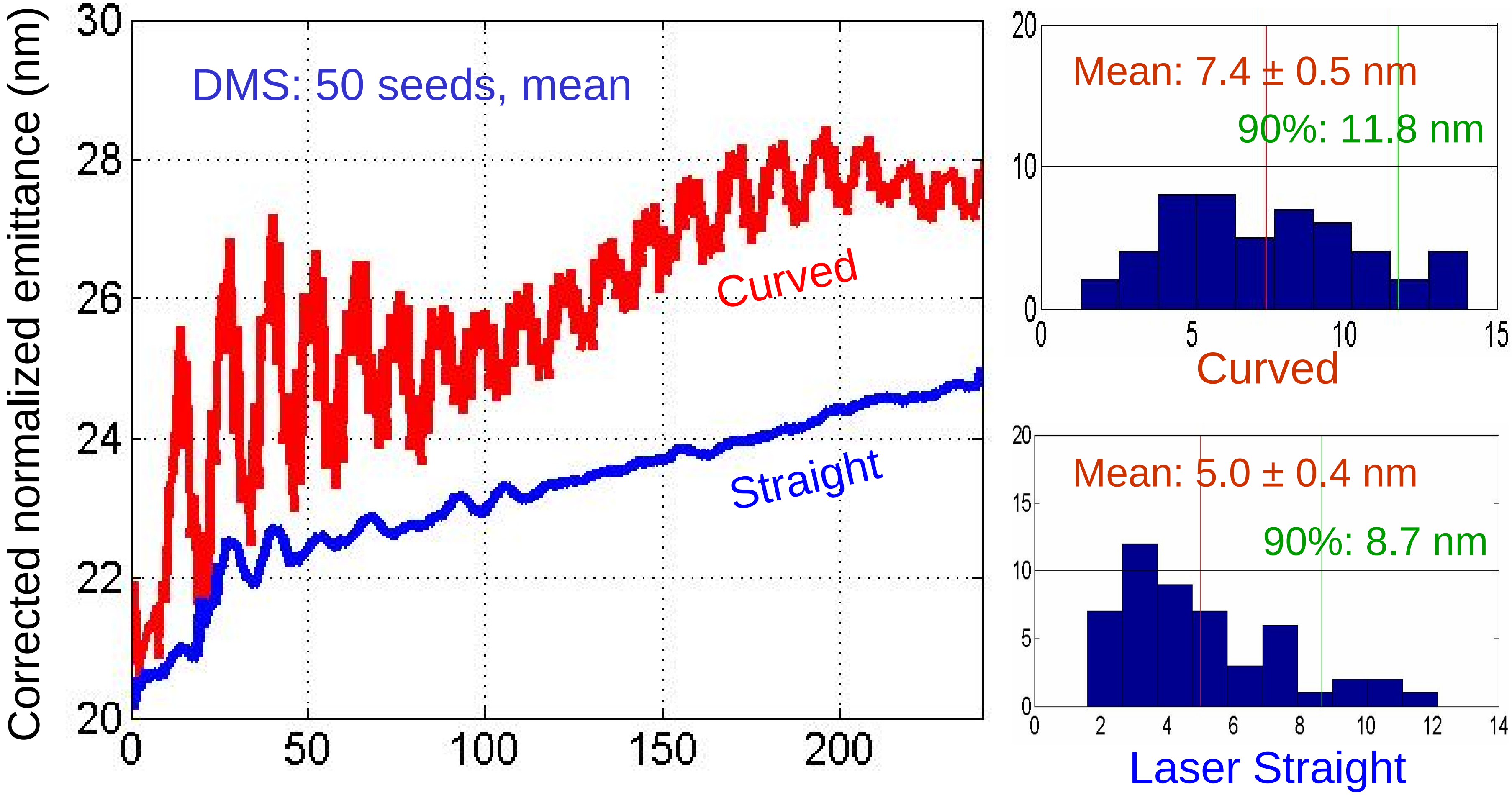
- **2 tunnel design**
- **identical RF and cryo distribution systems**
- **1 cryoplant/service building**
- **large access shaft plus emergency egress paths**

Realistic ILC Lattice (with cryo-segmentations)

- CM length from the current “draft” design
- Quad spacing 1Q/3CM
  - Extra 2m drift space for cold boxes every 12 CM’s (cryo-string)
  - Extra Drift space = 1CM_no_Quad for warm insertion for beam diagnostics and vacuum valves. Every 48 CM (cryo-segment ~ 580m).



Curved vs. Straight LINAC BCD LATTICE



DMS parameters not optimized for Curved Linac

Static Tuning: Dispersion MATCHED Steering
(for straight linac, it's Dispersion FREE Steering)

- 1-to-1 steering in the whole Linac
- DMS from the 8th BPM onwards
- First 7 BPMs are assumed to have smaller offset ~ 30 um.
- Minimized orbit: (yb_dfs_b - yb_dfs_a - design_diff) , where
  - yb_dfs_b is the BPM readings for off energy orbit, i.e., for E2 = Eo – ΔE
  - yb_dfs_a is the BPM readings for on energy orbit, i.e., for E1 = Eo
  - design_diff is the orbit difference coming from design dispersion = η*(E2–E1)/E1

***ab initio* (Nominal) installation conditions**

Tolerance	Vertical (y) plane
BPM Offset w.r.t. Cryostat	300 μm
Quad offset w.r.t. Cryostat	300 μm
Quad Rotation w.r.t. Cryostat	300 μrad
Cavity Offset w.r.t. Cryostat	300 μm
Cryostat Offset w.r.t. Survey Line	200 μm
Cavity Pitch w.r.t. Cryostat	300 μrad
Cryostat Pitch w.r.t. Survey Line	20 μrad
BPM Resolution	1.0 μm

Flat Beams from Photoinjector

	A0 photoinjector	A0 photoinjector - comment	ILC
bunch charge (nC)	up to 16		3.2
bunch spacing (nsec)	1000		330
RF pulse length (ms)	up to .6	new gun design required to prevent overheating and breakdown	1
pulse repetition rate (Hz)	1	requires RF upgrade to increase rep. rate	5
normalized horizontal emittance (mm-mrad)	40 (@ 0.5nC)		8 (DR extraction); 10 (IP)
normalized vertical emittance (mm-mrad)	.4 (@ 0.5 nC)		.02 (DR extraction); .04 (IP)
emittance ratio	100 (@ 0.5nC)		400 (DR extraction); 250 (IP)
RMS bunch length after bunch compression (mm)	.5 (@1 nC)		.3
RMS momentum spread after compression (%)	~4 (@1 nC)		1.1
polarized?	no	R&D in progress -- vacuum issues may be difficult	yes

Test Linac Parameters

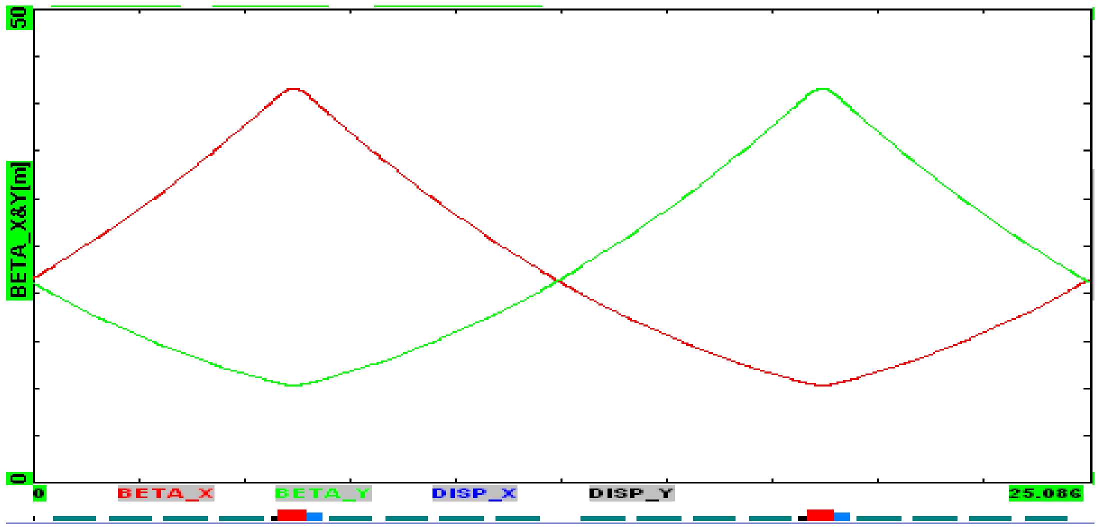
18 ILC-type cryomodules,
Each containing Quadrupole,
Total length ~226 m
Betatron phase advance
75/75 per cell

Two modes of operation
are considered:

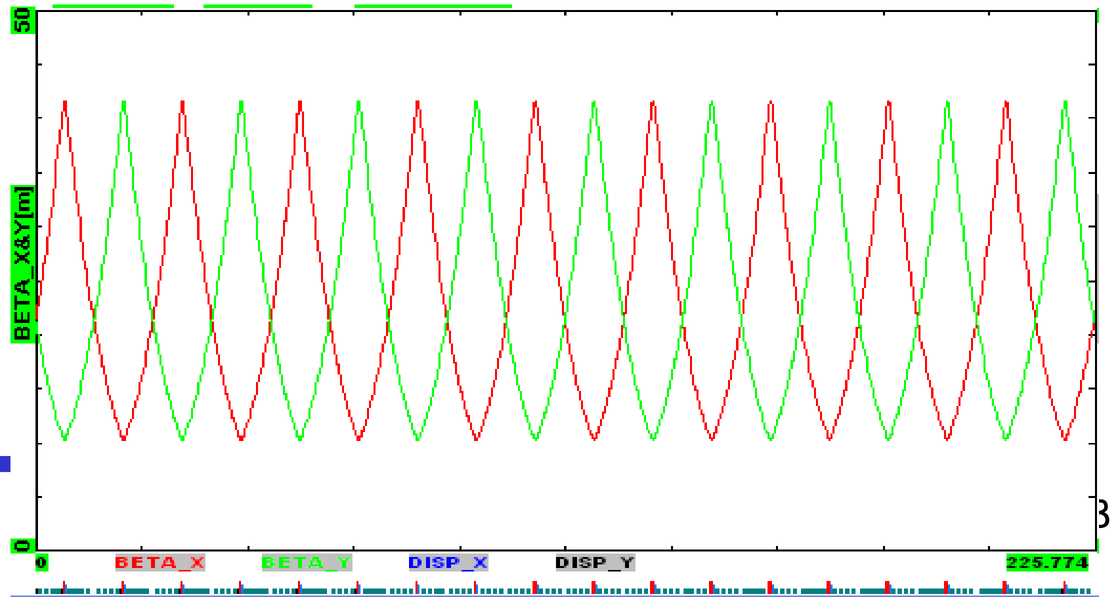
1. 500 MeV – 5 GeV,
With initial vertical emittance
400 nm
2. 5 GeV – 9.5 GeV,
With initial vertical emittance
20 nm

All mis-allignments are nominal
and static

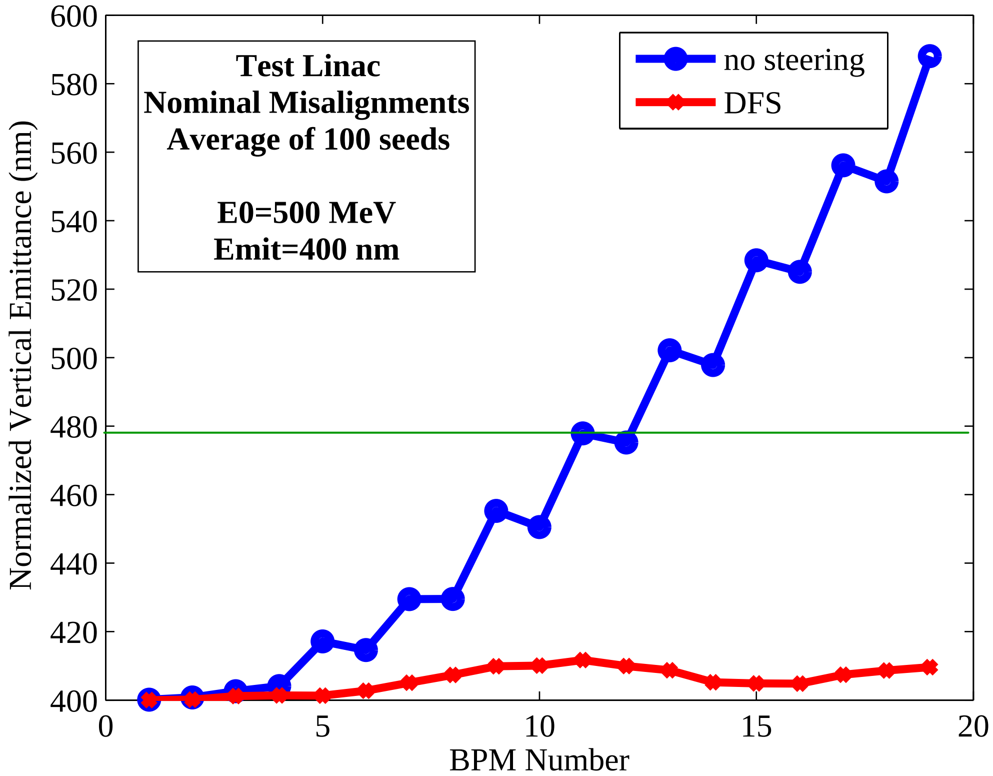
Beta-functions of a FODO cell



Beta-functions of the entire linac



Emittance Transport in the Test Linac
E0=0.5GeV, Ef=5GeV, ε0=400nm

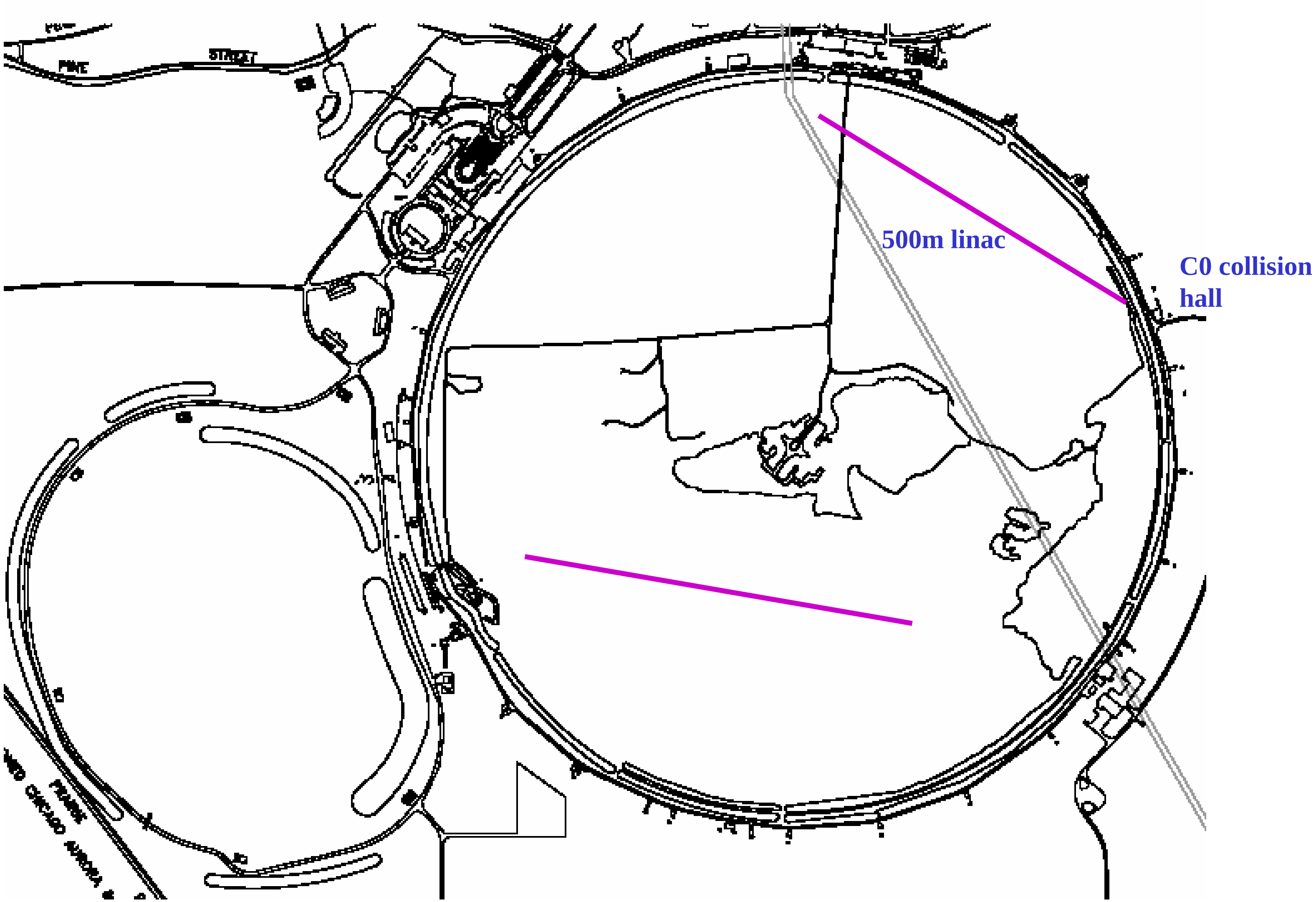


MatLIAR Simulation

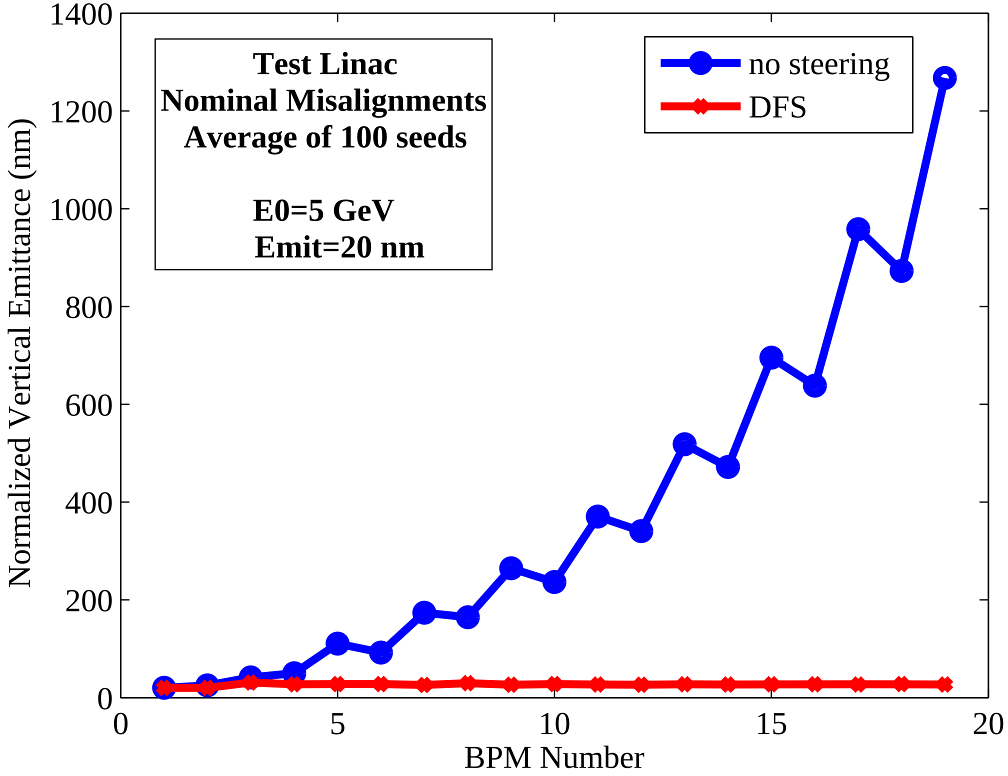
Detection uncertainty limit (beam size @10%)

- Uncorrected static emittance growth is nearly 50%
  - Can be used for DFS verification
  - With no acceleration – will have better sensitivity

Possible Locations of 500m Linac Inside Tevatron Ring



Emittance Transport in the Test Linac
E0=5GeV, ε0=20nm



MatLIAR Simulation

Conclusion

- In a 5-GeV linac with a 0.4-μm emittance beam, the emittance growth due to static misalignments is detectable. May be enhanced by reducing acceleration rate.