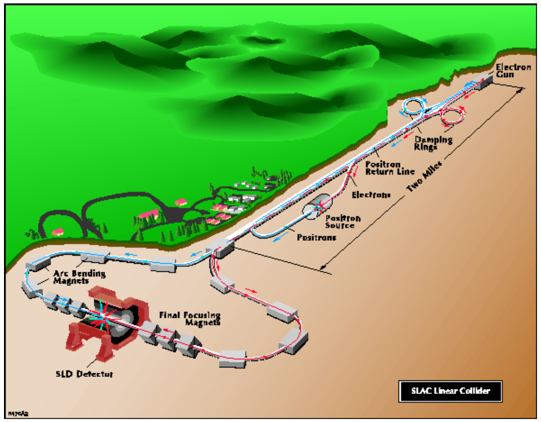
Tests of Beam-Based Alignment at FACET

A. Latina (and E. Adli)

CLIC Beam Physics Meeting, Feb 8 2012

SLAC Accelerator Center

- SLAC (Stanford Linear Accelerator Center) is a lab with a glorious past
- SLAC has been operational since 1966 and has produced three (and ½) Nobel Prizes in Physics:
  - 1976: The charm quark—see J/ψ meson
  - 1990: Quark structure inside protons and neutrons
  - 1995: The tau lepton
  - 2008: B-factories confirm matter-antimatter asymmetry (SLAC-Babar, together with the Belle experiment at KEK)

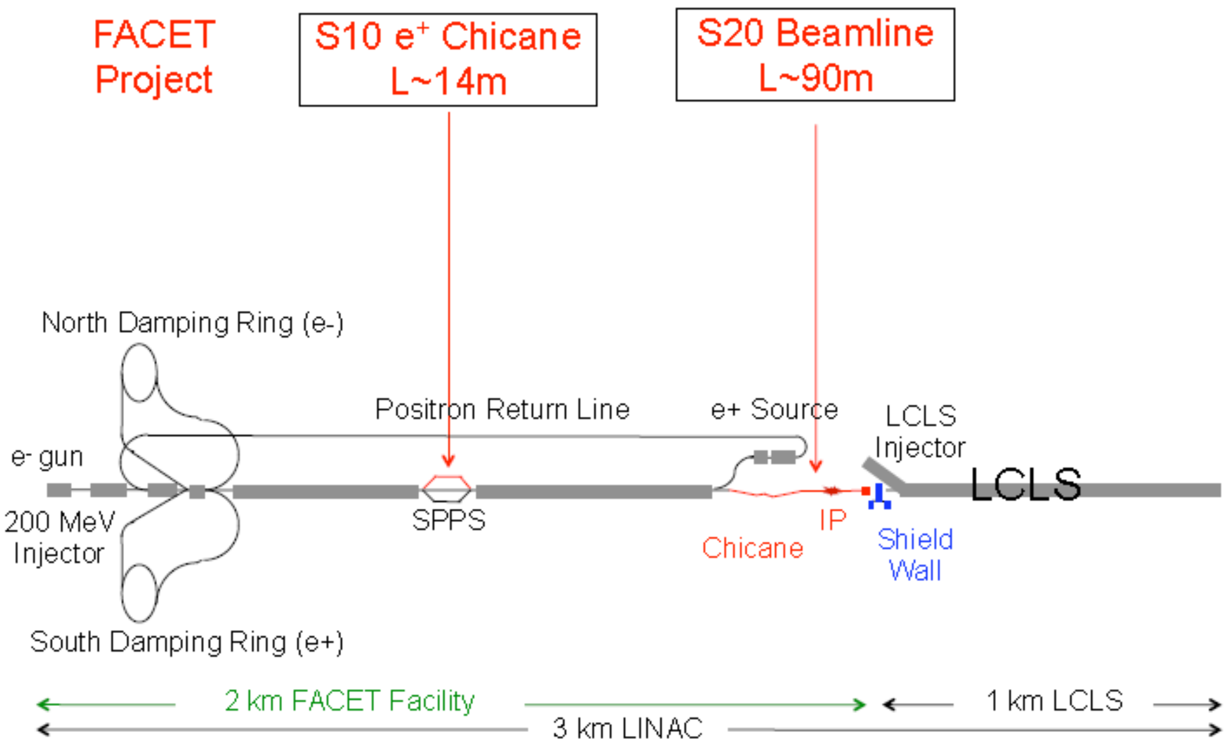


- SLC is a 3km-long e^+e^- linac, the longest linear accelerator in the world

Facility for Advanced aCcelerator Experimental Tests

- FACET was designed to meet the Department of Energy Mission Need Statement for an Advanced Plasma Acceleration Facility, open to users

- FACET uses the first two-thirds (Sectors 0 thru Sector 20) of the SLAC linac to deliver e+ e- beams to an experimental area



Final Focus is Sector 20.

Beam parameters at S02 injection:
- ✓ Emittance:
  30 um rad x 2.5 um rad
- ✓ Bunch length: 1.5 mm
- ✓ Energy 1.19 GeV
- ✓ Charge: 3.24 nc

Beam parameters at IP:
- ✓ Transverse size:
  10 um x 10 um
- ✓ Bunch length: 20 um
- ✓ Energy 23 GeV
- ✓ Charge: 3.24 nc

CLIC Proposals for FACET

The University of Manchester
MANCHESTER 1824
The Cockcroft Institute of Accelerator Science and Technology
CERN
CLIC

Proposal for Experiments at FACET

Update of earlier talk by R.M. Jones
G. de Michele (EPFL, PSI and CERN), A. Latina (CERN) and
E. Adli (University of Oslo and SLAC)
for
the CLIC/CTF3 Collaboration

Aug 30, 2011

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E. Adli (University of Oslo and SLAC.) on behalf of CLIC/CTF3 Collaboration., FACET User Meeting, SLAC, Aug, 2011

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Dear Dr Latina

Invitation Letter for FACET 2012

We welcome you to FACET this year to verify the effectiveness of linear collider final-focus feedbacks and alignment algorithms. We have given your tests the designation T-501.

You are invited to come to SLAC in the period 26th January to 4th August.

The schedule for 2012 is shown below:

7th March 2012	Start of electron beam commissioning at FACET
13th April 2012	Start of FACET User Run 1 (part A)
16th May 2012	1 week downtime period for major installations
25th May 2012	Start of FACET User Run 1 (part B)
27th June 2012	Predicted end of FACET User Run 1

Specifically, we would like for you to come for shifts in the first week of the User Run (13th April – 18th April).

We submitted three Proposals:

(1) Measurement of wakefields in CLIC A.S.

(2) Tests of Beam-Based Alignment and System Identification;

(3) Collimator wakefields

BBA and SI have been accepted '*tout court*' as tests for machine development

Why BBA as an experiment

Why BBA ?

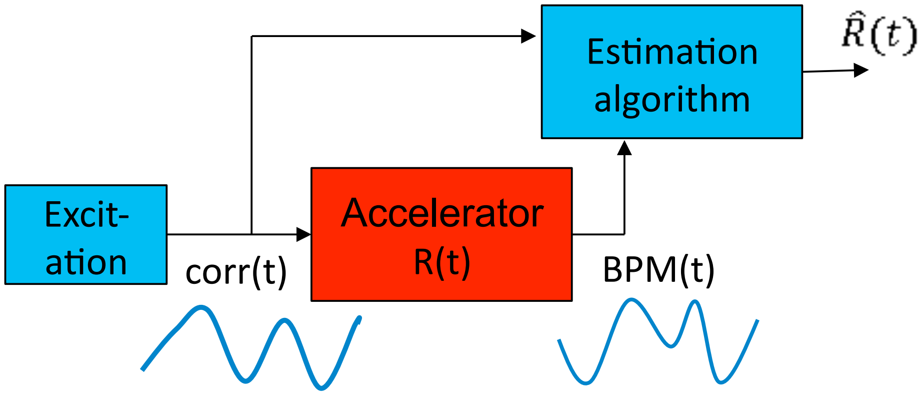
- BBA is vital tool for any future linear collider, to mitigate static imperfections and allow low emittance transport
- advanced FB systems are vital to preserve beam quality
- Many advanced BBA techniques have been simulated with a variety of codes (PLACET, LUCRETIA, MERLIN) but never actually been tested on a real machine

Why at FACET/SLAC ?

- Only linac that can well represent a future LC optics (length, F. focus)
- Its linac is long enough, in terms of betatron wavelengths (CTF3's linac not sufficient)
- It has similar optics to the LC final focus systems

Beam Line Model

- **One important ingredient of the dispersion free steering is the knowledge of the lattice**
  - Convergence of the dispersion free steering depends on this
- **Would like to determine expected error of the model**



In CLIC main linac difficult

- Time consuming: 2000 correctors and BPMs
- Sensitive to noise: 200 betatron oscillations along main linac and decoherence due to energy spread
- Want to avoid luminosity loss during measurement

My visits to SLAC so far

First: last summer (exploratory)

- Meet with the experts
- Acquire the lattice decks
- Setup a PLACET simulation of FACET layout Sector 02 thru 20
- Study feasibility of our tests
- Start to work on the proposal

Second: last week (preparatory)

- Take contact with the machine physicists
- Study the integration of your algorithms in their control system
- Get computer account in the MCC
- Assorted Q/A with local experts
- Other formalities (get a badge, dosimeter, …)

BBA Simulations: 1-to-1, DFS

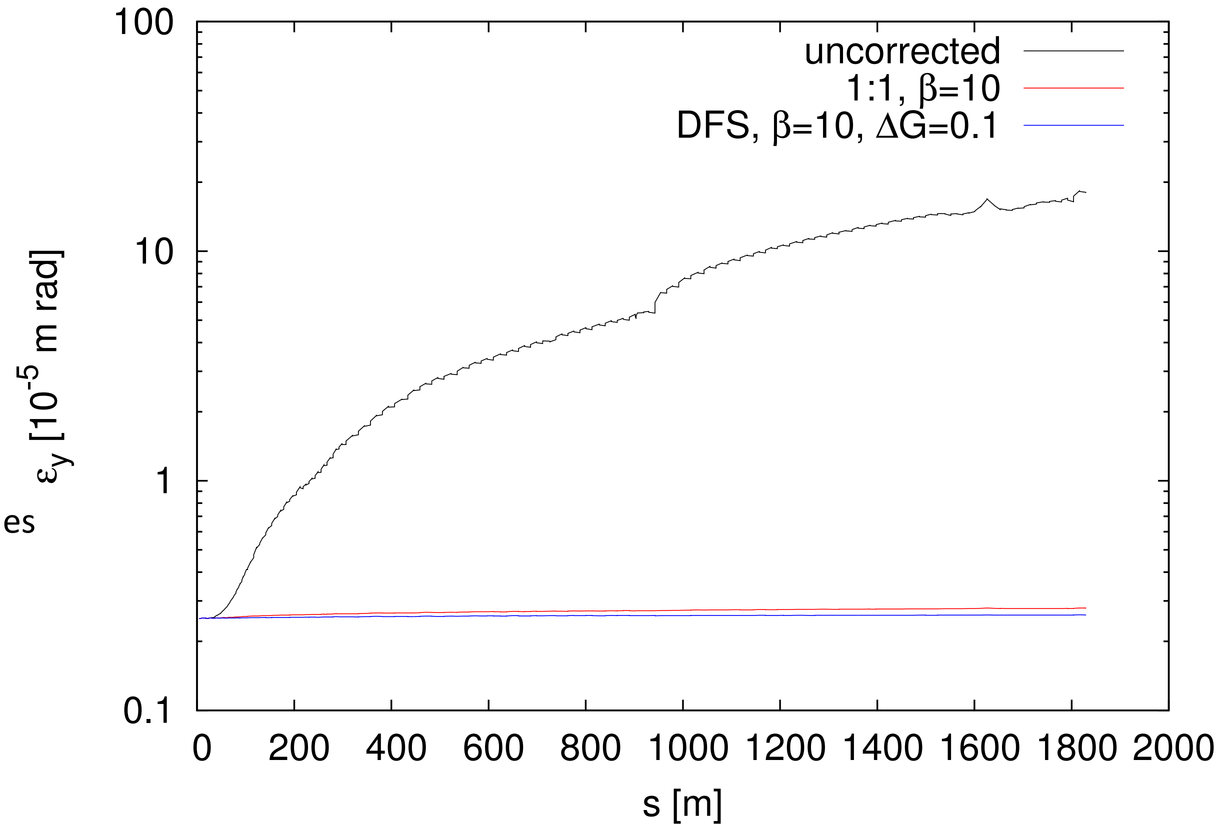
Relevant beam parameters at injection

Symbol	Value
$\gamma\epsilon_x$	$3.0 \cdot 10^{-5}$ m · rad
$\gamma\epsilon_y$	$0.25 \cdot 10^{-5}$ m · rad
σ_z	1 mm
σ_E	1%
q	3.24 nC
E_0	1.19 GeV

Misalignment and BPM precision values

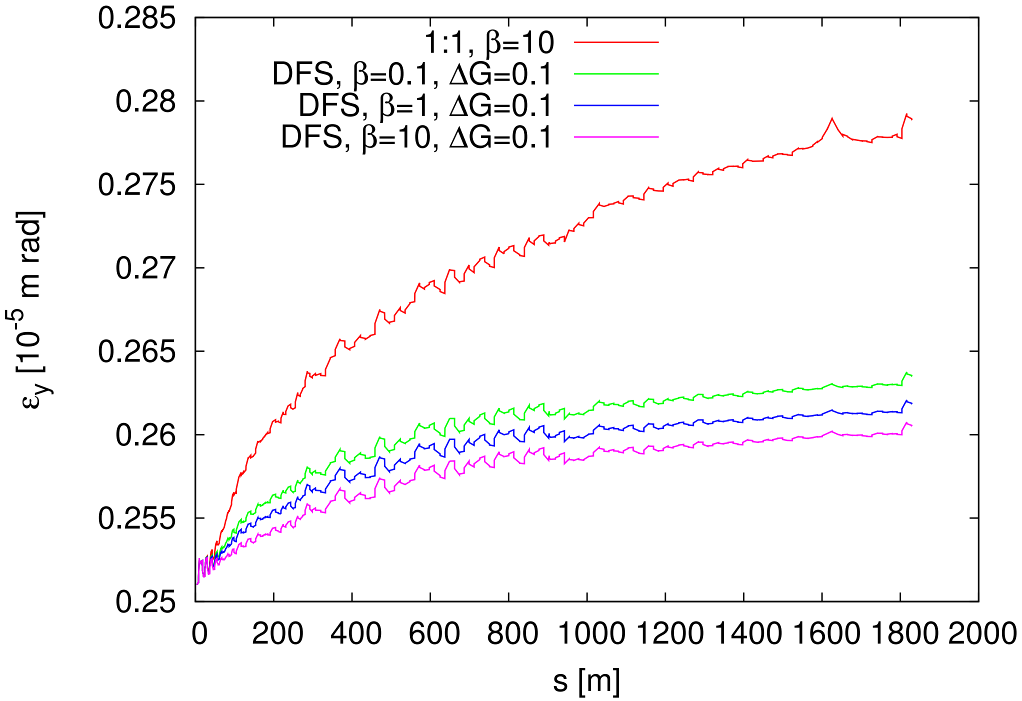
Symbol	Value, RMS
$\sigma_{\text{quadrupole offset}}$	100 μm
$\sigma_{\text{bpm offset}}$	100 μm
$\sigma_{\text{bpm precision}}$	50-80 μm

Simulation results for 100 misalignment seeds



BBA Simulations: 1-to-1, DFS

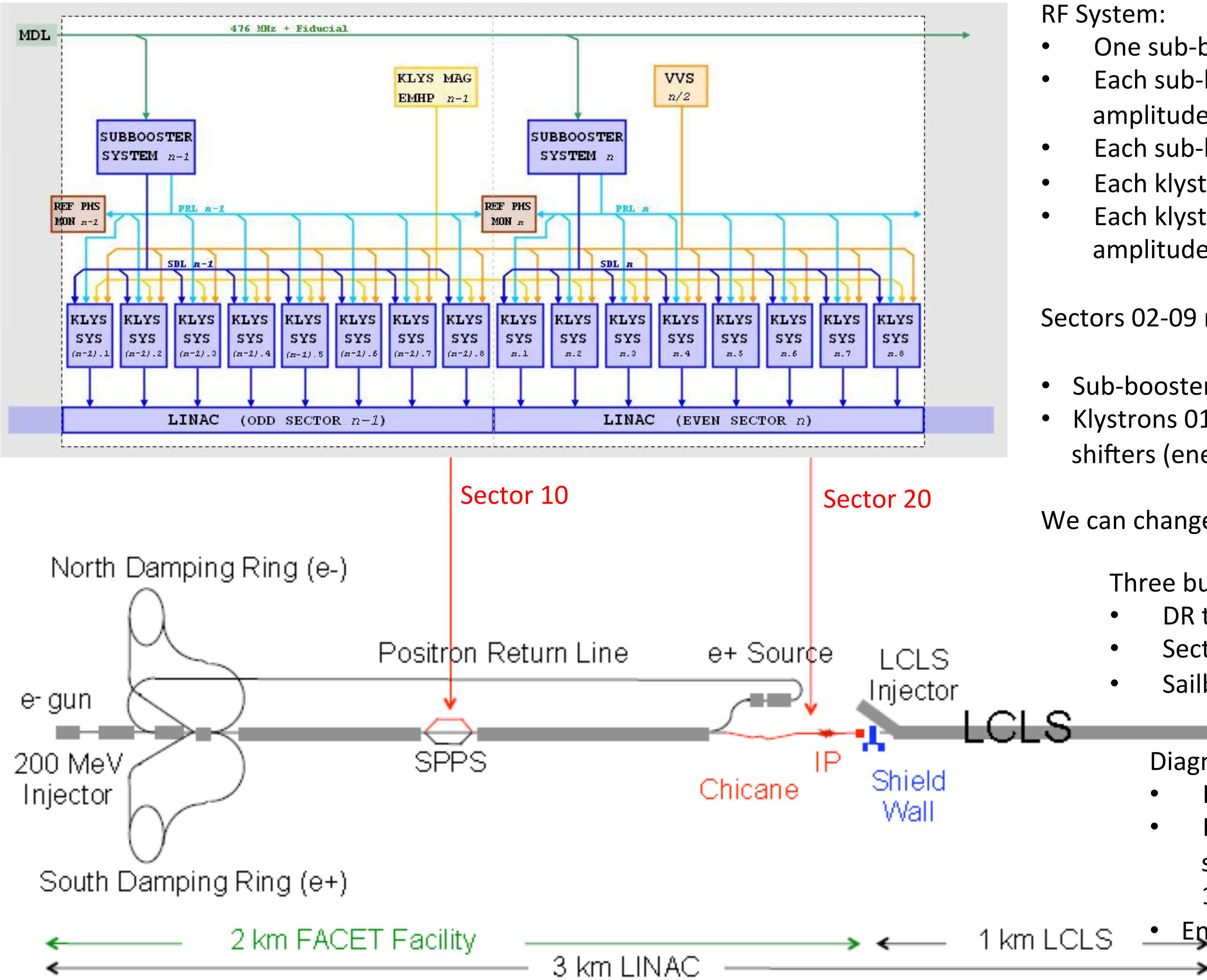
Summary of the simulation results for 100 misalignment seeds



	final emittance (H, V) [10^{-5}m·rad]	emittance growth (H,V)
injected	(3.0, 0.25)	(0%, 0%)
uncorrected	(24.3, 18.0)	(710%, 7100%)
1:1 corrected	(3.1, 0.28)	(3.7%, 11.6%)
DFS corrected	(3.09, 0.26)	(3%, 4%)

Detailed Layout and RF System

RF System



RF System:

- One sub-booster per sector
- Each sub-booster is characterized by (phase, amplitude)
- Each sub-booster feeds 8 klystrons
- Each klystron feeds 4 accelerating structures
- Each klystron is characterized by (phase, amplitude)

Sectors 02-09 run off-phase to create energy chirp

- Sub-boosters 17-18 feature fast phase-shifters
- Klystrons 01-02 in Sector 9 feature fast phase-shifters (energy correction in 1st chicane)

We can change each phase.

Three bunch length compressions:

- DR to Linac section : 5mm to 1.5 mm
- Sector 10 : 1.5 mm to 50 μm
- Sailboat chicane : 50 μm to 20 μm

Diagnostic available:

- Bpms (~190)
- Emittance measurement (multi-wire, single-wire): Sector 02, Sector 11, Sector 18
- Energy measurement:
  - Sector 10, Sector 20

Q/A with Machine Physicists

What is the Latency time of setting correctors / klystron phases [/ magnets]

Few secs, About 5 secs

How do we get the realistic initial bunch parameters ?

1. How do we get the realistic final bunch parameters ?
2. What intermediate diagnostics is it available ?

Emittances are calculated and measured at the beginning of sector 02, using 5 wire scanners. The measurement is slow and takes about 20 minutes, therefore it can be performed only once in a while. Usually, it is performed likely once a day.

An emittance measurement station is being installed also at end of sector 18. It's a single wire measurement, that requires a quad scan. The emittance measurement takes about 10 minutes per plane.

There is an emittance measurement station, using multi-wires, in sector 11. The measurement takes about 5 minutes per plane.

Bpm readings are in [mm].

Q/A with Machine Physicists

How accurate is the model w.r.t. reality

Typical optical errors = 0.1%

Does anything drift in time ?

- Yes: the phase of the klystrons w.r.t. the beam time reference. The reason is not known. Maybe the beam is moving in time (phase of DR) - seems correlated with the temperature. Time scale = 1 hour.
- Emittance changes in time. Time scale = days
- Example of failure: A short in a quadrupole coil might induce an error in the magnetic strength. Typical order of magnitude = 10%
- Slow ground motion. The middle of the linac slowly moves downward. Time scale = years.

Has quad-shunting ever be performed?

Yes, quad-shunting has been performed, so the bpm center corresponds to the magnetic center of the quads within 100 um. QS is usually performed once a year. It might be performed sometime during this commissioning.

Note that QS was recently performed in sector 20. Bpms to magnetic center error-bars are in average 20 um - 30 um.

Are there plotting routines available in Matlab? (trajectory, and other things..)

Yes.

Some Information

- They use the historical SLC control program (SCP, pronounced “SKIP”), now coated with a robust, easy-to-use, Matlab interface
  - We will only interface through Matlab
- Complete status of the machine can be totally “downloaded” from the Control System through a Matlab procedure:
  - Magnetic strengths, kicker strengths, bending angles, klystrons and sub-booster phases and amplitudes
- Each of the mentioned quantities can be set
- Natural interfacing with PLACET (e.g. same units to represent magnetic strengths, and voltage of kickers). Placet can be used as “flight-simulator”

Considerations

- FACET is an excellent test-bench for BBA algoritms:
  1-to-1, DFS, Kick Minimization, new ideas,
  Emittance tuning knobs

- FACET is an excellent test-bench for System Identification algorithms:
  Measured Responses, Numerical Responses, Adaptive Responses can be tested

- Natural interfacing between PLACET and their Acquisition system (same units to represent magnetic strengths, and voltage of kickers)

- Placet-Octave extremely beneficial to simulate "numerical experiments" and prepare "ready-to-be-used" scripts for Matlab

- Placet can be used as flight simulator

Work Plan

- There will be many “unknown unknowns”
- So: we must take care in advance of all the “known unknowns”
- Next weeks at CERN will be crucial for preparation
- The 5-days experiment in April will be very exciting !