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Plans for the CLIC Crab cavity proposal

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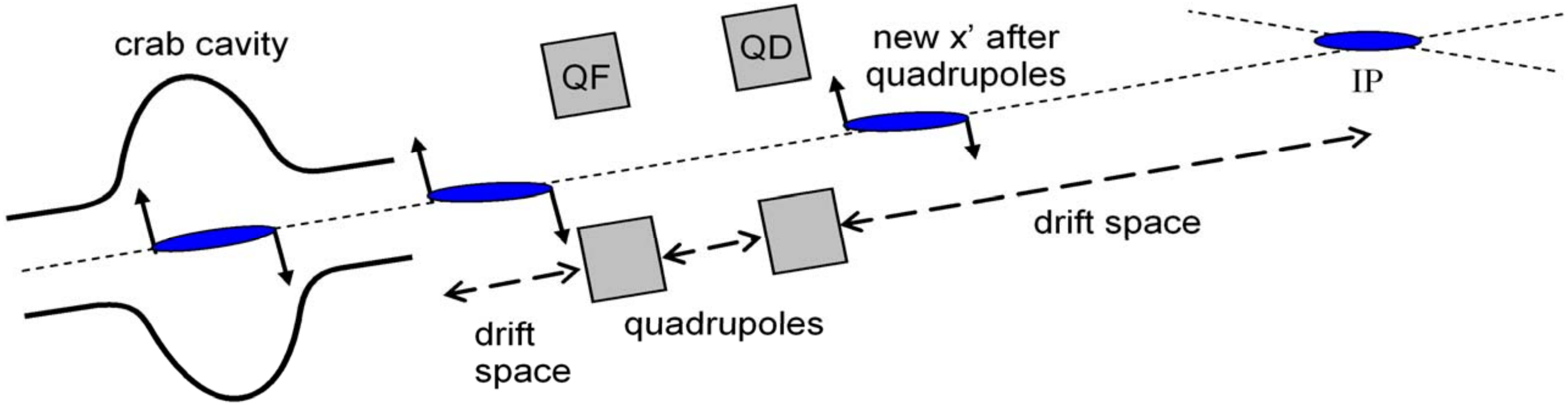
Crab Cavity Function

Crab cavities are required for ILC, LHC upgrade and CLIC



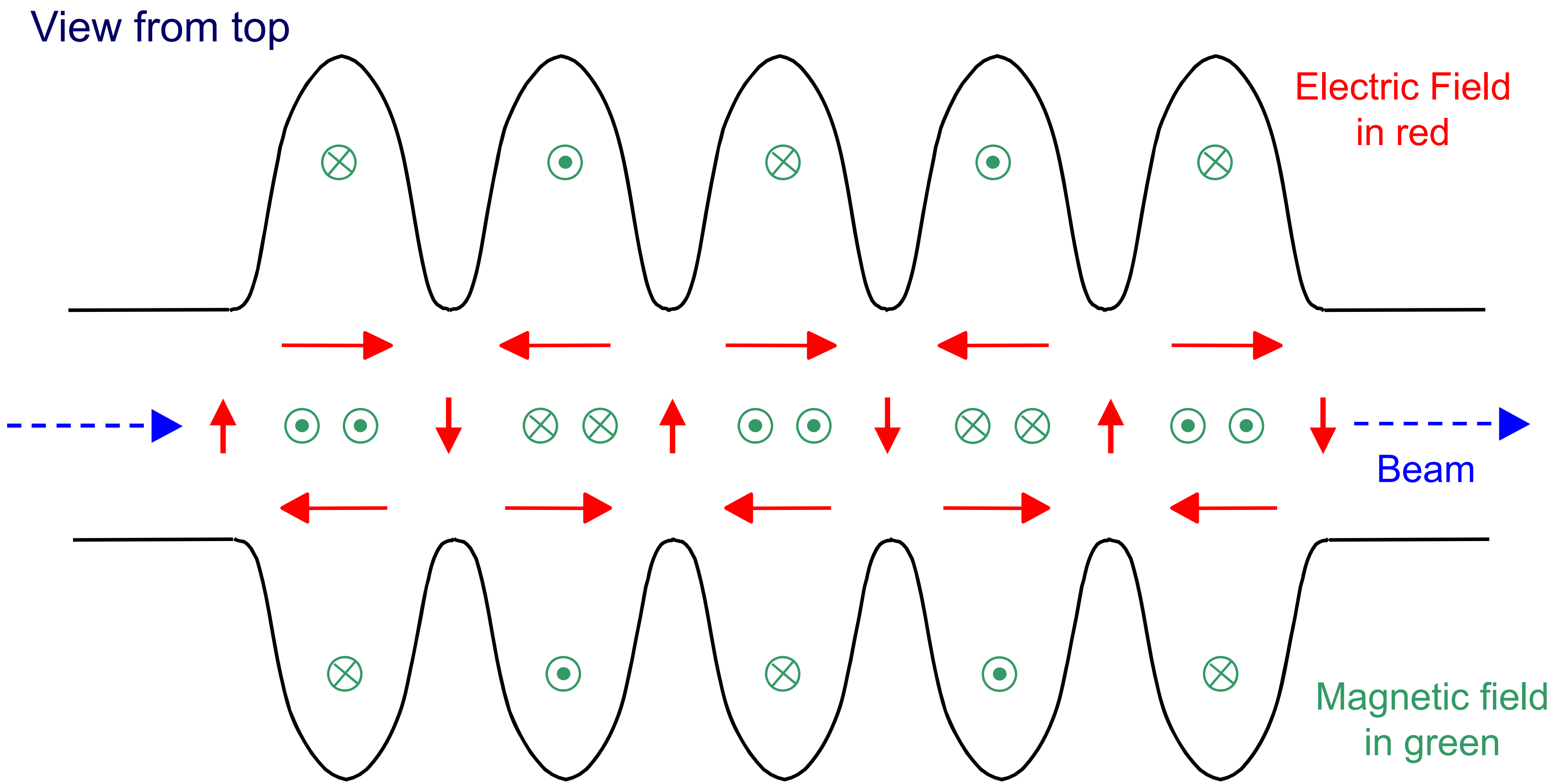
The crab cavity is a deflection cavity operated with a 90° phase shift.

A particle at the centre of the bunch gets no transverse momentum kick and hence no deflection at the IP.

A particle at the front gets a transverse momentum that is equal and opposite to a particle at the back.

The quadrupoles change the rate of rotation of the bunch.

TM110 Dipole mode cavity



For a crab cavity the bunch centre is at the cell centre when E is maximum and B is zero

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Crab Cavity Issues

- Wakefields - cause kicks and emittance growth
- Phase Stability - causes kicks

Key Required Outcomes

1. Damp, measure and confirm the predicted wakes.
2. Establish feasible/achievable level of phase control performance. (Current requirement is more than ten times state of the art)

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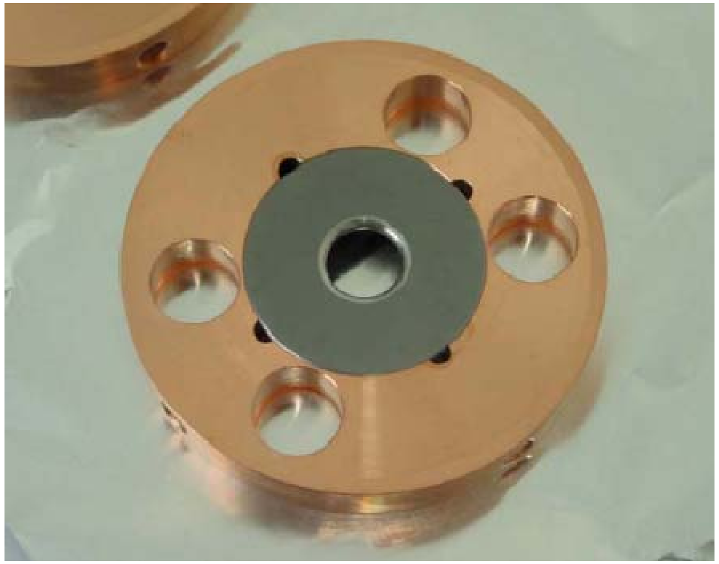
Cavity Requirements

- Travelling wave cavity at 12 GHz
- Damped, detuned structure
- Synergy with the main linac



- Require 2.4 MV (for R12 = 25 m).
- Can achieve a transverse gradient of about 20 MV/m.
- This means about 20 cells using a 2pi/3 TW mode.
- This requires up to 5 MW of X-band RF.

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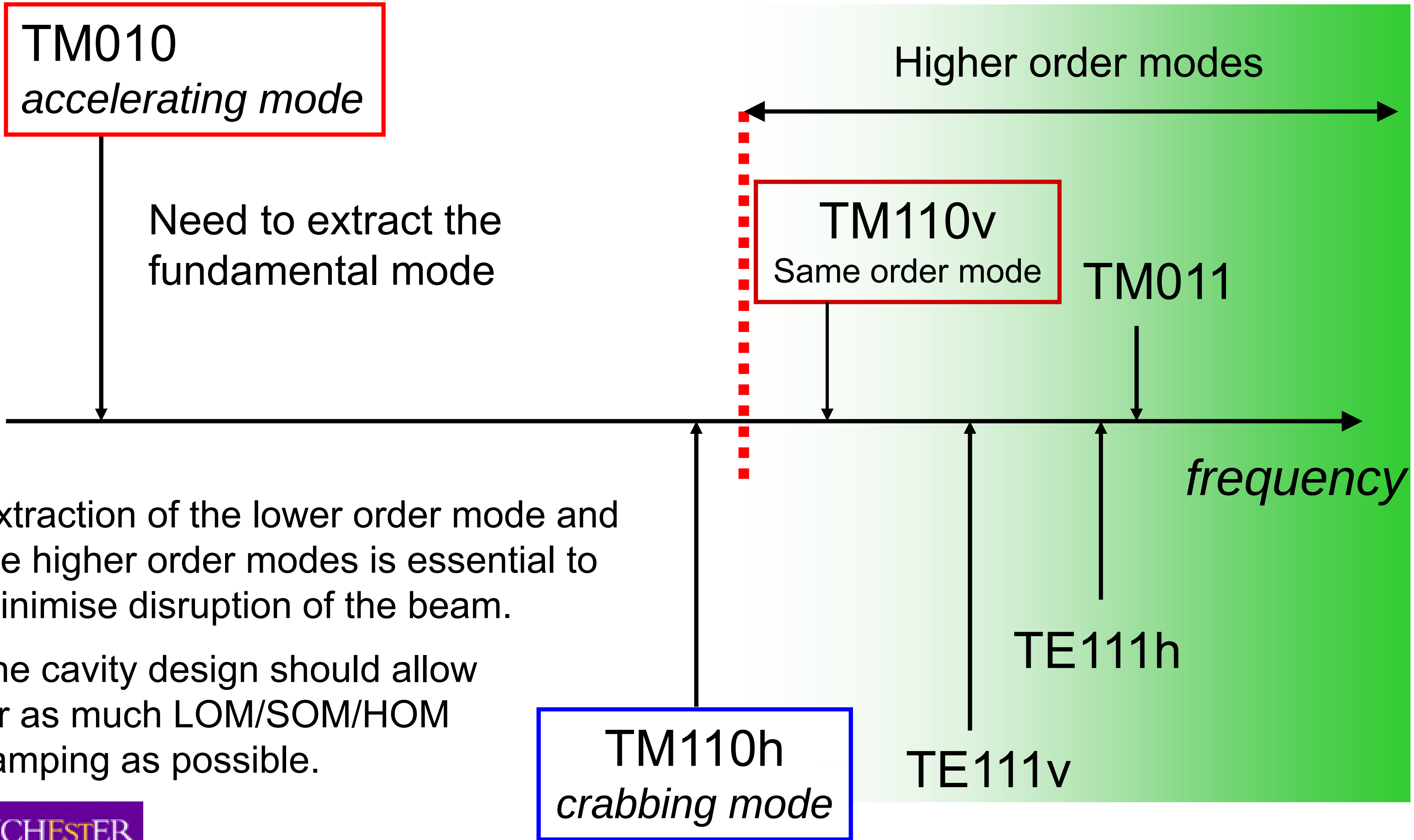
Wakefields in Crab cavities



Extraction of the lower order mode and the higher order modes is essential to minimise disruption of the beam.

The cavity design should allow for as much LOM/SOM/HOM damping as possible.

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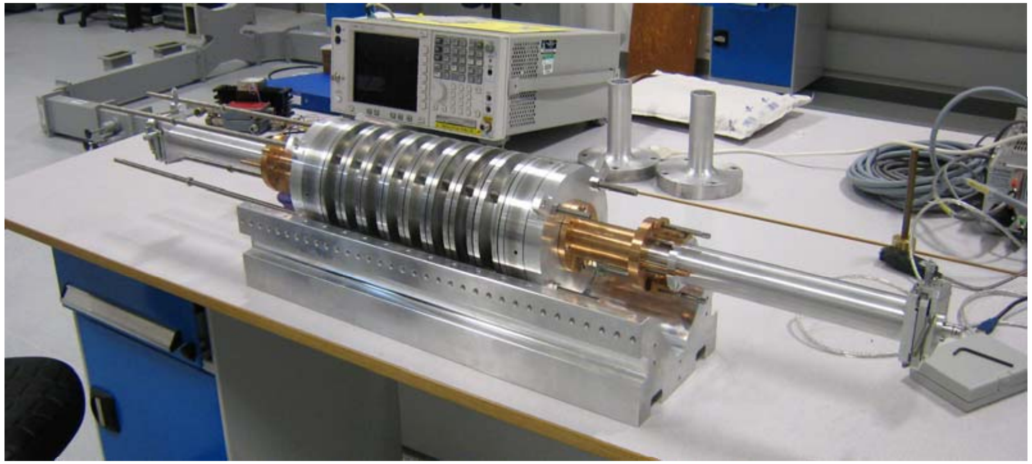
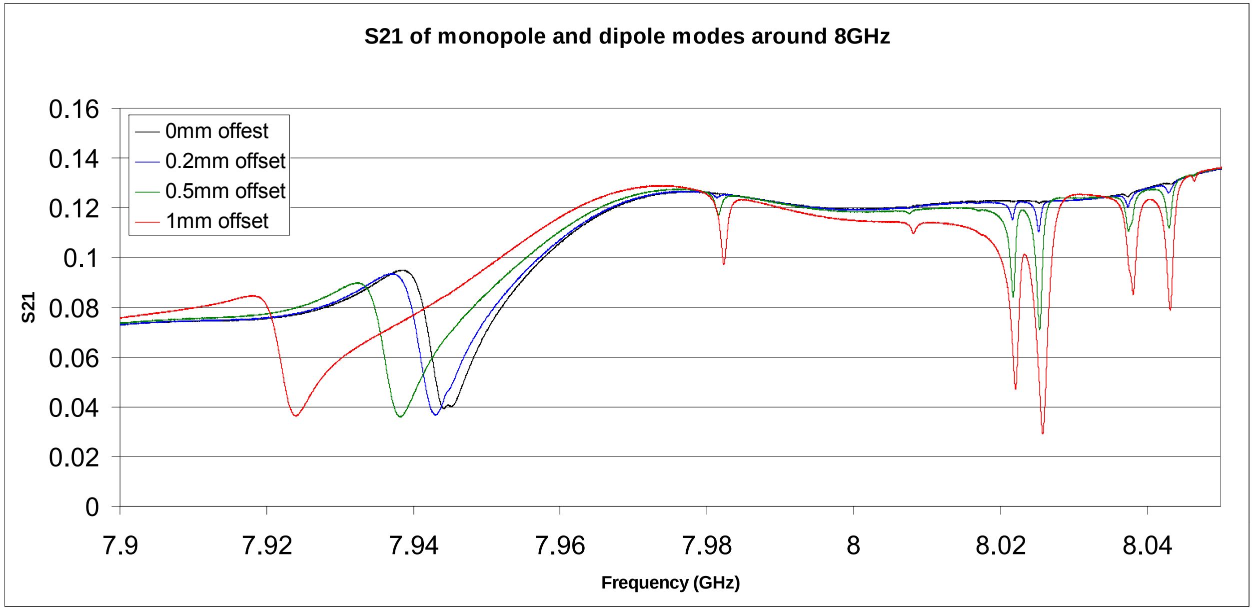
Wire tests

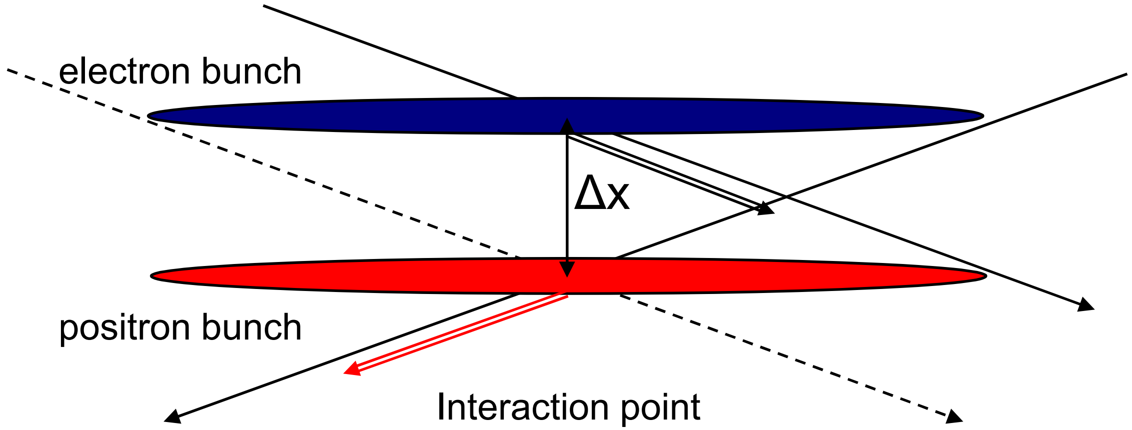


Our team has significant experience in cold testing cavities, including the ILC crab cavity and the NLC accelerating structures.



LLRF tolerances and system

Crabbed crossing angle with phase jitter



For a 20 mrad crossing timing tolerance is ~3.5 fs .

- Hybrid digital-analogue system
- Digital for train to train effect (Synergetic with ILC)
- Analogue for fast control

- Interferometer required between cavities
- Synergetic with ILC development

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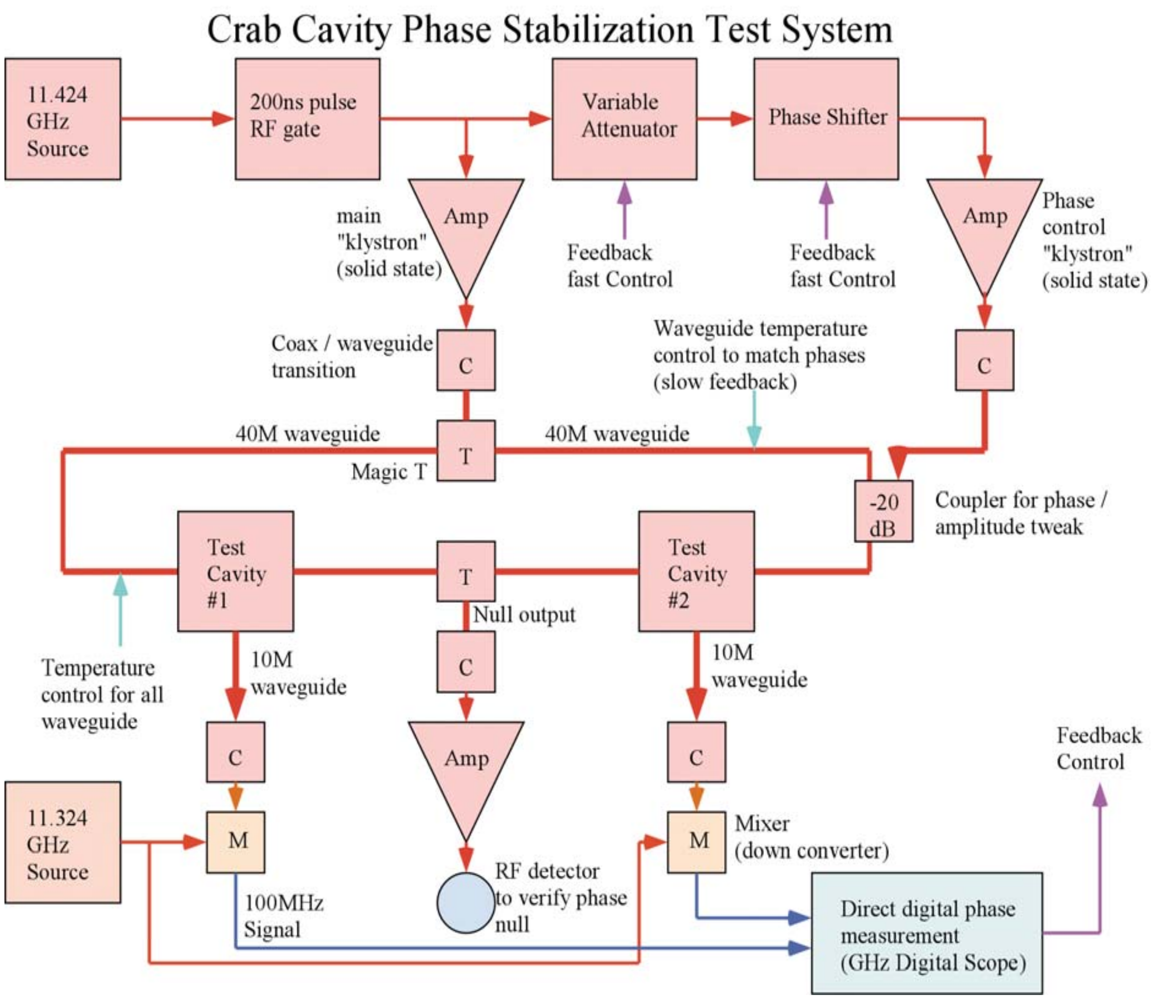
NLC phase synchronisation proposal

No significant work was undertaken!



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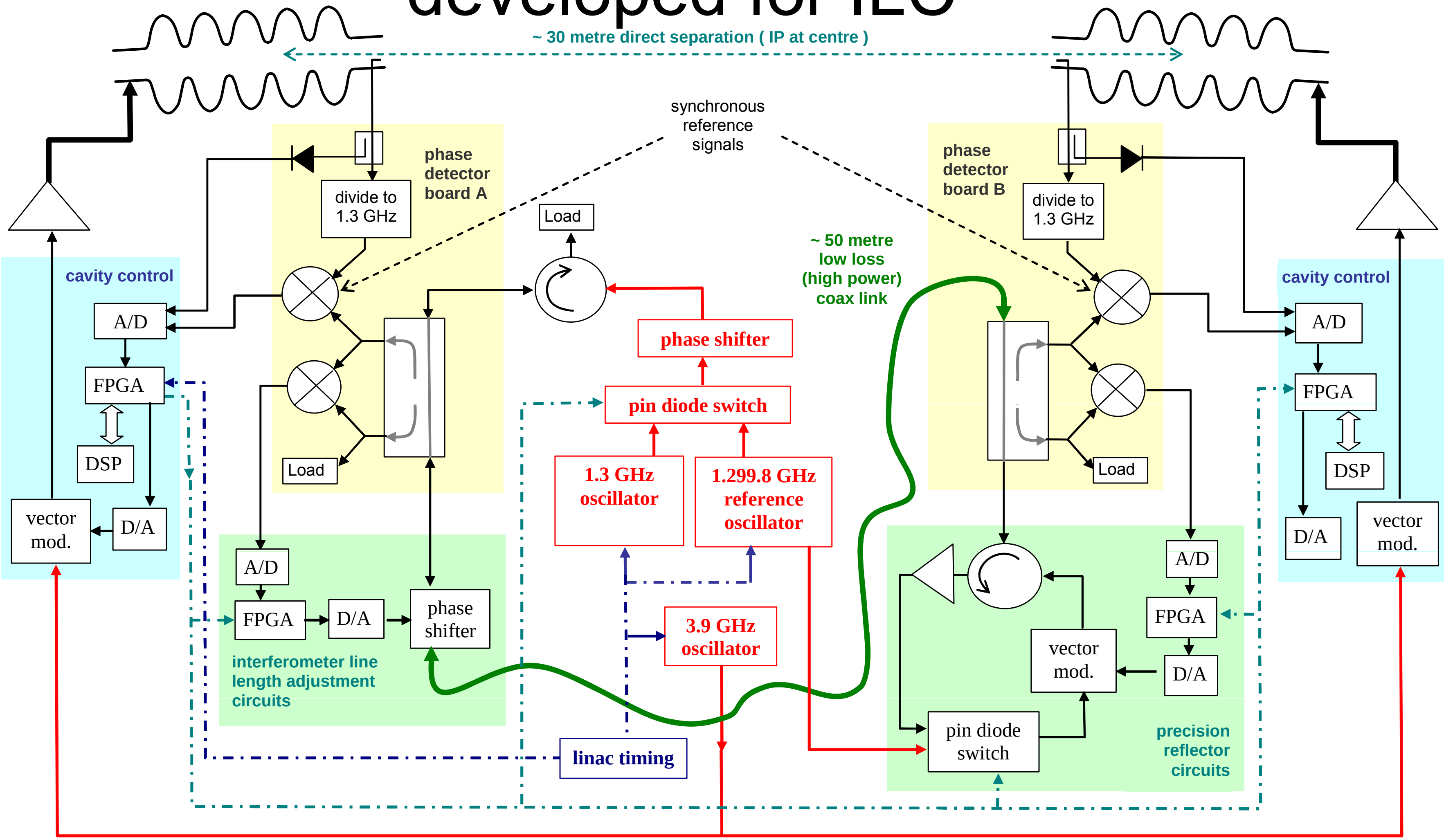
J. Frisch

CLIC workshop October 2007

Interferometer Scheme being developed for ILC



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Synergy with the ILC

Cockcroft funded RA from Nov 07 to work on CLIC Crab

Tasks, science and R&D common with ILC funded program

- Interferometer
- Klystron modelling
- Phase control simulation software
- Some LLRF control hardware
- Roll tuner
- Active Feedback on SOM
- Wire measurements and beadpull
- Modelling effects in PLACET

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Crab Cavity Workplan

- Task 1: Cavity and Coupler design and cold test.
- Task 2: Phase Control system and interferometer development.
- Task 3: Simulate Crab cavity and main linac wakefields.
- Task 4: Test cavity at CTF3 at full power with beam.

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APPENDIX

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Kick for 3 TeV CM

To minimise required cavity kick R12 needs to be large hence put the cavity close to IP (25 metres suggested)

For 20 mrad crossing and using as 12 GHz structure

$$V_{max} = \frac{\theta_r E_o c}{R_{12}\omega} = \frac{10^{-2} \times 1.5 \times 10^{12} \times 3 \times 10^{8}}{25 \times 2\pi \times 12 \times 10^{12}} = 2.4\text{MV}$$

As vertical kicks caused by unwanted modes in the cavity are dangerous one would like R34 to be small.

Key Equations

Luminosity reduction factor
(Consequence of no crab cavity)

$$= \left\{ 1 + \left(\frac{\sigma_z \theta_c}{2\sigma_x} \right)^2 \right\}^{-0.5}$$

Relation between displacement at ip
and transverse kick at the crab cavity

$$x_{ip} = R_{12} x'_c = \sqrt{\beta_{ip}} \sqrt{\beta_{crab} - \beta_o}\; x'_c$$

Kick depends on relative time of arrival t
(note voltage kick defined from eV=pc)

$$x'_c = \frac{\Delta p}{mc} = \frac{V_{max}}{E_o} \sin(\omega t)$$

Displacement for late
arrival at time t_o

$$\Delta x_{ip} = R_{12} \frac{V_{max}}{E_o} \sin(\omega t)$$

Kick voltage V_{max} required from system to
achieve a rotation angle of θ_o is given by

$$\theta_r = \frac{\Delta x_{ip}}{\sigma_z} \cong R_{12} \frac{V_{max}}{E_o} \frac{\omega}{c}$$

CLIC Crab Cavity Work Plan

First objective

Establish and verify prototype designs
for the CLIC crab cavity system,
its high power RF drive,
the synchronisation technology.

Second objective

take a prototype crab cavity system to CTF3,
test it operating as part of the linac

Third objective

Ensure that the system including the crab cavity can continue
to meet the luminosity specification taking full account of linac and
beam delivery system wakefields.

In parallel with this work the means to damp and control wake-fields in the main linac will be explored.

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Task 1 - Cavity Development

1.1 Travelling Wave Cavity design

1.2 Input coupler design

1.3 Manufacture and test prototype stacks

1.4 Manufacture and low power tests of full structure

Testing includes, cavity tuning, matching couplers and bead pull to determine mode frequencies and field flatness.

Our fabrication requirements will be synergetic with the fabrication demands of the main linac and our fabrication effort will be strongly intermeshed with the CLIC main linac development program/team.

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Task 2 Wakefield and Beam Dynamic Studies

2.1 Simulation of crab wakefields and design of damping

2.2 Study of manufacturing tolerances on wakefield and phase stability performance

2.3 Beam dynamic simulation and emittance dilution in crab cavity

2.4 Main linac wakefield simulation

2.5 Beam dynamic simulation of emittance dilution and BBU for main linac

2.6 Stretched wire measurements to probe HOMs in the crab cavity and main linac.

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Task 3 LLRF development

3.1 Develop phase control concepts.

3.2 Performance simulation of possible CLIC crab cavity LLRF systems.

3.3 Develop and test phase control components.

3.3 Provision of control system for cavities at CTF3.

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Task 4 Testing at CTF3

4.1 High power tests on crab cavity

4.2 Measure cavity wakefields
(May not be possible at CTF3 but is at ASSeT SLAC)

4.3 Measure deflection of a beam by
a single cavity at CTF3

4.4 Test phase stability of two crab cavities
(Due in follow on project)

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Anticipated Contribution from CERN

to collaborate on the iterative design of the X-band accelerating cavities with a view to minimising both electrical breakdown and wake-fields

to provide high power RF to drive X band cavities.

to provide services such as cooling water for cavity etc..

to install cavity with assistance as required from CI

to provide instrumentation on beam to measure deflection

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