ILC BDS-EDR Kick-off Meeting

Crab Cavity System Optimisation and EDR Planning

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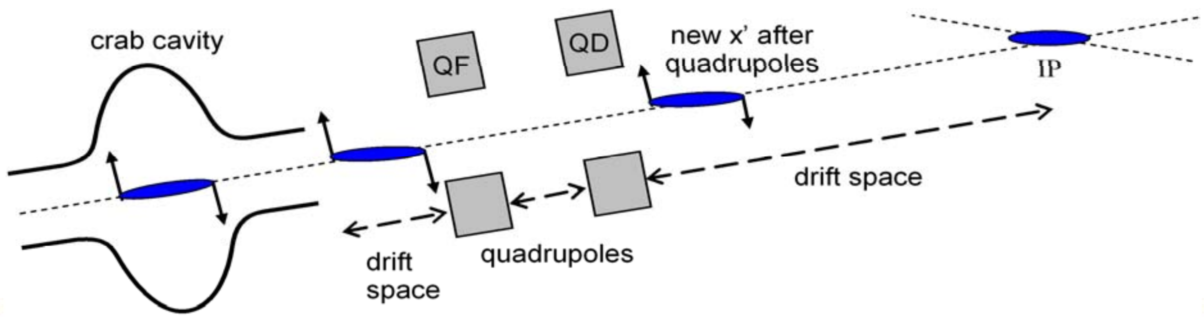
Crab System Specifications

Crossing angle	14 mrad
Number of cryovessels per IP	2
Number of 9-cell cavities per cryovessel	2
Required bunch rotation , mrad	7
Location of crab cavities from the corresponding IP, m	13.4 – 17.4
Longitudinal space allocated per cryovessel, m	3.8
RMS Relative Phase Stability, deg	0.095
RMS Beam Energy Jitter, %	0.33
X offset at IP due to crab cavity angle (R12), m/rad	16.3
Y offset at IP due to crab cavity angle (R12), m/rad	2.4
Amplitude at 1TeV CM, MV	2.64
Max amplitude with operational margin, MV	4.1

- TM_{110} mode dipole cavity.
- e^+ and e^- beams receive transverse momentum kick:
  - **Each bunch rotated to maximise Luminosity at the IP.**
- Crab cavities positioned close to IP @ ~ 15 m.
- Not using the crab cavities loses about 80% of the luminosity.



Key Technical Challanges

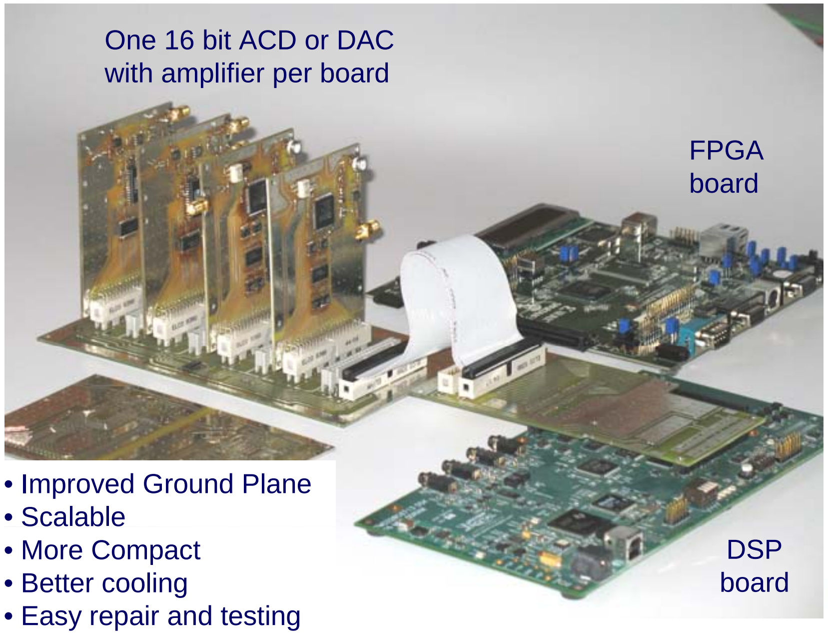
- LLRF and synchronisation stability
- Damping and Couplers:
  - **Input (based on DESY/FNAL 3rd harmonic)**
  - **LOM (multipacting, tuneability, fabrication)**
  - **SOM (very high damping required, tuneability)**
  - **HOM (multipacting, tuneability, fabrication)**
- Tuning
  - **Field polarisation (±1 mrad)**
- Cryomodule:
  - **Microphonics rejection (RF power overhead, LLRF control)**
  - **Cavity alignment (6 nm vertical beam size at IP)**
  - **ILC installation constraints (extraction beamline ~18 cm away)**
- Beam test verification:
  - **Verify cavity/wakefield design (single cavity)**
  - **Verify LLRF and synchronisation stability (single/dual cavity)**
  - **Verify crabbing field polarisation (single/dual cavity)**

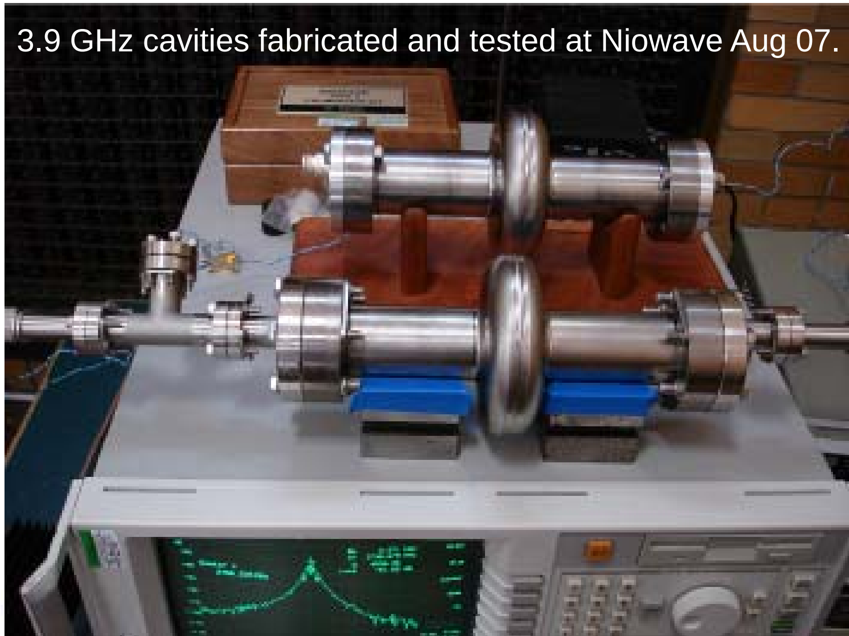
LLRF and Synchronisation

- Bunch-RF phase error in a crab cavity causes unwanted centre-of-mass kick.
- Providing both crab cavities are phase balanced, can compensate these COM kicks.
- Crab cavity zero crossings need synchronisation to 94 fs for the 2 % luminosity loss budget.
- A crab cavity to crab cavity timing error of 250 fs loses about 30% of the luminosity.
- Main linac timing requirement is nominally 0.1^{o} at 1.3 GHz or ~ 200 fs and hence cannot be relied upon directly to provide timing signals for the crab cavities.

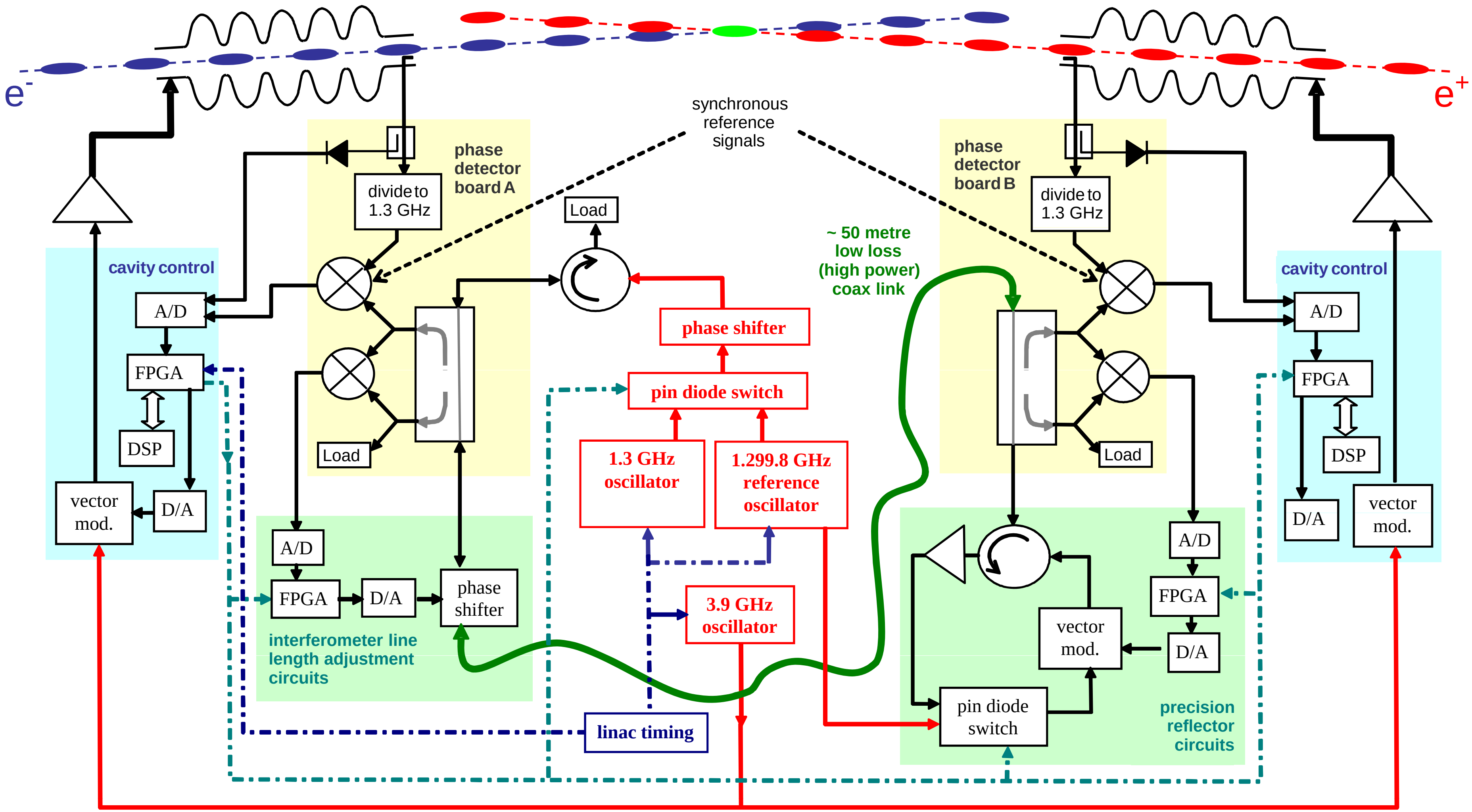
Proposed LLRF/Synchronisation System

- The phase of the field in each cavity is sampled, compared to the timing reference and the error sent to a digital signal processor (DSP) to determine how the input signal must be varied to eliminate the error.
- Provide an interferometer between each crab cavity so that the same cavity clock signal is available at both systems.
- 16-bit DAC/ADC architecture (high resolution).
- Scheduled to test system with 2 x single-cell SRF 3.9 GHz cavities in Jan 08.

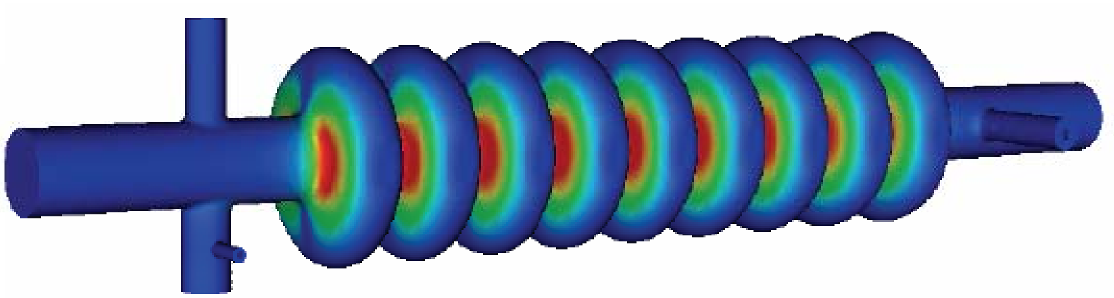


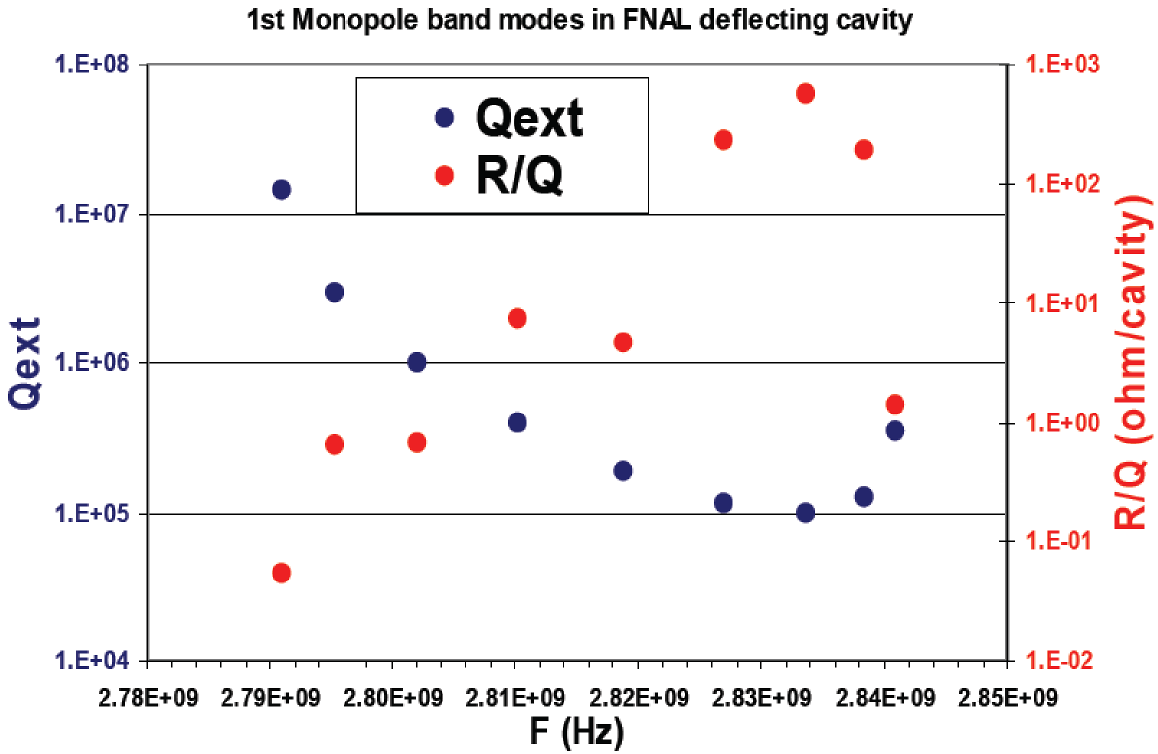

3.9 GHz cavities fabricated and tested at Niowave Aug 07.

LLRF and Synchronisation Topology



Coupler Development

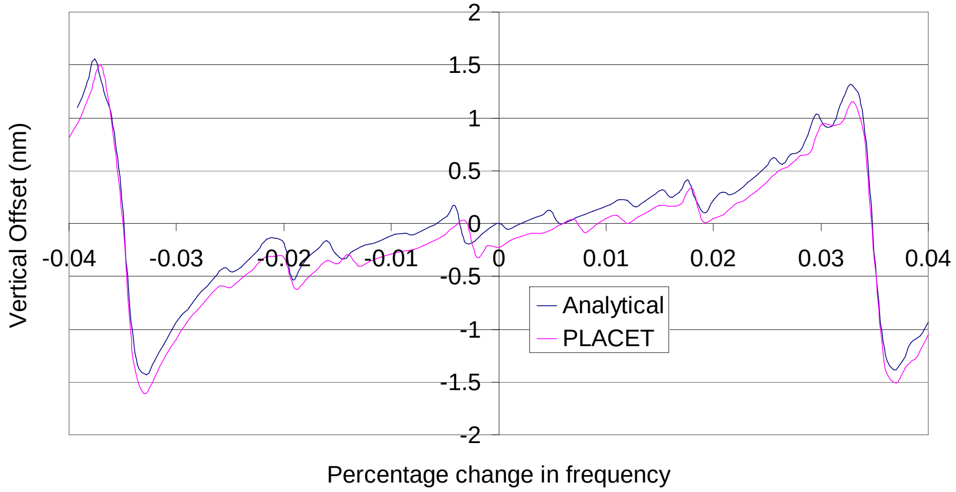




- SLAC design for HOM and LOM couplers and Cockcroft Institute SOM and Power coupler designs used in prototypes.
- Cockcroft design for integrated SOM/LOM coupler will be evaluated by FNAL Engineers.
- Copper prototype testing will commence this month at Daresbury.

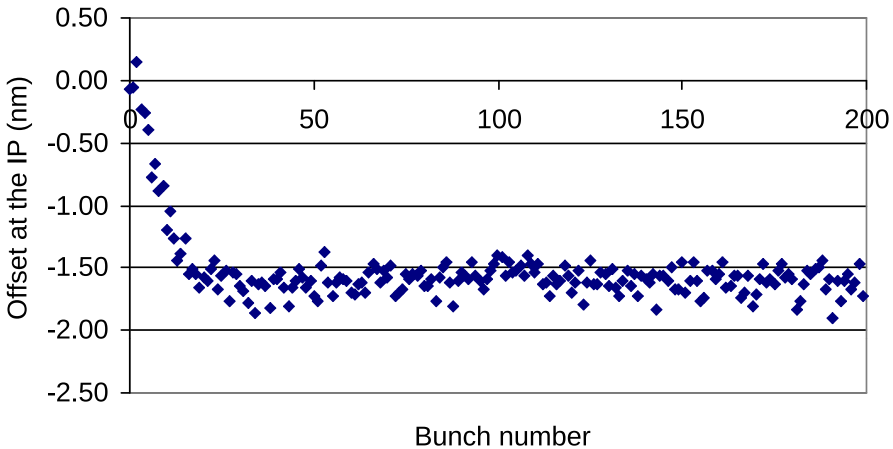
Wakefield Summary

- A 9-cell SRF cavity design developed to achieve ILC specs.
- 35 µm vertical offset at cavity with nominal ILC parameters.



- The PLACET results show when the damping tolerances are met the maximum vertical offset is 1.5 nm.

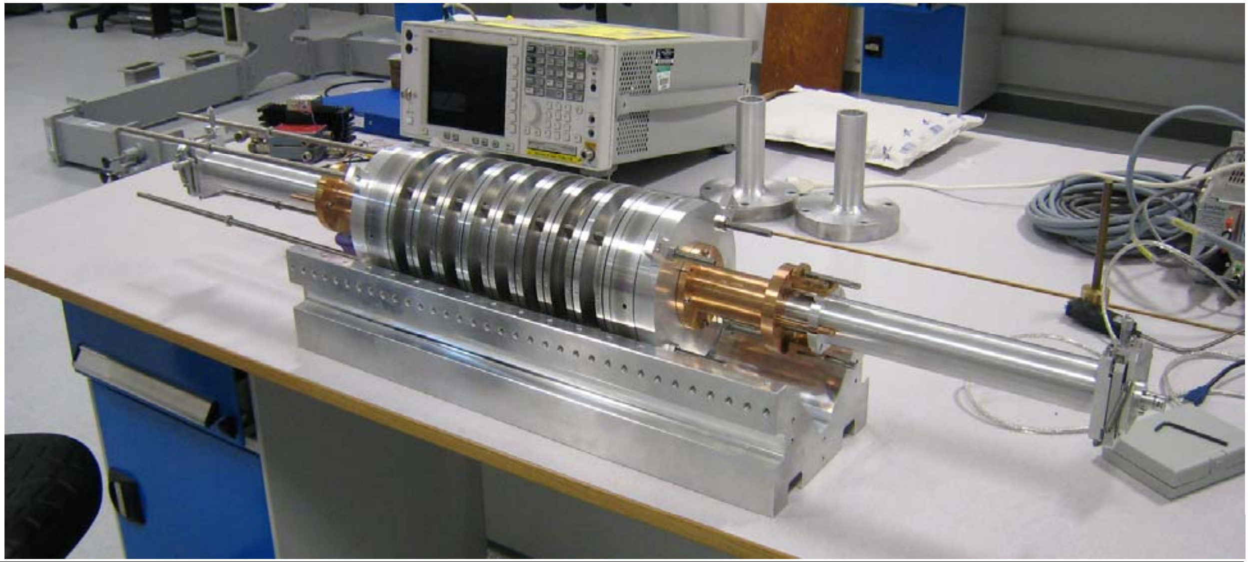
- The results give good agreement with the previous analytical results, and show little emittance growth.

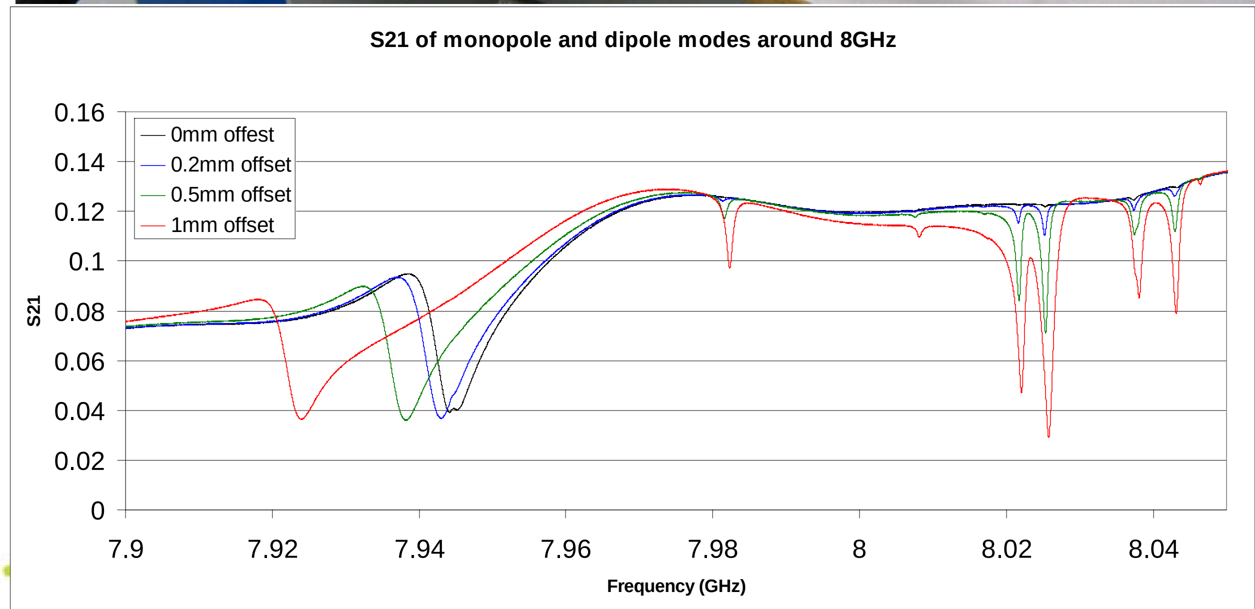


Wakefield Summary (cont'd)

- The proposed 9-cell crab cavity has been simulated using MAFIA and Omega 3P:
  - **All modes to 18 GHz identified.**
  - **R/Qs calculated.**
  - **Mode damping requirements determined from analytical and PLACET wakefield analysis.**
- All calculated cavity parameters have been confirmed up to 15 GHz with a cold testing program of bead pull and stretched wire measurements.

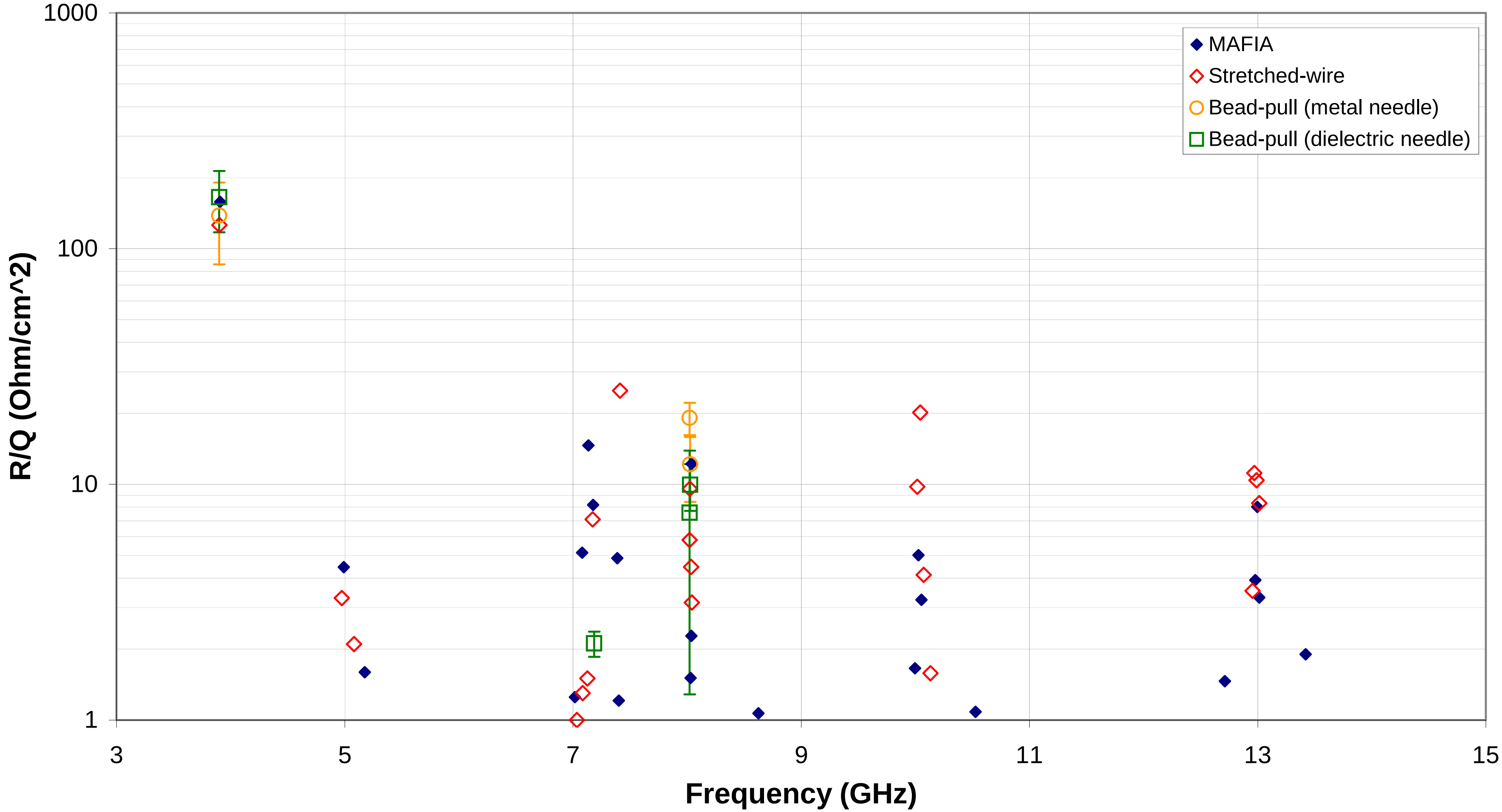
Wakefield Summary (cont'd)





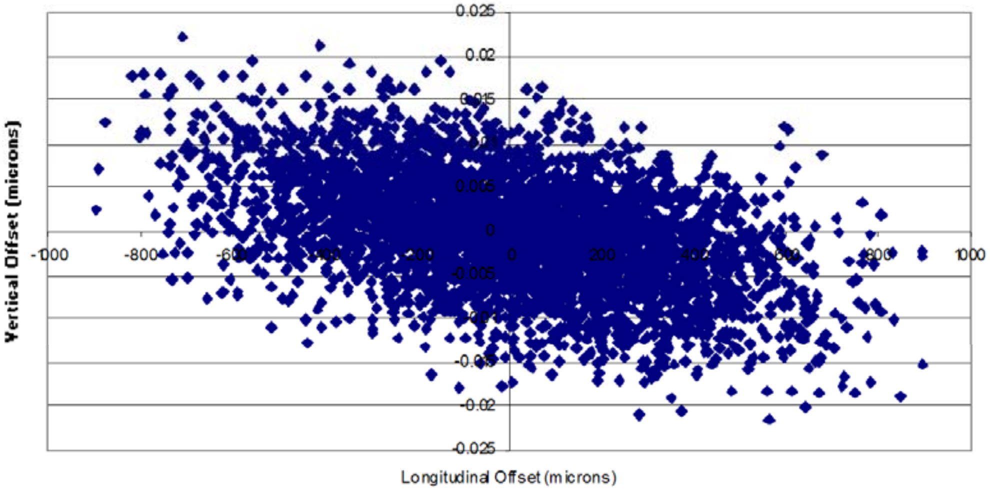
Mode Measurements

Dipole mode R/Q calculated by MAFIA compared to measurements



Crabbing Field Polarisation

- If the crab cavity isn't aligned properly it will cause a spurious vertical crabbing effect.

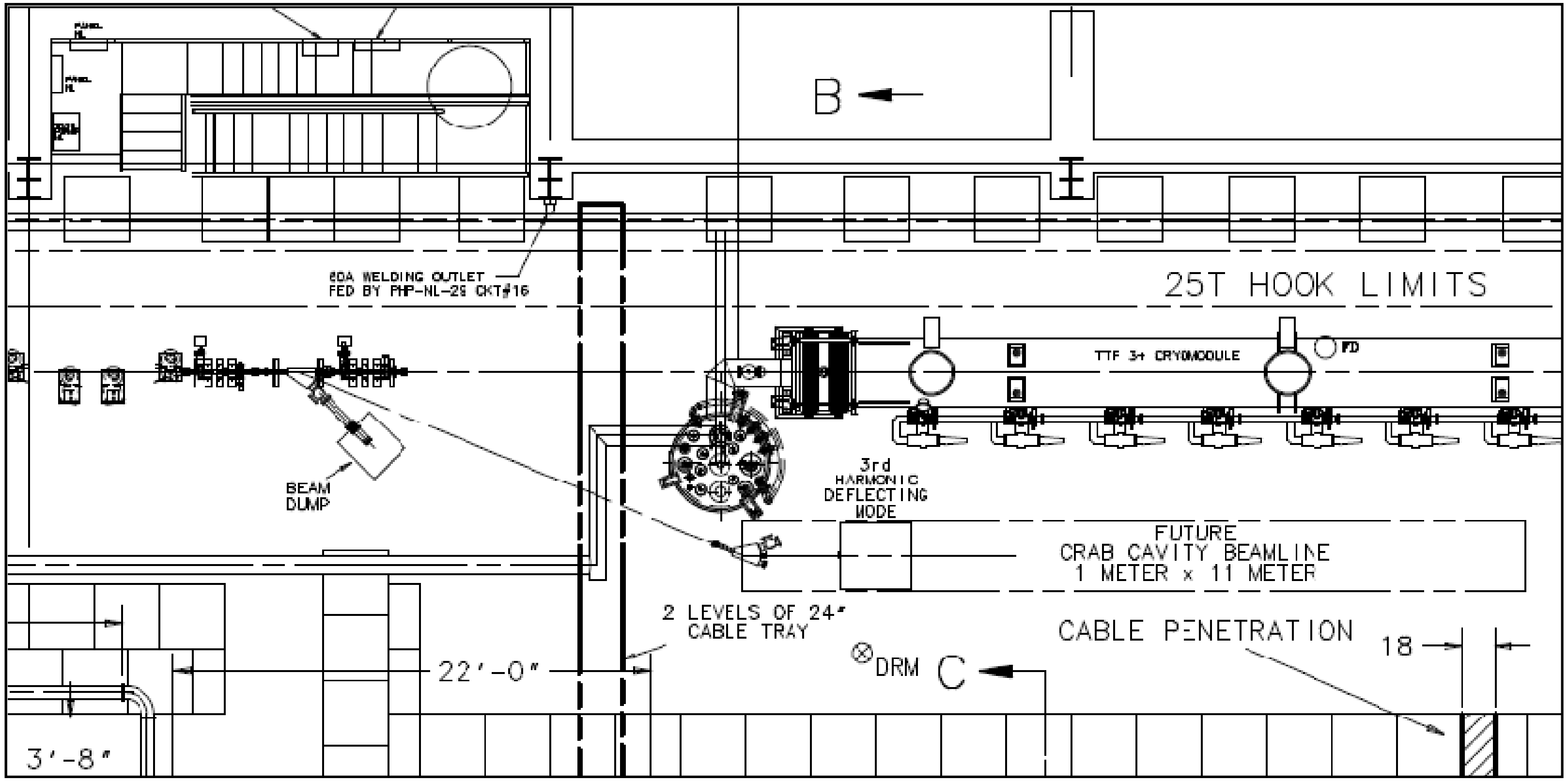


- Need an alignment tolerance of better than ±1 mrad!
- Can employ:
  - **Reduce fabrication tolerances (costly/difficult)**
  - **Provide field polarisation adjustment mechanically in the cryomodule (not obviously easy)**
  - **Utilise an additional dipole cavity (single-cell) to compensate for this effect.**

ED Crab Cavity System Tests

- Prototyping and testing without beam would:
  - **Verify cavity design and manufacturability.**
  - **Resistance to multipacting.**
  - **Verify modes, Qs and wakefields via bead-pull and stretched wire measurements.**
  - **Assess CKM-style cold tuner, power coupler.**
- Tests of a single cavity with beam on ILCTA would:
  - **Verify cavity (long and short range) wakefields as a function of beam offset.**
  - **Assess beamloading.**
  - **Verify mode coupler power handling capability, 2nd Qe study.**
  - **Verify bunch to single cavity timing stability.**
  - **Allow for measurement of beam profile (long and trans)**
  - **Determine microphonics sensitivity and impact on LLRF control.**
  - **Provide operational experience.**
- Tests of two cavities with beam on ILCTA would:
  - **Verify the requirement to parasitic vertical crab effect is met (dipole field polarisation stability).**
  - **Verify stability of phase balance between 2 crab cavities.**
  - **Verify the compensation of parasitic COM kicks is met.**
  - **Full system microphonics sensitivity.**

ILCTA Provisions



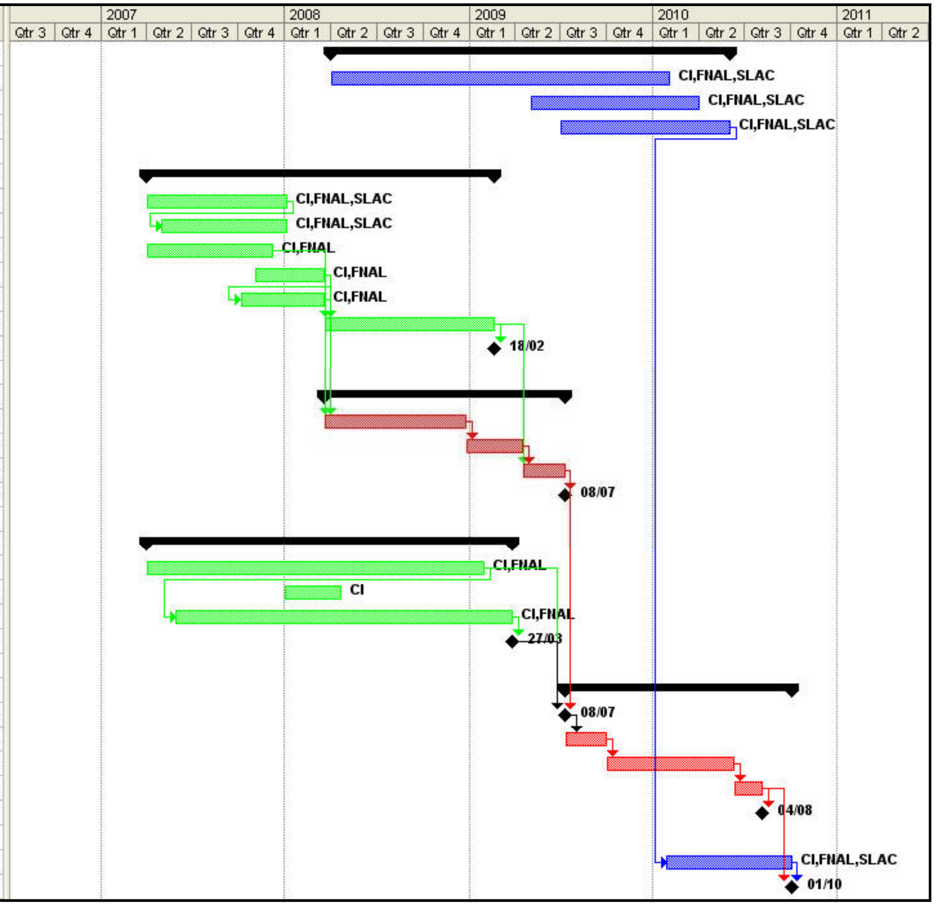
- ILCTA (FNAL NML) will have an isochronous dogleg (40 MeV) to a second beamline for crab system testing.

EDR Goals (ED PM Plan)

- Demonstrate that all major accelerator components can be engineered to meet the required ILC performance specifications.
- Provide an overall design such that machine construction could start within 2 - 3 years if the project is approved and funded.
- Mitigate technical risks by providing viable documented fallback solutions with estimates of their costs.
- Develop a detailed project execution plan.
- Limit options and focus R&D and industrialization efforts on those issues where technical decisions are not yet final.
- Design the conventional construction and site-specific infrastructure in enough detail to provide the information needed to allow potential host regions to estimate the technical and financial risks of hosting the machine, including local impact, required host infrastructure, and surface and underground footprints.
- Provide a complete value cost estimate.

Preliminary Crab System ED Plan

Task Name	Duration	Start	Finish
Project Management	**566 days**	**Tue 01/04/08**	**Tue 01/06/10**
Value Engineering	24 mons	Tue 01/04/08	Mon 01/02/10
Construction schedule and Resource Profile	12 mons	Fri 01/05/09	Thu 01/04/10
Project Implementation Plan	12 mons	Wed 01/07/09	Tue 01/06/10
WP1: Crab Cavity Design	**493 days**	**Mon 02/04/07**	**Wed 18/02/09**
Cavity Design	10 mons	Mon 02/04/07	Fri 04/01/08
HOM/LOM/SOM Coupler Designs	9 mons	Mon 30/04/07	Fri 04/01/08
Input Coupler Design	9 mons	Mon 02/04/07	Fri 07/12/07
Frequency Tuner Design	5 mons	Thu 01/11/07	Wed 19/03/08
Field Polarisation Compensation	6 mons	Thu 04/10/07	Wed 19/03/08
Fabricate Cavity System	12 mons	Thu 20/03/08	Wed 18/02/09
Cavity Components Available	0 days	Wed 18/02/09	Wed 18/02/09
WP2: Cryomodule Design	**340 days**	**Thu 20/03/08**	**Wed 08/07/09**
Cryomodule Design	10 mons	Thu 20/03/08	Wed 24/12/08
Fabricate Cryomodule	4 mons	Thu 25/12/08	Wed 15/04/09
Integrate cavity into cryomodule	3 mons	Thu 16/04/09	Wed 08/07/09
Integrated Cryomodule Available	0 days	Wed 08/07/09	Wed 08/07/09
WP3: LLRF and Synchronisation	**520 days**	**Mon 02/04/07**	**Fri 27/03/09**
LLRF System Design	24 mons	Mon 02/04/07	Fri 30/01/09
Complete LLRF synchronisation tests with single cell SRF cavities	4 mons	Tue 01/01/08	Mon 21/04/08
Synchronisation System Design	24 mons	Mon 28/05/07	Fri 27/03/09
LLRF and Synchronisation System Available	0 days	Fri 27/03/09	Fri 27/03/09
WP4: Best Test Verification	**322 days**	**Wed 08/07/09**	**Fri 01/10/10**
Ship Module to ILCTA	0 mons	Wed 08/07/09	Wed 08/07/09
Install Module Infrastructure	3 mons	Thu 09/07/09	Wed 30/09/09
Complete Beam Tests	9 mons	Thu 01/10/09	Wed 09/06/10
Document System Performance	2 mons	Thu 10/06/10	Wed 04/08/10
ILC Crab Cavity System Verified	0 days	Wed 04/08/10	Wed 04/08/10
EDR Report	9 mons	Mon 25/01/10	Fri 01/10/10
EDR Report Complete	0 days	Fri 01/10/10	Fri 01/10/10



- Success oriented plan.
- Critical resources needed for cryomodule development:
  - **EDR funding request being initiated at FNAL.**
  - **EU FP7 funding request initiated.**

Crab System ED Deliverables

- WP1: Cavity Design (CI, FNAL and SLAC)
  - **9-cell, 3.9 GHz cavity design**
  - **SOM coupler design**
  - **LOM coupler design**
  - **HOM coupler design**
  - **Frequency tuner design**
  - **Field polarisation tuner design**
  - **Complete Cavity System Fabrication and Verification**
- WP2: Cryomodule Design (No effort as yet!)
  - **Single cavity cryomodule design**
  - **Cryomodule fabrication**
  - **Cavity String Integration**
- WP3: LLRF and Synchronisation (CI and FNAL)
  - **LLRF system design**
  - **Synchronisation system design**
  - **LLRF and Synchronisation System Fabrication and Verification**
- WP4: Beam Test Verification (No effort as yet!)
  - **Full System Verification on ILCTA @ FNAL**
- Look at integrating into BDS WBS structure.

Crab System ED Status

- Cockcroft Institute (UK) is the only funded institute pursuing ILC crab system R&D.
- UK only has funding to fabricate a single crab cavity, its couplers, tuners, the LLRF and synchronisation system.
- FNAL and SLAC are assisting in an unfunded mode at present (vis-à-vis ILC application).
- Critical resources are needed to:
  - **Develop a suitable cryomodule design.**
  - **Fabricate a 2nd crab cavity cryomodule for ILCTA beam test validation of complete system.**
- To successfully deliver a validated system design by Oct 2010, additional funding is required.

EDR Resources Needed

- Cryomodule R&D
  - **Integrate UK ‘dressed’ cavity assembly**
- 2nd Cryomodule
  - **Final cryomodule design**
- High Power RF Components
  - **Klystron/Modulator or SSA, waveguide etc.**
- ILCTA Dogleg components, cryogenics, diagnostics, vacuum pipes, valves, supports, pumps, quads, correctors, BPMs, EO monitor, laser etc.
  - **Included in the FNAL initiative.**

Conclusions

- Crab cavity design well underway:
  - **Simulations have been verified with measurement**
- Coupler designs are ongoing and hope to converge by end 2007.
- LLRF and synchronisation system prototype to be validated in early 08 with SRF cavities.
- For the ED phase:
  - **Resources available to:**
    - Design and build a single, fully ‘dressed’ cavity
    - Develop the LLRF and synchronisation system
  - **Require additional resources to:**
    - Design and build a cryomodule and integrate cavity
    - Build a 2^{nd} cavity/cryomodule
    - Procure high power RF and cryogenic system hardware
    - Install and complete beam test validation on ILCTA