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ILC CC: Design and Test Results

Peter McIntosh
(as part of the ILC CC Design Team)

LHC-CC08 Workshop, BNL
25-26 February 2008



Overview

- ILC CC Collaboration Team
- CC System Specifications
- Key Technical Design Challenges:
 - Cavity Wakefields
 - Coupler Developments
 - Crabbing Polarisation
 - LLRF and Synchronisation
- Beam Testing
- UK ILC Funding Situation
- Summary





ILC Crab Cavity Collaboration Team

- **Cockcroft Institute:**

- Graeme Burt (Lancaster University)
- Richard Carter (Lancaster University)
- Amos Dexter (Lancaster University)
- Philippe Goudket (ASTeC)
- Roger Jones (Manchester University)
- Alex Kalinin (ASTeC)
- Lili Ma (ASTeC)
- Peter McIntosh (ASTeC)
- Imran Tahir (Lancaster University)

- **FNAL:**

- Leo Bellantoni
- Mike Church
- Tim Koeth
- Timergali Khabiboulline
- Sergei Nagaitsev
- Nikolay Solyak

- **SLAC:**

- Chris Adolphson
- Kwok Ko
- Zenghai Li
- Cho Ng
- Andrei Seryi
- Liling Xiao

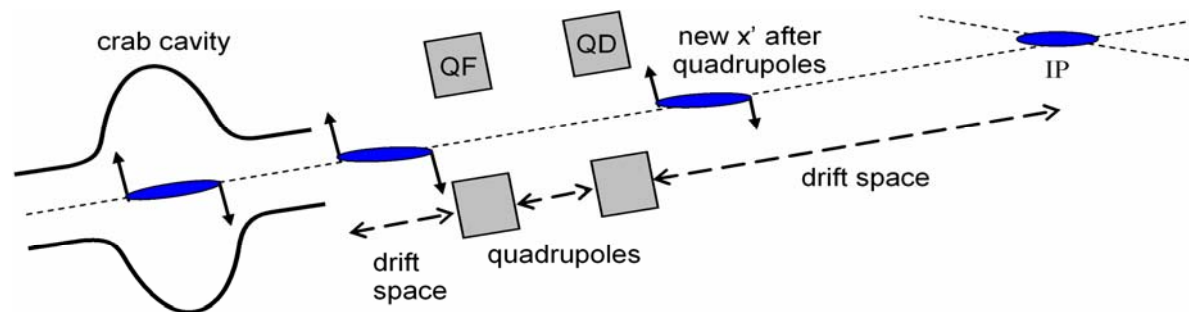




ILC CC System Specification

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 Challenges

- Damping and Couplers:
 - Input (based on DESY/FNAL 3rd harmonic),
 - LOM (multipacting, tuneability, fabrication),
 - SOM (very high damping required, tuneability),
 - HOM (multipacting, tuneability, fabrication).
- Cryomodule:
 - Field polarisation (± 1 mrad),
 - 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 stability.





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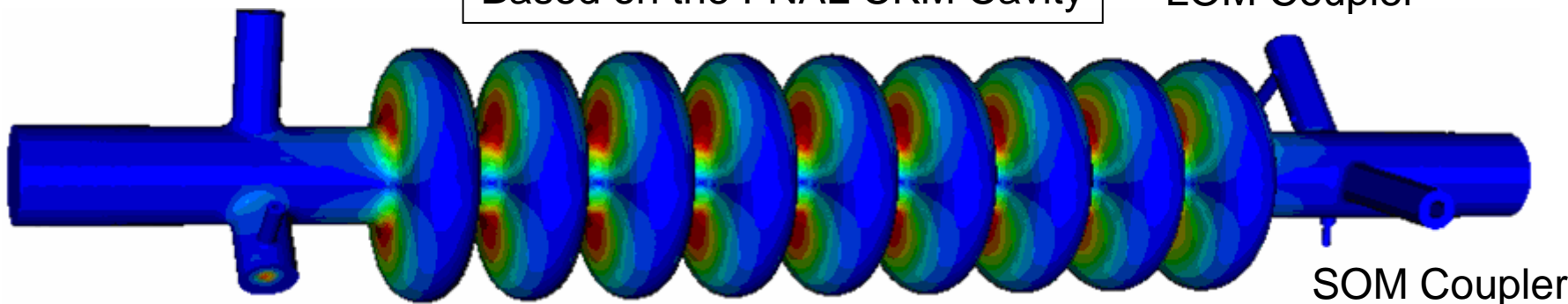
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ILC CC Design

Input Coupler

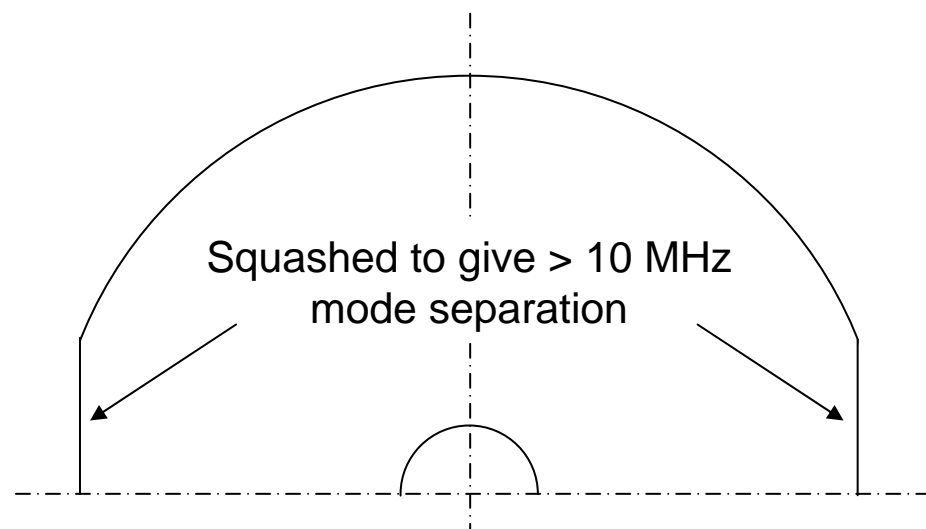
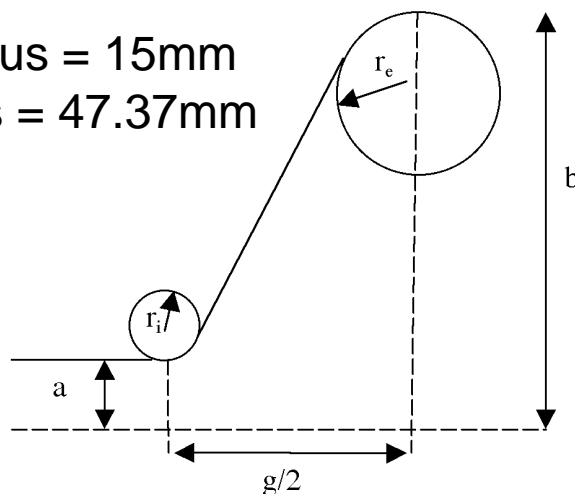
Based on the FNAL CKM Cavity

LOM Coupler



HOM Coupler

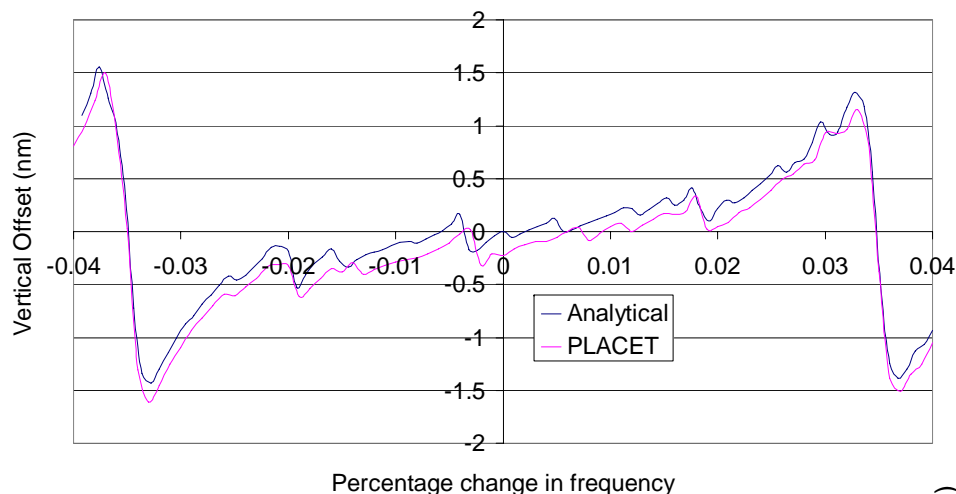
Beam-pipe radius = 15mm
Equator Radius = 47.37mm





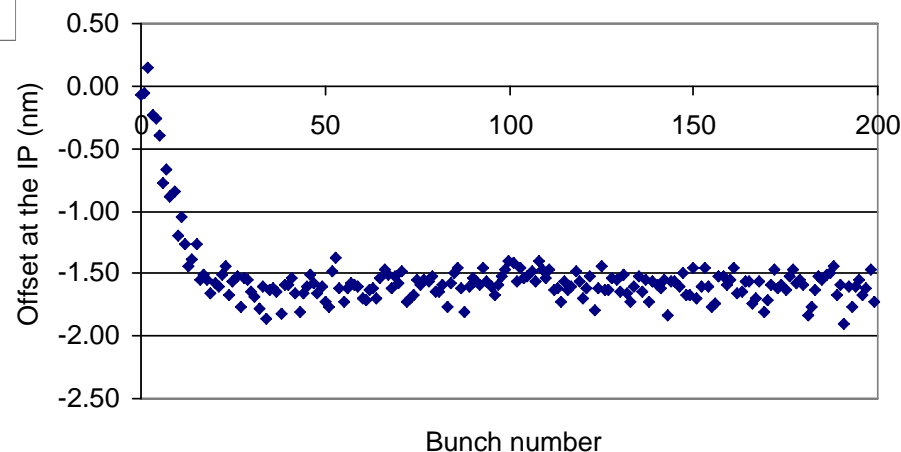
Wakefield Suppression

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



- Gives good agreement with analytical results, and shows little emittance growth.

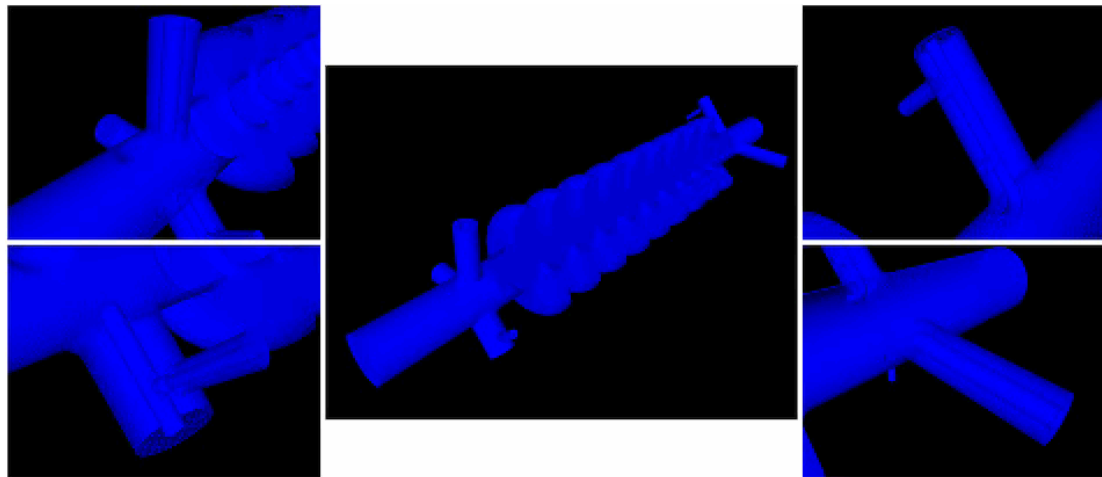
- The PLACET results show when the damping tolerances are met the maximum vertical offset is 1.5 nm.





Wakefield Verification

- 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.

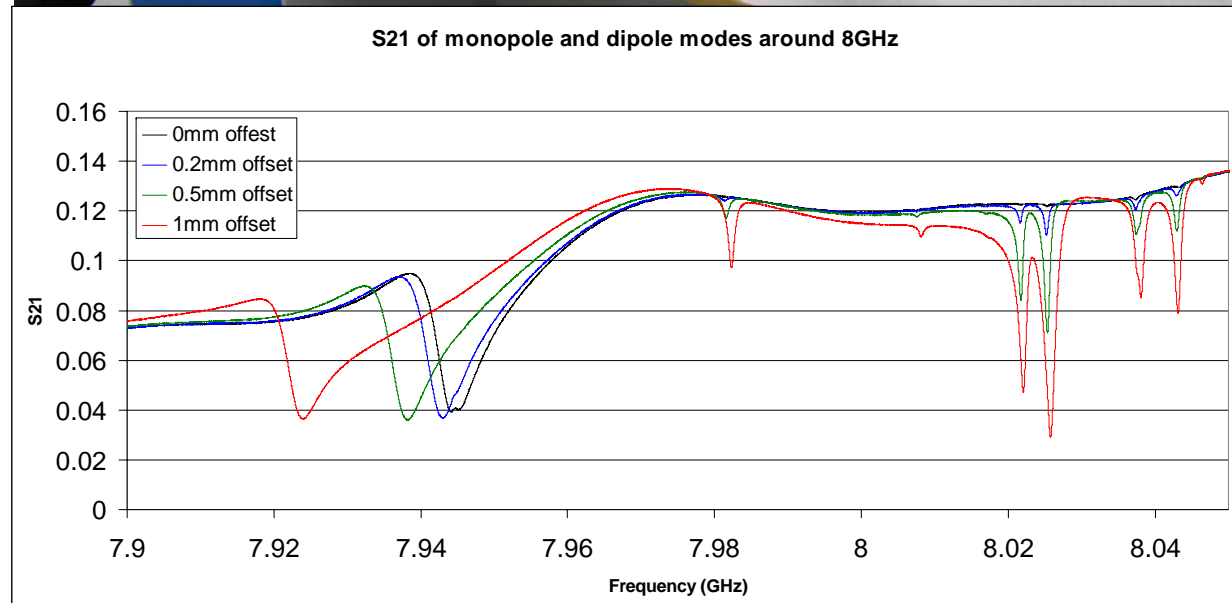
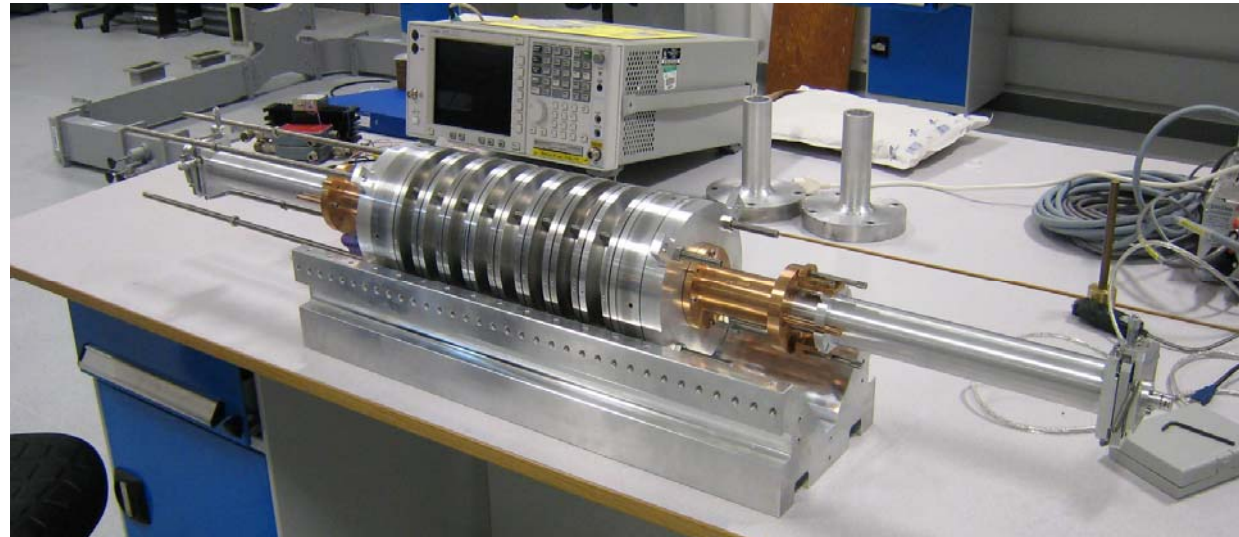




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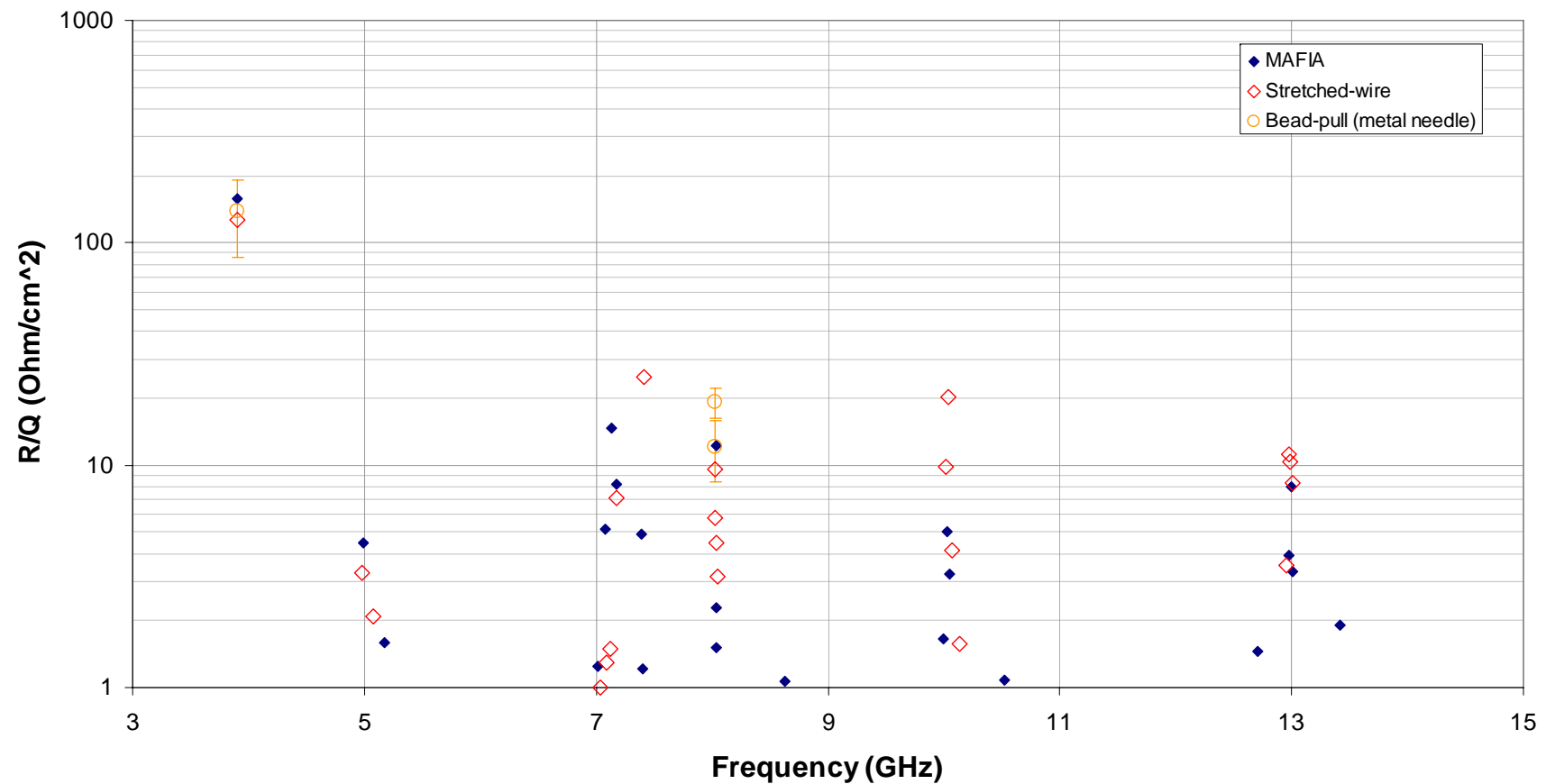
Stretched Wire Characterisation





Mode Measurements

Dipole mode R/Q calculated by MAFIA compared to measurements

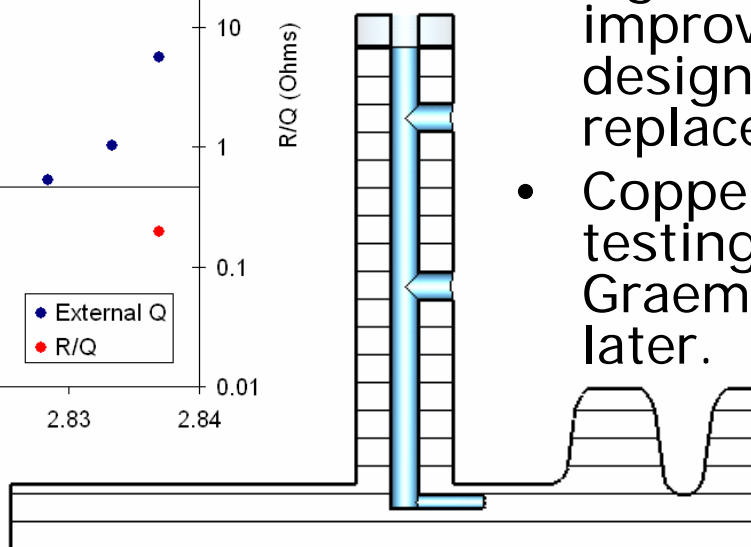
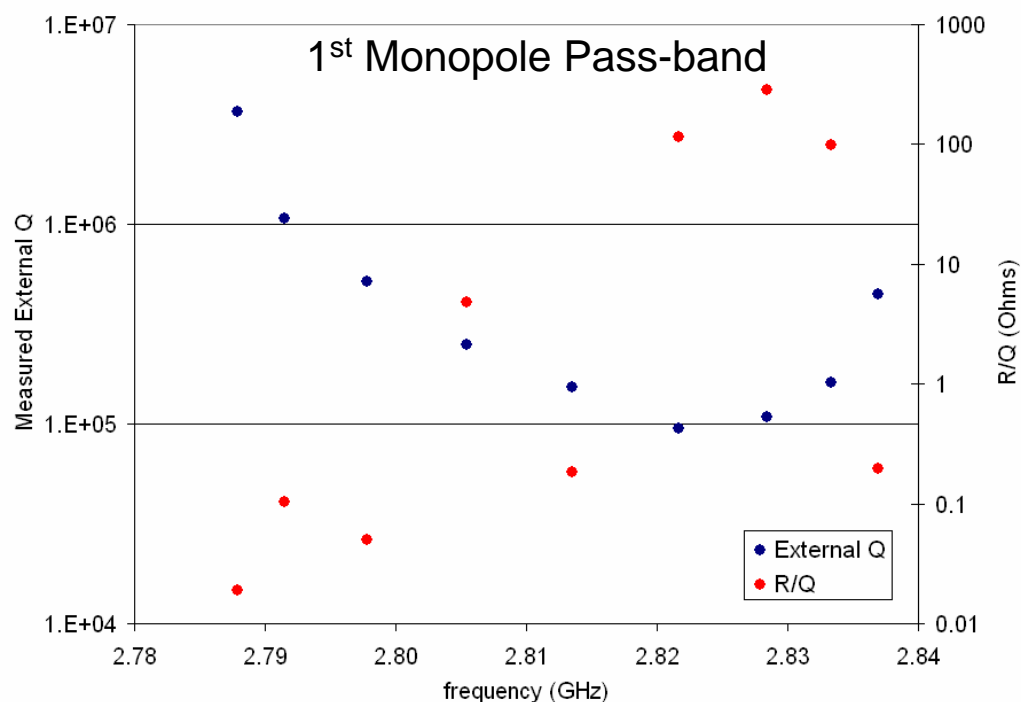
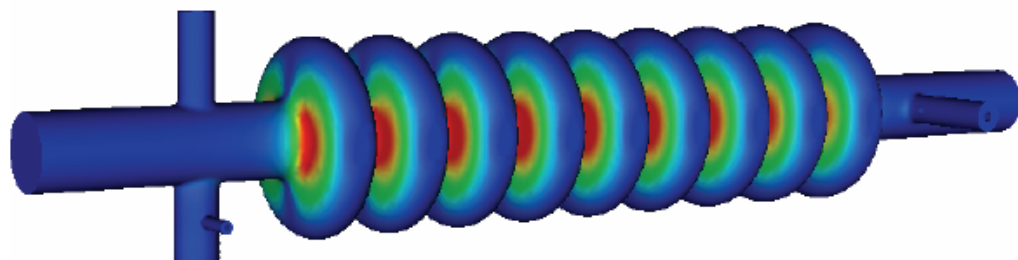




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Coupler Development



- SLAC design for HOM and LOM couplers and Cockcroft Institute SOM and Power coupler designs used in prototypes.
- New Cockcroft design for integrated SOM/LOM coupler is a significant improvement on SLAC designs and will replace them.
- Copper prototype testing is presented in Graeme Burt's talk later.



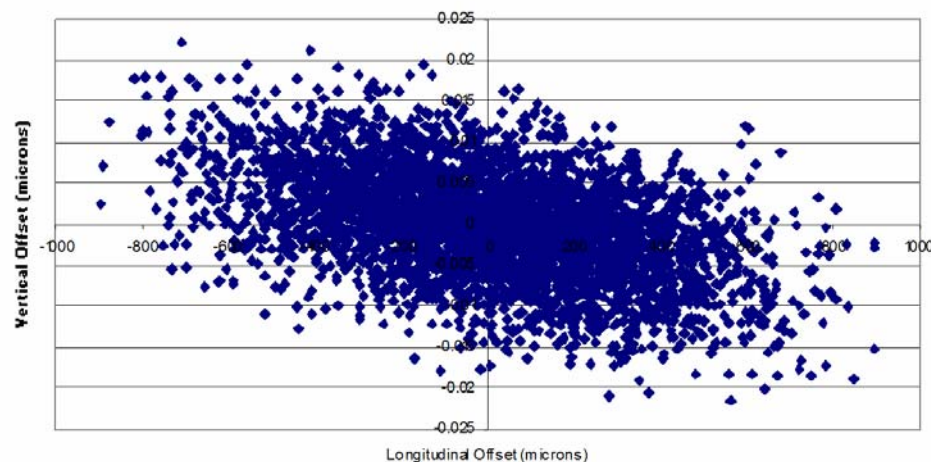
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Crabbing Field Polarisation

- If the crab cavity isn't aligned properly it will cause a spurious vertical crabbing effect (remember $\sigma_v \sim 6\text{nm}$).



- Need a polarisation alignment tolerance of $< \pm 1$ mrad!
- Can employ:
 - Reduced fabrication tolerances (costly),
 - Field polarisation adjustment mechanically in the cryomodule (not easy),
 - An additional dipole cavity (single-cell) to compensate for this effect (preferred).





LLRF and Synchronisation

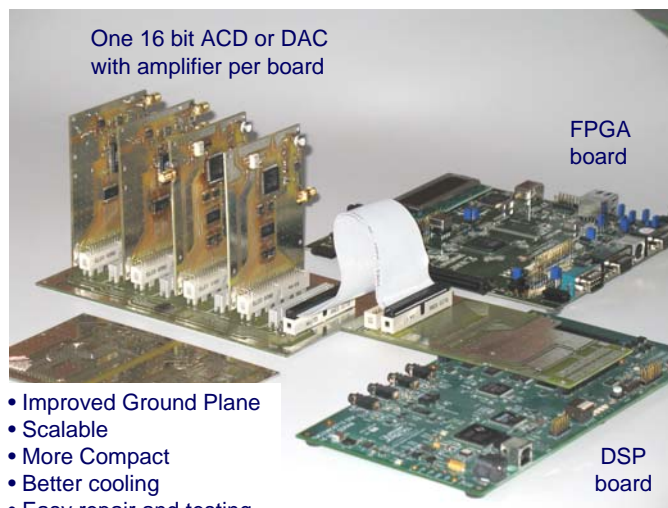
- Bunch-RF phase error in a crab cavity causes unwanted centre-of-mass kick.
- Providing both crab cavities are phase balanced, can compensate these COM kicks.
- ILC crab cavity zero crossings need synchronisation to 94 fs for the 2 % luminosity loss budget.
- A crab cavity to crab cavity timing error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





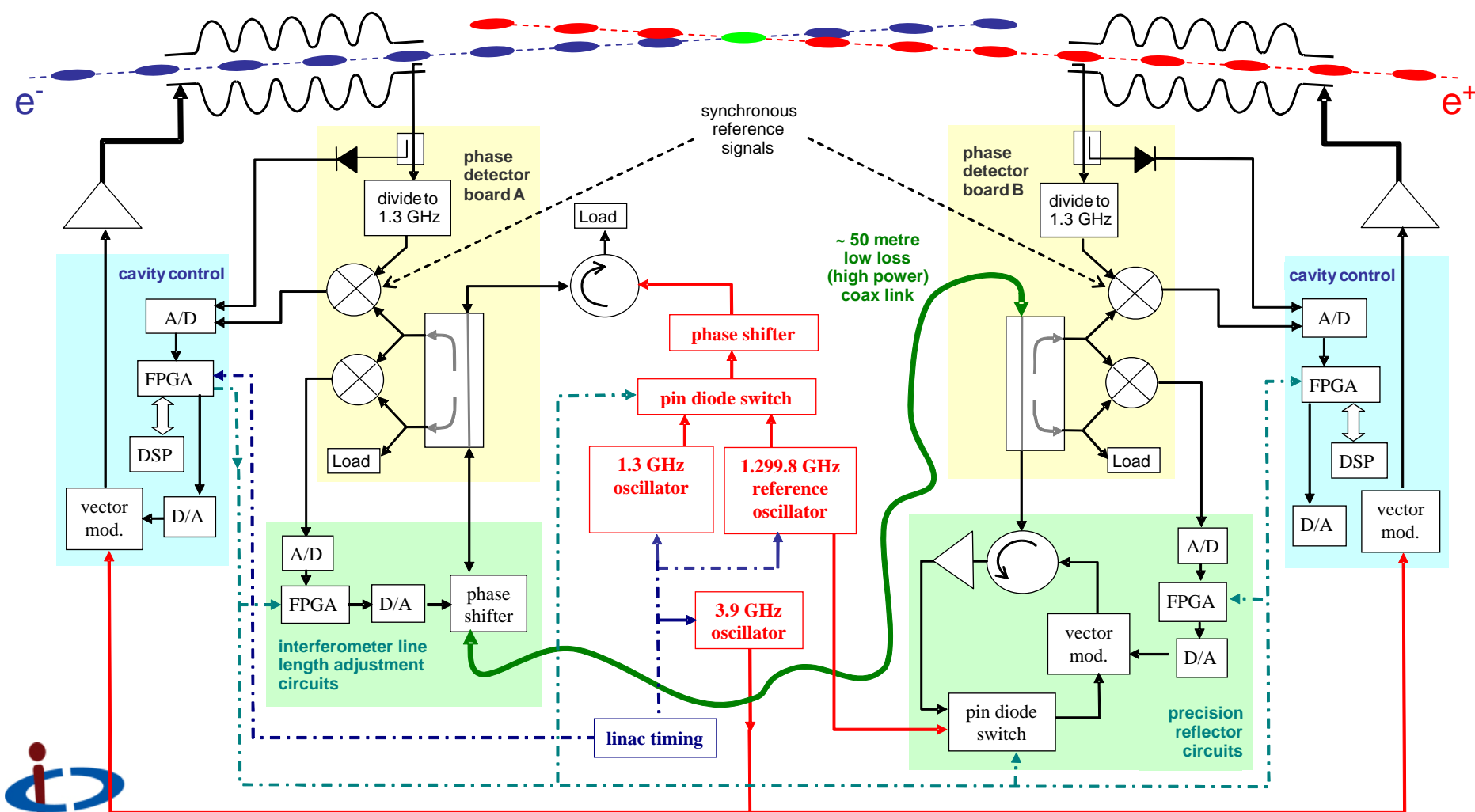
Synchronisation System

- 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 Apr 08.
- See Amos Dexter's talk later.





LLRF/Synchronisation Scheme

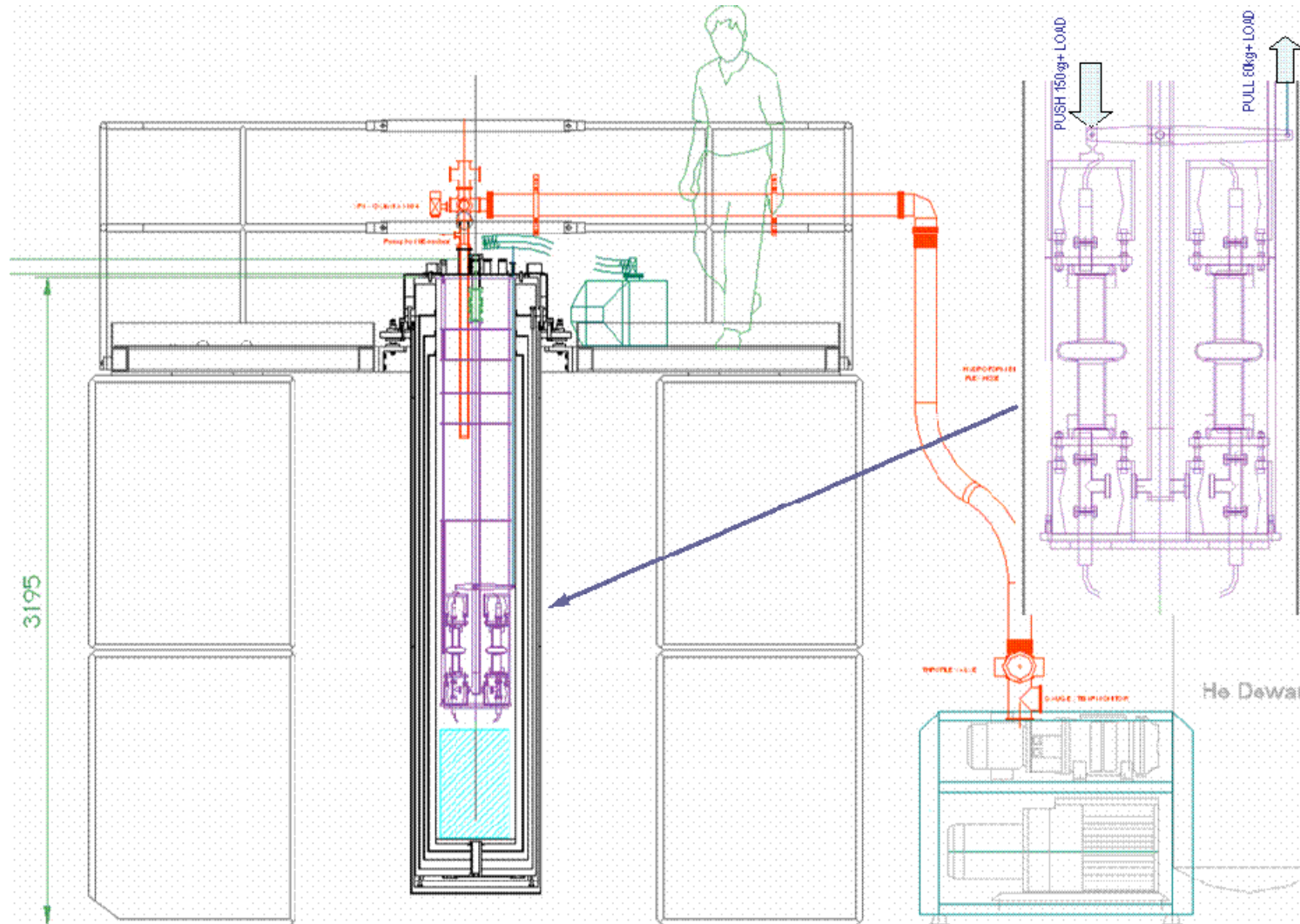




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LLRF and Synchronisation Tests

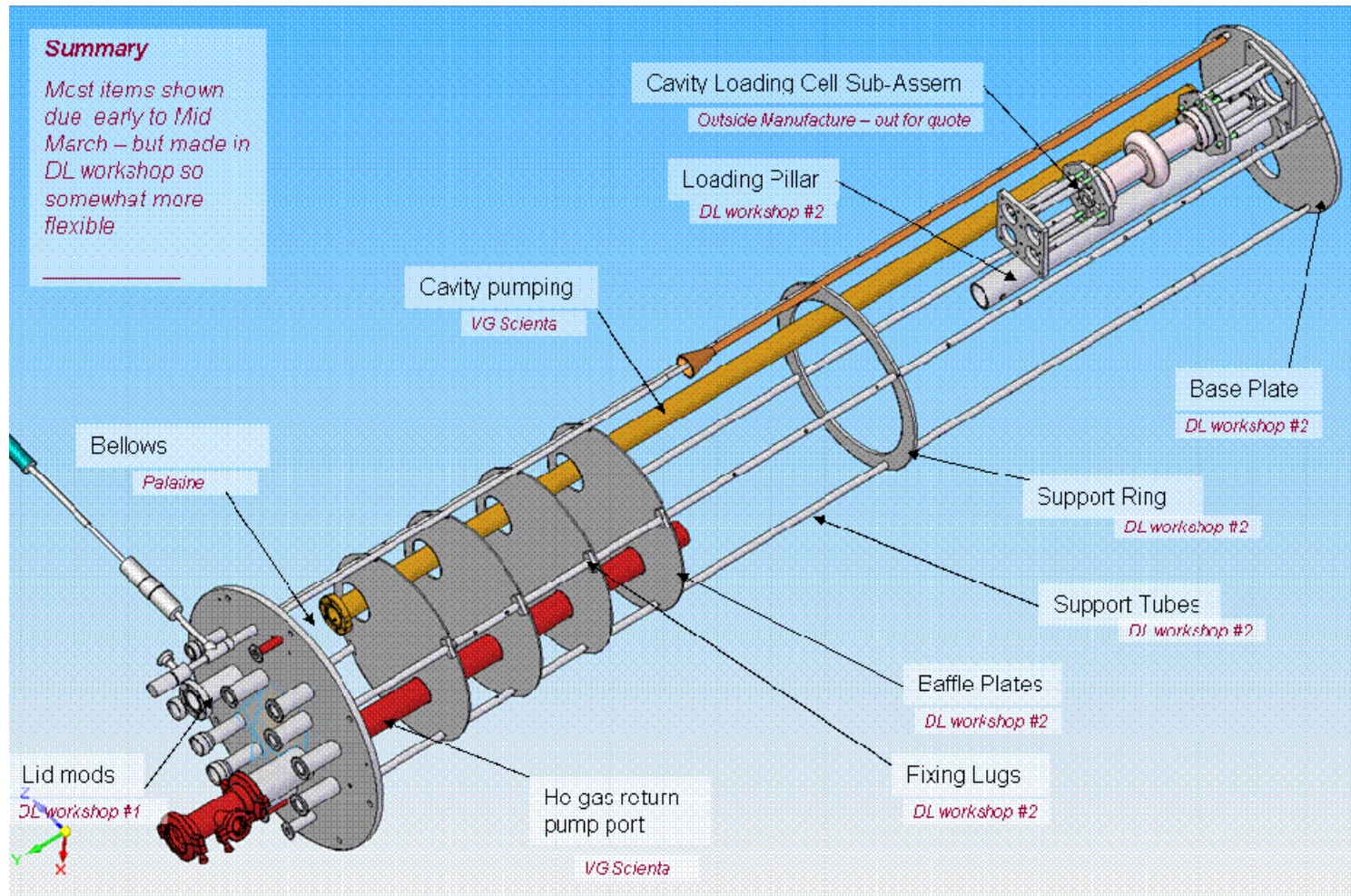


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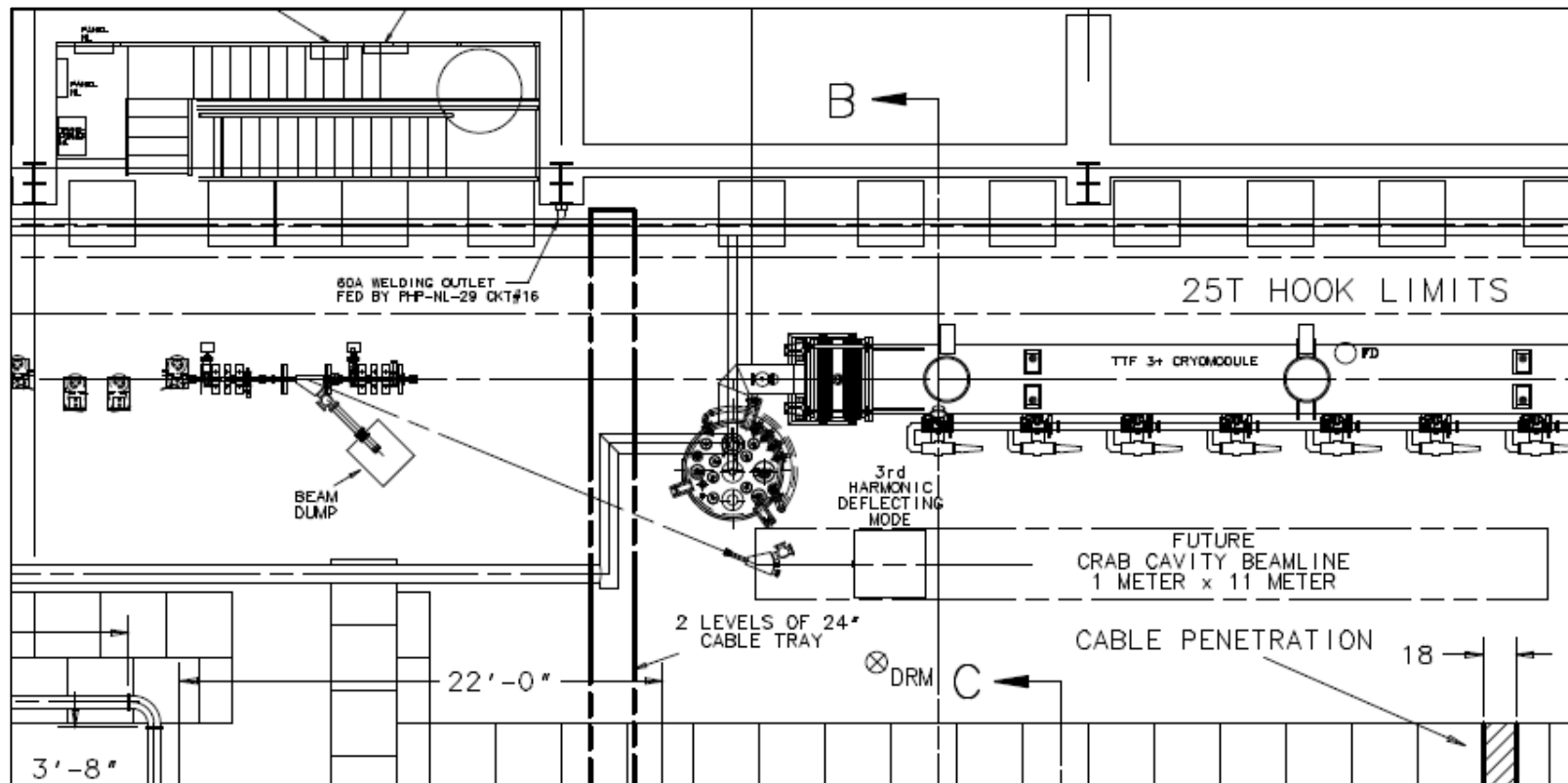


Cavity Insert Fabrication Progress





ILCTA Testing Provisions



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





CC 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 dipole field polarisation stability.
 - Verify stability of phase balance between 2 crab cavities.
 - Verify the requirements to parasitic COM kicks are met.
 - Provide full system microphonics sensitivity measurements.





UK ILC Funding Situation

- On Dec 11th 2008, STFC's 3-year Delivery Plan announced.
- Particle Physics Strategy:
 - Highest priority is to exploit LHC @ CERN,
 - 'We will cease investment in the International Linear Collider. We do not see a practicable path towards the realisation of this facility as currently conceived on a reasonable timescale',
 - Significantly reduce spend on University grants.
- ILC R&D funding will cease by end Sept 08.
- May still be some ILC 'life-support' funds to maintain progress in certain areas.
- CI now looking to exploit developed ILC expertise on other synergetic projects:
 - LHC, CLIC, light sources etc.





Summary

- Cavity design developed that meets ILC wakefield thresholds:
 - Simulations verified with cavity model.
- Mode coupler designs maintain cavity wakefield compliance:
 - Prototype couplers verified with cavity model.
- LLRF and synchronisation architecture developed to reach ILC phase and amplitude control stability:
 - Prototype system fabricated and awaiting full system test with SRF cavities in April 08.

