NANOBEAM 2002

26th Advanced ICFA Beam Dynamics Workshop on Nanometre Size Colliding Beams

September 2-6, 2002, Lausanne, Switzerland

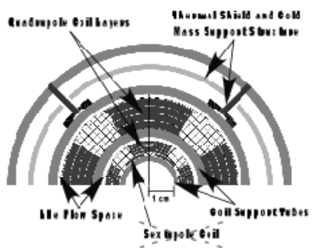
BROOKHAVEN NATIONAL LABORATORY
Superconducting Magnet Division

ILC - The Next Linear Collider Project

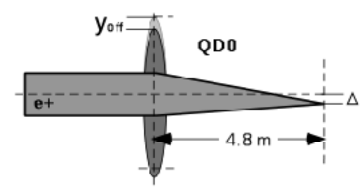
Session 4: Interaction Region Subgroup
Chairs: Fulvia Pilat, Tom Markiewicz
(Tuesday afternoon)

Superconducting Final Focus Magnet Issues

presented by Brett Parker for the BNL Superconducting Magnet Division



BNL Small Coil Test Winding



Linear Collider Final Focus Magnet Issues (Top Level).

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IR magnet design optimization (beam aperture, field requirements, coil/pm–material layout, vacuum, energy deposition, support etc.).

Getting magnetic center stable at the nm level (Vibration).

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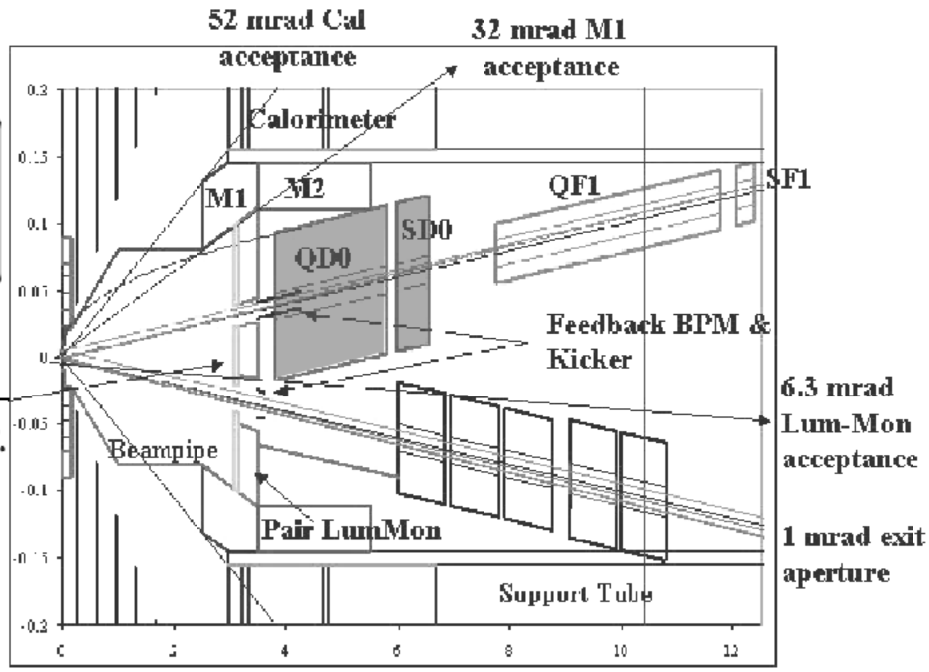
LCD-L2 (3T) with 3.8m L* Optics

Separate (Easier?) Extraction Line θ_C=20 mrad

For QDO
G = 144 T/m
R_{apt} = 10 mm



- Permanent magnet.
- Gradient is fixed...
- Except for changes due to solenoid.
- Net force (μ>1).

The TESLA and JLC Final Focus Quadrupole Concepts.

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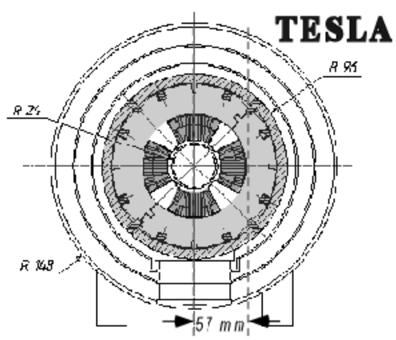
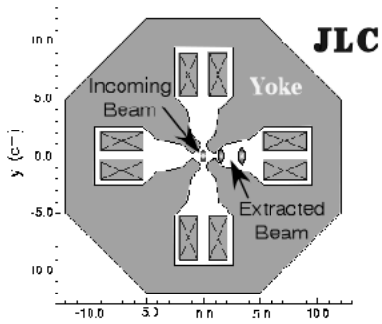


- Large aperture superconducting magnet (has both beams in the central region).
- Vertical extraction via electrostatic separator at 20 m and a shielded septum at 50 m.



- Iron magnet inside a superconducting compensator magnet (avoid saturation, buck out detector solenoid field).
- Extract the beam through coil pocket.

Superconducting Magnets for the HERA–II Luminosity Upgrade.

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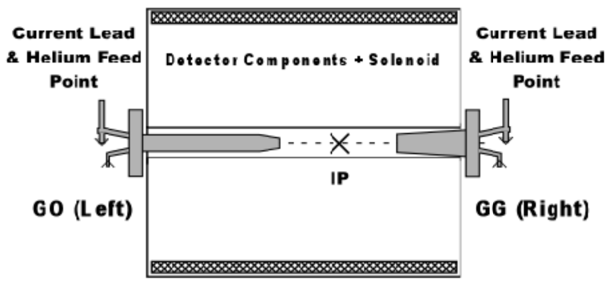
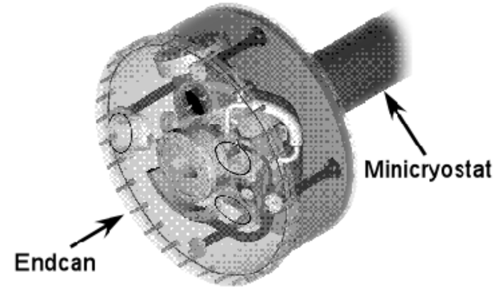
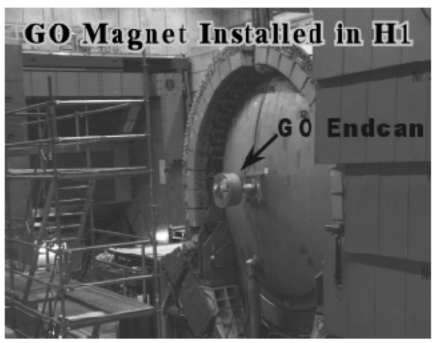
HERA–II Upgrade Schematic







- Superconducting magnets installed into existing ZEUS and H1 detectors (solenoid, so no iron yoke).
- Coils for separating beams and reducing e-ring β^* (dipole, quad, skew-quad, skew-dipole & sextupole).
- Met extremely tight radial budget for cryostat.
- Met demanding field harmonic requirements.
- Technology now will be used for BEPC-II Upgrade and possibly the SLAC PEP-II B-Factory Upgrade.

Superconducting Magnets for the HERA–II Luminosity Upgrade.

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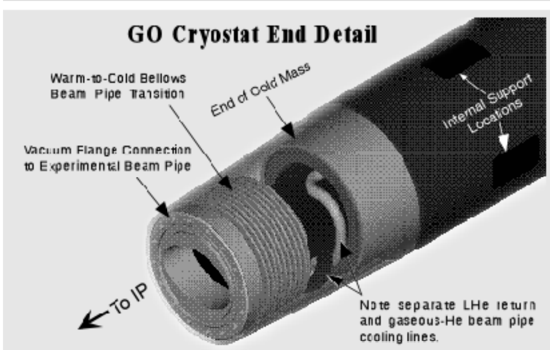

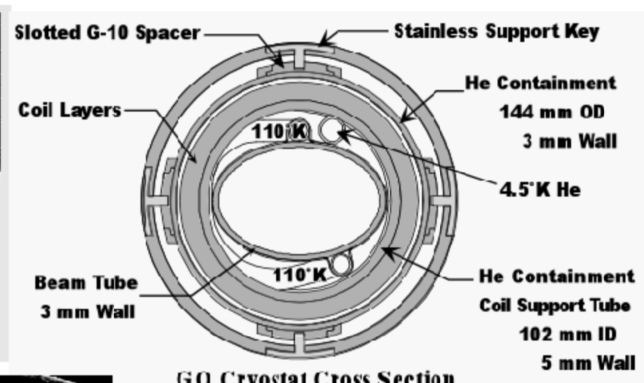

- Fiberglass prestress for each coil layer (note thick inner support tube).
- LHe flows between coil and the outer He containment (note "warm" beam tube).
- Key in G10 slots to pass force from cold mass to the warm outer cryostat wall.
- Test GO & GG horizontal in BNL Magcool.

Superconducting Magnets for the HERA Luminosity Upgrade.

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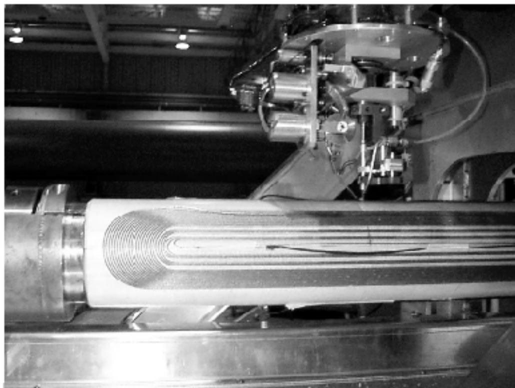
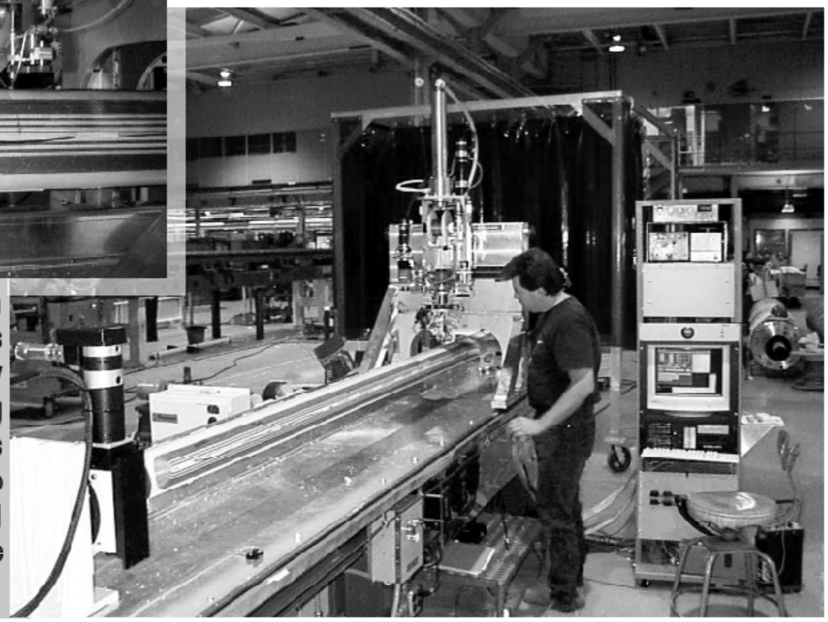


File used for field harmonics gives winding machine the path in space for the conductor.



Insulated conductor with b-stage epoxy coating is payed out under hollow stylus. Ultrasonic heating and rapid cooling leaves conductor bonded to substrate. Typically a coil goes next to magnetic measurements.

Superconducting Alternative to a Permanent Magnet Quadrupole.

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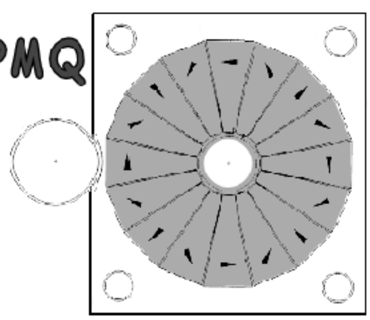
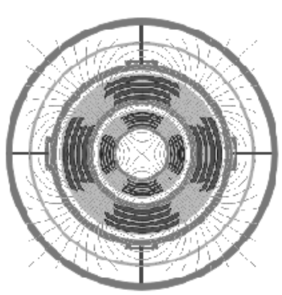
PMQ



SCQ



- Should fit in same space. ✓
- Should give same gradient. ✓
- Net force or torque in solenoid for SCQ ≈ zero (unlike PMQ).
- PMQ has extra longitudinal & transverse fields (unlike SCQ).
- For SCQ disrupted beam passes through non-zero field (unlike PMQ).

QD0 Cross Section with a Cold Beam Tube (at support location).

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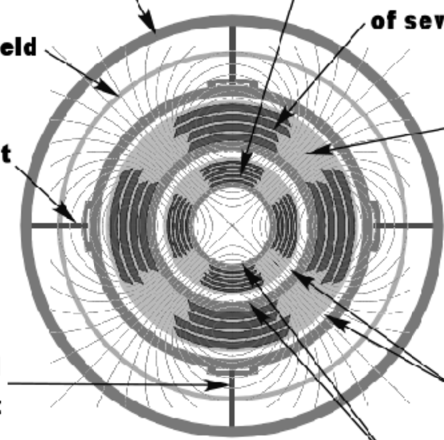
Inner Beam Tube	20 mm ID
Outer Cryostat Tube	114 mm OD

QDO Coil Parameters

Inner Quad	63 T/m
Outer Quad	81 T/m
Total Quad	144 T/m



Design Concept: Two independent coil windings. Integrated helium flow. Copper inside inner coil support tube.

Recent Winding Tests Using Small Diameter Support Tubes.

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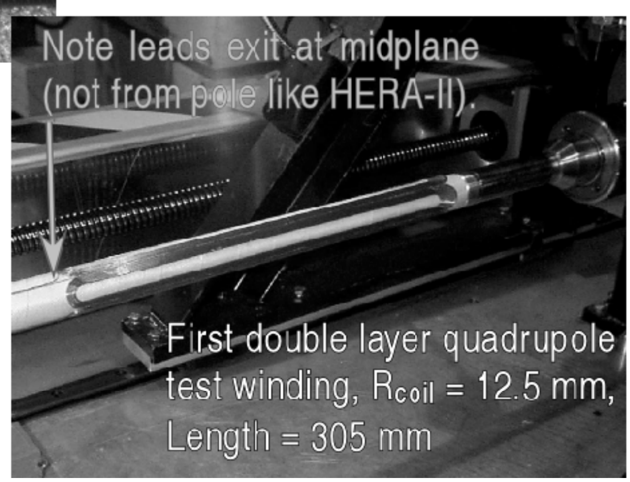
First we demonstrated the ability to wind small diameter coils with the desired features.

Then we wound a double layer quadrupole test coil on a 20 mm ID support tube.

Finally we will produce, under a BNL LDRD, a full length, 2 m, prototype of the NLC inner coil structure that will be cold tested.



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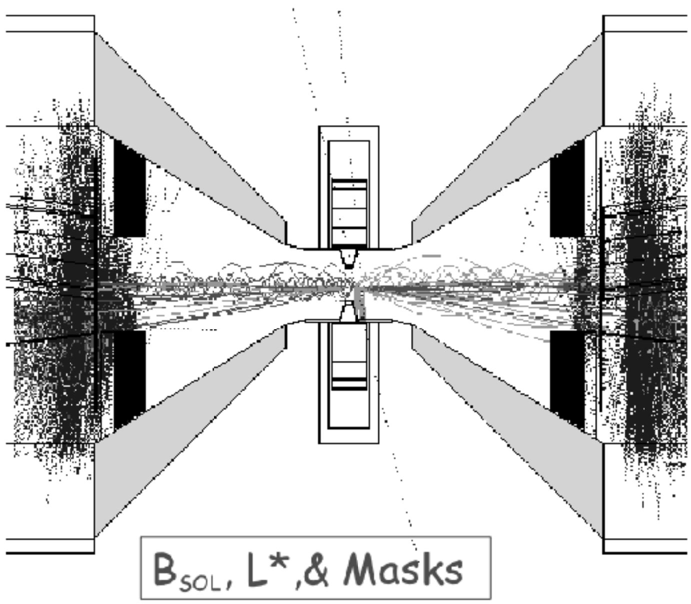
e+,e- pairs from beams. γ interactions



pairs scales w/ Luminosity

1-2x10⁹/sec

0.85 mW per side

Luminosity Monitor & Pair Monitor will Shield QD

Tom Markiewicz

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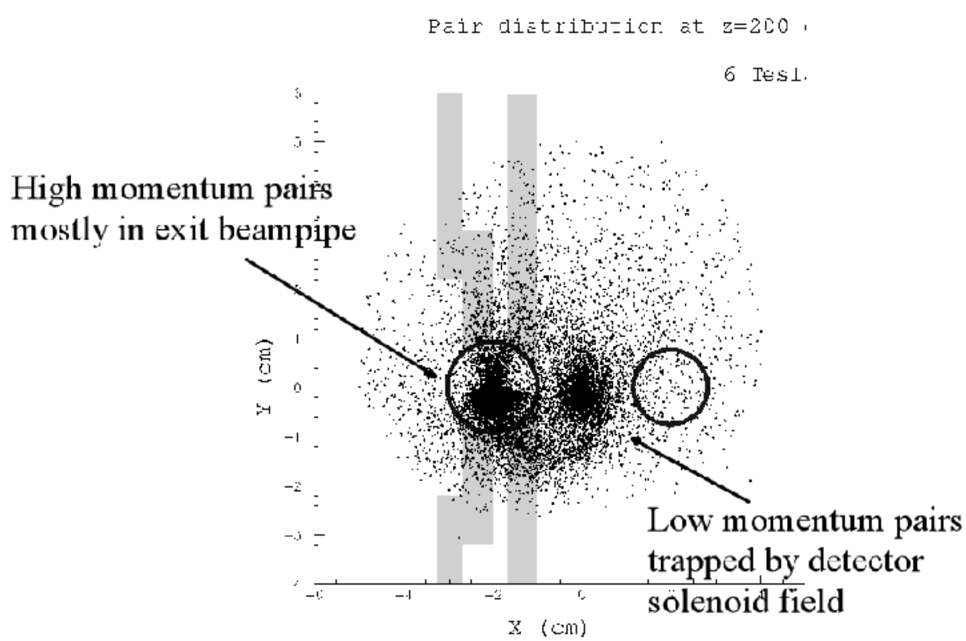
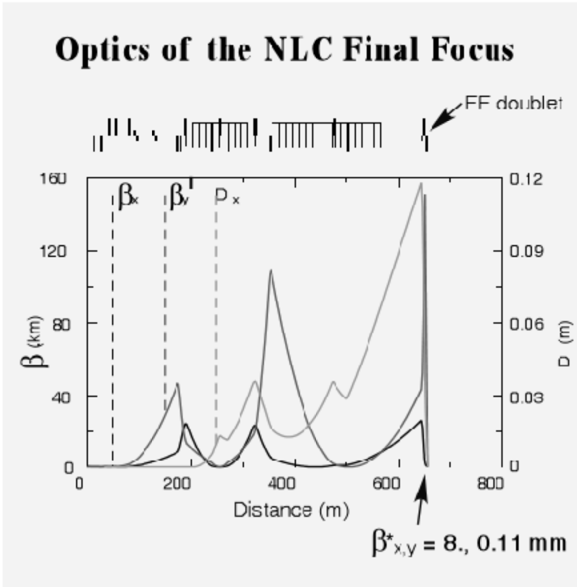
e,γ,n secondaries made when pairs hit high Z surface of LUM or Q1



Tom Markiewicz

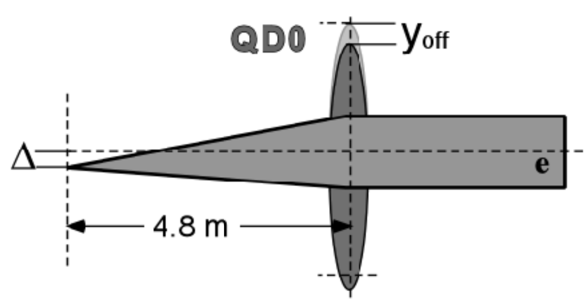
NLC Beam Delivery System: Final Focus Optics Summary.



- Extreme vertical demagnification at IP $(0.11\ \text{mm} \div 150\ \text{km})^{1/2} = 2.7 \times 10^{-5}$.
- Sextupoles needed to correct chromaticity (compensate for momentum spread).
- Beam sizes $\sigma_x/\sigma_y = 243./3.0$ nm at IP (but a few tenths of a mm in FF doublet).
- Small kicks in FF doublet can cause beams to miss each other (Y–offset sensitivity).

NLC Beam Delivery System: QD0 Vertical Offset Sensitivity.

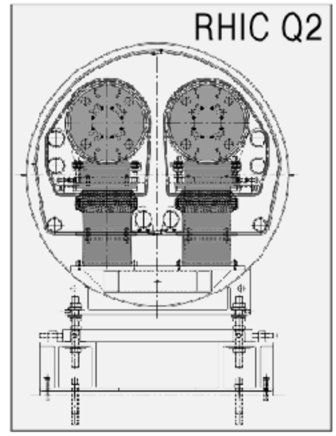
A QD0 vertical offset of 1 nm gives a 250 GeV beam a fraction of a nano-radian kick… that then leads to nm scale vertical offset at the IP.

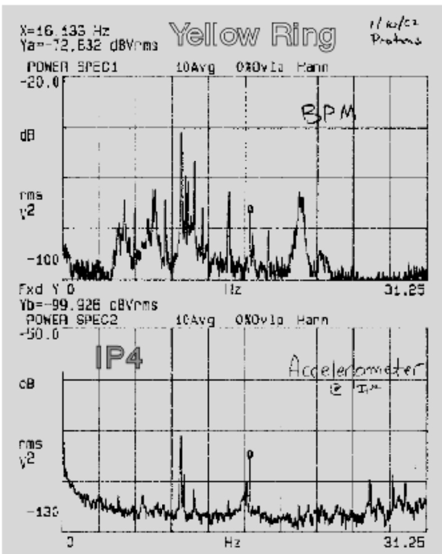


With this simple model vertical quadrupole movement of 10^{-5} σ causes the beam to move by ≈ ½σ at the IP.

Recent work looking for IR quadrupole vibration in RHIC.

As reported at Nanobeam 2002, Christoph Montag has been able to correlate oscillatory signals on BPMs with vibration lines measured at IR cryostats.



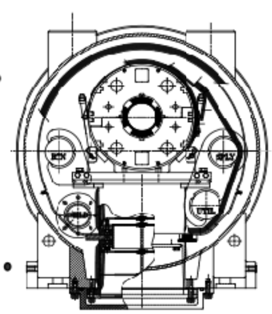


He has observed about 200 nm horizontal but no measurable vertical oscillations. This may not be too surprising for a RHIC cryostat design which was not optimized for vibration.

Note that a traditional cryostat design has a heavy cold mass sitting atop long posts (like an inverted pendulum). A driving source in the feed can is suspected. Obviously this shows a need for careful investigation...

BNL near term plans for vibration measurements in superconducting magnets.

- Sensors ordered for a vibration survey in the BNL Magcool test area.
- Team formed from BNL SMD and C-AD to investigate NLC accelerator physics issues.
- A RHIC CQS magnet will be assembled with sensors on the cold mass and cryostat.


RHIC CQS

We expect though that active stabilization is needed to make good e.g. nm measurements!

- Magnetic measurement techniques are being developed in parallel.

Using LDRD funds we will make & measure 2 m NLC prototype, but without its cryostat.

Active vibration isolation of the cold mass.

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The choice of cooling scheme, mechanical design, and passive damping will be required to minimize vibration of the cold mass to a level that an active system can reduce further to the nanometer level. Use of existing nanometer positioning sensors, piezoelectric actuators, and low noise accelerometers will need to be investigated for use in a cryogenic system and in the presence of a moderate magnetic field.

These sensors and actuators are currently being used in active vibration isolation systems. The technology used in these sensors and actuators should allow them to perform in this environment but an active isolation system for the cold mass will require six degrees of freedom.

This will mean that many sensors and actuators will be needed and a DSP based control system will be needed for feedback, feed-forward, and sensor processing.

Compact Superconducting FF Quadrupole Magnet Summary.

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- For NLC energy and optics tuning an adjustable magnet is desirable. We now have a concept for a superconducting quadrupole (similar to HERA-II) that meets basic space and strength requirements.
- Presently not enough is known about the challenges for stabilizing such magnets at the nm level and this is an important area for future study.
- Making a realistic prototype seems desirable but many options exist (4.5° subcooled helium, 2° superfluid helium and conduction cooling) and much work must be done before finalizing the design.