WG2d "Magnets" Summary

Conveners: F. Kircher, M. Kumada & B. Parker

Permanent Magnet Quadrupole Designs
T. Mihara

ILC Lessons Based Upon KEKB Experience
K. Tsuchiya

Advanced Superconducter Research
M. Kumada

Compact Superconducting Quadrupole Designs
B. Parker

High Gradient Large Aperture Superconducting Magnet Designs
F. Kirchner

Vibration Measurements of a Cryogenic System
A. Jain

WG2d "Magnets" Summary

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7 Talks...

PMQ for Final Quad in a Linear Collider

Takanori MIHARA Kyoto Univ.

merit/demerit

- Strong field gradient. (>120T/m is achieved with ϕ20mm bore diameter and ϕ100mm magnet size.)
- small size ,light weight (our PMQ weighs about 100kg with 40cm x 40cm x 23cm)
- Less power consumption
- No vibration source (power cable, cooling water, or He pipe, etc...)
- Edge of effective length equals to L* (Super-Q needs 20cm more space for thermal shield)
- Temperature dependency (It can be compensated with temperature compensation alloys.)
- Radiation damage
- Aged deterioration(0.5%/year on NEOMAX30H)

The AC properties of QMG coil magnets

- The development of new type High-T$_c$ high J$_c$ superconducting magnets -

M. Morita, NSC, Chiba,
M. Kumada, NIRS, Chiba,
A. Sato, NIMS, Ibaraki,
H. Teshima, NSC, Chiba and
H. Hirano, NSC, Chiba

Comments on the design of ILC final focus system

KEK
K. Tsuchiya

1 View*

BROOKHAVEN Superconducting Magnet Division

NANOBEAM2005

Uji Campus, Kyoto University, October 17-21, 2005

Recent Progress Designing Compact Superconducting Final Focus Magnets for the ILC

Brett Parker, representing the Brookhaven Superconducting Magnet Division

QD0, the final focus magnet closest to the IP for the ILC 20 mr crossing angle layout, must provide strong focusing yet be adjustable to accommodate collision energy changes for energy scans and low energy calibration running and it must be compact to allow disrupted beam and Beamstrahlung coming from the IP to pass outside into an independent instrumented beam line to a high-power beam absorber. In designing QD0 we take advantage of BNL experience making direct wind superconducting magnets. We present test results for a QD0 magnetic test prototype and introduce a new shielded magnet design to replace the previous side-by-side design concept, that greatly simplifies the field correction scheme and holds promise of working for crossing angles as small as 14 mr.

dapnia cea saclay

High Gradient and Large Aperture Nb3Sn Quadrupole Magnets for the ILC IR

Olivier Delferrière
François Kircher
Olivier Napoly
Jacques Payet

CEA Saclay
DSM/DAPNIA/SACM

Vibration Measurements in a RHIC Quadrupole at Cryogenic Temperatures

Animesh Jain, Sevan Aydin, Ping He, Michael Anerella, George Ganetis, Michael Harrison, Brett Parker and Stephen Plate

Superconducting Magnet Division
Brookhaven National Laboratory, Upton, NY 11973

Nanobeam 2005, October 17-21, 2005, Kyoto, Japan

BROOKHAVEN Superconducting Magnet Division

NANOBEAM2005

Uji Campus, Kyoto University, October 17-21, 2005

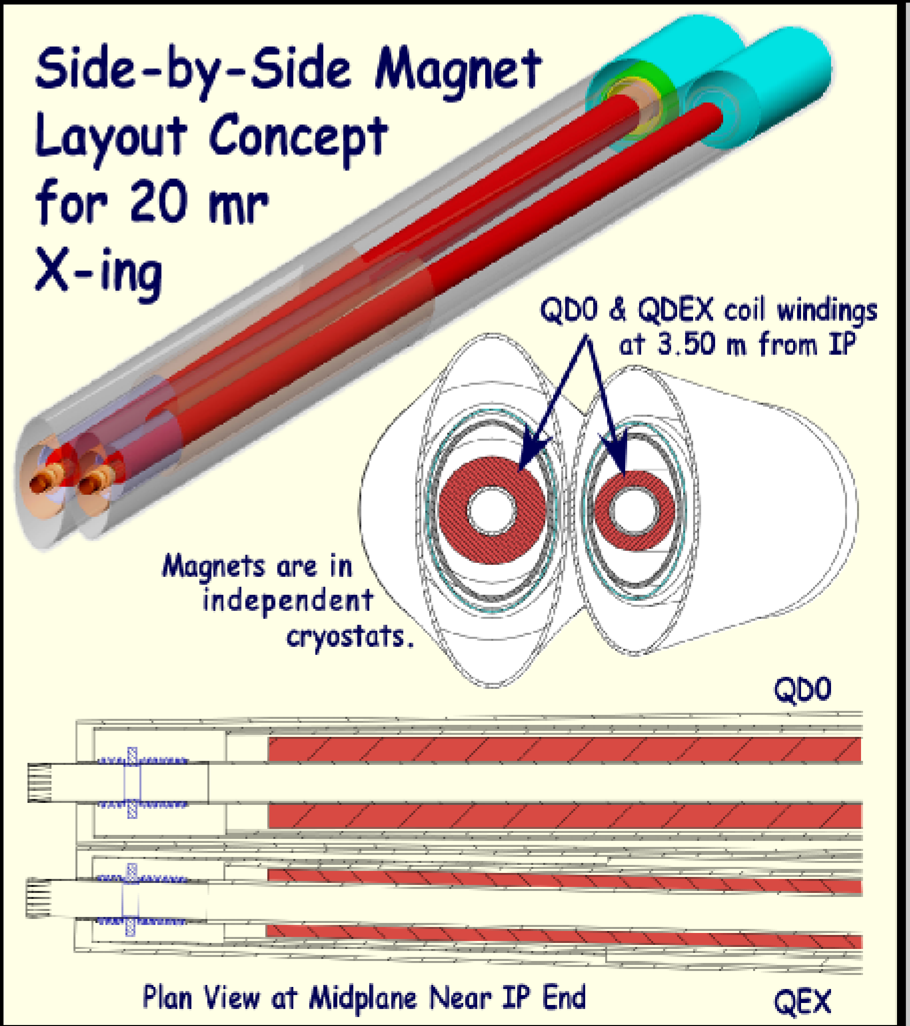
R&D Activities Regarding ILC Compact Superconducting Final Focus Magnets

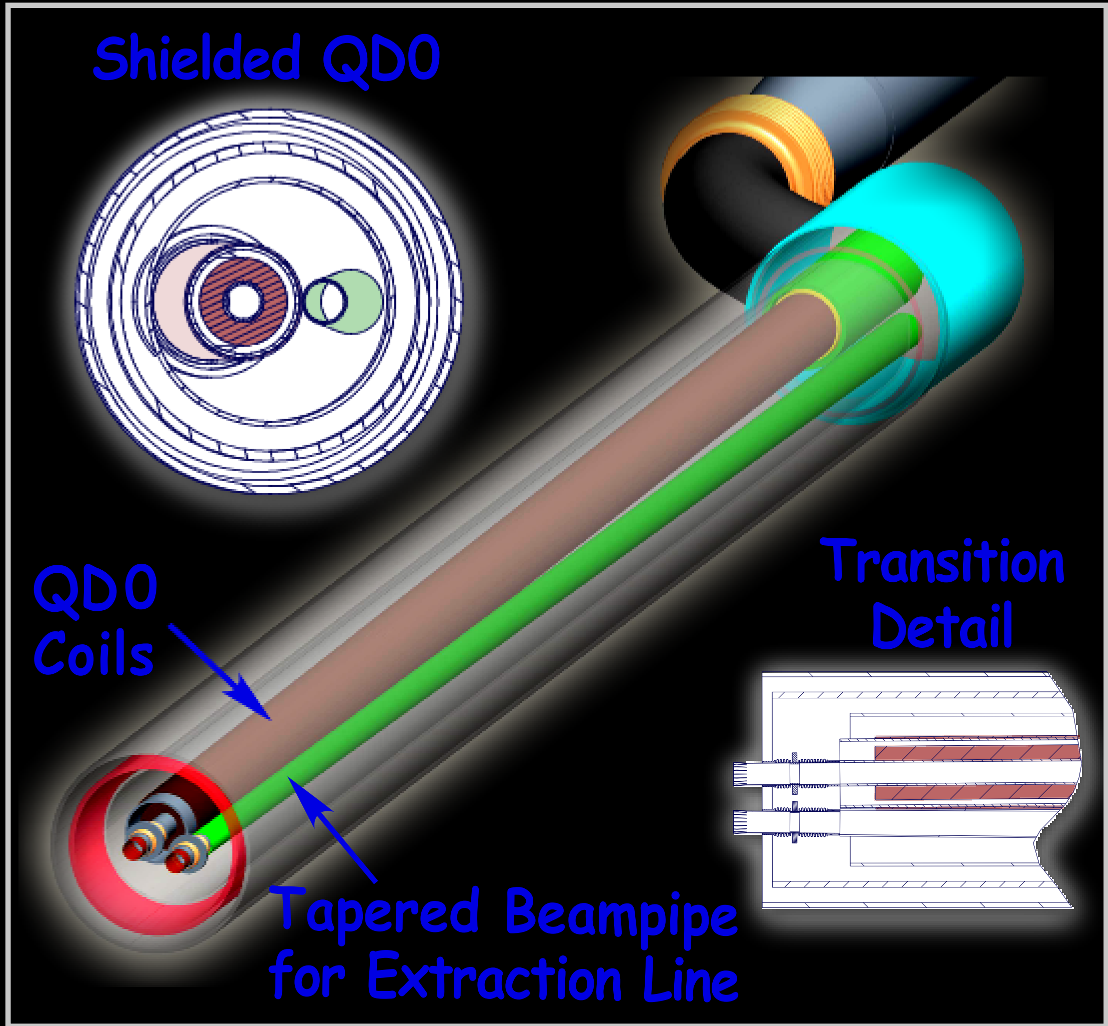
Brett Parker & Animesh Jain
Brookhaven Superconducting Magnet Division

My co-conveners seem to have trusted me to make a summary on my own (no feedback)... so the views expressed here are personal.

*So please look at the original talks when they are available for yourself!

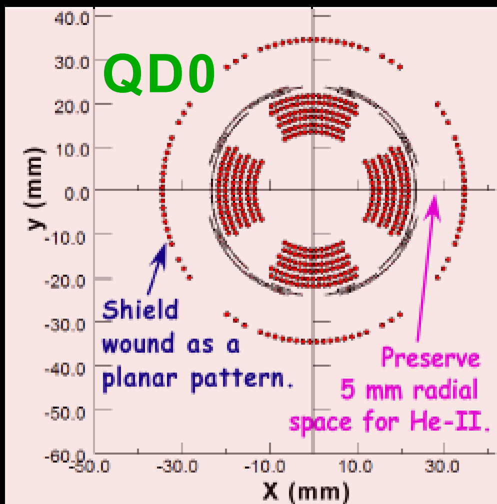
Since Snowmass'05 new compact shielded superconducting magnet designs were developed that replace the previous "side-by-side" magnet layout for 20 mr crossing angle.

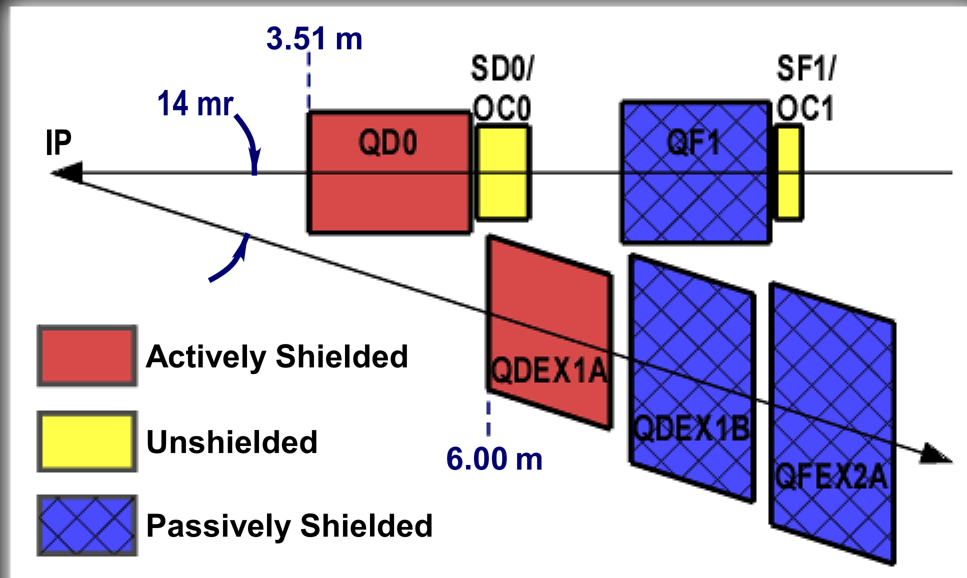




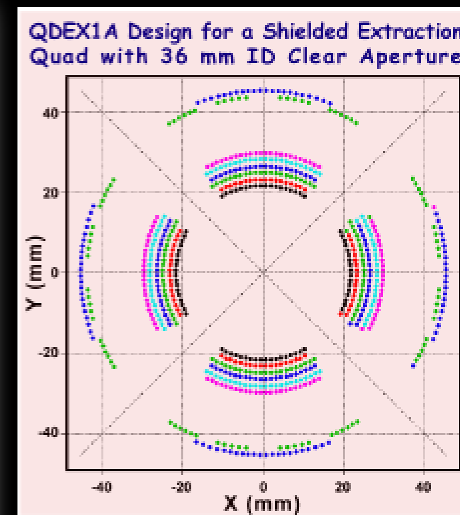
"Recent Progress Designing Compact Superconducting Final Focus Magnets"
presented by: B. Parker

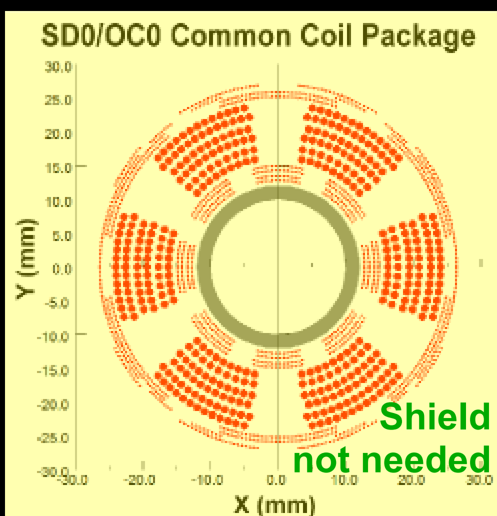
New design uses a combination of active (coil) and passive (magnetic yoke) shielding and may be pushed to 14 mr X-ing.

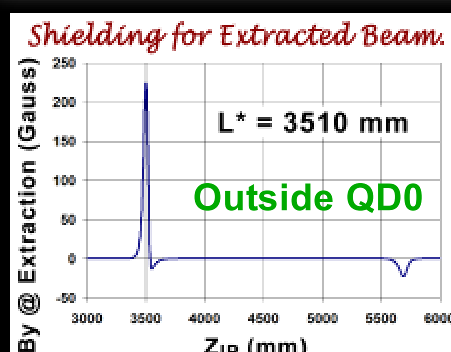


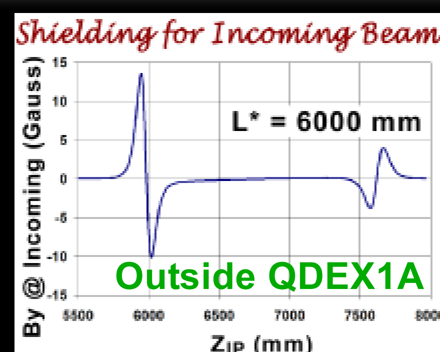


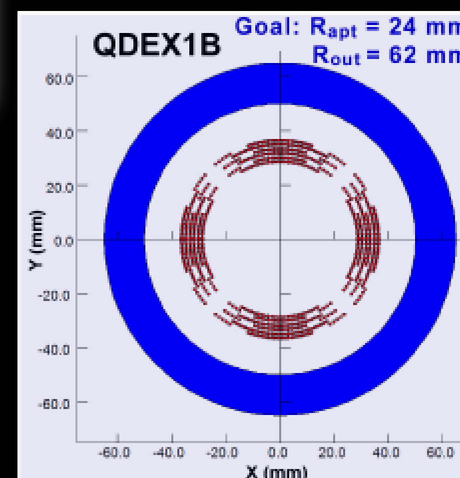
Possible 14 mr Layout Schematic





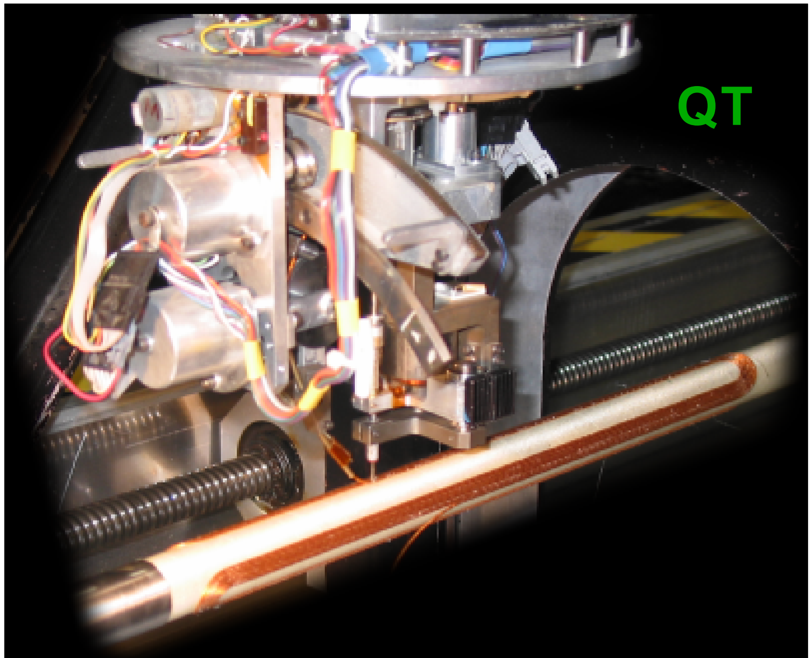






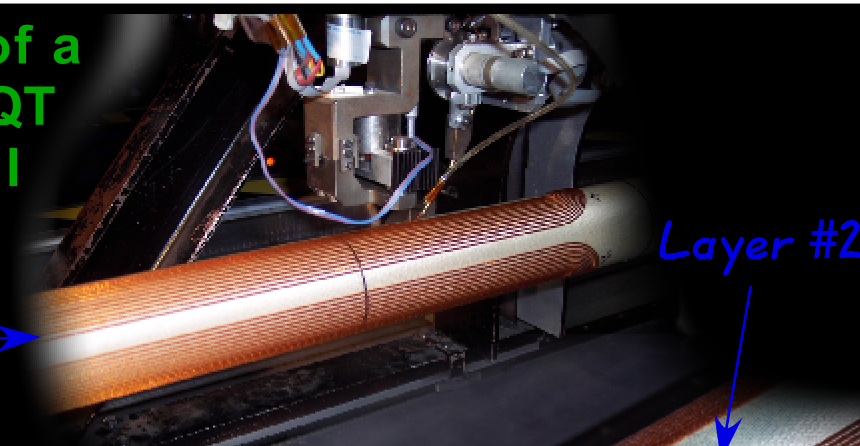
"Recent Progress Designing Compact Superconducting Final Focus Magnets"
presented by: B. Parker

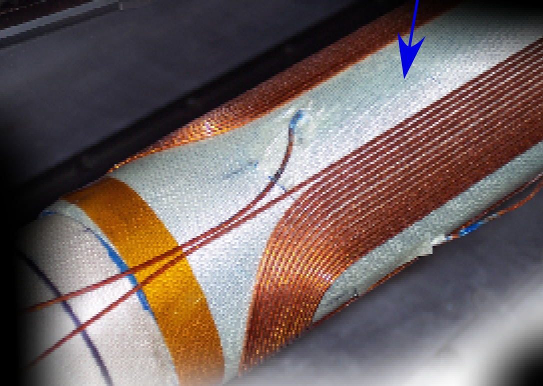
Winding and testing a bare QT prototype demonstrates we can meet field quality and magnetic performance goals but does not yet tell us about vibration stability of the final system (cryostat!).

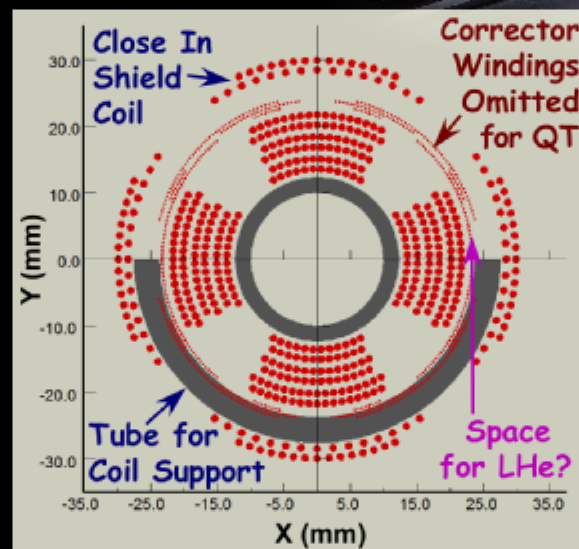


Before Snowmass'05 QT, a short, QD0 magnetic prototype was successfully tested in a back-ground solenoidal field and exhibit-ed excelent field quality and quench performance.

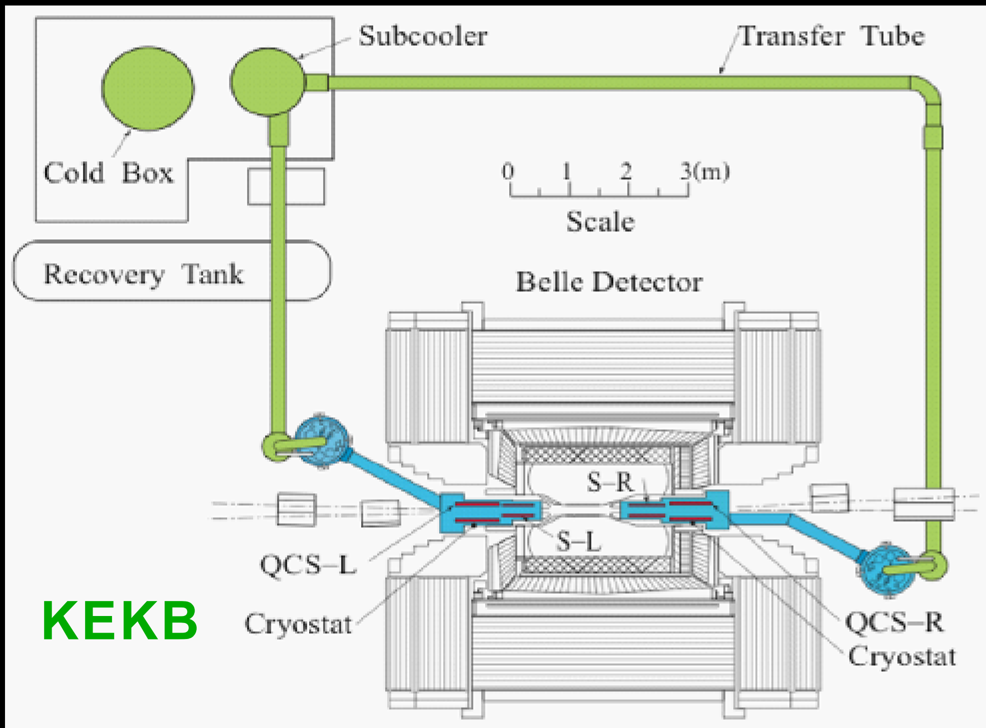
Winding of a two-layer QT shield coil

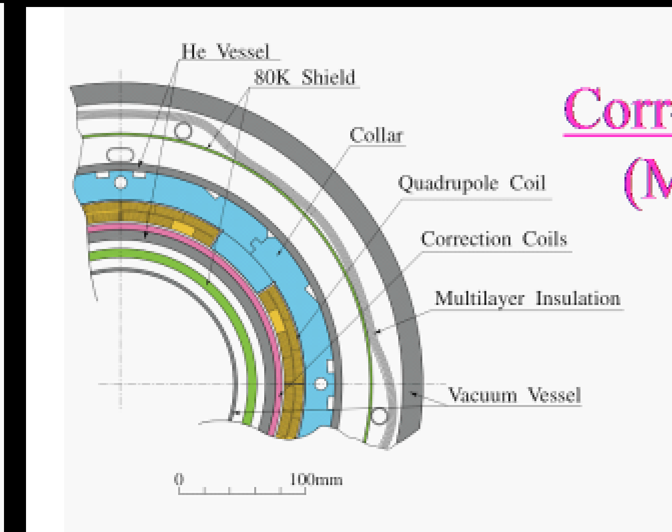






The shield coil is now complete and a shielded QT prototype will soon be tested.





Correction coils:
(MF mover)

- H dipole
- V dipole
- Skew quad

- Design of the vacuum system and the assembling method of the IR region should be started as soon as possible.

  These things might exert a large influence upon the design of the SC magnet.

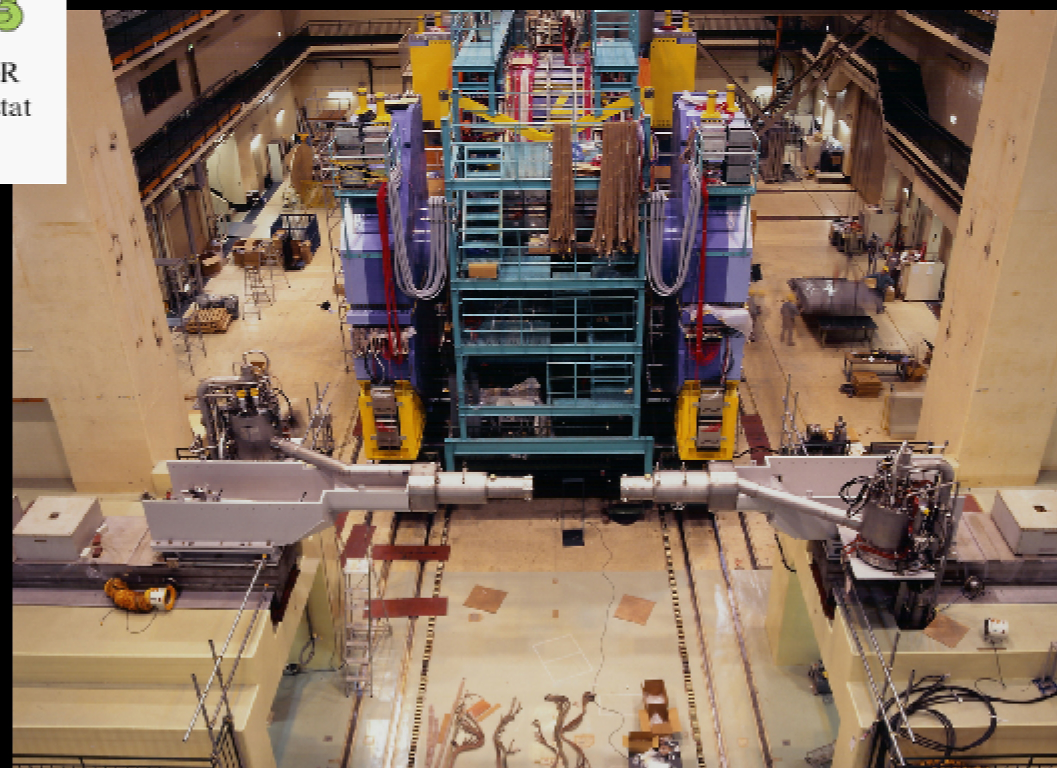
- SC magnet

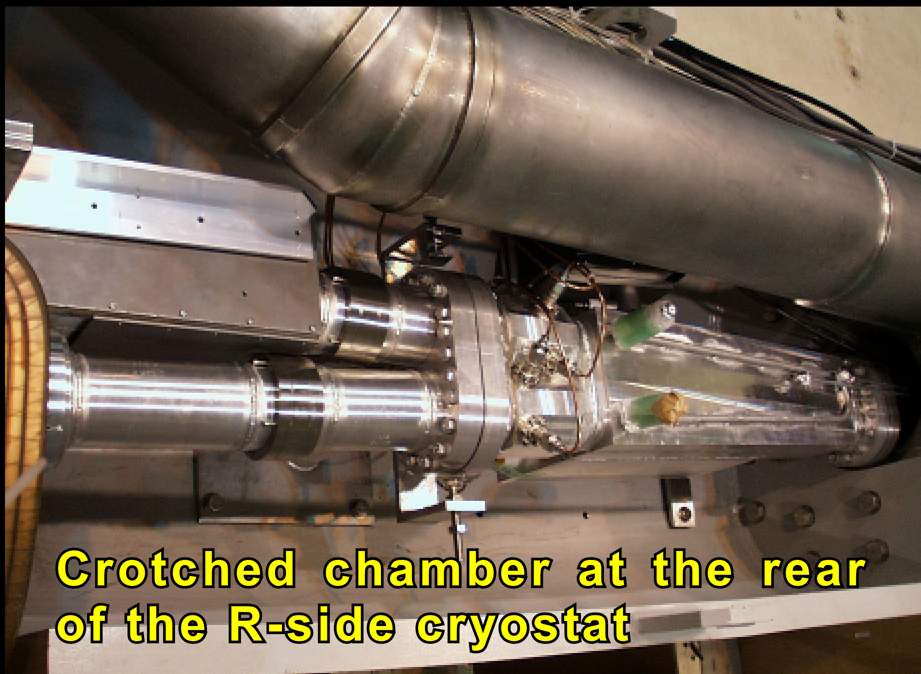
  Self shield NbTi coil; ΔG/G 2D is OK but 3D ?

  Nb_3Sn coil ; need large R&D

- Fancy (sophisticated) mover system might be mechanically weak. Think about a magnetic field(MF) mover.

  We have a good experience of MF mover in KEKB-IR.





Constraints

- Time schedule

Boundary condition

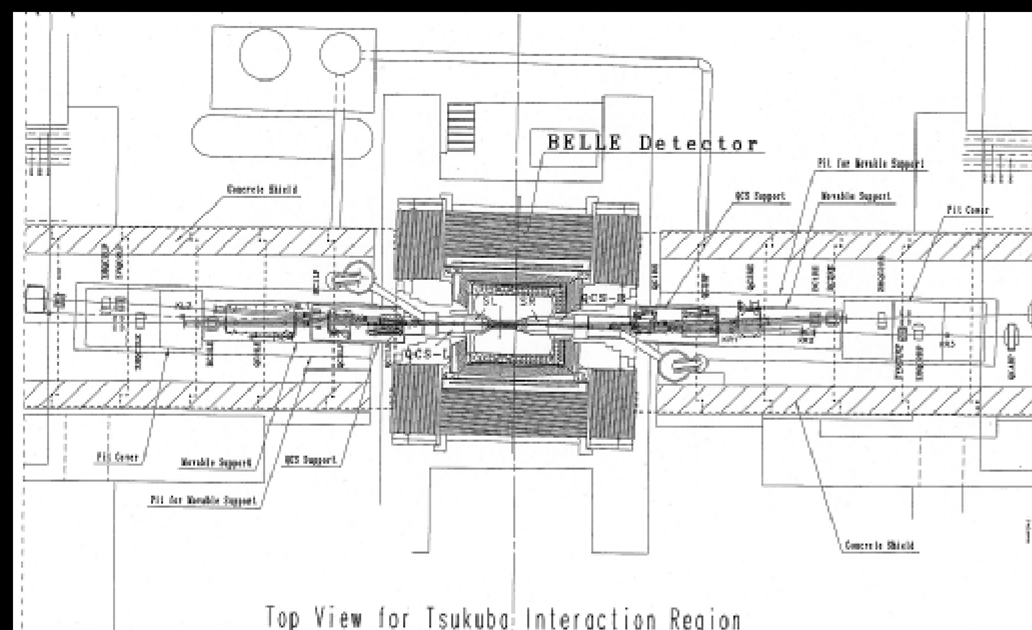
(need discussion with detector people)

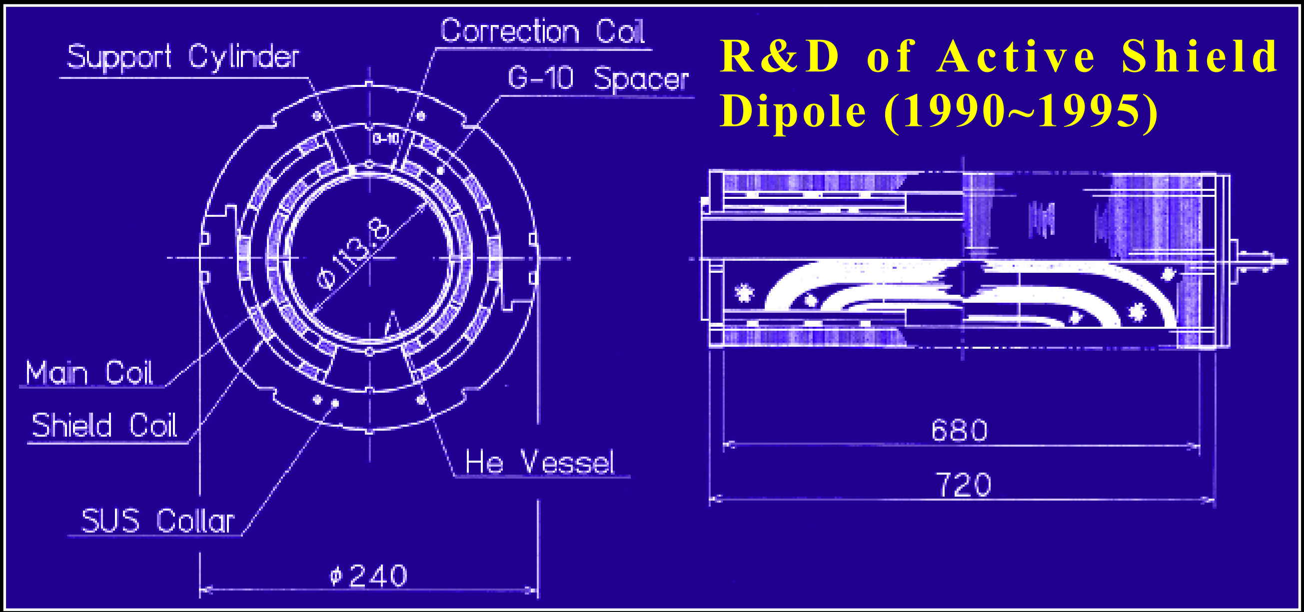
- Available space for IR equipments
- Beam background

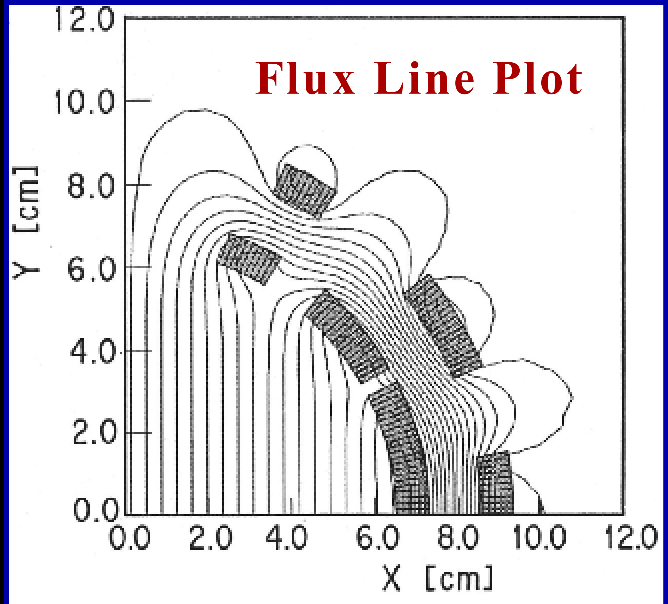
Requirements from beam optics

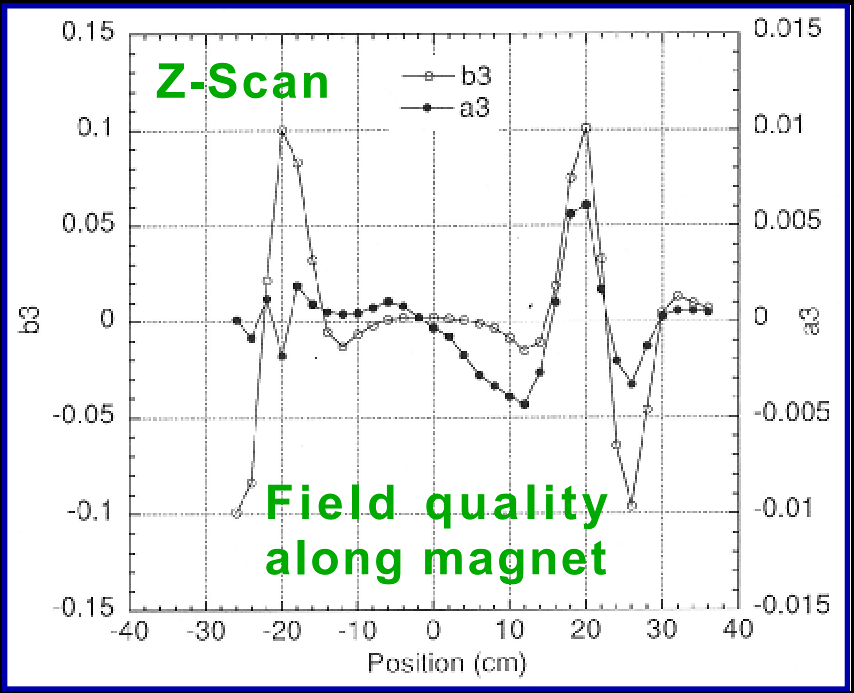
IR vacuum	vacuum level, cold or warm
Quadrupole	G(T/m), L(m), Aperture(m)
	ΔG/G
Alignment	range, accuracy, frequency etc.

There are many important details to be worked out and unfortunately some of these details can have fundamental impact on the final focus magnet design.





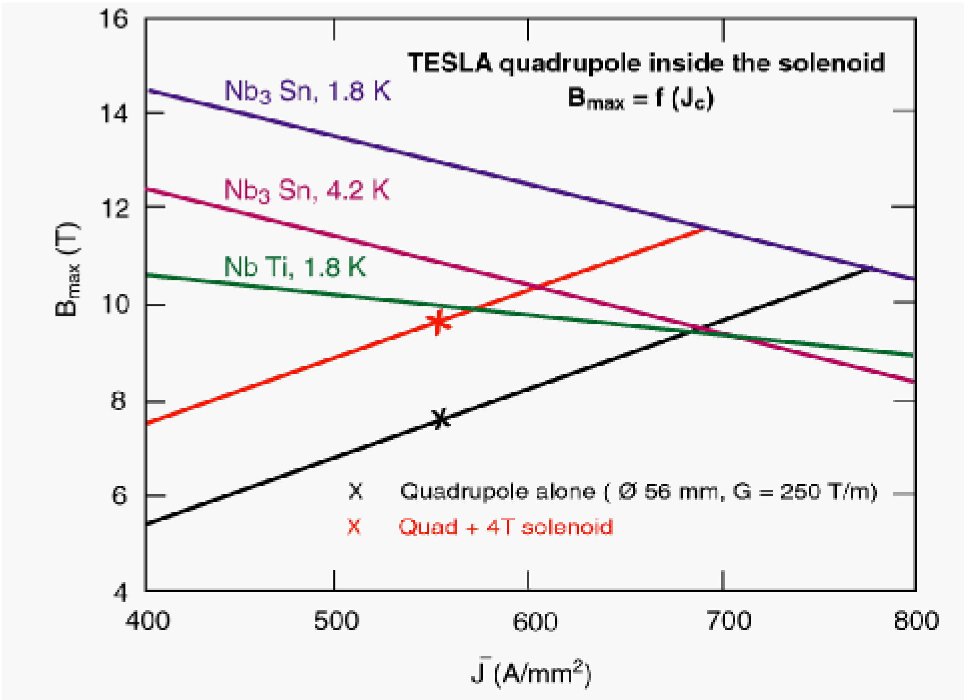




Making actively shielded magnets can be quite challenging and it is important to do 3D calculations and not just depend upon 2D estimations. Also it is good to make and test a prototype.

Dipoles are harder than quads due to slower external field fall off. - B.P.

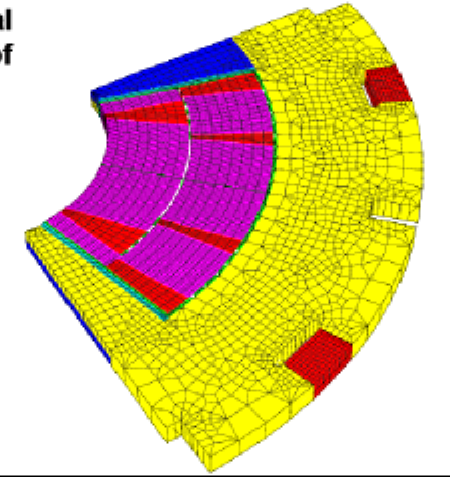
Why might we want to use Nb_3Sn?



Electromagnetic and mechanical design is similar to the design of the LHC arc quadrupole magnets.

A 3D contact finite-element model of the structure has been developed using the COFAST3D module with CASTEM software package

All successive steps of loading history, from collaring to cool-down and to excitation are described.

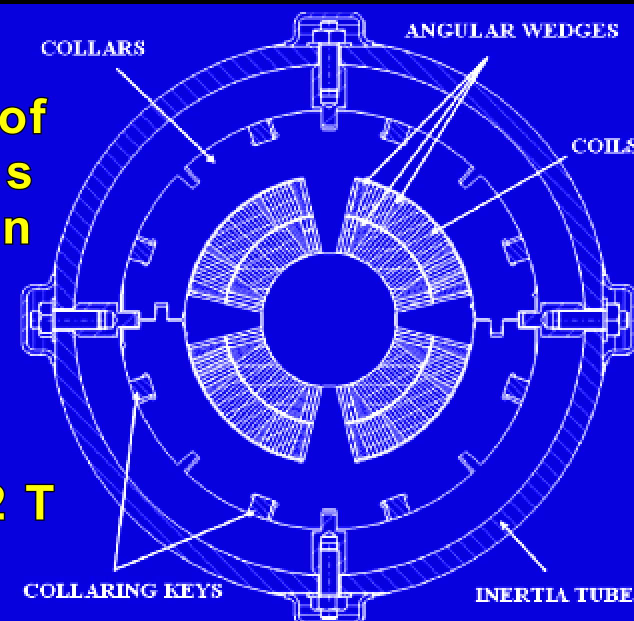


Use the wind and react technique

Saclay Nb_3Sn Quadrupole Program

Completion of cold mass is now foreseen for mid 06 & tests by end of 06.

Will test in 2 T solenoid.

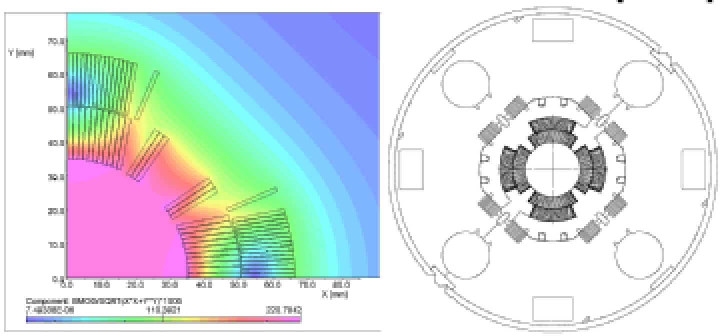


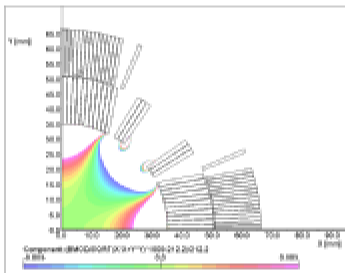
56 mm bore quadrupole (TESLA TDR)

"High Gradient and Large Aperture Nb3Sn Quadrupole Magnets for the ILC IR"
presented by: F. Kircher

A new 70 mm Diameter ILC Quadrupole

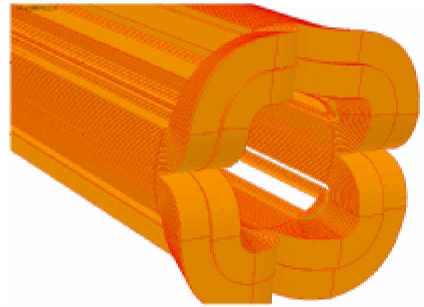
2D Simulation of FNAL MQXB cross section quadrupole





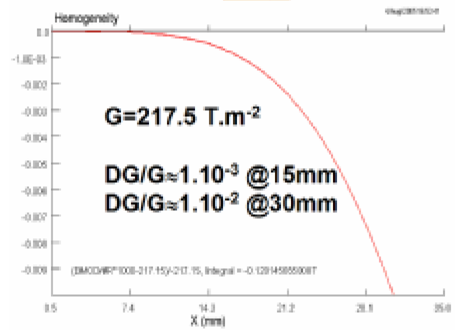
Coil radius	35 mm	
Gradient	210 Tm^{-1} (adapt. to 250 Tm^{-1})	
Nominal current	12800 A (adapt. to 15 000 A)	
Conductor characteristics (adapt. to Nb_3Sn)		
Conductor	internal	external
Radial length	15.4 mm	15.4 mm
Little side	1.326 mm	1.054 mm
Big side	1.587 mm	1.238 mm
Turns/pole	14	16

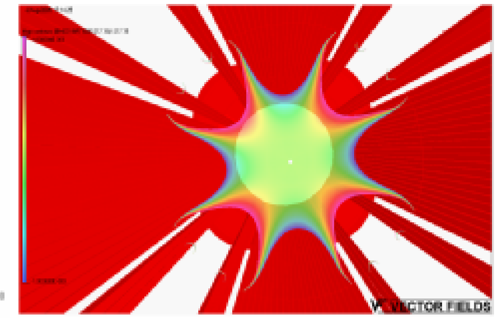
70 mm Diameter Quadrupole : Magnetic calculations



3D model of FNAL quadrupole assuming arbitrary coil heads :

➩Towards a full model Quadrupole+Solenoid for ILC IP

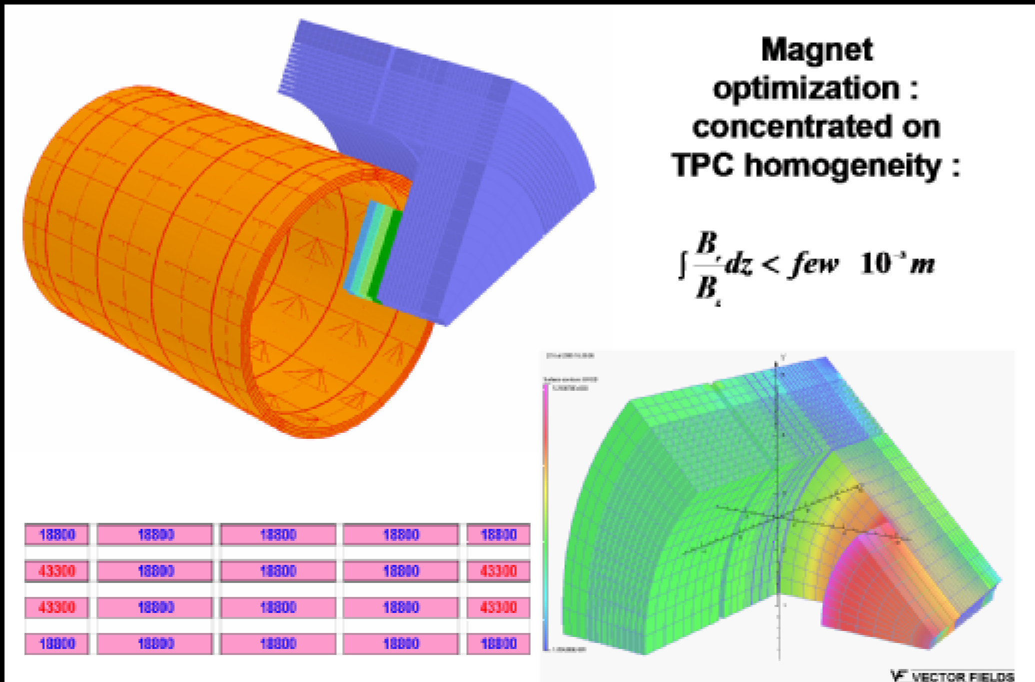


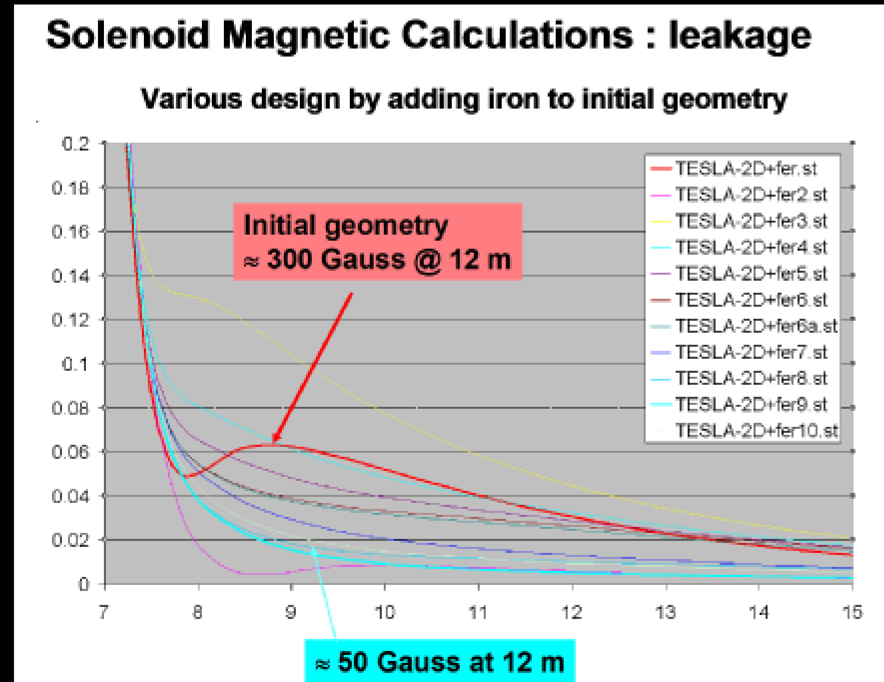


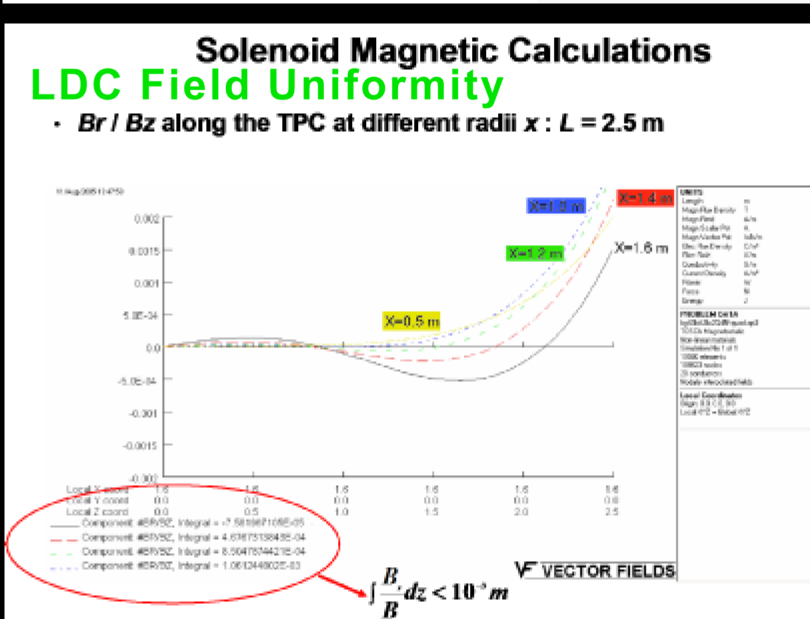
The ILC FF is not a large market; it will be difficult to develop a specific program, specially involving industry. Consequently, even if we cannot assume that LHC upgrade will solve all ILC challenges, we should not ignore what is done there . With a 2010 ILC decision several results expected for Nb3Sn magnets by this time (LARP in USA, Saclay and EFDA dipole for fusion conductor test facility). The magnets we are looking at are challenging but if the specifications can be kept within a reasonable range (say 70-90 mm coil aperture, 200 to 250 T/m), suggest focusing on specifications before making a definitive technology choice. First goal must be to define the parameters for these magnets in a reasonable range. Follow up of the expected progress for the LHC upgrade and development of HTS conductors will enable us to make a better informed technical choice within a few years. - [e.d. B.P.]

"High Gradient and Large Aperture Nb3Sn Quadrupole Magnets for the ILC IR"

presented by: F. Kircher







Have made extensive calculations (optimization) of LDC solenoid to achieve very good field uniformity (for TPC). Also look to reduce the external field outside.

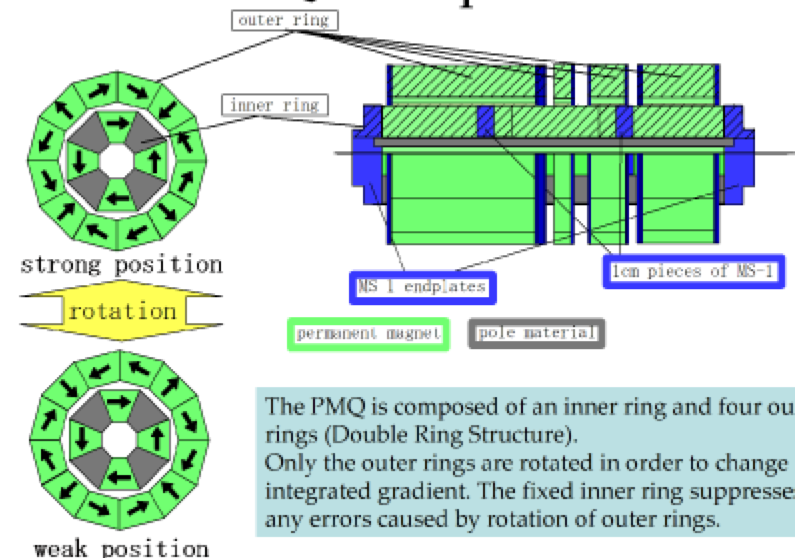
But what are realistic requirements? Much work was done... but seems that a looser spec' is possible? DID? - B.P.

"High Gradient and Large Aperture Nb3Sn Quadrupole Magnets for the ILC IR"
presented by: F. Kircher

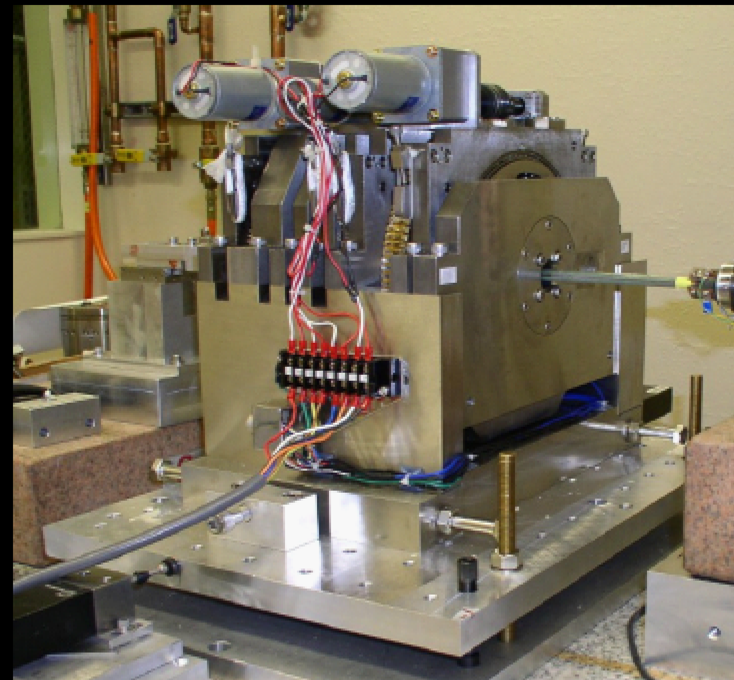
"Development of Final Focus Permanent Magnet"

presented by: T. Mihara

Adjustable Permanent Magnet Quadrupole



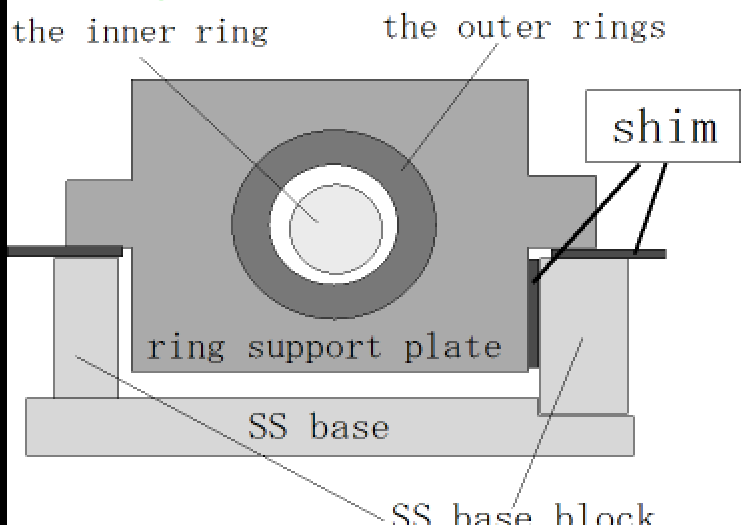
The PMQ is composed of an inner ring and four outer rings (Double Ring Structure).
Only the outer rings are rotated in order to change the integrated gradient. The fixed inner ring suppresses any errors caused by rotation of outer rings.



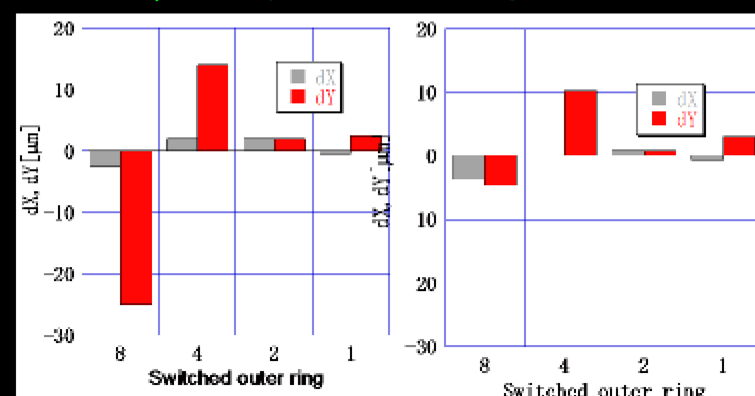
16 variations in the positions of the outer rings.

SWL	8cm	4cm	2cm	1cm
15	on	on	on	on
14	on	on	on	off
13	on	on	off	on
12	on	on	off	off
11	on	off	on	on
10	on	off	on	off
9	on	off	off	on
8	on	off	off	off
7	off	on	on	on
6	off	on	on	off
5	off	on	off	on
4	off	on	off	off
3	off	off	on	on
2	off	off	on	off
1	off	off	off	on
0	off	off	off	off

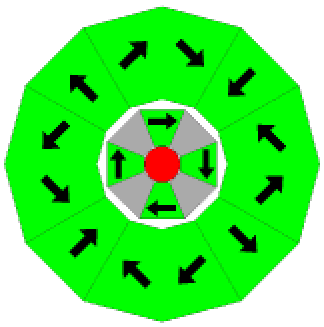
Tuning for a Fixed Field Center



Center shift of the Y coordinate by switching 8cm ring successfully reduced from over 20 μm to less than 5 μm by shimming.

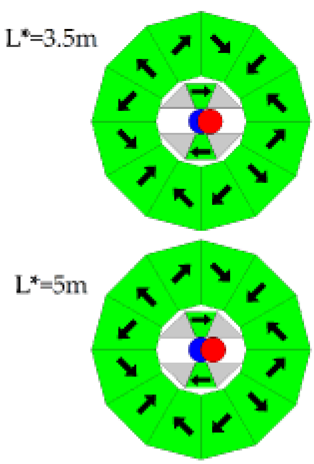


PMQ for Head-on

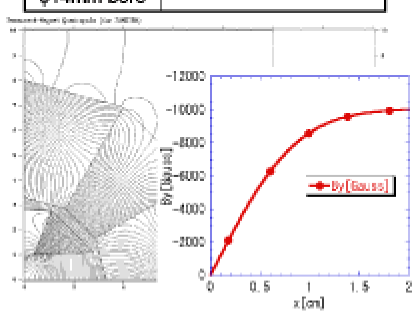


Outer diam	ϕ180mm
Bore diam	ϕ20mm
Grad. With ϕ20mm bore	180T/m(max) -20T/m (min)
Grad. With ϕ14mm bore	250T/m

PMQ for 2mrad(L*=3.5〜5)



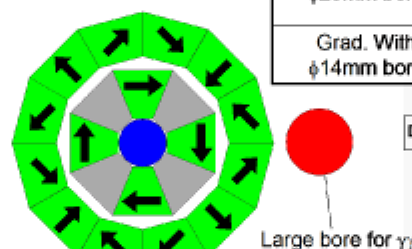
Outer Diam	ϕ180mm
Grad. With ϕ20mm bore	130T/m (max) -60T/m (min)
Grad. With ϕ14mm bore	190T/m

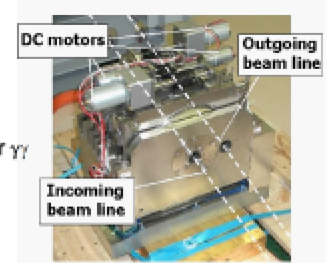


Wide variety of PMQ configurations have now been studied.

PMQ for 20mrad,L*=3.5m

Outer diam.	ϕ100mm
Bore diam.	ϕ20mm
Grad. With ϕ20mm bore	*120T/m(max) 8T/m(min)
Grad. With ϕ14mm bore	220T/m

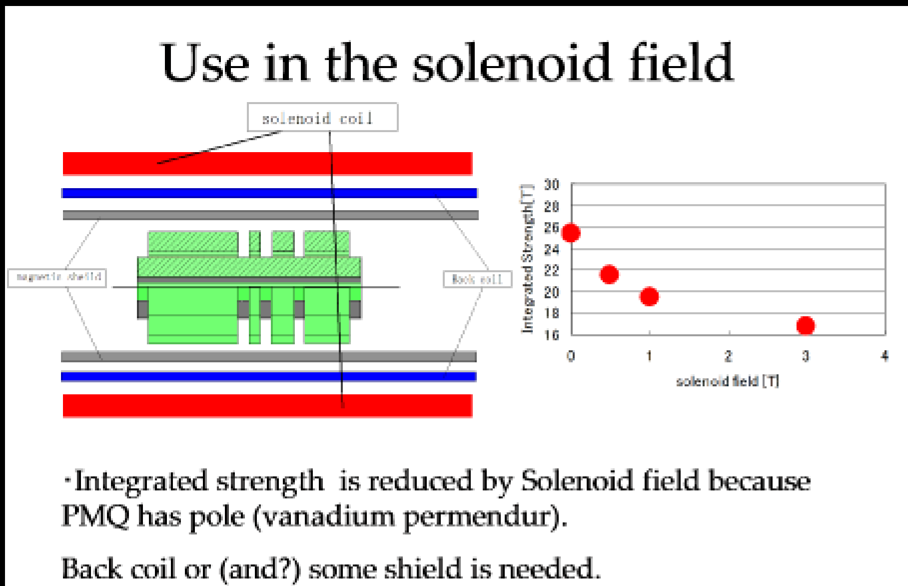




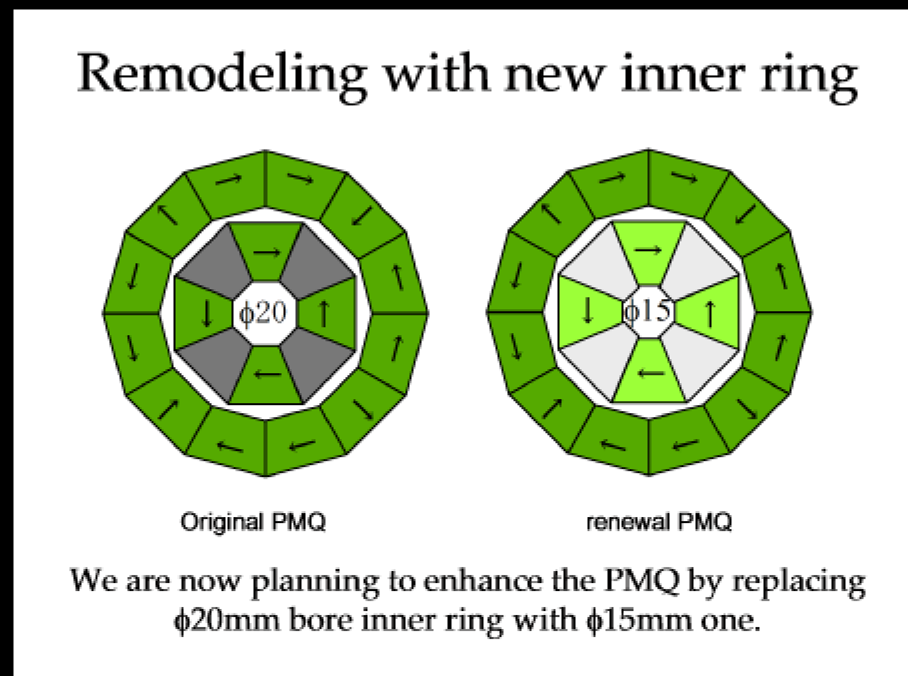
*160T/m without temp. compensation.

longer L* means stronger PMQ.

External field can naturally be made small and can use Permendur pole inserts to enhance/tailor the field.



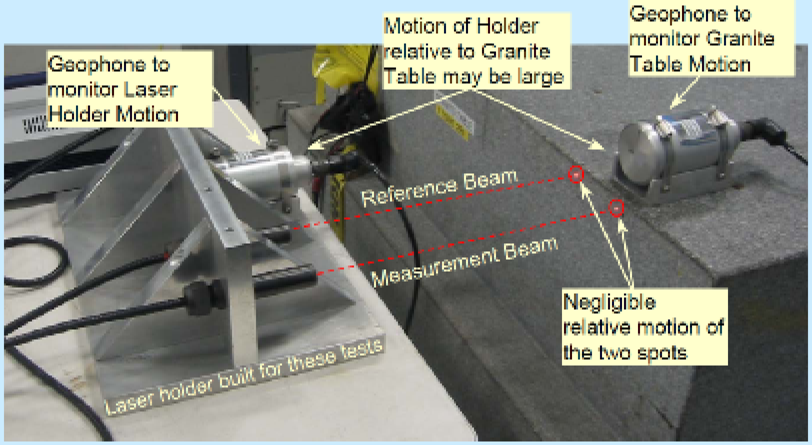
If Permendur gives trouble due in an uncompensated external magnetic field, then try trading off on inner size to get strength.



A magnetic pole material, like Vanadium Permendur, takes in solenoid flux until it saturates and will cause PMQ to be pulled towards the detector. Maybe we can try to kill this field at the PMQ with bucking coil and shield; how completely must this be done and what is the impact on the detector?

R&D: possible smaller step size (finer field increment); also look at radiation demagnetization.

Performance Tests: Dual Beam Mode



We do not yet have a cryostated ILC compact FF magnet. To get first idea of whether cryogenic flow can cause relative motion between cold mass and cryostat we can study a spare RHIC quadrupole (develop technique). Desire a method that does not touch the cold mass and works well cold in the presence of strong magnetic fields (laser).

Suitability of Laser Vibrometer

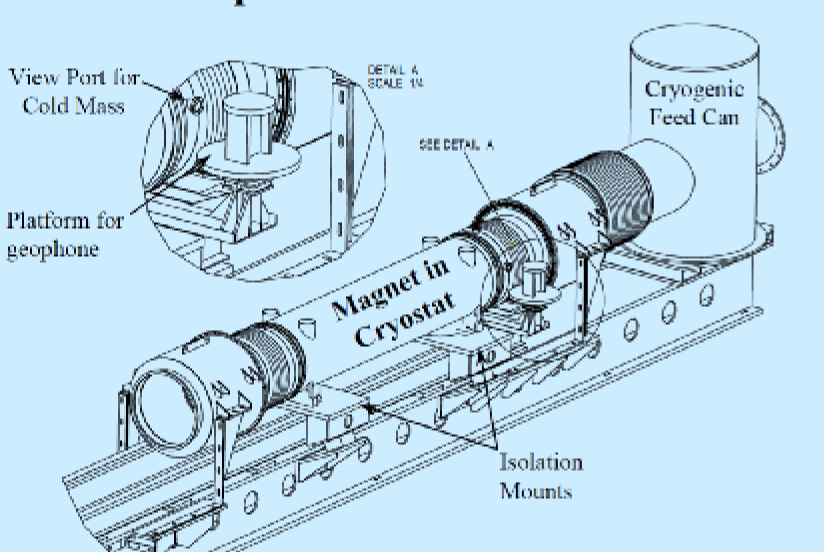
- Motion is measured by the Doppler shift in frequency of a laser beam bounced back from the object.
- Non-contact method – suitable for tight spaces.
- No parts are installed on the object – suitable for cryogenic environment and in magnetic field.
- Has the necessary resolution ~ nm at low frequencies.
- Some drawbacks:
  - Requires "line of sight" to the object (add viewports)
  - Measurements are sensitive to the motion of the laser head itself:
    - * Use a dual beam fiber optic laser head (diff. meas.)
    - * Many iterations of the laser holder design.

Summary of Laser Performance Tests

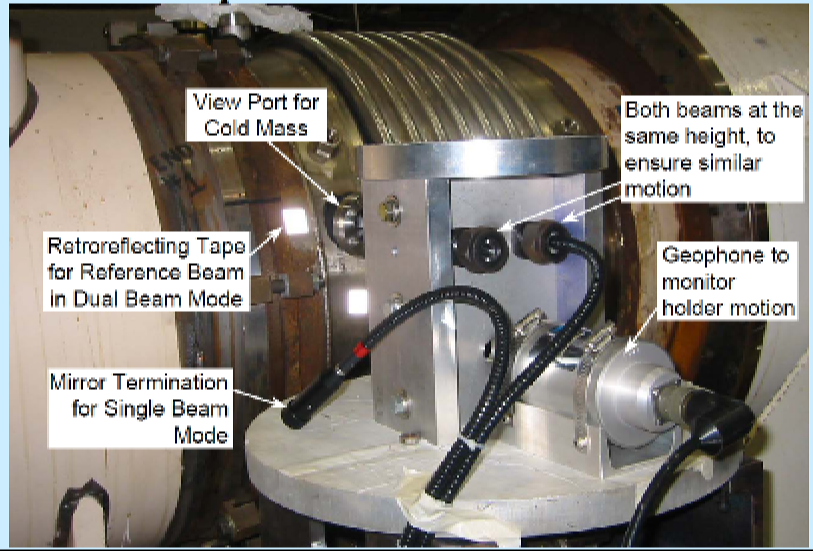
- Intrinsic noise, based on both beams terminated by mirrors, is below 1 nm/√Hz above ~ 2 Hz.
- Single beam measurements pick up motion of both the object and the laser head.
- Single beam measurements are consistent with motion derived from geophone data.
- Dual Beam differential data are consistent with the intrinsic noise (<1 nm/√Hz above ~ 2 Hz) when the absolute motion is also small.
- Absolute motion is largely suppressed (>10X) in the differential mode for most frequencies.
- Still need to keep the laser head motion as small as possible since the cancellation is not perfect.

"Vibration Measurements in a RHIC Quadrupole at Cryogenic Temperatures"
presented by: A. Jain

Laser Set up for Horizontal Measurements

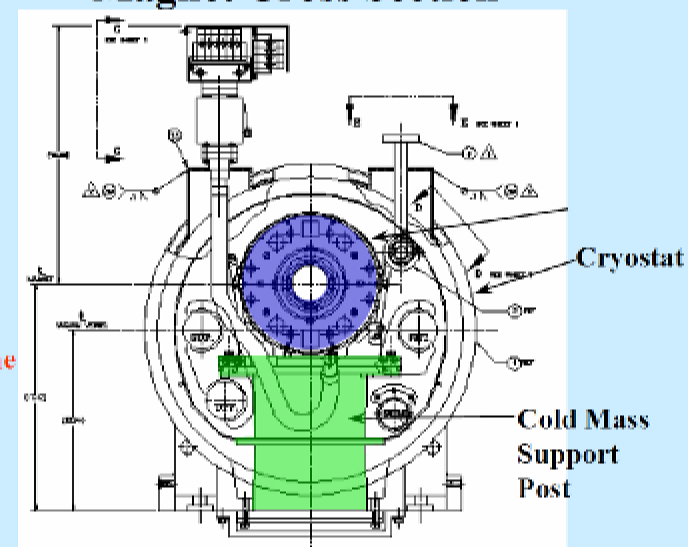


Laser Set up for Horizontal Measurements



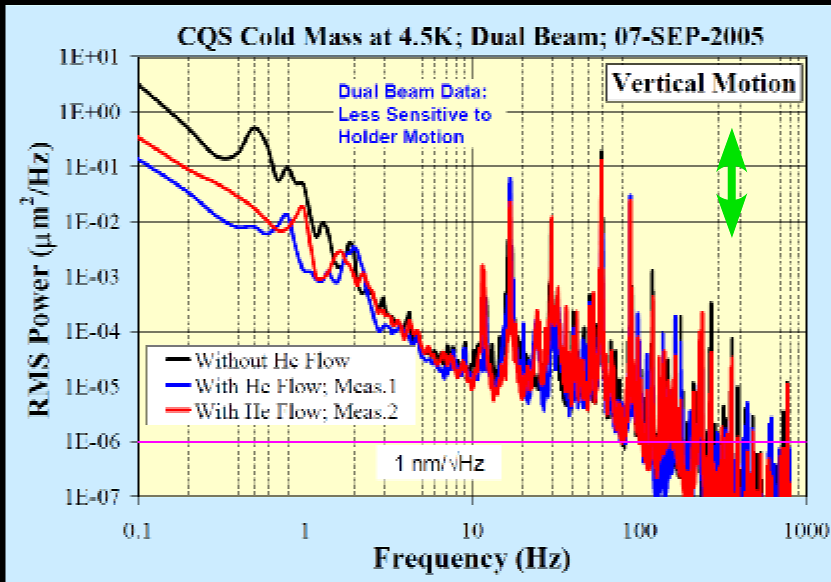
Magnet Cross Section

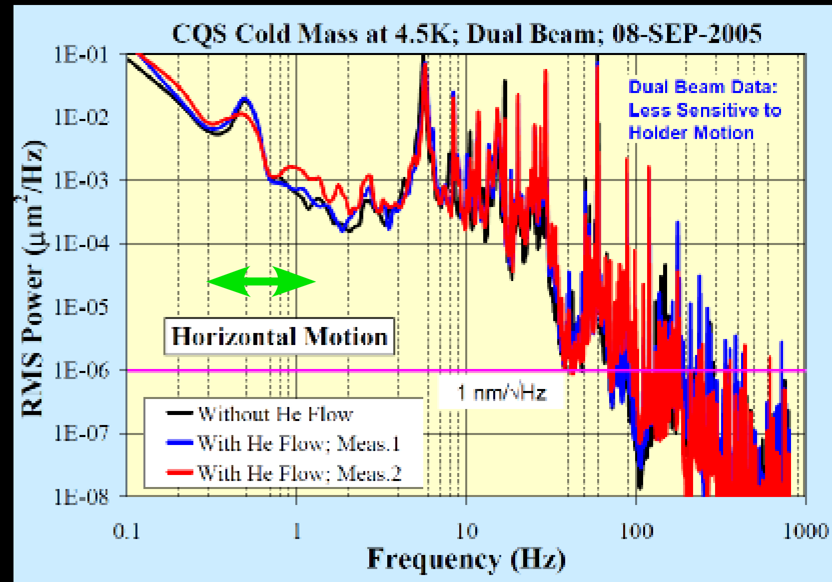
Note: Magnet is relatively free to move in the horizontal direction



Laser Set up for Vertical Measurements

"Vibration Measurements in a RHIC Quadrupole at Cryogenic Temperatures"
presented by: A. Jain

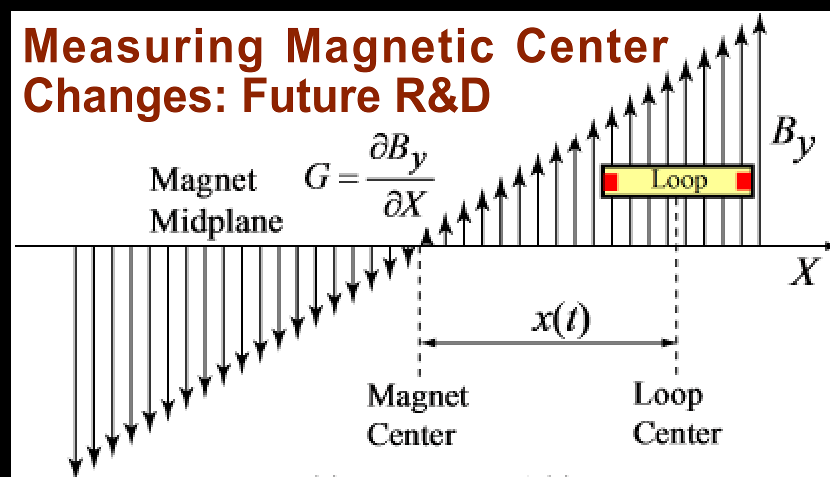




Summary

- Performance of the dual beam Laser Doppler Vibrometer is characterized in the single and dual beam modes.
- Measurements of cold mass vibrations have been carried out in a spare RHIC quadrupole at 4.5 K with and without cryogens flowing.
- The measurements show a small increase in the horizontal motion at a few frequencies with cryogen flow.
- Based on the dual beam data, there is no evidence of a systematic increase in the vertical motion of the cold mass with respect to the cryostat.
- These results are quite encouraging for applications of superconducting quadrupoles in the ILC.
- The measurement sensitivity is currently limited by the rather large total motion (200-300 nm).

Measuring Magnetic Center Changes: Future R&D



$$V(t) = wNLG \cdot \dot{x}(t)$$

For 10 mm x 500 mm x 400 turns in 140 T/m:
$V(t)$ = 280 V/(m/s) = same as a geophone

The AC properties of QMG coil magnets

- The development of new type High-T_c high J_c superconducting magnets -

M. Morita, NSC, Chiba,

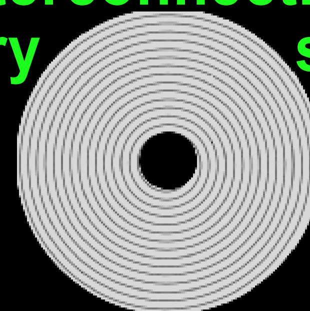
M. Kumada, NIRS, Chiba,

A. Sato, NIMS, Ibaraki,

H. Teshima, NSC, Chiba and

H. Hirano, NSC, Chiba

Neat trick is to slice single crystal and sandblast a spiral pattern to make a unit that can be stacked. After soldering layer interconnections then end up with a very small but powerful magnet.

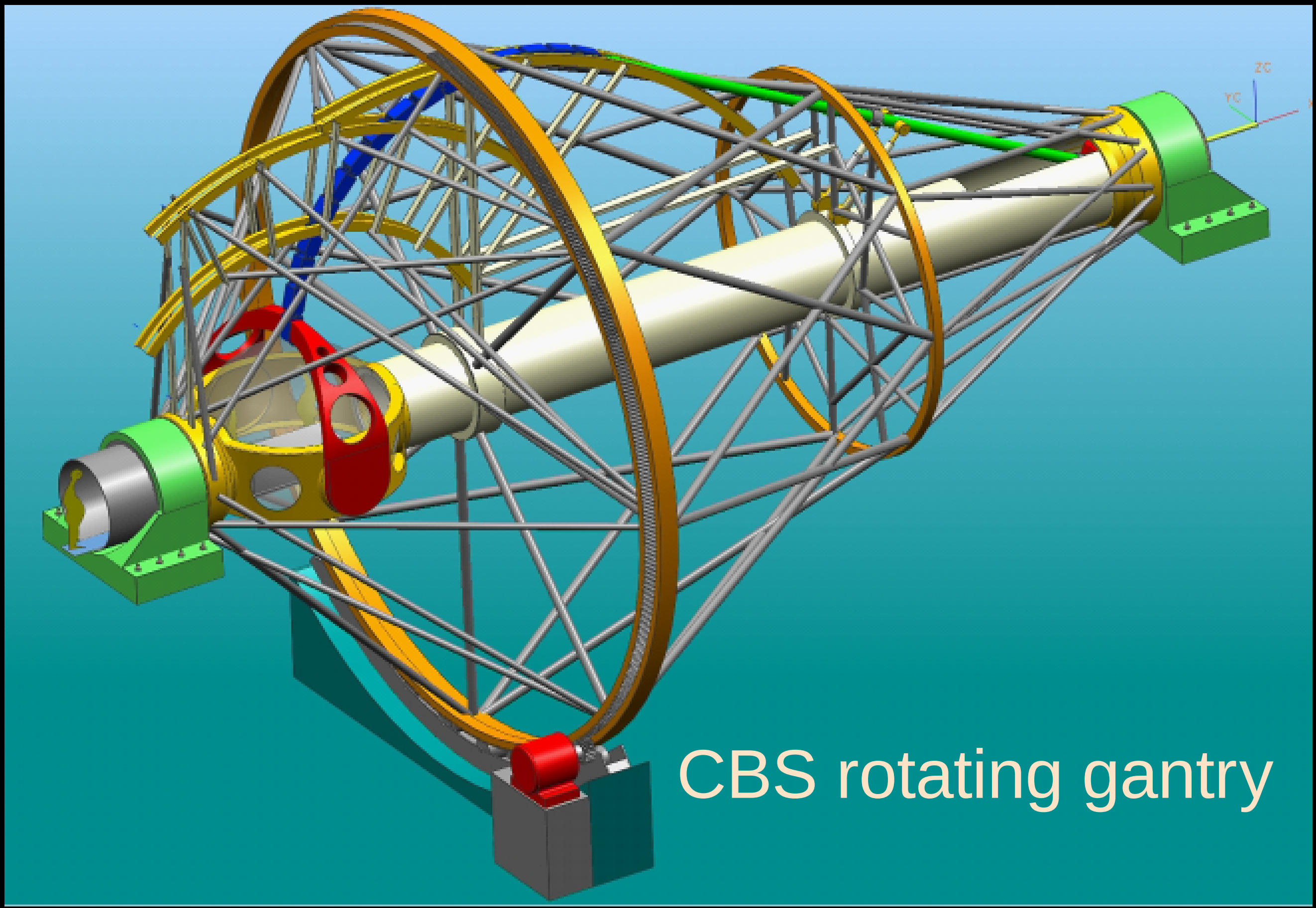


abstract

On high-Tc oxide bulk superconductors (QMG) which have high current capacity up to several 10^4 A/cm^2 at 77K we introduce development for the materials and their applications. Especially QMG eddy magnet is one of the important applications. QMG eddy magnet consists of eddy shape and planar superconducting QMG coils. These coils are stacked and connected in series by solder. Recently, we fabricated eight-layer QMG eddy magnets that have 11 turn and cross section of 1.0 x 2.1 mm and diameter of 74mm. The magnet generated 2.1T at 52K, 1.25T at 63K and 0.66T at 77K. We will also report hysteresis properties, rapid excitation properties and endurance for the heat-cycle.

One lesson I learned...

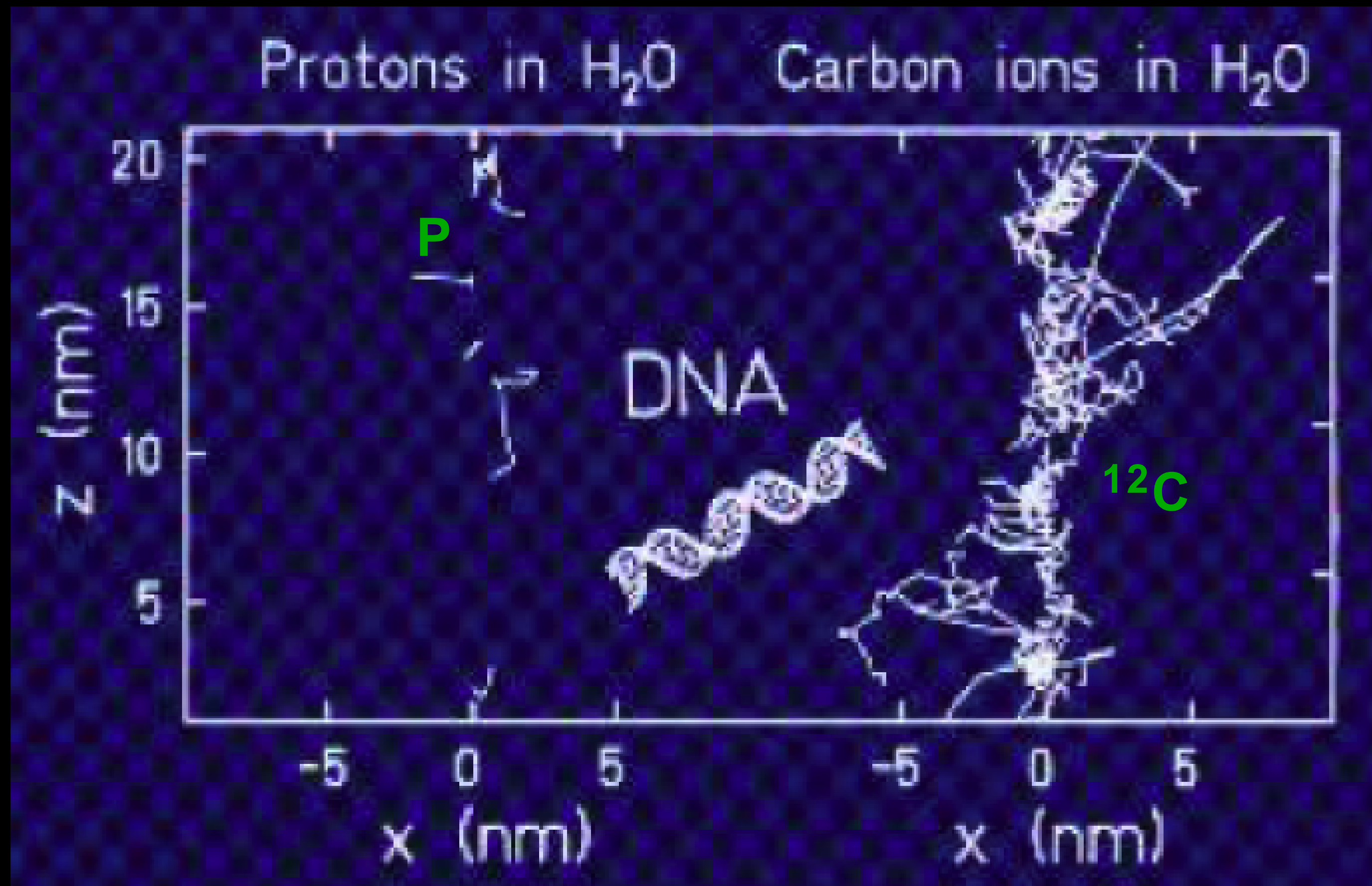
When making a session summary have a pdf file as backup in case the Powerpoint file will be missing something crucial.



For 12C treatment try to use advanced materials to make magnets as small & light as possible.

Superconductor having the best possible performance may be useful here since there is a huge advantage in reducing the gantry mass.

Particle therapy should be on a catergory of a nano meter scale technology



If the goal in radiation therapy is to break up DNA strands, then ^{12}C should be much more effective because of localized, few nm scale, final energy deposition.

Some

Other

Lessons

Learned

Thank you for your attention.

B. Parker