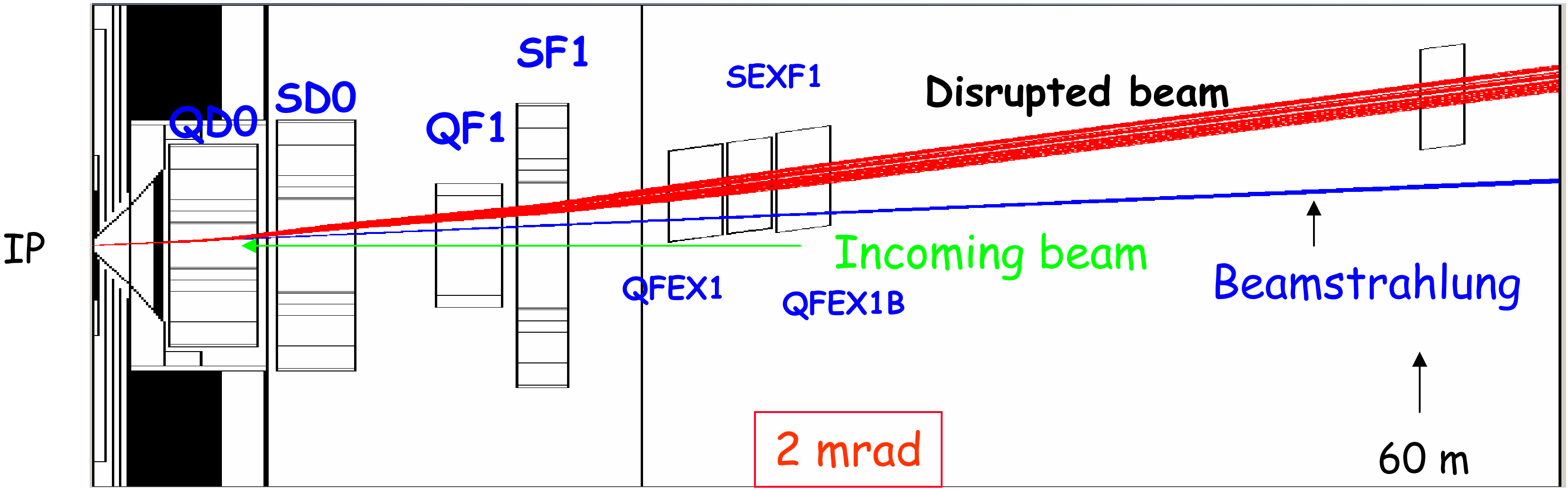
# 2 mrad IR magnets



| Magnet type | Bore radius, mm | Field at radius, T | Eff. length, m | Qty |
|---|---|---|---|---|
| Quad QD0 | 35 | 5.6 | 2.5 | 2 |
| Sextupole SD0 | 88 | 4.0 | 3.8 | 2 |
| Quad QF1 | 10 | 0.68 | 2.0 | 2 |
| Sextupole SF1 | 112 | 2.12 | 3.8 | 2 |
| SeptumQEX1A | 113 | 1.33 | 3.0 | 2 |

# Status of shared large-aperture magnets designs

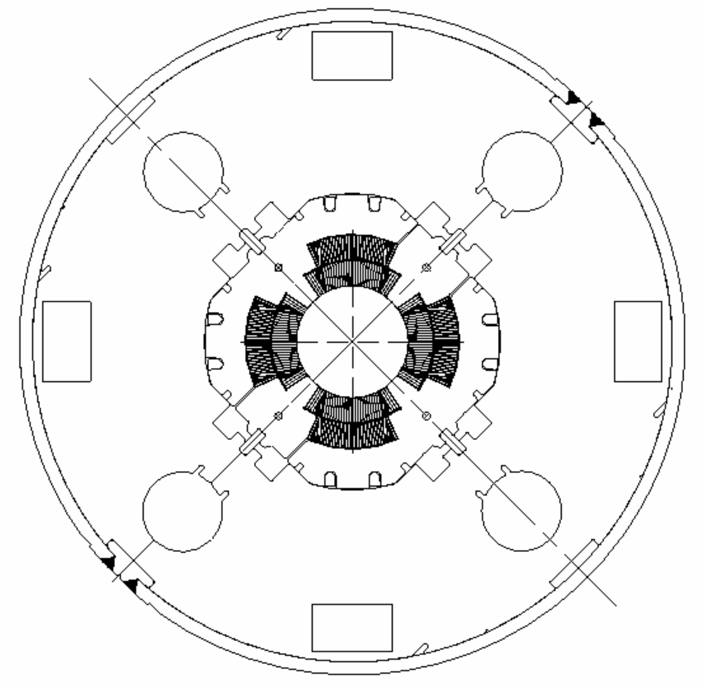
Approach to RDR cost estimate:

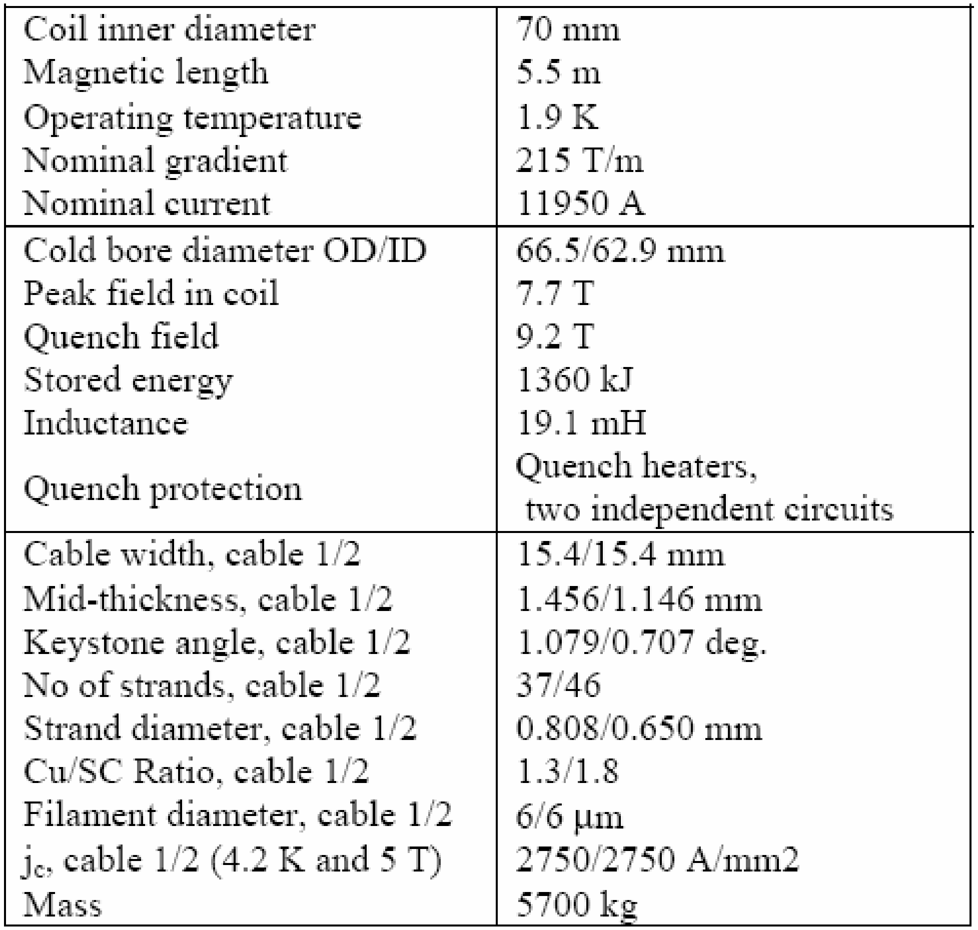
- IR magnets designs are based on 1.9K NbTi technology developed for first-generation LHC IR
- *Preliminary* analysis (Vl. Kashikhin & A. Zlobin) indicates that LHC-IR type 70-mm NbTi quadrupole magnet (MQXB) are adequate to meet QD0 requirements
- Sextupole *preliminary* design (Vl. Kashikhin) is also derived from MQXB experience and parameters (strand/cable, mechanical support concept etc) and meets specs

# Reference Design: LHC IR Quad MQXB

Features/Parameters

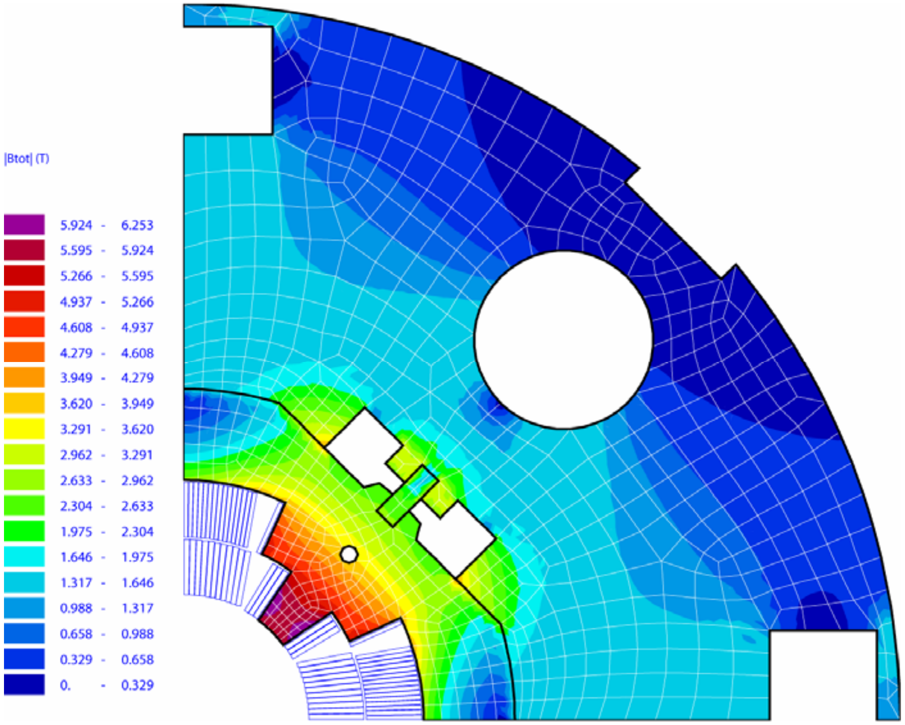
- Aperture 70 mm
- NbTi @ 1.9K
- Self-supporting collar





| | |
|---|---|
| Coil inner diameter | 70 mm |
| Magnetic length | 5.5 m |
| Operating temperature | 1.9 K |
| Nominal gradient | 215 T/m |
| Nominal current | 11950 A |
| Cold bore diameter OD/ID | 66.5/62.9 mm |
| Peak field in coil | 7.7 T |
| Quench field | 9.2 T |
| Stored energy | 1360 kJ |
| Inductance | 19.1 mH |
| Quench protection | Quench heaters,<br>two independent circuits |
| Cable width, cable 1/2 | 15.4/15.4 mm |
| Mid-thickness, cable 1/2 | 1.456/1.146 mm |
| Keystone angle, cable 1/2 | 1.079/0.707 deg. |
| No of strands, cable 1/2 | 37/46 |
| Strand diameter, cable 1/2 | 0.808/0.650 mm |
| Cu/SC Ratio, cable 1/2 | 1.3/1.8 |
| Filament diameter, cable 1/2 | 6/6 μm |
| $j_c$, cable 1/2 (4.2 K and 5 T) | 2750/2750 A/mm2 |
| Mass | 5700 kg |

# QD0 Design (Vl. Kashikhin)



| Parameter | Unit | Value |
|---|---|---|
| **$G_{nom}$** | **T/m** | **160.0** |
| **$I_{nom}$** | **kA** | **8.8** |
| **$B_{p\_nom}$** | **T** | **6.3** |
| **$B_{p\_q}(I_{nom})$** | **T** | **9.9** |
| **Field margin** | **T** | **3.6** |

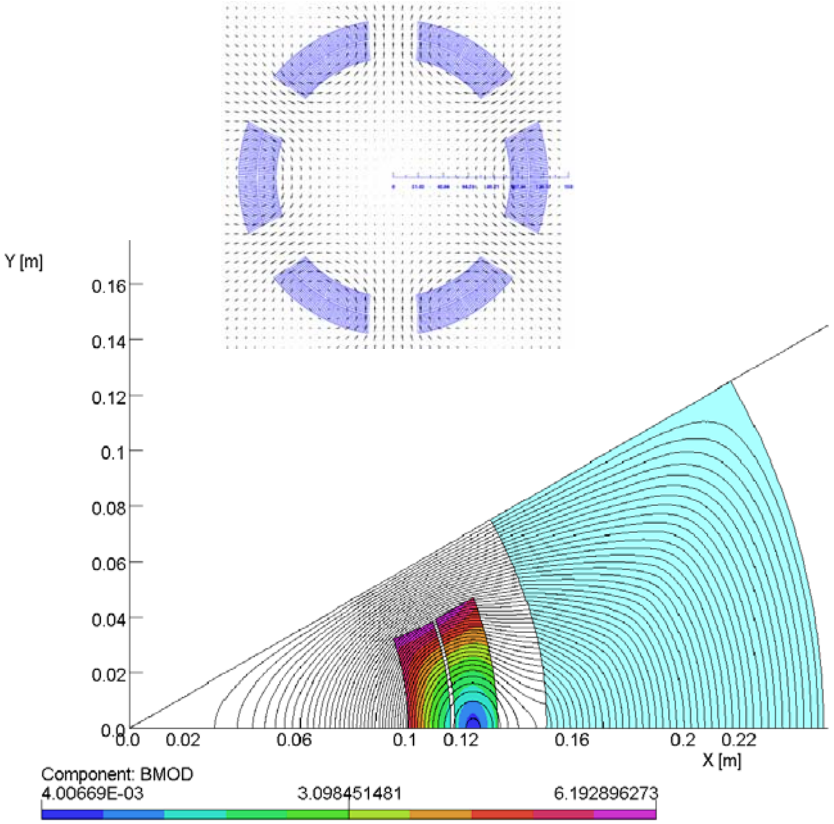
**There is 0.9 T field margin assuming 2.7 T detector’s background field**

# Large aperture sextupole design (Vl. Kashikhin)

Shell type coil sextupole with cold iron

Design close to LHC IR Quadrupoles

| | |
|---|---|
| **Coil ampere-turns** | **343 kA** |
| **Current** | **7 kA** |
| **Calculated strength** | **519.2 T/m$^2$** |
| **Coil maximum field** | **6.2 T** |
| **Iron core field (max)** | **3.8 T** |
| **Field energy** | **376 kJ/m** |
| **Lorentz force, Fx** | **56.5 t/m** |
| **Lorentz force, Fy** | **-83.2 t/m** |
| **Number of turns** | **22(inner) + 27(outer)** |
| **NbTi Superconducting cable** | **LHC IR inner** |
| **Jc at B=5 T, 4.2** | **2750 A/mm$^2$** |
| **Strand diameter** | **0.808 mm** |



# Open Issues for NbTi approach

- Required aperture has increased in later versions of the optics
- Additional bore space may be needed for corrector coils
- Peak coil fields will increase when detailed 3D effects, interaction with solenoid and anti-solenoid are considered

⇒ It appears that NbTi design margins are sufficient to take these effects into account, but it needs to be demonstrated

- More detailed calculations of magnetic center motion (SC magnetization, Lorentz forces, mechanics, iron saturation and hysteresis, etc)

⇒ present estimate is 1-5 μm magnetic center stability

⇒ need to develop correctors, optimize magnet movers for larger magnet weight/size

# Alternative approach using $Nb_3Sn$

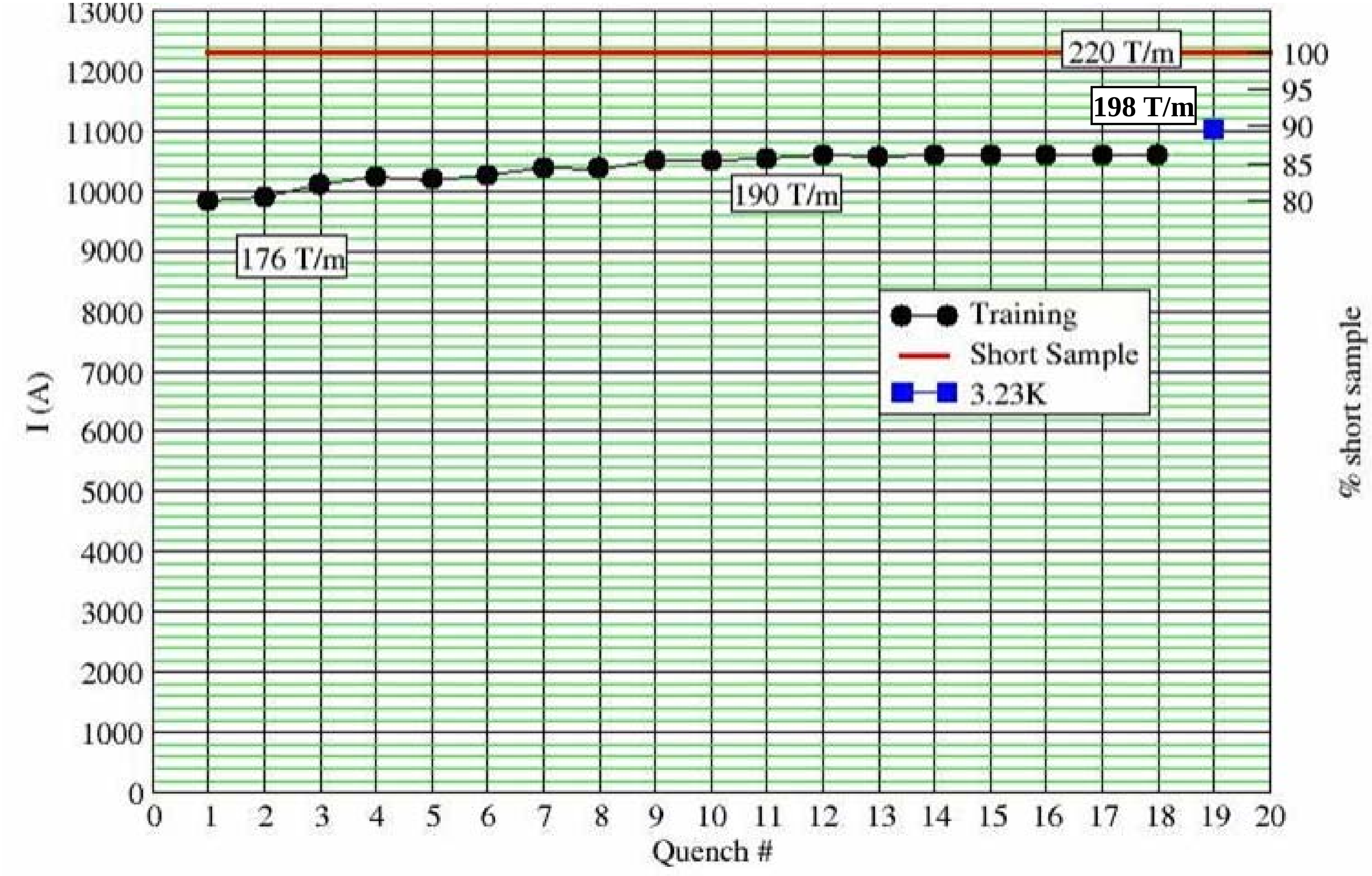
- LARP R&D status: first Technology Quad (TQ) achieved ~200 T/m in 90 mm aperture; second TQ ready for test; third TQ under fabrication
- After optimization, Technology Quads should provide up to 250 T/m
- LARP R&D Goal: 300 T/m in 90 mm aperture for High-Gradient Quad (HQ) by 2009

*Potential for high gradient/large bore/short length; thermal margin*
*Specify required aperture & gradient for SC quads, not "pole tip field"*
*Typical gradients for $Nb_3Sn$ should be 200-250 T/m in 90 mm bore (without taking into account solenoidal field)*

<u>Issues:</u>

- Support structure designs for high-performance, brittle conductor presently require large transverse size
- Effect of persistent currents on magnetic center stability
- Uncertainties in performance limits and cost

# TQS01 Quench Training



# Summary

- Large bore 2 mrad IR superconducting magnets are feasible
- R&D and prototyping are needed to confirm the specified performance and cost estimation.

Next steps:

- NbTi: detailed 3D magnetic and mechanical analysis (including effect of anti-solenoid, corrector package, possibly larger aperture, liner)
- $Nb_3Sn$: develop coil and structure designs tailored to the specific needs of ILC: focus on magnetic center positioning and small transverse size, relax requirements on higher harmonics, design for required aperture and gradient, interaction with detector solenoid
- Discussions are underway to develop effective collaboration on IR magnet designs for 2 mrad and head-on schemes
- Need to perform self consistent calculations (backgrounds, heat loads)
- Installation & maintenance procedures (combined detector/magnets)