Title

The UCLA Phi Factory Detector, the Integration of Superconducting Compensation Solenoids and Final Focus Interaction Region Quadrupoles

Permalink

https://escholarship.org/uc/item/84j4s8d3

Authors

Green, M A
Cline, D B

Publication Date

1992-06-01

LBL-32526
UC-414

Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

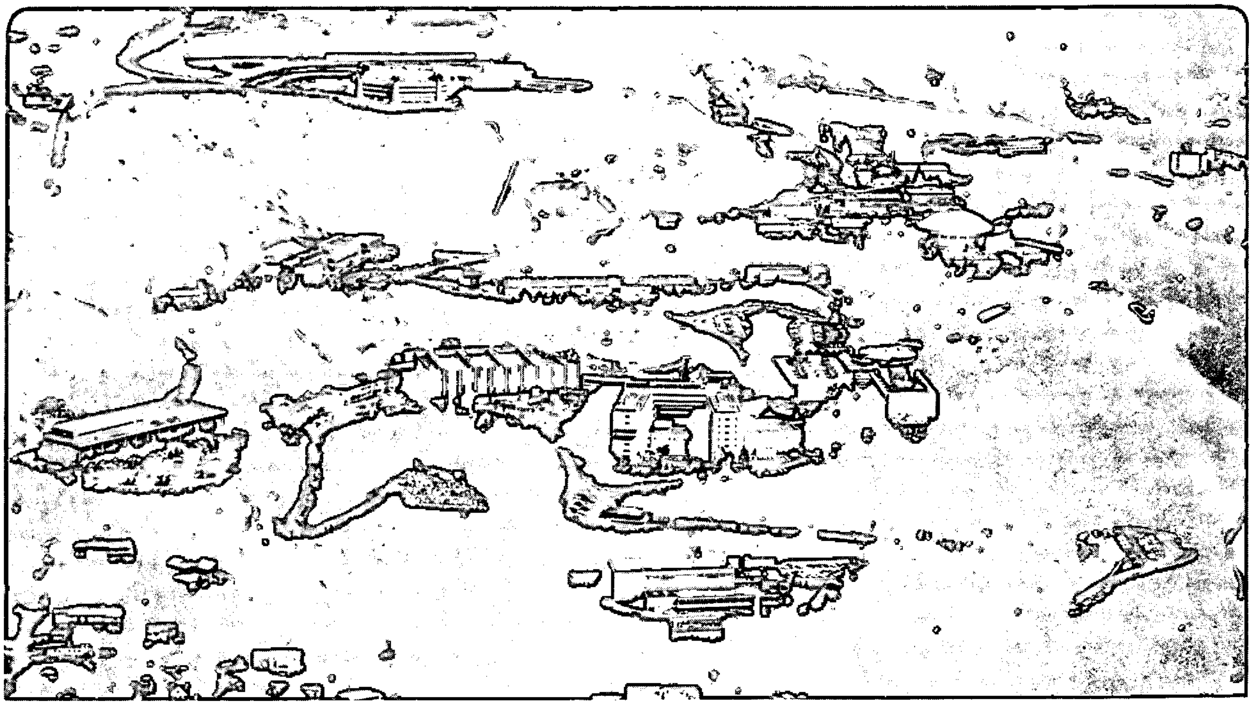
Engineering Division

Presented at the Fourteenth International Cryogenic Engineering
Conference, Kiev, Ukraine, June 8–12, 1992,
and to be published in the Proceedings

The UCLA Phi Factory Detector, the Integration of Superconducting Compensation Solenoids and Final Focus Interaction Region Quadrupoles

M.A. Green and D.B. Cline

June 1992



Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098

LBL-32526
SC-MAG-388

THE UCLA PHI FACTORY DETECTOR, THE INTEGRATION OF SUPERCONDUCTING COMPENSATION SOLENOIDS AND THE FINAL FOCUS INTERACTION REGION QUADRUPOLES

M. A. Green

Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

D. B. Cline

University of California at Los Angeles
Department of Physics
Los Angeles, CA. 90024

1992 International Cryogenics Engineering Conference and International Cryogenic Materials Conference
1CEC-14 and ICMC

Kiev, Ukraine
June 8-12, 1992

To be published in *cryogenics*

---

*This work was performed at the Lawrence Berkeley Laboratory with the support of the Ofiice of Astrophysics, NASA and the Director of the Office of Energy Research, Office of High Energy and Nuclear Physics, High Energy Physics Division, U. S. Department of Energy under Contract No. DE-AC03-76SF00098.

THE UCLA PHI FACTORY DETECTOR, THE INTEGRATION OF SUPERCONDUCTING COMPENSATION SOLENOIDS AND THE FINAL FOCUS INTERACTION REGION QUADRUPOLES

M. A. Green* and D. B. Cline**

* Lawrence Berkeley Laboratory, Berkeley CA. 94720, USA
** UCLA Department of Physics, Los Angeles CA. 90024, USA

The proposed Phi Factory for the University of California at Los Angeles (UCLA) is a small 510 MeV electron-positron colliding beam storage ring with high luminosity (greater than 10^{32} cm^{-2} s^{-1}). In order to do high quality Phi physics, a particle detector system with a large solid angle (preferably greater than 98 percent) is required. Particle detection and analysis will be done within a 0.5 tesla solenoidal magnetic field. The solenoidal field within the detector causes coupling between beam oscillations in the horizontal and vertical directions. Therefore, compensation solenoids are required to keep the circulating particle beams from seeing the effects of the field from the main detector solenoid. Since high luminosity and a large solid angle are required, the detectors and a pair of compensation solenoids must be integrated with the final focus quadrupoles within the detector straight section. This report describes the design of two tapered, 0.5 tesla, superconducting compensation solenoids which must go around six rare earth permanent final focus quadrupoles or six superconducting quadrupoles on either side of the beam collision point. A cryogenic cooling system for these two solenoids, which will be coupled with the cooling system for the primary detector solenoid, is also described.

BACKGROUND

The proposed Phi Factory at UCLA is a collaboration between UCLA, Lawrence Berkeley Laboratory (LBL), Lawrence Livermore Laboratory (LLL), Los Alamos Scientific Laboratory (LASL), the Institute for Nuclear Physics at Novosibirsk, Russia and several industrial and other university collaborators.[1] The UCLA Phi Factory is characterized by being a small single ring (only 32.7 meters in circumference) which circulates 510 MeV electrons and positrons. The machine itself will consist of eight 4 tesla, 0.4 meter long, superconducting, 47 degree bend, dipole magnets. The 4 tesla dipoles reduce the size of the ring and, in addition, they provide damping in the ring (an energy loss of 14.9 KeV per turn) so that the luminosity of the collider at the detector will be greater than 10^{32} cm^{-2} s^{-1}. The use of the superconducting bending magnets as dampers eliminates about 12 meters of rare earth cobalt wigglers which would be needed for damping if conventional dipoles (one would need eight 1.2 meter long dipoles) were used to bend the beams. Four dipoles provide a 4 degree reverse bend so that the machine can be run in the quasi-isochronous mode to permit one to increase the ultimate desired luminosity to 10^{33} cm^{-2} s^{-1} while operating at relatively low currents with as few as four bunches of each type of particle in the ring. The forty-four ring quadrupoles are conventional as are the six quadrupoles in the straight section used for injection and the radio frequency cavities. The six final focus quadrupoles in the detector straight section will either be superconducting or rare earth cobalt quadrupole (or a combination of the two types) in order to focus the bunches to a very small size and provide for a large solid angle for particles to be detected in the detector. A solid angle of 98 percent of four pi is what is desired for the kinds of physics one wants to do at the Phi Factory[2]. This report describes the interaction region quadrupoles and the compensation solenoids needed so that the horizontal and vertical beam oscillations remain decoupled. In addition to doing Phi physics, the small UCLA ring will be a compact light source for use by researchers from all over Southern California.

THE FINAL FOCUS QUADRUPOLES AND COMPENSATION SOLENOID

The detector will consist of the 2.04 meter warm bore superconducting solenoid built for the PEP-4 experiment at the Stanford Linear Accelerator Center (SLAC), liquid krypton calorimeters, a central tracking chamber (a TPC or drift chamber) and some sort of a vertex detector. The PEP-4 solenoid, which was designed to produce 1.5 tesla, will be operated at a central induction up to 0.5 tesla. The iron return yoke poles are designed to return the magnetic flux and insure that the solenoid field will be uniform. The central tracking chamber and krypton calorimeters surround the interaction point. Within these detectors, the electron and positron bunches enter the detector so that they collide at the interaction point at the center of the detector. The electron and positron beams travel down the bore of the detector solenoid. In order that these beams not see the solenoidal field, they will travel down the bore of a compensation solenoid so that the integrated solenoidal field the beams see is zero. The two compensation solenoids and

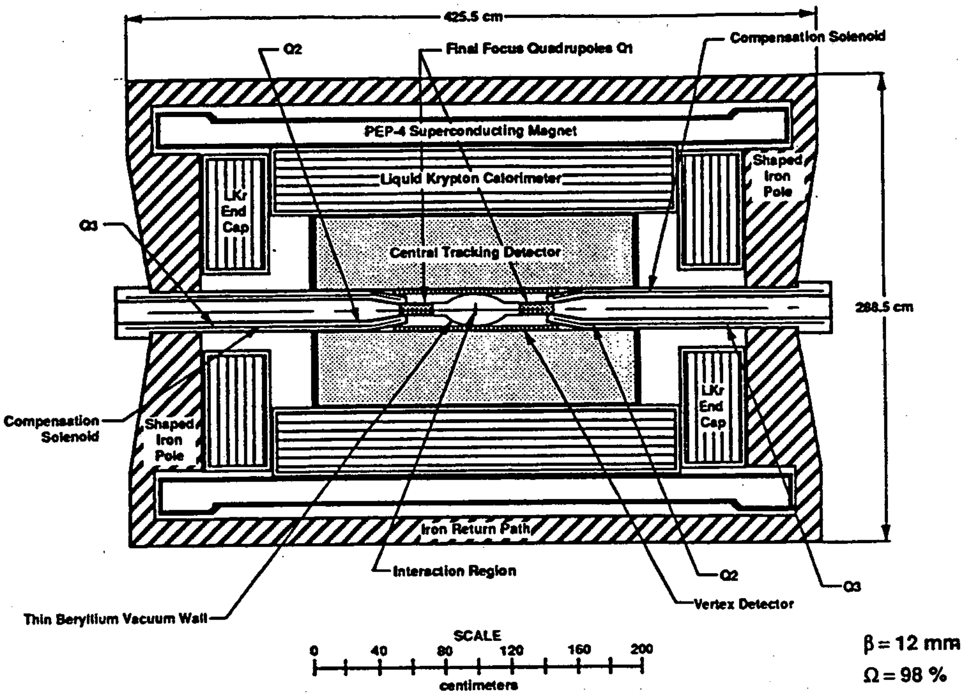


Fig.1 The UCLA Phi Factory Interaction Region, Detectors, Compensation Solenoid, and the Six Final Focus Quadrupoles.

the three final focus quadrupoles on either side of the interaction region must be located within the detector. Figure 1 shows the arrangement of the detectors, the PEP-4 solenoid, the return iron, the compensation solenoids, and the six final focus quadrupoles on either side of the interaction region.

The final focus quadrupole system for the Phi Factory permits one to focus the beams to extremely low values of beta star (as low as 4 mm). Low values of beta star require that the first final focus quadrupole be close to the interaction region. If a large detector solid angle is to be achieved, the diameter of the final focus quadrupole should be as small as possible.[3,4] If a solid angle of 98 percent of four pi is to be achieved, the diameter of the final focus quadrupole must be less than 40 percent of the distance to the collision point. If the experiment solid angle is reduced to 95 percent, the final focus quadrupole diameter can be as much as 67 percent of the distance from the quadrupole to the collision point. The final focus quadrupole aperture is determined by the horizontal and vertical beta values in the quadrupole and the horizontal and vertical emittance of the beam. Small values of beta star at the interaction point mean that the aperture of the first final focus quadrupole is large. Small values of beta star, needed to achieve higher luminosity are counter to the concept of having as large a solid angle as possible in the detector. There is a trade off between detector solid angle and beta star, hence luminosity for a given number of beam bunches.

The requirement of a compensation solenoid complicates the situation. The solenoid field integral along the axis of the solenoid axis must be nearly zero for the beams passing through the detector, yet the field around the collision point should be the 0.5 tesla generated by the PEP-4 detector solenoid. A pair of superconducting compensation magnets, which generate a field integral equal and opposite the field integral of the main detector solenoid, are proposed. The gap between the two compensation solenoids is equal to at least twice the distance from the first final focus quadrupole to the interaction point. The field inside these compensation solenoids is nearly zero. The six focus quadrupoles can be located inside of the compensation solenoid provided they are no iron quadrupoles. The four of the six quadrupoles inside.the compensation solenoids can be superconducting and they can share a common cryogenic system. The first final focus quadrupoles may be either superconducting or rare earth cobalt depending on which option results in the largest solid angle for the detector. It is desirable to taper the compensation solenoids at the end near the interaction point. A tapered compensation solenoid is shown in Figures 2 and 3. This taper at the end of the compensation solenoid increases the detector solid angle.

The advantages of superconducting first final focus quadrupoles are as follows: 1) The quadrupole strength can be adjusted, 2) The final focus quadrupoles can be integrated with the superconducting

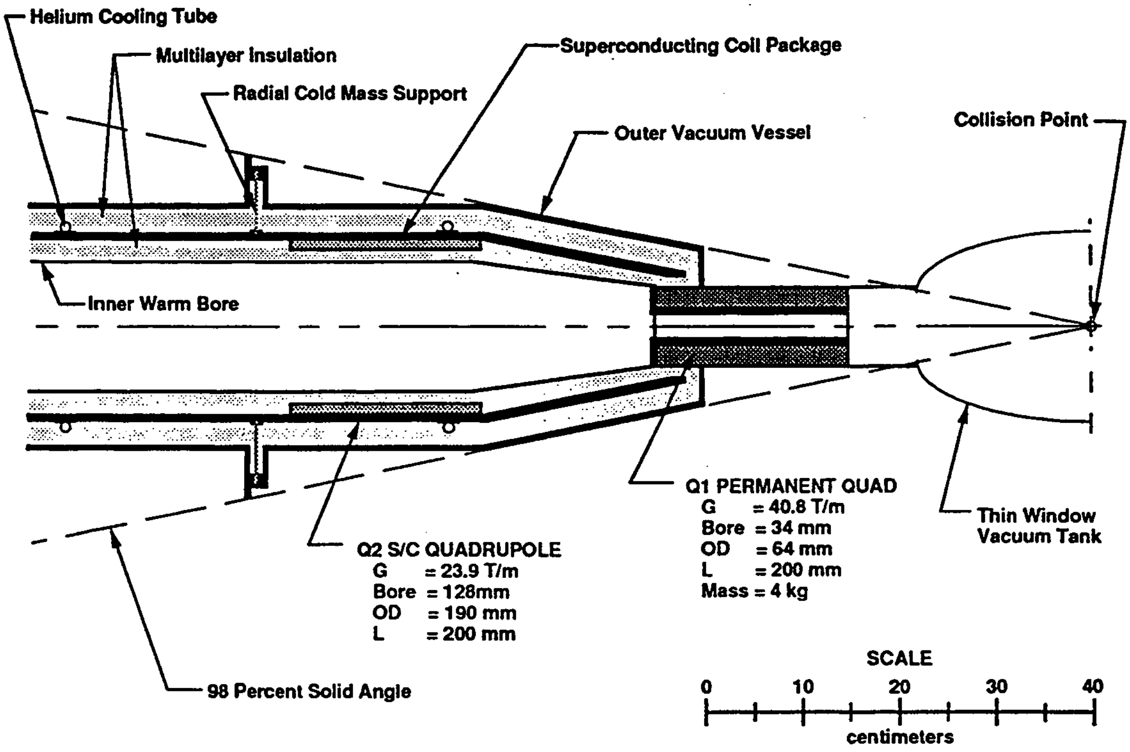


Fig. 2. The First Two Final Focus Quadrupoles with a Permanent First Quadrupole and a Tapered Compensation Solenoid for the Case where Beta Star at the Interaction Point is 12 Millimeters

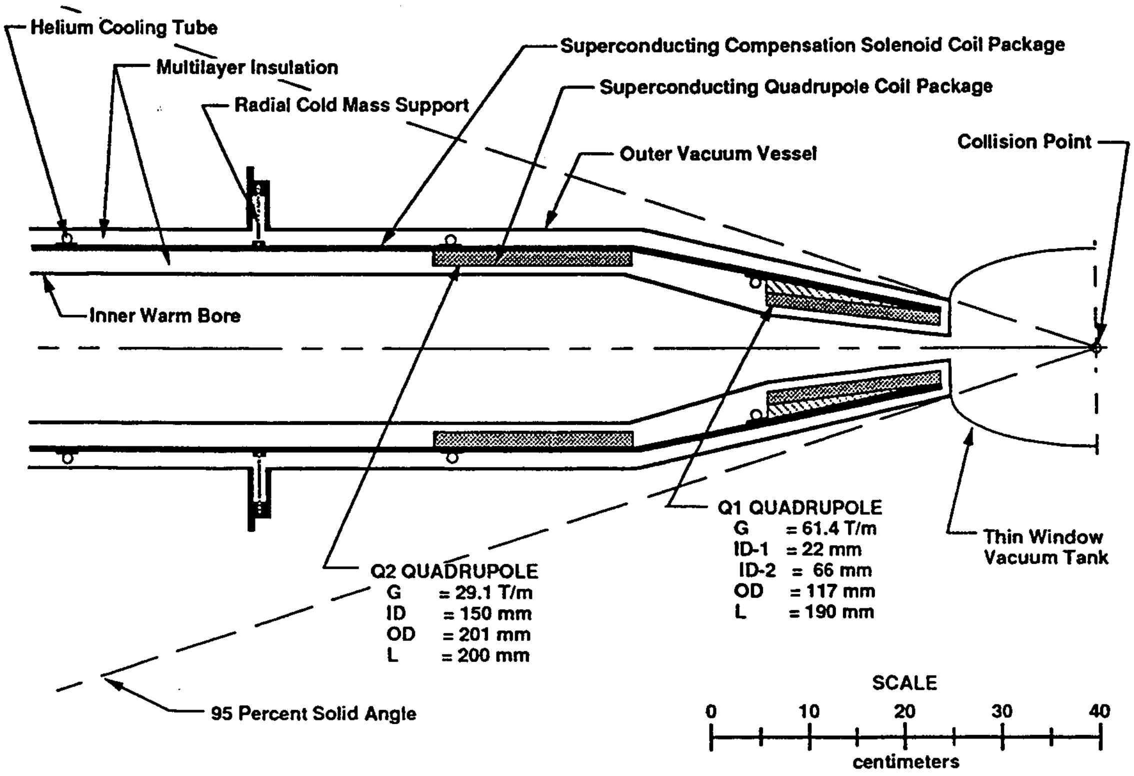


Fig. 3 The First Two Final Focus Quadrupoles with a Superconducting First Quadrupole and a Tapered Compensation Solenoid for the Case where Beta Star at the Interaction Point is 4 Millimeters

compensation solenoid. 3) High gradient quadrupoles with a larger aperture can be made with smaller outside dimensions. Superconducting quadrupoles use a minimum of 20 millimeters of radial space for the cryostat and a separate cryogenic system will be required unless the quadrupoles are integrated with the compensation solenoids. Permanent quadrupoles will have a very small outside dimension provided the bore is small and the pole field is less than 1 tesla. Permanent final focus quadrupoles must be cooled because variation of temperature with time means that their strength will vary with time. The cooling for the permanent quadrupoles requires an extra 5 millimeters of space. Permanent quadrupoles within the compensation solenoid will in most cases result in a larger diameter compensation solenoid. A larger compensation solenoid means more end effects to deal with in the detector.

The Phi factory ring has been studied so that the final beta star varies from about 12 millimeters down to about 4 millimeters. The smaller the beta star, the higher the luminosity of the machine per bunch or per unit current. Figure 2 shows the first two final focus quadrupoles and a compensation solenoid for a final focus system with a beta star of 12 millimeters. A permanent first final focus quadrupole is shown 250 millimeters from the interaction region. The second final focus quadrupole is superconducting. The solid angle for the detector in this case is almost 98 percent of four pi. Figure 3 shows the first two final focus quadrupoles and compensation solenoid for a final focus system which has a beta star of 4 millimeters. A tapered superconducting first final focus quadrupole is shown. Its location is 150 millimeters from the interaction region. The first quadrupole shown is tapered to fit the profile of the particle beam as it enters and leaves the interaction zone. Using a tapered quadrupole as a first quadrupole, a solid angle 95 percent of four pi for the detector can be achieved. If a straight first quadrupole with an aperture equal to the largest aperture for the first quadrupole were used in place of the tapered quadrupole, the detector solid angle would be about 90 percent of four pi.

A tapered final focus quadrupole will have a variable strength as one goes along the quadrupole. The quadrupole will be strongest at the end where its aperture is smallest. As a result, the tapered quadrupole may be located 10 to 20 millimeters further from the interaction point which increases the solid angle of the detector to 96 percent of four pi. This option is being studied by the UCLA beam dynamics group for the Phi Factory. To our knowledge, tapered superconducting quadrupoles have never been built, but a design for one is underway at the Lawrence Berkeley Laboratory. The beam dynamics issues for tapered quadrupoles and quadrupoles which are close together will require further study.

CONCLUSIONS

The final focus quadrupoles and the compensation solenoid within the Phi Factory detector are critical to the physics which can be performed by the machine. There is a trade-off between the beta star at the collision point and the solid angle of the detector. A large detector solid angle is required to do quality measurements of the events. A small beta star is desirable to increase the luminosity of the machine which increased the number of events to be seen by the Phi Factory detector. The first final focus quadrupole may be either a permanent rare-earth cobalt magnet or a superconducting one. The other final focus quadrupoles within the detector can be made superconducting and they can be combined with the compensation solenoid and share a common cryogenics system. When the machine beta star is 12 millimeters, the permanent quadrupole option combined with a tapered compensation solenoid looks attractive. When the beta star at the final focus point is reduced to 4 millimeters, the superconducting first final focus quadrupole becomes a necessity. Tapering the first final focus quadrupole along with the compensation solenoid is desirable because the detector solid angle can be increased.

ACKNOWLEDGEMENTS

This work was supported by the Office of High Energy and Nuclear Physics, Nuclear Sciences Division, United States Department of Energy, under contract number DE-AC03-76SF00098.

REFERENCES

1. UCLA Center for Advance Accelerators, "Progress on the Phi Factory Project," a series of notes prepared for the HEPAP Sub Panel, 22 February 1992

2. Arisaka, K., Altac, M., Cline, D., et al., "Notes of the Second UCLA Phi Factory Detector Workshop," 5-6 December 1991

3. Cline, D. B., and Green, M. A., "The UCLA Phi Factory Detector Machine Interface," presented in the Phi Factory Point Design Report, 29 July 1991

4. Green, M. A., "The Detector Magnet and the Detector-Machine Interface Issues for the UCLA Phi Factory," Lawrence Berkeley Laboratory Report LBID-1767, 5 August 1991

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
TECHNICAL INFORMATION DEPARTMENT
BERKELEY, CALIFORNIA 94720