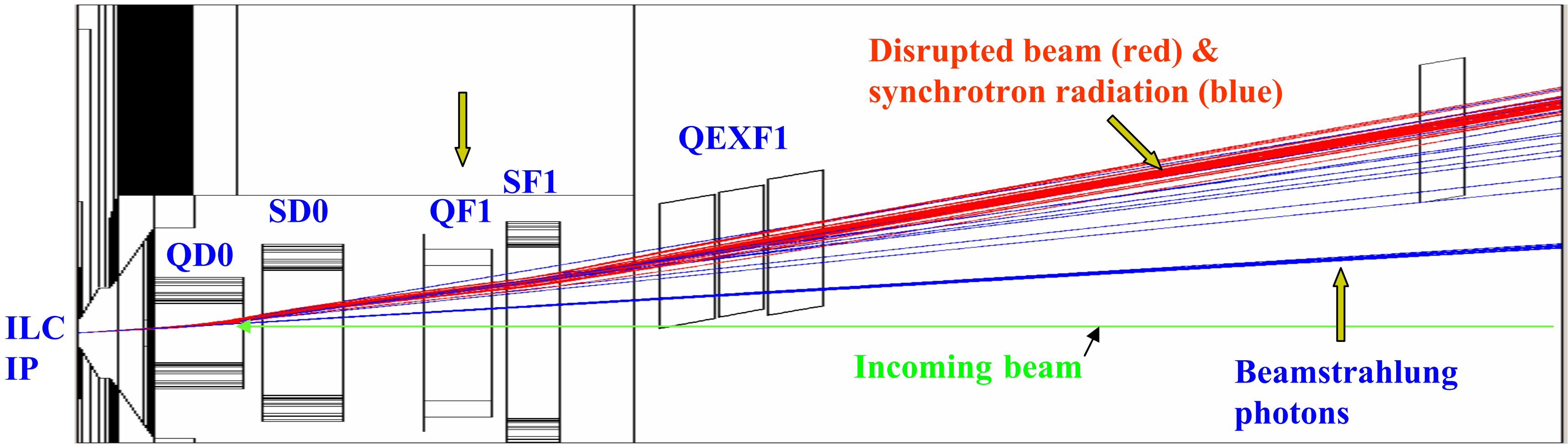
Magnet Modelling and its Various Uses at SLAC

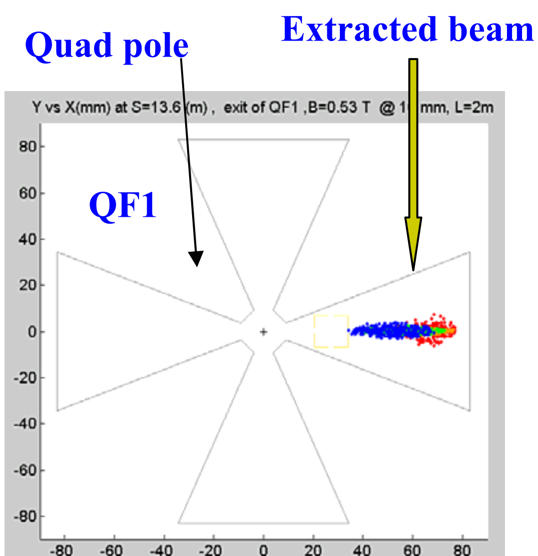
Informal presentation by Cherrill Spencer, SLAC's Magnet Engineer, to the Mini-Workshop on Magnet Simulations for Particle Accelerators at PAC05.

Topics To Be (briefly) Covered

- POISSON generated field predictions used in tracking particles through magnets near the International Linear Collider's (ILC) interaction point. (work of T. Maruyama and Y. Nosochkov)
- RADIA program used to model an elliptically polarizing pure permanent magnet UNDULATOR. (work of Roger Carr, SSRL)
- MERMAID program used to model the BaBar detector's solenoid field. (work of E.Antokhin, S. Mikhailov, L.Keller and many others)

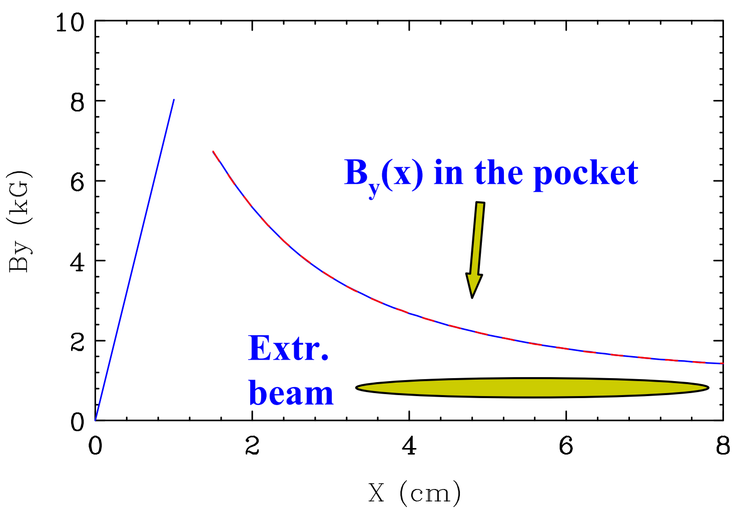
Representation of Field in a Quadrupole's Coil Pocket for Tracking an ILC Extraction Beam



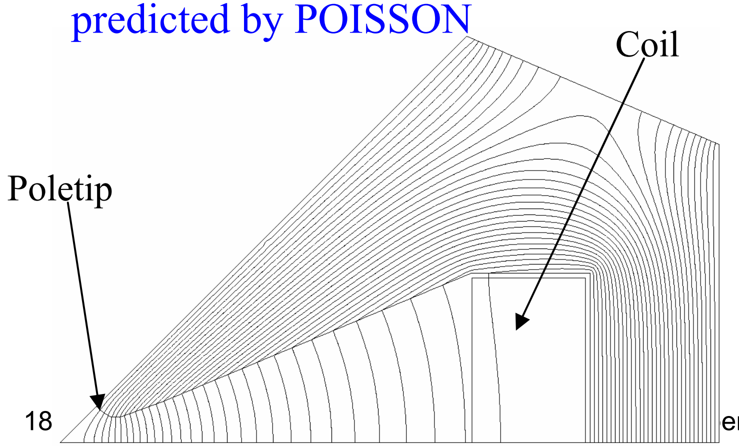


- •In ILC with a 2 mrad crossing angle at the IP incoming and extracted beams share some Final Focus magnets.
- •Incoming beam is on-center, and extracted beam is at an angle and off-center in FF magnets near IP.
- •In QF1 quad with 1cm aperture, extracted beam travels through aperture of a coil pocket in a significant field.
- •For beam optics calculations, the pocket field needs to be represented in the form of a multipole field used by most optics codes such as MAD.

QF1 design field $B_y(x)$ (blue) and multipole fit in the pocket (red dash)



Field in QF1 half-quadrant predicted by POISSON



- QF1 field B(x,y) is calculated using a magnet design code (e.g.POISSON) for the required magnet parameters.
- The highly non-linear field in the QF1 pocket has to be included in optics calculations for the extracted beam.
- Optics codes require that the field is represented in the form of a multipole field (dipole, quad, sextupole, etc.).
- The QF1 field data can be converted to multipoles by fitting $B_y(x,y=0)$ within x-range of extracted beam to a series:

$$B_y(x) = B_0 + B'x + B''\frac{x^2}{2!} + B'''\frac{x^3}{3!} + \ldots$$

- The fitted gradients B_0, B', B",… then are used to define a combination of dipole, quad, sextupole, etc. elements in the extraction line to represent the non-linear field in QF1 pocket.

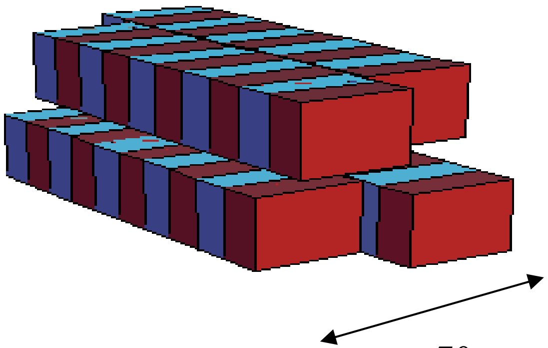
Tracking the ILC extraction beam, disrupted beam etc

- The collisions of the 250Gev electron bunches with the 250Gev positron bunches produce various particles which need to be tracked through magnetic fields and magnet bodies & beampipe- showers of e^+,e^- ,γ, p,n
- E.g. disrupted beams are caused by the interaction of the electric fields of the colliding bunches. They are spread out much more than incoming beams and empty space needs to be left for them to travel through. Use GEANT program to track the particles as they hit materials.
- If the disrupted beam passes through "regular" part of magnet then use analytic equation to describe field, if passes through non-standard part of magnet- e.g. coil pocket of QF1 or a Panofsky-shaped quad, then use the B_x, B_y field components on a grid of x,y, coordinates predicted by POISSON to represent the field in GEANT model.

Use of RADIA “program” to model magnets

- RADIA was written at the ESRF by Pascal Elleaume and Oleg Chubar
- RADIA comprises subroutine calls in Wolfram's Mathematica, i.e. Mathematica is a platform for RADIA
- RADIA uses Mathematica toolbox calls for field value calculations and graphics.
- RADIA runs under UNIX, Windows, and Macintosh OS
- RADIA is three -dimensional
- RADIA uses the boundary element method (like AMPERES) , not the finite element method (like TOSCA)
- RADIA elements have same properties over their volume, but meshing is not as difficult as TOSCA; no need to mesh empty space.
- RADIA has the ability to model non-linear, anisotropic and permeable materials
- RADIA needs large amounts of computer memory, and slows down dramatically as number of elements increases
- RADIA subroutines are FREE, you have to buy Mathematica
- Go to this website to find out how to get the code:
- http://www.esrf.fr/Accelerators/Groups/InsertionDevices/Software
- RADIA examples may be found on the ESRF website, and used as templates

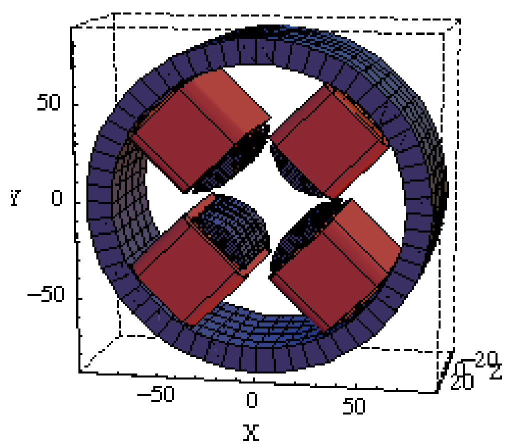
Two magnets modelled in RADIA



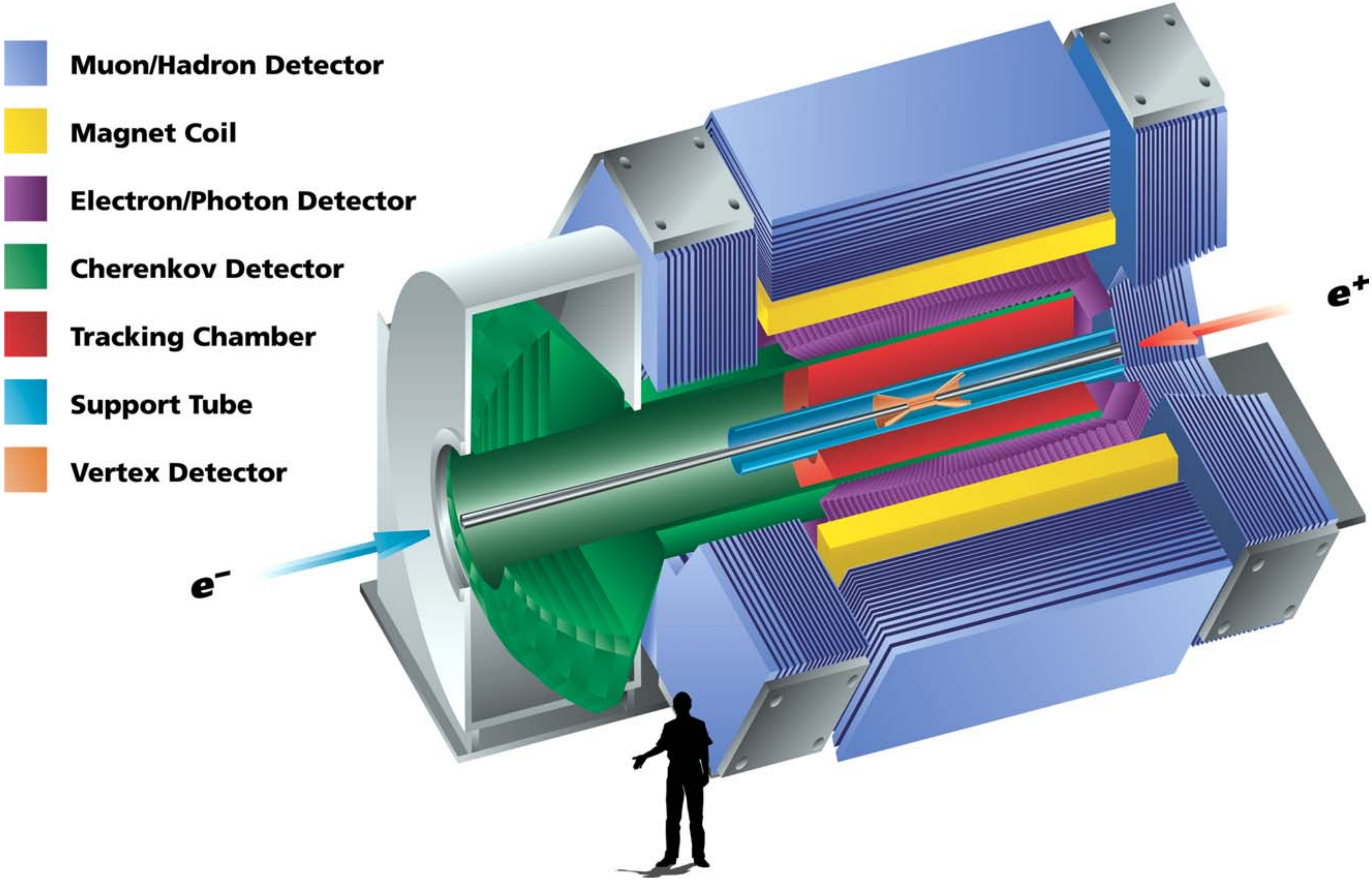
<u>Elliptically Polarizing Pure Permanent Magnet Undulator.</u> Geometric model made by RADIA of a *Halbach* array. Originally made for SPEARII at SSRL.

<u>Water-cooled electromagnet designed for the Linac Coherent Light Source at SLAC.</u>

Quadrupole for the spectrometer after the electron gun.

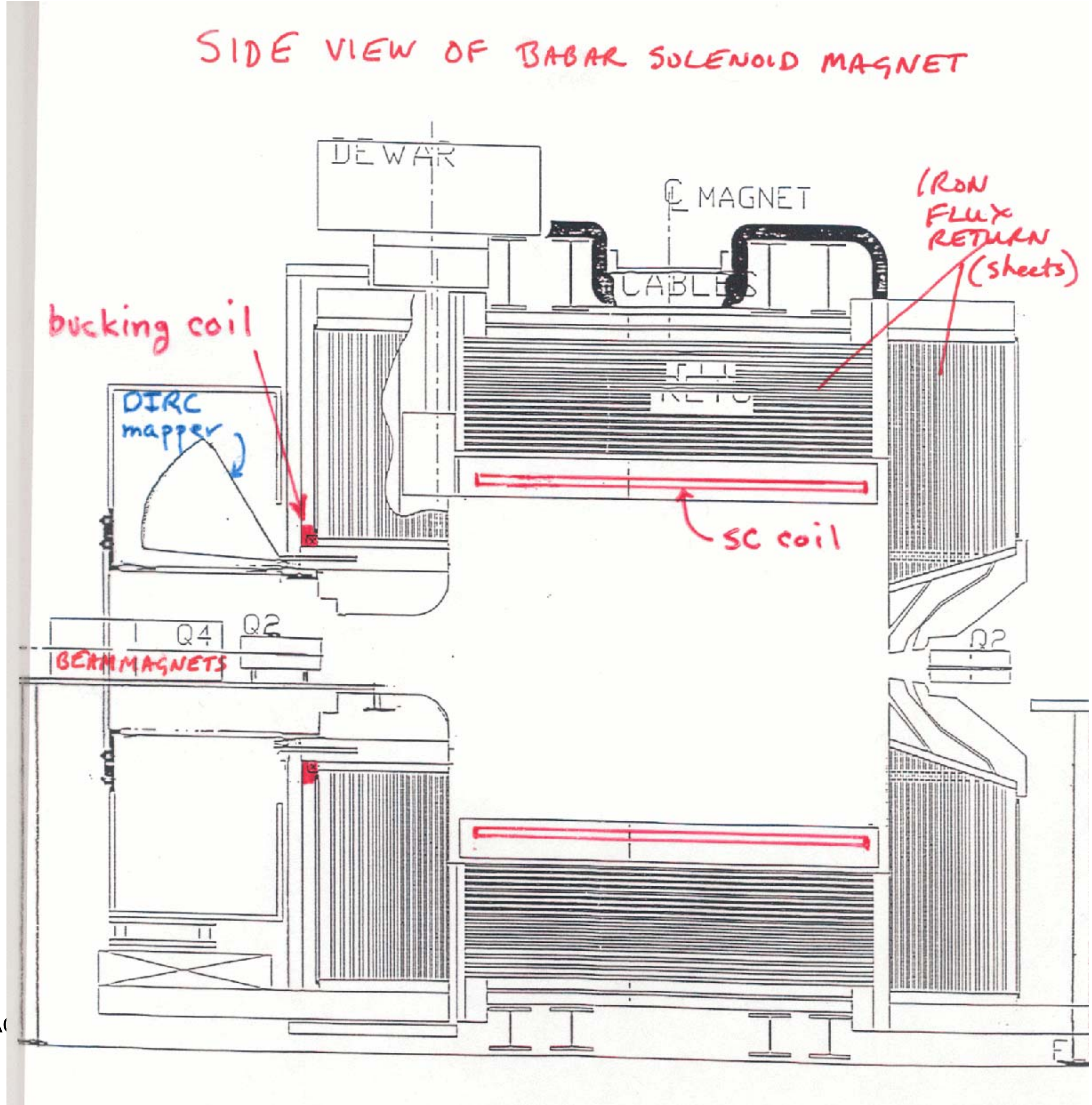


BABAR Detector

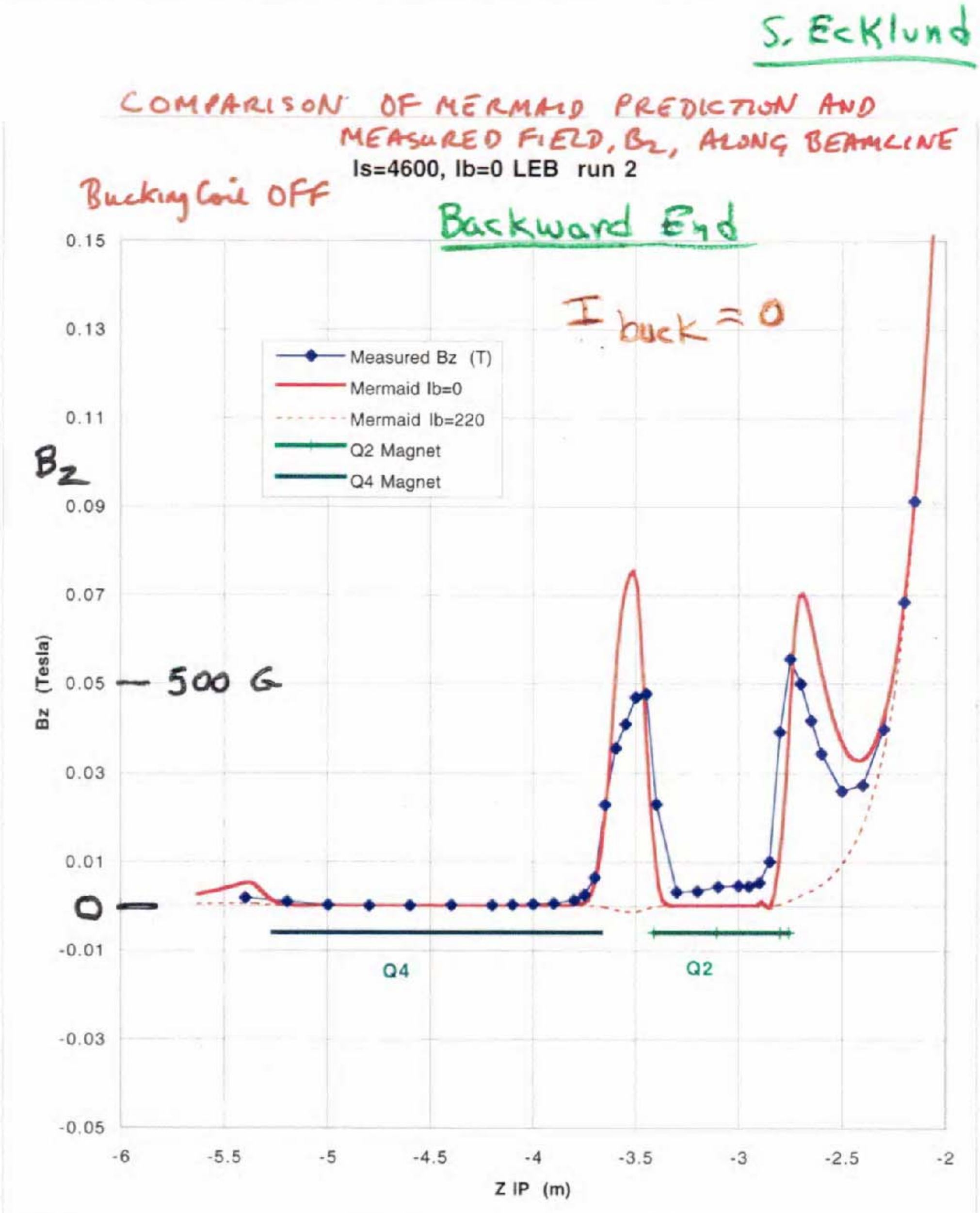


MERMAID modelled BaBar solenoid

- In 1996 the MERMAID 3-D magnetostatics program was used to design the 1.5T superconducting solenoid for the BaBar detector (at IP of PEPII colliding e^+,e^- rings)
- MERMAID predicted the B_r,B_x, B_φ and forces all over the asymmetric detector, especially in the "DIRC" section.
- In Spring 1998 BaBar magnet (3m diameter solenoid) was measured with a 3D array of 12 Hall probes.
- Agreement between MERMAID and measurements was to within 0.005T in the areas distant from the beam axis and better near the beam axis. This success with MERMAID and its ease of use means it continues to be used to model magnets at SLAC.

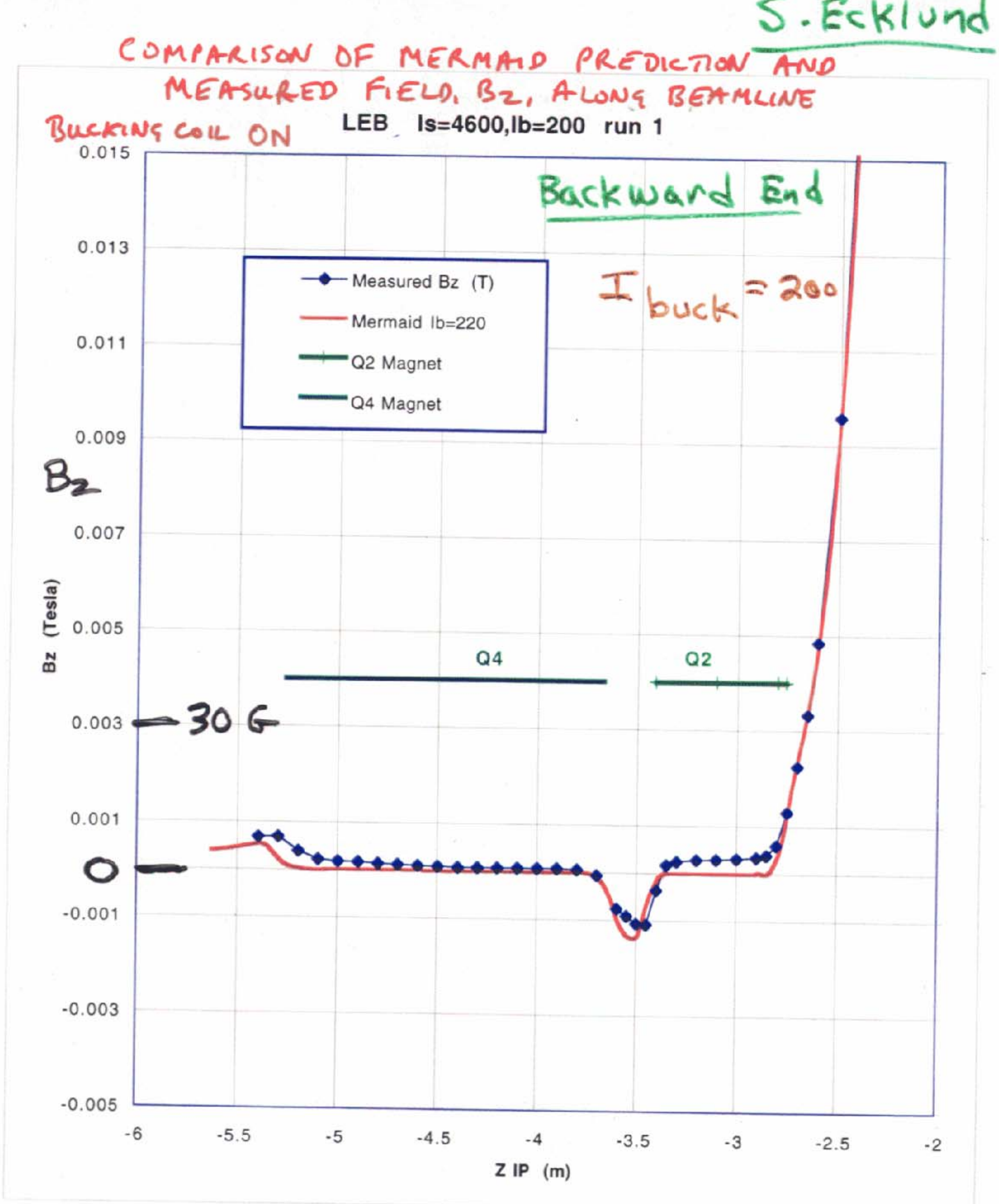

SIDE VIEW OF BABAR SOLENOID MAGNET
DEWAR
℄ MAGNET
CABLES
IRON FLUX RETURN (sheets)
bucking coil
DIRC mapper
SC coil
Q4
Q2
BEAM MAGNETS
Q2

BaBar Solenoid Field: Comparison of MERMAID Prediction and Measured Field. With Bucking coil OFF



BaBar Solenoid Field: Comparison of MERMAID Prediction and Measured Field.

With Bucking coil ON



MERMAID Technical Specifications

PACKAGE CONTENTS
One CD-ROM disk with Mermaid code
Printed Mermaid User's Guide

SYSTEM REQUIREMENTS
Pentium computer (128MB or more of RAM is recommended)
Windows 98/NT/2000/XP operating system

MAIN PARAMETERS
Mermaid for Windows for 2D electro/magnetostatics:
2D calculations of magnetostatics with nonlinear iron
Support for axial symmetric problems, electrostatics, helical undulators
Support for eddy-currents problems
The number of mesh nodes is limited only by size of computer memory
Calculation time is 10 minutes for 3,000,000 nodes on PentiumIV/2GHz/256MB

Mermaid for Windows for 3D magnetostatics:
3D calculations of magnetostatics with nonlinear iron
The number of mesh nodes is limited only by the size of computer memory
Calculation time is 20 minutes for 3,000,000 nodes on PentiumIV/2GHz/256MB.

Mermaid for Windows for 3D electrostatics:
3D calculations of electrostatics
The number of mesh nodes is limited only by the size of computer memory
Calculation time is 5 minutes for 3,000,000 nodes on PentiumIV/2GHz/256MB.

MERMAID Quotation and Contact

SIM Limited
Novosibirsk department
630058 Novosibirsk, P.O. Box 160, Russia
Phone/Fax: (+7-3832) 336843
E-mail: dubrovin@inp.nsk.su

SIM Limited is pleased to submit the following quotation:
Quotation on Mermaid for Windows code (in December 2004)

TERMS and CONDITIONS
For our quotation the following terms and conditions will apply:
TERMS of PAYMENT
The base price of first copy:

Mermaid for Windows for 3D magnetostatics -	2992.00 US $.
Mermaid for Windows for 3D electrostatics -	992.00 US $.
Mermaid for Windows for 2D magneto/electrostatics -	992.00 US $.

The price of additional copies at the same site is 50% of the of base price.
Academic and educational institutions are entitled to get 30% discount.