

STATUS REPORT ON THE ALIGNMENT ACTIVITIES AT SLAC *

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1. INTRODUCTION

The Stanford Linear Accelerator Center (SLAC) is located in California south of San Francisco next to Stanford University. SLAC is a department of Stanford University as well as a United States Department of Energy facility. In this report a summary of the major alignment activities that have taken place in the past two years is presented.

The main campus contains several unique facilities including fabrication and assembly buildings while the adjacent research yard holds a number of experimental structures tied into the most prominent feature, the Linear Accelerator (LINAC).

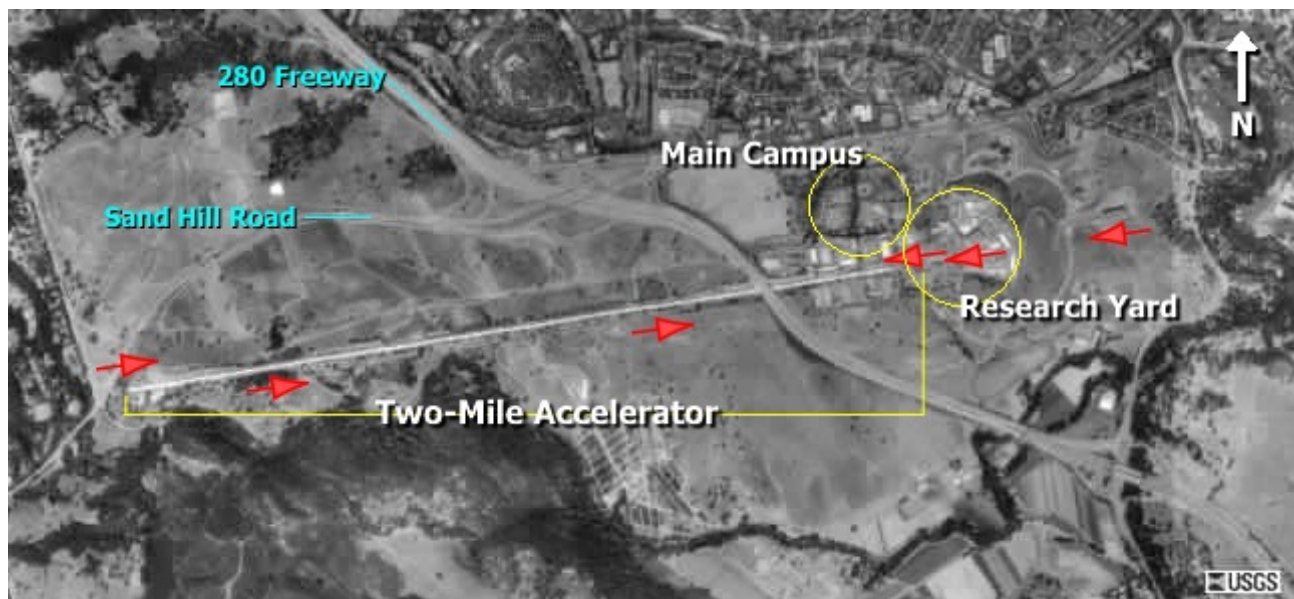


Fig.1 Location and Description of SLAC

The LINAC was originally used to accelerate particles into several buildings (see figures 1 and 2) in the research yard for interaction. Later the accelerator was modified to allow particle to particle interactions using new facilities such as the Positron Electron Project (PEP) completed in

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1980 and upgraded to PEP-II in 1998. The tunnel housing this experiment encircles the campus and research yard. Located in the research yard, a synchrotron facility called SPEAR (Stanford Positron Electron Accelerating Ring) has been upgraded a third time and is now known as SPEAR3.

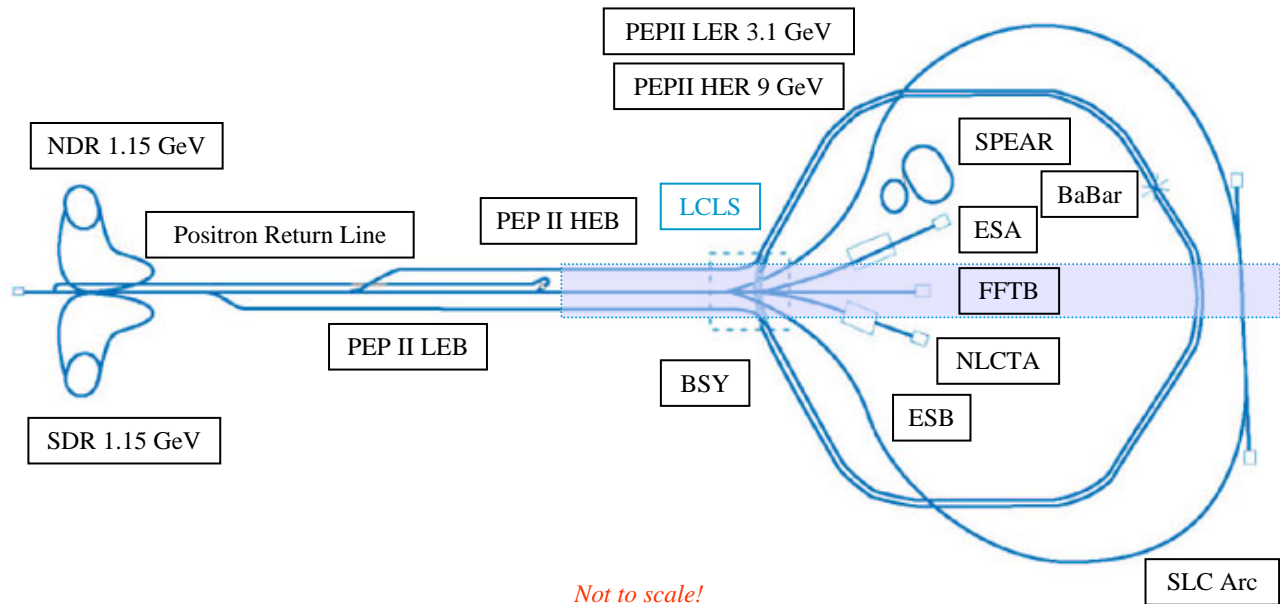


Fig.2 The SLAC and SSRL Site

A new experiment called the Linac Coherent Light Source (LCLS) is underway. Beginning part way down the existing accelerator, the new facility will parallel the linac and extend almost another kilometre through and under the research yard to create very bright x-ray laser light. Other new projects at SLAC include the building of the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC) and the assembly of the Gamma Ray Large Area Space Telescope (GLAST).

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1. SLAC PROJECTS

1.1. GLAST

The GLAST integration and test facility is being used to test components and assemble a flight grid consisting of 16 muon detecting "Tracker" Towers (TKR). Precise assembly of these devices is critical so that they do not crash into each other during the 2006 anticipated launch. In February 2004 the Alignment Engineering Group performed a simulation survey in the LAT (Large Area Telescope) integration facility using the previously installed 6 floor monuments and 10 crane monuments (see figure 3). The simulation provided a network verification and refinement of the a priori standard deviations for each type of observation with anticipated 30 μ m accuracy at 1 sigma.

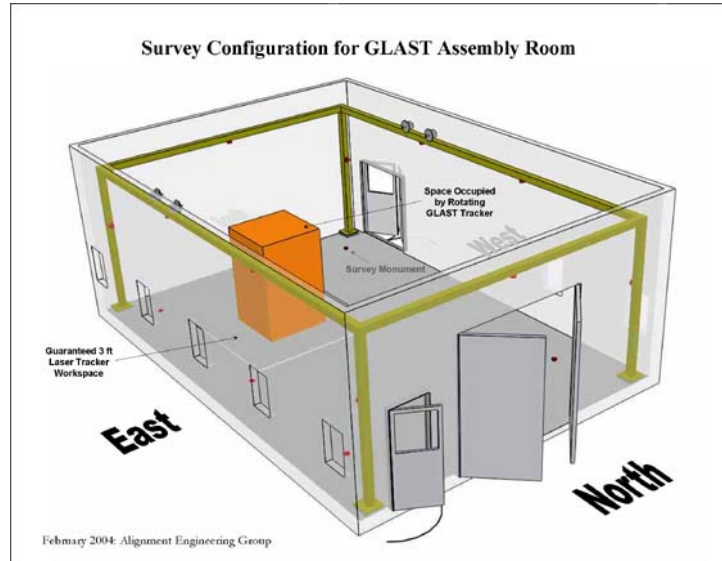


Fig.3 The LAT Integration Facility

1.2. LCLS

Initial preparatory work has begun for the construction of the LCLS. One of the first tasks requested for the Alignment Engineering Group was to mark on the ground a line or set of lines that represent the extension of the linac. A line representing the linac roof and other lines (as shown below in figure 4) were created and marked with wooden stakes. Later these lines were tied into some existing linac monumentation using GPS and conventional surveying techniques.



Fig 4 LINAC Reference Lines

A second early task for the LCLS was the surveying involved in the construction of an injector facility located about two thirds down the LINAC. The injector tunnel already existed for another purpose but was retro-fitted with a new concrete and metal shielding wall (see figure 5) and a new survey was completed tying a densified set of monuments in the LINAC with newly added monuments in the injector tunnel.



Fig.5 Surveying the New Shielding Wall

1.3. PEP-II

The B-Factory aims to study the CP violation from the collisions between circulating electrons and positrons in the PEP-II tunnel. This year was particularly successful and the following records have been reached:

- Peak luminosity: $9.2 \times 10^{33}/\text{cm}^2/\text{s}$
- I+ current: 2450 mA with 3 RF stations
- I- current: 1550 mA with 8 RF stations
- Daily integration record: 710 pb-1
- 2003-2004 run: over 100 fb-1
- Total integration since May 1999: 240 fb-1

In order to keep this progression, several improvements have been scheduled during this 2004 Summer/Fall downtime for the triple purpose of (1) increasing currents, (2) getting more stability and lifetime, and (3) reducing vertical emittance and backgrounds. As far as alignment activities specifically, this translated to an initial survey of IR2 during the first two days of the down and a complete survey of the positions and orientations of all sextupoles and quadrupoles in both rings. Additionally, different local set-ups for the installation of the new RF stations, the “Frascati” longitudinal kickers and the LER synchrotron light monitors were made to name a few.

Originally, a plan was established to look only at the quadrupole rolls, so the idea was to use a tiltmeter set on top of each magnet. When a request for determining the sextupole positions was added, a decision to use total station set-ups to cover both types of magnets in both rings was made. The LER counts 50 sextupoles and 316 quadrupoles. In general, each sextupole has 7 tooling balls (TBs) and each quadrupole can be set through a common fixture that sits either on the front or on the top of the magnet. The HER counts 104 sextupoles and 290 quadrupoles. The quadrupoles have 6 convenient TBs. The sextupoles have no fiducials; they are hard-mated to the quadrupoles and have not been observed since installation. To survey them, it was decided to use an extension arm held directly onto the laminations. The figure below shows the horizontal positions of all measured magnets in a beam-following system. The three red dots that are away from the smooth line are real and correspond to voluntary misplacements of these sextupoles. No major changes were found from the last complete ring survey observed during the 2002 summer down.

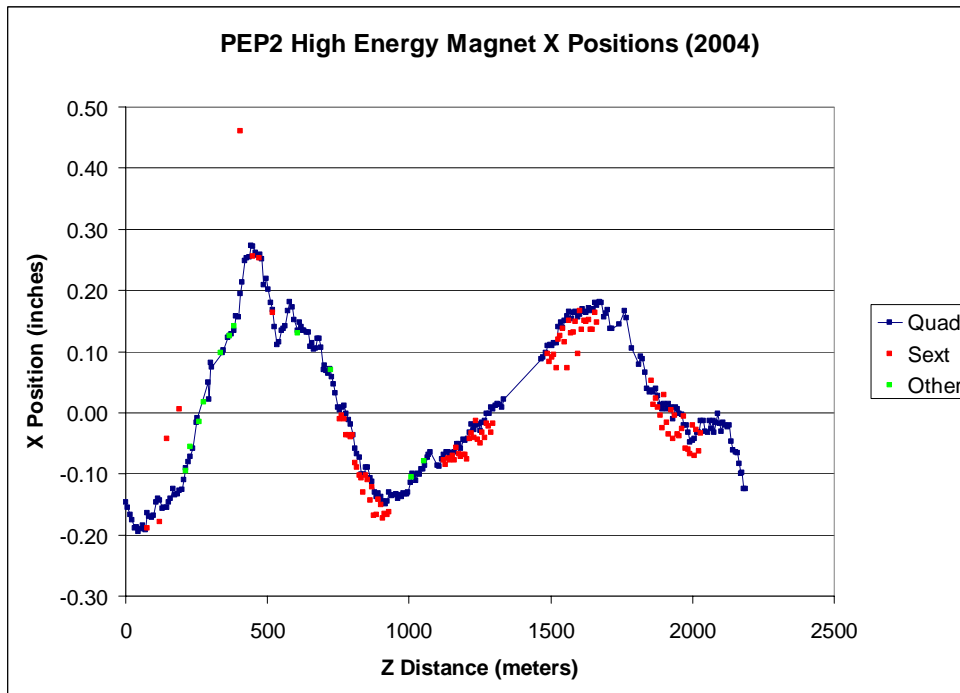


Fig.6 PEP2 HER Magnet X Positions

In parallel, extended work on the detector itself was planned. All 18 layers of RPCs are going to be removed and replaced by LST detectors and 7/8" thick brass absorbers. This summer, only the top and bottom sextants of the BaBar detector were modified. Because of the heavy weight of the brass addition (about 11.5 tons per sextant), a regular monitoring of the face of the detector had to be implemented. It should be noted that there are no permanent fiducials on the faces of the detector as rolling doors would cover them; the only permanent survey features for the detector are 6 holes on each side. For this application, 9 TB sockets were glued on the Bside face of BaBar, as well 3 others on the floor in front. A total station network of 4 stations was simulated as shown in figure 7.

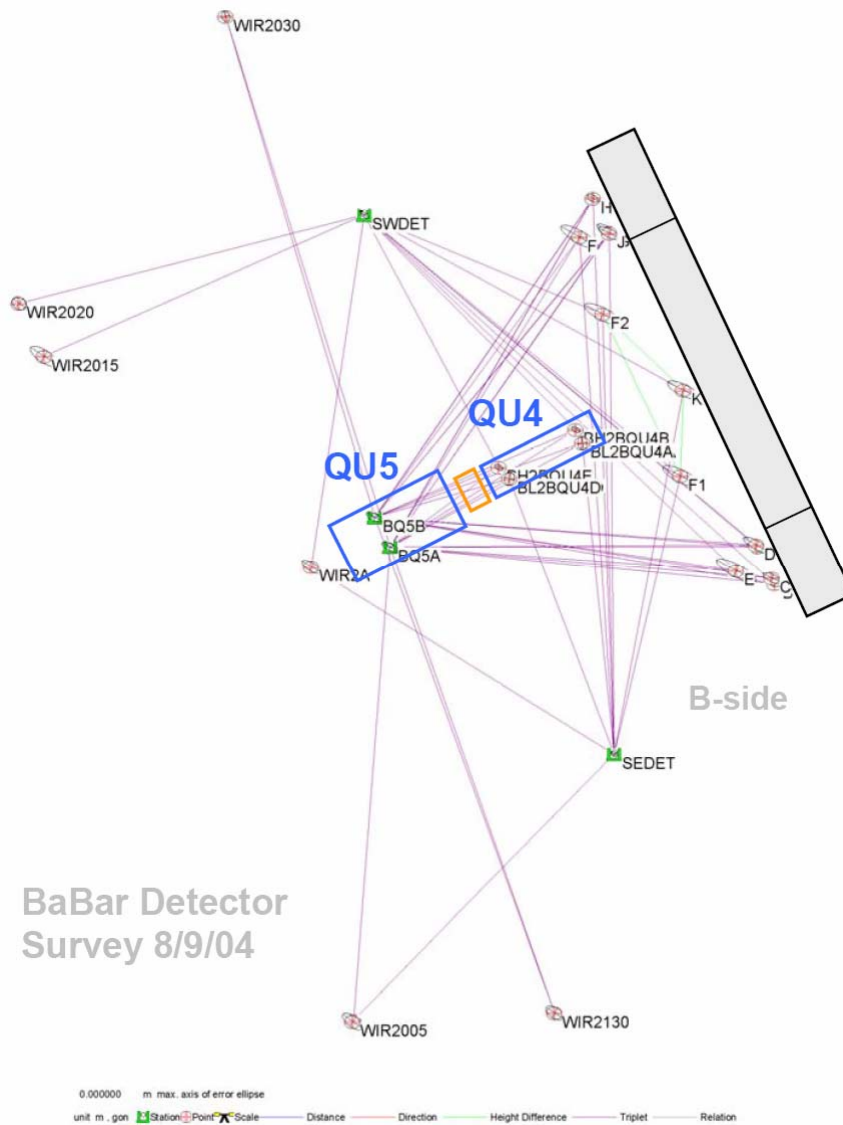


Fig.7 BaBar Network

The options for the adjustment were to rely on the verticality of the set-ups and to use the coordinates of the wall monuments for the determination of the datum. Additional precise level measurements were made between the new floor points and the bottom TBs on the detector. For a complete set of independent checks, a decision to survey the same detector TBs by optical tooling techniques was made. Two scribe lines (one on each side of the B face) were established. The TC2002 survey was re-analyzed to allow direct comparison with the optical tooling solution. A plane representing the face of the detector was made from all 9 points on the surface giving a reference to the two scribed lines. The comparison between the TC2002 and the optical survey was very satisfactory (between -9 and 12 mil differences) increasing confidence in the decision process

of deformation evaluation during the different steps of removal and assembly. At this time, the bottom sextants have been replaced without any difficulties giving the ultimate validation of no significant changes.

1.4. SPEAR3

The completion and successful commissioning of SPEAR3 early in 2004 was accomplished by an adaptive surveying approach for the newly installed ring. Critical constraints such as recreating a new ring (with all new and fiducialized components) so that the orbit of the beam would not change made this a challenging project that required several surveying networks to be measured before, during, and after ring installation. Further details – including almost total loss of monumentation due to construction – are found in reference [3]. A summary of the re-construction of the facility is documented in reference [4]. This follows a web-based timeline summarizing all the facets of the surveys that were necessary to build the new ring.

2. AEG SPECIAL PROJECTS

2.1. GPS Activities

Since the summer of 2002, the Alignment Engineering Group has been operating a permanent GPS station (SLAC M40) to serve as a master station for all real-time kinematic (RTK) operations on site. The choices for the station were presented in a poster at IWAA2002 and an update is provided in a follow-up poster (reference [8]). One of the advantages of continuous logging is the potential for time series analysis as illustrated in the following graph:

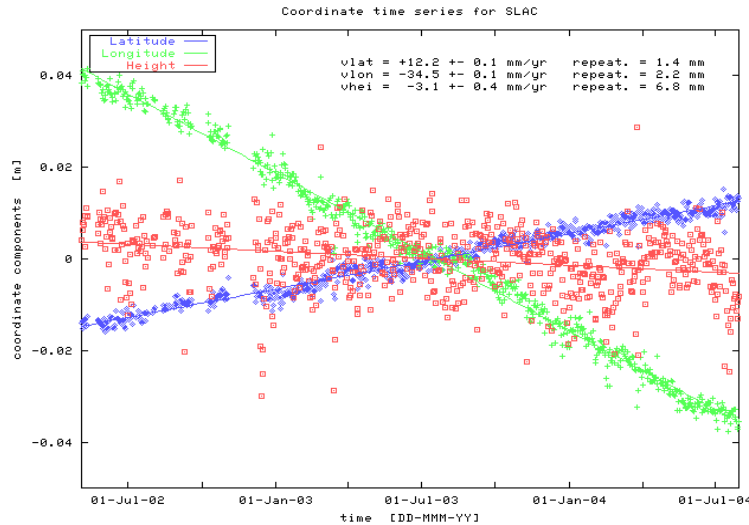


Fig.8 SLAC M40 Ellipsoidal Coordinate Series

2.2. Instrumentation Studies

During these past two years, The Alignment Engineering Group has had the opportunity to study different survey instruments: FARO arms, hydrostatic levels and wire offset sensors. A localized study on Applied Geomechanics and Leica Nivel tiltmeters has lead to an easy check for the roll of all quadrupoles in the PEP-II LER. Finally four major acquisitions: Leica TCRA1105 (see reference [7]), Trimble DiNi12, Leica DNA03 and Z+F Imager 5003 (see references [4] and [5]) as well as updating our data collectors (Allegro CE and CX) have complemented the group's existing toolbox. Of course the creation of a vertical comparator for digital level investigations has allowed a comprehensive plan for level rod calibration as well as better planning and practices for levelling campaigns (see reference [6]).

2.3. Software Development

Most of the specific survey and alignment software used by the Alignment Engineering Group have been developed in-house over time. The adjustment package LEGO is the common core network analysis tool used in SIMS to graphically derive network simulations and in WinGEONET to treat pre-processed data gathered in the field. The main software development occurring during the last two years follows previous work presented at IWAA2002 (see reference [9]) by expansion of LEGOServer. Several new features have then been implemented in SIMS such as wire offsets and weighted coordinates. But the main new direction was to move towards a component design that can be used by several environments, see figure below:

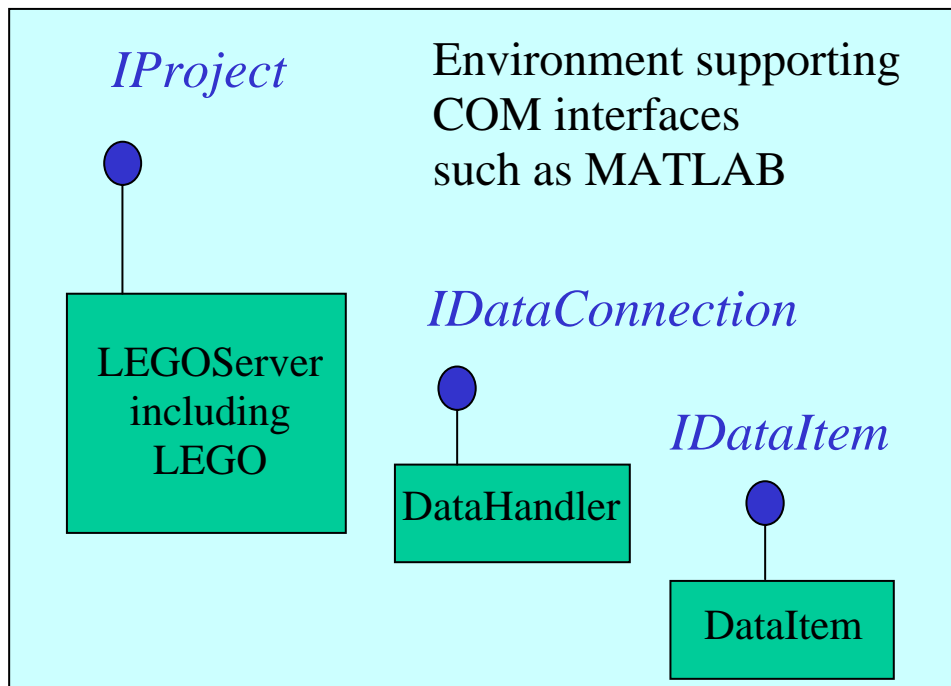


Fig.9 Component Architecture Design

In figure 9, LEGOServer is a COM-interface for LEGO while DataHandler is a tool for import from and export to commonly used data storage. DataItem is a tool used for flexible layouts of geodetic data. The main environment in mind was MATLAB which has a very powerful scripting language for technical computing and integrates computation, visualization and programming very well. The first application in this environment was the computation and display of 3D-error ellipsoids for simulation purposes. In this case, LEGO performed the error propagation and output the covariance matrix for each point. The diagonalization of the covariance matrices was made in MATLAB allowing the following graphical result representing a BaBar detector survey:

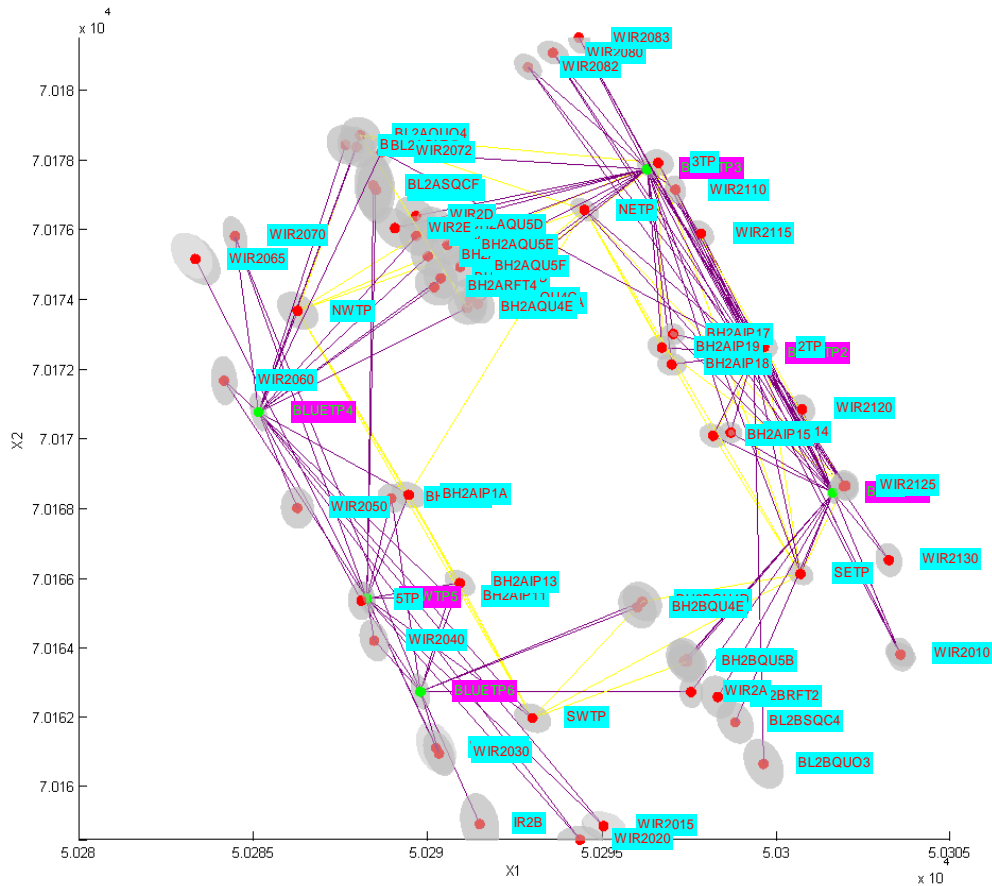


Fig.10 3D Error Ellipsoids for BaBar Survey Analysis

2.4. Immediate Future

During the next few weeks the group's emphasis will be on completing the 2004 Summer/Fall downtime. Soon after, the first measurements for the GLAST assembly should kick-in. Then, before the start of the next 6-month 2005 downtime, the three main directions of focus will be in the general preparation for LCLS, the familiarization with the new laser scanner, plus general software

maintenance and upgrades. The AEG web-page [1] provides an updated summary of past and current activities.

3. REFERENCES

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- [2] LeCocq et. al., "The SPEAR3 Upgrade Project; IWAA2004, CERN; October 2004.
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