第21回LC推進委員会　　平成15年7月4日
物理・測定器開発関係の報告

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1. 物理の検討
   LC Physics Study Group　での検討をサブグループ毎に進めている。 前回推進会以降以下のミーティング、講習会が開かれていて、各々20人程度の参加者がある。
   - 5/26 「Tools講習会」
     C++, ROOT, JSF などの講習
   - 5/27 「Higgs サブグループミーティング」
     解析テーマの分担
   - 5/30 「New Physics サブグループミーティング」
     Extra Dimension についての学習会
   - 7/2 「Higgs サブグループミーティング」

2. 測定器開発
   - VTX
     東北大核理研でCCD素子の耐放射線性能研究のためのビームテスト(7/8)準備中
   - CT
     従来のR&Dのまとめを執筆中。また、粒子軌跡毎の発生時間を再構成する能力についてSimulation による再評価を行っている。TPC等の場合についても比較する予定.
   - CAL
     ビームテスト(秋DESY, 冬KEK)の準備中。また、電磁カロリーメータの Granularity を上げた場合の性能向上に関してSimulation Study を進めている。
   - IR
     ISG10(6/23-27 @SLAC) に参加(Nicolas, 松田、田内)
   - Soft
     ACFA-SIM meeting (6/26)　Soft 開発に関する情報交換
   - その他
     韓国Korea 大よりVisitor滞在中(7～8月)。Intermediate Tracker に関する、Simulation Study を行う予定。
   - 「リニアーコライダーの測定器研究会(仮称)」
     各測定器パート合同の検討会を、現在R&Dに参加していない人にも呼びかけて開催すべく調整作業中。
     - 開催日の第1候補は8月18日の週
     - 目的は、これまでのR&Dの結果を踏まえて到達点・未達成・問題点を整理し、今後の方針を検討すること。
     - 体制・予算規模・年次計画などについても検討したい。

1. Annual Report 2002 の原稿
   添付資料参照

2. LeptonPhoton 2003 へのポスター
   - KEKとしては3枚、うち1枚は「GLC」
   - 担当：藤本、大森(素核研)、早野、荒木(加速器)
   - 全体打合せ：6月30日(月)、原稿〆切:7月11日(金)、完成：7月中(?)
     Lepton&Photon 2003 8月11日～16日＠FNAL

1 The GLC Project

1.1 Introduction

Through world wide extensive studies in last decades, the Standard Model has been established as a model for elementary particles and their interactions, except one missing ingredient, the Higgs boson. Since it is a key element for a model of massive particles, the understanding of its property is an inevitable step to go beyond the Standard Model for an ultimate theory of particles and interactions. Recent global analysis of electro-weak data suggest its mass is likely to be light. Its discovery and studies of the property are the primary goal of future collider experiments at energy frontier. In addition, since the Higgs boson is a scalar particle, its self energy diverges at high energy without new ingredients in models of elementary particles. Super symmetric models naturally cancel the divergence by introducing super symmetric particles at the energy region of next collider experiments. In another mode, additional space-time dimensions which can be probed only at high energy are proposed. If such signals are found, our understanding of the nature will be innovated. A high energy e^+e^- collider is suitable for these studies, because it provides collisions among elementary particles in small background environment and unambiguous theoretical predictions can be tested precisely with observations.

The linear collider project in Japan was conceived in the 1980s aiming for such research at energies well above those covered by LEP-II. Great efforts have been made to develop technology for such a collider and to establish detector technology suitable for experimentation. Asian Committee for Future Accelerator(ACFA), formed in 1996, issued two statements in 1997 and 2001, endorsing the linear collider project in the Asian-Pacific region with Japan as the host. ACFA Joint Linear Collider Physics and Detector Working group was formed soon after the first statement and the group published a report on "Particle Physics Experiments at JLC" in 2001. Accelerator R&D have been continued by international collaborations at various levels. Based on these activities, "Road Map report" was prepared in FY2002 and announced to the community at the ACFA symposium held in Feburary 2003. It was prepared by ACFA, Japan High Energy Physics Committee(JAHEPC) under JAHEP and KEK. The report describes the basic design of accelerator, facilities, site issues as well as roadmap toward project realization.

When the project was originally started two decades ago, the project was called Japan Linear Collider, JLC. Since then, the project has grown up to have more international nature and since ACFA statement in 1997, the JLC has been translated to be a Joint Linear Collider. But still sometime JLC is interpreted as Japan Linear Collider which is not suitable for international nature of the project. Thus taking a opportunity of the publication of "Road Map Report", we have decided to change the name of the project. Based on the discussion among ACFA colleagues, we now name the project as Global Linear Collider, GLC.

1.2 High lights of Detector R&D

The detector R&D's have so far been aiming at establishing component technologies. High lights of them in FY2002 are summarized as follows.

At GLC experiments, the interaction point(IP) must be stabilized to ensure collisions of nano-meter size beams. To do this, we plan to put components surrounding the interaction point into a support tube whose rigidity provides the stability. To verify this, we have constructed a 1/10 model, as shown in Fig. 1. It has 80 mm diameter and 800 mm length made of 10mm thick Aluminum tube. This prototype model is segmented into 4 pieces the same as real one. The segments shall be connected each other by tapered flanges as well as flat ones. A support tube consists of two cantilevers connecting with a central thin tube. Rigidity of the support tube must depend on this central tube, flange shape

Figure 1: The 1/10 model of the support tube for the test of rigidity.

Figure 2: The fiber-connection part of the strip-array of test EM calorimeter module.

as well as bolted joint strength. Vibrational properties of the cantilevers and the support tube have been measured in terms of natural frequencies and oscillation modes by shaking and hammering. These results were compared with a calculation by a finite element method in order to justify our evaluation method. We are planning to optimize the structure of support tube based on these detailed analyzes.

The vertex detector(VTX) is used to measure charged particle trajectories near IP. Since track densities are so high, charged coupled devices (CCDs) are used because of their thin structure and hyper performance in separating adjacent hits. On the other hand, CCDs have relatively less radiation immunity. We had studied radiation hardness by low energy electrons of Sr-90 β source. The expected e^+/e^- beam background of the linear collider, however, has energy of few tens of MeV. Since radiation damage by electrons depends on their energy (higher the energy, larger the damage), radiation damage test with high energy electrons is indispensable. In FY2002, we have carried out radiation damage test by irradiating a CCD with high energy electron beam. The preliminary result showed that energy dependence is less than expected, which is favorable for using CCDs at the linear collider experiments.

There has been an increased demand for very high granularity calorimetry for precise determination of the reaction final state. For this purpose, we have been developing a scintillator-strip array EM calorimeter. Test beam measurements of performances were carried out at KEK-PS for test modules of a strip-array calorimeter, a tile/fiber calorimeter with small rectangular tiles, and shower-max detectors with Wave Length Shifter fiber readout and with direct-Avalanche Photo Diode readout. Figure 2 is a photo of the fiber-connection part of the strip-array test module. Since the test module used Multi-Anode PMTs for optical readout, there were many messy optical fibers. They will be much tidily arranged, or even completely disappear, with Electron-Bombarded CCD or Silcon PM readout. Obtained shower direction resolutions as shown in Fig.2 are as good as usual gaseous calorimeters. Uniformity and cross-talk of the tile/fiber test module with tiles of 4cm-sq. and 1mm-thick are significantly worse than those with larger/thicker tiles. We are now working on improved design.

Before full-scale prototyping, we need to reconcile the basic detector parameters and reevaluate the performance of the detector system as a whole, with the hardware R&D results for component technologies taken into account. In parallel with the hardware R&D's, we have thus been developing a full detector simulator called JUPITER. JUPITER is based on Geant4 and works with its SATELLITES, both being written in C++ and hence taking full advantage of object-oriented technology. JUPITER

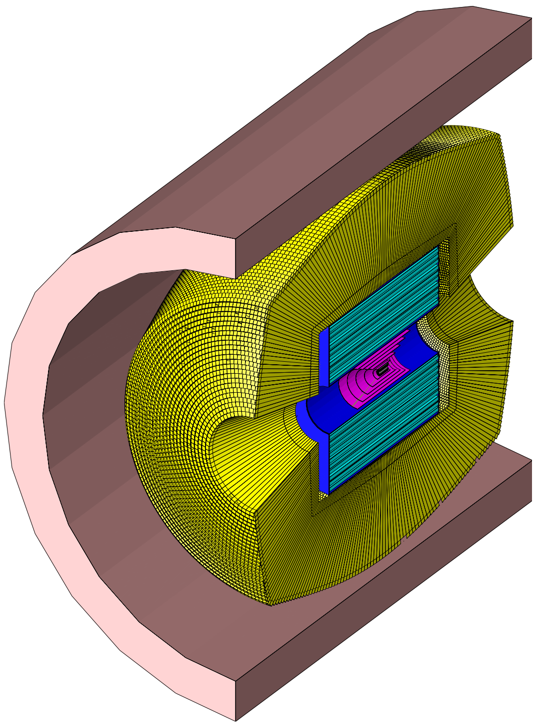

Figure 3: Cut view of the detector as implemented in JUPITER, a Geant4-based full detector simulator.

provides a unified framework to facilitate implementation of highly hierarchical structures of detector components and allows us to code details such as single pixels of CCD arrays of the vertex detector, individual drift cells and corresponding wires of the central drift chamber, etc. Fig. 3 shows a cut view of the current detector model as implemented in JUPITER. One can see the vertex detector (VTX), the intermediate silicon tracker (IT), the central drift chamber (CDC), the electromagnetic and hadron calorimeters (CAL), and a super-conducting solenoid (SOL) that surrounds them. The full simulator is now being used to study detector performance such as background estimation and time-stamping capability of the CDC in the presence of stereo layers.

1.3 High lights of accelerator R&D

The central focus of the accelerator R&D program continued on production and control of low-emittance electron beams at the Accelerator Test Facility(ATF) as well as the development of high-power RF sources and structures for the main linacs.

The ATF consists of a 1.54 GeV Linac and a Dumping Ring. It is a proto-type injector system for the GLC and the goal of the study is to produce low emittance beam suitable for the GLC accelerator. The goal has been met in the case of the single bunch mode of operation with a emittance coupling of $\epsilon_y/\epsilon_x \sim 1\%$. In 2002, as the first operation in Japan, In FY2002, the RF gun was installed and used to generate multi-bunch beams, which is the first time in Japan. The RF gun system installed at the ATF lilnac is shown in Figure 4. Compared with a conventional thermionic gun, RF field applied at the surface of electron source cathode gathers and accelerates electrons more efficiently in the case of the RF gun system. Thus it is suitable to generate intense multi-bunch beams for the GLC application. In FY2002, 18 bunches with 2.8 nano-sec separation have been operated and the test of multi-bunch instability are in progress.

At the GLC, electron/positron beams are accelerated by electro-magnetic wave of 11GHz frequency, which is created by Klystrons. We will use Periodic Permanent Magnet (PPM) Klystrons instead of conventional ones using solenoid magnets to save wall plug power. Four PPM Klystrons have been constructed and the design goal of 75MW power with 1.6 micro-sec pulse width have been achieved, though repetition rate is still limited to 50 Hz. The next target is an operation at the GLC repetition rate of 150 Hz with a design suitable for mass production, which shall be completed within FY2003.

The accelerator structure must hold a high power RF field for beam acceleration but get rid of wake fields which mess up ultra low emittance beams. A key point is to never use a sharp edge in the structure since it becomes a sources of discharge when the high power field is fed in. In addition, compromise between group velocity of the field and the acceleration gradient is also necessary, because smaller group velocity of the field, smaller the elec-

Figure 4: The RF gun implemented at ATF. Bronze wave guide to feed RF field to the gun is shown in the middle.

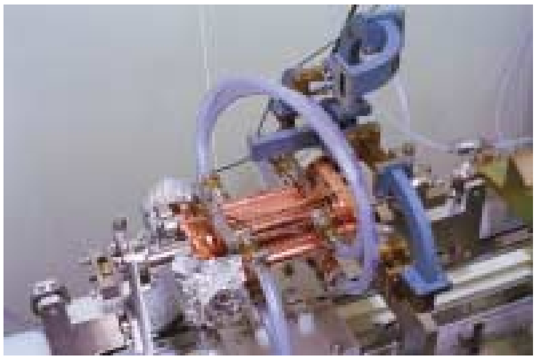

Figure 5: A test accelerator structure.

tric field on the surfaces and less discharge but lower accelerating voltage. After several trial, an optimized structure had been operated successfully at the GLC design acceleration gradient of 65 MV/m without beam loading. A test accelerator structure is shown in Figure 5. Further tests of structures are scheduled in FY2003 to verify performance with beam-on and wake field control.

The design of the GLC accelerator system has also been refined in FY2002. One of the major changes in the accelerator design was the change of the method to compress RF pulse; from the delay-line distributed system(DLDS) to SLED-II system. In the DLDS system, the RF pulse is compressed by placing Klystrons at proper distance so that a delay of the pulse naturally results to the compressed pulse at the accelerating structure. On the other hand, in the SLED-II system, the reflection of the RF power in the wave guide is used for compression. The efficiency of the RF compression in the case of DLDS is better than the case of SLED-II. But SLED-II design is adopted this year for a quick high power test since it requires only a quarter of Klystrons and structures which are required in the case of DLDS system. The system will be tested together with the accelerator structure in FY2003.