STATUS REPORT OF TRISTAN

Kazuo Ogawa,
VENUS Group
National Laboratory for High Energy Physics
Japan

ABSTRACT

Recent progress in Tristan e^+e^- colliding beam experiment is reported. The operation of the Tristan collider started at E_{cm}(W)= 50GeV in Nov.1986 for test collisions and experiments. The experiments continued from January to February, 1987 for about two weeks. Three of the four detectors (VENUS, AMY, and SHIP) were rolled into the interaction region in order to perform experiments. Here, we describe the status of the accelerator and detectors during the Jan. and Feb. runs, with an emphasis on the results of the VENUS experiment.

1. Introduction

The Tristan e^+e^- project[1] started five years ago in order to study new physics in the energy region above PETRA/PEP. Tristan offers a good place for testing the standard model, for searching for new particles such as the t-quark and heavy leptons, and for studying QCD, especially triple gluon coupling in 4-jet events.

The Tristan project was officially approved in April 1981 after a great deal of preparation and design work. Ground breaking took place in Nov. 1981. In Mar. 1983, two major experiments using general-purpose detectors, VENUS[2] and TOPAZ[3], were approved by TPAC (Tristan Program Advisory Committee) and detector construction immediately started. A half year after the approval of VENUS and TOPAZ, TPAC also approved an AMY[4] experiment with a compact spectrometer. As the fourth experiment, SHIP[5], a plastic detector for searching for highly ionizing particles, was approved in Mar. 1985. In Nov. 1983, just two years after ground breaking, we succeeded in circulating the first electron beam in the accumulation ring (AR). In Nov. 1985, the construction of a high-current electron linac for positron production was completed and the first positron beam was successfully circulated and accelerated in the AR.

By the end of 1985, all of the bending and quadrupole(Q) magnets of the Tristan main ring(MR) had been installed. After the installation of 64 RF cavities (60% of whole cavities), VENUS detector was rolled into the interaction region in Sep. 1986. Tests of electron and positron circulation in the MR started in Oct. 1986 with a beam energy of 25 GeV. The co-acceleration of electron and positron beams was successfully performed on Nov.14 at W= 50GeV. On Nov.19, we observed the first large-angle Bhabha event at W= 48GeV by the VENUS detector. Soon after, the first hadronic event was observed. In late November, the AMY was rolled into an interaction region and subsequently detected its first Bhabha event in December. The average luminosity at that time was 5×10^{28} $cm^{-2}s^{-1}$. After some improvement in the accelerator, a collision experiment was started again at W= 50GeV (Jan.28. to Feb. 20, 1987). The physics machine time was about two weeks. Beam parameters were studied during this period and final luminoisity was 2.5×10^{29} $cm^{-2}s^{-1}$.

2. The Tristan Accelerator

A schematic layout of the Tristan accelerator is shown in Fig. 1. Electrons are accelerated up to 2.5 GeV by a 390m linac with a 30MW peak power. The positrons produced by a 200 MeV high-current linac (10A at max.) are pre-accelerated up to 200 MeV and injected into the main linac to be accelerated to 2.5 GeV. Electrons and positrons of 2.5 GeV are then accumulated and accelerated up to 6-8 GeV by the AR. A typical current at the AR was 20 mA for electrons and 12 mA for positrons. Both beams are then injected into the MR and co-accelerated up to 25-28 GeV. The general parameters of the MR is given in Table 1. During operation between Jan. and Feb. 1987, the beam energy of 25 GeV was obtained by 64 RF cavities. The maximum current in the MR was about 1mA/bunch, resulting in a total current of 4 mA for a 2-bunch mode operation. The beam optics parameters βx^* and βy^* were investigated so as to reduce the backgrounds at the detectors. The final values for βx^* and βy^* were 2.5m and 0.07m, respectively and the luminosity was 2.5×10^{29} $cm^{-2}s^{-1}$. The beam life time was limited to about 1 hour due to the 10 times worse vacuum, 8×10^{-9} torr, of the beam pipe than the design value.

Table 1 General Parameters of Tristan Main Ring

Beam Energy	25-35 GeV
Circumference	3018.08 m
Average Radius of Curved Section	346.53 m
Bending Radius	246.53 m
length ob Long straight Section	194.35 m
Number of RF cavity cells	
conventional APS cavity	936
superconducting cavity	160
RF Frequency	508.58 Hz
Revolution Frequency	99.33 Hz
Radiation Loss/Turn	290 MeV(at 30GeV)
RF Peak Voltage	382 MV
Average Current	10 mA/Beam
Max. Design Luminosity	8×10^{31} $cm^{-2}s^{-1}$
$\beta x^*/\beta y^*$ at Collision Point	
Mini-β Optics	0.8/0.05 m
Backup Optics	1.6/0.1 m
Length of Experimental Insertion	
Mini-β Optics	5.4 m
Backup optics	9.0 m

3. Four Experiments at Tristan

3.1 SHIP

A SHIP detector consists of twelve modules having layers of CR-39 plastic sheets in order to search for highly ionizing particles. Twelve modules are so arranged that particles from an interaction point pass almost perpendicularly through plastic sheets. The detector opens horizontally and moves up and down at every beam injection and dumping in order to avoid beam background. During Jan. and Feb. runs, 40 CR-39 sheets were exposed for about 150 hours($\sim$100nb^{-1}). They have already been etched and analyses are presently in progress.

3.2 TOPAZ

One main feature of the TOPAZ detector is the choice of a time projection chamber (TPC) as a central tracking and particle identification device. A schematic view of the TOPAZ detector is shown in Fig. 2. The TPC has dimensions of 260cm in diameter and 300cm in length and comprises 8 sectors in each end. It is operated with a gas mixture of Ar(90%) and CH_4(10%) at a pressure of 4 atm. Signals from sense wires (175ch./sector) and pads (512ch./sector) are read by CCD's at 100 nsec intervals. The TPC is placed inside a superconducting magnet of 1 Tesla. An inner drift chamber(IDC) with a delay line readout was installed inside the TPC. Sixty four TOF counters around the TPC, combined with IDC, provide a main charged-track trigger. Outside of the magnet, there are drift tube chambers, an array of 4320 lead glass counters for an electromagnetic calorimeter, and muon chambers. In end cap regions, there are an electromagnetic calorimeter of lead and plastic tube sandwithes, and luminosity monitor. All detector components have been installed and tuned using cosmic rays. In fig. 3, a test result for a dE/dX measurement using the TPC is shown. The resolutions for dE/dX and momentum at 1 GeV/c are 5.5% and 2.5%, respectively (near the design values). TOPAZ is ready to be rolled into the interaction region and be used for physics runs starting in May, 1987.

3.3 AMY

A schematic view of an AMY detector is shown in Fig. 4. AMY is a relatively compact detector with a high magnetic field of 3 Tesla. The detector components are, from the interaction point to the barrel direction, a straw-tube tracking chamber, a central drift chamber, trigger counters, an X-ray detector for electron tagging, an electromagnetic calorimeter of lead and plastic tube sandwitches, a superconducting magnet, muon chambers, and muon counters. In the endcap region, there are pole tip counters, ring veto counters, and a small angle luminosity monitor. The central drift chamber has about 9000 sense wires (25 axial and 15 slant layers), and is operated with a gas mixture of $Ar/CO_2/CH_4$ at atmospheric pressure. The barrel electromagnetic calorimeter has fine lateral segmentation for distinguishing single gamma from π^0's. It is also segmented in depth (5-fold) to enhance e/π separation. With the exception of an X-ray detector, which will be installed later this year, almost all of the components were installed and working during Jan. and Feb. runs. Fig. 5 shows a differential cross section of Bhabha scattering measured by a pole tip counter where the nomalization is done using all the events shown in the figure. AMY collected 233 Bhabha events by a pole tip counter which corresponds to an integrated luminosity of about 60 nb^{-1}. They observed 26 barrel Bhabha events, 8 hadronic events, 2 gamma-gamma events, 3 radiative Bhabha events, 1 $\tau^+\tau^-$ candidate, and 1 $\mu^+\mu^-$ candidate during Jan. and Feb. runs. The detailed analyses are now in progress.

3.4 VENUS

Fig. 6 shows a schematic view of the VENUS detector. It is a large general-purpose detector that was constructed using conventional techniques so as to be ready for the first stage of Tristan operation. The central drift chamber(CDC) is 2.5m in diameter and 3m in length with 7104 sense wires(20 axial and 9 slant layers). It is operated with a gas mixture of Ar(89%), CO_2(10%), and CH_4(1%) at atmospheric pressure. It is placed in a magnetic field of 0.75 Tesla produced by a thin superconducting solenoid magnet. An inner drift chamber with a cathode readout for z-information is placed inside of the CDC. About 30 cm outside of the CDC, 3 layers of drift tubes(ODT) are installed to help the CDC to obtain a better momentum resolution. In the space between the CDC and the ODT, a transition radiation detector(TRD), which is now in the R. and D. stage, will be placed. Also, 96 TOF counters are placed between the ODT and magnet cryostat. As a electromagnetic calorimeter in the barrel region, an array of 5160 DF6 lead glass counters(LG) are installed outside of the magnet. They are arranged in a semi-tower type geometry to reduce double-hit probability. Two layers of streamer tube chambers are located in front of a lead glass array in order to determine the entrance positions of particles on the array. In the end cap region, a luminosity counter of lead and scintillator sandwitches is located in order to measure small-angle Bhabha events. All detector components except for a TRD mentioned above had been installed and were working during the Jan. and Feb. runs. As remaining components, we have a liquid argon calorimeter(LA) in the end cap region and muon chambers. A cool down test of the LA has been successfully completed. It will be installed in Feb. 1987. The muon chambers have been partially installed in the bottom region. Full installation for the barrel region will be finished in Mar. 1987.

The trigger of the VENUS experiment comprises the following 7 components; 1) a LG total energy trigger in which the total energy of LG is more than 5 GeV, 2) an LG segment energy trigger in which more than one LG segment have an energy of more than 500 MeV with more than 2 tracks, 3) a collinear-track trigger in which acollinear angle of two tracks is less than 30 degrees, 4) a high-multiplicity trigger in which there are more than 4 charged tracks with momenta of more than 700 MeV/c, 5) a luminosity trigger in which two tracks are in a back-to-back configuration with energies deposited in a luminosity counter of more than 17 GeV for both tracks, 6) a two-photon single-tag trigger in which an energy in a luminosity counter is more than 17 GeV and the energy in an LG segment is more than 500 MeV, and 7) a random trigger. The typical trigger rates at a luminosity of $2x10^{29}$ $cm^{-2}s^{-1}$ are 0.2, 1.3, 2, 0.6, 0.1, 0.1, and 0.1 Hz, respectively, for the above -mentioned seven triggers, resulting in a total trigger rate of 3.4 Hz.

Data were taken by Vax-11/780 through FASTBUS modules and sent to a host computor FACOM-382 and stored on cassette tapes. We have about 70 kB electronics channels: 9704 channels of TDC data, 5992 channels of ADC data, 1958 digital data, and so on. The typical data size is 5kB/event and the readout time is 25msec.

Analysis are performed according to the following flow: 1) process I to make data summary tapes and 2) process II for analyses of the physics. In process I, raw data are changed to physical parameters using calibration and monitoring data; LG ADC counts are changed to energy, tracks are reconstructed, and so on. This process is presently in progress. For monitoring, we have two quick-analysis programs for QED and hadronic events. The following are the results obtained by these quick analyses; thus, all the results should be considered as being preliminary.

We start with a QED analysis in the barrel region. We collected 1.4M events, including background triggers, during Jan. and Feb. runs. At first, the requirement that more than two LG clusters have energies more than one third of beam energy was imposed; 417 events were obtained. The second requirement was that the minimum of acollinear angle between any two clusters having energies more than one third of the beam energy is less than 40 degrees(82 event remained). Thirdly, we rejected cosmic ray events through an eyscan, and obtained 5 gamma-gamma and 63

Bhabha events, including large-angle radiative Bhabha. To calculate the integrated luminosity, we imposed the following for Bhabha events: 1) acollinear angle is less than 10 degrees, and 2) the scattering angle is between 40 and 140 degrees. We finally obtained 45 Bhabha events and found the integrated luminosity of 89 nb^{-1}. In Fig. 7, a differential cross section for Bhabha scattering is shown in which overall nomalization is performed using the data obtained by a luminosity counter. The data agreed well with the QED prediction within the statistical error. Fig. 8 shows the total cross section for gamma-gamma events. It also shows a good agreement with QED prediction. By using Bhabha events, we obtained energy resolution of 3.7% for a lead glass calorimeter. Momentum resolution $\Delta P/P$ of CDC is 1.5% x P_T, twice as bad as the design value. Corrections for parameters are presently being studied.

An analysis of hadronic events is now given. Again starting with 1.4M events, we at first required that the total LG energy is more than 4.5 GeV(36k events remained). The next requirement was that there be more than three tracks that come from origin where Z_{min} and R_{min} are less than 20 cm and 5 cm, respectively, or that there be more than two tracks that come from origin with a momentum of more than 0.1 GeV/c(197 event remained). Next, we rejected, by eyescanning, cosmic ray, Bhabha, and low multiplicity events with tracks less than 5(17 events remained). The final cut was imposed so that E_{vis} should be more than one half of CM energy and the sum of P_z/E_{beam} should be within ±0.4. Finally, we obtained 15 hadronic events. Figs. 9 and 10 show the momentum spectra and multiplicity distribution of charged particles for these 15 events, respectively. The solid line is the result of a Monte Carlo calculation using LUND53. Hadronic events look reasonable.

As a result of the above studies, detailed analyses are being intensively pursued. We are now in a good position to study frontier physics using the e^+e^- collider at CM energies above 50 GeV.

4. Future Plan

During the shut-down in Feb.-Apr. 1987, RF cavities will be installed up to 70% of the design total, and the vacuum system will be improved. The beam energy from May is expected to be 25 GeV or more with a beam life of several hours. Regarding detectors, VENUS will obtain a liquid argon calorimeter in the end cap region and muon chambers in the barrel region. Further, TOPAZ will be rolled into an interaction region, and four experiments will be in operation from this May. During the summer shut-down, RF cavities will be completely installed and the beam energy will be increased to 28 GeV.

Superconducting Q-magnets for mini-β optics are in preparation and will be installed at the beginning of 1989. Superconducting RF cavities are also being prepared for obtaining higher energies. A prototype cavity has been successfully tested with the result of 4.5MV/m acceleration gradient. Early in 1989, energy of Tristan will increase to 65 GeV, and reach 70 GeV soon.

References

1) T. Nishikawa, Proceedings of the 1985 International Symposium on Lepton and Photon Interactions at High Energies. P.791(1985)
2) VENUS Collaboration Proposal. Tristan-Exp-001, Mar. 1983, KEK.
3) TOPAZ Collaboration Proposal. Tristan-Exp-002, Mar. 1983, KEK.
4) AMY Collaboration Proposal. Tristan-Exp-003, Nov. 1984, KEK.
5) SHIP Collaboration Proposal. Tristan-Exp-004, Mar. 1985, KEK.
6) C. Yanagisawa, UTLICEPP-81-02, Apr. 1981.

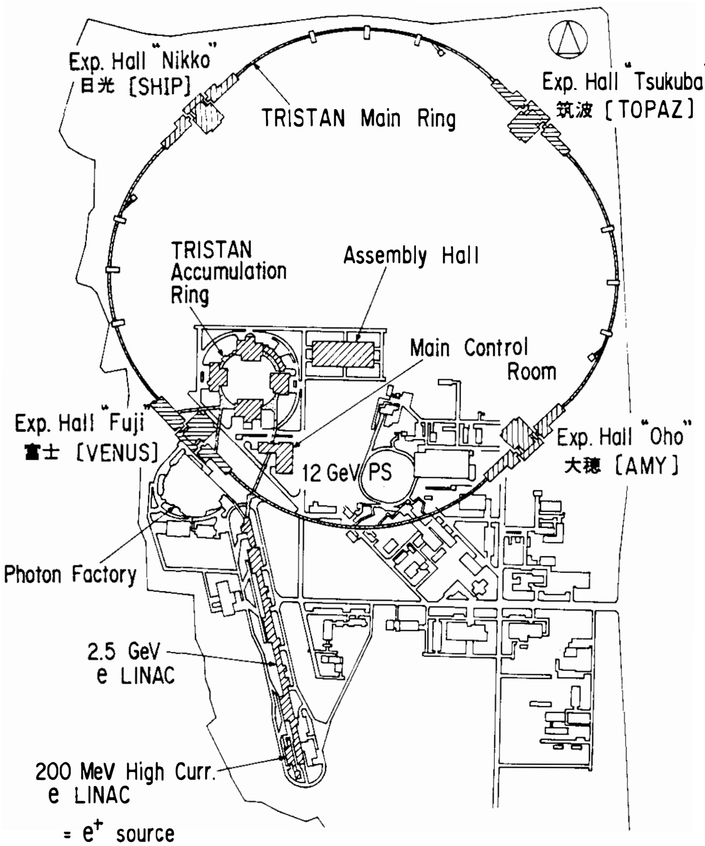

Fig. 1. Schematic layout of Tristan

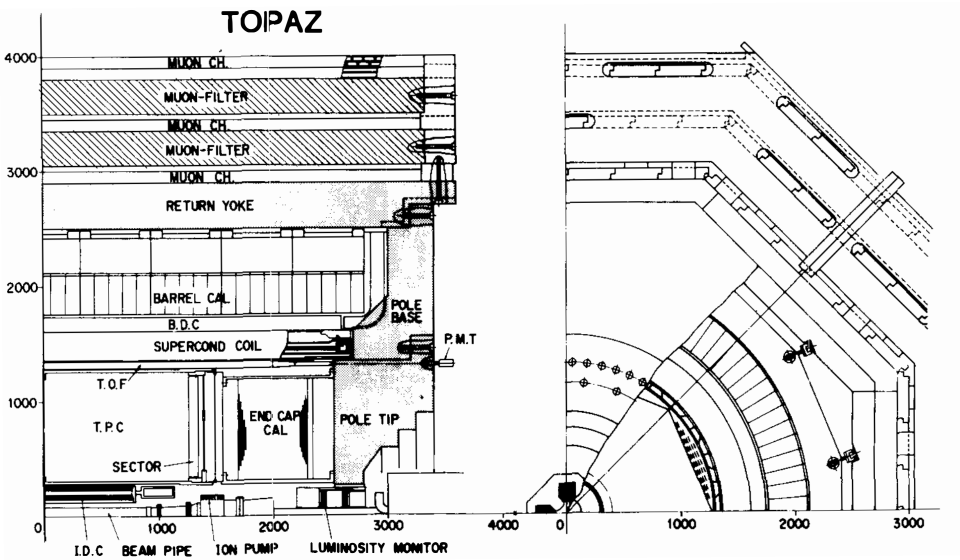

Fig. 2. Schematic layout of the TOPAZ detector

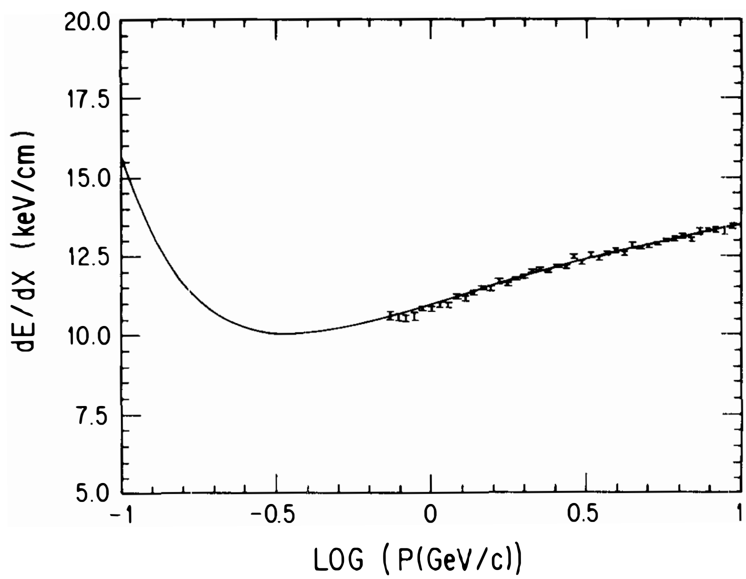

Fig. 3. Plot of dE/dX for cosmic rays measuered by TOPAZ TPC at 4 atm with a magnetic field of 1.0 Tesla.

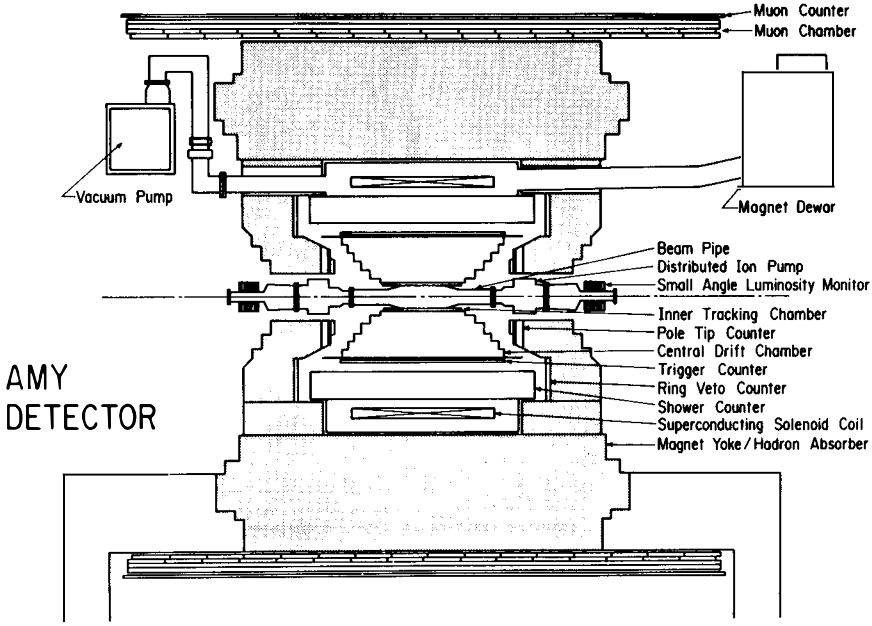

Fig. 4. Schematic layout of the AMY detector

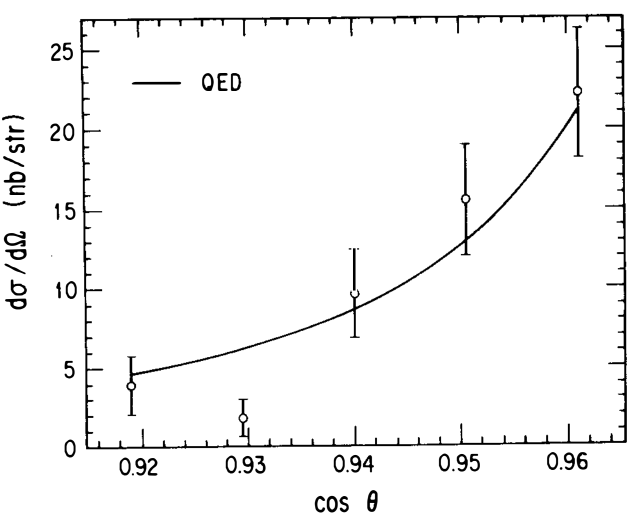

Fig. 5. Differential cross section of Bhabha scattering measured using the AMY pole tip counter. The solid line is a QED prediction.

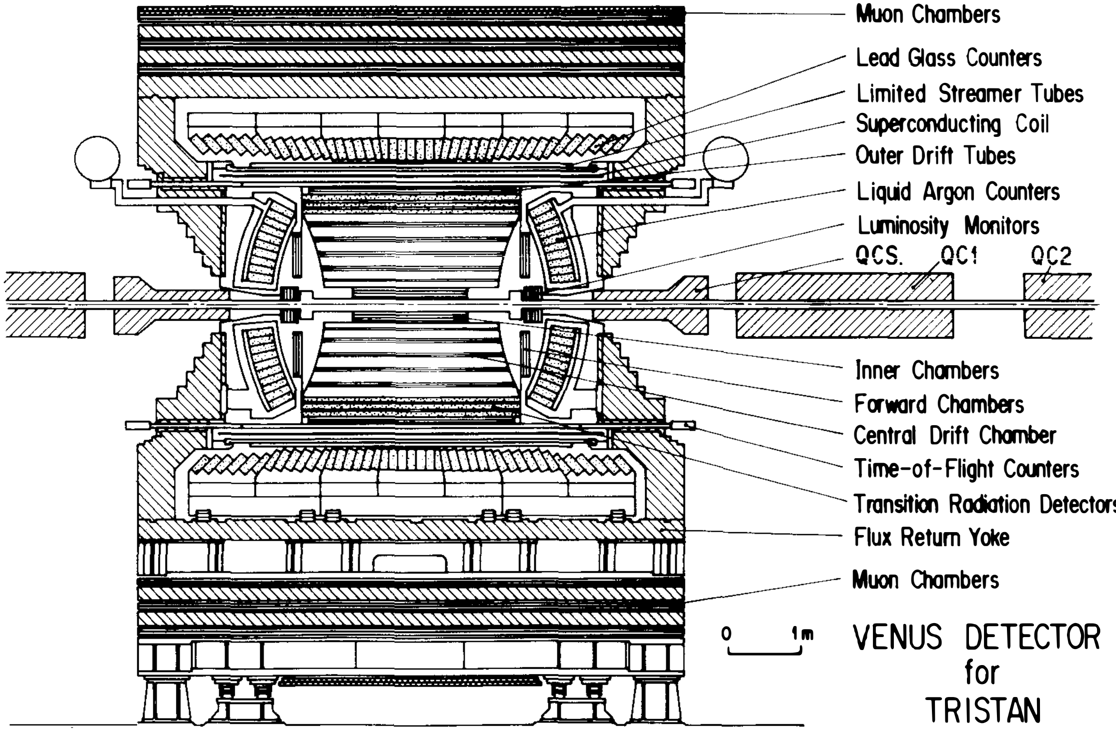

Fig. 6. Schematic layout of the VENUS detector.

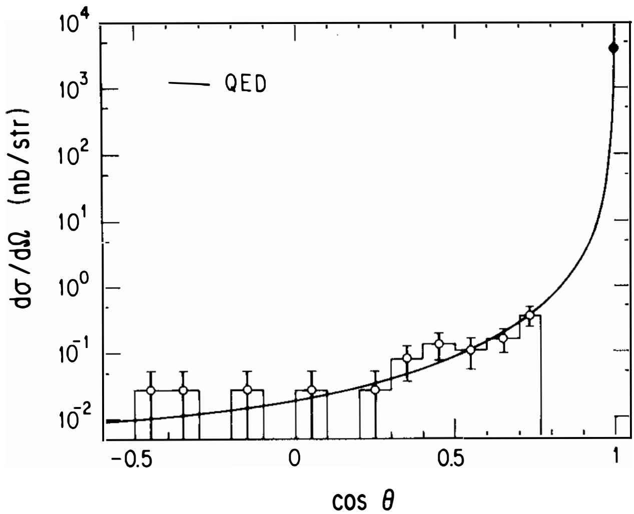

Fig. 7. Differential cross section of Bhabha scattering measured by the VENUS detector. Normalization was performed using the data measured by a luminosity counter (closed circle). The solid line is a QED prediction.

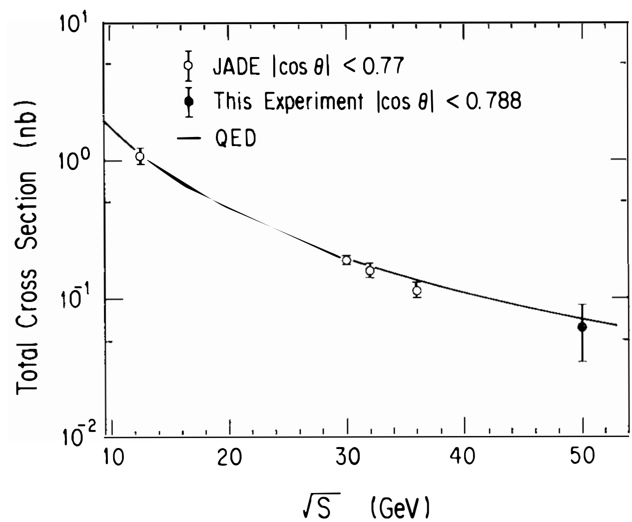

Fig. 8. Total cross section of $e^+e^- \to \gamma\gamma$ where the acceptance $|\cos\theta|$ is less than 0.788. The closed circle is from this experiment and open circles, from JADE experiment in which acceptance $|\cos\theta|$ is less than 0.77(Ref 6). The solid line is a QED prediction.

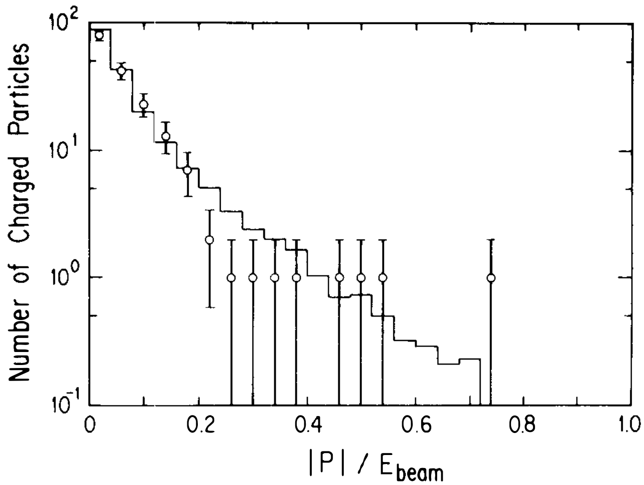

Fig. 9. Momentum distribution of charged particles for 15 hadronic events. The solid line is the result of a Monte Carlo calculation using LUND53.

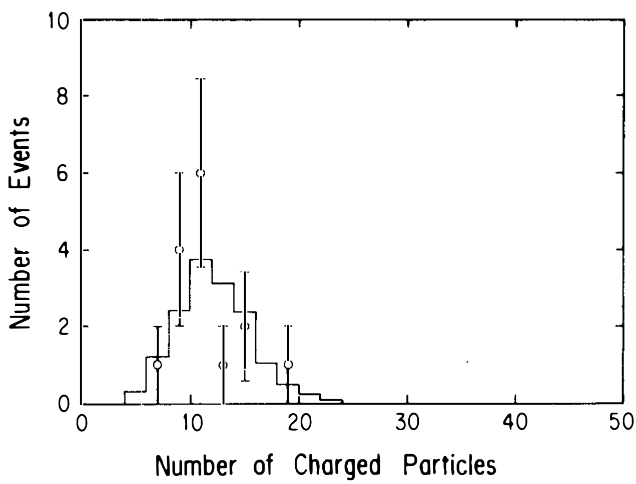

Fig.10. Multupilicity distribution of charged particles for 15 hadronic events. The solid line is the result of a Monte Carlo calculation using LUND53.