

## **Project Name**

### **Demonstration of Undulator-Based Production of Polarized Positrons at FFTB at SLAC**

#### **LCRD 2.37**

Classification-Accelerator

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#### **Motivation**

The physics potential of an  $e^+e^-$  linear collider is significantly enhanced if both electrons and positrons are polarized. Both the effective luminosity and measurement error in effective polarization are improved if the positron as well as the electron beam is polarized. The next Linear Collider baseline plan now includes production by a two step process where high energy electrons pass through an undulator, creating 10-50 MeV photons which are converted in a thin foil and the positrons collected, cooled and then accelerated. This technique avoids current limitations imposed by target damage caused by high energy electrons striking a thick target. If the undulator is replaced by a helical undulator, the resulting positrons are longitudinally polarized with polarization of 40-70 %.

#### **Project overview**

E166 at SLAC was proposed in 2001 at a demonstration experiment to provide a 1% scale test of the linear collider polarized positron production scheme. The linear collider baseline would utilize a helical undulator with period 1.2 cm and length 150m and using a 150 GeV electron beam. E166 uses the SLAC FFTB with electron energy 50 GeV and a helical undulator constructed by Cornell of length 1 meter and period 1.4mm.

A more complete description of the experiment can be found in the 2004 LCRD Accelerator proposal Section 2.37.1 (pages 202-217). A brief summary is given here. The low emittance 50 GeV electron beam with intensity  $2 \times 10^{10}$  electrons/pulse is passed through the helical undulator described above, producing  $4 \times 10^9$  photons with energy between 0 and 9.65 GeV. The beam size is  $40 \mu$  and passes through a stainless steel undulator tube 1 meter long and 0.9mm in diameter. An expected source of backgrounds are non-Gaussian beam tails which could provide a source of background if they collide with the undulator tube or the W collimator just upstream of the undulator. The polarization of the photons is measured by the transmission asymmetry when the photon beam passes through 15cm of magnetized iron whose magnetization can be reversed. The incident beam photon intensity above 5 MeV is measured by an aerogel Cherenkov counter preceding the magnetized iron. The photon count is independently measured by a 0.15 radiation length Tungsten silicon counter whose sensitivity extends downward to 1MeV. The energy weighted transmitted intensity is measured by a 23 X<sup>0</sup> Silicon Tungsten calorimeter and the photon intensity by another aerogel Cherenkov detector and independently by an additional 0.15 X<sup>0</sup> Tungsten Silicon counter. A variety of counters is used as the actual photon spectrum while well understood theoretically is not directly measured and response of different detectors yields useful information on the spectral shape.

The measurement of positron polarization is somewhat more difficult. The primary photon beam is passed thru a thin foil, the pair-produced polarized positrons collected and transported by a magnet system to a point well away from the primary photon beam where they are counted by a silicon detector and then converted back into polarized photons which are then polarization analyzed by transmission asymmetry in magnetized iron.. The transmitted photons are detected by a CsI crystal array constructed by DESY/Humboldt University. The size of this array and the low expected flux of  $\approx 2000$  photons/pulse with average energy 2 MeV makes it the most susceptible to interference from FFTB backgrounds and therefore it must be well shielded. .

## **Work performed by Tennessee.**

### Equipment

Tennessee has responsibility for construction, installation, testing and calibration of all E166 detectors with exception of CsI array and the aerogel counters. Specific items are mentioned below.

Construction by our group of 23  $X_0$  longitudinally segmented silicon calorimeter. This new device was installed and tested in June 2004.

Construction of 4 silicon sandwich ( $0.15X_0$ ) photon counters also installed and tested June 2004

Installation of rebuilt 23  $X^0$  SiW calorimeter and silicon sandwich photon counter built by Tennessee for E144, and installed in Fall 2003 for a series of FFTB background studies carried out parasitically while other experiments (E164, SPPS and E164) were taking data. These were replaced by the new detectors in June, but have been retained in the experiment as background monitors for the E166 runs.

Refurbishment and installation of a large E144 SiW calorimeter (PCAL) for background studies and a vital part of E166. This calorimeter serves as a sensitive detector of beam scraping in undulator tube, expected to be a major concern for low background running and beam tuning. It can detect positrons produced by a single electron striking the undulator tube or the upstream protection collimator and so serves as a pulse by pulse monitor of beam alignment and beam tails.

Tennessee has manned and been solely responsible for background studies (T467) carried out over the 1.5 year period prior to scheduled accelerator shutdown on July 1, 2004. Humboldt/DESY and SLAC provided 3 additional CsI detectors 2 with PMT and the other with photodiode readout. These were installed in T467 and were included in the DAQ for a portion of the background runs. The full CsI array and the aerogel detectors were not completed in time for inclusion in the background studies.

In addition to the detector work done at Tennessee, a large number of trips to SLAC were required for installation of T467 equipment and the background runs. While we were able to run the data acquisition from Tennessee physical presence was required for installation and counter reconfiguration.

### Background Measurements and Detector tests.

This proposal is not a suitable forum for reporting detailed results on background studies and detector tests. Over 300 data runs have been recorded and analyzed by our group in T467 under a wide variety of beam conditions and detector configurations. As T467 was a parasitic run we had no control over beam conditions or even access to the tunnel area for changing counter locations and installation preventing a truly systematic study. The running experiments E164-5 and SPPS in general had much larger backgrounds than those expected for E166 so we were able to measure only gross background effects and sources of background which must be shielded in E166. Further studies will no doubt be required for E166 run with the undulator and entire detector in place and the beam tuned for low background.

Appendix 1 is a single example of the type of study carried out. Taken during an E164 run it samples the background at a variety of background counter positions to identify and locate high background regions in the FFTB tunnel.

### **Schedule**

E166 was conditionally approved by SLAC EPAC in Spring 2003 subject to demonstration that backgrounds caused primarily by beam tails striking the tiny (0.9mm diameter) undulator tube were acceptably low. This approval was reconfirmed at the Fall, 2003 EPAC meeting. The original run schedule was divided into 3 segments:

- 1) T467 which began in summer 2003 installed 2 Si-W calorimetric devices, several scintillator paddles and a CsI crystal to study backgrounds present when other experiments were running (E165, E164 and SPPS) and to commission detectors and data acquisition system. T467 was completely parasitic and had no dedicated beam time, but was capable of routine recording of background data and has in fact been able to test the full data acquisition system and all of the detectors for the full experiment in parasitic running with 2 exceptions, the CsI array from DESY and the Princeton Silica-aerogel counters. It should be pointed out that the parasitic running was generally at background levels much higher than those expected for E166.
- 2) The original plan was to hold a special E166 background run in Spring 2004 with a dummy undulator tube to specifically establish that beam tails did not create unacceptable backgrounds by scraping the undulator tube.
- 3) E166 proper with all detectors and helical undulator in place to measure the photon and positron polarizations was planned for late 2005 (FY06) and would last approximately 6 weeks.

This run plan was modified in early 2004 by the scheduling committee to accommodate new request by E164, SPPS and E165 and in recognition of the necessity for beam line modifications required to switch from one experiment to another.

The new schedule proposed:

- 1) T467 continues to run parasitically until accelerator shutdown on July 1, 2004.
- 2) Setup for E166 in August/September 2004 (The entire apparatus (including undulator) for both background and polarization measurements must be installed)
- 3) Oct 4-8. Linac turn on and beam tune up, without PEP
- 4) Oct 8-Nov 1 Background test and first data taking.
- 5) Nov 1-Nov 4 Remove minimal E166 apparatus to reinstall SPPS
- 6) Nov 4-Dec 22 SppS data run
- 7) Dec 22-Jan 3, 2005 Reinstall E166
- 8) Jan 3-Jan 31 2005. Final data run(End of E166)

This represented a move forward in schedule of 8-9 months compressing both the construction and installation work. It involved an intensive period in August and September to make the necessary beamline modifications and vacuum work for installation of undulator support table and motion controls, new beam position monitors, beam toroids, collimators, magnets for polarization measurements, positron transport magnets, plus extensive background shielding for the recently delivered CsI array, These preparations were completed close to on schedule, beam tuning began on October 5 and initial 28GeV test beam was provided to E166 over the weekend of October 9 with the final undulator table installation scheduled for the following week by SLAC technicians.

However, as is well known by now the unfortunate electrical accident at SLAC resulted in immediate shutdown of the accelerator and the date of the resumption of E166 is not known at present. Speculation suggests that SPPS will run first and we may get a 1 month run in summer and another in late fall.

#### **Progress to date**

With the exception of a small amount of mechanical work to be completed on the support table for the undulator in the SLAC shops all equipment was present and installed in the beam line by 8 October, 2004 and beam tuning was complete for the initial phase of data taking. E166 had requested initial operation at 28GeV for detector calibration and ease of turn-on and while accelerator operations had not quite completed final tweaking of beam parameters it was decided to deliver test beam to E166 over the weekend of October 8-9. This was to be followed by completion of mechanical installation and shielding improvement during the next week, a switch to 50GeV beam followed by 2 weeks of E166 data acquisition exploring alignment and background questions, commissioning the undulator itself along with the new beam position monitors and toroids. The optimistic goal was to confirm by the end of October the predicted photon intensity from the undulator and to measure the average photon polarization.

This program was cut short by the lab shutdown after the accident and will be renewed at an as yet undetermined date but likely by summer 2005.

#### **Budget Discussion**

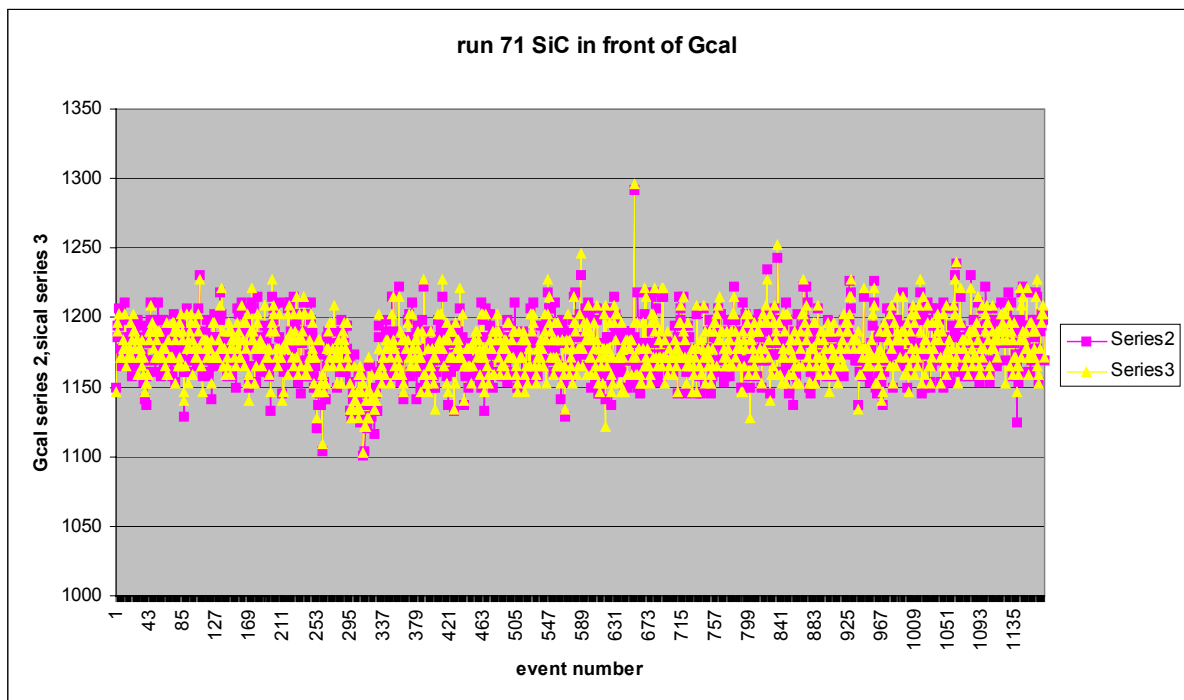
The operational delay in E166 due to the accelerator shutdown has engendered financial difficulty for our group which spent a large fraction of its resources in the early phases of E166 including continued background measurements, counter construction and testing at SLAC. Added to this was the intensive setup effort to prepare for the fall run which required presence of three faculty at SLAC for over 2 months. Much of this work will of necessity have to be repeated prior to resumption of the run since it seems likely that E166 will not be the first experiment to run when the FFTB resumes operation. The delay has made the personnel question for operation of the experiment a critical one. Princeton manpower consists of a single contributor (Co-PI Kirk MacDonald), a faculty member with teaching responsibilities, South Carolina has withdrawn from E166, our DESY colleagues have difficulty in making themselves available for the delayed run due to other commitments. Tennessee will in all likelihood find it necessary to provide the services of Bugg, Berridge and Efremenko for the duration of the setup and run to complement SLAC personnel.

SLAC has prepared the data acquisition programs for the experiment but only Tennessee personnel have experience in its use to take data and for analysis. To help alleviate this problem we ask, in addition to sufficient travel funds to operate at SLAC, for support for a graduate student to participate in E166. It is an ideal experiment for a student involving a wide variety of physical processes, detector technologies, data acquisition, and data analysis. Such an opportunity for broad hands on training is rare indeed for a student in a modern high-energy physics experiment.

## Appendix 1

### Study of position variation of backgrounds in FFTB

Run71-SiC (photon counter)directly in front of GCAL(SiW calorimeter)

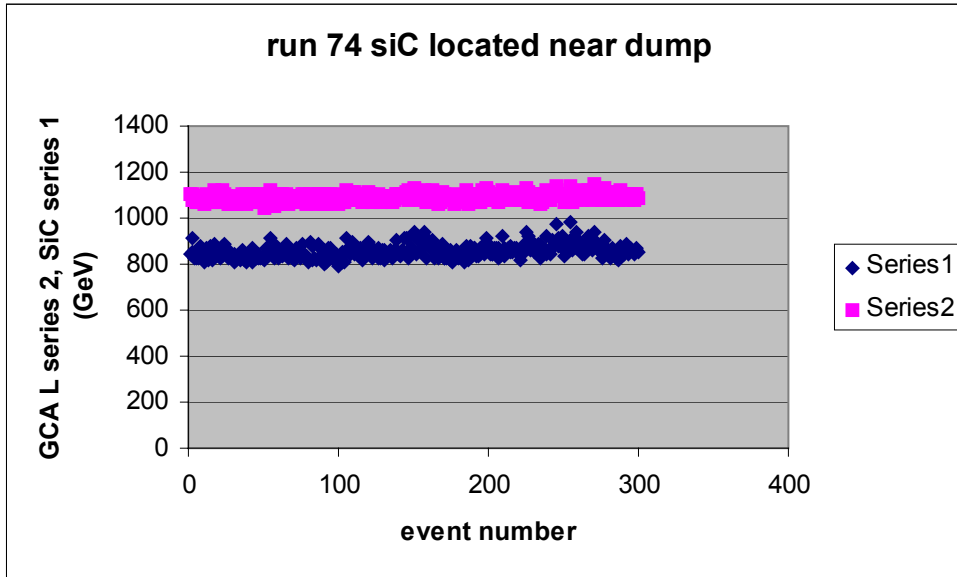


Here are GCAL and SiC signals for a series of runs with different SiC positions. Since the beam conditions vary from run to run and GCAL and SiC have same signal when they are located with SiC directly in front of GCAL the ratio of SiC to GCAL gives the relative response as function of position .

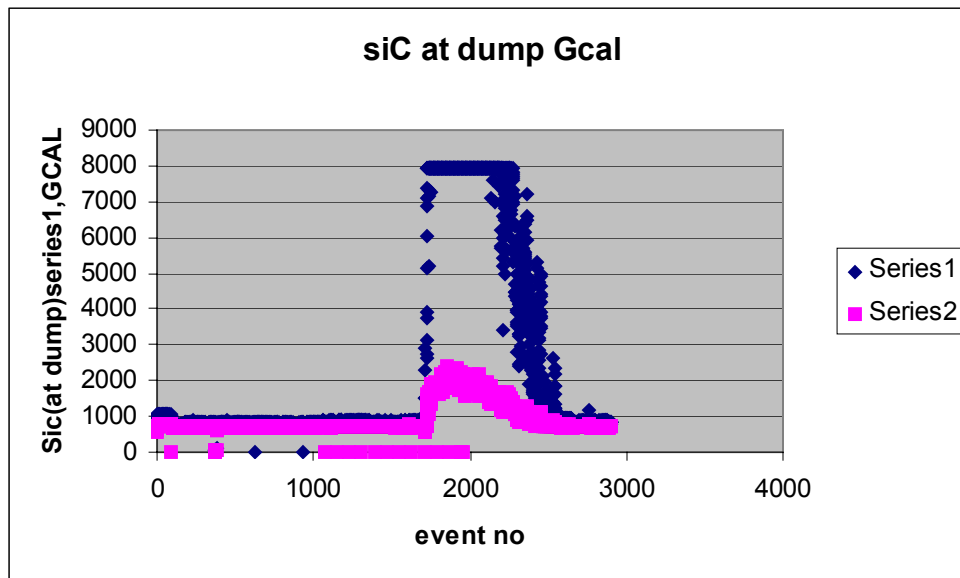
Ratio of SiC to GCAL will be designated R.

Also shown are some signals from a few other counters, scintillator paddles C1 and C2 and CsI crystals(SLAC PMT, DESYPMT and DESYcrystal with photodiode readout) from a very noisy run. The non-linear response of CsI indicates that photodiode electronics limits the useful range of the CsI array to less than 15 GeV/crystal. The expected signal in E166 less than 1 GeV/crystal.

RUN 74 SiC located near electron dump  
R=0.72

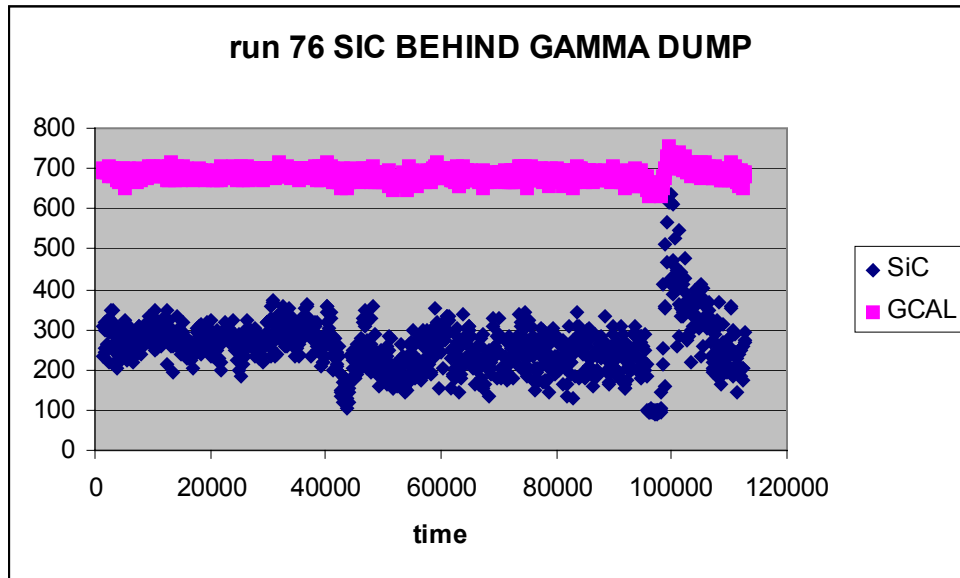


Same location as run74 but noisy beam

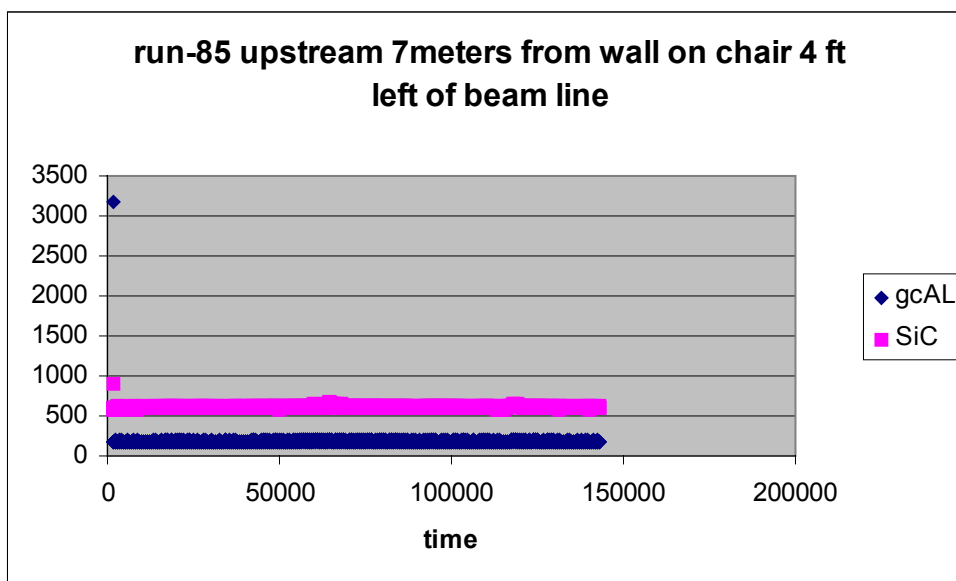


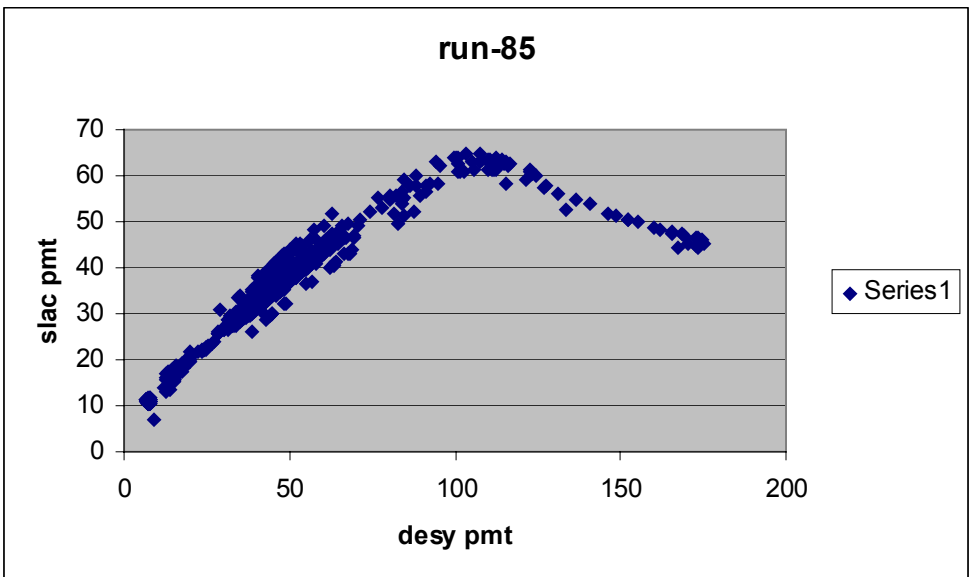
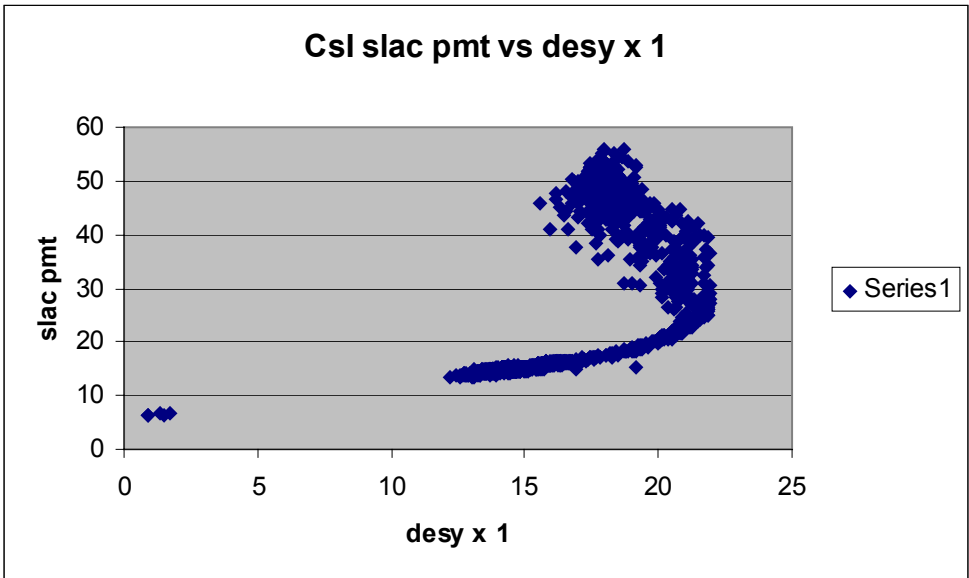
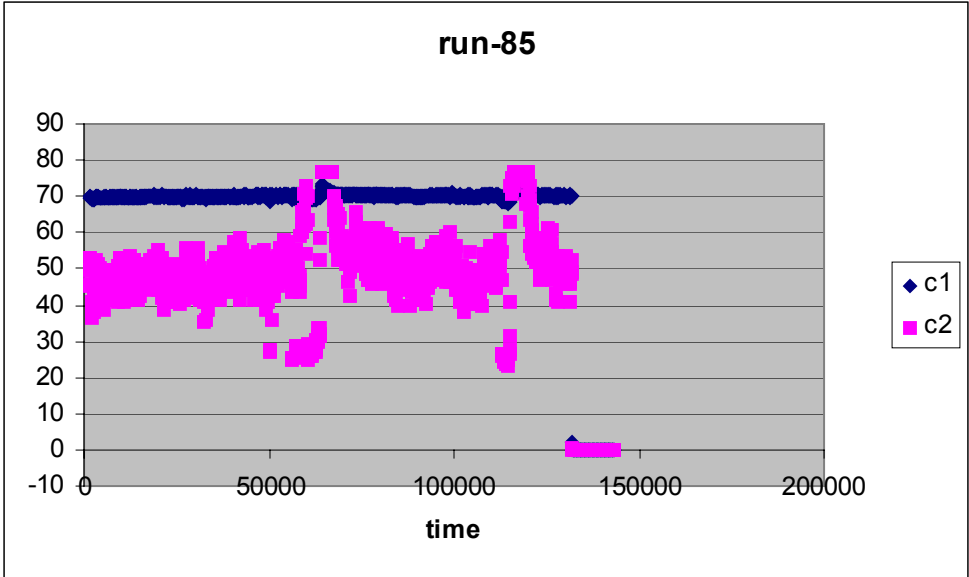
**Run 76 SiC just behind gamma dump**

**R=0.39**

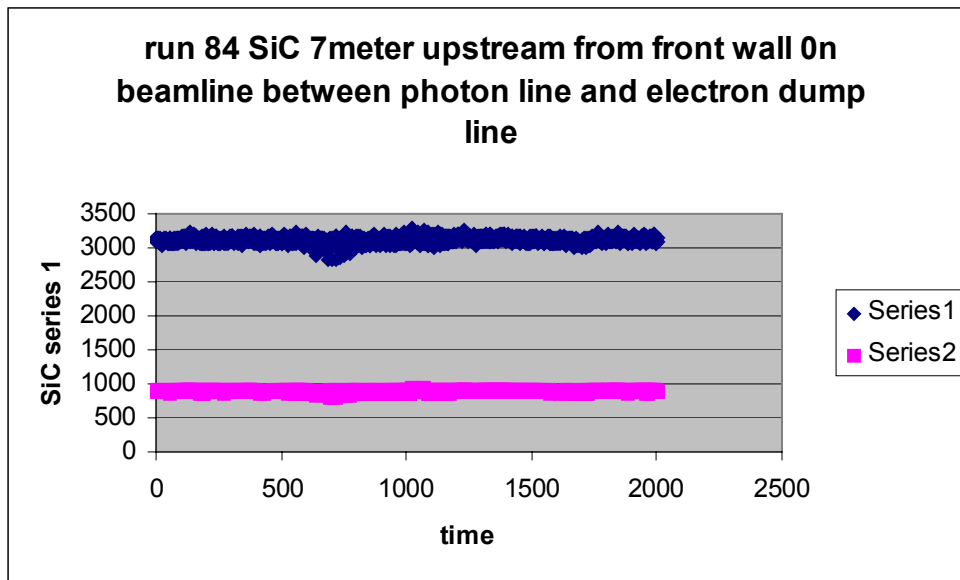


**Run 85 is a very noisy run. We include here the behavior of the CsI detectors to indicate the regions of operations where the non-linearity of the electronics limit their usefulness particularly for the photodiode array which will be used in the actual experiment.**





Run 84 SiC 7 meters upstream from front Pb wall on beamline close to photon line. R=3.5



Run 87 SiC behind front wall just in front of shielding cage for CsI. OTR(25 micron Ti foil) in place for 1'st 86 events. Note PCAL positron signal when upstream foil is inserted.

