Reaching for Higher Luminosity

Michael Sullivan
Stanford Linear Accelerator Center

Michael Sullivan

The success of the B-Factories in finding CP violation in the B-meson system with the value expected from the Standard Model has led to a search in rare B meson decays for a process that might hint at physics beyond the Standard Model. The signal could be either an observed decay process that should not happen or the absence of a decay process that should happen or a decay rate for a certain process that does not match prediction. This kind of search needs as much integrated luminosity as the accelerator can deliver in a reasonable amount of time (years). High luminosity is one of the two directions for discovery (the other being higher energy) and with this in mind the PEP-II accelerator at SLAC has been pushing for higher luminosity records in both peak and integrated values. Last summer, PEP-II attained a peak luminosity of just over 1.2×10^{34} cm^{-2}s^{-1} four times higher than design and a 24-hr integrated luminosity record of 911 pb^{-1} nearly 7 times the design value of 135 pb^{-1}.

The PEP-II accelerator at SLAC is a 2.2 km circumference double storage ring that collides a 9 GeV electron beam with a 3.1 GeV positron beam in a head-on collision at the center of the BaBar detector. PEP-II has achieved beam currents of 1.9 A for the high-energy beam (HEB) and just under 3.0 A for the low-energy beam (LEB) in 1722 beam bunches. The positron beam current is a world record for an anti-matter beam. The beam currents are maintained by continuously injecting beam into the storage rings. The typical injection rate for the low-energy ring (LER) is about 5 Hz while the rate for the high-energy ring (HER) is about 2 Hz. The BaBar collaboration has developed a technique whereby they blank out data coming from the beam bunches that most recently received an injected pulse until the injected particles have a chance to damp down. This minimizes the data loss to the detector while keeping backgrounds in the detector to a minimum. Figure 1 shows the monthly integrated luminosity totals for PEP-II since initial turn-on in 1999 and Figure 2 displays the integrated total. Figure 3 shows the peak luminosity achieved for each month of running.

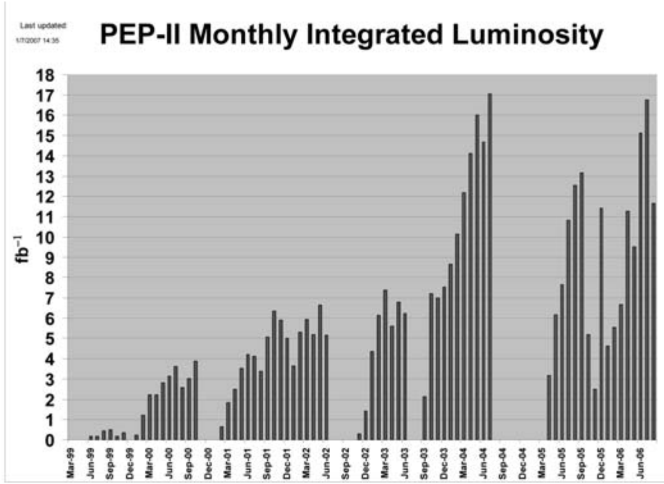

Figure 1. The monthly integrated luminosity delivered to the BaBar detector.

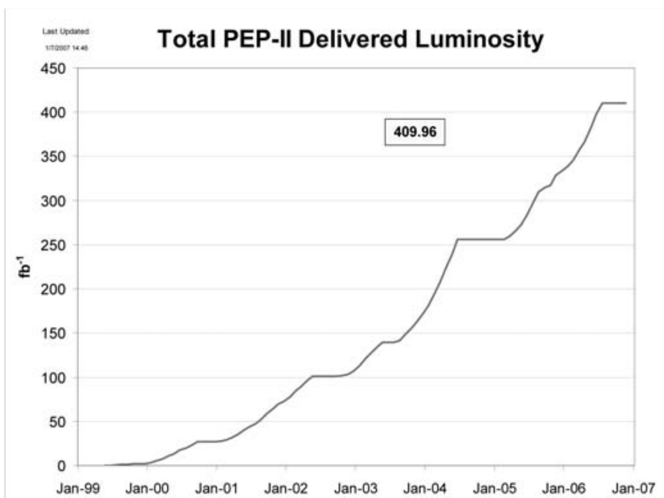

Figure 2. The total integrated luminosity delivered to the BaBar detector.

HIGH-CURRENT RUNNING

Running high current beams tends to reveal any weaknesses in several subsystems, in particular the vacuum chamber design, the RF system and the fast feedback systems. The vacuum system is tested by synchrotron radiation (SR) that is generated by the beams as well as by higher-order-mode power (HOM) left behind by the passing beam. The power from these sources has to be absorbed and controlled without causing damage to local components. The beams share a common beam pipe around the interaction point (IP) for about 5 m. It is not too surprising that this region is one of the places in the accelerator where a large amount of HOM power is generated. The total beam current through the shared pipe is nearly 5 A. In addition, two 0.5 m long strong bending magnets close to the IP bring the beams into and out of collision and these two magnets together are one of the largest source of local SR power in the entire ring. They generate a total of 120 kW when we have stored the beam currents mentioned above.

The run in 2006 uncovered several issues from HOM power that we addressed either during the run or during this last summer shutdown. We list some of these issues here.

1. A design flaw on an RF seal for the vacuum joint on a bellows section at the end of the shared beam pipe in the BaBar detector that produced arcing.
2. RF seal failure probably due to more vacuum chamber motion than the seal could accommodate in several areas of the HER.
3. Beam position monitor buttons that were press fit onto the vacuum feed-through pin that fell off due to overheating from too much HOM power absorption.

Speedy progress

America: a nation that has gone "directly from barbarism to degeneration without the usual interval of civilization.

Georges Clemenceau

Still waiting

One waits in vain for psychologists to declare the limits of their knowledge.

Noam Chomsky

Scientific objectivity?

It is remarkable how often the first interpretation of new evidence have confirmed the preoccupations of its discoverer.

John Reader

Blind date

To find a friend, one must close one eye. To keep him - two.

Norman Douglas

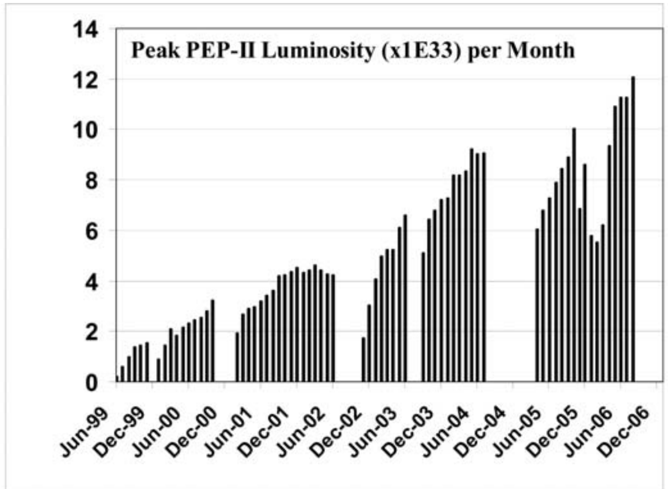

Figure 3. Plot of the peak luminosity achieved each month.

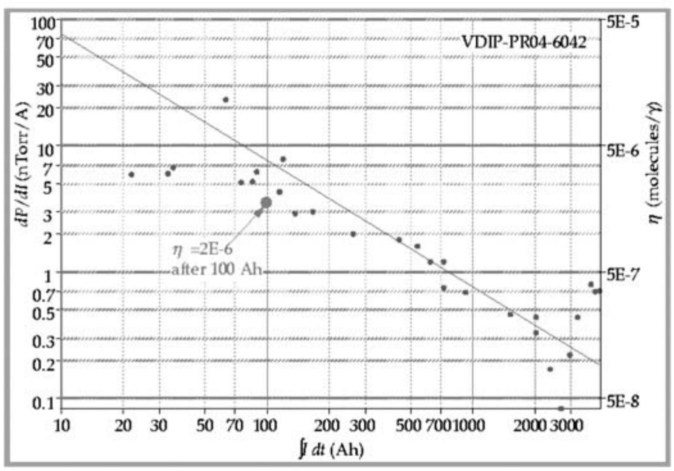

Figure 4. The data in this plot was collected a couple of years ago when we had integrated only about 5000 A-h in the HER. As you can see the photon desorption coefficient continues to decrease. The large green dot is the number we used when PEP-II was designed. At that time no accelerator had stored more than 100 A-h of beam current.

We replaced the RF seal that had the design flaw with one having an improved design. We have replaced the seals that appear to have failed due to too much vacuum chamber motion and we have replaced all of the bpms in 5 out of 6 arcs of the LER with a new improved design.

The RF system, which controls the klystron output power and accounts for the loading of the cavities from the beam through a series of overlapping feedback loops must be kept in good, reliable running condition in order to correctly control the RF from very low currents, while we fill the beams from the accelerator, up to full current. The LER system has to deliver 2.3 MW of precisely controlled power to the LEB and the HER system has to deliver 6.4 MW to the HEB.

PEP-II has accumulated a total of 31,000 A-hrs in the HER and 48,000 A-hrs in the LER. This is more stored beam current than any other accelerator has achieved. We have found that the photon desorption coefficient (the number of gas molecules that come out of the beam pipe wall per photon that strikes the wall) continuously decreases at the beam amp-hours increase. See Figure 4. This means that the overall vacuum pressure gradually improves over time and that the recovery time from having to vent a section of the vacuum chamber is relatively quick.

PLANS FOR FUTURE RUNNING

During this last shutdown, we installed another RF station (1 klystron and 2 new cavities) in the HER and also split up a 4 cavity RF station into 2 two-cavity stations by adding another klystron. This will let us attain a higher HER beam current of 2.2 A. We are also working on decreasing the beam spot size at the IP by lowering the emittance of the HER using a new lattice.

We have added several new vacuum components to the beam pipe on either side 9+/- 60 m) of the BaBar detector. These new elements are designed to shield the stored beam from HOM absorbing tiles and yet allow the very high frequency HOM power to get through the shield and be absorbed. Figure 5 shows a photograph of one of these components.

The present run in 2007 is scheduled to go until sometime this fall when we will shut down for 3 months. Then we will start up again in 2008 and run until October when we will cease running the B-factory at SLAC. By that time we plan to have delivered a total of almost 1000 fb^{-1} to the BaBar detector. We hope to have nearly doubled the peak luminosity from the present 1.2×10^{34} $cm^{-2}s^{-1}$ to 2.1×10^{34} $cm^{-2}s^{-1}$. In addition, encouraged by the discoveries of this last run, we hope to greatly improve the reliability of the accelerator and thereby improve our uptime, leading to greater integrated luminosity records for a given peak luminosity. The ultimate LER beam current we plan to achieve is 4.0 A.

SUMMARY

PEP-II has achieved a peak luminosity of $1.2\times10^{34}\text{cm}^{-2}\text{sec}^{-1}$, 4 times higher than the design luminosity. The record 24 hr luminosity is 911 pb^{-1} almost 7 times higher than the design value of 135 pb^{-1}. In the coming 2 years the PEP-II team plans to nearly double the peak luminosity yet again to $2.1\times10^{34}\text{cm}^{-2}\text{sec}^{-1}$ and to deliver nearly 600 fb^{-1} to the BaBar detector, more than doubling the present data set.

Figure 5. Picture of the RF shield for the upgraded bellows section at one end of the BaBar detector. Note the large gaps between the fingers. The HOM absorbing tiles can be seen behind the shield fingers.

Even truer today

We have long since lost the true names of things. It is precisely because squandering the goods of others is called generosity, and recklessness in wrong-doing is called courage, that the republic is reduced to extremities.

Cato the Younger

OTHER

IEEE Transactions on Medical Imaging APPLICANTS SOUGHT FOR EDITOR-IN-CHIEF

The Steering Committee of the *IEEE Transactions on Medical Imaging* (TMI) is seeking applicants for the Editor-in-Chief (EIC) of TMI starting January 2009. The new EIC will be selected in the fall of 2007, overlap with the current EIC in 2008 to permit a smooth transition, and take office in 2009.

SCOPE OF IEEE TMI

The *IEEE Transactions on Medical Imaging* is an archival journal published monthly. The journal publishes original contributions on medical imaging achieved by various modalities, such as ultrasound, X-rays (including CT), nuclear magnetic resonance, radionuclides, and light, as well as medical image data acquisition and retrieval, processing and analysis, and pattern recognition and related methods. The journal focuses on a unified common ground where instrumentation, systems, components, hardware and software, mathematics, and physics contribute to the studies.

QUALIFICATIONS AND REQUIREMENTS OF CANDIDATES

Applicants should have a broad and recognized expertise in the medical imaging community, have a scientific vision to expand one of the leading journals in the field, possess editorial experience, be able to lead an active editorial board and to work effectively with technical and publishing professionals, and be a member of the IEEE. Applicants must have employer support for this activity.

Major responsibilities of the future EIC of TMI include:

a) Identification and appointment of respected experts to his/her editorial board;
b) Solicitation of special issue proposals and manuscripts in specific areas;
c) Identification of emerging imaging modalities, devices, or analysis methods and active solicitation of high quality manuscripts in these areas;
d) Timely management of a large number of submissions and resolution of conflicts or problems, as necessary.

SEARCH PROCEDURE

Prospective candidates are asked to provide a condensed CV in summary form and a statement describing the candidate's vision for the future of TMI by June 1, 2007. Following initial screening by the committee, a complete CV will be requested. Nominations will also be accepted until May 1.

Applications and nominations should be sent to the Chair of the Steering Committee:

Professor Benoit M. Dawant
Box 1662-Station B
Vanderbilt University
Nashville, TN 37235
Tel: 615-322-7923
Fax: 615-343-6702
e-mail: Benoit.Dawant@Vanderbilt.edu