The E158 Status Review

SLAC - August 30, 2002

Persis Drell and Steve Williams reconvened the E158 Review Panel that met in March of this year. The purpose of this review was given in the charge to the Panel to determine:

(1) Has Run I demonstrated that the experiment is functioning well and achieved a significant fraction of the statistical sample needed for completing the experiment?

(2) What fraction of the proposal goals will be achieved with the planned data runs in October 1-November 15, 2002 (6 weeks at 120 Hz)?

and

(3) How many weeks will be required in FY04 to complete the experiment?

The Committee was chaired, as before, by Charles Prescott, with the following committee members: Stan Ecklund, Roger Miller, Peter Rowson, Sayed Rokni, Dave Schultz, and Bruce Schumm. All members are from SLAC, except for Bruce Schumm, from UCSC. The Charge to the Committee and the schedule of talks are appended to this report.

SUMMARY and response to CHARGES

The E158 chronology preceding this review is briefly summarized here. A first beam test at ASSET occurred in January 1999. A detector radiation hardness test occurred in February 2000, followed by commissioning of the polarized beam in November of 2000. First beam to ESA for E158 occurred in February 2001. The Winter/Spring 2002 running for E158 began with an engineering checkout run at low rate starting in February 2002. Production running for physics started on March 5 at 60 Hz. This run was interrupted by target problems that required several accesses to diagnose and repair. March 2002 running for physics amounted to 10 days at 60 Hz. Following the target repair, the rate was raised to 120 Hz, and the run ended on May 27, 2002 with 5 weeks of 120 Hz running going to tape. E158 has thus completed a physics run beginning in March and ending in late May. The accumulated statistics for Run I amounts to less than 20% of that needed to reach the proposal goals.

Two Readiness Reviews have been held previously for E158, the first on September 21, 2001 and a second on March 1, 2002. This August 30, 2002 Review consisted of a half-day of presentations on Overview and Systematics (Krishna Kumar), Beam Performance (Mike Woods), Accelerator Issues for Future Running (Franz Josef Decker), and Asymmetry Analysis (Yuri Kolomensky). A working lunch was held with the Committee and E158 representatives, and the review closeout was held following a short Committee working session.

Table 1 gives the systematic and statistical errors on asymmetries coming from various sources. (The physics raw asymmetry expected in the Standard Model is 110 ppb.) "Now" refers to the status as of the August 30 review; Run I refers to the expected final results from the April/May 2002 running period when the analysis is finished; Run II refers to the October/November 2002 period; and Run III refers to the FY2004 planned running.

Table 1: E158 Errors Summary

Issue	Now	Run I	Run II	Run III
Raw Asym.	10 ppb	4 ppb	3 ppb	2.5 ppb
e-p	20 ppb	10 ppb	4 ppb	4 ppb
Pions	7.5 ppb	2.5 ppb	2.5 ppb	2 ppb
Punch thru	10 ppb	5 ppb	1 ppb	1 ppb
Linearity	5%	3%	1%	1%
polarimetry	6%	5%	4%	3%
Total Sys		14 ppb	7 ppb	6 ppb
Stat error*		23 ppb	15 ppb	9.6-10.6 ppb

* 48 GeV and 45 GeV data combined

The Committee asked the E158 Collaboration to predict its future performance in response to the questions in the Charge. The Committee discussed these responses and the assumptions being made by E158 during the review. The Committee accepts and believes these estimates below are the most accurate at this time.

(1) *Has Run I demonstrated that the experiment is functioning well and achieved a significant fraction of the statistical sample needed for completing the experiment?*

The E158 Collaboration, working together with the Accelerator personnel, have made enormous progress toward their technical goals. A major achievement was in the laser stability, which ran routinely at a pulse to pulse jitter of 0.5% or below. With this stable source, tuning of the beam was not a problem, and the jitter on the beam monitors was accordingly low. Table 2 gives the beam monitoring summary for the Run I period.

Table 2: E158 Beam Monitoring Summary

Item	Goal	Run I (achieved)
Beam Charge	6×10^{11}	6×10^{11}
Intensity jitter	1% rms	0.5% rms
Position jitter	<10% of spot size	5% of spot size
Spotsize jitter	<10% of spotsize	5% of spotsize
Energy spread	0.3% rms	0.15% rms
Energy jitter	0.2% rms	0.03% rms
Polarization	75%	84%

E158 is limited by statistics in Run I, and will continue to be statistics limited in future runs. Combining statistical and systematic errors gives the following estimate:

$$\delta sin^2\Theta_W^{eff} \approx 0.0028 \quad \text{(Run I)}$$

(2) *What fraction of the proposal goals will be achieved with the planned data runs in October 1-November 15, 2002 (6 weeks at 120 Hz)?*

Approximately 50% of the needed run time. The initial physics runs during Run I were less efficient than later, as time to bring hardware online was required, and procedures were being streamlined. Table 1 above gives estimates the improvements in systematics from Run I to Run II. The Fall 2002 projections are based on the following assumptions: (i) beam intensity of 3.5×10^{11} per pulse at 48 GeV and 5.5×10^{11} at 45 GeV; (ii) 80 % beam delivery and 68% efficiency data taking to tape; (iii) 2.5 weeks at each energy, plus 1 week of checkout yields 20.5 ppb at 45 Gev and 22 ppb at 48 GeV (stat. error).

and

$$\delta sin^2\Theta_W^{eff} \approx 0.0017 \quad \text{(Run II)}$$

(3) *How many weeks will be required in FY04 to complete the experiment?*

More than 10 weeks at 120 Hz with PEP II running. Based on the assumption of 10 weeks at 120 Hz, an overall efficiency of data taking on tape of 65% efficiency, and modest improvements in the electronic noise, E158 would achieve 13.5 to 15 ppb at each energy and

$$\delta sin^2\Theta_W^{eff} \approx 0.0011 - 0.0013 \quad \text{(Run III)}$$

Combining Run I, II and III would then yield overall:

$$\delta sin^2\Theta_W^{eff} \approx 0.0009 - 0010 \quad \text{(Grand Average)}$$

Note: E158 was approved on a proposed sensitivity of

$$\delta sin^2\Theta_W^{eff} \approx 0.0008 \quad \text{(E158 Proposal)}$$

Discussion

First, the Committee wishes to congratulate the E158 Collaboration for the technical progress the E158 has made since the last review, and for the prompt response to the request for this review. The performance of the technical components supporting the E158 physics run are indeed impressive. The Committee takes note of this performance and congratulates the E158 Collaboration and the Accelerator and EFD personnel who made this happen.

(i) Target:

The earlier target problems seem to have been cleared, and the target performance was subsequently perfect. No presentation on the target system was deemed necessary at this review. The Committee notes that this target achieves a new level of performance in size (ie., length) and beam power capability. The cryogenics and engineering support by EFD has been strong throughout the setup and checkout of E158. This is noted and fully appreciated by the Committee.

(ii) Beam containment:

Based on the passive/active radiation surveys and beam tests, the radiation levels at various points outside the ESA for the last E158 run and the future weeks of high-power operation will remain within the radiation designed limits.

(iii) Backgrounds, detector noise, and luminosity:

The major experimental challenge for E158 is the control of backgrounds, detector noise, and luminosity fluctuation to the level that allows measurement of the pulse-pair asymmetry to the accuracy permitted by the underlying physics of Moller scattering. For the first time in this series of reviews, the proponents of E158 demonstrated that they had effectively achieved this goal. By methodically eliminating detector backgrounds and improving readout electronics, E158 has achieved a pulse-pair precision of about 1.9×10^{-4}, within 10-20% of their projected statistical width of the pulse-pair asymmetry. This is a major achievement for the group. In addition, the group believes that electronic pedestal noise is one of the contributing factors to the small remaining degradation, and will investigate methods of reducing this during Run II.

An effect that has emerged since the last review is the presence of an azimuthal dependence of the Moller signal, which is an expectation of QED for an electron beam with non-zero transverse polarization. E158 has confirmed this as the source by running briefly at 46 GeV, for which the transverse polarization is large. Currently, this effect, in concert with the variation of the detector response as a function of ϕ, lead to an change of approximately 10-15% in the measured asymmetry at 45 GeV, and about half that at 48 GeV. E158 presented two possibilities for reducing the size of this effect in Run II: understanding the azimuthal response function of the detector better, and/or adjusting the beam energy (on the scale of once a day) based on the magnitude of the azimuthal asymmetry in prior data. Since the transverse polarization effect was just recognized, neither of these alternatives has been fleshed out as of yet. However, it seems reasonable to expect that they will be able to control or understand this effect to the required degree of accuracy ($< 2\%$).

After some effort, E158 has been able to demonstrate a pulse-pair asymmetry resolution of about 1.3×10^{-4} with its luminosity monitor. Given that this is considerably smaller than the pulse-pair resolution on Moller scatters, the luminosity monitor measurement should provide potentially a valuable zero-asymmetry cross check to the Moller result. Although the intrinsic statistical power of the luminosity monitor is much better – roughly 0.5×10^{-4} – the current measurement is believed to be limited to beam jitter caused by higher-order effects that are difficult to regress from the data. It is therefore unlikely that the relative performance of the luminosity monitor will be improved, although the consistency check it will provide is of considerable value to the experiment. At the moment the luminosity monitor is also needed to estimate false left-right asymmetries due to target density fluctuations, a potentially serious effect which is not expected to be a problem, but needs still to be studied.

At the previous review, bench measurements combined with the projected detector operating point suggested that effects due to phototube non-linearity would be less than 5% in Run I. An in-situ measurement of the effect of non-linearity, making use of the charge dependence of the raw asymmetry, should provide an assessment of non-linearity effects to an accuracy of 2-3%. At the end of run II, E158 proposes a redundant check of the non-linearity with asymmetry data when both the polarized foil as well as the hydrogen target are in the beam. Variations of the central value of the resulting 200 ppm asymmetry with and without filtering of the light into the PMT provides information on linearity, while variation of the asymmetry width at different PMT gain will provide information on electronic noise

E158 expects to reduce significantly the charge asymmetry by feeding back on alcove toroids rather than ASSET toroids.

New profile-monitor hardware provided precise data on the spectrum of the Moller and Mott peaks at the last review, but the modelling of these peaks was not well understood. For this review, the Monte Carlo has been improved, and the agreement with data is now good enough that uncertainty on the Q^2 scale of the observed Moller scattering should not contribute appreciably to systematic error.

While the asymmetry of backgrounds due to radiative elastic e-p scattering is difficult to model, it is well measured in the high-radius e-p detector. A brief period of running at the beginning of Run II with the new 3CM8 collimator in place will allow the contribution of this background under the Moller peak to be constrained. E158 estimates that the resulting correction to the Run I asymmetry will be about (20$\pm$6)%. In Run II, data will be taken with the 3CM8 collimator in place, as well as increased masking of the beamline just upstream of the detector, leading to a smaller and more certain correction, estimated to be $(13 \pm 3)\%$. At this level, this systematic would be one of the dominant systematics, although still small relative to the 15% projected statistical error for Run II.

In total, the achievement of the nearly-full statistical power of the pulse pairs is a major victory for the E158, and is worthy of recognition. Other issues addressed here, while requiring some degree of further work, do not seem to threaten the overall goals of the experiment. The Committee feels that the attention and strategies proposed by the experiment to address these remaining issues should be appropriate to ensure the program's success.

(iv) Accelerator/Operational Issues

During the 120 pps operation of E158 in the period from April 25 through May 27, 2002 the accelerator met or exceeded all the performance goals for this experiment, delivering 3.5×10^{11} e^-/pulse at 48 GeV and 5 to 6×10^{11} e^-/pulse at 45 GeV. The polarization was $85 \pm 5\%$ and the beam delivery efficiency was greater than 65%. This was achieved while compatibly providing fills for PEP II during one of PEP's most productive runs. The beam energy, intensity, position and spot size stability met all of the experiments requirements. This remarkable achievement resulted from the extraordinary efforts of a large number of people at SLAC. Although this success resulted from many improvements in hardware and procedures a few of the most significant should be mentioned.

1. The intensity and stability of the laser for the polarized gun were greatly improved.

2. One of the new strained cathodes with graded doping, which eliminates the surface charge buildup and the resulting current limitation without hurting the polarization, was installed in the gun.

3. A new lattice which improves the compromise between PEP beams and the E158 beam was calculated and used.

4. Pulsed steering was installed at critical points along the linac.

5. A skew quadrupole was installed at the end of the A-line to mix the large stable emittance generated by synchrotron radiation in the horizontal plane into the vertical plane. This stable emittance then dominates the phase space distribution of the beam in both planes.

Having demonstrated that the accelerator can deliver the required beam at full repetition rate, the single remaining question is how long it will take to bring the accelerator back up to the full performance demonstrated last spring. The process is made easier because the Oct 1 to Nov 15 run will be dedicated to E158 with no other beams running. Nevertheless, bringing the beam up to full performance in one week (the schedule shows 3 days) is very, very challenging after a 3 month shut down.

(v) Injector Systems

The excellent operating conditions of the Injector and Linac in May contributed to the success of E158 Run I. The intensity jitter from the laser was very low ($\leq$ 0.5%) leading to low electron beam intensity, energy and position jitter. There is the potential for further improvements to the laser system, which could lead to lower intensity jitter for the upcoming run. The polarization of the electron beam was also very high. The photocathode used has an anomalously low asymmetry in linear polarization quantum efficiency, leading to a low beam charge asymmetry. This photocathode had been preserved in the CID gun to ensure its usefulness for Run II. The injection line was tuned into good shape.

There is a long-standing problem with multipactoring with the K02 klystron which may be addressed by wrapping a solenoid around its phase shifter. The tunability of the injector in the upcoming Run II will be improved by the lack of positrons in the line in this period of dedicated A-line operation. The experiment is now benefiting from the data it has collected in better understanding systematics. Run II will add to this understanding, and future runs will complete the data set needed for the precision measurement as proposed.

Appendices:

Charge to the Committee

August 30 Review Agenda