Proposal Update to Jefferson Lab PAC 23

UPDATE of E00003: NEUTRON SKIN OF ^{208}Pb THROUGH PARITY VIOLATING ELECTRON SCATTERING

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(This is a Hall A Collaboration Proposal)

Postscript copy of this update is at www.jlab.org/~rom/pbupdate.ps
And the original proposal is at www.jlab.org/~rom/pbpro.ps

Proposal Update: ^{208}Pb Parity

This is an update on proposal E00003, entitled "A Clean Measurement of the Neutron Skin of ^{208}Pb Through Parity Violating Electron Scattering" which has come under 3-year jeopardy. The original proposal will be attached. Here we update the scientific case, the collaboration status, and technical developments needed to perform the experiment. We are requesting 30 days at 50 μA and 850 MeV.

A postscript file of this update is at http://www.jlab.org/˜rom/pbupdate.ps and the original proposal is at http://www.jlab.org/˜rom/pbpro.ps

I INTRODUCTION

In a heavy nucleus like ^{208}Pb the difference between the neutron radius R_n and the proton radius R_p is believed to be several percent. This neutron skin has not been well established experimentally in stable nuclei. We plan to measure the neutron charge radius R_n (i.e. the RMS radius of neutrons in a nucleus) in a clean and model independent way analogous to the classic measurements [1] of the proton radius R_p and with unprecedented accuracy as suggested originally by Donnelly, Dubach, and Sick [2]. Experimentally R_n is rather poorly known [3]. There is some controversy about exactly how accurately R_n has been measured – probably 5%. Indeed the best estimates of R_n appear to come from nuclear theory [4], where models have been constrained primarily by data *other than* neutron radii. Therefore, a measurement of R_n will provide a powerful independent check of these models.

The experiment measures the parity violating asymmetry in elastic scattering $A = (\sigma_R - \sigma_L)/(\sigma_R + \sigma_L)$. This asymmetry arises due to the the interference of the Z^0 boson amplitude of the weak neutral interaction with the photon amplitude. The asymmetry is sensitive mainly to the neutron radius R_n because the weak charge of the neutron is much larger than that of the proton. In PWIA, the relationship between the asymmetry and the neutron form factor is given by equation (1)

$$A_{LR} = \frac{G_F Q^2}{4\pi\alpha\sqrt{2}}\left[1 - 4\sin^2\theta_W - \frac{F_n(Q^2)}{F_p(Q^2)}\right] \tag{1}$$

where G_F is the Fermi constant, $\alpha = \frac{1}{137}$ is the fine structure constant, θ_W is the Weinberg angle, and $F_n(Q^2)$ and $F_p(Q^2)$ are the neutron and proton form factor of the nucleus. Thus A_{LR} is approximately proportional to the ratio of neutron to proton form factors. In the above we used PWIA to illustrate. To achieve 1% accuracy requires corrections for Coulomb distortions, which have been calculated by Horowitz [5].

II UPDATE ON THE SCIENTIFIC CASE

In the past three years there have been several publications which have increased the scientific interest in this proposal. A single measurement of R_n with 1% accuracy can have an impact on several areas of physics, including nuclear theory [3], atomic parity violation [8], and neutron star structure [18].

In a recent analysis of neutron radii in nuclear mean field models, Furnstahl [21] showed that the variable range of R_n allowed by a large set of viable nuclear models was associated primarily with the density dependence of the nuclear symmetry energy. This is an energy cost associated with having unequal numbers of neutrons and protons. A measurement of R_n would pin down this one parameter and could potentially demonstrate that an entire class of models is less likely than another. For example, relativistic mean field models tend to favor larger neutron skins than nonrelativistic models because of a larger symmetry energy. Furnstahl's analysis also demonstrates clearly that our measurement of the neutron from factor at one low Q^2 point will measure R_n.

Recently, Clark and Kerr [9] have re-analyzed proton nucleus elastic scattering data and have found energy independent neutron radii and skin thicknesses for ^{40}Ca, ^{48}Ca, and ^{208}Pb. Their value for Pb is $R_n = 5.551 \pm 0.038$ fm which is better than 1% accuracy. However, it is important to verify this phenomenology. The present proposal will produce a clean, model independent result. It may serve to calibrate proton scattering, making it a useful tool for predicting R_n for many nuclei.

The impact of an accurate R_n measurement on atomic parity violation (APV) experiments has been analyzed by Pollock *et.al* [3], [8]. Knowledge of R_n at the 1% level is needed for interpreting atomic physics measurements of the Weinberg angle at the level of the Standard Model weak radiative corrections. The most accurate (1% in Q_{weak}) measurement of APV was carried out by Wieman and co-workers in atomic cesium ^{133}Cs [10]. Such low energy experiments provide powerful constraints on the standard model [11]. More independent tests of APV are needed at the accuracy of the Cesium experiment. An alternative approach which largely cancels the uncertainties due to difficult atomic structure calculations is to measure ratios of APV amplitudes between isotopes. This is being exploited for example in the Berkeley atomic Yb experiment [12]. However, Fortson *et.al.* [13] pointed out that this technique has an enhanced sensitivity to uncertainties in R_n. A recent analysis by Derevianko and Porsev [14] found that for $Z \leq 50$ the APV experiments with isotope chains may have sufficiently low uncertainties due to R_n, but for heavier elements improved accuracy of R_n at the 1% level is vital.

Another potentially relevant topic is the search for lepon number violation in the process $\mu + N \rightarrow e + N$. In certain models of flavor violation [15], [16] the predicted rate for these experiments is sensitive to the radius of the neutron distribution. New experiments are planned, including MECO at BNL(E940) and PRISM at JAERI/KEK [17] that will greatly extend the experimental sensitivity to this process.

Measurements of the equation of state of neutron rich matter are important for calculating the structure of neutron stars [18]. The radius of a neutron star is deduced from optical and X-ray observations, and the quality of these data are rapidly improving [19]. To rule in or out possible exotic phases of dense matter one needs to combine the high density measurements of neutron stars with low density precision measurements of R_n in nuclei. The proton fraction of neutron rich matter in beta equilibrium depends on the symmetry energy, which is calibrated by R_n. A large symmetry energy favors more protons, and if the proton fraction is high enough then the following "URCA" process can cool neutron stars $n \rightarrow p + e^- + \bar{\nu}_e \ ; \ p + e^- \rightarrow n + \nu_e$ where the $\nu_e, \bar{\nu}_e$ carry off energy. URCA cooling might explain recent Chandra observations of the neutron star 3C58, a remnant of the supernova seen in the year 1186 that appears to be unexpectedly cold [19]. A neutron skin larger than about 0.2 fm may imply that URCA cooling is possible, while a smaller skin implies it is probably not possible [20].

The physics interpretation of the experiment can be summarized as follows. From the measured asymmetry one may deduce the weak form factor, which is the Fourier transform of the weak charge density at the momentum transfer of the experiment. One must correct for Coulomb distortions, which has been done accurately by Horowitz [5] and others [6]. The weak charge density can be compared directly to theoretical calculations and this will constrain the density dependence of the symmetry energy. The weak density can be directly applied to atomic parity violation because the observables have approximately the same dependence on nuclear shape. From the weak charge density one can also deduce a neutron density at one Q^2 by making small corrections for known nucleon form factors. The uncertainty in these corrections for a realistic experiment have been estimated and are small [3]. The corrections considered were Coulomb distortions (which was by far the biggest), strangeness and the

TABLE 1. Acceptance Averaged Rate and Asymmetry

Measured Asymmetry (p_e A)	0.51 ppm
Beam Energy	850 MeV
Beam Current	50μA
Required Statistical Accuracy	3%
Energy Cut (due to detector)	4 MeV
Detected Rate (each spectrometer)	860 MHz
Running Time	680 hours

neutron electric form factor, parity admixtures, dispersion corrections, meson exchange currents, isospin admixtures, radiative corrections, and possible contamination from excited states and target impurities.

Finally from a low Q^2 measurement of the point neutron density one can deduce R_n. This requires knowledge of the surface thickness to about 25% to extract R_n to 1%. The spread in surface thickness among successful mean field models is much less than 25%, hence we can extract R_n with the desired accuracy. This was proved by Furnstahl [21]. In summary, the physics results of the experiment are the weak charge density, the point neutron density and R_n.

III EXPERIMENTAL OVERVIEW

Except for a new luminosity monitor (section VC) and the polarimetry (section VE), the experiment has not changed. We run at a beam energy of 850 MeV and a 6° scattering angle in Hall A using the two HRS spectrometer systems supplemented by septum magnets which focus elastically scattered electrons onto total-absorption detectors in their focal planes. A 50μA, 80% polarized beam with a 30 Hz helicity reversal will scatter from a foil of lead which is sandwiched between sheets of diamond to improve the thermal characteristics. Ratios of detected flux to beam current integrated in the helicity period are formed, and the parity–violating asymmetry in these ratios computed from the helicity–correlated difference divided by the sum: A = (σ_R - σ_L) / (σ_R + σ_L), where $\sigma_{R(L)}$ is the ratio for right(R) an left(L) handed electrons. Separate studies at lower rates are required to measure backgrounds, acceptance, and Q^2. Polarization measurements by Møller and Compton polarimetry are discussed in section VE.

Table 1 shows the rates, asymmetries, and running time for the ^{208}Pb parity experiment proposal.

IV COLLABORATION STATUS

The experiment remains a Hall A collaboration proposal, and the core experimental group is the HAPPEX collaboration which is performing two parity experiments in Hall A in the next two years. In addition, several collaborators have been working on the SLAC parity experiment E158. These experiments provide valuable experience and test many aspects of the Lead parity experiment as explained below. We will be trying to attract new collaborators to help with the polarimetry.

The collaboration list on the front cover is up-to-date, with some additions and subtractions from three years ago. We added the MIT group.

V TECHNICAL UPDATE

The primary technical issues of this experiment can be divided into the following categories: A) High Power Target Design; B) Helicity Correlated Systematic Errors; C) Luminosity Monitor; D) Q^2 Measurement; and E) Precision Polarimetry.

Beam tests at 80μA and calculations show that we have a good target design. This will be further tested in the next year in short beam tests with the septum magnet.

Regarding helicity correlated systematics and Q^2 measurement, our general strategy is to make the necessary improvements in preparation for the HAPPEX-2 run as explained in detail below. We plan on exceeding the requirements for HAPPEX-2 as a way of proving we can do Lead parity.

Experience from the SLAC experiment E158 is relevant to this proposal. Data already obtained by the E158 group have sufficient statistics to provide a measurement below the 20 ppb level. The systematic uncertainties due to helicity-correlated beam parameters are estimated to be significantly below this level based on a preliminary analysis.

Improvements in polarimetry accuracy are are described in section VE. These improvements are also important for the $Q_{\rm weak}$ proposal and for DIS parity at 12 GeV.

A Target Design

We have successfully tested our lead target at 80μA, thus proving that the design in our original proposal works. We have built a high power lead target which will be stable at 40 Watt for a 50 μA beam.

Improving the thermal properties of the target is necessary since lead has a low melting temperature. A 0.5 mm foil of lead is sandwiched between two 0.15 mm sheets of diamond, which is pure ^{12}C. This sandwich is clamped in a spring loaded copper block assembly which is cooled by liquid helium. The copper block has a hole to allow the beam to pass through; the beam only sees ^{208}Pb and ^{12}C. The diamond has an extremely high thermal conductivity, and calculations show this target should be stable up to 100 μA. This target was tested for 30 minutes at 80 μA, where we stopped due to some low trip points on radiation monitors. Measurements of the site boundary radiation show that a one month run with this target would use 25% of our yearly budget for allowable radiation, if no extra shielding is installed.

The target thickness required to maximize the rate in the momentum bite defined by the detector is 0.5 mm (10% RL). A thicker target suffers more radiative loss and hence less rate. By integrating the rate up to a cutoff of 4 MeV, we reduce the running time by 25% compared to a cutoff that would exclude the first excited state. The resulting contamination from inelastic scattering constitutes a fraction 0.5% of our signal. The systematic from inelastics and from ^{12}C background are tolerable [3]. The lead will be isotopically pure at 99.9%.

B Helicity Correlated Systematics

For the ^{208}Pb experiment the asymmetry of 0.5 ppm must be measured to 3% accuracy. Both absolute error (15 ppb) and the relative accuracy (3%) are challenging to achieve. The main issues affecting the absolute error are the control of false asymmetries associated with helicity correlations in beam parameters such as intensity, energy, and position. This will require good setup and feedback loops on the laser position at the source, as well as betatron matching in the accelerator. Progress on parity quality polarized source setup has been made at Jefferson Lab and at the SLAC experiment E158 [23], including new implementation of feedback on position and improved understanding of the laser optics. Betatron matching in the accelerator, which aims to prevent the phase space from developing a large tail in any of its components, will ensure maximal dampening of helicity correlated beam positions on target. This dampening occurs because of the relativistic boost, but if the accelerator is not well matched (e.g. if positions fluctuations turn into very strong angle fluctuations), one may observe helicity correlated positions differences of typically 1 μm on target at JLab. Experience with the accelerator setup procedure for parity quality beam for Hall A will be accumulated during the HAPPEX-2 run. We have synchronized DAQ systems at both the low energy and high energy ends, which permit precise and rapid information about the setup.

To measure the beam parameters accurately we are installing microwave cavity beam position and current monitors. The position monitors supplement the existing stripline monitors, which provides a complementary method with presumably different systematics and which provides an important redundancy necessary to unfold beam fluctuation noise from instrumentation noise. The beam fluctuations will be removed, leaving only instrumentation noise, a fundamental lower limit to the accuracy of measurements. Reaching this lower limit is necessary for ^{208}Pb because we want to maintain position differences to less than 1 nm with an accuracy of 0.1 nm averaged over a 1 month run. The charge asymmetry must be maintained to less than 100 ppb with an accuracy of 10 ppb.

The pulse-to-pulse noise in the lead experiment is 140 ppm. A similar noise level has been achieved during the SLAC experiment E158. It will be important to avoid long cable runs for our detectors, and therefore we are installing a distributed DAQ system during HAPPEX-2, in which the DAQ crates are situated near the detectors. For understanding the noise, beam systematics, and possible target boiling effects (the latter is relevant to the hydrogen target for HAPPEX-2), we are installing a luminosity monitor for the HAPPEX-2 run in 2003 (see section VC).

One part of the luminosity monitor stations is at a "larger" angle of $\geq 2^\circ$ and will see an extremely high rate. This is useful to measure the baseline electronics noise of the system, as it is difficult to measure sub-100 ppm electronics noise, and preferable to use a physical signal. A second part of the monitor is at a "smaller" angle of 0.5° and will see higher energy particles; it will be primarily sensitive to the beam parameters (position, angle). The small–angle monitor will be segmented to unfold the beam parameters. We describe these monitors more in section VC.

The data taken for HAPPEX-2 should prove that we have the necessary accuracy for Lead parity. In addition, we should have a few shifts to run at 1-pass energy with the lead target and septum magnet at 6° scattering angle which will check many technical aspects of the proposal, including rates, sensitivity to beam movements, distributions in the focal plane, radiation dose, and functionality of the high powered lead target. These issues were already successfully checked in beam development time with the lead target, but not yet with the septum magnet.

C Luminosity Monitor

One of the lessons learned from the SLAC experiment E158 was that a luminosity monitor is very important for high precision parity experiments. The MIT group headed by Stanley Kowalski is building a luminosity monitor for Hall A for the 2003 running period. In this section we describe the purposes of this monitor, its design, the schedule, and results from a prototype.

There are two purposes for the luminosity monitor: 1) To measure the noise of our electronics in the accelerator environment; 2) To measure the changes in beam parameters or target density. The sensitivity to beam parameters exceeds the sensitivity of the experiment, and the monitor is segmented to unfold the different parameters (position, angle, etc).

To meet these design criteria, we are installing two monitors, each made of quartz Cherenkov detectors. The quartz is radiation hard (≥ 1 GRad) "Spectrosil 2000" material, cut and polished into rectangular bars attached via a light guide to well-shielded PMTs. There will be two monitor stations, one at a "larger" angle (initially 6° during HAPPEX-2, probably 2° for the Lead experiment), and another at a very small angle (0.5°), see figure 1. The smaller angle detector requires modification to the beam exit pipe which is being done in the winter 2003 shutdown. The detectors will be extractable from the beam region, which will extend their lifetime and permit removal in case they cause background for other experiments. However, we don't expect any background in the shielded detector huts. The luminosity monitor is useful for other experiments to measure target boiling effects relevant to cross section measurements.

The large-angle monitor will see a very high rate from low-energy particles. For all upcoming parity experiments the rate seen by this monitor is at least an order of magnitude higher than that seen by the main detector in the spectrometer, and therefore will have a much smaller pulse-to-pulse noise due to counting statistics. This will provide a stringent test on the ability of our electronics to measure a sufficiently small pulse-to-pulse noise of order 50 ppm in an accelerator environment. The noise level (140 ppm) of the Lead experiment is determined by the high rate of elastically scattered electrons.

The second, small-angle detector, will see primarily higher energy particles and will be more directly sensitive to beam position and angle. The small-angle detector will be segmented into eight pieces placed symmetrically about the beam. The segmentation will permit us to unfold the different beam parameters (position, angle) in detail. Problems discovered here might require changes to the accelerator tune. This was the experience during E158 where such a luminosity monitor proved highly valuable.

The luminosity monitor will be installed in the shutdown periods leading up to HAPPEX-2, and will be used during the HAPPEX-2 run in 2003. A prototype monitor consisting of four bars of lucite attached to unshielded PMTs has been tested. Figure 2 shows noise level achieved by a prototype with a very thick target to provide high rates. The RMS of 120 ppm and the reasonably Gaussian shape shows good progress on this detector.

D Normalization Error due to Q^2

The two main issues affecting the relative error of 3% are the measurement of Q^2 and the beam polarization. The limitation in measuring Q^2 is the knowledge of the spectrometer angle, which requires accurate surveys. While we believe we can perform such surveys, we will also employ a recoil enegy technique which is a new idea since the original proposal, and which will be used during the HAPPEX-2 run in 2003. This method uses the difference in recoil energy for single arm elastic scattering for H and ^{12}C (using a CH2 target) and ^{208}Pb. The HAPPEX-2 experiment also uses the septum magnet at 6°.

E Precision Polarimetry

Improvements in polarimetry are of vital importance for the Jefferson Lab parity violation program. High accuracy (sub-1%) is important not only for this proposal but for the Q_{weak} proposal and for DIS parity at 12 GeV.

For this proposal, the polarization must be measured to 1% preferably, or at least 2%. With a polarization accuracy of 1% (2%) we can extract R_n to 1% (1.2%) respectively. Here we update our strategy to achieve this accuracy. In the original proposal, the strategy was to use the Hall A Compton polarimeter at 6 GeV (1.5% accuracy) to pin down the Møller polarimeter, whose accuracy is limited by knowledge of the foil polarization. Although the Compton polarimeter as it exists now does not work well below 1 GeV, it could provide adequate monitoring of the relative polarization during the running of the experiment. In addition, we can cross check to the Hall C Møller polarimeter which claims to have better than 1% systematic error [24].

Below we discuss two new alternatives being considered to improve the polarimetry. Both look feasible and can be done in 2 years at a cost of roughly 200 k$ each. We have not yet decided which of these approaches we will be able to take, or whether to upgrade the Hall A polarimeter along the lines of the Hall C design. Any approach we take will require significant facility development beam time that is not part of this proposal.

1 *Sub-1% Møller Polarimetry*

In this section we discuss prospects for upgrading the Møller polarimeter to reach sub-1% accuracy. A rough estimate of the manpower and cost is provided.

In contrast to the Compton polarimeter, the Møller polarimeter accuracy does not depend considerably on the beam energy, and the polarimeter can operate at 850 MeV, however the ferromagnetic target used gives serious limitations. The error on the target polarization is not better than 3%. Another systematic error comes from the limitation on the beam current for polarimetry. Because of the target heating by the beam and to a lesser extent because of the dead time, the beam current for polarimetry is limited to about 0.5-1.0μA, much lower than the current used in the experiment. At low currents, used for polarimetry, a contribution from the other hall beams, leaked through on the injector chopper, may be significant, on a level of a few percent. At least one of the other halls has the opposite polarization, since otherwise it is not possible to mix efficiently three beams of light. This may lead to a considerable polarization dilution. While it is possible to shut the other lasers off for short period of time, it is difficult to interfere with the other halls operations during a long data taking period. An iron target, saturated in a strong field of 4 T is used in Hall C Møller polarimeter [25]. While the target polarization is claimed to be known with an accuracy of 0.25%, the low current problem stays. Also, the "Levchuk effect" [26], caused by scattering on the target electrons from different atomic shells, may give a systematic error independently on the way the target is polarized.

We are considering the possibility to use the polarized atomic hydrogen gas, stored in an ultra-cold magnetic trap, as the Møller polarimeter target. Such a target of practically 100% polarized electrons could provide a superb systematic accuracy of better than 0.5% for beam polarization measurements, namely this target would remove the errors associated with the target polarization, Levchuk effect and the dead time. Other errors, coming from beam false asymmetries and backgrounds will be considerably reduced. The dominant error will be the average analyzing power, which is typically not worse than ~0.3%.

The technique of ultra-cold magnetic traps is well developed [[27], [29], [30], [28], [31], [33], [32], [34]]. The magnetic trap consists of a 5-8 T solenoid magnet and a coaxial copper cylinder cooled down to ~0.3 K by a dilution refridgerator. The cylinder is covered by a thin layer of superfluid ^{4}He, trapping the cold hydrogen atoms and preventing their recombinations in the direction perpendicular to the solenoid axis. Along the solenoid axis, the atoms of a certain electron polarization are attracted into the field, while the atoms of the opposite polarization are repelled. A density of about $3 \cdot 10^{15}$ atoms/cm^3 in the trap can be reached. A target of the effective target length of 10 cm would provide the target thickness of $3 \cdot 10^{16}$ atoms/cm^2. One can use such a target with high beam currents. The polarimeter acceptance will be practically the same as with the present Møller polarimeter. Scaling the statistical accuracy of the present polarimeter to the 100% target polarization and 30 μA beam current we estimate that a 1% statistical accuracy would be obtained in about 30 min of data taking. An important cross check of this new Møller polarimeter can be done against the existing Hall A Compton polarimeter at high energies which has 1.5% total relative accuracy.

The first round of feasibility studies have not revealed any serious problem with application of such a target in Hall A environment. More studies are under way. The spin group from University of Michigan under leadership of Professor A. Krisch is considering joining the project in order to provide the target. The first estimate of time needed and the cost is about 2 years and $200-300 k.

2 Compton Polarimetry at 850 MeV

In this section we discuss prospects for upgrading the Compton polarimeter to reach 1% accuracy. A rough estimate of the manpower and cost is provided. We reiterate that we have not decided yet whether to use this approach or the upgrade of Møller.

The best accuracy obtained so far with the Compton polarimeter is 1.5% total relative error within 40 minutes for a beam energy of 4.5 GeV. The electron detector is a key element of the analysis. It is used as a photon energy tagger to determine online the response function of the photon detector. Polarization measurements have also been performed with electron only data but the calibration leads to larger systematics, typically 2% at 4.5 GeV.

At 850 MeV and with the current IR laser (λ = 1064 nm), the scattered Compton electrons remain too close to the primary beam ($< 3mm$) to be detected. With no response function of the photon detector, the only way to keep the systematics below the 2% level is to perform an integrated polarization measurement where the beam polarization is deduced from asymmetry of counting rates integrated over the whole Compton energy range. If the detection threshold is negligible compared with the Compton edge the uncertainties from the resolution and the calibration don't contribute, only the detection efficiency has to be known. One drawback is that the mean compton asymmetry is very small (0.32%) and leads to long running time of order 3 days to reach the $\delta P_e/P_e = 1\%$ statistical accuracy. Nevertheless since Compton and parity data are averaged over the same data sets, this polarization measurement is still meaningful.

Requirements for the photon detector are a good detection efficiency in the range few 100 keV - 15 MeV, a large light yield to reach low detection thresholds and up to 100 kHz counting rate. The existing detector, made of PbWO4 crystals has a too low light yield. BGO or BaF_2 crystals are good candidates. In order to minimize systematic effects at threshold two separated electronic chains can be dedicated to different energy ranges (for instance 0.1-1 MeV and 1-15 MeV). The detector itself can be segmented in depth as well. Control of the detection efficiency and background subtraction are expected to be the dominant errors. First tests could be performed at 1.5 GeV with a simplified prototype during the GDH low Q^2 experiment in spring 2003.

The most efficient way to improve the compton figure of merit is to shorten the laser wave length. Going to a green laser brings the mean asymmetry to 0.65%. At the Compton edge the photon energy is 26 MeV and the associated scattered electron is 6 mm above the primary beam at the location of the electron detector. Assuming the same laser power of 1.5 kW at the Compton interaction point, a 1% statistical accuracy is achieved within 16 hours.

The replacement of all the optical elements is a major hardware change. Nevertheless important parts can be recycled like the remote controlled mirror and lenses supports and the cavity. Most of the electronics for the frequency feed-back should remain the same as well. The estimated cost is 175 k$ and required man power 2 man-years for the green laser upgrade. However, it may be sufficient and feasible to only upgrade the detector which would be considerably cheaper and easier. This is still to be studied.

Improvements on the electron detector are also possible to detect scattered electrons between 6 and 4.5 mm away from the primary beam. This would cover 25% of the Compton spectrum, allow the determination of a response function and keep a reasonable safety gap. Micro-strips of $100\mu m$ wide, available in the industry, would give a good enough calibration. At the moment further tests are needed to understand the background at such small distance from the primary beam.

VI BEAM TIME REQUEST

The original beam time request has not changed. We request 30 days of polarized beam running in Hall A at 850 MeV using the two septum magnets.

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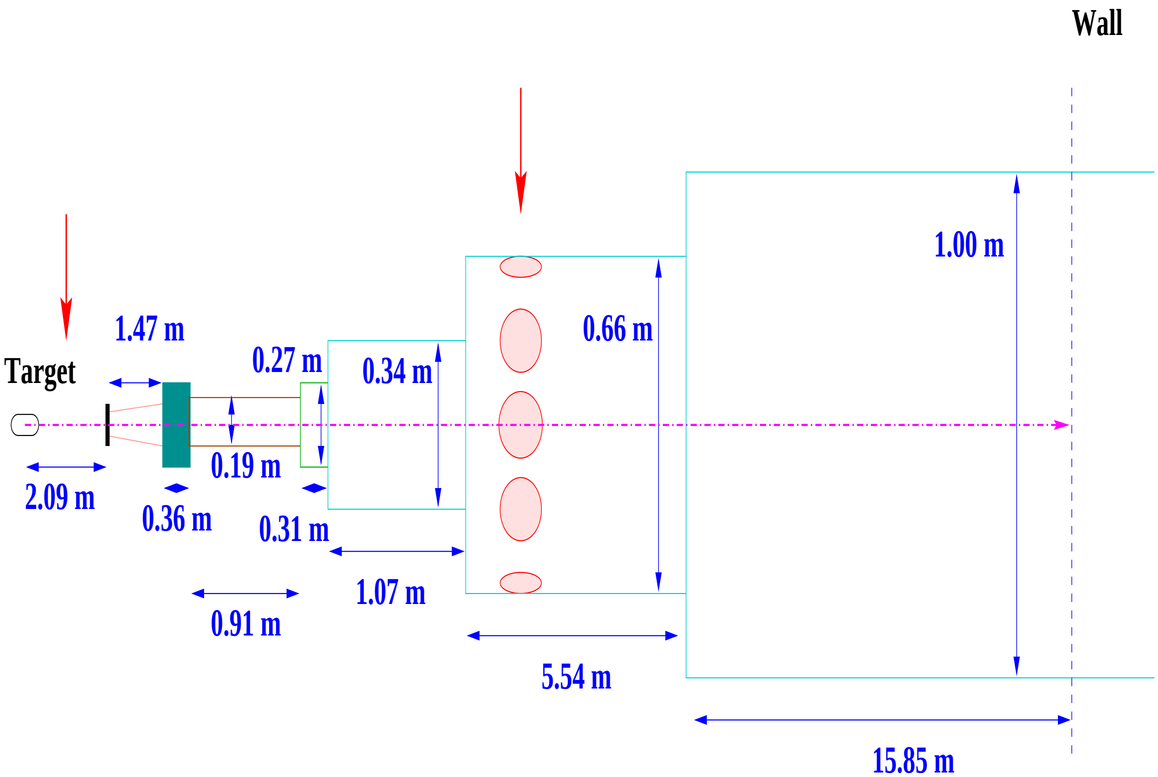

FIGURE 1. Location of the new luminosity monitors in the exit beam pipe after the target. There are two monitor stations at the locations shown by the arrows. The one near the target measures a high rate to constrain our electronics noise. The one further away is segmented and inserted into the holes shown (vacuum sealed penetrations) to 0.5° to measure systematics in beam parameters (position, angle, etc).

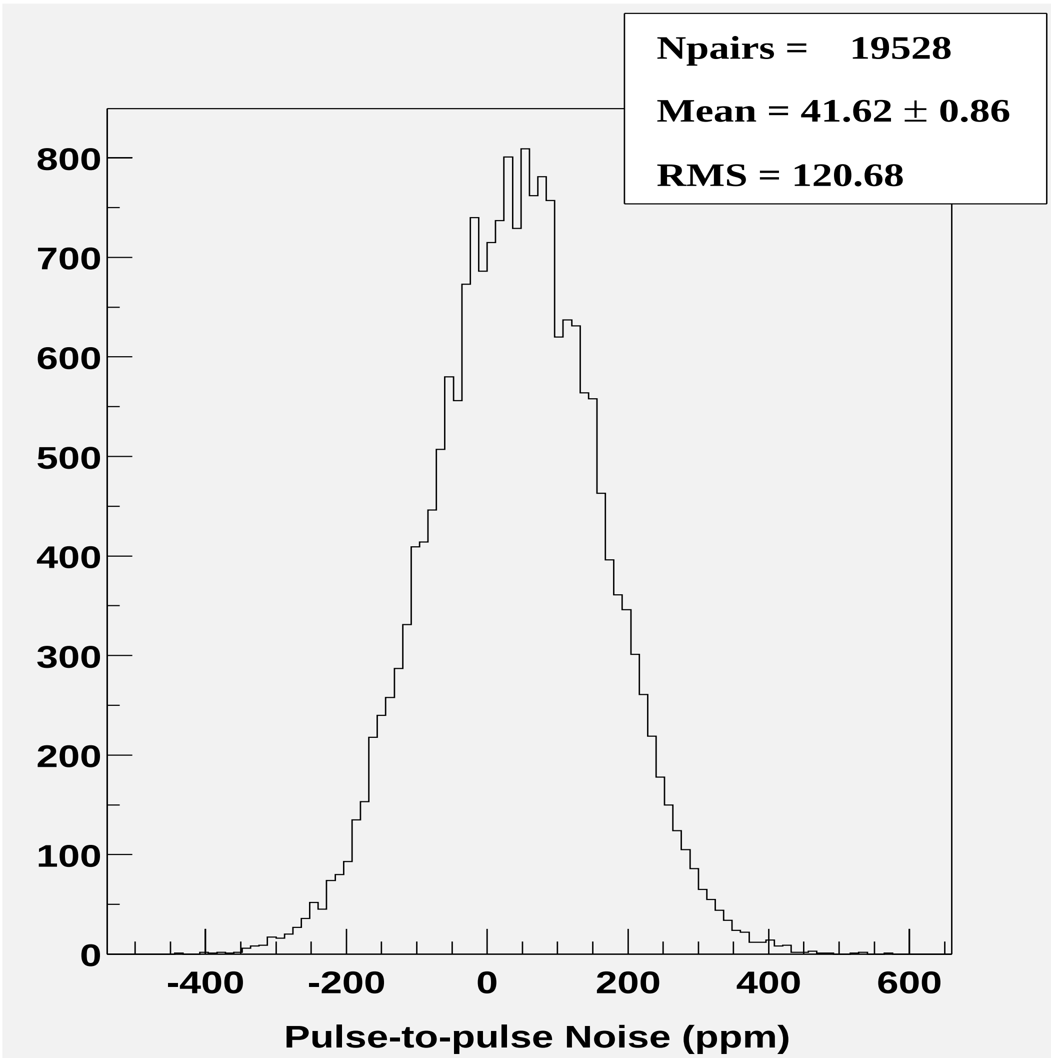

FIGURE 2. Results from the prototype luminosity monitor showing the noise level already achieved (RMS of 120 ppm in the luminosity). The monitor to be installed in winter 2003 is designed to be sensitive to even smaller noise.