A proposed set of instrumentation, collectively referred to as the Super Bigbite project, is presented. Used in three different configurations it will allow measurements of three nucleon electromagnetic form factors $G_E^n$, $G_E^p$, and $G_M^n$ with unprecedented precision to $Q^2$-values up to three times higher than existing data.

1. Scientific Motivation

The study of nucleon form factors has seen an enormous revival through the discovery by Jones et al.\(^1\), that $G_E^p/G_M^p$ drops almost linearly with $Q^2$ above a four-momentum transfer of something like 1 GeV\(^2\). Those results have stimulated huge amounts of theoretical activity, as evidenced by the nearly 500 citations of their original paper. One approach to explaining the data involves refined perturbative QCD calculations that include an $L = 1$ component in the quark light-cone wave function\(^2\). Also notable are relativistic constituent-quark calculations\(^3\), some of which even preceded the discovery by Jones et al. Perhaps the most realistic model is a calculation out of Argonne by Cloët, Roberts and coworkers that uses an approach based on the Dyson Schwinger Equations (DSEs) together with the Poincaré-covariant Faddeev equations\(^4\). Here, the constituent quarks have their masses dynamically generated using the DSE approach. While still a model, the DSE/Faddeev calculation from Argonne offers a solution that consistently incorporates both QCD-based dynamics along with dressed diquark degrees of freedom. Also, it is well constrained by the nucleon’s static properties such as mass and magnetic moment. It is limited, however, in that there are precisely three (and for instance, not five) constituent quarks used as input to the calculation. Even so, it is reasonable to assume dominance of the 3-quark component of the wave function at relatively high values of $Q^2$. Finally, truly \textit{ab initio} calculations of form factors using lattice QCD have been performed, some of which are extrapolated to a realistic pion-mass value using chiral perturbation theory\(^5\). While currently limited in
their $Q^2$-reach, it is likely that such calculations will reach higher $Q^2$-values with timescales consistent with the measurements proposed here.

Figure 1 shows existing data for $G^p_E/G^p_M$ and $G^n_E/G^n_M$, the projected errors for several approved experiments, and the results of several theoretical calculations. The approved experiments associated with the Super Bigbite experiment are E12-07-109, also known as GEp(5), and E12-09-016, which will measure $G^p_E/G^p_M$ and $G^p_E/G_M^p$ respectively. Figure 1 makes it clear that the only way to achieve clarity in discriminating between theoretical explanations of the form-factor data is to measure the form factors with considerable precision to high values of $Q^2$ in both the proton and the neutron. For example, three of the predictions shown, the relativistic constituent-quark model (RCQM)$^3$, the DSE/Faddeev calculation$^4$, and the refined pQCD calculation$^2$ ($F_2/F_1 \propto \ln^2(Q^2/\Lambda^2)/Q^2$), all show $G^p_E/G^p_M$ crossing zero somewhere in the neighborhood of 7 GeV$^2$. At the same time, the two VMD models$^6,7$ show $G^p_E/G^p_M$ approaching zero much more gradually. In contrast, in the case of the neutron, even by 10 GeV$^2$, the RCQM, pQCD and DSE/Faddeev calculations all differ wildly from one another. In the years following the discovery by Jones et al., it is not surprising that models have evolved that explain well the existing proton data. It is also not surprising that these models diverge strongly
where there are little or no data to constrain the calculations, such as at higher $Q^2$ for the proton or even moderate $Q^2$ for the neutron. In general, higher values of $Q^2$ also offer the advantage that there are simplifications that are not present at lower values. For instance, the role of vector mesons is suppressed at higher $Q^2$, as are higher Fock states in some of the phenomenological models. At high $Q^2$ there is increased clarity, and increased discovery potential, because there are generally fewer places to hide deficiencies in a model.

Even setting aside specific predictions, there is a crucial experimental question that is of tremendous importance. The linearity of the data for $G_{pE}^p/G_{pM}^p$ up to something like 6 GeV$^2$ is very striking. But to what value of $Q^2$ will this linearity continue? Looking again at Fig. 1, the preliminary results from GEp(3)\textsuperscript{9}, up to values of around 8.6 GeV$^2$, indicate that the rate of decline of $G_{pE}^p/G_{pM}^p$ appears to be slowing. It is hard to be certain, however, because the errors are relatively large, larger than those projected in the original GEp(3) proposal. By going to 14.5 GeV$^2$, the trend of $G_{pE}^p/G_{pM}^p$ should become clear, but only if the data have sufficient precision. To better illustrate this point, we have shown, with the dash-dotted lines, the relative size of the errors one could expect for $G_{pE}^p/G_{pM}^p$ using the original projected error for GEp(3) at $Q^2 = 8.6$ GeV$^2$, and taking the Figure-of-Merit to scale as the product of the cross section $\sigma$ and the square of the analyzing power $A_y$, $\sigma \cdot A_y^2$. We have assumed 30 days of data taking, as was assumed for the 8.6 GeV$^2$ point. With this scaling, it is clear that the projected errors for GEp(4) represent a considerable challenge in terms of beam time. In contrast, the projected errors for GEp(5), which is based on Super Bigbite, are quite small, even out to 14.5 GeV$^2$. This is because the innovative design of the Super Bigbite approach provides fully a factor of 10 improvement in the relevant Figure-of-Merit. Even with the striking behavior of $G_{pE}^p/G_{pM}^p$ at the values of $Q^2$ studied thus far, it is still the expectation (from pQCD) that this ratio should eventually level off and become constant. The observation of a transition to this behavior would provide valuable insight, and it is important to have an experiment capable of achieving the required precision.

With respect to the neutron, there are strong motivations to measure $G_{nE}^n/G_{nM}^n$ out to $Q^2 = 10$ GeV$^2$ and even higher. First of all, at 10 GeV$^2$, data on the neutron will already be solidly in the regime where intriguing behavior has been observed with the proton. And as pointed out earlier, in contrast to the case with the proton, the various predictions for the neutron all disagree strongly with one another for $Q^2 = 10$ GeV$^2$. Also, at $Q^2 = 10$ GeV$^2$, as is shown in Fig. 1, the Argonne DSE/Faddeev calculation shows a zero crossing for $G_{nE}^n/G_{nM}^n$, a feature due to the use of diquark degrees of freedom. As mentioned above, the Argonne calculation, while definitely still a model, contains features such as the dynamical generation of mass that suggest progress toward an actual analytical solution. It is intriguing that this sophisticated calculation appears to be so successful, and it is desirable to test its predictions as thoroughly as possible. With this in mind, we note that at 7 GeV$^2$, the predictions of the VMD models and the Argonne DSE/Faddeev calculation are

\[ \text{The SuperBigBite Project} \]
fairly close to one another. Thus, measuring well above 7 GeV\(^2\) should be a priority. Indeed, looking again at Fig. 1, our proposed measurement of \(G^n_E/G^n_M\) (E12-09-016) provides good precision all the way to 10 GeV\(^2\). In sharp contrast, the projected errors for the only competing experiment (E12-09-006) provide little discrimination between different theories even at 7 GeV\(^2\), the highest \(Q^2\) point for which it would provide data. The significant difference between E12-09-016 and E12-09-006 results from an intrinsic Figure-of-Merit associated with the Super Bigbite approach that is roughly a factor of 50 larger than is the case with E12-09-006.

There are, of course, many motivations for measuring the ground-state form factors that are not illustrated in the above figure. For instance, for both the proton and the neutron, the ground-state elastic form factors provide stringent model-independent constraints on Generalized Parton Distributions (GPDs). Thus, if we want to know the GPDs over a wide kinematic range, we need to study the elastic form factors over a similar range. The elastic form factors also provide a powerful check of lattice QCD. \textit{Ab initio} lattice calculations of ground-state form factors are making impressive progress, and the comparison of these results with experimental measurements is extremely important. Here, it is critical to have experimental results on both the proton and the neutron, and to cover the full \(Q^2\)-range being explored on the lattice. By the time the CEBAF upgrade is complete and the measurements described here have been made, it is quite likely that lattice results will extend up to roughly 10 GeV\(^2\), again making coverage of this range for both the proton and neutron extremely important.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.pdf}
\caption{Shown is a schematic but scaled representation of the setup that will be used for both the GEn(2) (E12-09-016) and the Hall A GMn experiments (E12-09-019). While the target will be polarized \(^3\)He for GEn(2) and deuterium for the GMn experiment, most other components are identical.}
\end{figure}

The Hall A GMn experiment will determine \(G^n_M\) by a detailed comparison of the unpolarized elastic cross sections of the two processes \(d(e,e'p)n\) and \(d(e,e'n)p\). It will use essentially the same apparatus as GEn(2), with the exception that the target will be the Hall A liquid deuterium cryotarget. A schematic representation of the experimental setup is shown in Fig. 2. We note that the GMn proposal actually included measurements up to 18.0 GeV\(^2\), something that, combined with
the fully approved Hall A $G_{M}^{n}$ measurement (not part of the Super Bigbite project), would enable the reconstruction of the individual $u$ and $d$ quark distributions with a spatial resolution of 0.05 fm. The EMFF collaboration plans to return to the PAC to request an additional two weeks to push to this higher $Q^{2}$, as the difference between the $u$ and $d$ quark distributions is an exciting question with implications for our understanding of nucleon structure in terms of QCD degrees of freedom.

Like the other Super Bigbite project form-factor measurements, the $G_{M}^{n}$ measurement in Hall A will provide excellent accuracy and reach in $Q^{2}$, well beyond all competing efforts. Considering only the portion of the experiment that is fully approved, the GMn experiment will require only 14 days of running. The CLAS12 $G_{M}^{n}$ experiment, which like the Hall A experiment is approved to make measurements up to 13.5 GeV$^{2}$, will require 56 days of running, and will obtain 5 times less statistics at the highest $Q^{2}$-point. When considering a full set of kinematics, the Hall A $G_{M}^{n}$ experiment has a Figure-of-Merit that is 30 times higher than that of the CLAS12 $G_{M}^{n}$ experiment. The existing data for $G_{M}^{n}$, together with the projected errors for both the Hall A and the CLAS12 experiments, are shown in Fig. 3. While the magnetic FF of the neutron has previously been measured up to 10 GeV$^{2}$, the few data that exist above 4.5 GeV$^{2}$ have uncertainties of about 10-20%. The GMn experiment in Hall A will provide sufficient accuracy to bring new understanding to this subject, including the aforementioned decomposition of the $u$ and $d$-quark distributions.

![Fig. 3. Published $G_{M}^{n}$ data together with the proposed data points of the CLAS12 $G_{M}^{n}$ experiment (E12-07-104), and the proposed data of the Hall A $G_{M}^{n}$ experiment (E12-09-019) that will be performed using the Super Bigbite apparatus.](image)

The ratio method has been used in a number of experiments, including one at JLab in which $G_{M}^{n}$ was determined with good precision up to $Q^{2} = 4.5$ GeV$^{2}$. When the recoil nucleon energy is above 2-3 GeV, the detection efficiency for the neutron and the proton are quite similar, so the ratio method becomes almost systematic free. Like GE$
u$(2), the Hall A GMn experiment will utilize the BigBite spectrometer with the caveat that the trackers will be based on GEMs instead of MWDCs. Again like GE$
u$(2), the Super Bigbite magnet itself will be placed in
the hadron arm, providing excellent separation between recoil protons and recoil neutrons. The magnet will also be turned on and off to study potential systematics.

Historically, and even quite recently, the ground-state form factors have provided considerable insight into the charge and magnetization densities of both individual nucleons as well as more complex nuclei. It is quite reasonable to argue that form factors provide us with the best “snapshots” we have of both the proton and the neutron. At small values of $Q^2$, the Fourier transforms of the electric and magnetic form factors can be interpreted as the charge and magnetization densities, respectively. Such interpretations by Hofstadter provided early understanding of the size of the proton, and the more recent application of such reasoning has led to the conclusion that the charge and magnetization densities of the proton are not coincident with one another. The neutron charge density is positive toward its center and is surrounded by negative charge, features that support the notion of a proton-like core embedded in a negative pion cloud. We should note, however, that relativistic effects limit the degree to which the interpretation of form factors as Fourier transforms of densities is correct. Attempts to better account for relativity in the lab frame have been conducted by Kelly. Another approach, pursued by Miller, is to define densities that can be computed on the light front. The aforementioned relativistic constituent-quark models and calculations based on the DSE/Faddeev approach both incorporate the basic idea of pion clouds. A nucleon with a pion cloud necessarily represents a five-quark state, something that is suppressed at high momentum transfer when $Q^2 \gg \Lambda^2_{QCD}$. There is considerable discovery potential in pushing to higher values of $Q^2$ where the short-distance-scale behavior of the nucleon can be revealed, and the structure itself becomes simpler and easier to understand.

All the arguments above underscore the importance of reaching high $Q^2$ while simultaneously maintaining high precision. The required beam time, however, scales roughly as $Q^{16}/E_{beam}^2$. It is thus critical to compensate for this large factor in the chosen experimental design. For the measurements proposed within the Super Bigbite project, the relevant Figure-of-Merit exceeds those of all competing experiments by factors ranging between 10 and 50, making the difference between meaningful and ambiguous measurements. These impressive capabilities are derived from using a large open-geometry dipole magnet for momentum analysis together with a detector package that has a direct view of the target. The very high rates associated with such a configuration are only tolerable because of the use of a GEM-based tracking system. A cutout in the Super Bigbite magnet also allows for the use of quite forward angles where the recoil nucleon needs to be detected with large solid angle. The feasibility of such an open geometry design has been unambiguously demonstrated in multiple experiments using Super Bigbite’s predecessor, BigBite. The Super Bigbite apparatus, however, based on the use of a larger magnet combined with GEM-based trackers, leads to a Figure-of-Merit that exceeds that of other competing efforts by a factor of 10 for $G_E^n/G_M^n$, around 30 for $G_M^n$, and 50 for $G_E^n/G_M^n$. Super Bigbite will advance the study of electromagnetic form factors
in a dramatic fashion for both the proton and the neutron. Without Super Bigbite, however, as shown earlier, measurements will be largely incapable of discriminating between the important theoretical predictions.

The Super-Bigbite apparatus will make possible three ground-breaking measurements of the nucleon’s elastic form factors:

- A measurement of $G^E_n$ (E12-09-016) up to 10 GeV$^2$ using the beam-target double-polarization technique that was approved in January of 2009\textsuperscript{14}.
- A measurement of $G^E_p$ (E12-07-109) up to 14.5 GeV$^2$ using the recoil-polarization technique that was approved by the JLab Program Advisory Committee (PAC) in August of 2007\textsuperscript{11}.
- A measurement of $G^M_n$ (E12-09-019) up to 13.5 GeV$^2$ by determining the cross section ratio for the two reactions D(e,e'n) and D(e,e'p) that was approved by the JLab PAC in January of 2009\textsuperscript{18} (a request for an extension to 18 GeV$^2$ is planned).

We note that the above experiments will make use of the results of JLab E12-07-108\textsuperscript{19} (not part of the Super Bigbite Project) that will measure $G^M_p$ up to 17.5 GeV$^2$. E12-07-108 was approved by the JLab PAC in 2007 and will use the exquisite calibration of the Hall A HRS spectrometers to achieve a 1-2% absolute measurement of the electron-proton elastic scattering cross section. This calibration will allow us to measure ratios of form factors rather than the absolute form factors themselves while still achieving our goals for absolute measurements. We thus have a plan to measure all of the ground-state electromagnetic form factors with sufficient accuracy and reach in $Q^2$ to study some of the most exciting questions in hadronic physics.

2. Instrumentation

The proposed instrumentation, that we refer to collectively as the Super Bigbite Project, includes a set of components that will be used in three different configurations for each of our measurements of $G^E_n$, $G^E_p$, and $G^M_n$, respectively. In all cases, the design philosophy incorporates the use of large open-geometry detection, high-rate-handling capability through the use of GEM technology, and the ability to measure at relatively forward angles. We describe our proposed instrumentation below, including the various configurations in which they will be used for our three proposed measurements.

The proposed Super Bigbite apparatus is shown in Fig. 4 in the configuration for the GEp(5) experiment\textsuperscript{11}. The key features of the apparatus are:

- The dipole magnet, which is an existing 48D48 used previously at BNL.
- Large solid angle, 10-15 times larger than in focusing spectrometers, such as HRS/HMS/SHMS.
Large momentum acceptance, from 2 GeV/c at nominal field settings.

- High luminosity capability, up to $8 \times 10^{38}$ electron/s x nucleon/cm$^2$, e.g., in GEp(5).
- Small scattering angle capability, down to 3.5°.
- Full acceptance for the long target (up to $y \approx \pm 20$ cm).
- Very good angular resolution, $\sigma_\theta$ [mrad] = 0.14 + $1.3/p$ [GeV/c].
- Good vertex resolution, $\sigma_y \approx 1-2$ mm.
- Good momentum resolution, $\sigma_p/p = 0.0029 \pm 0.0003 \times p$ [GeV/c].
- High energy trigger threshold via use of a hadron calorimeter.

**Proton form factors ratio, GEp(5) (E12-07-109)**

![Schematic diagram of the setup for GEp(5)](image)

The Super-Bigbite apparatus will be used in GEp(5) as a large-acceptance spectrometer, the Super Bigbite spectrometer (SBS). It will provide angular coverage up to $\sim 70$ msr, with a detector package, capable of operating at the largest possible luminosity, almost $10^{39}$ electron/s x nucleon/cm$^2$. The use of a simple dipole placed close to the target, made possible by a deep cut through the iron yoke of the magnet for the beam line, allows one to achieve the large angular acceptance in the spectrometer. The magnet deflects charged particles vertically and will be used with a field integral up to 2.5 T·m. The field in the beam line will be reduced to an acceptable level by specially developed magnetic shields. The relatively small bend angle is compensated for by the high coordinate resolution (70 µm) of the front GEM-based chambers resulting in a momentum resolution of 0.5% at 8 GeV/c in GEp(5) with the 40-cm long LH$_2$ target. The GEM technology solves the main challenge of this spectrometer, the very high counting rates, allowing tracking at background rates much higher than those expected for the experiments presented here. **These features combined will give SBS at least a factor of 10 advantage compared with any existing or proposed spectrometer at Jefferson lab for nucleon form-factor measurements.**
The electron beam parameters required for the EMFF measurements, such as energy, polarization, intensity and size, are all within the 12-GeV specifications. The GEn(2) experiment\textsuperscript{14} will use a polarized $^3$He target as a key component. A novel concept of a convective-flow cell will allow to increase the beam current up to 60 $\mu$A with a 60-cm-long cell. The GEp(5) experiment will use a 40-cm long liquid hydrogen target. A wide vacuum snout from the scattering chamber to the magnetic shield will allow one to avoid a direct view of the detector from the beam-line vacuum pipe elements, that will reduce the counting rate in the detector by a factor of 2.5. The GMn experiment\textsuperscript{18} will use standard 10-cm cryogenic targets of hydrogen and deuterium.

2.1. Trackers of the Super Bigbite apparatus

There will be three trackers in SBS for the GEp(5) experiment. The first one, FT, will be used to measure the proton momentum and its direction before interaction with the first CH$_2$ analyzer. This tracker with an active area of $40 \times 150$ cm$^2$ will include six chambers, each with two-dimensional read-out and three GEM amplification foil planes. The front tracker will be followed by a double polarimeter consisting of two trackers each preceded by a CH$_2$ analyzer. Adding this second polarimeter increases the Figure-of-Merit by a factor of 1.7, equivalent to a 30% reduction of the experimental statistical errors. The second tracker, ST, will measure the proton track after the proton passes through the first CH$_2$ analyzer. The third tracker, TT, will measure the direction of the track after the proton passes through the second CH$_2$ analyzer. The dimensions of the ST and the TT were chosen to be $50 \times 200$ cm$^2$ to keep the Figure-of-Merit above 90% of the ideal value, which corresponds to trackers of unlimited size. The ST and TT are required to have only four chambers each (compared with six in the FT) due to the reduced demand on coordinate resolution and the lower counting rates. Each GEM chamber will consist of $50 \times 40$ cm$^2$ sub-sections.

At the FT we expect high background hit rates of about 400 kHz/cm$^2$ (based on GEANT simulations) due to the direct view of the target. The background is dominated by soft photons originating from the target. Low-momentum charged particles are swept away by the magnet. The rates on the second and third trackers are expected to be 130 kHz/cm$^2$ and 64 kHz/cm$^2$, respectively, dominated by soft electrons/positrons converted from photons in the analyzers.

2.2. Hadron Calorimeter

The EMFF experiments deal with very small cross sections, so for meaningful results the luminosity should be as high as possible. Arrangement of the trigger and the detector structure for the high luminosity should take maximum advantage of the high energy of the recoil nucleon. The energy of the nucleon in the EMFF experiments ranges from 2 to almost 10 GeV, depending on the measurement. In GEp(5), the large proton energy will allow the use of a 3-4 GeV energy threshold in
the calorimeter without a significant loss of detection efficiency. Such a high energy threshold leads to the suppression of pion triggering and opens the possibility of using a coincidence for the DAQ trigger.

The total active area of the hadron calorimeter (HC) will be 5.5 m$^2$. It has a good time resolution of 1.5 ns, high granularity (15×15 cm$^2$), a very good coordinate resolution of 2 cm, and, in addition, a high energy threshold. All these features make the HC an attractive neutron detector for the two neutron EMFF experiments.

Positioned at the end of the SBS detector package the HC will be used in the GEp(5) experiment to trigger the DAQ, in coincidence with the signals from the existing electromagnetic calorimeter, BigCal. In addition, these two calorimeters will provide coordinate information that will be used to locate the proton track in the FT and in the TT by applying kinematic constraints. The active size of the HC in the GEp(5) experiment will be 150×300 cm$^2$, which is a little smaller than its full size and the total number of active modules will be 200.

2.3. Electron Arm

In all three EMFF experiments both the (quasi) elastically scattered electron and the recoil nucleon will be detected. This allows for the selection of the exclusive process, which has a very small cross section at high momentum transfer.

The existing Hall A BigBite spectrometer will be used for the detection of electrons in the GEn(2) and GMn experiments. The proposed FT and two chambers of the ST of SBS will be used as the tracker in the BigBite spectrometer. This switch does not require any reconfiguration of the GEM chambers. The Cherenkov counter and the large double-layer shower detector of the existing BigBite trigger system will be used in both neutron form-factor experiments.

The existing BigCal calorimeter will be used in the GEp(5) experiment for detection of the scattered electron. The calorimeter has 1744 lead-glass blocks coupled to PMTs of type FEU-84. Two sets of blocks are used, one 38×38×450 mm$^3$ and the second slightly larger, 40×40×400 mm$^3$. Blocks will be arranged in a matrix 20×75, a shape optimized for the largest acceptance at $Q^2 = 14.5$ GeV$^2$. The energy and coordinate resolutions of BigCal of about 5-7% and 7 mm, respectively, for 2.5 GeV electrons satisfy the trigger and tracking requirements. The calorimeter will be installed 3 m from the target at a central angle of 39° (at the largest $Q^2$). It will be shielded from the target by a 20 cm Al plate to reduce the radiation dose on the lead-glass. The angular correlation between the scattered electron and the recoil proton will be measured very accurately, especially the angle between the electron scattering plane and the proton recoil plane. Because of the small size of the electron beam, the angles of the electron and of the recoil proton can be determined with a very good accuracy of ~ 0.5 mrad. In order to achieve this, a 1 mm coordinate accuracy is required for the scattered electron. It will be provided by the Coordinate Detector, CD, consisting of two GEM-based chambers. The subsections of each chamber will be similar to those of the polarimeter chambers. The
overall dimensions are 80×300 cm² with 6 sections in 2 vertical columns.

2.4. Experimental Trigger

The DAQ trigger will have two levels: The first-level trigger will have a relatively short delay, ~100 ns, relative to the particle detection. It will be generated by the electron arm. This signal is required for operation of the GEM read-outs; despite their pipelined architecture, the APV25 front-end chips used in the GEMs require a fast trigger for marking “interesting” samples. Such a fast first-level trigger also eliminates the need for long delay lines for the conventional FASTBUS and VME electronics. The second-level trigger will be formed using a relatively complex coincidence logic, described below. It can have a latency of several microseconds.

The trigger is a critical part of the GEp(5) experimental design. It will have two main features: (1) a high energy threshold in the calorimeters in both arms (3-4 GeV for the proton and 2.5 GeV for the electron); and (2) “smart” FPGA-based coincidence electronics that allow second-level triggering on spatial correlations of hits in the two detector arms. The high energy thresholds will reduce the rate in the electron arm to 60 kHz and in the proton arm to about 1.5 MHz. With a coincidence time window of 50 ns, forming a simple coincidence between the two arms would result in a trigger rate of at least 5 kHz, which is too high (or at least close to the limit) for the expected total event size of ~20 kB. However, the small deflection of the proton trajectory in Super Bigbite makes it possible to use the angular correlation between the elastic electron and the proton trajectories, at the trigger level, to reduce the coincidence trigger rate further by a factor of five. In designing our second-level triggering system, it is important to note that real (not noise) calorimeter hits always cause several adjacent blocks to fire. We therefore construct what we call “macroblocks”, consisting of the sums of the individual signals from several nearby blocks. In HCAL, the size of the macroblocks is 4×4 (we call this a “sum-16”), and in the ECAL the size is 8×4 (“sum-32”). The different macroblocks overlap each other, such that each individual block contributes to the sums associated with several different (overlapping) macroblocks. In this way, at least one macroblock will always contain a large fraction of the deposited energy associated with a real hit.

In the GMn and the GEn(2) experiments the gas Cherenkov counter and the two-layer shower calorimeter of the BigBite spectrometer provide an efficient on-line selection of the electrons so that the DAQ trigger rate will be at the level of 2–3 kHz already without requiring an on-line coincidence with the hadron arm.

Summary

A funding proposal for the SuperBigBite project has been submitted to DOE, and further details about the project can be found in that proposal\textsuperscript{20}. If the Super Bigbite project is completed in the proposed schedule, one of the top priorities of the JLab upgrade, the study of the ground-state electromagnetic form factors, could
be achieved in the early years following commissioning. Studies have indicated that the Super Bigbite instrumentation provides a great potential for other experiments, such as studies of the neutron spin asymmetry $A_n^1$ through inclusive scattering and of the neutron Collins and Sivers functions through semi-inclusive pion and kaon production off a transversely polarized $^3$He target.

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