1 Overview of experiments

1.1 Overview of neutron form factor experiments

Both neutron form factor experiments measure quasi-free scattering on a nuclear target. The standard Hall A BigBite Spectrometer is used to detect the scattered electrons. Neutrons and protons are detected in the hadron calorimeter (HCAL) which is located behind the Super BigBite Spectrometer Magnet. The Coordinate Detector (CDET) will be placed in front of the hadron calorimeter. In the GEn experiment, the CDET will be used as a charge particle veto. In the GMn experiment, the CDET will be used as a proton tagger. The trigger for the experiments will be the BigBite spectrometer signel arm electron trigger which is discussed in Section **??**.

Due to the increase in luminosity, in comparison to earlier experiments, the tracking detectors (MWPC) need to be upgraded to GEM chambers and the gas Cherenkov detector upgraded to a highly segmented 510 photo-multiplier gas Cherenkov detector (known as the GRINCH). The BigBite detector stack will consist of: four GEM chambers (each covering 40x150 cm^2), the GRINCH gas cerenkov , one GEM chamber (60x200cm^2), scintillator paddle array, preshower and shower calorimeter. The scintillator array and preshower/shower calorimeter will be unchanged from previous experiments.

The preshower is 27 columns of two rows of lead glass which is placed perpendicular to the shower blocks. The shower calorimeter consist of 27 rows and 7 columns of lead glass blocks. The 243 channels of preshower and shower are readout in FASTBUS 1881M 64 channel ADC modules. The standard Bigbite scintillator array consists of one plane of scintillator paddles and can be used for the experiments. For the planned Hall A A_{1N} experiment, a 90 paddle scintillator array with PMTs on both ends is being built the University of Glasgow. It is probable that it will be ready for the SBS neutron form factor experiments, but it is not necessary for the experiments.

The 550 PMTs of the GRINCH gas Cherenkov detector will be input into 16 channel ampliflier/discriminator cards based which use the NINO chip. The University of Glasgow has developed the cards and the cards have been bought. The logical output from the cards will be readout in FASTBUS 1877S 96 channel TDC modules.

The front 4 GEM chambers are being built by INFN group and are part of the total of six that will be used as the front tracker for the proton form factor (GEp) experiment. Each chamber consists of 3 GEM modules. Each GEM module covers an area of 40x50 cm^2. The readout plane is pitched at 400 μm and is readout using 128 channel APV25 chips. Each module is readout by a total of 18 APV25 chips (8 along the 40 cm and 10 along the 50 cm). So a GEM front chamber has 6912 channels which gives a total of 27648 channels for the 4 GEM chambers. The APV25 chips will be readout by a VME64x/VXS Multi-Purpose Digitizer (MPD) that was develop by an INFN group. It has been used in previous experiments. Details are given in Section.

The rear GEM chamber is being built by the University of Virginia and is part of the toal of 10 GEM chambers that will be used as the rear tracker for the GEp experiment. Each chamber consist of 4 GEM modules. Each GEM module covers an area of 60x50 cm^2 and are combined into a chamber with an area of 60x200 cm^2. The readout plane is pitched at 400 μm and two strips are combined to reduce the number of readout channels. Readout is done using 128 channel APV25 chips. Each module is readout by a total of 12 APV25 chips (6 along the 60 cm and 6 along the 50 cm). So a GEM rear chamber has 6144 channels which gives a total of 61,440 channels for the 10 GEM chambers. The readout of the GEM rear chamber APV25 chips will use the same INFN MPD electonics as the front GEM chambers.

The hadron calorimeter, HCAL, is a 12x24 block array which will be readout by a JLab FADC250, a 16-channel 12-bit Flash ADC sampling at 250 MHz. For the neutron form factor experiments, the HCAL is not part of the trigger. For the neutron form factor experiments, timing resolution is important at the 500ps level and the JLab FADC250 has demonstrated sub 300ps timing resolution. The FADC250 is readout through the VXS pipelined electronics which is explained in Section **??**.

The Coordinate Detector is two planes of scintillator. Each plane consist of 1176 scintillator bars. Each scintillator bar is readout by a wavelength shifting fiber. Fourteen of the WLS will be coupled to a 16 channel multianode PMT. Each analog output of the PMT will be input to a 16 channel amplifier/discriminator card base on the NINO chip. The logic signals from the NINO chip will go to FASTBUS 1877s 96 channel TDC modules. Since the CDET is using only 14/16 channels , space is need for 2688 TDC channels (16/14*2352).

1.2 Overview of proton form factor experiments

The proton form factor, GEp, experiment measures elastic electron-proton scattering. For electron detection, a large lead glass calorimeter, ECAL, will be used with the Coordinate Detector, CDET, placed in front of ECAL. The CDET is the same as used in the neutron form factor experiments except that it will be arranged with one scintillator plane behind the other. The CDET is primarily used to make a high precision measurement of the electron out-of-plane angle. The proton will be detected in the SBS spectrometer which consist of front tracker INFN GEMs, a polarimeter and the HCAL. The front tracker will consist of 6 INFN GEM chambers (each GEM INFN chamber is 3 GEM modules of 40x50cm^2). The polarimeter consists of two groups of 5 University of Virginia GEM chambers (each UVa GEM chamber is 4 GEM modules of 60x50cm^2). The trigger will be a coincidence between the ECAL and HCAL.

The electronics for the front and rear GEM trackers will be the same as used in the neutron form factor experiments. The CDET electronics will be the same. The HCAL electronics will be still use the FADC250, but it will be part of the trigger. Details of the trigger are discussed in Section **??**.

ECAL is a large array of lead glass bars. In a previous proton form factor, GEp3, experiment, 1784 lead bars were used in a calorimeter which was a mixture of 1024 blocks with 3.8x3.8 cm^2 cross sectional area and 760 blocks with 4x4 cm^2 cross sectional area. A larger pool of the same size lead glass bars is available at Jefferson Lab. The electronics and cabling from that experiment will be re-used. The lead glass bars will be readout out by FASTBUS 1881M 64 channel ADC modules. As done in the GEp3 experiment, the analog signals from 8 blocks will be summed together in groups of 2x4 using custom built "summing" modules. The "summing" modules have two sets of eight inputs. Each set of eight inputs is summed together and six summed analog outputs for each group of eight are available. In addition the "summing" module produces the 16 individual analogs signal with an amplification of 4.2 that can be sent to an ADC. There will be 1710 individual blocks. Other analog outputs from the "group of 8" would be sent to additional FI/FO units to form summed analog signal from a group of 32 blocks to be used in the ECAL trigger as explained in Section ??.

1.3 Detector configuration summary

GEp Detectors	Channels	Readout	Type
SBS Proton arm			
Front tracker (6 GEM chambers)	41,472	APV25 MPD	VME
Rear tracker (10 GEM chambers)	61,440	APV25 MPD	VME
HCAL	288	FADC 250	VME
Electron arm			
ECAL	1710	ADCs 1881M	Fastbus
ECAL sums	214	TDCs 1877S	Fastbus
CDET	2688	TDCs 1877S	Fastbus

GEn/GMn Detectors	Channels	Readout	Type
SBS Proton arm			
HCAL	288	FADC 250	VME
CDet	2688	TDCs 1877S	Fastbus
BigBite Electron arm			
PreShower/Shower	243	ADCs 1881M	Fastbus
Scintillator	180	ADCs 1877S	Fastbus
Gas Cerenkov	550	ADCs 1877S	Fastbus
Front Tracker (4 GEM chambers)	27648	APV25 MPD	VME
Rear Tracker (1 GEM chamber)	6144	APV25 MPD	VME

2 Trigger

2.1 Neutron form factor experiments

The shower calorimeter consist of an 7x27 array of lead glass blocks. A preshower layer of 2x27 is placed in front of the shower An analog sum of 7 blocks is made. This sums are further added using 4 channels linear fan module. A preshower layer 2x27 is placed in front of the shower but is usually used off line for pion electron identification. This make a total of 189 + 54 = 243 lead glass blocks to be readout. The readout of the detector will be done using fastbus using ADCs 1881M. The trigger for the neutron form factor experiments will use the standard electron trigger using the preshower and shower calorimeter which was developed for previous experiments. For the quasi-free kinematics of the experiments, the trigger provides sufficient pion rejection to keep the trigger rate below 5 KHz. There is a side project to include the gas cerenkov in the trigger, but this is not necessary for the experiments and the main focus is for the A_{1N} experiment .

2.2 Proton form factor experiments

The trigger is a coincidence between the electron calorimeter, ECAL, and the hadron calorimeter, HCAL. Both ECAL and HCAL each form a trigger separately. Then a coincidence between the two is made which takes into account the elastic angular correlation to reduce backgrounds.

2.2.1 ECAL trigger

In Fig. **??**, the left plot shows the distribution of events at the front of the ECal and overlayed on the individual blocks. The middle plot shows the groups of 2x4 blocks (outlined in red) which will go into the sum of 8 modules. Around the edges the groups include less than 8 blocks (outlined in green). There are a total of 219 sum of 8 modules needed. The sum of 8 modules pass the individual analog signal of each block to a connector in the back of the module. A cable goes from this connector goes to a nearby patch panel on the ECal platform. The patch panel goes to a long 500ns delay cable which brings the signal to another patch panel in the electronics hut. This patch panel changes from the individual BNC cables into a 16 channel ribbon cable which goes into the 1881M ADC. Table **??** gives the total propagation time of the individual signal from each block along with the breakdown into the different components.

For the formation of the trigger, the sum of 8 modules have 6 outputs of the summed signal. In the right plot of Fig. **??**, the groups of 32 blocks which sum 4 groups of 8 blocks are indicated by purple filled circles at the intersection of 4 groups of 8. The group of 32 blocks overlap by two groups of 8 in both horizontal

Cable length from PMT to sum of 8 module	40ns
Sum of 8 module transit time	10ns
Cable from back of the Sum of 8 module to patch panel on ECal	6ns
Cable from ECal patch panel to patch panel in electronics hut	500ns
Ribbon Cable from patch panel on ECal	15ns
Total time	571ns

Table 1: The contributions to total propagation time of the ECal calorimeter signals.

Cable length from PMT to sum of 8 module	40ns
Sum of 8 module transit time	10ns
Cable from Sum of 8 module to FI/FO for group of 32	24ns
FI/FO module transit time	10ns
Cable from FI/FO to the 16 channel discriminator	4ns
16 channel discriminator transit time	10ns
Cable from the 16 channel discriminator to 16 channel mixed logic unit	4ns
16 channel mixed logic unit transit time	10ns
Cable from the 16 channel mixed logic units to final 16 channel mixed logic unit	4ns
16 channel mixed logic unit transit time	10ns
50M fast cable from the ECal platform to Trigger Supervisor	200ns
Transit time in TS to produce the ADC gate	40ns
Cable from TS to back of FASTBUS crate	25ns
Total time	391ns

Table 2: The contributions to total time formation of the ECal Level One trigger sued as the ADC gate.

and vertical directions. So most of the groups of 8 have to go to 4 groups of 32. At the edges the groups of 8 feed into two groups of 32. There are 192 groups of 32. The output of the groups of 32 would go into 16 channel discriminators. A total of twelve 16-channel discriminators would be needed. The outputs of the discriminator would go into a 16-channel mixed logic unit to produce an "OR" for each set of 16 inputs. The 12 "OR" signals would go into a final 16-channel mixed logic unit to a trigger that needs to be sent to the Trigger Supervisor as the Level One trigger. A 50m fast R8 cable will bring the trigger from the ECal platform to the Trigger Supervisor which will be located in a VXS crate in the electronics hut. The Trigger Supervisor takes 40ns to produce the ADC gate and the cable from the Trigger Supervisor to the trigger distribution card in the back of the FASTBUS crate takes 25ns. The total time is 391ns which is 180ns less than the 571ns for the propagation time of the individual signals to the ADC.

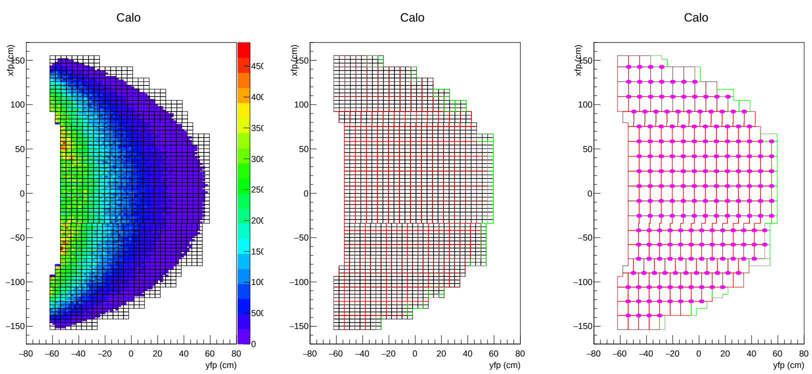

Figure 1: The left plot is the distribution of elastic electrons in ECAL with the black rectangles representing groups of 2x4 lead glass blocks. The right plot demonstrates the scheme for make overlapping groups of 32 lead glass blocks to be used in the ECAL trigger with details explained in text.