Software packages for the Super Bigbite Spectrometer experiments

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Abstract

Super Bigbite Spectrometer is a new instrument in preparation to take data in Hall A at Jefferson Laboratory starting in 2021. It will consist of a large aperture magnet with a modular detector package, and will be combined together with another arm (that will vary depending on the measurement). Its core physics program consists in the measurement of the nucleon form factors at large values of Q^2, but it is versatile enough to perform other measurements such as semi-inclusive DIS or even tagged DIS. Those measurements have in common to require high luminosity, which, combined with the large solid angle and open geometry, induces large trigger and background rates, which makes those measurements particularly challenging.

Overcoming those challenges will require a lot of preparation including simulations to both evaluate actual experimental conditions and prepare pseudodata samples to develop the analysis.

This document reviews the simulation and software framework, with a specific focus on the simulation digitization and its interface to the SBS analysis software SBS-offline.

keywords: High luminosity/rates/background experiments, simulation, software.

1 Introduction to the SBS software

2 G4SBS simulation

2.1 Description and features

3 Simulation digitization

3.1 Description and features of libsbsdig

The currently developped version of libsbsdig is a standalone program which uses the information from g4sbs to produce realistic ADC and TDC values from the detector. Similarly to g4sbs, the output ADC and TDC values are stored as series of stl vectors The necessary input to operate this program is fairly simple:

- one unique configuration file to setup all the detectors tunable parameters (i.e. gains, pedestals means and widths, thresholds, number of ADC and TDC bits...
- one text file to list the g4sbs input files.
- optionally one input root file storing background histograms (see section 3.3)

A more complete documentation is available on https://redmine.jlab.org/projects/sbs-software/wiki/Documentation_of_libsbsdig

3.2 Digitization algorithms

In this section we detail the algorithms which are used to digitize

3.2.1 GEMs

The digitization algorithm for the GEMs can be decomposed into four main steps.

Step 1: Ionization During this step we perform the following actions:

- Use the energy deposit to estimate the number of ions generated;
- Distribute these ions uniformly between x_{in}, y_{in}, z_{in} and x_{out}, y_{out}, z_{out};

Step 2: Avalanche In this step we simulate the avalanche for each of these ions, according to a Cauchy-Lorentz function (which width will depend on the speed of diffusion of the ions in the gas, etc, and the amplitude will depend on the gain);

Step 3: Numerical integration of the avalanche In this step we numerically integrate the avalanche on each of the strips: the integrated charge normalizes a pulse function $f(t) = C(t - t_0)/\tau^2 exp(-(t - t_0)/\tau)$. (where $\tau = 56$ns and t_0 depends on the time of the hit registered by g4sbs) This function is then integrated on the six 25ns samples and converted into ADC values.

Step 4: Pedestal addition and saturation The pedestal is added on top of the ADC value for each of the sample. The pedestal value is indicated in the configuration file, and the pedestal width is typically $\sigma = 20$ ADC. The total ADC value is then capped to the maximal ADC value which for the APV chips is $2^{12} = 4096$ to simulate ADC saturation.

Note: In the full background case, steps 1, 2, 3 are repeated for the background hits before applying the pedestal and the saturation.

3.2.2 PMT detectors

The digitization algorithm for the PMT detectos can be decomposed into four main steps. There is a bit of variability depending on the readout electronics (if it uses TDCs or not).

Step 1: Number of photoelectrons estimation The number of photoelectrons is from the energy deposit. This estimation depends on the detector e.g. for the timing hodoscope or the HCal, there is a dependence of the light yield on the hit position; The number of photoelectrons multiplied by the PMT gain is used to normalize a pulse function $f(t) = C(t - t_0)/\sigma^2 exp(-(t - t_0)/\sigma)$ where σ is the FWHM of the PMT provided in the configuration file.

Step 2: Timing estimation for TDCs If the DAQ involves TDCs, the pulse is compared to the threshold (provided in the configuration file). If the pulse crosses the threshold, the leading and trailing times are recorded.

Step 3: ADC/TDCs conversion The integral of the pulse is converted into ADC values; the times are converted into TDC values; In the case of HCal (readout by FADC 250), the pulse is integrated on 4ns ADC samples

Step 4: 4th step: apply a pedestal on the ADC value(s). The mean and width of the pedestal is provided in the configuration file; The total ADC value is then capped to the maximal ADC value 2^{ADC_bits} (with ADC_bits provided in the configuration file) to simulate ADC saturation.

Note: In the full background case, steps 1, 2, 3 are repeated for the background hits before applying the pedestal and the saturation.

3.3 Background addition

The first step for the background addition is a "pre-processing" of beam-on-target g4sbs files to generate background histograms for:

- hit multiplicity (within a certain time window);
- distribution of hit position;
- energy deposit
- number of photoelectrons (when applicable);

These histograms are fed as an input to sbsdig, which uses them to (re)generate hits by sampling those histograms. These hits time is distributed uniformly within the detector time window. Once those hits are generated, they are processed and superimposed to the signal hits (see section 3.2).

4 SBS-offline analysis software

4.1 Description and features

4.2 interface with digitized simulation