Analysis Techniques: E02-013

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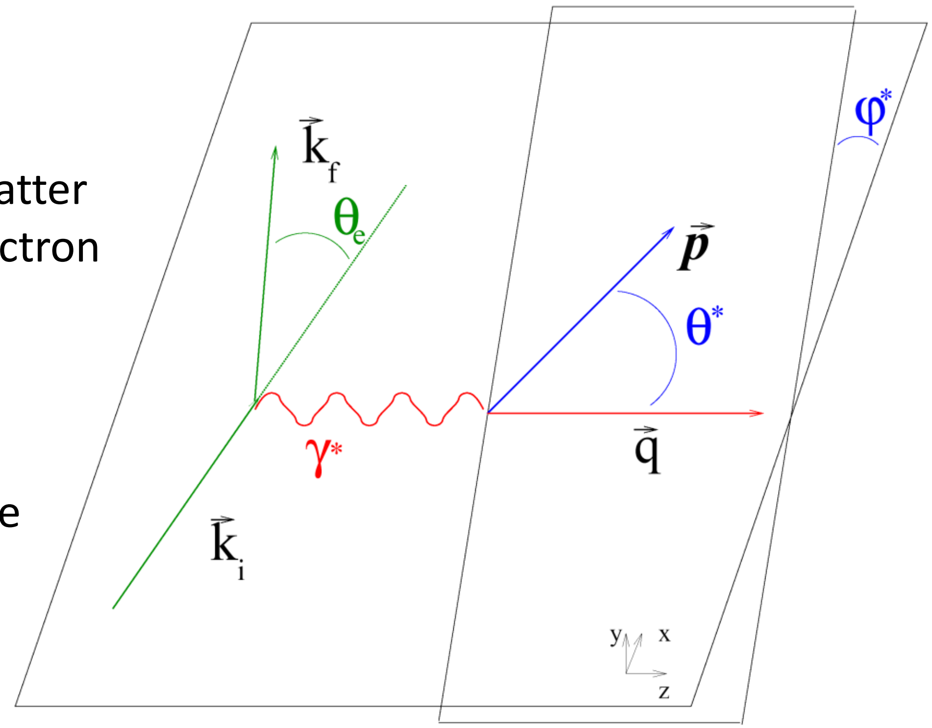
Double Polarization Method

$$^{3}\overrightarrow{\mathrm{He}}(\vec{e}, e'n)pp$$

In the experiment, polarized electrons scatter from polarized helium-3 and the final electron and hadron are detected.

The polarized cross section has helicity dependent term. The asymmetry determined from this is dependent on the form factor ratio and kinematic coefficients.

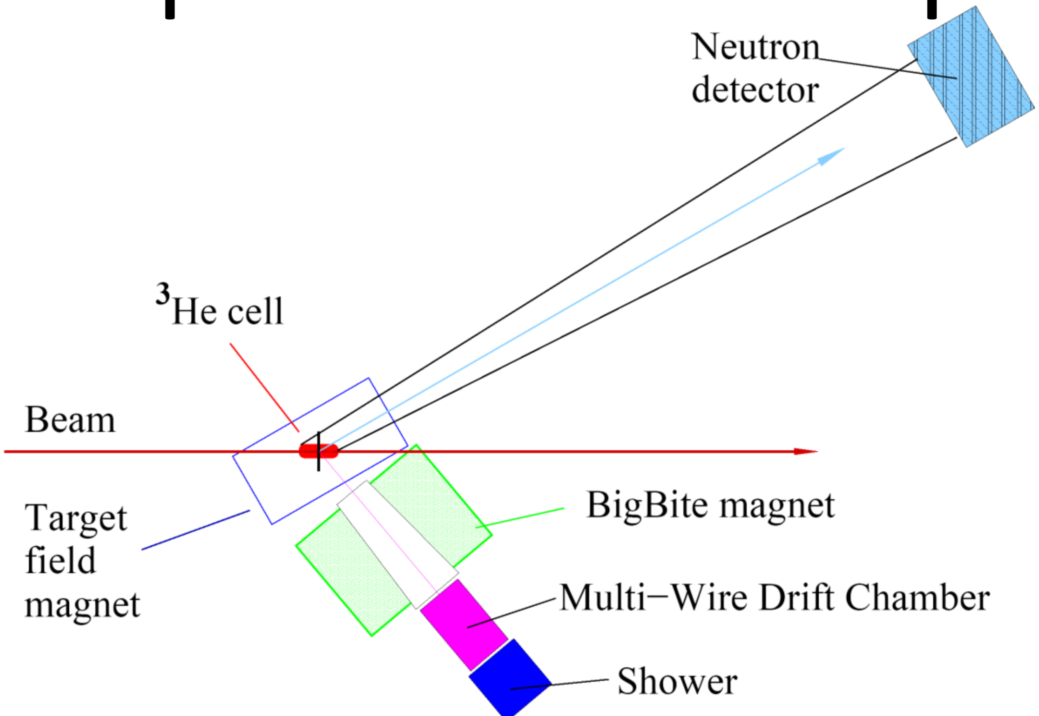


$$A = \frac{\sigma_{\rightarrow\uparrow} - \sigma_{\leftarrow\uparrow}}{\sigma_{\rightarrow\uparrow} + \sigma_{\leftarrow\uparrow}}$$

Beam Helicity   Target Polarization

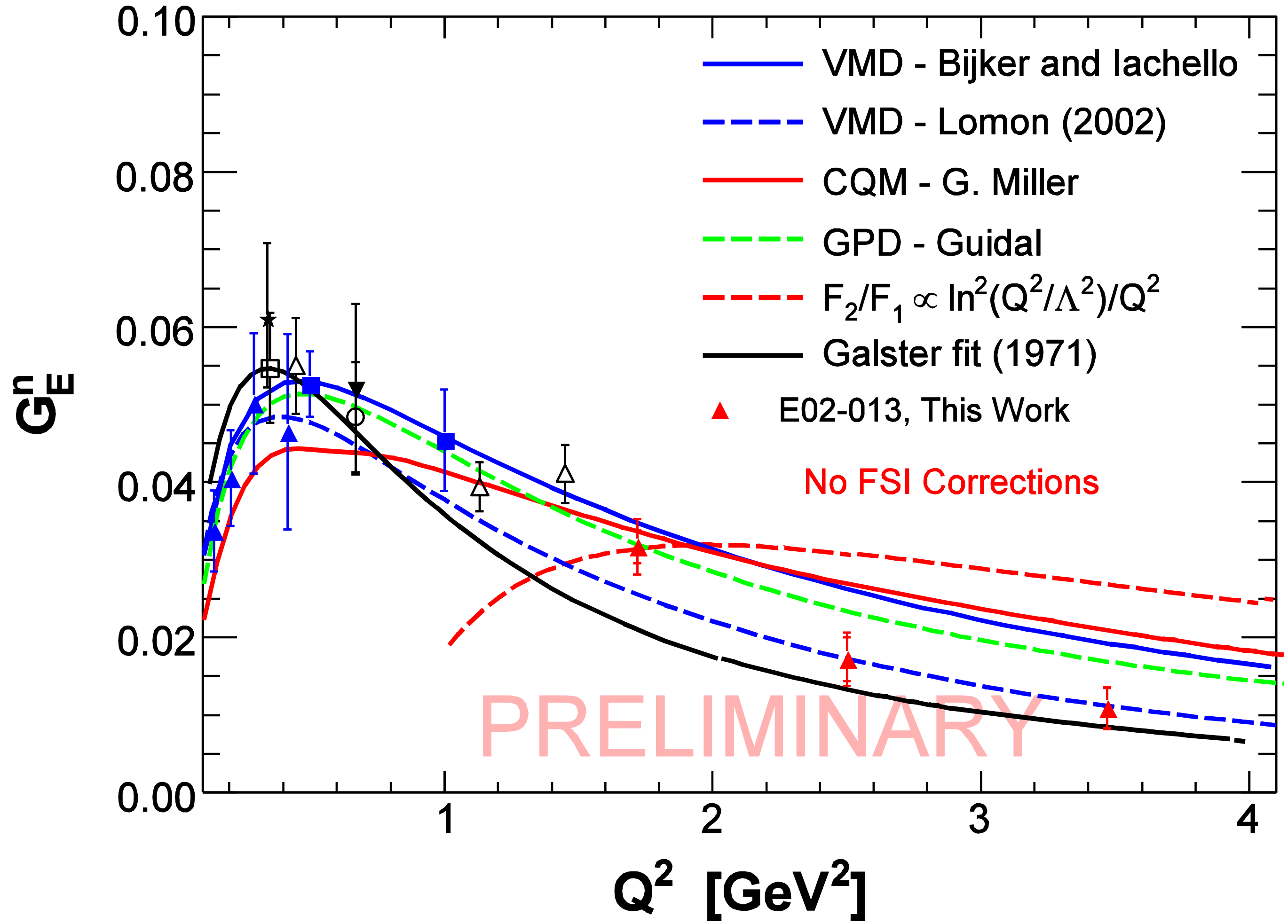
$$= \frac{-\frac{G_E}{G_M}\, 2\sqrt{\tau(1+\tau)}\tan\left(\frac{\theta_e}{2}\right)\sin\theta^*\cos\phi^* - 2\tau\sqrt{1+\tau+(1+\tau)^2\tan^2\left(\frac{\theta_e}{2}\right)}\tan\left(\frac{\theta_e}{2}\right)\cos\theta^*}{\left(\frac{G_E}{G_M}\right)^2 + \left(\tau+2\tau(1+\tau)\tan^2\left(\frac{\theta_e}{2}\right)\right)}$$

Experimental Setup



- CEBAF provides a polarized (83%) electron beam.
- The polarized ^3He (45-50% polarization) acts as a free polarized neutron target.
- Big Bite is a large acceptance spectrometer for scattered electrons.
- The Neutron Arm, with an $11m^2$ active area, detects and identifies protons and neutrons.

Electric Form Factor of the Neutron



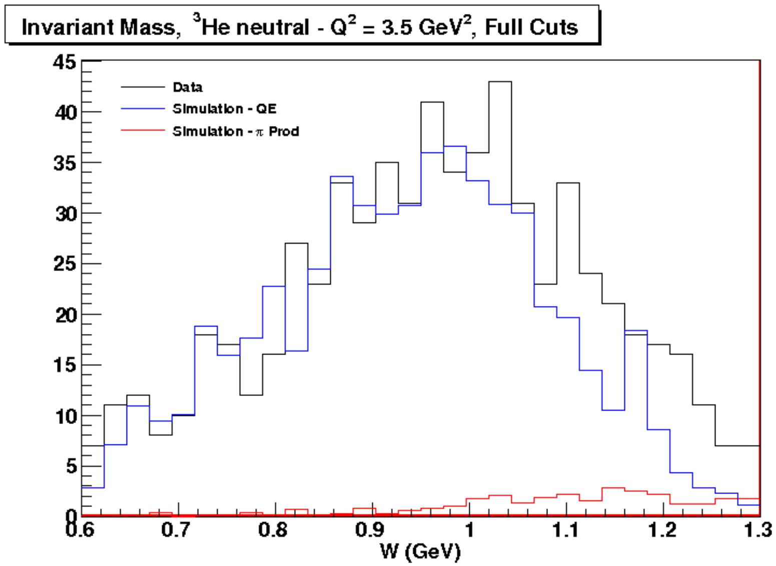
Monte Carlo: Motivation

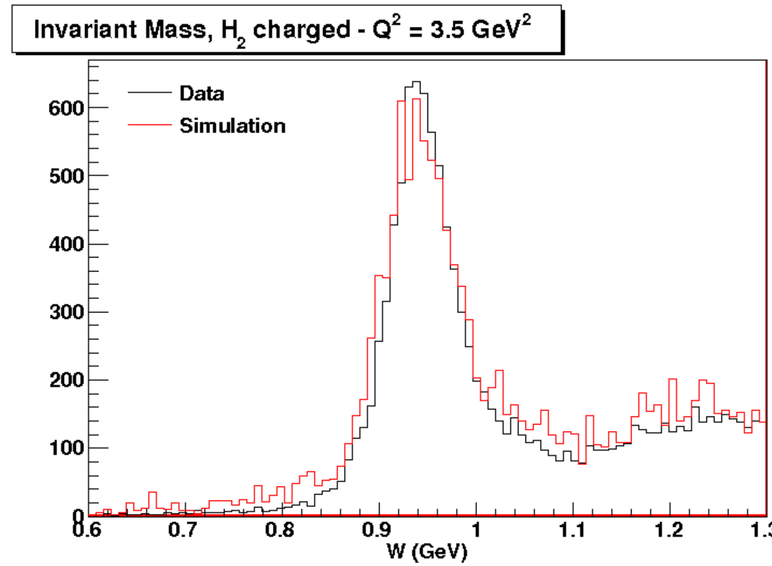
- The Neutron Arm detector response.
- Nucleon charge misidentification mechanisms.
- π electroproduction cross section and asymmetry contributions.
- The inelastic contribution above an invariant mass of 1 GeV so that this region can be included in the analysis.
- The acceptance and expected yields.

Monte Carlo – Mechanism

- Elastic Cross Sections and Asymmetries from Form Factors.
- π electroproduction crossections and asymmetries from MAID.
- Electron Radiative Corrections following MCEEP.
- Quasielastic scattering described by free moving nucleon.
  - Momentum distribution for Helium 3 from Schiavella.
  - No binding effects included.
- Resolution effects for Big Bite included, NA just Gaussian.
- Big Bite and Neutron Arm acceptances included.
- Only electrons and nucleons tracked.
- Big Bite simulated with electron propagation from target to DC with the field set to match the data (no fringe effects).

Monte Carlo – Results Invariant Mass

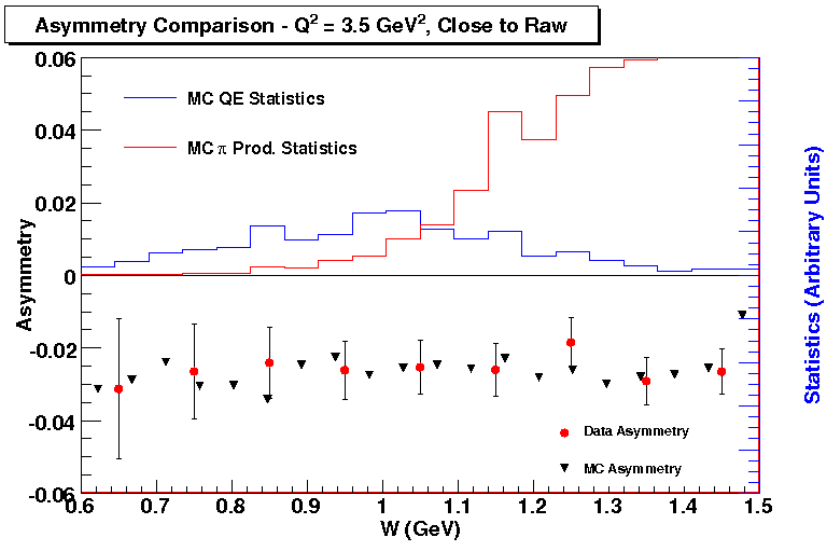


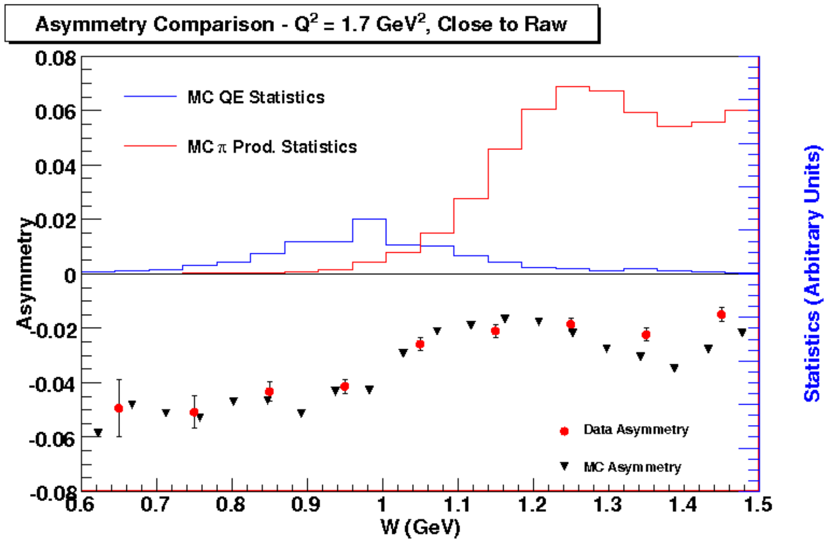


Simulation, also showing the inelastic events that come in under our elastic events in our cuts. Inelastic contribution of ~2%.

The MC matches the elastic data quite well, the features above 1 GeV for the simulation are too ‘sharp’.

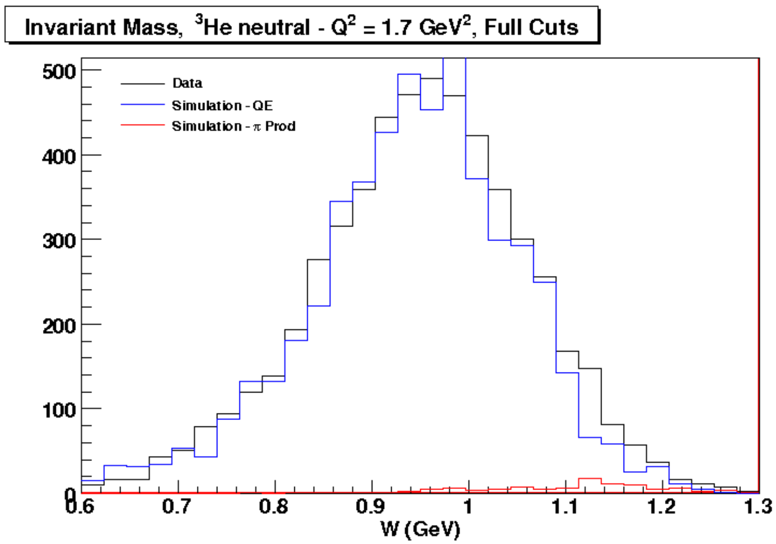
Monte Carlo – Results Asymmetry

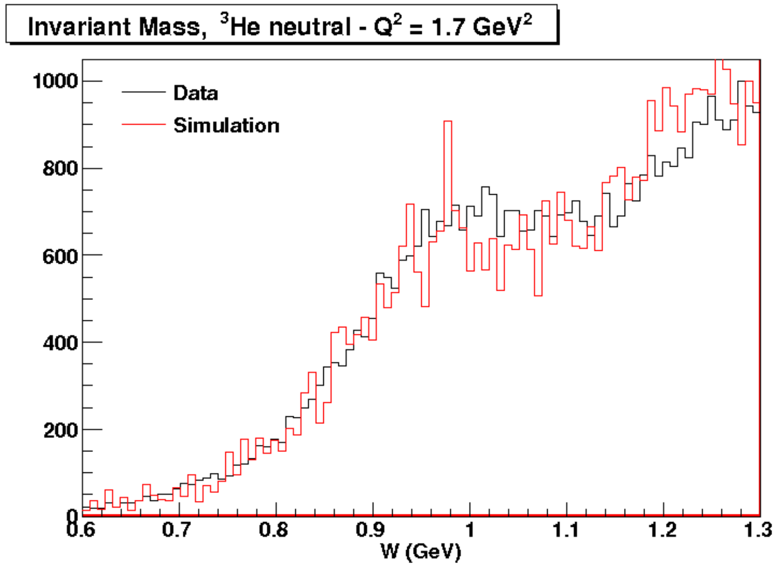




The simulated asymmetries match the data very well. This shows that the asymmetry contamination from the inelastic events is minimal.

Monte Carlo – Results Invariant Mass





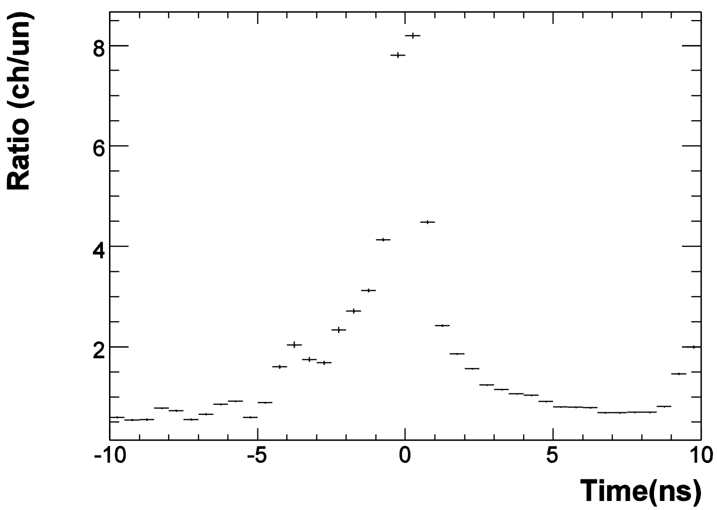
The invariant mass spectrum for the lower kinematic. For this kinematic the contamination is less than 1% and mostly above 1.1 GeV.

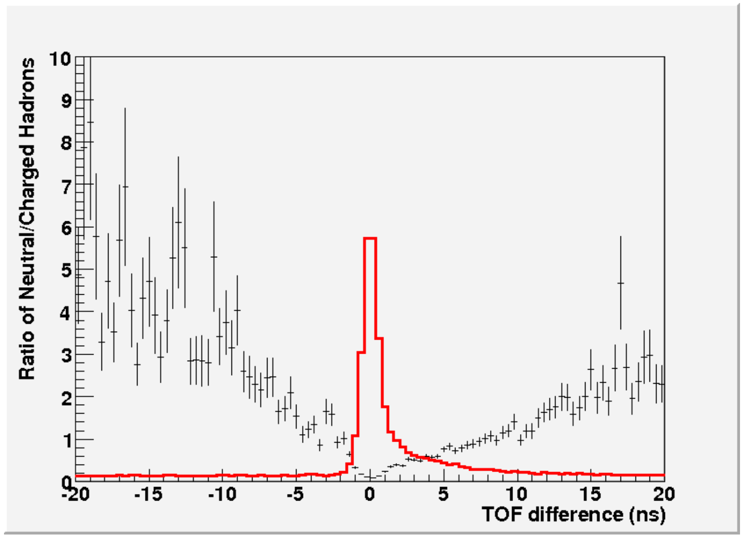
Monte Carlo – Future Work

- GEANT4 simulations of the Neutron Arm.
  - PMT amplitude and time response need to be simulated.
  - Neutron arm tracking needs to be simulated and integrated with scattering MC.
- Include π and γ tracking in the MC.
- Vary cuts, determine uncertainty in MC and determine the point where uncertainty from MC becomes greater then uncertainty in statistics.
- Target cell, box, and ladder geometries need to be included.

Background Analysis Techniques: Motivation

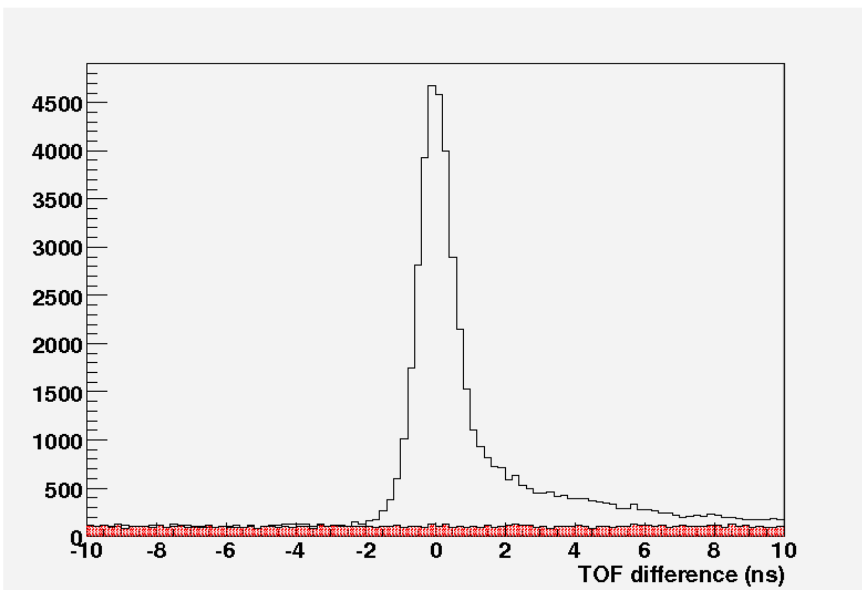
1. Most quasielastic events are protons, and because a range of veto is used in charge determination, these protons will contaminate the uncharged sample (both of accidental and quasielastic events).
2. Charged accidental events can similarly effect the sign of the neutral quasielastic events.
3. Standard method is that the accidental neutral background is unknown an estimate the error based on that.
4. Alternate method counts only events with a single hit within a broad region containing both quasielastic events and background.





Standard Background Analysis Technique – Mechanism

Accidental Counts – Shift



Accidental Charge Ratio

As developed by Seamus:

$$\Sigma_{back}^{ch} = N_{back}^{ch} + \frac{N_{back}^{un}}{2} \pm \frac{N_{back}^{un}}{\sqrt{12}}$$

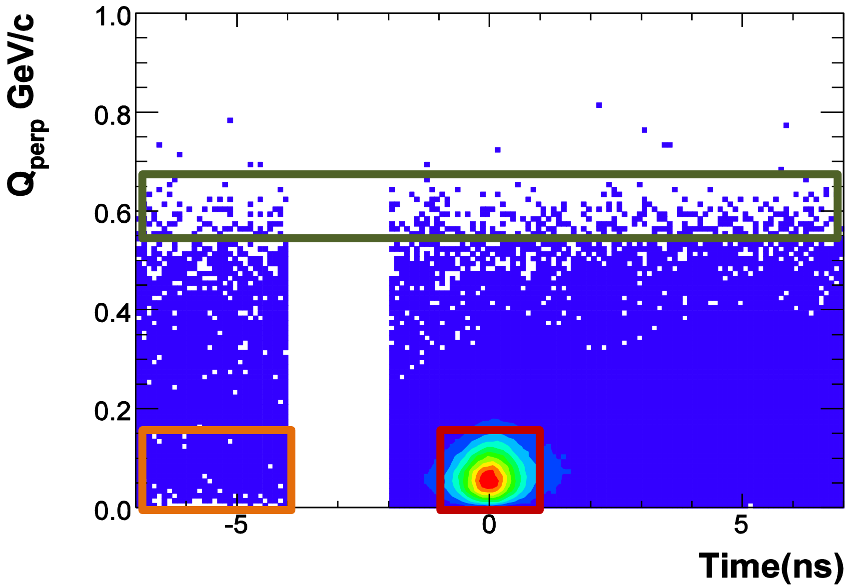
$$\Sigma_{back}^{un} = \frac{N_{back}^{un}}{2} \pm \frac{N_{back}^{un}}{\sqrt{12}}$$

$$< N >_{RMS} = \left(\int_{\frac{N}{2}}^{\frac{N}{2}} \frac{x^2}{N} dx \right)^{\frac{1}{2}} = \frac{N}{\sqrt{12}}$$

Alternate Background Analysis Technique – Mechanism

Here is the formula for the total number of hadron hits in regions A and B. The label *back* refers to background accidentals while *QE* refers to quasi-elastic hits. Here the | means with at least one other hit of the type of event referred to in the region.

$$N_{full}^{A+B} = N_{back}^{A} + N_{QE}^{A} + N_{QE}^{A}|_{back} + N_{back}^{A}|_{back} + N_{back}^{B}|_{back} + N_{QE}^{B}|_{back} + N_{QE}^{A}|_{QE} + N_{back}^{A}|_{QE} + N_{back}^{B} + N_{back}^{B}|_{QE}$$

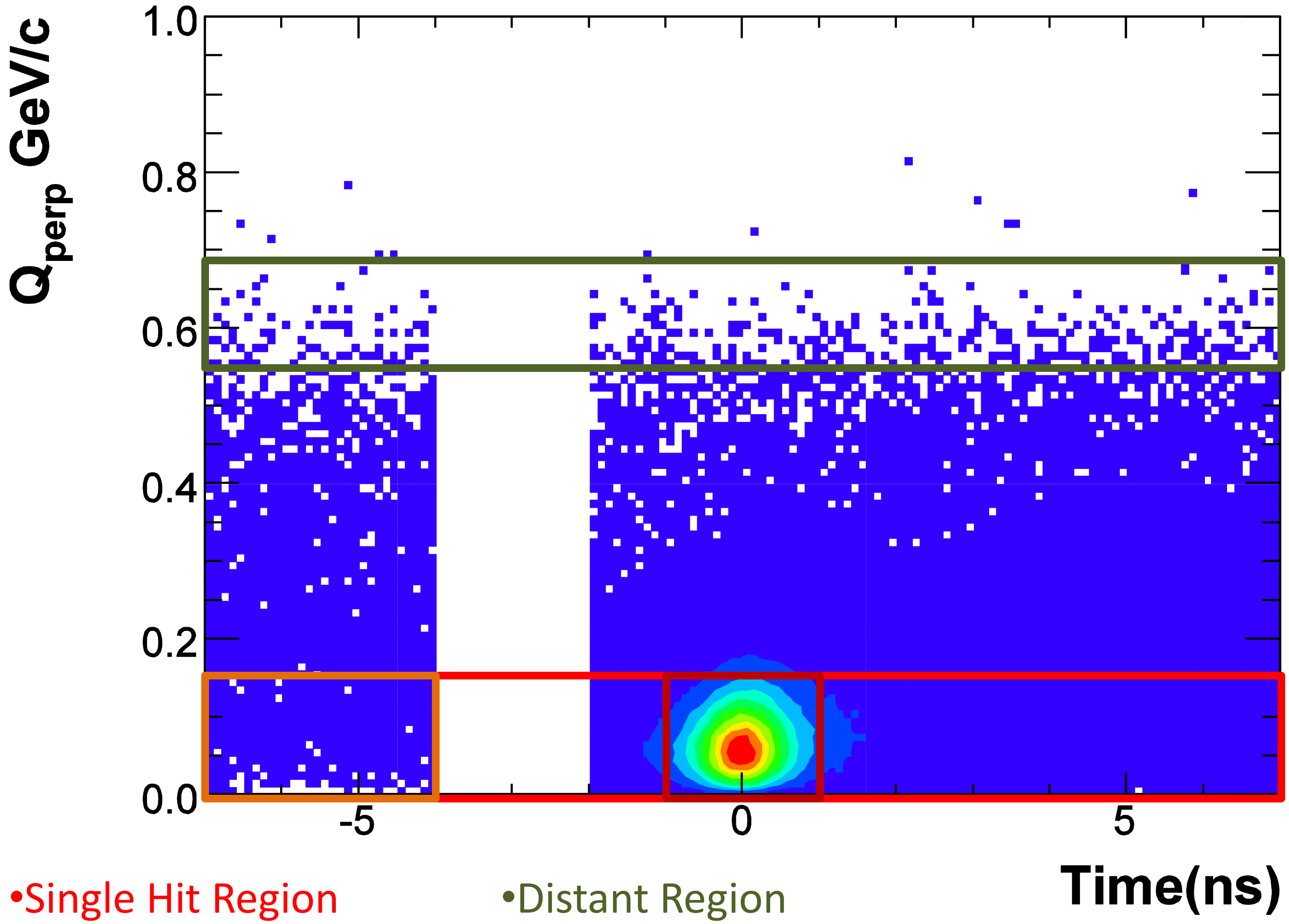


Once the regions are properly scaled, the proper number of accidental quasi-elastic events can be determined. Since only a single event can be in region *A* or *B*, we are left with:

$$N_{SQE}^{B} = N_{back}^{B}$$

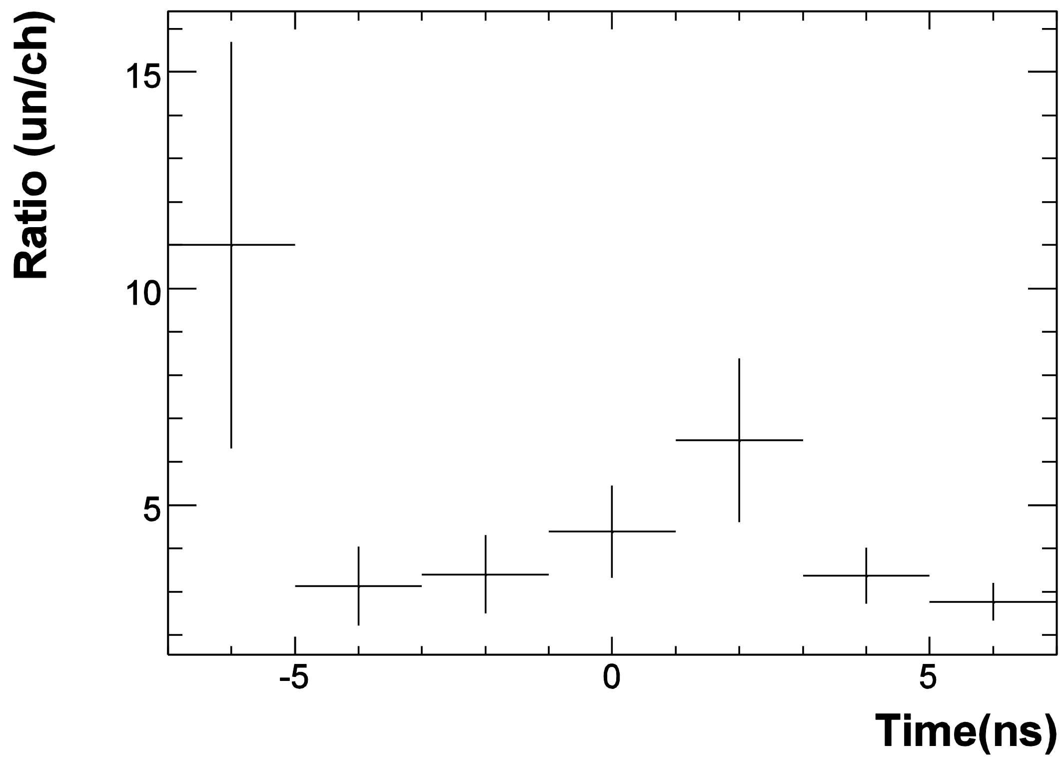
$$N_{SQE}^{A} = N_{back}^{A} + N_{QE}^{A}$$

Alternate Background Analysis Technique – Region Selection



- Single Hit Region
- Distant Region
- Region B
- Region A

Alternate Background Analysis Technique - Ratio



Looking far in q_{perp} is the same as looking in a distant part of the neutron detector. The quasielastic hit should not change the charge of this ‘distant’ accidental.

Background Analysis Technique: Results

Alternate Method	
Neutral Candidates	**32632**
Neutral Asymmetry	-0.038
Background Counts	960
Background Asymm.	0.014
Percent Background	2.9%
D_{back}	97.1

Standard Method	
Neutral Candidates	**50197**
Neutral Asymmetry	-0.034
Background Counts	1261
Background Asymm.	-0.005
Percent Background	2.5%
D_{back}	97.5

- Alternate method sacrifices statistics for smaller background.
- Asymmetries can’t be compared because the proton to neutron conversion dilution factor is heavily dependent on the selection.
- Separate analysis run using both methods showed a difference of < 2% in the value of G_E^n as of last week.