Configuration and calibration of the BigBite spectrometer

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on behalf of E05-102 collaboration

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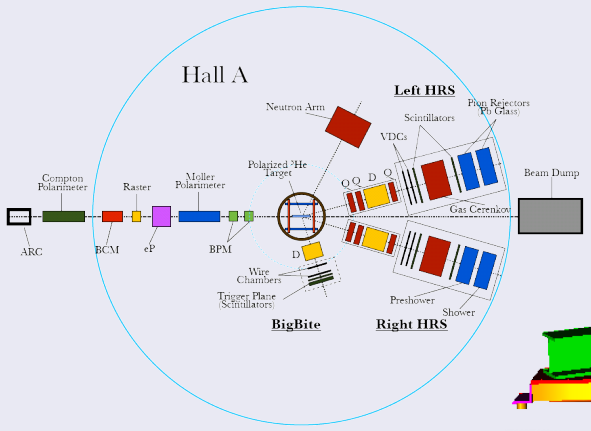
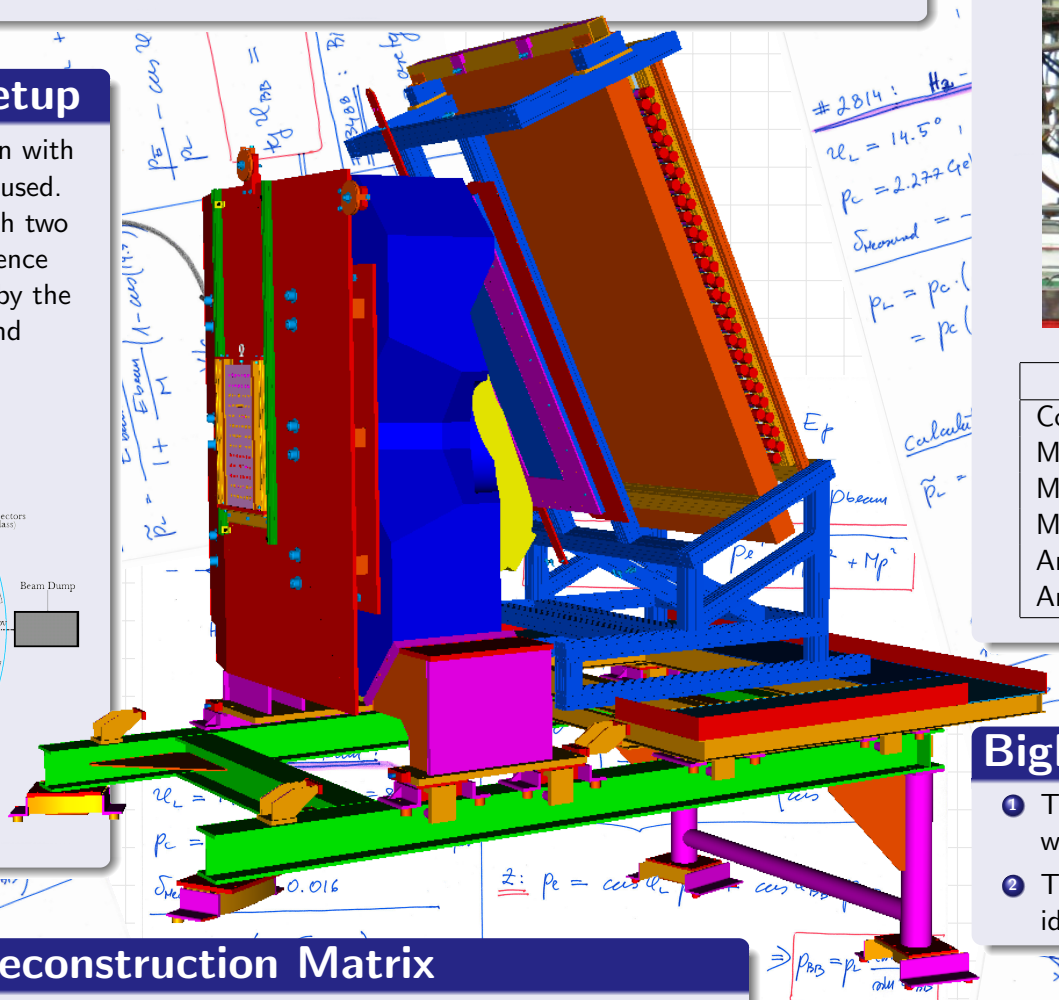
Introduction and Motivation

Experiment E05-102 in Jefferson Lab's Hall A studied $^3\vec{\mathrm{He}}(\vec{e},e'd)$, $^3\vec{\mathrm{He}}(\vec{e},e'p)$ and $^3\vec{\mathrm{He}}(\vec{e},e'n)$ reactions in the quasi-elastic region. The purpose of the experiment was to use Faddeev calculations of the three-body system to understand the effects of S'- and D-state contributions to the $^3\mathrm{He}$ ground-state wave-function. The beam-target asymmetries $\mathrm{A_x}$ and $\mathrm{A_z}$ were measured in the range of the recoil momenta from 0 to approximately 300 $\mathrm{MeV/c}$. For that we need a precise knowledge of momenta of the ejected hadrons, which requires a fine optical calibration of the BigBite spectrometer.

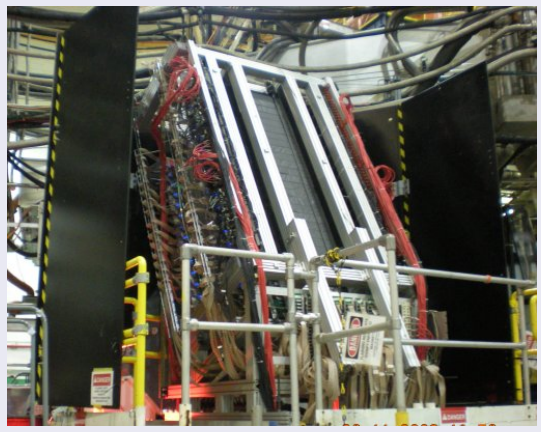
E05-102 experimental setup

A 60% polarized $^3\mathrm{He}$ target in conjunction with 88% polarized 2 GeV electron beam was used. The scattered electrons were detected with two High-Resolution Spectrometers in coincidence with the deuterons and protons detected by the large-acceptance spectrometer BigBite, and neutrons in the neutron detector HAND.





BigBite Spectrometer



Main design characteristics	
Configuration	Dipole
Momentum range	$200-900$ MeV
Momentum acceptance	$-0.6 \leq \delta_{Tg} \leq 0.8$
Momentum resolution	4×10^{-3}
Angular acceptance	≈ 100 msr
Angular resolution	≈ 1 msr

BigBite Detector Package

1. Two MWDCs for tracking, each consisting of 6 wire planes (u,u',v,v',x,x')
2. Two scintillation planes E/dE for particle identification & energy determination

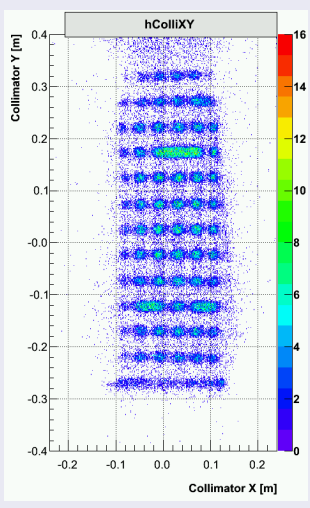
BigBite Calibration & Reconstruction Matrix

The purpose of optics calibration is the ability to calculate target variables $(y_{Tg},\phi_{Tg},\theta_{Tg},\delta_{Tg})$ from the focal plane variables $(x_{Fp},\theta_{Fp},y_{Fp},\phi_{Fp})$ using standard approach of the polynomial expansion:

$$\Omega_{Tg}=\sum_{i,j,k}\theta_{Fp}^{i}y_{Fp}^{j}\phi_{Fp}^{k}\sum_{l=0}^{7}a_{ijkl}^{\Omega_{Tg}}x_{Fp}^{l}\quad,\qquad \Omega_{Tg}=(\delta_{Tg},\theta_{Tg},\phi_{Tg},y_{Tg})$$

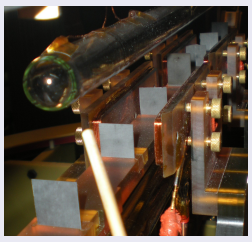
The determination of the parameters $a_i^{\Omega_{Tg}}$ is the main goal of calibration. A χ^2-minimization technique has been applied by using the simplex search method implemented in Matlab. For each target variable Ω_{Tg} different calibration runs were processed.

Results for θ_{Tg} and ϕ_{Tg}



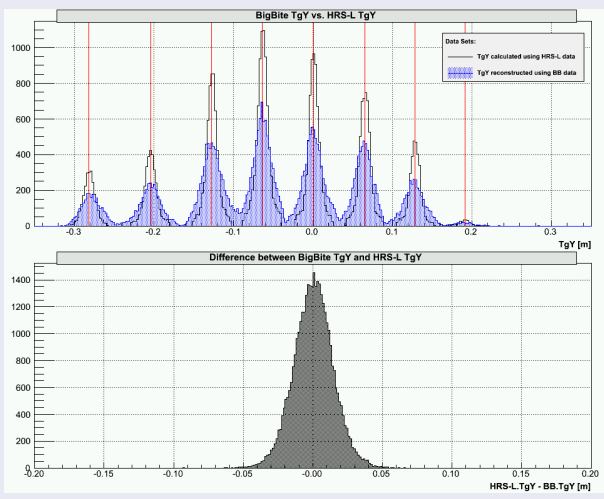
Calibration of θ_{Tg},ϕ_{Tg} was done using ^{12}C data with sieve-slit in front of the BigBite. Precise reconstruction of the sieve-pattern suggests that matrix reconstruction works well.

Results for y_{Tg}



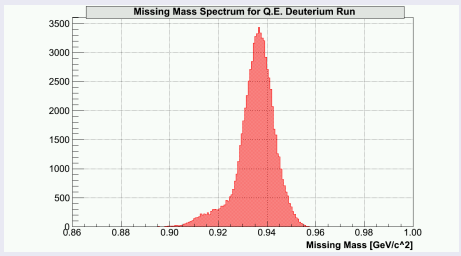
For Y_{Tg} calibration the 7-foil $^{12}C/\mathrm{Be0}$ optics target was used. Current resolution is:

$$\sigma_{y_{Tg}}\lesssim 1.0\,\mathrm{cm}.$$

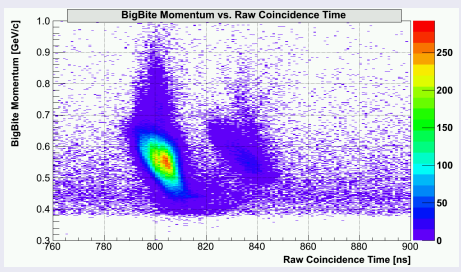


Results for δ_{Tg}

Target variable δ_{Tg} is being determined using elastic H_2 and quasi-elastic D_2 data, by minimization of the width of the missing-mass peak. Current missing-mass resolution is $\sigma_{\delta_{Tg}}\lesssim 6\,\mathrm{MeV/c^2}$.

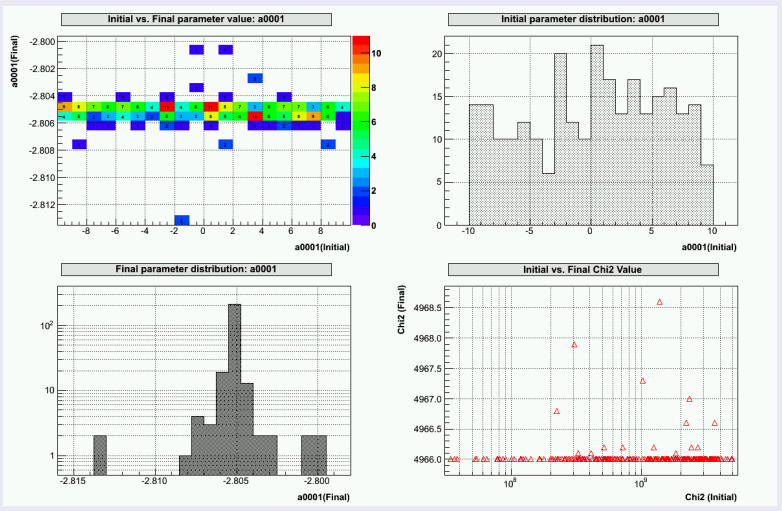


Protons and deuterons in BigBite have similar momenta, but different velocities. Therefore they can be clearly distinguished in the coincidence time spectrum.



Robustness of the Method

Calibration of the target variable Ω_{Tg} requires the determination of approx. 30 matrix elements $a_{ijkl}^{\Omega_{Tg}}$. Initial parameters for the χ^2 minimization are arbitrary. Due to the numerical compexity of the problem it is not certain that the solution is unique. The robustnes of the method is tested by checking the convergence of the minimization for a large number of randomly chosen initial sets of parameters. Our method is robust over a wide range of initial parameters.



References

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