Hall A Analysis Tutorial

1) Hall A equipment

2) GEANT Simulations

3) Data Analysis
The goal is to measure the average cross section per missing momentum bin.

We measure a number of tritons per missing momentum bin $n(p_m)$. This is given by

$$n(p_m) = < \sigma(p_m) > \Delta\Omega_e \Delta\Omega_p \Delta E_e N_e N_{tgt} * EFF$$

$$EFF = ACC(p_m) * LTdaq * RC * BH(I) * LTelectronics$$

$< \sigma(p_m) >= d^5\sigma/(d\Omega_e d\Omega_p dE_e)$ is the average cross section in the p_m bin.

$\Delta\Omega_e$, $\Delta\Omega_p$ are the solid angles cuts used by the spectrometer apertures

ΔE_e is the size of the electrons' momentum bin in coincidence with protons

N_e = Q/e, is the number of electrons that passed through the target, where Q is the total charge and e = charge on electron

$N_{tgt} = \rho(I) * z_{tgt}$ is the number of nuclei per cm^2 in the beam, $\rho(I)$ is the number of nuclei per cm^3, z_{tgt} is the cut on target length and I is the beam current.

The effificiency factor EFF is made from

$ACC(p_m)$ = kinematical acceptance of coincidence events for a given missing momentum

$LTdaq$ is the live time of the data acquisition system

$LTelectronics$ is the live time of the electronics

RC is the radiative correction to account for the radiative tail that is outside our missing energy cut

$BH(I)$ is the beam heating effect for current I and

$$\rho(I) = \rho(Temperature, Pressure) * BH(I)$$

Our goal is to measure the average cross section per missing momentum bin.

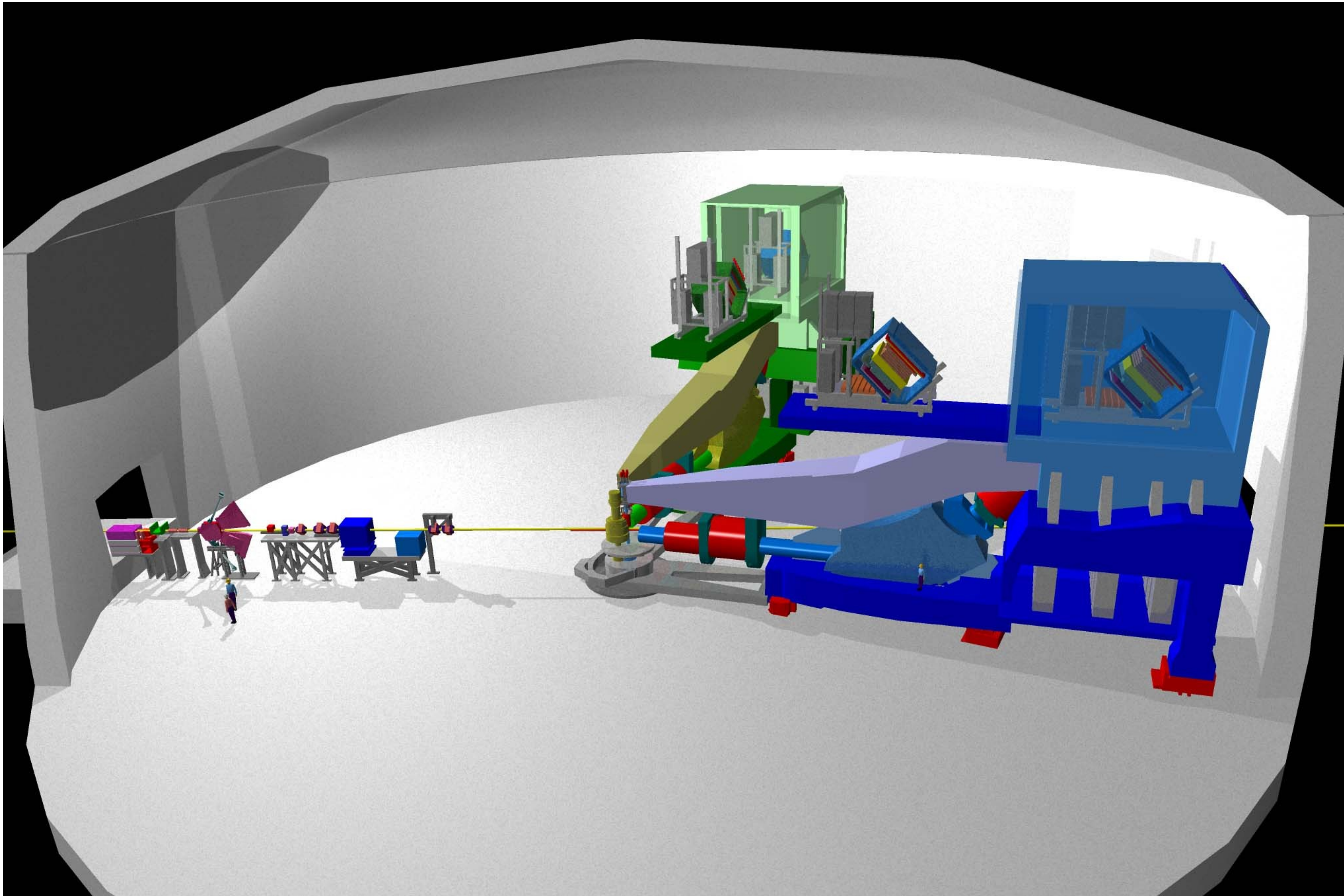
$$< \sigma(p_m) >= n(p_m)/(\Delta\Omega_e \Delta\Omega_p \Delta E_e N_e N_{tgt} * EFF)$$

Hall A Equipment

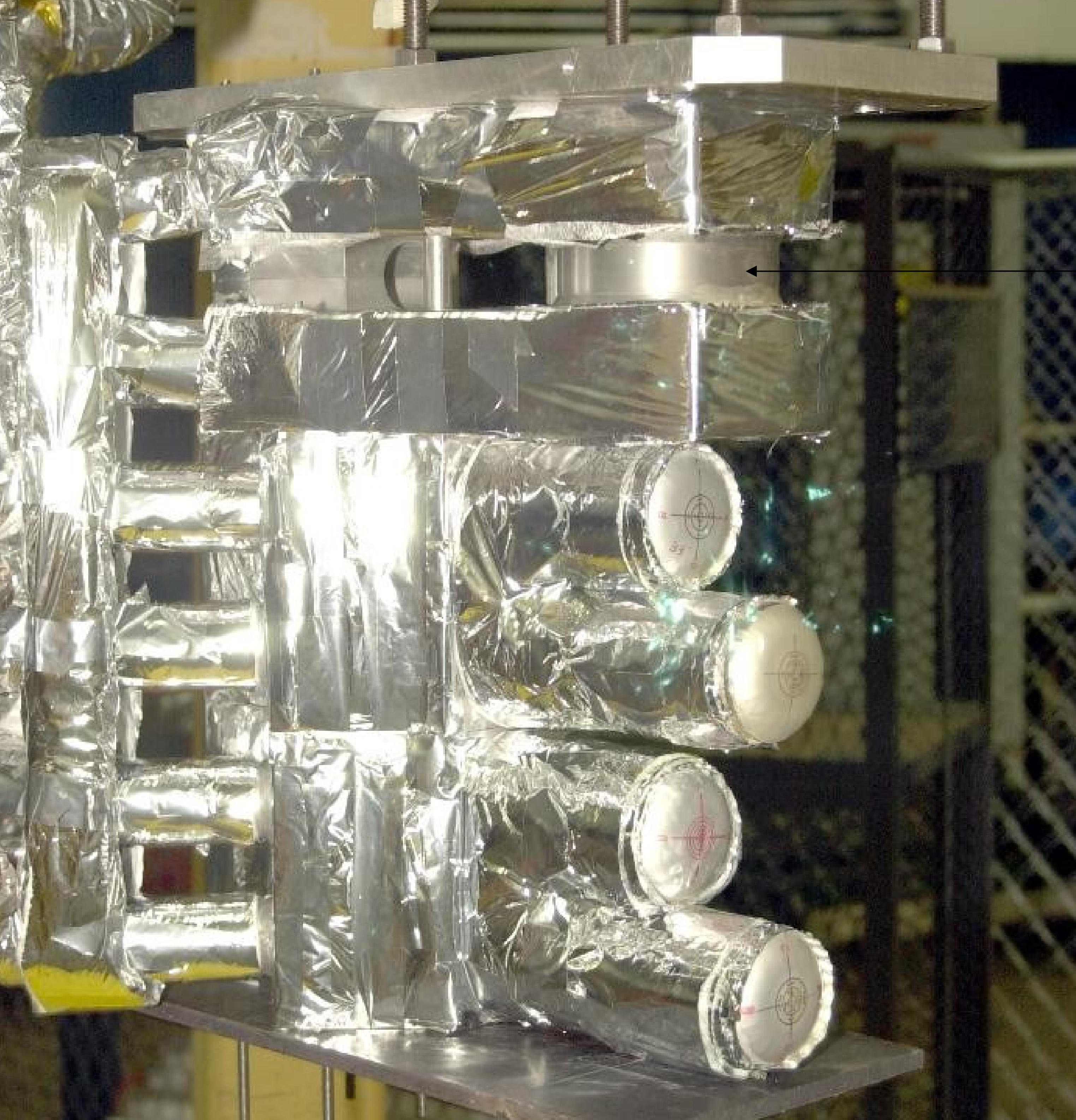
1) Two high resolution magnetic spectrometers
a) three magnetic quadrupole focussing magnets
b) dipole magnet for momentum analysis
   I) $F = qv \times B$, Lorentz force

2) Concrete shielding Hut contains detectors
a) plastic scintillators with photomultiplier tubes
b) vertical drift chambers(VDC) for trajectories
c) Cherenkov detectors for particle I.D.
d) electromagnetic shower counters for particle I.D.

Hall A with High Resolution Magnetic Spectrometers




Proton Spectrometer



Cryogenic target
Tuna Can target
T=20K, p=190psia
Thin walls of Al
About 0.010” thick

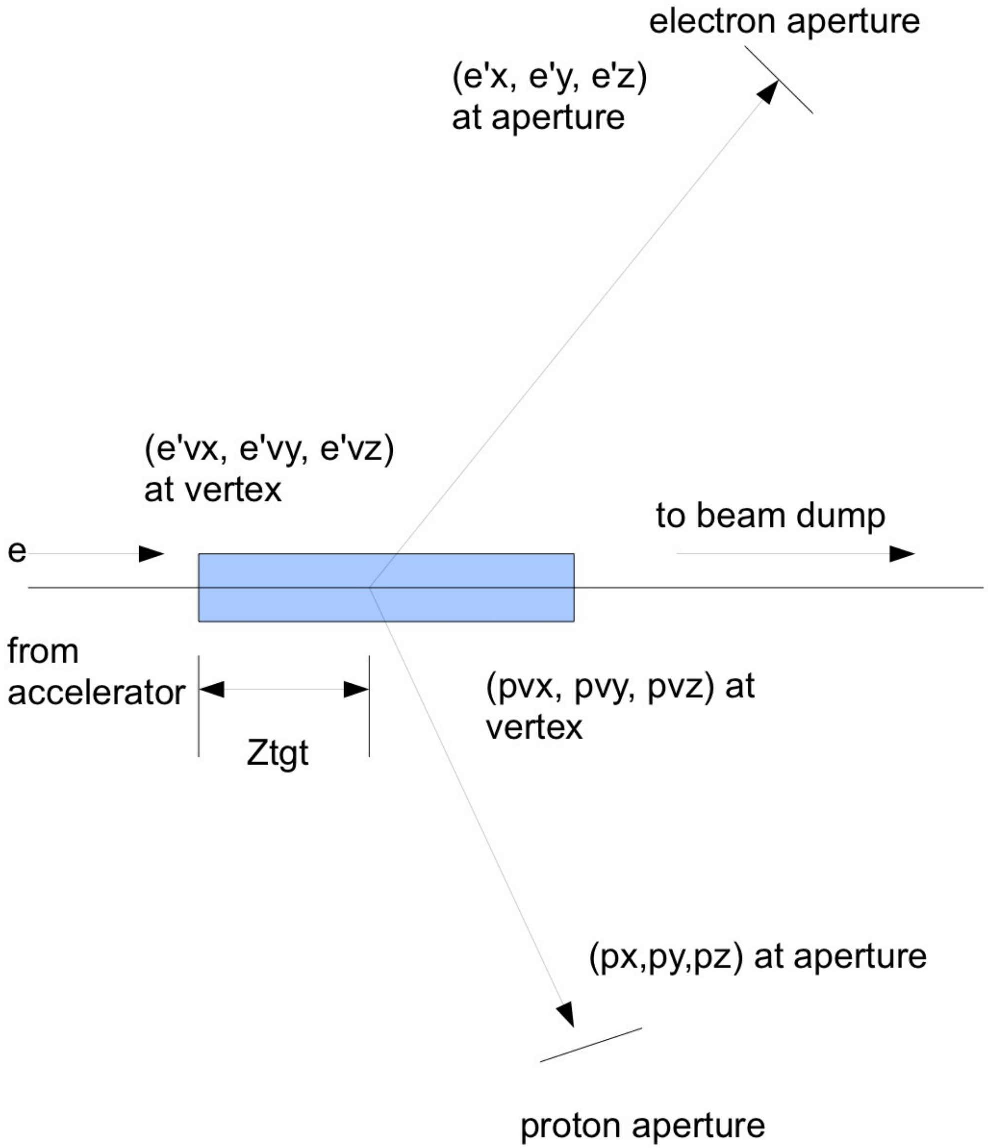
GEANT SIMULATION

Monte Carlo simulations are crucial for data analysis

Assumes we know basic process to follow particles
from the target through materials until they enter the
Spectrometer entrance apertures.

GEANT allows us to store the information about the
positions and momenta of particles throughout their history.

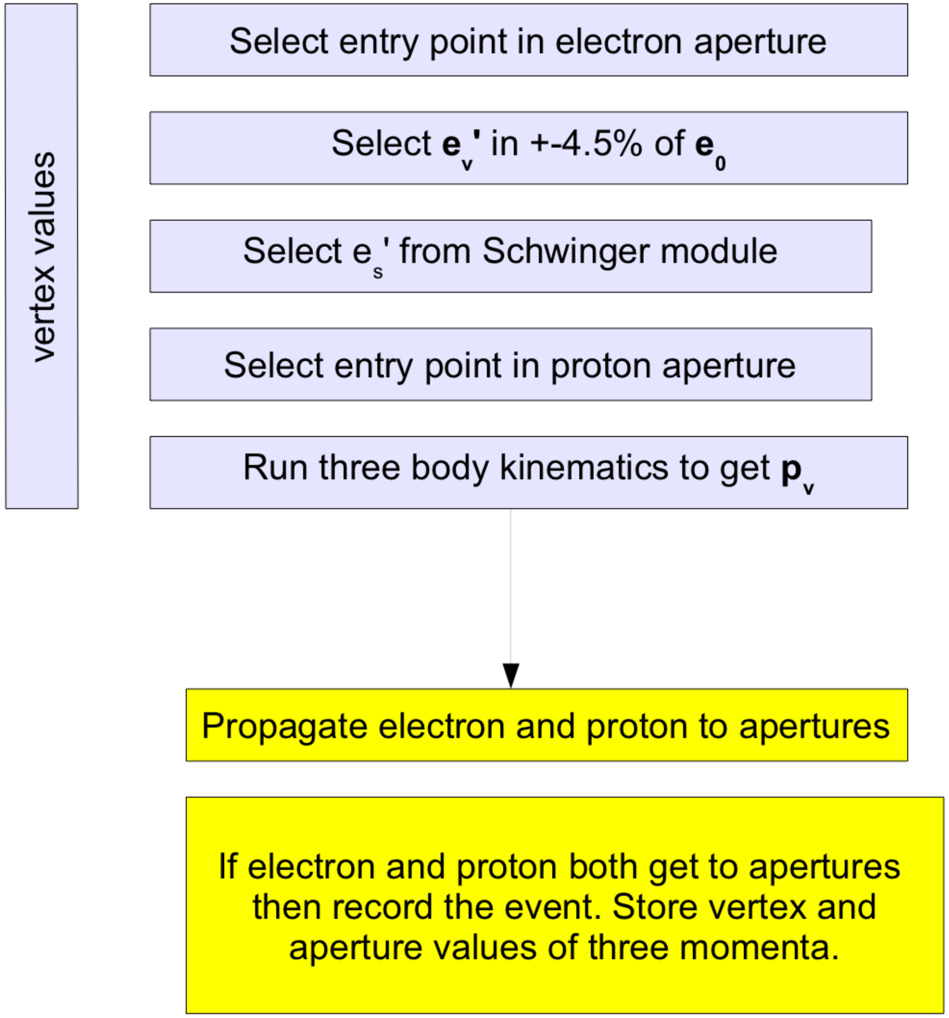
GEANT allows us to create root files which can
subsequently be analyzed and treated like data



^{4}He(e,e'p)X scattering from an extended gas target.

Electrons and protons from a vertex interaction in the ^{4}He gas enter the electron and proton spectrometers through apertures. The momenta at the vertex and at the apertures are recorded by GEANT.

GEANT Simulation steps



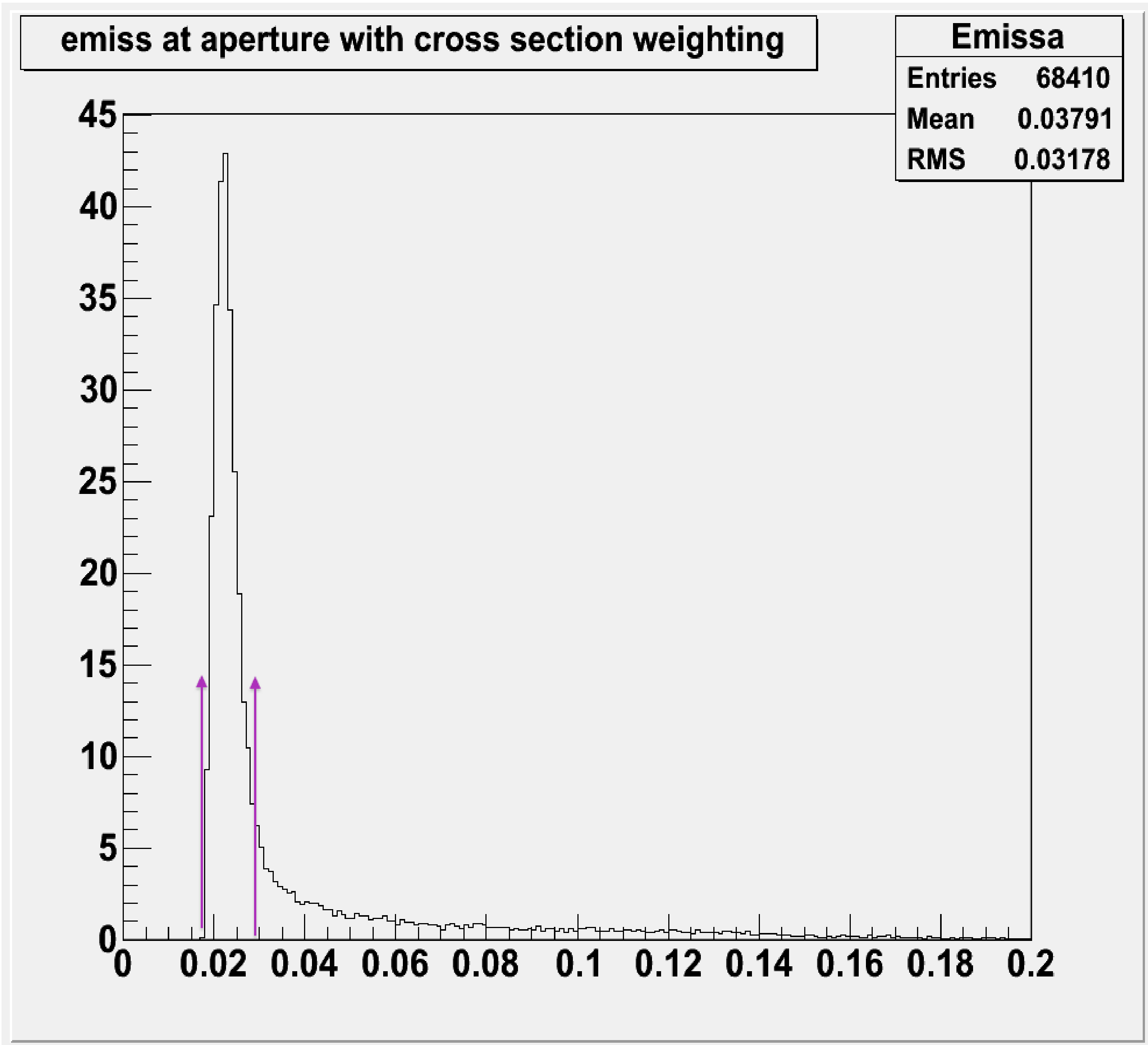
GEANT simulation steps.

The electron and proton three momenta are determined at the vertex. After propagating the electron and proton to the apertures the measured three momenta can be combined to yield the missing momentum and missing energy.

In the GEANT simulation we can specify the final three body state of e, p, and ^3H. We can plot the missing energy and missing momentum spectra.

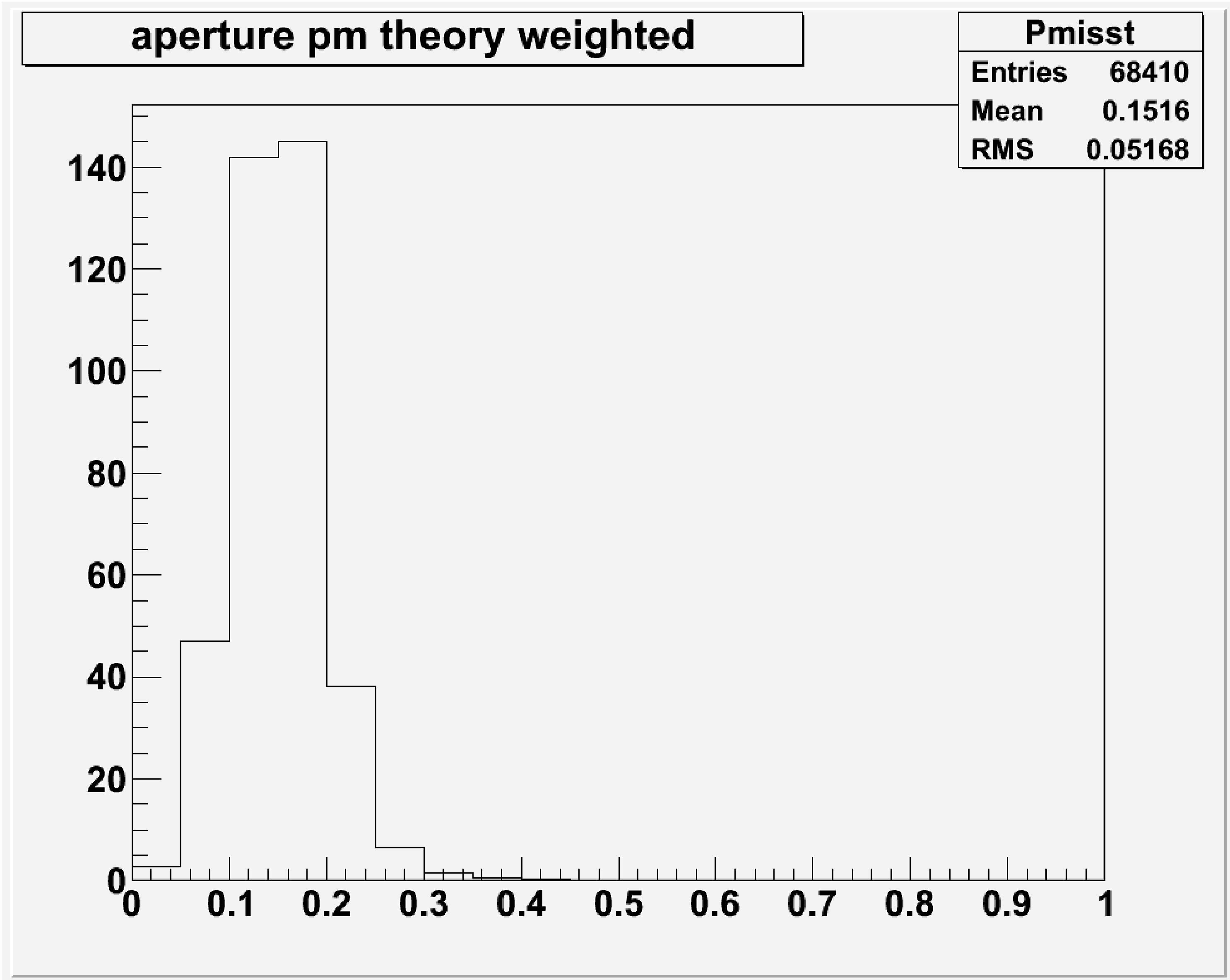
$$\text{Emiss} = \text{Ee} + \text{mass}(^4\text{He}) - (\text{Ee}' + \text{Ep} - \text{mass}(^3\text{H}))$$

Pmiss = Pe – Pe' – Pp (note: Use vector momenta!)



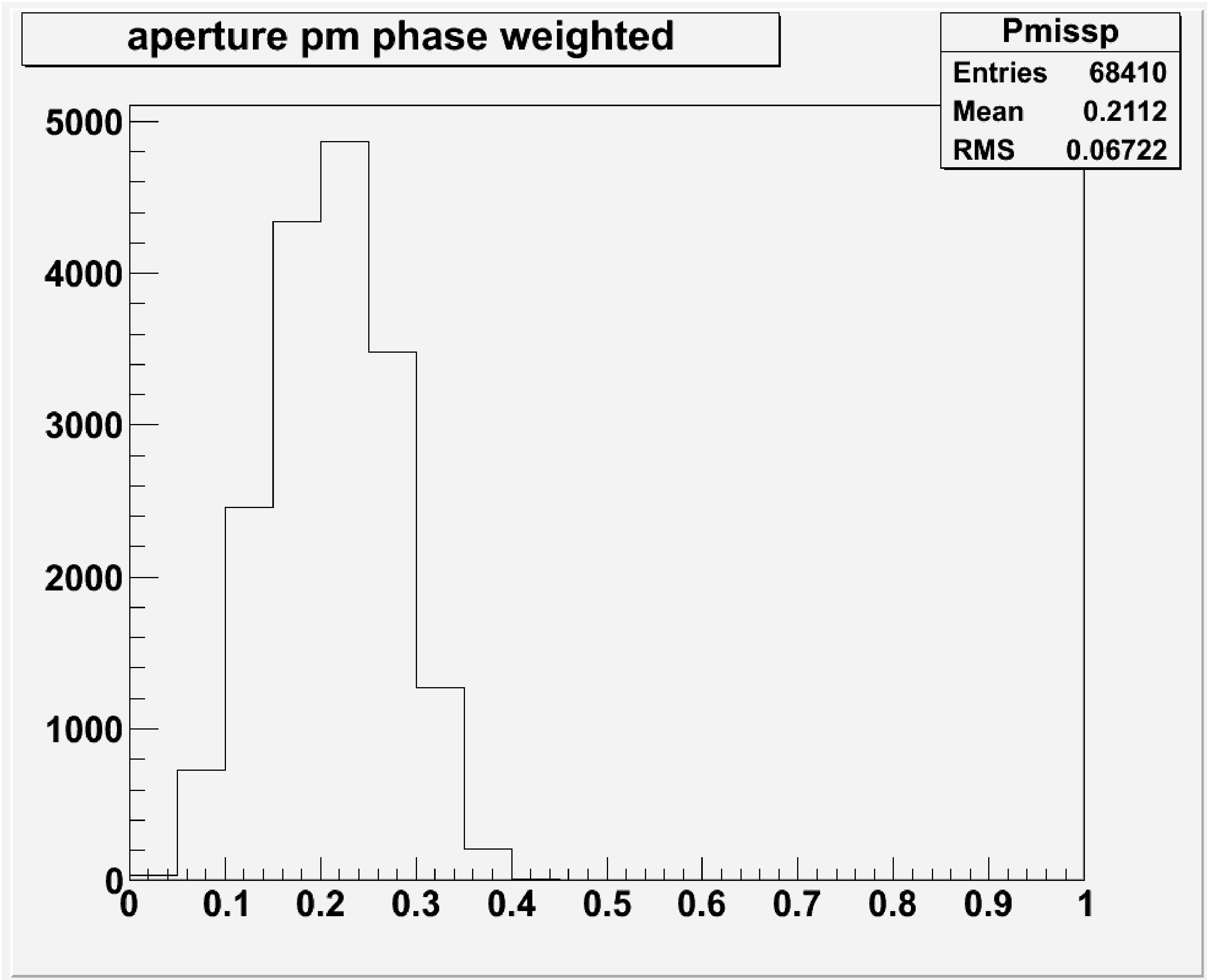
GEANT simulation

Missing energy (GeV)



GEANT simulation

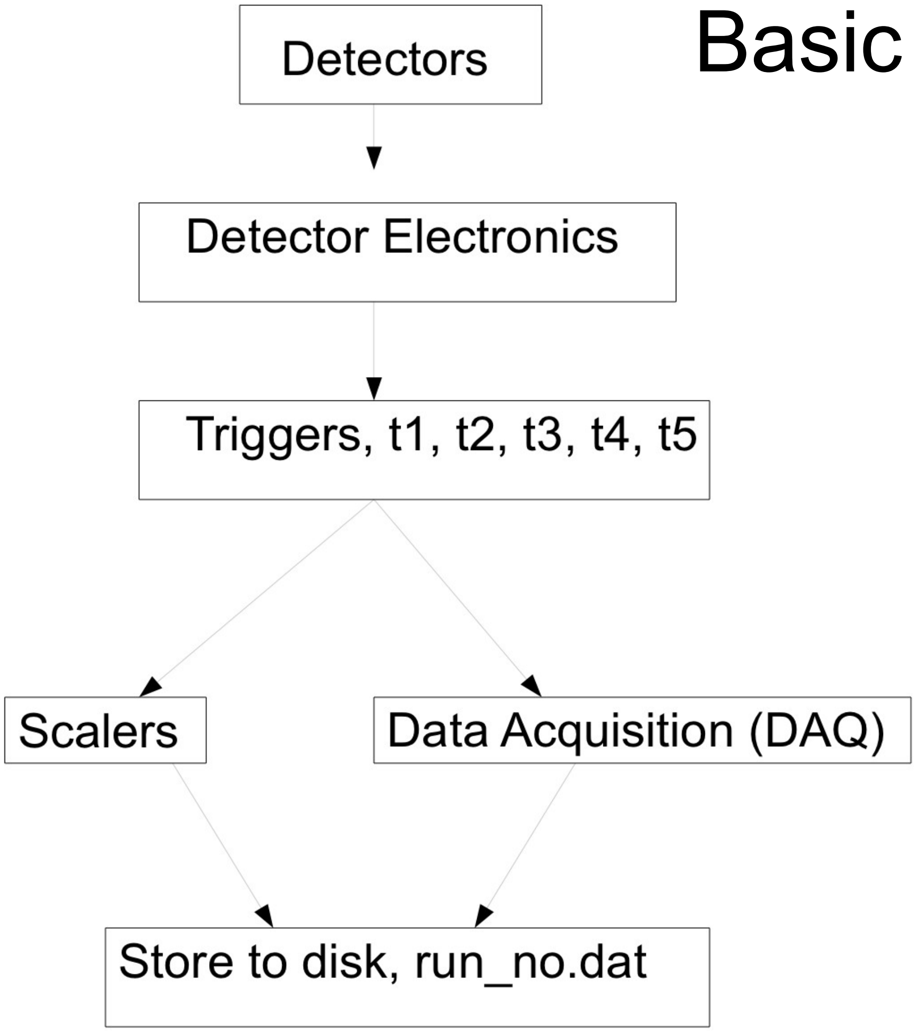
Missing momentum, GeV/c



GEANT simulation

Missing momentum, GeV/c

Basic Data Acquisition for Hall A



Basic Data Acquisition for Hall A

Data acquisition flow

Scalers are fast and have small, but measurable, deadtime.

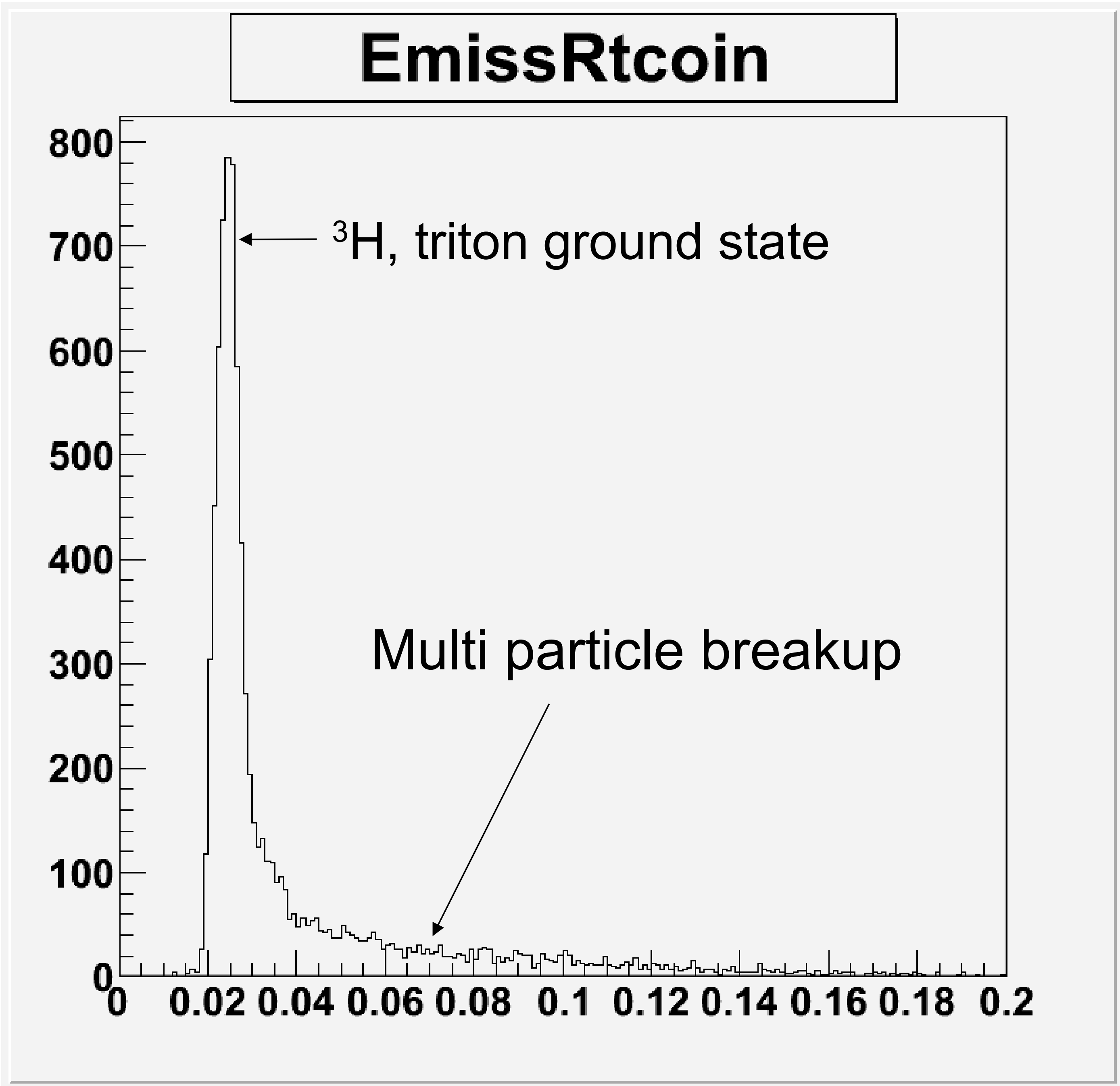
DAQ gives the main deadtime effect. Events actually recorded on disk are compared to total triggers sent to the scalers to get DAQ live time.

Data Analysis

1) Tabulate the triggers t1, t2, t3, t4, t5 and events recorded per run to get data acquisition dead time.

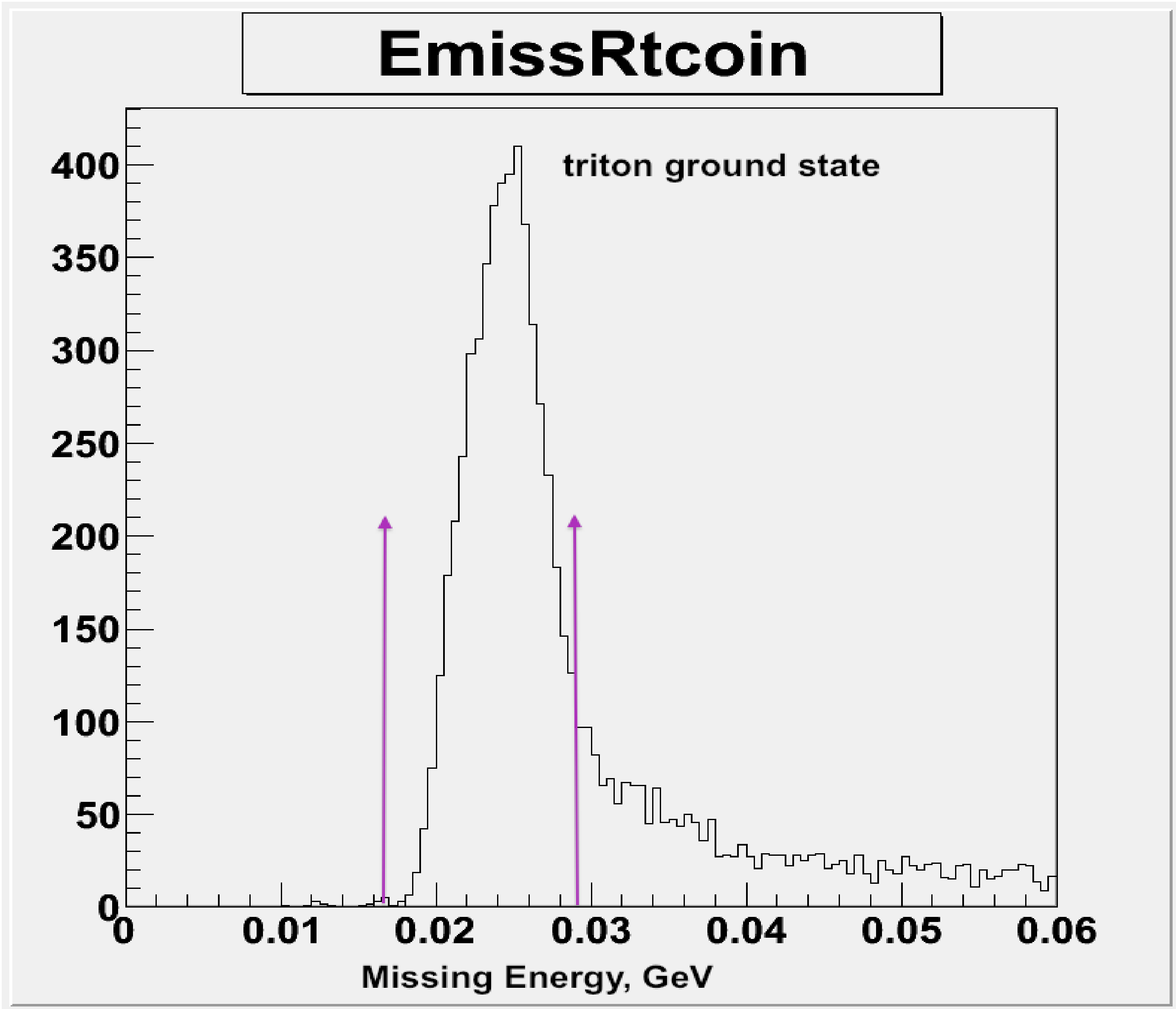
2) Select the cut in the missing energy spectrum to determine the valid region for triton (^3H) events. This is needed to make the correction for the radiative tail under the high missing energy portion of the spectrum.

3) Record the target temperature and pressure and total charge that passed through the target. Record the beam current magnitude to make the beam heating effect correction.



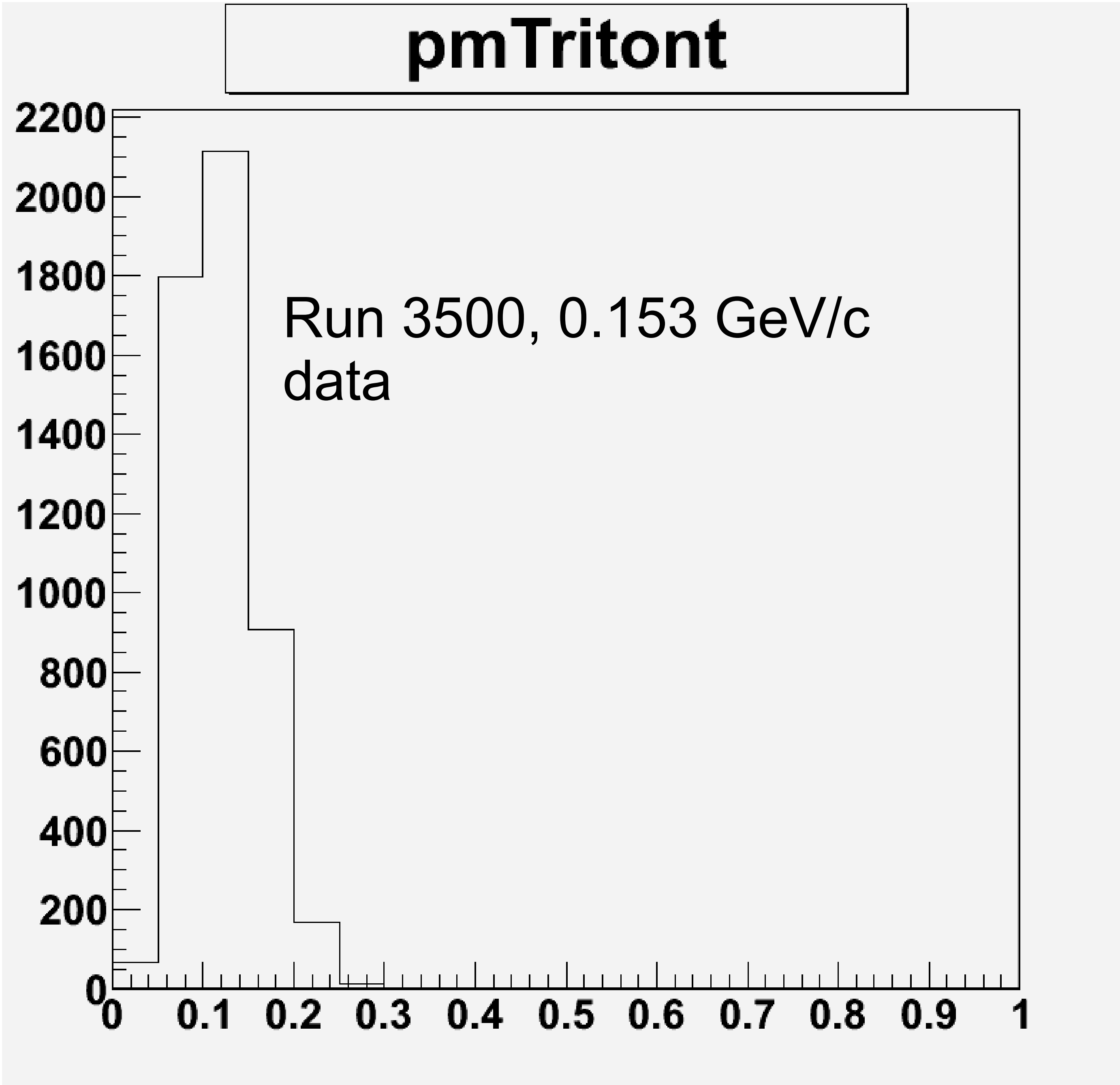
Missing energy (GeV) for run 3500, data

$^{4}He(e,e'p)X$



Run 3500 expanded view showing the region assumed to be good tritons

Missing energy (GeV)



Missing momentum GeV/c

Missing momentum spectrum with a cut on the triton peak in the missing energy spectrum.

The cross section for a missing momentum bin requires that we divide the measure counts per p_{miss} bin by the detection efficiency for that pmiss bin.

Use the GEANT simulation to obtain the p_{miss} detection efficiency.

Table 1: GEANT simulation for the 0.153 GeV/c missing momentum setting for e08009. Missing momentum is weighted by phase = $sin(\theta_e)sin(\theta_p)$ for the vertex values and the aperture values(See fig. 3.). The efficiency(eff(p_m)= counts(p_m)/17389) for missing momentum acceptance at the aperture is tabulated. The theoretical cross section weighted by the $sin(\theta_e)sin(\theta_p)$ (See fig. 4.) is tabulated. The average cross section for the missing momentum bin in nb/MeV/Sr^2 is the last entry. Note that the theoretical cross sections for $p_m <$ 0.153 GeV/c are deliberately fixed at the cross section for 0.153 GeV/c missing momentum*.

p_m bin GeV/c	vertex phase	aperture phase	efficiency(p_m)	aperture theory	average cross section nb/MeV/Sr^2
00.0-0.05	50.6	38.7	0.00223	2.7	0.06977*
0.05-0.10	854	731	0.04204	47	0.06430*
0.10-0.15	2623	2456	0.14124	142	0.05782*
0.15-0.20	4428	4341	0.24964	145	0.03340
0.20-0.25	4791	4864	0.2792	38	0.00781
0.25-0.30	3354	3484	0.20036	6.5	0.00187
0.30-0.35	1155	1270	0.07303	1.46	0.00115
0.35-0.40	161	204.6	0.01177	0.6	0.00293
total		17389	1.00		

Example of obtaining the p_{miss} detection efficiency from GEANT