Analysis Updates for A_1^n

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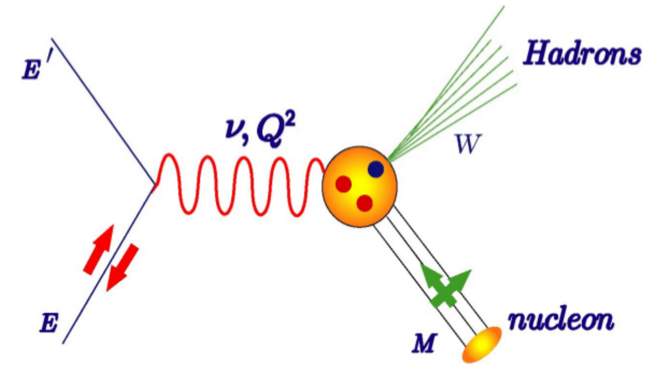
Outline:

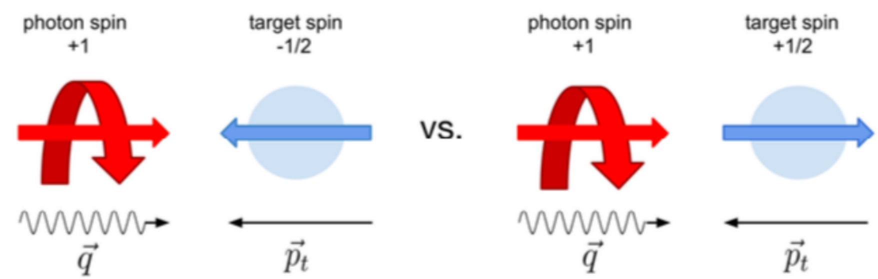
1. Introduction
2. Window Dilution Study
3. A_1^n Asymmetry Analysis
4. Summary and Future work
5. Extra Slides: PID Studies

Longitudinal Virtual Photon Asymmetry A_1

- $Q^2 =$ 4-momentum of virtual photon squared
- $\nu =$ Energy transfer
- $\theta =$ Scattering angle
- $x = \frac{Q^2}{2M\nu} =$ Fraction of nucleon momentum carried by the struck quark



$$A_1 = \frac{g_1 - \frac{(2Mx)^2}{Q^2} g_2}{F_1} = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}}$$



Anti-parallel spins

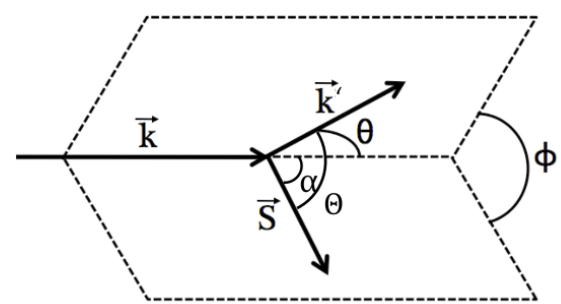
Parallel spins

$$A_1 = \frac{1}{(E+E')D'}\left[(E - E'\cos\theta)A_{\parallel} - \frac{E'\sin\theta}{\cos\phi}A_{\perp}\right]$$

$$\boxed{A_{\parallel} = \frac{\sigma_{\downarrow\uparrow} - \sigma_{\uparrow\uparrow}}{\sigma_{\downarrow\uparrow} + \sigma_{\uparrow\uparrow}}}$$

$$\boxed{A_{\perp} = \frac{\sigma_{\downarrow\rightarrow} - \sigma_{\uparrow\rightarrow}}{\sigma_{\downarrow\rightarrow} + \sigma_{\uparrow\rightarrow}}}$$

$$\boxed{D' = \frac{(1-\epsilon)(2-y)}{y[1+\epsilon R]}}$$



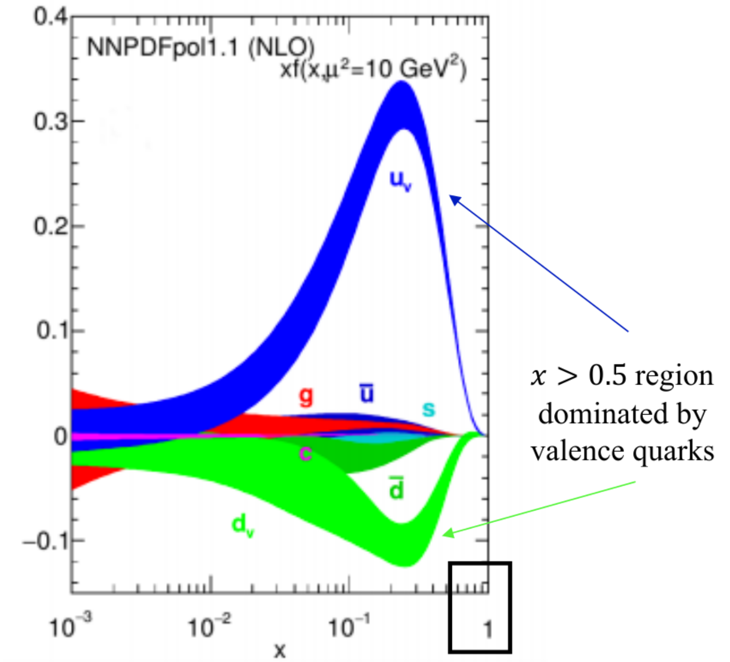
- Angular kinematics for polarized electron scattering

Goals for A_1^n Experiment

- Precisely measure the neutron spin asymmetry A_1^n in the far valence domain (0.61<x<0.77) for the first time.
- Explore the Q^2 dependence of A_1^n with large x value.
- After combining with proton data (CLAS12), extract polarized to unpolarized parton distribution function (PDF) ratios Δu/u (Δd/d) for large x region.
- Give more insights on understanding the spin structure of nucleon.

	$\frac{F_2^n}{F_2^p}$	$\frac{d}{u}$	$\frac{\Delta d}{\Delta u}$	$\frac{\Delta u}{u}$	$\frac{\Delta d}{d}$	A_1^n	A_1^p
DSE-1	0.49	0.28	−0.11	0.65	−0.26	0.17	0.59
DSE-2	0.41	0.18	−0.07	0.88	−0.33	0.34	0.88
$0^+_{[ud]}$	$\frac{1}{4}$	0	0	1	0	1	1
NJL	0.43	0.20	−0.06	0.80	−0.25	0.35	0.77
SU(6)	$\frac{2}{3}$	$\frac{1}{2}$	$-\frac{1}{4}$	$\frac{2}{3}$	$-\frac{1}{3}$	0	$\frac{5}{9}$
CQM	$\frac{1}{4}$	0	0	1	$-\frac{1}{3}$	1	1
pQCD	$\frac{3}{7}$	$\frac{1}{5}$	$\frac{1}{5}$	1	1	1	1

Table 1: Predictions for the x = 1 value of various models. From Craig D. Roberts et al 10.1016/j.physletb.2013.09.038



Polarized and sea quark PDFs for Q^2 = 10 GeV^2 from the NNPDFpol1.1 parameterization

See *Nocera ER, et al. Nucl. Phys. B887:276 (2014).*

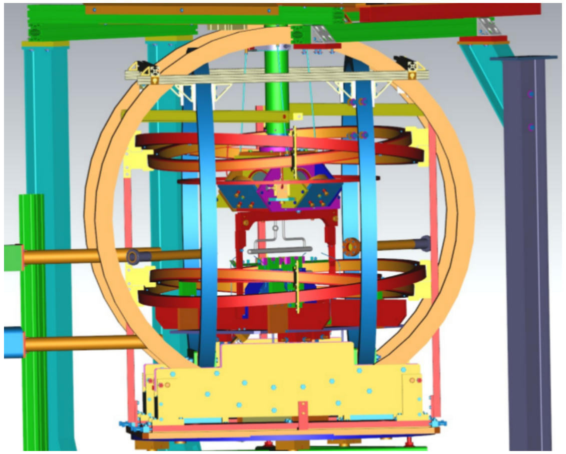
Experimental Setup

Kine	Spec	E_b GeV	E_p GeV	θ ($\circ$)	beam time (hours)
$\Delta(1232)$	SHMS	2.17	-1.79736	8.5	4.0
Elastic	SHMS	2.17	-2.12860	8.5	8.0

Electron Beam:

- E_{beam}=2.17 GeV (1-pass commission)
- E_{beam}=10.38 GeV (5-pass DIS production)
- Beam polarization: 85%
  (<3% uncertainty by Moller Polarimeter)
- Circular beam raster with 2.0-2.5mm radius
- < 50 ppm charge asymmetry
  (average over ~ 1–2 hr run)

Kine	Spec	E_b GeV	E_p GeV	θ ($\circ$)	e^- production (hours)	e^+ prod. (hours)	Tot. Time (hours)
DIS							
3	HMS	10.38	2.90	30.0	88.0	0.0	88.0
4	HMS	10.38	3.50	30.0	511.0	0.0	511.0
B	SHMS	10.38	3.40	30.0	511.0	4.0	515.0
C	SHMS	10.38	2.60	30.0	88.0	4.0	92.0



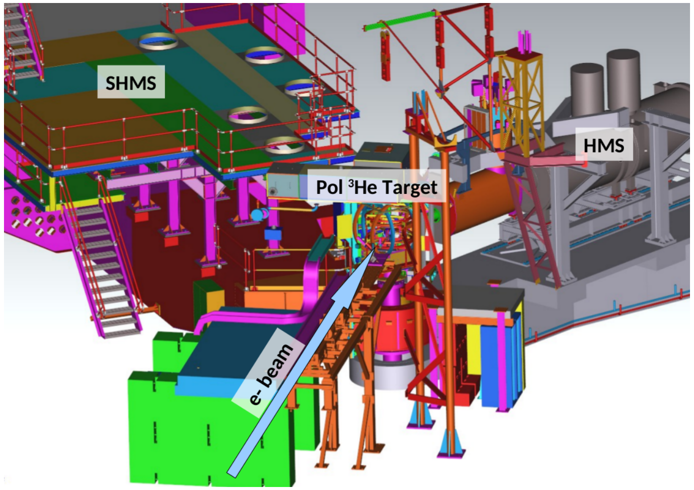
- A_1^n production run begins on Jan 12th, 2020 and ended on March 13th, 2020.

Polarized ^{3}He target:

- ^{3}He production cell (40cm)
- 55–60% polarization without beam
- Reached over 50% polarization with 30 uA beam current
  (doubles performance compare to 6 GeV era)
- About 3% uncertainty for polarimetry

Spectrometers:

- High Momentum Spectrometer (HMS)
- Super HMS (SHMS)



Window Dilution Study

- Using mc-single-arm to generate events for simulation and F1F2IN09 model (from rc-externals) for radiated cross-section to get the simulation for target chamber of the ^{3}He production cell and empty reference cell.
- Perform simulation separately for different target material (N_2 gas between upstream beam-line window and upstream target window; Upstream target window; ^{3}He in target chamber ; Downstream target window), then combine them to obtain the simulation for entire target.
- Get replayed data from hallc_replay with updated optics matrix. After weighted by yield, make comparison with simulation and replayed data.
- Based on simulation and replayed data, determine the window contribution along reconstructed z_{target}.

Propose and Goal of the Study

Propose:

- Provide a guide to determine z_{target} cuts to remove events coming from glass windows while preserve most of events from ^3He inside target chamber.
- Estimate window dilution factor for certain production run condition (certain target cell, kinematics, spec) based on simulated results and replayed data.

Goal:

- For certain production run condition (certain target cell, kinematics, spec), the variation of window dilution factor is less than 3%.
- Find a proper z_{target} cuts so that the ΔA_{phys} become minimal.

Determine Yield

(for compare simulation with replayed data)

Replayed data:

- Obtain total charge (BCM1 Coulomb value) for a run from corresponding report file after hallc_replay.
- Then the yield is determined to weight the replayed histograms:

$$\boxed{Yield = \frac{number\ of\ events}{total\ charge\,(C)}}$$

Simulation:

- For simulation, DIS cross-section $\frac{d^2\sigma}{dE\,d\Omega}$ for each target material is calculated by Jixie's "CreateXSTree" program using F1F2IN09 model.

- Then the yield is determined to weight the simulation histograms:

$$\boxed{Yield = rate\,\frac{1}{beam\,current\,(A)} = \frac{d^2\sigma}{dE\,d\Omega}\,E'\,\frac{\Delta E}{E}\,\Delta\phi_{tag}\,\Delta\theta_{tag}\,\rho_N\,\frac{target_{length}}{e_{charge} * N_{trials}}}$$

Where p_N is atom number density: $\boxed{\rho_N = \frac{\rho_m N_A}{M}}$

Cut used for Comparison
(Simulation vs. replayed data)

HMS cuts:

Acceptance cut:

- Delta cut: (-8%, 8%)
- Theta cut: (-70 mr, 70 mr)
- Phi cut: (-100 mr, 100 mr)

z_{tar} cut:

- abs(H.react.z)<30.0 (cm)

Current cut:

- ibcm1>1.0 (uA)

PID cut:

- H.cal.etracknorm>0.8 && H.cal.etracknorm<2.0 && H.cer.npeSum>1

Simulation cut used for comparison between simulation and replayed results :

- istop==0 (remove failed events)

SHMS cuts:

Acceptance cut:

- Delta cut: (-10%, 22%)
- Theta cut: (-55 mr, 55 mr)
- Phi cut: (-50 mr, 50 mr)

z_{tar} cut:

- abs(P.react.z)<30.0 (cm)

Current cut:

- ibcm1>1.0 (uA)

PID cut:

- P.cal.etracknorm>0.8 && P.cal.etracknorm<2.0 && P.ngcer.npeSum>1

Simulation cut used for comparison between simulation and replayed results :

- istop==0 (remove failed events)

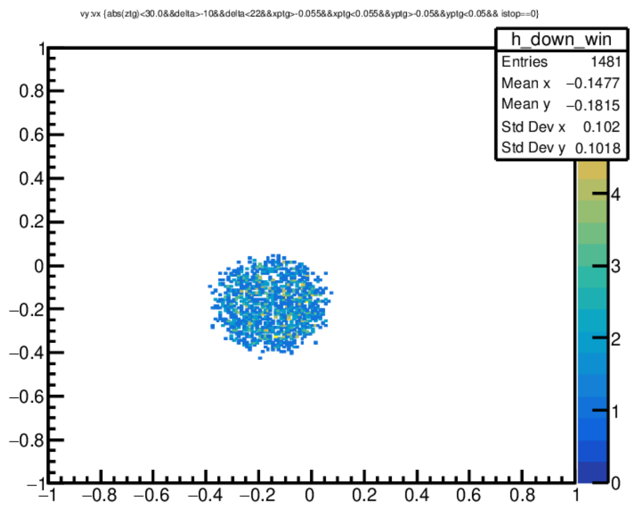
Note on replay cuts:

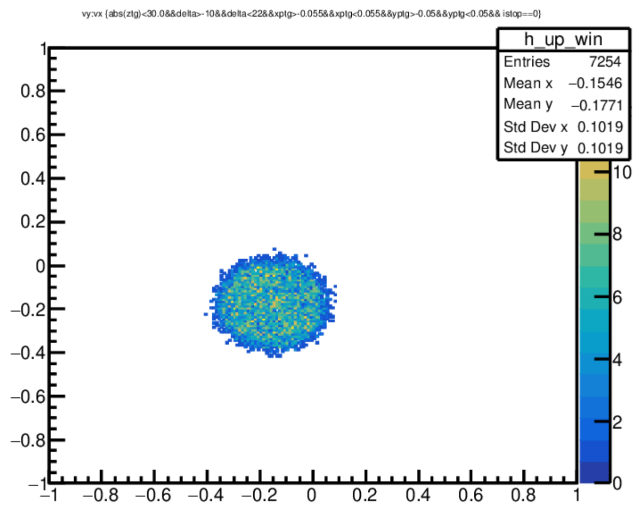
- Current cut is used to remove non-physical events during beam trip.
- PID cut provides requirement for good track and remove pion contamination.

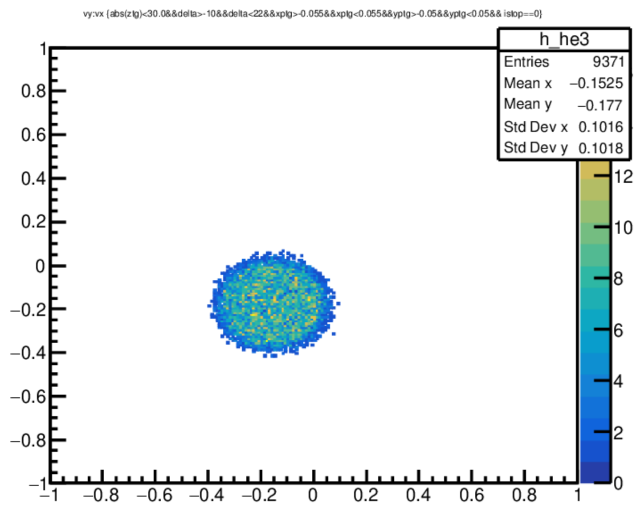
Circular Raster

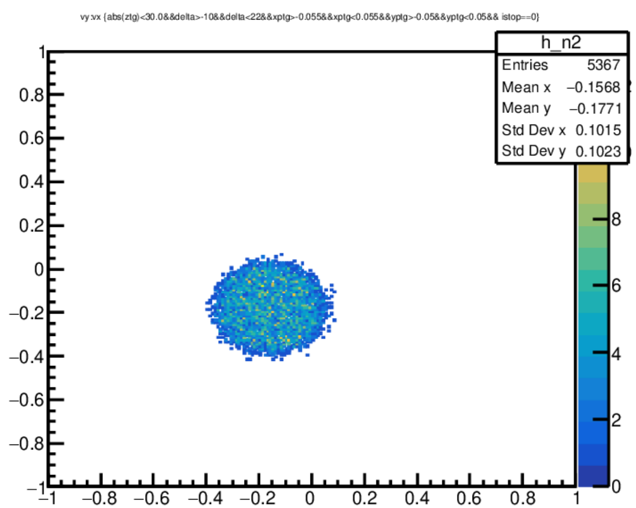
(Plot of y_{beam} vs. x_{beam})

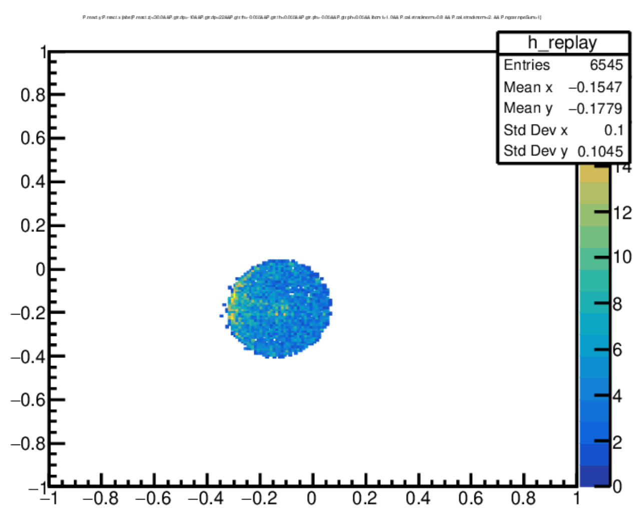
- SHMS 10602: ^{3}He DIS, Transverse 90°
- E_p=-3.4 GeV, 30°, kin-B
- Trigger: 3/4 (hTRIG1)











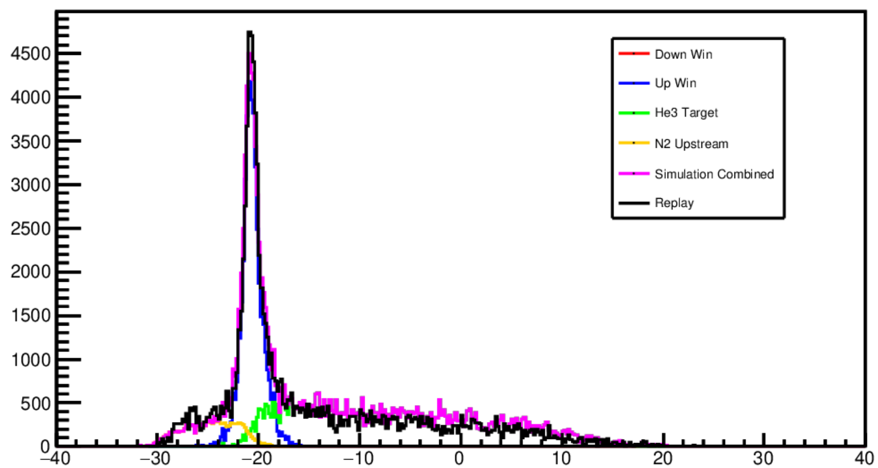
- From replayed runs, obtain x_{beam} and y_{beam} offsets from mean value.
- Add x_{beam} and y_{beam} offsets from replay into simulation in order to compare replayed data with simulated results.

^{3}He Target Simulation

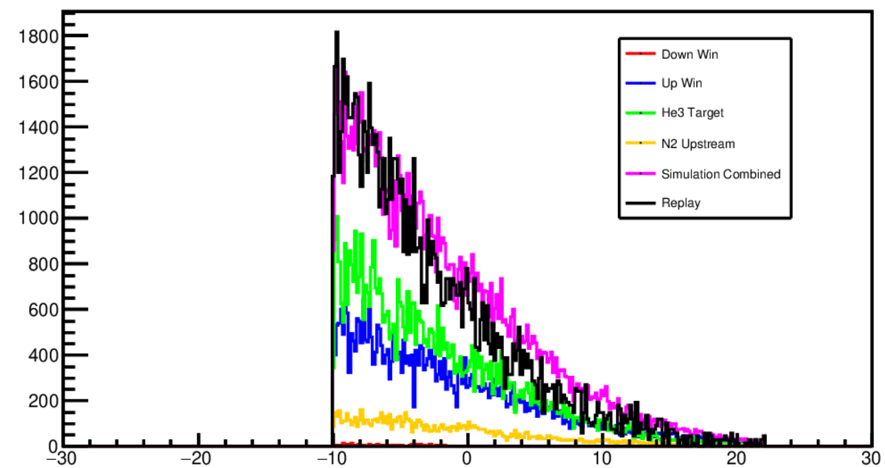
(Compare with replayed root file results)

- SHMS 10602: ^{3}He DIS, Transverse 90°
- E_p=-3.4 GeV, 30°, kin-B
- Trigger: 3/4 (hTRIG1)

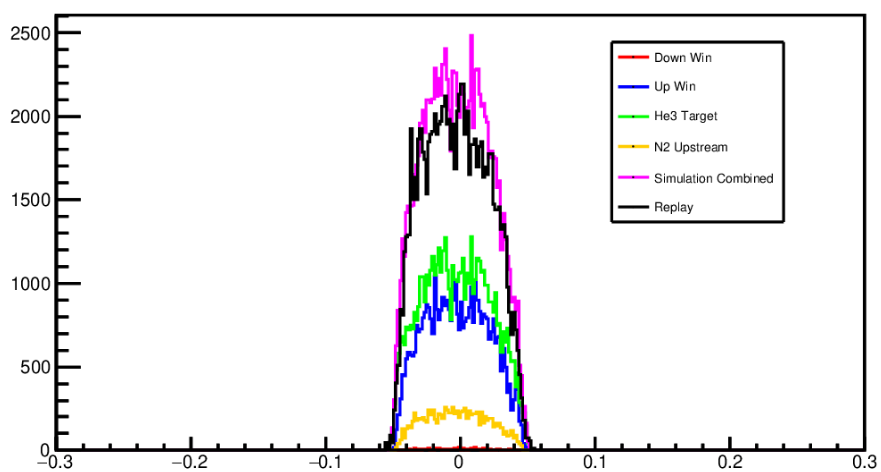
ztg_combined Weighted by Yield



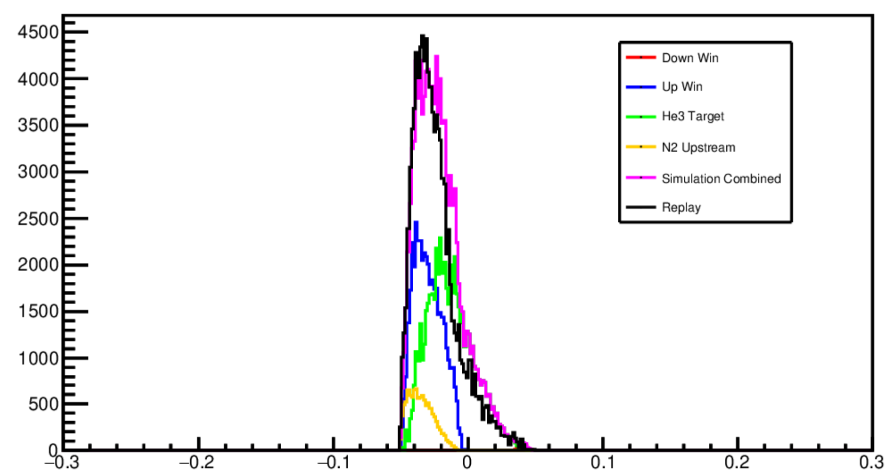
delta_combined Weighted by Yield



theta_combined Weighted by Yield



phi_combined Weighted by Yield

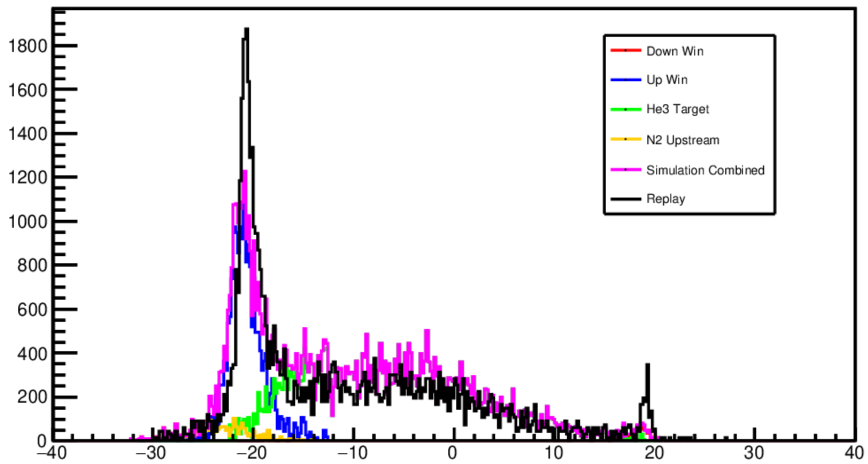


^{3}He Target Simulation

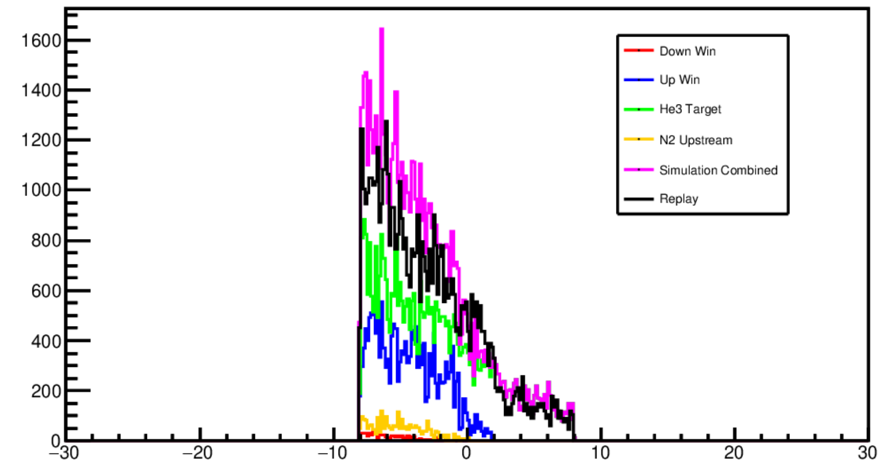
(Compare with replayed root file results)

- HMS 3408: ^{3}He DIS, Transverse 90°
- E_p=-3.5 GeV, 30°, kin-4
- Trigger: 3/4 (hTRIG1)

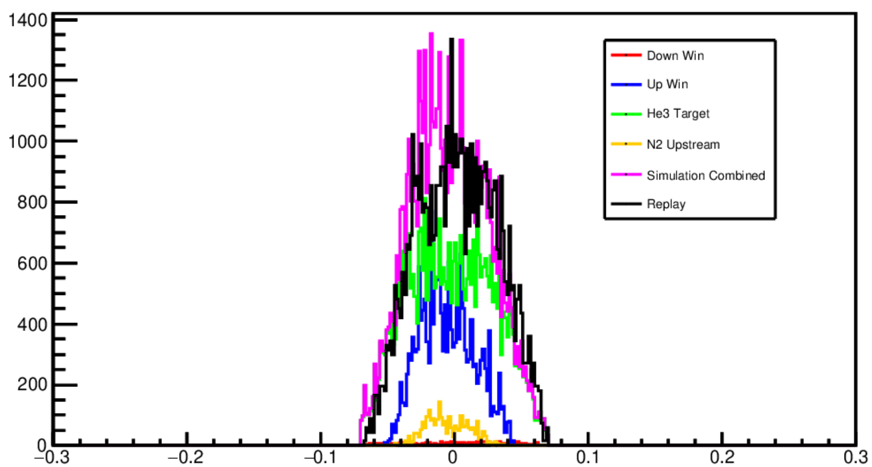
ztg_combined Weighted by Yield



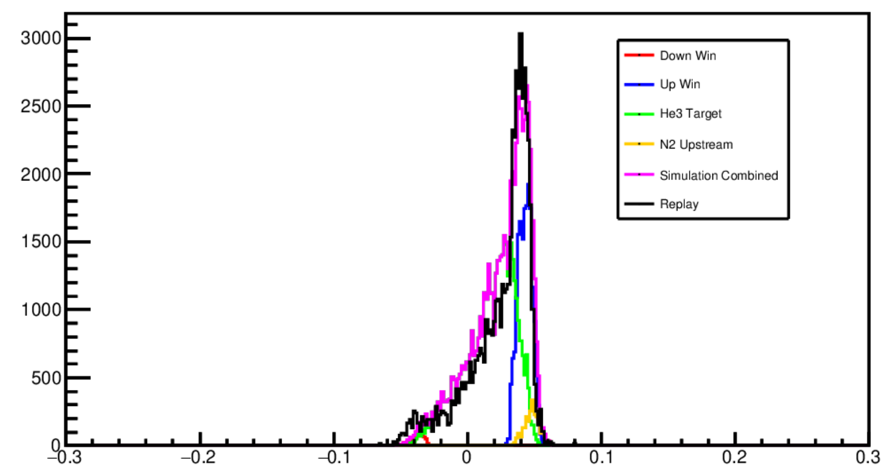
delta_combined Weighted by Yield



theta_combined Weighted by Yield

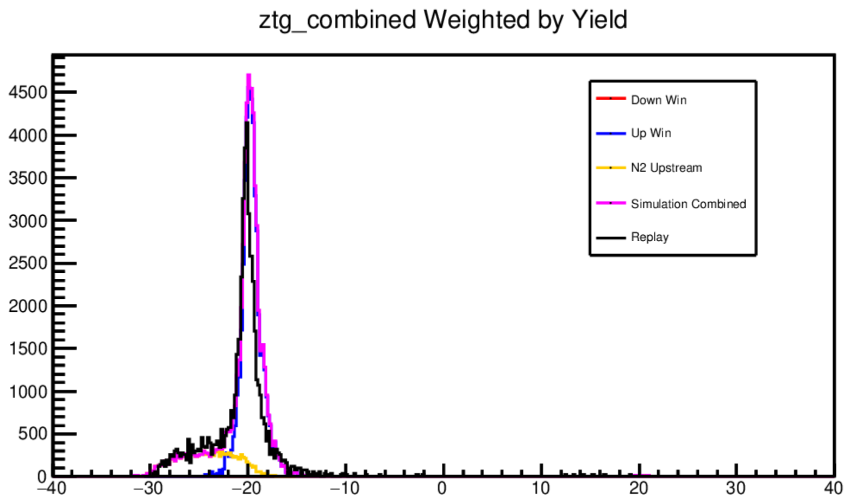


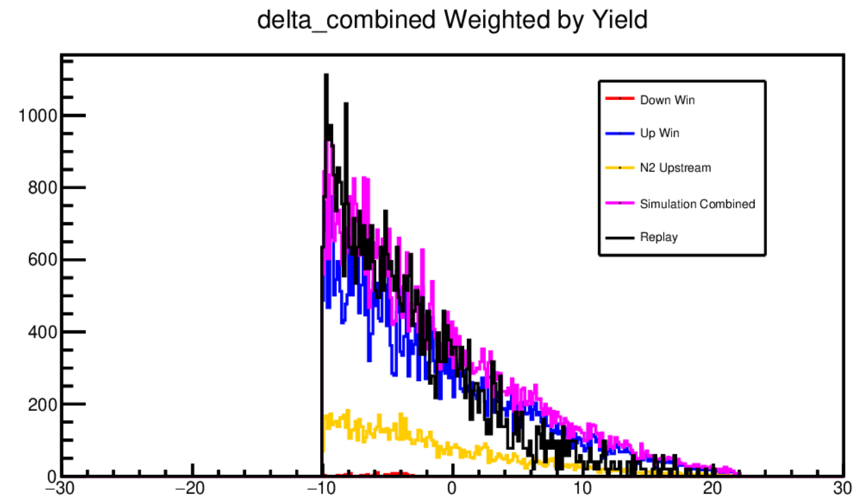
phi_combined Weighted by Yield

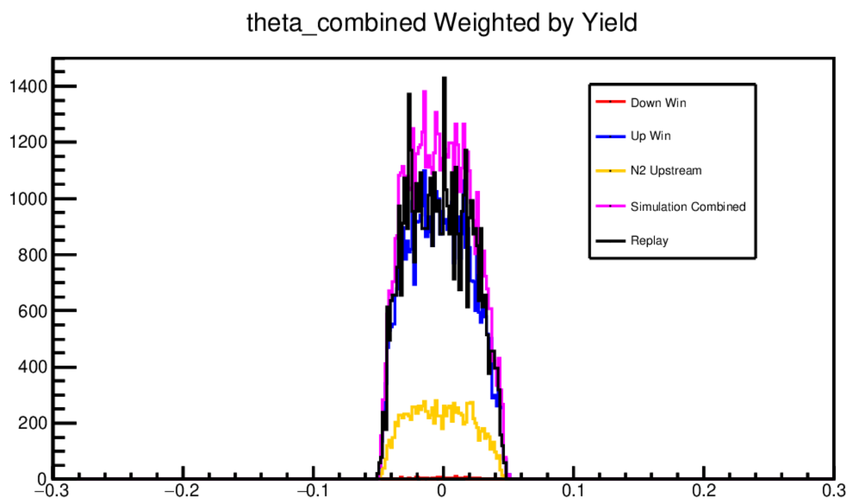


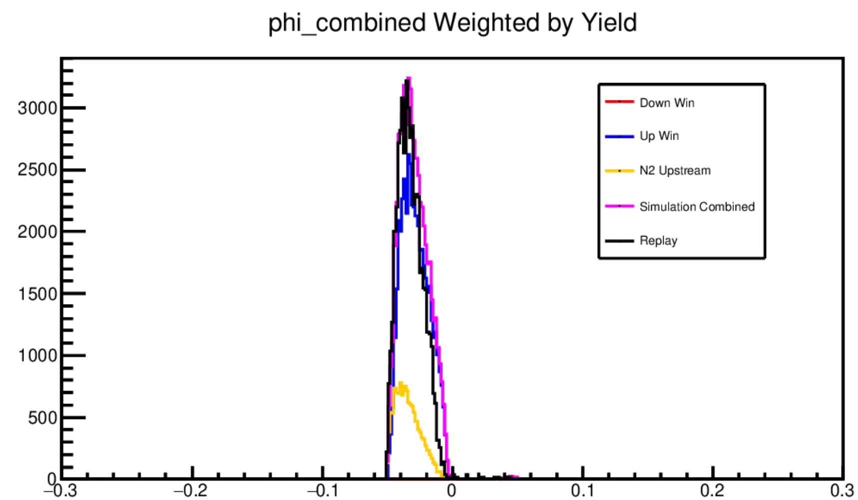
Empty Target Simulation
(Compare with replayed root file results)

- SHMS 10267: Empty Target DIS, Transverse 90°
- E_p=-3.4 GeV, 30°, kin-B
- Trigger: 3/4 (hTRIG1)



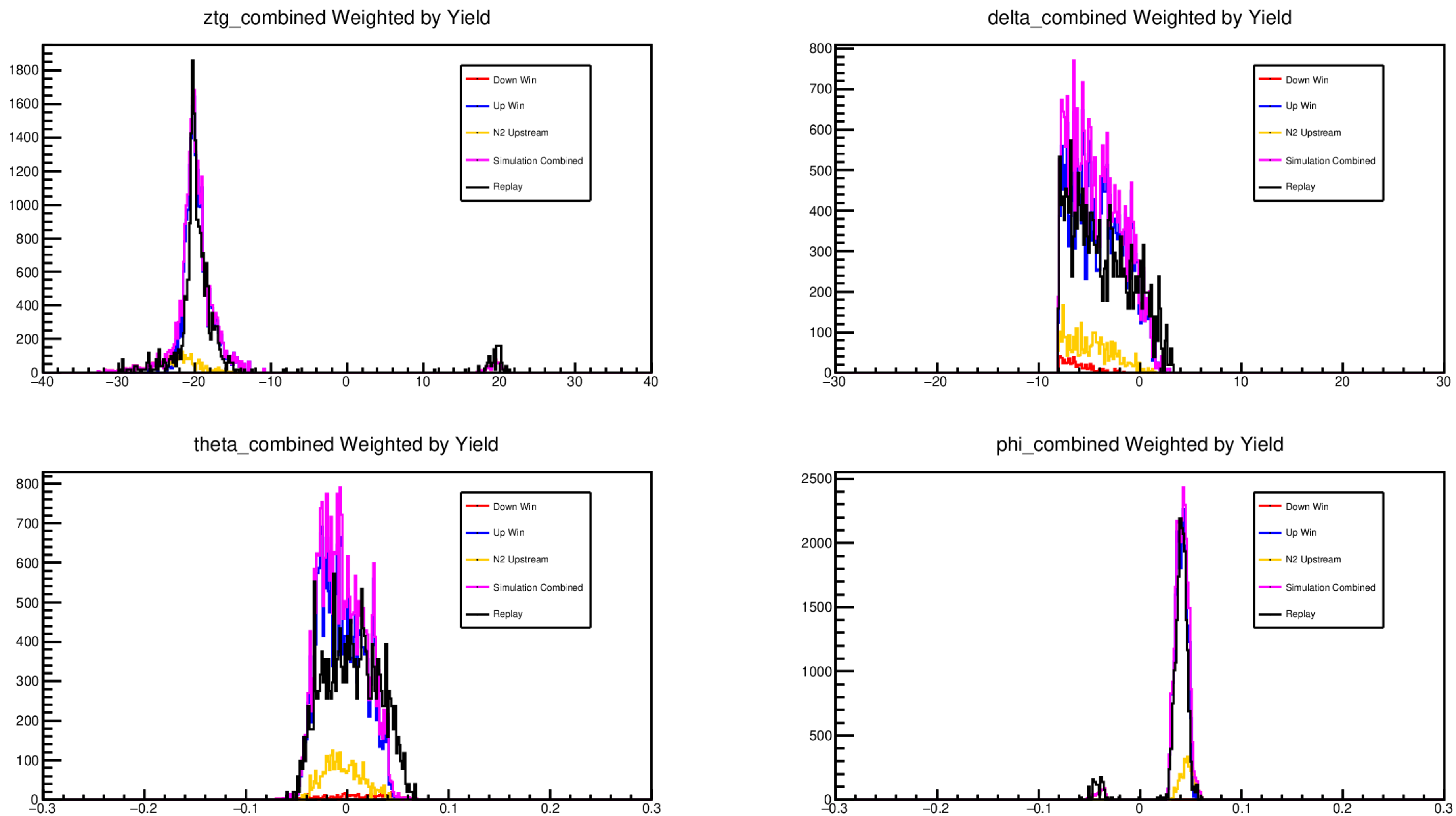






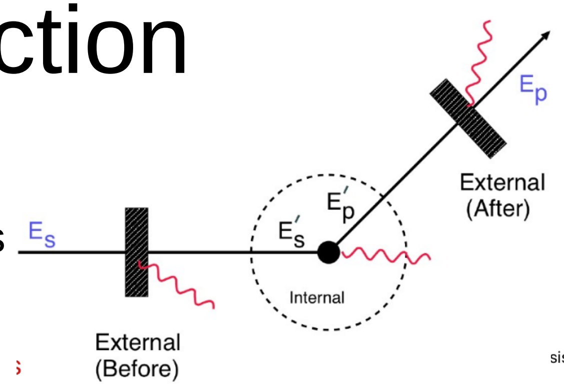
Empty Target Simulation
(Compare with replayed root file results)

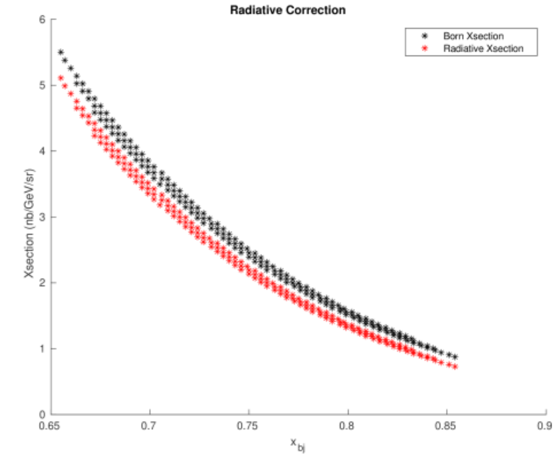
- HMS 3077: Empty Target DIS, Transverse 90°
- E_p=-3.5 GeV, 30°, kin-4
- Trigger: 3/4 (hTRIG1)



Radiated Cross Section

(Bilinear Interpolation)

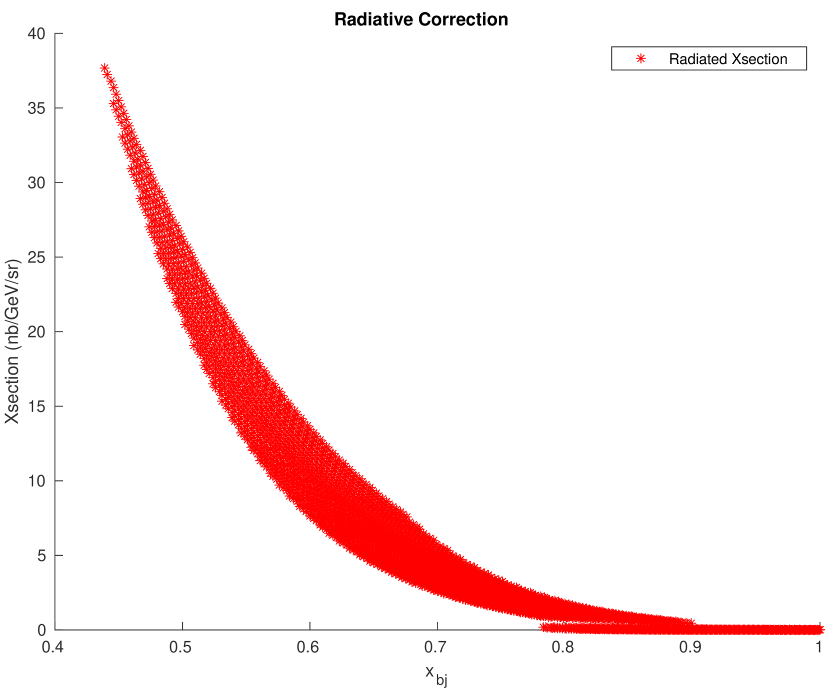




- The measured cross section contains effects due to interactions with materials (ionization, bremsstrahlung) and vertex effects (bremsstrahlung)
- The radiated cross section is:

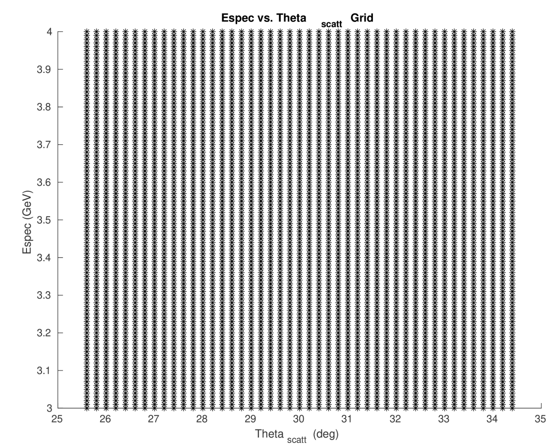
$$\sigma_{rad} = \sigma_{Born} + \sigma_{RC}$$

- Use "rc-externals" obtain (p0, theta0, rad_xsec) square grid, then apply billinear interpolation to get rad xsection for give mc simulated event.



- Dutch upstream win hms kine4

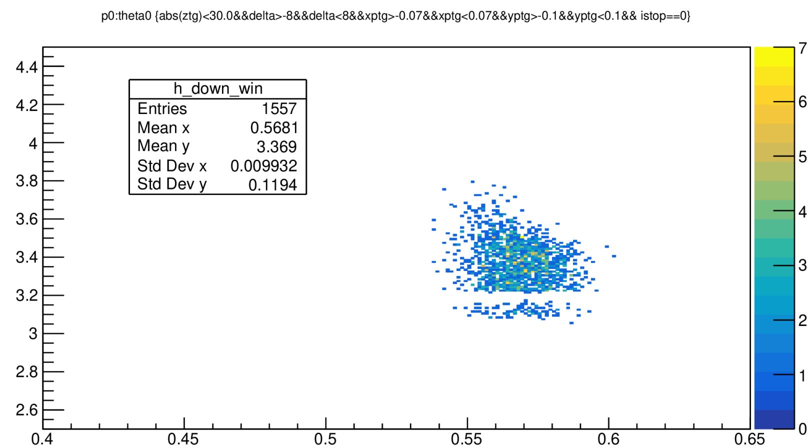
```
//[determine order of four points]
double fll,fhl,flh,fhh;
double xl,xh,yl,yh;//fll to xl; fhl to yl; flh to yh; fhh to xh
double x0,y0;
x0=p0temp;
y0=theta0temp;
fll=rad_corr_temp1;
fhl=rad_corr_temp2;
flh=rad_corr_temp3;
fhh=rad_corr_temp4;
xl=p0_table_1;
yl=theta0_table_2;
yh=theta0_table_3;
xh=p0_table_4;
```

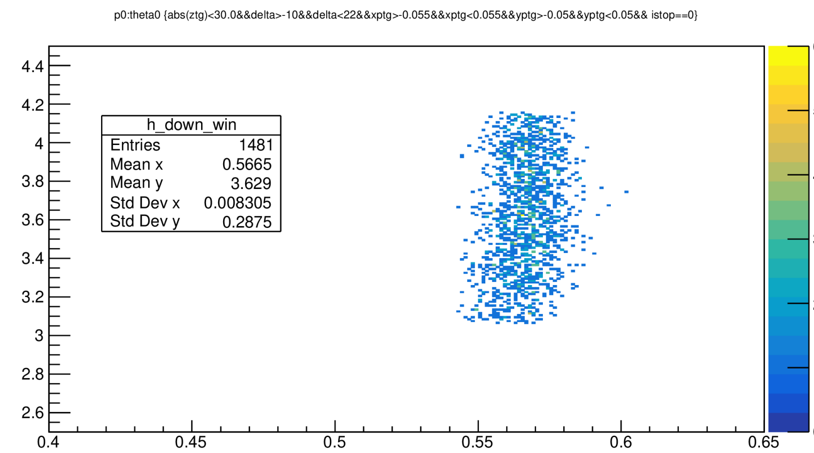


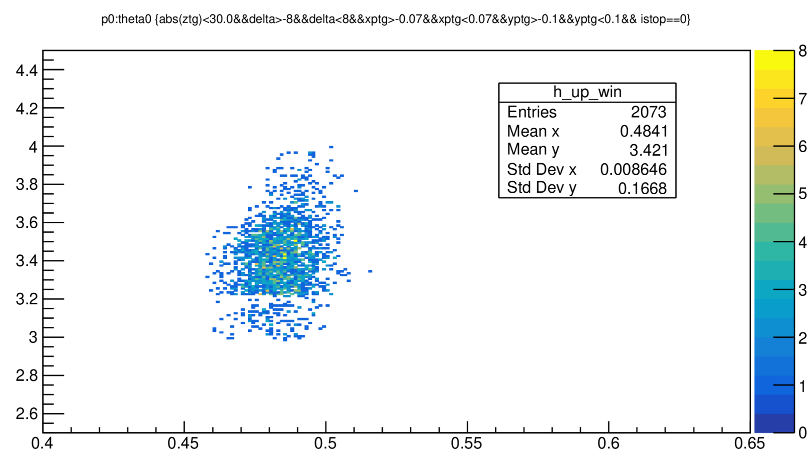

```
//[2d bilinear interpolation]

        // weight factors for interpolation
        double xwl  = (x0-xl)/(xh-xl);
        double xwh  = (xh-x0)/(xh-xl);
        double ywl  = (y0-yl)/(yh-yl);
        double ywh  = (yh-y0)/(yh-yl);
 // put everything together
        double F00 = ywh*(xwh*fll + xwl*fhl) + ywl*(xwh*flh + xwl*fhh);
 xs_rad_temp=F00;
return xs_rad_temp;
}
```

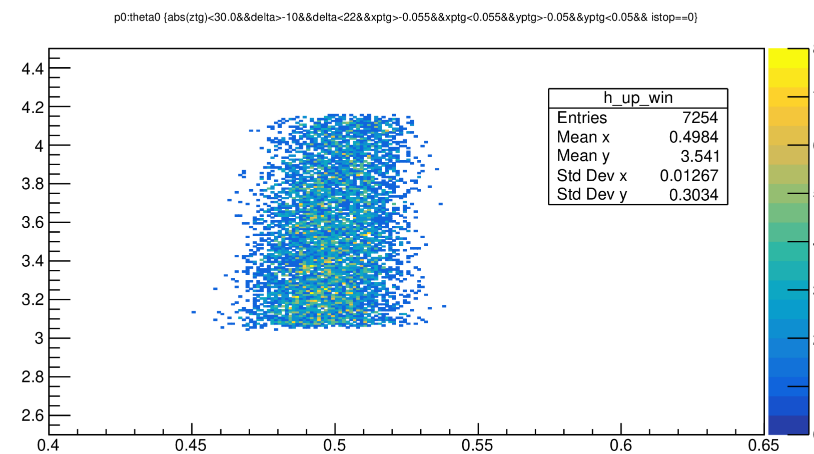
p0 vs theta0 from mc-single-arm

(for glass windows: Cell Dutch)









- HMS kine4 (with cuts)
  p0 range: 3 to 4 GeV
  theta0 range:25.6 to 34.6 deg

- SHMS kineB (with cuts)
  p0 range: 3.05 to 4.16 GeV
  theta0 range: 25.6 to 34.6 deg

```
p_rate_up=xs_rad_up*p_spec*p_accept*th_accept*ph_accept*dens_ge180*1e-34*beam_curr*1e-6*tar_len_up/100.0/(1.6*1e-19*n_trials);
p_rate_down=xs_rad_down*p_spec*p_accept*th_accept*ph_accept*dens_ge180*1e-34*beam_curr*1e-6*tar_len_down/100.0/(1.6*1e-19*n_trials);
```

Window Dilution

From Pol 3He target cell z_{target} histogram weighted by yield:

- N_{up}(3He)= integrated number of simulated events of upstream window within the z cut
- N_{down}(3He)= integrated number of simulated events of downstream window within the z cut
- N_0(3He)=integrated number of replayed events within the z cut

From empty reference cell z_{target} histogram weighted by yield:

- N_{up}(em)= integrated number of simulated events of upstream window within the z cut
- N_{down}(em)= integrated number of simulated events of downstream window within the z cut
- N_0(up, em)=integrated number of replayed events within the z cut for upstream window region
- N_0(down, em)=integrated number of replayed events within the z cut for downstream window region

- Then define window dilution factor f_{win}:

$$f_{win}=\frac{N_0(up,em)\frac{N_{up}(^3He)}{N_{up}(em)}+N_0(down,em)\frac{N_{down}(^3He)}{N_{down}(em)}}{N_0(^3He)}$$

- Since:

$$A_{phys}=\frac{A_{raw}}{P_b P_t f_{N2}(1-f_{win})}$$

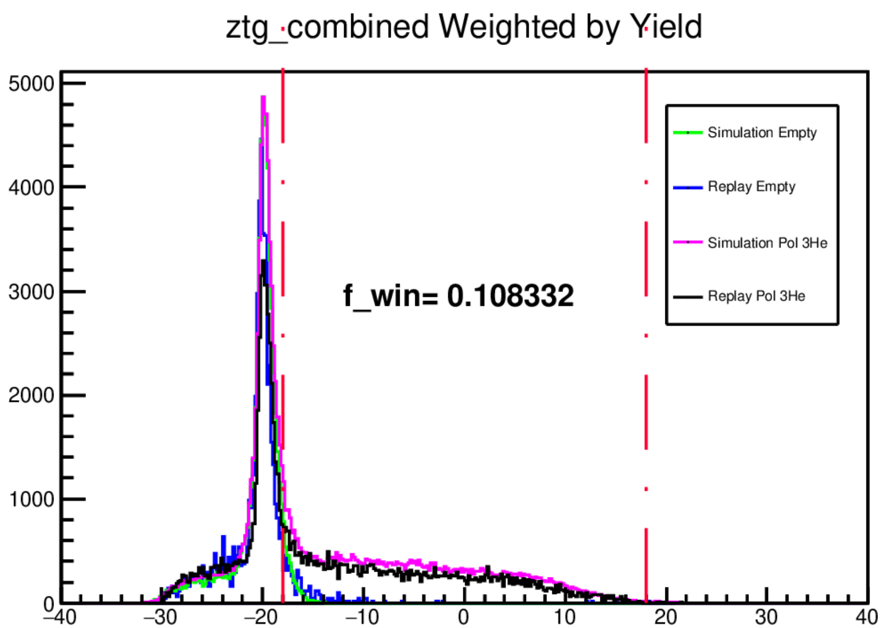
- We would like to place a proper window z cut to minimize ΔA_{phys}:

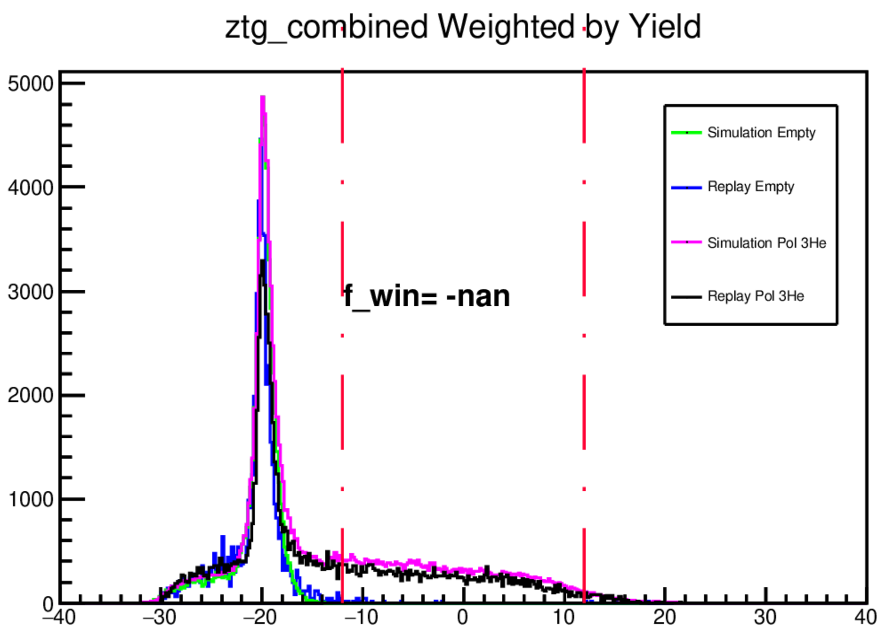
$$\Delta A_{phys}\propto\frac{1}{\sqrt{(N_0(^3He))}(1-f_{win})}$$

^{3}He Target Simulation

(Compare with replayed root file results)

$$f_{win}=\frac{N_0(up,em)\frac{N_{up}(^3He)}{N_{up}(em)}+N_0(down,em)\frac{N_{down}(^3He)}{N_{down}(em)}}{N_0(^3He)}$$





- z cut at z=±18.0 cm away from target chamber center position.

- z cut at z=±12.0 cm away from target chamber center position.

Pol 3He run on cell Dutch:

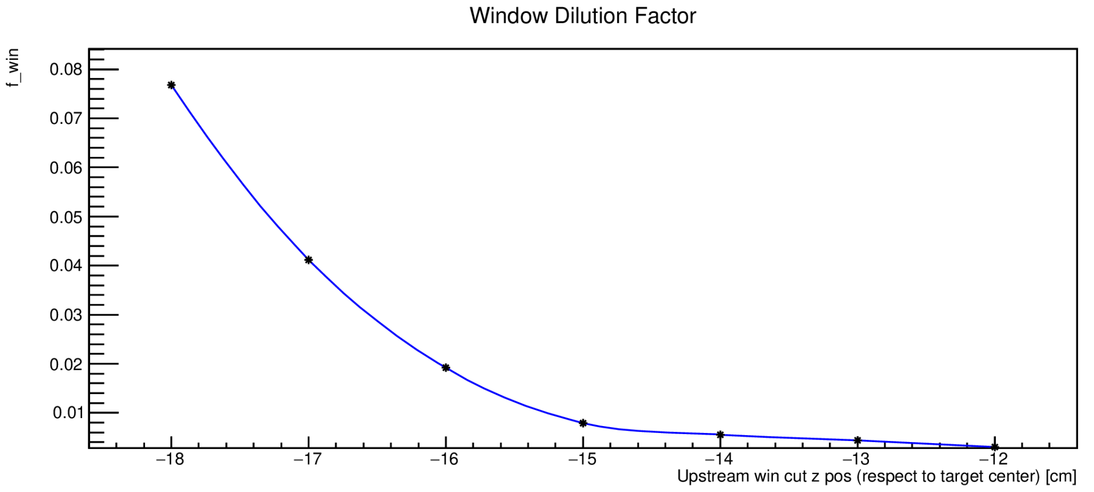
- SHMS 9956: ^{3}He DIS, Longitudinal 180°
- E_p=-3.4 GeV, 30°, kin-B
- Trigger: 3/4 (hTRIG1)

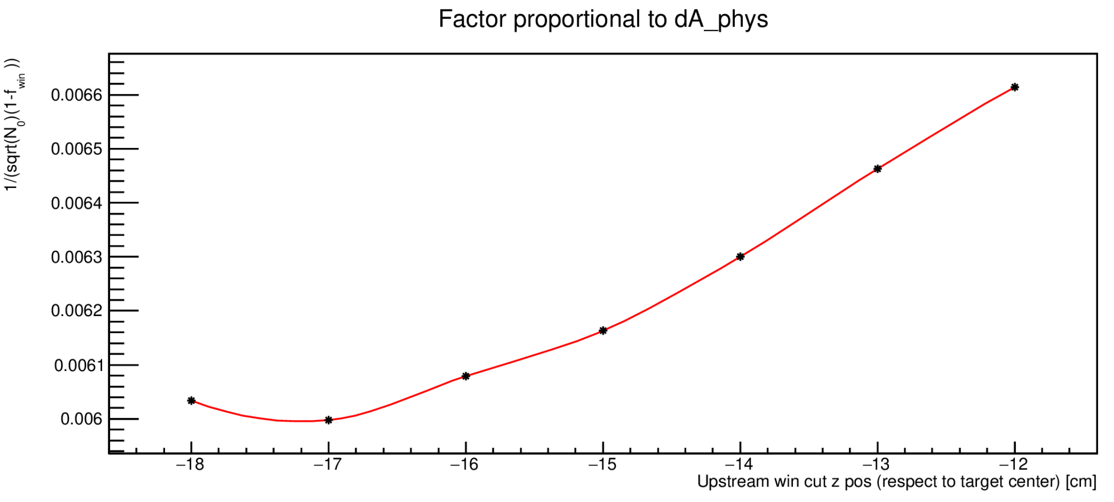
Empty run on reference cell Will:

- SHMS 10267: Empty Target DIS, Transverse 90°
- E_p=-3.4 GeV, 30°, kin-B
- Trigger: 3/4 (hTRIG1)

Window Dilution

(effect of upstream window z cut position)





$$f_{win} = \frac{N_0(up,em)\frac{N_{up}(^3He)}{N_{up}(em)} + N_0(down,em)\frac{N_{down}(^3He)}{N_{down}(em)}}{N_0(^3He)}$$

Pol 3He run on cell Dutch:

- SHMS 9956: ^{3}He DIS, Longitudinal 180°
- E_p=-3.4 GeV, 30°, kin-B
- Trigger: 3/4 (hTRIG1)

Empty run on reference cell Will:

- SHMS 10267: Empty Target DIS, Transverse 90°
- E_p=-3.4 GeV, 30°, kin-B
- Trigger: 3/4 (hTRIG1)

- Fix downstream window z cut at z=+18.0 cm away from target chamber center position.
- Adjust upstream window z cut to minimize

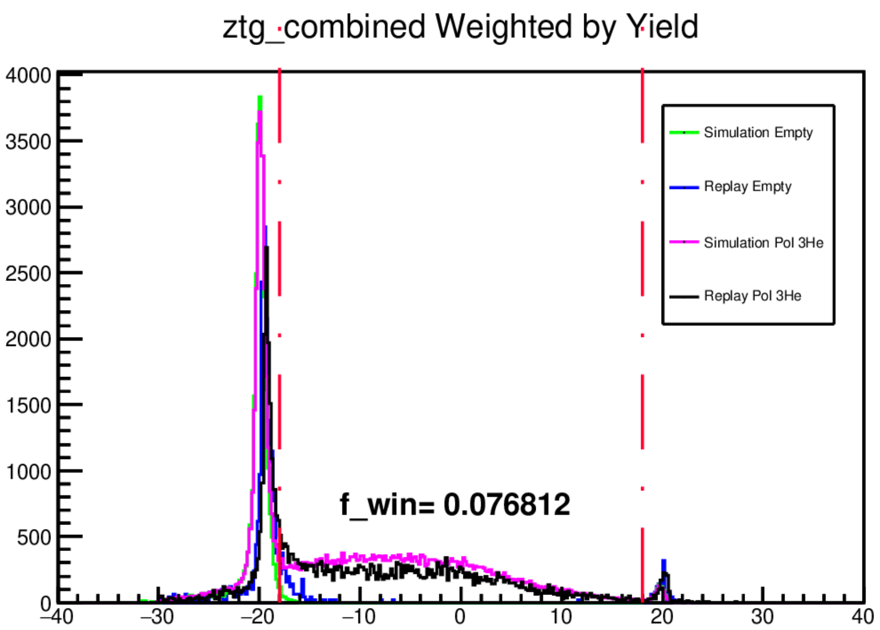
$$\Delta A_{phys} \propto \frac{1}{\sqrt{(N_0(^3He))}(1-f_{win})}$$

- For z cut be (-17 cm,+18 cm), ΔA_{phys} is around minimal.

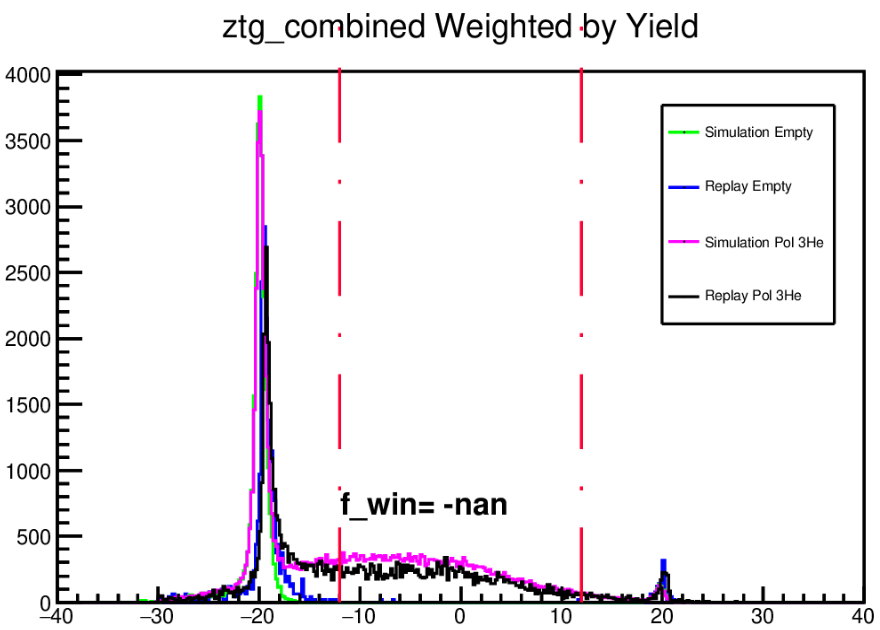
^{3}He Target Simulation

(Compare with replayed root file results)

$$f_{win}=\frac{N_0(up,em)\frac{N_{up}(^3He)}{N_{up}(em)}+N_0(down,em)\frac{N_{down}(^3He)}{N_{down}(em)}}{N_0(^3He)}$$



- z cut at z=±18.0 cm away from target chamber center position.



- z cut at z=±12.0 cm away from target chamber center position.

Pol 3He run on cell Dutch:

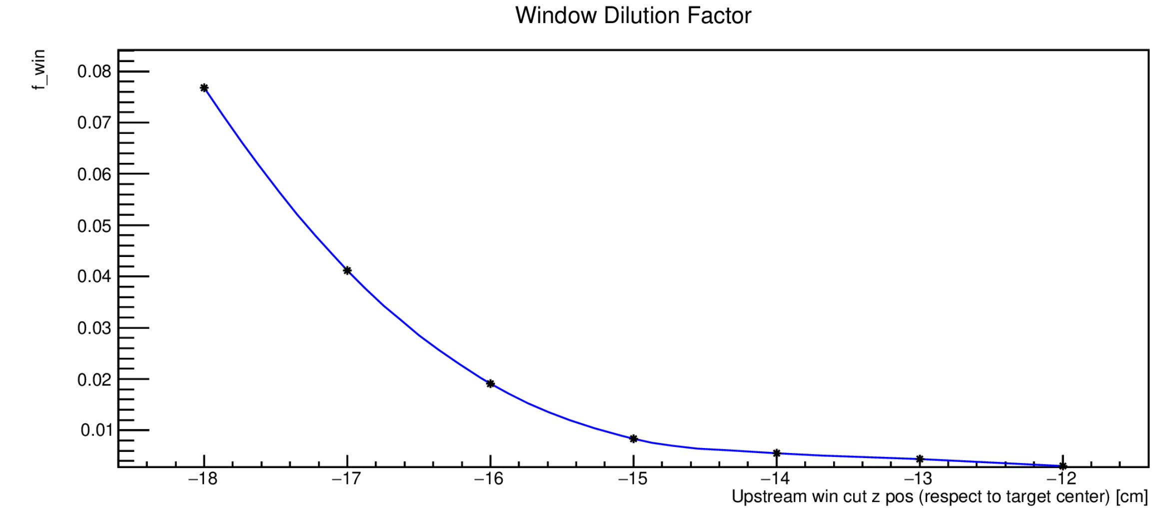
- HMS 2771: ^{3}He DIS, Longitudinal 180°
- E_p=-3.5 GeV, 30°, kin-4
- Trigger: 3/4 (hTRIG1)

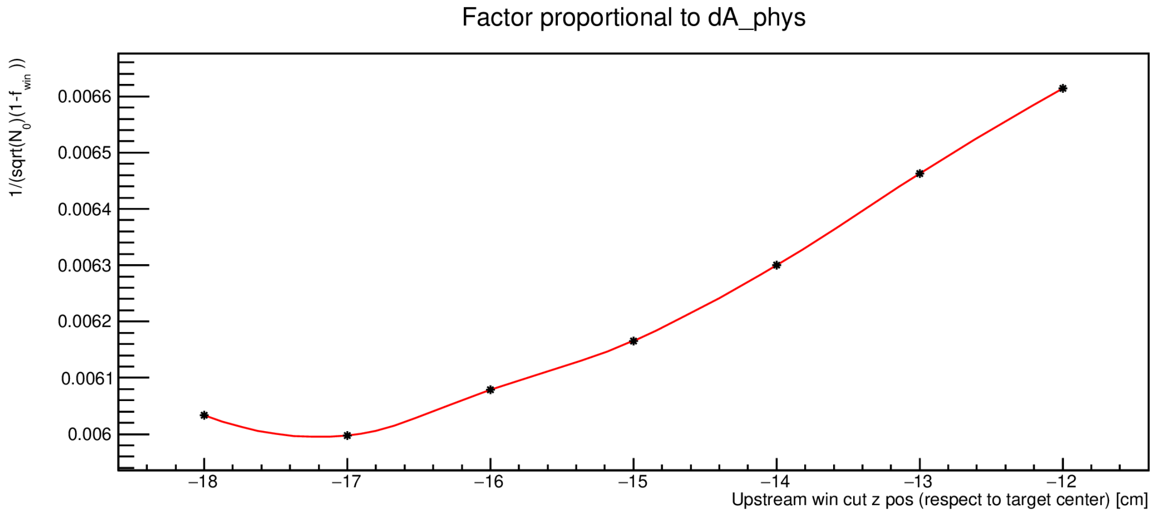
Empty run on reference cell Will:

- HMS 3077: Empty Target DIS, Transverse 90°
- E_p=-3.5 GeV, 30°, kin-4
- Trigger: 3/4 (hTRIG1)

Window Dilution

(effect of upstream window z cut position)





$$f_{win}=\frac{N_0(up,em)\frac{N_{up}(^3He)}{N_{up}(em)}+N_0(down,em)\frac{N_{down}(^3He)}{N_{down}(em)}}{N_0(^3He)}$$

Pol 3He run on cell Dutch:

- HMS 2771: ^{3}He DIS, Longitudinal 180°
- E_p=-3.5 GeV, 30°, kin-4
- Trigger: 3/4 (hTRIG1)

Empty run on reference cell Will:

- HMS 3077: Empty Target DIS, Transverse 90°
- E_p=-3.5 GeV, 30°, kin-4
- Trigger: 3/4 (hTRIG1)

- Fix downstream window z cut at z=+18.0 cm away from target chamber center position.
- Adjust upstream window z cut to minimize

$$\Delta A_{phys}\propto\frac{1}{\sqrt{(N_0(^3He))}(1-f_{win})}$$

- For z cut be (-17 cm,+18 cm), ΔA_{phys} is around minimal.

SHMS
APPLIED CUTS

A_1^n Asymmetry Analysis

(results from Melanie Rehfuss)

$$A_{raw} = \frac{N^+ - N^-}{N^+ + N^-}$$

$$A_{raw,CORR} = \frac{N^+/(Q^+\eta^+_{LT}) - N^-/(Q^-\eta^-_{LT})}{N^+/(Q^+\eta^+_{LT}) + N^-/(Q^-\eta^-_{LT})}$$

N^+, N^-: Beam trip, Acceptance & PID cuts
Q^+, Q^-: Beam trip cuts
η^+, η^-: Beam trip cuts

Acceptance Cuts:
```
-10 < P.gtr.dp < 22
|P.gtr.ph| < 0.07
|P.gtr.th| < 0.05
|P.react.z| < 17
```

3.4 GeV

Electron Sample/PID cuts:
```
P.ngcer.npeSum > 12
 && shower E/P > 0
 Total E/P > 0.80
```

2.6 GeV

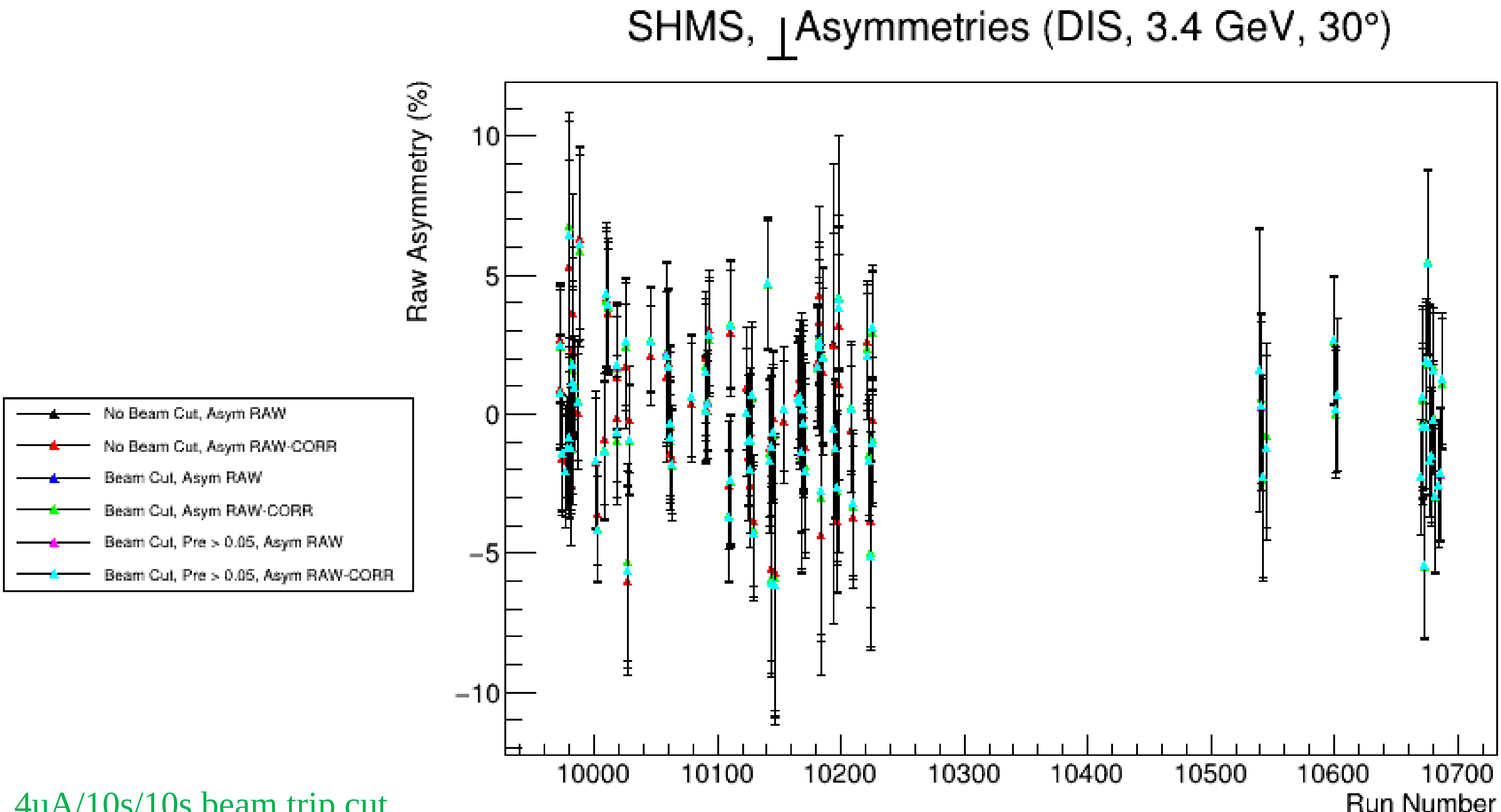
Electron Sample/PID cuts:
```
P.ngcer.npeSum > 8
 && shower E/P > 0
 Total E/P > 0.80
```

$$A_{raw} = \frac{N^+ - N^-}{N^+ + N^-}$$

A_1^n Asymmetry Analysis

Remove low-stat runs

(results from Melanie Rehfuss)



4uA/10s/10s beam trip cut
+ preshower E/P > 0.05 PID cut

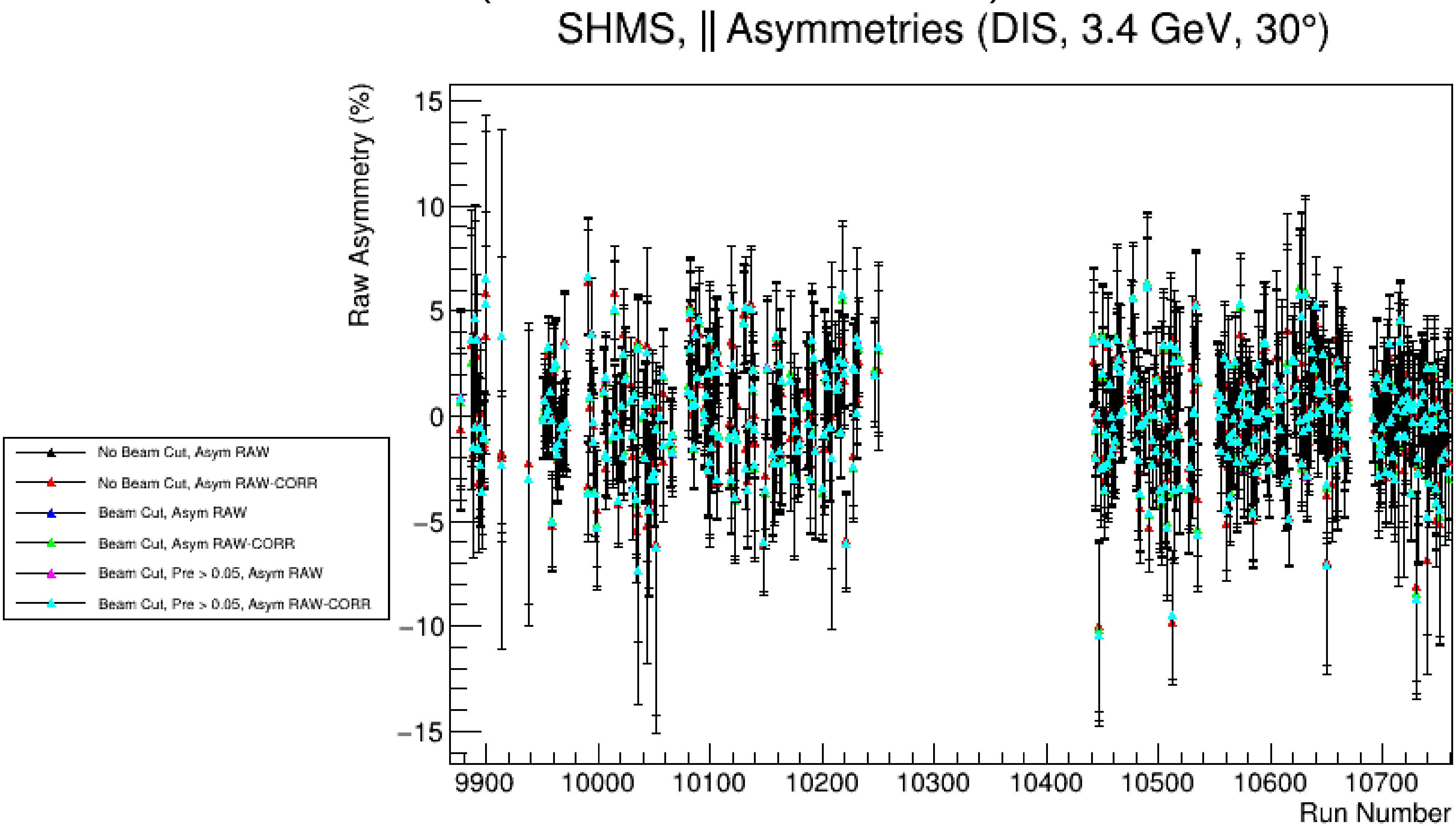
$$A_{raw,CORR} = \frac{N^+/(Q^+\eta^+_{LT}) - N^-/(Q^-\eta^-_{LT})}{N^+/(Q^+\eta^+_{LT}) + N^-/(Q^-\eta^-_{LT})}$$

$$A_{raw} = \frac{N^+ - N^-}{N^+ + N^-}$$

A_1^n Asymmetry Analysis

Remove low-stat runs

(results from Melanie Rehfuss)



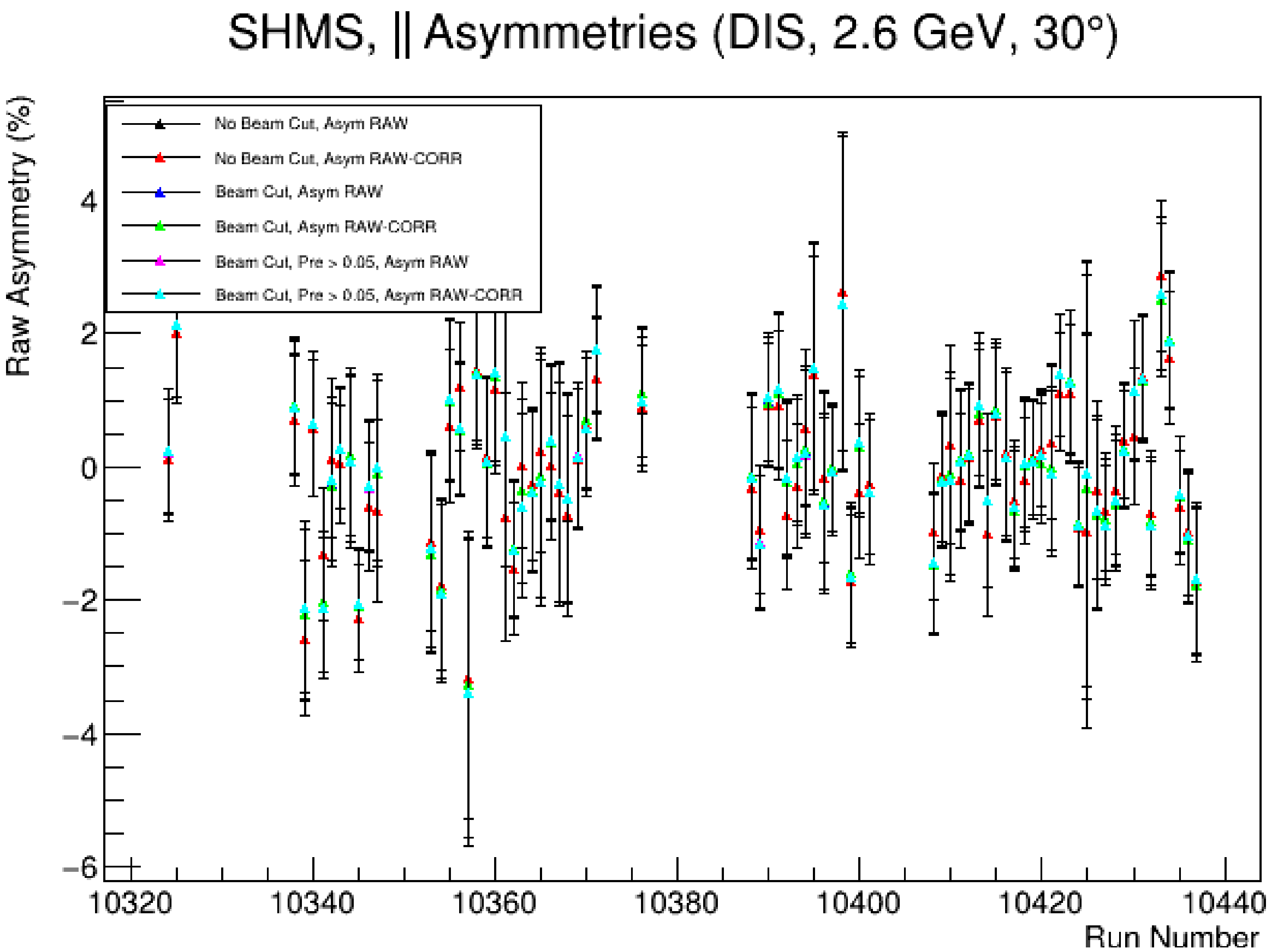
$$A_{raw,CORR} = \frac{N^+/(Q^+\eta^+_{LT}) - N^-/(Q^-\eta^-_{LT})}{N^+/(Q^+\eta^+_{LT}) + N^-/(Q^-\eta^-_{LT})}$$

4uA/10s/10s beam trip cut
+ preshower E/P > 0.05 PID cut

$$A_{raw} = \frac{N^+ - N^-}{N^+ + N^-}$$

A_1^n Asymmetry Analysis

(results from Melanie Rehfuss)



4uA/10s/10s beam trip cut
+ preshower E/P > 0.05 PID cut

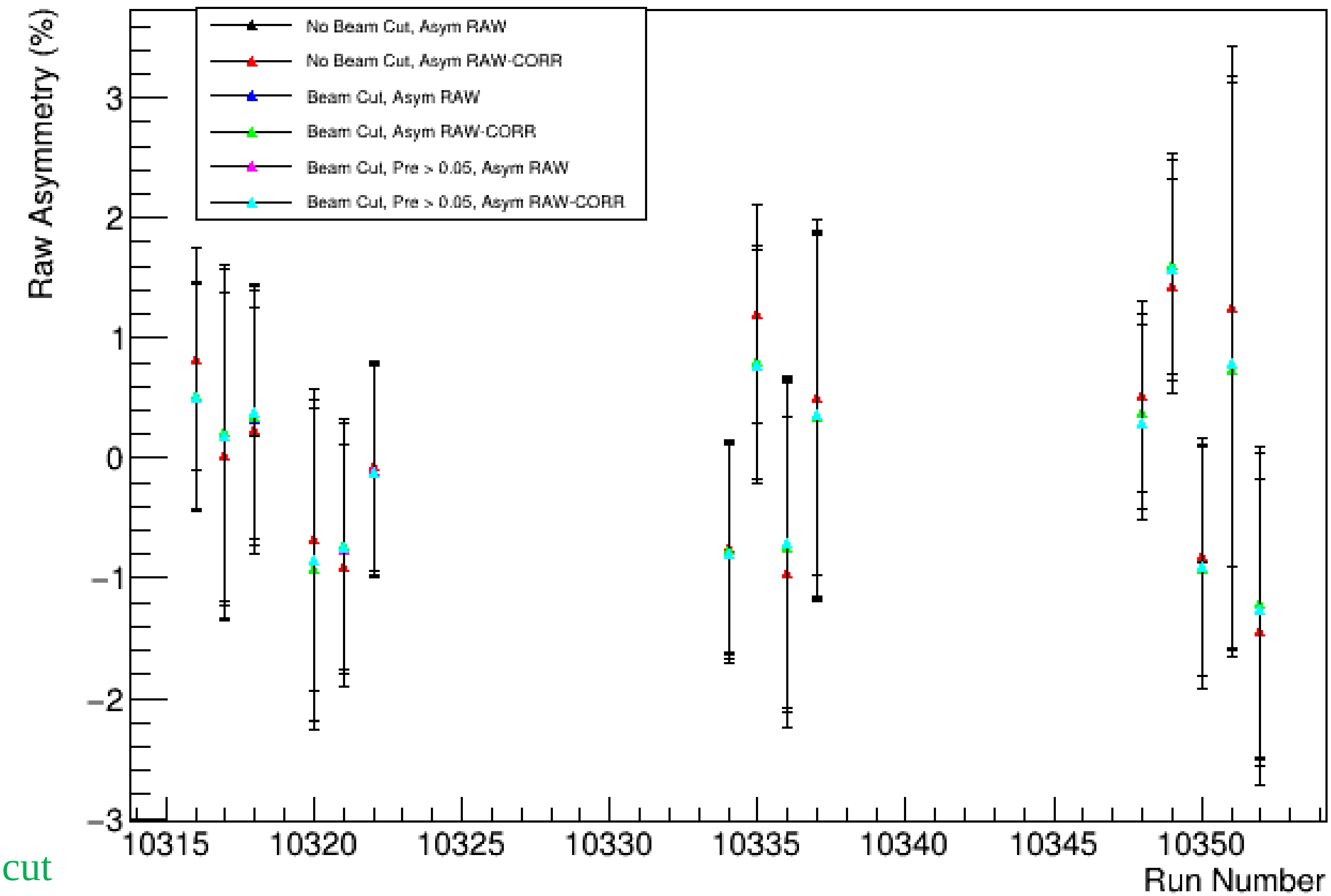
$$A_{raw,CORR} = \frac{N^+/(Q^+\eta^+_{LT}) - N^-/(Q^-\eta^-_{LT})}{N^+/(Q^+\eta^+_{LT}) + N^-/(Q^-\eta^-_{LT})}$$

$$A_{raw} = \frac{N^+ - N^-}{N^+ + N^-}$$

A_1^n Asymmetry Analysis

(results from Melanie Rehfuss)

SHMS, ⊥Asymmetries (DIS, 2.6 GeV, 30°)



4uA/10s/10s beam trip cut
+ preshower E/P > 0.05 PID cut

$$A_{raw,CORR} = \frac{N^+/(Q^+\eta^+_{LT}) - N^-/(Q^-\eta^-_{LT})}{N^+/(Q^+\eta^+_{LT}) + N^-/(Q^-\eta^-_{LT})}$$

HMS
APPLIED CUTS

A_1^n Asymmetry Analysis

(results from Melanie Rehfuss)

$$A_{raw} = \frac{N^+ - N^-}{N^+ + N^-}$$

$$A_{raw,CORR} = \frac{N^+/(Q^+\eta_{LT}^+) - N^-/(Q^-\eta_{LT}^-)}{N^+/(Q^+\eta_{LT}^+) + N^-/(Q^-\eta_{LT}^-)}$$

N^+, N^-: Beam trip, Acceptance & PID cuts
Q^+, Q^-: Beam trip cuts
η^+, η^-: Beam trip cuts

Acceptance Cuts:
```
-8 < H.gtr.dp < 8
|H.gtr.ph| < 0.06
|H.gtr.th| < 0.1
|H.react.z| < 15
```

3.5 GeV

Electron Sample/PID cuts:
```
H.cer.npeSum > 5.5
 && shower E/P > 0
 Total E/P > 0.80
```

2.9 GeV

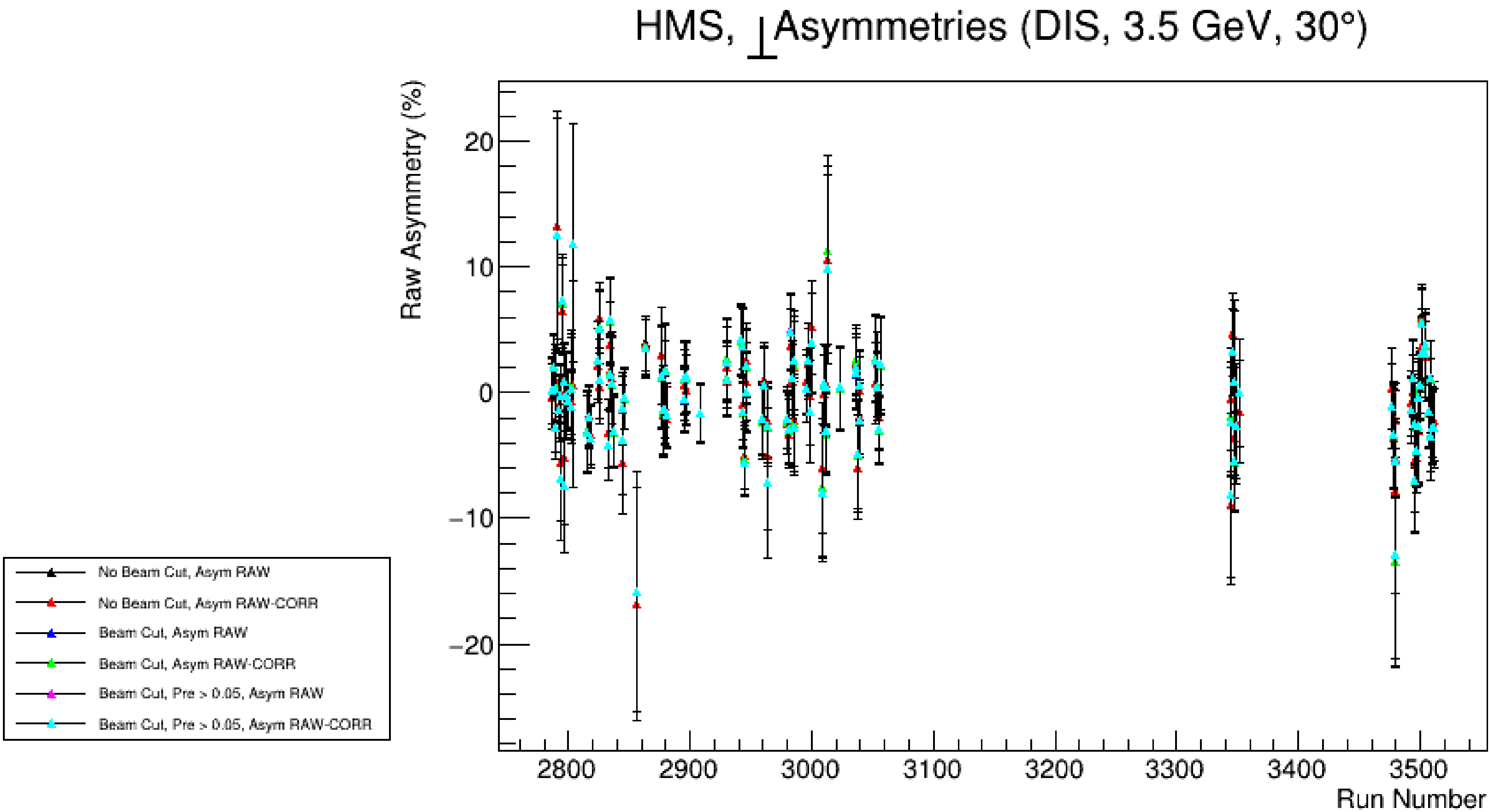
Electron Sample/PID cuts:
```
H.cer.npeSum > 5
&& shower E/P > 0
Total E/P > 0.80
```

$$A_{raw} = \frac{N^+ - N^-}{N^+ + N^-}$$

A_1^n Asymmetry Analysis

Remove low-stat runs

(results from Melanie Rehfuss)



4uA/10s/10s beam trip cut
+ preshower E/P > 0.05 PID cut

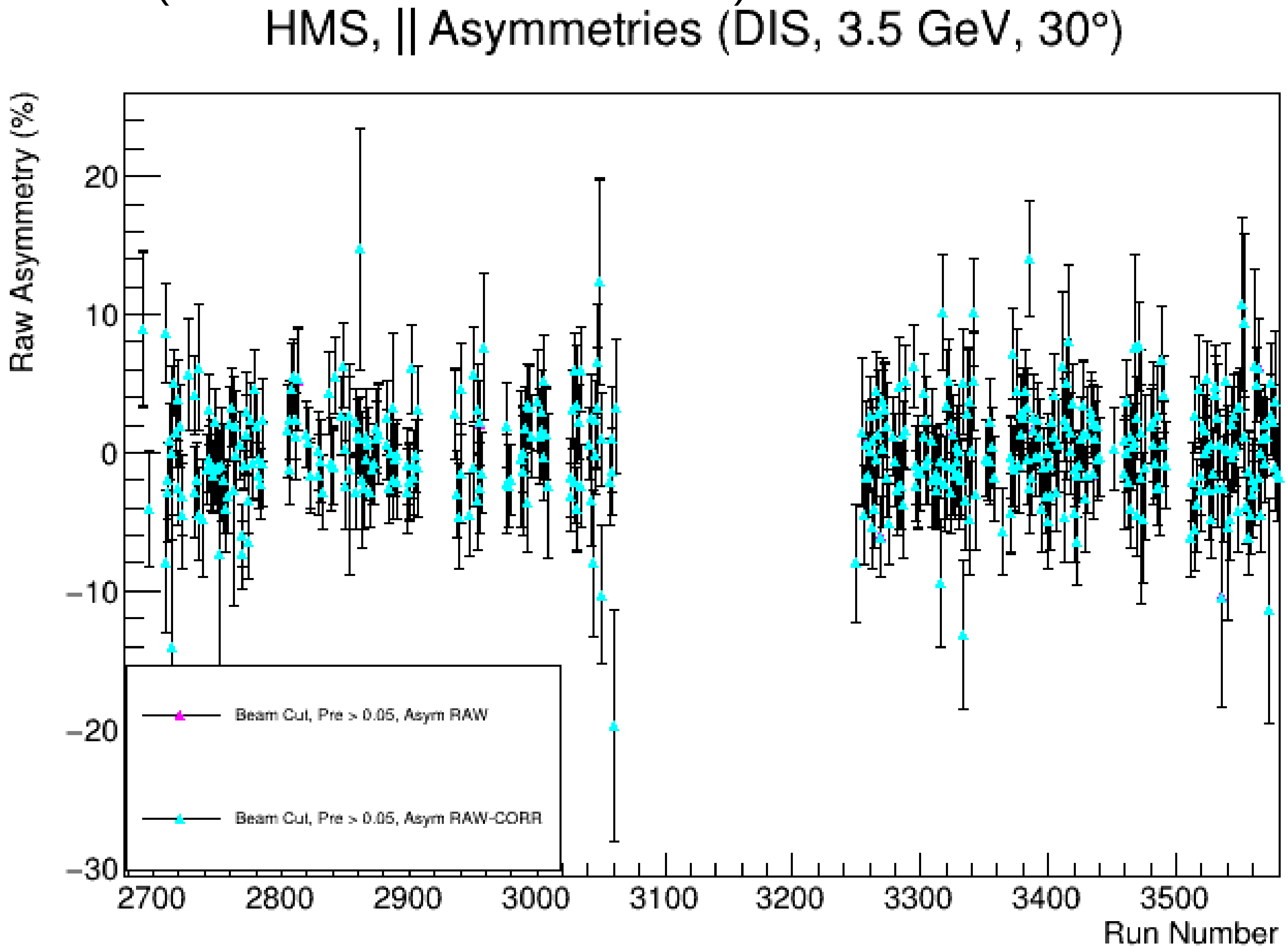
$$A_{raw,CORR} = \frac{N^+/(Q^+\eta_{LT}^+) - N^-/(Q^-\eta_{LT}^-)}{N^+/(Q^+\eta_{LT}^+) + N^-/(Q^-\eta_{LT}^-)}$$

$$A_{raw} = \frac{N^+ - N^-}{N^+ + N^-}$$

A_1^n Asymmetry Analysis

Remove low-stat runs

(results from Melanie Rehfuss)



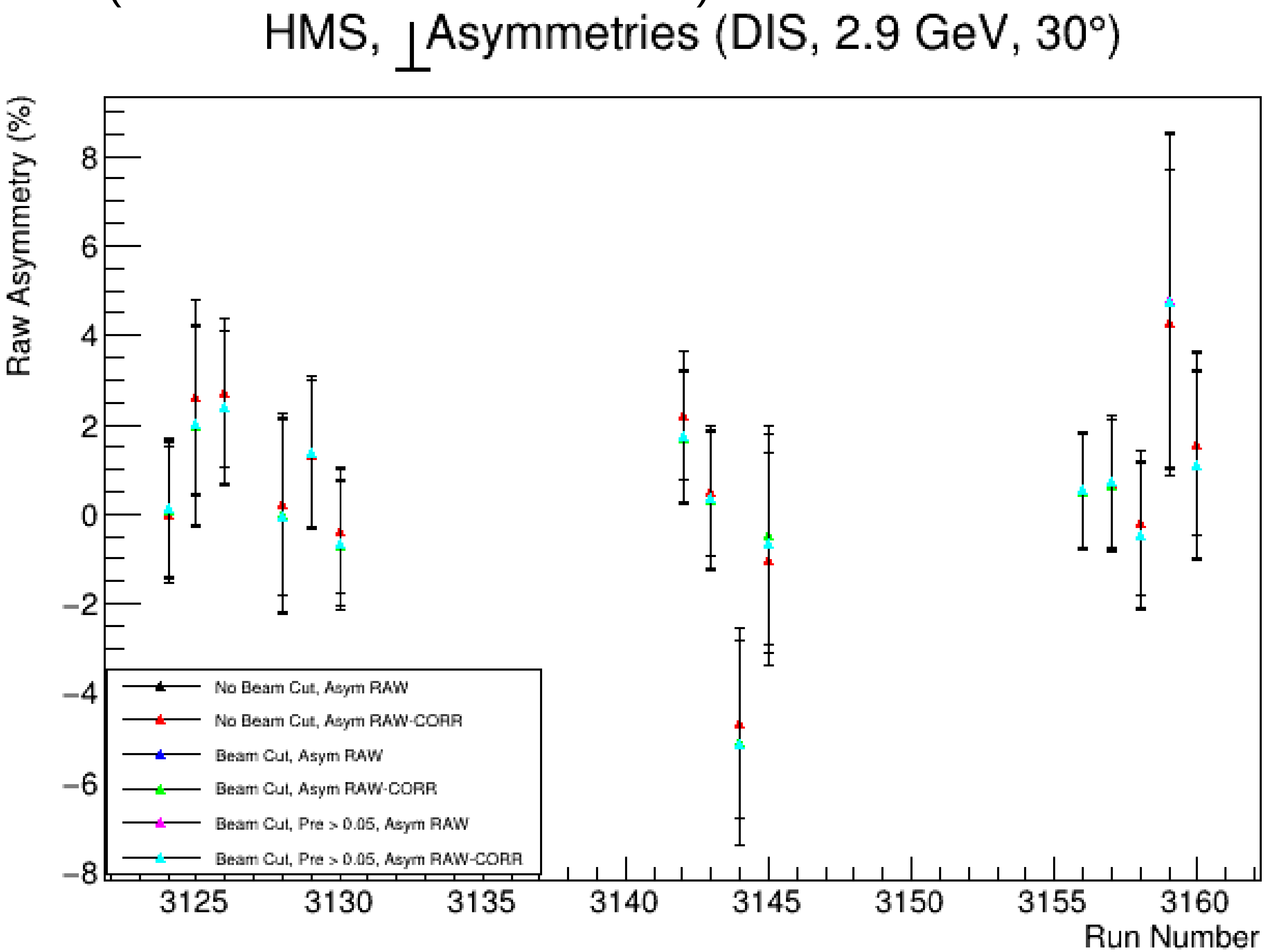
4uA/10s/10s beam trip cut
+ preshower E/P > 0.05 PID cut

$$A_{raw,CORR} = \frac{N^+/(Q^+\eta_{LT}^+) - N^-/(Q^-\eta_{LT}^-)}{N^+/(Q^+\eta_{LT}^+) + N^-/(Q^-\eta_{LT}^-)}$$

$$A_{raw} = \frac{N^+ - N^-}{N^+ + N^-}$$

A_1^n Asymmetry Analysis

(results from Melanie Rehfuss)



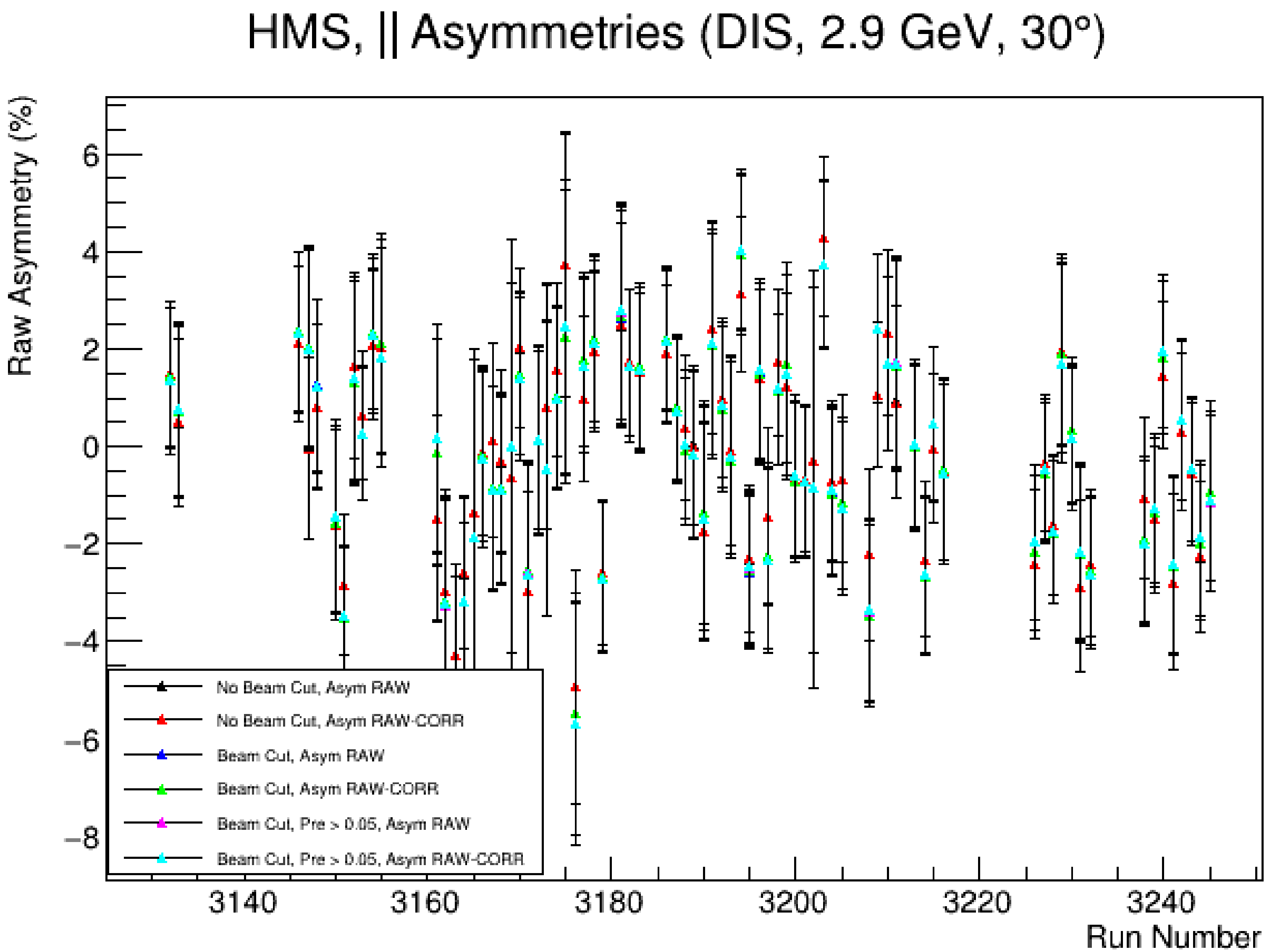
4uA/10s/10s beam trip cut
+ preshower E/P > 0.05 PID cut

$$A_{raw,CORR} = \frac{N^+/(Q^+\eta^+_{LT}) - N^-/(Q^-\eta^-_{LT})}{N^+/(Q^+\eta^+_{LT}) + N^-/(Q^-\eta^-_{LT})}$$

$$A_{raw} = \frac{N^+ - N^-}{N^+ + N^-}$$

A_1^n Asymmetry Analysis

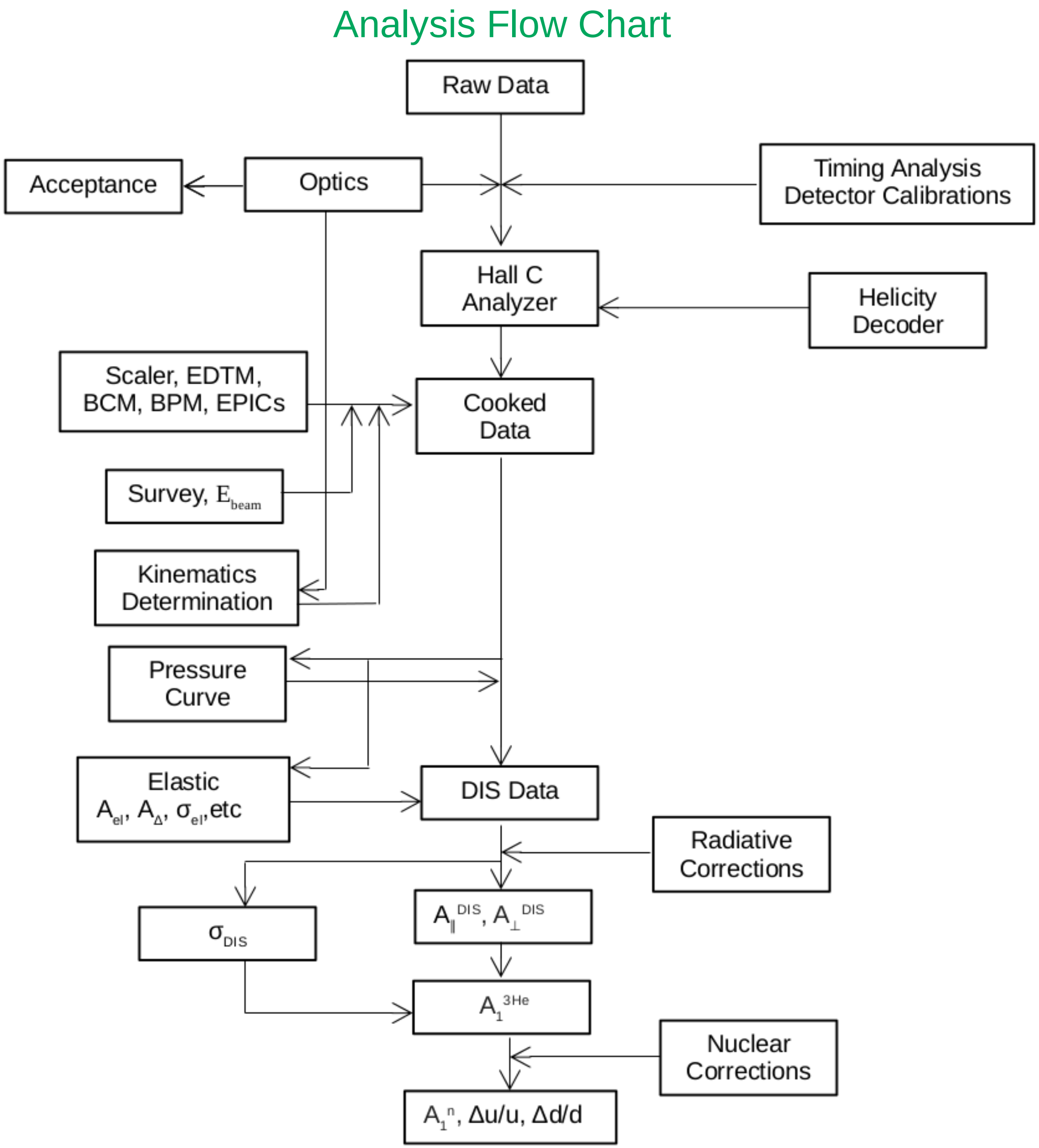
(results from Melanie Rehfuss)



4uA/10s/10s beam trip cut
+ preshower E/P > 0.05 PID cut

$$A_{raw,CORR} = \frac{N^+/(Q^+\eta_{LT}^+) - N^-/(Q^-\eta_{LT}^-)}{N^+/(Q^+\eta_{LT}^+) + N^-/(Q^-\eta_{LT}^-)}$$

Summary



- The A_1^n experiment (E12-06-110) is a flag-ship, high impact experiment which will give more insights on understanding the spin structure of nucleon.
- Timing analysis, detector calibrations, PID cuts complete.
- Window dilution study and offline A_1^n asymmetry analysis ongoing.

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PhD Candidates   Spokespeople

Institutions

A.I. Alikhanian National Science Laboratory; Argonne National Laboratory; Artem Alikhanian National Laboratory (AANL).; Christopher Newport University; Duke University; Florida International University; Hampton University ; James Madison University ; Jefferson Lab; Kent State University; Mississippi State University; Ohio University; Old Dominion University; Rutgers University; Syracuse University; Temple University; The College of William and Mary; Univ. of Ljubljana; University of Connecticut; University of Kentucky; University of Kentucky; University of New Hampshire; University of Regina; University of Tennessee; University of Virginia; University of Virginia; University of Zagreb

Backup Slides

PID Studies for Spectrometers

(by Melanie Rehfuss)

Particle Identification (PID) Studies

We're measuring an asymmetry, so we need **clean electron** detection

The SHMS & HMS have two independent detectors for PID:

Combined Pion Rejection Factor = $PRF_{cherenkov} * PRF_{calorimeter}$

1. The **Gas Cherenkov**

$$Cherenkov\ Efficiency = \frac{electron\ sample\ that\ passed\ the\ Cherenkov\ cut}{electron\ sample\ selected\ with\ the\ Calorimeter}$$

$$Cherenkov\ PR\ Factor = \frac{pion\ sample\ selected\ with\ the\ Calorimeter}{pion\ sample\ that\ passed\ the\ Cherenkov\ cut}$$

→ e^-, π samples determined by the Calorimeter, Cherenkov used for PID

2. The Lead-Glass **Calorimeter**

$$Calorimeter\ Efficiency = \frac{electron\ sample\ that\ passed\ the\ Calorimeter\ (total\ \&\ preshower)\ cut}{electron\ sample\ selected\ with\ the\ Cherenkov}$$

$$Calorimeter\ PR\ Factor = \frac{pion\ sample\ selected\ with\ the\ Cherenkov}{pion\ sample\ that\ passed\ the\ Calorimeter\ (total\ \&\ preshower)\ cut}$$

→ e^-, π samples determined by the Cherenkov, Calorimeter used for PID

PID Studies for Spectrometers

(by Melanie Rehfuss)

PID: Noble Gas Cherenkov (NGC) Efficiency & Pion Rejection

SHMS Runs:
10334-10347,
, ^{3}He @ 180°/90°
E_p= -2.6 GeV, 30°

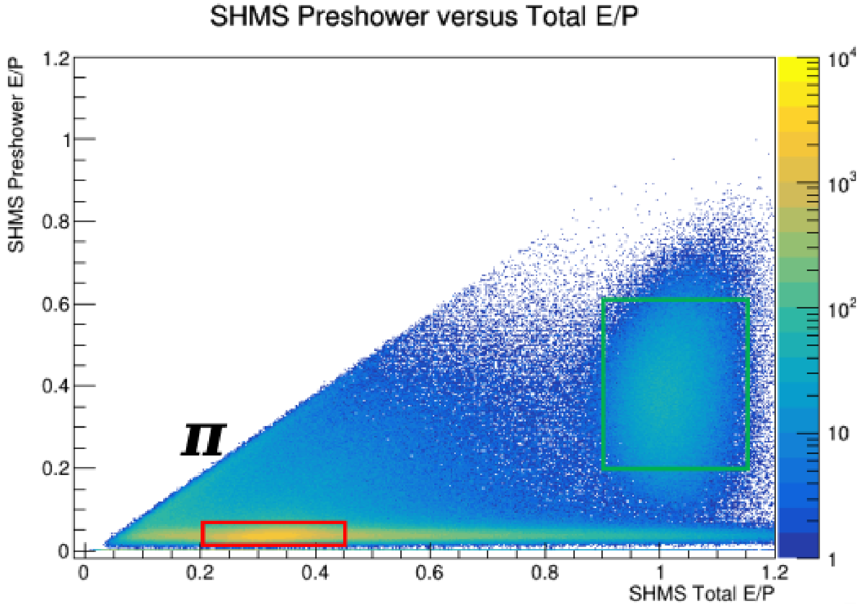
Noble Gas Cherenkov (NGC)

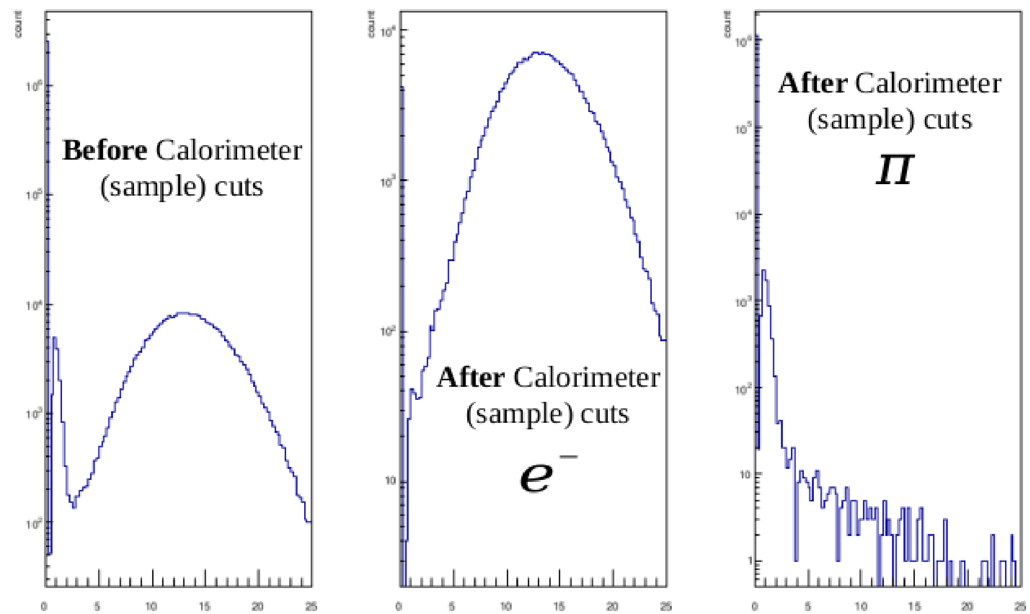
Step 1: Use 2D Graphical Cuts
to determine and samples

Threshold Energies
N_2 @ 1atm, 20°C
: 21.6 MeV
: 5.9 GeV
1.35°

0.90 < Total E/P < 1.15
&&
0.20 < Preshower E/P < 0.60

0.20 < Total E/P < 0.45
&&
0.02 < Preshower E/P < 0.05





SHMS Cherenkov # npe's

PID Studies for Spectrometers

(by Melanie Rehfuss)

PID: Noble Gas Cherenkov (NGC) Efficiency & Pion Rejection

SHMS Runs:
10334-10347,
, ^{3}He @ 180°/90°
E_p= -2.6 GeV, 30°

Noble Gas Cherenkov (NGC)

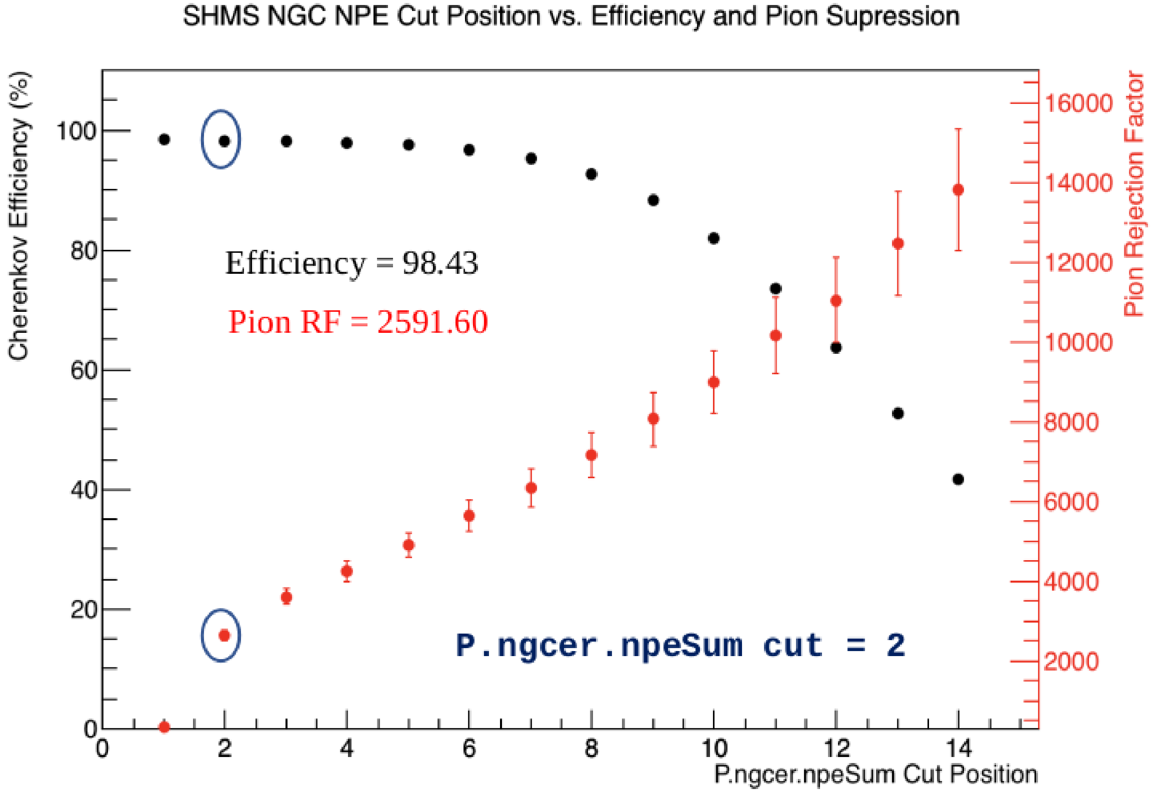
Step 2: Determine how many
and pass the NGC sum cut
(total # of photoelectrons)

Threshold Energies
N_2 @ 1atm, 20°C
: 21.6 MeV
: 5.9 GeV
1.35°

0.90 < Total E/P < 1.15
&&
0.20 < Preshower E/P < 0.60

0.20 < Total E/P < 0.45
&&
0.02 < Preshower E/P < 0.05

Nominal Acceptance Cuts Used



PID Studies for Spectrometers

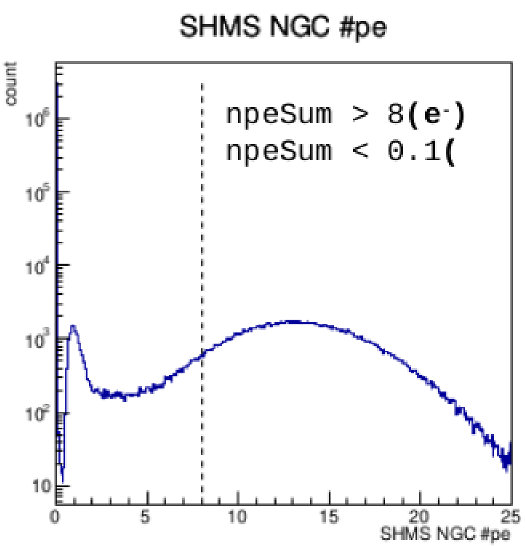
(by Melanie Rehfuss)

PID: Calorimeter Efficiency & Pion Rejection

SHMS Runs:
10334-10347,
, ^{3}He @ 180°/90°
E_p= -2.6 GeV, 30°

Calorimeter

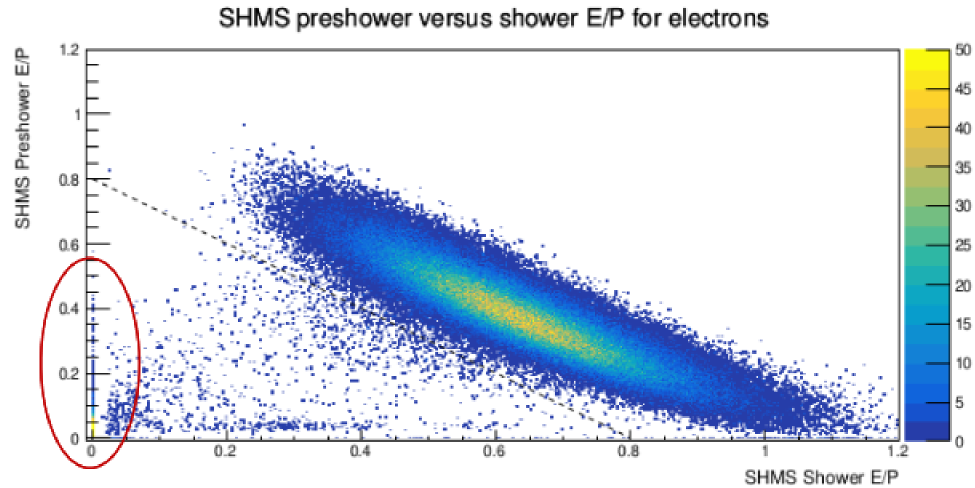
Step 1a: Use the NGC npe sum cut to determine and samples

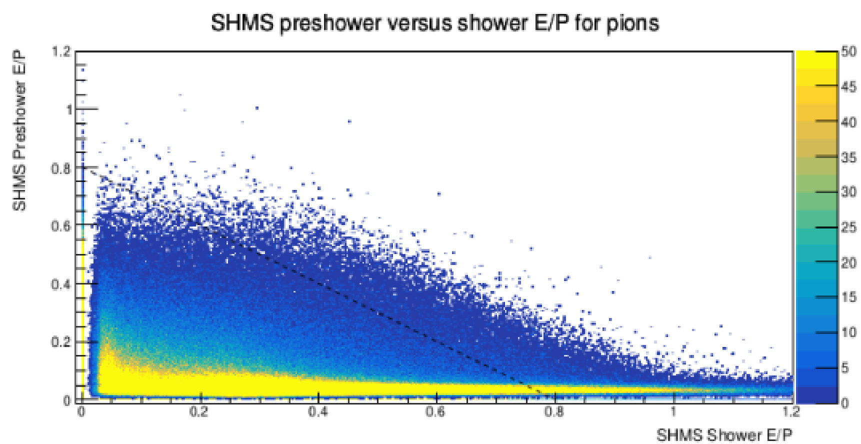


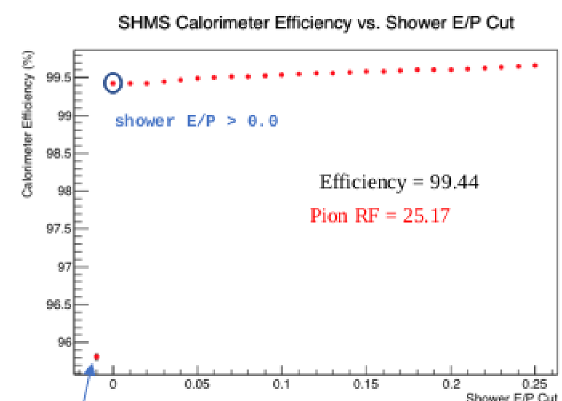
Low-energy electrons are surviving the Cherenkov cut but not making the total calorimeter cut (dying in the pre-shower)

Step 1b:

To ensure we're counting only good electrons, impose a **cut on the shower energy > 0.0**







no shower E/P cut

PID Studies for Spectrometers

(by Melanie Rehfuss)

PID: Calorimeter Efficiency & Pion Rejection

SHMS Runs:
10334-10347,
, ^{3}He @ 180°/90°
E_p= -2.6 GeV, 30°

Calorimeter

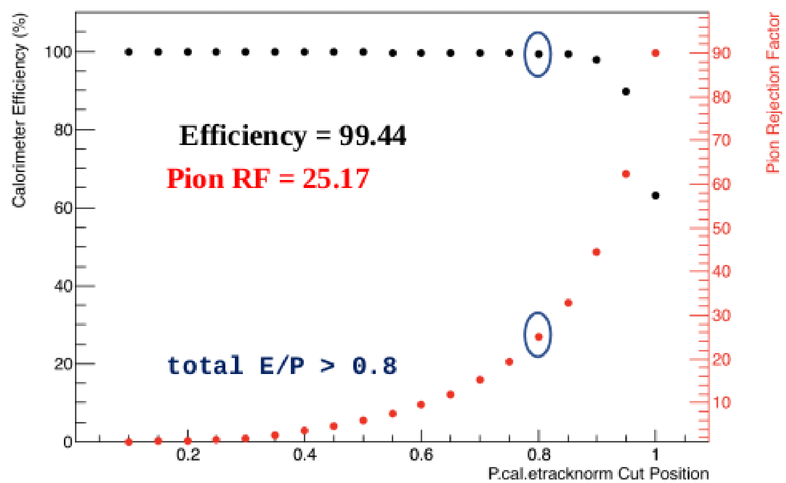
Nominal
Acceptance
Cuts Used

Sample Cuts:
NGC npeSum > 8
&& Shower E/P > 0(e^-)
NGC npeSum < 0.1 ()

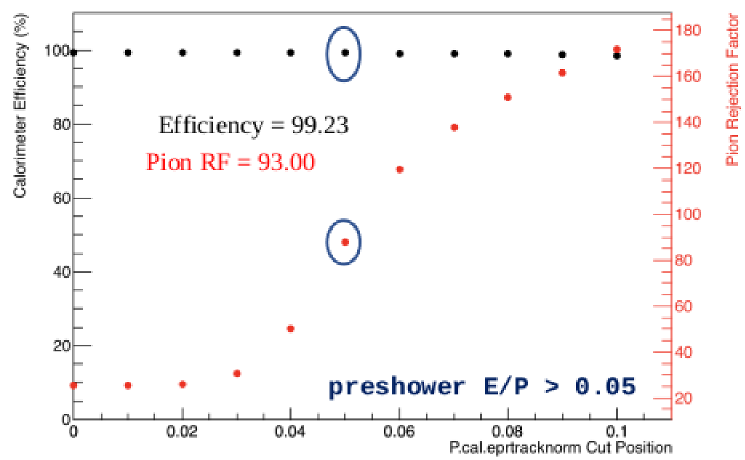
PID Cuts:
Total E/P > 0.80

✓ Combined Pion Rejection Factors for all settings > 10^4

Step 2: Determine how many and pass the total E/P cut



Add a preshower cut to the PID cut for a PRF boost



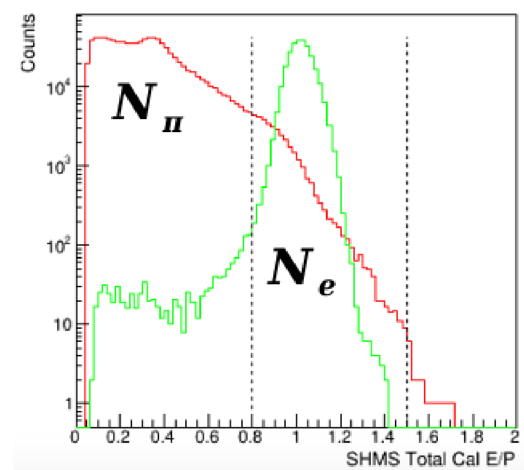
Pion Contamination with a Preshower Cut

pion contamination =

PID Cuts: Preshower E/P > 0.05

npeSum > 8 && shower E/P > 0

npeSum < 0.1



PC from Calorimeter Only:

Histogram is integrated over [0.80,1.50] to **find percentage of pions in electron sample** = **11.31%**

(1/PRF) @ 2 npeSum cut from NGC study (1/2591.60)

PC from Calorimeter + NGC: = **0.01%**

✓ goal is a contamination of < 0.4%

PID Studies for Spectrometers

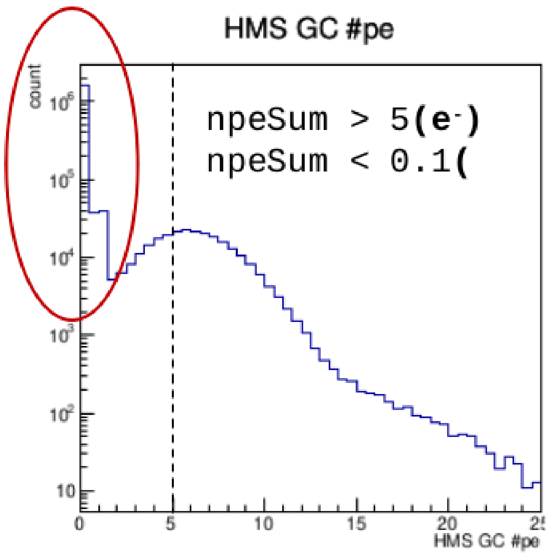
(by Melanie Rehfuss)

PID: Calorimeter Efficiency & Pion Rejection

HMS Runs:
3181-3183
3186-3205
^{3}He @ 180°
E_p= -2.9 GeV, 30°

Calorimeter

(causing low cherenkov efficiency)

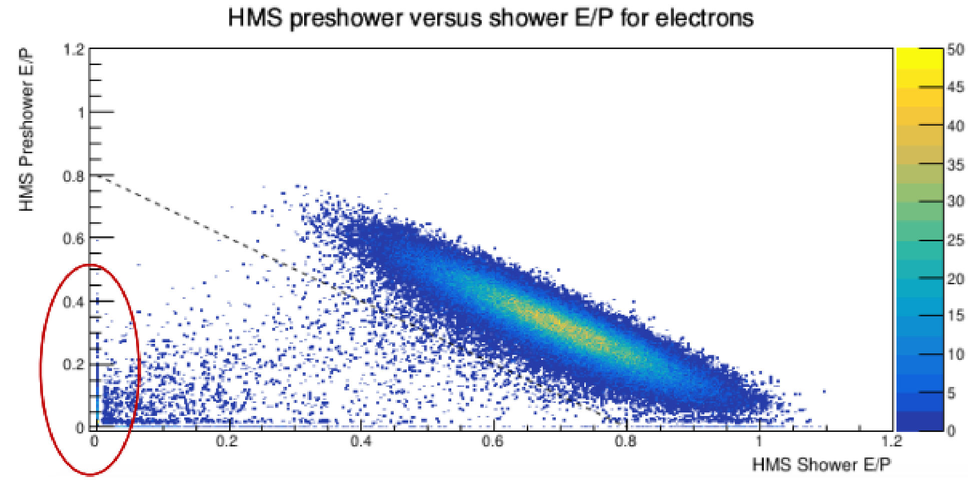


Step 1a: Use the cherenkov npe sum cut to determine and samples

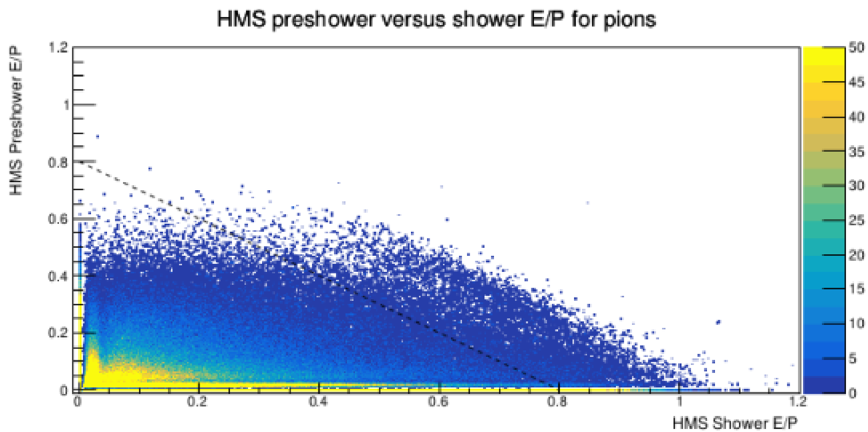
Low-energy electrons are surviving the Cherenkov cut but not making the total calorimeter cut (dying in the pre-shower)

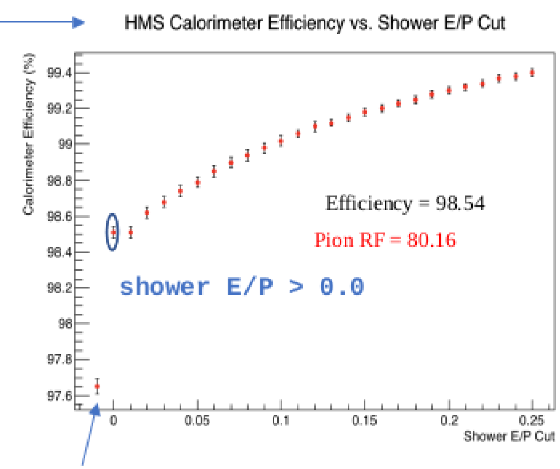
Step 1b:

To ensure we're counting only good electrons, impose a **cut on the shower energy > 0.0**



need to explore upward trend in efficiency against shower E/P cut





no shower E/P cut

PID Studies for Spectrometers

(by Melanie Rehfuss)

PID: Calorimeter Efficiency & Pion Rejection

HMS Runs:
3181-3183
3186-3205
^{3}He @ 180°
E_p= -2.9 GeV, 30°

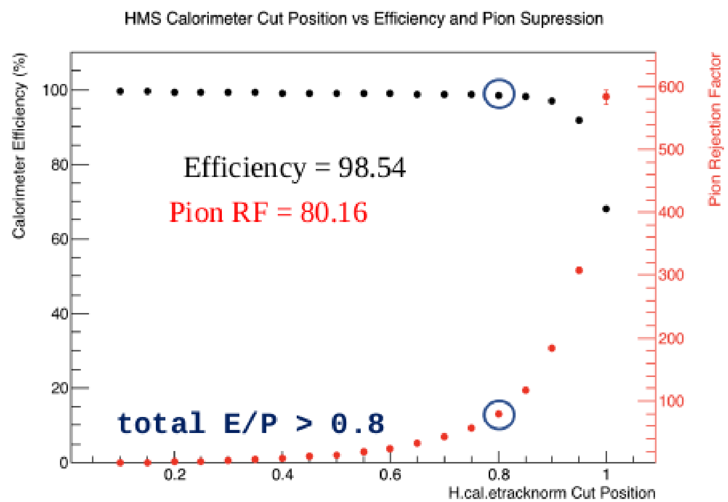
Calorimeter

Nominal Acceptance Cuts Used

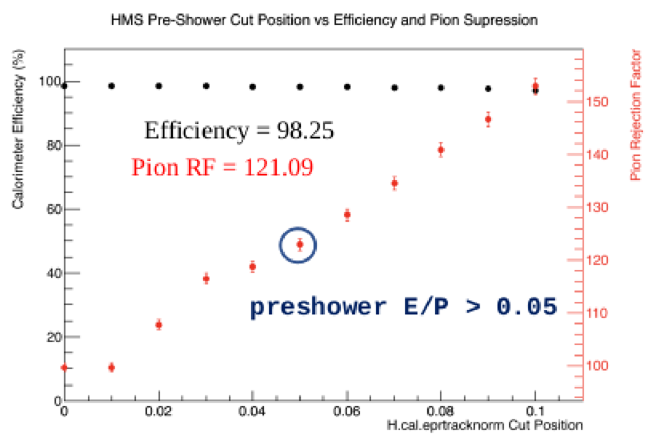
Sample Cuts:
`GC npeSum > 5`
`&& shower E/P > 0(`e^-`)`
`GC npeSum < 0.1 ()`

PID Cuts:
`Total E/P > 0.80`

Step 2: Determine how many and pass the total E/P cut



Add a preshower cut to the PID cut for a PRF boost



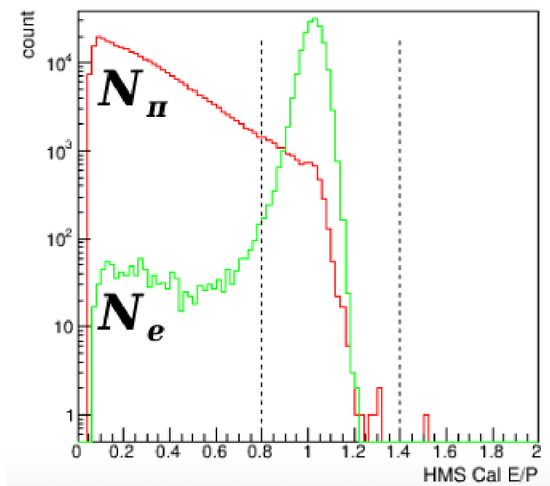
Pion Contamination with a Preshower Cut

Step 3: find the **percentage of pions in electron sample**

pion contamination =

PID Cuts: `Preshower E/P > 0.05`

`npeSum > 5 && shower E/P > 0 (`e^-`)`
`npeSum < 0.1()`



Histogram is integrated over `[0.80,1.40]` to **find percentage of pions in electron sample**

PC from Calorimeter Only: = **7.50%**

(1/PRF) @ 1 npeSum cut from GC study (1/37.26)

PC from Calorimeter + GC: = **0.20%**

PID Studies for Spectrometers

(by Melanie Rehfuss)

PID SUMMARY

Spec.		Cherenkov Cut Position	Cherenkov Efficiency	PRF	Calorimeter Cut Position	Calorimeter Efficiency	PRF	Combined Pion Cont.
SHMS	2.6 GeV	# npe’s > 2	98.43 0.03% 99.43 0.03%	2591.60 136.75 2907.27 619.73	Total E/P > 0.8	99.44 0.02% 99.32 0.03%	25.17 0.08 38.85 0.35	**0.016%**
SHMS	3.4 GeV	# npe’s > 2	99.82 0.01%	21.00 0.55 (pushing threshold!)	Total E/P > 0.8	99.33 0.02%	146.39 7.36	**0.006%**
SHMS	5.6 GeV	# npe’s > 2	99.80 0.01%	N/A (above threshold)	Total E/P > 0.8 Pre E/P > 0.05	99.29 0.01%	103.24 4.51	**0.012%**
SHMS	6.4 GeV	# npe’s > 2	99.73 0.01%	N/A (above threshold)	Total E/P > 0.8 Pre E/P > 0.05	99.80 0.01%	28.11 1.13	**0.102%**
SHMS	7.5 GeV	# npe’s > 2	97.08 0.04%	N/A (above threshold)	Total E/P > 0.8	98.54 0.03%	80.16 0.66	**0.101%**
HMS	2.9 GeV	# npe’s > 1	97.84 0.04%	33.75 0.99	Total E/P > 0.8	98.87 0.05%	76.36 1.34	**0.310%**
HMS	3.5 GeV	# npe’s > 1	98.85 0.02%	36.27 .20	Total E/P > 0.8	99.11 0.02%	82.88 1.27	**0.182%**
HMS	4.0 GeV	# npe’s > 1			Total E/P > 0.8			**0.063%**

mc-single-arm Simulation Setup

- Number of trails=100 k

HMS Acceptance:

- Delta range: (-15%, 15%)
- Theta range: (-100 mr, 100 mr)
- Phi range: (-100 mr, 100 mr)

SHMS Acceptance:

- Delta range: (-20%, 30%)
- Theta range: (-70 mr, 70 mr)
- Phi range: (-80 mr, 80 mr)

- HMS Simulation Optics File:

  recon_cosy_refit_1.576_60cm.dat

- SHMS Simulation Optics File:

  shms-2017-26cm-monte_q1_1018_q2_1027_q3_1018_recon_60cm.dat

Simulated Pol ^{3}HeTarget: Cell Bigbrother

HMS and SHMS:

- Upstream Window: GE180, Z=-21 cm, Length=0.01009 cm
- Downstream Window: GE180, Z=+19 cm, Length=0.01382 cm
- ^{3}He Target Chamber: 12.0 amg, Z=-1.0 cm, Length=40.0 cm
- N_2 gas: 1.0 atm, Z=-25.5 cm, Length=9.0 cm

  (from Z=-30.0 cm to Z=-21.0 cm)

Simulated Empty Reference Target: cell Will

HMS and SHMS:

- Upstream Window: GE180, Z=-20 cm, Length=0.015 cm
- Downstream Window: GE180, Z=+20cm, Length=0.015 cm
- N_2 gas: 1.0 atm, Z=-25.0 cm, Length=10.0cm

  (from Z=-30.0 cm to Z=-20.0 cm)

Table of Batch Farm Jobs
(for glass windows)

Exp	Cell	Target	Spec	Kine	status
A1n	Prod Dutch	Up Win; Down Win	HMS	4	Complete
A1n	Prod Dutch	Up Win; Down Win	SHMS	B	Complete
A1n	Empty Will	Up Win; Down Win	HMS	4	Complete
A1n	Empty Will	Up Win; Down Win	SHMS	B	Complete
A1n	Prod Bigbrother	Up Win; Down Win	HMS	4	To do
A1n	Prod Bigbrother	Up Win; Down Win	SHMS	B	To do
A1n	Prod Bigbrother	Up Win; Down Win	HMS	3	To do
A1n	Prod Bigbrother	Up Win; Down Win	SHMS	C	To do
A1n	Empty Will	Up Win; Down Win	HMS	3	To do
A1n	Empty Will	Up Win; Down Win	SHMS	C	To do

Note:

For glass windows in order to save time:

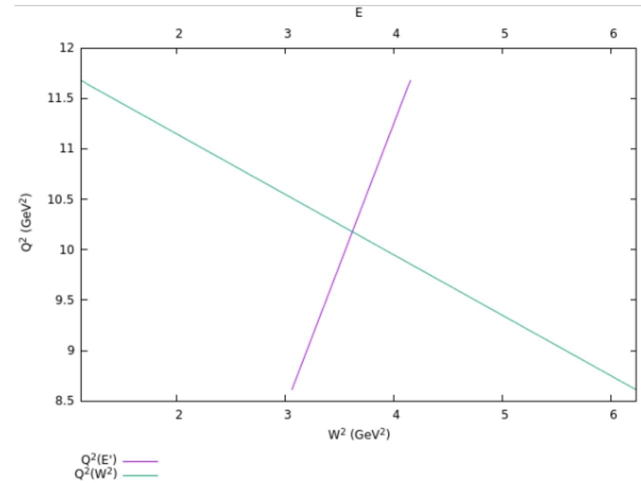
- Separate into small scattering angle range (3 angle values each).

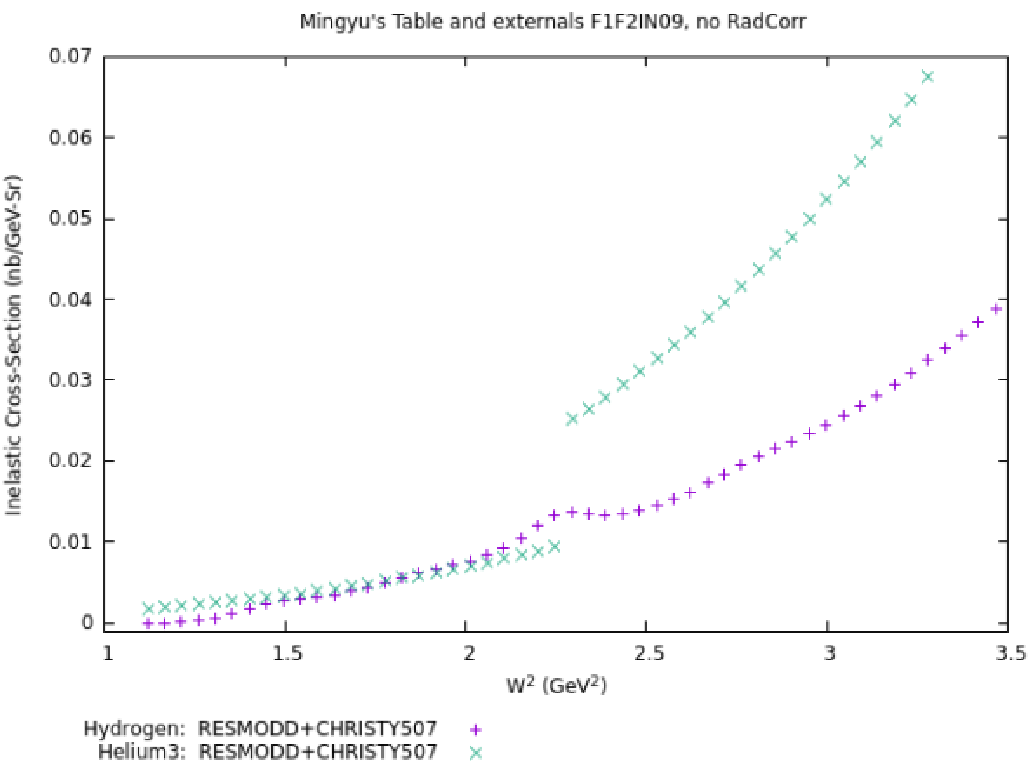
Exp	Cell	Target	Spec	Kine	status
d2n	Prod Austin	Up Win; Down Win	HMS	C	To do
d2n	Prod Austin	Up Win; Down Win	SHMS	Z	To do
d2n	Prod Austin	Up Win; Down Win	HMS	A	To do
d2n	Prod Austin	Up Win; Down Win	SHMS	X	To do
d2n	Empty Christen	Up Win; Down Win	HMS	C	To do
d2n	Empty Christen	Up Win; Down Win	SHMS	Z	To do
d2n	Prod Briana	Up Win; Down Win	HMS	C	To do
d2n	Prod Briana	Up Win; Down Win	SHMS	Z	To do
d2n	Prod Briana	Up Win; Down Win	HMS	A	To do
d2n	Prod Briana	Up Win; Down Win	SHMS	X	To do
d2n	Prod Tommy	Up Win; Down Win	HMS	C	To do
d2n	Prod Tommy	Up Win; Down Win	SHMS	Z	To do
d2n	Prod Tommy	Up Win; Down Win	HMS	A	To do
d2n	Prod Tommy	Up Win; Down Win	SHMS	X	To do
d2n	Empty Fauci	Up Win; Down Win	HMS	A	To do
d2n	Empty Fauci	Up Win; Down Win	SHMS	X	To do

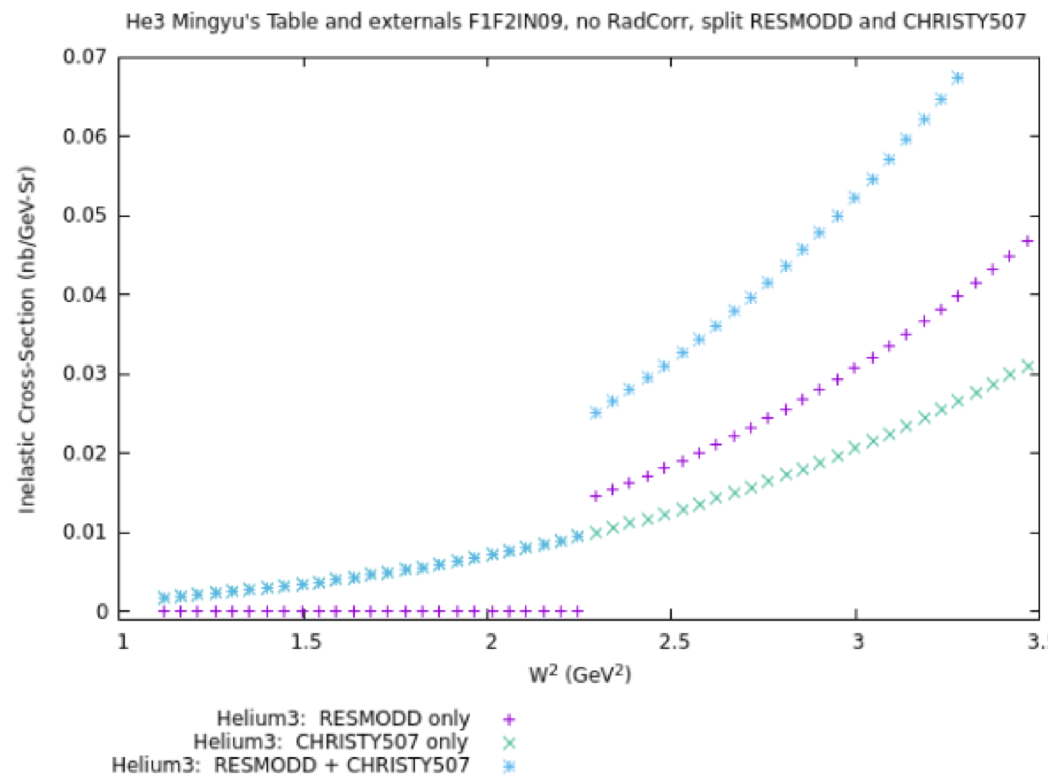
Target Cell Window Thickness

[Cell Dutch] 01/04/2020 to 02/10/2020				
Density (amg)	V_tot (cc)	V_pc (cc)	V_tt (cc)	
7.759	441.54	297.15	32.52	
Production Cell "Dutch" Wall Thickness				
	Measurement location	Position away from center (along Z) [cm]	Ultrasonic thickness gauge [mm]	Hclog link
TC front	#1	-12.5±0.16	1.323±0.01	https://logbooks.jlab.org/entry/3757788
	#2	-6.25±0.16	1.295±0.01	
	#3	0.0±0.16	1.275±0.01	
	#4	6.25±0.16	1.286±0.01	
	#5	12.5±0.16	1.267±0.01	
TC rear	#6	-12.5±0.16	1.341±0.01	
	#7	-6.25±0.16	1.342±0.01	
	#8	0.0±0.16	1.334±0.01	
	#9	6.25±0.16	1.339±0.01	
	#10	12.5±0.16	1.361±0.01	
Window Thickness	Front window (um)	Back Window (um)	Cold life Time (hr)	Max Polarization no beam (%)
	134.142 ± 0.063	143.475±0.072	29.4 (UVa)	53 (UVa)
	Downstream z=+20 cm	Upstream z=-20 cm		

F1F2IN09 Function

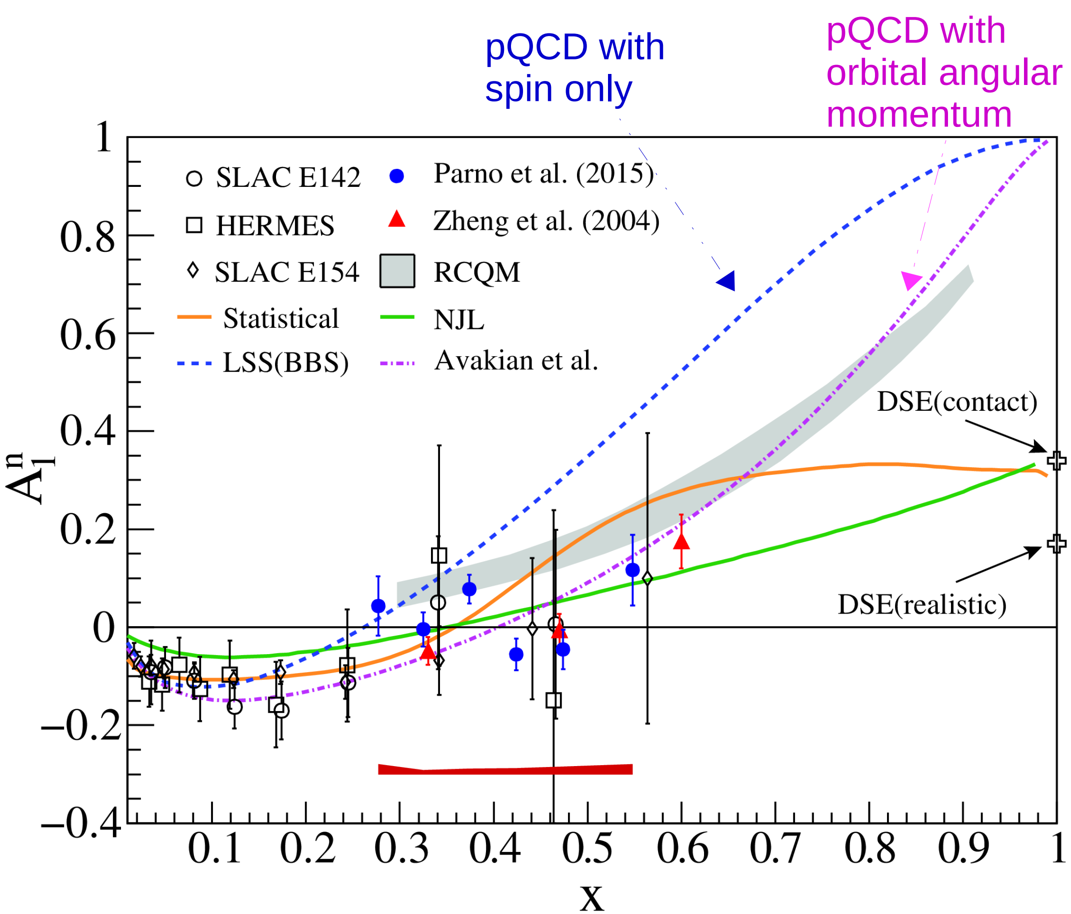


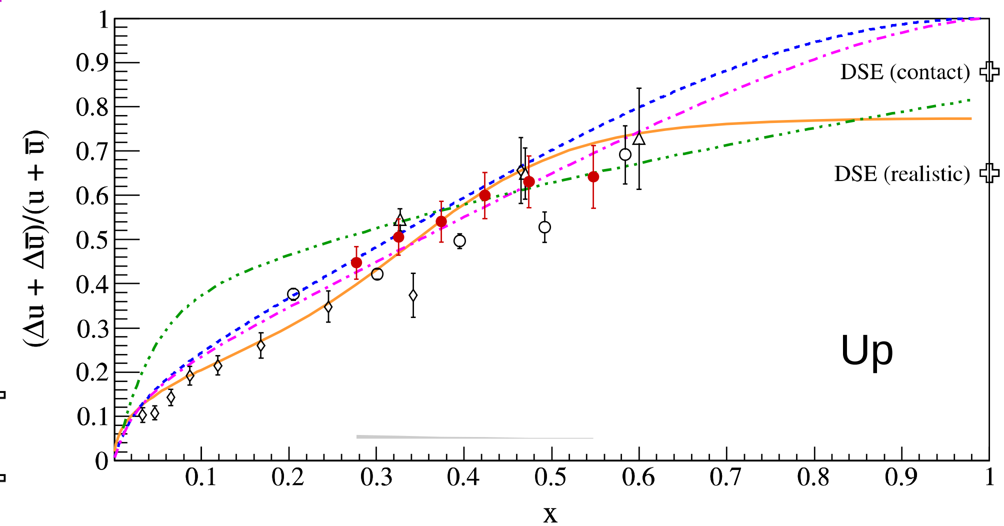


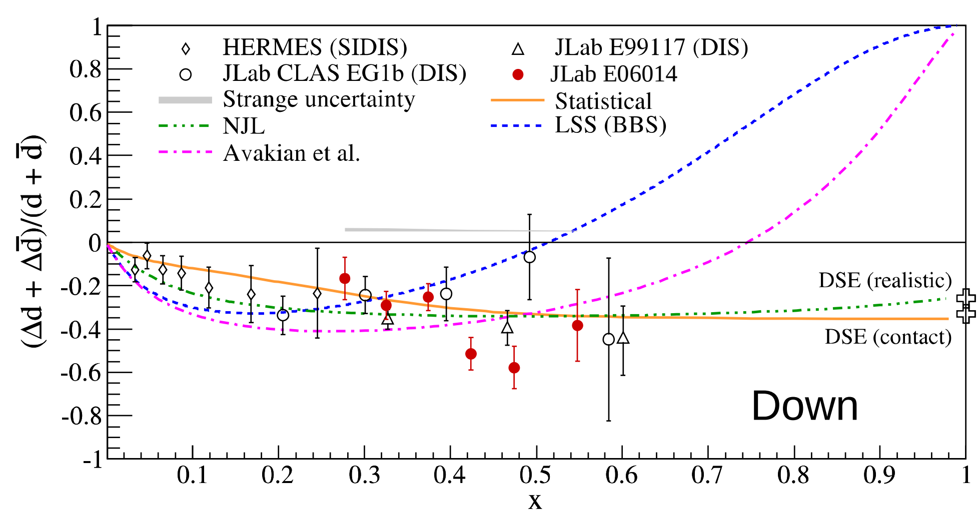


- When calling F1F2IN09 for any nucleus (including hydrogen) the function calls CHRISTY507 and RESMODD.
- The RESMODD function does not work for $Q^2>11$ GeV^2. For this example, the E' values greater than 3.88GeV correspond with a Q^2 value greater than 11 GeV^2.

Previous Results for A_1^n and PDF

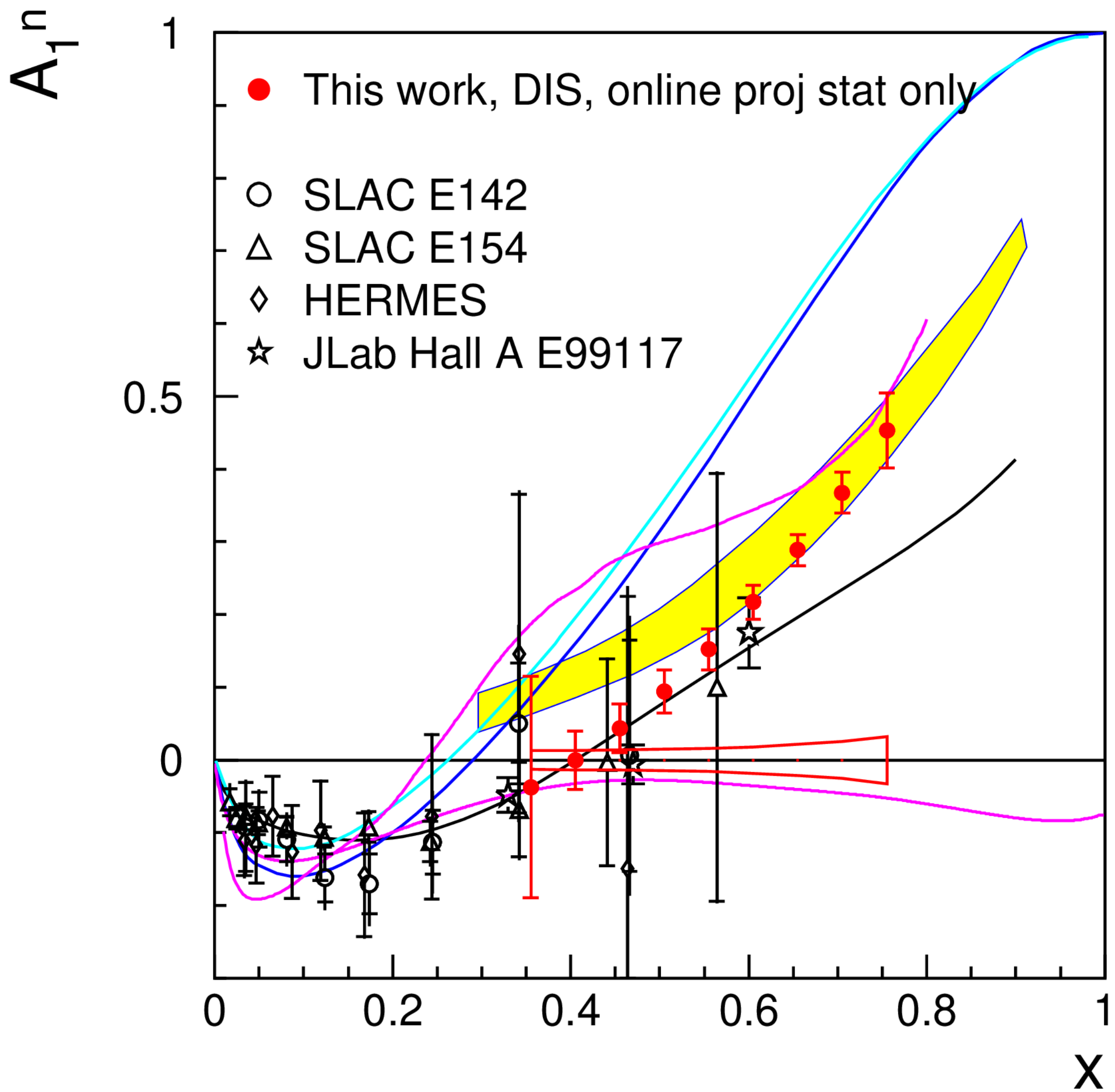






Parno et al., Phy Let B DOI: 10.1016/j.physletb.2015.03.067
X. Zheng et al., PRL 92, 012004 (2004); PRC 70, 065207 (2004)

A_1^n Online Projected Results



- From online statistics
- x range covered: (0.40, 0.75)
- Statistical uncertainty expected: ΔA_1^n=0.053 @ x=0.755