Simulation Status

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March 25, 2021

Outline:

1. Introduction
2. Compare simulation with replayed data for A_1^n DIS kinematics
3. Window dilution study
4. Summary and Future work

Introduction

- Using mc-single-arm to generate events for simulation and Peter Bosted model for cross-section to get the simulation for target chamber of the ^3He 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; ^3He 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:

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

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 Peter Bosted model.

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

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

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

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)

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)

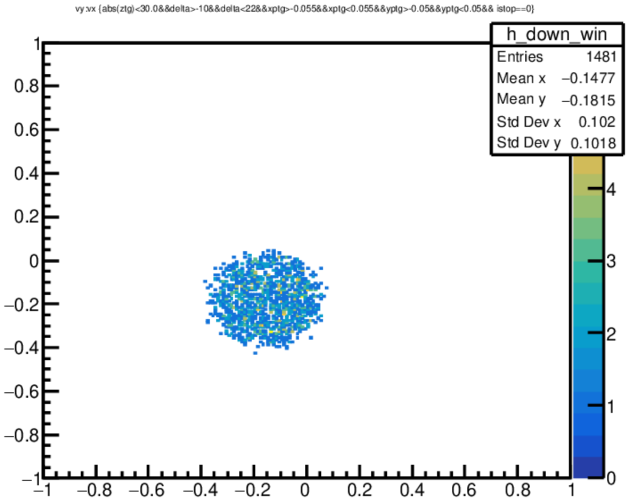
Note on replay cuts:

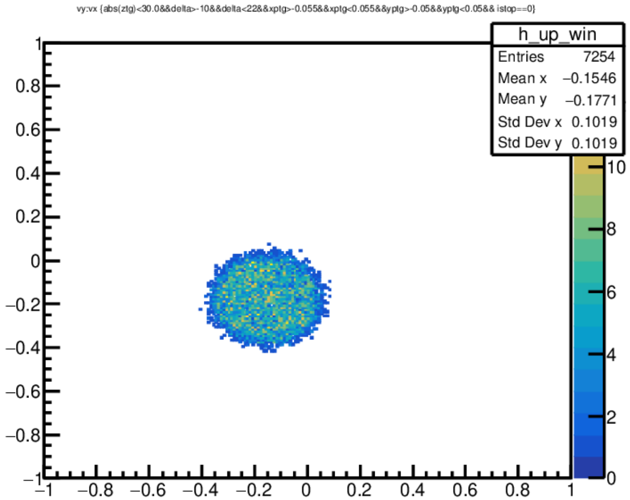
- Current cut is used to remove non-physical events during beam trip.
- PID cut provides requirement for good track and remove pion contamination.

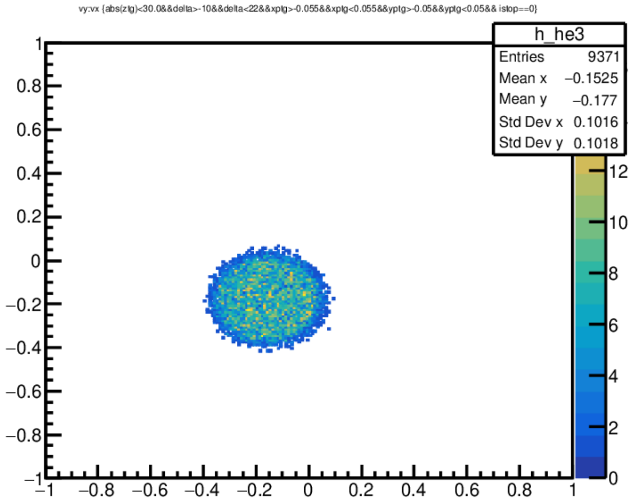
Circular Raster

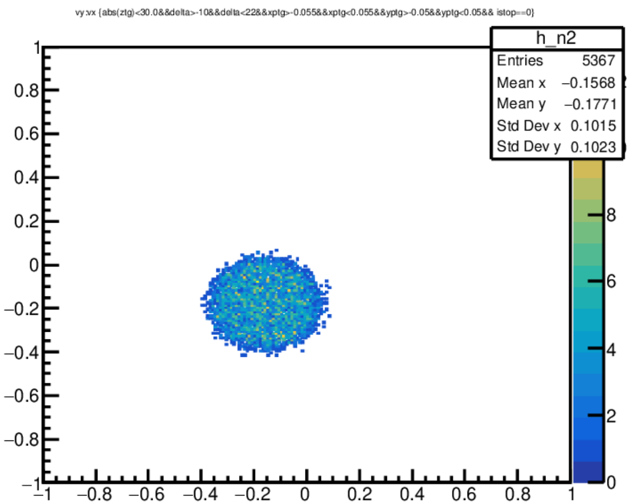
(Plot of y_{beam} vs. x_{beam})

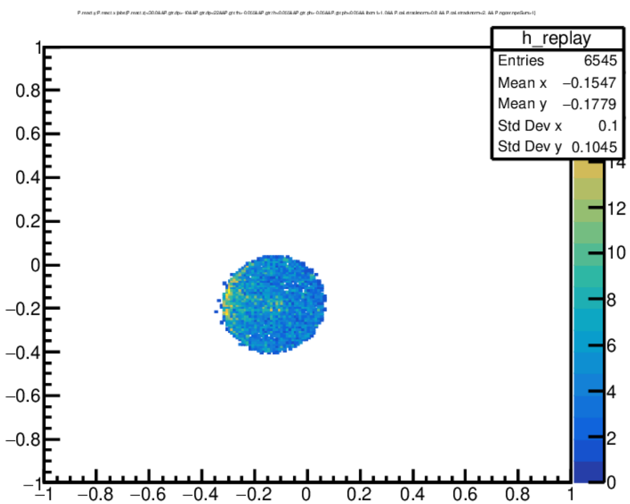
- SHMS 10602: ^{3}He DIS, Transverse 90°
- E_p=-3.4 GeV, 30°, kin-B
- Trigger: 3/4 (hTRIG1)









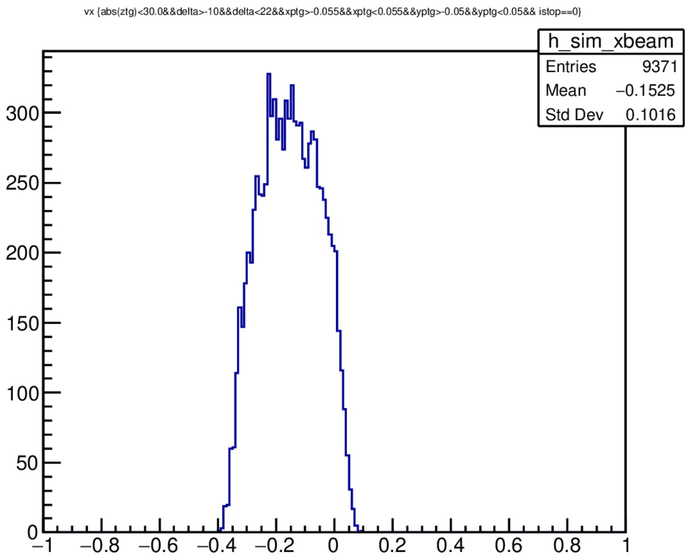


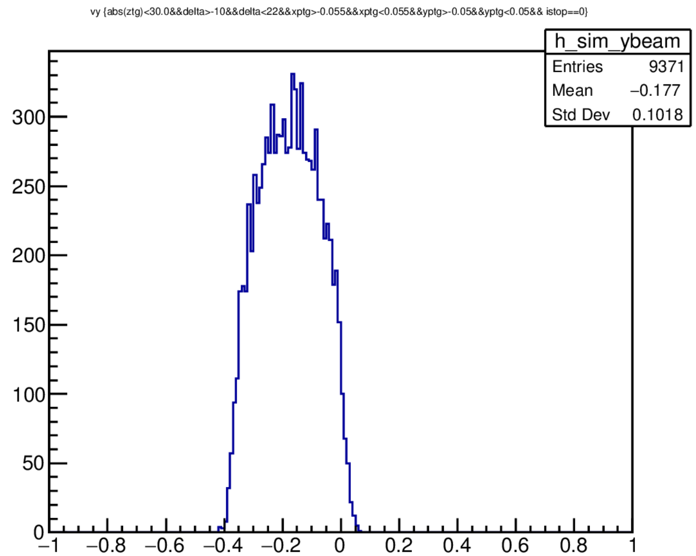
- From replayed runs, obtain x_{beam} and y_{beam} offsets from mean value.
- Add x_{beam} and y_{beam} offsets from replay into simulation in order to compare replayed data with simulated results.

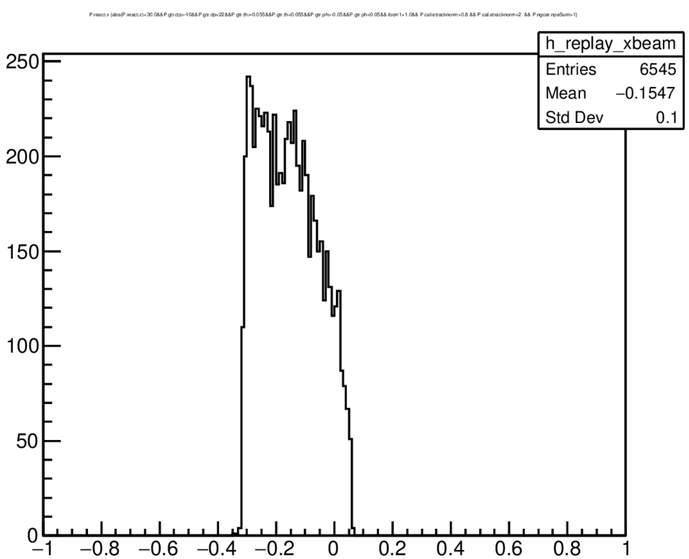
Circular Raster

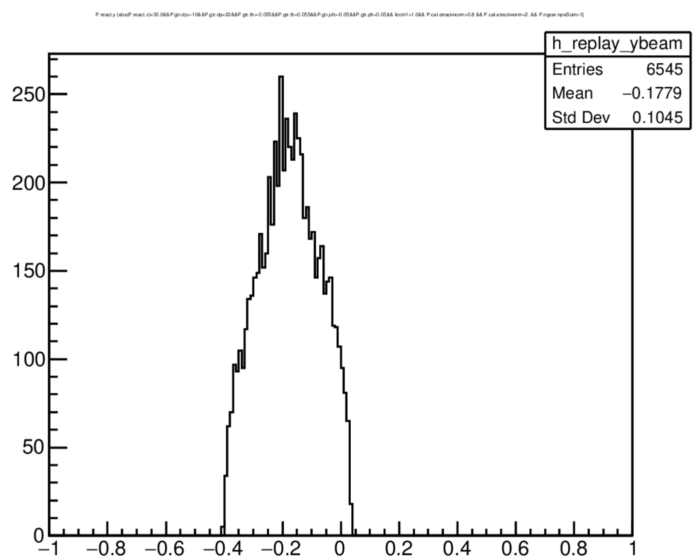
(plot of 1D x_{beam} and 1D y_{beam})

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







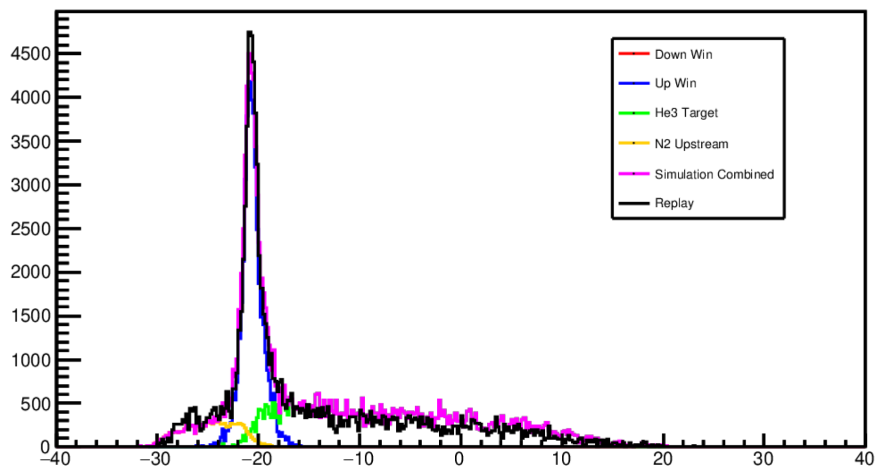


- From replayed runs, obtain x_{beam} and y_{beam} offsets from mean value.
- Add x_{beam} and y_{beam} offsets from replay into simulation in order to compare replayed data with simulated results.

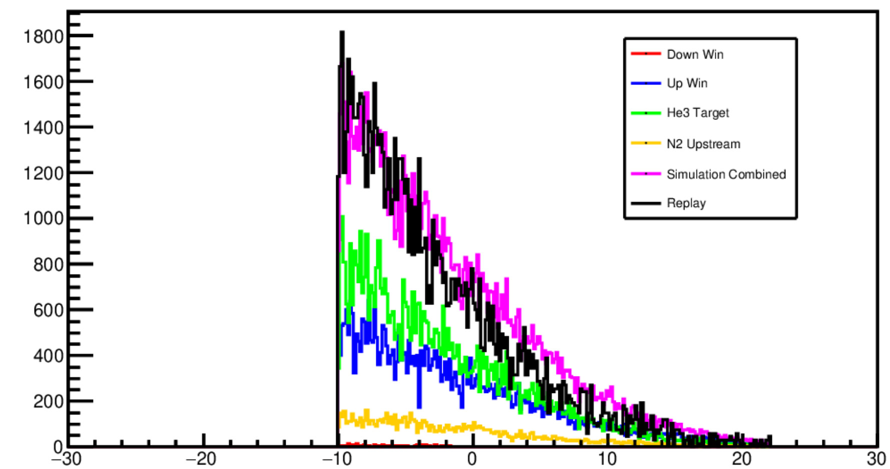
^{3}He Target Simulation
(Compare with replayed root file results)

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

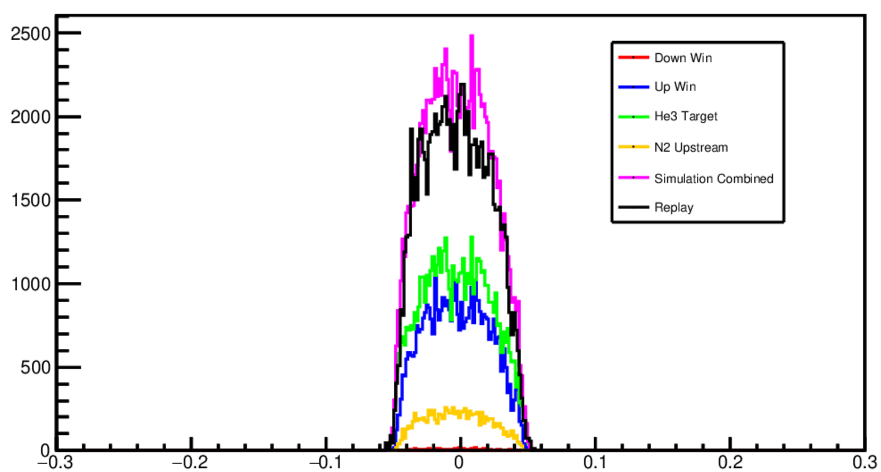
ztg_combined Weighted by Yield



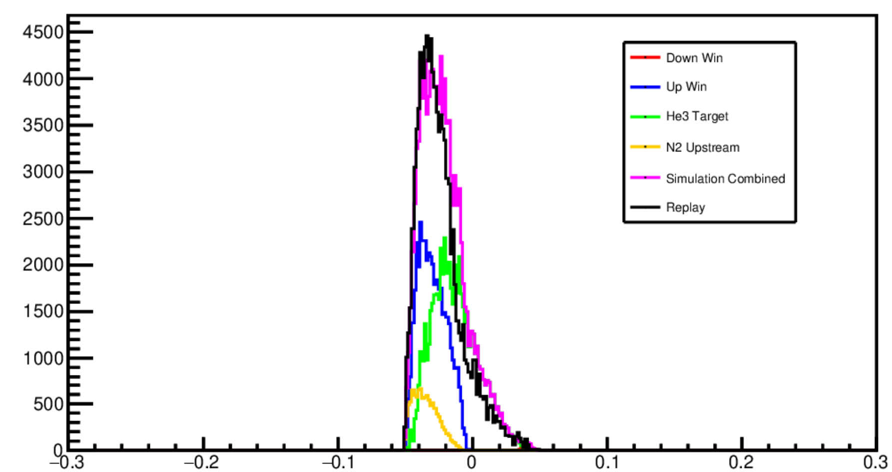
delta_combined Weighted by Yield



theta_combined Weighted by Yield



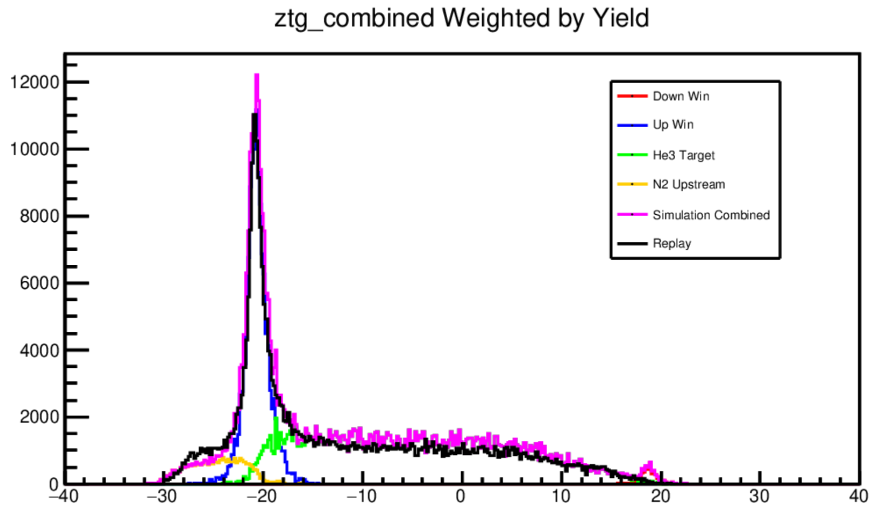
phi_combined Weighted by Yield

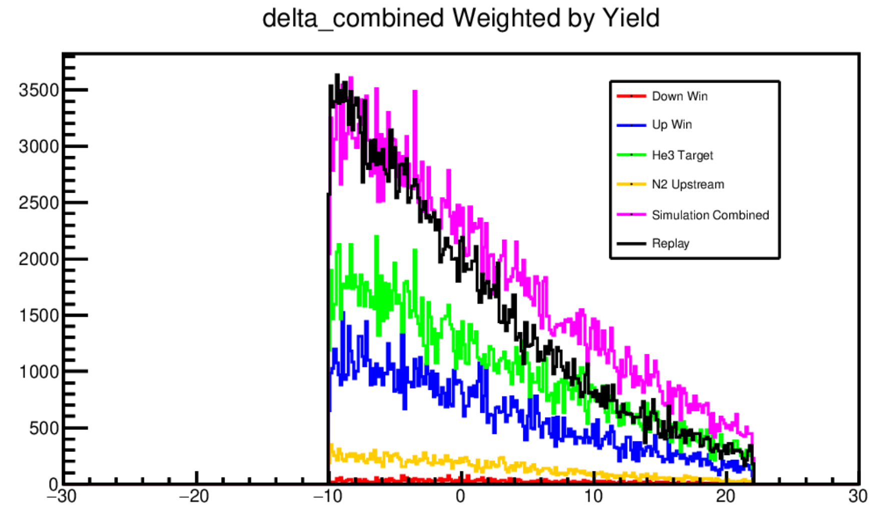


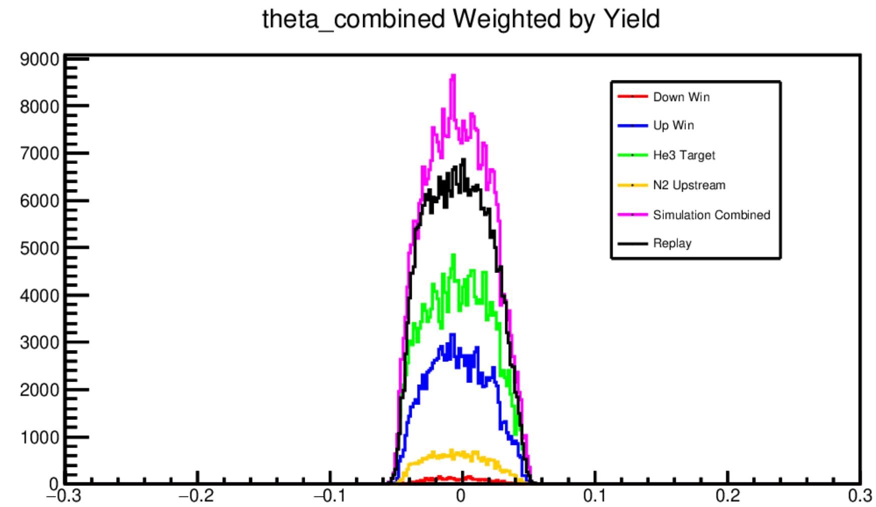
^{3}He Target Simulation

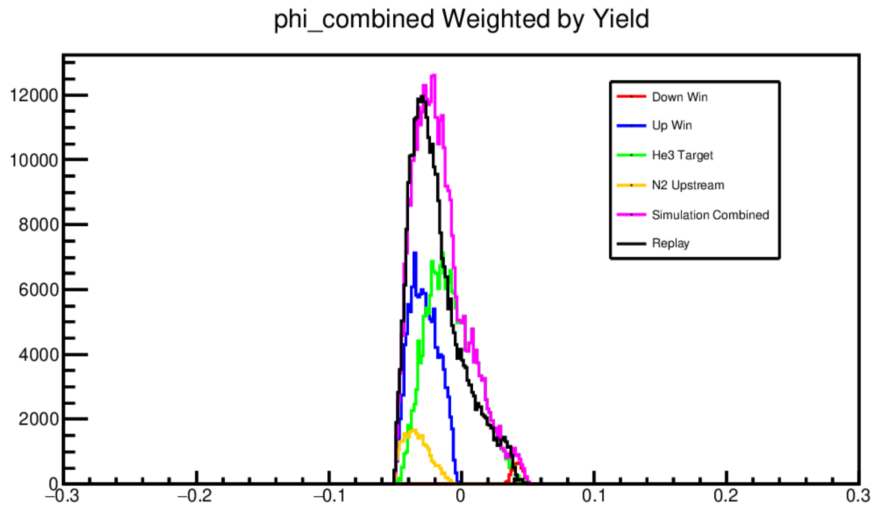
(Compare with replayed root file results)

- SHMS 10345: ^{3}He DIS, Longitudinal 180°
- E_p=-2.6 GeV, 30°, kin-C
- Trigger: 3/4 (pTRIG1)







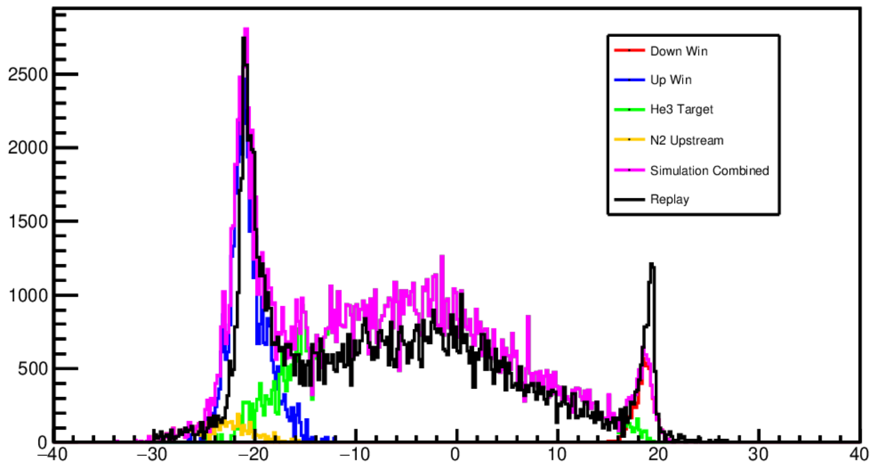


^{3}He Target Simulation

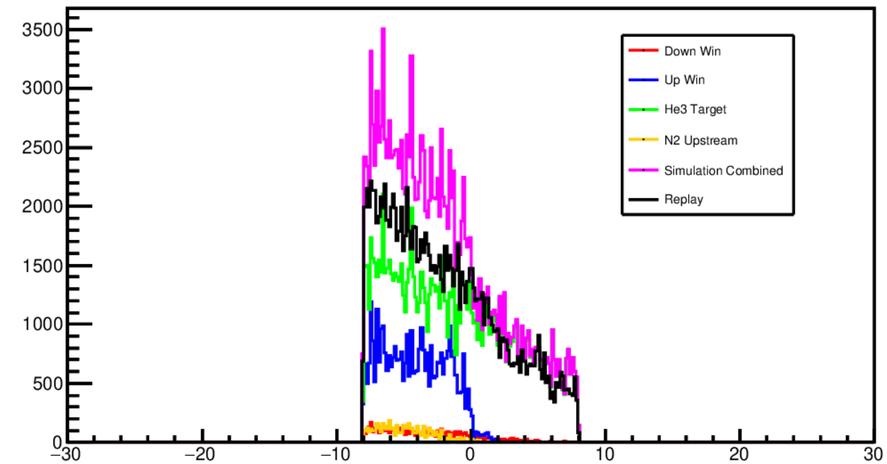
(Compare with replayed root file results)

- HMS 3149: ^{3}He DIS, Longitudinal 180°
- E_p=-2.9 GeV, 30°, kin-3
- Trigger: 3/4 (hTRIG1)

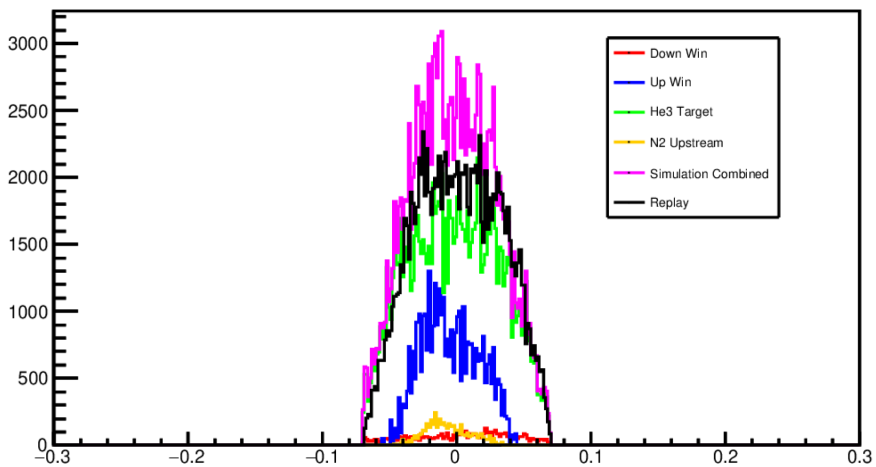
ztg_combined Weighted by Yield



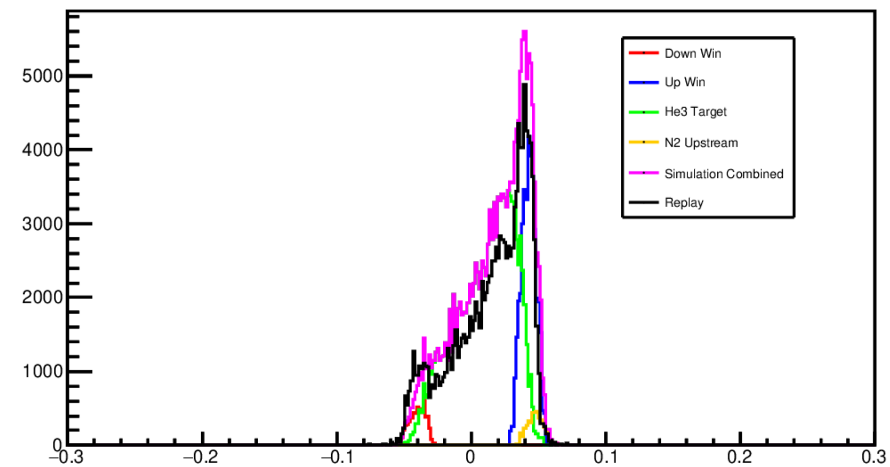
delta_combined Weighted by Yield



theta_combined Weighted by Yield



phi_combined Weighted by Yield

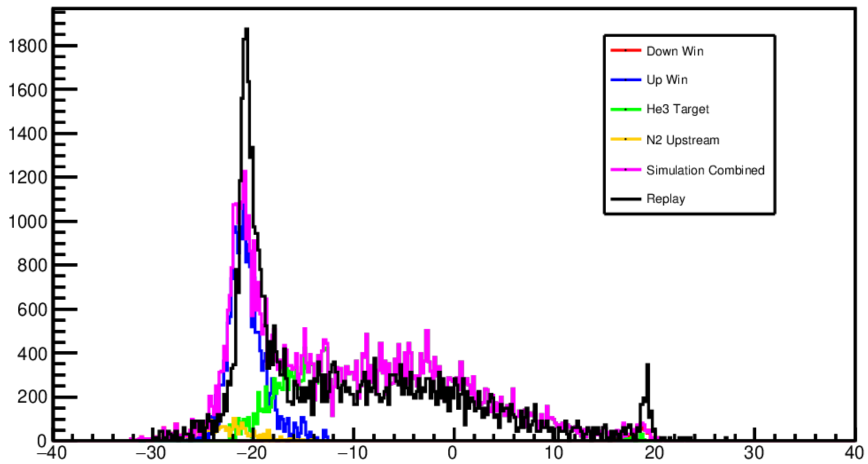


^{3}He Target Simulation

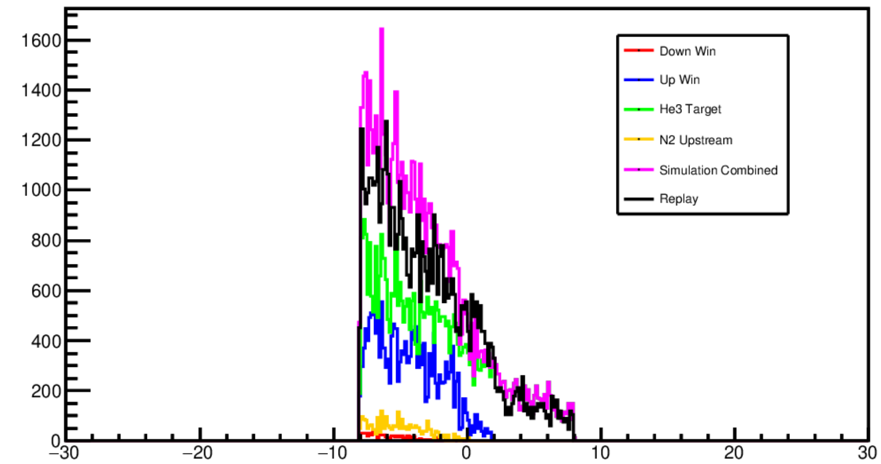
(Compare with replayed root file results)

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

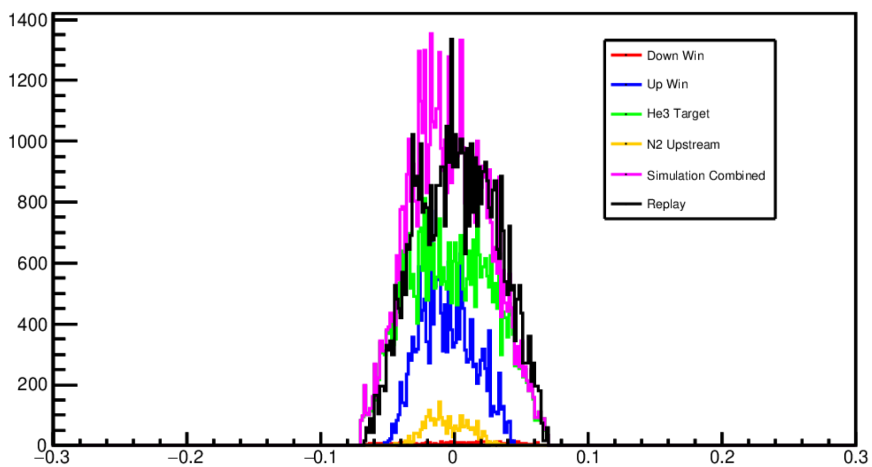
ztg_combined Weighted by Yield



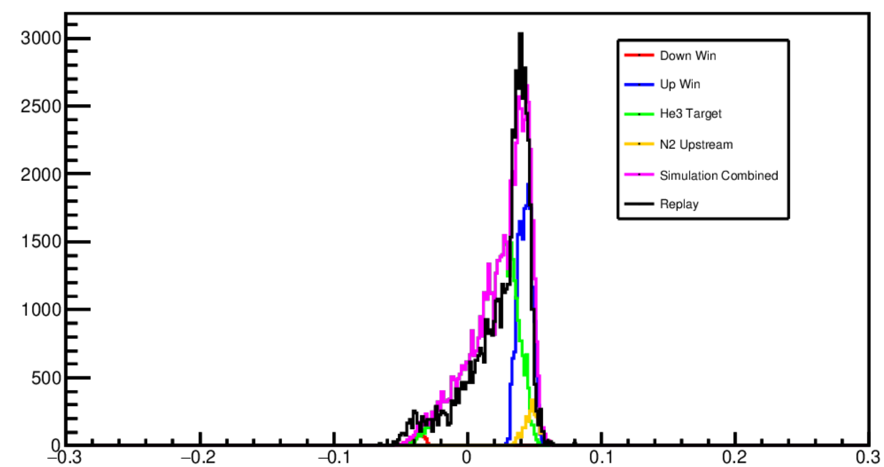
delta_combined Weighted by Yield



theta_combined Weighted by Yield



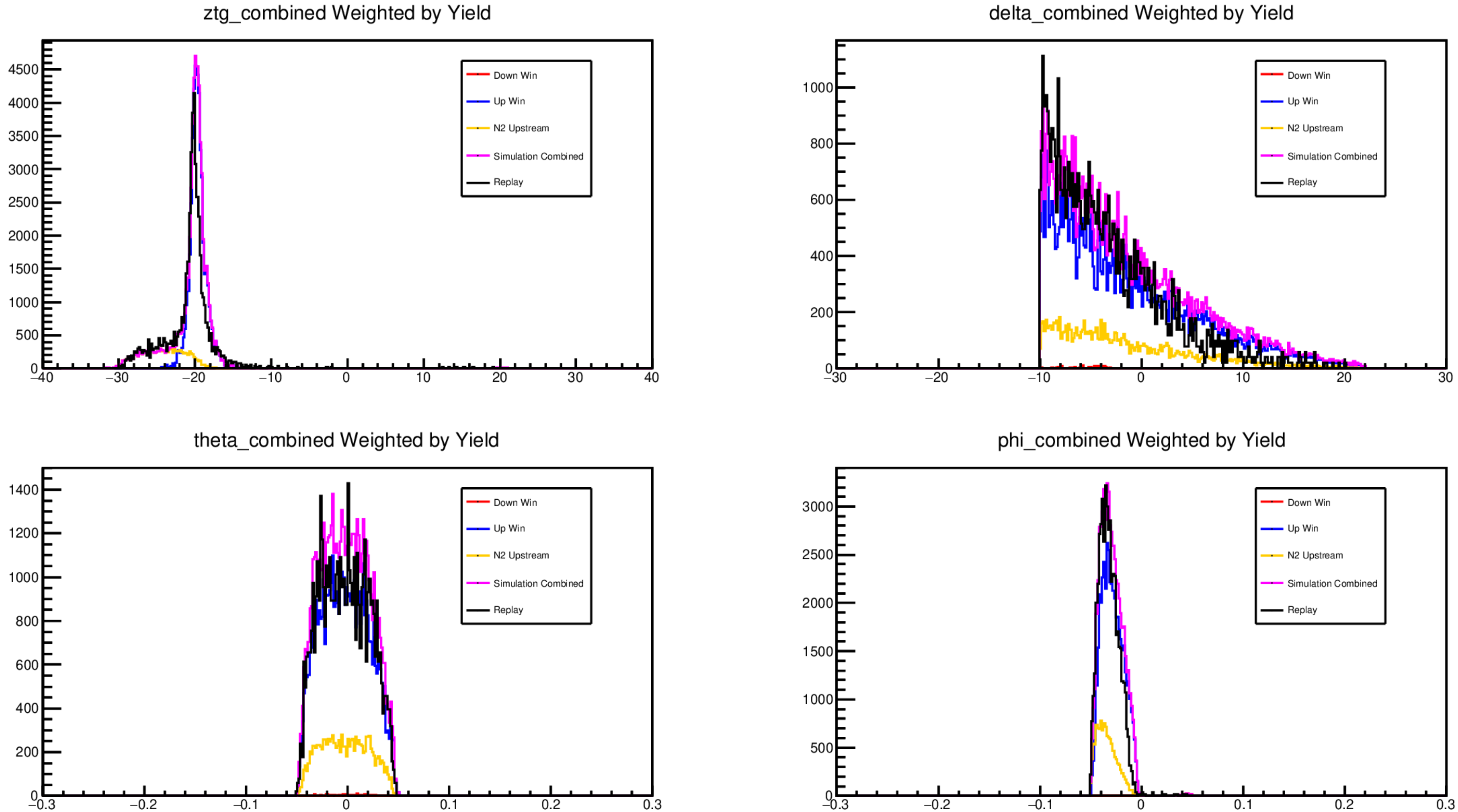
phi_combined Weighted by Yield



Empty Target Simulation

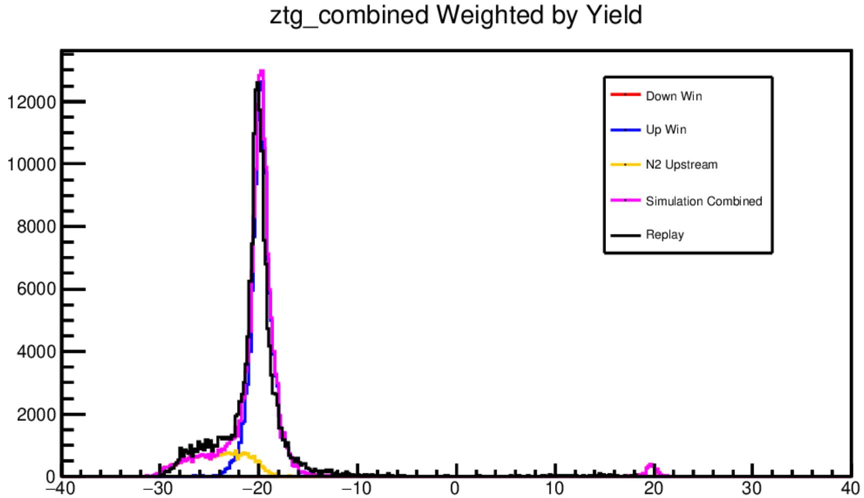
(Compare with replayed root file results)

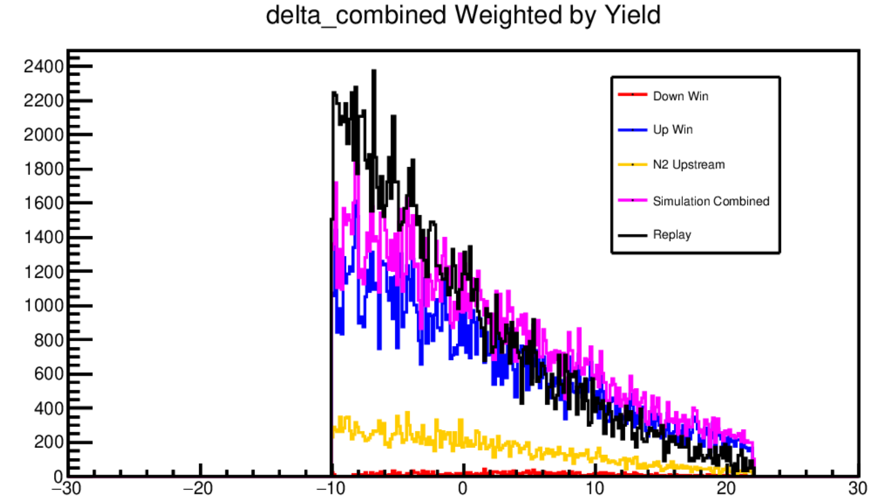
- SHMS 10267: Empty Target DIS, Transverse 90°
- E_p=-3.4 GeV, 30°, kin-B
- Trigger: 3/4 (hTRIG1)

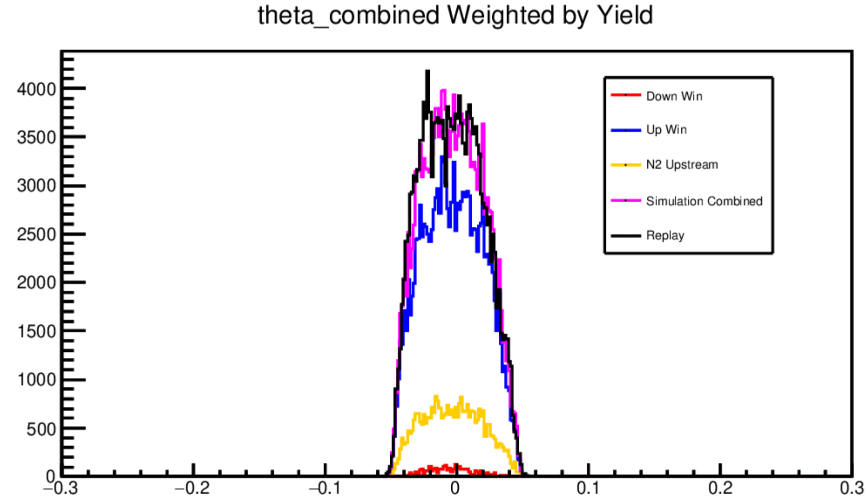


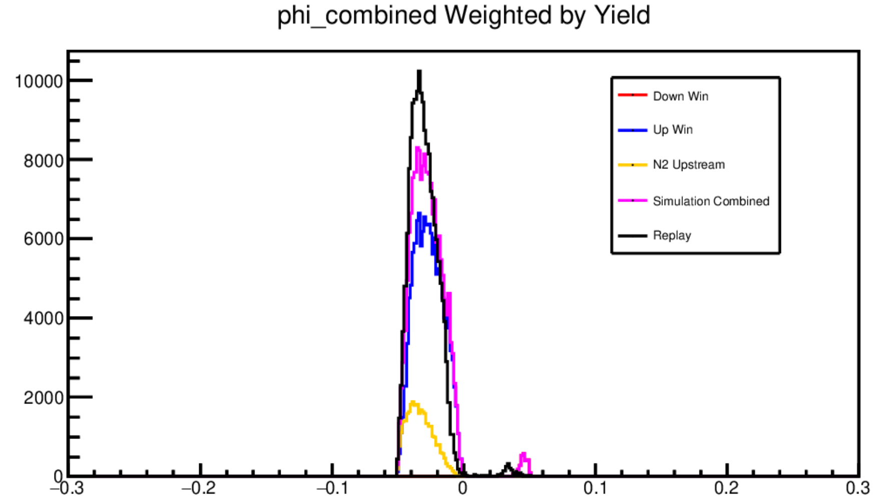
Empty Target Simulation
(Compare with replayed root file results)

- SHMS 10262: Empty Target DIS, Longitudinal 180°
- E_p=-2.6 GeV, 30°, kin-C
- Trigger: 3/4 (hTRIG1)







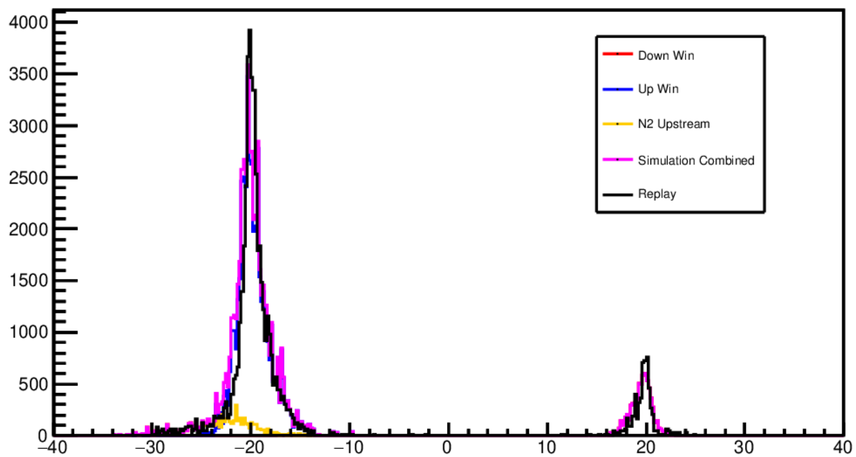


Empty Target Simulation

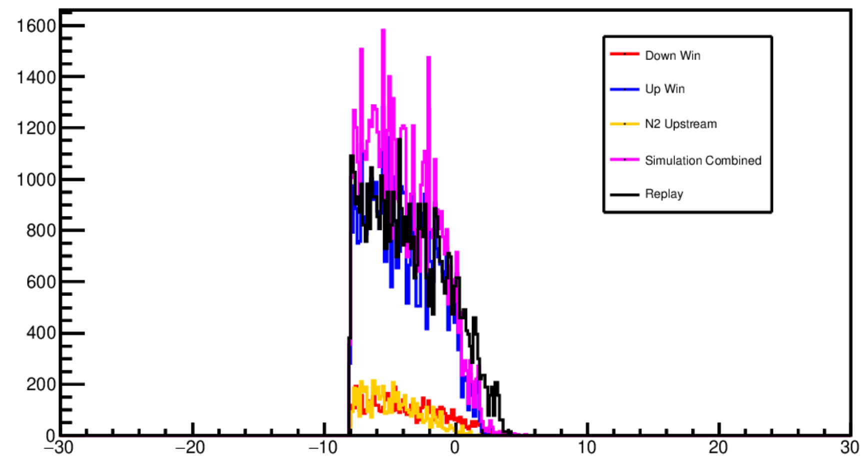
(Compare with replayed root file results)

- HMS 3072: Empty Target DIS, Longitudinal 180°
- E_p=-2.9 GeV, 30°, kin-3
- Trigger: 3/4 (hTRIG1)

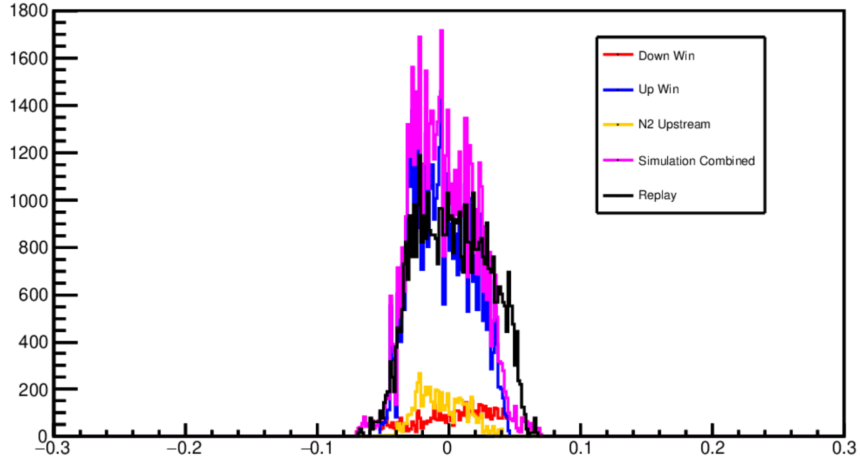
ztg_combined Weighted by Yield



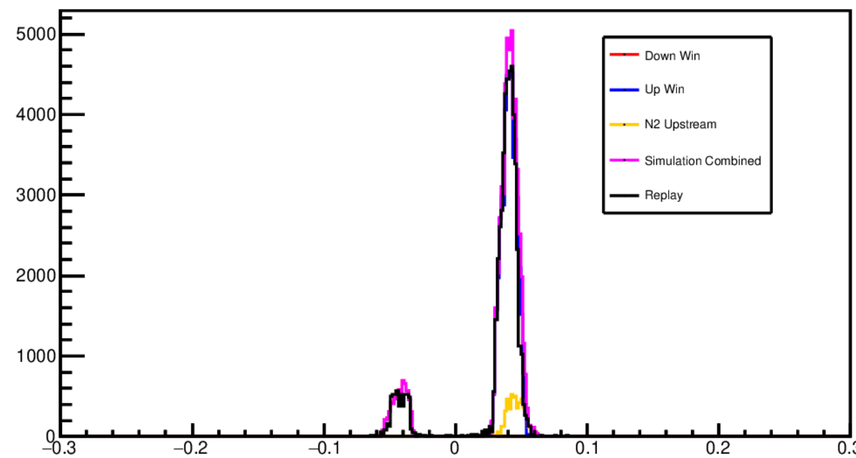
delta_combined Weighted by Yield



theta_combined Weighted by Yield

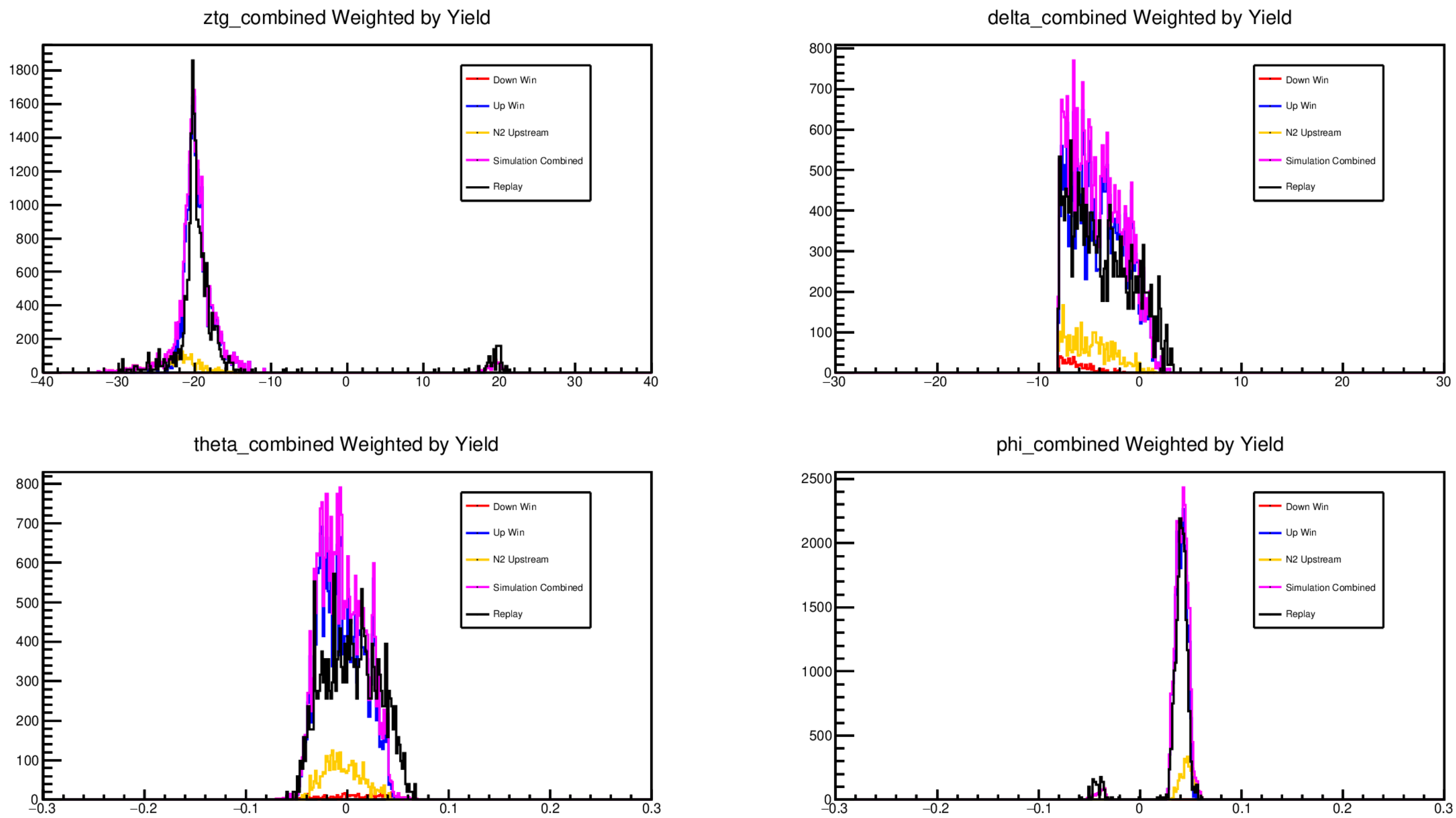


phi_combined Weighted by Yield



Empty Target Simulation
(Compare with replayed root file results)

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



Window Dilution

- N_{up}= integrated number of events from upstream window contribution within the z cut
- N_{down}= integrated number of events from downstream window contribution within the z cut
- N_0=integrated number of replayed events within the z cut

Note:

- Use empty reference cell runs to find first order window contribution.
- Use simulation results to do second order corrections on window contribution.

- Then define window dilution factor f_{win}:

$$f_{win}=\frac{N_{up}+N_{down}}{N_0}$$

- Since:

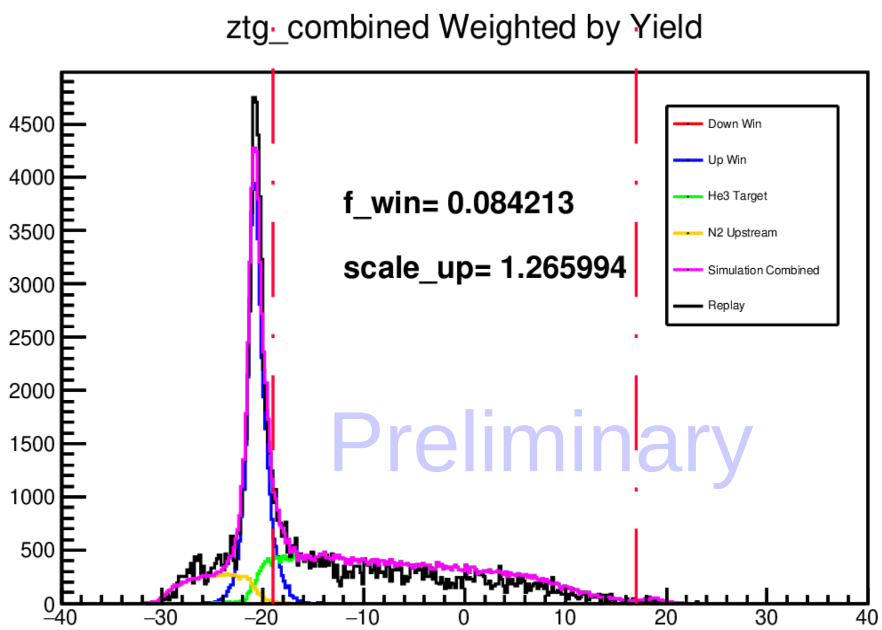
$$A_{phys}=\frac{A_{raw}}{P_b P_t f_{N2}(1-f_{win})}$$

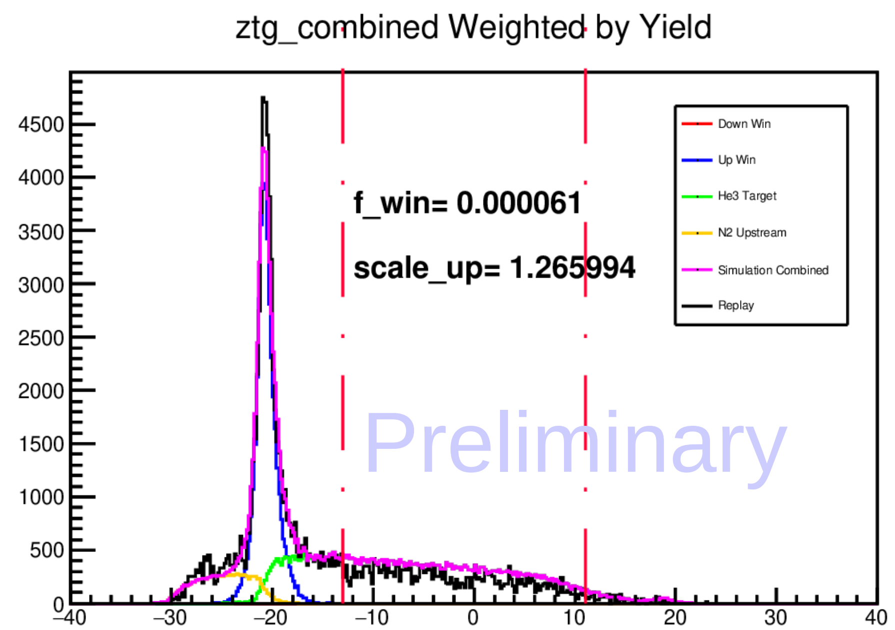
- We would like to place a proper window z cut to minimize ΔA_{phys}:

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

Window Dilution

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





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

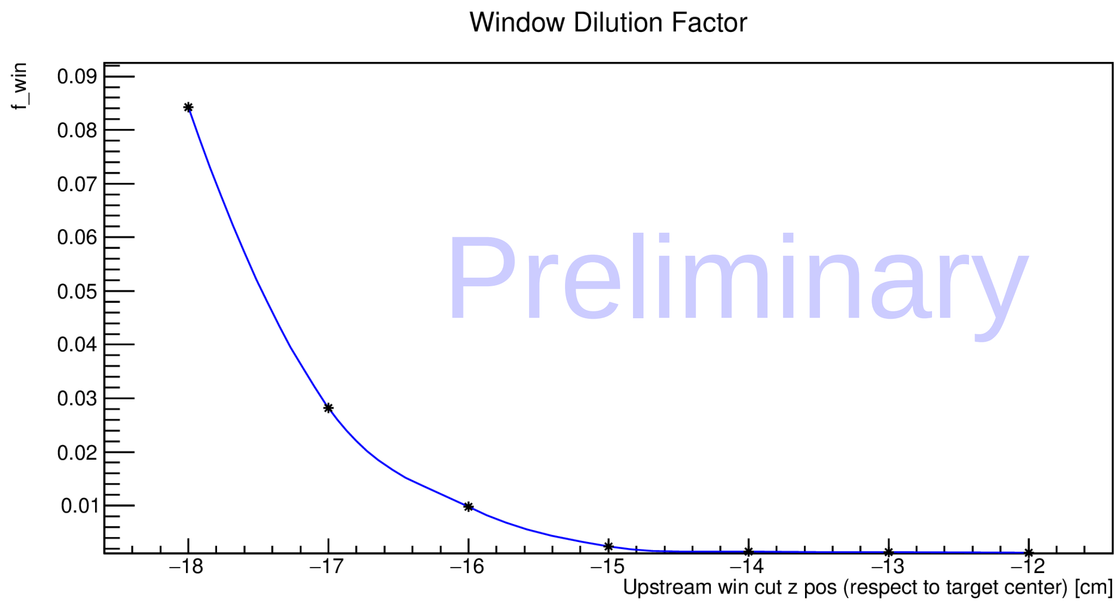
Note:

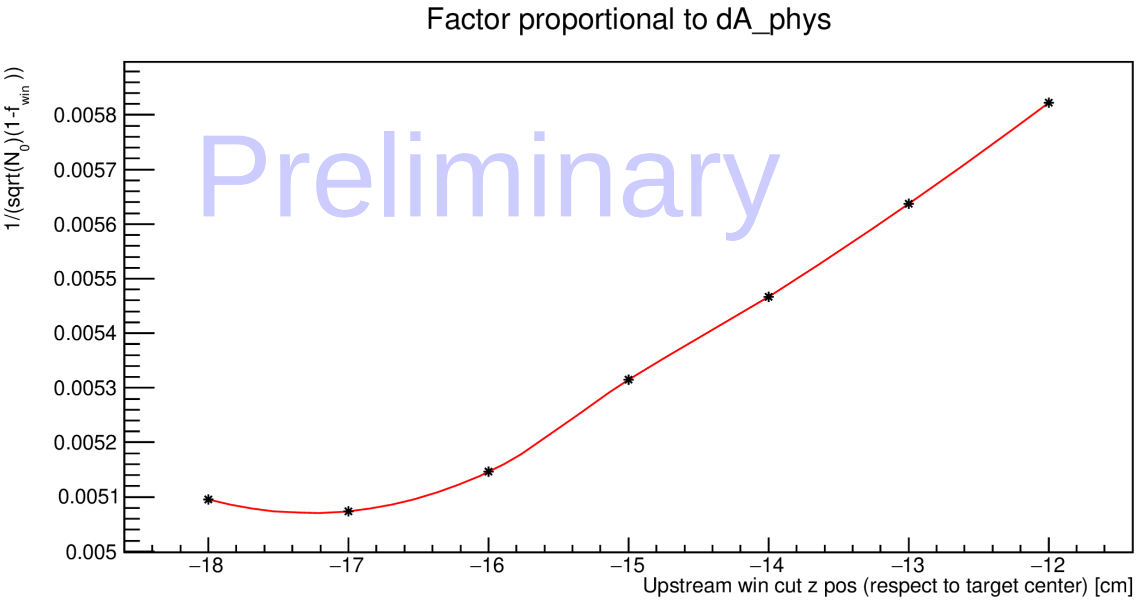
- Scale simulated upstream window histogram bins around z=-20.0 cm to match replayed data. (h_upstream*scale_up)
- For downstream window, use same scale factor as upstream window. (h_downstream*scale_up)
- Need to consider the effect of x_{beam}, y_{beam} offsets for simulation of the windows.

Window Dilution

(effect of upstream window z cut position)

- SHMS 10602: ^{3}He 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

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

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

Note:

- For window dilution study needs more statistics (1M trials for simulation; chain multiple runs for replayed data)
- More study needs be done to finalize the z_{target} cuts.

Summary and Future Work

Summary:

- By using mc-single-arm simulation, the contribution from windows could be characterized.
- For A_1^n DIS kinematics, the simulation is comparable to replayed data for both the ^{3}He production cell and empty reference cell.

Future Work:

- Develop proper acceptance cuts to better compare simulation with data.
- Finish window dilution study, obtain window dilution factor for every production run condition during A_1^n experiment.
- Once the window z_{target} cut is finalized, will shift focus to getting the A_1^n asymmetry from replayed data.

Backup Slides

Example of input file for Simulation

(for ^{3}He gas in target chamber)

```
!-----------------------------------------------------------------------------
! Input file for MC_SINGLE_ARM
!-----------------------------------------------------------------------------
  100000       Monte-Carlo trials
       2       Spectrometer (1=HMS, 2=SHMS, 3=..)
  3400.0       Spectrometer momentum (in MeV/c)
    30.0       Spectrometer angle (in degrees)C
   -20.0       M.C. DP/P  down limit
    30.0       M.C. DP/P  up   limit
   -80.0       M.C. Phi ( dy/dz) down limit (mr)
   80.0        M.C. Phi down limit (mr)
   -70.0       M.C. Theta (dx/dz)  down limit (mr)
   70.0        M.C. Theta down limit (mr)C
   0.0089      Horiz beam spot size in cm (Full width of +/- 3 sigma)
   0.0042      Vert  beam spot size in cm (Full width of +/- 3 sigma)
   40.0        Length of target (Full width, cm)
   0.4         Raster full-width x (cm)
   0.4         Raster full-width y (cm)
   100.0       DP/P  reconstruction cut (half width in % )
   100.0       Theta reconstruction cut (half width in mr)
   100.0       Phi   reconstruction cut (half width in mr)
   100.0       ZTGT  reconstruction cut (Half width in cm)
   44947.0     one radiation length of target material (in cm)
  -0.1547      Beam x offset (cm)  +x = beam left
  -0.1779      Beam y offset (cm)  +y = up
  -1.0         Target z offset (cm)+z = downstream
   0.0         Spectrometer x offset (cm) +x = down
   0.0         Spectrometer y offset (cm)
   0.0         Spectrometer z offset (cm)
   0.0         Spectrometer xp offset (mr)
   0.0         Spectrometer yp offset (mr)
   0           particle identification :e=0, p=1, d=2, pi=3, ka=4
   1           flag for multiple scattering
   1           flag for wire chamber smearing
   1           flag for storing all events (including failed events with stop_id > 0)
   0           flag for beam energy, if >0 then calculate for C elastic
   0           flag to use sieve
```

For Hall C optics interchanged theta and phi

- Turn on flag for save all events

Simulation cut used for comparison between simulation and replayed results :

- istop==0 (remove failed events)

Variables in replayed ROOT files:

- Target reconstructed quantities are golden track variables:

  P.gtr.dp → delta

  P.gtr.x → x target

  P.gtr.y → y target

  P.gtr.ph → y' target

  P.gtr.th → x' target

- Technically, tangents of the angles

$$x' = \frac{dx}{dz} \qquad y' = \frac{dy}{dz}$$

Optics Matrix Used for hallc_replay

hcana.param — /group/c-polhe3/Users/mychen/GitLab/hallc_replay/PARAM/HMS/GEN

```
; Parameters that were built into Fortran analyzer that we want
; to pass as parameters so that the resulting code can be more generic.
;
; Scintillator parameters
href_npaddles = 0
href_nsperchan = 0.1
href_offset = 0.0

;HMS Central Path Lenth from target to focal plane
HMS_CentralPathLen = 22.*100    ; 22 m (or 2200 cm)

hcal_num_layers = 4

rraster_num_signals = 4

# Exclusion band width for the calorimeter's fiducial volume.
hcal_fv_delta = 5.

# Constants for the coordiante correction of the calorimeter energy depositions
hcal_a_cor = 200.
hcal_b_cor = 8000.
hcal_c_cor = 64.36, 64.36       # for positive and negative sides
hcal_d_cor =  1.66,  1.66

hcal_layer_names = "1pr 2ta 3ta 4ta"

# The following were defined in REPLAY.PARAM
;h_recon_coeff_filename =    'DATFILES/hms_recon_coeff.dat'  ;hms optics matrix
;h_recon_coeff_filename =    'DATFILES/hms_recon_coeff_opt2018.dat'  ;hms optics matrix
h_recon_coeff_filename =    'DATFILES/hms_newfit_poltar.dat'  ; new fit hms optics matrix
```

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pcana.param — /group/c-polhe3/Users/mychen/GitLab/hallc_replay/PA...

```
;SHMS Central Path Lenth from target to focal plane
SHMS_CentralPathLen = 18.1*100    ; 18.1 m (or 1810 cm)


; Parameters we need to keep THcHallCSpectrometer Happy
;p_recon_coeff_filename = "DATFILES/SHMS_fr3_rec__order_5.dat"
;p_recon_coeff_filename = "DATFILES/shms-2011-26cm-monte_q2_p20_rec.dat"
;p_recon_coeff_filename = "DATFILES/shms-2011-26cm-monte_q2_m015_rec.dat"
;p_recon_coeff_filename = "DATFILES/shms_dipole_2plow.dat"
;p_recon_coeff_filename = "DATFILES/shms-2017-optimized.dat"
;p_recon_coeff_filename = "DATFILES/shms-2017-optimized_delta_newfit3.dat"

; New SHMS Optics by Holly from August 2020
;p_recon_coeff_filename = "DATFILES/hsv_fit_global.dat"
p_recon_coeff_filename = "DATFILES/newfit_global_zbin_allA1n.dat"

; fall 2019 defocused tune -> Q2 current set to 120% of nominal tune
; p_recon_coeff_filename = "DATFILES/shms-2017-26cm-
monte_quads_p18_q2_120_rec.dat"
```

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- Hall C replay Optics Matrix for HMS:

  hallc_replay/DATFILES/
  hms_newfit_poltar.dat

- Hall C replay Optics Matrix for SHMS:

  hallc_replay/DATFILES/
  newfit_global_zbin_allA1n.dat

Summary of Sampled Runs

1) A_1^n Sampled Runs:

Date	Run start time	Run end time	Run num	Field Direction (deg)	Spec	Kine	Spec angle (deg)	E_p (GeV)	Trigger	Target Type	Replayed Event #	BCM1 Coulomb value (uC)	Comment
03/02	17:09	18:09	3408	90	HMS	Kine-4	30	-3.5	3/4	Pol-^{3}He	All; -1	66634.94	Cell Bigbrother
02/16	22:49	00:07	10345	180	SHMS	Kine-C	30	-2.6	3/4	Pol-^{3}He	All; -1	108080.51	Cell Bigbrother
02/16	18:51	19:56	3149	180	HMS	Kine-3	30	-2.9	3/4	Pol-^{3}He	All; -1	72592.49	Cell Bigbrother
03/02	17:09	18:09	10602	90	SHMS	Kine-B	30	-3.4	3/4	Pol-^{3}He	All; -1	66550.76	Cell Bigbrother
02/12	05:05	06:04	3072	180	HMS	Kine-3	30	-2.9	3/4	Vacuum	All; -1	63214.82	Cell Will
02/12	05:05	06:04	10262	180	SHMS	Kine-C	30	-2.6	3/4	Vacuum	All; -1	63191.39	Cell Will
02/12	18:53	19:43	3077	90	HMS	Kine-4	30	-3.5	3/4	Vacuum	All; -1	50611.94	Cell Will
02/12	18:53	19:42	10267	90	SHMS	Kine-B	30	-3.4	3/4	Vacuum	All; -1	50383.88	Cell Will

Summary of Sampled Runs

1) A_1^n Sampled Runs:

Date	Run start time	Run end time	Run num	Field Direction (deg)	Spec	Kine	Spec angle (deg)	E_p (GeV)	Trigger	Target Type	X_{beam} Mean (cm)	Y_{beam} Mean (cm)	Comment
03/02	17:09	18:09	3408	90	HMS	Kine-4	30	-3.5	3/4	Pol-^{3}He	-0.1566	-0.1702	Cell Bigbrother
02/16	22:49	00:07	10345	180	SHMS	Kine-C	30	-2.6	3/4	Pol-^{3}He	-0.1332	-0.1825	Cell Bigbrother
02/16	18:51	19:56	3149	180	HMS	Kine-3	30	-2.9	3/4	Pol-^{3}He	-0.1384	-0.1725	Cell Bigbrother
03/02	17:09	18:09	10602	90	SHMS	Kine-B	30	-3.4	3/4	Pol-^{3}He	-0.1547	-0.1779	Cell Bigbrother
02/12	05:05	06:04	3072	180	HMS	Kine-3	30	-2.9	3/4	Vacuum	-0.1336	-0.1658	Cell Will
02/12	05:05	06:04	10262	180	SHMS	Kine-C	30	-2.6	3/4	Vacuum	-0.1279	-0.1718	Cell Will
02/12	18:53	19:43	3077	90	HMS	Kine-4	30	-3.5	3/4	Vacuum	-0.1279	-0.1577	Cell Will
02/12	18:53	19:42	10267	90	SHMS	Kine-B	30	-3.4	3/4	Vacuum	-0.123	-0.1742	Cell Will

Cell Window Position
(from survey group)

VALUES IN MM AND DEGREES RELATIVE TO HALL C TARGET CENTERLINE
A POSITIVE X IS BEAM LEFT, A POSITIVE Y IS UP AND A POSITIVE Z IS DOWNSTREAM
Surveyed on 10/06/2020

	CELLS	
Reference US	-196.4	****Measured to 3d printed fixture placed against cell surface
Reference DS	199.3	
TGT CELL US	-190.3	
TGT CELL DS	210.7	

- For Production Cell “Tommy” and reference cell “Fauci” after d_2^n experiment
- No survey results for production cell and reference cell during A_1^n experiment

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
	#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	
TC front	#5	12.5±0.16	1.267±0.01	
	#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	
TC rear	#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		

Target Cell Window Thickness

	[Cell Bigbrother] 02/12/2020 to 03/13/2020			
Density (amg)	V_ pc (cc)	V_tc (cc)	V_tt (cc)	
7.093	293.82	100.76	32.6	
	Production Cell "Bigbrother" Wall Thickness			
	Measurement location	Position away from center (along Z) [cm]	Ultrasonic thickness gauge [mm]	Hclog link
TC front	#1	-12.5±0.16	1.507±0.01	https://logbooks.jlab.org/entry/3762599
	#2	-6.25±0.16	1.531±0.01	
	#3	0.0±0.16	1.528±0.01	
	#4	6.25±0.16	1.517±0.01	
	#5	12.5±0.16	1.533±0.01	
TC rear	#6	-12.5±0.16	1.415±0.01	
	#7	-6.25±0.16	1.436±0.01	
	#8	0.0±0.16	1.407±0.01	
	#9	6.25±0.16	1.405±0.01	
	#10	12.5±0.16	1.406±0.01	
Window Thickness	Front window (um)	Back Window (um)	Cold life Time (hr)	Max Polarization no beam (%)
	138.1961±0.059	100.8740±0.0698	26 (UVa)	60 (UVa)
	Downstream z=+20 cm	Upstream z=-20 cm		

Calculation of Atom Number Density

$$\rho_N = \frac{\rho_m N_A}{M}$$

- For p_m be mass density, M be molar mass, N_A be Avogadro’s Number=6.022E23/mol

Target Type	Mass Density p_m (g/cm^3)	Molar Mass M (g/mol)	Pressure	Number Density p_N ($\#/m^3$)
^{3}He target	1.345E-4	3.01603	1.0 amg	2.686E25
N_2 gas	1.1602E-2	14.0067	1.0 atm	4.987E25
GE180	2.77	54.7251	NA	3.0481E28
C_{12}	2.267	12.01078	NA	1.6532E28

- For ^{3}He target chamber, use 12.0 amg to calculate yield for simulation
- For N_2 gas between Z=(-30,-20) cm between beamline exit window and upstream glass window, use 1.0 atm to calculate yield for simulation.